VALIDATION STUDY
FOR
South Shore of Staten Island, New York
FORT WADSWORTH TO OAKWOOD BEACH

FINAL BENEFITS REPORT

September 2023

Pertinent Updates

This appendix is prepared to provide up-to-date economics for the South Shore of Staten Island Coastal Storm Risk Management (SSSI CSRM) study Validation report. It highlights the changes in economic variable inputs between Feasibility and Validation study phases and in all instances maintains fidelity with the feasibility phase analysis as documented in the Final Benefits Appendix (2016) attached here.

Purposes and Assumptions

The purpose of this economic update is to support the validation report. The economic analysis is limited to reviewing and updating estimated project benefits and affirm previous assumptions. The validation report recommends the following adjustments to the design of the authorized plan: 1) use double sheet pile seawall section rather than buried rock seawall section, and 2) increase the project height from +19.4 ft NAVD88 to +21.4 ft NAVD88. This appendix highlights the differences in benefits between the feasibility report and validation report.

Flood damage reduction benefits were calculated based on comparison of annual damages under the most likely with- and without-project conditions. Benefit-cost ratios (BCRs) are calculated based on the benefits in the latest approved official document, the SSSI CSRM Director's Report, in accordance with ER 1105-2-100. Feasibility phase analysis was completed using the Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) economic benefit model Version 1.2.5a. For the validation report, HEC-FDA Version 1.4.3 was used to analyze damages.

Estimates of Feasibility report damages were based on July 2014 price level and a 50-year analysis period. Damages were annualized over the 50-year period using the then October 2015 discount rate of 3.375%. Initial benefits were subsequently updated to October 2016 price levels annualized over the 50-year period of analysis using the FY17 Federal Discount rate of 2.875 % prior to submission to Congress. Damages for the Validation report updates price levels from July 2014 to October 2022 and annualized over the 50-year period using October 2023 discount rate of 2.5%.

Comprehensive Benefits

This section is prepared in accordance with policy directive *Comprehensive Documentation of Benefits in Decision Document* issued by the Assistant Secretary of the Army on 5 January 2021. The policy updates current procedures to ensure the USACE decision framework considers, in a comprehensive manner, the total benefits of project alternatives. Considerations are given to economic (NED and RED), environmental (EQ) and social (OSE) accounts including an assessment of potential life loss.

National Economic Development (NED)

This section describes the updates to NED benefits established for the Feasibility report adapted to the current recommended plan (21.4 ft NAVD88 seawall). The benefits are presented in a manner similar to the costs to illustrate the changes in benefits from the Feasibility report to the current estimate, and to display the incremental increase in benefits associated with an increase in the proposed height.

Storm damage reduction benefits were calculated based on comparison of annual damages under the with- and without-project condition using HEC-FDA software. For this Validation effort, the model was rerun with updated economic inputs and site-specific hydrodynamic inputs. Economic inputs include an update to the structure inventory, a price level update, and the new federal discount rate was applied.

Structure Inventory Update

As part of resiliency efforts in response to Hurricane Sandy, the New York State Acquisition for Redevelopment Program offered eligible property owners affected by Hurricane Sandy the opportunity to sell their property to

New York State. Future without project assumptions made during the Feasibility study phase excluded structures in the floodplain that were eligible for buyout. However, the acquisition program was completely voluntary, and the expected full take-up did not materialize. A desktop review identified nineteen structures that were erroneously excluded, and those structures were added back into the inventory. The desktop review also revealed 107 structures (between stations 567 to 595 within reach A-4) that were included in the Feasibility study structure inventory but have since been demolished. Those structures are removed from the structure inventory for this Validation Report.

The Marshall Valuation Service (MVS) extended life method was used to estimate the rate of depreciation to the value of buildings. For the feasibility phase, structures were assigned depreciated replacement values for damage estimation, however, the passage of time does not in itself create an additional need for further depreciation if the property or component is well maintained and functionally sound. A desktop review shows that the condition of structures in the inventory appear representative of the current condition, and there appears to be minimal variation in the remaining useful life, therefore, no further depreciation is applied to the depreciated replacement structure values established during feasibility.

Benefits Updates

Table 1 displays the inundation reduction benefits contained in the Feasibility Report, in October 2016 price levels and updated benefits to support the recommended changes to the project. Benefits presented here represent changes due to price level and stillwater elevations. Benefits from the proposed plan of improvement were estimated by comparing damages with and without the proposed measures under existing and future conditions. Columns 1 and 2 show benefits developed for the feasibility effort using 0.33% AEP stillwater (SWL) elevations obtained from FEMA Post-Sandy (2013) plus the USACE low relative sea level change (RSLC) change scenario in the original fiscal year 2017 price level and updated to fiscal year 2023 price levels. Columns 3 and 4 display benefits of the plan evaluated against the NACCS 0.33% AEP SWL plus the low intermediate rate of RSLC.

Estimates of damages reduced over a 50-year period of analysis use, for the feasibility study, FY17 price levels and discount rate of 2.875% and for the validation study, FY23 price levels and the FY23 discount rate of 2.5%

As shown in Table 1 for the feasibility study, annual project benefits were estimated at $30,374,000 (FY17) and updated to $44,943,000 in FY23 price levels. The recommended plan benefits are $87,988,000 (FY 23) using the intermediate scenario of sea level change. For comparison, benefits are presented for both the authorized height and the recommended height using the intermediated scenario. Project economic performance at all three rates of RSLC is shown in Table 2 (in section titled *NED Benefits Sea Level Rise Sensitivity*).

Table 1 Project Benefits

[1] **Feasibility Report Benefits** **19.4 ft height** **FY 17 Price Levels** **Low Scenario**	**[2]** **Feasibility Report Benefits** **19.4 ft height** **FY23 Price Level Update** **Low Scenario**	**[3]** **Validation Report Benefits** **19.4 crest elevation** **FY23 Price Level** **Intermediate Scenario**	**[4]** **Validation Report Benefits** **21.4 crest elevation** **FY23 Price Level** **Intermediate Scenario**
FEMA	**FEMA**	**NACCS**	**NACCS**
$30,374,000	$44,943,000	$77,807,000	$87,988,000

***All values are rounded to the nearest 1000s.**

NED Benefits Sea Level Rise Sensitivity

Average annual benefits for the recommended plan were re-computed using the "low", "intermediate" and "high" rates of sea level rise. For comparison with the feasibility phase, benefits are shown at the low rate of relative sea level change (RSLC) for both the 19.4 ft and the +21.4 ft NAVD88 crest elevations as well as the intermediate and high rates of RSLC in Table 2.

*Table 2 NED Benefits SLR Sensitivity**

Benefits			
21.4 ft Plan	**Low**	**Intermediate**	**High**
Line of Protection	$56,126,000	$77,916,000	$193,555,000
Boardwalk	$606,000	$649,000	$688,000
Interior Drainage	$9,423,000	$9,423,000	$9,423,000
Total Benefits	$66,155,000	$87,988,000	$203,666,000
Benefits			
19.4 ft Plan	**Low**	**Intermediate**	**High**
Line of Protection	$47,176,000	$67,938,000	$169,909,000
Boardwalk	$410,000	$446,000	$474,000
Interior Drainage	$9,423,000	$9,423,000	$9,423,000
Total Benefits	$57,009,000	$77,807,000	$179,806,000

Evaluation
The Cost Appendix presents the basis for the project costs as summarized in Table 3.

Table 3 Annualized Cost Summary

Project Cost*	
Project First Cost (Oct 2022 P/L)	**$2,021,357,000**
IDC (2.50% Interest)	$71,520,000
Total Investment	$2,347,724,000
Annualized Investment	$72,150,000
OMRR&R	$2,005,000
Total Annual Cost	$74,155,000

*Project first cost includes expended costs to date. Annual costs are annualized using FY 23 interest rate of 2. 5% and 50-year period of analysis at October 2022 price level. IDC based on 101 months of construction.

Benefits are based on damages that will be prevented by the project over the 50-year period of analysis annualized at the FY23 discount rate of 2.5% in October 2022 price levels. Table 4 presents the benefits-cost ratio and net benefits of the 21.4 ft. NAVD88 recommended plan evaluated under the low, intermediate and high scenarios of sea level rise. As shown in the table, benefits increase going from the low to high scenario of sea level rise for example, going from the low to intermediate adds $21 million in annual benefits. The implication is that the structures in study area experience more frequent flooding and higher flood depths and therefore higher damages. This is consistent with the bowl-like topography of the study area.

Table 4 Recommended Plan Evaluation

	Validation Recommended Plan +21.4ft NAVD88 (FY23, 2.5% interest rate) Low Scenario	Validation Recommended Plan +21.4ft NAVD88 (FY23, 2.5% interest rate) Intermediate Scenario	Validation Recommended Plan +21.4ft NAVD88 (FY23, 2.5% interest rate) High Scenario
Annual Cost	$74,155,000	$74,155,000	$74,155,000
Annual Benefits	$66,155,000	$87,988,000	$203,666,000
Net Benefits	$8,000,000	$13,833,000	$129,511,000
BCR	0.89	1.2	2.7

Rounded to nearest hundreds

Net benefits under the low scenario are below zero and positive under the intermediate and high scenarios. Figure 1 shows sea level data and projections for the Sandy Hook, New Jersey gauge (closest gauge to the study area) from the Sea Level Tracker tool. Monthly mean sea level (represented in light blue) is currently plotting mostly between the intermediate (dark green line) and the high (red line) since around 2010.This indicates that the intermediate is more representative of the existing and expected future without project conditions and that the low/historic rate of sea level change is lower than the recent trends and not representative of actual conditions.

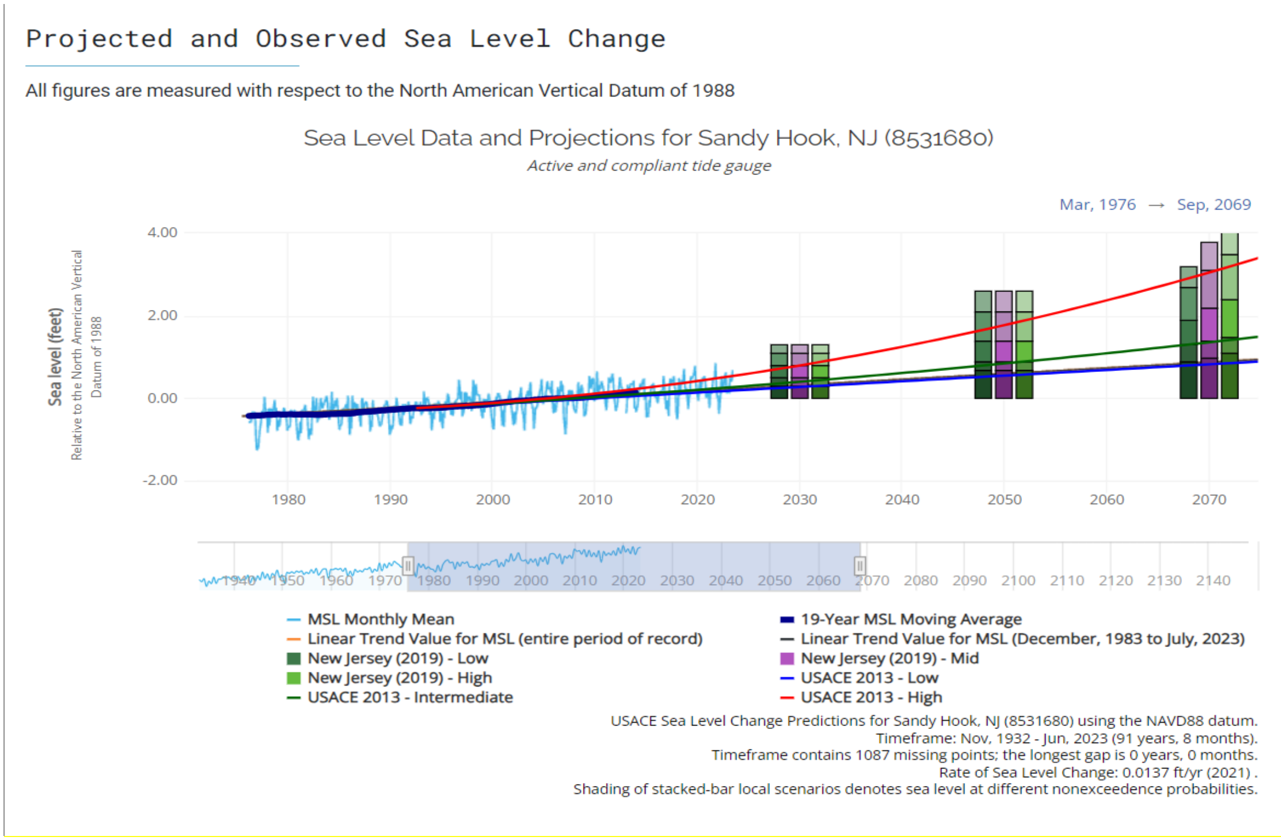

Figure 1 Sea Level Tracker Projections for Sandy Hook, NJ

Critical Infrastructure

Critical infrastructure in the study area include the Staten Island Railway (SIR), schools, utilities, fire and law enforcement stations and the Staten Island University Hospital (SIUH) (see Figure 2). Hylan Boulevard is a major roadway that runs approximately fourteen miles parallel to the shoreline. Hylan Blvd is a commercial corridor that serves local residents and summer visitors[1]. Figure 2 shows storm surge extents for a category 3 hurricane inundation created by the National Hurricane Center (NHC) Storm Surge Unit with the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model. The red color on the map highlights areas within storm surge zones that have the greatest exposure (i.e., surge greater than 9 feet above ground). Approximate locations of critical facilities are overlaid onto the hazard zone and shows SIUH, several schools (in green) and a law enforcement station are in high hazard areas.

[1] New York City (2013) A Stronger More Resilient New York: East and South Shore of Staten Island

Figure 2 NOAA Coastal Hazard Map and Critical Facilities for the SSSI study area

These facilities are community lifelines so there were protective actions planned and executed which limited operational impacts during Sandy. SIUH has a campus in the northern part of Staten Island on higher ground where patients were evacuated to during Sandy. Four schools in the hazard zone were impacted, with two remaining closed for almost a month following the storm but students enrolled at those schools were sent to alternative locations. Tottenville High School located outside of the impact area served as an evacuation intake center for affected residents. Hylan Blvd. which lies parallel to the coast and lies in the high-risk area remains at risk of inundation in the future without-project condition. The low-lying road was inundated in many areas during Sandy, causing delays in bus service and businesses on the strip were forced to close for several days. The boulevard is an important road that would need to be crossed in order for people to evacuate to higher ground. If an event makes the road impassable, residents could get trapped trying to escape. Staten Island residents accounted for 5-percent of the citywide resident workforce in 2016 (most recent data available), yet they made up a disproportionate share of the City's firefighters (39 percent), police officers (20 percent) and elementary and middle school teachers (10 percent)[2]. It is necessary that important roadways like Hylan Blvd. are clear and accessible for these first responders to assist when emergencies happen. Also, the SIR which connects residents to the ferry to Manhattan (where more than a one quarter of residents are employed) is another vulnerable facility that remains at risk of inundation. The seawall, designed primarily to resist storm surge along the coast, will protect these critical infrastructure from inundation and provide savings by alleviating human and financial loss.

Other Social Effects (OSE)

Life Safety

[2] Office of the New York State Comptroller, "An Economic Snapshot of Staten Island" Report 7-2019

Hazards and Consequences

Sandy storm created enhanced wind speeds and contributed to record setting surge. making Sandy one of the largest Atlantic tropical storms ever recorded. Of the 23 storm-related deaths on Staten Island—more than in any other borough—all but one occurred on the East and South Shores of Staten Island, ten of those deaths were in Midland Beach alone.

Staten Island Historical Life Safety Risk

Storm surge and wind from the Sandy storm caused deaths both directly and indirectly. Directly caused deaths were attributed to storm surge causing flooding in homes. In addition to storm surge forces, the area saw gusty winds that resulted in downed trees and power lines. Hurricane Sandy caused a massive power outage in the Northeast, leaving residents without power for days, even months, after the storm. According to U.S. Department of Energy, Office of Electricity Delivery and Reliability, approximately 1.9 million electricity meters were without service in New York one day after the storm had exited the area. This led to unsafe conditions where street light outages led to under regulated traffic creating hazardous roads. Power outages also caused the disruption of services for individuals dependent on electrically powered medical equipment such as ventilators and oxygen concentrators.

The speed, intensity and duration of the storm was catastrophic in terms of life loss due to a lack of timely evacuation prior to the storm. The decision to evacuate hinges on whether evacuation orders are given and with enough lead time for those at risk to prepare and respond. Other factors play a role in whether the population at risk (PAR) decides to evacuate, such as whether there are evacuation options available and how to access those options, for example, if a household had knowledge of where to shelter to and whether they had the ability to get to those places. Father Capodanno Boulevard, which is slightly elevated relative its surroundings (similar to a low berm), provides a low level of protection against coastal flooding, and was overtopped causing damaging floods on roadways. When the road was overtopped, low lying areas behind the roadway filled rapidly, trapping residents in the floodplain. Whatever the reason behind a decision not to evacuate, 68% of residents of low-lying areas were left exposed to coastal storm impacts during and in the aftermath of Hurricane Sandy.

South Shore Staten Island Risk Assessment

The proposed South Shore Staten Island (SSSI) Coastal Storm Risk Management project was analyzed by the Risk Management Center (RMC) as a Risk-Informed Design project in 2020. A Semi-Quantitative Risk Assessment (SQRA) was conducted by RMC team members, New York District employees, and other contractors. Additional hydraulic and hydrologic modeling was conducted by the risk assessment team in order to understand how wave over wash could impact the protected area and impact the probability of the project failing. The SQRA considered the levee/floodwall/seawall elevations shown below in Table 7. As shown, the rock seawall elevation analyzed by the RMC was 21.4 ft-NAVD88 or higher.

Table 5 Project Section Elevations

Distance (ft)	Start Station (ft)	End Station (ft)	Structure	Sub-Reach	Structure Crest Elevation (ft-NAVD88)
3392.9	4292.9	4293	Levee	Levee	16.9
1102.9	1521.9	1522	Floodwall	I-Wall	17.4
1691.9	3213.9	3214	Floodwall	T-Wall	19.4
1279.9	2279.9	2280	Rock Seawall	Oakwood Beach West	21.4
2294.9	4574.9	4575	Rock Seawall	Oakwood Beach East	23.4
1804.9	6379.9	6380	Rock Seawall	Cedar Grove	23.4

1959.9	8339.9	8340	Rock Seawall	New Dorp Beach	23.4
2573.9	10913.9	10914	Rock Seawall	Miller Field	23.4
2869.9	3799.9	3800	Rock Seawall	Midland Beach	21.4
4799.9	8599.9	8600	Rock Seawall	Ocean Breeze	21.4
2999.9	11599.9	11600	Rock Seawall	South Beach	21.4
2674	14274	14457	Rock Seawall	Fort Wadsworth	21.4

SSSI SQRA Without Project Condition (WOPC) Results

Life loss estimation was performed using Hydrologic Engineering Center Loss of Life Simulation software (HEC-LifeSim v. 2.0) to model life risk under inundation scenarios for the without and with project conditions. For the SSSI study area, daytime and nighttime population at risk (PAR) are shown in Table 8 for several inundation without project condition (WOPC) scenarios.

Table 6 Population at Risk

Scenario Name	Structures Inundated	Daytime PAR	Nighttime PAR
WOPC 1-ft OT	11,084	32,557	38,865
WOPC TOL	10,780	31,181	36,698
WOPC 100-yr	7,750	15,336	25,479
WOPC 10-yr	957	1,856	3,069
WOPC 2-yr	53	90	177

Median estimated life loss for the without project condition under various inundation scenarios with ample warning are shown in Table 9 or both day and nighttime. The ample warning scenario models a coastal storm scenario where hazard identification is set to 24 hours prior to the breach (-24 hours) and people have some time to plan and respond to the threat. As shown in the table, although people are able to take protective action (i.e., evacuate) expected life loss is still significant for the top of levee (TOL) elevation without project condition. The WOPC results are used to compare life loss consequences against the With Project Condition (WPC) scenarios.

Table 7 Median Estimated Life Loss Without Project Condition (WOPC)

Scenario Name	Daytime Median Life Loss	Nighttime Median Life Loss
WOPC 1-ft OT	98	85
WOPC TOL	81	70
WOPC 100-yr	7	10
WOPC 10-yr	0	0
WOPC 2-yr	0	0

Residual Risk

Residual flood risk (nonbreach) is the life loss that remains in the floodplain after a proposed flood risk management project is implemented. Table 10 presents median estimated nonbreach life loss for the with-project condition (WPC) under the same inundation scenarios presented for the without project. According to the HEC-LifeSim results, the median percentile of non-breach life loss is 0 (during the day) and 0 (at night) with ample warning for the top of levee (TOL) scenario. With the project in place, life risk is reduced at least one order of magnitude compared to the without project condition.

Table 8 With Project Median Life Loss

Scenario Name	Median Life Loss Daytime	Median Life Loss Nighttime
WPC 1-ft OT	14	17
WPC TOL	0	1
WPC 100-yr	0	0
WOPC 10-yr	0	0
WOPC 2-yr	0	0

The results indicate that remaining risk is driven by individuals' inability to take protective action. To further reduce risk to life safety, an emergency action plan should be implemented. Residual risk is estimated based on the assumption that the project works as designed and is not breached. The real-world possibility is that a storm event could cause the project to fail and therefore it is important to also consider incremental risk.

SQRA Incremental Life Loss

To evaluate incremental risk for the with-project condition, the Semi-Quantitative Risk Assessment (SQRA) was performed to determine incremental consequences due to failure of the SSSI coastal storm risk management project (project height of +21.4 ft NAVD88 for Boardwalk and Promenade seawalls). Using methods for failure modes analysis and life loss estimation, breach and non-breach scenarios were identified and compared. A failure mode is a unique set of conditions and/or sequence of events that could result in the sudden, rapid, and uncontrolled release of impounded water (FEMA 2003).

The recommended +21.4 ft NAVD88 double sheet pile seawall will strengthen the resilience of the eastern portion of the south shore of Staten Island against future severe coastal storm surge flooding and wave forces. However, the project to reduce the risk of flooding will not eliminate all flood risk. Storm induced inundation risk scenarios of primary concern for life loss risk are overtopping with no breach and breach prior to overtopping where inundation velocities arrive with little advance warning due to project failure.

Non-breach risk occurs when the flood risk reduction capacity of the levee is exceeded, and flood waters overtop the structure. At this point, the levee transitions from managing the flood to passing the flood. For levees[3], the transition occurs when the flood stage exceeds the levee crest. This elevation corresponds to the annual probability of non-breach inundation but may not result in life loss. The annual probability of flooding with non-breach life loss was estimated to be 1/750 AEP (1.33E-03) based on the top of levee (TOL) elevation (USACE 2021). This event exceeds the design criteria of the +21.4 ft NAVD88 seawall. The SQRA results show that the primary incremental (i.e., breach minus non-breach) risk-driver potential failure modes are wave overtopping of the seawall within the boardwalk reach followed by freeflow (i.e., still water) overtopping of the levee embankment, which occur at flood loading events that exceed design criteria. Table 12 compares breach and non-breach life loss estimates for the ample warning scenario at Breach Location 2 (BL2) (near Midland) of the +21.4 ft NAVD88 height project for the 1000-year event.

Table 9 Estimated Life Loss for (BL2 1,000-yr) Breach

Percentile Range	Life Loss for Ample Warning Scenario					
	Breach		Non-Breach		Incremental	
	Day	Night	Day	Night	Day	Night
95th Percentile	38	47	31	42	7	5

[3] Levees refers to a structure that excludes floods. In this case the structure is the seawall.

Percentile Range	Life Loss for Ample Warning Scenario					
	Breach		Non-Breach		Incremental	
	Day	Night	Day	Night	Day	Night
75th Percentile	27	33	21	27	6	6
Median	18	21	14	17	4	4
25th Percentile	9	11	6	9	3	2
5th Percentile	1	2	0	1	1	1

SQRA results show there is significant overtopping that could lead to life loss in the non-breach scenarios and that in the event of breach, the incremental life risk will be minimal. This illustrates that the greatest contributor to residual risk is a result of overtopping of the structure during storm events with a surge height that exceeds the levee height. The loading scenarios that are most likely to result in project failure is associated with the 1000-year event. The 1,000-year coastal storm event represents a major storm event that would likely incur ample warning time due to advanced forecasting of this high category storm. It is likely that the majority of the population at risk (PAR) will mobilize in response to an expected mandatory evacuation due to their past experience with Hurricane Sandy.

Risks to life safety in the face of hurricane forces as experienced with Sandy, will be driven by individuals' ability to get out of harm's way, for example, drowning deaths occurred to people who did not get out of the way of fast approaching storm surge. Life safety risk analysis considers public warning issuance, the mobilization rate, and structure attributes in high-risk areas. Almost the entirety of the leveed area is densely developed, which is primarily residential, but there is also a significant amount of commercial, industrial, and public structures. At some locations of the leveed area, life safety risk decreases due to high foundation heights of residential structures. Many of the residential homes at-risk are built over a garage or the foundation has been built up by several feet. Additionally, the maximum floodwater velocities are not significant enough to cause structures to collapse. For the 1-ft overtopping breach scenario, no structures are collapsed or swept off their foundation. Life safety risk is further decreased if structures in high-risk areas are two-stories and/or if the population at risk (PAR) is able to evacuate upstairs or to the roof. Life safety risk is significantly higher if people choose to evacuate by vehicle, especially if evacuation occurs shortly before or after wave overtopping or breach occurs. If a large portion of the PAR evacuates as floodwaters arrive, there is a possibility for vehicles to get submerged or swept away, which would lead to life loss. Most of the modeled life loss in the with-project condition occurs on roads during evacuation rather than in structures. The depth of flooding in the structures is significantly reduced in the with-project condition, but one foot of flooding on a roadway can contribute to loss of life.

SSSI SQRA Risk Matrix

For the visual representation, the incremental life safety risk matrix is shown in Figure 3 which displays the outcome of the SQRA on the +21.4 ft NAVD88 seawall with annual likelihood of failure on the vertical axis and average annual life loss on the horizontal axis. The weighted average of life loss is estimated for risk-driving potential failure modes (i.e., the ways that the project is most likely to fail and/or result in incremental consequences). Project risk increases as the plotting position moves up and to the right on the graph. The non-breach plot (shaded in green) shows that there is considerable life risk prior to failure and that in this scenario, societal risk is not being properly managed. Societal risk (represented by the dashed line on the plot) is the probability of adverse consequences and risks that plot beyond the societal life risk line are considered unacceptable. For the 1,000-year scenario, breach and non-breach inundation are very similar, resulting in minimal incremental flow, with freeflow overtopping significantly contributing to the non-breach life safety risk. The plot of incremental risk (shown in red) is just within what is considered acceptable to society. There is less incremental life loss compared to nonbreach life loss because incremental life loss is equal to breach life loss minus non-breach life loss. Incremental life loss is not synonymous with breach life loss.

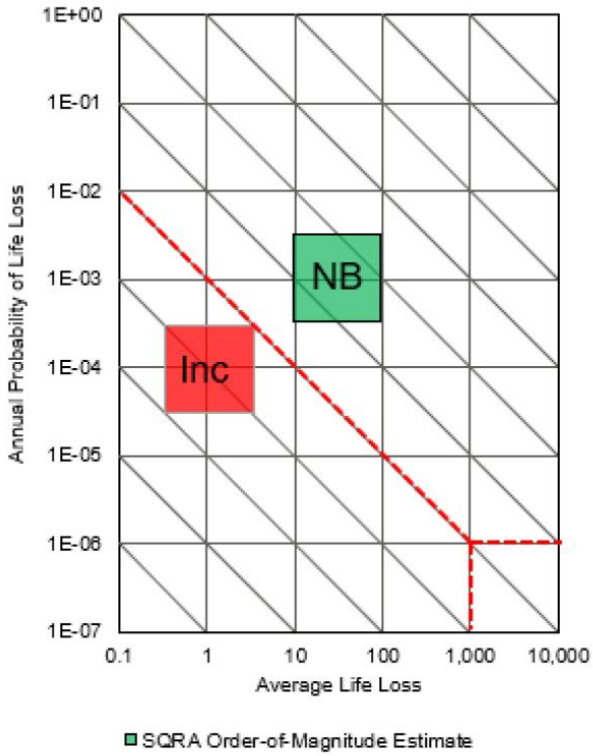

Figure 3 Incremental Life Loss plot

The +21.4 ft-NAVD88 recommended height of the seawall will reduce the volumes and velocity of the storm surge peril and provide significant life loss risk reduction to the PAR. The residual risk (i.e., non-breach risk combined with incremental risk) is currently plotting relatively high on the risk matrix. If the height of the structure is reduced to +19.4 ft-NAVD88, the non-breach life loss will shift up on the y-axis of the risk matrix (i.e., non-breach life loss will occur more frequently) and incremental risk will also likely shift up on the y-axis somewhat, which could push the incremental risk above of the societally tolerable risk line and the risk management capacity of the structure would be diminished. It's possible that non-breach average life loss could also shift towards the right as more life loss would occur during more frequent events. In other words, lowering the height of the seawall would shift both the non-breach and incremental risk higher on the chart shown above to unacceptable levels, and would increase residual life safety risk significantly.

Qualitative Life Safety Evaluation of Final Array Alternatives

To determine if the seawall is the most effective at meeting planning objective of life loss risk reduction compared to other measures in the final array, a qualitative evaluation is performed. This evaluation broadly considers the performance and exposure components of risk based on what is driving the risk to life safety in the area. Risks to life safety is driven by people who remain exposed to the hazard. The performance risk component speaks to whether the measure manages flood velocities and exposure informs evacuation rates.

Final Array

The final array consisted of four plans plus the no action plan to include beach fill, partial road raising, full road raising and the seawall. The primary measure for Alternative 1 called for beach fill along the shorefront which required 3.2 million cy (cubic yards) of placement to protect against the 1-percent storm as estimated during feasibility phase plan formulation. Alternatives 2 and 3 required full and partial road raising as the primary measure to manage coastal storms. Alternative 2 required road raising for the entire length of Father Capodanno Boulevard which runs parallel to the shore for approximately 14,000 ft and 6800 ft of armored levee from Miller Field to Oakwood Beach. Alternative 3 is a slight variation of Alternative 2 but called for *partial* road raising of Father Capodanno Blvd. and raising of the existing promenade. The primary measure for Alternative 4 is a seawall to run the length of the study area shoreline from Oakwood Beach to Fort Wadsworth.

Final array life safety considerations are evaluated on how well it reduces life risk by affecting the performance of the system. Corps Engineering Pamphlet, "Guide for Incorporating Life Risk in USACE Flood and Coastal Storm Risk Management and Project Development" (EP 1105-2-63) provides examples of measures and the component of risk that measure primarily impacts. All of the measures in the final array impact performance (manages the velocity of flooding) component of risk[4].

As long as there is an exposed population where people cannot or will not take protective action, risk to life safety will remain. Life safety risk reduction would be further reduced with a project that performs well and works in tandem with plans that reduce exposure. New York City Office of Emergency Management has a robust hurricane readiness plan and provides access to the Hurricane Evacuation Zone Finder tool that allows users to find nearby evacuation centers and identify whether they are located in a high-risk zone.

Socially Vulnerable

Certain households in the study area occupy two or more storied structures where occupants are able to escape to upper floors in the event of rising waters. However, those who are aged or have mobility issues would not be able to egress vertically as easily as those who are younger and more agile. Of the deaths that occurred in the area, elderly residents were hit especially hard, with close to half of the people who died being aged 65 or older[5]. Presented in Table 11 is the breakdown of socially vulnerable populations at risk within the study area. The table shows overall populations for several categories in New York State, Richmond County and select US Census tracts representing the floodplain.

Table 10 Socially Vulnerable Population

	New York State		**Richmond County**		**Floodplain**	
	Count	Percent	Count	Percent	Count	Percent
Population	19,276,809		471,599		70,205	
Poverty	2,581,048	13.4%	50,804	10.8%	7,680	10.9%
Under 5	1,140,669	5.9%	27,153	5.8%	3,802	5.4%
65+	3,221,702	16.7%	77,313	16.4%	11,565	16.5%
Black	3,002,401	15.6%	48,623	10.3%	3,594	5.1%
Native	76,535	0.4%	1,149	0.2%	116	0.2%
Asian	1,674,216	8.7%	47,605	10.1%	8,045	11.5%
Hispanic	3,720,707	19.3%	87,733	18.6%	11,210	16.0%

Environmental Justice

Environmental justice (EJ) considerations for the SSSI study area is carried out pursuant to the memorandum[6] from the Assistant Secretary of Civil Works dated 15 March 2022, which provides the framework for implementing environmental justice through projects that have been authorized.

As defined by the memo, environmental justice is the fair and meaningful involvement of all people regardless of race, color, national origin or income regarding the development, implementation and enforcement of environmental laws, regulations, and policies, with no group bearing a disproportionate burden of environmental

[4] EP 1105-2-63 does not show these measures as having a primary impact on the following risk components: hazard, vulnerability and consequence.
[5] New York Times, November 12, 2012, "Mapping Hurricane Sandy's Deadly Toll
[6] Assistant Secretary of the Army, Memorandum for Commanding General dated 15 March 2022, US Army Corps of Engineers, "Implementation of Environmental Justice and the Justice40 Initiative"

harms and risks. This section examines whether a disproportionate impact as a result of the project accrues to disadvantaged communities within the study area.

The White House Council on Environmental Quality Climate and Economic Justice Screening Tool (CEJST) was used to understand the potential impacts to the communities in the leveed area. Relevant categories of environmental burden considered for SSSI are Climate Change and Critical Clean Water & Wastewater Infrastructure[7]. Figure 4 below is a map of the study area (bounded by the yellow and orange lines from Oakwood to Fort Wadsworth) to include areas highlighted by the tool for some category of burden.

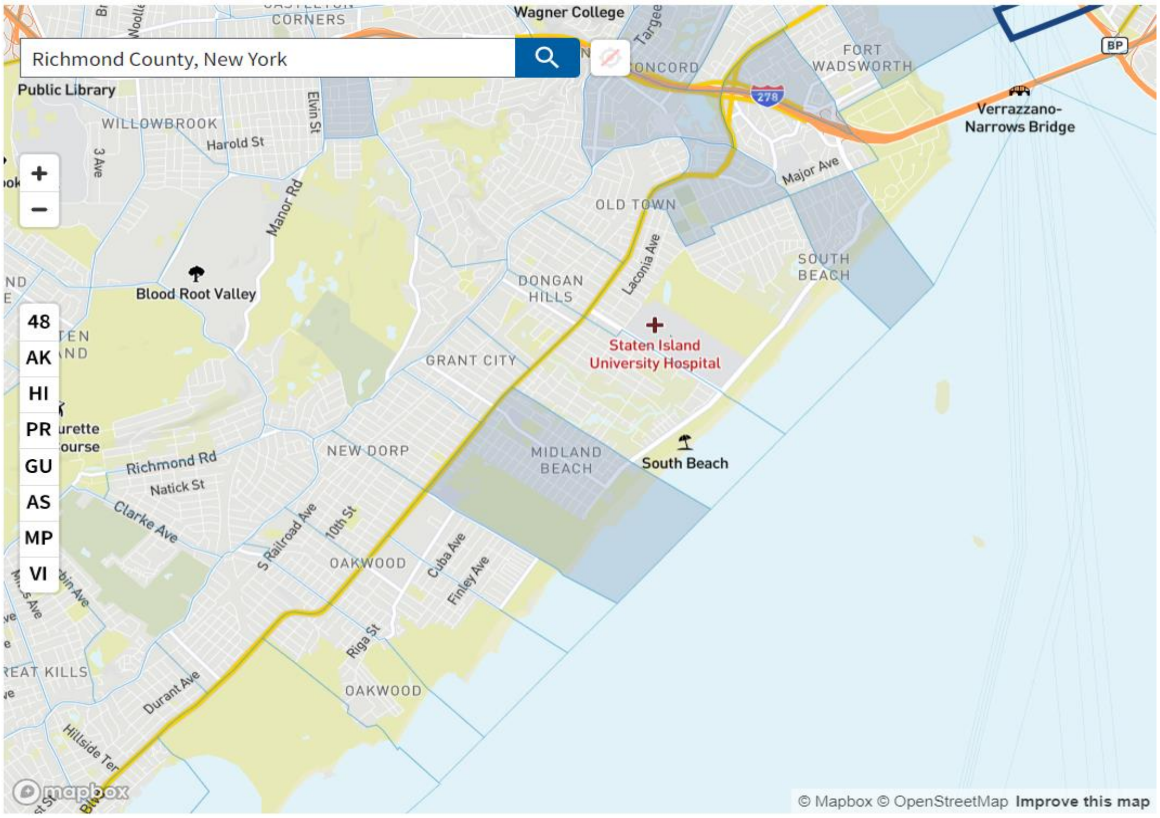

Figure 4 Environmental Justice Map of Disadvantaged Communities in the SSSI Study Area

The CEJST highlights three "problem areas" that warrant further inspection as to whether there is a potential environmental justice issue to a disadvantaged community. In accordance with ASA memo dated 14 March 2023[8], communities identified by the CEJST tool as those highlighted in Figure 3 are considered economically disadvantaged. For a community to be considered disadvantaged on the climate change burden, the tract must exceed the 90th percentile of more than one of the following burden indicators, expected building loss, population loss, projected flood risk, and wildfire risk and also meet the low-income threshold. Similarly, for a tract to be recognized for the wastewater burden the tract would have to meet or exceed the 90th percentile for underground storage tanks and be low-income. Neither of the highlighted tracts meet these criteria. For example, the Midland Beach tract exceeds the 90th percentile threshold for three climate burden indicators

[7] USACE CEJST burden categories: **climate change** Tracts ARE at or above the 90th percentile for expected agriculture loss rate OR expected building loss rate OR expected population loss rate OR projected flood risk OR projected wildfire risk; **clean water and wastewater infrastructure** Tracts ARE at or above the 90th percentile for underground storage tanks and releases OR wastewater discharge AND are at or above the 65th percentile for low income.

[8] Assistant Secretary of the Army, Memorandum for Commanding General, US Army Corps of Engineers, "Implementation Guidance for Section 160 of the Water Resources Development Act of 2020, Definition of Economically Disadvantaged Community"

(expected building loss, population loss, and projected flood risk) but does not meet the minority or low-income threshold.

While a burden exists for the highlighted areas on the map, those areas are not representative of minority, low income or Tribal communities. Referring to the Socially Vulnerable Population table above, US Census estimates show that Black and Hispanic populations in the floodplain are 5% and 16% respectively, well below that of the county and national populations. The Lenape tribe were a sovereign nation on the west side of Staten Island but today that population make up a diaspora[9], less than 1% of residents in the study area identify as Tribal/Native. Tracts in the study area highlighted by the CJEST tool represent communities with a workforce development disadvantage where occupants exceed the 90st percentile for linguistic isolation and the percent of residents without a high school diploma exceeds the 10% threshold.

Impacts of the project which runs the length of the shore will not accrue to any single tract or population and the project will have beneficial impacts to all populations within the study area by providing storm protection and promoting resiliency to communities in high-risk areas.

Regional Economic Development (RED)

The regional benefit associated with construction is the indirect and induced economic output that would be produced for an assumed construction cost.

Of total expenditures, a portion will be captured within the local impact area and portions will accrue to the state and nation. Direct expenditures capture direct impacts to the area's employment and income based on the goods and services necessary to complete construction of the alternative. Construction will also generate secondary economic activity often called expenditure multiplier effects. This would be realized through consumer spending for example, companies that supply materials or services to companies engaged in construction. It should be noted that the extent of the multiplier effect is dependent upon how consumers respond to the additional income. Also, as the Bureau of Labor Statistics reports, there are other influences on consumer spending habits (aside from changes in income) for example, the onset of the COVID-19 pandemic in 2020 affected spending across 14 major spending categories differently from 2019 to 2020 (BLS 2020).

The USACE certified RECONS input/output model was used to determine the expenditure multiplier associated with the specific work activity of alternatives considered in the final array. The RECONS model assumes 100-percent expenditure impact for all activities in a spending profile therefore, because all categories require labor, the impact on labor spending is used to compare the alternatives. Table 12 compares the impact on labor due to specific construction activity for the alternatives in final array. The beach fill option is classified under the Construction or Major Rehabilitation of Earth Dams and Spillways which uses MCACES[10] factors for construction of earth dams (MCACES Code 4a) to allocate the costs among construction labor. Beach fill is a fairly labor-intensive project, with construction labor accounting for approximately 17% of project costs. Road raising activities are classified under Construction, Repair, and Major Rehabilitation of Earth, Concrete, and Steel Channels and Canals (does not include dredging). MCACES Code 9b was used to allocate the costs associated with construction labor work activities which accounts for approximately 20% of project costs. The seawall option is classified under Construction and Major Rehabilitation of Earth, Concrete, and Mechanical/Electrical Levees and Floodwalls. MCACES Code 11B was used to allocate the costs among construction labor which accounts for approximately 27% of project costs. The seawall construction activity would add the most to the regional labor economy if costs for each project were the same. There is high confidence that although costs for all of the alternatives in the final array have not been fully developed for this effort, the seawall option remains the least cost solution because price increases would impact each alternative

[9] https://barnard.edu/news/tour-native-new-york#:~:text=In%20New%20York%20City%2C%20there,make%20up%20a%20diaspora%20today.

[10] Micro-Computer Aided Cost Estimating System (MCACES) is a multi-user software program used by the U.S. Army Corps of Engineers for the preparation of detailed construction cost estimates for military, civil works, and environmental projects.

similarly. Being the least expensive option could put the seawall at a disadvantage and make the other options more attractive as far as contribution to labor because the more the project expenditures are, the more favorable an impact on the regional economy.

Table 11 Expenditure Multiplier for Labor

Construction Activity	Impact on Labor
Beach Fill	+17%
Road Raising	+20%
Seawall	+27%

The RECONS software was used to estimate the overall impact of construction expenditures for the seawall alternative based on current cost estimates. Summarized in Table 13 is the predicted impact of the seawall alternative measured in output, jobs, labor income, and gross regional (value added) product. The expenditures associated with construction work activities for the seawall at Richmond County, New York were estimated as $1,671,321,000. The expenditures would support a total of 19,339.2 full-time equivalent jobs, $1,337,261,000 in labor income, $1,419,386,000 in the gross regional product, and $2,149,590,000 in economic output in the local impact area. More broadly, these expenditures support 30,960.1 full-time equivalent jobs, $2,218,423,000 in labor income, $2,765,705,000 in the gross regional product, and $4,602,615,000 in economic output in the nation.

Table 12 Regional Output Summary

Area	Local Capture	Output	Jobs	Labor Income	Value Added
Richmond County					
Direct Impact		$1,285,121,000	14,461.6	$1,055,954,000	$912,840,000
Secondary Impact		$864,469,000	4,877.6	$281,307,000	$506,546,000
Total Impact	$1,285,121,000	$2,149,590,000	19,339.2	$1,337,261,000	$1,419,386,000
New York State					
Direct Impact		$1,485,695,000	16,100.0	$1,213,618,000	$1,074,747,000
Secondary Impact		$1,424,212,000	6,920.5	$525,717,000	$889,814,000
Total Impact	$1,485,695,000	$2,909,907,000	23,020.4	$1,739,335,000	$1,964,560,000
United States					
Direct Impact		$1,625,174,000	17,336.7	$1,266,415,000	$1,140,910,000
Secondary Impact		$2,977,441,000	13,623.3	$952,007,000	$1,624,795,000
Total Impact	$1,625,174,000	$4,602,615,000	30,960.1	$2,218,423,000	$2,765,705,000

Dollar values in the table have been rounded to the nearest thousands.

Environmental Quality

No impacts to threatened and endangered species, land use and zoning, air quality, HTRW, coastal zone management, and transportation. Impacts to water resources, socioeconomics and environmental justice, cultural resources, recreation, visual resources, and noise were within the range of impacts documented in the FEIS and were determined to be ‘de minimis’. There may be potential beneficial impacts to wildlife, as the reduced slope of the seawall allows for easier crossings by wildlife.

The proposed action results in a quantitatively larger impact to soils than in the FEIS, however, qualitatively the impact has not changed as the same soil types will be impacted by the wider seawall footprint. There is a net loss of 6.55 acres of wetlands due to construction of the project. However, a functional assessment was conducted and determined that there is a net gain of function units of both freshwater (+87.51 units) and tidal (+6.68 units) wetland habitats. No compensatory mitigation is necessary. Potential impacts of design changes are presented in tabular form in the Memorandum for Record.

Comprehensive Benefits Summary

The seawall alternative performs well across the four accounts. As evaluated in the SQRA, life safety risk consequences are reduced with project. The +21.4 ft NAVD88 seawall maximizes net economic benefits, reduces the risks to life safety and would add over 19,000 FTE jobs to the county and over 30,000 jobs overall. Recommended changes to the seawall alternative have been evaluated for environmental quality and it has also been shown to have minimum impacts. The project will have beneficial impacts to all populations within the study area by providing storm protection and promoting resiliency to communities.

Benefits to Costs Ratio

This section restates the benefit cost ratios for the feasibility plan, and the provides economic performance of the recommended plan, and demonstrates that the project remains economically justified. Benefits and costs for the authorized project as described in the Director's Report were annualized over a 50-year period of analysis at the then discount rate for FY17 of 2.875% (October 2016). The total annualized cost was estimated at $23,458,000 and annual storm risk management benefits were $30,374,000 (based on the historic rate of sea level change). Annual net benefits were $6,916,000 and the benefit-cost ratio (BCR) was 1.3.

For the purposes of comparison, Table 14 presents the evaluation of the Director's Report project as well as the Validation study updates, using updated stillwater elevations, at current price levels and current discount rate of 2.5% FY 23 for October 2022 price levels. The economic performance of the recommended plan is shown at all three rates of relative sea level change.

Table 13 Benefit-Cost Ratios

	Director's Report Project +19.4 ft NAVD 88 (FY17, 2.875 interest rate)	Validation Report +19.4 ft NAVD 88[1] (FY22, 2.5% interest rate)	Validation Recommended Plan +21.4ft NAVD88 (FY23, 2.25% interest rate) Low Scenario	Validation Recommended Plan +21.4ft NAVD88 (FY23, 2.5% interest rate) Intermediate Scenario	Validation Recommended Plan +21.4ft NAVD88 (FY23, 2.5% interest rate) High Scenario
Annual Cost	$23,458,000	$44,946,000	$74,155,000	$74,155,000	$74,155,000
Annual Benefits	$30,374,000	$52,028,000	$66,155,000	$87,988,000	$203,666,000
Net Benefits	$6,916,000	$7,082,000	-$8,000,000	$13,833,000	$129,511,000
BCR	1.3	1.2	0.89	1.2	2.7

[1] Costs from +19.4 ft NAVD88 DSP wall, contingency developed through ARA..
[2] Estimated using FEMA water elevations. Other columns are using the NACCS water elevations
[3] Cost for +21.4 ft NAVD88 DSP wall has contingency developed through CSRA. If the +19.4 ft NAVD88 DSP wall were refined through CSRA, the costs would be closer to what is shown for the +21.4 NAVD88 DSP wall.
[4] The high rate of SLC plots significantly higher than intermediate and low curves resulting in higher estimated damages.

Summary of Four Accounts

Preliminary screening results established during plan formulation as well as post authorization results from the SQRA and Environmental MFR are used to summarize beneficial contributions to life-safety consideration, economics, or environmental impact of each alternative.

Alternative	Alternative #1 Beach Fill	Alternative #2 Raised Road	Alternative #3 Partial Raised Road	Alternative #4 Seawall
NED*	BCR above 1. Increased beach area may provide recreation opportunities.	BCR above 1. Additional costs incurred for relocation of utilities. Creates additional interior drainage cost for handling runoff between road and shoreline	BCR above 1. Additional costs incurred for relocation of utilities. Creates additional interior drainage cost for handling runoff between road and shoreline	BCR above 1 No private property would be directly impacted
	Source: Plan formulation alternatives screening			
OSE*	Increased beach area may provide recreation opportunities. Requires nourishment to maintain effectiveness.	Elevating Father Cappodano Blvd a foot or higher above grade could result in substantial interior draining ponding and increased life loss risk. Road elevation would require elevation of ~ 49 structures along the road	Does not create potential public safety issues	Reduction in life risk by 1 order of magnitude. Access routes remain open during flood events.
	Source: Plan formulation screening and post authorization SQRA			
RED*				+30,000 FTE
	Source: Post authorization results. FTE=full time equivalent jobs to US			
EQ*	Bay bottom shoreline disturbance. Size required for effective project may exceed footprint acceptable to resource agencies or New York state.	Minimal impact to environmental resources	Minimal impact to environmental resources	Minimal impact to environmental resources
	Source: Plan formulation screening and post authorization Environmental MFR			

Economic Performance

The overall economic performance of both the authorized height (19.4ft NAVD88) and the recommended height (21.4 ft. NAVD88) is presented in Table 15 for the line of protection plan as computed by HEC-FDA. Without project damages under the intermediate scenario of RSLC is $95,815,000 (annualized and rounded). With project damages amount to $17,899,000 and total inundation reduction benefits from the project is $77,916,000 for the recommended height.

Table 14 Economic Performance- Coastal Storm Damage Reduction Only

	Equivalent Annual Damage			Probability that Damage Reduced Exceeds:		
Alternative	Without Project	With Project	Damage Reduced	75%	50%	25%
21.4 NAVD	$95,815,000	$17,899,000	$77,916,000	$58,810,000	$80,682,000	$98,017,000

Risk and Uncertainty

CSRM Feature - Project Performance and Risk Analysis

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 results from the HEC-FDA model were also used to calculate the long-term annual exceedance probability (AEP) and the conditional non-exceedance probability, or assurance, for various probability storm events. The model provided a target stage to assess project performance for each study area reach for the base year, 2032, and the last year in the 50-year period of analysis under both without-project and with-project conditions. For study area reaches without proposed levees or berms, the target stage was set by default at the elevation where the model calculated five percent residual damages for the 1% AEP (100-year) event. The HEC-FDA model calculated a target stage AEP with a median and expected value that reflected the likelihood that the target stages will be exceeded in a given year. The results show the long-term risk or the probability of the target stage being exceeded over 10-year, 30-year, and 50-year periods. Finally, the model results show the conditional non-exceedance probability or the likelihood that a target stage will not be exceeded by the 10% AEP (10 year), the 4% AEP (25-year), the 2% AEP (50-year), the 1% AEP (100-year), the 0.4% AEP (250-year), and the 0.2% AEP (500-year).

Table 15 Project Performance

Project Performance Analysis - Line of Protection		
Annual Exceedance Probability of Target Stage	Median	0.63%
	Expected	0.98%
Long Term Exceedance Probability	10 Years	9%
	30 Years	26%
	50 Years	39%
	10%	100%
	4%	100%
	2%	86%

Project Performance Analysis - Line of Protection		
Conditional Non-Exceedance Probability	1%	62%
	0.40%	38%
	0.20%	13%

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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

June 2016

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SUB APPENDIX A

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. 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. 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

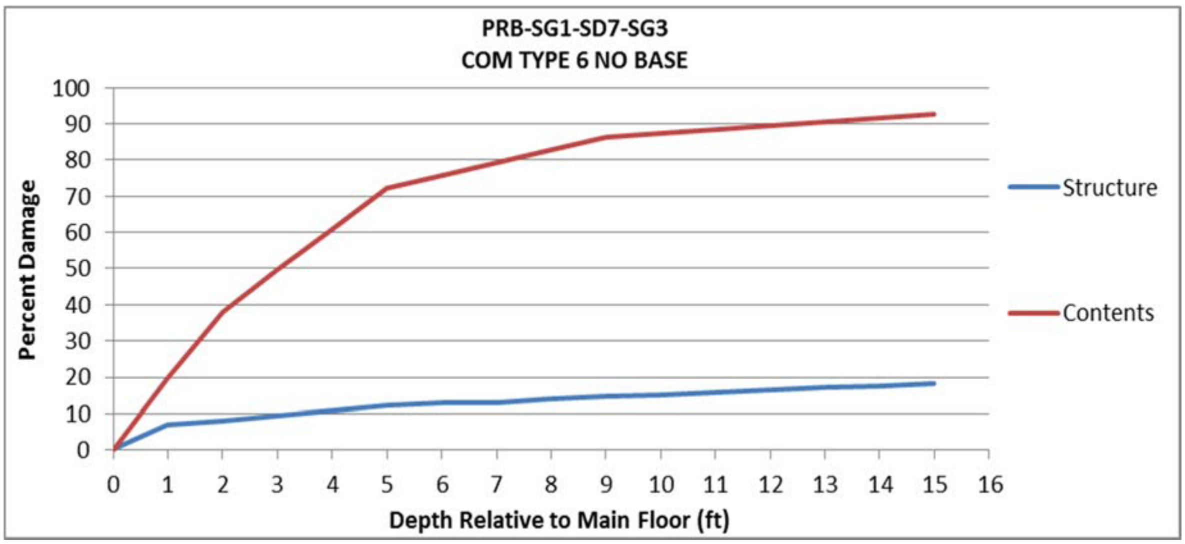
65. Based on the type, usage and size of each structure inventoried, damage was calculated relative to the main floor elevation of the structure. For this analysis two separately developed classes of depth- percent damage functions were used for all structures in the project area with the exception of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

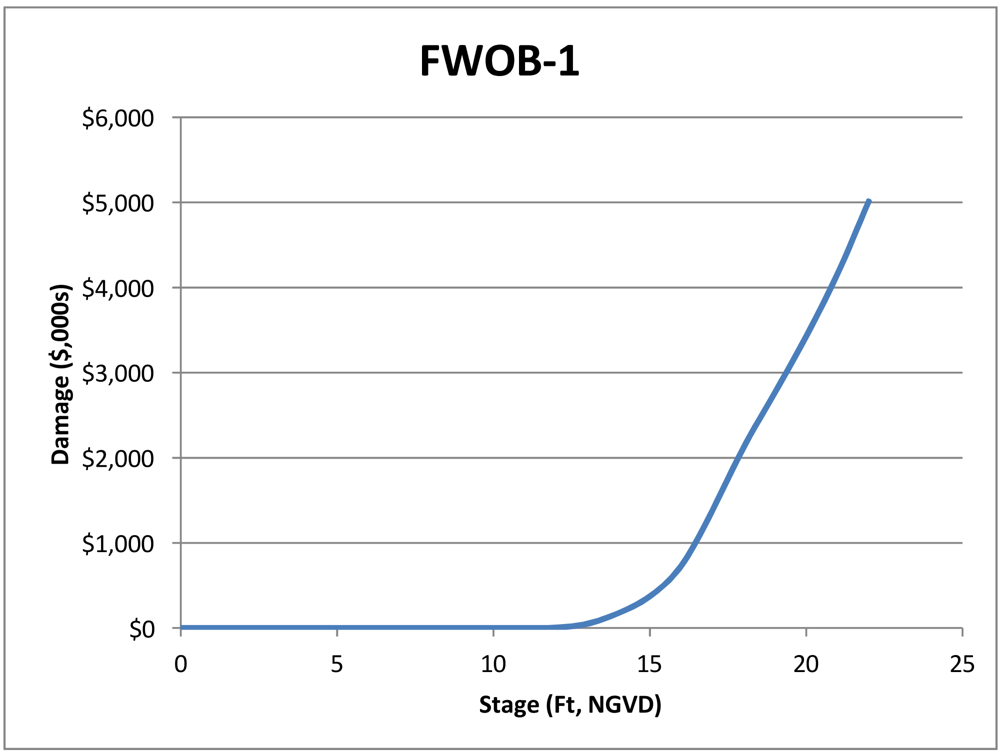
Introduction

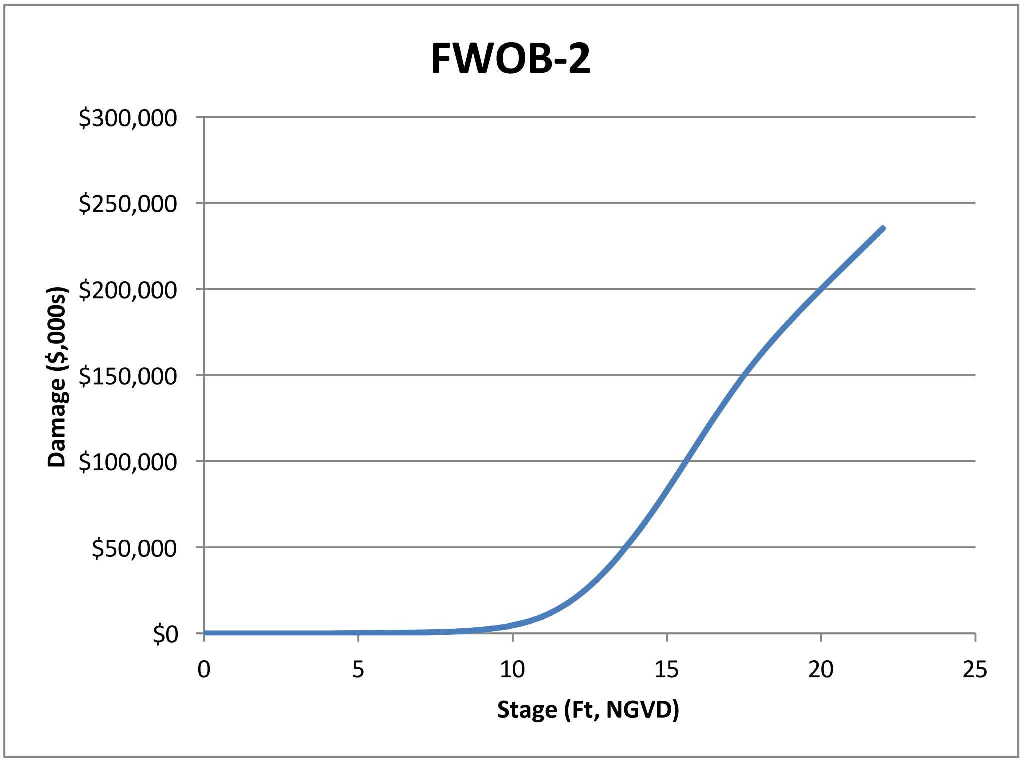
86. Several alternative plans to reduce the risk of storm damage were formulated and analyzed. The majority of plans were dismissed during screening analyses conducted prior to Hurricane Sandy. As described in the main text, a seawall/armored levee was determined to meet the study objectives in the most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

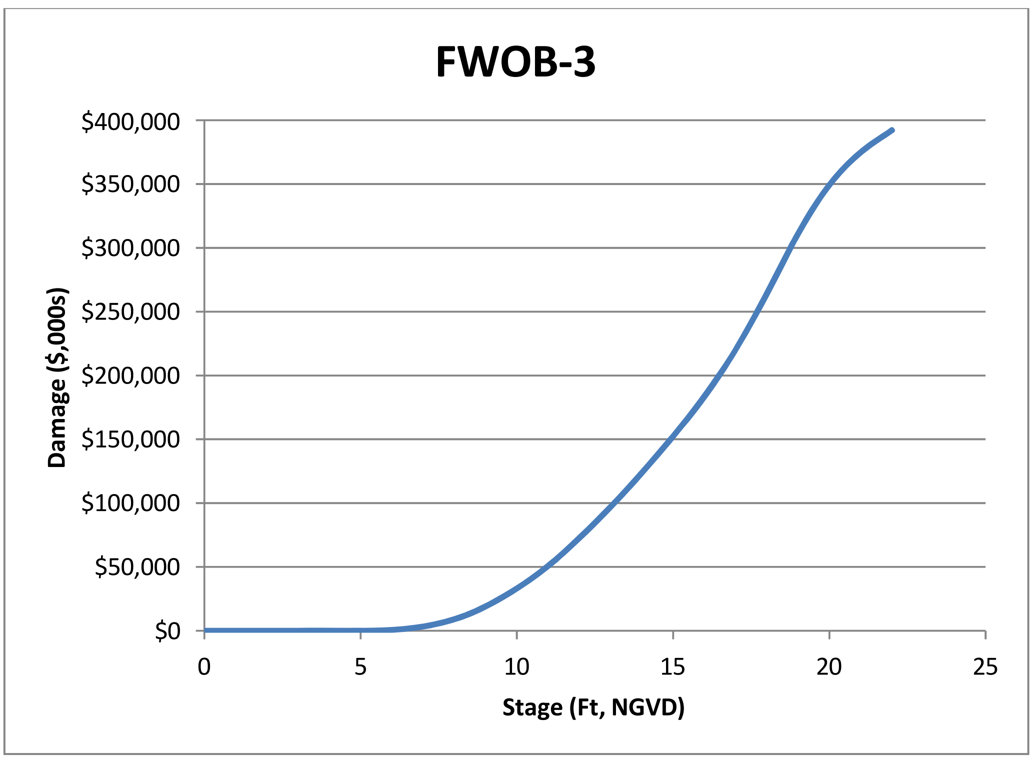
Methodology and Assumptions

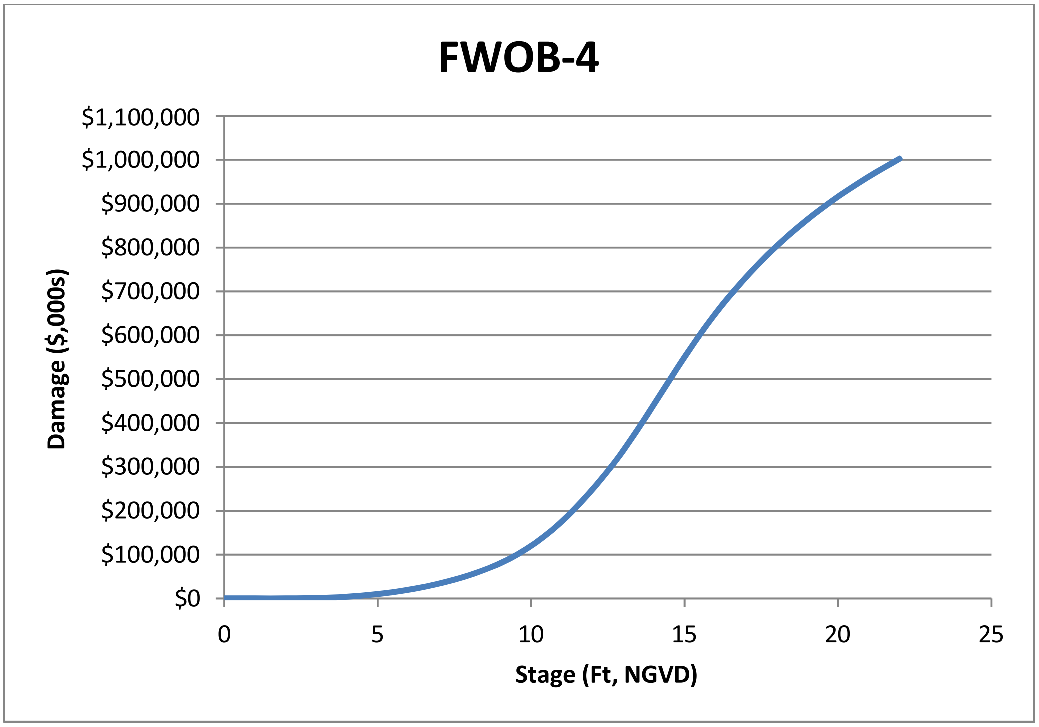
87. Benefits from the proposed plans of improvement were estimated by comparing damages with and without the proposed measures under existing and future conditions.

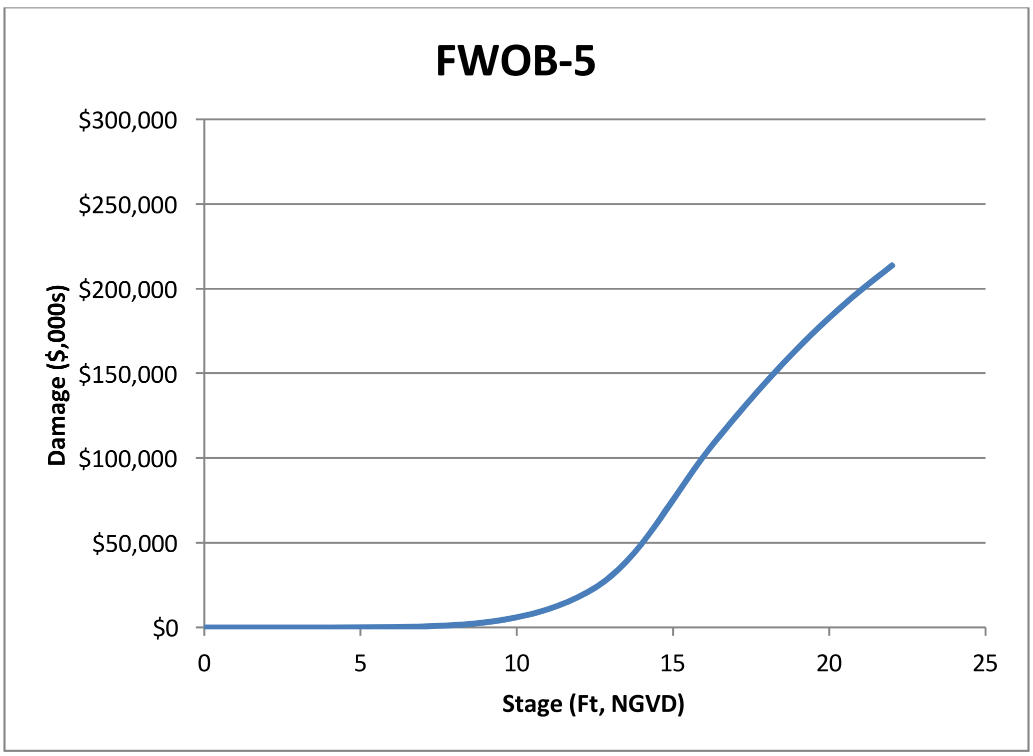
88. The area analyzed for structural alternatives covers economic reaches FWOB-1, -2, -3, -4, -5, -6 and -7 (and a sub-reach for the Oakwood Beach WWTP). Flood damages were calculated at various stages using HEC-FDA, and summarized below for each reach.

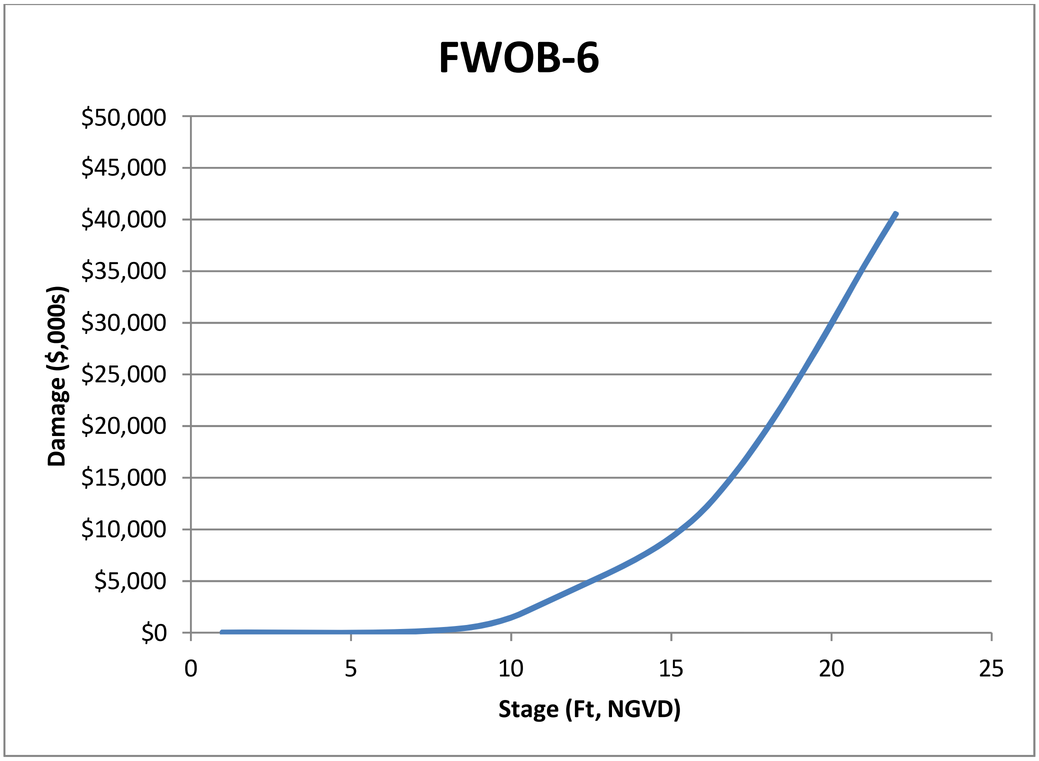


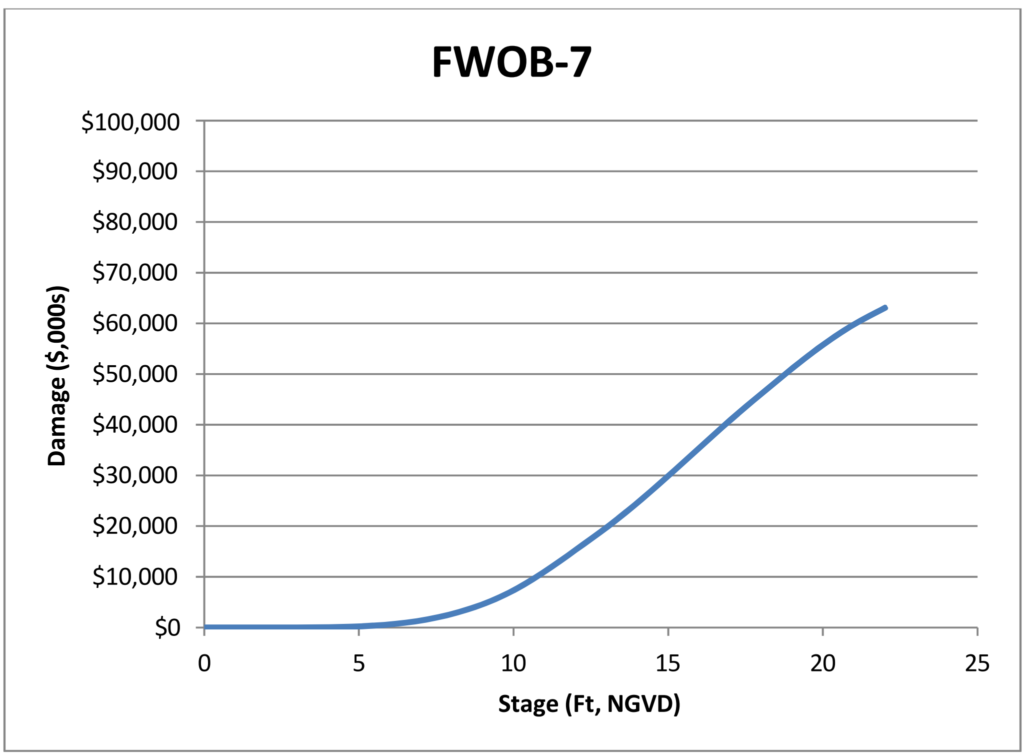

FWOB-2
Damage ($,000s)
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
0
5
10
15
20
25
Stage (Ft, NGVD)


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


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


FWOB-5
$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-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.

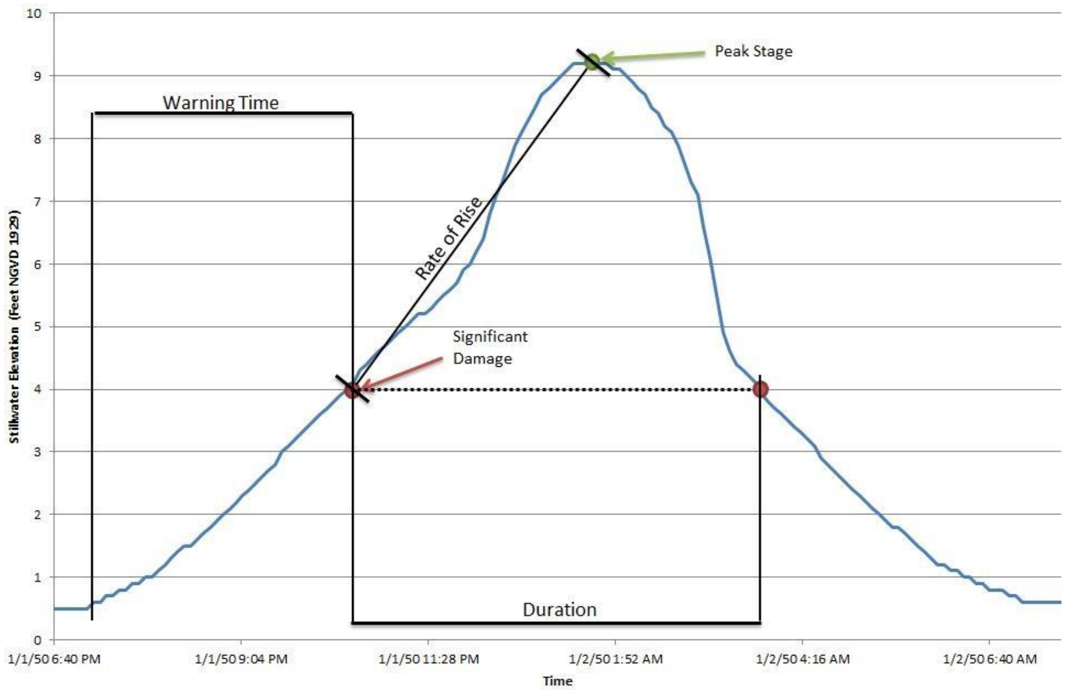


Figure 1 - Sample Interior Area Stage-Time Plot

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