SOUTH SHORE OF STATEN ISLAND, NY
COASTAL STORM RISK MANAGEMENT

INTERIM FEASIBILITY STUDY
FOR
FORT WADSWORTH TO OAKWOOD BEACH

Final Benefits Appendix

US Army Corps of Engineers
New York District

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INTRODUCTION

Purpose and Scope

1. This interim report documents procedures and results of the economic storm damage analysis for the South Shore of Staten Island, New York, Interim Feasibility Study. This document presents the findings of economic assessments for the without-project conditions, as well as analysis results for both structural and nonstructural coastal risk management alternatives.
2. Economic analyses include development of stage versus damage relationships and annual damages over a 50-year analysis period. Damage assessments include damages due to tidal flood inundation along the shoreline and damages caused by residual flooding due to ponding of runoff behind the Line of Protection. The method to estimate residual flood damage benefits and additional results on the residual damage for various alternatives have also been provided.
3. Benefits that were evaluated for the alternatives are:
    - Reduced inundation damage to structures
    - Reduced Federal Insurance Administrative costs
4. Estimates of damages are based on July 2014 price levels and a 50 year analysis period. Damages have been annualized over the 50 Year period using the fiscal year 2015 discount rate of 3.375%.
5. The Benefits Appendix:
    - Provides an overview of the problems and opportunities,
    - Describes the without-project future conditions,
    - Summarizes the analysis methodologies,
    - Evaluates storm damage reduction benefits

Prior Studies

History of Federal Participation

6. In an application dated January 6, 1959, a cooperative beach erosion control study was initiated by the State of New York acting through the Long Island State Park Commission. The application requested a study of the Atlantic Coast of Nassau County, New York, between Jones Inlet and East Rockaway Inlet; Atlantic Coast of New York City, between East Rockaway Inlet and Norton Point; and Staten Island, New York, between Fort Wadsworth and Arthur Kill. The Chief of Engineers approved the application on March 23, 1959, in accordance with Section 2 of Public Law 520 (River and Harbor Act of 1930).

7. In response to severe damage to coastal and tidal areas of the eastern and southeastern United States from the hurricanes of August 31, 1954 and September 11, 1954 in New England, New York and New Jersey and the damages caused by other hurricanes in the past, a hurricane study was authorized by Public Law 71, 84th Congress, 1st Session on June 15, 1955. A combined report covering the cooperative beach erosion control study and the hurricane survey was approved by the Chief of Engineers on December 7, 1960.

8. A previous federal project, spanning from Fort Wadsworth to Arthur Kill, Staten Island, New York, was authorized by the Flood Control Act of October 27, 1965. Design modifications to the authorized project were developed in a realignment feasibility study dated September 1969. Following a review of the realignment feasibility report concerning the plan of improvement extending eastward to Fort Wadsworth, the Chief of Engineers, on April 7, 1970, directed the extension plan to be incorporated in the project design. This authorized and modified project was not constructed due to a lack of non-federal financing as discussed below.

Previously Authorized Federal Project

9. The federal project authorized in House Document No. 181, 89th Congress, 1st Session provided combined shore and hurricane protection between Fort Wadsworth and Oakwood Beaches. The recommended protective works included beach fill with dunes, groins, levees, floodwalls, and interior drainage facilities including pumping stations and relocations. Preconstruction planning for the project was initiated in January 1966 and was brought to 60 percent of completion.

10. The Draft Environmental Impact Statement was completed in March 1976 and the General Design Memorandum for Fort Wadsworth to Oakwood Beach was completed in June 1976. Further work was suspended at the request of local authorities. In a letter dated October 3, 1977, the New York State Department of Environmental Conservation (NYSDEC) requested to defer their decision on local cooperation because of the fiscal problems of New York City.

11. The portion of the plan addressed by the 1976 GDM extended from Great Kills Park to Fort Wadsworth. The plan of improvement from Oakwood Beach to Graham Beach was comprised of 24,000 feet of levee and 11,200 feet of beach fill. From Graham Beach to Fort Wadsworth, the plan was developed in accordance with the City's recommendation, and included 13,000 feet of levee.

12. The plan called for six pumping stations with pump capacities ranging from 135 to 540 cfs designed to discharge interior drainage outside of the Line of Protection improvements. The three pumping stations at the eastern end of the project area between Graham Beach and Fort Wadsworth were to be located just north of the concrete I-wall on the landward side of the promenade and boardwalk. In addition, drainage ditches along the protected side of the wall, draining into major storm sewers, were recommended for interior runoff in areas of the improvement where runoff is not handled by existing storm lines.

Reconnaissance Study of June 1995

13. During the reconnaissance level investigation, federal interest was evaluated for the shoreline from Fort Wadsworth to Oakwood Beach and Annadale Beach. Several flood control and coastal risk management alternatives were investigated based on local needs and preferences, comparative costs, and implementation constraints. In addition to an alternative providing a level of coastal risk management equivalent or slightly higher than a 100 year event as authorized in 1976, alternatives providing lower levels of coastal risk management were also investigated. The reconnaissance level analysis indicated that there was federal interest in continued study.

Prior Projects

14. Since 1935, two Federal projects and two State/City project have been completed along the study area. Three of these were beach fill projects and are shown in Table 1. The third project was constructed in 1999 near the Oakwood Beach Waste Water Treatment Plant (WWTP) and is described at the bottom of this section. The beach fill projects contributed to a total of 2,880,000 cubic yards of fill placed along 15,600 feet (50%) of the shoreline.

15. From 1936 to 1937, the federal government built six timber and rock groins, constructed a timber bulkhead, and placed an estimated 1,000,000 cubic yards of hydraulic fill at South Beach. The total cost of the construction was approximately $1,000,000.

16. The State and City placed about 1,880,000 cubic yards of fill between New Creek and Miller Field in 1955 at a cost of about $745,000. The cost of additional work performed by private interests is not known, but it is estimated to be several hundred thousand dollars. The material, which consists of medium grained sand, was placed along the shore and has helped it remain stable. The beaches provide a measure of risk management against tidal flooding as well as a recreational area. Two concrete storm sewer outfalls that extend through the fill have acted as groins, helping to further stabilize the beach.

TABLE 1 - REPORTED FILL VOLUMES PLACED SINCE 1935				
Location	**Fill Quantity (cu. Yd.)**	**Project Length (ft.)**	**Year**	**Work Performed By**
South Beach	1,000,000	7,500	1937	U.S. Government
Midland Beach	1,880,000	8,100	1955	State and City
Total	**2,880,000**	**15,600**	-	-

17. As part of other post-Sandy efforts, NYC initiated short term dune improvements as part of its Special Initiative for Rebuilding and Resiliency (SIRR) that included beach nourishment and dune construction along the study area in attempt to decrease future losses from coastal storm events. This program was completed in October 2013. Location and quantities of beach fill are unavailable.

18. The USACE constructed a project in 1999 to manage risk in the Oakwood Beach area from Bay flooding. The project consisted of two earthen levee segments, one tide gate structure, underground storm water storage, and road raising. The first levee segment, located south of the treatment plant and east of Oakwood Creek running parallel to the creek, had a top elevation of 10 feet NGVD 1929. The second levee segment, located north of the treatment plant and running approximately northward and westward, was a raised road system with a top elevation varying between 7.9 ft. NGVD 1929 to 8.4 ft. NGVD 1929. The project also consists of: (1) a new tide gate; (2) the raising of an access road at the northwestern area of the treatment plant property; and (3) underground storm runoff storage. The project was based on a 10-year period of analysis and provides risk management against a 15-year coastal storm (6.7% chance of occurring in any given year).

Description of the Study Area

Location

19. The study area consists of approximately six miles of coastline in the Borough of Staten Island, New York City, New York, extending along the Lower New York Bay and Raritan Bay. The approximate west and east limits (i.e. along the south shoreline) of the study area are Oakwood Beach and the easternmost point of land within Fort Wadsworth at the Narrows. Across from Staten Island's western shore is the New Jersey shoreline at the southern shore of Raritan Bay,

which extends from the community of South Amboy to the Sandy Hook peninsula. East of Staten Island is Brooklyn on the Narrows, Coney Island on the Lower New York Bay, and Rockaway Point on the Atlantic Ocean. The approach to Lower New York Bay from deep water in the ocean is through a 6-mile wide opening between Sandy Hook, New Jersey and Rockaway Point, New York.

20. The overall study area lies within the borough of Staten Island, County of Richmond, within the limits of the City of New York. The reach evaluated in the Interim Feasibility Study includes the area from Fort Wadsworth to Oakwood Beach.

21. New York City is divided into 59 community districts. As per the City charter, the community boards for these districts submit annual expense and capital budget priorities to City agencies. These priorities are considered when allocating budget dollars for new facilities or for substantial changes in existing facilities.

22. There are three Community Districts on Staten Island and portions of two of these districts lie within the study area. Community District 2 includes the neighborhoods of South Beach, Midland Beach and New Dorp Beach. Community District 3 includes the neighborhoods of Oakwood Beach. The dividing line between Community Districts 2 and 3 is Tysens Lane and Ebbits Street.

Physical Setting

23. The project area terrain ranges from high bluffs at the west and east end of the study area to low lying areas in much of its center. The west end is fronted by low narrow beaches intersected by several creeks and freshwater lakes. The east end generally has a wide low beach intersected by several drainage structures contained in groins. Behind the east end beaches are low-lying residential areas. The shoreline is irregular because of the downdrift offsets at groins and headlands.

24. Historical flood records and existing topography indicate that many structures within the study area neighborhoods are susceptible to significant flooding. Approximately 7,400 buildings were identified as being susceptible to storm damage with over half of these located in the 1% annual chance event (ACE) floodplain.

Accessibility

25. Staten Island is the southernmost borough of New York City. Major interstates provide convenient access from New Jersey and Brooklyn to the study area. From the north, Route 440 crosses from New Jersey via the Bayonne Bridge to connect with the Staten Island Expressway (Interstate 278). On the northwest, the Goethals Bridge provides access from New Jersey's Union County and also connects with the Staten Island Expressway. On the southwest, the Outer Bridge Crossing provides access from New Jersey's Middlesex County, where the Garden State Parkway and the New Jersey Turnpike connect to the Outer Bridge Crossing via Route 440. The Verrazano Narrows Bridge, located in the northeastern side of Staten Island, provides land access to Brooklyn. The Staten Island Ferry provides a direct connection to Manhattan.

Population & Housing Units

26. Richmond County (Staten Island) is the most rapidly developing borough in the City of New York. According to the year 2010 Census, the population of the Borough of Staten Island was 468,730, between 2000 and 2010, the population of Staten Island grew by 5.6 % (25030).

27. Multi-person households represent 69.1% of all households within the Borough of Staten Island (compared to 54.5% for New York City).

TABLE 2 – POPULATION AND PROJECTION OF FUTURE POPULATION RICHMOND COUNTY AND SURROUNDING AREA								
	Census 1980	**Census 1990**	**Census 2000**	**Census 2010**	**2015**	**2020**	**2025**	**2030**
New York State *•	17,558,072	17,990,455	18,976,457	19,651,127	20,136,000	20,896,000	21,656,000	22,416,000
New York City *+	7,071,639	7,322,564	8,008,278	8,175,136	8,406,000	8,637,000	8,868,000	9,100,000
Staten Island * +	352,121	378,977	443,728	468,730	489,600	510400	531,200	552,000
Community Districts 2 & 3 ◆	213,377	240,900	279,979	292,212	--	--	--	--

* *Census data from US Census Bureau website*
• *Population projections from US Census Bureau website*
◆ *Population Division, NYC Department of City Planning website*
\+ *Population projections from New York Metropolitan Transportation Council (NYMTC) website*
-- *Information Unavailable*

28. The population of the study area is estimated at approximately 30,000. Population data and projections can be found in Table 2. Population data by census tract can be found in Table 3.

TABLE 3 - ESTIMATED STUDY AREA POPULATION			
2010 Census Tract No. (west to east)	**Approx. Percent In Study Area**	**2010 Census Tract Population**	**Approximate Population in Study Area**
128.04	0.85	4,259	3,620
112.02	0.95	6,428	6,107
122	0.15	3,813	571.95
114.02	0.45	3,450	1,553
114.01	0.5	3,067	1,534
112.01	1	5,758	5,758
96.02	0.25	3,461	865.25
70	0.95	8,525	8,099
74	0.5	4,693	2,347
		Total:	***30,453***

Land Use and Economy

29. The Borough of Staten Island represents 25.4% of the land area of New York City, covering 63.2 square miles. The majority of land within the study area consists of residential development. Residential development ranges from small cottages to expensive homes. The remaining lands within the study area are characterized by commercial development (concentrated primarily along Hylan Boulevard), wetlands, forests, ponds, creeks, meadows and beaches. Developed parks with large parking areas and shore-parallel boardwalks also line the beachfront. Coastal structures include revetments to protect uplands and groins containing drainage outlets. Approximately 75% of the study area shoreline is publicly held land, consisting of City and federal parks.
30. The largest portion of land use in Community Districts 2 and 3 is for one and two family residential housing. Vacant land and open space/recreational areas make up the next largest land use percentage. A summary of the land use by Community District for the study area is shown in Table 4:

TABLE 4 – LAND USE BY COMMUNITY DISTRICT, STATEN ISLAND, NEW YORK

Land Use Category	Community District 2	Community District 3
1 –2 Family Residential	30%	42%
Multi-Family Residential	3%	2%
Mixed Resid./Commercial	0%	0%
Commercial/Office	4%	2%
Industrial	6%	3%
Transportation/Utility	10%	5%
Institutions	14%	9%
Open Space/Recreation	15%	11%
Parking Facilities	0%	0%
Vacant Land	16%	24%

Source: Community District Needs, Staten Island, Fiscal Year 2002/2003, NYC Dept. of City Planning

31. According to the 2010 Census, 60.4% were in the labor force, while 4.3% were unemployed. The median household income was $73,496 compared with median household incomes of $51,865 for the City and $57,683 for the State. Approximately 8.4% of the population of Staten Island lived below the poverty level.

Development Within the 1% ACE Floodplain

32. Within the study area, there are a total of approximately 7,300 structures. Of these approximately 4,600 (over 63%) lie within the 1% ACE floodplains, as shown in Table 5.

Parks

33. In Midland Beach and South Beach, the Franklin Delano Roosevelt Boardwalk and Beach is a 2.5 mile long, 638.5 acre recreation area extending west from Ocean Avenue to Miller Field. The wooden boardwalk transitions to a paved, at-grade asphalt roadway at Sea View Avenue and continues southwest to Miller Field.

DESCRIPTION OF THE PROBLEM

General

34. Historically, lands along the south shore of Staten Island have proven to be susceptible to storm damage during severe extra-tropical storms, nor'easters, and hurricanes. Damage along the shorefront has been caused by wave action, erosion and storm surges. Inland areas from Forth Wadsworth to Oakwood Beach also incur damage when tidal floodwaters overtop shorefront dunes or structures and quickly spread over the broad, low-lying floodplain. In portions of the study area, storm induced erosion has removed much of the beachfront and expedited deterioration of the existing coastal protection and drainage structures. In addition to these physical alterations, tidal surges often block existing storm drainage systems and cause interior flooding.

35. Past and future storm damages are directly related to the topography, location and development. The area from Fort Wadsworth to Oakwood Beach has a wide floodplain and contains the majority of the study area development. Within this reach the immediate shorefront is characterized by higher elevations (typically 9 to 11 feet NGVD 1929) while the areas further inland contain low elevations (typically 4 to 8 feet NGVD 1929).

36. Some of the most damaging storms that have impacted the Borough include:

- Hurricane of November 1950 - During this storm, an inland low pressure area along with easterly winds blowing strongly for over 17 hours caused a surge level in Lower Bay of 8.2 feet (measured at Fort Hamilton, just east of Fort Wadsworth). The total damages along Staten Island's south shore were estimated at $2,100,000[1]. Hundreds of homes were destroyed and thousands of residents were forced to evacuate their homes and seek temporary emergency shelter.

- Extratropical Storm of November 6-7, 1953 - High water levels associated with this storm caused nearly $1,000,000[2] in damage to Staten Island. Ferry service to Manhattan was suspended, and hundreds were forced to evacuate their homes along the south shore. Hundreds of homes were damaged or destroyed by the rising floodwaters.

[1] 1950 price level
[2] 1953 price level

- Hurricane Donna (September 12, 1960) – Total estimated damage for this Hurricane on Staten Island was $3,161,000[3]. Hundreds of homes and roadways were inundated or destroyed. Many residents were evacuated. Thousands of cubic yards of beachfront sand were lost.

- Nor'easter of March 6-8, 1962 – During this storm, maximum water levels at the Battery and Willets Point were 7.7 and 9.2 ft. NGVD 1929, respectively. Damage to beaches, bluffs, buildings, and erosion control structures on Staten Island were estimated at nearly $1,200,000[4].

- January 23, 1966 – Strong winds at high tide caused flooding on Staten Island's south shore in the Great Kills area. Many residents had to be rescued from their homes during this event.

- November 11, 1977 – At the time of its occurrence, this storm was identified by many as the worst storm in island history. The 7 inches of rain that fell in a 24 hour period caused homes to be flooded and left most local roadways closed.

- Nor'easter of December 11-12, 1992 – Gale force winds in combination with high tides caused the worst flooding in decades on Staten Island. Thousands of homes were damaged or destroyed and hundreds of residents were evacuated as floodwaters inundated local neighborhoods.

- Hurricane Sandy (October 29-30, 2012): Hurricane Sandy was a very large system, having a diameter spanning approximately one-thousand miles. The large girth of the storm caused abnormally high storm surge elevations along the shoreline in addition to a naturally occurring high astronomical tide (spring tide) causing record flood levels and inundation along the North Atlantic Coast. Within the study area, Hurricane Sandy had a maximum high water mark around +14 feet NGVD29 and with waves up to six feet in height (NY Rising, 2014). Twenty-four individuals lost their lives as a result of the storm in Staten Island. Along the study area, residences, businesses and cars were heavily damaged and whole blocks of homes were removed from their foundations (NHC, 2013). Record storm tides (storm surge + normal astronomical tide) and storm surges were measured in the NYC metropolitan area with flooding depths up to nine feet above the local ground level measured in Staten Island. As of October 15, 2013 more than $7.9

[3] 1960 price level
[4] 1962 price level

billion in National Flood Insurance Program (NFIP) payments had been made to policy holders to account for the damages from Hurricane Sandy (FEMA, 2013).

37. While these storms may be the most notable of those having impacted the study area, many more have made landfall along Staten Island’s south shore. For example, in the 30 years prior to 1962, no less than 90 hurricanes, tropical storms or extra-tropical storms significantly impacted the New York City Area (USACE, 1964), often bringing with them storm surges of over 4 feet.

38. The high ground elevations along the shorefront in South Beach and Midland Beach provide protection from tidal flooding for storms with a surge below 9.6 feet NGVD. The study area does flood from tidal surges until floodwaters rise above this controlling elevation due to local topography. After the waters rise above that controlling elevation then large low-lying portions of inland areas become flooded. For storm surges below the controlling elevation the structures are also subject to flooding due to blockage of the interior drainage systems. The approximate ground elevations of all structures in the study area are summarized in Table 5.

TABLE 5 - FORT WADSWORTH TO OAKWOOD BEACH STRUCTURE Ground Elevations (ft NGVD) *													
Economic Reach**	**Below 3ft**	**3-3.9 ft.**	**4 4.9ft.**	**5-5.9 ft**	**6-6.9 ft.**	**7-7.9 ft**	**8-8.9 ft**	**9.0-9.9 ft**	**10-10.9 ft**	**11-11.9 ft**	**12-12.9 ft**	**13 ft +**	**Total Structures in reach**
FWOB-1 *(Fairlawn Ave. to Buffalo St.)*	0	0	0	0	0	0	0	0	0	0	0	22	22
FWOB-2 *(Buffalo St. to Tysens La.)*	0	0	4	3	7	17	4	52	38	156	147	572	1,000
FWOB-3 *(Tysens La. to New Dorp Lane)*	0	0	0	4	20	125	147	214	93	235	124	371	1,333
FWOB-4 *(New Dorp Lane to Delaware Ave.)*	7	89	242	374	160	292	164	340	244	496	183	1,069	3,660
FWOB-5 *(Delaware Ave. to Andrew St.)*	0	0	0	6	1	21	17	51	48	117	82	476	819
FWOB-6 *(Andrew St. to Sand Lane)*	0	0	0	3	1	12	14	22	14	13	8	159	246
FWOB-7 *(Sand Lane to USS Iowa Circle)*	0	0	1	18	4	42	23	40	34	36	15	73	286
Total:	*7*	*89*	*247*	*408*	*193*	*509*	*369*	*719*	*471*	*1,053*	*559*	*2,742*	*7,366*
Cumulative	*7*	*96*	*343*	*751*	*944*	*1,453*	*1,822*	*2,541*	*3,012*	*4,065*	*4,624*	*7,366*	

**Townhouses and apartment buildings containing multiple units are shown as one structure.*
***Not including a sub-reach delineated solely for the analysis of the Oakwood Beach Wastewater Treatment Plant*

WITHOUT-PROJECT FUTURE CONDITIONS

39. The without-project future conditions for the south shore of Staten Island have been identified as: (1) flooding and wave impacts from future storm events (2) continued erosion of unprotected bay front shorelines and (3) continued development and fill of low-lying flood storage areas.

40. It is expected that future storms will continue to cause damages in this area. Although protection from small storm events (e.g. 2-year event) is provided by local topography, a large storm event in the future will cause extensive damages. Since no major changes to the shorefront are expected, the level of protection will decline as sea level rises and storm surge impacts become more severe.

41. It is also expected that continued development, subject to local floodplain management ordinances, will occur in the floodplain. Small residences will continue to be displaced by larger new homes and townhouses. Fill in the floodplain will also occur as new construction is elevated above the base flood elevation. This fill may reduce storage of runoff and thereby exacerbate flood conditions.

42. While no long-term plan exists to maintain private bulkheads and seawalls, historic patterns indicate that they will be rebuilt after storm-related failure. Since the amount of beach in front of private bulkheads is limited, continued erosion will significantly alter the future stability of these structures. Future without-project renourishment requirements, however, will be based on the historic data.

43. Tidal inundation is expected to increase gradually over time, in direct relation to the anticipated rise in relative sea level. Based upon long-term trends measured at the Sandy Hook Gage, a 0.014 foot per year increase is anticipated, resulting in a 0.7 foot increase over the 50-year period of analysis for the project. In future years this will result in more frequent and higher stages of flooding.

44. It is assumed that no new drainage outfalls will be constructed along the shoreline, and that the existing drainage structures will continue to be maintained by the City. It is also assumed that the existing project at Oakwood Beach will be maintained and will continue to provide protection against small storm events.

45. A number of structures in low-lying areas are to be acquired and demolished, and the land left as open space in perpetuity, to prevent future flood damages. Coordination with State and City agencies has identified 188 structures meeting this description as of December 2013, which have been removed from the database of structures at risk.

STORM DAMAGE

General

46. In order to address the storm damage problem on the south shore of Staten Island, various alternatives have been developed to provide additional coastal storm risk reduction. These alternatives are being developed in coordination with New York State and with the City of New York (Department of Environmental Protection and Department of Parks and Recreation). They include several independent protection features. These features are specific to the type of flooding/erosion problems in the reach they are assigned.

47. The following basic steps were used in the analysis of inundation damage:
    - Assign evaluation reaches,
    - Inventory floodplain development,
    - Estimate depreciated replacement cost,
    - Assign generalized damage functions,
    - Calculate aggregated stage vs. damage relationships.

48. Flood damage calculations were performed using Version 1.2.5 of the Hydrologic Engineering Center's Flood Damage Analysis computer program (HEC-FDA). This program applies Monte Carlo Simulation to calculate expected damage values while explicitly accounting for uncertainty in the input data.

Project Reaches

49. The South Shore of Staten Island Feasibility Study originally included the area from Fort Wadsworth to Tottenville, which was divided into three project reaches. For the interim report, only the single project reach of Fort Wadsworth to Oakwood Beach (FWOB) was considered.

Economic Reaches

50. To simplify the development of stage vs. damage relationships, the study area project reach was further divided into seven economic reaches. Economic reach selection was determined by the following criteria:

- Interior drainage areas. Areas subject to residual damages from interior drainage.

- Potential protection limits. Separate economic reaches were delineated for areas which may be impacted by protection features and those that may not.

51. Reach descriptions and structure counts for the economic reaches are presented in Table 6.

TABLE 6 - ECONOMIC REACHES AND NUMBERS OF STRUCTURES

Economic Reach	Economic Reach Description	Number of Structures		
		Res.	Non-Res.	Total
FWOB-1	*Fairlawn Ave. to Buffalo Street*	18	4	22
FWOB-2	*Buffalo St. to Tysens Lane*	949	51	1,000
FWOB-3	*Tysens La. to New Dorp Lane*	1,276	57	1,333
FWOB-4	*New Dorp Lane - Delaware Avenue*	3,340	320	3,660
FWOB-5	*Delaware Ave. to Andrew Street*	794	25	819
FWOB-6	*Andrew St. to Sand Lane*	234	12	246
FWOB-7	*Sand Lane to USS Iowa Circle*	253	33	286
FWOB-TP	*Oakwood Beach WWTP*	0	1	1
	Total:	***6,864***	***503***	***7,367***

*Individual structures associated with the Oakwood Beach Wastewater Treatment Plant were not subject to the inventory methodology described below (see paragraph 66 for the approach used).

Conditions

52. Estimates of damages are based on July 2014 price levels and a 50-year period of analysis. Damages have been annualized over the 50-year analysis period using the fiscal year 2015 discount rate of 3.375%.

Inventory Methodology

53. The original structure database and updates pre-Sandy were generated by a "windshield survey" of the structures in the project area using topographic mapping with a 2-foot contour interval. The physical characteristics were used to categorize the structure population into groups having common physical features. Data pertaining to structure usage, condition, size and number of stories assisted in the structure value analysis. For each building, data was also gathered pertaining to its damage potential including ground and main floor elevations, lowest opening, construction material, basement, and proximity to the shorefront. Table 7 describes the physical characteristics, obtained for the windshield building inventory or updated from aerial imagery.

54.

TABLE 7 – INFORMATION RECORDED FOR STRUCTURES

1) Structure ID	9) Number of Attached Garage Openings
2) Map Number	10) Exterior Construction
3) Type	11) Quality of Construction
4) Usage	12) Current Condition
5) Footprint Size	13) Ground Elevation*
6) Stories	14) Main Floor Height Above Grade
7) Foundation/Basement Type	15) Low Opening Relative to Main Floor
8) Exterior Construction	

** Ground Elevations collected in NAVD 1988 and converted to NGVD 1929.*

55. One of the most critical parameters required for the estimation of flood damages in this analysis is the elevation of the main floor of each structure. During the field survey ground elevations were estimated for structures using the contour lines on topographic mapping and the main floor height above the lowest adjacent ground was estimated by eye: surveyors made this visual estimation using established techniques such as counting the number of steps from grade to main floor entrances and assuming that each step represents a rise of 8". Thus the main floor elevation for each structure input to the HEC-FDA model was the lowest adjacent ground elevation plus the main floor height above grade.

Structure Values

56. The depreciated replacement value of each building in the floodplain was originally calculated using standard building cost estimating procedures from Marshall and Swift. This analysis combined the physical characteristics obtained in the inventory with standard unit prices per square foot. Depreciation was then calculated based on the quality and condition of each structure.

57. The inventory of structures contributing to storm damages was revised to reflect post-Sandy conditions via a review of publicly available aerial photographs and other pertinent information and via a field survey of a randomly selected sample of structures for the purposes of developing an overall update factor.

58. From the study of recent aerial photographs 61 buildings were identified which had been destroyed by Hurricane Sandy or demolished for other reasons and not rebuilt. These structures were deleted from the inventory database. Information from State and City agencies was also used to identify a significant number of structures which are in the process of being acquired and demolished for mitigation purposes in the Oakwood Beach section of the study area. In total 188 structures were identified as subject to acquisition programs and were also deleted from the inventory database. The field survey also aimed to identify any structures damaged during Sandy which have subsequently been elevated or for which applications for elevations have been submitted. However, no recently elevated structures were observed during the field survey, and pertinent information from agencies implementing and administering building elevations was not available.

59. The sample set of structures for the field survey was developed by randomly selecting 25 ‘seed’ structures and then adding the next 19 structures in the sequential list following each seed to generate clusters of 20 structures totaling 500. The sample set was adjusted to ensure that there were no overlaps between clusters and that no clusters were split between geographically distant areas. During the review of aerial photographs 24 additional structures were identified as having been constructed since the previous inventory value update in 2009 and these were added to the field survey list.

60. Section 308 of the Water Resources Development Act of 1990 excludes certain structures built after July 1, 1991 from flood damage analyses. Applicable structures are those in the 1% Annual Chance Exceedance Floodplain which have main floor elevations below the contemporary Base Flood Elevation (BFE). Of the 24 structures identified as constructed

since the 2009 update, two were identified as having main floors approximately one foot below the contemporary BFE, of which one is a residence and the other is an indoor sports facility. In both cases it is possible that the actual elevation meets the BFE requirement given the uncertainty in map and inventory elevations. Adjusting or removing these two structures would have a negligible effect on the results of the damage analyses.

61. On completion of the field survey, depreciated structure replacement values at a July 2014 price level were calculated for all surveyed structures using RS Means Square Foot Costs 2014. Structure values from the 2009 inventory were compared to the values calculated at the July 2014 price level to compute an overall value update factor of 1.21. This factor was then applied to all structures in the revised inventory which were not included in the field survey.

62. The total post-Sandy depreciated replacement value of all structures within the study area is approximately $3.2 billion. A summary of structure values by economic reach is presented in Table 8.

63.

TABLE 8 – ESTIMATED DEPRECIATED STRUCTURE REPLACEMENT VALUE BY REACH

Price Level: July 2014

Project Reach	Number of Structures	Total Depreciated Structure Replacement Value
FWOB-1	22	$11,287,000
FWOB-2	1,000	$375,885,000.00
FWOB-3	1,333	$591,764,000
FWOB-4	3,660	$1,633,719,000
FWOB-5	819	$346,969,000
FWOB-6	246	$77,037,000
FWOB-7	286	$120,150,000
FWOB-TP	1	N/A
Total, All Reaches	***7,367***	***$3,156,811,000***

Stage Frequency Data

64. Table 9 summarizes the basic external stage vs. frequency data used in the damage analysis for the line of protection.

TABLE 9 – STAGE VS. FREQUENCY DATA		
RETURN PERIOD (YEARS)	**ELEVATION, EXISTING (FT NGVD 1929)**	**ELEVATION, FUTURE YEAR (FT NGVD 1929)**
2	5.30	6.00
5	7.20	7.90
10	8.50	9.20
25	10.00	10.70
50	11.30	12.00
100	12.60	13.30
200	14.00	14.70
500	15.90	16.60

Stillwater elevations obtained from FEMA Post-Sandy (2013)

Inundation Damage Functions

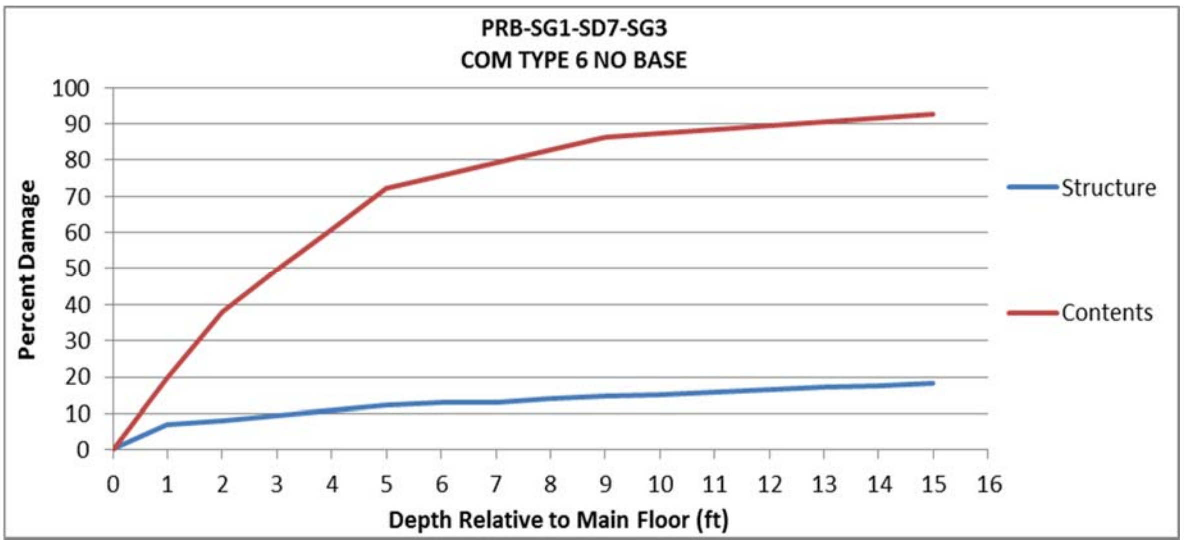
65. Based on the type, usage and size of each structure inventoried, damage was calculated relative to the main floor elevation of the structure. For this analysis two separately developed classes of depth- percent damage functions were used for all structures in the project area with the exception of the Oakwood Beach Wastewater Treatment Plant:

- US Army Corps of Engineers generic damage functions for single-family residential and similar structures.
- Passaic River Basin (PRB) Study damage functions for other residential structures and all non-residential structures.

66. The USACE depth-damage functions for residential structures were sourced from Economics Guidance Memoranda EGM 01-03 (December 2000) and EGM 04-01, (October 2003). The PRB damage functions were originally developed in 1982 and were updated in 1995. These damage functions were found to be applicable as originally formulated and no adjustments to the damage functions are recommended.

67. In addition to multi-family residential structures and apartment buildings, the PRB damage functions were also used for nonresidential structures, since they include numerous

functions for specific non-residential usages. The PRB functions were considered appropriate for use in this study since the relatively small number of non-residential structures in the inventory (approximately 7% of the total) was not sufficient to warrant the development of project-specific damage functions. Also, the PRB functions were considered applicable due to the similar nature of the building stock in the study area and the Passaic River Basin (the two areas are only 25-30 miles apart), and the similar nature of the expected flooding (a mix of salt and fresh water inundation). Damage categories include commercial, industrial, municipal, and utility structures, and an example of a PRB depth-damage function is provided below. This function was used for food and convenience stores and has been selected since it was the most frequently assigned depth-damage function for non-residential structures in this analysis.



68. Damage to external features such as landscaping, vehicles, storage sheds, and garages, plus evacuations and other non-physical costs, were evaluated as a percentage of structure value by the *other* component of the PRB damage functions.

69. For the Oakwood Beach Wastewater Treatment Plant, a custom damage function relating actual dollar damages directly to a range of flood depths was developed, based on several data sources including historical flooding information (including flooding from Hurricane Sandy) and the New York City Department of Environmental Protection's June 2013 Flood Vulnerability and Adaptation Assessment report for the plant. This approach did not require depreciated structure values to be computed for the plant and associated structures.

70. Damages and benefits were also evaluated separately for the boardwalk which is a feature both of the existing conditions and the four formulation alternatives. The existing 1.6-mile long boardwalk was assumed for the purposes of this study to have a depreciated replacement value of $26.7 million, while the 2.5-mile long boardwalk featured in each of the alternatives was assumed to have a value of $41.8 million. Damage to the pile-supported boardwalk occur when breaking waves impact the stringers; initially this damage is limited to the stringers and electrical conduits, estimated to be 5% of the structure value. When wave crests exceed the boardwalk deck elevation the decking is subject to uplift and material failure or displacement of whole sections (estimated to be 25% of the value). When waves reach 1-2 feet above the deck waves break on the deck itself causing widespread failure of the decking and some stringers (75% of the value). When the surge plus setup reaches the stringers the piles are likely to suffer vertical displacement, and 100% damage is assumed. The mechanism described above was used to compute the boardwalk damages in a separate HEC-FDA model.

AVERAGE ANNUAL DAMAGES

General

71. The HEC-FDA program quantifies uncertainty in discharge-frequency, stage-discharge, and stage-damage functions and incorporates it into economic and performance analyses of existing conditions and alternative plans. The process applies a procedure (Monte Carlo simulation) that computes the expected value of damage while accounting for uncertainty in the basic value. The HEC-FDA program presents results for expected annual damages and equivalent annual damages, where equivalent annual damage is the sum of the discounted value of the expected annual damage, which is then annualized over the period of performance. The impacts of sea level rise were also incorporated.

Uncertainty

72. Under current Corps of Engineers guidance, risk and uncertainty must be incorporated into flood risk management studies. The following areas of uncertainty were incorporated into the HEC-FDA program:
    - stage vs. frequency
    - structure main floor elevation
    - structure value
    - content-to-structure value ratio
    - other-to-structure value ratio

73. The stage vs. frequency and associated uncertainty data used in the previous iterations of this study were derived by the Coastal Hydraulics Laboratory (CHL) using a procedure known as the Empirical Simulation Technique (EST). During the Post-Sandy analyses, it was decided that the stage vs frequency curve should be updated to reflect new modeling undertaken for FEMA's New York City coastal Flood Insurance Study (FIS). However, the 2013 FEMA stage-frequency did not include any associated uncertainty data, and HEC-FDA was used to best replicate the original standard deviations provided by CHL. The HEC-FDA program generates stage vs. frequency uncertainty using order statistics and equivalent record lengths, so by a trial and error process an equivalent record length of 25 years was found that best replicated the standard deviations provided by CHL. The 25 year record length was then used

as input to HEC-FDA to analyze the Fort Wadsworth to Oakwood Beach line of protection. Table 10 presents a summary of the impact of equivalent record length on stage vs. frequency uncertainty for the project reach.

TABLE 10 - STAGE VS FREQUENCY UNCERTAINTY					
Storm Event Return Period	**CHL Stage**	**CHL Standard Deviation**	**Standard Deviations for Various Order Statistic Equivalent Record Lengths***		
			10yr	**25yr**	**100yr**
2 yr.	5.3	0.4	0.7	0.43	0.21
5 yr.	7.0	0.3	1.0	0.85	0.44
10 yr.	8.8	0.7	1.2	1.03	0.52
25 yr.	9.9	1.0	1.31	1.14	0.64
50 yr.	10.9	1.3	1.42	1.25	0.70
100 yr.	11.8	1.4	1.52	1.34	0.75
500 yr.	13.6	2.0	1.71	1.52	0.85
**Standard deviations determined using HEC-FDA graphical stage frequency procedure.*					

200 yr comparison omitted since CHL data included only the 250 yr elevation between the 100 and 500 years.

74. Table 11 compares the CHL and FEMA curves and the standard deviations generated by both curves by HEC-FDA.

TABLE 11 - STAGE VS FREQUENCY UNCERTAINTY COMPARISON (BASE YEAR)					
Storm Event Return Period	**CHL Stage**	**CHL Standard Deviation***	**CHL Standard Deviation (HEC-FDA)****	**FEMA Post-Sandy (2013) Stage*****	**Post-Sandy Standard Deviation (HEC-FDA)****
2 yr.	5.3	0.4	0.43	5.3	0.46
5 yr.	7.0	0.3	0.85	7.2	0.77
10 yr.	8.8	0.7	1.03	8.5	0.91
25 yr.	9.9	1.0	1.14	10.0	1.07
50 yr.	10.9	1.3	1.25	11.3	1.21
100 yr.	11.8	1.4	1.34	12.6	1.35
500 yr.	13.6	2.0	1.52	15.9	1.71

**Standard deviations determined using EST Procedure.*

***Standard deviations determined using HEC-FDA graphical stage frequency procedure.*

****Stages used in the line of protection analysis (see Table 9)*

75. A normal distribution with a standard deviation of 0.6 feet was selected to represent the uncertainty associated with the main floor elevation, based on recommendations in the USACE Engineering Manual, EM 1110-2-1619, Table 6-5, and the 2-foot contour intervals provided in the project topographic mapping.

76. The uncertainty associated with structure value was assumed to follow a normal distribution with a 10% standard deviation, to be consistent with other recently accepted flood risk reduction studies for same region. EM 1110-2-1619 suggests that in lieu of better site-specific information, content-to-structure value ratios based on large samples of Flood Insurance Administration (FIA) claims records can be used (Table 6-4 presented in EM 1110-2-1619). A normal distribution with average standard deviation of 25% was utilized for structure-to-content value ratio uncertainty for both residential and non-residential content value in accordance with the referenced table. Since the damage functions present other damage as a percent of structure value, the other-to-structure value ratio was estimated to have a standard deviation of 10% for all categories.

77. The economic analysis incorporated the existing protection afforded by high shorefront elevations from the Fort Wadsworth to Oakwood Beach project reach. Since damages from tidal storms cannot occur until the storm surge overtops the high ground, the analysis of existing conditions modeled the affected reach using the levee function in HEC-FDA. This approach allowed the existing level of protection to be taken into account when calculating project damages and benefits. Since the high ground elevation along the shorefront varies, a weighted average elevation is used for each economic reach. Under existing conditions, no damages result until water levels exceed the controlling elevation. The elevations used for the Fort Wadsworth to Oakwood Beach project reach was 9.6 ft. NGVD 1929.

78. The Monte Carlo simulation technique which HEC-FDA uses as the basis for computing flood damages while accounting for risk and uncertainty associated with key variables is based on random sampling from the user-selected probability distributions used to define each uncertain variable. During each execution of the model, the program performs many iterations of the damage computations while sampling from the input probability distributions until an allowable tolerance in the overall mean damage is attained. This analysis used default tolerance within the HEC-FDA program of 0.5%, which represents an error of approximately $119,000 in the without-project base year expected annual damage (see Table 12). Use of this default tolerance is standard practice and is consistent with other recently accepted flood risk reduction studies for same region. Inspection of the model outputs indicates that most simulations require 20,000 – 50,000 iterations before the 0.5% tolerance is reached.

Estimated Damages

79. Estimated storm inundation damages include structure, content and other damages at specific buildings. Expected annual damages for the without-project/base year condition, and for the without-project/future year conditions are provided in Tables 12 and 13, respectively. Equivalent annual damages over the 50-year project life are presented in Table 14.

TABLE 12 - SUMMARY OF WITHOUT-PROJECT CONDITION/BASE YEAR AVERAGE ANNUAL DAMAGE						
Economic Reach	Damage Categories					Total
	Apartment	Commercial	Industrial	Municipal	Residential	
FWOB-1	$0	$1,280	$0	$150	$6,270	$7,700
FWOB-2	$0	$32,970	$0	$2,430	$1,572,360	$1,607,760
FWOB-3	$8,890	$202,990	$20	$37,610	$3,937,190	$4,186,700
FWOB-4	$530	$2,581,960	$14,110	$488,110	$11,664,860	$14,749,570
FWOB-5	$0	$194,510	$220	$1,230	$1,168,340	$1,364,300
FWOB-6	$0	$1,840	$1,210	$370	$370,610	$374,030
FWOB-7	$5,510	$167,780	$2,220	$120	$788,620	$964,250
FWOB-TP	$0	$0	$0	$113,940	$0	$113,940
Boardwalk	-	-	-	-	-	$397,830
Totals	*$14,930*	*$3,183,320*	*$17,780*	*$643,960*	*$19,508,250*	*$23,766,080*

Price Level: July 2014

TABLE 13 - SUMMARY OF WITHOUT-PROJECT CONDITION/FUTURE YEAR AVERAGE ANNUAL DAMAGE						
Economic Reach	Damage Categories					Total
	Apartment	Commercial	Industrial	Municipal	Residential	
FWOB-1	$0	$1,820	$0	$220	$8,890	$10,930
FWOB-2	$0	$44,850	$0	$3,430	$2,158,220	$2,206,500
FWOB-3	$12,660	$269,250	$30	$53,370	$5,238,470	$5,573,780
FWOB-4	$760	$3,503,570	$18,450	$650,640	$15,431,490	$19,604,910
FWOB-5	$0	$274,850	$310	$1,750	$1,583,040	$1,859,950
FWOB-6	$0	$2,550	$1,590	$530	$493,890	$498,560
FWOB-7	$7,780	$220,960	$3,140	$170	$1,048,980	$1,281,030
FWOB-TP	$0	$0	$0	$160,430*	$0	$160,430
Boardwalk	-	-	-	-	-	$564,020
Totals	*$21,200*	*$4,317,850*	*$23,520*	*$870,540*	*$25,962,970*	*$31,760,110*

Price Level: July 2014

*Future without-project damages at the Oakwood Beach Wastewater Treatment Plant may be reduced significantly following the implementation of FEMA-funded measures to mitigate flood damage to the plant's electrical systems (see Paragraph 81).

TABLE 14 - SUMMARY OF WITHOUT-PROJECT CONDITION EQUIVALENT ANNUAL DAMAGE						
Economic Reach	**Damage Categories**					**Total**
	Apartment	**Commercial**	**Industrial**	**Municipal**	**Residential**	
FWOB-1	$0	$1,470	$0	$180	$7,210	$8,860
FWOB-2	$0	$37,220	$0	$2,790	$1,781,930	$1,821,940
FWOB-3	$10,240	$226,690	$20	$43,250	$4,402,660	$4,682,860
FWOB-4	$610	$2,911,620	$15,660	$546,250	$13,012,200	$16,486,340
FWOB-5	$0	$223,250	$250	$1,410	$1,316,680	$1,541,590
FWOB-6	$0	$2,090	$1,350	$420	$414,710	$418,570
FWOB-7	$6,320	$186,800	$2,550	$140	$881,750	$1,077,560
FWOB-TP	$0	$0	$0	$130,570	$0	$130,570
Boardwalk	-	-	-	-		$457,280
Totals	*$17,170*	*$3,589,140*	*$19,830*	*$725,010*	*$21,817,140*	*$26,625,580*

Price Level: July 2014
**50 Year Period of Analysis, 3.375 % interest rate*
**Does not include wave damage; totals may not match due to rounding.*

Sea Level Rise

80. Sea level rise is a significant factor contributing to future impacts of tidal inundation and wave action. Based upon NOAA tide gauge readings at Sandy Hook, sea level has been increasing at an average rate of 0.014 feet per year. This is equivalent to a 0.7 foot increase in tidal stage over the 50-year period of analysis. In future years, more frequent and higher-stage flooding is likely. The calculated existing base year without-project condition expected annual damage for the 7,367 structures in the study area is $2,900 per structure. Economic analysis results indicate that the average annual expected without-project damage to residential structures would increase to $3,900 per structure by the end of the 50-year analysis period.

Damage Verification

81. In order to determine the accuracy of the modeled results, information from the Federal Emergency Management Agency (FEMA) from the storm of December 1992 was used as a

point of reference. A review of the data indicated that, during the December 1992 storm, 229 homeowners insured under the National Flood Insurance Program (NFIP) received a total of $1,802,000 (1992 dollars) to repair residential structure damages - an average of $7,869 per residence (1992 dollars). In year 2010 dollars, this is equivalent to a total of $2,249,018 or $9,821 per residence.

82. Modeled results for a storm of magnitude similar to the December 1992 storm (10 feet NGVD 1929) indicated that residential structure damages within the study area would total $27,961,755 based on the pre-Sandy inventory (2010 dollars). With approximately 3,435 structures in the study area which are susceptible to damage during a 10 ft. NGVD 1929 flood; this is equivalent to modeled residential structure damages of $8,140 per residence. In the absence of detailed data pertaining to NFIP coverage of the study area in 1992 (including the number of vulnerable properties not covered by NFIP policies for various reasons, and the limits of coverage for other properties), a comparison of the damages per structure is the only appropriate means to attempt to verify the modeled damages.

83. The difference between measured and modeled results is 20.7%; since not all affected homeowners have flood insurance and since only certain items are covered, the reported total damage value is reasonable relative to the calculated value.

84. The study area was subject to devastating flooding during Hurricane Sandy. Accurate reports such as flood insurance claims data are not complete for this event, hence no direct comparison can yet be made between modeled damages and recorded damages. However, since the mapped extent of Sandy flooding and the associated estimated frequency of occurrence are publicly available, some comparisons can be made regarding the number of structures flooded. GIS analysis of the flooding extent suggests that approximately 4,100 individual structures were affected by Sandy, which had an estimated annual exceedance chance of 1%. Interrogation of the HEC-FDA model yielded approximately 4,600 structures affected by the modeled 1% annual chance exceedance event. One possible reason for the apparently higher number of structures in the model is that the GIS analysis counted whole structures, regardless of different uses within them, while the structure inventory methodology for HEC-FDA allows for buildings to be subdivided into multiple structures to more accurately model values and damages.

85. In addition, for the Oakwood Beach Wastewater Treatment Plant, $3.4 million in damage was recorded for Hurricane Sandy, the bulk of which was attributed to damage to the plant's

electrical systems. As a result of this damage, the New York City Department of Environmental Protection has been awarded a $4.3 FEMA hazard mitigation grant, specifically to be used to elevate or otherwise floodproof electrical systems and equipment at the plant.

COASTAL RISK MANAGEMENT BENEFITS

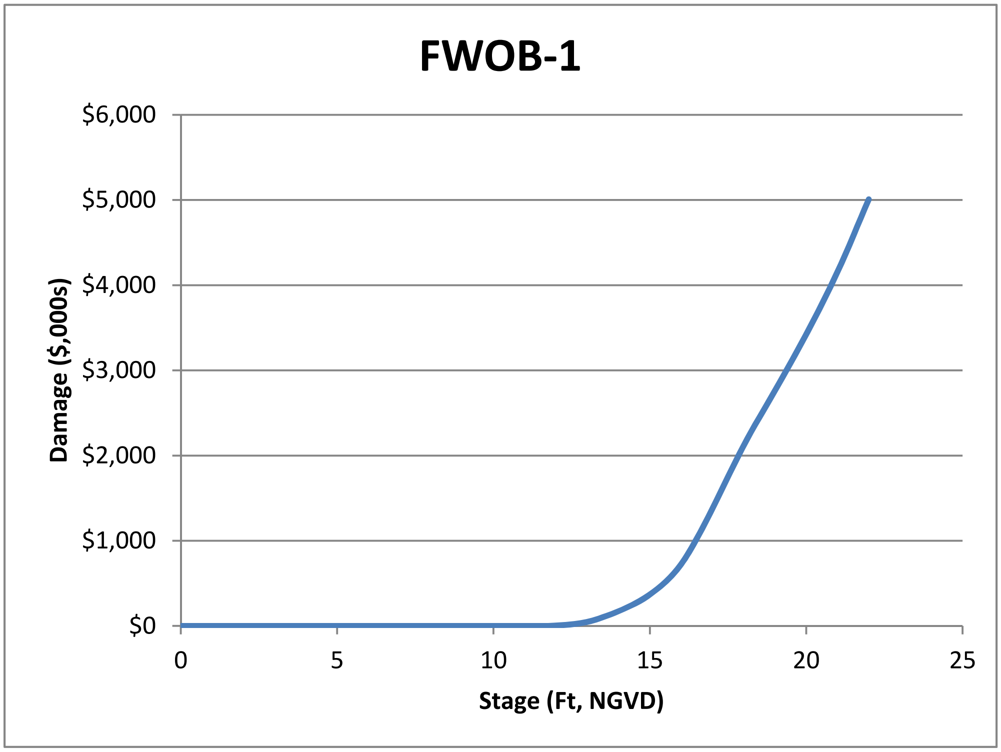
Introduction

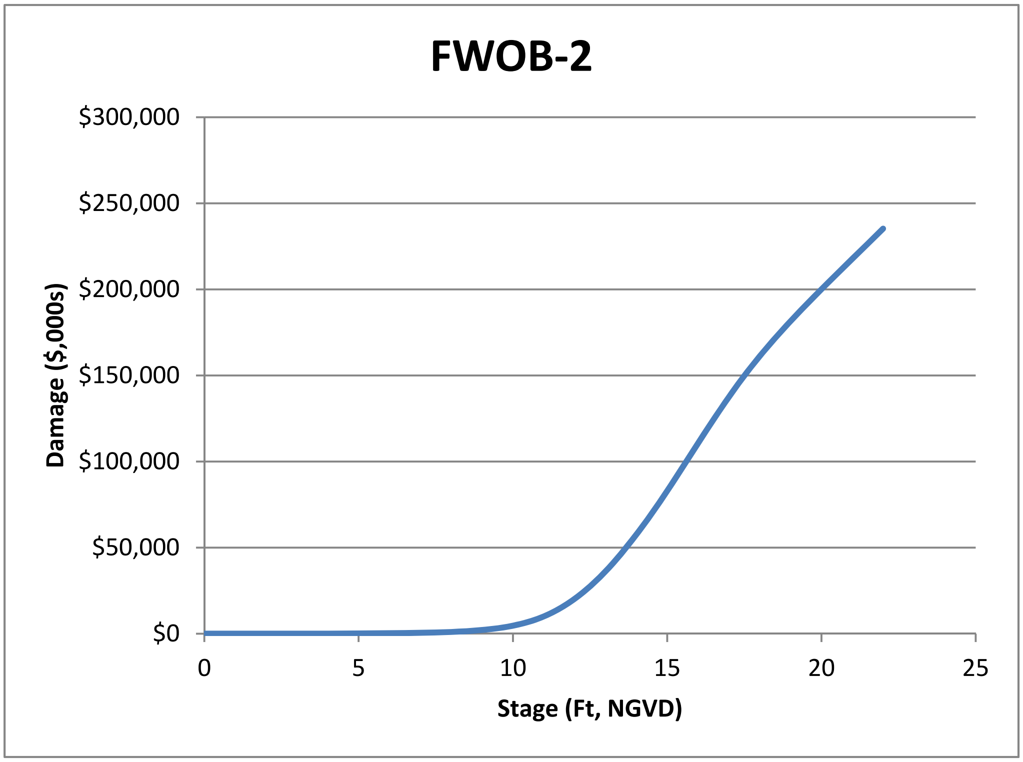
86. Several alternative plans to reduce the risk of storm damage were formulated and analyzed. The majority of plans were dismissed during screening analyses conducted prior to Hurricane Sandy. As described in the main text, a seawall/armored levee was determined to meet the study objectives in the most cost-effective manner. This Appendix evaluates the benefits of that plan.

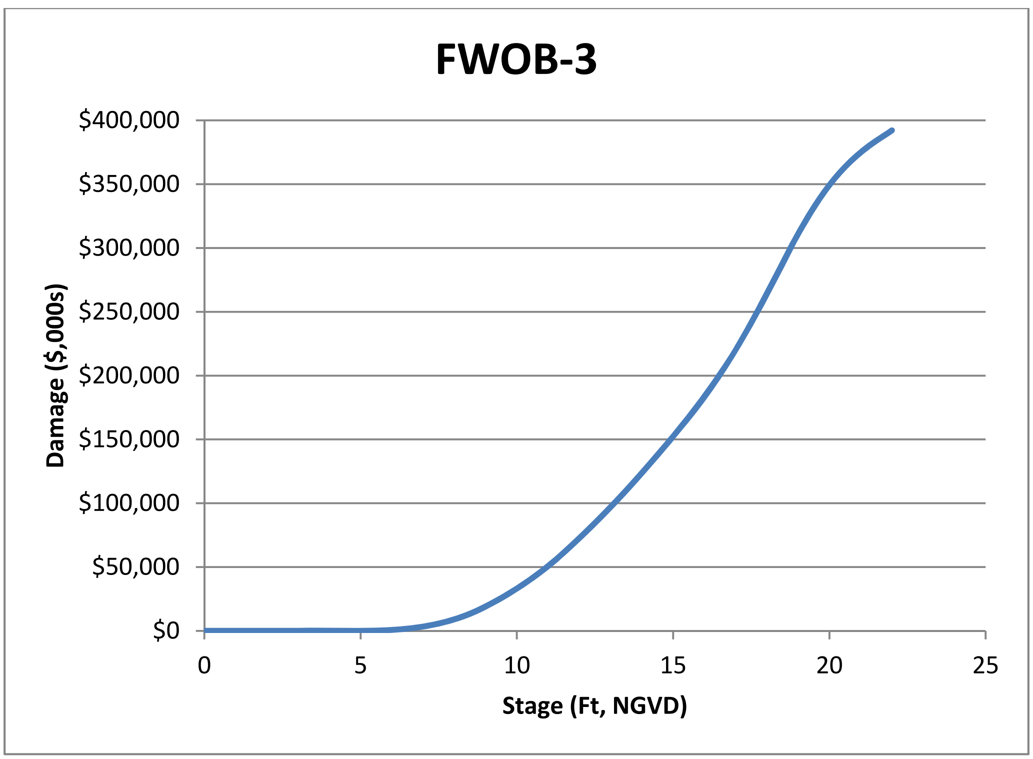
Methodology and Assumptions

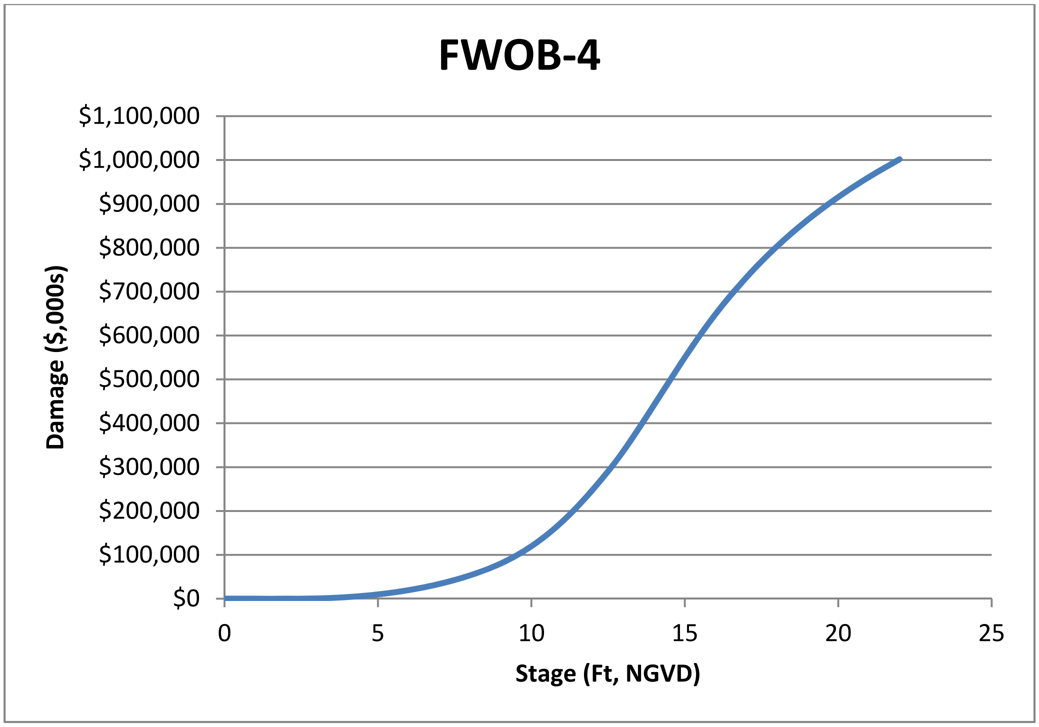
87. Benefits from the proposed plans of improvement were estimated by comparing damages with and without the proposed measures under existing and future conditions.

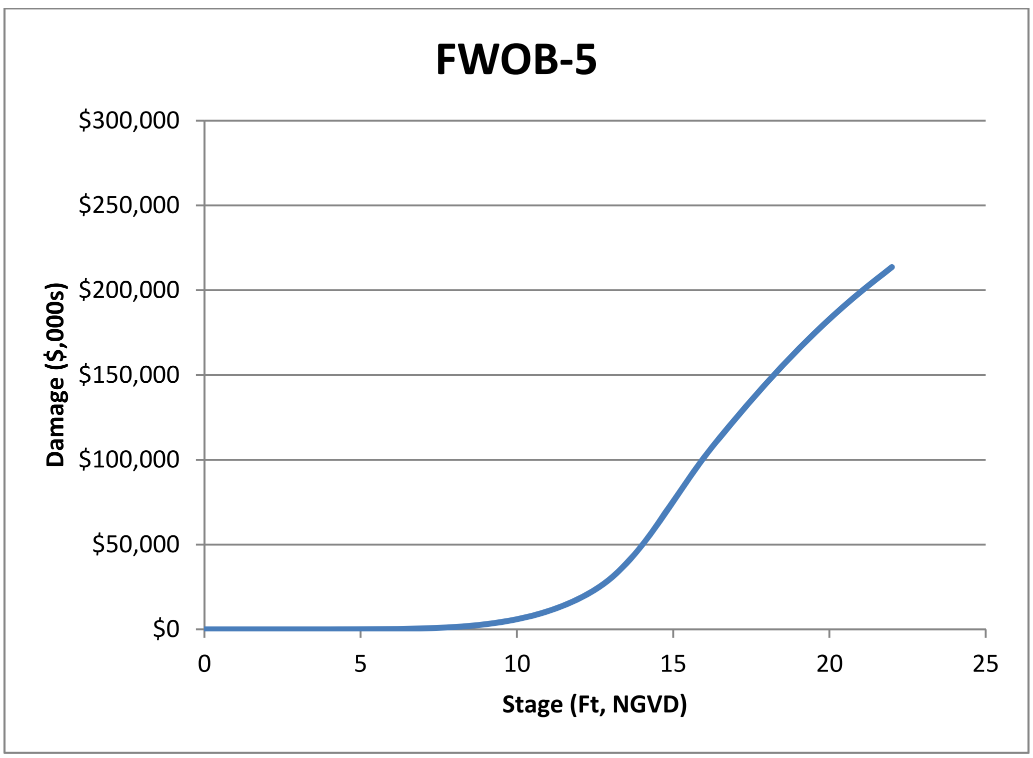
88. The area analyzed for structural alternatives covers economic reaches FWOB-1, -2, -3, -4, -5, -6 and -7 (and a sub-reach for the Oakwood Beach WWTP). Flood damages were calculated at various stages using HEC-FDA, and summarized below for each reach.

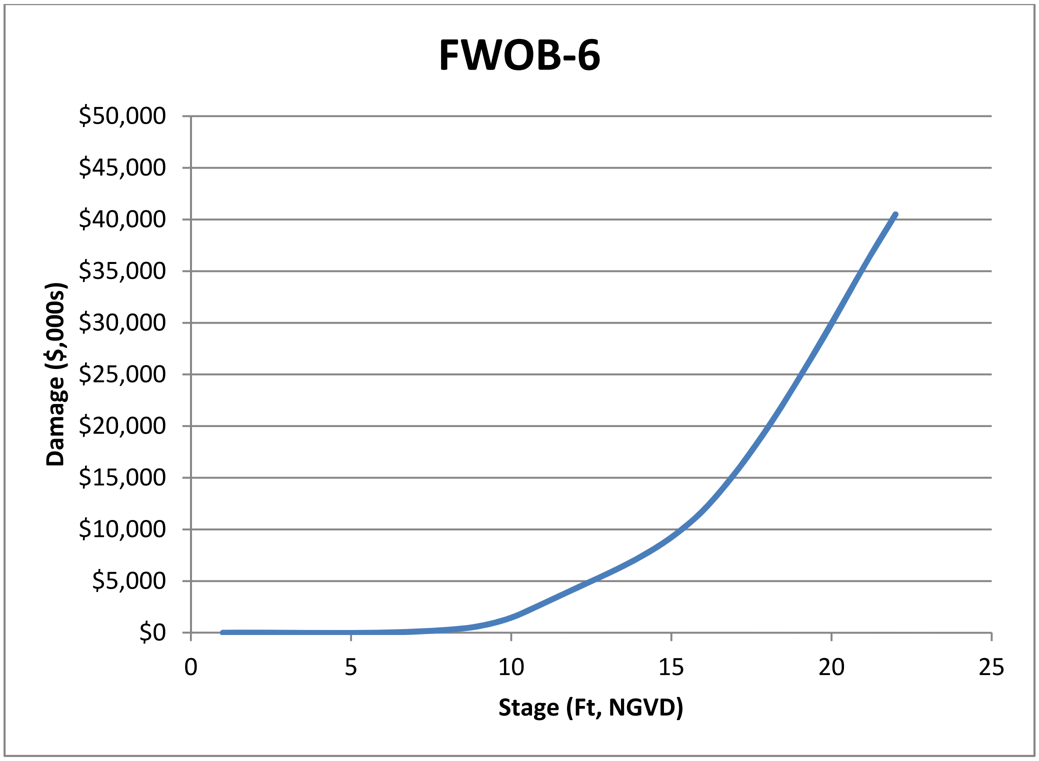


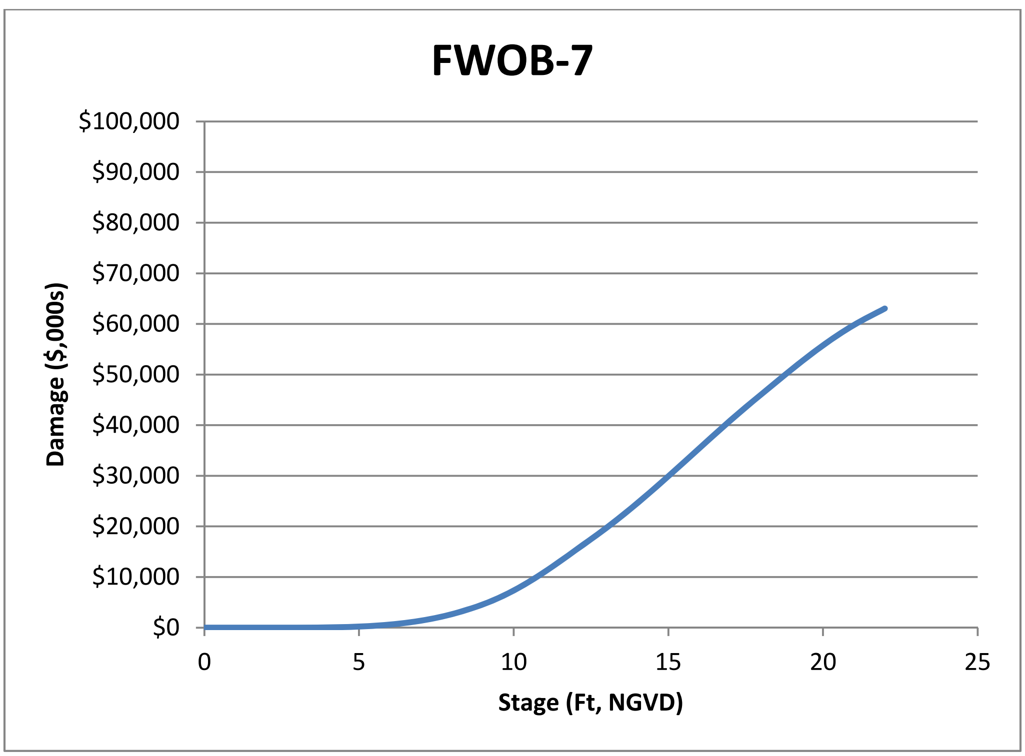

FWOB-2
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Damage ($,000s)
0
5
10
15
20
25
Stage (Ft, NGVD)


FWOB-3
$400,000
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Damage ($,000s)
0
5
10
15
20
25
Stage (Ft, NGVD)


FWOB-4
Damage ($,000s)
$1,100,000
$1,000,000
$900,000
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
0
5
10
15
20
25
Stage (Ft, NGVD)


FWOB-5
Damage ($,000s)
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
0
5
10
15
20
25
Stage (Ft, NGVD)


FWOB-6
$50,000
$45,000
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Damage ($,000s)
0
5
10
15
20
25
Stage (Ft, NGVD)


FWOB-7
$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
Damage ($,000s)
0
5
10
15
20
25
Stage (Ft, NGVD)

The Line of Protection Plan includes the following components:

- Buried seawall /armored levee and raising of existing promenade
- Levees and floodwall at Oakwood Beach
- New chambers and tidegate to prevent flooding from storm surges entering the drainage structures.

89. Four alternative stillwater design elevations were considered in the analyses, and the respective storm damage reduction benefits are presented in Table 15. Details of the design and alternative costs are provided in the Engineering and Design Appendix, and a more detailed summary of the with-project damages and benefits directly attributable to the line of protection is presented in Tables 18 and 19.

TABLE 15 - FORT WADSWORTH TO OAKWOOD BEACH LINE OF PROTECTION OPTIMIZATION				
Line of Protection (Design Stillwater Elevation)	13.3 ft. NGVD	14.3 ft. NGVD	15.6 ft. NGVD	16.6 ft NGVD
Annual Benefits	$15,816,000	$18,690,000	$21,450,000	$22,970,000

Price Level: July 2014
3.375% Discount Rate, 50-year period of analysis

Storm Damage with Plans

90. Residual damage from storm surges over topping the line of protection was calculated for each reach. The stillwater design elevations were used to determine whether storm surges would impact the protected area after plan implementation.

Residual Interior Damage

91. In addition to potential damage from storm surges over topping the levees and floodwalls, runoff from rainfall in the interior of the protected area may also cause damages. The

drainage analysis subdivided the protected area five interior drainage areas of Fort Wadsworth. Interior flood risk management alternatives were formulated independent from the line of protection as described in the Interior Drainage Appendix. A variety of interior facilities at each location were evaluated for hydrologic and economic impacts. The economic assessments for interior drainage features utilized the structure inventory and HEC-FDA model developed for the study. The residual damages for the selected interior features are presented in Table 16. Details of the interior drainage plan formulation and costs are presented in the Interior Drainage Appendix.

TABLE 16 - SUMMARY OF SELECTED INTERIOR DRAINAGE FEATURES WITH BENEFITS

Interior Area	Selected Feature	Annual Residual Damage	Damage Reduction vs. Minimum Facility
Area A	Minimum Facility	$84,970	N/A
Area B	Minimum Facility	$115,890	N/A
Area C	Alternative 4: 377,200 cy Ponds	$1,255,560	$4,367,530
Area D	Minimum Facility	$137,490	N/A
Area E	Alternative 2: 222,720 cy Ponds	$288,840	$1,915,110

Price Level: July 2014
3.375% Discount Rate, 50-year period of analysis

Reduced FIA Administrative Costs

92. Due to the remaining risk with structural measures, it is anticipated that a significant portion of the population will continue to purchase flood insurance. As such no benefits were assumed for the structural alternatives from the Flood Insurance Administration (FIA) benefits point of view.

Summary

93. Flood damage reduction benefits were calculated based on comparison of annual damages under the with- and without-project condition. Without and with project damages for the study area and the annual benefits for various stillwater design levels are summarized in Tables 17 through 19.

TABLE 17 - WITHOUT PROJECT DAMAGE SUMMARY			
Reach/ Interior Area	**Base Year**	**Future Year**	**Equivalent Annual Damage*****
FWOB-1	$7,700	$10,930	$8,860
FWOB-2	$1,607,760	$2,206,500	$1,821,940
FWOB-3	$4,186,700	$5,573,780	$4,682,860
FWOB-4	$14,749,570	$19,604,910	$16,486,350
FWOB-5	$1,364,300	$1,859,950	$1,541,590
FWOB-6	$374,030	$498,560	$418,570
FWOB-7	$964,250	$1,281,030	$1,077,560
FWOB-TP	$113,940	$160,430	$130,570
Boardwalk	$397,830	$564,020	$457,280
Subtotal Coastal Storm Damage*	$23,766,080	$31,760,110	$26,625,580
Interior Area A	$77,800	$97,900	$84,970
Area B	$100,730	$143,110	$115,890
Area C	$5,178,700	$6,421,100	$5,623,090
Area D	$116,300	$175,500	$137,490
Area E	$2,107,200	$2,377,600	$2,203,940
Subtotal Interior Flood Damage**	$7,580,730	$9,215,210	$8,162,380
Total Without Project Damage	$31,346,810	$40,975,320	$34,790,960

Price Level: July 2014
*Coastal storm damage associated with storm surges greater than existing line of protection
**Interior flood damage associated with storm surge below existing line of protection
***3.375% Discount Rate, 50-year period of analysis

TABLE 18 - WITH PROJECT DAMAGE SUMMARY				
Reach	**Equivalent Annual Damage**			
	Alt 1 (Levee 13.3 ft)	**Alt 2 (Levee 14.3 ft)**	**Alt 3 (Levee 15.6 ft)**	**Alt 4 (Levee 16.6 ft)**
FWOB-1	$9,000	$9,000	$9,000	$9,000
FWOB-2	$1,067,000	$829,000	$570,000	$413,000
FWOB-3	$1,781,000	$1,315,000	$883,000	$645,000
FWOB-4	$6,096,000	$4,386,000	$2,771,000	$1,910,000
FWOB-5	$876,000	$693,000	$483,000	$352,000
FWOB-6	$169,000	$130,000	$93,000	$71,000
FWOB-7	$393,000	$287,000	$188,000	$133,000
FWOB-TP	$101,000	$89,000	$68,000	$52,000
Boardwalk	$318,000	$198,000	$111,000	$71,000
Interior Area A	$85,000	$85,000	$85,000	$85,000
Area B	$116,000	$116,000	$116,000	$116,000
Area C	$1,256,000	$1,256,000	$1,256,000	$1,256,000
Area D	$137,000	$137,000	$137,000	$137,000
Area E	$289,000	$289,000	$289,000	$289,000
Total With Project Damage	**$12,693,000**	**$9,819,000**	**$7,059,000**	**$5,539,000**

Price Level: July 2014
3.375% Discount Rate, 50-year period of analysis

TABLE 19 - WITH PROJECT BENEFITS SUMMARY				
Reach	**Annual Benefits**			
	Alt 1 (Levee 13.3 ft)	**Alt 2 (Levee 14.3 ft)**	**Alt 3 (Levee 15.6 ft)**	**Alt 4 (Levee 16.6 ft)**
FWOB-1	$0	$0	$0	$0
FWOB-2	$755,000	$993,000	$1,252,000	$1,409,000
FWOB-3	$2,902,000	$3,368,000	$3,800,000	$4,038,000
FWOB-4	$10,390,000	$12,100,000	$13,715,000	$14,576,000
FWOB-5	$666,000	$849,000	$1,059,000	$1,190,000
FWOB-6	$250,000	$289,000	$326,000	$348,000
FWOB-7	$685,000	$791,000	$890,000	$945,000
FWOB-TP	$30,000	$42,000	$63,000	$79,000
Boardwalk	$139,000	$259,000	$346,000	$386,000
Interior Area A	$0	$0	$0	$0
Area B	$0	$0	$0	$0
Area C	$4,367,000	$4,367,000	$4,367,000	$4,367,000
Area D	$0	$0	$0	$0
Area E	$1,915,000	$1,915,000	$1,915,000	$1,915,000
Total Benefits	**$22,098,000**	**$24,972,000**	**$27,732,000**	**$29,252,000**

Price Level: July 2014
3.375% Discount Rate, 50-year period of analysis

94. Under Alternative 3 approximately $7,000 in annual interior damage related to process flows would remain at the Oakwood Beach Wastewater Treatment Plant. Using the current interest rate a complete reduction of $7,000 in residual flood damage could support additional mitigation measures up to the value of approximately $150,000 (total first cost).

95. While the risks to the wastewater treatment plant from storm surge would be reduced, a review of the plant hydraulics indicates that there are limitations in plant discharge capacity during high storm surges which may cause treated effluent to overflow into plant facilities, resulting in low levels of damage. Since the plant continued to operate during the flood levels associated with Hurricane Sandy, no interruption of plant operations is expected due to these hydraulic limitations.

Sub Appendix A

Line of Protection - Project Performance and Risk Analysis

Line of Protection - Project Performance and Risk Analysis

1. The Line of Protection will be the first line of defense against surge and wave action during future coastal events. Extremely rare frequency coastal events where the stillwater level exceeds the 15.6 NGVD 1929 NED Plan design level (the 100-yr stillwater elevation + 3 ft.) such as a 500-yr Hurricane or an even rarer event, may cause damages to structures and life-safety risks that are comparable to those seen during Hurricane Sandy. Though the damages from overtopping surge may be similar to Sandy, the chance that the Line of Protection will be overtopped will drastically decrease with the implementation of the project, effectively reducing the risks to life and property within the study area.

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

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

The overall economic performance of the selected line of protection plan has been computed by HEC-FDA and the results are presented in Table A1.

Table A1 - Expected and Probabilistic Values of Structure/Contents Damage Reduced

Alternative	Equivalent Annual Damage* (Line of Protection Only)			Probability that Damage Reduced Exceeds the Indicated Values		
	Without Project	With Project	Damage Reduced	75%	50%	25%
15.6 NGVD 1929 Stillwater Design	$26,168,000	$5,058,000	$21,110,000	$11,293,000	$18,490,000	$28,473,000

*Not including interior damages for Oakwood Beach WWTP or the boardwalk, which were evaluated separately.

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

4. The target stage for each reach was used in HEC-FDA to calculate the base year median and expected annual exceedance probability for the NED Plan. The median value reflects the basic as-designed performance of the plan without the application of uncertainty to the basic discharge-frequency and stage-discharge functions, while the expected value is computed from the results of the Monte Carlo simulations which take into account uncertainty in hydrologic/hydraulic functions and project features such as diversion structures. Hence the difference between the two is an indication of the uncertainty associated with the project performance

5. The long-term risk of exceedance is the probability that the design stage will be exceeded at least once in the specified durations of 10, 30, and 50 years, and the conditional non-exceedance probability measures the likelihood that the project will not be exceeded by a specified hydrologic event. For this analysis the base year conditional non-exceedance probability has been computed for each alternative for the 10%, 4%, 2%, 1%, 0.4% and 0.2% annual chance exceedance events (10-, 25-, 50-, 100-, 250- and 500-year floods). These indicators of project performance and residual risk for the NED Plan are presented in Table A2.

Table A2- Project Performance Analysis - Line of Protection

Annual Exceedance Probability of Target Stage	Median	0.2%
	Expected	0.3%
Long Term Exceedance Probability	10 Years	3%
	30 Years	9%
	50 Years	14%
Conditional Non-Exceedance Probability	10%	100%
	4%	100%
	2%	100%
	1%	98%
	0.4%	77%
	0.2%	43%

Interior Drainage Residual Risk Analysis

6. For storm events where the Line of Protection stillwater design level is not exceeded, there are still residual flood risks from precipitation-runoff from the Interior Drainage Areas landward of the Line of Protection. As part of the NED Plan, Interior Drainage Measures are to be implemented as to ensure that the project does not induce flooding as mandated by the criteria of the Minimum Facility, but also to be studied as to discover where additional measures may be implemented to increase the Net Benefits of the Plan.

7. Local flooding of roadways and some structural damages will occur around the 10-yr storm event even with the NED Plan in place. A significant damage elevation was defined by the stage in which non-nominal damages begin to occur within each Interior Drainage Area. The significant damage elevations for the study area are:

- Significant Damage Elevation in Drainage Area A = 4.50 ft. NGVD 1929
- Significant Damage Elevation in Drainage Area B = 5.11 ft. NGVD 1929
- Significant Damage Elevation in Drainage Area C = 3.12 ft. NGVD 1929
- Significant Damage Elevation in Drainage Area D = 8.11 ft. NGVD 1929
- Significant Damage Elevation in Drainage Area E = 5.12 ft. NGVD 1929

8. By setting significant damage elevations, it is possible to quantify different important flooding characteristics other than just the peak flood stage such as the warning time, the rate of rise of floodwaters, and the duration of inundation. Other important considerations are the number of structures that will experience flood related damage in the with-project conditions and the remaining possibility for loss of life. Figure 1 below, a sample stage-time plot with a significant damage elevation set to 4 ft. NGVD 1929 presents visual interpretation of warning time, rate of rise, and duration.

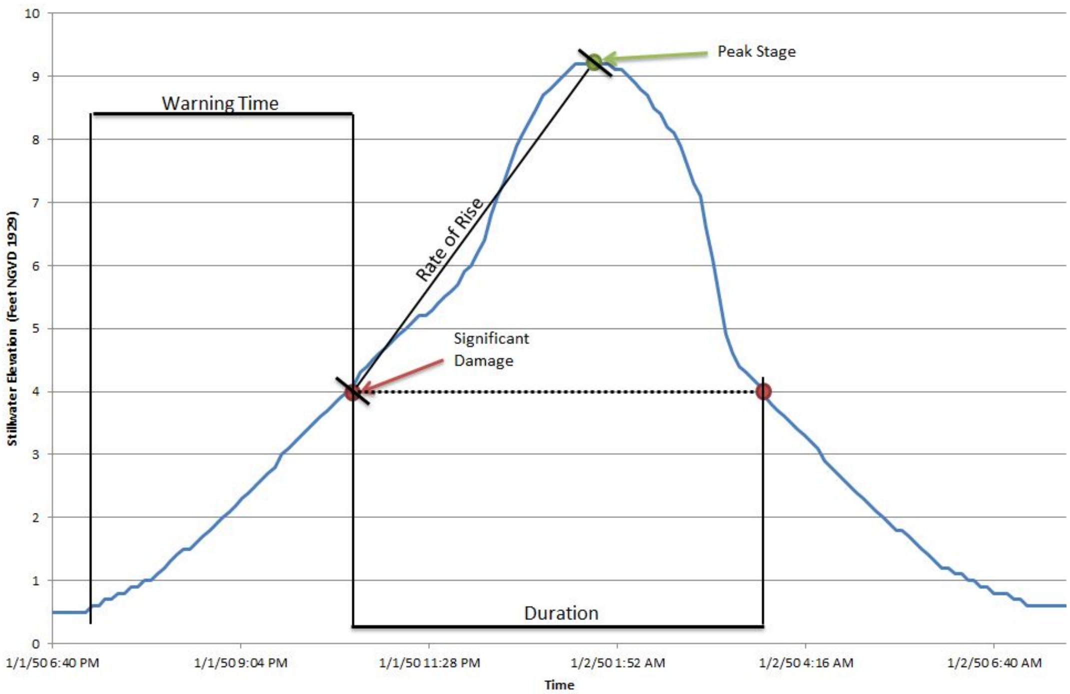


Figure 1 - Sample Interior Area Stage-Time Plot

Warning Time of Impending Inundation

9. The start point for the warning times listed below in Table begins at the inflection point on the stage storage curve where the instantaneous change in stage begins to accelerate. In effect, this point in time is when the increase in exterior tide level begins blocking outflow through the stormwater outfalls and the stormwater conveyance system reaches full capacity. Prior to this point in time, there is only a steady and slight change in interior flood stages during an extended period of initial rainfall. The end value for the warning time function is the time when the interior stage equals the established significant damage elevation. Typically the more severe the event, the shorter the warning time.

Table A3- Warning Time, Residual Flooding			
Drainage Area	Warning time (hours minutes)		
	10-yr Event	50-yr Event	100-yr Event
Area A	4hr 55min	4hr 20min	4hr 20min
Area B	6hr 05min	5hr 35min	5hr 30min
Area C	7hr 10min	5 hr. 30min	5hr 10min
Area D	5hr 05min	5hr 05min	5hr 05min
Area E	5hr 55min	5hr 15min	5hr 10min

Rate of Rise and Duration of Flooding

10. Information on the rate of rise for the 10-year, 50-year, and 100-year storm events, which measures the rate of change in flood levels per minute, is presented in Table . The rate is an average speed value from the time where the flood stage first reaches the significant damage elevation until it reaches the peak flood stage.

Table A4 - Rate Of Rise, Residual Flooding			
Drainage Area	Rate of Rise (in/min)		
	10-yr Event	50-yr Event	100-yr Event
Area A	0.48	0.34	0.31
Area B	0.08	0.24	0.29
Area C	0.07	0.12	0.16
Area D	0.24	0.17	0.13
Area E	0.10	0.31	0.41

11. The amount of time where the flood stage is above the significant damage elevation, or duration of flooding, is presented in Table A5. Here the duration of flooding is controlled by the tide, which blocks the outfalls when the exterior stage is increased above the elevation of the outfall.

Table A5 – Duration, Residual Flooding			
Drainage Area	Duration (minutes)		
	10-yr Event	50-yr Event	100-yr Event
Area A	190	230	245
Area B	120	175	190
Area C	115	380	480
Area D	95	215	265
Area E	155	265	300

Access and Egress Problems & Impacts to Public Services

12. For more frequent storm events (e.g. 2-yr or 5-yr event), local property owners may still experience some local road closures and access issues. For events that produce higher rainfall and or coastal surge, Hylan Boulevard and other main thoroughfares can be expected to experience some level of inundation. The coastal surge from the 500-yr event will cause extensive road closures and inundation of public facilities throughout the study area, starting from the shoreline and reaching all the way past Hylan Boulevard for a majority of the study area.

13. The WWTP is currently subject to flooding when storm elevations reach the micro-strainer building at +11.7 ft NGVD (+10.6 ft NAVD). During Hurricane Sandy, storm surge elevations were reported as +14.2 ft NGVD (+13.1 ft NAVD) near the WWTP. The proposed line of protection is designed to reduce damages from flooding with storm surges up to 15.6 ft NGVD (14.5 ft NAVD). The buried seawalls, levees and floodwalls will reduce the probability of flooding (under historic sea level conditions) from approximately 5% per year to below 0.4% per year.

14. Areas behind the line of protection may sometimes be flooded from interior runoff, seepage or other sources of inflow. Because the plant is at a higher elevation than adjacent areas, runoff is directed away from the WWTP and will pond in the lower lying areas when high stages block the stormwater outfalls. At the WWTP an additional source of flooding is overflow from the wastewater process during high storm tides, when discharge from the chlorine contact tank is limited due to high surge conditions. The effects and flood damage associated with overtopping from the treatment process are part of the residual interior flood conditions.

15. The solution to address the overflow of the wastewater under high surge conditions would be the construction of an effluent pumping system, likely consisting of pumps and a surge tank to overcome the hydrostatic pressure of tidal conditions and head loss through the outfall. In order for the Corps to recommend the construction of an effluent pumping system, the costs of this system would need to be offset by the reduction in flooding damages that would accrue from the system. USACE has evaluated the vulnerability of the plant, and the storm damages that would remain with the line of protection in-place. The Corps has determined that the construction of an effluent pumping system to maintain discharge capacity against storm flood elevations for purposes of storm damage reduction would not be supported based upon the cost of the system and the reduced damages to the sewage treatment plant and surrounding areas. It is recognized that an effluent pumping system would allow the WWTP to maintain operations and discharge capacity under high surge conditions, and provide additional benefits beyond what the Corps can consider as storm damage reduction benefits. The construction of an effluent pump, if undertaken by others would complement the existing project by further reducing the flooding damages, and negative environmental effects that would continue to occur under high surge conditions.

Potential Loss of Life

16. The implementation of the NED Plan will not eliminate the potential for loss of life. The NED Plan will reduce the frequency of flooding from Bay surge reaching the structures in the study area and therefore individuals. Instead of high velocity overtopping flows from the coast, the Interior Drainage Areas will experience pools of water in low-lying areas from surface run-off. Interior Drainage flooding is predicted to have waters that rise over two feet per hour in some areas, which may generate life safety risks in addition to those created by the depth of flooding alone.

17. A coastal storm event that produces surges that exceed the capacity of the Line of Protection stillwater design, could create a situation similar to Hurricane Sandy (October 29-30, 2012). Within the study area fourteen individuals lost their lives during Sandy after record surge levels overtopped the existing coastal barrier.

Residual Flood Damage

18. The NED Plan will provide risk management for the two most common sources of flood damage in the Study Area: Hurricanes and Nor'easters. It, however, will not eliminate all flood related damages behind the Line of Protection. There are a number of structures within the study area that are still at risk of being flooded above adjacent ground level due to interior run-off flooding during the with-project condition. The counts of structures by frequency and Drainage Area that experience flooding at least above the adjacent grade in both the without and with-project conditions are presented in Table A6. Table A7 shows the residual damage values by Economic Reach and Drainage Area.

Table A6- Damage, Residual Flooding

Drainage Area	Number of Structures Flooded					
	10-yr Event		50-yr Event		100-yr Event	
	Without Project	With Project	*Without Project*	With Project	*Without Project*	With Project
Area A	*20*	8	*198*	11	*287*	15
Area B	*335*	11	*962*	12	*1,144*	33
Area C	*1,325*	95	*2,402*	334	*2,579*	337
Area D	*11*	11	*149*	33	*212*	33
Area E	*171*	34	*408*	43	*460*	43
Totals	***1,862***	**159**	***4,119***	**432**	***4,682***	**461**

Table A7 - With Project Residual Damage Summary	
Economic Reach	**Equivalent Annual Damage**
FWOB-1	$9,000
FWOB-2	$570,000
FWOB-3	$883,000
FWOB-4	$2,771,000
FWOB-5	$483,000
FWOB-6	$93,000
FWOB-7	$188,000
FWOB-TP	$68,000
Boardwalk	$111,000
Total	$5,176,000
Drainage Area	**Equivalent Annual Damage**
Drainage Area A – Minimum Facility	$85,000
Drainage Area B – Minimum Facility	$116,000
Drainage Area C – Alternative 4: 377,200 cy, 6 Ponds	$1,256,000
Drainage Area D – Minimum Facility	$137,000
Drainage Area E – Alternative 2: 222,720 cy, 4 Ponds	$289,000
Total	$1,883,000
Total With Project Damage	**$7,059,000**

3.375% Discount Rate, 50-year period of analysis