DECEMBER, 2014
NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMMISSION

GREAT KILLS HARBOR BREAKWATER STUDY: FINAL PROJECT SUMMARY REPORT

SUMMARY REPORT

This document was prepared for the Hudson River Estuary Program, New York State Department of Environmental Conservation, with support from the New York State Environmental Protection Fund, in cooperation with the New England Interstate Water Pollution Control Commission. The viewpoints expressed here do not necessarily represent those of NEIWPCC or NYSDEC, nor does mention of trade names, commercial products, or causes constitute endorsement or recommendation for use.

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DECEMBER 23, 2014
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SUMMARY REPORT

PROJECT NO.	214038
DOCUMENT NO.	T06_01
VERSION	3.0
DATE OF ISSUE	December 23, 2014
PREPARED	BRCO
CHECKED	TPMA
APPROVED	AZSL

Executive Summary

Historically, the South Shore of Staten Island was comprised of a multitude of shallow water ecosystems with extensive subtidal flats and shoals serving to protect much of the coastline. This shoreline also provided a recreational economy for Staten Island. The early 1900s saw a decrease in water quality and shipping channels were carved through the flats resulting in the current, urbanized edge condition of the Staten Island South Shore. The partially hardened shoreline has been further armored following coastal storms such as Sandy, with private homeowners adding seawalls in a piecemeal fashion. Often, these local protections are disrupting coastal processes, cutting off cultural access to the water and leading to the call for rethinking our relationship to coastal protection.

The Great Kills Harbor Breakwater study was performed to provide guidance on the use of offshore breakwaters as an adaptive strategy to respond to wave damage and erosion due to coastal storm events and long-term coastal land loss (*Hudson River Estuary Action Agenda Goal 6, Target 1*). The coastal protection offered by a breakwater was also examined as opportunity to restore and enhance aquatic habitat functions and values for a range of biota - including shellfish, crustaceans, and juvenile finfish. In addition, offshore breakwaters were examined as a potential avenue towards ecologically-enhanced shoreline erosion protection (*Hudson River Estuary Action Agenda Goal 2, Target 2*). The study is also based on initiative # 13 of the New York City report: *A Stronger, More Resilient New York (SIRR)* which specifically calls for the study of an offshore breakwater system in this location. The project's objective was to determine the technical feasibility and marine habitat consequences/benefits offered by an offshore breakwater system outside of, but adjacent to, Great Kills Harbor.

The first task of this project involved developing a Quality Assurance Project Plan, or "QAPP" which was the strategic system used by the project team to deliver high-quality products on time and within budget.

The team reviewed publically available data and precedent projects which influenced the design of shore protection approaches. Onshore, near shore and offshore field investigations were performed to further identify site characteristics. The project team assessed multiple approaches for improved shoreline resiliency. Two modeling scenarios, (1) a breakwater on the ocean-side of Crooke's Point with a harbor-wide breakwater at the mouth of Great Kills Harbor; (2) dune on Crooke's Point with smaller offshore breakwaters along Crescent beach and inside the harbor, were selected for further development.

The project team developed hydrodynamic models of each scenario under four storm and sea level rise (SLR) conditions: (1) A storm similar to the December 1992 Nor'easter, (2) A storm similar to Hurricane Sandy, (3) the nor'easter storm including 31 inches of SLR, and (4) the Sandy-like storm including 31 inches of SLR. Each scenario was developed while focusing on economic (damage assessment), ecological, social, implementation, and adaptation and maintenance considerations.

A stakeholder meeting was held to productively communicate the team's results and solicit vital feedback from city, state, and federal agencies, governmental officials, and community members. The team presented their findings on the ecological data collection and assessment, damage assessment, modeling results, and recommendations for next steps forward.

Key Findings

The study yielded several key findings relevant to the project stakeholders to inform broader initiatives.

Breakwater Design and Risk Reduction

- *Breakwaters may be more effective located closer to shore.* Holding breakwater crest elevation constant, breakwaters located closer to shore (0.10 mi offshore) created a longer zone of protection along the shoreline than breakwaters located further offshore (0.25 mi offshore), which had more wave run-around and a smaller zone of protection behind. Breakwaters located closer to shore can be assumed to be in shallower water which reduces construction costs and footprint area.

- *Breakwater crest elevations greater than +11 feet NAVD88 may be needed to mitigate waves from a Sandy-like storm, unless breakwaters are combined with another strategy.* The wave-breaking capacity of breakwaters is directly tied to their crest elevation. In this study, it was found that a crest elevation of +11 NAVD88 was effective in breaking waves for a nor'easter and less effective in breaking waves for a Sandy-like storm. A higher crest elevation would be more effective at breaking waves in more intense storms, however a taller breakwater would increase the footprint of construction, cost, and visual impact on the shoreline.

- *Future designs should consider gap sizes less than 75 feet between breakwater segments or overlapping breakwater segments.* Refined modeling (REFDIF model) reveals the penetration of waves through a segmented breakwater system with a length of 200’ and gaps of approximately 75-100’. Gap size should be reduced and/or breakwaters could be staggered or gaps minimized to reduce this wave penetration. This refines the analysis performed with the SIRR report using the ADCIRC and SWAN models which modeled no gaps in a breakwater at this location.

› *The overall length of the breakwater should extend beyond the limits of the intended protection area.* The Great Kills area is impacted by waves coming from various directions depending on the type of storm. Waves will refract around the ends of the breakwater allowing for larger waves to impact the areas near the end of the breakwater. Extending the overall length will allow for consistent performance for the entire intended protection area.

› *Realignment of the Crooke's Point channel may improve coastal protection and reduce channel maintenance needs.* As Crooke’s Point peninsula migrates to the south west it intercepts the federal navigation channel. This increases the need for channel dredging, however the migration of the peninsula provides additional protection from storm-generated waves to vulnerable areas (Crescent Beach). A reconsideration of the federal channel location could help reduce dredging demands and protect a longer reach of shoreline from storm-generated waves.

Ecological Impacts

It may be possible to generalize some of the environmental findings from benthic survey to other areas of the South Shore and NY Harbor, including:

› *Habitat for key species and ecosystems (northern quahog, salt marshes) may be enhanced on the lee side of breakwaters due to the reduction of energy along the shoreline. (Comparison of transect 1+4)*

› *Structured habitat for structure-loving species (tautog, lobster, etc) will be created by a conventional rock breakwater.* This habitat has historic precedent in the harbor and is in need of restoration.

› *Breakwaters can negatively impact water circulation and flushing and lead to measureable reductions in water quality (Comparison of transect 2+3).* Sediment and water quality data collection and modeling should inform future designs to understand and eliminate potential water quality reductions.

› *Breakwater construction will have negative impacts on species located within and adjacent to the footprint of construction. Mitigation of these impacts is necessary.*

› *Construction within high energy sites with distinct patterns of longshore drift (transect 4) would negatively impact fewer critical species than construction within lower energy edges (transect 1).*

Further studies and research needs

Additional research and understanding would aid in the selection of offshore breakwaters as part of a shoreline resiliency strategy.

- *Use iterative modeling to optimize the design of a breakwater system(including erosion and water quality modeling) for different storms and different risks.* Modeling results will inform design changes and in-turn require verification from further modeling. The iteration is needed to maximize potential damage reduction while avoiding unanticipated impacts to sediment movement and water quality.

- *Model a large spectrum of storms to develop a comprehensive basis to assess impacts.* The modeling should attempt to quantify event-based and gradual erosion, and should be modeled over a greater time frame and number of storm events to derive a more complete understanding of damage reduction benefits over time.

- *Wave damage curves are needed for a wide range of asset types*. Research is needed to develop wave damage curves for a wider range of asset types to properly assess damage from waves. This report used a limited set of damage curves to evaluate wave damage reduction benefits. Wave damage curves for a wider range of asset types will improve quantification of damage reduction benefits associated with wave mitigation strategies.

- *Inventory of shoreline structure conditions.* Incorporation of asset condition information into the damage curves can also help to refine the damage estimates.

- *Refinement of strategies to adapt breakwaters to sea level rise is needed* (i.e. increase toe at time of construction; this is hard to do in the future.)

Regulatory / Permitting

- *Further design refinements, modeling, stakeholder engagement, and evaluation are needed to address design and permitting challenges.* Close coordination with regulatory agencies is recommended. See section 8 for additional detail.

Stakeholder Engagement + Community Impacts

- *It will be important to combine breakwaters with other on-shore strategies to mitigate flood risk.* A flexible, layered system could be designed that would prioritize the factors of coastal protection, visual impact, and ecological impact different along different stretches of shoreline. For example, areas where visual access to the water is a priority, breakwaters could be taller and further from the shore with more on-shore strategies. Areas with critical infrastructure close to the shoreline could host taller breakwaters closer to the shore. Areas with critical species offshore could host subtidal or intertidal breakwaters, designed to reduce everyday erosion and build juvenile fish habitat, and be paired with additional on-shore coastal protection techniques (dunes, seawalls) for enhanced protection.

› *An adaptable, flexible layered solution, including both on-shore and off-shore strategies will be more effective than a singular breakwater strategy.*

› *Further outreach to community stakeholders is needed to develop a layered approach that is consistent with local waterfront goals and mitigates visual impacts.*

Applicability to other sites

A coastal protection strategy which includes a breakwater has potential applicability to other areas within New York City. The following set of specific, site criteria has been identified to help determine the applicability for shorelines elsewhere:

› Areas of exposed shoreline that experience wave action, erosion, and high mobility of sediment.

› Areas where the primary waves are generated offshore with consistent and predictable wind direction, not primarily from local wind-driven conditions.

› Areas of shoreline where essential benthic habitat could be enhanced by the introduction of a breakwater system.

› Areas with benthic and shoreline habitat that could benefit from calmer waters and slower long-shore transport.

› Areas with critical infrastructure, businesses, or homes that would benefit from additional wave action protection.

› Areas with existing or proposed shoreline edge treatments (such as constructed dunes or wetlands) that could benefit from erosion protection.

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1.1 Document Control

Recommended Citation: Sleicher, Azure Dee, P.E., Orff, Kate RLA, Manson, Todd P. PE, Marrone, Joseph F., P.E., December 1, 2014, "Great Kills Harbor Breakwater Study- Final Project Summary Report", prepared by OCC|COWI, SCAPE/Landscape Architecture, Arcadis US, Biohabitats, Inc., and Parsons Brinckerhoff for the Hudson River Estuary Program, New York State Department of Environmental Conservation and the New England Interstate Water Pollution Control Commission.

Table 1-1: Revision History

Revision	Date	Prepared By	Checked By	Approved By
Final Draft 1.0	12/1/2014	BRCO	TPMA	AZSL
Final 2.0	12/19/2014	BRCO	TPMA	AZSL
Revision 1	12/23/2014	TPMA	TPMA	AZSL

1.2 Distribution List

The organizations identified in section 1.3, Project Organization will be provided copies of the Summary Report.

1.3 Project Organization

New England Interstate Water Pollution Control Commission (NEIWPCC) is the client for this study.

Key Staff:

- Mike Jennings, Senior Program Manager

with the **New York State Department of Environmental Conservation (NYS DEC)**

Key Staff:

- Kristin Marcell, Special Project Coordinator, Hudson River Estuary Program, in cooperation with Cornell WRI
- Becky Thomas, NEIWPCC Information Officer III, DEC Hudson River Estuary Program Finance, Contracts and Administration/Coordination

in consultation with the **New York City Mayor's Office of Recovery and Resiliency (NYC ORR)**

Key Staff:

- Curtis Cravens, Senior Program Manager, Coastal Protection

and with the **New York City Department of City Planning (NYC DCP)**

Key Staff:

- Jessica Fain, Planner, Waterfront and Open Space Division

Ocean & Coastal Consultants, a COWI Company (OCC|COWI) is serving as the project co-lead and coastal engineer.

Key Staff:

- Joseph F. Marrone, P.E., Project Director
- Azure Dee Sleicher, P.E., Chief Project Manager
- Todd P. Manson, P.E., Project Manager
- Michael Ludwig, Biologist

SCAPE/Landscape Architecture (SCAPE), project co-lead and landscape architect

Key Staff:

- Kate Orff, RLA, Founder and Partner
- Gena Wirth, Associate
- Lauren Elachi, Designer

ARCADIS US (ARCADIS) developed hydrodynamic models and associated modeling analysis and interpretation.

Key Staff:

- Hugh Roberts, PE, Principal Engineer
- Shan Zou, PhD, Project Engineer

Biohabitats, Inc. (Biohabitats) involvement consisted principally of identification of ecological conditions and environmental evaluation of the shore protection systems.

Key Staff:

- Teresa Doss, Hudson River Bioregion Team Leader & Senior Ecologist

Parsons Brinckerhoff (PB) contributed professional staff time and insights, data, observations, visualization talent, contacts, and other information to the project. Parson Brinckerhoff's involvement consisted principally of economic impact analysis, evaluation of regulatory processes and forecasting including long term storm response and recovery costs evaluation.

Key Staff:

- Richard Tomer, Regulatory Specialist
- Pippa Brashear, Planner/Landscape Designer
- Chris Dorney, Senior Planner

1.4 Problem Definition and Background

Historically the South Shore of Staten Island was comprised of a much more subtle edge and multitude of shallow water ecosystems with extensive subtidal flats and shoals serving to protect much of the coastline. These flats supported natural oyster beds that, in turn, fostered a thriving ecology within their ecological communities. These shellfish resources were leased and actively farmed providing a major economic base for New York and New Jersey residents. This this shoreline also provided a recreational economy for Staten Island, with the beaches around Crescent Beach proving to be particularly popular with sunbathers and swimmers. The early 1900s saw a sharp decrease in water quality in response to the development of industry along the shoreline. The resulting habitat degradation along with shellfish overharvesting exacerbated the problems, and these ecological communities were destroyed. Shipping channels were carved through the flats as the harbor was further developed resulting in the current, urbanized edge condition of the Staten Island South Shore. This partially hardened shoreline has been further armored in the wake of coastal storms such as Sandy, with private homeowners adding seawalls in a piecemeal fashion in front of their properties. Often times these local protections are disrupting coastal processes, cutting off cultural access to the water and leading to the call for rethinking our relationship to coastal protection.

The Great Kills Harbor Breakwater study was performed to provide guidance on the use of offshore breakwaters as an adaptive strategy to respond to wave damage and erosion due to coastal storm events and long-term coastal land loss (*Hudson River Estuary Action Agenda Goal 6, Target 1*). The coastal protection offered by a breakwater was also examined as opportunity to restore and enhance aquatic habitat functions and values for a range of biota - including shellfish, crustaceans, and juvenile finfish. In addition, offshore breakwaters were examined as a potential avenue towards ecologically-enhanced shoreline erosion protection (*Hudson River Estuary Action Agenda Goal 2, Target 2*). The study is also based on initiative # 13 of the New York City report: *A Stronger, More Resilient New York (SIRR)* which specifically calls for the study of an offshore breakwater system in this location. This effort studied the concept, investigating potential benefits from reducing wave action and shoreline erosion while providing habitat value. The project's objective was to determine the technical feasibility and marine habitat consequences/benefits offered by an offshore breakwater system outside of, but adjacent to, Great Kills Harbor. The results of the study serve to inform New York City's Office of Recovery and Resiliency (ORR), New York City's Department of City Planning (DCP), New York State's Department of Environmental Conservation (DEC) and The Hudson River Estuary Program (HREP) and other agencies and community groups for community planning, shoreline adaptation, and resiliency.

1.5 Purpose

The purpose of the Task 6: Final Project Summary Report is to convey the details of the work, illustrate key findings, and provide recommendations on areas for future investigation and examination. This report contains the compiled deliverables of the study which include the development of the project Quality Assurance Action Plan (QAPP, Task 1), identifying and evaluating approaches for offshore breakwater systems (Task 2), hydrodynamic modeling (Task 3), development of selected approaches (Task 4), and a summary of stakeholder's meeting (Task 5).

The primary focus of this report is the development of the selected approaches, key findings of the study, and recommendations (Tasks 4-6). Tasks 1-3 are summarized within this report with detailed task reports appended to this document.

1.6 Scope of Work

The scope of work which comprised the breadth of this study includes six tasks as follows:

1.6.1 Task 1 – Develop an Approved Quality Assurance Action Plan

The first task of this project involved developing a Quality Assurance Project Plan, or "QAPP" which was the strategic system for consistently delivering high-quality products on time and within budget. The QAPP is integrated with and relies on OCC|COWI's ISO 9001:2008 Accredited Quality Management System (QMS). Additional information on the QAPP is summarized in Section 2 below.

1.6.2 Task 2 – Identify and Evaluate Approaches for a Shoreline Protection System

In Task 2, the team gathered and reviewed publically available reports and data, and assembled and reviewed a list of precedent projects which influenced the design and selection of the shore protection approaches. The team identified key areas in and around Great Kills which are the most vulnerable to coastal storms. The primary coastal storm influences were identified for input into the hydrodynamic modeling which included storm driven waves. A field investigation along the shoreline and in the water was performed to identify basic site characteristics. Multiple approaches for improved shoreline resiliency were reviewed and assessed based on several criteria categories. Two modeling scenarios were selected for development: (1) A breakwater on the ocean-side of Crooke's Point with a harbor-wide breakwater at the mouth of Great Kills Harbor; (2) dune on Crooke's Point with smaller breakwaters / offshore interventions along Crescent beach and inside the harbor. Additional information on Task 2 is summarized in Section 3 below.

1.6.3 Task 3 – Hydrodynamic Modeling

In task 3 of the Great Kills Harbor Breakwater study, ocean surface wave propagation computer models were developed to determine the effectiveness of the strategies recommended during Task 2, as compared to a baseline scenario. The project team modeled each scenario under four storm and sea level rise (SLR) conditions: (1) A storm similar to the December 1992 Nor'easter, (2) A storm similar to Hurricane Sandy, (3) the nor'easter storm including 31 inches of SLR, and (4) the Sandy-like storm including 31 inches of SLR. Additional information on Task 3 is summarized in Section 4 below.

1.6.4 Task 4 – Development of Each Selected Approach

The two selected breakwater options identified at the conclusion of Task 2 were developed concurrently with the hydrodynamic modeling (Task 3). The development focused on the following critical areas: economic (damage assessment), ecological, social, implementation, and adaptation and maintenance considerations. Next steps and recommendations for additional study were examined and discussed. The findings for Task 4 are incorporated within Sections 5 through 10 below.

1.6.5 Task 5 - Stakeholder Meeting

A stakeholder meeting was held to productively communicate the team's results and solicit vital feedback on the project. Constituents from New York City (DCP, DPR), New York State (DOS, DEC, GOSR), and federal agencies (NPS, HUD, USACE), governmental officials (Staten Island Borough President's Office, Councilman Ignizio's office), and community members (New York City Councilman's office, Fisherman's Conservation Association, Gotham Whale) were invited to attend. The team presented their findings on the ecological data collection and assessment, damage assessment, modeling results, and recommendations for next steps forward. Additional information is presented in Section 11 below.

1.6.6 Task 6 - Final Project Summary Report

This document, the Task 6 Final Project Summary Report, encompasses the work performed by the team in Tasks 1 through 5.

2 Identification and Evaluation of Approaches for a Shoreline Protection System (Task #2)

In Task 2 of the Great Kills Harbor Breakwater study, the project team identified approaches for a shore protection system adjacent to and south of Great Kills Harbor. The approach focused on systems that integrate coastal wave protection, habitat enhancement, and shoreline erosion reduction. The text presented in this section is a brief summary of the work completed within Task 2; the detailed Task 2 Report is found in Appendix A.

In the first step of this task, the team gathered and reviewed publically available reports and data, and assembled and reviewed a list of precedent projects which influenced the design and selection of the shore protection approaches. The team identified key areas, such as maritime business, infrastructure, and low-lying properties, in and around Great Kills which are the most vulnerable to coastal storms. The primary coastal storm influences were identified for input into the hydrodynamic modeling which included storm driven waves. Existing site information published by reliable sources was collected and catalogued for reference. In addition, the team, in conjunction with city and state agencies, identified areas where insufficient data exists.

A field investigation along the shoreline and in the water was performed to identify basic site characteristics. The shoreline investigation included characterizing the assessment area, performing a GIS analysis to determine ecological structure, and conducting an assessment using the Evaluation for Planned Wetlands (EPW) worksheets. The in-water investigation consisted of sediment sampling, video recording and photographic documentation. A professional dive team accompanied by a marine biologist completed the offshore field investigation. The team obtained samples to identify the nature and diversity of the benthic community and the geological character of the substrate.

Multiple approaches for improved shoreline resiliency were reviewed and assessed based on several criteria categories. An explanation of the approaches and evaluation criteria and the summary of the evaluation, along with the overall score, was presented in matrix format for each approach.

On August 5, 2014, the OCC\SCAPE team met with project stakeholders to review the then-current project status, review project goals, specific boundaries, constraints and assumptions, discuss potential shoreline protection strategies, review the use of an objective matrix to evaluate and assess shore protection strategies and solicit input on the development of modeling scenarios.

Based on the matrix analysis and stakeholder meetings, two modeling scenarios were agreed upon: (1) A breakwater on the ocean-side of Crooke's Point with a harbor-wide breakwater at the mouth of Great Kills Harbor; (2) Dune on Crooke's Point with smaller breakwaters / offshore interventions along Crescent beach and inside the harbor. These options were selected to be advanced for the remaining scope of the study.

Model Option 1 (Figure 1) includes a harbor-wide breakwater which spans the length of Crescent Beach from Retford Ave. to Robinson Ave. (1450 ft) and aims to blocks direct wave propagation from offshore into the harbor ('L' shape). Wave diffraction through openings on a harbor-wide breakwater will likely be significant, therefore the structure is recommended without gaps. The distance from the shoreline is recommended at approximately ¼ mile to reduce the potential for wave regeneration in the lee of the breakwater. An additional breakwater on the ocean-side of Crooke’s Point was also included to protect Nichols Marina. This breakwater is 1400 ft in length, located in front of the National Park Service (NPS) facilities on Crooke’s Point, and is located 1/10 mile from the shoreline.

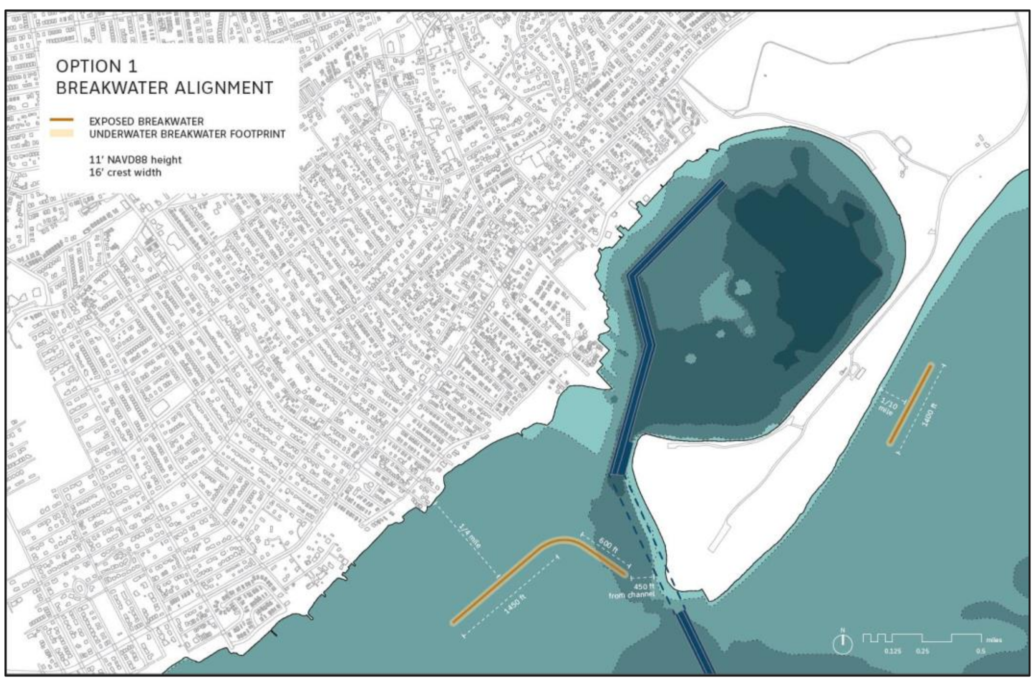

Figure 1: Model Option 1

Model Option 2 (Figure 2) includes a segmented breakwater along the length of Crescent Beach from Retford Ave. to Winman Ave. Empirical results of wave diffraction through breakwater lengths of approximately 250 ft suggested an average 85 ft gap between segments would be effective at attenuating waves while allowing some wave energy to pass through the breakwater line. This scenario would be located closer to shore (approximately 1/10 mile) to encourage sedimentation and reduce the potential for superposition of the diffracted waves in the lee of the breakwaters. Along Crooke's Point, a 600 ft constructed dune was proposed to connect the topographical high points and protect Nichols Marina.

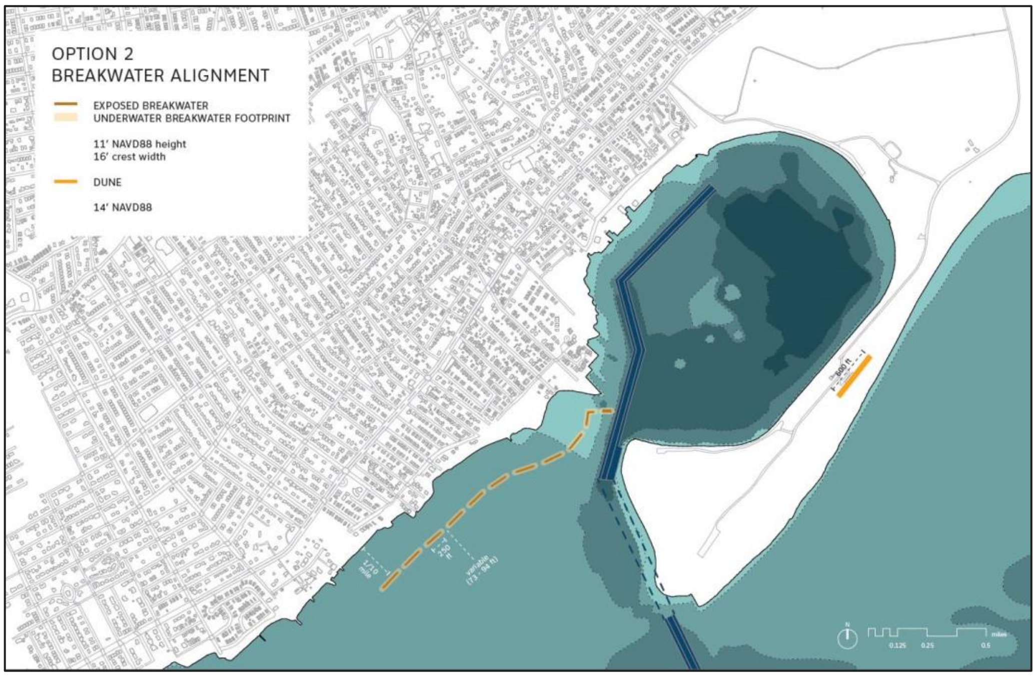

Figure 2: Model Option 2

The orientation of the Great Kills Harbor entrance suggests it is vulnerable from waves propagating from the south, typically occurring during nor'easters. The damage caused by Sandy was devastating, however damage from nor'easters has the potential to occur at a higher frequency. Therefore, the project team recommended modeling four storm cases in Task 3: (1) Nor'easter-type, (2) Nor'easter-type with 31" sea level rise, (3) Sandy-like storm, and (4) Sandy-like storm with 31" sea level rise.

The Task 2 Summary Report is included in Appendix A.

3 Hydrodynamic Modeling (Task #3)

In task 3 of the Great Kills Harbor Breakwater study, ocean surface wave propagation computer models were developed to determine the effectiveness of the strategies recommended during Task 2, as compared to a baseline scenario. Project team member ARCADIS US, Inc. was the designated task lead for the hydrodynamic modeling. Two options were selected from the work in Task 2 for various storm scenarios, as described in Section 2 above.

3.1 Method

The study area was broken into two sub regions, referred to as Inside Harbor and Outside Harbor. The sub regions were established to account for the unique wave conditions associated with the two areas. For both sub regions, offshore wave propagation and attenuation with and without study conditions was assessed using the Refraction/Diffraction (REFDIF) numerical wave model. REFDIF captures the propagation of waves over complex bathymetry, topography, and coastal structures and accounts for the interaction of many processes including shoaling, refraction, diffraction, reflection and dissipation.

In addition to the REFDIF analysis, the Inside Harbor sub region assessment included a local wind wave analysis conducted using the Automated Coastal Engineering System (ACES) numerical analysis tool. Limited wave propagation into the harbor from offshore due to wave shoaling and the geometry of the harbor entrance results in a small portion of the total wave energy within Great Kills. The combination of the ACES wind wave analysis and REFDIF offshore waves assessment describes the overall wave climate in the harbor.

3.2 Results & Recommendations

3.2.1 Waves inside the Harbor

The model results indicated a small portion of the total wave energy expected within Great Kills Harbor comes from waves propagating into the harbor. The secondary analysis using ACES indicated a strong influence on the wave climate comes from local wind generated waves. As such, the placement of the breakwaters to mitigate waves propagating into the harbor has limited effect.

3.2.2 Breakwater crown elevations

The crown elevation of 11.0 feet NAVD88 studied shows considerable benefits for both the 1992 Nor'easter event (9.0 feet NAVD88 stillwater elevation) and 1992 Nor'easter event with SLR (11.6 feet NAVD88 stillwater elevation), particularly for Option 1. Less substantial benefits are seen for the Hurricane Sandy event (12.3 feet NAVD88 stillwater elevation). Minimal to no benefits are shown for the Hurricane Sandy event with SLR (14.9 feet NAVD88 stillwater elevation).

3.2.3 Breakwater distance from the shoreline

The Option 1 breakwater at Crescent Beach is further from the shore (0.25 miles) than the Option 2 breakwater at Crescent Beach (0.10 miles), yet the Option 1 breakwater generally shows the greatest wave reduction at its lee side because it is a continuous and relatively long breakwater alignment. Option 2 however provides wave attenuation for 4.5 foot waves during the 1992 Nor'easter event for a broader area than Option 1 largely due to the proximity to the coast. An alignment closer to the coast provides a broader shadow area at the shoreline.

3.2.4 Breakwater openings

As mentioned above relative to the distance to the shoreline, Option 1 generally performs better than Option 2 due to the continuous breakwater structure, though Option 2 has a more ideal position relative to the shoreline. The current openings (85 feet average) in Option 2 allow for waves to penetrate through the breakwater. Breakwater openings should be significantly smaller than the wave lengths in the area, which are on the order of 90 to 100 feet. Opening sizes in the range of 20 to 40 feet would attenuate waves with increased efficiency.

3.2.5 Breakwater length

In general, the longer the breakwater length, the broader the area protected on the lee side. The shadow area shown in the model outputs illustrate this. The limited reduction provided by the Option 1 breakwater near Great Kills Park and the Option 2 breakwater (which could be considered as many short breakwaters when evaluating the effects of breakwater length) highlights the need to extend a breakwater sufficiently far beyond the target areas of protection in order to provide a sufficiently large shadow zone.

The complete Hydrodynamic Modeling report is included in Appendix B.

4 Assessment of Selected Approaches (Task #4)

The two selected breakwater options identified at the conclusion of Task 2 were developed concurrently with the hydrodynamic modeling (Task 3). The development focused on the following critical areas:

• Economic: An evaluation is presented of the potential risk reduction benefits in terms of damage avoidance, offered by the two breakwater design options studied under four storm scenarios. The quantitative assessment of damage avoidance was studied only for the scenarios modeled and does not provide a full accounting of potential damages avoided benefits accrued over time. The potential for accumulated benefits over time is discussed qualitatively in the report.

• Ecological: The potential negative and positive effects on the ecology and environment were assessed, as well as potential co-benefits provided both on-shore and offshore. Habitat creation, enhancement, and displacement were addressed, as well as the habitat diversity that may be created or modified by the selected approaches. The shoreline assessment was performed in a similar procedure to Guide to Functional Design Using the Evaluation for Planned Wetlands (EPW) Procedure, tailored to the in-shore and near-shore environments of the project site. Offshore environments were assessed by comparison to existing benthic community habitats and use level characterizations.

• Social: Existing public access to the water was evaluated, as well as local and regional connections to the water through recreational opportunities both in the water and along the shoreline with particular focus on the recreational fishing and boating communities. Opportunities to enhance the existing social focus of the community were examined.

• Implementation: Challenges for project implementation were identified and assessed, including the identification of areas for additional study, replicability, and refinement. In addition, a discussion on the ease of construction and likely permitting and regulatory requirements and potential hurdles were examined.

• Adaptation and Maintenance Considerations: Techniques and strategies were identified to discuss project adaptation potential and future maintenance considerations. Elements discussed include wave attenuators inside the harbor, shoreline response, a paired resiliency approach, sea-level rise adaptation, ecological enhancement, and structure maintenance.

• Next Steps: Recommendations and the proposed next steps for modeling and design to advance the work performed are discussed.

5 Assess Approaches: Economic

The goal of the economic impacts evaluation was to identify and evaluate the potential risk reduction benefits in terms of damage avoidance, offered by one of the breakwater design options, Option 1, under the four storm scenarios considered. This assessment of damage avoidance is studied only for the storm scenarios modeled and does not provide a full accounting of potential damages avoided over time. The potential for accumulated benefits over time is discussed qualitatively in the report.

The hydrodynamic results (wave reduction) for design Option 1 and Option 2 showed the designs were not optimum for shoreline protection (See Section 4). Therefore, the option which had the best potential to demonstrate the assessment approach and allow for the team to draw conclusions and recommendations for further study was chosen.

5.1 Economic Assessment: Damages Avoided Background

5.1.1 Spatial extent of analysis

The preliminary coastal modeling conducted for the study indicated that, for the storms analyzed, the breakwater designs that were developed had negligible effects on wave heights within Great Kills Harbor. In fact, the results illustrate that waves did not significantly propagate into the harbor in any of the scenarios studied. This suggests that the existing harbor configuration is effective at attenuating incoming waves and that any observed waves within the harbor are primarily attributable to other factors (local wind) and that more localized interventions within the harbor (wave screens, etc.) would be required to address them. Benefits from the breakwaters were more pronounced outside the Harbor on Crooke's Point and at Crescent Beach. Of these two areas, the damage avoidance assessment focused on the Crescent Beach neighborhood since only this area contained assets whose damage costs were quantifiable given the scope of this study. Figure 3 shows the location of the Crescent Beach risk reduction study area within the context of the broader project study area boundary.

Figure 3: Location of the Crescent Beach Risk Reduction Study Area

5.1.2 Types of impacts quantified

The analysis of damage avoidance is limited to those factors where damage impacts can be attributed to waves and erosion and where valid sources quantifying such attribution of damages is available. Buildings and shoreline structures were chosen for study because the amount of damage they incur during storm events can be directly tied to wave action; the primary damage parameter that breakwaters mitigate.[1] Roads can also be damaged by wave action during storms and waves can also cause the loss of land through erosion, but undertaking the engineering assessments necessary to properly assess such damages was beyond the scope of this project. This section first summarizes the approach used for assessing damages avoided to buildings followed by the approach for shoreline structures. The impacts of event-based and gradual erosion are discussed qualitatively with some discussion of anticipated magnitude of impacts.

5.1.3 Sources of Risk: Coastal Storm Events

To frame this analysis, it is important to understand the ways in which breakwaters reduce risk from both (1) the acute hazard of coastal storms and (2) gradual erosion. The potential damage reduction benefits of both of these will be discussed, however, it should be noted that only the damages from storms were modeled as a part of this study. For the purpose of this study, the focus of the assessment is on physical property damages. A brief discussion of other damages for future consideration can be found at the end of this section.

Hazard: Coastal storms

Damage to property and threats to health and safety as a result of coastal storm events are caused by a variety of environmental stressors. Breakwaters address some, but not all of these stressors. Waves and coastal erosion are the environmental stressors that are the focus of this study based on the potential for the breakwaters to reduce exposure of the coast line, inland areas and assets along it to these factors. During storm events, additional damage can be expected from surge inundation and wind. However, these stressors are not mitigated by the breakwater designs and thus breakwaters are unlikely to generate damage reduction benefits associated with these factors. Magnitude of damage may also be attributed to water velocities, and it has been suggested that breakwaters may be able to generate some reduction in water velocities; however, these were not modeled and analyzed as part of this study. These factors / forces, how they result in damage, and the potential for breakwaters to reduce this damage is summarized in Table 5-1.

[1] Breakwaters do not prevent storm surge inundation or inundation from general sea level rise.

Table 5-1: Major factors / forces of a coastal storm that cause damage

Factor / force	Property damage impacts	Breakwater potential to mitigate	Analyzed in this study?
Stillwater surge	Water level rise during coastal storm events will cause flooding and inundation of buildings, infrastructure and other assets resulting in flood/water damage.	Breakwaters will have little to no impact on stillwater surge elevations	No
Waves	Breaking waves as well as the additional force created by wave run-up will cause damages above and beyond those caused by flooding alone, including more severe structural damage to built structures.	Breakwaters attenuate waves, reducing wave heights and wave force inland of the breakwaters	Yes
Event-based erosion	Waves and wave energy combined with other water currents during storm events can cause sudden and catastrophic erosion resulting in damage	Breakwaters can reduce the forces causing sudden erosion by attenuating waves and potentially altering water currents.	No[2]
Wind	Wind associated with coastal storms can cause direct damage to structures and vegetation and also contribute to larger waves.	Breakwaters have no direct impact on wind relative to damage caused to on-land property	No

It should also be noted that the wave model selected specifically analyzes the propagation of waves into the study area and does not account for local wind driven waves, such as those that could re-form inside the harbor or after being broken by the breakwaters or other features. Thus, damage resulting from local wind-driven waves is not included in the damage assessment.

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[2] Event based erosion was examined in the course of this study; however, the data derived from the analysis provided inconclusive and incomplete information to quantify the impacts of event-based erosion on the shoreline and shoreline structures at Crescent Beach for the storms modeled. Further modeling would be required.

Vulnerabilities

Not all assets are equally susceptible to damage. The design standard or type of construction of features such as buildings and shoreline structures will determine how vulnerable (susceptible to damage) a given structure is. For buildings, the type of structural construction influences the structure's vulnerability – e.g. light wood frame construction is more susceptible to wave damage than heavier masonry construction, likewise shallow foundation buildings will be more susceptible to structural damage than those with deeper, pile foundations. The more information available regarding the design parameters of a building or other structure, the more accurately damage to such a structure can be estimated.

For the purpose of this study, information on building structures was derived from a combination of New York City Department of City Planning (NYC DCP) MapPLUTO14v1 and building footprint datasets in ESRI shapefile format as well as aerial and street level observations from Google Earth and Bing Maps. Individual building level analysis or surveys were not performed.

5.1.4 Translating hazards and vulnerabilities to damage

Waves

The ways in which wave action / energy translates to damage to assets / property are described below.

› Most notably, waves add energy and force to floodwaters hitting buildings, infrastructure and other assets which can generate structural damage beyond flooding alone. For instance: a few feet of water on the first floor is very different than a house coming off its foundation. Damage resulting from waves is generally attributed to two factors:

  ▪ Waves breaking at / on structures: It is generally understood that wave damage can be attributed to breaking waves striking a structure. For instance, there is general acceptance that waves striking a building at or above the first floor of a structure will result in severe damage to the building.

  ▪ Wave run-up: This is the elevation reached by a wave relative to the stillwater flood level (elevation of flooding if there were no waves). Wave run-up results in a force applied to a structure in the run-up path, which can also result in damage beyond what would be caused by stillwater flooding alone.

› Waves can also represent the difference between flooding and not flooding as they add additional height to floodwaters arriving at the shoreline. While not a steady surge height, the additional flood depths created by wave heights on top of stillwater surge elevations can cause inundation.

In order to associate damages avoided with the breakwaters, a clear nexus between the damages and the wave action must exist. Put simply, we must be able to say, "if not for the breakwaters, this damage would have occurred or been worse." To quantify such damages, a credible source must exist which relates a measurable wave impact (e.g. reduction in wave height) to a definable damage impact (e.g. percent damage). Damage specifically resulting from waves can be difficult to estimate and isolate from other potential damage impacts.

For flood and coastal storms, damage assessment is traditionally done through the creation of "damage curves" which relate an expected value of damage to structures (or contents of structures) to particular storm-related impacts (depth of flooding, wave heights, erosion, etc.). The USACE and the Federal Emergency Management Agency (FEMA) publish such curves for a variety of types of assets (e.g. buildings by type of construction, presence of foundation, etc.) and locations. The most common and heavily used of these are "depth damage curves" which relate a particular depth of flooding to a specified level of damage. Such curves can be generalized or site-specific and are often derived based on historical damage information.

The challenge presented for the analysis of the damage reduction benefits of breakwaters is that the research and available information relating depth to damage is much more robust than what is available for waves or erosion. Most widely available damage curves relate damage levels to depth of flooding only, either (1) relating damage levels to the impacts of stillwater flooding only, or (2) relating damage levels to the combined impacts of stillwater flooding and waves. Neither approach allows the attribution of damages to waves alone, thus making it difficult to impossible to assess damage impacts. However, some approaches have been developed to address this issue and there are some resources and potential approaches for attributing damages to buildings to waves:

1 **The development of separate depth damage curves for high wave energy zones versus areas with little wave impacts:** This is the approach generally taken by FEMA. FEMA, for use with their HAZUS software, publishes separate depth damage curves for what are determined to be high wave energy zones (V zones with wave heights greater than 3 feet) versus other flood zones (waves less than 3 feet). While this can provide a useful source for high level analysis, the results of studies and panels suggest that elevated damages due to waves are likely to be seen at wave heights below 3 feet and wave heights overall may have a more dynamic impact on overall damages than is described by two curves alone (meaning the relationship between damage impacts and wave height or force may vary by wave height).

2 **The development of damage curves specific to waves (wave heights, wave periods, etc.):** the USACE has developed damage curves that relate wave height to damage. The curves generally define a percent damage based on the height difference between the top of the wave crest and the elevation of the first floor or lowest structural member. This approach provides a more detailed and dynamic

description of damages associated with wave height. That said, while conceptually there is a distinction between damage caused by wave attack and inundation damage, in actuality, the wave damage curves in use will probably include both components. Due to this potential duplication of results, the wave-damage curves should not be used at the same location / for the same structures as inundation depth-damage curves. Also, structures themselves are fairly effective wave attenuators, and so wave impact damages may only be relevant for the line of buildings closest to the shoreline, if structures further inland have buildings located between them and the shoreline.[3]

It should be noted that while available for building structures, this study did not reveal similar damage curves available for infrastructure features such as shoreline protective structures or piers.

Building Damage Assessment

A total of 1,068 buildings lie within the Crescent Beach study area including single-family homes, duplexes, townhouse condominiums, a medical office, and various outbuildings.[4] Based on the extent of wave height data available from the models used for this study and the desire to understand the damage impacts at a range of wave heights, the second approach described above was used to determine damage impacts to these buildings.

During coastal storm events, buildings can be damaged by wind, waves, and inundation from storm surge. Of these factors, breakwaters mitigate wave heights thereby reducing (but not eliminating) building damage costs. To estimate the reduction in damage costs to buildings, a geographic information system (GIS) assessment was undertaken that compared modeled wave crest elevations at each building subjected to storm surge with the percentage of building damage expected from those wave heights. The specific wave-damage relationships that were used in this study (see Table 5-2 below) were the aforementioned damage curves developed by the USACE during an expert practitioner's workshop in 2002 aimed at improving the quality of damage curves for coastal economic assessments.[5]

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[3] US Army Corps of Engineers. Edisto Beach Coastal Storm Damage Reduction General Investigation Study. Appendix B: Economics.

[4] Note: This statistic counts each individual duplex and townhouse condominium unit as a separate building

[5] US Army Corps of Engineers. Edisto Beach Coastal Storm Damage Reduction General Investigation Study. Appendix B: Economics.

Table 5-2: Damage Function for Wave Impacts to Shallow Foundation Single-Family Structures & Contents

Wave Crest Elevation Above First Floor (Ft.)	% Damage
0	0%
0.5	33%
1	66%
1.5	100%

The damage function shown represents what the participating expert practitioners thought would be the most likely relationship between wave elevations and damages for shallow foundation single-family structures (the predominate property type in the study area). As shown in the table, the function relates the percent damage to the wave crest elevation above the lowest horizontal members on the first floor. For the purposes of this analysis, it was assumed that the horizontal members on the first floor are one foot higher than the ground elevation of the structure on all buildings in the study area, based on observations of foundation elevations made using Google Earth Street View. In reality, the actual elevation will vary from building to building; however, it was beyond the scope of the study to be able to determine a precise measurement for each structure.

The percent damages derived from the damage function were then applied to estimates of each building's value *plus* the value of the contents within it (assumed to be 50% of the building's value) to arrive at a total damage cost per building per storm both with and without breakwater design Option 1. Estimated building values were calculated based on applying a $150 per square foot cost for residential housing[6] to building square footage data obtained from version 14 of New York City's MapPLUTO property database.[7] The $150 per square foot housing value was chosen to be

[6] The one non-residential structure in the study area, an ophthalmologist's office, was also assumed to be valued at $150 per square foot.

[7] Ten structures were missing square footage information in MapPLUTO. The square footage of each of these structures was estimated by considering other information in the MapPLUTO database and through visual inspection using Google Street View. Also, some structures had multiple buildings on them (typically a house and a detached garage) whereas the building square footage was provided for the parcel as a whole. However, in all such cases, only residential square footage was provided by MapPLUTO so all square footage was assigned to

consistent with recent and ongoing economic analyses being conducted by the New York City Office of Emergency Management.[8] For the future storm scenarios with sea level rise, it was assumed that the building stock would remain the same as today. The $150 per square foot housing value was also retained to provide a consistent point of comparison across the storm scenarios.

Building locations were derived from the NYC Department of Community Planning (DCP) building footprints shapefiles. Wave crest elevations and the ground elevations at the center point of each structure were obtained from the hydrographic modeling results performed in Task 3.

Shoreline Structures Damage Assessment

The Crescent Beach shoreline is protected by many types of shoreline structures including 3,698 linear feet of piers, 2,352 linear feet of seawalls, 880 linear feet of sloped stone revetments, 565 linear feet of breakwaters, 540 linear feet of dunes, and 271 linear feet of jetties. There are no known sources such as published wave height-damage curves or tables which isolate damages to these types of coastal structures from wave heights alone. Methodologies to determine forces on structures that could cause damages during storms are as much a function of the surge level at the toe of the structure and freeboard above the surge as wave height. Detailed coastal and structural evaluations of each individual shoreline structure could be performed to determine the potential for damage/failure in each of the modeled storm and breakwater scenarios. However, these analyses would require detailed information on the existing conditions of each structure which is not known. Further, this type of detailed structural analysis is not within the scope of this study.

One methodology to determine potential damage to seawalls and revetments is based on the prediction of mean discharge (wave overtopping) over the structure as described in *Wave Overtopping of Seawalls Design and Assessment Manual*, HR Wallingford Ltd, February 1999. This manual outlines methodologies by Owen (1980) and van der Meer and de Waal (1992) to predict overtopping and assess risk of damage to the crest and rear slope of the structure as well as landside infrastructure such as roads and buildings. These methodologies have also been adopted by the USACE and are included in the *Coastal Engineering Manual*. The mean discharge can be determined based on the significant wave height, mean wave period, stillwater level (surge), and coastal structure geometry including slope, freeboard (height of structure above the stillwater level) and elevation at the toe. Critical values of mean discharge rates were then correlated to structural safety and a determination made as to whether there is likely to be damage to the structure itself and landward infrastructure. Since the mean

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the house. The square footage of outbuildings was calculated based on the area of their building footprints (they were all single-story structures).

[8] Summary methodology supplied to team by New York City Department of City planning.

discharge rate is still a function of the stillwater level as well as the wave height, there are limitations in our ability to use this assessment tool on a broad scale. Further, it is not recommended that overtopping be the sole or final determination of whether or not a structure will be damaged. The purpose of the analysis is to demonstrate a positive effect on a potential indicator of damage due to reduced wave heights.

To assess whether the breakwaters would mitigate damage to these facilities within the Crescent Beach area during the storm events tested, each shoreline structure was split into 250 foot long segments and wave overtopping calculations were prepared for each. The elevations representing the crest of the structure and the depth at the toe were extracted from the elevation model used to model the storm scenarios. Input wave characteristics were extracted from the REFDIF model results for each point. The mean discharge rate was determined for the Nor'easter scenario with and without the breakwater.

The assessments showed that all of the dunes and seawalls would experience damage both with and without breakwater design Option 1, therefore these facilities were not included in the economic analysis of project benefits. Benefits exist for preventing damage to stone revetments and jetties only during the 1992 Nor'easter event. The value of those benefits was calculated based on the costs avoided from having to repair the structures (assumed to equal $250 per linear foot).

Other Assets / Properties

While the impacts quantified as a part of this study are limited to buildings and shoreline structures, it is worth noting that conceptually, there are other damages that may be related to waves even though there are not existing resources that describe this relationship or data was not collected as part of this study. These include:

› **Marinas (piers and docks):** There are four clusters of marinas within Great Kills Harbor. However, as the breakwaters provided little impact on waves / wave heights within Great Kills Harbor, damage to these facilities was not analyzed as part of this study. Preliminary research of available damage information provided some information regarding damage estimates to such structures which is worth noting. The level of damage incurred by piers and other marina infrastructure will depend on the design level of the infrastructure (surge and wave height which the structures are designed to resist) and the intensity of the storm event. A review of a limited number of studies indicated that target 'not to exceed' wave height design levels for small craft harbors were usually between .25 and 1 foot for weekly events, between .5 and 1 foot for annual events and .75 and 2 feet for 50-year events.[9]

[9] Source: Target wave heights for breakwater designs for small craft harbors are described by American Society of Civil Engineers, Planning and Design of Small Craft Harbors, (2012) and others (including: Cox et. al "Emulating Nature by Building an Island Style Breakwater in the

› **Roads:** There are 5.4 miles of roads within the Crescent Beach study area. It is anticipated that waves breaking on roadways would likely result in damage beyond inundation alone due to the added force applied to roadway surfaces, however, it was not possible to separate such forces from damage potentially caused by scour, buckling and other forces or processes not attributable to waves.

› **Parks / park facilities:** The Crescent Beach study area contains two parks: Crescent Beach Park and Seaside Wildlife Nature Park. Additional parks lie within the broader project study area including, most prominently, Great Kills Park on Crooke's Point. Similar to buildings, it is anticipated that the additional force created by waves would result in greater damage to park structures—fences, lights, play equipment, etc.—than stillwater surge alone. However, it is difficult to separate such damage from damage resulting from surge and water velocity, and wave damage reduction curves were not available for these features.

Event-based Erosion

Similar to the wave damage curves described above, the USACE has also developed damage curves for the erosion footprint compromised which provide damage values related to the undermining of foundation support at associated structures. However, application of such damage curves require information on the extent of erosion, which was not modeled as a part of this study. Evaluation of erosion would require further analysis of past erosion rates and modeling including use of models such as SBEACH and Beach-fx to determine the actual erosion and erosion impacts from the storm events studied.

5.1.5 Sources of Risk: Gradual Erosion

Neither approach described above accounts for the contribution of gradual impacts of erosive forces which would need to be considered separately. A qualitative assessment of the potential impacts on gradual, long term erosion is discussed in the Section 6.2.

5.2 Findings

5.2.1 Storm Damage reduction for scenarios modeled

Estimated damages avoided were quantified and calculated according to the approach described above for design Option 1 under all four storm scenarios. Design Option 1 was selected for analysis over design Option 2 since Option 2 allowed significant wave

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Fort Pierce Marina) who cite *Recommended Criteria for a "Good" Wave Climate in Small Craft Harbors" prepared for Fisheries Canada (Northwest Hydraulic Consultants, 1982).*

transmission through the gaps in the breakwaters. A high level discussion of the impacts of each scenario can be found at the end of this section. A discussion of the potential increased benefits with an optimized scenario can be found in the conclusions, recommendations and next steps section (Section 11).

The damage reduction benefits are quantified and summarized below in two ways:

› The monetized damage reduction benefits to buildings and shoreline structures based on the methodology described above.

› A summary of impacts by wave height zone including maps illustrating the extent of > 4.5 feet, 3 feet and 1.5 feet wave zones as well as a summary of the land area and number of buildings in each wave zone. These materials were prepared to provide a different perspective and visualization of potential impacts.

Full resolution versions of Figure 5 through Figure 11 are provided in Appendix C.

Monetized damage reduction benefits to buildings and shoreline structures (values rounded to the nearest $1,000)

Table 5-3: Monetized damage reduction benefits: '92 Nor'easter

SCENARIO	'92 Nor'easter-like Storm		
	Without breakwaters	*With breakwater Option 1*	*Damages avoided[10]*
Building Damages			
Buildings (residential and commercial) shallow foundation	$68,998,000	$68,683,000	$315,000
Shoreline Structure Damages			
Dune	$0	$0	$0
Revetments (sloped, stone)	$222,000	$0	$222,000
Seawalls (vertical, concrete)	$0	$0	$0
Jetties (groins)	$32,000	$0	$33,000
TOTAL			**$569,000**

Table 5-4: Monetized damage reduction benefits: '92 Nor'easter +31" SLR

SCENARIO	'92 Nor'easter-like Storm + 31" SLR		
	Without breakwaters	*With breakwater Option 1*	*Damages avoided*
Building Damages			
Buildings (residential and commercial) shallow foundation	$147,040,000	$146,379,000	$661,000
Shoreline Structure Damages			
Dune	$0	$0	$0
Revetments (sloped, stone)	$0	$0	$0
Seawalls (vertical, concrete)	$0	$0	$0
Jetties (groins)	$0	$0	$0
TOTAL			**$661,000**

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[10] Damages avoided = estimated damages with breakwaters minus estimated damages without breakwaters

Table 5-5: Monetized damage reduction benefits: Sandy

SCENARIO	**Sandy-like storm**		
	Without breakwaters	*With breakwater Option 1*	*Damages avoided*
Building Damages			
Buildings (residential and commercial) shallow foundation	$167,083,000	$166,544,000	$539,000
Shoreline Structure Damages			
Dune	$0	$0	$0
Revetments (sloped, stone)	$0	$0	$0
Seawalls (vertical, concrete)	$0	$0	$0
Jetties (groins)	$0	$0	$0
TOTAL			**$539,000**

Table 5-6: Monetized damage reduction benefits: Sandy+ 31" SLR

SCENARIO	**Sandy-like storm + 31" SLR**		
	Without breakwaters	*With breakwater Option 1*	*Damages avoided*
Building Damages			
Buildings (residential and commercial) shallow foundation	$233,519,000	$233,407,000	$112,000
Shoreline Structure Damages			
Dune	$0	$0	$0
Revetments (sloped, stone)	$0	$0	$0
Seawalls (vertical, concrete)	$0	$0	$0
Jetties (groins)	$0	$0	$0
TOTAL			**$112,000**

Summary of impacts by wave zones

'92 Nor'easter

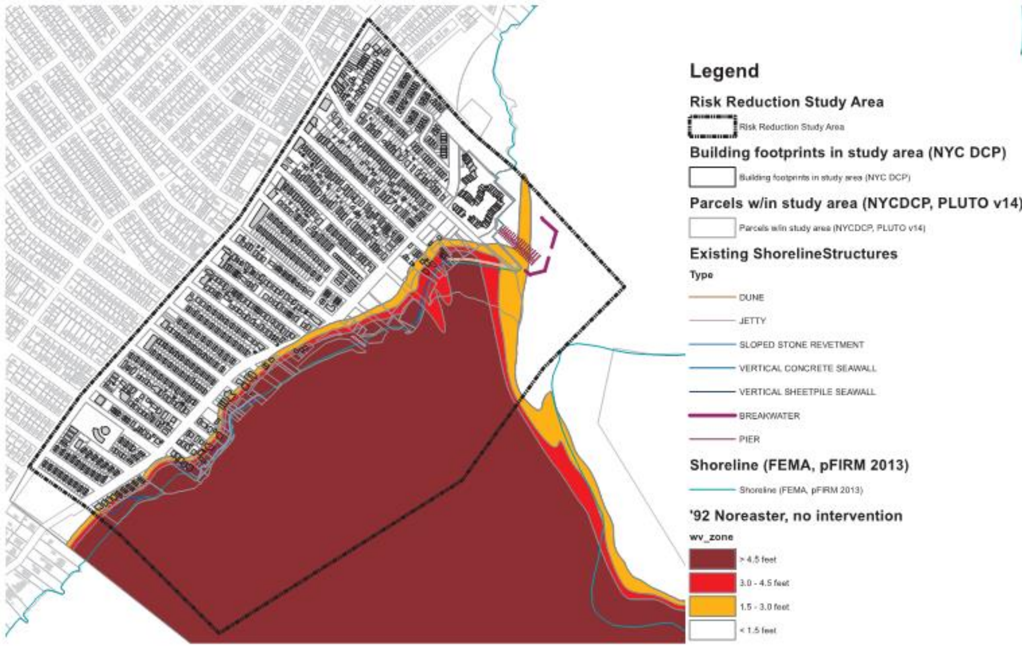


Figure 4: '92 Nor'easter, no intervention

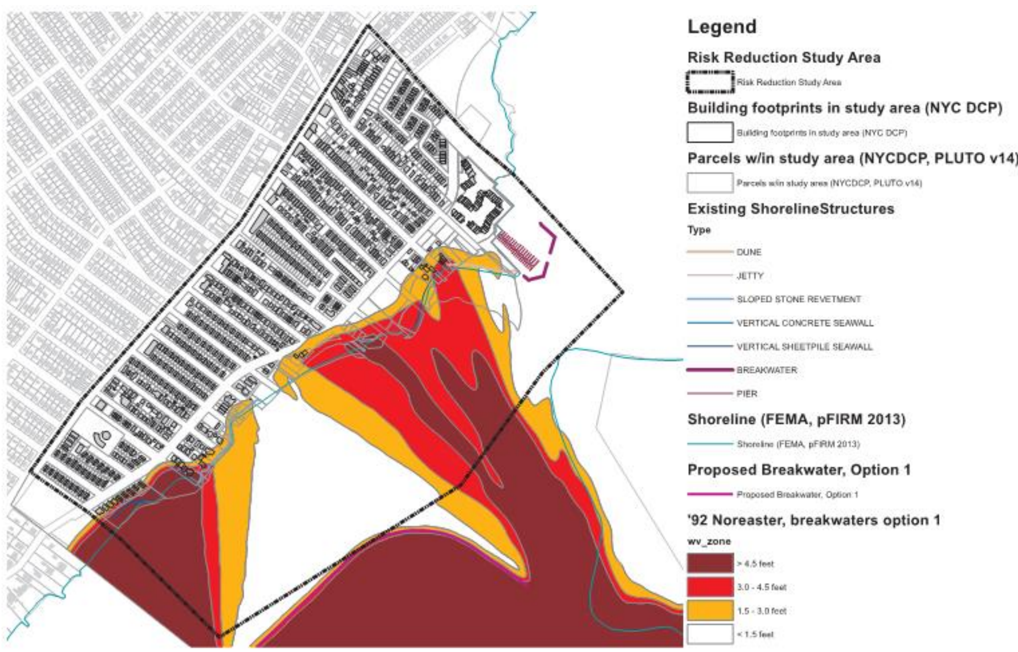


Figure 5: '92 Nor'easter, breakwater Option 1

Table 5-7: Building Impacts by Wave Height: Nor'easter

Nor'easter, Without Intervention				
Wave Height	Building Area	Number of Buildings	Units of Residential	Total Units
1.5 - 3.0 feet	40,143	23	29	29
3.0 - 4.5 feet	26,494	13	11	11
> 4.5 feet	9,075	5	6	6
Total > 1.5 feet	75,712	41	46	46
Total > 3.0 feet	35,569	18	17	17
Nor'easter, Breakwater Option 1				
Wave Height	Building Area	Number of Buildings	Units of Residential	Total Units
1.5 - 3.0 feet	32,912	21	22	22
3.0 - 4.5 feet	8,688	6	5	5
> 4.5 feet	748	1	1	1
Total > 1.5 feet	42,348	28	28	28
Total > 3.0 feet	9,436	7	6	6
Nor'easter, Impacts Avoided				
Wave Height	Building Area	Number of Buildings	Units of Residential	Total Units
1.5 - 3.0 feet	-7,231	-2	-7	-7
3.0 - 4.5 feet	-17,806	-7	-6	-6
> 4.5 feet	-8,327	-4	-5	-5
Total > 1.5 feet	-33,364	-13	-18	-18
Total > 3.0 feet	-26,133	-11	-11	-11
Nor'easter, Impacts Avoided (% Change)				
Wave Height	Building Area	Number of Buildings	Units of Residential	Total Units
1.5 - 3.0 feet	-18.0%	-8.7%	-24.1%	-24.1%
3.0 - 4.5 feet	-67.2%	-53.8%	-54.5%	-54.5%
> 4.5 feet	-91.8%	-80.0%	-83.3%	-83.3%
Total > 1.5 feet	-44.1%	-31.7%	-39.1%	-39.1%
Total > 3.0 feet	-73.5%	-61.1%	-64.7%	-64.7%
Data Source: REFDIF model Results NYC DCP MapPLUTO, 14v10				

Nor'easter+ 31" Sea Level Rise

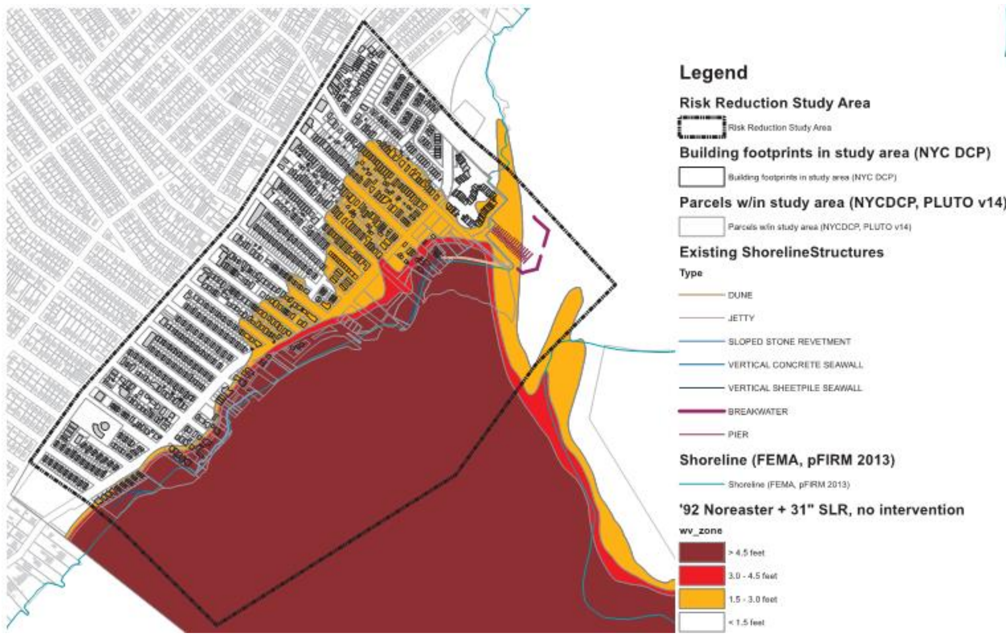


Figure 6: '92 Nor'easter + 31" SLR, no intervention

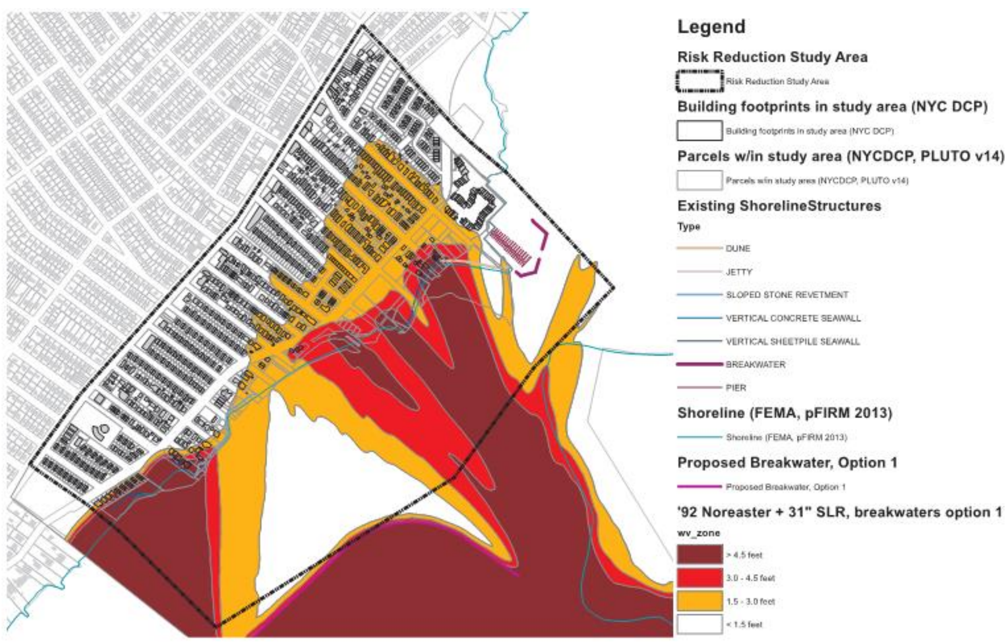


Figure 7: '92 Nor'easter + 31" SLR, breakwater Option 1

Table 5-8: Building Impacts by Wave Height: Nor'easter + 31" SLR

Wave Height	Building Area	Number of Buildings	Units of Residential	Total Units
Nor'easter +31" SLR, Without Intervention				
1.5 - 3.0 feet	349,724	237	255	255
3.0 - 4.5 feet	32,177	21	23	23
> 4.5 feet	34,319	17	18	18
Total > 1.5 feet	416,220	275	296	296
Total > 3.0 feet	66,496	38	41	41
Nor'easter +31" SLR, Breakwater Option 1				
1.5 - 3.0 feet	359,247	246	264	265
3.0 - 4.5 feet	26,928	21	20	20
> 4.5 feet	7,896	4	3	3
Total > 1.5 feet	394,071	271	287	288
Total > 3.0 feet	34,824	25	23	23
Nor'easter +31" SLR, Impacts Avoided				
1.5 - 3.0 feet	9,523	9	9	10
3.0 - 4.5 feet	-5,249	0	-3	-3
> 4.5 feet	-26,423	-13	-15	-15
Total > 1.5 feet	-22,149	-4	-9	-8
Total > 3.0 feet	-31,672	-13	-18	-18
Nor'easter +31" SLR, Impacts Avoided (% Change)				
1.5 - 3.0 feet	2.7%	3.8%	3.5%	3.9%
3.0 - 4.5 feet	-16.3%	0.0%	-13.0%	-13.0%
> 4.5 feet	-77.0%	-76.5%	-83.3%	-83.3%
Total > 1.5 feet	-5.3%	-1.5%	-3.0%	-2.7%
Total > 3.0 feet	-47.6%	-34.2%	-43.9%	-43.9%
Data Source: REFDIF model Results NYC DCP MapPLUTO, 14v10				

Storm Scenario: Sandy-like Storm

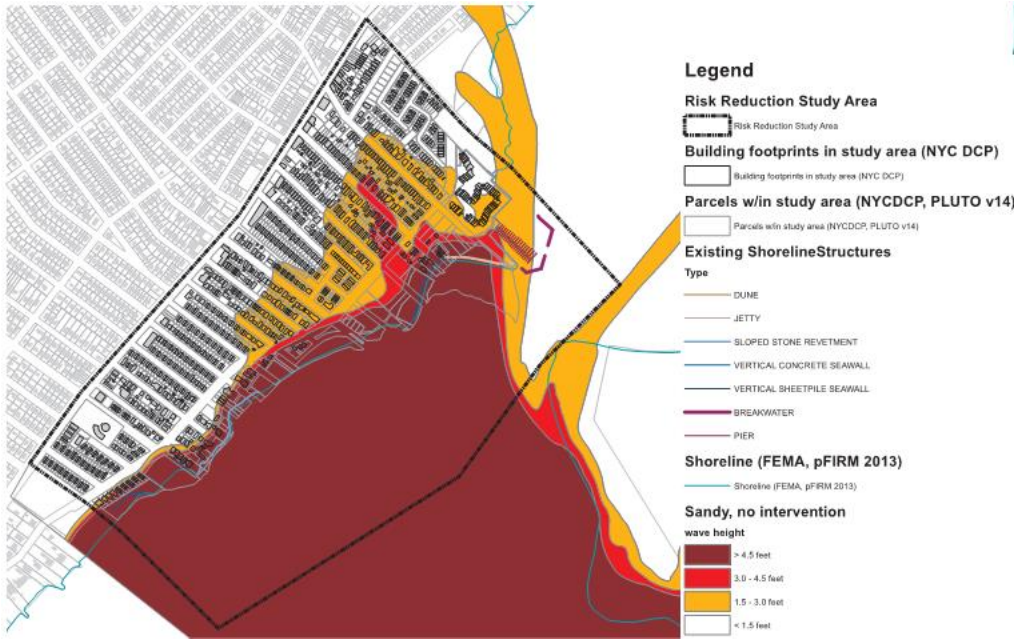


Figure 8: Sandy-like storm, no intervention

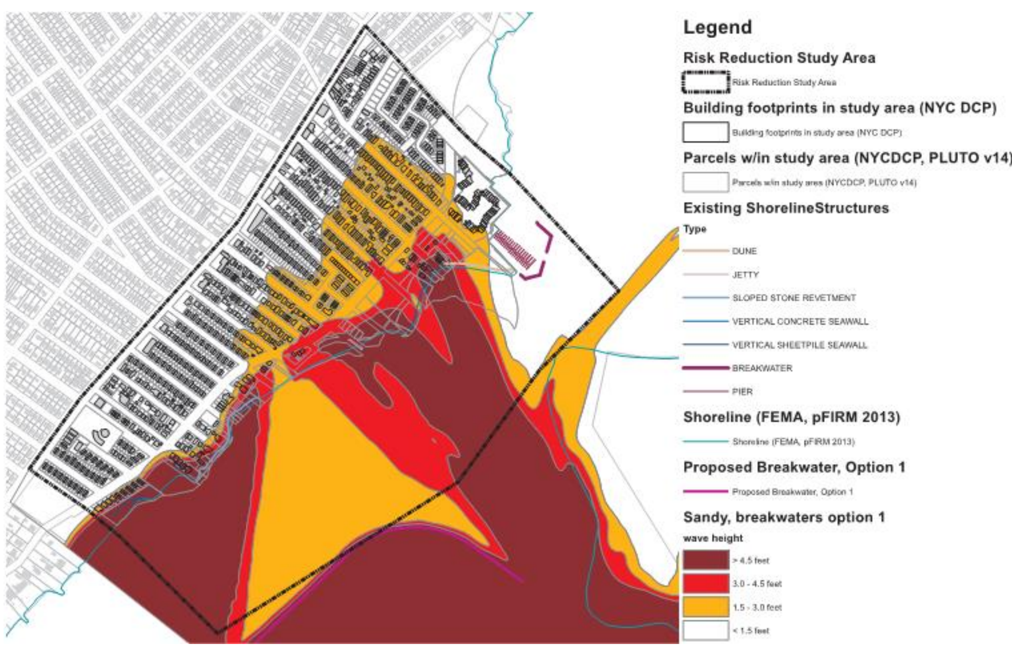


Figure 9: Sandy-like storm, breakwater Option 1

Table 5-9: Building Impacts by Wave Height: Sandy-like storm

Wave Height	Building Area	Number of Buildings	Units of Residential	Total Units
Sandy-like Storm, Without Intervention				
1.5 - 3.0 feet	377,709	255	279	280
3.0 - 4.5 feet	58,004	43	39	39
> 4.5 feet	49,975	26	27	27
Total > 1.5 feet	485,688	324	345	346
Total > 3.0 feet	107,979	69	66	66
Sandy-like Storm, Breakwater Option 1				
1.5 - 3.0 feet	427,810	288	315	316
3.0 - 4.5 feet	38,875	27	22	22
> 4.5 feet	14,612	9	8	8
Total > 1.5 feet	481,297	324	345	346
Total > 3.0 feet	53,487	36	30	30
Sandy-like Storm, Impacts Avoided				
1.5 - 3.0 feet	50,101	33	36	36
3.0 - 4.5 feet	-19,129	-16	-17	-17
> 4.5 feet	-35,363	-17	-19	-19
Total > 1.5 feet	-4,391	0	0	0
Total > 3.0 feet	-54,492	-33	-36	-36
Sandy-like Storm, Impacts Avoided (% Change)				
1.5 - 3.0 feet	13.3%	12.9%	12.9%	12.9%
3.0 - 4.5 feet	-33.0%	-37.2%	-43.6%	-43.6%
> 4.5 feet	-70.8%	-65.4%	-70.4%	-70.4%
Total > 1.5 feet	-0.9%	0.0%	0.0%	0.0%
Total > 3.0 feet	-50.5%	-47.8%	-54.5%	-54.5%
Data Source: REFDIF model Results NYC DCP MapPLUTO, 14v10				

Storm Scenario: Sandy-like storm + 31" Sea Level Rise

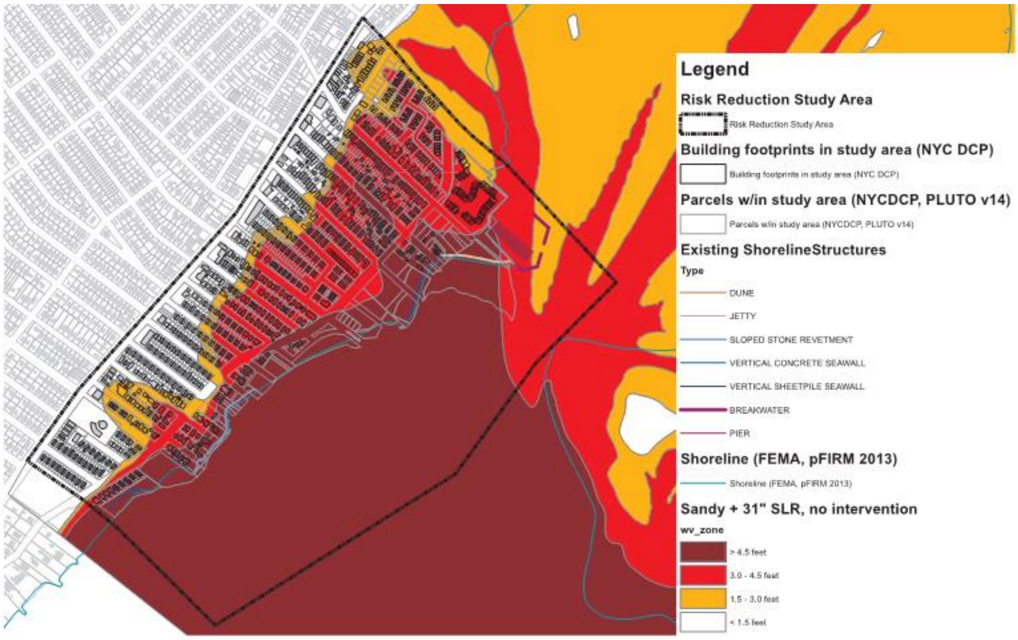


Figure 10: Sandy-like storm + 31" SLR, no intervention

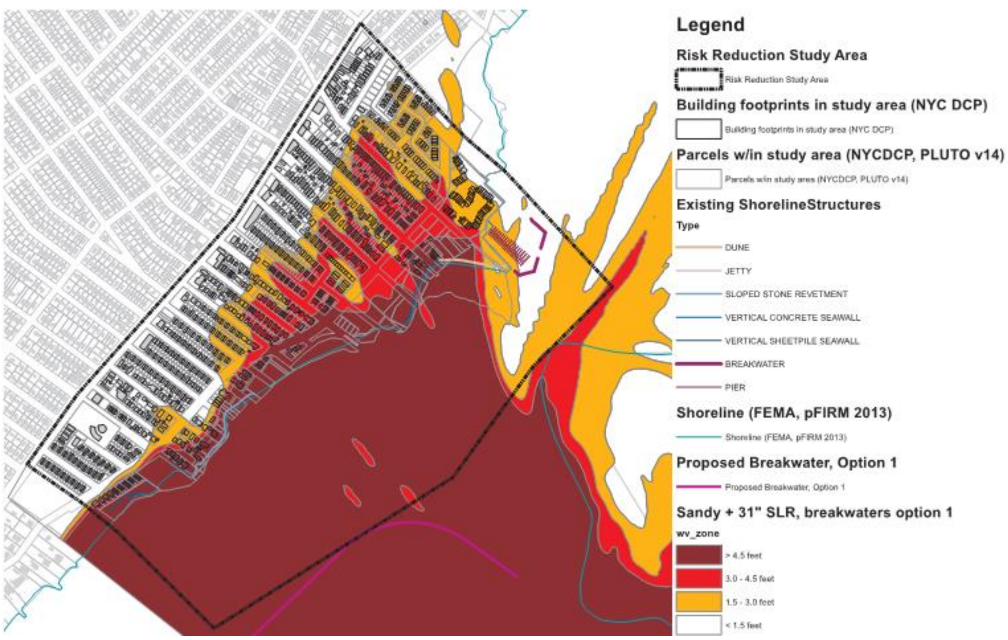


Figure 11: Sandy-like storm + 31" SLR, breakwater Option 1

Table 5-10: Building Impacts by Wave Height: Sandy-like storm + 31" SLR

Wave Height	Building Area	Number of Buildings	Units of Residential	Total Units
Sandy-like Storm +31" SLR, Without Intervention				
1.5 - 3.0 feet	152	152	157	171
3.0 - 4.5 feet	390	480	532	533
> 4.5 feet	114	71	68	68
Total > 1.5 feet	656	703	757	772
Total > 3.0 feet	504	551	600	601
Sandy-like Storm +31" SLR, Breakwater Option 1				
1.5 - 3.0 feet	229	309	346	347
3.0 - 4.5 feet	186	196	203	203
> 4.5 feet	87	46	50	50
Total > 1.5 feet	502	551	599	600
Total > 3.0 feet	273	242	253	253
Sandy-like Storm +31" SLR, Impacts Avoided				
1.5 - 3.0 feet	77	157	189	176
3.0 - 4.5 feet	-204	-284	-329	-330
> 4.5 feet	-27	-25	-18	-18
Total > 1.5 feet	-154	-152	-158	-172
Total > 3.0 feet	-231	-309	-347	-348
Sandy-like Storm +31" SLR, Impacts Avoided (% Change)				
1.5 - 3.0 feet[11]	50.7%	103.3%	120.4%	102.9%
3.0 - 4.5 feet	-52.3%	-59.2%	-61.8%	-61.9%
> 4.5 feet	-23.7%	-35.2%	-26.5%	-26.5%
Total > 1.5 feet	-23.5%	-21.6%	-20.9%	-22.3%
Total > 3.0 feet	-45.8%	-56.1%	-57.8%	-57.9%
Data Source: REFDIF model Results NYC DCP MapPLUTO, 14v10				

[11] Wave heights in the 3.0 – 4.5 foot range are attenuated to the 1.5 – 3.0 foot range, thereby increasing the properties exposed to the 1.5 – 3.0 foot range. Overall, the number of exposed structures to all waves is decreased.

Conclusions and caveats

The following critical caveats must be made regarding this damage assessment:

- The damages avoided are calculated only for the designs modeled. As discussed in Section 3, Hydrodynamic Modeling, and reiterated later in the findings, modeling revealed limitations to the design scenarios modeled, and it is anticipated that modifications could result in greater reduction in wave heights at the shoreline and on shore, which would yield greater damage reduction benefits than those reflected here.

- These damage assessments do not quantify damages to event-based erosion as this could not be quantified as part of the analysis. Significant event-based erosion was observed at various locations along the south shore of Staten Island as a result of Sandy, and it is anticipated that for those sections of shoreline lacking protective structures that further erosion would be observed during coastal storm events with wave action, but that this process would be lessened with the presence of breakwaters due to the fact that they attenuate wave and reduce wave forces at the shoreline.

- These damage assessments account only for those damages that could be attributed to waves. As discussed in the approach, given the difficulty to attribute damages to waves, it is likely that damages to other features such as roadways, or property such as parks, are partially attributable to waves. However, resources were not available for this study to separate damages partially due to waves from damage due to inundation alone.

- This damage assessment is based on the limited number of storm scenarios modeled and represents damage associated resulting from a single occurrence of these events. Thus, this assessment does not include damages which might result from a multitude of other storm events as well as gradual erosive processes nor does it account for accumulated damages over time, which would be much greater.

Discussion of results: buildings

Overall building damage reduction impacts were small relative to the overall estimated damage to buildings calculated for each scenario. However, this is largely attributable to the minimal wave reduction seen at the shoreline as a result of the breakwater design modeled. It is anticipated that a design that maximized wave reduction at building locations would yield greater damage reduction benefits. The breakwater alignment in Option 1 yielded significant wave reduction behind the breakwater, however modeling revealed that the combination of the extent of the breakwater and its distance from the shoreline did not maximize this reduction at building footprints along the shoreline.

Discussion of results: shoreline structures

Based on the elevation data, many of existing shoreline structures are relatively low-lying compared to the surge of the storm scenarios modeled in this study such that structures are submerged or nearly submerged by the stillwater alone regardless of the wave impact. The analysis indicated that the vertical seawalls and bulkheads have the potential to be damaged due to overtopping with and without the breakwater. However, the analysis did yield positive results regarding reduction in damage potential from wave overtopping to the riprap revetments as a result of reduced waves from the breakwater.

5.2.2 Discussion of Potential Long term Impacts

As noted above, the damages avoided for the '92 Nor'easter and Sandy-like storm modeled are not a full accounting of the benefits provided by the project since the breakwaters are likely to provide protection against multiple storms of varying intensity levels over their lifespans as well as regular wave action and water currents. While unable to quantify these benefits as part of this study, the potential of the breakwaters to provide additional risk reduction benefits over time should be considered and are discussed qualitatively below. A lifecycle analysis considering the benefits over the full range of storm events would be needed to obtain a true picture of the benefits of the project relative to its costs and to develop a realistic benefit-cost ratio. Given the realities of climate change, any such effort needs to consider the shifting probabilities of events over time due to sea level rise and possible changes to storm intensities and tracks associated with global warming.

Potential to prevent erosion

While sediment movement was not modeled as a part of this study, an empirical analysis based on typical breakwater behavior was performed revealing both design options, over the long term (50 + years,), would halt or even reverse further erosion of the shoreline.

The section of shoreline in Crescent Beach is in the coastal erosion hazard area and has seen significant historic erosion. Comparison of the 1924 and present-day shorelines (see Figure 12 and Figure 13) reveals areas of significant historic erosion over the last 80 years.[12] Due to significant human alteration of this shoreline over the period in question, —including landfill as well as construction of shoreline features such as revetments and seawalls, historic erosion rates are not likely to be representative of future shoreline change. This said, the construction of seawalls, stone revetments, and a jetty suggest that there has been an ongoing attempt to combat erosion. The ability of the breakwaters to halt long-term erosion and lessen event-based erosion as well as

[12] 1924 shoreline was traced from georeferenced historic aerial imagery of the site. The 2013 shoreline is based on the FEMA shoreline provided in the FEMA Preliminary FIRM maps. Land lost between the two timeframes was derived by calculating the area between the two shorelines (land gained – land lost) and dividing by the total length of the 2013 shoreline.

reduce wave action on existing shoreline structures would likely provide a number of damage reduction benefits over the long term:

› For areas without existing protective features such as revetments and seawalls, the reduction or reversal in erosion would mean no further loss of land along this shoreline. Avoided damages would include the value of the land that would no longer be lost to erosion or the cost of alternative protective measures required to prevent further land loss such as revetments or beach nourishment. For those areas with roadways or other infrastructure, this cost would be increased by the cost of repair, replacement or long-term protection or ongoing maintenance of these features.

› For any buildings within the anticipated erosion area, this would result in the retention rather than loss of these structures that would be entirely lost or the structural damage caused by partial damage to the building's foundation. Avoided damages would include either the value of the structural loss / damage avoided or the cost of alternative protective measures required to ensure that the building would not be impacted.

› Waves and erosive forces can also contribute to failure of shoreline structures due to scour at the base. Reduction in wave heights can reduce the forces and cyclic wear and tear that can be another factor for maintenance and structure replacement. Thus, while we are unable to directly quantify the benefits, we would also expect reduced wave heights and erosive forces to have a positive impact (reduction) on the maintenance and replacement needs/costs of the coastal structures along the shoreline both on a day to day basis and in extreme storm events, lengthening the lifespan of existing or new shoreline structures, reducing repair and maintenance costs over the long term.

For each of the impacts described above, the factor of sea level rise would also need to be considered and discounted from the impacts as the breakwaters have an impact on erosion but not sea level rise.

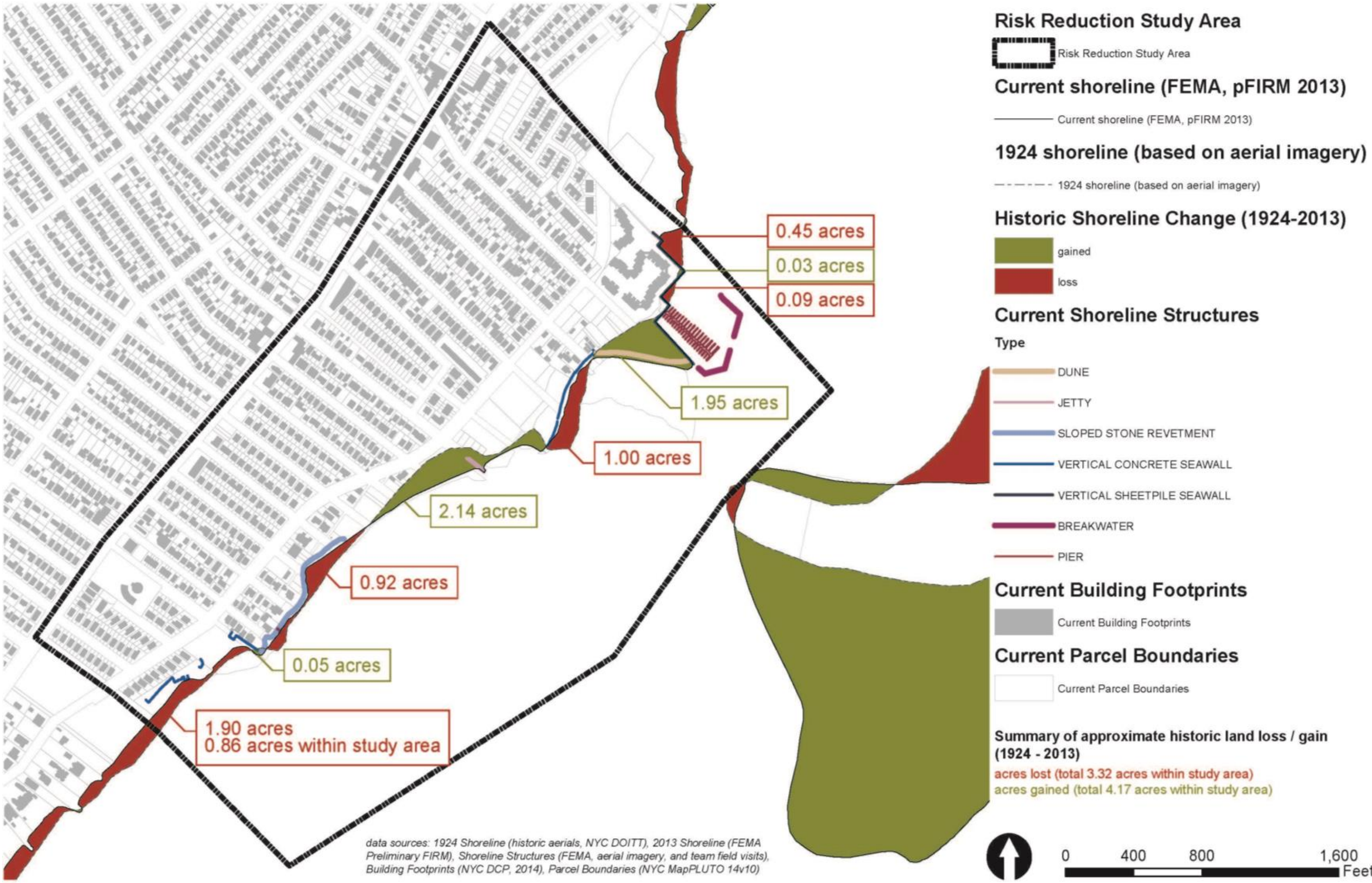
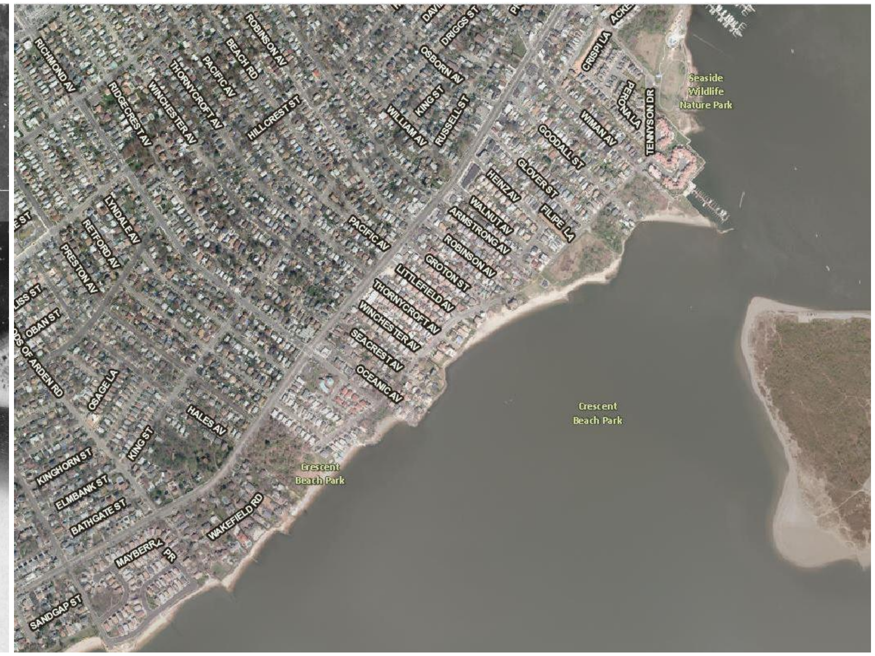


Figure 12: Historic Erosion Trends in Crescent Beach, 1924 - 2013



Crescent Beach in 1924 (NYCityMap, NYC DOITT)

Crescent Beach in 2012 (NYCityMap, NYC DOITT)

Figure 13: Historic Erosion Trends

Wave and overtopping reduction during lower-level more frequent storm events

Overtopping rates and corresponding potential damage on the shoreline structures were determined for a range of stillwater elevations such as high water and lesser magnitude storm events for which the coastal structures are not inundated. It was clear from these additional analyses that a reduction in wave height alone, with all other parameters being equal, can reduce potential damages to the structures. Since these other scenarios were not modeled as part of this study we cannot directly quantify these benefits, however, given the frequency of these lower level surge and wave events, the cumulative impacts of this avoided damage could be substantial.

6 Assess Approaches: Ecological

The two options studied were assessed for the potential negative and positive effects on the ecology and environment. As discussed in the Task 2 summary report, the evaluation of the current ecology and environment was segmented into the shoreline region and offshore region. The shoreline assessment was performed in a similar procedure to the *Guide to Functional Design Using the Evaluation for Planned Wetlands (EPW) Procedure*, tailored to the project site. The offshore assessment was performed by comparing existing benthic community characteristics to published benthic sampling reports which established the baseline for comparison.

6.1 General Site Characteristics

In general, each site presented its own unique issues, but certain characteristics were common throughout all of the sites. Development within the shoreline area has caused a loss in ecosystem function and structure, breaking down the natural processes that a healthy shoreline ecosystem would typically provide.

- Each site had experienced significant disturbances from human activity over time.
- Most all of the sites have been man-made fill in some manner.
- Development surrounds the sites, resulting in a loss of habitat and habitat fragmentation. Over time, this has resulted in a loss of eelgrass, forage fish and shellfish within the system.
- Hydrologic regimes have been altered as a result of the surrounding development; the sites are not naturally connected to a floodplain and there is little riparian vegetation.
- High levels of impervious surface are observed throughout.

- Stormwater runoff for the most part is uncontrolled; storm and sewer outfalls are also potentially point sources of contamination.

- Eroding shorelines are common where there have been shoreline modifications. Modifications, generally bulkheads and seawalls, are prevalent along the Crescent Beach area and northeastern side of the harbor.

- Erosion within the small streams, particularly in Great Kills Park, causes sediments to wash out into the harbor during storm events.

- Most sites have multiple shoreline use conflicts.

- The navigation channel and sections of the inner harbor continue to be dredged, creating more instability in the area (e.g. Crooke's Point migrating southwest).

- Flooding in some areas is becoming more frequent.

- Despite improved water quality in the area, there is a strong potential for nutrients and pathogens to degrade water quality especially during storm events.

With sea level rise, it is expected that many of these issues will become even more problematic.

The waters of the Lower Bay and Inner Harbor provide a number of opportunities for public access. The site is regularly used for fishing, boating, hiking, biking, and other forms of passive and active recreation. Many areas within the project area are protected park lands and are being actively managed for their conservation and preservation. And there are opportunities for restoration. However, because the beach areas are generally narrow and have development abutted up against them, most of the opportunities for restoration are within the aquatic zone, or would require the relocation or removal of development.

6.2 Shoreline Areas

Overall, the natural shoreline areas of the inner harbor and Great Kills Beach exhibited the highest functional values. These are the most stable areas, with the least development and greatest opportunities for habitat. Crooke’s Point has a high functional value for wildlife as well, but the instabilities caused by the dredging of the navigation channel decrease its functionalities related to erosion control, sediment stabilization and water quality. Figure 14 below illustrates how the shoreline was divided into similar typologies for the assessment.

Figure 14: Upland and Littoral Zone Investigation Sections

Crescent Beach and the armored shorelines of the inner harbor exhibited the lowest functional values, due to the amount of development and disturbance that have occurred within the shoreline area.

Data sheets that summarize the EPW process and the Functional Capacity Index scores are provided in Attachment B. The EPW was revised to account for the shoreline zone rather than wetland habitat, and the “Fish” indicator was not utilized for the shoreline areas since it was not applicable. Summaries for the remaining five indices are described below.

Shoreline Bank (SB) Erosion Control: The SB section of the EPW considers the influence of a number of elements on the potential for erosion within the shoreline area. These elements include shoreline structures and obstacles, physical influences (e.g., fetch, boat traffic) and properties of the vegetation located on site.

The site that was observed to have the highest functionality in terms of shoreline bank erosion control was the natural shoreline areas found within the harbor – Sites 6 and 8. These areas are subject to a relatively small fetch, are vegetated, have little to no development within the shoreline zone, and have gradual shoreline slopes. The Great Kills Beach site has a slightly lower functional value due both to its large fetch and lack of vegetation within the upper shoreline zones.

Low functional values for shoreline bank erosion control were exhibited at the armored areas of the inner harbor and the Crescent Beach and Crooke’s Point sites. The shorelines of Crescent Beach and Inner Harbor have been altered over time and as a result have steep slopes and are lacking in vegetation. The Crooke’s Point has a low functional value related to shoreline bank erosion control due to the active dredging of the navigation channel and nourishment of the sandy beach which has created instability within the shoreline zone.

Sediment Stabilization (SS): The SS score reflects a combination of elements (disturbance-related, vegetation and slope stability), resulting in a measure of the capacity of the shoreline to stabilize and retain sediments.

Great Kills Beach and the inner harbor, both the armored and natural shoreline areas, exhibited the highest functions for sediment stabilization. The shoreline at Great Kills Beach and at the natural areas of the inner harbor are stable due to their gradual slopes and natural habitats. The armored areas of the inner harbor also have stable sediments within the shoreline zones due to the bulkhead and riprap areas.

At Crooke’s Point, the sediments on the shoreline are unstable due to the navigation channel dredging and beach nourishment activities, while at Crescent Beach, the shoreline is not stable due to the filling of the upper shoreline, newly nourished sand beaches with little or no vegetation, and the stormwater flows that drain to the beached from the adjacent streets and residential developments.

Water Quality: The WQ function is a measure of the ability of an area to retain and process particulate or dissolved materials, benefiting downstream water quality. It incorporates elements that include hydrology, disturbance, shoreline conditions, substrate and vegetation. For the WQ function, the natural shoreline areas within the inner harbor and Great Kills Beach exhibited the highest value of 0.9, slightly higher than Crooke's Point (at 0.8). These areas have natural habitats with a sandy substrate that allow for the areas to naturally retain and process materials. Crooke's Point is slightly lower in functional values due to the offshore dredging activities and related onshore erosion.

Crescent Beach had the lowest functional value of 0.5 due to the filling of the upper shore zone with bulkheads and riprap, the narrow beach area, erosion caused by the waves hitting the shoreline structures, stormwater runoff from the streets across the beach, and lack of vegetation in the area. The armored shoreline within the inner harbor had slightly higher water quality functional values (0.6) only because erosion is not as much of an issue within these areas.

Wildlife: All of the assessed sites except for the armored shoreline areas within the inner harbor had moderately high functional values for wildlife, due to the relative diversity and complexity of habitat at the sites. The armored shorelines within the harbor exhibited little functional value for wildlife due primarily to the developed shorelines and lack of native habitat.

Uniqueness/Heritage: The UH functional capacity index incorporates several factors about the site, including its capacity to support endangered species, rarity of the site, unique features on the site, historical or archaeological significance of the site, natural landmarks located on site, park or sanctuary status of the site, and the potential for scientific research to occur on site. All of the sites received a score of 1.0 since each site is part of a park and most sites have the potential to provide habitat for a threatened or endangered species.

6.3 Water Areas

Shoreline Bank Erosion Control: The SB section of the EPW considers the influence of a number of elements on the potential for erosion. For the in-water assessment, these elements include shoreline structures and their effects on the nearshore benthic environment and physical influences (e.g., fetch, boat traffic).

Of the four areas, the shorelines along Great Kills Beach and the Crescent Beach were the most stable relative to their effects on the adjacent waters. The active erosion at Crooke's Point is evidence of a lack of erosion control functionality. Similarly, the armoring of the majority of the inner harbor's shoreline indicates that this ecosystem has lost its erosion control functionality (except in the areas of Site 6 and 8).

Sediment Stabilization: The SS score results from a combination of elements (disturbance-related, vegetation and slope stability), resulting in a measure of the benthic environment's overall stability.

Although there is a natural westward drift of the littoral material at Great Kills Beach, overall the site is functionally stable. The nearshore benthic environment off of Crescent Beach is, for the most part, functionally stable, in part due to protections provided by Crooke's Point.

Due to the ongoing dredging in the navigation channel off of Crooke's Point, the nearshore benthic environment is not stable and erosion on shore and along the channel is evidence that the ecological functions at the site are fluctuating. Similarly, in the inner harbor, the benthic areas are not stable as reflected in the low functional values due to the ongoing human disturbances.

Water Quality: The WQ function is a measure of the ability of an area to retain and process particulate or dissolved materials, benefiting downstream water quality. It incorporates elements that include hydrology, disturbance, shoreline conditions, substrate and vegetation.

The water quality across the project area, for the most part, is fairly equivalent across all four sites (based on the factors measured by the EPW analysis), with slight variations due to water circulation and on-going human disturbances. For the most part, however, all sites have seen improvement in water quality over the past 20 years.

The inner harbor was observed to have the lowest functional value based on poor water circulation, on-going human disturbances both on land and in the water, and very little natural shoreline to attenuate flows from the upland areas. Conversely, Great Kills Beach, is subject to less disturbance, has wider natural shorelines and daily tidal exchange across its span and there has a higher water quality functionality.

Fish-Tidal: Within the EPW, the functional capacity of a site to support fish habitat is determined through observations related to the limiting factors of fish passage, availability of food and cover, and water quality. For this project assessment, fish passage was not seen as a factor. Factors that separated one site from another in terms of functionality included shoreline bank stability, disturbances in land and on water, substrate suitability, potential cover, and overall water quality.

The fish functional assessment followed the patterns of the other ecological functions – the benthic environments of the inner harbor and Crooke's Point exhibited lower values than Great Kills Beach and Crescent Beach due to instability, disturbances, substrate and overall water quality.

Uniqueness/Heritage: The UH functional capacity index incorporates several factors about the site, including its capacity to support endangered species, rarity of the site, unique features on the site, historical or archaeological significance of the site, natural landmarks located on site, park or sanctuary status of the site, and the potential for scientific research to occur on site. All of the sites received a score of 1.0 since each site is part of a park and most sites have the potential to provide habitat for a threatened or endangered species.

6.4 Future Conditions

Based on the studies performed for a potential breakwater in the project area, it was determined that the only area where a breakwater could potentially provide some protection against storm wave energies would be off of Crescent Beach (Sites 1 – 4). Therefore, future conditions under EPW were only assessed for Crescent Beach. The assessments are seen in Table 6-1.

Crescent Beach was found to exhibit relatively higher functional values for the following site characteristics:

- Water – disturbance
- Substrate suitability for SAV and fish
- Gradual shoreline slope and nearshore benthic habitat
- Relatively good water quality, which has been observed to be improving
- Provides some wildlife habitat with wildlife attractors
- Good water circulation
- Relatively wide, stable shoreline
- Potential for region to serve as a unique area for the community and visitors, while also potentially providing habitat for threatened and endangered species.

For the analysis of future conditions, use of the EPW is helpful to find out which functional values might be potentially improved. Those site characteristics which were found to have lower relative functional values included:

- Human disturbances on land and in water, in the past and on-going
- Lack of shoreline stability
- Long fetch
- Disturbances at northern end of site related to on-going dredging of the navigation channel
- Stormwater runoff eroding the shoreline
- Lack of natural habitat in upper shoreline areas that have been filled
- Lack of submerged aquatic vegetation
- Narrow shoreline width and steep slopes in areas where the shoreline has been filled
- Lack of fish cover
- Lack of vegetation and diverse habitat along shoreline

For the assessment of future conditions, the focus was on determining if a breakwater could ecologically improve those conditions that had lower functional values without degrading those conditions that exhibited relatively higher functional values.

Table 6-1: Crescent Beach Site Characteristics

Site Characteristics	Existing Conditions	Potential Future Conditions	Notes
1a. Water Contact with Toe of Bank	0.1	0.5	Potential to decrease daily wave action
1b. Shoreline Bank Stability	0.1		Potential to improve stability
2. Fetch	0.1	1.0	Potential to reduce fetch
3. Shoreline Structures	0.1	0.1	Shoreline structures not likely to be removed in place of natural dune
4a & b. Disturbance at Site – on land and in water	0.1	0.1	Will be same disturbance on land and likely more disturbance in water due to construction of breakwater
5a &b. Surface Runoff from Upslope Areas	0.5	0.5	No change as a result of the breakwater
9b. Substrate Type	0.5	0.5	No change – site will likely remain sandy with some silt/clay – key will be to investigate whether silt/clay content increases nearshore
9c. Substrate Suitability for Fish	1.0	1.0	No change but same concerns as for 9b.
10b. Plant Cover	0.1	0.5	Potential increase in plant cover on shoreline due to decreased wave energies on shore
10f. Rooted Vascular Aquatic Beds	0.1	0.5	Potential for SAV in nearshore area with less energies
14a. Steepness of Existing Shore	1.0	1.0	Gradual slope of lower shoreline and nearshore area is not expected to change but would need to conduct further sediment investigations to ensure nearshore area is a site of accretion/deposition.
14c. Site Slope	0.1	0.5	Potential to widen shoreline, and creating less steep slopes in areas which have been previously disturbed.
16a. Shoreline Width	0.1	0.5	Potential for breakwater to increase width of shoreline.
20b. Water Quality Ratings	0.5	0.5	No change expected.
20c. Nutrient or Contaminant Sources	0.5	0.5	No change expected.
20d. Dissolved Oxygen	1.0	?	More investigations are needed to ensure that nearshore areas, west of the breakwater, do not create poorer water circulation, resulting in higher temps and DO levels.
20f. Maximum Temperature	1.0	?	
21b. Shape of Shoreline	0.5	0.5	Shoreline could potentially become more irregular
22b. Available Fish Cover/Attractors	0.3	1.0	A breakwater would create more habitat/cover for fish and shellfish. Key would be to site the breakwater in area not highly populated with Northern Quahog.

Table 6-1: Crescent Beach Site Characteristics Continued

Site Characteristics	Existing Conditions	Potential Future Conditions	Notes
29. Endangered Species	1.0	1.0	The site will still have the potential to provide habitat for T&E species.
30. Rare or Uncommon Habitat	0.0	?	The site may have an increased potential to serve as a rare or uncommon habitat.
31. Unique Features	0.0 - 1.0	?	The site may have an increased potential to create unique shoreline and benthic features, as well as a unique site for the community and visitors.
36. Scientific Research Study Site	0.0	1.0	If constructed, the breakwater will provide new scientific information with potential use around the NY Harbor.

6.5 Conclusions

Shoreline and ecosystem processes which play a direct role in forming the structure of the shoreline and aquatic habitat, have been degraded, which in turn has impacted the type and performance of the ecological functions and values at the site scale.

Anticipated ecological benefits and impacts would need to be studied further through more detailed benthic surveys and sediment characterization, along with a thorough mapping of the shoreline ecosystems and their functionality if the project were to move forward. However, the site analysis and modeling performed during this study reveals some potential effects of the proposed breakwaters within and adjacent to the study area.

Juvenile fish and other organisms will benefit from the addition of breakwaters into the water column, as these types of marine life prefer rocky substrate, which provides topographic relief, feeding opportunities, and shelter to survive. With the degradation of oyster reefs in Raritan Bay in the early 1900s, this type of complex substrate has been diminished in the bay. Raritan Bay is home to many juvenile species, including diadromous fish. These species seek out the benefits of shallow water and cryptic habitat as essential fish habitat. Diadromous species who spend their juvenile years in this area before moving out to open water were reported by Mackenzie (1992) as using the area as a part of their life cycle pattern. Also, rocky habitat allows for a more complex habitat in which they can hide from predators. In turn, these breakwaters have the potential to become hubs of fish activity that can have recreational and economic benefits for local fishermen.

The breakwaters also calm the water in their lee, having beneficial impacts on the shoreline and protected benthic communities. In Transect 4, the long-shore sediment transport was highly dynamic, keeping soft-bodied organisms from establishing themselves. Transect 1, because of the protection provided to it by Crooke's Point, had more benthic activity and a more substantial Northern quahog population. Breakwaters could serve to further protect these benthic communities from wave action and expand sediment-rich habitat for soft bodied organisms.

Additionally, it is anticipated that a breakwater strategy would halt erosion along the shoreline. Many beaches in the study area are increasingly narrow, and tidal marsh habitats have been degraded by coastal erosion along with urbanization. Not only would the breakwaters allow for heightened protection, but in some cases (notably in Option 2) could serve to accumulate sediment along the shoreline and allow for marsh vegetation to grow more vigorously.

Habitat tradeoffs are necessary to evaluate in this proposal, and further benthic information is needed to determine the impacts of the breakwater footprint. In the current design configuration, Option 1 has a total footprint of approximately 265,000 sf and Option 2 has a total footprint of approximately 210,000 sf. The physical footprint of these structures will have habitat implications for benthic species. The benthic information gathered from the diver transects shows that, particularly in Transect 1, a thriving clam population exists off the shoreline of Crescent Beach. Breakwaters will disturb some of this habitat, but could also provide a calmer, more sediment rich area in their lee to foster clam habitat.

Breakwaters may provide habitat for species deemed undesirable by local fishermen or natural resource managers, such as cormorants (which have been observed living on the remains of barges in the area) or potentially invasive species such as Common reed grass *Phragmites australis*. These concerns and criteria for determining the appropriate species to target should be developed in tandem with State, city and local stakeholders, primarily New York State Department of Environmental Conservation (NYSDEC). In order to mitigate these concerns, it is important to develop early on a maintenance and monitoring regime for the project along with possible funding streams. This not only will help to maintain the structures in a way that is in line with NYCDEC and other stakeholder interests, but will also serve as a method to monitor and understand the 'lessons learned' from the project, and adapt the structures to be more environmentally compatible in the future.

Other south shore sites exposed to open ocean waves are likely to be comparable to Transect 4. Breakwater protection could encourage the creation of habitat similar to Transect 1. Breakwater construction in Transect 4 zone would have less habitat impact due to existing longshore drift. Conversely, construction in the Transect 1 zone would have higher impacts within its construction footprint, but could enhance habitats on the lee side over time.

7 Assess Approaches: Social

Anticipated social benefits and impacts will need to be further qualitatively analyzed through community meetings and a detailed damage assessment as the project advances. However, some larger, qualitative potential effects from the project can be noted, informed by stakeholder involvement and knowledge of the area.

Great Kills Harbor is used by many shellfishermen (commercial) and fishermen (commercial and recreational) that use Raritan Bay as a means of enjoyment and profit. Additional rocky substrate (see Task 5.2) can contribute to bolstering fish landings by increasing the population of desirable fish (Zanuttghi et al, 2011). This in turn will have economic impacts on the harbor economy, including the expansion of the recreational fishing and tourism economy. However, navigational considerations around these breakwaters should be evaluated within the design process, ensuring that all hazards are marked appropriately as instructed by the Coast Guard and included on navigational charts. The breakwaters were located so that they do not interfere with the existing federal navigation channel.

Additionally, the involvement of Gateway National Recreation Area would be necessary for any interventions along or off of Crooke's Point. The introduction of breakwaters or dune systems could provide a diversified set of programming opportunities for NPS, including camping, youth educational programs, and a wider selection of in-water recreational activities.

The calmer water in the lee of the breakwaters would not only serve to protect shoreline ecosystems, but also the recreational activities that currently exist along the shoreline. This could result in increased water-based activities (kayaking, sports diving) as well as beach activities (educational programming, increased public access). Currently, there are informal spaces along the Crescent Beach shore, such as the termination of Goodall Street, that are being used as kayak launches or for beach access, but a more formalized program could help to bolster these activities.

Educational initiatives to jointly discuss issues of resiliency and ecology and the risks of living along the shoreline would benefit from a location that is safe and informative for citizens to go along the beach. These types of programming would need to be developed in conjunction with community members and organizations. As shown in Task 2, views along the shoreline will be impacted by the introduction of breakwaters. Currently the breakwaters are designed to be 11' NAVD88 above the water line, though depending on the level of protection required may need to be higher. For Option 1, the breakwater is located ¼ mile from the Crescent Beach shoreline, which allows for less intrusion on the viewshed though the breakwater forms a continuous line on the horizon (see Figure 15). Option 2 is located 1/10 mile off shore, and though there are breaks in the structure that allow views between the breakwaters, it has significant impact on the coastal views (see Figure 16). Further studies are recommended to analyze combined offshore and onshore treatments, which would allow for a lower height of breakwater, lessened view impacts, and a greater diversity of ecology along the shoreline. Community engagement is recommended to analyze the desirability of the potential viewshed, recreational, habitat and hazard mitigation tradeoffs associated with a breakwater system.

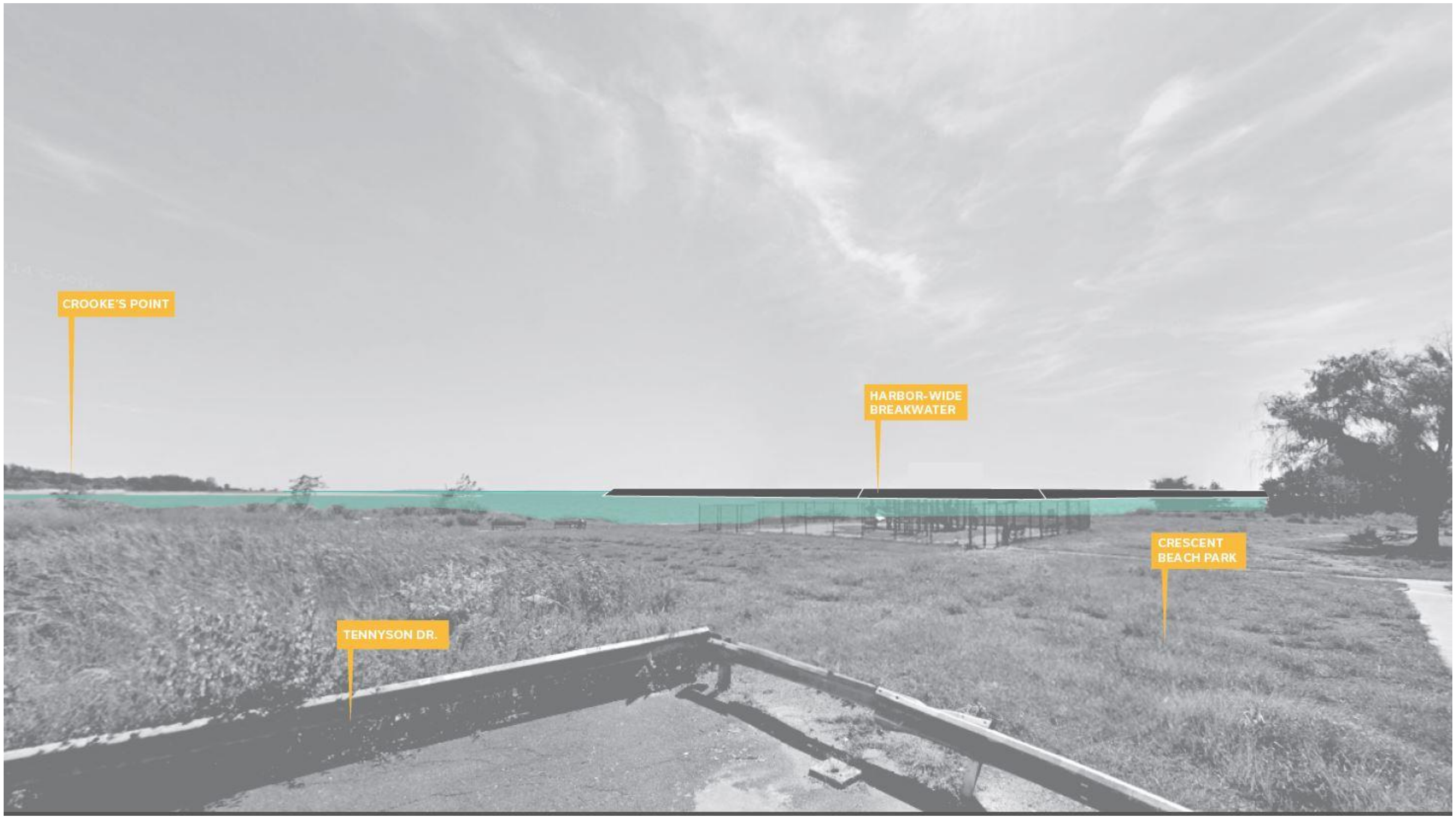


Figure 15: Perspective of breakwater Option 1 from Tennyson Drive (Crescent Beach Park)

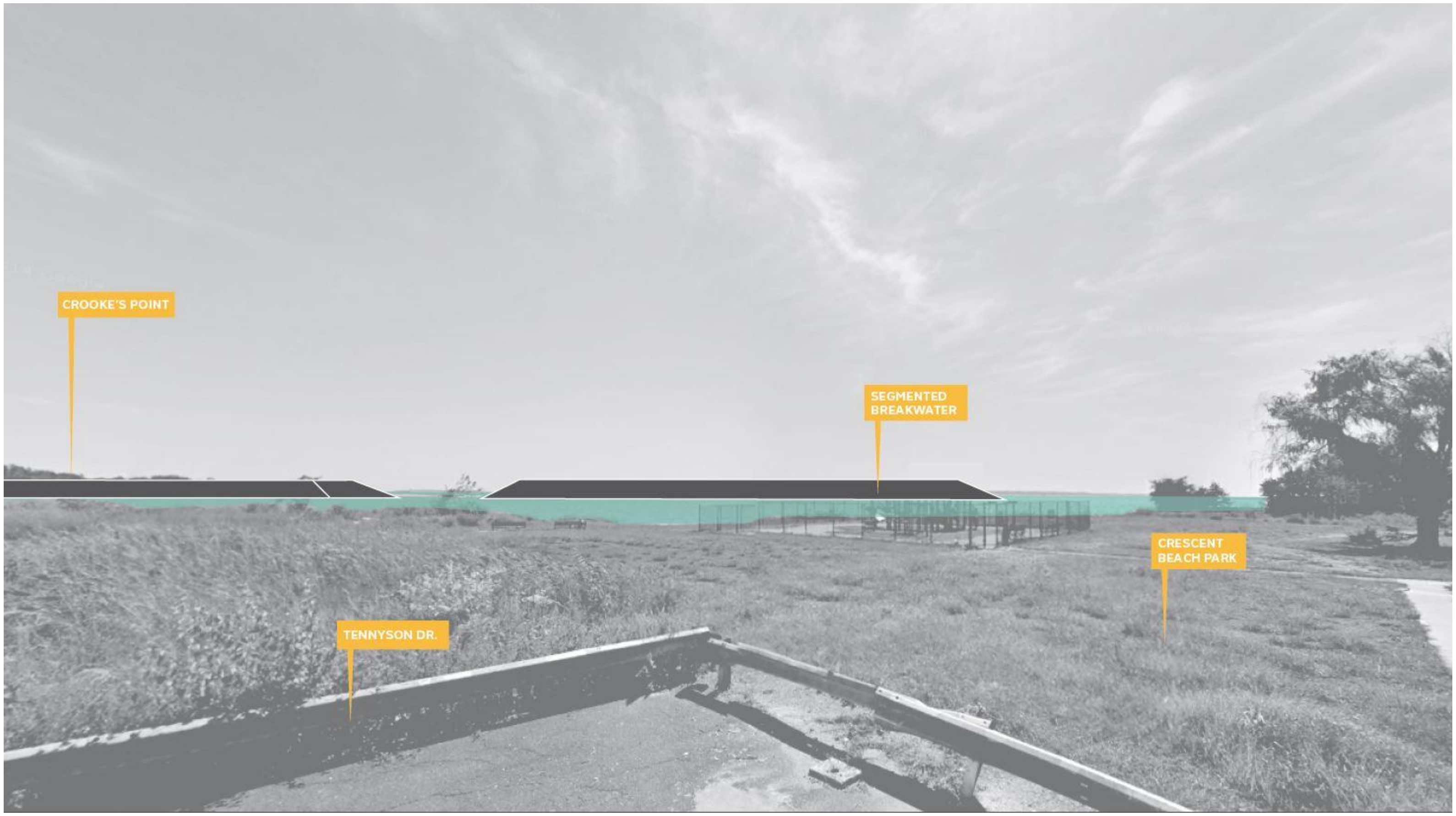


Figure 16: Perspective of breakwater Option 2 from Tennyson Drive (Crescent Beach Park)

8 Assess Approaches: Implementation

Waterfront and offshore construction is, by its very nature, more complex than land-based construction. Typical in-water construction is performed using floating barges to hold equipment and materials. The barges are usually held in place using spud piles and moved with the assistance of tug boats. Breakwater materials will be towed to the site from an onshore transfer area as they are needed.

Specialized heavy marine construction contractors employ skilled operators, dockbuilders, and longshoreman to perform the work. Work is typically performed during normal daylight hours with one work crew. Since the work is performed on the water, severe weather may suspend work due to concerns for safety.

Breakwater construction is typically staged in segments where the underlayers or “bedding” and “core” materials are not exposed to the environment for extended time periods before the armor stone is placed. A typical construction day may see the placement of a geotextile or marine mattress, followed by placement of the bedding stone across the entire structure cross-section. The core material would then be placed atop the bedding stone and covered with the armor stone layer. After a designated length is reached, equipment would be moved to the next segment where the process is repeated.

Sourcing large stone may be difficult within close proximity to the project site. Proper investigating of the stone source, material quality, and handling procedure will ensure deficient material is not used for construction. The US Army Corps of Engineers' engineering and design manual for construction with large stone (EM 1110-2-2302) provides criteria and guidance for the selection, evaluation and use of large stone materials.

The property ownership along the project area will need to be further coordinated for this project to move forward. Along Crescent Beach, a combination of private, public, and state property forms the length of the shoreline, whereas off Crooke’s Point the shoreline and underwater lands belong to NPS. For this phase of the project, the team did not consider land ownership as a restriction for the design alternatives, but this will be a major factor should the project move forward into implementation. Breakwaters depicted in Option 1 are located on underwater public lands owned and managed by the city and state. The nearshore breakwaters depicted in Option 2 intersect a wider range of underwater property ownership types, including city, state, and private property within the 1/10th mile zone from the shoreline and would require property procurement or easements for implementation. Further studies could refine the design to strategically minimize development on private property.

8.1 Regulatory and permitting considerations

Located in the waters of New York Harbor south of Great Kills Harbor, and adjacent to a federally maintained channel, regulation of the breakwaters will fall under the jurisdiction of multiple federal, state and city agencies and be dictated by the requirements of laws and regulations at all three levels of government. There is no single shoreline approach that is preferred by the regulatory agencies throughout all of New York City or New York Harbor. Rather, the identification of permitting constraints will be specific to site conditions and the type of shoreline reconstruction measure being considered. This section provides the following for the breakwater options described:

- Identifies the regulating agencies likely to be involved in the review, approval and permitting of the project described;
- Provides a summary of the likely permits, reviews and approvals that it is anticipated would be required for implementation;
- Discusses the most likely permitting and regulatory issues to be encountered with the project described, and
- Summary of strategies to minimize permitting and regulatory issues.

8.1.1 Regulating agencies

It is anticipated that construction of the breakwaters studied here would require review, permitting or approvals by all or most of the following agencies. The regulating agencies are listed in order of relevance / likelihood and the reasons for their relevancy, including relevant laws noted:

- US Army Corps of Engineers (USACE) / New York State Department of Environmental Conservation (NYSDEC). Waters and wetlands.
- New York State Department of State (NYSDOS) / New York City Department of City Planning (NYCDCP). Coastal zone management compliance (US Coastal

Zone Management Act, NYS Waterfront Revitalization of Coastal Areas and Inland Waterways Act, NYC Waterfront Revitalization Program).

- New York State Department of Environmental Conservation (NYSDEC) Clean water certification.
- NYSDEC / United States Environmental Protection Agency (USEPA). Historic fill may be contaminated.
- United States Fish and Wildlife Service (USFWS) / National Marine Fisheries Service (NMFS). Threatened and endangered species (Endangered Species Act) and essential fish habitat (Sustainable Fisheries Act).
- State Historic Preservation Office (SHPO). Made land/historic fill requires archeological investigation.
- National Park Service (NPS). Special Use Permit required for activities in National Recreation Area.
- New York State Office of General Services (NYSOGS), lands underwater ownership.
- US Coast Guard (USCG), Aids to Navigation;
- Utility agencies (coordination).

8.1.2 Likely required permits, reviews, etc.

The assessment of the known regulatory permits, approvals and regulatory reviews likely required for project implementation are presented in Appendix D.

8.1.3 Key regulatory and permitting hurdles likely to be encountered

The initial understanding of regulatory and permitting issues has been developed based on experience with regulatory agencies and stakeholders on past projects in New York Harbor including both previous built work, but also similar proposals, especially projects in Staten Island like the Rebuild by Design Living Breakwaters project. This initial assessment would need to be refined with the regulatory agencies and stakeholders and additional site-specific investigations completed were the project to proceed to planning, design, or implementation. The known general and site-specific regulatory and permitting issues are presented in the permit matrix as well (See Appendix D). The following list should be considered as falling within the requirements of the National Environmental Act (NEPA) and the State Environmental Quality Review Act (SEQRA) project review procedures. Both review procedures seek to identify and understand unavoidable environmental impacts that may arise from undertaking a breakwater installation.

Potential regulatory and permitting issues that may be encountered with a general breakwater strategy include the following conditions (relevant agencies are noted); these issues are not specific to the options studied.

Clear (risk reduction) benefits must be illustrated: The benefits/effectiveness and potential adverse impacts of a breakwater project must be clearly established. (USACE/DEC).

Alternatives: Practicable alternatives may exist with less environmental impact that would accomplish the project purpose and must be evaluated (USACE/DEC).

There may be existing critical and/or high value habitat: Examples include critical habitat (like spawning grounds) for federal or state endangered species and Essential Fish Habitat or shellfish harvesting waters. Note that the presence of endangered or EFH species by itself doesn't mean the habitat is critical or of high value for them (DEC/NMFS).

There may be historic resources: The most common example would be shipwrecks (SHPO).

There may be resource conflicts: Areas where a project would be incompatible with an established public or commercial water resource use, like clam harvesting beds and fishing grounds (USACE, DEC, NYSDOS).

Underwater infrastructure may be present: Existing infrastructure, like utility line corridors and piers or marinas that could be silted in or have their access blocked, may be incompatible with the project. Conversely, some infrastructure, like shore protection structures, may be compatible with the project (USACE, NYSDOS).

Navigation: There may be navigation channels and anchorages nearby; the USACE or the Coast Guard may strongly object to a project that adversely affects these areas. Local stakeholders like the commercial pilots may also object (USACE, USCG).

Property issues: The project may adversely affect the use of public or private property, which would be an issue for regulating agencies and private landowners. This includes any substantive man-made changes to NPS property (USACE, DEC, NPS).

Water quality: In the instance that the project generates negative changes in water quality according to state water quality standards, this may become an issue (DEC).

Erosion and accretion patterns: The project will impact sediment transport in the region. Changed accretion patterns can affect maritime uses, like increasing siltation in channels or marinas (USACE, DEC, NYSDOS).

Impact to structures from long-term change, like sea level rise, and how structures will be maintained: Structures may not maintain their effectiveness over their lifetime with rising sea levels and other climate impacts. This decline in effectiveness could be a concern. (USACE, DEC).

Impact on/relation to existing studies or shoreline projects: There would be need for coordination with studies like the USACE Phase II Staten Island Study. Conflicts with ongoing projects would provide a problem to implementing agencies (USACE).

Mitigation for habitat displacement or loss: It will need to be determined if mitigation is required for displaced or damaged habitat. This is critical because this type of mitigation has a high level of uncertainty which could translate to high cost and project delay. (USACE, NYSDEC)

8.1.4 Recommendations: strategies for minimizing permitting and regulatory hurdles

Recommended approaches for advancing regulatory review and minimizing potential regulatory issues are discussed below. The following strategies are approaches, that if taken, will help support early identification of potential regulatory issues and may avoid or minimize potential regulatory issues with a breakwater strategy:

Barrier avoidance: Identify the barriers to implementation and avoid them as much as possible, either by changing location or minimizing temporary impacts with actions like seasonal work windows. Examples include not placing breakwaters where they will interfere with navigation channels, and mapping and avoiding known areas of concern like important fish/shellfish habitat, historic resources and utility lines.

Early and frequent coordination with regulatory agencies and stakeholder organizations to educate them about the project, understand their concerns, and learn how to avoid or minimize impacts that are important to these groups. This action also includes obtaining commitments from the senior leadership in these groups and resolving policy issues, and partnering with involved agencies and stakeholder organizations to facilitate regulatory review and approval by identifying/addressing concerns prior to regulatory agencies public comment periods.

Ensure that the project is consistent with the NYSDEC review standards for issuing a permit (these standards are generally applicable for all the regulatory agencies):

› The proposal is reasonable and necessary (this is achieved by demonstrating both need and benefits of the project).

› The proposal will not endanger the health, safety and welfare of the people of the State of New York.

› The proposal will not cause unreasonable, uncontrolled or unnecessary damage to the natural resources of the state including soil, forests, water, fish and aquatic and related environment (in other words the project must be compatible with the preservation, protection and enhancement of the present and potential values of the water resources).

Ensure that the project is consistent with the NYSDOS/NYCDCP Coastal Zone Policies (some of these standards are generally applicable for all the regulatory agencies).

Continue to stress the project benefits of protecting the public health and welfare by noting the loss of life and property/infrastructure damage from past storms and showing what the project will do to avoid/reduce this damage.

Use case studies: Avoid unnecessary or duplicative work by utilizing applicable case studies, like the Plumb Beach EA/FONSI and EFH Assessment.

Perform community outreach: Outreach is important for early identification of community issues and ways to address those issues, as well as garnering public support (both public support – as indicated by positive comments from community groups and representatives – and a lack of public objections will avoid regulatory delays).

Close data gaps: Regulatory and advisory agencies lack the resources to obtain all the data that is important for their review processes; without sufficient data they are more inclined to request additional data requests which leads to project delays. For this reason filling data gaps (within reason) early in the permit process and/or making commitments for follow-on studies will avoid delay.

Link the project into an approved regional framework, either using regional shore protection plans and/or ecosystem improvement plans (e.g. CRP).

Navigation: Impacts to navigation can be minimized by coordinating with maritime agencies and stakeholders, like the USCG and marina operators, and by adequately marking (e.g. buoys, lights) breakwaters to ensure that boaters avoid areas that are hazardous to general navigation and specify who will be responsible for maintaining the markers.

Stress the effectiveness of the project in accomplishing project goals: Clearly state what the project goals are and how the design will accomplish these goals.

NEPA/SEQRA: Promote Cooperating Agency Status during NEPA review. Avoiding or minimizing impacts, especially the key regulatory agency concerns, can help avoid significant impact determinations that will trigger the need for extensive environmental review (EIS).

Complement existing projects/studies: If feasible the project should complement, or at least be compatible with existing projects/studies.

Long-term viability: Explain the viability of structures to long-term change, like sea level rise.

Monitoring can fill critical data gaps for decision-makers: Need monitoring plan with clear data standards that is accepted by all involved agencies.

Maintenance: Need for clear maintenance responsibility and adequate maintenance funding source.

9 Assess Approaches: Adaptation & Maintenance Considerations

We recognize that this project could potentially have long-term impacts, both positive and negative, along the shoreline of Great Kills. Many of these impacts would need to be further studied through more detailed modeling, and the addition of a water quality / circulation and sediment modeling process, which was not in the scope of this feasibility study.

9.1 Localized Wave Attenuators in Great Kills Harbor

The results of the hydrodynamic modeling, discussed in Section 4, revealed Crooke's Point effectively attenuates waves entering the harbor from Raritan Bay. Further analysis shows that a majority of the waves within the harbor are generated from local winds. Of the storm scenarios modeled, approximately one-third of the wave height within the harbor is attributed to waves propagating into the harbor.

Localized wave attenuating structures were given cursory examination to determine the feasibility of their application. The study examined two types: a floating, box-type wave attenuator, and a fixed wave screen (wave fence) attenuator. A floating wave attenuator is currently utilized at the marina adjacent to the Port Regalle development, while the closest known fixed wave screen is in use at the FDNY facility in Stapleton. Water levels, wave heights, and wave periods were used from the results of the hydrodynamic modeling task.

9.1.1 Floating Wave Attenuators

Floating wave attenuators are typically a dock-like structure anchored to the seafloor by guide piles. Various empirical equations have been developed which relate the breakwater width, draft, water depth, and wavelength to the attenuator's efficacy. For the purposes of this study, the floating wave attenuators were assumed to be 6 feet wide with 5 feet draft. The following table summarizes the results of the floating attenuators for the storm scenarios.

Table 9-1: Floating Wave Attenuator Efficacy

Floating Wave Attenuator Efficacy	
Current Mean Sea Level – Nor'easter	50%-80% Reduction
Current Mean Sea Level – Sandy-like	40%-70% Reduction
MSL + 31" Sea Level Rise – Nor'easter	40%-80% Reduction
MSL + 31" Sea Level Rise – Sandy-like	30%-70% Reduction

As shown, the floating attenuators lose efficacy as storm intensity grows and as the water level increases. The floating attenuator's anchorage system should be properly designed to reduce the risk of attenuator to breaking loose of the anchor. Alternatively, an operations plan may be implemented whereby the attenuator is removed from the anchors and properly stowed during storms projected to exceed the design.

9.1.2 Fixed Wave Screens

Fixed wave screens are typically slender in cross-section and are constructed using support piles, battered piles, and flat-faced panels. Similarly to the floating attenuators, several empirical equations have been developed to estimate the wave screen's efficacy. The fixed wave screen examined assumes 5 feet of draft below the water surface elevation. The results of the attenuator's efficacy are shown in the following table.

Table 9-2: Fixed Wave Screen Efficacy

Fixed Wave Screen Efficacy	
Current Mean Sea Level – Nor'easter	80%-90% Reduction
Current Mean Sea Level – Sandy-like	70%-85% Reduction
MSL + 31" Sea Level Rise – Nor'easter	75%-80% Reduction
MSL + 31" Sea Level Rise – Sandy-like	70%-80% Reduction

The effectiveness of the fixed attenuator is superior to that of a floating attenuator, however the design elevation of the structure is critical to its success. The wave screen will extend above the normal high tide considerably when designed for future storms and sea level rise. This may present a visual nuisance when compared to the floating attenuator.

9.2 Shoreline Response

A comprehensive sedimentation analysis was not performed as part of this study and is recommended to fully characterize the impacts to the sedimentation. However, empirical methods exist where a generalized shoreline response can be characterized.

Part 5, Chapter 3 of the US Army Corps of Engineers' *Coastal Engineering Manual* identifies several relationship methodologies for shoreline response to nearshore breakwater design.

A beach response index is calculated using the breakwater sediment length and distance from the shoreline. The index is then associated with a shoreline response ranging from permanent tombolo formation (I=1) to no sinuosity (I=5). The beach response index computed for the harborwide breakwater (Option 1) is 4.1, while the segmented breakwater (Option 2) is 4.5.

The response index for Option 1 indicates a strong possibility for subdued salient formation along the shoreline. The Option 2 response index indicates a moderate possibility for subdued salient formation.

9.3 Layered Resiliency Approach

A layered design approach allows for multiple lines of defense and reduces risk for coastal communities while still maintaining the shoreline connection that many people value highly. This approach allows for the development of a range of alternative futures that are effective, resilient, and complimentary to the ongoing shoreline work of the area. It extends across a thick section, creating multiple lines of defense that will not fail singularly and catastrophically.

In Staten Island, a layered strategy could be developed that introduces protective breakwaters and interior tidal flats to the shoreline that dissipate wave energy and slow the water, while rebuilding sustainable shellfish populations within Raritan Bay. This layered approach allows for a combination of coastal resiliency infrastructure with habitat enhancement techniques and community engagement models, linking in-water protection and on-shore interventions. Not only does this help protect the shoreline from periodic weather extremes, but it also improves the quality of everyday lives.

People are a critical part of any ecosystem. Thus, this framework links people to the shoreline and the water through education, engagement, and the expansion of a water-based recreational economy. Slow, clean, and safe water opens up a variety of in- or near-water programming opportunities, all enabled by the layered approach to risk reduction.

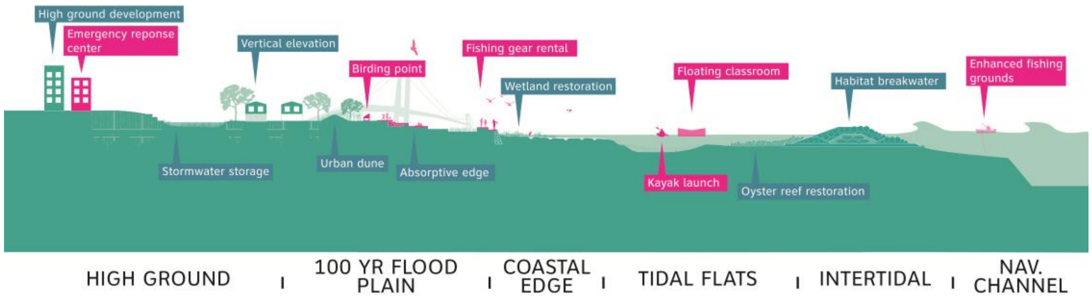


Figure 17: HUD Rebuild by Design: The Layered Approach along the Staten Island Shoreline

9.4 Sea Level Rise Adaptation

Constructing the breakwaters with large stone allows for the potential to adapt the structures later in the life cycle for rising seas or higher intensity storms forecasted. Adding an additional armor layer to raise the crest elevation is likely to be the simplest course of action, however planning for a future adaption must take place during the initial design and construction.

The structure toe is vitally important to the stability of the structure. It is difficult to shore the toe of an existing rubble mound structure without substantial reconstruction. An increased toe should be considered during construction if additional armoring is anticipated as an adaption strategy over time.

An additional armor stone layer will need to be integrated into the existing armor layers so the structure is interlocked throughout. This may require re-seating some of the existing armor stones or adding smaller stones to fill large voids.

9.5 Ecology Enhancement

One advantage of creating a living system that could possibly host an oyster population in the future is the potential to adapt with sea level rise (Rodriguez et al., 2014). Oyster reefs have the ability to outpace sea level rise, allowing for a dynamic set of breakwaters that do not need to be physically amended within their subtidal zones to be resilient in the future. This type of living system should be further considered for its ecological, economic, and infrastructural value. Oysters and other calcium carbonate forming species have the ability to strengthen man-made breakwater infrastructure over time through the process of biogenic buildup, reducing maintenance and repair costs. Allowing or creating a living system within a functional breakwater creates the potential for habitat disruption when adapting for sea level rise as discussed above, therefore ecosystem design and physical design need to be jointly considered as the project advances. While oysters are a target species and critical habitat provider identified in the Hudson River Estuary Comprehensive Waterfront plan, urban oyster restoration in New York City is an evolving science and poses a number of permitting and regulatory hurdles. These hurdles, primarily related to questions of habitat displacement and attractive nuisance, should be addressed in all future ecosystem design strategies that incorporate oysters.

9.6 Structure Maintenance

Rubble mound breakwater structures are durable and flexible structures which generally perform well over their design life. Maintenance to the structures typically stem from wearing or breakage of the stone over time, or dislodging of the stone after a major storm. Part 6, Chapter 8 of the US Army Corps of Engineers' *Coastal Engineering Manual* (EM 1110-2-1100) identifies several implementation considerations for the design of repairs to breakwater structures. Selected considerations are:

› The existing structure may be deflated with a lowered crest elevation and milder slopes than originally built.

› The original armor may be mixed with underlayer stone.

› Changing the armor slope to suit design parameters is difficult.

› Embedding and securing a new armor slope toe is more difficult than new construction.

› Transitions between the repair section and the existing undamaged slope must be accomplished without creating weakness in the armor layer.

› It may be necessary to remove part or all of a damaged armor slope in order to begin repairs.

The engineering manual also acknowledges small repairs may be difficult to justify financially since mobilization of equipment and sourcing small amounts of materials will be at a premium.

The project should be inspected on a periodic basis above and below the water due to the high energy wave environment to which it is exposed. In addition, the structure should be inspected after every major storm or other event which may cause damage, or when reports from local users indicate deficiencies.

10 Stakeholder Meeting

The stakeholder meeting, held in GOSR's offices on November 13, 2014, was productive in communicating the team's results and receiving vital feedback on the project. Constituents from multiple city, state, and federal agencies (DOS, DEC, DCP, DPR, GOSR, NPS, HUD, USACE), governmental officials (Staten Island Borough President's Office, Councilman Ignizio's office), and community members (Fisherman's Conservation Association, Gotham Whale) were in attendance. The team presented their findings on the ecological data collection and assessment, damage assessment, modeling results, and recommendations for next steps forward.

Attendees, particularly the DEC, were interested in learning more about the conclusions from the ecological data assessment phase, as outlined in Section 5.1. Specifically, the type of habitat quality in relation to other areas in the harbor, and how the introduction of a breakwater system would affect the quality of the ecosystem. OCC likened the habitat along Crescent Beach to that in Long Island, and also described the anoxic environment inside the harbor. This environment is likely the product of failing septic tanks and fine sediment from runoff entering the harbor system.

The Borough President's office was interested in how to communicate the damage assessment results and risks to the public. They asked if a 'best-case scenario' existed, and if so what that would be or if there is an optimum level of protection that could be offered. This is an ongoing conversation with city and state agencies, however all agencies were in agreement that combining a breakwater system with a layered approach on shore would help to bolster and strengthen the argument for these types of strategies and should be studied further.

The team asked the stakeholders present to comment on any immediate red flags or recommendations that they had during the meeting. The large concern was over displacing clam habitat, particularly if the next iteration of design considers moving breakwater structures to 1/10 of a mile offshore. Additionally, many were interested in sedimentation and water quality impacts, outside of the scope of this project. These types of models are critical to moving the project forward. The primary recommendation was to look at a layered approach to designing these systems, building in redundancy in the form of dunes, vertical elevation, or wetland build-out.

Documents from the Stakeholder Meeting, including the Meeting Agenda, Presentation and a Takeaway Handout are found in Appendix E.

11 Conclusions and Recommendations

The modeling and damage assessment revealed several key findings which help inform the potential for future studies or actions which may be undertaken within the project area. These conclusions are presented below along with the recommended next steps for future study, resiliency needs, and replicability.

11.1 Design Conclusions

Crooke's Point acts as an effective wave attenuator for **Nichols Marina** and the harbor interior for storm generated waves and the addition of breakwater structures (or dunes) would not be beneficial to attenuate waves. Local wind generated waves can be effectively mitigated in the harbor through waves screens or comparable structures. The Point is currently migrating to the south into the USACE federal channel, which was dredged in 2014.

Crescent Beach is vulnerable to storm-generated waves and breakwaters may be used to mitigate these risks. Neither option studied was optimal, however lessons can be learned from both:

› Effective wave attenuation can be provided by breakwaters in the Crescent Beach area.

› Option 1 provides more protection to smaller section of shoreline.

› Option 2 provides less protection, mostly due to the size of the gaps in the breakwater design.

Breakwater Option 2 has the potential to provide the highest level of benefits to the Crescent Beach area. The recommended optimization elements for the breakwater are:

› To attenuate waves at a stillwater elevation higher than 11.5 feet NAVD88, an increase in the crest height between 2ft and 6 ft is recommended. Alternatively, a layered approach to wave reduction including on-shore and off-shore coastal infrastructure should be considered.

- Based on the limited REFDIF results and engineering judgment, a breakwater of 0.10 miles offshore is preferable to a breakwater 0.25 miles offshore.
- Reducing the width of breakwater gap segments.
- A staggered or overlapping opening design would further limit wave penetration and is recommended.
- The necessary length is directly correlated to the distance from the shoreline and the two should be considered together in the next design phase.

11.2 Ecological Assessment Conclusions

The ecological assessment from the shoreline survey and the benthic survey within the Great Kills Harbor study area concluded the following:

- Habitat for key species and ecosystems (northern quahog, salt marshes) may be enhanced on the lee side of breakwaters due to the reduction of energy along the shoreline. (Comparison of transect 1+4)
- Structured habitat for structure-loving species (finfish, tautog, lobster, etc) will be created by a conventional rock breakwater. This habitat has historic precedent in the harbor and is in need of restoration.
- Breakwaters can negatively impact water circulation and flushing and lead to measureable reductions in water quality (Comparison of transect 2+3). Sediment and water quality data collection and modeling should inform future designs to understand and eliminate potential water quality reductions.
- Breakwater construction will have negative impacts on species located within and adjacent to the footprint of construction. Mitigation of these impacts is necessary.
- Construction within high energy sites with distinct patterns of longshore drift (transect 4) would negatively impact fewer critical species than construction within lower energy edges (transect 1).

11.3 Damage Assessment Conclusions

The damage assessment and associated research performed provided some information regarding the potential for breakwaters to reduce property damage and impact to both public and private facilities, it is perhaps most useful in framing a series of research needs and recommended next steps for assessing the potential damage reduction impacts for breakwaters. The following conclusions and recommendations are made for further study:

Further design development and iteration is needed to maximize potential damage reduction. Modeling revealed that modifications to the designs studied could provide further reduction in wave impacts. Given the relation between damage functions and wave height, it important to iterate the design and arrive at a more optimal alignment, location and spacing of breakwaters if the aim is to achieve maximum risk reduction. Further design iteration is recommended prior to further damage reduction impact analysis in order to provide the best potential results.

Breakwater impacts should be modeled over a greater timeframe and number of storm events in order to be able to derive a more complete understanding of damage reduction benefits over time. While the damages during singular events may be significant with a breakwater design optimized for wave height reduction based on the findings from this study, the findings also indicate that there may be significant benefits from breakwaters during lower intensity, more frequent storm events. Thus, including these events in further modeling will be important. Further modeling should also include a broader number of wave events – the lower higher frequency storm events such as a 5 year event as well as interim and lower frequency events, e.g. 20 year, 50 year, 500 year, such that there are sufficient data points that damages for interim events can be interpolated. This would allow for an effective assessment of damages over time. This will require further modeling to determine wave height and period reduction over time. Tools such as Beach-fx, developed by the USACE, could then be used to estimate future scenarios with and without the project.

Future modeling and analysis should attempt to quantify event-based and gradual erosion. This study provided critical information for how breakwaters function to attenuate waves during storm events that will inform the refinement of breakwater design to better maximize wave reduction benefits. Since the current erosion pattern and erosion-reduction capacity of the breakwaters was not included in this study it could not be quantified as part of this damage assessment. However, considering the land, buildings, and the shoreline structures that could be impacted by erosion, it is anticipated, the erosion reduction capacity of breakwaters could be their greatest benefit in terms of damages avoided. This is consistent with their use in other locations in New York Harbor and around the country. Models and analysis to further understand erosion rates and breakwater's impacts on them are recommended for future studies.

Examine other potential sites. The analysis revealed that breakwaters have the potential to reduce wave heights behind them, and while it was not quantified, reduce, halt or even reverse gradual erosion rates over time. With this in mind, if the aim is to maximize damage reduction cause by these coastal forces, further and future studies should identify sites / areas where:

1 There are significant number / area of assets (building, infrastructure, etc.) at risk of erosion. The Coastal Erosion Hazard Area (CEHA) represents areas likely at risk of erosion. A further review of historic erosion rates (comparison of previous and current shoreline could also be used to assess this where protective structures do not exist.

2 There are a significant number of cultural and natural assets (beaches, marinas, critical habitat) at risk of erosion. Though qualitative in their assessment, these assets can be both protected and enhanced through the inclusion of a layered breakwater system along the shoreline.

3 There are significant number / area of assets (building, infrastructure, etc.) in high wave energy zones which are consistently exposed to the offshore wave climate. While detailed models of wave energy zones are not available for multiple storm scenarios, the FEMA FIRM maps do indicate areas of waves greater than three feet (V zone) and waves greater than 18 inches—the Coastal A zone or area below the limit of moderate wave action (LiMWA)—for a 1% chance (100 year) storm event. This can be used as an indicator of where optimally designed breakwaters would have an impact on building damage levels.

4 Identify areas where critical infrastructure, including roads, are in either of these zones. Damage reduction impacts to most buildings and shoreline structures only have impacts that can be quantified for the people and property directly behind them. Infrastructure such as roads, sewers, waterlines, etc. as well as facilities such as distribution centers or pump stations, generally serve a much broader area. If impacts to surrounding areas are taken into account, damages avoided to these structures would yield additional value of damages avoided beyond the cost of their damage alone.

There are broader data and research needs surrounding the quantification of damages that can be attributed to waves rather than surge alone. It would benefit future damage assessment to develop damage reduction curves such as those used for the buildings for other structures, particularly infrastructure (roads, sewer, water, etc.) and shoreline protection structures.

11.4 Recommended Next Steps

Many of the comments that were voiced during the most recent stakeholder meeting are key to informing the recommendations of the team and the proposed next steps for the project at large, should further design work be pursued. Water quality and circulation modeling and sediment modeling are essential to the success and further development of the project. The team recommends an iterative modeling approach, allowing for design refinement throughout the process and lessons learned from previous model runs. Further community outreach in the Great Kills area with marina owners, environmental non-profits, and residents will also be necessary next steps for the project.

Iterative modeling can also serve to inform the design team about the advantages and proper combination of on-shore and off-shore strategies in a more layered shoreline protection approach. This type of strategy was supported heavily by the stakeholders at the most recent meeting, emphasizing the connection between the breakwater systems proposed and already existing initiatives such as New York Rising and the temporary dune structures installed by DPR along the Crescent Beach shoreline. This needs to be tested through with a hydrodynamic model that has the capability to isolate the impacts from different strategies in a combined system, such as the REFDIF model used for this study.

11.5 Applicability to other sites

The team found that not only can these strategies be used for the Great Kills site, with modification, but they also have potential applicability to other areas within the harbor. A set of specific, site criteria can be used to determine the applicability for shorelines elsewhere, with these criteria as follows:

- Areas of exposed shoreline that experience wave action, erosion, and high mobility of sediment.

- Areas where the primary waves are generated offshore with consistent and predictable wind direction, not primarily from local wind-driven conditions.

- Areas of shoreline where essential benthic habitat will not be disturbed, or could be enhanced by the introduction of a breakwater system.

- Areas with benthic and shoreline habitat that could benefit from calmer waters and slower long-shore transport.

- Areas with critical infrastructure, businesses, or homes that would benefit from additional wave action protection.

- Areas with existing or proposed shoreline edge treatments (such as constructed dunes or wetlands) that could benefit from erosion protection.

- An additional recommendation is to further consider the management system that is in place to dredge the channel to the south of Crooke's Point. The Point is migrating southwards because of the current dynamics in the area, encroaching into the Federal Navigation Channel. In 2014, the USACE dredged this channel and cut through part of the sand bar located at the tip of Crooke's Point. The results from Transect 1 show that this area benefits from the protective shadow of the Point, and with further migration more of the Crescent Beach shoreline may become protected as well. A study as to the feasibility of realigning the channel would be helpful in understanding the complex ecological, protective, and economic benefits and impacts a management strategy like this could have.

These criteria could serve to further the city's goals through SIRR and other initiatives, giving a way to categorize appropriate shorelines as a result of this feasibility study.

12 References

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Appendix A Task 2 Summary Report: Identify and Evaluate Approaches for a Shoreline Protection System

Appendix B Task 3 Summary Report: Hydrodynamic Modeling

Appendix C Wave Height Zone Maps

Wave Height Zone Maps		
Document Number	File	No. Pages (PDF)
01	'92 Nor'easter, No Intervention	1
02	'92 Nor'easter, Option 1	1
03	'92 Nor'easter + 31" SLR, No Intervention	1
04	'92 Nor'easter + 31" SLR, Option 1	1
05	Sandy-like Storm, No Intervention	1
06	Sandy-like Storm, Option 1	1
07	Sandy-like Storm + 31" SLR, No Intervention	1
08	Sandy-like Storm + 31" SLR, Option 1	1

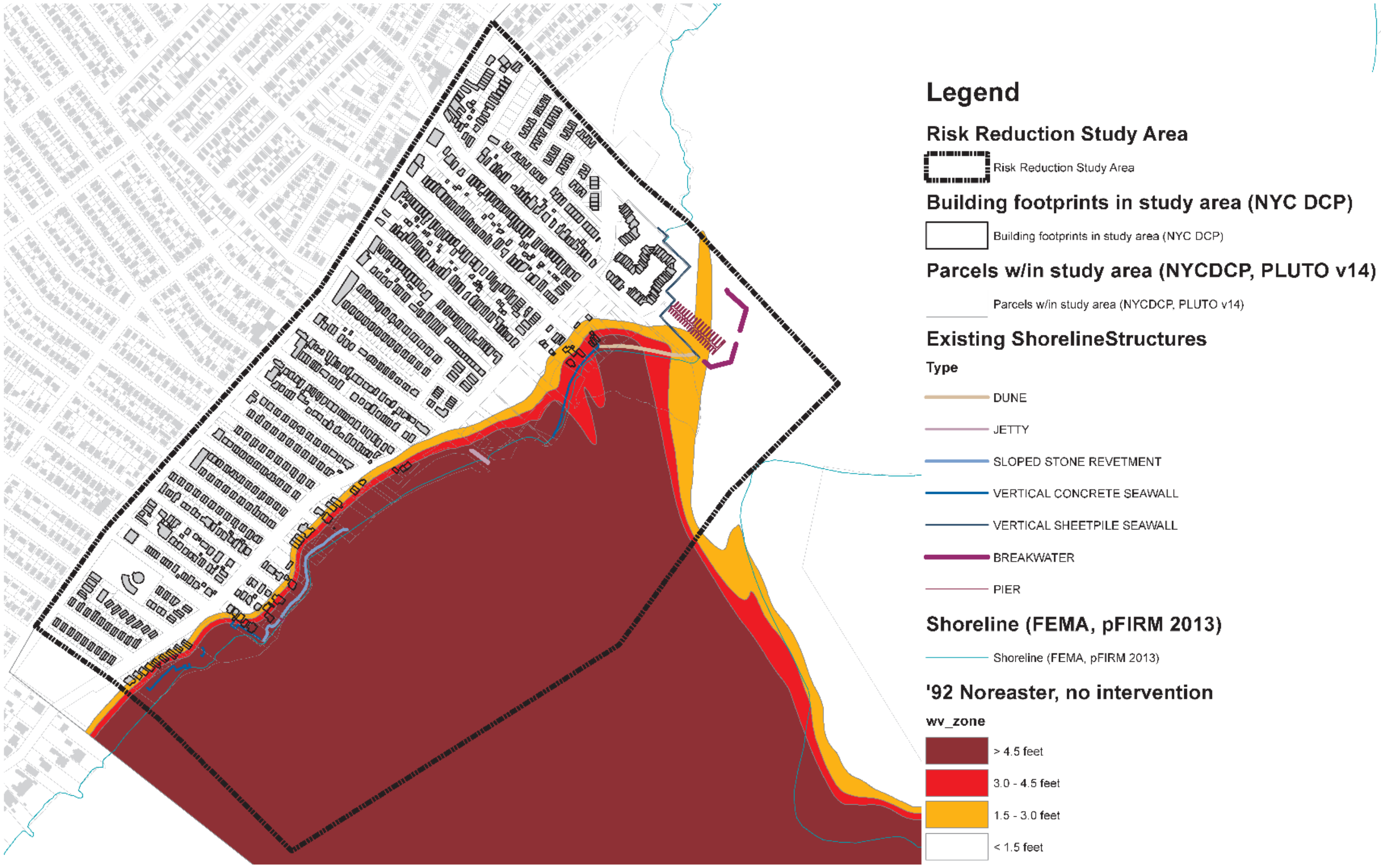

Figure C-1: Wave Height Zone Map - '92 Nor'easter, No Intervention

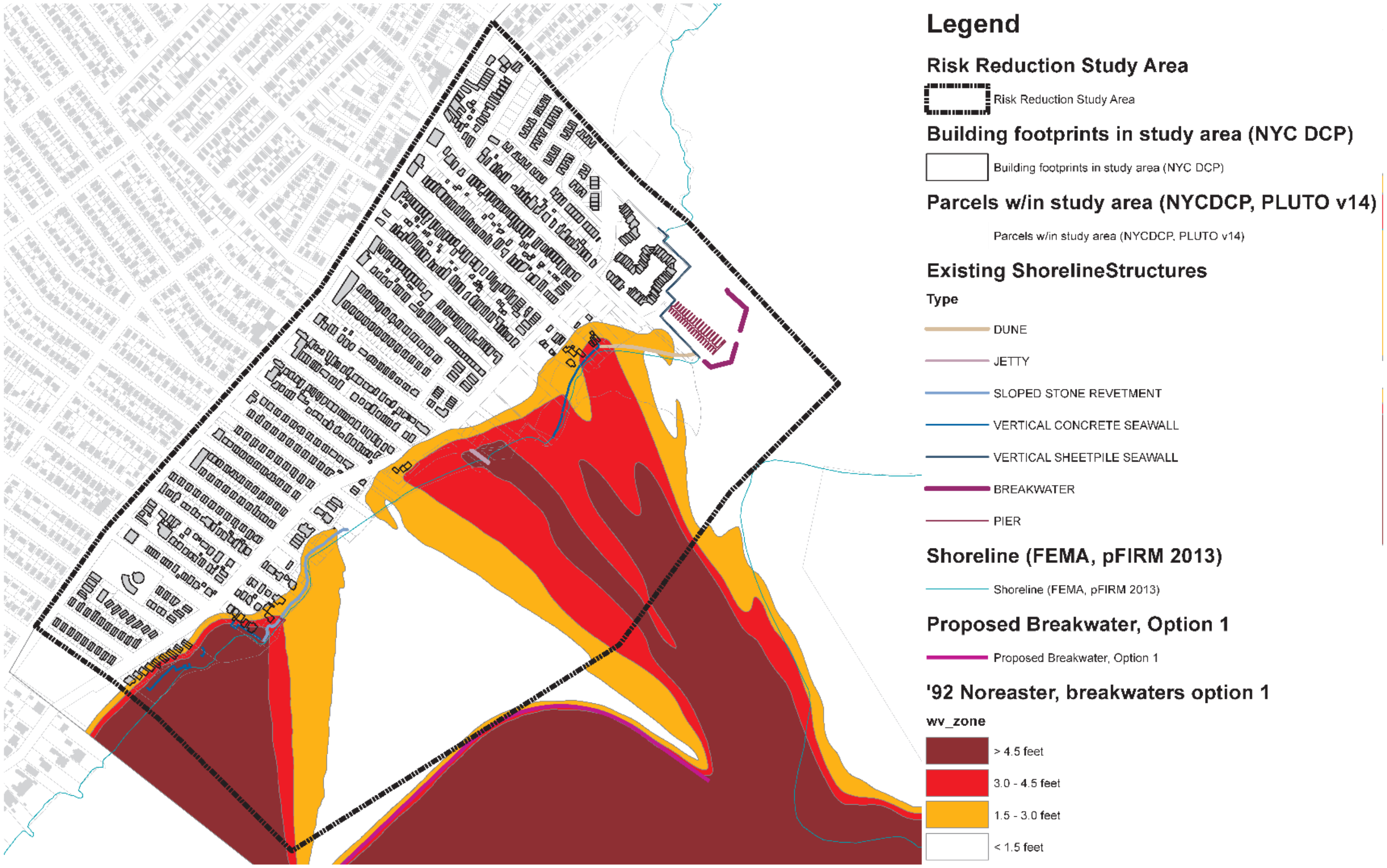

Figure C-2: Wave Height Zone Map - '92 Nor'easter, Option 1

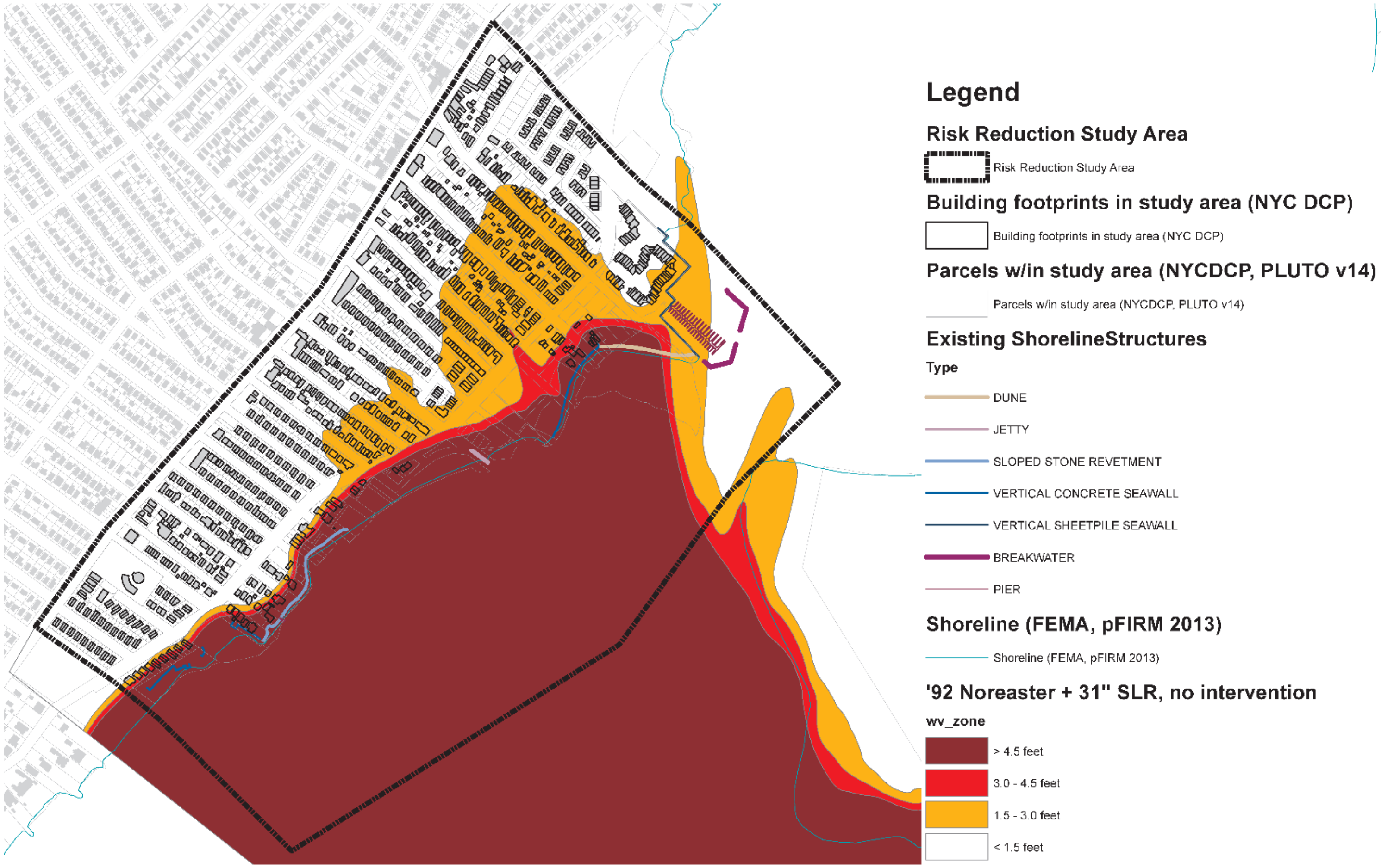

Figure C-3: Wave Height Zone Map - '92 Nor'easter + 31" SLR, No Intervention

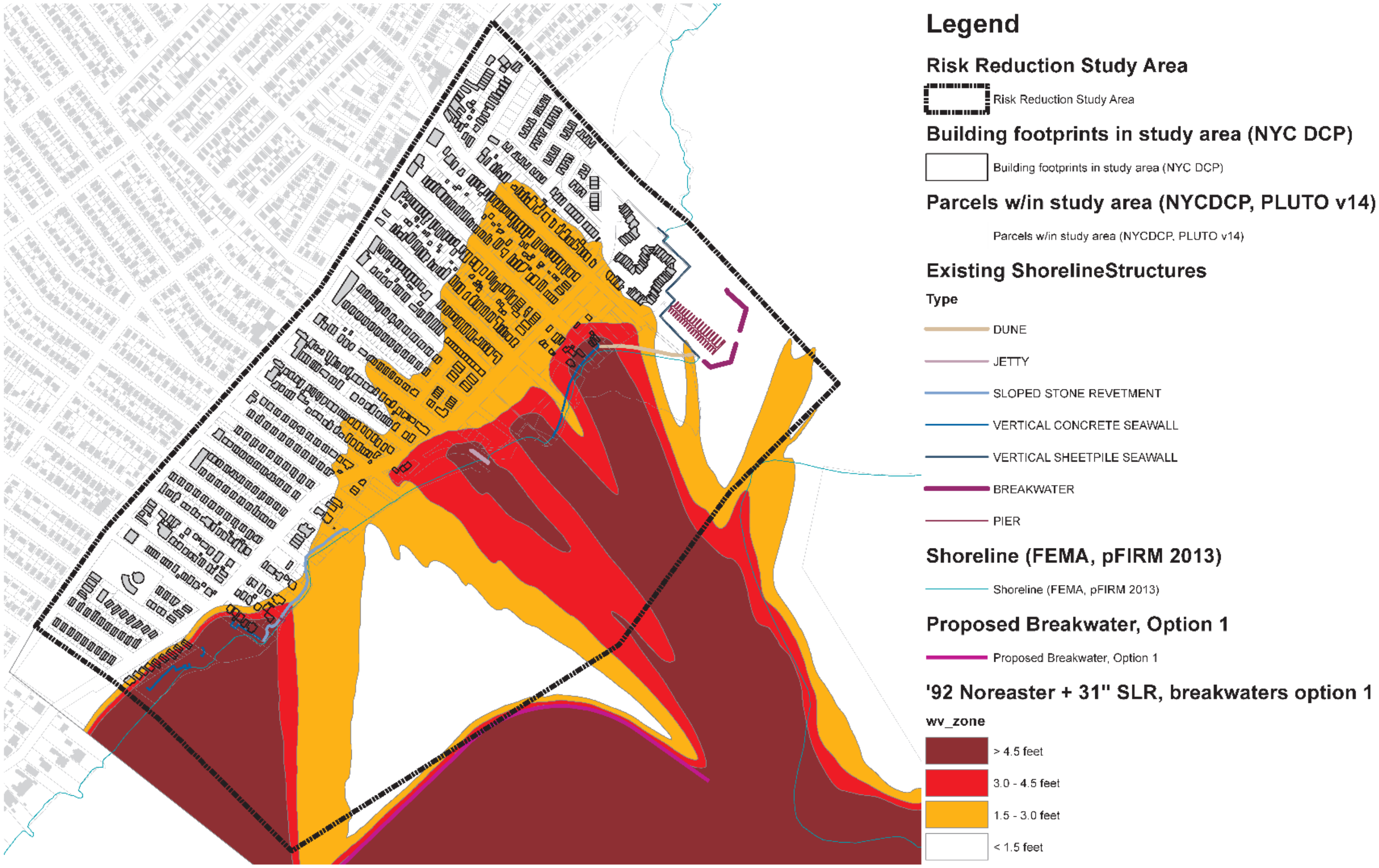

Figure C-4: Wave Height Zone Map - '92 Nor'easter + 31" SLR, Option 1

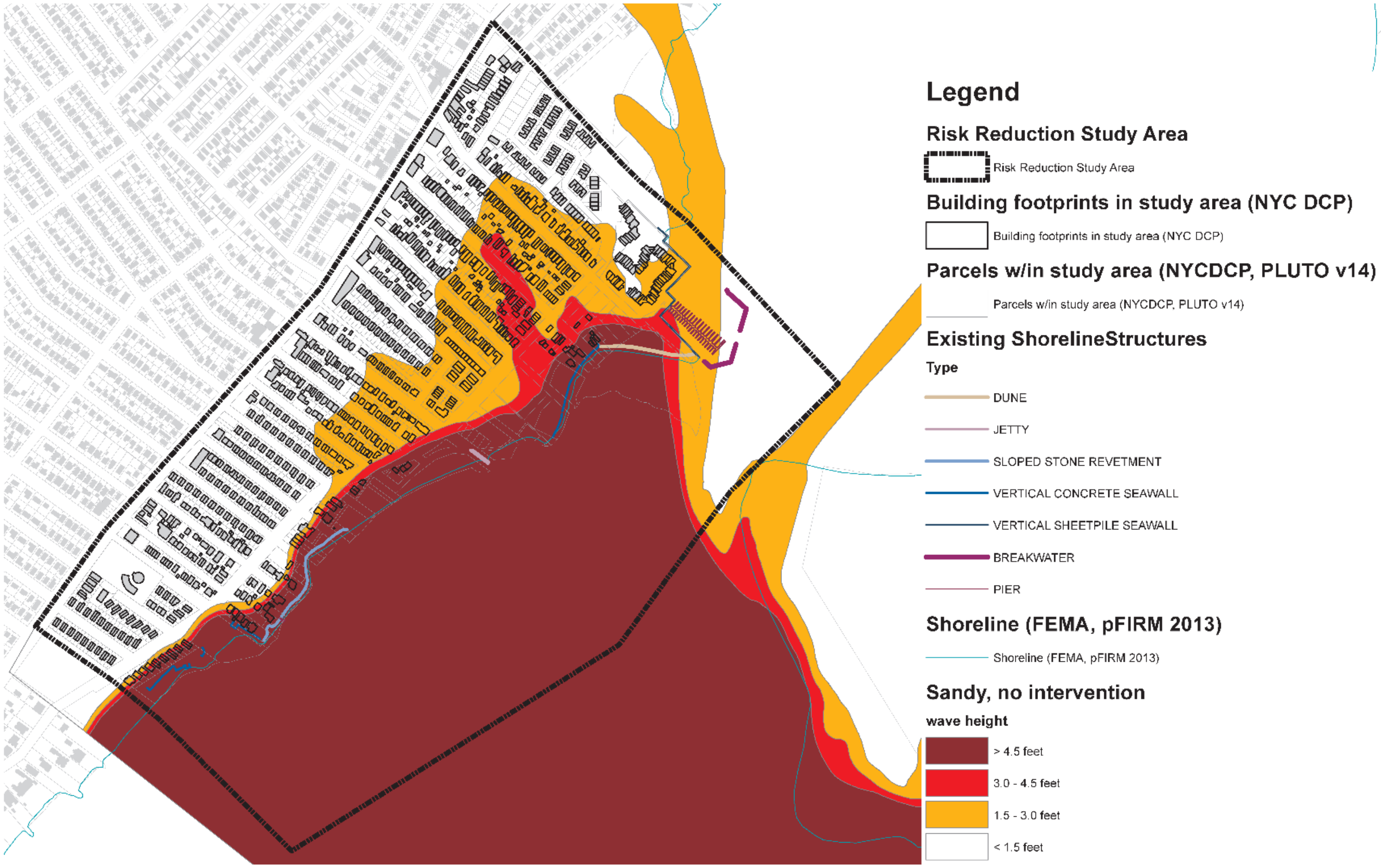

Figure C-5: Wave Height Zone Map - Sandy-like Storm, No Intervention

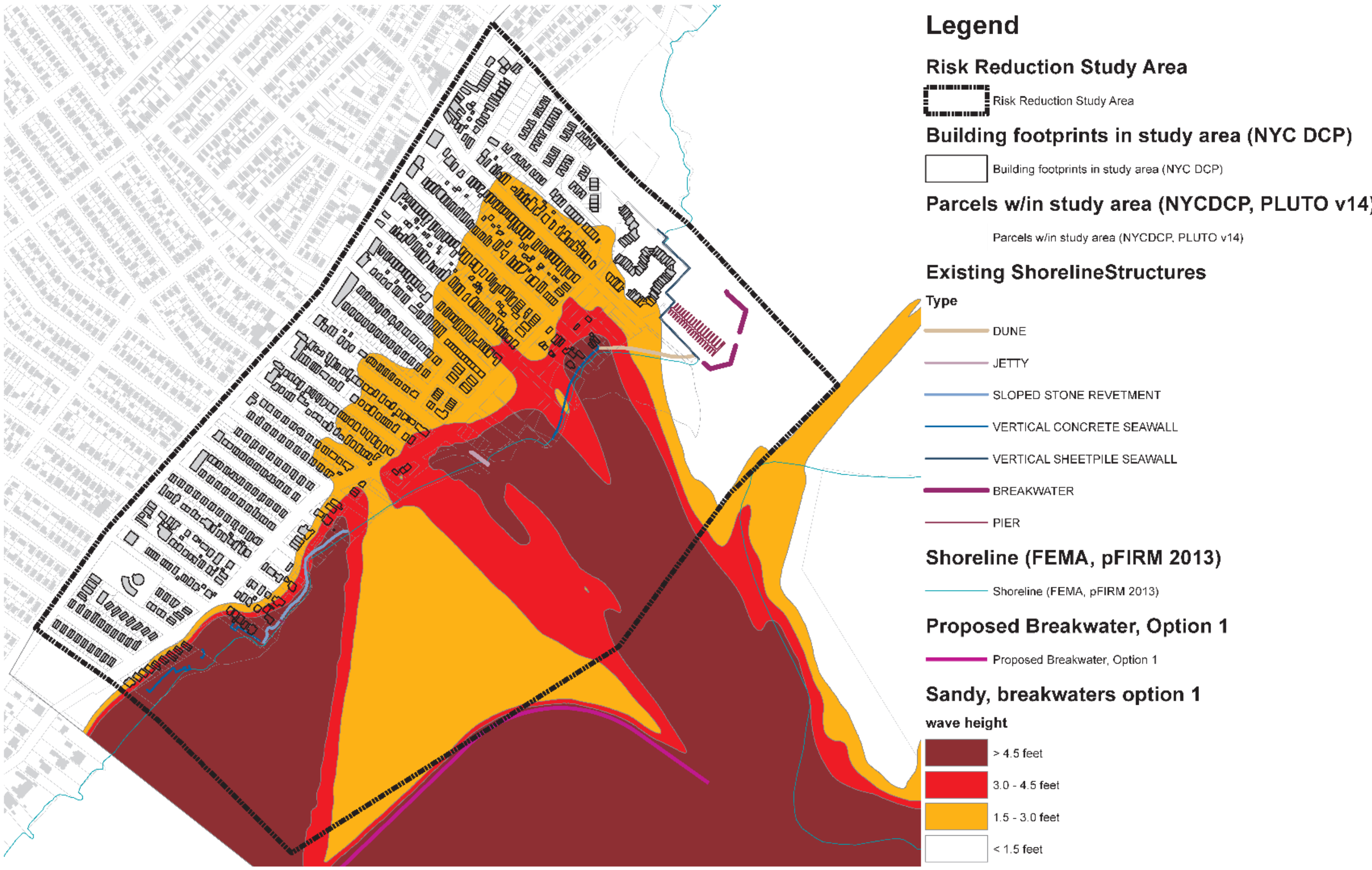

Figure C-6: Wave Height Zone Map - Sandy-like Storm, Option 1

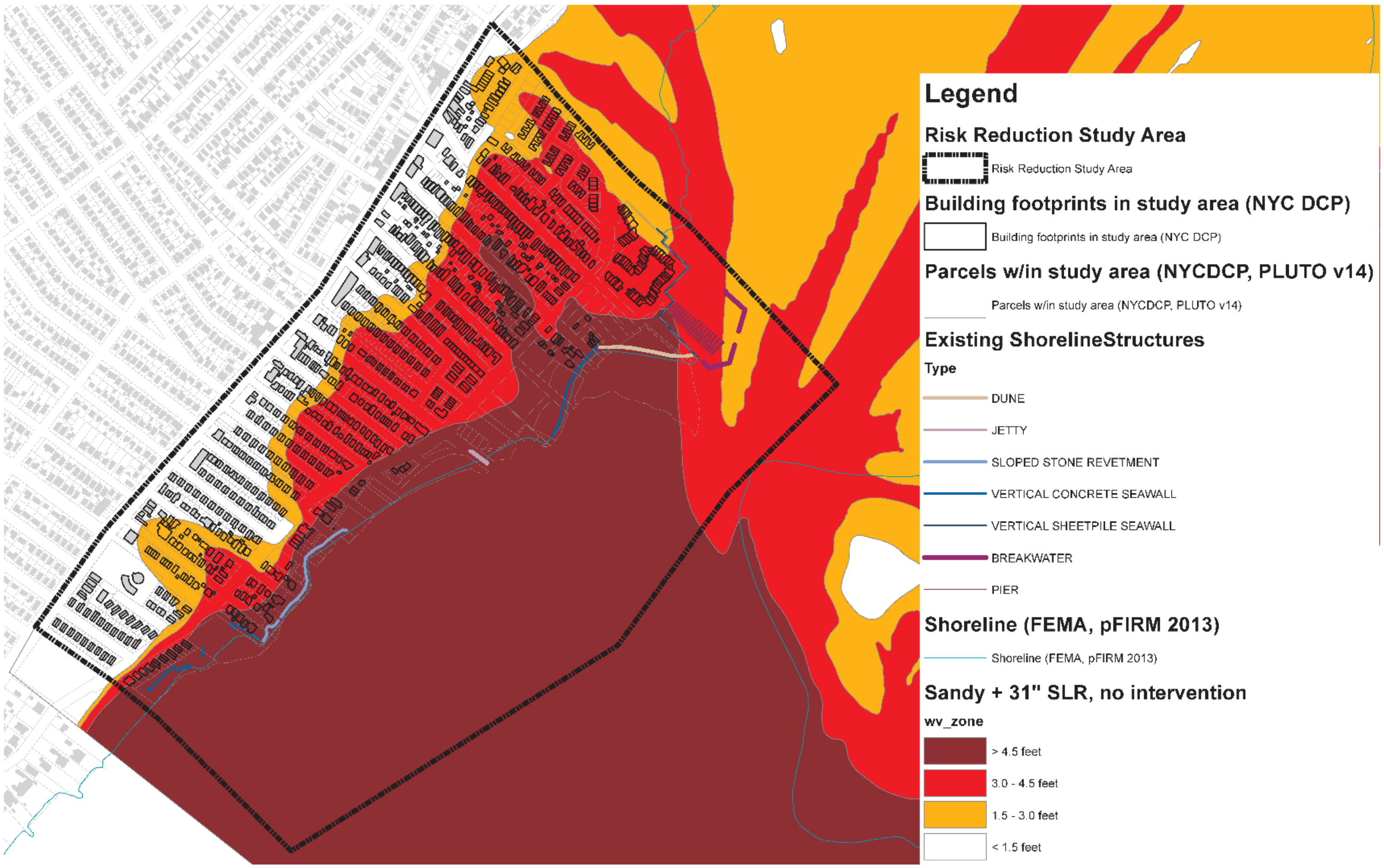

Figure C-7: Wave Height Zone Map - Sandy-like Storm + 31" SLR, No Intervention

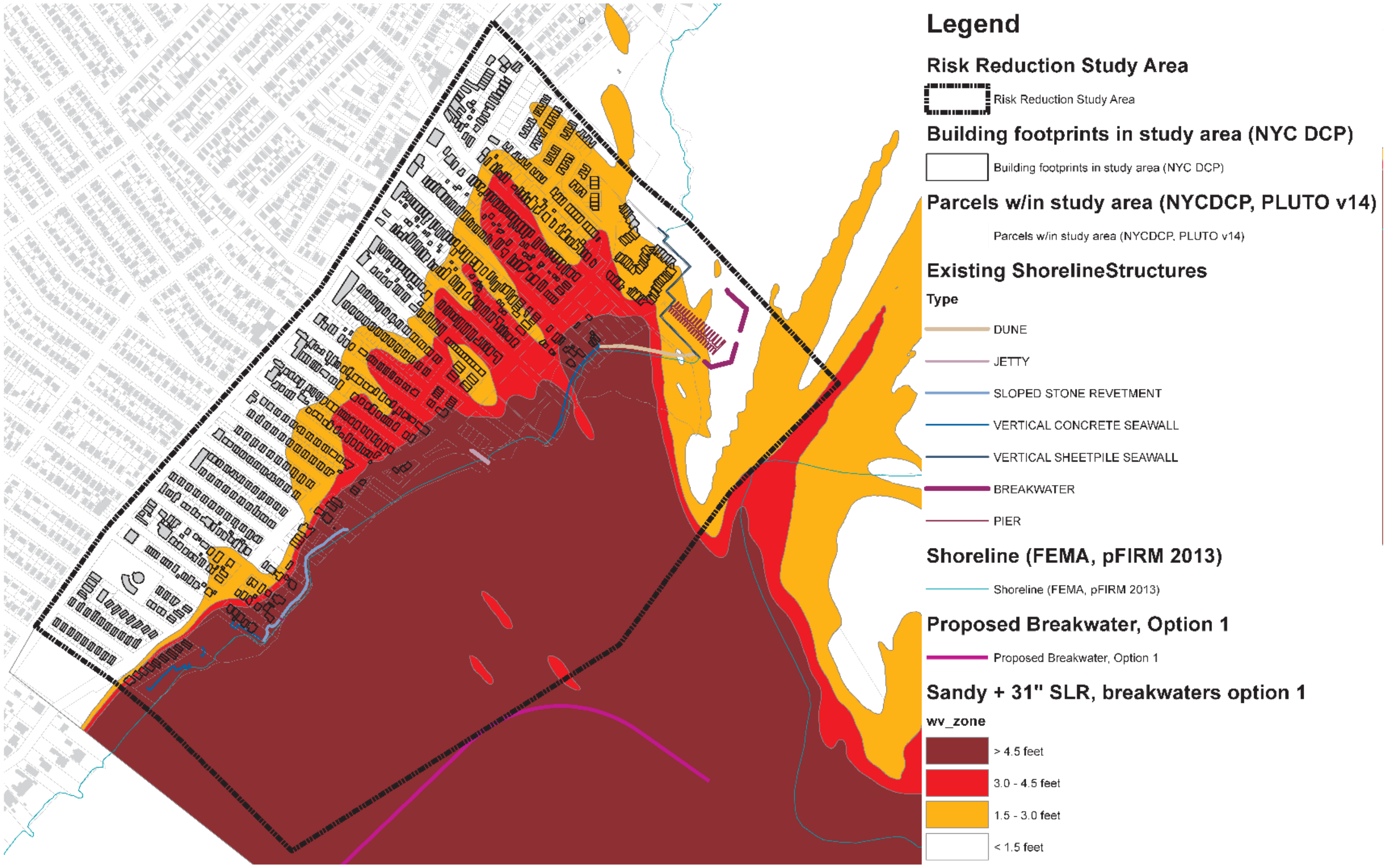

Figure C-8: Wave Height Zone Map - Sandy-like Storm + 31" SLR, Option 1

Appendix D Regulatory and Permitting Considerations

November 13, 2014 Meeting		
Document Number	File	No. Pages (PDF)
01	Summary of Permits, Reviews and Approvals	4
02	Agency/Permit Key	1

D.1 Summary of Permits, Reviews and Approvals Likely Required

Type	Name of permit or approval	Permitting / Regulatory agency	Other agencies involved	Likelihood	Complexity	Description of permit	Requirements / Prerequisites	Submissions/ Studies required for permit	Approx timeframe (min, typical, max)
	Permits required								
Permit	Section 10	USACE	NYSDOS, NYCDCP, NMFS, USFWS, USEPA, USCG, SHPO	DEFINITELY REQUIRED	Medium *Must demonstrate that project features do not adversely impact navigation channels, general navigation, and existing public and private property*	Section 10 of the Rivers and Harbors Act requires authorization from the USACE for the construction of structures in or over any navigable water of the United States, excavation/dredging or deposition of material in these waters or any obstruction or alteration in a "navigable water" (all tidal waters are navigable waters of the US). Issue in conjunction w/ Section 404.	CZM Consistency, NEPA Compliance, EFH Assessment, ESA, FWCA, NHPA	Modeling for sedimentation & erosion to determine impact to navigation channels and shoreline; Response to public comments EFH Assessment	6 mo – 1yr – 3 yrs
Permit	Section 404	USACE	Same as above, plus NYSDEC	DEFINITELY REQUIRED	Medium *Comply with 404b(1) Guidelines regarding alternatives and potential need for mitigation of impacts*	Section 404 of the Clean Water Act, as amended, requires authorization from the USACE to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Issue in conjunction w/ Section 10.	CZM Consistency, NEPA Compliance, EFH Assessment, ESA, FWCA, NEPA WQC	Demonstrate lack of practicable alternatives to accomplish project purpose Document that project benefits offset detrimental impacts	Same as above for Section 10
Permit	Protection of Waters	NYSDEC	State or local SEQRA lead agency	DEFINITELY REQUIRED	Medium-High *Unacceptable loss of habitat or habitat displacement can preclude issuance or trigger need for costly mitigation*	Under Article 15 of the Environmental Conservation Law a permit is required from the NYSDEC for: Disturbance of the bed or banks of a "protected stream" or other watercourse; Construction, reconstruction or repair of dams and other impoundment structures; Construction, reconstruction or expansion of docking and mooring facilities; and Excavation or placement of fill in "navigable waters" and their adjacent and contiguous wetlands. The Protection of Waters Program regulates waterways based on the designation given to the specific body of water.	SEQRA, CZMP/LWRP for activities in State coastal zone	Assessment of the impact the proposal will cause to the natural resources of the state including soil, forests, water, fish and aquatic and related environment.	6 mo – 1yr – 3 yrs
Permit	Tidal Wetlands	NYSDEC	State or local SEQRA lead agency NYSOGS NYSDOS NYCDCP	DEFINITELY REQUIRED (given how DEC defines tidal wetlands)	*Same as for Protection of Waters permit*	Under Article 25 of the Environmental Conservation Law a permit is required from NYSDEC for almost any activity that will alter wetlands or the adjacent areas. In general, tidal wetlands consist of all the salt marshes, non-vegetated as well as vegetated flats and shorelines subject to tides. The adjacent areas extend up to 300 feet inland from the wetland boundary (up to 150 feet inland within New York City). Official tidal wetlands maps showing the exact locations of New York's regulated wetlands are on file at NYSDEC regional offices and in the County Clerks' Offices.	Same as above for Protection of Waters permit, plus underwater land approval or easement,	Same as for Protection of Waters permit, plus assessment of impact to shellfish, and underwater land approval or easement	Same as above for Protection of Waters permit

Type	Name of permit or approval	Permitting / Regulatory agency	Other agencies involved	Likelihood	Complexity	Description of permit	Requirements / Prerequisites	Submissions/ Studies required for permit	Approx timeframe (min, typical, max)
Permit	Fresh-water Wetlands	NYSDEC	State or local SEQRA lead agency	UNLIKELY only for on-shore components	*Same as for Protection of Waters permit*	This permit allows an applicant to perform an activity or erect a structure that will impact a NYSDEC-regulated freshwater wetland or an adjacent area. Generally, the permit applies to freshwater wetlands that are 12.4 acres or larger in area or smaller wetlands deemed to be of unusual local importance, and which appear on the Freshwater Wetlands regulatory maps.	None	Delineate freshwater wetland boundary and show on project plans	Same as above for Protection of Waters permit
Permit	Coastal Erosion Manage-ment Permit	NYSDEC	State or local SEQRA lead agency	LIKELY	Medium must minimize damage to property and natural protective features, other natural resources, prevent exacerbation of erosion hazards, and protect human life.	The Coastal Erosion Hazard Area (CEHA) Permit is the written approval required by 6 NYCRR Part 505 to undertake any regulated activity within erosion areas as shown on coastal erosion hazard area maps. DEC staff review permit applications for construction and other activities within specified coastal areas.	None	A general permit has been issued for repairs due to Hurricane Sandy. Coastal communities with local CEHA ordinance laws need to complete the Local Coastal Erosion Management Program Annual Assessment Form.	
Permit	Special Use Permit	NPS	None	MAYBE will be required if work is planned on NPS property, including NPS underwater lands	Medium - High Alternatives that involve the least disturbance to Park lands are preferred				
Permit	Aids to Navigation Permit	USCG	None	MAYBE may be required for USACE permits to be issued	Low do not anticipate issues	The U.S. Aids to Navigation System is a system maintained by the U.S. Coast Guard, establishes standards consisting of visual, audible, and electronic signals which are designed to assist the prudent mariner in the process of navigation. This review provides for reasonable marking of marine features that may pose a hazard to mariners.			
	Reviews and Approvals (Required for the permits listed above)								

Type	Name of permit or approval	Permitting / Regulatory agency	Other agencies involved	Likelihood	Complexity	Description of permit	Requirements / Prerequisites	Submissions/ Studies required for permit	Approx timeframe (min, typical, max)
Approval	Water Quality Certification	NYSDEC	USACE	DEFINITELY REQUIRED required for USACE permits to be issued	Medium potential to reduce water circulation and/or flushing	This certification, pursuant to Section 401 of the Clean Water Act, is required when a Federal agency (e.g. The Army Corps of Engineers) issues a Section 404 permit for the discharge of dredged or fill material that might diminish the quality of the waters within a state. In order for the Federal agency to issue such a permit, an authorized state agency (NYSDEC) must certify that the project will not diminish the quality of the state's waters to the point where they do not meet the standards of the Clean Water Act	None	Assessment of the impact the proposal will have on the quality of the State's waters	< 1 yr (typ)
Approval	Coastal Zone Management (CZM) Consistency	NYSDOS and NYCDCP		DEFINITELY REQUIRED required as part of USACE and DEC permit	Medium do not anticipate issues, but project will receive attention if resource conflicts are present	The Coastal Zone Management Act (CZMA) creates a set of State coastal policies. These policies are intended to guide the development of the State's coastal waterfronts. If a project is located in a coastal area and approval (a permit) is needed from a State or Federal agency, the agency must obtain a Coastal Consistency Certification from the New York State Department of State before it can give its approval. This certification states that the proposed agency action (issuing a permit) will not detract from the goals and policies set out in the Coastal Zone Management Plan.	None	Federal Consistency Assessment Form	Completed during USACE and NYSDEC permit process
Assessment	Essential Fish Habitat (EFH) Assess-ment	NMFS	None	DEFINITELY REQUIRED pre-requisite for USACE permit	Medium potential for habitat loss or displacement problems	Under Section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act, Federal agencies must consult with NMFS on actions that may adversely affect EFH. NMFS provides recommendations (which may include measures to avoid, minimize, or offset adverse EFH affects) to conserve EFH. Study Impacts to EFH-designated species Coordinate with NMFS/USACE to determine if an abbreviated or expanded EFH consultation is required	None	EFH Assessment (pre-requisite for USACE permit)	EFH consultation between USACE and NMFS completed during USACE permit process
Review	SEQRA	NYSDEC	State or local SEQRA lead agency	DEFINITELY REQUIRED required as part of DEC permit	Medium getting a Negative declaration is key	New York's State Environmental Quality Review Act (SEQRA) requires all Federal, State and local government agencies to consider environmental impacts equally with social and economic factors during discretionary decision-making (e.g. permitting). This means these agencies must assess the environmental significance of all actions they have discretion to approve, fund or directly undertake. If the agency decides that an action will have a significant effect of the environment, the impacts of an action are analyzed in a document called an Environmental Impact Statement.	None	NYSDEC Environmental Assessment FormNeed environmental & socio-economic studies/data to support Negative Declaration	6 mo – 1yr – 3 yrs

Type	Name of permit or approval	Permitting / Regulatory agency	Other agencies involved	Likelihood	Complexity	Description of permit	Requirements / Prerequisites	Submissions/ Studies required for permit	Approx timeframe (min, typical, max)
Review	NEPA	USACE	EPA, USFWS, NMFS	DEFINITELY REQUIRED required as part of USACE permit	Medium getting a Finding of No Significant Impact (FONSI) is key	The National Environmental Policy Act (NEPA) established environmental protection as a national policy goal and directed all federal agencies to consider the environmental consequences of their projects and permitting actions. The NEPA review provides opportunities for integration of national environmental policy into project planning; public and agency review of potential environmental effects of federal actions (including issuance of federal permits) and programs; coordinated and inter-disciplinary program planning; and resolution of disputes among agencies.	None	Need environmental & socio-economic studies/data to support FONSI.	6 mo – 1yr – 3 yrs
Review	Fish & Wildlife Coordination Act (FWCA)	NMFS & USFWS	None	DEFINITELY REQUIRED required as part of USACE permit	Medium NMFS could raise issues on non-EFH species like oysters and clams; do not anticipate issues with FWS as they generally stick to fresh water fisheries	Assess impacts to fish and wildlife resources, including commercial use Discuss with fisherman, NMFS, and NYSDEC	None	Response to comments from NMFS or USFWS	
Review	Endangered Species Act (ESA)	NMFS & USFWS		DEFINITELY REQUIRED required as part of USACE permit	Low do not anticipate issues, however there is a slim chance of interference with Sea Turtle habitat	Determine impacts, if any, to federally endangered species	None	Data on any federally threatened or endangered species use that may be affected by the project	ESA consultation between USACE and USFWS/NMFS completed during USACE permit process
Review	Historic Preservation	SHPO	USACE, NYSDEC	UNLIKELY typically not required for waterfront work; only relevant if historic properties are impacted	lowvery low probability, BUT, if triggered could be a major hurdle, e.g. shipwrecks, or archeologic sites now in water due to erosion	Determine impacts, if any, to historic resources	None	Depending on level of expected impacts NYSDEC may require a completed Structural Archaeological Assessment Form, and in certain cases, a cultural resource survey. USACE has a similar process.	Consultation with SHPO completed during permit process
Review	Under-water Land Owner-ship Review	NYS office of General Services		DEFINITELY REQUIRED required as part of DEC permit	low do not anticipate issues,	Need to determine ownership on underwater land and obtain approval / easement from owner. owner is most likely ..	None	Either approval from the land owner OR an easement is needed	

D.2 AGENCY/PERMIT KEY:

Acronym	Agency
NPS	National Park Service
USACE	US Army Corps of Engineers
USCG	US Coast Guard
USN	US Navy
NMFS	National Marine Fisheries Service
USFWS	US Fish and Wildlife Service
USEPA	US Environmental Protection Agency
FAA	Federal Aviation Authority
NJDEP	NJ Department of Environmental Protection
NYSDEC	NY State Department of Environmental Conservation
NYCDEP	NYC Department of Environmental Protection
NYCEDC	NYC Economic Development Corporation
NYCP&R	NYC Department of Parks and Recreation
DOT	Department of Transportation
SEQR	State Environmental Quality Review (NYS)
CEQR	City Environmental Quality Review (NYC)
SHPO	State Historic Preservation Office
NYCDCP	New York City Dept. of City Planning
NYCCPC	New York City Planning Commission
NYSDOS	New York State Department of State
EFH	Essential Fish Habitat (NMFS)
ESA	Endangered Species Act (NMFS and USFWS)
FONSI	Finding of No Significant Impact (in Environmental Review, this will allow a project to proceed with EA rather than a more comprehensive EIS)
FWCA	Fish and Wildlife Coordination Act (NMFS and USFWS)
WQC	Section 401 Water Quality Certification (NYSDEC)
NHPA	National Historic Preservation Act
NYSOGS	New York State Office of General Services

Appendix E Task 5 Outreach: Stakeholder Meeting Documents

November 13, 2014 Meeting		
Document Number	File	No. Pages (PDF)
01	Meeting Agenda	1
02	Stakeholder Presentation	57
03	Stakeholder Takeaway	3