Fire Island Inlet to Montauk Point, NY
Final General Reevaluation Report

FIRE ISLAND INLET
to
MONTAUK POINT
Reformulation Study

APPENDIX D

ECONOMIC BENEFITS

U.S. Army Corps of Engineers

New York District

February 2020

FIRE ISLAND TO MONTAUK POINT REFORMULATION STUDY – FINAL GRR

Appendix D

Economic Benefits

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The purpose of the Fire Island Inlet to Montauk Point (FIMP) Reformulation Study is to identify and evaluate long term solutions for storm damage reduction along the south shore of Long Island from Fire Island Inlet to Montauk Point.

The Fire Island Inlet to Montauk Point (FIMP) study area is located entirely in Suffolk County, Long Island, New York, along the Atlantic and bay shores of the towns of Babylon, Islip, Brookhaven, Southampton and East Hampton. The study area includes three estuarial bays: Great South Bay, Moriches Bay and Shinnecock Bay. These estuaries are connected to the Atlantic Ocean through Fire Island Inlet, Moriches Inlet, and Shinnecock Inlet, respectively, all of which are Federally-maintained navigation channels. The study area includes the ocean and bay shorelines, bays, inlets, barrier island beaches, the mainland, as well as suitable offshore borrow areas for possible beach nourishment and replenishment.

The goal of the plan formulating process is to identify alternatives that can optimize benefits through reducing damages to homes and other infrastructure located on both barrier islands and the mainland from coastal storms, while preserving and protecting human and ecological resources. The Reformulation Study reevaluates the 1960 Authorized Plan (which is based on House Document 1960) based on current study area conditions and in accordance with current Corps of Engineers policies. Along with the Reformulation Study, several other efforts have been performed under the envelope of the Reformulation effort. These include:

- Moriches Inlet to Shinnecock Inlet Interim Project (commonly referred to as the “Westhampton Interim Project”)
- Fire Island Inlet to Moriches Inlet Interim Project (“Fire Island Interim” project or FIIP)
- West of Shinnecock Inlet Interim Project (WOSI)
- Breach Contingency Plan (BCP)

As described in the GRR Main Report and Appendix E - Plan Formulation, the FIMP project must be mutually agreed to between the USACE and the Department of Interior. Extensive coordination of alternative plans have been completed and have resulted in a Tentative Federally Selected Plan (TFSP) as documented in Fire Island to Montauk Point Reformulation Study, Draft Formulation Report, May 2009. This appendix provides a description of the analysis methods used to calculate storm damage and benefits as presented in the Plan Formulation Appendix. This document also describes the updated results of the Recommended Plan (RP).

2 ECONOMIC BASE CONDITIONS

2.1 Data Sources

Economic data for the Reformulation Study was derived from a number of sources. The primary source was a structure database that gathered various attributes to characterize each structure in the study area up to approximate elevation 16 ft NGVD, including depreciated structure replacement value (DSRV). This database was developed through a comprehensive field surveys initiated in 1982 and updated with limited resurveys of existing and new development to allow development characteristics and structure values to be updated to 1 Oct 2015 conditions price level. Other sources of data include the 1980, 1990 and 2000 U.S. Censuses of Population, the Long Island State Park Commission (LISPC), the New York State Office of Parks, Recreation, and Historic Preservation (OPRHP), as well as reports from the Long Island Regional Planning Board (LIRPB) and Suffolk County Planning Department (SCPD).

The in-field survey recorded the construction material of building (e.g.; wood or masonry), usage, occupancy, number of stories, size, ground elevation, main floor elevation, low opening elevation, exterior material, map number, unique structure identification number, the type of basement, which town, and whether it was in a wave-impact zone. Buildings were inventoried up to approximately elevation 16 ft NGVD, considered the probable maximum extent of future inland flooding. Over 47,000 buildings along the south shore of Long Island, including both the barrier island and the mainland, were entered into the database. Depreciated structure replacement costs were determined for each of the buildings, based on the information collected. The National Geodetic Vertical Datum of 1929 (NGVD29) was used to compile the structure inventory and to develop the stage-probability relationships used in these analyses.

2.2 Demographics

2.2.1 Population

After World War II, tremendous housing development and population growth took place on Long Island. Much of this growth and development occurred before the implementation of the National Flood Insurance Program guidelines for local floodplain management. Between 1940 and 1970, the County's population increased by nearly 500 percent, with the greatest growth occurring between 1950 and 1960, when the population increased by 140 percent. Much of this post-war growth occurred in the low-lying bayfront areas along the South Shore, before the enactment of National Flood Insurance Program and related local floodplain management ordinances. There are over 19,000 buildings in the regulated flood hazard zone in the study area, of which more than 3,300 are located in areas potentially vulnerable to wave impacts.

The western towns of Babylon and Islip have experienced a leveling-off of population in the last 20 years, but in the less-developed eastern towns of Brookhaven and East Hampton, population has continued to grow. The County's population is projected to increase by 19% for the next two decades, with the greatest growth in the Town of Riverhead, followed in order by the Towns of Southampton, Southold, East Hampton, Shelter Island, and Brookhaven. Table 1 shows the population for each town in the study area according to the U.S. Censuses from 1940 to 2010.

The population of Suffolk County increased approximately 3% between 1980 and 1990, approximately 7% between 1990 and 2000, and 5% between 2000 and 2010.

Table 1 - Historic Population Trends

	1940	1950	1960	1970	1980	1990	2000	2010
Town of Babylon	24,297	45,556	142,309	204,256	203,483	202,940	211,471	213,603
Town of Islip	51,182	71,465	172,959	278,880	298,897	299,587	323,504	335,543
Town of Brookhaven	32,117	44,522	109,900	245,260	365,015	407,977	448,020	486,040
Town of Southampton	15,295	17,013	27,095	36,154	43,146	45,909	55,216	56,790
Town of East Hampton	6,529	6,325	8,827	10,980	14,029	16,132	19,647	21,457
Suffolk County	197,355	276,129	666,784	1,127,030	1,284,231	1,322,535	1,419,369	1,493,350
NY State	13,479,142	14,830,192	16,782,304	18,241,391	17,558,072	17,990,455	18,976,457	19,378,102

Source - U.S. Census, Long Island Power, "Current Population Estimates for Nassau and Suffolk Counties and the Rockaway Peninsula, 2005"

2.2.2 Income

As shown in Table 2, there is significant variation in the per capita income of the various study area towns. Per capita income in the study area is above the state average. In the study area towns, the median family income is higher than the median family income for the State of New York for 1990 and 2000.

Table 2 - Study Area Income Trends

Location	Per Capita Income	Median Family Income	Families below Poverty
New York State	$32,382	$70,670	11.7%
Suffolk County	$36,945	$100,652	4.6%
Town of Babylon	$31716	$91,340	5.3%
Town of Islip	$31,922	$94,144	4.2%
Town of Brookhaven	$34,581	$99,535	5.0%
Town of South Hampton	$44,847	$91,217	5.5%
Town of East Hampton	$48,386	$91,731	4.2%

Source: American Community Survey 2009-2013 5-year Estimate

2.3 Development

The bulk of the post-war building boom and drastic population growth on Long Island happened before the adoption of the National Flood Insurance Program (NFIP) and its restrictions on floodplain development. Consequently, much of the development in the study area does not meet NFIP regulations. Although new structures built after inception of the NFIP and adoption of local Flood Insurance Rate Maps (FIRM) are required to meet NFIP regulations, there is still the possibility of damage due to nonconformance to building regulations, damage to expendable elements such as breakaway walls, steps, docks, damage to vehicles, landscaping or other outside facilities; or from floods exceeding the regulated Base Flood Elevation (BFE).

With over 47,000 structures located below elevation 16 feet NGVD, there is extensive development in the study area. These structures represent over $14 billion in structure value alone with the majority of development located in the western portion of the study area.

The number of housing units continued to increase throughout the study area, with higher rates of the development occurring towards the eastern end of the study area. When compared nationally, Long Island has a significantly high percentage of owner-occupied housing units, ranking second highest of the 75 largest metropolitan areas

Median housing values for census tracts comprising the study area vary widely with higher values reported in the eastern end of the study area and lower housing values in the western end. Housing values in the study area soared in the 1980s and again in the late 1990s and early 2000s.

2.4 Land Use

In general, there is more vacant land toward the eastern part of the island. In the Town of Babylon, for example, only about 6% of the land is categorized as vacant, where approximately 50% of the land in the Towns of East Hampton and Southampton is vacant. As shown in Table 3, the eastern towns, including Southampton and East Hampton, have a significant portion of land use devoted to agriculture and a relatively small portion devoted to commercial/industrial use. To the west, near the Nassau County border, there is very little agricultural use and more commercial and/or industrial use. As of 2002, there were approximately 34,000 acres classified as farmland in Suffolk County, generating nearly $150 million dollars a year in revenue. However, the number of acres in agricultural production is in decline under the pressures from new residential constructions and urban sprawl.

Table 3 - Study Area Land Use Summary

Location	Total Acres	Percent Residential (%)				Percent Other Uses (%)			
		Low Density	Medium Density	High Density	Total	Commercial/ Industrial/ Institutional	Recreation	Agriculture	Other
Town of Babylon (2007)	35,950	0.3	17.2	15.5	33.0	13.9	31.7	0	21.4
Village of Amityville	1,064	0.9	44.9	20.9	66.7	26.9	4.0	0	2.4
Village of Babylon	1,187	2.1	42.2	28.2	72.5	13.8	10.9	0	2.8
Village of Lindenhurst	1,790	0.1	31.2	45.7	77.1	16.9	3.1	0	2.9
Town of Islip (2007)	68,110	2.9	31.6	6.4	40.9	14.7	21.5	0.1	22.8
Village of Brightwaters	421	2.4	81.2	4.2	87.8	5.3	4.4	0	2.5
Village of Ocean Beach	73	0	6.1	74.9	81	10.4	4.8	0	3.8
Village of Saltaire	140	0	35.3	22.4	57.8	2.1	30	0	10.1
Town of Brookhaven (2007)	166,598	8.2	24.1	3.8	36.1	11.7	25.8	2.4	24
Village of Patchogue	1,222	3.6	39.7	19.2	62.5	22.1	8	0	7.4
Town of Southampton (1999)	88,963	17.1	12.3	0.7	30	5.9	27	8.9	28.2
Town of East Hampton (1999)	46,996	16.9	12.3	0.9	30.1	2.5	31.6	3.2	32.6

Source: 1999 Existing Land Use Inventory – Eastern Suffolk County, Suffolk County Department of Planning, July 2000; and Suffolk County Department of Planning, 2007 personal communication

2.4.1 Accessibility

The study area has a large network of heavily traveled roadways. A number of highways provide east-west access including the Long Island Expressway (Interstate 495), the Northern State Parkway, the Southern State Parkway, Sunrise Highway (Route 27) and the Montauk Highway (route 27A/27). The eastern end of the study area has few major north-south corridors. However, further to the west, the William Floyd Parkway provides a major north-south route across Long Island and connects Smith Point County Park on Fire Island with the mainland. At the western end of the study area on Jones Island, Ocean Parkway provides east-west access along the Island and connects at its eastern end to the Robert Moses Causeway and the Sagtikos State parkway and at its western end with the Wantagh and Meadowbrook Parkways providing additional north-south routes.

Other large north-south thoroughfares include those listed below.

- Moriches-Riverhead Road (Route 51) extends from Riverhead southwest to East Moriches and connects the Sunrise Highway and Montauk Highway.
- Westhampton Road (Route 111) connects the Long Island Expressway to the Sunrise Highway.
- Nicholls Road (Route 97) connects the Long Island Expressway, Sunrise Highway and Montauk Highway.
- Veterans Memorial Highway (Route 454) provides access from the Long Island Expressway to the Sunrise Highway.
- Route 110 connects the Long Island Expressway, Southern State Parkway and Montauk Highway

To the east of the Village of Southampton, the Montauk Highway (Route 27) provides the only major east-west roadway and is therefore a crucial transportation corridor in terms of its impact from potential flooding. To the west of the Village of Southampton, Dune Road provides east-west access along the barrier island and connects to the mainland shore by bridge. Between the Village of Southampton and Shinnecock Inlet, Dune Road provides east-west access from the barrier island via Halsey Neck Road, Cooper Neck Lane, First Neck Lane and South Main Street. From Shinnecock Inlet westward to Moriches Inlet (near Cupsogue County Park), Dune Road also provides east-west access along the barrier island. Between Moriches and Shinnecock Inlets, Dune Road is connected to the mainland via the Ponquogue Bridge in Ponquogue, by Post Lane in Quogue, and by Beach Lane and Jessup Lane in Westhampton Beach.

On Fire Island there are no roadways except at its eastern and western most ends. At the western end of Fire Island, the Robert Moses Causeway connects Robert Moses State Park to Jones Island and to the mainland shore and at the eastern end of Fire Island the William Floyd Parkway connects Smith Point County Park to the mainland shore. Access to the remainder of Fire Island is limited to commercial ferry service from Bay Shore, Sayville and Patchogue and private boat access. Vehicles are only allowed to drive on the beach with special permits issued by the Fire Island National Seashore (FIIS). The barrier island beachfront provides a critical link for municipal vehicles such as the local school bus and fire departments, as well as for building contractors vehicles, equipment, and supplies. There are also Sportsman’s Vehicle Permits available to allow recreational vehicles to drive at certain times on designated portions of FIIS.

Figure 1 - Major Access Roads connecting the Study Area

In addition to these roadways, the Montauk Branch of the Long Island Railroad (LIRR) provides passenger railroad service from Montauk Point to New York City via Jamaica, New York.

Traffic congestion on Long Island has increased over the years due to increases in population and the number of drivers. Suffolk County's population is geographically dispersed, making intra-county transportation via mass transit difficult and traffic congestion a major problem (LIRPB, 1997). Furthermore, despite major transportation corridors along the south shore of Long Island, a number of the villages are only connected to major roadways via local roadways of lesser capacity.

Flooding and washout of roadways may create nuisance or serious emergency conditions. Small storms may create local flooding requiring rerouting of local traffic. Bridges over tidal creeks may have to be temporarily closed due to the danger of high flood waters causing washout. During smaller storms rerouting of traffic can occur but for larger storms alternative routes may not exist. For example, during the northeaster of 1992 residents of Westhampton Beach had to be evacuated in amphibious vehicles due to severe flooding. Some of the study area villages are connected to the mainland via low lying local roadways which may become flooded or washed out. When this occurs, all access to these communities is lost. In addition to the flooding and washout of local roadways, Montauk Highway, which is a major east-west thoroughfare, has low spots at various locations and is subject to closure.

2.4.2 Recreation

The South Shore of Long Island has extensive recreational assets. The beaches along the Atlantic coast provide an exceptional range of recreation opportunities that are used by millions of visitors annually. These waterfront resources include the Fire Island National Seashore (FIIS), Robert Moses State Park, Smith Point County Park, and a number of municipal beaches. The recreational activities offered include swimming, picnicking, surfing, and fishing. Users come from local communities, the larger metropolitan region, as well as from other states and abroad.

The beaches are located on barrier islands as at Fire Island National Seashore and mainland areas, such as Main Town Beach in the Montauk area of the Town of East Hampton. The beaches are the major component of the area's status as a tourist destination. Depending on the specific location, visitors arrive at the public beaches via automobile, bus, public ferries, train, bicycle, or private boat. The most heavily visited facilities, Robert Moses State Park and Smith Point County Park, have direct automobile access from the mainland of Long Island. Other beaches, such as Ocean Beach and the Watch Hill Visitor's Center on Fire Island, can only be accessed by ferry. In 2006, the National Park Service recorded 636,030 recreational visits to FIIS facilities and areas. For the same year, there were 1.6 million ferry passenger visits to Fire Island destinations (Bureau of Transportation Statistics, 2006). Visits range in length from day-trips to trips of a week or longer. Much of Fire Island's recreational facilities and developed areas are accessed via passenger ferry since cars are not allowed without a permit and there are very limited roadways on the developed portions of the island. Table 4 provides a summary of Ferry trips to Fire Island broken down by ferry operator and origin.

Table 4 - Ferry Travel to Fire Island

Operator	Origin	Destinations	Total Passengers (2006)*
Fire Island Ferries	Bay Shore	Kismet, Saltaire, Fair Harbor, Dunewood, Atlantique, Ocean Beach, Seaview, & Ocean Bay Park	980,671
Sayville Ferry Service	Sayville	Cherry Grove, Fire Island Pines, Sailors Haven/Sunken Forest, Talisman/Barrett Beach, Water Island	469,000
Davis Park Ferry Company	Patchogue	Watch Hill & Davis Park	152,753
		Total Ferry Trips to Fire Island	**1.6 million**

* 2006 data is the most recent available data at BTS

In 2014, the nine State-operated parks along Suffolk County's south shore received over 7.3 million visitors. As shown in Table 5, overall State park attendance increased from 1986 to 1996, but declined in the period from 1996 to 2007, and increased slightly from 2007 to 2014. In addition, there are also numerous village, town and county parks along the shore which provide swimming, boating and fishing access as well as hiking and scenic opportunities.

Table 5 - Summary of State Park Use

Park	1986 Attendance	1996 Attendance	2007 Attendance	2014 Attendance
Captree	1,658,639	1,710,027	1,261,871	1,124,776
Heckscher	1,006,700	1,374,900	757,503	982,530
Hither Hills	299,022	363,445	347,795	425,642
Montauk Point	586,560	875,975	870,595	816,970
Napeague	Unrecorded	181,195	190,820	65,985
Robert Moses	2,729,472	3,024,148	3,427,551	3,477,086

Source: Long Island State Park Commission, 1997, 2007 (note: no attendance figures are kept for Gilgo State Park)

The Long Island State Park Commission, established in 1924, planned and landscaped the vehicle expressway system to the same high standard as all the island's parks. The parkway system was designed to furnish access to individual parks from congested centers of population, such as New York City's boroughs, to outlying Long Island without interference from commercial traffic, and via scenic arteries of rapid travel.

In addition to the state parks in the study area, there are several parks operated by Suffolk County. Table 6 shows 2007 park attendance for county parks in the study area. Also, Jones Beach, operated by Nassau County located to the west of the study area, has had annual attendance of 6.4 million people in 2007 and is a significant recreational resource for the larger region. (New York State Office of Parks, Recreation, and Historic Preservation, NYSOPRHP, 2007).

Table 6 - Summary of County Park Use

Park	2007 Attendance
Cupsogue Beach, Westhampton	101,728
Meschutt Beach, Hampton Bays	34,752
Sears Bellows County Park, Hampton Bays	1,876
Smith Point County Park, Shirley	211,593
Southhaven County Park, Brookhaven	27,069

Source: Suffolk County Parks Department, 2007

In addition to the facilities described above, the local towns and villages in the study area maintain park facilities and beaches along the shoreline. These facilities are generally open to the public at large; however, parking fees and permit requirements often vary between residents and non-residents. Details of the Project Public Access Plan are provided as Appendix G.

3 REACH DELINEATION

The study area from Fire Island Inlet to Montauk Point is comprised of a variety of features affecting the development of long-term storm damage reduction solutions. Dividing the project area into reaches is necessary in order to study site-specific physical, economic and environmental differences. Storm and erosion reduction alternatives may then be tailored to the needs and constraints of each location.

Three types of reaches were defined, namely: (1) Project, (2) Physical/Design and (3) Economic. These five project reaches defined by their location and coastal storm damage exposure are (1) Great South Bay, (2) Moriches Bay, (3) Shinnecock Bay, (4) Ponds, (5) Montauk. This incremental assessment is required to ensure that each element of the reformulated plan provides benefits in excess of costs. Physical/Design reaches represent areas of uniform design constraint and are described in Appendix A Engineering and Design, Economic reaches are described the following sections.

3.1 Economic Reaches

Economic reaches are shore segments that may be considered as distinct units when evaluating storm damage reduction benefits. The reaches are delineated to account for geographic and political boundaries, differences in shoreline orientation, and differences in hydraulics such as different flood stage frequency relationship. For example, the mainland shore Moriches Bay is divided into three economic reaches since these sections of the bayshore respond differently to storms. Because the hydraulics for these areas are different, the corresponding damages (and benefits) are also different. Separate economic reaches were also assigned (where appropriate) to the barrier oceanfront, barrier bayfront and the mainland. For example, in Great South Bay, there are three economic reaches assigned from the ocean to the mainland: an oceanfront reach on Fire Island, a bayshore reach on Fire Island and a mainland shore reach. These reaches were delineated due to varying hydraulics and varying damage mechanisms in the three areas. Oceanfront areas may be damaged by inundation, direct wave impact and both short- and long-term erosion.

The Fire Island Bay Shore reach may be damaged by both flooding from the bay and possible overwash and/or breaching of the Island. The Fire Island Bay Shore reach is not subject to the same wave and erosion effects as the oceanfront reach and, consequently, will not be subject to the same damage mechanisms. To allow more concise reporting of development and damage data some tables have aggregated reaches by bay or sub-bay. For example, Tables 8 through 13 aggregate structure data in Great South Bay into Western, Central and Eastern Great South Bay. These areas are referenced as WGSB, CGSB, and EGSB respectively.

Economic reaches are based primarily on institutional borders and coastal features which affect the economic analysis parameters for different reaches. Development density and hydrodynamic differences also affect economic reach delineation. Reach locations are presented in Figure 5.1 and a description of these reaches is given in the following section.

As a result of location differences, the exposure to storm forces varies on a regional basis and thus, two different general procedures were used to assess damages as part of the economic analysis. The procedures are applicable to areas subject to:

- inundation only
- inundation, wave attack, long term erosion and storm recession

The study area can be divided into those reaches which are primarily impacted by inundation damages and those reaches where waves and erosion are also major damage mechanisms. In general, the barrier island bay shore and the mainland bay shores of Great South Bay, Moriches Bay and Shinnecock Bay are primarily affected by inundation damages. Waves and erosion are also major damage mechanisms for the barrier island ocean front reaches and the eastern end mainland ocean front reaches (economic reaches 1 through 8).

In order to apply the two different damage estimation procedures in the assessment of flood damages, it was necessary to partition the study area into parts with generally similar exposure to storm forces. Although development and topography vary within an economic reach, hydraulic parameters and damage mechanisms are considered to be uniform across the reach.

For the bayshore reaches of the barrier island and mainland and the eastern end ocean front reaches, the damage assessment is limited to inundation damages. Although this procedure may be applicable to the bay shore reaches, it is probably not an appropriate procedure for the eastern end ocean front mainland shore reaches. Even though the structures in the eastern end mainland ocean front reaches are generally set back from the oceanfront or protected by a substantial dune system, there have been reported damages due to waves and erosion in these areas.

The most comprehensive procedure, which considers damage associated with inundation, wave attack and erosion, is applied to those reaches located along the barrier oceanfront. In these reaches, the assessment considers the effects of storm induced and long-term erosion on wave exposure and structural stability.

A description of the economic reaches is provided below. The description begins at the easternmost reach (Reach 1) at Montauk Point, and then proceeds west along the mainland to the Suffolk/Nassau County border. A description of the economic reaches on the barrier island is also provided. In some areas, the hydrodynamic modeling required the subdivision of reaches into sub-sections, where the sub-sections are assigned different hydraulic nodes. For example, Economic Reach 26, which extends from Neguntatogue Creek Venetian Shores beach west to the Nassau/Suffolk border, is subdivided into reaches 26.1, 26.2, and 26.3.

3.2 Mainland Oceanfront Economic Reaches

Economic Reach 1 - Area extending from Montauk Point westward to just east of Hither Hills State Park; conditions are very diverse including bluff areas and low-lying Ditch Plains. This reach contains localized bluff erosion that will not be explicitly analyzed in the economic assessment. The analysis will focus on low-lying Ditch Plains. Figure 2 shows the location of mainland oceanfront economic reaches.

Economic Reach 2 - Contains the areas of Hither Hills and Napeague Parks and adjacent sparsely developed areas. This reach is primarily comprised of undeveloped parks.

Economic Reach 3 - Contains the developed areas of Beach Hampton and extends west to the Hook Pond area. The primary problem within this reach is the potential loss of dune at Beach Hampton.

Economic Reach 4 - Area around Hook Pond including the outfall and the areas of armored shoreline to the west. The western limit is near the area of high ground between Lily Pond and Georgica Pond.

Economic Reach 5 - Georgica and Wainscott Pond areas westward to the East Hampton/Southampton town line. The analysis will focus on ponding drainage for Georgica Pond and eliminating the gap in the dune line seaward of the ponds.

Economic Reach 6 – Easterly Southampton town line to high ground west of Sagaponack Pond. The primary concern in this reach is the drainage and the dune at Sagaponack Pond. Erosion of the dune line in the remainder of the reach affects isolated structures.

Economic Reach 7 - Mecox Bay area including Channel Pond, Jule Pond, Sayre Pond, Phillips Pond, Wickapogue Pond and Old Town Pond which could be hydraulically connected during a severe coastal storm. The analysis focus for this reach is flood protection through drainage outfalls and eliminating gaps in the dune line at Mecox Bay. Since there are very few low-lying structures around Wickapogue Pond and Old Town Pond, the reach extends from just east of Mecox Bay westward to the high ground between Old Town Pond and Agawam Lake.

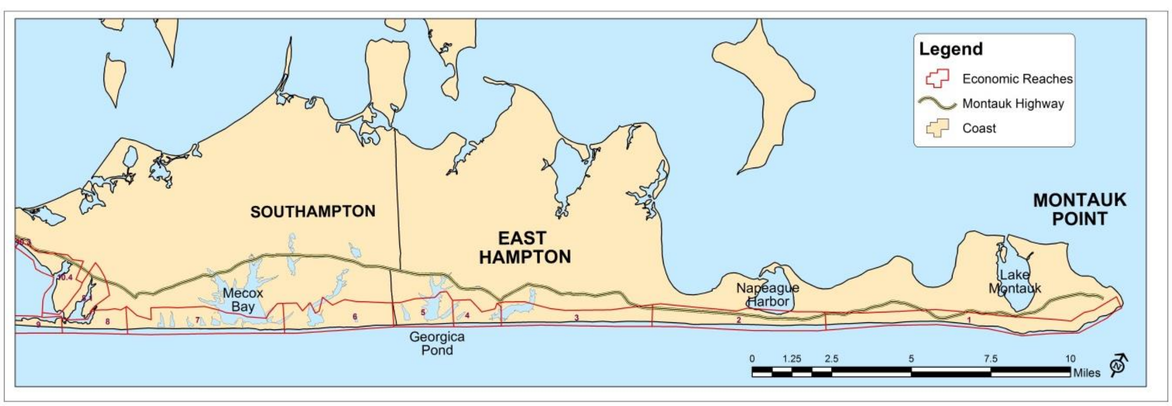

Figure 2 – Mainland oceanfront economic reaches

The following is a description of the bayshore reaches for both the mainland and barrier islands. The bayshore reaches are subdivided by bay: Shinnecock Bay, Moriches Bay, and Great South Bay. Figure 3 shows the location of reaches in Great South Bay, Moriches Bay and Shinnecock Bay.

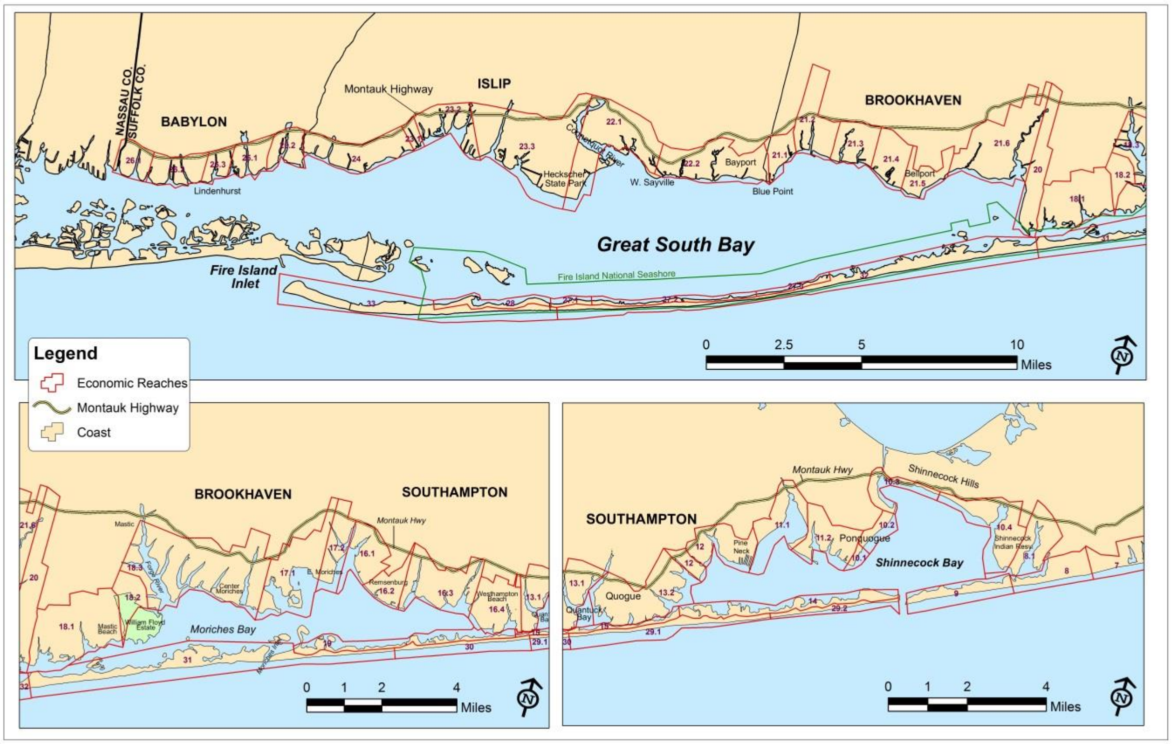

Figure 3 – Economic reaches – Great South Bay, Moriches Bay and Shinnecock Bay

3.3 Shinnecock Bay Economic Reaches

Economic Reach 8 - Area from just east of Agawam Lake westward to where Heady Creek and Shinnecock Bay meet. This area is most likely to be flooded from Shinnecock Bay. Low elevations allow floodwater from Shinnecock Bay to back up Taylors Creek and flow overland to the areas of Halsey Neck Pond and Coopers Neck Pond.

Economic Reach 9 - Barrier spit between Heady Creek and Shinnecock Inlet. Structures in this area are generally located behind the dune line and are expected to be damaged primarily by inundation from Shinnecock Bay.

Economic Reach 10 - Reach contains large portion of Shinnecock Bay east of Ponquogue Point.

Economic Reach 11 - Area west of Ponquogue Point to Pine Neck Point. The mainland structures in this area are the most exposed to overwash at Tiana Beach.

Economic Reach 12 - Area along the mainland of Shinnecock Bay from Pine Neck Point west to Phillips Creek.

Economic Reach 13 – This reach contains the Quantuck Bay and canal areas from the easterly entrance of the Quogue Canal at Shinnecock Bay to the westerly entrance of Quantuck Canal at Moriches Bay.

Economic Reach 14 – This reach contains bayside structures on the barrier island from Ponquogue Bridge (near the limit of the west of Shinnecock Interim Project) westward to Post Lane.

Economic Reach 15 - Bayside of the barrier island from Post Lane near the mouth of the Quogue Canal westward to Quantuck Canal near Beach Lane. The western limit is approximately at the start of the Westhampton groin field.

3.4 Moriches Bay Economic Reaches

Economic Reach 16 - Reach contains floodprone structures along the mainland of Moriches Bay from Quantuck Canal westward to the Southampton / Brookhaven border.

Economic Reach 17 - Reach reflects conditions in central Moriches Bay on the mainland shore from the Brookhaven Town line to Radio Point. This is the mainland area closest to Moriches Inlet.

Economic Reach 18 - Reach covers the western portion of Moriches Bay mainland shore from Radio Point westward to Smith Point.

Economic Reach 19 - Reach contains bayshore barrier island structures from Quantuck Canal at Beach Lane to Groin 15, the most westerly groin in Westhampton. This portion of the Westhampton Barrier is subject to inundation damage from Moriches Bay.

There is no economic reach assigned to the bayside of the barrier island for the area between groin 15 of the Westhampton groin field and Moriches Inlet. In the future, the limited level of protection and duration of renourishment of the interim project in this area suggests that structures in this area may be subjected to direct wave or overwash effect and thus the barrier ocean front reach is more appropriate. There also is no economic reach assigned to the area from Moriches Inlet to Smith Point due to the lack of structures.

3.5 Great South Bay Economic Reaches

Economic Reach 20 - Reach contains the west facing mainland shoreline in Great South Bay from Smith Point to Sandy Point in Bellport Bay.

Economic Reach 21 - Reach extends westward along the mainland shore from Long Point to the Brookhaven / Islip Town line. Mainland portions of the town of Brookhaven within Great South Bay are contained in this reach.

Economic Reach 22 - Reach extends along the mainland shore from the Brookhaven / Islip town border in a westerly direction to Nicoll Point at Heckscher State Park.

Economic Reach 23 - Reach contains mainland shore from Heckscher State Park to western border of Village of Brightwaters. Area includes Great Cove in Bayshore.

Economic Reach 24 - Reach extends westward along the mainland from Village of Brightwaters past the Robert Moses Causeway to the Islip / Babylon town line at Sampawams Point.

Economic Reach 25 - Reach includes Babylon mainland shore from the Islip / Babylon town line to Venetian Shores Beach.

Economic Reach 26 - Reach covers the remaining mainland shore from Venetian Shores Beach westward to the county line.

Economic Reach 27 - Reach extends along the bayshore of the barrier island from the western end of Smith Point County Park to the Brookhaven / Islip town line.

Economic Reach 28 - Reach includes the remaining Fire Island bayshore areas extending from the Brookhaven / Islip town line to Fire Island Inlet.

3.6 Barrier Island Oceanfront Reaches

Economic Reach 29 - Reach extends along the oceanfront from Shinnecock Inlet to Beach Lane in Westhampton Beach. For that portion of the reach from Shinnecock Inlet west to Ponquogue Bridge, the reach encompasses the entire width of the barrier island. (Because of this, there is no bayside reach identified from the inlet to the bridge.)

Economic Reach 30 - Reach includes the ocean front from Beach Lane in Westhampton Beach to the western end of the Westhampton groin field (Groin 15).

Economic Reach 31 - Reach extends from the groin field (Groin 15) to Moriches Inlet. If future conditions after the interim project life do not maintain this area, this reach could be subject to overwash and breaking waves similar to occurrences in 1992 and as such extends across the entire barrier island.

Economic Reach 32 - Reach includes barrier island oceanfront from the western end of Smith Point County Park to the Brookhaven / Islip town line. The reach includes both developed and park areas.

Economic Reach 33 - Reach covers the remaining Fire Island oceanfront from the Brookhaven / Islip town line to Fire Island Inlet. Reach includes both developed and park areas.

There is no economic reach assigned to the area from Moriches Inlet to Smith Point due to the lack of structures. Economic Reaches 32 and 33 cover the oceanfront portion of Fire Island. At this time, it is believed that the two reaches will adequately model storm damage on Fire Island. The cost of additional detail by splitting reaches is not warranted since the uncertainty band for the storm erosion modeling is expected to be at least as great as the variation in erosion over the length of the reach. Although these reaches include both developed and undeveloped lands, the economic analysis uses storm erosion results based on beach profiles representative of the developed areas.

4 STRUCTURE DATABASE DEVELOPMENT

4.1 Structure Inventory

The following information on buildings at risk is developed based upon an inventory of buildings on the barrier island, along the shorefront and on the mainland floodplain undertaken for this study. The storm damage analysis required specific data about the individual structures potentially subject to damage, including the type of structure and its foundation, its commercial or residential use, and its vulnerability to storm damage as measured by its elevation and its distance from the beach and dune. As part of the Reformulation Study, a complete inventory of structures on the mainland and barrier island was performed. Critical cost parameters (size, occupancy, basement, the number of stories, garages and construction material) were identified and analyzed for current conditions during sample surveys, to ensure the building data and price level are up to date. The most recent field update occurred in 2015, and building values and updated to 2015 price levels.

4.1.1 Shorefront Structure Inventory

As part of prior work on the FIMP project, a complete inventory of structures on both the mainland and barrier beaches was performed using Inventory Guidelines for the Fire Island Inlet to Montauk Point Damage Study. Additional field and aerial photo inspections were performed to update to post Sandy conditions. These investigations revealed that along the shorefront there have been structure failures, as well as reconstruction or relocation of some buildings. The inventory has also been adjusted to remove structures scheduled for acquisition as part of the ongoing FIMI project.

Table 7 identifies the number of the shorefront structures in each Design-Sub Reach which would be impacted under baseline conditions by erosion associated with a storm with a 1% probability of occurrence in a given year. To convey the risk of future damages, this table also shows the number of structures that could be impacted in the future when accounting for long-term erosion and shoreline undulation, in addition to a storm with a 1% annual probability of occurrence.

Table 7 helps to illustrate locations along the shorefront which are at greatest risk to damages now and in the future and presents a summary of the number of structures that could be at risk of erosion damage over the period of analysis. The table was developed by combining the expected shoreline change over the analysis period with the maximum storm erosion distance to identify the landward limit of erosion damage. The greatest number of structures currently at risk is on Fire Island. The number of structures at risk increases dramatically over time and illustrates that areas presently not at risk in eastern portions of the project area are likely to be threatened in the future. Shore line change associated with higher rates of sea level rise would be expected to increase the number of structures becoming vulnerable during the analysis period. The current analysis assumes that shorefront are assumed destroyed when they incur damage greater than 50% of their depreciated replacement value, and that structures destroyed by erosion during the analysis period will be rebuilt in compliance with local floodplain management ordinances unless they are located in the Coastal Erosion Hazard Area (CEHA), defined and administered by the New York State Department of Environmental Conservation.

Table 7- Shorefront Structures Potentially at Risk from Erosion

Design Sub-Reach/ Project Reach	Name	Baseline Erosion	2030 Erosion	2060 Erosion
GSB-1A	Robert Moses State Park	0	0	0
GSB-2A	Kismet to Lonelyville	110	184	199
GSB-2B	Town Beach to Corneille	37	55	55
GSB-2C	Ocean Beach to Seaview	28	58	68
GSB-2D	OBP to Point O'Woods	39	67	68
GSB-3A	Cherry Grove	2	36	43
GSB-3C	Fire Island Pines	25	65	84
GSB-3D	Talisman to Water Island	0	1	2
GSB-3E	Water Island	0	0	3
GSB-3F	Water Island to Davis Park	0	0	0
GSB-3G	Davis Park	0	23	31
GSB-3H	Watch Hill	0	0	0
GSB-4A	Wilderness Area West	0	0	0
GSB-4B	Wilderness Area	0	0	0
Great South Bay		*241*	*489*	*553*
MB-1A	Smith Point CP West	0	1	1
MB-1B	Smith Point CP East	0	0	0
MB-2A	Great Gun	0	0	0
MB-2B	Moriches Inlet West	0	0	0
MB-2C	Cupsogue Park	0	0	1
MB-2D	Pikes	0	23	125
MB-2E	Westhampton	0	0	1
Moriches Bay		*0*	*23*	*127*
SB-1A	Hampton Beach	0	19	33
SB-1B	Sedge Island	4	41	55
SB-1C	Tiana Beach	12	18	23
SB-1D	Shinnecock Inlet Park West	1	1	2
SB-2A	Ponquogue	0	0	0
SB-2B	WOSI	1	3	3
SB-2C	Shinnecock Inlet - East	0	0	0
SB-3A	Southampton Beach	0	3	5
SB-3B	Southampton	1	5	6
SB-3C	Agawam	16	27	28
Shinnecock Bay		*35*	*117*	*155*
P-1A	Wickapogue	8	13	16
P-1B	Watermill	3	13	16

Design Sub-Reach/ Project Reach	Name	Baseline Erosion	2030 Erosion	2060 Erosion
P-1C	Mecox Bay	1	5	5
P-1D	Mecox to Sagaponack	8	39	50
P-1E	Sagaponack Lake	1	1	2
P-1F	Sagaponack to Potato Road	0	19	23
P-1G	Potato Road	5	22	23
P-1H	Wainscott	4	8	9
P-1I	Georgica Pond	0	0	0
P-1J	Georgica to Hook Pond	8	23	29
P-1K	Hook Pond	0	0	0
P-1L	Hook Pond to Amagansett	0	4	5
Ponds		*38*	*147*	*178*
M-1A	Amagansett	12	56	59
M-1B	Nepeague State Park	0	0	0
M-1C	Nepeague Beach	0	2	5
M-1D	Hither Hills SP	0	0	1
M-1E	Hither Hills to Montauk Beach	1	20	35
M-1F	Montauk Beach	7	22	38
M-1G	Montauk Beach to Ditch Plains	0	12	19
M-1H	Ditch Plains	2	50	87
M-1I	Ditch Plains to Montauk Beach	0	9	20
Montauk		***22***	***171***	***264***
Totals		**336**	**947**	**1,277**

4.1.2 Back Bay Development Potentially at Risk

Development along the mainland back bay shoreline is extensive. The density of development is generally greatest in the areas further to the west and becomes less dense farther east. It is also important to note that much of the development in the western portions of the study area also tends to be older construction, built prior to the introduction of the National Flood Insurance Program. As such, these buildings tend to be at lower elevations, and more susceptible to flooding. The study area reaches along the back bay mainland include the areas south of the Montauk Highway, and generally below elevations +16 ft NGVD. Within this area there is a range of building types, including residential, commercial, and public buildings. In addition to the structures on the mainland, the back bay also includes structures present on north side of the barrier islands. These structures are considered to be at risk from only inundation from the back bay and not from erosion. Tables 8 and 9 provide a summary by the major bay reaches including the number and type of structures within each.

Table 8 - Summary of Back Bay Mainland Structures at Risk within the Study Area

Project Reach/ Sub-Bay	Structure Type					
	Residential	Commercial	Industrial	Municipal	Utility	Total
WGSB	19,423	1,676	111	110	11	21,331
CGSB	6,377	489	47	48	4	6,965
EGSB	1,896	57	1	12	0	1,966
Great South Bay	*27,696*	*2,222*	*159*	*170*	*15*	*30,262*
MOR	6,006	386	9	17	0	6,418
Moriches Bay	*6,006*	*386*	*9*	*17*	*0*	*6,418*
WSHN	2,431	132	5	9	1	2,578
SHN	583	37	1	6	0	627
Shinnecock Bay	*3,014*	*169*	*6*	*15*	*1*	*3,205*
Total Back Bay	**36,716**	**2,777**	**174**	**202**	**16**	**39,885**

Table 9 - Summary of Back Bay Barrier Structures along North of Barrier Island

Project Reach/ Sub-Bay	Structure Type					
	Residential	Commercial	Industrial	Municipal	Utility	Total
WGSB	2,412	16	0	3	0	2,431
CGSB	895	2	0	3	0	900
EGSB	0	0	0	0	0	0
Great South Bay	*3,307*	*18*	*0*	*6*	*0*	*3,331*
MOR	258	0	0	0	0	258
Moriches Bay	*258*	*0*	*0*	*0*	*0*	*258*
WSHN	76	0	0	0	0	76
SHN	0	0	0	0	0	70
Shinnecock Bay	*76*	*0*	*0*	*0*	*0*	*76*
Total Back Bay	**3641**	**18**	**0**	**6**	**0**	**3,665**

Tables 10 and 11 provide a summary of the number of structures which fall within different floodplains under the baseline conditions in each project reach and sub bay.

One of the future risks considered within the benefits analysis is the potential for the development and growth of breaches in the barrier island resulting in an increase in flood stages within the bays. Tables 12 and 13 provide a summary of the numbers of structures subject to flooding at events with the maximum number and size of open breaches. Details on the relevant hydraulic modelling are provided in Appendix A: Engineering Design.

Table 10 - Summary of Back Bay Mainland Structures within Baseline Flood Plains

Project Reach/ Sub bay	**Buildings #**	**50% ACE (2 Year) Floodplain Buildings**	**10% ACE (10 Year) Floodplain Buildings**	**4% ACE (25 Year) Floodplain Buildings**	**1% ACE (100 Year) Floodplain Buildings**	**0.2% ACE (500 Year) Floodplain Buildings**
WGSB	21,331	164	2,054	3,354	4,279	4,512
CGSB	6,965	228	1,016	1,067	1,394	1,478
EGSB	1,966	23	165	222	314	595
Great South Bay	*30,262*	*415*	*3,235*	*4,643*	*5,987*	*6,585*
MOR	6,418	481	1,075	1,640	1,973	2,494
Moriches Bay	*6,418*	*481*	*1,075*	*1,640*	*1,973*	*2,494*
WSHN	2,578	112	378	561	898	1,168
SHN	627	35	72	132	307	408
Shinnecock Bay	*3,205*	*147*	*450*	*693*	*1,205*	*1,576*
Total Back Bay	***39,885***	***1,043***	***4,760***	***6,976***	***9,165***	***10,655***

Table 11 - Summary of Back Bay Structures along North Shore of Barrier Island within Baseline Flood Plains

Project Reach/ Sub bay	**Buildings #**	**50% ACE (2 Year) Floodplain Buildings**	**10% ACE (10 Year) Floodplain Buildings**	**4% ACE (25 Year) Floodplain Buildings**	**1% ACE (100 Year) Floodplain Buildings**	**0.2% ACE (500 Year) Floodplain Buildings**
WGSB	2,431	329	1,529	1,649	1,703	1,760
CGSB	900	129	364	390	423	445
EGSB	0	0	0	0	0	0
Great South Bay	*3,331*	*458*	*1,893*	*2,039*	*2,126*	*2,205*
MOR	258	58	93	140	216	241
Moriches Bay	*258*	*58*	*93*	*140*	*216*	*241*
WSHN	76	48	73	76	76	76
SHN	0	0	0	0	0	0
Shinnecock Bay	*76*	*48*	*73*	*76*	*76*	*76*
Total Back Bay	**3,665**	**564**	**2,059**	**2,255**	**2,418**	**2,522**

Table 12 - Summary of Back Bay Mainland Structures within Baseline Flood Plain during Maximum Open Breaches

Project Reach/ Sub bay	**Buildings #**	**50% ACE (2 Year) Floodplain Buildings**	**10 % ACE (10 Year) Floodplain Buildings**	**4% ACE (25 Year) Floodplain Buildings**	**1% ACE (100 Year) Floodplain Buildings**	**0.2% ACE (500 Year) Floodplain Buildings**
WGSB	21,331	4,101	6,343	8,217	9,379	9,515
CGSB	6,965	1,397	2,626	2,742	3,325	3,419
EGSB	1,966	313	613	709	898	1,031
Great South Bay	*30,262*	*5,811*	*9,582*	*11,668*	*13,602*	*13,965*
MOR	6,418	1,075	2,096	2,819	3,550	4,029
Moriches Bay	*6,418*	*1,075*	*2,096*	*2,819*	*3,550*	*4,029*
WSHN	2,578	227	716	996	1,408	1,641
SHN	627	95	190	271	410	462
Shinnecock Bay	*3,205*	*322*	*906*	*1,267*	*1,818*	*2,103*
Total Back Bay	***39,885***	***7,208***	***12,584***	***15,754***	***18,970***	***20,097***

Table 13 - Summary of Back Bay Structures along North Shore of Barrier Island within Baseline Flood Plain during Maximum Open Breaches

Project Reach/ Sub bay	**Buildings #**	**50% ACE (2 Year) Floodplain Buildings**	**10% ACE (10 Year) Floodplain Buildings**	**4% ACE (25 Year) Floodplain Buildings**	**1% ACE (100 Year) Floodplain Buildings**	**0.2% ACE (500 Year) Floodplain Buildings**
WGSB	2,431	1,703	2,144	2,160	2,250	2,263
CGSB	900	437	628	649	656	692
EGSB	0	0	0	0	0	0
Great South Bay	*3,331*	*2,140*	*2,772*	*2,809*	*2,906*	*2,955*
MOR	258	123	216	243	256	257
Moriches Bay	*258*	*123*	*216*	*243*	*256*	*257*
WSHN	76	54	76	76	76	76
SHN	0	0	0	0	0	0
Shinnecock Bay	*76*	*54*	*76*	*76*	*76*	*76*
Total Back Bay	**3,665**	**2,317**	**3,064**	**3,128**	**3,238**	**3,288**

5 DAMAGE FUNCTIONS

The estimation of annual storm damages in this analysis is based on the application of appropriate damage functions to the structures in the study area to capture damage incurred by those structures and their contents during storm events with varying probability of occurrence. For structures on the mainland of Long Island and the backbay side of the barrier islands, damage functions were applied to capture damage from flood inundation only. For structures in the shorefront sections of the study area, additional functions were applied to capture damage from erosion and wave attack in addition to flood inundation.

5.1 Inundation Depth-Damage Functions

Flood inundation provides by far the largest source of damage in the study, and the depth-damage functions used to compute these damages were drawn from generic sources published by the US Army Corps of Engineers Institute for Water Resources (USACE-IWR), and from site-specific functions that were developed for certain structure types solely for use in the Fire Island to Montauk Point study area. These functions compute flood damage in terms of a percentage of the depreciated structure replacement value at increments of depth above the main finished floor.

For single-family residential structures (and two- or multi-family residences of similar construction), the study utilized generic depth-damage functions for structure and content damage published by USACE-IWR in EGM 01-03 (4 December, 2000) and EGM 04-01 (10 October, 2003). These EGMs provide specific functions for one-story, two-story, and split-level residences with and without basement. These functions were assigned to all residential structures in the mainland and backbay barrier sections of the study area, with the exception of manufactured homes, large mansions, and apartment buildings.

For manufactured homes, mansions, apartment buildings, and all non-residential structures, the study utilized a set of damage functions that were developed specifically for use in this study area. The study area-specific functions were derived from detailed data recorded in interviews conducted with a representative sample of structure owners in the study area. For this exercise, approximately 1,500 interviews were conducted in 10 geographic locations with randomly selected residential and business owners, ultimately resulting in depth-damage functions for more than 60 categories of commercial, industrial, municipal and utility structures. Study area-specific residential damage functions derived from these interviews were also used to capture inundation damages for structures in shorefront areas, since residences in these areas are predominantly built on pile foundations and not consistent with the structures that were used to compile the generic USACE-IWR depth-damage functions.

The analysis also captured flood inundation damage incurred by motor vehicles associated with residential structures by utilizing the generic depth-damage relationships for motor vehicles issued by USACE in EGM 09-04 (22 June, 2009). The analysis accounted for the possibility that owners would move vehicles to safety in advance of storm events in accordance with the methodology in EGM 09-04 and drew on publicly available information such as the US Census Bureau for data such as the number of cars per household and their average value.

5.2 Wave Failure and Erosion Damages

Wave failure damage relationships were developed for application to structures in the shorefront areas using established methodologies for calculating wave crest heights from the still water depth (including wave setup) at the structure. These relationships were modified to account for different non-pile structure/foundation types observed in the shorefront areas: For structures on piers, wave failure occurs when the wave crest elevation exceeds the main floor elevation, while for other non-pile foundation structures, wave failure occurs when the water surface elevation including wave setup exceeds three feet above ground level (wood frame structures) or four feet above ground level (masonry structures).

For buildings on pile foundations, the primary mechanism of structural failure is a combination of wave and erosion forces; hence it was necessary to determine the pile embedment depth required to resist wave forces at various flood depths. The vulnerability of structures on piled foundations was analyzed using the Griffith and the Czerniak equations, which relate the stability of the structure at any storm surge depth to the required pile embedment depth. The results of these analyses were used to develop relationships relating the still water depth to the required pile embedment for pile-supported structures with pile lengths six feet or less and for pile-supported structures with pile lengths greater than six feet (Figure 4). The wave damage mechanism assumed that structures on piles would fail when the wave crest elevation impacted the lowest horizontal supporting members, which were assumed to be two feet below the main floor elevation for structures on piles.

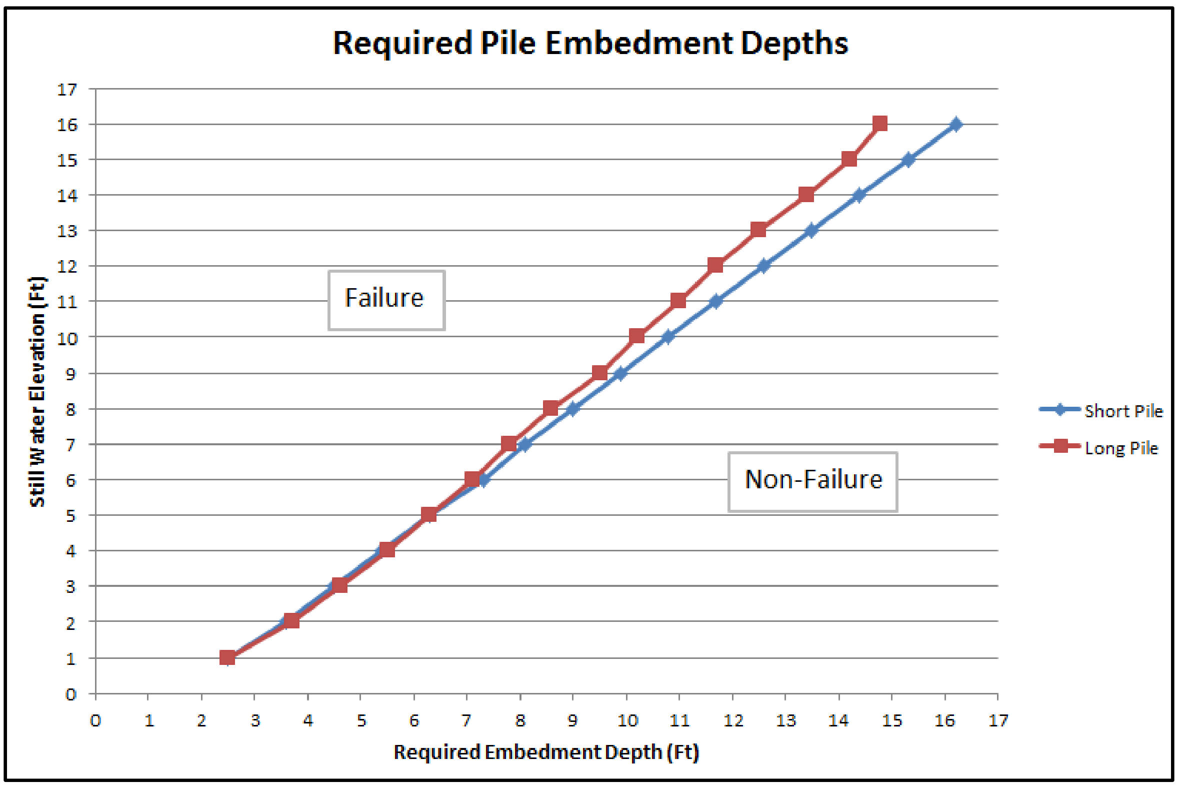

Figure 4: Required Pile Embedment Depths for Stability of Shorefront Structures on Piles

Erosion damage functions were developed separately for application to structures in the shorefront areas with slab-on-grade foundations: For these structures, any undermining by erosion of the slab was assumed to cause damage, and such structures were assumed to fail and consequently experience 100% damage when 50% of the foundation slab was undermined, in accordance with current FEMA guidelines. Between the onset of damage when the erosion reaches the seaward face of the slab, and the occurrence of 100% damage at the slab midpoint, erosion damage was assumed to increase linearly.

6 STORM DAMAGE CRITERIA

6.1 Overview

The reduction in coastal storm damages is the primary purpose and provides the primary benefits of the FIMP project. As described earlier in this Appendix the storm damage analysis had been split into the shorefront areas subject to inundation, wave and erosion damage, and non-shorefront areas subject to inundation damage only. The selection of analysis methods was different for each of these areas and was driven by the nature of the damages to be evaluated and by the engineering and technical data available to evaluate storm damage risks and how they change over the period of analysis.

The current analyses assume that the existing breach at the Otis Pike Wilderness Area remains open over the period of analysis and that this area is not subject to further breaching in the future.

6.2 Overview of Hydraulic Engineering Inputs

The development of engineering inputs to the storm damage and benefit analysis is described in Appendix A. The discussions below provide an overview of how key technical analyses used in the storm damage computations were developed and how they are incorporated into the storm damage analysis. The shorefront and non-shorefront models referred to in the following sections were developed specifically for use in the Fire Island to Montauk Point analyses. The models were approved for this single specific use following review by the National Planning Center of Expertise for Coastal Storm Risk Management (PCX-CSRM) via a memorandum from the Chief of the Office of Water Project Review, Planning and Policy Division, Directorate of Civil Works, dated 12 January, 2016.

6.2.1 Sea Level Change

Sea level in the study area is rising and is an important consideration in evaluating future storm impacts, especially from flooding. For purposes of this analysis, the baseline estimate of future sea level rise is based upon the historical rate of change for the gage at Sandy Hook. In recognition of the fact that a significant degree of uncertainty surrounds the selection of a rate of sea level rise for use in this analysis, a sensitivity analysis for alternative sea level rise scenarios was performed. In addition to the historic rate of sea level rise, the storm damage analysis considered two accelerated rates of rise reflected in NOAA Curves 1 and 3.

6.2.2 Long Term Erosional Trends

Long-term erosional trends are those conditions which are due to differences in long-shore transport rates due to natural physical conditions and constructed features such as inlets which impact long-shore transport, the net loss associated with storms and the effects of sea level rise. The long-term erosion rates are important in quantifying future changes that are likely to occur in a given area, as to whether the area is erosional, stable, or accreting. For the shorefront areas the long-term erosion and standard deviation in erosion rates are input directly into the analysis. For the non-shorefront areas long term erosion is reflected as a combination of a background erosion rate and the unrecovered portion storm erosion.

6.2.3 Shoreline Undulations

Shoreline undulations, in contrast to long-term erosion trends, are an erosional signature that is apparent to different degrees along the study area that are short-term in nature, and somewhat ephemeral. Shoreline undulations are also referred to as “circulation cells”, and “erosional hot spots”. The exact cause of these shoreline undulations is unknown, but it is assumed that there is a correlation between the condition of the nearshore bar, and the localized erosion. Analysis has been undertaken to evaluate historic shorelines to identify locations where these undulations are likely to occur, and the likely magnitude of these shoreline undulations. These analyses show that the undulations tend to form and may migrate alongshore for a distance before disappearing. Although it appears that there are areas which may be more or less prone to these undulations, analysis of the undulations indicates that they could occur anywhere along the shoreline. For purposes of the storm damage analyses, we have assumed that the undulations can occur anywhere, and have a random impact on the beach width at any year in the future. The landward and seaward amplitude of the undulations were quantified as 16 meters (52 feet).

6.2.4 Storm Surge and Erosion Analysis

Storm-surge numerical modeling was performed to produce peak storm water levels at 49 locations throughout the study area. These 49 locations were selected to capture the variability in storm water levels along the open coast and within the three bays. The storm-surge numerical modeling strategy for FIMP addressed a comprehensive list of physical processes (wind conditions, barometric pressure, astronomic tide, wave conditions, morphologic response, [namely barrier island overwash and breaching], and localized wind and wave setup) by merging hydrodynamic, wave, and sediment transport models. Details of the models and results are presented in Appendix A - Engineering and Design. The following paragraphs present an overview of key inputs to the storm damage analysis.

An ADCIRC model was used to simulate the ocean and nearshore, outside the surf zone, storm water levels (Luettich et al., 1992). ADCIRC is a long-wave hydrodynamic finite-element model that simulates water surface elevations and currents from astronomic tides, wind, and barometric pressure by solving the two-dimensional, depth-integrated momentum and continuity equations. The analysis considered numerous historic storms and the possibility that they could occur with a full range of tide conditions.

SBEACH was used for both the hydrodynamic modelling, and also separately to evaluate the shorefront response for the design and evaluation of beachfill alternatives. SBEACH (Larson and Kraus 1989a; Larson, Kraus, and Byrnes 1990) is a numerical model for predicting beach, berm, and dune erosion due to storm waves and water levels. In the context of the hydrodynamic modeling, SBEACH was applied to estimate dune lowering that occurred prior to a dune being overtopped. In the coastal storm erosion context, SBEACH was used to calculate the change in the beach profiles during the storm including erosion the dune crest. The multivariate Empirical Simulation Technique (EST), as discussed in Appendix A, was used to generate response frequency curves for 19 SBEACH output variables for use in the design and economic analyses.

The analysis of offshore and nearshore storm water levels was supplemented with an analysis of how barrier island and inlet conditions could change during the storm and how these changes would affect the storm surge within the bays. The DELFT3D-FLOW model applied for this analysis simulates water level and currents from tidal, meteorological, and wave forcing by solving a two-dimensional depth-integrated flow and transport phenomena. The grid for this study extended from East Rockaway Inlet eastward to the east side of Shinnecock Bay. The model grid includes Great South, Moriches, and Shinnecock Bays, and their inlets, and extends up to 5 km from across the nearshore, with variable resolution. DELFT3D-FLOW was linked to the offshore water level time series from ADCIRC, including the storm wind and pressure fields.

The morphological changes, namely barrier island overwash and breaching, were simulated using DELFT3D-MOR. Three-dimensional transport of suspended sediment is calculated in DELFT3D by solving the three-dimensional advection-diffusion (mass-balance) equation for the suspended sediment.

The outputs from these models were then input into a statistical modeling tool to estimate the likelihood of storm occurrence. The Empirical Simulation Technique (EST) was applied to generate response curves including stage frequency and erosion frequency curves. EST are a group of nonparametric methods for proceeding directly from hydrometeorological storm data to simulations of future storm activity and coastal impact, without introducing parametric assumptions concerning the probability law formulas and related parameters of the data (Scheffner et al., 1999).

For the FIMP stage frequency analysis, the one-dimensional (1-D) EST methodology was applied in a manner to account for the possibility that historic storms could impact the areas at any tide condition. In order to apply this approach, 21 additional alternate tide events were run, to provide an improved estimate of the storm effects under different tide conditions. Along the open coast, the total surge generally can be added to the various tide conditions to develop the total surge effect, but this approach does not work well within the bays, due to the complicated hydrodynamics of flows through the inlets and over the barrier island. With the inclusion of these alternate tide scenarios, final stage-frequency curves were generated to represent stage frequency relationships for the study area, at the 49 locations output from the model.

6.2.5 Shorefront Storm Damage Modelling

A shorefront storm damage model has been developed to quantify the impact of storms and erosion on the existing development in the Study area. The immediate shorefront area is subject to storm damage from waves, storm erosion/recession undermining buildings, and inundation. The model was designed to evaluate each of these damage sources and select the largest or critical source of damage.

The model accounts for changing future conditions by incorporating the impact of long-term erosion on reducing berm width and dune height, limitations on reconstruction of damaged buildings and the impact of sea level rise on surge elevations. In some reaches the profile is anticipated to migrate landward and retain the current dimensions. In other reaches the profile (and profile storm response) is anticipated to change in response to erosion narrowing of the berm and/or lowering of the dune.

6.2.6 Storm Response Data

A key input to the shorefront storm damage analysis was the Storm Induced Beach Change Model (SBEACH) numerical simulation model. The SBEACH model was used to calculate beach profile changes for range of storm events. The model predicts profile response to storms as well as wave heights, wave setup and wave runup. For the present SBEACH modeling analysis, a total of 19 specific responses were identified to satisfy input requirements for overtopping and economic analyses. These responses allow the interpolation of the profile elevation and water levels at each point on the shorefront profile. This analysis was conducted for 22 representative existing condition profiles, plus an additional 7 profiles representing potential without project future condition beach conditions. Six reaches out of the 22 profiles, did not have any structures and, therefore, were not used in the model.

Because the study area shorefront is such a dynamic environment, the storm damage analysis incorporates a lifecycle approach to track the impact of multiple storm events on the future vulnerability of each individual structure. The life-cycle approach required development of potential storm sequences which represent the random occurrence of future events. The Storm Response Database (SRD) for the shorefront analysis used the multivariate Empirical Simulation Technique (EST), as discussed in Appendix A. The EST used sampling of the calculated SBEACH responses to generate 500 simulations of 200 years of storm activity for each beach profile. For the shorefront damage analysis, these individual simulations were combined to create a database of 100,000 years of random storms and the associated profile responses. These events were then divided into 1,000 lifecycles of 100 years.

6.2.7 Storm Damage Lifecycle Simulations

Storm damage calculations for shorefront structures are performed in a computer model (referred to as model SFD in subsequent text and footnotes) structured to analyze damage through a series of loops. For each structure, the model reads in all of the Shoreline Response Database (SRD), which contains responses of shoreline parameters for lifecycle storms. The SRD is broken into 100-year time periods appropriate for the economic period of analysis. The year represented by existing conditions, the project base year, the total number of years to be evaluated in each lifecycle simulation, and the number of years in the period of analysis (the period following base year for which benefits are calculated) are specified. For the Fire Island, and Downtown Montauk areas that have ongoing or scheduled beach nourishment efforts, the base line conditions are specified as the completion of those projects (varies from 2015 to 2017) and the beach profile conditions for the baseline year are adjusted to reflect the project design conditions. For other areas the base line condition is specified as 2012 to reflect the latest available beach conditions. The beach and dune conditions in these areas are updated to incorporate the profile changes (erosion or accretion) since the year 2000 LiDAR, which was used to determine setbacks for the buildings in the damage database.

The appropriate SRD information is selected or interpolated based on pre-storm conditions, specifically beach width, and dune height. As each new storm is read into the analysis, the year of the storm is read and adjustments made to reflect changes in the profile, sea level rise and changes related to building failure and rebuilding limitations. For any structures located in the

New York State designated Coastal Erosion Hazard Area (CEHA), any buildings suffering greater than 50% damage are assumed not to be rebuilt and are removed from subsequent years of the lifecycle. For buildings located outside the CEHA area, any buildings destroyed or damaged more that 50% are assumed to be elevated above the regulatory Base Flood Elevation (BFE).

Damages and possible structure failure are evaluated for each mechanism of damage (erosion, wave, or inundation). The damages from each mechanism are compared and the maximum damage is retained for use as the critical damage. As each storm is processed, the damages are multiplied by the appropriate present worth factors and summed. At the end of the period of analysis, the total damages are multiplied by the capital recovery factor to determine Equivalent Annual Damage (EAD) for that lifecycle simulation. This process is repeated for each of the 1000 lifecycles representing different storm sequences. During the simulations the structure value, content value, long term erosion rates and amplitude of shoreline undulations are allowed to vary randomly to capture uncertainty in these input variables. The average EAD for all of the lifecycles is calculated and reported for each of the engineering design sub-reaches and aggregated for planning reaches in Table 14. The variance between the lifecycle simulations can be calculated to represent uncertainty in the results.

Table 14 - Summary of Shorefront Damages

Project Reach	Sub Reach	Critical Asset	Name	Approximate Length	Equivalent Annual Damage* 2028 - 2078
GSB	GSB-1	1A	Robert Moses State Park	25,700	$0
		1B	FI Lighthouse Tract	6,700	$0
	GSB-2	2A	Kismet to Lonelyville	8,900	$2,613,700
		2B	Town Beach to Corneille Estates	5,100	$1,500,400
		2C	Ocean Beach & Seaview	3,800	$404,200
		2D	OBP to Point O' Woods	7,400	$699,000
		2E	Sailors Haven	8,100	$0
	GSB-3	3A	Cherry Grove	3,000	$306,000
		3B	Carrington Tract	1,500	$0
		3C	Fire Island Pines	6,600	$260,200
		3D	Talisman to Water Island	7,300	$20,900
		3E	Water Island	2,000	$33,400
		3F	Water Island to Davis Park	4,700	$700
		3G	Davis Park	4,100	$204,600
		3H	Watch Hill	5,000	$0
	GSB-4	4A	Wilderness Area - West	19,000	$0
		4B	Wilderness Area	16,000	$0
GSB Subtotal:					**$6,043,100**

Project Reach	Sub Reach	Critical Asset	Name	Approximat e Length	Equivalent Annual Damage* 2028 - 2078
MB	MB-1	1A	Smith Point CP- West	6,300	$0
		1B	Smith Point CP - East	13,500	$0
	MB-2	2A	Great Gun	7,600	$0
		2B	Moriches Inlet - West	6,200	$0
		2C	Cupsogue Co Park	7,500	$800
		2D	Pikes	9,700	$274,900
		2E	Westhampton	18,300	$13,700
			MB Subtotal:		**$289,400**
SB	SB-1	1A	Hampton Beach	16,800	$292,300
		1B	Sedge Island	10,200	$1,626,300
		1C	Tiana Beach	3,400	$229,100
		1D	Shinnecock Inlet Park West	6,300	$5,600
	SB-2	2A	Ponquogue	5,300	$100
		2B	WOSI	3,900	$10,300
		2C	Shinnecock Inlet - East	9,800	$170,500
	SB-3	3A	Southampton Beach	9,200	$35,500
		3B	Southampton	5,300	$194,400
		3C	Agawam	3,800	$140,400
			SB Subtotal:		**$2,704,500**
P	P-1	1A	Wickapogue	7,700	$342,500
		1B	Watermill	8,800	$217,800
		1C	Mecox Bay	1,400	$18,900
		1D	Mecox to Sagaponack	10,400	$382,900
		1E	Sagaponack Lake	1,100	$2,900
		1F	Sagaponack to Potato Rd	9,300	$83,200
		1G	Potato Rd	4,300	$1,852,200
		1H	Wainscott	4,600	$23,100
		1I	Georgica Pond	1,200	$0
		1J	Georgica to Hook Pond	11,200	$650,600
		1K	Hook Pond	1,100	$0
		1L	Hook Pond to Amagansett	19,200	$37,000
			Ponds Subtotal:		**$3,611,100**
M	M-1	1A	Amagansett	10,400	$196,500
		1B	Napeague State Park	9,100	$0

Project Reach	Sub Reach	Critical Asset	Name	Approximate Length	Equivalent Annual Damage* 2028 - 2078
		1C	Napeague Beach	9,900	$96,600
		1D	Hither Hills SP	7,000	$19,900
		1E	Hither Hills to Montauk B	15,800	$1,013,400
		1F	Montauk Beach	4,700	$960,000
		1G	Montauk B to Ditch Plains	4,700	$93,500
		1H	Ditch Plains	3,400	$4,700
		1I	Ditch Plains to Montauk Pt	19,300	$171,400
Montauk Subtotal:					**$2,556,000**
Total					***$15,204,100***

Oct 2018 PL, Interest Rate 2.875%, 50-Year Period of Analysis
*Includes damage by erosion, wave action, and inundation.

Damages in Table 14 include damages to shorefront structures and contents only; loss of land has not been evaluated in this study. Initial assessments indicated that over the 50-year period of analysis almost all of the erosion would be to beaches used for recreation purposes and that loss of any recreation land is captured in the recreation benefits.

6.2.8 Non-Shorefront Damage Models

The Non-shorefront coastal inundation damage analysis has been developed to quantify the impact of storms on development along Great South Bay, Moriches Bay, and Shinnecock Bay in the Study area. Because structural failures are not altering the database of structures in response to storm events, the analysis uses the certified model HEC-FDA to develop aggregated stage damage curves with uncertainty for use in the evaluation of inundation damages. The HEC-FDA models used to develop the stage-damage relationships incorporated uncertainty associated with key parameters including structure value and main floor elevation via normal probability distributions, in accordance with current accepted practice. The HEC-FDA models also incorporated uncertainty associated with generic residential depth-damage functions via normal distributions, in accordance with Economic Guidance Memoranda EGM 01-03 and 04-01.

Physical conditions in the study area are expected to be quite dynamic in the future conditions resulting in changes in the extent and frequency of inundation as barrier island conditions evolve in response to storms and other factors. Engineering model simulations have identified that bay water levels are sensitive to conditions of the barrier island beach and dunes. This analysis identified ten barrier locations that are particularly vulnerable to overwash or breaching, which would then impact the bay water levels. A lifecycle analysis model was therefore developed to track storm erosion, long term and short-term shoreline change, and coastal management (beach nourishment, inlet bypassing, breach formation and closure) impacts to the barrier condition at the vulnerable locations, and to estimate the resulting changes in the bay stage frequency relationships and the associated inundation damages.

6.2.9 Stage Damages

The information on building types, elevation and value was combined with the damage criteria described above to develop relationships between elevation (NGVD) and dollar damages typically known as stage damage curves. These relationships were developed for each structure type for reach in the study area using the Hydraulic Engineering Center Flood Damage Assessment (HEC-FDA) program. Figure 3 provides a sample of stage damage curves for Reach 24, which contains nearly 3,000 buildings in the area from Sampawams Point to Great Cove in Western Great South Bay. In addition to estimating the expected or mean stage damage curves, HEC-FDA also evaluated the confidence band for each curve. These confidence bands reflect the potential impact of data limitations including certainty in building elevation & value, and the variance in the depth vs damage relationships. The key inputs to the HEC-FDA model are the building inventory dataset including structure values and flood depth vs percent of value damaged functions. In order to define the range of elevations to be considered in the stage damage curves, a typical range of stages and frequencies must also be entered into HEC-FDA.

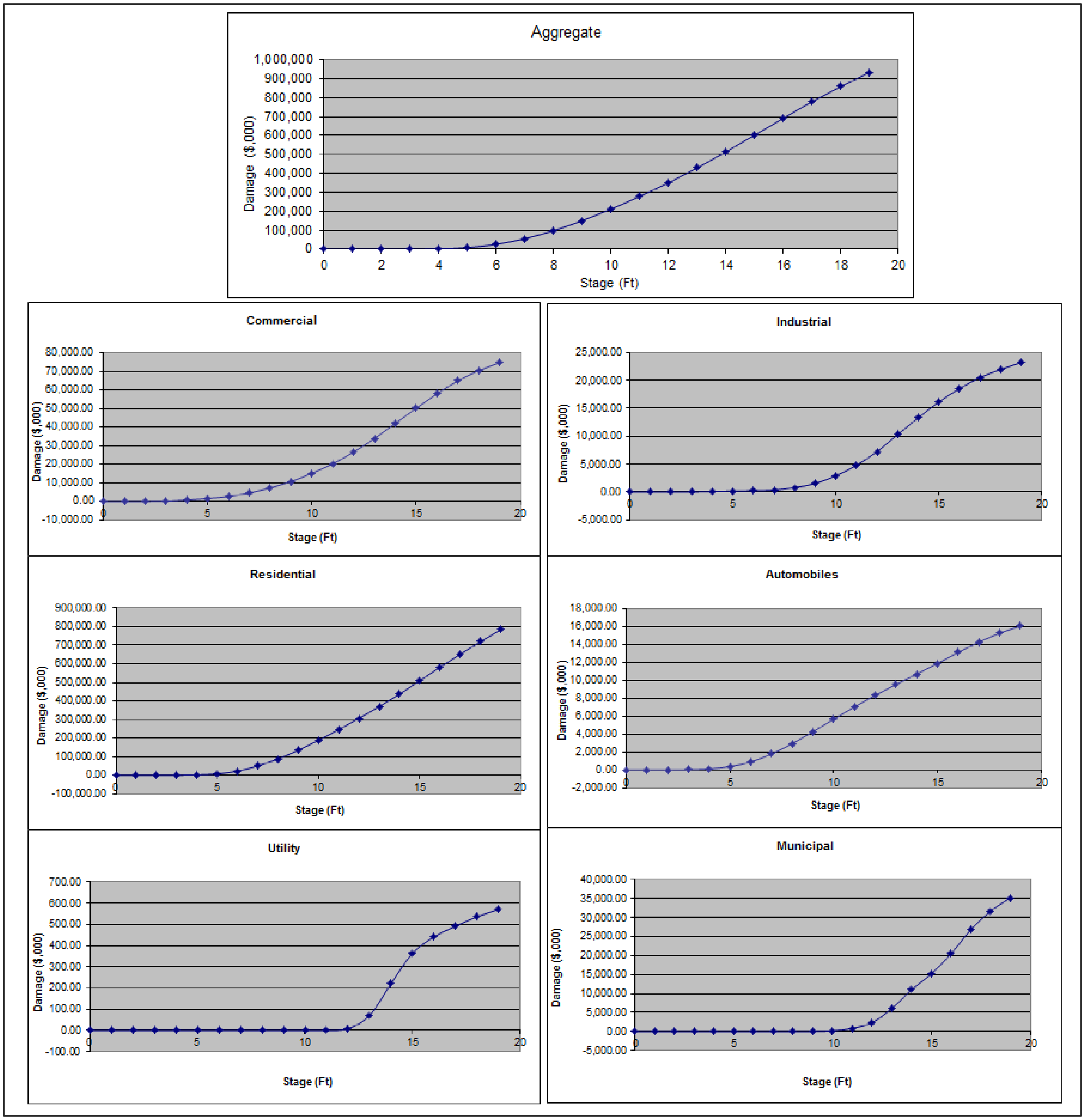

Figure 5 – Stage Damage Curves for Reach 24

6.2.10 Lifecycle Simulation Models

In order to develop a true understanding of the impact of flooding, the flood stage vs damage curves are typically combined with flood frequency data to express damage in average annual terms. Often this is completed using the HEC-FDA program, which can evaluate annual damages for both a baseline and a future condition. HEC-FDA however, requires that changes in damage conditions occur in a predictable linear manner. Within the FIMP study area however, flood levels and therefore damages are expected to vary in relation to both future sea level and barrier island conditions. Because future barrier island conditions are strongly influenced by storm activity in prior years, it was determined that a lifecycle approach was needed to allow conditions and damages to very in response to prior storm events.

Three separate damage simulation models were developed to link the hydrodynamic modeling of flood depths to the stage vs damage data. The first simulation model was developed to evaluate Breach Open Conditions and what impact a barrier island breach will have on storm damages. The model quantifies the increase in damages if a breach is open and provides input to the second model, the Breach Lifecycle Analysis. This model simulates breach occurrence & calculates average annual closure costs and breach induced increases in damage over project life. The model was developed to quantify lifecycle impacts and to compare breach management alternatives. The third model is the Lifecycle Damage Analysis, which simulates storms and bay water levels including the impacts of erosion/storms in creating Future Vulnerable Conditions. Each of the models uses the @-Risk add-in to Excel to allow the calculation and processing of multiple lifecycle iterations, each representing a different series of random storms. Uncertainty in other parameters including sea level rise, erosion rates, and stage damage relationships, are also reflected in the models using Monte Carlo sampling techniques. The reported results represent the average of numerous possible future lifecycles (between 12,500 and 25,000 depending on the model) to ensure the full range of conditions are reflected in the results. Future updates of this report will also present results for key damages and benefits in probabilistic terms in accordance with Engineer Regulation ER 1105-2-101 of January 2006.

The Breach Open Condition model (model BOC) calculates the increase in storm damage while breach is open. The model assumes a breach has occurred and simulates breach condition/size in the following months. Peak water levels are estimated based on the breach size, predicted increase in tide range, and the increased storm surge associated with random storm events. For each peak water level, the damage is identified using the stage vs damage curves. The key inputs to the model are the breach open water levels related to breach size, breach growth & closure rates, and the stage vs damage relationship. A total of 27 conditions were modeled for each of the 43 reaches for each breach closure alternative. These reflect combinations of 5 different breach location scenarios (No Breach & 4 Breach Open Conditions), breaches occurring in Tropical or Ex-tropical seasons, and sea level conditions of baseline (zero), 0, 0.5, 1.0, 2.0, and 3.0 feet rises. The model results were tabulated to provide a summary of increased inundation damage for various breach open scenarios, and sea level rise conditions, assuming breaches remain open for 12 months in the without-project condition and for three months in the with-project condition, for use as lookup tables in the Breach Only Lifecycle Model.

The Breach Only Lifecycle Model was developed to evaluate the impact of barrier island breaches and alternative closure designs & response times on the average annual storm damage and closure costs. The model considers the impacts of random storm events, and both long term and short-term shoreline change at the 10 locations identified as most vulnerable to breaching. Key inputs to the model include incremental breach damages computed using model BOC, stage frequency and storm erosion frequency relationships, post storm profile recovery rates, threshold surge elevations causing overwash, partial breaching and full breaching for various profile conditions, short term profile variability associated with shoreline undulations, and incremental damage associated with increased back bay flood elevations and undermining of barrier island development. The model uses the @-Risk add-in to Excel to simulate the random occurrence of storms in future years, and if the surge elevation is sufficient to cause an overwash or breaching condition it calculates the associated damages, breach closure cost, or profile maintenance costs. The model tracks changes in the profile condition and relates the breach and overwash threshold surge elevations to these changes.

The Inundation Damage Lifecycle model was developed to quantify baseline and future condition non-shorefront inundation damage. The model simulates storms and water levels including the impacts of erosion/storms in creating the Future Vulnerable Conditions (FVC) and the associated increases in bay water levels. The key model inputs include the bay stage frequency relationships for Baseline, Future Vulnerable, With-Project and Breach Closed Conditions. The model applies weighting factors to interpolate between Baseline and Future Vulnerable conditions. Breach water level thresholds, ocean stage frequency, storm/long term erosion & recovery rates, temporal shoreline undulations and stage vs damage relationships are also critical to the analysis.

The model simulates the random occurrence of both tropical and extra-tropical storms and tracks the impact of storms in altering the beach profile at the 10 locations most vulnerable to overwash and breaching. As the profile at these locations approaches the Future Vulnerable Conditions used to develop the FVC stage vs frequency relationship, the model interpolates bay water levels between the Baseline condition stage and the FVC stage. For each year storms are simulated, and the damage is identified from the stage vs. damage curves. Table 15 provides a summary of the average damages that were simulated for years 2028 and 2078 for all non-shorefront reaches. The damage in each year is multiplied by the present worth factor to adjust to base year values. The present worth of damage is summed and multiplied by the Capital Recovery Factor to calculate the equivalent annual damage for each simulated lifecycle. All damages in Table 15 and subsequent damage/benefit tables include damages to structures, structure contents, and to vehicles associated with residential structures.

Table 15 - Summary of Back- Bay Inundation Damages

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	**Mainland Reach ID**	**Location Name**			**Year 2028**	**Year 2078**	**Equivalent Annual**
26.1	GSB-M-1A	Unqua Point (County Line) to Copiague Beach	1,683	WGSB	$6,164	$11,587	$8,209
26.2	GSB-M-1B	Copiague Beach to Venetian Shores Beach	4,674	WGSB	$4,563	$9,820	$6,385
26.3	GSB-M-1C	Venetian Shores Beach to Neguntatogue Creek	2,268	WGSB	$6,230	$12,128	$8,260
25.1	GSB-M-1D	Neguntatogue Creek to Santapogue Point	1,931	WGSB	$2,042	$4,200	$2,776
25.2	GSB-M-1E	Santapogue Point to Sampawams Point (Town Line)	2,404	WGSB	$5,423	$11,188	$7,498
24	GSB-M-2A	Sampawams Point (Town Line) to Great Cove	3,154	WGSB	$2,879	$6,510	$4,196
23.1	GSB-M-2B	Brightwaters	364	WGSB	$254	$628	$392
23.2	GSB-M-2C	Lawrence Creek to Seatuck Refuge	1,717	WGSB	$5,676	$11,524	$7,741
23.3	GSB-M-2D	Seatuck Refuge to Heckscher Park (Nicoll Point)	2,982	WGSB	$1,961	$4,060	$2,749
28		Fire Island Lighthouse to Seaview (Fire Island)	1,994	WGSB	$13,220	$23,846	$17,080
27.1		Ocean Bay Park to Oakleyville (Fire Island)	433	WGSB	$1,213	$2,203	$1,594
Subtotal - Western Great South Bay Sub-Bay			*23,604*		*$49,625*	*$97,695*	*$66,880*
27.2		Sailors Haven to Water Island (Fire Island)	712	CGSB	$2,844	$5,279	$3,758
27.3		Water Island to Watch Hill (Fire Island)	188	CGSB	$757	$1,513	$1,033
22.1	GSB-M-3A	Heckscher Park (Nicoll Point) to Green Point	1,949	CGSB	$11,649	$20,353	$15,243
22.2	GSB-M-3B	Green Point to Blue Point (Town Line)	2,075	CGSB	$4,317	$7,709	$5,567
21.1	GSB-M-4A	Blue Point (Town Line to Tuthill Creek (Blue Point)	513	CGSB	$903	$1,790	$1,254
21.2	GSB-M-4B	Tuthill Creek to Swan River (Patchogue)	1,628	CGSB	$4,635	$8,834	$6,177
21.3	GSB-M-4C	Swan River to Mud Creek	751	CGSB	$704	$1,450	$977
Subtotal - Central Great South Bay Sub-Bay			*7,816*		*$25,810*	*$46,929*	*$34,009*

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	**Mainland Reach ID**	**Location Name**			**Year 2028**	**Year 2078**	**Equivalent Annual**
21.4	GSB-M-5A	Mud Creek to Howell Creek	745	EGSB	$1,713	$3,210	$2,275
21.5	GSB-M-5B	Howell Creek to Bellport Marina	224	EGSB	$162	$326	$220
21.6	GSB-M-5C	Bellport Marina to Carmans River	421	EGSB	$1,113	$2,046	$1,434
20	GSB-M-6A	Carmans River to Smith Point Bridge	571	EGSB	$635	$1,244	$852
Subtotal - Eastern Great South Bay Sub-Bay			*1,961*		*$3,623*	*$6,827*	*$4,781*
19		Moriches Inlet to Quantuck Canal (Westhampton Barrier)	241	MOR	$6	$13	$9
18.1	MB-M-1A	Smith Point Bridge to William Floyd Estate	3,052	MOR	$10,561	$17,448	$13,256
18.2	MB-M-1B	William Floyd Estate to Forge River	206	MOR	$502	$818	$632
18.3	MB-M-1C	Forge River to Radio Point	1,332	MOR	$6,604	$10,950	$8,283
17.1	MB-M-2A	Radio Point to Harts Cove	219	MOR	$1,681	$2,783	$2,142
17.2	MB-M-2B	Harts Cove to Seatuck Creek (Town Line)	93	MOR	$25	$49	$32
16.1	MB-M-3A	Seatuck Creek (Town Line) to Fish Creek	134	MOR	$416	$796	$565
16.2	MB-M-3B	Fish Creek to Speonk Point	317	MOR	$1,614	$2,910	$2,143
16.3	MB-M-3C	Speonk Point to Apacuck Point	431	MOR	$1,980	$3,739	$2,678
16.4	MB-M-3D	Apacuck Point to Quantuck Bay	609	MOR	$3,796	$6,489	$4,858
Subtotal - Moriches Bay Sub-Bay			*6,634*		*$27,185*	*$45,995*	*$34,599*
15		Quantuck Canal to Village Park (Westhampton Barrier)	93	WSHN	$25	$64	$40
13.1	SB-M-1A	Quantuck Bay West	297	WSHN	$3,823	$6,099	$4,728
13.2	SB-M-1B	Quantuck Canal to Phillips Point	586	WSHN	$4,786	$8,045	$5,993
12	SB-M-2A	Phillips Point to Pine Neck Point	783	WSHN	$1,874	$3,352	$2,421
11.1	SB-M-2B	Pine Neck Point to West Point	280	WSHN	$1,129	$1,929	$1,426

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	**Mainland Reach ID**	**Location Name**			**Year 2028**	**Year 2078**	**Equivalent Annual**
11.2	SB-M-2C	West Point to Ponquogue Point	616	WSHN	$1,577	$2,856	$2,022
Subtotal - Western Shinnecock Bay Sub-Bay			*2,655*		*$13,214*	*$22,344*	*$16,629*
10.1	SB-M-3A	Ponquogue Point	39	SHN	$160	$310	$216
10.2	SB-M-3B	Cormorant Point	6	SHN	$14	$23	$17
10.3	SB-M-3C	Shinnecock Canal Region	199	SHN	$907	$1,460	$1,127
10.4	SB-M-3D	Shinnecock Indian Reservation	258	SHN	$797	$1,426	$1,050
8b	SB-M-4A	Heady Creek	119	SHN	$137	$248	$182
Subtotal - Shinnecock Bay Sub-Bay			*621*		*$2,015*	*$3,468*	*$2,592*
Total: Back Bay Area			***43,291***		**$121,471**	**$223,258**	**$159,492**

Oct 2018 PL, Interest Rate 2.875%, 50-Year Period of Analysis

7 WITHOUT PROJECT CONDITIONS

As described in the previous chapter there are a number of different storm impacts that result in damage. Each of the significant damage sources are described below.

7.1 Damage Categories

Tidal Inundation: These damages occur when vulnerable structures are flooded by high tides and storm surges in the back bay, where the water levels are sensitive to the conditions of the barrier islands. Inundation damages have been divided into those occurring on the back bay mainland and those on the back bay side of the barrier islands, since some alternatives reduce damages in the former area but not the latter. In order to illustrate the relative contribution of barrier island breaching and overwash to the total damages, these inundation damages have been separated out to show those damages which occur due to flooding through the inlets, and wave setup in the bay; and those damages that arise due to the increased flooding during the storm event that results in breaching and overwash. This breakout has been developed by evaluating the damages that occur if the barrier island is in a condition to preclude breaching and overwash. For each of these categories, inundation damages have been divided into those occurring on the back-bay mainland and those on the back-bay side of the barrier islands.

Breach - Inundation: Breach inundation damages occur when structures are flooded by increases in back bay water elevations caused by breaches in the barrier islands. These damages are limited to structures in back bay mainland areas and on the back bay side of the barrier islands. Damages in this category have been separated to reflect both the increase in annual damage associated the existing breach at the Wilderness Area and damages anticipated to occur between the formation and closure of any additional breaches over the period of analysis.

The impact of the existing breach was calculated using the breach lifecycle model described above. This model is designed to calculate the incremental damage of having a breach open for some time period relative to a no breach condition. As described in Appendix A, hydrodynamic models were developed to identify the change in storm surge elevations with the Wilderness Area Breach remaining open. The incremental damages of a new breach in the without project condition are calculated using the water levels associated with multiple breaches (Wilderness Area included) minus the damages calculated using the water levels associated with the breach at the Wilderness Area only. Likewise, the damages of the existing breach at the Wilderness Area are the damages calculated using the water levels associated with the breach at the Wilderness Area minus the damages calculated using the water levels associated with no breach.

Breach – Structure Failure: These damages occur on the barrier islands only and are triggered when structures are undermined and lost to erosion when breaches in the barrier islands are allowed to grow in directions parallel to the shoreline. Since potential structure failure damages may also be captured as part of the shorefront damage analyses, damages associated with structure failure during breach growth have been excluded from the tabulated results in order to avoid potential double counting of damage and benefits.

Shorefront: These damages occur only in the shorefront areas of the barrier islands and the mainland, and are caused by cross-shore erosion, wave action, ocean inundation, or combinations thereof. The shorefront damages are summarized in Table 14.

Emergency Repairs: These damages are associated with repair and closure of breaches. The damages reflect the costs of closing breaches based on a nine month delay to obtain permits, funding, and to mobilize a dredge to the site of the breach. The breach lifecycle analysis simulates possible future breach formation and cost of breach closures. The closure costs for any future breach were multiplied by the appropriate present worth factor and summed to calculate the total present worth of the closure costs. The total present worth was multiplied by the capital recovery factor to calculate the equivalent annual emergency closure costs.

Other Damage Categories not Evaluated in the Study: The analysis did not consider changes to population and development, damages to agriculture, or traffic delay benefits. No damages to agriculture were reflected in the analysis as there was no anticipated with-project change in the agricultural areas. The potential transportation disruption was of limited duration, and guidance provided at the time of the analysis recommended that any exploration of transportation disruption costs avoided would incur more project cost than generate benefits. Duration of flooding at key access points require detours but do not entirely disrupt transit through the area for a significant amount of time.

Recreation: In addition to storm damage and other categories described above, analyses have been conducted to quantify benefits arising from the recreational use of beaches in the study area. The methodology and evaluation of these benefits is described in detail in Sub-Appendix D1 – Recreation Report.

Table 16 provides a summary of the total without project damages for all evaluated damage categories.

Table 16 - Summary of Without Project Annual Damages

Damage Category	Without Project Damage
Total Project	
Tidal Inundation occurring due to inlet conditions and wave setup in back bay	
Mainland	$113,405,000
Barrier	$19,611,000
Total	*$133,016,000*
Tidal Inundation occurring due to storm breaching and overwash	
Mainland	$22,572,000
Barrier	$3,903,000
Total	*$26,475,000*
Total Mainland Inundation	*$135,977,000*
Total Barrier Island Inundation	*$23,514,000*
Total Inundation	*$159,491,000*
Damages from Inundation due to a breach remaining open*	
Inundation (Open Wilderness Breach)	$9,030,000
Inundation (Future Breaches)	$10,432,000
Total Breach Open Damages	*$19,462,000*
Shorefront Damages	$15,204,000
Emergency Costs/Breach Closure	$3,148,000
Total Damage	***$197,305.000***

Oct 2018 PL, Discount Rate 2.875%, Period of Analysis 50 years

Notes:

1. *Breach-related structure failures are not included in the total breach damage due to the potential for double count these damages with other barrier island damage categories. All breach-related damages and costs were modeled under the assumption that the existing breach at Wilderness Area remains open during the analysis period in both without- and with-project conditions.
2. Damages include the effects of the historic rate of Sea Level Rise projected over the Analysis Period

8 WITH PROJECT CONDITIONS

8.1 Alternatives

As described in the GRR Main Report and Appendix E - Plan Formulation, the FIMP project must be mutually agreed to between the USACE and the Department of Interior. Extensive coordination of alternative plans has been completed and have resulted in a Tentative Federally Selected Plan (TFSP) as documented in Fire Island to Montauk Point Reformulation Study, Draft Formulation Report, May 2009. This appendix provides a description of the analysis methods used to calculate storm damage and benefits as presented in the Plan Formulation Appendix. This document also describes the updated results of the Recommended Plan (RP).

Phase 1 of the FIMP Plan Formulation process considered a comprehensive list of measures to identify which measures met the Planning Objectives. Individual measures which met the planning objectives were then evaluated in Phase 2 as described in Chapter 4 of Appendix E - Plan Formulation. The benefits of these alternatives are presented in Chapter 4, Phase 2, Evaluation of Individual Storm Damage Reduction Alternatives. Phase 3 of the formulation combined alternatives according to the project planning vision to incrementally evaluate comprehensive plans. The benefits for those plans, documented in Appendix E, supported the identification of the TFSP.

In March 2011, USACE and DOI reached agreement on a TFSP that was largely based on the modified Plan 3g described in Appendix E - Plan Formulation, and requested concurrence by the State of New York in a joint letter dated March 11, 2011.

By letter dated December 29, 2011, the State provided comments to the RP. To address the State's comments, USACE proposed a "Modified 2B Plan" that excludes beach fill measures and that an alternative comparison including the previously identified RP (Alternative 3G), and the No Action alternative. On June 28, 2012, the State provided additional comments to the "Modified 2B Plan". Prior to providing formal responses to the State's comments, Hurricane Sandy struck on October 29, causing extensive damage to the project area, and which also included several breaches of the barrier island. All of the breaches were closed with the exception of a breech within the OPWA, which the DOI has continued to monitor.

On June 14, 2013 the State of New York indicated support of the modified RP that included changes to address the Hurricane Sandy impacts. This Appendix describes the benefit analyses underway to validate that the Modified RP.

The modified RP includes the following:

Inlet Sand Bypassing

- Provides for sufficient sand bypassing across Fire Island, Moriches, and Shinnecock Inlets to restore the natural longshore transport of sand along the barrier island for 50 years. Scheduled O&M dredging of the authorized navigation channel and deposition basin with sand placement on the barrier island will be supplemented, as needed, by dredging from the adjacent ebb shoals of each inlet to obtain the required volume of sand needed for bypassing.

- The bypassed sand will be placed in a berm template at elevation +9.5 ft NGVD 29 in identified placement areas.
- Monitoring is included to facilitate adaptive management changes.

Mainland Nonstructural

- Addresses approximately 4,432 structures within the 10 percent floodplain using nonstructural measures, primarily, structural elevations and building retrofits, based upon structure type and condition.
- Ring walls are provided for 91 structures that are not suitable for nonstructural treatment. The ring walls will meet all structural requirements, per PB 2014-01, and will have an O&M Plan.
- Includes localized acquisition in areas subject to high frequency flooding, and reestablishment of natural floodplain function.

Breach Response Plans

- Proactive Breach Response – is a response plan that is triggered when the level of project performance at the shoreline falls below the condition under which the 4 percent flood would be capable of breaching the barrier island.
- Reactive Breach Response – is a response plan that is triggered when a breach has occurred, and there is an exchange of ocean and bay water during normal tidal conditions. It is applicable to locations where there is agreement that a breach should be mechanically closed quickly, such as Robert Moses State Park and the Talisman Federal tract.
- Conditional Breach Response – is a response plan that is triggered when a breach has occurred, and there is an exchange of ocean and bay water during normal tidal conditions. It is applicable to most Federally-owned tracts within FIIS. A decision about potential breach closure will be made by the Breach Closure Team. Mechanical closure of the breach will take place if the breach does not close naturally within 60 days of opening, or if modeling indicates the breach will not close naturally.
- Wilderness Breach Response – is a response plan that is triggered when a breach has occurred, and there is an exchange of ocean and bay water during normal tidal conditions. It is applicable to the Federally-owned Wilderness tracts within FIIS. A decision about potential breach closure will be made by the Breach Closure Team. Mechanical closure of the breach will take place if the breach does not close naturally within 60 days of opening, or if the breach is likely to contribute to significant flood damage.

Beach and Dune Fill on Shorefront

- Provides for a 90 ft width berm and +15 ft dune along the developed shorefront areas on Fire Island and Westhampton barrier islands.
- All dunes will be planted with dune grass except where noted.
- On Fire Island the post-Hurricane Sandy optimized alignment is followed and includes overfill in the developed locations to minimize tapers into Federal tracts.

- Renourishment takes place approximately every 4 years for up to 30 years after project completion; while proactive breach response takes place from years 31 to 50.
- Provides for adaptive management to ensure the volume and placement configuration accomplishes the design objectives of offsetting long-term erosion.
- Provides for construction of a feeder beach every 4 years for up to 30 years at Montauk Beach.

Groin Modification

- Provides for removal of the existing Ocean Beach groins.

Coastal Process Features (CPFs)

- Provides for 12 barrier island locations and two (2) mainland locations (**Error! Reference source not found.**) as coastal process features and provide habitat for protected species.
- Includes placement of approximately 4.2 M cy of sediment in accordance with the Policy Waiver granted by the Office of the Assistant Secretary of the Army, Civil Works (ASA[CW]) on October 11, 2017. Sediment will be placed along the barrier island bayside shoreline over the 50-year period of analysis that reestablishes the natural coastal processes consistent with the reformulation objective of no net loss of habitat or sediment. The placement of sediment along the bay shoreline will be conducted in conjunction with other nearby beach fill operations undertaken on the barrier island shorefront.
- The CPFs will compensate for reductions in cross-island transport and sediment input to the Bay, offset Endangered Species Act impacts from the placement of sediment along the barrier island shorefront, augment the resiliency and enhance the overall barrier island and natural system coastal processes.

Adaptive Management

- Provides for monitoring and the ability to adjust specific project features to improve effectiveness and achieve project objectives
- Climate change will be accounted for with the monitoring of climate change parameters, identification of the effect of climate change on the project design, and identification of adaptation measures that are necessary to accommodate climate changes as it relates to all the project elements.

Integration of Local Land Use Regulations and

- Upon project completion, USACE's Annual Inspection of Completed Works (ICW) program provides for monitoring and reporting of any new development within the project area to the appropriate Federal, state, and local entities responsible for enforcing applicable land use regulations.

Since the storm damage reduction benefits of any alternative are the difference in the damages in the with- and without-project conditions, these analyses help to identify the cost-effectiveness of each alternative. In all the following analyses, the FY19 discount rate of 2.875%, a project base year of 2028, and a period of analysis of 50 years have been applied.

8.2 With Project Damage Analyses

The evaluation of damages for all of the alternatives and the Final Array of Plans was performed by modifying various inputs to the without project damage analysis. Each of the measures included in the Plan required specific changes to inputs which are summarized below.

8.2.1 Inlet Bypassing

The reduction in storm damages arising from the implementation of the Inlet Bypassing is generally reflected as a reduction in the long-term erosion rates. For the shorefront damage analysis, the impacts are directly input as the estimated with project shoreline change rates. For analysis of non-shorefront and breach related damages the reduced erosion rates are input in the lifecycle economic analysis models as an increase in the post storm recovery rate to produce a lower long-term erosion rate. Where dredging and bypassing of the inlet is part of the initial construction the base year profile conditions are modified to reflect the expected sand placement.

8.2.2 Non-Structural

An array of four nonstructural plans covering incrementally larger groups of structures was evaluated during the original formulation. These groups were aggregated by ground elevation, effectively forming clusters of structures at similar risk from flooding. The formulation of nonstructural plans was based on the overall economic justification of structures in each aggregated group and did not explicitly evaluate the benefits for individual structures.

The effect of the measures included in the non-structural plans is to alter the impact of flooding on the individual structures and reduce the damages occurring at each flood stage. The evaluation of the non-structural plans requires modifying the inputs to the HEC-FDA model used to develop the non-shorefront stage vs damage relationships. The modified stage vs damage relationships were inserted to the lifecycle economic analysis models to calculate damages with the non-structural features in place. Figure 4 provides a sample stage vs damage relationship comparison with and with-out the non-structural measures for Reach 17.1 which contains about 325 structures located in Moriches Bay.

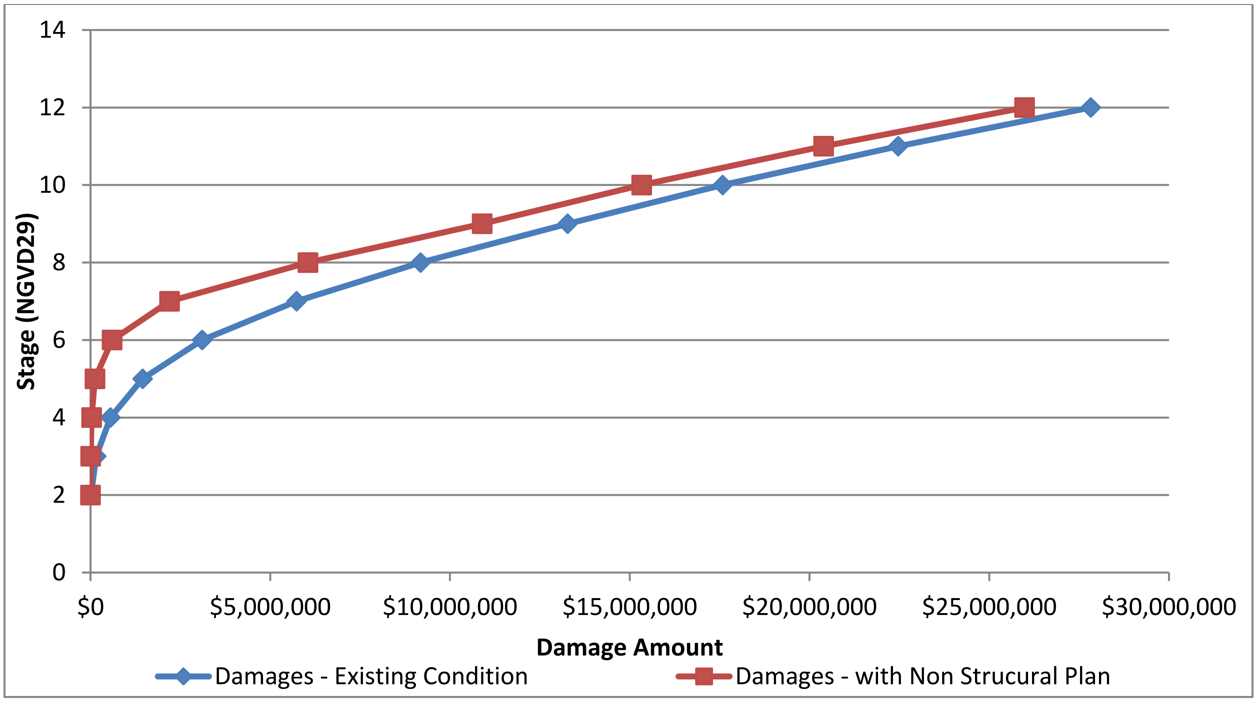

Figure 6 – Average Stage Damage Comparison for Reach 17.1

8.2.2.1 Structure Elevation

The elevation of the structures obviously increases the first floor elevation of the individual structures. In addition, elevating structures with basements will require filling the basement and relocating any utilities to the elevated floor level. For these structures the depth vs damage relationships were modified from a “with basement” to a “no basement” condition. In some cases, it was determined that it would be less costly to rebuild a structure than to elevate in place. For those structures the structure value was adjusted to reflect an “as new” condition.

8.2.2.2 Structure Buyout

Structure buyouts eliminate the buildings from the potential hazard area. The ground and floor elevations of these structures were modified to remove them from the floodplain.

8.2.2.3 Floodproofing

Floodproofing structures can involve several approaches, but generally prevents flood damages below a certain depth. These changes were incorporated into the HEC-FDA model by modifying the start of damage variable for the specific structures.

8.2.2.4 Elevated Roadways/ Berms

The elevation or raising of road grades will provide a barrier to frequent flooding similar to a low elevation levee. The structures located on the landside of these roads were identified and incorporated into a separate HEC-FDA model. Stage damage curves were modified to truncate the damages, setting all damage below the road elevation to zero.

8.2.3 *Breach Management*

The reduction in storm damages arising from the implementation of various breach closure alternatives was modeled using the Breach Only Lifecycle and the Inundation Lifecycle models described in Appendix A – Engineering.

8.2.4 *Proactive BRP*

The plan formulation identified some areas where there is a strong desire to avoid future breaching, but where a standard beach nourishment project is either not economically justified or is not preferred due to potential impacts. In these locations some of the initial alternatives and the final array of plans include Proactive Breach Response. The proactive breach response plan involves mobilizing and placing beach nourishment when vulnerable locations are threatened by breaching. The evaluation of future with-project breach response was conducted using the breach only lifecycle model and identified threshold beach profile conditions that would trigger a response, the effective width of the restored profile, an estimated length of the placement area, and unit prices for dredge mobilization and fill placement, parameters which are adjusted in the breach damage lifecycle model to compute with-project residual damages arising from breach closure alternatives. Table 17 provides a summary of the pro-active breach response threshold, post construction conditions, and the number of response actions anticipated at key locations with the RP over the 50-year period of analysis. The pro-active breach response provides project benefits by reducing the impacts of overwash and breaching on storm surge levels and associated flood damages in the bays and reducing the frequency future breaches and closure activities.

Table 17 - Proactive Breach Response

Location	Bay	Effective Profile Width (Ft)[1]		Placement Length (Ft)	Proactive Breach Response Actions[2]		
		Threshold	Restored		Minimum	Mean	Maximum
Fire Island Lighthouse	GSB	35	142	2,100	0	0.4	2
Talisman/Blue Point	GSB	54	104	1,700	0	0.3	6
Sedge Island	SHN	50	136	1,200	0	0.4	2
Tiana	SHN	50	224	1,200	0	0	1
West of Shinnecock Inlet	SHN	100	185	1,200	0	0.5	5

Notes

1. See Table 7-33 and Figure 7-6 in Appendix A: Engineering and Design

2. During the 50-year period of analysis (25,000 simulations).

8.2.5 *Responsive BRP*

For some alternatives and locations various plans include a responsive breach closure plan which will expedite the closure of any breaches that do occur. Since breaches increase over time until they reach a stable dimension the longer it takes to respond to a breach the more it will cost to close and the greater the hydraulic impacts to flood stages in the bay. The benefits of the expedited response plan are to reduce the amount of time that a breach has to grow larger, which in turn reduces the amount of fill and the costs necessary to close the breach. Reducing both the maximum size of the breach also reduces the potential storm surge levels in the bay and reducing the duration the breach is open reduces the probability of having a one or more storms before the breach is closed. Table 18 provides a summary of breach closure reference costs for various locations and response scenarios.

The beneficial impacts of the accelerated breach closure are determined by recalculating the breach closure costs for the reduced breach area and fill volume and by recalculating the potential increased storm damage with the shorter duration of an open breach. The model then used to re-evaluate the potential breach scenarios, closure costs and increased flood damages for every year of the analysis period to calculate average annual impacts.

Table 18 - Breach Closure Reference Costs

Location - Large and Standard Breach	Construction Alternative Resulting in Lowest Total Cost	Without Project Closure Cost	BCP Closure Cost
FI Lighthouse Tract	Hopper Dredge	$38,987,425	$31,689,217
Town Beach to Corneille Estates	Cutterhead Dredge	$36,837,420	$18,612,316
Talisman to Water Island	Cutterhead Dredge	$28,710,076	$13,889,596
Davis Park	Cutterhead Dredge	$28,737,131	$13,899,421
Wilderness Area West	Cutterhead Dredge	$31,469,134	$15,435,697
Wilderness Area East	Cutterhead Dredge	$28,031,824	$14,133,247
Smith Point County Park	Hopper Dredge	$24,599,965	$18,208,062
Sedge Island	Cutterhead Dredge	$16,710,948	$10,254,929
Tiana Beach	Cutterhead Dredge	$16,194,807	$10,033,388
WOSI	Hopper Dredge	$19,159,535	$15,374,275
Location - Small Breach	**Construction Alternative Resulting in Lowest Total Cost**	**Without Project Closure Cost**	**BCP Closure Cost**
FI Lighthouse Tract	Hopper Dredge	$10,919,328	$8,647,621
Town Beach to Corneille Estates	Cutterhead Dredge	$10,746,227	$7,340,820
Talisman to Water Island	Cutterhead Dredge	$9,340,158	$6,677,611
Davis Park	Cutterhead Dredge	$9,345,042	$6,679,387
Wilderness Area West	Cutterhead Dredge	$9,861,252	$7,065,152
Wilderness Area East	Cutterhead Dredge	$9,240,913	$6,829,861

8.3 Beach and Dune Nourishment

The placement of beach and dune nourishment provides direct reductions in wave propagation and erosion distance for the properties along the ocean shorefront. These benefits were in the shorefront model evaluated by adjusting the beach width and dune crest elevations in the damage calculations for structures at the design beach areas. The effects of re-nourishment are captured by resetting the dune and beach parameters to the minimum design dimensions for the start of the first year of each renourishment cycle. In the lifecycle economic analysis models the beach and dune nourishment plans are modeled by adjusting or resetting the profile widths, threshold water levels for breach and overwash, and the post-storm profile recovery.

The impact of beach and dune nourishment on bay water levels was also evaluated. As described in Appendix A, the storm surge modelling identified the impact of overwash and breaching on flood stages in the bay. For conditions with nourished beaches and dunes changes in the volume and rate of storm surge entering the bay were modelled for various storms and new bay water surfaces were calculated. The presence of higher dunes and wider beaches will also reduce the likelihood of storms causing a breach and will reduce future breach closure costs. The with-project cost of breach closures is considered a project cost and are not included in the with-project damage summary tables.

8.4 Sediment Management Feeder Beach

Some alternatives, including the RP, provide for feeder beaches to restore or supplement sediment transport rates and to reduce the extent of downdrift erosion. The feeder beach locations were selected to areas of comparatively high existing damage risk which provides additional storm damage reduction by periodically increasing beach widths in these vulnerable locations.

Damages with the feeder beach in place are calculated for the shorefront structures in the SFD model by modifying the long-term erosion rates to reflect impacts of wider future beach widths in reducing wave and erosion damages.

8.5 Groin Modification

Groin modifications included in the plans will modify long term sediment transport rates to restore more natural conditions. In order to avoid increased erosion and future damages in some locations the groin removals will be performed in conjunction with beach nourishment and re-nourishment. The impacts of groin removal are therefore seen in a more uniform erosion of the nourished beaches which reduces the potential for erosion “hot spots” that require more frequent re-nourishment.

8.6 Coastal Process Restoration

The coastal process restoration features will provide an increase in the long-term stability of the coastal landscape including beaches and barrier islands. While coastal process restoration impacts on storm damages have not been quantified, have not been quantified, the increased long-term stability is consistent with the Department of Interior’s goal to preserve the natural resources of the National Seashore for future generations.

8.7 With Project Damage Results

As shown in Table 19, the total equivalent Shorefront annual damages with the RP are $6,911,000. For the non-shorefront reaches (Back Bay areas), the total equivalent inundation damages with the constructed RP are $77,929,000, as shown in Table 20. Table 21 shows the non-shorefront inundation damages with only the Nonstructural component of the RP, while Table 22 shows the non-shorefront inundation damages with only the Coastal Measures component of the RP (e.g. berm and dune fill, inlet modifications, groin modifications, breach response, sediment management, and coastal process features). Table 23 provides an overall summary of the total project equivalent damages, with $95,669,000 in residual damages from all sources under the RP, as compared to $110,361,000 and $170,188,100 under the non-structural only and coastal measures only RP components, respectively.

Table 19 - Shorefront Damages – RP

Project Reach		Critical Asset	Name	Approximate Length	Equivalent Annual Damage 2028 - 2078
GSB	GSB-1	1A	Robert Moses State Park	25,700	$0
		1B	FI Lighthouse Tract	6,700	$0
	GSB-2	2A	Kismet to Lonelyville	8,900	$1,656,400
		2B	Town Beach to Corneille Estates	5,100	$328,900
		2C	Ocean Beach & Seaview	3,800	$292,100
		2D	OBP to Point O' Woods	7,400	$389,800
		2E	Sailors Haven	8,100	$0
	GSB-3	3A	Cherry Grove	3,000	$264,700
		3B	Carrington Tract	1,500	$0
		3C	Fire Island Pines	6,600	$147,300
		3D	Talisman to Water Island	7,300	$10,600
		3E	Water Island	2,000	$16,400
		3F	Water Island to Davis Park	4,700	$300
		3G	Davis Park	4,100	$83,100
		3H	Watch Hill	5,000	$0
	GSB-4	4A	Wilderness Area - West	19,000	$0
		4B	Wilderness Area	16,000	$0
GSB Subtotal:					**$3,189,600**
MB	MB-1	1A	Smith Point CP- West	6,300	$0
		1B	Smith Point CP - East	13,500	$0
	MB-2	2A	Great Gun	7,600	$0
		2B	Moriches Inlet - West	6,200	$0
		2C	Cupsogue Co Park	7,500	$800
		2D	Pikes	9,700	$274,900
		2E	Westhampton	18,300	$13,700
MB Subtotal:					**$289,400**
SB	SB-1	1A	Hampton Beach	16,800	$292,300
		1B	Sedge Island	10,200	$501,600
		1C	Tiana Beach	3,400	$64,300
		1D	Shinnecock Inlet Park West	6,300	$5,600
	SB-2	2A	Ponquogue	5,300	$100
		2B	WOSI	3,900	$10,300

Project Reach		Critical Asset	Name	Approximate Length	Equivalent Annual Damage 2028 - 2078
		2C	Shinnecock Inlet - East	9,800	$170,500
	SB-3	3A	Southampton Beach	9,200	$35,500
		3B	Southampton	5,300	$194,400
		3C	Agawam	3,800	$140,400
SB Subtotal:					**$1,415,000**
P	P-1	1A	Wickapogue	7,700	$342,500
		1B	Watermill	8,800	$217,800
		1C	Mecox Bay	1,400	$5,700
		1D	Mecox to Sagaponack	10,400	$103,400
		1E	Sagaponack Lake	1,100	$2,000
		1F	Sagaponack to Potato Rd	9,300	$17,500
		1G	Potato Rd	4,300	$31,300
		1H	Wainscott	4,600	$23,100
		1I	Georgica Pond	1,200	$0
		1J	Georgica to Hook Pond	11,200	$650,600
		1K	Hook Pond	1,100	$0
		1L	Hook Pond to Amagansett	19,200	$37,000
Ponds Subtotal:					**$1,430,900**
M	M-1	1A	Amagansett	10,400	$196,500
		1B	Napeague State Park	9,100	$0
		1C	Napeague Beach	9,900	$96,600
		1D	Hither Hills SP	7,000	$6,200
		1E	Hither Hills to Montauk B	15,800	$61,700
		1F	Montauk Beach	4,700	$24,700
		1G	Montauk B to Ditch Plains	4,700	$24,400
		1H	Ditch Plains	3,400	$4,700
		1I	Ditch Plains to Montauk Pt	19,300	$171,400
Montauk Subtotal:					**$586,200**
Total					***$6,911,100***

Includes damages due to inundation, wave action, and erosion.
Oct 2018 PL. Discount Rate 2.875%, Period of Analysis 50 years

Table 20 - Non-shorefront Inundation damages - RP

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	Mainland Reach ID	Location			Year 2028	Year 2078	Equivalent Annual
26.1	GSB-M-1A	Unqua Point (County Line) to Copiague Beach	1,683	WGSB	$1,953	$4,215	$3,310
26.2	GSB-M-1B	Copiague Beach to Venetian Shores Beach	4,674	WGSB	$2,341	$5,712	$4,348
26.3	GSB-M-1C	Venetian Shores Beach to Neguntatogue Creek	2,268	WGSB	$2,593	$5,873	$4,567
25.1	GSB-M-1D	Neguntatogue Creek to Santapogue Point	1,931	WGSB	$977	$2,480	$1,891
25.2	GSB-M-1E	Santapogue Point to Sampawams Point (Town Line)	2,404	WGSB	$1,849	$4,683	$3,575
24	GSB-M-2A	Sampawams Point (Town Line) to Great Cove	3,154	WGSB	$830	$2,880	$2,042
23.1	GSB-M-2B	Brightwaters	364	WGSB	$153	$482	$337
23.2	GSB-M-2C	Lawrence Creek to Seatuck Refuge	1,717	WGSB	$1,840	$5,162	$3,809
23.3	GSB-M-2D	Seatuck Refuge to Heckscher Park (Nicoll Point)	2,982	WGSB	$855	$2,249	$1,702
28		Fire Island Lighthouse to Seaview (Fire Island)	1,994	WGSB	$9,538	$19,661	$16,396
27.1		Ocean Bay Park to Oakleyville (Fire Island)	433	WGSB	$914	$1,868	$1,532
Subtotal - Western Great South Bay Sub-Bay			***23,604***		***$23,844***	***$55,267***	***$43,509***
27.2		Sailors Haven to Water Island (Fire Island)	712	CGSB	$2,022	$4,768	$3,727
27.3		Water Island to Watch Hill (Fire Island)	188	CGSB	$526	$1,473	$1,030
22.1	GSB-M-3A	Heckscher Park (Nicoll Point) to Green Point	1,949	CGSB	$2,201	$6,002	$4,642
22.2	GSB-M-3B	Green Point to Blue Point (Town Line)	2,075	CGSB	$691	$2,133	$1,521
21.1	GSB-M-4A	Blue Point (Town Line to Tuthill Creek (Blue Point)	513	CGSB	$292	$757	$571
21.2	GSB-M-4B	Tuthill Creek to Swan River (Patchogue)	1,628	CGSB	$1,236	$3,567	$2,629

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	**Mainland Reach ID**	**Location**			**Year 2028**	**Year 2078**	**Equivalent Annual**
21.3	GSB-M-4C	Swan River to Mud Creek	751	CGSB	$190	$540	$406
Subtotal - Central Great South Bay Sub-Bay			***7,816***		***$7,158***	***$19,240***	***$14,527***
21.4	GSB-M-5A	Mud Creek to Howell Creek	745	EGSB	$351	$902	$688
21.5	GSB-M-5B	Howell Creek to Bellport Marina	224	EGSB	$49	$160	$115
21.6	GSB-M-5C	Bellport Marina to Carmans River	425	EGSB	$245	$648	$481
20	GSB-M-6A	Carmans River to Smith Point Bridge	571	EGSB	$266	$758	$554
Subtotal - Eastern Great South Bay Sub-Bay			***1,966***		***$911***	***$2,468***	***$1,838***
19		Moriches Inlet to Quantuck Canal (Westhampton Barrier)	241	MOR	$4	$12	$8
18.1	MB-M-1A	Smith Point Bridge to William Floyd Estate	3,052	MOR	$2,028	$5,019	$3,937
18.2	MB-M-1B	William Floyd Estate to Forge River	206	MOR	$112	$260	$208
18.3	MB-M-1C	Forge River to Radio Point	1,332	MOR	$2,154	$4,768	$3,781
17.1	MB-M-2A	Radio Point to Harts Cove	219	MOR	$191	$472	$363
17.2	MB-M-2B	Harts Cove to Seatuck Creek (Town Line)	93	MOR	$11	$36	$25
16.1	MB-M-3A	Seatuck Creek (Town Line) to Fish Creek	134	MOR	$187	$463	$356
16.2	MB-M-3B	Fish Creek to Speonk Point	317	MOR	$308	$695	$553
16.3	MB-M-3C	Speonk Point to Apacuck Point	431	MOR	$531	$1,106	$941
16.4	MB-M-3D	Apacuck Point to Quantuck Bay	609	MOR	$941	$1,940	$1,623
Subtotal - Moriches Bay Sub-Bay			***6,634***		***$6,466***	***$14,771***	***$11,794***
15		Quantuck Canal to Village Park (Westhampton Barrier)	93	WSHN	$12	$58	$39
13.1	SB-M-1A	Quantuck Bay West	297	WSHN	$444	$956	$778
13.2	SB-M-1B	Quantuck Canal to Phillips Point	586	WSHN	$782	$1,820	$1,445
12	SB-M-2A	Phillips Point to Pine Neck Point	783	WSHN	$493	$1,310	$1,008

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	**Mainland Reach ID**	**Location**			**Year 2028**	**Year 2078**	**Equivalent Annual**
11.1	SB-M-2B	Pine Neck Point to West Point	280	WSHN	$267	$558	$464
11.2	SB-M-2C	West Point to Ponquogue Point	616	WSHN	$808	$1,758	$1,417
Subtotal - Western Shinnecock Bay Sub-Bay			***2,655***		***$2,806***	***$6,460***	***$5,150***
10.1	SB-M-3A	Ponquogue Point	39	SHN	$62	$147	$120
10.2	SB-M-3B	Cormorant Point	6	SHN	$4	$6	$5
10.3	SB-M-3C	Shinnecock Canal Region	199	SHN	$209	$419	$359
10.4	SB-M-3D	Shinnecock Indian Reservation	258	SHN	$250	$503	$438
8b	SB-M-4A	Heady Creek	119	SHN	$98	$218	$180
Subtotal - Shinnecock Bay Sub-Bay			***621***		***$622***	***$1,293***	***$1,102***
Total: Back Bay Area			**43,291**		**$41,806**	**$99,498**	**$77,920**

Oct 2018 PL, Discount Rate 2.875%, Period of Analysis 50 years

Table 21 - Non-shorefront Inundation damages – Non-structural component of RP only

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	Mainland Reach ID	Location Name			Year 2028	Year 2078	Equivalent Annual
26.1	GSB-M-1A	Unqua Point (County Line) to Copiague Beach	1,683	WGSB	$2,223	$4,706	$3,378
26.2	GSB-M-1B	Copiague Beach to Venetian Shores Beach	4,674	WGSB	$3,052	$6,485	$4,551
26.3	GSB-M-1C	Venetian Shores Beach to Neguntatogue Creek	2,268	WGSB	$3,221	$6,629	$4,726
25.1	GSB-M-1D	Neguntatogue Creek to Santapogue Point	1,931	WGSB	$1,290	$2,848	$1,980
25.2	GSB-M-1E	Santapogue Point to Sampawams Point (Town Line)	2,404	WGSB	$2,474	$5,397	$3,758
24	GSB-M-2A	Sampawams Point (Town Line) to Great Cove	3,154	WGSB	$1,308	$3,344	$2,214
23.1	GSB-M-2B	Brightwaters	364	WGSB	$224	$570	$367
23.2	GSB-M-2C	Lawrence Creek to Seatuck Refuge	1,717	WGSB	$2,622	$6,059	$4,061
23.3	GSB-M-2D	Seatuck Refuge to Heckscher Park (Nicoll Point)	2,982	WGSB	$1,111	$2,720	$1,821
28		Fire Island Lighthouse to Seaview (Fire Island)	1,994	WGSB	$13,220	$23,846	$17,080
27.1		Ocean Bay Park to Oakleyville (Fire Island)	433	WGSB	$1,213	$2,203	$1,594
Subtotal - Western Great South Bay Sub-Bay			***23,604***		***$31,958***	***$64,807***	***$45,530***
27.2		Sailors Haven to Water Island (Fire Island)	712	CGSB	$2,844	$5,279	$3,758
27.3		Water Island to Watch Hill (Fire Island)	188	CGSB	$757	$1,513	$1,033
22.1	GSB-M-3A	Heckscher Park (Nicoll Point) to Green Point	1,949	CGSB	$3,314	$6,923	$5,123
22.2	GSB-M-3B	Green Point to Blue Point (Town Line)	2,075	CGSB	$1,067	$2,398	$1,724
21.1	GSB-M-4A	Blue Point (Town Line to Tuthill Creek (Blue Point)	513	CGSB	$427	$865	$627
21.2	GSB-M-4B	Tuthill Creek to Swan River (Patchogue)	1,628	CGSB	$1,900	$3,962	$2,909

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	**Mainland Reach ID**	**Location Name**			**Year 2028**	**Year 2078**	**Equivalent Annual**
21.3	GSB-M-4C	Swan River to Mud Creek	751	CGSB	$303	$629	$462
Subtotal - Central Great South Bay Sub-Bay			***7,816***		***$10,612***	***$21,569***	***$15,637***
21.4	GSB-M-5A	Mud Creek to Howell Creek	745	EGSB	$499	$1,055	$748
21.5	GSB-M-5B	Howell Creek to Bellport Marina	224	EGSB	$89	$183	$129
21.6	GSB-M-5C	Bellport Marina to Carmans River	421	EGSB	$356	$750	$528
20	GSB-M-6A	Carmans River to Smith Point Bridge	571	EGSB	$177	$331	$239
Subtotal - Eastern Great South Bay Sub-Bay			***1,961***		***$1,121***	***$2,319***	***$1,644***
19		Moriches Inlet to Quantuck Canal (Westhampton Barrier)	241	MOR	$6	$13	$9
18.1	MB-M-1A	Smith Point Bridge to William Floyd Estate	3,052	MOR	$3,195	$5,637	$4,595
18.2	MB-M-1B	William Floyd Estate to Forge River	206	MOR	$171	$295	$240
18.3	MB-M-1C	Forge River to Radio Point	1,332	MOR	$3,062	$5,040	$4,160
17.1	MB-M-2A	Radio Point to Harts Cove	219	MOR	$265	$533	$401
17.2	MB-M-2B	Harts Cove to Seatuck Creek (Town Line)	93	MOR	$23	$36	$30
16.1	MB-M-3A	Seatuck Creek (Town Line) to Fish Creek	134	MOR	$271	$534	$391
16.2	MB-M-3B	Fish Creek to Speonk Point	317	MOR	$431	$765	$600
16.3	MB-M-3C	Speonk Point to Apacuck Point	431	MOR	$702	$1,263	$1,024
16.4	MB-M-3D	Apacuck Point to Quantuck Bay	609	MOR	$1,284	$2,169	$1,741
Subtotal - Moriches Bay Sub-Bay			***6,634***		***$9,411***	***$16,285***	***$13,191***
15		Quantuck Canal to Village Park (Westhampton Barrier)	93	WSHN	$25	$64	$40
13.1	SB-M-1A	Quantuck Bay West	297	WSHN	$579	$1,058	$818
13.2	SB-M-1B	Quantuck Canal to Phillips Point	586	WSHN	$1,096	$2,012	$1,534

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	**Mainland Reach ID**	**Location Name**			**Year 2028**	**Year 2078**	**Equivalent Annual**
12	SB-M-2A	Phillips Point to Pine Neck Point	783	WSHN	$811	$1,518	$1,083
11.1	SB-M-2B	Pine Neck Point to West Point	280	WSHN	$374	$604	$489
11.2	SB-M-2C	West Point to Ponquogue Point	616	WSHN	$1,020	$1,896	$1,474
Subtotal - Western Shinnecock Bay Sub-Bay			***2,655***		***$3,906***	***$7,151***	***$5,438***
10.1	SB-M-3A	Ponquogue Point	39	SHN	$86	$159	$120
10.2	SB-M-3B	Cormorant Point	6	SHN	$4	$6	$5
10.3	SB-M-3C	Shinnecock Canal Region	199	SHN	$249	$463	$351
10.4	SB-M-3D	Shinnecock Indian Reservation	258	SHN	$302	$527	$417
8b	SB-M-4A	Heady Creek	119	SHN	$108	$232	$183
Subtotal - Shinnecock Bay Sub-Bay			***621***		***$749***	***$1,386***	***$1,076***
Total: Back Bay Area			**43,291**		**$57,758**	**$113,518**	**$82,516**

Oct 2018 PL, Discount Rate 2.875%, Period of Analysis 50 years

Table 22 - Non-shorefront Inundation damages – Coastal components of RP only

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	Mainland Reach ID	Location Name			Year 2028	Year 2078	Equivalent Annual
26.1	GSB-M-1A	Unqua Point (County Line) to Copiague Beach	1,683	WGSB	$5,073	$9,694	$8,085
26.2	GSB-M-1B	Copiague Beach to Venetian Shores Beach	4,674	WGSB	$3,361	$7,972	$6,112
26.3	GSB-M-1C	Venetian Shores Beach to Neguntatogue Creek	2,268	WGSB	$4,933	$10,030	$8,066
25.1	GSB-M-1D	Neguntatogue Creek to Santapogue Point	1,931	WGSB	$1,451	$3,463	$2,646
25.2	GSB-M-1E	Santapogue Point to Sampawams Point (Town Line)	2,404	WGSB	$4,028	$9,107	$7,212
24	GSB-M-2A	Sampawams Point (Town Line) to Great Cove	3,154	WGSB	$1,983	$5,340	$3,965
23.1	GSB-M-2B	Brightwaters	364	WGSB	$165	$505	$360
23.2	GSB-M-2C	Lawrence Creek to Seatuck Refuge	1,717	WGSB	$4,183	$9,465	$7,398
23.3	GSB-M-2D	Seatuck Refuge to Heckscher Park (Nicoll Point)	2,982	WGSB	$1,349	$3,421	$2,626
28		Fire Island Lighthouse to Seaview (Fire Island)	1,994	WGSB	$9,538	$19,661	$16,396
27.1		Ocean Bay Park to Oakleyville (Fire Island)	433	WGSB	$914	$1,868	$1,532
Subtotal - Western Great South Bay Sub-Bay			***23,604***		***$36,977***	***$80,526***	***$64,398***
27.2		Sailors Haven to Water Island (Fire Island)	712	CGSB	$2,022	$4,768	$3,727
27.3		Water Island to Watch Hill (Fire Island)	188	CGSB	$526	$1,473	$1,030
22.1	GSB-M-3A	Heckscher Park (Nicoll Point) to Green Point	1,949	CGSB	$8,725	$17,369	$14,459
22.2	GSB-M-3B	Green Point to Blue Point (Town Line)	2,075	CGSB	$3,038	$6,484	$5,212
21.1	GSB-M-4A	Blue Point (Town Line to Tuthill Creek (Blue Point)	513	CGSB	$658	$1,494	$1,168
21.2	GSB-M-4B	Tuthill Creek to Swan River (Patchogue)	1,628	CGSB	$3,196	$7,301	$5,772

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	Mainland Reach ID	Location Name			Year 2028	Year 2078	Equivalent Annual
21.3	GSB-M-4C	Swan River to Mud Creek	751	CGSB	$440	$1,166	$871
Subtotal - Central Great South Bay Sub-Bay			***7,816***		***$18,604***	***$40,055***	***$32,238***
21.4	GSB-M-5A	Mud Creek to Howell Creek	745	EGSB	$1,309	$2,641	$2,183
21.5	GSB-M-5B	Howell Creek to Bellport Marina	224	EGSB	$103	$264	$203
21.6	GSB-M-5C	Bellport Marina to Carmans River	421	EGSB	$847	$1,717	$1,375
20	GSB-M-6A	Carmans River to Smith Point Bridge	571	EGSB	$392	$1,030	$763
Subtotal - Eastern Great South Bay Sub-Bay			***1,961***		***$2,651***	***$5,653***	***$4,523***
19		Moriches Inlet to Quantuck Canal (Westhampton Barrier)	241	MOR	$4	$12	$8
18.1	MB-M-1A	Smith Point Bridge to William Floyd Estate	3,052	MOR	$7,843	$14,762	$12,298
18.2	MB-M-1B	William Floyd Estate to Forge River	206	MOR	$364	$718	$588
18.3	MB-M-1C	Forge River to Radio Point	1,332	MOR	$4,911	$9,374	$7,778
17.1	MB-M-2A	Radio Point to Harts Cove	219	MOR	$1,343	$2,410	$2,067
17.2	MB-M-2B	Harts Cove to Seatuck Creek (Town Line)	93	MOR	$12	$37	$28
16.1	MB-M-3A	Seatuck Creek (Town Line) to Fish Creek	134	MOR	$297	$660	$525
16.2	MB-M-3B	Fish Creek to Speonk Point	317	MOR	$1,275	$2,504	$2,065
16.3	MB-M-3C	Speonk Point to Apacuck Point	431	MOR	$1,592	$3,141	$2,551
16.4	MB-M-3D	Apacuck Point to Quantuck Bay	609	MOR	$2,852	$5,620	$4,633
Subtotal - Moriches Bay Sub-Bay			***6,634***		***$20,493***	***$39,238***	***$32,541***
15		Quantuck Canal to Village Park (Westhampton Barrier)	93	WSHN	$12	$58	$39
13.1	SB-M-1A	Quantuck Bay West	297	WSHN	$3,175	$5,283	$4,614
13.2	SB-M-1B	Quantuck Canal to Phillips Point	586	WSHN	$3,850	$6,781	$5,802

Location			Buildings #	Sub Bay	Inundation Damages ($,000)		
Economic Reach	Mainland Reach ID	Location Name			Year 2028	Year 2078	Equivalent Annual
12	SB-M-2A	Phillips Point to Pine Neck Point	783	WSHN	$1,368	$2,847	$2,302
11.1	SB-M-2B	Pine Neck Point to West Point	280	WSHN	$865	$1,653	$1,382
11.2	SB-M-2C	West Point to Ponquogue Point	616	WSHN	$1,180	$2,232	$1,978
Subtotal - Western Shinnecock Bay Sub-Bay			***2,655***		***$9,636.49***	***$16,822.55***	***$12,144.52***
10.1	SB-M-3A	Ponquogue Point	39	SHN	$128	$256	$215
10.2	SB-M-3B	Cormorant Point	6	SHN	$12	$20	$17
10.3	SB-M-3C	Shinnecock Canal Region	199	SHN	$785	$1,284	$1,132
10.4	SB-M-3D	Shinnecock Indian Reservation	258	SHN	$688	$1,284	$1,078
8b	SB-M-4A	Heady Creek	119	SHN	$98	$218	$199
Subtotal - Shinnecock Bay Sub-Bay			***621***		***$1,711***	***$3,063***	***$2,622***
Total: Back Bay Area			**43,291**		**$90,888**	**$187,388**	**$152,439**

Oct 2018 PL, Discount Rate 2.875%, Period of Analysis 50 years

***Table 23* – Summary of Total Project Damages**

Damage Category	With Project Equivalent Annual Damage: RP	With Project Equivalent Annual Damage: Nonstructural only RP component	With Project Equivalent Annual Damage: Coastal Measures only RP component
Total Project			
Tidal Inundation occurring due to inlet conditions and wave setup in back bay			
Mainland	$46,026,000	$49,207,000	$108,175,000
Barrier	$18,959,000	$19,611,000	$18,959,000
Total	*$64,985,000*	*$68,818,000*	*$127,134,000*
Tidal Inundation occurring due to storm breaching and overwash			
Mainland	$9,161,000	$9,794,000	$21,531,000
Barrier	$3,774,000	$3,903,000	$3,774,000
Total	*$12,935,000*	*$13,697,000*	*$25,305,000*
Total Mainland Inundation	*$55,187,000*	*$59,001,000*	*$129,706,000*
Total Barrier Inundation	*$22,733,000*	*$23,514,000*	*$22,733,000*
Total Inundation	*$77,920,000*	*$82,515,000*	*$152,439,000*
Damages (Inundation and Structure Failure) due to a breach remaining open			
Inundation (Open Breach at Wilderness Area)	$9,030,000	$9,030,000	$9,030,000
Inundation (Future Breaches)	$284,000	$464,000	$4,077,000
Total Breach Open Damages	*$9,314,000*	*$9,494,000*	*$9,314,000*
Shorefront Damages	$6,911,000	$15,204,000	$6,911,000
Emergency Costs/Breach Closure (Including Proactive Breach Maintenance Costs)	$1,524,000	$3,148,000	$1,524,000
Total Damage	***$95,669,000***	***$110,361,000***	***$170,188,000***

Oct 2018 PL, Discount Rate 2.875%, Base Year 2028, Period of Analysis 50 years

9 SUMMARY OF RP BENEFITS

Tables 24 and 25 provide summaries of the RP shorefront storm damage reduction benefits for the Shorefront and non-shorefront reaches, respectively. Table 26 presents a summary of the benefits for the overall RP and also the benefits with the non-structural only and coastal measures only RP components.

Table 24 - Storm Damage Reduction by Reach - Shorefront

Project Reach		Critical Asset	Name	Approximate Length	Equivalent Annual Benefits
GSB	GSB-1	1A	Robert Moses State Park	25,700	$0
		1B	FI Lighthouse Tract	6,700	$0
	GSB-2	2A	Kismet to Lonelyville	8,900	$957,300
		2B	Town Beach to Corneille Estates	5,100	$1,171,500
		2C	Ocean Beach & Seaview	3,800	$112,100
		2D	OBP to Point O' Woods	7,400	$309,200
		2E	Sailors Haven	8,100	$0
	GSB-3	3A	Cherry Grove	3,000	$41,300
		3B	Carrington Tract	1,500	$0
		3C	Fire Island Pines	6,600	$112,900
		3D	Talisman to Water Island	7,300	$10,300
		3E	Water Island	2,000	$17,000
		3F	Water Island to Davis Park	4,700	$400
		3G	Davis Park	4,100	$121,500
		3H	Watch Hill	5,000	$0
	GSB-4	4A	Wilderness Area - West	19,000	$0
		4B	Wilderness Area	16,000	$0
GSB Subtotal:					**$2,853,500**
MB	MB-1	1A	Smith Point CP- West	6,300	$0
		1B	Smith Point CP - East	13,500	$0
	MB-2	2A	Great Gun	7,600	$0
		2B	Moriches Inlet - West	6,200	$0
		2C	Cupsogue Co Park	7,500	$0
		2D	Pikes	9,700	$0
		2E	Westhampton	18,300	$0

Project Reach		Critical Asset	Name	Approximate Length	Equivalent Annual Benefits
MB Subtotal:					**$0**
SB	SB-1	1A	Hampton Beach	16,800	$0
		1B	Sedge Island	10,200	$1,124,700
		1C	Tiana Beach	3,400	$164,800
		1D	Shinnecock Inlet Park West	6,300	$0
	SB-2	2A	Ponquogue	5,300	$0
		2B	WOSI	3,900	$0
		2C	Shinnecock Inlet - East	9,800	$0
	SB-3	3A	Southampton Beach	9,200	$0
		3B	Southampton	5,300	$0
		3C	Agawam	3,800	$0
SB Subtotal:					**$1,289,500**
P	P-1	1A	Wickapogue	7,700	$0
		1B	Watermill	8,800	$0
		1C	Mecox Bay	1,400	$13,200
		1D	Mecox to Sagaponack	10,400	$279,500
		1E	Sagaponack Lake	1,100	$900
		1F	Sagaponack to Potato Rd	9,300	$65,700
		1G	Potato Rd	4,300	$1,820,900
		1H	Wainscott	4,600	$0
		1I	Georgica Pond	1,200	$0
		1J	Georgica to Hook Pond	11,200	$0
		1K	Hook Pond	1,100	$0
		1L	Hook Pond to Amagansett	19,200	$0
Ponds Subtotal:					**$2,180,200**
M	M-1	1A	Amagansett	10,400	$0
		1B	Napeague State Park	9,100	$0
		1C	Napeague Beach	9,900	$0
		1D	Hither Hills SP	7,000	$13,700
		1E	Hither Hills to Montauk B	15,800	$951,700
		1F	Montauk Beach	4,700	$935,300

Project Reach		Critical Asset	Name	Approximate Length	Equivalent Annual Benefits
		1G	Montauk B to Ditch Plains	4,700	$69,100
		1H	Ditch Plains	3,400	$0
		1I	Ditch Plains to Montauk Pt	19,300	$0
Montauk Subtotal:					**$1,969,800**
Total					***$8,293,000***

Oct 2018 PL, Discount Rate 2.875%, Base Year 2028, Period of Analysis 50 years

Table 25 - Storm Damage Reduction by Reach – Non-Shorefront

Location			Buildings #	Sub Bay	Equivalent Annual Benefits: Inundation Damages ($,000)
Economic Reach Number	**Mainland Reach ID**	**Location Name**			
26.1	GSB-M-1A	Unqua Point (County Line) to Copiague Beach	1,683	WGSB	$4,899
26.2	GSB-M-1B	Copiague Beach to Venetian Shores Beach	4,674	WGSB	$2,037
26.3	GSB-M-1C	Venetian Shores Beach to Neguntatogue Creek	2,268	WGSB	$3,693
25.1	GSB-M-1D	Neguntatogue Creek to Santapogue Point	1,931	WGSB	$885
25.2	GSB-M-1E	Santapogue Point to Sampawams Point (Town Line)	2,404	WGSB	$3,923
24	GSB-M-2A	Sampawams Point (Town Line) to Great Cove	3,154	WGSB	$2,154
23.1	GSB-M-2B	Brightwaters	364	WGSB	$55
23.2	GSB-M-2C	Lawrence Creek to Seatuck Refuge	1,717	WGSB	$3,932
23.3	GSB-M-2D	Seatuck Refuge to Heckscher Park (Nicoll Point)	2,982	WGSB	$1,046
28		Fire Island Lighthouse to Seaview (Fire Island)	1,994	WGSB	$684
27.1		Ocean Bay Park to Oakleyville (Fire Island)	433	WGSB	$62
Subtotal - Western Great South Bay Sub-Bay			***23,604***		***$23,371***
27.2		Sailors Haven to Water Island (Fire Island)	712	CGSB	$31
27.3		Water Island to Watch Hill (Fire Island)	188	CGSB	$3
22.1	GSB-M-3A	Heckscher Park (Nicoll Point) to Green Point	1,949	CGSB	$10,600
22.2	GSB-M-3B	Green Point to Blue Point (Town Line)	2,075	CGSB	$4,045

Location			Buildings #	Sub Bay	Equivalent Annual Benefits: Inundation Damages ($,000)
Economic Reach Number	**Mainland Reach ID**	**Location Name**			
21.1	GSB-M-4A	Blue Point (Town Line to Tuthill Creek (Blue Point)	513	CGSB	$682
21.2	GSB-M-4B	Tuthill Creek to Swan River (Patchogue)	1,628	CGSB	$3,548
21.3	GSB-M-4C	Swan River to Mud Creek	751	CGSB	$571
Subtotal - Central Great South Bay Sub-Bay			***7,816***		***$19,482***
21.4	GSB-M-5A	Mud Creek to Howell Creek	745	EGSB	$1,588
21.5	GSB-M-5B	Howell Creek to Bellport Marina	224	EGSB	$104
21.6	GSB-M-5C	Bellport Marina to Carmans River	421	EGSB	$953
20	GSB-M-6A	Carmans River to Smith Point Bridge	571	EGSB	$298
Subtotal - Eastern Great South Bay Sub-Bay			***1,961***		***$2,943***
19		Moriches Inlet to Quantuck Canal (Westhampton Barrier)	241	MOR	$1
18.1	MB-M-1A	Smith Point Bridge to William Floyd Estate	3,052	MOR	$9,319
18.2	MB-M-1B	William Floyd Estate to Forge River	206	MOR	$424
18.3	MB-M-1C	Forge River to Radio Point	1,332	MOR	$4,502
17.1	MB-M-2A	Radio Point to Harts Cove	219	MOR	$1,780
17.2	MB-M-2B	Harts Cove to Seatuck Creek (Town Line)	93	MOR	$8
16.1	MB-M-3A	Seatuck Creek (Town Line) to Fish Creek	134	MOR	$209
16.2	MB-M-3B	Fish Creek to Speonk Point	317	MOR	$1,590
16.3	MB-M-3C	Speonk Point to Apacuck Point	431	MOR	$1,737
16.4	MB-M-3D	Apacuck Point to Quantuck Bay	609	MOR	$3,235
Subtotal - Moriches Bay Sub-Bay			***6,634***		***$22,805***
15		Quantuck Canal to Village Park (Westhampton Barrier)	93	WSHN	$1
13.1	SB-M-1A	Quantuck Bay West	297	WSHN	$3,950
13.2	SB-M-1B	Quantuck Canal to Phillips Point	586	WSHN	$4,548
12	SB-M-2A	Phillips Point to Pine Neck Point	783	WSHN	$1,413
11.1	SB-M-2B	Pine Neck Point to West Point	280	WSHN	$962
11.2	SB-M-2C	West Point to Ponquogue Point	616	WSHN	$605
Subtotal - Western Shinnecock Bay Sub-Bay			***2,655***		***$11,479***
10.1	SB-M-3A	Ponquogue Point	39	SHN	$97
10.2	SB-M-3B	Cormorant Point	6	SHN	$12

Location			Buildings #	Sub Bay	Equivalent Annual Benefits: Inundation Damages ($,000)
Economic Reach Number	Mainland Reach ID	Location Name			
10.3	SB-M-3C	Shinnecock Canal Region	199	SHN	$768
10.4	SB-M-3D	Shinnecock Indian Reservation	258	SHN	$612
8b	SB-M-4A	Heady Creek	119	SHN	$2
Subtotal - Shinnecock Bay Sub-Bay			***621***		***$1,491***
Total: Back Bay Area			**43,291**		**$81,571**

Oct 2018 PL, Discount Rate 2.875%, Base Year 2028, Period of Analysis 50 years

All damage and benefit estimates were computed incorporating risk and uncertainty in accordance with current planning guidance, as outlined in previous sections above.

Table 26 - Summary of Benefits by Plan Features

Benefit Category	With Project Equivalent Annual Benefits: RP	With Project Equivalent Annual Benefits: Nonstructural only RP component	With Project Equivalent Annual Benefits: Coastal Measures only RP component
Total Project			
Tidal Inundation occurring due to inlet conditions and wave setup in back bay			
Mainland	$67,379,000	$64,198,000	$5,230,000
Barrier	$652,000	$0	$652,000
Total	*$68,031,000*	*$64,198,000*	*$5,882,000*
Tidal Inundation occurring due to storm breaching and overwash			
Mainland	$13,411,000	$12,778,000	$1,041,000
Barrier	$129,000	$0	$129,000
Total	*$13,540,000*	*$12,778,000*	*$1,170,000*
Total Mainland Inundation	*$80,790,000*	*$76,976,000*	*$6,271,000*
Total Barrier Inundation	*$781,000*	*$0*	*$781,000*
Total Inundation	*$81,571,000*	*$76,976,000*	*$7,052,000*
Damages (Inundation and Structure Failure) due to a breach remaining open			
Inundation (Open Breach at Wilderness Area)	$0	$0	$0
Inundation (Future Breaches)	$10,148,000	$9,968,000	$6,355,000
Total Breach Open Damages	*$10,148,000*	*$9,968,000*	*$6,355,000*
Shorefront Damages	$8,293,000	$0	$8,293,000
Emergency Costs/Breach Closure Avoided	$3,148,000	$0	$3,148,000

Benefit Category	With Project Equivalent Annual Benefits: RP	With Project Equivalent Annual Benefits: Nonstructural only RP component	With Project Equivalent Annual Benefits: Coastal Measures only RP component
Total Storm Damage Reduction Benefits	***$103,160,000***	***$86,944,000***	***$24,848,000***
Non-Federal Renourishment Cost Avoided	$3,007,000	$0	$3,007,000
Recreation Benefits	$24,623,000	$0	$24,623,000
TOTAL BENEFITS	**$130,790,000**	**$86,944,000**	**$52,478,000**

Oct 2018PL, Discount Rate 2.875%, Period of Analysis 50 years

10 SENSITIVITY ANALYSES

Table 28 presents a summary of the costs and benefits of the Recommended Plan under three sea level change scenarios, in accordance with EC 1165-2-211. Comprehensive details and discussion of the project costs can be found in Appendix C: Cost.

Table 27 - Cost, Damages and Benefits Summary for RP with RSLC Scenarios

	Formulation Summary	Selected Plan		
		Low RSLC[1]	**Intermediate RSLC[1]**	**High RSLC[1]**
Initial Cost	06 Fish & Wildlife Facilities	$1,015,500	$1,015,500	$1,015,500
	10 Breakwater & Seawalls	$5,031,200	$5,031,200	$5,031,200
	17 Beach Replenishment	$126,804,200	$126,804,200	$126,804,200
	18 Cultural Resources	$14,971,900	$14,971,900	$14,971,900
	19 Buildings, Grounds & Utilities	$850,231,200	$850,231,200	$850,231,200
	Construction Estimate Totals	*$998,054,000*	*$998,054,000*	*$998,054,000*
	01 Land and Damages	$153,276,600	$153,276,600	$153,276,600
	30 Planning, Engineering & Design	$281,129,800	$281,129,800	$281,129,800
	31 Construction Management	$87,737,600	$87,737,600	$87,737,600
	Project Cost Totals	*$1,520,198,000*	*$1,520,198,000*	*$1,520,198,000*
	IDC	$29,646,600	$29,646,600	$29,646,600
	Investment Cost	**$1,549,844,600**	**$1,549,844,600**	**$1,549,844,600**
Annualized Cost	Investment Cost	$58,814,000	$58,814,000	$58,814,000
	Renourishment / Sediment Management	$20,867,000	$20,867,000	$20,867,000
	Inlet Bypassing	$9,335,000	$9,335,000	$9,335,000
	Proactive Breach Closure	$685,000	$636,000	$468,000
	Breach Closure Costs	$839,000	$1,162,000	$3,060,000
	Coastal/Engineering Monitoring	$1,263,600	$1,263,600	$1,263,600
	Environmental Monitoring	$2,331,000	$2,331,000	$2,331,000
	O&M	$659,200	$659,200	$659,200
	Major Rehab	$1,890,000	$1,890,000	$1,890,000
	SLC Adaptation	$0	$647,000	$3,133,000
	Total Annual Cost	**$96,683,800**	**$97,604,800**	**$101,820,800**

	Formulation Summary	Selected Plan		
		Low RSLC[1]	**Intermediate RSLC[1]**	**High RSLC[1]**
Damages	Damages – Breach Open	$9,314,000	$26,999,000	$139,081,000
	Damages – Back Bay Inundation	$77,920,000	$81,351,000	$256,539,000
	Damages – Shorefront	$6,911,100	$8,004,000	$13,450,000
	Total Damages	***$94,145,100***	***$116,354,000***	***$409,070,000***
Benefits	Cost Avoided – Breach Closure	$3,148,000	$4,296,000	$11,558,000
	Benefits – Breach Open	$10,148,000	$33,268,000	$482,197,000
	Total Breach Closure Benefits	$13,296,000	$37,564,000	$493,755,000
	Benefits – Back Bay Inundation	$81,571,000	$133,317,000	$288,701,000
	Benefits – Shorefront	$8,293,000	$8,289,000	$7,926,000
	Total Storm Damage Reduction Benefits	*$100,012,000*	*$174,874,000*	*$778,824,000*
	Non-Federal Renourishment Cost Avoided	$3,007,000	$3,007,000	$3,007,000
	Recreation Benefits	$24,623,000	$24,623,000	$24,623,000
	Total Benefits	**$130,790,000**	**$206,800,000**	**$818,012,000**
	Net Benefits	**$34,106,000**	**$109,195,000**	**$716,191,000**
BCR		**1.4**	**2.1**	**8.0**

1 Low SLC, Int. SLC, and High SLC based on USACE guidance. ETL, dated 30 June 2014.

2 Price level October 2018, Federal Discount Rate 2.875%, Base year 2028

11 PROJECT PERFORMANCE

The probabilistic performance of the recommended plan under the low sea level rise condition has been computed by HEC-FDA and the results are presented in Table 28, in accordance with ER 1105-2-101, "Risk Analysis for Flood Damage Reduction Studies (USACE, 17 July, 2017).

Table 28 - Expected and Probabilistic Values of Damage Reduced

	Low/Historic Sea Level Rise Scenario	**Probability that Damage Exceeds the Indicated Values**		
		Mean	**Mean**	**Mean**
	Total Annual Cost	**$96,684,000**	**$96,684,000**	**$96,684,000**
		75%	**Mean**	**25%**
Damages	Damages – Breach Open	$7,484,000	$9,314,000	$10,552,000
	Damages – Back Bay Inundation	$53,222,000	$77,920,000	$94,248,000
	Damages – Shorefront	$4,274,000	$6,911,000	$9,564,000
	Total Damages	***$64,980,000***	***$94,145,000***	***$114,364,000***
Benefits	Cost Avoided – Breach Closure	$1,322,000	$3,148,000	$4,510,000
	Benefits – Breach Open	$5,443,000	$10,148,000	$14,110,000
	Total Breach Closure Benefits	*$6,765,000*	*$13,296,000*	*$18,620,000*
	Benefits – Back Bay Inundation	$78,345,000	$81,571,000	$88,912,000
	Benefits – Shorefront	$7,481,000	$8,293,000	$9,090,000
	Total Storm Damage Reduction Benefits	*$91,269,000*	*$100,012,000*	*$112,112,000*
	Non-Federal Renourishment Cost Avoided	$3,007,000	$3,007,000	$3,007,000
	Recreation Benefits[1]	$21,715,000	$24,623,000	$27,530,000
	Total Benefits	**$117,313,000**	**$130,790,000**	**$147,159,000**
	Net Benefits	**$20,629,000**	**$34,106,000**	**$50,475,000**
BCR		**1.2**	**1.4**	**1.5**

Price level October 2018, Federal Discount Rate 2.875%, Base year 2028