Urban Coastal Resilience: Valuing Nature's Role

CASE STUDY: HOWARD BEACH, QUEENS, NEW YORK | JULY 2015

Aerial view of Howard Beach with Shellbank Basin and Cross Bay Blvd © Michael Eckrich-Neubauer

This report was developed by The Nature Conservancy, with technical support from CH2M Hill and Davey Resource Group. Primary funding was provided by The JPB Foundation, with additional support from The Rockefeller Foundation and TD Bank. The Nature Conservancy is a nonprofit organization that works to conserve the lands and waters on which all life depends. CH2M Hill is a global engineering firm with expertise in coastal engineering.

About The Nature Conservancy

The mission of the Nature Conservancy is to protect the lands and waters on which all life depends. The Nature Conservancy in New York uses science to guide us toward conservation success. We contributed significantly to advancing the role of nature and nature-based infrastructure in the New York State 2100 Commission's plan, whose purpose is to improve the resilience and strength of the state's infrastructure in the face of natural disasters and emergencies. The Nature Conservancy's New York City Program protects and promotes nature and environmental solutions to protect and restore natural systems and enhance the quality of life of all New Yorkers. We are committed to improving the City's air, land, and water, and we advance strategies that create a healthy, resilient, and sustainable urban environment.

Globally, The Nature Conservancy's Climate Risk and Resilience Program is helping the world's most climate-vulnerable communities by showing that investments in ecosystem protection and restoration are viable and cost-effective ways to protect lives and property and increase nature's resilience to floods and storms. Our Climate Change Team—a network of Conservancy scientists and specialists—provides worldwide leadership by forging high-impact partnerships, developing policy strategies, and leading research, science, and innovation in climate change and conservation. In objectively assessing how nature and nature-based infrastructure can contribute to the resilience of coastal urban communities, this report is well aligned with the Conservancy's science-based approach to public policy and management challenges and expertise in coastal resilience and climate change effects.

By sharing knowledge of our on-the-ground work, from the consequences of climate change to expertise in adaptation and forest conservation solutions, we engage governments, businesses, and communities to support policy action on climate change. This report is an effort to further that work, and to advance a methodology for valuing nature and nature-based infrastructure in coastal resilience efforts.

This report is dedicated to the memory of our friend and CH2M Hill colleague Matthew Wilson, in recognition of his hard work and commitment to furthering the science of ecosystem service valuation. Special thanks to Rebecca Benner, Meera Bhat, Stuart Gruskin, Lise Hanners, Chris Hawkins, Rob McDonald, Lauren Miura, Elizabeth Schuster, and Nathan Woiwode of The Nature Conservancy for providing thoughtful feedback, and to Stephen Lloyd of The Nature Conservancy for his GIS contributions to this report.

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Glossary and Abbreviations

avoided flood damages	financial benefits, modeled with HAZUS, that include avoided costs of relocation plus avoided losses to buildings and other infrastructure, income, rental income, and wages resulting from flood damages
benefit transfer	an economic method used to monetize a subset of ecosystem services by applying available information from studies completed in another location and/or context
berm	a flat strip of land, raised bank, or terrace bordering a river or canal[1]
cost-benefit analysis (CBA)	a set of procedures for defining and comparing the benefits and costs associated with a project or investment
discount rate	a reflection of how much the public values past or future benefits or losses today
discounted service acre-year (dSAY)	ecological benefits provided per acre per year that are discounted and summed across different years
ecological benefits	the biotic and abiotic functions of a habitat that contribute to a healthy ecosystem, measured in this study with Habitat Equivalency Analysis
ecological uplift	increase in the condition of resources and habitat functions relative to current or baseline conditions (see ecological benefits)
ecosystem function	biological, geochemical, and physical processes that occur within and sustain ecosystems and biodiversity[2]
ecosystem services	the benefits provided by nature to people
eutrophication	the process that ensues after a high concentration of nutrients (e.g., nitrogen, phosphorus) enters a waterbody: the nutrients promote rapid growth of algae, whose decomposition depletes the water of dissolved oxygen

floor-area ratio (FAR)	the area (measured in square feet or square meters) of a structure divided by the area of the lot, used as an indicator of density. Higher FAR indicates greater density
gray infrastructure	engineered infrastructure such as sea walls and flood gates that does not include natural features
groin	a structure built out from an ocean shore or a river bank to interrupt water flow and limit the movement of sediment[3]
habitat equivalency analysis (HEA)	a methodology to evaluate the future ecological benefits of a habitat relative to the current conditions. The results an HEA are measured in discounted service acre-years
HAZUS	a geographic information system–based natural hazard loss estimation software package, developed and distributed by the Federal Emergency Management Agency
hydrodynamic modeling	a tool that describes or represents the motion of water
nature and nature-based infrastructure	infrastructure that uses the natural environment and engineered systems [that mimic nature] to provide clean water, conserve ecosystem values and functions, and provide benefits to people and wildlife[4]
National Data Buoy Center (NDBC)	a NOAA based center that designs, develops, operates, and maintains a network of data collecting buoys and coastal stations
net present value	the aggregated sum of discounted annual benefits minus the aggregated sum of discounted annual costs
New York City Panel on Climate Change (NPCC)	a panel of experts that advises the Mayor of New York City on issues related to climate change and adaptation. The panel comprises experts in climate change science, the law, and insurance and risk management, and is modeled on the Intergovernmental Panel on Climate Change

National Oceanic and Atmospheric Administration (NOAA)	A U.S. federal agency focused on the conditions of the oceans and the atmosphere
North American Vertical Datum (NAVD)	A base measurement point adopted by the U.S. federal government (or set of points) from which all elevations are determined. Unless otherwise noted, all elevations are in feet relative to NAVD
operations and maintenance (O&M)	the activities and systems necessary for gray, , and nature-based infrastructure to perform their intended functions
resilience	the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and function, capacity for self-organization, and capacity to adapt to stress and change[5]
Special Initiative for Rebuilding and Resiliency (SIRR)	a plan launched by Mayor Michael Bloomberg to prepare New York City for the future impacts of climate change
transferable development right (TDR)	a land use regulation strategy that creates financial incentives to shift growth away from flood zones and develop revenue streams for coastal infrastructure

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Jamaica Bay wetlands © Jessica Sheridan/Flickr via a Creative Commons license

1. Executive Summary

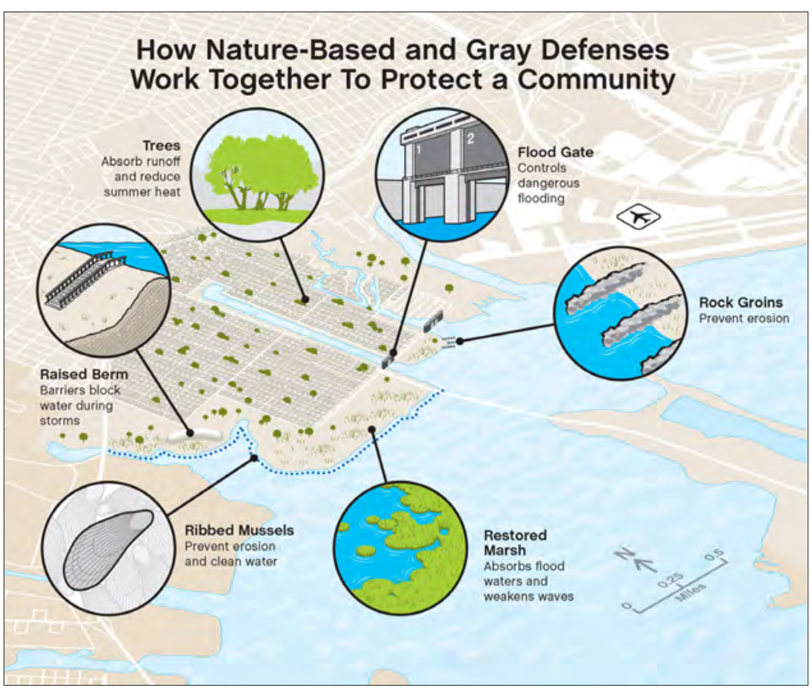
This report considers the use of natural infrastructure to address flood and other climate change–induced risks in an urban area. It has three primary objectives:

- to evaluate the relative merits of various approaches to climate change resilience, using the New York City community of Howard Beach, Queens, as a case study,
- to propose an innovative approach to quantifying ecosystem functions and services; and
- to establish replicable methods for making decisions about using natural infrastructure in this context.

This report supersedes The Nature Conservancy's 2013 study, "Integrating Natural Infrastructure into Urban Coastal Resilience, Howard Beach, Queens," which compared the efficacy of nature and nature-based infrastructure and conventional "gray" infrastructure. That report, prepared at the request of the City and produced with technical and analytical input from CH2M Hill, suggested questions that merited further exploration: how would nature, nature-based and hybrid infrastructure compare with gray-only, and what would a more robust cost-benefit analysis of the options indicate? Reviewers also asked which methods would be most useful in addressing the issues. This report answers these questions and provides updated information. The innovative finance section, however, has not been updated and stands as our recommended strategies for consideration and is presented in Appendix J. The lead authors of this updated report relied heavily on the work of the original report co-authored by Adam Freed, Erin Percifull, and Charlotte Kaiser, and thus they are listed as part of the project team for this report.

The report is divided into three parts. First, Sections 1 and 2 provide context for the study, background on our sample community, and details on the components of our analysis. Next, Sections 3 through 9 contain technical and analytical information on the projections, modeling, methods, and protocols we applied. Breaking down our analysis into its parts and addressing strengths and weaknesses are essential to understanding the value of this approach and the additional work that may follow this report. Finally, Section 10 discusses our results, conclusions, limitations, and recommended next steps.

Among the highlights of the report are a discussion of how a cost-benefit analysis can account for environmental benefits that have historically been difficult to quantify, and the application of a Habitat Equivalency Analysis, typically used in other circumstances, to consider the benefits of natural infrastructure such as wetlands, beaches, berms, and shellfish reefs. Five conceptual alternative kinds of protective infrastructure were considered for both their flood protection efficacy and their ecosystem services co-benefits, which when combined contribute to resilience.



The study finds that when ecosystem functions and services are included in a cost-benefit analysis, hybrid infrastructure—combining nature and nature-based infrastructure with gray infrastructure—can provide the most cost-effective protection from sea-level rise, storm surges, and coastal flooding. All-gray flood protection can cost more and miss opportunities for generating additional economic benefits and ecosystem services, such as recreation, carbon capture, and habitat. Specifically:

- The alternative that provides the most community protection while also maximizing environmental benefits at a reasonable cost is a hybrid. It saves $225 million[6] in damages from a 1-in-100-year storm event while generating ecosystem services, for the highest net benefit.
- The all-gray alternative provides the highest level of flood protection and also avoids $225 million in flood damages, but it has unintended consequences for the surrounding community, generates the least ecosystem services and ecological benefits, and is not the best fiscal choice. Accordingly, it is not the most effective option.
- The two nature and nature-based alternatives do not meet the flood mitigation objective—they avoid less than $1 million in flood damage losses.
- Benefits provided by nature and nature-based infrastructure can be monetized, quantified in nonmonetary units, or qualitatively described. Combining these methods generates a richer, more robust comparison.
- Region-specific data increase the accuracy of the cost-benefit analysis. Without high-quality locally-specific information, an analysis may not capture the full suite of costs and benefits of nature and nature-based infrastructure. Thus, we recommend needed data sets for the New York City region to help inform future projects.
- Mitigating flood risks provides significant public and private benefits to the City and property owners. The benefits for different groups can be monetized to offset construction and maintenance costs.
- It is the methodology presented in this study, not the findings, that is replicable.

Nature and nature-based infrastructure not only contribute to flood protection but also increase ecosystem and social resilience by enhancing both the environment—including water quality, air quality, and habitat—and the quality of life in surrounding communities. Both environmental and quality-of-life improvements have economic benefits for the City and for property owners. Nature and nature-based infrastructure elements are effective tools in protecting lands and waters for people and nature, which is The Nature Conservancy's core mission.

This report evaluates potential resilience strategies for one coastal neighborhood, but our interest is much broader than Howard Beach. We are pleased to contribute this analysis to advance the practice of protecting coastal communities across New York City, New York State, the nation, and the world.

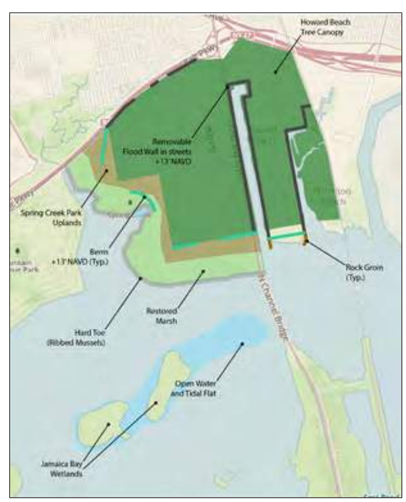
Overview of Alternatives

Alternative 1

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 5,400 feet, tied into existing high land, not continuous
- Restored Charles Memorial Park Beach, 11 acres
- Rock breakwater, 600 feet
- Two rock groins at beach, 700 feet

Alternative 2

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 5,400 feet, tied into existing high land, not continuous
- Restored marsh island, 121 acres
- New marsh island, 72 acres
- Hard toe of ribbed mussels around islands, 8,000 feet



Alternative 3

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 5,400 feet, tied into existing high land, not continuous
- Restored Charles Memorial Park Beach. 11 acres
- 2 rock groins at beach, 700 feet
- Removable flood wall at Belt Parkway, 800 feet
- Removable flood walls at Howard Beach and Old Howard Beach, 13,200 feet

Alternative 4

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 3,120 feet
- Restored Charles Memorial Park Beach, 11 acres
- Floodgate structure at Belt Parkway
- Sheet pile channel closure structures to narrow channels to 45 feet
- Two 45-foot-wide gates at channel entrances

Alternative 5

- Flood-control gate at Belt Parkway
- Sheet pile channel closure structures to narrow channels to 45 feet
- 45-foot-wide operable gates at channel entrances (Shellbank and Hawtree basins)
- Flood wall along Spring Creek Park and western perimeter of Howard Beach and Belt Parkway +13 feet, 12,600 feet
- Flood walls at Charles Memorial Park and Hamilton Beach +14 feet, 1,950 feet

Figure 1-1 Overview of Alternatives

Howard Beach pier and boat damage © Pam Andrade/Flickr via a Creative Commons license

2. Introduction

On October 29, 2012, Superstorm Sandy brought storm surges that exceeded 13 feet and caused more than $19 billion in damages to New York City. Across the region, more than 125 people died, including 48 New York City residents. As fires raged in some city neighborhoods, water destroyed homes in others. Although climate change predictions had indicated that a catastrophic storm could happen someday, for most people, the destruction was beyond imagination. This was a loud, stark wake-up call to the reality of our changing climate.

Now, three years after Superstorm Sandy made landfall in New York City, significant work remains necessary to protect the city from the consequences of climate change. Sandy not only revealed the harsh realities of increasingly severe weather, it also forced a critical conversation about adaptation.

To further that conversation, in 2013 the New York City Special Initiative for Rebuilding and Resiliency (SIRR) asked The Nature Conservancy to evaluate the role of nature and natural infrastructure in protecting communities from sea-level rise, storm surges, and coastal flooding.

The City selected Howard Beach as the focus for the commissioned study because of the amount of damage it suffered during Sandy and its vulnerability to high-frequency, low-impact flooding from sea-level rise—risks that will increase over time. The current 1-in-25-year storm causes $30 million in losses. The current 1-in-100-year storm is estimated to result in $1.216 billion in losses, and an increase in sea level of 32 inches, as projected by the New York City Panel on Climate Change (NPCC), will significantly increase that estimated loss.

2.1 Context for This Study

In June 2013, SIRR published a "A Stronger, More Resilient New York," which detailed more than 250 initiatives, including specific actions for Howard Beach and Jamaica Bay. The analysis and potential coastal resilience strategies developed by the Conservancy were created on a parallel track to the work completed by the SIRR; however, there are many similarities in the findings and strategies.

The SIRR report calls for the U.S. Army Corps of Engineers, subject to funding, to implement a wetlands restoration project designed to attenuate waves for Howard Beach. This project would build on the existing work of the Hudson-Raritan Estuary Comprehensive Restoration Plan and leverage the work contained in this report, which was cited by the City in the SIRR report. The goal is to complete this project within four years after the Army Corps of Engineers study.

In addition to restoring wetlands, the SIRR report recommends that the City, subject to funding, raise bulkheads and other shoreline structures to minimize the risk of regular flooding in low-lying neighborhoods, including Howard Beach, the bay side of the Rockaway Peninsula, Broad Channel in Queens, West Midtown in Manhattan, Locust Point in the Bronx, Greenpoint in Brooklyn, and the north shore of Staten Island.

As the original Howard Beach report was going to press in December 2013, New York State announced an ambitious plan that would help protect Howard Beach by implementing an innovative resilience project on 150 acres of National Park Service land along Spring Creek and Jamaica Bay. This commitment goes well beyond the nature and nature-based infrastructure options evaluated in this report and represents a significant and valuable investment by the state in using natural systems to protect communities and provide other benefits.

Given the significant public investments in coastal resilience projects both in the region and nationally, the time is ripe to develop better methods for evaluating the role of nature and nature-based infrastructure in planned and future projects, which is the purpose of this report.

2.2 Scope of Work

Although Superstorm Sandy was the impetus for this report, our charge was to evaluate the current and future climate risks facing a sample community, Howard Beach, with an emphasis on coastal flooding, and to demonstrate the potential role and value of an integrated suite of strategies that include nature and nature-based and gray infrastructure. The goal was not to model the impacts of Sandy or to develop strategies to mitigate the damage caused by a similar storm.

The analysis required expertise in ecology, environmental economics, and coastal engineering. We relied heavily on in-house expertise in ecology and environmental economics, and we retained CH2M Hill, a global engineering firm with expertise in coastal engineering, to complement our knowledge about nature and nature-based infrastructure and environmental economics. Together, we developed five suites of strategies (Alternatives 1–5) containing nature and nature-based and gray infrastructure elements, and modeled their ability to mitigate damage caused by a 1-in-10-year, 1-in-25-year, and 1-in-100-year storm. Three alternatives were further modeled for risk reduction capacity using sea-level rise projections of 12 and 32 inches to determine how their protective capacity would change over the next 50 years. Flood levels and sea-level rise projections were based on analysis conducted by the Federal Emergency Management Agency (FEMA) and NPCC.

Our case study looks at neighborhood-scale protection alternatives and offers a methodology that can be replicated and applied in other coastal communities to evaluate the efficacy and relative costs and benefits of coastal resilience strategies. Because of population and building density, in many parts of the City it is more cost-effective to protect people and property from climate risks at the neighborhood or regional scale than home-by-home or through relocation. In Howard Beach, the total estimated cost of elevating every home above the base flood elevation plus the recommended 2 feet of freeboard, as recommended by the FEMA, exceeds $700 million (approximately $164,000 per home), or more than 2.5 times the most expensive alternative identified in this analysis.

Estimated losses were calculated using HAZUS, a software tool developed by FEMA. Because HAZUS does not include public infrastructure damage in its projections, economic loss estimates are limited to building damage, vehicle losses, and business interruption. Damage to public infrastructure is likely to be significant during 1-in-100-year storms, which would increase the cost-effectiveness for many of the scenarios analyzed in this report.

We evaluate potential strategies for one neighborhood to illustrate how integrated approaches to mitigating flood risk can be valued and compared. We show methods to account for a range of benefits as well as potential costs from flood mitigation projects. Our estimates of the benefits are conservative and should be viewed as a starting point, since we do not fully quantify all ecosystem services or ecological benefits.

The framework we use is defensible, replicable, and consistent with federal policy. It supports decisions that maximize both risk reduction and ecosystem and ecological services with net benefits to society. It relies on modeling software calculations to estimate the losses from natural disasters; habitat equivalency analysis (HEA) to describe the gains and losses in ecological benefits over time; environmental economic analysis to evaluate the value of ecosystem services; and cost-benefit analysis to determine net financial benefits of flood protection measures.

The subsequent sections of the report proceed as follows:

3. Background on Howard Beach and New York City's resilience strategy.
4. Discussion of the climate change scenarios that will test the infrastructure alternatives.
5. Five conceptual alternatives to address resilience in the community of Howard Beach: two composed of solely nature and nature-based infrastructure; a gray-only approach; and two hybrids.
6. Explanation of cost-benefit analysis, net present value, discount rates, and uncertainty.
7. Modeling of storm surge with sea-level rise.
8. Modeling of flood damage and economic losses.
9. Valuation of ecosystem services and ecological benefits provided by each conceptual alternative.
10. Application of cost-benefit analysis, integrating economic and ecosystem costs and benefits, with:
    - results,
    - conclusions, with recommendations for future research; and
    - potential next steps.

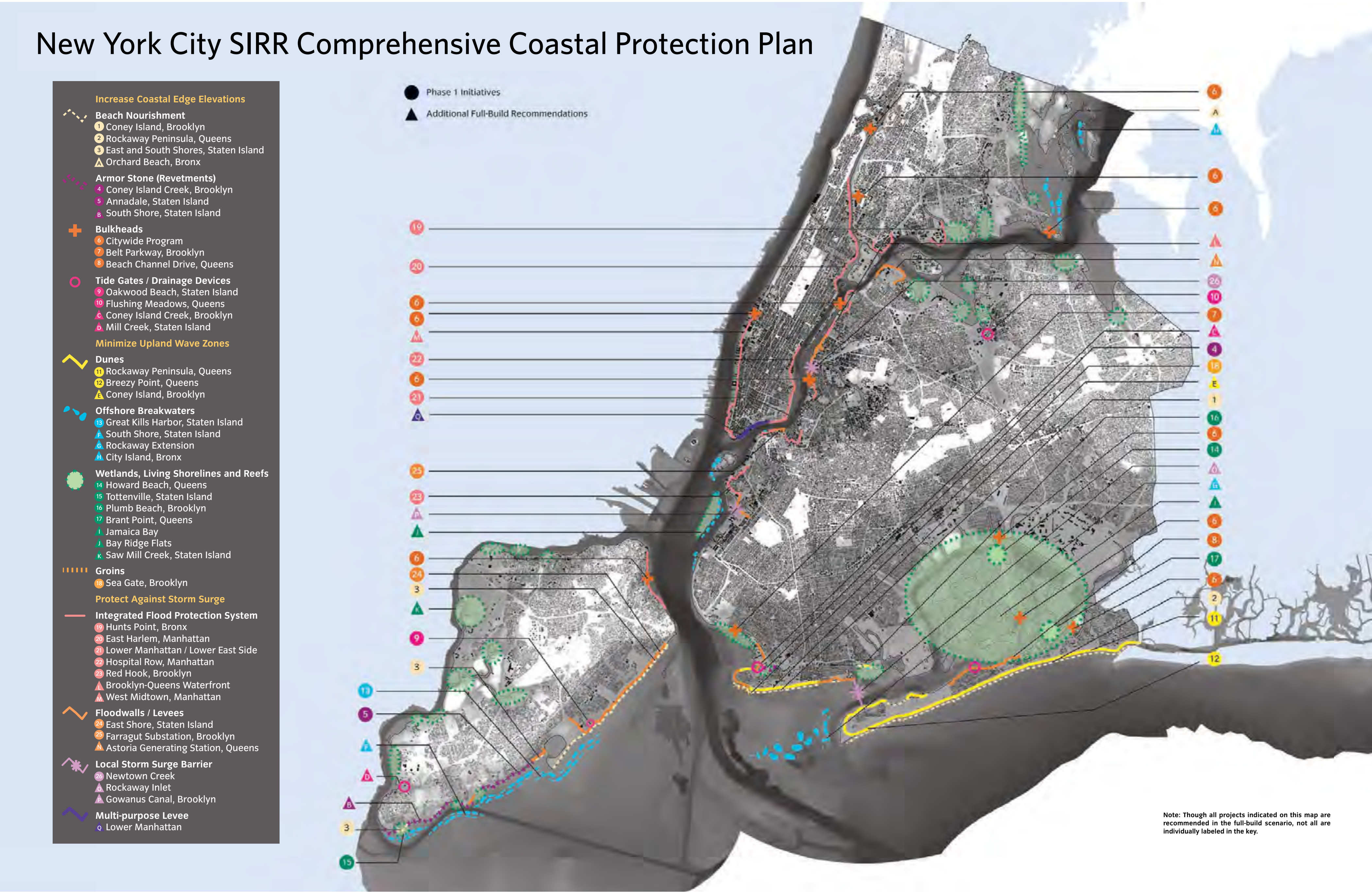
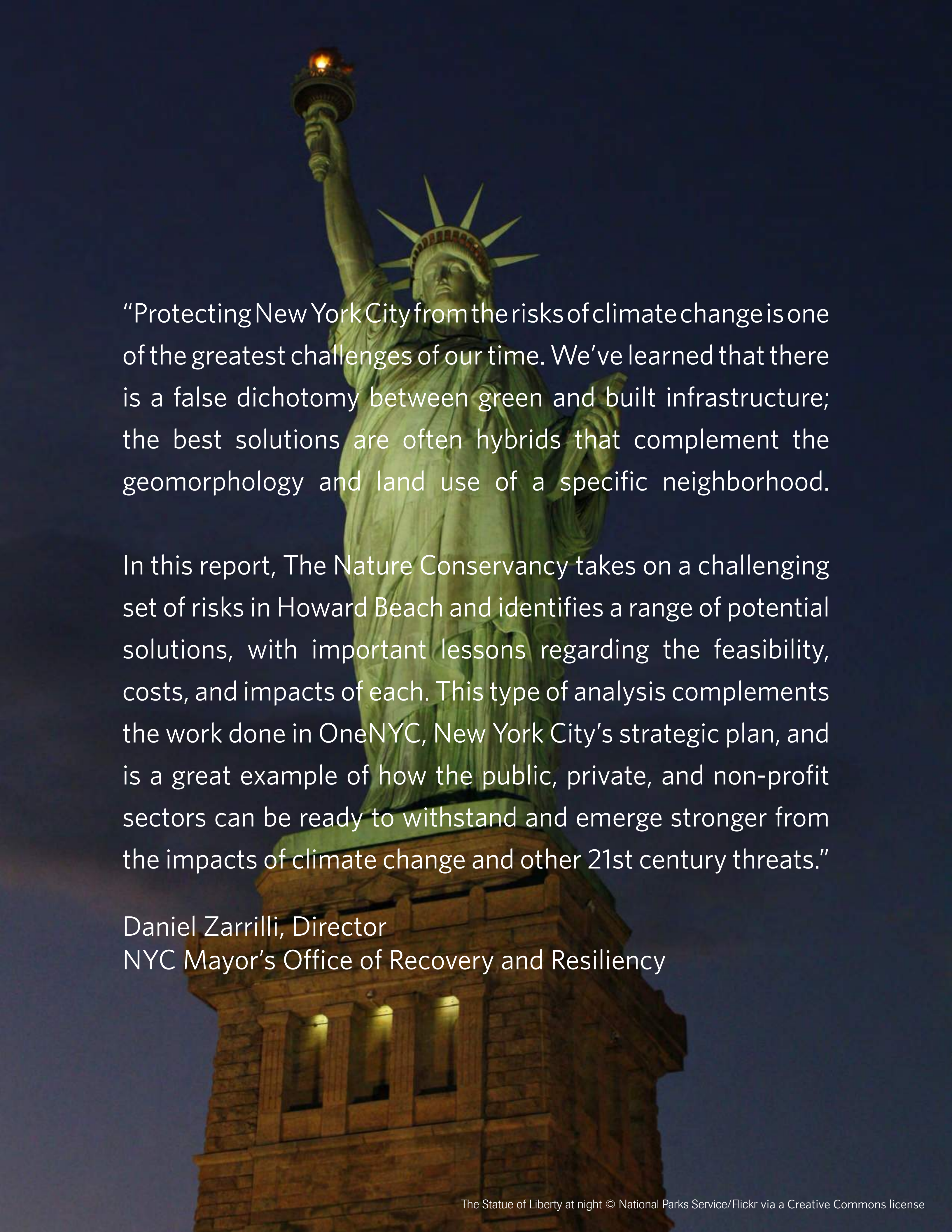


Figure 2-1 New York City SIRR Comprehensive Coastal Protection Plan



"Protecting New York City from the risks of climate change is one of the greatest challenges of our time. We've learned that there is a false dichotomy between green and built infrastructure; the best solutions are often hybrids that complement the geomorphology and land use of a specific neighborhood.

In this report, The Nature Conservancy takes on a challenging set of risks in Howard Beach and identifies a range of potential solutions, with important lessons regarding the feasibility, costs, and impacts of each. This type of analysis complements the work done in OneNYC, New York City's strategic plan, and is a great example of how the public, private, and non-profit sectors can be ready to withstand and emerge stronger from the impacts of climate change and other 21st century threats."

Daniel Zarrilli, Director
NYC Mayor's Office of Recovery and Resiliency

The Statue of Liberty at night © National Parks Service/Flickr via a Creative Commons license

Aerial view of Howard Beach, Queens © Adrian Madlener

3. Overview of Howard Beach

Howard Beach is a low-density residential neighborhood along Jamaica Bay in the southwestern portion of Queens. The community covers approximately 1,530 acres (2.4 square miles) and is bordered to the north by the Belt Parkway and South Conduit Avenue, to the south by Jamaica Bay, to the east by 102nd–104th streets, and to the west by 78th Street. This section provides an overview of Howard Beach's demographics, infrastructure, and natural environment.

3.1 Population

Howard Beach is home to approximately 14,700 residents. The neighborhood's population is generally older (35 percent are older than 55 years), wealthier (median household income is approximately $80,000), and less heterogeneous (86 percent of residents are white, non-Hispanic) than the rest of the City (Table 3-1). More than 90 percent of the population speaks English as a first language or "very well."

Residents have generally lived in Howard Beach for a long time. Only 2 percent of residents moved into the area within the past four years, and more than 80 percent have lived in Howard Beach more than 20 years.

Compared with other neighborhoods along Jamaica Bay—and the City as a whole—Howard Beach has a relatively high employment rate, with 93 percent of the over-16 population in the labor force. The neighborhood also has a low poverty rate (only 8 percent of residents are below the poverty line) and a high level of education attainment (approximately 44 percent of residents older than 25 years have attended some college or have an associate's or bachelor's degree, and 23 percent have a bachelor's degree).

3.2 Housing

Single-family detached homes are the dominant type of residence, accounting for 71 percent in Howard Beach as a whole and more than 93 percent in the western portion of Howard Beach. Most of the rest, 24 percent, are buildings with two apartment units, most of them in the eastern section (Old Howard Beach).

More than 90 percent of the residential buildings were built before 1980, before national flood protection standards were put in place, with a majority constructed between 1940 and 1979. As a result, many buildings are below the recommended base flood elevation and have basements.

Approximately 85 percent of housing units in Howard Beach are owner-occupied—a level significantly higher than the citywide average. Only 44 percent of these units have mortgages, which require owners to have flood insurance.

Source: © Mapbox © OpenStreetMap

Figure 3-1 Howard Beach Locator Map

(This is perhaps explained, in part, by the long length of tenure of many residents.) As a result, many homes may not have flood insurance.

Howard Beach's residential units have a median value of approximately $550,000, which is slightly higher than the citywide median value.

Table 3-1 Comparison of Howard Beach and New York City Demographics

Demographic Indicators	Howard Beach	Citywide
Population	14,700	8,175,133
Over 55 years old	35%	23%
White, non-Hispanic	86%	44%
Tenure of 20 years or more	80%	NA
English-speaking	90%	71%
Economic Indicators	**Howard Beach**	**Citywide**
Median household income	~$80,000	~$51,270
Households receiving Social Security income	49%	NA
Employed (active labor force 16+ years old)	93%	NA
Postsecondary education	44%	NA
Housing Indicators	**Howard Beach**	**Citywide**
Housing units	5,679	3,371,062
Median home value	$550,000	$514,900
Owner-occupied homes	85%	29%
Owner-occupied homes with mortgages	44%	64%

NA=not available
Source: U.S. Bureau of the Census, 2011

3.3 Social Vulnerability

In addition to physical characteristics, other critical factors of a community's resilience include the economic, social, and physical status of its population, as well as demographic characteristics (e.g., race, age, ethnicity). A community with little connectivity or few community organizations and networks (e.g., churches, civic groups, nonprofits), high rates of health issues (e.g., asthma or limited mobility), linguistic or physical isolation, poor building stocks, low incomes, or high unemployment is generally more vulnerable to climate risks and other shocks. While we don't treat all of these factors in this study, understanding community dynamics is crucial for vulnerability, and thus is worthy of discussion.

Howard Beach's relatively high median income, homeownership rate, education attainment, employment rate, concentration of English speakers, and ethnic makeup are indicators of high community resilience; however, portions of the population are more vulnerable to climate risks. Elderly residents, as well as people with existing health conditions, are more susceptible to heat-related illnesses, which are likely to increase as temperatures rise and the city faces more days with temperatures above 90 degrees Fahrenheit each year. The City's mortality and morbidity rates increase an estimated 8 percent on the second consecutive day with temperatures above 90 degrees Fahrenheit (New York City Department of Health and Mental Hygiene 2006). In addition, elderly residents are more likely to have mobility issues or need assistance, which could complicate evacuations in advance of a storm event.

3.4 Infrastructure

Howard Beach has limited major built infrastructure. The A-train stops at the Howard Beach elevated subway station, which connects to the Port Authority's Air Train to JFK International Airport. The Belt Parkway, a state-owned major thoroughfare, forms the northern boundary of the neighborhood.

In addition, the northern terminus of the Marine Bridge connects Crossbay Boulevard, the commercial heart of Howard Beach, to the Rockaways. Crossbay Boulevard has restaurants, event halls, retail stores, hotels, and car dealerships. Additional commercial activities are located along 103rd Street and 159th Avenue in Old Howard Beach.

3.5 Natural Environment

Howard Beach's most obvious natural feature is Jamaica Bay, an 18,000-acre wetland estuary almost equal in area to Manhattan. The bay consists of numerous islands, waterways, meadowlands, and freshwater ponds.

Jamaica Bay has a history of chronic eutrophication and low flushing, or turnover time, that results in poor water quality. Wetlands, once expansive throughout the bay, have diminished substantially in size. The environmental challenges in the bay were recognized by SIRR (2013), and new initiatives to create a resilience strategy are underway (i.e., the Science and Resilience Institute at Jamaica Bay).

Howard Beach is adjacent to parkland managed by the City, the State and the National Park Service. Spring Creek Park and Frank M. Charles Memorial Park, which are in Howard Beach, have upland maritime forests fragmented by

Figure 3-2 Tree Canopy Cover in Howard Beach

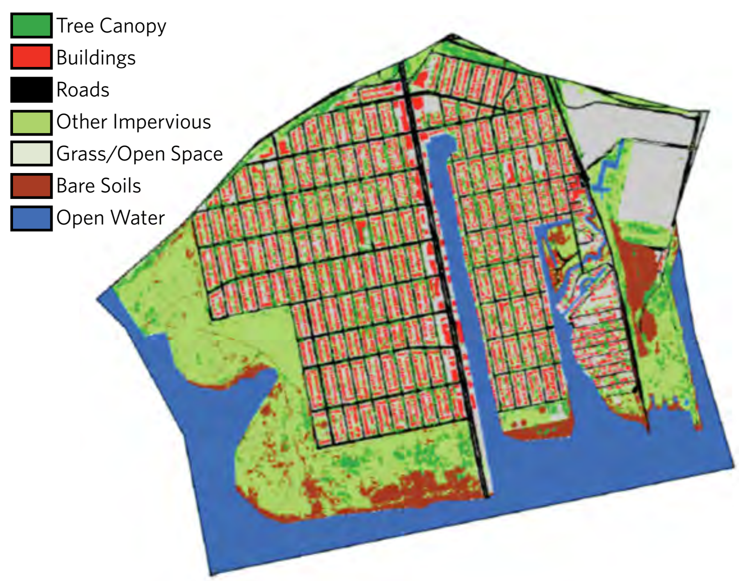


Figure 3-3 Surface Conditions in Howard Beach

the invasive reed, *Phragmites australis*, which intergrade into high and low marsh habitats that fringe the coastline and transition to unvegetated beach and mudflat. These parks provide recreational access to Jamaica Bay and offer views of JFK airport and the Manhattan skyline. (A more complete description of the status of the various habitats can be found in Section 9.)

Howard Beach has two canals—Hawtree Basin and Shellbank Basin—that are defining characteristics of the neighborhood. These waterways abut numerous commercial and residential properties and are used for recreational boating; they also present significant flood risks.

Impervious surfaces, including roadways, parking lots, buildings, and sidewalks, cover 42 percent of Howard Beach. This hardscape can exacerbate surface flooding from rainfall. As part of this research, the Conservancy worked with Davey Resource Group to evaluate the benefits of existing trees and potential to expand the tree canopy cover in Howard Beach. Trees and vegetated areas can be managed specifically to reduce flooding from rainfall, in addition to improving air quality and reducing the urban heat island effect. An increase in tree canopy reduces flooding by absorbing the rain that would have become stormwater runoff. Approximately 8.45 percent of Howard Beach is covered with tree canopy (TNC 2013). (Section 9 discusses the carbon sequestration and flood reduction benefits of the tree canopy of Howard Beach.)

Consistent with the age demographics of the neighborhood, almost half of Howard Beach households (49 percent) receive Social Security income and 30 percent receive retirement income. Residents who depend solely on these sources of income could have a limited ability to handle economic shocks caused by climate events.

Other factors that could affect community vulnerability and resilience, such as social and political capital, were not analyzed.

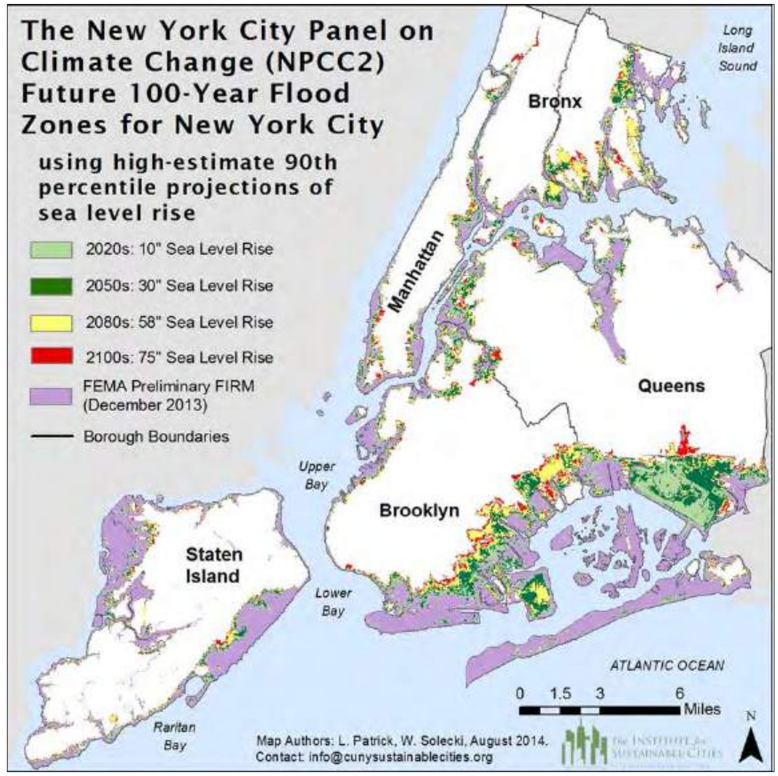
Street flooding after Superstorm Sandy in Howard Beach, Queens © Pam Andrade/Flickr via a Creative Commons license

4. Climate Risks

Given its waterfront location, flat topography, and canals, the most significant climate-associated risks to Howard Beach are coastal flooding and storm surges. Figure 4-1 shows that much of the neighborhood is inside the 1-in-100-year flood zone designated by FEMA, and in fact, Howard Beach experienced significant damage from Hurricane Irene (2011) as well as Superstorm Sandy. During the 2012 storm, surge height in Howard Beach peaked at 11.2 feet, and the water depth at some buildings reached 18 feet (Figure 4-2), based on U.S. Geological Survey high-water marks.

According to the advisory maps issued by FEMA after Sandy, the entire neighborhood—including all buildings and public infrastructure—is likely to fall inside the 1-in-100-year flood zone when FEMA finalizes its flood maps for the City (FEMA issued preliminary flood insurance rate maps in December 2013). Flood heights associated with the 1-in-100-year event range between 14 feet at the coastline to 10 to 11 feet farther inland.

Building codes require new structures in the 1-in-100-year flood zone to be elevated at least 2 feet above the base flood elevation but do not apply to existing structures. In addition, as in many neighborhoods in the city, structures in Howard Beach can experience surface and basement flooding during intense rainfall events.



Source: Freed et al. (2013)

Figure 4-1 Future 100-Year Flood Zones for New York City

4.1 Climate Change Projections

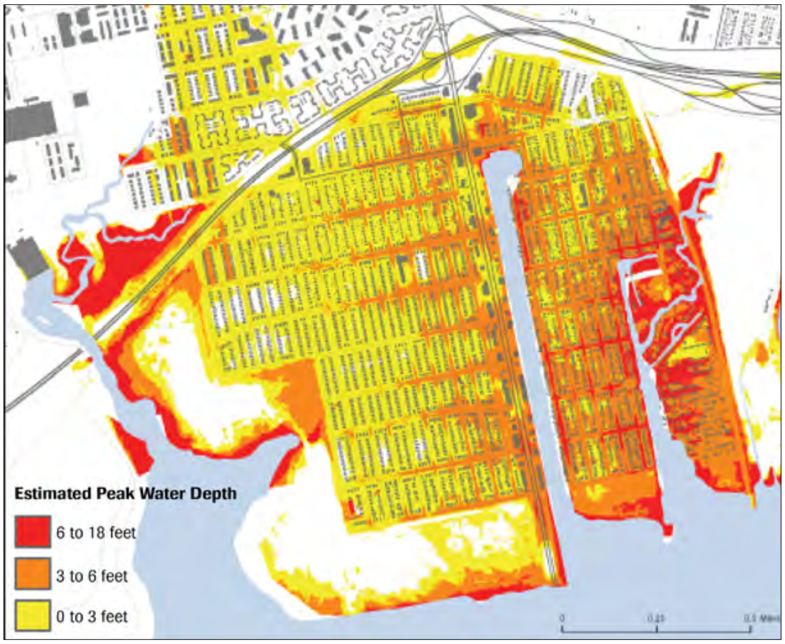
New York is likely to experience more frequent and intense rainstorms by the 2050s (Horton et al. 2015). Moreover, sea levels are projected to rise by 11 to 30 inches (the higher end of the projections representing a "rapid ice melt" scenario)— a critical factor for Howard Beach and other coastal neighborhoods. Table 4-1 and Figure 4-1 show the sea-level rise projections in New York City for the next 85 years. Figure 4-2 shows the water depth at buildings during Superstorm Sandy. Figure 4-3 shows an example of tidal flood risk in Howard Beach per NPCC projections.

Table 4-1 New York City Sea Level Rise Projections

Baseline (2000–2004) 0 in	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
2020s	2 in	4-8 in	10 in
2050s	8 in	11-21 in	30 in
2080s	13 in	18-39 in	58 in
2100	15 in	22-50 in	75 in

Source: Horton et al. (2015)

Note: Projections are based on a six-component approach that incorporates both local and global factors. The model-based components are from 24 global climate models and two representative concentration pathways. Projections are relative to the 2000–2004 base period.



Source: Freed et al. (2013)

Figure 4-2 Water Depth at Buildings during Superstorm Sandy

If sea levels rise as projected, by the 2050s Howard Beach could be at risk of daily or weekly tidal inundation even without a storm. As sea levels rise, the probability of a flood event with heights associated with the current 1-in-100-year storm (approximately 10 to 13 feet in Howard Beach) will increase. Thus, the flooding associated with the current 1-in-100-year storm is likely to recur, on average, once every 35 to 50 years by the 2050s. The flood heights associated with a 1-in-100-year storm will also increase as sea levels rise, and less intense flooding will occur more frequently as well.

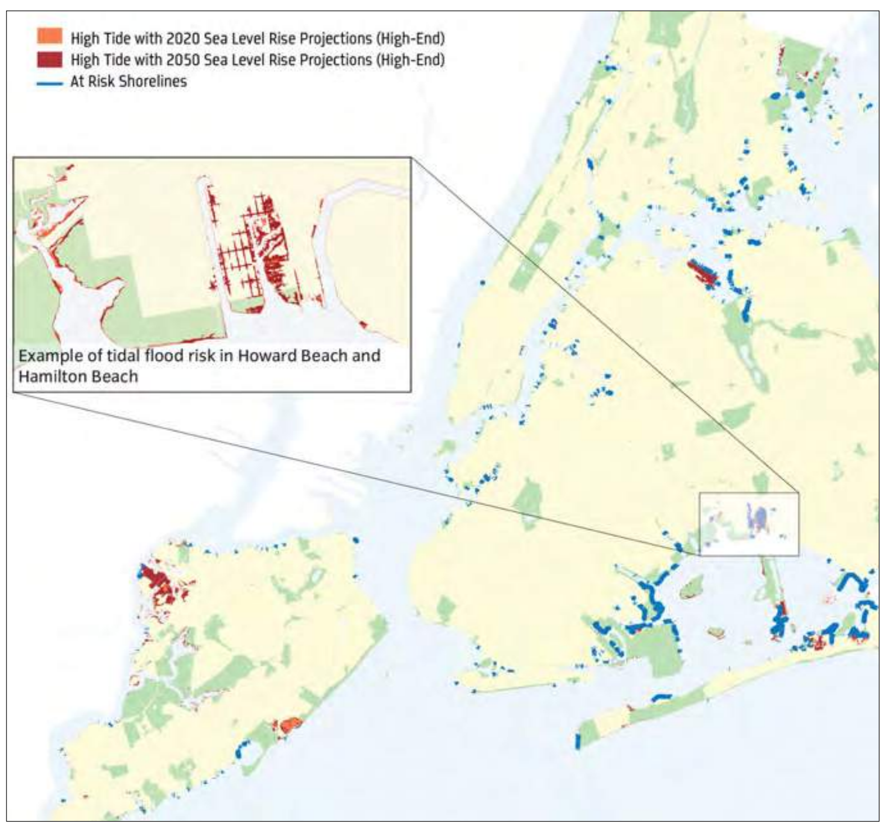


Figure 4-3 Projected Impacts of Sea Level Rise on High Tides

View from the water in Howard Beach, Queens © David Shankbone/Wikimedia via a Creative Commons license

5. Resilience Alternatives

To develop flood protection strategies, the Conservancy hosted two design charrettes with CH2M Hill and various City agencies. The strategies were compiled into five suites of interventions ("alternatives") ranging from all-nature and nature-based strategies to all-gray infrastructure.

This section provides an overview of each alternative strategy and their specific nature and nature-based and gray dimensions. Further, in this section, we present all maps, figures and analytical results as applied to each alternative. The methods applied to achieve these results will be described in Sections 6 - 9. We present these results here in order to satisfy the curiosity of the reader, but a detailed discussion of these results follows.

5.1 Developing the Resilience Alternatives

Development of the alternatives commenced with an evaluation of flooding for the base case (i.e., present conditions) during a 1-in-100-year flood and future sea-level rise scenarios (Section 4), and also consideration of flood processes from the hydrodynamic modeling of the hybrid alternatives. This identified the following major risks of flooding:

- ***Inundation of low-lying areas adjacent to Shellbank and Hawtree basins.*** Land elevations are lowest here, and this is the primary source of flooding of the neighborhood.
- ***Inundation from the north along the Belt Parkway.*** Low elevation in this area creates flow pathways from the creek located north of the parkway.
- ***Inundation via low-lying areas of Spring Creek Park.*** Elevated areas in the park provide some protection against flooding, dissipating and deflecting incoming floodwaters. This protection is not continuous, however, and some sections provide flow pathways to the lower-lying residential area inland of the park.

The design charrettes identified the following natural infrastructure to be used in the alternatives:

- berms;
- marshes;
- edges hardened with ribbed mussel toes;
- rock groins and breakwaters; and
- constructed islands and wetlands.

The following gray infrastructure elements were also identified:

- removable flood walls;
- permanent flood walls; and
- floodgates.

For mitigating flood risks, it is important to dampen wave action on the coastline. Coastal protection elements were sited based on topography and geometry, direction of incoming wind and wave action, and the location of the study area within Jamaica Bay.

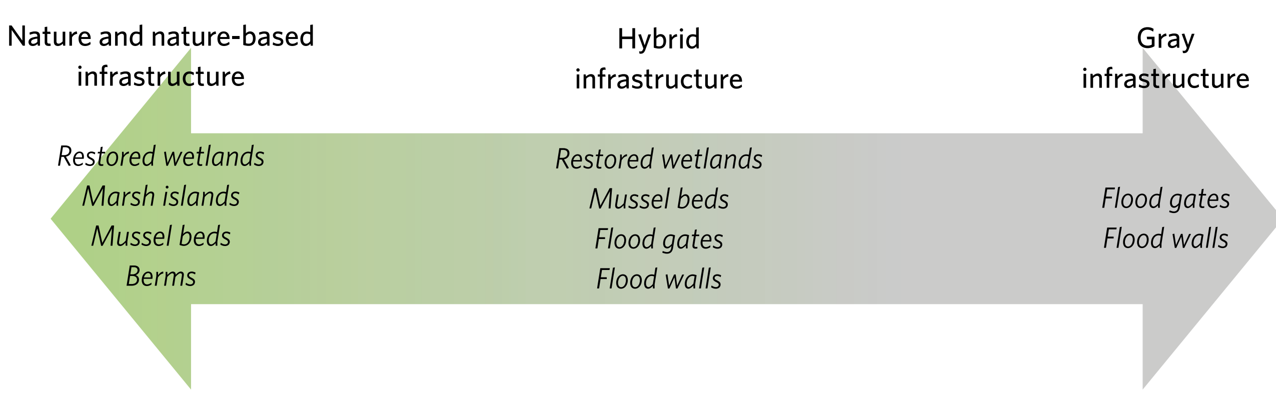


Figure 5-1 Green-to-Gray Scale of Alternatives 1 - 5

Alternative 1: Nature and Nature-Based Infrastructure (Shoreline)

In this all-green scenario, approximately 140 acres of wetland are created and restored at Spring Creek Park (Figure 5-2). This project enhances existing wetlands and convert low-quality *Phragmites*-dominated uplands to intertidal habitats. The newly created salt marsh is supplemented with a created ribbed mussel toe measuring approximately 5 feet wide along the entire length of the shoreline (approximately 1.2 acres). The marsh islands in Jamaica Bay do not receive any restoration, dredge placement, or supplemental vegetation.

Elements:

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 5,400 feet, tied into existing high land, not continuous
- Restored Charles Memorial Park Beach, 11 acres
- Rock breakwater, 600 feet
- Two rock groins at beach, 700 feet

Figure 5-2 Alternative 1: Natural Infrastructure (Shoreline)

Alternative 2: Nature and Nature-Based Infrastructure (Wetlands)

This all-green infrastructure scenario involves more ecological restoration than the other alternatives. The Spring Creek Park wetland is restored and enlarged as in Alternative 1. An additional 193 acres of marsh in Jamaica Bay (Figure 5-3) includes restoration of existing wetlands and creation of wetlands in an area of open water.

Elements:

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 5,400 feet, tied into existing high land, not continuous
- Restored marsh island, 121 acres
- New marsh island, 72 acres
- Hard toe of ribbed mussels around islands, 8,000 feet

Figure 5-3 Alternative 2: Natural Infrastructure (Wetlands)

Alternative 3: Hybrid with Removable Walls

In this hybrid scenario, 120 acres of wetland are restored at Spring Creek Park, and no wetland restoration or creation is conducted on Jamaica Bay's marsh islands, as in Alternative 1. Movable flood walls are installed in three areas (Figure 5-4). Given the nature of the properties along Shellbank Basin and the configuration of Hawtree Basin, it is not possible to install removable flood walls on the water side of adjacent properties. As a result, these properties, including commercial properties on the west side of Crossbay Boulevard and all of Old Howard Beach, would not be protected from flooding.

Elements:

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 5,400 feet, tied into existing high land, not continuous
- Restored Charles Memorial Park Beach. 11 acres
- 2 rock groins at beach, 700 feet
- Removable flood wall at Belt Parkway, 800 feet
- Removable flood walls at Howard Beach and Old Howard Beach, 13,200 feet

Figure 5-4 Alternative 3: Hybrid with Removable Walls

Alternative 4: Hybrid with Operable Flood Gates

This hybrid scenario is the same as Alternative 3 except that it uses floodgates (Figure 5-5) to close Shellbank and Hawtree basins during storm events as well as double-layer sheet pile walls to narrow each channel to 45 feet, which reduces the costs of the floodgates. The gates are constructed of steel plates that when closed point toward the bay so that the water pressure helps keep them closed.

Although the gates could be automated, our analysis anticipates using manual gates with long levers extending to the land on either side, operated by one or two people. Similar mechanisms are used for canal locks. Our analysis did not look at potential water quality and other environmental impacts of narrowing or temporarily closing the basins.

Elements:

- Restored marsh, onshore, 142 acres
- Hard toe of ribbed mussels, 2,700 cubic yards
- Berms in marshland +13 feet, 3,120 feet
- Restored Charles Memorial Park Beach, 11 acres
- Floodgate structure at Belt Parkway
- Sheet pile channel closure structures to narrow channels to 45 feet
- Two 45-foot-wide gates at channel entrances

Figure 5-5 Alternative 4: Hybrid with Operable Flood Gates

Alternative 5: Flood Wall and Flood Gates

The gray infrastructure option to mitigate flood risk does not restore or create wetlands at Spring Creek Park or in Jamaica Bay. Instead, it relies on a flood wall extending along the vulnerable perimeters of the neighborhood plus floodgates at the both Shellbank and Hawtree basins (Figure 5-6).

The flood wall, a reinforced-concrete structure with a piled foundation to resist lateral forces (Figure 5-7), runs along the landward perimeter of Spring Creek Park, then along the northern perimeter of the neighborhood adjacent to the Belt Parkway. Access points would be provided along the wall, either steps, and ramps over the wall or floodgates through the wall (to be closed in a surge event).

Flood walls would also be built in the eastern part of the neighborhood, along Charles Memorial Park and Hamilton Beach.

Tide gates would be located at the mouths of both Shellbank and Hawtree basins. The gates would be closed during high-water events. A mitre gate concept is proposed, in which the two gates swing together and the force of the external surge keeps the gates sealed (Figure 5-8).

Figure 5-6 Alternative 5: Gray Infrastructure

Alternative 5: Flood Wall and Flood Gates

Elements:

- Flood-control gate at Belt Parkway
- Sheet pile channel closure structures to narrow channels to 45 feet
- 45-foot-wide operable gates at channel entrances (Shellbank and Hawtree basins)
- Flood wall along Spring Creek Park and western perimeter of Howard Beach and Belt Parkway +13 feet, 12,600 feet
- Flood walls at Charles Memorial Park and Hamilton Beach +14 feet, 1,950 feet

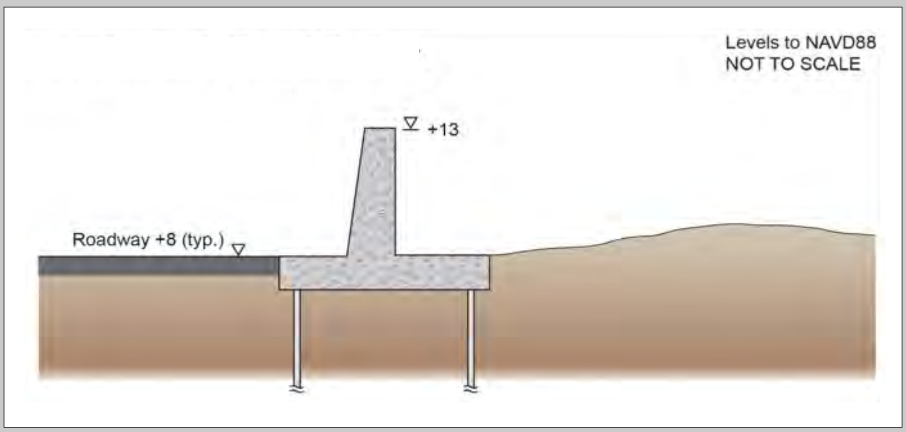


Figure 5-7 Alternative 5: Flood Wall Concept

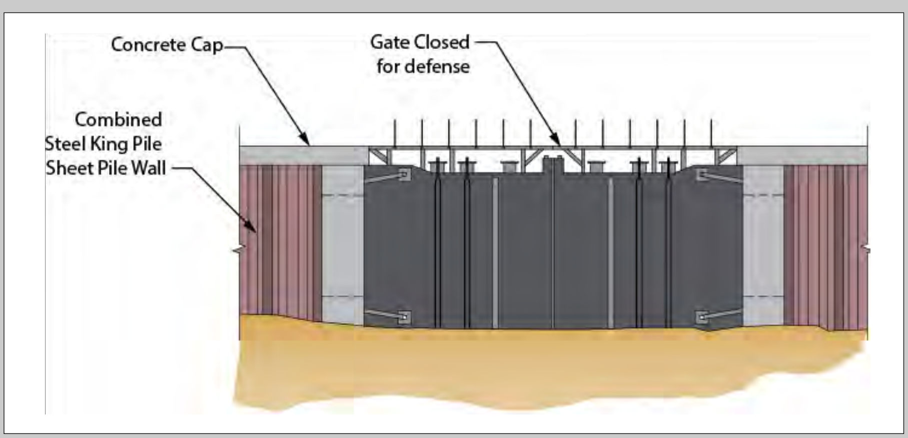


Figure 5-8 Alternative 5: Typical Flood Gate

5.2 Construction Costs

The estimated construction costs for the five alternatives are summarized in Table 5-1. All costs are in 2014 dollars. These costs are used in the cost-benefit analysis and comparison of the alternatives.

Table 5-1 Construction Costs, by Alternative

		Alt1	Alt 2	Alt 3	Alt 4	Alt 5
Construction costs	$M	23.9	52.7	149	45.5	58.8
30% contingency	$M	9.7	21.5	60.7	18.5	15.6
25% profit and overhead	$M	6.2	13.9	39.5	12	24
Total capital cost	**$M**	**40.1**	**88.2**	**249.3**	**75.9**	**98.4**

5.3 Maintenance Costs

Operation and maintenance (O&M) costs for all alternatives are summarized in Table 5-2. The design life of gray infrastructure is typically in the range of 30 to 100 years. A 50-year design life has been assumed in this case. These estimates also inform the cost-benefit analysis.

Table 5-2 Maintenance Costs, by Alternative

	Frequency	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Inspections	Annual	$17,500	$15,750	$47,250	$29,750	$17,500
Concrete flood wall repairs	5 years	—	—	—	—	$100,000
Closure actions[b]	10 years	—	—	$510,000	$30,000	$30,000
Gate repairs	10 years	—	—	—	$1,000,000	$1,000,000
Wetland maintenance[a]	Years 1–53[c]	$950/acre	$950/acre	$950/acre	$950/acre	—
	Year 5 onward[c]	$317/acre	$317/acre	$317/acre	$317/acre	—
Wetland maintenance: plant capital investment[b]	Once	$20,000	$20,000	$20,000	$20,000	
Mussel bed maintenance[d]	Annual	$110,200	$220,400	$110,200	$110,200	—
Beach maintenance[e]	Annual	$18,400	$18,400	$18,400	$18,400	—

Notes:
[a]The wetland cost estimates do not include the costs of maintaining developed facilities (e.g., signage, comfort facilities, trails) of recreational programming or of an on-site park manager.
[b] Purchase of Bobcat, $20,000 (NYCDPR).
[c] Based on costs from Marit Larson, NYC Parks and Recreation; costs fall by two-thirds after Year 5.
[d] Cost for mussel bed maintenance are from John McLaughlin of NYC DEP. The mussel bed is assumed to be established after four years of maintenance. Absent a severe storm event, no additional mussel bed maintenance would be required. The maintenance costs associated with such severe storm events are uncertain and have not been included.
[e] Source: City of New York.

5.4 Scenarios and Scenario Selection

The alternatives developed through the charrette were modeled for a 1-in-100-year storm to determine their ability to reduce flood risks compared with current conditions in Howard Beach (base case). Alternatives 3, 4, and 5 were further modeled to estimate how they would perform with 12 and 32 inches of sea-level rise (Tables 8-1 to 8-3). Alternatives 1 and 2 were not modeled for sea-level rise because they failed to reduce risks under current flooding conditions.

These alternatives are not the only strategies that could increase the resilience of Howard Beach. Rather, they represent a first attempt to create a suite of representative coastal protection options for an urban neighborhood, to help the City understand the costs and benefits of coastal protection using nature and nature-based and gray infrastructure. Actionable strategies require further analysis and modeling and could include a mix of strategies from each alternative or other options.

Base Case: 100-Year Flood Scenario

Associated Economic Costs

Building Loss	$61 million
Content Loss	27
Inventory Loss	4
Relocation Loss	684
Income Loss	6
Rental Income Loss	212
Wage Loss	11
Direct Output Loss	26
Debris Removal	137
Shelter	35
Vehicle Loss	7
Transportation Loss	3
Utility Loss	3
Total Damages	1,216
Avoided Losses	0

Debris	
Tons removed	4,482,192

Displacement	
Individuals displaced	1,443

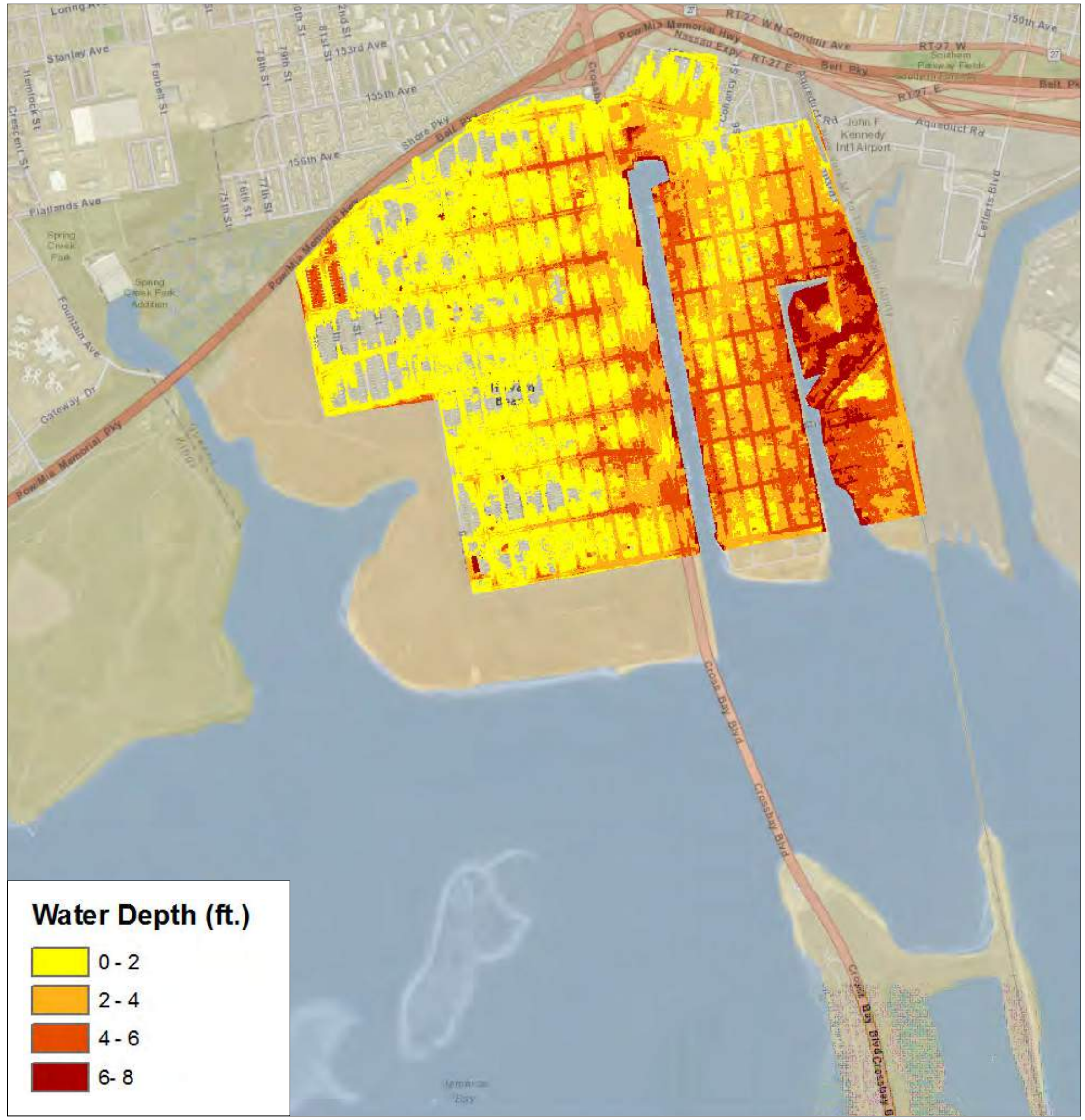


Figure 5-9 Base Scenario: 1-in-100-Year Flood (Present) Map

Base Case: 100-Year Flood Scenario (2050, +12-Inch Sea-Level Rise)

Associated Economic Losses

Building Loss	$74 million
Content Loss	37
Inventory Loss	6
Relocation Loss	782
Income Loss	9
Rental Income Loss	242
Wage Loss	17
Direct Output Loss	41
Debris Removal	176
Shelter	38
Vehicle Loss	9
Transportation Loss	5
Utility Loss	3
Total Damages	1,439
Avoided Losses	0

Debris	
Tons removed	5,736,939

Displacement	
Individuals displaced	1,577

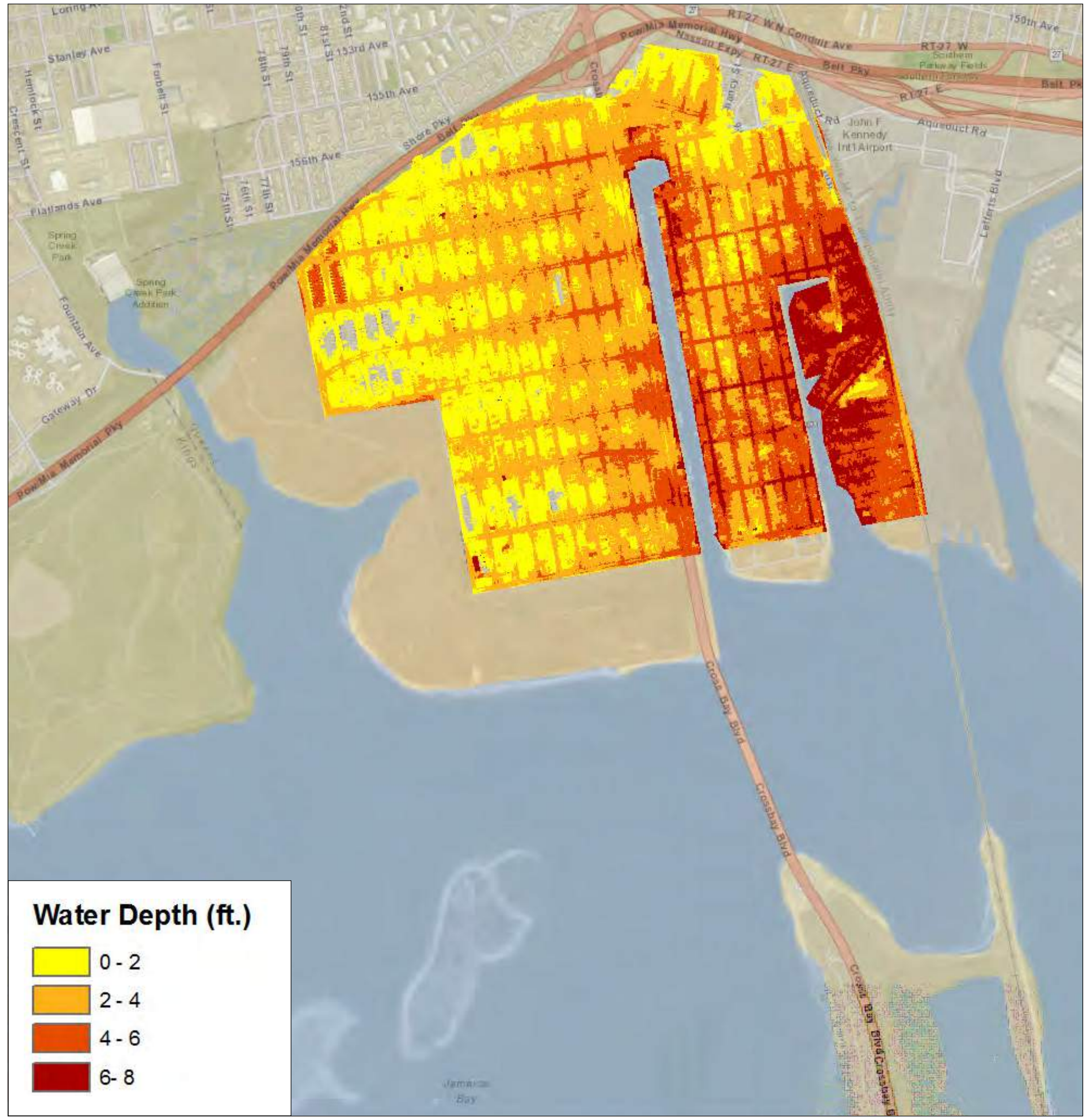


Figure 5-10 Base Scenario: 1-in-100-Year Flood (2050, +12-Inch Sea-Level Rise) Map

Base Case: 100-Year Flood Scenario (2050, +32-Inch Sea-Level Rise)

Associated Economic Losses

Building Loss	$104 million
Content Loss	63
Inventory Loss	11
Relocation Loss	876
Income Loss	14
Rental Income Loss	275
Wage Loss	26
Direct Output Loss	62
Debris Removal	266
Shelter	40
Vehicle Loss	14
Transportation Loss	6
Utility Loss	4
Total Damages	1,761
Avoided Losses	0

Debris	
Tons removed	8,713,416

Displacement	
Individuals displaced	1,633

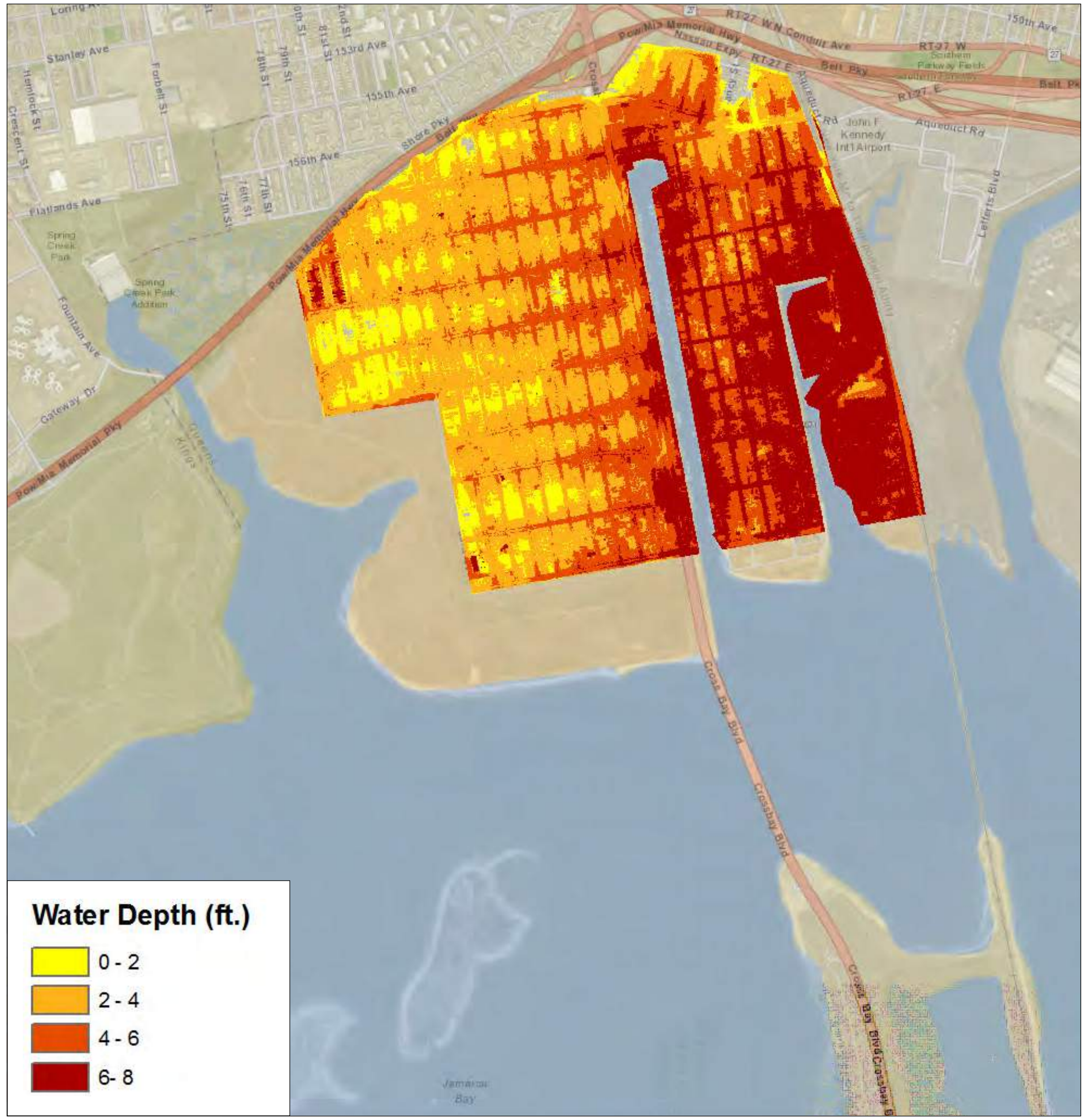


Figure 5-11 Base Scenario: 1-in-100-Year Flood (2050, +32-Inch Sea-Level Rise) Map

Alternative 1: Element Map

Associated Economic Costs

Construction costs	$23.9 million
30% contingency	9.7
25% profit and overhead	6.2
Total capital cost	40.1
Total life-cycle O&M costs	5.1

Figure 5-12 Alternative 1: Element Map

Alternative 1: 100-Year Flood Scenario

Associated Economic Losses

Building Loss	$60 million
Content Loss	27
Inventory Loss	4
Relocation Loss	674
Income Loss	6
Rental Income Loss	208
Wage Loss	11
Direct Output Loss	25
Debris Removal	149
Shelter	35
Vehicle Loss	7
Transportation Loss	3
Utility Loss	3
Total Damages	1,212
Avoided Losses	4

Debris	
Tons removed	4,857,444

Displacement	
Individuals displaced	1,443
Annual ecosystem services benefits	**$1,056,125**

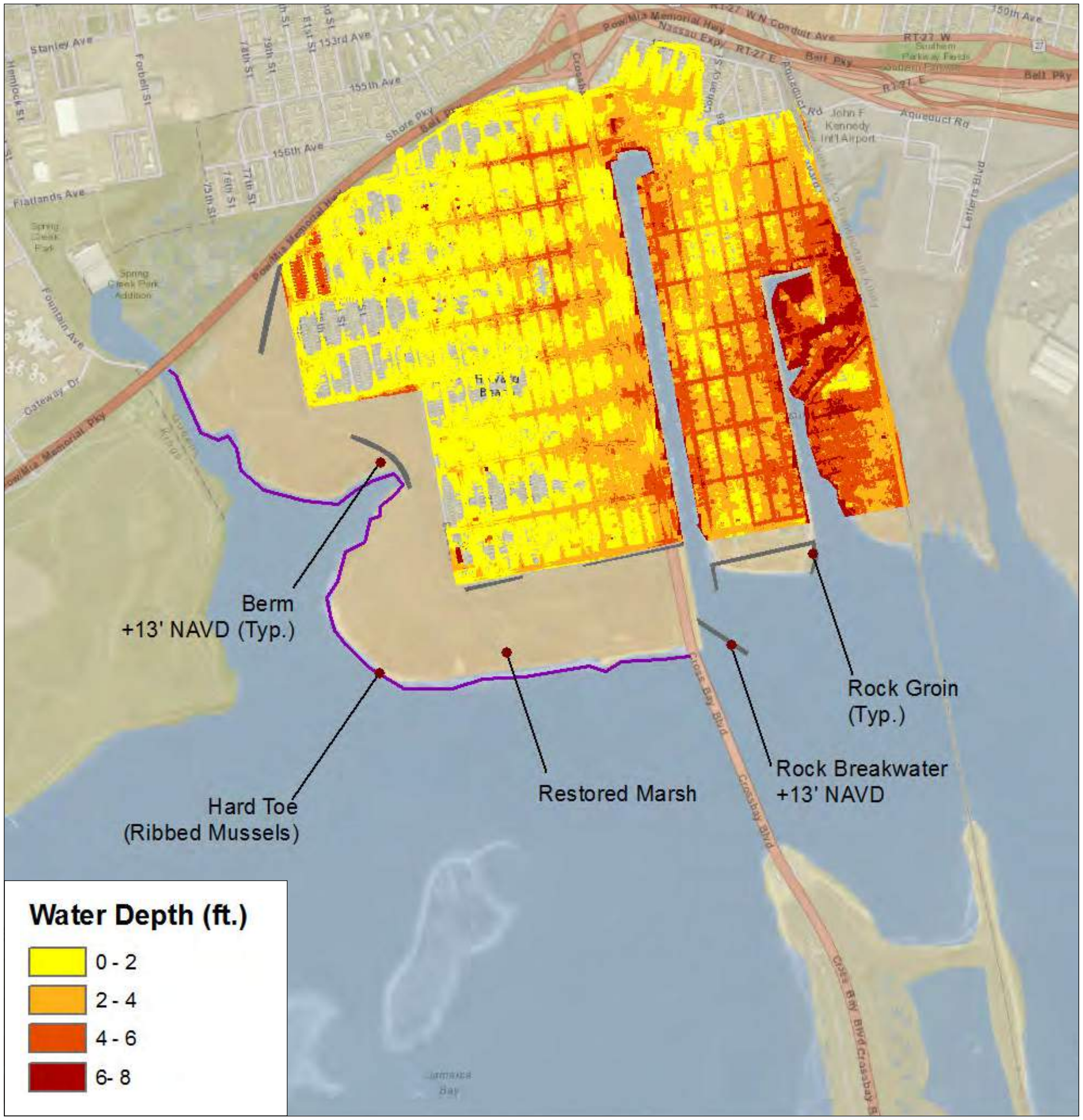


Figure 5-13 Base Scenario: 1-in-100-Year Flood (2050, +32-Inch Sea-Level Rise) Map

Associated Economic Costs

Construction costs	$52.7 million
30% contingency	21.5
25% profit and overhead	13.9
Total capital cost	**88.2**
Total life-cycle O&M costs	**9.1**

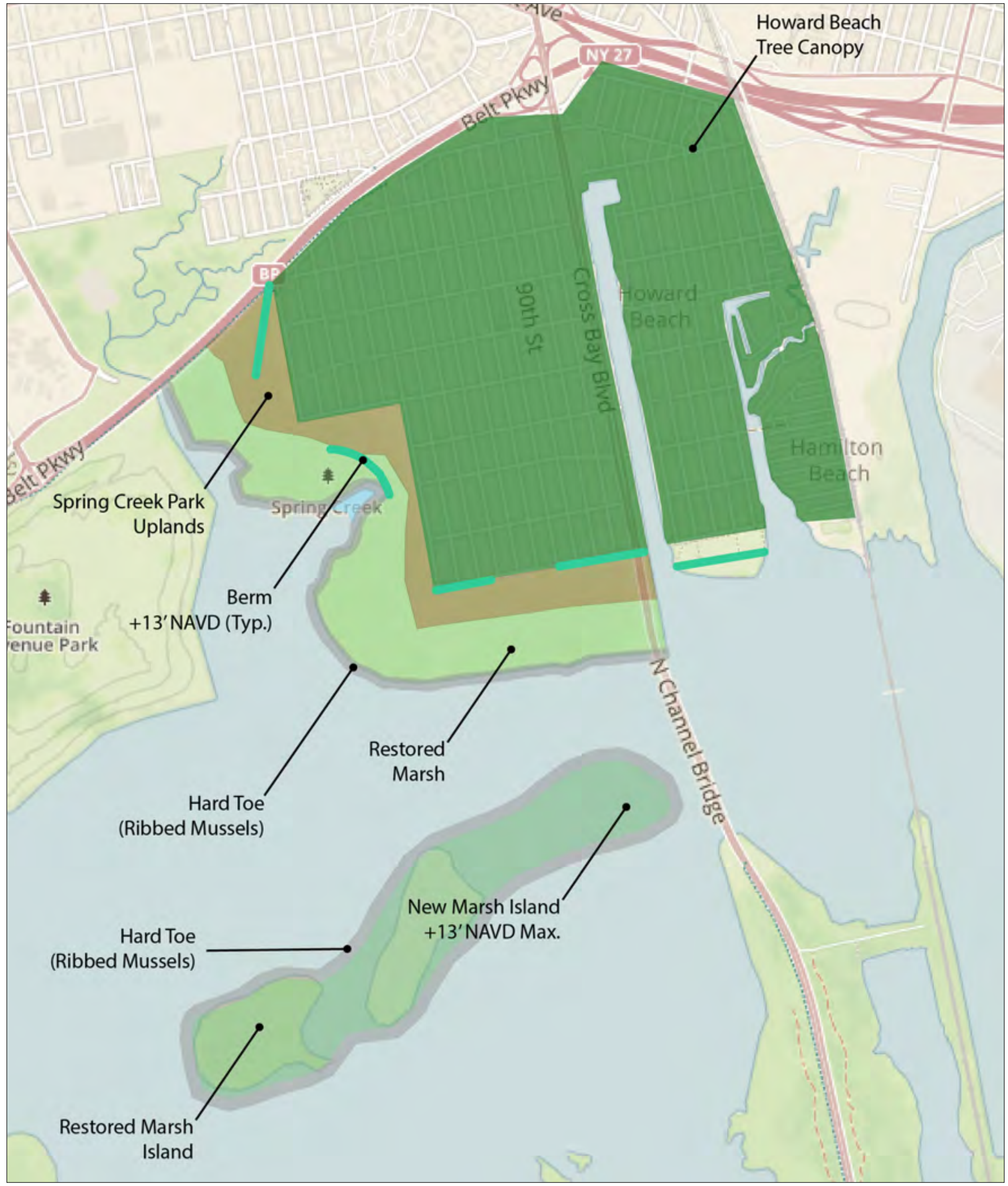


Figure 5-14 Alternative 2: Element Map

Alternative 2: 100-Year Flood Scenario

Associated Economic Losses

Building Loss	$57 million
Content Loss	25
Inventory Loss	3
Relocation Loss	650
Income Loss	6
Rental Income Loss	201
Wage Loss	11
Direct Output Loss	26
Debris Removal	125
Shelter	35
Vehicle Loss	6
Transportation Loss	3
Utility Loss	3
Total Damages	1,151
Avoided Losses	65

Debris	
Tons removed	4,066,011

Displacement	
Individuals displaced	1,443
Annual ecosystem services benefits	**$1,119,120**

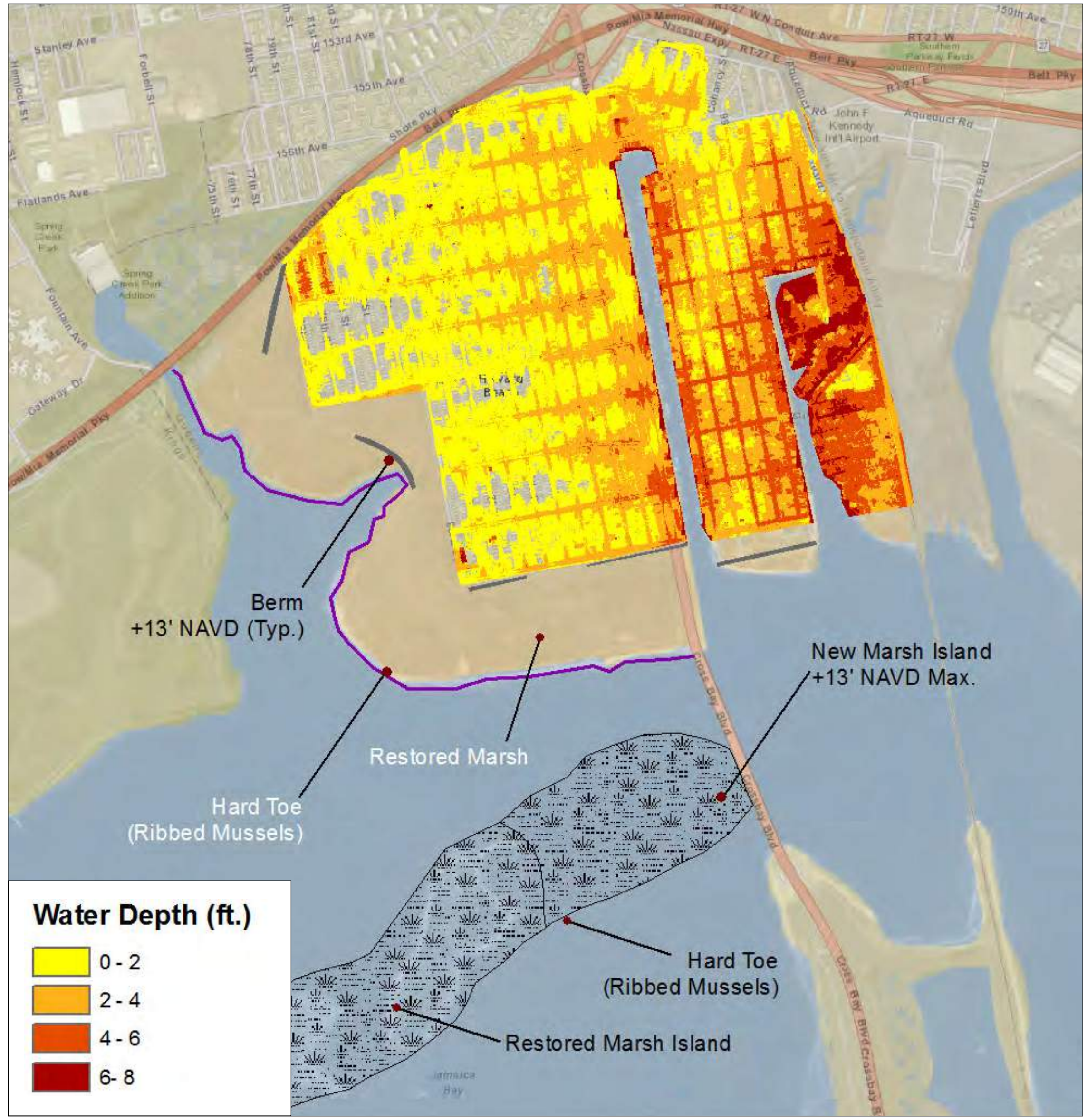


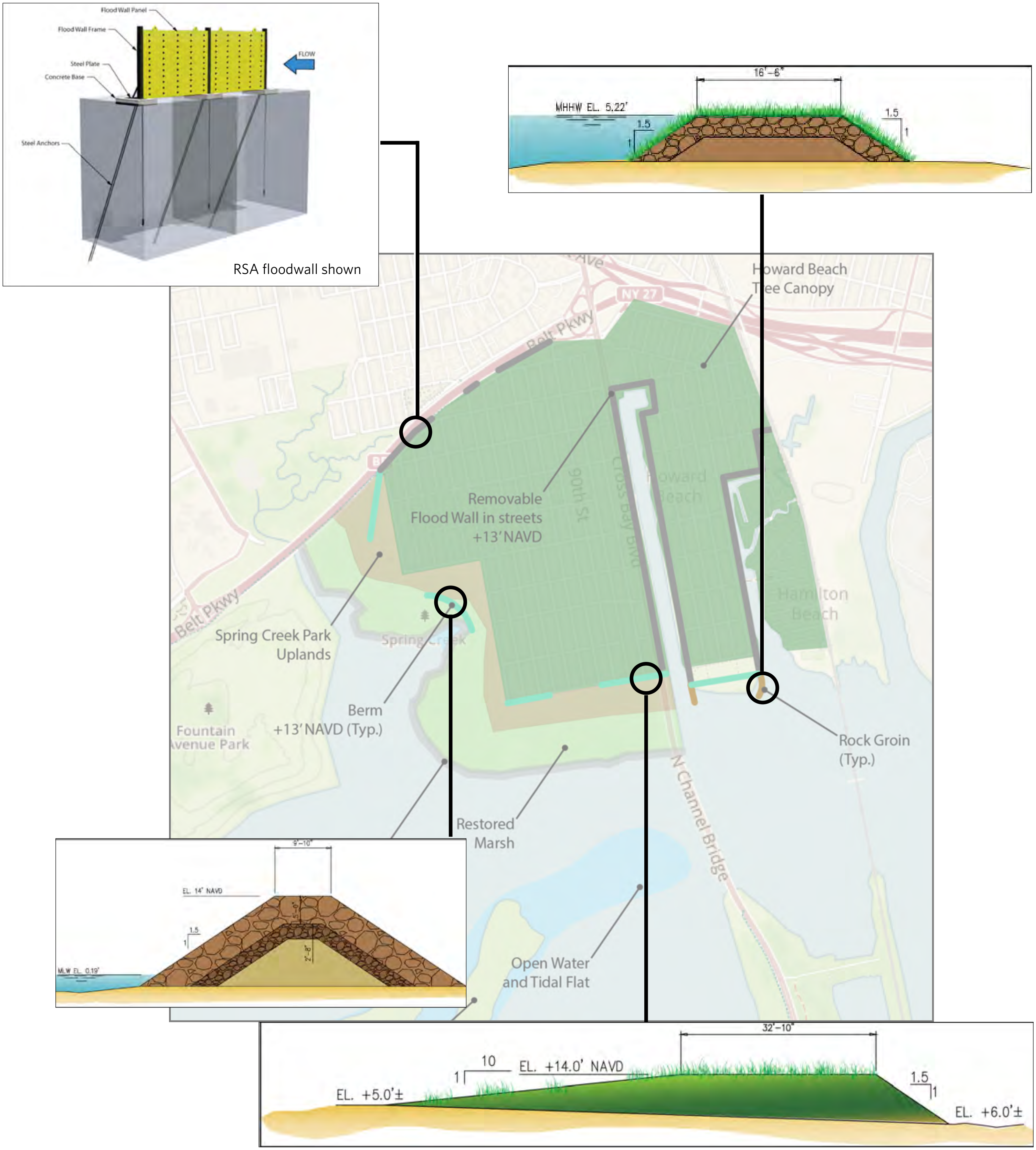
Figure 5-15 Alternative 2: Element Map

Associated Economic Costs

Construction costs	$149.0 million
30% contingency	60.7
25% profit and overhead	39.5
Total capital cost	**249.3**
Total life-cycle O&M costs	**9.1**

Figure 5-16 Alternative 3: Element Map

Figure 5-17 Alternative 3: Element Diagrams



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Associated Economic Losses

Building Loss	$15 million
Content Loss	9
Inventory Loss	2
Relocation Loss	55
Income Loss	2
Rental Income Loss	19
Wage Loss	4
Direct Output Loss	9
Debris Removal	50
Shelter	5
Vehicle Loss	2
Transportation Loss	0
Utility Loss	0
Total Damages	172
Avoided Losses	1,044

Debris	
Tons removed	1,645,630

Displacement	
Individuals displaced	185
Annual ecosystem services benefits	**$1,119,120**

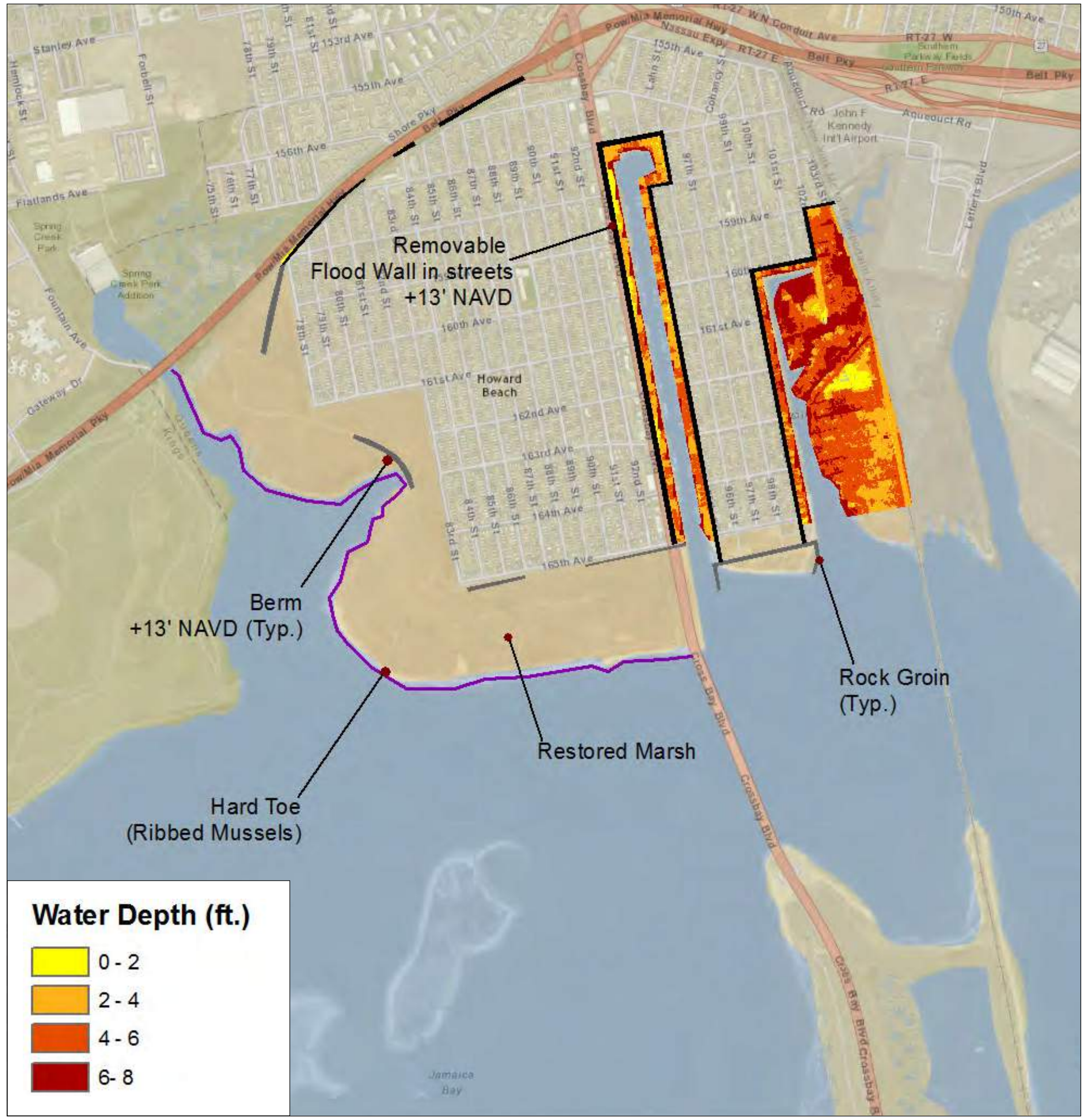


Figure 5-18 Alternative 3: 1-in-100-Year Flood (Present)

Alternative 3: 100-Year Flood Scenario (2050, +12-Inch Sea-Level Rise)

Associated Economic Losses

Building Loss	$17 million
Content Loss	12
Inventory Loss	4
Relocation Loss	54
Income Loss	4
Rental Income Loss	54
Wage Loss	6
Direct Output Loss	14
Debris Removal	54
Shelter	5
Vehicle Loss	4
Transportation Loss	1
Utility Loss	3
Total Damages	232
Avoided Losses	1,207

Debris	
Tons removed	1,749,560

Displacement	
Individuals displaced	186
Annual ecosystem services benefits	**$1,056,125**

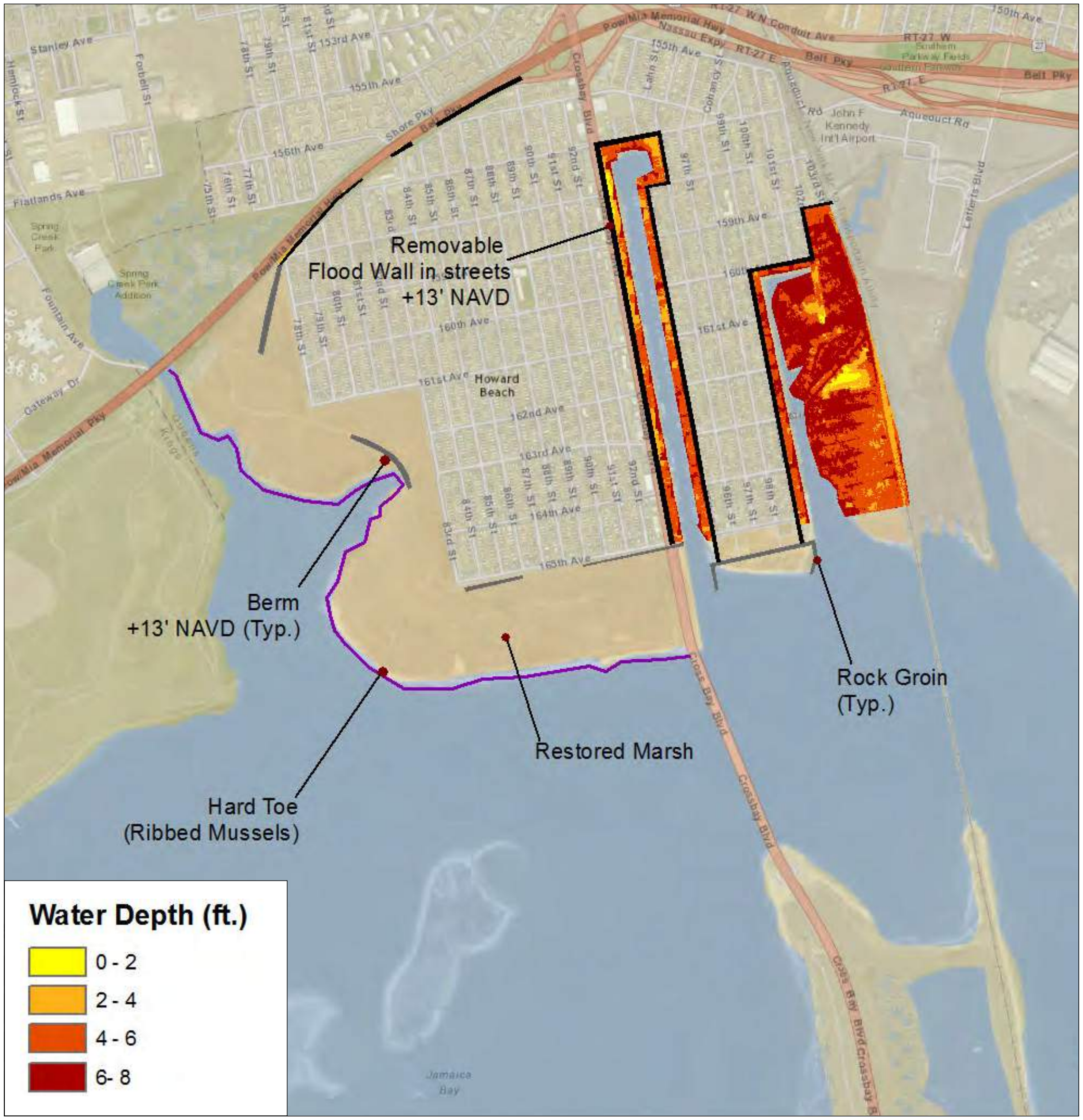


Figure 5-19 Alternative 3: 1-in-100-Year Flood (2050, +12-Inch Sea-level Rise)

Associated Economic Losses

Building Loss	$104 million
Content Loss	62
Inventory Loss	11
Relocation Loss	861
Income Loss	14
Rental Income Loss	268
Wage Loss	26
Direct Output Loss	61
Debris Removal	266
Shelter	39
Vehicle Loss	13
Transportation Loss	3
Utility Loss	4
Total Damages	1,732
Avoided Losses	1

Debris	
Tons removed	8,670,492

Displacement	
Individuals displaced	1,600
Annual ecosystem services benefits	**$1,056,125**

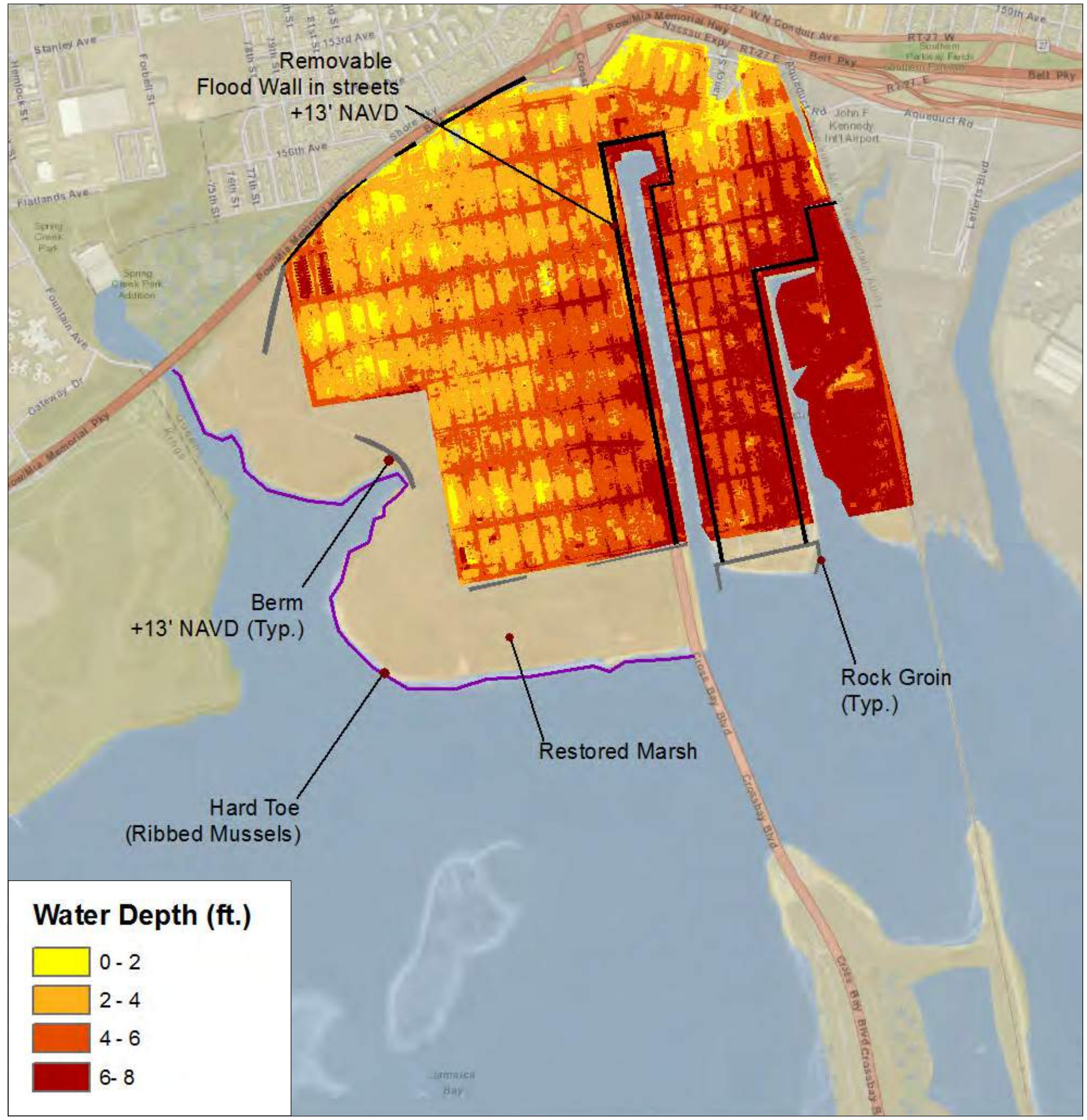


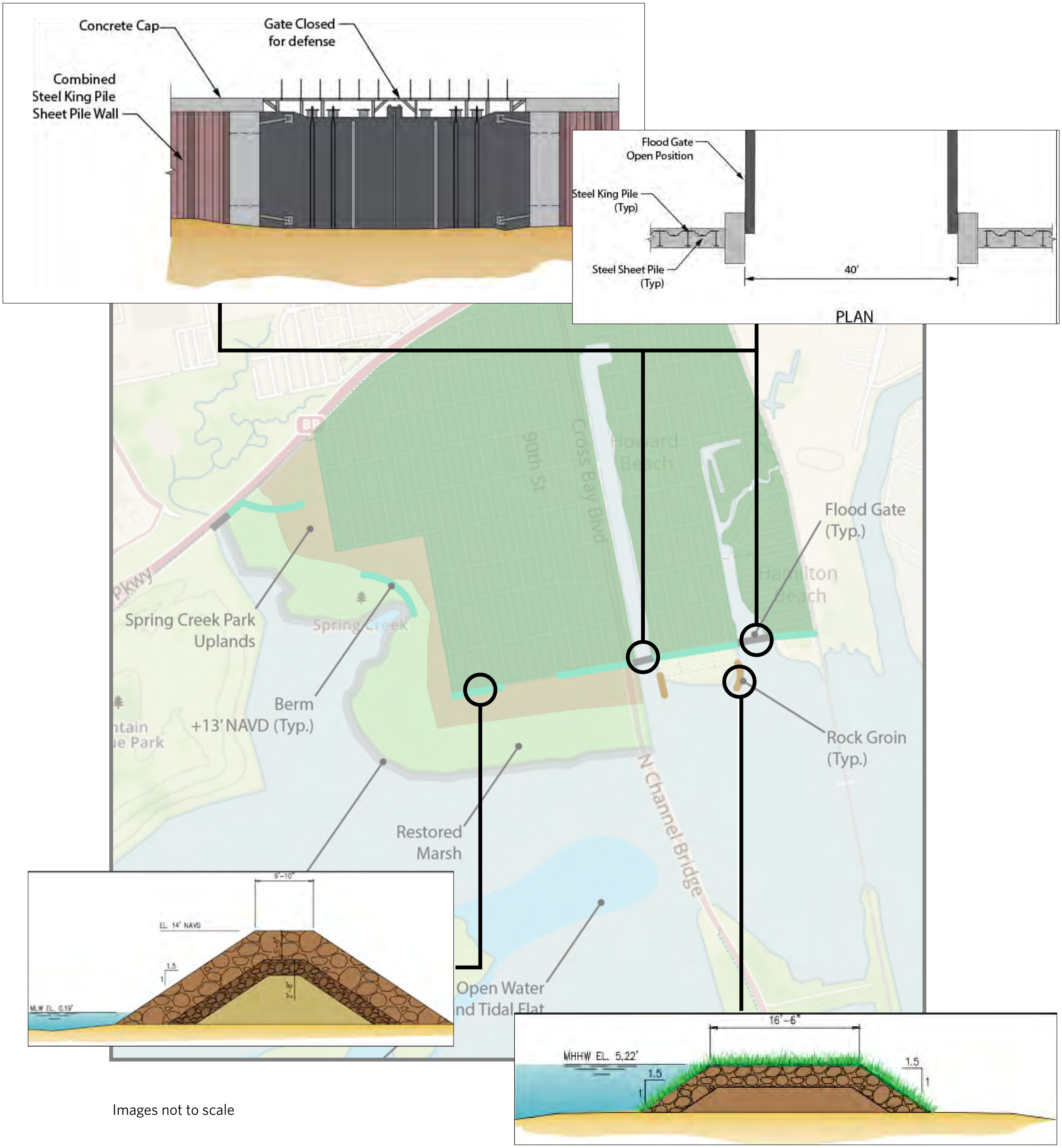
Figure 5-20 Alternative 3: 1-in-100-Year Flood (2050, +32-Inch Sea-Level Rise)

Associated Economic Costs

Construction costs	$45.5 million
30% contingency	18.5
25% profit and overhead	12.0
Total capital cost	**75.9**
Total life-cycle O&M costs	**10.8**

Figure 5-21 Alternative 4: Element Map

Figure 5-22 Alternative 4: Element Diagrams



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Associated Economic Losses

Building Loss	$0 million
Content Loss	0
Inventory Loss	0
Relocation Loss	0
Income Loss	0
Rental Income Loss	0
Wage Loss	0
Direct Output Loss	1
Debris Removal	0
Shelter	0
Vehicle Loss	0
Transportation Loss	0
Utility Loss	0
Total Damages	1
Avoided Losses	1,215

Debris	
Tons removed	4,375

Displacement	
Individuals displaced	4

Annual ecosystem services benefits $1,056,125

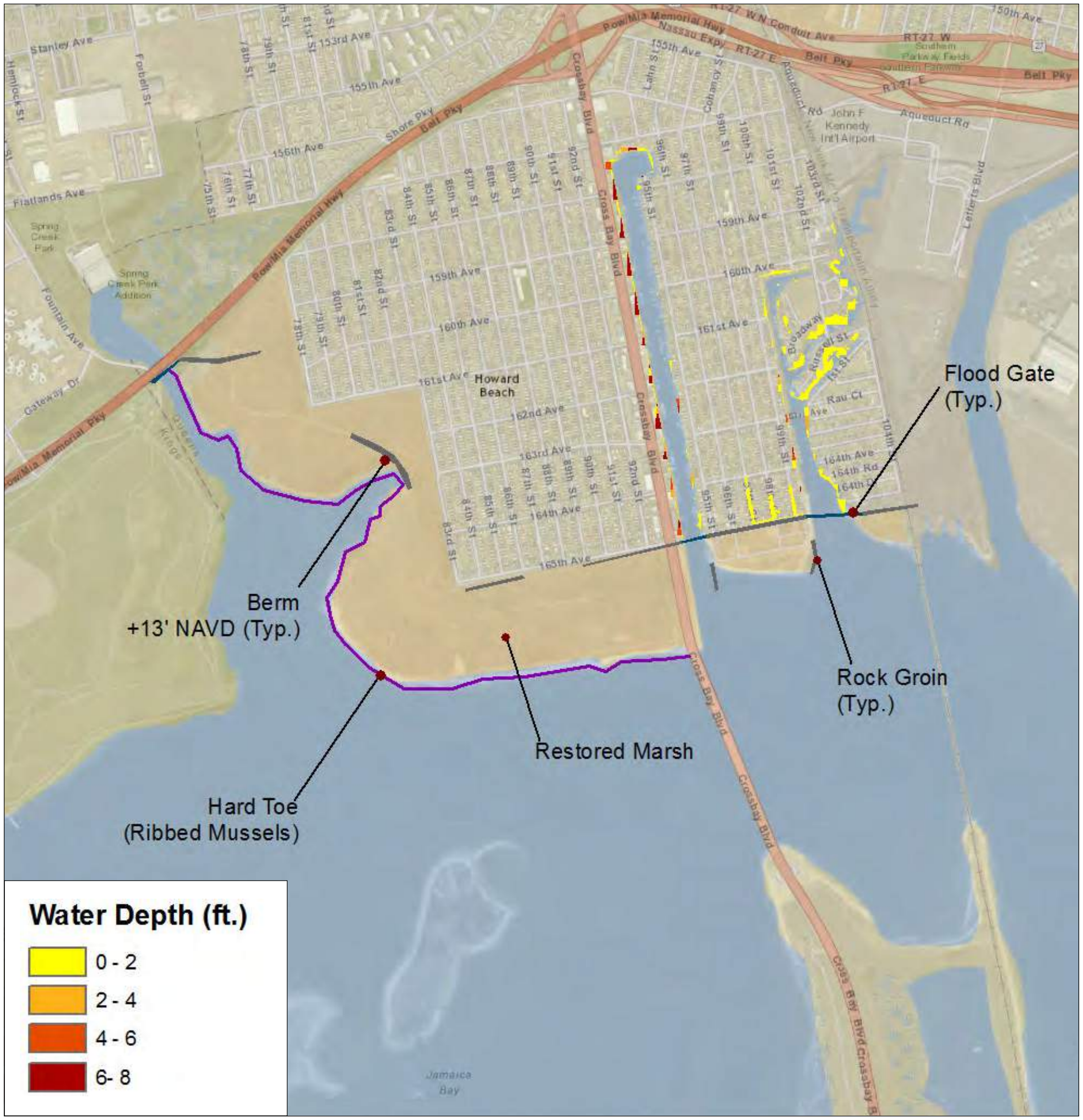


Figure 5-23 Alternative 4: 1-in-100-Year Flood (Present)

Alternative 4: 100-Year Flood Scenario (2050, +12-Inch Sea-Level Rise)

Associated Economic Losses

Building Loss	$71 million
Content Loss	34
Inventory Loss	5
Relocation Loss	767
Income Loss	8
Rental Income Loss	237
Wage Loss	14
Direct Output Loss	34
Debris Removal	161
Shelter	38
Vehicle Loss	8
Transportation Loss	5
Utility Loss	3
Total Damages	1,385
Avoided Losses	54

Debris	
Tons removed	5,239,126

Displacement	
Individuals displaced	1,565

Annual ecosystem services benefits	$1,056,125

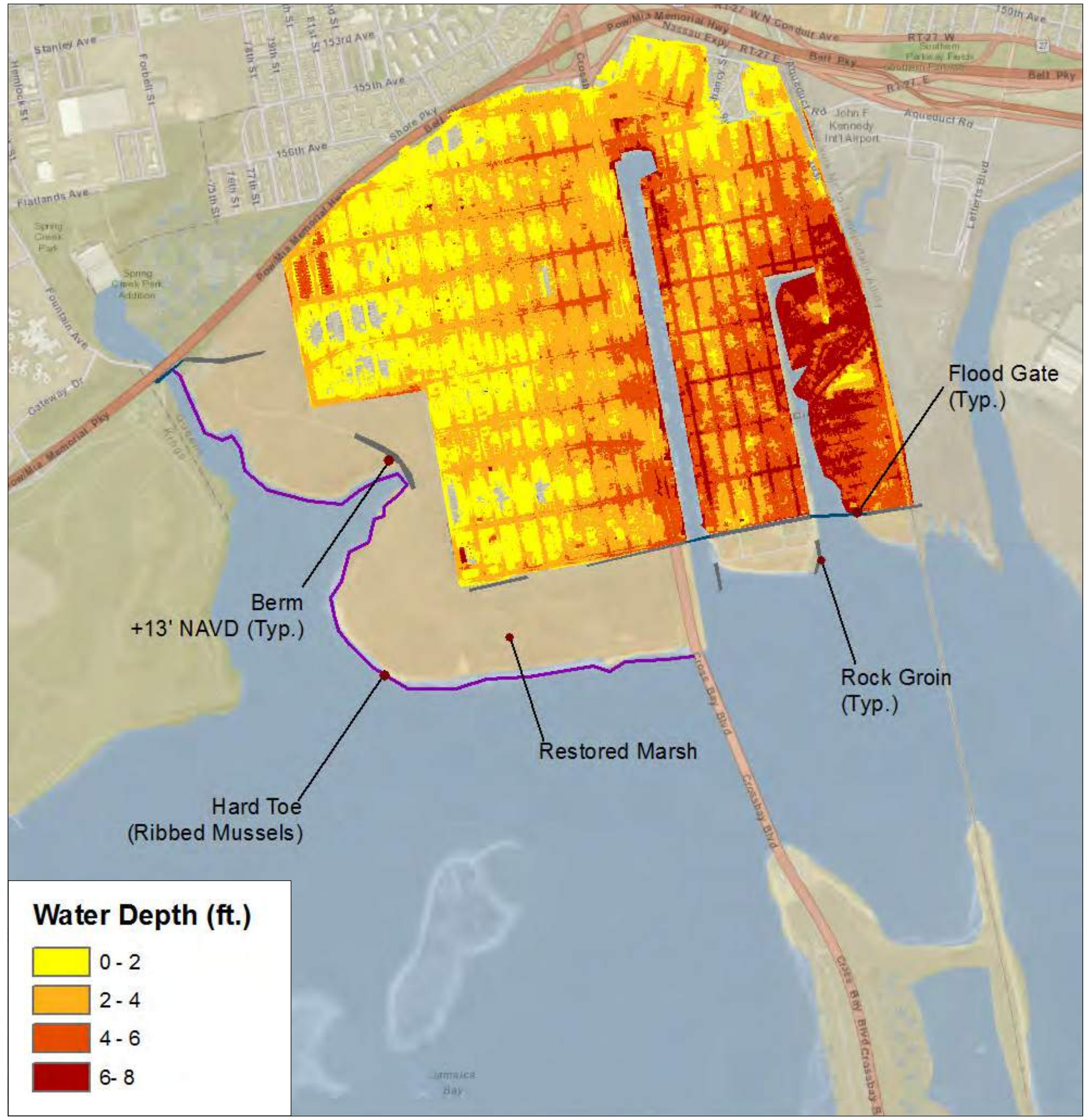


Figure 5-24 Alternative 4: 1-in-100-Year Flood (2050, +12-Inch Sea-Level Rise)

Alternative 4: 100-Year Flood Scenario (2050, +32-Inch Sea-Level Rise)

Associated Economic Losses

Building Loss	$104 million
Content Loss	62
Inventory Loss	11
Relocation Loss	857
Income Loss	14
Rental Income Loss	266
Wage Loss	26
Direct Output Loss	62
Debris Removal	265
Shelter	40
Vehicle Loss	13
Transportation Loss	3
Utility Loss	4
Total Damages	1727
Avoided Losses	6

Debris	
Tons removed	8,643,189

Displacement	
Individuals displaced	1,626
Annual ecosystem services benefits	**$1,056,125**

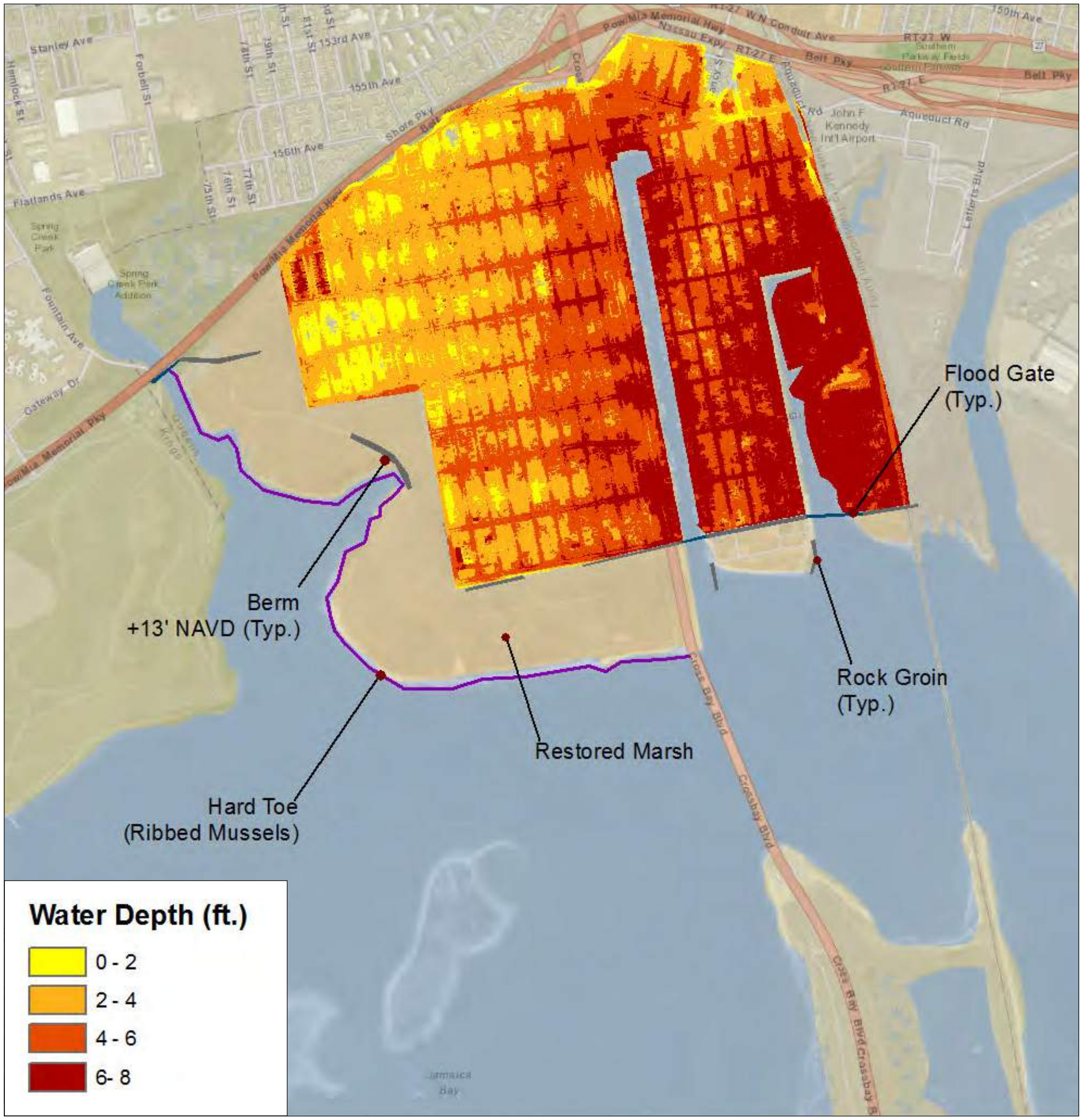


Figure 5-25 Alternative 4: 1-in-100-Year Flood (2050, +32-Inch Sea-Level Rise)

Associated Economic Costs

Construction costs	$58.8 million
30% contingency	15.6
25% profit and overhead	24.0
Total capital cost	**98.4**
Total life-cycle O&M costs	**7.0**

Figure 5-26 Alternative 5: Element Map

Alternative 5: 100-Year Flood Scenario (2050, +32-Inch Sea-Level Rise)

Associated Economic Losses

Building Loss	$108 million
Content Loss	66
Inventory Loss	11
Relocation Loss	878
Income Loss	13
Rental Income Loss	273
Wage Loss	24
Direct Output Loss	58
Debris Removal	272
Shelter	39
Vehicle Loss	14
Transportation Loss	6
Utility Loss	4
Total Damages	1,766
Avoided Losses	0

Debris	
Tons removed	7,499,891

Displacement	
Individuals displaced	1,623

Annual ecosystem services benefits	$0

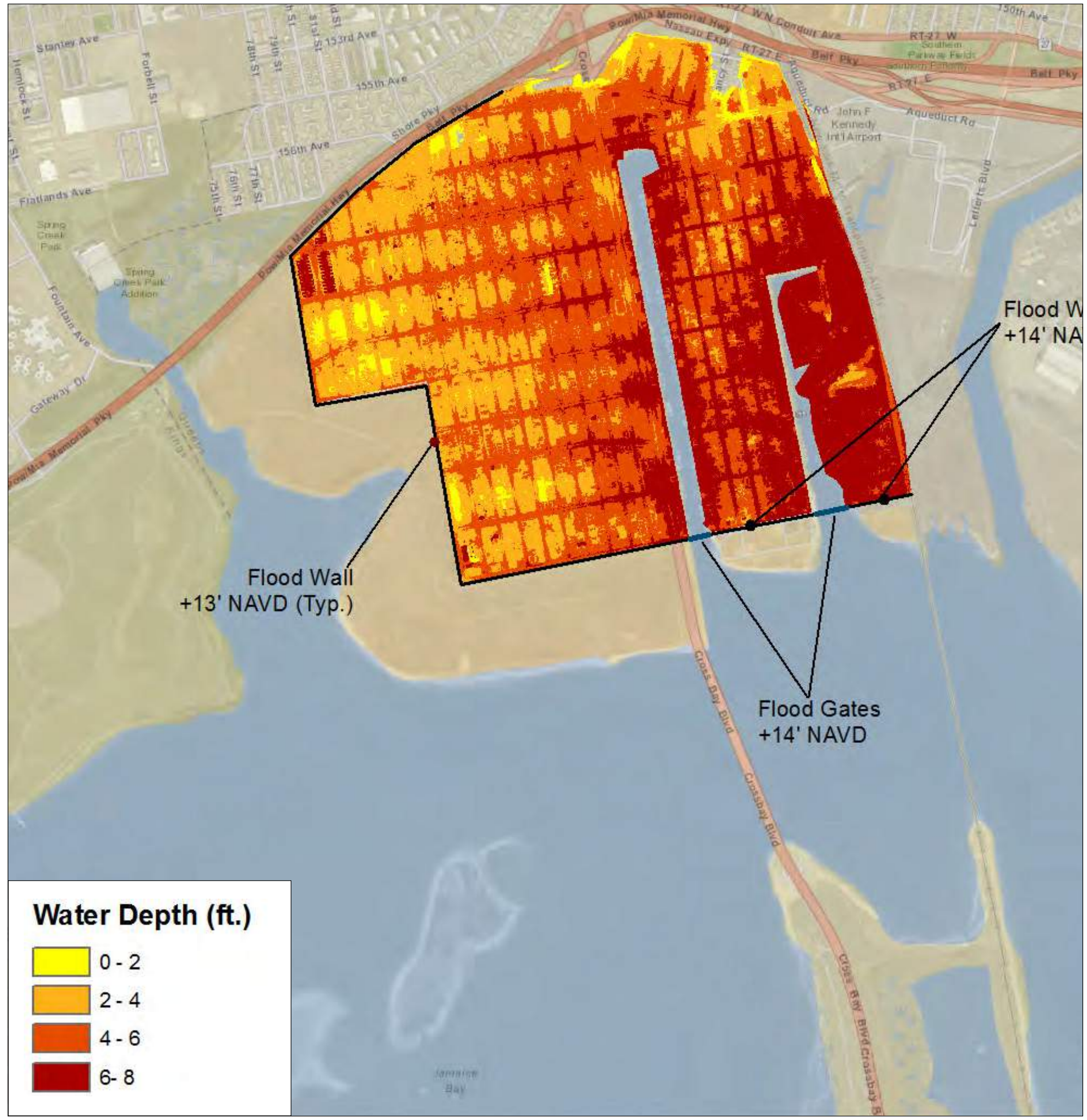


Figure 5-27 Alternative 5: 1-in-100-Year Flood (2050, +32-Inch Sea-Level Rise)

Spring Creek Park © Lauren Alleman/TNC

6. Alternatives Assessment Framework

We undertook an innovative approach to assess the various benefits and costs of each alternative using specific methodologies including cost-benefit analysis and the novel application of habitat equivalency analysis (HEA).

Figure 6-1 and Table 6-1, below, summarize our overall assessment framework and methods. In this chapter, we describe our assessment framework and then describe conventional cost-benefit analysis. We suggest our more comprehensive assessment framework as an expansion of conventional CBA to help better quantify the true costs and benefits of the alternatives.

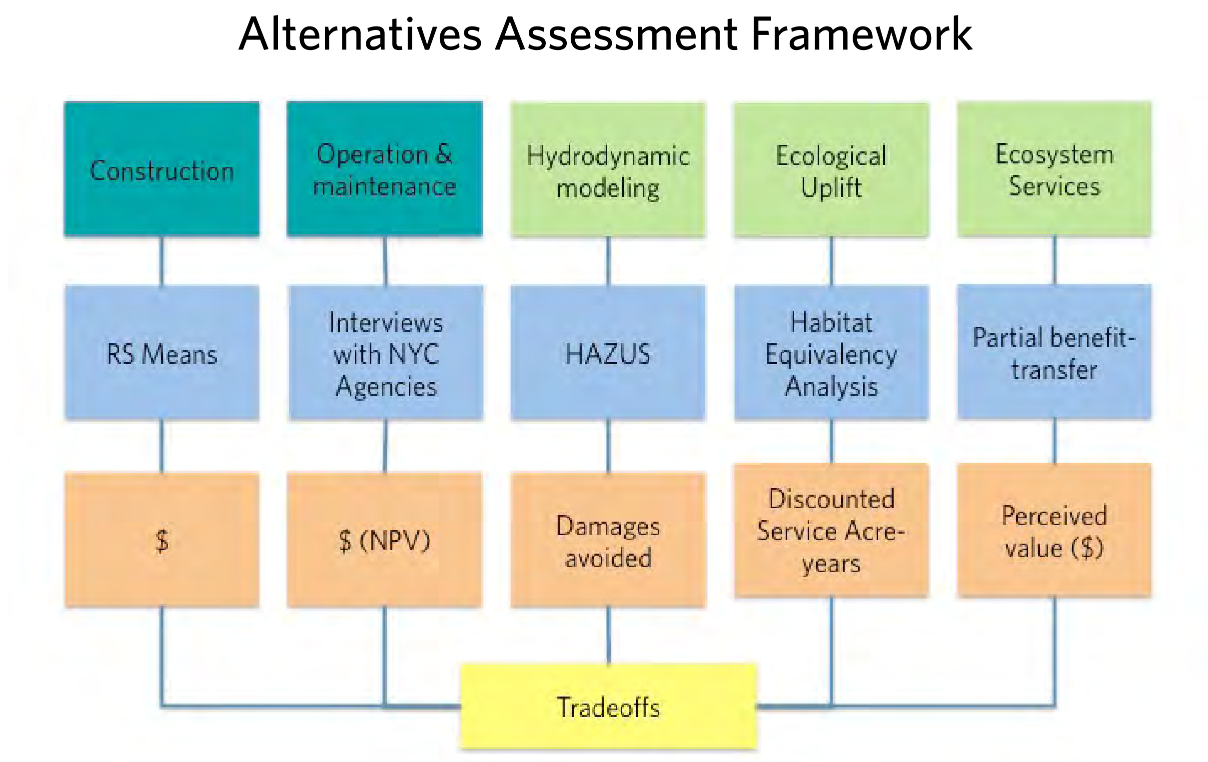


Figure 6-1 Alternatives Assessment Framework

6.1 Cost-Benefit Analysis, Explained

Cost-benefit analysis (CBA) is a set of procedures for defining and comparing the benefits and costs associated with a project or investment. Both benefits and costs are expressed in monetary (i.e., constant dollar value) terms and thus directly comparable. CBA can show whether the value of the expected benefits from a project exceeds the estimated costs, making the project an economically efficient use of resources. A project or program has a net benefit if the net present value (explained below) of the benefits is greater than the net present value of costs.

CBA provides a framework for analyzing data in a logical and consistent way. It yields a quantitative measure of the net benefit of an investment, allowing direct comparisons of dissimilar projects. It also encourages clear thinking about the estimated worth of a proposal relative to what would happen in the absence of the project (i.e., doing nothing)—a difference that can be viewed as the value added.

Thus, CBA helps decision makers answer the following types of questions:

- Does the alternative provide a net benefit to society as a whole?
- Should the proposed project, program, or policy be undertaken?
- Should the project or program be continued?
- Which of various alternative projects or programs should be undertaken?

A CBA provides the decision-maker with quantitative comparisons of options, together with supporting information for any costs and benefits that could not be monetized in dollar terms. CBAs serve to aid decision-making. However, a CBA does not substitute for sound judgment based on a wide range of considerations, such as applicable regulations and the preferences of affected communities.

The approach is limited if it fails to consider the value of ecosystem functions and services, which are often omitted because of the difficulty of expressing them in monetary terms. The omission can skew comparisons of project alternatives. The approach undertaken in this report addresses this limitation in two ways. First, the ecological benefits that accrue from the project alternatives are quantified via habitat equivalency analysis to show trade-offs across alternatives. Second, selected "human use" benefits—the economic value of human activities that use natural resources—are monetized using the benefit transfer method and incorporated into the CBA.

Standardized tools and methods are used to identify costs and benefits. The benefits and costs are expressed in constant dollars and discounted to the present, referred to as the net present value, to account for the time value of money. The stream of discounted costs over time can thus be aggregated and subtracted from the aggregated stream of discounted benefits to yield a single value that expresses the net present value of the alternatives. If a project has a net present value greater than zero, the benefits outweigh the costs. Alternatives can thus be ranked in terms of maximizing net present value, and alternatives with a negative net present value can be eliminated (unless substantial unmeasured benefits or costs would change the conclusions).

Table 6-1 Recommended Assessment Framework: Decision-Making Components

	Methodology	Output	Unit
Cost (C1). Capital investment for infrastructure	Cost estimating	$	$
Cost (C2). Operations and maintenance	Best professional judgment and interviews with practitioners	$	$
Benefit (B1). Flood damages avoided	HAZUS modeling	Net present value of flood damages avoided	$
Benefit (B2). Ecological benefits: nutrient cycling, wave attenuation, habitat provision, primary and secondary productivity, biodiversity, water quality	Habitat Equivalency Analysis	Annualized ecological benefit units	Discounted service acre-years
Benefit (B3). Human uses in salt marsh habitat: recreation, bird-watching	Literature review and benefit transfer analysis	Net present value of benefits	$

6.2 Considerations in Developing a CBA

Since benefits and costs of projects occur through time, the choice of discount rate is an important consideration in CBA development. The discount rate can be thought of as a reflection of how much the public values past or future benefits or losses today. For the purpose of evaluating federal projects and regulations, the U.S. Office of Management and Budget recommends a bounding approach to the discount rate, where 3 percent is the lower bound, representing the social rate of time preference, and 7 percent is the upper bound, representing the social opportunity cost of capital.[7]

The social rate of time preference, as approximated by the long-term U.S. Treasury rate (approximately 3 percent), generally reflects how individuals discount future consumption. This rate would be the uncontested rate for discounting benefits and costs for CBA of projects involving government funds, but it accounts for distortions (e.g., taxes, risk, and imperfect capital markets) in the private market. It has been argued that the social opportunity cost of capital is preferred to the social rate of time preference because funds for government projects have an opportunity cost in terms of forgone investments and therefore future consumption.

Both EPA and the Office of Management and Budget recommend the bounded approach in their guidelines for conducting regulatory impact analysis, including CBA (USEPA 2010), which is the approach we have included here. For transparency, EPA also recommends displaying the undiscounted time path of benefits and costs.[8]

6.3 Net Present Value and Time Period of Analysis

Net present value (NPV) calculations involve the aggregated or total sum of discounted annual benefits minus the aggregated sum of discounted annual costs. The same discount rate must be used for both benefits and costs because nearly any policy, program, or action might be justified if one chose a sufficiently low discount rate for benefits or sufficiently high discount rates for costs.

The benefits and costs need to be placed properly in time, accounting for time to implement an action and for the consequences of the action to occur. The placement of benefits and costs in time will affect the results of the net present value calculations.

The time period of the analysis depends on two primary factors:

- the life of the capital investments, including replacement capital; and
- how long the stream of benefits is expected to flow absent additional investments to maintain the project.

For the Howard Beach alternatives, the design period is 50 years. As discussed above, discount rates of 3% and 7% are recommended for the NPV calculations.

6.4 Uncertainty in Costs and Benefits

Even with the best available engineering and science, some uncertainty will always remain about how both gray and nature and nature-based infrastructure perform over time. There is also uncertainty about how natural ecosystems will respond to disturbance and how much maintenance will be needed to maintain the desired function. While determining costs and benefits of the alternatives, we made several assumptions, such as representing several parameters by single-value estimates instead of a wide range of estimates reflecting their inherent variability. Although it was outside the scope of this study to perform sensitivity analysis, uncertainty analysis, or risk assessment, such analyses would account for the uncertain nature of input variables so that decisions could be made in awareness of the degree of reliability of the estimates and the effectiveness of the alternatives.

Waves during Hurricane Sandy © Stephen Bonk/iStock Photo

7. Hydrodynamic Modeling

This section presents the hydrodynamic modeling that was undertaken to assess flooding for the alternatives under present-day conditions and future sea-level rise scenarios. The results produced here are used as inputs to assess the avoided flood damages (Section 8).

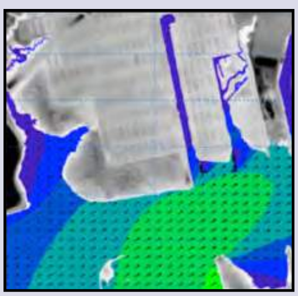
A coupled hydrodynamic and wave model was developed to simulate along-shore variations in water levels, currents, and waves in Jamaica Bay. The model was calibrated to match the 100-year FEMA advisory base flood elevation at Howard Beach, during the previous phase of the work.

The wave model uses the MIKE21 Spectral Wave (DHI 2012a) module to simulate the propagation and transformation of offshore waves to the nearshore area. This third-generation spectral wind-wave model simulates the growth, decay, and transformation of wind-generated waves and swells in offshore and coastal areas. It includes mechanisms for nonlinear wave-wave interaction, dissipation due to white-capping, bottom friction, depth-induced shoaling and wave breaking, refraction, wave-current interaction, and the effect of time-varying water depth. The model uses a flexible mesh, which allows for coarse spatial resolution for offshore areas and higher-resolution near areas of interest, and is thus particularly applicable for simultaneous wave analysis at both regional and local scales.

The hydrodynamic model uses the MIKE21 Hydrodynamics module (DHI 2012b). It also has a flexible mesh and solves the two-

Hydrological Modeling

MIKE by DHI



- Storm surge
- Wave/wind calculations
- Water depths
- Bathymetry
- Topography
- Develop hydrodynamic characteristics of 1-in-100 year storm
- Apply hydrodynamic input to alternatives

Water Depth Flood Analysis

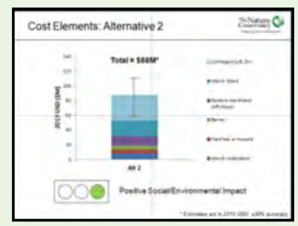
Flood Modeller

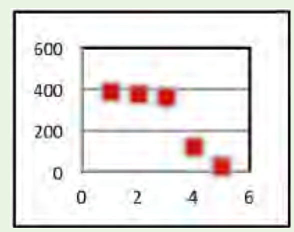
- Develop extent of coastal flooding and upland flood depths

Demographic & Economic Losses

- 2010 Census
- City parcel data
- Physical damage
- Economic loss
- Transportation loss
- Utility loss
- Debris removal costs
- Social impact

Cost/Benefit Analysis





- Cost estimates
- Cost benefits
- Avoided cost
- Economic analysis

Figure 7-1 Modeling Methodologies for Flood Model dimensional, depth-integrated shallow-water equations of continuity and momentum, as well as transport equations for salinity and temperature. The equations are spatially discretized using a cell-centered finite volume approach on the triangular (flexible mesh) elements.

The flood model is the Flood Modeller software suite, developed by Halcrow[9], a CH2M Hill company. Predicted water-level time series along the project frontage serve as an input to the Halcrow Flood Modeller, which propagates the floodwater inland and produces flood extent and depth mapping on Howard Beach.

The steps below describe the chronological order taken to provide detailed information of the steps taken to build the flood model. Figure 7-1 gives an overview of the modeling methodologies and software used in the development of the flood model.

1. Build a numerical model that includes New York City bathymetry (underwater contours) and Howard Beach site topography.
2. Back-calculate the open-water storm surge height for 1-in-100-year flood elevations using the FEMA's advisory base flood elevations map for Jamaica Bay, excluding contributions from wind and wave setup and from wave run-up.
3. Develop the open-water peak storm surge elevation based on actual storm surge measurements at The Battery and Jamaica Bay, scaled to match 100-year storm surge predictions.
4. Estimate the 1-in-100-year return period wind from observed wind records at nearby airport weather stations (JFK International, La Guardia, Islip).
5. Run the hydrodynamic model (using MIKE21 Hydrodynamics module; see Section 7 for details) to determine the surge in Jamaica Bay and at Howard Beach. Compare the results with FEMA's surge level predictions (item 2) to verify model accuracy.
6. Run the Halcrow Flood Modeller to determine flooding extent and depths at Howard Beach.
7. Compare predicted flood elevations (item 6) with flood levels given in the FEMA map (item 2) to verify model accuracy.

7.1 Water Levels

Water-level variations at the project site result from the combination of regular and periodic tidal variation, infrequent storm surge, wind and wave effects, and long-term sea-level rise.

Tides

Daily tidal fluctuations at the project site are semidiurnal, with two highs and two lows per day. The nearest NOAA NDBC tidal benchmark station is #8531680, located at Sandy Hook, New Jersey (Lat: 36° 56.8 N, Lon: 76° 19.8 W) (Figure 7-2).

Table 7-1 shows the tidal planes for the Sandy Hook station from the 1983 to 2001 tidal epochs. The mean daily tidal range is approximately 1.43 meters. The 1929 National Geodetic Vertical Datum (NGVD 29) is approximately 0.27 meters below the mean sea level.

Storm Surge

Storm surge is an increase in the water level above the mean caused by a wind field that

Table 7-1 Tidal Planes for NOAA NDBC Station #8531680, Sandy Hook

Tidal plane	Relative to mean low water (meters)
Mean high water	1.59
Mean high water	1.49
NAVD 88	0.86
Mean sea level	0.79
NGVD 29	0.52
Mean low water	0.06
Mean low water	0.00

drives the water shoreward over an extended period of time. Storm surge during hurricanes may be enhanced by lower atmospheric pressure. The surge heights offshore Howard Beach at Point Lookout were inferred from a comparison of measured water levels at The Battery and Inwood stations (Figure 7-2). Colle et al. (2010) summarize moderate surge events (surges of less than 1 meter) in the New York City area from 1959 to 2007 (Appendix D). Coincident measured water levels were available only at these three stations for the last moderate surge event, in 2005 (Figure 7-3). The data show that measured tide and surge are comparable between The Battery and Inwood stations. Predicted extreme surges at The Battery station can therefore be scaled to 10-year, 25-year, and 100-year return period surges by using the scale factor between measured water levels at the Point Lookout and Inwood stations. Figures 7-4 and 7-5 show surge, tide, and total water-level time series used to derive coupled hydrodynamic and wave model boundary conditions for the 100-year return period storm condition at The Battery and Point Lookout stations. The maximum surges are approximately 1.5 and 2.2 meters at The Battery and Point Lookout boundaries, respectively.

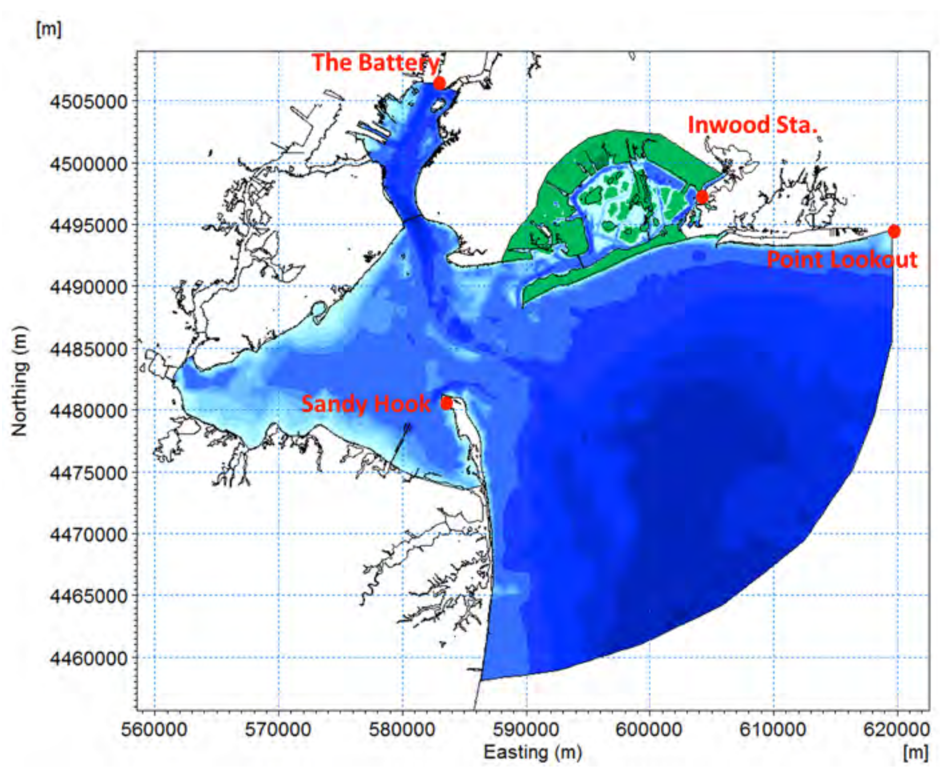


Figure 7-2 Locations of Water Level Stations

Point Lookout, Inwood and The Battery Tide Gauge Stations

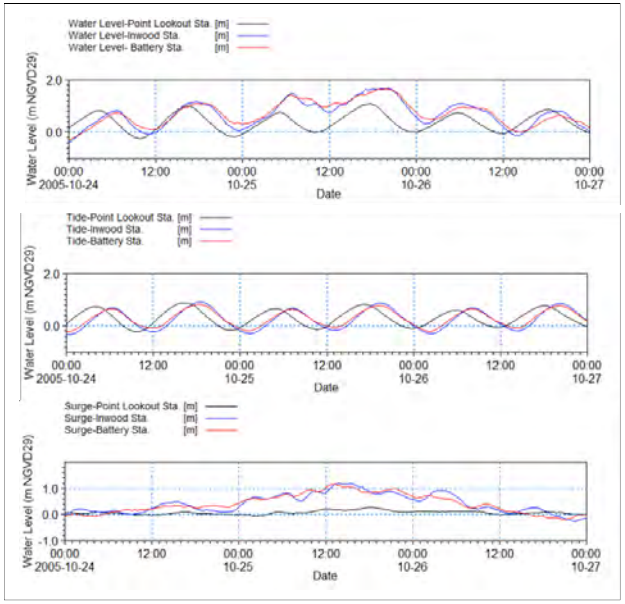


Figure 7-3 Measured Total Water-Level (Top), Tide (Middle) and Surge (Bottom) at Point Lookout, Inwood and The Battery Stations, October 24–27, 2005.

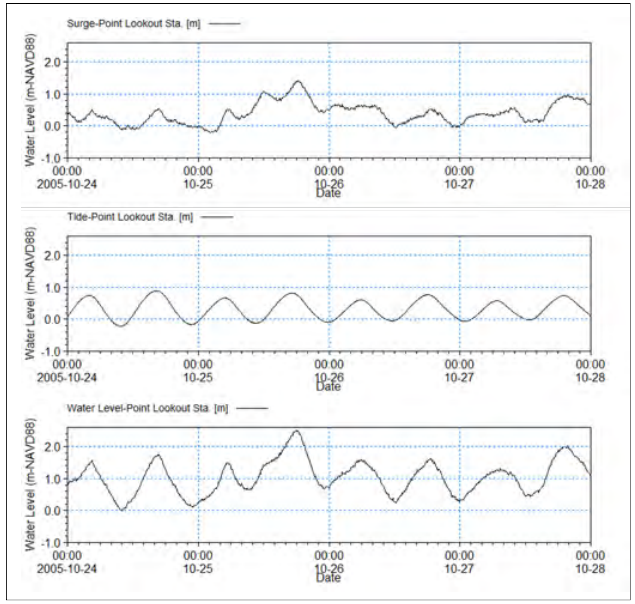


Figure 7-4 Surge (Top), Tide (Middle) and Total Water Level (Bottom) for 100-Year Return Period Storm Condition at Point Lookout Station

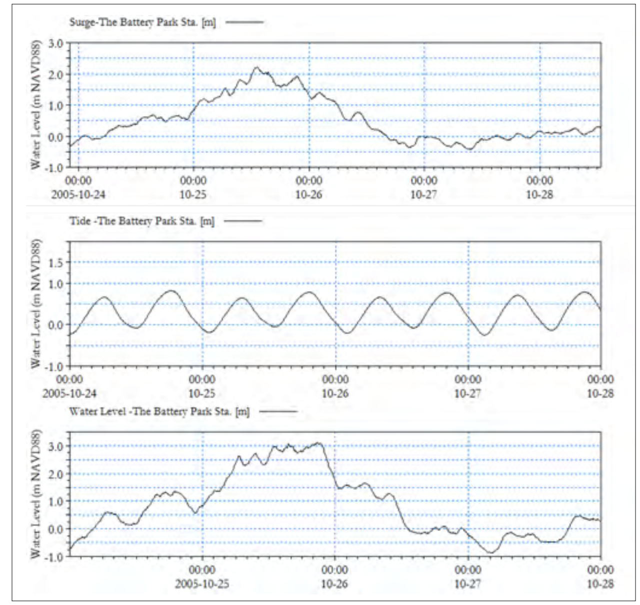


Figure 7-5 Surge (Top), Tide (Middle) and Total Water Level (Bottom) for 100-Year Return Period Storm Condition at The Battery Station

Sea-Level Rise

Long-term sea-level rise is the combined effect of the eustatic (i.e., global average) sea-level increase due to global warming, combined with land subsidence in a particular region. The Long Island shoreline is subsiding because of geological processes. Therefore, the net relative sea-level rise at the study area is higher than the eustatic sea-level rise. The future sea-level rise for the project site comes from the New York City Panel on Climate Change (2013) report, which projects a midrange of 11 to 24 inches and a high estimate of 32 inches by the 2050s, using 2000–2004 as a baseline. Therefore, for the 50-year design life of any new gray infrastructure (i.e., 50 years from today, 2065), the estimates used in the modeling scenarios are 12 inches (0.3 meter) and 32 inches (0.8 meter).

Extreme Wind Data

Extreme wind speed values for various return periods come from the database compiled by the U.S. Department of Commerce at 129 airport stations in the contiguous United States that have reliable wind records for consecutive years (U.S. Bureau of the Census, 1979). Wind data for 1947–1977, collected at the La Guardia Airport weather station were corrected to 10-meter anemometer elevation by the U.S. Department of Commerce and did not require any additional correction. Table 7-2 presents omni-directional extreme wind speeds for the 10-year, 25-year, and 100-year return period conditions.

Table 7-2 Extreme Wind Speeds at La Guardia Airport, New York

Return period (years)	Wind speed (meters/second)
10	26.7
25	28.5
100	32.5

7.3 Model Domain and Hydrodynamic Model Simulation Results

The model domain used in this study represents the existing conditions at Howard Beach and in Jamaica Bay. The model covers the entire New York–New Jersey Harbor approximately 30 kilometers seaward from the Rockaway Peninsula, including Jamaica Bay (Figure 7-6). The model bathymetry comprises water depth information from the MIKE C-MAP and DEM from the U.S. Army Corps of Engineers. A two-dimensional flexible

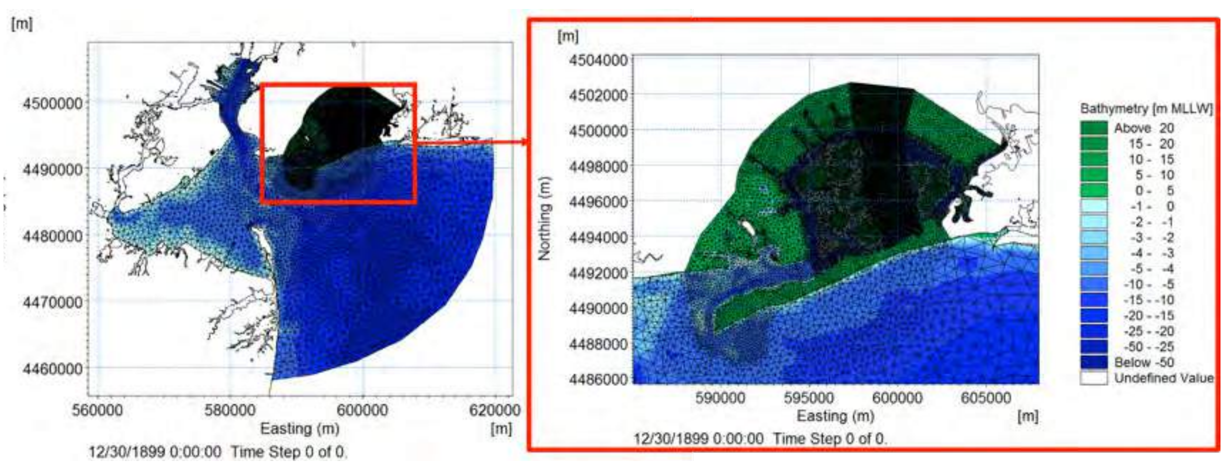


Figure 7-6 Hydrodynamic Model Domain with Computational Mesh

mesh, depth-averaged grid represents the project area with 50,786 elements and 25,758 nodes. The resolution of elements progressively increases shoreward. The hydrodynamic model has two water-level boundaries, The Battery (northwest) and Point Lookout (southeast).

The base case scenario was analyzed for the full range of conditions: 10-year, 25-year, and 100-year storms with no ice melt, with 12 inches of sea-level rise, and with 32 inches of sea-level rise (Table 7-3). In addition, each alternative was evaluated for the current 1-in-100-year storm with no sea-level rise. Since Alternatives 1 and 2 were found to be largely ineffectual in preventing flooding in the current condition, they were not modeled with sea-level rise. Alternatives 3, 4, and 5 were analyzed with for 1-in-100-year storm with sea-level rise to determine the level of protection that they would provide. Maps depicting the hydrodynamic model simulation results for the base case and Alternatives 1–5 are presented with avoided losses, quantified using HAZUS, in Section 5.

Overall, Alternative 5 reduces Howard Beach's flood risk significantly more than Alternatives 1, 2, or 3. The level of protection is comparable with that of Alternative 4 under the present-day conditions, with no flooding. Under the 12-inch sea-level rise scenario, Alternative 5 performed better than the other alternatives, preventing flooding. Under the 32-inch sea-level rise scenario, performance was broadly the same as other options, with the entire project area being inundated.

Table 7-3 Scenarios Modeled

	Current conditions			No ice melt, +12 inches sea-level rise			Rapid ice melt, +32 inches sea-level rise		
	10-year storm	25-year storm	100-year storm	10-year storm	25-year storm	100-year storm	10-year storm	25-year storm	100-year storm
Base case	✔	✔	✔	✔	✔	✔	✔	✔	✔
Alt 1			✔						
Alt 2			✔						
Alt 3			✔			✔			✔
Alt 4			✔			✔			✔
Alt 5			✔			✔			✔

Property damage after Superstorm Sandy, Howard Beach, Queens © Pam Andrade/Flickr via a Creative Commons license

8. Flood Damages Avoided

The cost-benefit analysis included the value of flood damages avoided for each alternative.

HAZUS produces loss estimates for direct economic loss including building loss, content loss, inventory loss, relocation loss, income loss, rental income loss, wage loss, and direct output loss; number of impacted structures; debris generation; shelter requirements; vehicle loss; and bridge loss. Debris removal costs, shelter costs, utility loss and road loss were also calculated using available datasets.

To help calculate the economic impacts for the different Alternatives at Howard Beach in terms of flood risk reduction, the HAZUS software was used together with local vulnerability data and the results from the hydrodynamic model (as described in Section 7). The 100-year flood was assessed under present day and future sea-level rise scenarios to determine flood damages avoided.

Losses not included in the total economic loss values are induced losses such as debris removal and shelter needs. HAZUS models debris estimates for different kinds of structural debris. To calculate loss, a value of cost per cubic yard was identified from previous events. The U.S. Army Corps of Engineers uses an average cost of $46/cubic yard (Lipton 2013).

HAZUS also models the shelter requirements required after the scenario in terms of number of people requiring shelter. During Superstorm Sandy, 3,000 people required shelter, which cost the city $73 million (Blau et al. 2013), or $24,333 per person.

8.1 HAZUS Modeling

The Federal Emergency Management Agency developed HAZUS, a freely available geographic information system (GIS) software, as a standardized risk assessment methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes. HAZUS estimates the physical, economic, and social impacts of disasters. It graphically illustrates high-risk locations and helps users visualize the spatial relationships between populations and other more permanently fixed geographic assets or resources for the hazard being modeled. It also allows the user to import inundation depths produced from other models.

The HAZUS analysis for the resilience alternatives used detailed local data in order to obtain accurate potential economic losses. Out of the box, HAZUS calculates losses at the Census Block level, using an area-weighted analysis. HAZUS assumes the buildings are evenly distributed across the Census Block so that if half of the Census Block is inundated, then half of the buildings are assumed to be impacted. To overcome this limitation, our analysis was run at the site level, such that every structure was modeled independently (Appendix C). The site-level data were then used to update the Census Block information to obtain more accurate debris, vehicle, and shelter loss estimates. The demographic data in HAZUS were also updated to 2010 Census figures.

The hydrodynamic modeling results from the base case and the five alternatives were integrated into the software to produce loss estimates for each alternative and scenario combination. HAZUS uses the depths in the inundation models, along with depth-damage functions corresponding to different types of infrastructure, to determine the loss. These depth-damage functions also vary by flooding: the V zone has waves of 3 feet or higher, coastal A zone has waves of 1.5 to 3 feet, and A zone, inland areas subject to 100-year flooding.

8.2 HAZUS Results

HAZUS results are summarized in Tables 8-1 to 8-3. Considering flood risk alone, the results indicate that Alternatives 4 and 5 offer the highest levels of flood risk reduction to the community and avoid comparable levels of damages. Under the present-day 100-year flood, these alternatives provide complete protection to the neighborhood, avoiding all potential losses.

For the 12-inch sea-level rise scenario, Alternative 3 does not prevent flooding of Howard Beach. Alternative 5 experiences no losses under this scenario. Alternative 4 involves significantly greater losses compared with Alternatives 3 and 5, with flooding via the Belt Parkway to the north of the project area; constructing defenses adjacent to the Belt Parkway would reduce flooding via this pathway.

For the 32-inch sea-level rise scenario, none of the alternatives avoid losses altogether.

Alternatives 1 and 2 were not modeled for sea-level rise because they failed to reduce risks under current flooding conditions and thus would also fail with any increases in sea-level.

Although Alternative 5 offers the highest level of flood risk reduction of the alternatives analyzed, Alternative 4 is preferable because it includes a similar level of risk reduction plus additional benefits, such as greater ecological uplift, while minimizing negative side effects, such as decreased viewsheds and lack of waterfront access. These benefits feed into the broader evaluation of the alternatives (Section 9).

Table 8-1 Economic Losses ($M) for 100-Year Flood, Base Case and Alternatives 1–5

Loss category	Base case	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Building loss	$61	$60	$57	$15	$0	$0
Content loss	27	27	25	9	0	0
Inventory loss	4	4	3	2	0	0
Relocation loss	684	674	650	55	0	0
Income loss	6	6	6	2	0	0
Rental income loss	212	208	201	19	0	0
Wage loss	11	11	11	4	0	0
Direct output loss	26	25	26	9	1	0
Debris removal	137	149	125	50	0	0
Shelter	35	35	35	5	0	0
Vehicle loss	7	7	6	2	0	0
Transportation loss	3	3	3	0	0	0
Utility loss	3	3	3	0	0	0
Total damage	**1,216**	**1,212**	**1,151**	**172**	**1**	**0**
Avoided loss	**0**	**4**	**65**	**1,044**	**1,215**	**1,216**

Table 8-2 Economic Losses ($M) for 100-Year Flood +12-Inch Sea-Level Rise, Base Case and Alternatives 3–5

Loss category	Base case	Alt 3	Alt 4	Alt 5
Building loss	$74	$17	$71	$0
Content loss	37	12	34	0
Inventory loss	6	4	5	0
Relocation loss	782	54	767	0
Income loss	9	4	8	0
Rental income loss	242	54	237	0
Wage loss	17	6	14	0
Direct output loss	41	14	34	0
Debris removal	176	54	161	0
Shelter	38	5	38	0
Vehicle loss	9	4	8	0
Transportation loss	5	1	5	0
Utility loss	3	3	3	0
Total damage	1,439	232	1,385	0
Avoided loss	0	1,207	54	1,439

Table 8-3 Economic Losses ($M) for 100-Year Flood +32-Inch Sea-Level Rise, Base Case and Alternatives 3–5

Loss category	Base case	Alt 3	Alt 4	Alt 5
Building loss	$104	$104	$104	$108
Content loss	63	62	62	66
Inventory loss	11	11	11	11
Relocation loss	876	861	857	878
Income loss	14	14	14	13
Rental income loss	275	268	266	273
Wage loss	26	26	26	24
Direct output loss	62	61	62	58
Debris removal	266	266	265	272
Shelter	40	39	40	39
Vehicle loss	14	13	13	14
Transportation loss	6	3	3	6
Utility loss	4	4	4	4
Total damage	1,761	1,732	1,727	1,766
Avoided loss	0	1	6	0

A more detailed breakdown of these losses appears in Appendix B, and the results are mapped in Appendix C.

8.3 Net Present Value of Flood Damages Avoided

Having determined the infrastructure costs, avoided costs, and losses for each resilience alternative under the different scenarios, we determined the net present value (Section 6.3) of the avoided expected value of flood damage under two discount rates, 3 percent and 7 percent, in 2014 dollars. The value of the avoided flood damage cost remains the same irrespective of the year it occurs.

Project life is assumed to be 50 years. We also assume that the infrastructure is maintained and does not deteriorate or lose its protective function throughout the design life.

The probability of the 100-year event during the 50-year life of the infrastructure is 39 percent (CIRIA/CUR/CETMEF 2007, Table 2.4). This probability remains constant throughout the design life of the project. The occurrence of the 100-year event in any given year is equally likely. That is, it can be assumed to be uniformly distributed.

Tables 8-4 and 8-5 show the net present value of the expected avoided flood damage losses.

Table 8-4 Net Present Value ($M) of Avoided Losses with Discount Rate of 3% and 100-Year Flood

	Base case	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Avoided loss	$0	$4	$65	$1,044	$1,215	$1,216
NPV	0	0.8	13	210	244	244
NPV (delayed benefits)	0	0.74	12.04	193.39	225.07	225.25

Table 8-5 Net Present Value ($M) of Avoided Losses with Discount Rate of 7% and 100-Year Flood

	Base case	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Avoided loss	$0	$4	$65	$1,044	$1,215	$1,216
NPV	0	0.4	7	112	131	131
NPV (delayed benefits)	0	0.35	5.72	91.95	107.01	107.10

Birders at Jamaica Bay © sekernas/iStock Photo

9. Natural Infrastructure Valuation

Critical to valuing infrastructure is capturing the benefits and costs of both engineered and natural systems. Having described the effects of current and future flood modeling on Howard Beach and defined infrastructure alternatives and their mitigation effects, we identify, quantify, and monetize a subset of the ecosystem functions and services for each alternative to inform our assessment.

We first define and identify the ecosystem functions and services of our study through an ecosystem services typology and assessment framework. We then used two techniques to quantify and monetize their value:

- Habitat equivalency analysis (HEA), which describes the gains and losses of ecosystem functions of each alternative over time; and
- Benefit transfer, which is used to monetize a subset of ecosystem services.

Below, we explain these approaches—their inputs and outputs, their limits, and their results—we discuss the results.

Functioning environmental systems deliver ecosystem services and ecological benefits. With advances in applied economics, it is possible to value changes in ecosystem services in monetary terms so that environmental outcomes receive equal consideration with the financial benefits and costs. A detailed comprehensive assessment, however, is onerous, costly, and time consuming because it requires integrated modeling of the ecological and human landscapes. For this study, ecosystem functions and services were first identified for all alternatives and then quantified, and a small subset of the services was monetized as an example. In this way, trade-offs between the net present value of the monetized benefits and costs and the ecological costs and benefits are more transparent.

In this section, we present methods that identify, quantify, and monetize ecosystem functions and services to elucidate their strengths and weaknesses and demonstrate how they can be used together.

9.1 Definition and Classification of Ecosystem Functions and Services

Ecosystem services are the benefits human obtain from nature (Millennium Ecosystem Assessment 2005). Because they flow from natural resources, alternative management options that affect the environment will affect the type, quality, and quantity of benefits. Ecosystem functions and services can be classified in a variety of ways. A common approach involves classifying ecosystem functions and services into four broad groups (Millennium Ecosystem Assessment 2005; Farber et al. 2006) (Table 9-1):

- *supportive* structures and functions that are essential to the delivery of ecosystem services;
- *regulating* services and functions that maintain essential ecological processes and life support systems for human well-being;
- *provisioning* of natural resources and raw materials; and
- *cultural* services that enhance emotional, psychological, and cognitive well-being.

Table 9-1(a) Supportive Ecosystem Functions and Services

Supportive Functions and Structures Ecological structures and functions that are essential to the delivery of ecosystem services		
Type	*Description*	*Examples*
Nutrient cycling	Storage, processing and acquisition of nutrients within the biosphere	Nitrogen cycle, phosphorus cycle
Net primary production	Conversion of sunlight into biomass	Plant growth
Pollination and seed dispersal	Movement of plant genes	Insect pollination, animal seed dispersal
Habitat	Physical place where organisms reside	Refugium for resident and migratory species, spawning and nursery grounds
Hydrological cycle	Movement and storage of water through the biosphere	Evapotranspiration, stream runoff, groundwater retention

Table 9-1(b) Regulating Ecosystem Functions and Services

Regulating Services Maintenance of essential ecological processes and life support systems for human well being		
Type	*Description*	*Examples*
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	Biotic sequestration of carbon dioxide and release of water, vegetative absorption of volatile organic compounds
Climate regulation	Regulation of local to global climate processes	Direct influence of land cover on temperature, precipitation, wind, humidity, etc.
Disturbance regulation	Dampening of environmental fluctuations and disturbance	Storm surge protection, flood protection
Biological regulation	Species interactions	Control of pests and diseases, reduction of herbivory (crop damage)
Water regulation	Flow of water across the planet surface	Modulation of the droughts, flood cycle, purification of water
Soil retention	Erosion control and sediment retention	Prevention of soil loss by wind and runoff, avoiding buildup of silt in lakes and wetlands
Waste regulation	Removal or breakdown of non-nutrient compounds and materials	Pollution detoxification, abatement of noise pollution
Nutrient regulation	Maintenance of major nutrients within acceptable bounds	Prevention of premature eutrophication in lakes, maintenance of soil fertility

Table 9-1(c) Provisioning Ecosystem Functions and Services

Provisioning Services Provisioning of natural resources and raw materials		
Type	*Description*	*Examples*
Water supply	Filtering, retention and storage of freshwater	Provision of freshwater for drinking; transportation irrigation
Food	Provisioning of edible plants and animals for human consumption	Hunting and gathering (fish, game, fruits, etc.), small-scale subsistence farming and aquaculture
Raw materials	Building and manufacturing	Lumber, skins, plant fibers, oils, dyes, etc.
	Fuel and energy	Fuel wood, organic matter (e.g., peat)
	Soil and fertilizer	Topsoil, krill, leaves, litter, excrements, etc.
Genetic resources	Genetic resources	Genes to improve crop resistance to pathogens and pests and other commercial applications
Medicinal resources	Biological and chemical substances for use in drugs and pharmaceuticals	Quinine, Pacific yew, *Echinacea*
Ornamental resources	Resources for fashion, handcrafts, jewelry, pets, worship, decoration, and souvenirs	Feathers used in decorative costumes, shells used as jewelry

Table 9-1(d) Cultural Ecosystem Functions and Services

Cultural Services Enhancing emotional, psychological and cognitive well being		
Type	*Description*	*Examples*
Recreation	Opportunities for rest, refreshment, and recreation	Ecotourism, bird-watching, outdoor sports
Aesthetic	Sensory enjoyment of functioning ecosystems	Proximity of houses to scenery, open space
Science and education	Use of natural areas for scientific and educational enhancement	Field laboratory and reference areas
Spiritual, historic	Spiritual or historical information	Use of nature as national symbols, natural landscapes with significant religious values

9.2 Application of the Ecosystem Function and Services Valuation Assessment Framework

Understanding the mix of ecosystem functions and services associated with the resilience alternatives is the first step toward better valuing the trade-offs among them. In this section, we apply the ecosystem services classification, presented above, and this assessment framework to the specific case of alternatives at Howard Beach. Each alternative design at the site—nature and nature-based - shoreline (Alternative 1), nature and nature-based - wetlands (Alternative 2), hybrid with removable walls (Alternative 3), hybrid with operable flood gates (Alternative 4), and gray infrastructure (Alternative 5)—presents a different 'suite' of potential ecosystem functions and services that might be generated if constructed. The alternatives are summarized in Table 9-2. The assessment framework utilized in the Howard Beach analysis consisted of two steps:

- determining what ecosystem features would be affected; and
- identifying which ecosystem functions and services would be affected.

This evaluation of the ecosystem services associated with each identified infrastructure solution presents an examination of best practices for valuation broadly and accurately accounts for the economic, environmental and social costs and benefits of the alternatives considered. While providing an assessment framework facilitates the Howard Beach case to be assessed, it also enables adoption and use for the evaluation of future coastal resilience project alternatives.

Step 1. Determine the Affected Ecosystem Features

The first step in the process is to define the ecosystems that are positively and negatively affected by the alternatives and the spatial extent of change (Table 9-2).

The infrastructure design elements of the alternatives that are largely nature and nature-based include:

- Berms
- Beach
- Restored and created wetlands
- Edges hardened with ribbed mussel toes
- Rock groins and breakwaters

The gray infrastructure design elements of the alternatives include:

- Removable flood walls
- Operable flood gates
- Permanent flood walls

Construction of the nature and nature-based infrastructure elements involves either restoration of existing habitat (e.g., the shoreline wetlands at Spring Creek Park would be restored) or replacement of one habitat with another (e.g., bottom substrate and open water would be replaced by wetland). Although certain gray infrastructure elements and nature-based elements with small footprints (e.g., rock groins, breakwaters, and berms) would also eliminate or temporarily disturb habitat, the total affected area would be minimal and disrupt only bottom substrate and open water—the most common habitat—or relatively poor-quality upland in Spring Creek Park (which would be replaced by berms). Therefore, the losses in ecosystem functions and services associated with elements having small footprints were not assessed. Also not included were the benefits associated with beach nourishment at Charles Memorial Park Beach and storm damage to coastal habitat function and quality.

Overall, the changes associated with the natural infrastructure elements would be more significant, with wetlands (restored wetland, upland converted to wetland, and bottom substrate or open water converted to wetland) accounting for the largest area affected. Each element is associated with benefits and costs of potential ecosystem functions and services, which can be valued in different ways. Detailed habitat acreage changes associated with natural infrastructure elements are presented in Section 9.3, Habitat Equivalency Analysis.

Step 2. Identify Ecosystem Functions and Services Likely to Be Affected

In Step 2, ecosystem functions and services likely to be affected are listed in Table 9-2, along with the likely direction of change, positive (plus) or negative (minus). In some cases, the likely direction is not well understood and is noted as "NA," for not applicable. The table also lists the valuation methods that are generally most amenable to quantifying the value of each ecosystem function and service; the valuation methods are described in Appendix H. Depending on factors such as the definition of each ecosystem function and service and perspective on scale, the case could be made to add or subtract ecosystem services on this list.

Table 9-2(a) Likely Effects on Ecosystem Functions and Services, by Alternative and Element or Site Feature, with Valuation Method

Element or site feature	*Ecosystem function/service*	*Alt 1*	*Alt 2*	*Alt 3*	*Alt 4*	*Alt 5*	*Valuation method(s)*
Restored or created marsh	Habitat	+	+	+	+	NA	P, CV, HEA
	Disturbance regulation	+	+	+	+	NA	AC, HEA
	Nutrient regulation	+	+	+	+	NA	AC, P, CV, HEA
	Water regulation	+	+	+	+	NA	AC, TC, HEA
	Net primary production	+	+	+	+	NA	HEA
	Recreation	+	+	+	+	NA	TC, CV, ranking
	Aesthetics and amenity	+	+	+	+	NA	H, CV, TC, ranking
Mussel hard toe	Habitat	+	+	+	+	NA	P, CV, HEA
	Water regulation	+	+	+	+	NA	AC, TC, HEA
	Food and raw materials	+	+	+	+	NA	M, P
	Nutrient regulation	+	+	+	+	NA	AC, P, CV, HEA
Beach	Recreation	+	NA	+	+	NA	TC, CV, ranking
	Aesthetics and amenity	+	NA	+	+	NA	H, CV, TC, ranking
Berms	Habitat	+	+	+	+	NA	P, CV, HEA
	Aesthetics and amenity	–	–	–	–	NA	H, CV, TC, ranking

Table 9-2(b) Likely Effects on Ecosystem Functions and Services, by Alternative and Element or Site Feature, with Valuation Method

Element or site feature	*Ecosystem function/service*	*Alt 1*	*Alt 2*	*Alt 3*	*Alt 4*	*Alt 5*	*Valuation method(s)*
Rock breakwater	Disturbance regulation	+	NA	NA	NA	NA	AC, HEA
	Aesthetics and amenity	–	NA	NA	NA	NA	H, CV, TC, ranking
Rock groins	Disturbance regulation	+	NA	+	+	NA	AC, HEA
	Aesthetics and amenity	–	NA	–	–	NA	H, CV, TC, ranking
Marsh island	Habitat	NA	+	NA	NA	NA	P, CV, HEA
	Disturbance regulation	NA	+	NA	NA	NA	AC, HEA
	Nutrient regulation	NA	+	NA	NA	NA	AC, P, CV, HEA
	Water regulation	NA	+	NA	NA	NA	AC, TC, HEA
	Net primary production	NA	+	NA	NA	NA	HEA
	Recreation	NA	+	NA	NA	NA	TC, CV, ranking
	Aesthetic and amenity	NA	+	NA	NA	NA	H, CV, TC, ranking
Removable flood walls	Aesthetics and amenity	NA	NA	–	NA	NA	H, CV, TC, ranking
Floodgates	Aesthetics and amenity	NA	NA	NA	–	–	H, CV, TC, ranking
	Habitat	NA	NA	NA	+	+	P, CV, HEA
Permanent flood walls	Aesthetics and amenity	NA	NA	NA	NA	–	H, CV, TC, ranking
Upland	Habitat	–	–	–	–	–	P, CV, HEA
	Disturbance regulation	–	–	–	–	–	AC, HEA
	Soil retention	–	–	–	–	–	AC, HEA
	Net primary production	–	–	–	–	–	HEA
	Recreation	–	–	–	–	–	TC, CV, ranking
	Aesthetics and amenity	–	–	–	–	–	H, CV, TC, ranking
Open water, bottom substrate	Habitat	–	–	–	–	–	P, CV, HEA
	Hydrological cycle	–	–	–	–	–	HEA
	Recreation	–	–	–	–	–	TC, CV, ranking
	Aesthetics and amenity	–	–	–	–	–	H, CV, TC, ranking

AC=avoided cost; CV=contingent valuation; H=hedonic pricing; HEA=habitat equivalency analysis; M=market pricing; NA=not applicable; P=production approach; TC=travel cost.

9.3 Habitat Equivalency Analysis

We assessed the net ecological uplift of each alternative using habitat equivalency analysis (HEA). The HEA concept was developed initially by EPA (King and Adler 1991) and then modified by the U.S. Fish and Wildlife Service (Unsworth and Bishop 1994). It is the preferred method to scale compensatory restoration options in Natural Resource Damage Assessment activities under the Comprehensive Environmental Response, Cleanup, and Liability Act of 1980, and the Oil Pollution Act of 1990 (NOAA 1997a, 1997b; Peterson et al. 2003; Dunford et al. 2004) and has been used to compare alternatives by federal and many state agencies, including the U.S. Army Corps of Engineers, NOAA, and the Bureau of Land Management (e.g., Marstel-Day et al. 2008; USACE 2009; SWCA Consultants 2008). Recently, NOAA and Gulf Coast state agencies used HEA to determine natural resource damages and offsets for the *Deepwater Horizon* oil spill.

HEA can be used to evaluate the relative ecological "uplift," or ecological benefits over time relative to the current conditions. For example, the Army Corps of Engineers has used HEA to scale compensatory mitigation and determine the amount of restoration that is required to offset impacts to natural systems resulting from construction activities (Ray 2009). HEA is frequently used to compare the net ecological benefits of various management alternatives, particularly in situations where contamination, development, or disturbance poses a threat to an ecosystem or to human health (Marstel-Day et al. 2008). Here, HEA is used in accordance with the assessment framework discussed in Section 9.1 to quantify net ecological uplift for supporting and regulating ecosystem services, which are difficult to monetize.

Gains and losses associated with actions that affect the environment are quantified using a measure of the change in the flow of ecological benefits, or service flows, over time. Service flows are measured in units of ecological benefit provided per acre per year, or service acre-years (SAYs). Accounting for acreage and the relative percentage differences in the amount of services enables calculation of the number of SAYs provided by the habitats in question each year. For example, 10 acres of habitat functioning at 50 percent of reference services (e.g., the highest-quality habitat) in a given year provides 5 SAYs (10 acres x 0.50) in that year. Because benefits occur over time, an adjustment is typically made using a discount rate, usually 3 percent (NOAA 1999), for society's time rate of preference for ecological benefits (Dunford et al. 2004). Discounting and summing across the SAYs occurring in different years yields discounted SAYs (dSAYs).

Changes in ecological benefits are quantified with an indicator that represents the benefits or service flows provided by the habitat in question and expressing the changes in services (for that indicator) under the different alternatives as a percentage change from a baseline or reference condition. The indicator, a proxy for ecological benefits, is measured or estimated over time based on scientific knowledge to develop a curve that represents the loss or gain of services throughout the project life span, relative to the base case. The indicator can be a structural or a functional parameter, and it is widely recognized that the most important but difficult aspect of HEA is selecting the appropriate indicator (Peterson et al. 2003). For example, plant stem density, a structural parameter, may be used to represent the change in ecosystem services provided by a wetland (NOAA 2006b). Primary and secondary productivity in a salt marsh is an example of a functional indicator parameter (French McCay et al. 2002). In some cases, several metrics may be used to represent the service flows. When multiple metrics are combined into an index, the values for different parameters are often weighted. An example of this type of metric is a natural resource agency-endorsed habitat quality assessment protocol such as the Habitat Evaluation Procedures developed by U.S. Fish and Wildlife or the Hydrogeomorphic Approach for Assessing Wetland Functions developed by the Army Corps of Engineers.

The HEA methodology is flexible and can be adapted to individual sites and to the level knowledge about site ecology. Often, local natural resources professionals can help develop HEA inputs and answer questions about the time period required for a habitat type to mature and the likely level of quality and functionality that will be attained. This type of "best professional judgment" from a knowledgeable source can be a cost-effective and valuable option to inform an HEA (NOAA 2006a).

Ecological benefits, also referred to as service curves (benefits expressed as a percentage based on the indicator parameter versus time) are often estimated for a 100-year period, a discrete time-approximate for perpetuity. Because of discounting, marginal ecological value is likely to be provided beyond 100 years; however, the value would depend on the overall acreage of the habitat affected by an action.

Because 1 SAY of a certain habitat is not necessarily equivalent to 1 SAY of a different habitat, summing dSAYs across habitat types requires making assumptions. In the absence of contrary information, the base assumption could be that there is no inherent difference in the absolute value of habitat types. However, in some cases, conversion factors are applied to reflect differences in real or perceived value (French McCay et al. 2002). Examples include situations where native habitat is compared with a maintained landscape of ornamental species, or when stakeholders assign greater importance to one habitat type because of its rarity, aesthetics, or charismatic wildlife species. In Jamaica Bay, wetlands have been declining for decades, and there is a general preference for restoring wetlands rather than maintaining or increasing open-water habitats (SIRR 2013).

Comparing net ecological benefits using HEA

1. Define the **total cumulative area** that would be affected by the alternatives. If construction is involved, this includes access and staging areas.

2. **Delineate the various habitat types** and subtypes based on differences in quality and **calculate the area of each delineated polygon**. This constitutes the current baseline condition.

3. For each of the polygons derived in Step 2, **consider how they may change over time under the base case.** For example, will invasive plant species continue to spread? Will high stormwater flows continue to erode a stream bank?

4. For each alternative, **revise the base case polygons to reflect the anticipated changes associated with implementation and the new end states**. For example, will habitat be created, expanded, destroyed, degraded, or improved? Will one habitat be replaced by a different habitat? Will a habitat be temporarily affected and then restored? Calculate the new areas. The total area of the polygons should be same for the base case and alternatives.

5. Review the primary ecological benefits the habitats provide (or could provide) and **select an indicator parameter(s) for characterizing the quality and functionality of each habitat type**. The indicator parameter(s) is a proxy for one or many ecosystem services flowing from the area.

6. **Determine the time frame for the analysis**. It should be long enough to capture the objectives of the alternatives as well as intergenerational equity considerations. In habitats that are rapidly changing, such as coastal areas experiencing sea-level rise, land conversion rates should be incorporated into estimates of the project life span.

7. For each polygon under each alternative (including the base case), develop or **estimate values for the selected indicator parameters to establish the level of quality or functionality of that habitat over time**. A service curve should be created for each polygon that reflects the flow of ecosystem services over time (i.e., percentage of ecosystem services versus time).

8. Choose and **apply the appropriate discount rate** (see Section 6).

9. For each polygon, **quantify the services for the base case** (i.e., the value under the discounted curve). Sum the polygon-specific dSAYs for each habitat type, and then sum the dSAYs across habitats. If conversation factors are being used to reflect absolute differences in the value of different habitat types, apply the conversion factors first and then sum the dSAYs. **Repeat this process for each alternative**.

10. **Calculate the net ecological benefit** for each alternative by subtracting the dSAY value for the base case from that of each alternative.

Uncertainties associated with HEA include how well the selected indicator parameters represent the service flows, and how services flow over time. However, in this type of application, HEA is considered an order-of-magnitude analysis (Dunford et al. 2004): the goal is to identify significant differences in net ecological benefits and consider them in relation to cost and performance measures associated with the primary goal of the project (e.g., avoiding flood damage).

9.3.1 Change in Ecological Benefits over Time

The HEA for Howard Beach evaluates the net change in ecological benefits associated with the major infrastructure features of each alternative and also takes into account the longer-term projected effects of sea-level rise. With the exception of damage to the urban tree canopy, we assume that any storm damage to habitats will be minor and temporary, consistent with post-Sandy damage assessments (Hudson River Foundation 2012). The assumptions made about specific habitat features and the degree of long-term maintenance associated with the infrastructure are documented in Appendix I. It was not our intention to develop detailed design; generic infrastructure features were simply evaluated for their ability to reduce flooding impacts. In general, we made the basic assumption that each alternative designed and constructed high-quality habitats, maintained over time with a reasonable level of effort.

The study area encompasses Spring Creek Park, a 272-acre property belonging jointly to the New York City Department of Parks and Recreation and the National Park Service, and approximately 250 acres of open water and estuarine habitats in Jamaica Bay. It also includes the community of Howard Beach. Howard Beach land cover types include trees, grass or lawn, bare soils, and impervious surfaces (none of which were evaluated in the HEA).

The total study area evaluated by the HEA, including the partial footprints of Jamaica Bay, Spring Creek Park, and the community of Howard Beach, is approximately 1,219 acres (Figure 9-2).

We assessed the current quality and distribution of habitats in September 2014. The majority of Spring Creek Park habitats are uplands dominated by invasive species, particularly common reed *(Phragmites australis)* and mugwort *(Artemesia vulgaris)*. The uplands contain several small groves of maritime forest, consisting of native black cherry *(Prunus serotina)* and invasive tree of heaven *(Ailanthus altissima)* (Figure 9-1). Recreational trails traverse the uplands and connect the community to the waterfront.

Figure 9-1 Invasive Mugwort (Artemesia vulgaris), Common Reed (Phragmites australis), and Tree of Heaven (Ailanthus altissima) in Uplands

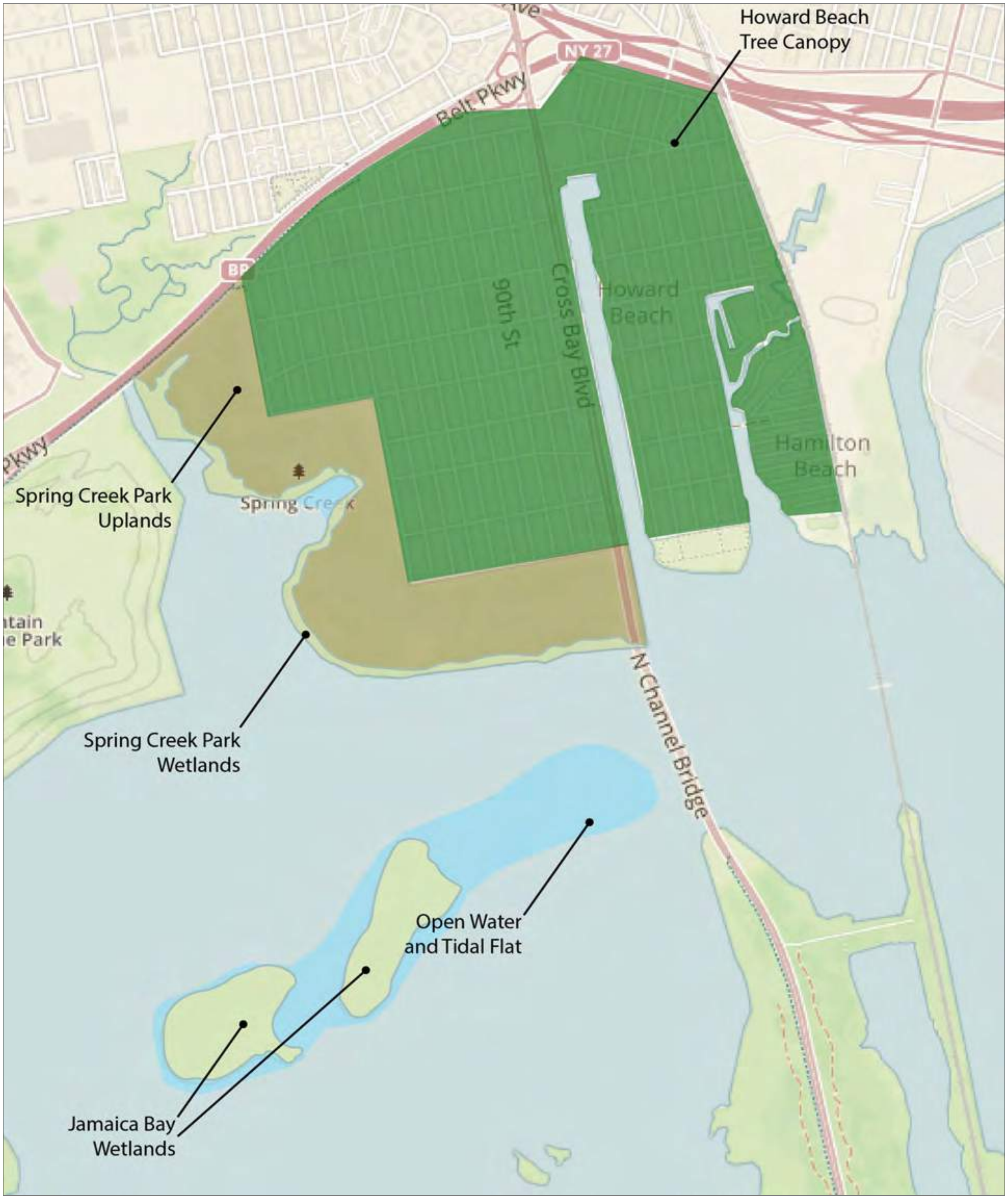


Figure 9-2 Base Case (Existing Conditions)

Figure 9-3 Isolated Patches of Remnant Salt Marsh with Ribbed Mussel (Geukensia demissa) Toe at Southern Spring Creek Park Shoreline

Figure 9-4 Low Marsh (Spartina alterniflora), High Marsh, and Uplands (Phragmites australis)

The shoreline of Spring Creek Park is a mixture of unvegetated beach interspersed with patches of salt marsh grass *(Spartina alterniflora)*. The areal extent and connectivity of salt marsh increases along the western and northern shoreline of Spring Creek Park. Narrow bands of high marsh are adjacent to the low marsh *(Spartina alterniflora)*, framed with ribbed mussels (*Geukensia demissa)* along the toe of the vegetation (Figure 9-3). These patches of wetland quickly transition to common reed *(Phragmites australis)* in the uplands. The areas adjacent to the shoreline are tidal flats that grade to open water (Figure 9-4). The existing water quality in Jamaica Bay is characterized by low dissolved oxygen, low mixing and flushing, and salinity ranging from 20 to 26 parts per thousand (ppt) (Jamaica Bay Institute 2008).

With future sea-level rise, existing marshes are projected to migrate upslope and inland, replacing upland habitats (Morris et al. 2002). The Sea Level Affecting Marsh Migration (SLAMM) model, developed by Clough et al. (2014), predicts where marshes may migrate based on the processes of inundation, erosion, overwash, saturation, accretion, and sea-level rise rates. According to the model predictions, the uplands in Spring Creek Park are expected to transition to wetlands over the 100-year life span of the project. SLAMM predicts a decrease in total area of uplands because they are bounded by impervious surfaces, including roads along the northern and northeastern edges, and cannot migrate further.

The existing marsh islands and open water in Jamaica Bay have historically high rates of land loss due to chronic eutrophication, low flushing and high residence time, and low sediment inputs. The SLAMM model predicts that these marsh islands, dominated by *Spartina* *alterniflora*, will transition to open water and tidal flats.

The existing tree canopy in Howard Beach covers approximately 8.5 percent of the area, or about 64 acres (Freed et al. 2013). The most common trees are red and sugar maples, honey locust, callery pear, black cherry, London plane, and pin oak (NYC Open Data 2013).

Although Howard Beach's tree canopy cover could be increased—particularly on manufacturing and commercial sites and along residential sidewalks—even a 10 percent cover would have a limited benefit for stormwater management. However, it might have other benefits, such as reducing the heat island effect.

Below, we discuss the ecosystem functions and services of the five alternatives.

Table 9-3 Land Cover Assessment in Howard Beach, 2014

Land cover	2010	2113	Percentage change
Tree canopy	8.81%	8.45%	-4.09
Impervious surface	41.76	41.77	0.02
Grass, open space	21.73	22.08	1.61
Bare soils	5.97	5.97	0
Open water	21.72	21.72	0

Source: Davey Resource Group

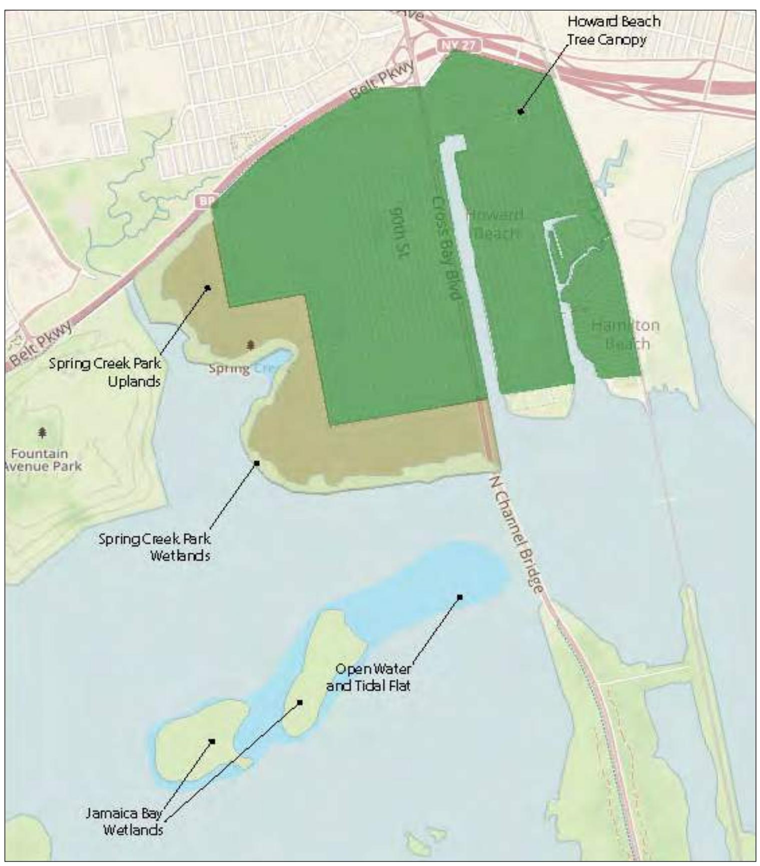


Figure 9-5 Base Case in 2100

Alternative 1: Nature and Nature-Based Infrastructure (Shoreline)

This project enhances existing wetlands, converts low-quality *Phragmites*-dominated uplands to diverse intertidal marsh habitats, and establishes a toe of ribbed mussels along the shoreline (Figure 9-6).

Newly planted wetland vegetation requires at least two years to achieve comparative aboveground biomass with reference marshes (Craft et al. 1999) and is assumed to remain healthy throughout the project life span. Projected sea-level rise eventually causes the wetlands in Spring Creek Park to expand at the expense of the uplands (Clough et al. 2014). Over time, background rates of land loss continue, and the marsh islands in Jamaica Bay transition to tidal flats and open water (Clough et al. 2014).

In the absence of site-specific knowledge of ribbed mussel filtration rates in Jamaica Bay, we estimate the quantity of nitrogen a mature oyster reef can assimilate per acre per year after three years (time to maturity) and hold this value constant throughout the life span of the project (Doiron 2008; Kellogg et al. 2011; Higgins et al. 2011).

These 64 acres of urban tree canopy in the study area provide shade, sequester carbon, and intercept storm water (Nowak and Crane, 2002, Foderaro, 2012, Gregory, 2013). However, With 1-in-100-year storms projected to flood Howard Beach every 35 to 50 years (Section 7), we assume that episodic flooding stresses the trees, diminishes their capacity to absorb stormwater and sequester carbon, causes mortality of 25 percent of trees after 35 years, and kills another 25 percent after 70 years.

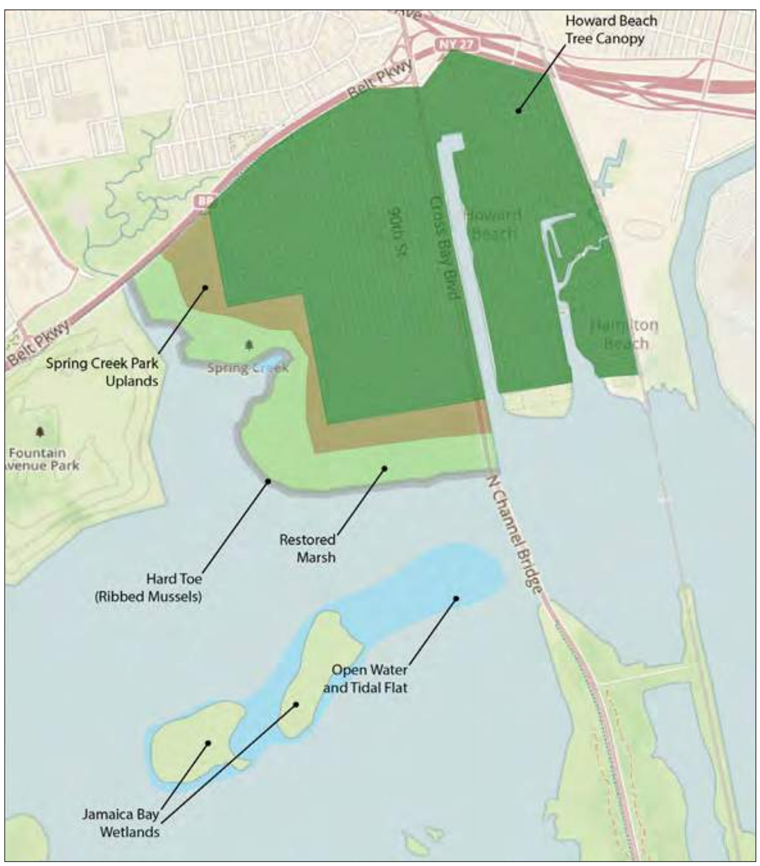


Figure 9-6 Alternative 1: Nature and Nature-Based Infrastructure (Shoreline)

Alternative 2: Nature and Nature-Based Infrastructure (Wetlands)

This all-nature and nature-based infrastructure scenario involves more ecological restoration than Alternative 1 (Figure 9-7). The features provide the same benefits as described for Alternative 1.

Restored wetland vegetation does not achieve equivalent aboveground biomass with reference conditions immediately (Craft et al. 1999). Ribbed mussels installed at the edge of created marsh islands provide nitrogen assimilation ecosystem services for the lifespan of the project according to the assumptions above (see Alternative 1).

In the future, wetlands at Spring Creek Park increase in area as they migrate inland and upslope into the uplands. However, sea-level rise, eutrophication, and a deficient sediment budget are projected to decrease the total land area of the created and restored marsh islands. As in Alternative 1, episodic storm events that create widespread flooding kill some urban trees.

Figure 9-7 Alternative 2: Nature and Nature-Based Infrastructure (Wetlands)

Alternatives 3 and 4: Hybrid with Removable Walls and Hybrid with Operable Flood Gates

These hybrid scenarios add to the features of Alternative 1 either removable flood walls or floodgates (Figure 8-8).

The two gray infrastructure elements provide comparable flood protection to the community of Howard Beach. They also protect the urban tree canopy of Howard Beach. Over the 100-year time horizon, the protection afforded by the flood walls and floodgates reduces flooding and tree mortality compared with Alternatives 1 and 2.

Figure 9-8 Alternatives 3 and 4: Hybrid with Removable Walls and Hybrid with Floodgates

Alternative 5: Flood Wall and Flood Gates

This all-gray scenario has the same habitats as the base case. As in Alternatives 3 and 4, the flood wall and floodgates protect the community and the urban forest during episodic storm events.

Figure 9-9 Alternative 5: Flood Wall and Floodgates

9.3.2 Project Performance over Time

Our habitat equivalency analysis includes project performance over time, as affected by sea-level rise and climate change. The sea-level rise rate of 2.7 mm per year (Hartig et al. 2002) is expected to increase the frequency and duration of flooding in estuarine habitats (Clough et al. 2014).

SLAMM modeling estimates habitat migration for discrete time steps in the future under four sea-level rise scenarios. We used a scenario equivalent to 1 meter of sea-level rise by 2100. This estimate is in between the estimates used in hydrodynamic and HAZUS modeling, 12 inches by 2050 and 32 inches by 2050. We estimated a rate of land conversion, confirmed that it was nearly linear, and applied this to the habitat types over time. We applied the same land conversion rates to each alternative's project life span (Table 9-4).

Table 9-4 Habitat Conversion Rates

Unit	Habitat in HEA	Conversion rate (acres/year)
Spring Creek Park	Wetland and unconsolidated shore	+0.23
Spring Creek Park	Upland	-0.28
Spring Creek Park	Open water and tidal flat	+0.05
Jamaica Bay	Marsh islands and unconsolidated shore	+0.04
Jamaica Bay	Open water and tidal flat	−0.04
Jamaica Bay	Mussels	Unknown
Jamaica Bay	Tree canopy	not applicable

The performance of the infrastructure, whether nature, nature-based or gray, must also be considered in a cost-benefit analysis. Routine maintenance and supplemental restoration, such as debris removal and plantings, are among the factors that determine whether a project performs as intended over time. In this study, we assume that routine maintenance for both gray and nature and nature-based infrastructure maintains project performance over time. Table 9-5 summarizes the type and frequency of maintenance to prolong project life span.

The design year for the project is 50 years, after which major capital replacements would be necessary. Some elements of gray infrastructure may have salvage value at the end of the project life; this is included in the net present value calculations. For example, steel and other metals can be recovered and resold. In the case of green (natural) elements, the ecosystem may continuing functioning on its own and not require active management or expenditure of funds for well beyond 50 years, thus providing the equivalent of salvage value. For Howard Beach, we assume that the nature and nature-based infrastructure will continue to generate ecosystem services for an additional 50 years, or for 100 years in total, without the necessity of annual maintenance expenditures.

We assigned a 3 percent annual discount rate to ecological benefits accrued in the HEA. A comprehensive assessment would also entail running the calculations at a 7 percent discount for sensitivity analysis (see Section 6).

Table 9-5 Maintenance Requirements for Nature & Nature-Based and Gray Infrastructure

Infrastructure	Limiting factors	Maintenance	Frequency
Floodgates	Salt water	Inspection	Annual
		Closures during storm events	Semiannual
		Repairs	Every 10 years
Flood walls	Salt water, erosion	Inspection	Annual
		Closures during storm events	Semiannual
		Repairs	Every 10 years
Wetlands	Sea-level rise, erosion, water quality	Monitoring	Annual
		Supplemental planting	As needed
		Thin-layer sediment slurry and/or dredge placement	As needed
Oyster reefs	Water quality, current velocity	Monitoring	Annual
		Cultch and spat placement	As needed, typically after winter
Beaches, dunes	Erosion, wave energy	Renourishment	As needed and after storms
		Sand fencing	
Uplands	Fragmentation, compaction	Monitoring	Annual
		Invasive species removal	Seasonal
		Mowing	Seasonal

9.3.3 Proxies for Ecosystem Functions and Services

HEA requires the selection of one or more indicators that are proxies for function or service provision from each habitat. The flow of ecological benefits varies spatially and temporally; therefore, a functional assessment that addresses several features of the habitat is generally preferred over one based on a single feature, even though it requires more information, adds uncertainty to the projections, and requires more resources to develop. A summary of the proxies developed for habitat at Howard Beach is presented in Table 9-6.

Wetlands and Marsh Islands: Evaluation for Planned Wetlands

The Evaluation for Planned Wetlands was developed to support wetland design and compensatory mitigation planning (Bartoldus et al. 1994). It estimates six wetland functions:

- shoreline bank erosion control;
- sediment stabilization;
- water quality;
- wildlife habitat;
- fish habitat (tidal, nontidal river or stream, or nontidal pond or lake); and
- uniqueness or heritage.

Table 9-6 Ecosystem Function Proxies for Howard Beach Habitats

Habitat	Service metric	Minimum–maximum values[a]	Notes
Wetlands	Average of wetland functions from Evaluation for Planned Wetlands (erosion control, sediment stabilization, water quality, wildlife habitat, fish habitat)	32%–84%	Overall functional capacity index is generated from average of all five functions (each weighted equally); in general, erosion control scored highest, and fish habitat lowest.
Uplands	Invasive species and width of upland buffer, from Wetland Rapid Assessment Procedure	33%	Sites are dominated by *Phragmites australis*, *Artemesia vulgaris*, and *Ailanthus altissima*.
Open water	Habitat suitability for coastal striped bass, from Habitat Evaluation Procedure	8%	Eutrophication and high residence time have created low dissolved oxygen that limits habitat suitability for fish.
Mussel beds	Denitrification/nitrogen assimilation, from literature review	16.7%–100%	Oyster denitrification rates and time to maturity are based on literature.
Urban tree canopy	Carbon sequestration and stormwater interception, from literature review	3.6%–8.5%	Estimates assume that carbon sequestration and stormwater services are optimized.

[a] Relative to 100% service as defined by functional assessments (e.g., Evaluation for Planned Wetlands, Wetland Rapid Assessment Procedure, Habitat Evaluation Procedure).

Seven to 20 elements are combined into a functional capacity index for each function, on a scale of 0.0 to 1.0. Some elements influence the index to a greater degree than others, either because they are explicitly weighted in the equations or because they are implicitly weighted and appear throughout the calculations. We averaged the indexs of five functions (uniqueness or heritage value is accounted for elsewhere). We estimated the function of the existing wetlands in the base case and newly created wetlands in Alternatives 1, 2, 3, and 4 at several time steps: at present (Time 0), when the constructed wetland plants reached maturity (Time 2), and when the effects of sea-level rise, climate change, and population growth influenced the projects (Time 50).

Open Water: Habitat Evaluation Procedure, Coastal Striped Bass

The Habitat Evaluation Procedure was developed by the U.S. Fish and Wildlife Service to estimate the suitability of a habitat for a particular species of wildlife through a habitat suitability index (HSI), on a scale of 0.0 to 1.0. The index most applicable to the open water habitat in the study area was developed for coastal striped bass, a recreationally important fish species in Jamaica Bay. The coastal striped bass habitat suitability index evaluates the suitability of water and substrate for different life stages of the species using seven variables. The agency recommends selecting the lowest index for the life stages evaluated; in this study, the habitat conditions are most limiting to larval striped bass (largely because of low dissolved oxygen during the growing season). The index is calculated at present (Time 0) and assumed to remain constant in the absence of specific water-quality improvement projects.

Upland: Modified Wetland Rapid Assessment Procedure

There is no rapid assessment for uplands in New York City. Therefore, we need to identify a rapid assessment that could be adapted to assess the uplands. In this case, we modified the Wetland Rapid Assessment Procedure, developed by the South Florida Water Management District to facilitate compensatory wetland mitigation and planning (Miller and Gunsalus 1997). It consists of variables that evaluate wetland functions, including the condition of adjacent upland buffer. The variable related to the upland buffer includes a measure of native and invasive species and total width (extent). The variable is measured on an ordinal scale of 0 to 3, which we converted to the same scale as the other rapid assessments (i.e., 0.0 to 1.0). We assumed that the dominance of invasive species would remain constant over time and that the buffer width would decrease with sea-level rise and, for some alternatives, wetland creation.

Urban Tree Canopy: Literature Review

We researched the benefits of urban tree canopies to communities and found that on an annual basis, trees sequester approximately 0.12 kg of carbon per square meter (Nowak and Crane 2002) and are estimated to intercept 13.5 million cubic feet of stormwater in Howard Beach (Freed et al. 2013). Tree canopy covers approximately 64 acres of the 752-acre developed area (i.e., 8.5 percent of the total area of the community), and we assume that the trees are functioning optimally for carbon and stormwater capture (i.e., 100 percent service). This equates to an 8.5 percent service level over the entire developed area.

Following Superstorm Sandy, some trees in coastal areas died because of flooding and saltwater intrusion (Foderaro 2012; Gregory 2013). The probability of a comparable 1-in-100-year storm is every 35 to 50 years (Freed et al. 2013). Therefore, based on general accounts of tree mortality after Sandy (Foderaro 2012; Gregory 2013), we assume that storms would cause a 25 percent reduction in service twice over the 100-year HEA analysis. Although this is a conservative estimate, empirical data on street tree damage, sublethal stress, and mortality attributable to Sandy would improve the resolution of ecological benefits from this resource.

Ribbed Mussels: Literature Review

There is little research specific to ribbed mussel restoration in Jamaica Bay. Anecdotally, ribbed mussels facilitate salt marsh grasses *(Spartina alterniflora)* (Save the Bay 1998), but preliminary research on how mussel toes reduce erosion rates is inconclusive (Moody 2012). Lacking site- and species-specific information, we reviewed literature on the benefits of eastern oysters and selected denitrification (used interchangeably with nitrogen assimilation) as the service metric (Piehler and Smyth 2011; Higgins et al. 2011). We assume that mussels assimilate nitrogen in a manner comparable to the eastern oyster *(Crassostrea virginica)* (Lindahl et al. 2005). Mature eastern oysters filter volumes of water proportional with their size (ZuErmgassen et al. 2012), which can translate to nitrogen assimilation rates of approximately 382 kg of nitrogen per hectare (Higgins et al. 2011). In a suitable area, oysters take approximately three to four years to reach maturity (Doiron 2008; Kellogg et al. 2011; Kroeger 2012) and reach 100 percent of their nitrogen assimilation potential.

9.3.4 Results

The results of the habitat equivalency analysis enable us to compare the ecological services provided by each resilience alternative, in discounted service acre-years (Figure 9-10).

With no ecological restoration or maintenance, the benefits flowing from the base case (no intervention) and Alternative 5 are likely to decline in quality and quantity over time. The majority of the ecological services provided flow from the degraded uplands (the largest habitat unit by area, approximately 230 acres). The only difference is that Alternative 5's flood protection reduces tree mortality following storm events, for a net uplift of 203 dSAYs.

Alternatives 1, 3, and 4 provide similar total ecological benefits (approximately 7,620 to 7,830 dSAYs each). The 142 acres of wetland restoration is predicted to produce 2,928 dSAYs. Alternatives 3 and 4 perform slightly better than Alternative 1—producing about 200 more dSAYs—because the floodgates and flood walls protect the urban tree canopy.

In Alternative 2, with 193 acres of wetland creation and enhancement, the ecological restoration at Spring Creek Park and in Jamaica Bay produces 12,115 dSAYs, of which the restored wetlands contribute nearly 9,000 dSAYs. With sea-level rise, wetlands along Spring Creek Park migrate inland and upslope at a rate of 0.23 acres per year[10]. Additional

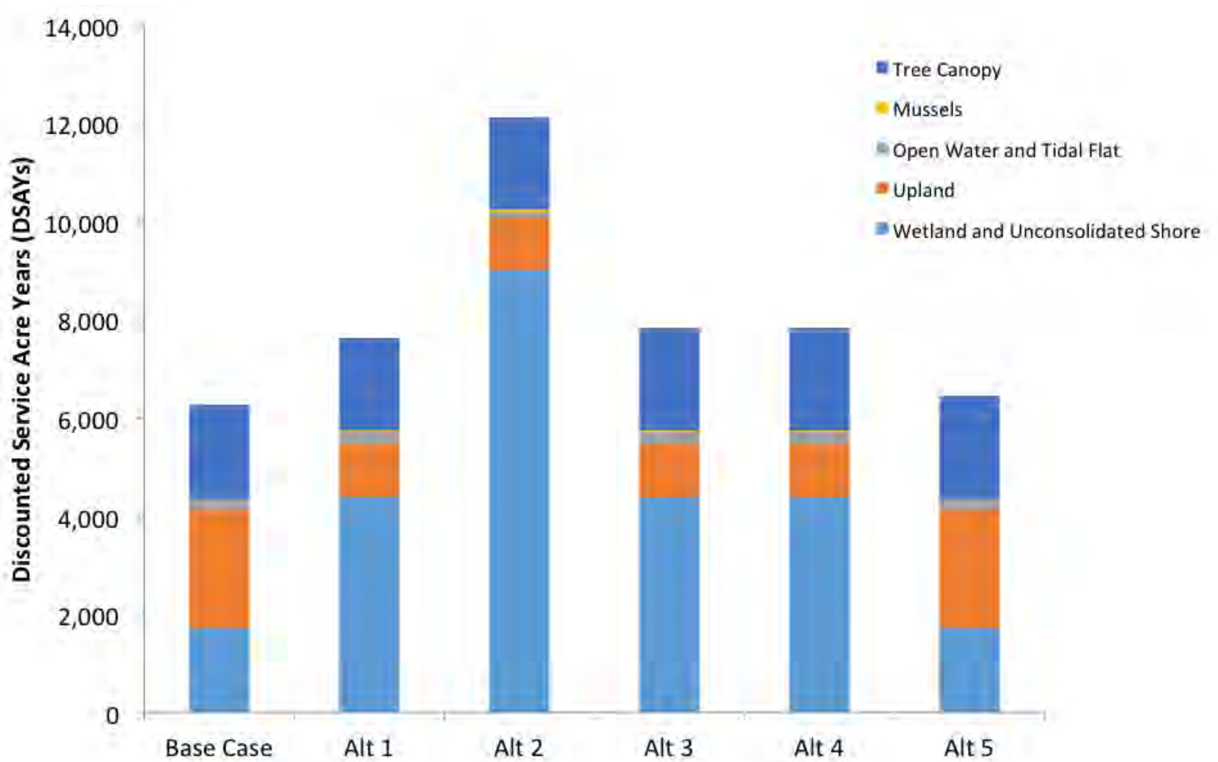


Figure 9-10 Total Ecological Uplift, by Alternative and Habitat Type

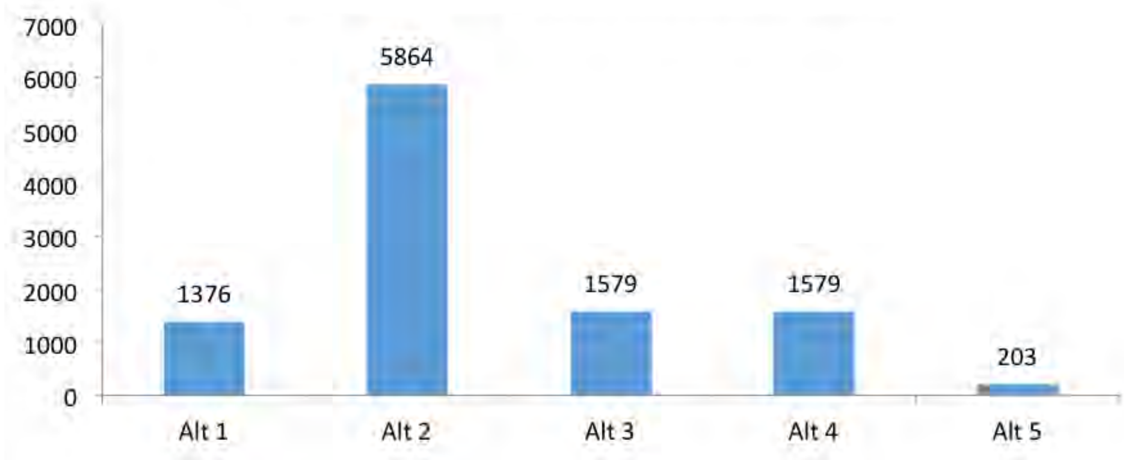


Figure 9-11 Net Ecological Uplift in dSAYs of Alternatives 1—5, Base Case Subtracted

benefits flow, in descending order, from the tree canopy, uplands, open water, and mussels.

Thus, Alternative 2 provides the greatest net ecological uplift relative to present conditions, and Alternative 5 provides negligible net uplift (Figure 9-11). The absolute quantity of discounted service acre-years is less important than the relative differences. Each alternative's land area, rate of habitat conversion with sea-level rise, service metrics, service proxy (indicator parameter) assumptions, and total ecological uplift are summarized in Appendix I. The results of the HEA analysis contribute to the integrated assessment, in Section 10.

9.3.5 Limitations of the Analysis

Data and other limitations necessitated the use of some assumptions in conducting the HEA. In this section we offer caveats and indicate the need for better data on current site-specific conditions and the performance of restored habitats in urban ecosystems.

Service Metrics for Urban Habitats

The HEA methodology relies heavily on the selection of a service proxy, or indicator parameter. Because there is no rapid assessment methodology for the coast and upland habitats of the New York–New Jersey Harbor, we adapted techniques and planning tools, such as the Evaluation for Planned Wetlands and the Habitat Evaluation Procedure, from surveys of pristine and non-urbanized habitats around the United States.

Urban habitats face different pressures, however. Chronic nitrogen pollution, urban heat island effects, fragmentation, invasive species, air pollution, compacted soils, and the effects of a high concentration of people all affect the function and performance of ecosystems. Some assessments quantify the value of a particular indicator based on regional reference conditions. The Mid Atlantic Tidal Wetland Rapid Assessment Method, for example, contains a metric to assess the condition of the buffer based on the surrounding development, ranging from no development (0 percent) to heavy development (15 percent or more), but in

New York, the areas adjacent to most wetlands are much more than 15 percent developed. Such metrics may therefore not be appropriate for habitats in New York City. However, there are certain thresholds below which ecosystem function is degraded or impaired regardless of population density and development. A region-specific baseline of habitats in the New York–New Jersey Harbor is needed.

Single vs. Multiple Ecosystem Function and Service Proxies

We used functional assessment methodologies to estimate the service flows from the base case conditions and the five alternatives. We also used literature reviews and single attributes when we could not locate an ideal functional assessment. There are a number of trade-offs when using a multi-attribute metric versus a single parameter.

A complex, multi-attribute metric provides a robust estimate of function and service provision if it is based on a detailed design for restored habitats and a thorough survey for base case conditions. If those are lacking, researchers must make assumptions, and the assumptions are compounded when each variable is estimated at several time steps into the future (e.g., after plants reach maturity).

Assumptions are also required about the accuracy with which each variable (e.g., nitrogen turnover rate, stem density, biomass) can represent ecosystem services. For a habitat that has not been well studied, it is necessary to select parameters from a reference site in the literature and apply them to the restoration site and assume the restored site will eventually function like the reference site. This temporal component is important as well: HEA requires an estimate for the time it takes a restored site to reach full functionality (maturity) relative to reference conditions. Some systems may achieve different types of functional equivalence more quickly than others. For example, restored salt marsh vegetation achieves equivalence with reference conditions after several years, but biogeochemical cycling takes more than 20 (e.g., Craft et al. 1999). Depending on the indicator parameter, it is possible to either over- or underestimate the performance of a restored habitat over time.

Quality vs. Quantity of Habitat

HEA outputs increase proportionally with area, since service acre-years are the product of habitat quality and habitat quantity. Therefore, habitats that have a small footprint will always produce fewer dSAYs than habitats with a large footprint. In this case study, mussel habitats have a small footprint but may provide services that affect a larger area by filtering water and removing nitrogen from Jamaica Bay. In addition, urban trees have a relatively small footprint in tree pits along streets but provide significant heat and stormwater mitigation. Additional research is required to better understand the contribution of shellfish habitats and urban forests to ecosystem-level processes for the region.

Functional Equivalence between Habitat Types

Various habitats produce different types and quantities of ecosystem services. This analysis assumes that the value of all habitats and their services is equal, but some are arguably worth more than others. For example, of the metropolitan region's historical coastal wetland area, only about 15 percent remains (PlaNYC 2012). Given the ability of wetlands to provide flood protection and assimilate nutrients, it may be reasonable to prioritize the creation and restoration of wetlands over uplands or open water. A comprehensive assessment of frequency, abundance, and condition of habitats in and around New York City would help characterize priority habitats and allow them to be weighted in a regional functional assessment.

Synergistic Effects

Little is known about how gray infrastructure affects natural systems. The project life span, whether driven by sea-level rise and land loss or by mechanical failure, has a large influence on the total ecological value derived from a HEA. If flood protection infrastructure—both green and gray—can be designed for a longer life span, the total value of the project should improve, and maintenance costs will fall.

It will be important for the City's coastal resilience projects—Nature and Nature-Based Infrastructure (U.S. Army Corps of Engineers), Rebuild by Design (U.S. Department of Housing and Urban Development), NY Rising (State of New York)—to closely track the performance of all elements of hybrid solutions for flood protection.

9.4 Monetary Valuation of Ecosystem Services: An Example

The HEA results allow us to quantify and compare the flow of ecological benefits across a wide range of ecosystem functions. In this section we map the changes in ecosystem services over time to their direct human uses, passive use values or indirect human uses, and then apply a partial benefit transfer to assess changes in benefits over time. This approach yields monetary values for a sample ecosystem service, which can then be used in the cost-benefit analysis.

Although not all ecosystem services are modeled, the approach demonstrates how nature and nature-based benefits can be incorporated more formally into CBA. Extending the analysis to assess the benefits associated with each infrastructure element is beyond the scope of this report but is recommended for supporting future decisions.

The list of ecosystem services (Table 9-2) reveals that the saltwater marsh ecosystem provides direct and passive use economic benefits. Direct use includes the economic benefits of ecosystem services from "consumptive" activities, such as commercial and recreational fishing, and also nonconsumptive uses, such as wildlife photography and bird-watching. Passive use includes the economic benefits of ecosystem services that come from knowing that a natural resource exists. For example, people place value on wilderness even if they have no immediate plans to go wilderness camping. We therefore selected the saltmarsh ecosystem to demonstrate how benefits can be assessed and considered in a CBA. In addition, the Spring Creek Park conversion provides a good illustration, since it has benefits under the base case that could be lost with the flood management actions, thus resulting in negative values.

The selection of the valuation method for each service and the level of rigor of the assessment depend on the type of human use, the availability of data, and the likely magnitude of the economic effects. Data availability pertains both to evidence for the underlying physical changes, such as a change in fish populations, and to economic parameters, such as the number of people likely to be affected by that change.

Benefit-Transfer

The empirical economic literature finds that wetlands have direct, passive, and indirect use values, based on one or more valuation methods. Through statistically reliable survey-based ("stated preference") methods, such as contingent valuation and conjoint analysis, economists have consistently found that the public finds passive use value in protecting, restoring, and preserving wetland species habitat (Loomis and Richardson 2008; Schuyt and Brander 2004; Stevens et al. 1995). Given the time and expense of conducting original research, analysts have developed benefit transfer techniques that allow researchers to extract values from existing empirical literature for new situations. Loomis and Richardson (2008) have evaluated benefit transfer approaches for valuing wetlands, including saltmarshes, and concluded that the meta-analysis by Borrisova-Kidder (2006) is the most defensible.

The Borrisova-Kidder meta-analysis includes 72 observations of wetland values from 33 studies. Their criteria for including studies in their analysis were as follows:

» Study was conducted in the United States

» Study supports calculation of wetland values per acre

» Wetlands in the study are characterized in terms of:

» *Geographic location*

» *Type (freshwater marsh, saltwater marsh, swamp, pothole)*

» *Size*

» *Wetland services supporting direct human uses and passive use values including one or more of the following:*

» ***habitat for species (e.g., passive use value of species preservation)***

» ***flood protection (e.g., flood damages avoided)***

» *water quality (i.e. decreases water treatment costs)*

» *water supply (e.g., groundwater recharge)*

» *recreational fishing (i.e. improvements in recreational fisheries on-site or offsite)*

» *commercial fishing (i.e. improvements in commercial fisheries either on-site or offsite)*

» *birdhunting (i.e. site supports waterfowl hunting)*

» ***birdwatching (i.e. site supports birdwatching and other wildlife observation)***

» ***amenity (i.e. property amenity due to proximity to wetland open space)***

Four services—flood protection, habitat, bird-watching, and amenity—are applicable to the salt marsh at Howard Beach. Flood protection is valued in Section 8. The following subsections address the monetization of habitat, bird-watching, and amenity values. Although some saltmarshes can contribute toward the un-bolded services, those services are not supported at the Howard Beach location.

The meta-analysis also includes regionally specific characteristics to be entered into the model. However, the model does not explicitly account for the size of the population that values the resource (sometimes called the market). Details on this and other limitations of benefits transfer applications can be found in Boutwell and Westra (2013) and Boyle et al. (2010). Although meta-analysis tends to reduce errors in benefit transfer, it does not eliminate them.

Habitat Value

Restored or created salt marsh, an important element of Alternatives 1–4, provides habitat for juvenile nekton (fish, crabs, shrimp), wading and shore birds, and invertebrates. Applying the meta-analysis to the salt marsh creation at Spring Creek Park and the marsh islands in Jamaica Bay, the estimated passive use value for the associated species habitat is $1,529 per acre in 2014 dollars. To obtain the net benefits under each alternative, this figure is multiplied by the number of newly created wetland acres. Table 9-7 shows the net acres of marsh for each alternative. For example, Spring Creek has 20.9 marsh acres under the base condition; whereas each of the restoration alternatives raises that figure to 142 acres for a net increase of 121.1 acres.

Although restoring the existing degraded marshes in the base case would also provide benefits, the meta-analysis does not have sufficient resolution to assess the value of incremental changes in marsh quality; a monetary value is assigned only to new acres of wetland. A value was not assigned to the improvement of existing acres of wetland because the meta-analysis tool was not designed to assess the passive use value of incremental changes in the quality of wildlife habitat. However, the meta-analysis can capture the value of replacing open water habitat with new wetland habitat because it is assumed that the area of open water to be converted is of marginal value to the public. The meta-analysis function and definitions of

Table 9-7 Net Acres of Marsh Habitat, by Alternative

	Acres		Increase from base case acreage		Net acreage	
Alternative	*Spring Creek marsh*	*Marsh islands*	*Spring Creek marsh*	*Marsh islands*	*Passive use*	*Birding/ wildlife observation*
Base case	20.9	121	—	—	—	—
Alternative 1	142	121	121.1	0	121.1	121.1
Alternative 2	142	193	121.1	72	193.1	121.1
Alternative 3	142	121	121.1	0	121.1	121.1
Alternative 4	142	121	121.1	0	121.1	121.1
Alternative 5	20.9	121	0	0	—	—

Table 9-8 Salt Marsh Passive Use Monetized Value, by Alternative

	Alt 1	*Alt 2*	*Alt 3*	*Alt 4*	*Alt 5*
Acres of saltmarsh	121.1	193.1	121.1	121.1	0
Passive use value ($/acre)	$1,529	$1,529	$1,529	$1,529	$1,529
Total annual value	**$186,385**	**$249,380**	**$186,385**	**$186,385**	**$0**

variables are given in Appendix A. Table 9-8 presents the passive use values of the salt marsh area for each alternative. Appendix G provides further details on these values.

Recreation

Birdwatching/Wildlife Observation

The creation of salt marsh at Spring Creek Park, with its tidal flats, marshland, and upland, is a site for observing birds and other wildlife, and the coastline affords scenic views of Jamaica Bay. The park is primarily accessible only to nearby residents, however, because it does not provide parking, is not near a bus or train stop, and does not provide comfort facilities or picnic tables.

The wetland created under Alternatives 1–4 expands the area of salt marsh, and with improved signage, facilities, access, and programming (e.g., naturalist presentations, guided ranger walks), the park could attract additional visitors (personal communication, Marit Larson, New York City Parks, October 12, 2014). The visitors would likely be similar to the recreational users who frequent the nearby Jamaica Bay Wildlife Refuge: people who enjoy bird-watching, wildlife observation, and nature study as well as fishing (personal communication, Shalini Gopie, Jamaica Bay Wildlife Refuge, October 13, 2014).

Two methods are used to estimate and then cross validate the potential increased usage. The first method uses the Jamaica Bay Wildlife Refuge as a reference park, whereby visitation at the Refuge is used to predict visitation at the enhanced Spring Creek Park. The second method uses the results from the wetland meta-analysis for birding/other wildlife recreation and recreational fishing.

The refuge, with more than 9,000 acres of land and open water, contains salt marsh, grassland, beach, dune, maritime forest, ponds, and freshwater wetland habitats. It has attracted more than 500,000 visitors annually between 2004 and 2013[11]. Visitation is high during spring (bird migration), in June (when the horseshoe crabs lay their eggs), in June through August (nesting season for diamond

Table 9-9 Bird-Watching and Wildlife Observation Monetized Values, by Alternative

	Alt 1	*Alt 2*	*Alt 3*	*Alt 4*	*Alt 5*
Acres	121.1	121.1	121.1	121.1	0
Birding/Wildlife Observation $/acre	$7,182	$7,182	$7,182	$7,182	$7,182
Total Annual $	**$869,740**	**$869,740**	**$869,740**	**$869,740**	**$0**

back terrapins), in late summer (shorebird migration) and on winter days when snowy owls are sighted.

We also use the results from the wetland meta-analysis for bird-watching and other wildlife recreation and recreational fishing, which suggest that a salt marsh in New York managed for bird-watching and wildlife observation generates about $7,182 per acre per year in recreational bird-watching value with about 115 visitors per acre per year[12]. The meta-analysis function is provided in Appendix A. For the 150 acres of the Jamaica Bay Wildlife Refuge, this works out to approximately 47 visitors per day. This estimate appears consistent with actual visitation at the refuge. For the purposes of this analysis, it is assumed that the additional acres of salt marsh created at Spring Creek Park will also attract about 115 visitors per acre per year at $62.57 per visit for $7,182/acre/year in benefits (USFWS 2001). Table 9-9 presents the meta-analysis results for each alternative for bird-watching and wildlife observations.

The salt marsh created on the marsh islands in the middle of Jamaica Bay would be relatively inaccessible today, but a proposed canoe trail in Jamaica Bay may expand the potential audience for this amenity. Because baseline recreational use of Spring Creek Park is not known, we assume that the increase in recreational use of the park for bird-watching and wildlife observation is limited to the new wetland acres. This assumption is conservative: enhancements to existing acres could also lead to higher visitation.

Aesthetics

The value of Spring Creek Park's current open space—an aesthetic value—may already be captured by property values in the neighboring community, and some of these properties have water views, which can be a highly valued amenity. The salt marsh restoration and creation would likely increase the open-space aesthetics in the foreground while diminishing the open-water background aesthetics. This could dampen some property values. However, the same measures that affect the viewscape are simultaneously providing protection against storm surges that cause flooding. The analysis of avoided flood damages (Section 8) captures the protective aspects of the alternatives and may overstate the benefit for homeowners who lose their water views. Hedonic property pricing, an economic valuation method, is often applied to valuing such aesthetic amenities, but we are not aware of any studies that have valued the simultaneous changes.

View of Jamaica Bay © Alex Potemkin/iStock Photo

10. Final Discussion

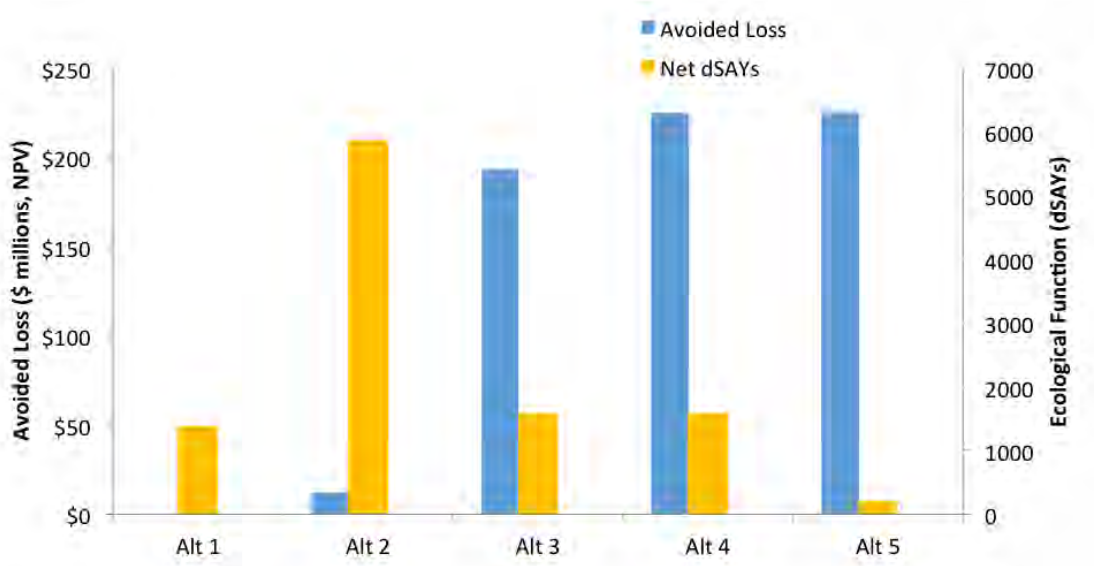
In this assessment, we illustrate the identify-quantify-monetize framework including the various outputs and how they can be used: i) the potential changes in the aesthetics of Spring Creek Park were qualitatively described; ii) the functions of the salt marsh (i.e. net primary productivity, water regulation, nutrient regulation, and improved habitat for fisheries) were quantified in ecological service units using HEA and the results are presented alongside the CBA; iii) the benefits of salt marshes were identified and monetized - passive use values for species habitat and recreational birding/wildlife observation - and these are integrated in the CBA.

Having calculated the monetary benefits and costs of each resilience alternative in the previous sections, we have the necessary data for a comparative analysis of the alternatives, including conventional data included in a cost-benefit analysis and a complementary dataset generated by the HEA. If flood damages avoided were the only benefits, the alternatives could be evaluated based solely on their cost-effectiveness at achieving the flood mitigation objective. However, for multiple types of benefits, the appropriate valuation framework is cost-benefit analysis, which allows us to compare a wide range of effects including flood protection and ecosystem services associated with each alternative, in terms of net present value. Ecological benefits, as discussed in section 9 are analyzed using HEA and the results are expressed in discounted service acre-years (dSAYs). All values, other than the HEA, are calculated with discount rates of 3 percent and 7 percent. The HEA is calculated with a discount rate of 3 percent.

10.1 Integrated Results

This analysis shows that for Howard Beach, neither all-nature and nature-based nor all-gray infrastructure provides adequate ecosystem functions and services and complete flood protection. However, hybrid infrastructure can afford good and cost-effective flood protection while enhancing ecosystem services.

In this case, solely nature and nature-based Alternatives 1 and 2 do not meet the flood mitigation objective and provide less than $1 million in flood damage avoided losses under a 1-in-100 year storm event. Alternative 2, with the largest wetland restoration effort of any alternative, provides the greatest ecological uplift (nearly double the net dSAYs of the other scenarios). Both Alternatives 1 and 2 produce the greatest total ecological uplift and the most cost-effective dSAYs (ranging from approximately $5,900 to $8,050 per unit).



Avoided Losses ($ millions, NPV) and Ecological Functions (dSAYs), by Alternative

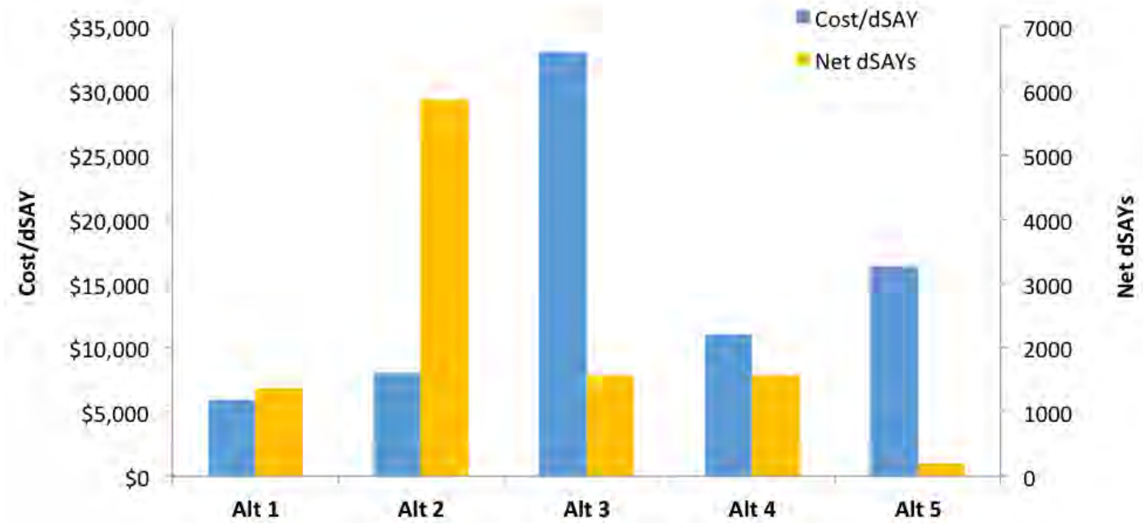


Figure 10-2 Total Cost (Capital plus O&M) per Ecological Functions (dSAYs)

Table 10-1 Benefit-Cost Analysis and Habitat Equivalency Analysis ($ 2014 Million) Summary, by Alternative

	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
NPV benefits @ 3%	25.8	39.7	218.5	250.1	225.3
NPV costs @ 3%	39.4	85.8	232.8	74.6	93
(NPV B – NPV C) @ 3%	-13.6	-46	-14.4	175.5	132.2
NPV dSAYs @ 3%	1376	5864	1579	1579	203

dSAY = discounted service acre-year;
NPV = net present value.

Table 10-2 Benefit-Cost Analysis ($ 2014 Million) Summary, by Alternative

	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
NPV benefits @ 7%	12.3	18.9	103.9	118.9	107.1
NPV costs @ 7%	34.3	75.1	206.3	64.6	81.7
(NPV B – NPV C) @ 7%	-22.1	-56.2	-102.4	54.4	25.4

NPV = net present value.

Hybrid Alternatives 3 and 4 save $193 and $225 million from storm-related damages, respectively. They both provide significant uplift, sufficient protection, and similar ecosystem services (NPV). Given design and capital cost differences, Alternative 4 is more cost-effective: each dSAY costs approximately $11,000 (Figure 10-1). In comparison, each dSAY in the Alternative 3 scenario costs more than $33,000.

Gray-only Alternative 5 maximizes avoided losses from flooding, but would create backflow flooding under certain scenarios, impede public access to the waterfront and shoreline amenities, and possibly damage amenity values by blocking open views with the flood walls. Although it produces a substantially positive NPV given its significant flood reduction benefits, it generates very limited gains in ecological benefits by protecting trees from flooding. It ranks below Alternative 4 both in NPV and dSAYs NPV meaning that it both is not the most cost-effective choice, nor does it provide sufficient ecological benefits.

Alternatives 1 and 2, in addition to not meeting the flood mitigation objective, also show a negative net present value at both discount rates. They generate substantial gains in ecological services, but the negative NPV shows that the flood damages avoided are not justified by the project costs. Alternative 3 achieves substantial flood reduction benefits, but it, too, has a negative NPV and is clearly inferior to Alternative 4. Alternative 4 maximizes NPV and generates a substantial gain in ecological benefits. It is the preferred alternative.

The overall conclusion from the results is that Alternative 4, a hybrid solution, is the preferred alternative for its benefit-cost relationship, significant flood protection, ecosystem services, and ecological benefits.

10.2 Limitations

The resilience strategies evaluated in this report do not represent the only strategies that could increase the resilience of Howard Beach and other coastal communities. Rather, they are representative coastal protection options for an urban neighborhood, chosen so that we could explore the trade-offs of nature and nature-based and gray defenses.

Since we conducted the analysis, FEMA has developed new information and flood maps, and NPCC3 has released updated climate projections, which may alter the results our calculations if applied. The methodology, however, would remain the same, and further assessments and evaluations of infrastructure options for coastal resilience can use it as updated information becomes available.

Although this report has found a preferred conceptual alternative, it does not recommend a specific course of action. That would require further analysis and coordination with the region's other restoration and redevelopment plans.

Although this case study has accounted for a range of effects, flood mitigation measures can have other types of beneficial or adverse effects that were not considered here. For example, flood protection can affect reservoirs, hydropower facilities, and navigation. The potential for such effects should be considered in a comprehensive assessment of flood mitigation alternatives.

Our analysis assumes a 100-year flood event. The analysis does not include damages from less severe or more severe storm events, and thus the expected value of flood damages avoided is underestimated (see Section 8.4). Future assessments should include the full range of storm events to derive these values and should also consider multiple design years, in addition to our assumed 50-year life span for the infrastructure elements.

Our analysis includes the capital costs for the infrastructure (Table 5-1), operation and maintenance costs (Table 5-2), the economic benefits from avoided flood damages (Tables 8-2 to 8-4), and the value of a subset of ecosystem services (Figure 9-9, Tables 9-7, 9-8). Incorporating all the ecological benefits associated with all the nature and nature-based infrastructure elements (not just wildlife habitat but also water purification, nutrient cycling, carbon sequestration, and other ecosystem services) is beyond the scope of this project, but a more comprehensive approach is recommended for supporting future decisions.

The choice of discount rate, 3 percent or 7 percent, did not alter the conclusions: Alternatives 1–3 still fail to pass the benefit-cost test, and Alternative 4 remains the preferred alternative. Nonetheless, the NPV decreases substantially for each of the alternatives, indicating that the discount rate can have a dramatic effect on the outcome.

10.3 Conclusions and Recommendations

Neither all-nature and nature-based or all-gray flood protection infrastructure options provide adequate ecological services and sufficient flood protection in terms of avoided damages and losses. Hybrid infrastructure constructed to withstand high-intensity storms can afford flood protection while providing a number of ecosystem services such as habitat for wildlife, water purification, nutrient cycling, and carbon sequestration. Additional research and adaptive management is needed to provide insight into whether synergistic benefits exist between flood walls/gates and coastal habitats.

Nature and nature-based infrastructure projects can contribute economically valuable services to society. We have used a defensible, replicable cost-benefit analysis framework to determine the net benefits provided by five alternatives to flood protection for Howard Beach, Queens. Whereas cost-effectiveness analysis can evaluate projects with a single outcome, cost-benefit analysis is more appropriate for flood mitigation projects, which can deliver ecosystem services while decreasing flood risks and avoiding the associated damages. We have shown how to account for the wide range of benefits, including negative benefits (costs),that flow from both nature and nature-based infrastructure and gray infrastructure.

Future sea-level rise affects the extent of benefits and losses and requires planning for adaptation.

Under our 12-inch sea-level rise scenario, Alternatives 3, 4 and 5 performed well, but with a 32-inch sea-level rise, no alternative provided much protection against flood damages. To mitigate increased flood risk, based on actual sea-level rise, some infrastructure could later be adapted—for example, by extending flood walls or raising the crest elevations of existing defenses. Consideration of future sea-level rise is critical for identifying the alternative that maximizes net benefit.

A full range of storm events and multiple design years should also be considered.

This analysis did not explore how each alternative avoids damages from storms of less or greater severity than a 1-in-100-year storm. The expected value of flood damages avoided is therefore underestimated for each alternative. Future assessments should include the full range of storm events to derive this expected value. In addition, the present analysis is based on infrastructure of a 50-year design. A more comprehensive assessment would consider multiple design years to find the optimum.

Funding should be prioritized to target the economically most significant benefits and costs.

The dollar value of avoided flood damages is a critical component of the cost-benefit analysis. Additional research is needed to increase understanding of the likely magnitude of damages not captured in HAZUS modeling, such as the loss of transportation services due to flooded roadways and bridges and the loss of power from flooded transformers and substations.

Additional research is needed on the flood protection value of green infrastructure components.

For Howard Beach, gray infrastructure elements would provide the most flood protection benefit: Alternatives 4 and 5 were the only options with a net benefit. The flood protection contribution of nature and nature-based infrastructure was relatively limited but added significant cost. This finding suggests that research should determine the incremental flood protection value of nature and nature-based infrastructure elements and the contexts in which they would add the most value. They can then be paired with gray infrastructure to optimize both flood protection and other benefits.

Economic benefits can be monetized, quantified in nonmonetary units, or described qualitatively.

Monetizing ecosystem service benefits is most appropriate when the link between the physical change and the direct or passive uses is clear and either quality information supports benefit transfer or original empirical research can be conducted to estimate the economic value. For direct uses, a qualitative description of benefits or costs may also be appropriate. For indirect uses, using an ecological metric (e.g., habitat equivalency analysis) for quantifying gains and losses in ecosystem functions captures benefits for which monetization is not practical.

Good data can increase the accuracy of cost-benefit analyses and inform project design.

Our analysis is based on many assumptions, ranging from projected park visits and the level of required maintenance to changes in the level of ecosystem services through time. A cost-effective approach to data collection would consider which components of the analysis have the most weight and the types of information that would advance the assessment. For example:

Park visitation. This was an important factor in the cost-benefit analysis, but neither current nor projected visitation data for Spring Creek Park were available. Our estimates of current and projected recreational use could be verified as follows:

- develop a visitor sampling method and collect baseline data onpark and beach usage; and

- continue collecting visitor-day data following park improvements and beach enhancements.

Aesthetics. More information would help determine whether obstruction of water views warrants an assessment of the effects on property values. We offer recommendations for assessing effects on aesthetics:

- develop visual assessments of the existing viewscapes;
- identify primary observation points;
- prepare simulations to show the viewscapes under each alternative; and
- determine the number of parcels that would be affected.

Ecosystem functions and services. If nature and nature-based infrastructure elements are implemented, a data collection program for restored or created habitats should track changes in ecosystem quality and function to better understand ecological performance and restoration investments in a complex urban setting.

Recreational fishing. Gathering additional information on recreational fishing activity does not appear warranted because how fish populations might respond to the saltmarsh creation is unknown. Absent scientific predictions, it would be difficult to develop a defensible forecast for increases in fishing activity.

Cost-benefit analyses should include sensitivity analysis for discount rates.

In this study, the choice of discount rate, 3 percent or 7 percent, does not affect any of the conclusions: Alternatives 1–3 still fails to demonstrate a net benefit and Alternative 4 remains the preferred alternative. Nonetheless, the net present value decreases substantially for each alternative, showing that the discount rate could affect the outcome.

10.4 Potential Next Steps

This report represents preliminary analysis of the risks facing Howard Beach and the types of options that could mitigate these risks. A more comprehensive study would include other communities along Jamaica Bay and consider the bay as a whole system, to improve the resilience of bayshore region and ensure the safety of its hundreds of thousands of residents. Next steps for parties interested in advancing the discourse on coastal resilience and nature and nature-based infrastructure could include the following:

1. **Expand the analysis from Howard Beach to all communities along Jamaica Bay and conduct a baywide study.**

2. **Conduct additional analysis of costs and benefits of the alternatives.**

- Evaluate the efficacy and benefits under other climate change scenarios (e.g., more frequent but less intense storms).
- Evaluate water quality and other ecological effects.
- Evaluate the social consequences.
- Analyze the benefits for neighboring communities and upland areas.
- Conduct a robust community information and input process to inform decisions about resilience solutions, planning, policies, and practices.

- Conduct a 30-year return-on-investment analysis of the alternatives.

3. **Collect higher-resolution and local data on existing habitat performance and longevity in the urban ecosystem.**

- Compile data and develop baseline assessments for habitats in the New York–New Jersey Harbor.
- Monitor synergies among natural, nature-based, and gray infrastructure (life span, performance, etc.).
- Collect data on the performance of existing marshes, mussel beds, beaches, dunes, uplands, and urban trees as they recover from disturbances.
- Collect data on restored habitats to determine the level of maintenance required to sustain ecosystem functions.
- Develop recommendations for empirical, place-based surveys required to further monetize the ecosystem services at Howard Beach.
- Calibrate literature on performance of restored habitats to urban ecosystems such as Jamaica Bay.

4. **Further assess financing options presented in Appendix J as written in the original report.**

- Analyze the feasibility of financing options, including assessments of development opportunities and demand.

In conclusion, using nature and nature-based infrastructure in conjunction with gray infrastructure to make the City more resilient in the face of climate change is critical to the future of people living along its 520 miles of coastline. Protecting, rebuilding, and restoring wetlands, dunes, shellfish beds, and maritime forests can help safeguard coastal communities by slowing waves, reducing storm surge, preventing erosion, and absorbing precipitation while providing quality-of-life and environmental benefits. These natural assets create an insurance policy for the future: they are nature's cushion against rising sea levels and storm surge, and they remove pollution from the millions of gallons of freshwater that flow into our oceans every minute while providing other significant services to both human and natural communities.

This report demonstrates that it is possible to better quantify and monetize the benefits and services that nature and nature-based infrastructure provide.

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[8] When either costs or benefits fall disproportionately in later years (beyond a 50-year time horizon), selecting the appropriate discount rate becomes more complicated. The benefits and costs accrue to different generations, and future generations are not present to state their preferences. Also, in the longer time horizon, discount rate uncertainty and variability will have a noticeable effect on net present value calculations. In these circumstances, EPA recommends using one of the following:

• an estimated time declining discount factor (Newell and Pizer 2003; Groom et al. 2007; Hepburn et al. 2009);

• more detailed alternatives, such as the Ramsey method (USEPA 2010); or

• a constant but lower range in rates (e.g., 2.5 percent as the lower bound and 5 percent as the upper bound); this is the most practical.

In any case, long time horizons call for thoughtful consideration of the reasons for selecting a given approach, with justifications and sensitivity analysis.

[9] Halcrow 2014, https://www.floodmodeller.com.

[10] However, marsh islands in Jamaica Bay are expected to transition to tidal flats and open water at rate of 0.04 acres/year.

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[12] The output from the meta-analysis is $7,182 per acre per year for saltmarsh bird-watching in New York. To estimate the associated number of visitor-days per acre, this figure must be divided by the dollar value of bird-watching, for which the U.S. Fish and Wildlife Service estimates $62.57 (in 2014 dollars) per day, with about 88 percent New York residents and 12 percent visitors (USFWS 2001).

Appendix A: Wetland Value Meta-Analysis

Variable	Mean	Coefficient	Product
Constant	1.00	-2.297	-2.297
INCOME (/1000)	43.95	0.095	4.175155
YEAR	16.32	0.197	3.21504
ACRES	356640.19	-3.85E-07	-0.137306473
SHARE	0.13	-5.415	-0.70395
FRESHWATER MARSH	0.54	-1.088	-0.58752
SALTWATER MARSH	0.28	-2.087	-0.58436
PRARIE POTHOLE	0.10	-1.961	-0.1961
HEARTLAND	0.07	1.316	0.09212
NORTHERN CRESCENT	0.28	2.681	0.75068
MISSISSIPPI PORTAL	0.17	-0.158	-0.02686
ALL OTHER REGIONS	0.31	-0.585	-0.18135
FLOOD	0.25	-0.477	-0.11925
WATER QUALITY	0.28	1.235	0.3458
WATER SUPPLY	0.21	0.929	0.19509
RECFISH	0.32	-0.015	-0.0048
COMFISH	0.28	1.073	0.30044
BIRDHUNT	0.32	0.015	0.0048
BIRDWATCH	0.24	1.57	0.3768
AMENITY	0.19	-1.518	-0.28842
HABITAT	0.32	0.023	0.00736
CVM	0.39	-1.437	-0.56043
HP	0.04	-0.154	-0.00616
TCM	0.06	-0.658	-0.03948
NFI	0.19	0.628	0.11932
PFMP	0.07	-1.827	-0.12789
EA	0.03	5.296	0.15888
PUBLISH	0.69	2.489	1.71741
Ln $/acre of wetland			$ 5.60
$/acre (2003 base year)			$ 269.89

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(Dissertation Advisor Alan Randall). Agricultural, Environmental, and Development Economics Graduate Program, Ohio State University, Columbus, OH, 2006.

Variable	Variable Definition
$ / Acre	Annual $ value of an acre of wetlands, converted to 2006 base year. For a description of value, see 'Definition of Benefits' tab.
INCOME	Annual household income, (divided by 1000).
YEAR	Year in which study was conducted, coded as 1969=1, 1970=2, etc.
ACRES	Amount of wetland acres used in the study valuation.
SHARE	Share of wetland acres in the area by FIPS codes as reported by the NRI 1997 data.
FRESHWATER MARSH	Coded as 1 if a wetland is a freshwater marsh, 0 if not.
SALTWATER MARSH	Coded as 1 if a wetland is a saltwater marsh, 0 if not.
SWAMP	Coded as 1 if a wetland is a swamp, 0 if not.
PRARIE POTHOLE	Coded as 1 if a wetland is a prarie pothole, 0 if not.
FLOOD	Reduced damage due to flooding and/or stabalization of the sediment for erosion reduction, coded as 1 if wetland function is provided by policy site, 0 if not.
WATER QUALITY	Reduced costs of water purification, coded as 1 if wetland function is provided by policy site, 0 if not.
WATER SUPPLY	Increased water quantity, coded as 1 if wetland function is provided by policy site, 0 if not.
RECFISH	Improvements in recreational fisheries either on or off site, coded as 1 if wetland function is provided by policy site, 0 if not.
COMFISH	Improvement in commercial fisheries either on or off site, coded as 1 if wetland function is provided by policy site, 0 if not.
BIRDHUNT	Hunting of wildlife, coded as 1 if wetland function is provided by policy site, 0 if not.
BIRDWATCH	Recreational observation of wildlife, coded as 1 if wetland function is provided by policy site, 0 if not.
AMENITY	Amenity values provided by proximity to the environment, coded as 1 if wetland function is provided by policy site, 0 if not.
HABITAT	Nonuse appreciation of the species, coded as 1 if wetland function is provided by policy site, 0 if not.
CVM	1 if study used Contingent Valuation Method, 0 if not.
HP	1 if study used Hedonic Pricing Method, 0 if not.
TCM	1 if study used Travel Cost Method, 0 if not.
RC	1 if study used Replacement Cost Method, 0 if not.
NFI	1 if study used Net Factor Income Method, 0 if not.
PFMP	1 if study used Production Function or Market Prices method, 0 if not.
EA	1 if study used Energy Analysis Method, 0 if not.
PUBLISH	1 if study is a journal article, 0 if not.
HEARTLAND	1 if study conducted in the region. (southeast SD, northeast NE, southwest MN, IA, northern and mid MO, IL, IN, west and mid OH, west KY)
NORTHERN CRESCENT	1 if study conducted in the region. (northeast MN, WI, MI, northeast OH, PA, NJ, NY, CT, RI, MA, NH, VT, ME)
FRUITFUL RIM	1 if study conducted in the region. (west and mid WA, west and east OR, southern ID, western CA, mid and southern AZ, west and south TX, FL, east GA, east SC)
MISSISSIPPI PORTAL	1 if study conducted in the region. (east LA, east AR, north and west MS, west TN)
ALL OTHER REGIONS	1 if study conducted in Eastern Uplands, Northern Great Plains, Prairie Gateway, or Southern Seaboard, 0 if not.

Appendix B: HAZUS Results - Tables

Economic Losses

100 year flood

Table B-1 Base Case Direct Economic Loss – 100 year flood (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**969,118**	59,195	22,987	0	679,122	0	207,815	0	0
COM	**59,949**	1,341	3,239	3,565	5,359	5,891	3,693	10,916	25,946
EDU	**75**	12	63	0	0	0	0	0	0
REL	**502**	30	471	0	0	0	0	0	0
IND	**0**	-	-	0	0	0	0	0	0
GOV	**271**	56	215	0	0	0	0	0	0
TOTAL	**1,029,915**	**60,633**	**26,976**	**3,565**	**684,481**	**5,891**	**211,507**	**10,916**	**25,946**

Total Direct Economic Loss is $1,029,915,000

Table B-2 Alternative 1 Direct Economic Loss – 100 year flood (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**954,085**	58,381	22,721	-	668,437	-	204,546	-	-
COM	**58,512**	1,343	3,240	3,513	5,210	5,734	3,589	10,624	25,257
EDU	**96**	15	81	-	-	-	-	-	-
REL	**503**	30	472	-	-	-	-	-	-
IND	**-**	-	-	-	-	-	-	-	-
GOV	**287**	62	225	-	-	-	-	-	-
TOTAL	**1,013,482**	**59,831**	**26,740**	**3,513**	**673,648**	**5,734**	**208,135**	**10,624**	**25,257**

Total Direct Economic Loss is $1,013,482,000

Table B-3 Alternative 2 Direct Economic Loss – 100 year flood (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**918,409**	55,369	21,459	-	644,385	-	197,196	-	-
COM	**59,858**	1,211	2,880	3,193	5,434	5,980	3,743	11,079	26,339
EDU	**34**	5	29	-	-	-	-	-	-
REL	**470**	27	443	-	-	-	-	-	-
IND	**-**	-	-	-	-	-	-	-	-
GOV	**243**	51	192	-	-	-	-	-	-
TOTAL	**979,014**	**56,663**	**25,002**	**3,193**	**649,819**	**5,980**	**200,939**	**11,079**	**26,339**

Total Direct Economic Loss is $979,014,000

Table B-4 Alternative 3 Direct Economic Loss – 100 year flood (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**90,773**	14,522	6,395		52,734		17,121		
COM	**23,491**	886	2,215	2,409	2,082	2,337	1,456	3,532	8,574
EDU	**-**	-	-	-	-	-	-	-	-
REL	**-**	-	-	-	-	-	-	-	-
IND	**-**	-	-	-	-	-	-	-	-
GOV	**82**	29	53	-	-	-	-	-	-
TOTAL	**114,346**	**15,437**	**8,663**	**2,409**	**54,816**	**2,337**	**18,577**	**3,532**	**8,574**

Total Direct Economic Loss is $114,346,000

Table B-5 Alternative 4 Direct Economic Loss – 100 year flood (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**197**	29	11	-	118	-	39	-	-
COM	**1,570**	49	173	188	114	164	77	230	576
EDU	**-**	-	-	-	-	-	-	-	-
REL	**-**	-	-	-	-	-	-	-	-
IND	**-**	-	-	-	-	-	-	-	-
GOV	**-**	-	-	-	-	-	-	-	-
TOTAL	**1,767**	**78**	**184**	**188**	**231**	**164**	**115**	**230**	**576**

Total Direct Economic Loss is $1,767,000

No losses were incurred for Alternative 5 under the 100 year flood.

Economic Losses

100 year flood + 12" sea level rise (SLR)

This scenario was not run for Alternatives 1 and 2 as losses were so significant under the present day 100 year flood.

Table B-6 Base Case Direct Economic Loss – 100 year flood + 12" SLR (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**1,109,006**	70,851	28,482	-	$773,676	-	$235,998	-	-
COM	**97,960**	2,361	6,510	6,288	$8,679	$9,363	$5,987	$17,391	41,382
EDU	**638**	100	538	-	-	-	-	-	-
REL	**888**	83	805	-	-	-	-	-	-
IND	**0**	-	-	-	-	-	-	-	-
GOV	**678**	158	520	-	-	-	-	-	-
TOTAL	**1,209,170**	**73,553**	**36,855**	**6,288**	**782,355**	**9,363**	**241,985**	**17,391**	**41,382**

Total Direct Economic Loss is $1,209,170,000

Table B-7 Alternative 3 Direct Economic Loss – 100 year flood + 12" SLR (Values in $1,000s)

Occupancy	**Total Loss**	**Building Loss**	**Content Loss**	**Inventory Loss**	**Relocation Loss**	**Income Loss**	**Rental Income Loss**	**Wage Loss**	**Direct Output Loss**
RES	**90,091**	15,490	7,348	-	50,778	-	16,475	-	-
COM	**40,611**	1,631	4,593	4,412	3,453	3,911	2,417	5,896	14,298
EDU	**0**	-	-	-	-	-	-	-	-
REL	**0**	-	-	-	-	-	-	-	-
IND	**0**	-	-	-	-	-	-	-	-
GOV	**311**	106	205	-	-	-	-	-	-
TOTAL	**131,014**	**17,227**	**12,146**	**4,412**	**54,231**	**3,911**	**18,892**	**5,896**	**14,298**

Total Direct Economic Loss is $131,014,000

Table B-8 Alternative 4 Direct Economic Loss – 100 year flood + 12" SLR (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**1,086,874**	68,674	27,154	-	759,422	-	231,625	-	-
COM	**81,460**	1,905	5,290	5,457	7,206	7,782	4,969	14,453	34,398
EDU	**439**	69	370	-	-	-	-	-	-
REL	**692**	48	644	-	-	-	-	-	-
IND	**0**	-	-	-	-	-	-	-	-
GOV	**535**	123	412	-	-	-	-	-	-
TOTAL	**1,169,999**	**70,819**	**33,869**	**5,457**	**766,627**	**7,782**	**236,594**	**14,453**	**34,398**

Total Direct Economic Loss is $1,169,999,000

No losses were incurred for Alternative 5 under the 100 year flood with 12" sea level rise.

Economic Losses

100 year flood + 32" sea level rise (SLR)

Table B-9 Base Case Direct Economic Loss – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**1,240,083**	97,721	42,197	-	843,070	-	257,095	-	-
COM	**154,271**	4,673	13,913	11,132	13,115	14,072	9,052	26,125	62,188
EDU	**4,650**	727	3,924	-	-	-	-	-	-
REL	**2,018**	276	1,742	-	-	-	-	-	-
IND	**0**	-	-	-	-	-	-	-	-
GOV	**1,431**	311	1,120	-	-	-	-	-	-
TOTAL	**1,402,453**	**103,707**	**62,895**	**11,132**	**856,186**	**14,072**	**266,147**	**26,125**	**62,188**

Total Direct Economic Loss is $1,402,453,000

Table B-10 Alternative 3 Direct Economic Loss – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**1,247,414**	98,308	42,336	-	848,132		258,639		
COM	**151,712**	4,569	13,546	11,010	12,863	13,640	8,878	25,832	61,374
EDU	**4,606**	720	3,887	-					
REL	**2,026**	278	1,749	-					
IND	**0**	-	-	-					
GOV	**824**	229	595	-					
TOTAL	**1,406,584**	**104,103**	**62,112**	**11,010**	**860,995**	**13,640**	**267,517**	**25,832**	**61,374**

Total Direct Economic Loss is $1,406,584,000

Table B-11 Alternative 4 Direct Economic Loss – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	1,241,536	97,856	41,994	-	844,235	-	257,450	-	-
COM	152,428	4,569	13,565	10,968	13,007	13,914	8,978	25,861	61,566
EDU	4,375	684	3,691	-	-	-	-	-	-
REL	1,944	265	1,679	-	-	-	-	-	-
IND	0	-	-	-	-	-	-	-	-
GOV	1,401	303	1,098	-	-	-	-	-	-
TOTAL	1,401,683	103,676	62,028	10,968	857,242	13,914	266,428	25,861	61,566

Total Direct Economic Loss is $1,401,683,000

Table B-12 Alternative 5 Direct Economic Loss – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Total Loss	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
RES	**1,276,481**	101,964	44,202	-	866,141	-	264,174	-	-
COM	**145,702**	4,813	14,306	11,245	12,169	13,011	8,398	24,182	57,578
EDU	**5,302**	828	4,474	-	-	-	-	-	-
REL	**2,096**	288	1,808	-	-	-	-	-	-
IND	**-**								
GOV	**1,505**	321	1,184	-	-	-	-	-	-
TOTAL	**1,431,086**	**108,215**	**65,973**	**11,245**	**878,310**	**13,011**	**272,572**	**24,182**	**57,578**

Total Direct Economic Loss is $1,431,086,000

Loss Ratio

100 year flood

Table B-13 Base Scenario Loss Ratio – 100 year flood (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	59,195	998,034	6%
Commercial	1,341	76,012	2%
Educational	12	33,967	0%
Religious	30	6,054	1%
Industrial	-	0	0%
Government	56	6,680	1%
TOTAL	**60,633**	**1,120,747**	**5%**

Table B-14 Alternative 1 Loss Ratio - 100 year flood (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	58,381	998,034	6%
Commercial	1,343	76,012	2%
Educational	15	33,967	0%
Religious	30	6,054	1%
Industrial	0	0	0%
Government	62	6,680	1%
TOTAL	**59,831**	**1,120,747**	**5%**

Table B-15 Alternative 2 Loss Ratio – 100 year flood (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	55,369	998,034	6%
Commercial	1,211	76,012	2%
Educational	5	33,967	0%
Religious	27	6,054	0%
Industrial	-	0	0%
Government	51	6,680	1%
TOTAL	**56,663**	**1,120,747**	**5%**

Table B-16 Alternative 3 Loss Ratio – 100 year flood (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	14,522	998,034	1%
Commercial	886	76,012	1%
Educational	-	33,967	0%
Religious	-	6,054	0%
Industrial	-	0	0%
Government	29	6,680	0%
TOTAL	**15,437**	**1,120,747**	**1%**

Table B-17 Alternative 4 Loss Ratio – 100 year flood (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	29	998,034	0.0%
Commercial	49	76,012	0.1%
Educational	-	33,967	0.0%
Religious	-	6,054	0.0%
Industrial	-	0	0.0%
Government	-	6,680	0.0%
TOTAL	**78**	**1,120,747**	**0.0%**

No losses were incurred for Alternative 5 under the 100 year flood.

Loss Ratio

100 year flood + 12" sea level rise (SLR)

This scenario was not run for Alternatives 1 and 2 as losses were so significant under the present day 100 year flood.

Table B-18 Base Case Direct Loss Ratio – 100 year flood + 12" SLR (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	70,851	998,034	7%
Commercial	2,361	76,012	3%
Educational	100	33,967	0%
Religious	83	6,054	1%
Industrial	-	0	0%
Government	158	6,680	2%
TOTAL	**73,553**	**1,120,747**	**7%**

Table B-19 Alternative 3 Direct Loss Ratio – 100 year flood + 12" SLR (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	15,490	998,034	2%
Commercial	1,631	76,012	2%
Educational	-	33,967	0%
Religious	-	6,054	0%
Industrial	-	0	0%
Government	106	6,680	2%
TOTAL	**17,227**	**1,120,747**	**2%**

Table B-20 Alternative 4 Direct Loss Ratio – 100 year flood + 12" SLR (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	68,674	998,034	7%
Commercial	1,905	76,012	3%
Educational	69	33,967	0%
Religious	48	6,054	1%
Industrial	-	0	0%
Government	123	6,680	2%
TOTAL	**70,819**	**1,120,747**	**6%**

No losses were incurred for Alternative 5 under the 100 year flood with 12" sea level rise.

Loss Ratio

100 year flood +32" Sea Level Rise (SLR)

Table B-21 Base Case Direct Loss Ratio – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	97,721	998,034	10%
Commercial	4,673	76,012	6%
Educational	727	33,967	2%
Religious	276	6,054	5%
Industrial	-	0	0%
Government	311	6,680	5%
TOTAL	**103,707**	**1,120,747**	**9%**

Table B-22 Alternative 3 Direct Loss Ratio – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	98,308	998,034	10%
Commercial	4,569	76,012	6%
Educational	720	33,967	2%
Religious	278	6,054	5%
Industrial	-	0	0%
Government	229	6,680	3%
TOTAL	**104,103**	**1,120,747**	**9%**

Table B-23 Alternative 4 Direct Loss Ratio – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	97,856	998,034	10%
Commercial	4,569	76,012	6%
Educational	684	33,967	2%
Religious	265	6,054	4%
Industrial	-	0	0%
Government	303	6,680	5%
TOTAL	**103,676**	**1,120,747**	**9%**

Table B-24 Alternative 5 Direct Loss Ratio – 100 year flood + 32" SLR (Values in $1,000s)

Occupancy	Building Loss	Howard Beach Total	Loss Ratio
Residential	101,964	998,034	10%
Commercial	4,813	76,012	6%
Educational	828	33,967	2%
Religious	288	6,054	5%
Industrial		0	0%
Government	321	6,680	5%
TOTAL	**108,215**	**1,120,747**	**10%**

Impacted Structures

100 year flood

Table B-25 Base Case Number of Impacted Structures – 100 year flood

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3523	4281	82%
Commercial	179	197	91%
Educational	2	9	22%
Religious	6	8	75%
Industrial	0	0	-
Government	4	7	57%
TOTAL	**3714**	**4502**	**82%**

Table B-26 Alternative 1 Number of Impacted Structures– 100 year flood

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3523	4281	82%
Commercial	167	197	85%
Educational	2	9	22%
Religious	6	8	75%
Industrial	0	0	-
Government	4	7	57%
TOTAL	**3702**	**4502**	**82%**

Table B-27 Alternative 2 Number of Impacted Structures – 100 year flood

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3523	4281	82%
Commercial	179	197	91%
Educational	2	9	22%
Religious	6	8	75%
Industrial	0	0	-
Government	4	7	57%
TOTAL	**3714**	**4502**	**82%**

Table B-28 Alternative 3 Number of Impacted Structures – 100 year flood

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	552	4281	13%
Commercial	79	197	40%
Educational	0	9	0%
Religious	0	8	0%
Industrial	0	0	-
Government	3	7	43%
TOTAL	**634**	**4502**	**14%**

Table B-29 Alternative 4 Number of Impacted Structures– 100 year flood

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	6	4281	0%
Commercial	2	197	1%
Educational	0	9	0%
Religious	0	8	0%
Industrial	0	0	-
Government	0	7	0%
TOTAL	**8**	**4502**	**0%**

No losses were incurred for Alternative 5 under the 100 year flood.

Impacted Structures

100 year flood + 12" sea level rise (SLR)

This scenario was not run for Alternatives 1 and 2 as losses were so significant under the present day 100 year flood.

Table B-30 Base Case Number of Impacted Structures – 100 year flood + 12" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3863	4281	90%
Commercial	185	197	94%
Educational	2	9	22%
Religious	8	8	100%
Industrial	0	0	-
Government	4	7	57%
TOTAL	**4062**	**4502**	**90%**

Table B-31 Alternative 3 Number of Impacted Structures – 100 year flood + 12" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	553	4281	13%
Commercial	80	197	41%
Educational	0	9	0%
Religious	0	8	0%
Industrial	0	0	-
Government	3	7	43%
TOTAL	**636**	**4502**	**14%**

Table B-32 Alternative 4 Number of Impacted Structures – 100 year flood + 12" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3863	4281	90%
Commercial	181	197	92%
Educational	2	9	22%
Religious	8	8	100%
Industrial	0	0	-
Government	4	7	57%
TOTAL	**4058**	**4502**	**90%**

No losses were incurred for Alternative 5 under the 100 year flood with 12" sea level rise.

Impacted Structures

100 year flood + 32" sea level rise (SLR)

Table B-33 Base Case Number of Impacted Structures – 100 year flood + 32" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3960	4281	93%
Commercial	194	197	98%
Educational	5	9	56%
Religious	8	8	100%
Industrial	0	0	-
Government	6	7	86%
TOTAL	**4173**	**4502**	**93%**

Table B-34 Alternative 3 Number of Impacted Structures – 100 year flood + 32" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3964	4281	93%
Commercial	194	197	98%
Educational	5	9	56%
Religious	8	8	100%
Industrial	0	0	-
Government	5	7	71%
TOTAL	**4176**	**4502**	**93%**

Table B-35 Alternative 4 Number of Impacted Structures – 100 year flood + 32" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3961	4281	93%
Commercial	196	197	99%
Educational	5	9	56%
Religious	8	8	100%
Industrial	0	0	-
Government	6	7	86%
TOTAL	**4176**	**4502**	**93%**

Table B-36 Alternative 5 Number of Impacted Structures– 100 year flood + 32" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3970	4281	93%
Commercial	196	197	99%
Educational	9	9	100%
Religious	8	8	100%
Industrial	0	0	-
Government	7	7	100%
TOTAL	**4190**	**4502**	**93%**

Table B-34 Alternative 3 Number of Impacted Structures – 100 year flood + 32" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3964	4281	93%
Commercial	194	197	98%
Educational	5	9	56%
Religious	8	8	100%
Industrial	0	0	-
Government	5	7	71%
TOTAL	**4176**	**4502**	**93%**

Table B-35 Alternative 4 Number of Impacted Structures – 100 year flood + 32" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3961	4281	93%
Commercial	196	197	99%
Educational	5	9	56%
Religious	8	8	100%
Industrial	0	0	-
Government	6	7	86%
TOTAL	**4176**	**4502**	**93%**

Table B-36 Alternative 5 Number of Impacted Structures– 100 year flood + 32" SLR

	Number of Structures Impacted	Total Number of Structures	Percent Impacted (%)
Residential	3970	4281	93%
Commercial	196	197	99%
Educational	9	9	100%
Religious	8	8	100%
Industrial	0	0	-
Government	7	7	100%
TOTAL	**4190**	**4502**	**93%**

Vehicle Losses

Table B-37 Vehicle Loss – Day Estimate

Flood event		Car Loss	Lt Truck Loss	Hvy Truck Loss	Total Loss
100 year	**Base**	$3,855,666	$2,553,723	$186,279	**$6,595,668**
	Alternative 1	$3,960,898	$2,615,229	$189,626	**$6,765,753**
	Alternative 2	$3,472,233	$2,352,485	$168,184	**$5,992,902**
	Alternative 3	$1,145,176	$872,285	$51,605	**$2,069,067**
	Alternative 4	$8,594	$9,559	$408	**$18,561**
	Alternative 5	0	0	0	**$0**
100 year + 12" SLR	**Base**	$4,693,726	$3,159,008	$227,019	**$8,079,753**
	Alternative 3	$2,248,899	$1,777,661	$101,839	**$4,128,399**
	Alternative 4	$4,508,141	$3,048,417	$221,279	**$7,777,837**
	Alternative 5	0	0	0	**$0**
100 year + 32" SLR	**Base**	$7,380,292	$4,530,891	$323,458	**$12,234,641**
	Alternative 3	$6,911,175	$4,312,342	$307,742	**$11,531,259**
	Alternative 4	$7,274,000	$4,446,342	$315,210	**$12,035,552**
	Alternative 5	$8,653,186	$4,953,425	$353,587	**$13,960,198**

Table B-38 Vehicle Loss – Night Estimate

Flood event		Car Loss	Lt Truck Loss	Hvy Truck Loss	Total Loss
100 year	**Base**	$4,140,013	$2,488,394	$193,866	**$6,822,273**
	Alternative 1	$4,269,493	$2,561,259	$197,425	**$7,028,177**
	Alternative 2	$3,654,078	$2,227,686	$174,927	**$6,056,691**
	Alternative 3	$1,599,784	$1,057,681	$89,504	**$2,746,969**
	Alternative 4	$4,847	$4,755	$420	**$10,021**
	Alternative 5	0	0	0	**$0**
100 year + 12" SLR	**Base**	$5,166,093	$3,171,719	$236,772	**$8,574,584**
	Alternative 3	$1,891,970	$1,335,328	$105,657	**$3,332,955**
	Alternative 4	$4,925,970	$3,020,194	$230,328	**$8,176,492**
	Alternative 5	0	0	0	**$0**
100 year + 32" SLR	**Base**	$8,473,640	$4,795,185	$338,084	**$13,606,909**
	Alternative 3	$8,022,842	$4,593,958	$321,226	**$12,938,026**
	Alternative 4	$8,317,360	$4,671,711	$328,770	**$13,317,841**
	Alternative 5	$7,509,578	$4,625,066	$338,973	**$12,473,617**

Bridge Repairs

Table B-39 Bridge Repair Costs

		Number of Bridges Impacted	Total Repair Cost ($)
100 year	**Base**	1	**$106,282**
	Alternative 1	1	**$106,282**
	Alternative 2	1	**$106,282**
	Alternative 3	1	**$49,053**
	Alternative 4	0	**$0**
	Alternative 5	0	**0**
100 year + 12" SLR	**Base**	2	**$1,233,460**
	Alternative 3	1	**$106,230**
	Alternative 4	2	**$1,029,070**
	Alternative 5	0	**$0**
100 year + 32" SLR	**Base**	5	**$2,586,662**
	Alternative 3	4	**$1,641,340**
	Alternative 4	5	**$2,586,662**
	Alternative 5	5	**$2,586,662**

Road Repairs

Table B-39 Road Repair Costs

		Impacted Road (Miles)	Repair Cost ($ per mile)	Total Repair Cost ($)
100 year	**Base**	31.95	100000	**3,194,921**
	Alternative 1	31.75	100000	**3,175,166**
	Alternative 2	31.75	100000	**3,175,166**
	Alternative 3	3.24	100000	**324,402**
	Alternative 4	0.95	100000	**94,575**
	Alternative 5	0	0	**0**
100 year + 12" SLR	**Base**	33.25	100000	**3,325,133**
	Alternative 3	3.25	100000	**324,807**
	Alternative 4	32.85	100000	**3,284,674**
	Alternative 5	0	100000	**0**
100 year + 32" SLR	**Base**	33.86	100000	**3,385,776**
	Alternative 3	32.85	100000	**3,284,674**
	Alternative 4	33.66	100000	**3,366,109**
	Alternative 5	33.48	100000	**3,347,675**

Debris

Table B-40 *Debris removal costs*

		Finish Tons	Structure Tons	Foundation Tons	Total Tons	Removal Costs
100 year	**Base**	4,296,981	110,256	74,954	4,482,192	**$137,453,878**
	Alternative 1	4,673,246	109,654	74,545	4,857,444	**$148,961,624**
	Alternative 2	3,881,038	110,115	74,858	4,066,011	**$124,691,007**
	Alternative 3	1,535,088	65,806	44,736	1,645,630	**$ 50,465,979**
	Alternative 4	2,726	993	656	4,375	**$ 134,157**
	Alternative 5	0	0	0	0	**$0**
100 year + 12" SLR	**Base**	5,529,221	124,133	83,585	5,736,939	**$175,932,805**
	Alternative 3	1,635,088	68,409	46,063	1,749,560	**$53,653,159**
	Alternative 4	5,045,517	115,571	78,038	5,239,126	**$160,666,544**
	Alternative 5	0	0	0	0	**$0**
100 year + 32" SLR	**Base**	8,412,473	181,885	119,058	8,713,416	**$267,211,411**
	Alternative 3	8,371,032	180,989	118,471	8,670,492	**$265,895,098**
	Alternative 4	8,343,473	181,117	118,599	8,643,189	**$265,057,798**
	Alternative 5	7,242,474	155,242	102,176	7,499,891	**$ 229,996,655**

Shelter

Table B-41 *Shelter Needs and Costs*

		Shelter Needs	Costs
100 year	**Base**	1,443	**$35,112,519**
	Alternative 1	1,443	**$35,112,519**
	Alternative 2	1,443	**$35,112,519**
	Alternative 3	185	**$4,501,605**
	Alternative 4	4	**$97,332**
	Alternative 5	0	**0**
100 year + 12" SLR	**Base**	1,577	**$38,373,141**
	Alternative 3	186	**$4,525,938**
	Alternative 4	1,565	**$38,081,145**
	Alternative 5	0	**0**
100 year + 32" SLR	**Base**	1,633	**$39,735,789**
	Alternative 3	1,600	**$38,932,800**
	Alternative 4	1,626	**$39,565,458**
	Alternative 5	1,623	**$39,492,459**

Appendix C: HAZUS Results - Maps

Figure C2: Baseline Impacts - 100 year flood
N
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 18.361
Low : 0.001
0 0.125 0.25 0.5 Miles
112

Figure C3: Baseline Losses - 100 year flood
N
Legend
Total Economic Loss (x$1000)
0 - 5000
5001 - 15000
15001 - 50000
50001 - 100000
100001 - 139596
0 0.125 0.25 0.5 Miles
113


Figure C4: Baseline Debris - 100 year flood
N
Legend
Debris
(Tons)
0 - 10000
10001 - 30000
30001 - 60000
60001 - 100000
100001 - 235053
0 0.125 0.25 0.5 Miles
114


Figure C5: Alternative 1
Impacts -100 year flood
N
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 18.413
Low : 0.001
0 0.125 0.25 0.5 Miles
115


Figure C6: Alternative 1
Losses - 100 year flood
N
Legend
Total Economic Loss
(x$1000)
0 - 5000
5001 - 10000
10001 - 40000
40001 - 80000
80001 - 141447
0 0.125 0.25 0.5 Miles
116


Figure C7: Alternative 1
Debris - 100 year flood
N
Legend
Debris
(Tons)
0 - 25000
25001 - 50000
50001 - 100000
100001 - 250000
250001 - 841787
0 0.1250.25 0.5 Miles
117


Figure C8: Alternative 2
Impacts - 100 year flood
N
Legend
Impacted
Non-Impacted Structures
Inundation
(Feet)
High : 18.373
Low : 0.001
0 0.125 0.25 0.5 Miles
118


Figure C9: Alternative 2
Losses - 100 year flood
N
Legend
Total Economic Loss
(x$1000)
0 - 5000
5001 - 10000
10001 - 40000
40001 - 80000
80001 - 139596
0 0.125 0.25 0.5 Miles
119


Figure C10: Alternative 2
Debris - 100 year flood
N
Legend
Debris
(Tons)
0 - 10000
10001 - 25000
25001 - 50000
50001 - 100000
100001 - 277417
0 0.125 0.25 0.5 Miles

120

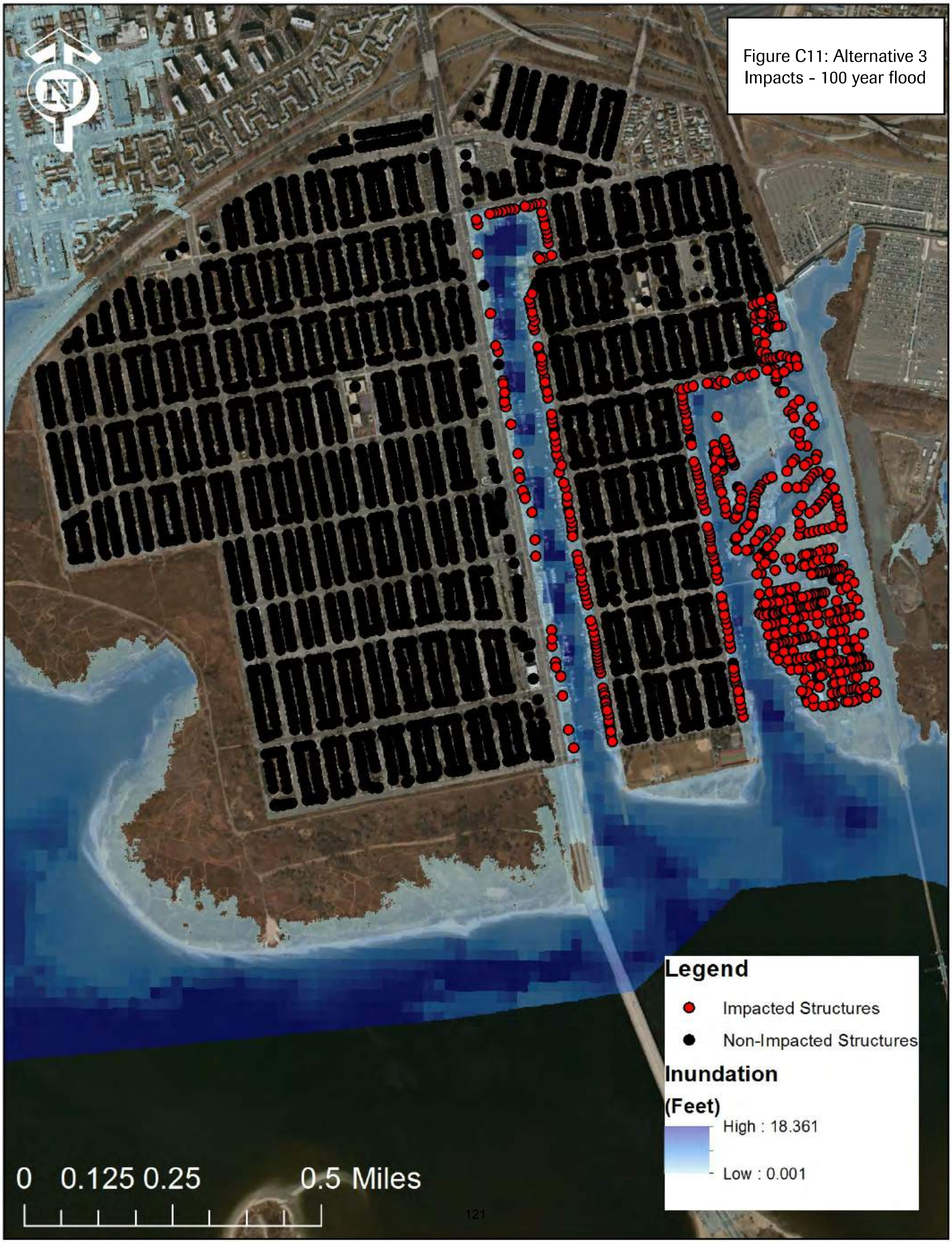
Figure C11: Alternative 3
Impacts - 100 year flood
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 18.361
Low : 0.001
0 0.125 0.25 0.5 Miles
121

Figure C12: Alternative 3
Losses - 100 year flood
Legend
Total Economic Loss
(x$1000)
2 - 1000
1001 - 5000
5001 - 10000
10001 - 25000
25001 - 92236
0 0.125 0.25 0.5 Miles
123


Figure C13: Alternative 3
Debris - 100 year flood
N
Legend
Debris
(Tons)
17 - 10000
10001 - 25000
25001 - 50000
50001 - 100000
100001 - 235053
0 0.125 0.25 0.5 Miles
122


Figure C14: Alternative 4
Impacts - 100 year flood
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 15.682
Low : 0.001
0 0.125 0.25 0.5 Miles
124


Figure C15: Alternative 4
Losses - 100 year flood
N
Legend
Total Economic Loss
(x$1000)
0 - 1000
1001 - 5000
5001 - 10000
10001 - 20000
20001 - 43345
0 0.125 0.25 0.5 Miles
125

Figure C16: Alternative 4
Debris - 100 year flood
N
Legend
Debris
(Tons)
0 - 1000
1001 - 5000
5001 - 10000
10001 - 25000
25001 - 122748
0 0.125 0.25 0.5 Miles
126

Figure C17: Baseline Impacts - 100 year flood +12" SLR
N
Legend
Impacted Structures
Non-Impacted Structures
Inundation (Feet)
High : 18.759
Low : 0.001
0 0.125 0.25 0.5 Miles
127


Figure C18: Baseline Losses - 100 year flood +12" SLR
N
Legend
Total Economic Loss
(x$1000)
0 - 5000
5001 - 10000
10001 - 40000
40001 - 80000
80001 - 145607
0 0.125 0.25 0.5 Miles
128


Figure C19: Baseline Debris - 100 year flood +12” SLR
Legend
Debris
(Tons)
0 - 5000
5001 - 20000
20001 - 50000
50001 - 100000
100001 - 248802
0 0.1250.25 0.5 Miles
129

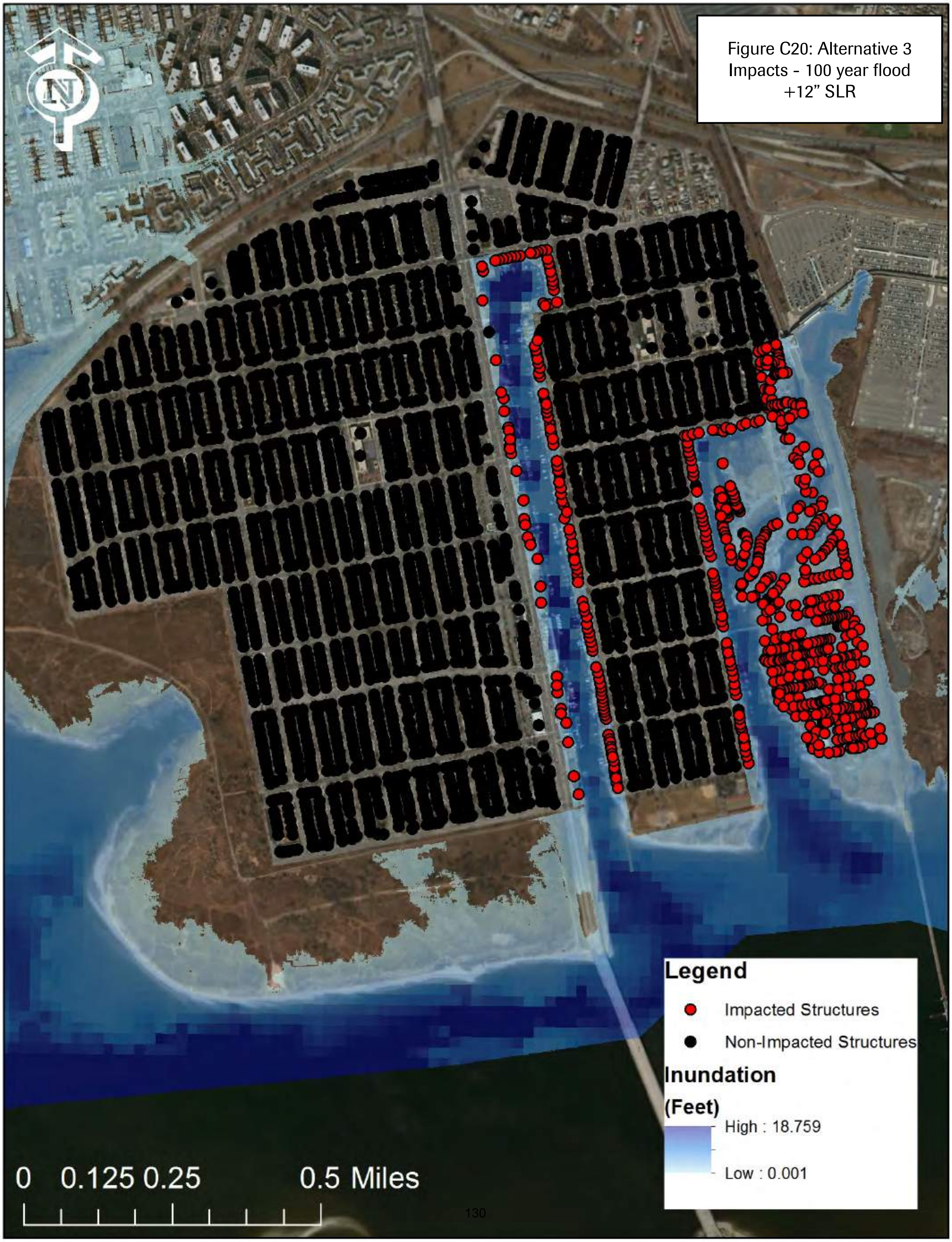
Figure C20: Alternative 3
Impacts - 100 year flood
+12" SLR
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 18.759
Low : 0.001
0 0.125 0.25 0.5 Miles
130

Figure C21: Alternative 3
Losses - 100 year flood
+12" SLR
N
Legend
Total Economic Loss
(x$1000)
6 - 1500
1501 - 3000
3001 - 10000
10001 - 40000
40001 - 97438
0 0.125 0.25 0.5 Miles
131


Figure C22: Alternative 3
Debris - 100 year flood
+12" SLR
N
Legend
Debris
(Tons)
0 - 10000
10001 - 25000
25001 - 50000
50001 - 100000
100001 - 248802
0 0.125 0.25 0.5 Miles
132


Figure C23: Alternative 4
Impacts - 100 year flood
+12" SLR
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 18.632
Low : 0.001
0 0.125 0.25 0.5 Miles
133


Figure C24: Alternative 4
Losses - 100 year flood
+12" SLR
N
Legend
Total Economic Loss
(x$1000)
0 - 5000
5001 - 10000
10001 - 40000
40001 - 80000
80001 - 141447
0 0.125 0.25 0.5 Miles
134


Figure C24: Alternative 4
Debris - 100 year flood
+12" SLR
Legend
Debris
(Tons)
0 - 10000
10001 - 30000
30001 - 60000
60001 - 100000
100001 - 244203
0 0.125 0.25 0.5 Miles
135


Figure C26: Baseline Impacts - 100 year flood +32” SLR
N
Legend
Impacted Structures
Non-Impacted Structures
Inundation (Feet)
High : 19.267
Low : 0.017
0 0.125 0.25 0.5 Miles
136


Figure C27: Baseline Losses
- 100 year flood
+32" SLR
Legend
Total Economic Loss
(x$1000)
0 - 5000
5001 - 10000
10001 - 50000
50001 - 100000
100001 - 152465
0 0.125 0.25 0.5 Miles


Figure C28: Baseline Debris -
100 year flood
+32" SLR
Legend
Debris
(Tons)
3 - 10000
10001 - 25000
25001 - 50000
50001 - 100000
100001 - 277049
0 0.1250.25 0.5 Miles
138


Figure C29: Alternative 3
Impacts - 100 year flood
+32" SLR
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 19.267
Low : 0.006
0 0.125 0.25 0.5 Miles
139

Figure C30: Alternative 3
Losses - 100 year flood
+32" SLR
Legend
Total Economic Loss
(x$1000)
0 - 5000
5001 - 15000
15001 - 35000
35001 - 70000
70001 - 137132
0 0.125 0.25 0.5 Miles
140


Figure C31: Alternative 3
Debris - 100 year flood
+32" SLR
Legend
Debris
(Tons)
0 - 15000
15001 - 30000
30001 - 75000
75001 - 150000
150001 - 277049
0 0.125 0.25 0.5 Miles
141


Figure C32: Alternative 4 Impacts - 100 year flood +32" SLR
N
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 19.198
Low : 0.006
0 0.125 0.25 0.5 Miles
142


Figure C33: Alternative 4 Losses - 100 year flood +32" SLR
N
Legend
Total Economic Loss (x$1000)
0 - 5000
5001 - 10000
10001 - 50000
50001 - 100000
100001 - 151471
0 0.125 0.25 0.5 Miles
143


Figure C34: Alternative 4
Debris - 100 year flood
+32" SLR
Legend
Debris
(Tons)
0 - 10000
10001 - 40000
40001 - 80000
80001 - 150000
150001 - 277049
0 0.125 0.25 0.5 Miles
144


Figure C35: Alternative 5
Impacts - 100 year flood
+32" SLR
N
Legend
Impacted Structures
Non-Impacted Structures
Inundation
(Feet)
High : 19.267
Low : 0.017
0 0.125 0.25 0.5 Miles
145


Figure C36: Alternative 5
Losses - 100 year flood
+32" SLR
Legend
Total Economic Loss
(x$1000)
0 - 5000
5001 - 10000
10001 - 50000
50001 - 100000
100001 - 151627
0 0.125 0.25 0.5 Miles
146


Figure C35: Alternative 5
Debris- 100 year flood
+32” SLR
N
Legend
Debris
(Tons)
0 - 10000
10001 - 25000
25001 - 50000
50001 - 100000
100001 - 277417
0 0.125 0.25 0.5 Miles
147

Appendix D: Surge Events in NYC Area (1959 - 2007)

List of the Dates (Time is UTC) and Amount of Surge for the 46 Moderate-Surge (>1.0 m above MHW) Events in the NYC Area from 1959 to 2007

Date	Surge (m)
0600 19 Feb 1960	1.08
0600 26 Feb 1960	1.03
1800 12 Sep 1960	1.73
1000 4 Feb 1961	1.33
0600 9 Mar 1961	1.01
1400 13 Apr 1961	1.11
1900 6 Mar 1962	1.39
1600 13 Jan 1964	1.01
1600 23 Jan 1966	1.14
1400 30 Jan 1966	1.13
2100 27 Jan 1967	1.12
1500 12 Nov 1968	1.37
1000 17 Dec 1970	1.1
1000 28 Aug 1971	1.22
1100 25 Nov 1971	1.25
0500 4 Feb 1972	1.08
2100 19 Feb 1972	1.01
2200 8 Nov 1972	1.08
0100 16 Dec 1972	1.1
0400 10 Aug 1976	1.17
0300 8 Nov 1977	1.01
1700 20 Jan 1978	1.19
0000 7 Feb 1978	1.11

Date	Surge (m)
0200 25 Jan 1979	1.38
1800 25 Oct 1980	1.33
1800 4 Dec 1983	1.01
1400 29 Mar 1984	1.57
1700 27 Sep 1985	2
1000 5 Nov 1985	1.13
0100 23 Jan 1987	1.12
0900 31 Oct 1991	1.4
1700 11 Dec 1992	1.75
0100 5 Mar 1993	1.09
2200 13 Mar 1993	1.46
1500 4 Jan 1994	1.01
1000 3 Mar 1994	1.18
0900 24 Dec 1994	1.01
0000 15 Nov 1995	1.24
0600 8 Jan 1996	1.35
0300 20 Mar 1996	1.11
1900 19 Oct 1996	1.01
1200 6 Dec 1996	1.16
0400 30 Dec 1997	1.02
1500 5 Feb 1998	1.05
2300 16 Sep 1999	1.07
1300 25 Oct 2005	1.12

Appendix E: Net Present Value Calculation

Considering the 100-year event, the expected net present value of the avoided flood damage cost can be calculated using the following formula:

(1) $$E[NPV] = \sum_{t=1}^{N} p1 * p_t \frac{C_t}{(1+r)^t}$$

Using above assumptions, p1 = 39/100 = 0.39, pt = 1/50 = 0.02, and Ct = C1 = C2, = ... =C50 = C.

Substituting these values in equation (1) and simplifying, the equation (1) can be written as:

(2) $$E[NPV] = \sum_{t=1}^{N} p1 * p_t \frac{C_t}{(1+r)^t}$$

where NPW is the net present worth factor given as:

(3) $$NPW = \frac{(1+r)^N - 1}{r(1+r)^N}$$

The NPW values are 25.73 and 13.80 for discount rates of 3% and 7% respectively.

The resulting NPV vales of flood damage are given in Tables 7-5 and 7-6 for the 100 year flood.

A second set of NPV calculations corresponds to the present case where the benefits are delayed due to the time lag to construct the project before it can begin accruing benefits. The calculations for this case are provided in the Appendix E along with the other monetized benefits.

Appendix F: Capital & Operational Maintenance Costs - NPV Calculations

Howard Beach Flood Protection Options
Nature Conservancy
Queens, NY

Cost in Real Terms						1	2	3	4	5	6	7	8	9	10	11	12
	Year		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
	Total	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Alternative 1																	
Capital Costs	**40,100,000.0**		13366700	13366700	13366700												
Wetland Maintenance Costs	**2,764,500**	-	-	-	154,900	134,900	134,900	134,900	134,900	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**	-	-	-	110,200	110,200	110,200	110,200									
Beach Maintenance Costs	**938,400**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs - Inspections	**892,500**	-	-	-	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Operating Costs - Closures	**N/A**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	45,136,200																
Alternate No. 1 Life Cycle Cost - Real	**45,136,300**	**-**	**13,366,700**	**13,366,700**	**13,667,700**	**281,000**	**281,000**	**281,000**	**170,800**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**
Alternative 2																	
Capital Costs	**88,200,000.0**		29,400,000	29,400,000	29,400,000												
Wetland Maintenance Costs	**6,519,200.0**	-	-	-	365,400	318,300	318,300	318,300	318,300	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100
Mussel Bed Maintenance Costs	**881,600.0**	-	-	-	220,400	220,400	220,400	220,400									
Beach Maintenance Costs	**938,400.0**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs	**803,250.0**	-	-	-	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750
Operating Costs - Closures	**N/A**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	97,342,450																
Alternate No. 2 Life Cycle Cost - Real	**97,342,450**	**-**	**29,400,000**	**29,400,000**	**30,019,950**	**572,850**	**572,850**	**572,850**	**352,450**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**
Alternative 3																	
Capital Costs	**249,300,000.0**	-	83,100,000	83,100,000	83,100,000	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Maintenance Costs	**2,764,500**	-	-	-	154,900	134,900	134,900	134,900	134,900	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**	-	-	-	110,200	110,200	110,200	110,200									
Beach Maintenance Costs	**938,400**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs	**2,409,750**	-	-	-	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250
Operating Costs - Closures	**2,601,000**	-	-	-	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000
	258,454,450																
Alternate No. 3 Life Cycle Cost - Real	**258,454,450**	**-**	**83,100,000**	**83,100,000**	**83,481,750**	**361,750**	**361,750**	**361,750**	**251,550**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**
Alternative 4																	
Capital Costs	**75,900,000.0**	-	25,300,000	25,300,000	25,300,000	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Maintenance Costs	**2,764,500**	-	-	-	154,900	134,900	134,900	134,900	134,900	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**	-	-	-	110,200	110,200	110,200	110,200									
Beach Maintenance Costs	**938,400**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs - including floodwall	**6,517,250**	-	-	-	29,750	29,750	29,750	29,750	29,750	29,750	29,750	29,750	29,750	1,029,750	29,750	29,750	29,750
Operating Costs - Closures	**153,000**	-	-	-	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
	86,713,950																
Alternate No. 4 Life Cycle Cost - Real	**86,713,950**	**-**	**25,300,000**	**25,300,000**	**25,616,250**	**296,250**	**296,250**	**296,250**	**186,050**	**96,150**	**96,150**	**96,150**	**96,150**	**1,096,150**	**96,150**	**96,150**	**96,150**
										-	-	-	-	-	-	-	-

Assumptions
Construction commences in January 2015 and is completed by the end of 2017. Maintenance costs commence in 2017.
Cost for Wetland maintenance are assumed to be measured as the increment to current costs under no action. The estimates are based upon costs from Maritt Larson NYC Parks and Recreation (without wetland scientist) with the following adjustments:
1. The costs for the Bobcat of $20,000 are incurred the first year along with the remaining $134,900 in annual costs are spread out over the 142 acre wetland (which gives $1,090/acre the first year).
2. Years 2- 5 the O&M costs are $134,900 for 142 acres or $950/acre.
3. Thereafter, consistent with Marritt Larson's assumption, the wetland maintenance costs are assumed to be reduced by 2/3 to $44,968 or about $317/acre.
4. These same per acre costs are used for alternative 2, which includes 335 acre rather than 142 acres.

The wetland cost estimates are not assumed to include the costs of maintaining developed facilities (e.g., signage, comfort facilities, trails) of recreational programming or an on-site park manager.
Cost for Mussel Bed Maintenance are from John McLaughlin NYC DEP. The Mussel bed is assumed to be eestablished after 4 years of maintenance.
Absent a severe storm event, no additional mussel bed maintenance would be required. The maintenance costs associated with such severe storm events are uncertain and have not been included in the costs.
The gate closures for alternatives 3 and 4 are based on the assumption that a flood event with sufficient severity to require a gate closure is expected to occur one out of ten years.
1. For alternative 3 we assume a uniform distribution for when that would occur and thus divide the $510,000 event costs by 10 to get the expected cost of $51,000 each year.

Howard Beach Flood Protection Options
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Cost in Real Terms						1	2	3	4	5	6	7	8	9	10	11	12
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Alternative 1																	
Capital Costs	**40,100,000.0**		13366700	13366700	13366700												
Wetland Maintenance Costs	**2,764,500**	-	-	-	154,900	134,900	134,900	134,900	134,900	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**	-	-	-	110,200	110,200	110,200	110,200									
Beach Maintenance Costs	**938,400**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs - Inspections	**892,500**	-	-	-	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Operating Costs - Closures	**N/A**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	45,136,200																
Alternate No. 1 Life Cycle Cost - Real	**45,136,300**	**-**	**13,366,700**	**13,366,700**	**13,667,700**	**281,000**	**281,000**	**281,000**	**170,800**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**
Alternative 2																	
Capital Costs	**88,200,000.0**		29,400,000	29,400,000	29,400,000												
Wetland Maintenance Costs	**6,519,200.0**	-	-	-	365,400	318,300	318,300	318,300	318,300	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100
Mussel Bed Maintenance Costs	**881,600.0**	-	-	-	220,400	220,400	220,400	220,400									
Beach Maintenance Costs	**938,400.0**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs	**803,250.0**	-	-	-	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750
Operating Costs - Closures	**N/A**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	97,342,450																
Alternate No. 2 Life Cycle Cost - Real	**97,342,450**	**-**	**29,400,000**	**29,400,000**	**30,019,950**	**572,850**	**572,850**	**572,850**	**352,450**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**
Alternative 3																	
Capital Costs	**249,300,000.0**	-	83,100,000	83,100,000	83,100,000	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Maintenance Costs	**2,764,500**	-	-	-	154,900	134,900	134,900	134,900	134,900	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**	-	-	-	110,200	110,200	110,200	110,200									
Beach Maintenance Costs	**938,400**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs	**2,409,750**	-	-	-	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250
Operating Costs - Closures	**2,601,000**	-	-	-	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000
	258,454,450																
Alternate No. 3 Life Cycle Cost - Real	**258,454,450**	**-**	**83,100,000**	**83,100,000**	**83,481,750**	**361,750**	**361,750**	**361,750**	**251,550**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**
Alternative 4																	
Capital Costs	**75,900,000.0**	-	25,300,000	25,300,000	25,300,000	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Maintenance Costs	**2,764,500**	-	-	-	154,900	134,900	134,900	134,900	134,900	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**	-	-	-	110,200	110,200	110,200	110,200									
Beach Maintenance Costs	**938,400**	-	-	-	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs - including floodwall	**6,517,250**	-	-	-	29,750	29,750	29,750	29,750	29,750	29,750	29,750	29,750	29,750	1,029,750	29,750	29,750	29,750
Operating Costs - Closures	**153,000**	-	-	-	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
	86,713,950																
Alternate No. 4 Life Cycle Cost - Real	**86,713,950**	**-**	**25,300,000**	**25,300,000**	**25,616,250**	**296,250**	**296,250**	**296,250**	**186,050**	**96,150**	**96,150**	**96,150**	**96,150**	**1,096,150**	**96,150**	**96,150**	**96,150**
										-	-	-	-	-	-	-	-

Assumptions

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Howard Beach Flood Protection Options
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Cost in Real Terms		30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
	Year	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
	Total	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063
Alternative 1																		
Capital Costs	**40,100,000.0**																	
Wetland Maintenance Costs	**2,764,500**	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**																	
Beach Maintenance Costs	**938,400**	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs - Inspections	**892,500**	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
Operating Costs - Closures	**N/A**																	
	45,136,200																	
Alternate No. 1 Life Cycle Cost - Real	**45,136,300**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**	**80,900**
Alternative 2																		
Capital Costs	**88,200,000.0**																	
Wetland Maintenance Costs	**6,519,200.0**	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100	106,100
Mussel Bed Maintenance Costs	**881,600.0**																	
Beach Maintenance Costs	**938,400.0**	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs	**803,250.0**	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750	15,750
Operating Costs - Closures	**N/A**																	
	97,342,450																	
Alternate No. 2 Life Cycle Cost - Real	**97,342,450**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**	**140,250**
Alternative 3																		
Capital Costs	**249,300,000.0**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Maintenance Costs	**2,764,500**	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**																	
Beach Maintenance Costs	**938,400**	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs	**2,409,750**	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250	47,250
Operating Costs - Closures	**2,601,000**	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000	51,000
	258,454,450																	
Alternate No. 3 Life Cycle Cost - Real	**258,454,450**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**	**161,650**
Alternative 4																		
Capital Costs	**75,900,000.0**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wetland Maintenance Costs	**2,764,500**	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Mussel Bed Maintenance Costs	**440,800**																	
Beach Maintenance Costs	**938,400**	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400	18,400
Operating Maintenance Costs - including floodwall	**6,517,250**	29,750	29,750	29,750	29,750	29,750	29,750	29,750	29,750	29,750	1,029,750	29,750	29,750	29,750	29,750	29,750	29,750	29,750
Operating Costs - Closures	**153,000**	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
	86,713,950																	
Alternate No. 4 Life Cycle Cost - Real	**86,713,950**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**	**1,096,150**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**	**96,150**

Howard Beach Flood Protection Options
Nature Conservancy
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Cost in Real Terms	Year / Total	47 50 2064	48 51 2065	49 52 2066	50 53 2067	NPV @ 3%	NPV @ 7%
Alternative 1							
Capital Costs	**40,100,000.0**					$36,707,960.58	32,783,594
Wetland Maintenance Costs	**2,764,500**	45,000	45,000	45,000	45,000	$1,463,255.12	824,265
Mussel Bed Maintenance Costs	**440,800**					$374,864.21	304,700
Beach Maintenance Costs	**938,400**	18,400	18,400	18,400	18,400	$436,982.50	207,762
Operating Maintenance Costs - Inspections	**892,500**	17,500	17,500	17,500	17,500	$415,608.36	197,600
Operating Costs - Closures	**N/A**				-		-
							-
	45,136,200						-
Alternate No. 1 Life Cycle Cost - Real	**45,136,300**	**80,900**	**80,900**	**80,900**	**80,900**	**$39,398,671**	**34,317,921**
Alternative 2							
Capital Costs	**88,200,000.0**					$83,161,174	77,154,892
Wetland Maintenance Costs	**6,519,200.0**	106,100	106,100	106,100	106,100	$3,450,969	1,944,182
Mussel Bed Maintenance Costs	**881,600.0**					$749,728	609,400
Beach Maintenance Costs	**938,400.0**	18,400	18,400	18,400	18,400	$436,983	207,762
Operating Maintenance Costs	**803,250.0**	15,750	15,750	15,750	15,750	$374,048	177,840
Operating Costs - Closures	**N/A**				-		
	97,342,450						
Alternate No. 2 Life Cycle Cost - Real	**97,342,450**	**140,250**	**140,250**	**140,250**	**140,250**	**$85,750,731**	**75,046,559**
Alternative 3							
Capital Costs	**249,300,000.0**	-	-	-	-	$228,211,266	203,813,704
Wetland Maintenance Costs	**2,764,500**	45,000	45,000	45,000	45,000	$1,463,255	824,265
Mussel Bed Maintenance Costs	**440,800**					$374,864	304,700
Beach Maintenance Costs	**938,400**	18,400	18,400	18,400	18,400	$436,983	207,762
Operating Maintenance Costs	**2,409,750**	47,250	47,250	47,250	47,250	$1,122,143	533,520
Operating Costs - Closures	**2,601,000**	51,000	51,000	51,000	51,000	$1,211,202	575,862
	258,454,450						
Alternate No. 3 Life Cycle Cost - Real	**258,454,450**	**161,650**	**161,650**	**161,650**	**161,650**	**$232,819,712**	**206,259,813**
Alternative 4							
Capital Costs	**75,900,000.0**	-	-	-	-	$69,479,483	62,051,585
Wetland Maintenance Costs	**2,764,500**	45,000	45,000	45,000	45,000	$1,463,255	824,265
Mussel Bed Maintenance Costs	**440,800**					$374,864	304,700
Beach Maintenance Costs	**938,400**	18,400	18,400	18,400	18,400	$436,983	207,762
Operating Maintenance Costs - including floodwall	**6,517,250**	29,750	29,750	1,029,750	29,750	$2,760,497	1,151,290
Operating Costs - Closures	**153,000**	3,000	3,000	3,000	3,000	$71,247	33,874
	86,713,950						
Alternate No. 4 Life Cycle Cost - Real	**86,713,950**	**96,150**	**96,150**	**1,096,150**	**96,150**	**$74,586,329**	**64,573,477**
					-		-

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Cost in Real Terms - 2014

Task Description	Frequency	Quantity Unit	Occurrence Cost	Total Life Cycle Cost	Total	1 2014	2 2015	3 2016	4 2017	5 2018	6 2019	7 2020	8 2021	9 2022	10 2023	11 2024	12 2025	13 2026	14 2027	15 2028
Alternative 5																				
Capital Costs				98,400,000		-	32,800,000	32,800,000	32,800,000	-	-	-	-	-	-	-	-	-	-	-
Operational Maintenance Costs - 50 Year Cycle																				
Pile Supported Concrete Flood Wall																				
Annual Inspections of In-Place Structures	Annual	Total Inspection	17,500	892,500	**892,500**	-	-	-	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
					99,292,500	**-**	**32,800,000**	**32,800,000**	**32,817,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**
Capital Maintenace Cost																				
Pile Supported Concrete Flood Wall																				
Repair Flood Wall as Required - Every Five Years	5 Year	Repair Event	100,000	1,000,000	**1,000,000**	-	-	-	-	-	-	-	100,000	-	-	-	-	100,000	-	-
Repair Channel Miter Gate - Once Per Decade	Decade	Repair Event	1,000,000	5,000,000	**5,000,000**	-	-	-	-	-	-	-	-	-	-	-	-	1,000,000	-	-
					6,000,000	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**100,000**	**-**	**-**	**-**	**-**	**1,100,000**	**-**	**-**
Operational Costs - Flood Event																				
Pile Supported Concrete Flood Wall																				
Close Structures in Anticipation of Flood Event	Decade	Event	30,000	153,000	**153,000**	-	-	-	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
					153,000	**-**	**-**	**-**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**
Grand Total					**105,445,500**	-	32,800,000	32,800,000	32,820,500	20,500	20,500	20,500	120,500	20,500	20,500	20,500	20,500	1,120,500	20,500	20,500

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Cost in Real Terms - 2014																					
Task Description	**Frequency**	**Quantity Unit**	**Occurrence Cost**	**Total Life Cycle Cost**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
					2029	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Alternative 5																					
Cap					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
perational Maintenance Costs - 50 Year Cycle																					
Pile Supported Concrete Flood Wall																					
Annual Inspections of In-Place Structures	Annual	Total Inspection	17,500	892,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
					17,500	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**
Capital Maintenace Cost																					
Pile Supported Concrete Flood Wall																					
Repair Flood Wall as Required - Every Five Years	5 Year	Repair Event	100,000	1,000,000	-	-	100,000	-	-	-	-	100,000	-	-	-	-	100,000	-	-	-	-
Repair Channel Miter Gate - Once Per Decade	Decade	Repair Event	1,000,000	5,000,000	-	-	-	-	-	-	-	1,000,000	-	-	-	-	-	-	-	-	-
					-	**-**	**100,000**	**-**	**-**	**-**	**-**	**1,100,000**	**-**	**-**	**-**	**-**	**100,000**	**-**	**-**	**-**	**-**
Operational Costs - Flood Event																					
Pile Supported Concrete Flood Wall																					
Close Structures in Anticipation of Flood Event	Decade	Event	30,000	153,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
					3,000	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**
Grand Total					20,500	20,500	120,500	20,500	20,500	20,500	20,500	1,120,500	20,500	20,500	20,500	20,500	120,500	20,500	20,500	20,500	20,500

Nature Conservancy
Queens, NY

Cost in Real Terms - 2014					33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Task Description	**Frequency**	**Quantity Unit**	**Occurrence Cost**	**Total Life Cycle Cost**	**2046**	**2047**	**2048**	**2049**	**2050**	**2051**	**2052**	**2053**	**2054**	**2055**	**2056**	**2057**	**2058**	**2059**	**2060**	**2061**	**2062**	**2063**
Alternative 5																						
Capital Costs				98,400,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Operational Maintenance Costs - 50 Year Cycle																						
Pile Supported Concrete Flood Wall																						
Annual Inspections of In-Place Structures	Annual	Total Inspection	17,500	892,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500	17,500
					17,500	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**	**17,500**
Capital Maintenace Cost																						
Pile Supported Concrete Flood Wall																						
Repair Flood Wall as Required - Every Five Years	5 Year	Repair Event	100,000	1,000,000	100,000	-	-	-	-	100,000	-	-	-	-	100,000	-	-	-	-	100,000	-	-
Repair Channel Miter Gate - Once Per Decade	Decade	Repair Event	1,000,000	5,000,000	1,000,000	-	-	-	-	-	-	-	-	-	1,000,000	-	-	-	-	-	-	-
					1,100,000	**-**	**-**	**-**	**-**	**100,000**	**-**	**-**	**-**	**-**	**1,100,000**	**-**	**-**	**-**	**-**	**100,000**	**-**	**-**
Operational Costs - Flood Event																						
Pile Supported Concrete Flood Wall																						
Close Structures in Anticipation of Flood Event	Decade	Event	30,000	153,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
					3,000	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**	**3,000**
Grand Total					1,120,500	20,500	20,500	20,500	20,500	120,500	20,500	20,500	20,500	20,500	1,120,500	20,500	20,500	20,500	20,500	120,500	20,500	20,500

Howard Beach Flood Protection - Hard Infrastructure
Nature Conservancy
Queens, NY

Job No.: 650985

Cost in Real Terms - 2014										
Task Description	**Frequency**	**Quantity Unit**	**Occurrence Cost**	**Total Life Cycle Cost**	**51 2064**	**52 2065**	**53 2066**	**5 2067**	**NPV @3%**	NPV@ 7%
Alternative 5										
Capital Costs				98,400,000	-	-	-	-	90,076,167	80,446,324
Operational Maintenance Costs - 50 Year Cycle										
Pile Supported Concrete Flood Wall										
Annual Inspections of In-Place Structures	Annual	Total Inspection	17,500	892,500	17,500	17,500	17,500	17,500	415,608	197,600
					17,500	**17,500**	**17,500**	**17,500**	**90,491,776**	80,643,923
Capital Maintenace Cost										
Pile Supported Concrete Flood Wall										
Repair Flood Wall as Required - Every Five Years	5 Year	Repair Event	100,000	1,000,000	-	-	100,000		443,507	195,897
Repair Channel Miter Gate - Once Per Decade	Decade	Repair Event	1,000,000	5,000,000	-	-	1,000,000		2,053,963	815,370
					-	**-**	**1,100,000**	**-**	**2,497,469**	1,011,267
Operational Costs - Flood Event										
Pile Supported Concrete Flood Wall										
Close Structures in Anticipation of Flood Event	Decade	Event	30,000	153,000	3,000	3,000	3,000	3,000	71,247	33,874
					3,000	**3,000**	**3,000**	**3,000**	**71,247**	**33,874**
Grand Total					20,500	20,500	1,120,500	20,500	**93,060,492**	**81,689,065**

Appendix G: Benefits - Net Present Value Calculations

Benefits in Real Terms $2014

	Number of Acres	$ 2014/Acre	2014	2015	2016	2017	2018	2019	2020
Alternative 1									
Flood Damages Avoided			0	0	0	0.0312	0.0312	0.0312	0.0312
Passive Use Value Saltmarsh Habitat	121.1	1,529	0	0	0	0.1851619	0.1851619	0.1851619	0.185162
Birding and Other wildlife Observation	121.1	7,182	0	0	0	0.8697402	0.8697402	0.8697402	0.86974
Total									
Alternative 2									
Flood Damages Avoided			0	0	0	0.507	0.507	0.507	0.507
Passive Use Value Saltmarsh Habitat	193.1	1,529	0	0	0	0.2952499	0.2952499	0.2952499	0.29525
Birding and Other wildlife Observation	121.1	7,182	0	0	0	0.8697402	0.8697402	0.8697402	0.86974
Total									
Alternative 3									
Flood Damages Avoided			0	0	0	8.1432	8.1432	8.1432	8.1432
Passive Use Value Saltmarsh Habitat	121.1	1,529	0	0	0	0.1851619	0.1851619	0.1851619	0.185162
Birding and Other wildlife Observation	121.1	7,182	0	0	0	0.8697402	0.8697402	0.8697402	0.86974
Total									
Alternative 4									
Flood Damages Avoided			0	0	0	9.477	9.477	9.477	9.477
Passive Use Value Saltmarsh Habitat	121.1	1,529	0	0	0	0.1851619	0.1851619	0.1851619	0.185162
Birding and Other wildlife Observation	121.1	7,182	0	0	0	0.8697402	0.8697402	0.8697402	0.86974
Total									
Alternative 5									
Flood Damages Avoided			0	0	0	9.4848	9.4848	9.4848	9.4848
Passive Use Value Saltmarsh Habitat			NA						
Birding and Other wildlife Observation			NA						
Total									

Benefits in Real Terms $2014

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Alternative 1											
Flood Damages Avoided	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.1851619	0.1851619	0.1851619	0.1851619	0.1851619	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.8697402	0.8697402	0.8697402	0.8697402	0.8697402	0.86974	0.86974	0.86974
Total											
Alternative 2											
Flood Damages Avoided	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507
Passive Use Value Saltmarsh Habitat	0.29525	0.29525	0.29525	0.2952499	0.2952499	0.2952499	0.2952499	0.2952499	0.29525	0.29525	0.29525
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.8697402	0.8697402	0.8697402	0.8697402	0.8697402	0.86974	0.86974	0.86974
Total											
Alternative 3											
Flood Damages Avoided	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.1851619	0.1851619	0.1851619	0.1851619	0.1851619	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.8697402	0.8697402	0.8697402	0.8697402	0.8697402	0.86974	0.86974	0.86974
Total											
Alternative 4											
Flood Damages Avoided	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.1851619	0.1851619	0.1851619	0.1851619	0.1851619	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.8697402	0.8697402	0.8697402	0.8697402	0.8697402	0.86974	0.86974	0.86974
Total											
Alternative 5											
Flood Damages Avoided	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848
Passive Use Value Saltmarsh Habitat											
Birding and Other wildlife Observation											
Total											

Benefits in Real Terms $2014

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Alternative 1													
Flood Damages Avoided	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 2													
Flood Damages Avoided	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507
Passive Use Value Saltmarsh Habitat	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 3													
Flood Damages Avoided	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 4													
Flood Damages Avoided	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 5													
Flood Damages Avoided	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848
Passive Use Value Saltmarsh Habitat													
Birding and Other wildlife Observation													
Total													

Benefits in Real Terms $2014

	2036	2037	2038	2039	2040	2041	2042	2043	2044	2053	2054	2055	2056
Alternative 1													
Flood Damages Avoided	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 2													
Flood Damages Avoided	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507
Passive Use Value Saltmarsh Habitat	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 3													
Flood Damages Avoided	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 4													
Flood Damages Avoided	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974
Total													
Alternative 5													
Flood Damages Avoided	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848
Passive Use Value Saltmarsh Habitat													
Birding and Other wildlife Observation													
Total													

Benefits in Real Terms $2014

	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	$ Million NPV @ 3%	$ Million NPV @ 7%
Alternative 1													
Flood Damages Avoided	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	0.0312	$0.74	$0.35
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	$4.40	$2.09
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	$20.66	$9.82
Total												**$25.79**	**$12.26**
Alternative 2													
Flood Damages Avoided	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	$12.04	$5.72
Passive Use Value Saltmarsh Habitat	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	0.29525	$7.01	$3.33
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	$20.66	$9.82
Total												**$39.71**	**$18.88**
Alternative 3													
Flood Damages Avoided	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	8.1432	$193.39	$91.95
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	$4.40	$2.09
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	$20.66	$9.82
Total												**$218.45**	**$103.86**
Alternative 4													
Flood Damages Avoided	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	9.477	$225.07	$107.01
Passive Use Value Saltmarsh Habitat	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	0.185162	$4.40	$2.09
Birding and Other wildlife Observation	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	0.86974	$20.66	$9.82
Total												**$250.12**	**$118.92**
Alternative 5													
Flood Damages Avoided	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	9.4848	$225.25	$107.10
Passive Use Value Saltmarsh Habitat													
Birding and Other wildlife Observation													
Total													

Appendix H: Valuation Methods

Market Methods (M)

In the case of market goods, society's WTP is represented graphically by the area under the aggregate demand curve for the good or service. A market demand curve traces out the quantities that consumers are willing to buy at different prices. For a measure of net benefits, the cost to the consumer (price) is subtracted from total WTP. This net WTP is called the consumer surplus, or the benefit received over and above the cost to the consumer. Similarly, on the supply side of the market, the net benefit to the producer is the amount received in payment over and above the cost of production, or producer surplus. The total benefits of the alternative are given by the sum of the changes in consumer and producer surpluses in the affected markets plus any additional WTP for the non-market goods or services that result from the action, all measured relative to the no-action alternative. Natural systems supply market goods such as fish, timber, drinking water, nuts, cranberries, and furs.

Avoided Cost – AC (also includes Defensive Expenditure or Averting Behavior Models)

Avoided costs, defensive expenditure and averting behavior models infer values from behaviors that individuals undertake to avoid harm or to mitigate the impacts of environmental damages. This method can be applied to estimate the benefits of reduced flood damages as well as reduced human health risks, especially associated with such effects as drinking water contamination, cancer risks, or contamination from radon. Flood damages avoided can include avoiding losses of buildings and contents, vehicles, infrastructure, parks, business interruptions, as well as costs associated with relocating people, and emergency response. Flood mitigation measures can also protect natural systems, such as treatment wetlands and can thus avoid costs associated with replacing the services of the natural system. In the case of defensive expenditures, such as Individuals who may purchase bottled water or boil water before drinking it to avoid contamination, the cost of such behaviours is considered a lower bound on the individual's WTP. This method (like others described here) is often referred to as a revealed preference model. The data requirements for revealed preference models can be quite extensive. In addition, it can be difficult to isolate the cause or reason for the behaviors to separately value the environmental change of interest. For example, some people who purchase bottled water may perceive other health or convenience benefits besides avoiding contamination. That is, their motivation may be to avoid disadvantages such as unpleasant tastes or odors.

Hedonic Pricing Models (H)

Hedonic pricing models are sometimes used to estimate the willingness to pay for environmental amenities such as improved water quality, cleaner air, unobstructed scenic views, clean-up of contaminated sites nearby, reduced flood damage, and improved fish and wildlife habitat. These models rely on differentials in housing and property prices to determine how much extra people are willing to pay for environmental enhancements compared to similar properties without such enhancements. The applicability of hedonic pricing models depends on the extent to which the alternatives are expected to result in measurable environmental improvements that would be reflected in property values. In addition, extensive data requirements and significant empirical issues are generally important considerations in choosing this valuation method. Economic theory offers limited guidance in sorting through such issues as the choice of functional form and the definition of the extent of the market, and yet both of these decisions can have a significant effect on the benefit estimates. Also, this method can only capture the benefits for property owners, so it must generally be combined with other methods to capture all of the benefits. Finally, when attempting to combine hedonic pricing models with other methods, care must be taken to avoid double counting benefits.

Stated Preference Methods (e.g., Contingent Valuation – CV)

Stated preference methods attempt to measure WTP based on what people say rather than inferring it by observing their behavior. These methods generally use surveys of a representative sample of the relevant population to elicit their preferences regarding WTP (i.e., contingent valuation methods) or to infer WTP based on the choices survey respondents make when offered tradeoffs (i.e., conjoint analysis and contingent ranking methods). Such surveys are different than public opinion polls because contingent valuation surveys attempt to elicit the respondents' behavioral intentions or the actual choices they would make given the opportunity. These methods can be used to value direct services such as health improvements and recreation opportunities, as well as the passive use values associated with protecting or restoring natural resources and ecosystem services. Their comparative advantage is in estimating passive use values, as these values cannot be estimated using market or revealed preference methods. Stated preference methods are costly to implement and are controversial because of the difficulties associated with clearly defining what is being valued and with ensuring that respondents are willing and able to articulate their WTP or express behavioral choices in a survey situation.

Production Function Methods (P)

Production functions (or cost functions) can be estimated for either market or non-market goods. This valuation tool is used predominantly for indirect services to value their contribution toward production of the primary good or service. For example, changes in air quality can affect agriculture and commercial timber industries, and water quality changes can affect water supply treatment costs or the production costs of industry processors, irrigation operations, and commercial fisheries. For small changes in ecological service flows, the welfare change is given by the change in the value of the final product. This welfare change is known as the marginal product of the factor input. For larger changes, marginal cost curves will shift, and the area between the old and new marginal cost curves gives the welfare measures. Estimating production, cost, or profit functions requires data on *all* inputs and their prices. Although data intensive, the production function methods result in benefit estimates that are relatively understandable to most stakeholders and are thus easier to defend than some of the benefits estimated from most of the other methods.

Cost of Illness or Injury (COI)

As the name implies, the cost of illness (COI) method for estimating the benefits of avoiding illness combines estimates of the direct and indirect costs associated with the illness. Direct costs represent the expenditures associated with diagnosis, treatment, rehabilitation, and accommodation. Indirect costs represent the value of illness-related lost income, productivity, and leisure time. This method is an alternative to a stated preference approach, which relies on surveys to ask people to state their willingness to pay for avoiding the illness. The COI method does not include estimates for pain and suffering associated with the illness and tends to underestimate the benefits of avoiding illnesses where these costs are large. The COI method is straightforward to implement and explain to decision-makers and has a number of other advantages. The method has been used for many years and is well developed. Collecting data to implement it often is less expensive than for other methods, improving the feasibility of developing original COI estimates in support of evaluating project alternatives. COI methods are used to value morbidity avoidance, but not fatality avoidance. In the case of preventing mortality, the preferred approach is based upon the value of a statistical life saved.

Travel Cost Recreation Demand Models (TC)

Outdoor recreation in a natural setting is often unpriced or underpriced, especially when it takes place on public property, such as in national, regional, or local parks and waterways. Improved recreation opportunities can be a significant source of benefits from establishing new parks, as well as making improvements to existing resources such as increasing fish populations, wildlife habitat and populations, streamside aesthetics, and water quality improvements. Recreation demand models, including travel cost demand models and random utility models, can be used to estimate the recreation benefits generated by the changes in environmental conditions. In such models, the observed recreation patterns of users is related to the cost of travel, including travel time, and the quality characteristics of the recreation sites (for example, fish catch rates of desirable species) available to the relevant population of users. These models essentially estimate demand curves for recreation, where the cost of travel is assumed to correspond to price of admission to the site. Because recreation demand models rely on observed recreation patterns, the resultant benefit estimates are generally more credible to most stakeholders than the results from stated preference studies. However, the data requirements for conducting an original study can be substantial and the results can be sensitive to the model specification. Also, sometimes the environmental change to be evaluated is beyond the range in the observed behavior. This can be addressed by combining the stated preference approach with the recreation demand model approach.

Benefit Transfer Methods (BT)

The benefits transfer method is a practical alternative to valuation methods involving the collection of original data on preferences. This valuation method relies on approaches toward transferring value estimates, WTP functions or meta-analyses from existing studies to a different application. The reliability and validity of such transferred values depend on the quality of the original studies as well as the degree of similarity between the original context in which the values were estimated and the new context.

The issues related to the reliability and validity of value estimates obtained from any other valuation method are, therefore, present and exacerbated in the case of benefit transfer analysis. The benefits transfer method is a practical valuation alternative when direct survey data concerning an identified issue are unavailable, but at best it will produce ball park estimates. As with each of the valuation tools, if the degree of accuracy is not sufficient for supporting a decision, further analysis may be required. Although benefit transfer methods are less costly and time consuming than the other valuation methods, they nonetheless require some effort to produce credible results. For example, some minimal data collection effort may be required to establish the environmental change being valued and the population likely to experience the resultant effects. The latter is sometimes referred to as the extent of the market, or the spatial boundaries for capturing the majority of the relevant population. The analyst must review the available studies for quality and applicability to the proposed action, determine which benefits transfer method is supported by the data and required by the situation, and conduct the analysis. Subjective judgments and assumptions, their expected impact on final estimates, and expected ranges in uncertainty all require descriptions to interpret the results.

The ability to transfer valuations from one context to another may be useful for the cost-effective use of service-based valuations. However, not all ecosystem services are equally amenable to such transfers. Some ecosystem services may be provided at scales where benefits are easily transferable, such as the avoided greenhouse gas costs of carbon sequestration. Other services are available at local scales but are so general that valuation in one context may be meaningfully transferred to another; such as the recreational value of a picnic in a park or birdwatching at a wildlife refuge. Other local scale services may have very limited transferability; such as the cultural value of salmon and steelhead to Native Americans versus non-Native Americans.

Social Cost of Carbon (SCC)

The economic damages from carbon dioxide (CO_2) emissions are known as the social cost of carbon (SCC). The social cost of carbon is estimated by the present value of the stream of future economic damages associated with an incremental increase (by convention, 1 metric ton) in CO_2 emissions in a particular year. Metric tons emitted in different years will have a different social cost that reflects changes in agricultural productivity, human health risks, property damages and loss of business from increased flood and storm frequencies, and the loss of ecosystem services. Simplifying assumptions have been made to develop estimates using the current state of knowledge, but the climate economics literature is evolving at a relatively rapid rate. The published estimates have been based on an integrated assessment model "that combine(s) climate processes, economic growth, and feedbacks between the two in a single modeling framework" (EPA 2010). Many uncertainties underlie the estimates, but one variable, the discount rate, has been singled out for sensitivity analysis. The marginal SCC for 2010 emissions was estimated to range from $5 to $65 in 2007 US dollars.

Habitat Equivalency Analysis—HEA

The HEA concept was developed initially by the U.S. Environmental Protection Agency (King, 1991) and then modified by the U.S. Fish and Wildlife Service (USFWS) (Unsworth and Bishop, 1994). It is the preferred method to scale compensatory restoration options in Natural Resource Damage Assessment under the Oil Pollution Act of 1990 (OPA) (NOAA, 1997a; b) and has been used by the US Army Corps of Engineers and other US federal agencies to compare alternatives (USACE, 2009).

HEA is an economic model often used to value non-market services which indirectly benefit humans. Although it is based on the same conceptual framework as other economic methods, HEA focuses on determining ecological service flow losses and gains from the biological and ecological perspective without using explicit economic values (i.e., the per unit monetary values of the gains and losses are identical and constant by assumption).

HEA takes quality and time into account and utilizes one or more indicator parameters to represent the ecological service flows from a habitat.

The HEA metric is service acres years (SAYs) or, when discounting is applied, discounted SAYs (DSAYs). When applied to evaluate the net benefit of alternatives, the service estimate for the baseline, "no action" case is subtracted from the service estimate for each alternative to calculate net change.

Index-based methods (rating or ranking choice models, expert opinion)

Index- and group-based methods also provide information for the assessment of the value of alternatives, but can be viewed as less rigorous. A positive aspect of these techniques is that they can be implemented relatively inexpensively. Two such methods are summarized here, qualitative scales and group-based methods.

Qualitative scales

In many projects there will be effects that are important to decision making that cannot be measured quantitatively. In those circumstances, it is important that the indicator be included in the analysis and measured using a qualitative scale (often referred to as a "constructed scale"). For qualitative scales it is important to develop a verbal representation of various points of measure along the scale to ensure consistency in scoring among options, and to enhance transparency of the analysis for stakeholders. An example of how qualitative scales can be constructed is provided in Table F-1.

Table F-1 Example Qualitative Scales

Example Indicator	Best (5)	Medium (3)	Worst (1)
Complexity of partnership(s) required to realize flood mitigation objectives	Single or limited number of partners needed to fulfill vision. Partnership structure similar to what agency has historically entered into. Requirements can be articulated in contract(s) with partners. Partnerships can be created prior to project development.	Single or limited number of partners needed to fulfill vision. Partnership structure not too dis-similar to what agency has historically entered into. Some uncertainty about ability to articulate requirements in contract(s) with partners. Some partnerships required after project development.	Multiple number of partners (>3) needed to fulfil vision. Partnerships structure new to the agency. Agency has limited ability to articulate requirements in contract(s) with partners. Partnerships are entered into over a long period of time and timing is uncertain.
Impact to surrounding community	Final site configuration will be compatible with existing and proposed land use in the surrounding community, and existing community views are not likely to change with the project.	Final site configuration will be compatible with existing and proposed land use in the surrounding community but there will be moderate impacts to views with the project.	Final site configuration is likely to result in a substantial negative impact to the surrounding community and/or existing community views will be reduced substantially by the project.

When scoring alternatives, it is also important to prepare a short 1-2 sentence documentation of the rationale for each score given (i.e., explain why was one option scored a "3" and another a "4"). This is often done by preparing a matrix table with options as columns and indicators as rows. For indicators measured qualitatively, each "cell" in the matrix includes the rationale for each qualitative score given.

Group-based methods (voting mechanisms, focus groups, citizen juries)

As described at the beginning of this section, the objective of the economic valuation methods is to estimate society's aggregate WTP for the goods and services associated with each alternative. A second best approach is to rely upon input from smaller groups such as focus groups or citizen panels in the hope that the individuals will be representative of the preferences of society as a whole. This assumption is likely to be violated, but the results of such inquires may nonetheless provide useful information especially when the individuals are well informed and thoughtful.

Appendix I: HEA Inputs Summary

Scenario and Unit	Habitat	Acreage (Time 0)	Habitat Conversion Rate	Service Estimates Over Time (year, % service)	Total Discounted Service Acre-Years	Assumptions: Lifespan and Performance Over Time	References
Base Case (existing)							
Spring Creek Park	Wetland and Unconsolidated Shore	20.9	+0.23 ac/year	(0, 39) (100, 32)	284	The quality of wetlands degrades over time due to eutrophication in Jamaica Bay. Sea-level rise results in marsh migration into uplands at Spring Creek Park.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012
Spring Creek Park	Upland	229.4	-0.28 ac/year	(0, 33) (100, 33)	2,384	Uplands dominated with *Phragmites australis* and *Artemesia vulgaris* (>75% cover). Service provision rated on a buffer condition; degraded condition persists into future.	Wetland Rapid Assessment Procedure (Miller and Gunsalus 1997)
Spring Creek Park	Open Water and Tidal Flat	22.3	+0.05 ac/year	(0, 8) (100, 8)	62	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Open Water and Tidal Flat	72.9	+0.04 ac/year	(0, 8) (100, 8)	193	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Marsh Islands and Unconsolidated Shore	121	-0.04 ac/year	(0, 39) (100, 32)	1,447	Wetland islands experience subsidence and erosion due to chronic nitrogen enrichment, sea-level rise, and inadequate sediment subsidy to maintain sufficient accretion.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012 SLAMM 2014
Howard Beach	Tree Canopy	752	n/a	(0, 8.5) (35, 6.4) (70, 4.8) (100, 4.8)	1,881	8.5% of Howard Beach is covered by tree canopy. Urban trees sequester 0.12 kg/C/yr and intercept 13.5 ft3 of stormwater annually. Two 1-in-100 year storms (10 to 13 feet of inundation at Howard Beach) and associated flooding results in sub-lethal stress of 25% of trees after 35 years, and 25% of trees after 70 years.	Nowak and Crane 2002 Davey Resource Group 2013 NY Times 2012 and 2013
TOTAL		1218.5			6251		
Alternative 1: Natural Infrastructure							
Spring Creek Park	Wetland	142	+0.23 ac/year	(0, 54.6) (2, 67.8) (100, 43.2)	2,928	Wetland plants require two years to reach maturity after restoration. Episodic storms and proximity to Phragmites-dominated upland reduce total plant cover over time without maintenance.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012
Spring Creek Park	Upland	108.3	-0.28 ac/year	(0, 0.33) (100, 0.33)	1,082	Uplands dominated with *Phragmites australis* and *Artemesia vulgaris* (>75% cover). Service provision rated on a buffer condition; degraded condition persists into future.	Wetland Rapid Assessment Procedure (Miller and Gunsalus 1997)
Spring Creek Park	Open Water and Tidal Flat	21.1	+0.05 ac/year	(0, 8) (100, 8)	59	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Spring Creek Park	Mussels	1.2	n/a	(0, 16.7) (2, 83.3) (100, 100)	37	Growth rates and nitrogen removal estimates for shellfish in Jamaica Bay not available; highly spatially and temporally vaiable. Assume nitrogen assimilation at a constant rate of 0.40 tons of nitrogen per acre per year and 3 years to maturity.	Doiron 2008 Kellogg et al. 2011 DeAngelis 2014
Jamaica Bay	Open Water and Tidal Flat	72.9	+0.04 ac/year	(0, 8) (100, 8)	193	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Marsh Islands	121	-0.04 ac/year	(0, 39) (100, 32)	1,447	Wetland islands experience subsidence and erosion due to chronic nitrogen enrichment, sea-level rise, and inadequate sediment subsidy to maintain sufficient accretion.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012 SLAMM 2014
Howard Beach	Tree Canopy	752	n/a	(0, 8.5) (35, 6.4) (70, 4.8) (100, 4.8)	1,881	Two 1-in-100 year storms (10 to 13 feet of inundation at Howard Beach) and associated flooding results in sub-lethal stress of 25% of trees after 35 years, and 25% of trees after 70 years. Storm impacts and return intervals provided by CH2MHILL.	Nowak and Crane 2002 Davey Resource Group 2013 NY Times 2012 and 2013
TOTAL		1218.5			7627		
Alternative 2: Natural Infrastructure							
Spring Creek Park	Wetland	142	+0.23 ac/year	(0, 61.2) (2, 84) (100, 76)	3,923	Wetland plants require two years to reach maturity after restoration. Episodic storms and proximity to Phragmites-dominated upland reduce total plant cover over time without maintenance.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012
Spring Creek Park	Upland	108.3	-0.28 ac/year	(0, 33) (100, 33)	1,082	Uplands dominated with Phragmites australis and Artemesia vulgaris (>75% cover). Service provision rated on a buffer condition; degraded condition persists into future.	Wetland Rapid Assessment Procedure (Miller and Gunsalus 1997)
Spring Creek Park	Mussels	1.2	n/a	(0, 16.7) (2, 83.3) (100, 100)	37	Growth rates and nitrogen removal estimates for shellfish in Jamaica Bay not available; highly spatially and temporally vaiable. Assume nitrogen assimilation at a constant rate of 0.40 tons of nitrogen per acre per year and 3 years to maturity.	Doiron 2008 Kellogg et al. 2011 DeAngelis 2014
Spring Creek Park	Open Water and Tidal Flat	21.1	+0.05 ac/year	(0, 8) (100, 8)	59	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Open Water and Tidal Flat	0	+0.04 ac/year	(0, 8) (100, 8)	29	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Marsh Islands	193	-0.04 ac/year	(0, 61.2) (2, 84) (100, 76)	5,076	Wetland plants require two years to reach maturity after restoration. Episodic storms, limited sediment subsidy, and chronic eutriphication in Jamaica Bay result in slow degradation over time.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012
Jamaica Bay	Mussels	0.9	n/a	(0, 16.7) (2, 83.3) (100, 100)	28	Growth rates and nitrogen removal estimates for shellfish in Jamaica Bay not available; highly spatially and temporally vaiable. Assume nitrogen assimilation at a constant rate of 0.40 tons of nitrogen per acre per year and 3 years to maturity.	Doiron 2008 Kellogg et al. 2011 DeAngelis 2014
Howard Beach	Tree Canopy	752	n/a	(0, 8.5) (35, 6.4) (70, 4.8) (100, 4.8)	1881	Two 1-in-100 year storms (10 to 13 feet of inundation at Howard Beach) and associated flooding results in sub-lethal stress of 25% of trees after 35 years, and 25% of trees after 70 years. Storm impacts and return intervals provided by CH2MHILL.	Nowak and Crane 2002 Davey Resource Group 2013 NY Times 2012 and 2013
TOTAL		1218.5			12115		
Alternatives 3, 4: Hybrid with Removable Walls or Operable Gate							
Spring Creek Park	Wetland and Unconsolidated Shore	142	+0.23 ac/year	(0, 54.6) (2, 67.8) (100, 43.2)	2,928	Wetland plants require two years to reach maturity after restoration. Episodic storms and proximity to Phragmites-dominated upland reduce total plant cover over time without maintenance.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012
Spring Creek Park	Upland	108.3	-0.28 ac/year	(0, 33) (100, 33)	1,082	Uplands dominated with Phragmites australis and Artemesia vulgaris (>75% cover). Service provision rated on a buffer condition; degraded condition persists into future.	Wetland Rapid Assessment Procedure (Miller and Gunsalus 1997)
Spring Creek Park	Mussels	1.2	n/a	(0, 16.7) (2, 83.3) (100, 100)	37	Growth rates and nitrogen removal estimates for shellfish in Jamaica Bay not available; highly spatially and temporally vaiable. Assume nitrogen assimilation at a constant rate of 0.40 tons of nitrogen per acre per year and 3 years to maturity.	Doiron 2008 Kellogg et al. 2011 DeAngelis 2014

Scenario and Unit	Habitat	Acreage (Time 0)	Habitat Conversion Rate	Service Estimates Over Time (year, % service)	Total Discounted Service Acre-Years	Assumptions: Lifespan and Performance Over Time	References
Spring Creek Park	Open Water and Tidal Flat	21.1	+0.05 ac/year	(0, 8) (100, 8)	59	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Open Water and Tidal Flat	72.9	+0.04 ac/year	(0, 8) (100, 8)	193	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Marsh Islands	121	-0.04 ac/year	(0, 39) (100, 32)	1,447	Wetland islands experience subsidence and erosion due to chronic nitrogen enrichment, sea-level rise, and inadequate sediment subsidy to maintain sufficient accretion.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012 SLAMM 2014
Howard Beach	Tree Canopy	752	n/a	(0, 8.5) (100, 8.5)	2084	Flood gates and walls prevent flood damage to trees; carbon assimilation and stormwater interception service remain constant over time.	Nowak and Crane 2002 Davey Resource Group 2013 NY Times 2012 and 2013
TOTAL		1218.5			7830		
Alternative 5: Flood Wall							
Spring Creek Park	Wetland and Unconsolidated Shore	20.9	+0.23 ac/year	(0, 39) (100, 32)	284	The quality of wetlands degrades over time due to eutrophication in Jamaica Bay. Sea-level rise results in marsh migration into uplands at Spring Creek Park.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012
Spring Creek Park	Upland	229.4	-0.28 ac/year	(0, 33) (100, 33)	2384	Uplands dominated with *Phragmites australis* and *Artemesia vulgaris* (>75% cover). Service provision rated on a buffer condition; degraded condition persists into future.	Wetland Rapid Assessment Procedure (Miller and Gunsalus 1997)
Spring Creek Park	Open Water and Tidal Flat	22.3	+0.05 ac/year	(0, 8) (100, 8)	62	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Open Water and Tidal Flat	72.9	+0.04 ac/year	(0, 8) (100, 8)	193	Chronic nitrogen loading and degraded water quality issues limit habitat value for marine life. Low dissolved oxygen and retention time limit habitat suitability for fish; remains constant throughout project lifespan.	Habitat Suitability Index for Coastal Striped Bass (USFWS 1982) NYCDEP Jamaica Bay Institute (NPS)
Jamaica Bay	Marsh Islands	121	-0.04 ac/year	(0, 39) (100, 32)	1447	Wetland islands experience subsidence and erosion due to chronic nitrogen enrichment, sea-level rise, and inadequate sediment subsidy to maintain sufficient accretion.	Evaluation for Planned Wetlands (Bartoldus 1994) National Wetland Inventory (2010) Hartig et al. 2012 SLAMM 2014
Howard Beach	Tree Canopy	752	n/a	(0, 8.5) (100, 8.5)	2084	Flood gates and walls prevent flood damage to trees; carbon assimilation and stormwater interception service remain constant over time.	Nowak and Crane 2002 Davey Resource Group 2013 NY Times 2012 and 2013
TOTAL		1218.5			6454		

Appendix J: Financing Options

The following Appendix is copied directly from Integrating Natural Infrastructure into Urban Coastal Resilience. The data that is presented has not been updated.

We explored several different financing mechanisms that could capture the value of avoided losses and transfer that value to the primary beneficiaries, the City and homeowners. We sought case studies of successful applications of our proposed models to serve as demonstration projects for each mechanism. The viability of these mechanisms for Howard Beach needs further exploration and testing.
In identifying and developing the financing options, we had five objectives:

• Minimize costs. Create financing structures that use capital efficiently and minimize costs and risks to the City.

• "Beneficiary pays." The principle is that the financial burden of living in a flood zone should be borne by those who live and work there, to encourage residents and business owners to conduct their cost-benefit analysis.

• Distinguish public from private benefits. In determining to whom benefits accrue, effort should be made to separate public benefits (e.g., protecting a subway station) from private benefits (e.g., protecting a private residence). In theory, the cost of adaptation actions can be split between the entities.

• Incentivize resilient land use and building design. Well-designed financing mechanisms can create an incentive for developing property outside flood zones or in ways that minimize risks, thereby reducing property losses from future storms.

• Minimize use of general obligation debt. As with the "beneficiary pays" principle, investments in coastal resilience strategies with large private benefits should be supported by payment streams generated by the beneficiaries, rather than be the general obligation of the City.

To assess the feasibility of asking private property owners to contribute to the cost of flood risk mitigation, we made a rough estimate of the financial burden borne by the beneficiaries of each proposed intervention scenario. A very simple back-of-the- envelope calculation shows the cost per protected home of each alternative (column 4, "Cost per house"). Note that Alternative 1 has the lowest total cost but also protects fewer homes. Alternatives 3 and 4 protect the maximum number of homes at somewhat higher costs.

Assuming a financing vehicle supported by 30-year bonds, the cost per house per year (column 4) suggests that the maximum annual financial burden per household of Alternative 4 is less than $700. This assumes 30-year financing at 3 percent, based on the City's credit rating and current borrowing rate. By comparison, the estimated cost of elevating a single-family home out of the flood zone is $125,000, or $4,100 per year over 30 years.

Figure J-1 Cost per House of Alternatives

	Total construction cost ($M)	Total houses	Houses affected	Houses protected	Cost per house	Cost per house per year**
Alternative 1	$40	4281	3,523	758	$53,000	$2,704.02
Alternative 2	$88	4281	3,523	758	$116,000	$5,918.23
Alternative 3	$249	4281	552	3,729	$67,000	$3,418.29
Alternative 4	$76	4281	6	4,275	$18,000	$918.35
Alternative 5	$98	4281	0	4,281	$23,000	$1,173.44
Elevate Homes	$700	4281	0	4,281	$164,000	$8,367.16

* - estimated
** - assumes 30-year financing at 3%, based on the City's credit rating and current borrowing rate.
Source: CH2M Hill, The Nature Conservancy

Potential Role of Flood Insurance

In this section we outline how the City can use repayment streams outside general obligation debt to support the financing. This analysis is not meant to suggest that homeowners alone should pay for coastal protective measures. The public benefits associated with reduced flood risks (e.g., preventing subway flooding and protecting other infrastructure) are significant and should be factored into any financing schemes.

Flood insurance could be as high as $9,500 a year as new pricing formulas that were part of the 2013 congressional reauthorization of the National Flood Insurance Program come into effect. Higher rates will affect Howard Beach homeowners who are required to have flood insurance if they have a mortgage.

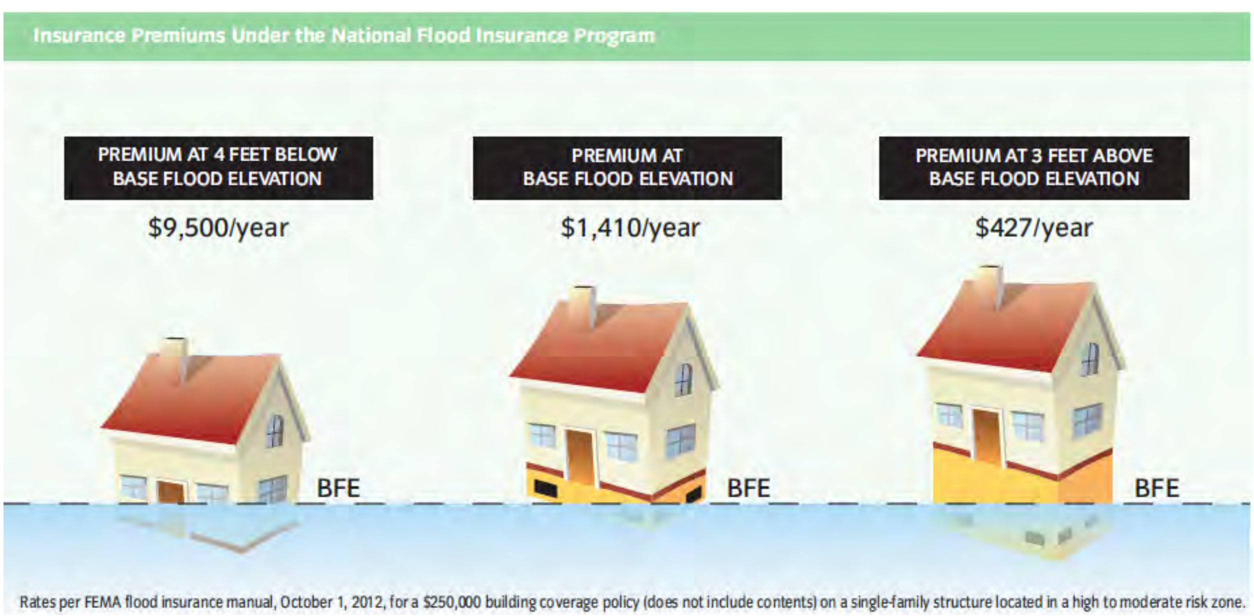
Coastal resilience strategies can reduce rates for many properties by reducing the height of the FEMA-designated base flood elevation, which is a factor in determining insurance premiums. This can produce significant savings for property owners. Assuming that shoreline measures reduce the size of and base flood elevations associated with a 1-in-100-year flood, this could result in individual annual savings of $1,000 to $9,000 per home for residential properties with flood insurance.

A portion of the savings could help fund the coastal resilience measures that would produce these premium reductions (similar to programs that pay for energy efficiency retrofits via anticipated energy savings).

11.2 "Beneficiary Pays" Approaches

We focus on Howard Beach, but many potential solutions can be used borough- or even citywide. As a result, we examined financing mechanisms at multiple scales: neighborhood, borough, and city. We also differentiated between financing opportunities to support private beneficiaries vs. public goods. Some financing vehicles are applicable at multiple scales and for multiple types of beneficiaries, while others are suitable at one scale and work best in either a public or private context.

Figure J-1 Potential Flood Insurance Premiums at Varying Elevations



Source: Federal Emergency Management Agency

Figure J-2 Potential Sources of Payment by Scale

BENEFICIARY/SOURCE OF PAYMENT

SCALE	PRIVATE	PUBLIC
city-wide	• Transferable development rights • Wetlands mitigation banking	• Pay-for-performance contract
neighborhood		• Pay-for-performance contract
borough	• Coastal development insurance product • Property-Assessed Coastal Resilience financing	• Coastal development corporation • Property-Assessed Coastal Resilience financing • Pay-for-performance contract

Financing Strategy 1: Transferable Development Rights

This strategy creates financial incentives to shift growth away from flood zones and develop revenue streams for coastal infrastructure. This mechanism would support citywide investment in protecting private property. We suggest two possible models.

Transfer or sell development rights away from coastal communities. Coastal zone properties that are not at maximum floor-area ratio could sell floor-area ratio (FAR) or development rights to property developers in commercial districts elsewhere. This would freeze future development in the coastal zone while encouraging growth in less risky locations. The concept relies on the presence of unutilized FAR in coastal communities, and incipient commercial districts outside the flood zone where more growth is desired, which would typically be candidates for upzoning.

Coastal protection bonus. Modeled on an initiative in Hudson Yards (described below), a coastal protection bonus would generate funds for coastal protection by creating and then selling "bonus" FAR to developers in inland commercial districts. Proceeds from these sales could be used to finance coastal defenses. This mechanism has been used for a variety of public policy goals, most notably affordable housing (e.g., inclusionary zoning).

Example: Hudson Yards

As part of the redevelopment of the far West Side of Manhattan, the City created the Hudson Yards Special District, in which FAR can be purchased to increase developable space in new buildings. Proceeds from the FAR sales are directed to the Hudson Yards District Improvement Fund. The fund is used by the City to finance $3 billion in infrastructure improvements, including the extension of the No. 7 subway line and new parks and open space.

The Hudson Yards Development Corporation is authorized to sell transferable development rights (TDRs) to owners of certain properties within a subdistrict. These TDRs are available for purchase under a pricing policy adopted by the development corporation.

In addition to TDRs, projects in the Hudson Yards Special District can purchase additional FAR by paying a district improvement bonus. The baseline bonus price, $100 per square foot, was established through a zoning resolution and can be adjusted by the Department of City Planning based on the Consumer Price Index.

Additional information can be found at http://www.hydc.org/html/home/home.shtml and http://www.hydc.org/downloads/pdf/hy_development_information.pdf.

Financing Strategy 2: Pay-for-Performance Contract

Modeled on traditional infrastructure public-private partnerships (PPPs), this solution borrows the PPP structure as well as a recent innovation in pay-for-performance contracts known as social impact bonds. We believe this mechanism could be a primary source of financing for coastal flood protection focused on avoiding damage to public infrastructure.

The City would contract with a private party that commits to deliver coastal resilience infrastructure and/ or protection from flood events of a certain level (e.g., 1-in-500 year storm). The delivery and maintenance risk are held by the private party, which either self-finances the project or issues bonds on the capital markets. The City pays based on the achievement of agreed-upon flood control.

It is assumed that the same kinds of cost savings achieved through infrastructure PPPs would be obtained through this structure, alongside the risk reduction attributes of social impact bonds.

Example: Pevensey Bay

In response to flooding in the 1990s in Pevensey Bay, England, the UK Environment Agency awarded a contract to Pentium Coastal Defence Ltd (now Pevensey Coastal Defence Ltd) to manage the sea defenses—open beaches, artificial groins—along a 9-kilometer stretch of coastline.

The 25-year, £30 million contract, which is the world's only private finance initiative PPP sea defense contract, requires Pevensey Coastal Defence Ltd to protect the coast from any storm of less than 400-year frequency. Performance is measured by the continued physical presence and function of the defenses.

A company project manager described the arrangement succinctly: "We've committed to protecting Sussex from a one in 400 event. That's the contract, and it's up to us how we do that." Ongoing activities include shingle replenishments, groin maintenance, recycling material around the beach, and reprofiling the beaches during and after storms.

The sea defenses provide protection from permanent flooding of a 50-square-kilometer area, which has more than 10,000 properties, important recreational and commercial sites, transport links (main road and railway), wetlands of international importance, and two important nature reserves.

Additional information can be found at http://www.pevensey-bay.co.uk/index.html and http://www.pevensey-bay.co.uk/resources/pdf/Pevensey%20supplement.pdf

Financing Strategy 3: Wetlands Mitigation Banking

Wetlands offer natural flood protection by buffering flood zones and attenuating wave action. A wetlands mitigation bank can create a stream of payments from private developers who want to develop wetland fragments in low flood-risk areas. These developers finance wetland restoration in critical flood management regions. Despite the development on some wetlands, the banks support investment in restoration of fragmented, degraded wetlands in high-priority areas while allowing development to occur in places where natural systems cannot easily be restored.

New York lags far behind regional neighbors in the development and implementation of a wetlands mitigation banking strategy. New Jersey has 15 mitigation banks helping to preserve and restore thousands of acres of open space; New York State has just three.

A wetlands mitigation bank in New York City faces challenges. In particular, the watersheds in which EPA typically approves mitigation offsets are small and do not aggregate areas of high development demand with areas of need for wetlands preservation and restoration. However, other regions have addressed this problem in creative ways that may work in New York. For example, New Jersey allows for compensation in adjacent watersheds, as do Ohio, Texas, and Virginia.

Example: Eugene, Oregon

The Eugene Wetlands Mitigation Bank is a publicly managed venture of the City of Eugene Parks and Open Space Division. By creating the mitigation bank, Eugene was able to simplify regulatory processes, preserve ecosystem function, and include public values outside the usual mitigation process, such as recreation and education.

Since its creation in 1994, the bank has protected or restored more than 250 acres of wetlands within greater Eugene. The bank is part of an integrated plan for development and protection of the wet prairies west of the city. Prices for wetland credits are almost 40 percent lower for projects within the urban growth boundary of Eugene than for projects outside the growth boundary.

The bank provides significant benefits to the community:

• enhanced air and water quality treatment for nonpoint source pollution (e.g., agricultural runoff);

• flood control and water quality treatment through an interconnected system of wetland and riparian areas;

• a diverse array of native plants and animals and wildlife habitat connectivity;

• access to large natural areas near downtown Eugene for all citizens to enjoy; and

• educational and recreational opportunities in and along the wetlands and stream corridors.

Additional information can be found at http://www.eugene-or.gov/index.aspx?NID=497 and http://www.ecosystemcommons.org/sites/default/files/wew_final.pdf.

Financing Strategy 4: Coastal Development Corporation

Derived from a business improvement district, this strategy entails creating a quasi-public entity with bonding authority that would issue debt to finance coastal protection projects. (The pay-for-performance contract described above could also be used by a coastal development corporation.) Bonds could be repaid by a fee assessed on the population (e.g., property owners in the district who benefit from coastal protection). Alternatively, repayment could come through a structure that captures cost savings from reduced insurance rates (similar to PACE financing for energy efficiency loans). This may be problematic in Howard Beach, where only 44 percent of owner-occupied housing units have outstanding mortgages.

Assessments could be restricted to commercial properties because Fannie Mae and Freddie Mac view the fees as an impermissible senior lien ahead of their mortgages. Fees could be assessed specifically on businesses in coastal areas (perhaps as part of a coastal development corporation), or more broadly across the city to support large-scale coastal protection projects.

Example: Waterfront Toronto

To finance a massive downtown waterfront revitalization project, the City of Toronto launched Waterfront Toronto, which uses tax increment financing to fund infrastructure improvements that stimulate economic development within a designated area. Tax increment financing leverages future tax revenue increases within the covered zone and allocates the incremental tax revenue to support the infrastructure project's capital repayment obligations.

Waterfront Toronto was seeded with $1.5 billion from governments of Toronto, Ontario, and Canada. These investments are projected to yield more than $10 billion in benefits. The redevelopment project includes the following elements:

• $219.6 million in municipal infrastructure, utilities, and flood protection for 26 hectares of land for development pull-up line;

• $113.6 million in land acquisition to assemble development blocks for future private sector investment;

• $161 million to create and/or improve 17 parks or public spaces; and

• generation of $136 million in annual property taxes from new development.

Additional information can be found at http://www.waterfrontoronto.ca/.

Financing Strategy 5: Neighborhood Improvement District

Neighborhood improvement districts are modeled on business improvement districts, with the primary difference being that private residences are included. They may be created in areas seeking public-use improvements, which are paid for by tax assessments on property owners in the area where the improvements are being done. The projects must provide a benefit for the property in the designated area and be for facilities used by the public.

Neighborhood improvement districts can be created through a vote or petition of voters and/or property owners in the proposed district. The proposal must include scope of project, cost of project, and assessment limits to property owners in the district. Typical improvement projects would target parks, playgrounds, and recreational facilities; flood control works; drainage, storm, and sanitary sewer systems; and service connections from utility mains, conduits, and pipes.

Example: Hudson River Park

Friends of the Hudson River Park, a park advocacy group, is advocating for the creation of New York City's first neighborhood improvement district with a $10 million-a-year funding stream. Currently, the 5-mile-long park does not receive City or state funds for operations. Money for operations and maintenance was intended to come from nearby commercial and pier revenues, but those revenues have not covered the full operations and maintenance costs.

All property owners (except nonprofits) within the proposed district would pay a tax-deductible assessment to fund the upkeep of Hudson River Park. Assessments would be 7.5 cents per square foot for residential properties, and commercial properties, 15 cents per square foot for commercial properties. The boundaries of the proposed district run along the west side of Manhattan from 59th Street south to Chambers Street, with varying East/West boundaries.

The idea is modeled on the 67 business improvement districts already located in New York City. Assessments are levied on businesses within the district to augment public services and provide benefits to participating businesses (e.g., marketing). A majority of businesses must vote to create the district and levy an assessment. Including residential properties in a neighborhood improvement district would be akin to combining a homeowners association and a business improvement district.

More information can be found at http://www.hudsonriverpark.org/explore-the-park/neighborhoods http://www.hrpnid.com/the-faqs/.