US Army Corps
of Engineers
New York District

# Atlantic Coast of New York, East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

## Draft Integrated Hurricane Sandy General Reevaluation Report and Environmental Impact Statement

### Plan Formulation Appendix

**May 2016**

# Plan Formulation Appendix:
# Atlantic Coast of New York
# East Rockaway Inlet to Rockaway Inlet and Jamaica Bay

# Draft Hurricane Sandy General Reevaluation Report and Environmental Impact Statement

## Executive Summary

**Description of the Report**

This report is an integrated Draft Integrated Hurricane Sandy General Reevaluation Report/Environmental Impact Statement (HSGRR/EIS) examining coastal storm management (CSRM) problems and opportunities for the East Rockaway Inlet to Rockaway Inlet and Jamaica Bay study area, which was devastated by the impacts of Hurricane Sandy in 2012. Consistent with current U.S. Army Corps of Engineers (USACE) planning guidance, the study team identified and screened alternatives to address CSRM, and is presenting a tentatively selected plan (TSP).

The TSP identifies the overall project features, with the acknowledgement that the specific dimensions of the plan have not been finalized. These final design components will be undertaken after review of this report. This Draft HSGRR/EIS will undergo public review, policy review, Agency Technical Review (ATR), and Independent External Peer Review (IEPR). The USACE study team will respond to review comments, then present a recommended plan and develop a Final HSGRR/EIS.

This report and its recommendations are a component of the USACE response to the unprecedented destruction and economic damage to communities within the study area caused by Hurricane Sandy. The recommendations herein include a systems-based approach for coastal storm risk management that provides a plan for the entire area, which has been formulated with two planning reaches to identify the most efficient solution for each reach. Project partners include the New York State Department of Environmental Conservation, the New York City (NYC) Mayor's Office of Recovery and Resiliency, the NYC Department of Parks and Recreation, the NYC Department of Environmental Protection, and the National Park Service.

The study area (Figure 1), consisting of the Atlantic Coast of New York City between East Rockaway Inlet and Rockaway Inlet, and the water and lands within and surrounding Jamaica Bay, New York is vulnerably located within the Federal Emergency Management Agency (FEMA) regulated 100-year floodplain. The shorefront area, which is a peninsula approximately 10 miles in length, generally referred to as Rockaway, separates the Atlantic Ocean from Jamaica

Bay immediately to the north. The greater portion of Jamaica Bay lies in the Boroughs of Brooklyn and Queens, New York City, and a section at the eastern end, known as Head-of-Bay, lies in Nassau County. More than 850,000 residents, 48,000 residential and commercial structures, and scores of critical infrastructure features such as hospitals, nursing homes, wastewater treatment facilities, subway, railroad, and schools are within the study area (Figure 2).

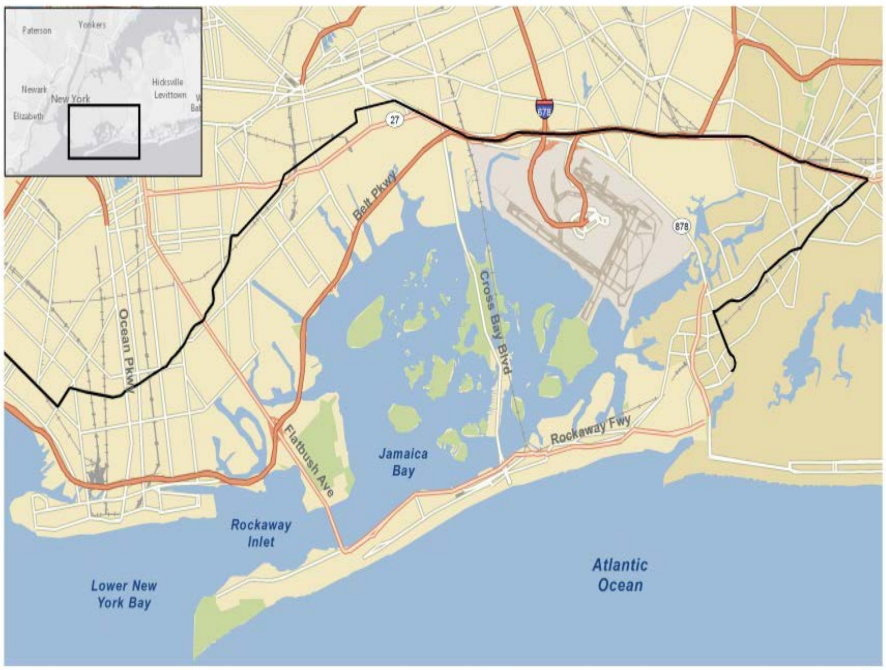


**Figure 1: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay Study Area**

During Hurricane Sandy, tidal waters and waves directly impacted the Atlantic Ocean shoreline. Tidal waters amassed in Jamaica Bay by entering through Rockaway Inlet and by overtopping and flowing across the Rockaway Peninsula. Effective coastal storm risk management for communities within the study area requires reductions in risk from two sources of coastal storm damages: inundation, wave attack with overtopping along the Atlantic Ocean shorefront of the Rockaway peninsula and flood waters amassing within Jamaica Bay via the Rockaway Inlet.

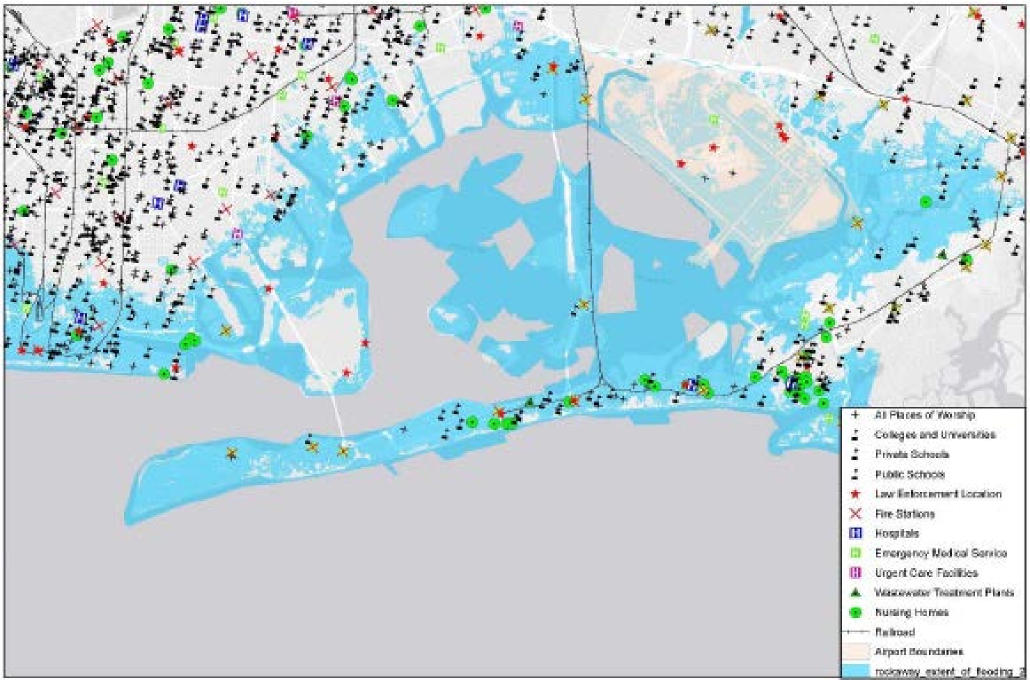


**Figure 2: Critical Infrastructure**

## Study Area Problems

The study area was one of the areas most devastated by Hurricane Sandy. Within the study area, 10 fatalities and damage to 1,000 structures were attributed to Hurricane Sandy. The New York City Department of Buildings post-Sandy damage assessment indicates the disproportionate vulnerability of the study area to storm surge damage. Of all buildings city-wide that were identified as unsafe or structurally damaged, 37% were located in the southern Queens portion of the study area, which is far greater than the percentage of all buildings in the Hurricane Sandy inundation zone that are located in southern Queens portion of the study area (24%). In addition to the structural impacts caused by waves and inundation, fires ignited by the storm surge inundation of electrical systems destroyed 175 homes at the Rockaway Peninsula portion of the study area.

Hurricane Sandy hit the study area at almost exactly high tide. Waves eroded beaches, breached boardwalks and seawalls, and broke against buildings in the oceanfront communities. Storm surge inundation reached as much as 10 feet above ground in some portions of the study area. In addition more than 1.5 million cubic yards of sand was torn from Rockaway Beach and deposited on oceanfront communities or washed out to sea.

Floodwaters funneled through Rockaway Inlet amassing a storm surge that inundated all the neighborhoods surrounding Jamaica Bay. The low-lying neighborhoods in the central and northern portions of the Bay, where the narrow creeks and basins provide the marine aesthetic of the neighborhood, were especially devastated by flood waters. Damage to the elevated portion of the subway system in Jamaica Bay and Rockaway (A line) disrupted service for months affecting about 35,000 riders daily. In the southern Queens portion of the study area 37 schools were closed for up to two months.

**Study Area Opportunities**

For many years prior to Hurricane Sandy, study area CSRM efforts have emphasized Atlantic shoreline features with the State of New York as the local sponsor. Awareness of the need for an integrated approach to CSRM opportunities in Jamaica Bay and surrounding communities has increased since Hurricane Sandy impacted the area in 2012. As a result of the devastation associated with Hurricane Sandy, the USACE has been tasked to address “coastal resiliency” and “long-term sustainability” in addition to the traditional USACE planning report categories of “economics, risk, and environmental compliance” (USACE 2013) The goal of the Draft HSGRR/EIS is to identify solutions that will reduce Atlantic shoreline and Jamaica Bay vulnerability to storm damage over time, in a way that is sustainable over the long-term, both for the natural coastal ecosystem and for communities.

**Study Objectives**

Five principal planning objectives have been identified for the study, based upon a collaborative planning approach. These planning objectives are intended to be achieved throughout the study period, which is from 2020 – 2070:

1. Reduce vulnerability to storm surge impacts;
2. Reduce future flood risk in ways that will support the long-term sustainability of the coastal ecosystem and communities;
3. Reduce the economic costs and risks associated with large-scale flood and storm events;
4. Improve community resiliency, including infrastructure and service recovery from storm effects; and
5. Enhance natural storm surge buffers, also known as natural and nature-based features (NNBFs), and improve coastal resilience.

**Alternative Plan Development**

Structural and non-structural management measures, including NNBFs, were developed to address one or more of the planning objectives. Management measures were developed in consultation with the non-federal sponsor (NYSDEC), state and local agencies, and non-governmental entities. Measures were evaluated for compatibility with local conditions and relative effectiveness in meeting planning objectives.

Effective measures were combined to create CSRM alternatives for two distinct planning reaches: the Atlantic Ocean shorefront and Jamaica Bay. Integrating CSRM alternatives for the two reaches provides the most economically efficient system-wide solution for the vulnerable communities within the study area. It is important to note that any comprehensive approach to CSRM in the study area must include an Atlantic Ocean shorefront component because overtopping of the Rockaway peninsula is a source of flood waters into Jamaica Bay. Efficient

CSRM solutions were formulated specifically to address conditions at the Atlantic Ocean Shorefront Planning Reach. The best solution for the Atlantic Ocean Shorefront Planning Reach was included as a component of the alternative plans for the Jamaica Bay Planning Reach.

The Atlantic Ocean Shorefront Planning Reach is subject to wave attack, wave run up, and over topping along the Rockaway peninsula. The general approach to developing CSRM along this reach was to evaluate features that optimize life-cycle costs in combination with a single beach restoration plan to select the most cost effective renourishment approach prior to the evaluation of alternatives for coastal storm risk management. The most cost effective alternative is beach restoration with increased renourishment (Figure 3). This alternative had the lowest annualized costs over the 50-year project life and the lowest renourishment costs over the project life. Renourishment costs are identified in Table 3: Alternative Plan Annual Costs. Renourishment also provides recreation benefits to beach users, which are included in the evaluation of CSRM alternatives and identified in Table 4: Alternative Plan Annual Benefits.


**Figure 3: Beach Restoration with Increased Renourishment**

A screening analysis was performed to evaluate the level of CSRM provided by a range of dune and berm dimensions and by reinforced dunes, which would be combined with features that optimize life-cycle costs to provide the most efficient and effective CSRM at the Atlantic Ocean shorefront. Other factors such as prior projects at Rockaway Beach, project constraints, stakeholder concerns, and engineering judgment were also applied in the evaluation and selection. A composite seawall was selected as the best coastal storm risk management alternative. The composite seawall protects against erosion and wave attack and also limits storm surge inundation and cross-peninsula flooding (Figures 4 and 5). The structure crest elevation is +17 feet (NAVD88), the dune elevation is +18 feet (NAVD88), and the design berm width is 60 feet. The armor stone in horizontally composite structures significantly reduces wave breaking pressure, which allows smaller steel sheet pile walls to be used in the design if the face of the wall is completely protected by armor stone. The composite seawall may be adapted in the future to rising sea levels by adding 1-layer of armor stone and extending the concrete cap up to the elevation of the armor stone.

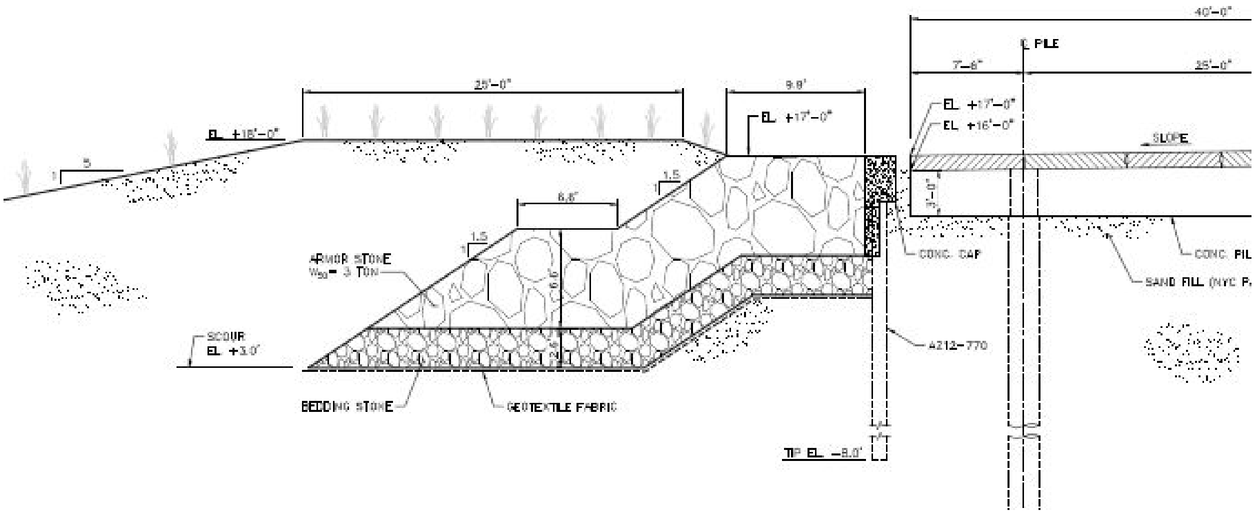


**Figure 4: Composite Seawall Beach 19th St. to Beach 126th St.**

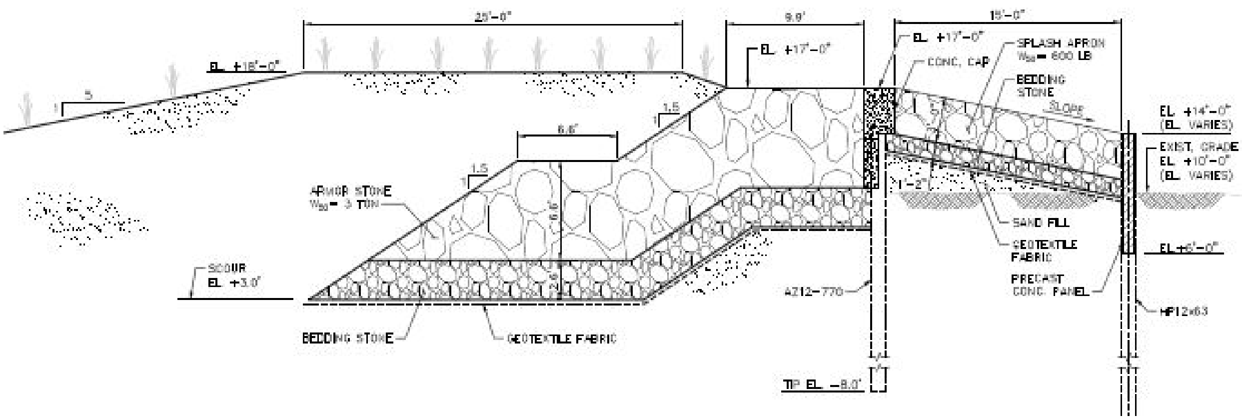


**Figure 5: Composite Seawall Beach 126th St. to Beach 149th St.**

**Jamaica Bay Planning Reach**

The communities surrounding and within Jamaica Bay are subject to storm surges that amass in Jamaica Bay by entering through Rockaway Inlet and by overtopping and flowing across the Rockaway Peninsula (the Atlantic Ocean Shorefront Planning Reach). Preliminary screening of alternative plans for the Jamaica Bay Planning Reach resulted in a final array of two alternatives: a Jamaica Bay Perimeter Plan and a Storm Surge Barrier Plan. Design details for the final array of alternative plans were refined prior to alternative plan evaluation to address key uncertainties identified during the preliminary screening process. Key uncertainties that were addressed to facilitate alternative plan evaluation include:

- Potential Storm Surge Barrier impacts to tidal exchange within Jamaica Bay;
- Real estate requirements and impacts to utilities;

- In-water construction costs;
- Operations and Maintenance costs;
- Impacts to submerged utilities; and
- Mitigation costs.

The Jamaica Bay Perimeter Plan includes CSRM at the Atlantic Ocean Shorefront Planning Reach and creates a nearly 44-mile contiguous barrier along the Jamaica Bay interior, with the exception of JFK Airport (JFK Airport already has infrastructure providing coastal storm risk management). The community at Broad Channel, which is effectively within Jamaica Bay - as opposed to being a community on the fringe of Jamaica Bay- would not benefit from the Perimeter Plan (Figure 6).


**Figure 6: Jamaica Bay Perimeter Plan**

The Jamaica Bay Perimeter Plan (Plan D) would require 13 tributary flood gates (Sheepshead Bay, Gerritsen Inlet, Mill Basin, Paerdegat Basin, Fresh Creek, Hendrix Basin, Spring Creek, Shellbank Creek, Hawtree Basin, Head-of-Bay, Negro Bar Channel, Norton Basin and Barbados Basin) and five roadway flood gates across Rockaway Parkway at Canarsie Pier, Pennsylvania Avenue, Hendrix Street, Fountain Avenue, and the Edgemere landfill service road. Additionally a railroad floodgate would be required at 104$^{th}$ Street for the Long Island Railroad.

The Storm Surge Barrier Plan (Plan C) would require a hurricane barrier across Rockaway Inlet and includes CSRM at the Atlantic Ocean Shorefront Planning Reach. Three alternative alignments of the Storm Surge Barrier Plan (C-1, C-2, and C-3) were assessed. The C-3 alignment was screened out from the more detailed analysis based on relatively higher construction costs and O&M costs due to its longer in-water footprint, while providing the same level of benefits as alignments C-1 and C-2. In addition, alignment C-3 required a complicated tie-in to Breezy Point. Each alternative alignment advanced for more detailed analysis (Figure 7) includes CSRM at the Atlantic Ocean Shorefront Planning Reach. CSRM at the Atlantic Ocean Shorefront Planning Reach is required for full functionality of the Storm Surge Barrier Plan.

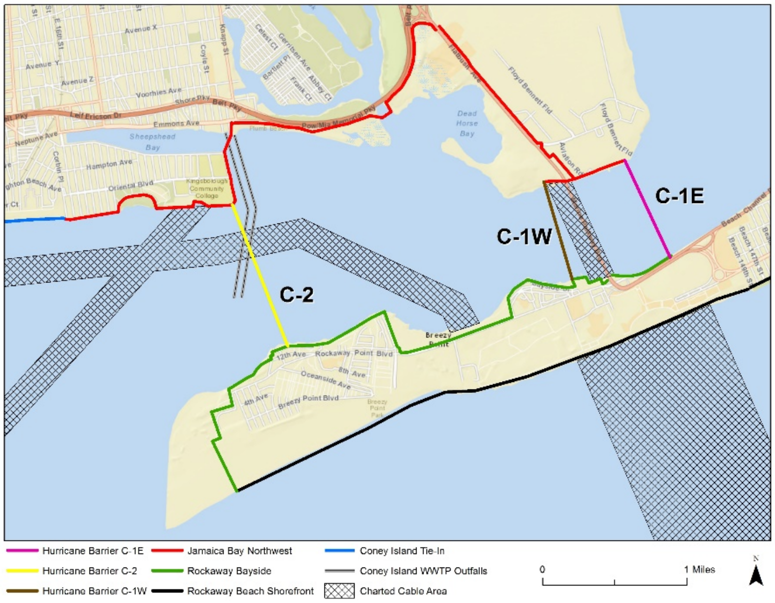


**Figure 7: Storm Surge Barrier Plan**

Alignment C-2 and two alternative alignments for C-1 (C-1E and C-1W) were evaluated for impacts to tidal amplitude and velocities in Jamaica Bay for various tide gate configurations and Storm Surge Barrier alignments. Alignment C-1E with 1,100 linear feet of gate opening and alignment C-2 with 1,700 linear feet of gate opening were identified as having the least hydrodynamic impacts to the bay. Both alignments resulted in a change in tidal amplitude of less than 0.2 feet for a range of tide conditions. Limited changes to the water column indicate that the natural environment driven by water circulation would be undisturbed and water chemistry would be consistent with and without a Strom Surge Barrier. In addition, flow speeds and directions for both alignments are similar to without-project conditions, which imply that circulation within Jamaica Bay would be minimally impacted. Additional water quality investigations concerning Storm Surge Barrier alignment and design will be performed prior to the Final Draft of the HSGRR/EIS.

Prior to the comparison of the Jamaica Bay Perimeter Plan to the Storm Surge Barrier Plan it was determined that alignment C-1E would be preferred over alignment C-1W. Advantages of Storm Surge Barrier alignment C-1E over alignment C-1W include the likelihood that C-1E would:

- result in less scour at the Gil Hodges Memorial Bridge;
- result in less real estate and aesthetic impacts to the Roxbury Community where alignment C-1W would tie in;
- be located in a more stable channel location; and
- avoid potential impacts to submerged cables.

However, additional analyses, public outreach, and agency coordination will be required to finalize the Storm Surge Barrier alignment.

During the plan selection process, the Jamaica Bay Perimeter Plan (Plan D) and the Storm Surge Barrier (Plan C: alignments C-1E and C-2) were evaluated for habitat impacts, real estate impacts, costs (construction, mitigation, real estate, and O&M), and net benefits. Note that CSRM at the Atlantic Ocean Shorefront Planning Reach is a component of both Plan C and Plan D and the impacts, costs, and benefits of CSRM at the Atlantic Ocean Shorefront Planning Reach are included in the evaluations of Plans C and D.

**Alternative Plan Evaluation: Environmental Impacts and Mitigation**

Evaluation for Planned Wetlands (EPW) was paired with a Benthic Index of Biological Integrity (B-IBI) to evaluate ecological impacts and mitigation requirements for structural alternatives. The combined EPW and B-IBI provides a means to comprehensively evaluate the loss of ecological functions and services across a wide range of habitats, which may not have equal value or provide equivalent levels of service to the Jamaica Bay ecosystem.

**Table 1: Alternative Plan Habitat Impacts and Mitigation**

| | Plan C-1E | Plan C-2 | Plan D |
|---|---|---|---|
| Temporary Impact (acres) | 128.9 | 86.2 | 249.1 |
| Permanent Impact (acres) | 129.7 | 62.2 | 247 |
| Mitigation Cost | $90,833,000 | $75,783,000 | $123,383,000 |

Mitigation projects for the alternative plans are sourced from high priority restoration projects identified in the Hudson Raritan Estuary Comprehensive Restoration Program (HRECRP). Construction of the Dead Horse Bay and Duck Point HRECRP projects satisfy the mitigation requirements for Storm Surge Barrier alignment C-2. The mitigation requirements for Storm Surge Barrier alignment C-1E are satisfied by a combination of constructing the Floyd Bennett Field Wetlands Habitat Creation project and the Elders Island project. The combination of the Dead Horse Bay project and the Floyd Bennett Field Wetlands Habitat Creation project satisfies the mitigation requirements for the Jamaica Bay Perimeter Plan. Future modeling can facilitate refinement of these mitigation costs at a later date, but future refinement will not have an impact on plan selection.

**Alternative Plan Evaluation: Costs and Benefits**

Real estate impacts of the alternative plans were assessed in GIS software by overlaying the completed structure footprints and associated right of way easements necessary for structure maintenance on the building footprints, tax lots, and public right-of-way. Those structures and easements intersecting private buildings are assumed to require the purchase of the building and the entirety of the associated tax lot. Those structures and easement intersecting tax lots, but not intersecting any structure on the tax lot, are assumed to require the purchase of only that portion of the parcel necessary for the footprint of the structure. Construction and maintenance right of way easements are assumed to be obtained for those areas intersecting the structure easement, but no land acquisition is assumed to be required.

The value of impacted real estate is based on the 2016 assessment values identified in the New York City tax maps. If an alternative structure feature footprint intersects a building on a private tax lot, real estate costs are the entire tax lot, including the building. If an alternative structure feature footprint intersects a private tax lot, but no buildings are affected, real estate costs are that portion of the tax lot intersected by the structure footprint as calculated as a percentage of the 2016 market value.

Alternative plan construction cost estimates were developed at the Class 4 level of detail according to Engineering Record 1110-2-1302 (USACE 2008). The primary characteristic of a Class 4 estimate is that the level of project definition is between 1 and 15 percent. Class 4 estimates utilize a methodology that is primarily stochastic, i.e. unit rates are based on the probability distribution of historical rates. Estimating at a Class 4 level of detail is appropriate for concept and alternative selection studies. The construction cost for each alternative plan is based on the types of structures and associated quantities (or linear distances). Additionally, construction costs for the Storm Surge Barrier alignment C-1E vary based on alternative tie-in locations. Tables 2 and 3 present the highest cost scenario for Storm Surge Barrier alignment C-1E; however, alternative tie-in locations can reduce annual equivalent costs to a range of $74 million to $120 million. Storm Surge Barrier alignment C-2 does not have alternative tie-in locations.

**Table 2: Construction, Mitigation, and Real Estate Costs**

| | Alternative C-1E | Alternative C-2 | Alternative D |
|---|---:|---:|---:|
| Construction | $3,328,135,000 | $3,361,337,000 | $4,467,352,000 |
| Mitigation | $90,833,000 | $75,783,000 | $123,383,000 |
| Real Estate | $29,436,000 | $17,386,000 | $179,955,000 |
| First Cost Total | $3,448,404,000 | $3,454,506,000 | $4,770,690,000 |
| IDC | $333,029,000 | $336,274,000 | $424,262,000 |
| Total Construction Cost | $3,781,433,000 | $3,790,780,000 | $5,194,952,000 |

**Table 3: Annual Costs**

| | Alternative C-1E | Alternative C-2 | Alternative D |
|---|---:|---:|---:|
| Construction | $150,474,000 | $150,846,000 | $206,722,000 |
| Renourishment | $5,740,000 | $5,740,000 | $5,740,000 |
| OMRR&R | $7,424,000 | $7,124,000 | $14,954,000 |
| Total AAEQ | $163,638,000 | $163,710,000 | $227,416,000 |

Operation and Maintenance (O&M) costs include maintenance for passive CSRM structures such as floodwalls and levees and for active CSRM structures such as floodgates and roadway gates. Maintenance activities for each CSRM structure were scheduled with weekly, bi-weekly, monthly, quarterly, annual, 5-year, or 15-year occurrence. Order-of-magnitude O&M costs are based in information from the South Shore of Staten Island, New York Feasibility Study, a reconnaissance level study for the Mississippi Storm Surge Barrier, and information for the Stamford Hurricane Protection Barrier located in Stamford, Connecticut. Average annual equivalent values (AAEQ) were calculated using the FY16 federal discount rate of 3.125% and a 50-year time period.

There are three components to the NED benefits provided by the alternative plans: bayside coastal storm risk reduction, shorefront coastal storm risk reduction, and improved recreation (Table 4). Bayside coastal storm risk reduction is based on reductions in the economic costs and risks associated with property inundation during storm and flood events. Shorefront coastal storm risk reduction includes reductions in the economic costs and risks associated with wave attack on shorefront properties. Recreation benefits are based on improved recreation opportunities at Rockaway Beach, which result in an increased value per visit and in an increase in total visits. Note that both Storm Surge Barrier alignments (C-1E and C-2) provide the same amount of economic benefits. The Jamaica Bay Perimeter Plan (Alternative D) provides fewer benefits because the Perimeter Plan provides no coastal storm risk management at Broad Channel.

**Table 4: Alternative Plan Benefits (AAEQ)**

| | Alternative C-1E | Alternative C-2 | Alternative D |
|---|---|---|---|
| Inundation Bayside Damage Reduction | $444,218,000 | $444,218,000 | $432,567,000 |
| Atlantic Shorefront Damage Reduction | $32,017,000 | $32,017,000 | $32,017,000 |
| Total Damages Avoided | $476,235,000 | $476,235,000 | $464,584,000 |
| Atlantic Shorefront Recreation | $32,998,000 | $32,998,000 | $32,998,000 |
| Total Benefits | $509,233,000 | $509,233,000 | $497,582,000 |

**Alternative Plan Comparison**

The Storm Surge Barrier Plan, regardless of alignment, provides substantially more net economic benefits, has less of an environmental impact, and has less of a real estate impact than the Jamaica Bay Perimeter Plan. In addition, the Storm Surge Barrier includes residual risk reduction opportunities that are not available for the Perimeter Plan. Therefore the TSP is selected from among the alternative Storm Surge Barrier alignments. Storm Surge Barrier alignment C-1E may be constructed with alternative tie-in locations (alignments BZ, 149, FB, and 149 & FB listed in Table 5 and shown in Figures 5-10 through 5-13 in the Main Report), which provide flexibility for the final design. Additionally Storm Surge Barrier C-1E has less construction and cost uncertainty than alignment C-2, because alignment C-1E avoids submerged cables and pipelines, which increase uncertainty for alignment C-2. Therefore, Storm Surge Barrier C-1E, which includes CSRM at the Atlantic Ocean Shorefront Planning Reach, is currently the TSP.

**Table 5: Alternative Plan Comparison – AAEQ Costs and Benefits ($000's)**

| | Storm Surge Barrier Plan Alternative Alignments | | | | | | |
|---|---|---|---|---|---|---|---|
| | C-1E | C-1E BZ | C-1E 149 | C-1E FB | C-1E 149&FB | C-2 | Interior Plan D |
| Costs | $163,638 | $153,549 | $114,715 | $113,759 | $94,882 | $163,710 | $227,416 |
| Benefits | $509,233 | $509,233 | $500,884 | $426,107 | $417,757 | $509,233 | $497,582 |
| Net Benefits | $345,595 | $355,684 | $386,169 | $312,348 | $322,875 | $345,523 | $270,166 |
| BCR | 3.1 | 3.3 | 4.4 | 3.7 | 4.4 | 3.1 | 2.2 |

**Plan Recommendation**

Based on the planning objectives and USACE policy, the Storm Surge Barrier alignment C-1E is the TSP and is likely to be considered the Recommended Plan (Figure 8), as listed above. Analyses performed to identify and assess coastal storm risk management alternatives for the East Rockaway Inlet to Rockaway Inlet and Jamaica Bay study area support the recommendation for comprehensive storm risk management. This does not preclude a decision to refine or alter the TSP at the Agency Decision Milestone (ADM) based on responses from public, policy, and technical reviews of this Draft HGRR/EIS, specifically for the alignment of the Storm Surge Barrier and residual risk features. A final decision will be made at the ADM following the reviews and higher-level coordination within USACE to select a plan for feasibility-level design and recommendation for implementation. Coordination with the natural resource agencies will continue throughout the study process as required by the Fish and Wildlife Coordination Act.


**Figure 8: Recommended Plan**

Analyses conducted to date support the recommendation for a composite seawall and associated beach restoration with increased renourishment at the Atlantic Ocean shorefront along the Rockaway peninsula (shown in black in Figure 8). The structure crest elevation is +17 feet (NAVD88), the dune elevation is +18 feet (NAVD88), and the design berm width is 60 feet.

Multiple Storm Surge Barrier alignments and tie-in scenarios are available for the recommended Storm Surge Barrier Plan. Final design and selection of the Storm Surge Barrier alignment and associated tie-ins are deferred until additional analyses and design refinements can be conducted. Final Storm Surge Barrier design will be made in the future based on responses from public, policy, and technical reviews of this Draft HSGRR/EIS and additional investigations conducted for that purpose.

**Residual Risks**

Construction of composite seawall along the Atlantic Ocean shorefront in advance of construction of the remainder of the Storm Surge Barrier Plan would provide CSRM to vulnerable communities along the Rockaway peninsula. The recommended composite seawall is adaptable to alternative sea level change scenarios and can be modified in the future to maintain effectiveness as sea levels rise. Solutions to residual risk during design and construction of the Storm Surge Barrier and for those communities vulnerable to high frequency events (during which the Storm Surge Barrier gates would be open), such as Edgemere, Mott Basin, and others have been proposed and will be refined in future phases. The final costs of the TSP include conceptual costs for twenty six residual risk measures, and five have been designed at this time. Further detail is provided in Appendix A-2.

**Major Findings and Conclusions**

Thorough coordination and collaboration was conducted with Federal, State and local agencies, non-governmental organizations and interested stakeholders throughout the study process and public meetings. The recommendations contained herein reflect the information available at this time. This report presents an overview of CSRM problems and opportunities in the Jamaica Bay Region, evaluated and selected CSRM measures along the Atlantic Ocean shoreline on the Rockaway peninsula and evaluated and selected a coastal flooding measure for interior communities within Jamaica Bay. This approach consolidates the extensive Atlantic Ocean shorefront analyses conducted prior to Hurricane Sandy with post-Sandy analyses into a single Draft HSGRR/EIS. Based on based on responses from public, policy, and technical reviews of this Draft HSGRR/EIS, USACE may consider a phased decision process. Phased decision making may allow USACE to move forward with implementation of the component measures that can be decided first, while making progress toward the overall goals incrementally, acknowledging that the full benefits wouldn’t be realized until all components are complete.

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# GLOSSARY OF TERMS, ACRONYMS, AND ABBREVIATIONS

| | |
|---|---|
| APE | Area of Potential Effects |
| ASTM | American Society for Tests and Materials |
| BiOp | Biological Opinion |
| BMPs | Best Management Practices |
| BSNP | Bank Stabilization and Navigation Project |
| CEQ | Council on Environmental Quality |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| cfs | Cubic feet per second |
| Corps | United States Army Corps of Engineers |
| CRP | Construction Reference Plane |
| DPR | Detailed Project Report |
| DPR/EIS | Detailed Project Report/Environmental Impact Statement |
| EM | Engineering Manual |
| EO | Executive Order |
| EPA | United States Environmental Protection Agency |
| ER | Engineering Regulation |
| FEIS | Final Environmental Impact Statement |
| FEMA | Federal Emergency Management Agency |
| FR | Feasibility Report |
| FWCA | Fish and Wildlife Coordination Act |
| GIS | Geographic Information System |
| HTRW | Hazardous, Toxic, And Radiological Wastes |
| msl | Elevation above mean sea level |
| NED | National Economic Development |
| NEPA | National Environmental Policy Act |
| NHP | Natural Heritage Program |
| NPL | National Priority List |
| NRCS | Natural Resource Conservation Service |
| O&M | Operations And Maintenance |
| P&G | Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies |
| PMP | Project Management Plan |
| RC&D | Resource Conservation & Development |
| RM | River Mile |
| SWH | Shallow Water Habitat |
| USACE | United States Army Corps of Engineers |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish And Wildlife Service |
| USGS | United States Geological Survey |
| WMA | Wildlife Management Area |
| WRDA | Water Resources Development Act |
| WSEL | Water Surface Elevation |

# Plan Formulation Appendix: East Rockaway Inlet to Rockaway Inlet and Jamaica Bay Reformulation Study

## Hurricane Sandy General Reevaluation Report and Draft Environmental Impact Statement

# 1 INTRODUCTION

The purpose of the East Rockaway Inlet to Rockaway Inlet and Jamaica Bay Reformulation Study is to reevaluate the project that was authorized in 1974, which had last been modified in 2010, and recommend opportunities to implement cost-effective measures of managing coastal storm damage risk within the study area. The Water Resources Development Act (WRDA) of 1974 provided for the separate construction of beach erosion control on the Rockaway Peninsula, independent of construction of a Storm Surge Barrier across Rockaway Inlet. The authorized but never constructed hurricane protection portion of the original project was subsequently de-authorized by WRDA of 1986. WRDA of 1986 also authorized beach re-nourishment on the Rockaway Peninsula at periodic intervals through 2004. Maintenance material from East Rockaway Inlet is periodically placed on the Rockaway Peninsula, with the most recent placement for the purpose of erosion control occurring in 2010.

This reformulation study utilizes a comprehensive system approach that includes both the shorefront and back-bay area of the Rockaway Peninsula and Jamaica Bay. The analyses are presented in a single Hurricane Sandy General Reevaluation Report and Environmental Impact Statement. This Plan Formulation Appendix presents the plan formulation investigations and results in support of the Tentatively Selected Plan Milestone.

## 1.1 Study Authority

The multiple purpose (coastal erosion control and coastal flooding protection) project for East Rockaway Inlet to Rockaway Inlet and Jamaica Bay, New York was authorized by the Flood Control Act of 1965 (Public Law 89-298), in accordance with the recommendations of the Chief of Engineers in House Document No. 215, 89th Congress, 1st Session. The project, as originally authorized, provided for a Storm Surge Barrier across the entrance to Jamaica Bay with a permanent navigation opening, gates on each side of the opening, dikes, levees and floodwalls, fill placement along oceanfront floodwall; and stoplog structures, stairways, ramps, road raising, and other appurtenant works, including fishing platforms on the hurricane barrier.

This project authority was modified by Section 72 of the Water Resources Development Act of 1974 (Public Law 93-251) (88 Stat. 30) to provide for the separate construction of the beach erosion control portion of the project, independent of the hurricane protection portion. The hurricane protection portion of the originally authorized project was authorized but unconstructed and subsequently de-authorized by the Water Resources Development Act of 1986.

The Reformulation Study for East Rockaway Inlet to Rockaway Inlet and Jamaica Bay was authorized by the House of Representatives, dated 27 September 1997, as stated within the Congressional Record for the US House of Representatives. It states, in part:

> *"With the funds provided for the East Rockaway Inlet to Rockaway Inlet and Jamaica Bay, New York project, the conferees direct the Corps of Engineers to initiate a reevaluation report to identify more cost-effective measures of providing storm damage protection for the project. In conducting the reevaluation, the Corps should include consideration of using dredged material from maintenance dredging of East Rockaway Inlet and should also investigate the potential for ecosystem restoration within the project area."*

Public Law 113-2 (29Jan13), The Disaster Relief Appropriations Act of 2013 (the Act), was enacted in part to "improve and streamline disaster assistance for Hurricane Sandy, and for other purposes". The Act directed the Corps of Engineers to:

> "…reduce future flood risk in ways that will support the long-term sustainability of the coastal ecosystem and communities and reduce the economic costs and risks associated with large-scale flood and storm events in areas along the Atlantic Coast within the boundaries of the North Atlantic Division of the Corps that were affected by Hurricane Sandy" (PL 113-2).

In partial fulfillment of the requirements detailed within the Act, the Corps produced a report assessing "authorized Corps projects for reducing flooding and storm risks in the affected area that have been constructed or are under construction". The East Rockaway Inlet to Rockaway Inlet, NY project met the definition in the Act as a constructed project. In accordance with the Act, the Corps is proceeding with this Reformulation Study to address resiliency, efficiency, risks, environmental compliance, and long-term sustainability within the study area (USACE, 2013a).

## 1.2 Stage of the Planning Process

This Plan Formulation Appendix supports the Tentatively Selected Plan Milestone. Preliminary plan formulation for the Atlantic shoreline and Jamaica Bay portions of the study area were conducted independently due to the very different geographic settings of the Rockaway Peninsula and Jamaica Bay. As alternative plans were developed, discrete CSRM units were developed to address the local characteristics of different portions of the study area. These

CSRM units have been combined to form alternative plans. Sone CSRM units are common to each of the final alternative plans.

In terms of the SMART Feasibility Study Process, the Reformulation Study is currently in the Alternative Formulation and Analysis Phase (Figure 1-1). The Tentatively Selected Plan Milestone was held in March 2016 (Table 6).


**Figure 1-1: SMART Feasibility Study Process**

**Table 6: Study Schedule**

| Date | Milestone |
|---|---|
| Dec 14 | Project Start |
| Oct 14 | Alternatives Milestone |
| Mar 16 | **Tentatively Selected Plan Milestone** |
| May 16 | Draft GRR and EIS |
| Nov 16 | Agency Decision Milestone |
| May 17 | *Final GRR* |
| Sep 17 | Civil Works Review Board |
| Jan 18 | Chief's Report Submittal |

## 1.3 Problem Description/Purpose and Need for USACE Action

To date, study area coastal storm risk management (CSRM) efforts have emphasized Atlantic shoreline features with the State of New York as the local sponsor. Awareness of the need for an integrated approach to CSRM opportunities in Jamaica Bay and surrounding communities has increased since Hurricane Sandy impacted the area in 2012. As a result of the devastation associated with Hurricane Sandy, the USACE has been tasked to address “coastal resiliency” and “long-term sustainability” in addition to the traditional USACE planning report categories of “economics, risk, and environmental compliance (USACE, 2013a).” The goal of the Reformulation Study is to identify solutions that will reduce Atlantic shoreline and Jamaica Bay vulnerability to storm damage over time, in a way that is sustainable over the long-term, both for the natural coastal ecosystem and for communities.

The relationships and interactions among the natural and built features (e.g., floodwalls, flood gates, etc.) comprising a coastal risk reduction system are important variables determining coastal vulnerability, reliability, risk, and resilience (USACE, 2013b). Improving resilience, which is a key factor in reducing risk, includes improving the ability to anticipate, prepare for, respond to, and adapt to changing conditions and to recover rapidly from disruptions (USACE, 2013c).

Atlantic shoreline CSRM alternatives include traditional structural and non-structural solutions with an emphasis on reducing vulnerability to wave attack and erosion. Alternatives developed prior to Hurricane Sandy include dune and berm construction with structural features to reduce renourishment volumes and frequencies. Additional features are proposed and analyzed to ensure that the Atlantic shoreline and Jamaica Bay measures provide a cohesive line of protection to the structures at risk in the study areas.

Jamaica Bay CSRM alternatives will include traditional structural and non-structural solutions with an emphasis on incorporating natural and nature-based features (NNBFs) to complement or enhance the functionality of structural measures. Natural Features (NF) are defined as features that are created and/or evolve over time through the actions of physical, biological, geologic, and chemical processes operating in nature. NF in a coastal ecosystem take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, marsh islands, dunes, beaches, wetlands, and maritime forests. Nature-based features (NBF) are defined as those features that may mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as coastal risk reduction. Examples of NBF include constructed wetlands, or a beach and dune system engineered for coastal storm damage reduction. Consistent with the North Atlantic Coast Comprehensive Study (USACE, 2013b), these features are referred to jointly throughout this study. NNBFs are commonly combined to implement the concept of a “living shoreline”.

## 1.4 Location of the Study Area

The study area consists of the Atlantic Coast of New York City between East Rockaway Inlet and Rockaway Inlet, and the water and lands within and surrounding Jamaica Bay, New York. The coastal area, which is approximately 10 miles in length, is a peninsula located entirely within the Borough of Queens, New York City. This peninsula, generally referred to as the

Rockaways, separates the Atlantic Ocean from Jamaica Bay immediately to the north. The greater portion of Jamaica Bay lies in the Boroughs of Brooklyn and Queens, New York City, and a section at the eastern end, known as Head of Bay, lies in Nassau County (Figure 9). More than 48,000 residential and commercial structures in the study area fall within the Federal Emergency Management Agency (FEMA) regulated 100-year floodplain.

Effective CSRM requires that risk management measures reduce flood risk from inundation at Jamaica Bay and the Rockaway peninsula and also reduce flood risk and the effects of wave attack along the Atlantic shorefront of the Rockaway peninsula. Reducing flood risk from inundation at Jamaica Bay cannot be fully effective without also reducing flood risk at the Atlantic shorefront on the Rockaway peninsula because flood waters would be able to inundate low lying areas of the Jamaica Bay side of the Rockaway peninsula, if the Atlantic shorefront risk reduction component were not in place.

### 1.4.1 Rockaway Peninsula

The communities located on the Rockaway peninsula from west to east include Breezy Point, Roxbury, Neponsit, Belle Harbor, Rockaway Park, Seaside, Hammel, Arverne, Edgemere and Far Rockaway. The former Fort Tilden Military Reservation and the Jacob Riis Park (part of the Gateway National Recreation Area) are located in the western half of the peninsula between Breezy Point and Neponsit. The characteristics of nearly all of the communities on the Rockaway peninsula are similar. Ground elevations rarely exceed 10 feet, except within the existing dune field. Elevations along the Jamaica Bay shoreline side of the peninsula generally range from 5 feet, increasing to 10 feet further south toward the Atlantic coast. An estimated 7,900 residential and commercial structures on the peninsula fall within the FEMA regulated 100-year floodplain. .

### 1.4.2 Jamaica Bay

Jamaica Bay is the largest estuarine waterbody in the New York City metropolitan area covering an approximately 20,000 acres (17,200 of open water and 2,700 acres of upland islands and salt marsh). Jamaica Bay measures approximately 10 miles at its widest point east to west and four miles at the widest point north to south, including approximately 26 square miles in total. The mean depth of the bay is approximately 13 feet with maximum depths of 60 feet in the deepest borrow pits. Navigation channels within the bay are authorized to a depth of 20 feet. Jamaica Bay has a typical tidal range of five to six feet. The portions of New York City and Nassau County surrounding the waters of Jamaica Bay are urbanized, densely populated, and very susceptible to flooding. An estimated 41,000 residential and commercial structures within the FEMA regulated 100-year Jamaica Bay floodplain.


**Figure 9: Study Area**

## 1.5 Project Area

The project area includes locations of potential alternative plans proposed by other agencies or the area that may be directly and indirectly impacted by construction or operations, which is typically a smaller footprint than the study area. The Project Area is divided into two distinct planning reaches: the Atlantic Ocean Shorefront Planning reach (Section 1.5.1) and the Jamaica Bay Planning Reach (Section 1.5.2). It is important to note that any comprehensive approach to CSRM in the study area must include an Atlantic Ocean shorefront component because overtopping of the Rockaway peninsula is a source of flood waters into Jamaica Bay. Efficient CSRM solutions were formulated specifically to address conditions at the Atlantic Ocean Shorefront Planning Reach. The best solution for the Atlantic Ocean Shorefront Planning Reach was included as a component of the alternative plans for the Jamaica Bay Planning Reach.

The Atlantic Ocean Shorefront Planning Reach is subject to wave attack, wave run up, and over topping along the Rockaway peninsula. The communities within the Jamaica Bay Planning Reach are subject to storm surges that amass in Jamaica Bay by entering through Rockaway Inlet and by overtopping and flowing across the Rockaway Peninsula (the Atlantic Ocean Shorefront Planning Reach).

### 1.5.1 Atlantic Ocean Shorefront Planning Reach

The Atlantic Ocean Shorefront Planning Reach along the Rockaway Peninsula is subdivided into six reaches for the purpose of this analysis. Each reach is developed based upon site-specific physical, economic, and institutional differences. Considerations include hydrodynamic differences, coastal features, sediment transport boundaries, shoreline stability, existing projects, and development patterns. Reach designations help characterize the problems, needs, and opportunities and to identify alternatives viable for each reach. Division of the Atlantic Ocean Shorefront Planning Reach into reaches does not imply separable projects or construction areas.

The six Atlantic Ocean Shorefront Planning Reaches (Figure 10) include:

- Reach 1: Rockaway Point to Beach 193$^{rd}$ Street;
- Reach 2: Beach 193$^{rd}$ Street to Beach 149$^{th}$ Street;
- Reach 3: Beach 149$^{th}$ Street to Beach 109$^{th}$ Street;
- Reach 4: Beach 109$^{th}$ Street to Beach 86$^{th}$ Street;
- Reach 5: Beach 86$^{th}$ Street to Beach 42$^{nd}$ Street; and
- Reach 6: Beach 42$^{nd}$ Street to Beach 9$^{th}$ Street.

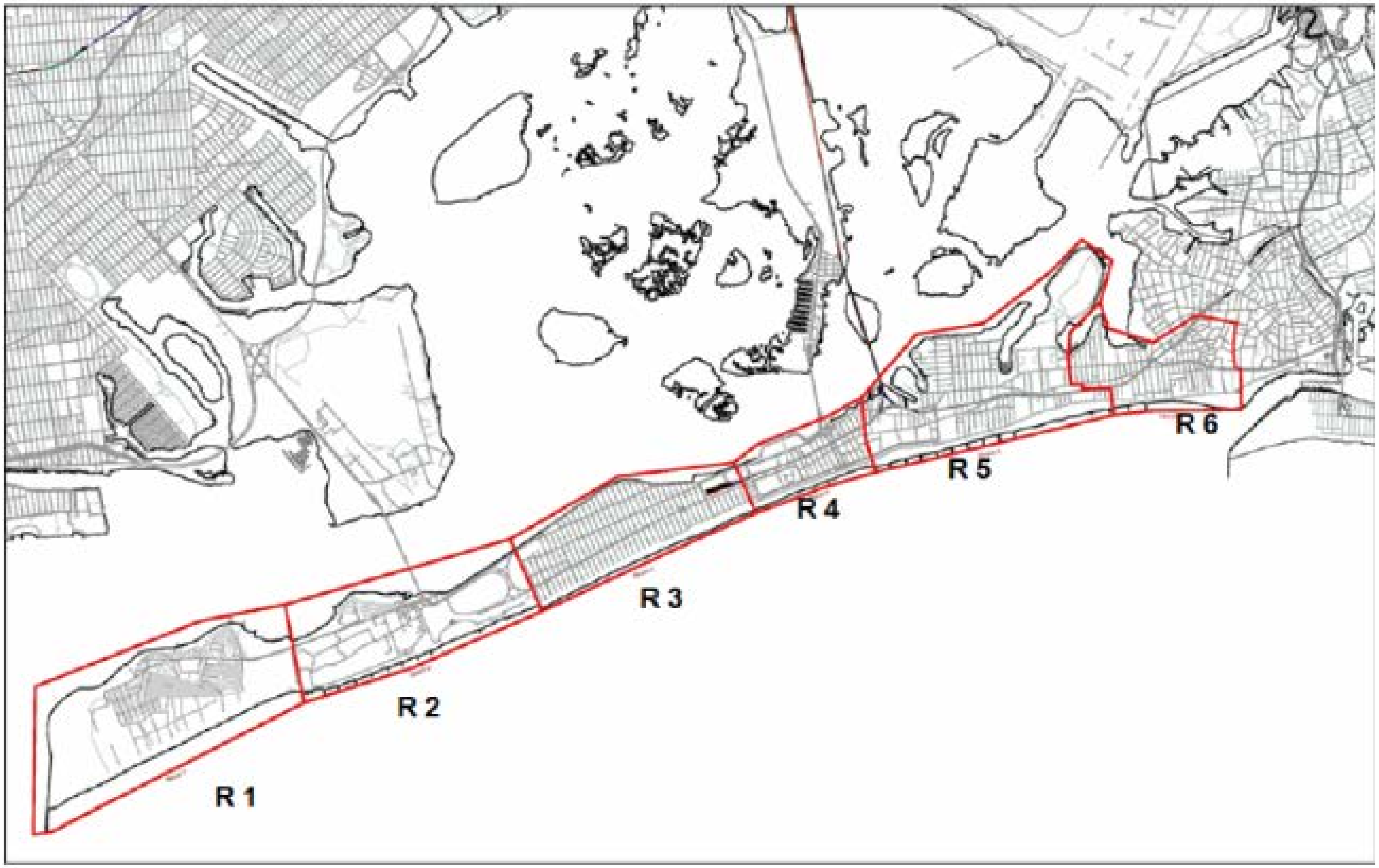


**Figure 10: Atlantic Ocean Shorefront Reaches**

### 1.5.2 Jamaica Bay Planning Reach

In order to develop alternative plans and to evaluate the risk reduction provided by those plans, the Jamaica Bay Planning Reach was configured into six economic reaches that are defined by a common inundation elevation and existing community designations (Figure 11). For the development and preliminary screening of alternatives, each economic reach was defined as an area (*i.e.*, a GIS polygon) which would be inundated at a stillwater elevation of +11 feet (NAVD88). Eleven feet is generally equivalent to the stillwater elevation for a storm event with 1% probability of annual occurrence in 2070 including mid-range sea level rise.

Six reaches sufficiently define the project area because much of the shoreline and adjacent uplands that surround Jamaica Bay are low-elevation permeated with numerous basins, tidal creeks, and inlets, which provide little proximate access to areas of high ground. Configuring the reaches defined by a common inundation elevation resulted in six separable reaches. Individual plans were developed for each of the six reaches. Structures within low-lying areas shoreward of the adjacent uplands were assigned to these distinct reaches so that coastal storm damages may be estimated for each reach.

JFK Airport was not included within any of the economic reaches for which stand-alone alternatives were developed. Federal Aviation Administration regulations preclude the construction of barriers (e.g., floodwalls and levees) on airport property, which renders any alternative to directly protect the airport infeasible on an institutional basis. In addition, the airport is on relatively high ground, and nonstructural solutions may be a more appropriate solution for any flooding problems. Nevertheless, the Port Authority of New York and New Jersey has been and will continue to be consulted throughout the plan formulation process.

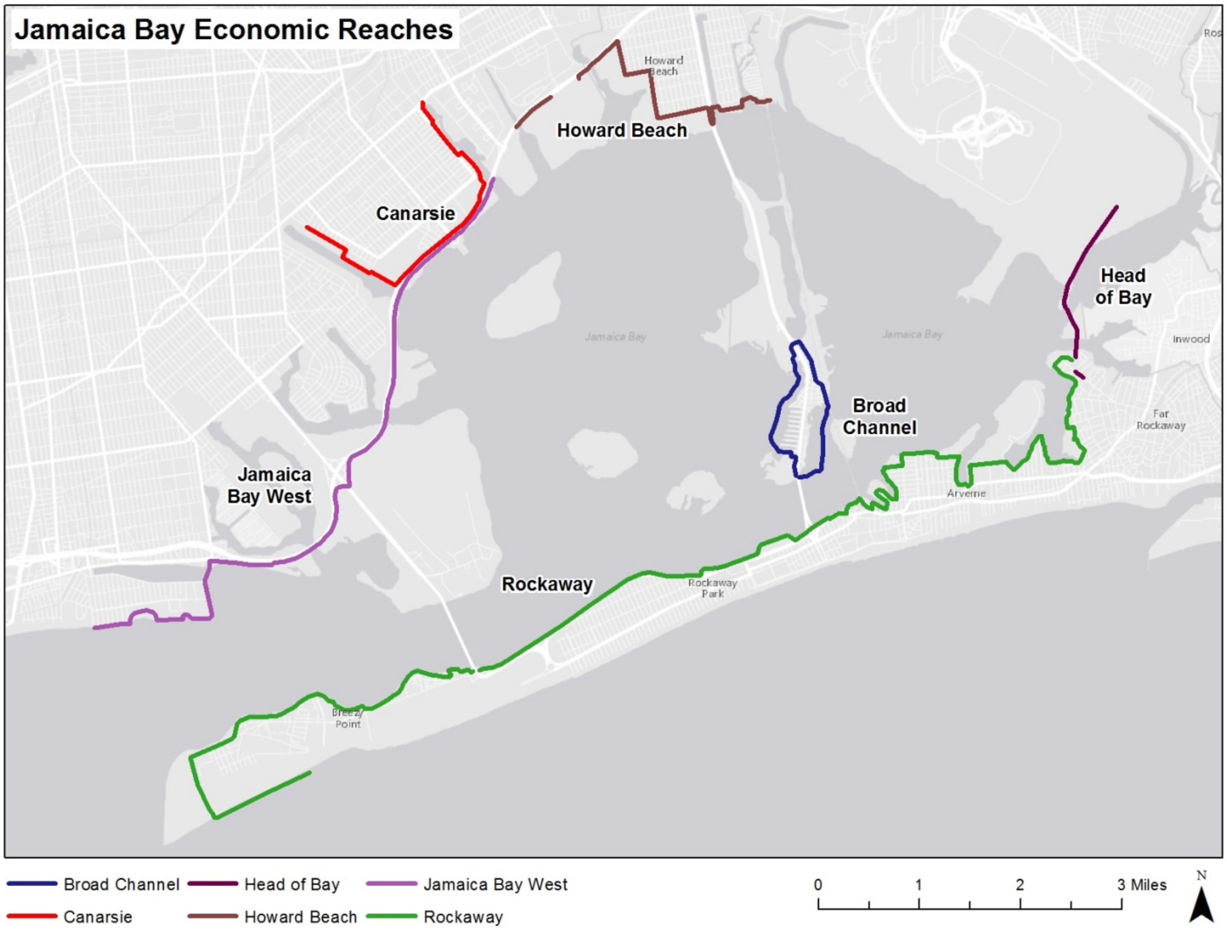


**Figure 11: Economic Reaches – Jamaica Bay**

## 1.6 Project History

Within the House Document 215 (1965), the District Engineer found that the Rockaway Peninsula and low-lying areas surrounding Jamaica Bay, particularly Howard Beach, were subject to frequent and severe damages from tidal inundation (flooding), and that the ocean front between East Rockaway Inlet and Rockaway Inlet was subject to considerable damage from wave attack. Improvement of the shore and provision of flood control works were needed to provide adequate beach erosion control.

The problem in the study area, as identified in 1965, was a combination of shore erosion from wave attack along the Atlantic coast of the Rockaways, and inundation from storm tides from both the ocean and Jamaica Bay. The inundation problem was further complicated by an inadequate storm sewer system in the Rockaways and an incomplete system in the residential areas fronting on the north side of the bay. This resulted in severe hardship to hundreds of families requiring evacuation during times of flood, and extensive property damage. The most severe damages occurred in the Rockaway Peninsula, the Howard Beach area, Broad Channel, and Rosedale sections of Queens.

Section 72 of WRDA of 1974 authorized construction of beach erosion control separately from the construction of hurricane protection. The beach erosion control aspect of the project provided for the restoration of a protective beach along 6.2 miles of Rockaway Beach, between Beach 149th Street on the west at the boundary with Jacob Riis Park and Beach 19th Street on the east at East Rockaway Inlet. The project authorization also provided for federal participation in the cost of periodic beach nourishment to stabilize the restored beach for a period not to exceed 10 years after the completion of the initial beach fill.

The initial nourishment construction was completed from 1975 to 1977. The first phase of the initial construction (1975) consisted of placing 3,669,000 cubic yards of sand between Beach 110th Street and Beach 46th Street. In the second phase of construction (1976), 1,490,000 cubic yards of fill were pumped onto the beach between Beach 46th Street and Beach 19th Street. The third phase of initial construction (1977) had 1,205,000 cubic yards placed between Beach 110th Street and Beach 149th Street.

The storm damage reduction features of the authorized project on the Rockaway Peninsula consisted only of a 100-foot berm width at an elevation of +10 ft NGVD (8.9 feet NAVD88) over the peninsula's entire project length (from Beach 19th Street to Beach 149$^{th}$ Street). The additional width sections of 150 feet and 200 feet of the authorized project provided for separable recreation benefits. The authorized hurricane protection aspect of the project was never constructed, and was de-authorized by WRDA of 1986.

Nourishment operations occurred at two-year intervals during the ten years following the completion of the initial fill, with the last operation being in 1988. A Post Authorization Change recommending a modification to the authorized Beach Erosion Control Project was approved on 8 June 1979. The modification provided for the construction of a 380-foot long quarry stone groin at the western limit of the project in the vicinity of Beach 149$^{th}$ street. The groin design provided for a structure which would hold the project beach fill and allow for maximum bypassing to the downdrift shore. The construction of the groin was completed in September 1982 and included placement of 163,300 cubic yards of beach fill on both sides of the groin.

The project was re-nourished in 1996, 2000, and 2004 under the authority of Section 934 of the Water Resource Development Act (WRDA) of 1986. The project had not been re-nourished since 2004, because Section 934 of WRDA 1986 did not authorized additional re-nourishment after 2004. Maintenance material from the navigation channel at East Rockaway Inlet has been periodically placed on the beach with the last placement occurring in 2010. The authorized re-nourishment and the maintenance material placement were implemented as beach erosion control measures and not as a flood damage reduction project (USACE, 2013d).

## 1.7 Prior Studies, Reports, and Existing Projects

USACE has worked on projects in the study area under multiple Congressional authorizations, including the Flood Control Act of 1965, WRDA of 1974, and section 934 of WRDA of 1986..

### 1.7.1 1965 Authorization

The Beach Erosion Control and Hurricane Protection Project recommended by the State of New York and USACE. The Authorization came from the Flood Control Act of 1965, as prescribed by House Document No. 215, 89th Congress, First Session. The project included a Storm Surge Barrier across the entrance to Jamaica Bay and 4,000,000 cubic yards of beach fill along the ocean front.

### 1.7.2 1974 Authorization

The WRDA of 1974 (Public Law 93-251) authorized the Beach Erosion Control portion of the 1965 Authorization. The Hurricane Protection portion was subsequently deauthorized. The project provided five beach nourishments at two year intervals after the completion of the initial fill. Construction completed in 1977. Severe storms in 1977 and 1978 eroded areas of the beach. A Post Authorization Change recommended a modification to the Beach Erosion Control Project. The authorization for change was approved on 8 June 1979 by the Office of the Chief of Engineers (OCE). The modification prompted the construction of a 380-foot long quarry stone groin at the western limit of the project. The five beach nourishments ended in 1988.

### 1.7.3 Section 934 and Reformulation Study

The State of New York requested a report in 1993 under the authority of Section 934 of WRDA 1986. It resulted in an authorization of three beach nourishments in 1996, 2000, and 2004. The 1993 report also recommended a “reformulation study” to account for the changes to the project in the interest of storm damage reduction. Also, the state wanted to reduce the nourishment costs and determine the whether Federal participation is needed for the project for an additional 50 years. Due to funding limitations, the Reformulation Study started in 2003 when NYSDEC and USACE signed an agreement to cost share the cost.

### 1.7.4 Jamaica Bay Study

A 1990 Study resolution for Jamaica Bay, Marine Park, and Plumb Beach New York resulted in the completion of a Reconnaissance Study by USACE New York District. The study recommended feasibility investigations for storm damage reduction in areas of areas of Arverne, Plumb Beach, Howard Beach and Broad Channel. The storm damage reduction study ended in the reconnaissance phase due to lack of local support at the time. The report also recommended a feasibility study for environmental restoration in Jamaica Bay, which moved forward. Some of the features recommended in the Jamaica Bay Study are considered in this reevaluation study for both coastal storm damage functions and restoration purposes.

## 1.8 Planning Process

The planning process consists of six major steps: (1) Specification of water and related land resources problems and opportunities; (2) Inventory, forecast and analysis of water and related land resources conditions within the study area; (3) Formulation of alternative plans; (4) Evaluation of the effects of the alternative plans; (5) Comparison of the alternative plans; and (6) Selection of the recommended plan based upon the comparison of the alternative plans. Water resources project planning is an iterative process, such that any of the six major steps may be revisited as additional information comes to light during the performance of a subsequent step.

In general, the chapters of the report relate to the six steps of the planning process as follows:

- The second chapter of this report, Problems and Objectives, specifies water and related land resources problems, opportunities, objectives, and constraints, and provides an inventory of water related resources;
- The third chapter of this report, Measures and Alternatives, covers the identification and preliminary screening of measures formulation of alternatives, comparison, and selection of the Final Array of Alternatives;
- The fourth chapter of this report, Alternative Plan Evaluation, provides a detailed description of evaluation of the Final Array of Alternatives; and
- The fifth chapter of this report, Tentatively Selected Plan, provides a description of the TSP

# 2 PROBLEMS AND OBJECTIVES

This chapter presents the results of the first step of the planning process: the specification of water and related land resources problems and opportunities in the study area. The chapter concludes with the establishment of planning objectives and planning constraints, which is the basis for the formulation of alternative plans.

## 2.1 Problems and Opportunities

### 2.1.1 Atlantic Ocean Shorefront Planning Reach Problems

Problems are the undesirable conditions that effective plans avoid, reduce/minimize, or mitigate. Areas along the Atlantic shoreline show vulnerability to storm damages from different mechanisms along the ocean and bay, and to varying degrees. The problems and opportunities identified in the Atlantic shoreline portion of the study area have been identified for specific reaches along the Atlantic shoreline.

The Rockaway Study Area comprises varying conditions. The area is subdivided into reaches for the purpose of this analysis. Each reach is developed based upon site-specific physical, economic, and institutional differences. Considerations include hydrodynamic differences, coastal features, sediment transport boundaries, shoreline stability, existing projects, and development patterns. Reach designations help characterize the problems, needs, and opportunities and to identify alternatives viable for each reach. Division of the study area into reaches does not imply separable projects or construction areas..

#### 2.1.1.1 Reach 1: Rockaway Point to Beach 193rd Street

Reach 1 contains the area between Rockaway Point and Beach 193rd Street. This reach consists of the Breezy Point and Rockaway Point communities. These communities consist mostly of private properties ranging from year round residences to seasonal vacation houses. Commercial development in the area is minimal. Structures sit on piles of varying depths in the area. Most residents have closed up their original crawl spaces between the main floors. Some residents utilize the space for storage and other damageable utilities.

The ocean-side beach of Breezy Point is wide. The beach has no established dune which results in the vulnerability of the area to tidal inundation from both the ocean and bay. Reach 1 consists of low-lying accretion areas with large buildings. The developments are subject to flooding both from the bay and the ocean due to its low ground elevations.

Figure 12 presents the buildings with potential flooding at different surge heights. In this reach, the surge levels are nearly the same on the Atlantic Ocean and Jamaica Bay ides of the peninsula. As shown, the entire reach is vulnerable to inundation at a +9 feet NAVD elevation.


**Figure 12: Atlantic Shoreline Reach #1**

#### 2.1.1.2 Reach 2: Beach 193rd Street to Beach 149th Street

Reach 2 includes the former Fort Tilden and Jacob Riis Park areas, and the community of Roxbury along the Jamaica Bay shoreline. The reach has some of the highest ground elevations along the Rockaway peninsula.

As shown in Figure 5, the shoreline contains a number of groins. These groins and the continued sediment supply from the east have resulted in the ocean-front shoreline being relatively stable. The east of the area has limited development. Most of the bay shoreline has a continuous wall which addresses low wave height, high frequency bayside flooding.

Reach 2 sits on a relatively high area. This reach, which supports recreational areas with limited shorefront development, has vulnerability to erosion, wave attack, and inundation. The community of Roxbury along the Jamaica Bay shoreline is susceptible to flooding from the bay where buildings are flooded at elevation +6feet NAVD, also shown in Figure 13.

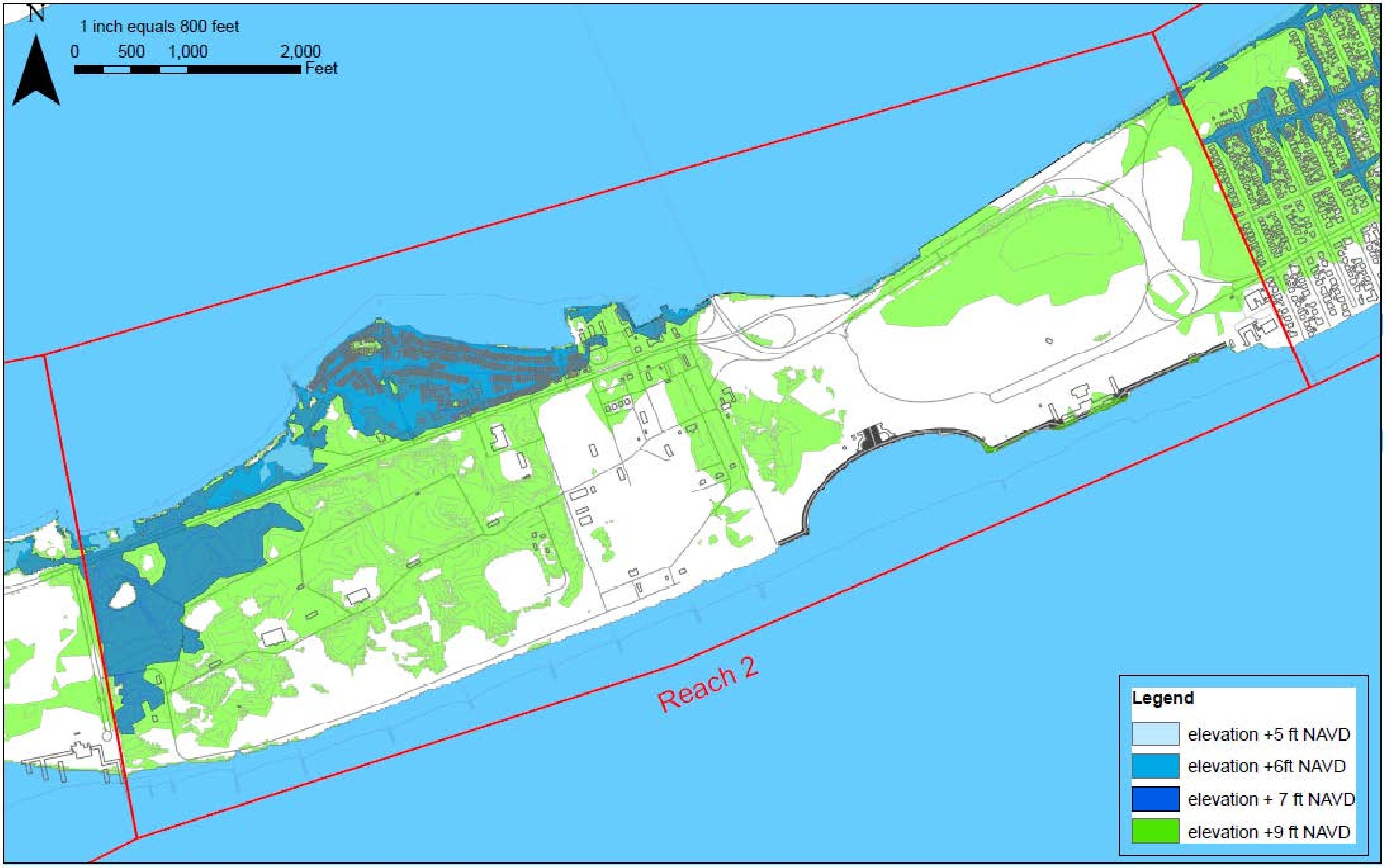


**Figure 13: Atlantic Shoreline Reach # 2**

#### 2.1.1.3 Reach 3: Beach 149th Street to Beach 109th Street

Reach 3 is a heavily developed area from ocean to bay. Ground elevations at the ocean end of the streets are about 10 to 11 feet NAVD with evidence of relict dunes. Landward of Reach 3, ground elevations drop to 5 to 6 feet NAVD along the bay shoreline. The reach has received sand fill from the existing, authorized project.

A retaining wall with a top elevation of approximately 3 to 4 feet above grade (roughly +10ft NAVD) protects the bay shoreline. The wall provides significant a degree of protection to the low lying areas of the reach.

Reach 3 contains densely developed areas on the shoreline. The existing authorized project includes this reach as part of its footprint. The reach has experienced low to moderate erosion. Significant infrastructure is at risk to ocean-side wave attack and flooding. The existing retaining wall along the bayside functions as a flood wall and reduces the risk of flooding along the bayside.

Figure 14 shows the areas of the reach that would be flooded at different elevations in the absence of the retaining wall. The figure also illustrates the potential for flooding on the reach where the surge runs across the island and ponds behind the existing floodwall.


**Figure 14: Atlantic Shoreline Reach #3**

#### 2.1.1.4 Reach 4: Beach 109th Street to Beach 86th Street

Reach 4 is a heavily developed area, similar to Reach 3. As part of the existing, authorized project, the reach has required a relatively large volume of material. The shore-front area contains several deteriorated wood pile groins. The Jamaica Bay shoreline is hardened with a low bulkhead at elevations near +6ft NAVD.

Surfers consider this area as a highly desirable surfing location. A surfing beach has been designated in this reach.

Erosion in the area persists despite wood pile groins. Severe erosion losses have required the reach to receive large volumes of beach fill material. Inundation from Jamaica Bay is not as extensive as other reaches due to this bulkhead. Significant infrastructure is still at risk. Figure 15 illustrates the developments impacted under different storm surge heights.


**Figure 15: Atlantic Shoreline Reach # 4**

#### 2.1.1.5 Reach 5: Beach 86th Street to Beach 42nd Street

Reach 5 consist of some developed areas near the ocean side of the peninsula. The developed areas sit at a higher elevation that Reaches 3 and 4. The reach has been relatively stable due to existing stone groins and its high elevations. Much of the development is at higher elevations compared to developed areas in Reaches 3 and 4, which results in the structures being less susceptible to storm damages. Also, the irregular shoreline of the area makes the design of line of protection measures very complex and costly.

The Arverne community in Reach 5 has low ground elevations ranging from 4.5 feet to 6 feet NAVD. The low elevations make the area susceptible to inundation. Figure 16 shows the developments impacted under different surge heights. Almost half of the reach gets submerged at a surge height of +6 feet NAVD.

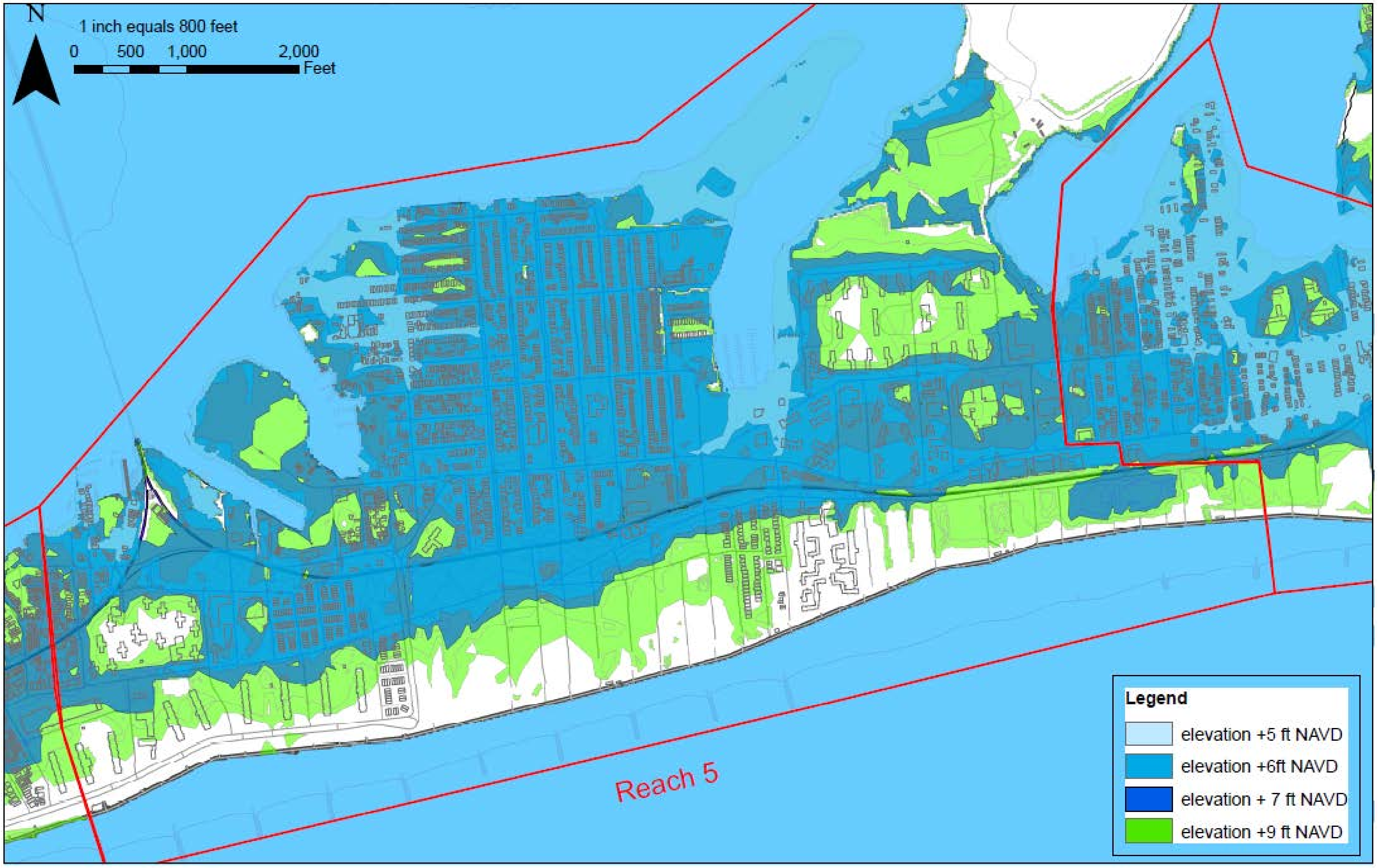


**Figure 16: Atlantic Shoreline Reach #5**

#### 2.1.1.6 Reach 6: Beach 42nd Street to Beach 9th Street

Reach 6 is located in the immediate vicinity of the inlet. The reach includes a heavily developed shoreline with some undeveloped shore front parcels. It experiences extremely high erosions rates and receives large amount of beach fill from the existing authorized project. The Jamaica Bay shoreline in this area is very irregular and low-lying, almost similar to Reach 5.

At times, the ocean shoreline has receded to and landward of the boardwalk. The area has required large amounts of fill placement as part of the existing authorized project. The reach also receives the dredge material from East Rockaway Inlet.

Figure 17 shows the developments impacted by different storm surge heights. As shown, most of the area gets affected by water depths as low as +5 feet NAVD. Also, portions of the main access road within this area get flooded by low water depths.

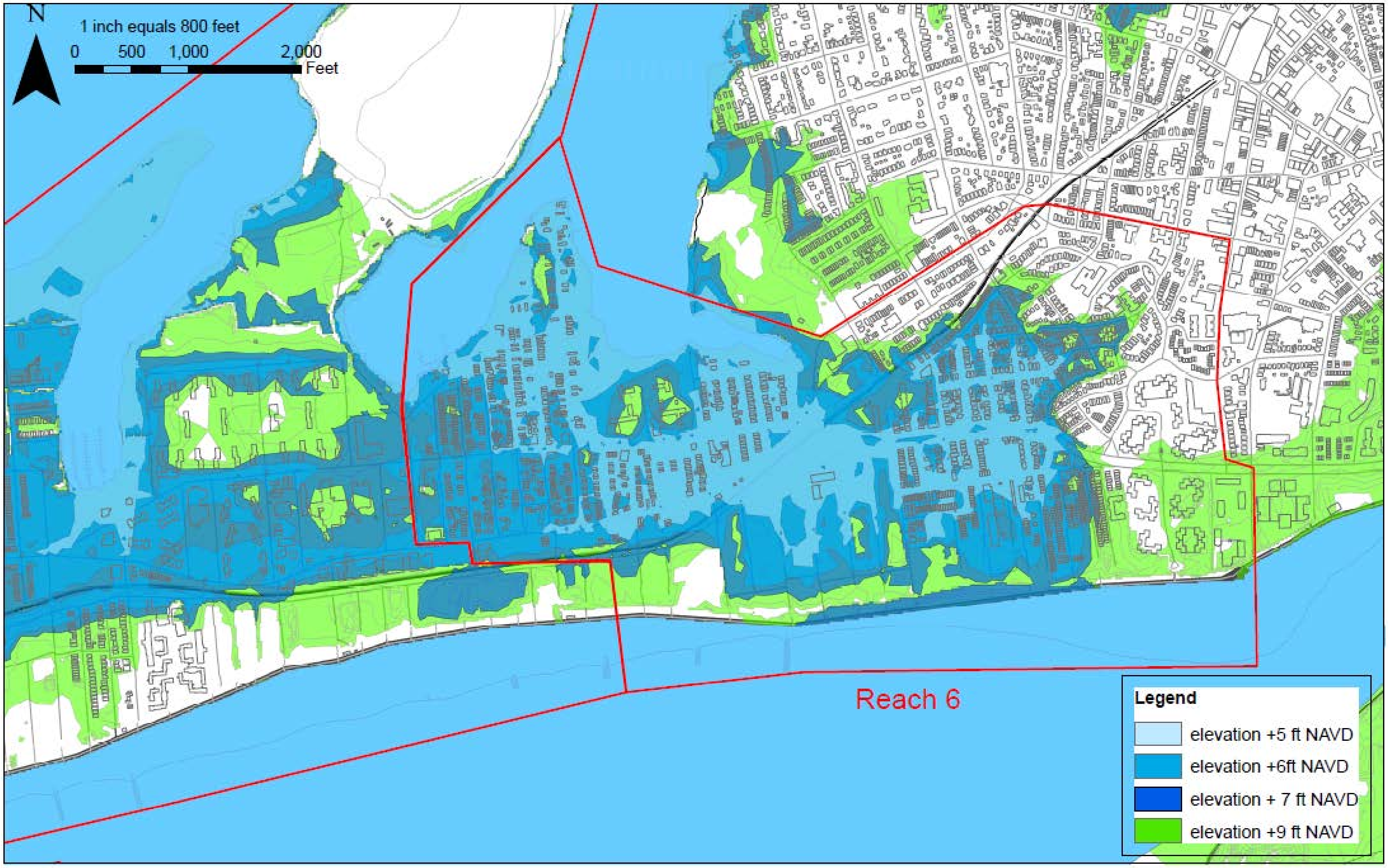


**Figure 17: Atlantic Shoreline Reach #6**

Table 7 presents the Atlantic Ocean shorefront reaches and their problems. It also illustrates the magnitude of the risk as indicated by the number of plus (+) signs of the problem. As shown, Reach 6 has the most risk of experiencing the problems.

**Table 7: Atlantic Shoreline Reach Problem Summary**

| Problem ID | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 |
|---|---|---|---|---|---|---|
| Ocean-Side Erosion | 0 | + | + | ++ | + | +++ |
| Ocean-Side Inundation | + | + | ++ | ++ | ++ | ++ |
| Ocean-Side Wave Attack | 0 | + | ++ | ++ | ++ | ++ |
| Bayside Flooding | + | + | + | + | ++ | ++ |
| Bayside Erosion | + | + | 0 | 0 | 0 | 0 |

Table 8 presents the structures at risk at different surge heights within each Atlantic Ocean shorefront reach. As shown, Reach 6 has the most developments affected in varying heights of surges. Reach 2 has the least number of developments vulnerable to storm damages at less than 500 buildings below elevation +9 feet NAVD.

**Table 8: Atlantic Shoreline Reach Structures at Risk**

| Reach | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|
| Buildings in the Reach | 2,460 | 510 | 4,620 | 1,260 | 2,160 | 1,940 | 12,950 |
| Buildings in Regulated Floodplain | 1,850 | 390 | | | | | |
| Buildings Below Elevation 9' NAVD | 2,300 | 470 | 4,010 | 1000 | 2,080 | 1,520 | 11,380 |
| - Return Period Ocean / Bay | 25 / 280 | 25 / 280 | 25/ 280 | 25 / 720 | 25 / 720 | 25 / 720 | |
| Buildings Below Elevation +7' NAVD | 1,090 | 420 | 2,600 | 630 | 1,920 | 1,380 | 8,040 |
| - Return Period Ocean / Bay | 6 / 50 | 6 / 50 | 6 / 50 | 6 / 130 | 6 / 130 | 6 / 130 | |
| Buildings Below Elevation +6' NAVD | 280 | 300 | 1,070 | 9 | 1,620 | 1,200 | 4,479 |
| - Return Period Ocean / Bay | 3 / 20 | 3 / 20 | 3 / 20 | 3 / 50 | 3 / 50 | 3 / 50 | |
| Buildings Below Elevation +5' NAVD | 0 | 3 | 70 | 1 | 170 | 730 | 974 |
| - Return Period Ocean / Bay | 1 / 5 | 1 / 5 | 1 / 5 | 1 / 15 | 1 / 15 | 1 / 15 | |

### 2.1.2 Atlantic Ocean Shorefront Planning Reach Opportunities

Various opportunities exist with the implementation of an effective coastal storm risk management plan for the study area. The greatest opportunity would be to provide protection against tidal inundation and flooding, enhancing access of the study area and reducing the amount of damage to the structures in the area. Opportunities for each reach are described below:

- **Reach 1 -** low-lying accretion area with wide, low berm. Reduce the risk of coastal storm damage to buildings and infrastructure in this reach, which are subject to flooding damages due to storm surge both from the ocean and bay;
- **Reach 2** - a relatively higher area with wide beach and dune formation. Reduce the risk of coastal storm damage to recreational areas and limited shorefront development;
- **Reach 3** - a densely developed stretch of shoreline that has experienced low to moderate erosion. Reduce the risk of coastal storm damage to infrastructure at risk to ocean-side wave attack and flooding during severe storm;
- **Reach 4** - a densely developed stretch of shoreline which has experienced moderate to high storm erosion. Reduce the risk of coastal storm damage to infrastructure vulnerable to damages from the ocean wave attack and inundation;
- **Reach 5** - a densely developed stretch of shoreline. The shoreline has experienced low erosion rate due to stabilization from existing groin field. Reduce the risk of coastal storm damage to a large quantity of infrastructure vulnerable to damages from the ocean-side erosion, wave attack and inundation; and
- **Reach 6** - a densely developed stretch of shoreline which has experienced high erosion rates. Reduce the risk of coastal storm damage to significant infrastructure that is vulnerable to damages from the ocean-side erosion, wave attack and inundation.

## 2.2 Preliminary Reach Designations – Jamaica Bay Planning Reach

The Jamaica Bay portion of the study area (Figure 18) has been divided into fifteen preliminary reaches (Figure 10), each of which includes a set of characteristics which would affect the implementation of a planning measure within that reach. The preliminary reaches were defined based on characteristics such as unique geographic, hydrologic, hydraulic, and land use features. Table 9 lists the reach names corresponding with each identification number shown in Figure 10.

**Table 9: Jamaica Bay Planning Reach, Preliminary Geographic Reaches**

| Reach ID | Geographic Name | Description |
|---|---|---|
| 1 | Sheepshead Bay | Establishes the far western boundary of the study area. Measures in this reach are assumed to tie into the dune that is part of in the USACE Atlantic Coast of New York City, Rockaway Inlet to Norton Point (Coney Island) Study. This assumption is significant, and very different scenarios will result if this assumption does not prove true. The implications of different scenarios are discussed in appendix X. |
| 2 | Gerritsen Beach | Separates Sheepshead Bay and Gerritsen Bay. Measures specific to the two bays, their adjacent terrain, and land use can be evaluated individually. |
| 3 | Floyd Bennett Field | Unique land use as National Park Service land |
| 4 | Mill Basin and Bergen Beach | Measure evaluation in this reach will consider the unique nature of Mill Basin, which branches into east and west basins upstream from a single inlet to Jamaica Bay |
| 5 | Canarsie | Measures evaluation in this reach will consider the unique nature of Paerdegat Basin, which is a narrow navigable inlet that includes a recently constructed low and high marsh restoration project. |
| 6 | Fresh Creek to Howard Beach | The northern shore of the bay, from Fresh Creek to Howard Beach, has been selected as one large reach, rather than individual domains separated by each creek. This enables integrated solutions along the shore to be more easily assessed. NNBF measures in this area, particularly those near Howard Beach, must consider wildlife hazards associated with the JFK airport. |

**Table 9: Jamaica Bay Planning Reach, Preliminary Geographic Reaches**

| Reach ID | Geographic Name | Description |
|---|---|---|
| 7 | JFK Airport | Measure implementation in this reach is restricted by runway obstruction and wildlife hazards. |
| 8 | Bayswater, Far Rockaway, and Idlewild Park | This reach is outlined to capture measures applicable for a generally soft Jamaica Bay edge and for the low lying terrain inland of Head of Bay. NNBF measures in this area must consider wildlife hazards associated with the JFK airport. |
| 9 | Rockaway East | Defined by both soft and hardened bay edges east of Cross Bay Boulevard. NNBF measures in this area must consider wildlife hazards associated with the JFK airport. |
| 10 | Rockaway West | Defined by its hardened edge and urbanized land use between the Gil Hodges Bridge and the Cross Bay Boulevard. |
| 11 | Breezy Point and Roxbury | Breezy Point and Roxbury make up the western extents of the Rockaways Peninsula. Measures in this reach will tie into the dune being considered for the ocean side of the Rockaway peninsula in the USACE East Rockaway Inlet to Rockaway Inlet and Jamaica Bay Reformulation Study. |
| 12 | Rockaway Inlet | Requires measures, such as hurricane barriers, unique to the entrance of the bay. This reach is the water body between Lower New York Bay and Jamaica Bay. |
| 13 | Bay Interior West | The bay interior with NNBF measure applications that are not generally restricted by wildlife hazard considerations near the airport. |
| 14 | Broad Channel | The bay interior surrounding Broad Channel and Cross Bay Boulevard. Includes urban footprints and an evacuation route. |
| 15 | Bay Interior East | The bay interior with NNBF measure applications that are generally restricted by wildlife hazard considerations near the airport. |


**Figure 18: Preliminary Geographic Reaches- Jamaica Bay Planning Reach**

### 2.2.1 Jamaica Bay Planning Reach Problems and Opportunities

Problems are the undesirable conditions that effective plans avoid, reduce/minimize, or mitigate. Viewing from a systems context, the general problem within the Jamaica Bay Planning Reach is that the combination of naturally low-lying topography, densely populated areas, extensive low-lying infrastructure, and degraded coastal ecosystems have resulted in communities that are vulnerable to extensive inundation during storm surges. In addition, projected future climate changes are expected to exacerbate existing problems. Projected future climate changes, including sea level rise, precipitation increase, temperature increase, and changes in extreme weather events' frequency and/or intensity will increase coastal storm flooding (Melillo, *et al.*, eds. 2014), erosion and wetland loss (NPS, 2014).

Opportunities are occasions to beneficially influence future conditions. In this analysis, opportunities exist to avoid, reduce/minimize, or mitigate storm related flooding impacts in and around Jamaica Bay and the Atlantic shoreline of the Rockaway peninsula. In addition, there is an overall opportunity to complement ongoing system recovery, ecosystem restoration, and CSRM efforts being conducted by state and local agencies. For the purposes of this study, ecosystem restoration is inclusive of creation, restoration, and enhancement measures.

Specific problems and opportunities include:

- Problem 1 - Projected future storm-related flooding damages:
    - The Sandy storm surge (more than 10 feet above ground in some parts of Jamaica Bay) resulted in extensive inundation of neighborhoods in Brooklyn and Queens, and hamlets in Nassau County (SIRR, 2013);
    - Future storms are projected to be more severe with higher storm surges and more extensive inundation (Orton, *et al*., 2014); and
    - The frequency of intense storms, such as Sandy, is projected to increase in the future (Orton, *et al*., 2014); and
    - Storm-related flooding damages also occur with more frequent storms of less intensity than Sandy.
- Opportunity to Address Problem 1: Prevent or reduce future storm surge and inundation damages.

- Problem 2 - Insufficient resiliency in natural and man-made systems:
    - Recovery from the damage caused by the Sandy storm surge and inundation was inconsistent across the region, with some systems taking an unacceptable time to recover (SIRR, 2013); and
    - Long lasting service disruptions (healthcare, transportation, telecommunications, electricity, liquid fuels, water supply, wastewater treatment) due to the Sandy storm surge impacted communities within and outside of the storm surge inundation area (SIRR, 2013).
- Opportunity to Address Problem 2: Improve the community's ability to recover from damages caused by storm surges by reducing the duration of interruption in services provided by man-made and natural systems.

- Problem 3 - Environmental degradation:
    - Jamaica Bay has lost 63-percent of its vegetated wetlands between 1951 and 2003 (USACE, 2009), inclusive of salt marshes that continue to diminish at a high rate and which their long term stability is threatened (DOI, 2013);
    - Remaining freshwater marshes and high saltmarshes in Jamaica Bay typically have been severely degraded by the nonnative common reed (*Phragmites australis)*, which forms dense monocultures that competitively exclude naturally occurring, native plant species (DOI, 2013);

    - Maritime and coastal forests within Jamaica Bay, which provide a natural storm surge buffer while also protecting adjacent coastal wetland habitats (DOI, 2013) have become increasingly rare; and
    - Historical borrow pits and channelization have increased the average depth of Jamaica Bay from 11 feet to 16 feet (DOI, 2013).
- Opportunity to Address Problem 3: Restore natural coastal features including, but not limited to, wetlands, reefs, and/or dunes and beaches. In addition, restore transitional upland natural features such as maritime or coastal forests that provide a storm surge buffer while also protecting adjacent natural aquatic features.

- Problem 4 – Impacts to human health and safety:
    - Multiple deaths by drowning, many victims perished within their homes during the Sandy storm surge (NY Times, 17 November 2012);
    - Service disruptions, some lasting for weeks, due to the Sandy storm surge and inundation, included critical electricity, water, heat, transportation, and health services (SIRR, 2013); and
    - Coney Island Hospital was evacuated due to the Sandy storm surge and inundation (SIRR, 2013).
- Opportunity to Address Problem 4-: Enhance human health and safety by improving the performance of critical infrastructure during and after storm surge events.

## 2.3 Historical and Existing Conditions

Jamaica Bay and its saltmarsh islands form one of the most recognizable and striking natural features within the urban landscape of New York City. Prior to the extensive urban development occurring over the past 150 years, tidewater grasslands colonized postglacial outwash plains at the ends of many creeks and streams in Jamaica Bay creating fringing salt marshes which encircled the bay. Figure 11, which reproduces a survey map from 1889, depicts the extensive saltmarsh islands and many more thousands of acres of fringing marshes and transitional uplands that once adjoined the mainland. Figure 12, the current NOAA navigation chart, depicts current conditions in which nearly all fringing marshes are now gone because of filling for development, dredging, and pollution-related degradation (NPS, 2014).

The contrast of Figures 19 and 20 illustrate the extent of the modifications of the Jamaica Bay in the last 130 years. Islands have been removed by dredging or extended to the nearby mainland by fill; shorelines have been altered by dredge and fill activities; bulkheads have been installed to stabilize and protect shorelines; channels and borrow areas been dredged, altering bottom contours and affecting flows; and natural tributaries have essential disappeared with sediment input in these tributaries only in the form of silts and particulates from urban runoff (DEP, 2007).

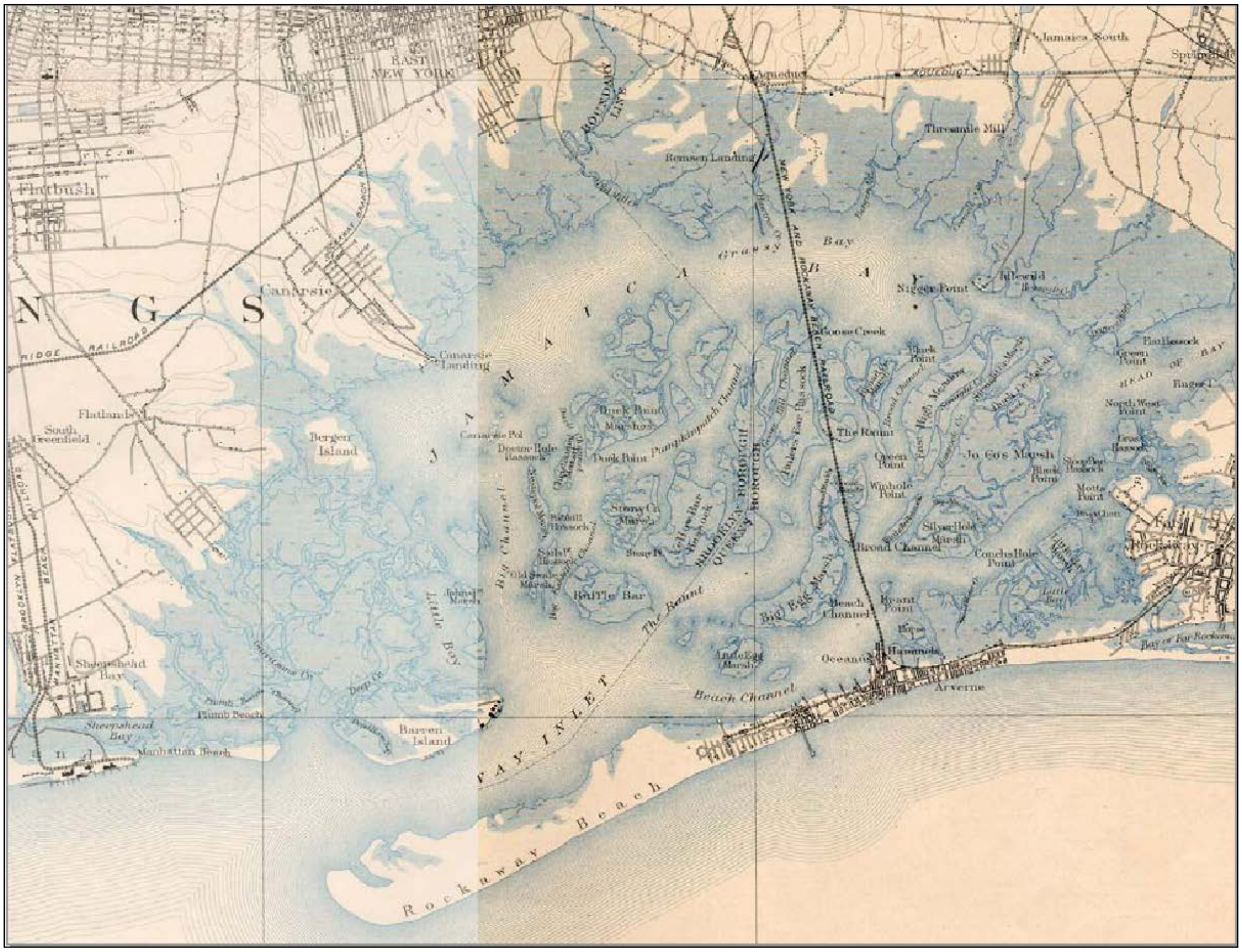


**Figure 19: Jamaica Bay circa. 1889**

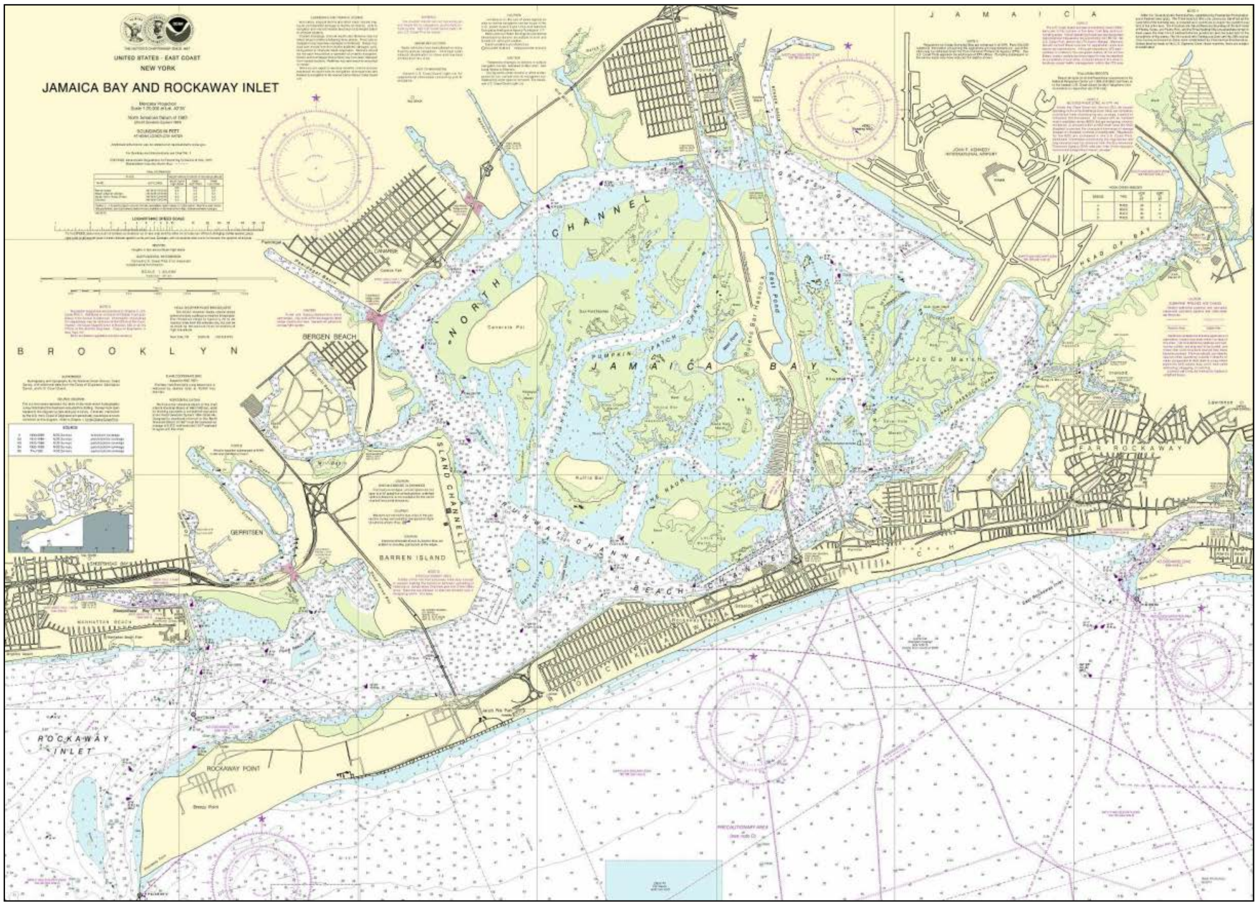


**Figure 20: Jamaica Bay circa. 2014**

### 2.3.1 Urban Development Impact on Natural Processes

The 71,000 acre Jamaica Bay watershed is comprised of the highly urban communities of Brooklyn and Queens as well as a small portion of Nassau County. Three hundred years ago, the area north of Jamaica Bay was host to numerous freshwater wetlands and uplands with grassland, shrubland, and forest plant communities. Creeks would have meandered through large wetlands on their way to Jamaica Bay. Most of the precipitation reaching the ground surface infiltrated into the soil or collected into natural stream channels and the nutrients entering the Bay from the watershed would have been easily assimilated into the Bay. Today's landscape surrounding Jamaica Bay is an urban environment with residential, commercial, industrial, and transportation infrastructure having replaced the natural vegetation (DEP, 2007). The upland areas adjacent to the marsh are largely underlain by urban fill or dredged materials (NPS, 2014).

The natural surface water tributaries to Jamaica Bay have been mostly filled, routed through pipes, or diverted (NPS, 2014). The remaining tributaries are now either substantially engineered, such as Sheepshead Bay and Paerdegat Basin, or are remnant creeks, such as Spring Creek and Brookville Creek. Major tributaries have been altered by channelization and tend to have little freshwater flow other than that conveyed during storm events (NPS, 2014). As a result, the primary sources of freshwater into the bay are wastewater treatment facility discharges (240-340 million gallons per day) and stormwater drainage (i.e., episodic urban runoff) through numerous combined storm water and sewer overflow (CSO) pipes (NPS, 2014).

A sediment budget is the exchange of sediment input, deposition, and transport out of the system. Usually, the sediment budget is expressed in terms of the volume of sediment gained or lost per year for a given area. Hardened shorelines around the perimeter of Jamaica Bay and the replacement of natural features with expanses of impervious surfaces throughout the watershed reduce the input of upland sediment. Filling of inlet connections to the ocean in the southeastern portion of the Rockaway Peninsula (Sommerville Basin, Norton Bay, and Little Bay as examples) and extension of the peninsula to the west by nearly 16,000 feet (3 miles) over the last 125 years has reduced sediment input to Jamaica Bay from the ocean side of the Rockaway Peninsula.

Historically, the average depth of Jamaica Bay has been estimated to be approximately three feet. Dredging of Jamaica Bay sediments as a source for fill material and for navigation began in the 1800's (Rhoads, et al, 2001). Currently, the average depth is approximately 13 feet, with navigation channel depths in excess of 20 feet, and numerous borrow pits with depths in excess of 50 to 60 feet (NOAA, 2014). Due to the combination of reduced sediment inputs from the watershed under current conditions and historical removal of large volumes of sediment, most locations within Jamaica Bay are experiencing a long-term negative sediment budget (NPS, 2014), which has severely impacted the natural inland migration and stability of Jamaica Bay's marshes.

These large scale historical changes to the physical environment have substantially reduced the presence of living shorelines within Jamaica Bay. Figure 21 presents Jamaica Bay profile approximations for pre-development and current conditions (DEP, 2007). The loss of living shoreline within Jamaica Bay has substantially reduced ecosystem resiliency by removing the natural substrate that would have provided areas for wetland migration and transitional habitats.

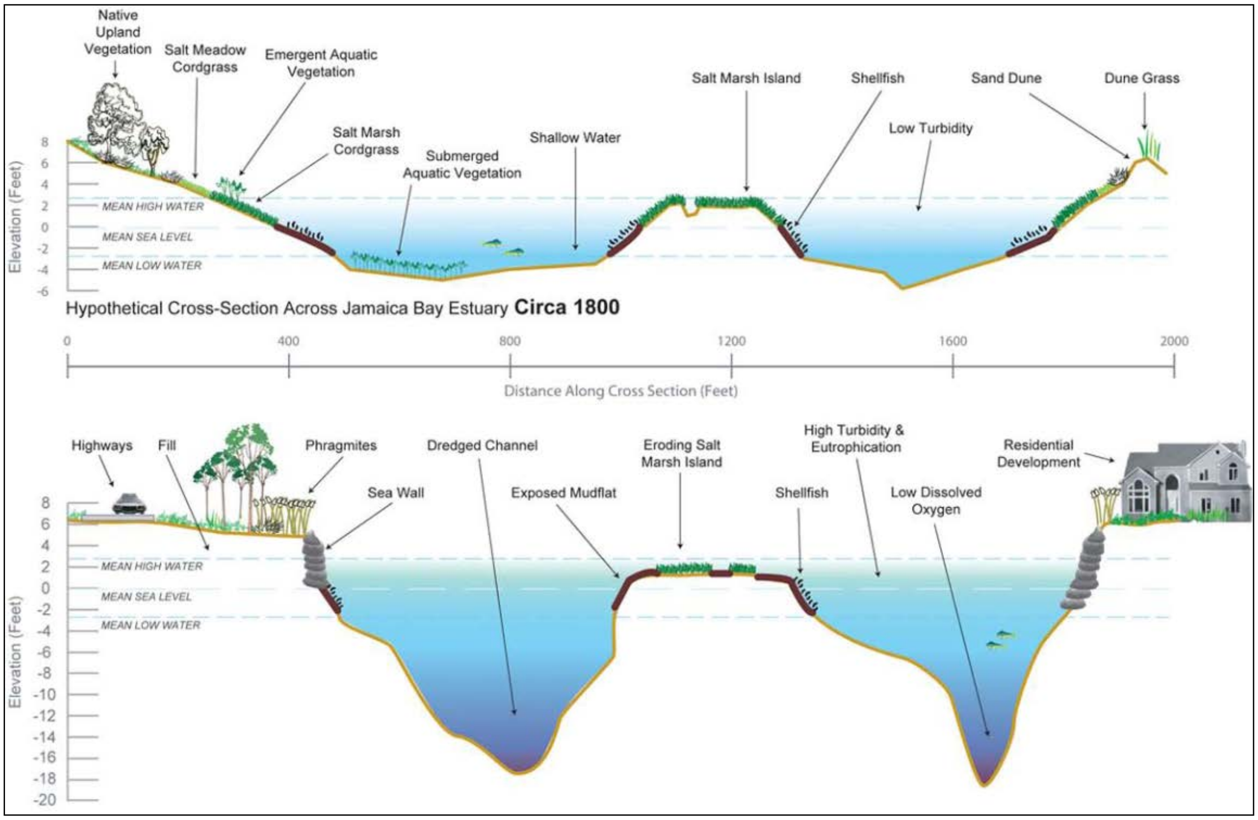


**Figure 21: Jamaica Bay Profiles - Pre-Development and Current**

### 2.3.2 Coastal Storm Hazards

Frequent and severe damage from tidal inundation at the inland areas surrounding Jamaica Bay has long been identified as a problem for the study area (USACE, 1964). Historical flood impacts include evacuations during times of flood and extensive property damage in communities along the low-lying areas of Jamaica Bay (USACE, 1993). The entire Jamaica Bay study area, with the exception of JFK Airport, is designated as either Evacuation Zone 1 or Evacuation Zone 2, the most at-risk zones, by the New York City Office of Emergency Management (NYCOEM, 2014).

Coastal storm surges in the study area occur from hurricanes, tropical storms, and winter storms known as “nor’easters”. High tide combined with storm surge and wind speed increases flooding (NPS, 2014). There are no long-term historical tide gauge data for Jamaica Bay, however; 23 major storms have been identified as impacting the New York City region since 1815 with impacts including fatalities, widespread structural damage, the opening of Shinnecock Inlet, and the obliteration and removal of Hog Island from offshore of the Rockaway coast (Weather2000, 2014).

Figure 22 presents historical extreme tide gauge readings for the Battery off of Manhattan Island in New York Harbor. Although there are no data identifying the areas of inundation in Jamaica Bay associated with most of the storm events identified in Figure 14, one reference point is the inundation that occurred during Hurricane Sandy (October 2012), which is associated with a tide gauge reading of 13.986 feet above MLLW at the Battery. Acknowledging that associating tide gauge readings at the Battery with inundation at Jamaica Bay is an approximation at best, Figure 15 presents approximate inundation at Jamaica Bay based on two foot increments in tide gauge height at the Battery from 6 feet above MLLW to 14 feet above MLLW. Although a rough approximation, Figure 23 nevertheless demonstrates the susceptibility of the study area to tidal inundation.

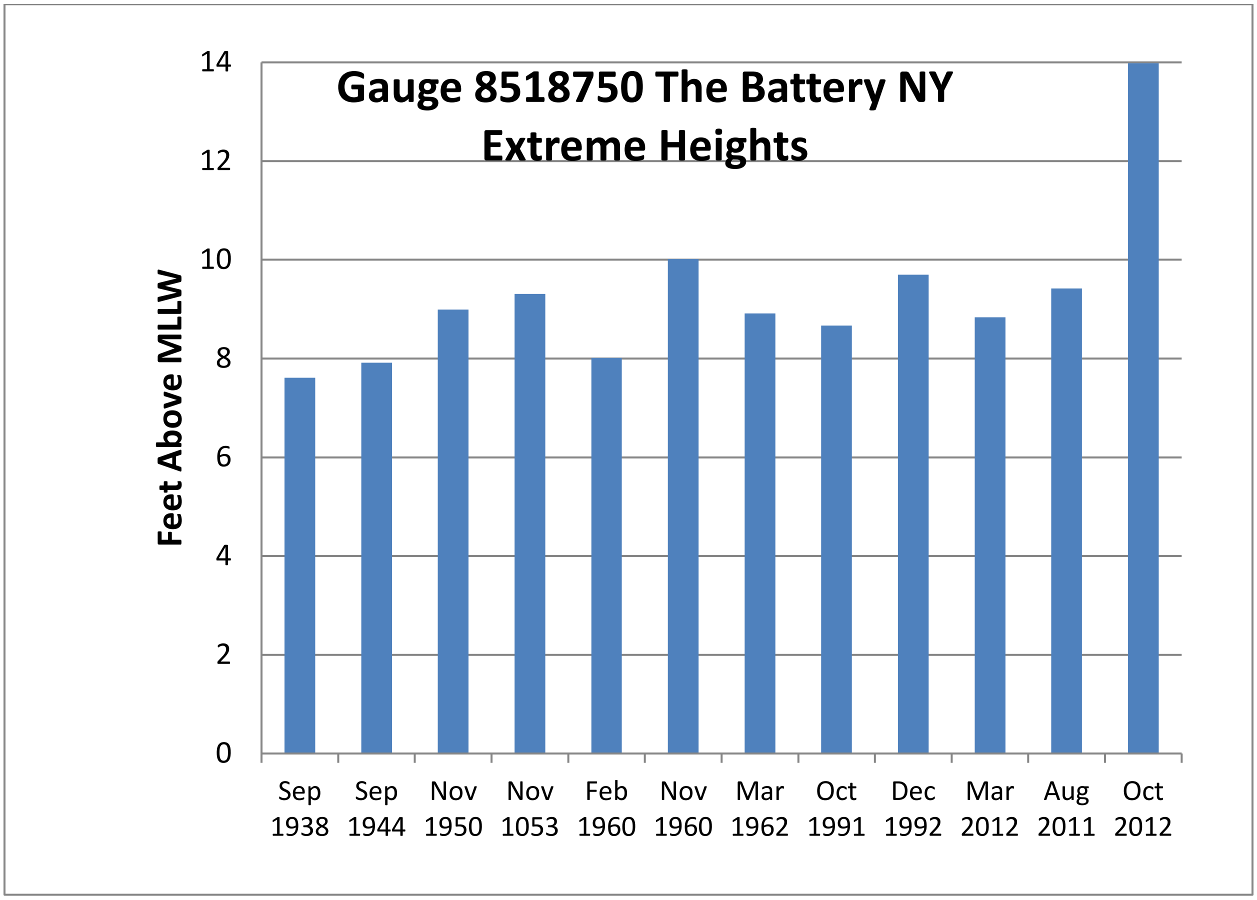


**Figure 22: Battery New York Extreme Tide Gauge Heights**

Source: http://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=8518750

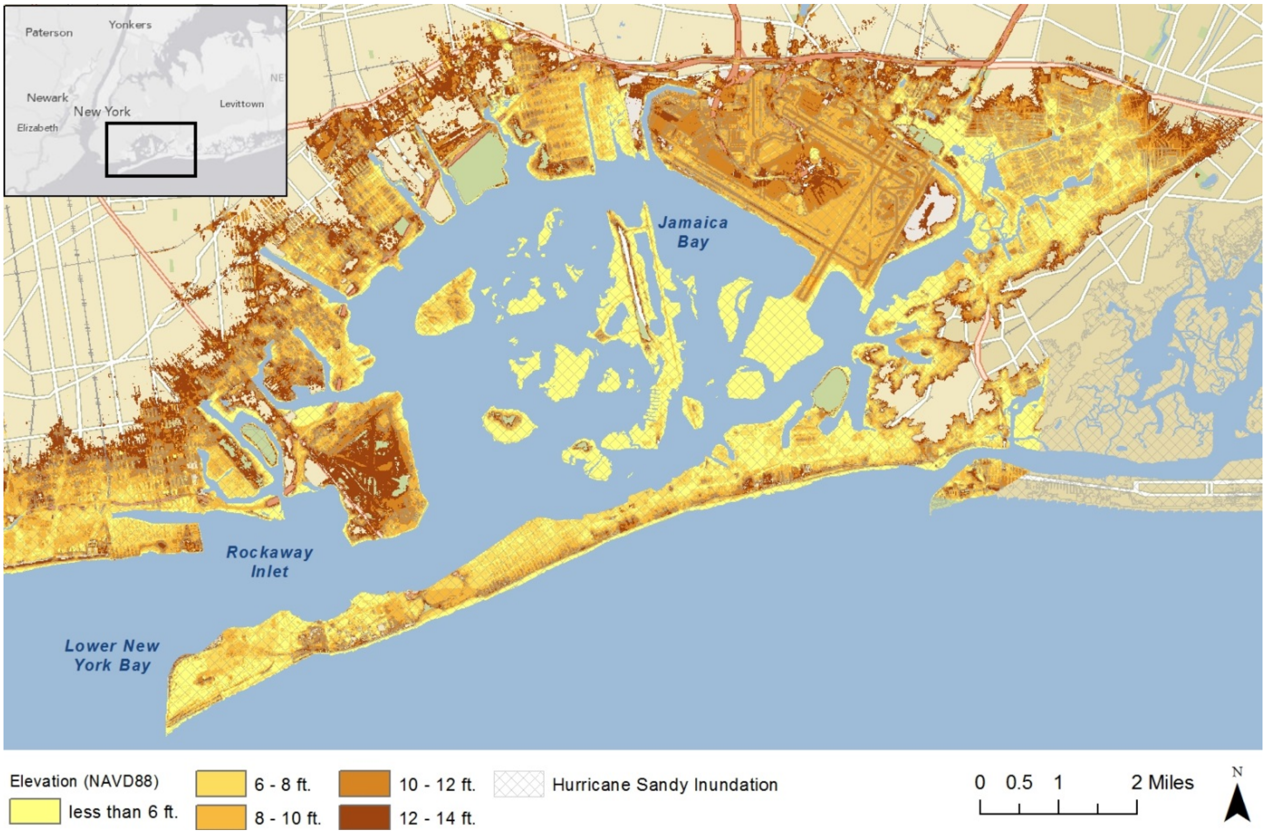


**Figure 23: Approximate Historical Study Area Inundation at Various Water Elevations**

For the purposes of the preliminary screening described in this document, major storms are identified to be those which produce surge tide and wave conditions similar to the 100-year[1] base flood elevation (BFE), as defined by Federal Emergency Management Agency (FEMA), with additional consideration of projected sea-level change (SLC). FEMA recently released Preliminary Flood Insurance Rate Maps (FIRMs) in the New York City portion of the study area,

[1] Note that this document uses the FEMA risk designation. The 100-year event is equivalent to the 1% annual percentage chance exceedance.

which include consideration of stillwater elevations and wave conditions, which illustrate current flood risks in the study area. Though these maps are not yet the effective FIRMs in New York City, they are believed to be the best available information for defining 100-year flood elevations. The portions of the study area in Nassau County are assessed using the Nassau County 2009 Flood Insurance Study (FIS) 100-year effective Base Flood Elevation (BFE) data. These data were released in 2009 by FEMA (FEMA 2009) and include consideration of still water levels and wave action throughout Nassau County. Figure 24 shows the preliminary FIRMs for New York City and the effective BFEs in Nassau County.

Note that in subsequent phases of the study, major storms may be defined as flood elevations which are different than the 100-year elevation defined by FEMA. The FEMA 100-year elevations are used as baseline data to define risks in the study area for the preliminary screening only.


**Figure 24: Preliminary FEMA Map Elevations (NAVD88) for the Study Area**

### 2.3.3 Impacts of Hurricane Sandy

Forty-three fatalities were attributed to Hurricane Sandy, with a number of these being reported in the study area (NY Times, 2012). During Hurricane Sandy, tidal waters amassed in Jamaica Bay by entering through Rockaway Inlet and by overtopping the Rockaway Peninsula. In the Brooklyn portion of Jamaica Bay, Sheepshead Bay, Gerritsen Inlet, and Shell Bank Creek acted as conduits conveying floodwaters into the surrounding neighborhoods (SIRR, 2013). Figures 25 and 26 identify the New York City Department of Buildings assessment of structural damage in Brooklyn and Queens using the "tag system". A yellow tag indicates that the building is damaged and entry limitations have been imposed. Yellow tag damages may include basement flooding, loss of sanitary facilities, or compromised electrical systems. A red tag indicates that the building is unsafe to enter or occupy, however; the building may be repaired (NYCDOB, 2014). Note that many more structures were damaged than were tagged because the damage was not sufficient to cause entry restrictions.

In the Queens portion of Jamaica Bay, flood heights reached above land inundating many of the bayside neighborhoods along the Rockaway Peninsula where bulkheads failed leaving homes unprotected. The low-lying neighborhoods in the central and northern portions of the Bay including Broad Channel, Old Howard Beach, New Howard Beach, and Hamilton Beach, where the narrow creeks and basins provide the marine aesthetic of the neighborhood, were especially devastated by flood waters (Figure 26). Damage to the elevated portion of the subway system in Jamaica Bay and Rockaway (A line) disrupted service for months affecting about 35,000 daily riders (USACE, 2013d).

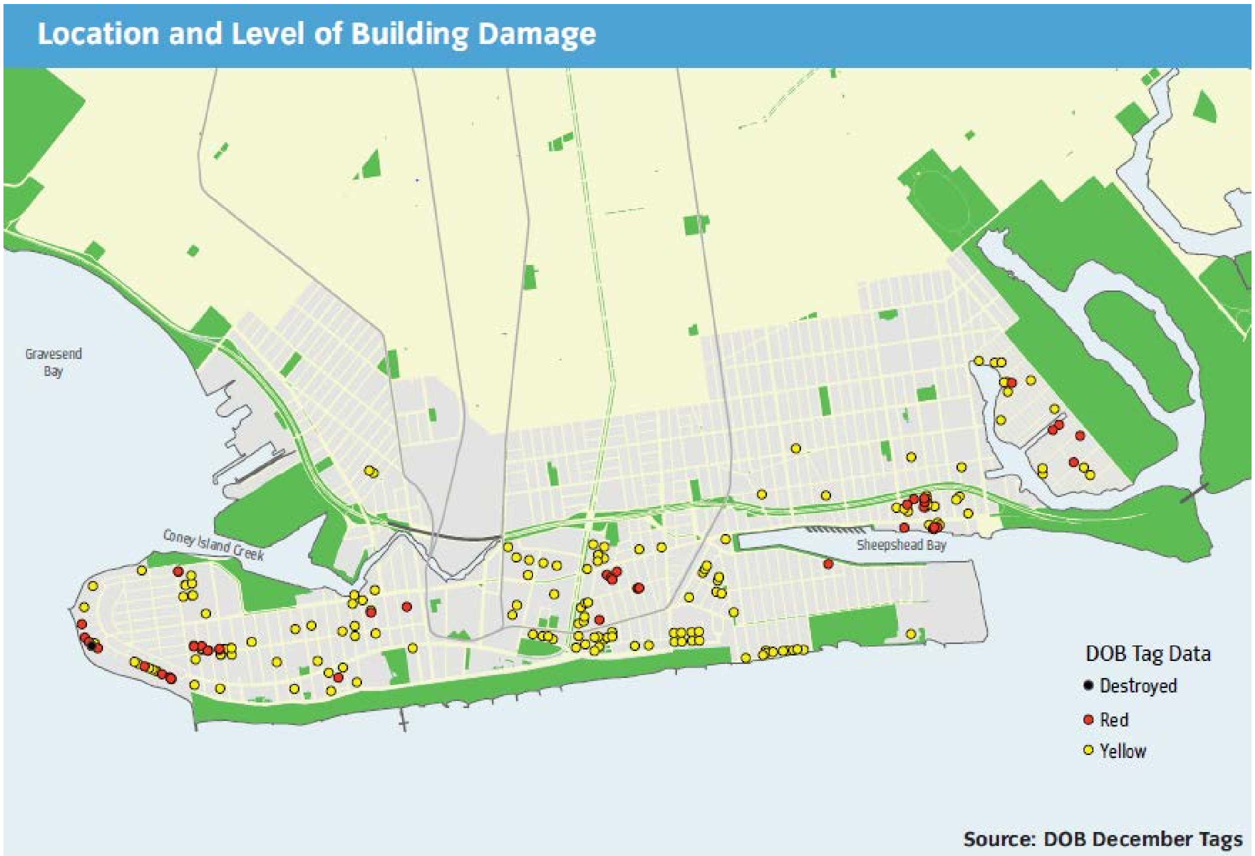


**Figure 25: Hurricane Sandy Building Damage - Brooklyn**

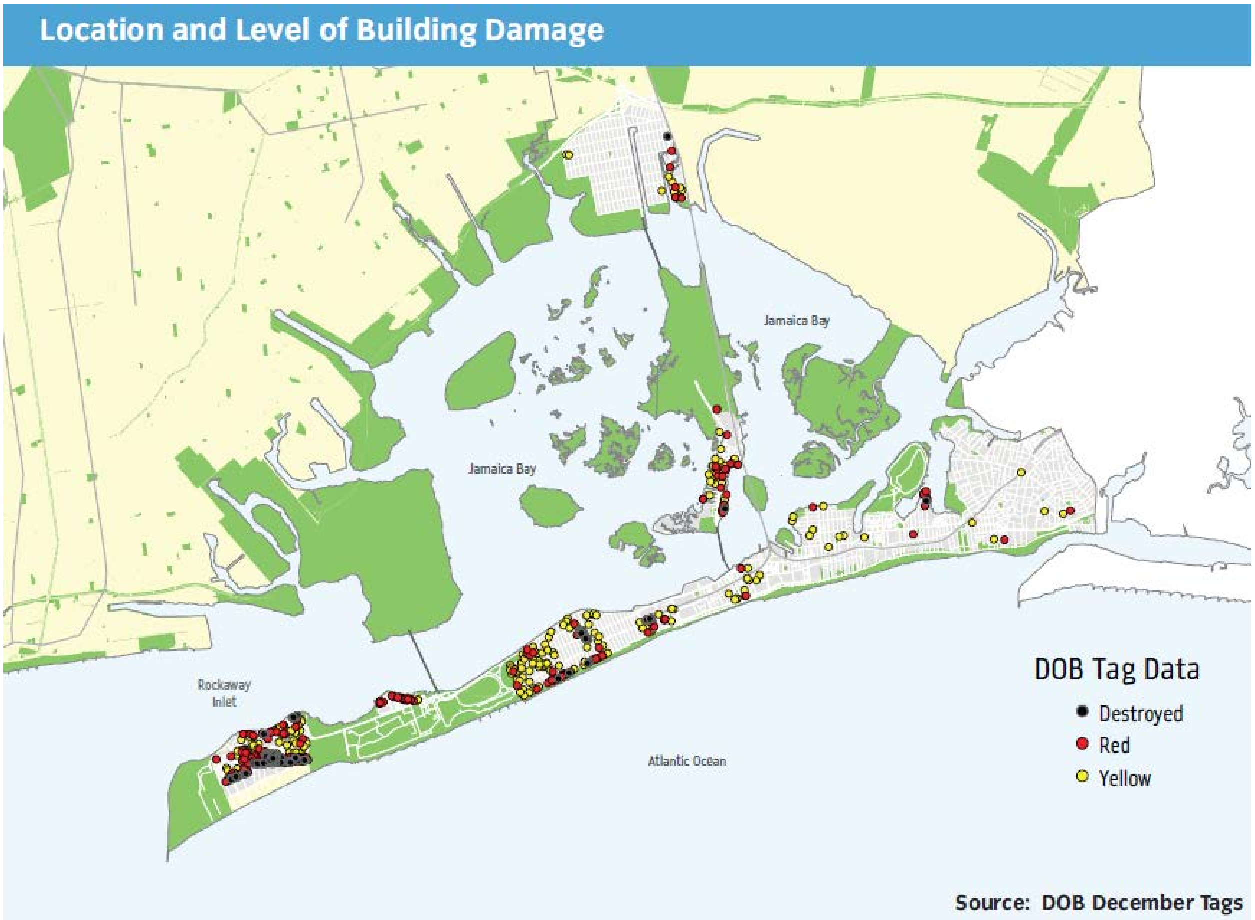


**Figure 26: Hurricane Sandy Building Damage - Queens**

This project (East Rockaway Inlet to Rockaway Inlet and Jamaica Bay) was identified as being within the Area of Extreme Exposure during Hurricane Sandy, which is defined as an area exposed to wave heights greater than +9 feet MHHW onshore and greater than 30 feet offshore (USACE, 2013d). The height of the beach erosion control project on the Rockaway Peninsula at the time Hurricane Sandy hit is unknown, but project height was below design dimensions (USACE, 2013d). Although the beach berm on the Rockaway Peninsula had been overtopped, widespread flooding, inundation, and damages were also due to back-bay flooding, which had not been addressed through implementation of coastal flood risk management measures in project construction authorization (USACE, 2013d). Additional information concerning high-water marks with photos is available on the Hurricane Sandy Storm Tide Mapper website, at http://water.usgs.gov/floods/events/2012/sandy/sandymapper.

Figures 27 through 31 presents critical infrastructure within the study area and critical infrastructure within the Hurricane Sandy area of impact.

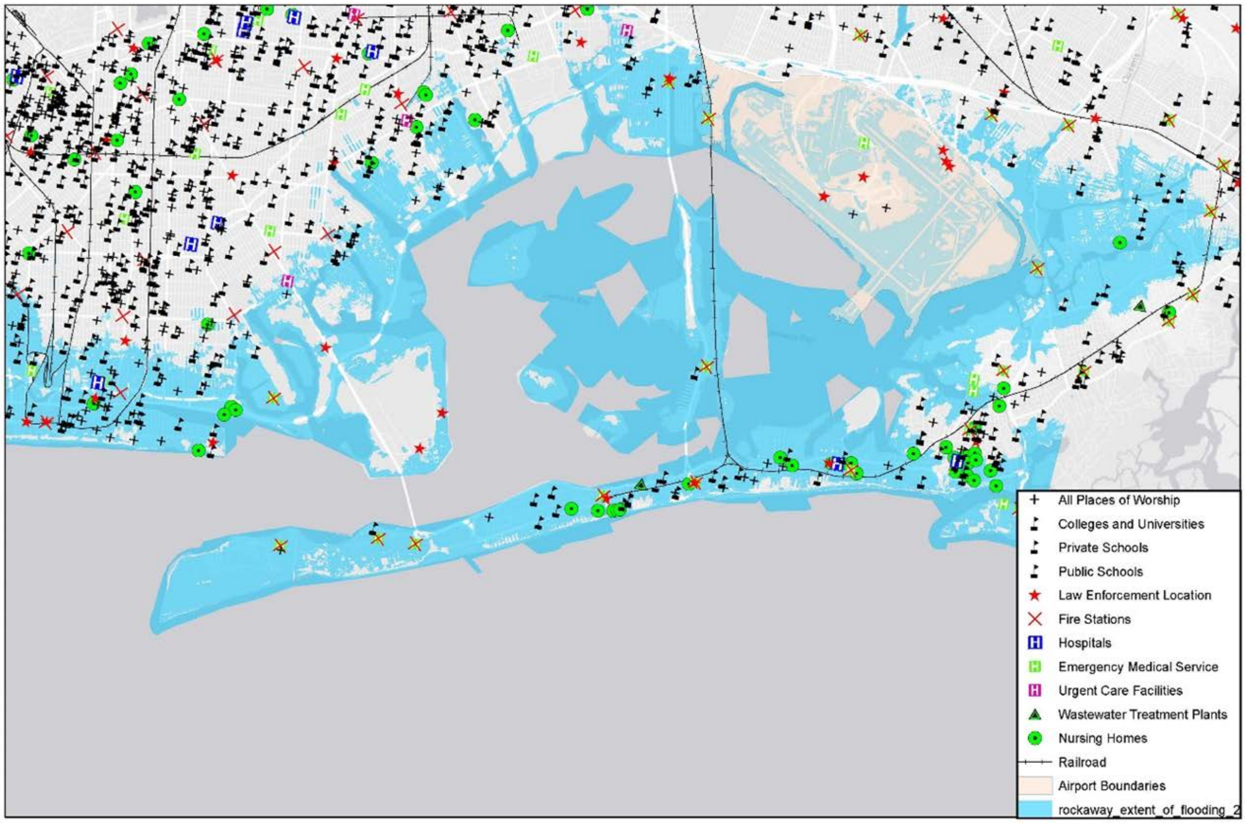


**Figure 27: Study Area Critical Infrastructure and Hurricane Sandy Impact Area**

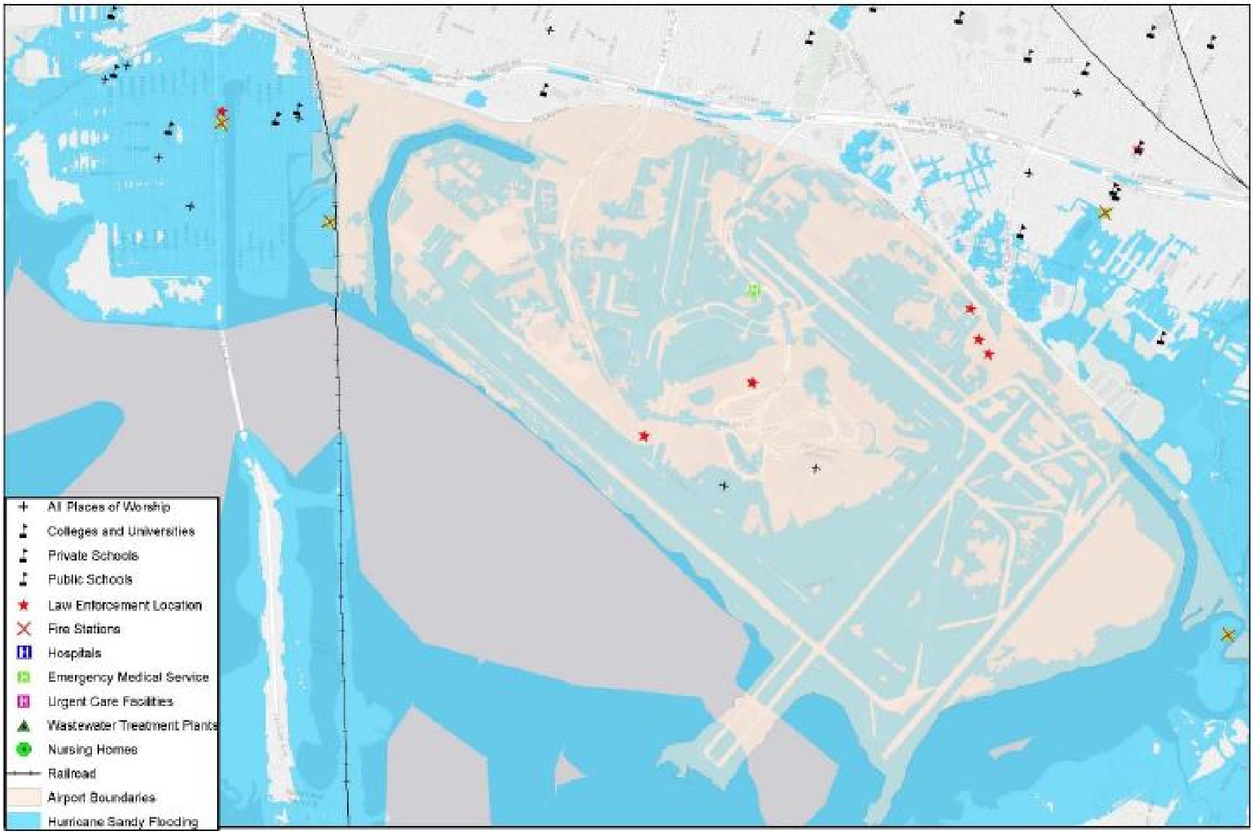


**Figure 28: JFK Critical Infrastructure**


**Figure 29: Arverne Critical Infrastructure**

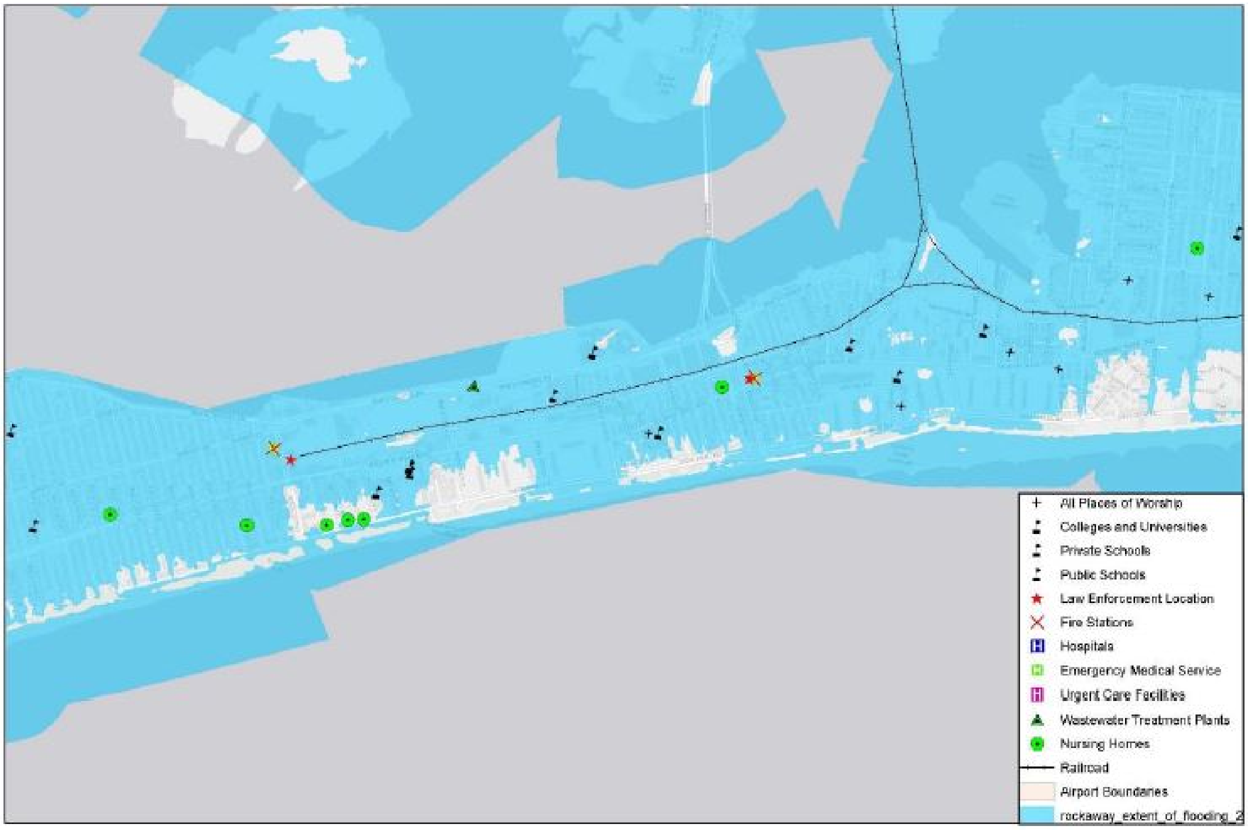


**Figure 30: Cross Bay Critical Infrastructure**

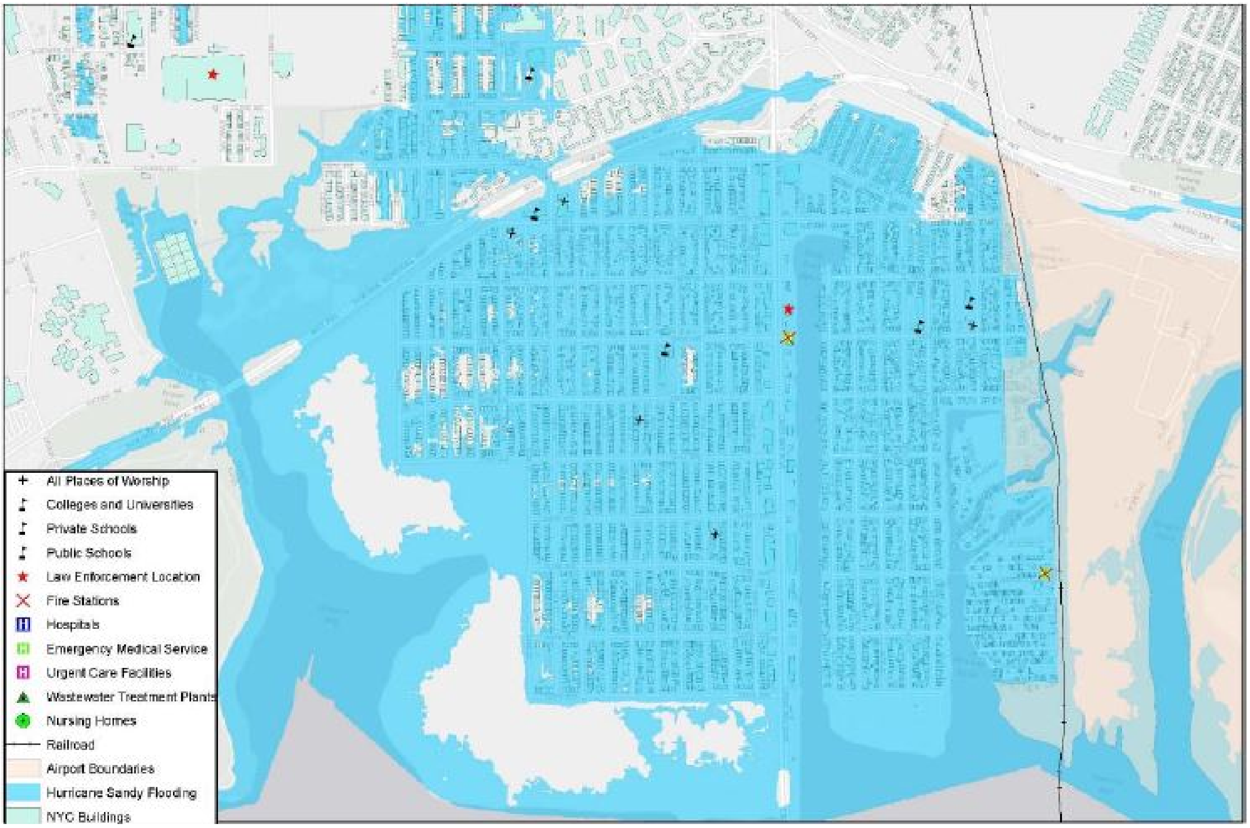


**Figure 31: Howard Beach Critical Infrastructure**

This analysis recognizes that the structures along the Atlantic shorefront have a greater exposure to impacts from wave attack and wave run up than structures within Jamaica Bay. Therefore, problems and opportunities are presented separately for the Atlantic shorefront and Jamaica Bay portions of the study area. The chapter concludes with the establishment of planning objectives and planning constraints, which is the basis for the formulation of alternative plans.

## 2.4 Without-Project Future Conditions

### 2.4.1 Sea Level Change

Sea-level change (SLC) was considered in the preliminary screening of measures based on the guidance contained in the most recent Engineering Regulation (ER) 1100-2-8162 (USACE 2013e), which is the successor to the Engineering Circular (EC) 1165-2-212 (USACE 2011). Per ER 1100-2-8162:

> Planning studies and engineering designs over the project life cycle, for both existing and proposed projects, will consider alternatives that are formulated and evaluated for the entire range of possible future rates of SLC, represented here by three scenarios of "low," "intermediate," and "high" SLC. These alternatives will include structural, nonstructural,

nature based or natural solutions, or combinations of these solutions. Alternatives should be evaluated using "low," "intermediate," and "high" rates of future SLC for both "with" and "without" project conditions.

ER 1100-2-8162 considers the historic rate of SLC as the low rate. The intermediate and high rates are computed from the modified National Research Council (NRC) Curve I and III respectively, considering both the most recent Intergovernmental Panel on Climate Change (IPCC) projections and modified NRC projections with the local rate of vertical land movement added.

For the purposes of the Reformulation Study, the year of construction is assumed to be 2020, with a design life of 50 years. Table 10 and Figure 32 show the USACE SLC data and curves for 2010 to 2100 at The Battery, NY based on ER 1100-2-8162. The intermediate SLC rate is considered for this phase of the study. Hence, a SLC of 1.3 feet in 2070, as compared to the 1992 sea level values, or slightly greater than one foot as compared to the 2014 sea level value, is added to the FEMA preliminary FIRM 100-year elevations to identify future risk levels.

**Table 10: USACE SLC Projections (feet) at The Battery, NY (Gauge: 8518750)** [2]

| Year | Low | Intermediate | High |
|---|---|---|---|
| 2010 | 0.17 | 0.20 | 0.29 |
| 2015 | 0.22 | 0.27 | 0.42 |
| 2020 | 0.27 | 0.34 | 0.56 |
| 2025 | 0.32 | 0.41 | 0.72 |
| 2030 | 0.36 | 0.49 | 0.90 |
| 2035 | 0.41 | 0.58 | 1.10 |
| 2040 | 0.46 | 0.66 | 1.31 |
| 2045 | 0.51 | 0.76 | 1.55 |
| 2050 | 0.56 | 0.85 | 1.80 |
| 2055 | 0.60 | 0.96 | 2.07 |
| 2060 | 0.65 | 1.06 | 2.37 |
| 2065 | 0.70 | 1.17 | 2.67 |
| 2070 | 0.75 | 1.29 | 3.00 |
| 2075 | 0.80 | 1.41 | 3.35 |
| 2080 | 0.84 | 1.53 | 3.71 |
| 2085 | 0.89 | 1.66 | 4.10 |
| 2090 | 0.94 | 1.79 | 4.50 |
| 2095 | 0.99 | 1.93 | 4.92 |
| 2100 | 1.03 | 2.07 | 5.36 |

[2] Values shown to hundredth of foot per direct calculations from EC 1165-2-212, Equation 2: $E(t) = 0.0017t + bt^2$ and illustrate the incremental increase of sea level change over time.

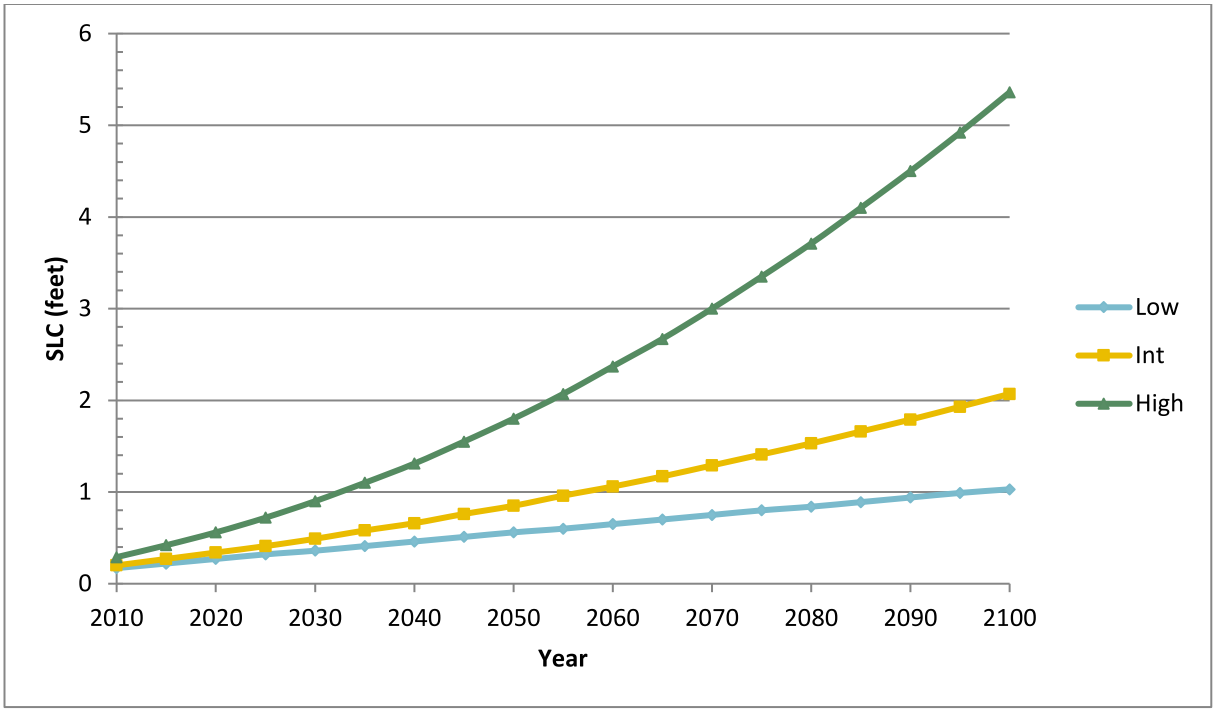


**Figure 32: USACE SLC Projections (feet) at The Battery, NY (Gauge: 8518750)**

With the addition of SLC to the current floodplain, the floodplain for the region expands in area and depth. Regions currently in the floodplain are at risk of higher flood depths during storm events (e.g., a BFE of 13 feet can become a BFE of 14 feet). Similarly, the floodplain will extend further inland, increasing the number of assets at risk of flooding. Figure 33 depicts the current and projected future area of inundation, which would occur during a 100-year event (also referred to as the 1% annual chance flood hazard event) in the study area.

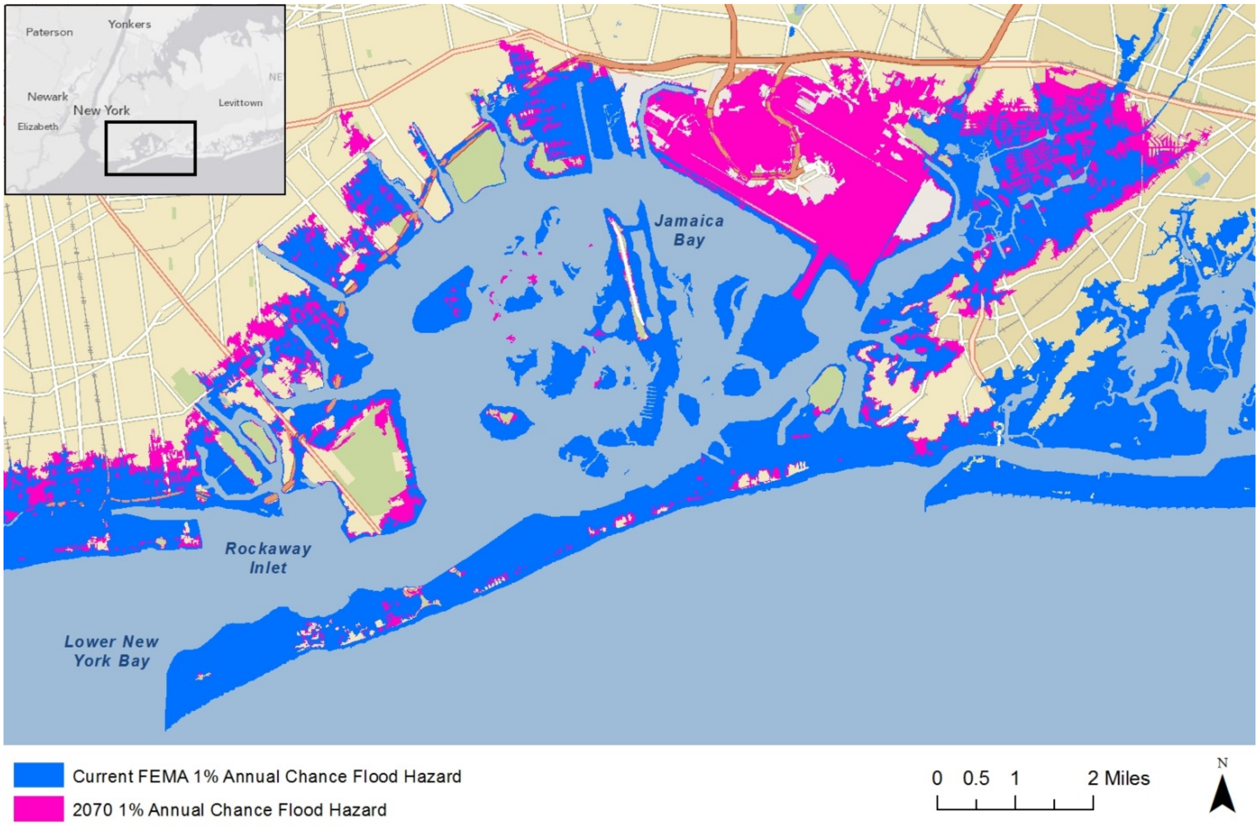


**Figure 33: 1% Annual Chance (100-year) Flood Hazard with Mid-Range SLC**

While Figure 33 illustrates the 100-year annual chance flood hazard in the study area, it is important to note that no design elevation has been decided upon for any of the Jamaica Bay reaches or measures that are being considered. Future efforts for the Reformulation Study, including economic and cost considerations, will be necessary to determine the most appropriate design elevation to protect each reach.

Research supported by the City of New York projected future increases in sea level rise are expected to substantially affect future flood heights in and around Jamaica Bay (Orton, *et al*., 2014). Table 11 presents projected flood heights (NAVD88) at Howard Beach, Queens for baseline sea level (1983-2001) and future decades with sea level rise as presented in Orton, *et al*. The projected flood heights are based on hydrodynamic modeling conducted by Orton, *et al*., which includes the effects of factors such as winds, friction, and other factors, although; at Howard Beach the flood heights generated by Orton, *et al* 's hydrodynamic modeling are within inches of flood heights predicted by static models. Based on the modeling results presented in Table 11, projected flood heights for similar chance events will increase by 2.9 feet from the baseline (1983 – 2001) to the 2050's. Note that the Orton, *et al*. research conducted for New York City includes SLC estimates, which are higher than the USACE SLC estimates presented in Table 11 and Figure 20.

**Table 11: Projected Flood Heights at Howard Beach**

| | 1% Annual Chance Flood Hazard (feet) | 0.2% Annual Chance Flood Hazard (feet) |
|---|---|---|
| Baseline (1983 - 2001) | 9.7 | 11.7 |
| 2020s | 10.8 | 12.7 |
| 2050s | 12.6 | 15.0 |
| 2080s | 15.0 | 16.6 |

Source: Philip Orton, Sergey Vinogradov, Alan Blumberg and Nickitas Georgas, Hydrodynamic Mapping of Future Coastal Flood Hazards for New York City, 27 February 2014, Table 5.1, page 13.

Figure 34 depicts the current and projected future (2050) area of inundation occurring with a 1% annual chance flood hazard in the study area based on higher SLC estimates than presented in Figure 33 (Orton *et al.*, 2014 for New York City and LiDAR data analysis for Nassau County).

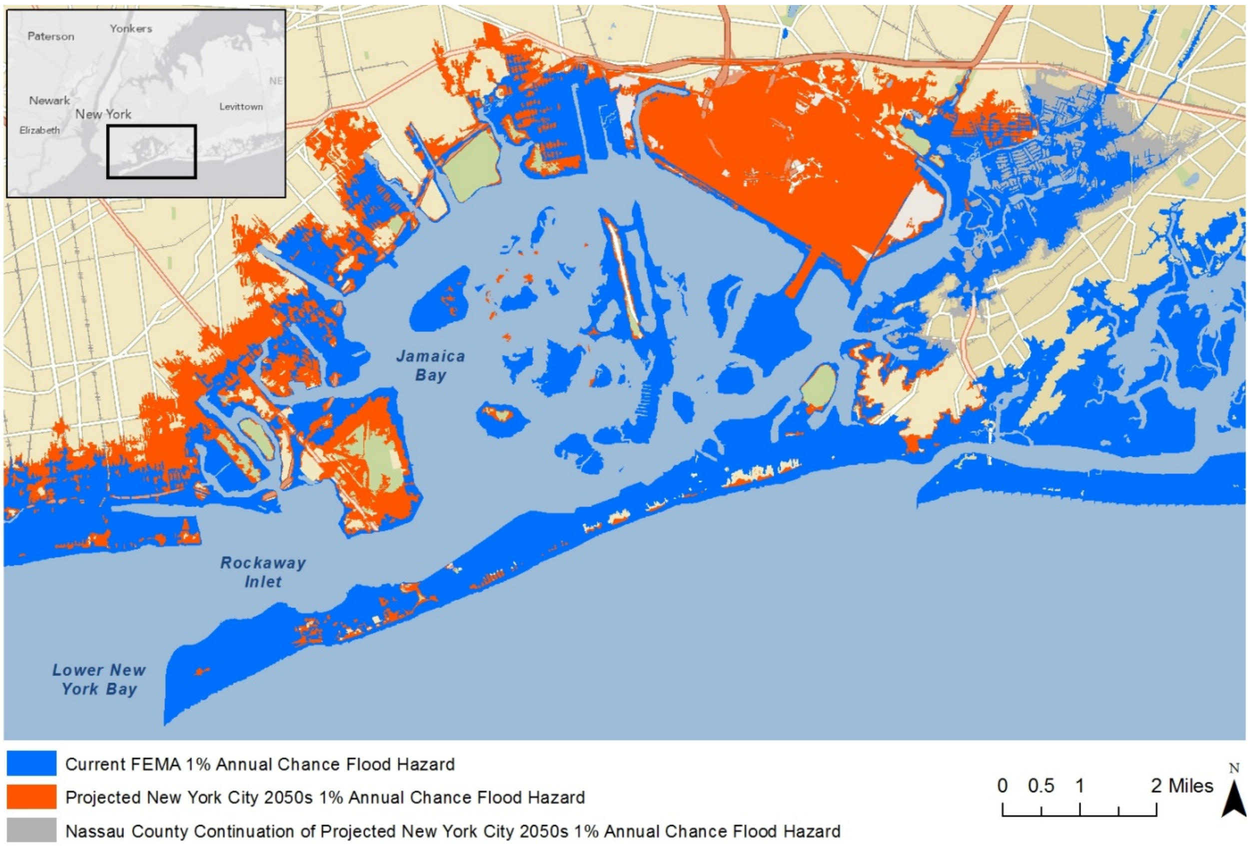


**Figure 34: Current and Projected Future 1% Annual Chance (100-year) Inundation Area**

### 2.4.2 Jamaica Bay Planning Reach Refined Reach Designations and Structural Inventory

In order to develop alternative plans and to evaluate the risk reduction provided by those plans, the study area was reconfigured from the 15 preliminary geographic reaches into six economic reaches that are defined by topographic features and existing community designations (Figure 35). Individual plans were developed for each of the six reaches. For the development and preliminary screening of alternatives, each economic reach was defined as an area (*i.e.*, a GIS polygon) which would be inundated at a stillwater elevation of +11 feet (NAVD88). Eleven feet is generally equivalent to the stillwater elevation for a storm event with 1% probability of annual occurrence in 2070 including mid-range sea level rise.

JFK Airport was not included within any of the economic reaches for which stand-alone alternatives were developed. Federal Aviation Administration regulations preclude the construction of barriers (e.g., floodwalls and levees) on airport property, which renders any alternative to directly protect the airport infeasible on an institutional basis. In addition, the airport is on relatively high ground, and nonstructural solutions may be a more appropriate solution for any flooding problems. Nevertheless, the Port Authority of New York and New Jersey has been and will continue to be consulted throughout the plan formulation process.

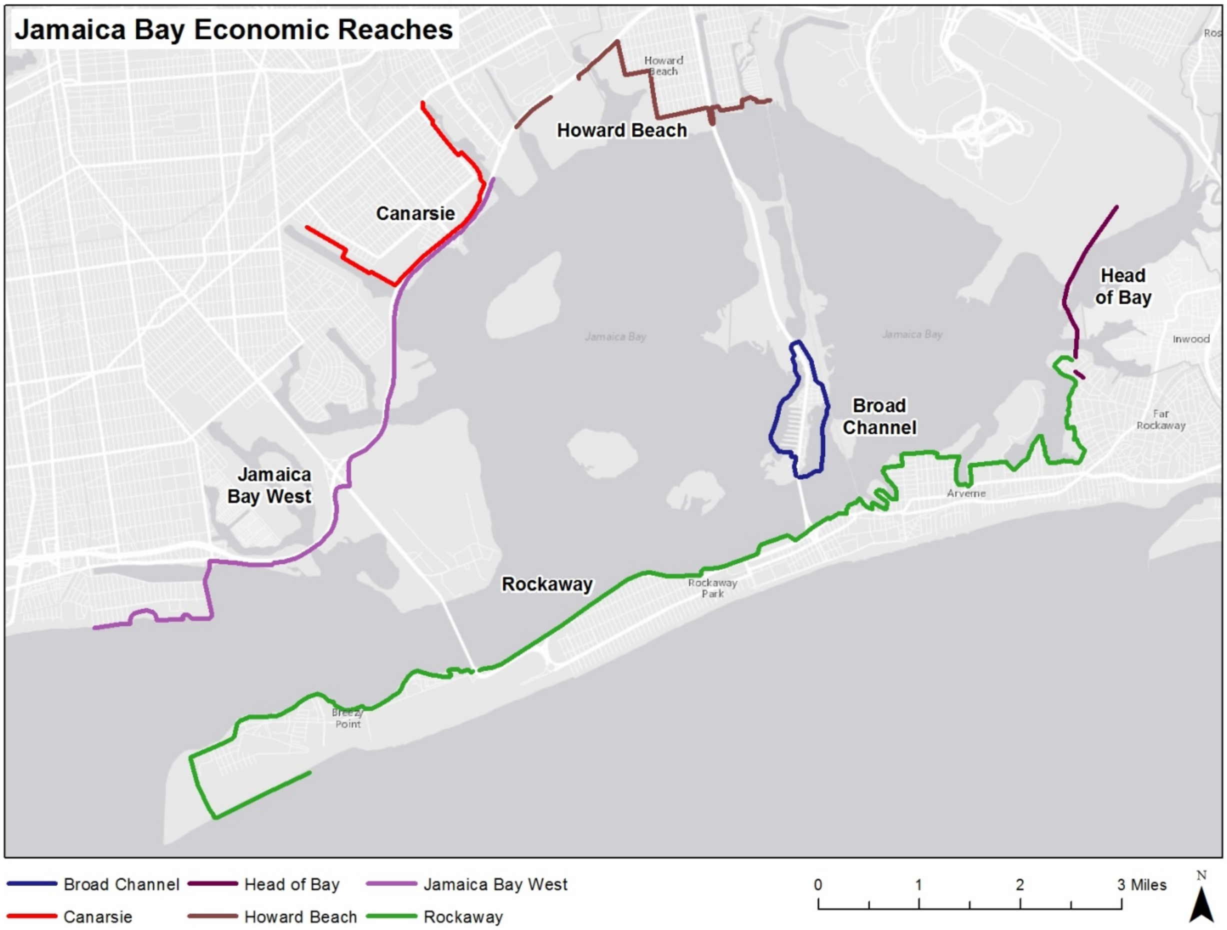


**Figure 35: Economic Reaches – Jamaica Bay**

Because much of the shoreline and adjacent uplands that surround Jamaica Bay are low-elevation permeated with numerous basins, tidal creeks, and inlets, which provide little proximate access to areas of high ground, configuring the reaches defined by a common inundation elevation reduced the number of reaches from 15 to six. Structures within low-lying areas shoreward of the adjacent uplands were assigned to these distinct reaches so that coastal storm damages may be estimated for each reach. Tables 12 -17 present the general categories and number of structures within each reach that would be inundated within the +11-foot flood height.

**Table 12: Jamaica Bay West Economic Reach Structures Within FEMA 1% Annual Chance Flood Area**

| | Occupancy Category & Description | Structures |
|---|---|---|
| RES1 | Single Family Dwellings | 7,149 |
| RES3A | Multi-Family Dwellings (Duplex) | 6,439 |
| RES3B | Multi-Family Dwellings (3-4 Units) | 1,556 |
| RES3C | Multi-Family Dwellings (5-9 Units) | 42 |
| RES3D | Multi-Family Dwellings (10-19 Units) | 17 |
| RES3E | Multi-Family Dwellings (20-49 Units) | 22 |
| RES3F | Multi-Family Dwellings (over 50 Units) | 107 |
| RES4 | Temporary Lodging (Hotel/Motel) | 2 |
| RES6 | Nursing Homes | 8 |
| COM1 | Retail Trade (Stores) | 521 |
| COM2 | Wholesale Trade (Warehouses) | 2 |
| COM3 | Personal & Repair Services | 10 |
| COM4 | Professional/Technical Services (Offices) | 144 |
| COM5 | Banks | 9 |
| COM6 | Hospital | 1 |
| COM7 | Medical Office/Clinics | 3 |
| COM8 | Entertainment, Recreation, Restaurants, Bars | 9 |
| COM9 | Theaters | 1 |
| COM10 | Multi-Unit Parking Garages | 12 |
| IND2 | Light Industrial | 14 |
| GOV2 | Government Emergency Response | 5 |
| EDU1 | Grade Schools | 36 |
| EDU2 | Colleges/Universities | 1 |
| REL1 | Church/Non-Profit | 67 |
| | **TOTAL** | **16,178** |

**Table 13: Canarsie Economic Reach Structures Within FEMA 1% Annual Chance Flood Area**

| | Occupancy Category & Description | Structures |
|---|---|---|
| RES1 | Single Family Dwellings | 1,361 |
| RES3A | Multi-Family Dwellings (Duplex) | 3,119 |
| RES3B | Multi-Family Dwellings (3-4 Units) | 584 |
| RES3C | Multi-Family Dwellings (5-9 Units) | 1 |
| RES3D | Multi-Family Dwellings (10-19 Units) | 1 |
| RES3F | Multi-Family Dwellings (over 50 Units) | 5 |
| RES6 | Nursing Homes | 2 |
| COM1 | Retail Trade | 37 |
| COM2 | Wholesale Trade (Warehouses) | 1 |
| COM4 | Professional & Technical Services | 6 |
| COM5 | Banks | 1 |
| EDU1 | Grade Schools | 8 |
| REL1 | Church/Non-Profit | 9 |
| | **Total** | **5,135** |

**Table 14: Howard Beach Economic Reach Structures Within FEMA 1% Annual Chance Flood Area**

| | Occupancy Category & Description | Structures |
|---|---|---|
| RES1 | Single Family Dwellings | 3,389 |
| RES3A | Multi-Family Dwellings (Duplex) | 908 |
| RES3B | Multi-Family Dwellings (3-4 Units) | 95 |
| RES3C | Multi-Family Dwellings (5-9 Units) | 24 |
| RES3F | Multi-Family Dwellings (over 50 Units) | 5 |
| RES4 | Temporary Lodging (Hotel/Motel) | 1 |
| RES5 | Institutional Dormitories | 1 |
| COM1 | Retail Trade (Stores) | 96 |
| COM3 | Personal & Repair Services | 3 |
| COM4 | Professional/Technical Services (Offices) | 27 |
| COM5 | Banks | 4 |
| COM7 | Medical Office/Clinics | 1 |
| COM8 | Entertainment, Recreation, Restaurants, Bars | 8 |
| IND2 | Light Industrial | 1 |
| GOV1 | Government General Services (Office) | 1 |
| GOV2 | Government Emergency Response | 2 |
| EDU1 | Grade Schools | 6 |
| REL1 | Church/Non-Profit | 7 |
| | **TOTAL** | 4,579 |

**Table 15: Head of Bay Economic Reach Structures Within FEMA 1% Annual Chance Flood Area**

| | Occupancy Category & Description | Structures |
|---|---|---|
| RES1 | Single Family Dwellings | 4 |
| RES3A | Multi-Family Dwellings (Duplex) | 20 |
| RES3B | Multi-Family Dwellings (3-4 Units) | 15 |
| RES3C | Multi-Family Dwellings (5-9 Units) | 2 |
| RES3D | Multi-Family Dwellings (10-19 Units) | 8 |
| RES3E | Multi-Family Dwellings (20-49 Units) | 1 |
| RES3F | Multi-Family Dwellings (over 50 Units) | 4 |
| RES4 | Temporary Lodging (Hotel/Motel) | 92 |
| RES5 | Institutional Dormitories | 7 |
| COM1 | Retail Trade | 6 |
| COM2 | Wholesale Trade (Warehouses) | 7 |
| COM3 | Personal & Repair Services | 233 |
| COM4 | Professional & Technical Services | 8 |
| COM5 | Banks | 1,384 |
| COM7 | Medical Office/Clinics | 6 |
| COM8 | Entertainment, Recreation, Restaurants, Bars | 5 |
| COM10 | Multi-Unit Parking Garages | 32 |
| IND1 | Heavy Industrial | 36 |
| IND2 | Light Industrial | 119 |
| GOV2 | Government Emergency Response | 9,430 |
| EDU1 | Grade Schools | 2 |
| REL1 | Church/Non-Profit | 82 |
| | **TOTAL** | 11,503 |

**Table 16: Rockaway Economic Reach Structures Within FEMA 1% Annual Chance Flood Area**

| | Occupancy Category & Description | Structures |
|---|---|---|
| RES1 | Single Family Dwellings | 3,307 |
| RES3A | Multi-Family Dwellings (Duplex) | 3,364 |
| RES3B | Multi-Family Dwellings (3-4 Units) | 729 |
| RES3C | Multi-Family Dwellings (5-9 Units) | 83 |
| RES3D | Multi-Family Dwellings (10-19 Units) | 25 |
| RES3E | Multi-Family Dwellings (20-49 Units) | 17 |
| RES3F | Multi-Family Dwellings (over 50 Units) | 44 |
| RES4 | Temporary Lodging (Hotel/Motel) | 1 |
| RES5 | Institutional Dormitories | 3 |
| RES6 | Nursing Homes | 13 |
| COM1 | Retail Trade (Stores) | 168 |
| COM2 | Wholesale Trade (Warehouses) | 6 |
| COM3 | Personal/Repair Services | 9 |
| COM4 | Professional/Technical Services (Offices) | 36 |
| COM5 | Banks | 3 |
| COM6 | Hospital | 3 |
| COM7 | Medical Office/Clinics | 2 |
| COM8 | Entertainment, Recreation, Restaurants, Bars | 3 |
| COM10 | Multi-Unit Parking Garages | 9 |
| IND1 | Heavy Industrial | 2 |
| IND2 | Light Industrial | 25 |
| GOV1 | Government General Services (Office) | 4 |
| GOV2 | Government Emergency Response | 7 |
| EDU1 | Grade Schools | 25 |
| REL1 | Church/Non-Profit | 54 |
| | **Total** | 7,942 |

**Table 17: Broad Channel Economic Reach Structures Within FEMA 1% Annual Chance Flood Area**

| | Occupancy Category & Description | Structures |
|---|---|---|
| RES1 | Single Family Dwellings | 777 |
| RES3A | Multi-Family Dwellings (Duplex) | 81 |
| RES3B | Multi-Family Dwellings (3-4 Units) | 2 |
| COM1 | Retail Trade | 17 |
| COM3 | Personal & Repair Services | 1 |
| COM8 | Entertainment, Recreation, Restaurants, Bars | 3 |
| COM10 | Multi-Unit Parking Garages | 2 |
| GOV2 | Government Emergency Response | 1 |
| EDU1 | Grade Schools | 2 |
| REL1 | Church/Non-Profit | 5 |
| | **Total** | 891 |

## 2.5 National Objective

The overall federal objective in formulating alternative plans for water resource problems is based largely on contributions to National Economic Development (NED). Contributions to NED are increases in the net value of the national output of goods and services expressed in monetary units. Contributions to NED are the direct net economic benefits that accrue in the planning area and in the rest of the nation. NED benefits for coastal storm risk management projects are the reduction in projected future coastal flooding-related damages (USACE, 2000). Because it may not be possible to express all project benefits and costs in monetary units, the most efficient alternative may not be the plan with the greatest monetary net benefits. The plan formulation analysis must identify and include the relative importance of non-monetized benefits and costs in the evaluation of alternative plans (USACE, 2013e). Planning objectives; therefore, are not limited to monetary contributions to NED.

## 2.6 Planning Objectives

Objectives are the measurable outcomes of effective plans to avoid, reduce, or mitigate the problems; planning objectives must address the identified problems. In addition, planning objectives must be measurable so that alternative plans may be evaluated on their effectiveness and efficiency in meeting planning objectives.

In the aftermath of Hurricane Sandy, many potential actions have been proposed to reduce storm-related effects to the region. After a thorough review of the published literature as well as meetings with communities and other stakeholders, five principal planning objectives have been identified. These planning objectives are intended to be achieved throughout the projected life of the project, which is from 2020 – 2070. The planning objectives for the Jamaica Bay portion of the East Rockaway Inlet to Rockaway Inlet and Jamaica Bay Reformulation Study include:

6. Reduce vulnerability to storm surge impacts;
7. Reduce future flood risk in ways that will support the long-term sustainability of the coastal ecosystem and communities;
8. Reduce the economic costs and risks associated with large-scale flood and storm events;
9. Improve community resiliency, including infrastructure and service recovery from storm effects; and
10. Enhance natural storm surge buffers (NNBFs) and improve ecosystem resiliency

Each of these objectives has the potential to address at least two of the identified problems. All of the problems may be addressed if multiple objectives are achieved. Table 18 depicts the problems addressed by each objective.

**Table 18: Problems and Objectives Matrix**

| Objectives | Problem 1: Storm Surge Damages | Problem 2: Insufficient Resiliency | Problem 3: Environmental Degradation | Problem 4: Human Health & Safety Impacts |
|---|---|---|---|---|
| Reduce Vulnerability | X | - | - | X |
| Reduce Flood Risk while Supporting Sustainability | X | - | X | X |
| Reduce Economic Costs and Risks | X | - | - | - |
| Improve Community Resiliency | - | X | X | X |
| Enhance Natural Buffers and Ecosystem Resiliency | X | X | X | - |

In order for USACE to support the long-term sustainability of the coastal ecosystem and communities and reduce the economic costs and risks associated with large-scale flood and storm events (as directed in the Disaster Relief Appropriations Act of 2013), planning for CSRM requires an integrated strategy for reducing coastal risks and increasing human and ecosystem community resilience. Integration occurs through formulating alternatives using a combination of the full array of measures, which includes natural, nature-based, nonstructural, and structural measures. These measures are fully defined in Section 3: Alternatives. The full range of environmental and social benefits produced by the component features of an alternative plan must be evaluated to meet the National Objective. Integration of natural and nature-based features requires improved quantification of the value and performance of NNBFs for coastal risk reduction. In order to fulfill the National Objective and the directives of the Disaster Relief Appropriations Act of 2013, this analysis will:

- Evaluate NNBFs, not as stand-alone features, but as part of an integrated system and in combination with other measures; and
- Develop a consistent approach to valuing the benefits of NNBFs that contribute to coastal storm risk reduction and improved resilience.

Alternative plans are developed to achieve the identified planning objectives. Metrics are developed to measure the effectiveness and efficiency with which alternative plans achieve these objectives. Reductions in vulnerability are evaluated by measuring projected reductions in coastal storm risk and associated reductions in projected monetary damages.

Improvements to resiliency also are evaluated, in part, by measuring projected reductions in coastal storm risk and associated reductions in projected monetary damages. Improvements to resiliency are likely to be a function of reducing the time-to-recovery and may also be influenced by bringing the more important systems back on-line before other services. The prioritization of infrastructure and systems is likely to be informed by the effects on human health and safety.

The enhancement of natural buffers and ecosystem resiliency also are evaluated, in part, by measuring projected reductions in coastal storm risk and associated reductions in projected monetary damages. The enhancement of natural buffers and ecosystem resiliency also is likely to be evaluated in terms of the acreage of habitat provided and the cost effectiveness of providing that habitat.

## 2.7 Planning Constraints

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that limit what could be done and are recognized as constraints because they should not be violated in the planning process. The planning constraints identified in this study are as follows:

- Do not negatively impact ongoing recovery, ecosystem restoration, and risk management efforts by others;
    - There are multiple agencies, which are planning and constructing infrastructure, ecosystem, and risk management improvements within the project area. Some of this work is in response to Hurricane Sandy, other efforts are part of other ongoing programs (e.g., National Park Service's Gateway National Recreation Area General Management Plan (NPS, 2014), New York City Department of Environmental Protection's Jamaica Bay Watershed Protection Plan (NYCDEP, 2007);

- Do not negatively impact navigation access through Rockaway Inlet;
  - The Federal navigation channel serves navigation interests including commercial cargo transport, charter fishing fleets, and recreational boaters, which use marinas within Jamaica Bay as their homeport;
- Do not induce flooding in areas not currently vulnerable to flooding and do not induce additional flooding in flood-prone areas;
- Do not reduce community access and egress during emergencies;
  - Island and peninsular communities within the study area currently have limited access, egress, and emergency evacuation routes;
- Do not impact operations at John F. Kennedy International Airport.
- Do not negatively affect plants, animals, or critical habitat of species that are listed under the Federal Endangered Species Act or a New York State Endangered Species Act.

# 3 ALTERNATIVES

This chapter describes the development of alternative plans based on screened measures and the evaluation of alternative plans. Plan selection is based on the plan's ability to meet the planning objectives within the planning constraints.

Structural and non-structural management measures, including NNBFs, were developed to address one or more of the planning objectives. Preliminary alternative plans will be developed from the most effective measures based on professional judgment and will be evaluated using available mapping tools and data, and very preliminary estimates of project costs and benefits. A viable array of alternatives will be selected for more detailed analysis.

Alternative plans proposed for CSRM in one portion of the study area must be formulated to function complementarily with alternative plans proposed in other portions of the study area For this project, an iterative process screens measures to address area specific vulnerabilities. Subsequent analysis within the feasibility phase will ensure that the Atlantic shoreline measures function in concert with the Jamaica Bay measures. Initial screening considers the damage mechanisms for each distinct area, which are described separately.

Plan formulation for the East Rockaway Inlet to Rockaway Inlet and Jamaica Bay Reformulation Study has been conducted in accordance with the six-step planning process described in *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (1983) and the *Planning Guidance Notebook* (ER 1105-2-100, dated April 2000).

## 3.1 Management Measures – Atlantic Ocean Shorefront Planning Reach

Management measures developed for the Atlantic shoreline portion of the study area include no action, non-structural, and structural measures. The following paragraphs briefly describe the objective and the evaluation of each measure.

*Continue Existing Practice (No Action).* Under No Action, no additional measures would be taken to provide for storm damage protection at the Atlantic shoreline portion of the study area. Section 934 authorized the placement of dredged material from East Rockaway Inlet channel on the beach as nourishment material, which provided temporary beach nourishment; however, no long-term planning and engineering were conducted. This plan fails to meet any of the objectives or needs of the project. While this measure was not considered for further development, it does provide the basis by which the with-project benefits are measured. Additionally, this measure would be implemented if project costs far exceed project benefits thus indicating that shore protection measures are not in the Federal interest under current NED guidelines.

Non-Structural Measures. Non-structural measures include buy-out, floodplain management/zoning, and floodproofing/elevated building, and road raising. These plans are discussed briefly below and developed in more detail in a separate section.

- ***Floodplain Management /Zoning.*** Through proper land use regulation, floodplains can be managed to insure that their use is compatible with the severity of a flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce losses by controlling the future use of floodplain lands.
- ***Acquisition.*** This measure includes permanent evacuation of existing areas subject to storm damage and/or inundation. This plan involves the acquisition of this land and its structures, either by purchase or by exercising the powers of eminent domain. Following this action, all development in these areas is either demolished or relocated.
- ***Relocation.*** This measure includes moving the structure out of the floodplain, either within the existing property boundary (if sufficient space is available) or to another property;
- ***Rebuild.*** This measure involves demolishing an existing flood-prone structure and replacing with a new structure built to comply with local regulations regarding the new construction and substantial improvements in a floodplain, and therefore at a lower risk;
- ***Floodproofing /Elevated Building.*** Floodproofing and raising of the basement and/or first floor elevation, by definition, is a method for preventing damages due to floods, and requires adjustments both to structures and to building contents. It involves keeping water out of structures, as well as reducing the effects of water entry. Such adjustments can be applied by an individual or as part of a collective action, either when buildings are under construction or as part of a remodeling or retrofitting of existing structures. Floodproofing and raising building elevation, like other methods of preventing flood damages, has its limitations. It can generate a false sense of security and discourage timely evacuations. It fails to protect non-building assets such as automobiles, utilities and landscaping. Indiscriminately used, it tends to increase the uneconomical use of floodplains resulting from unregulated floodplain development.

Structural Measures. Structural measures evaluated for use at the Atlantic shoreline portion of the study area include sediment management and beach restoration.

- ***Sediment Management.*** In addition to the existing practice of placing channel maintenance dredging material on beach, littoral material deposited in both Rockaway and East Rockaway channels will be periodically bypassed or back-passed on the beach. Sediment bypassing or backpassing can be achieved via hydraulic pumping from sediment deposition basin downdrift of the inlet jetty, or re-distribute excess sediment accumulation from an updrift jetty to eroded shoreline. This alternative may be combined with other measures to provide improved results.

- ***Beach Restoration***. Beach restoration involves the placement of sand from a borrow source on an eroding shoreline to restore its form and to provide an adequate protective beach. A beach fill typically includes a berm backed by a dune and both elements combine to prevent erosion and inundation damages to leeward areas. For Rockaway beaches along the Atlantic shoreline, a high berm was used instead of combination of dune and beach. Beach restoration requires the periodic placement of beach sand to offset erosion of the beach fill thus maintaining an adequate level of protection. Storm-induced erosion, however, may be severe, requiring significant rehabilitation of the fill section, as well as a high level of residual damage. As long-term and storm-induced erosion at some critical project sites are extreme, renourishment and rehabilitation may prove costly. In this regard it is advisable to consider a beach restoration alternative in concert with structural options which provide either redundant shore protection in the event of severe storms or stabilize the beach fill against long-term erosion. Beach restoration is considered an essential element of project planning at the project site, and, consequently, is carried forward for more detailed evaluation as a single corrective action and as a complementary feature of all other alternatives.

## 3.2 Management Measures – Jamaica Bay Planning Reach

The USACE Project Delivery Team used previous USACE investigations, Rockefeller Foundation analyses supporting the Science and Resiliency Institute at Jamaica Bay's "Towards a Master Plan for Jamaica Bay" initiative, and meetings with local stakeholders to identify the universe of potential measures that may be applicable to the Jamaica Bay component of the Reformulation Study. A comprehensive inventory of proposals compiled as part of the stakeholder outreach facilitated by the Science and Resiliency Institute at Jamaica Bay was reviewed to identify the breadth of measures to be considered for the study. The measures evaluated in this analysis are listed in Table 19 and discussed in greater detail in the following sections.

**Table 19: Comprehensive Inventory of Measures Evaluated for Jamaica Bay**

| Nonstructural Measures | NNBF Measures |
|---|---|
| Acquisition | Living shoreline |
| Managed Retreat | Wetland |
| Floodplain zoning | Maritime forest |
| Floodproofing | Reef |
| Flood warning system | Dunes and Beaches |
| **Structural Measures** | Swale/Channel |
| Flood gate | **Other Measures** |
| Hurricane barrier | Bay shallowing |
| Levee | Storm water improvement |
| Floodwall | Wastewater treatment |
| Bulkhead/Seawall | Park access and recreation |
| Breakwater | Evacuation routes |

### 3.2.1 Preliminary Measure Evaluation Criteria

Preliminary screening criteria were developed from the planning objectives, including:

- Can the measure provide either CSRM or ecosystem restoration benefits, in accordance with USACE Civil Works missions and authorities;
- Is the measure effective in providing CSRM benefits (reduce vulnerability, flood risk, and economic costs associated with coastal storms) or ecosystem benefits either as a stand-alone measure or as a part of a larger system when joined with other measures;
- Can the measure provide improvements in resiliency sustainability which include reductions of the time-to-recovery for the natural coastal ecosystem and for communities; and
- Can the measure also provide improvements in habitat quantity and quality for restoration, mitigation or other regulatory purposes?

### 3.2.2 Nonstructural Measures Evaluation

Nonstructural measures were fully considered in plan formulation. Four nonstructural measures were identified as potentially applicable to flood damage reduction in the study area, including: acquisition of flood-prone property, floodplain zoning, floodproofing, and flood warning systems. None of these nonstructural measures were carried forward as potential stand-alone alternatives, however; some measures were carried forward as potential complements to structural measures. The screening of nonstructural measures is summarized below.

### 3.2.3 Acquisition of Flood-Prone Properties

Permanent evacuation of the floodplain involves acquisition of land and structures by fee purchase, either voluntarily or by exercising powers of eminent domain. Following acquisition, all structures and improvements are demolished or relocated out of the floodplain. With the high number of structures in the 100-year floodplain and lack of available undeveloped flood-free properties in the region, the depreciated replacement cost of structures and relocation costs make wholesale acquisition prohibitively expensive.

New York State has established the NY Rising Buyout and Acquisition Program for homeowners whose homes were substantially damaged or destroyed during Hurricane Sandy, Hurricane Irene, and tropical Storm Lee. The program is fully voluntary and does not exercise eminent domain. Buyouts performed under the NY Rising Buyout and Acquisition Program are defined as purchases from within designated areas to reduce the continual risk of flood impacts. The are no NY Rising Buyout and Acquisition Program designated areas within the study area. Acquisitions are defined as purchases in areas outside the buyout area. Buyouts will be maintained in perpetuity as coastal buffer zones, while properties purchased as acquisitions will be eligible for redevelopment in the future in a resilient manner to protect future occupants of this property.

Although acquisition is unlikely to have a major role in any alternative plan, this measure is carried forward for further consideration as a potential complement to structural measures in alternative plans.

### 3.2.4 Managed Retreat

Managed retreat is a policy of allowing natural shoreline erosion to occur and incrementally removing or relocating shoreline structures and infrastructure as they eventually become unsafe for intended use. Land acquisition may be an element of a managed retreat policy. Managed retreat is not being carried forward as a measure which would be implemented on a large scale. However, small scale managed retreat may be a non-structural component of a larger, comprehensive plan for the study area.

### 3.2.5 Floodplain Zoning

Through proper land use regulation, floodplains can be managed to ensure that their use is compatible with the severity of a flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building and housing codes. Their purpose is to reduce future losses by controlling the future use of floodplain lands. New York City and Nassau County participate in the National Flood Insurance Program and manage floodplain land uses consistent with the program. In response to Hurricane Sandy, New York City has amended its zoning regulations (Flood Resilience Zoning Text Amendment, adopted by the City Council on 09 October 2013) to promote rebuilding and to increase the city’s resilience to future coastal floods and storm surge. However, most of the buildings in the study area floodplain were built prior to the adoption of the revised zoning regulations and are not affected by current floodplain zoning regulations. Therefore, zoning, as a planning measure, cannot be considered independently as a long-term solution for flood damage reduction to existing structures. However, it is a necessary component of a comprehensive future flood damage reduction plan. This measure is not carried forward for further consideration as a planning measure because of the limited effectiveness zoning regulations have on existing structures.

### 3.2.6 Floodproofing

Floodproofing reduces flood damages through adjustments to existing structures and relocation of susceptible building contents. Floodproofing techniques involve keeping water out of the structure, as well as reducing the effects of inundation. Floodproofing adjustments, such as the elevation of structures, can be applied by an individual or as part of a collective action through retrofitting an existing structure. Floodproofing, as a stand-alone alternative, was found to be prohibitively expensive, since a majority of structures would require costly raising and many structures are multilevel and multiuse with commercial uses on the ground floor. While eliminated as a major element in the formulation of alternative plans, limited floodproofing was retained for further consideration as a potential complement to structural measures in alternative plans.

### 3.2.7 Flood Warning Systems

Flood warning systems can be utilized to warn property owners of pending floods and provide time for safe evacuation and relocation of movable property subject to flood damage.

New York City Office of Emergency Management has a Coastal Storm Plan, which has been in effect since 2000. This plan was updated in 2006 and was implemented during Hurricane Sandy. The New York City and Nassau County Offices of Emergency Management have designated the areas within their respective jurisdictions within Jamaica Bay as either Evacuation Zone 1 or Evacuation Zone 2, which are the most at-risk zones for flood hazards due to coastal storms. The single exception is JFK Airport, which is designated as Evacuation Zone 3. The New York City Mayor and Nassau County Executive may recommend or order an evacuation. Evacuation routes, evacuation centers, and preparedness actions have been identified by the City and the County, and are widely disseminated and available to the public.

Although state-of-the-art coastal storm warning systems and emergency plans are in place, a warning system and emergency plan alone would not provide sufficient time to significantly reduce flood damages. This flood damage reduction measure, while important as a project feature, was eliminated from further consideration as a stand-alone planning measure.

### 3.2.8 Structural Interventions Evaluation

The following sections identify and evaluate structural measures based on the criteria identified in Section 3.2.1. For those measures being carried forward for more detailed analysis, a discussion of potential CSRM benefits is provided. Ecosystem benefits of living shorelines are considered in terms of habitat created in this initial screening analysis. More thorough assessment of ecosystem benefits and potential impacts of all structural measures, including considerations such as sedimentation impacts, water quality regulation, and salinity will be evaluated in the next, detailed evaluation phase of the Reformulation Study.

### 3.2.9 Flood Gates

Flood gates are defined herein as "an opening through which water may flow freely when the tide moves in one direction, but which closes automatically and prevents the water from flowing in the other direction," (USACE 2013d). Flood gates prevent flood waters from entering the protected area and flooding the region. When the water level inside the protected area is higher, the flood gates open, allowing water to flow away from the region (Charland 1998). In this manner, flood gates ensure that water does not flow backwards through drainage infrastructure effectively reducing flood risk by maintaining low tide conditions.

A flood gate provides CSRM benefits, specifically the ability to reduce the vulnerability to major and higher frequency storms over time through flood inundation reduction. Important factors that can influence the performance of a flood gate include the wave period and water levels in the region. Flood gates located on tributaries to Jamaica Bay would very likely require adjacent measures, such as levees or floodwalls over land, to provide CSRM benefits for major storm events doe to the predominantly low elevation of adjacent lands.

This measure is being carried forward for further evaluation in this Reformation Study.

### 3.2.10 Hurricane Barrier

Hurricane Barriers are defined herein as "large moveable in-water gates and connecting levees or floodwalls on adjacent shores" (SIRR, 2013), which is consistent with the Storm Surge Barrier originally authorized in 1965, but never constructed. Hurricane barriers are designed to permit normal maritime and boating operations in non-storm conditions; however, in advance of a severe storm event, the barrier can be closed in an effort to prevent upland regions from being exposed to extensive flooding. Gate operating procedures would be determined during the design phase, which would to identify the storm criteria used to trigger gate closure.

A Storm Surge Barrier provides CSRM benefits, specifically the ability to reduce the vulnerability to major and higher frequency storms over time through surge and wave attenuation. Important factors that can influence the performance of a Storm Surge Barrier include the barrier height, wave height, wave period, and water levels in the region.

This measure is being carried forward for further evaluation in this Reformation Study.

### 3.2.11 Levee

A levee is defined herein as a "(1) a ridge or embankment of sand and silt, built up by a stream on its floodplain along both banks of its channel, or (2) a large dike or artificial embankment, often having an access road along the top, which is designed as part of a system to protect land from floods," (USACE 2013d). Levees are a traditional approach to flood management that provides flood protection for upland communities (SIRR 2013).

A levee provides CSRM benefits, specifically the ability to reduce the vulnerability to major and higher frequency storms over time, through surge and wave attenuation and/or dissipation. Important factors that can influence the performance of a levee include the levee height, levee slope, levee crest width, wave height, wave period, and water levels in the region (USACE 2013d). Levees within Jamaica Bay would likely require adjacent measures, such as a flood gate in some reaches, to provide benefits for major storm events due to the many inlets and creeks throughout the study area. Levees could be an integral component of living shorelines designed to provide CSRM and ecological benefits.

This measure is being carried forward for further evaluation in this Reformation Study.

### 3.2.12 Floodwall

As defined herein, a floodwall is a "wall, retired from the seaward edge of the seawall crest, to prevent water from flowing onto the land behind," (USACE, 2013d). Floodwalls block surge and attenuate waves.

A floodwall provides CSRM benefits, specifically the ability to reduce the vulnerability to major and higher frequency storms over time, through surge and wave attenuation and/or dissipation. Important factors that can influence the performance of a floodwall include the floodwall height and geometry, wave height, wave period, and water levels in the region. Floodwalls within Jamaica Bay would likely require adjacent measures to provide benefits during major storm events due to the many inlets and creeks within the study area.

This measure is being carried forward for further evaluation in this Reformation Study.

### 3.2.13 Bulkhead and Seawall

As indicated in the *Design of Coastal Revetments, Seawalls and Bulkhea*ds, issued by USACE:

> The terms bulkhead and seawall are often used interchangeably. However, a bulkhead is primarily intended to retain or prevent sliding of the land, while protecting the upland area against wave action is of secondary importance. Seawalls, on the other hand, are more massive structures whose primary purpose is interception of waves. Bulkheads may be either cantilevered or anchored (like sheetpiling) or gravity structures (such as rock-filled timber cribs). Their use is limited to those areas where wave action can be resisted by such materials (USACE 1995).

Bulkhead and seawall structures provide CSRM benefits, specifically the ability to reduce the vulnerability to major and higher frequency storms over time, through their ability to reduce flooding, reduce wave overtopping and stabilize the shoreline behind the structure. Important factors that can influence the performance of a bulkhead or seawall include wave height, wave period and water levels in the region, as well as scour protection. Bulkhead and seawall structures within Jamaica Bay would likely require adjacent measures to provide benefits for major storm events due to the many inlets and creeks within the study area.

This measure is being carried forward for further evaluation in this Reformation Study.

### 3.2.14 Breakwater

As defined herein, a breakwater is a structural feature composed of rock or other earthen materials, located in an ocean or bay, to attenuate wave energy offshore (SIRR, 2013), which is consistent with the application of breakwaters for flood protection in the USACE document, "Cooperative Beach Erosion Control and Hurricane Study" (USACE 1964). Breakwaters absorb the force and energy from waves prior to the water reaching the coast and upland areas.

Breakwater structures can provide CSRM benefits, including the ability to reduce the vulnerability to major and more frequent storms over time through wave attenuation and shoreline stabilization behind the breakwater. There are many factors that can influence a breakwater's ability to meet CSRM goals, including wave height and water level in the region, as well as breakwater geometry, breakwater permeability, and breakwater location and orientation (USACE 2013c). In addition, breakwater structures can provide improvements in aquatic habitat through their ability to reduce coastal erosion and wave damage reduction, while providing new habitats for in-water organisms.

It should be noted that floating breakwaters were also considered as an option for wave attenuation, but they will not be carried forward for further evaluation. Floating breakwaters are a reasonable wave attenuation alternative in regions with relatively steady wave climates, caused by winds or boat wakes. However, in regions exposed to highly variable conditions, such as regions prone to hurricanes and Nor'easters, floating breakwaters are unlikely to effectively provide CSRM benefits. This is due to both mooring requirements (anchors would need to be heavily over-designed for normal conditions to ensure the breakwater did not break away during a severe storm) and design dimensions (which must be tailored to the characteristics of the waves to be attenuated).

Stationary breakwaters are being carried forward for further evaluation in this Reformation Study.

### 3.2.15 Bay Shallowing

Two types of bay shallowing strategies have been proposed in Jamaica Bay. The first is a strategy of reducing channel or inlet depths to moderate the tidal prism in the bay. Note that this measure would necessarily impact navigation within Jamaica Bay. Reducing the tidal prism would lead to a reduction in storm tide elevations and extents for most storm events. Though this measure has not been examined extensively, the concept has the potential to provide significant CSRM benefits. Major storms impact basins like Jamaica Bay by initially filling the basin and then "tilting" the raised water levels in the basin as high winds pass. Initial filling rates vary with each storm. However, this strategy would be particularly beneficial for storms with a relatively fast forward speed and/or small radius to maximum winds, where the initial filling could be most substantially reduced. Additionally, the effect of reducing the initial filling has an additional reduction in the localized tilting, due to the shallower water depths at the time of high winds.

Furthermore, the inlet shallowing measure has the potential to provide ecological and resiliency related benefits by introducing sediment and maintaining sediment in the bay due to the reduction in the tidal prism and the associated reduction in sediment transport out of the bay. An increase in sediment availability could improve overall wetland sustainability, particularly when considering SLC. An adverse impact of this concept is the diminished flushing in the bay, likely substantially impacting water quality.

Ultimately, this measure is not being carried forward as a part of this project due to its conflict with USACE navigation projects in Jamaica Bay. To be effective, the entrance channel to the bay would have to be significantly shallowed to reduce the advance of the surge. Deauthorization of the existing navigation projects, most notably the channel in Rockaways Inlet, would need to occur to move this concept forward. Since this solution is not more effective than other alternatives, it is not recommended that navigation interests be altered to allow this to be implemented.

The second form of proposed shallowing focuses on the infilling of borrow pits throughout the bay. Borrow pits, particularly the deepest pits adjacent to JFK airport and in other locations, are a concern for pollutant and low dissolved oxygen levels. Residence time in these borrow pits is long. Filling borrow pits could serve as a means to cap pollutants, decrease residence time in many bay waters, and add a one-time sediment source to the bay, improving water quality and ecological health in the bay. These improvements would result in a more sustainable and resilient ecosystem; however, the objective of this study is to provide direct ecological and resiliency benefits along with CSRM benefits in a cost effective manner. The potentially minimal direct benefits and expected high costs associated with filling the borrow pits results in measures that will not be carried forward, particularly when compared the expected benefits of other proposed nature based solutions.

To further investigate cost effectiveness of inlet shallowing, potential fill volumes and costs have been approximated to partially fill various reaches (for a detailed discussion see *Rockaway Inlet to East Rockaway Inlet and Jamaica Bay Reformulation Study Memorandum for the Record (MFR) #1)*. Fill volumes are calculated based on an assumed flat surface at a given bathymetric elevation to approximate the volume necessary to fill the deepest portions of the reach to a constant elevation. For instance, a fill depth of 25 feet, NAVD88 implies that all deeper bathymetry will be filled to that elevation and all other portions of the reach remain constant (i.e., higher elevations are not lowered).

Costs are computed based on available estimates. According to the analyses completed as part of “Blue Dunes – The Future of Coastal Protection” for Rebuild by Design, the WXY/West 8 team calculated the cost of offshore fill and found that costs range from $2.52 to $5.08 dollars per cubic yard for dredge and placement of large quantities (2013). This range is dependent upon primarily the source location and these numbers are also applicable to the large scale shallowing effort for the Bay.

Inlet shallowing to a depth sufficient to provide CSRM benefits is likely prohibitively expensive. In order to sufficiently reduce the tidal prism in the inlet, an elevation in the range of -5 to -10 feet, NAVD88 is likely necessary. Initial fill costs without maintenance range from a low of $3.6 billion to fill reaches 12, 13, and 15 to a depth of -10 feet to a high of $23.2 billion to fill the same reaches to a depth of -5 feet.

This measure is not being carried forward for further evaluation by this Reformation Study based on the expected cost of implementation and maintenance, conflict with USACE navigation projects in Jamaica Bay, and lack of direct ecological and resiliency benefits.

## 3.3 Natural and Nature-Based Features / Measures Evaluation

Natural features are created by and evolve over time through the actions of physical, biological, geologic, and chemical processes operating in nature. Nature-based features are those that may mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as CSRM and improved resiliency. Nature-based features are acted on by the same physical, biological, geologic, and chemical processes operating in nature, and as a result, they generally must be maintained in order to reliably provide the intended level of services (USACE 2013d).

Natural and nature-based features (NNBFs) can enhance the resilience of coastal areas challenged by sea level change (Borsje et al., 2011) and coastal storms (Gedan et al., 2011; Lopez, 2009) because the natural system can be adaptive to climate change (Shepard et al., 2011), mitigate coastal hazards (Barbier et al., 2011; Barbier et al., 2013), and in many cases are able to recover and regenerate following damages (Paling et al., 2008; Spalding et al., 2013). While NNBFs may provide CSRM benefits for daily wind wave climates or high frequency storms that produce low flood elevations compared to major storms, NNBF effectiveness may be overwhelmed when facing low frequency, major storms (Resio and Westerink 2008; Feagin et al., 2010). Slow moving storms and those with a long duration of high winds cause extreme flooding and reduce the surge reduction benefits of wetlands (Resio and Westerink 2008).

Depending on the storm tide and wave characteristics that ultimately define a major storm in this study - which will be determined at a later phase - CSRM benefits for NNBFs previously identified by other USACE reports or other agencies and organizations may not be applicable for all storms, particularly when considering SLC projections. However, it's important to note that CSRM and resiliency benefits are likely still present for a wide range of storm events, as discussed below.

NNBFs may also provide ecosystem resiliency by providing transitional areas, which allow for natural retreat and transition of wetland types in response to sea level rise and storm induced erosion. NNBFs can additionally provide required mitigation within Jamaica Bay to offset potential unavoidable impacts to waters and wetlands, threatened and endangered species, and/or water quality. In addition, engineered structural interventions may require a softening or green component (i.e., integration of NNBFs) to satisfy federal or state regulatory conditions associated with the Clean Water Act Sections 404 and 401, New York State Tidal Wetland Act and Freshwater Wetland Act, and/or federal and New York State endangered species acts.

The following text summarizes whether each NNBF measure or feature is being carried forward for further evaluation in the Reformation Study based on potential benefits related to CSRM, resiliency, and/or regulatory and mitigation value.

### 3.3.1 Living Shorelines

Living shorelines are defined herein as coastal edges that incorporate a combination of reefs, breakwaters, maritime or coastal forests or shrub communities, and fresh and tidal wetlands to reduce wave action and erosion, while providing resiliency and habitat restoration benefits. Living shorelines can be combined with a structural intervention, such as a levee, creating what is also known as a hybrid intervention (Spalding et al., 2013), to provide CSRM benefits. Figures 36 and 37 depict examples of hybrid interventions to create a single measure. Both include a structural intervention at the inland extent of the living shore. The structural intervention in these diagrams is similar to a levee, while the living shoreline is depicted as coastal wetlands and maritime forest.

The two measures differ only in the slope of the land between the levee toe and the bay shoreline. Both measures provide CSRM benefits, which are largely driven by the levee design parameters for major storms, and resiliency and ecological benefits related to the living shoreline. The measure shown in Figure 37 provides additional CSRM and resiliency benefits as compared to the measure shown in Figure 36, due to the improved wave attenuation potential resulting from the more gradual slope from the top of the structure to the bay's edge. Note that USACE regulation does not allow planting directly on a levee. The additional fill is more costly for this measure: however, the wave attenuation would likely result in a reduced design elevation, offsetting measure costs. The living shoreline would typically result in a lower crest elevation than would be required for a "hard' structure because the extended slope of the living shoreline, which would not be incorporated into a "hard" structure, provides CSRM through wave attenuation.

From a CSRM perspective, in order effectively manage storm tide impacts during a major storm, it is assumed for this Reformulation Study that a living shoreline will slope up from the bay to a design elevation at its inland extents, incorporating maritime forests and/or structural interventions using solutions like those shown in Figures 36 and 37. Through cooperation with project stakeholders for funding purposes, the structural intervention could also incorporate a social / recreation feature (i.e., walking / bike path).

From ecological and social perspectives, a living shoreline can provide the following benefits:

- Shoreline stabilization;
- Ecosystem and community resiliency;
- Water quality / biogeochemical functioning;
- Native plant community restoration, and in turn terrestrial habitat services or functions;
- Aquatic habitat restoration, either structural (i.e., reef) or vegetative (i.e., eel grass bed); and
- Integration in public shoreline access providing community social value.

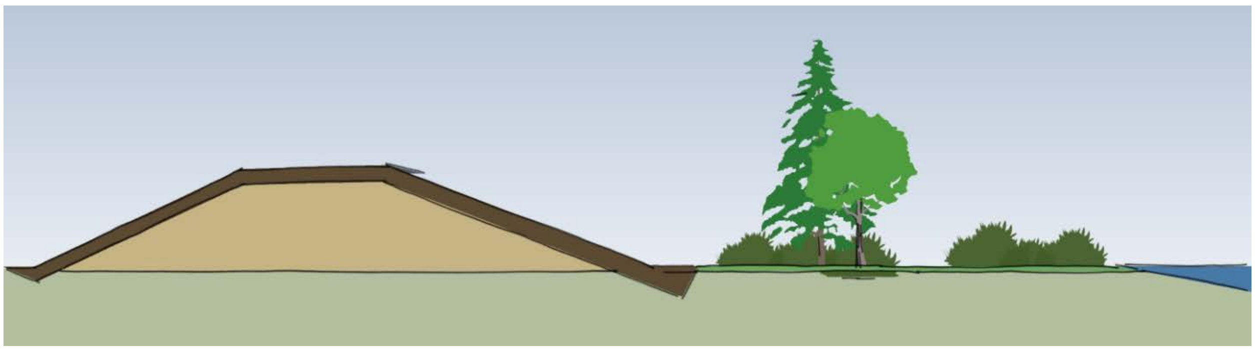

**Figure 36: Living Shoreline Typology (a)**

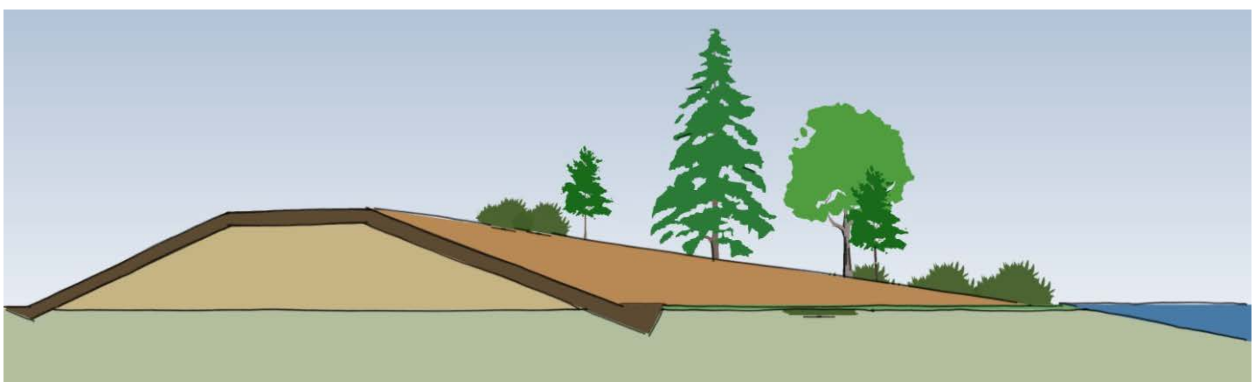

**Figure 37: Living Shoreline Typology (b)**

This measure is being carried forward for further evaluation in this Reformation Study.

### 3.3.2 Coastal Wetlands

Coastal wetlands are defined herein as areas tidally influenced and connected to open waters that are inundated or saturated by surface- or ground-water frequently enough to support vegetation that thrives in wet soil conditions. Wetland restoration measures (assumed to be inclusive of enhancement, restoration or creation) evaluated by this Reformulation Study were either stand-alone projects (e.g., restoration of marsh islands) or complementary of other measures (e.g., part of living shoreline).

For some storm events, the dense vegetation and shallow water in wetlands can slow the advance of storm surge somewhat and slightly reduce the storm surge or slow its arrival time (Wamsley et al., 2009 and 2010). Wetlands can also dissipate wave energy, potentially reducing the amount of destructive wave energy propagating on top of the surge. However, the degree to which waves are attenuated and surge are buffered depends on water depth, vegetation morphology, plant stiffness, the wetland footprint, and wave dynamics (Nepf and Vivoni 2000; Nikora et al., 2001; Lowe et al., 2007; Irish et al., 2008; Suzuki et al., 2008; Lövstedt and Larson 2010; Gedan et al., 2011; Chen and Zhao 2012; Barbier, 2013). For instance, vegetative resistance is influential when the vegetation roughness layer takes up an ample portion of the total water depth (Nepf and Vivoni 2000; Wilson and Horritt 2002). During high frequency, low impact storms, coastal wetlands are near emergent or moderately submerged, which contribute to CSRM through wave attenuation, sediment stabilization, and/or surge reduction. As a stand-alone measure in Jamaica Bay, Due to the extensive wetland acreage that would be required to produce significant levels of CSRM benefits, a wetland project would not be appropriate as a standalone measure. The CSRM benefit of a wetland project would likely be negligible for major storms since extensive wetland acreage is not available in Jamaica Bay (Fritz and Blount 2007).

Based on available literature, it has been determined that stand alone wetland restoration projects likely will not provide substantial CSRM benefits within Jamaica Bay for major storms. This will be confirmed once the storm tide and wave characteristics associated with a major storm are defined in a later phase of this Reformulation Study. Regardless of the parameters defining a major storm, it is recognized that in higher frequency, less severe storms, coastal wetlands contribute to coastal storm protection through wave attenuation and sediment stabilization, providing potentially substantial resiliency benefits.

Wetland restoration does provide a benefit to this Reformation Study from an ecological perspective. The many ecosystem benefits of wetland restoration, included below, can be used to offset unavoidable impacts to waters and wetlands, threatened and endangered species, and/or water quality from other CSRM measures. From ecological and social perspectives, a coastal wetland can provide the following benefits:

- Shoreline stabilization;
- Ecosystem and community resiliency;
- Water quality / biogeochemical functioning;
- Native plant community restoration, and in turn terrestrial habitat services or functions;
- Aquatic habitat restoration;
- Integration in public shoreline access providing community social “value”, and important areas for recreational boating and fishing.

This measure is being carried forward for further evaluation by this Reformation Study.

### 3.3.3 Coastal and Maritime Forests

Maritime forests are defined herein as native upland plant communities that are influenced by strong salt spray, high winds, and unstable substrates (e.g., unconsolidated sand). These forests, often described as "strand forests", have characteristically stunted and contorted trees (National Biological Service 1995; Yozzo et al., 2003; Edinger et al., 2002). Coastal forests are non-maritime communities found within the coastal plain, but which are not exposed to the same intensity of salt spray, wind, and substrate shifting. Coastal and maritime forests provide protection from wind and salt spray (Takle et al., 2007), and from coastal storms (Wolanski 2007; Krauss et al., 2009).

As a complementary measure with other structural interventions, coastal and maritime forests may provide some CSRM benefits within the context of this Reformulation Study. Coastal and maritime forests may be restored as a part of a living shoreline and can be tied into associated or complementary structural interventions (e.g., the living shorelines in Figure 12 and Figure 13). Restored forests provide an additional buffer to a low elevation defense line, such as coastal wetlands, dunes and reefs. In comparison to wetland marshes, forest trees have stiff, thick, and tall trunks, which are likely effective for both long-period wave reduction (e.g., storm surge) (Fritz and Blount, 2007) and short wave attenuation, if tree trunk and foliage density is sufficient (Wilson et al., 2008; Vo-Luong and Massel, 2008). In addition, this measure mitigates shoreline erosion and improves soil retention via vegetation root structures.

Restoration of maritime and coastal forests also provides a benefit from an ecological perspective. Much of the natural vegetation within and adjacent to Jamaica Bay has been disturbed or altered; forests have been cut for use as firewood or building materials, and formerly forested lands have been converted to agricultural and then urban land uses (NPS, 2014). These plant communities are important ecological corridors, providing habitat and food resources to support many wildlife species. Specifically, they provide a variety of valuable functions, including: habitat for species of concern, nesting habitat, food sources, seed sources, corridors for wildlife, stormwater reclamation, shoreline/land stabilization, aesthetic value, and landscape features naturally adaptable to climate change.

This measure is being carried forward for further evaluation by this Reformation Study.

### 3.3.4 Reefs

Reefs are defined herein as a spatially-complex offshore feature or structure that is important for many estuarine organisms and which typically occurs below sea level. Within Jamaica Bay, reef restoration commonly targets oysters; however, the spatially complex structure can also provide benefits to other aquatic species such as fish, crab, lobsters, and macro-invertebrates. Specific to oyster reefs, the deep crevices created by the oyster shells provide refuge for numerous species of small aquatic organisms.

Within the context of this Reformation Study, oyster reefs could only provide sufficient CSRM benefits as part of a complementary measure, such as a living shoreline. As a natural breakwater existing below low water elevation, reefs provide resiliency benefits, including breaking and dissipating waves (Scyphers et al. 2011; Spalding et al. 2013), primarily in the instance of high frequency, lower impact storms.

As a stand-alone restoration project, oyster reefs provide benefits from an ecosystem perspective. Oysters are valuable organisms that can actually promote the growth and viability of other habitats. By filtering particulate material from the water column, oysters form an important link between the pelagic (open water) and benthic food webs (Yozzo et al., 2001). By improving water clarity, oysters can enhance other subtidal habitats like eelgrass by increasing the amount of light that can penetrate the water (Cerco and Noel 2007). In some geographic areas, oyster reefs may develop substantial vertical relief off the sea floor, altering patterns of current flow and possibly creating or expanding shallow water habitat by trapping sediments. Oyster reefs can encourage the growth and expansion of salt marshes located inshore of the reefs by functioning as natural breakwaters (Coen and Luckenbach, 2000).

This measure is being carried forward for further evaluation by this Reformation Study.

### 3.3.5 Dunes and Beaches

Beaches are the narrow strip of shore land in immediate contact with water consisting of unconsolidated sediments, usually sand. The beach berm is the portion of a beach above water, including the intertidal zone, and is actively influenced by tidal and wave action. The slope of a beach berm can vary widely among and within locations depending on the type of wave action or season. Beaches with berms of sufficient height, width, and slope can attenuate the effects of wave energy from storms. Dunes are defined here as typically reinforced sand mounds located along the back edge of a beach which break waves and keep floodwaters from inundating neighborhoods. Both beaches and dunes can erode during significant storm events, although beaches are more susceptible to erosional forces during storms because of their location. In many cases dunes provide a sediment source for beach recovery after a storm passes. Depending on the severity and intensity of a storm, beaches and sometimes dunes may require maintenance and sand replenishment after a storm event.

Beach restoration and dune restoration measures, if elevations are sufficient, may provide CSRM benefits as a stand-alone feature. Restoration of dunes also provides a benefit from an ecosystem perspective. These communities are important components of the coastal ecosystem, and provide corridors/habitat and food resources to support many wildlife species. Specifically, they provide a variety of valuable functions, including: habitat for species of concern, nesting habitat, food sources, seed sources, corridors for wildlife, storm water reclamation, shoreline/land stabilization, aesthetic value, and landscape features naturally adaptable to climate change.

This measure is being carried forward for further evaluation by this Reformation Study.

### 3.3.6 Swales and Channels

Some project measures outlined as part of the ongoing Rockefeller Foundation initiative "Towards a Master Plan for Jamaica Bay" include developing overland swales or deeper channels connecting the bay to the harbor or Atlantic Ocean to improve the flushing of the bay and decrease residency time of water (RAND and Happold 2014). From an ecological perspective, these measures could provide:

- Water quality / biogeochemical functioning;
- Native plant community restoration, and in turn terrestrial habitat services or functions; and
- Integration in public shoreline access providing community social "value" with important areas for recreational boating and fishing

From a CSRM perspective, these measures do not provide significant benefits and, for some storm conditions, could cause adverse effects. While swales and channels could help drain the bay more quickly following a storm event, lower land elevations associated with these measures could increase maximum storm tide elevations in the bay, as these measures also provide an additional passage for flood waters to enter the bay in the earlier stages of the storm.

The adverse CSRM impacts would vary based on the dimensions of the swale or channel (both width and depth), as well as the storm properties (e.g., track, central pressure, wind speed, and forward speed). For instance, if wider and deeper swales were constructed, it could lead to more significant impacts. Based on engineering judgment, for the existing configuration in the study area (e.g., Rockaway Inlet open), the potential increase in maximum storm tide elevations due to swales or channels is likely less than half of a foot within Jamaica Bay, though additional studies would be required confirm this estimate and to further assess and quantify impacts. Modeling experiments, including numerical and physical models, are described in some of the projects consulted in this analysis, though none have been completed to specifically address this issue. The existing models are however well equipped to further assess these measures.

Water levels in Jamaica Bay due to swales and channels are expected to increase by a half foot or less for some storms because the flow rate through one of these measures would be significantly smaller than the flow rate through Rockaway Inlet. This is due to the relative size of the cross sectional area of the measure compared to the significantly larger Inlet. Rockaway Inlet would remain the primary passageway for flood waters from the Atlantic into Jamaica Bay. Additionally, flow rates through the measures are relative to the head differential between the Atlantic Ocean and Jamaica Bay, meaning that the higher bay stillwater elevations rise due to inflows through Rockaway Inlet, the lower the flow rate through the proposed swales and channels and vice versa. The interconnectivity between the Rockaway Inlet, swales and channels, and the Atlantic Ocean side of Rockaways Peninsula makes for a complex relationship which is best analyzed with numerical modeling experiments.

Ultimately, regardless of the impact of these measures on peak stillwater elevations, it should be noted that the potential adverse effects offset any potential CSRM benefits associated with more quickly draining the bay after a storm. Unless flow control structures are considered as part of the measure, the benefit of more quickly draining the bay will not come without the risk of potentially higher water levels to drain.

While the measures provide additional passages for floodwaters to exit the bay, they similarly provide additional passages for water to enter the bay. Though ecological benefits could be noteworthy, those benefits may be achieved through other NNBF measures that do not have potentially adverse CSRM effects. This measure is not being carried forward for further evaluation by this Reformation Study.

### 3.3.7 Other Measures

The following text summarizes other measures that have been proposed for Jamaica Bay. These measures are not being carried forward for further evaluation by this Reformulation Study because these measures are either:

- in conflict with planning constraints;
- inadequate at providing cost effective ecosystem benefits; or
- inconsistent with the existing USACE missions of CSRM and ecosystem restoration.

However, it is possible that some of these measures, such as stormwater improvements, can be included as part of a comprehensive watershed based solution, and thus are discussed in greater detail below.

#### 3.3.7.1 Stormwater Improvement

Stormwater improvement measures, which were identified as possible project measures as part of the ongoing Rockefeller Foundation initiative “Towards a Master Plan for Jamaica Bay” (RAND and Happold 2014), include, pump station upgrades, bioswales, increased capture capacity, permeable concrete installation, and outfall upgrades.

As standalone measures, stormwater improvements are not cost effective options to provide substantial CSRM, ecological or resiliency benefits. However, these measures will be included as part of a comprehensive solution when necessary. An example is the inclusion of pumps for mitigating against induced interior drainage flooding caused by the placement of a structural intervention. Infrastructure will additionally be considered for building retrofits under the nonstructural evaluation, to identify damage reduction measures specific for essential infrastructure in the study area.

This measure is not recommended for further evaluation in the Reformulation Study as a means to provide direct CSRM, resiliency, or ecological benefits

#### 3.3.7.2 Wastewater Treatment

Wastewater treatment measures, which were identified as possible project measures as part of the ongoing Rockefeller Foundation initiative "Towards a Master Plan for Jamaica Bay" (RAND and Happold 2014), include elevation of infrastructure, installation of site specific floodproofing, increase in nitrogen reduction capacity of current facilities, and upgrade of pump stations.

The New York City Department of Environmental Protection (NYCDEP) is currently implementing floodproofing improvements at wastewater treatment facilities within the study area. NYCDEP implementation of wastewater treatment improvements measures will be accounted for in the alternatives formulation phase of the study, as appropriate. This measure is not being carried forward for further evaluation by this Reformation Study as a means to provide direct CSRM, resiliency, or ecological benefits.

#### 3.3.7.3 Park Access and Recreation

Park access and recreation measures, which were identified as possible project measures as part of the ongoing Rockefeller Foundation initiative "Towards a Master Plan for Jamaica Bay" (RAND and Happold 2014), include addition of further access routes for existing parks, construction of new parks, and addition of trails on berms within parks.

This measure is not being directly carried forward for further evaluation by this Reformation Study as a means to provide direct CSRM, resiliency, or ecological benefits. However, park access and recreation will be a consideration during the alternatives formulation phase of the study.

#### 3.3.7.4 Evacuation Routes

Raised road elevations for current evacuation routes and relocation of evacuation routes to regions more protected from major storm events were identified as possible project measures as part of the ongoing Rockefeller Foundation initiative "Towards a Master Plan for Jamaica Bay" (RAND and Happold 2014). These measures, as stand-alone measures, are not being carried forward for further evaluation by this Reformation Study because they provide very limited and localized benefits. It may be the case that raised road elevation may be a component of a larger plan that combines multiple measures to provide CSRM. It is important to note that evacuation routes are important to overall community resiliency and may be integrated into structural interventions, such as roadways placed on top of levees or floodwalls.

### 3.3.8 Measures Screening Summary

Figure 38 presents a summary of the measures screened in the previous sections. For measures that achieved the particular screening criterion, a solid, blue marker was been placed in the appropriate row and column and that measure is retained for further evaluation. If a measure likely achieves the particular screening criterion only during high frequency storm events, a striped blue and yellow marker used to indicate this detail and the measure also is retained for further evaluation. Measures identified by a grey box are not carried forward for further evaluation, including swale/channel, bay shallowing, storm water improvement, wastewater treatment, park access and recreation, and evacuation routes.

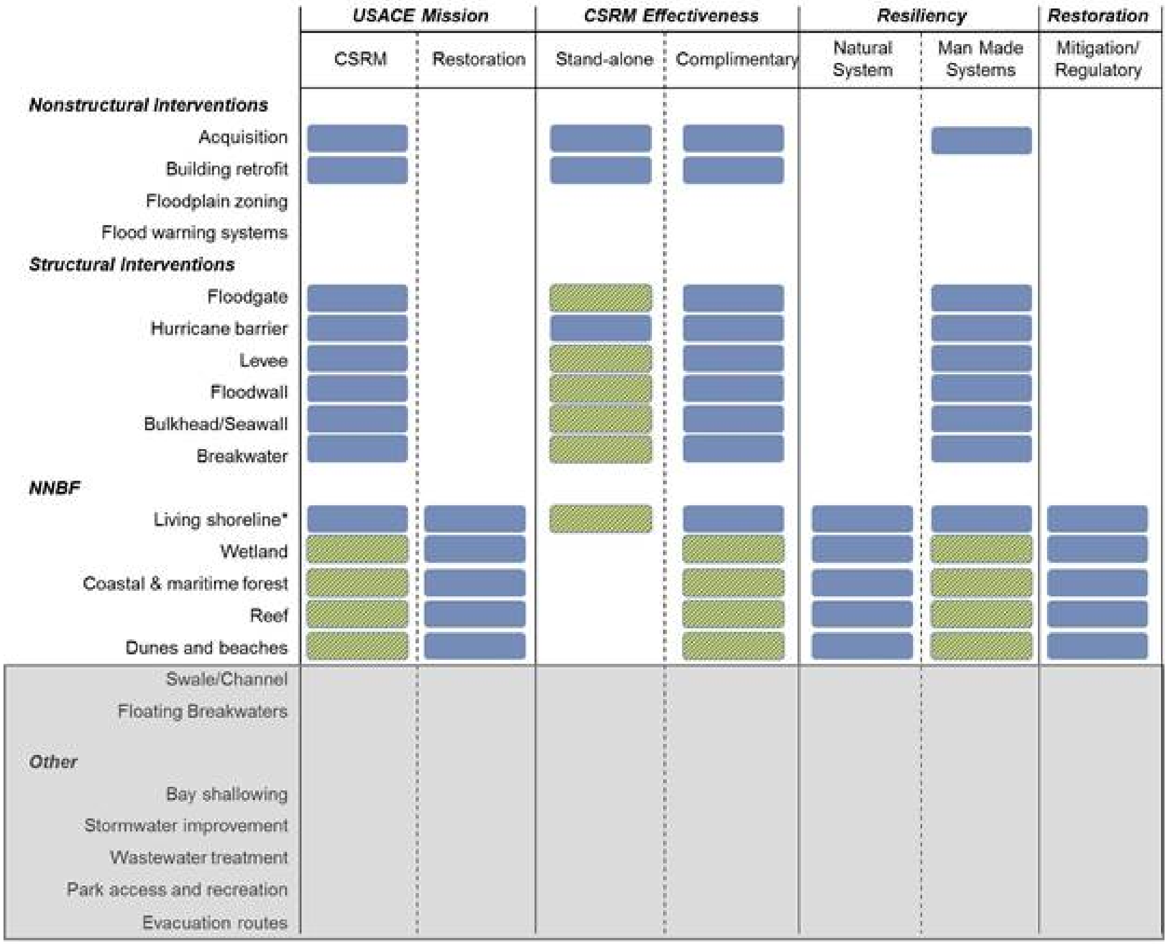


**Figure 38: Summary of Preliminary Screening of Jamaica Bay Planning Reach Measures**

### 3.3.9 Selected Measures by Preliminary Geographic Reach

Preliminary alternatives were developed from planning measures based on the preliminary geographic reaches where each measure would likely be applied (Figure 39). These measures include structural, nonstructural, and NNBF interventions. This section identifies the measures, which may be implemented in each reach, with a brief discussion of why these measures may be suitable for the reach. The next section (Section 3.4 Alternative Plan Development) further analyzes measures for each reach and ultimately combines measures within and across reaches to develop alternatives that will achieve study objectives.

In Jamaica Bay reach 1, Sheepshead Bay, a combination of structural measures, including NNBFs, were assessed for the area. These structural measures, including flood gates, floodwalls, and bulkhead/seawalls could potentially tie into the dune that is part of the USACE Atlantic Coast of New York City, Rockaway Inlet to Norton Point (Coney Island) project. In addition, living shorelines and/or dunes and beaches may be suitable for portions of the reach as a result of the topography and geology of the region and could provide ecological benefits.

Non-structural measures as a standalone solution were not considered suitable for this densely populated area consisting largely of multi-story structures, although non-structural measures may be included as a component of a more comprehensive alternative plan.

In Jamaica Bay reach 2, Gerritsen Beach, a combination of structural measures, including NNBFs, were assessed for the area. Structural measures, including flood gates, floodwalls, bulkheads/seawalls are feasible along structural alternatives to protect the region along Rockaway Inlet from upland flooding. Levees to tie into high ground may additionally be suitable east of Gerritsen Bay, where space to build structural measures is more readily available. NNBFs, including living shorelines, wetlands, maritime and coastal forests, and dunes and beaches may be applicable in portions of the reach including Plumb Beach and Marine Park.

Non-structural measures as a standalone solution were not considered suitable for this densely populated area consisting largely of multi-story structures, although non-structural measures may be included as a component of a more comprehensive alternative plan.

In Jamaica Bay reach 3, Floyd Bennett Field, a combination of structural measures, including NNBFs, may be suitable for this area. The most suitable structural intervention is believed to be a levee, such that the feature can be integrated into NNBFs and other recreational measures proposed for the National Park Service land. NNBFs to soften the land edge and provide ecosystem benefits are additionally applicable in the area.

Non-structural measures as a standalone solution were not considered suitable for this densely populated area consisting largely of multi-story structures, although non-structural measures may be included as a component of a more comprehensive alternative plan.

In many instances, interventions suitable for Jamaica Bay reaches 4, 5 and 6 are analogous to those suitable for Jamaica Bay reach 2 as a result of relatively similar topography and land use. Flood gates along creeks and basins, from Mill Basin to Howard Beach are possible measures. Levees, floodwalls, and bulkhead/seawalls may be suitable for each reach. Portions of the reaches may have sufficient space to integrate a levee and a living shoreline (inclusive of coastal wetlands and/or maritime forests). Note that NNBFs, particularly those in Jamaica Bay reach 6 near Howard Beach, must consider wildlife hazards associated with the JFK airport.

Non-structural measures as a standalone solution were not considered suitable for this densely populated area consisting largely of multi-story structures, although non-structural measures may be included as a component of a more comprehensive alternative plan.

Jamaica Bay reach 7 is the JFK airport. As a result of restrictions due to runway obstruction and wildlife hazards, the only structural measures potentially suitable for the region are flood gates, levees, floodwalls, and bulkhead/seawalls. Flood gates could be placed at either end of the airport. Additionally, all structural solutions would need to be evaluated to determine whether the profile and crown elevation meets runway obstruction requirements. NNBFs, such as living shorelines, may be suitable for the reach; however, airport-related restrictions must be considered.

In Jamaica Bay reaches 8 and 9, nonstructural, structural, and NNBF measures may be suitable for the reaches. Low lying terrain at the water front and inland, soft edges along portions of the reaches, and hardened edges, particularly in Jamaica Bay reach 9, make integrated solutions considering all three intervention types possible. Again, special consideration will be given to measures possibly impacting runway obstruction and bird hazards related to JFK airport.

Jamaica Bay reach 10, Rockaway West, is defined by its hardened edge and urbanized land use between the Gil Hodges Bridge and the Cross Bay Boulevard Bridge. As a result of these defining characteristics, the only nonstructural intervention that may be suitable is floodproofing, and the only structural interventions that may be suitable are those that require a generally narrow footprint including floodwalls and bulkhead/seawalls. No NNBF measures are independently applicable for the reach, though ecologically enhanced bulkheads and seawalls will be considered.

In Jamaica Bay reach 11, Breezy Point and Roxbury, structural measures, including levees, floodwalls, and bulkhead/seawalls, and NNBFs, such as including living shorelines and dunes and beaches, are suitable for the reach. Note that dunes considered in this reach will tie into the dune being considered for the ocean side of the Rockaway Peninsula in the USACE East Rockaway Inlet to Rockaway Inlet and Jamaica Bay Reformulation Study and would be designed to provide CSRM benefits.

Non-structural measures as a standalone solution were not considered suitable for this densely populated area consisting largely of multi-story structures, although non-structural measures may be included as a component of a more comprehensive alternative plan.

Jamaica Bay reach 12, the Rockaway Inlet, will include the evaluation of a Storm Surge Barrier at multiple locations at the entrance of the bay. Breakwaters or NNBF solutions in this area intended to provide CSRM or ecological benefits along the perimeter of this reach will be considered as part of the evaluation of Jamaica Bay reaches 1, 2, 3 and 11.

In Jamaica Bay reaches 13, 14, 15, nonstructural, structural, and NNBF measures are being carried forward. For Jamaica Bay reach 14, the central reach, nonstructural interventions, including acquisition and floodproofing, are being carried forward due to the presence of very low-lying communities at Broad Channel and Cross Bay Boulevard. For Jamaica Bay reaches

13, 14, and 15, the only structural measures that may be suitable for each reach are breakwaters. With regards to NNBF measures, wetlands and reefs may be suitable for all three reaches and will be carried forward. Specifically to Jamaica Bay reaches 14 and 15, special consideration will be given for wetlands due to possible bird hazards related to JFK airport.

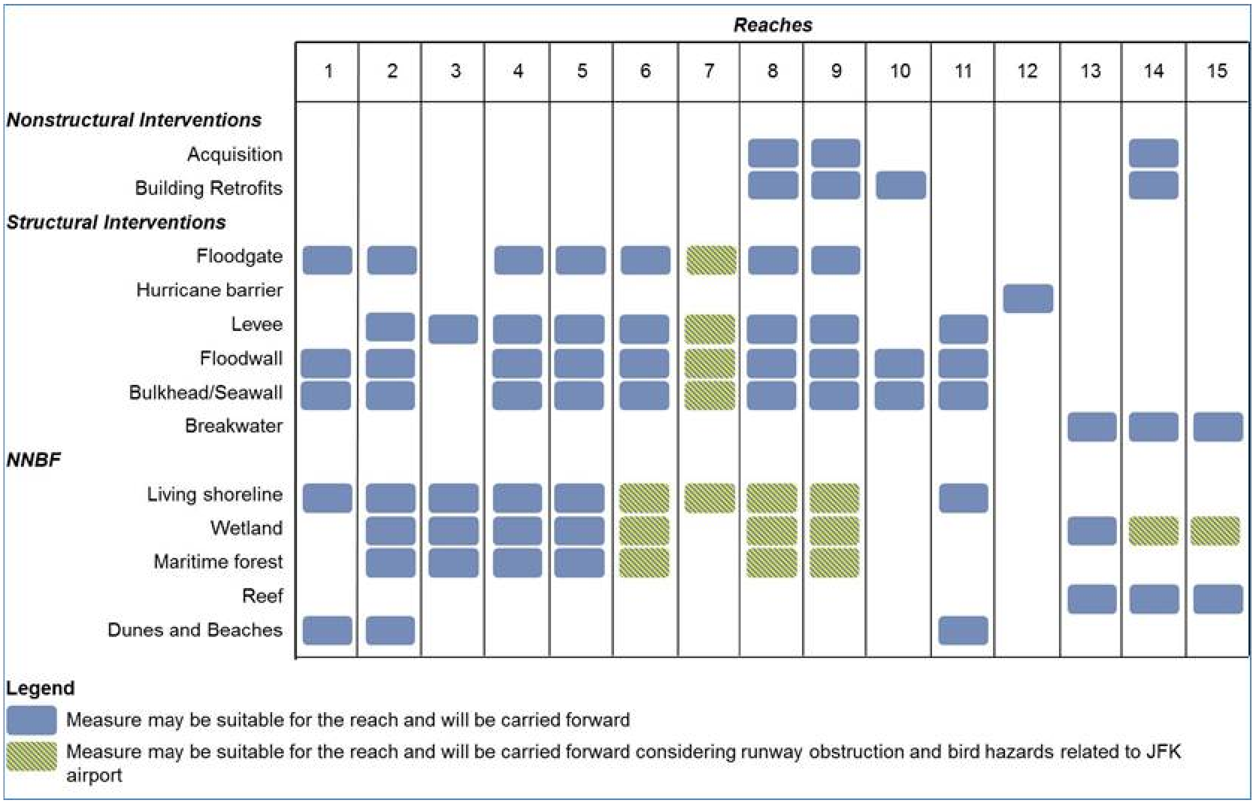


**Figure 39: Measures Carried Forward by Reach – Jamaica Bay**

## 3.4 Alternative Plan Development

For this preliminary screening, alternative plans were developed and evaluated independently for the Atlantic shoreline and Jamaica Bay portions of the study area.

### 3.4.1 Atlantic Ocean Shorefront Planning Reach Alternative Plan Development

The general approach to identifying a tentatively selected plan is to evaluate erosion control alternatives in combination with a single beach restoration plan to select the most cost effective approach to reducing project renourishment (i.e., reduce erosion control lifecycle costs). This analysis is a lifecycle cost comparison to ensure that the most cost effective renourishment approach has been identified prior to the evaluation of alternatives for coastal storm risk management. All of the coastal storm risk management alternatives include beach restoration and a dune. The most cost effective erosional control features are included as part of all five of the coastal storm risk management alternatives.

The coastal storm risk management (CSRM) plans consist of various beachfill, dune and seawall measures to reduce future storm damages. The plans were evaluated based on a comparison of their quantified storm risk management benefits in comparison to their costs. The plan that provides the greatest net CSRM benefits in excess of costs is identified as a component of the Tentatively Selected Plan.

**Optimal Life-Cycle Features Alternatives Development**

The general approach to developing CSRM for the Atlantic Ocean Shorefront Planning Reach was to evaluate features that optimize life-cycle costs as a first step in developing overall CSRM for the Planning Reach. Plan formulation of the optimal life-cycle features focused on identifying the least-costly solution to maintaining a wide beach and dune over the 50-year planning horizon. The optimal life-cycle feature alternative analysis did not consider storm damage reduction benefits; each of the optimal life-cycle feature alternatives was evaluated based on the same generic design berm and dune. Four optimal life-cycle feature alternatives (Figure 40) were short-listed by the PDT and selected to be evaluated in detail:

- Optimal Life-Cycle Feature Alternative 0: No Action
- Optimal Life-Cycle Feature Alternative 1: Beach Restoration
- Optimal Life-Cycle Feature Alternative 2: Beach Restoration + Reduced Erosion Control
- Optimal Life-Cycle Feature Alternative 3: Beach Restoration + Increased Erosion Control

The short-listed optimal life-cycle feature alternatives include various measures such as new groins, shortening/lengthening of existing groins, and boardwalk relocation that have the potential to reduce future renourishment requirements and life-cycle costs

Detailed one-dimensional shoreline change modeling (GENESIS) was conducted to identify future renourishment requirements for each optimal life-cycle feature alternative. The screening level design consisting of plan layouts, cross-sections, quantities, and costs, was performed for each alternative to estimate the life-cycle costs.

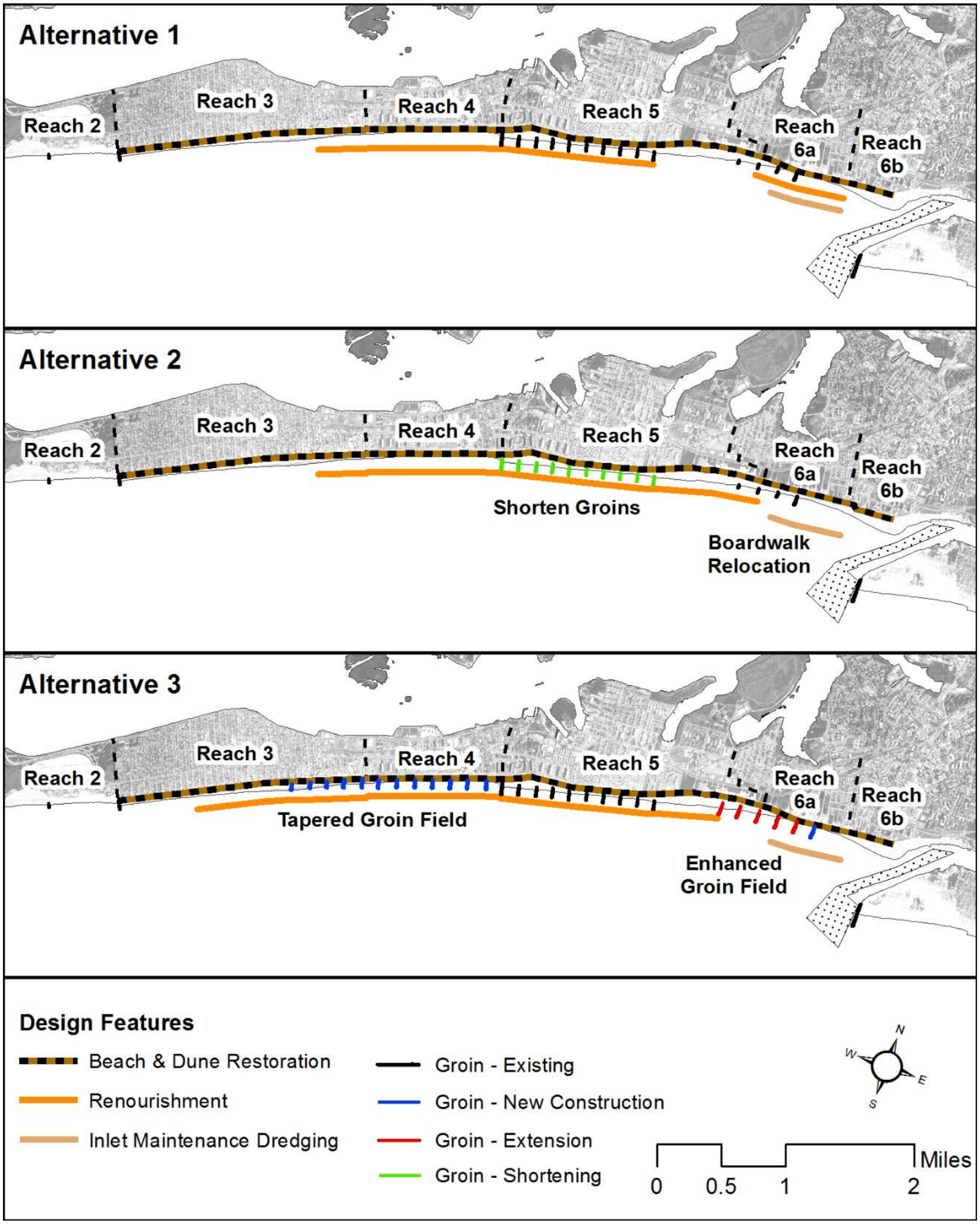


**Figure 40: Optimal Life-Cycle Feature Alternatives**

Shoreline change modeling results indicate that the design beach profile can be maintained over the life of project in all three erosion control alternatives if sufficient advance fill is placed and regular renourishment operations are performed. Optimal Life-Cycle Feature Alternative 1 experienced high sediment losses in the two historical erosional hot spots (EHS) requiring large renourishment quantities and a relatively short 3-year renourishment cycle.

Optimal Life-Cycle Feature Alternatives 2 and 3 reduced the sediment losses in the two historical EHS by either increasing sediment flow into the hot spots (Alternative 2) or reducing sediment flow out of the hot spots (Alternative 3). As a result, Optimal Life-Cycle Feature Alternatives 2 and 3 had lower renourishment quantities and a longer, 4-year, renourishment cycle than Optimal Life-Cycle Feature Alternative 1.

Initial construction and renourishment operation cost estimates for the three alternatives are presented in Tables 20 and 21. Optimal Life-Cycle Feature Alternative 1 has the lowest initial construction costs, but the highest renourishment costs. The cost of each renourishment operation in Erosion Control Alternative 1 is about the same as in Optimal Life-Cycle Feature Alternatives 2 and 3, but because renourishment operations are required every 3 years for Optimal Life-Cycle Feature Alternative 1 instead of every 4 years, the total renourishment costs for Optimal Life-Cycle Feature Alternative 1 are much higher.

Renourishment costs for Optimal Life-Cycle Feature Alternatives 2 and 3 are similar, however the initial construction costs for Optimal Life-Cycle Feature Alternative 3 are much lower. The initial construction costs for Optimal Life-Cycle Feature Alternative 2 are relatively high due to the real estate costs associated with boardwalk relocation.

A summary of the overall life-cycle cost estimate for each erosion control alternative is presented in Table 22. The recommended erosion control alternative is Optimal Life-Cycle Feature Alternative 3 - Beach Restoration + Increased Erosion Control. This alternative had the lowest annualized costs over the 50-year project life and the lowest renourishment costs over the project life. However, the difference in the annualized cost estimates between Optimal Life-Cycle Feature Alternative 1 and Optimal Life-Cycle Feature Alternative 3 is relatively small (2%) and well within the margin of uncertainty in the cost estimates.

**Table 20: Optimal Life-Cycle Feature Alternatives - Initial Construction Cost Estimates**

| Item | Alt 1 | Alt 2 | Alt 3 |
|---|---:|---:|---:|
| Beachfill | $17,220,000 | $13,562,000 | $14,876,000 |
| Groins | $0 | $11,498,000 | $27,844,000 |
| Boardwalk Relocation | $0 | $59,677,000 | $0 |
| PED | $1,722,000 | $4,474,000 | $4,272,000 |
| Construction Management | $1,395,000 | $3,234,000 | $3,110,000 |
| Contingency | $3,679,000 | $35,732,000 | $10,699,000 |
| **Total** | **$24,016,000** | **$128,177,000** | **$60,801,000** |

Notes: Effective price level January 2015

### Table 21: Optimal Life-Cycle Feature Alternatives - Renourishment Cost Estimates

| Item | Alt 1[1] | Alt 2[2] | Alt 3[2] |
|---|---|---|---|
| Beachfill | $16,167,000 | $17,017,000 | $16,450,000 |
| PED | $1,617,000 | $1,702,000 | $1,645,000 |
| Construction Management | $1,319,000 | $1,382,000 | $1,341,000 |
| Contingency | $5,374,000 | $5,656,000 | $5,468,000 |
| **Total Per Operation** | **$24,477,000** | **$25,757,000** | **$24,904,000** |
| **Total Over Project Life[3]** | **$184,941,000** | **$142,430,000** | **$137,730,000** |

Notes: [1] 3-year renourishment cycle

[2] 4-year renourishment cycle

[3] Present Worth

### Table 22: Optimal Life-Cycle Feature Alternatives – Life-Cycle Cost Estimates

| Rockaway Beach Formulation Summary | | Low SLR | | |
|---|---|---|---|---|
| | | **Alternative 1** | **Alternative 2** | **Alternative 3** |
| Initial Cost | Initial Construction | $ 24,016,000 | $ 128,177,000 | $ 60,801,000 |
| | IDC | $ 125,000 | $ 2,204,000 | $ 1,273,000 |
| | **Investment Cost** | **$ 24,141,000** | **$ 130,381,000** | **$ 62,074,000** |
| | | | | |
| Annualized Cost | Investment Cost | $ 1,006,000 | $ 5,434,000 | $ 2,587,000 |
| | Renourishment (Planned/Emergency) | $ 7,708,000 | $ 5,936,000 | $ 5,740,000 |
| | O&M | $ 403,000 | $ 403,000 | $ 573,000 |
| | Major Rehab | $ 332,000 | $ 332,000 | $ 332,000 |
| | SLR Adaption | $ - | $ - | $ - |
| | **Total Annual Cost** | **$ 9,449,000** | **$ 12,105,000** | **$ 9,232,000** |

Note: Effective price level January 2015

## Coastal Storm Risk Reduction Alternatives Development

A screening analysis was performed prior to the detailed economic modeling to narrow down the number of possible coastal storm risk management alternatives to five:

- CSRM Alternative 1 - Beach Restoration, +16 foot Dune, 60 foot Berm
- CSRM Alternative 2 - Beach Restoration, +18 foot Dune, 80 foot Berm
- CSRM Alternative 3 - Beach Restoration, +20 foot Dune, 100 foot Berm
- CSRM Alternative 4 - Beach Restoration, +18 foot Reinforced Dune – Buried Seawall
- CSRM Alternative 5 - Beach Restoration, +18 foot Reinforced Dune – Composite Seawall

The screening analysis evaluated the level of protection provided by a range of dune and berm dimensions as well as reinforced dunes to aid in the selection of appropriate dimensions. Other factors such as prior projects at Rockaway Beach, project constraints, stakeholder concerns, and engineering judgment were also applied in the selection of the final set of alternatives.

***Beach Restoration and Dune Alternatives***

The smallest design beach fill profiles alternatives under consideration is slightly narrower than the Flood Control and Coastal Emergencies (FCCE) project but wider than the prior WRDA 1974 and Section 934 projects, with a dune height of +16 ft NAVD and a berm width of 60 feet. The two additional design beach fill profiles under consideration have wider berms and higher dunes (Figure 41).

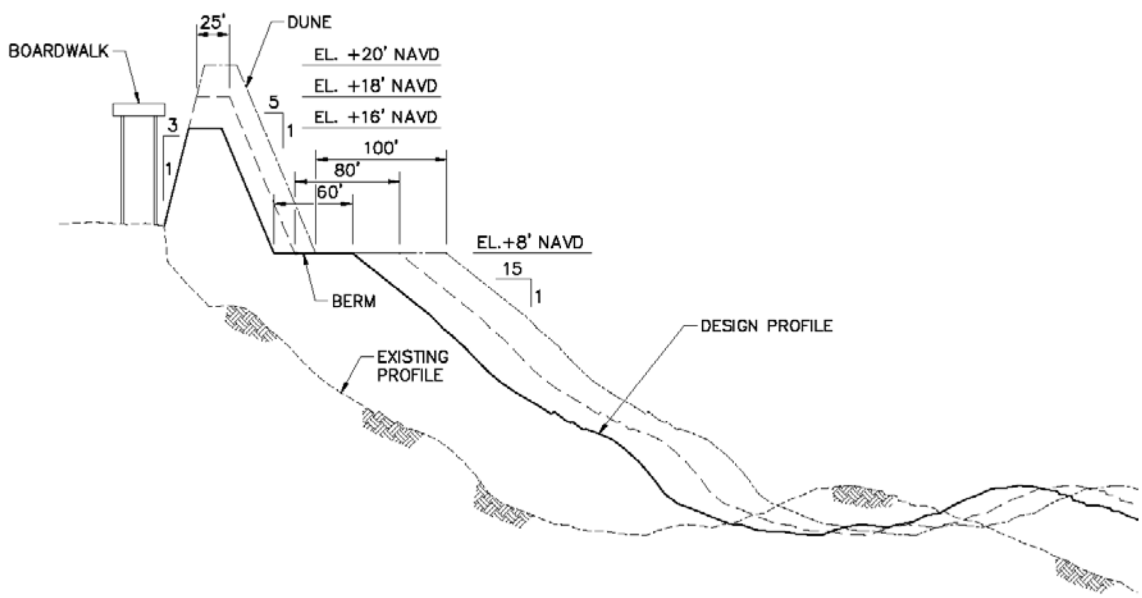


**Figure 41: Beach Restoration and Dune Alternatives**

***Beach Restoration and Reinforced Dune Alternatives***

Two reinforced dune concepts have been proposed for Rockaway Beach. The first type, buried seawall, is designed to protect inland areas from erosion and wave damages during severe storm events such as Hurricane Sandy. The second type, composite seawall, is designed to also limit storm surge inundation and cross-island flooding during severe storm events. The composite seawall is compatible with a comprehensive storm surge barrier for Jamaica Bay. A typical section of the buried seawall and composite seawall is shown in Figure 42.

The first concept is a buried seawall. Buried seawalls are essentially dunes with a reinforced rubble mound core and were developed as an alternative to larger standalone seawalls. Buried seawalls are designed to function in conjunction with beach restoration projects and dunes. The primary advantage of buried seawalls over traditional dunes is the additional protection against erosion and wave attack provided by the stone core. Since the purpose of the buried seawall is wave protection, it may be constructed intermittingly along the shoreline in the most vulnerable areas.

The second reinforced dune concept is a composite seawall with an impermeable core (i.e. steel sheet pile). The purpose of the composite seawall is to not only protect against erosion and wave attack but also to limit storm surge inundation and cross-island flooding. The composite seawall provides a high level of protection that may not be practical to achieve with a dune because of the necessary height and footprint of such a dune. In addition, the composite seawall is compatible with a comprehensive storm surge barrier for Jamaica Bay.

Several design concepts were initially considered before selecting a horizontally composite seawall: rubble mound, vertical steel sheet pile wall, vertically composite, and horizontally composite structure. The vertical sheet pile wall and vertically composite wall were eliminated from further consideration because of the large lateral forces acting on the steel sheet pile and the required length and size of steel piles to withstand these forces. The armor stone in horizontally composite structures has been demonstrated to significantly reduce the wave breaking pressure (Takahashi, 2002). This allows smaller steel sheet pile walls to be used in the design if the face of the wall is completely protected by armor stone.

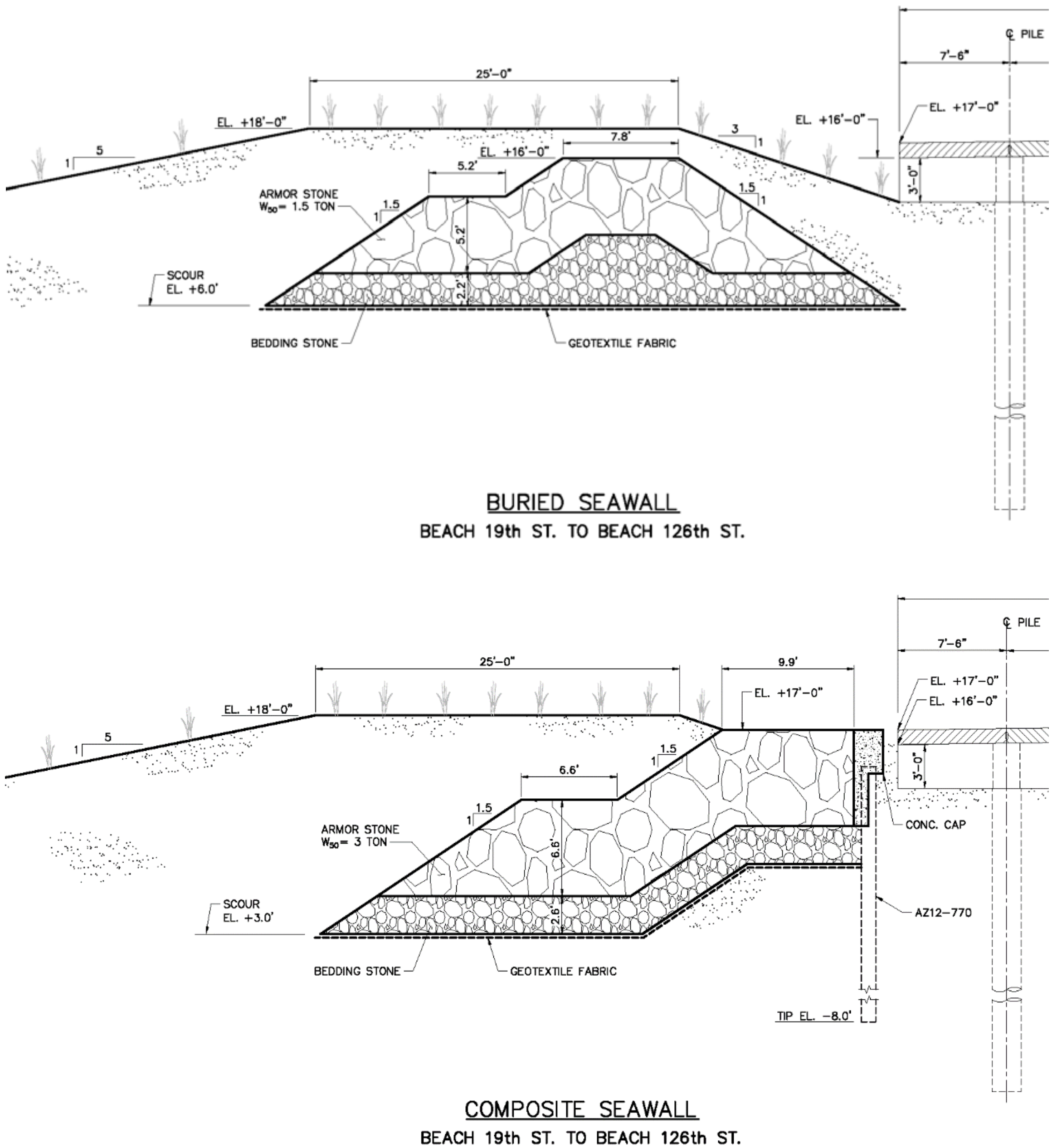


**Figure 42: Reinforced Dune Alternatives**

## 3.4.2 Jamaica Bay Planning Reach Alternative Plan Development

Four categorical alternatives were developed to reduce coastal storm risk within the study area, including:

- Alternative A – No Action;

- Alternative B – Non-Structural Alternatives;
- Alternative C – Storm Surge Barriers; and
- Alternative D – Jamaica Bay Interior Barriers.

Note that Alternatives B, C, and D include natural and nature based features.

The National Environmental Policy Act (NEPA) requires that in analyzing alternatives to the proposed action, a federal agency consider an alternative of taking "No Action." Likewise, Section 73 of the WRDA of 1974 (PL 93-251) requires federal agencies to give consideration to non-structural measures to reduce or prevent flood damage; Alternative A (the No Action Alternative) and Alternative B (Non-structural Alternatives) are these required alternatives. Under Alternative A there would be no additional coastal storm risk reduction actions taken at any economic reach other than actions already identified in the without-project condition. Plans under Alternative B would typically reduce risk for individual structures or groups of structures within an economic reach. Non-structural measures, such as acquisition and floodproofing, are projected to have very localized applications to individual structures or elements of infrastructure, and are suitable as standalone alternatives due to the density of structures and prevalence of multi-story structures in the study area. Non-structural plans were not included in the preliminary evaluation of alternative plans as standalone plans; however, non-structural alternatives will be carried forward and evaluated with the focused array of alternatives as elements of more comprehensive plans.

In addition to these required alternatives, structural alternatives were formulated based on the measures identified through input by the CENAN PDT, engineering and design consultants, local government agencies, NGOs (Jamaica Bay Science and Resilience Institute, NY Rising Community Reconstruction Program, Rebuild By Design, etc.), and the public within the study area. The structural alternatives developed for this analysis include Alternative C, which provides comprehensive coastal storm risk management for Jamaica Bay with an inlet barrier across the Rockaway Inlet and Alternative D, which provides reach-specific barriers along the Jamaica Bay shoreline.

### 3.4.3 Jamaica Bay Structural Alternative Plans Development

Structural alternative plans for the Jamaica Bay portion of the study area (Alternative C and Alternative D) were developed by grouping measures together to create a contiguous barrier, which would avert inundation for the entire bay (Alternative C) or for an entire economic reach (Alternative D) at a stillwater elevation of 11 feet. Eleven feet is generally equivalent to the stillwater elevation for a storm event with 1% probability of annual occurrence in 2070 including mid-range sea level rise.

Measures were selected for inclusion into an alternative plan based on four criteria, though not necessarily in this order. First, where possible, measures were selected to be consistent with current conditions. For instance dunes and beaches, seawalls, and bulkheads have been recommended in locations where these measures currently exist though require improvements to meet CSRM goals. Second, measures providing more substantial ecological and resiliency benefits, such as living shorelines, were chosen where feasible. Third, measures were selected based on cost. An example is that levees are more affordable than T-walls and have been recommended where space permits. Lastly, some measures were selected to meet site specific needs, such as T-walls or seawalls in areas with narrow right-of-way opportunities. Note that structure crest elevations are higher than the targeted stillwater elevation to account for wave run-up.

Plans under Alternative C include three Storm Surge Barrier alignments (Figure 43). Each alignment is based on a generalized location. Specific alignments will be identified during detailed evaluation.

- Alignment 1 (Gil Hodges Memorial Bridge)
- Alignment 2 (Kingsborough Community College to Rockaway Point); and
- Alignment 3 (Manhattan Beach to Breezy Point).

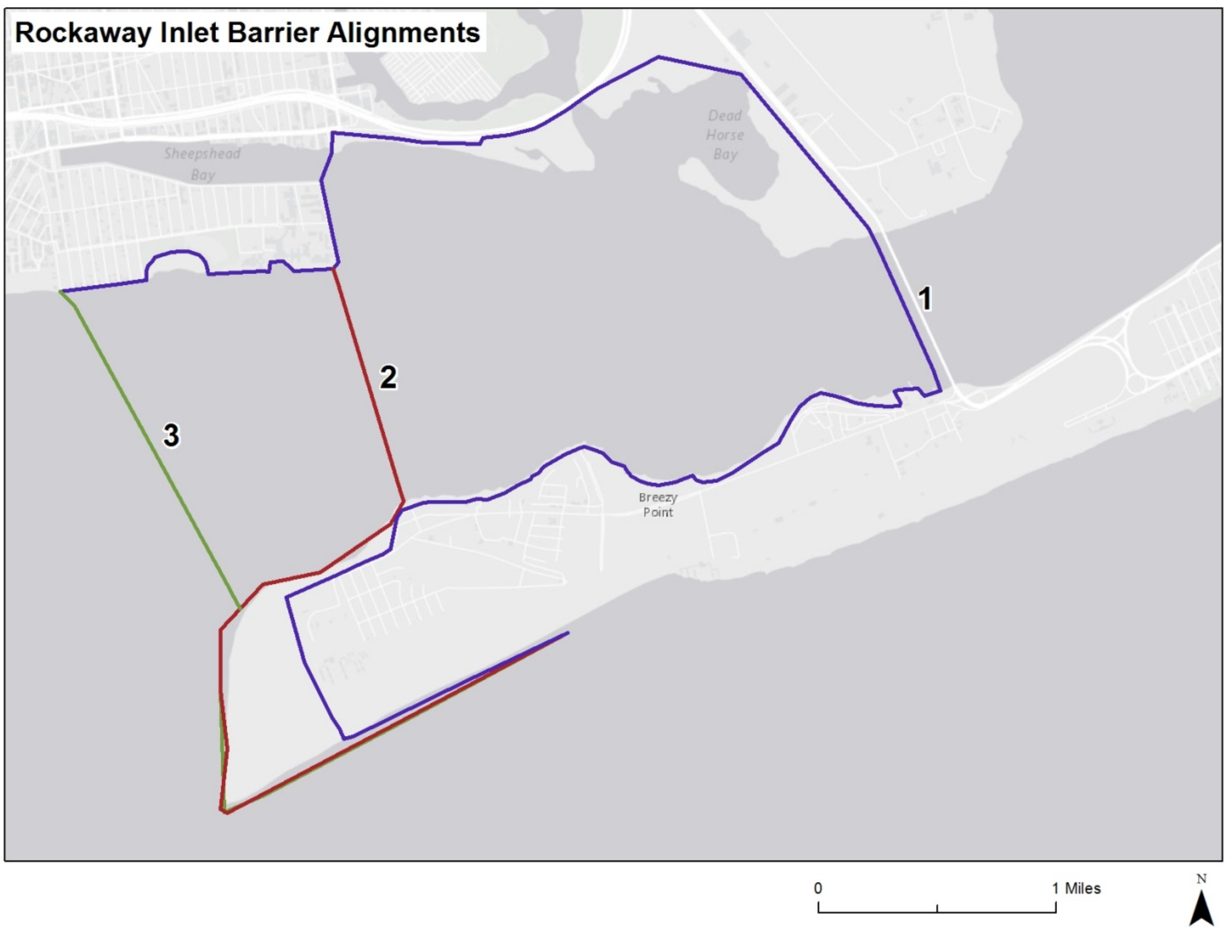


**Figure 43: Storm Surge Barrier Alignments**

Alternative Storm Surge Barrier plans are differentiated by their alignment (1, 2, or 3) and by the combined widths of the navigational and non-navigational openings, which range from 1,000 feet to 5,000 feet in 1,000-foot increments (Table 23). Each alternative Storm Surge Barrier plan includes a navigation gate, non-navigational gates, and other components, which may include seawalls, dunes and beach, and living shoreline to provide a complete inlet barrier.

**Table 23: Alternative C Plan Nomenclature**

| | Plan Name | | |
|---|---|---|---|
| **Opening Width** | **Alignment 1** | **Alignment 2** | **Alignment 3** |
| 1,000 feet | Plan C-1a | Plan C-2a | Plan C-3a |
| 2,000 feet | Plan C-1b | Plan C-2b | Plan C-3b |
| 3,000 feet | N/A | Plan C-2c | Plan C-3c |
| 4,000 feet | N/A | Plan C-2d | Plan C-3d |
| 5,000 feet | N/A | N/A | Plan C-3e |

Note: N/A indicates that the opening width is not feasible for this alignment

Inlet barrier plans configured along Alignment 1 (Plan C-1a and Plan C-1b) provide a barrier along the Brooklyn shore on the north side of the inlet from approximately Corbin Place on Coney Island to Flatbush Avenue at Floyd Bennett Field (Figure 44). This north shore barrier includes seawalls, dunes and beaches, T-walls, navigation gates at Sheepshead Bay and Gerritsen Inlet, and a living shoreline (Table 24 and Figure 44). This alternative provides 159 acres of coastal habitat consisting of living shoreline and dunes and beaches. The barrier along the south shore of the inlet on the Rockaway Peninsula includes dunes and beaches and a levee.

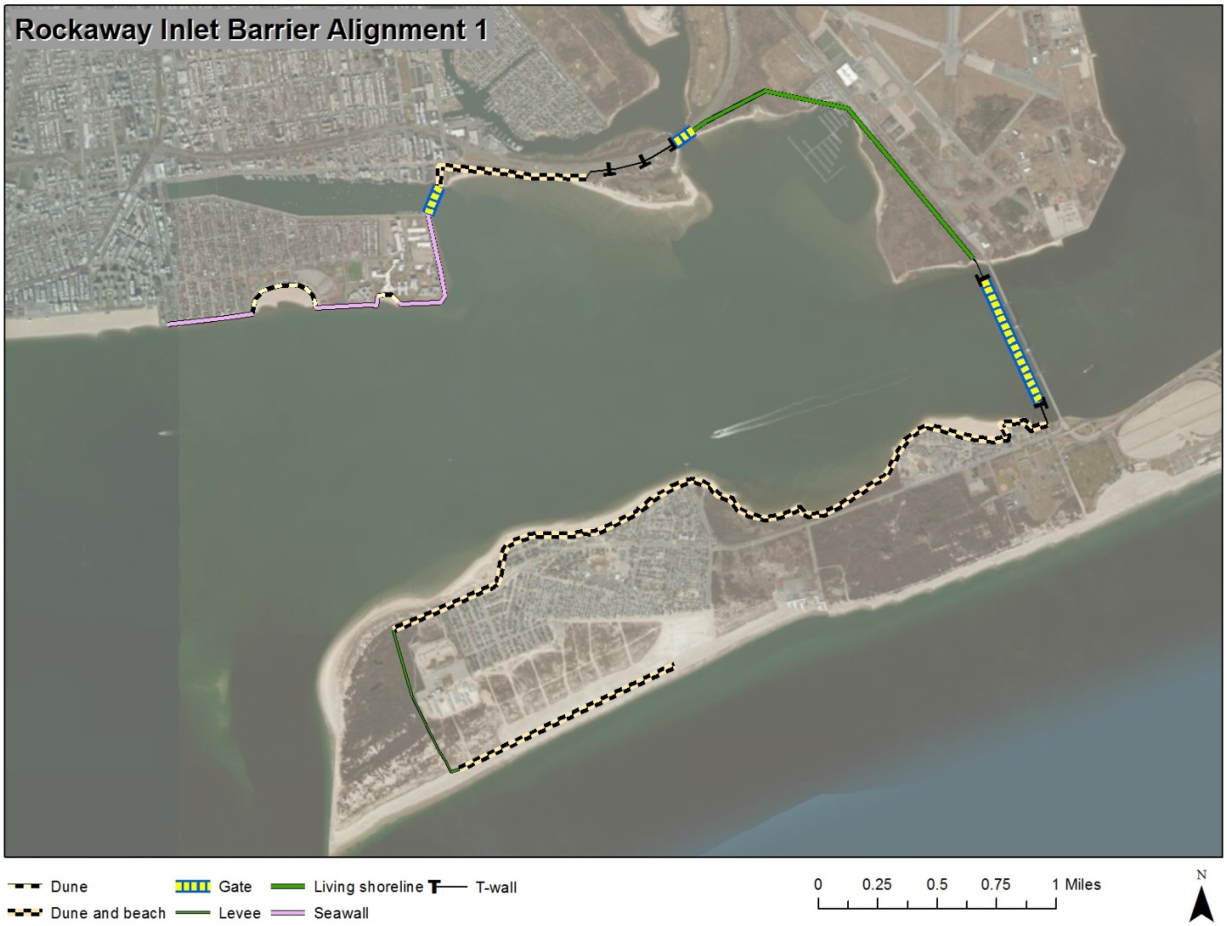


**Figure 44: Alternative Plan C-1 (Alignment 1)**

**Table 24: Alternative C-1 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Rockaway Inlet Navigable gates (multiple) | 200 each | Living Shoreline | 23.3 |
| Rockaway Inlet Non-navigable gates (multiple) | 800 each | Dunes and Beaches | 135.6 |
| Combi-wall | varies | **Total Acres** | **158.9** |
| Sheepshead and Gerritsen Inlet Navigable gates | 100 each | | |
| Sheepshead and Gerritsen Inlet Non-navigable gates | 200 each | | |
| Seawall | 6,500 | | |
| T-wall | 3,200 | | |
| Dune and Beach | 29,500 | | |
| Living shoreline/levee | 8,200 | | |
| **Total Barrier Length** | **56,100** | | |

Inlet barrier plans configured along Alignment 2 (Plans C-2a through C-2d) provide a barrier along the Brooklyn shore on the north side of the inlet from approximately Corbin Place on Coney Island to the eastern end of Coney Island at Kingsborough Community College (Figure 45). This north shore barrier includes seawalls, dunes and beaches (Table 25 and Figure 45). This alternative provides 72 acres of coastal habitat consisting of dunes and beaches. The barrier along the south shore of the inlet on the Rockaway Peninsula includes dunes and beaches and a levee.

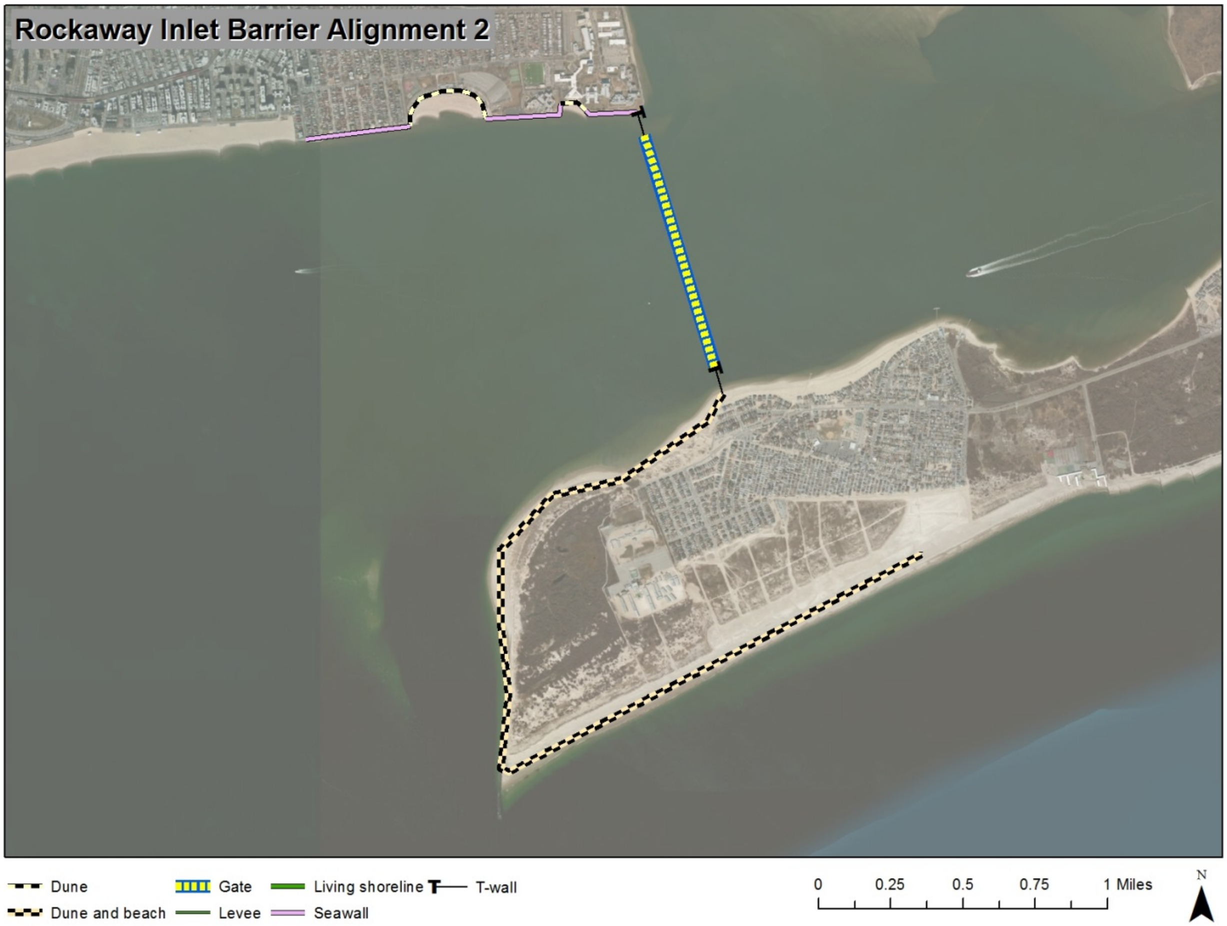


**Figure 45: Alternative Plan C-2 (Alignment 2)**

**Table 25: Alternative C-2 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Rockaway Inlet Navigable gates (multiple) | 200 each | Dunes and Beaches | 71.6 |
| Rockaway Inlet Non-navigable gates (multiple) | 800 each | **Total** | **71.6** |
| Combi-wall | varies | | |
| Seawall | 3,500 | | |
| T-wall | 1,000 | | |
| Dune and Beach | 15,600 | | |
| **Total Barrier Length** | **25,500** | | |

Inlet barrier plans configured along Alignment 3 (Plans C-3a through C-3e) tie into the Brooklyn shore on the north side of the inlet from approximately Corbin Place on Coney Island (Figure

46). The barrier along the south shore of the inlet on the Rockaway Peninsula includes dunes and beaches (Table 26 and Figure 46). This alternative provides 60 acres of coastal habitat consisting of dunes and beaches.


**Figure 46: Alternative Plan C-3 (Alignment 3)**

**Table 26: Alternative C-3 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Rockaway Inlet<br>Navigable gates (multiple) | 200 each | Dunes and Beaches | 59.7 |
| Rockaway Inlet<br>Non-navigable gates (multiple) | 800 each | **Total Acres** | **59.7** |
| Combi-wall | varies | | |
| T-wall | 1,000 | | |
| Dune and Beach | 13,000 | | |
| **Total Barrier Length** | **22,200** | | |

Plans under Alternative D were developed by placing measures adjacent to each other to create a continuous barrier for individual economic reaches within Jamaica Bay. Alternative Jamaica Bay Interior Barrier plans are defined as the group of measures, which, when constructed as a contiguous series avert inundation within an economic reach at a stillwater elevation of 11 feet. The following presents the initial list of plans under Alternative D;

- Alternative Plan D-1: Jamaica Bay West;
- Alternative Plan D-2: Canarsie;
- Alternative Plan D-3: Howard Beach;
- Alternative Plan D-4: Head of Bay;
- Alternative Plan D-5: Rockaway Peninsula;
- Alternative Plan D-6: Broad Channel Breakwater; and
- Alternative Plan D-7: Jamaica Bay Northwest.

During plan evaluation multiple plans under Alternative D will be evaluated in combination.

Jamaica Bay Interior Barrier Plan D-1: The first added increment for the Jamaica Bay West plan D-1 is a seawall at approximately Corbin Place on Coney Island (Figure 47). Adjacent measures were added eastward along the Brooklyn shore of Jamaica Bay until inundation at a stillwater elevation of 11 feet would be averted throughout the Jamaica Bay West economic reach. Because of the low-lying landscape and numerous inlets, contiguous measures were required from Corbin Place on Coney Island to the western side of Fresh Creek. It is important to note that this reach requires tying into high ground at the Pennsylvania Avenue Landfill, which may not be feasible.

Plan D-1 includes navigation gates at Sheepshead Bay, Gerritsen Inlet, Mill Basin, Paerdegat Basin, and Fresh Creek. Plan D-1 also includes seawalls, dunes and beach, levees, T-walls and living shorelines (Table 27). The living shoreline included in plan D-1 provides more than 265 acres of coastal habitat. Estimates of acres of restored habitat types are based on existing restoration projects which would be included in the living shoreline.


**Figure 47: Alternative Plan D-1 (Jamaica Bay West)**

**Table 27: Alternative D-1 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Navigable gates (5) | 540 | Low Marsh | 81 |
| Non-navigable gates (4) | 800 | High Marsh | 7 |
| Marine T-wall | 1,000 | Sub-tidal | 4.6 |
| Seawall | 6,500 | Maritime Forest | 97 |
| Dune and Beach | 6,300 | Coastal Forest | 0 |
| T-wall | 2,200 | Natural Dune | 27.7 |
| Levee or T-wall | 4,000 | Living Shoreline | 19.1 |
| Living shoreline/levee | 13,900 | Dunes and Beaches | 29.0 |
| **Total Barrier Length** | **35,400** | **Total Acres** | **265.4** |

Alternative Plan D-2: Canarsie uses high ground at the western side of Paerdegat Basin, the Belt Parkway, and the eastern side of Fresh Creek to create a U-shaped continuous barrier consisting of T-walls, levees, and living shorelines (Figure 48). The barrier requires a road gate at Rockaway Parkway to allow waterfront access. The living shoreline included in Plan D-2 provides more than 10 acres of coastal habitat (Table 28). Estimates of acres of restored habitat types are based on existing restoration project which would be included in the living shoreline. Additional habitat acreage that would be created by the living shoreline can be determined with *more detailed analysis prior to the TSP Milestone*.


**Figure 48: Alternative Plan D-2 (Canarsie)**

**Table 28: Alternative D-2 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| T-wall | 6,700 | Living Shoreline | 10.5 |
| Levee | 5,300 | **Total Acres** | **10.5** |
| Road gate | 100 | | |
| Living Shoreline/levee | 3,700 | | |
| **Total Barrier Length** | **15,800** | | |

Alternative Plan D-3: Howard Beach begins at high ground at the western end of Hendrix Creek and provides a continuous barrier eastward ending at high ground along the western shore of Bergen Basin (Figure 49). This alternative includes navigation gates at Hendrix Creek, Spring Creek, Shellbank Basin, and Hawtree Basin. Plan D-3 also includes T-walls, sea walls, a road gate at the rail road (Metropolitan Transit Authority), and living shoreline (Table 29). It is important to note that this alternative plan requires tying into high ground at the Flatlands Landfill, which may not be feasible.

The living shoreline included in plan D-3 provides 160 acres of coastal habitat. Estimates of acres of restored habitat types are based on existing restoration projects which would be included in the living shoreline.


**Figure 49: Alternative Plan D-3 (Howard Beach)**

**Table 29: Alternative D-3 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Navigable gates (2) | 380 | Low Marsh | 49 |
| Non-navigable gates (2) | 200 | High Marsh | 10 |
| Marine T-wall | 530 | Sub-tidal | 6 |
| T-wall | 13,900 | Maritime Forest | 44.1 |
| Seawall | 1,000 | Natural Dune | 42.3 |
| Living shoreline/levee | 3,200 | Living Shoreline | 8.6 |
| Rail Road gate | 100 | **Total Acres** | **160.0** |
| **Total Barrier Length** | **19,210** | | |

Alternative Plan D-4: Head of Bay (Figure 50) includes a T-wall adjacent to the eastern edge of JFK Airport, levees, a navigation gate across the inlet to Grass Hassock, and another navigation gate across to Motts Point at Bayswater Park. This alternative also includes a levee with road elevation at Mott Avenue and living shoreline, which provides 14 acres of coastal habitat (Table 30). Additional habitat acreage that would be created by the living shoreline can be determined with *more detailed analysis prior to the TSP Milestone.*


**Figure 50: Alternative Plan D-4 (Head of Bay)**

**Table 30: Alternative D-4 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Navigable gates (2) | 300 | Living Shoreline | 14 |
| Non-navigable gates (2) | 350 | **Total Acres** | **14** |
| Marine T-wall | 600 | | |
| T-wall | 6,100 | | |
| Levee | 1,500 | | |
| Living shoreline/levee | 5,200 | | |
| Levee road elevation | 500 | | |
| **Total Barrier Length** | **14,550** | | |

Alternative Plan D-5: Rockaway Peninsula provides a continuous barrier from Motts Point westward along the Jamaica Bay side of the Rockaway Peninsula, continuing around Breezy Point, to tie into ocean-side dunes along the Atlantic Ocean side of the peninsula as proposed by the East Rockaway Inlet to Rockaway Inlet study (Figure 51). This alternative includes T-walls, bulkheads, levees, dunes and beaches, and living shoreline (Table 31). The living shoreline included in plan D-5 provides more than 168 acres of coastal habitat. Estimates of acres of restored habitat types are based on existing restoration projects which would be included in the living shoreline. Additional habitat acreage that would be created by the living shoreline can be determined with *more detailed analysis prior to the TSP Milestone*.

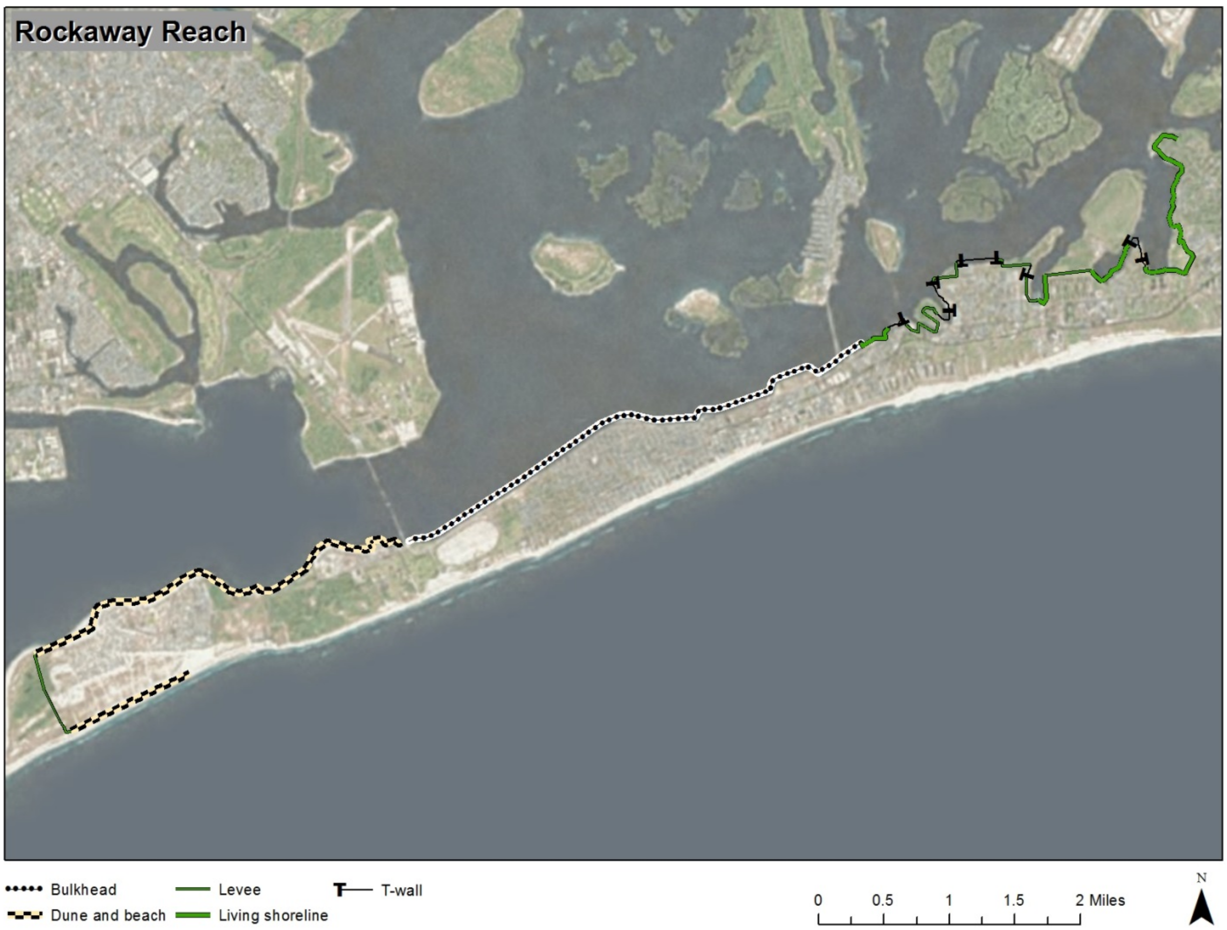


**Figure 51: Alternative Plan D-5 (Rockaway)**

**Table 31: Alternative D-5 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| T-wall | 6,700 | Low Marsh | 12.5 |
| Seawall | 21,000 | High Marsh | 0.6 |
| Levee | 14,300 | Sub-tidal | 0.7 |
| Dune and beach | 23,200 | Maritime Forest | 13 |
| Living Shoreline/levee | 15,100 | Living Shoreline | 34.9 |
| **Total Barrier Length** | **80,300** | Dunes and Beaches | 106.6 |
| Railroad (1) & Marina gates (4) | 500 | **Total Acres** | **168.3** |

Alternative Plan D-6: Broad Channel Breakwater provides a continuous barrier around the community of Broad Channel (Figure 52). This alternative includes breakwaters with four navigation gates, T-walls, levees, a road gate at Cross Bay Boulevard, and living shoreline, which provides 11 acres of coastal habitat (Table 32).


**Figure 52: Alternative D-6 (Broad Channel)**

**Table 32: Alternative D-6 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Navigable gates (2) | 200 | Living Shoreline | 11.0 |
| Non-navigable gates (3) | 150 | **Total Acres** | **11.0** |
| Marine T-wall | 350 | | |
| Breakwater | 8,500 | | |
| T-wall | 800 | | |
| Levee | 2,000 | | |
| Road gate | 100 | | |
| Living shoreline/levee | 5,300 | | |
| **Total Barrier Length** | **17,400** | | |

Alternative Plan D-7: Jamaica Bay Northwest provides a continuous barrier from Corbin Place on Coney Island to high ground along the western shore of Bergen Basin (Figure 53). This alternative plan is a combination of Alternative Plan D-1: Jamaica Bay West and Alternative Plan D-3: Howard Beach (Table 33). This plan avoids tying into the two Brooklyn landfills and is structurally more feasible than Alternative Plans D-1 or D-3.

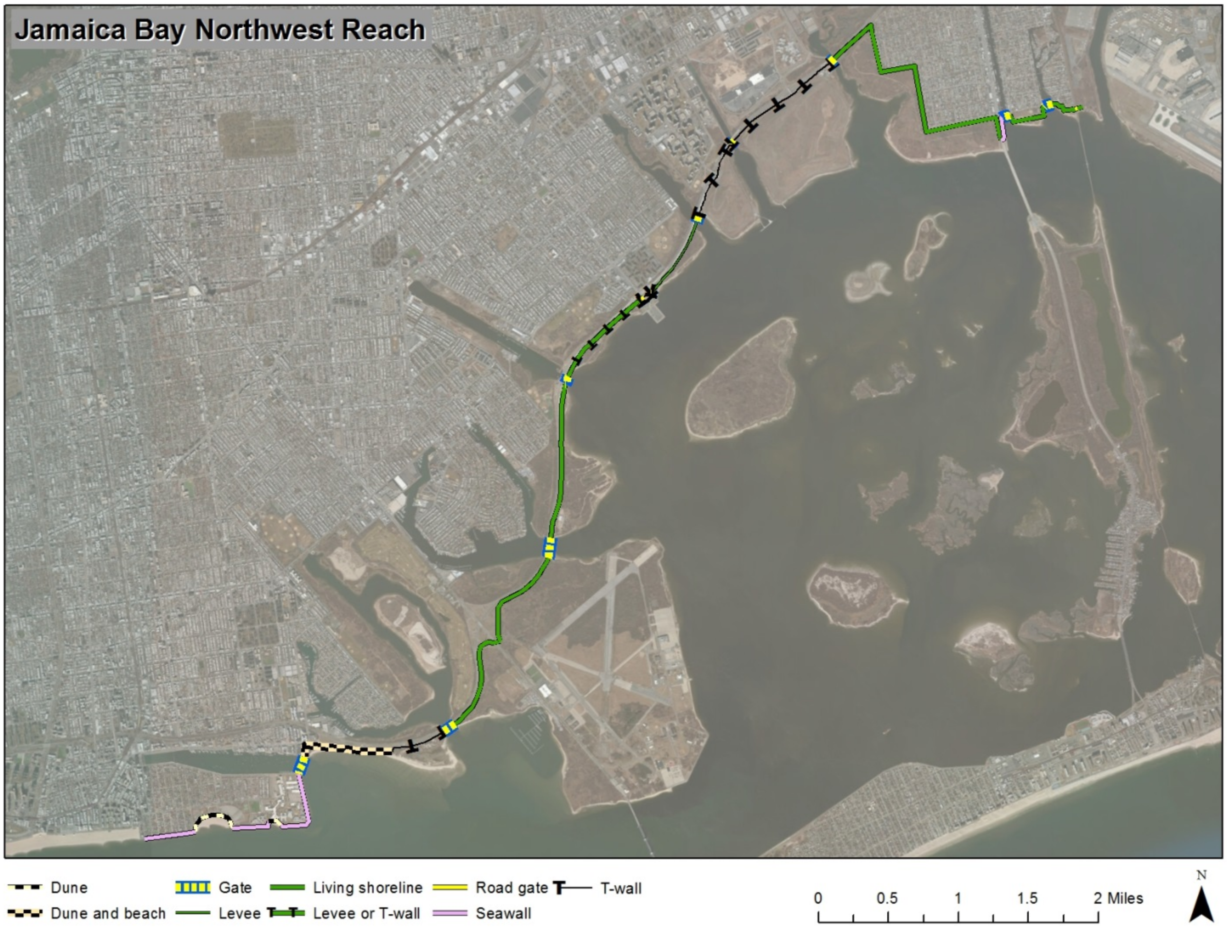


**Figure 53: Alternative D-7 (Jamaica Bay Northwest)**

**Table 33: Alternative D-7 Plan Elements**

| Barrier Element | Linear Feet | Habitat Type | Acres Created |
|---|---|---|---|
| Navigable gates (2) | 920 | Low Marsh | 130 |
| Non-navigable gates (3) | 1,000 | High Marsh | 17 |
| Marine T-wall | 1,700 | Sub-tidal | 10.6 |
| Seawall | 7,500 | Maritime Forest | 141.1 |
| T-wall | 19,100 | Natural Dune | 7 |
| Levee | 4,000 | Living Shoreline | 27.7 |
| Road gate | 30 | Dunes and Beaches | 29.0 |
| Living shoreline/levee | 17,100 | **Total Acres** | **425.4** |
| Dune and Beach | 6,300 | | |
| **Total Barrier Length** | **57,650** | | |

## 3.5 Preliminary Structural Plan Costs

Cost estimates were developed separately for the Atlantic shoreline and Jamaica Bay portions of the study area. Atlantic shoreline cost estimates are presented in FY 2011 price levels, although they will be updated prior to selection of the TSP. The Jamaica Bay cost estimates are presented in FY 2014 price levels.

### 3.5.1 Atlantic Shoreline Preliminary Structural Plan Costs

The initial construction costs for each of the CSRM alternatives includes all of the required project features including erosion control measures, beach, dune and seawall features for each plan, any modifications to existing structures, such as boardwalk access ramps, and associated costs for engineering design and construction management (Table 34).

**Table 34: Preliminary Atlantic Shoreline Structural Plan Construction Costs (FY 2011)**

| Alternative | Construction Cost |
|---|---|
| Alternative 1 | $56,058,000 |
| Alternative 2 | $85,145,000 |
| Alternative 3 | $56,740,000 |

Note: Costs to be revised and updated to current fiscal year prices prior to TSP Milestone

For average annual cost calculations, interest during construction has been added to the initial construction costs to reflect different investment opportunity costs between alternatives. Average annual costs (Table 35) also include the amortized value of the initial construction (50 years, 3.375 interest rate), annualized value of periodic renourishment, Operations and Maintenance (O&M), average annual costs for structure repair after major storm events (major rehabilitation), and costs for adapting the structure for sea level rise (intermediate sea level rise as measured at the Sandy Hook gauge).

**Table 35: Atlantic Shoreline Preliminary Structural Plan Average Annual Equivalent (AAEQ) Costs**

| Plan Name | Construction Cost | Maintenance Cost | Total Cost |
|---|---|---|---|
| Alternative 1 | $2,390,000 | $4,101,000 | $6,491,000 |
| Alternative 2 | $3,629,000 | $1,900,000 | $5,529,000 |
| Alternative 3 | $2,419,000 | $2,000,000 | $4,419,000 |

Note: AAEQ calculated at FY14 price levels, 3.5% discount rate, and 50-year period of analysis

### 3.5.2 Jamaica Bay Preliminary Structural Plan Costs

Parametric cost estimates were developed for each structural alternative for the Jamaica Bay portion of the study area, which include construction costs (e.g. site preparation, materials, an assumed haul/transportation distance for materials, and labor) and contingencies to account for potential constructability concerns (Table 36). All costs were estimated at Fiscal Year 2014 price levels. Note that for some plan elements, contingencies for parametric costs may be as high as 50% to account for plan segments with high cost uncertainties, such as those that require in water construction and to account for utility relocations. Construction costs are based on information gathered from previously constructed projects and professional judgment as described in *Rockaway Inlet to East Rockaway Inlet and Jamaica Bay Reformulation Study Memorandum for the Record (MFR) #2 and #4*. Note that these MFR's will constitute an appendix to the Report Synopsis as the drafts are finalized.

Parametric costs associated with living shorelines are based upon average project costs from *Jamaica Bay, Marine Park and Plumb Beach, New York Environmental Restoration Project, Draft Interim Feasibility Report, Kings and Queens Counties, New York. Volume 3 (USACE 2010).* Parametric costs for ecological plan elements used in this analysis are based on an average of the eight ecosystem restoration projects which were evaluated in the 2010 feasibility study.

The development of these parametric costs is intended for initial screening purposes only. These cost estimates allow for early comparisons of functional performance of measures and magnitude of costs. Cost engineering guidance defines rigorous cost estimating practices for the feasibility phase of study. Following the Alternatives Milestone, the costs will be refined in accordance with ER1110-2-1302; ER 1110-1-1300; EM1110-2-1304; EP 1110-1-8; ETL1110-2-573; and ECB2012-18.

Note that construction costs do not include the following:

- Interest During Construction;
- Operations and maintenance;
- Real estate;
- Mobilization/demobilization;
- Permitting;
- Additional studies or detailed engineering and design;
- Construction management costs; and
- Longer than expected haul distances.

**Table 36: Preliminary Jamaica Bay Structural Plan Construction Costs ($000's)**

| Alternative C: Storm Surge Barrier Plans | | Alternative D: Jamaica Bay Interior Barrier Plans | |
|---|---|---|---|
| **Plan Name** | **Construction Cost** | **Plan Name** | **Construction Cost** |
| C-1a | $2,727,850 | D-1 | $1,688,310 |
| C-1b | $3,382,850 | D-2 | $89,105 |
| C-2a | $2,198,300 | D-3 | $597,255 |
| C-2b | $2,743,300 | D-4 | $834,250 |
| C-2c | $3,288,300 | D-5 | $313,186 |
| C-2d | $3,833,300 | D-6 | $1,030,865 |
| C-3a | $2,815,100 | D-7 | $2,300,157 |
| C-3b | $3,360,100 | | |
| C-3c | $3,905,100 | | |
| C-3d | $4,450,100 | | |
| C-3e | $4,995,100 | | |

## 3.6 Preliminary Alternative Plan Evaluation – Jamaica Bay Planning Reach

The preliminary structural plans under Alternative C (Storm Surge Barrier) and Alternative D (Jamaica Bay Interior Barrier) are evaluated for their effectiveness and efficiency in contributing to the five planning objectives. The metrics used to assess plan effectiveness are described below. Efficiency is measured by comparing the costs and benefits of each effective alternative plan.

Reducing vulnerability to storm surge impacts is measured by estimating the number of structures that have reduced inundation levels under with-project conditions. Reducing future flood risk in ways that will support the long-term sustainability of the coastal ecosystem and communities is measured by the increase in habitat functionality (Functional Capacity Unit score) provided by natural and nature based features, which are elements of alternative plans. The reduction in economic costs and risks associated with large-scale flood and storm events is measured by estimating the economic damages avoided by each alternative. Improvements to community resiliency are identified by opportunities provided by each alternative to anticipate, prepare for, respond to, and adapt to the effects of storm surge and wave impacts.

Enhancements to natural and nature based storm buffers and ecosystem resiliency are measured by increases in habitat acreage created by NNBFs, which offset projected reductions in future without project wetland acreage due to sea level rise. NNBFs are integral components of Alternative C: Storm Surge Barriers and Alternative D: Jamaica Bay Interior Barriers. NNBFs can provide coastal storm risk management functions, improve ecosystem resiliency, and reduce risk while supporting ecosystem sustainability as quantified in this section of the report.

### 3.6.1 Reduced Vulnerability

Reduced vulnerability under each alternative is measured by the number of structures that have reduced inundation levels with the alternative in operation. The number of inundated structures is presented for the 10-year, 50-year, and 100-year storm events (Table 37). Each alternative effectively reduces vulnerability.

**Table 37: Jamaica Bay Planning Reach Affected Structures by Return Interval**

| | Number of Structures | | |
|---|---|---|---|
| | **10-year** | **50-year** | **100-Year** |
| Plans C-1, C-2 & C-3 | 10,304 | 32,059 | 41,093 |
| Plan D-1 | 1,918 | 11,261 | 16,178 |
| Plan D-2 | 246 | 3,815 | 5,135 |
| Plan D-3 | 1,197 | 3,926 | 4,579 |
| Plan D-4 | 2,370 | 8,549 | 11,503 |
| Plan D-5 | 3,966 | 7,432 | 7,942 |
| Plan D-6 | 853 | 891 | 891 |
| Plan D-7 | 3,115 | 15,187 | 20,757 |

### 3.6.2 Reduced Flood Risk While Supporting Coastal Ecosystem Sustainability

All of the alternative plans reduce flood risk as indicated in Table 37. Supporting ecosystem sustainability is being measured in this preliminary analysis by the magnitude of increases in habitat functionality provided by the natural and nature based features of the alternative plan (Table 38). Habitat functionality is measured by making a qualitative assessment of habitat functionality through field observations and other means to calculate a Functional Capacity Index (FCI), which is a measure of habitat quality (see *Rockaway Inlet to East Rockaway Inlet and Jamaica Bay Reformulation Study Memorandum for the Record #3* for details). The FCI is multiplied by the acreage of the area assessed to create a Functional Capacity Unit (FCU), which represents the quantity of functional capacity of the area assessed. Increases in habitat functionality, as measured in FCUs, are calculated as the difference between existing conditions and with-project conditions for each alternative.

Habitat functionality for each alternative plan is calculated by multiplying the total number of habitat acres improved or created by each alternative (see Total Acres in Tables 26 - 33) by the average FCU increase per acre (.385 FCU/acre) for 30 Jamaica Bay ecosystem restoration projects evaluated in *Rockaway Inlet to East Rockaway Inlet and Jamaica Bay Reformulation Study Memorandum for the Record #3*.

**Table 38: Jamaica Bay Alternative Plan Habitat Functionality Improvements**

| Storm Surge Barrier Plans | | Jamaica Bay Interior Barrier Plans | |
|---|---|---|---|
| **Plan Name** | **FCU increase** | **Plan Name** | **FCU Increase** |
| C-1 | 61.1 | D-1 | 112.1 |
| C-2 | 27.6 | D-2 | 4.0 |
| C-3 | 23.0 | D-3 | 65.1 |
| | | D-4 | 5.4 |
| | | D-5 | 65.2 |
| | | D-6 | 4.2 |
| | | D-7 | 177.2 |

Alternative Plan C also has the potential to impact habitat functionality by affecting circulation in the bay and water volume exchange between the bay and the ocean due to flow restrictions at the barrier openings. Plans under Alternative C have been developed with openings ranging from 1,000 feet to 5,000 feet as applicable (Table 39). Potential effects to circulation and tidal exchange could impact Jamaica Bay habitats, if those effects are of sufficient magnitude. In order to assess the potential for habitat impacts, the effects of alternative openings at each alignment on tidal prism were approximated by estimating the ratio of tidal amplitude inside the bay to the adjacent ocean (see MFR # 4 for a discussion of the method applied).

The ratio of tidal amplitude for existing conditions (no Storm Surge Barrier) has been compared to the proposed conditions for all three alignments and applicable opening sizes. The percentage of existing conditions tidal amplitude provided by each alterative (Table 39) is used to evaluate the potential impact on habitat sustainability within Jamaica Bay. For example, Plan C-3 with an opening of 1000 feet will reduce the tidal amplitude ratio to 58% of the existing condition ratio (a reduction of 42% from existing conditions).

**Table 39: Percentage of Existing Tidal Amplitude within Jamaica Bay**

| Opening Width | Plan C-1 | Plan C-2 | Plan C-3 |
|---|---|---|---|
| 1,000 feet | 58% | 73% | 58% |
| 2,000 feet | 91% | 90% | 70% |
| 3,000 feet | N/A | 93% | 79% |
| 4,000 feet | N/A | 95% | 81% |
| 5,000 feet | N/A | N/A | 90% |

Note: N/A indicates that the opening width is not feasible for this alignment

For the purposes of preliminary plan evaluation, based on engineering judgment, the percentage of existing conditions tidal amplitude should be at least 90 percent in order for a plan to be carried forward for further consideration. The threshold for determination of a viable project in future phases may be more stringent (e.g. 95 percent). However, in this phase it is recognized that the tidal amplitude estimation method has notable uncertainty and may overestimate the reduction in the tidal prism.

### 3.6.3 Reduced Economic Costs and Risks

Reduction in economic costs and risks associated with large-scale flood and storm events is measured by estimating the economic damages avoided by each alternative. Equivalent annual flood damages (EAD) are defined as the monetary value of physical losses and non-physical damages that can occur in any given year based on the magnitude and probability of losses from all possible flood events. The typical basis for determining EAD are losses actually sustained as a result of historical floods, supplemented by appraisals, application of depth-damage curves, and an inventory of capital investment within the floodplain. EAD are computed using standard damage-frequency integration techniques and computer models that relate hydrologic and hydraulic flood variables such as discharge and stage to damages and to the probability of occurrence. Damages are computed by the application of depth-damage functions, which include application of generalized curves, or site-specific relationships between inundation depth and damage determined by field surveys. EAD can then be computed from the definition of stage-damage, stage-discharge, and discharge-frequency relationships. All of these relationships are developed using a risk-based analytical framework, in accordance with Corps regulations.

EAD calculations were performed using Version 1.2.5 of the Hydrologic Engineering Center's Flood Damage Analysis computer program (HEC-FDA, October 2010). This program applies Monte Carlo Simulation to calculate expected damage values while explicitly accounting for uncertainty in the input data. HEC-FDA models were prepared for existing without-project conditions and future without-project conditions, which incorporate an anticipated one-foot rise in water surface elevations (see Figure 14: USACE SLC Projections (feet) at The Battery, NY) over the 50-year period of analysis.

In the typical flood damage reduction study, every potentially damageable floodplain property is inventoried in order to establish structure type, physical characteristics, and approximate values and elevations. Surveys of all residential properties are conducted in many studies, and representative samples in most others. Industrial, public and unique commercial properties typically require 100% sampling and more detailed on-site inspections. Given the scope and scale of the preliminary formulation phase of the Rockaways study, on-site inspection of all, or a significant percentage of, floodplain properties at this stage of the analysis was not feasible. However, GIS-based structure location data and complete aerial imagery has provided much of the data gathered in a typical Corps flood damage reduction on-site survey.

Based on the type, usage and size of each structure included in the GIS data base (over 90,000 for this analysis) damages were calculated relative to the main floor elevation of the structure. Using structure and ground elevation data, the depth vs. damage relationships were converted to corresponding stage (NAVD88) vs. damage relationships. Generalized depth-percent damage functions for structure, structure content and other items were applied to structures for calculation of inundation damage. For this analysis, generalized depth-percent damage functions used for multi-family residential and all non-residential structures were taken from the HAZUS-MH MR4 Technical Manual. Depth-percent damage functions used for single family residential dwellings with basements were taken from Corps of Engineers' Economic Guidance Memoranda EGM 04-01. Depth-percent damage functions used single family residential dwellings without basements were taken from *Depth-Damage Relationships For Structures, Contents, and Vehicles and Content-To-Structure Value Ratios in Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study – March, 2006* (USACE 2006). The damage curves represented in the Louisiana study were used in this analysis because they represent damages occurring from short-duration saltwater intrusion, which typifies coastal flooding experienced in the Jamaica Bay study area. Alternative depth-percent damage functions for single family residential dwellings without basements are available from Corps of Engineers' Economic Guidance Memoranda EGM 01-03, but these functions represent riverine flooding, not coast flooding, and therefore, were not used in this analysis.

For each structure, EADs were calculated for a range of protection levels (10, 25, 50, 100, 250, and 500-year). It is important to note that, the EAD for a structure's 50-year level of protection is not equal to damages incurred by a structure from a 50-year event. Rather, the EAD for a 50-year level of protection represents the average annual equivalent benefits of protecting a structure for storms up to and including the 50-year event, which also includes the 2, 5, 10, and 25-year events. The calculation incorporates the probabilities of various levels of flood events and the associated damages from those events

Table 40 presents EADs for each alternative plan for the 10-year, 50-year and 100-year events. The EADs for all plans under Alternative C (Inlet Barriers) are equivalent because each plan under Alternative C provides the same level of protection for all economic reaches. The Canarsie economic reach is a sub-reach within the Jamaica Bay West economic reach. Note that additional economic benefits, which would be expected to accrue from coastal storm risk reduction, such as reductions in emergency service costs, municipal maintenance costs, flood insurance administrative costs and ancillary recreation benefits are not included in this stage of the analysis.

**Table 40: Jamaica Bay Alternative Plan Equivalent Annual Damage ($000's)**

| Alternative Plan | 10-year event | 50-year event | 100-year event |
|---|---|---|---|
| C-1, C-2 &C-3: Inlet Barriers | $55,084 | $215,262 | $265,833 |
| D-1: Jamaica Bay West | $11,188 | $71,049 | $88,664 |
| D-2: Canarsie | $571 | $11,089 | $14,980 |
| D-3: Howard Beach | $6,757 | $20,088 | $24,847 |
| D-4: Head of Bay | $13,704 | $55,408 | $71,036 |
| D-5: Rockaway | $16,154 | $56,211 | $67,896 |
| D-6: Broad Channel | $7,281 | $12,506 | $13,390 |
| D-7: Jamaica Bay Northwest | $17,945 | $91,137 | $113,511 |

Note: EADs calculated at FY14 price levels, 3.5% discount rate, and 50-year period of analysis

Figures 54 – 60 present the geographic extent of damage reduction (footprint of benefits) provided by each of the Jamaica Bay Interior Barrier plans during a 100-year event. Note that the Inlet Barrier Plans provide damage reduction throughout the entire geographic area of damage reduction provided by the all the interior barrier plans combined.

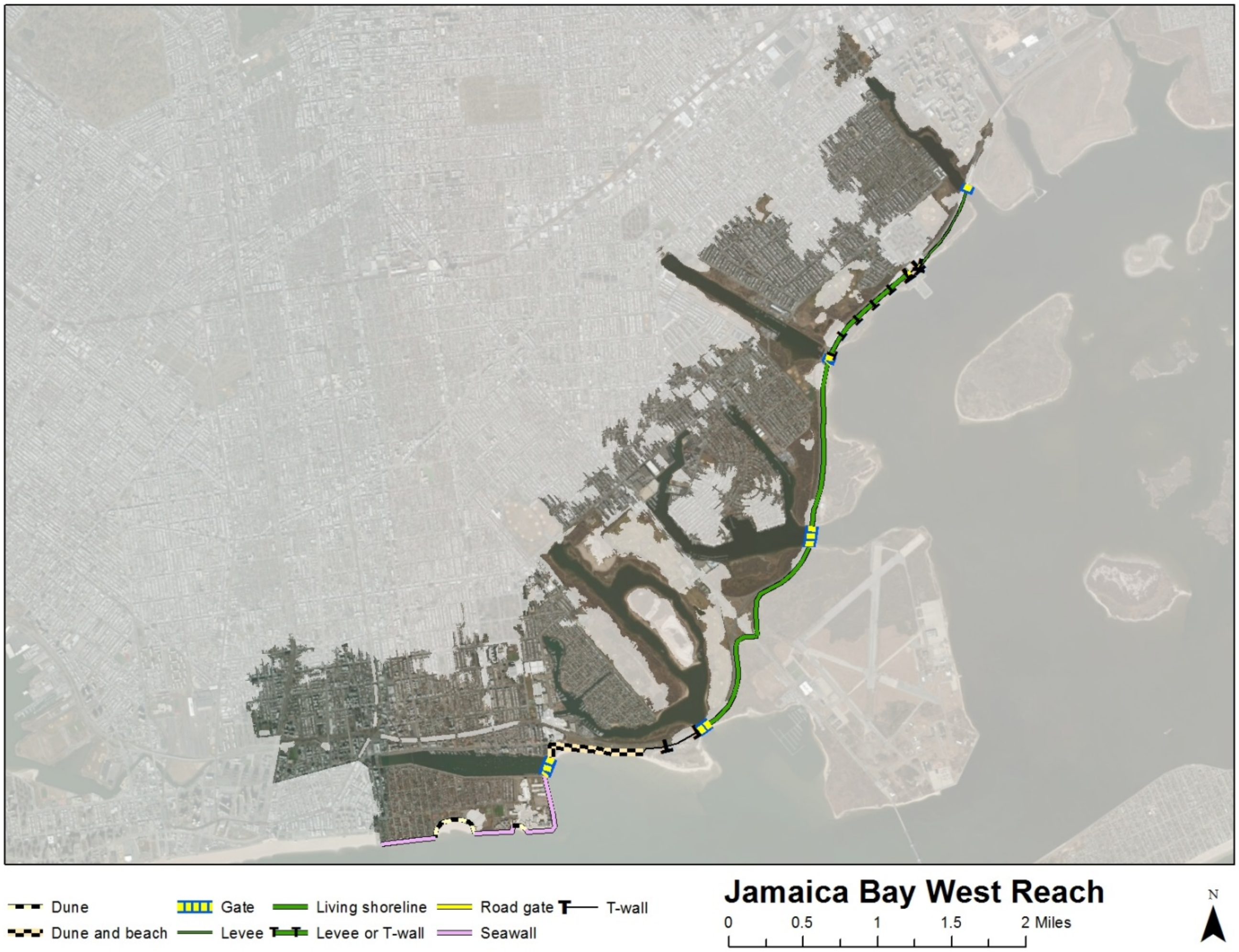


**Figure 54: Plan D-1 Geographic Extent of Damage Reduction**


**Figure 55: Plan D-2 Geographic Extent of Damage Reduction**

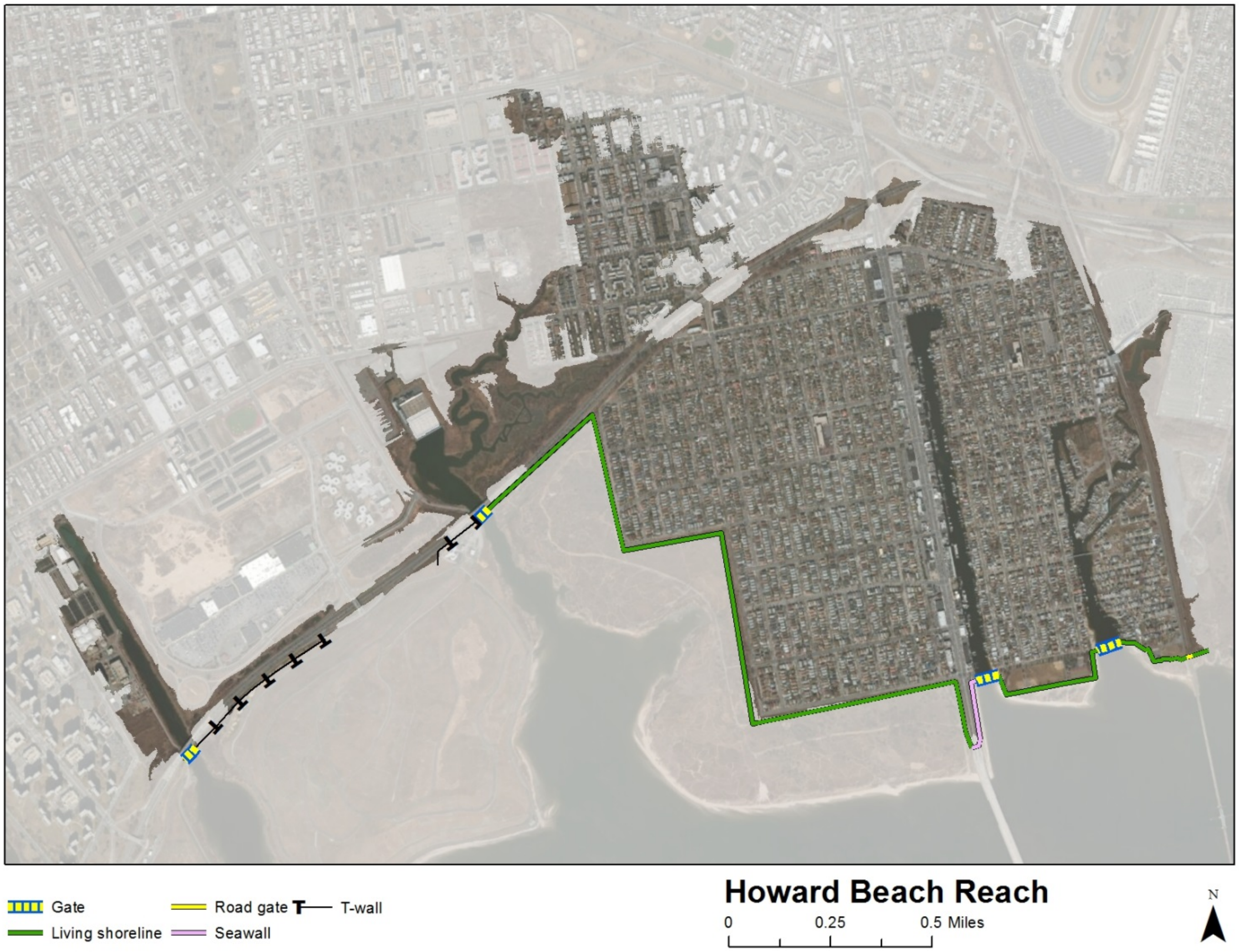


**Figure 56: Plan D-3 Geographic Extent of Damage Reduction**

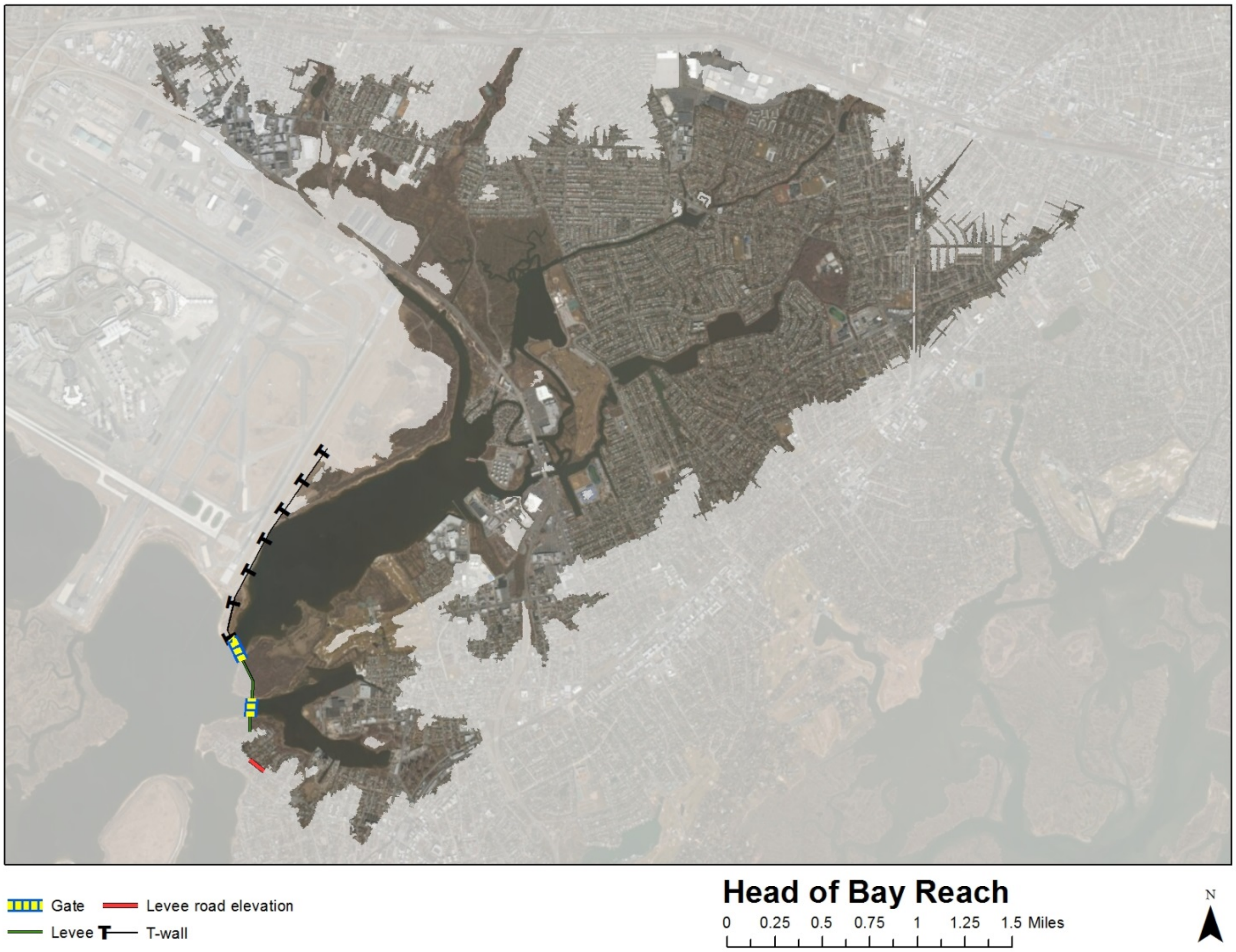


**Figure 57: Plan D-4 Geographic Extent of Damage Reduction**

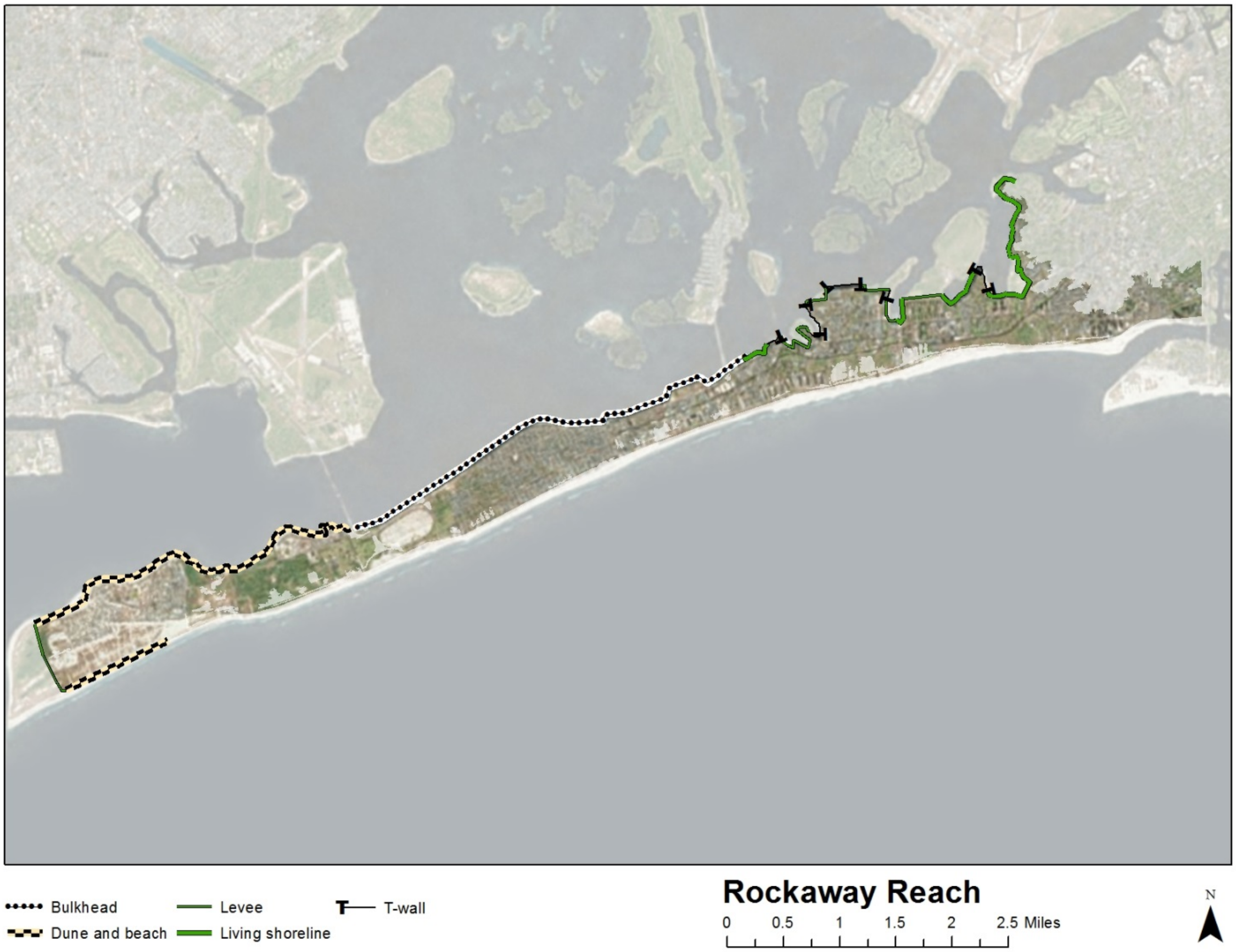


**Figure 58: Plan D-5 Geographic Extent of Damage Reduction**

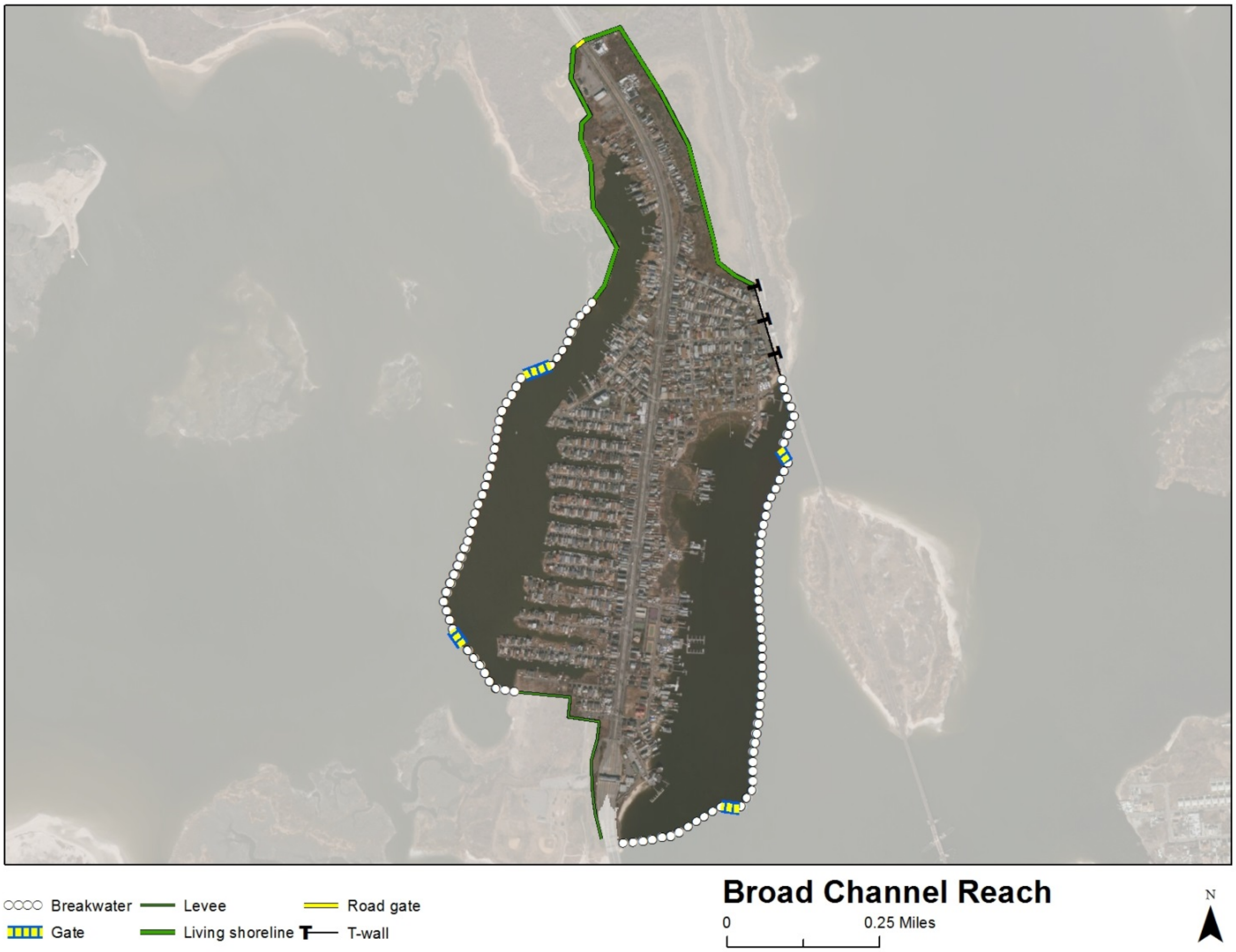


**Figure 59: Plan D-6 Geographic Extent of Damage Reduction**

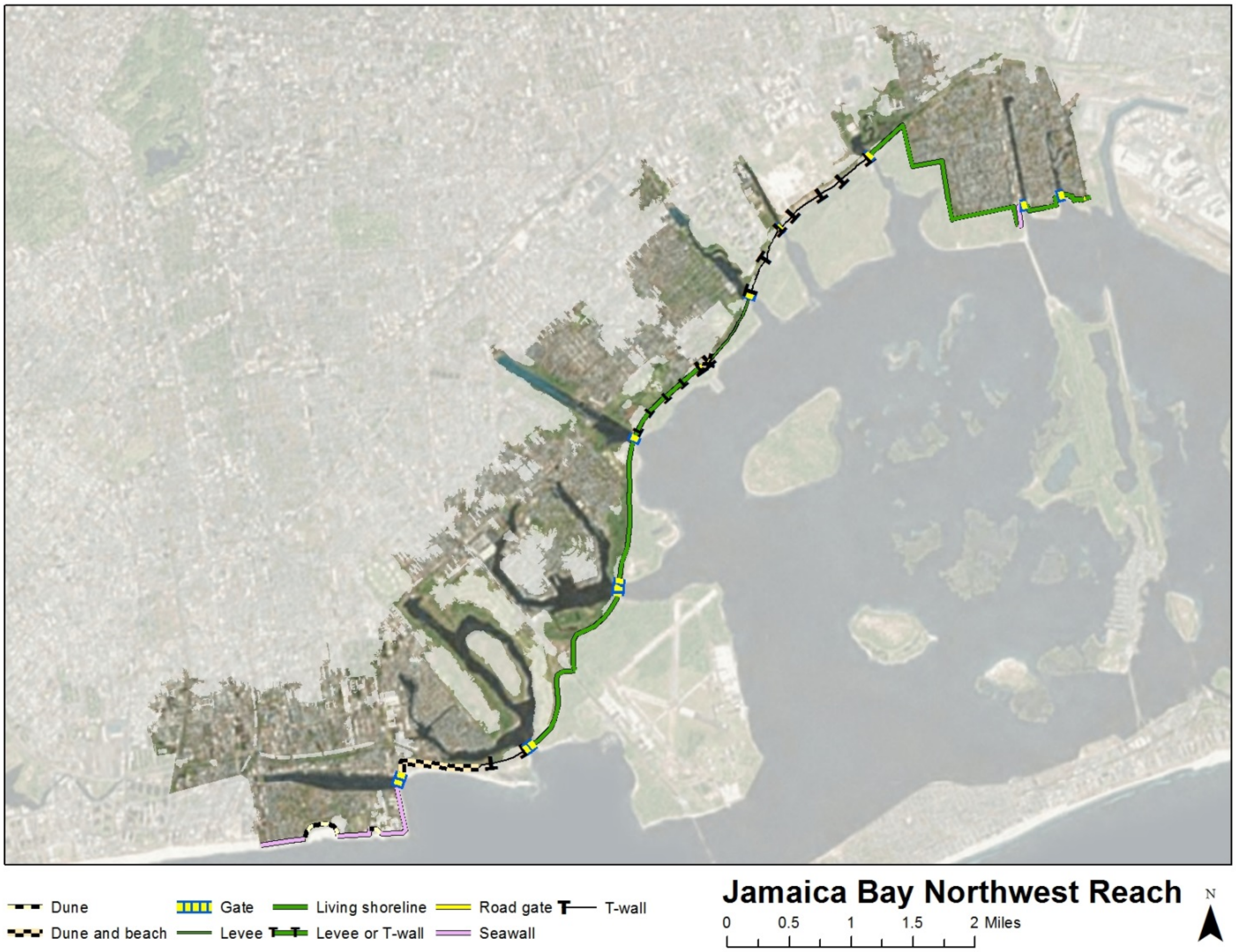


**Figure 60: Plan D-7 Geographic Extent of Damage Reduction**

### 3.6.4 Improve Community Resiliency

Improvements to community resiliency are identified by the opportunities provided by each alternative to anticipate, prepare for, respond to, and adapt to the effects of storm surge impacts. One example of potential improvements to community resiliency is reduced roadway flooding (Table 41), which provides access and egress. Other examples might include faster recovery of mass transit, which is an important element of economic activity within the study. *Additional opportunities are likely to be found when more detailed analyses of Alternative Plan design and hydrodynamic effects of alternative plans are conducted prior to the TSP Milestone.* In addition, a detailed economic analysis may estimate the economic benefits of improved community resiliency by assessing the economic benefits of faster recovery to flood conditions under with-project conditions. All alternative plans provide opportunities to improve community resiliency, however, more extensive identification and quantification of these types of improvements requires more detailed information than is available in this phase of the analysis. Non-structural alternatives also would likely improve community resiliency; however, sufficient information is not available at this stage of the analysis to assess the effects of non-structural alternatives. Improvements to community resiliency will be evaluated in greater depth during the detailed evaluation of alternatives phase.

**Table 41: Sample Opportunities to Improve Community Resiliency – Reduced Roadway Flooding**

| Plan | Major Roadways with Reduced Flooding |
|---|---|
| Plan C-1 | Belt Parkway; Rockaway Point Blvd, others. |
| Plan C-2 | Oriental Blvd; Rockaway Point Blvd, others. |
| Plan C-3 | Rockaway Point Blvd, others. |
| Plan D-1 | Oriental Blvd; Belt Parkway, others. |
| Plan D-2 | Remsen Ave; Rockaway Parkway, others |
| Plan D-3 | Belt Parkway; Cross Bay Blvd, others. |
| Plan D-4 | Mott Ave; Sheridan Blvd, others. |
| Plan D-5 | Rockaway Fwy; Beach Channel Dr.; others. |
| Plan D-6 | Cross Bay Blvd, others. |
| Plan D-7 | Oriental Blvd; Belt Parkway, Rockaway Pt. Blvd, others. |

### 3.6.5 Enhance Natural and Nature-based Storm Buffers and Improve Ecosystem Resiliency

Enhancements to natural and nature based storm buffers and ecosystem resiliency are measured by increases in habitat acreage created by NNBFs, which offset projected reductions in wetland acreage due to sea level rise that is anticipated to occur under future without project conditions. Each alternative structural plan includes NNBFs, which are specifically designed to enhance the storm buffering capability of existing natural features. For example, in Interior Barrier Plan D-3, the existing natural shoreline at Lower Spring Creek would be reconfigured to provide CSRM benefits and create an additional 24 acres of low marsh. The reconfiguration of the shoreline (living shoreline) would include construction of a shoreline slope that would provide a flood barrier, wave attenuation and/or dissipation, and would provide a natural retreat area where low marsh can adapt to sea level rise.

Historical sea level rise has been identified as a contributing factor to the substantial reduction in saltmarsh acreage at Jamaica Bay. The continued loss and degradation of saltmarshes within Jamaica Bay is projected to worsen as future sea level rise continues and accelerates. Marsh soils, including those on Jamaica Bay islands, would likely be submerged if the rate of sea level rise outpaces that of sediment deposition (NPS 2014). A living shoreline constructed with the appropriate shoreline slope would provide an area for saltmarshes to adapt to sea level rise by migrating up the shoreline slope to habitable levels of inundation and duration. A living shoreline, which provides low marsh and a shoreline slope that accommodates the natural retreat of saltmarsh in response to sea level rise, provides ecosystem resiliency through adaption to sea level rise. Each of the plans under Alternative D provides additional low marsh acreage and a living shoreline to accommodate saltmarsh natural retreat (Tables 28 - 33).

## 3.7 Preliminary Alternative Plan Comparison – Jamaica Bay Planning Reach

The preliminary structural plans under Alternative C (Storm Surge Barrier) and Alternative D (Jamaica Bay Interior Barrier) were evaluated for their effectiveness in contributing to the five planning objectives in Section 3.6 Preliminary Alternative Plan Evaluation. In this section alternative plans are compared (Table 42) based on their effectiveness in achieving the five planning objectives:

1. Reduce vulnerability to storm surge impacts;
2. Reduce future flood risk in ways that will support the long-term sustainability of the coastal ecosystem and communities;
3. Reduce the economic costs and risks associated with large-scale flood and storm events;
4. Improve community resiliency, including infrastructure and service recovery from storm effects; and
5. Enhance natural storm surge buffers (NNBFs) and improve ecosystem resiliency

**Table 42: Alternative Plan Effectiveness Comparison**

| | Objectives | | | | |
|---|---|---|---|---|---|
| **Plan** | **1** | **2** | **3** | **4** | **5** |
| Plan C-1a | √ | No | √ | √ | √ |
| Plan C-1b | √ | √ | √ | √ | √ |
| Plan C-2a | √ | No | √ | √ | √ |
| Plan C-2b | √ | √ | √ | √ | √ |
| Plan C-2c | √ | √ | √ | √ | √ |
| Plan C-2d | √ | √ | √ | √ | √ |
| Plan C-3a | √ | No | √ | √ | √ |
| Plan C-3b | √ | No | √ | √ | √ |
| Plan C-3c | √ | No | √ | √ | √ |
| Plan C-3d | √ | No | √ | √ | √ |
| Plan C-3e | √ | √ | √ | √ | √ |
| Plan D-1 | √ | √ | √ | √ | √ |
| Plan D-2 | √ | √ | √ | √ | √ |
| Plan D-3 | √ | √ | √ | √ | √ |
| Plan D-4 | √ | √ | √ | √ | √ |
| Plan D-5 | √ | √ | √ | √ | √ |
| Plan D-6 | √ | √ | √ | √ | √ |
| Plan D-7 | √ | √ | √ | √ | √ |

Six plans (C-1a, C-2a, C-3a, C-3b, C-3c, and C-3d) are not effective in meeting planning objective #2: Reduce future flood risk in ways that will support the long-term sustainability of the coastal ecosystem and communities (Table 42). The opening widths associated with these Storm Surge Barrier Plans constrain tidal amplitude (Table 39) to an extent that would likely have unacceptable impacts to Jamaica Bay habitats. These six plans will not be carried forward for more detailed analysis due to potential ecological impacts.

Effective plans are compared for efficiency by calculating net benefits (project costs less project benefits) and identifying a benefit to cost ratio. Costs and benefits of each alternative plan are compared in average annual terms. Estimates of total project costs and benefits are incomplete at this stage of the analysis, but are sufficient for identification of a focused array of alternatives to be advanced for more detailed analysis.

Annual operation and maintenance (O&M), monitoring, and rehabilitation costs for maintaining the project (Table 43) are estimated for this analysis based on similar costs calculated for the *Draft Raritan Bay and Sandy Hook Bay, New Jersey Hurricane Sandy Limited Reevaluation Report for Coastal Storm Risk Management Union Beach, New Jersey, September 2014 (USACE 2014*). Costs attributed to O&M in the Union Beach study include annualized replacement costs, repair, anticipated energy charges, and labor charges for the care and cleaning of project facilities. Project components requiring routine care include the flood gates, levees and floodwalls, interior drainage closure and manhole structures, road closure gates, pump stations, beach dune grass and sand fence. Major mechanical equipment within the storm gate and interior drainage pump stations have anticipated life expectancies of 20-25 years. The cost of periodic equipment replacement has been estimated, annualized over the 50-year period of analysis, and incorporated into the O&M charge. In addition, electric power requirements based on the anticipated frequency of pump station and storm gate operation have been added to the project's annual operation charge. Total annual O&M costs estimated for the Union Beach study are $1.7 million. Total annual O&M costs used in this analysis are scaled from the Union Beach study costs based on the ratio of total linear length of risk management features for the Union Beach study compared to the total linear length of risk management features in each alternative plan. Total O&M costs are added to construction costs to estimate total costs (Table 43) used in the preliminary efficiency evaluation.

**Table 43: Jamaica Bay Preliminary Structural Plan Average Annual Equivalent (AAEQ) Costs**

| Plan Name | Construction Cost | Maintenance Cost | Total Cost |
|---|---|---|---|
| C-1b | $144,197,000 | $3,815,000 | $148,012,000 |
| C-2b | $116,935,000 | $1,734,000 | $118,669,000 |
| C-2c | $140,166,000 | $1,734,000 | $141,900,000 |
| C-2d | $163,397,000 | $1,734,000 | $165,131,000 |
| C-3e | $212,920,000 | $1,510,000 | $214,430,000 |
| D-1 | $71,965,000 | $2,408,000 | $74,373,000 |
| D-2 | $3,798,000 | $1,074,000 | $4,872,000 |
| D-3 | $25,458,000 | $1,306,000 | $26,764,000 |
| D-4 | $35,561,000 | $989,000 | $36,550,000 |
| D-5 | $13,349,000 | $5,460,000 | $18,809,000 |
| D-6 | $43,941,000 | $1,183,000 | $45,124,000 |
| D-7 | $98,046,000 | $3,920,000 | $101,986,000 |

Note: AAEQ calculated at FY14 price levels, 3.5% discount rate, and 50-year period of analysis

The efficiency of effective alternative plans is measured as the net benefits (Table 44) generated by each plan. Net benefits are calculated as the difference between alternative plan benefits, which are calculated as the EAD's avoided for the 100-year storm event (Table 40) and alternative plans total average annual equivalent costs (Table 43).

**Table 44: Jamaica Bay Alternatives Preliminary Average Annual Net Benefits (AAEQ)**

| Plan Name | Total Cost | Benefits | Net Benefits | BCR |
|---|---|---|---|---|
| C-1b | $148,012,000 | $265,833,000 | $117,821,000 | 1.80 |
| C-2b | $118,669,000 | $265,833,000 | $147,164,000 | 2.24 |
| C-2c | $141,900,000 | $265,833,000 | $123,933,000 | 1.87 |
| C-2d | $165,131,000 | $265,833,000 | $100,702,000 | 1.61 |
| C-3e | $214,430,000 | $265,833,000 | $51,403,000 | 1.24 |
| D-1 | $74,373,000 | $88,664,000 | $14,291,000 | 1.19 |
| D-2 | $4,872,000 | $14,980,000 | $10,108,000 | 3.07 |
| D-3 | $26,764,000 | $24,847,000 | ($1,917,000) | 0.93 |
| D-4 | $36,550,000 | $71,036,000 | $34,486,000 | 1.94 |
| D-5 | $18,809,000 | $67,896,000 | $49,087,000 | 3.61 |
| D-6 | $45,124,000 | $13,390,000 | ($31,734,000) | 0.30 |
| D-7 | $101,986,000 | $113,511,000 | $11,545,000 | 1.11 |

Note: EADs and AAEQ costs calculated at FY14 price levels, 3.5% discount rate, and 50-year period of analysis

## 3.8 Focused Array of Alternatives: Plan Selection

The focused array of alternatives identifies the alternative plans to be presented at the Alternatives Milestone. These alternative plans will be forwarded for more detailed analysis, including analyses of costs, benefits, and environmental effects in order to determine the TSP.

### 3.8.1 Focused Array of Alternatives – Atlantic Ocean Shorefront Planning Reach

Three alternative plans for CSRM improvements at the Atlantic Ocean Shorefront Planning Reach are advanced for more detailed analysis. These alternative plans include:

- Alternative 1: Beach Restoration with Periodic Maintenance
- Alternative 2: Beach Restoration w/Sediment Retaining Structures and Reduced Maintenance
- Alternative 3: Shoreline and Structural Modification with Reduced Beachfill and Maintenance

### 3.8.2 Focused Array of Alternatives – Jamaica Bay Planning Reach

The focused array of alternatives for the Jamaica Bay Planning Reach (Table 45 and Figure 61) consists of the best performing plans based on the alternative plan evaluations conducted in section 3.7. The best performing plans are identified as the most efficient of the effective plans. For plans under Alternative C: Storm Surge Barrier, plans C-1b and C-2b are carried forward for further analysis in the Focused Array of Alternatives. Plans C-2c and C-2d are not carried forward for further analysis because they provide the same benefits as plan C-2b, but at a higher cost. Plan C-3e is not carried forward for further analysis because it provides the same benefits as C2-b at nearly twice the cost resulting an approximately one-third of the net benefits provided by C2-b.

Alternative Plans D-1 and D-3 are not carried forward for further analysis because they are likely to be structurally infeasible due to the necessity of a tie-in at the two Brooklyn landfills and because the same benefits can be achieved by Alternative Plan D-7. Alternative Plan D-6 is also not carried forward for more detailed analysis because of the plan's low production of benefits relative to project cost. Costs for Alternative Plan D-6 are more than three times the value of avoided damages (benefits). Non-structural solutions will be evaluated for the Broad Channel reach prior to the TSP Milestone.

**Table 45: Jamaica Bay Focused Array of Alternatives – Plan Performance**

| Plan Name | Net Benefits | BCR | Habitat Acreage | FCU Increase |
|---|---|---|---|---|
| C-2b | $147,164,000 | 2.24 | 71.6 | 27.6 |
| D-2 | $10,108,000 | 3.07 | 10.5 | 4.0 |
| D-4 | $34,486,000 | 1.94 | 14.0 | 5.4 |
| D-5 | $95,807,000 | 3.61 | 168.3 | 65.2 |
| D-7 | $11,545,000 | 1.11 | 425.4 | 177.2 |

Note: EADs and costs calculated at FY14 price levels, 3.5% discount rate, and 50-year period of analysis

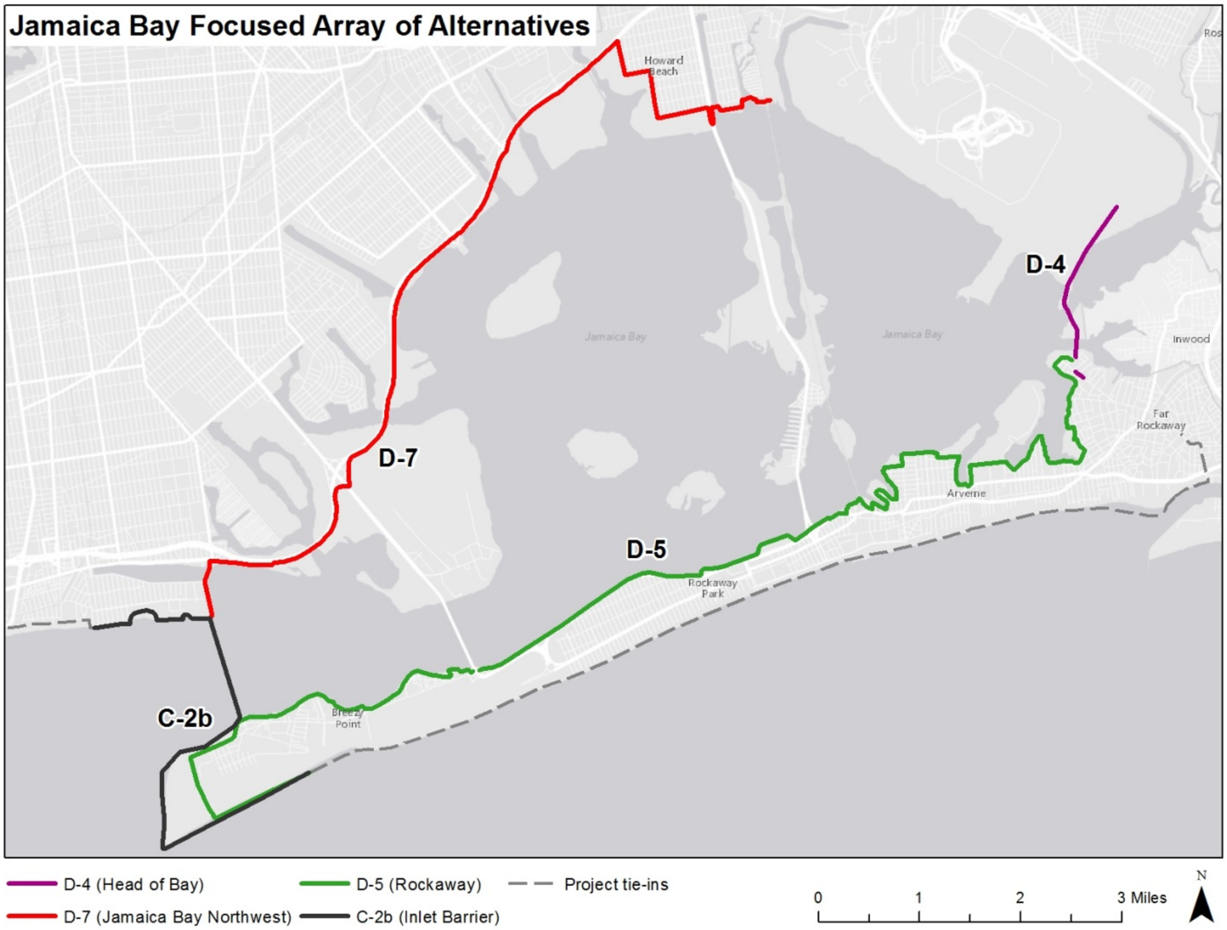


**Figure 61: Jamaica Bay Planning Reach Focused Array of Alternatives**

## 3.9 Final Array of Plans Comparison

This chapter describes the development of alternative plans based on combinations and refinements of screened measures. Measures were combined into distinct CSRM units, including CSRM units common to multiple plans. Alternative storm surge barrier and Jamaica Bay interior barrier plans were developed from common and plan-specific CSRM units.

### 3.9.1 CSRM Units Common to Multiple Plans

Common CSRM units include Rockaway shorefront, Rockaway shorefront eastern tie-in, Coney Island tie-in, and the Jamaica Bay northwest interior barrier. These common CSRM units are required for full functionality of each alternative plan (see section 12.2 Alternative Plans).

Rockaway Shorefront CSRM Unit

The Rockaway shorefront CSRM unit was developed to a relatively high level of detail because of its significance as the primary CSRM feature addressing wave attack and wave run up on the Rockaway peninsula. The general approach to developing this CSRM unit was to evaluate erosion control alternatives in combination with a single beach restoration plan to select the most cost effective renourishment approach prior to the evaluation of alternatives for coastal storm risk management. The most cost effective erosion control alternative is Beach Restoration + Increased Erosion Control. This erosion control alternative had the lowest annualized costs over the 50-year project life and the lowest renourishment costs over the project life.

A screening analysis was performed to evaluate the level of protection provided by a range of dune and berm dimensions and by reinforced dunes, which would be combined with Beach Restoration + Increased Erosion Control to optimize the Rockaway shorefront CSRM unit. Other factors such as prior projects at Rockaway Beach, project constraints, stakeholder concerns, and engineering judgment were also applied in the evaluation and selection (see the Plan Formulation Appendix).

The Rockaway shorefront CSRM unit consists of optimized beach restoration and increased erosion control plus a composite seawall, which provides the highest net benefits of all Rockaway shorefront alternatives considered. The armor stone in horizontally composite structures significantly reduces wave breaking pressure, which allows smaller steel sheet pile walls to be used in the design if the face of the wall is completely protected by armor stone. The composite seawall may be adapted in the future to rising sea levels by adding 1-layer of armor stone and extending the concrete cap up to the elevation of the armor stone.

The composite seawall protects against erosion and wave attack and also limits storm surge inundation and cross-island flooding. The structure crest elevation is +17 feet (NAVD88), the dune elevation is +18 feet (NAVD88), and the design berm width is 60 feet. The composite seawall alternative is compatible with the Storm Surge Barrier alternative and the Jamaica Bay Interior Barrier alternative.

The Rockaway shorefront CSRM unit optimization was conducted for reaches 3 – 6 along the Rockaway shorefront (beach 149th Street to Beach 19th Street). It is assumed that similar design elevations and costs are applicable for Rockaway shorefront reaches 1 and 2 up to the tie-in with the Rockaway bayside CSRM unit (see section 11.2 Key TSP Milestone Uncertainties).

Rockaway Shorefront Eastern Tie-in

The Rockaway Shorefront eastern tie-in consists of an eastward extension of the Rockaway shorefront CSRM unit running along the backside of the beach until it turns inland at Beach 17th Street. The alignment continues until termination near the north end of the Yeshiva Darchei Torah campus. The alignment includes concrete floodwalls and two roadway gates.

Coney Island Tie-in

At the Alternatives Milestone Meeting it was assumed that the Storm Surge Barrier alternative and the Jamaica Bay Interior Barrier alternative would have their western terminus at a tie-in at Corbin Place on Coney Island. For the TSP Milestone this tie-in has been extended west in coordination with the Coney Island Creek Tidal Barrier and Wetland Feasibility Study (NYCEDC). The revised Coney Island tie-in alignment includes Coney Island Beach, Sea Gate, Coney Island Creek, and Gravesend, tying into high ground at Bensonhurst Park. The alignments and feasibility level cost information have been provided for this analysis by NYCEDC.

Jamaica Bay Northwest CSRM Unit

The full extent of the Jamaica Bay Northwest CSRM unit runs from Coney Island to Bergen Basin, which had previously been identified as alignment D-7 for the Alternatives Milestone. The full extent of the Jamaica Bay Northwest CSRM unit is a major component of the Jamaica Bay Interior Barrier Alternative Plan (Plan D). Shorter sections at the western end of the Jamaica Bay Northwest CSRM unit are required to achieve the full functionality of the Storm Surge Barrier Alternative by providing a tie-in between the Storm Surge Barrier alignment and the CSRM structure at Coney Island. The design and cost of the Manhattan Beach section of the Jamaica Bay CSRM unit is based on the Rockaway Shorefront CSRM unit composite seawall design and costs (see section 11.2 Key TSP Milestone Uncertainties).

### 3.9.2 Jamaica Bay Interior Barrier Alternative (Plan D)

The Jamaica Bay Interior Barrier Alternative Plan (Figure 62) consists of three common CSRM units (Coney Island tie-in, Rockaway Shorefront CSRM unit, and the Rockaway shorefront eastern tie-in) and three geographically discrete CSRM units (Jamaica Bay Northwest, Head of Bay, and Rockaway Bayside).

The Jamaica Bay Interior Barrier Alternative Plan creates a contiguous barrier along the Jamaica Bay interior, with the exception of JFK Airport. The Jamaica Bay Interior Barrier Alternative Plan would avert inundation at a stillwater elevation of 11 feet for communities surrounding the Bay. Eleven feet is generally equivalent to the stillwater elevation for a storm event with 1% probability of annual occurrence in 2070 including mid-range sea level rise. The community at Broad Channel, which is effectively within Jamaica Bay - as opposed to being a community on the fringe of Jamaica Bay - , would not benefit from the Jamaica Bay Interior Barrier Alternative Plan.

After the Alternatives Milestone, additional analyses were conducted to reduced uncertainties associated with the final array of alternatives. A major objective of the additional analyses was to refine alignments to minimize costs, impacts to private property, and habitat disturbances associated with the Jamaica Bay Interior Barrier Alternative Plan.

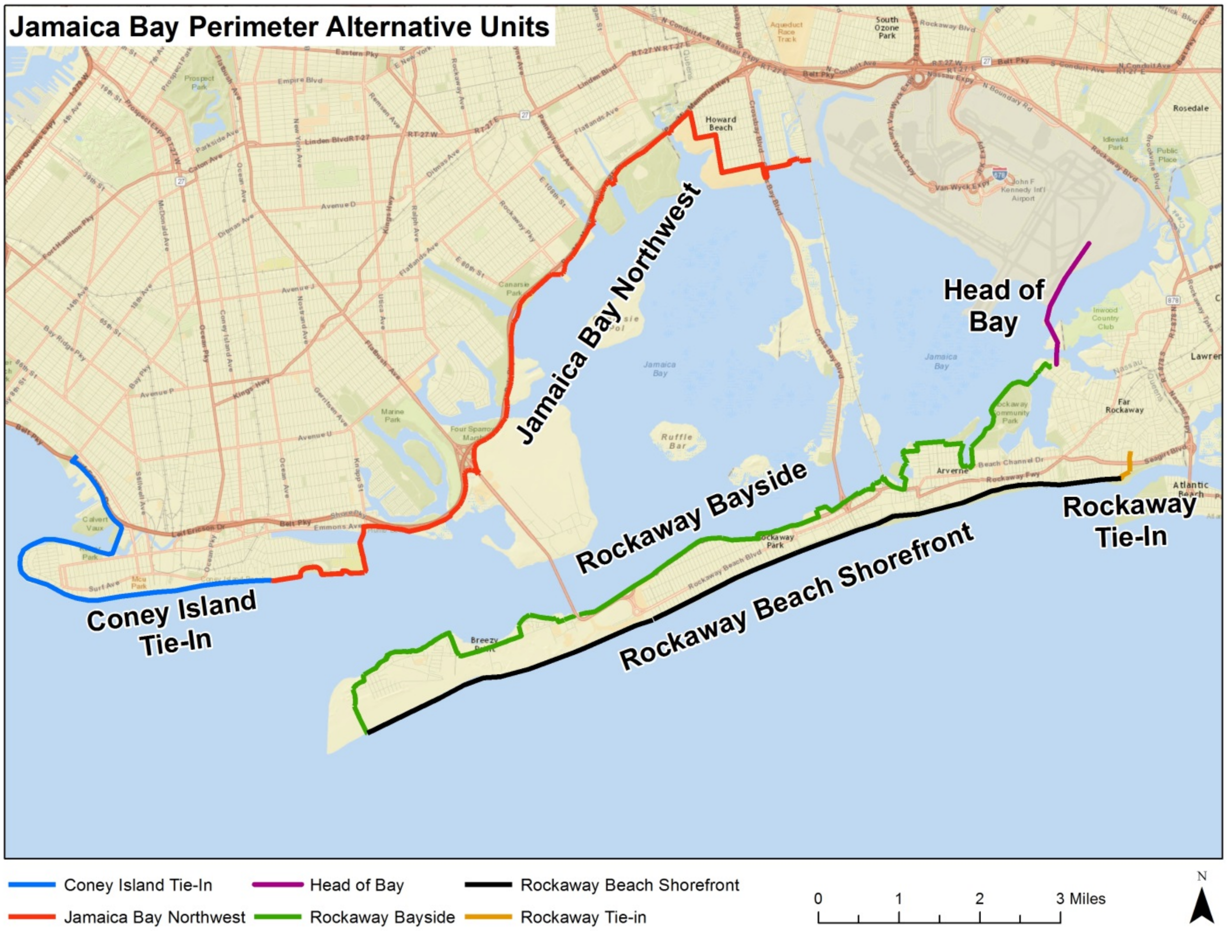


**Figure 62: Plan D Jamaica Bay Interior Barrier**

The following describes the three geographically discrete CSRM units (Jamaica Bay Northwest, Head of Bay, and Rockaway Bayside) that comprise the Jamaica Bay Northwest Interior Barrier (including references to the appropriate design sheets found in the Engineering Appendix).

The Jamaica Bay Northwest CSRM unit runs from Manhattan Beach on Coney Island to Hamilton Beach at Bergen Basin (Plan Sheets JBV-00 through JBV16). The western terminus of the unit ties in at Manhattan Beach (see section 11.2 Key TSP Milestone Uncertainties). The eastern terminus of the unit ties in at high ground at Bergen Basin. Floodgates are provided at Sheepshead Bay (JBV-01), Gerritsen Inlet (JBY-03), Mill Basin (JBV-05), Paerdegat Basin (JBV-07), Fresh Creek (JBV -09), Hendrix Basin (JBV-11), Old Mill/Spring Creek (JBV-12), Shellbank Creek (JBV-14), and Hawtree Basin (JBV-16). The Jamaica Bay Northwest CSRM unit alignment generally follows the Belt Parkway and Jamaica Bay Greenway, which minimizes costs, impacts to private property, and disturbances to existing habitat. Roadway floodgates are provided at the Canarsie Pier (JBV-08), Pennsylvania Avenue (JBV-10.1), Hendrix Street (JBV

10.1), and Fountain Avenue (JBV-10.2). A railroad floodgate is positioned at 104th Street for the Long Island Railroad.

The Jamaica Bay Northwest CSRM unit also includes construction of vertical living shorelines at Bergen Beach (JBV-06), Charles Memorial Park (JBV 15.1), Spring Creek (JBV-12), and Hawtree Point (JBV-16). The vertical living shorelines were included in the CSRM unit to dissipate wave energy, reduce shoreline erosion, address anticipated sea level change within the bay, and to offset impacts resulting from other features of the CSRM unit. The vertical living shorelines proposed for Bergen Beach and Charles Memorial Park (Type "B") is specifically designed for locations where a bicycle path is adjacent to the roadway and the protected side does not have space for a levee. The design includes a vertical wall on the protected side that accommodates the space constraints present due to the existing bicycle path (i.e., Jamaica Bay Greenway) and roadway (i.e., Belt Parkway). The Type "B" living shoreline would be planted with high marsh and low marsh vegetation.

The vertical living shorelines proposed for Spring Creek and Hawtree Point (Type "D") have fill placed on top of the 3:1 levee core to accommodate a gentle slope from the middle of the bay side face of the levee to an extent of approximately 25 feet from the toe of the levee. This gentle slope facilitates restoration opportunities for shrubland and maritime forest and provides a functional transition to the existing upland habitats that maximizes ecological functions and/or services to Jamaica Bay.

The <u>Head-of-Bay CSRM unit</u> runs from the Perimeter Road at the eastern side of JFK Airport (RPV-00) to the tie-in at Bayswater Point State park (RPV-04). The northern terminus of the unit ties in to high ground along Perimeter Road at JFK Airport. The southern terminus of the unit ties in to the Rockaway Bayside CSRM unit at Bayswater Point State Park. Floodgates are provided at Head-of-Bay (RPV-01) and Negro Bar Channel (RPV-03). There are no roadway or railroad gates for this unit.

The <u>Rockaway Bayside CSRM unit</u> runs from the tie-in with the Negro Bar Channel floodgate at Bayswater Point State Park (RPV-04) to the tie in at reach 1 of the Rockaway Shorefront CSRM unit (RPV-16). The northeastern terminus of the unit ties in to the Negro Bar Channel floodgate at Bayswater Point State Park (RPV-04). The southwestern terminus of the unit ties in to the Rockaway Shorefront CSRM unit at approximately Beach 149th Street (RPV-16; see section 11.2 Key TSP Milestone Uncertainties). A land-based floodwall is proposed for the more than 3-mile stretch along the northern side of Beach Channel Drive. At the Edgemere Landfill, rip rap and a shallow foundation sheet pile or T-wall core are proposed for construction on top of the landfill cap to allow the alignment to tie in to the high ground provided at the landfill (RPV-07 and RPV-08).

Floodgates are provided at Norton Basin (RPV-07) and Barbados Basin (RPV-10). Roadway/beach access gates are provided at various locations along Breezy Point and at Riis landing. Roadway flood gates are provided at the Edgemere landfill Service Road (RPV-07 and RPV-08), Note that an alternative alignment for the Rockaway Bayside CSRM unit would include a southwestern terminus at Beach 169th Street, which avoids alignments around Breezy Point. This alternative alignment would tie-in to high ground at the Marine Parkway Bridge ramps to the north (RPV-13) and to the south at reach 1 of the Rockaway Shorefront CSRM unit (RPV-16).

The Rockaway Bayside CSRM unit also includes construction of vertical living shorelines at Bayswater Point State Park (RPV-04), Somerville Basin (RPV-08), and Beach 86th Street (RPV-13). The vertical living shorelines were included in the CSRM unit to dissipate wave energy, reduce shoreline erosion, address anticipated sea level change within the bay, and to offset impacts resulting from other features of the CSRM unit. The vertical living shorelines proposed for the Rockaway Bayside CSRM unit (Type "D") have fill placed on top of the 3:1 levee core to accommodate a gentle slope from the middle of the bay side face of the levee to an extent of approximately 25 feet from the toe of the levee. This gentle slope facilitates restoration opportunities for shrubland and maritime forest and provides a functional transition to the existing upland habitats that maximizes ecological functions and/or services to Jamaica Bay.

### 3.9.3 Storm Surge Barrier Alternative (Plan C)

Three alternative alignments of the Storm Surge Barrier Plan (C-1, C-2, and C-3) were assessed for the TSP Milestone (Figure 63). Each alternative alignment also includes common CSRM units, which are required for full functionality of the Storm Surge Barrier (Plan C). These common CSRM units include Rockaway shorefront, Rockaway shorefront eastern tie-in, Coney Island tie-in, and the Jamaica Bay northwest interior barrier.

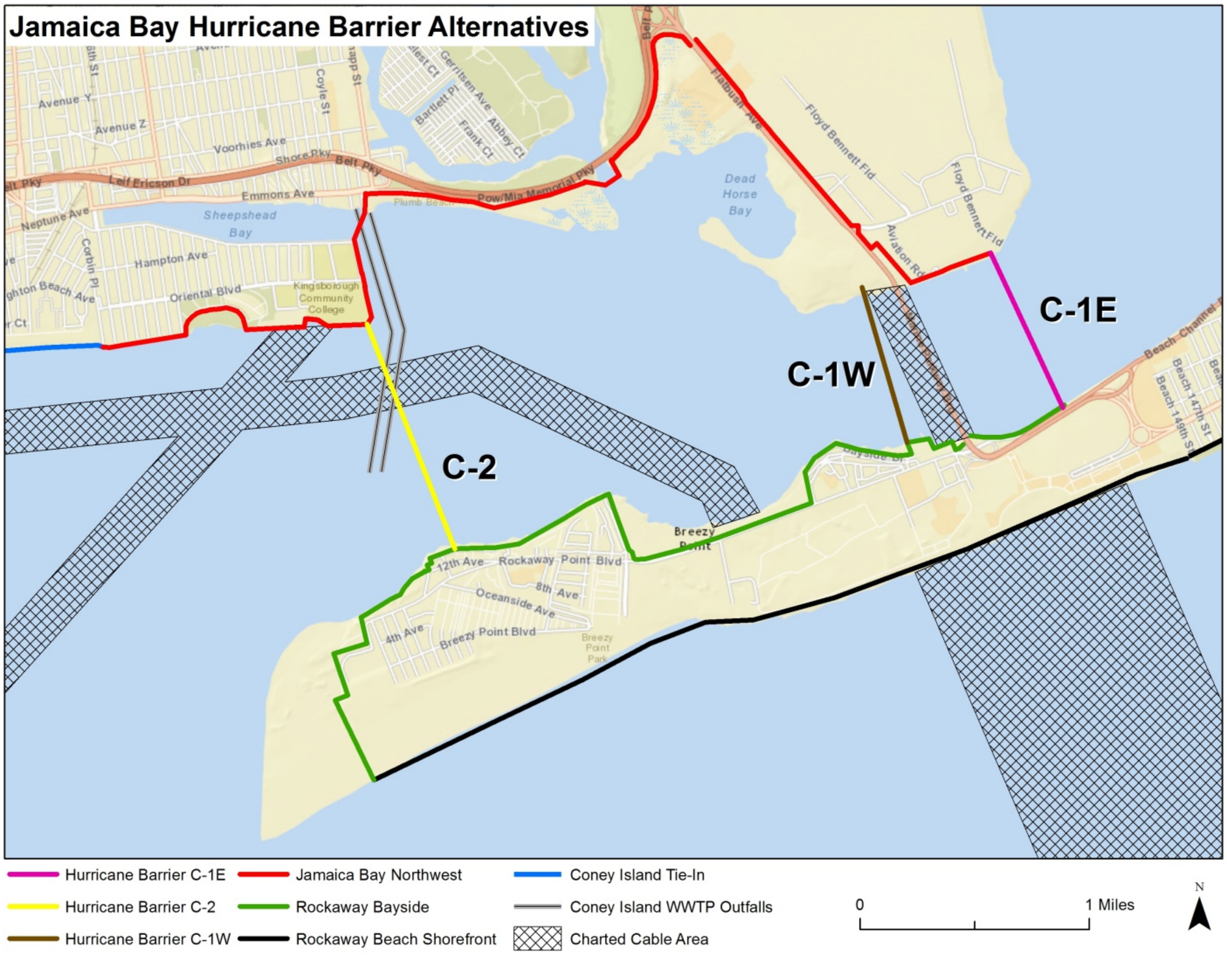


**Figure 63: Storm Surge Barrier Alignments**

The C-3 alignment was screened out from the more detailed analysis conducted for alignments C-1 and C-2 because alignment C-3 proved to have higher construction costs and O&M costs due to its longer in-water footprint, while providing the same level of benefits as alignments C-1 and C-2. In addition, alignment C-3 did not prove to have the advantage of a less complicated tie-in to Breezy Point that was initially envisioned at the Alternatives Milestone.

Alignment C-2 and two alternative alignments for C-1 (C-1E and C-1W) were analyzed using the ADCIRC numerical model to evaluate changes in tidal amplitude and velocities in Jamaica Bay for various gate configurations and Storm Surge Barrier alignments. Storm Surge Barrier alignment C-1E is preferred over alignment C-1W because alignment C-1E:

- would likely result in less impact to the Gil Hodges Memorial Bridge;
- would result in less real estate and aesthetic impacts to the Roxbury Community where alignment C-1W would tie in;
- is located in a more stable channel location; and
- avoids potential impacts to submerged cables.

The ADCIRC modeling identified alignment C-1E with 1,100 linear feet of gate opening and alignment C-2 with 1,700 linear feet of gate opening as having the least hydrodynamic impacts to the bay (Table 46). Both alignments result in a maximum tidal amplitude change of 0.2 feet, which indicates that there would not be any major changes in the water column throughout the bay. Limited changes to the water column indicates that the natural environment driven by water circulation would be undisturbed and water chemistry, including the benthic layer, would be consistent with and without a hurricane barrier. In addition, flow speeds and directions for both alignments are similar to without-project conditions, which imply that circulation within the bay would be minimally impacted.

**Table 46: Storm Surge Barrier Alternative Alignment Gate Opening Aggregate Length**

| Alignment | Total Opening (ft) | Number of 100-foot Vertical Lift Gates | Number of 200-foot Sector Gates |
|---|---|---|---|
| C-1E | 1,100 | 7 | 2 |
| C-2 | 1,700 | 11 | 3 |

Storm Surge Barrier alignment C-1E includes a Storm Surge Barrier (design elevation = 16.0 feet NAVD88) with seven 100-foot wide vertical lift gates and two 200-foot wide sector gates. Alignment C-1E runs in a northwesterly direction from Jacob Riis Park on the Rockaway peninsula to Barren Island at Floyd Bennet Field, Gateway National Recreation Area (HB-01). On the Rockaway peninsula, alignment C-1E ties in to the Rockaway Bayside CSRM unit, which continues west along the Rockaway peninsula and around Breezy Point prior to tying into reach 1 of the Rockaway Shorefront CSRM unit (RPV-16). Note that an alternative alignment for the Rockaway Bayside CSRM unit would include a southwestern terminus at Beach 169$^{th}$ Street, which avoids alignments around Breezy Point. This alternative alignment would tie-in to high ground at the Marine Parkway Bridge ramps to the north (RPV-13) and to the south at reach 1 of the Rockaway Shorefront CSRM unit (RPV-16).

On Barren Island, alignment C-1E ties in to a modification of the Jamaica Bay Northwest CSRM unit (HB-01), which runs from the U.S. Marine Corps Reserve Center at Floyd Bennett Field north along Flatbush Avenue. At the Belt Parkway, the Jamaica Bay Northwest CSRM unit continues west along the same alignment identified for the Jamaica Bay Interior Barrier Plan (JBV-00 through JBV-04) with the western terminus of the unit tying in at Manhattan Beach (see section 11.2 Key TSP Milestone Uncertainties). This modified version of the Jamaica Bay Northwest CSRM unit includes floodgates at Sheepshead Bay (JBV-01) and Gerritsen Inlet (JBY-03).

Storm Surge Barrier alignment C-1E (Figure 64) also includes the Coney Island tie-in and the Rockaway shorefront eastern tie-in CSRM units as described for the Jamaica Bay Interior Barrier Plan.

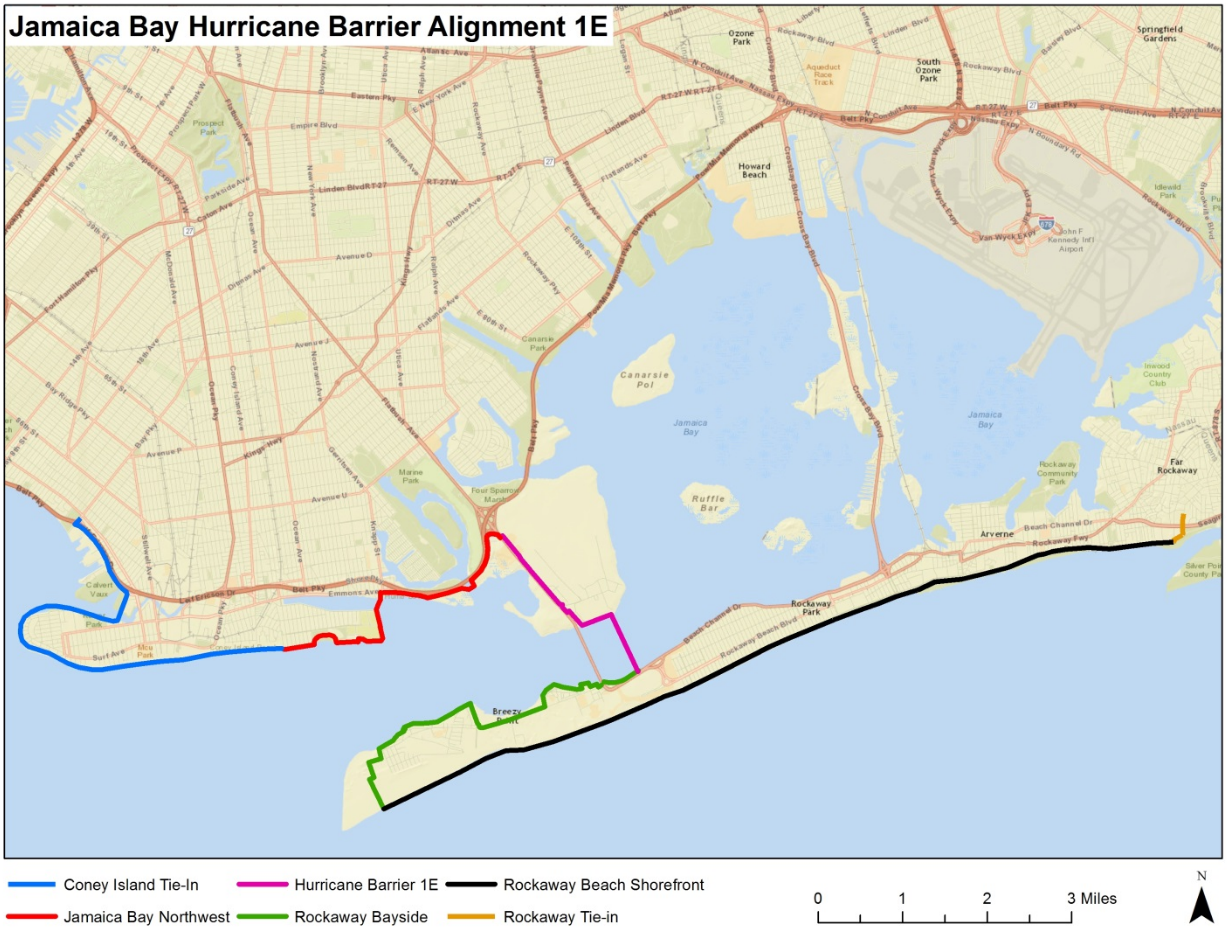


**Figure 64: Storm Surge Barrier Plan C-1E**

<u>Storm Surge Barrier alignment C-2</u> includes a Storm Surge Barrier (design elevation = 16.0 feet NAVD88) with eleven 100-foot wide vertical lift gates and three 200-foot wide sector gates. Alignment C-2 runs in a northwesterly direction from approximately Beach 218$^{th}$ Street on the Rockaway peninsula to Seawall Avenue at Kingsborough Community College (HB-02). On the Rockaway peninsula, alignment C-2 ties in to the Rockaway Bayside CSRM unit. For this alignment the Rockaway Bayside CSRM unit continues west along the Rockaway peninsula, circles around the tip of the peninsula around Breezy Point, then turns east prior to tying into reach 1 of the Rockaway Shorefront CSRM unit (RPV-16).

At Kingsborough Community College, alignment C-2 ties in to a modification of the Jamaica Bay Northwest CSRM unit (HB-01), which runs from Kingsborough Community College west to the terminus at Manhattan Beach. This modified version of the Jamaica Bay Northwest

CSRM unit does not include tributary floodgates. Storm Surge Barrier alignment C-2 (Figure 65) also includes the Coney Island tie-in and the Rockaway shorefront eastern tie-in CSRM units as described for the Jamaica Bay Interior Barrier Plan.

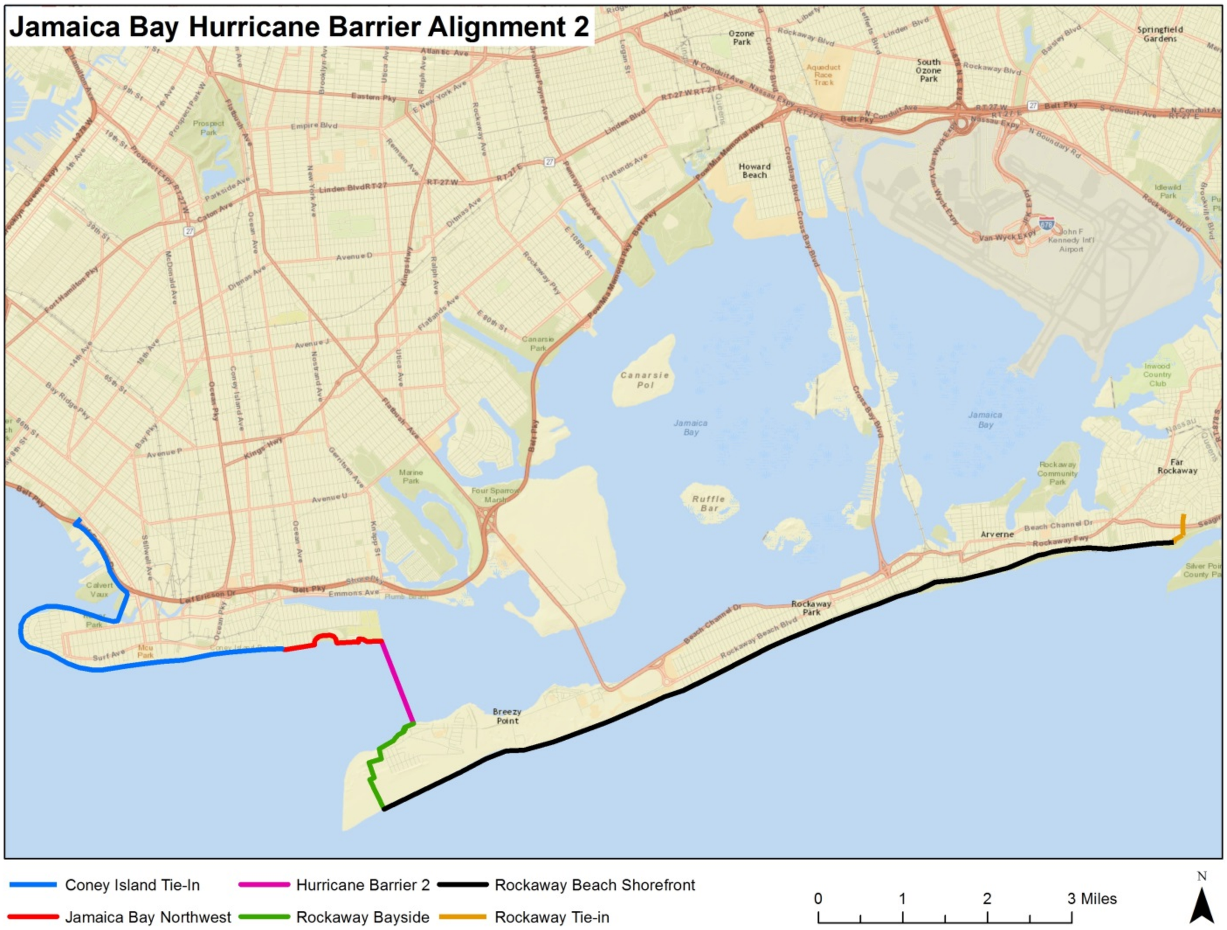


**Figure 65: Storm Surge Barrier Plan C-2**

# 4 ALTERNATIVE PLAN EVALUATION AND COMPARISON

The Jamaica Bay Interior Barrier (Plan D) and the Storm Surge Barrier (Plan C alignments C-1E and C-2) were evaluated for habitat impacts, real estate impacts, costs (construction, mitigation, real estate, and O&M), and net benefits.

## 4.1 Habitat Impacts and Mitigation Requirements

The ecosystem assessment tool developed for the Alternatives Milestone was paired with a Habitat Equivalency Analysis (HEA) to evaluate ecological impacts and mitigation requirements for structural alternatives. The HEA provides a means to comprehensively evaluate the loss of ecological functions and services across a wide range of habitats, which may not have equal value or provide equivalent levels of service to the Jamaica Bay ecosystem.

Table 47 presents permanent and temporary habitat impacts using an acreage metric. This metric provides a traditional measure of impacts and mitigation needs, but does not account for the level of ecological service and/or functions provided by the habitats.

**Table 47: Permanent and Temporary Habitat Impacts (acres)**

| | Permanent | | | Temporary | | |
|---|---|---|---|---|---|---|
| **Habitat Type** | **C-2** | **C-1E** | **D** | **C-2** | **C-1E** | **D** |
| Subtidal Bottom | 37.7 | 34.6 | 45.1 | 0.1 | 1.2 | 13 |
| Intertidal Mudflat | 3.3 | 7.5 | 25.1 | 3.8 | 8.8 | 24.2 |
| Intertidal Wetlands | 0 | 0 | 9.4 | 0 | 0.1 | 7 |
| Non-Native Wetlands | 0 | 0.4 | 3.5 | 0 | 0.4 | 0.3 |
| Beach | 0 | 13 | 17 | 61 | 69.9 | 69.6 |
| Dune | 3.1 | 4 | 6.8 | 10.4 | 11.3 | 10.3 |
| Maritime Forest/Shrub | 6.71 | 20.6 | 31.5 | 3.9 | 11.4 | 30.3 |
| Ruderal | 0.43 | 24.4 | 46.7 | 0.6 | 12.6 | 49.4 |
| Rip Rap/Bulkhead | 4.2 | 6.5 | 13.5 | 0.2 | 0.4 | 3.5 |
| Urban | 6.7 | 18.7 | 48.4 | 6.2 | 12.8 | 41.5 |
| Total | 62.14 | 129.7 | 247 | 86.2 | 128.9 | 249.1 |

The HEA model used to evaluate habitat impacts and mitigation requirements measures impacts or ecological benefits in terms of Service Acre Years (SAYs). The HEA model also discounts those services that would be lost or provided in future years, accounting for the time it takes to achieve full functionality. Future services are discounted to a present day value measured in Discounted Service Acre Years (DSAYs). The discounted loss of ecological services for each alternative measured in DSAYs is presented in Table 48.

**Table 48: Loss of Ecological Services (DSAYs)**

| Alternative Plan | Loss (-) of Service in DSAYs |
|---|---|
| C-2 | -971 |
| C-1E | -1,875 |
| D | -2,811 |

It is important to note that the net loss for the Jamaica Bay Interior Barrier is -2,811 DSAYs, which accounts for an ecological impacts of 3,276 DSAYs that is partially offset by the 465 DSAY benefit provided by living shorelines as described in section 12.2.2 Jamaica Bay Interior Barrier (Plan D).

Two mitigation projects, which have previously been identified as high priority restoration projects by the HRECRP have been selected as mitigation projects for the alternative CSRM plans. Lower Spring Creek represented both the highest level of ecological benefit (i.e., returned

DSAYs) as well as one the most efficient values (i.e., cost per DSAY) for any of the selected projects. For the purposes of this evaluation, cost per DSAY is assumed as the measure that best facilitates selection of a "best buy plan" as the model described herein has also been developed to discount service years over a life of a project. Specifically, Lower Spring Creek has the potential to return approximately 2,250 DSAYs at a cost of approximately $25,869 per DSAY. This project also has a significant level of past evaluation and design (i.e., USACE 2010), and considerable current momentum with local stakeholders to be moved forward. This project is recommended to be carried forward within the context of mitigation for all three evaluated alternative alignments.

Constructing the Spring Creek project as mitigation for Alternative C-2 provides an excess of 1,270 DSAYs. Due to the low cost per DSAY ratio for Spring Creek, this project provides more cost effective mitigation than attempting two smaller projects. The Spring Creek project also satisfies the mitigation requirements for Alternative C-1E. However, it is assumed that this alternative would also require a comparable level of excess mitigation to at least that proposed for Alternative D. As such, an additional 385 DSAYs are required beyond those realized from implementation of Spring Creek. Potential additional projects include one of the following: Pumpkin Patch (+430), Elders Island East (+752), or Duck Point (+412). Assuming an average cost per DSAY of $45,000 which is the average cost per DSAY across all the projects evaluated, these additional DSAYs would costs an additional $17,325,000.

The HRECRP restoration project at Dead Horse Bay is recommended to be carried forward as mitigation for Alternative D (combined with Lower Spring Creek). This project has the potential to return 1,320 DSAYs at a cost of approximately $45,362 per DSAY. Specific to Alternative D, both Spring Creek and Dead Horse Bay being carried forward provides an excess of 759 DSAYs (Table 49). This excess credit is included to account for the unknown environmental impacts associated with minor changes in bay hydrodynamics. Future modeling can facilitate refinement of these mitigation costs at a later date, but future refine will not have an impact on the current TSP selection.

**Table 49: Mitigation Service Gains and Costs**

| Alternative | Service Loss (DSAYs) | Mitigation Service Gain (DSAYs) | Excess Service Gain (DSAYs) | Mitigation Construction Cost |
|---|---|---|---|---|
| C-2 | -971 | +2,250 | +1,279 | $58,213,000 |
| C-1E | -1,875 | +2,635 | +760 | $75,538,000 |
| D | -2,811 | +3,570 | +759 | $118,087,000 |

## 4.2 Real Estate Impacts and Costs

Real estate impacts resulting from implementation of planning alternatives were assessed in GIS software by overlaying the completed structure footprints and associated right of way easements necessary for structure maintenance on the building footprints, tax lots, and public right-of-way. Those structures and easements intersecting private buildings are assumed to require the purchase of the building and the entirety of the associated tax lot. Those structures and easement intersecting tax lots, but not intersecting any structure on the tax lot, are assumed to require the purchase of only that portion of the parcel necessary for the footprint of the structure. Construction and maintenance right of way easements are to be obtained for those areas intersecting the structure easement, but no land acquisition is required.

The acreage assumed to be required for purchase and easement is presented for privately owned and publically owned parcels based on the land use designation for the tax lot as identified in the MapPLUTO dataset (see the Real Estate Appendix for additional details.). Publically owned parcels are assumed to include the following land use categories: Open Space and Outdoor Recreation, Parking Facilities, Public Facilities and Institutions, Transportation and Utility (excludes gas stations), and Vacant Land. All other land use categories are assumed to be in private ownership (Table 50).

**Table 50: Real Estate Impact (acres)**

| | Purchase Required | | Easement Required | | |
|---|---|---|---|---|---|
| **Alternative** | **Public** | **Private** | **Public** | **Private** | **Total** |
| C-1E | 31.3 | 2.2 | 42.4 | 0.8 | 76.6 |
| C-2 | 17.1 | 0.5 | 11.2 | 0.01 | 28.7 |
| D | 85.1 | 5.9 | 84.6 | 2.3 | 177.9 |

Estimated real estate costs (Table 51) are based on the “FULLVALUE16” field in the MapPLUTO dataset. If an alternative structure feature footprint intersects a building on a private tax lot, real estate costs are the entire tax lot, including the building. If an alternative structure feature footprint intersects a private tax lot, but no buildings are affected, real estate costs are that portion of the tax lot intersected by the structure footprint as calculated as a percentage of the 2016 market value.

**Table 51: Real Estate Costs (2015$’s)**

| | Entire Tax Lot | Partial Tax Lot | | |
|---|---|---|---|---|
| **Alternative** | **Private** | **Private** | **Public** | **Total Costs** |
| C-1E | | $1,868,000 | $27,568,400 | $29,436,400 |
| C-2 | | $414,300 | $16,971,500 | $17,385,800 |
| D | $4,851,000 | $3,233,800 | $171,870,200 | $179,955,000 |

If an alternative structure feature footprint intersects a building on a public tax lot, real estate costs are the assessed value of the building and that portion of the tax lot intersected by the structure footprint as calculated as a percentage of the 2016 market value. If an alternative structure feature footprint intersects a public tax lot, but no buildings are affected, real estate costs are that portion of the tax lot intersected by the structure footprint as calculated as a percentage of the 2016 market value.

The acreage and costs of intersecting private and public properties with CSRM structures does not indicate the full real estate impacts of the alternative plans. Additionally, CSRM structures near residential properties inhibit views and/or reduce access to the waterfront. The Rockaway Bayside CSRM unit has many instances where a series of multiple houses along the waterfront would have both water view and waterfront access severely impacted by CSRM structures.

There is a very large difference in water view impacts for the Rockaway peninsula terminus of the two alternative Storm Surge Barrier alignments, which will have 50-foot vertical gate elevations in the open position. Storm Surge Barrier alignment C-1E terminates at the Jacob Riis Park parking lot, which is nearly one-half mile from the nearest residential area. Storm Surge Barrier alignment C-2, on the other hand is immediately adjacent to a residential area at Breezy Point (Figure 66).

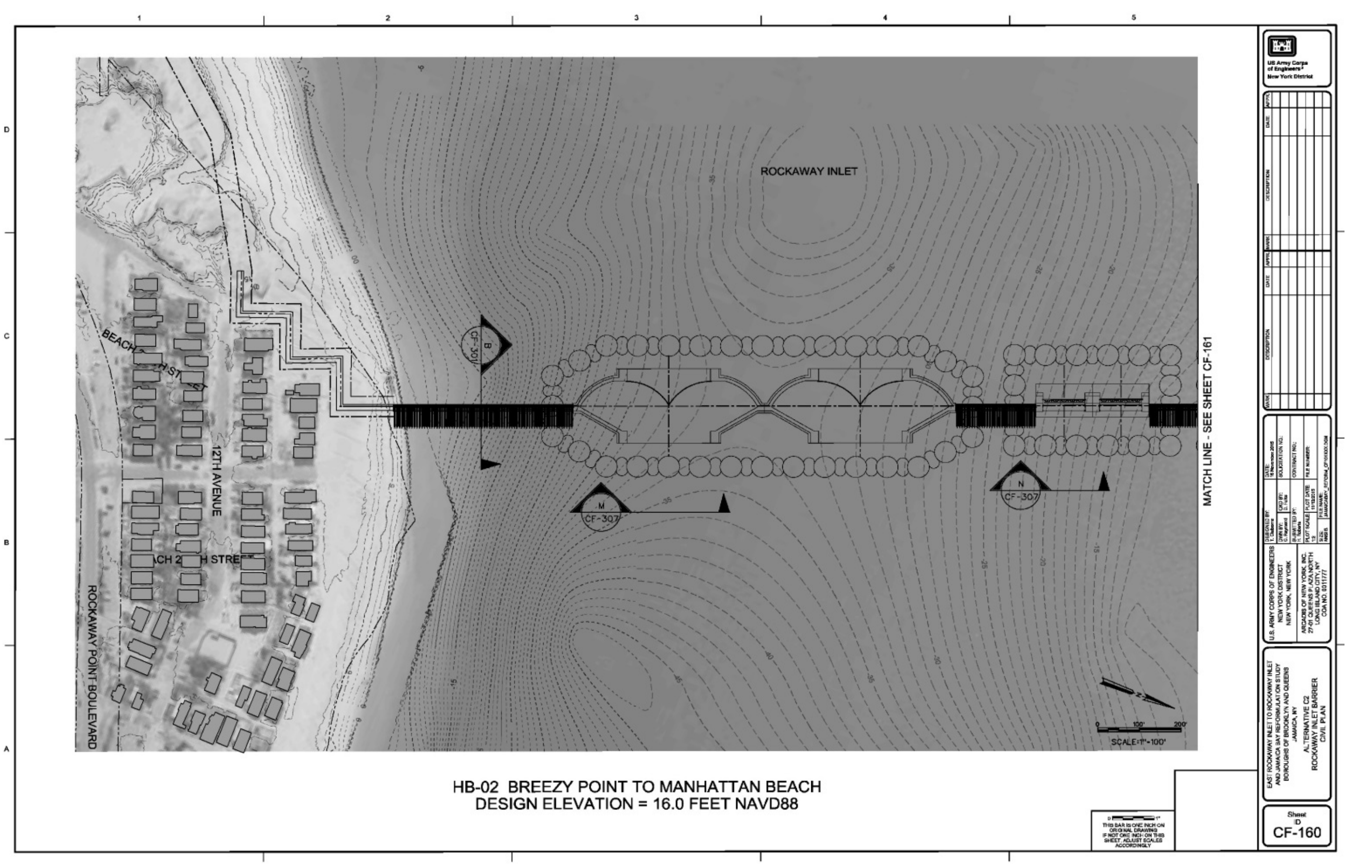


**Figure 66: Alt C-2 Proximity to Residential Area**

## 4.3 Revised Alternative Plan Costs

In accordance with the USACE's SMART Planning principles, the estimates prepared for this analysis were developed at the level of detail required during the Alternatives Formulation & Analysis Phase, i.e. Alternatives Milestone to Tentatively Selected Plan Milestone. According to Engineering Record 1110-2-1302 (USACE 2008), the estimate classification for the Pre-Authorization Alternatives Study costing is required to be a Class 4 estimate as defined in American Society for Testing and Materials (ASTM) E 2516-06 (ASTM 2006). Cost estimate assumptions and details are provided in MFR #6 and accompanying appendices.

The primary characteristic of a Class 4 estimate is that the level of project definition is between 1 and 15 percent. Class 4 estimates utilize a methodology that is primarily stochastic, i.e. unit rates are based on the probability distribution of historical rates. Estimating at a Class 4 level of detail is appropriate for concept/alternatives studies, and the expected accuracy ranges from +100 percent to –50 percent. Because they are based on a very limited project definition, areas of risk and uncertainty in the project should be identified to determine the amount of contingency that should be added to the estimate to reduce uncertainty to an acceptable level.

Construction costs for each alternative are based on the structures (Table 52) and associated quantities (or linear distances).

**Table 52: CSRM Structures and Associated Quantities**

| | CSRM Structure Length (ft) | | |
|---|---|---|---|
| **CSRM Structure** | **Alternative C-1E** | **Alternative C-2** | **Alternative D** |
| Inlet Barrier | 3,930 | 5,715 | |
| Buried Seawall | 55,062 | 55,062 | 55,062 |
| Concrete Floodwall (Bulkhead) | 2,356 | | 21,521 |
| Concrete Floodwall (Deep Water) | 742 | | 5,903 |
| Concrete Floodwall (Land) | 25,367 | 578 | 50,068 |
| Concrete Floodwall (Shallow Water) | | | 8,770 |
| Elevated Promenade (Berm-Face) | 5,041 | | 10,435 |
| Elevated Promenade (Vertical-Face) | 4,234 | | 8,268 |
| Elevated Promenade with Living Shoreline | | | 1,038 |
| Levee | 4,920 | 4,920 | 8,533 |
| Levee w/ Living Shoreline (Berm w/ Maritime Forest) | | | 12,631 |
| Levee w/ Living Shoreline (Tidal Marsh Rock Sill) | | | 1,134 |
| Raised Road | | | 137 |
| Road Gate | 180 | | 882 |
| Seawall Reconstruction | 7,599 | 3,967 | 6,554 |
| Sector Gate | 1,048 | | 4,282 |
| Shoreline Restoration | 1,702 | 1,702 | 1,702 |
| Vertical Lift Gate | | | 486 |
| Rockaway Shorefront East Tie-In | 2,135 | 2,135 | 2,135 |

**Table 52: CSRM Structures and Associated Quantities**

| CSRM Structure | CSRM Structure Length (ft) Alternative C-1E | Alternative C-2 | Alternative D |
|---|---|---|---|
| Coney Island Tie-In | 32,338 | 32,338 | 32,338 |
| Total Linear Feet | 46,654 | 106,418 | 231,880 |
| Total Miles | 27.8 | 20.2 | 43.9 |

Construction costs (Table 53) notably do not include costs for utility relocations. Note that Storm Surge Barrier alignment C-2 crosses a submerged cable area, but relocation costs for these cables have not been accounted for (see 11.2 Key TSP Milestone Uncertainties). Mitigation costs were previously discussed in section 13.1 Habitat Impacts and Mitigation. Real estate costs were previously discussed in section 13.2 Real Estate Impacts and Costs. Interest during construction (IDC) for each alternative is calculated based on a five-year construction period, with an equal distribution of funds each year at the FY16 federal discount rate of 3.125%.

**Table 53: Construction, Mitigation, and Real Estate Costs**

| | Alternative C-1E | Alternative C-2 | Alternative D |
|---|---|---|---|
| Construction | $3,328,135,000 | $3,361,337,000 | $4,467,352,000 |
| Mitigation | $90,833,000 | $75,783,000 | $123,383,000 |
| Real Estate | $29,436,000 | $17,386,000 | $179,955,000 |
| First Cost Total | $3,448,404,000 | $3,454,506,000 | $4,770,690,000 |
| IDC | $333,029,000 | $336,274,000 | $424,262,000 |
| Total Construction Cost | $3,781,433,000 | $3,790,780,000 | $5,194,952,000 |

Operation and Maintenance (O&M) costs include maintenance for passive CSRM structures such as floodwalls and levees and for active CSRM structures such as floodgates and roadway gates. Maintenance activities for each CSRM structure were scheduled with weekly, bi-weekly, monthly, quarterly, annual, 5-year, or 15-year occurrence. Order-of-magnitude O&M costs are based in information from the South Shore of Staten Island, New York Feasibility Study, a reconnaissance level study for the Mississippi Storm Surge Barrier, and information for the Stamford Hurricane Protection Barrier located in Stamford, Connecticut. Average annual equivalent values (AAEQ) were calculated using the FY16 federal discount rate of 3.125% and a 50-year time period (Table 54).

**Table 54: Annual Costs**

| | Alternative C-1E | Alternative C-2 | Alternative D |
|---|---|---|---|
| Construction | $150,474,000 | $150,846,000 | $206,722,000 |
| Renourishment | $5,740,000 | $5,740,000 | $5,740,000 |
| OMRR&R | $7,424,000 | $7,124,000 | $14,954,000 |
| Total AAEQ | $163,638,000 | $163,710,000 | $227,416,000 |

## 4.4 Revised Alternative Plan Benefits

The preliminary benefits used to define the Focused Array of Alternatives were based on FEMA stillwater elevations and a relative sea level rise estimate of 1.0 foot. The revised benefits used to identify the TSP are based on updated NACCS elevations (Table 55) and a relative sea level rise estimate of 1.3 feet. Revised total project benefits include equivalent annual flood damages (EAD) in the Jamaica Bay Planning Reach, reductions in the economic costs and risks associated with wave attack, wave run up, and inundation of shorefront properties at the Atlantic Ocean Shorefront Planning Reach, and recreation benefits based on improved recreation opportunities at Rockaway Beach on the Atlantic Ocean Shorefront Planning Reach (see the Economics Appendix for detailed discussion).

**Table 55: Preliminary (FEMA) and Revised (NACCS) Flood Elevations**

| | FEMA | | | NACCS | | |
|---|---|---|---|---|---|---|
| | mean | stdev | range | mean | stdev | range |
| 10 | 6.6 | 0.92 | 5.7 - 7.5 | 7.5 | 0.39 | 7.2 - 7.9 |
| 50 | 8.9 | 0.36 | 8.5 - 9.3 | 9.5 | 0.33 | 9.2 - 9.8 |
| 100 | 9.9 | 0.29 | 9.6 - 10.2 | 10.5 | 0.33 | 10.2 - 10.8 |
| 500 | 12.4 | 0.39 | 12 - 12.8 | 13.7 | 0.43 | 13.3 - 14.1 |

*All values reported in ft, NAVD88*

Reduction in economic costs and risks associated with large-scale flood and storm events is measured by estimating the economic damages avoided by each alternative. EAD are defined as the monetary value of physical losses and non-physical damages that can occur in any given year based on the magnitude and probability of losses from all possible flood events. The typical basis for determining EAD are losses actually sustained as a result of historical floods, supplemented by appraisals, application of depth-damage curves, and an inventory of capital investment within the floodplain. EAD are computed using standard damage-frequency integration techniques and computer models that relate hydrologic and hydraulic flood variables such as discharge and stage to damages and to the probability of occurrence. Damages are computed by the application of depth-damage functions, which include application of generalized curves, or site-specific relationships between inundation depth and damage determined by field surveys. EAD can then be computed from the definition of stage-damage, stage-discharge, and discharge-frequency relationships. All of these relationships are developed using a risk-based analytical framework, in accordance with Corps regulations.

EAD calculations were performed using Version 1.2.5 of the Hydrologic Engineering Center's Flood Damage Analysis computer program (HEC-FDA, October 2010). This program applies Monte Carlo Simulation to calculate expected damage values while explicitly accounting for uncertainty in the input data. HEC-FDA models were prepared for existing without-project conditions and future without-project conditions, which incorporate an anticipated one-foot rise in water surface elevations over the 50-year period of analysis.

In the typical flood damage reduction study, every potentially damageable floodplain property is inventoried in order to establish structure type, physical characteristics, and approximate values and elevations. Surveys of all residential properties are conducted in many studies, and representative samples in most others. Industrial, public and unique commercial properties typically require 100% sampling and more detailed on-site inspections. Given the scope and scale of the preliminary formulation phase of the Rockaways study, on-site inspection of all, or a significant percentage of, floodplain properties at this stage of the analysis was not feasible. However, GIS-based structure location data and complete aerial imagery has provided much of the data gathered in a typical Corps flood damage reduction on-site survey.

Based on the type, usage and size of each structure included in the GIS data base (over 90,000 for this analysis) damages were calculated relative to the main floor elevation of the structure. Using structure and ground elevation data, the depth vs. damage relationships were converted to corresponding stage (NAVD88) vs. damage relationships. Generalized depth-percent damage functions for structure, structure content and other items were applied to structures for calculation of inundation damage. For this analysis, generalized depth-percent damage functions used for multi-family residential and all non-residential structures were taken from the HAZUS-MH MR4 Technical Manual. Depth-percent damage functions used for single family residential dwellings with basements were taken from Corps of Engineers' Economic Guidance Memoranda EGM 04-01. Depth-percent damage functions used single family residential dwellings without basements were taken from *Depth-Damage Relationships For Structures, Contents, and Vehicles and Content-To-Structure Value Ratios in Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study – March, 2006* (USACE 2006). The damage curves represented in the Louisiana study were used in this analysis because they represent damages occurring from short-duration saltwater intrusion, which typifies coastal flooding experienced in the Jamaica Bay study area. Alternative depth-percent damage functions for single family residential dwellings without basements are available from Corps of Engineers' Economic Guidance Memoranda EGM 01-03, but these functions represent riverine flooding, not coast flooding, and therefore, were not used in this analysis.

For each structure, EADs were calculated for a range of protection levels (10, 25, 50, 100, 250, and 500-year). It is important to note that, the EAD for a structure's 50-year level of protection is not equal to damages incurred by a structure from a 50-year event. Rather, the EAD for a 50-year level of protection represents the average annual equivalent benefits of protecting a structure for storms up to and including the 50-year event, which also includes the 2, 5, 10, and 25-year events. The calculation incorporates the probabilities of various levels of flood events and the associated damages from those events

Table 56 presents EADs for each alternative plan for the 10-year, 50-year and 100-year events. The EADs for both Storm Surge Barrier Plans are equivalent because each plan under Alternative C provides the same level of protection for all economic reaches.

**Table 56: Alternative Plan Equivalent Annual Damage ($000's)**

| Alternative Plan | 10-year event | 50-year event | 100-year event |
|---|---|---|---|
| C-1E | $149,828 | $382,393 | $444,218 |
| C-2 | $149,828 | $382,393 | $444,218 |
| D | $144,344 | $371,601 | $432,567 |

There are three components to the NED benefits (Table 57) provided by the alternative plans: bayside coastal storm risk reduction, shorefront coastal storm risk reduction, and improved recreation. Bayside coastal storm risk reduction is based on reductions in the economic costs and risks associated with property inundation during storm and flood events. Shorefront coastal storm risk reduction includes reductions in the economic costs and risks associated with wave attack, wave run up, and inundation of shorefront properties. Recreation benefits are based on improved recreation opportunities at Rockaway Beach on the Atlantic Ocean Shorefront Planning Reach, which result in an increased value per visit and in an increase in total visits.

**Table 57: Alternative Plan Component Benefits (AAEQ)**

| | Alternative C-1E | Alternative C-2 | Alternative D |
|---|---|---|---|
| Inundation Bayside Damage Reduction | $444,218,000 | $444,218,000 | $432,567,000 |
| Atlantic Shorefront Damage Reduction | $32,017,000 | $32,017,000 | $32,017,000 |
| Total Damages Avoided | $476,235,000 | $476,235,000 | $464,584,000 |
| Atlantic Shorefront Recreation | $32,998,000 | $32,998,000 | $32,998,000 |
| Total Benefits | $509,233,000 | $509,233,000 | $497,582,000 |

# 5 IDENTIFICATION OF THE TENTATIVELY SELECTED PLAN

Table 58 presents the average annual costs, benefits, net benefits, and benefit-to-cost ratio for each of the alternative plans.

**Table 58: Alternative Plan Average Annual Net Benefits (AAEQ)**

| Plan Name | Total Cost | Benefits | Net Benefits | BCR |
|---|---|---|---|---|
| C-1E | $163,638,000 | $509,233,000 | $345,595,000 | 3.1 |
| C-2 | $163,710,000 | $509,233,000 | $345,523,000 | 3.1 |
| D | $227,416,000 | $497,582,000 | $270,166,000 | 2.2 |

Storm Surge Barrier Plan alignment C-2 provides the most net benefits of the final set of alternative plans. However, there are three compelling factors that make Storm Surge Barrier Plan alignment C-1E the Tentatively Selected Plan (Figure 67):

- The costs for C-1E include far less uncertainty that the costs for C-2. The costs for C-2 do not include the likely high cost of relocating submerged cables that interest with the C-2 alignment footprint (see 11.2 Key TSP Milestone Uncertainties). There is no need for submerged cable relocations for alignment C-1E.
- Although the real estate costs for alignment C-2 are lower than real estate costs for C-1E (Table 51), real estate costs do not account for the severe impact to water views that are imposed on a Breezy Point neighborhood by alignment C-2 (Figure 66). Storm Surge Barrier Plan alignment C-1E is nearly one-half mile away from residential structures on the Rockaway peninsula.
- Alignment C-1E provides flexibility in the determination of whether to include and to what extent to include Breezy Point and Jacob Riis Park into the project. The Rockaway peninsula terminus of alignment C-2 cannot be removed from Breezy Point in a cost effective manner. In other words, alignment C-2 requires the inclusion of and impacts to Breezy Point. The Rockaway terminus of alignment C-1E is approximately one-half mile from Breezy Point. There are numerous potential configurations of the Rockaway Bayside and the Rockaway Shorefront CSRM units that can provide alternative levels of CSRM at Breezy Point.

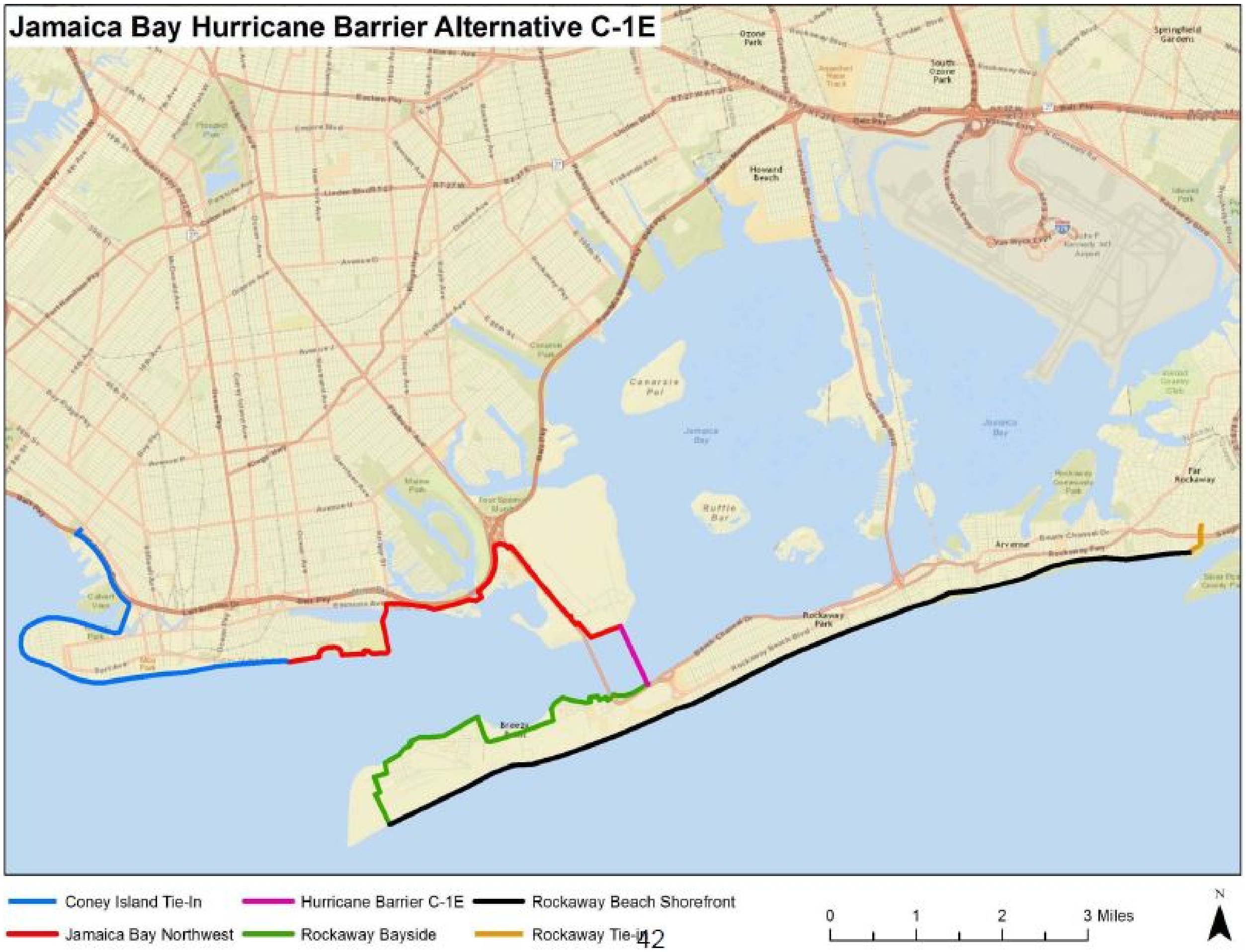


**Figure 67: Storm Surge Barrier - TSP**

The Storm Surge Barrier Plan, regardless of alignment, provides substantially more net economic benefits, has less of an environmental impact, and has less of a real estate impact than the Interior Barrier Plan. Therefore the Storm Surge Barrier, which includes CSRM at the Atlantic Ocean Shorefront Planning Reach, is currently the TSP. Additionally, Storm Surge Barrier alignment C-1E may be constructed with alternative tie-in locations (listed in Table 59 and presented in Figures 68 to 71), which provide flexibility for the final design.

**Table 59: Alternative Plan Comparison – AAEQ Costs and Benefits ($000's)**

| | Storm Surge Barrier Plan Alternative Alignments | | | | | | |
|---|---|---|---|---|---|---|---|
| | C-1E | C-1E BZ | C-1E 149 | C-1E FB | C-1E 149&FB | C-2 | Interior Plan D |
| Costs | $163,638 | $153,549 | $114,715 | $113,759 | $94,882 | $163,710 | $227,416 |
| Benefits | $509,233 | $509,233 | $500,884 | $426,107 | $417,757 | $509,233 | $497,582 |
| Net Benefits | $345,595 | $355,684 | $386,169 | $312,348 | $322,875 | $345,523 | $270,166 |
| BCR | 3.1 | 3.3 | 4.4 | 3.7 | 4.4 | 3.1 | 2.2 |

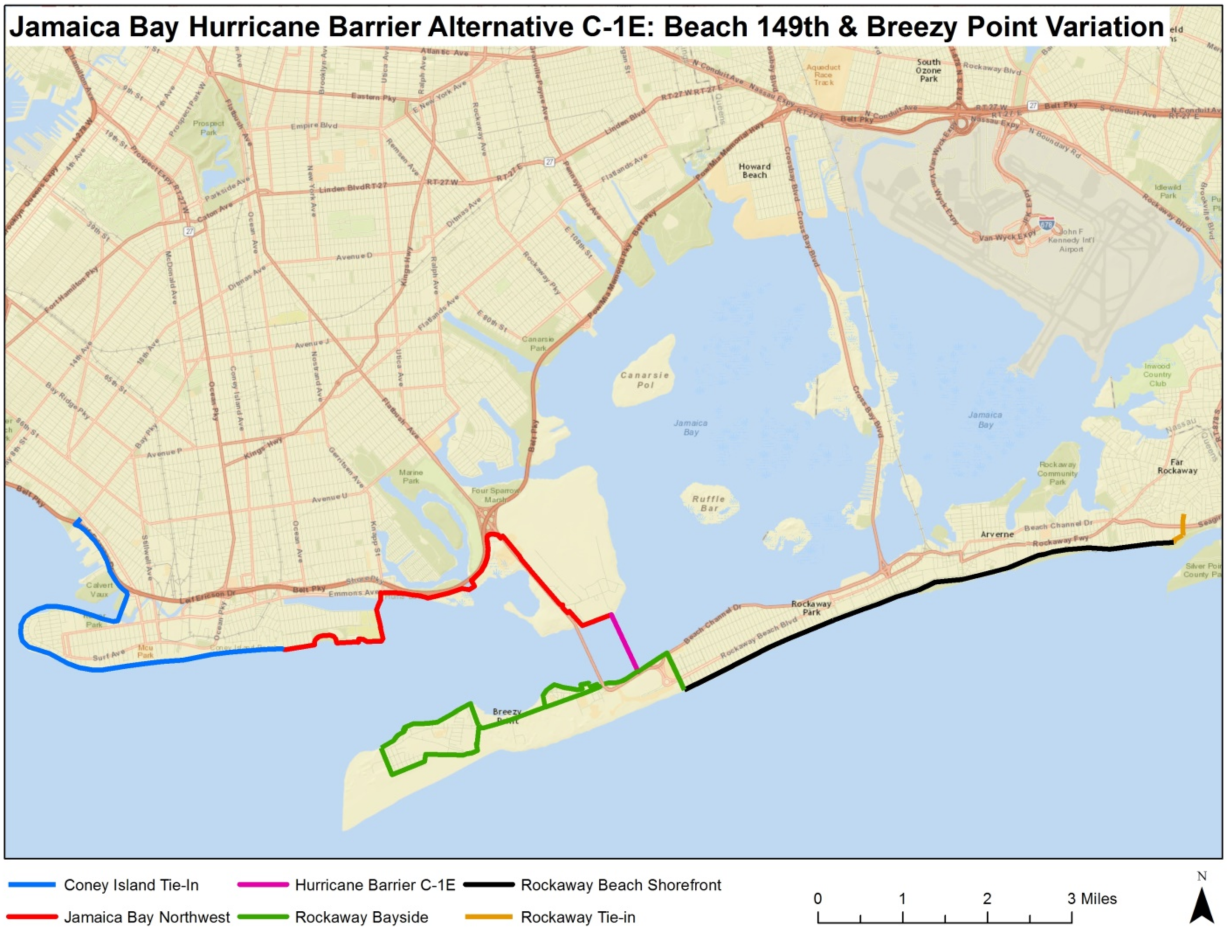


**Figure 68: TSP Breezy Point Variation (C-1E BZ)**

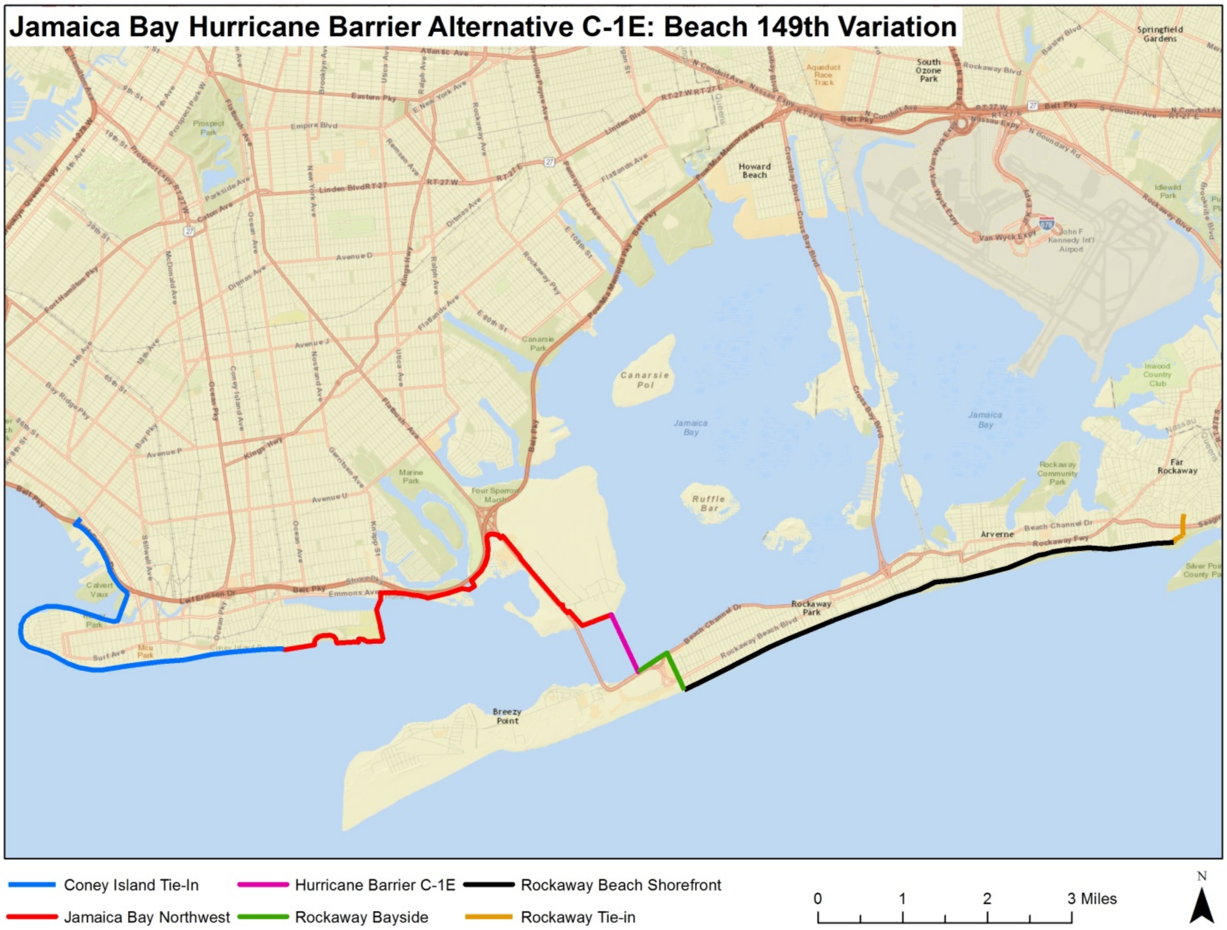


**Figure 69: TSP Beach 149th Street Variation (C-1E 149)**

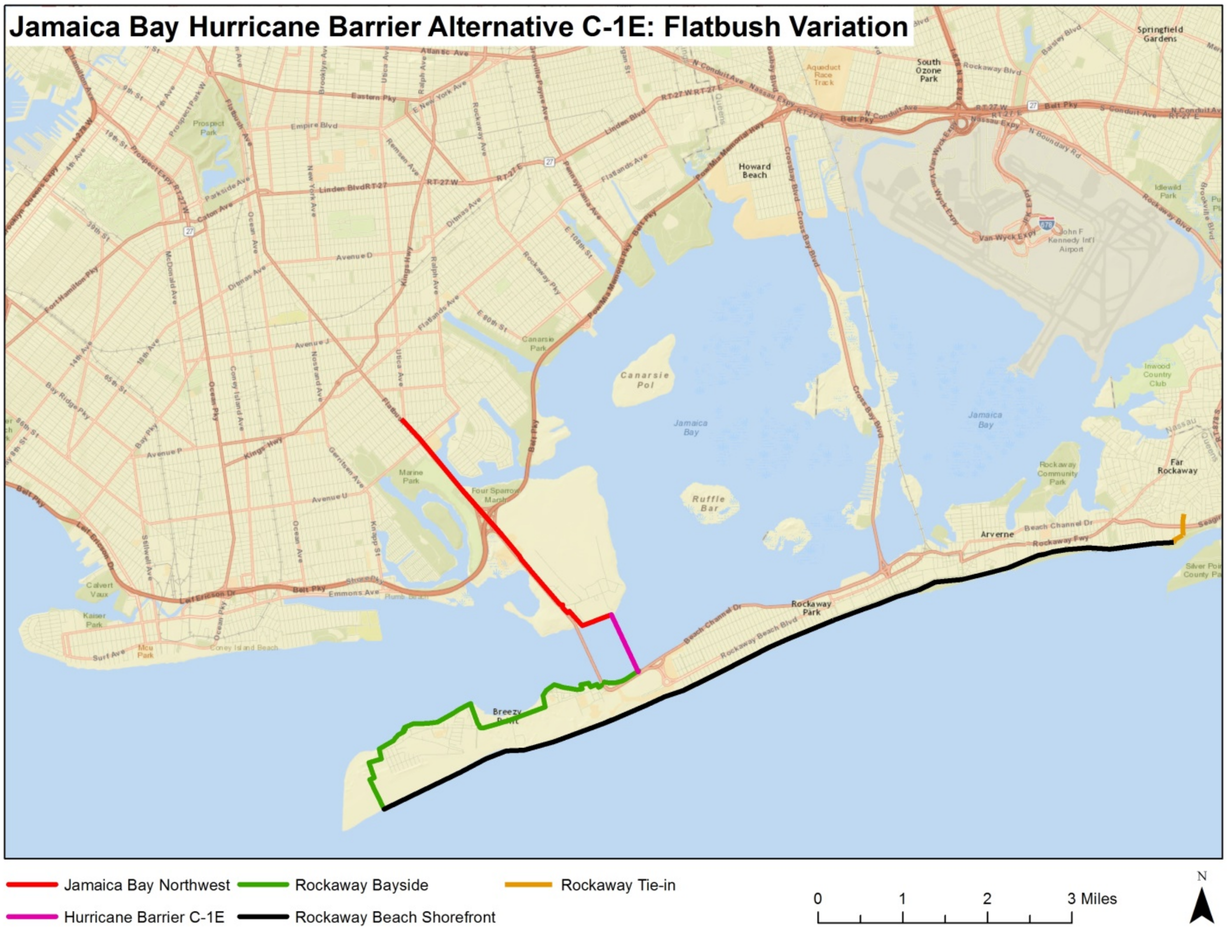


**Figure 70: Flatbush and Beach 149th Street Variation (C-1E FB)**

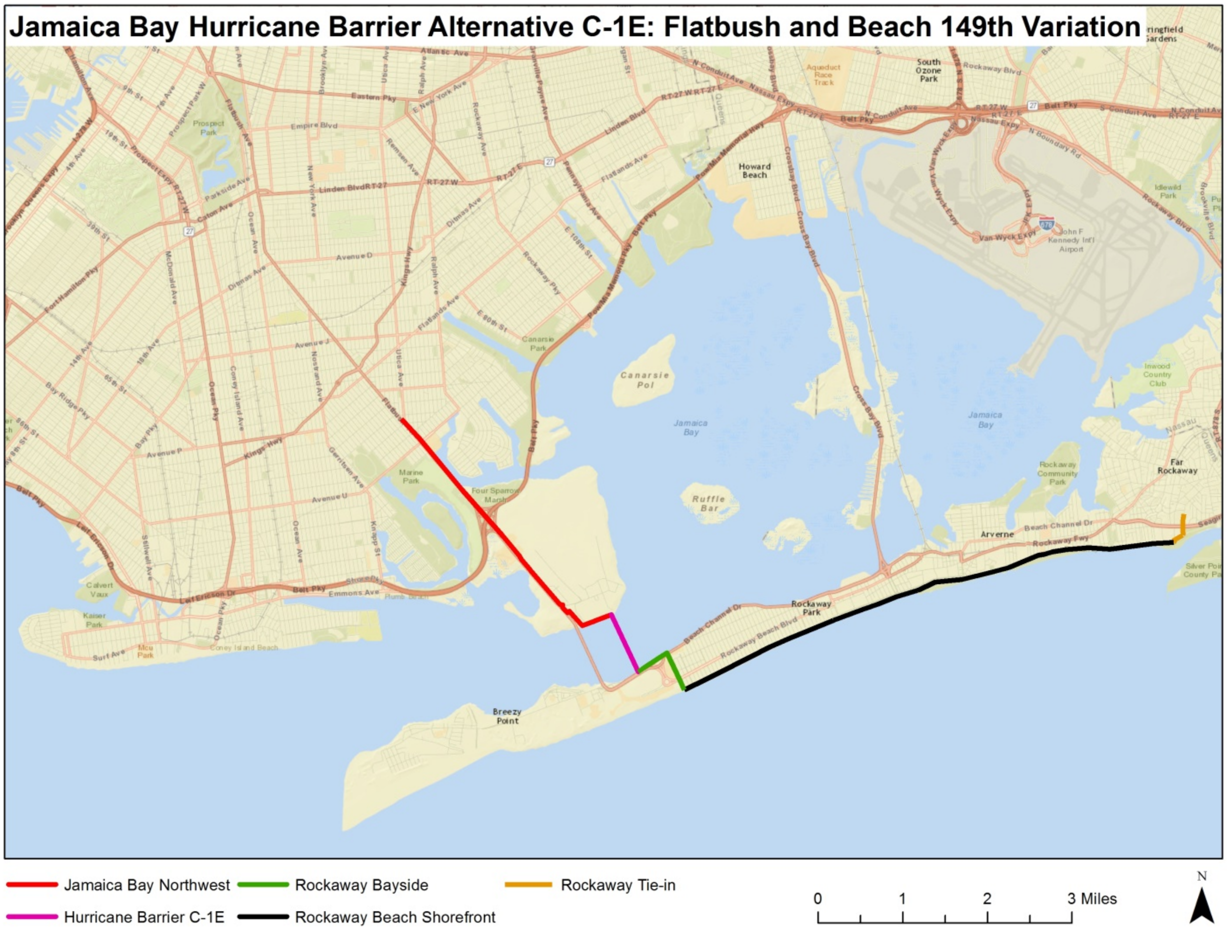


**Figure 71: Flatbush and Beach 149th Street Variation (C-1E 149 & FB)**

Table 60 presents a summary of comparisons among the three final alternatives, which supports selection of Storm Surge Barrier Plan C-1E as the TSP.

| Table 60: Alternative Plan Comparison Summary | | | | | | |
|---|---|---|---|---|---|---|
| **Category** | **Alternative C-1E (recommended)** | | **Alternative C2** | | **Alternative D** | |
| Construction Cost | $2,531,022,000 | | $2,263,392,000 | | $4,467,352,000 | |
| On-land structures (ln ft) | 44,000 | | 15,000 | | 125,000 | |
| In-water structures (ln ft) | 4,900 | | 7,900 | | 11,000 | |
| Number of tributary gates | 2 | | N/A | | 16 | |
| Number of barrier gates | 9 | | 14 | | N/A | |
| | **Pro** | **Con** | **Pro** | **Con** | **Pro** | **Con** |
| Geomorphology | Hardened shoreline makes longshore sedimentation a smaller risk than C-2 | | | Longshore sedimentation a greater risk than C-1E | | |
| | | Marine Parkway - Gil Hodges | Bridge foundation scour | | | |

| Table 60: Alternative Plan Comparison Summary | | | | | | |
|---|---|---|---|---|---|---|
| **Category** | **Alternative C-1E (recommended)** | | **Alternative C2** | | **Alternative D** | |
| | | Memorial Bridge may require scour protection | not likely | | | |
| Utilities | **No conflict with charted submarine cable area** | | | **Conflicts with charted submarine cable area** | **No conflict with charted submarine cable area** | |
| | | Potential Coney Island WWTP effluent line conflict near Sheepshead Bay – some realignment required | | **Current alignment, which has smallest in-water footprint, conflicts with Coney Island WWTP effluent line; substantial realignment required to avoid conflict** | | Potential Coney Island WWTP effluent line conflict near Sheepshead Bay – some realignment required |

| | | | | | | |
|---|---|---|---|---|---|---|
| Environmental Impact (Permanent Impact to Habitat Acres) | | Moderate level of environmental impact (130 acres) | | **Lowest level of environmental impact (62 acres)** | **Facilitated incorporation of 8 living shoreline projects within alignment.** | Highest level of environmental impact (247 acres) |
| Mitigation | Moderate Level Mitigation Costs. $90,833,000. Includes carrying forward Floyd Bennett Field Wetlands Creation and Elders Island. | Unknown, potential impacts to water quality and tidal amplitude in most up-gradient reaches of tidal inlet channels. Excess mitigation recommended to account for this unknown. | Lowest required mitigation costs. $75,538,000. Includes carrying forward Dead Horse Bay and Duck Point. | Unknown, potential impacts to water quality and tidal amplitude in most up-gradient reaches of tidal inlet channels. Excess mitigation recommended to account for this unknown. | | Highest required mitigation costs. $123,383,000. Includes carrying forward Dead Horse Bay and Floyd Bennett Field Wetlands Creation. Unknown, potential impacts to water quality and tidal amplitude in most up-gradient reaches of tidal inlet channels. Excess mitigation recommend |

**Table 60: Alternative Plan Comparison Summary**

| Category | Alternative C-1E (recommended) | | Alternative C2 | | Alternative D | |
|---|---|---|---|---|---|---|
| | | | | | | ed to account for this. unknown. |
| Annual O&M Costs | $7,424,000 | | $7,124,000 | | $14,954,000 | |

## 5.1 Selection of the Recommended Plan

USACE guidance requires selection of the TSP as the Recommended Plan unless there are other Federal, state, local, or international concerns that make another alternative viable to recommend at full cost sharing. In addition, there is an opportunity for the local sponsor to request implementation of a locally preferred plan (LPP) in which they would fully fund the cost above the NED plan if it were higher, or the plan would be reduced in cost if they preferred a smaller plan. Any plan other than the NED Plan would require a waiver from the Assistant Secretary of the Army for Civil Works.

This draft report will undergo public, policy, Agency Technical Review (ATR), and Independent External Peer Review (IEPR), and the study team will address all comments from these reviews. Based particularly on input from public and agency reviews concerning public safety and infrastructure concerns, it may be appropriate for USACE to consider recommending a more robust plan for the Orange-Jefferson CSRM after the Agency Decision Milestone (ADM) is conducted. The ADM is the decision point where a Senior Leader Panel confirms the TSP and makes the decision on the Recommended Plan to carry forward for detailed feasibility-level design based on policy, public, ATR, and IEPR reviews of the draft report.

# 6 TENTATIVELY SELECTED PLAN

The TSP efficiently provides system-wide CSRM benefits to the study area, including the Jamaica Bay Planning Reach and the Atlantic Ocean Shorefront Planning Reach. This draft report will undergo public, policy, Agency Technical Review (ATR), and Independent External Peer Review (IEPR), and the study team will address all comments from these reviews. Based particularly on input from public and agency reviews concerning public safety and infrastructure concerns, a final alignment for the Storm Surge Barrier and final selection of residual risk measures will be determined. Final design of the Storm Surge Barrier and residual risk measures will be assessed prior to the Final Draft HSGRR/EIS.

## 6.1 Plan Components

The TSP integrates CSRM structures for two reaches that provide system-wide benefits to the vulnerable communities within the study area. The major components of the TSP include:

- Beach restoration with renourishment and a composite seawall along the Atlantic Ocean Shorefront Planning Reach;
- A Storm Surge Barrier and associated tie-ins at the Jamaica Bay Planning Reach; and
- Small scale CSRM features for areas vulnerable to high frequency events and to provide CSRM in the short term prior to construction of the Storm Surge Barrier.

### 6.1.1 TSP Description

TSP plan components (Table 61 and Figures 72 to 74) are described in greater detail for alignment C-1E, which includes a tie-in to the Coney Island CSRM project currently in development by NYC and provision of CSRM to the Breezy Point community. The design and placement of TSP tie-ins and the extent of CSRM provided to Breezy Point by the TSP will be refined during analyses to be conducted prior to the Final Draft HSGRR/EIS.

**Table 61: TSP Plan Components (Structure length in linear feet)**

| CSRM Structure | Length | CSRM Structure | Length |
|---|---|---|---|
| Inlet Barrier | 3,930 | Road Gate | 180 |
| Buried Seawall | 55,062 | Seawall Reconstruction | 7,599 |
| Concrete Floodwall (Bulkhead) | 2,356 | Sector Gate | 1,048 |
| Concrete Floodwall (Deep Water) | 742 | Shoreline Restoration | 1,702 |
| Concrete Floodwall (Land) | 25,367 | Rockaway Shorefront East Tie-In | 2,135 |
| Elevated Promenade (Berm-Face) | 5,041 | Coney Island Tie-In | 32,338 |
| Elevated Promenade (Vertical-Face) | 4,234 | Total Linear Feet | 46,654 |
| Levee | 4,920 | Total Miles | 27.8 |

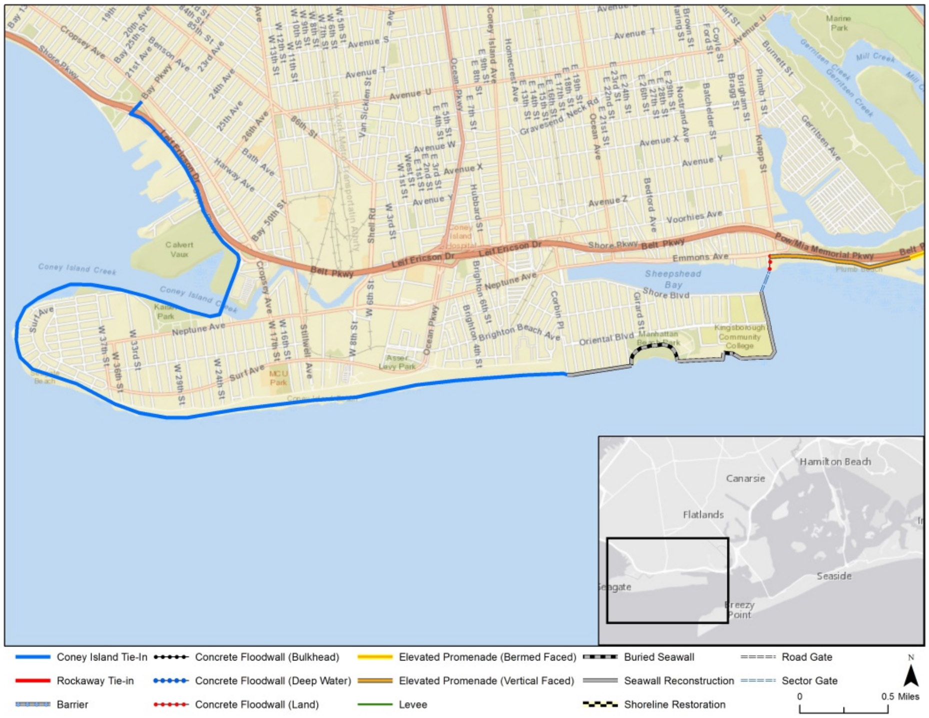


**Figure 72: TSP Structures (1 of 3)**

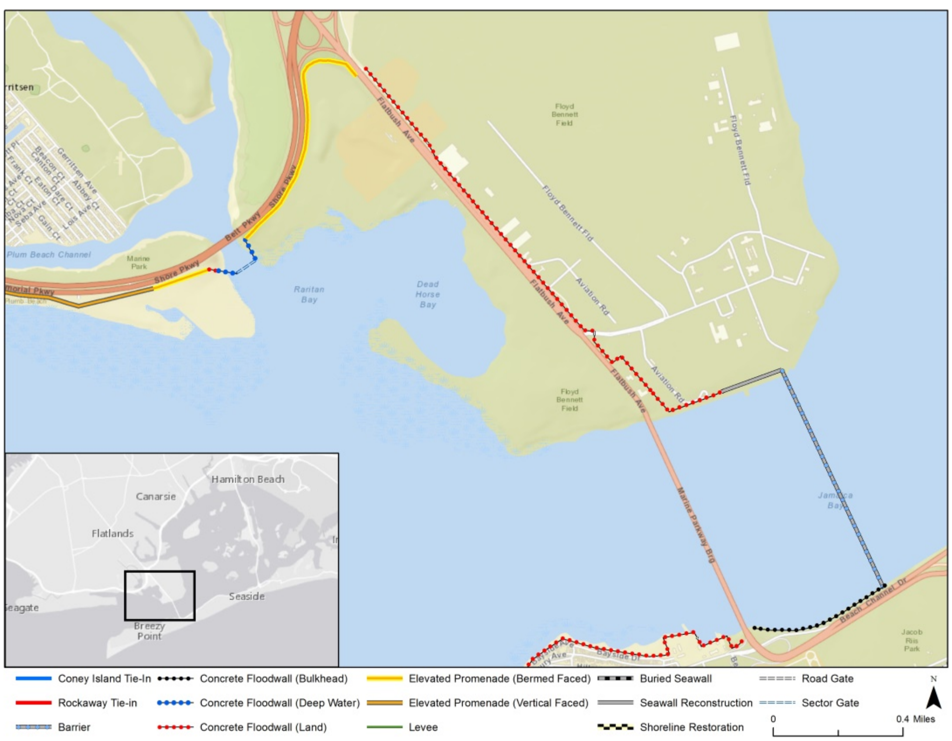


**Figure 73: TSP Structures (2 of 3)**

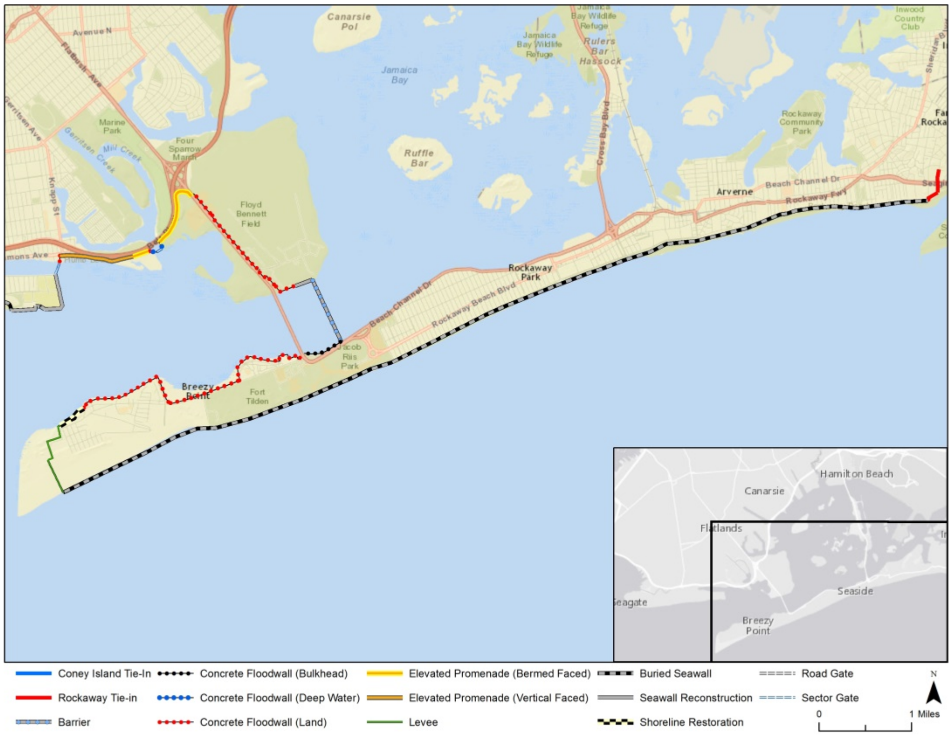


**Figure 74: TSP Structures (3 of 3)**

### 6.1.2 Separable Elements

A separable element is any part of a project which has separately assigned benefits and costs, and which can be implemented as a separate action (at a later date or as a separate project). There are two separable elements of the TSP. The CSRM Plan for the Atlantic Ocean Shoreline can function individually and is separable. The residual risk CSRM features, which would provide CSRM benefits to communities vulnerable to high frequency events and during the time prior to full TSP construction, are also separable elements.

The Storm Surge Barrier, on the other hand, would not be fully effective without the CSRM Plan for the Atlantic Ocean shoreline because storm waters could flood Jamaica Bay by over topping the Rockaway peninsula. The Storm Surge Barrier also requires tie-ins to high ground to be fully effective and therefore is not separable from those components of the TSP.

Based on based on responses from public, policy, and technical reviews of this Draft HSGRR/EIS, USACE may consider a phased decision process. Phased decision making may allow USACE to move forward with implementation of the component measures that can be decided first, while making progress toward the overall goals incrementally, acknowledging that the full benefits wouldn't be realized until all components are complete.

The first phase of decision making may consider construction recommendations to address erosion, storm surge, and wave damage along the Atlantic Ocean shorefront and residual risk measures. A second phase decision might address the details of Storm Surge Barrier construction (specific alignment, operation needs, site-specific mitigation measures, etc) and will provide the basis for the implementation of the Storm Surge Barrier and related decisions for the interior of Jamaica Bay.

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