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

APPENDIX H: Draft Plan Formulation

Details of Phases 1 & 2

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

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1.1 Description of Flood Risk Management Measures

Following is a description of the regional, structural, nonstructural and ecosystem restoration measures for flood risk management and ecosystem enhancement. A discussion of the regional measures, which would be applied to all study area communities, is provided first. Regional measures are implementable outside the boundary and authority of individual municipalities, and include techniques such as large-scale flood forecasting and warning, and reservoir management. Structural measures, which seek to redirect or restrain the flow of floodwaters, are then described. The following sections describe nonstructural options, grouped into the categories of land use and regulatory measures; building retrofit measures; and land acquisition measures. This is followed by a description of ecosystem restoration measures and a description of potential ecosystem restoration opportunities in the study area.

1.2 Regional Measures

1.2.1 Flood Warning System

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

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. The Corps worked with NWS to incorporate flood inundation mapping into the Advanced Hydrologic Prediction Service (AHPS) along the main stem Delaware River for nine gaging locations. This allows stakeholders in flood-prone areas to have Internet access to maps showing anticipated extents of flooding in the vicinity of these river gages.

While flood forecasting and warning are generally regional in nature and, thus, appropriately handled by agencies with larger jurisdictions, flood preparedness and planning are a local responsibility and part of the All Hazard Mitigation Plan currently required by FEMA. Upon request, and within available funding, the Corps can provide technical assistance and access to data for all applicable sections of the planning process, including but not limited to flooding hazards.

1.2.2 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. Typically such coordination would require the involvement of multiple municipalities, counties or states. The multi-state DRBC is responsible for multi-use reservoir management in the study area. The DRBC cannot act without the agreement of the Decree Parties of the Flexible Flow Management Program for the New York City Delaware Basin Reservoirs.

1.2.3 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. Large-scale dams or impoundments would be substantially greater in size than the localized measures discussed in Section 1.3.4.

1.3 Structural Measures

1.3.1 Backflow Prevention Structures

In general, stormwater and drainage systems are designed to carry upland drainage into a waterbody. However, during times of flooding, water can back up from the waterbody through the stormwater system, up a tributary, or through a line of protection such as a levee or canal embankment. This can lead to localized interior flooding. 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.

1.3.2 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, which are manually installed over roadways, bridges, and railways prior to flooding to provide a continuous barrier against flooding to a pre-determined elevation. 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. Temporary floodwalls are stored as reusable segmented sections that are then put in place and attached to each other in anticipation of the arrival of floodwaters. Typically, temporary floodwalls can take the place of sandbag floodwalls. They can also be used to augment permanent flood barriers such as berms or levees. 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.

1.3.3 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. Dredging involves mechanical removal of shoaled or deposited material (sediment) from river and tributary beds.

1.3.4 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. Behind dry dams, the land reserved for the temporary flood pool can host compatible uses, such as farming or recreation, when a pool is not present. Since dry dams do not require a permanent pool, they may be more acceptable to the local community.

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. Stored floodwaters would then be released slowly through a downstream outlet. Placing flood control storage areas in the floodplain would require an extensive amount of land to achieve any measurable water surface elevation reductions.

1.3.5 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 reducing 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.

1.4 Nonstructural Measures

1.4.1 Land Use and Regulatory Measures

The measures described below are designed to direct the location and nature of new development and redevelopment to manage risks from flooding and other hazards.

Zoning and Land Use Controls: State and regional regulations and municipal ordinances can be used to restrict development or redevelopment of structures in at-risk areas. The controls may restrict permitted uses, size, density, and structural siting. Examples include required setbacks from riverfronts or other flood-prone areas. If widely applied, such restrictions can help provide a buffer area between development and areas of greatest risk.

New Infrastructure Controls and Landform/Habitat Regulations: Restrictions on the installation of infrastructure or new connections to existing infrastructure in hazard areas can serve to reduce development, while the use of higher infrastructure standards such as recharge basins can reduce flood risk during storms. Landform and habitat regulations can restrict development in floodprone and/or environmentally sensitive areas and promote the function of natural floodplains.

Construction Standards and Practices: Locally adopted, enforceable codes can regulate the use of building materials and design standards to minimize damage from assorted hazards, including high winds, heavy rains, and flooding. Examples include reinforced foundation footings, piers and foundations, roof anchoring, and provision of adequate drainage.

Insurance Program Modifications: In general, this technique consists of modifications to the NFIP to adjust risk classifications and premiums to reflect flooding hazards at current levels. This can be achieved through remapping floodprone areas using the latest available hydrology, topographic mapping, and modeling methods. Accurate classification of flood risk may discourage or reduce development or redevelopment within high-risk areas. As of February 2015, FEMA is preparing Digital FIRMs, or DFIRMs, for Delaware River-area communities in New Jersey.

Tax Incentives: This technique provides tax benefits to property owners for various measures to reduce or eliminate future flooding damage. Such measures include retrofits to existing buildings to reduce flood damage and the establishment of conservation easements, land donation arrangements, or other development restrictions on undeveloped land susceptible to flooding.

1.4.2 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. Description of the assorted techniques follows.

Structure Relocation: Structure relocation involves physically picking a structure up and moving it out of the floodplain. As with buyouts, structure relocation can be a very effective means of eliminating losses from flood damage.

Relocation is, in many respects, the most effective method for retrofitting an existing structure to reduce damage. Ideally, the structure would be entirely removed from the hazard area, eliminating any potential for flood damage and adverse environmental effects such as the collapse of on-site waste disposal systems. A building can be relocated to a new site, or if sufficient space is available outside the floodplain, within the existing lot.

Structure Elevation: Structure elevation involves raising the structure in place, such that floodwaters flow beneath the occupied portion of the building. As described in *Selecting Appropriate Mitigation Measures for Floodprone Structures* - FEMA 551, March 2007, "Elevating a structure to prevent floodwaters from reaching living areas is an effective and one of the most common mitigation methods. The goal of the elevation process is to raise the lowest floor to or above the required level of protection. This can be done by elevating the entire structure, including the floor, or by leaving the structure in its existing position and constructing a new, elevated floor within it. The method used depends on the construction type, foundation type, and flooding conditions." This method is most applicable to frame construction. If a basement were present, it would need to be filled in. Structure elevation projects are more appropriate in areas that experience slower moving floodwaters.

Structure Rebuilding: Structure rebuilding involves construction of a new building on the same property instead of elevating, retrofitting, or otherwise modifying the existing building. The new building will be in compliance with local floodplain management requirements, with the main floor above the base flood elevation. This technique can be used when the existing building is in poor condition, has low value, may require special methods or remedial treatments to elevate, or because of its function is not suitable for elevation or other means of retrofit. Structures in the latter category include large non-residential structures such as firehouses. The existing building would be demolished and a new building be constructed, adhering to applicable floodplain management requirements and building codes.

Free-Standing Barriers: Structure perimeter protection is generally provided by a small levee or floodwall. Perimeter protection is more applicable to multi-building installations or small groups of buildings. A berm can be integrated into a landscaping plan to make it less intrusive. The structure must incorporate a method for discharging precipitation falling inside the perimeter, as well as any floodwaters that exceed the design of the structure.

Dry Floodproofing: Dry floodproofing is making a structure "watertight below the level that needs flood protection to prevent floodwaters from entering. A structure can be dry floodproofed using waterproof coatings or impermeable membranes to prevent seepage of floodwater through the walls, installing watertight shields over doors or windows, and installing sewer backup prevention measures"[1]. Because water will be accumulating outside the building, but not inside it, hydrostatic pressure will build up. If a basement is present, it must be specially designed to withstand the hydrostatic pressure, though pressure on all walls and floors must be considered. Applying a waterproof seal to the structure works best with heavily constructed masonry or concrete structures and flood conditions that are relatively brief in duration. Given the hydrostatic pressure against the structure, this technique is limited to areas that will experience less than three feet of flooding. This technique is not allowed under the NFIP for new or substantially improved or damaged residential structures located in the floodplain; however, it is allowed for non-residential structures in the floodplain.

The velocity of flooding is a primary consideration in the evaluation of dry floodproofing for a given structure. The technique is appropriate only for areas with slow flood velocity (less than three feet-per-second or fps), without threat of flash-flooding, and where flooding depths will be less than three feet.

Wet Floodproofing: Wet floodproofing a structure "consists of modifying the uninhabited portions (such as a crawlspace or an unfinished basement) to allow floodwaters to enter and exit. This ensures equal hydrostatic pressure on the interior and exterior of the structure and its supports. Equalized pressure will reduce the likelihood of wall failures and structural damage. Wet floodproofing is not practical for most slab-on-grade structures that have the living space at or near ground level. Whether or not floodproofing is appropriate depends on the flood conditions, the design and construction of the structure, and whether the structure has been substantially damaged or is being substantially improved. However, many industrial or commercial structures could benefit greatly from wet floodproofing techniques" [1]. All utilities need to be elevated or put in a watertight room. FEMA cautions that "(w)et floodproofing does not reduce flood insurance premium rates on residential structures. Premium rates can only be reduced through elevation of the residential structure above Base Flood Elevation. Non-residential structures can reduce flood insurance premium rates through other forms of floodproofing."

The velocity of flooding is a primary consideration in the evaluation of wet floodproofing for a given structure. The technique is appropriate only for areas with slow flood velocity (less than three feet-per-second or fps) and without threat of flash-flooding. Wet floodproofing can be applied to a greater range of flooding depths (including deep flooding over six feet in depth). Thus, if the technique may be indicated for a given building, then a review of flood velocities in specific locations (e.g., at locations of the candidate building) will be required.

Protection of Utilities: The protection of utilities is the management of flood risk to building utilities such as electrical panels, HVAC units, and hot water heaters through in-place protection (placing utilities in flood-proof enclosures) or by elevating utilities above flood height, often by placing utilities in an addition to the original building. Utilities can be enclosed in floodproof concrete chambers or relocated from a flood-prone basement to a location above base flood elevation. The technique is most effective in areas with frequent low-level flooding below the main floor of structures.

Structure Acquisition: Structure acquisition (also known as structure buyout) is described thus: "acquiring and demolishing or simply demolishing a flood-prone structure is the most successful means of ensuring that a structure will not accumulate additional losses from future flood events"[1]. The structure is bought by a public party (such as the local sponsor) using cost-shared funds, and is no longer occupied. The structure is typically demolished and the property may be converted to recreational use. Acquisitions should accomplish the following: *a.* public acquisition and removal of flood-prone structures; *b.* assembly of vacant parcels to preclude development; *c.* prohibitions against new structures in the floodplain, or floodproofing and stormwater management in some limited cases; *d.* creation of recreation or natural wildlife areas and wetlands in appropriate areas; *e.* development of permanent public open space to provide new recreational opportunities; *f.* removal of, or adjustments to, the public infrastructure to eliminate intrusions into the floodplains and to prevent interruption of essential services during floods; and *g.* enforcement of land use controls to prevent redevelopment in acquired areas and establishment of water management standards at un-acquired properties[1].

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[1] *Selecting Appropriate Mitigation Measures for Floodprone Structures* (FEMA 551), March 2007

1.5 Land or Structure Acquisition Measures

1.5.1 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.

1.5.2 Purchase of Property

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.

1.5.3 Easements and Deed Restrictions

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.

1.6 Ecosystem Restoration Measures

1.6.1 Floodplain Reclamation/Wetland Restoration

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. Habitat enhancements to benefit wildlife can also be incorporated into wetland restoration projects, including control of invasive species to promote the viability of desired native vegetation. Creation of wetlands from former uplands through changes in hydrology can support growth of wetlands vegetation, as well as yield the flood risk management benefits of wetlands, if properly placed within the landscape.

Based on a series of site visits and trip reports, several sites were identified as possessing some of these restoration opportunities. Table 1.1 provides a summary of the identified sites and potential restoration measures.

While the option of wetlands restoration will be considered for the whole study area, the nature of the geography and development indicates that it is likely to be most applicable in Greenwich and Logan Townships.

Table 1.1: Potential Ecosystem Restoration Opportunities

Site and Location	Habitat Impairment	Restoration Opportunities	Potential Techniques
Pequest River and Pophandusing Brook in White Township and Belvidere	• Stream bank erosion and sediment deposition that reduces flow capacity and potential for fish habitat • Dams on the Pequest River	• Reduce sediment and pollutant loading • Enhance fish habitat/passage • Increase vegetative diversity and habitat values	• Implement bioengineering solutions for increased stream bank stability and sediment load reduction • Remove dams and restore pond area back to floodplain wetlands • Install fish ladder(s) • Restore wetlands and riparian forest to act as buffer, slow run-off to increase base flows, and intercept sediment and pollutant loads
Harmony Township	• Stream bank erosion, loss of vegetation and sedimentation due to breaches at abandoned quarry in Brainards section	• Reduce sediment and pollutant loading • Remove sediment to eliminate eddies • Increase vegetative diversity and habitat values	• Repair breaches and implement bioengineering solutions for increased stream bank stability and sediment load reduction • Remediate quarry using clean fill • Create wetland to improve habitat diversity and provide flood storage
Town of Phillipsburg	• Sewage overflows from WWTP during flood events	• Reduce pollutant loading and improve water quality	• Flood protection for WWTP and pump stations

(Continued): Potential Ecosystem Restoration Opportunities

Site and Location	Habitat Impairment	Restoration Opportunities	Potential Techniques
Borough of Frenchtown	• Sedimentation at Nishisakawick Creek	• Reduce sediment load and restore flow conditions	• Implement bioengineering solutions for increased stream bank stability and sediment load reduction • Restore wetlands and riparian forest to act as buffer, slow run-off to increase base flows, and intercept sediment and pollutant loads
Greenwich Township and Logan Township	• Historic tidal wetland converted to freshwater habitat. • Extensive invasive species	• Restore tidal flows • Create habitat diversity	• Alter tide gate operations in conjunction with other flood risk management actions • Removal of dense *Phragmites* stands and restoration of plant diversity

2.0 Screening of Measures

A more detailed review under the criteria of completeness, effectiveness, efficiency and acceptability of measures was conducted for each of the study area communities. Description of these criteria is provided below. 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. (See Section 3: Community Evaluations for this discussion).

Each measure that was recommended for further study was assigned to (a) this Federally-cost shared flood risk management study; (b) other Federal flood risk management plans, such as those prepared by FEMA; and/or (c) the FPMP. Measures that have been assigned to the Federal flood risk management plan may be implementable under current Corps authorities. Measures that have been assigned to the non-FPMP are those for which it was determined that sufficient authority for Corps participation does not exist. An overview of the evaluation is presented below; additional details on measures recommended for further evaluation can be found in the community-specific matrices contained in Section 3: Community Evaluations.

2.1 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 paragraphs discuss each of these criteria and identify some potential issues considered in the evaluation of the various alternative measures. Where pertinent, changes in environmental regulations, land use, and Corps engineering standards and policies were noted that may alter the conclusions presented in the 1984 *Delaware River Basin Study Survey Report*.

2.1.1 Completeness

Completeness is the extent to which any alternative accounts for all necessary investments or other actions necessary to achieve the expected benefits. While the plans presented are generally technically complete, environmental regulations are likely to require mitigation for negative environmental effects and for induced flood impacts. The screening of alternatives recognizes that it is necessary to offset any loss of wetlands or in-stream habitats. This includes potential water temperature impacts if levee, floodwall or channel modification plans require the removal of trees and other vegetation. In addition, many of the areas along the river and canal are used as parkland or open space. Some of the structural measures may require “diversion” of parkland along the river. This diversion of use may require mitigation or replacement.

The assessment of flood detention reservoirs was based on prior evaluations that did not incorporate current dam safety requirements or water supply and power needs. Detailed assessments of the PMF and requirements to address design uncertainties and to ensure reliable performance may reduce the available storage estimated in prior reports by five to ten feet, possibly more at some locations. These requirements will make implementation of flood risk management reservoirs even less effective than evaluations in prior reports indicated.

For the line of protection (levee/floodwall/barrier) alternatives, the residual interior drainage flood risks are not fully integrated into the initial screening assessments. While some allowances for the cost of interior drainage have been included, current approaches to hydrologic modeling and development of interior drainage protection plans may identify extensive interior flood damages that require additional outlets, detention storage, or pumps to mitigate. Such features may significantly alter the screening assessments. (Interior drainage needs were modeled later during Phase 4 of plan formulation.)

In some areas existing structures (although not federally certified landforms), such as canal embankments or locally built berms, have become depended upon to act as a levee providing a line of protection from Delaware River flooding. For more frequent events, these existing structures are depended upon to provide protection from direct flooding from the Delaware River. Several communities have requested consideration of flood closure gates to prevent Delaware River flood stages from backing up through smaller creeks, rivers and storm drains into the communities. In some cases, the elimination of flooding on the landward side of these structures may increase the hydrostatic forces on the structure. As an increase in forces could result in damage or collapse of the existing structure, the use of flood closure gates without identifying and addressing potential stability concerns is not considered a complete solution.

At some locations, various types of FEMA flood or hazard mitigation funds may have been used to acquire properties subject to flood damage. The use of FEMA funds for these properties includes deed restrictions that would preclude the use of the property for structural flood risk management. Because the initial screening analysis has not attempted to identify any conflicts with such properties, there is a possibility that the structural alignments are not implementable without considerable revision.

2.1.2 Effectiveness

Effectiveness is the extent to which any alternative addresses the problems and opportunities. The nature of flood problems in each community have not changed significantly since the prior reports were completed, though more recent flood events have increased community awareness of the flood risks. In general terms, the different measures considered for this screening vary in their effectiveness in addressing flood problems. Some of the structural measures, such as levees and floodwalls, seek to fully eliminate flooding from most events and avoid damage to both property and infrastructure and to avoid disruption of the community. Other measures, such as flood warning systems, are effective in reducing risks to life and easily moved property (cars and furnishings), but do not address the damage to building and infrastructure. The limitations in effectiveness are considered in the evaluation of various measures.

Future detailed assessments of effectiveness for the current study will be based on updated analysis of flood frequency, hydraulic flow lines and flood risk management. In order to comply with current Corps guidance regarding risk and uncertainty (R&U), each of these assessments now require explicit consideration of the uncertainty, or level of confidence, in the data. The various uncertainties will be incorporated into the Flood Damage Reduction Analysis (HEC-FDA) model and used to calculate the expected damage, confidence bands and the risk-based reliability. Such risk-based assessments typically include long-term risks and conditional non-exceedance assessments.

2.1.3 Efficiency

Efficiency is the extent to which each alternative represents a cost-effective use of resources. The primary measures of efficiency on a Federal project are the net NED Benefits, NER benefits and the BCR. The procedures to evaluate NED benefits have changed dramatically since the prior studies. The introduction of R&U into the analysis has in some cases resulted in higher annual damage estimates, and in some cases, lower optimized levels of protection. Nonstructural measures such as building retrofits or acquisition are typically cost-effective for structures with a high average annual probability of significant flood damage. For areas where nonstructural measures appear technically feasible and implementable, the assessments evaluate protection limited to a range of floodplains, including areas with a high frequency of flooding. The existing and future level of risk management provided by any existing embankments or landforms will be examined. However, since the embankments and landforms were neither constructed nor maintained for flood risk management, and are highly unlikely to meet such standards, it is not expected that their existence will reduce the cost-effectiveness of measures.

2.1.4 Acceptability

Acceptability is a measure of the implementability of each alternative with respect to support by the State and local entities and the public and the compatibility of the plans with existing laws, regulations and policies. The greatest concern about acceptability is the potential for levee/floodwall measures to have a negative impact on community character by cutting off the physical and visual connection to the river.

Other potential acceptability issues are related to the possibility of potential fatal flaws in the environmental permitting process or an inability to obtain the necessary lands, easements or relocations. At this time there is insufficient information to identify any such fatal flaws.

2.2 Regional Alternatives

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. Table 2.1 provides additional discussion of the completeness, effectiveness, efficiency, and acceptability of these measures.

Regional-scale structural measures such as dams and major detention basins have been evaluated under previous Corps studies. In 1962, after the 1955 flood of record, Congress authorized the construction of the Tocks Island Dam on the main stem of the Delaware River, just north of the Delaware Water Gap. The dam was designed to control water levels for hydroelectric power generation, reduce downstream flooding, and create a 37-mile long reservoir in the center of the newly created Delaware Water Gap National Recreation Area. 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 deauthorized the Tocks Island Dam Project.

Impoundments are areas behind dams used to collect and store floodwaters, for later release at gradual, non-damaging rates. The 1984 Corps of Engineers *Delaware River Basin Study Survey Report* described efforts to identify and screen impoundment sites in the basin. The report states:

> *"U.S. House [of Representatives] Document 522, 87th Congress, 2nd Session reports on investigations of impoundments which ranged from runoff management in the uppermost headwaters through small detention reservoirs in the intermediate upstream areas to major impounding reservoirs on the principal water courses. For the entire Delaware River Basin, a total of 386 small and 193 major dam and reservoir sites were identified. Of those, 70 sites met minimum storage criteria of 20,000 acre-feet. Work since 1962 has resulted in the identification of 37 more project variations or sites increasing the total to 107. All of these sites were once again considered. This consideration was given not only to traditional flood water impoundment, but also to off-line flood or high-flow skimming."*

The report evaluated all forms of impoundments, including increasing flood control capacity, addition of flood control storage at new or existing multipurpose and single purpose projects, dry dams, permanent pool projects and off-line flood skimming. The report stated, "From the beginning it was obvious that the difficulty with impoundments lies in developing enough control to significantly lower stages along the main stem of the Delaware River without use of a main stem reservoir". Recognizing the impediments to implementing main stem reservoirs (as seen with the Tocks Island Dam Project), main stem impoundments were not considered further. Screening criteria were developed to evaluate the 107 sites and were described in the report:

1. Project should be located above the City of Trenton, NJ to be considered as having any real contribution to the study area. Below Trenton, floods are causes by a combination of fluvial and tidal influences.
2. Projects should have a minimum of 20,000 acre-feet of storage available for flood control. Conventional storage projects should control a minimum drainage area of 50 square miles which is currently uncontrolled. Projects were considered further if the potential exists to pump water into the reservoir and, therefore, control a much larger drainage area.
3. Projects will not be located on Federal or state-designated scenic rivers or protected areas, nor on the main stem of the Delaware River.
4. Projects which are part of the DRBC Level "B" Comprehensive plan, and are designated for water supply, are considered unavailable to provide protection unless they have additional capacity to add-on flood control.
5. Projects cannot require such an "extensive" relocation of major roads, railways, or structures which makes them "obviously" economically infeasible.
6. Environmentally and socially sensitive areas would not preclude further consideration in itself but would reinforce other negative findings. However, sites which have been previously eliminated or deferred for environmental, social, or cultural reasons will automatically be eliminated.

7. Projects cannot be economically feasible as a single purpose flood control project if they are already infeasible as a flood control component of a multipurpose project. The advantages of a multipurpose project would preclude this; however, the concepts were reviewed for any abnormal situations.

Following the application of these criteria to determine suitability for flood control, only the Aquashicola and Cherry Creek project locations in Pennsylvania remained. Aquashicola was found to have a relatively small capacity and would only control Lehigh River flows entering the Delaware River at Easton, PA, well below much of the study area. It was therefore eliminated from further consideration as a means to reduce main stem flood damages. Cherry Creek was an off-line flood-skimming project requiring main stem diversions by pumping stations and tunnels, and was eliminated because of its small flow reduction potential and prohibitively high costs. (Corps of Engineers, 1984)

In light of these findings from this previous detailed study effort, no additional evaluation of impoundment sites was conducted as part of the Interim Feasibility Study for New Jersey.

2.2.1 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.

2.2.2 Reservoir Management

Reservoir management improvement efforts are also recommended for continued development. 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.

Table 2.1: Evaluation of Regional Alternatives (Entire Study Area)

	Evaluation Criteria			
Regional Alternatives	**Completeness**	**Effectiveness**	**Efficiency**	**Acceptability**
Flood Warning Systems	While many of the communities have active flood warning systems (FWS) in place, other communities have indicated that they would benefit from an improved warning system. The FWS requires a long-term commitment to operations and maintenance and active response at times of flood threat. A FWS is also an important element of an effective structural plan, providing the warning necessary to deploy closure structures and ensure proper staffing.	As a stand-alone measure, flood-warning systems contribute to improved public safety and some reduction in damages. Many other damages will not be addressed and it is likely that communities will face difficult periods of post-storm recovery.	An enhanced FWS has comparatively low costs, can be highly cost-effective and is complimentary to many other flood risk management measures.	There are no known issues with enhancing the existing FWS.
Multi-Use Reservoir Management	The existing reservoir system on the Delaware River serves several different purposes including water supply, power generation, recreation, and flood risk management. The reservoirs developed strictly for flood risk management purposes control too small a proportion of the drainage area to provide significant flood relief to communities in New Jersey. Changes in the allocation of reservoir storage to provide for additional flood risk management will require constant monitoring to ensure that all of the sometimes-competing water resource needs are met.	The effectiveness in changes to the allocation of reservoir storage to provide for additional flood risk management will vary depending on specific storm and storage conditions. Because the specific purpose of the large New York City reservoirs is to provide a reliable source of drinking water to millions of people, additional flood storage can only be allocated on a temporary basis when projected future inflows are sufficient to meet water supply needs. Therefore, there is no guarantee that flood storage will be available when needed.	Improvements in the management of reservoir storage are likely to be the most efficient of the entire range of measures available to provide flood risk management and to address the full range of water resource needs.	Communities in the study area appear to support the concept of multi-use management of the reservoirs. The allocation of capacity for flood storage, however, must not interfere with the storage necessary to meet the primary goals of the reservoirs.

2.3 Structural Measures

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 conducted in Section 3: Community Evaluations. A summary of the evaluation results and recommendations for further study (if warranted) are provided in the sections below. In cases where structural lines of protection (LOPs) may be indicated, concept- level plans were developed to provide "order of magnitude" annual cost estimates. These costs were compared against the AAD of buildings that would be protected to determine a "potential benefit-cost ratio" to see if further evaluation is warranted.

2.3.1 Backflow Prevention Structures

In much of the study area, a primary concern is the flow of Delaware River floodwaters directly up stormwater pipes, or up a tributary, and then into the stormwater infrastructure. Consideration will be given to the applicability of installing flap gates on the end of storm drains to allow only the one-way flow of water and limit inundation upward through the stormwater system. It should be noted that the Corps typically cannot financially support work on local stormwater systems.

Backflow prevention structures are appropriate for use in cases where there is constructed or natural high ground between the river and the locations to be protected or where levees/floodwalls are being considered. In many study area locations, high natural stream banks or rail, roadway or canal embankments have been serving as such a line of protection, though they were not designed or maintained for flood risk management. A functioning LOP would prevent floodwaters from the main stem of the Delaware River from entering tributaries and adjacent low-lying areas, and allows the installation of flap gates, floodgates, backflow prevention valves, and pumping equipment necessary for interior drainage of tributaries during main stem flooding conditions. As gates and other backflow prevention devices create additional flow resistance and may result in an increase in flow depth, the design of backflow prevention structures requires careful consideration of hydrologic conditions in the tributaries to avoid possibilities of induced flooding. For installation of backflow prevention structures on existing storm sewers, construction of a LOP is typically not required.

In general, the Corps participates in the design and construction of backflow prevention structures as an integral part of a levee or floodwall line of protection. Projects to modify local drainage structures typically are not considered as stand-alone Corps project features unless they address a "major drainage" channel with a 10% ACE flood discharge (10-year flood) of 800 cfs or more. Installing gates or backflow prevention for local drainage, however, may be appropriate for local implementation or for other Federal programs not limited to major drainage.

2.3.2 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.

The 1984 study of the area (*Delaware River Basin Study Survey Report*) found that relatively high zero-damage flood stages, relatively steep and narrow floodplains, past individual self-help efforts and community floodplain management efforts resulted in lowering AAD and, consequently, lowering potential benefits. At the same time, older urban communities have very complex infrastructures along potential project alignments that result in very high relocation and construction costs. These factors resulted in the infeasibility of levee and floodwall protection. The current study determines whether any of these factors have changed and what the net effect is in terms of feasibility of floodwalls and levees. Additional attention will also be given to temporary structures. In addition, both levee relocation and levee replacement or repair were considered for Greenwich and Logan Townships.

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. For the communities evaluated, one or more concept-level LOPs were developed and order of magnitude cost estimates were prepared. A number of standard costs or percentages were applied to developing the cost estimates. For the Lands and Damages category, a fee value of $3,800 per acre for park and open space, public property, conservation areas and wetland was estimated. Construction of a levee or other feature on such land was estimated to have a 20% impact on the fee value, for a project cost of $670 per acre. For residential lands, the underlying fee value was estimated as $7.15 per square foot or $311,454 per acre. A similar 20% reduction in the fee value was estimated for construction of levees or other risk management features, resulting in a project cost of $62,790 per acre for residential lands.

Construction costs were prepared at the October 2009 price level. For those projects proposed for or adjacent to wetlands, rivers, parks, or potential Green Acres properties, a mitigation cost of 5% of the construction cost was added. As appropriate, the mitigation cost can be increased up to 15% of the total construction cost. Planning, Engineering and Design (PE&D) costs of 15% of the construction cost were added, as well as Construction Management (CM) costs of 10% of the construction cost. There are exceptions for increases to these standard percentages for project locations with historic characteristics, such as the D&R Canal. Total project costs were annualized using a period of analysis of 50 years and the FY2011 Federal discount rate of 4.125%.

A comparison is provided between the estimated annual costs of the structural measures and the AAD of the buildings protected for the calculation of an initial screening BCR. The actual benefits to buildings from the concept-level LOP have not been calculated in the HEC-FDA computer program in this phase of the study. HEC-FDA (HEC-Flood Damage Analysis) is a Corps-developed program for estimating flood damages, and incorporates risk analysis methods to address uncertainty of key data, parameters, and functions into project benefit and performance analyses. Table 2.8: Concept-Level Plans-Estimated Costs for Lines of Protection (included in Section 2.6) provides a summary description of the various structural alternatives evaluated and estimated costs. All costs should be considered preliminary estimates only, and subject to future revision. In addition, the estimation of AAD does not incorporate any level of risk management from existing features such as levees and canal embankments; however, since the landforms were neither constructed nor maintained for flood risk management, and are highly unlikely to meet such standards, they are not expected to have major impact on the AAD. Any structural measures with positive initial screening BCRs at this stage will be further evaluated to document the maintenance, history of performance and structural integrity of the existing features. BCR values need to be greater than 1.0 to be considered cost-effective. (As per Corps guidance, the initial screening BCR values shown below are shown to one decimal place, unless the value is between 0.9 and 1.1. In these cases, values are shown to two decimal places). In this study, an initial screening BCR of 0.7 or higher is the threshold for further evaluation. Site number references are provided in parentheses to cross-reference with Table 2.8: Concept-Level Plans: Estimated Costs for Lines of Protection. References for the figures provided in Section 3: Community Evaluations are also provided below.

Knowlton Township: The estimated annual cost of a 4,000 linear foot (LF) floodwall to protect 31 structures along the Delaware River is $910,000, and the AAD of those buildings is $57,000 (Site 1; see Figure 3.4). The initial screening BCR is below 0.1, and thus clearly not cost-effective, and thus there would be no Corps or other Federal program support for such an alternative.

Phillipsburg: A 700 LF floodwall for the right bank of Lopatcong Creek to protect 16 structures would have an estimated annual cost of $340,000 in comparison to AAD of $18,000 (Site 2a). The initial screening BCR is below 0.1 and thus there would be no Corps or other Federal program support for such an alternative (See Figure 3.15). A concept-level plan to construct a 1,725 LF ringwall to protect the municipal wastewater treatment plant (WWTP) on the left bank was prepared. (See Figure 3.15). The ringwall at the WWTP is estimated to have an annual cost of $630,000 (Site 2b). An estimation of the AAD of the WWTP has not been made at this phase in the study, and would be required for further evaluation of this alternative. An evaluation will also be needed to determine whether construction of a ringwall at the WWTP would increase water levels on the right bank of Lopatcong Creek, and if so, whether the higher levels would increase damages on that bank. If damages on the right bank would be increased substantially, additional measures may be necessary to mitigate induced flooding.

Frenchtown: A 7,000 LF floodwall (Figure 3.22) on top of the existing bicycle path and embankment was estimated to have annual costs of $810,000 (Site 3). The AAD for the 117 buildings behind this LOP is $141,000, producing an initial screening BCR of 0.2. This alternative is unlikely to be cost-effective and thus there would be no Corps or other Federal program support.

Stockton: Costs were estimated for providing an upgraded line of protection of 5,400 LF (Figure 3.27) using the Delaware & Raritan Canal embankment (Site 4). This measure would have an estimated annual cost of $350,000 in comparison to AAD of $359,000 for the 115 buildings behind this LOP (Site 4). The initial screening BCR is 1.03, which indicates the measure is potentially cost-effective and highlights the need to refine construction costs and

AAD. The existing and future level of protection provided by the canal embankment will be examined. However, since the embankments were neither constructed nor maintained for flood risk management, and are highly unlikely to meet such standards, it is not expected that their existence will reduce the BCR.

Lambertville: Construction of a 590 LF levee segment to protect against Delaware River backwater at Alexauken Creek was evaluated in combination with an 810 LF floodwall segment along the D&R Canal (Figure 3.30). The estimated annual cost of the measure is $210,000, and it would provide protection to 38 buildings with AAD of $610,000, plus an unquantified amount of infrastructure (Site 5). If the existing embankments are stable, this measure could be highly cost-effective with an initial screening BCR of 2.9. This measure should be further evaluated for inclusion in the Federal flood risk management plan. In other sections of Lambertville, such as the downtown, development is so close to the river or canal that it would be difficult to construct an effective line of protection without substantial impacts to the community character. In addition, due to the narrow and steep riverbank between the properties on Lambert Lane and the river, it is unlikely that there is sufficient area for easements for construction and operation, as well as room for the alignment in supportable soils. Thus, no structural measures that are considered reasonably implementable were identified for Corps participation in the central and southern portions of the community, where the majority of flooding damages occur.

Ewing Township: There is an extensive area of floodplain to the east of Route 29, which follows the river (Figure 3.35). The roadway provides protection against flooding from the Delaware River under a wide range of flooding conditions, with the majority of flooding stemming from the river backing up storm sewers. However, during high flood stages such as 1% ACE (100-year), this section of the road can be overtopped. A 7,700 LF floodwall with an estimated annual cost of $1,450,000 could provide protection to 146 buildings with AAD of $640,000 (Site 6). This alternative has an initial screening BCR of 0.4. If Route 29 is expected to provide any significant level of protection in the future, the LOP would be further reduced. This alternative does not meet the initial screening BCR threshold of 0.7 for further Corps evaluation.

Trenton - Glen Afton and The Island: A concept-level line of protection was evaluated for the Glen Afton and The Island sections of Trenton (Site 7a.1; see Figure 3.40). A permanent 7,280 LF T-wall reaching a height of 13 feet above grade would have an estimated annual cost of $2,820,000 and would provide protection to 287 buildings with AAD of $1,463,000. This would produce an initial screening BCR of 0.5, and thus this alternative does not meet the initial screening BCR threshold of 0.7 for further Corps evaluation.

Because visual and physical access to the river are important parts of the community character, the possible use of a portable flood defense system for a portion of the line of protection was investigated. Assuming a mix of 60% permanent floodwall interspersed with removable sections (40% total), this alternative would have higher annual costs of approximately $4.2 million, due to offsite storage requirements, maintenance, and installation (Site 7a.2). These higher costs would produce an initial screening BCR of 0.3. This alternative does not meet the initial screening BCR threshold of 0.7 for further Corps evaluation.

In addition, estimated costs were obtained for installation of permanently installed, deployable flood barrier (known as a FloodBreak barrier) in this location (see http://www.floodbreak.com for more information). If employed in the Glen Afton/The Island section of Trenton, this system would have the advantage of not blocking access or views to the Delaware River during non-flooding conditions.

The design alternatives for the FloodBreak barrier were for an installation that would reach 5 feet above the ground when deployed (which would slightly exceed the water levels during the 2004-06 floods), and an alternative that would reach 13 feet high. This higher alternative is assumed to provide 1% ACE (100-year) protection, and for preliminary cost estimation purposes, a 3-foot allowance for freeboard. (A risk and uncertainty analysis would be required to determine the actual required additional allowance). For a 7,280 LF deployable barrier, estimated annual costs, including installation, are:

- Site 7a.3: 5 feet above grade (deployed height), vehicle-load coating: annual cost of $1,380,000 versus without project AAD of $1,463,000
- Site 7a.4: 5 feet above grade (deployed height), pedestrian-load coating: annual cost of $810,000 versus without project AAD of $1,463,000
- Site 7a.5: 13 feet above grade (deployed height), vehicle-load coating: annual cost of $3,570,000 versus without project AAD of $1,463,000

The initial screening BCRs for these measures are:

- Site 7a.3: 5 feet above grade (deployed height), vehicle-load coating: 1.06
- Site 7a.4: 5 feet above grade (deployed height), pedestrian-load coating: 1.8
- Site 7a.5: 13 feet above grade (deployed height), vehicle-load coating: 0.4

The different deployed heights above grade provide different levels of flood risk management. The typical approach to risk management within the Corps is to identify the NED alternative, which maximizes net economic benefits from risk management. Life safety and local preferences (as expressed in a Locally Preferred Plan alternative) are also major considerations in the planning process. Consideration of these factors may lead to recommendation of a level of protection higher or lower than the NED Plan. If a demonstration can be made that a catastrophic loss of life may occur at levels of flooding higher than addressed by the identified NED plan, a higher level of protection may be authorized. For example, the plan providing maximum NED benefits may provide protection at the 2% ACE (50-year) level for a specific area, but if the potential loss of life at the 1% and 0.2% ACE levels (100-year and 500-year) is determined to be catastrophic, there is a basis for extending the level of protection to the higher level.

Conversely, a local community may wish to select a lower level of protection, or opt for temporary versus permanent flood protection, to reduce impacts to community character, maintain access to riverside areas, or reduce visual effects from a larger or permanent structure. In such a case, the community must be made aware of residual risk, and adopt appropriate institutional measures during flooding. For example, during flooding conditions the community and its leadership would need to act as though no risk management features had been installed, and conduct necessary measures such as evacuation. Because of a risk of structural failure, the resulting inundation of areas behind the risk management feature would likely be more rapid than would have occurred without the feature. Examples include floodwall overtopping and slippage of temporary barriers due to underseepage and lateral hydrostatic pressure. These alternatives will be further evaluated as part of the Federal study to determine the level of protection provided, particularly at the 5-foot height above grade.

Trenton - Downtown: In downtown Trenton, Route 29 provides a nearly complete line of protection to extensive development (Figure 3.41). The flood risk management provided by Route 29 is a beneficial impact, but was not specific to the primary project construction purpose of providing a roadway for transportation needs. However, there is a low-lying section that leads to flooding of adjacent buildings, including several State-owned facilities. As shown on the effective FIRM, there is an additional low-lying area on US Route 1 at Bridge Street (approximately 150 feet) that allows floodwaters to contribute to inundation of the area south of Route 1 and east of Route 29. (This area borders the property adjacent to the low-lying section of Route 29). The area includes sections of Ferry Street, Lamberton Street, Bridge Street, Power Street, Asbury Street, and Union Street. During floods, the gaps in this protection could be eliminated using portable floodwalls placed on permanent installed foundations. Approximately 525 LF of portable floodwall would be required. Annual costs for this alternative (Site 7b.1) were estimated at $120,000, assuming good foundation conditions and no extensive traffic maintenance requirements.

In addition, this protection could be provided by using a deployable, buoyant flood barrier, such as the FloodBreak system. A single, 150 LF long barrier with a deployed height of six feet high above ground, with the vehicle-load coating could be constructed at the US Route 1/Bridge Street location for approximately $50,000 annual cost (Site 7b.2). At the Route 29 location, a deployable barrier could be built in a single 400 LF section, with a deployed height of six-feet above ground and the vehicle-load coating for approximately $110,000 per year (Site 7c.1); or in two sections of 130 and 120 LF each with permanent berm in between for $60,000 (Site 7c.2). Thus, annual costs for protection in this area would range from $110,000 to $160,000, depending on the type of treatment selected. However, as described below, the AAD for structures in this reach is extremely low at $2,400. Thus, the initial screening BCRs for these measures are well below 0.1 and thus they are not recommended for further Corps evaluation.

The initial evaluation of flooding conditions in downtown Trenton was based on FEMA Q3 floodplain mapping (based on effective FIRMs, dated 10/15/1981 and 2/02/1990, by panel). The AAD data and subsequent analysis of structural and nonstructural measures, however, is based on flood elevation modeling FEMA and the State of New Jersey have prepared for creation of DFIRM. In downtown Trenton, many of the buildings shown to be within the 1% ACE floodplain (100-year) on the Q3 mapping have first floor elevations above the 1% ACE floodplain elevation in the DFIRM data. Thus, the AAD for these buildings is very low. Because of the low cost-effectiveness of these measures, they are not recommended for further evaluation as part of a Federal flood risk management plan.

Greenwich and Logan Townships: In Gloucester County, the community of Gibbstown in Greenwich Township has approximately $131 million of floodplain development and as of 2015 depends on flood risk management from the Delaware River by a non-certified levee initially constructed in the early 1800's for agricultural purposes that was estimated by the Corps in 1968 to provide a 10% to 7% ACE (10-14 year) level of protection against storm surge.

There may be hazardous waste contamination in or near the levee due to former industrial activities. The northern parts of the levee are located on property owned by the DuPont and Ashland/Hercules corporations. As of 2015, some remediation has been done on the Ashland/Hercules site. The DuPont property, known as the Repauno Facility, is a listed Superfund site. Contamination within the site is being effectively held in place through use of a groundwater interceptor and treatment system installed in 1985 and in use since. No remediation work is being conducted on the levee itself in 2015.

The levee extends downstream into Logan Township. Ownership of the portion of the levee within Logan Township is in question. It appears that some residents are unaware that their property contains a portion of the levee, and the levee alignment is not always clearly marked on the municipal tax maps.

It is also uncertain whether the previously identified level of protection provided by the levee is still accurate. To the north of Gibbstown, high storm surge into Mantua Creek can flood through the Borough of Paulsboro southward into Gibbstown. The concept-level line of protection developed for the screening includes a new levee and flood wall extending northward from high ground near Floodgate Rd, along the west side of Gibbstown until reaching high ground in Paulsboro. (See Figure 3.46). An additional levee/floodwall segment is included along Mantua Creek. Such an alignment would protect 805 buildings in Gibbstown at an estimated initial cost of $78.4 million, with an average annual cost of $3,730,000 (Site 8). The AAD for buildings behind this LOP is $12,582,000. With an initial screening BCR of 3.4, this LOP should be further evaluated in the Federal study. Damage amounts should be refined to reflect protection from the existing levee. Initial borings along the existing levee show that it would not be acceptable based on Corps criteria. A continuous impervious portion (e.g.; clay core or shell) is typically required for the length of a levee structure. The existing foundation of organic soils and loose to medium density sands with interbedded sandy gravel layers does not comply with current standards for stability or seepage. The organic soils are prone to settlement, which can cause voids in the levee and lead to seepage or settlement of the crest, which may lead to overtopping or cracking of the levee. Loose to medium density sands with sandy gravel lenses in the foundation allows for seepage under the levee, which can lead to flooding or piping of levee materials, causing a failure of the levee. These existing materials, in addition to the lack of regular maintenance, lead to the conclusion that the levee, as is, cannot be counted on to provide flood risk management to Corps of Engineers standards.

Some additional costs may be needed for gates and/or pump stations at the larger creek crossings; however, detailed interior drainage analysis would be needed to quantify the size and cost of such structures. A number of homes and several industrial properties located outside of this line of protection would require some sort of nonstructural flood risk management measure such as elevation or a ring levee. The LOP alignment as presented would also protect buildings in the adjoining community of Paulsboro; however, the AAD for these structures has not been calculated. Several alternative alignments have been developed to protect areas of Gibbstown only. The length and cost of these alignments is expected to be similar to the $78.4 million cost described above. Table 2.2 provides a summary of potential Federal interest for additional investigation of the structural measures described.

Table 2.2: Potential Federal Interest for Additional Investigation of Structural Measures

Town	Structural Protection	Suitable for Additional Corps Investigation	Initial Screening Benefit-Cost Ratio (BCR)	Notes/Assessment
Knowlton Township	4,000 LF T-wall floodwall with levee tie-off	No	0.1	Unlikely to be cost-effective. No further evaluation recommended.
Town of Phillipsburg	700 LF T-wall floodwall at Lopatcong Creek	No	<0.1	Unlikely to be cost-effective. No further evaluation recommended.
	1,725 LF ringwall (T-wall floodwall) at Wastewater Treatment Plant (WWTP)	Yes	--	Need to quantify AAD at WWTP.
Frenchtown Borough	7,000 LF floodwall along bike path (sheetpile-supported I-wall)	No	0.2	Unlikely to be cost-effective. No further evaluation recommended.
Stockton Borough	Reinforce canal bank along 5,400 LF - Elevate bank height; assume 50% of a new levee	Yes	1.03	Possibly cost-effective. Refine damage/benefit assessment for concept-level Line of Protection (LOP) layout and costs. Benefit-cost ratio (BCR) assumes no protection from D&R Canal embankment, which was not constructed nor maintained for flood risk management and highly unlikely to meet standards for that purpose.
Lambertville	590 LF levee at Alexauken Creek and 810 LF floodwall at D&R Canal	Yes	2.9	Likely to be cost-effective. Refine damage/benefit assessment for concept-level Line of Protection (LOP) layout and costs.

(Continued): Potential Federal Interest for Additional Investigation of Structural Measures

Town	Structural Protection	Suitable for Additional Corps Investigation	Initial Screening Benefit-Cost Ratio (BCR)	Notes/Assessment
Ewing Township	7,700 LF T-wall floodwall with levee tie-off	No	0.4	Unlikely to be cost-effective. BCR assumes no protection from Route 29, which was not constructed nor maintained for flood risk management and highly unlikely to meet standards for that purpose. No further evaluation recommended.
Trenton (Glen Afton/The Island)	7,280 LF flood barrier (various treatments with range of BCRs. BCR shown for 13-ft. fixed floodwall)	Yes	0.5; other alternatives have higher BCRs	Possibly cost-effective. Refine damage/benefit assessment and concept layout/costs.
Trenton (Downtown)	Flood barrier (various treatments)	No	<0.1	Unlikely to be cost-effective. Few buildings in downtown Trenton are below 100-year floodplain elevation. No further evaluation recommended.
Greenwich and Logan Twps. (Gibbstown)	25,000 LF Levee/floodwall; 40% T-wall floodwall	Yes	3.4	Likely to be cost-effective. Refine damages to reflect protection from existing levee, which was not constructed nor maintained for flood risk management and highly unlikely to meet standards for that purpose.

2.3.3 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.

As was noted in the 1984 *Delaware River Basin Study Survey Report*, 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. For channel modification to be effective in lowering flood profiles at the flood damage areas, modifications would have to extend well beyond the actual damage reach. Channelizing only portions of the river would move floodwaters more rapidly downstream, thereby accentuating problems in affected areas. In many instances, the proximity of developed property to the riverbank would require the acquisition of some of that property considered for protection. The possible adverse environmental effect of extensive channel modifications on fish and wildlife, as well as on the conservation and recreation potential of the river are additional factors that must be considered. As in 1984, consideration of these factors leads to the elimination of channel modification for the main stem Delaware River as a viable alternative measure for flood risk management. Modifications to increase the capacity of tributaries will have no impact on flooding caused by high Delaware River stages and none have been identified for continued Corps study. Channel modification to reduce flooding on major tributaries could be considered for other Federal programs or local implementation.

2.3.4 Dams or Flow Detention

In 1984, the use of flood risk management projects including dry dams on Delaware River tributaries was investigated in the Delaware River Basin study. (See Section 2.2, Regional Alternatives, for previous discussion of dams and flow detention). 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. With regard to the main stem of the river, the Delaware is the longest undammed river east of the Mississippi River, traveling 330 free-flowing miles from its headwaters in New York State down to the Atlantic Ocean. 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 deauthorized 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.

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. The continued or expanded use of stormwater management facilities, such as detention and infiltration basins, on the Delaware River tributaries should be strongly supported to reduce flooding along the tributaries.

2.3.5 Dams Removal

The Delaware River is a free-flowing waterbody, and thus dam removal is not applicable to the main stem. There are, however, dams on some tributaries and 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). The dams may also keep the channel from accommodating more of the backflow of floodwaters from the Delaware River. Please see the discussion of Belvidere, NJ in Section 3: Community Evaluations.

2.4 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, building retrofit measures, and land acquisition measures. In Tables 5.44 and 5.45, a general evaluation of nonstructural measures is presented. If applied, nonstructural measures would be broadly the same in nature across the study area communities, varying mainly in the number of structures treated, the selection of specific treatments and in the case of regulations, and the manner of application. Further information on the building retrofit measures at the community level are provided in Section 3: Community Evaluations.

2.4.1 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. A review of specific land use and regulatory measures is provided below. Table 2.3 provides the criteria screening of land use and regulatory measures, and is followed by additional discussion of each measure and a recommendation for inclusion in further screening.

Table 2.3: General Evaluation of Nonstructural Measures (Land Use/Regulatory) for Study Area Communities

Nonstructural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Land Use/Regulatory				
Zoning/Land Use Controls	Limits new development/redevelopment in at-risk areas. Requires local adoption and enforcement of enhanced controls.	Technique would not reduce flood risk for existing structures; potentially very effective for new development. Less applicable in built-out areas.	Reduces or eliminates future development in at-risk areas at relatively small costs.	Would require adoption at local level, beyond existing controls. Likely to vary by location.
New Infrastructure Controls	May require secondary controls on new development that does not connect to municipal infrastructure.	Could limit or eliminate new construction in at-risk areas. Would not reduce flood risk for existing structures. Less applicable in built-out areas.	Reduces municipal infrastructure spending (cost avoided), precludes development and thus risk in hazardous areas. Likely to lower property values in subject areas.	May be challenged by property owners with buildable land in subject areas. May reduce or eliminate new growth, with effect on municipal tax base. May adversely affect property values in at-risk areas and be subject to legal challenge.
Landform/Habitat Regulations	Limits new development/redevelopment in at-risk areas. Requires local adoption and enforcement of enhanced controls.	Technique would not reduce flood risk for existing structures; potentially very effective for new development. May provide significant habitat protection. Less applicable in built-out areas.	Restricts impacts to natural buffer areas, such as floodplains or riverbanks, which have risk management value. May lower property values.	May be challenged by property owners with buildable land in subject areas. May reduce or eliminate new growth, with effect on municipal tax base. May adversely affect property values in at-risk areas and be subject to legal challenge.

(Continued): General Evaluation of Nonstructural Measures (Land Use/Regulatory) for Study Area Communities

Nonstructural Measures.	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Construction Standards & Practices	Would require change in law and approval and adoption at local or state levels, as appropriate.	Would reduce risk of damage to new or redeveloped structures by mandating appropriate construction methods for relevant risks. Would not reduce flood risk for existing structures.	Can be very cost-effective for reducing risk to new or redeveloped structures. Small increase in construction costs can greatly reduce risk of future damage.	Standards would have to recognize presence of historic structures. Increased costs of construction to meet standard may meet resistance.
Insurance Program Modifications	Requires change in authorizing legislation for NFIP (Act of Congress); not within authority of Corps to modify.	Could reduce new construction in at-risk locations, promote retrofit/relocation of repetitive loss properties. Not all at-risk properties are insured under NFIP.	Has not been evaluated; could work to reduce number of repetitive loss properties. May reduce construction and risk in flood hazard areas. Efficiency varies; some approaches may be a transfer payment and not a true NED benefit.	Increases in NFIP premiums (e.g., change to actuarial risk for pre-FIRM properties) likely to meet public resistance.
Tax Incentives	Would require change in law and approval and adoption at local, state, or Federal levels, as appropriate.	May promote retrofit of at-risk buildings or donation of at-risk property (e.g., for open space use).	Majority of land in study area floodplain is already developed; efficiency may be high for retrofit or future damages avoided through land donation.	If incentives are voluntary, likely to be accepted by property owners interested in land donation or structure retrofit.

Zoning and Land Use Controls: Zoning and land use controls are effective tools in reducing the potential for damage to new development and redevelopment while achieving the additional objectives of preserving natural resources and recreation access. While the State of New Jersey and all of the study area communities have adopted many codes and regulations to limit development in hazard areas, additional opportunities may exist. However, some of these such as lot setback requirements, height restrictions and other zoning criteria could create constraints to relocating or elevating existing structures to reduce flood damage. Flood risk management could be recognized as a valid reason for zoning variances. 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 FPMP. As explained in Corps Policy Guidance Letter (PGL) No. 52, the "non-Federal FPMP should: (1) implement measures, practices, and policies which will reduce the loss of life, injuries, damages to property and facilities, public expenditures, and other adverse impacts associated with flooding, (2) preserve and enhance natural floodplain values, and (3) address measures which will help preserve levels of protection provided by the Corps flood damage reduction or hurricane or storm damage reduction project."

Based on community input, the development of the FPMP could consider a range of new or revised zoning and land use controls. Where existing programs are considered sufficient, the communities or other local implementing authorities may simply wish to continue the current regulatory practices.

New Infrastructure Controls and Landform/Habitat Regulations: New infrastructure controls and landform/habitat regulations have similar effects in limiting additional development in specific hazard areas. These measures are considered most effective in achieving the objectives in areas with the greatest potential for future development. 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. Based on community input, the development of the FPMP could consider new or revised initiatives. In other cases, the existing programs may be considered sufficient in light of possible implementation constraints.

Construction Standards and Practices: Construction standards and practices are important in reducing the potential damage to new construction. The objectives could be achieved both through adopting new construction standards and improving compliance with current standards. Both of these efforts require action by individual communities and are recommended for consideration in developing the FPMP. Some of the types of changes that could be considered include an allowance to address design uncertainties and to ensure reliable performance, and improved enforcement by providing additional support and training for building code officials. 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: Tax incentives could be effective in promoting appropriate uses of land in flood hazard areas. Unlike most land use and regulatory measures, however, tax incentives are an important component of efforts to reduce damages to existing development. Retrofitting efforts, such as relocating or raising a threatened structure, often involve a considerable financial investment that increases property values. Many homeowners are concerned that actions to reduce future damage will result in reassessment of their property. Tax policies may therefore act as economic constraints to implementation of the building retrofitting measures described below. This constraint may be eliminated or reduced through agreements not to reassess retrofitted property for some period of time. Another possible tax incentive could be the alteration of the income tax deduction for property damage. However, 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.

2.4.2 Building Retrofit Measures

The Corps' national experience has shown that a building typically has to withstand approximately $5,000 in AAD to be a cost-effective candidate for nonstructural retrofitting. This guideline is based on the calculation that approximately $4,000 in annual benefits (on the assumption that not all damage to the building is prevented) will support approximately $80,000 in project costs at the current interest rates, which is an upper-level cost for building elevation. Thus, buildings that fall below this threshold of annual damage may not be economically justified for retrofitting.

It should be noted that FEMA's NFIP regulations require that the lowest floor of new and substantially improved residential structures be elevated to or above the base (1% ACE/100-year) flood elevation. However, non-residential structures may be floodproofed below that elevation, provided that the structure is watertight, with walls that are impermeable to floodwaters. Also, Corps participation in implementation would have to follow technical document ER 1105-2-100, 3.3 b.(7), which states, "The Corps will not participate in structural flood damage reduction for a single private property. Nor will it participate in nonstructural flood damage reduction measures, unless single property protection is part of a larger plan for structural or nonstructural measures benefiting multiple owners collectively." Implementation of structure elevation could also be affected by the fact that the project sponsor has to acquire some form of interest in the property in order to be able to meet its obligation to operate and maintain the "floodproofing" aspects of the buildings.

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. Federal funding for a portion of the costs may be available through FEMA's Hazard Mitigation Assistance (HMA) grant programs, which provide funding for eligible mitigation activities that manage flood risks. FEMA administers the following HMA grant programs (further information can be found at http://www.fema.gov/government/grant/):

- Hazard Mitigation Grant Program (HMGP)
- Pre-Disaster Mitigation (PDM)
- Flood Mitigation Assistance (FMA)
- Repetitive Flood Claims (RFC)
- Severe Repetitive Loss (SRL)

The HMA programs recognize that there are substantial public costs associated with flood damage to private property, and seek to reduce both public and private expenses. Public funding, however, is subject to specific rules including cost-benefit comparisons. Additional efforts desired by local communities could be identified as part of the FPMP. Such measures could include protecting access to public safety or health facilities, such as police stations, fire stations, rescue squads, and hospitals.

The use of building retrofits may also help avoid or minimize environmental impacts by reducing or eliminating the need for structural flood risk management measures. As discussed earlier, the Corps cannot participate in nonstructural flood risk management measures for a single private property, unless single property protection is part of a larger plan for structural or nonstructural measures benefiting multiple owners collectively. A review of building retrofit measures under the four criteria of completeness, effectiveness, efficiency, and acceptability is provided below, in Table 2.4.

Table 2.4: General Evaluation of Nonstructural Measures (Building Retrofits) for Study Area Communities

Nonstructural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Building Retrofits				
Structure Relocation	New site and utility connections required. Existing site should be restored. Where possible, ecosystem restoration features should be included.	Removes building from floodplain and risk of damage. Does not reduce general flooding in area or municipal clean-up and general recovery costs (e.g., removal of vegetative flood debris and infrastructure repair).	Depends on frequency of flooding; typically not cost-effective for structures that are damaged infrequently.	May have negative effect on community cohesion and character and tax base if building is moved to different municipality.
Structure Elevation	May require variances under municipal height ordinance.	Building structure and contents will not suffer damage during floods at or below design elevation. Does not reduce general flooding in area or municipal clean-up and general recovery costs (e.g., removal of vegetative flood debris and infrastructure repair).	Depends on frequency of flooding and cost of elevation; typically not cost-effective for structures that are damaged infrequently.	May have negative visual effects on the structure (particularly if historic) or on neighborhood. May block views of river for nearby buildings.

(Continued): General Evaluation of Nonstructural Measures (Building Retrofits) for Study Area Communities

Nonstructural Measures	Completeness	Effectiveness	Efficiency	Acceptability
Structure Rebuilding	May require variances under municipal height ordinance if structure is rebuilt to the same number of stories as previous.	Building structure and contents will not suffer damage during floods at or below design elevation. Does not reduce general flooding in area or municipal clean-up and general recovery costs (e.g., removal of vegetative flood debris and infrastructure repair).	Depends on frequency of flooding; typically not cost-effective for structures that are damaged infrequently. Typically only cost-effective for structures in poor condition and/or having a specialized function incompatible with other nonstructural techniques.	May have negative visual effects on neighborhood. If rebuilt at higher elevation, may block views of river for nearby buildings.
Free-Standing Barriers	Downstream impact of displaced flooding must be evaluated; also whether any rise in floodway elevation will occur. Access must be designed according to building purpose (e.g., school or municipal office). Seepage analysis must be conducted. Requirements for interior drainage must be evaluated.	Flood risk management for building structure and contents is effective to the design depth, which is limited by hydrostatic pressure and site constraints. Does not reduce general flooding in area or municipal clean-up and general recovery costs (e.g., removal of vegetative flood debris and infrastructure repair).	Cost-effective for higher value facilities, such as wastewater treatment plants or schools. Depends on frequency and depth of flooding.	Adjacent or downstream property owners may object to displaced flooding affecting their property.

(Continued): General Evaluation of Nonstructural Measures (Building Retrofits) for Study Area Communities

Nonstructural Measures	Completeness	Effectiveness	Efficiency	Acceptability
Wet Floodproofing	Foundation stability testing required. The building may not be accessible or usable during flooding.	Does not reduce general flooding in area or municipal clean-up/recovery costs. Inundation of designated portions of structure reduces uplift from buoyancy. Appropriate only for areas with slow velocity flooding (less than three fps) and no flash-flooding.	May provide cost-effective flood risk management in areas of limited flooding depth. Efficiency is greatest in areas with frequent low-level flooding.	May have undesirable visual effects on historic properties. Typically less alteration of structure is required than with other retrofit methods. Minimal impact on adjacent properties.
Dry Floodproofing	Foundation stability testing required; determination of acceptable level of human intervention needed to install or operate devices.	Flood risk management for building structure and contents is provided to a limited depth of flooding (typically three ft. or less) due to hydrostatic pressure and uplift buoyancy forces. Does not reduce general flooding in area or municipal clean-up/recovery costs.	May provide cost-effective flood risk management in areas of limited flooding depth. Efficiency is greatest in areas with frequent low-level flooding.	May have undesirable visual effects on historic properties. Typically less alteration of structure is required than with other retrofit methods. Minimal impact on adjacent properties.
Utilities Protection	Potential visual impact on historic structures that may require additional architectural treatment; anchoring and stability of raised platforms.	May eliminate damage to utilities. Does not reduce flooding to overall structure. Does not reduce general flooding in area or municipal clean-up/recovery costs.	Depends on frequency of flooding; typically not cost-effective for structures that are damaged infrequently.	May have undesirable visual effects on historic properties. Adjacent property owners may object if utility platform is elevated on exterior of structure.

A screening algorithm of potential nonstructural retrofit measures was applied to identify an appropriate measure for buildings; further discussion of these measures is provided below, accompanied by the results of the screening and whether the resulting alternatives are suitable for further evaluation. 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 the following nonstructural retrofit measures:

- Dry floodproofing – this treatment involves fully sealing all openings and waterproofing all walls of a structure such that no part of it becomes inundated during floods.
- Wet floodproofing - this treatment allows for the inundation of lower areas of the structure but protects utilities (by elevation) and in some cases provides additional utility or living areas to compensate for usable spaces infilled or allowed to flood.
- Elevation - this treatment involves physically raising the structure such that the main floor is at or above the design elevation.
- Ringwall - this measure involves the construction of a floodwall around an individual structure or complex.
- Rebuilding - this measure requires the demolition of the structure and subsequent building of an equivalent structure within the same property boundary to the design elevation.
- Acquisition – this measure involves the purchase of the property and the removal of the structure from the floodplain through demolition. The land is then preserved in perpetuity for open space uses.

The algorithm initially assigns one of the first four measures listed above to each treated structure on the basis of engineering feasibility. Subsequently, the algorithm replaces the initially selected measure with either rebuild or acquisition if either of those two measures is estimated to cost less than the initially selected measure. To estimate the total acquisition cost for this secondary step, an assumption was made that land costs are equal to 50% of depreciated structure replacement values.

Typical retrofit treatment costs from prior projects were used as base reference costs, updated to a 2010 price level, and with adjustment factors incorporated to account for the variations in size and other key dimensions when applied to individual structures in the Delaware River datasets. Design elevations were developed by adding vertical offsets taken from flood profiles in the municipal Flood Insurance Studies to the 1% annual chance flood elevations used by the HEC-FDA model to approximate the New Jersey Flood Hazard Area Design Flood (NJFHADF) elevation at each structure.

Structures with a ground elevation greater than that of the 1% ACE flood used by the HEC-FDA model at that location and structures for which the HEC-FDA model reported no damage were eliminated from consideration in the nonstructural analysis.

The nonstructural algorithm was applied to 1,701 structures across the 16 communities in the Delaware River dataset, representing 63% of the original dataset. The remaining 37% were considered ineligible for nonstructural treatments because they have recorded ground elevations above that of the 1% ACE flood used by the HEC-FDA model, or because the probability-weighted AAD recorded for these structures by HEC-FDA is zero.

In post-processing the results of the nonstructural analysis, a number of assumptions were made to convert the construction costs of each applied measure to total project costs for annualization and subsequent comparison with AAD: the calculation of total project cost assumes that each measure would be subject to survey and appraisal costs of $10,000 per structure, engineering and design costs of $10,000 per structure, supervision and administration costs per structure of 12% of the construction costs, and that structures elevated or rebuilt would also incur a temporary occupants' relocation cost of $10,000 per structure. An overall contingency of 30% was added to the construction cost, and total project costs were annualized using a period of analysis of 50 years and the FY2011 Federal discount rate of 4.125%.

All the cost estimates for individual treatments should be regarded as preliminary and subject to revision following more detailed future studies. Also, the number of potential rebuilds and acquisitions would be likely to change given more detailed data; in particular, data related to land values associated with individual structures.

The preliminary costs and potential benefit-cost ratios for nonstructural measures have been aggregated by risk (floodplain) to identify locations for more detailed analysis in Tables 2.9 and 2.10. Please see Section 3: Community Evaluations, for additional discussion of these measures at the community level.

It should also be noted that the initial screening benefit/cost ratios that have been calculated for each community are based on the assumption that the benefits realized may equal up to 100% of the estimated without-project damage. In practice, however, no nonstructural measure except for acquisition is likely to completely eliminate the potential for future flood damages, and hence the plans aggregated for each community may be less cost-effective than the preliminary results suggest. A summary of the screening and results for each community is presented, in downstream order from Knowlton Township to Greenwich and Logan Townships. Table 2.5 provides a summary of potential Federal interest for additional investigation of nonstructural measures.

Table 2.5: Potential Federal Interest for Additional Investigation of Nonstructural Measures

Town	Suitable for Additional Corps Investigation	Initial Screening Benefit-Cost Ratio (BCR)	Notes/Assessment (*)
Knowlton Township	No	0.3	Unlikely to be cost-effective. No further evaluation recommended.
White Township	Yes	1.2	7 structures in the 1% ACE (100-year) floodplain.
Town of Belvidere	Yes	0.8	9 structures in the 10% ACE (10-year) floodplain.
Harmony Township	Yes	0.8	32 structures in the 20% ACE (5-year) floodplain.
Town of Phillipsburg	Yes	0.9	3 structures in the 4% ACE (25-year) floodplain.
Pohatcong Township	No	0.9	Only 1 structure in the 50% ACE (2-year) floodplain meets the BCR threshold of 0.7. The Corps cannot modify single private structures.
Holland Township	No	0.6	Unlikely to be cost-effective. No further evaluation recommended.
Frenchtown Borough	No	0.4	Unlikely to be cost-effective. No further evaluation recommended.
Byram (in Kingwood Twp.)	Yes	0.8	12 structures in the 20% ACE (5-year) floodplain.
Stockton Borough	No	1.6	Only a single structure in the 50% ACE (2-year) floodplain has a positive BCR. The Corps cannot modify single private structures.
City of Lambertville	Yes	0.8	25 structures in the 10% ACE (10-year) floodplain.
Hopewell Township	Yes	1.3	2 structures in the 20% ACE (5-year) floodplain.
Ewing Township	No	0.3	Unlikely to be cost-effective. No further evaluation recommended.
City of Trenton (Glen Afton/The Island)	Yes	0.8	46 structures in the 20% ACE (5-year) floodplain (in Glen Afton/The Island). Not recommended for further evaluation in downtown Trenton.
Greenwich and Logan Twps. (Gibbstown)	Yes	2.6	420 buildings in the 1% ACE (100-year) floodplain.

(*) Details shown for plan with greatest number of structures at or above 0.7 BCR threshold being applied in the screening process to determine if suitable for additional Corps investigation.

Structure Relocation: As with buyouts, relocation requires a municipality to address maintenance and future use of an empty lot if the building is moved off-site. (If sufficient space above the flood hazard is available on the existing lot, the building can be moved on-site. In the more densely-developed communities in the study area, lot sizes typically do not allow for on-site relocation). Structure relocation can also be very costly. From a technical standpoint, it is most appropriate where flooding creates deep water, the building owner gets only a short warning time (as with flash floods), there is high flow velocity, or there is risk of substantial volumes of debris in the floodwater. Relocation is easiest for relatively small, square, frame structures, in comparison to other building types that present a variety of complications. More detailed evaluation of structures receiving high AAD will be required to determine if sufficient space outside the floodplain is available on the existing lot, or if a suitable site can be found. Identification of candidate structures has not been completed as part of this phase of the study. The use of structure relocation is recommended for continued consideration as part of the Federally-cost shared plan and the FPMP.

Structure Elevation: Elevation of structures above the flood hazard is effective in reducing flood damage and may reduce the potential for structure failure due to high flow velocities. Heavy vegetation and limited equipment access on the banks of the Delaware River may present significant logistical and technical challenges to elevating some buildings. These factors would have to be evaluated on a per-building basis.

The use of structure elevation is recommended for continued consideration as part of the Federally-cost shared plan and the FPMP.

Structure Rebuilding: Structure rebuilding is effective in managing flood risk and may reduce the potential for structure failure due to high flow velocities. The technique is suitable when a building that would otherwise be recommended for elevation or other means of retrofit is in poor condition, would require remedial repair before it could be elevated, or elevation would conflict with its continued usage (as in the case of a firehouse or other large, non-residential building). In these cases, structure rebuilding may be recommended as a lower cost alternative. Heavy vegetation and limited equipment access on the banks of the Delaware River may present significant logistical and technical challenges to constructing new buildings on site. These factors would have to be evaluated on a per-building basis. New structures would be built on-site, with the main floor designed to be above the base flood elevation.

The use of structure rebuilding is recommended for continued consideration as part of the Federally-cost shared plan and the FPMP.

Free-Standing Barriers: Free-standing barriers are scaled-down levees or floodwalls and are sometimes the most effective measure for reducing flood damage to large structures or groups of structures. Their primary use would be to protect larger institutional or commercial buildings, or groups of buildings such as apartment complexes and industrial parks.

The use of freestanding barriers is recommended for continued consideration as part of the Federally-cost shared plan and the FPMP.

Dry Floodproofing: Dry floodproofing is generally only effective for relatively low depths of flooding and requires that the buildings have a structurally sound slab to prevent water from entering from underneath the structure. It often involves the use of shields or other devices that must be installed in response to a threat. These measures are typically more appropriate for use in commercial rather than residential buildings. Dry floodproofing should be considered as a component of a retrofit plan for appropriate buildings.

The use of dry floodproofing is recommended for continued consideration as part of the Federally-cost shared plan and the FPMP.

Wet Floodproofing: Wet floodproofing may be useful for buildings in areas prone to flooding velocities less than three fps, as detailed by the National Floodproofing Committee. It can be applied in areas with minimal to deeper flooding (over six feet). As with other methods of building retrofit, an analysis of individual building characteristics and the risk and type of flooding would be required as part of the evaluation.

The use of wet floodproofing is recommended for continued consideration as part of the Federally-cost shared plan and the FPMP.

Protection of Utilities: Protection of utilities may reduce both the economic and environmental costs of flooding. This measure should be considered as part of a retrofit plan when the living space of a structure is located above the flood hazard, while utilities such as the incoming electrical service, and heating and air conditioning units are on a lower level, within the flood hazard zone, and thus are subject to damage. This measure can involve relatively simple actions, such as relocating circuit panels, or more significant efforts such as the addition of an elevated utility room and the abandonment of an existing basement.

The use of utility protection is recommended for continued consideration as part of the Federally-cost shared plan and the FPMP.

2.4.3 Land or Structure Acquisition Measures

Land or Structure Acquisition may be effective in achieving many of the project objectives. It could be used to purchase natural lands and vacant properties from willing sellers in areas vulnerable to flood damage, or to purchase 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. Any effects on community character would vary according to the acreage of property acquired and the planned future use of the land. For example, the acquisition of a substantial area of undeveloped land may be perceived by some residents to have negative effects on ability of the community to expand, while other residents may see the acquisition and preservation of undeveloped properties as a significant enhancement of community character. Land acquisition may be effective in preventing additional development in hazard areas. Federal cost-sharing through the project may be available if the benefits to the national economy exceed the cost of acquisition. Typically, such benefits include the value of prevented flood damage and additional opportunities for recreation and public access; additional benefits may include habitat and endangered species protection and restoration and water quality protection. Table 5.47 provides further discussion of these measures under the criteria of completeness, effectiveness, efficiency, and acceptability.

Table 2.6: General Evaluation of Nonstructural Measures (Land Acquisition) for Study Area Communities

	Evaluation Criteria			
Land Acquisition	**Completeness**	**Effectiveness**	**Efficiency**	**Acceptability**
Structure Acquisition	Eliminates future damage to acquired structure and property. Requires local control of property; identification of appropriate future use (typically open space), and enforced prohibition on future development.	Eliminates potential for damage to structures and contents on purchased property.	Once land is purchased and any structures removed, there will be no future structure damage at site.	Appropriate future use of land may be well-received by community. Cost implications (purchase price and reduction in tax revenue) may meet resistance.
Purchase of Property	Precludes new development in at-risk areas. Requires local control of property; identification of appropriate future use (typically open space), and enforced prohibition on future development.	Eliminates potential for damage to future development. Does not reduce level of flooding in community or associated recovery costs.	If land is undeveloped at time of purchase, there is no history of structure damage at site and any project benefit is limited to avoidance of future damage.	If developable but at-risk properties are converted to public use (e.g., open space), likely to be acceptable to public. Cost implications (purchase price and reduction in tax revenue for precluded future development) may meet resistance.
Easements and Deed Restrictions	Removes or limits development potential of at-risk properties. Requires willingness on part of owner and/or municipality to restrict future use as necessary. May require public ownership/management of property.	Reduces or eliminates potential for damage to structures and contents on purchased property. Does not reduce level of flooding in community or associated recovery costs.	Not likely to reduce damage to existing structures. May lower property value of deed-restricted area.	Will vary with impact on property values and municipal tax base, and ability to attract new development to community.

(Continued): General Evaluation of Nonstructural Measures (Land Acquisition) for Study Area Communities

	Evaluation Criteria			
Land Acquisition	**Completeness**	**Effectiveness**	**Efficiency**	**Acceptability**
Exchange of Property	"Land swap" requires available parcel and willing parties to exchange. May require public ownership of receiving parcel and administration of a "land bank".	Transfers development from at-risk to not at-risk location. Eliminates future damage from "sending" parcel. Does not reduce level of flooding in community or associated recovery costs.	Once land is purchased and any structures removed, there will be no future structure damage at site. If land is undeveloped at time of purchase, there is no history of structure damage at site and any project benefit is limited to avoidance of future damage.	If development on "receiving" site is within same municipality, effects on tax base are avoided.
Transfer of Development Rights	Requires municipal approval of TDR concept, and oversight of program. Requires available land outside risk area to receive development credits.	Transfers development from at-risk to not at-risk location. Eliminates future damage from "sending" parcel. Does not reduce level of flooding in community or associated recovery costs.	Once land is purchased and any structures removed, there will be no future structure damage at site. If land is undeveloped at time of purchase, there is no history of structure damage at site and any project benefit is limited to avoidance of future damage. Allows more intensive development in "receiving" parcel.	Increased allowable level of development on receiving parcel may benefit municipal tax base; may eliminate need to extend infrastructure to "sending" parcel, thus reducing costs.

Structure Acquisition: Local communities are sometimes concerned about the effects of acquisition because they can experience a reduction in the tax base and have to address maintenance of the empty lot. Also worth noting is the potential presence of hazardous materials on a property; the Corps cannot purchase contaminated property, nor be responsible for its cleanup. (FEMA funds also cannot be used for the purchase of contaminated property). In addition, when conducted as part of a Corps project, unless specifically authorized otherwise, buyouts 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 Federal government will reimburse any LERRD costs in excess of the 35% non-Federal cost-share amount. 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 FPMP.

Purchase of Property: Purchase of property can be an effective method of precluding future development and potential flood-related damage. However, any future development in the study area would be subject to NFIP and local floodplain management regulations, and thus should be at limited risk to flood damage from the 1% ACE (100-year) event. In addition, there would be no immediate NED benefit to the Corps in purchasing undeveloped lands. Thus, this technique should be eliminated from further evaluation as part of the Federal flood risk management plan. However, it may be appropriate for inclusion in the 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. Other applications of the measure, such as prohibitions on parcel subdivision, are not covered under the Corps' authority, and typically are exercised by local governments. A reduction in future damages may be realized by preventing intensification of development in flood-prone areas that would otherwise likely experience extensive construction in the future. This measure should be evaluated in conjunction with structural measures, both as part of a Federally cost-shared plan and as part of the FPMP.

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 FPMP.

2.5 Ecosystem Restoration

An evaluation of the ecosystem restoration measures is presented in Table 5.48. It evaluates their completeness, effectiveness, efficiency, acceptability, and significance. Significance is defined according to the following criteria:

- Scarcity – trends and relative abundance of the habitat.
- Connectivity- contributes to the connection of other important habitat pockets.
- Special Status Species- significant contribution to some key life requisite of special status species.
- Plan Recognition- contributes to watershed or basin plans.

To be considered for Corps funding, sites are generally required to meet these multiple criteria. Regional or national significance is typically identified based on institutional, public or technical recognition.

Because only a limited number of restoration opportunities have been 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 appears that only the site in Greenwich and Logan Townships would meet the significance requirement:

Table 2.7: Evaluation of Potential Ecosystem Restoration Sites

Site and Location	Completeness	Effectiveness	Efficiency	Acceptability	Significance
White Township and Town of Belvidere: Pequest River and Pophandusing Brook in (Stream bank erosion and dams on Pequest River).	Yes, opportunities to reduce bank erosion or remove dams to restore habitat can be completed without other required actions.	Yes, effective designs are available.	Unknown, the habitat area that could be restored and the associated costs have not been evaluated.	Yes, the community supports such plans and no significant constraints have been identified.	Unknown, the habitat area created is likely to be relatively small and does not appear to be rare within the region. It is unclear if the habitat would support endangered species, adding to national significance.
Harmony Township (Stream bank erosion and sedimentation due to breaches at abandoned quarry in Brainards section)	Yes, opportunities to restore the breaches to protect and restore habitat are not dependent on other actions. The NRCS report does not recommend restoration of the breach to reduce flooding damage.	Yes, effective designs are available.	Unknown, the habitat area that could be restored and the associated costs have not been evaluated. Possible multi-purpose opportunities for flood storage or dredge material placement could reduce costs.	Unknown, the community supports such plans but there are potential real estate ownership and contamination issues.	Unknown, the habitat area created is likely to be relatively small and does not appear to be rare within the region. It is unclear if the habitat would support endangered species, adding to national significance.

(Continued): Evaluation of Potential Ecosystem Restoration Sites

Site and Location	Completeness	Effectiveness	Efficiency	Acceptability	Significance
Town of Phillipsburg (Sewage overflow from WWTP)	No, opportunities to prevent overflows are likely to be dependent on addressing flood risk at the WWTP. A combined Restoration / Flood Risk Management plan is appropriate.	Yes, effective designs are available.	Unknown. Neither the ecological impact of the WWTP sewage overflow to the river nor the economic impact of flood risk management have been assessed.	Yes, the community supports such plans and no significant constraints identified.	Unknown, while the habitat area protected may be large, the impact to the habitat and to water quality is very intermittent.
Borough of Frenchtown (Sedimentation at Nishisakawick Creek)	Yes, opportunities to reduce bank erosion to reduce sedimentation at Nishisakawick Creek can be completed without other required actions.	Yes, effective designs are available.	Unknown, the habitat area that could be restored and the associated costs have not been evaluated.	Yes, the community supports such plans and no significant constraints identified.	No, the habitat area created is likely to be relatively small and does not appear to be rare within the region.

(Continued): Evaluation of Potential Ecosystem Restoration Sites

Site and Location	Completeness	Effectiveness	Efficiency	Acceptability	Significance
Greenwich Township and Logan Township (Historic tidal wetland converted to freshwater habitat; extensive invasive species)	No, opportunities to restore tidal flows and address the presence of invasive species are limited if the existing gates are operated strictly to prevent tidal flooding. The restoration is therefore dependent on effective flood risk management for the area and a combined plan is therefore necessary.	Yes, effective designs are available and have been implemented in other nearby locations.	Unknown. Neither the ecological impact of the restoration nor the economic impact of flood risk management measures have been assessed in detail.	Unknown, some landowners may see increased tidal inundation. Inundation may occur unless properties are acquired.	Likely, the area of new tidal habitat created could vary widely depending on plan details, but it would contribute diversity to a large area of largely undeveloped freshwater habitats.

The Greenwich and Logan Townships site appears to meet policy and budget guidance on opportunities for offsetting trends of loss of tidal wetlands and for increasing the connectivity of habitats. Any ecosystem restoration measures at that location could be integrated as part of an overall watershed plan. This indicates that restoration opportunities should be evaluated further in combination with flood risk management measures at the site.

The other sites evaluated for ecosystem restoration opportunities do not appear to meet the significance criteria. However, the other alternatives would provide benefits to the environment and could be considered for implementation as part of the FPMP or other non-Corps initiatives. As part of the flood risk management options at the municipal WWTP located at the Lopatcong Creek confluence in Phillipsburg, there is an opportunity (through construction of a ringwall around the facility) to reduce or eliminate wastewater discharges during flooding. This may in turn lead to improvements in water quality and habitat quality. The ecosystem structure benefits (if extant) would come directly from the flood risk management measure, and would not be a separable ecosystem restoration measure. Ecosystem structure is defined as "the state and spatial distribution of material forms within the ecosystem at a specified time. It includes both microscopic and macroscopic components in diverse living and non-living assemblages." (USACE EP 1165-2-502, 1999). A determination of the resulting ecosystem structure benefits would require additional study.

2.6 Summary of Evaluation Measures

Potential solutions to frequent flooding problems and related environmental degradation were evaluated for selected New Jersey communities within the Delaware River Basin. An array of potential solutions is available for consideration to address flooding issues. Most of these options were addressed by the Corps in the August 1984 *Delaware River Basin Study Survey* Report. The current study revisits the previously identified options, using updated information, including surveys, mapping and modeling in the assessment, as well as considering new or modified alternatives.

For each community, the identified flood problems were described and compared to a series of evaluation criteria addressing the technical, economic, environmental, and social aspects of the problems and potential flood risk management and environmental restoration plans. Where possible, the estimated annual costs of concept-level structural measures were compared to AAD of protected development to help guide assessments of cost effectiveness and economic efficiency and determine initial screening BCRs. For nonstructural measures, a screening algorithm was applied to the building inventory of floodplain buildings for identification of suitability for nonstructural retrofit. The algorithm determined the most suitable, least-cost retrofit method for each building based on its structure type, method of construction, size, and elevation.

Documented ecosystem habitat impairments were consolidated into a tabular format and potential restoration measures were identified for each of the impaired sites. Restoration opportunities at these sites were compared to the evaluation criteria, and interrelationships between restoration and flood risk management measures were identified.

2.6.1 Structural Measures

Table 5.49 provides a summary of structural measures, including construction cost and an initial screening benefit/cost ratio. Regarding the municipal wastewater treatment plant in Phillipsburg, additional evaluation including an estimation of AAD will be required to determine whether structural protection of the facility is cost-effective.

In Stockton, the initial assessment indicates the proposed measure (enhancements to the existing embankment of the D&R Canal) is potentially cost-effective and the cost and benefit assessments will have to be further refined.

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

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 is required before a decision can be reached on cost-effectiveness and suitability for Federal participation.

In Greenwich and Logan Townships, an extensive levee/floodwall line of protection is likely to provide cost-effective protection to 805 structures in Gibbstown, plus unquantified benefits to the community of Paulsboro. Nonstructural protection would be included for a number of residences outside the LOP, as well as a ringwall for a light industrial manufacturing facility. This measure should be further evaluated for Federal participation.

The structural measures evaluated for Knowlton Township, along the Lopatcong Creek in Phillipsburg, Frenchtown, Ewing Township, and downtown Trenton are not likely to be cost-effective, and no further evaluation for Corps participation is recommended.

2.6.2 Nonstructural Measures

The following nonstructural measures were evaluated and found to meet the evaluation criteria: elevation, wet floodproofing, dry floodproofing, ringwalls, rebuilding, and acquisition. A screening algorithm was used to evaluate each building in the 1% ACE (100-year) floodplain, to assign appropriate retrofit measures, and to calculate their likely costs.

As with the structural screening, the calculation of AAD assumes no protection from existing features such as levees, railroad beds or canal embankments. The annual costs were compared to the AAD to determine the initial screening BCRs, assuming all flood risks are mitigated. From Knowlton Township to Trenton, 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 upper basin communities: White Township, Belvidere, Harmony Township, Phillipsburg, Pohatcong Township, Byram (in Kingwood Twp.), Stockton, Lambertville, Hopewell Township, and Trenton. Further evaluation of Federal participation in nonstructural retrofit in these communities is warranted, with the exception of Pohatcong Township and Stockton, where only single private structures met the BCR threshold. The Corps cannot participate in the nonstructural retrofit of single private structures. Based on initial screening BCRs below the 0.7 threshold, further evaluation of nonstructural measures in Knowlton Township, Holland Township, Frenchtown, and Ewing Township is not recommended.

For the upper basin 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. (See Table 5.50 for details).

In Greenwich and Logan Townships, nonstructural treatments 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. (See Table 5.51 for details).

2.6.3 Ecosystem Restoration

The potential for Corps participation in ecosystem restoration measures 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. Flood risk management at the municipal wastewater treatment plant (WWTP) in Phillipsburg would not only reduce flood damages, but would also address habitat impairment due to flood-related sewage overflow.

In addition to the measures identified for continued study as part of the current Interim Feasibility Study for New Jersey, numerous measures 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.

Table 2.8: 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

(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

(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.

Table 2.9 presents a summary of the nonstructural retrofit costs by floodplain for Knowlton Township downstream to Trenton.

Table 2.9: Summary of Nonstructural Costs by Floodplain: Knowlton Township to Trenton

Delaware River Basin: Knowlton Township to Trenton	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*

Table 2.10 presents summary information of the nonstructural retrofit costs by floodplain for Greenwich and Logan Townships in Gloucester County, NJ:

Table 2.10: Summary of Nonstructural Costs by Floodplain: Greenwich and Logan Townships

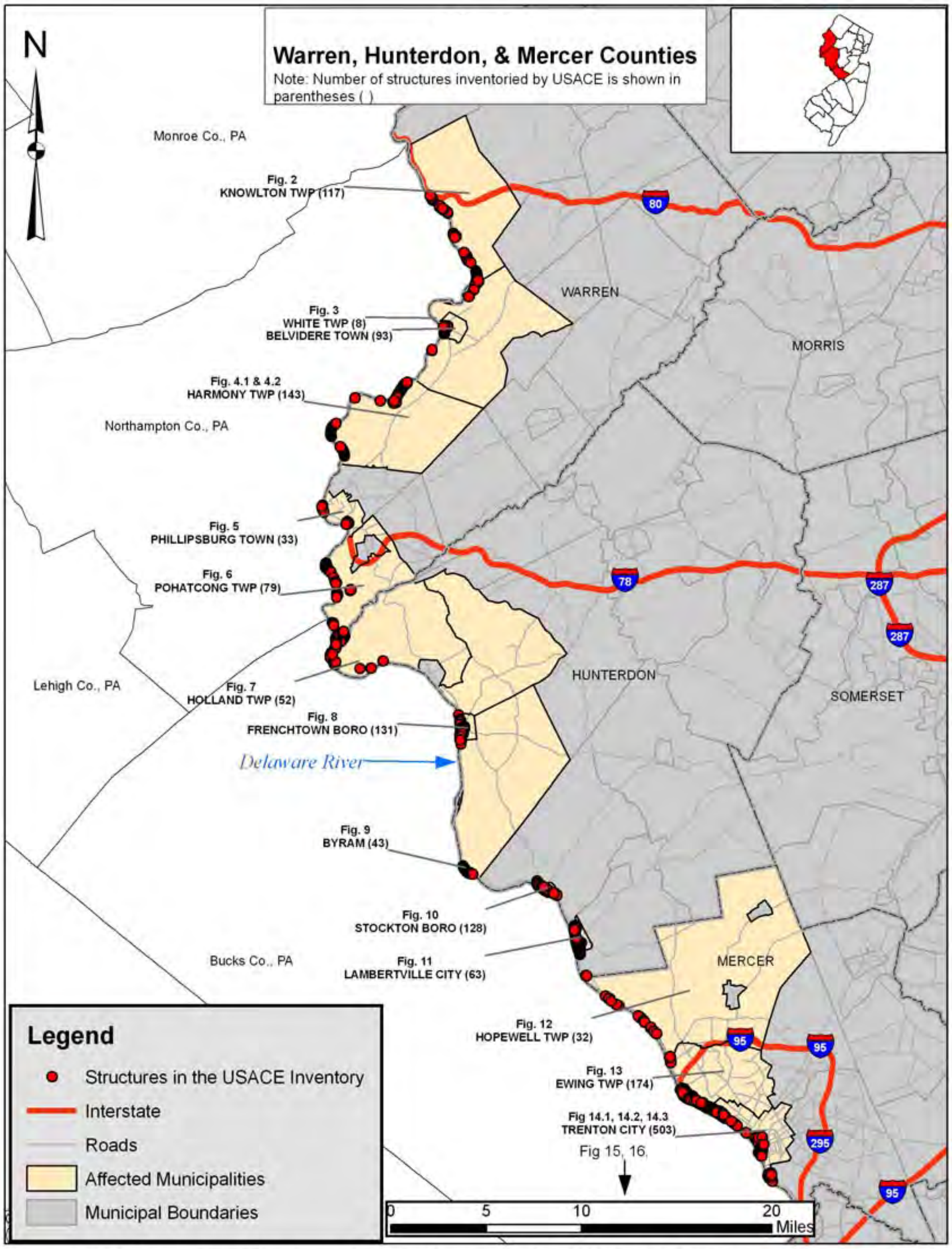
Greenwich and Logan Townships Total:	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Structures Treated	*254*	*299*	*325*	*380*	*396*	*420*
Total Annual Damage	$9,817,432	$10,085,100	$10,254,503	$10,330,538	$10,385,826	$10,394,420
First Cost	$30,281,644	$35,109,430	$38,342,640	$43,876,825	$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*

3.0 Community Evaluations

A description of the flooding hazard and damage history of each community is provided below, presented in downstream order on the Delaware River. Where appropriate, evaluations of specific structural and nonstructural measures are provided at the community level. Much of the information on the sources and extents of flooding was provided to the Corps by local officials and representatives during community visits.

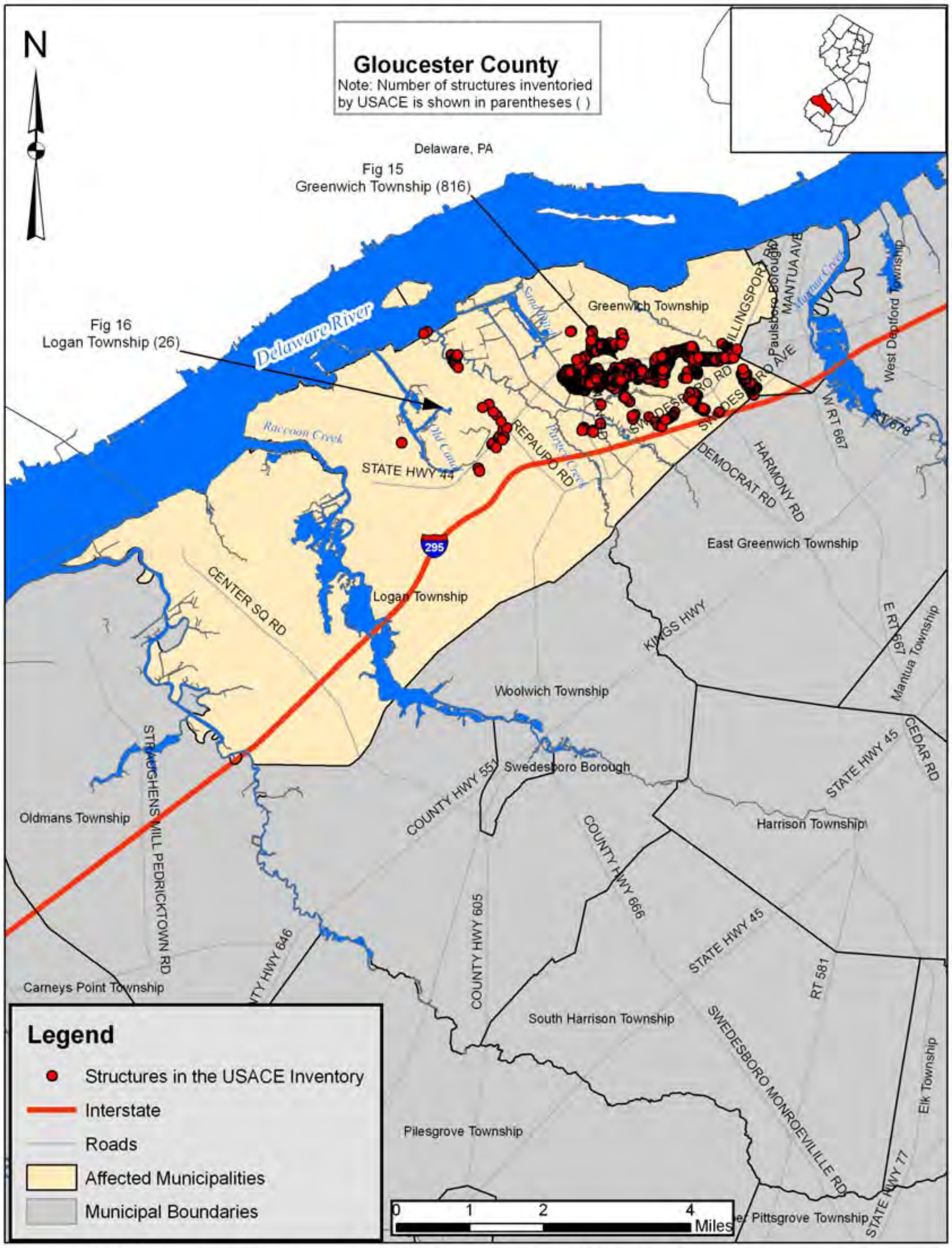
For those measures that are identified for further evaluation under the next phase of the Interim Feasibility Study for New Jersey, recommendations are provided showing the appropriate authority under which that evaluation and any potential implementation would occur; specifically, the Corps' flood risk management plan, other Federal agencies, or a non-Federal Flood Plain Management Plan. Alternatives recommended for elimination from the next phase are marked accordingly. Figures 3.1 and 3.2 are provided below as general location maps.

Figure 3.1: Warren, Hunterdon, & Mercer Counties



Source: NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; NJDOT, Roads 2008

Figure 3.2: Gloucester County



Source: NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; NJDOT, Roads 2008

3.1 Warren County

3.1.1 Knowlton Township

This community has a population of 2,977 (*Census 2000*), with an area of approximately 27 square miles. The majority of homes are single-story structures. As noted by local officials, flooding occurred in Knowlton during the 1996, 2004, 2005, and 2006 events. According to the USGS gage at the Delaware Water Gap, the 2004 flood was a 4% ACE (25-year) event; the 2005 flood was a 1.8% ACE (55-year) event; and the 2006 flood was a 1.4% ACE (70-year) event. See Figure 3.3 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

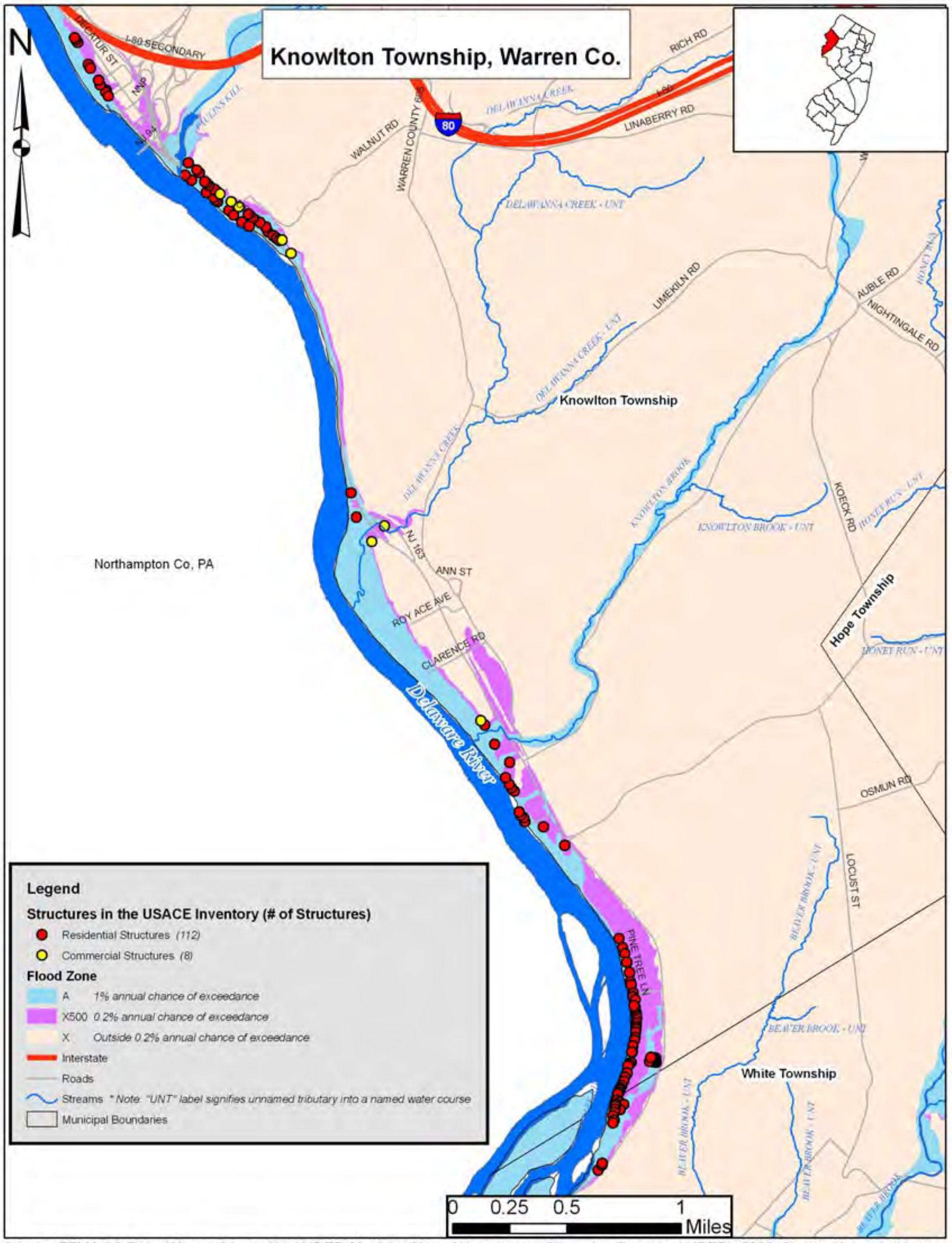
Local representatives stated that the Paulins Kill tributary backs up from Delaware River floodwaters; however, Paulins Kill flooding does not affect housing and infrastructure. Damage to homes and infrastructure occurs from direct flooding by the Delaware River overtopping its banks from the US I-80/Route 46 interchange southward. Flooding also occurs along Route 46 and on smaller roads next to the Delaware River, such as Willow Lane.

The developed floodplain area from the Route 80 interchange southward to the NJ-94 bridge (approximately 2,000 feet in length) contains one row of structures, which are situated on local streets perpendicular to the river. The floodplain area from NJ-94 southward (approximately 3,400 feet in length) contains structures on both sides of Route 46. The majority of homes are single-story structures, and many have basements. Approximately 35 homes are affected by flooding, with 13 subject to first floor flooding depths of 3' to 5' and damages of $30,000 to $40,000 per occurrence. Five to six homes suffer repetitive losses. Twenty-two homes had basement level flooding only.

3.1.1.1 Structural Flood Risk Management Alternatives

Since there is a significant cluster of 31 flood-prone structures found immediately south of the US-94 bridge (including two commercial structures), a local structural measure was evaluated. (See Figure 3.4). These buildings are located on either side of US-46 in a long, narrow floodplain. To protect this area, a new line of protection (LOP) of approximately 3,200 LF in length with a 400 LF tie-off at the upstream end (including two flood gates across Rt. 46) and a 200 LF tie-off at the downstream end of the area would be required. Initial order of magnitude estimates indicate that a LOP would have a construction cost of $13.5 million and provide risk management for approximately $3 million in buildings plus an unquantified amount of infrastructure. Comparing "order of magnitude" cost estimates to the value of protected development indicates that a structural line of protection is likely not cost effective in the Township of Knowlton. Table 3.1 provides an evaluation of structural alternatives in Knowlton Township.

Figure 3.3: Knowlton Township, Warren County



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 3.4: Knowlton – Concept Level Line of Protection

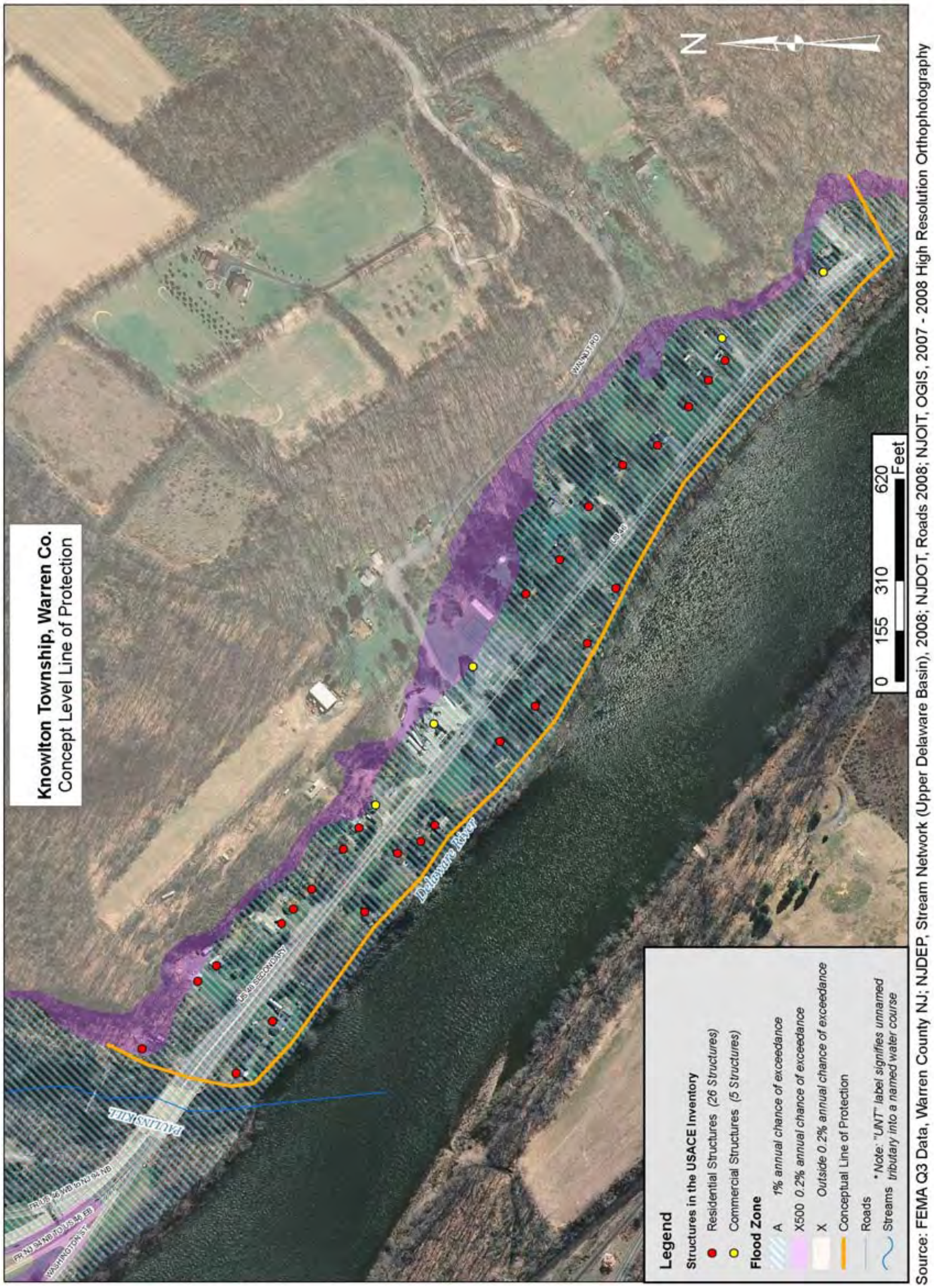


Table 3.1: Evaluation of Structural Measures: Knowlton Township

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Risk Management				
Backflow Prevention Structures	Flooding of developed areas is from overtopping of the Delaware River and thus backflow preventers will not reduce it. Tributary flooding does not affect developed areas.	Would not reduce flooding from main stem of Delaware River.	Unknown.	No known issues.
Levees and Floodwalls	May require mitigation for natural resource impacts, and will likely require interior drainage modifications (e.g., pumping) and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures.	Will reduce main stem flood damages.	Unlikely to be cost effective. Will require two road closures.	Potential aesthetic impacts by blocking view/access to the river. May require unacceptable excavation and construction along river bank.
Removable Barriers	May require mitigation for natural resource impacts, and will likely require interior drainage modifications (e.g., pumping) and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for deployment of barriers.	May limit the number of properties protected if located along road, which appears to be the most appropriate, accessible location.	Potentially similar initial costs to floodwall. Deployable barriers may require higher operation and maintenance.	Deployment may be too labor intensive for the limited application. Finding storage space near site may be an issue.
Road Raisings	Limits risk management to properties landward of the roadway. May require additional interior drainage, utility relocation and reconfiguration of access roads.	Limits risk management to one side of roadway.	Due to limited benefits, not likely to be cost-effective.	Impacts to properties adjacent to the roadway are likely to be unacceptable.

	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Area Risk Management				
Channel Modification	n/a	Due to the flat river profile, no effective channel modifications have been identified.	No, length of channel modification would be many miles longer than area of potential benefits.	Unlikely due to extremely high level of instream habitat impact.
Dams or Impoundments	Would require appropriate mitigation and an emergency action plan to meet dam safety requirements.	Potential detention sites identified in prior studies are likely to have minimal impact on main stem flooding.	Unlikely to be cost effective.	Likely to be opposed by local residents and fishing interests.
Diversion	n/a	No effective diversion opportunities have been identified.	n/a	n/a

3.1.1.2 Concept-Level Line of Protection: Cost and Initial Screening Benefits

The estimated annual cost of a 4,000 linear foot (LF) floodwall to protect 31 structures is $910,000, and the AAD of those buildings is $57,000 (Site 1). The initial screening BCR is below 0.1, and thus clearly not cost-effective, and thus there would be no Corps or other Federal program support for such an alternative.

3.1.1.3 Nonstructural Flood Risk Management Alternatives

As stated by local officials, the majority of the at-risk properties in Knowlton Township receive basement flooding, with one-third subject to extensive first floor flooding. Relocation and buyout are typically cost-effective only for structures receiving regular and extensive damage to the finished floors. Thus, the structures subject to flooding at the basement level only should be evaluated for wet and dry floodproofing, utilities protection, and elevation.

A substantially damaged or improved residential structure must be brought into compliance with National Flood Insurance (NFIP) criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than three fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

The properties experiencing first floor flooding should be evaluated for elevation, relocation, and acquisition. Free-standing structures (such as ringwalls) are typically not indicated for residential structures in close proximity to adjoining structures. Local officials said that residents of Knowlton Township have stated a preference for elevation and property acquisition as the means of flood risk management.

3.1.1.4 Nonstructural Screening Results

The initial dataset included 117 individual structures in Knowlton Township, of which 78 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Knowlton Township resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.2 and Table 3.3:

Table 3.2: Knowlton Township: Summary of Nonstructural Costs by Floodplain

Knowlton	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*0*	*2*	*11*	*37*	*56*	*78*
Total Annual Damage	$0	$6,000	$27,000	$70,000	$91,000	$108,000
First Cost	$0	$237,000	$1,100,000	$3,564,000	$5,161,000	$7,517,000
Temp Relocation	$0	$20,000	$110,000	$370,000	$560,000	$760,000
Contingency	$0	$77,000	$363,000	$1,180,000	$1,716,000	$2,483,000
Construction Cost	$0	$334,000	$1,574,000	$5,114,000	$7,438,000	$10,760,000
Survey/Appraisal	$0	$20,000	$110,000	$370,000	$560,000	$780,000
E&D	$0	$20,000	$110,000	$370,000	$560,000	$780,000
S&A	$0	$40,000	$189,000	$614,000	$893,000	$1,291,000
Total Project Cost	$0	$414,000	$1,982,000	$6,468,000	$9,450,000	$13,611,000
Total Annual Cost	$0	$20,000	$94,000	$308,000	$449,000	$647,000
Initial Screening BCR	*0.0*	*0.3*	*0.3*	*0.2*	*0.2*	*0.2*

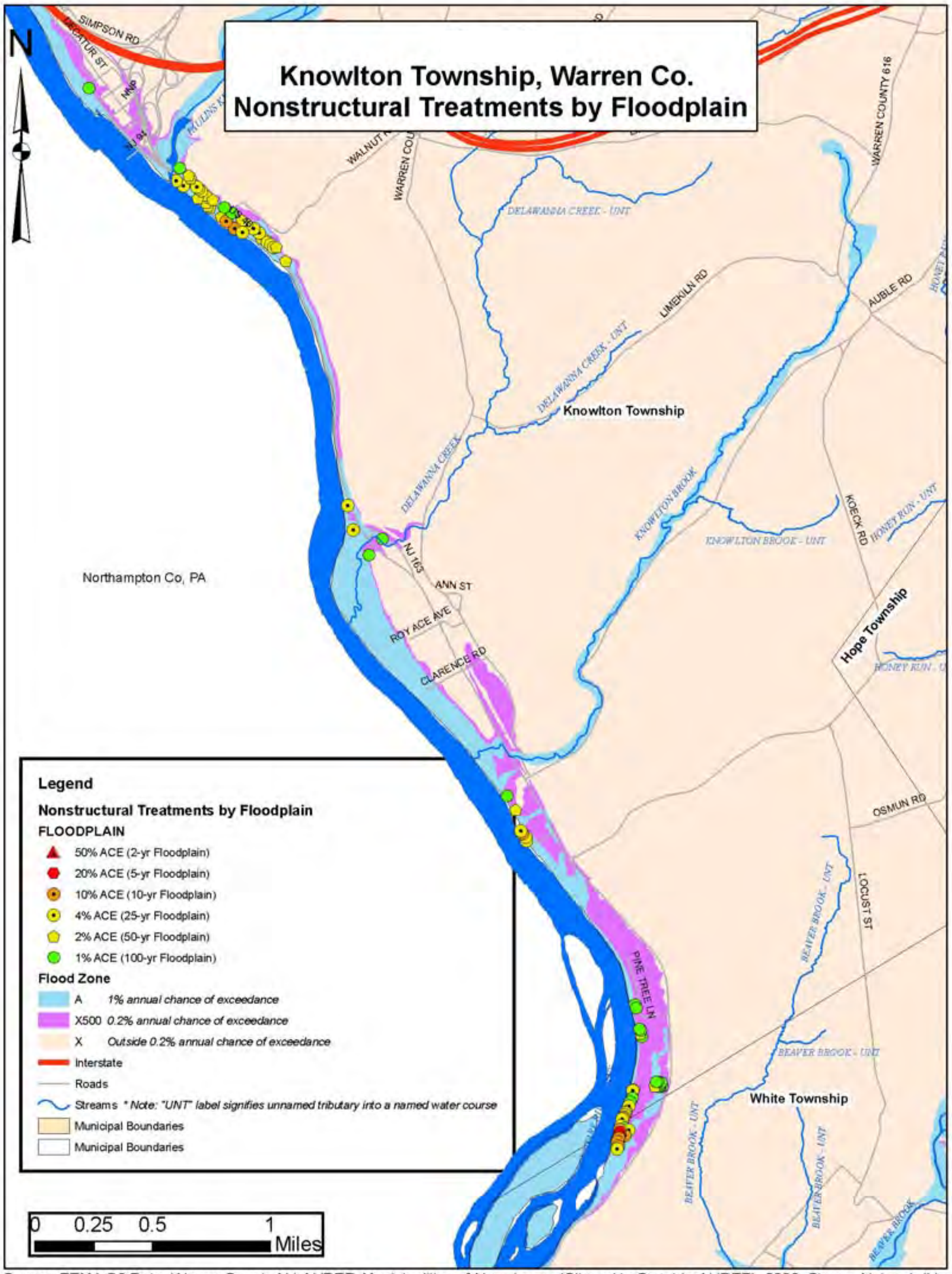
Table 3.3: Knowlton Township: Summary of Nonstructural Treatments by Floodplain

Knowlton	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	0	2	10	33	45	54
Wet Floodproof	0	0	0	0	0	2
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	0
Rebuild	0	0	1	4	11	22
Acquisition	0	0	0	0	0	0
Totals	*0*	*2*	*11*	*37*	*56*	*78*

See Figure 3.5 for a map of the nonstructural treatments by floodplain. Of the 78 structures in Knowlton Township for which potential nonstructural treatments have been identified, 91% are residential, and the remaining structures are commercial structures. The majority of structures eligible for treatment (69%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 22.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. None of the nonstructural treatments for the various floodplains in Knowlton Township reach this threshold, and thus no further evaluation of these measures is recommended. Table 3.4 provides recommendations for further evaluation of measures in the community.

Figure 3.5: Knowlton – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.4: Recommendations for Further Evaluations, Knowlton Township, Warren County

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
Structural Measures **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits				✓
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.1.2 White Township

This community of 5,300 residents experienced flooding in September 2004, April 2005, and June 2006. During a community visit by the Corps, municipal representatives provided the following information on the sources and extent of flooding and related damage. Floodwaters from the Delaware River backed up the Pequest River and Beaver Brook and flooded adjacent areas. The representatives expressed concern about debris in the river not being removed after flooding events, which can cause debris dams at bridge abutments. Up to 30 houses experience flooding in the basement or above when the Delaware River backs up the tributaries and when there is a local storm. Flooding occurs on a low-lying section of US-46 along the Delaware River. The representatives have stated that they are not provided with advance notice when a release is planned from the reservoirs owned by the New York City Department of Environmental Protection (NYCDEP); in addition, they reported that the Delaware River rises one foot (1’) in White Township when a release occurs.

A row of cottages owned by Pennsylvania Power and Light (PP&L) on Foul Rift Road has historically flooded due to low elevations on the bank of the Delaware. PP&L has removed a number of the cottages and did not renew the leases on the remaining cottages, which expired in October 2008. These structures are not included in the building inventory.

The inventoried floodplain properties are grouped in isolated clusters of two to three structures. See Figure 3.6 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA’s Q3 digital floodplain data.

3.1.2.1 Structural Flood Risk Management Alternatives

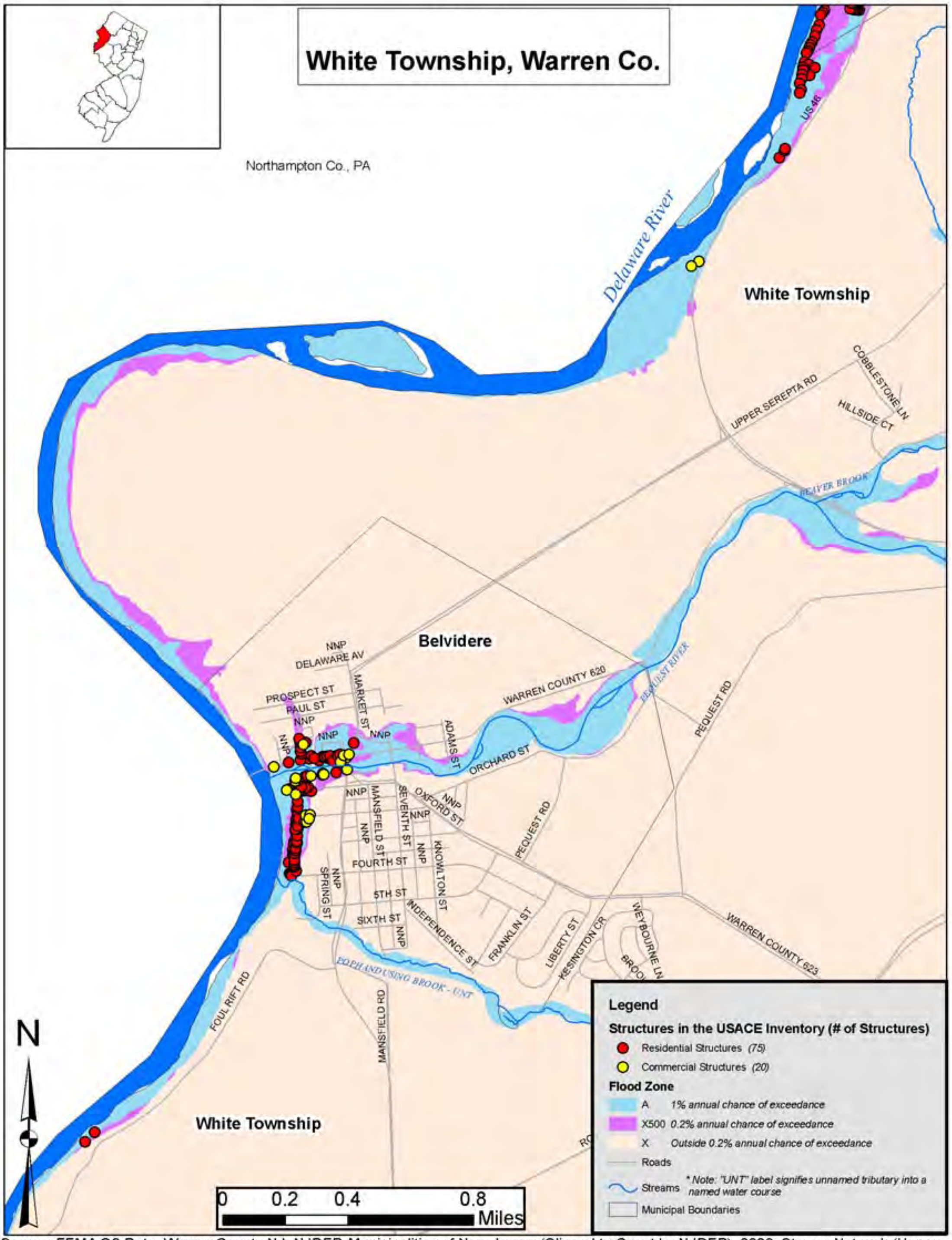
The limited number of structures subject to flooding and the distances between them indicate that nonstructural measures would be more appropriate and cost-effective in White Township. No opportunities for structural measures were identified or evaluated.

3.1.2.2 Nonstructural Flood Risk Management Alternatives

The generally limited depth of flooding indicates that structure elevation, wet or dry floodproofing, and utilities protection would be the most appropriate methods for the at-risk structures, and should be further evaluated. Relocation and acquisition should also be evaluated.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than three fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Figure 3.6: White Township, Warren County



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

3.1.2.3 Nonstructural Screening Results

The initial dataset included eight individual structures in White Township, of which seven were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in White Township resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.5 and Table 3.6:

Table 3.5: White Township: Summary of Nonstructural Costs by Floodplain

White	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Structures Treated	*0*	*1*	*5*	*6*	*7*	*7*
Total Annual Damage	$0	$11,000	$111,000	$115,000	$116,000	$116,000
First Cost	$0	$98,000	$1,010,000	$1,100,000	$1,187,000	$1,187,000
Temp Relocation	$0	$10,000	$50,000	$60,000	$70,000	$70,000
Contingency	$0	$33,000	$318,000	$348,000	$377,000	$377,000
Construction Cost	$0	$141,000	$1,378,000	$1,508,000	$1,634,000	$1,634,000
Survey/Appraisal	$0	$10,000	$50,000	$60,000	$70,000	$70,000
E&D	$0	$10,000	$50,000	$60,000	$70,000	$70,000
S&A	$0	$17,000	$165,000	$181,000	$196,000	$196,000
Total Project Cost	$0	$178,000	$1,644,000	$1,809,000	$1,971,000	$1,971,000
Total Annual Cost	$0	$8,000	$78,000	$86,000	$94,000	$94,000
Initial Screening BCR	*0.0*	*1.4*	*1.4*	*1.3*	*1.2*	*1.2*

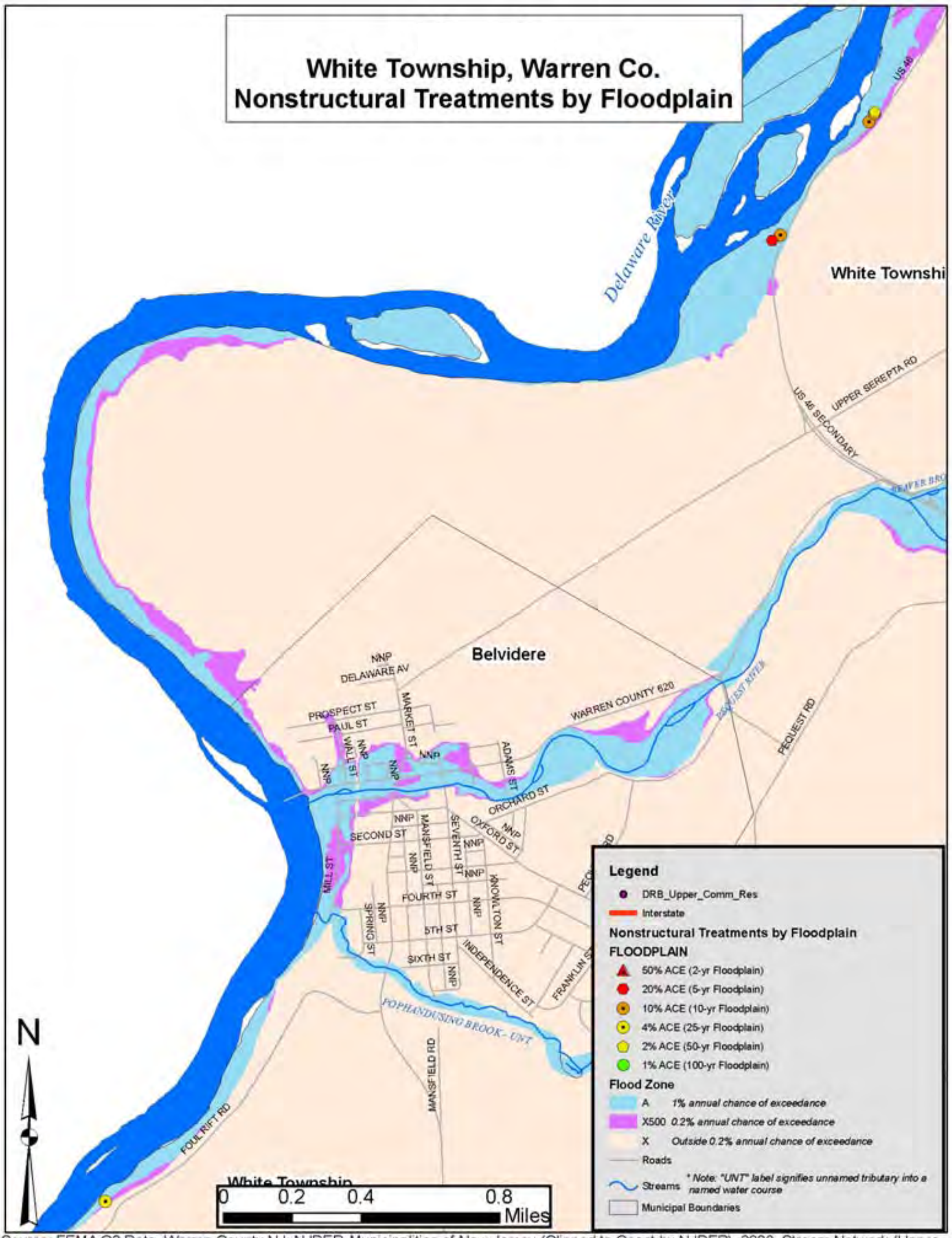
Table 3.6: White Township: Summary of Nonstructural Costs by Floodplain

White	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Elevation	0	1	3	4	5	5
Wet Floodproof	0	0	0	0	0	0
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	0
Rebuild	0	0	2	2	2	2
Acquisition	0	0	0	0	0	0
Totals	*0*	*1*	*5*	*6*	*7*	*7*

See Figure 3.7 for a map of the nonstructural treatments by floodplain. Of the seven structures in White Township for which potential nonstructural treatments have been identified, five are residential and the remaining structures are commercial properties. All except two of the structures eligible for treatment would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild the remaining two structures, one of which is a commercial property, and the other is residential.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatments for the 20% ACE (5-year) through 1% ACE (100-year) floodplains in White Township meet or exceed this threshold, and thus are recommended for further evaluation of costs and benefits. See Table 3.7 for further evaluation of measures.

Figure 3.7: White – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.7: Recommendations for Further Evaluation, White Township, Warren County

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	Other Federal Agency Flood Risk Management Plan	Non-Federal Flood Plain Management Plan (FPMP)	Eliminate from Further Evaluation
Structural Measures **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.1.3 Town of Belvidere

The Town of Belvidere, the county seat of Warren County, is located at the confluence of the Pequest and Delaware Rivers and has a bridge leading to Riverton, PA. The bridge is located immediately north (upstream) of the confluence of the two rivers. Belvidere has a population of 2,771 (*Census 2000*) and an area of 1.3 square miles, with a densely developed business district. During a community visit by the Corps, municipal representatives provided the following information on the sources and extent of flooding and related damage. The primary source of flooding is the backflow from the Delaware into the Pequest. Water in the Pequest then surcharges through storm drains and floods adjacent areas. At higher stages, the Pequest will overtop its banks and cause additional flooding. The Pequest floods sections of Wall Street, Water Street, Front Street, and DePue Street. The Delaware River does not directly overtop its banks in this area. See Figure 3.8 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

On the southern edge of Belvidere, the Delaware River floodwaters back up the Pophandusing Brook, and also scour out the river bank. Flooding from the brook occurs on DePue Street and Mansfield Road. Just upstream from the confluence of the river and the brook, the Pophandusing flows in an "S" shaped meander that is constrained by a culvert through a railroad embankment and by the end of DePue Street. The brook shows signs of attempting to realign itself as seen in the significant erosion along its banks. Some local residents have deposited boulders on portions of the embankment in an attempt to keep the brook's alignment from encroaching on DePue Street.

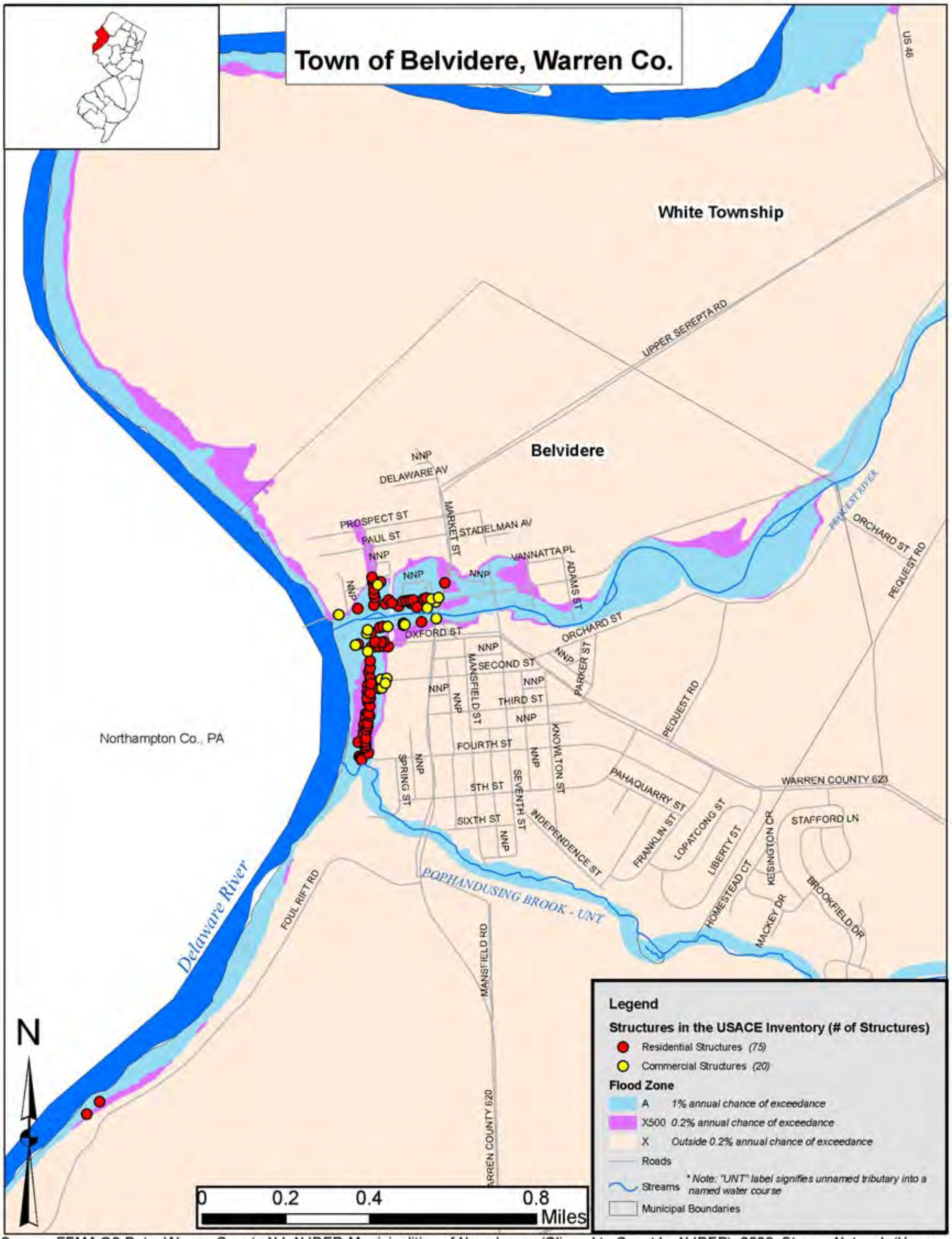
During major floods (such as the 2004-2006 events), approximately 55 homes have been flooded; 22 of those homes are flooded at a depth of 3' to 5' on the first floor, with the remainder experiencing basement flooding. Municipal representatives stated that typical damages range from $50,000 to $75,000 for homes with first floor flooding.

There are two "run of river" type dams within Belvidere on the Pequest River. The dam furthest downstream is known as the E.R. Collins & Son Dam-Railroad Dam (NJDEP File No. 24-28) and is located immediately downstream of the railroad (Conrail) bridge near the intersection with Water St. The second dam, known as the E.R. Collins & Son Dam-Market Street Dam (NJDEP File 24-29), is located just upstream of the Greenwich Street bridge. The Railroad Dam was purchased by the State of New Jersey with Green Acres funding and is currently operated by the NJDEP, Division of Fish and Wildlife. Residents report siltation within the Pequest River, notably behind and downstream of the lower Railroad Dam. The majority of the flooded structures are located upstream of the railroad dam and downstream of the Market Street Dam.

The municipality uses reverse-911 to warn residents of impending flooding, which has allowed time for the removal of contents to higher floors. Municipal officials have encouraged residents to raise utilities above flood levels, seal basements from groundwater, and evacuate when instructed. Officials also have indicated that they would like to see portions of the Pequest River dredged if it would limit flooding, and would like to know if floodwaters can be diverted onto the undeveloped State of NJ-owned property on the south side of the Pequest River, rather than the developed portions on the northern side. The potential effects of dredging have not been established by study. However, it is unlikely that increasing the capacity of the Pequest River channel would decrease the volume of water backflowing from the Delaware River. Increasing the channel capacity may allow for additional volumes of water to backflow into the Pequest. Detailed hydraulic modeling would be needed to fully quantify the hydraulic effects of dredging. Officials also want to know whether removal of the downstream Railroad Dam on the Pequest River would reduce the backwater flooding from the Delaware River by allowing the Pequest to carry its floodwater more efficiently; in addition, they wish to evaluate whether channelization of the Pequest would improve the situation.

In April 1985, the United States Department of Agriculture, Soil Conservation Service (SCS) (now known as the Natural Resource Conservation Service (NRCS)), completed a report titled "Lower Pequest River Watershed, Warren County, New Jersey" which evaluated methods to reduce flooding along the river within Belvidere. The report evaluated two dam removal alternatives; under the first, the Market Street Dam would be removed which would lead to reduced flooding in the downtown. In the second alternative, the Railroad Dam would also be removed to improve canoeing access along the Pequest River through the elimination of portages, and improved access to the stream for anadromous fish. The study determined the elimination of the Railroad Dam would not significantly decrease flooding. Both alternatives were determined to be economically justified at the time.

Figure 3.8: Town of Belvidere, Warren County



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

3.1.3.1 Structural Flood Risk Management Alternatives

Restoration and dam removal on Pequest River may be a viable alternative; however, current hydrologic data indicates that the primary source of flooding on the lower Pequest is from backwater from the Delaware River, and not from excessive volumes on the Pequest itself. Removal of the lower dam on the Pequest would not reduce flooding from Delaware River backwater and, thus, not address the goal of this study. As noted above, the 1985 NRCS study stated that dam removal would decrease local flooding from the Pequest. Dam removal may reduce water temperatures in the river, which would be a habitat improvement for resident fish.

Channel deepening or diverting flow from the Pequest River would not address the major issue of Delaware River backwater flooding.

There are no obvious opportunities for construction of a levee or floodwall line of protection at the confluence of the Pequest and Delaware Rivers. Large floodgates and pumps would be needed to convey the flows of the Pequest river over the LOP. In addition, there is insufficient space to build a LOP along the banks of the Pequest. To construct a LOP along the Pequest would require the removal of many of the structures the LOP would be intended to protect. Additional evaluation of structural measures is provided in Table 3.8.

3.1.3.2 Nonstructural Flood Risk Management Alternatives

As stated by local officials, approximately 55 homes have been flooded during major floods such as those in 2004-2006; 22 of those homes are flooded at a depth of 3’ to 5’ on the first floor, with the remainder experiencing basement flooding. The damages range from $50,000 to $75,000 for homes with first floor flooding. For the structures flooded only to the basement level, wet or dry floodproofing and utilities protection should be further evaluated. For structures with significant first floor flooding, building elevation should also be evaluated. If structures with first-floor flooding have sufficient space to permit it and the technique would not impede the function of the structure, free-standing barriers can be evaluated as well.

NFIP criteria do not allow the use of dry-floodproofing for substantially damaged or improved residences. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Table 3.8: Evaluation of Structural Measures: Town of Belvidere

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Flood Risk Management				
Backflow Prevention Structures	Gates or other backflow prevention structures on the Delaware River or tributaries would need to tie into a line of protection (such as levee or floodwall) to prevent overland flooding. Backflow preventers on storm drains typically wouldn't require an accompanying LOP.	Without a line of protection (LOP), may only provide limited effectiveness during low frequency events. Could also address surcharging of Pequest River through storm drains.	Unknown.	No known issues.
Levees and Floodwalls	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures.	Easement requirements may preclude need for construction.	Flood-prone properties are located at the water's edge. May require acquisition of properties in order to construct LOP. Property acquisition would defeat purpose of LOP.	Not likely due to required property acquisition.
Removable Barriers	Barriers cannot be adequately deployed due to structures' proximity to the river.	Limited application due to structure locations.	Cannot realize significant benefits.	Not likely
Road Raisings	Primary flood center is on river side of the roadway.	Not effective.	No.	No.
Area Flood Risk Management				
Channel Modification	n/a	Modification of the Pequest Channel will not address main stem flooding.	Due to the flat river profile, no effective main stem channel modification has been identified.	Unlikely due to extremely high level of instream habitat impact.

Structural Measures	Evaluation Criteria			
	Completeness	Effectiveness	Efficiency	Acceptability
Dams or Impoundments	Removal of downstream dam will not mitigate backwater flooding from Delaware River.	Dam removal will not impact primary source of flooding, which is the main stem of the Delaware River. However, the 1985 NRCS study suggests plans may be cost effective for flooding on the Pequest tributary.	Potential detention sites on the Pequest identified in prior studies are likely to have minimal impact on main stem flooding.	New dams/detention likely to be opposed by local residents and fishing interests. Removal of existing dam may be acceptable.
Diversion	n/a	Ineffective against main stem flooding.	n/a	n/a

3.1.3.3 Nonstructural Screening Results

The initial dataset included 93 individual structures in Belvidere, of which 86 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Belvidere resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.9 and Table 3.10:

Table 3.9: Belvidere: Summary of Nonstructural Costs by Floodplain

Belvidere	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Structures Treated	*0*	*2*	*9*	*30*	*64*	*86*
Total Annual Damage	$0	$19,000	$101,000	$166,000	$210,000	$257,000
First Cost	$0	$242,000	$1,672,000	$4,129,000	$8,346,000	$12,591,000
Temp Relocation	$0	$20,000	$70,000	$280,000	$610,000	$810,000
Contingency	$0	$79,000	$523,000	$1,323,000	$2,687,000	$4,020,000
Construction Cost	$0	$341,000	$2,264,000	$5,731,000	$11,643,000	$17,421,000
Survey/Appraisal	$0	$20,000	$90,000	$300,000	$640,000	$860,000
E&D	$0	$20,000	$90,000	$300,000	$640,000	$860,000
S&A	$0	$41,000	$272,000	$688,000	$1,397,000	$2,091,000
Total Project Cost	$0	$422,000	$2,716,000	$7,019,000	$14,320,000	$21,231,000
Total Annual Cost	$0	$20,000	$129,000	$334,000	$681,000	$1,010,000
Initial Screening BCR	*0.0*	*1.0*	*0.8*	*0.5*	*0.3*	*0.3*

Table 3.10: Belvidere: Summary of Nonstructural Treatments by Floodplain

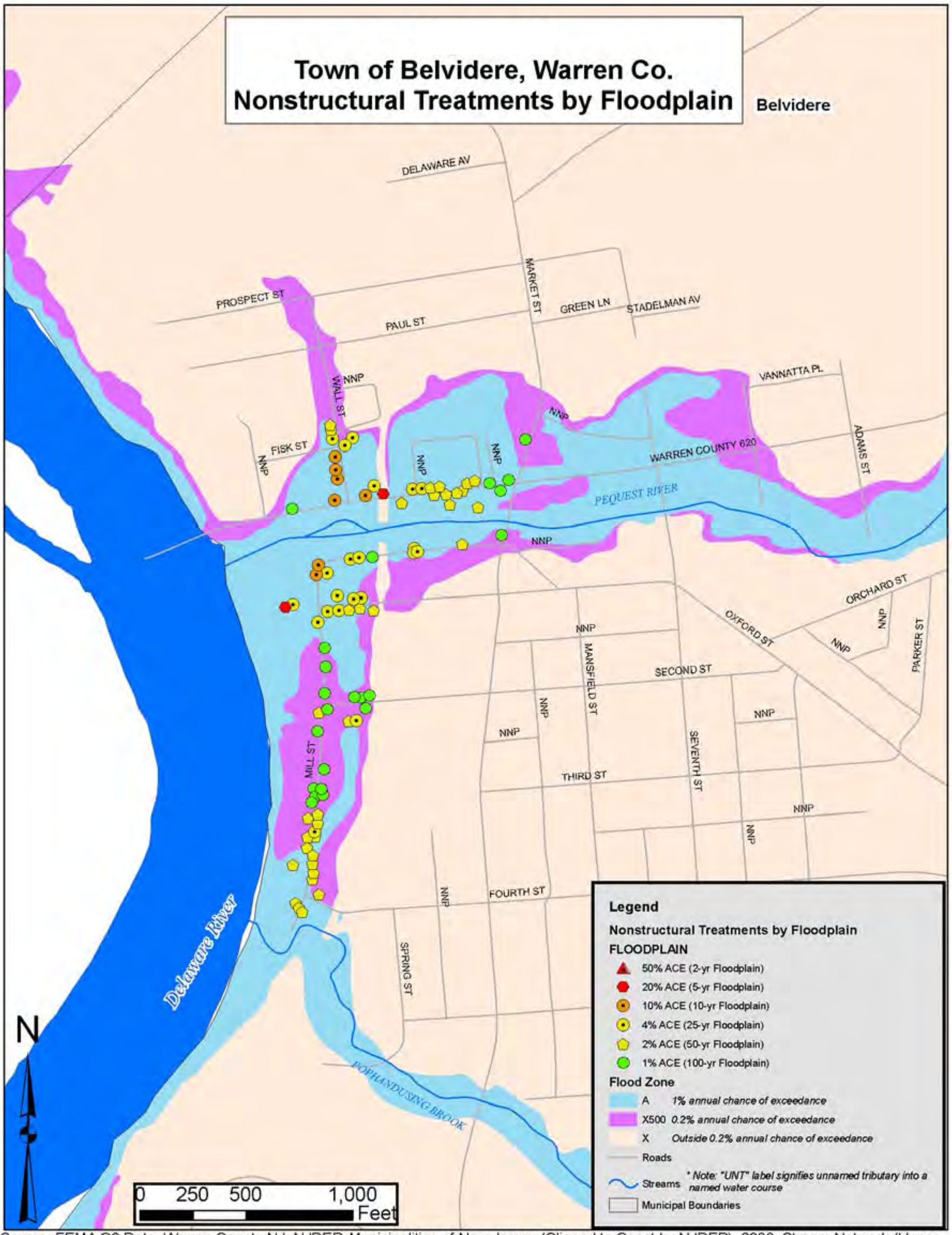
Belvidere	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Elevation	0	2	7	26	56	71
Wet Floodproof	0	0	0	0	1	1
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	2
Rebuild	0	0	0	2	5	10
Acquisition	0	0	2	2	2	2
Totals	*0*	*2*	*9*	*30*	*64*	*86*

See Figure 3.9 for a map of the nonstructural treatments by floodplain. Of the 86 structures in Belvidere for which potential nonstructural treatments have been identified, 78% are residential, and the remaining structures are commercial, light industrial, or storage structures. The majority of structures eligible for treatment (82%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 10 structures and to acquire two. All except three of the structures currently identified for rebuilding or acquisition are non-residential properties.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatments for the 20% ACE (5-year) and 10% ACE (10-year) floodplains in the Town of Belvidere meet or exceed this threshold, and thus are recommended for further evaluation of costs and benefits.

Table 3.11 provides recommendations for the further evaluation of measures in the Town of Belvidere.

Figure 3.9: Belvidere – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.11: Recommendations for Further Evaluation, Town of Belvidere

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
Structural Measures **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout	✓		✓	
Land Acquisition		✓	✓	
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.1.4 Harmony Township

This rural community experienced damage during all three of the 2004 to 2006 floods. Municipal officials report that approximately 125 homes were flooded, and at least 50% of those homes had 2'-3' deep of flooding on the first floor. The Hutchinson section of Harmony Township, along Riveredge Lane, is the lowest-lying area and has the greatest depth of flooding. See Figures 3.10 and 3.11 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

In six to eight homes, floodwaters reached the eaves, and many owners have since substantially elevated their homes (15 feet or more). In 2006, six properties in Hutchinson were demolished and the land restricted to open space uses. This property acquisition was accomplished using funds from FEMA and the NJDEP Green Acres Program. Additional elevations and acquisitions are under way.

In the Brainards sections of Harmony Township, the municipality has foreclosed on the portion of the abandoned quarry property landward of the railroad tracks that traverse the site. Portions of the property are known to be contaminated. The municipality does not want to take on the risks associated with the contaminated property on the river side of the railroad tracks (primarily the water-filled pit). Local officials reported that the property owner has never conducted any remediation for the site. [Note: If it should appear that ecosystem restoration activities would be recommended for this site, then further Hazardous, Toxic and Radioactive Waste (HTRW) investigations would be conducted]. The land between the pit and the Delaware River has breached in two locations, with the breach likely worsening during each of the 2004-06 events. The breach at the southern end of the quarry is approximately 130 LF, according to a NRCS engineering trip report (NRCS, 2008). The crest of the breach has eroded significantly to below river stage, permitting backwater from the river to enter the quarry. There has been significant scouring of the river bank downstream of the southern breach, with a loss of vegetation. This has caused a large depositional area in the river, accompanied by formation of an eddy. In extreme flood events, the flow of the Delaware River is deep enough to overtop the berm; in less significant and more frequent events, river flows are also causing continued erosion. The railroad track dividing the upland portion and the water-filled pit is used for freight trains going to the Con Agra facility and the PP&L plant. There is concern that the trestle over the Delaware River may be affected by the change in river hydraulics associated with the breaches and related shoaling. Whether the trestle may be affected has not been established by study. Harmony Township has reported that NJDEP Green Acres Program potentially has interest in the quarry property.

The NRCS report states:

> <u>*Conclusions*</u>
> "*The dike between the Delaware River and the quarry continues to erode. Backwater into the quarry and the higher flows through the upstream breach will equalize the water level between the water and the quarry. Flood flows over the dike should be less erosive than in the past.*
>
> *The downstream sediment bar by the boat ramp is performing naturally and is protecting the streambank by the house. As the dike continues to erode, the property north of the*

house will be subject to erosion. However, the sediment bar and wooded bank will protect the house by the boat ramp for some time to come.

The bottom of the quarry does not extend well below the riverbed as originally suspected. Therefore, the possibility that a total breach could result in a headcut that would adversely affect upstream reaches is no longer a concern.

Recommendations
No repairs to the dike were deemed necessary at this time. The extremely high cost of repair could only be justified if the failure of the dike would result in catastrophic damage. Based on the 1996 survey of the quarry, the evolution of the site over the past 18 months, and the current condition, the eventual breach of the dike should not have far-reaching negative effects.

[David] Derrick [Corps, Vicksburg] suggested that erosion pins be installed in the opposite bank to monitor erosion rates on the opposite bank. Basic survey information could be verified, such as the riverbed elevation, the breach crest and dimensions, and the bottom of the quarry for the purpose of monitoring change. However, Derrick did not feel that the thalweg [note: deepest channel] of the stream would be redirected into the quarry.

The Township should continue to monitor the site after major flood events." (NRCS, 2008)

Figure 3.10: Harmony Township, Warren County

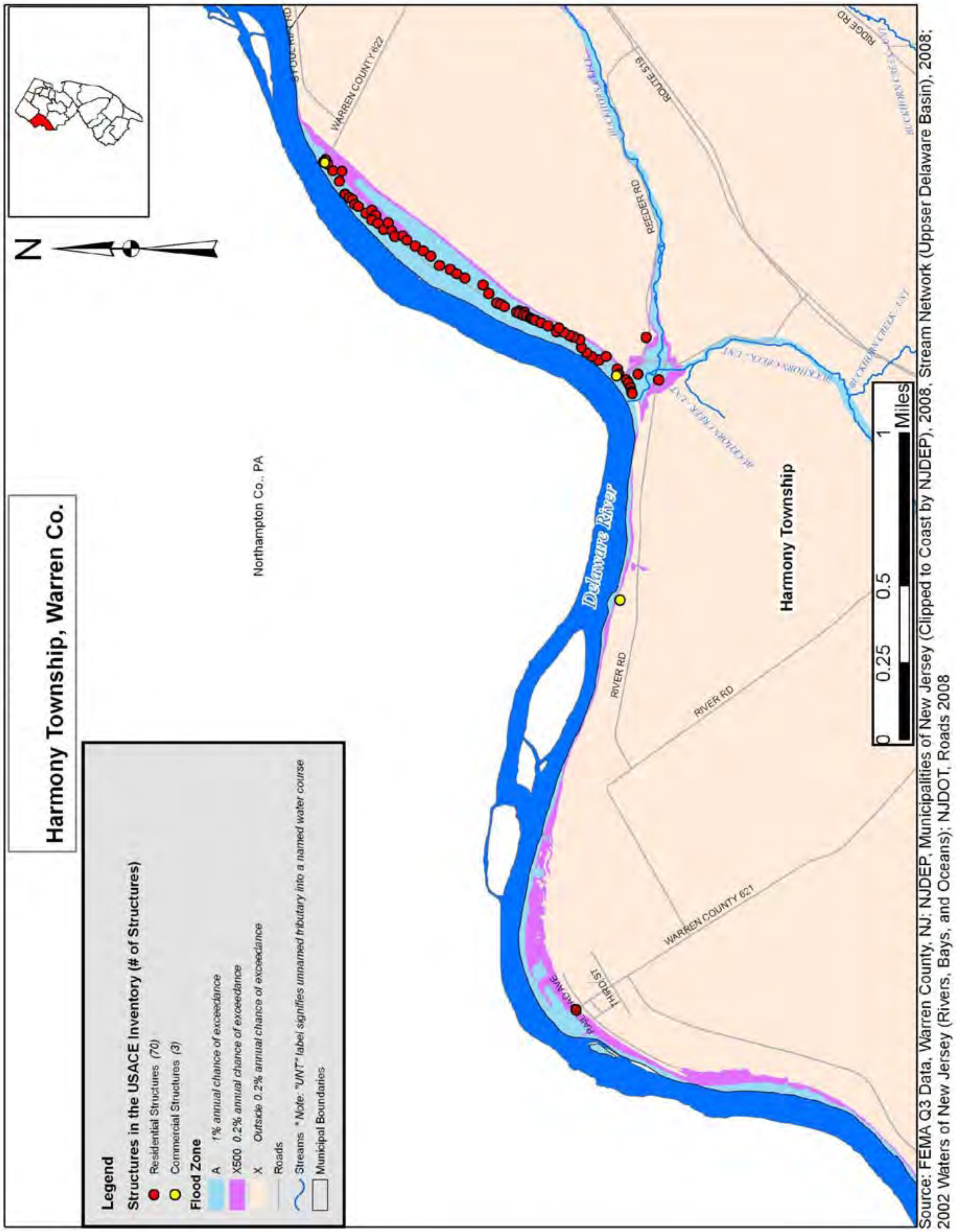
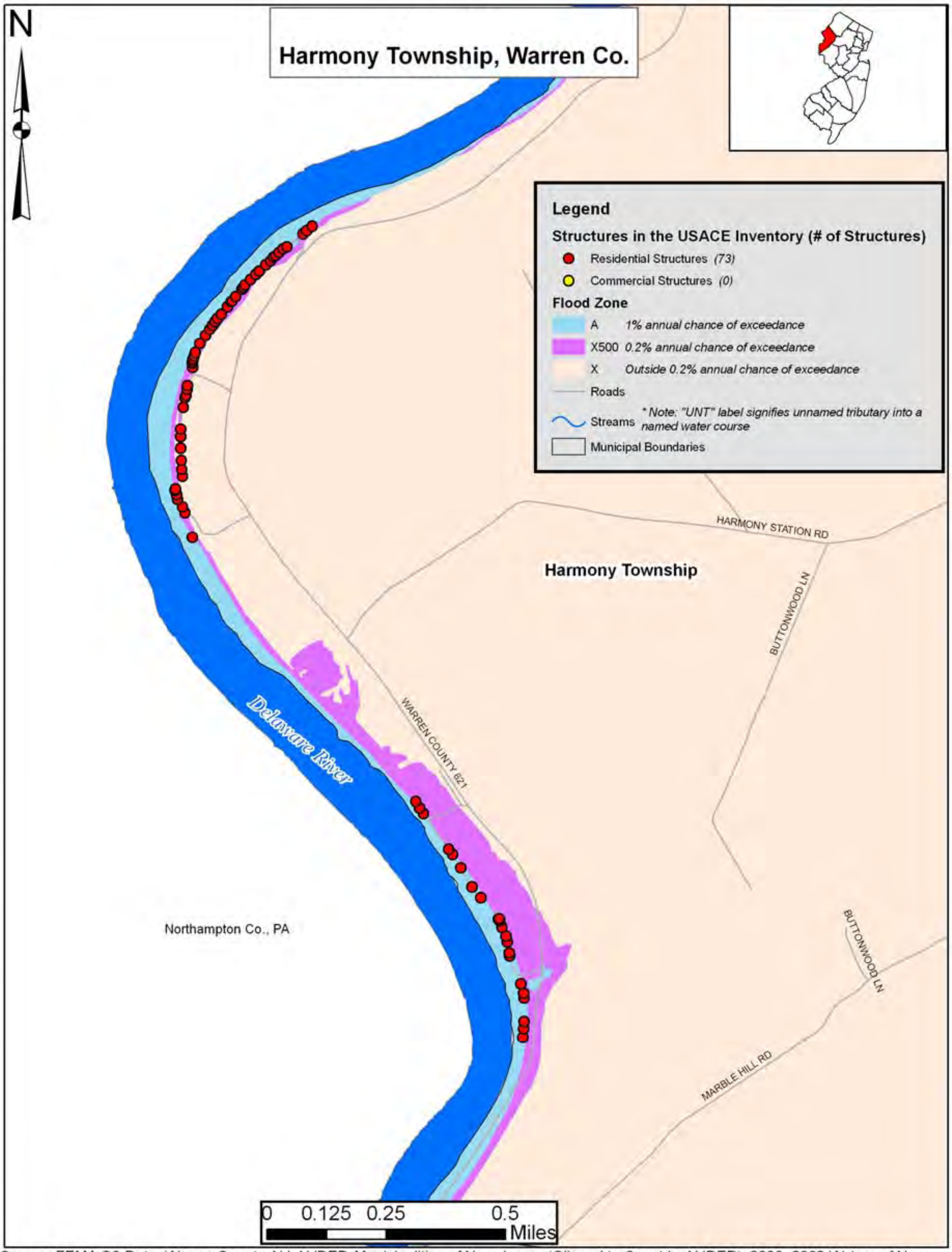


Figure 3.11: Harmony Township (Continued), Warren County



Source: FEMA Q3 Data, Warren County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

3.1.4.1 Structural Flood Risk Management Alternatives

The narrow floodplain along the Delaware typically contains one to two rows deep of housing, such as seen in the Hutchinson section. A floodplain of this type causes structural measures such as a line of protection to be inefficient, given the extensive lengths required to manage flood risks for a limited number of buildings. The depths of flooding experienced at this site, given the low ground elevation, would further increase the cost and dimensions of any LOP. In addition, the properties that have been acquired using FEMA funds are deed-restricted for future use as open space, and cannot be used as part of a Corps project.

The quarry site in Brainards could serve as an environmental restoration opportunity by addressing the large deposition area, the loss of habitat, site contamination, and ongoing erosion. Dredged material from the Delaware River could serve as part of the site restoration. Restoration of the quarry does not present an opportunity for flood risk management, as the breaching does not induce flooding on adjacent areas.

Additional evaluation of structural measures is provided in Table 3.12.

Table 3.12: Evaluation of Structural Measures: Harmony Township

Structural Measures	**Evaluation Criteria**			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Flood Risk Management				
Backflow Prevention Structures	n/a – Flooding is from bank overtopping.	n/a	n/a	n/a
Levees and Floodwalls	May not be possible due to deed restrictions on previously bought-out properties. May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects.	Not implementable.	Not cost-effective.	Not likely. Community focus is on continued buyouts.
Removable Barriers	Barriers cannot be adequately deployed due to structures' proximity to the river.	Limited application due to structure locations.	Cannot realize significant benefits.	Not likely.
Road Raisings	Primary flood center is on river side of the roadway.	Not effective.	No.	No.
Area Flood Risk Management				
Channel Modification	n/a-Flooding is from the main stem of Delaware River.			
Dams or Impoundments	n/a			
Diversion	n/a			

3.1.4.2 Nonstructural Flood Risk Management Alternatives

To manage flood risks in the community, it appears that elevation and acquisition, as are occurring in Hutchinson along Riveredge Lane, are the most appropriate options for evaluation. For the structures flooded only to the basement level, wet or dry floodproofing and utilities protection should be further evaluated.

Wet and dry floodproofing should be evaluated for the flood-prone structures. For those structures with first floor flooding, building relocation, elevation, and purchase of property should also be evaluated. The majority of the structures are wood-framed and suitable for elevation on pilings or extended foundation walls.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

If structures with first-floor flooding have sufficient space to permit it and the technique would not impede the function of the structure, free-standing barriers can be evaluated as well. However, given the depths of flooding in many sections of the community, this technique may not be widely practicable. For example, a 10-foot high barrier around a home would radically alter the home’s usability as a residence, given the difficulties in access or need for flood gates/barriers, as well as interior drainage.

3.1.4.3 Nonstructural Screening Results

The initial dataset included 146 individual structures in Harmony Township, of which 144 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Harmony Township resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.13 and Table 3.14:

Table 3.13: Harmony Township: Summary of Nonstructural Costs by Floodplain

Harmony	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*17*	*32*	*61*	*104*	*135*	*144*
Total Annual Damage	$134,000	$190,000	$335,000	$408,000	$443,000	$451,000
First Cost	$1,410,000	$2,745,000	$5,754,000	$9,987,000	$13,028,000	$14,154,000
Temp Relocation	$170,000	$320,000	$600,000	$1,030,000	$1,330,000	$1,420,000
Contingency	$474,000	$919,000	$1,906,000	$3,305,000	$4,307,000	$4,672,000
Construction Cost	$2,054,000	$3,984,000	$8,260,000	$14,322,000	$18,666,000	$20,247,000
Survey/Appraisal	$170,000	$320,000	$610,000	$1,040,000	$1,350,000	$1,440,000
E&D	$170,000	$320,000	$610,000	$1,040,000	$1,350,000	$1,440,000
S&A	$246,000	$478,000	$991,000	$1,719,000	$2,240,000	$2,430,000
Total Project Cost	$2,640,000	$5,102,000	$10,471,000	$18,121,000	$23,606,000	$25,556,000
Total Annual Cost	$126,000	$243,000	$498,000	$862,000	$1,122,000	$1,215,000
Initial Screening BCR	*1.1*	*0.8*	*0.7*	*0.5*	*0.4*	*0.4*

Table 3.14: Harmony Township: Summary of Nonstructural Treatments by Floodplain

Harmony	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	17	29	53	86	112	120
Wet Floodproof	0	0	0	0	1	1
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	0
Rebuild	0	3	7	17	21	22
Acquisition	0	0	1	1	1	1
Totals	*17*	*32*	*61*	*104*	*135*	*144*

See Figures 3.12 and 3.13 for maps of the nonstructural treatments by floodplain. Of the 144 structures in Harmony Township for which potential nonstructural treatments have been identified, all except two are residential properties. The majority of structures eligible for treatment (83%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 22 structures and to acquire one. With the exception of one storage structure, all the buildings identified for rebuilding are residential properties, as is the single structure identified for acquisition. An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatments for the 50% ACE (2-year), 20% ACE (5-year), and 10% ACE (10-year) floodplains in Harmony Township meet or exceed this threshold, and thus are recommended for further evaluation of costs and benefits.

Figure 3.12: Harmony – Nonstructural Treatments by Floodplain

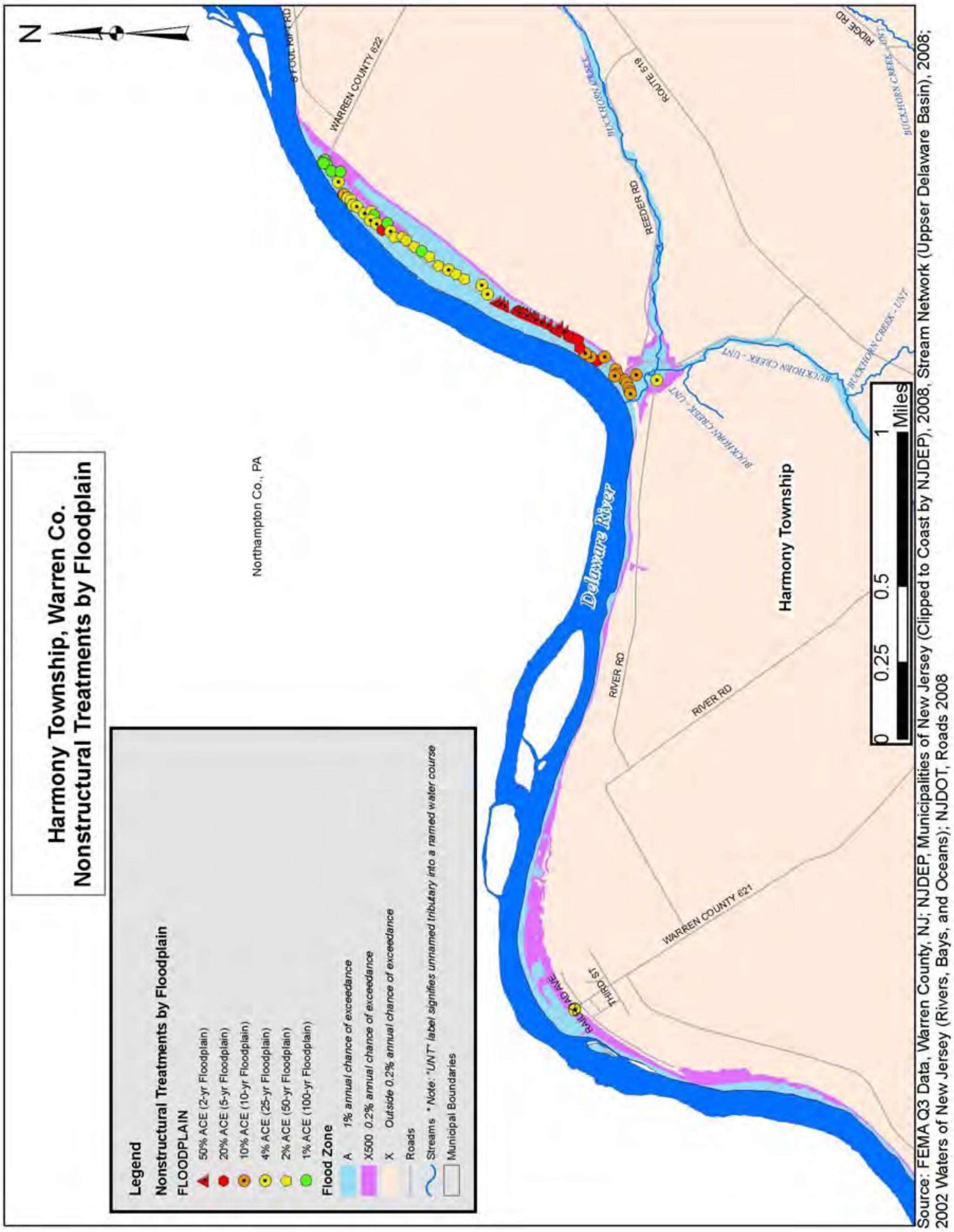
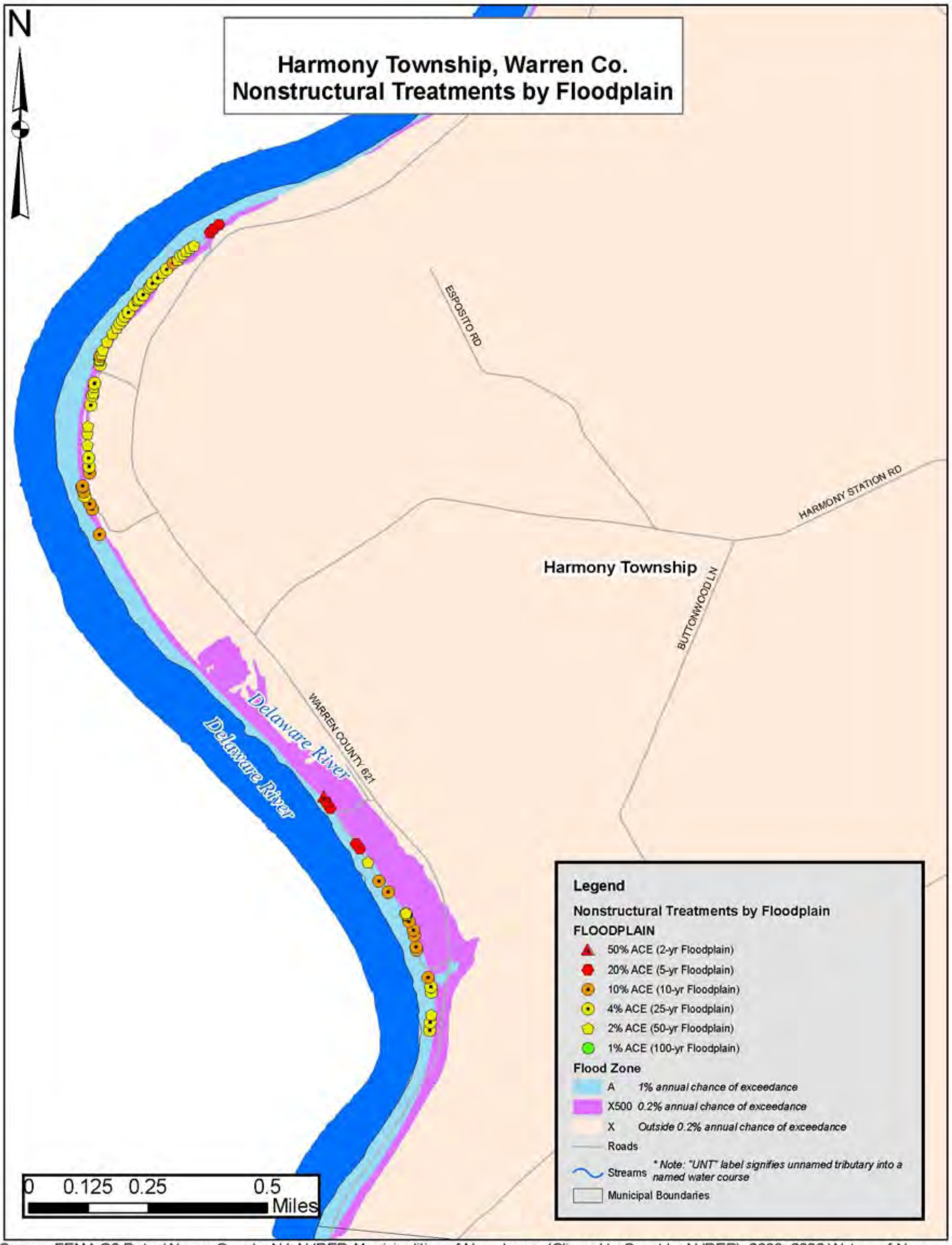


Figure 3.13: Harmony (Continued) – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Warren County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.15 provides recommendations for the further evaluation of measures in Harmony Township.

Table 3.15: Recommendations for Further Evaluation, Harmony Township

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
Structural Measures **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout	✓		✓	
Land Acquisition		✓	✓	
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions			✓	

3.1.5 Town of Phillipsburg

Phillipsburg, located across the river from Easton, PA, has a population of 15,166 (*Census 2000*) and a land area of 3.3 square miles. It is the second largest and densest community in the study area after Trenton. The main areas of flooding are Union Square in the downtown, and the area along the Lopatcong Creek to the south. See Figure 3.14 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

Local officials provided the following information on the sources and extent of flooding. The Delaware River overtopped its banks in 1955 and flooded Union Square to a depth of several feet above grade. The 2004-2006 storms caused flooding by backflow from the Delaware River. The 2004 storm also included 10.5" of rain in Phillipsburg, causing flooding along Lopatcong Creek, and affecting more properties than the 2005 and 2006 events. The Union Square area, from the Route 22 bridge (also known as the "toll bridge") to just south of the Northampton Street Bridge, is a mix of businesses and residential properties. Some of the flooding problem in this area stems from backflow from the Delaware River backing up stormwater pipes. There are ten outfalls into the Delaware River, with outfalls #1 and #6 experiencing the greatest volume of backflow. The section of North Main Street behind the railroad embankment (north of Northampton Street) was flooded from stormwater backup in the 2004-2006 floods. The stormwater was trapped between the masonry row houses and the railroad embankment, causing basement and first floor flooding.

The Lopatcong Creek area, south of downtown, is residential. Two apartment complexes and twenty homes were flooded in this area in 2004 due to heavy rains. In the apartment complexes, basements and first floors were flooded, with some second floor flooding. A private dam was removed from Lopatcong Creek in 2005, which has alleviated some of the flooding problem along its banks. Several properties near the confluence of the creek with the Delaware River were flooded in 2005 and 2006 when the Delaware backed up Lopatcong Creek.

The municipal pumping station between the Route 22 bridge and Northampton Street bridge was inundated in the 2004-06 floods, resulting in the discharge of raw sewage into the Delaware River. The municipal wastewater treatment plant (WWTP) near Lopatcong Creek was also inundated and damaged in all three recent floods, and the plant's lift station had to be replaced.

Municipal officials have stated their greatest concerns are protection of the wastewater treatment plant and the pumping station, and installation of backflow prevention gates on the stormwater system.

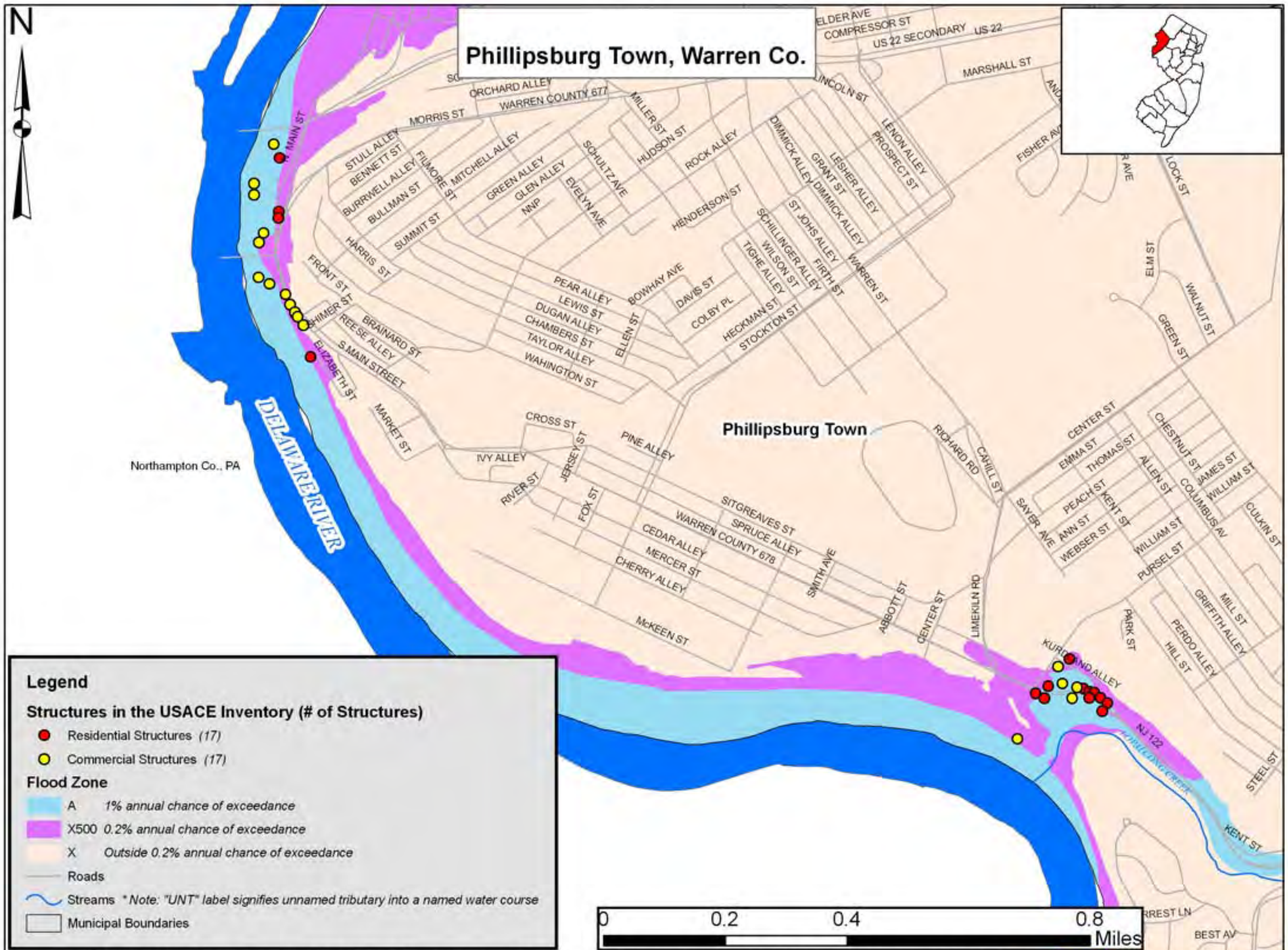
3.1.5.1 Structural Flood Risk Management Alternatives

The low-lying floodplain areas along Lopatcong Creek are a potential candidate for construction of a LOP along the right bank of the creek. (See Figure 3.15). This LOP would protect the homes and apartment complexes, while a ring levee is indicated for in-place protection of the WWTP. The LOP would tie into high ground at the confluence with the Delaware River. Initial order of magnitude estimates indicate that a LOP will cost $4.8 million or more and provide flood risk management to approximately $2 million in buildings plus an unquantified amount of infrastructure. The initial estimate for a ring levee around the WWTP is $13.0 million or more to provide flood risk management to the $15 million plant.

An evaluation will also be needed whether construction of a ringwall at the WWTP would increase water levels on the right bank of Lopatcong Creek, and if so, whether the higher levels would increase damages on that bank. If damages on the right bank would be increased substantially, additional measures may be necessary to mitigate induced flooding. A combined plan of a right bank LOP and a free-standing ringwall will be evaluated in a future phase of the study to provide flood risk management to the entire floodplain in this area, and avoid induced flooding effects from a ringwall at the treatment plant without a LOP for the right bank. Additionally, flood risk management of the treatment plant would reduce or eliminate outflow of sewage during flooding, which would be an environmental enhancement.

Backflow prevention structures are indicated in the Union Square area to reduce or prevent the type of flooding that occurred in the recent events. However, unless a Corps-adopted or designed LOP is in place in the area, the necessary gates, valves, and outfalls structures would be the responsibility of non-Federal interests, and thus would not be eligible as part of a Corps project. Additional evaluation of structural measures is provided in Table 3.16.

Figure 3.14: Phillipsburg Town, Warren County



Source: FEMA Q3 Data, Warren County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.16: Evaluation of Structural Measures: Phillipsburg

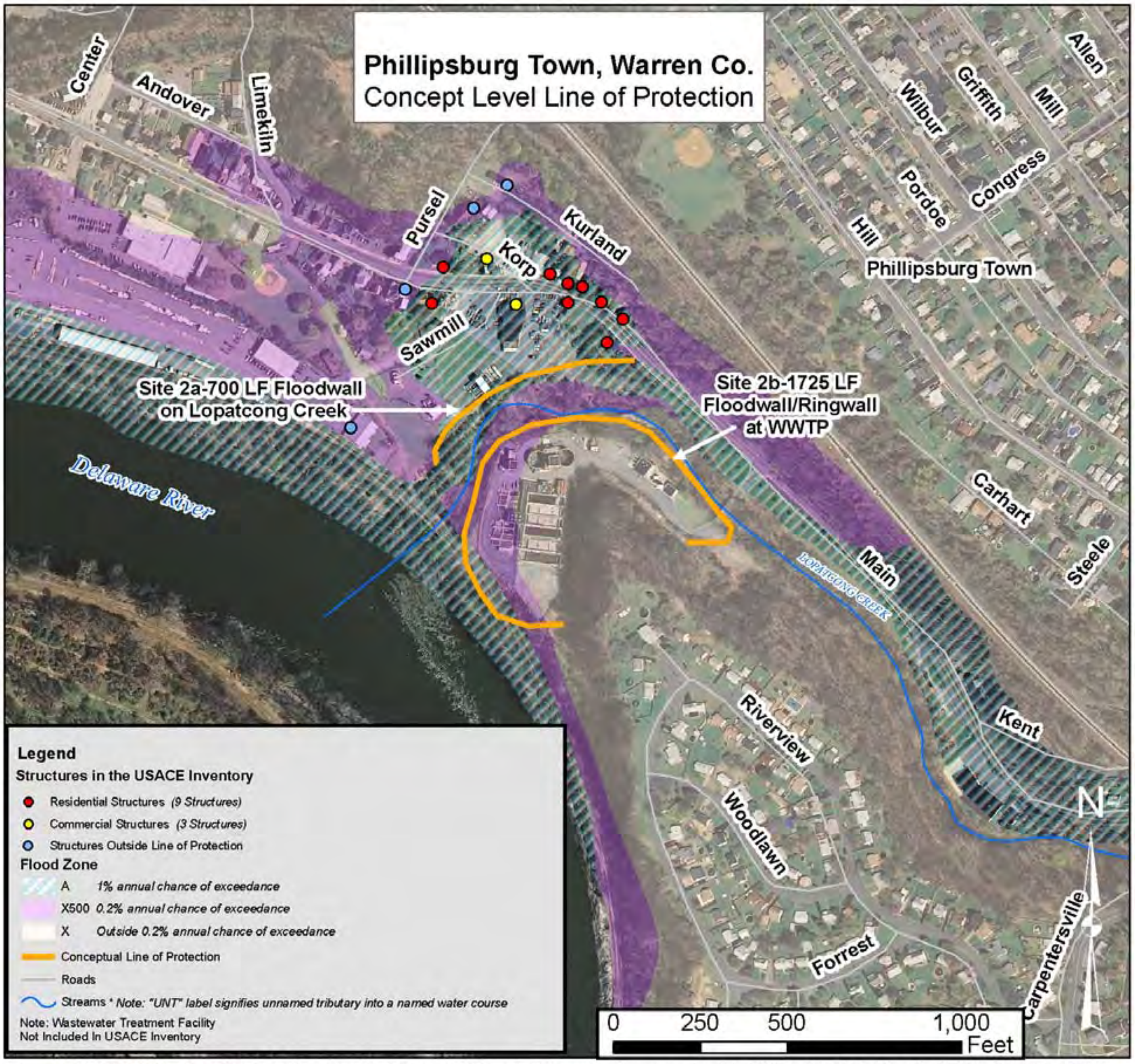
Structural Measures	Evaluation Criteria			
	Completeness	Effectiveness	Efficiency	Acceptability
Local Flood Risk Management				
Backflow Prevention Structures	Gates or other backflow prevention structures on the Delaware River or tributaries (e.g.; Lopatcong Creek) would need to tie into a line of protection (such as levee or floodwall) to prevent overland flooding. Backflow prevention structures on storm drains typically would not require an accompanying LOP.	Without a LOP, may only provide limited effectiveness during low frequency events.	Unknown.	No known issues.
Levees and Floodwalls	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures.	Will reduce tributary flood damages. Effectiveness of measure for the right bank of Lopatcong Creek must be evaluated jointly with protection of WWTP on left bank.	May be cost effective.	No known issues.
Removable Barriers	Difficulty in deployment along the riverbank. Would require pumping to provide interior drainage.	Support requirements almost equivalent to a hard structure. In that case, a levee or floodwall would be more appropriate.	Unknown.	Hard structure may be more effective and thus preferable.
Road Raisings	Primary flood center is on river side of the roadway.	Not effective.	No.	No.

	Evaluation Criteria			
	Completeness	Effectiveness	Efficiency	Acceptability
Area Flood Risk Management				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.1.5.2 Concept-Level Lines of Protection: Costs and Initial Screening Benefits

In Phillipsburg, a 700-foot floodwall for the right bank of Lopatcong Creek to protect 16 buildings would have an estimated annual cost of $340,000 in comparison to AAD of $18,000 (Site 2a). The initial screening BCR is below 0.1 and thus there would be no Corps or other Federal program support for such an alternative (See Figure 3.15). A plan to construct a 1,725 LF ringwall to protect the WWTP on the left bank was prepared. The ringwall at the WWTP is estimated to have an annual cost of $630,000 (Site 2b). An estimation of the AAD of the WWTP has not been made at this phase in the study, and would be required for further evaluation of this alternative. (See Figure 3.15).

Figure 3.15: Phillipsburg – Concept Level Line of Protection



Source: FEMA Q3 Data, Warren County, NJ; Stream Network (Upper Delaware Basin), 2008; NJDOT, Roads 2008; NJOIT, OGIS 2007 - 2008 High Resolution Orthophotography

3.1.5.3 Nonstructural Flood Risk Management Alternatives

Based on a field visit and building inventory, the residences subject to flooding in the Union Square area are multi-story apartments constructed of masonry. The apartments are constructed as rowhouses and may share common walls. Thus, they would likely be more expensive to elevate than single-family homes of frame construction. These buildings are subject to flooding from backwater through the storm sewer drains in the roadway, and thus structural measures such as backflow prevention devices are recommended for further evaluation. Wet or dry floodproofing and utilities protection appear to be the most appropriate nonstructural techniques to reduce risk for these buildings.

Both wet and dry floodproofing should be evaluated. A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. The residences in the Union Square area are in use and do not appear, based on initial inspection, to have been substantially damaged as defined by the NFIP during the 2004-2006 floods. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

The commercial structures in Union Square are a mix of free-standing wood frame and masonry construction. Several of the structures appear to be from the late 19th century. The wood frame buildings should be evaluated for wet or dry floodproofing, elevation, and utilities protection. The masonry structures should be evaluated for wet or dry floodproofing and utilities protection, subject to the criteria stated above. Because the commercial properties require ease of access for patrons, a permanent free-standing barrier is not indicated. Acquisition or relocation of these structures is typically not recommended, as their location in the downtown Union Square business district is integral to their commercial operation.

The residential properties (single-family homes and two apartment complexes) in the Lopatcong Creek floodplain are subject to backwater flooding. The floodwater depths range from the basement to first floor for the majority of the single-family homes; at the apartment complexes, flooding ranged from the basement to the second floor. These buildings should be evaluated for elevation, relocation, acquisition, wet and dry floodproofing, utilities protection, and free-standing barriers.

3.1.5.4 Nonstructural Screening Results

The initial dataset included 33 individual structures in the Town of Phillipsburg of which 16 were considered eligible for individual nonstructural flood risk management measures.

Application of the nonstructural treatment algorithm to the eligible structures in Phillipsburg resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.17 and Table 3.18:

Table 3.17: Phillipsburg: Summary of Nonstructural Costs by Floodplain

Phillipsburg	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*0*	*1*	*3*	*3*	*14*	*16*
Total Annual Damage	$0	$1,000	$20,000	$20,000	$62,000	$65,000
First Cost	$0	$19,000	$253,000	$253,000	$2,410,000	$3,330,000
Temp Relocation	$0	$10,000	$20,000	$20,000	$120,000	$140,000
Contingency	$0	$9,000	$82,000	$82,000	$759,000	$1,041,000
Construction Cost	$0	$38,000	$355,000	$355,000	$3,290,000	$4,511,000
Survey/Appraisal	$0	$10,000	$30,000	$30,000	$140,000	$160,000
E&D	$0	$10,000	$30,000	$30,000	$140,000	$160,000
S&A	$0	$5,000	$43,000	$43,000	$395,000	$541,000
Total Project Cost	$0	$62,000	$458,000	$458,000	$3,964,000	$5,373,000
Total Annual Cost	$0	$3,000	$22,000	$22,000	$189,000	$255,000
Initial Screening BCR	*0.0*	*0.3*	*0.9*	*0.9*	*0.3*	*0.3*

Table 3.18: Phillipsburg: Summary of Nonstructural Treatments by Floodplain

Phillipsburg	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	0	0	1	1	5	6
Wet Floodproof	0	0	0	0	1	1
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	0
Rebuild	0	1	1	1	7	8
Acquisition	0	0	1	1	1	1
Totals	*0*	*1*	*3*	*3*	*14*	*16*

See Figure 3.16 for a map of the nonstructural treatments by floodplain. Of the 16 structures in Phillipsburg for which potential nonstructural treatments have been identified, seven are residential, and the remaining structures are commercial or storage structures. All the residential structures would be subject to elevation, with the exception of one multi-unit structure, which is identified for rebuilding under the current data and assumptions. All the non-residential structures in Phillipsburg eligible for treatment have been identified for rebuilding, with the exception of one commercial structure for which acquisition may be the most cost-effective treatment, and one commercial structure identified for which a wet floodproof treatment has been identified as the most appropriate measure. As noted previously, the acquisition of a commercial structure may not be feasible or acceptable to the property owner.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatments for the 10% ACE (10-year) and 4% ACE (25-year) floodplains in Phillipsburg meet or exceed this threshold, and thus are recommended for further evaluation of costs and benefits.. Table 3.19 provides recommendations for further evaluation of measures in the Town of Phillipsburg.

Figure 3.16: Phillipsburg – Nonstructural Treatments by Floodplain

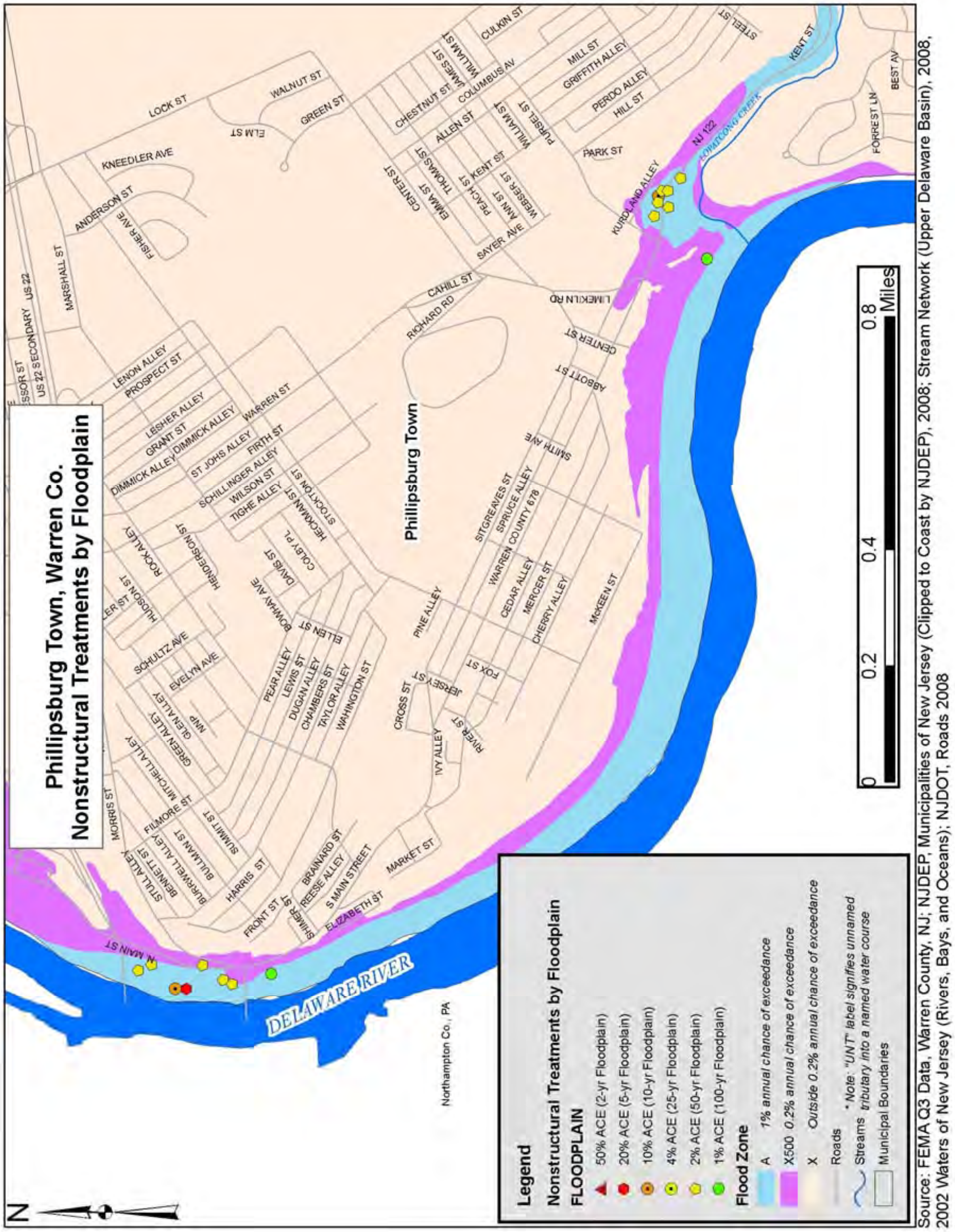


Table 3.19: Recommendations for Further Evaluation, Town of Phillipsburg

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	Other Federal Agency Flood Risk Management Plan	Non-Federal Flood Plain Management Plan (FPMP)	Eliminate from Further Evaluation
Structural Measures **Local Risk Management**				
Backflow Prevention Structures		✓	✓	
Levees and Floodwalls	✓	✓	✓	
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout	✓		✓	
Land Acquisition		✓	✓	
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.1.6 Pohatcong Township

As identified by local officials, there are multiple sources of flooding in this community. The Delaware River overtops along the length of River Road. The floodwaters pose a particular problem when trapped landward of the railroad track below Raubs Island. See Figure 3.17 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA’s Q3 digital floodplain data.

Additional sources of flooding:

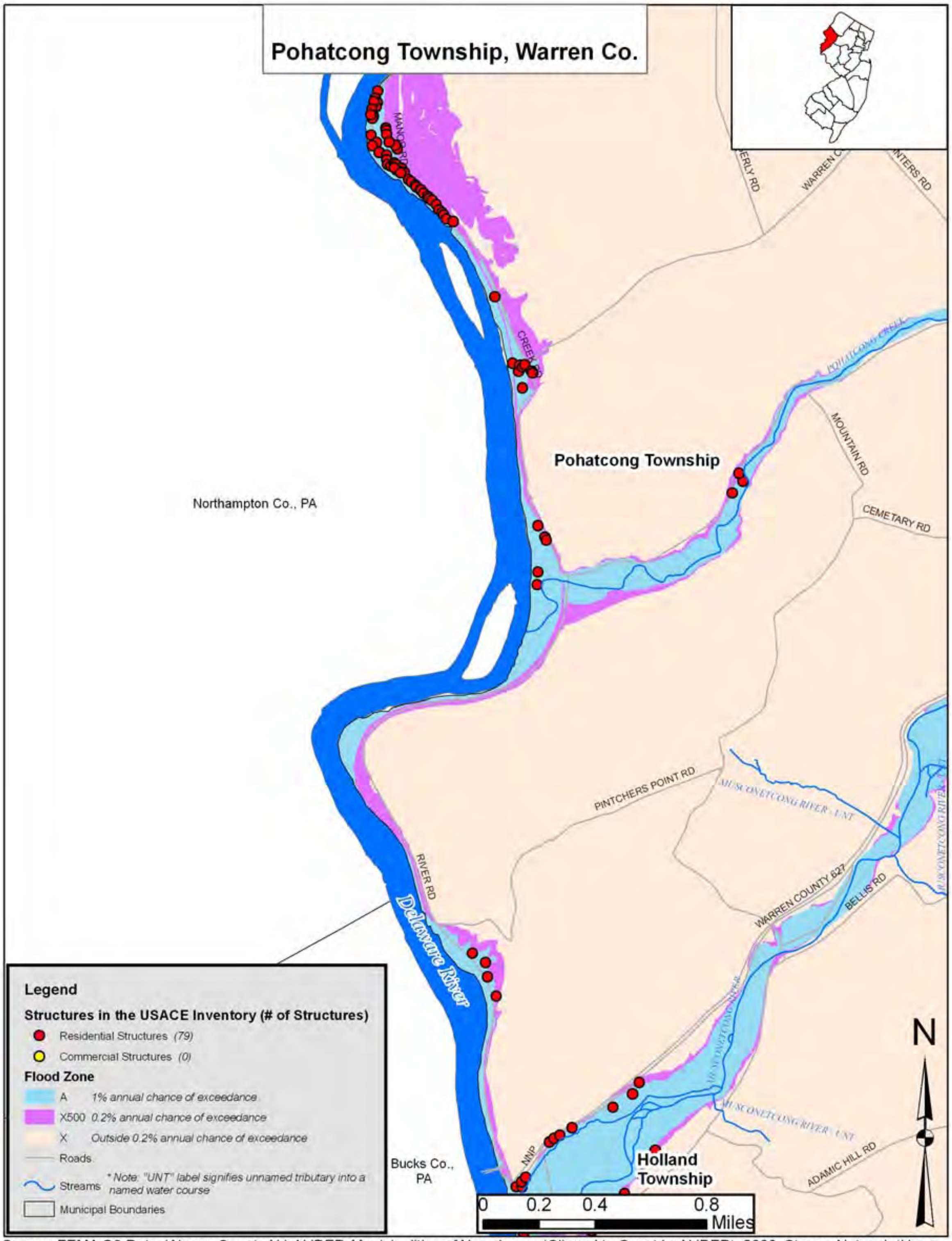
- Overtopping of the small portion of Lopatcong Creek located in Pohatcong.
- Backwater from the Delaware River up Pohatcong Creek.
- Backwater from the Delaware River up the Musconetcong River, causing flooding in the Finesville area.
- Local rainfall causing flooding of Mountain Road in April 2007.

All flooding has been limited to residential structures. Approximately six houses have been raised or were in process as of 2007. Two homes have been acquired. Local officials state there is significant interest in elevation on the part of homeowners, but that residents have reported that Increased Cost of Compliance (ICC) funds from the NFIP (typically $30,000) are insufficient to elevate homes.

3.1.6.1 Structural Flood Risk Management Alternatives

The largest concentration of buildings in the floodplain is approximately 45 homes along River Road. The majority of the buildings are located on the river side of the road, with very little space between the building and the river’s edge. Because of the limited number of properties in the area, their alignment along a narrow floodplain, and the lack of sufficient space between properties and the river, a LOP alternative is not indicated in this area. Further evaluation of structural measures is provided in Table 3.20. Future evaluation will focus on nonstructural alternatives such as elevation.

Figure 3.17: Pohatcong Township, Warren County



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware River Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.20: Evaluation of Structural Measures: Pohatcong Township

Structural Measures	**Evaluation Criteria**			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Flood Risk Management				
Backflow Prevention Structures	Gates or other backflow prevention structures on the Delaware River or tributaries would need to tie into a line of protection (such as levee or floodwall) to prevent overland flooding. Backflow preventers on storm drains typically wouldn't require an accompanying LOP.	Without a LOP, may only provide limited effectiveness during low frequency events.	Unknown.	No known issues.
Levees and Floodwalls	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects.	Not likely due to scattered structures and linear nature of the floodplain.	Not cost-effective.	Not likely.
Removable Barriers	Barriers cannot be adequately deployed for protection due to structures' proximity to the river.	Limited application due to structure locations.	Cannot realize significant benefits.	Not likely.
Road Raisings	Primary flood center is on river side of the roadway.	Not effective.	No.	No.
Area Flood Risk Management				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.1.6.2 Nonstructural Flood Risk Management Alternatives

Based on the structure type and the depth and frequency of flooding, elevation and utilities protection should be evaluated as a means of flood risk management. Many residents have stated their interest in elevating their homes. Relocation and acquisition should also be evaluated, but appear less likely to be cost-effective. Some area residents have stated their interest in acquisition, while others have stated they wish to remain in the buildings at their present location.

Both wet and dry floodproofing should be evaluated. A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Ringwall levees are typically applied to larger commercial or municipal structures. Many of the at-risk homes are in close proximity along the river front and there may not be sufficient space between buildings to construct the necessary line of protection. However, the technique should be evaluated, particularly for homes that have sufficient space to construct a line of protection and are located adjacent to higher ground that could be used to “tie off” the line of protection. In such cases, the use of a berm or earthen levee should be evaluated.

3.1.6.3 Nonstructural Screening Results

The initial dataset included 79 individual structures in the Pohatcong Township, of which 68 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Pohatcong Township resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.21 and Table 3.22:

Table 3.21: Pohatcong Township: Summary of Nonstructural Costs by Floodplain

Pohatcong	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*1*	*11*	*22*	*37*	*55*	*68*
Total Annual Damage	$9,000	$42,000	$68,000	$90,000	$109,000	$117,000
First Cost	$120,000	$1,076,000	$2,138,000	$3,711,000	$5,739,000	$7,163,000
Temp Relocation	$10,000	$110,000	$220,000	$370,000	$550,000	$660,000
Contingency	$39,000	$356,000	$707,000	$1,224,000	$1,887,000	$2,347,000
Construction Cost	$170,000	$1,541,000	$3,065,000	$5,305,000	$8,175,000	$10,169,000
Survey/Appraisal	$10,000	$110,000	$220,000	$370,000	$550,000	$680,000
E&D	$10,000	$110,000	$220,000	$370,000	$550,000	$680,000
S&A	$20,000	$185,000	$368,000	$637,000	$981,000	$1,220,000
Total Project Cost	$210,000	$1,946,000	$3,873,000	$6,682,000	$10,256,000	$12,750,000
Total Annual Cost	$10,000	$93,000	$184,000	$318,000	$488,000	$606,000
Initial Screening BCR	*0.9*	*0.5*	*0.4*	*0.3*	*0.2*	*0.2*

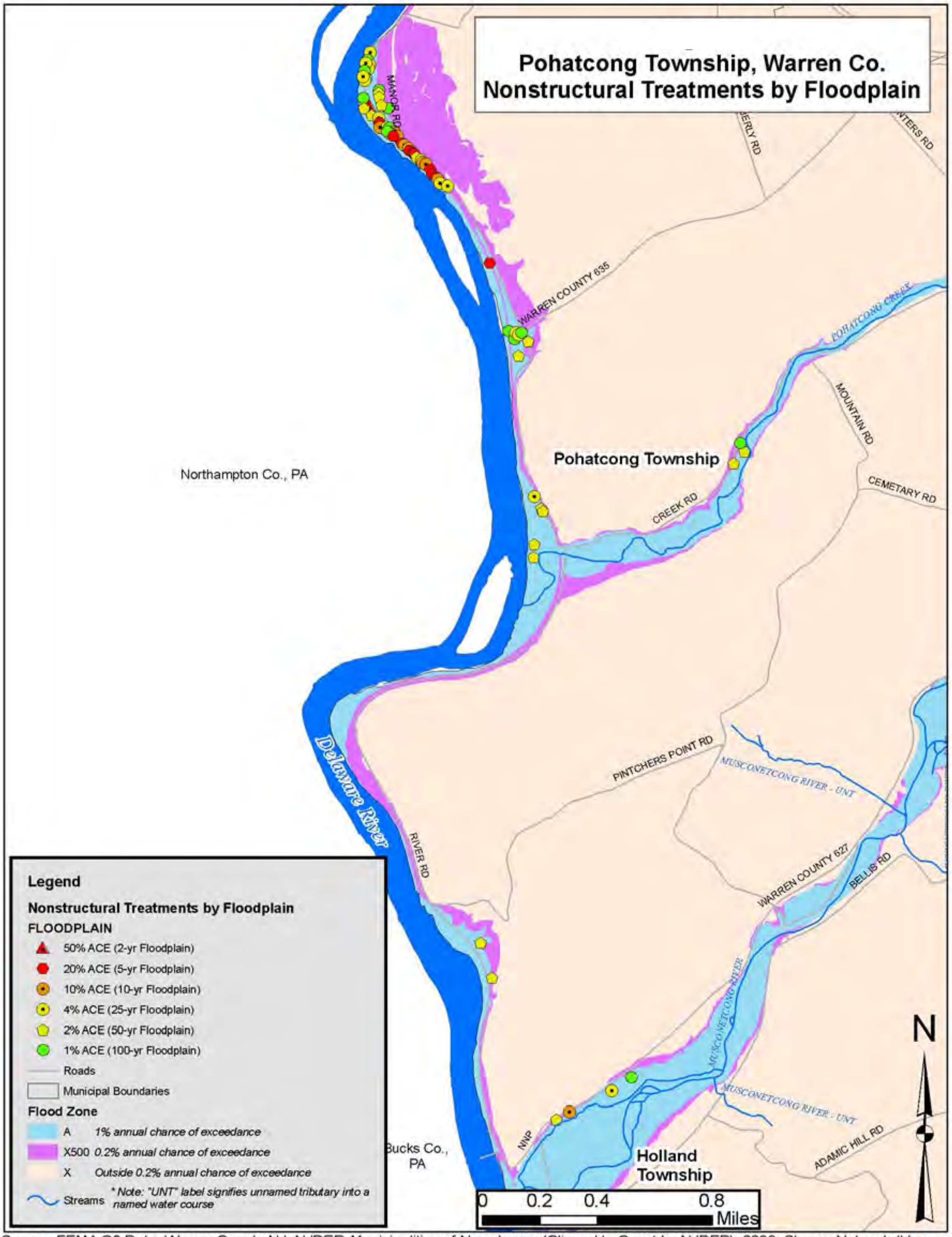
Table 3.22: Pohatcong Township: Summary of Nonstructural Treatments by Floodplain

Pohatcong	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	0	5	11	24	38	46
Wet Floodproof	0	0	0	0	0	2
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	0
Rebuild	1	6	11	13	17	20
Acquisition	0	0	0	0	0	0
Totals	*1*	*11*	*22*	*37*	*55*	*68*

See Figure 3.18 for a map of the nonstructural treatments by floodplain. All the structures in Pohatcong Township for which potential nonstructural treatments have been identified are residential properties and the majority (68%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 20 structures.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. While the treatment for the 50% ACE (2-year) floodplain in Pohatcong Township exceeds this threshold, it involves only a single structure. The Corps cannot provide flood risk management measures for a single private structure and there is no structural plan for this work to be part of. Thus, the nonstructural treatment of the single structure in the 50% ACE (2-year) floodplain cannot be recommended for further evaluation. Table 3.23 provides recommendations for the further evaluation of measures in Pohatcong Township.

Figure 3.18: Pohatcong – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware River Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.23: Recommendations for Further Evaluation, Pohatcong Township

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	Other Federal Agency Flood Risk Management Plan	Non-Federal Flood Plain Management Plan (FPMP)	Eliminate from Further Evaluation
<u>Structural Measures</u> **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				✓
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *<u>Land Use/Regulatory</u>*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices			✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
<u>Building Retrofits</u>				✓
<u>Land Acquisition</u>				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.2 Hunterdon County

3.2.1 Holland Township

The westernmost municipality in Hunterdon County, Holland Township is a rural area located on a bend of the Delaware River. The Musconetcong River joins the Delaware here and serves as the northern border of the township. As stated by local officials, the sources of flooding are the Delaware River overtopping its banks and flooding homes on River Road, and the Delaware backing up the Musconetcong River and flooding Route 627 to mile marker 6. See Figure 3.19 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data. The community was flooded in 2004-06, and in 1996 from an ice jam.

Officials provided the following information on the extent of flooding and damage. Of the 21 homes on River Road, 16 are affected by flooding. A number of the homes on River Road are old and appear to be historic. On Route 627, some houses were flooded to the rooflines. The ground and first floor elevations of the structures along Route 627 vary significantly, with some houses heavily damaged while other structures are unaffected during flood events. Some homeowners in the community are interested in elevating their buildings.

Another house on Route 627 (south of River Road) gets basement flooding. This occurs through a culvert under a railroad. The railroad embankment acts as a levee protecting the adjacent homeowner's property, except at the location of the culvert which funnels floodwater from the Delaware River onto the property. The owner has asked the NJDEP if he can install a floodgate and valve in the culvert to stop the flow.

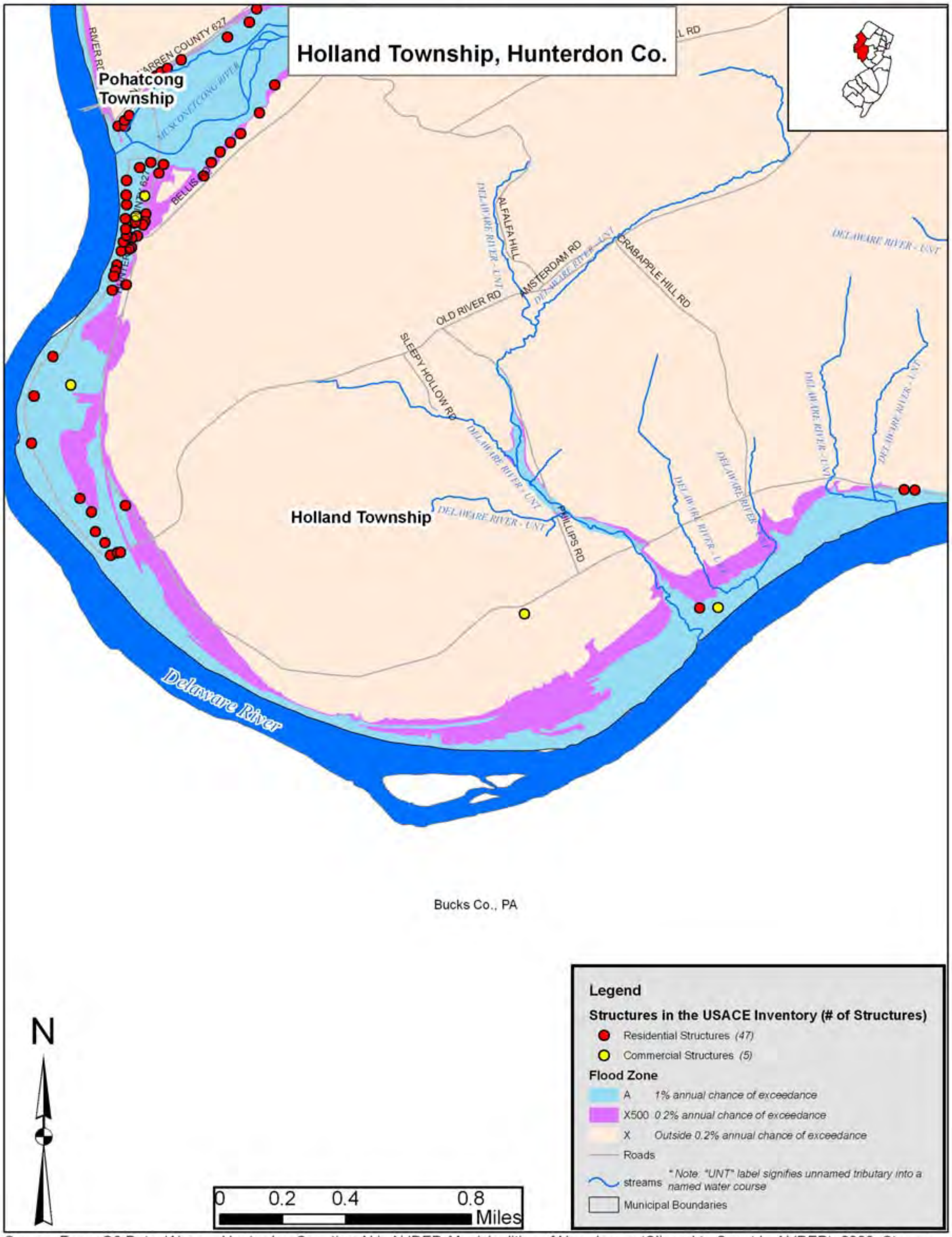
Two industrial properties on Route 627, Corrugated Paper Group and Gilbert Generating Plant/Reliant Energy, experience flooding. The parking lot at the Corrugated Paper Group facility was badly damaged by inundation. At the Reliant Energy site, floodwaters reached some buildings, but did not affect the generating capacity (turbines, cooling towers, etc.)

As stated by local officials, the municipality believes the Delaware River is silting in with debris and sediment, and thus can't convey water as efficiently as in previous years, and that dredging the river would increase capacity and reduce flooding. The effects of siltation and of dredging the river have not been established by study.

3.2.1.1 Structural Flood Risk Management Alternatives

The floodplain along the Delaware and Musconetcong Rivers is generally narrow, and contains at most two rows of housing. The majority of the floodplain contains single rows of houses. In addition, there is limited space between structures on the river side of Route 627 and the river itself. Thus, structural measures are not indicated for the residential properties. The industrial properties have not experienced significant flooding of the core structures but primarily the outlying area, such as the parking lots. Thus, structural measures are not indicated for these properties. Additional evaluation of structural measures is provided in Table 3.24.

Figure 3.19: Holland Township, Hunterdon County



Source: Fema Q3 Data, Warren, Hunterdon Counties, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.24: Evaluation of Structural Measures: Holland Township

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Flood Risk Management				
Backflow Prevention Structures	Gates or other backflow prevention structures on the Delaware River or tributaries would need to tie into a line of protection (such as levee or floodwall) to prevent overland flooding. Backflow preventers on storm drains typically wouldn't require an accompanying LOP.	Without a LOP, may only provide limited effectiveness during low frequency events.	Unknown.	No known issues.
Levees and Floodwalls	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects.	Not likely due to scattered structures and linear nature of the floodplain.	Not cost-effective.	Not likely.
Removable Barriers	Barriers cannot be adequately deployed due to structures' proximity to the river.	Limited application due to structure locations.	Cannot realize significant benefits.	Not likely
Road Raisings	Primary damage locations are on river side of the roadway.	Not effective.	No.	No.
Area Flood Risk Management				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.2.1.2 Nonstructural Flood Risk Management Alternatives

Based on the structure type and the depth and frequency of flooding, elevation of structures and utilities should be evaluated. There are a number of old homes along River Road that appear to be historic. The effects of retrofitting on the historic character of these structures are a consideration. The grade level varies widely along Route 627, and thus the extent of raising required to achieve the desired level of risk management would vary by building. Relocation and acquisition should also be evaluated, but appear less likely to be cost-effective. Both wet and dry floodproofing should be evaluated. A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Ringwalls or free-standing barriers are typically applied to larger commercial or municipal structures. Many of the at-risk homes are in close proximity along the river front and there may not be sufficient space between buildings to construct the necessary line of protection. However, the technique should be evaluated, particularly for homes that have sufficient space to construct a line of protection and are located adjacent to higher ground that could be used to “tie off” the LOP. In such cases, the use of a berm or earthen levee as the LOP should be evaluated.

3.2.1.3 Nonstructural Screening Results

The initial dataset included 52 individual structures in Holland Township, of which 20 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Holland Township resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.25 and Table 3.26:

Table 3.25: Holland Township: Summary of Nonstructural Costs by Floodplain

Holland	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*0*	*1*	*3*	*7*	*15*	*20*
Total Annual Damage	$0	$4,000	$12,000	$30,000	$37,000	$206,000
First Cost	$0	$99,000	$314,000	$800,000	$1,536,000	$4,224,000
Temp Relocation	$0	$10,000	$30,000	$70,000	$140,000	$180,000
Contingency	$0	$33,000	$103,000	$261,000	$503,000	$1,321,000
Construction Cost	$0	$142,000	$447,000	$1,131,000	$2,179,000	$5,726,000
Survey/Appraisal	$0	$10,000	$30,000	$70,000	$150,000	$200,000
E&D	$0	$10,000	$30,000	$70,000	$150,000	$200,000
S&A	$0	$17,000	$54,000	$136,000	$261,000	$687,000
Total Project Cost	$0	$179,000	$560,000	$1,407,000	$2,740,000	$6,813,000
Total Annual Cost	$0	$9,000	$27,000	$67,000	$130,000	$324,000
Initial Screening BCR	*0.0*	*0.4*	*0.4*	*0.4*	*0.3*	*0.6*

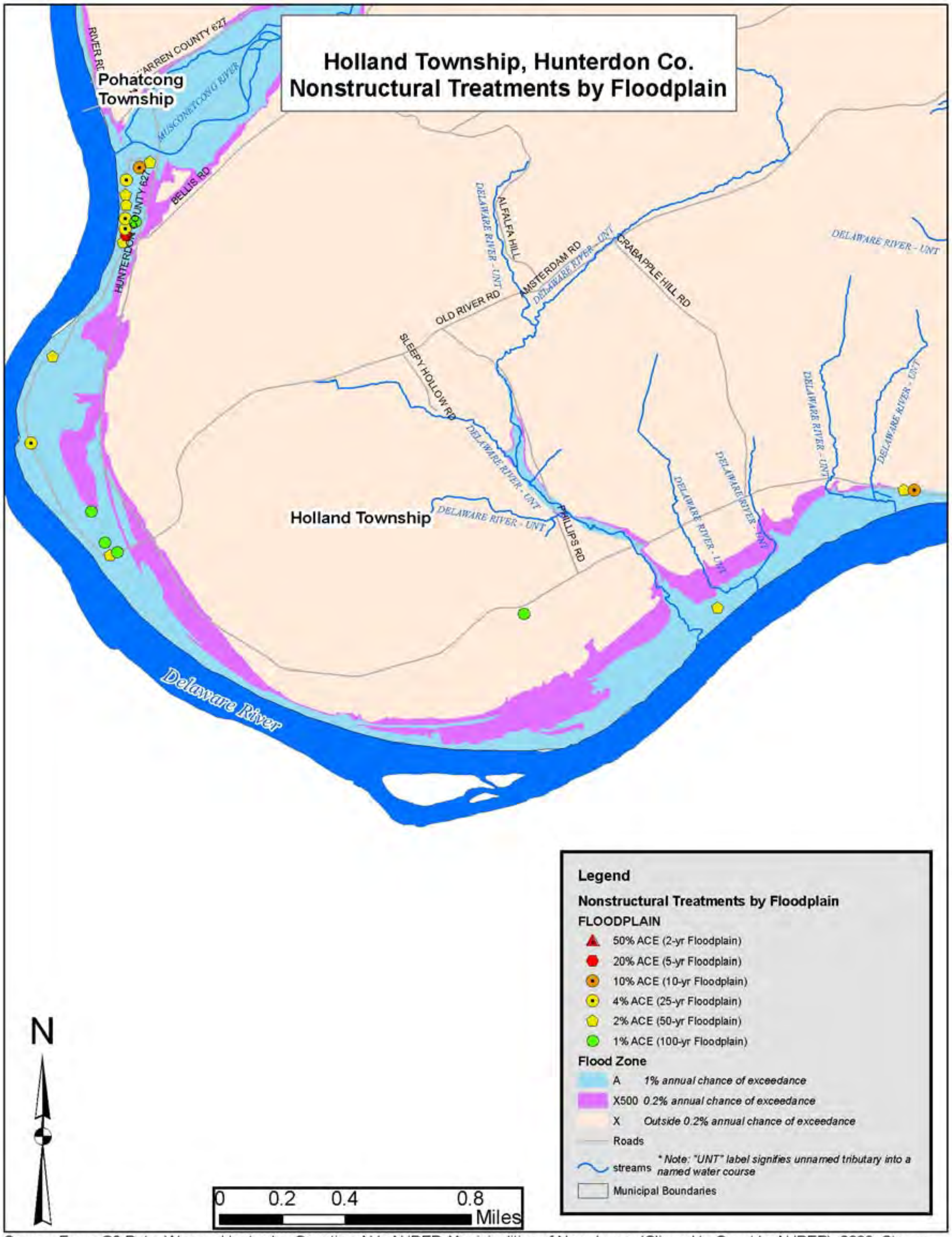
Table 3.26: Holland Township: Summary of Nonstructural Treatments by Floodplain

Holland	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	0	1	2	6	11	14
Wet Floodproof	0	0	0	0	1	1
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	1
Rebuild	0	0	1	1	3	4
Acquisition	0	0	0	0	0	0
Totals	*0*	*1*	*3*	*7*	*15*	*20*

See Figure 3.20 for a map of the nonstructural treatments by floodplain. Of the 20 structures in Holland Township for which potential nonstructural treatments have been identified, all except two are residential properties. One of the two non-residential properties is a sizable power generating facility, to which a ringwall has been assigned. The majority of structures eligible for treatment (70%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild four structures, of which three are residential properties and the fourth is a storage structure.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. None of the nonstructural treatments for the various floodplains in Holland Township reach this threshold, and thus no further evaluation of these measures is recommended. Table 3.27 provides recommendations for the further evaluation of measures in Holland Township.

Figure 3.20: Holland – Nonstructural Treatments by Floodplain



Source: Fema Q3 Data, Warren, Hunterdon Counties, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.27: Recommendations for Further Evaluation, Holland Township

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	Other Federal Agency Flood Risk Management Plan	Non-Federal Flood Plain Management Plan (FPMP)	Eliminate from Further Evaluation
<u>Structural Measures</u> **Local Risk Management**				
Backflow Prevention Structures		✓	✓	
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *<u>Land Use/Regulatory</u>*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
<u>Building Retrofits</u>				✓
<u>Land Acquisition</u>				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.2.2 Borough of Frenchtown

Frenchtown is one of the more densely-developed communities in the study area, with a population of 1,488 (*Census 2000*) in 1.3 square miles, for a density of 1,160 residents per square mile. The community was flooded in 1996, 2004, 2005, and 2006. Local officials described how an old railroad right-of-way and embankment, now owned by NJDEP Parks and Forestry, runs parallel to the Delaware River and is currently used as a bicycle path. The embankment serves as a levee and protects the majority of Frenchtown from any water that overtops the bank of the Delaware River. The embankment has been overtopped only once, during the flood of record in 1955, at the lowest point in the path.

Floodwaters from the Delaware River back up the tributaries Nishisakawick Creek and Little Nishisakawick Creek, as well as the storm sewers and large culverts under the bicycle path embankment. See Figure 3.21 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

There are distinct areas of flooding identified by local officials and FEMA flood mapping:

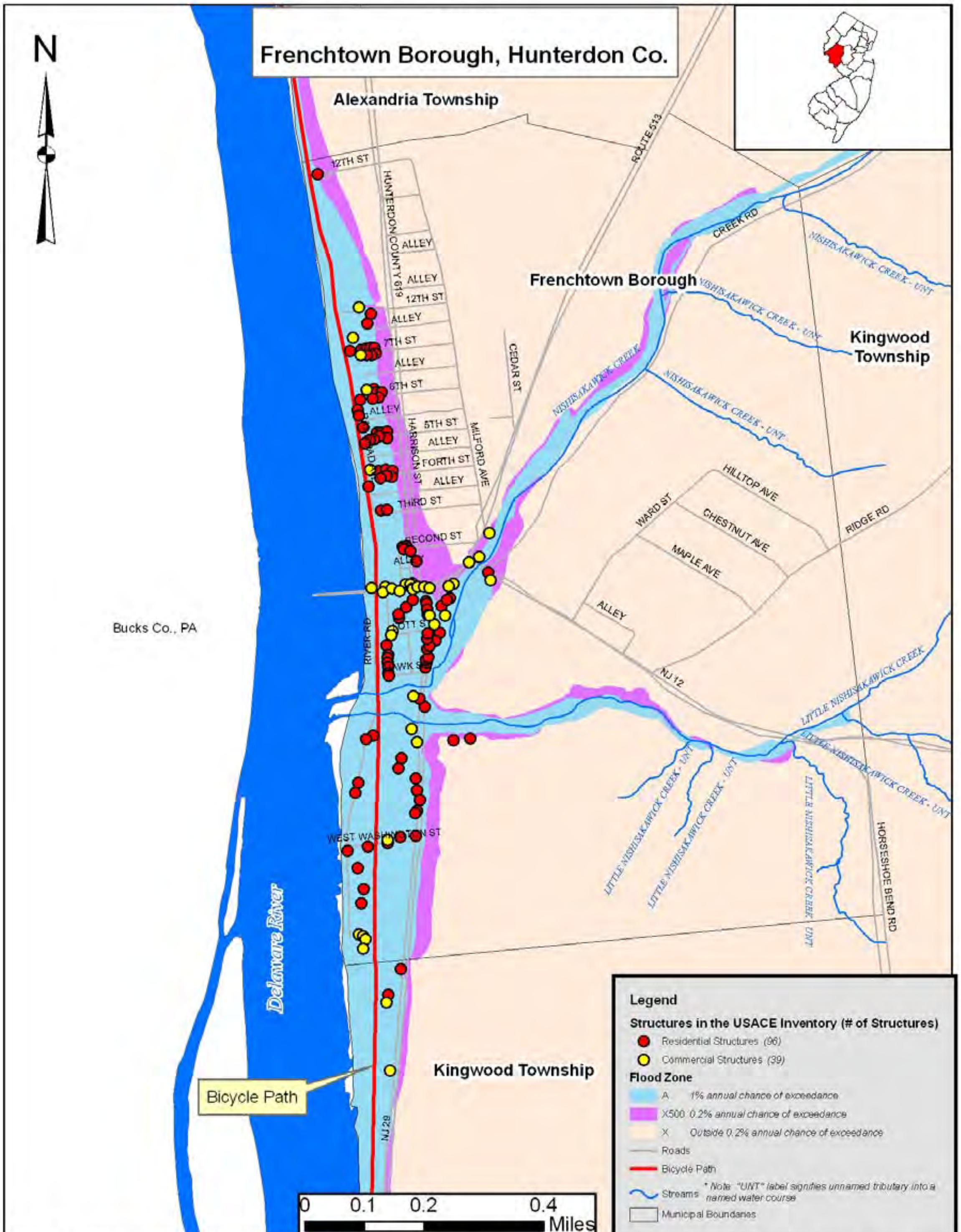
- The grounds of the wastewater treatment plant at the southern end of River Road, and along River Road.
- The area next to Nishisakawick Creek, generally bounded by Hawk Street, Trenton Avenue, River Road, and Bridge Street.
- The area between Bridge and 3rd Streets, and between the bike path and Harrison Road.
- Along Railroad Avenue.

On the Delaware River side of the bike path, municipal officials reported that 11 structures experienced flood damage in the 2004-06 floods, including the pumps and garage at the wastewater treatment plant, and houses. One house had only basement damage while the rest had first floor flooding. Two elevated structures were not damaged.

When the Delaware River backs up the two creeks, the water flows through the culverts under the bike path, which led to flooding of 23 homes, businesses, and the Post Office in 2005.

The municipality is in the process of designing a new wastewater treatment plant at the southern end of River Road to replace the capacity-limited existing facility. The lot immediately adjacent to (downstream of) the treatment plant is a known Hazardous, Toxic and Radioactive Waste (HTRW) site on the National Priorities List (NPL, or Superfund). The site is under remediation and monitoring.

Figure 3.21: Frenchtown Borough, Hunterdon County



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Municipal officials have stated they would like the Corps of Engineers to install bladders and floodgates to block the culverts on the Nishisakawick and Little Nishisakawick creeks. The inflatable bladders would be installed an hour or two before the flood while the floodgates would be permanent. The municipality reports that most of the runoff coming down the creek occurs before the Delaware River backflows into the creeks.

There is a bend in the Delaware River above town. Municipal officials have stated their belief that this has caused sediment deposits and islands to form at the confluence of Nishisakawick Creek with the Delaware River. They believe that this sediment reduces the conveyance capacity of the river, which then increases the backflow of the main stem waters into the creeks. The municipality believes that removing this sediment would reduce flooding in the area. Preliminary hydraulic analysis of the effects of deepening the existing channel indicates that up to a two-foot deepening of the main stem Delaware riverbed would have only minor effects on main stem flooding. In turn, deepening the main stem would have even less effect on backwater flooding on tributary creeks. Sedimentation may still be accumulating at the mouth of the Nishisakawick Creek without being captured in the model. This accumulation, if any, could impact flows coming down the Nishisakawick Creek but not the flows on the Delaware River, since the Delaware is so much larger than the tributary itself.

The municipality is interested in raising the bike path 3”-4” each year through the placement of stone, and has also considered adding a stormwater backflow prevention bladder in the culverts under the path.

3.2.2.1 Structural Flood Risk Management Alternatives

An option is to use the existing flood risk management afforded by the bicycle path embankment as part of a new (or redesigned) LOP meeting Corps design standards (See Figure 3.22). The bike path in Frenchtown was overtopped during the 1955 flood of record, and floodwater from the Delaware backflows through openings in the path into the tributaries of Nishisakawick and Little Nishisakawick Creek and through culverts and storm sewers. By increasing the stability and, where needed, the elevation of the bike path embankment, the existing level of flood risk management can be increased. The necessary interior drainage improvements, such as backflow prevention, would then be eligible as part of the Corps project. This LOP would be approximately 7,000’ in length, with an outlet structure every 400’, and a pump station at the confluence of the Nishisakawick Creek and Little Nishisakawick Creek. If the bike path was raised to protect against potential overtopping by a flood similar to the 1955 event or greater, and backwater flooding prevented through the tributary confluences and storm sewers, the sources of flooding in Frenchtown would be comprehensively addressed.

The quality, condition, and performance of the bicycle path as a risk management feature have not been evaluated by the Corps. The bicycle path was neither constructed, nor maintained, for flood risk management and is highly unlikely to meet standards for that purpose. The approach to the calculation of average annual damage is to evaluate without project damages assuming that non-certified features provide no flood risk management. If the annual cost of the structural alternative exceeds the annual damages under this assumption, it is not necessary to refine the analysis to reflect the level of flood risk management actually provided by the existing feature. If the annual damages exceed the annual costs, then further analysis is necessary to determine the level of risk management and potential reduction in damages the existing feature provides. Any structures not designed as a levee would require an investigation to determine their structural integrity. Also, an increase in the elevation of a structure serving as a LOP would necessitate an increase in the width of its base.

Any backflow prevention devices (such as floodgates or bladders) on the creeks through the bike path would require pumping stations for interior drainage or significant upstream detention and storage capacity. Installation of pressure diversion lines and upstream retention will minimize the interior drainage requirements behind the LOP.

The 10% ACE (10-year) flow rate of the Nishisakawick and Little Nishisakawick Creeks would need to be 800 cfs or more to qualify as a “major drainage area” and be eligible for drainage or flood management improvements to be made by the Corps.

It is assumed that the new wastewater treatment facility will be built in compliance with NFIP regulations and be located above the BFE, or otherwise protected from floodwaters, through means such as a ring levee. Additional evaluation of structural measures is provided in Table 3.28.

Table 3.28: Evaluation of Structural Measures: Borough of Frenchtown

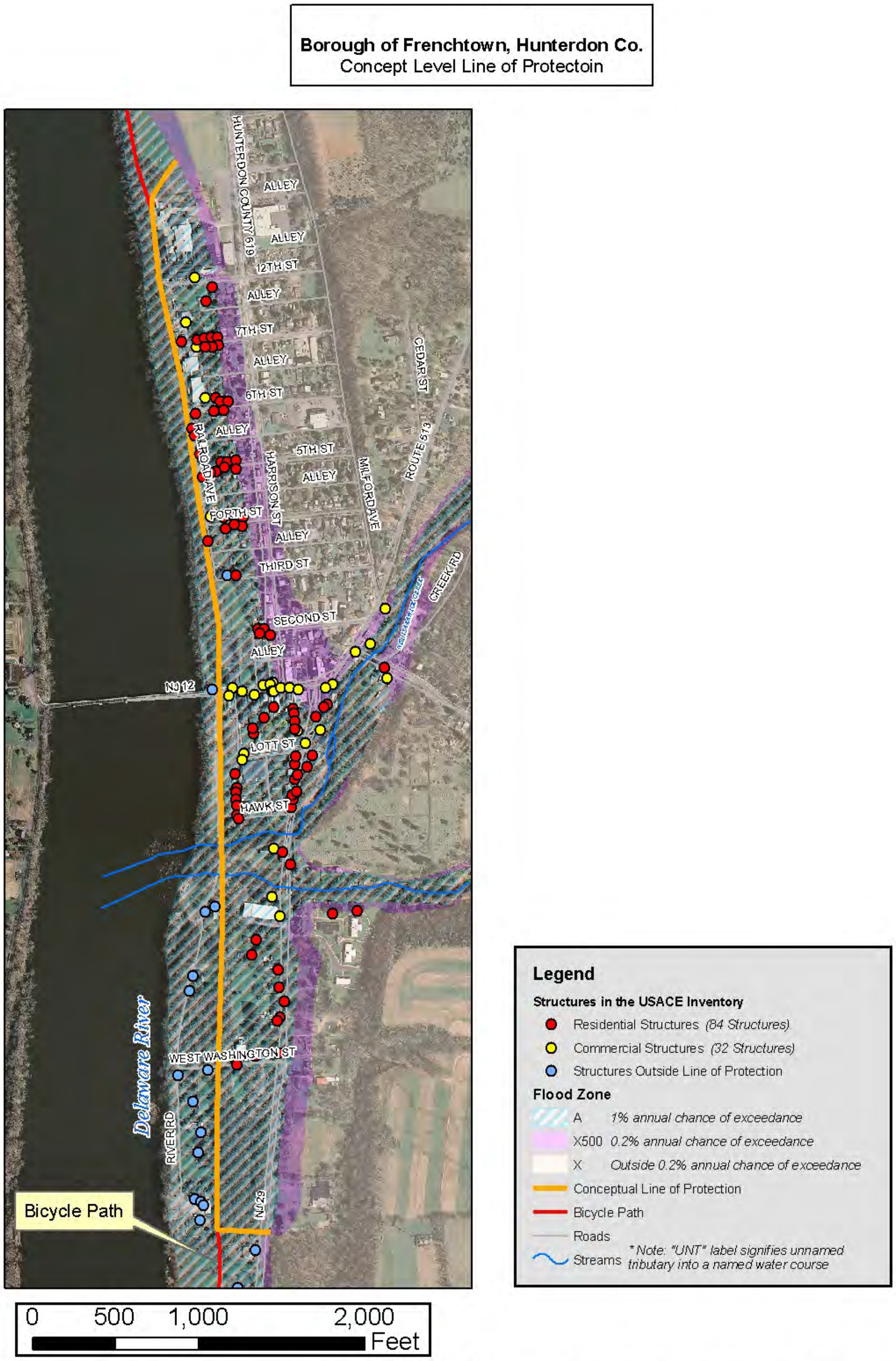
Structural Measures	**Evaluation Criteria**			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Flood Risk Management				
Backflow Prevention Structures	Would require a stability analysis for the existing LOP (bike path) to establish a viable LOP. Backflow prevention on the two creeks would require significant interior drainage facilities, and would require construction of a LOP along the creeks to prevent overland flooding. Backflow prevention on storm drains would not typically require a LOP.	Without a viable LOP on main stem of Delaware River or tributaries, may only provide limited effectiveness during low frequency events.	Unknown.	No known issues.
Levees and Floodwalls	Augmentation of existing landform (bike path) may provide substantial flood risk management. Detailed structural analysis of existing LOP required. May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures.	Will reduce main stem flood damages.	Unknown.	Potential aesthetic impacts by blocking views/access to the river.
Removable Barriers	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Existing design (width, stability) of bike path may limit options for deployability. Flood Warning is critical for deployment of floodwalls to alert residents to flooding conditions and conduct evacuations during floods. Interior drainage pumping may be required.	Will reduce main stem flood damages.	Unknown.	Structural issues similar to levee floodwall. Design of bike path may limit or restrict deployability. May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects.
Road Raisings	Primary flood center is on river side of the roadway.	Not effective.	No.	No.

	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Area Flood Risk Management				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.2.2.2 Concept-Level Line of Protection: Costs and Initial Screening Benefits

In Frenchtown (Figure 3.22), a 7,000 LF floodwall on top of the existing bicycle path and embankment was estimated to have annual costs of $810,000 (Site 3). The AAD for the 117 buildings behind this LOP is $140,000, producing an initial screening BCR of 0.2. This alternative is unlikely to be cost-effective and thus there would be no Corps or other Federal program support.

Figure 3.22: Frenchtown – Concept Level Line of Protection



Source: FEMA Q3 Data, Hunterdon County NJ; NJDEP, Stream Network (Upper Delaware Basin), 2008; NJDOT, Roads 2008; NJOIT, OGIS, 2007 - 2008 High Resolution Orthophotography

3.2.2.3 Nonstructural Flood Risk Management Alternatives

As described above, the buildings at risk in Frenchtown typically flood when Delaware River flooding backs up the tributaries and flows through culverts in the bicycle path. The bicycle path itself has only overtopped once with water from the main stem, during the record flood of 1955. Based on the structure type and the depth and frequency of flooding, elevation and utilities protection should be evaluated as means of flood risk management for these buildings, along with wet and dry floodproofing.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

A determination will be needed on the historic character of any building suitable for retrofit, and whether the effects of retrofitting on the historic character of the structure are a consideration. Relocation and acquisition should be evaluated. Space for relocation of properties within the community may be limited. If widely applied, these alternatives would have a significant impact on the character of the community, and would have to be reviewed for negative effects to any historically significant buildings, and to the community overall.

Ringwall levees are typically applied to larger commercial or municipal structures. Many of the at-risk homes are in close proximity in the main section of the community and there does not appear to be sufficient space between buildings to construct the necessary line of protection.

The wastewater treatment plant on River Road at the southern boundary of the community is slated for expansion and/or replacement. Existing structures (e.g., maintenance garage, office, etc.) that ultimately feature in the new facility, if any, should be evaluated for wet and dry floodproofing, and where it would not interfere with the daily operation, stand-alone barriers.

3.2.2.4 Nonstructural Screening Results

The initial dataset included 131 individual structures in the Borough of Frenchtown, of which 59 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Frenchtown resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.29 and Table 3.30:

Table 3.29: Frenchtown: Summary of Nonstructural Costs by Floodplain

Frenchtown	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*0*	*3*	*15*	*31*	*43*	*59*
Total Annual Damage	$0	$19,000	$79,000	$105,000	$135,000	$161,000
First Cost	$0	$636,000	$2,442,000	$3,910,000	$6,646,000	$9,700,000
Temp Relocation	$0	$20,000	$120,000	$270,000	$380,000	$500,000
Contingency	$0	$197,000	$769,000	$1,254,000	$2,108,000	$3,060,000
Construction Cost	$0	$852,000	$3,331,000	$5,434,000	$9,134,000	$13,260,000
Survey/Appraisal	$0	$30,000	$150,000	$310,000	$430,000	$590,000
E&D	$0	$30,000	$150,000	$310,000	$430,000	$590,000
S&A	$0	$102,000	$400,000	$652,000	$1,096,000	$1,591,000
Total Project Cost	$0	$1,014,000	$4,031,000	$6,706,000	$11,090,000	$16,031,000
Total Annual Cost	$0	$48,000	$192,000	$319,000	$527,000	$762,000
Initial Screening BCR	*0.0*	*0.4*	*0.4*	*0.3*	*0.3*	*0.2*

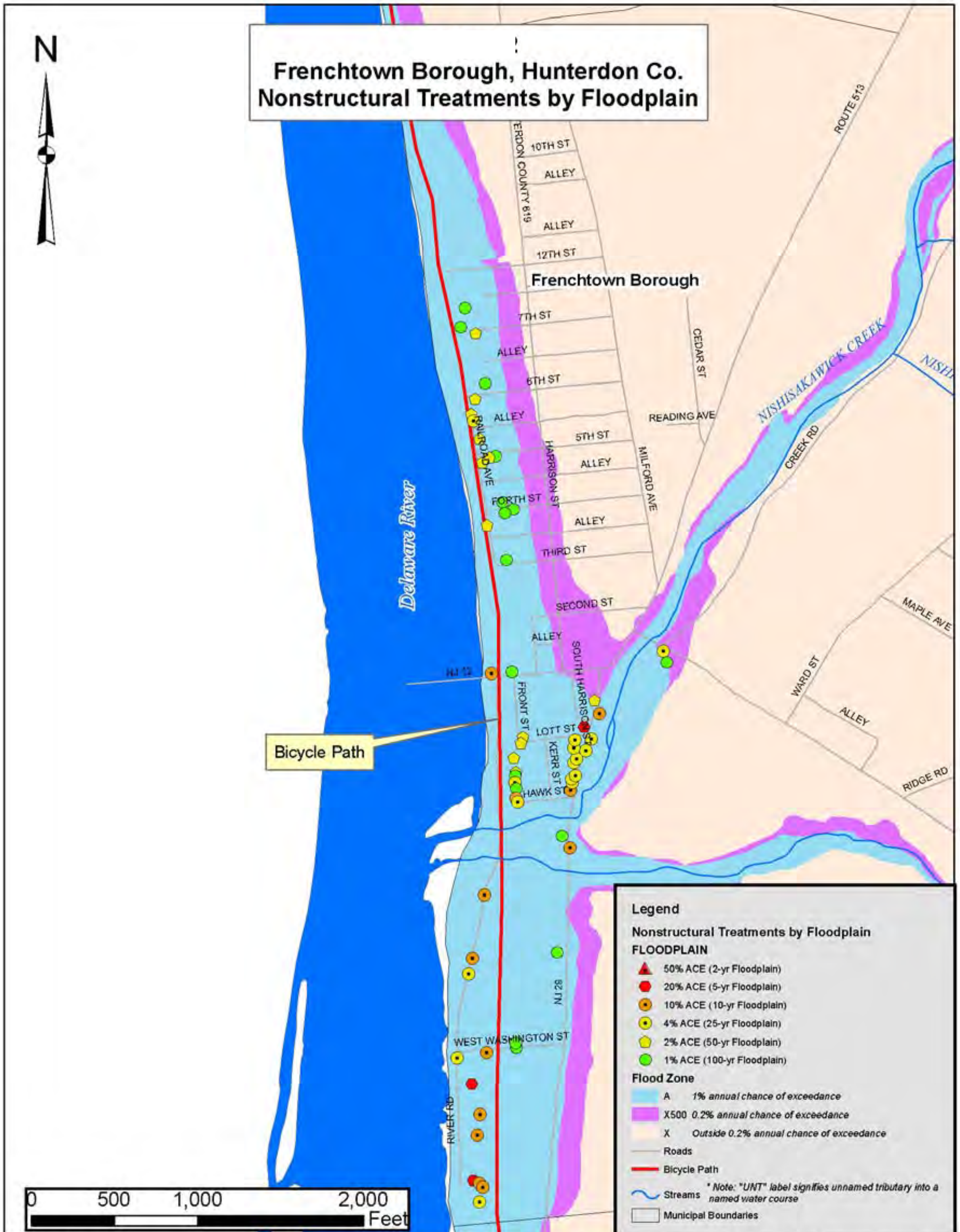
Table 3.30: Frenchtown: Summary of Nonstructural Treatments by Floodplain

Frenchtown	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	0	0	7	21	28	39
Wet Floodproof	0	1	2	3	4	6
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	1	1	1	3
Rebuild	0	2	5	6	11	11
Acquisition	0	0	0	0	0	0
Totals	*0*	*3*	*15*	*31*	*44*	*59*

See Figure 3.23 for a map of the nonstructural treatments by floodplain. Of the 59 structures in Frenchtown for which potential nonstructural treatments have been identified, 75% are residential, and the remaining structures are commercial, light industrial, storage structures, and a post office. The majority of structures eligible for treatment (66%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 11 structures. All except one of the structures currently identified for rebuilding are non-residential properties.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. None of the nonstructural treatments for the various floodplains in Frenchtown reach this threshold, and thus no further evaluation of these measures is recommended. Table 3.31 provides recommendations for the further evaluation of measures in the Borough of Frenchtown.

Figure 3.23: Frenchtown – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.31: Recommendations for Further Evaluation, Borough of Frenchtown

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
Structural Measures **Local Risk Management**				
Backflow Prevention Structures		✓	✓	
Levees and Floodwalls			✓	
Removable Barriers			✓	
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits				✓
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.2.3 Byram (in Kingwood Township)

Byram is a low-lying "colony association" of approximately 40 homes located along Old River Road and a private roadway called Byram Lane, immediately adjacent to the Delaware River in a section of Kingwood Township. See Figure 3.24 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

Residents stated that their homes are flooded from the Delaware River overtopping its banks, and by rainwater flowing down Route 29 and the old railroad right-of-way (ROW). At times, the runoff from Route 29 and the railroad floods the area before the Delaware overtops its banks. Flooding in 2004-2006 inundated the first floors of many homes in Byram. Several residents have significantly elevated their homes, and others have installed flood-resistant materials such as waterproof wall board and spray-on insulation.

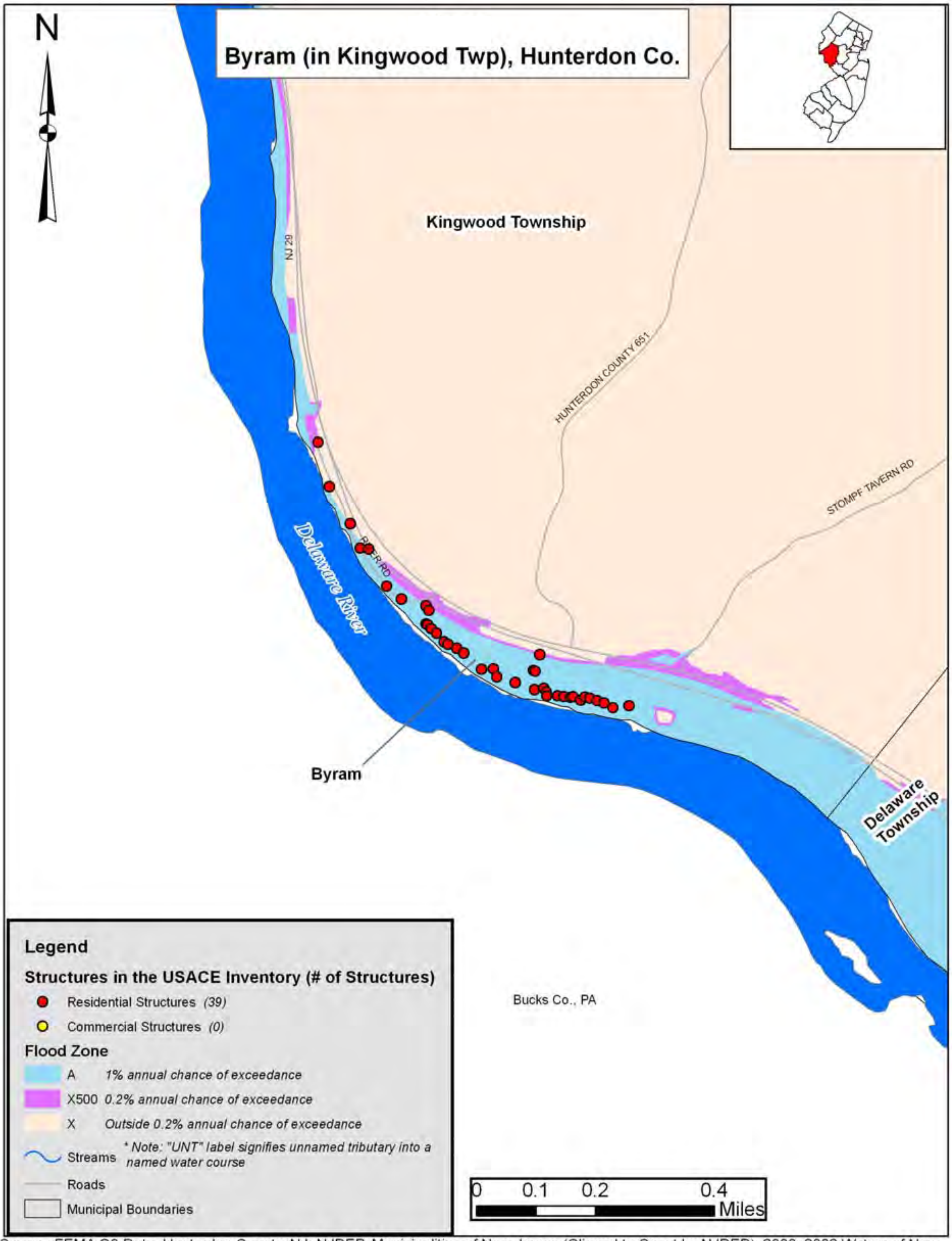
The residents have stated they value their riverfront location and are not interested in relocating out of the floodplain. The vast majority of residents are reported to be in favor of building elevation. Residents also expressed interest in whether a floodwall would be effective in providing flood risk management.

3.2.3.1 Structural Flood Risk Management Alternatives

The riverbank and property areas in Byram are extremely low compared to the river and BFE. The BFE was determined from the effective Flood Insurance Rate Maps (FIRMs) at the time of writing of this report. There is a single row of housing in the community. The entire neighborhood and all structures are located within the Special Flood Hazard Area.

The BFE ranges from approximately elevation 103' NAVD at the upstream end of the community to 100' NAVD at the downstream end. The ground elevation at the structures ranges from 95.8' to 88.7' NAVD (moving downstream). At the downstream end of the community, the difference between the ground elevation and BFE is approximately 12.8'. Any structural measures would have to rise to this height above the ground, plus an allowance to address design uncertainties and to ensure reliable performance. Such a structure would be extremely costly when compared to the value of the housing it would protect. In addition, there is very limited space between the structures and the riverbank, which would increase the difficulty of construction and possibly require the relocation of the structures; furthermore, it may require construction and excavation work in the main stem of the Delaware River. Thus, a floodwall is not considered a viable flood risk management alternative. No other candidate structural measures were identified. Additional evaluation of structural measures is provided in Table 3.32.

Figure 3.24: Byram (in Kingwood Township), Hunterdon County



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.32: Evaluation of Structural Measures: Byram (in Kingwood Township)

Structural Measures	Evaluation Criteria			
	Completeness	Effectiveness	Efficiency	Acceptability
Local Flood Risk Management				
Backflow Prevention Structures	Flooding is from Delaware River overtopping its banks. Gates or other backflow prevention structures are not applicable.	Not applicable.	Unknown.	No known issues.
Levees and Floodwalls	Will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures. Construction close to the river may require acquisition of structures.	Would reduce main stem flood damages.	Not likely to be cost effective due to the limited number of structures, and the low ground elevation compared to BFE of effective FIRM.	Potential aesthetic impacts by blocking view/access to the river. May require unacceptable excavation and construction along river bank and in river.
Removable Barriers	Barriers cannot be adequately deployed due to structures' proximity to the river.	Limited application due to structure locations.	Cannot realize significant benefits.	Not likely.
Road Raisings	Primary flood center is on river side of the roadway.	Not effective.	No.	No.
Area Flood Risk Management				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.2.3.2 Nonstructural Flood Risk Management Alternatives

As reported by residents, flooding along Old River Road and Byram Lane filled the first floor of homes during the floods of 2004-2006. The overwhelming majority of residents have expressed a strong interest in elevating their homes. Several homes have already been elevated by their owners. The structure types appear to be suitable for elevation on pilings, raised foundation walls, or other methods appropriate to the construction of the building, most notably its foundation type (basement, slab-on-grade, or crawlspace). For buildings with basements, the National Nonstructural/Flood Proofing Committee (NNFPC) recommends that raised foundation walls be used to elevate. Basements can also be filled in to eliminate flooding through low openings.

The majority of structures have a finished floor elevation within 5’ of the adjacent grade. As of 2010, four structures have been elevated by their owners above the BFE, with resulting finished floor heights of 101.7’ to 107.4’ NAVD. Any additional structures to be elevated above BFE would have to be similarly raised a significant height to provide the necessary level of risk management.

Utilities protection (ideally as part of a structure elevation) should be evaluated. Because of the depth of flooding and the almost entirely residential usage of the buildings, dry floodproofing is not suitable for further evaluation. Wet floodproofing should be evaluated, subject to a review of floodwater depth and velocity at the site.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet (or dry) floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of wet floodproofing, the depth of flooding can be greater than six feet but the velocity should be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of this technique. Given the low ground elevations of the buildings, it is not likely to be an effective method for flood risk management in this location.

Relocation and acquisition should be evaluated for those residents who are willing to consider the techniques. As noted, the majority of residents strongly wish to remain in their existing location. The entire Byram area is within the designated Special Flood Hazard Area; however, there may be non-floodplain areas available within the Kingwood Township or adjacent communities.

Ringwall levees are typically applied to larger commercial or municipal structures. Many of the at-risk homes are in close proximity in the main section of the community and there does not appear to be sufficient space between buildings to construct the necessary line of protection.

3.2.3.3 Nonstructural Screening Results

The initial dataset included 43 individual structures in the community of Byram, of which 40 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Byram resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.33 and Table 3.34:

Table 3.33: Summary of Nonstructural Costs by Floodplain

Byram	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*3*	*12*	*25*	*37*	*39*	*40*
Total Annual Damage	$24,000	*$90,000*	*$141,000*	*$179,000*	*$181,000*	*$182,000*
First Cost	$266,000	$1,387,000	$2,781,000	$4,174,000	$4,360,000	$4,539,000
Temp Relocation	$30,000	$120,000	$240,000	$360,000	$380,000	$390,000
Contingency	$89,000	$452,000	$906,000	$1,360,000	$1,422,000	$1,479,000
Construction Cost	$385,000	$1,959,000	$3,927,000	$5,894,000	$6,162,000	$6,408,000
Survey/Appraisal	$30,000	$120,000	$250,000	$370,000	$390,000	$400,000
E&D	$30,000	$120,000	$250,000	$370,000	$390,000	$400,000
S&A	$46,000	$235,000	$471,000	$707,000	$739,000	$769,000
Total Project Cost	$491,000	$2,434,000	$4,899,000	$7,342,000	$7,682,000	$7,977,000
Total Annual Cost	$23,000	$116,000	$233,000	$349,000	$365,000	$379,000
Initial Screening BCR	*1.0*	*0.8*	*0.6*	*0.5*	*0.5*	*0.5*

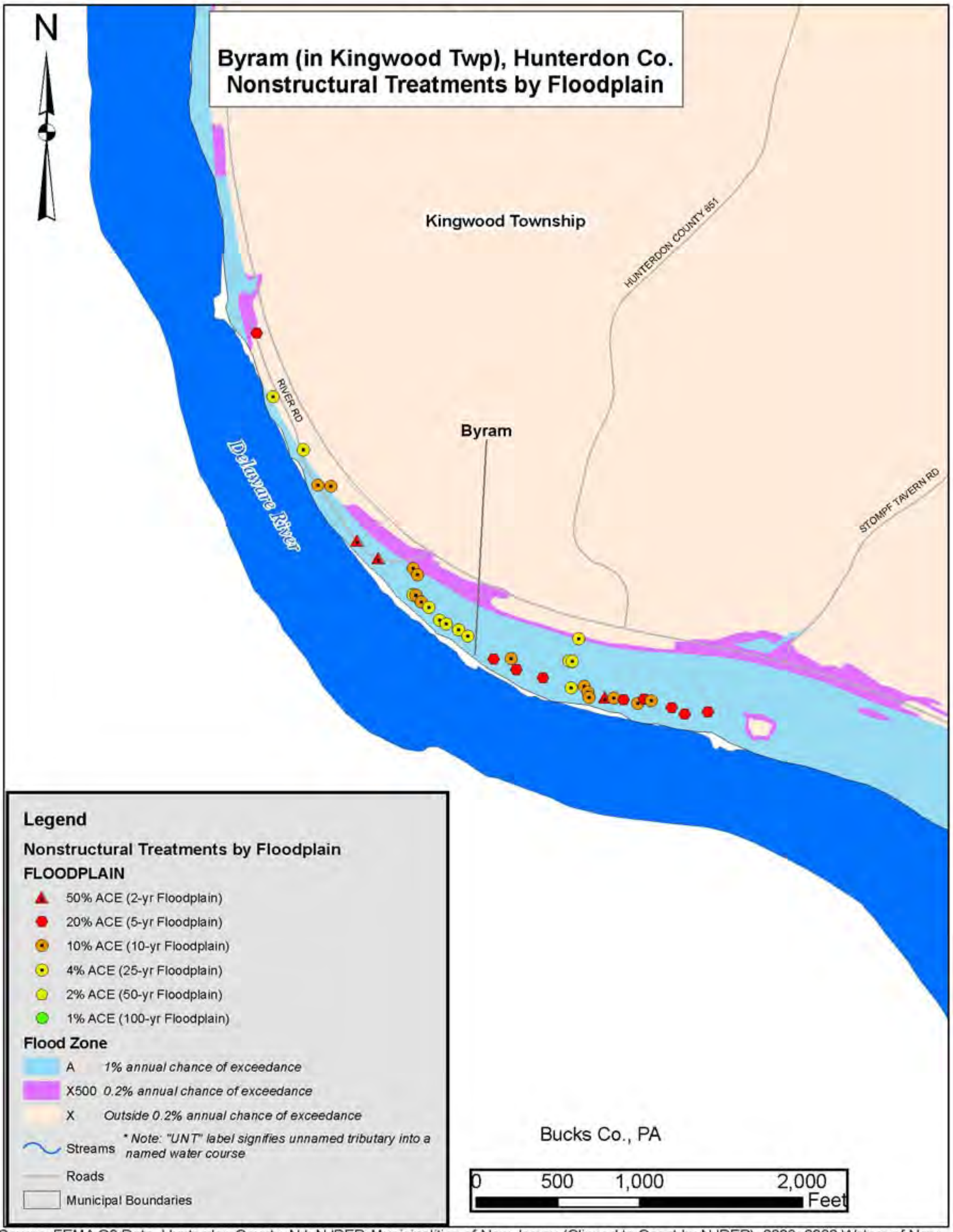
Table 3.34: Byram: Summary of Nonstructural Treatments by Floodplain

Byram	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	3	12	21	30	32	33
Wet Floodproof	0	0	1	1	1	1
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	0
Rebuild	0	0	3	6	6	6
Acquisition	0	0	0	0	0	0
Totals	*3*	*12*	*25*	*37*	*39*	*40*

See Figure 3.25 for a map of the nonstructural treatments by floodplain. Of the 40 structures in Byram for which potential nonstructural treatments have been identified, all except one are residential properties, and the remaining structure is a commercial property that has been identified for elevation. The majority of the residential structures eligible for treatment (85%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild six residential structures.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatments for the 50% ACE (2-year) and 20% ACE (5-year) floodplain in Byram meet or exceed this threshold, and thus are recommended for further evaluation of costs and benefits. Table 3.35 provides recommendations for the further evaluation of measures in Byram.

Figure 3.25: Byram – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.35: Recommendations for Further Evaluation, Byram (in Kingwood Township)

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	Other Federal Agency Flood Risk Management Plan	Non-Federal Flood Plain Management Plan (FPMP)	Eliminate from Further Evaluation
Structural Measures **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.2.4 Borough of Stockton

Stockton is a compact borough of 0.6 square miles in area, joined to Solebury Township, PA by the toll-free Centre Bridge-Stockton Bridge. The borough is located near the northern terminus of the “feeder canal” on the Delaware and Raritan Canal (D&R Canal). See Figure 3.26 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA’s Q3 digital floodplain data.

All structures within 300’ of the D&R Canal are affected by its historic designation; this area covers from Route 29 to the Delaware River. Local officials reported that minimal flooding occurred in Stockton in 2004, with greater flooding in 2005 and 2006. Brookville and Prallsville, two areas on Route 29 in the upstream (northern) end of town were inundated, as was Mill Street, which is parallel to the river immediately south of the bridge. Prallsville is the location of the historic Prallsville Mill complex.

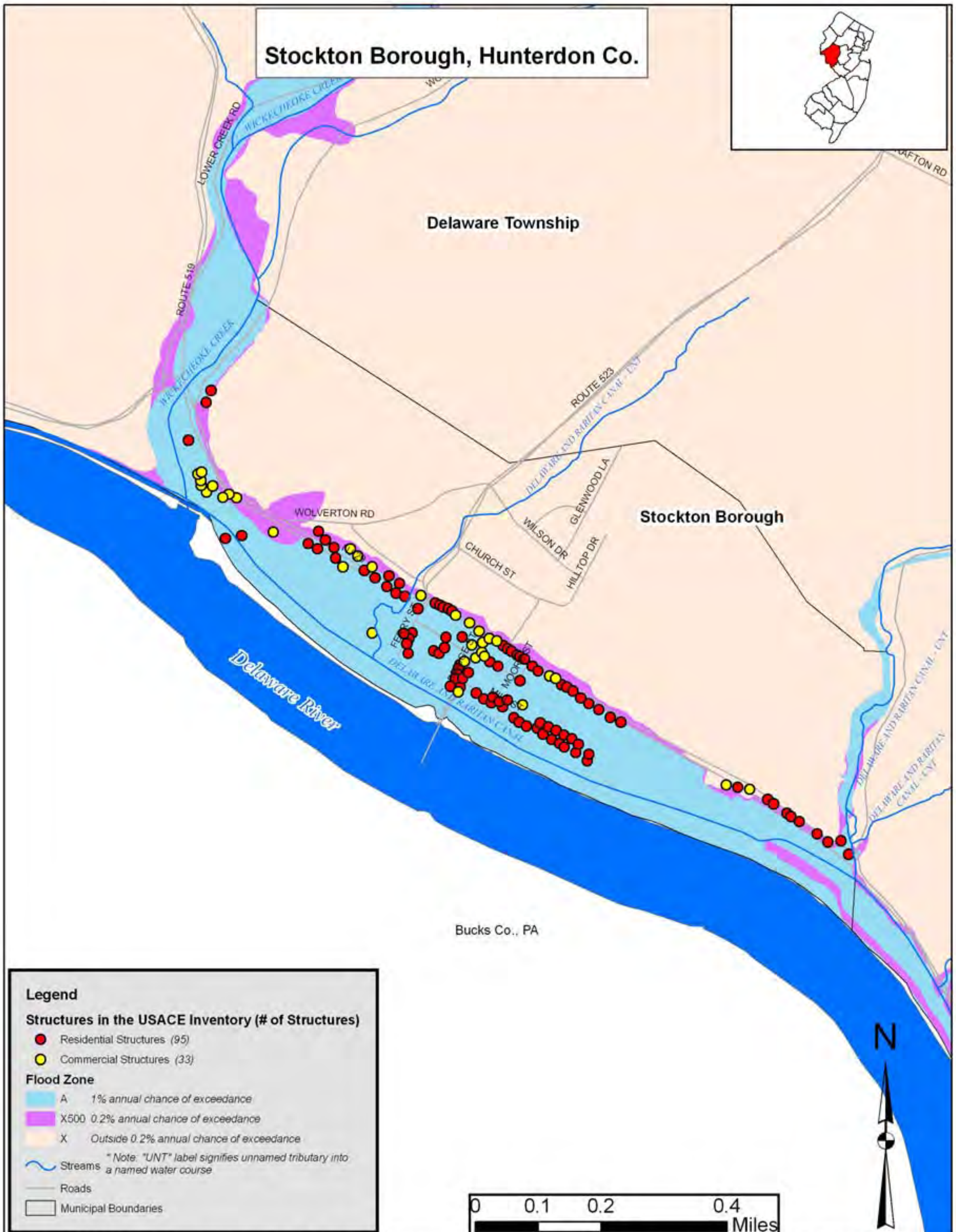
During the April 2005 flood the D&R Canal embankment was breached just south of the Prallsville Mill (north of the downtown). The canal wall was also breached south of Mill Street. During the 2006 flood, the canal wall breached in town at the south end of Mill Street. The canal also breached during the flood of record in 1955. When the canal embankment breaches, floodwaters from the Delaware River enter the D&R Canal, and in turn, flood the adjacent developed areas. The canal provides flood risk management until it is breached or overtopped.

The site of the canal embankment breach adjacent to Prallsville Mill, and the section of the embankment downstream of the Centre Bridge-Stockton Bridge are noticeably narrower and steeper than the typical dimensions of the canal embankment. (The bridge lies to the north of the main area of flooding). Numerous trees are in the embankment top and sides, creating instability. The embankment can adequately contain the canal water, but the outer wall is prone to failure against increased pressure and velocities during flooding on the Delaware. The breach locations have been repaired to the pre-existing elevations, and protective rip-rap armoring added to the base in those sections.

The canal is owned by NJDEP-Parks and Forestry, and NJ Water Supply Authority (NJWSA) is responsible for maintenance, including repair of embankment breaches. This portion is part of the “feeder canal” to the main canal, which NJWSA uses to provide drinking water to other areas in the state. The repair work in 2005 and 2006 cost approximately $500,000 each time, with a portion of the 2006 work reimbursed by FEMA.

The NJWSA contracted with French & Parello Associates to prepare an overall assessment report for the canal embankment in Stockton. The western canal embankment was “...generally found to be in poor overall condition and in need of significant improvement.

Figure 3.26: Stockton Borough, Hunterdon County



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

The need is beyond what is normally considered routine maintenance." The report also stated that "[s]ince very little is known of its material makeup and having failed twice since April of 2005, a thorough investigation and analysis should be made of the embankment before improvements are made." (French & Parello, 2006)

During the 2005 and 2006 floods, local officials stated that flooding filled basements and some first floors. Thirty-seven basements were pumped out, and 77 homes were evacuated. Thirty-seven properties have experienced repetitive flooding. The sanitary sewer system was inundated in 2005 and 2006 and the pumping station was taken out of service. The Centre Bridge-Stockton Bridge was reconstructed to repair damage from debris impacts during these floods.

The municipality is interested in an improved warning system, such as a reverse-911, to notify residents of forecast flooding and canal embankment breaches.

3.2.4.1 Structural Flood Risk Management Alternatives

The trees in the canal embankment pose a threat to its stability. Removal of the trees would likely increase water temperatures in the canal, which would be a negative impact on resident fish, such as trout. Any tree removal would require coordination with NJDEP-Parks and Forestry and the NJWSA. In addition, because of the poor condition of the canal embankment, the removal of trees could "cause serious stability problems with the embankment if not combined with other rehabilitative measures." (French & Parello, 2006)

Regarding the overall condition and stability of the canal embankment, the Recommendations section of the French & Parello Associates report states:

> *"The Western Embankment was generally found to be in poor overall condition and in need of significant improvement. The need is beyond what is normally considered routine maintenance. Routine maintenance on dam embankments consists of removing trees, brush, and woody vegetation, maintaining grass cover, repairing surface ruts and repairing rodent borrows. Routine maintenance applies to embankments that are in good condition, stable and not in need of significant repair or rehabilitation. Due to the extent of tree cover and possible root development, lack of vegetative cover and steepness of the slope on the canal side and existence of trees and disturbance of the stone masonry in many locations on the river side, removing the trees could cause serious stability problems with the embankment if not combined with other rehabilitative measures. Since very little is known of its material makeup and having failed twice since April of 2005, a thorough investigation and analysis should be made of the embankment before improvements are made. Recommendations for improvements should be based on an agreed to criteria.*
>
> *The criteria for dams in New Jersey is well defined in the New Jersey Dam Safety Standards (N.J.A.C. 7:20). There are no State criteria for the design of dikes or levees along rivers. The Western Embankment provides protection to the Stockton area for floods on the Delaware River which should be taken into account in establishing the criteria." (French & Parello, 2006)*

Thus, additional analysis of the embankment structure, and its stability, would be required before any improvements were made. Additional stability for the canal embankment could be obtained where needed by constructing sections of levee with a sheet pile cut-off wall on the river side of the canal embankment. The cut-off wall would extend to a sufficient depth to block the seepage path from the river. Fill would be placed behind the wall to increase stability and blend with the existing embankment and pathway. A cost assessment will be needed to evaluate specific upgrade requirements.

The quality, condition, and performance of the D&R Canal embankment as a risk management feature have not been evaluated by the Corps. The D&R Canal embankment was neither constructed, nor maintained, for flood risk management and is highly unlikely to meet standards for that purpose. The approach to the calculation of average annual damage is to evaluate without project damages assuming that non-certified features provide no flood risk management. If the annual cost of the structural alternative exceeds the annual damages under this assumption, it is not necessary to refine the analysis to reflect the level of flood risk management actually provided by the existing feature. If the annual damages exceed the annual costs, then further analysis is necessary to determine the level of risk management and potential reduction in damages the existing feature provides.

Initial “order of magnitude” estimates indicate that a LOP will cost $7.3 million and provide flood risk management to approximately $20 million in buildings plus an unquantified amount of infrastructure. The necessary annual damage assessments will be highly sensitive to the level of risk management provided by the existing embankment.

The Delaware and Raritan Canal Commission has permit authority over actions affecting the canal.

As stated on the Commission’s website: (http://www.dandrcanal.com/drcc/regulatory.html)

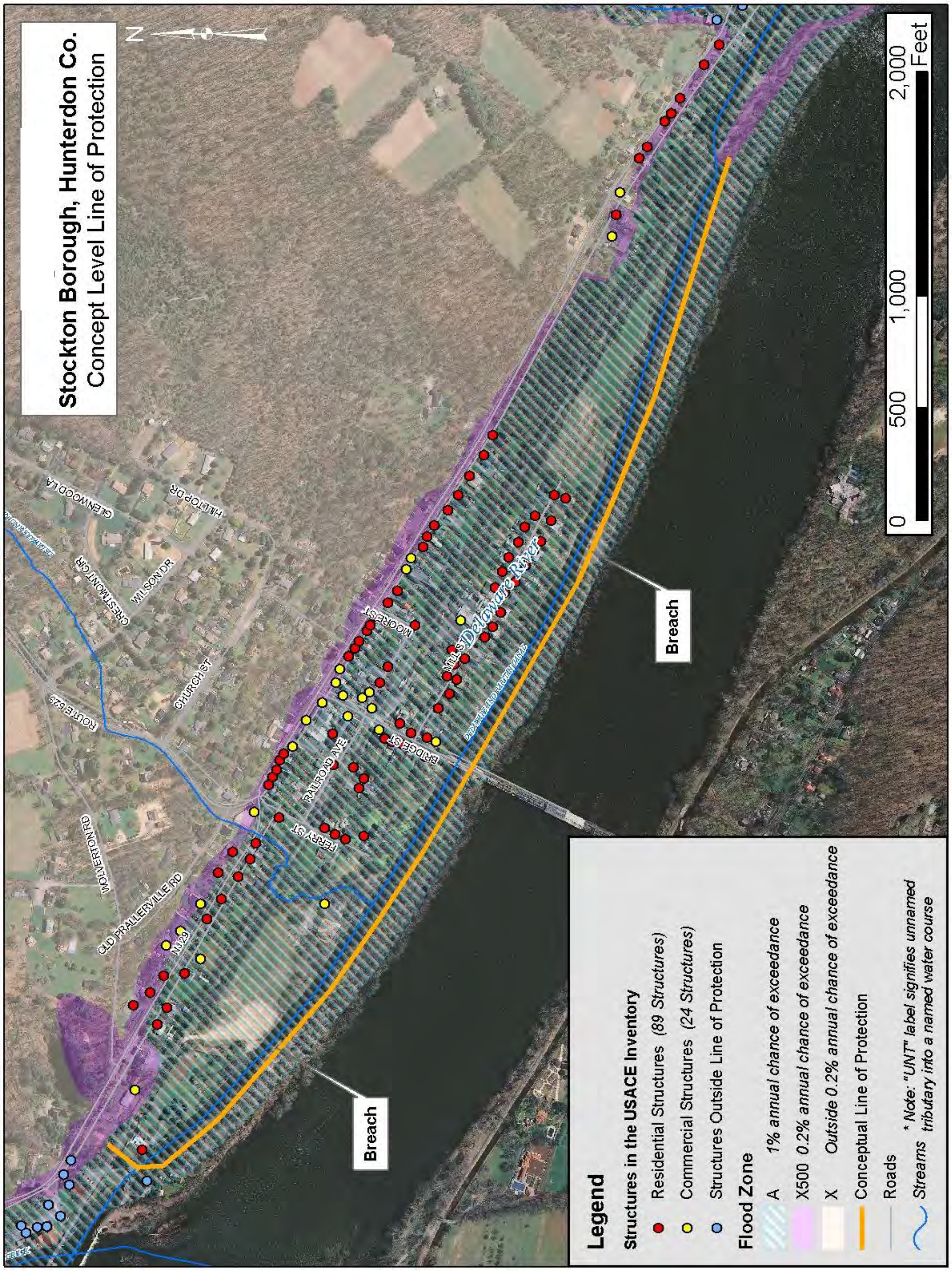
> *“The D&R Canal Commission administers a land-use regulatory program within the area where new development could have drainage, visual or other ecological impact on the Canal Park. The area within which there could be a drainage impact is almost 400 square miles, including parts of Mercer, Hunterdon, Somerset, Middlesex and Monmouth Counties. Major projects (those that involve an acre or more of impervious surface as of 1980) must meet the Commission’s standards for managing storm water runoff.*
>
> *If a project of any size is proposed for that area that is within 1,000 feet of the canal, it is reviewed for its visual impact on the park. Further, the Commission reviews large projects that are within a mile of the park for their traffic impact, and the Commission requires the preservation of corridors along the major streams that enter the park.”*

Any structural modifications made to the Canal, which is listed on the NJ Register of Historic Places, would have to be coordinated with the Delaware and Raritan Canal Commission, the Delaware and Raritan Canal State Park, NJWSA and the State Historic Preservation Office (SHPO) to eliminate, minimize, or mitigate any effects on the historic resource. Additional evaluation of structural measures is provided in Table 3.36.

Table 3.36: Evaluation of Structural Measures: Stockton

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Flood Risk Management				
Backflow Prevention Structures	Not applicable.	n/a	n/a	n/a
Levees and Floodwalls (REINFORCE)	Augmentation of existing landforms (canal bank) may provide flood risk management. Detailed structural analysis of existing landform required. New material and/or structures would be integrated with existing canal banks to increase width, height, and resistance to breaching, as needed. May require mitigation for natural resource impacts, may provide an opportunity for interior drainage modifications, and may require mitigation of induced flooding due to hydrologic or hydraulic effects.	Will reduce main stem flood damages.	Unknown.	Ownership (and maintenance) issues. D&R Canal is a historic structure. Also, reinforcement or elevation of the bank would require extensive tree removal; canal is a trout maintenance water body.
Levees and Floodwalls (ELEVATE)	Elevation of existing canal bank, would require additional tie-off through canal control structure. Interior drainage incorporating canal would be required.	Elevation of existing line of protection would provide additional flood risk management.	Unknown.	Ownership (and maintenance) issues. D&R Canal is a historic structure. Also, reinforcement and elevation of the bank would require extensive tree removal; canal is a trout maintenance water body.
Removable Barriers	Not applicable.	n/a	n/a	n/a
Road Raisings	Not applicable.	n/a	n/a	n/a
Area Flood Risk Management				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

Figure 3.27: Stockton – Concept Level Line of Protection



Source: FEMA Q3 Data, Hunterdon County NJ; NJDEP, Stream Network (Upper Delaware Basin), 2008; NJDOT, Roads 2008; NJOIT, OGIS, 2007 - 2008 High Resolution Orthophotography

3.2.4.2 Concept-Level Line of Protection: Costs and Initial Screening Benefits

Costs were estimated for providing an upgraded line of protection of 5,400 LF using the Delaware & Raritan Canal embankment (Figure 3.27). This measure would have an estimated annual cost of $350,000 in comparison to AAD of $359,000 for the 115 buildings behind this line of protection (Site 4). The initial screening BCR of 1.03 indicates the measure may be potentially cost-effective, and identifies the need to refine construction costs, and damages to reflect the existing and future level of flood risk management provided by the canal embankment. If the embankment were expected to provide any significant level of flood risk management in the future, the line of protection would likely not be cost-effective and thus not suitable for Federal participation.

3.2.4.3 Nonstructural Flood Risk Management Alternatives

As described above, substantial flooding in Stockton occurred in 2005 and 2006 when Delaware River flooding breached the western embankment of the Delaware and Raritan Canal. In addition, the vast majority of buildings located west of Risler St., North Main St., and South Main St. are located in the Special Flood Hazard Area. Based on the structure type and the depth and frequency of flooding, elevation and utilities protection should be evaluated as a means of flood risk management for at-risk buildings, along with wet and dry floodproofing.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

A determination would be needed on the historic character of any building suitable for retrofit, and whether the effects of retrofitting on the historic character of the structure are a consideration. The historic designation of the Canal affects all buildings within 300’.

Relocation and acquisition should be evaluated. Space for relocation of properties within the community may be limited. If widely applied, these alternatives would have a significant impact on the character of the community, and would have to be reviewed for negative effects to any historically significant buildings, and to the community overall. Municipal officials have stated that residents are interested in acquisition and elevation. Some structures have already been raised by their owners.

Ringwall levees are typically applied to larger commercial or municipal structures. Many of the at-risk homes are in close proximity in the main section of the community and there does not appear to be sufficient space between buildings to construct the necessary lines of protection.

3.2.4.4 Nonstructural Screening Results

The initial dataset included 128 individual structures in the Borough of Stockton, of which 112 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Stockton resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.37 and Table 3.38:

Table 3.37: Stockton: Summary of Nonstructural Costs by Floodplain

Stockton	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Structures Treated	1	7	10	66	82	112
Total Annual Damage	$14,000	$68,000	$73,000	$329,000	$366,000	$399,000
First Cost	$103,000	$1,403,000	$1,550,000	$9,416,000	$12,037,000	$16,284,000
Temp Relocation	$10,000	$60,000	$90,000	$630,000	$750,000	$1,020,000
Contingency	$34,000	$439,000	$492,000	$3,014,000	$3,836,000	$5,191,000
Construction Cost	$148,000	$1,902,000	$2,133,000	$13,059,000	$16,623,000	$22,496,000
Survey/Appraisal	$10,000	$70,000	$100,000	$660,000	$820,000	$1,120,000
E&D	$10,000	$70,000	$100,000	$660,000	$820,000	$1,120,000
S&A	$18,000	$228,000	$256,000	$1,567,000	$1,995,000	$2,699,000
Total Project Cost	$185,000	$2,271,000	$2,589,000	$15,946,000	$20,258,000	$27,435,000
Total Annual Cost	$9,000	$108,000	$123,000	$758,000	$963,000	$1,305,000
Initial Screening BCR	*1.6*	*0.6*	*0.6*	*0.4*	*0.4*	*0.3*

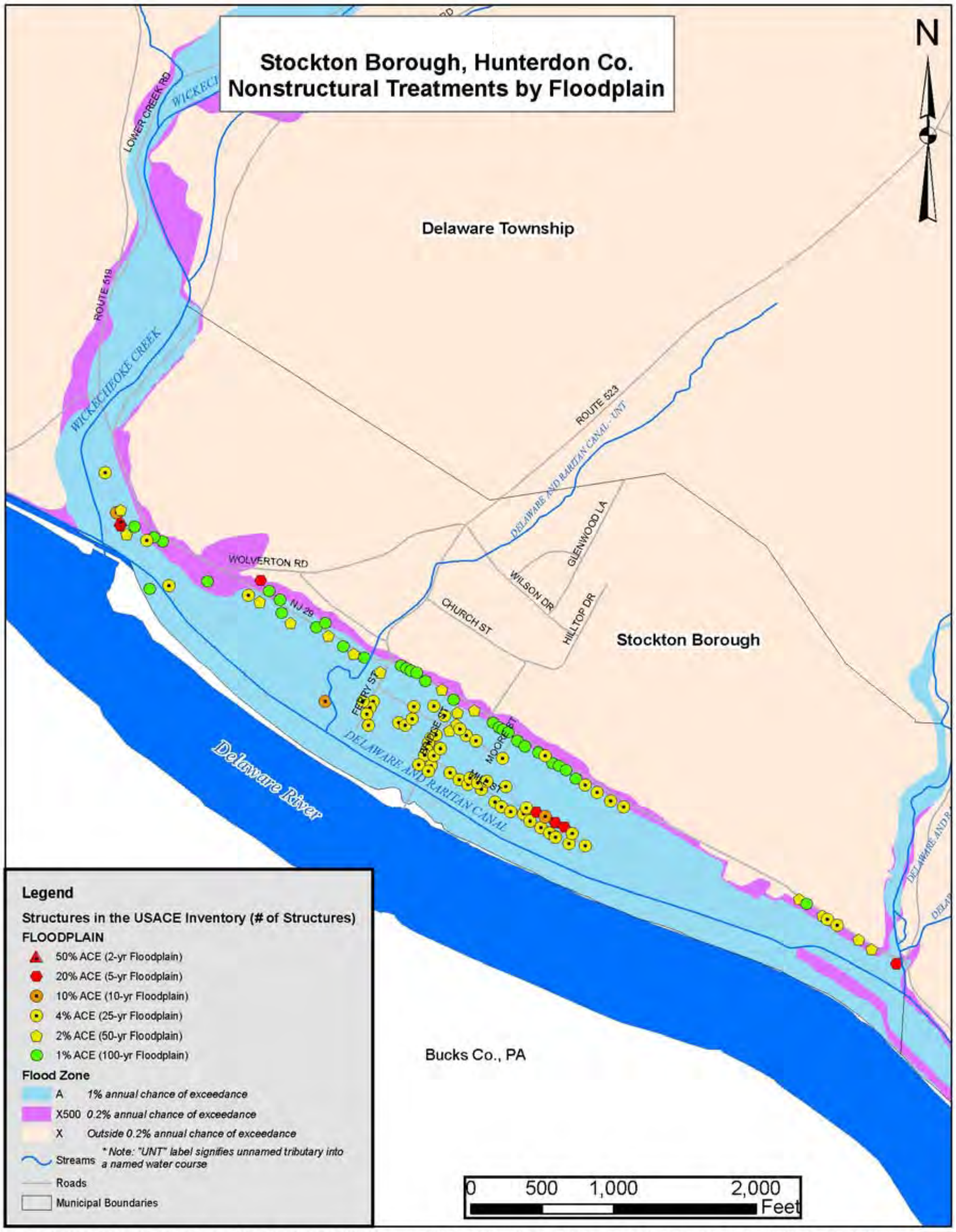
Table 3.38: Stockton: Summary of Nonstructural Treatments by Floodplain

Stockton	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Elevation	1	6	7	53	61	84
Wet Floodproof	0	0	0	2	4	6
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	1	1	1	3	4
Rebuild	0	0	2	10	14	18
Acquisition	0	0	0	0	0	0
Totals	*1*	*7*	*10*	*66*	*82*	*112*

See Figure 3.28 for a map of the nonstructural treatments by floodplain. Of the 112 structures in Stockton for which potential nonstructural treatments have been identified, 76% are residential, and the remaining structures are mostly commercial, agricultural, or storage structures. The non-residential structures identified for treatment also include several buildings of significance to the local community, including the borough office, a museum, fire house, and post office. The majority of structures eligible for treatment (75%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 18 structures. All except four of the structures currently identified for rebuilding are non-residential properties.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. While the treatment for the 50% ACE (2-year) floodplain in Stockton exceeds this threshold, it involves only a single structure. The Corps cannot provide flood risk management measures for a single private structure under a nonstructural project. Thus, the nonstructural treatment of the single structure in the 50% ACE (2-year) floodplain cannot be recommended for further evaluation. Table 3.39 provides recommendations for the further evaluation of measures in Stockton.

Figure 3.28: Stockton – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.39: Recommendations for Further Evaluation, Borough of Stockton

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
Structural Measures **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls	✓	✓	✓	
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits				✓
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.2.5 City of Lambertville

Lambertville is a densely-developed historic community of 3,868 people (*Census 2000*) in a 1.3 square mile area on the Delaware River. The city is joined to New Hope, PA by the New Hope-Lambertville Toll Bridge, which carries U.S. Route 202, and the free New Hope-Lambertville Toll-Supported Bridge that connects PA 179 and NJ 179. (The Toll-Supported Bridge is owned and maintained as a toll-free bridge by the Delaware River Joint Toll Bridge Commission. Its operation is supported by toll revenue from the fee-charging bridges under the Bridge Commission's authority). See Figure 3.29 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data. The early development and subsequent growth of the city as a manufacturing and transportation center was heavily dependent on its location next to the Delaware River and D&R Canal. After the decline of its manufacturing base, a long-term revitalization effort has transitioned the community into a key center for regional tourism.

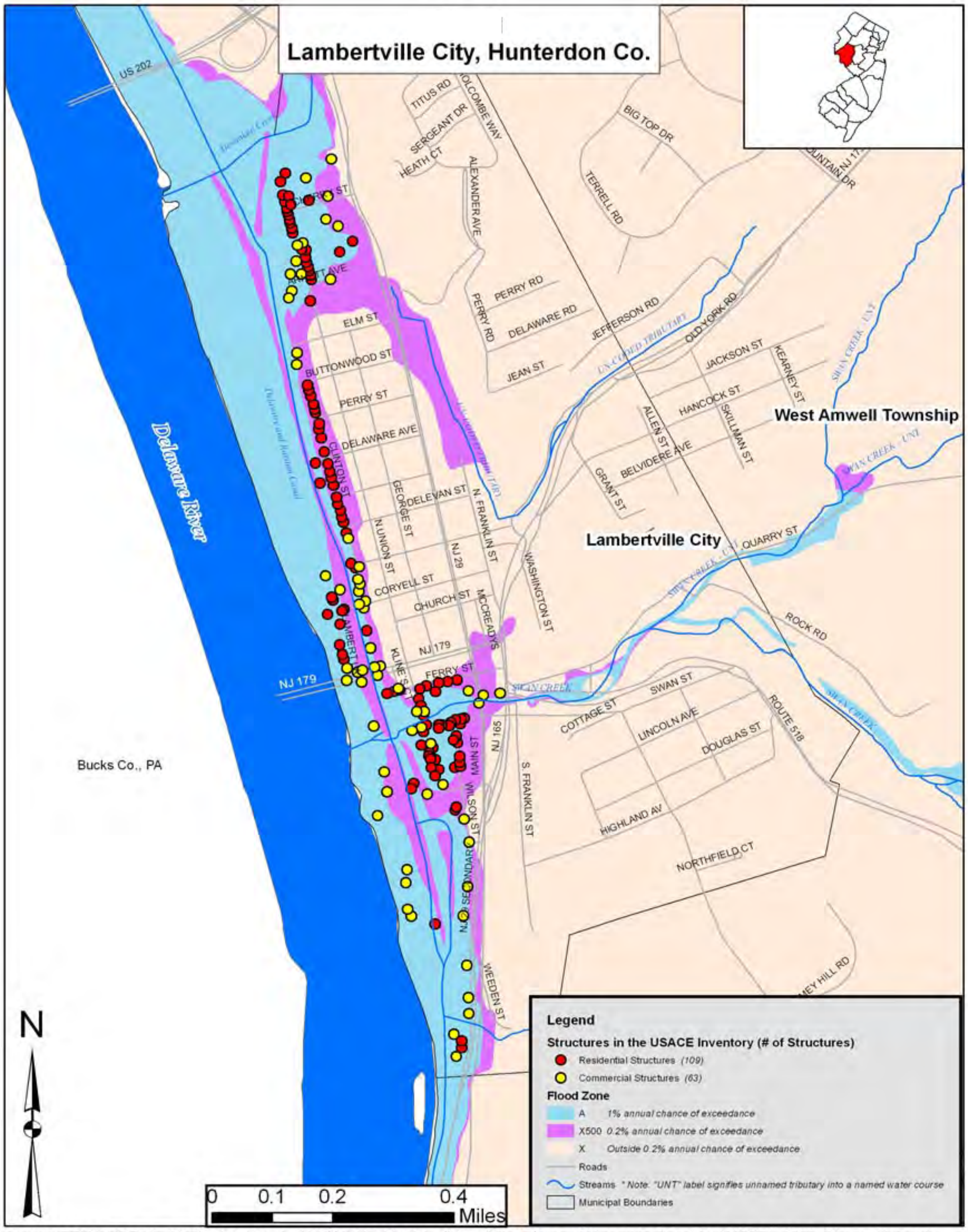
As reported by local officials, the city experienced major flooding in the 2004-2006 events, with millions of dollars in damage. The 2005 flood level was 6" higher than the 2004 and 2006 levels.

The riverfront area along Lambert Lane is located on the river side of the D&R Canal embankment, which serves as a levee for the majority of the town. Houses and commercial properties along the west side of Lambert Lane from Bridge Street to north of the Coryell Street intersection are flooded from the Delaware River overtopping its banks. The bankside in this section is steep and narrow between the buildings and the river. Buildings along Lambert Lane have been flooded in basements and 1st floors. One home on the street that flooded in 2005 was subsequently elevated, and fared well during the 2006 flood.

The main source of flooding in the interior areas of the town is backwater from the Delaware affecting the tributaries Alexauken Creek, Ely Creek, and Swan Creek. Alexauken Creek lies upstream towards the city's northern border and has a 15 square-mile drainage area. Nearing the confluence with the Delaware River, Alexauken Creek goes under a railroad bridge and then is carried under the D&R Canal aqueduct approximately 300 feet before it meets the Delaware. In addition to overland flooding, floodwater from the Delaware main stem backflows into Alexauken Creek through the stormwater drainage system, and floods area homes (primarily basements) and the CVS Pharmacy. The area of flooding includes the northernmost section of North Union Street and north of Cherry Street. Storm sewers that were installed as part of the redevelopment of the CVS building backflow and surcharge into the Canal Studios building east of North Union Street and midway between Cherry Street and Arnett Avenue. Local officials believe the installation of a backflow prevention device within the storm sewer system would lessen flooding in this area (Lambertville Natural Hazard Mitigation Plan, 2007).

Ely Creek is a much smaller watercourse, providing local drainage. The creek begins at the base of Music Mountain at the intersection of Route 179 and York Street, and travels through a series of culverts and surface channels until it runs under the D&R Canal and discharges to Island Creek and the Delaware River (Lambertville, 2007). En route, the creek goes into a covered section through the Niece Lumber property and then exits through a culvert. Backwater flooding on Ely Creek causes it to overflow the buried section and culvert and flood the adjacent low-

Figure 3.29: Lambertville City, Hunterdon County



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

lying area bounded by the D&R Canal, Arnett Avenue, and Cherry Street. In December 2010, the City of Lambertville was awarded cost-shared funding from FEMA to install a slide gate and small pump on Ely Creek to prevent backflow from the Delaware River into Ely Creek and to return interior drainage to the D&R Canal while the gate is closed. The city was awarded approximately $145,000 by FEMA, which will pay for three-quarters of the project cost. The city will pay the remaining portion. The project is expected to reduce flooding for 29 buildings with basement flooding, and will reduce first-floor flooding for five commercial buildings ("FEMA grant to help Lambertville flood control project", Times of Trenton Regional News, NJ.com, December 2010). The main stem of Swan Creek flows along Rocktown-Lambertville Road, which then becomes Quarry Street. It flows towards the D&R Canal and Delaware River between Ferry St. to the north and Swan Street to the south. The creek is carried under the D&R Canal by an aqueduct, and then enters the river. A second structure returns overflow from the D&R Canal into Swan Creek, from where it is then returned to the Delaware River.

The drainage area of Swan Creek is approximately 3 square miles. The 10% ACE (10-year) peak flow is 680 cubic feet per second (cfs) and the 1% ACE (100-year) peak is 1675 cfs, as modeled by the NRCS using the winTR20 model. (See "Swan Creek Watershed-Preliminary Flood Damage and Mitigation Report", January 2007). The NRCS report found that "under the assumption that low tailwater conditions from the Delaware River exist when peak flows pass from Swan Creek, it appears that there is sufficient capacity provided by the two structures under the D&R Canal to contain the FIS (FEMA Flood Insurance Study) 1% ACE (100-year) peak flow of 1000 cfs, within the stream corridor although localized out of bank flooding does occur. With the NRCS estimated 1% ACE (100-year) peak of 1675 cfs, damages would be more significant with several structures receiving basement and first floor flooding" (NRCS, 2007).

The NRCS report also states: "Flooding in the vicinity of Swan Creek, however, becomes much more severe when the Delaware River rises to the 2% ACE (50-year) and 1% ACE (100-year) flood stages, backing up into Swan Creek and the adjacent neighborhood" (NRCS, 2007). The area of inundation from Swan Creek overflow is bounded to the north by Ferry Street, the east by South Main Street, to the south by Hope Street, and to the west by the D&R Canal embankment. The primary cause of damage to structures in this area is from Delaware River backwater on Swan Creek, and from the creek's peak flows. Approximately 60 buildings in the area have been flooded repetitively to the basement and first floor levels.

3.2.5.1 Structural Flood Risk Management Alternatives

The community character of Lambertville was formed to a great extent by its proximity and easy access to the river and D&R Canal. This proximity is a primary component of its past development and modern status as a tourism destination. As such, a new LOP that severed the connection between the city and the river would have substantial negative effects on the community and would likely not be acceptable to its residents.

The quality, condition, and performance of the D&R Canal embankment as a risk management feature have not been evaluated by the Corps. The D&R Canal embankment was neither constructed, nor maintained, for flood risk management and is highly unlikely to meet standards for that purpose. The approach to the calculation of average annual damage is to evaluate without project damages assuming that non-certified features provide no flood risk management. If the annual cost of the structural alternative exceeds the annual damages under this assumption, it is not necessary to refine the analysis to reflect the level of flood risk management actually provided by the existing feature. If the annual damages exceed the annual costs, then further analysis is necessary to determine the level of risk management and potential reduction in damages the existing feature provides.

Smaller scale structural alternatives may be able to manage flooding risks in certain areas, without the undue effects mentioned. A description of possible techniques is provided below:

Alexauken Creek: a new, limited LOP could be constructed that would tie into high ground on North Main Street and into the railroad embankment, working in combination with a new floodwall segment along the D&R Canal. The stability of the railroad embankment high ground would need to be determined for suitability. Initial order of magnitude estimates indicate that a LOP will cost approximately $4.4 million and provide flood risk management to approximately $20 million in buildings plus an unquantified amount of infrastructure. (See Figure 3.30).

Ely Creek: As discussed in the report titled “Application Package for the City of Lambertville, Ely Creek Backflow Prevention Project under the Hazard Mitigation Grant Program, June 15, 2007”, prepared by Princeton Hydro, and in subsequent news articles, a slide gate will be installed on Ely Creek adjacent to Niece Lumber. This gate will prevent Delaware River backflow from flooding the low-lying area centered on North Union Street and Arnett Avenue, and a pump will return the Ely Creek flow to the Delaware River. Ely Creek does not meet the Corps definition of “major drainage”, which requires a 10% ACE (10-year) flow of 800 cfs, and thus, could not have been included as a stand-alone element in a Corps project.

Swan Creek: As detailed in the NRCS report, a backflow prevention device installed at the D&R Canal embankment, with necessary interior drainage equipment, is a viable means of reducing backwater flooding from the Delaware River. As with Ely Creek, Swan Creek does not meet the Corps definition of “major drainage” (the 10% ACE, or 10 year, flow does not meet the 800 cfs threshold). If a new Corps-designed LOP were constructed in Lambertville to provide risk management from flooding by the main stem of the Delaware River, or an existing LOP upgraded to Corps standards (e.g., the D&R Canal embankment), then the necessary improvements to allow sufficient interior drainage may become eligible as part of the Corps project.

The D&R Canal embankment was not designed to serve as a levee against main stem flooding, and thus may not have the height, dimension, or structural stability to withstand flood flows and velocities during significant river floods. Further investigation would be required of its construction and stability before it could be considered for this use.

Lambert Lane: This area is flooded directly from the Delaware River overtopping its banks. Thus, the only structural option was determined to be the construction of a new LOP to function as a ring levee around the structures, with closure gates at Bridge Street. The bank area between the buildings and the river is too narrow to support the required LOP and footings, and would likely require the acquisition of the buildings intended for flood risk management by the LOP. In addition, construction of a LOP would require work in the main stem of the Delaware River and installation of permanent features altering the shoreline and riverbank. Because of these limitations and associated effects on the main stem, this alternative was dropped from further consideration. Additional evaluation of structural measures is provided in Table 3.40.

Table 3.40: Evaluation of Structural Measures: City of Lambertville

Structural Measures	**Evaluation Criteria**			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Protection				
Backflow Prevention Structures	Gates or other backflow prevention structures on the Delaware River or tributaries would need to tie into a line of protection (such as levee or floodwall) to prevent overland flooding. Backflow preventers on storm drains typically wouldn't require an accompanying LOP.	Without a LOP, may only provide limited effectiveness during low frequency events.	Unknown.	No known issues.
Levees and Floodwalls (MAIN STEM)	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures.	Augmentation of natural structure (canal) would have limited impact on most flood-prone structures, which are on the river side of the canal. The most flood-prone are too close to the river for structural measures to be constructed or installed.	Not likely.	Potential aesthetic impacts by blocking view/access to the river. May require unacceptable excavation and construction along river bank.
Levees and Floodwalls (ALEXAUKEN CREEK)	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures.	Addresses flooding in the northern end of the community along the creek.	May be cost-effective.	Structure would be in the Delaware and Raritan Canal State Park. Potential Green Acres mitigation issues.
Removable Barriers	Not feasible.	n/a	n/a	n/a
Road Raisings	Not feasible.	n/a	n/a	n/a
Area Protection				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

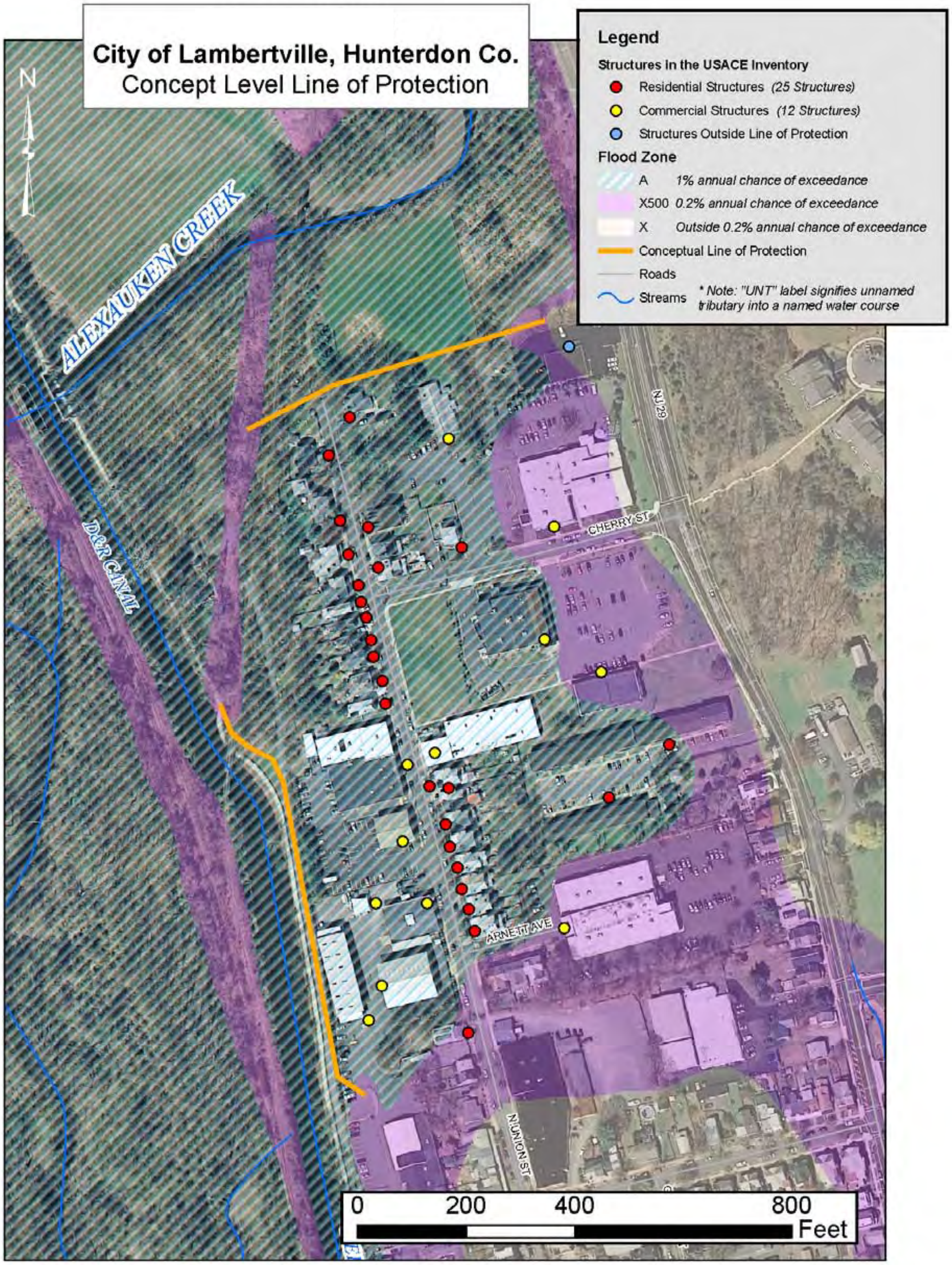
3.2.5.2 Concept-Level Line of Protection: Cost and Initial Screening Benefits

Construction of a 590 LF levee segment to protect against Delaware River backwater at Alexauken Creek was evaluated in combination with an 810 LF floodwall segment along the D&R Canal (Figure 3.30). The estimated annual cost of the alternative is $210,000, and it would provide flood risk management to 38 buildings with AAD of $610,000, plus an unquantified amount of infrastructure (Site 5). If the existing embankments are stable, this short levee segment could be highly cost-effective with an initial screening BCR of 2.9. This measure should be further evaluated for inclusion in the Federal flood risk management plan. In other sections of Lambertville, such as the downtown, development is so close to the river or canal that it would be difficult to construct an effective line of protection without substantial impacts to the community character. In addition, due to the narrow and steep riverbank between the properties on Lambert Lane and the river, it is unlikely that there is sufficient area for easements for construction and operation, as well as room for the alignment in supportable soils. Thus, no structural measures suitable for Corps participation were identified for the central and southern portions of the community, where the majority of flooding damages occur.

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

The 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.

Figure 3.30: Lambertville – Concept Level Line of Protection



Source: FEMA Q3 Data, Hunterdon County NJ; NJDEP, Stream Network (Upper Delaware Basin), 2008; NJDOT, Roads 2008; NJOIT, OGIS, 2007 - 2008 High Resolution Orthophotography

3.2.5.3 Nonstructural Risk Management Alternatives

As described above, recent flooding in the interior areas of Lambertville has typically occurred when Delaware River flooding has entered the tributaries of Alexauken Creek, Ely Creek, and Swan Creek. Subsequent flooding has inundated adjacent areas, causing damage to homes, businesses, and municipal infrastructure. Direct inundation by Delaware River floodwaters affects the structures on Lambert Lane, which face the main stem of the river. Overall, there are 42 buildings with repetitive losses, and two with severe repetitive losses. Masonry is a common construction method throughout the at-risk area, and a significant number of structures are historic. Based on the structure type and the depth and frequency of flooding, building elevation and utilities protection should be evaluated as a means of flood risk management for at-risk buildings, along with wet and dry floodproofing. It should be noted that the elevation of masonry structures can be technically complex and typically incurs increased cost.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

A determination would be needed on the historic character of any building suitable for retrofit, and whether the effects of retrofitting on the historic character of the structure are a consideration.

Relocation and acquisition should be evaluated. Space for relocation of properties within the community is limited. If widely applied, these alternatives would have a significant impact on the character of the community, and would have to be reviewed for negative effects to any historically significant buildings, and to the community overall. Municipal officials have stated their preference for elevation as the means of flood risk management.

Ringwall levees are typically applied to larger commercial or municipal structures. The at-risk structures are in close proximity in the main section of the community and there does not appear to be sufficient space between buildings to construct the necessary line of protection. If indicated by specific circumstances, this technique could be evaluated for municipal facilities.

3.2.5.4 Nonstructural Screening Results

The initial dataset included 172 individual structures in the City of Lambertville, of which 115 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Lambertville resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.41 and Table 3.42:

Table 3.41: Lambertville: Summary of Nonstructural Costs by Floodplain

Lambertville	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Structures Treated	*5*	*14*	*25*	*65*	*97*	*115*
Total Annual Damage	$199,000	$399,000	$535,000	$1,181,000	$1,381,000	$1,496,000
First Cost	$1,560,000	$5,680,000	$9,553,000	$25,465,000	$31,981,000	$37,711,000
Temp Relocation	$50,000	$120,000	$220,000	$590,000	$890,000	$1,010,000
Contingency	$483,000	$1,740,000	$2,932,000	$7,817,000	$9,861,000	$11,616,000
Construction Cost	$2,093,000	$7,540,000	$12,705,000	$33,872,000	$42,732,000	$50,338,000
Survey/Appraisal	$50,000	$140,000	$250,000	$650,000	$970,000	$1,150,000
E&D	$50,000	$140,000	$250,000	$650,000	$970,000	$1,150,000
S&A	$251,000	$905,000	$1,525,000	$4,065,000	$5,128,000	$6,041,000
Total Project Cost	$2,444,000	$8,725,000	$14,730,000	$39,236,000	$49,800,000	$58,678,000
Total Annual Cost	$116,000	$415,000	$700,000	$1,866,000	$2,368,000	$2,790,000
Initial Screening BCR	*1.7*	*1.0*	*0.8*	*0.6*	*0.6*	*0.5*

Table 3.42: Lambertville: Summary of Nonstrucutral Treatments by Floodplain

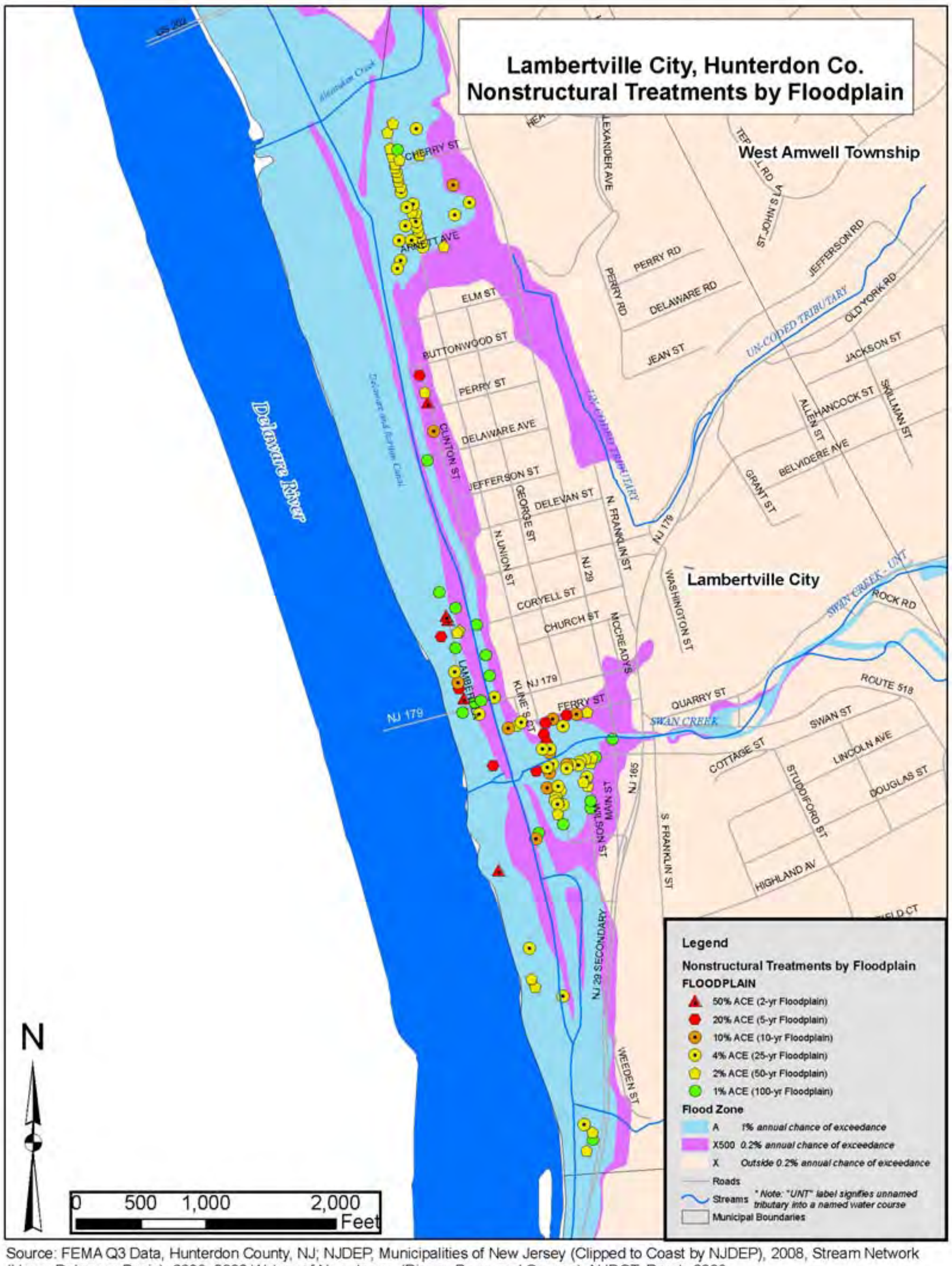
Lambertville	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Elevation	3	7	15	34	59	69
Wet Floodproof	0	1	1	1	2	4
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	1	2	5	6	10
Rebuild	2	5	7	25	30	32
Acquisition	0	0	0	0	0	0
Totals	*5*	*14*	*25*	*65*	*97*	*115*

See Figure 3.31 for a map of the nonstructural treatments by floodplain. Of the 115 structures in Lambertville for which potential nonstructural treatments have been identified, 70% are residential, and the remaining structures are commercial or storage structures, as well as several facilities significant to the local community, including the municipal court and a firehouse. The majority of the structures eligible for treatment (60%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 32 structures. Almost one third of the structures currently identified for rebuilding or acquisition are stretches of row houses and multiple-unit low-rise residential apartment buildings, and all except two of the remainder are commercial properties and storage structures.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatments for the 50% ACE (2-year), 20% ACE (5-year), and the 10% ACE (10-year) floodplains in Lambertville meet or exceed this threshold, and thus are recommended for further evaluation of costs and benefits.

Table 3.43 provides recommendations for the further evaluation of measures in Lambertville.

Figure 3.31: Lambertville – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.43: Recommendations for Further Evaluations

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	Other Federal Agency Flood Risk Management Plan	Non-Federal Flood Plain Management Plan (FPMP)	Eliminate from Further Evaluation
Structural Measures **Local Risk Management**				
Backflow Prevention Structures		✓	✓	
Levees and Floodwalls	✓	✓	✓	
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.3 Mercer County

3.3.1 Hopewell Township

Hopewell is a rural/suburban area, with the majority of the Township on a plateau above the Delaware River and thus not subject to flooding. However, local officials have stated that a low-lying section of the D&R Canal embankment (approximately 150' in length) overflows onto Route 29 in western Hopewell. See Figure 3.32 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

The flooding prevents access to the 900-inmate Mercer County Correction Center (MCCC), inundates the water supply pumping station for the facility, and requires the water supply to be shut down. This leads to temporary relocation of the inmates to alternate locations during floods. The flooding also affects one business and one vacant home owned by Mercer County. The floods of 2004-06 had the same extent and level of inundation within Hopewell Township.

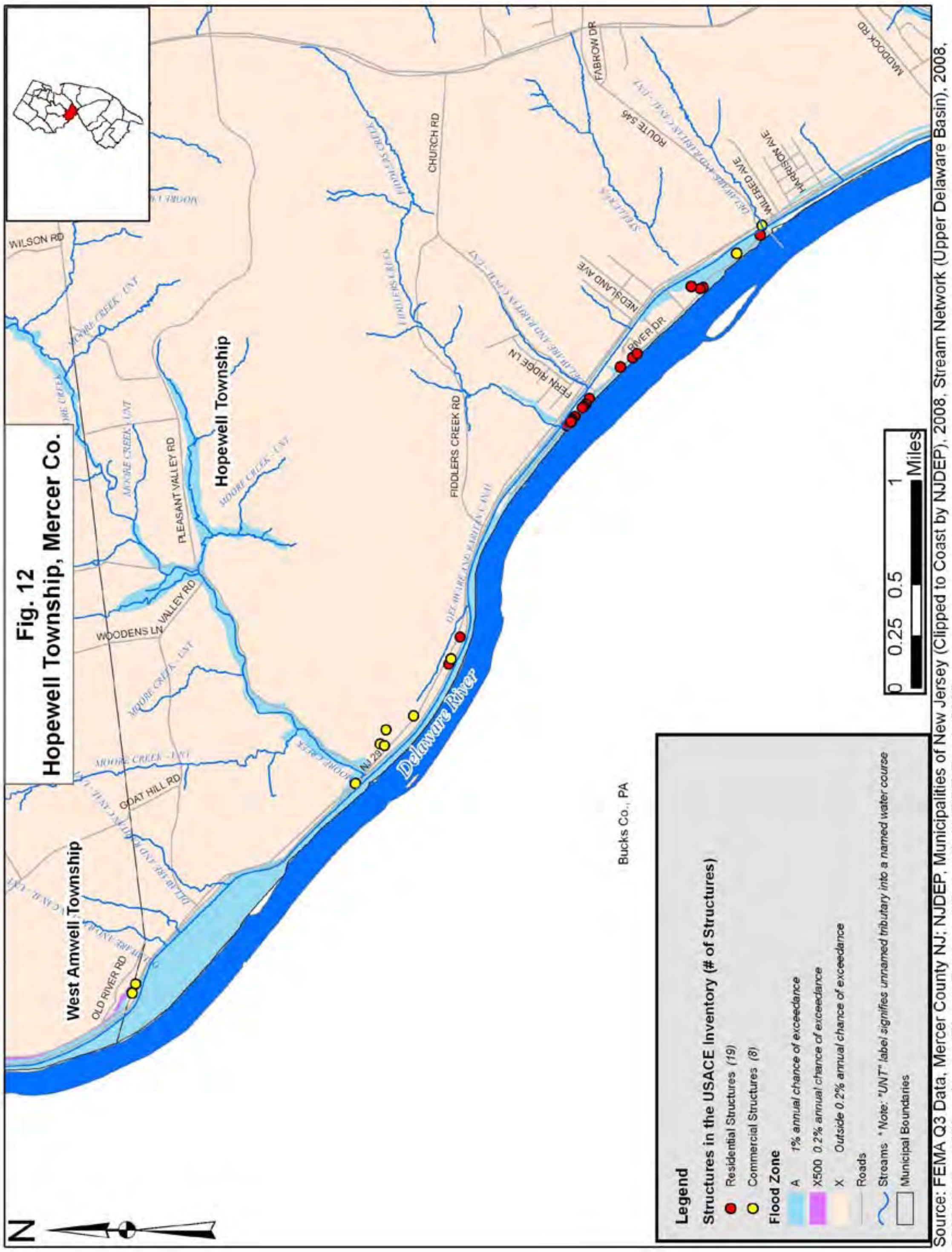
In addition, there is a section of the community known as Titusville, located on the river side of Route 29 and the D&R Canal. Six to ten houses in Titusville flood, with water rising to 3" – 4" on the first floor. Repetitive damage occurs at six of the properties located on the lower section of River Drive. The flooding has not caused structural damage to the buildings, and residents have stated they do not wish to pursue installation of a levee or other line of protection. The municipality has explored elevating the flood-prone structures or, at a minimum, elevating the utilities from the basement to the first floor. The majority of the houses in Titusville are located on a higher bluff area and have not experienced flooding during recent events, according to officials.

Municipal officials have stated they do not believe the river level gauge at Washington Crossing, NJ is sufficient for their use in making flood forecasts, and are interested in installation of a new, closer gauge. The municipality is interested in raising the berm of the D&R Canal over the extent of the low-lying area on Route 29.

3.3.1.1 Structural Risk Management Alternatives

Raising 150 LF of D&R Canal Embankment: This measure could reduce overtopping, reduce flooding on the roadway, prevent damage to the water intake and pump for the MCCC on Route 29/River Rd. at Pleasant Valley Road, and prevent loss of access to the facility during flooding and the subsequent need for temporary relocation of inmates. While the benefit would be limited to a single structure (the Correction Center), Corps policy allows for such measures when the single user is a public facility, as is the case here. The MCCC main facility is located well outside the floodplain adjacent to the river, and does not experience flooding. Thus, only a section of Route 29, the water supply pumping station, one business, and one vacant structure undergo flooding. The primary benefit to this measure would be avoiding closure of the MCCC and the costs of the temporary relocation of inmates. Flood risk management through nonstructural means to the buildings is feasible. However, nonstructural measures would not reduce or eliminate flooding of Rt. 29 and resulting lack of access to the MCCC. The costs of facility closure and temporary relocation of inmates have not been quantified as part of this study. These costs will be required to perform additional evaluation of this measure.

Figure 3.32: Hopewell Township, Mercer County



The Corps has not evaluated the quality, condition, and performance of the D&R Canal embankment as a flood risk management feature. The D&R Canal embankment was neither constructed, nor maintained, for flood risk management and is highly unlikely to meet standards for that purpose. The approach to the calculation of average annual damage is to evaluate without project damages assuming that non-certified features provide no flood risk management. If the annual cost of the structural alternative exceeds the annual damages under this assumption, it is not necessary to refine the analysis to reflect the level of flood risk management actually provided by the existing feature. If the annual damages exceed the annual costs, then further analysis is necessary to determine the level of risk management and potential reduction in damages the existing feature provides.

Residential Flooding in Titusville: The majority of homes in Titusville are not flooded above the first floor, with six to ten structures receiving 3” to 4” of flooding during the 2004-06 events. These structures are located in a lower-lying section of the area. Structural measures are not indicated due to the limited depth of flooding at the buildings and the limited number of buildings that would benefit. Additional evaluation of structural measures is provided in Table 3.44.

Table 3.44: Evaluation of Structural Measures: Hopewell Township

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Protection				
Backflow Prevention Structures	n/a	n/a	n/a	n/a
Levees and Floodwalls	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects.	Not implementable.	Not cost-effective.	Not likely.
Removable Barriers	In Titusville, barriers cannot be adequately deployed due to structures' proximity to the river.	Limited application due to structure locations.	Cannot realize significant benefits.	Not likely.
Road Raisings	Would reduce flood risk for a very limited number of buildings. Could reduce/eliminate need for temporary relocation of inmates from MCCC.	Would reduce flooding to structures and potentially allow access to and continued operation of MCCC during floods.	Temporary relocation costs not quantified at this time.	Likely.
Area Protection				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.3.1.2 Nonstructural Risk Management Alternatives

For the six to ten buildings affected by the 2004-06 floods, elevation and utilities protection should be evaluated. The structure types appear to be suitable for elevation on pilings, raised foundation walls, or other methods appropriate to the construction of the building, most notably its foundation type (basement, slab-on-grade, or crawlspace). For buildings with basements, the National Nonstructural/Flood Proofing Committee (NNFPC) recommends that raised foundation walls be used to elevate.

Wet and dry floodproofing should be evaluated. A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Residents have stated a preference for remaining in their present locations. The proximity and view of the river were cited as primary reasons for selecting to live in the area. Thus, while relocation and acquisition can be evaluated, they may not have local support. In addition, given the limited depth of flooding, these measures do not initially appear to be cost-effective.

Ringwall levees are typically applied to larger commercial or municipal structures. Given the priority placed by the residents on river access and views, this technique is not likely to be locally supported. The limited depth of flooding would also not support this technique; thus, it should not be evaluated further.

Regarding the water intake and pumping station for the MCCC, further evaluation should be made of nonstructural methods to protect the equipment. The intake and pumping station were not visited during this phase of the study.

3.3.1.3 Nonstructural Screening Results

The initial dataset included 32 individual structures in the Borough of Hopewell, of which 26 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Hopewell Township resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.45 and Table 3.46:

Table 3.45: Hopewell Township: Summary of Nonstructural Costs by Floodplain

Hopewell	**Annual Chance Exceedance Floodplain**					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*1*	*2*	*6*	*13*	*24*	*26*
Total Annual Damage	$1,000	$19,000	$30,000	$63,000	$69,000	$70,000
First Cost	$89,000	$165,000	$544,000	$1,230,000	$1,901,000	$1,990,000
Temp Relocation	$10,000	$20,000	$60,000	$130,000	$200,000	$210,000
Contingency	$30,000	$56,000	$181,000	$408,000	$630,000	$660,000
Construction Cost	$129,000	$241,000	$786,000	$1,768,000	$2,731,000	$2,860,000
Survey/Appraisal	$10,000	$20,000	$60,000	$130,000	$240,000	$260,000
E&D	$10,000	$20,000	$60,000	$130,000	$240,000	$260,000
S&A	$15,000	$29,000	$94,000	$212,000	$328,000	$343,000
Total Project Cost	$164,000	$310,000	$1,000,000	$2,241,000	$3,539,000	$3,724,000
Total Annual Cost	$8,000	$15,000	$48,000	$107,000	$168,000	$177,000
Initial Screening BCR	*0.1*	*1.3*	*0.6*	*0.6*	*0.4*	*0.4*

Table 3.46: Hopewell Township: Summary of Nonstructural Treatments by Floodplain

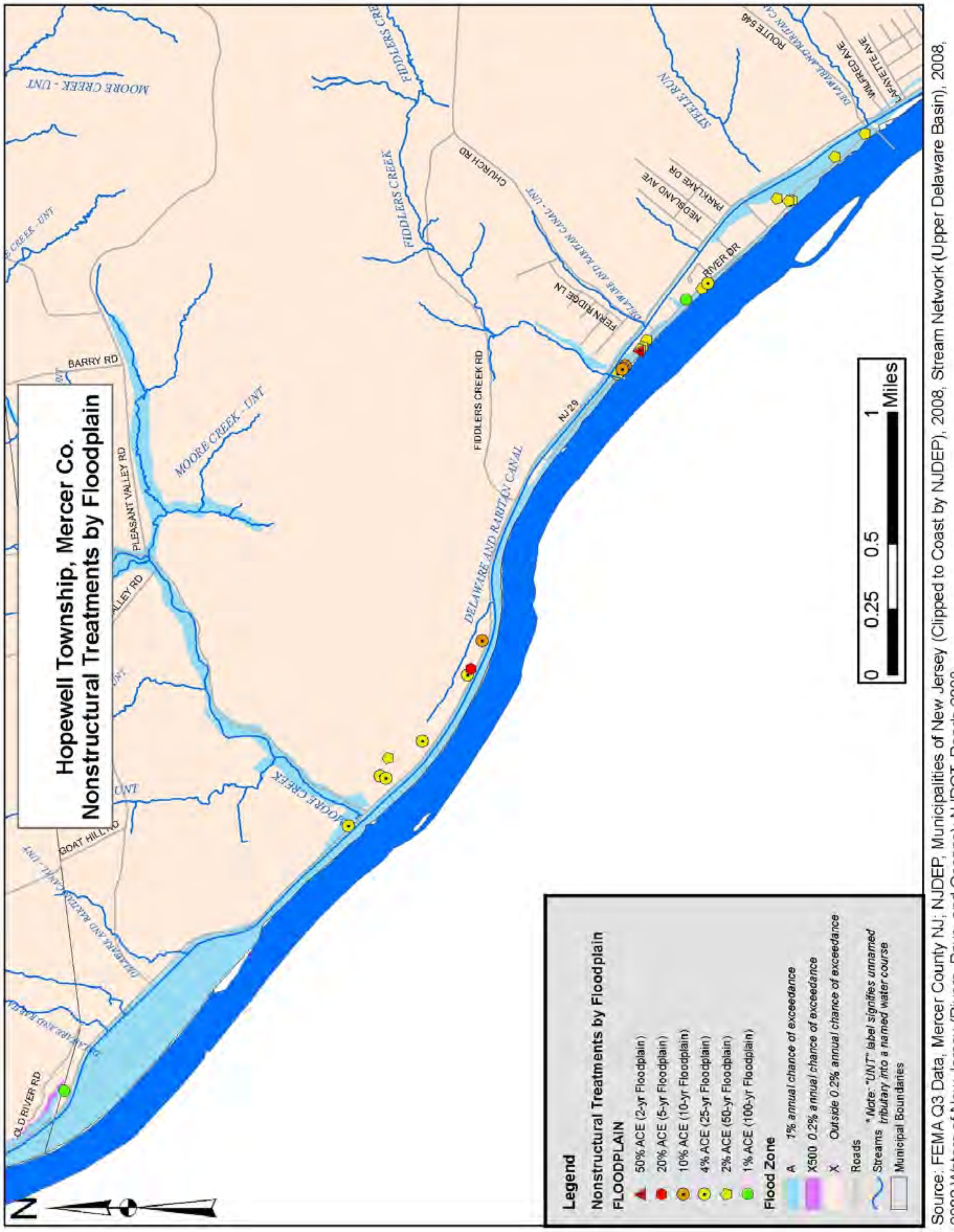
Hopewell	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	1	1	3	8	12	12
Wet Floodproof	0	0	0	0	4	5
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	0	0	0
Rebuild	0	1	3	5	8	9
Acquisition	0	0	0	0	0	0
Totals	*1*	*2*	*6*	*13*	*24*	*26*

See Figure 3.33 for a map of the nonstructural treatments by floodplain. Of the 26 structures in Hopewell Township for which potential nonstructural treatments have been identified, 69% are residential, and the remaining structures are commercial, light industrial, or storage structures. Just under half the structures eligible for treatment (46%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild nine structures, of which three are residential properties.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatment for the 20% ACE (5-year) floodplain in Hopewell exceeds this threshold, and thus is recommended for further evaluation of costs and benefits.

Table 3.47 provides recommendations for the further evaluation of measures in Hopewell Township.

Figure 3.33: Hopewell – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Mercer County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.47: Recommendations for Further Evaluation, Hopewell Township

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
Structural Measures **Local Risk Management**				
Backflow Prevention Structures				✓
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings	✓	✓	✓	
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property			✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions			✓	

3.3.2 Ewing Township

This is a suburban community bordering the Delaware River. The area of the township at risk from flooding is located between the western embankment of the D&R Canal and the Delaware River, and is locally known as the Wilburtha neighborhood. There is an extensive area of floodplain to the east of Route 29, which follows the river. See Figure 3.34 for a general map of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

The roadway stems flooding from the Delaware River under a wide range of flooding conditions, with the majority of flooding stemming from the river backing up storm sewers. However, under greater flooding conditions, the Delaware River can overtop Route 29 and inundate the low-lying areas behind the roadway. When available, hydrologic information can be used to better quantify the risk of the roadway being overtopped by the river during larger events, e.g., the 1% ACE (100-year) flood. Local officials stated that approximately 25 homes plus apartment buildings on and around River Road flood during storm events. During the 2004-06 floods, only one house flooded over the first floor, while the remaining homes had basement flooding that reached just below the first floor. The commercial complex at 770 River Road floods, as does a nearby dry cleaner, Revere Restaurant, and the adjacent gas station. The gasoline storage tanks have been removed.

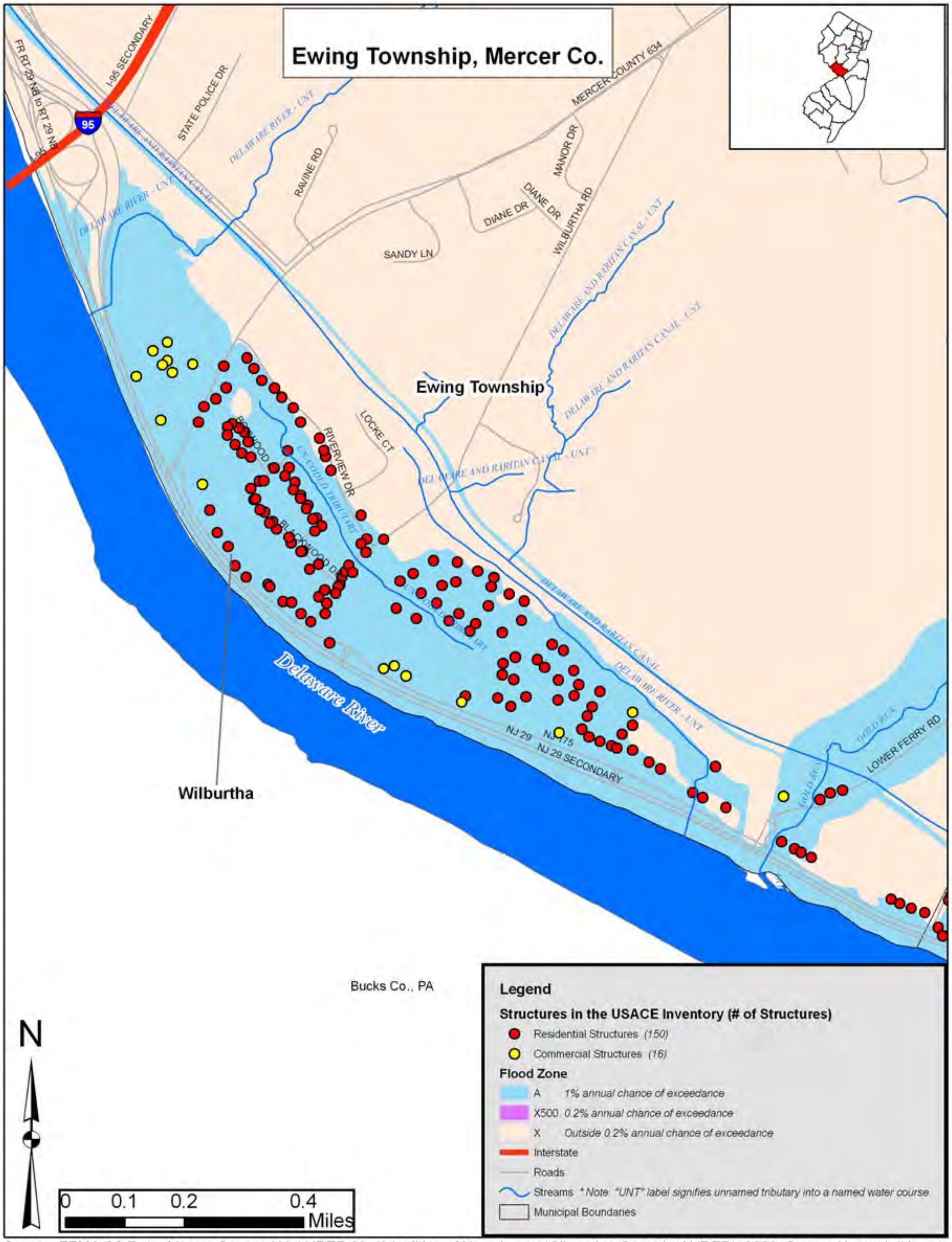
The municipality currently shuts off the power to an entire section of the power grid if any structures in that part have flooding, which requires all residents and building occupants within that section to go without power or to evacuate. The municipality has discussed with PSE&G changing the electrical grid pattern so that they will only have to shut off service to those houses that flood. The municipality would like backflow prevention devices (unidirectional flap gates) installed on the storm sewer outlet pipes. NJDOT owns these storm sewers and has installed such devices downstream in Trenton. This was estimated to cost the municipality $150,000. In addition, there is expressed local interest in installing a local river gage.

3.3.2.1 Structural Flood Risk Management Alternatives

A line of protection along the river side of Route 29 from the I-95 bridge downstream for a distance of 7,000 LF could reduce risk from higher-level flooding events. (See Figure 13.1). The cost-effectiveness of such a line of protection would depend on the level of existing risk management provided by Route 29 for lower-level floods.

If a line of protection meeting Corps standards is constructed, flap gates and other backflow prevention devices required to provide interior drainage would become an eligible component.

Figure 3.34: Ewing Township, Mercer County



Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

The Corps has not evaluated the quality, condition, and performance of Route 29 as a risk management feature. Route 29 was neither constructed, nor maintained, for flood risk management and is highly unlikely to meet standards for that purpose. The approach to the calculation of average annual damage is to evaluate without project damages assuming that non-certified features provide no flood risk management. If the annual cost of the structural alternative exceeds the annual damages under this assumption, it is not necessary to refine the analysis to reflect the level of flood risk management actually provided by the existing feature. If the annual damages exceed the annual costs, then further analysis is necessary to determine the level of risk management and potential reduction in damages the existing feature provides.

Initial “order of magnitude” estimates indicate that a LOP will cost approximately $30.5 million and provide flood risk management to approximately $49 million in buildings plus an unquantified amount of infrastructure. Decisions regarding more detailed evaluation of a line of protection at this location should be deferred until the without-project damage analysis is complete. It may be possible that existing flood risk management provided by Route 29 results in relatively low annual damages. Further evaluation is needed of the level of flooding through storm sewers and culverts that occurs during more frequent events. Additional evaluation of structural measures is provided in Table 3.48.

Table 3.48: Evaluation of Structural Measures: Ewing Township

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Protection				
Backflow Prevention Structures	Installation of gates or other backflow prevention structures to storm sewers would not require installation of a new LOP. Backflow prevention structures would not reduce flooding from Delaware River if it overtops Route 29.	Would be effective at reducing backflow during higher-frequency events.	Unknown.	No known issues.
Levees and Floodwalls	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for operation of closure structures.	Will reduce main stem flood damages.	Unknown. Will require two road closures.	Potential aesthetic impacts by blocking view/access to the river.
Removable Barriers	May require mitigation for natural resource impacts, will likely require interior drainage modifications and may require mitigation of induced flooding due to hydrologic or hydraulic effects. Flood Warning is critical for deployment of floodwalls. Interior drainage (pumping) may be required.	May limit the number of properties protected if located along road, which appears to be the most appropriate, accessible location.	Potentially similar initial costs to floodwall. Deployable barriers may have higher operation and maintenance costs.	Deployment may be too labor intensive for the limited application. Providing storage space near site may be an issue.
Road Raisings	May require additional interior drainage, utility relocation and reconfiguration of access roads.	Will reduce main stem flood damages.	Unknown.	Route 29 is a major roadway in the area. Elevation may require additional ramps impacting adjacent properties. Significant transportation impacts during construction. Need for mitigation or property easement impacts possible.
Area Protection				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.3.2.2 Concept-Level Lines of Protection: Cost and Initial Screening Benefits

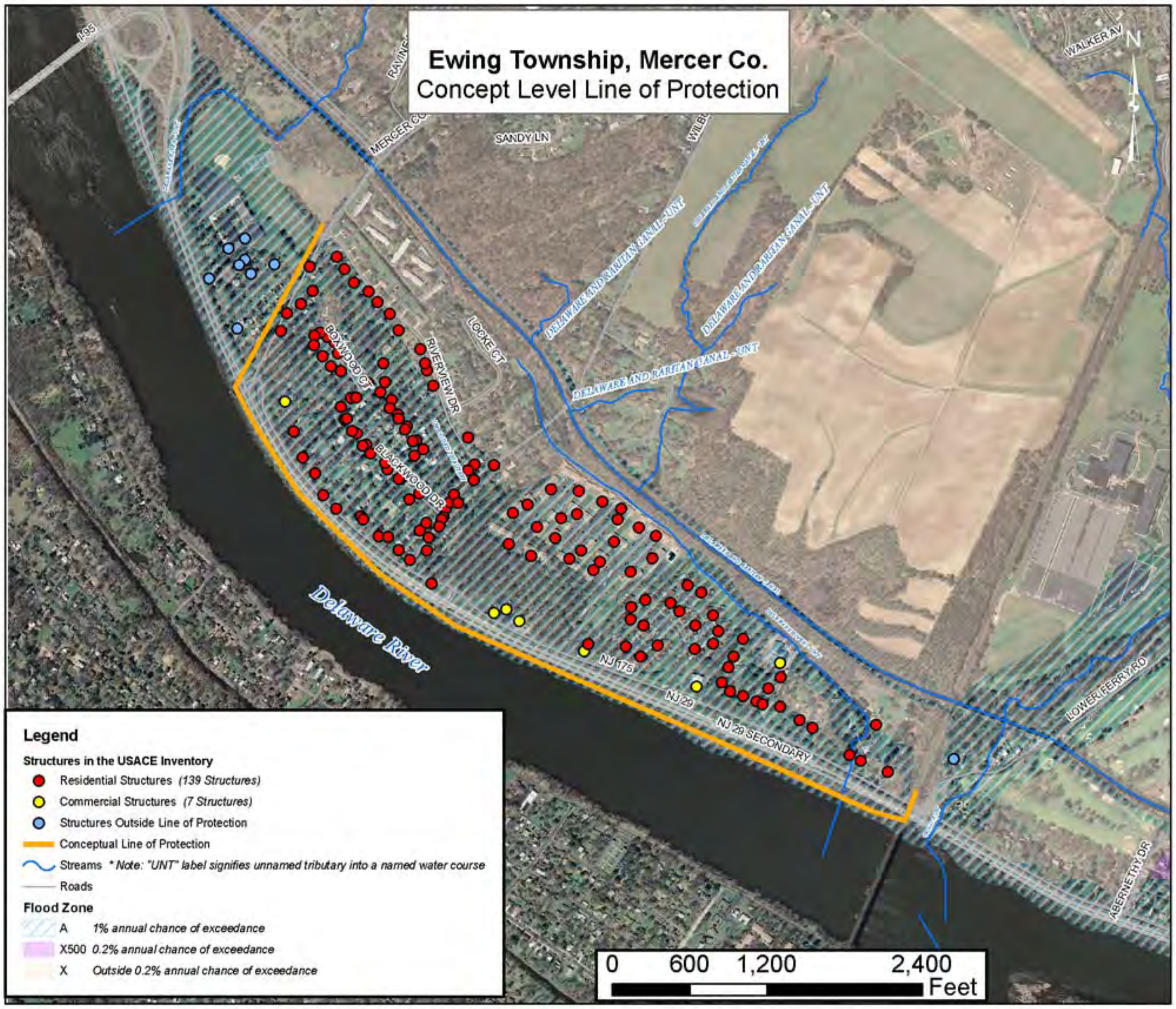
Costs were estimated for a 7,700 LF floodwall along Route 29 (see Figure 3.35). The line of protection would have an estimated annual cost of $1,450,000 and would provide protection to 146 buildings with AAD of $640,000 (Site 6). This would provide an initial screening BCR of 0.4. (Figure 13.1), which does not meet the cost-effectiveness threshold of 0.7 to be considered suitable for further Federal evaluation. Thus, no further evaluation of this measure is recommended. As noted, Corps participation in the installation of backflow prevention valves could be pursued as part of an overall line of protection alternative. However, since a line of protection is clearly not-cost effective, the Corps will not pursue installation of such valves. As described in Corps guidance document ER 1165-2-21, the provision or enhancement of drainage through existing stormwater systems is considered a local responsibility and not eligible for Corps participation as a stand-alone measure. State or local interests may wish to pursue enhancements to the existing system. Nonstructural Risk Management Alternatives

Given the limited depth of flooding typically experienced in this area, utilities protection, wet floodproofing, and dry floodproofing should be the primary means of risk management evaluated for the at-risk structures in this area.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Depending on the depth of flooding that would occur under less frequent but more damaging conditions (e.g., the 2% ACE event), elevation and free-standing barriers should also be evaluated. Relocation and acquisition should be evaluated, but likely would only be cost-effective if structures have significant damage at the 10% annual chance flood event.

Figure 3.35: Ewing – Concept Level Line of Protection



Source: FEMA Q3 Data, Mercer County NJ; NJDEP, Stream Network (Upper Delaware Basin), 2008; NJDOT, Roads 2008; NJOIT, OGIS, 2007 - 2008 High Resolution Orthophotography

3.3.2.3 Nonstructural Screening Results

The initial dataset included 174 individual structures in Ewing Township, of which 135 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Ewing Township resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.49 and Table 3.50:

Table 3.49: Ewing Township: Summary of Nonstructural Costs by Floodplain

Ewing	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*0*	*2*	*13*	*74*	*113*	*135*
Total Annual Damage	$0	$2,000	$122,000	$513,000	$630,000	$656,000
First Cost	$0	$1,145,000	$8,727,000	$25,844,000	$38,370,000	$46,777,000
Temp Relocation	$0	$20,000	$120,000	$710,000	$1,080,000	$1,280,000
Contingency	$0	$349,000	$2,654,000	$7,966,000	$11,835,000	$14,417,000
Construction Cost	$0	$1,514,000	$11,501,000	$34,521,000	$51,285,000	$62,474,000
Survey/Appraisal	$0	$20,000	$130,000	$740,000	$1,130,000	$1,350,000
E&D	$0	$20,000	$130,000	$740,000	$1,130,000	$1,350,000
S&A	$0	$182,000	$1,380,000	$4,142,000	$6,154,000	$7,497,000
Total Project Cost	$0	$1,736,000	$13,141,000	$40,143,000	$59,699,000	$72,671,000
Total Annual Cost	$0	$83,000	$625,000	$1,909,000	$2,839,000	$3,456,000
Initial Screening BCR	*0.0*	*0.0*	*0.2*	*0.3*	*0.2*	*0.2*

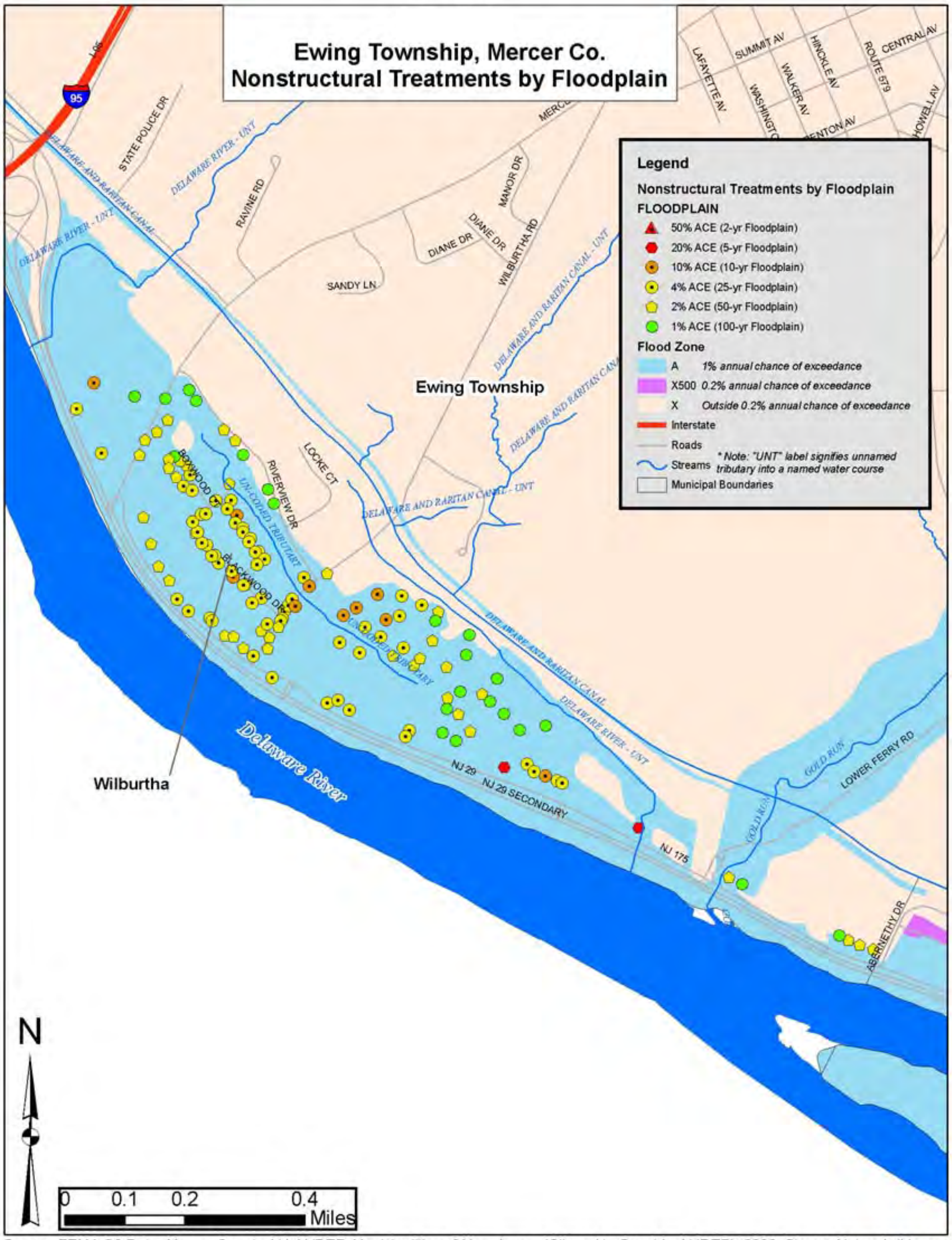
Table 3.50: Ewing Township: Summary of Nonstructural Treatments by Floodplain

Ewing	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	0	1	7	54	81	92
Wet Floodproof	0	0	0	0	0	0
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	1	3	5	7
Rebuild	0	1	5	17	27	36
Acquisition	0	0	0	0	0	0
Totals	*0*	*2*	*13*	*74*	*113*	*135*

See Figure 3.36 for a map of the nonstructural treatments by floodplain. Of the 135 structures in Ewing Township for which potential nonstructural treatments have been identified, 93% are residential, and the remaining ten structures are commercial properties and a school. The majority of structures eligible for treatment (68%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 36 structures. All but six of the structures currently identified for rebuilding are multiple-unit low-rise residential apartment buildings, with the remainder being mostly commercial properties.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. None of the nonstructural treatments for the various floodplains in Ewing Township reach this threshold, and thus no further evaluation of these measures is recommended. Table 3.51 provides recommendations for the further evaluation of measures in Ewing Township.

Figure 3.36: Ewing – Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.51: Recommendations for Further Evaluation, Ewing Township

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
<u>Structural Measures</u> **Local Risk Management**				
Backflow Prevention Structures		✓	✓	
Levees and Floodwalls				✓
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *<u>Land Use/Regulatory</u>*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
<u>Building Retrofits</u>				✓
<u>Land Acquisition</u>				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.3.3 City of Trenton

Trenton is the state capital of New Jersey and is the most populated community in the study area. Local officials provided information on the source and extents of flooding. The 1955 flood of record inundated portions of the city when the Delaware overtopped its banks. In 2004, the river did not overtop, but backflow of river floodwaters into the storm sewer system caused localized flooding. In 2005 and 2006, the Delaware overtopped its banks for the first time since 1955. In the 2006 flood, floodwaters from the river also backflowed into the storm sewers. See Figures 3.37 to 3.39 for general maps of the community, its floodplains, and the location of buildings in the structure inventory. The floodplains shown are based on FEMA's Q3 digital floodplain data.

The Trenton stormwater infrastructure flowed directly to the Delaware River before Route 29 was constructed. When the road was built alongside the river, the municipal system was bisected and junctioned into the stormwater system associated with the roadway (owned by the New Jersey Department of Transportation, or NJDOT). When the river overflows its banks, the water runs along Route 29 and compounds the flooding problem.

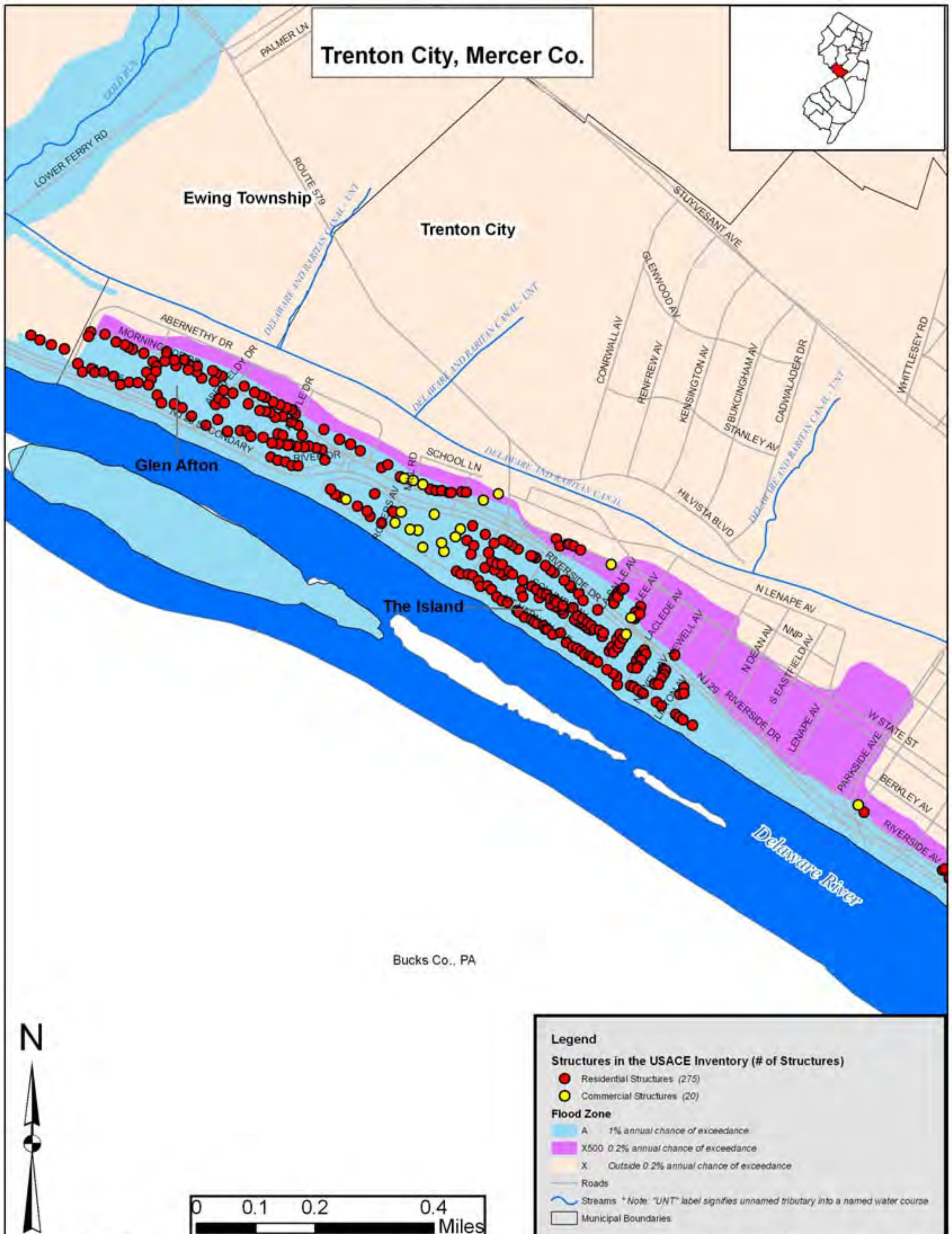
In the section of Trenton known as The Island (located west of Route 29 on the riverbank), approximately 170 structures have had basement flooding. (See Figure 3.37) Flooding on Clearfield Avenue, near an apartment building, renders the street impassable. According to municipal representatives, residents may be amenable to having houses elevated. Many of these buildings are constructed of stone and masonry. Residents have expressed a desire to remain in their present location, and structural actions that would reduce the view of the river are not widely supported. However, municipal officials have stated that structural alternatives should not be eliminated, due to the level of damage experienced in the recent flooding.

In the Glen Afton section of Trenton (across Route 29 from The Island), approximately 225 structures were affected by flooding, including 100 rental units in an apartment complex. (See Figure 3.38) Several basements (not living areas) were full of water. Fifteen of the apartment units are below grade and were flooded. The other apartments were affected because the electricity was shut off. Floodwater from Ewing Township comes southbound down River Road, turns left on Afton Avenue and turns right onto Morningside Drive, flooding properties as it proceeds southward. In 2005 and 2006, water also overtopped the riverbank, which caused flooding from two directions.

In the downtown section of the city, river backwater flowing along Route 29 by the State House flooded the adjacent parking garage through NJDOT-owned storm drains. This was followed by the river overtopping its banks, which added additional volumes of floodwater. (See Figure 3.38 for floodplain centered on Warren Street, and Figure 3.39 for floodplain along Lamberton Road).

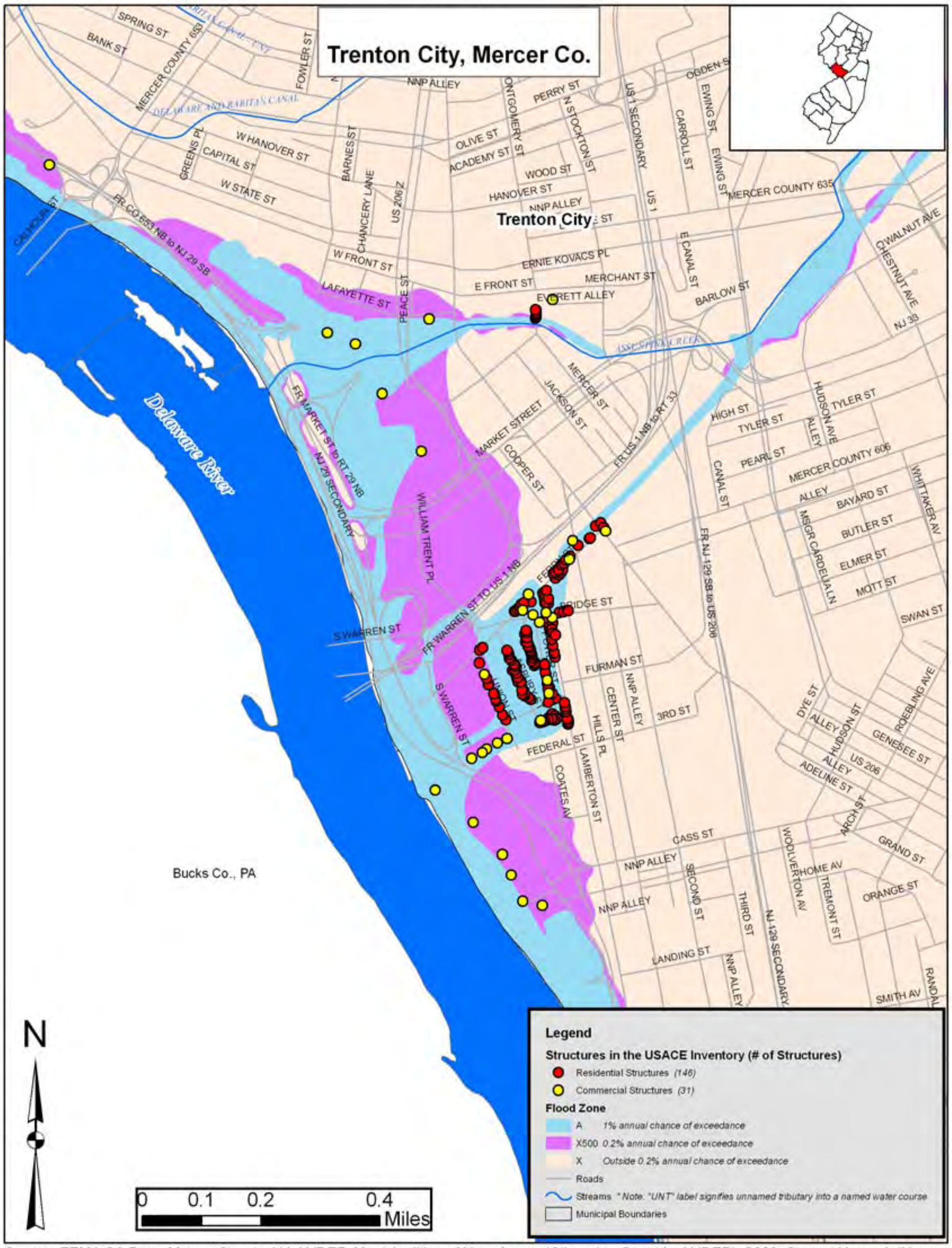
No recognized historic structures have been damaged in the city, and there has been no major structural damage from flooding.

Figure 3.37: Trenton City, Mercer County



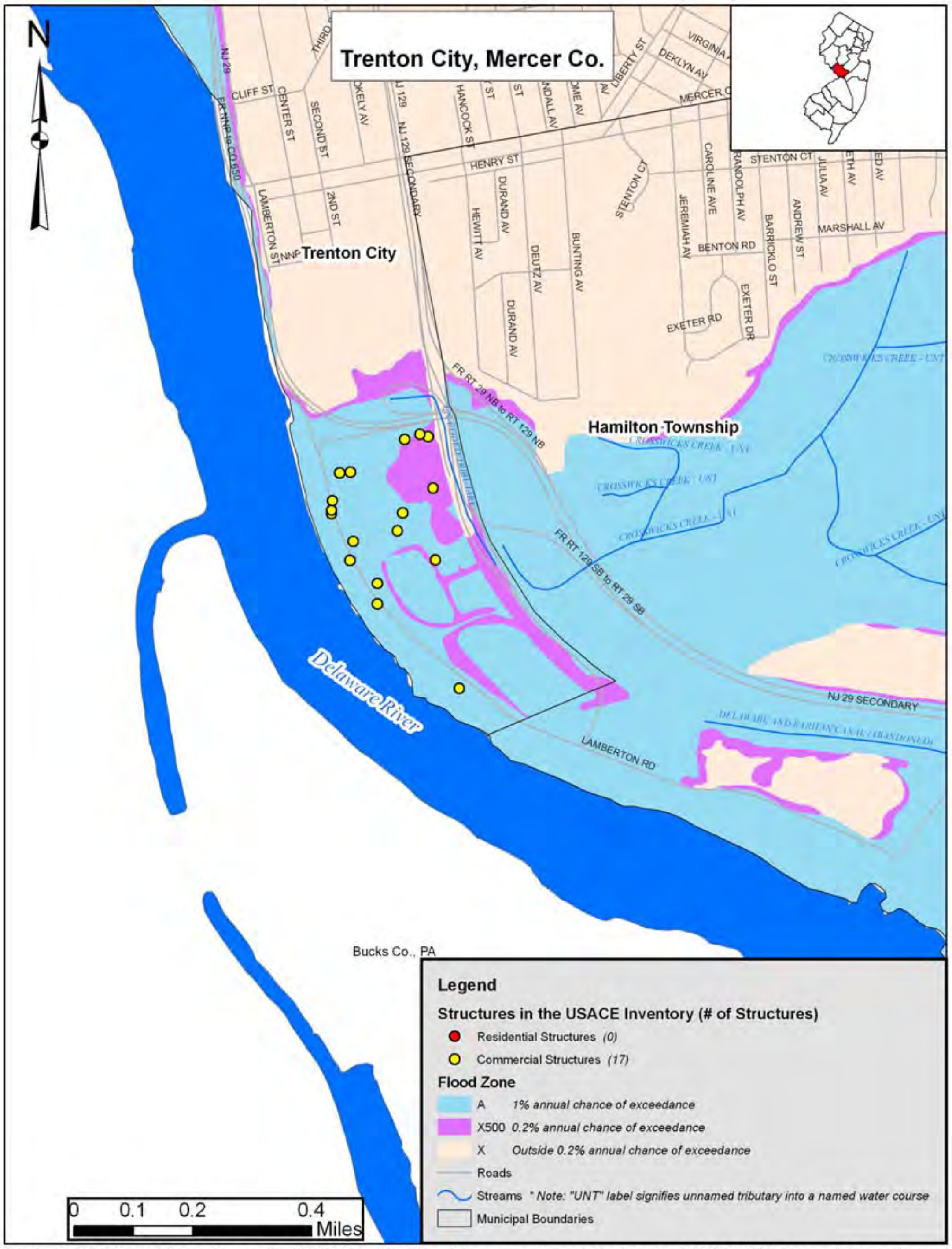
Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 3.38: Trenton City (continued), Mercer County



Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 3.39: Trenton City (continued), Mercer County



Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Lower Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

3.3.3.1 Structural Risk Management Alternatives

A concept-level line of protection was evaluated for Glen Afton and The Island sections of Trenton (Figure 3.40). At an initial concept-level of design, including three feet of freeboard above the 1% ACE (100-year) flood elevation of approximately 34 ft. NGVD results in a wall height about 9 to 13 feet above street grades in The Island section. (A detailed study would be required to identify the required height allowance to address design uncertainties and to ensure reliable performance).

Given these design heights and the proximity and slope of the riverbank, a large "T-wall" design section is indicated to provide the necessary stability. (A "T-wall", so named because it resembles an upside-down letter "T", features a wider horizontal base below the vertical wall or stem. The base provides additional stability.) The cost for a permanent 7,280 LF T-wall is estimated at approximately $59 million. Because visual and physical access to the river are important parts of the community character, the possible use of a portable flood defense system for a portion of the line of protection was investigated. Assuming a mix of 60% permanent floodwall interspersed with removable sections (40% total), a multiplier of 1.5 was applied to the cost for the entirely permanent floodwall. This multiplier, based on engineering judgment, is assumed to cover the additional costs of the removable sections and the necessary storage of those sections when not in use. Specific costs for these items have not been developed at this stage of the study, so a conservatively high estimate was selected. Applying the 1.5 multiplier to the base fixed floodwall construction cost gives an estimated cost of approximately $88 million for the mixed permanent/removable design. It is uncertain if portable wall designs are feasible at this location, and additional study would be required for a full evaluation.

In addition, estimated costs were obtained for installation of permanently installed, deployable flood barrier (known as a FloodBreak barrier) in this location (http://www.floodbreak.com). The barrier has a permanent foundation and consists of a buoyant panel that hinges into a recess in the foundation. The default position for the panel is down, which allows it be installed in a roadway or walkway without impeding access. During flooding conditions, the panel is raised into position by the hydrostatic force of oncoming floodwater. Once raised, the barrier will remain in place until the floodwaters drop. The system does not require manual intervention to raise or lower. This system has been installed in numerous locations nationally, including installations funded by FEMA. If employed in the Glen Afton/The Island section of Trenton, this system would have the advantage of not blocking access or views to the Delaware River during non-flooding conditions.

The barrier is available in a variety of exterior coatings capable of withstanding different exterior loads. The pricing obtained for the Trenton location provides prices for pedestrian-load and vehicle-load coatings. The design alternatives for the FloodBreak barrier were for an installation that would reach 5 feet above the ground when deployed (which would slightly exceed the water levels during the 2004-06 floods), and for cost comparison, a design that would reach 13 feet high above grade. This higher design is assumed to provide flood risk management to the 1% ACE (100-year) level, and for cost estimation purposes, includes a 3-foot allowance for freeboard. A risk and uncertainty analysis would be required to determine the actual required additional height allowance. For a 7,280 LF deployable barrier, estimated costs, including installation, are:

- 5 feet above grade (deployed height), vehicle-load coating: $29 million
- 5 feet above grade (deployed height), pedestrian-load coating: $17 million
- 13 feet above grade (deployed height), vehicle-load coating: $75 million

Decisions regarding more detailed evaluation of a line of protection at this location should be deferred until the without-project damage analysis is complete.

In downtown Trenton, Route 29 provides a nearly complete *de facto* line of protection to about $10 million in development (Figure 3.41). However, there is a low-lying section that leads to flooding of adjacent State-owned facilities. There is an additional low-lying area on US Route 1 at Bridge Street (approximately 150 LF) that allows floodwaters to contribute to inundation of the area south of Route 1 and east of Route 29. (This area borders the property adjacent to the low-lying section of Route 29). The area includes sections of Ferry Street, Lamberton Street, Bridge Street, Power Street, Asbury Street, and Union Street. During floods, the gaps in Route 29 could be eliminated using portable floodwalls placed on permanent installed foundations. Approximately 525 LF of portable floodwall would be required. Costs for this alternative were estimated to be $2.4 million, depending on foundation conditions and maintenance of traffic requirements.

The quality, condition, and performance of Route 29 as a risk management feature have not been evaluated by the Corps. Route 29 was neither constructed, nor maintained, for flood risk management and is highly unlikely to meet standards for that purpose. The approach to the calculation of average annual damage is to evaluate without project damages assuming that non-certified features provide no flood risk management. If the annual cost of the structural alternative exceeds the annual damages under this assumption, it is not necessary to refine the analysis to reflect the level of flood risk management actually provided by the existing feature. If the annual damages exceed the annual costs, then further analysis is necessary to determine the level of risk management and potential reduction in damages the existing feature provides.

In addition, flood risk management could be provided by using deployable, buoyant flood barrier, such as the FloodBreak system. A single, 150’ long barrier with a deployed height of six feet high above ground, with the vehicle-load coating could be constructed at the US Route 1/Bridge Street location for approximately $1 million. At the Route 29 location, a deployable barrier could be built in a single 400’ section, with a deployed height of six-feet above ground and the vehicle-load coating for approximately $2.3 million; or in two sections of 130’ and 120’ each with permanent berm in between for $1.3 million. These barriers would provide flood risk management for approximately $10 million in buildings plus an unquantified amount of infrastructure. Additional evaluation of structural measures is provided in Table 3.52.

Table 3.52: Evaluation of Structural Alternatives: City of Trenton

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Protection				
Backflow Prevention Structures	Gates or other backflow prevention structures added to storm drains typically would not require a LOP. Prevention of overland flooding from the Delaware River would require a LOP.	Would reduce backflow and related damage during higher-frequency events.	Unknown.	No known issues.
Levees and Floodwalls (ISLAND AREA)	Floodwall along Riverside Drive and Rt. 29 would require major closure structures on Rt. 29, a primary transportation artery to Trenton. Minimal space for interior drainage facilities due to urban development. May impact Green Acres property, requiring mitigation.	Could comprehensively address flooding concerns.	May be cost effective.	A significant portion of the floodwall would be located in or along the park at Riverside Drive. A partly removable or deployable floodwall may be more acceptable. Closure structures required on Rt. 29 would have major impact on transportation; however, the roadway is typically closed during major flood events.
Removable or Deployable Barriers (ISLAND AREA)	The extent of flooding may limit feasibility of a completely removable barrier (approx. 7,280 feet). A mix of permanent floodwall sections and removable barriers, or deployable barriers (FloodBreak) would be easier to install/maintain (see levee/floodwall above). Interior drainage (pumping) may be required.	In conjunction with a hard structure.	May be cost effective.	Large storage requirement; significant labor to install 4,000 LF of structure. Deployable barriers (FloodBreak) are installed on-site and do not need separate storage.
Levees and Floodwalls (DOWNTOWN)	Not feasible. Downtown flooding is primarily due to backwater flooding through low lying underpasses. Interior drainage (pumping) may be required.	n/a	n/a	n/a
Removable or Deployable Barriers (DOWNTOWN)	Removable barriers at key underpasses may limit backwater flooding into the downtown area. Interior drainage (pumping) may be required.	Limited application of barriers could address major flooding in downtown area.	May be cost effective.	No significant issues.
Road Raisings	Major transportation arteries would need to be elevated. Closure gates would still be required.	May have no significant advantage over levee or floodwall.	Not likely to be cost effective due to the size of the roadways.	Impacts during roadway elevation, construction of gates.

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Area Protection				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.3.3.2 Concept-Level Lines of Protection: Costs and Initial Screening Benefits

A concept-level line of protection was evaluated for the Glen Afton and The Island sections of Trenton (see Figure 3.40). A permanent 7,280 LF T-wall reaching a height of 13 feet above grade would have an estimated annual cost of $2,820,000 and would provide flood risk management to 287 buildings with AAD of $1,463,000. This would produce an initial screening BCR of 0.5. This alternative does not meet the BCR threshold of 0.7, and thus no further evaluation for Corps participation is recommended.

Because visual and physical accesses to the river are important parts of the community character, the possible use of a portable flood defense system for a portion of the line of protection was investigated. Assuming a mix of 60% permanent floodwall interspersed with removable sections (40% total), this alternative would have higher costs due to offsite storage requirements, maintenance, and installation (Site 7a.2). These higher costs would produce an annual cost of $4,220,000 and an initial screening BCR of 0.3. It is uncertain if portable wall designs are feasible at this location, and additional study would be required for a full evaluation. However, because this alternative does not meet the BCR threshold of 0.7, no further evaluation for Corps participation is recommended.

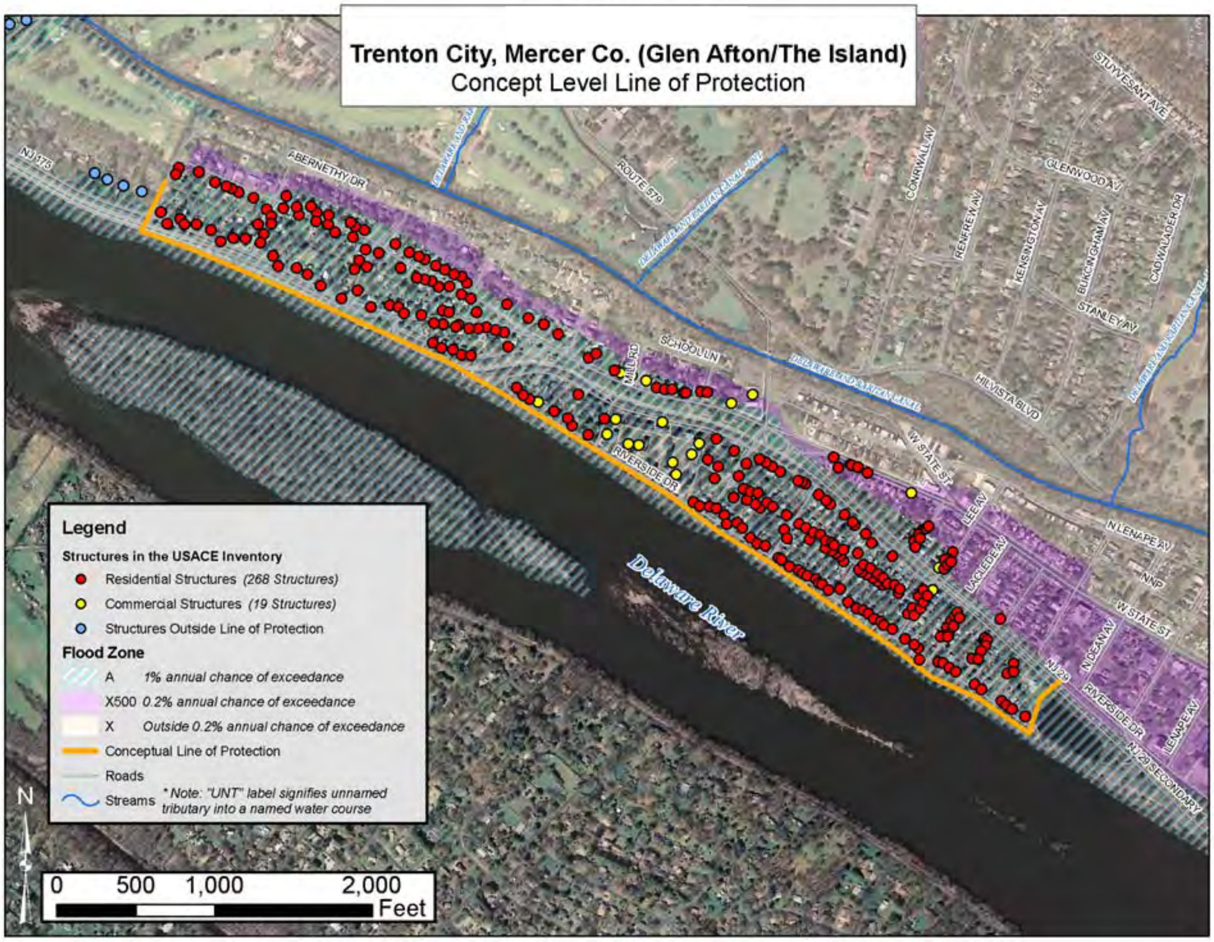
In addition, estimated costs were obtained for installation of permanently installed, deployable flood barrier (known as a FloodBreak barrier) in this location (www.floodbreak.com). If employed in the Glen Afton/The Island section of Trenton, this system would have the advantage of not blocking access or views to the Delaware River during non-flooding conditions.

The design alternatives for the FloodBreak barrier were for an installation that would reach 5 feet above the ground when deployed (which would slightly exceed the water levels during the 2004-06 floods), and an alternative that would reach 13 feet high. This higher alternative is assumed to provide flood risk management to the 1% ACE (100-year) level, and for preliminary cost estimation purposes, a 3-foot allowance for freeboard. (A risk and uncertainty analysis would be required to determine the actual required additional allowance). For a 7,280 LF deployable barrier, estimated annual costs, including installation, are:

- Site 7a.3: 5 feet above grade (deployed height), vehicle-load coating: annual cost of $1,380,000, in comparison to without project annual damage of $1,463,000.
- Site 7a.4: 5 feet above grade (deployed height), pedestrian-load coating: annual cost of $810,000, in comparison to without project annual damage of $1,463,000.

- Site 7a.5: 13 feet above grade (deployed height), vehicle-load coating: annual cost of $3,570,000; in comparison to without project annual damage of $1,463,000.

Figure 3.40: Trenton – (Glen Afton/The Island) Concept Level Line of Protection



Source: FEMA Q3 Data, Mercer County NJ; NJDEP, Stream Network (Upper Delaware Basin), 2008; NJDOT, Roads 2008; NJOIT, OGIS, 2007 - 2008 High Resolution Orthophotography

The different deployed heights above grade provide different levels of flood risk management. The typical approach to risk management within the Corps is to identify the National Economic Development (NED) alternative, which maximizes net economic benefits. Life safety and local preferences (as expressed in a Locally Preferred Plan alternative) are also major considerations in the planning process. Consideration of these factors may lead to recommendation of a level of flood risk management higher or lower than the NED Plan. If a demonstration can be made that a catastrophic loss of life may occur at levels of flooding higher than addressed by the identified NED plan, a higher level of flood risk management may be authorized. For example, the plan providing maximum NED benefits may provide risk management to the 2% ACE (50-year) level for a specific area, but if the potential loss of life at the 1% and 0.2% ACE levels (100-year and 500-year) is determined to be catastrophic, there is a basis for raising the line of protection to provide the higher level of flood risk management.

Conversely, a local community may wish to select a lower level of flood risk management, or opt for temporary versus permanent flood barriers, to reduce impacts to community character, maintain access to riverside areas, or reduce visual effects from a larger or permanent structure. In such a case, the community must be made aware of residual risk, and adopt appropriate institutional measures during flooding. For example, during flooding conditions the community and its leadership would need to act as though no risk management features had been installed, and conduct necessary measures such as evacuation. Because of a risk of structural failure, the resulting inundation of areas behind the risk management feature would likely be more rapid than would have occurred without the feature. Examples include floodwall overtopping and slippage of temporary barriers due to underseepage and lateral hydrostatic pressure.

The initial screening BCRs for these measures are:

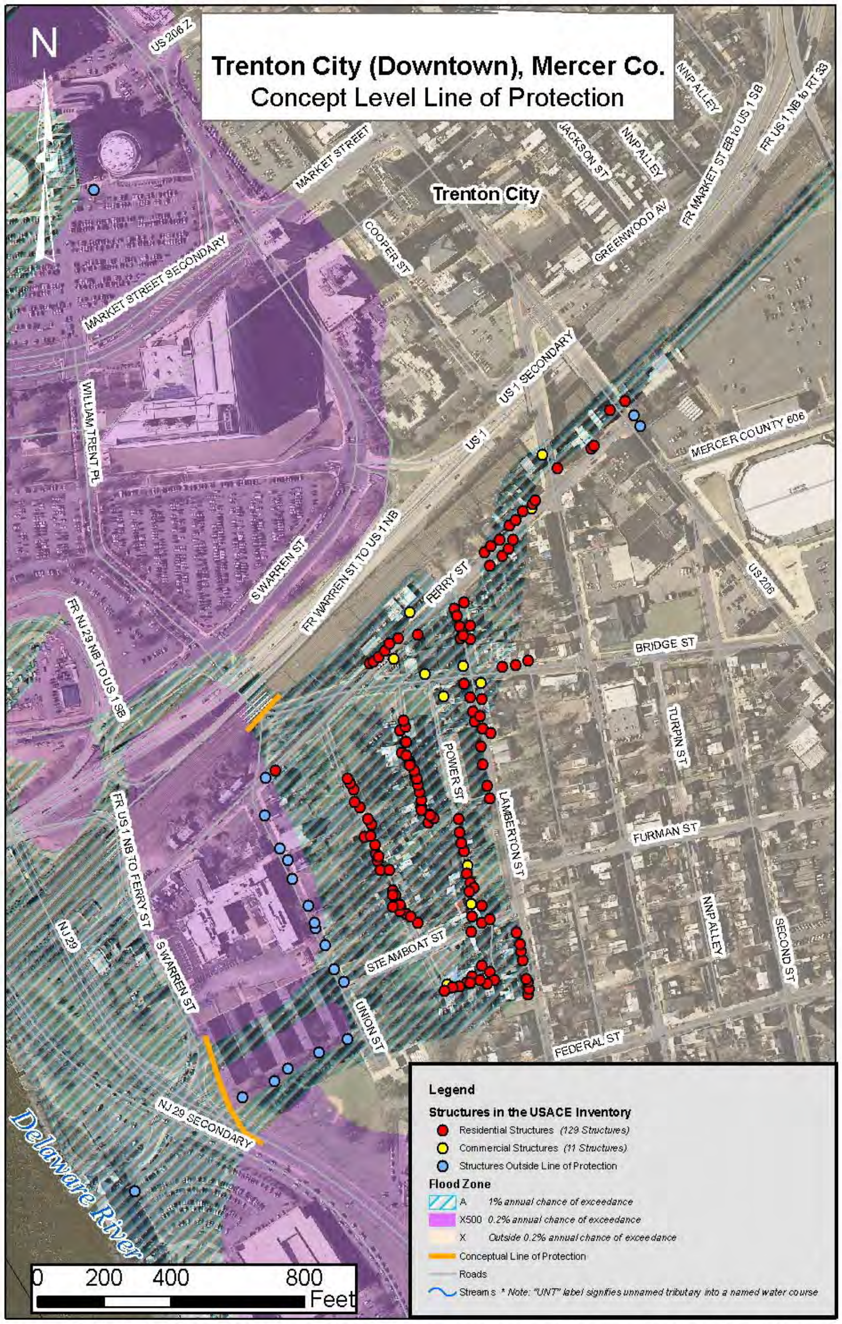
- Site 7a.3: 5 feet above grade (deployed height), vehicle-load coating: 1.06
- Site 7a.4: 5 feet above grade (deployed height), pedestrian-load coating: 1.8
- Site 7a.5: 13 feet above grade (deployed height), vehicle-load coating: 0.4

These alternatives will be further evaluated as part of the Federal study to determine the level of flood risk management provided, particularly at the 5-foot height above grade.

In downtown Trenton, Route 29 provides a nearly complete line of protection to extensive development (Figure 3.41). However, there is a low-lying section that leads to flooding of adjacent buildings, including several State-owned facilities. As shown on the effective Flood Insurance Rate Map (FIRM), there is an additional low-lying area on US Route 1 at Bridge Street (approximately 150 LF) that allows floodwaters to contribute to inundation of the area south of Route 1 and east of Route 29. (This area borders the property adjacent to the low-lying section of Route 29). The area includes sections of Ferry Street, Lamberton Street, Bridge Street, Power Street, Asbury Street, and Union Street. During floods, the gaps in this line could be eliminated using portable floodwalls placed on permanent installed foundations. Approximately 525 LF of portable floodwall would be required. Annual costs for this alternative (Site 7b.1) were estimated at $120,000, assuming good foundation conditions and no extensive traffic maintenance requirements.

In addition, a deployable, buoyant flood barrier, such as the FloodBreak system, could be used here. A single, 150’ long barrier with a deployed height of six feet high above ground, with the vehicle-load coating could be constructed at the US Route 1/Bridge Street location for approximately $50,000 annual cost (Site 7b.2). At the Route 29 location, a deployable barrier could be built in a single 400’ section, with a deployed height of six-feet above ground and the vehicle-load coating for approximately $110,000 per year (Site 7c.1); or in two sections of 130’ and 120’ each with a permanent berm in between for $60,000 (Site 7c.2). Thus, annual costs for flood risk management in this area would range from $50,000 to $110,000, depending on the type of treatment selected. However, as described below, the AAD for structures in this reach is extremely low at $2,400. Thus, the BCRs for these measures would be well below 0.1. The initial evaluation of flooding conditions in downtown Trenton was based on existing FEMA Q3 floodplain mapping. The AAD data and subsequent analysis of structural and nonstructural measures, however, is based on flood elevation modeling FEMA and the State of New Jersey have prepared for creation of Digital Flood Insurance Rate Maps (DFIRM). Many of the buildings shown to be within the 1% ACE floodplain (100-year) on the Q3 mapping have first floor elevations above the 1% ACE floodplain elevation in the DFIRM data. Thus, the AAD for many buildings in downtown Trenton is very low. Because of the low cost-effectiveness of these measures, they are not recommended for further evaluation as part of a Federal flood risk management plan.

Figure 3.41: Trenton – (Downtown) Concept Level Line of Protection



Source: FEMA Q3 Data, Mercer County NJ; NJDEP, Stream Network (Upper Delaware Basin), 2008; NJDOT, Roads 2008; NJOIT, OGIS, 2007 - 2008 High Resolution Orthophotography

3.3.3.3 Nonstructural Risk Management Alternatives

Elevation and utilities protection should be evaluated for all buildings in the at-risk areas. Many of the structures are of masonry construction with basements, and there is limited room between buildings for construction access. For buildings with basements, the National Nonstructural/Flood Proofing Committee (NNFPC) recommends that raised foundation walls be used to elevate. These factors will increase the cost and may limit or eliminate the technical feasibility of elevation in specific instances.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Residents have stated a preference for remaining in their present locations. For many, proximity and view of the river were a primary reason for selecting to live in the area. Thus, while relocation and acquisition can be evaluated, they may not have local support. Given the lack of major structural damage during the 2004-2006 flooding, it would appear these techniques would have limited cost-effectiveness.

Ringwall levees are typically applied to larger commercial or municipal structures. Given the priority placed on river access and views, this technique is not likely to be locally supported. In addition, there appears to be insufficient room between many of the buildings to construct a ringwall. However, the technique may be feasible for the apartment buildings, which would be extremely difficult to elevate. Thus, it should be evaluated for that structure type.

3.3.3.4 Nonstructural Screening Results

The initial dataset included 503 individual structures in the City of Trenton, of which 281 were considered eligible for individual nonstructural flood risk management measures. Application of the nonstructural treatment algorithm to the eligible structures in Trenton resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.53 and Table 3.54:

Table 3.53: Trenton: Summary of Nonstructural Costs by Floodplain

Trenton	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Structures Treated	*0*	*46*	*118*	*171*	*228*	*281*
Total Annual Damage	$0	$463,000	$870,000	$1,137,000	$1,680,000	$1,760,000
First Cost	$0	$6,969,000	$17,479,000	$27,419,000	$43,933,000	$53,966,000
Temp Relocation	$0	$460,000	$1,180,000	$1,680,000	$2,140,000	$2,530,000
Contingency	$0	$2,229,000	$5,598,000	$8,730,000	$13,822,000	$16,949,000
Construction Cost	$0	$9,658,000	$24,257,000	$37,829,000	$59,895,000	$73,445,000
Survey/Appraisal	$0	$460,000	$1,180,000	$1,710,000	$2,280,000	$2,810,000
E&D	$0	$460,000	$1,180,000	$1,710,000	$2,280,000	$2,810,000
S&A	$0	$1,159,000	$2,911,000	$4,539,000	$7,187,000	$8,813,000
Total Project Cost	$0	$11,737,000	$29,528,000	$45,788,000	$71,643,000	$87,879,000
Total Annual Cost	$0	$558,000	$1,404,000	$2,177,000	$3,407,000	$4,179,000
Initial Screening BCR	*0.0*	*0.8*	*0.6*	*0.5*	*0.5*	*0.4*

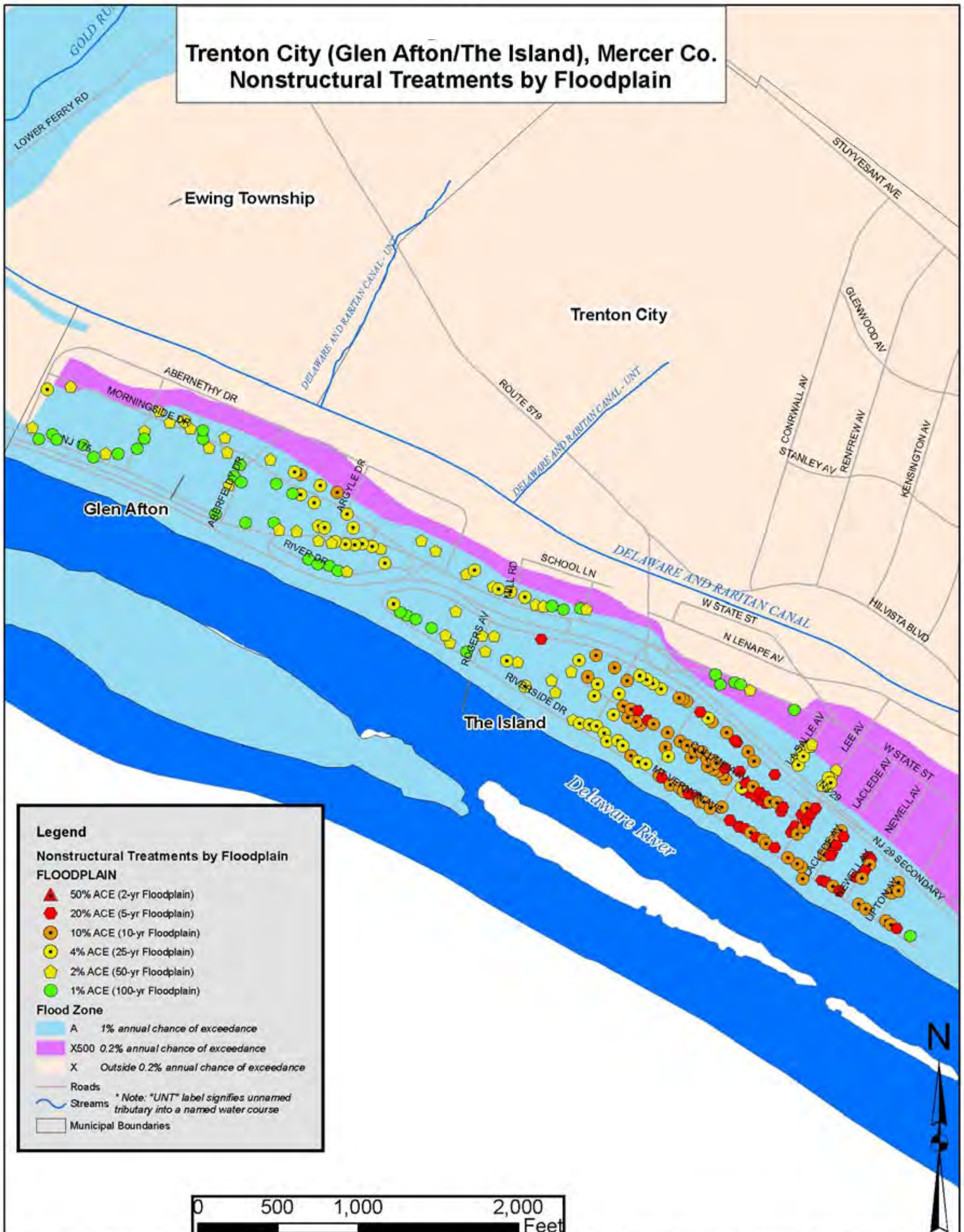
Table 3.54: Trenton: Summary of Nonstructural Treatments by Floodplain

Trenton	Annual Chance Exceedance Floodplain					
	50%	20%	10%	4%	2%	1%
Elevation	0	41	105	150	191	225
Wet Floodproof	0	0	0	0	3	13
Dry Floodproof	0	0	0	0	0	0
Ringwall	0	0	0	3	11	15
Rebuild	0	5	13	18	23	28
Acquisition	0	0	0	0	0	0
Totals	*0*	*46*	*118*	*171*	*228*	*281*

See Figure 3.42 (Glen Afton/The Island) and Figure 3.43 (Downtown) for maps of nonstructural treatments by floodplain. Of the 281 structures in Trenton for which potential nonstructural treatments have been identified, 93% are residential, of which approximately 6% are multiple unit apartment buildings. The remaining structures identified for treatment are commercial, light industrial, or warehouse structures, and two local government buildings, including the New Jersey Department of Human Services. The majority of structures eligible for treatment (80%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 28 structures. Most of the structures currently identified for rebuilding or acquisition are residential properties.

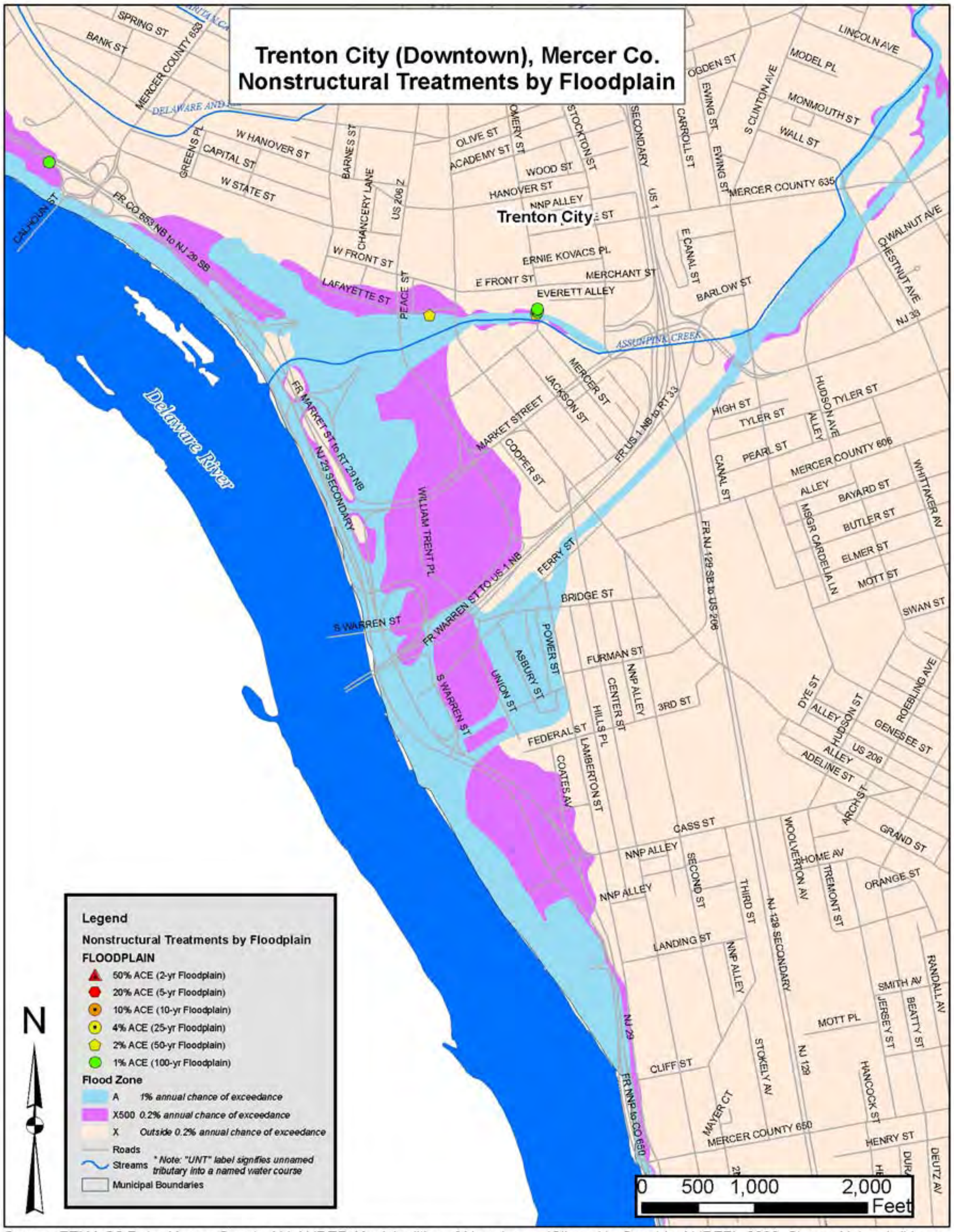
An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatment for the 20% ACE (5-year) floodplain in Trenton meets this threshold, and thus is recommended for further evaluation of costs and benefits. Table 3.55 provides recommendations for the further evaluation of measures in the City of Trenton.

Figure 3.42: Trenton – (Glen Afton/The Island) Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 3.43: Trenton – (Downtown) Nonstructural Treatments by Floodplain



Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Table 3.55: Recommendations for Further Evaluation, City of Trenton

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	Other Federal Agency Flood Risk Management Plan	Non-Federal Flood Plain Management Plan (FPMP)	Eliminate from Further Evaluation
Structural Measures **Local Risk Management**				
Backflow Prevention Structures		✓	✓	
Levees and Floodwalls	✓	✓	✓	
Removable Barriers	✓	✓	✓	
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout			✓	
Land Acquisition				✓
Exchange of Property		✓	✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions		✓	✓	

3.4 Gloucester County

3.4.1 Greenwich Township and Logan Township

These are the southernmost communities in the study area, and have extensively flat topography. A levee known as the Repaupo Levee or the Gibbstown Levee extends for 4.5 miles along the Delaware River through the area, and was originally constructed in the early 1800s for land reclamation for farming of salt hay. However, due to a later lack of demand for salt hay and subsequent development of residences and businesses behind the levee, this use is no longer required. Although the levee was not constructed to be a flood risk management structure, nor is it maintained to be one, it is being depended upon by area residents and property owners to serve that function. (See Figure 3.44 for Greenwich Township and Figure 3.45 for Logan Township). The floodplains shown are based on FEMA's Q3 digital floodplain data.

The former owner of the levee was the Repaupo Meadow Company, a now-defunct state-chartered entity that maintained the levee using fees collected from the property owners behind the levee. The current owners of the levee include at least three commercial entities: DuPont, Ashland/Hercules, and Paulsboro Refinery. Greenwich Township owns the levee in that municipality downriver of DuPont. Ownership of the portion of the levee within Logan Township is in question. It appears that some residents are unaware that their property contains portions of the levee, and levee alignment is not always clearly marked on the municipal tax maps.

The three private corporations at the north end of the levee maintain the portion that runs through their properties. Greenwich Township maintains its portion. Responsibility for the southern end of the levee in Logan Township (downriver from the Repaupo Floodgate) is contested.

There are four floodgates that drain the four creeks of Repaupo Creek, White Sluice Race, Sand Ditch, and Clonmell Creek. A fifth floodgate, commonly referred to as the E.L. Sluice floodgate, controls drainage exclusively from the DuPont site, and a sixth floodgate controls drainage primarily from the Paulsboro Refinery. This sixth floodgate, which is near the upriver end of the levee, has been abandoned and the drainage flow is pumped to a treatment system prior to being discharged into the Delaware River. All of the floodgate structures on the levee have flap gates. The Clonmell Creek and E.L. Sluice gates are circular in shape, as most flap gates are, and the remaining four are rectangular.

The populated area in Greenwich Township is known as Gibbstown, with approximately 4,500 residents. Portions of the area are topographically located below the levee and below high tide on the Delaware River.

At this point in the study, no determination has been made of the historical status of the levee. Future evaluation of alternatives at the levee site will include an exploration of the historic status, if any, of the levee. There may be hazardous waste contamination in or near the levee due to former industrial activities by DuPont and Ashland/Hercules. The northern parts of the levee are located on property owned by the DuPont and Ashland/Hercules corporations. As of 2015, some remediation has been done on the Hercules site. The DuPont property, known as the Repauno Facility, is a listed Superfund site. Contamination within the site is being effectively held in place through use of a groundwater interceptor and treatment system installed in 1985 and in use since. No remediation work is being conducted on the levee itself in 2015.

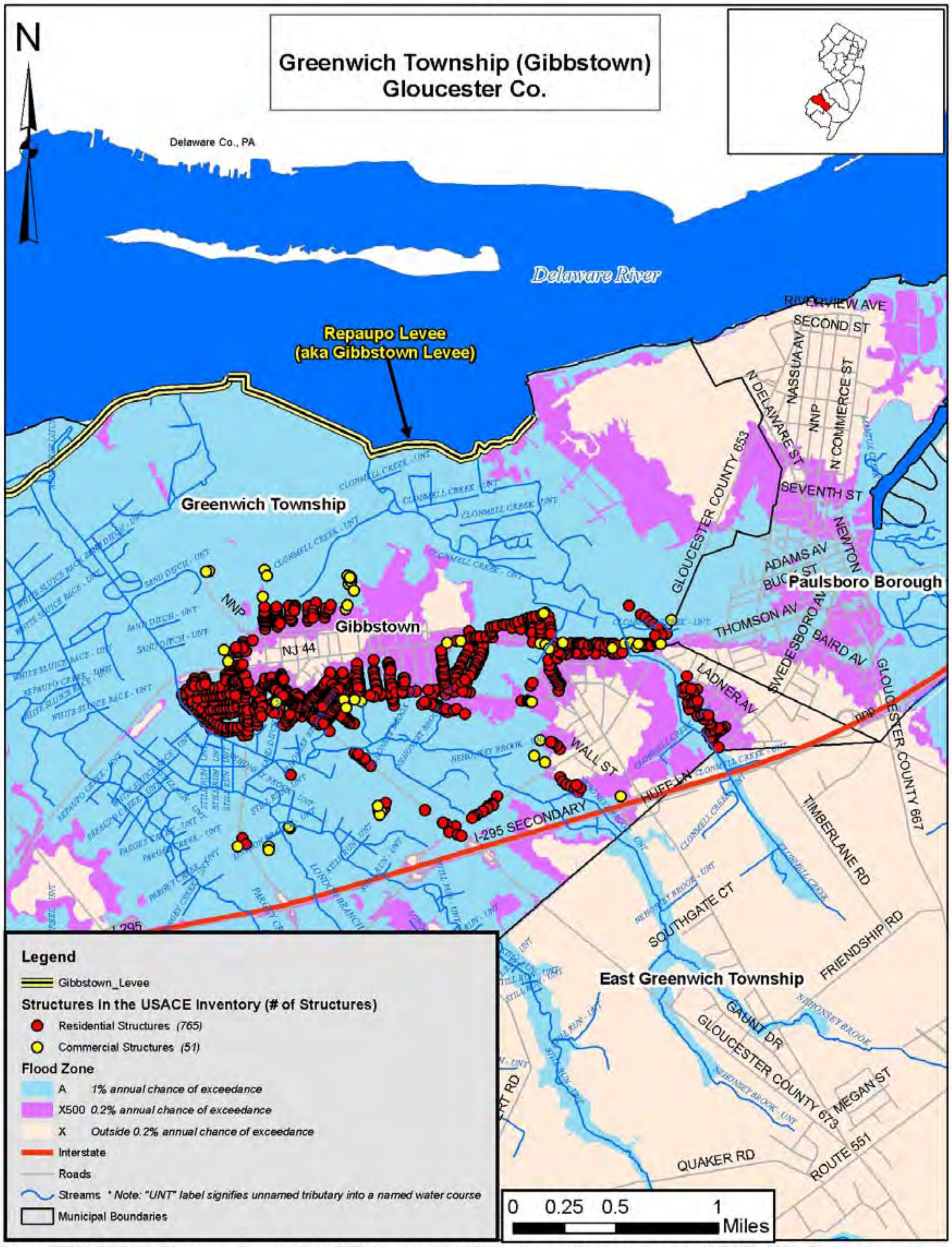
As noted above, the original purpose of the levee to reclaim land for agricultural use is no longer needed. The aging structure is often in some state of disrepair and was not built to provide adequate flood risk management for residential and commercial structures. In the past there have been breaches in the levee. It now provides something of a false sense of security to inland areas, and there is no single entity with the authority and financial ability to pay for needed maintenance.

The Repaupo Creek Floodgate was constructed at a historically low point on the levee. The levee itself had a top elevation of approximately elevation 8.0 ft, North American Vertical Datum 1988 (NAVD88). The top of the original floodgate was 1 to 1.5 feet lower than the adjacent levee. As part of renovations beginning in 2009, the floodgate was reconstructed to a top height of elevation 11.0, and a total of 900 feet of the levee (on both sides of the floodgate) was raised two to three feet in height to elevation 11.0 feet NAVD 88.

Downriver of the gate, the Delaware River once cut through the levee. Water became trapped behind the levee in the impoundments and could not escape. There is also a concern about rainwater running behind the levee and getting trapped if the Delaware River is high and the flap gates are consequently closed. Based upon the 2007 LiDAR mapping of the watershed, the Repaupo Creek watershed (including Clonmell Creek) drains an area of 26 square miles. The Repaupo Creek, White Sluice Race, and Sand Ditch (not including Clonmell Creek) drain an area of 21.5 square miles.

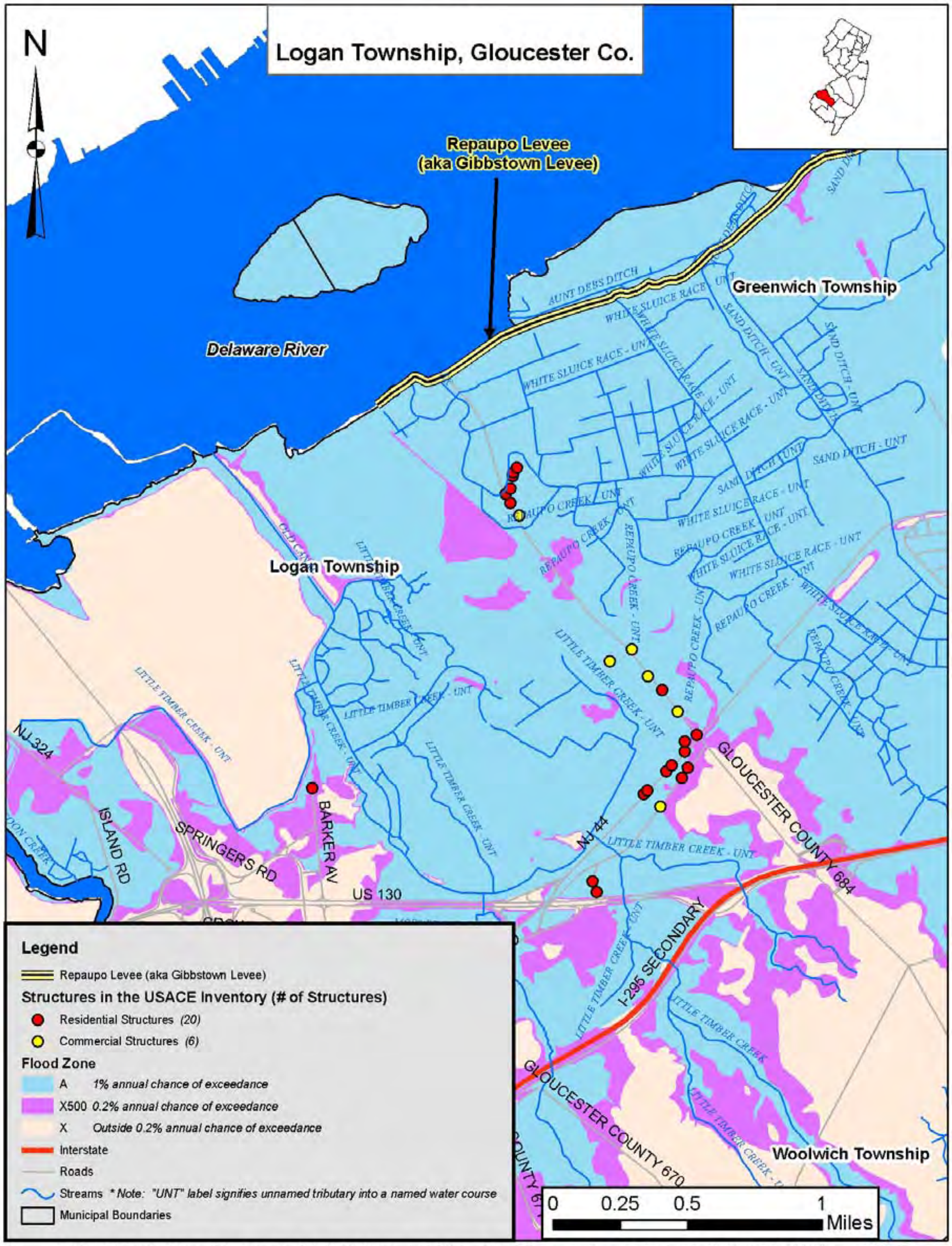
The main concern for flooding is from a hurricane traveling up the Delaware River estuary.

Figure 3.44: Greenwich Township (Gibbstown), Gloucester County



Source: FEMA Q3 Data, Gloucester County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Lower Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 3.45: Logan Township, Gloucester County



Source: FEMA Q3 Data, Gloucester County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Lower Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

In 1962, the levee breached and the Corps provided emergency repairs. The NRCS also replaced the White Sluice Race floodgate in the same year. A 1967 Corps Reconnaissance Study estimated the level of flood risk management provided by the levee at about a 7.14% ACE (14-year) event, and proposed raising the levee to provide a 1% ACE (100-year) level of risk management. In 1969, the sponsor was unable to provide the necessary construction funds. In 1973, the sponsor requested the study be reactivated but was unable to secure real estate easements and the study was again terminated.

In 2000, the Corps provided emergency repairs to the Repaupo Floodgate, including placement of sandbags and plastic sheeting. In addition, field inspections have been performed over the years. In 2005, the Corps provided further emergency repairs to the Repaupo Floodgate.

As noted above, more recently, the NJDEP Bureau of Dam Safety & Flood Control provided a 75% matching flood control grant to the Gloucester County Improvement Authority to repair the Repaupo Floodgate and raise adjacent segments of levee.

3.4.1.1 Structural Risk Management Alternatives

The current levee along the Delaware River in Logan and Greenwich Townships is depended upon for a limited level of protection to the community of Gibbstown and industrial sites owned by DuPont and Ashland/Hercules. While there may be options to upgrade the levee at its current location, the non-Federal sponsor must provide land and easements free of contamination. The presence of active remediation projects or contaminants at the industrial sites along the current alignment is a potential fatal flaw in any such alignment. However, use of the current alignment should be evaluated as an alternative. Options for use of the current alignment include reinforcement of the existing structure, or if it's structural integrity is found to not meet Corps standards, its replacement through construction of a new levee. A new levee could be constructed in the present location of the existing structure, or in close proximity landward of the existing structure. As discussed below and in Section 3.4.1.2, initial borings indicate that the levee would not be acceptable in its present condition for use as a flood risk management measure, based on Corps criteria. Costs for use of the current alignment have not been developed.

The screening has also considered significantly more landward (and upland) alignments to protect Gibbstown while avoiding known HTRW contamination issues. A more landward line of protection, through replacement and modification of the existing levee, would provide opportunities for ecosystem restoration. Construction of a more landward line of protection would occur to the east of the existing levee, and would allow for tidal river water to flow onto the area between the river bank and the new levee. Modification of the existing levee would involve increased flow from the river, which could be achieved by modification of the existing floodgates and/or their operation. In general, a more landward LOP would allow the formerly protected areas to transition (at least in part) back to their historic state as intertidal freshwater marsh. These areas now feature a monoculture of the reed *Phragmites australis* in some areas, with a mix of upland wooded areas and wetlands in others. Mr. Lee Widjeskog of NJ Division of Fish and Wildlife-Lands Management provided an overview of site conditions and possible ecosystem restoration measures. Mr. Widjeskog noted that the existing levee requires substantial maintenance and provides limited flood risk management. A more upland flood risk management levee would allow for the modification of the flow regime to the areas behind the existing levee, while protecting the population centers of Gibbstown and Paulsboro. Risk management measures (such as elevation, relocation or acquisition) would be needed for buildings outside the line of protection. The increased flow of water could reduce the *Phragmites* cover and support increased populations of native freshwater wetland vegetation. These changes may increase the value of the area as foraging habitat and increase its use by shorebirds and wading birds and raptors, including the bald eagle. Modifications to the flow regime could be made through a variety of techniques to achieve partial or open tidal flow, including: increasing the flow through the existing levee through maintenance, upgrade or replacement of the existing tide gates; installation of additional tide gates in the existing levee; and removal of the existing tide gates combined with channel modification and creation.

Potential releases from contaminated areas would need to be considered as part of the ecosystem restoration planning. Depending on the extent of flow regime modification, tidal inundation of contaminated areas may be increased. This could be addressed by construction of a dike or levee adjacent to the DuPont property, with a tie-in to a new upland levee. An alternative method would be to not open the tide gate closest to the DuPont property, and regulate flows through each of the other gates to keep from increasing the flooding risk to the DuPont property. This method may limit the extent of restoration opportunities because of the reduced extent of tidal inundation. Quantifying the extent and impact of changes in tidal inundation will require additional hydraulic modeling.

The potential for ecosystem restoration at this site is similar to the Pond Creek Salt Marsh Restoration Project, Cape May County, NJ. An Environmental Assessment, resulting in a Finding of No Significant Impact (FONSI) has been prepared for Pond Creek under Section 1135-Ecosystem Restoration by the Philadelphia District of the Corps and the New Jersey Field Office, US Fish and Wildlife Service in Pleasantville, NJ.

The quality, condition, and performance of the Repaupo Levee as a flood risk management feature have not been recently evaluated by the Corps. (They were subsequently assessed in Phase 3 of this study, per Policy Guidance Letter 26.) The Repaupo Levee embankment was neither constructed, nor maintained, for flood risk management and is highly unlikely to meet standards for that purpose. The levee was built to control flooding of salt hay fields for farming; it was not built to provide flood risk management for dwellings, industry, commercial establishments, or other related types of structures. Initial borings along the existing levee show that it would not be acceptable based on Corps criteria. (See additional discussion of the initial borings in section 3.4.1.2). The approach to the calculation of average annual damage is to evaluate without project damages assuming that non-certified features provide no flood risk management. If the annual cost of the structural alternative exceeds the annual damages under this assumption, it is not necessary to refine the analysis to reflect the level of risk management actually provided by the existing feature. If the annual damages exceed the annual costs, then further analysis is necessary to determine the level of risk management and potential reduction in damages the existing feature provides.

Initially, a line of protection alignment was identified for the Gibbstown area only. The alignment was based on FEMA's Q3 digital floodplain data, and was developed with regards to balancing the following: reduction of wetlands impacts, providing risk management for the greatest number of structures possible, and minimizing required length. The floodplain extends from the Delaware River towards Gibbstown, and borders the community on all sides. To the north of Gibbstown, high storm surge into Mantua Creek can flood through the Borough of Paulsboro southward into Gibbstown. Based on FEMA's Q3 flood data, it appears that the line of protection could be extended to provide flood risk management to a large, densely-developed floodplain area in the Borough of Paulsboro, as part of the concept-level plan of flood risk management for Gibbstown. A substantial portion of Paulsboro is in the 1% ACE (100-year) floodplain. This portion appears to be primarily residential.

The concept-level line of protection developed for the screening includes a new levee and flood wall extending northward from high ground near the intersection of Floodgate Rd./Repaupo Station Road and NJ Route 44 (see Figure 3.46). The primary considerations in developing the alignment were minimization of impacts to adjacent wetlands, provision of risk management to structures, and potential for ecosystem restoration through increased flow of water into adjacent historic wetlands. The topography, the extent of the floodplain, and presence of existing wetlands dictate that a landward alignment should be placed close to the developed areas of Gibbstown. The concept-level alignment would begin along Repaupo Station Road and then turn east to proceed along Route 44 to create a barrier between western Gibbstown and the floodplain, for a length of approximately 16,100 LF. Approximately 9,900 LF of this section would be floodwall. This section of alignment would then meet a second levee section of approximately 7,900 LF, which would begin again on NJ Route 44 in eastern Gibbstown, and proceed east to the intersection of Route 44 and Gloucester County Road 653. The alignment would turn north up County Road 653 and then terminate at high ground. Placement along NJ Route 44 would likely minimize impacts to wetlands. An additional 1,000 LF levee/floodwall segment is included along Mantua Creek. The alignment as described would have an overall length of approximately 25,000 LF and would protect both Gibbstown and Paulsboro, with the line of protection costs estimated at approximately $78.4 million. Some additional costs may be needed for gates and/or pump stations at the larger creek crossings; however, detailed interior drainage analysis would be needed to quantify the size and cost of such structures. Some individual structures (homes and several industrial properties) located to the south and west of Gibbstown would remain outside of the line of protection and should be evaluated for nonstructural measures such as elevation or a ring levee. Many of these structures are located on Floodgate Road. Costs for these nonstructural treatments have been included in the overall cost for the line of protection alternative. Alternatives to the alignment described above are provided in Section 3.4.1.2; these alternatives are limited to providing risk management for Gibbstown only.

Paulsboro was not initially identified for inclusion in the study; therefore, baseline information was not collected. If this alternative is pursued further, all necessary data (such as a building inventory) will be collected.

Paulsboro is a densely-developed community of approximately 6,100 residents, with a mix of industrial and residential primary uses. It is approximately two square miles in size. The population density in 2000 was 3,140 per square mile, with 2,628 housing units at an average density of 1,339 units per square mile (U.S. Census, 2000). As described above, an alignment was identified to avoid flooding in Paulsboro from Mantua Creek. (See Figure 3.46). A review of FEMA flood mapping for Paulsboro indicates that development is adjacent to low, tidal marshlands that are susceptible to flooding from high water flowing down Mantua Creek from the Delaware River, when the Delaware is at high levels. The dead-end streets between Ladner Avenue and Clonmell Creek are also subject to tidal flooding. The tops of the floodgates on the existing levee are at an elevation equivalent to the 2% ACE (50-year) annual tide; however, low spots in the berm between the gates could mean flooding from lower-level tides could potentially inundate the area. The extent of inundation has not been established as part of this study.

The FEMA National Flood Insurance Program claims database indicates that only two properties in Paulsboro have filed flood insurance claims over the last twenty years, with the claims dating to the late 1980s. The effective flood mapping shows several blocks of residential and commercial structures in the 100-year floodplain. The average annual damage (AAD) of buildings in Paulsboro has not yet been established and would be a requirement for further evaluation.

Initial order of magnitude estimates indicate that a LOP, protecting Gibbstown and extended to Paulsboro as shown, combined with nonstructural treatment of 20 buildings outside the LOP, would cost approximately $78.4 million and provide risk management to 805 buildings in Gibbstown plus an unquantified amount of infrastructure. Additional evaluation of structural measures is provided in Table 3.56.

Table 3.56: Evaluation of Structural Alternatives: Greenwich and Logan Townships

Structural Measures	Evaluation Criteria			
	Completeness	**Effectiveness**	**Efficiency**	**Acceptability**
Local Protection				
Backflow Prevention Structures	The existing levee has multiple gates to allow creek flow to the Delaware River. Any new LOP would similarly require gates or other backflow prevention structures. Backflow prevention could be added to storm drains if surcharging occurs during periods of high water or heavy rainfall.	Are now used to prevent high water from Delaware River from inundating areas behind levee.	Unknown.	No known issues.
Levees and Floodwalls	A levee system can include both Gibbstown and Paulsboro or Gibbstown alone. Alignments can include the present location of the levee, or a more landward alignment focused on risk management for developed areas. A number of backflow gates on wetland tributaries would be required as well as interior drainage structures. A tie-off structure would be required in Paulsboro. Flood Warning is critical for operation of closure structures.	Will manage main stem flood damages.	Unknown.	A new levee would replace an existing levee with approximately 7.14% ACE (14-year) level of risk management (as evaluated in 1967). Potentially significant wetlands impacts. Other option is to leave existing levee in place and improve upon it, which would likely have lesser wetlands impacts. Potential contamination on site of existing alignment.
Removable Barriers	Not feasible due to the flat terrain and distances between tie-off locations.	n/a	n/a	n/a
Road Raisings	Not feasible. Given depth of flooding in absence of existing levee or a breach, no roadway alignments are present that would be viable candidates for elevation to required height.	n/a	n/a	n/a
Area Protection				
Channel Modification	n/a			
Dams or Impoundments	n/a			
Diversion	n/a			

3.4.1.2 Concept-Level Lines of Protection: Costs and Initial Screening Benefits

To the north of Gibbstown, high storm surge into Mantua Creek can flood through the Borough of Paulsboro southward into Gibbstown. The concept-level line of protection developed for the screening includes a new levee and flood wall extending northward from high ground near Floodgate Rd, along the west side of Gibbstown until reaching high ground in Paulsboro. Included in the plan is the nonstructural treatment of 20 buildings that would be outside the alignment. (See Figure 3.46). An additional levee/floodwall segment is included along Mantua Creek. Such an alignment would protect 805 buildings in Gibbstown at an estimated initial cost of $78.4 million, with an average annual cost of $3,730,000. The AAD for buildings behind this LOP is $12,582,000. With an initial screening BCR of 3.4, this LOP should be further evaluated in the Federal study. This plan includes the nonstructural protection of approximately 20 residences outside the LOP alignment, and a ringwall around a light industrial building. Damage amounts should be refined to reflect the actual risk management provided by the existing levee. The historic performance, maintenance and structural integrity of the levee will be evaluated further; however, the levee is unlikely to be considered to perform flood risk management and the benefit-cost ratio is unlikely to be reduced. As noted, the existing levee was not constructed for flood risk management purposes and has not been rigorously maintained over its lifespan.

Initial borings along the existing levee show that it would not be acceptable based on Corps criteria. A continuous impervious portion (i.e.; clay core or shell) is typically required for the length of a risk management levee structure. The existing foundation of organic soils and loose to medium density sands with interbedded sandy gravel layers does not comply with current standards for stability or seepage. The organic soils are prone to settlement, which can cause voids in the levee and lead to seepage or settlement of the crest, which may lead to overtopping or cracking of the levee. Loose to medium density sands with sandy gravel lenses in the foundation allows for seepage under the levee, which can lead to flooding or piping of levee materials, causing a failure of the levee. These existing materials, in addition to the lack of regular maintenance, lead to the conclusion that the levee, as is, cannot be counted on to provide flood risk management to Corps of Engineers standards.

Some additional costs may be needed for gates and/or pump stations at the larger creek crossings; however, detailed interior drainage analysis would be needed to quantify the size and cost of such structures. The LOP alignment as presented would also protect buildings in the adjoining community of Paulsboro; however, the AAD for these structures has not been calculated. Several alternative alignments have been developed to protect areas of Gibbstown only. The length and cost of these alignments is expected to be similar to the $78.4 million cost described above. These alternative alignments are shown in Figure 3.47. The section of the alignment labeled as “1” in Figure 3.47 is the same alignment for this area as seen in Figure 3.46 (Site 8), along NJ Route 44. The section of the alignment labeled as “2” in Figure 3.47 is a different method of providing risk management to Gibbstown. (If constructed, only section 1 or 2, not both, would be built). Section 2 would likely have increased impact on wetlands. The use of section 2 would leave approximately 40 additional structures outside the LOP, compared to section 1 or the alignment shown in Figure 3.46 (Site 8).

Figure 3.46: Greenwich (Gibbstown) – Concept Level Line of Protection

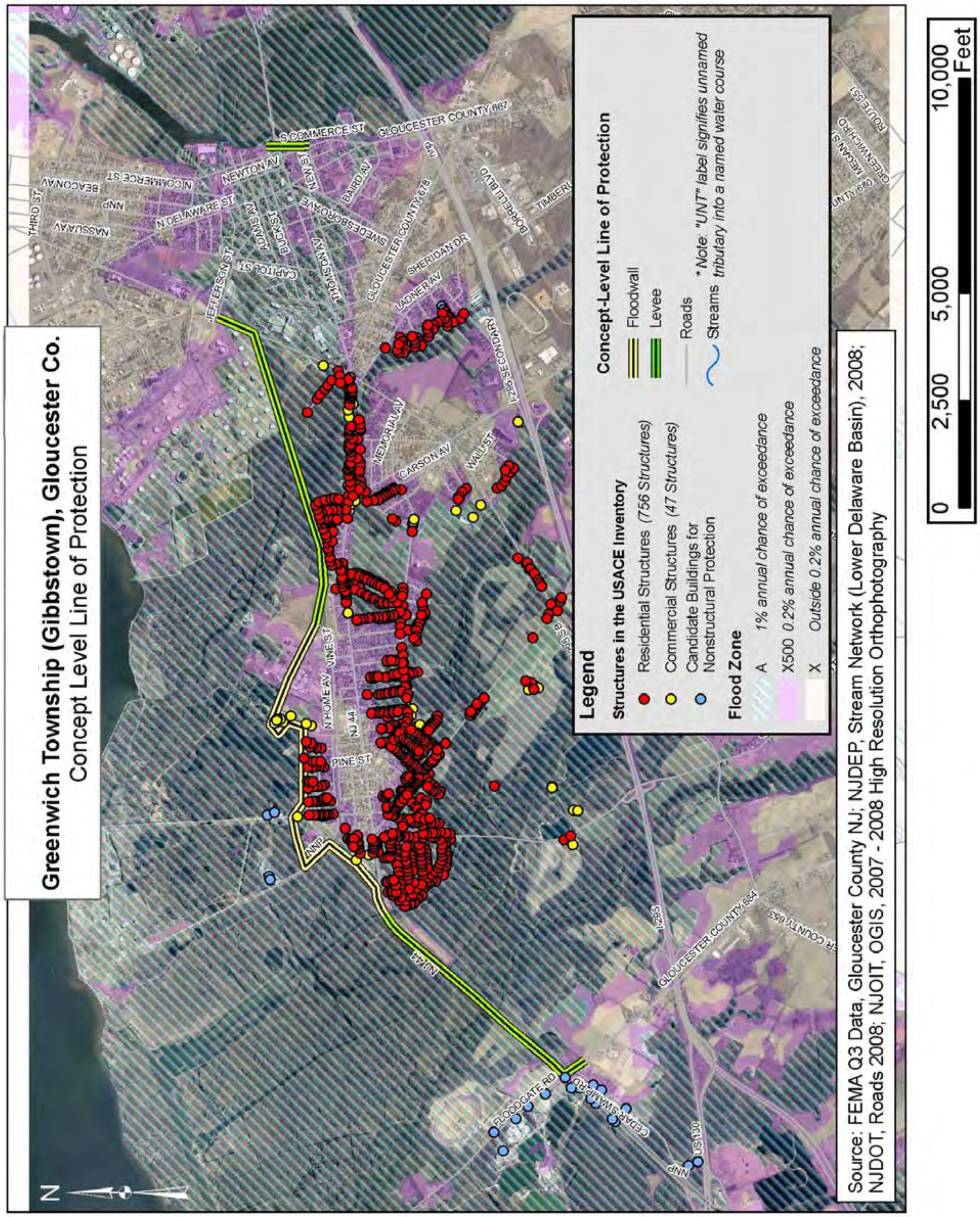
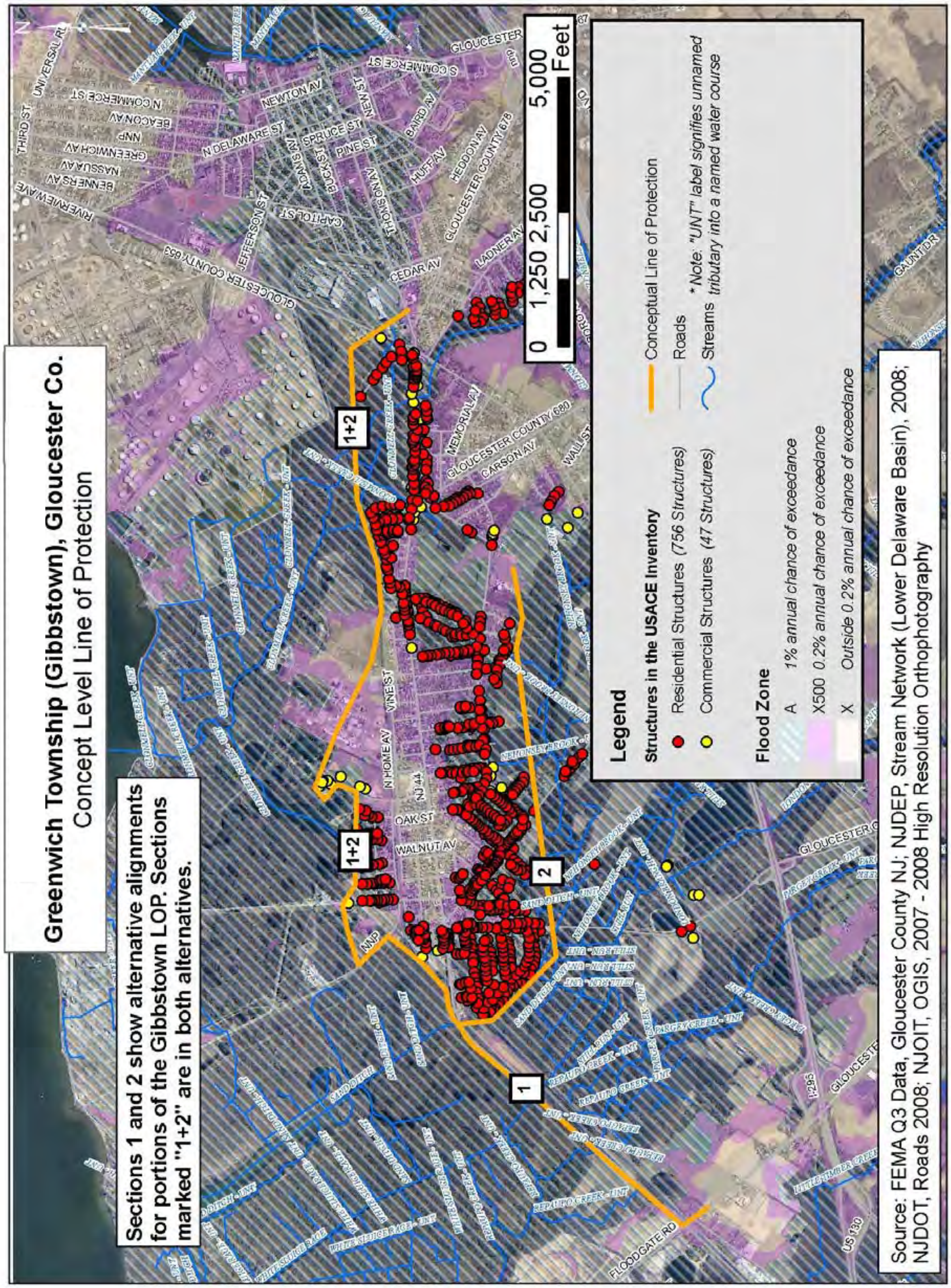


Figure 3.47: Greenwich (Gibbstown) – Alternative Concept Level Line of Protection



3.4.1.3 Nonstructural Risk Management Alternatives

Given the concentration of development and the risk for high levels of flooding if the existing levee is overtopped or breached, the full range of nonstructural alternatives should be evaluated for Greenwich and Logan Townships. As detailed above, structural risk management measures are being evaluated for the area. If recommended, a new or reconstructed LOP would likely omit 20 structures located on Floodgate Road, including residences and one large industrial facility, as seen in Figure 3.46. (Other alignments may omit additional structures, as seen in Figure 3.47). These structures would require nonstructural treatment as part of an integrated structural/nonstructural plan. In particular, acquisition, elevation, wet floodproofing and dry floodproofing should be evaluated.

A substantially damaged or improved residential structure must be brought into compliance with NFIP criteria and the locally-adopted floodplain management ordinance. These laws prohibit the use of wet or dry floodproofing to bring residential structures into compliance. Thus, a substantially damaged residence would likely be elevated or relocated to achieve compliance. Wet or dry floodproofing could be applied to a non-substantially damaged or improved residence, but the technique is not credited with any insurance premium reduction under NFIP. The National Nonstructural/Flood Proofing Committee (NNFPC) criteria for flood risk management measures state that for use of dry floodproofing, the depth of flooding should be less than three feet and the velocity of flow should be less than three feet per second (fps). For wet floodproofing, the depth of flooding can be greater than six feet but the velocity should also be less than 3 fps. Thus, the depth and velocity of flooding will be key factors for the evaluation of these techniques.

Given the large size of the industrial property Godwin Pumps of America, a free-standing barrier should be evaluated as a risk management measure for the facility. As described below, a screening algorithm was applied to the building inventory in Greenwich and Logan Townships to develop a nonstructural-only alternative.

3.4.1.4 Nonstructural Screening Results

The initial dataset included 840 individual structures in Greenwich and Logan Townships, of which 420 were considered eligible for individual nonstructural flood risk management measures. This plan was developed assuming the absence of structural lines of protection. Application of the nonstructural treatment algorithm to the eligible structures in Greenwich and Logan Townships resulted in the assignment of treatments and associated preliminary estimated costs presented in Table 3.57 and Table 3.58:

Table 3.57: Greenwich and Logan: Summary of Nonstructural Costs by Floodplain

Greenwich & Logan	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Structures Treated	*254*	*299*	*325*	*380*	*396*	*420*
Total Annual Damage	$9,817,000	$10,085,000	$10,255,000	$10,331,000	$10,386,000	$10,394,000
First Cost	$30,282,000	$35,109,000	$38,343,000	$43,877,000	$45,390,000	$47,782,000
Temp Relocation	$2,430,000	$2,810,000	$3,030,000	$3,420,000	$3,500,000	$3,580,000
Contingency	$9,813,000	$11,376,000	$12,412,000	$14,189,000	$14,667,000	$15,409,000
Construction Cost	$42,525,000	$49,295,000	$53,784,000	$61,486,000	$63,557,000	$66,770,000
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	$5,103,000	$5,915,000	$6,454,000	$7,378,000	$7,627,000	$8,012,000
Total Project Cost	$52,708,000	$61,191,000	$66,739,000	$76,464,000	$79,104,000	$83,183,000
Total Annual Cost	$2,506,000	$2,910,000	$3,173,000	$3,636,000	$3,761,000	$3,955,000
Initial Screening BCR	*3.9*	*3.5*	*3.2*	*2.8*	*2.8*	*2.6*

Table 3.58: Greenwich and Logan: Summary of Nonstructural Treatments by Floodplain

Greenwich & Logan	Annual Chance Exceedance Floodplain					
	50%	**20%**	**10%**	**4%**	**2%**	**1%**
Elevation	218	254	275	303	311	318
Wet Floodproof	8	15	18	34	39	53
Dry Floodproof	0	0	0	0	3	4
Ringwall	3	3	4	4	4	5
Rebuild	25	27	28	39	39	40
Acquisition	0	0	0	0	0	0
Totals	*254*	*299*	*325*	*380*	*396*	*420*

See Figure 3.48 for a map of the nonstructural treatments by floodplain. Of the 420 structures in Greenwich and Logan Townships for which potential nonstructural treatments have been identified, 92% are residential and the remaining structures are mostly commercial, industrial, agricultural, and storage buildings. The non-residential structures identified for nonstructural treatment also include several buildings of significance to the local community, including a fire house, school, and church. The majority of the structures identified for nonstructural treatment (76%) would be subject to elevation, while current data and assumptions indicate that it may be more cost-effective to rebuild 40 structures. Just over half of the structures identified for rebuilding are residential properties, while the remaining rebuild structures are mostly industrial, storage, or agricultural buildings.

An initial screening BCR of 0.7 has been set as the threshold for future Corps evaluation of nonstructural measures. The treatments for the 50% ACE (2-year) to the 1% ACE (100-year) floodplains in Greenwich and Logan Townships meet or exceed this threshold, and thus are recommended for further evaluation of costs and benefits. Table 3.59 provides recommendations for the further evaluation of measures in Greenwich and Logan Townships.

Figure 3.48: Greenwich & Logan (Gibbstown) – Nonstructural Treatments by Floodplain

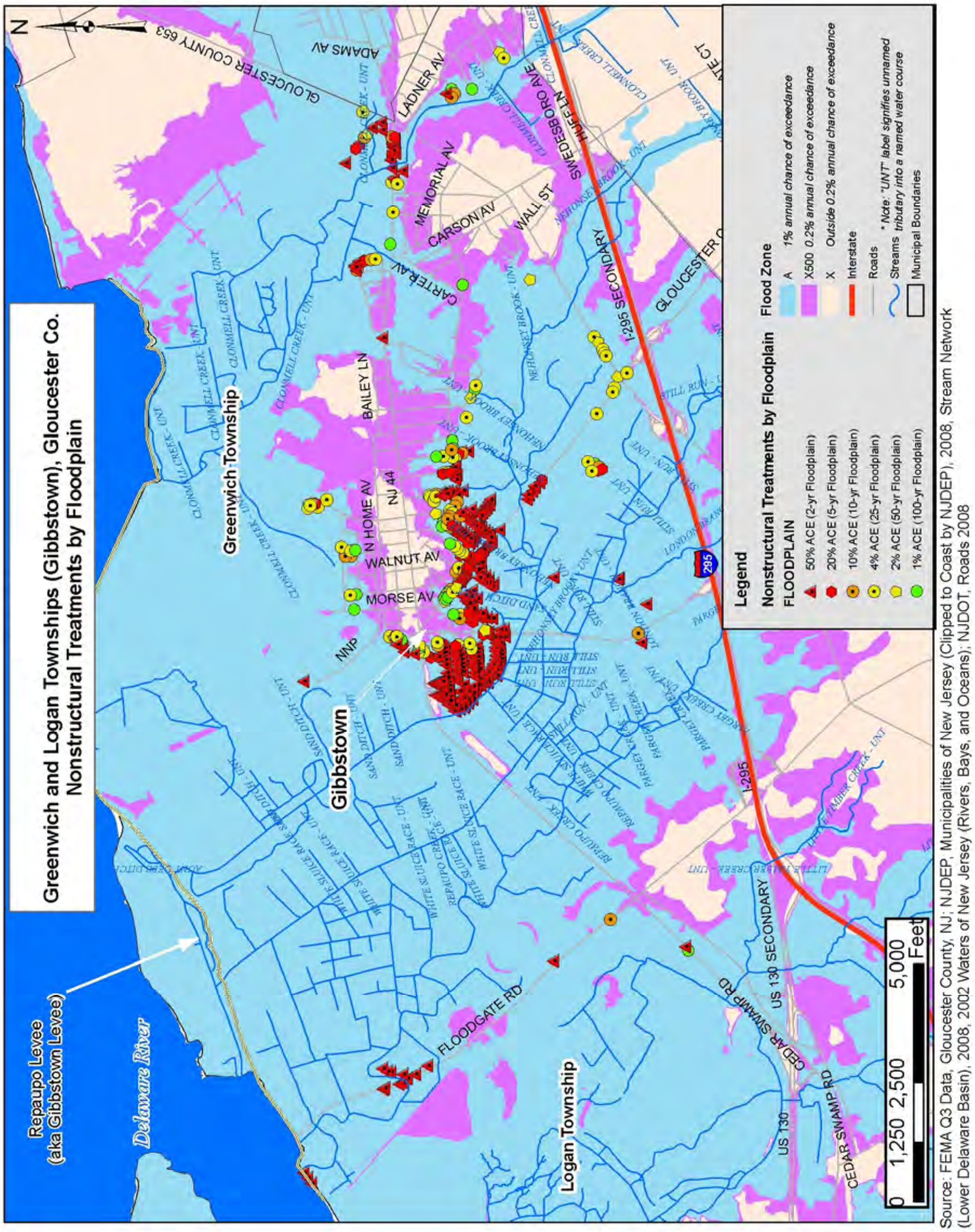


Table 3.59: Recommendations for Further Evaluation, Greenwich and Logan Townships

	Recommendations for Further Evaluation:			
	Corps Flood Risk Management Plan	**Other Federal Agency Flood Risk Management Plan**	**Non-Federal Flood Plain Management Plan (FPMP)**	**Eliminate from Further Evaluation**
Structural Measures **Local Risk Management**				
Backflow Prevention Structures	✓	✓	✓	
Levees and Floodwalls	✓	✓	✓	
Removable Barriers				✓
Road Raisings				✓
Area Risk Management				
Channel Modification				✓
Dams or Impoundments				✓
Diversion				✓
Nonstructural Measures *Land Use/Regulatory*				
Zoning/Land Use Controls			✓	
New Infrastructure Controls			✓	
Landform/Habitat Regulations			✓	
Construction Standards & Practices		✓	✓	
Insurance Program Modifications		✓		
Tax Incentives		✓	✓	
Building Retrofits	✓	✓	✓	
Land Acquisition				
Structure Acquisition/Buyout	✓		✓	
Land Acquisition				✓
Exchange of Property			✓	
Transfer of Development Rights			✓	
Easements and Deed Restrictions	✓	✓	✓	

3.5 ATTACHMENT 1: Detailed Description of Nonstructural Screening

For the screening of nonstructural measures, rather than using aggregate data by reach, the analysis used the structure-specific flood depth and damage tabulations contained in the HEC-FDA output file FDA_Strucdetail.out (FDAout) to identify order of magnitude average annual damage (AAD) by property. The approach imported the FDAout data into Microsoft Excel and was used to screen out the structures with low or zero annual damages. Because HEC-FDA does not output risk-based damages by individual structure, the FDAout data by event was used to calculate probability-weighted annual damage for the structures. In some of the study area communities, there are canal or levee structures providing some level of flood protection, such as the levees in Gibbstown or the canal embankments in Stockton. Annual damage estimates based on the FDAout files, which assume no risk management from these features, may need to be modified in a subsequent phase of the study to account for these flood barriers. Because these structures were neither built nor maintained for flood risk management, they are not likely to meet Corps standards as flood risk management structures.

The assumptions inherent to the screening of buildings for suitability for nonstructural retrofit are provided below in Table 3.60. These assumptions are based on previous Corps of Engineers nonstructural projects, and reflect current floodplain management policy and nonstructural retrofit techniques and construction practices. The key features of the algorithm used to evaluate structures for suitability of nonstructural retrofit are provided below in Table 3.61. Following the application of the most feasible or appropriate retrofit measure, each treated structure was then considered for complete rebuild or acquisition. If either rebuilding or acquisition were found to be a lower cost measure than the initially assigned measure, then acquisition or rebuilding (as appropriate) would be assigned. Acquisition offers the benefit of eliminating flood risk, and may allow for beneficial alternative use of the property such as public open space. A complete rebuild would result in a structure with a longer useful life, and may pose less construction difficulty than retrofitting an existing structure. This is particularly relevant in cases where the existing structure would require remedial measures to be suitable for retrofitting due to poor condition.

Costs for nonstructural measures such as floodproofing and elevation are based on calculated quantities and unit prices for typical structures from previous similar Corps nonstructural projects, and were applied to individual structures in the study area using adjustment factors to account for differences in size and other physical characteristics. These unit prices were originally calculated using commercially available construction cost estimating guides and have been adjusted for location and escalation since their original compilation, using factors published in the *RSMeans Building Construction Costs Manual* for 2010.

Table 3.60: Assumptions Inherent to the Screening of Nonstructural Alternatives

General Assumptions	• Flow velocity is negligible. • Debris impacts will not be considered. • The study area is considered non-coastal and thus not subject to wave and erosion impacts. • Buildings elevated in non-coastal areas will be raised (finished floor elevation) to the 100-year water surface plus 1 foot of freeboard. • Flooding is gradual (no flash flooding).
Foundation Walls	• All basement foundation types are assumed to be unreinforced, 8" concrete masonry units (CMUs).
Raised Structures (Crawlspace)	• No utilities are located in the crawlspace. • Wet floodproofing of raised structures includes the elevation of utilities only.
Slab-On-Grade Structures	• Wet floodproofing is possible if the expected flood elevation is below the main floor (shallow flooding). This alternative includes the elevation of utilities only. • Consistent with Corps' floodproofing guidance, structures will not be dry floodproofed for flooding depths greater than 2 feet with a maximum 3 feet of dry floodproofing protection.
Structures With Basements	• All basements are unfinished and contain major utilities.
Bi-Levels	• The lower portion of the first floor walls are masonry construction. • The foundation is slab-on-grade. • The main floor can be raised separately from the lower level by lifting off the sill of the masonry wall.
Raised Ranches	• The first floor (lower) walls are masonry. • The foundation is slab-on-grade. • The main floor can be raised separately from the lower level (similar to a structure with a basement).
Split-Levels	• The lower level is slab-on-grade. • The lower portion of the lower-level walls are masonry construction. • The main floor level is raised over a crawl space. • The main floor and upper level can be separated from the lower level by raising at the sill.

Application to the Overall Floodplain, Generalized Design Criteria and Floodproofing Screening Algorithm

A screening algorithm written for the *SAS* computer program was used to assign floodproofing alternatives to study area buildings. Alternatives were considered based on flood levels above or below the main floor. The algorithm assigned treatments to the buildings in accordance with the assumptions in Table 3.60, and then calculated costs based on detailed cost estimates for the application of the treatments to typical/reference structures compiled for previous Corps projects. Costs for treatments to specific structures were calculated by adjusting the reference cost to account for differences in ground and floor elevations, and building size. The general practice for dry floodproofing is to limit protection to a maximum of three feet due to hydrostatic loads, both lateral and vertical (buoyancy), on foundation walls and slabs. This protection level includes a maximum of two feet of flood protection plus one foot of freeboard.

For some structures without basements and for which the design protection elevation falls below the main floor, the treatment (wet floodproofing) may only consist of installing adequate vents in the crawlspace to allow for the equalization of water pressure and/or the raising of exterior utilities such as air-conditioning units. Dry floodproofing (sealant and closures) was recommended any time the flood level or protection level was above the main floor and less than three feet above the adjacent grade. Elevation was recommended if either the flood level or protection level was above the main floor and more than three feet above the adjacent grade.

For structures with subgrade basements, filling the basement and adding a utility room was recommended if the flood level and the protection level were both below the main floor. Otherwise, the building was identified as a candidate for elevation.

For raised structures, if both the flood level and protection level were found to be below the level of the main floor, wet floodproofing (raise the air conditioning unit and install flood louvers) was recommended. Otherwise, the building was identified as a candidate for elevation.

For structures with walkout basements, wet floodproofing (construction of an interior floodwall) was recommended if the flood level and protection level were both below the main floor and less than three feet. If the first condition was met but the three foot threshold was exceeded, then the structure was identified for elevating the lower floor and providing utility space above the protection level. Any time the flood level or the protection level was found to be at or above the main floor, these structure types were recommended for elevation.

For bi-levels and raised ranches, dry floodproofing was recommended if the flood level and protection level were both below the level of the main floor and less than three feet. If the first condition was met but the three foot threshold was exceeded, it was recommended that the lower floor be raised and utility space above the protection level be provided. Any time the flood level or the protection level was found to be at or above the main floor, these structure types were recommended for elevation.

For split level structures, dry floodproofing was recommended if the flood level and protection level were both below the level of the main floor and less than three feet. Otherwise, the building was identified for elevation.

These relationships are illustrated in Table 3.61.

Table 3.61: Relationships in Nonstructural Screening Algorithm

Typical Structure Type	Flood Level	Design Elevation Condition 1	Design Elevation Condition 2	Nonstructural Alternative
Slab-On-Grade	>= Main Floor	Design Elevation – Ground < 3	n/a	Sealant & Closures
		Design Elevation – Ground >= 3	n/a	Elevate Building
	< Main Floor	< Main Floor	n/a	Raise AC/utilities
		>= Main Floor	Design Elevation – Ground < 3	Sealant & Closures
			Design Elevation – Ground >= 3	Elevate Building
Basement-Subgrade	>= Main Floor	n/a	n/a	Elevate Building
	< Main Floor	< Main Floor		Fill Basement + Utility Room
		>= Main Floor	n/a	Elevate Building
Raised (Crawlspace)	>= Main Floor	n/a	n/a	Elevate Building
	< Main Floor	< Main Floor	n/a	Raise AC + Louvers
		>= Main Floor	n/a	Elevate Building
Basement-Walkout	>= Main Floor	n/a	n/a	Elevate Building
	< Main Floor	< Main Floor	Design Elevation – Ground < 3	Interior Floodwall
			Design Elevation – Ground >= 3	Raise Lower Floor + Space
		>= Main Floor	n/a	Elevate Building
Bi-Level/Raised Ranch	>= Main Floor	n/a	n/a	Elevate Building
	< Main Floor	< Main Floor	Design Elevation – Ground <= 3	Sealant & Closures
			Design Elevation – Ground >3	Raise Lower Floor + Space
		>= Main Floor	n/a	Elevate Building
Split Level	>= Main Floor	n/a	n/a	Elevate Building
	< Main Floor	< Main Floor	Design Elevation – Ground < 3	Sealant & Closures
			Design Elevation – Ground >=3	Elevate Building
		>= Main Floor	n/a	Elevate Building