MAMARONECK & SHELDRAKE RIVERS
NEW YORK
FLOOD RISK MANAGEMENT
GENERAL REEVALUATION REPORT
FOR
THE VILLAGE OF MAMARONECK

APPENDIX D: ECONOMICS

US Army Corps of Engineers®
New York District

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1.0 Introduction

1.1 Purpose and Scope

This economic analysis is conducted to assess whether changes in existing conditions since the evaluation within 1989 GDM and changes to the recommended plan are economically justified. ER 1105-2-100 §4.1 (b), dated 22 April 2000, establishes that post-authorization change reports are required when economic, engineering, or environmental changes occur in the project area. The 1989 General Design Memorandum for this project was completed twenty years ago, and conditions have changed significantly. A new Feasibility Study is not warranted, as the project remains authorized in accordance with Section 401(a) of the Water Resources and Development Act (WRDA) of 1986 (P.L. 99-662). This GRR incorporated all changes into the reformulation of the project, and the economic evaluation reflects those.

Economic benefits warrant reevaluation since changes in land use and development, and increases in the water flows in the area are evident. While newer buildings have been constructed above the 100-year floodplain, garages and utility spaces at ground level are subjected to flood damage from both the Mamaroneck and Sheldrake Rivers and area disruptions pose loss of economic activity in the area.

The tabulation of economic benefits in the Mamaroneck and Sheldrake Rivers Basin within the Village of Mamaroneck are consistent with ER 1105-2-100 §4.1 (b) dated April 22, 2000.

1.2 Benefit Types

Benefit analysis for a feasibility study include quantifiable benefits in the four accounts as put forth in ER 1105-2-100 and non dollar denominated impacts for the evaluation and comparison of alternatives as directed by WRDA and various guidance documents.

The damages consist of primary tangible damages, including (1) physical damages to property, such as damages to buildings and other structures, and loss of contents, including furnishings, inventory and equipment and autos; (2) emergency costs, such as additional expenses due to evacuation and reoccupation, personnel and equipment expenses incurred in floodfighting; (3) extra costs due to traffic interruptions and delays, and (4) advanced bridge replacement costs.

1.2.1 Physical damages to property

The study area is divided into study reaches for formulation purposes and to facilitate analysis of alternatives. Average annual damages to property and contents were calculated for each reach by combining water surface elevations with structure inventory data and damage functions specific to the type of structure.

The Flood Damage Reduction Analysis (HEC-FDA) software developed by the US Army Corps of Engineers' Hydrologic Engineering Center (HEC) integrates hydrologic engineering and economic analysis to evaluate flood risk management plans. HEC-FDA combines hydrologic and economic data and computes expected annual damage (EAD) and equivalent annual damages, and implements the risk analysis procedures described in EM 1110-2-1619.

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Hydrologic engineering and portions of the economics are performed separately, but in a coordinated manner after specifying the study configuration and layout, and merged for the formulation and evaluation of the potential flood risk management plans.

Average annual damages to property and contents are described in greater detail and by reach in subsequent sections.

1.2.2 Emergency Costs

Emergency costs include expenses that result from a flood. Emergency costs include expenses for emergency evacuation, flood fighting, administrative costs of disaster relief, public clean up costs, and increased costs of police fire, and military patrol. Emergency costs were derived from actual emergency costs incurred by the Village of Mamaroneck during significant flood events and interpreted for and applied to different frequency events. Derivation of benefits in this category is detailed in Section 4.1.1.6.2

1.2.3 Bridge Replacement

The plans of protection along the Mamaroneck and Sheldrake Rivers will require the replacement of several existing bridges. The bridges considered to be replaced in the alternatives included Ward Street, Halstead Avenue, Station Plaza and Hillside Bridge. The replacement of an existing bridge extends the life of the structure with a reduction of maintenance costs. These net reductions were considered as benefits accruing to the plans of protection. Derivation of the benefits in this category is detailed in Section 4.1.1.6.3.

1.2.4 Residual risk to Life safety

A significant benefit of flood risk reduction efforts is the resulting reduction in risk to the people living and working in the study area. While no accepted method exists to quantify a dollar value for the risk reduction, the study considered risk with and without project conditions in the evaluation of alternative plans using HEC FIA.

Three different hydraulic conditions were modeled for two project conditions, the Existing Conditions and the With-Project Conditions. The three hydraulic conditions that were selected for the unsteady hydraulic modeling were the 25yr, 100yr, and 10,000yr recurrence interval events. These events correspond to a 4%, 1%, and 0.01% annual exceedance probability. The 10,000yr (0.01%) event also has significance as the Standard Project Flood (SPF) event.

The analysis indicated that, while the with-project conditions provide a reduction in the estimated life-loss, the overall life-loss is still very low for either existing or with-project conditions.

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1.2.5 Transportation disruptions

The transportation routes within the study area experience significant disruption in service during flood events. Major access routes which wind through the study area and larger routes which have access and exit ramps in the Village of Mamaroneck are inaccessible under flood conditions.

Quantification of transportation disruptions is complex and detailed, and for this study area would not generate benefits which significantly affect the comparability of plans of improvement. Therefore, the study does not include monetized transportation disruptions in the benefit calculation beyond the costs of emergency personnel responding to dangerous and inaccessible roadways. Those impacts are captured within the emergency costs.

2.0 Description of the Study Area

2.1 Location and Setting

The Mamaroneck and Sheldrake Rivers Basin is located entirely in Westchester County and contains portions of the Village and Town of Mamaroneck, the City of White Plains, the Village and Town of Harrison, Village of Larchmont, the City of Rye, North Castle, and the Village of Scarsdale, New York. The combined watershed of the Mamaroneck and Sheldrake Rivers has a total drainage area of 23.63 square miles. Delineation of the 500-year floodplain in the Mamaroneck and Sheldrake Rivers Basin indicates the majority of the structures within the floodplain are located in the Village of Mamaroneck.

2.1.1. Town & Village of Harrison

Approximately 7.48 square miles of Harrison are located in the Mamaroneck River watershed and 17.13 stream miles of the Mamaroneck River flow through the town. Of the 11,136 acres within the Town, approximately 1,604 acres are devoted to public or private open space and recreational uses, with 600 acres of the Town mapped as vacant land. This vacant land is mostly outside of the Mamaroneck River watershed, and changes to these properties would not have an effect on the hydrologic characteristics of the watershed. In summary, there is not expected to be any significant changes in the land use characterization within the Town of Harrison over the 50 year period of analysis.

2.1.2 City of White Plains

Approximately 6.50 square miles of White Plains are in the Mamaroneck River watershed, and 7.3 linear miles of the Mamaroneck River flow through the City. The City of White Plains is substantially urbanized and has undertaken a major revitalization of its downtown, which includes an urban shopping complex with tenants such as Target. The redevelopment of the downtown is leading to the creation of a new skyline for White Plains, characterized by residential towers (such as the Pinnacle) and a Ritz-Carlton Hotel.

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2.1.3 Village of Scarsdale

Approximately 1.32 square miles of Scarsdale are in the Mamaroneck River watershed and approximately 0.5 mile of the Mamaroneck River flows through Scarsdale. Approximately 2.27 square miles of Scarsdale are located in the Sheldrake River watershed, with approximately 1.58 stream miles of the Sheldrake River flowing through Scarsdale. Of the 2,377 acres within the Village, only 1.8% or 78 acres, remains as vacant land. 1,000 acres is set aside as open space or recreation land. It is expected that there will be little change to the acreage of open space available The Assistant to the Village Manager provided the following that will be taken into account during the development of alternatives and Tentatively Selected Plan selection for the Mamaroneck/Sheldrake watershed study.

The Quaker Ridge Golf Club is privately owned and actively used as a golf course. If the current use of the property were to change it would fall in the 2-acre zoning district. Said zoning allows for single family homes to be built on lot sizes that have a minimum of 2 acres provided other criteria are met. The Village's Comprehensive plan completed in 1994 and recently updated identifies the Quaker Ridge Golf Club and Fenway Golf Club as potential for open space and that the Village should negotiate a right of first refusal with the property owners if there should be a change in use or the property look to be sold.

2.1.4 Town of Mamaroneck

Approximately 0.75 square miles of Mamaroneck Town is located in the Mamaroneck River watershed. Approximately 0.87 mile of the Mamaroneck River flows through Mamaroneck Town. Approximately 1.48 square miles of Mamaroneck Town are located in the Sheldrake River sub-watershed. Approximately 2.13 miles of the Sheldrake River flows through the town. The unincorporated area of the Town of Mamaroneck is characterized mainly by residential development. The Villages of Larchmont and Mamaroneck serve as local centers for this residential population. One of the most significant projects is an approved Forest City Daly apartment building on Madison Avenue, near the I-95 ramps and Larchmont border.

The Town of Mamaroneck has implemented recreational development practices so as to preserve to the maximum extent possible wetlands, wetland control areas, flood hazard areas, designated critical environmental areas and other unique natural features, including but not limited to the highest crest of hills, natural rock outcroppings and major tree belts. These development practices also ensure that no construction takes place on areas which have slopes greater than 25% prior to any disturbance of the natural contours of the property or on wetland control areas and to minimize cut and fill; roads should follow natural topography wherever possible. Further, there shall be maintained a minimum of 20% of the area of a parcel as a permanent open space. However, communication with the Town of Mamaroneck indicates there are no specific future land use developments or significant planned projects that would appreciably alter the existing pervious/impervious space that would affect the hydrology of the watershed over the 50-year period of analysis.

2.1.5 City of New Rochelle

Approximately 1.48 square miles of New Rochelle are located in the Sheldrake River watershed and approximately 2.13 miles of the Sheldrake River flow through the city. Based on land use trends, it is unlikely that any significant changes in the Sheldrake River watershed within the City of New Rochelle

will occur over the 50-year period of analysis. The suburban character of this portion of the municipality as well as the water courses and features (Larchmont Gardens Lake, Sheldrake Reservoir, etc.) will remain. These are not used for water supply, nor are they used for flood risk management. Larchmont Gardens Lake is a park-like recreational feature, used for passive recreation. Sheldrake Reservoir is used for non-motorized boating activities.

2.1.6 Village of Mamaroneck

Approximately 1.38 square miles of the Village of Mamaroneck are located in the Mamaroneck River watershed. Approximately 0.15 miles of the Mamaroneck River flow through Mamaroneck Village. The Village of Mamaroneck consists of just over 2,000 acres of land. Of this, only approximately 60 acres is identified as park land within the Village. The remainder of the land within the Village is developed as residential, industrial, office and commercial, or community and institutional areas. The 2008 Draft Comprehensive Plan Update for the Village does indicate that the Village will attempt to acquire underutilized lots on the Sheldrake River (e.g. the former Blood Brothers site) in an attempt to prevent additional development in the floodway. However, in general, there is not expected to be any significant changes in the land use characterization within the Village of Mamaroneck over the 50 year period of analysis.

2.2 Accessibility

The Mamaroneck and Sheldrake Rivers watershed is located along the northern coast of Long Island Sound within the New York City metropolitan area. The Mamaroneck and Sheldrake Rivers Basin lies entirely within Westchester County, New York and contains portions of the Village and Town of Mamaroneck, the Cities of New Rochelle and White Plains, the Towns of Harrison and North Castle, and the Village of Scarsdale.

The project area is comprised of river bank and adjacent properties which include public areas accessible in Columbus Park and private areas flanking residences and businesses. Public access to the river is limited to Columbus Park, which is adjacent to Metro North rail service. Various county and state roads provide access the study area.

2.3 Population and Housing

The 2010 U.S. Census data indicates that there are 18,929 people living in the Village of Mamaroneck (Table 1). The 2010 U.S. Census data also indicates that the population for the state of New York has increased by 2.1% since year 2000, and Westchester County increased by 2.78%, while the population of the Village of Mamaroneck increased nearly 1%. Because the Village of Mamaroneck is already fully developed, the future population increase is expected to be negligible.

As of the census of 2010, there were 18,929 people and 6,998 households in the Village. The population density was 5,971.3 people per square mile and 7,512 housing units. Table 1 compares the Village of Mamaroneck demographics to Westchester County and those of New York State. The median income for a household in the Village was $85,803. The per capita income for the Village was $49,696. Approximately 7.4% of the population lives below the poverty line.

Table 1: 2010 Demographics

	New York State	Westchester County	Village of Mamaroneck
Population (2010 census)	19,487,053	949,113	18,929
Population *	19,651,127	968,802	19,237
Area (mi^2)**	54,555	500	6.7
Density (ppl/sq-mi)	411.2	2,204.7	5971.3
Median Household Income*	$58,003	$81,946	$85,803
Persons Below Poverty (%)*	15.3	9.5	7.4
Housing Units*	8,113,270	369,996	7,693
Median Value of Housing Units*	$288,200	$518,400	$582,800

*2013 American Community Survey Estimates
**USGS, Total Area including water area

2.4 Land Use

Residential. Residential uses account for the vast majority of the Village's land area. Residential characteristics vary from waterfront estates, suburban developments, apartment houses, townhouse complexes, condominiums, apartments above storefronts, and single- and two-family houses. Older residences were not constructed to minimize flood impacts. Recent housing developments which concentrate many dwellings within smaller footprints have been constructed which comply with flood elevation standards, but which are still threatened with service interruptions and damage to vehicles and utility services.

Commercial and Institutional. The largest community and institutional uses within the Village include the water-treatment plant, the Village Hall, Mamaroneck Avenue School, and Mamaroneck High School. The traditional commercial and service core of Mamaroneck was centered along Mamaroneck Avenue between the Boston Post Road and Halstead Avenue. Recent growth has brought commercial uses, such as service and retail to the entire length of Mamaroneck Avenue and the Boston Post Road.

Industrial. The industrial area of the Village is located in the northwest, bounded by the railway to the south, Fenimore Road to the west, the New England Thruway to the north and Rockland Avenue to the east. This area is located in the M-1 zoning district, and since 1968 residences have been a non-conforming use. Several residential uses remain here interspersed among the industrial businesses.

The structure inventory for the project area included 225 non-residential structures, 466 single family residential structures, and 12 apartment buildings. Development of the structure inventory is described in greater detail in Section 4.1.1.2 in this appendix.

2.5 Income and Economy

A summary of the income and economy in the project study area is presented in Table 2.

Table 2: 2010/2011 Income and Economy

	New York State	Westchester County	Village of Mamaroneck
Private Non-Farm Establishments	527,001	31,496	795**
Private Non-Farm Employment	7,556,521	378,508	7,902*
Total Number of Firms	1,956,733	120,727	2,756
Median Household Income*	$58,003	$81,946	$85,803
Persons Below Poverty (%)*	15.3	9.5	7.4
High School graduate or higher, % of persons over 25*	85.2	87.6	87.9
Bachelors Degree or higher, % of persons over 25*	33.3	44.3	51.5

*2013 American Community Survey Estimates
**2012 US Census NAICS Business Pattern Data

2.6 Recreation

The Study Area includes several recreational areas which are impacted by inundation, but the recreational impacts do not qualify as benefit sources for NED purposes.

Columbus Park, located at the confluence of the Mamaroneck and Sheldrake rivers is a passive park with playground equipment, pedestrian paths and pedestrian bridges over the rivers. The park is adjacent to the train station and commercial areas. During flooding incidents, the park is inaccessible and vehicles within the park are susceptible to damage.

Saxon Woods Park is a 700-acre property offering a variety of recreational facilities at the northernmost extent of the project area. According to Westchester County, the park contains an 18-hole golf course as well as a miniature golf course, the county's largest swimming pool, a children's aquatic playground and picnic areas. It is also the site of the county's only playground that is accessible to the disabled.

A trail system connects the southern section to the northern wooded part of the park, popular with hikers, cross country skiers and horseback riders. The entire system extends along the Hutchinson River Parkway to Twin Lakes Park and north to Maple Moor Golf Course and links to the Leatherstocking Trail and Colonial Greenway and contains archeologically sensitive areas. No measures are proposed which will impact the recreational resources or accrue recreational benefits.

3.0 Problem Identification

3.1 Historical Flood Events

Until the Tax Day Storm of April 2007, the most damaging flood of record resulted from the storms of 15-16 October 1955, 18-19 June 1972, and 26-27 September 1975. Other floods occurred in October 1877, September 1882, July 1889, October 1903, March 1936, July 1938, September 1938, July 1942, August 1942, September 1944, May 1946, March 1953, August 1955, August 1960, April 1961, Ash Wednesday nor'easter of March 1962, August 1971, September 1974, April 1983 and September 1999 (Tropical Storm Floyd). While other areas in Westchester County suffered floods in April and July 1984, the Village of Mamaroneck suffered minimal flood damages. Flood damages for the June 1972 and the September 1975 floods are described in the following paragraphs.

During the June 1972 flood, hundreds of residents, employees and school children were evacuated by boats and trucks as the Mamaroneck and Sheldrake Rivers overflowed their banks, inundating local streets and numerous homes and business establishments. Areas inundated in the Village of Mamaroneck from this flood include approximately 107 acres of industrial, commercial and residential property. Along the Mamaroneck River, the flood damage area was located on both banks between Ward Street and First Street. From First Street upstream to the New England Thruway damages were confined to the left bank and in the reach between Chestnut Avenue and the Joint Waterworks Dam; the Village flood damage area lies on the right bank. Along the Sheldrake River the flood damage area was on both banks between the confluence with the Mamaroneck River and Fenimore Road. Between Fenimore Road and the Village line the damage area lies on the right bank.

During the June 1972 flood, 26 industrial structures, 33 commercial establishments, 5 public buildings and 207 dwellings were flooded. Columbus Park was completely submerged. The industrial park was inundated to a depth of two feet and many businesses were not able to resume production for a week or more. Hardest hit industrial areas were at the Sealectro Corporation Plant on Hoyt Street, where 60 employees were evacuated, and the Bordow Corporation, located at Mamaroneck and Jefferson Avenues, which had several feet of water in its buildings.

The main floors of many dwellings between Mamaroneck Avenue and the Mamaroneck River were flooded to a depth of one (1) foot. Along Chestnut Avenue basements were flooded to a depth of five (5) feet causing severe content damage. Several homes along Winfield Avenue suffered first floor flooding when the Winfield Avenue Bridge was overtopped.

If the Standard Project Flood (as identified in the 1977 Feasibility Study) were to occur along the Mamaroneck and Sheldrake Rivers in the Village of Mamaroneck, approximately 300 acres would be

inundated up to depths in excess of 16 feet. The flood of September 1975[1] produced stages in the Village of Mamaroneck of approximately 10.15 feet, 0.44 feet higher than those produced during the June 1972 flood. Total flood damages from the September 1975 flood in the Village of Mamaroneck are estimated at $91,900,000 (October 2015 prices). More than 65 percent of these damages were suffered by the industrial and commercial establishments of the village, particularly at the reach along the right bank of the lower Sheldrake River. This flood resulted in stages of up to three (3) feet above the main floors of several of the industries in this reach. Again, the hardest-hit industrial plants along the Sheldrake River included Sealectro Corporation (a manufacturer), and also Marval Industries (plastics), Elgene Chemicals, Westchester Light Company and Magnetic Media Corporation (electronics).

Additionally, several industries which were not seriously affected by past floods also suffered damages from the September 1975 flood, including Sockolof Brothers (wood products), Philips Offset Company and Schrier Brothers (a paper company). The residential areas of the Village were also severely flooded once again during this flood.

The April 15-16 2007 nor'easter storm dropped about three (3) to ten inches of rain on the watersheds within the New York District's civil works boundaries between the early morning of Sunday April 15th, 2007 and the early afternoon of Monday April 16th, 2007, resulting in new flood peaks of record at ten USGS gages in New Jersey, and, in New York, at the USGS gages Saw Mill River at Yonkers and, most importantly for the present study, Mamaroneck River at Mamaroneck (Halstead Avenue) New York.

Unlike Tropical Storm Floyd, which broke the summer 1999 drought and fell on dry ground, the April 2007 nor'easter caused as much flooding as it did because it was preceded by the smaller March 1-2 and April 12-13 2007 storms, and, as such, and for other reasons of antecedent soil moisture conditions, fell on saturated ground.

The March 1-2 2007 storm also caused flooding within the Mamaroneck River basin, albeit far less than the flooding resulting from the April 15-16 2007 storm. Total basin rainfall for this storm was estimated at 3.18 inches using rain data from the Dobbs Ferry-Ardsley and Westchester County Airport rain gages. It was estimated to have caused a peak flow of 2680 cfs at the Mamaroneck gage.

A peak flow of 5340 cfs on April 15, 2007 was estimated at the Mamaroneck gage by hydrologic modeling, and subsequently confirmed by hydraulic calibration to recorded high water marks on the Mamaroneck and Sheldrake Rivers. This is a 100 year flood peak on the current existing conditions peak discharge vs. frequency curve at the Halstead Avenue gage. Total rainfall over the study basin was estimated at 7.90 inches using data from the Westchester County Airport rain gage, and local observations of total storm rainfall at East White Plains and New Rochelle, New York. Damage estimates for the April 2007 storm are well over $50 million. However, a final damage estimate is still being calculated.

Damage Areas

The flood damage areas are located in the Village of Mamaroneck and the Town of Harrison, New York. On the Mamaroneck River, the damage area extends from below Tompkins Avenue upstream to the

[1] The September 1975 flood was the flood of record prior to the September 2004 and the April 2007 floods. The 1977 Feasibility Report and the 1989 GDM refer to the September 1975 flood as the flood of record.

Westchester Joint Waterworks Dam. On the Sheldrake River damages occur from the confluence with the Mamaroneck River upstream to the Village line at the New England Thruway Bridge.

4.0 Without-Project Future Condition

4.1 General

The future without-project condition was determined by projecting conditions in the study area over a 50-year period of analysis. The period of analysis is determined to be from 2020, the year that construction is implemented and construction is complete for a period of 50 years. In the absence of Federal action, flooding problems associated with rainfall events in the study area are expected to continue. These problems may be exacerbated by increased damage potential in the floodplain of the Village of Mamaroneck within the Mamaroneck and Sheldrake Rivers Basin, based upon increases in the values of structures and contents, and by climate change, leading to an increase in intensity and frequency of storm events. It is expected, based on future land use projections in the study area, there will be limited additional development within the Basin in the future period of analysis. Within the State of New York, if applicants for new construction can show that their facilities will not increase the 100-year flood elevation, they are generally permitted to build flood proofed structures where the lowest floor including any basement, must be at or above the base flood elevation plus two feet beginning in 2007.

The watershed is highly urbanized with residential densities ranging from one-eighth- to two acre lots. Existing development and land use patterns within the study area are varied and diversified. The upper reaches of the Mamaroneck and Sheldrake rivers generally consist of low- to medium-density residential neighborhoods. While the streams here have generally suffered from increasing development and encroachment along their banks, there remain many areas that are still somewhat reminiscent of their undeveloped state. The lower reaches of the Mamaroneck and Sheldrake rivers consist of low-, medium- and high-density residential neighborhoods as well as varied commercial (retail and office) and light industrial properties. Many of these have been constructed to the edge of the river banks.

Examining the land use patterns within the Mamaroneck and Sheldrake Rivers Basin, it is clear that this is a very urbanized watershed. Following the river from its headwaters in the Town of Harrison, to the mouth at the Village of Mamaroneck, most of the watershed has been developed and is characterized as residential, commercial or industrial development.

4.1.1 Flood Damages

4.1.1.1 Delineation of Project Reaches

In order to conduct economic benefit analyses for without-project and with-project alternative plans, the study area has been divided into three streams containing 13 economic reaches; five along the Mamaroneck River downstream of its confluence with the Sheldrake River, four along the Sheldrake River, and four along the Mamaroneck River upstream of the confluence. The upstream and downstream limits of the reaches were selected to be consistent with the hydrologic/hydraulic modeling and were mostly located at the location of bridges considered for replacement and the inlet/outlet structures for

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alternatives featuring diversion tunnels, so that the effects of these measures could be modeled in detail. A summary of the economic reaches is presented in Table 3:

Table 3
Summary of Economic Reaches

Stream	Reach	Description	D/S Station	Index Station	U/S Station
Mamaroneck Downstream	MD1	Harbor to Tompkins Ave Bridge	431	809	1230
	MD2	Tompkins Ave Bridge to Ward Ave Bridge	1230	1698	2162
	MD3	Ward Ave Bridge to Valley Place Bridge	2162	2419	2712
	MD4	Valley Place Bridge to Halstead Ave Bridge	2712	2908	3038
	MD5	Halstead Ave Bridge to confluence	3038	3279	3524
Sheldrake	S1	Confluence to Mamaroneck Ave Bridge	79	220	683
	S2	Mamaroneck Ave Bridge to Fenimore Ave Bridge	683	1755	3468
	S3	Fenimore Ave Bridge to Rockland Ave Bridge	3468	4309	5239
	S4	Rockland Ave Bridge to upstream of I-95 Bridge	5239	5933	6991
Mamaroneck Upstream	MU1	Confluence to Hillside Ave Bridge	138	841	1293
	MU2	Hillside Ave Bridge to I-95 Bridge	1293	2780	4198
	MU3	I-95 Bridge to Winfield Ave Bridge	4198	5711	7486
	MU4	Winfield Ave Bridge to Mamaroneck Reservoir Dam	7486	7791	8210

4.1.1.2. Structure Inventory Methodology

A structure inventory for the project area was compiled in stages for use in the HEC FDA model.

Initially populated from the FEMA 500 year floodplain data in a GIS format, staff conducted a 100% survey of structures and generated a database confirming existing structures and their defining characteristics, and adding new developments to the inventory. Commercial, industrial, and residential properties were described by building type, number of stories, use, and condition for valuation purposes.

Characteristics such as low opening, main floor elevation and building material were recorded to determine the percent damage to the structures resulting from inundation levels.

Elevations and square footage were elicited from GIS resources and confirmed in the field at the time of inventory.

Residential valuations were assigned in accordance with RS Means square foot costs for depreciated replacement value, adjusted for the current price level and regional price factors.

Commercial valuations were derived through Marshall Swift square foot costs which were also adjusted for regional differences in construction factors and for current price level.

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Project formulation initially assessed a broad range of project alternatives for flood risk reduction and cost effectiveness. Following the identification of the Tentatively Selected Plan (TSP), multiple iterations of the formulation process and optimization of the TSP resulted in the development of the Engineering improvements and local sponsor consultation have continued since the initial comparisons were made and added considerable time to the study. The cost and benefits of the initial screening process have not been updated to 2015 price levels or current discount rate, since the comparisons will not be affected by the updates. Subsequent comparisons of the revised alternatives are presented in current price level and discount rates to ensure that all impacts are evaluated in current terms.

4.1.1.3 Summary of Structure Types and Values

For the purposes of flood damage estimation, components of individual buildings with different usages to the 'parent' structure were considered to be individual structures with unique identification numbers, since different usages are subject to different square foot values and different depth-damage functions. For example, structure 2296 has been split into three components (2296.1, 2296.2, and 2296.3) to reflect the different usages within the structure (customized clothing supplier, auto body repair, and storage warehouse). After accounting for all individual buildings and those divided by usage, there were found to be 705 structures in the project data set for the purposes of damage estimation. Table I1 presents a summary of the distribution of building types (grouped by damage categories) and total depreciated structure values by reach, at an October 2011 price level. Almost two thirds of the structures in the dataset are of residential (one- or two-family) use, while slightly more than one quarter are commercial properties. Apartment, public, and industrial structures together account for less than 10% of the structures in the inventory. However, in terms of depreciated structure value, a more even distribution is apparent, with residential, commercial, and apartment/industrial/public each accounting for approximately one third of the total inventory value.

The full inventory of structures used for the calculation of estimated damages also includes estimates of the numbers and values of motor vehicles likely to be present in the study area and hence exposed to flood damage. The assumptions used to compile these estimates are discussed in detail in Section 4.1.1.4.

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Table 4
Summary of Structure Inventory by Reach and Category

Stream / Reach	Structure Damage Category											
	Residential		Apartment		Commercial		Industrial		Public		Reach Total	
	Number	Value	Number	Value	Number	Value	Number	Value	Number	Value	Number	Value
Mamaroneck Downstream												
MD1	5	$1,524,930	1	$15,368,040	11	$7,281,380	0	$0	0	$0	17	$24,174,350
MD2	3	$714,230	0	$0	1	$466,740	0	$0	0	$0	4	$1,180,970
MD3	14	$3,021,070	0	$0	1	$142,910	1	$168,820	0	$0	16	$3,332,800
MD4	3	$898,910	0	$0	4	$3,304,040	0	$0	0	$0	7	$4,202,950
MD5	2	$461,490	0	$0	1	$570,300	0	$0	0	$0	3	$1,031,790
Total	*27*	*$6,620,630*	*1*	*$15,368,040*	*18*	*$11,765,370*	*1*	*$168,820*	*0*	*$0*	*47*	*$33,922,860*
Sheldrake												
S1	13	$3,115,420	4	$12,190,630	16	$7,604,480	0	$0	1	$451,860	34	$23,362,390
S2	165	$38,924,790	4	$5,249,190	93	$45,939,250	23	$21,153,330	0	$0	285	$111,266,560
S3	15	$3,213,430	0	$0	32	$21,291,010	8	$4,816,350	0	$0	55	$29,320,790
S4	12	$2,515,800	0	$0	0	$0	0	$0	0	$0	12	$2,515,800
Total	*205*	*$47,769,440*	*8*	*$17,439,820*	*141*	*$74,834,740*	*31*	*$25,969,680*	*1*	*$451,860*	*386*	*$166,465,540*
Mamaroneck Upstream												
MU1	81	$20,631,940	4	$20,197,360	16	$18,280,000	0	$0	4	$30,517,980	105	$89,627,280
MU2	101	$22,339,500	0	$0	12	$8,860,730	0	$0	1	$354,200	114	$31,554,430
MU3	52	$13,475,040	0	$0	0	$0	0	$0	0	$0	52	$13,475,040
MU4	0	$0	0	$0	1	$521,880	0	$0	0	$0	1	$521,880
Total	*234*	*$56,446,480*	*4*	*$20,197,360*	*29*	*$27,662,610*	*0*	*$0*	*5*	*$30,872,180*	*272*	*$135,178,630*
Project Total	**466**	**$110,836,550**	**13**	**$53,005,220**	**188**	**$114,262,720**	**32**	**$26,138,500**	**6**	**$31,324,040**	**705**	**$335,567,030**

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4.1.1.4 Inundation Damage Functions

The computation of annual flood damages in this analysis is based on the application of depth-damage functions to the structures in the study area to compute damage incurred by structures and contents during flood events of different probability of occurrence. The primary source of depth-damage functions for this study were the generic depth-damage functions for residential structures developed by the U.S. Army Corps of Engineers and the damage functions for non-residential structures that were developed following an expert opinion elicitation exercise carried out by FEMA and USACE/Institute for Water Resources:

Single-family residential structures (and two- or multi-family structures with similar physical characteristics) without basements: *Economic Guidance Memorandum (EGM) 01-03, "Generic Depth-Damage Relationships", December 4, 2000.*

Single-family residential structures (and two- or multi-family structures with similar physical characteristics) with basements: *Economic Guidance Memorandum (EGM) 04-01," Generic Depth-Damage Relationships for Residential Structures with Basements", October 10, 2003.*

Non-residential structures (plus apartment buildings and large multi-family structures): *"Expert Opinion Elicitation for the Development of Nonresidential Depth-Damage Functions (Draft)", April 2009.*

While the USACE residential depth-damage functions do not differ depending on the type or complexity of material used in their construction, the non-residential damage functions do vary depending on whether the structure is considered to be 'Engineered' or 'Pre-Engineered': Engineered structure types require significant engineering design prior to construction and are constructed primarily of materials considered to be non-combustible, such as structural steel frames, reinforced concrete, and masonry. Pre-engineered structures require less engineering design prior to construction and include wood frame stock designs that can be readily replicated in different locations. Altogether a total of 37 different depth-damage functions were applied to cover the diversity of structure types and usages in the study area.

While depreciated structure replacement values were derived using the methodology outlined in Section 4.1.1.2, the value of contents for each structure was determined according to pre-defined content-structure value ratios for each damage function. For the USACE residential damage functions, content value was assumed to be equal to 100% of the structure value, since these functions model content damage as a percentage of the structure value. The content-structure value ratio for non-residential depth-damage functions varies since it was developed independently for each structure type during the expert elicitation process.

In addition to damage to structures and associated contents, the study attempted to capture damages to motor vehicles left in the study area during flood events, using USACE guidance found in *Economic Guidance Memorandum 09-04, "Generic Depth-Damage Relationships for Vehicles", June 22, 2009*. To expedite this component of the analysis, a number of simplifying assumptions were made during the estimation of the number and value of vehicles likely to be present in the study area during flood events:

1. It was assumed that 1.5 vehicles are associated with each housing unit in the Village of Mamaroneck, based on U.S. Census bureau data.
2. The average depreciated value of a vehicle in the study area is $10,000, a value which has been accepted for use in similar studies for USACE elsewhere in the country.
3. Sedans were assumed to be the predominant vehicle type in the study area; hence the Sedan depth-damage function in Table 4 of EGM 09-04 was applied to all vehicles in the inventory.
4. The total number of housing units was estimated by assuming that each structure covered by one of the generic USACE residential depth-damage functions contained a single unit, and that the number of units in an apartment building can be derived by dividing the building's total square footage by 1,200 (1,000 square feet for the assumed average apartment size plus an additional 200 square feet to account for hallways and other common areas).
5. The probability that vehicle owners would move their vehicles to higher ground before a flood was assumed to be 73%. In the absence of any specific information regarding local warning times in advance of flood events this figure was derived by taking an average of the percentages given in Table 5 of EGM 09-04.
6. It was assumed that no vehicles would remain outside non-residential structures during a flood event.

A summary of the assumed distribution and value of vehicles in the summary area is presented in Table 5:

Table 5
Distribution of Motor Vehicles in Study Area

Reach	Motor Vehicles (Assumed)		
	Number	Value	Modeled Value*
MD1	233	$2,330,000	$627,750
MD2	5	$50,000	$12,150
MD3	21	$210,000	$56,700
MD4	5	$50,000	$12,150
MD5	3	$30,000	$8,100
Total	*267*	*$2,670,000*	*$716,850*
S1	188	$1,880,000	$506,250
S2	315	$3,150,000	$850,500
S3	23	$230,000	$60,750
S4	18	$180,000	$48,600
Total	*544*	*$5,440,000*	*$1,466,100*
MU1	392	$3,920,000	$1,057,050
MU2	152	$1,520,000	$409,050
MU3	78	$780,000	$210,650
MU4	0	$0	$0
Total	*622*	*$6,220,000*	*$1,676,750*
Project Total	**1,433**	**$14,330,000**	**$3,859,700**

*Value adjusted for the probability that vehicles will be removed by owners prior to a flood event.
FY 2012 Price Level

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4.1.1.5 Risk and Uncertainty Parameters

This study has been conducted in accordance with Engineering Manual EM 1110-2-1619, "Risk-Based Analysis for Flood Damage Reduction Studies (USACE, August 1, 1996), which requires that primary elements of the damage estimation computations are explicitly subjected to probabilistic analyses. Estimates of annual flood damage were computed for this study using version 1.2.5 of the Hydrologic Engineering Center's Flood Damage Analysis computer program (HEC-FDA), which applies Monte Carlo simulation techniques to calculate expected damage values while explicitly accounting for uncertainty in the input data.

Uncertainty was incorporated into the following components of the flood damage calculations:

- Discharge-frequency functions
- Inflow/outflow transform functions
- Stage-discharge functions
- Structure first floor elevation
- Structure depreciated replacement value
- Depth-damage functions

Uncertainty associated with the discharge-frequency relationship in each reach is calculated in HEC-FDA using order statistics and equivalent record lengths. For this analysis an equivalent record length of 60 years was used to generate uncertainty bands for all reaches in all conditions.

In analyzing alternatives featuring diversion tunnels and reservoir modification, transform functions were used to model inflow/outflow relationships without artificially narrowing the uncertainty bands associated with the basic discharge-frequency function. Uncertainty associated with the outflow was applied to these functions using a specific triangular probability distribution (most likely values, upper and lower bounds specified for each outflow) for each affected reach.

Uncertainty was applied to stage-discharge functions using a normal probability distribution with a standard deviation of 0.5 feet for all reaches in all conditions except reach MD1, for which a triangular distribution was applied.

Uncertainty associated with the main floor elevation of structures was applied using a normal distribution with a standard deviation of 0.6 feet, in accordance with guidance in Table 6-5 of EM 1110-2-1619 for inventories compiled by visual survey and topographic mapping with two-foot contour intervals.

The depreciated structure replacement value was subjected to uncertainty via the application of a normal probability distribution with a coefficient of variation of 10%, in accordance with previously accepted practice for similar USACE flood damage reduction studies.

Depth damage functions were subjected to uncertainty in accordance with the guidance referenced in Section 4.1.1.4: Residential damage functions for both structure and content damage were subjected to uncertainty using normal distributions (standard deviation varying with depth), while non-residential

damage functions for both structure and content damage were subjected to uncertainty using triangular distributions (upper and lower bound values varying with depth) as per the tables in the respective guidance documents.

More information on the uncertainty applications can be found in the Hydraulic appendix.

4.1.1.6 Additional Benefit Categories

Benefit analysis for a feasibility study include quantifiable benefits in the four accounts as put forth in ER 1105-2-100 and non dollar denominated impacts for the evaluation and comparison of alternatives as directed by WRDA and various guidance documents.

The damages consist of primary tangible damages, including (1) physical damages to property, such as damages to buildings and other structures, and loss of contents, including furnishings, inventory and equipment and autos; (2) emergency costs, such as additional expenses due to evacuation and reoccupation, personnel and equipment expenses incurred in floodfighting; and (3) extra costs due to traffic interruptions and delays, and (4) advanced bridge replacement costs.

4.1.1.6.1 Physical damages to property

The study area is divided into study reaches for formulation purposes and to facilitate analysis of alternatives. Average annual damages to property and contents were calculated for each reach by combining water surface elevations with structure inventory data and damage functions specific to the type of structure.

The Flood Damage Reduction Analysis (HEC-FDA) software developed by the US Army Corps of Engineers' Hydrologic Engineering Center (HEC) integrates hydrologic engineering and economic analysis to evaluate flood risk management plans. HEC-FDA combines hydrologic and economic data and computes expected annual damage (EAD) and equivalent annual damages, and implements the risk analysis procedures described in EM 1110-2-1619.

Hydrologic engineering and portions of the economics are performed separately, but in a coordinated manner after specifying the study configuration and layout, and merged for the formulation and evaluation of the potential flood risk management plans.

Average annual damages to property and contents are described in greater detail and by reach in subsequent sections.

4.1.1.6.2 Emergency Costs

Emergency costs were estimated from actual historical emergency costs incurred by the village and a probability weighted value for varying storm frequencies.

A nuisance level of emergency costs, including traffic rerouting and public assistance was estimated from actual, frequent flood events in the village. Actual emergency costs from significant events were tabulated and correlated to the observed frequency and a relationship was estimated for the various storm frequencies estimated during the project study period. The intermediate frequencies were interpolated from the data for the frequencies for real events, which were the 18.5 year event and the 100 year event.

Table 6: Emergency Cost Derivation

Exceedance Interval (yr)	Exceedance Probability	Cost at event	Probability Interval	Average Damage in Interval	Probability Weighted Damage
1	90%	-			
			40.00%	$ 5,000	$ 2,000
2	50%	$ 10,000			
			44.59%	$ 105,000	$ 46,824
18.5	5.41%	$ 200,000			
			1.41%	$ 314,724	$ 4,423
25	4.00%	$ 429,448			
			2.00%	$ 644,172	$ 12,883
50	2.00%	$ 858,896			
			0.67%	$ 1,073,620	$ 7,157
75	1.33%	$ 1,288,344			
			0.22%	$ 1,417,178	$ 3,149
90	1.11%	$ 1,546,012			
			0.11%	$ 1,573,006	$ 1,748
100	1.00%	$ 1,600,000			
Balance			1.00%	$ 1,600,000	$ 16,000

Total Annual Damage	**$ 94,185**

FY 2012 Price Level, 4% Interest Rate

4.1.1.6.3 Advanced Bridge Replacement

If a bridge is replaced as the result of a flood control project, a benefit can be claimed to at least partially offset the cost of bridge replacement. Advanced bridge replacement benefits are quantified for the period that the useful life of the bridge is extended by the project. County and Village Department of Public Works personnel were consulted to assess the anticipated date bridge replacement dates in the absence of a federal project. The dates were estimated following their assessment of the condition of the bridges and the necessary federal standards they must meet.

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Table 7 Station Plaza Replacement Benefit Computation	
Cost of New Bridge	7,000,000
Life of new bridge	50
Remaining life of existing bridge	8
Extended life of the bridge	42
Rate	0.0400
Capital Recovery Rate	0.05
Annual Cost of New Bridge	325,900
PW annuity for extended life	20
Benefits in year to be replaced	6,578,500
Single payment pw for replacement year	0.73
Present worth in year 1	4,806,800
Average annual benefit	223,800

FY 2012 Price Level

4.1.1.6.4 Pre Base Year Benefits

Benefits of completed portions of the project provide benefits while subsequent portions are constructed. Table 8 presents the total pre base year benefits of each of the alternatives. Characteristics of each alternative are noted below the table.

Table 8: Pre Base Year Benefits in Dollars

Alternative	Year 0	Year -1	Year -2	TOTAL
1	0	0	0	0
2	3,596,476	0	0	3,596,476
3	3,596,476	3,596,476	0	7,192,952
4	3,596,476	3,596,476	3,596,476	10,789,429
5	3,596,476	0	0	3,596,476
6	0	0	0	0
8	719,667	719,667	0	1,439,333
1S	3,596,476	0	0	3,596,476
1M	3,596,476	0	0	3,596,476
1L	3,596,476	3,596,476	0	7,192,952

FY 2012 Price Level, 4% Interest Rate

Alt 1 Project complete in 3 years, no pre base year benefits assumed.
Project complete in 4 years, The Alt 1 components will be complete Base Year -1.

Alt 2 One year of Benefits at Alt 1 Average Annual rate are assumed.
Project complete in 5 years, The Alt 1 components will be complete Base Year -2.

Alt 3 Two years of Benefits at Alt 1 Average Annual Rate are Assumed.
Project will take about 6 years to complete and the downstream portion would be complete in 3 years.
While the downstream portion would not be exactly the same as Alt 1 the benefits would be similar and

Alt 4 would accrue for 3 years before completion.

	Project will take about 5 years to complete and the downstream portion would be complete in 3 years.
Alt 5	(Same as Alt #3)
Alt 6	Non Structural. Assume Benefits liquidate IDC after 3-6 construction period per structure.
	Plan would take about 3 years to complete. There would be some early benefits in the first two years.
Alt 8	Estimate a third of the benefits at the end of each year.
	Project complete in 4 years, The Alt 1 components will be complete Base Year -1.
Alt 1S	One year of Benefits at Alt 1 Average Annual rate are assumed.
	Project complete in 4 years, The Alt 1 components will be complete Base Year -1.
Alt 1M	One year of Benefits at Alt 1 Average Annual rate are assumed.
	Project complete in 5 years, The Alt 1 components will be complete Base Year -2.
Alt 1L	Two years of Benefits at Alt 1 Average Annual Rate are Assumed.

4.1.1.7 Without-Project Damages Summary

Using HEC-FDA, Average Annual Damages (AAD) were calculated for the without-project base year and future condition, and Equivalent Annual Damages (EAD) were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and federal plan formulation discount rate of 4.0%. A summary of equivalent annual damages for the without-project condition is presented in Table 9.

Table 9
Summary of Equivalent Annual Damages for the Without-Project Condition

Reach	Damage Categories						Reach Total
	Residential	Apartment	Commercial	Industrial	Public	Vehicles	
MD1	$20	$1,720	$1,820	$0	$0	$6,790	$10,350
MD2	$130	$0	$980	$0	$0	$0	$1,110
MD3	$12,770	$0	$230	$0	$0	$440	$13,440
MD4	$470	$0	$10,360	$0	$0	$20	$10,850
MD5	$70	$0	$0	$0	$0	$0	$70
Stream Total	*$13,460*	*$1,720*	*$13,390*	*$0*	*$0*	*$7,250*	*$35,820*
S1	$109,430	$7,470	$124,610	$0	$7,620	$28,830	$277,960
S2	$590,530	$7,610	$660,520	$396,730	$0	$36,420	$1,691,810
S3	$9,580	$0	$48,880	$26,650	$0	$360	$85,470
S4	$3,870	$0	$0	$0	$0	$110	$3,980
Stream Total	*$713,410*	*$15,080*	*$834,010*	*$423,380*	*$7,620*	*$65,720*	*$2,059,220*
MU1	$268,200	$880	$236,390	$0	$104,020	$14,510	$624,000
MU2	$397,380	$0	$1,580	$0	$1,040	$22,720	$422,720
MU3	$256,730	$0	$0	$0	$0	$4,940	$261,670
MU4	$0	$0	$6,900	$0	$0	$0	$6,900
Stream Total	*$922,310*	*$880*	*$244,870*	*$0*	*$105,060*	*$42,170*	*$1,315,290*
Project Total	**$1,649,180**	**$17,680**	**$1,092,270**	**$423,380**	**$112,680**	**$115,140**	**$3,410,330**

Price level: FY2012, 4.0% Discount rate.

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Inspection of the results shows that 60% of the without-project condition damages are being incurred by structures considered to be primarily flooded by the Sheldrake River, and 50% of the total damages are being incurred in just one reach (S2). While significant damages (almost 40% of the total) are being incurred by flooding on the Mamaroneck River upstream of the confluence, flooding on the Mamaroneck downstream of the confluence accounts for approximately 1% of the total damages.

A summary of equivalent annual damages per structure (excluding motor vehicles) is presented in Table 10.

Table 10
Summary of Annual Damage per Structure for the Without-Project Condition

Reach	Damage Categories					Reach Average
	Residential	Apartment	Commercial	Industrial	Public	
MD1	$4	$1,720	$165	$0	$0	$209
MD2	$43	$0	$980	$0	$0	$278
MD3	$912	$0	$230	$0	$0	$813
MD4	$157	$0	$2,590	$0	$0	$1,547
MD5	$35	$0	$0	$0	$0	$23
Stream Average	*$499*	*$1,720*	*$744*	*$0*	*$0*	*$608*
S1	$8,418	$1,868	$7,788	$0	$7,620	$7,327
S2	$3,579	$1,903	$7,102	$17,249	$0	$5,808
S3	$639	$0	$1,528	$3,331	$0	$1,547
S4	$323	$0	$0	$0	$0	$323
Stream Average	*$3,480*	*$1,885*	*$5,915*	*$13,657*	*$7,620*	*$5,165*
MU1	$3,311	$220	$14,774	$0	$26,005	$5,805
MU2	$3,934	$0	$132	$0	$1,040	$3,509
MU3	$4,937	$0	$0	$0	$0	$4,937
MU4	$0	$0	$6,900	$0	$0	$6,900
Stream Average	*$3,941*	*$220*	*$8,444*	*$0*	*$21,012*	*$4,681*
Project Average	**$3,539**	**$1,360**	**$5,810**	**$13,231**	**$18,780**	**$4,674**

Price level: FY 2012, 4.0% Discount rate.

4.1.1.8 Damage Verification

Efforts to verify the computed damages consisted of four principal activities:

- An additional field visit to verify the physical attributes of structures exhibiting very high damages in the initial model runs.
- A comparison of event damages computed by HEC-FDA with National Flood Insurance Program (NFIP) payouts for flood events with established return periods.
- Discussions with local residents whose properties have suffered from flooding to determine flood depths and damages at established return period events.

- Outreach to selected local businesses with the intention of developing specific depth-damage functions for properties whose losses may not be adequately captured by the standard/generic functions

The additional field visit was undertaken after the initial computation of damages and was focused on those structures exhibiting damage in the model at the 50% annual chance exceedance ("two-year") event, and/or those exhibiting annual average damages in excess of $20,000. These structures were targeted since significant flooding at that frequency has not been locally reported, and it was assumed that any structure experiencing that magnitude of flooding would have been rendered unusable/uninhabitable. The targeted structures were inspected and adjustments were made to key attributes such as ground and main floor elevations, foundation type, and usage in order to align the damages more closely with local reports and expectations.

Structure and contents damages computed for HEC-FDA were compared with reported damages (in the form of claims paid by the National Flood Insurance Program) for two flood events in Mamaroneck events with known or accepted return periods; the flood of March 2007, which was considered to have been slightly less than a 20% annual chance exceedance (or "5-year") event, and the April 2007 flood, which has been estimated to be close to a 1% annual chance exceedance (or "100-year") event. The results of the comparison are presented in Table 11.

Table 11
Comparison of Modeled versus Recorded Damages

Flood Event	*HEC-FDA Structures Damaged* / NFIP Claims	*HEC-FDA Damage* / NFIP Payouts	*Damage* / Payout per Structure
HEC-FDA 20% ACE	*91*	*$2,266,000*	*$24,901*
March 2007 Flood	70	$1,263,000	$18,043
HEC-FDA 1% ACE	*426*	*$42,695,000*	*$100,223*
April 2007 Flood	208	$10,405,000	$50,024

FY 2012 Price Level

Differences of this order between modeled damages and NFIP losses, particularly for lower frequency events, are not uncommon and may be accounted for by several factors:

- The comparison in Table V1 suggests that not all of the structures in the floodplain eligible to be covered by the NFIP actually have a policy in place, resulting in significant damages that would not appear in NFIP loss records. NFIP coverage is only mandatory for properties in the Special Flood Hazard Area (as indicated on the effective Flood Insurance Rate Map, or FIRM) purchased or constructed using grants or loans (e.g. mortgages) from a federal agency or federally-regulated lending institution. While current FEMA records state that there are over 1,000 NFIP policies currently in place in the Village of Mamaroneck, address data for these policies is not publicly available information, and many may be held by property owners outside the study area floodplain, particularly in the substantial flood hazard areas adjacent to Long Island Sound.

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- Some property owners (particularly non-residential owners) may have experienced damage exceeding their coverage. While data is not readily available to determine the coverage levels for all policy holders in the study area, the NFIP data does show a number of paid loss amounts matching the limit of available coverage, which implies that the damage did exceed the payouts in some cases. The results from HEC-FDA indicate that approximately $5 million of the discrepancy at the 100-year event could be accounted for by damages exceeding available coverage for the 10 most-damaged non-residential structures.
- The comparison does not take into account price level escalation from 2007 to 2011 or policy holders' deductibles and out-of pocket expenses.

Telephone discussions were held with Mamaroneck residents whose properties had experienced flooding in the events of 2007 and 2011. Residents of Chestnut Avenue, Urban Street, and North James Street in the northern section of the study area were contacted and asked questions regarding their properties' main floor elevations, the depth of flooding they experienced during various events and the damages suffered. The discussions resulted in some minor adjustments to structure attributes in order to calibrate the modeled damages in that area.

Surveys were mailed to selected businesses in the study area for the purposes of developing property-specific depth-damage functions for structures whose losses are potentially not fully captured by the initially assigned generic functions. Recipients of the surveys were drawn from non-residential structures with NFIP claims histories featuring:

- High content damage compared to structure damage
- Substantial total repetitive losses
- Substantial losses during the flood events of 2007 and 2011

While twelve businesses were contacted in this exercise, only one responded with useful information. Marval Industries, Inc. is a manufacturer of polymer resins and compounds for use in the plastics industry, and their facility, which comprises five structures in the HEC-FDA inventory, is located in reach S2. Although the information provided by Marval was not sufficient to allow unique depth damage curves to be generated, the additional data enabled more specific contents values to be entered for the Marval structures, overwriting those generated by the content-structure value ratio inherent in the applied generic depth-damage function. In this way the model was calibrated to calculate damages for these structures more closely aligned with actual losses experienced.

5.0 Evaluation of Alternatives

5.1 Overview

Alternatives for the proposed action were formulated in consideration of study area problems and opportunities, as well as study goals, objectives and constraints with consideration of four criteria: completeness, effectiveness, efficiency, and acceptability.

• Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.

• Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.

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

• Acceptability is the workability and viability of the alternative plan with respect to acceptance by state and local entities and the public and compatibility with existing laws, regulations, and public policies.

At a minimum, the potential Flood Risk Management measures examined in the reevaluation report included the "no action" alternative, non-structural measures, structural measures as well as a combination of the previous solutions. This included; variations of the recommended plan's components: e.g. channel work, diversion tunnel, levees and floodwalls. More specifically, the tunnel's alignment and desired level of protection was re-evaluated as the previously authorized plan. Non-structural measures such as buyouts, flood-proofing and preservation and/or creation of open space in the floodplain was also reconsidered in light of changes to existing conditions and changes to environmental policy.

However, since the Feasibility Report (1977) and GDM (1989) have already been completed, the GRR focuses efforts on review of plans which were the most feasible, based on the prior information. Therefore, preliminary alternatives in the GRR included:

1. Authorized (GDM) Plan (channel modification and diversion tunnel);
2. Channel modification only;
   - Mamaroneck below confluence
   - Mamaroneck River only
   - Mamaroneck and Sheldrake Rivers
3. Channel modification with new tunnel alignment (Ward Avenue diversion with an outlet into the East Basin of Mamaroneck Harbor);
4. Non-structural plan alone.
5. Reservoir Management & Bridge Removal Plan.
6. No Action Plan.

Ultimately, the GRR will detail the optimal plan for flood risk management in the Mamaroneck and Sheldrake Rivers Basin, based on NED plan criteria. The reevaluation report will serve to document the re-evaluation of the recommended plan, (including any adjustments or variations of said plan) and provide a basis for a decision on construction authorization of the project (if needed) and serve as the decision document for execution of a Project Partnership Agreement.

The formulation of potential modifications and re-evaluation of the recommended plan is constrained by technical, environmental, economic, and social considerations. These constraints shall appropriately limit and screen proposed modifications to the recommended plan and serve to focus formulation efforts. During the re-evaluation, once existing conditions are reassessed and without project conditions established, the analysis shall proceed to a "with-project conditions" assessment. Plan formulation

techniques shall be employed to guide the development, screening and selection of opportunities for improvement to the recommended plan, in accord with local interests' needs, while meeting planning objectives and within the aforementioned constraints. Formulation will seek to maintain the recommended plan's purposes of flood risk management, while employing environmentally sound solutions.

5.2 Alternative 1

5.2.1 Description

Alternative 1 includes channel deepening and widening along both the Mamaroneck and Sheldrake Rivers from a little above the confluence to the Tomkins Avenue Bridge (tidal limit). Five bridges will be removed and/or replaced. These are: Station Plaza, Halstead Avenue, Ward Avenue, and the two Columbus Park pedestrian bridges. Along the Mamaroneck River, channel work extends from the Tompkins Avenue Bridge to 400 ft above the Hillside Avenue Bridge, for an approximated total length of 4,200 ft. Along the Sheldrake River; channel work extends from the confluence to 700 ft above the Mamaroneck Avenue Bridge, for an approximated total length of 1,400 ft. The river will be realigned just downstream of the confluence and below the Ward Ave Bridge. Trapezoidal channel improvements will consist of a natural bed channel with a 30 to 50 ft width and side slopes of one vertical on two and a half horizontal (1:2.5). Concrete retaining walls will be used where space is limited. The existing channel side slopes range from one vertical on one horizontal (1:1), to one vertical on three horizontal (1:3). The width of the existing channel varies from 30 to 50 ft for the Mamaroneck River and from 20 to 40 ft in the Sheldrake River. Downstream of the confluence, the overbank area is highly vegetated and with a high amount of loose rocks. The channel bottom has a moderate slope, approximately 12 ft per mile.

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5.2.2 Alternative 1 Cost Estimate:

ACCT#	CWBS FEATURE	**Alt 1**
02	RELOCATIONS	$390,522
08	ROADS, RAILROADS AND BRIDGES	$26,471,095
09	CHANNELS AND CANALS	$7,982,430
11	LEVEES AND FLOODWALLS	$4,990,399
12	FLOODWAY CONTROL & DIV STR	$0
16	ENVIRONMENTAL MITIGATION	$900,000
	TOTAL CONSTRUCTION COST	$40,734,446
01	LANDS & DAMAGES	$5,248,839
30	ENGINEERING & DESIGN	$6,111,024
31	CONSTRUCTION MANAGEMENT	$3,258,756
	TOTAL FIRST COST	**$55,353,065**
	IDC	$3,082,628
	TOTAL INVESTMENT COST	**$58,435,693**
	ANNUAL COST	$2,720,193
	O&M	$203,700
	MAJOR REHAB/REPLACEMENT	$0
	TOTAL NED ANNUAL COST	**$2,923,893**

FY 2012 Price Level, 4% Interest Rate

5.2.3 Residual Damages and Benefits

Using HEC-FDA, Average Annual Damages were calculated for the base year and future years with Alternative 1 in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and formulation discount rate of 4.0%. A summary of equivalent annual damages and benefits for Alternative 1 is presented in Table 12. A summary of all benefits arising from the implementation of Alternative 1 and the resulting benefit-cost ratio is presented in Section 6.0.

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Table 12: **Summary of Damages and Benefits for Alternative 1**			
Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 1	
MD1	$10,350	$10,040	$310
MD2	$1,110	$1,430	-$320
MD3	$13,440	$280	$13,160
MD4	$10,850	$460	$10,390
MD5	$70	$0	$70
Stream Total	*$35,820*	*$12,210*	*$23,610*
S1	$277,960	$23,270	$254,690
S2	$1,691,810	$275,380	$1,416,430
S3	$85,470	$25,740	$59,730
S4	$3,980	$1,500	$2,480
Stream Total	*$2,059,220*	*$325,890*	*$1,733,330*
MU1	$624,000	$37,820	$586,180
MU2	$422,720	$117,960	$304,760
MU3	$261,670	$234,940	$26,730
MU4	$6,900	$6,900	$0
Stream Total	*$1,315,290*	*$397,620*	*$917,670*
Project Total	**$3,410,330**	**$735,720**	**$2,674,610**

Price level: FY 2012, 4.0% Discount rate.

5.3 Alternative 2

5.3.1 Description

Alternative 2 includes most of Alternative #1 and additional work along the Mamaroneck River up to the Winfield Avenue Bridge. Six bridges will be removed and/or replaced. These are: Station Plaza, Halstead Avenue, Ward Avenue, Hillside Avenue and the two Columbus Park pedestrian bridges. Along the Mamaroneck River, channel work extends from the Tompkins Avenue Bridge to 270ft above Winfield Avenue Bridge, for an approximated total length of 6,700ft. Along the Sheldrake River, channel work extends from the confluence to 750ft above the Mamaroneck Avenue Bridge, for an approximate total length of 1,500ft. The river will be realigned just downstream of the confluence and just below the Ward Avenue Bridge. Trapezoidal channel improvements will consist of a natural bed channel with side slopes of one vertical on two and a half horizontal (1:2.5), with retaining walls where space is limited. Columbus Park will be used as the staging area during construction. Articulated concrete mats may be used through and just downstream of the Winfield Avenue Bridge due to the high stream velocities.

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5.3.2 Alternative 2 Cost Estimate

ACCT#	CWBS FEATURE	**Alt 2**
02	RELOCATIONS	$616,116
08	ROADS, RAILROADS AND BRIDGES	$32,587,043
09	CHANNELS AND CANALS	$11,261,575
11	LEVEES AND FLOODWALLS	$7,702,763
12	FLOODWAY CONTROL & DIV STR	$0
16	ENVIRONMENTAL MITIGATION	$1,800,000
	TOTAL CONSTRUCTION COST	$53,967,497
01	LANDS & DAMAGES	$9,369,504
30	ENGINEERING & DESIGN	$8,096,210
31	CONSTRUCTION MANAGEMENT	$4,317,400
	TOTAL FIRST COST	**$75,750,611**
	IDC	$5,736,396
	TOTAL INVESTMENT COST	**$81,487,007**
	ANNUAL COST	$3,793,237
	O&M	$269,900
	MAJOR REHAB/REPLACEMENT	$0
	TOTAL NED ANNUAL COST	**$4,063,137**

FY 2012 Price Level, 4% Interest Rate

5.3.3 Residual Damages and Benefits

Using HEC-FDA, Average Annual Damages were calculated for the base year and future years with Alternative 2 in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and formulation discount rate of 4.0%. A summary of equivalent annual damages and benefits for Alternative 2 is presented in Table 13. A summary of all benefits arising from the implementation of Alternative 2 and the resulting benefit-cost ratio is presented in Section 6.0.

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Table 13: Summary of Damages and Benefits for Alternative 2			
Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 2	
MD1	$10,350	$10,620	-$270
MD2	$1,110	$1,560	-$450
MD3	$13,440	$310	$13,130
MD4	$10,850	$540	$10,310
MD5	$70	$0	$70
Stream Total	*$35,820*	*$13,030*	*$22,790*
S1	$277,960	$29,850	$248,110
S2	$1,691,810	$308,700	$1,383,110
S3	$85,470	$27,550	$57,920
S4	$3,980	$1,620	$2,360
Stream Total	*$2,059,220*	*$367,720*	*$1,691,500*
MU1	$624,000	$55,500	$568,500
MU2	$422,720	$22,300	$400,420
MU3	$261,670	$8,460	$253,210
MU4	$6,900	$3,090	$3,810
Stream Total	*$1,315,290*	*$89,350*	*$1,225,940*
Project Total	**$3,410,330**	**$470,100**	**$2,940,230**

Price level: FY2012, 4.0% Discount rate.

5.4 Alternative 3

5.4.1 Description

Alternative 3 includes Alternative #2 with additional channel deepening along the Sheldrake River. Eight bridges will be removed and/or replaced. These are: Station Plaza, Halstead Avenue, Ward Avenue, Valley Place (Anita Lane Sewer Bridge), Hillside Avenue, Centre Avenue and the two Columbus Park pedestrian bridges. Along the Mamaroneck River, channel work extends from Tompkins Avenue Bridge to 270ft above Winfield Avenue Bridge, an approximated total length of 6,700ft. Meanwhile, the Sheldrake River channel work extends from the confluence to 450ft above the Rockland Avenue Bridge, for an approximated total length of 6,700ft, a significant amount of retaining walls will be used for this alternative. The river will be realigned throughout the confluence and just below the Ward Avenue Bridge. Trapezoidal channelization will consist of a natural bed channel with side slopes of one vertical on two and a half horizontal (1:2.5), and concrete retaining walls will be used where space is limited. Articulated concrete mats will be used through and just downstream of Winfield Avenue Bridge due to the high stream velocities. A rectangular channel with concrete retaining walls and channel bottom is needed from the Railroad Bridge to the Halstead Avenue Bridge. Columbus Park will be use as the staging area during construction.

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5.4.2 Alternative 3 Cost Estimate

ACCT#	CWBS FEATURE	**Alt 3**
02	RELOCATIONS	$829,027
08	ROADS, RAILROADS AND BRIDGES	$34,138,217
09	CHANNELS AND CANALS	$17,198,628
11	LEVEES AND FLOODWALLS	$8,172,283
12	FLOODWAY CONTROL & DIV STR	$0
16	ENVIRONMENTAL MITIGATION	$2,760,000
	TOTAL CONSTRUCTION COST	$63,098,155
01	LANDS & DAMAGES	$14,100,100
30	ENGINEERING & DESIGN	$9,464,848
31	CONSTRUCTION MANAGEMENT	$5,047,852
	TOTAL FIRST COST	**$91,710,955**
	IDC	$8,828,863
	TOTAL INVESTMENT COST	**$100,539,818**
	ANNUAL COST	$4,680,149
	O&M	$315,500
	MAJOR REHAB/REPLACEMENT	$0
	TOTAL NED ANNUAL COST	**$4,995,649**

FY 2012 Price Level, 4% Interest Rate

5.4.3 Residual Damages and Benefits

Using HEC-FDA, Average Annual Damages were calculated for the base year and future years with Alternative 3 in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and formulation discount rate of 4.0%. A summary of equivalent annual damages and benefits for Alternative 3 is presented in Table 14. A summary of all benefits arising from the implementation of Alternative 3 and the resulting benefit-cost ratio is presented in Section 6.0.

Table 14:
Summary of Damages and Benefits for Alternative 3

Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 3	
MD1	$10,350	$10,890	-$540
MD2	$1,110	$1,660	-$550
MD3	$13,440	$590	$12,850
MD4	$10,850	$140	$10,710
MD5	$70	$0	$70
Stream Total	*$35,820*	*$13,280*	*$22,540*

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Table 14: Summary of Damages and Benefits for Alternative 3			
Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 3	
S1	$277,960	$8,020	$269,940
S2	$1,691,810	$27,430	$1,664,380
S3	$85,470	$1,930	$83,540
S4	$3,980	$300	$3,680
Stream Total	*$2,059,220*	*$37,680*	*$2,021,540*
MU1	$624,000	$14,570	$609,430
MU2	$422,720	$9,280	$413,440
MU3	$261,670	$6,540	$255,130
MU4	$6,900	$3,090	$3,810
Stream Total	*$1,315,290*	*$33,480*	*$1,281,810*
Project Total	**$3,410,330**	**$84,440**	**$3,325,890**

Price level: FY 2012, 4.0% Discount rate

5.5 Alternative 4

5.5.1 Description

Alternative 4 is comprised of the 1989 GDM river diversion and channel improvements, consists of a tunnel system running beneath Fenimore Road from the Sheldrake River to the West Basin of Mamaroneck Harbor. This 16 ft wide by 16 ft high tunnel system which is approximately 4,010 ft in length is comprised of an inlet structure, the tunnel works and the outlet structure. Channel work in the Mamaroneck River includes a trapezoidal channelization consisting of a natural bed channel, 45 to 60 ft wide. Side slopes of one vertical on three horizontal (1:3) with concrete retaining walls where space is limited. Sheldrake improvements extend from the Mamaroneck Avenue to I-95 with a trapezoidal channel with a natural bed channel 30 ft wide. The 1989 GDM improvements on the Mamaroneck and Sheldrake Rivers are based on the 200-year frequency flood.

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5.5.2 Alternative 4 Cost Estimate

ACCT#	CWBS FEATURE	**Alt 4**
02	RELOCATIONS	$11,385,454
08	ROADS, RAILROADS AND BRIDGES	$0
09	CHANNELS AND CANALS	$92,957,847
11	LEVEES AND FLOODWALLS	$0
12	FLOODWAY CONTROL & DIV STR	$0
16	ENVIRONMENTAL MITIGATION	$500,000
	TOTAL CONSTRUCTION COST	$104,843,302
01	LANDS & DAMAGES	$8,279,083
30	ENGINEERING & DESIGN	$15,731,104
31	CONSTRUCTION MANAGEMENT	$8,387,464
	TOTAL FIRST COST	**$137,240,953**
	IDC	$17,240,189
	TOTAL INVESTMENT COST	**$154,481,142**
	ANNUAL COST	$7,191,128
	O&M	$524,300
	MAJOR REHAB/REPLACEMENT	$0
	TOTAL NED ANNUAL COST	**$7,715,428**

FY 2012 Price Level, 4% Interest Rate

5.5.3 Residual Damages and Benefits

Using HEC-FDA, Average Annual Damages were calculated for the base year and future years with Alternative 4 in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and formulation discount rate of 4.0%. A summary of equivalent annual damages and benefits for Alternative 4 is presented in Table 15. A summary of all benefits arising from the implementation of Alternative 4 and the resulting benefit-cost ratio is presented in Section 6.0.

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Table 15: Summary of Damages and Benefits for Alternative 4			
Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 4	
MD1	$10,350	$6,660	$3,690
MD2	$1,110	$660	$450
MD3	$13,440	$480	$12,960
MD4	$10,850	$230	$10,620
MD5	$70	$0	$70
Stream Total	*$35,820*	*$8,030*	*$27,790*
S1	$277,960	$12,100	$265,860
S2	$1,691,810	$0	$1,691,810
S3	$85,470	$360	$85,110
S4	$3,980	$240	$3,740
Stream Total	*$2,059,220*	*$12,700*	*$2,046,520*
MU1	$624,000	$28,360	$595,640
MU2	$422,720	$18,400	$404,320
MU3	$261,670	$7,850	$253,820
MU4	$6,900	$1,730	$5,170
Stream Total	*$1,315,290*	*$56,340*	*$1,258,950*
Project Total	**$3,410,330**	**$77,070**	**$3,333,260**

Price level: FY 2012, 4.0% Discount rate

5.6 Alternative 5

5.6.1 Description

Alternative 5 includes channel works throughout Mamaroneck and Sheldrake Rivers. Five bridges will be removed and/or replaced. These are: Ward Avenue, Hillside Avenue, Centre Avenue and the two Columbus Park pedestrian bridges. The Ward Avenue Bridge will be relocated approximately 20 ft upstream of its current location to allow the proposed tunnel to discharge downstream of the bridge. Because of the relocation, approximately 130 ft of approach road on in each of the bridge side is going to be impacted by construction.

Along the Mamaroneck River, channel work extends from Tompkins Avenue Bridge to 270 ft above Winfield Avenue Bridge, for an approximate total length of 6,700 ft. In the Sheldrake River, channel work extends from the confluence to 450 ft above the Rockland Avenue Bridge, for an approximate total length of 5,700 ft. Trapezoidal channel improvements will consist of a natural bed channel with side slopes of one vertical on two and a half horizontal (1:2.5), with concrete retaining walls where space is limited by structures and private properties. Columbus Park will be used as the staging area during construction.

A diversion tunnel with an ogee spillway is to be constructed just downstream of the confluence between the Mamaroneck and Sheldrake Rivers. The ogee spillway will be approximately 5.3 ft in height and 40 ft

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long. The diversion tunnel, of approximately 1,050 ft in length and 13 ft in diameter, will start at the confluence and run under the railroad and under Ward Avenue, discharging back into the Mamaroneck River just downstream of a new Ward Avenue Bridge.

5.6.2 Alternative 5 Cost Estimate

ACCT#	CWBS FEATURE	**Alt 5**
02	RELOCATIONS	$808,793
08	ROADS, RAILROADS AND BRIDGES	$8,016,010
09	CHANNELS AND CANALS	$15,304,878
11	LEVEES AND FLOODWALLS	$1,978,499
12	FLOODWAY CONTROL & DIV STR	$25,680,298
16	ENVIRONMENTAL MITIGATION	$2,760,000
	TOTAL CONSTRUCTION COST	$54,548,478
01	LANDS & DAMAGES	$14,508,963
30	ENGINEERING & DESIGN	$8,180,184
31	CONSTRUCTION MANAGEMENT	$4,363,878
	TOTAL FIRST COST	**$81,601,503**
	IDC	$7,855,648
	TOTAL INVESTMENT COST	**$89,457,151**
	ANNUAL COST	$4,164,248
	MAJOR REHAB/REPLACEMENT	$0
	TOTAL NED ANNUAL COST	**$4,437,048**

FY 2012 Price Level, 4% Interest Rate

5.6.3 Residual Damages and Benefits

Using HEC-FDA, Average Annual Damages were calculated for the base year and future years with Alternative 5 in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and formulation discount rate of 4.0%. A summary of equivalent annual damages and benefits for Alternative 5 is presented in Table 16. A summary of all benefits arising from the implementation of Alternative 5 and the resulting benefit-cost ratio is presented in Section 6.0.

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Table 16 **Summary of Damages and Benefits for Alternative 5**			
Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 5	
MD1	$10,350	$4,990	$5,360
MD2	$1,110	$1,780	-$670
MD3	$13,440	$650	$12,790
MD4	$10,850	$180	$10,670
MD5	$70	$0	$70
Stream Total	*$35,820*	*$7,600*	*$28,220*
S1	$277,960	$15,690	$262,270
S2	$1,691,810	$74,030	$1,617,780
S3	$85,470	$3,650	$81,820
S4	$3,980	$360	$3,620
Stream Total	*$2,059,220*	*$93,730*	*$1,965,490*
MU1	$624,000	$29,710	$594,290
MU2	$422,720	$18,380	$404,340
MU3	$261,670	$7,730	$253,940
MU4	$6,900	$2,440	$4,460
Stream Total	*$1,315,290*	*$58,260*	*$1,257,030*
Project Total	**$3,410,330**	**$159,590**	**$3,250,740**

Price level: FY2012, 4.0% Discount rate

5.7 Alternative 6 (Nonstructural)

5.7.1 Description and Methodology

A nonstructural alternative is one in which the physical mechanism and extent of flooding is largely unchanged (no riverine structures are constructed or modified to substantially constrain, impede or redirect floodwater) but the existing buildings within the floodplain are instead adapted or the regulatory framework that governs new development is modified to reduce the damage incurred during flood events. For this study, only nonstructural measures which directly affect existing buildings have been incorporated into the analysis.

Nonstructural treatments were applied to structures in the study area using an algorithm which considered physical characteristics including building configuration, usage, footprint size, foundation type, and existing main floor elevation in order to select and cost the most appropriate/feasible treatment for each structure. The nonstructural analysis considered 10 different treatment measures for application, which can be described under the following broad categories:

- Elevation: the structure is physically raised so that the main floor of the structure is at or above the specified design protection level.

- Dry floodproof: all openings are sealed or fitted with moveable watertight barriers and the exterior walls are treated to make them waterproof to the design protection level.
- Wet floodproof: wet floodproofing is generally applied to structures with a main floor elevation already above the design protection level but which still incur significant damages due to the presence of basements and vulnerable utilities. Treatments include the vacating or filling of basements, removal of utilities, and the provision of equivalent facilities above the design protection level. Wet floodproofing also includes a number of minor treatments such as the raising of exterior air conditioning units and the provision of louvers in crawlspace walls to allow the equalization of hydrostatic pressure.
- Ringwall: the structure (and in some cases, groups of closely adjacent structures) is encircled by a floodwall constructed to the design protection elevation.

The design protection level for this analysis was based on the water surface elevation with a 1% annual chance of being equaled or exceeded (the "100-year flood") plus one foot of freeboard, and the analyzed alternative included all structures considered to be in the 100-year floodplain. While nonstructural measures reduce the risk of damage to individual structures and their contents, they are assumed not to reduce damages to exterior items such as vehicles and landscaping. It should also be noted that except for ringwalls and dry floodproof measures, some residual structure damage can still be incurred below the design level of protection following the implementation of nonstructural measures. For the purposes of this analysis no other benefits (such as reductions to emergency costs) are assumed to be realized by a nonstructural alternative.

The treatments applied in the analyzed nonstructural alternative are summarized by reach and by categories of affected structure in Tables 17 and 18.

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Table 17 **Summary of Nonstructural Treatments by Structure Category**						
Reach	Damage Categories					Reach Total
	Residential	Apartment	Commercial	Industrial	Public	
MD1	0	0	0	0	0	0
MD2	0	0	0	0	0	0
MD3	2	0	0	0	0	2
MD4	0	0	1	0	0	1
MD5	0	0	0	0	0	0
Stream Total	*2*	*0*	*1*	*0*	*0*	*3*
S1	12	3	14	0	1	30
S2	125	3	67	19	0	214
S3	5	0	15	6	0	26
S4	2	0	0	0	0	2
Stream Total	*144*	*6*	*96*	*25*	*1*	*272*
MU1	49	2	12	0	2	65
MU2	47	0	0	0	0	47
MU3	28	0	0	0	0	28
MU4	0	0	1	0	0	1
Stream Total	*124*	*2*	*13*	*0*	*2*	*141*
Project Total	**270**	**8**	**110**	**25**	**3**	**416**

For the purposes of the nonstructural summary tables, treatments applied to individual sub-components of larger structures (which have been treated as individual structures for the calculation of damages in HEC-FDA) have been counted as individual treatments.

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Table 18 **Summary of Nonstructural Treatments by Reach**						
Reach	Treatments Assigned					Reach Total
	Ringwall	Elevation	Wet Floodproof	Dry Floodproof	Minor Floodproof	
MD1	0	0	0	0	0	0
MD2	0	0	0	0	0	0
MD3	0	2	0	0	0	2
MD4	1	0	0	0	0	1
MD5	0	0	0	0	0	0
Stream Total	*1*	*2*	*0*	*0*	*0*	*3*
S1	18	10	1	0	1	30
S2	79	46	55	19	15	214
S3	7	1	0	16	2	26
S4	0	1	1	0	0	2
Stream Total	*104*	*58*	*57*	*35*	*18*	*272*
MU1	16	31	12	5	1	65
MU2	2	28	15	0	2	47
MU3	1	18	8	0	1	28
MU4	1	0	0	0	0	1
Stream Total	*20*	*77*	*35*	*5*	*4*	*141*
Project Total	**125**	**137**	**92**	**40**	**22**	**416**

5.7.2 Alternative 6 Cost Estimate

ACCT#	CWBS FEATURE	**Alt 6**
02	RELOCATIONS	$1,452,200
	TOTAL CONSTRUCTION COST	$68,268,040
01	LANDS & DAMAGES	$4,356,000
30	ENGINEERING & DESIGN	$7,864,478
31	CONSTRUCTION MANAGEMENT	$5,242,985
	TOTAL FIRST COST	**$85,731,600**
	IDC	$1,560,616
	TOTAL INVESTMENT COST	**$87,292,216**
	ANNUAL COST	$4,063,470
	O&M	$170,700
	MAJOR REHAB/REPLACEMENT	$0
	TOTAL NED ANNUAL COST	**$4,234,170**

FY 2012 Price Level, 4% Interest Rate

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5.7.3 Residual Damages and Benefits

Using HEC-FDA, Average Annual Damages were calculated for the base year and future years with Alternative 6 in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and formulation discount rate of 4.0%. A summary of equivalent annual damages and benefits for Alternative 6 is presented in Table 19. The benefit-cost ratio resulting from the implementation of Alternative 6 is presented in Section 6.0.

Table 19
Summary of Damages and Benefits for Alternative 6 (Nonstructural)

Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 6	
MD1	$10,350	$10,350	$0
MD2	$1,110	$1,120	-$10
MD3	$13,440	$2,310	$11,130
MD4	$10,850	$4,840	$6,010
MD5	$70	$70	$0
Stream Total	*$35,820*	*$18,690*	*$17,130*
S1	$277,960	$68,690	$209,270
S2	$1,691,810	$331,600	$1,360,210
S3	$85,470	$39,660	$45,810
S4	$3,980	$2,490	$1,490
Stream Total	*$2,059,220*	*$442,440*	*$1,616,780*
MU1	$624,000	$145,410	$478,590
MU2	$422,720	$67,980	$354,740
MU3	$261,670	$29,030	$232,640
MU4	$6,900	$1,090	$5,810
Stream Total	*$1,315,290*	*$243,510*	*$1,071,780*
Project Total	**$3,410,330**	**$704,640**	**$2,705,690**

Price level: FY2012, 4.0% Discount rate

5.7.4 Potential Acquisition of Structures

Structure acquisition (also known as buyout) is considered to be a nonstructural measure and is defined as the purchase by a public party (such as the local sponsor) and demolition of a flood-prone structure. Since the property is subsequently left undeveloped in perpetuity and may be converted for use in recreation or ecosystem restoration, acquisition is considered to be the most effective means to ensure that a structure will not accumulate additional losses from future flood events.

The preliminary assessment of acquisition structures was carried out as a supplemental exercise following the main analysis of the nonstructural alternative, to identify structures for which acquisition is a

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potentially cheaper option than the initially assigned nonstructural treatment. Potential buyout structures were identified via a comparison of the assigned treatment cost and the structure value including an adjustment factor to account for land costs and the difference between market value and depreciated structure value. The adjustment factor was developed from data obtained from the online real estate database www.zillow.com, which lists recent sale prices of residential properties. Sale prices were found for 11 properties also present in the HEC-FDA structure inventory, allowing direct comparisons of market and depreciated structure replacement values to be made. The average ratio of market value to depreciated structure replacement value was found to be 2.3, and this value was used as the aforementioned adjustment factor to convert the structure value to estimated market value, such that any structure (or group of structures covered by a single measure) with an assigned treatment cost / (depreciated structure replacement value x 2.3) ≥ 1 was assumed to be a potential candidate for acquisition. Using this criterion, a total of 10 structures were identified as potential acquisition candidates, all of which were assigned ringwalls in the initial nonstructural analysis. These structures are summarized in Table 20:

Table 20
Potential Acquisition Structures (Preliminary)

Reach	Street	Category	Ratio of Assigned Treatment Cost to Estimated Market Value
S2	Fayette Avenue	Industrial	2.46
S2	Waverly Avenue	Commercial	1.73
S2	Center Avenue	Residential	1.48
S2	Old White Plains Road	Apartment	1.39
S2	Madison Street	Commercial	1.37
MU1	Mamaroneck Avenue	Commercial	1.06
MU4	Winfield Avenue	Commercial	1.04
MU1	Elliott Avenue	Residential	1.02
MU2	1st Street	Residential	1.02
MU1	Mamaroneck Avenue	Commercial	1.00

FY 2012 Price Level

More detailed descriptions of each structure (i.e. full addresses) which would allow these structures to be publicly identified have not been included in Table N3, since this is very much a preliminary assessment and is subject to significant limitations and uncertainties, particularly regarding the adjustment factor used in the value comparison. Strictly speaking, the buyout value for residential structures must be based on the market value of a structure in a flood-free condition, and since the only properties for which price data was readily available for the calculation of the adjustment factor were in the floodplain, the current factor may therefore be an underestimate. The current adjustment factor is also possibly invalid for non-residential structures since it was derived solely from residential properties and does not account for additional factors such as severance costs which must be accounted for in the acquisition process for commercial properties.

5.8 Alternative 8

5.8.1 Description

Alternative 8 was proposed by NYSDEC and Westchester County and consists of a combination of detention areas, the realignment of confluence and bridge removal and/or replacement. The two areas identified for possible detention are the Mamaroneck Reservoir and Sheldrake Lake/Larchmont Reservoir. For the Mamaroneck Reservoir the plan includes the removal of sediment accumulation near Mamaroneck Avenue Bridge, a major cause of ineffective flows or dead storage within Mamaroneck Reservoir. The new slope in this area is 0.0015ft/ft. In order to maximize storage, allowing low flow to go through without filling Water Works Dam and Mamaroneck Reservoir, a new lower level outlet design is required. For the existing Sheldrake Lake/Larchmont Reservoir, the plan includes dredging and sediment removal. This adds approximately 85.4 million gallons of volume capacity, approximately a 50% increase in the reservoir volume. The dam will require an additional 30in diameter pipe below existing outlet and 5ft above the reservoir lowest bottom elevation. The last component of the alternatives is bridge Modification and/or removal. The Ward and Winfield Avenue Bridges were completely removed as well as the Glendale Ave abutments (Road to No-where). The Halstead Avenue, Valley Place (Anita Lane), Hillside Avenue and Jefferson Avenue Bridges were modified. The confluence was re-aligned and Station Plaza Bridge was aligned with the Rail Road and Halstead Ave Bridges.

5.8.2 Alternative 8 Cost Estimate

ACCT#	CWBS FEATURE	**Alt 8**
02	RELOCATIONS	$256,498
08	ROADS, RAILROADS AND BRIDGES	$26,802,230
09	CHANNELS AND CANALS	$32,929,886
11	LEVEES AND FLOODWALLS	$12,650
12	FLOODWAY CONTROL & DIV STR	$0
16	ENVIRONMENTAL MITIGATION	$1,347,892
	TOTAL CONSTRUCTION COST	$61,349,156
01	LANDS & DAMAGES	$2,534,882
30	ENGINEERING & DESIGN	$9,204,846
31	CONSTRUCTION MANAGEMENT	$4,907,933
	TOTAL FIRST COST	**$77,996,817**
	IDC	$4,638,842
	TOTAL INVESTMENT COST	**$82,635,659**
	ANNUAL COST	$3,846,706
	O&M	$306,800
	TOTAL NED ANNUAL COST	**$4,153,506**

FY 2012 Price Level, 4% Interest Rate

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5.8.3 Residual Damages and Benefits

Using HEC-FDA, Average Annual Damages were calculated for the base year and future years with Alternative 8 in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2012 fiscal year USACE project evaluation and formulation discount rate of 4.0%. A summary of equivalent annual damages and benefits for Alternative 8 is presented in Table 21. A summary of all benefits arising from the implementation of Alternative 8 and the resulting benefit-cost ratio is presented in Section 6.0.

Table 21
Summary of Damages and Benefits for Alternative 8

Reach	Damages		Damage Reduction Benefits
	Without-Project	With Alternative 8	
MD1	$10,350	$2,030	$8,320
MD2	$1,110	$720	$390
MD3	$13,440	$3,480	$9,960
MD4	$10,850	$1,990	$8,860
MD5	$70	$0	$70
Stream Total	*$35,820*	*$8,220*	*$27,600*
S1	$277,960	$63,990	$213,970
S2	$1,691,810	$491,530	$1,200,280
S3	$85,470	$27,230	$58,240
S4	$3,980	$990	$2,990
Stream Total	*$2,059,220*	*$583,740*	*$1,475,480*
MU1	$624,000	$145,090	$478,910
MU2	$422,720	$229,490	$193,230
MU3	$261,670	$169,020	$92,650
MU4	$6,900	$470	$6,430
Stream Total	*$1,315,290*	*$544,070*	*$771,220*
Project Total	**$3,410,330**	**$1,136,030**	**$2,274,300**

Price level: FY 2012, 4.0% Discount rate

6.0 Summary of Screening Benefits and BCRs

A summary of all damages, benefits, costs, and subsequent benefit-cost ratios for all structural and nonstructural plans evaluated for the Mamaroneck, NY study area is presented in Table 22.

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Table 22

Summary of Damages, Benefits, and BCRs

Alternative	Stream/Benefit Source	Annual Flood Damages		Annual Benefits	Total Investment Cost	Total Annual cost	Net Excess Benefits	BCR
		Without Project	With Project					
Alt 1	Mamaroneck D/S	$35,820	$12,210	$23,610				
	Sheldrake	$2,059,220	$325,890	$1,733,330				
	Mamaroneck U/S	$1,315,290	$397,620	$917,670				
	Pre Base Year	N/A	N/A	$0				
	Bridge Replacement	N/A	N/A	$553,300				
	Emergency	$94,190	$30,320	$63,870				
	Total	*$3,410,330*	*$735,720*	*$3,291,780*	*$54,434,000*	*$2,724,300*	*$567,500*	***1.2***
Alt 2	Mamaroneck D/S	$35,820	$13,030	$22,790				
	Sheldrake	$2,059,220	$367,720	$1,691,500				
	Mamaroneck U/S	$1,315,290	$89,350	$1,225,940				
	Pre Base Year	N/A	N/A	$153,230				
	Bridge Replacement	N/A	N/A	$675,000				
	Emergency	$94,190	$22,980	$71,210				
	Total	*$3,410,330*	*$470,100*	*$3,839,670*	*$72,705,000*	*$3,625,400*	*$214,300*	***1.1***
Alt 3	Mamaroneck D/S	$35,820	$13,280	$22,540				
	Sheldrake	$2,059,220	$37,680	$2,021,540				
	Mamaroneck U/S	$1,315,290	$33,480	$1,281,810				
	Pre Base Year	N/A	N/A	$312,590				
	Bridge Replacement	N/A	N/A	$683,600				
	Emergency	$94,190	$12,330	$81,860				
	Total	*$3,410,330*	*$84,440*	*$4,403,940*	*$95,961,000*	*$4,772,100*	*-$368,200*	***0.9***
Alt 4	Mamaroneck D/S	$35,820	$8,030	$27,790				
	Sheldrake	$2,059,220	$12,700	$2,046,520				

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Table 22

Summary of Damages, Benefits, and BCRs

Alternative	Stream/Benefit Source	Annual Flood Damages		Annual Benefits	Total Investment Cost	Total Annual cost	Net Excess Benefits	BCR
		Without Project	With Project					
Alt 4 (Cont.)	Mamaroneck U/S	$1,315,290	$56,340	$1,258,950				
	Pre Base Year	N/A	N/A	$478,330				
	Bridge Replacement	N/A	N/A	$684,800				
	Emergency	$94,190	$12,130	$82,060				
	Total	*$3,410,330*	*$77,070*	*$4,578,450*	*$154,481,000*	*$7,715,400*	*-$3,137,000*	***0.6***
Alt 5	Mamaroneck D/S	$35,820	$7,600	$28,220				
	Sheldrake	$2,059,220	$93,730	$1,965,490				
	Mamaroneck U/S	$1,315,290	$58,260	$1,257,030				
	Pre Base Year	N/A	N/A	$153,230				
	Bridge Replacement	N/A	N/A	$266,600				
	Emergency	$94,190	$14,410	$79,780				
	Total	*$3,410,330*	*$159,590*	*$3,750,350*	*$91,151,000*	*$4,529,300*	*-$779,000*	***0.8***
Alt 6 Nonstructural	Mamaroneck D/S	$35,820	$18,690	$17,130				
	Sheldrake	$2,059,220	$442,440	$1,616,780				
	Mamaroneck U/S	$1,315,290	$243,510	$1,071,780				
	Total	*$3,410,330*	*$704,640*	*$2,705,690*	*$86,082,000*	*$4,007,100*	*-$1,301,400*	***0.7***
Alt 8	Mamaroneck D/S	$35,820	$8,220	$27,600				
	Sheldrake	$2,059,220	$583,740	$1,475,480				
	Mamaroneck U/S	$1,315,290	$544,070	$771,220				
	Pre Base Year	N/A	N/A	$68,340				
	Bridge Replacement	N/A	N/A	$530,100				
	Emergency	$94,190	$41,380	$52,810				
	Total	*$3,410,330*	*$1,136,030*	*$2,925,550*	*$79,178,000*	*$3,979,300*	*-$1,053,800*	***0.7***

Price level: FY 2012, 4.0% Discount rate

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6.1 Project Performance and Risk Analysis

This study has been conducted in accordance with ER 1105-2-101, "Risk Analysis for Flood Damage Reduction Studies (USACE, January 3, 2006), which stipulates that the risk analysis for a flood protection project should quantify the performance of all alternatives and evaluate the residual risk, including the consequences of the project's capacity exceedance. In addition to the basic economic performance of a project, the guidance stipulates that the engineering performance of the project is to be reported in terms of:

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

The economic performance of all analyzed alternatives has been computed by HEC-FDA and the results are presented in Table 1, in a format consistent with example tables given in ER 1105-2-101 (note that Table 23 includes only those damages modeled by HEC-FDA, and does not include the additional benefits outlined in Section 4.1.1.6, which have been calculated separately):

Table 23
Expected and Probabilistic Values of Structure/Contents Damage Reduced by Alternative

Alternative	Equivalent Annual Damage			Probability that Damage Reduced Exceeds the Indicated Values		
	Without Project	With Project	Damage Reduced	75%	50%	25%
1	$3,410,000	$736,000	$2,675,000	$1,675,000	$2,457,000	$3,450,000
2	$3,410,000	$470,000	$2,940,000	$1,851,000	$2,710,000	$3,792,000
3	$3,410,000	$84,000	$3,326,000	$2,014,000	$3,010,000	$4,311,000
4	$3,410,000	$77,000	$3,333,000	$2,029,000	$3,031,000	$4,344,000
5	$3,410,000	$160,000	$3,251,000	$1,988,000	$2,956,000	$4,206,000
6	$3,410,000	$705,000	$2,706,000	$1,759,000	$2,529,000	$3,489,000
8	$3,410,000	$1,136,000	$2,274,000	$1,471,000	$2,115,000	$2,912,000

FY 2012 Price Level, 4% Interest Rate

The annual exceedance probability of a project is the likelihood that a target elevation is exceeded by flood waters in any year and can be considered as an indication of the level of protection provided by the alternative. The target elevation is the point at which significant damage is incurred in the with-project condition, and in line with current practice the significant damage elevation was defined as the water surface elevation which results in damages equal to 5% of damages incurred by the 1% annual chance exceedance event ("100-year" event) in the without-project condition.

The target stage derived for each reach was used in HEC-FDA to calculate the base year median and expected Annual Exceedance Probability (AEP) for every evaluated alternative, as presented in Table 24.

Table 24

Annual Exceedance Probability of Target Stage (Years)

Reach	Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5		Alternative 6		Alternative 8	
	Median	Expected	Median	Expected	Median	Expected	Median	Expected	Median	Expected	Median	Expected	Median	Expected
MD1	9	5	8	5	9	5	16	6	8	5	370	196	32	7
MD2	63	51	57	47	56	45	86	68	33	28	233	167	34	25
MD3	250	172	227	164	213	147	227	172	233	147	185	139	53	38
MD4	179	128	161	122	263	192	189	147	303	200	164	125	61	44
MD5	147	105	135	100	270	179	182	139	345	208	149	119	42	31
S1	76	56	69	53	152	109	88	82	88	63	167	123	37	26
S2	34	28	33	27	270	196	>500	>500	145	95	172	125	32	19
S3	7	5	7	5	100	76	357	333	78	55	192	125	24	14
S4	6	5	6	5	57	41	81	53	49	35	185	122	25	16
MU1	52	40	46	37	111	89	60	47	55	43	169	132	19	16
MU2	7	7	74	60	101	82	91	72	92	72	208	154	8	6
MU3	4	4	82	71	127	102	116	92	116	92	167	133	7	6
MU4	3	3	11	10	11	10	11	10	11	10	333	250	29	26

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The median value reflects the basic as-designed performance of the alternative without the application of uncertainty to the basic discharge-frequency and stage-discharge functions, while the expected value is computed from the results of the Monte Carlo simulations which take into account uncertainty in hydrologic/hydraulic functions and project features such as diversion structures. Hence the difference between the two is an indication of the uncertainty associated with the project performance

The long-term risk of exceedance is the probability that the design stage will be exceeded at least once in the specified durations of 10, 30, and 50 years, and the conditional non-exceedance probability measures the likelihood that the project will not be exceeded by a specified hydrological event. For this analysis the base year conditional non-exceedance probability has been computed for each alternative for the 10%, 4%, 2%, and 1% events (10-, 25-, 50-, and 100-year floods). For simplicity and brevity these two indicators of project performance and residual risk have been presented in Table 25 only for Alternative 1, which is the tentatively recommended alternative, based on the comparison of benefit-cost ratios in Table 25.

Table 25
Project Performance Analysis: Alternative 1

Reach	Long Term Exceedance Probability			Conditional Non-Exceedance Probability			
	10 Years	30 Years	50 Years	10%	4%	2%	1%
MD1	88%	100%	100%	53%	24%	11%	4%
MD2	18%	45%	63%	100%	90%	60%	31%
MD3	6%	16%	25%	100%	100%	96%	81%
MD4	8%	21%	32%	100%	100%	92%	72%
MD5	9%	25%	38%	100%	99%	89%	65%
S1	17%	42%	60%	100%	89%	63%	42%
S2	31%	67%	84%	97%	61%	36%	21%
S3	87%	100%	100%	37%	8%	3%	1%
S4	91%	100%	100%	27%	3%	9%	0%
MU1	23%	54%	72%	100%	83%	49%	18%
MU2	80%	99%	100%	32%	4%	1%	0%
MU3	96%	100%	100%	7%	0%	0%	0%
MU4	97%	100%	100%	2%	0%	0%	0%

7.0 Optimization of the National Economic Development Plan

7.1 Identification of the National Economic Development Plan

Following evaluation of the initial array of alternatives, the National Economic Development plan was identified. Alternative 1 was demonstrated to be the plan that maximizes net benefits, and is therefore

the National Economic Development Plan. During consultation with the local sponsor, the project delivery team evaluated optimization of the plan to ensure the scale addressed the greatest possible portion of the study area. This optimization generated four scales of Alternative 1, identified as 1S, 1M, 1L, and 1F. These scales were developed to include increasing lengths of channel work.

Table 26 presents the costs for each scale of alternative. Table 27 compares the benefits to the costs and indicates that the plan that optimizes the annual net benefits is Alternative 1F. Alternative 1L shows negative annual net benefits and therefore was dropped from further analysis and consideration. However, Alternative 1M, provides a higher level of flood risk management than Alternative 1F and 1S and was be retained for further consideration. Because Alternative 1S includes elements of Alternative 1F (including the non-structural solution in the Harbor Heights reach whereas Alternative 1M includes channelization in the Harbor Heights reach), any cost refinement and/or benefit refinement applied to Alternative 1S would also apply to Alternative 1F, proportionately. Therefore, further cost refinement was applied to Alternative 1M and 1F only. This cost refinement was applied to Alternative 1S to ensure the appropriate identification of the NED Plan. As a result, Alternative 1M and Alternative 1F were retained for further analysis.

Table 26 Cost Summary of Scales of NED Plan

ACCT#	CWBS FEATURE	Alt 1S	Alt 1M	Alt 1L	Alt 1F
02	RELOCATIONS	$663,151	$710,516	$670,234	$663,151
08	ROADS, RAILROADS AND BRIDGES	$11,450,852	$13,010,363	$29,184,434	$13,010,363
09	CHANNELS AND CANALS	$10,358,374	$12,796,645	$11,976,202	$10,358,374
11	LEVEES AND FLOODWALLS	$6,371,782	$7,254,497	$13,586,641	$6,371,782
12	FLOODWAY CONTROL & DIV STR				
16	ENVIRONMENTAL MITIGATION	$1,800,000	$2,280,000	$1,800,000	$1,800,000
	TOTAL CONSTRUCTION COST	$30,644,159	$36,052,021	$58,536,865	$33,523,024
01	LANDS & DAMAGES	$9,693,750	$11,787,500	$9,693,750	$9,693,750
30	ENGINEERING & DESIGN	$4,597,269	$5,408,562	$8,781,762	$5,029,159
31	CONSTRUCTION MANAGEMENT	$2,451,533	$2,884,162	$4,682,949	$2,681,842
	TOTAL FIRST COST	**$47,386,711**	**$56,132,245**	**$81,695,326**	**$50,927,775**
	IDC	$2,638,983	$3,126,022	$4,549,638	$2,836,182
	TOTAL INVESTMENT COST	**$50,025,694**	**$59,258,267**	**$86,244,964**	**$53,763,957**
	ANNUAL COST	$2,328,706	$2,758,484	$4,014,720	$2,502,723
	O&M	$153,300	$180,300	$292,700	$167,700
	MAJOR REHAB/REPLACEMENT	$0	$0	$0	$0
	TOTAL NED ANNUAL COST	**$2,482,006**	**$2,938,784**	**$4,307,420**	**$2,670,423**

FY 2012 Price Level, 4% Interest Rate

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Table 27: Comparison of Scales of Alternative 1

Plan	Stream	Without Project Damages	With Project Damages	Annual Benefits	Total Investment Cost	Total Annual Cost	Net Excess Benefits	BCR
Alt 1S	Mamaroneck DS	$35,820	$7,750	$28,070				
	Sheldrake	$2,059,220	$339,810	$1,719,410				
	Mamaroneck US	$1,315,290	$420,980	$894,310				
	Pre Base Year	N/A	N/A					
	Bridge Replacement	N/A	N/A	$357,700				
	Emergency	$94,185	$31,225	$62,960				
	Total	*$3,410,330*	*$799,765*	*$3,050,350*	*$50,026,000*	*$2,482,000*	*$568,350*	*1.23*
Alt 1M	Mamaroneck DS	$35,820	$5,620	$30,200				
	Sheldrake	$2,059,220	$173,100	$1,886,120				
	Mamaroneck US	$1,315,290	$246,400	$1,068,890				
	Pre Base Year	N/A	N/A					
	Bridge Replacement	N/A	N/A	$357,700				
	Emergency	$94,185	$21,741	$72,444				
	Total	*$3,410,330*	*$446,861*	*$3,403,254*	*$59,258,000*	*$2,938,800*	*$465,454*	*1.16*
Alt 1L	Mamaroneck DS	$35,820	$5,670	$30,150				
	Sheldrake	$2,059,220	$203,110	$1,856,110				
	Mamaroneck US	$1,315,290	$121,220	$1,194,070				
	Pre Base Year	N/A	N/A					
	Bridge Replacement	N/A	N/A	$874,300				
	Emergency	$94,185	$19,114	$75,071				
	Total	*$3,410,330*	*$349,114*	*$4,000,301*	*$86,245,000*	*$4,307,400*	*(-307,099)*	*.92*
Alt 1F	Mamaroneck DS	$35,820	$5,870	$29,950				
	Sheldrake	$2,059,220	$254,180	$1,805,040				
	Mamaroneck US	$1,315,290	$272,660	$1,042,630				
	Pre Base Year	N/A	N/A					
	Bridge Replacement	N/A	N/A	$357,700				
	Emergency	$94,185	$24,712	$62,960				
	Total	*$3,410,330*	*$557,422*	*$3,298,279*	*$53,763,957*	*$2,670,423*	***$627,856***	*1.24*

FY 2012 Price Level, 4% Interest Rate

7.2 Value Engineering Recommendations

Recommended changes to the design were suggested during the value engineering phase. The recommended change substituted an alternate relief culvert at Station Plaza. This eliminated the need to remove and replace Station Plaza Bridge. Functionally, the culvert provides the same flood risk reduction

as the original alternative with bridge work instead of a culvert. As a result, the only change to the benefit cost comparison of the NED plan is that advanced bridge replacement benefits would be reduced to reflect that no changes are made to Station Plaza Bridge. The plan as amended results in a benefit cost ratio greater than unity, and are economically justified.

7.3 Incremental Justification

The total cost of channel modification in Alternative 1M for the Harbor Heights reach is approximately $6.4M with a total annual equivalent cost of approximately $322K and annual benefits of only $147K for a BCR of 0.46.

The total cost for the non-structural solution in Alternative 1F (currently the NED plan) for the Harbor Heights reach is approximately $2.4M with a total annual equivalent cost of approximately $114,100 and annual benefits of $154,700 for a BCR of 1.36.

Based on the above analysis in Step 1 and step 2, channel modification is not incrementally justified and only provides a 5 year "level of protection. Therefore, a new Alternative 1 was developed during the optimization, Alternative 1Z. Alternative 1Z is exactly the same as alternative 1M below the Harbor Heights upstream Mamaroneck River reach. In the Harbor Heights reach (upper Mamaroneck) channel modification has been replaced with the non-structural elevation of eight residential structures.

Table 28 provides the updated cost and benefit analysis including Alternative 1Z comparison to Alternative 1M and 1F. The alternative costs have been updated for Alternative 1F and 1M to include post-ATR refinements and preliminary CSRA contingencies. Based on this refined analysis and revision, Alternative 1Z is the updated NED Plan and the recommended plan for implementation.

It was determined that the cost of Alternative 1S would increase proportionately with Alternative 1M and 1F, but Alternative 1S does not include the Harbor Heights reach at all. Therefore, Alternative 1S would not reap the benefits of the increase of annual net benefits (but would reap the cost increases noted in 1F and 1M) and therefore a total decrease in annual net benefits, Alternative 1S annual net benefits will change relative to Alternative 1F. Alternative 1F is identical to Alternative 1S with the exception of Harbor Heights. Alternative 1S does not include any flood works in Harbor Heights. Therefore, the Annual Net Benefits for Alternative 1S will always remain below those of Alternative 1F and therefore below Alternative 1Z, the NED Plan. Alternative 1S was removed from further consideration.

7.4 Final adjustments to benefit pool.

The final cost and benefit comparison of the two scales of plan changed in two ways. The structure inventory was updated to reflect the change in price level of the final two plans under consideration. The updated benefits are shown in the final benefit cost comparison table. Structures and content values were adjusted to the current price level with the changed with RSMeans indices, and the bridge benefits were adjusted with the CWBS Indices for Feature Code 08, Roads, Railroads and Bridges.

7.4.1 Advanced wall replacement benefits

Advanced wall replacement benefits were added to the benefit pool upon final assessment of the design team during the optimization phase. The hydrologic data generated to assess with and without project conditions assumes the stability of the floodwalls is maintained throughout the 50 year evaluation period. The final assessment of the engineering team, and the final cost estimates which resulted, reflect that the existing walls will not withstand the channel work required. The final plans require replacement of the existing walls, and advanced wall replacement benefits are calculated as an avoided cost in the near future.

The existing walls were constructed in the 1930's as WPA efforts and have not been repaired. They are constructed of rocks with both dry stack and mortar stack and have already failed in some places. The engineers confirm that without a federal project, the walls would require replacement. There is no active budgeting, planning or design underway to replace the wall. Since it was determined that the walls would need to be replaced in the without project condition in year 2020. This benefit is comparable to the advanced bridge replacement benefits described earlier in Section 4.1.1.6.3. If a floodwall is replaced as the result of a flood control project, a benefit can be claimed to at least partially offset the cost of bridge replacement. Advanced wall replacement benefits are quantified for the period that the useful life of the floodwall is extended by the project. Derivation of the wall replacement benefits is presented in Table 28.

Table 28 Wall Replacement Benefit Computation	NED
Cost of New Wall	3,361,000
Life of new wall	50
Remaining life of existing wall	4
Extended life of the wall	46
Discount Rate	0.03
Capital Recovery Rate	0.04
Annual Cost of New Wall	140,100
PW annuity for extended life	23
Benefits in year to be replaced	3,249,400
Single payment pw for replacement year	1
Present worth in year 1	2,845,400
Average annual benefit	118,600

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7.5 Updated Cost and Benefit Summaries of Optimized NED Plan

Significant time has elapsed since the initial formulation and cost and benefit calculations. Therefore, prior to refining the design for Alternative 1F and Alternative 1M, the economics for the plans were updated (also the costs were updated to incorporate the Value Engineering design modifications results to Alternative 1F and 1M). The cost summary of the optimized alternatives and the benefits comparisons are presented in October 2014 price level, and at the FY15 discount rate of 3.375%.

The cost and benefit comparison changed in two ways. The structure inventory was updated to reflect the change in price level and the updated benefits are shown in the final benefit cost comparison table. Structures and content values were adjusted to the current price level with the changed with RSMeans indices, and the bridge benefits were adjusted with the CWBS Indices for Feature Code 08, Roads, Railroads and Bridges. Advanced wall replacement benefits were added to the benefit pool upon final assessment of the design team during the optimization phase. The hydrologic data generated to assess with and without project conditions assumes the stability of the floodwalls is maintained throughout the 50 year evaluation period. The final assessment of the engineering team, and the final cost estimates which resulted, reflect that the existing walls will not withstand the channel work required. The final plan requires replacement of the existing walls, and advanced wall replacement benefits are calculated as an avoided cost in the near future, since it was determined that the walls would need to be replaced in the without project condition in year 2020. This benefit is comparable to the advanced bridge replacement benefits. If a floodwall is replaced as the result of a flood control project, a benefit can be claimed to at least partially offset the cost of bridge replacement. Advanced wall replacement benefits are quantified for the period that the useful life of the floodwall is extended by the project.

Based on the economic update, Alternative 1F still provides the maximum annual net benefits with a BCR of 1.21. Alternative 1M was also economically justified with a BCR of 1.17 and affording a higher level of protection. The comparison of these costs and benefits and project actions are presented in Tables 29 and 30.

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Table 29: Comparison of the Benefits and Costs of the 1F and 1M

Plan	Stream/Benefit Source	Flood Damages Without Project	Flood Damages With Project	Annual Benefits	Ratio	Updated Benefits	Total Investment Cost	Total Annual cost[2]	Net Excess Benefits	BCR
1M	Mamaroneck DS	$35,820	$5,620	$30,200	1.07	$32,222				
	Sheldrake	$2,059,220	$173,100	$1,886,120	1.07	$2,012,383				
	Mamaroneck US	$1,315,290	$246,400	$1,068,890	1.07	$1,140,445				
	Pre Base Year	N/A	N/A	$165,494	1.07	$176,573				
	Wall Replacement	N/A	N/A	$160,500	1.00	$160,500				
	Bridge Replacement	N/A	N/A	$119,900	1.06	$127,100				
	Emergency	$94,185	$21,741	$72,444	1.09	$78,891				
	Total	*$3,410,330*	*$446,861*	*$3,503,548*		*$3,728,114*	*$70,079,000*	*$3,181,000*	*547,100*	*1.17*
1F	Mamaroneck DS	$35,820	$5,870	$29,950	1.07	$31,955				
	Sheldrake	$2,059,220	$254,180	$1,805,040	1.07	$1,925,876				
	Mamaroneck US	$1,315,290	$272,660	$1,042,630	1.07	$1,112,427				
	Pre Base Year	N/A	N/A	$165,494	1.07	$176,573				
	Wall Replacement	N/A	N/A	$118,600	1.00	$118,600				
	Bridge Replacement	N/A	N/A	$119,900	1.06	$127,100				
	Emergency	$94,185	$24,712	$62,960	1.09	$68,563				
	Total	*$3,410,330*	*$557,422*	*$3,344,574*		*$3,561,093*	*$64,958,000*	*$2,951,000*	*610,100*	*1.21*

FY 2015 Price Level, 3.375% Interest Rate

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Table 30: Comparison of the Benefits and Costs of the 1F, 1M and 1Z

Project Plan	Total Project Cost	Total First Cost	Real Estate Cost	Harbor Heights	O&M	IDC	Annual Cost	Annual Benefits	Net Benefits	BCR
Alt 1M Channelization in Harbor Heights Reach	$70,021,000	$67,778,000	$6M	$6,481,232	$311,846	$2,243,720	$3,2,30,159	$3,581,438	$351,279	1.11
Alt 1Z non-structural in Harbor Heights Reach Alt 1F & 1M HYBRID PLAN	$64,212,440	$62,265,040	$4.9M	$2,429,725	$270,663	$1,947,396	2,946,861	$3,403,704	$456,843	1.16
Alt 1F Non-structural in Harbor Heights Reach	$64,772,400	$62,825,000	$4.9M	$2,429,725	$270,663	$1,947,396	$2,970,200	$3,368,217	$398,019	1.13

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7.4 Cost and Benefit Summary of the NED Plan

As noted in Section 4 of this appendix, significant time has elapsed since the initial formulation and cost and benefit calculations. HEC FDA model outputs of the initial formulation have not been updated for the first iteration of formulation for the initial screening of alternatives. The cost summary of the optimized alternatives and the NED and the benefits comparisons are presented in October 2015 price level, and at the current FY16 discount rate of 3.125%.

A final step of the optimization of Alternative 1, demonstrated that channel modification is not incrementally justified and only provides a 5 year "level of protection. Therefore, a new Alternative 1 was developed during the optimization of Alternative 1, Alternative 1Z. Alternative 1Z is exactly the same as Alternative 1M below the Harbor Heights upstream Mamaroneck River reach. However, the exception is that the Harbor Heights reach (Upper Mamaroneck) no longer includes channelization. Channel modification in Harbor Heights has been removed and the non-structural elevation of nine (9) homes (and a ring levee on the Sheldrake River) for the Harbor Heights reach has been added.

7.4.1 Cost Summary of the NED Plan

ACCT#	CWBS FEATURE	NED- Plan 1Z
02	RELOCATIONS	8,190,600
08	ROADS, RAILROADS AND BRIDGES	1,066,900
09	CHANNELS AND CANALS	38,850,300
12	FLOODWAY CONTROL & DIV STR	2,975,900
19	BUILDINGS, GROUNDS & UTILITIES	2,401,800
	TOTAL CONSTRUCTION COST	**54,013,500**
01	LANDS & DAMAGES	4,913,500
30	ENGINEERING & DESIGN	7,010,400
31	CONSTRUCTION MANAGEMENT	3,765,100
	TOTAL FIRST COST	**67,702,600**
	IDC	2,191,000
	TOTAL INVESTMENT COST	**$72,037,019**
	ANNUAL COST	$2,860,800
	O&M	$286,100
	TOTAL NED ANNUAL COST	**$3,146,900**

7.5 Final adjustments to benefit pool.

The final cost and benefit comparison of the two scales of plan changed in two ways. The structure inventory was updated to reflect the change in price level of the final two plans under consideration. The updated benefits are shown in the final benefit cost comparison table. Structures and content values were adjusted to the current price level with the changed with RSMeans indices, and the bridge benefits were adjusted with the CWBS Indices for Feature Code 08, Roads, Railroads and Bridges.

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7.6 Determination of Economic Justification

Alternative 1Z was demonstrated to provide the maximum net benefits and a BCR of 1.1, and therefore was identified as the National Economic Development plan. The comparison of these costs and benefits are presented in Table 31.

Table 31 Updated Comparison of the Benefits and Costs of the NED

Plan	Stream/Benefit Source	Flood Damages Without Project	Flood Damages With Project	Annual Benefits	Ratio	Updated Benefits	Total Investment Cost	Total Annual cost	Net Excess Benefits	BCR
1Z	Mamaroneck DS	$35,820	$5,620	$30,200	1.07	$32,222				
	Sheldrake	$2,059,220	$173,100	$1,886,120	1.07	$2,012,383				
	Mamaroneck US	$1,315,290	$246,400	$1,042,630	1.07	$1,147,914				
	Non-Structural			145,000	1.07	154,707				
	Wall Replacement	N/A	N/A	$118,600	1.00	$118,600				
	Bridge Replacement	N/A	N/A	$133,900	1.06	$142,497				
	Emergency			$62,960	1.09	$68,563				
	Total	*$3,410,330*	*$532,710*	*$3,306,380*		*$3,403,704*	*$71,893,100*	*$3,146,900*	*$256,800*	*1.1*

FY 2016 Price Level, 3.125% Interest Rate

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