PLAN FORMULATION APPENDIX

NASSAU COUNTY BACK BAYS COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

PHILADELPHIA, PENNSYLVANIA

APPENDIX A

August 2021

U.S. Army Corps of Engineers
Philadelphia District

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1.0 Introduction

Nassau County is located on Long Island, NY, between Queens County to the west and Suffolk County to the east. Nassau County has a population of approximately 1.3 million people, a land area of 287 square miles, and 166 square miles of water. Southern Nassau County is typified by dense, low elevation mixed-use development (residential and commercial), a highly developed shoreline, and many roads, rail roads, and critical facilities that serve Long Island and parts of New York City. The NCBB region currently lacks a comprehensive CSRM program. Therefore, the NCBB region experienced major impacts and devastation during Hurricane Sandy and subsequent coastal events, resulting in major disruption to millions of lives and significant damage to property and infrastructure.

2.0 Study Area

2.1 Initially Scope Study Area

At the onset of this feasibility study, the study area (**Error! Reference source not found.**) extended approximately 30 miles in the east-west direction, primarily in Nassau County, but also in adjacent portions of Queens and Suffolk Counties. It included all of the tidally influenced bays and estuaries hydraulically connected to the south shore of Nassau County on the Atlantic Ocean. The regular rise and fall of tide in the ocean leads to tidal flow through East Rockaway, Jones, and Fire Island Inlets that causes a corresponding rise and fall of water levels in the back bays. The study area was thus subject to tidal impacts under non-storm conditions, as well as to more widespread inundation during coastal storm events. The study area limits were established using the following principles and assumptions.

Northern Boundary. The northern study area boundary along the mainland of Long Island was established using NACCS water level statistics for the 0.2% annual exceedance probability, or AEP (500-year return period). The vertical datum used in the NACCS water level calculations is local mean sea level (LMSL) in meters. The NACCS water surface elevations were converted to units of feet relative to NAVD88 using the application known as VDatum, developed and maintained by NOAA. This conversion was necessary because NAVD88 is the standard vertical datum used for topographic (elevation) surveying and mapping. Three feet was added to the NACCS water surface elevations to account for potential future relative sea level change (RSLC), then each value was rounded to the nearest whole foot. The resulting elevation contour selected as the northern study area boundary was thus +19 feet NAVD88. The boundary line was smoothed using engineering judgment so that it did not cut through real estate parcels. The typical distance from the northern study area boundary to the ocean shoreline of Long Beach, Jones, and Fire Islands is between 5 and 7 miles.

Southern Boundary. The southern boundary corresponded to the Atlantic Ocean offshore of Long Beach, Jones, and Fire Islands.

U.S. Geological Survey (USGS) hydrologic units were used to identify and select the east and west boundaries of the study area. USGS Hydrologic Unit Code (HUC) 12-digit sub-watersheds were adopted as the appropriate level of geographic detail for this study.

Western Boundary. Hook and Motts Creeks are hydraulically connected to Jamaica Bay at Head of Bay south of John F. Kennedy International Airport and act as conduits for storm surge that floods portions of eastern Queens and western Nassau Counties. The Hook Creek-Head of Bay watershed was included in both the NCBB and New York – New Jersey Harbor and Tributaries Study (NYNJHATS) areas. There is a risk that the economic benefits of a project that reduces flood risk in this area may not be captured if they are only investigated in one study. For example, if the area is included only in the NYNJHATS and a storm surge barrier at Jamaica Bay is subsequently screened from further consideration in that study, then the Project Delivery Teams (PDTs) may miss the opportunity to investigate different measures as part of the study. In addition, Nassau County has invested in CSRM infrastructure in the watershed and has stated that this is an important area for investigation. The NCBB and NYNJHATS PDTs will continue to coordinate about this matter throughout plan formulation and selection.

Eastern Boundary. The study is evaluating the potential for ocean storm surge to enter the back bays through East Rockaway, Jones, and Fire Island Inlets. Structural measures, such as a storm surge barrier at Fire Island Inlet or a cross-bay barrier, would also have the potential to affect storm water elevations in the portion of western Suffolk County that adjoins Nassau County. Consequently, the PDT adopted the eastern extent of the West Channel-Dickerson Channel watershed as the eastern study area boundary.

Communities in the study area included villages and unincorporated municipalities in the towns of Hempstead and Oyster Bay that border Hewlett Bay, Middle Bay, Jones Bay, South Oyster Bay, and connected creeks, channels, and minor water bodies, as well as the City of Long Beach. Also included were the Suffolk County towns of Babylon and Islip that border Great South Bay.

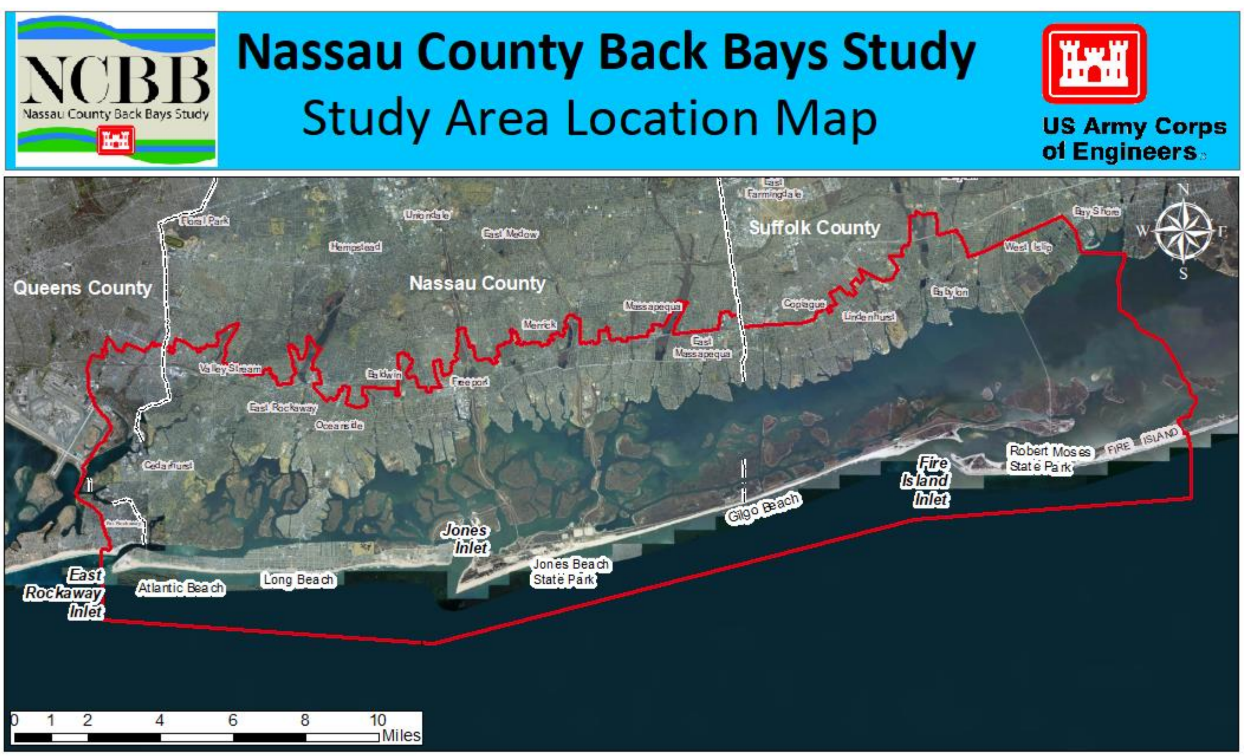

Figure 1 - Initially Scoped Study Area

2.2 Re-Scoped Study Area

During the execution of this feasibility study, USACE determined that the size and scope of the study and potential project would require significant study time and significant input of public resources. Therefore, USACE requested a 3x3x3 exemption because the study scope exceeded the traditional feasibility level analysis required for a USACE study. In addition, the study will require significant action by Federal, state, or local agencies in the form of reviewing proposed plans and assessing environmental impacts. During the 3x3x3 exemption process, USACE re-scoped the study to focus on the geographic limits of Nassau County as the vulnerable areas in Queens (to the west of Nassau County) and Suffolk Counties (to the east of Nassau County) are being addressed under other study authorities (Jamaica Bay-Rockaway NY and Fire Island to Montauk Point NY, respectively). In addition, the aforementioned studies addressing Queens and Suffolk Counites have construction capability as part of the Sandy Appropriation (PL 113-2); therefore, the east-west boundary of this feasibility study will be limited to the east-west extent of Nassau County (Figure 2). The northern and southern boundaries will remain the same as originally scoped.

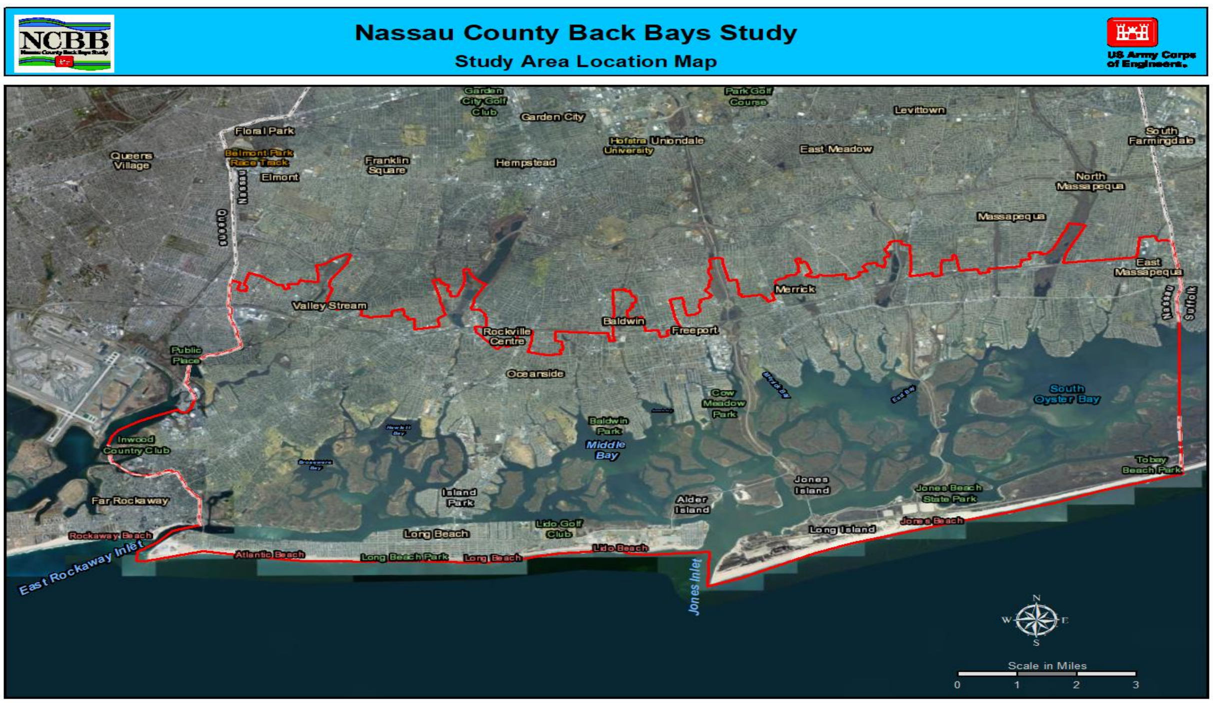

Figure 2 - Re-Scoped Study Area

3.0 Problems & Opportunities

The following problems and opportunities were identified based on public coordination and an examination of existing and future without project (FWOP) conditions:

<u>Problems</u>

- **Inundation -** The NCBB study area is vulnerable to coastal storm-related inundation damages, including economic disruption to residential structures and infrastructure & life and safety risks.
- **RSLC/Climate Change -** The study area risk from storm damages will likely increase with RSLC for the FWOP condition.

- **Erosion -** The study area experiences shoreline losses from wave attack, wind forces and other elements.
- **Degraded Ecosystems -** The study area's coastal ecosystems fail to provide their natural ecosystem services.

Opportunities

- Manage coastal storm risk to structures, infrastructure and life safety.
- Apply solutions that are adaptable and sustainable with rising sea levels.
- Establish solutions designed to combat erosion.
- Integrate storm risk management and apply the qualitative NACCS resilience criteria designed to improve adaptive capacity.
- Improve ecosystem goods and services provided through quantitative review of measures and alternatives.

4.0 Planning Objectives, Constraints & Considerations

The Federal Government investigates prospective projects from a national point of view. When determining the need for Federal investment in a project, the primary analysis centers on the significance of the problem and the benefits of possible solutions. In the case of this study, the primary goal is focused on CSRM benefits. It is also in the Federal and non-Federal sponsor's interest to select a cost-efficient plan, specifically one in which the benefits exceed the costs. It is important to note that benefits can include non-monetary benefits such as reducing life-safety issues and improving the environmental quality. Federal interest in the project is identified when both requirements are satisfied.

USACE developed planning objectives to apply to the entire study area over the 50-year period of analysis (2030 to 2080):

- Reduce potential life loss related to coastal flooding in the study area through 2080.
- Reduce the risk of coastal storm damage to public infrastructure and important societal resources, as well as highly vulnerable portions of Nassau County through 2080.
- Contribute to the long-term sustainability and resilience of coastal communities in Nassau County through 2080.

Planning Constraints

- Avoid construction within Coastal Barrier Resources Act (CBRA) System Units
- Avoid impacts to life safety activities for the U.S. Coast Guard
- Avoid impacts to Federal navigation channels
- Avoid impacts to constructed and planned resilience projects
- Avoid impacts to Threatened and Endangered Species
- Minimize or avoid effects on cultural resources and historic structures, sites and features

Planning Considerations

- Avoid induced coastal flooding in adjacent communities, and flooding from rainfall or overwhelming of existing interior drainage systems
- Avoid degradation to water quality

5.0 Plan Formulation Summary

A CSRM plan for the NCBB study area has been developed to address the previously identified (Chapter 1) problems and opportunities and avoiding the constraints where possible. Plan formulation has focused on meeting the Federal objective of water resources project planning which is to contribute to NED consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Plan formulation also considers the effects to each of the four evaluation accounts identified in the Principles and Guidelines (ER 1105-2-100) (1983) which include the NED, RED, EQ, and OSE. The four Planning Criteria including effectiveness, efficiency, acceptability and completeness identified in the Principles and Guidelines (ER 1105-2-100) (1983) were also considered in plan formulation.

The NCBB study is guided by the principle of iterative planning, which encourages risk-informed decision making and the appropriate levels of detail for each round of alternative formulation. Initial steps in the plan formulation process are broad-based analyses followed by more specific, detailed analyses during successive levels of the plan formulation process. Throughout the study, the study team will: a) use existing data and tools as applicable including the NACCS evaluations and state and local datasets (county, municipal, nongovernmental organizations, and academic institutions; b) coordinate with and leverage other federal, state and NGO resilience projects, studies and efforts; and c) integrate federal and state agency, public and stakeholder outreach comments as gathered through the series of NCBB outreach events.

The NCBB plan formulation process includes the integration of the Principles and Guidelines (ER 1105-2-100) (1983) 6-step planning process, including the following steps:

- Step 1 – Identifying Problems and Opportunities
- Step 2 – Inventorying and Forecasting Conditions
- Step 3 – Formulating Alternative Plans
- Step 4 – Evaluating Alternative Plans
- Step 5 – Comparing Alternative Plans
- Step 6 – Selecting a Plan

The focused array of alternative plans identified as part of this DIFR-EIS is consistent with the findings and recommendations of the NACCS. The NACCS risk management framework is designed to help local communities better understand changing flood risks associated with climate change and to provide tools to help those communities better prepare for future flood risks. In particular, it encourages planning for resilient coastal communities that incorporates wherever possible sustainable coastal landscape systems that take into account, future sea level and climate change scenarios. The process used to identify the focused array of alternative plans herein utilized the NACCS framework that included evaluating alternative solutions and also considering future sea level change and climate change.

5.1 Management Measure Summary

The NACCS full array of CSRM measures was used as the starting point for this study. Although many of the categories generally correspond to standard CSRM strategies, specific applications are not constrained to the usual solutions. Opportunities for innovative designs, technologies, materials, and combinations of standard measures are expected to be key to managing coastal risks and promoting resilience.

5.1.1 Overview of Potential CSRM Measures

The No Action plan provides no additional measures to provide CSRM in the study area. The No Action plan represents the FWOP Condition against which alternatives plans will be evaluated. No actions to reduce storm damage to the study area will result in $1 billion in storm damages over the 50-year period of analysis.

5.1.1.1 Non-Structural Measures

Section 73 of the Water Resources Development Act of 1974 requires consideration of non-structural alternatives (measures) in all flood risk management studies. They can be considered independently or in combination with structural measures (ER 1105-2-100). Planning Bulletin (PB 2016-01) signed on 22 December 2015 further clarifies Corps policy on non-structural measures for the plan formulation phase on investigations and implantation. PB 2016-01 states that it is the policy of the USACE to formulate a full array of alternatives consisting of non-structural measures and structural measures and that not all non-structural measures need to meet the USACE criteria for agency participation and cost share implementation. It further clarifies that a 100% voluntary participation for acquisition, relocation and permanent evacuation is not considered a complete plan and is not acceptable for USACE participation. USACE participation must include the option to use eminent domain, where warranted, and costs for relocation, and should include the provision of relocation assistance under P.L. 91-646.

The definition of non-structural is to reduce human exposure to a flood hazard without altering the nature or extent of the hazard. Non-structural management measures in general are intended to reduce the consequences that flooding would have to assets exposed to flood peril, as opposed to a structural measure that alters the characteristics or the probability of the flood peril to occur (USACE 2014b). Operation and maintenance costs of non-structural measures are typically low and are usually sustainable over long-term planning horizons (USACE 2014c).

Non-structural CSRM measures are divided into two primary categories, physical and non-physical. Physical non-structural measures include: buyout/acquisition, dry flood proofing, wet flood proofing, elevation and relocation.

- Buyout/Acquisition – purchase and elimination of flood damageable structures, allowing for inhabitants to relocate to locations away from flood hazards.
- Dry Flood Proofing – sealing building walls with waterproofing compounds, impermeable sheeting or other materials to prevent the entry of floodwaters into damageable structures.
- Wet Flood Proofing – allows floodwater to enter the structure, while vulnerable items (utilities, furnaces, etc.) are relocated or waterproofed at higher locations.
- Elevation – raising the buildings in place so the structure sees a reduction in frequency and/or depth of flooding during high-water events. Elevations can be done on fill, foundation walls, piers, piles, posts or columns. The selection of the proper elevation method depends on the flood characteristics, such as depth or velocity.
- Relocation – moving the structure to another location away from flood hazards.

Non-physical non-structural measures include: evacuation plans, flood emergency preparedness plans, floodplain mapping, land use regulation, risk communication, zoning, flood Insurance and flood warning systems.

- Evacuation Planning – requires detailed hydrologic analyses for determining the rate of rise of floodwaters for various rainfall or snowmelt events. When used in conjunction with flood warning systems, this measure can provide significant loss of life avoidance and flood risk management benefits. Evacuation planning considers vertical evacuation as well as the traditional horizontal evacuation. This measure should only be implemented when there is signification response and action time available for floodplain occupants to evacuate. Rally points as well as evacuation routes should be thoughtfully planned and communicated to the public.
- Flood Emergency Preparedness Plans – local officials are encouraged to develop and maintain a flood emergency preparedness plan (FEPP) that identifies hazards, risks and vulnerabilities, and encourages the development of local mitigation. The FEPP should include the community's response to flooding, location of evacuation centers, evacuation routes, and flood recovery processes.
- Floodplain Mapping – identifies flood risk, whether in the form of a map which portrays flood boundaries or as an inundation map illustrating the depth of flooding.
- Land Use Regulation – the principles of these tools are based in the National Flood Insurance Program (NFIP) which requires minimum standards of floodplain regulation.
- Risk Communication – develops and uses educational tools such as presentations, workshops, hand-outs, and pamphlets to communicated flood risk and flood risk reduction measures to government entities and floodplain occupants in an effort to reduce the consequences associated with flooding.
- Zoning - Communities at risk of flood peril have the regulatory authority to address local land use, zoning, and building codes to avoid development in floodplains. Communities participating in the NFIP must incorporate flood resistant construction standards into building codes. Local ordinances have been established in some municipalities to reduce impervious surfaces such as driveways and parking areas, promote uniform bulkhead elevations, and require buildings to have an additional 2-3 ft. of freeboard above the FEMA BFE. An interagency task force could help municipalities incorporate climate change and sea level change in their planning, zoning, and adaptation plans.

  Overlay zoning works in concert with existing zoning laws to apply an additional measure of approval for construction in high hazard coastal areas. Overlays can set development densities, building regulations, or setback requirements based on the location of the site in relation to flood sources. Downzoning reduces the use intensity of an existing zone by reducing densities or permitted use in the area. Specific downzoning techniques could change the classification of a zone from residential to conservation to reduce the development density. Un-inhabitability refers to the safety and livability of a coastal area in the face of coastal storms, sea level rise and erosion.
- Flood Insurance - provides insurance to assist in recovery from a flood event.
  - National Flood Insurance Program (NFIP) Refinement - Refinements to the NFIP (including increasing homeowner participation and increasing municipal protection in the CRS) also represents a non-structural opportunity at an agency level.

- Increase Homeowner Participation - Residents that are uncertain about reducing risk to their belongings may be prone to attempt to remain in vulnerable areas during storm events, creating further risk. Knowing that personal property is insured, residents may be more comfortable with evacuating vulnerable areas at the approach of a storm. Flood insurance rates and regulations directly and indirectly impact property owners' decisions to reduce risk to their property through favorable construction practices.
- Increase Municipal Participation in Community Rating System (CRS) – Community participation in the NFIP is conditional on meeting program guidelines. Participating communities must manage development within their floodplains in accordance with FEMA standards or risk removal from the program, which risks cancellation of all flood insurance policies within the community. Under the CRS, flood insurance premium rates are discounted to reward community actions that meet the three goals of the CRS, which are: (1) reduce flood damage to insurable property; (2) strengthen and support the insurance aspects of the NFIP; and (3) encourage a comprehensive approach to floodplain management. Participation in the CRS helps strengthen and enforce floodplain management policies.
- Voucher System to Assist Lower Income Groups - One way to increase participation in the NFIP is a voucher system to provide assistance to lower income groups. Rising insurance rates and expanded flood plains have a greater burden on low income groups who may not be able to afford the increasing premiums associated with the Biggert-Waters Flood Insurance Reform Act.

- Flood Warning Systems - alert inhabitants in flood prone areas of impending high water. Depending on the type of warning system and advance time, inhabitants have the opportunity to evacuate damageable property and themselves from the flood prone area.

5.1.1.2 Structural Measures

Structural CSRM measures are engineering solutions to manage flood risk and reduce damage from coastal storms. Typical structural solutions include levees, floodwalls, beaches, and dunes, which are intended to physically limit flood water inundation from causing damage. Although many of the structural measures generally correspond to standard CSRM strategies, specific applications are not constrained to the usual solutions. Opportunities for innovative designs, technologies, materials, etc., should be considered when evaluating specific application of any of these measures.

1. Floodwalls (Permanent)

Floodwalls are vertical structures often constructed with steel or concrete that are used to reduce risk of flooding. Floodwalls are most frequently used in urban and industrial areas where smaller structure footprints are desired and there is limited space for large flood risk management measures. Two of the most common types of floodwalls are cantilevered I-walls and pile supported T-walls, both of these and other floodwall types will be considered in the study.

2. Deployable Floodwalls

Deployable floodwalls are vertical structures that can be rapidly deployed during a storm event to reduce the risk of flooding. Deployable floodwalls are particularly useful for flood risk management in smaller areas and are usually considered for areas where access to the waterfront is essential to the economy or character of a community. Often, traditional floodwalls, or levees are used to reduce risk to some portions of the waterfront, with intermittent closure structures like a deployable floodwall.

3. Crown Walls

Crown walls are relatively small reinforced concrete walls constructed on top of a new or existing vertical structure (bulkhead, seawall, curb, or gravity wall) to reduce the risk of flooding. Crown walls are relatively small structures, 1 to 3 ft., which are drilled and grouted to connect to the existing concrete surface.

4. Bulkheads

Bulkheads are vertical structures with the primary purpose of retaining land and preventing the sliding of land at the shoreline. Bulkheads are normally constructed in the form of a vertical wall built in concrete, stone, steel or timber. The concrete, steel or timber walls can be piled and anchored walls, whereas the concrete and stone walls can also be constructed as gravity walls. Their use is limited to those areas where wave action can be resisted by such materials. In areas of intense wave action, massive concrete seawalls are generally required. Bulkheads, unlike floodwalls and levees, are generally constructed at or near the existing grade and flood risk management is of secondary importance.

5. Inlet Storm Surge Barriers

Storm surge barriers reduce risk to back bay environments and estuaries against storm surge, flooding and waves. In most cases the storm surge barrier consists of a series of movable gates that stay open under normal conditions to allow navigation and tidal flow to pass but are closed during storm surge events. Storm surge barriers range in scale from small/local gates reducing risk to a small coastal inlet to very large barrier “systems” reducing risk to a large estuary or bay and consist of a series of coastal dikes and gates.

6. Interior Bay Surge Barriers

Interior bay surge barriers across the interior of the bay are essentially the same as storm surge barriers at the inlet. The only difference is location. Interior bay surge barriers could be constructed across the interior of the bay and potential adjacent to existing roads, bridges and causeways with dynamic navigable gates across the waterway and additional auxiliary flow gates to allow tidal flow to pass under normal conditions.

7. Levees

Levees are earthen embankments with an impervious core constructed along a waterfront to reduce risk to flooding. Levees may be constructed in urban areas or coastal areas; however, large tracts of real estate are usually required due to the levee footprint. If a levee is located in an erosive shoreline environment, armoring may be needed.

8. Beach Restoration/Groins/Breakwaters

Beach restoration, also commonly referred to as beach nourishment or beachfill, typically includes the placement of sand fill to either replace eroded sand or increase the size (width and/or height) of an existing beach, including both the beach berm and dunes. Beach restoration reduce risk to storm surge flooding, waves, and erosion. Beach restoration is most applicable to areas with an existing beach.

Additional erosion control measures such as groins and breakwaters may be included in a beach restoration project to reduce erosion and increase the longevity of the project and reduce future renourishment requirements.

9. Seawalls

Seawalls are typically massive structures constructed along the shoreline whose primary purpose is interception of waves, prevention of upland erosion and reduction of wave-induced overtopping and flooding. If constructed with impermeable materials (not just stone) seawalls may also reduce flood risk to low-lying coastal areas.

10. Revetments

Revetments are sloped structures with the principal function of protecting the shoreline from erosion. Revetments are typically constructed with cladding of stone, concrete, or asphalt to armor sloping natural shoreline profiles. Existing revetments may be retrofitted with an impermeable concrete L-wall at the top of the revetment to increase the elevation of the structure by 1 to 3 ft. and reduce flood risk.

5.1.1.3 Natural and Nature-Based Features (NNBF)

Natural Features are created and evolve over time through the actions of physical, biological, geologic, and chemical processes operating in nature. Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, dunes, beaches, wetlands, and maritime forests. The relationships and interactions among the natural and built features comprising the coastal system are important variables determining coastal vulnerability, reliability, risk, and resilience. Conversely, 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. The built components of the system include nature-based and other structures that support a range of objectives, including erosion control and storm risk management, as well as infrastructure providing economic and social functions. An integrated approach to coastal resilience and risk reduction will employ the full array of measures, in combination, to support coastal systems and communities.

1. Living Shorelines

Open and exposed shorelines are prone to erosion due to waves. Living shorelines are essentially tidal wetlands constructed along a shoreline to reduce coastal erosion. Living shorelines maintain dynamic shoreline processes, and provide habitat for organisms such as fish, crabs and turtles. An essential component of a living shoreline is constructing a rock structure (breakwater/sill) offshore and parallel to the shoreline to serve as protection from wave energy that would impact the wetland area and cause erosion and damage or removal of the tidal plants.

2. Reefs

The development of artificial reefs in bays provides a means to re-establish and enhance reef communities. Artificial reefs provide shoreline erosion protection through the attenuation of wave energy. Artificial reefs are established for various reasons, such as restoring degraded or damaged natural reefs, providing three-dimensional habitat structure above the bottom, and providing fishing and scuba diving opportunities.

3. Wetland Restoration

Wetlands may contribute to CSRM, wave attenuation and sediment stabilization. The dense vegetation and shallow waters within wetlands can slow the advance of storm surge somewhat and slightly reduce the surge landward of the wetland or slow its arrival time (Wamsley et al. 2010). Wetlands can also dissipate wave energy; potentially reducing the amount of destructive wave energy, though evidence suggests that slow-moving storms and those with long periods of high winds that produce marsh flooding can reduce this benefit (Resio and Westerlink 2008). The magnitude of these effects depends on the specific characteristics of the wetlands, including the type of vegetation, its rigidity and structure, as well as the extent of the wetlands and their position relative to the storm track.

Functionally restored wetlands act in the same manner as natural wetlands, though design features may be included to enhance risk reduction or account for adaptive capacity considering future conditions (e.g., by allowing for migration due to changing sea levels).

4. Submerged Aquatic Vegetation (SAV) Restoration

SAV are grasses that grow to the surface of shallow water, but do not emerge from the water surface. SAV performs many important functions, including: wave attenuation, shoreline buffering by stabilizing sediments with plant roots, water quality improvement, primary production, food web support for secondary consumers, and provision of critical nursery and refuge habitat for fisheries species.

5. Green Stormwater Management

Green stormwater management is a resilient approach that mimics nature to store and treat rainfall at its source. Green stormwater management can be used to reduce runoff and increase the capacity of existing storm water systems and reduce the risk of flooding. Green stormwater management includes measures such as rain gardens, bioswales, permeable pavements, rainwater harvesting, downspout disconnection, planter boxes, and green roofs.

5.1.2 Application of Management Measures in the Study Area

Based on the aforementioned planning constraints, including but not limited to the extensive CBRA System Unit, the USACE formulated the study to focus on more complete/effective/efficient/acceptable measure that would improve CSRM in the study area. Specifically, the feasibility study focused on critical infrastructure and HVAs in Nassau County, NY with an overall study goal to promote resilience and sustainability of communities in the study area by reducing risk to life safety and reducing potential structure/content damage while allowing solutions to be adaptable to RSLC.

The study utilized data from the NACCS, which ranked the value and density of critical infrastructure in Nassau County. Per the NACCS, the Department of the Army Field Manual (FM) 3-34.170 was utilized to rank infrastructure that supports populations and communities. The sewage, water, electricity, academics, trash, medical, safety and other considerations (SWEAT-MSO) assessment process provided immediate feedback concerning the status of the basic services necessary to sustain population, as detailed in the FM. The SWEAT-MSO assessment represents a complete evaluation of both assets susceptible to direct exposure from storm damage, but also the indirect damages that would follow by identifying the assets within and support to a community. In addition, AAD outputs from HEC-FDA were evaluated and mapped to identify HVAs with a high AAD potential.

Based on this analysis, four HVAs (encompassing approximately 29% of the study area) with a combination of dense critical infrastructure and high AAD (and little or no geographic overlap with the CBRA System Units) were identified: The Village of Freeport, Oceanside & East Rockaway Villages, Island Park Village and City of Long Beach.

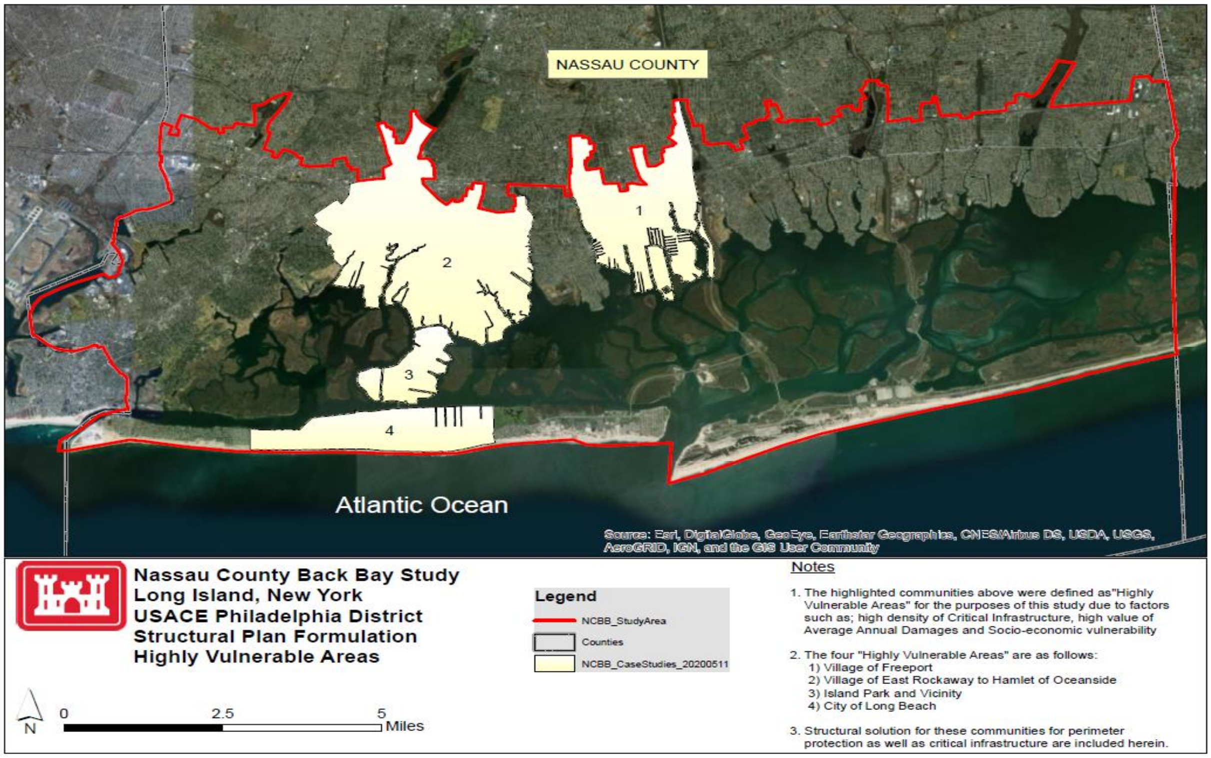

Figure 3 - Highly Vulnerable Areas in Nassau County

The highly urbanized (and in some cases industrial) HVAs were less constrained by the presence of the CBRA System Unit, when compared to the rest of the study area; therefore, structural, non-structural and NNBF measures were formulated in these areas. While the formulation in the remainder of the County was more constrained, the USACE was still able to formulate extensive non-structural and NNBF measures in these areas, as well as localized structural measures.

5.1.3 Initial Management Measure Screening

Initially, all measures were compared against the study objectives to see if they were in line with the study purpose. In order for measures to be carried forward for further analysis, they must have met at least two of the three study objectives (Table 1).

Table 1 - Objectives/Measures Matrix

Management Measure	Non-Structural	Structural	NNBF	Objective 1: Manage potential life loss related to coastal flooding in the study area through 2080.	Objective 2: Manage the risk of coastal storm damage to public infrastructure and important societal resources, as well as highly vulnerable portions of Nassau County through 2080.	Objective 3: Contribute to the long-term sustainability and resilience of coastal communities in Nassau County through 2080.	Management Measure Carried Forward for Further Analysis (Y/N)?
Buyout/Acquisition	X			X	X	X	Y
Dry Flood Proofing	X			X	X	X	Y
Wet Flood Proofing	X			X	X	X	Y
Elevation	X			X	X	X	Y
Relocation	X			X	X	X	Y
Evacuation Plans	X			X	X	X	Y
Flood Emergency Preparedness Plans	X			X	X	X	Y
Floodplain Mapping	X			X	X	X	Y
Land Use Regulation	X			X	X	X	Y
Risk Communication	X			X	X	X	Y
Zoning	X			X	X	X	Y
Flood Insurance	X			X	X	X	Y
Flood Warning Systems	X			X	X	X	Y
Floodwalls		X		X	X	X	Y
Bulkheads		X					N
Storm Surge Barriers		X		X	X	X	Y
Levees		X		X	X		Y
Beach Nourishment		X	X	X	X	X	Y
Seawalls		X		X	X	X	Y
Revetments		X		X	X	X	Y
Living Shorelines			X	X	X	X	Y
Reefs			X	X	X	X	Y
Wetland Restoration			X	X	X	X	Y
SAV Restoration			X	X	X	X	Y
Green Stormwater Management			X			X	N

Non-Structural Measures. Each non-structural measure type has a varying level of CSRM function/adaptive capacity. Because each non-structural measure potentially reduces risk to life safety and structure content/damage and ultimately increases community resilience, each non-structural measure was initially carried forward for further analysis.

Structural Measures. During the initial stages of measure screening, the USACE determined that storm surge barriers (inlet barriers and interior bay surge barriers) met all the planning objectives. Floodwalls (permanent, deployable, crown walls) and levees were also carried forward because they met two of three planning objectives, including reducing risk to life safety and reducing structure/content damage in Nassau County.

Seawalls, revetments and beach nourishment were all carried forward because they met each of the planning objectives. Specifically, seawalls were considered potentially applicable to low lying areas, such as beaches, that are still susceptible to waves and erosion. In addition, seawalls were also considered to potentially tie storm surge barriers into high ground or existing adjacent oceanfront projects. Revetments are sloped structures that help mitigate shoreline erosion. Beach nourishment was possibly applicable at existing beach locations to reduce risk related to storm surge flooding, waves, and erosion.

During the initial stage of screening, bulkheads were the only structural measures that were not carried forward for further analysis because bulkheads (unlike floodwalls and levees) are generally constructed at or near the existing grade and CSRM is of secondary importance.

Natural and Nature-Based Features (NNBF). Four (living shorelines, reefs, wetland restoration, SAV restoration) of the five NNBF measures were initially carried forward for further analysis because they met each of the objectives. The USACE recognizes that land development and traditional stormwater infrastructure has altered the historic interaction between surface water and groundwater. However, while green stormwater infrastructure can increase infiltration, improve water quality and capture the “first flush” from frequent storm events, it is not as efficient and effective at providing a large volume or peak flow rate reduction. These particular measures do not typically store large volumes of runoff and effectively mitigate potential life loss and damages for less frequent storm events; therefore, they were not carried forward for further analysis.

Living shoreline creation involves the placement of sand, planting marsh flora, and if necessary, construction of a rock structure on the shoreline or in the near shore (VIMS 2013). Per the NACCS, living shoreline materials may include sand fill, clean dredged material, tree and grass roots, marsh grasses, mangroves, natural fiber logs, concrete, filter fabric, seagrasses, etc. (Maryland DNR, 2007). They are generally applicable to relatively low current and wave energy environments in estuaries, rivers and creeks. Reefs can enhance the resilience of coastal areas by reducing the degradation and shoreline erosion that would occur during a storm event. Reef sites may be developed using natural materials such as oyster shells, clam shells, or rock. Wetlands can increase shoreline resiliency by contributing to coastal CSRM wave attenuation and sediment stabilization. The magnitude of these effects depends on the specific characteristics of the wetlands, including the type of vegetation, its rigidity and structure, as well as the extent of the wetlands and their position relative to the storm track. Sandy sediment is preferred in wetlands so that plant roots develop more effectively; however, wetlands can contain a higher percentage of fines than the beach region in front of them. SAV can also increase shoreline resiliency by contributing to CSRM via wave attenuation and shoreline buffering by stabilizing sediments with plant roots.

5.1.4 Additional Management Measure Screening

As referenced above, seawalls, revetments and beach nourishment were originally carried forward because they met each of the planning objectives; however, further analysis indicated that these measures did not avoid all the planning constraints. Specifically, these measures would likely be formulated within the limits of a CBRA System Unit, as the USACE intended to evaluate these measures along the open ocean coast. That being said, they have been eliminated from further consideration and will not be evaluated within the back bay environment of Nassau County, as they are typically more effective at providing CSRM benefits in high wave energy and erosive environments analogous to the open ocean coastline. Further, within the back bay environment the USACE determined that floodwalls and levees provide a more efficient approach to CSRM as they do not have the potential real estate and environmental impacts associated with seawalls and revetments. Also, beach nourishment is generally more applicable at existing beach locations (i.e. the open ocean coastline) to reduce risk related to storm surge flooding, waves, and erosion.

Storm surge barriers (inlet barriers and interior bay surge barriers) met each of the planning objectives and were modeled (by the USACE Engineer Research and Development Center – ERDC) with various combinations to evaluate their effectiveness in this study area. It is important to note that there are two principal processes that are responsible for back bay flooding in the NCBB study area: storm surge propagation through tidal inlets (East Rockaway Inlet, Jones Inlet and Fire Island Inlet) and local wind-driven storm surge along the east-west bay axis. As a result, four inlet barrier/interior bay surge barrier combinations were evaluated and modeled.

- Combination 1A – This combination included three storm surge barriers at each of the three inlets.
- Combination 1B, 1C and 1D – The three additional storm surge barrier/interior bay surge barrier combinations added differing locations of interior bay surge barriers to reduce flooding from the local wind-driven surge along the bay.

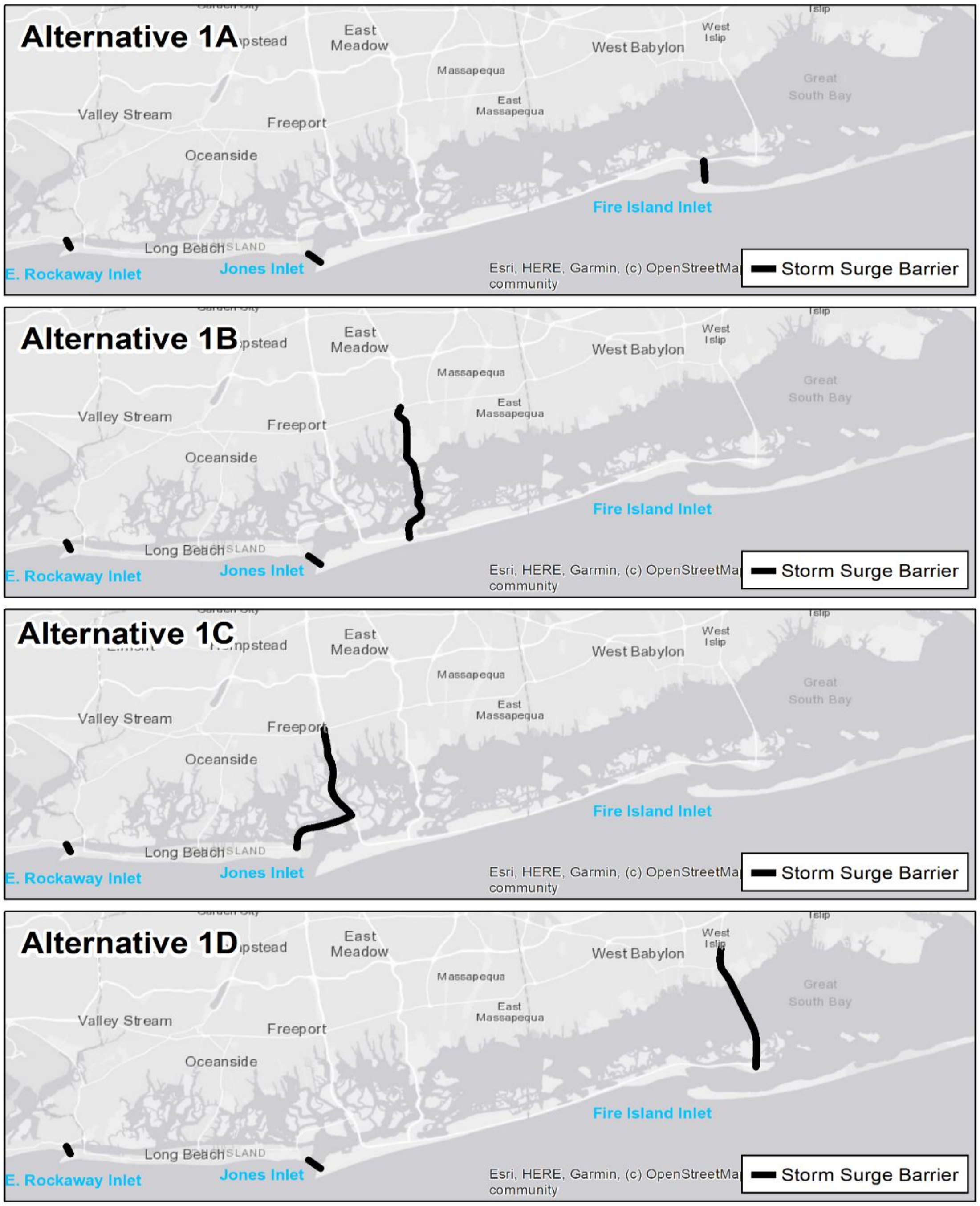

Figure 4 - Storm Surge Barrier Combinations

Model results for Combination 1A indicated that inlet surge barriers alone were only able to reduce the 1% AEP water elevation by approximately one foot, from 10 feet NAVD88 to 9 feet NAVD88. Even with the three inlets closed, winds push water in Great South Bay westward into the study area limiting the effectiveness of Combination 1A. Therefore, based on the limited water surface reduction and associated damage reduction, it is highly likely that the proposed storm surge barrier combination would have low economic efficiency when calculating net benefits.

In order to reduce the surge of water traveling from east to west across the bay a series of interior bay surge barriers was evaluated as Combinations 1B, 1C and 1D. The model results for Combinations 1B, 1C, and 1D indicated that the combination of storm surge barriers and interior bay surge barriers was successful at reducing water elevations inside the inlet barrier/interior bay surge barrier system. However, outside the system, specifically east of the bay surge barriers in Great South Bay, the modeled 1% AEP water elevations increase by 2 to 4 feet over extensive areas (10 to 20 miles). An increase in water elevations is the result of local wind-driven storm surge "piling up" at the interior bay surge barriers. From an economic feasibility perspective, the increase in modeled storm damages to communities east of the interior bay surge barrier would have negated many of the damage reduction benefits within Nassau County and greatly reduced the net benefits of the storm surge barrier combinations. Additionally, inducing flooding to communities may not constitute an acceptable nor complete plan. It is also likely that the addition of expensive CSRM measures to alleviate induced flooding impacts (extending 10 to 20 miles into Great South Bay) would have further reduced economic feasibility.

These combinations were also evaluated against potential impacts to CBRA System Units managed by the US Fish and Wildlife. Combinations 1A through 1D have at least one storm surge barrier and/or interior bay surge barrier located entirely within the footprint of a CBRA System Unit. Figure 5 includes a figure of the four Combinations 1A through 1D relative to the CBRA System Unit. Eliminating storm surge barrier and/or interior bay surge barriers located in the CBRA System Units will render these storm surge barriers even less effective at reducing storm surge by severely limiting their ability to block storm surge from both of the principal processes responsible for NCBB back bay flooding. Therefore, given the limited effectiveness and efficiency of the storm surge barriers and the large geographic presence of the CBRA System Unit, the USACE screened storm surge barriers from further consideration.

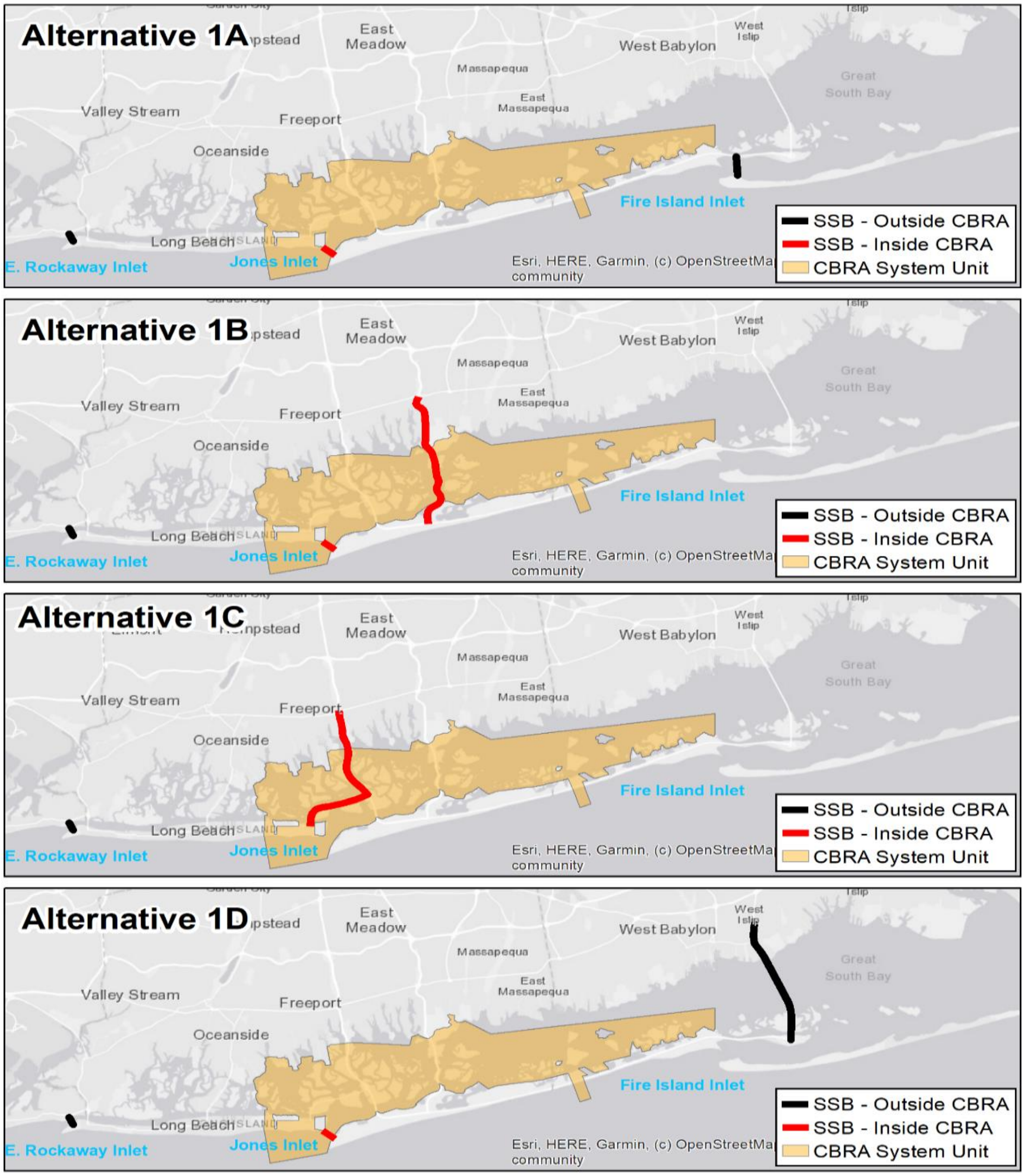

Figure 5 - Storm Surge Barrier Combinations Relative to CBRA System Unit

After additional measure analysis screened out seawalls, revetments, beach nourishment and storm surge barriers, floodwalls and levees were the only structural measures carried forward for further analysis. Given the highly urbanized and in some cases industrial nature of the HVAs, comprehensive floodwalls were formulated as the primary structural measure in these areas based on their ability to reduce flood inundation without requiring a large structural footprint (as compared to other larger CSRM measures). Levees were proposed in isolated sections of the comprehensive floodwall footprints, depending on available open space and topography. In addition, localized floodwalls were formulated as complementary measures to manage risk to critical infrastructure throughout the entirety of Nassau County.

While each non-structural measure potentially reduces risk to life safety and structure content/damage and ultimately increases community resilience, at this stage of the analysis, detailed non-structural measure analysis has only been performed for elevation of residential structures and dry flood proofing of non-residential and public structures. That being said, none of the non-structural measures have been screened out at this point because they will be further analyzed during feasibility-level design to ensure a complete non-structural alternative is formulated.

Natural Features, such as salt marshes, have an ability to reduce wave energy and coastal erosion. Initial NNBF measure analysis utilized modeling efforts/results conducted for the New Jersey Back Bays (NJBB) CSRM feasibility study. For the NJBB study, NNBF measures were modeled as stand-alone and complementary measures to structural measures (such as storm surge barriers or floodwalls) to see if the NNBF improved the effects on water surface elevation reduction. The results indicated the majority of simulated water level reduction was attributable to the structural measures, rather than the NNBFs. The addition of NNBFs to the structural measures provided some further reductions or increases, depending on the pattern of water level response but those changes are lesser in magnitude than those induced by the structural measures. While water level change attributable to NNBF for most of the NJBB domain was relatively modest (on the order of 4 to 12 inches with some areas up to 20 inches), for many storms, the reductions in water levels occurred over a several-hour time span (~10 hours for storm 350 at save point 50 in Absecon Bay, for example). In areas protected by other structural measures such as levees or floodwalls, the duration of the reduction of peak water levels can lead to reductions in flooding due to overtopping of structures as well as the load stress by shortening the duration of the highest water levels.

Applying lessons learned from the NJBB study to the NCBB study area, NNBF was initially evaluated as a systemic approach utilizing smaller/targeted creation of NNBF where appropriate to compliment other CSRM measures. Given this approach and the presence of marsh across the study area, marsh conservation and restoration (including wetlands and SAV) showed the greatest potential as a strategy for leveraging existing NNBF to further manage flood risk within the back bay environment as a whole. In addition, the above-referenced modeling associated with the consideration of storm surge barriers illustrated the significant hydraulic impact of north/south oriented structures on wind driven water surface elevations towards the west within the study area. Along the lines of the theoretical barriers, the distribution of marsh within the study area likely reduces the east to west wind-driven flow of water across the back bays relative to their deterioration into open water. Their loss may allow greater volumes of water to accumulate as greater uninterrupted fetch was opened up.

Given the extensive distribution of marsh alongside limited resources, study-wide NNBF consideration therefore focused on determining what marshes to prioritize conserving and/or restoring. The USACE developed an approach to identify which marsh complexes to prioritize in terms of protecting. A basic index assessment approach utilized existing data to classify past wetland trends, current marsh health based on vegetation extent, and likely future tidal marsh conditions. Data utilized for the Long Island Tidal Wetlands Trends Analysis Report (2015) was used to identify portions of marsh complexes lost between 1974 and 2008. Recent calculated unvegetated to vegetated marsh ratio (UVVR) values from USGS were used assigned a range of 0 -1 as an indicator of marsh health and stability. Finally, data from Sea Level Affecting Marshes Model (SLAMM) run based on intermediate sea level change conducted for the state of New York were used to add a future element of future marsh condition. A first order analysis of these data at the marsh complex scale used by the Long Island Tidal Wetlands Trends Analysis highlights the concentrated priority of conserving and/or restoring marsh in central study area, in between where Meadowbrook State Parkway and Wantagh State Parkway cross the bay to Jones Beach (**Error! Reference source not found.** In addition to being along an evacuation route, this position is east of the HVAs identified by the study. If justified, further evaluation of marsh conservation and restoration in this area in order to leverage NNBF strategies will be considered during feasibility-level design and optimization.

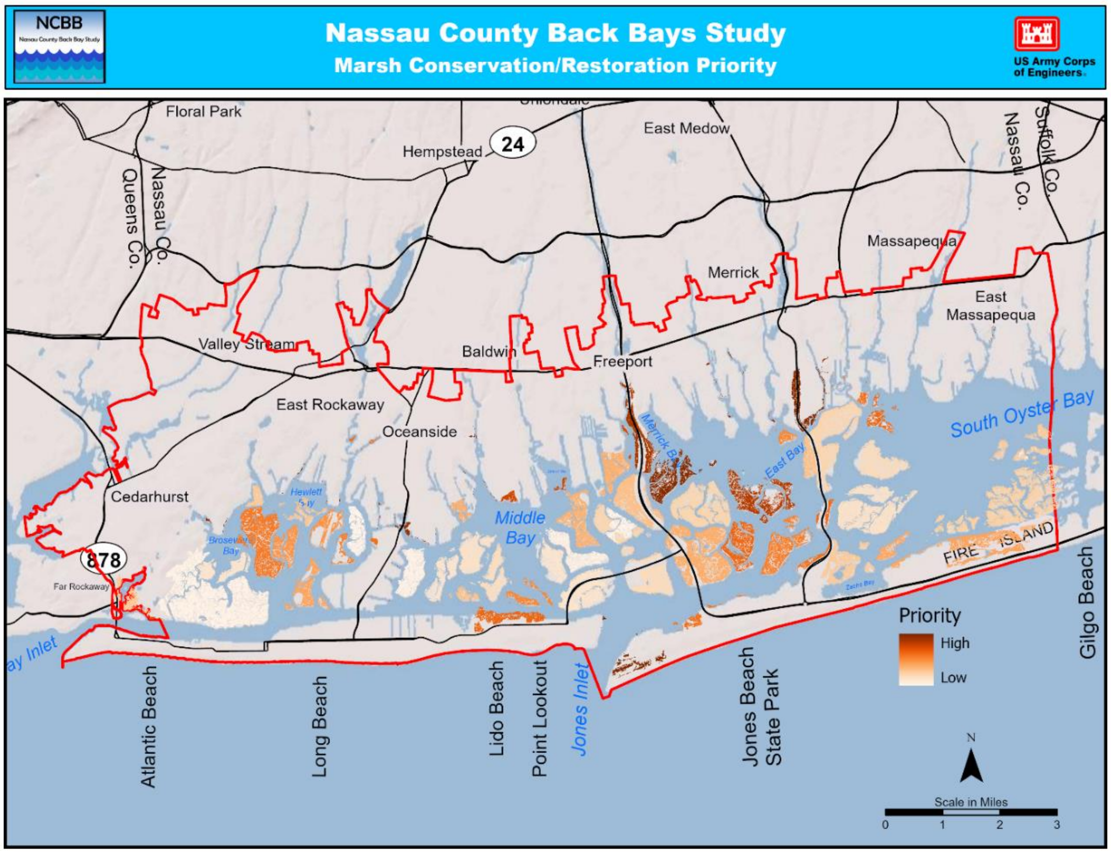

Figure 6 - Unweighted Index Considering Past Marsh Loss (1974 – 2008)

5.2 Alternative Development

As referenced above, floodwalls (and levees in select areas), non-structural measures and NNBF (with the exception of green stormwater infrastructure) were carried forward to develop the array of alternatives. All other structural measures; including bulkheads, storm surge barriers, beach nourishment, seawalls and revetments; were screened from further consideration.

Initially in the HVAs, alternative plan development began with the formulation of non-structural elevation of residential structures and dry flood proofing of industrial/commercial structures, as well as comprehensive floodwalls. Non-structural plans were also formulated throughout the remainder of Nassau County. NNBF features were formulated throughout Nassau County as complementary measures to be further analyzed during plan optimization.

Within the HVAs, comprehensive floodwalls were formulated with varying scales of risk management in the Village of Freeport, Oceanside & East Rockaway Villages, Island Park Village and the City of Long Beach. Based on lessons learned from the NJBB feasibility study, the USACE looked at floodwall alignments that provided risk management associated with the 5% AEP (20-year storm equivalent) and 1% AEP (100-year storm equivalent). In addition, the team also incorporated the 20% AEP (5-year storm equivalent) into the formulation to evaluate impacts related to high frequency flooding. The modeled floodwall crest elevations for the 1% AEP, 5% AEP and 20% AEP were +16 feet NAVD88, +13 feet NAVD88 and +9 feet NAVD88, respectively. It is important to note that due to the spatial variability in water levels, wave conditions and wave overtopping the required crest elevation of the floodwalls could be higher or lower than the preliminary crest elevations. The AANB of each risk management scale were incrementally compared against each other in each HVA. The incremental analysis indicated that the risk management scale associated with the 1% AEP had the highest net benefits in each of those areas (Figures 7 through 10).

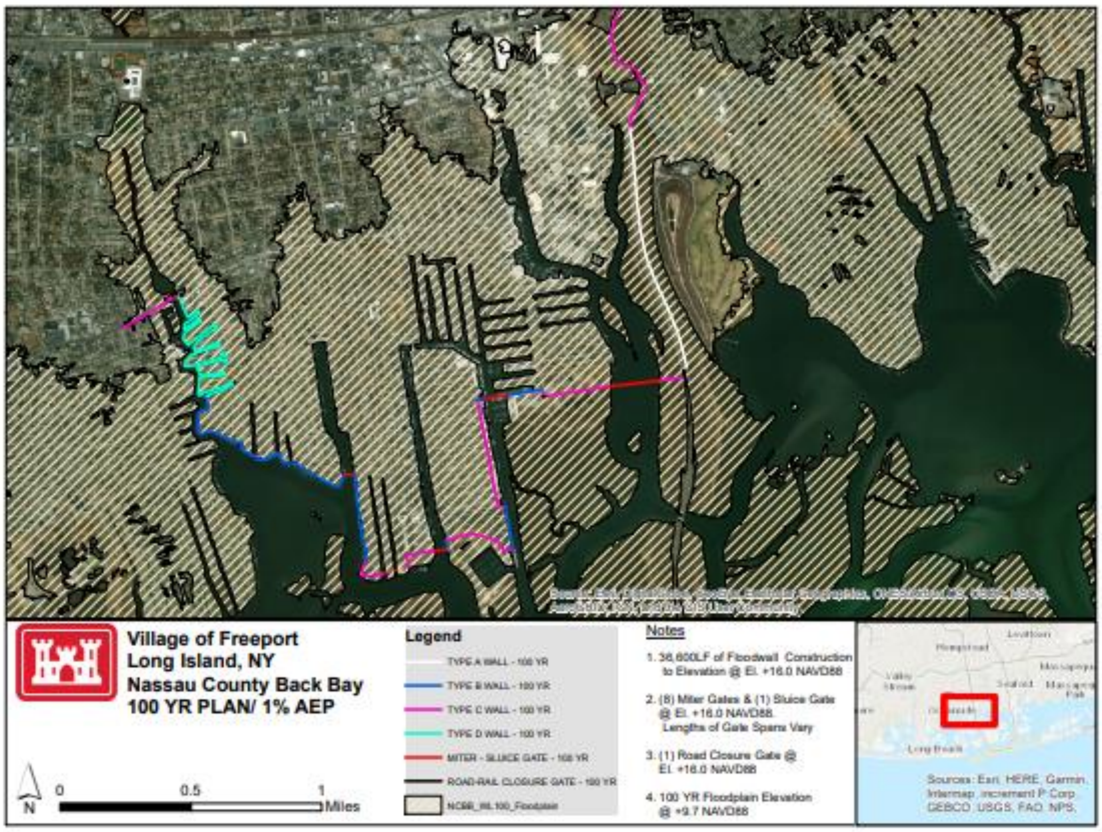

Figure 7 - Comprehensive Floodwall for the Village of Freeport (1% AEP Alignment)

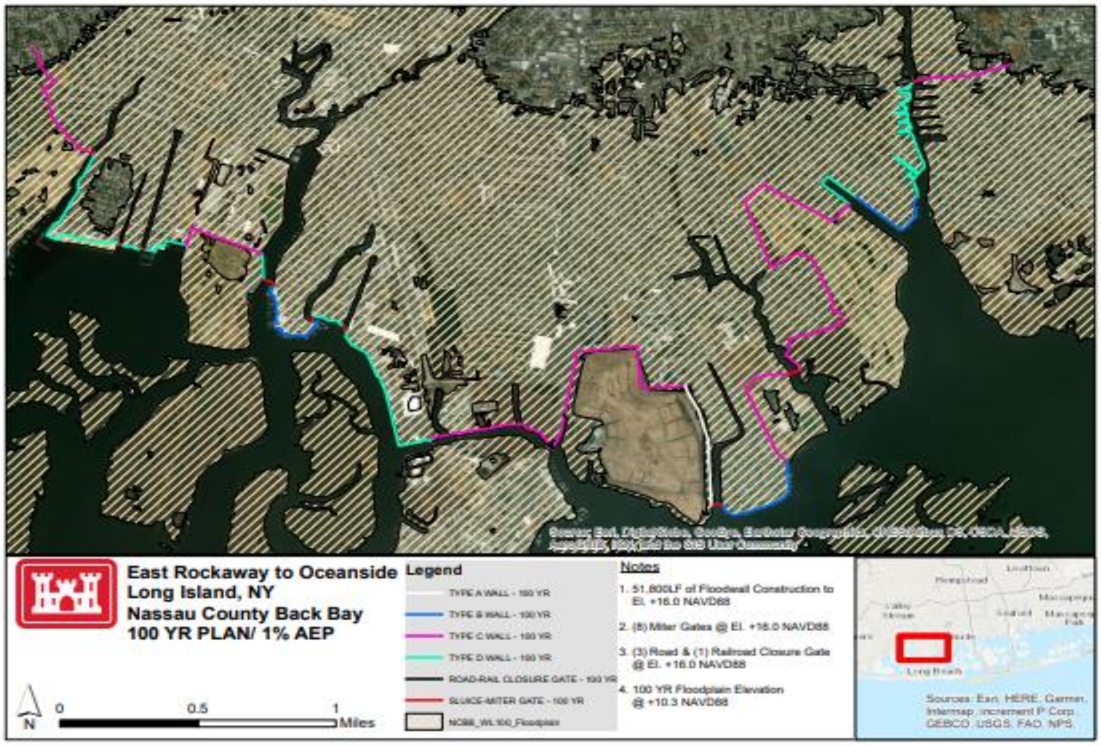

Figure 8 - Comprehensive Floodwall for East Rockaway to Oceanside (1%AEP Alignment)

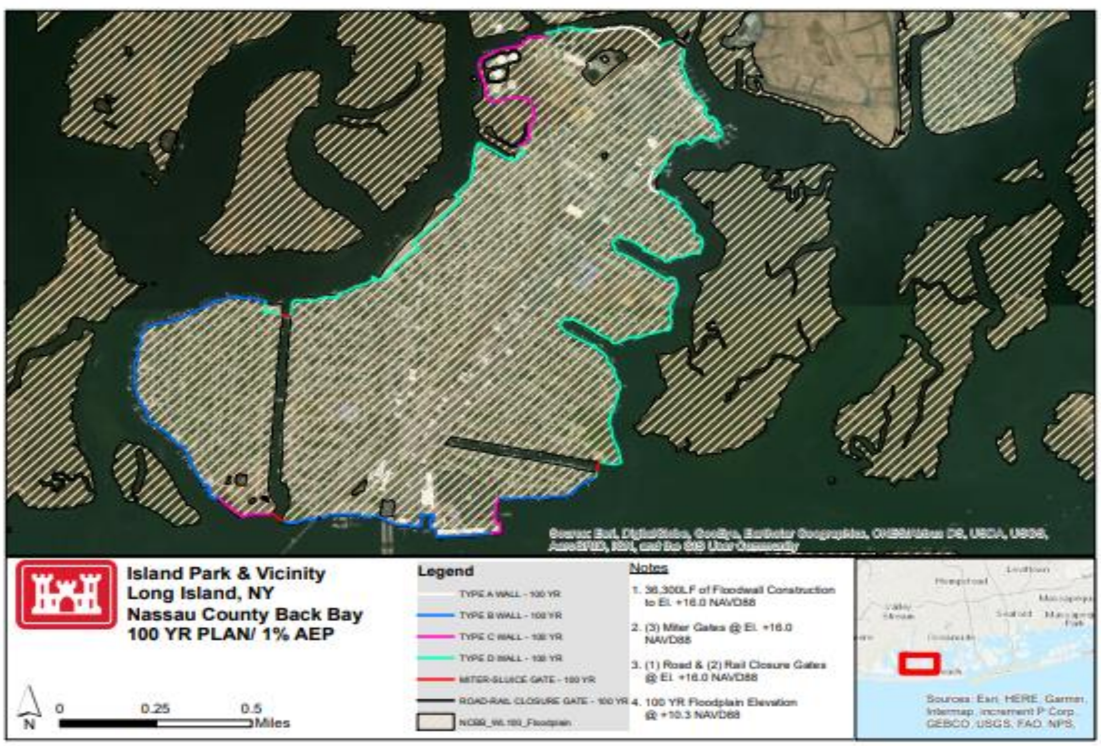

Figure 9 - Comprehensive Floodwall for Island Park & Vicinity (1% AEP Alignment)

Figure 10 - Comprehensive Floodwall for the City of Long Beach (1% AEP Alignment)

For the non-structural formulation, structures that had a first floor elevation (FFE) at or below the 5% AEP (predicted to occur at the end of the 50-year period of analysis – 2080) were considered at-risk structures eligible for non-structural alternatives. At this point in the study, non-structural analysis focused on the previously defined at-risk structures.

As at-risk structure threshold is dependent upon the SLC rate, non-structural alternatives were formulated for Low (Historic), Intermediate, and High SLC scenarios in accordance with ER 1100-2-8162 *Incorporating Sea Level Change in Civil Works Programs*.

The current non-structural economic analysis outlines a precautionary approach to SLC risk management. Using the Year 2080 5% AEP event stage (for each USACE SLC curve), at-risk structures are identified and elevated/flood proofed by the base year. All non-structural costs are incurred by the base year and benefits start accruing in the base year for all retrofitted structures (depending on their relative vulnerability over the period of analysis). Additionally, industrial/commercial structures are eligible based on their vulnerability to the 1% AEP flood event by the Year 2080.

For the at-risk residential structures, structure elevation was formulated to the modeled 1% AEP non-structural design water surface elevation, which includes intermediate sea level change projected to 2080. If elevation requirements are greater than 12 feet above ground level, structure acquisition/relocation would likely be considered instead because such a height introduces additional structure risk factors (i.e. hydrodynamic forces and wind). However, the combined 2080 non-structural design water surface elevation at 1% AEP with the intermediate SLR projection is not anticipated to be greater than 12 feet above ground level; therefore, it is highly likely that acquisition/relocation of residential structures will not need to be considered based on those constraints. That being said, acquisition/relocation is still being considered based on repetitive losses, value and vulnerability.

For at-risk industrial/commercial facilities, dry flood proofing, consisting of sealing all areas from the ground level up to approximately 3 feet of a structure, is being formulated to reduce the risk of damage from storm surge. Such dry flood proofing measures will help make walls, doors, windows and other openings resistant to penetration by storm surge waters. For example, walls may be coated with sealants or waterproofing compounds, while plastic sheeting can be placed around the walls and covered. In addition, dry flood proofing includes prevention mechanisms (such as drain plugs, standpipes, grinder pumps and back-up valves) for back-flow from water and sewer lines. Openings, such as doors, windows, sewer lines and vents, may also be closed temporarily, with sandbags or removable closures.

Recognizing that the initial non-structural formulation will inherently have residual risk, none of the other non-structural measures have been screened out at this point because they will be further analyzed during feasibility-level design to ensure a complete plan is formulated.

Localized structural floodwall alignments targeting risk management at large-scale critical infrastructure (supporting populations and communities throughout Nassau County) were also formulated to reduce residual risk and increase community resilience. While the non-structural formulation targeted all critical infrastructure in the study area, the USACE evaluated larger structural floodwalls at select large-scale critical infrastructure, based on the criteria listed below:

- Must meet Army SWEAT-MSO guidelines for critical infrastructure.
- Must fall within the 1% AEP floodplain limits.
- Risk management must maintain the functionality of the facility.
- No adverse impacts to surrounding properties/facilities.
- Cannot be within the CBRA System Unit.

Per the criteria listed above and the USACE priority to manage risk to critical infrastructure without negatively impacting the functionality of the facility and the surrounding properties, localized floodwalls were only formulated for select large-scale critical infrastructure. In many locations that were highly developed, localized floodwalls were not formulated because the USACE determined that the floodwalls would not only impact the functionality of the critical facility, but also impact other properties in terms of stormwater conveyance, property encroachment and viewshed impacts.

5.3 Focused Array of Alternatives

The development and analysis of alternatives that included structural, non-structural and NNBF measures helped shaped the focused array of alternatives that were ultimately evaluated and compared. The focused array of alternatives included the following:

1. No Action Plan
2. Non-Structural (NS) Countywide Plan
    - Elevation of 14,183 residential structures to the modeled 1% AEP non-structural design water surface elevation (which includes intermediate sea level change projected to 2080).

- Dry flood proofing of 2,667 industrial/commercial (non-residential) structures from the ground surface up to 3 feet above ground.

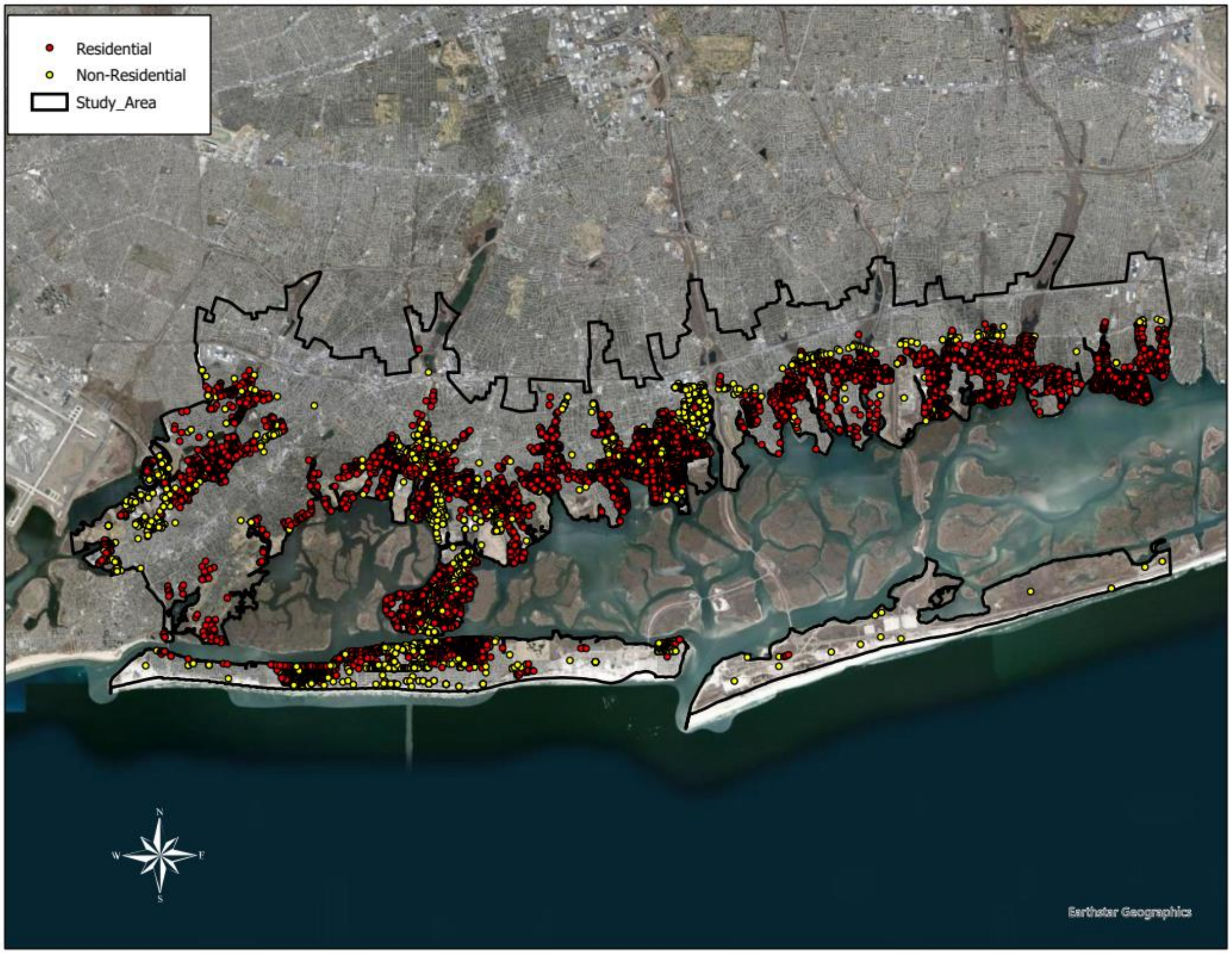

Figure 11 - Non-Structural Countywide Plan

3. Comprehensive Structural Highly Vulnerable Area (HVA) & NS Plan
    - Comprehensive Floodwall at the City of Long Beach
        - 46,400 linear feet of floodwall construction at elevation +16 feet NAVD88
        - Floodwall Type – Type B & Type C

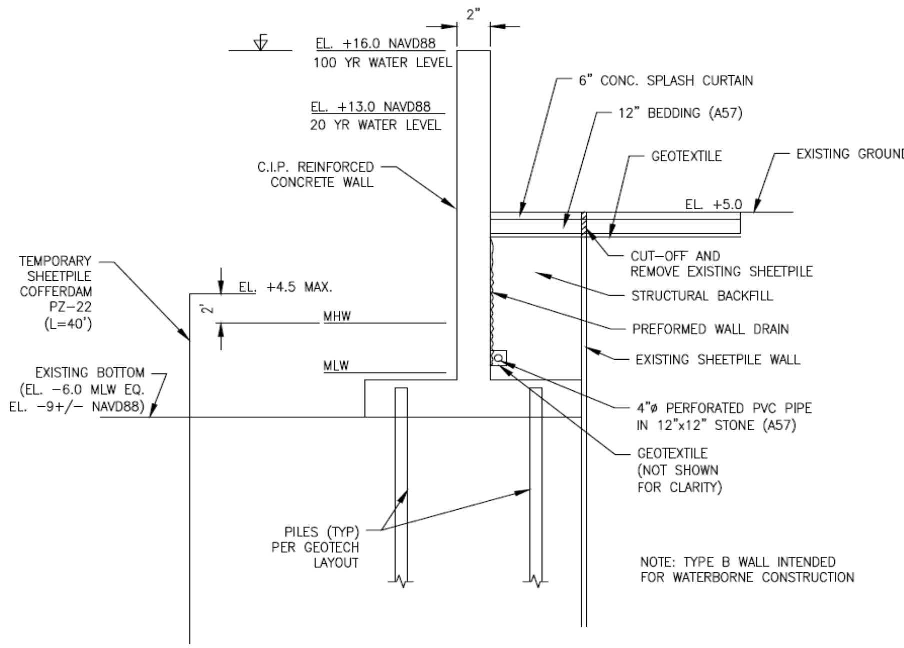

Figure 12 - Typical Section - Concrete Cantilever Wall on Piles - Type B

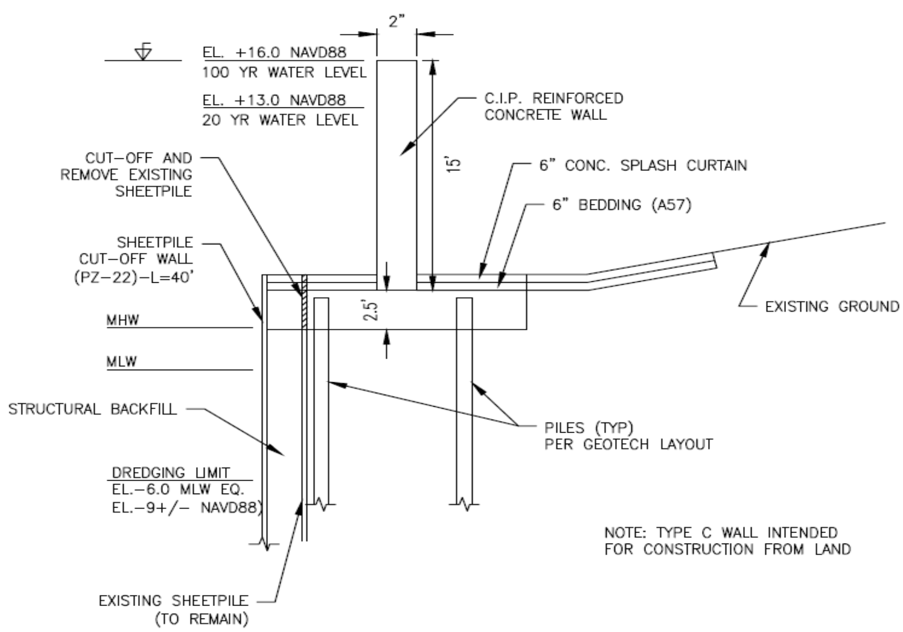

Figure 13 - Typical Section - Concrete Cantilever Wall on Piles - Type C

- 5 miter gates at elevation +16 feet NAVD88
- 4 road & 1 rail closure gate(s) at elevation +16 feet NAVD88

- Elevation of 12,251 residential structures to the modeled 1% AEP non-structural design water surface elevation (which includes intermediate sea level change projected to 2080).
- Dry flood proofing of 2,140 industrial/commercial structures from the ground surface up to 3 feet above ground.

4. Localized Structural Critical Infrastructure (CI) & NS Plan
    - Elevation of 14,159 residential structures to the modeled 1% AEP non-structural design water surface elevation (which includes intermediate sea level change projected to 2080).
    - Dry flood proofing of 2,427 industrial/commercial structures from the ground surface up to 3 feet above ground.
    - Protection of evacuation routes: Evacuation routes were evaluated as a critical facility within the "Other" category of the SWEAT-MSO guidance. Figure 14 shows the four (4) major evacuation routes within Nassau County. Portions of Evacuation Routes No.1 and No. 4 that were within the 1% AEP floodplain are presented for consideration for a localized floodwall.
    - Localized floodwall around critical infrastructure in the Village of Freeport.

Figure 14 - Nassau County Evacuation Routes

a. Far Rockaway
    - Localized floodwall around Evacuation Route No. 1 (Far Rockaway, NY) (Figure 15):
        - 7,000 linear feet of floodwall construction at elevation +16 feet NAVD88
        - Floodwall Type – Type C
        - 4 road closure & 1 sluice gate at elevation +16 feet NAVD88

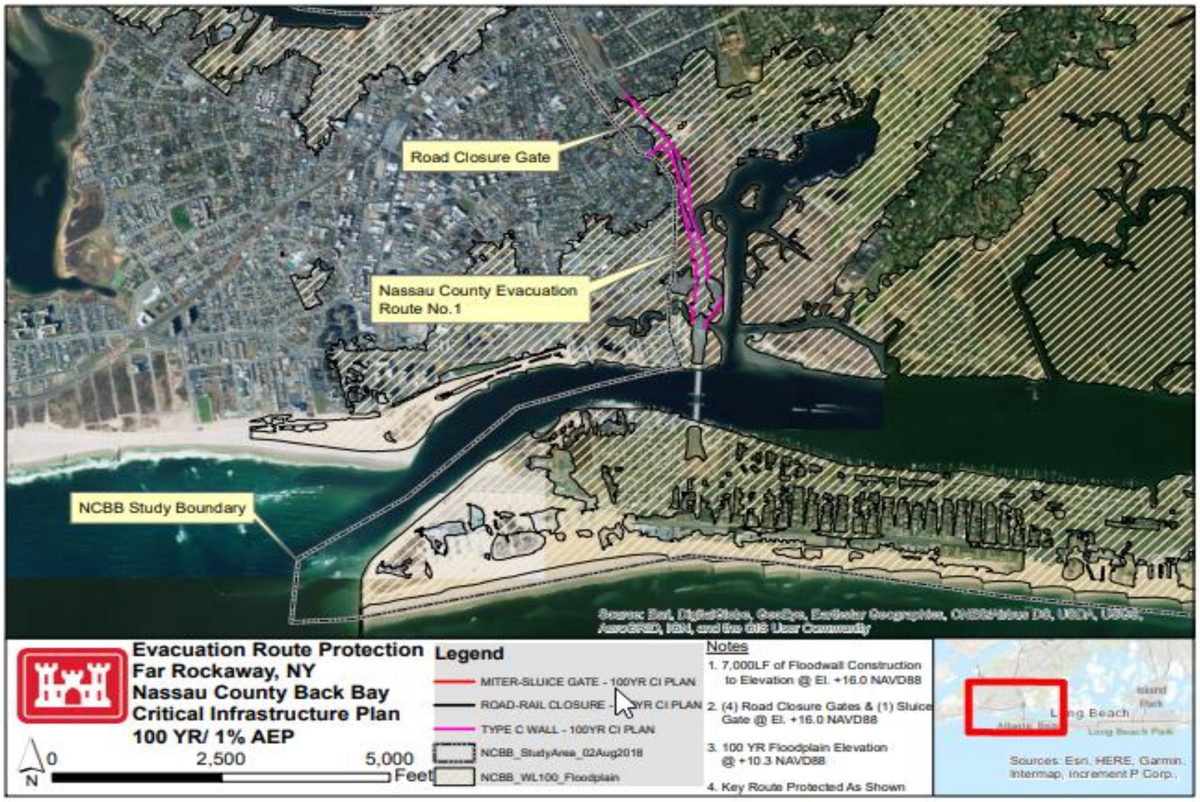

Figure 15 - Localized Floodwall for Evacuation Route No. 1

b. Village of Freeport
   - 12,250 linear feet of floodwall construction at elevation +16 feet NAVD88
   - Floodwall Type – Type B & Type C
   - 3 road closure gates at elevation +16 feet NAVD88

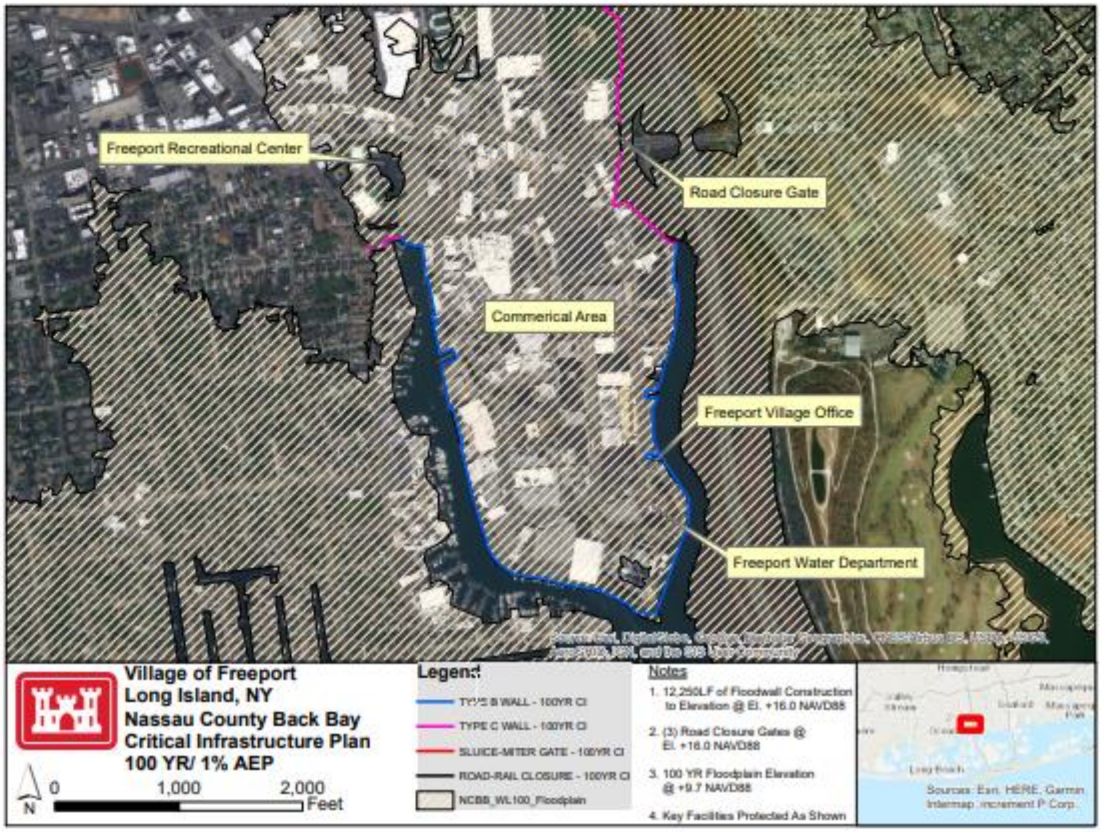

Figure 16 - Localized Floodwall for the Village of Freeport

c. Island Park

- Localized floodwall around critical infrastructure in Island Park & Vicinity
    - 6,950 linear feet of floodwall construction at elevation +16 feet NAVD88
    - Floodwall Type – Type C
    - 2 road closure gates at elevation +16 feet NAVD88
    - 2 sluice gates at elevation +16 feet NAVD88

Figure 17 - Localized Floodwall for Island Park & Vicinity

d. City of Long Beach
- Localized floodwall around critical infrastructure in the City of Long Beach
    - 10,280 linear feet of floodwall construction at elevation +16 feet NAVD88
    - Floodwall Type – Type C
    - 3 road & 1 rail closure gates at elevation +16 feet NAVD88

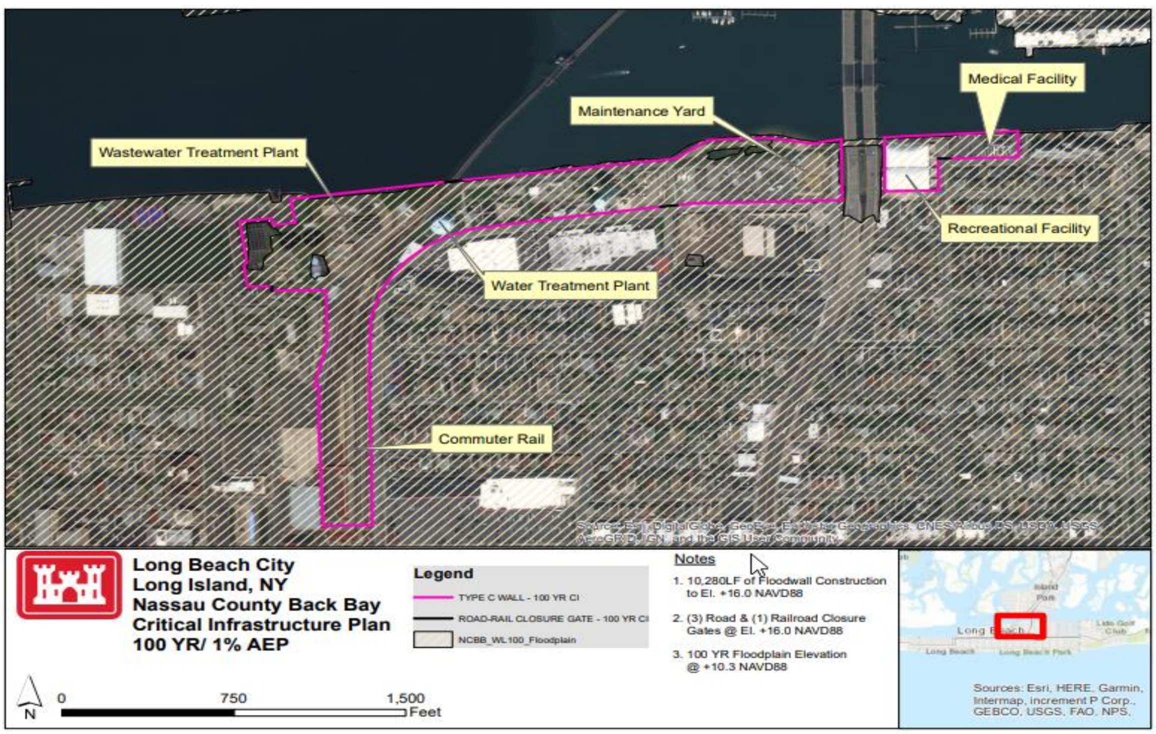

Figure 18 - Localized Floodwall in the City of Long Beach

The three localized floodwalls discussed above were formulated in the HVAs and preliminary cost/benefit analysis was conducted for them. However, the USACE did not limit localized floodwall for critical facilities just to HVAs. The team reached out to the Non-Federal Sponsor and coordinated a site visit to identify any additional areas that would meet the established criterion. From that visit, the Cedar Creek Wastewater Treatment Plant (WWTP) in Wantagh, NY was identified as another location.

e. Hamlet of Wantagh
   - Localized floodwall around Cedar Creek Wastewater Treatment Plant (Wantagh, NY)
     - 6,000 linear feet of floodwall construction at elevation +16 feet NAVD88
     - Floodwall Type – Type C
     - 1 road closure gate at elevation +16 feet NAVD88

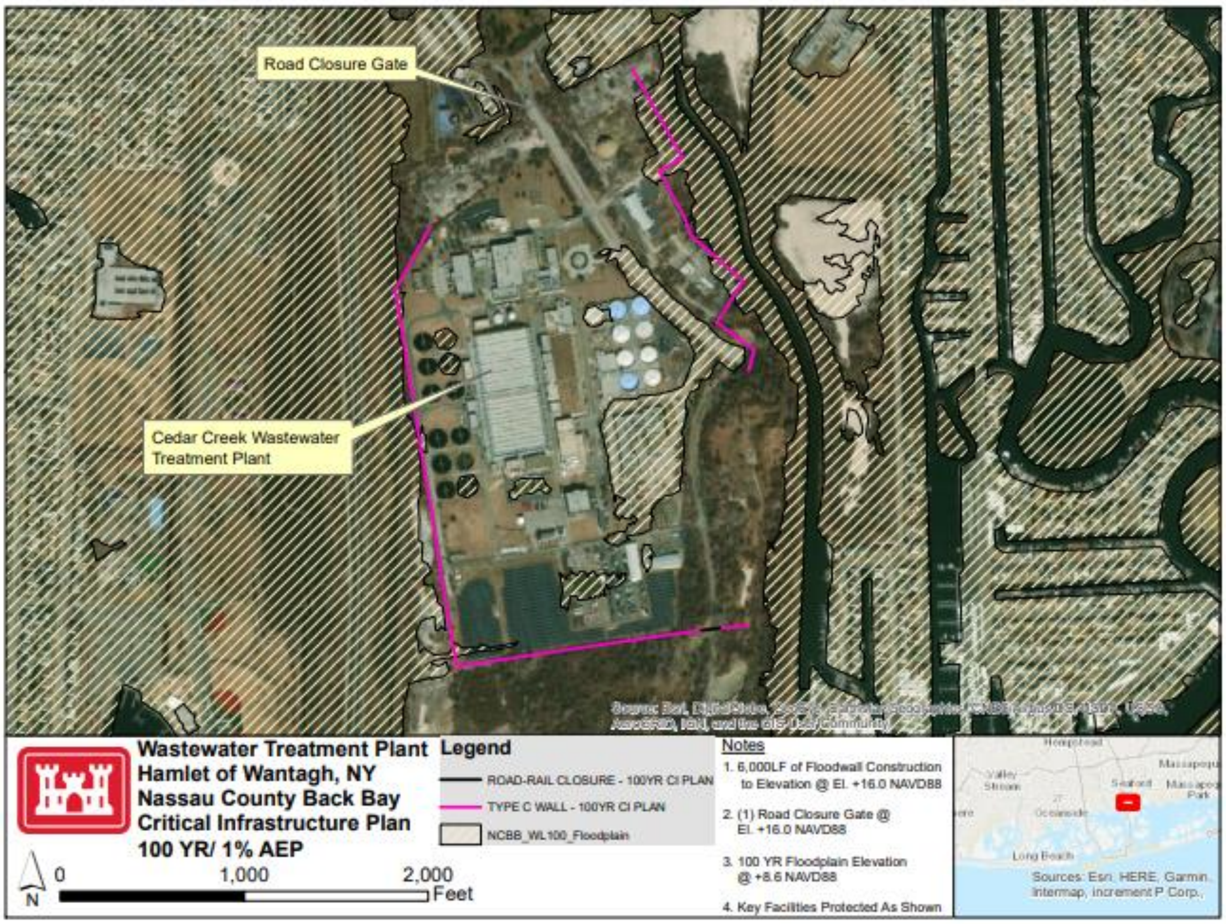

Figure 19 - Localized Floodwall for Cedar Creek Wastewater Treatment Plant

   - Localized floodwall around Evacuation Route No. 4 (Figure 20)
     - 800 linear feet of floodwall construction at elevation +16 feet NAVD88
     - Floodwall Type – Type C

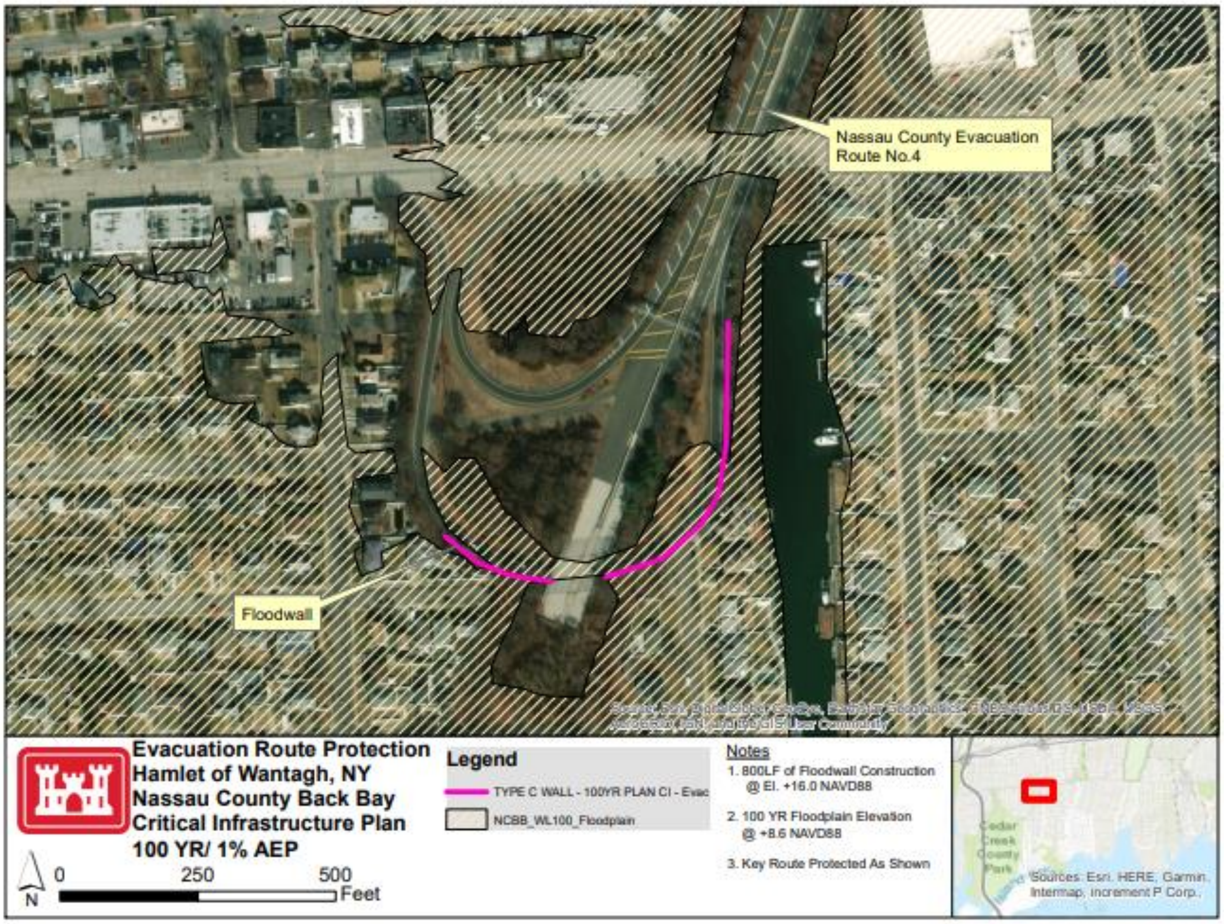

Figure 20 - Localized Floodwall for Evacuation Route No. 4

While the Cedar Creek WWTP localized floodwall and the Evacuation Routes 1 and 4 floodwalls have not gone through a cost/benefit analysis to date, their potential impacts are evaluated in this DIFR-EIS as they will be further analyzed as the study progresses.

It is important to note that per the criteria listed above and the USACE priority to manage risk to critical infrastructure without negatively impacting the functionality of the facility and the surrounding properties, localized floodwalls were only formulated for select large-scale critical infrastructure. In many locations that were highly developed, localized floodwalls were not formulated because the study team determined that the floodwalls would not only impact the functionality of the critical facility, but also impact other properties in terms of stormwater conveyance, property encroachment and viewshed impacts. For example, the Island Park Fire Department is located on a busy thoroughfare in a densely populated community. At this location it is not feasible to construct a large floodwall around the property as floodwall footprints would both encroach upon and increase stormwater runoff onto adjacent properties. Also, the function of a fire department is to quickly mobilize equipment and personnel to and from the firehouse. A wall around the perimeter would inhibit this mobility unless several closure gates were installed. This could be achieved but could potentially block driver viewshed when exiting the building which could impact traffic patterns. Therefore, USACE formulated non-structural measures at a facility such as this in order to maintain the current facility footprint.

Figure 21 - Island Park Fire Department

An example of a location that would meet the criteria developed for the screening is the Bay Park Wastewater Treatment Plan (WWTP). In this location a perimeter concrete floodwall and levee was constructed by the County after serious damage was sustained during Superstorm Sandy.

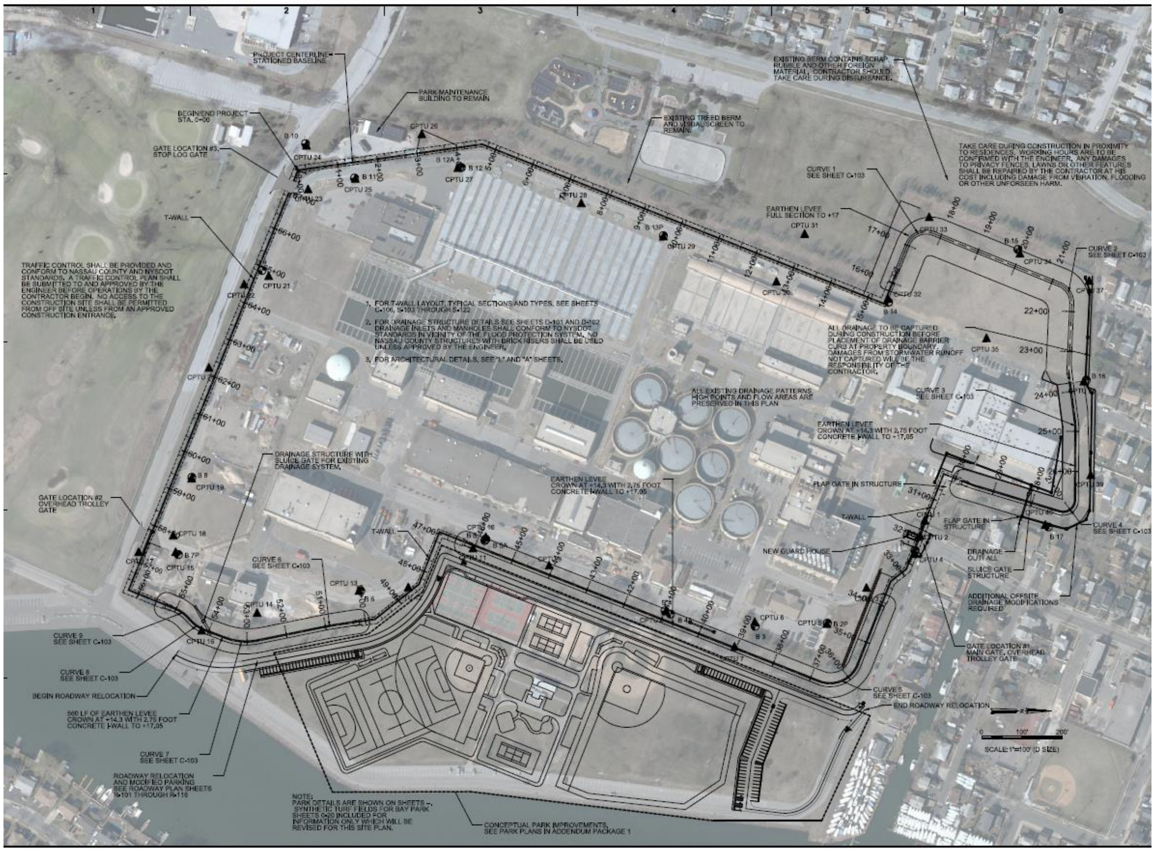

Figure 22 - Bay Park WWTP Protection Plan (Courtesy of Google Images)

The location of this facility is ideal for a localized floodwall due to its proximity to a large amount of open space, the number of structures within the facility (i.e. localized floodwall is more ideal for several component facilities rather than an individual facility) and proximity to the waterfront. The floodwall height at this location was designed for the 0.2% AEP (500-year storm). For this phase of the NCBB study, localized floodwalls were formulated to the 1% AEP design storm event (elevation +16.0 NAVD88), but formulation to the 0.2% AEP storm event could be optimized post-TSP if critical infrastructure plans are chosen. For this phase of the study, all critical infrastructure is assumed to remain in its current location and not to be relocated. Per E0-11988 the team must then ensure that if a facility must remain within the 1% AEP floodplain and is to be protected by a floodwall or levee then it must be designed to manage risk associated with the 0.2% AEP floodplain elevation. The 0.2% AEP storm event differs from the floodplain elevation, but this optimization could increase or decrease the localized floodwall heights.

5. Locally Preferred Plan – Not Applicable

Each alternative will potentially include NNBF measures as complementary features to be evaluated further during plan optimization.

The focused array of alternative plans is also consistent with the requirements of the policy directive issued by the Assistant Secretary of the Army for Civil Works (ASA – CW) on 05 January 2021. Specifically, this policy directive reiterated the USACE priority for “Comprehensive Documentation of Benefits in Decision Documents.” The directive stipulated that, at a minimum, the focused array of alternatives must include the following plans:

- The No Action Plan
- A plan that maximizes total benefits across all benefit categories
- A plan that maximizes net benefits consistent with the study purpose
- For flood-risk management studies, a non-structural plan, which includes modified floodplain management practices, elevation, relocation, buyout/acquisition, dry flood proofing and wet flood proofing
- A Locally Preferred Plan (LPP) if requested by the non-Federal sponsor

Specifically, the requirements to identify the No Action Plan and LPP (if applicable) have been addressed. In addition, the TSP meets both the requirement to identify the non-structural plan and the plan that maximizes net benefits consistent with the study purpose (NED Plan). Per the quantitative NED analysis and the qualitative RED, OSE and EQ analysis, the Localized Structural Critical Infrastructure (CI) & NS Plan maximizes total benefits across all benefit categories.

5.4 Focused Array of Alternatives Evaluation & Comparison

After the focused array of alternatives was formulated, the first task was to forecast the most likely with-project condition expected under each alternative plan. The criteria used to evaluate the alternative plans included: contributions to the Federal objective and the study planning objectives, compliance with environmental protection requirements, and the Principles & Guidelines' (P&G's) four evaluation criteria (completeness, effectiveness, efficiency and acceptability). The second task was to compare each with-project condition to the without-project condition and document the differences between the two. The third task was to characterize the beneficial and adverse effects of magnitude, location, timing and duration. The fourth task was to identify the plans that will be further considered in the planning process, based on a comparison of the adverse and beneficial effects and the evaluation criteria. The System of Accounts (National Economic Development, Environmental Quality, Regional Economic Development and Other Social Effects) was used to facilitate the evaluation and display of effects of alternative plans.

5.4.1 Alternative Comparison

National Economic Development (NED) – Contributions to the NED Account (increases in the net value of the national output of goods and services, expressed in monetary units) through the reduction in wave, erosion and inundation damages were measured with the following considerations: project cost, average annual cost (AAC), average annual benefits (AAB), average annual net benefits (AANB), benefit to cost ratio (BCR) and residual risk.

Table 2 - NED Alternative Comparison

Alternative	Initial Const.	AAC	AAB	AANB	BCR	Residual Risk
No Action Plan	N/A	N/A	N/A	N/A	N/A	N/A
NS Countywide Plan	$3,849,693,000	$135,733,000	$610,571,000	**$474,839,000**	4.5	40%
Comprehensive Structural HVA & NS Plan	$4,785,719,000	$180,345,000	$649,545,000	$469,200,000	3.6	36%
Localized Structural CI & NS Plan	$4,789,373,000	$176,411,000	$622,893,000	$446,481,000	3.5	38%
Locally Preferred Plan	N/A	N/A	N/A	N/A	N/A	N/A

Regional Economic Development (RED) – The RED account registers changes in the distribution of regional economic activity that result from each alternative plan. Two measures of the effects of the plan on regional economies are used in the account: regional income and regional employment.

Table 3 - RED Alternative Comparison

Alternative	Employment	Income
No Action Plan	While there is no project cost, the No Action Plan does not provide RED benefits and will allow for increasing coastal storm risk, thereby providing little or no employment benefits to the area.	While there is no project cost, the No Action Plan does not provide RED benefits and will allow for increasing coastal storm risk, thereby providing little or no employment benefits to the area.
NS Countywide Plan	Regionally, this plan could benefit the local economy by providing consistent CSRM benefits to residential and industrial/commercial structures. This plan may be less effective at minimizing economic disruption from storm-related impacts to large-scale CI (i.e. treatment plants and generating stations).	Regionally, this plan could benefit the local economy by providing consistent CSRM benefits to residential and industrial/commercial structures. This plan may be less effective at minimizing economic disruption from storm-related impacts to large-scale CI (i.e. treatment plants and generating stations).
Comprehensive Structural HVA & NS Plan	Regionally, this plan could benefit the local economy by providing consistent CSRM benefits to the area.	Regionally, this plan could benefit the local economy by providing consistent CSRM benefits to the area. The presence of comprehensive floodwalls in HVAs with large-scale CI

	The presence of comprehensive floodwalls in HVAs with large-scale CI will also minimize economic disruption by reducing storm-related impacts to large-scale CI (i.e. treatment plants and generating stations) and allowing communities to recover quicker from storms.	will also minimize economic disruption by reducing storm-related impacts to large-scale CI (i.e. treatment plants and generating stations) and allowing communities to recover quicker from storms.
Localized Structural CI & NS Plan	Regionally, this plan could benefit the local economy by providing consistent CSRM benefits to the area. In addition, this plan has a higher likelihood to reduce disruption to the local economy by reducing damage large-scale CI (at a lower cost than the Comprehensive HVA/NS Plan) and allowing communities to recover quicker from storms.	Regionally, this plan could benefit the local economy by providing consistent CSRM benefits to the areas. In addition, this plan has a higher likelihood to reduce disruption to the local economy by reducing damage to large-scale CI (at a lower cost than the Comprehensive HVA/NS Plan) and allowing communities to recover quicker from storms.
Locally Preferred Plan	N/A	N/A

Other Social Effects (OSE) – The OSE account is a means of displaying and integrating into water resource planning information on alternative plan effects from perspectives that are not reflected in the other three accounts. As discussed above, the feasibility study formulation focused on critical infrastructure and highly vulnerable areas. The highly vulnerable areas identified in the array of alternatives are very consistent with the Socially Vulnerable Areas that the Center for Disease Control (CDC) identified in Nassau County. Given that the CDC emphasizes the impacts of socioeconomic status, household composition/disability, race/ethnicity/language/minority status and housing/transportation on social vulnerability, the USACE believes the focused array of alternatives align with the intent of Executive Order 12989 (dated February 11, 1994). Specifically EO 12989 stipulates the importance of Environmental Justice, as defined by the USEPA: "the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies."

Table 4 - OSE Alternative Comparison

Alternative	Social Risk & Vulnerability	Community Cohesion	Quality of Life
No Action Plan	While there is no project cost, the No Action Plan does not provide OSE benefits and will allow for increasing coastal storm risk, thereby providing little or no social benefits to the area.	While there is no project cost, the No Action Plan does not provide OSE benefits and will allow for increasing coastal storm risk, thereby providing little or no community cohesion benefits to the area.	While there is no project cost, the No Action Plan does not provide OSE benefits and will allow for increasing coastal storm risk, thereby providing little or no quality of life benefits to the area.
NS Countywide Plan	While countywide non-structural measures would reduce damages to structure/content during low	While countywide non-structural measures would reduce damages to structure/content during low	Countywide non-structural measures would reduce damages to structure/content during

	and higher frequency events, there is risk that elevating structures might create a false sense of security during a storm event reducing compliance with evacuation orders. People sheltering in place will increase their personal risk and could also increase risk to emergency responders. Also, residual risk (approximately 40%) remains with this alternative in place. The residual risk varies throughout different regions of the study area.	and higher frequency events, residual risk to infrastructure and properties that don't qualify for elevation could reduce the robustness of coastal communities. Additionally, there might be community opposition to selective elevating of structures and the needed real estate easements.	low and higher frequency events.
Comprehensive Structural HVA & NS Plan	Potential for reduction in bayside views and access by floodwalls and levees. Real estate easements required to construct walls could be difficult to obtain. In addition, there is a high potential for increased with-project incremental life loss potential with overtopping or failure of the community-wide floodwall.	Potential for reduction in bayside views and access by floodwalls and levees. Real estate easements required to construct walls could be difficult to obtain. Also, portions of communities may be cut off from each other, especially on the western and eastern portions of the project where the floodwall cuts into neighborhoods and streets.	Floodwalls and levees would reduce inundation to communities during low and higher frequency events.
Localized Structural CI & NS Plan	While the risk still remains that elevating structures might create a false sense of security during a storm event, the localized floodwall measures will reduce damages to CI that will allow communities to be more resilient and recover quicker from storms. In addition, reducing damages to CI promotes a more socially equitable solution that benefits a wide range of citizens with varying socioeconomic conditions.	There might be community opposition to selective elevating of structures and the needed real estate easements; however, the added components of localized floodwalls will reduce damages to CI and allow communities to be more resilient and recover quicker from storms.	Non-structural measures would reduce damages to structure/content during low and higher frequency events and localized floodwall measures will reduce damages to CI that will allow communities to be more resilient and recover quicker from storms.
Locally Preferred Plan	N/A	N/A	N/A

Environmental Quality (EQ) – Beneficial effects in the EQ account are favorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources. Adverse effects in the EQ account are unfavorable changes in the ecological, aesthetic, and cultural attributes of natural and cultural resources.

Table 5 - EQ Alternative Comparison

Alternative	Physical Effects		Chemical Marine Effects		Biological Effects				
	Back Bay Circulation	Back Bay Sedimentation	Back Bay Water Quality	Air Quality	T&E Species	Fisheries/EFH	Aquatic Life	Wetlands/Aquatic Habitats	Terrestrial Habitats
No Action Plan	Sea level rise will continue but will not affect circulation	No change in sedimentation.	Climate change forecasts potential for increased temperature and precipitation - this could result in higher water temps that would deplete DO, increased run-off, which could increase nutrient levels in the estuaries.	No change in air quality.	Global climate change, sea level rise, and invasive species would continue to affect T&E species. Stressors include changes in distribution, prey distribution, habitat, etc.	Water quality, climate change, sea level rise, and invasive species will continue to be stressors on fisheries.	Water quality, climate change, sea level rise, and invasive species will continue to be stressors on aquatic life.	Climate change and sea level rise will result in conversion of intertidal and terrestrial habitat.	Climate change and sea level rise will result in conversion of terrestrial habitat to wetlands or aquatic habitat.
NS Countywide Plan	No effect on circulation. Sea level rise, as described under No Action would continue.	No change in sedimentation. On land construction will follow all erosion and sediment control requirements.	No impacts on water quality. Construction would comply with all applicable regulatory requirements. Changes as a result of climate change, as described under No Action/FWOP would continue.	Temporary adverse impacts from construction with unknown magnitude (minor, moderate, major). Construction would comply with all applicable regulatory requirements.	On land construction expected to occur within footprint of existing structures. Impacts on T&E species/habitat are expected to be minimal. Some potential for temporary negligible disturbance if present during construction. Impacts associated with climate change and sea level rise would continue, as described under No Action. Complementary NNBF measures would be incorporated to provide additional CSRM while improving ecosystem services. Structural measures may protect T&E species habitat (e.g. wetlands) from sea level rise.	No impacts. Construction would comply with all applicable regulatory requirements. Stressors as described under No Action would continue	No impacts. Construction would comply with all applicable regulatory requirements. Stressors as described under No Action would continue	No impacts. On land construction expected to occur within footprint. Impacts associated with climate change and sea level rise would continue, as described under No Action. Complementary NNBF measures would be incorporated to provide additional CSRM while improving ecosystem services Structural measures may protect intertidal and freshwater wetlands from the effects of sea level rise.	No impacts. On land construction expected to occur within footprint. Impacts associated with climate change and sea level rise would

									continue, as described under No Action.
Comprehensive Structural HVA & NS Plan	No net change on bay wide circulation. May be some negligible local impacts on circulation at bay surge barriers. Sea level rise, as described under No Action would continue.	Temporary minor changes in sedimentation during construction. Construction would comply with all applicable regulatory requirements. May be some localized scour or sedimentation at gate structures.	Temporary localized adverse impacts from construction associated with increases in turbidity from sediment disturbance. Magnitude is unknown magnitude (minor, moderate, major). Construction would comply with all applicable regulatory requirements. Changes as a result of climate change, as described under No Action would continue.	Temporary adverse impacts from construction (intensity – minor, moderate, major, unknown). Construction would comply with all applicable regulatory requirements.	Construction footprint uses existing footprint to the maximum extent possible. Marine habitat is primarily disturbed habitat. Impacts on T&E species/habitat are expected to be minimal. Some potential for temporary negligible impacts, if marine T&E species are present during construction. Impacts associated with climate change and sea level rise would continue, as described under No Action. Complementary NNBF measures would be incorporated to provide additional CSRM while improving ecosystem services. Structural measures may protect T&E species habitat (e.g. wetlands) from sea level rise.	Minimal temporary and long-term impacts on fisheries and EFH. Construction would comply with all applicable regulatory requirements. Stressors as described under No Action would continue	Minimal temporary impacts on aquatic life. Construction would comply with all applicable regulatory requirements. Stressors as described under No Action would continue	Minor temporary and long-term impacts on estuarine intertidal and subtidal wetlands and freshwater wetland. Construction footprint uses existing footprint to the maximum extent possible. Impacts associated with climate change and sea level rise would continue, as described under No Action. Complementary NNBF measures would be incorporated to provide additional CSRM while improving ecosystem services Structural measures may protect intertidal and freshwater wetlands from the effects of sea level rise.	Minor temporary and long-term impacts on terrestrial habitat. Construction footprint uses existing footprint to the maximum extent possible. Structural measures may protect habitat from effects of sea level rise.
Localized Structural CI & NS Plan	No effect on circulation. Sea level rise, as described under No Action would continue.	No change in sedimentation. On land construction will follow all erosion and sediment control requirements.	No impacts to water quality. Construction would comply with all applicable regulatory requirements. Changes as a result of climate change, as described under No Action would continue.	Temporary adverse impacts from construction (intensity – minor, moderate, major, unknown). Construction would comply with all applicable regulatory requirements.	On land construction expected to occur within footprint of existing structures. Impacts on T&E species/habitat are expected to be minimal. Some potential for temporary negligible disturbance if present during construction. Impacts associated with climate change and sea level rise would continue, as described under No Action. Complementary NNBF measures would be incorporated to provide additional CSRM while improving ecosystem services.	No impacts fisheries. Construction would comply with all applicable regulatory requirements. Stressors as described under No Action would continue.	No impacts. Construction would comply with all applicable regulatory requirements. Stressors as described under No Action would continue.	No impacts. On land construction expected to occur within footprint. Impacts associated with climate change and sea level rise would continue, as described under No Action. Complementary NNBF measures would be incorporated to provide additional CSRM while improving ecosystem services.	No impacts. On land construction expected to occur within footprint. Impacts associated with climate change and sea level rise would continue, as described under No Action.

Locally Preferred Plan	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

As indicated on the EQ comparison table, the NS Countywide Plan has little or no mitigation required, while the Localized Structural CI & NS Plan and Comprehensive Structural HVA & NS Plan will likely require mitigation related to the floodwall construction. That being said, the USACE qualitatively determined that the mitigation required for Localized Structural CI & NS Plan would be potentially offset by the plan's potential to minimize damage and associated environmental impacts related to critical infrastructure damage. For example, during Hurricane Sandy, the Bay Park Sewage Treatment Plant (Nassau County) was damaged resulting in the following:

- Pumping system was flooded under 9 feet of water
- Sewage backed up and overflowed into low-lying homes and streets
- Plant shut down ~2 days (44 hours) ~100 million gallons of raw sewage poured into Hewlett Bay
- Additional 2.2 billion gallons of partially treated sewage flowed into Rockaway Channel (from October 29th to December 21st)
- Electrical system was destroyed
- $730 million to help rebuild the Bay Park Sewage Treatment Plant

5.4.2 Alternative Evaluation

After alternatives were compared using the NED, RED, EQ and OSE system of accounts criteria, the remaining alternatives were evaluated against the four planning criteria. Table 6 provides analysis and screening of the focused array of alternatives against the four planning criteria (effectiveness, efficiency, acceptability and completeness):

- Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities
- Efficiency is the extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment
- Acceptability is the workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with existing laws, regulations, and public policies.
- Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.

Table 6 - Planning Criteria Alternative Evaluation

NCBB Alternative Evaluation	Planning Criteria			
	Effectiveness	**Efficiency**	**Acceptability**	**Completeness**
No Action Plan	This does not meet the effectiveness criteria because the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the study area.	This does not meet the efficiency criteria. While there is no project cost, the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the study area.	This does not meet the acceptability criteria as State and local entities are generally supportive of improved CSRM.	This does not meet the completeness criteria because the No Action Plan does not provide CSRM benefits and will allow for increasing erosional impacts and coastal storm risk to the study area.
NS Countywide Plan	Medium - will reduce damages to buildings (i.e. structure and content). At this point in the analysis, this plan includes dry flood proofing measures to reduce damage to CI; however, that may not be effective for large-scale CI (treatment plants, generating stations, etc.).	High (BCR>1) – Plan currently has highest AANB.	High – Since Hurricane Sandy hit this area, extensive non-structural (predominantly elevation) efforts have been undertaken in Nassau County; therefore, it appears that is a highly acceptable CSRM approach in this area.	Medium – Complements ongoing NS and CI risk management in the study area.
Comprehensive Structural HVA & NS Plan	Medium – will reduce damages to highly vulnerable areas; however, floodwalls are not adaptable to RSLC and potentially increase life loss consequences in the case of a structure failure.	Medium (BCR>1)	Low - there is risk that the project may not be implementable due to environmental laws. This risk is based on the very high uncertainty whether the high direct impacts of a floodwall would be acceptable to resource agencies.	Low – NS portion compliments ongoing NS and CI risk management in the study area; however, comprehensive floodwalls may be duplicative considering ongoing efforts to manage risk to CI in communities.
Localized Structural CI & NS Plan	High - will reduce damages to buildings (i.e. structure and content) and also provide more effective risk management to large-scale CI (treatment plants, generating stations, etc.) that allow communities to recover quicker from storms.	Medium (BCR>1) – The efficiency of this plan will likely increase as the analysis continues and secondary NED benefits (such as the number of customers served by different CI) are factored into the net benefit and BCR calculations.	High – since Hurricane Sandy struck this area, extensive non-structural (predominantly elevation) and CI risk management efforts have been undertaken in Nassau County; therefore, it appears that is a highly acceptable CSRM approach in this area.	Medium – Complements ongoing NS and CI risk management in the study area.
Locally Preferred Plan	N/A	N/A	N/A	N/A

5.5 Plan Selection

The TSP is the Non-Structural (NS) Countywide Plan. The TSP does not include the CI and NNBF measures but they are measures that will continue to be evaluated.

5.5.1 Description of the TSP

The NS Countywide Plan includes the following:

- Elevation of 14,183 residential structures to the modeled 1% AEP non-structural design water surface elevation (which includes intermediate sea level change projected to 2080).
- Dry flood proofing of 2,667 industrial/commercial (non-residential) structures from the ground surface up to 3 feet above ground.

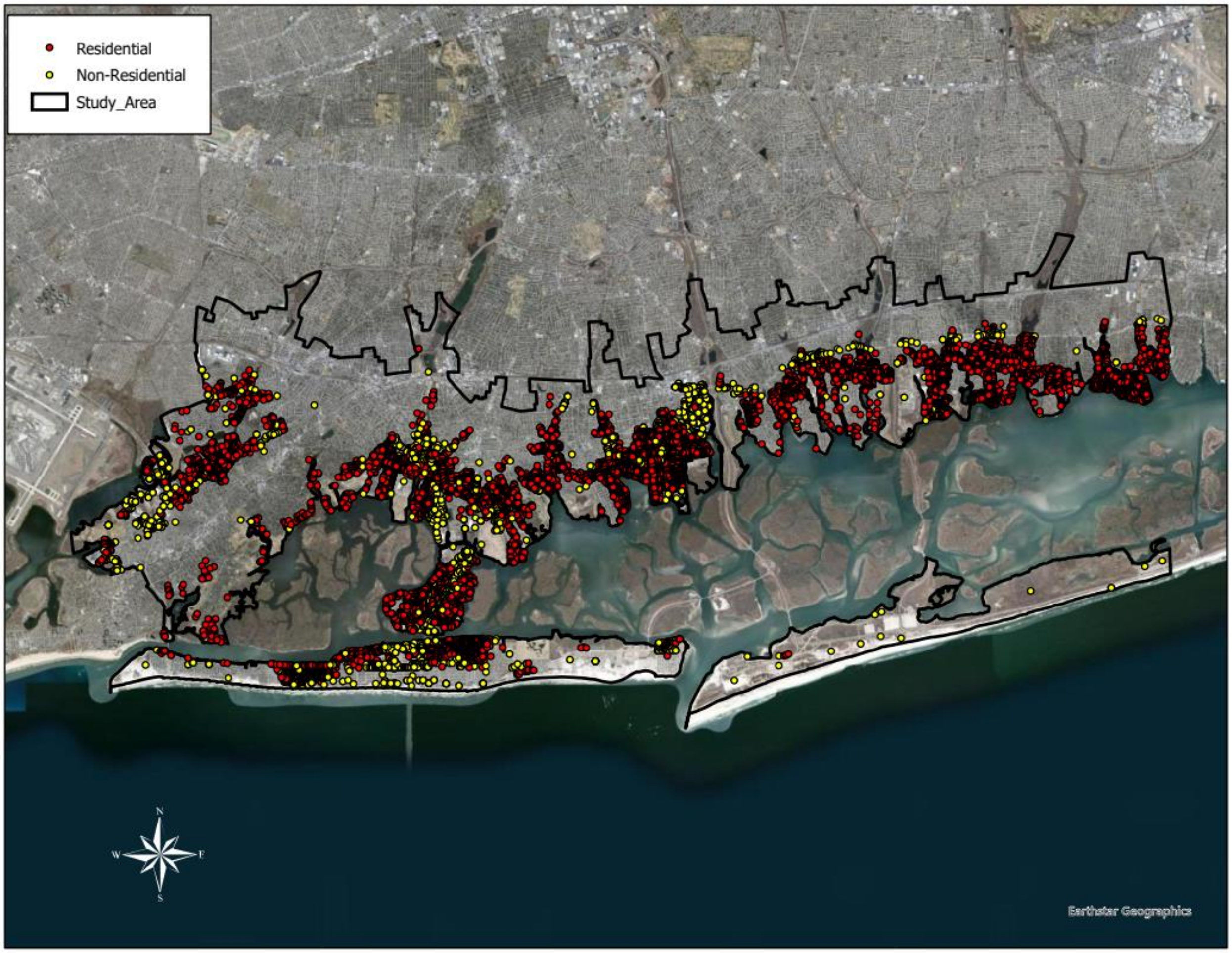

Figure 23 - TSP Location

5.5.1.1 TSP Components

At this stage of the analysis, at-risk structures identified in the TSP were selected based on their potential to incur damages from the 5% AEP (predicted to occur at the end of the 50-year period of analysis – 2080). For the at-risk residential structures, structure elevation was formulated to the modeled 1% AEP non-structural design water surface elevation, which includes intermediate sea level change projected to 2080. If elevation requirements are greater than 12 feet above ground level, structure acquisition/relocation would likely be considered instead because such a height introduces additional structure risk factors (i.e.

hydrodynamic forces and wind). However, the combined 2080 non-structural design water surface elevation at 1% AEP with the intermediate RSLC projection is not anticipated to be greater than 12 feet above ground level; therefore, it is highly likely that acquisition/relocation of residential structures will not need to be considered based on those constraints, but acquisition/relocation is still being considered based on repetitive losses, value and vulnerability. Based on the variability of structure type and condition in the study area, the USACE identified three potential methodologies for residential structure elevation: Elevation with Piles, Elevation with Posts/Columns and Elevation with Extended Foundations.

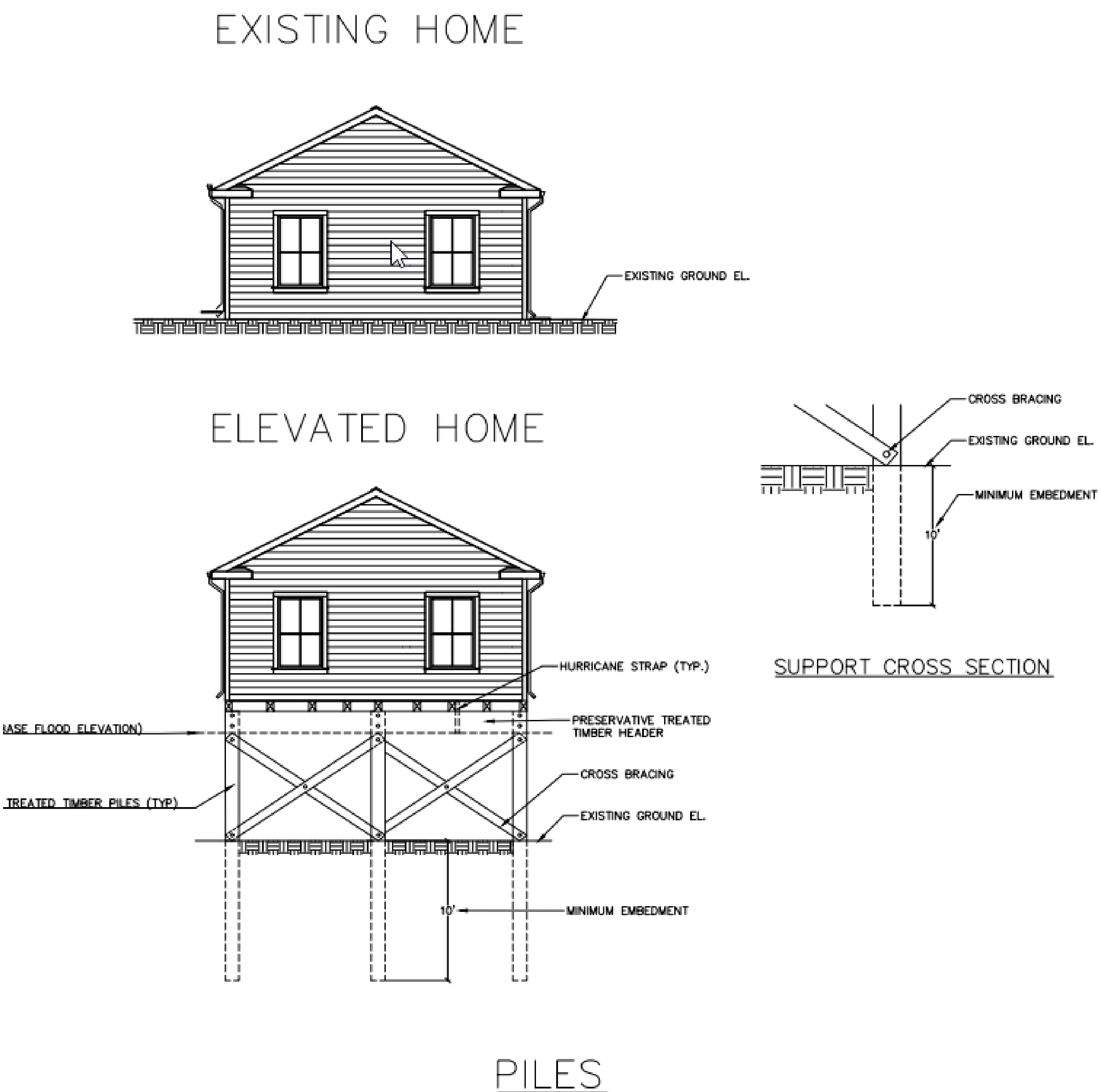

Figure 24 - Residential Elevation Concept with Piles

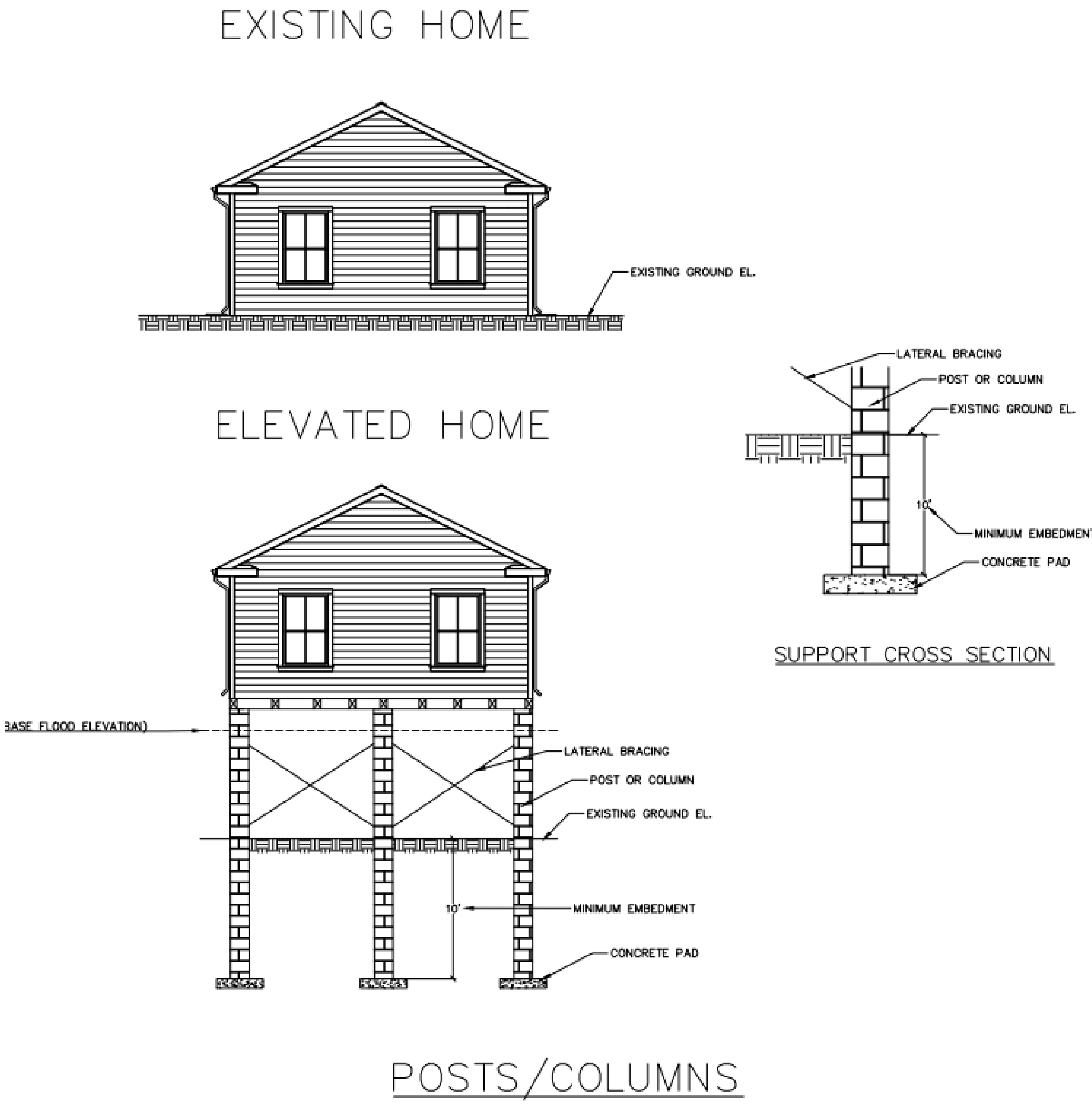

Figure 25 - Residential Elevation Concept with Posts/Columns

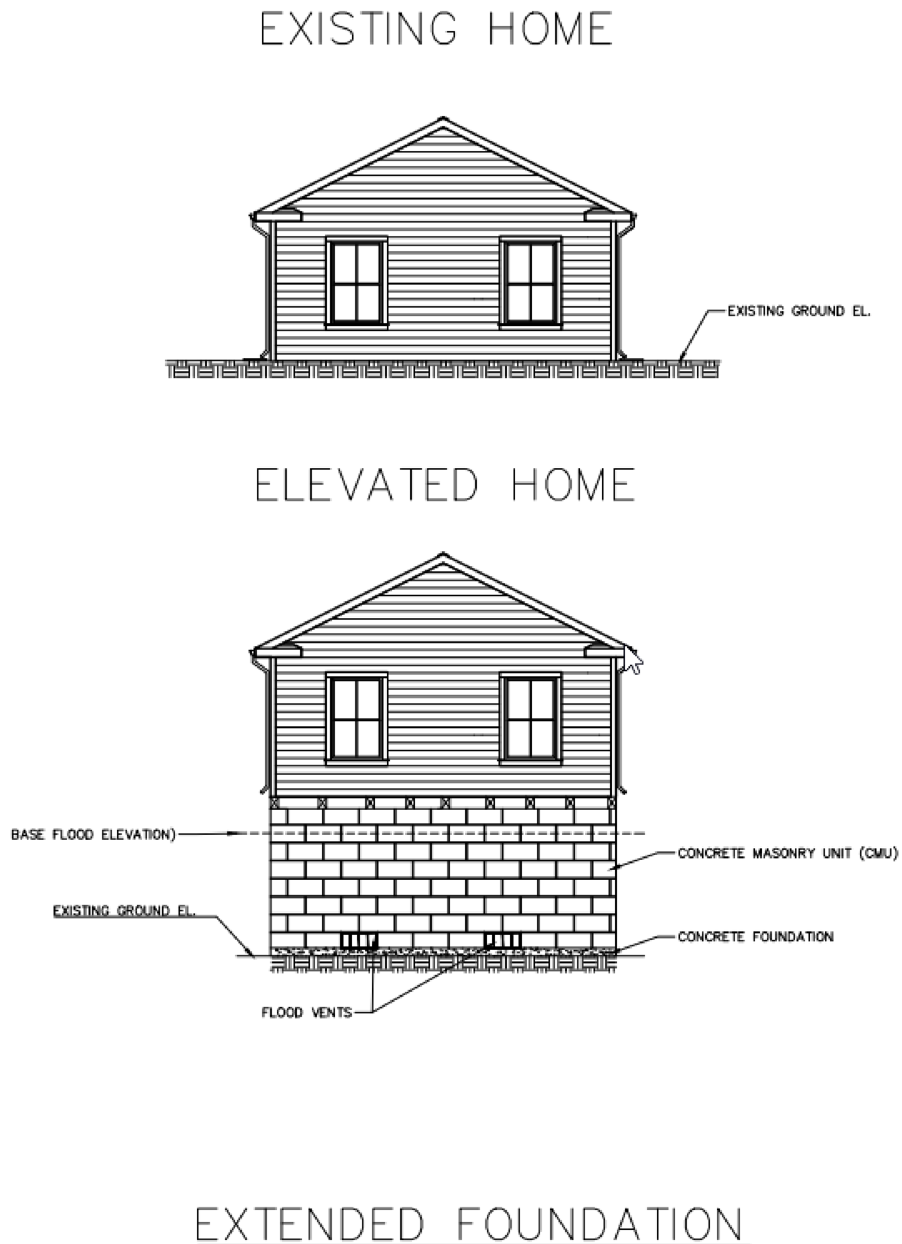

Figure 26 - Residential Elevation Concept with Extended Foundation

For at-risk industrial/commercial facilities, dry flood proofing generally consists of sealing all areas from the ground level up to approximately 3 feet of a structure. Such dry flood proofing measures will help make walls, doors, windows and other openings resistant to penetration by storm surge waters. Water and sewer back-flow prevention mechanisms (such as drain plugs, standpipes, grinder pumps and back-up valves) are also included in dry flood proofing. Openings, such as doors, windows, sewer lines and vents, may also be closed temporarily, with sandbags or removable closures.

Figure 27 - Dry Flood Proofing Rendering @ Island Park Fire Department

Recognizing that the initial non-structural formulation will inherently have residual risk, none of the other non-structural measures have been screened out at this point because they will be further analyzed during feasibility-level design to ensure a complete plan is formulated.

5.5.1.2 TSP Resiliency & Sustainability/Adaptability

As economic modeling results indicate, the study area is sensitive to RSLC. According to current USACE guidance (ER 1110-2-8162) relative sea level change has an equal probability of occurring at any rate between the Low (Historic) and High SLC rates. Per ER 1110-2-8162, the USACE compared all alternatives against each of the three USACE SLC curves to investigate the resiliency of proposed alternatives in terms of project performance and possible decision-timing strategies. As discussed in the Economics Appendix (Appendix F), decision-timing strategies are different approaches in managing sea level change risk over the period of analysis (or over the planning horizon). Decision-timing strategies include: Anticipatory (i.e. Precautionary), Managed Adaptive, and Reactive.

If the Anticipatory Strategy was applied to the TSP, all eligible structures (using the Year 2080 5% AEP stage height with SLC) would be retrofitted prior to the Base Year (2030). Figure 28 shows the structure retrofits (elevation and floodproofing) per SLC scenario.

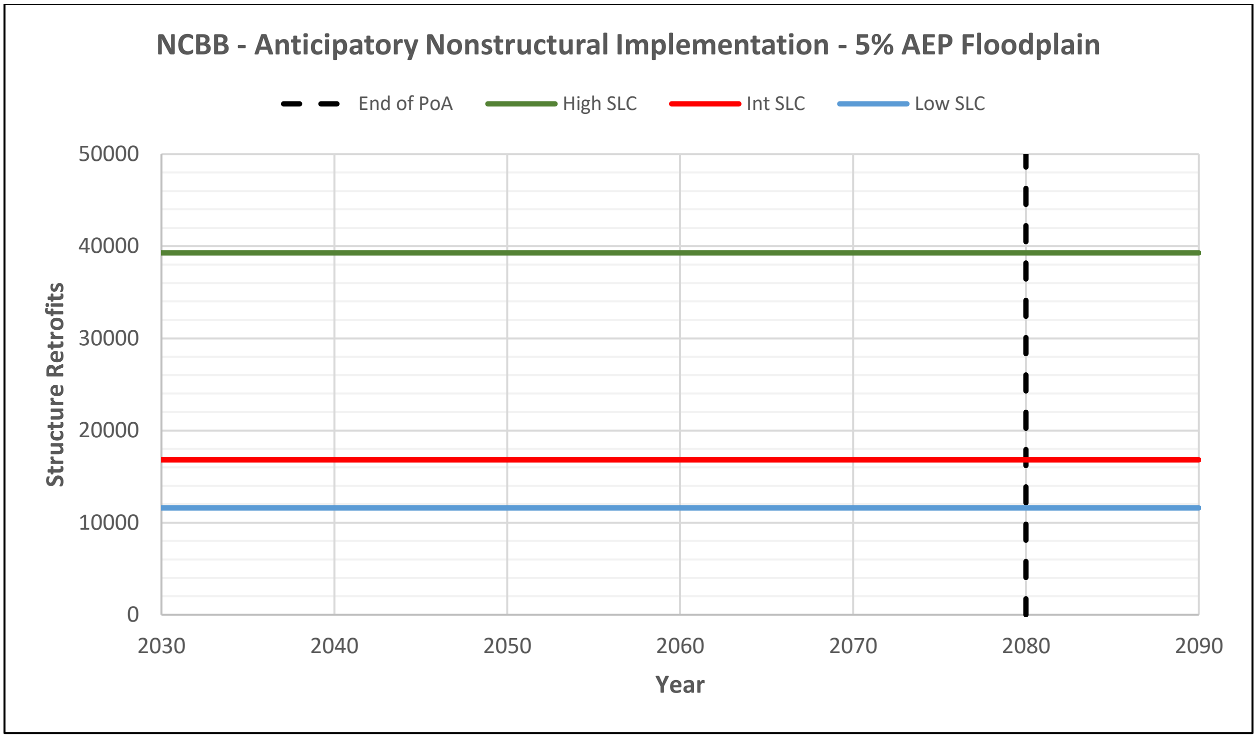

Figure 28 - TSP Anticipatory Strategy Retrofits

The main disadvantage of an Anticipatory approach is the potential to either unnecessarily overspend on project implementation (if SLC is less than expected) or the potential to leave significant residual risk in the study area (if SLC is higher than expected).

The Managed Adaptive Strategy would include periodically returning to the study area and retrofitting structures that are now vulnerable to coastal storm hazards based on the experienced SLC curve. This strategy requires active management over the 50-year period of analysis, but offers numerous advantages in terms of cost efficiency and improving plan resiliency. With a Managed Adaptive approach, plan formulation no longer needs to predict SLC rates and then attempt to fit nonstructural implementation to an uncertain curve. Rather, implementation of nonstructural retrofits can be accomplished incrementally to optimize measure resiliency.

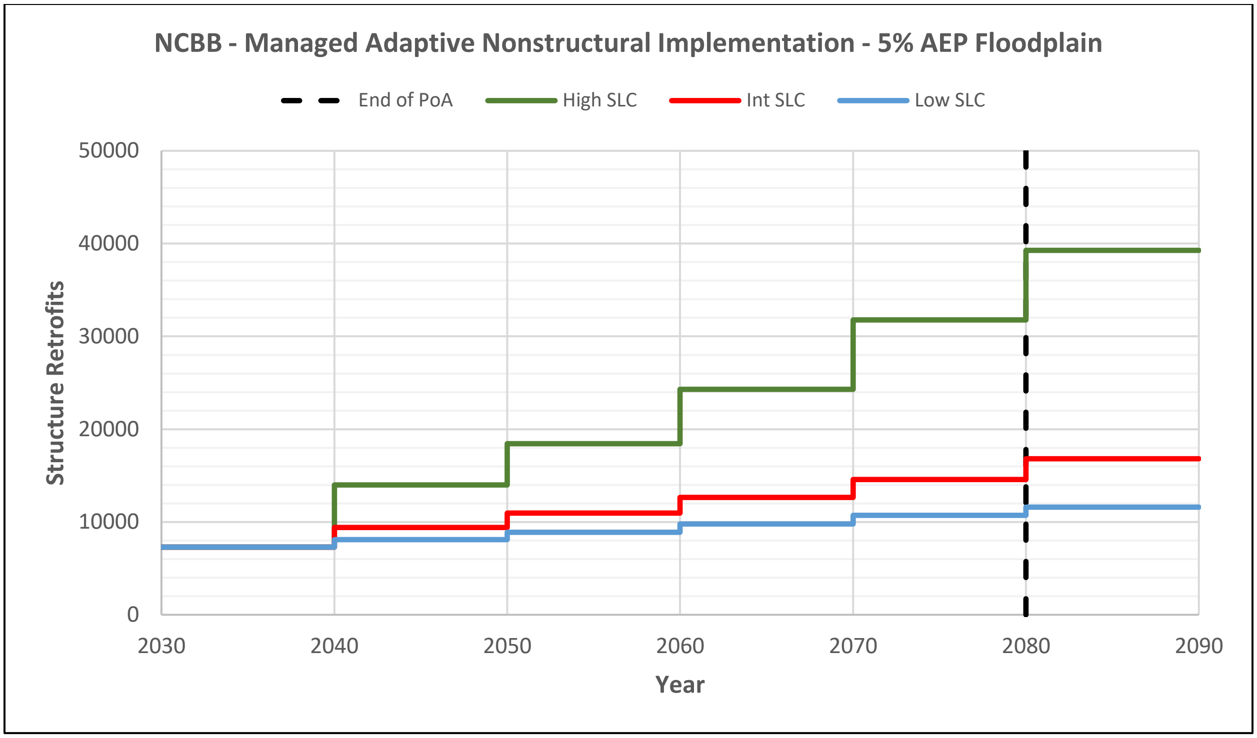

Figure 29 - TSP Managed Adaptive Strategy Retrofits

A Reactive strategy for the TSP is also possible, but not recommended for this study area. The approach would include elevating or floodproofing the 7,300 vulnerable structures by the Base Year (2030) without including any plans or procedures for re-evaluating coastal storm risk over the period of analysis. While this approach is the least expensive, the risk of significant residual damages is very high and the proposed measure is neither resilient nor robust for addressing SLC. As nonstructural is inherently adaptable to SLC due to the flexibility in assigning eligibility, there are few benefits to a nonstructural Reactive strategy for this study area.

5.5.1.3 TSP Risk Analysis

5.5.1.3.1 TSP Residual Risk

Residual risk is the coastal storm risk that remains in the floodplain even after a proposed coastal storm risk management project is constructed and implemented. Physical damages, as well as potential life loss consequences, can remain even after the project is implemented due to a variety of causes. For the TSP, residual risk across the study area is approximately 40% with varying levels throughout different regions of the study area. In the four HVAs, residual risk ranges from ~20% in the Village of Freeport to ~46% in the City of Long Beach, while it is approximately 48% throughout the remainder of County located outside of the HVAs.

The next phase of the study will investigate the necessity for a comprehensive life safety risk assessment based on the proposed measures of the TSP. The comprehensive life safety risk assessment would investigate estimated statistical life loss in the FWOP and the effectiveness of the various alternatives in reducing this life loss. efficiency and effectiveness of measures that contribute towards meeting the objectives.

5.5.1.3.2 TSP Risk & Uncertainty

Future Without Project Conditions Assumptions

For the FWOP conditions and the TSP (future with project) conditions, the structure inventory and assigned values are considered static throughout the 50-year period of analysis. Though this approach may ignore future condemnations of repeatedly damaged structures or, conversely, increases in the number or value of structures in the inventory due to future development, the variability and limitations of projecting future inventory changes over 50 years across such a wide study area are too significant to assign any reasonable level of certainty to the predicted inventory alterations. FWOP damages are used as the base condition and the potential project alternatives (including the TSP) are measured against this base to evaluate the project effectiveness and cost efficiency.

The FWOP modeling results are based on estimated structure damages, content damages, and vehicle damages. Additional benefit categories such as emergency costs foregone or indirect (non-physical) damages are not currently quantified in HEC-FDA.

Non-Structural Formulation Assumptions

For the non-structural TSP, it is important to note that non-structural implementation is applied on a house-by-house basis; thus, a true building retrofit (elevation and flood proofing) cost would also be developed for each structure individually based on their characteristics such as foundation type, wall type, size, condition, and available workspace. Individually surveying each structure to capture this data, however, is prohibitively time and resource intensive. In compliance with Planning Bulletin 2019-03 *Further Clarification of Existing Policy for USACE Participation in Nonstructural FRM and CSRM Measures*, "nonstructural analyses will formulate and then evaluate measures and plans using a logical aggregation method."

FFE is the addition of ground elevation and foundation height to measure the absolute elevation of the main floor of the structure. In addition to FFE, each structure occupancy type is assigned a begin-damage point to account for vulnerable entry points above (or below) the FFE. The economic model (HEC-FDA) begins to assign damage to structures when flood stage heights reach the first floor +/- the begin-damage point value. While the ground elevation is derived with a high degree of certainty via NOAA Digital Coast Bare Earth Light Detection and Ranging (LiDAR)-derived DEM, the foundation height is more difficult to measure and attribute for each individual structure. Techniques such as field surveys or mobile LiDAR can theoretically calculate foundation height for every structure with a high degree of certainty; however, the size of the study area and associated structure inventory makes these methods prohibitively time and resource consuming. Therefore, to calculate the FFE for structures within the model inventory, a stratified random sample was collected of structures within each occupancy type to assign a typical foundation height per structure type. The average foundation height for a given occupancy type was then added to the structure's unique ground elevation to calculate final FFE.

While this method of assigning average foundation height by occupancy type, and then selecting a certain volume of residential structures as "elevated," provides reasonable accuracy for estimating FFE across a large population, it does not allow for knowing the true FFE for each individual structure within the inventory; only the assigned FFE for a typical structure of a given occupancy type at that location. This has some impact on later plan formulation and evaluation, particularly for non-structural measures.

Cost Estimating Assumptions

Due to the size of the study area, elevation and flood proofing costs were developed for a “typical” structure in each of the HVAs and rest of county locations. Both a “typical” residential structure and “typical” non-residential structure were identified for each location using a stratified random sample. A per unit cost was then developed based on the dimensions and characteristics of those “typical” structures. More information on nonstructural cost estimation can be found in the Plan Formulation Appendix (Appendix A), Cost Engineering Appendix (Appendix D) and Economics Appendix (Appendix F).

For aggregated cost summaries, current analysis assumes a 100% participation rate in the nonstructural alternative. In compliance with National Nonstructural Committee (NNC) Best Practice Guide (BPG) 2020-02 *Considerations for Estimating Participation Rates in Voluntary Nonstructural Measures*, further analysis will be conducted to estimate the participation rate of the study area.

Identifying structures eligible for elevation and flood proofing focused on isolating structures with the highest coastal storm damage risk levels. Residential and non-residential structures with high vulnerability to coastal storm damage, whether due to geographic conditions or first floor elevation, are considered prime candidates for such building retrofits.

Application of ER 1100-2-8162

Non-structural analysis was focused on at-risk structures within the 5% AEP event floodplain. As this floodplain threshold is dependent upon the SLC rate, non-structural alternatives were formulated for Low (Historic), Intermediate, and High SLC scenarios in accordance with ER 1100-2-8162 *Incorporating Sea Level Change in Civil Works Programs*. As the eligibility threshold stage for each SLC scenario is different, the number of structures (both residential and non-residential) eligible under each SLC scenario is also different. Additionally, the 5% AEP event stage changes over the 50-year period of analysis depending on the modeled SLC curve scenario.

The current non-structural economic analysis outlines a precautionary approach to SLC risk management. Using the Year 2080 5% AEP event stage (for each USACE SLC curve), vulnerable structures are identified and elevated/flood proofed by the base year. All non-structural costs are incurred by the base year and benefits start accruing in the base year for all retrofitted structures (depending on their relative vulnerability over the period of analysis).

Critical Infrastructure Formulation Assumptions

Additionally, critical infrastructure assets are eligible based on their vulnerability to the 1% AEP flood event by the Year 2080. Non-structural measures are applicable for the majority of critical infrastructure assets such as hospitals, police stations, and medical offices. For large-scale infrastructure facilities such as wastewater treatment plants and electric power plants, it is uncertain whether non-structural measures alone are effective in mitigating coastal storm risk. At this stage of the analysis, non-structural measures are not applied to those facility types in the future with-project condition. The analysis to confirm whether non-structural measures are effective for large-scale critical infrastructure will occur prior to release of the final Integrated Feasibility Report/EIS.

For this study, critical infrastructure is divided into three broad categories:

- traditional building types (e.g. medical offices, hospitals),
- large scale infrastructure that resembles an entire industrial complex (e.g. wastewater treatment plants, natural gas power station),

- infrastructure that does not resemble buildings in any way (e.g. evacuation routes, ports, utility lines).

At this point in the study, only the direct (physical) damages for the first traditional and large-scale infrastructure types are quantified within HEC-FDA and currently contribute to NED damage estimates. None of the three critical infrastructure types are currently quantified for indirect (non-physical) coastal storm damages. In addition to physical and non-physical NED damages, critical infrastructure disruptions may also cause severe RED, OSE and EQ impacts due to regional business impacts and catastrophic health & safety and environmental concerns. RED, OSE and EQ impacts are currently handled qualitatively for all three infrastructure types.

Real Estate Costs

At this point in the analysis, LERRD costs are not included in the total project cost for the non-structural TSP. The study team assumed a 100% participation rate for project implementation; thus, acquisition costs were assumed to be negligible. In the event that additional study analysis indicates that a structure identified for elevation would likely be a candidate for acquisition instead, the study team believes acquisition costs would be lower than elevation costs in such cases. As the study continues, further analysis of the participation rate will be conducted to reduce data uncertainty. In addition where necessary, costs for acquisition will be evaluated in greater detail. From an engineering standpoint, a sampling of structures in the study area will be evaluated to support the refinement of LERRD costs. Specifically, FFEs will be further evaluated to verify a structure's eligibility for elevation and structure conditions will be analyzed to confirm the applicability of elevation to those structures. That being said, the study team recognizes that the current LERRD cost underestimates the potential for relocation assistance costs associated with elevation of residential properties occupied by renters. Therefore, a sensitivity analysis was conducted to account for this risk and associated uncertainty. Based on typical relocation costs applied on similar feasibility efforts, the study team assumed a $20,000/per structure relocation assistance cost for each residential structure in the TSP. This approach is considered conservative as the temporary rehousing cost would actually only apply to rental properties; however, the current structure inventory does not yet distinguish between rental and non-rental properties. This conservative sensitivity analysis indicated that the current TSP remains the plan with the highest AANB even with the added relocation assistance cost.

The real estate impact costs (Land, Easements, Rights-Of-Way, Relocation, and Disposal Areas – LERRD) for the floodwall measures were estimated as a percentage of construction costs. The percentages used for the NCBB study followed the methodology utilized to develop a floodwall cost per linear foot in the NJBB study. Specifically, a portion of the proposed NJBB floodwall(s) in Long Beach Island (LBI), New Jersey was selected as the sample to develop an approximate LERRD cost per linear foot of floodwall. For this sample set, the USACE estimated that there were 1,126 structures located behind the proposed floodwall in the LBI sample section. Rough order of magnitude LERRD costs ($93,002,000) were developed for 140 representative residential structures in the inventory of structures behind the wall. The stretch of floodwall in the sample section was approximately 100,658 feet long.

The unit cost of a representative structure or parcel can be determined by dividing the LERRD sample cost by the number of structures. Using the below equation, the LERRD unit cost for a representative structure located within the study area is $664,300.

Calculation: $93,002,000 / 140 structures = $664,300 per structure (LERRD Unit Cost)

Based on the projected 1,126 structures behind the floodwall, the total LERRD cost for the floodwall was estimated at $748,001,800, per the calculation below:

Calculation: 1126 structures * $664,300/structure = $748,001,800

Assuming the aforementioned floodwall length of 100,658 feet, the LERRD cost per linear foot of floodwall was calculated by dividing the total LERRD cost by the total length of floodwall, per the calculation below:

Calculation: $748,001,800 / 100,658-feet = $7431.12 / foot (Linear foot cost)

For non-structural measures, the USACE assumed a 100% participation rate and no LERRD costs as this point in the analysis. However, moving forward the USACE will further analyze the number of renters and owners in the study area to determine the applicability of adding relocation costs to the LERRD calculation.