Appendix E
Natural Resources
(Part 4)

Appendix E-4
Adjacent Artificial Habitat Survey Report

December 9th, 2015

Adjacent Artificial Habitat Survey Report

Tottenville, Southern Waterfront

SeArc – Ecological Marine Consulting LTD

PROJECT: Staten Island Living Breakwaters – Adjacent Artificial Habitat Survey

TASK ORDER I – Submission

LOCATION: Raritan Bay- Tottenville, Staten Island, NY, United States

ORDERING ENTITY: Governor's Office of Storm Recovery (GOSR)

Dr. Shimrit Perkol-Finkel

Dr. Ido Sella

Table of Contents

1 Executive Summary 5
2 Background 8
2.1 Purpose and Need 8
2.2 Study Goals 9
2.3 Meteorology and Oceanography 10
3 Material and methods 11
3.1 Statistical Analysis 15
4 Results 16
4.1 Live Cover, Biodiversity, Species Richness and Biomass 16
4.2 Point and Count 22
5 Discussion and General Observations 25
5.1 General Observations 26
5.2 Spacing between Building Units 26
5.3 Orientation of Substrate 27
5.4 Structure's Sediment "Halo" 27
5.5 Birds 28
5.6 Fishing Activity 28
6 Cited Literature 31

List of Figures

Figure 1. Adjacent Artificial Habitat, September 2015, Tottenville, SI, NY. Location of sampling stations – Green points, derived from the preliminary bathymetric survey. Station AR6, piles of a fishing pier, is a control station out of the proposed project area; Blue polygon is the area sampled by AKRF/ Normandeau in June and July 2015. 12
Figure 2. Example of quadrat scraping – [A] pre scraping; [B] post scraping. 14
Figure 3. An example of scraped mass from one of the stations. 14
Figure 4. Samples packed and marked for dry weight process. 14
Figure 5. A screenshot of the point & count work process in CoralNet. 15

Figure 6. Zoom-in on the left corner of figure 5, showing annotation points: purple – annotated; yellow – not annotated; green – under review. 15
Figure 7. Adjacent Artificial Habitat, September 2015, Tottenville, SI, NY. Taxa that were identified at all stations. [A] General view of the habitat on the rock piles in the various stations, including – sponges, anemones, shellfish bryozoans and other invertebrates; [B] Branching sponge – *Axinella* sp.; [C] Blue crab – *Callinectes sapidus* [D] Black clam – *Arctica islandica*; [E] Assorted shellfish; [F] Sea lettuce – *Ulva* sp. and Agardh's red weed – *Agardhiella* sp..... 17
Figure 8. Adjacent Artificial Habitat, September 2015. Relative abundance of each taxa at the two sampling depths. 21
Figure 9. Adjacent Artificial Habitat, September 2015. Average dry weight and total number of taxa in the sampled stations. Error bars represent standard deviation. 21
Figure 10. Adjacent Artificial Habitat, September 2015. Average number of species per station. Error bars represent standard deviation. 22
Figure 11. Adjacent Artificial Habitat, September 2015. Average species diversity index (Shannon H') per station. Error bars represent standard deviation. 23
Figure 12. Adjacent Artificial Habitat, September 2015. 2D MSD analysis of each station. Superimposed: 60% similarity level clustering. 24
Figure 13. Adjacent Artificial Habitat, September 2015. Cluster analysis. SIMPROF analysis indicates all significant differences (P <0.05) between each of the samples, red being non-significant and black being significant difference. 24
Figure 14. Adjacent Artificial Habitat, September 2015. Observations of biological community on artificial structures in the area. [A] Nesting and feeding birds; [B] Different size sheltered habitats; [C-D] Interactions of hard structure with halo of broken shells and calcium carbonate fractions originated from dethatched marine organisms; [E] Sublittoral vertical or steeply inclined surfaces presenting high cover and diversity; [F-H] Different size spacing between rocks corresponded to different species assemblages..... 30

List of Tables

Table 1. General outline of work procedure. 10

Table 2. Location, depth (bottom) and structure age of sampling stations. Note – station AR2 (highlighted in red) was sampled only visually, with no scraping. 'Contact' refers to numbers from bathymetric survey. Age information courtesy of Christopher Hudak and Jeff Yunker of the USCG. 13

Table 3. Adjacent Artificial Habitat, September 2015, Tottenville, SI, NY. Complete list of taxa identified at all six stations. Markings: [*] – alien species with uncertain invasiveness; [*$^{-}$] – non-invasive alien species; [*$^{+}$] – invasive alien species; [V] – presence of the taxa inside the scraped area of the quadrat; [O] – presence of the taxa at the visual survey only; empty cells indicate that the taxa was not found at that station. Species invasiveness information from Pagad et al. (2015). 18

Table 4. Total dry, organic and ash weights. 22

1 Executive Summary

This report summarizes the findings of a survey conducted as a part of the schematic design phase (30% design) for the Living Breakwaters Rebuild by Design Project being implemented by the New York Governor's Office of Storm Recovery (GOSR). The project site is on the South Shore of Staten Island in the waters of Raritan Bay, which is a shallow estuary that contains a variety of habitats and supports commercial fisheries. The Living Breakwaters project is a layered approach to increase coastal resilience by constructing breakwater structures made of stone and bio-enhancing concrete units, with the aim to reduce risk, increase habitat diversity, restore habitats, and prove opportunities for shellfish (oyster) restoration and education.

'SeArc Ecological Marine Consulting' (SeArc), a member of the SCAPE Landscape Architecture team, was commissioned in September 2015 to perform a baseline survey of "Adjacent Artificial Habitats" within the proposed project area for characterizing the fouling communities inhabiting artificial structures and provide input to the breakwater's design process for maximizing ecological performance. Sampling included a visual survey and quadrates sampling.

The survey revealed rich hard substrate habitats, with a total of 43 taxa including algae, invertebrates, fish, and birds. Algae dominated the shallows, while in the deeper water the most abundant taxa were tube worms (Polychaetes).

The average dry weight of fouling communities scraped from the surveyed artificial substrates habitat reached nearly 1 kg per m^2, which consisted of 75 percent inorganic material and 25 percent organic material. These values present noteworthy biogenic buildup capabilities, as supported by some of the species found during the survey which are known for their significant calcium carbonate deposition (such as barnacles, tube worms, and oysters). The fact that the youngest station sampled (2.5 y) presented high dry weight values suggests overall deposition rates in the area are quite high and comparable to values found in the literature for regions supporting biogenic reef formation in temperate environments.

Input for Design:

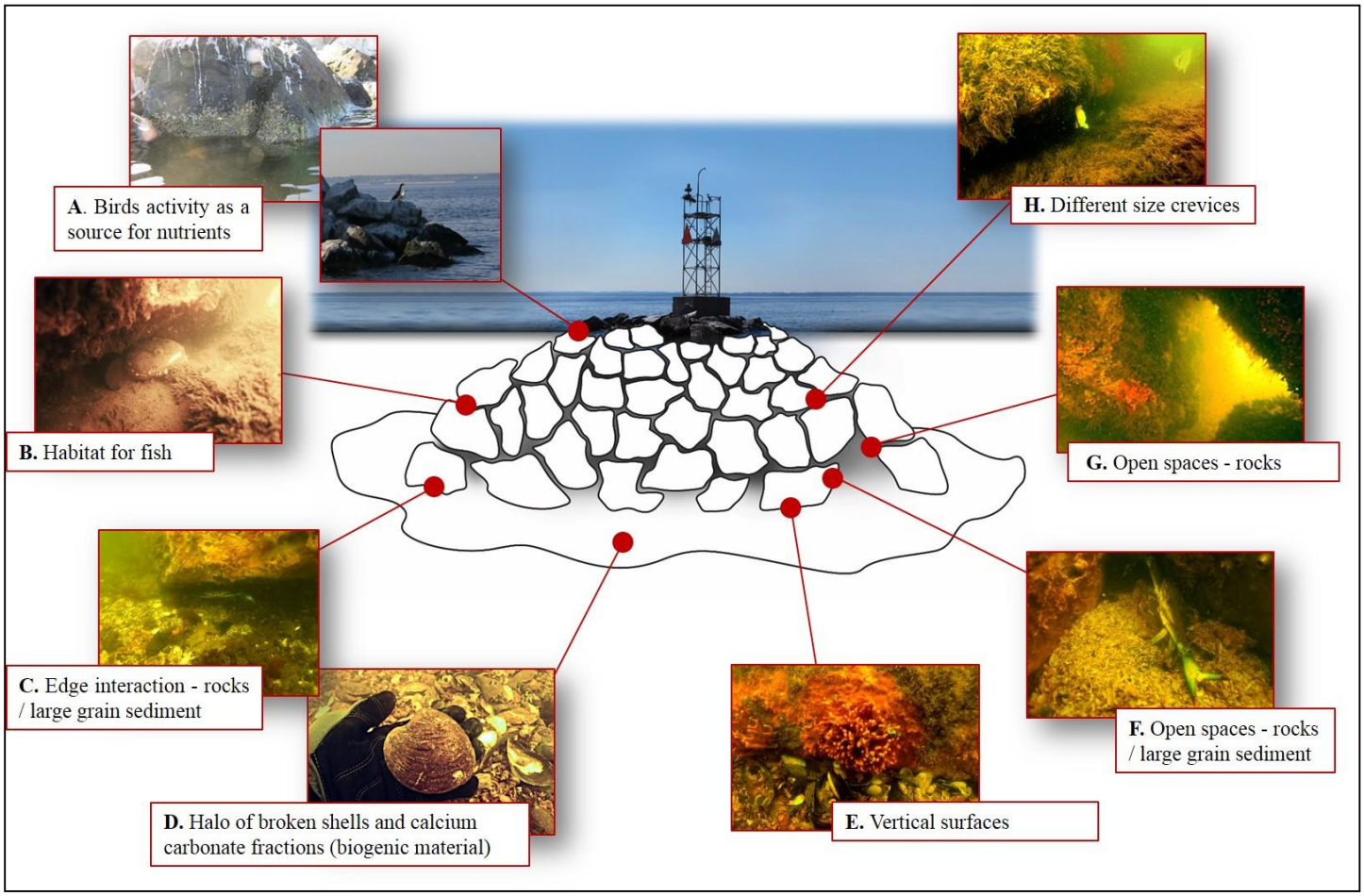
Spacing Between Building Units – Different spacing sizes between rocks corresponded to different species assemblages. Rock spacing varied from 1cm (0.5-inches) to 1m (40 inches). Some of the formed spaces had more than one opening to the water column. Areas that had a variety of spacing sizes had the greatest diversity and abundance of both fish communities and motile invertebrates.

Orientation of Substrate – Within the intertidal zone, horizontal surfaces had a larger quantity and more diverse observed benthic cover than vertical and steeply inclined surfaces. Below the intertidal zone, the opposite was noted, with vertical or steeply inclined surfaces presenting higher cover and diversity than horizontal ones.

Structure's Sediment "Halo" – All hard substrate structures sampled were surrounded by a belt of broken shells and other calcium carbonate fractions originating from marine organisms. This should to be addressed with respect to benthic habitats in the vicinity of the proposed structures.

Birds – Nesting and feeding birds were observed on protruding surfaces of the structures, and were noted as a source for nutrients within the intertidal zone. Increased nutrients, combined with high light penetration in the shallows, are regarded as the key reason for the high species richness and cover of algae in the intertidal area. Future design of protruding structures should address bird habitat creation that can support increased biodiversity, more complex food chains, and increased nutrients flux.

Fishing Activity – Fishing activities and associated debris were noted around hard structures in the area. The design will need to address fishing activities in terms of reducing the amount of debris, impact of selective fishing, and issues of user safety. In addition, any monitoring activity should address fishing activities that might affect data quality.



Adjacent Artificial Habitat, September 2015. Observations of biological community on artificial structures in the area. [A] Nesting and feeding birds; [B] Different sizes of sheltered habitats; [C-D] Interactions of hard structure with halo of broken shells and calcium carbonate fractions originating from detached marine organisms; [E] Sublittoral vertical or steeply inclined surfaces presenting high cover and diversity; [F-H] Different size spacing between rocks corresponded to different species assemblages.

2 Background

This report summarize the findings of a survey conducted as a part of the schematic design phase (30% design) for the Living Breakwaters Rebuild by Design Project, being implemented by the New York Governor's Office of Storm Recovery (GOSR). The Living Breakwaters project is a layered approach to increase coastal resilience by constructing breakwater structures made of stone and bio-enhancing concrete units, with the aim to reduce risk, increase habitat diversity, restore habitats, and providing opportunities for oyster restoration and education.

'SeArc Ecological Marine Consulting' (SeArc), a member of the SCAPE Landscape Architecture team, was commissioned in September 2015 to perform a baseline survey of "Adjacent Artificial Habitats" within the proposed project area for characterizing the fouling communities inhabiting artificial structures and provide input to the breakwater's design process for maximizing ecological performance. The project site is located on the South Shore of Staten Island and in the adjacent waters of Raritan Bay. Raritan Bay is a shallow estuary that contains a variety of habitats for invertebrates and fish. It supports commercial fisheries, as well as the harvest of hard clams.

2.1 Purpose and Need

Staten Island is exposed to extreme wave action and coastal flooding during hurricane and other severe storm events due to its location at the mouth of the New York Bight, which funnels and increases the intensity of storm surge into New York Harbor, Raritan Bay, and the shoreline of Staten Island. The South Shore of Staten Island is vulnerable to coastal erosion and land loss. Consistent with the City's Coastal Protection Initiatives and planning studies for the Tottenville area, the goal of the Living Breakwaters Project is to reduce risk and coastal erosion along the shoreline in Tottenville, while enhancing ecosystems and shoreline accessibility and use. This goal would be achieved using a layered approach that would address wave action, impacts of coastal flooding and event-based (i.e., short-term/storm-related) and long-term shoreline erosion, while restoring and enhancing ecosystems, improving waterfront access and engaging with the community through educational programs directly related to the coastal resiliency actions.

Specifically, the goals and objectives related to the project's purpose and need are:

Risk reduction

- Attenuate wave energy.
- Address both event-based and long-term shoreline erosion / preserve beach width.

Social resiliency

- Foster community education on coastal resiliency directly tied to and building off the structural components of this resiliency initiative.
- Increase physical and visual access to the water's edge.
- Enhance community stewardship of on-shore and in-water ecosystems.
- Increase access to recreational opportunities.

Ecological enhancement

- Increasing diversity of aquatic habitats consistent with the Hudson-Raritan Estuary plan priorities (e.g., oyster reefs and fish and shellfish habitat).

2.2 Study Goals

The main goal of this study is to provide field data on fouling communities on artificial structures, within the proposed project area. The acquired data will be used to maximize the ecological performance and habitat creation opportunities of the Living Breakwaters, and provide science based input to the design and future planned monitoring program. The results of the study constitute a database of existing conditions with respect to the recruitment potential and biological assemblages on existing artificial habitats in the area – piles of rock and pier piles. The results of the study include species lists, microhabitat characteristics, and accumulation of biogenic growth, which will assist in the overall planning of the breakwaters with respect to distance from the shoreline, internal design, spacing of building units, and 3D underwater design.

The study area extends from the mouth of the Arthur Kill for approximately 2.5 miles east along the shoreline of Tottenville on the south shore of Staten Island, and from the shoreline out to the navigation channel.

In order to allow efficient ecological design of the Living Breakwaters that would provide maximal biological and ecological benefits (e.g., in terms of habitat creation opportunities, enhanced biodiversity, and provision of ecosystem services) data was gathered in two complementary surveys:

1) Describing the natural benthic assemblages in the immediate project area: communities of algae, invertebrates, and fish found on natural habitats in the region (rocky reef formations, soft bottom habitats etc.). This information was collected under the EIS and coordinated by AKRF.
2) Describing the fouling assemblages inhabiting man-made/artificial structures in the area: communities of algae, invertebrates, and fish found on artificial habitats such as pier piles / rock piles and buoys. This information was collected under the schematic design phase (30% design) by SeArc, and the following report summarizes these results (Table 1).

Together, results from the two surveys provide a full picture of the communities in the area on both natural and artificial habitats. Moreover, the two types of surveys will allow for more accurate definitions of biological and ecological targets/ goals from the Living Breakwaters system.

Table 1. General outline of work procedure.

Dates	Assignment	Location	Executed by
Sept 17th – 21st 2015	Field survey – sample collection, taxonomic sorting and identification, dry weight and ash free dry weight.	Staten Island	Dr. Ido Sella Tomer Hadary
Oct – Nov 2015	Data analysis – Point and Count, species identification, statistical analysis.	SeArc lab	Dr. Ido Sella Dr. Shimrit Perkol-Finkel Raviv Shirazi Tomer Hadary
Nov 30th 2015	Draft 1 submission	SeArc lab	Dr. Ido Sella Dr. Shimrit Perkol-Finkel Raviv Shirazi Tomer Hadary
Dec 9th 2015	Final submission		

2.3 Meteorology and Oceanography

Timing the survey in late summer/early fall was selected purposefully, as this is the period during which the majority of benthic organisms are at the peak phase of recruitment. Moreover, it was important to obtain and analyze the data before the end of 2015 in order to have the information and conclusions available for the planning and design stages of the Living Breakwater tasked for 2016.

The survey was conducted on Sep 17th – 19th onboard the Survey-Diving Vessel – *Angler II* chartered out of Great Kills Marina. Sea conditions varied during the survey: wave height 0.1-0.3m (<1ft); water temperature 25-26°C (~78°F); air temperature 25-26°C (~78°F); wind speed 10-20 knots; wind direction S (http://www.ndbc.noaa.gov/station_history.php?station=44065).

3 Material and methods

In order to examine the benthic communities developing on non-enhanced, typical, man-made structures (piles of rock and pier piles) in the area, six stations (AR1-AR6) were sampled for species richness, percent live cover, biodiversity, benthic biomass and biogenic buildup, within the study area (Table 2, Figure 1). Sampling stations for this survey included fully submerged artificial rock structures identified during the bathymetric survey (presumably an old sewage pipe, contact 0028), rock piles serving as foundations for the shipping canal lighthouses (Red 42, 52, and 58) and concrete pier piles (Dorothy Fitzpatrick Fishing Pier in Lemon Creek Park). These stations were the only locations identified as hard bottom habitat, adjacent to the proposed project area, from the Side Scan Sonar survey results conducted by 'Hill International' (Hill) and their subcontractor Aqua Survey International (ASI).

Red 50 Light steel buoy was sampled as a reference station. However, the buoy was apparently recently maintained (painted with antifouling coat) and its anchoring unit was within the dragged area of the shipping channel (deeper than 40 feet), therefore only a quick visual survey was conducted to determine a lack of habitat and data from this station was excluded from all analyses.

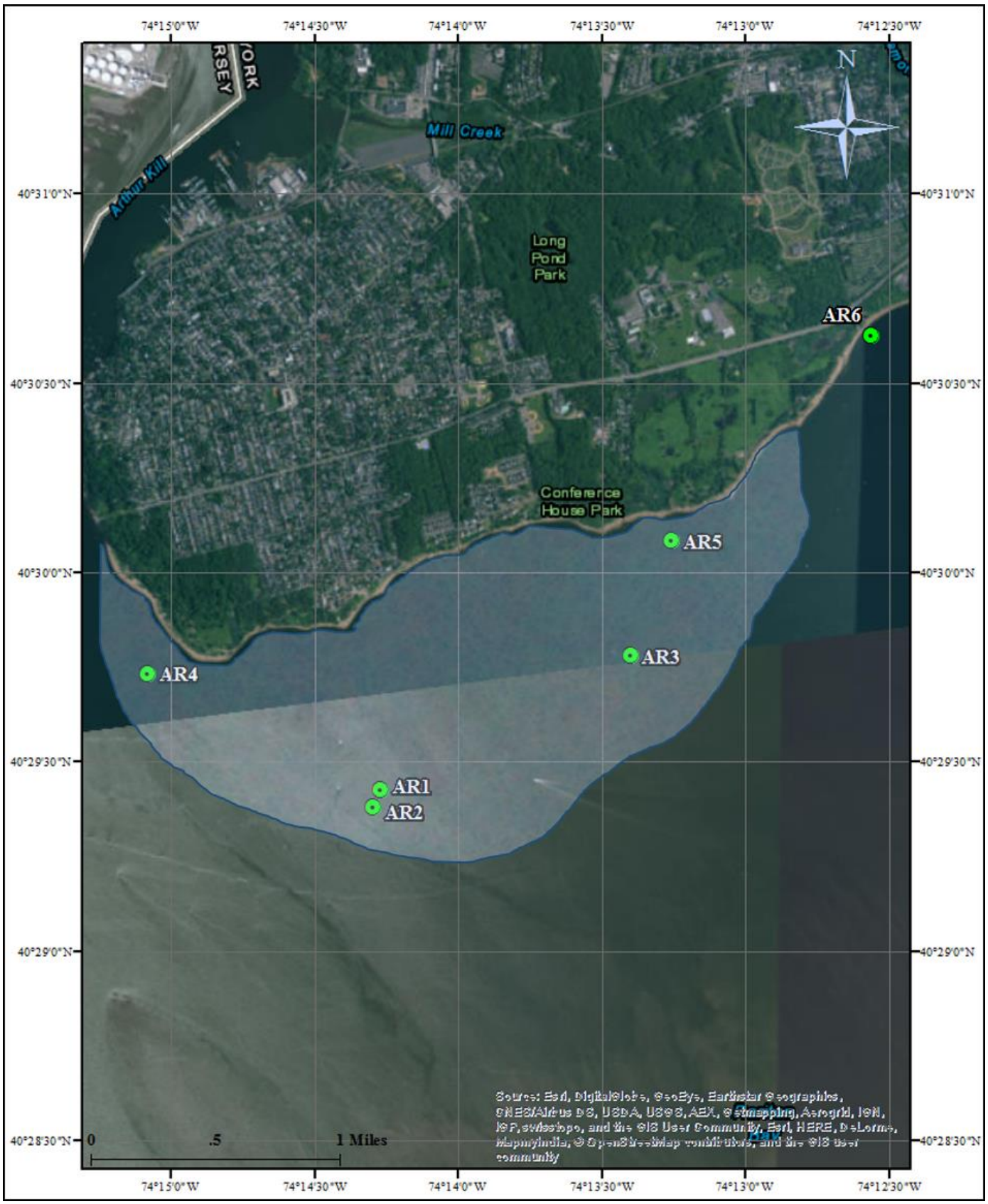


Figure 1. Adjacent Artificial Habitat, September 2015, Tottenville, SI, NY. Location of sampling stations – Green points, derived from the preliminary bathymetric survey. Station AR6, piles of a fishing pier, is a control station out of the proposed project area; Blue polygon is the area sampled by AKRF/ Normandeau in June and July 2015.

Table 2. Location, depth (bottom) and structure age of sampling stations. Note – station AR2 (highlighted in red) was sampled only visually, with no scraping. 'Contact' refers to numbers from bathymetric survey. Age information courtesy of Christopher Hudak and Jeff Yunker of the USCG.

Station	Map Identification	Longitude [W]	Latitude [N]	Depth [feet]	Age [years]	Structure
AR1	Red 52 Light	74.237765	40.490455	18	16	Rock Pile
AR2	Red 50 Light	74.238212	40.489700	>30	2.5	Steel Buoy
AR3	Red 42 Light	74.223290	40.496361	18	16	Rock Pile
AR4	Red 58 Light (contact 0015)	74.251265	40.495573	18	11	Rock Pile
AR5	Rock Pile (contact 0028)	74.220911	40.501436	4	Unknown	Rock Pile
AR6	Dorothy Fitzpatrick Fishing Pier	74.209307	40.510445	5	2.5	Pier pile

Sampling was conducted following the Hewitt and Martin (2001) protocols for detecting and quantifying species in ports and docks. In each station the work was conducted by 2 SeArc personnel (Principal Investigator (PI) + Scientific Diver) using SCUBA. Sampling began with a visual survey by both divers in order to locate the areas with the highest and most diverse benthic cover, and to identify and document motile invertebrates and fish that were not sampled within the quadrats (see below).

When the visual survey was complete, within each station 6 replicate samples of quadrats (metal frame) with a total surface area of 0.1m^2 (32cm X 32cm / 1.04'x1.04') were sampled at two depths: ~1m (~3') below MLW and ~1-2m (~3-7') above seabed. In shallow stations with <3m (10') bottom depth, only 6 quadrats in shallow depth were sampled. Quadrats were photographed using a Canon G15 digital camera with a fisheye lens and then scraped into a nylon bag (Ziploc) using a metal scraper. Large or fragile organisms were placed separately according to the instructions of the PI (Figure 2). The scraped material was sorted onboard and preserved on ice. Shortly thereafter, the preserved samples underwent enumeration and identification of the benthic organisms to the lowest practical taxon. Dry weight (60°C / 140°F for 72 hours) and ash free dry weight (450°C / 842°F for 6 hours) were measured for the biomass and biogenic growth analyses following Perkol-Finkel et al. (2006) (Figure 3 & Figure 4).

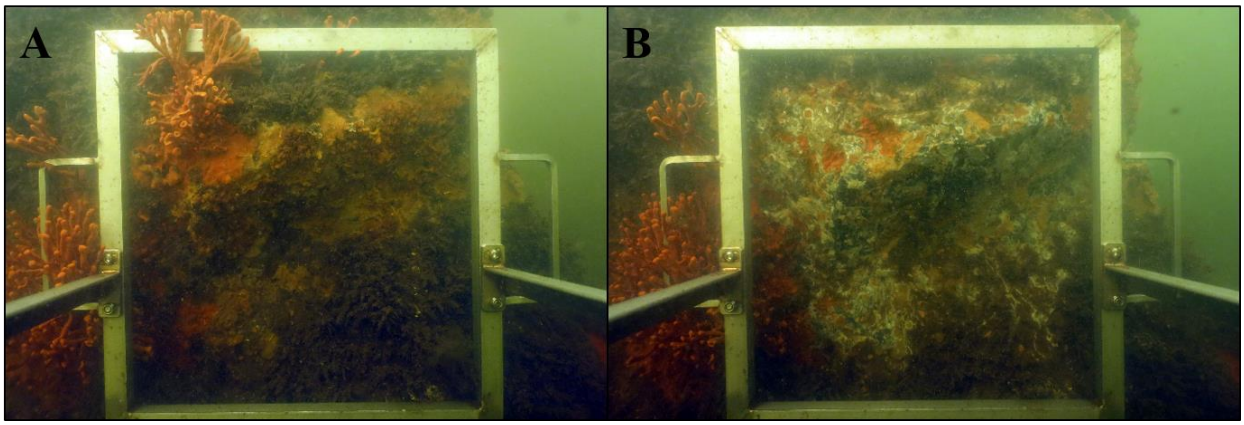


Figure 2. Example of quadrat scraping – [A] pre scraping; [B] post scraping.

Figure 3. An example of scraped mass from one of the stations.

Figure 4. Samples packed and marked for dry weight process.

At the lab, the fisheye lens distortion was corrected using Adobe Photoshop CS6 and the images were analyzed by CoralNet, a point and count software (Beijbom et al., 2012). The point generation method was a 10x10 grid of cells with one randomly generated point at each cell, thus creating 100 scattered points and avoiding "clouds" of points (Figure 5 & Figure 6). When photos annotation was completed, percent cover of different taxa and bare substrate were calculated. Taxa identification was done to species level when possible, or to a higher taxonomic levels or functional groups; organisms that could not be identified using photos (e.g., macro-algae or oysters) were divided into functional groups. In addition, each taxon was evaluated as to whether it is an introduced (alien) species, and if so, its degree of invasiveness, following the below EPA definitions:

Introduced Species – A species that has been intentionally or inadvertently brought into a region or area. Also called an exotic or non-native species.

Invasive Species – A type of plant, animal, or other organism that does not naturally live in a certain area but has been introduced there, often by people. An invasive species can spread quickly, especially if it has no natural predators in its new home. An invasive species can hurt native species, disrupt ecosystems, and create problems for people. (http://www3.epa.gov/)

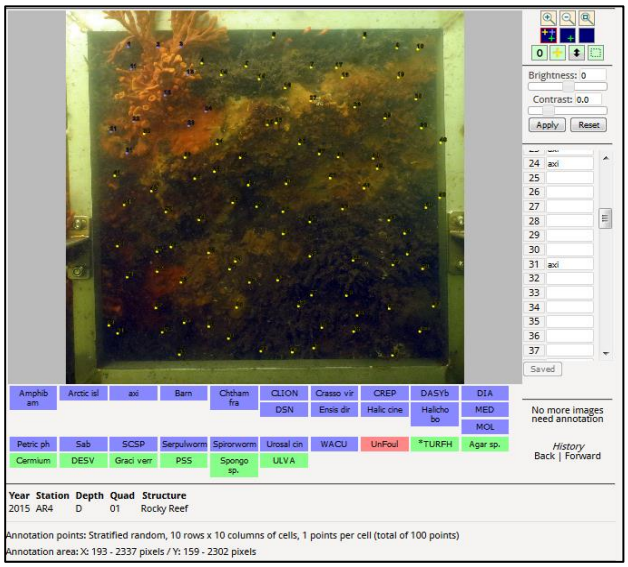


Figure 5. A screenshot of the point & count work process in CoralNet.

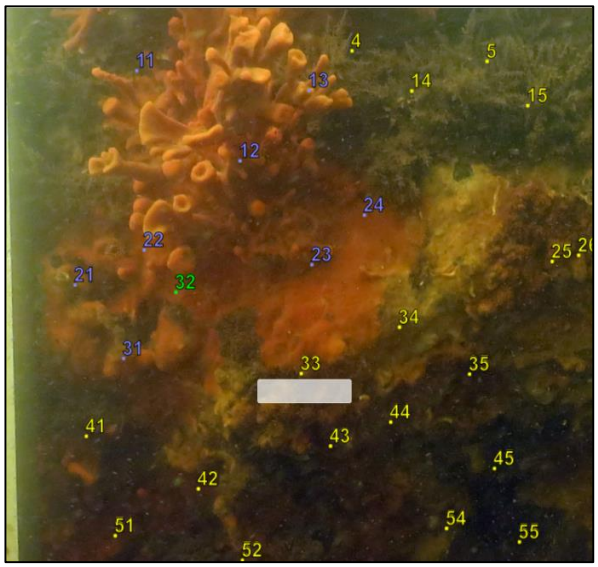


Figure 6. Zoom-in on the left corner of figure 5, showing annotation points: purple – annotated; yellow – not annotated; green – under review.

3.1 Statistical Analysis

Average cover of each taxon per site from the 6-12 replicate quadrats was calculated. Each sample underwent a sample-specific census profile of the number of identified taxa. The resemblance among the census profiles from the monitoring underwent statistical analyses using the PRIMER V6.1.13 (Clarke and Gorley, 2006) and PERMANOVA+ V1.0.3 programs (Anderson et al., 2008; Clarke et al., 2008).

Statistical analyses included univariate 1-way PERMONOVA tests, based on Euclidian Distances similarity index for species count, biomass and Shannon Wiener biodiversity index, as well as multivariate data analyses of taxa assemblages by a-parametric PERMANOVA tests, based on the Bray-Curtis Similarity Index. Post-hoc pair wise tests were applied where relevant.

MDS and Cluster plots were used to graphically represent trends in the multivariate data. Cluster analyses included a SIMPROF test that indicates the statistical significance of the various clusters in the plot. In addition, SIMPER analyses were conducted, highlighting the taxa responsible for the similarity within each station and for taxa differentiating between stations.

4 Results

This section summarizes the detailed Adjacent Artificial Habitat sampling results, taxonomic analyses, biomass accumulation, percent live cover, and a general species list. A total of 48 quadrats were sampled in the September 2015 survey. In stations AR1, AR3 and AR4 both 6 shallow quadrats and 6 deep quadrats were analyzed; and at AR5 and AR6 only 6 shallow quadrats were analyzed due to the shallow water depth at the sites. As mentioned above, station AR2 did not have a structure that could be sampled using quadrats, thus only a general survey was conducted.

4.1 Live Cover, Biodiversity, Species Richness and Biomass

A total of 43 taxa were observed in the six sampling stations – 8 algal species, 29 invertebrates, 4 fish, and 2 birds (Table 3, Figure 7). Seven of the invertebrate species were identified as introduced (alien) species, out of which one is classified as invasive, two are non-invasive, and the rest are uncertain. Full statistical analysis can be found in Appendix B.

Out of the total of 43 taxa, only those that were physically found in the scraped mass are referred to in all analyses.

Figure 7. Adjacent Artificial Habitat, September 2015, Tottenville, SI, NY. Taxa that were identified at all stations. [A] General view of the habitat on the rock piles in the various stations, including – sponges, anemones, shellfish bryozoans and other invertebrates; [B] Branching sponge – *Axinella* sp.; [C] Blue crab – *Callinectes sapidus* [D] Black clam – *Arctica islandica*; [E] Assorted shellfish; [F] Sea lettuce – *Ulva* sp. and Agardh's red weed – *Agardhiella* sp.

Table 3. Adjacent Artificial Habitat, September 2015, Tottenville, SI, NY. Complete list of taxa identified at all six stations. Markings: [*] – alien species with uncertain invasiveness; [*$^{-}$] – non-invasive alien species; [*$^{+}$] – invasive alien species; [V] – presence of the taxa inside the scraped area of the quadrat; [O] – presence of the taxa at the visual survey only; empty cells indicate that the taxa was not found at that station. Species invasiveness information from Pagad et al. (2015).

Taxa	Common Name	Species	AR1 D	AR1 S	AR2	AR3 D	AR3 S	AR4 D	AR4 S	AR5 S	AR6 S
Algae	Agardh's red weed	*Agardhiella* sp.			O					V	V
Algae	Banded weeds	*Ceramium* sp.		V	O		V				
Algae	Turf	*Turf algae*		V	O	V					V
Algae	Stringy acid kelp	*Desmarestia viridis*		V					V		
Algae	Ceylon moss	*Gracilaria verrucosa*					V				
Algae	Pitcher Siphon Weed	*Polysiphonia stricta*						V			
Algae	Green sea fern	*Spongomorpha* sp.					V				
Algae	Sea lettuce	*Ulva* sp.		V	O		V		V	V	
Invertebrates											
Arthropoda	Horseshoe crab	*Limulus polyphemus*$^{*-}$									O
Ascidiacea	White crusts	*Didemnum* sp.*			O						V
Ascidiacea	Sea Grape	*Molgula manhattensis*			O						
Bivalve	Black clam	*Arctica islandica*	O			O		O		O	O
Bivalve	Common oyster	*Crassostrea virginica**	O								
Bivalve	Common razor clam	*Ensis directus*	O								
Bivalve	Blue mussel	*Mytilus edulis*	V		O	V					
Bivalve	Angel wing	*Petricola pholadiformis*	V							V	
Bryozoa	Red crust	*Schizoporella* sp.	V		O	V				V	V
Bryozoa	Bryozoa	*Watersipora cucullata*	V		O	V	V	V	V	V	V
Cnidaria	Orangestriped green anemone	*Diadumene lineata*$^{*-}$	V		O			V		V	
Crustacea	Barnacles	*Amphibalanus* sp.*$^{+}$	V	V	O	V		V	V	V	V
Crustacea	Little gray barnacle	*Chthamalus fragilis*		V		V		V	V	V	V
Crustacea	Short belly crab (juv)	*Short belly crab (juv)*	V								

Crustacea	Blue crab	*Callinectes sapidus**	O	O	O	O	O	O	O	O	O
Crustacea	Green crab	*Carcinus maenas**	V								
Gastropoda	Common Atlantic slippersnail	*Crepidula fornicata*		V	O						
Gastropoda	Common Limpet	*Testudinalia testudinalis*			O						V
Gastropoda	Mud dog whelk	*Nassarius obsoletus*	V	V		V	V	V	V	V	V
Gastropoda	Oyster drill	*Urosalpinx cinerea*	V	V		V	V	V	V	V	V
Polychaeta	Tube worm	*Dasychone bairdi*	V	V	O			V	V		V
Polychaeta	Bristle worms	*Polychaeta worm (mobile)*		V		V	V			V	V
Polychaeta	Fan worms	*Sabellidae*				V		V	V	V	
Polychaeta	Calcareous tubeworm	*Serpulidae worm*	V		O	V		V		V	V
Polychaeta	Hard tube worms	*Spirorbid worms*						V			
Porifera	Branching sponge	*Axinella* sp.	V		O	V		V		V	
Porifera	Boring sponge	*Cliona* sp.	V								
Porifera	Bowerbank's halichondria	*Halichondria bowerbanki*			O					V	V
Porifera	Haliclona	*Haliclona (Reniera) cinerea*	V		O						
Fish											
Actinopteri (Fish)	Inland silverside	*Menidia beryllina*		O					O		
Actinopteri (Fish)	Oyster toadfish	*Opsanus tau*						O			
Actinopteri (Fish)	Spotfin butterflyfish	*Chaetodon ocellatus*	O		O			O			
Actinopteri (Fish)	Tautog	*Tautoga onitis*						O			
Birds											
Laridae	Seagulls	*Larus* sp.	O	O	O	O	O	O	O		
Phalacrocoracida	Cormorant	*Phalacrocorax* sp.	O	O	O	O	O	O	O		

A total of 30 taxa were identified and sorted from the scraped mass (8 algae and 22 invertebrates). In the shallow sampling 25 taxa were found, whereas in the deep sampling only 21 taxa were found. Apart from clear differences in the total number of taxa, there were significant differences in the taxa composition between the two sampled depths (PERMANOVA, *df*=1, Pseudo F=4.8699, P=0.006; Figure 8). For example, the most abundant taxa in the shallow samples were algae, while in the deep samples the most abundant taxa were polychaetes, with only two algae taxa being found.

Statistical analyses of the dry weight samples revealed significant differences between the sampled stations (PERMANOVA, *df*=4, Pseudo F=11.394, P=0.001) and the sampled depths (PERMANOVA, *df*=1, Pseudo F=6.519, P=0.015). Post-hoc analysis did not indicate any specific station as being responsible for the differences in dry weight; moreover, 3 pairs out of 10 showed no significant differences (Pair-wise: AR1, AR6 P(MC)=0.12; AR3, AR4 P(MC)=0.399; AR5, AR6 P(MC)=0.141).

Cross examination of the taxa richness and biomass data per station did not reveal any specific trend (Figure 9). For example, station AR3 S that offered the lowest dry weight (10.76±5.49), had a relatively high taxa number (12). The highest values, both for dry weight (210.82±115.05) and taxa number (15) were found in station AR5 S. This station, was the only one to offer shallow water areas with horizontal sampling surfaces (as opposed to other stations with only vertical or steeply inclined shallow water sampling area). This issue is further discussed below in the ‘Discussion and General Observations’ chapter.

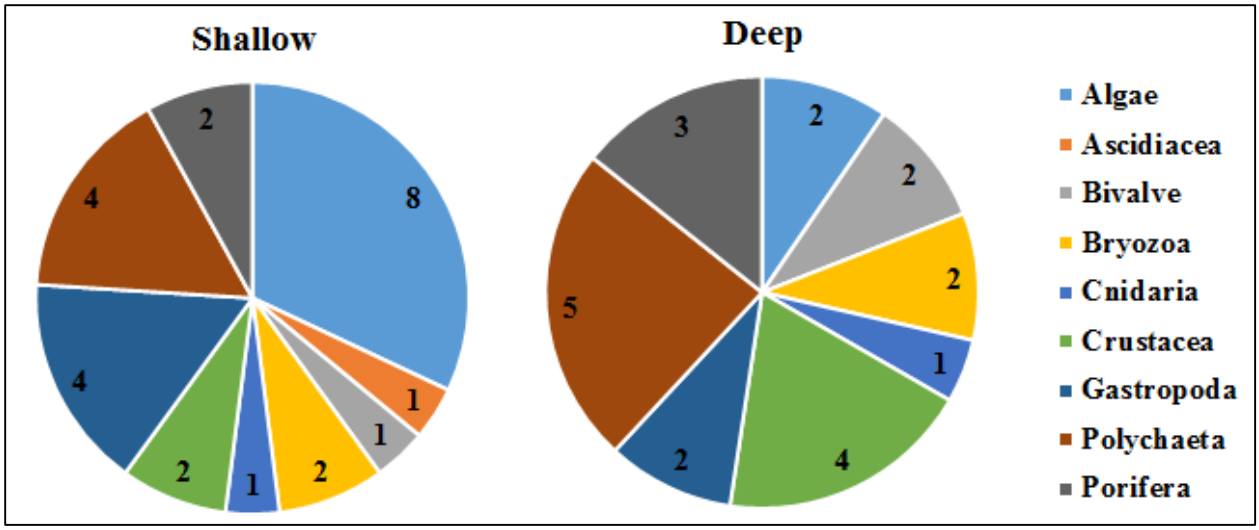


Figure 8. Adjacent Artificial Habitat, September 2015. Relative abundance of each taxa at the two sampling depths.

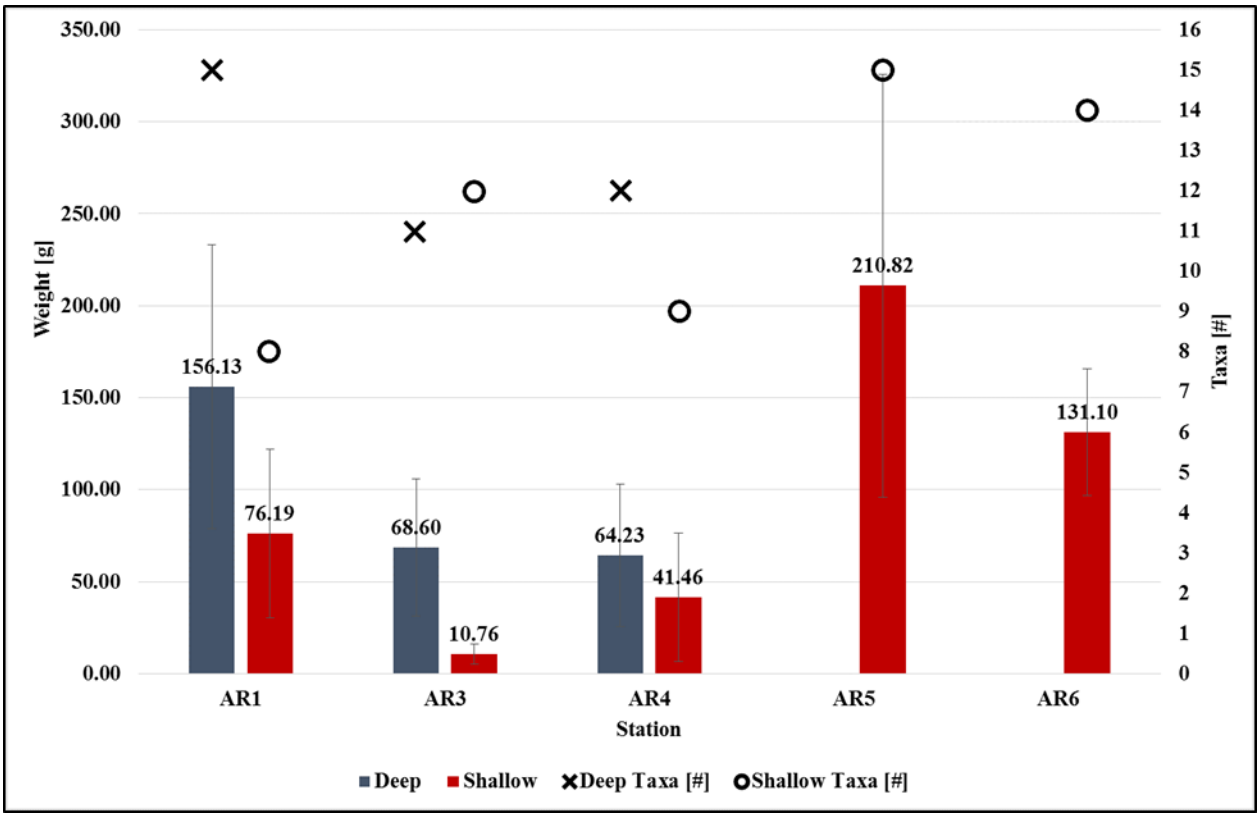


Figure 9. Adjacent Artificial Habitat, September 2015. Average dry weight and total number of taxa in the sampled stations. Error bars represent standard deviation.

Dry weight vs organic and inorganic (ash) weights are presented (Table 4) as a pool from all stations, in order to provide a datum that can be used during the design process. A total of 4,458.06 gr in dry weight were collected from a total area of 4.5 m^2 (48.672 ft^2). From this,

3,410.5 gr were inorganic weight (ash) and 1047.56 gr consisted of organic material. This inorganic-organic ratio of approximately3:1, translates to nearly 1 kg (990.68gr) of material per m^2 (20.35gr/ft^2) composed of 757.89 gr of inorganic weight (15.57gr/ft^2) and 232.79 gr (4.78gr/ft^2) of organic substance.

Table 4. Total dry, organic and ash weights.

Weights [gr]	Dry Weight	Ash	Organic
Total	4458.06	3410.5	1047.56
Per Square Meter	990.68	757.89	232.79
Per Square Foot	20.35	15.57	4.78

4.2 Point and Count

The average number of species (S values, Figure 10) differed significantly among stations (PERMANOVA, *df*=4, Pseudo F=2.8891, P=0.032) and between sampling depths (PERMANOVA, *df*=1, Pseudo F=27.605, P=0.001) with deep samples presenting higher values.

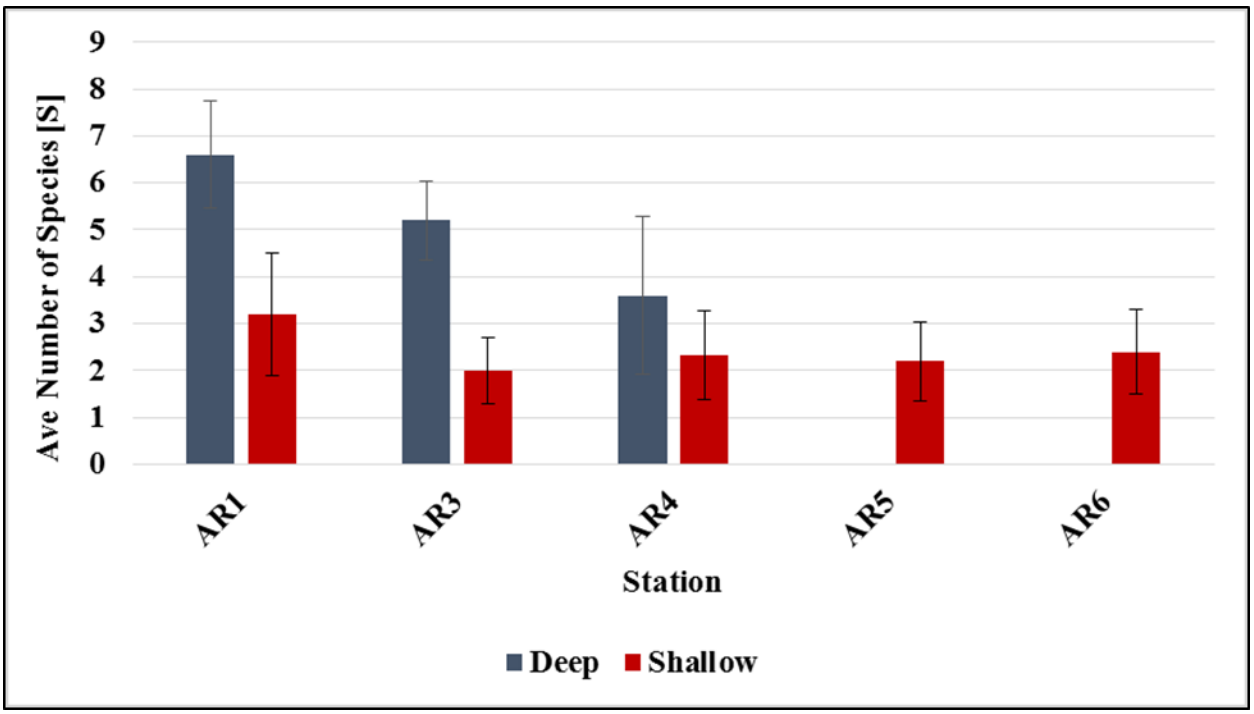


Figure 10. Adjacent Artificial Habitat, September 2015. Average number of species per station. Error bars represent standard deviation.

Species diversity (Shannon Weiner Index – H', Figure 11) differed significantly between sampling depths (PERMANOVA, *df*=1, Pseudo F=37.678, P=0.001) with deep samples presenting higher values; however, there were only marginal differences in H' values between

sampling stations, (PERMANOVA, *df*=4, Pseudo F=2.7645, P=0.05). Further analyses revealed significant differences only between stations AR1 and AR3 (Pair-wise, t=2.7074, P(MC)= 0.015) and between stations AR3 and AR6 (Pair-wise, t=2.8399, P(MC)= 0.02). Full statistical analysis can be found in Appendix B.

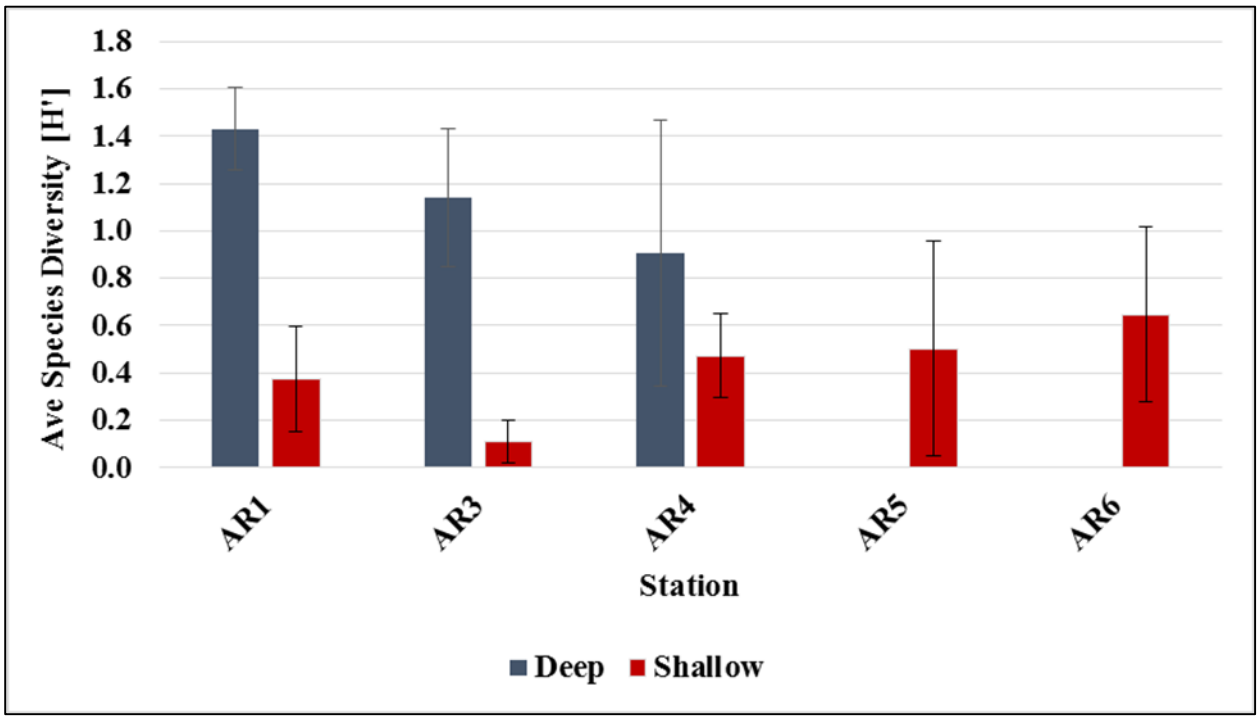


Figure 11. Adjacent Artificial Habitat, September 2015. Average species diversity index (Shannon H') per station. Error bars represent standard deviation.

When examining the full community structure of the sampled stations, significant differences are found between stations and sampling depths (PERMANOVA, P=0.001 for both). Furthermore, there was no trend in the differences of the community structure, as indicated by the "station X depth" analysis (PERMANOVA, *df*=2, Pseudo F=5.243, P=0.002). It is also evident that all stations differ significantly from one another, except to AR1 and AR4 (Pair-wise, t=1.4453, P(MC)= 0.149). The differences are clearly illustrated in the MDS plot and in the cluster dendrogram (Figure 12 and Figure 13, respectively). Full statistical analysis can be found in Appendix B.

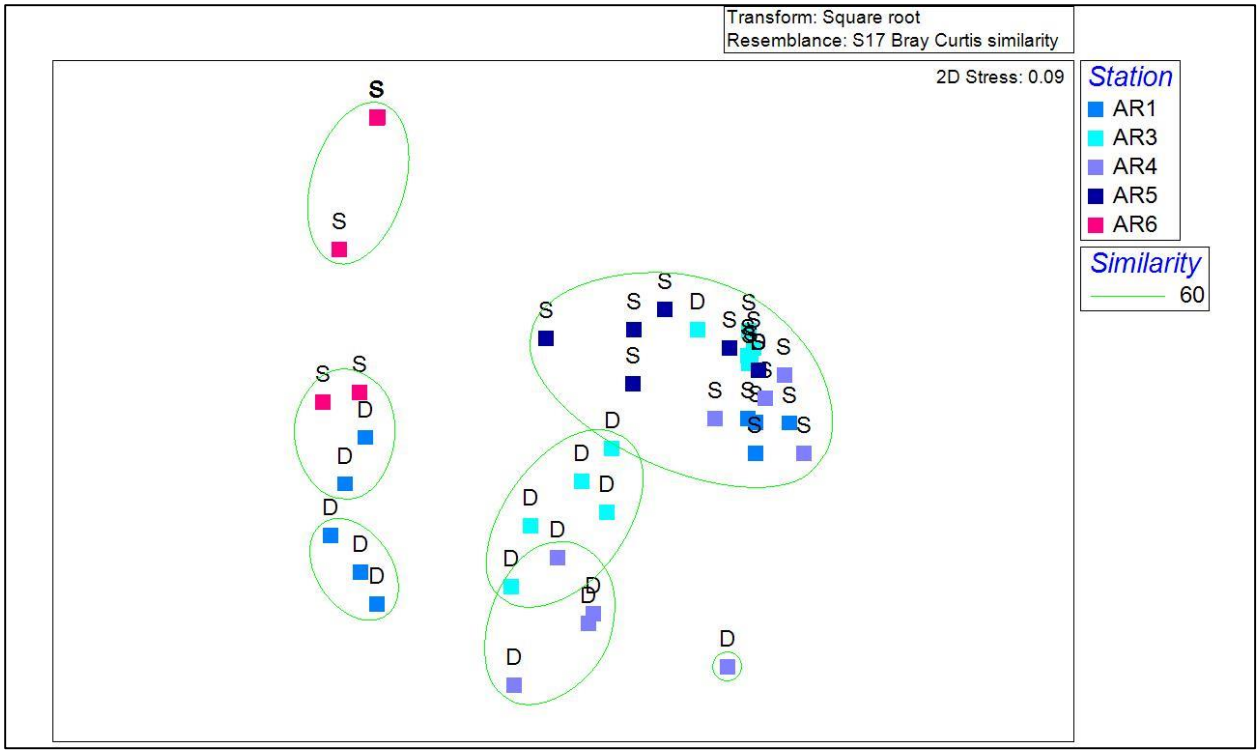


Figure 12. Adjacent Artificial Habitat, September 2015. 2D MSD analysis of each station. Superimposed: 60% similarity level clustering.

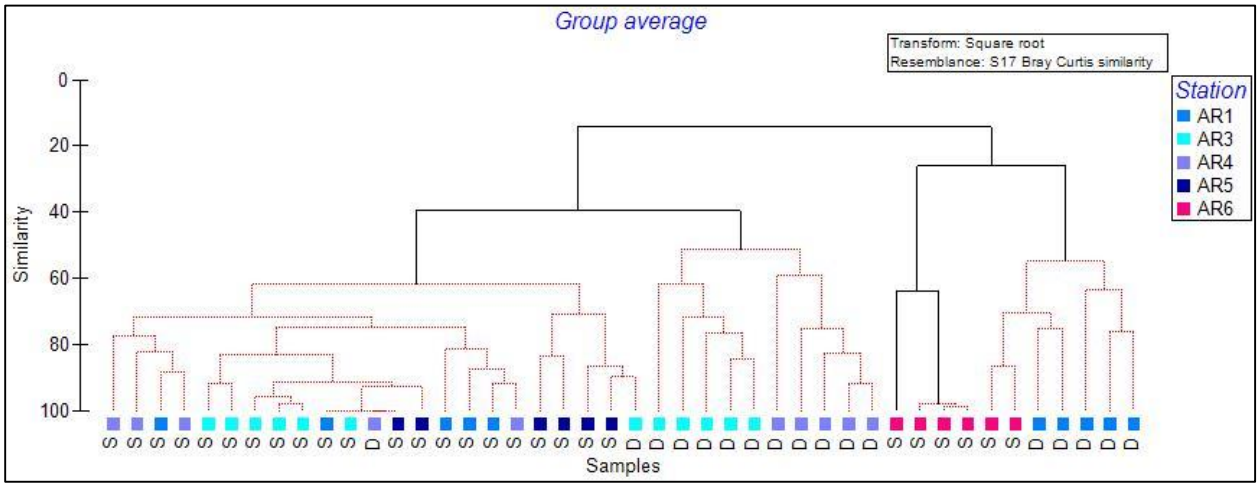


Figure 13. Adjacent Artificial Habitat, September 2015. Cluster analysis. SIMPROF analysis indicates all significant differences (P <0.05) between each of the samples, red being non-significant and black being significant difference.

5 Discussion and General Observations

The survey revealed rich, hard substrate, man-made habitats, with a total of 43 taxa in the six sampling stations including algae, invertebrates, fish, and birds. Only marginal differences in species diversity (Shannon Weiner Index – H') between sampling stations were found, however species diversity differed significantly between deep and shallow stations. Shallow habitats offered higher species richness than deep ones (25 vs 21 species), from total species count of scraped material that was analyzed after retrieving from the water, including mobile organisms that are not included in the point& count analysis. The opposite trend was noted from the point & count analysis (deeper>shallow), which only reflect sessile organisms on the substrate surface, and cannot identify organisms that are covered by algae or other organisms. Algae were dominant in the shallow areas while in deep ones, the most abundant taxa were Polychaetes. The algal abundance in the shallow stations is most likely due to greater light penetration in this zone, combined with a noted supply of nutrients from bird activity on the structures (see below).

Dry weight samples revealed significant differences between stations and depth, with no apparent relation between values of dry weight and the number of taxa. These differences can be attributed to environmental differences between the sampled sites, and due to the range of structures sampled (breaching lighthouses, pier piles and underwater rock pile). Examination of the organic/inorganic ratio in the samples reveled an overall ratio of approximately1:3 with almost 1kg of dry weight per m^2, of which 75 percent were of inorganic material and only 25 percent of organic. Although not all inorganic material is calcium carbonate deposition on the substrate which directly contributes to biogenic build up, these values present noteworthy biogenic buildup capabilities in the area. This is supported by the fact that the most common species found during the survey are known for their significant calcium carbonate deposition capabilities, such as barnacles, bryozoans, tube worms, and oysters.

The age of the structures sampled varied from 2.5 to 16 years, and no clear data on maintenance was available. As a result, obtaining values for rates of biogenic build up was difficult. Nonetheless, the fact that AR6 (Dorothy Fitzpatrick Fishing Pier), the youngest station sampled (2.5 y), presented one of the highest dry weight values found in shallow waters suggests that rates are generally quite high in the area. Furthermore, dry weight values obtained in the current survey are comparable to values found in the literature from areas characterized by the

formation of biogenic reefs both in the tropics (coral based) and in temperate environment (mostly bivalves based) (Perkol-Finkel and Sella, 2014).

5.1 General Observations

The following are observations made by the survey team during the field work, and were recognized as important input for the design process. Only observations that were repeated at more than 60% of the stations were included below, and although these are not a quantitative data, they are considered as important input yielded from the restricted sampling effort.

Due to the basic rock-mound design of the planned breakwaters, most of the observations below came from the four rock pile structures which were inspected in this survey (AR1, AR3, AR4 and AR5; Figure 14), three surface protruding structures (shipping canal lighthouses- Red 42, Red 52, and Red 58) and one fully submerged artificial rock structure (that appears to be the remains of an old sewage pipe- contact 0028).

5.2 Spacing between Building Units

In all rock piles surveyed, surveyors noted clear differences in the composition of species associated with different size spacing between rocks (Figure 14B, F-H). This observation was repeatedly noted at the base of the shipping canal lighthouses. Different size crevices and caves that create sheltered habitats for different size organisms and provided overhangs and ledges were utilized by cryptic species. Rock spacing varied from 1-30 cm (0.5-12 inches) to 0.5-1 m (20-40 inches), with some locations that had more than one opening exposed to the open waters. The larger crevices were especially rich in abundance and richness of fish species as well as motile invertebrates. The bases of the lighthouses were made of larger rocks than the top portions, resulting in more open spaces between units in the deeper portions of the structure. This area also presented divers a larger range of space sizes, as smaller rocks from the top settled between the larger rocks and served to increase complexity. It is important to note that no detached rocks were noted around the structures, suggesting an appropriate design and/or a well maintained structure.

5.3 Orientation of Substrate

According to the sampling protocol, sampling of quadrates was conducted in areas with the highest and most diverse observed benthic cover. At the end of the survey it was noted that 42 out of the 48 quadrates sampled were from vertical or steeply inclined surfaces (Figure 14E). Only station AR5, an underwater rock pile with no vertical surfaces, was large enough for the sampling quadrate, vertical quadrates were not chosen for sampling and horizontal ones were photographed. This is a clear indication for the effect of substrate orientation on the diversity of benthic cover in the area.

Apart from the diversity of the observed benthic cover, one of the most noted differences between substrate orientations was sediment accumulation. It seems that vertical surfaces accumulate less sediment then horizontal ones (the term "vertical" is referring to the overall orientation of substrate, which is an uneven rock surface with different micro habitats – cracks, ledges, indentations and overhangs). At the time of the survey (Sep 15), the most heavily sedimented areas were in the first few feet of water (1-3 ft. deep). This is mainly due to the high algal cover at these depths, which captures the sediment more effectively than the fouling community deeper in the water column. This finding is probably a temporal phase as sediment loads in the area vary with the seasonal changes in wind and currents, as is the algae cover.

Although vertical surfaces showed higher cover in general, it is important to note that the highest values, both for dry weight and taxa number (15), were found in shallow water at horizontal sampling areas of station AR5 S. This station was the only site that presented horizontal shallow substrates as opposed to the lighthouses stations that had vertical or steeply inclined shallow water habitat due to their structural design. The dominance of near vertical surfaces in manmade coastal structures is well documented (Dugan et al., 2011; Firth et al., 2014 and reference therein), as moderate sloped / horizontal habitats are usually poorly represented in man-made coastal and marine infrastructure. Since these habitats are known for supporting high biodiversity and species richness, their presence should be addressed during the breakwaters design process.

5.4 Structure's Sediment "Halo"

All fixed hard substrate stations sampled in this survey had a distinct halo around them, composed of broken shells and other calcium carbonate fractions originating from marine

organisms (Figure 14D). Such a halo or mound is typical to offshore structures and can be seen on breakwaters, jetties, and oil rigs (Schroeder and Love, 2004). The width of the "calcium fractions belt" differed between stations, where the lighthouses presented roughly the same width of ~10m (30f), the concrete pier piles ~3m (9f) and the underwater rock pile (AR5) ~1m (3f). This belt creates a unique habitat where the edge of the hard substrate connects with the sediment. Due to the relatively large grain size within this halo, biogenic material does not seem to clog the crevices in the structure (as might have been the case if finer grain size sediment was found in the area). Therefore, this halo seems to provide additional habitat for cryptic species (Figure 14C), and potentially contributes to reducing the overall sedimentation of the structure, which is often found near the bottom. This, in effect, opens the lower parts of the structure to colonization of organisms which are less tolerant to high sedimentation loads, such as encrusting bryozoans and calcium carbonate secreting tube worms (Serpulidae), both of which are high contributors to biogenic buildup processes.

5.5 Birds

Nesting and feeding birds were observed in all surveyed stations that had protruding surfaces (Figure 14A). This was especially noted on the three lighthouses that had fishing and nesting Cormorants (*Phalacrocorax* sp.) and Seagulls (*Larus* sp.). It seems that bird activity (droppings and carcasses) is a major source for nutrients flushed from the top of the structure, through the intertidal zone and into the water. This nutrient flush, together with high light penetration in the shallow waters around the lighthouses, can potentially account for the high species richness and cover of algae and incrusting sponges that was noted in shallow waters. During the design phase, protruding structures in the area should be designed in order to reduce risk on one hand, and increase the habitat availability on the other, especially for targets species like osprey, boobies, and gannets.

5.6 Fishing Activity

All surveyed stations had notable fishing debris such as fishing lines, hooks, and torn mooring lines. Fishing activities onshore and from boats were noted over the course of the survey, with a distinct increase over the weekend (during the day), when fishing boats (up to 3 at the same time) were moored around each of stations AR1-5, and over a dozen fishermen (at the

same time) were present on AR6 (Dorothy Fitzpatrick Fishing Pier). During the design phase this aspect of recreational fishing activity will need to addressed, in terms of reducing the risk of fishing debris to the developing biological communities, the potential impact of selective fishing on different species, and the safety of users.

Input for Design:

Spacing Between Building Units – Different spacing sizes between rocks corresponded to different species assemblages. Rock spacing varied from 1cm (0.5-inches) to 1m (40 inches). Some of the formed spaces had more than one opening to the water column. Areas that had a variety of spacing sizes had the greatest diversity and abundance of both fish communities and motile invertebrates.

Orientation of Substrate – Within the intertidal zone, horizontal surfaces had a larger quantity and more diverse observed benthic cover than vertical and steeply inclined surfaces. Below the intertidal zone, the opposite was noted, with vertical or steeply inclined surfaces presenting higher cover and diversity than horizontal ones.

Structure's Sediment "Halo" – All hard substrate structures sampled were surrounded by a belt of broken shells and other calcium carbonate fractions originating from marine organisms. This should to be addressed with respect to benthic habitats in the vicinity of the proposed structures.

Birds – Nesting and feeding birds were observed on protruding surfaces of the structures, and were noted as a source for nutrients within the intertidal zone. Increased nutrients, combined with high light penetration in the shallows, are regarded as the key reason for the high species richness and cover of algae in the intertidal area. Future design of protruding structures should address bird habitat creation that can support increased biodiversity, more complex food chains, and increased nutrients flux.

Fishing Activity – Fishing activities and associated debris were noted around hard structures in the area. The design will need to address fishing activities in terms of reducing the amount of debris, impact of selective fishing, and issues of user safety. In addition, any monitoring activity should address fishing activities that might affect data quality.

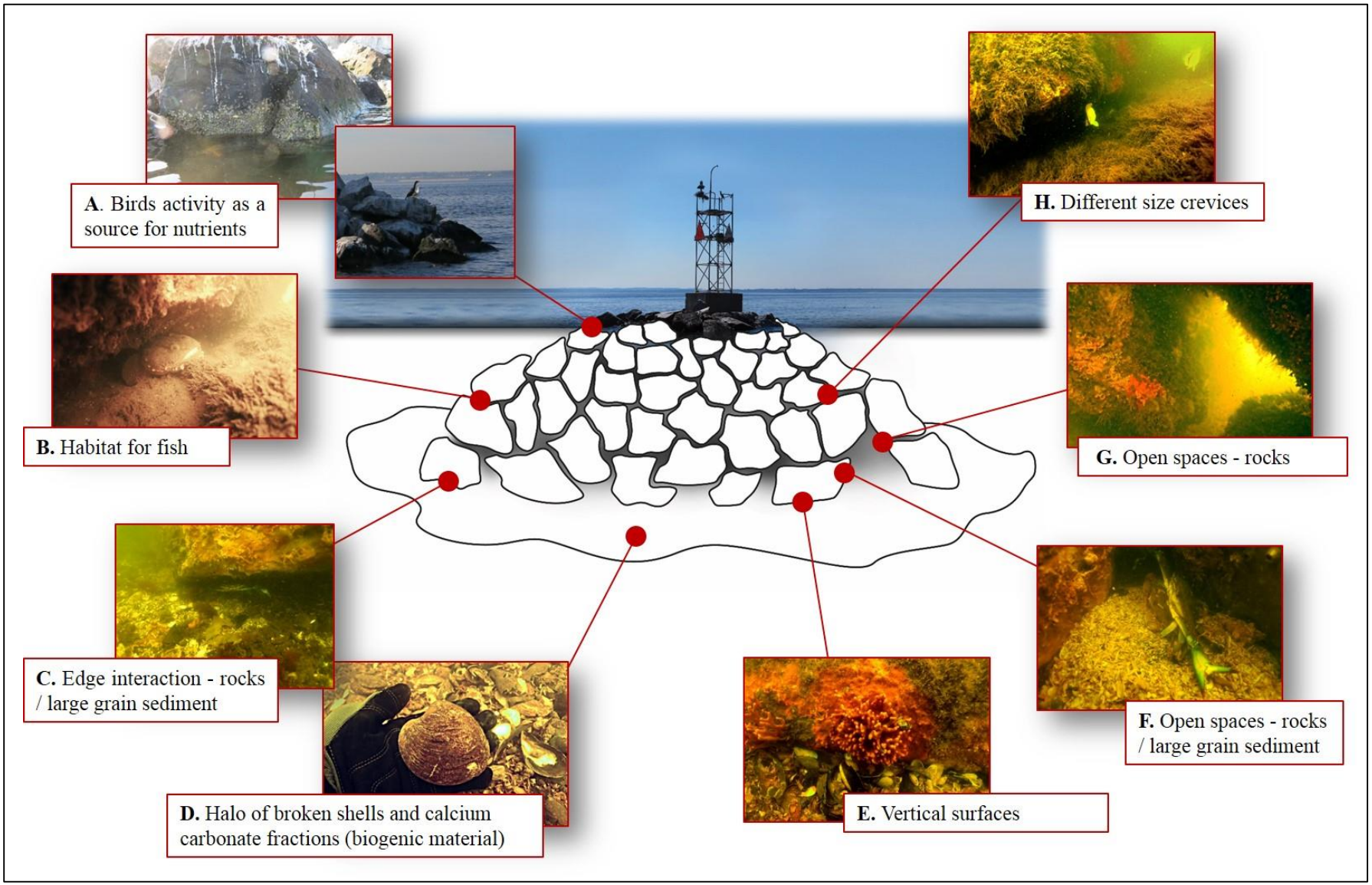


Figure 14. Adjacent Artificial Habitat, September 2015. Observations of biological community on artificial structures in the area. [A] Nesting and feeding birds; [B] Different size sheltered habitats; [C-D] Interactions of hard structure with halo of broken shells and calcium carbonate fractions originated from dethatched marine organisms; [E] Sublittoral vertical or steeply inclined surfaces presenting high cover and diversity; [F-H] Different size spacing between rocks corresponded to different species assemblages.

6 Cited Literature

Anderson, M., Gorley, R., Clarke, K., 2008. PERMANOVA+ for PRIMER. Guid to Software and Statistical Methods. PRIMER-E, Plymouth UK, 214pp

Beijbom, O., Edmunds, P.J., Kline, D.I., Mitchell, B.G., Kriegman, D., 2012. Automated annotation of coral reef survey images, Computer Vision and Pattern Recognition (CVPR), 2012 IEEE Conference on, pp. 1170-1177.

Clarke, K., Gorley, R., 2006. PRIMER v6: User Manual/Tutprial. PRIMER-E, Plymouth UK, 192pp

Clarke, K.R., Somerfield, P.J., Gorley, R.N., 2008. Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage. J Exp Mar Biol Ecol 366, 56-69.

Dugan, J.E., Airoldi, A., Chapman, M.G., Walker, S., Schlacher, T., 2011. Estuarine and coastal structures: environmental effects. A focus on shore and nearshore structures., in: Elliott, M., Dugan, J.E. (Eds.), Treatise on Estuarine and Coastal Science Elsevier New York pp. 17-41.

EPA, 2003. Mid-Atlantic Integrated Assessment. September 16, 2003. Introduced species.

Firth, L., Thompson, R., Bohn, K., Abbiati, M., Airoldi, L., Bouma, T., Bozzeda, F., Ceccherelli, V., Colangelo, M., Evans, A., 2014. Between a rock and a hard place: Environmental and engineering considerations when designing coastal defence structures. Coast. Eng. 87, 122-135.

Hewitt, C., Martin, R., 2001. Revised protocols for baseline port surveys for introduced marine species–design considerations, sampling protocols and taxonomic sufficiency. Centre for Research on Introduced Marine Pests Technical Report.

Pagad, S., Hayek, K., Katsanevakis, S., Costello, M.J., 2015. World Register of Introduced Marine Species (WRIMS).

Perkol-Finkel, S., Sella, I., 2014. Ecologically Active Concrete for Coastal and Marine Infrastructure: Innovative Matrices and Designs, in: Allsop, W., Burgess, K. (Eds.), From Sea to Shore - Meeting the Challenges of the Sea. ICE Publishing, pp. 1139-1149.

Perkol-Finkel, S., Zilman, G., Sella, I., Miloh, T., Benayahu, Y., 2006. Floating and fixed artificial habitats: effects of substratum motion on benthic communities in a coral reef environment. Marine Ecology Progress Series 317, 9-20.

Schroeder, D.M., Love, M.S., 2004. Ecological and political issues surrounding decommissioning of offshore oil facilities in the Southern California Bight. Ocean Coast Manage 47, 21-48.

Appendix E-5
Living Breakwaters Design Modeling Report

LIVING BREAKWATERS

30% DESIGN MODELING REPORT

Date: January 25, 2017

Prepared by: ARCADIS

version	Date	Notes
1.0	March 16, 2016	Baseline Modeling Report - Preliminary Draft.
2.0	June 10, 2016	Baseline Modeling Report - Updated Draft
3.0	October 12, 2016	30% Design Modeling Report
4.0	January 25, 2017	30% Design Modeling Report Final

TABLE OF CONTENTS

Table of Contents **2**

List of Acronyms **4**

Glossary of Terms **5**

Introduction **8**

Project Overview 8

Modeling Overview 8

Wave Transformation Modeling **10**

SWAN Model Overview 10

Model Inputs 11

Simulation Results 16

Conclusions 24

Shoreline Change Analysis **25**

Orthoimagery-Based Historical Shorelines 25

Uncertainty Estimates 29

Hurricane Sandy Shoreline Response 31

Shoreline Change Modeling **34**

GENESIS Model Overview 34

Baseline Model Inputs 35

Model Calibration and Validation 38

Baseline Simulations 38

30% Design Simulations 43

Conclusions 44

Design Wave Transformation Near Breakwaters **45**

REFDIF Model Overview 45

Baseline Model Inputs 46

Baseline Simulations 47

30% Design Simulations 53

Conclusions 61

Storm Induced Profile Response Modeling **62**

SBEACH and CSHORE Model Overview 62

Baseline Model Inputs 63

Baseline Simulations 72

30% Design Simulations 82

Conclusions 84
Water Circulation Modeling 85
Delft3d Model Overview 85
Baseline Model Inputs 85
Residence Time Modeling Setup 93
Residence Time Simulation Results 95
Conclusions 98
Summary and Conclusions 99
References 101
Appendix A – 30% Design Modeling Results Report
Appendix B – SBEACH and CSHORE Simulations

LIST OF ACRONYMS

ADCIRC	ADvanced CIRCulation numerical model
ADCP	Acoustic Doppler Current Profiler
CSHORE	Cross-SHORE beach erosion model
FEMA	Federal Emergency Management Agency
GENESIS	GENEralized model for SImulating Shoreline change
GEV	Generalized Extreme Value
LiDAR	Light Detection and Ranging
MHW	Mean High Water
MLLW	Mean Lower Low Water
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NYCDOITT	New York City Department of Information and Technology
NYSDEC	New York State Department of Environmental Conservation
PFIRM	Preliminary Flood Insurance Rate Map
REFDIF	REFraction DIFfraction numerical model
SBEACH	Storm-induced BEAch Change beach erosion model
SWAN	Simulating WAves Nearshore wave transformation model
TSPP	Tottenville Shoreline Protection Project
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WIS	Wave Information Studies

GLOSSARY OF TERMS

Astronomical Tide: Tidal levels resulting from gravitational effects from the sun and moon.

Backshore: Upper part of the active beach, above normal reach of high tides.

Bathymetry: Measurement of water depths for a given area.

Beach: Deposit of non-cohesive material situated on the interface between dry land and a large expanse of water.

Beach Profile: Cross-section taken perpendicular to the shoreline. Shows elevation change across offshore, swash, beach, and backshore zones.

Berm: Horizontal plateau on the beach face.

Bluff: High steep bank or cliff.

Breakwater: Offshore structure aligned parallel to the shore that provides protection from wave activity.

Cross Shore: Perpendicular to the shoreline.

D_{50} Sediment Size: Median particle diameter.

Depth of Closure: Offshore limit at which wave energy begins to have a negligible effect on shoreline change.

Diffraction: Multi-directional spreading of waves when entering a sheltered region.

Downdrift: Direction of predominant sediment movement.

Dune: Small hills or ridges of accumulated sand.

Extratropical Storm: Storm with cold air at its core that derives energy from release of potential energy when cold and warm air interact (Nor'Easters).

Foredune: Dune feature (beach slope fronting the dune) closest to the water.

Groin: Shore-protection structure extending roughly perpendicular from the shoreline.

Hindcast: Retrospective forecasting of waves using measured wind and wave information.

Hydrodynamics: Dealing with the motion of fluids.

Longshore: Parallel to the shoreline.

Neap Tide: Tides that rise and fall the least as a result of the moon being in quadrature.

Nearshore: Zone extending seaward from the shoreline including the breaker and swash zones.

Offshore: Direction seaward of the shore.

Onshore: Direction landward of the shore.

Orthoimagery: Image of the Earth's surface from satellite or airborne sensors.

Overwash: Part of the wave run-up that runs over the crest of a dune and does not flow directly back to the ocean. The effect of overwash is carrying sediment landwards.

Refraction: Effect by which the direction of a wave changes upon entering shallower water.

Return Period: Statistical period of time between occurrences of a given event. E.G. a 10-year storm event is a storm that produces surge elevations that occur on average once every 10 years.

Run-up: Vertical height above stillwater elevation that the rush of water up a beach reaches after the breaking of a wave.

Shoaling: Effect by which the height of a wave increases upon entering shallower water.

Significant Wave Height: Average height of the highest one-third of waves for a given wave climate.

Spectral Model: Wave model that simulates the sea surface as a spectrum of waves of varying frequencies.

Spring Tide: Tides that rise and fall the most as a result of a new or full moon.

Stillwater Elevation: Water surface elevation without wave action.

Storm Surge: Water elevation increases due to reduced atmospheric pressure, the onshore advection of water by winds, and wave setup by breaking waves.

Storm Tide: Storm surge plus astronomic tide without wave action.

Synthetic Storm: Hypothetical storm created using combinations of storm parameters from the historical storm record. Because severe storms are infrequent, the historical record does not capture all plausible combinations. Synthetic storms capture this variability statistically sampling historical storm parameters to create a suite of storms used in model simulations.

Swash Zone: The area of the shoreline where wave breaking occurs, extending from the limits of wave rundown and wave runup relative to the mean water level.

Tidal Flushing: Replacement of the water in an enclosed area by action of tidal currents.

Time Series: Series of values of a quantity obtained at successive times. Wave and surge time series are wave height and surge elevations at regular intervals (e.g. 1 hour) throughout the entirety of a storm event.

Transect Profile: See Beach Profile.

Tropical Storm: Storm with warm air at its core that derives its energy from the latent heat released when water vapor condenses into liquid.

Wave Direction: Direction from which the waves are coming.

Wave Height: Vertical distance between the crest (high point) and trough (low point) of the wave.

Wave Length: Distance between two successive wave crests.

Wave Period: Time required for two successive wave crests to pass a fixed point.

Wind Direction: Direction from which the wind is coming.

INTRODUCTION

PROJECT OVERVIEW

The Living Breakwaters project is an innovative implementation of coastal green infrastructure that aims to increase physical, ecological, and social resilience. The project is located in the waters of Raritan Bay (Lower New York Harbor) along the shoreline of Tottenville and Conference House Park in southern Staten Island. The Living Breakwaters, as currently proposed, consist of an approximately 1-mile-long system of breakwaters, with reef habitat enhancements.

The goals of the Living Breakwaters project are three-fold:

1) To reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville.

2) To enhance habitat functions and values supporting local ecosystems through the creation and improvement of near shore and coastal habitat.

3) To foster stewardship, recreational use, and educational use of the coast and nearshore through increased awareness, access, and participation.

MODELING OVERVIEW

To inform the design and the benefits of the Living Breakwaters, an understanding of the wave conditions and the shoreline response to the project are required. Additionally, understanding of the hydrodynamics and water circulation patterns will aid in understanding any potential water quality impacts of the breakwater system. In the following sections, the modeling and analysis performed to develop baseline wave conditions, shoreline response, and tidal currents are described. Some of these models were then used to evaluate potential breakwater alternative scenarios. An outline is summarized below:

- **Wave Transformation Modeling** – Development of nearshore wave conditions by transforming wave conditions in the offshore to the nearshore using the Simulating Waves Nearshore (SWAN) wave transformation model.

- **Shoreline Change Analysis** – Development of historical shoreline positions from orthoimagery to inform critical areas of shoreline change, and to provide data for which shoreline change modeling can be calibrated and validated.

- **Shoreline Change Modeling** – Long-term shoreline change modeling using the GENEralized model for SImulating Shoreline changes (GENESIS) with simulation results calibrated and validated to the historically observed shorelines presented in the Shoreline Change Analysis section. The model was used to screen alternative scenarios and to assess the 30% design scenario.

- **Design Wave Transformation Near Breakwaters –** Modeling of the transformation of design wave conditions in proximity to the Living Breakwaters using the REFraction DIFfraction (REFDIF) wave model.

- **Storm Induced Beach Profile Response Modeling –** Modeling of beach profile change in the project region outside the Tottenville Shoreline Protection Project (TSPP) using the Storm-induced BEAch CHange (SBEACH) and Cross-SHORE (CSHORE) beach erosion models.
- **Water Circulation Modeling –** A tidal circulation model will be used to assess preliminary potential water quality impacts using the 2D hydrodynamic mode of the Delft3D-FLOW model.

The results presented in the sections identified above will inform baseline wave conditions, water circulation, and shoreline change behavior for the without-project conditions. These baseline results will also help inform the performance of proposed Living Breakwaters layouts and geometries by optimizing their design to achieve the goals of reduced erosion and reduced wave exposure. The alternative scenarios (with-project) will also be modeled, and the results compared to the baseline conditions (without-project).

Modeling efforts have focused on advancing the breakwater layout for the selection of a 30% design preferred scenario. Initial efforts examined scenarios designed to evaluate the impact of breakwater length, spacing, and distance from shore on long-term shore change (erosion and accretion). Wave climate in the lee of the proposed breakwaters were also examined during these initial scenarios. Further simulations were then performed on potential breakwater system configurations to determine system performance at storm wave attenuation and erosion reduction/reversal, and to evaluate various layout options. Aided by these results a 30% design scenario was developed.

This report builds on and supersedes the Baseline Monitoring Report.

WAVE TRANSFORMATION MODELING

In the project area no long-term measured or modeled wave records exist. To support the design layout and geometry of the Living Breakwaters, the long-term wave climate in the nearshore adjacent to the potential Living Breakwaters alignments was developed. This section discusses the use of the SWAN wave transformation model to transform U.S. Army Corps of Engineer (USACE) wave hindcast data from the entrance of New York Harbor to the project area. From the long-term wave climate data, return period wave statistics are estimated which can further assist the design team in advancing the design and layout of the Living Breakwaters. Additionally, the long-term wave climate will form the boundary conditions to the shoreline change modeling presented in the Shoreline Change Modeling section.

SWAN MODEL OVERVIEW

The Simulating WAves Nearshore (SWAN) wave transformation model has been applied for the determination of wave condition estimates in coastal areas by a global community of researchers and engineering consultants. The model is frequently updated with the most current developments from the research community. The current version, used in this study, is version 41.01 (SWAN, 2006).

For wave transformation modelling in Lower New York Bay and Raritan Bay, the SWAN model is capable of simulating the important wave processes that govern the generation and transformation of waves from offshore to nearshore adjacent to the project site. The following relevant wave processes are simulated in SWAN:

- Wind-wave generation (wave growth due to winds)
- Shoaling (increase in wave height as waves enter shallower water)
- Refraction (change in direction of waves caused by changing water depth)
- Energy changes due to bottom friction, wave breaking, whitecapping, and wave-wave interactions

SWAN is a spectral model that allows concurrent modeling of higher-frequency, locally generated wind waves and lower-frequency waves that are generated farther offshore. SWAN is also capable of simulation in a parallel computing environment, which is important for long-term wave climate estimates.

The intent of the current wave simulation is to transform 30 years of hourly wave data offshore to usable wave climates at the project site. The following sections describe offshore wave data, water levels, wind forcing, and other model parameters used in the simulation. The results of the 30-year wave transform are then presented along with return period wave statistics that will help support design of the Living Breakwaters.

MODEL INPUTS

OFFSHORE WAVE DATA

Hourly hindcast wave data were available from 1982 to 2012 at the USACE's Wave Information Study (WIS) station #63126 (Jensen, 2010). The station location is shown on Figure 1. Station #63126 is the closest hindcast data available for Staten Island. The hourly wave condition data from WIS station #63126 were applied at the offshore boundary of the SWAN model for transformation to the Living Breakwaters project site.

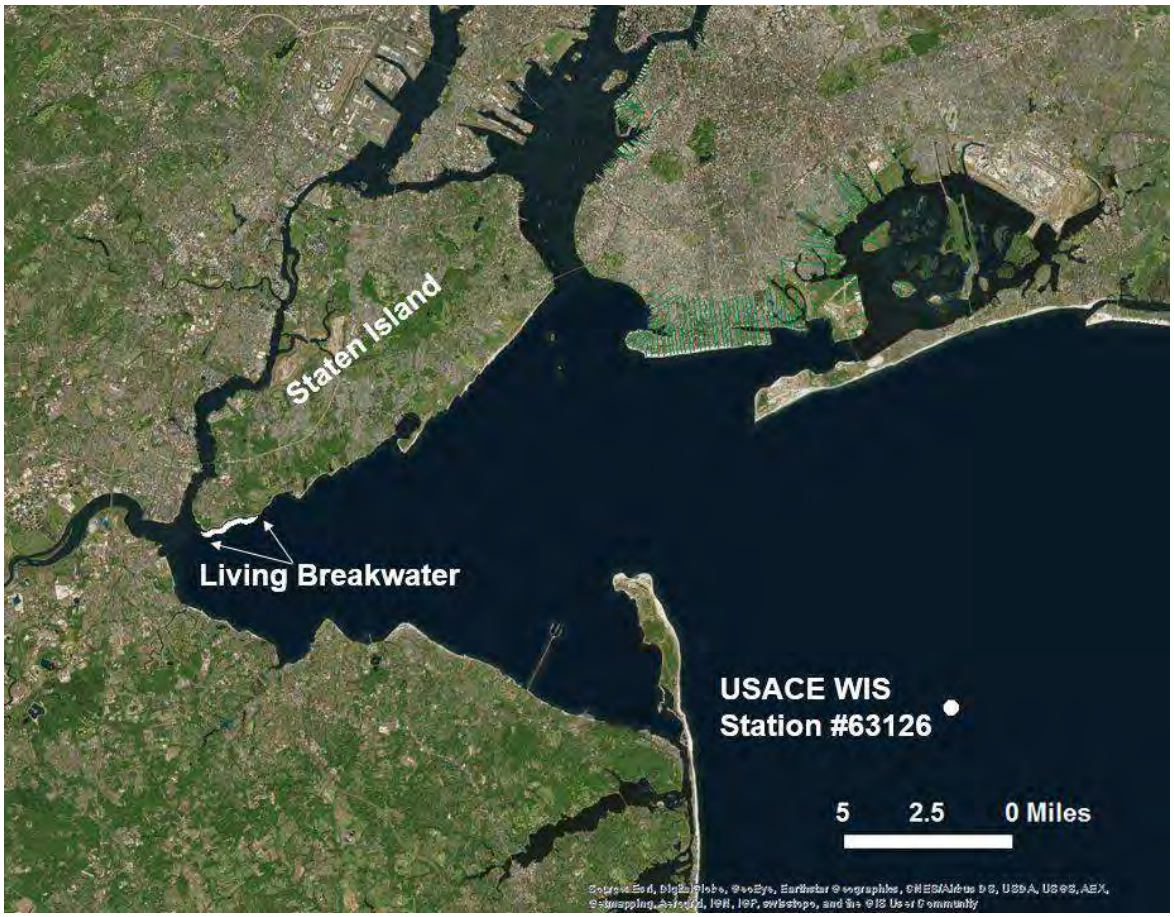


Figure 1. Location of USACE WIS station #63126 hourly wave hindcast data.

WATER LEVELS

Water level variation due to astronomical tide and storm surge was included in the wave model. Inclusion of water level variation improves wave transformation modeling, especially in the nearshore areas close to the Living Breakwaters. Water levels measured at the National Oceanic and Atmospheric Administration's (NOAA's) Sandy Hook station #8531680 were available over the 30-year simulation period. The NOAA Sandy Hook station, shown on Figure 2, is the closest to the project site.

Figure 2. Location of water level measurements at NOAA's Sandy Hook station #8531680.

WINDS

Long-term wind measurements were available at the following locations adjacent to the project site:

- John Fitzgerald Kennedy (JFK) Airport
- Newark Airport
- Sandy Hook
- Bergen Point

These locations are shown on Figure 3.

A comparison between each of the four measurement sites was made to determine if a better modeling approach would be to perform a spatial interpolation to define a spatially varying wind field or to simply apply a spatially uniform wind field. To compare each measurement location, all wind data were adjusted to the standard 10-meter elevation using the 1/7th power law (USACE, 1984) and to an over-water equivalent using a 0.85 coefficient (Simiu et al., 2007).

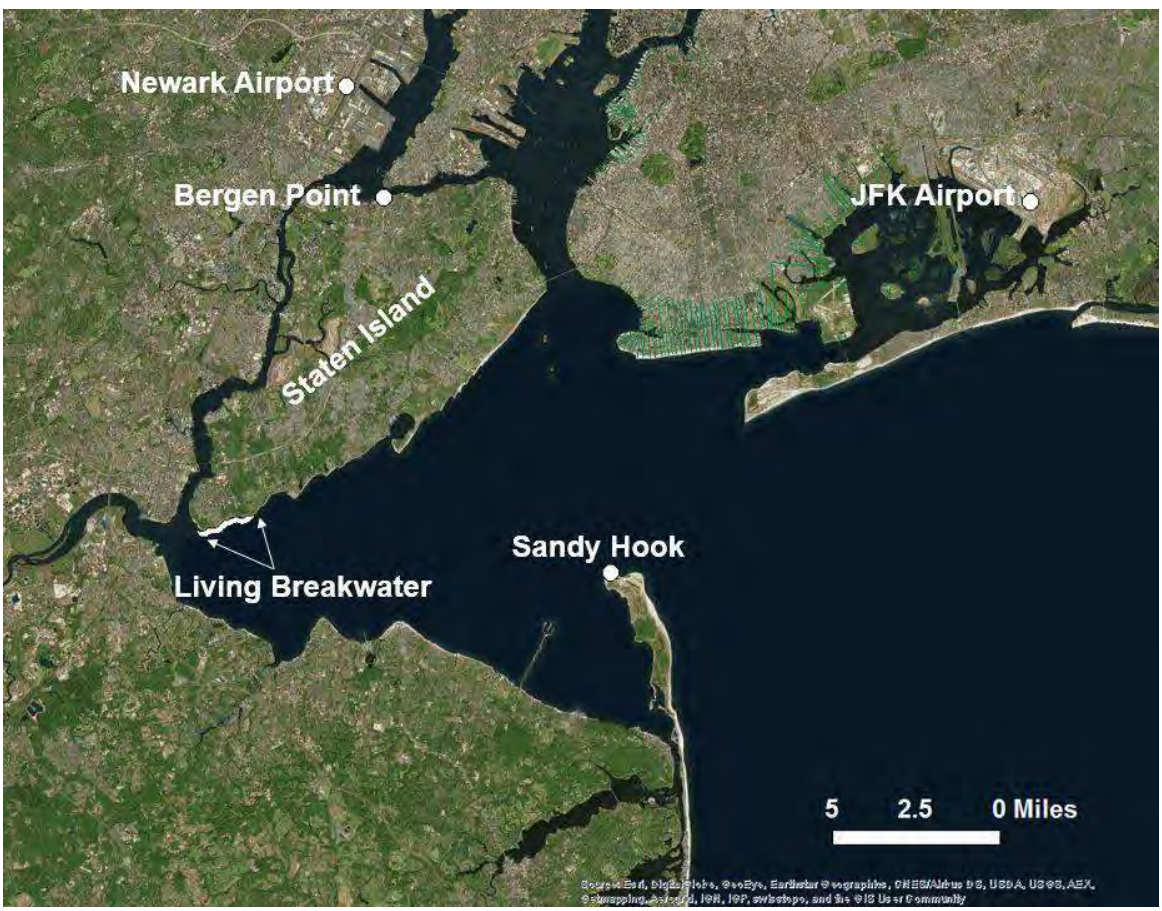


Figure 3. Location of nearest wind measurement locations: Newark Airport, JFK Airport, Sandy Hook, and Bergen Point.

As an example, Figure 4 compares measured wind data for the month of January 2012. Because of the general correlation of wind speed and direction between the four measurement locations, the wind field from the Newark Airport gage was selected for use in the SWAN model. As will be discussed in the Comparison to Measurements section, it was found that Newark Airport winds resulted in the best reproduction of SWAN-simulated waves relative to actual wave measurements.

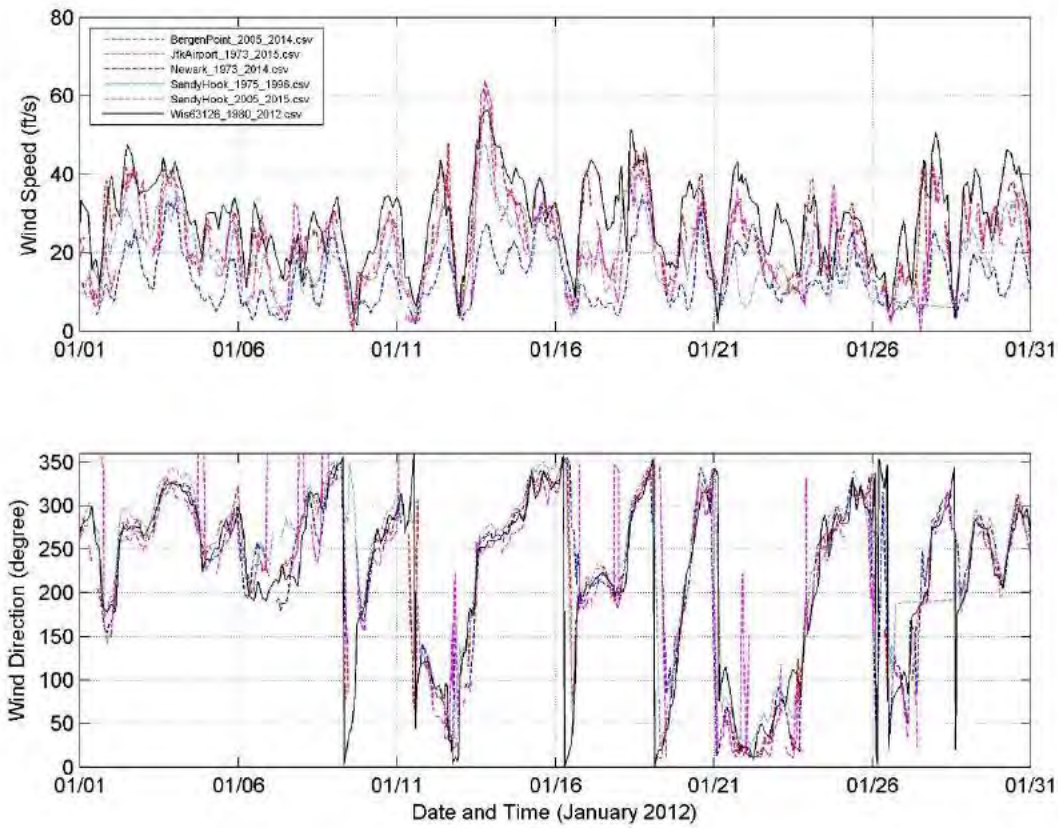


Figure 4. Comparison of wind measurements at four nearby locations during January 2012. Top image: wind speed in meters per second. Bottom image: wind direction in degrees clockwise from north.

BATHYMETRIC GRID

The computational grid for the SWAN model is shown on Figure 5. A 300-meter rectangular grid is refined in the nearshore areas to 50 to 100 meters. The bathymetric and topographic information assigned to the computational grid was the same developed as part of the Federal Emergency Management Agency's (FEMA's) Region II coastal analysis performed for New York City and New Jersey (FEMA, 2014a). Nearshore data in the vicinity of the Living Breakwaters obtained by multi-beam bathymetric and beach transect survey superseded FEMA's information within the survey limits (Hill International, 2015; MFS, 2015).

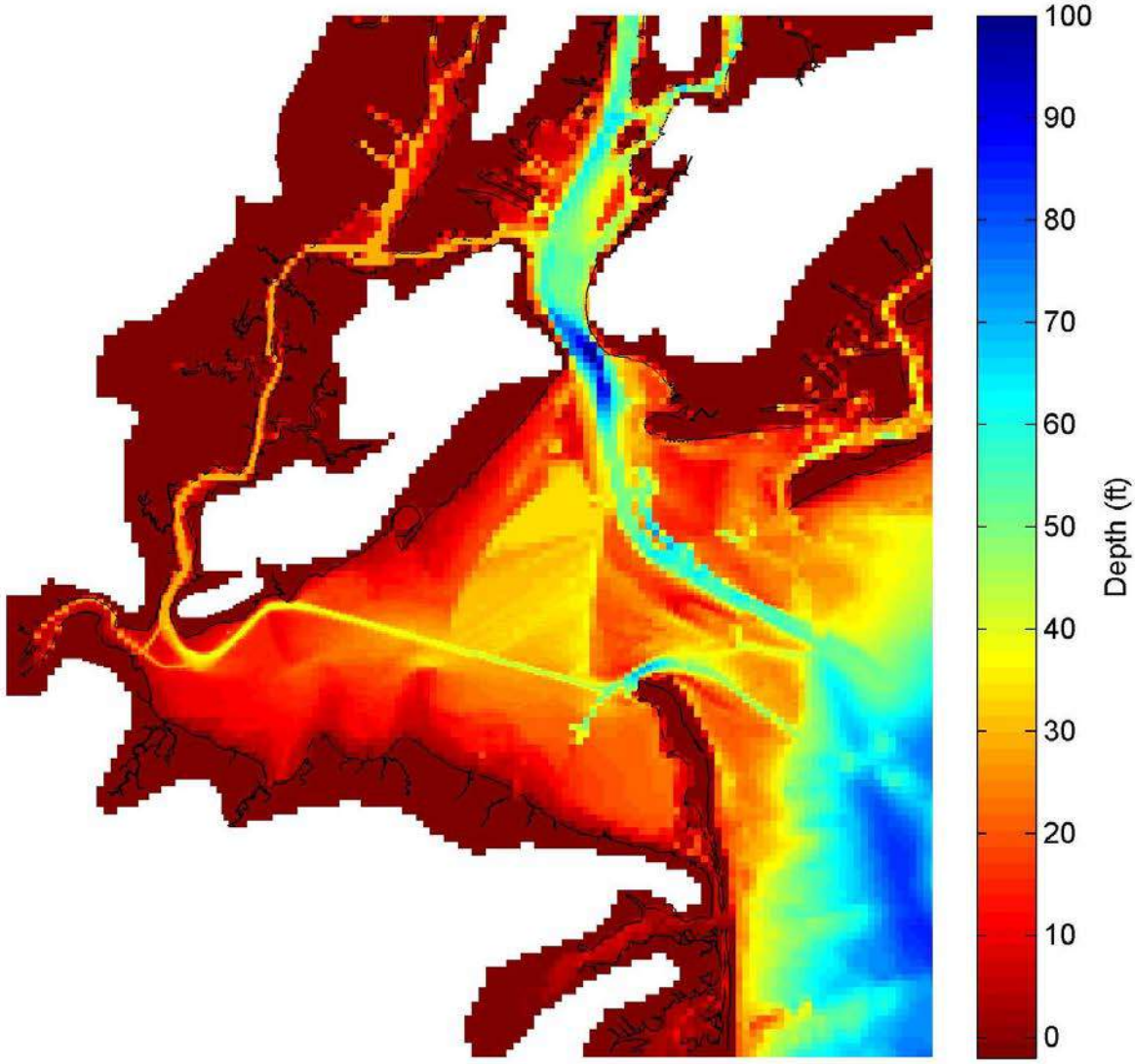


Figure 5. Bathymetry/topography (in feet) included in the SWAN model.

SIMULATION RESULTS

COMPARISON TO MEASUREMENTS

Simulation results from the SWAN model were validated against wave measurements made by an Acoustic Doppler Current Profiler (ADCP) deployed by Rutgers University from January 2012 to April 2012 (Roarty, 2016). The ADCP measurement location is shown on Figure 6.

Figure 6. Location of Rutgers ADCP measurements relative to the Living Breakwaters project site.

A comparison of measured versus simulated wave height (significant wave height), wave period, and wave direction is shown on Figure 7 for January 2012. During the comparison of simulated to measured wave heights, it was determined that Newark Airport winds resulted in the best match.

Figure 8 compares measured to simulated wave heights (significant wave height) for the full period of the Rutgers ADCP measurements.

In general, the simulated wave conditions match the measured wave conditions well. Short spikes in wave period and wave direction were observed in the Rutgers ADCP data. Given that no additional data filtering was performed on the data received from Rutgers, it is unclear if the source of short spikes in the measurement record is real observations or measurement noise that requires filtering. Ship wakes could play a role in producing wave period and wave direction spikes, especially considering the proximity of the Rutgers ADCP to navigation channels.

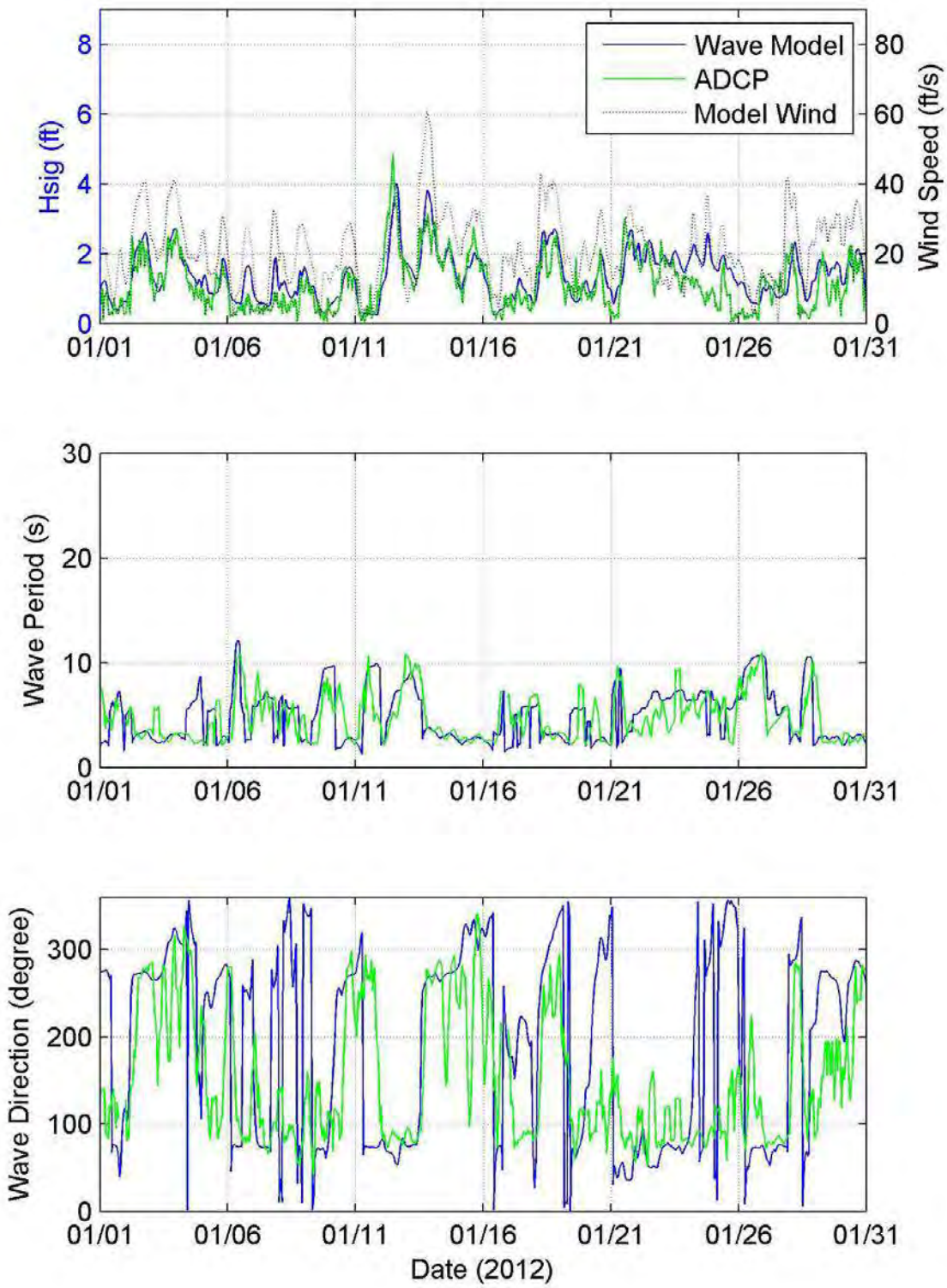


Figure 7. Comparison of simulated versus measured wave conditions for January 2012 at the Rutgers ADCP measurement location. Significant wave heights (top), wave periods (middle), and wave direction (bottom) in degrees clockwise from north.

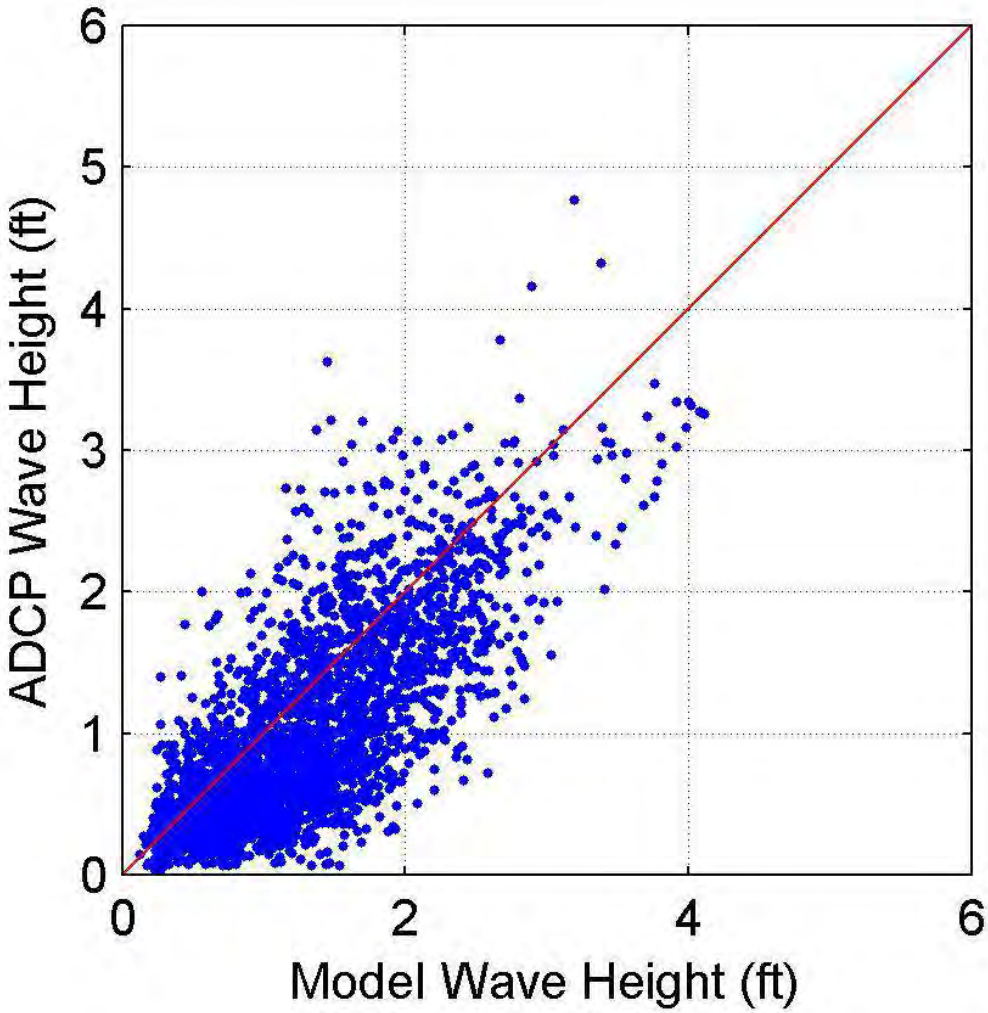


Figure 8. Comparison of model wave height to Rutgers ADCP wave height measurements between January and April 2012. The red line indicates a 1:1 match between measured and modeled wave heights.

NEARSHORE WAVE RESULTS

Wave transformation results were extracted in the vicinity of the potential breakwater alignment at eleven primary locations and eleven secondary locations. The primary locations are in the approximate limits of where breakwater alignments are proposed. Secondary locations are at the nearshore limit of the existing navigation channels. These extraction locations are summarized on Figure 9.

Figure 9. Wave transformation result locations.

p – indicates primary locations inside the proposed breakwater alignment.
s – indicates secondary locations adjacent to the navigation channels.

The 30-year, hourly wave data are summarized as wave roses at each of the primary locations, p1 through p11, on Figure 10. At eastern-facing locations, p3 through p11, the dominant wave direction is from the east nearly 20% of the time. The majority of waves are less than 0.4 meters (1.3 feet), with storm events resulting in wave heights in the 0.4 to greater than 1 meter (1.3 to greater than 3.3 feet) range from the east. At southern-facing locations, p1 and p2, Figure 10 demonstrates that the dominant direction shifts toward the southeast.

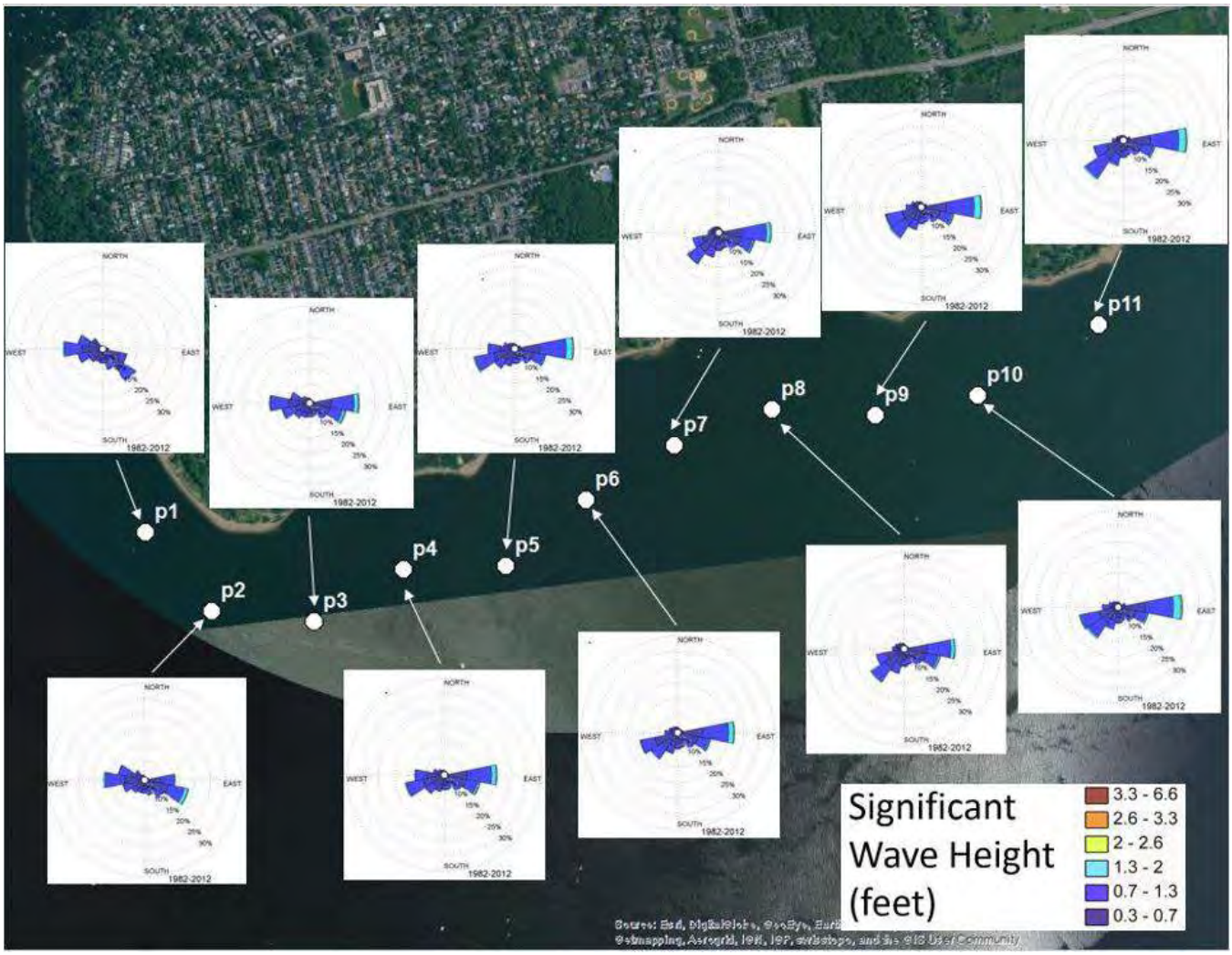


Figure 10. Wave roses of the 30-year hourly wave transformation results at primary locations p1 through p11. Significant wave heights in meters.

The wave transformation results at the secondary reporting locations, adjacent to the navigation channels, are shown on Figure 11. As was noted for the preliminary locations, for eastern-facing locations the dominant wave direction is from the east. For relatively southern-facing locations, the dominant wave direction shifts toward the southeast and southwest.

The wave field direction during a storm event was compared to the FEMA Preliminary Flood Insurance Rate Map (PFIRM) simulation results for the October 2005 event (FEMA, 2015). The FEMA PFIRM analysis was performed using the SWAN model as well. Figure 12 confirms an easterly direction for incoming wave directions in the vicinity of the Living Breakwaters site. Further comparisons of the wave transformation results to FEMA PFIRM results will be made in the Return Period Wave Conditions section.

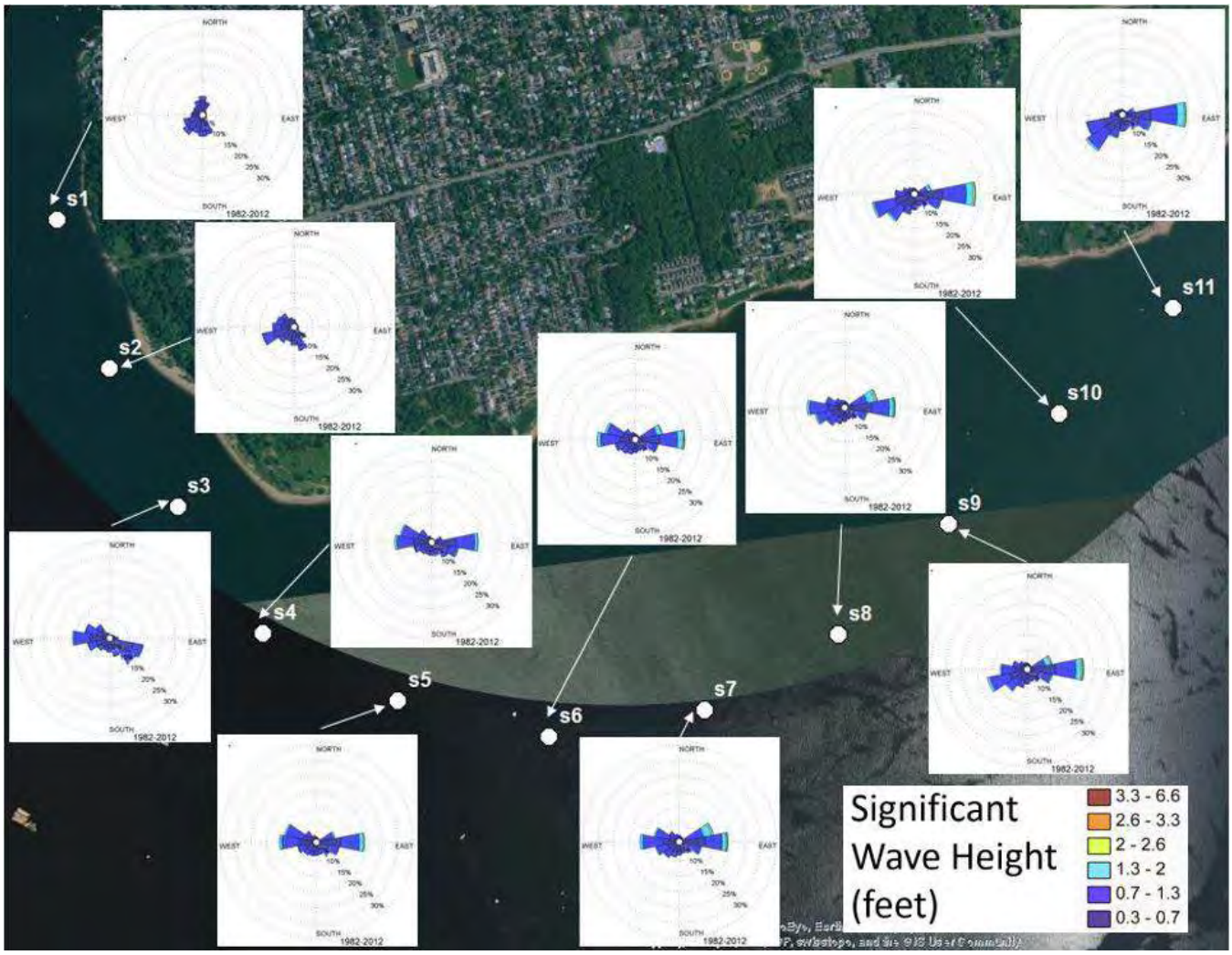


Figure 11. Wave roses of the 30-year hourly wave transformation results at secondary locations s1 through s11. Significant wave heights in meters.

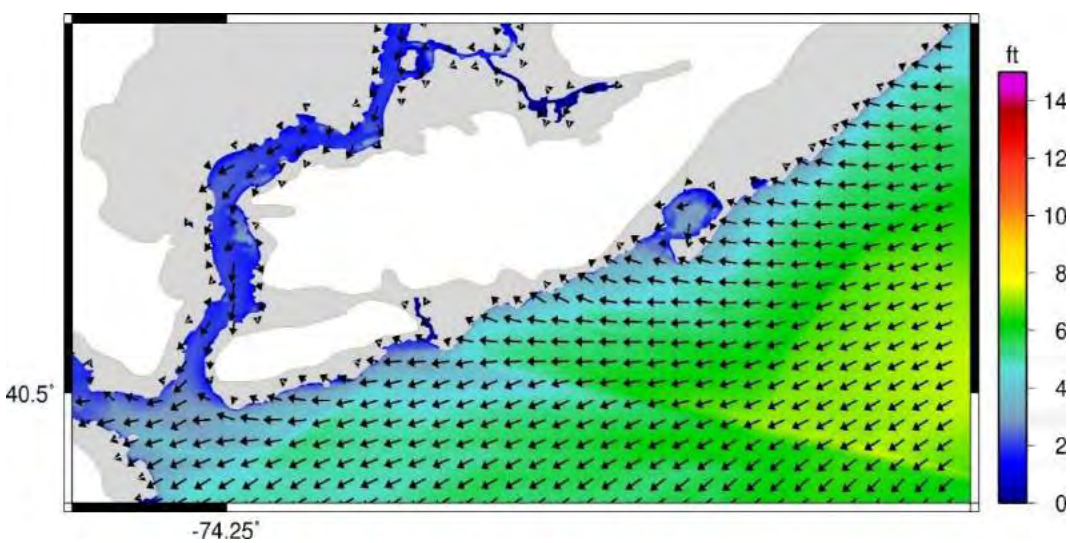


Figure 12. Wave directions during the FEMA PFIRM October 2005 event.

Waves arrive at the project site predominately from two general directions: ocean generated swells enter Raritan Bay past Sandy Hook from the East-Southeast (90- 120 degrees from North) and locally generated wind waves travel across the bay to the project area from the Southwest (195-240 degrees from the North). Over 70% of the waves observed over the past 30 years come from these two directional bands. The highest waves are driven on shore by storm events, which may come from any direction. However, analysis of wave conditions at the project site from the transformed wave hindcast data show that over the 30 year period, the largest significant waves come from the east and southeast. For the thirty years of modeled wave data 100% of the hourly significant waves over three feet in height came from the easterly to southeasterly direction and 56% of waves over 1.5 feet came from this direction.

RETURN PERIOD WAVE CONDITIONS

Location p6, shown on Figure 9, was selected as a primary location, central to the breakwater layout, for analysis and comparison of wave statistics. Return period wave conditions help to inform design conditions at the breakwaters site and to compare model outputs to studies performed by others in Raritan Bay. To estimate representative return wave periods, the transformed 30-year hourly wave data were used.

Annual maximum wave heights from each year of the simulation period (1982 to 2012) were used to estimate return period wave conditions. The Weibull, Gumbel, and Generalized Extreme Value (GEV) distributions were fit to the transformed annual maximum wave data. Comparing the best-fit from each of the three distributions, it was determined that the Gumbel distribution provided the best return period wave statistics for the transformed 30-year hourly wave data.

The wave heights for various return periods determined using the Gumbel distribution are summarized in Table 1. The wave heights shown in Table 1 were compared to the FEMA PFIRM values (FEMA, 2015). To develop the FEMA PFIRM significant wave height return periods, peak storm tide and the coincident significant wave height (at peak storm tide) were extracted from the 189 storm events that formed the FEMA PFIRM coastal analysis (30 historical extratropical storms and 159 synthetic tropical storms). FEMA PFIRM wave data were extracted at a location very close to the SWAN extraction location p6 in a water depth of -7.5 feet mean sea level.

A correlation between return period storm tide and return period significant wave height was developed from the FEMA PFIRM data as shown on Figure 13. An example determination of the 100-year wave height using the correlation to the published 100-year storm tide is also shown on Figure 13. This procedure of determining return period wave heights from the published FEMA PFIRM return period storm tides was also employed by the USACE for the Raritan Bay and Sandy Hook Bay, New Jersey, coastal storm risk management study (USACE, 2015a).

The FEMA PFIRM return period significant wave height closely matches the Gumbel distribution of the 30-year transformed wave data for all return periods, as shown in Table 1. The FEMA PFIRM return periods are approximately 3% to 10% less than the return periods of the Gumbel distribution over the range of return periods that are compared.

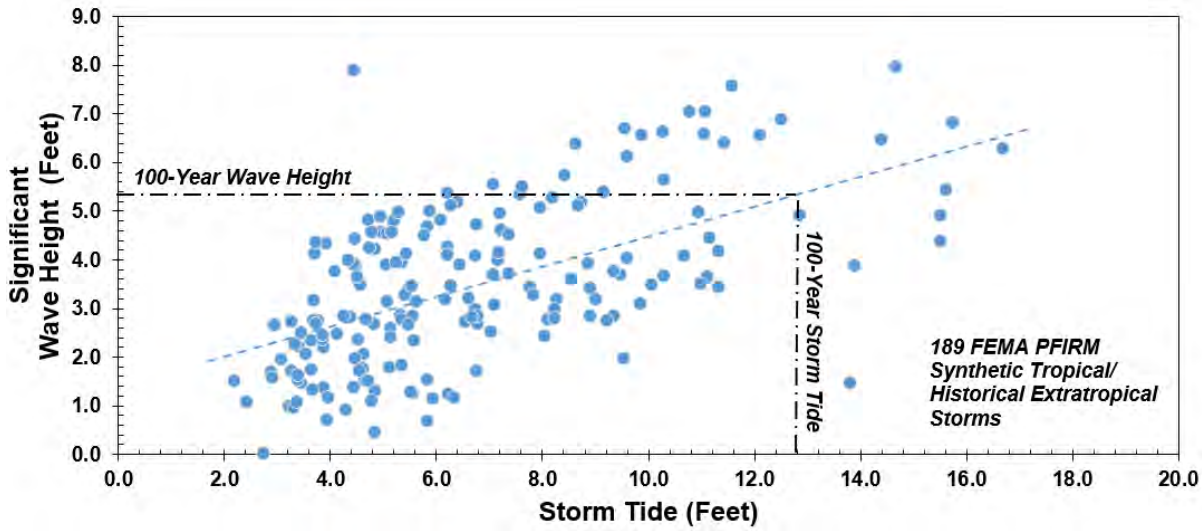


Figure 13. Significant wave height versus storm tide for each of the 189 synthetic tropical and historical extratropical storms of the FEMA PFIRM coastal analysis. Estimate of 100-year wave height at the published 100-year storm tide is shown (FEMA, 2015).

An additional comparison was made between wave condition return periods estimated from the 30-year transformed wave data at the location of the Rutgers ADCP site to return period wave conditions reported by the USACE (CERC, 2001). The Rutgers ADCP location correlates with validation of the SWAN model outputs and is in deep water similar to the USACE location (USACE reports the return period at -17 feet mean sea level west of Great Kills Harbor).

Table 2 shows the significant wave height return period correlation between the Gumbel distribution fit to the 30-year transformed wave data and the USACE study. The USACE study predicts higher return period significant wave heights for return periods less than the 25-year. However, the Gumbel distribution best-fit return periods are within 1% of the USACE study for the 50-, 100-, and 500-year return periods.

Table 1. Return period significant wave height for the Gumbel distribution best-fit to the 30-year transformed wave results at location p6. FEMA PFIRM return period significant wave heights for comparison (FEMA, 2015).

Significant Wave Height (Feet)		
Return Period	**Gumbel**	**FEMA PFIRM**
2 Year	**2.8**	**--**
5 Year	**3.6**	**--**
10 Year	**4.0**	**3.9**
25 Year	**4.7**	**4.3**
50 Year	**5.1**	**4.9**
100 Year	**5.6**	**5.3**
500 Year	**6.6**	**6.4**

Wave data near location p6 in a water depth of approximately -7.5 feet mean sea level.

Table 2. Return period significant wave height for the Gumbel distribution best-fit to the 30-year transformed wave results at the Rutgers ADCP location. USACE return period significant wave height for comparison (CERC, 2001).

Significant Wave Height (Feet)		
Return Period	**Gumbel**	**USACE 2001**
2 Year	**5.2**	**5.8**
5 Year	**6.0**	**6.5**
10 Year	**6.6**	**7.1**
25 Year	**7.4**	**7.5**
50 Year	**7.9**	**7.9**
100 Year	**8.5**	**8.4**
500 Year	**9.7**	**9.7**

SWAN data at Rutgers ADCP station. USACE at -17 feet mean sea level, west of Great Kills Harbor.

CONCLUSIONS

The SWAN wave transformation model was used to develop wave climate data in the vicinity of the Living Breakwaters project site. Thirty years of offshore wave, wind, and water level data were modeled and transformed to the project site. Results from the modeling effort compared favorably to the Rutgers ADCP measurements. The model results were also used to calculate return period wave conditions for the project site. These local wave climate data were then used to support subsequent modeling efforts and to help design layout geometry of the Living Breakwaters.

SHORELINE CHANGE ANALYSIS

A historical shoreline change analysis was performed based on orthoimagery available between 1978 and 2012, covering the range of the wave hindcast (1982 to 2012). The high water position for each orthoimage was delineated, allowing the long-term rate of change to be inferred. From the analysis, the locations where the largest shoreline change have occurred are presented. Related to the areas of largest shoreline change, the influence of existing shoreline structures is also discussed. The section concludes with the presentation of the effects of Hurricane Sandy on the shoreline.

ORTHOIMAGERY-BASED HISTORICAL SHORELINES

The historical shoreline position was determined using orthoimagery provided by the New York City Department of Information and Technology (NYCDOITT). Orthoimagery was available for the time periods shown in Table 3 covering the range of the wave hindcast (1982 to 2012). It can be seen that in some cases the exact date of imagery collection was unavailable or the orthoimagery was collected over multiple days.

Table 3. Orthoimagery collection dates.

Orthoimagery Date
11/03/12
3/30/2012 - 4/6/2012
4/1/2010 - 4/10/2010
3/10/2008 - 5/14/2008
04/2006
04/20/2004
04/14/2001
04/1996
1978

Shoreline position is developed from the orthoimagery by tracing the color change in the sand that results from the most recent high tide. Figure 14 provides an example of the high water shoreline. For each of the available orthoimages, the high water position was used to consistently define the shoreline position. The advantage to using the high water line is that orthoimagery will always be collected at or below the most recent high tide; therefore, the high water line can always be delineated (USGS, 2010).

Figure 14. Example determination of the recent high water shoreline position.

Figure 15 and Figure 16 present the high water shorelines in 1978 and March 30 to April 6, 2012. The rate of shoreline change over time was estimated between these two shorelines at a transect spacing of approximately 500 feet, with adjustments to capture rates at key areas and to avoid overlap with existing shoreline structures. Comparing rates of change over the largest temporal range in the available orthoimagery reduces uncertainty in the estimated rates of shoreline change, as will be discussed further in the Uncertainty Estimates section.

The rates of shoreline change exceed 1 foot per year mostly adjacent to Conference House Park, with the greatest shoreline erosion rate at 3.5 feet per year (±0.4 feet per year). This rate of erosion is consistent with the long-term erosion rates in the same part of the shoreline reported by Nordstrom et al. (1990) at 4.5 feet per year between 1911 and 1987.

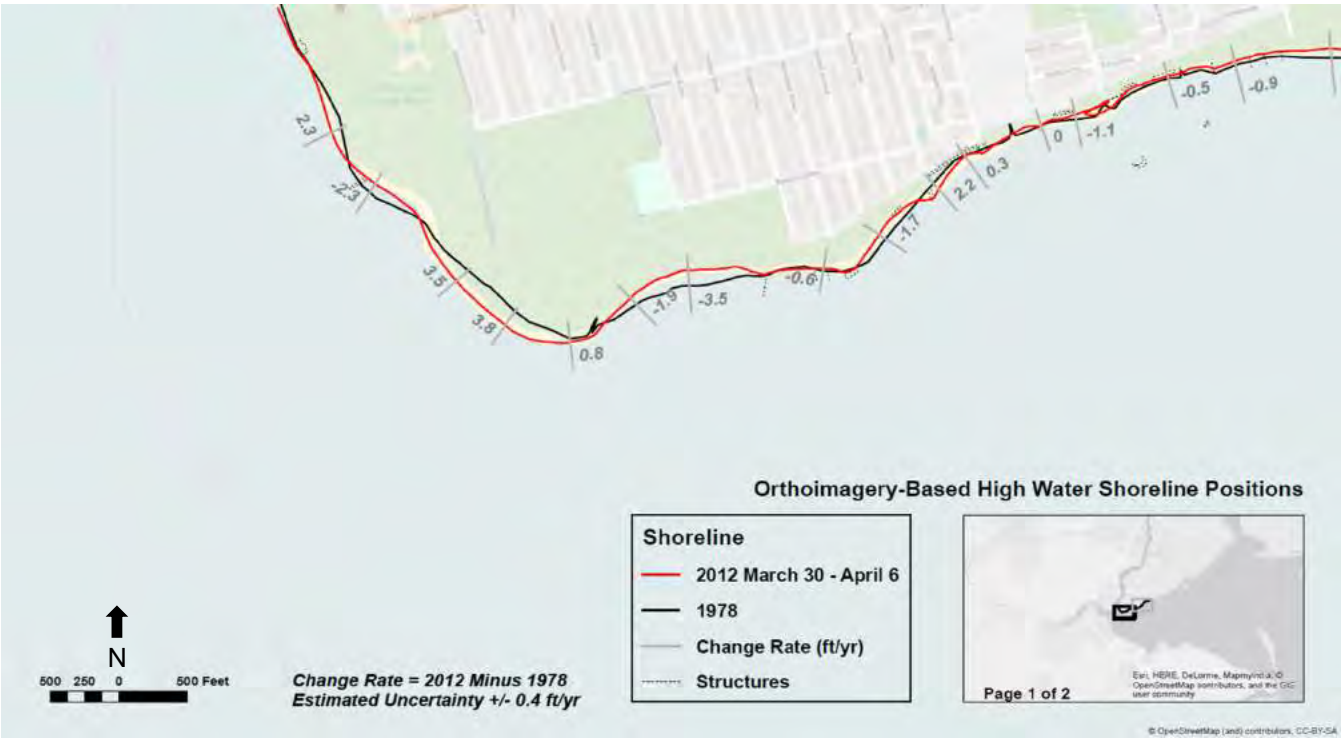


Figure 15. Shoreline change with rates in feet per year at the transects shown. Rates calculated as 2012 position minus 1978 position; negative rates indicate erosion and positive rates indicate accretion. (Image 1 of 2)

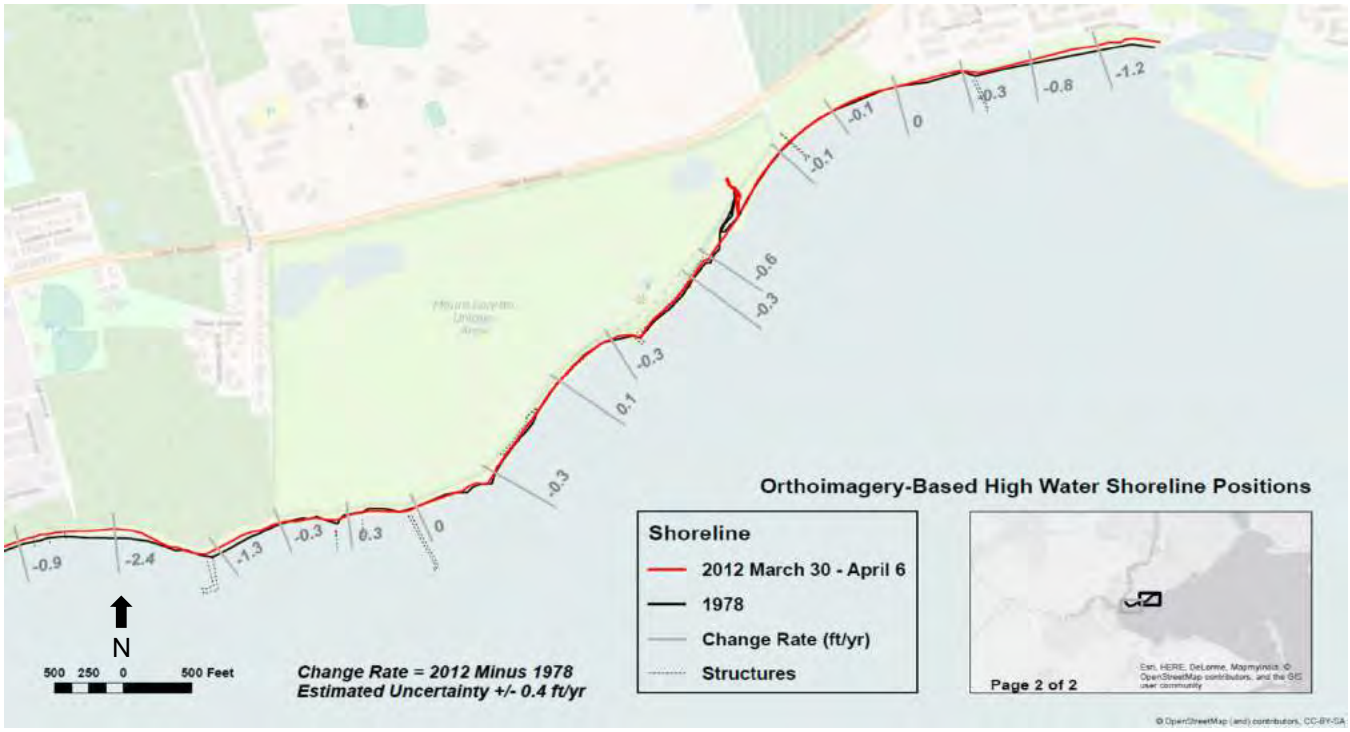


Figure 16. Shoreline change with rates in feet per year at the transects shown. Rates calculated as 2012 position minus 1978 position; negative rates indicate erosion and positive rates indicate accretion. (Image 2 of 2)

Most of the shoreline change rates moving to the northeast from Conference House Park along the shoreline are less than 1 foot per year, which is consistent with the results obtained by the USACE (2015b) and NYSDEC (1988). An exception is shown between Page Avenue and Richard Avenue where the long-term erosion rate is estimated at 2.4 feet per year (±0.4 feet per year). This area is downdrift of an L-shaped timber pile groin structure, which may have been a historic pier.

Areas of the most pronounced shoreline change are downdrift of existing groin structures, as shown on Figure 15 and Figure 16. Review of the orthoimagery indicates that many of the in-water shoreline structures were present from 1978 to 2012. A request for shoreline permits from the USACE and New York State Department of Environmental Conservation (NYSDEC) did not produce any permit records, likely indicating that many of the structures were installed before modern tidal wetland permitting requirements initiated in 1974.

Isolating the cause of the historical shoreline change rates from orthoimagery alone is constrained by an incomplete understanding of the physical mechanisms that influence the shoreline change. Temporally and spatially varying waves, water levels, and currents contribute to the observed shoreline change rates.

However, mean sea level rise is well-documented during the 1978 to 2012 period at NOAA's tide gage at Sandy Hook. Using the long-term mean sea level change rate at Sandy Hook along with the average beach slope reveals a long-term erosion of approximately 0.1 feet per year. This value is within the uncertainty of the analysis of 0.4 feet per year, indicating that either mean sea level rise is a small contributor to the overall shoreline change process or that an increase in mean sea level results is amplifying other processes that influence shoreline change such as waves, currents, and storm surge.

UNCERTAINTY ESTIMATES

Uncertainty in the position of the shoreline based on visual inspection of the high water line must be considered when interpreting shoreline change. Three relevant factors considered in the uncertainty estimates were:

- Consistent Georeferencing
- High Water Variation
- Wave Run-up Variation

The georeferencing uncertainty was estimated by comparing consistent shoreline structures between orthoimages. For example, a stormwater outfall headwall edge was observed in the 1978 image and compared to its location in the 2012 orthoimagery. The resulting uncertainty between images was estimated at ±1 foot. It should be noted that all images were previously georeferenced by NYCDOITT.

Due to the semidiurnal nature of astronomic tides in the New York City region and sensitivity to water level increases due to storm surge, high water variation was found to play a significant role in the uncertainty in high water shoreline position between orthoimages. Table 4 shows the most recent high water levels for the orthoimages that had reported dates.

Table 4. Orthoimagery date and recent high water elevation in feet NAVD88 (measured at NOAA's Sandy Hook station #8531680).

Orthoimagery Date	Recent High Water (feet NAVD88)
11/03/12	1.1
03/30/12	2.3
04/06/12	3.2
04/01/10	3.1
04/10/10	1.3
03/10/08	1.7
05/14/08	2.5
04/20/04	1.2
04/14/01	2.0

NAVD88 North American Vertical Datum of 1988.

For orthoimages that had a range of collection dates, the first and last days of those collections are shown in Table 4. For the nine dates listed in the table, the range of recent high water levels is approximately 2.1 feet. This is based on observed water levels at NOAA's Sandy Hook station #8531680. Because these are observed water levels, storm surge effects are included.

The plan view uncertainty that results from a vertical variation in the water level was estimated including the effects of shoreline slope. The average horizontal distance between 1.1 feet NAVD88 and 3.2 feet NAVD88 was estimated at 30 transects on the 2010 Light Detection and Ranging (LiDAR; NYCDOITT, 2012) and 2014 LiDAR (USGS, 2014) data. The average of these 60 estimates resulted in an uncertainty estimate of ±8 feet (in the plan view direction) due to vertical high water variation of 2.1 feet.

The wave conditions will vary depending on the day of collection of the orthoimagery, with the expectation that aerial flight dates will be made when weather conditions are not a safety risk (i.e. not storm conditions). Therefore, the wave transformation wave roses presented in the Nearshore Wave Results section were reviewed and a 0.2-meter (0.7-feet) wave height was used for wave run-up estimates.

The wave run-up was estimated using the method of Stockdon et al. (2006), which determined wave run-up as a function of deepwater significant wave height, beach slope, and deepwater wave length. Beach slope is calculated from the 2010 LiDAR and 2014 LiDAR data in the area between 1.1 and 3.2 feet NAVD88. Deepwater wave length was calculated for the SWAN peak wave period that correlated with the significant wave height. The wave parameters and wave run-up are summarized in Table 5.

Table 5. Summary of parameters used in estimating wave run-up using the relations of Stockdon et al. (2006).

Deepwater Significant Wave Height (feet)	Deepwater Wave Length (feet)	Beach Slope	Wave Run-up (feet)
0.7	35	0.125	0.5

The uncertainty due to georeferencing, high water variation, and wave run-up variation is then combined for a total horizontal uncertainty of ±9.5 feet, as summarized in Table 6. 86% of the uncertainty is due to variation in high water position. The shoreline position uncertainty rate between 1978 and 2012 is then estimated at ±0.4 feet per year ($\sqrt{9.5^2 + 9.5^2}/_{34\text{ years}}$) considering the propagation of uncertainty when rates are calculated between images. These uncertainty estimates are lower, but of the same order of magnitude, than those reported at the regional scale (USGS, 2010). Using the 0.125 beach slope estimate shown in Table 6, the plan distance uncertainty of ±0.4 feet per year correlates to ±0.05 vertical feet per year.

Table 6. Summary of horizontal uncertainty in orthoimagery-based high water shoreline positions.

Georeferencing	High Water Position	Wave Run-up	Total
±1 foot	±8 feet	±0.5 foot	±9.5 feet

HURRICANE SANDY SHORELINE RESPONSE

The effects of Hurricane Sandy on the shoreline were evaluated by comparing the March 30 to April 6, 2012, orthoimagery to the orthoimagery collected by NOAA on November 6, one week after Hurricane Sandy. The LiDAR data collected by the USGS on November 16 was also evaluated by delineating the high water line between mean high water, 2.4 feet NAVD88, and mean higher high water, 2.7 feet NAVD88 (NOAA Vertical Datum Transformation Tool, Version 3.4). A sample LiDAR-based high water shoreline position is shown on Figure 17.

The effect of Hurricane Sandy on the high water shoreline position, shown on Figure 19 and Figure 20, is small when compared to the long-term shoreline change rates presented in the Orthoimagery-Based Historical Shorelines section. The USACE reported that Hurricane Sandy transported material from the dunes and bluffs to the mean sea level position, but also reported changes in evaluation of the mean sea level position due to reflections in the LiDAR data. Additionally, the USACE compared the post-Sandy LiDAR data to the 2010 LiDAR data, which is a longer duration compared to the current analysis (USACE, 2015b).

Review of the November 6, 2012, orthoimagery does reveal that Hurricane Sandy created a significant amount of dune overwash in the Tottenville area. Overwash fans are observed from the dune into adjacent parks and into the neighborhoods as shown on Figure 18 near Page Avenue. It is unclear what portion of dune and bluff erosion was transported offshore in the cross-shore direction.

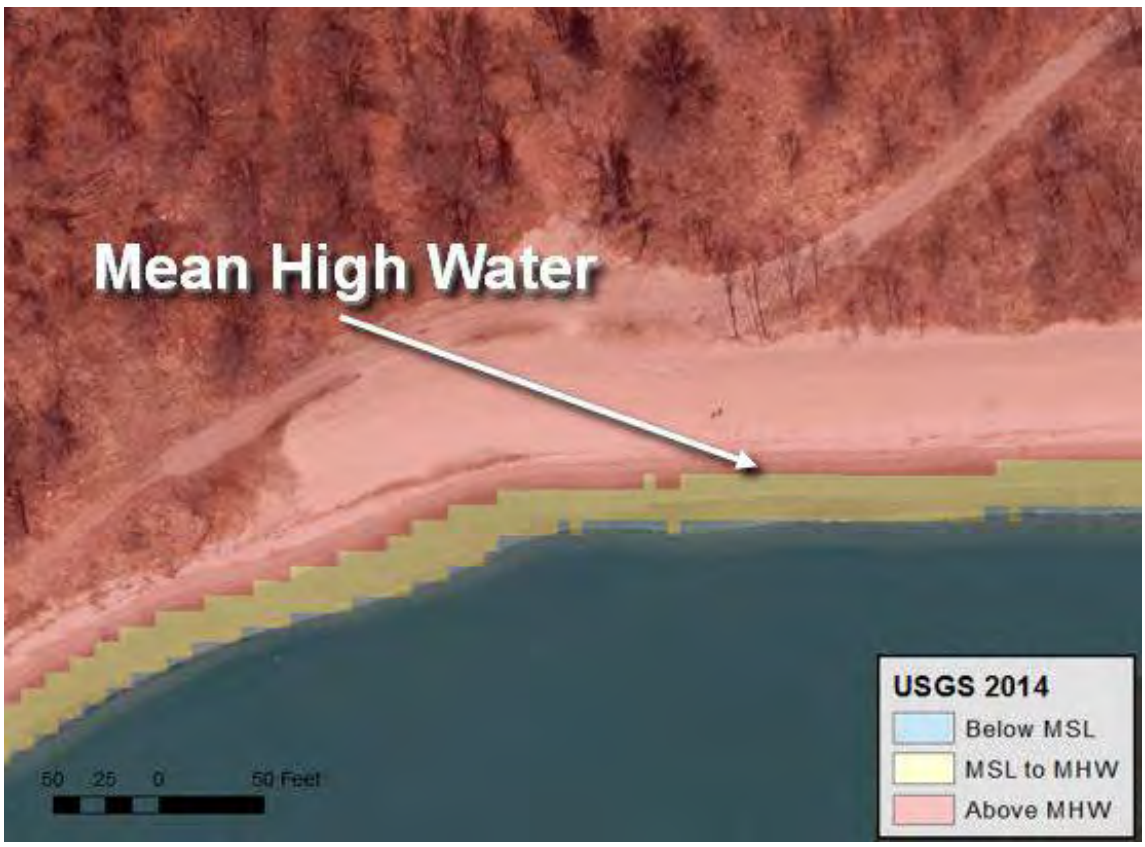


Figure 17. Shoreline position based on LiDAR position of the mean high water line.

Figure 18. Pre- and Post-Sandy aerial imagery demonstrating sand overwash near Page Avenue.

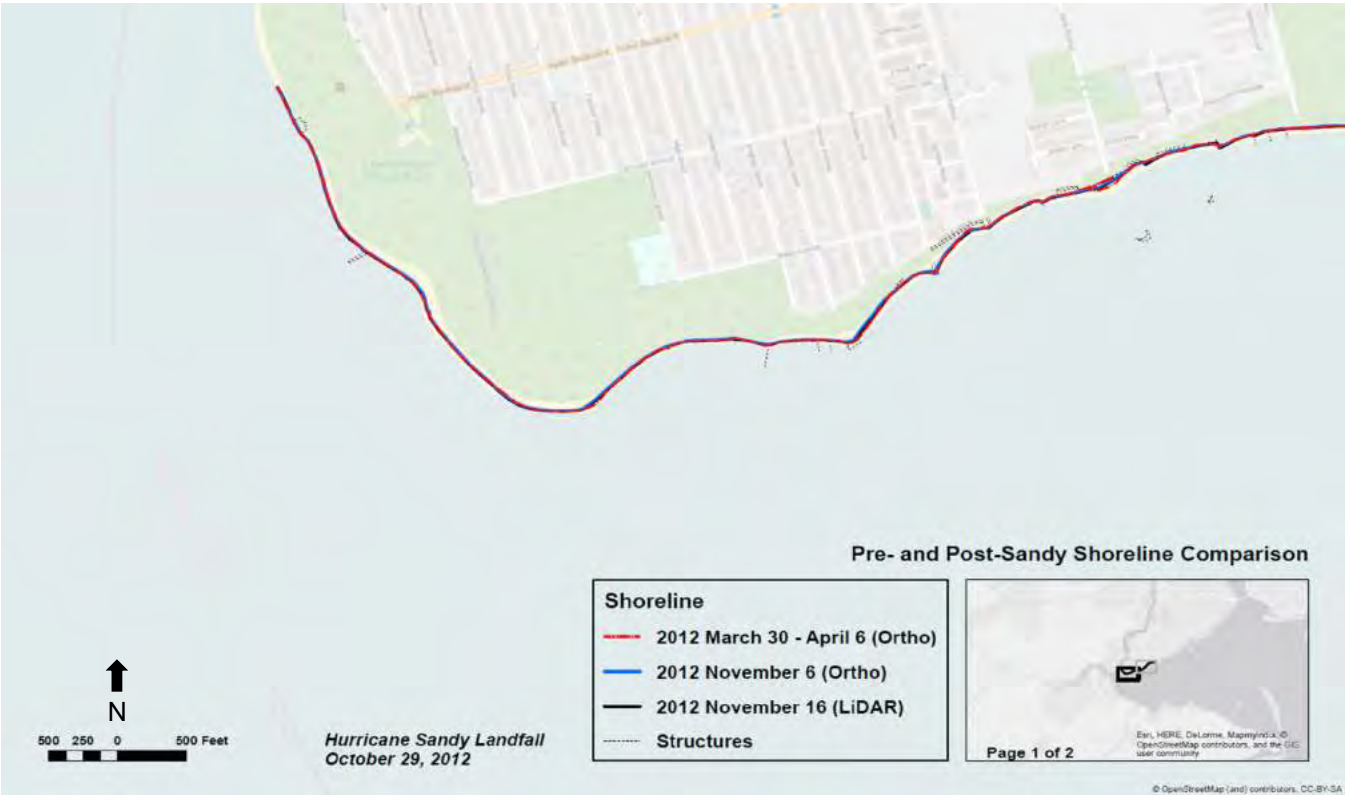


Figure 19. Pre- and Post-Sandy shoreline position comparisons. (Image 1 of 2)

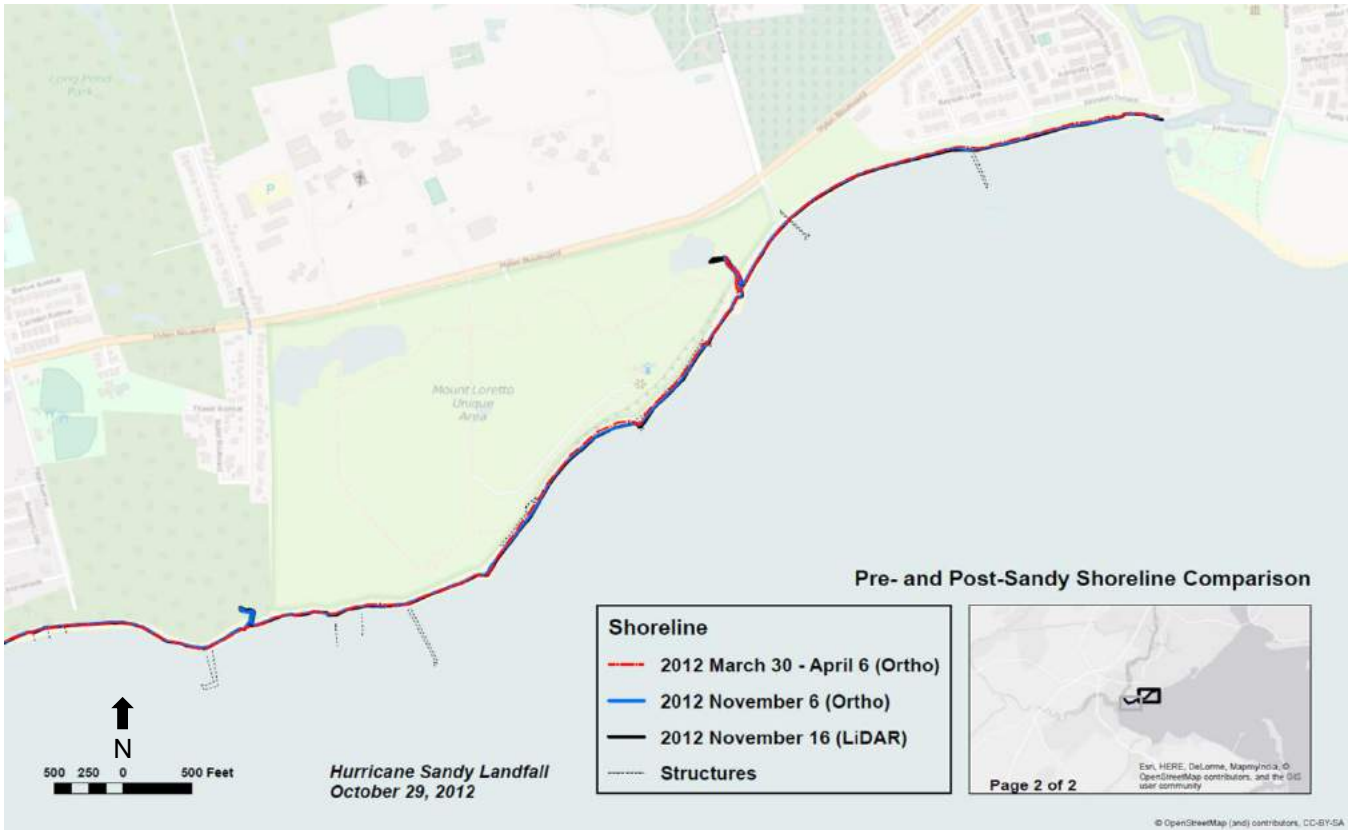


Figure 20. Pre- and Post-Sandy shoreline position comparisons. (Image 2 of 2)

SHORELINE CHANGE MODELING

Using the long-term nearshore wave climate conditions developed in the Wave Transformation Modeling section and the orthoimagery-based historical shoreline change described in the Shoreline Change Analysis section, a shoreline change model, using GENESIS, was developed. GENESIS is a commonly used and widely accepted shoreline change model, known as one-line model. The underlining assumption is that the cross-shore beach profile does not change with time, so that the active profile only moves parallel to itself, assuming the cross-shore profile is in long-term equilibrium. It simulates long term planform evolution of the shoreline in response changes in longshore sediment transport from incoming waves and coastal structures.

This section describes the model setup and calibration of results to the observed historical shoreline changes between 1978 and 1996. The calibrated model was validated to reproduce the shoreline changes between 1996 and 2012. The long-term (20 years) shoreline changes for the without-project, or baseline conditions, and 30% design breakwaters are then presented. The GENESIS modeling was performed over a 20 year period, which allows comparison of the various scenarios in development of the 30% design. The 20 year simulation period allows assessment of long term trends in shoreline change. While the proposed functional life of the project is 50 years, realistic prediction of 50 year shoreline position is beyond the reasonable expectation of the model. The GENESIS model is limited as to the length of wave record that can be simulated. For 30% design, use of a widely expected and relatively quick running model also allowed assessment and comparison of numerous alternatives over a 20 year simulation period.

GENESIS MODEL OVERVIEW

The GENEralized model for SImulating Shoreline change (GENESIS) model was developed by the USACE Engineering Research and Development Center as a tool to determine long-term evolution of the shoreline, including the effects of shoreline structures (Hanson, 1989). Model inputs include:

- Wave Conditions
- Sediment Characteristics
- Coastal Structure Layout and Geometry

With these inputs, long-term simulations of shoreline change are performed. The following sections discuss the selection of model inputs, the calibration and validation of simulated shoreline change to the observed shoreline change, and the estimated shoreline change under future without project (baseline) and future with-project conditions.

BASELINE MODEL INPUTS

WAVE DATA

Long-term wave condition data used in the GENESIS model were assigned from the SWAN model outputs described in the Wave Transformation Modeling section. Specifically, the wave conditions at location p8, shown on Figure 9, approximately 1,000 feet offshore of Bedell Avenue, were used as wave condition forcing in the model. The long-term wave rose at location p8 is shown on Figure 21. Wave conditions at location p8 were selected due to improved calibration and validation of GENESIS results.

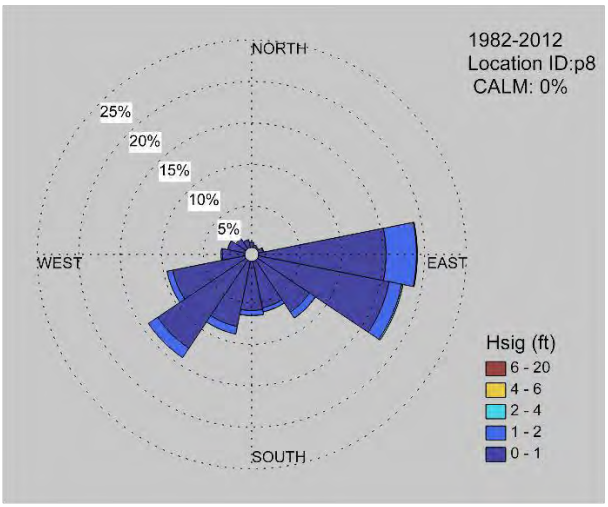


Figure 21. Long-term wave rose at SWAN model extraction location p8, which is approximately 1,000 feet offshore from Bedell Avenue.

WATER LEVELS AND SEDIMENT GRAIN SIZE

Water levels assigned to the model were based on the measured hourly water levels at the nearby NOAA Sandy Hook station #8531680. Sediment characteristics assigned in the model were obtained from initial grab samples taken close to the shoreline. The average D_{50} from the grab samples was measured at 0.35 millimeters (0.01 inch). This was the D_{50} used in the GENESIS model simulations. Note that this grain size is different from the average grain size determined once all the 30% design field data were collected which yielded an average D_{50} of 0.61 millimeters. This difference in D_{50} should not have a significant impact on the GENESIS results but is more critical to the beach profile change analysis. Further discussion of sediment grain sizes can be found in that section. The grain size was kept constant throughout all the GENESIS model runs to allow for direct comparison of the various scenarios. Additionally, sensitivity test simulations were preformed using both average D_{50} and showed almost no change to the resulting shoreline change. The GENESIS model is not highly sensitive to changes in grain size at 0.4 millimeters and greater.

BEACH PROFILE TRANSECTS

The cross-shore slope of the beach profile was assigned in the model based on the transect surveys performed by MFS (2015). These 23 cross-shore beach transects are shown on Figure 22. From these transects, a beach berm height of 1.0 meters (3.3 feet) was assigned along with a depth of closure of -6.0 meters (-19.7 feet).

The berm height elevation and the depth of closure were used to assign a cross-shore geometry to the model. The depth of closure is the offshore limit at which wave energy begins to have a negligible effect on nearshore shoreline change. At the Living Breakwaters site, the depth of closure generally correlates with the navigation channel.

SHORELINE STRUCTURES

Shoreline structures have a strong influence on the shoreline, as was presented in the Shoreline Change Analysis section. Therefore, all in-water structures were assigned as much detail as was available. For the majority of the structures, the site survey of structures performed by MFS (2015) provided sufficient detail of structure types, extents, and relevant elevations. For information not collected during the site survey, structure information was assigned through review of site photographs (MFS, 2015) and aerial imagery.

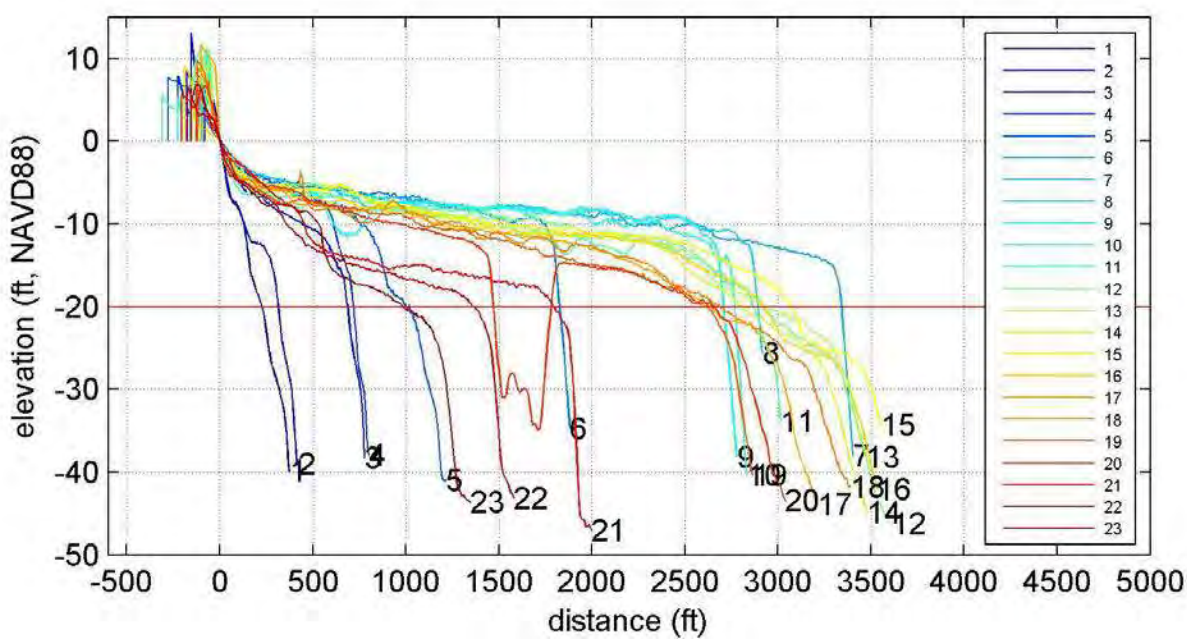


Figure 22. Cross-shore beach transects along the project length (MFS, 2015). Estimated closure depth of -6 meters shown by the horizontal red line.

BATHYMETRIC GRID

A computational grid was developed to extend offshore to the depth of closure and inland beyond the expected highest water elevations. The 10-meter (32.8-foot) rectangular grid extents are shown on Figure 23. The model grid extends from Conference House Park in the south to Butler Manor Woods in the north. Bathymetry was assigned to each grid cell using the multi-beam survey and the beach transect surveys performed in the Fall of 2015 (Hill International, 2015; MFS, 2015) and supplemented with data from the FEMA PFIRM coastal study (FEMA, 2014a).

Figure 23. Computational grid of the GENESIS model.

MODEL CALIBRATION AND VALIDATION

The historical shorelines described in the Shoreline Change Analysis section were used to calibrate and validate the performance of the GENESIS model. Calibration was performed for the shorelines between 1978 and April 1996, as shown on Figure 24. Results from each model run were compared with observed shoreline changes, with iterative adjustments to improve the model performance.

To achieve the results shown on Figure 24, the iterative calibration process resulted in the parameters shown in Table 7. The parameter K1 adjusts the rate of longshore transport influenced by obliquely incident waves and the K2 parameter adjusts the rate of longshore transport influenced by variations in wave breaking conditions along the shoreline (Hanson, 1989). The PERM parameter allows for sediment bypassing at structures perpendicular to the shoreline. A value of 0.6 assigned in the model accounts for permeability in the structure and the position of the structure relative to the water level. The PERM calibration parameter is not as sensitive as K1 and K2 in the model and was tested for sensitivity during calibration.

Using the calibrated model parameters, a validation simulation was performed between April 1996 and March 30 to April 6, 2012. The validation results, compared to observed orthoimagery-based shoreline change, are shown on Figure 25. The calibration and validation results demonstrate that the model is reproducing observed shoreline change behavior. Areas of the most significant shoreline change adjacent to Conference House Park, as discussed in the Shoreline Change Analysis section, are being reproduced by the model. Another area of significant historical shoreline change, northeast of Page Avenue, is also being reproduced by the model.

Table 7. Summary of GENESIS parameter values.

Parameter Name	Value
K1	0.55
K2	0.35
PERM	0.6

BASELINE SIMULATIONS

Using the calibrated and validated model parameters described above, a baseline 20-year simulation without-project was performed. For this simulation, the 1992 to 2012 water levels and wave conditions were used for the simulation. The results of the 20-year baseline simulation are shown on Figure 26.

Even with the assumptions and limitations of a 1-D model, GENESIS still should be able to predict the long term trends of shoreline changes. Figure 26 shows the modeled 20-year future shoreline change without project. The 20-year simulation, from 2015 to 2035, of the shoreline change rate was compared to observed rate in Figure 27. This analysis revealed that the computed shoreline change rates match the trend of observed rate reasonably well.

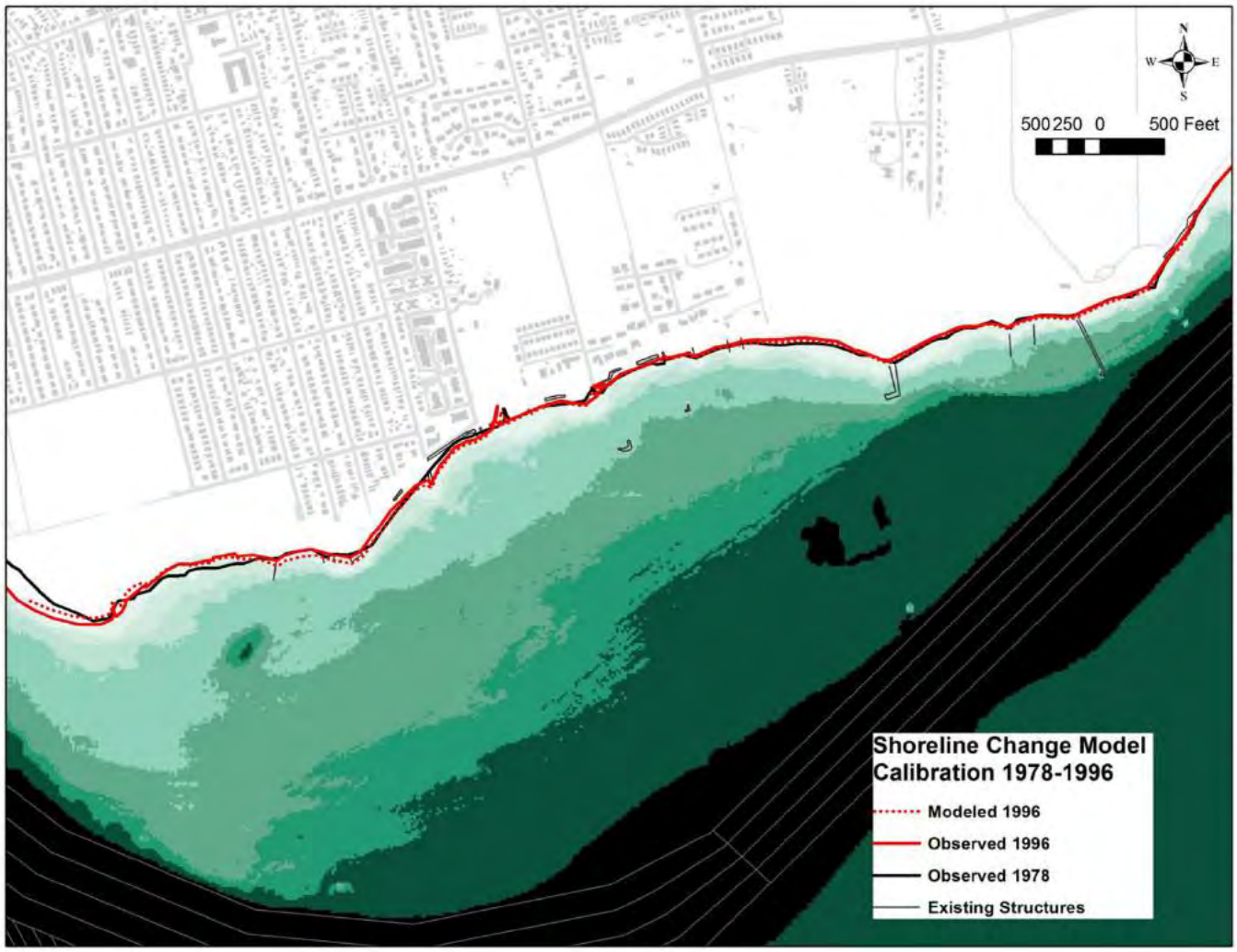


Figure 24. Shoreline change model calibration results comparing the observed shoreline in 1978 and the observed and modeled shoreline in April 1996.

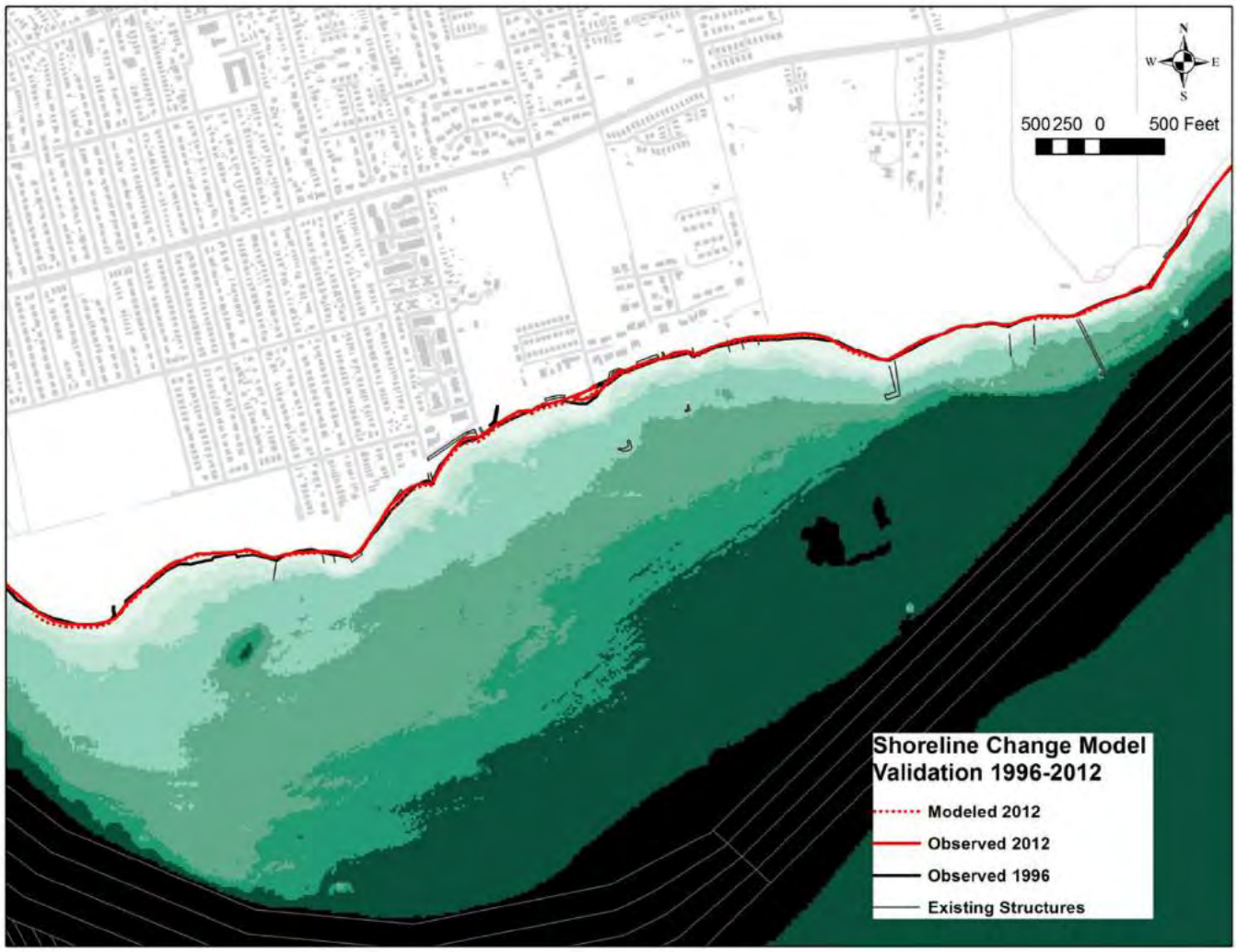


Figure 25. Shoreline change model validation results comparing the observed shoreline in April 1996 and the observed and modeled shoreline of March 30 to April 6, 2012.

Figure 26. Shoreline change under 20-year future without-project conditions. The initial shoreline of 2014-2015 is compared to the modeled shoreline in 2035.

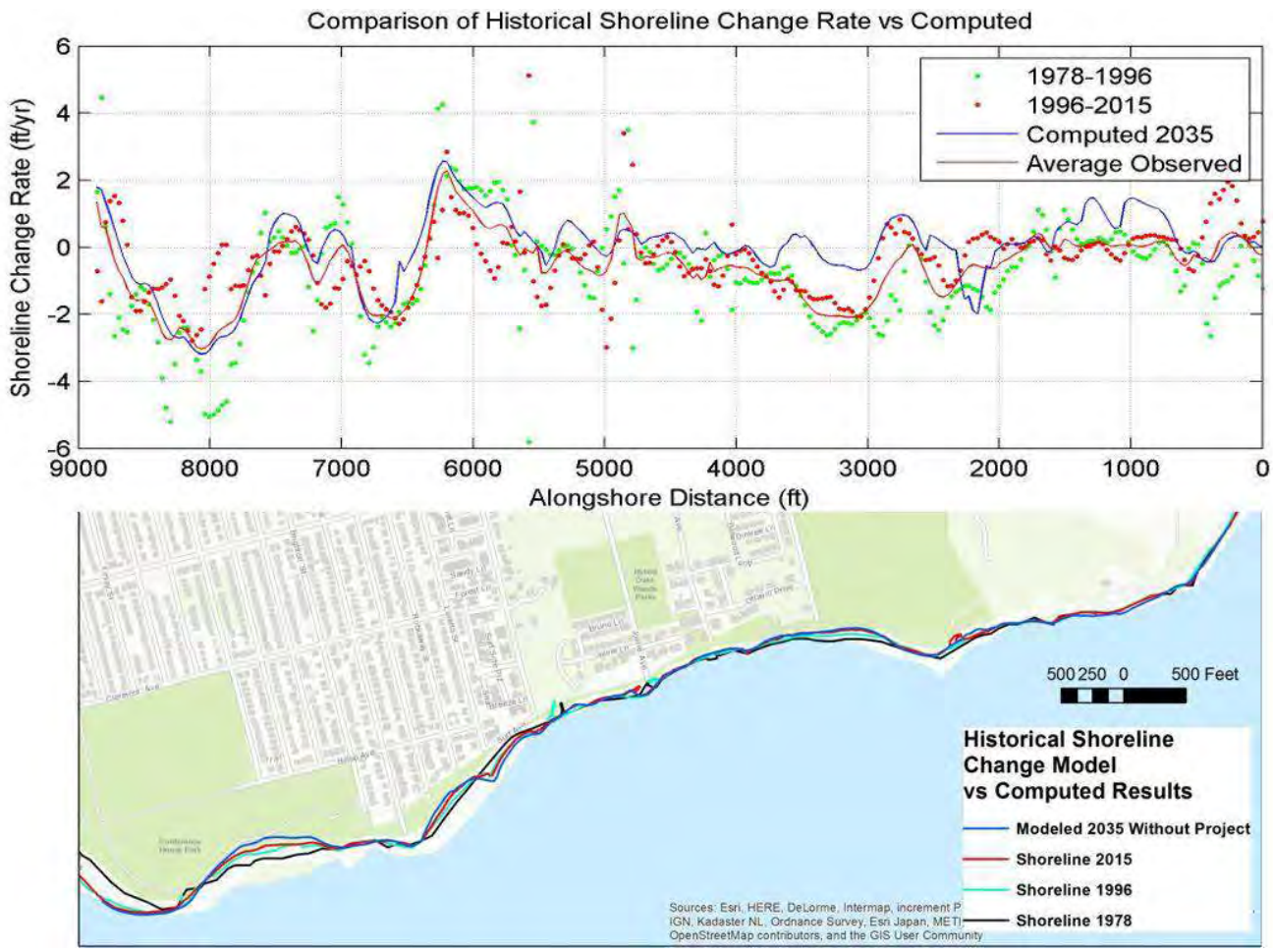


Figure 27. Comparison of computed shoreline change rates relative to observed shoreline change rates.

Figure 27 presents a comparison of the computed future shoreline change rates to the observed historic rates. This comparison revealed that in the southwestern portions of the site (south of Sprague Ave.) both the overall pattern and rates of shoreline erosion and accretion are likely to continue into the future, including the erosion rates of 1 to 2 feet per year between Loretto Street and Manhattan Street and between 2.0 and 3.5 feet per year in Conference House Park between Main Street and Wards Point. North of Sprague Avenue, the general pattern of erosion and accretion appear to remain the same, though rates of change simulated are slightly lower in the future than those historically observed. This may be due to adjustments of the shoreline over time as it attempts to reach a dynamic equilibrium.

30% DESIGN SIMULATIONS

In order to estimate the response of the shoreline to the breakwater layout of the 30% design scenario, the 10 breakwaters and targeted shoreline restoration were modeled for 20 years starting from the 2015 shoreline (MHW). The 30% design layout resulted from refinements and understanding of the breakwater system performance during 15 scenarios simulated by the GENESIS model. These scenarios are documented in Appendix A.

Figure 28 shows the shoreline response with the Living Breakwaters 30% design layout and shoreline restoration. The eastern pair of breakwaters are oriented to shelter the nearshore from the dominant wave direction while set far enough offshore to not completely arrest sediment transport. Sediment tends to accumulate along the shore on the eastern half of the project as the sediment transport gradient drops off with the reduction in wave energy due to the breakwaters. The simulated shoreline near Joline Avenue accretes up to 10 to 20 meters (30 to 60 feet). The addition of beach sediment for shoreline restoration builds the beach in an area where infrastructure is vulnerable and the breakwaters maintain the additional sediment in the region. The western-most breakwaters aid in holding the shoreline through areas of historical erosion at Conference House Park.

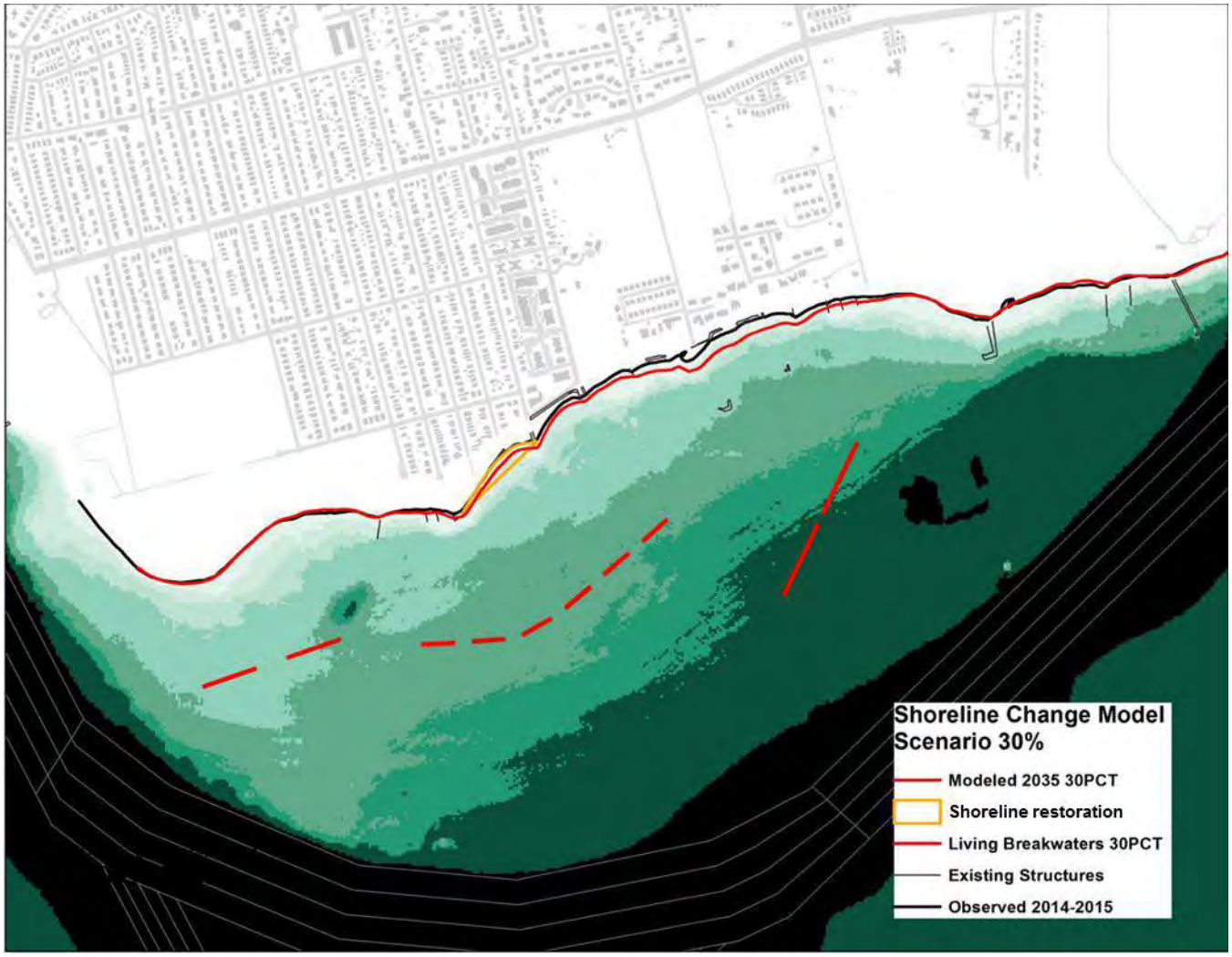


Figure 28. Shoreline changes of 20 years due to the proposed 30% design.

CONCLUSIONS

The GENESIS model was calibrated to shoreline change observed from 1978 to 1996 and validated to shoreline change observed from 1996 to 2012. The calibrated/validated model was then used to estimate future shoreline response, with and without Living Breakwaters. Without Living Breakwaters, the shoreline maintains erosion trends into the future that are similar to the historically observed. With the Living Breakwaters, the shoreline erosion is mitigated with extensive areas of shoreline accretion in the vicinity of the residential areas at most risk to storm damage.

Historical effects of sea level rise are included in the GENESIS model through the calibration parameters, however predicting future sea level rise effects on shoreline change is outside of the ability of the GENESIS model and is an area of active research nationwide. The GENESIS model is a 1-D model that assumes the cross shore profile does not change (it simply shifts landward and seaward but remains in a long term equilibrium shape). As sea level rises one of the impacts will be alternation of the cross shore profile as water levels rise shifting the shore position landward. With sea level rise there will be a complex interaction of the longshore and cross shore processes. The GENESIS model is not capable of representing these changes. When modeling predicted future shoreline change over long periods it should be noted that the model is intended to provide an understanding of overall trends and not predict specific shoreline future locations. The 30% design layout will be refined with more detailed modeling in the next phase.

DESIGN WAVE TRANSFORMATION NEAR BREAKWATERS

The transformation of the wave climate in the nearshore region close to the proposed Living Breakwaters alignments is important for understanding the Living Breakwaters performance relative to wave attenuation and optimizing its layout and geometry. This section describes the setup of the REFDIF model and the results of the wave transformation for baseline conditions (without the Living Breakwaters in place), and the results with the proposed 30% design in place.

REFDIF MODEL OVERVIEW

Close to a breakwater structure, wave refraction and diffraction are dominant processes. REFDIF is a coupled REFraction and DIFfraction wave model developed at the University of Delaware that is suitable for wave modeling near breakwaters. For this analysis, version 2.5 was used (Kirby et al., 1994). The REFDIF includes processes of wave refraction, diffraction, shoaling, and energy dissipation. REFDIF simulates wave propagation over nearshore bathymetry and around the structures allowing for the evaluation of the influence of variables such as water levels, wave directions, etc.

Incident waves are input at the project boundary and propagate through the model domain. REFDIF provides steady state monochromatic wave estimates by solving second-order nonlinear equations with a parabolic form. A limitation of the parabolic form technique is that wave directions cannot deviate at angles greater than ±30 degrees relative to the perpendicular of the boundary. Therefore, multiple computational grids must be developed for a range of approach wave directions. Additionally, REFDIF cannot model wave reflections or steep slopes (greater than 3 horizontal to 1 vertical). Because of the limitation on reflections, wave conditions on the wave approach side of the breakwaters should be interpreted with caution.

The model requires the following inputs:

- Wave height and wave period boundary conditions
- Side boundary conditions
- Computational grid/bathymetry
- Water level

These inputs are discussed further in the following section.

BASELINE MODEL INPUTS

WAVE DATA AND WATER LEVEL

Baseline simulations, without the Living Breakwaters, were performed for the combinations of wave conditions and water levels shown in Table 8. Wave conditions for each scenario were provided by the design team to inform performance under scenarios of interest for design and do not necessarily correlate with the wave return periods presented in the Wave Transformation Modeling section.

Table 8. Water levels and wave conditions for baseline simulations.

Water Elevation Event	Water Elevation (feet NAVD88)	Wave Height (feet)	Wave Period (seconds)
Mean High Water	**2.1**	**3.0**	**3.0**
FEMA PFIRM 1%-Annual-Chance	**12.9**	**5.3**	**5.0**

The wave conditions are applied perpendicular to the offshore boundary of the model. The following wave approach directions were analyzed for both of the events shown in Table 8.

- Southwest (225 degrees from N)
- East (90 degrees from N)
- Perpendicular (to general direction of shoreline, 150 degrees from N)

East and Southwest represent the most common wave directions and the perpendicular direction was also selected to assess the breakwaters wave attenuation capabilities.

BATHYMETRIC GRID

The computational grid was developed to extend well beyond the limits of the proposed Living Breakwaters layout zone. The computational grid was assigned a 5-meter (16.4-foot) spacing with a rectangular gird of 820 nodes by 940 nodes. The following data sources were used to assign bathymetry and topography to the computational grid:

- Bathymetry/NJ Topography - FEMA PFIRM coastal study (FEMA, 2014a)
- Bathymetry – Multibeam bathymetric survey and beach transects surveys in the vicinity of the initial Living Breakwaters alignments (Hill International, 2015; MFS, 2015)
- Topography – NYC 2010 1-foot LiDAR (NYCDOITT, 2012)

Figure 29 summarizes the water depths assigned to the computational grid, in meters NAVD88. The presence of the navigation channels is clear, forming the perimeter of the approximate Living Breakwaters alignment area with an assigned maintenance depth of approximately 10.7 meters (35 feet). Aside from the navigation channels, the majority of Raritan Bay within the computational domain is at a depth less than approximately 8 meters (26.2 feet).

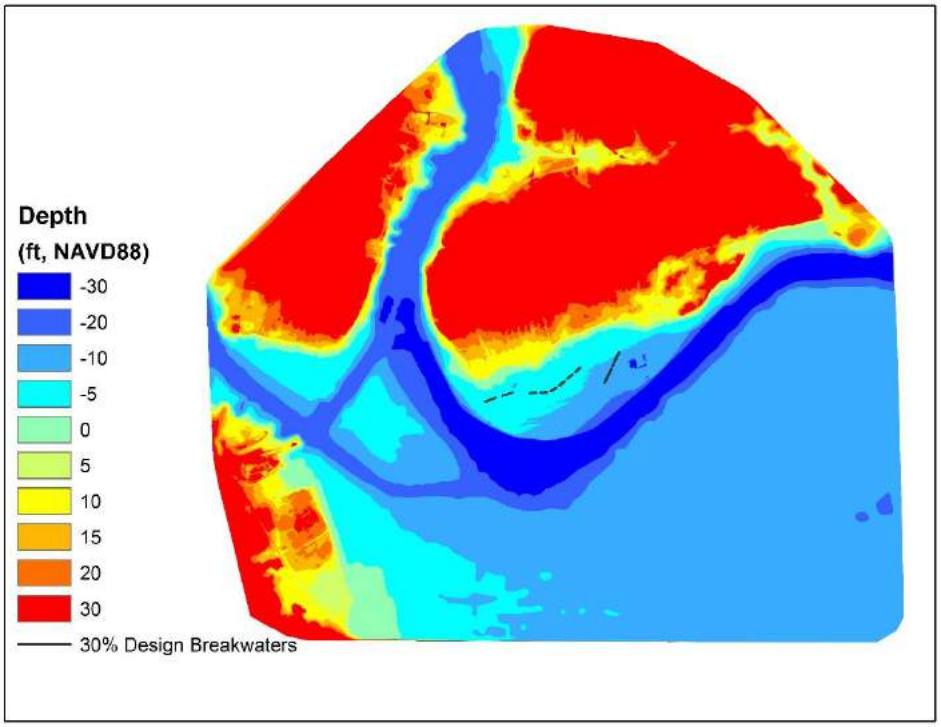


Figure 29. Computational depths in meters NAVD88 used in the REFDIF model.

BASELINE SIMULATIONS

The without-project simulations are illustrated by relative wave height (calculated wave height divided by incoming wave height imposed at the boundary) plots for each of the three wave approach directions on Figure 30 and Figure 31. Figure 30 shows the simulation results for the mean high water event with an imposed wave height of 3 feet and a wave period of 3 seconds. Figure 31 shows the simulation results for FEMA PFIRM 1% annual-chance event with an imposed wave height of 5.3 feet and a wave period of 5 seconds.

Each image shows a noticeable wave breaking line close to the shoreline, indicated by dark blue relative wave heights (close to zero). The breaker line advances landward for the increased water levels associated with the 1%-annual-chance event shown on Figure 31. Diffraction shadows are also clearly observed on the western side of the Staten Island peninsula for east and perpendicular wave directions during both water level events. These simulation results will form the baseline conditions to which with-project simulations are compared for each initial Living Breakwaters layout.

Additional insight into the transformation of waves in the nearshore area is shown on Figure 32. The wave crests and troughs are mapped for the 1%-annual-chance water elevation events. Wave transformation near the navigation channels, diffraction shadow zones on the western side of the tip of Staten Island, shoaling, and dissipation of waves close to the shoreline are clearly observed. SLR effects on the nearshore waves were simulated and the model results show the waves propagate further inland and the breaker line, indicated by dark blue color, were also pushed upland (See Figure 33 and Figure 34).

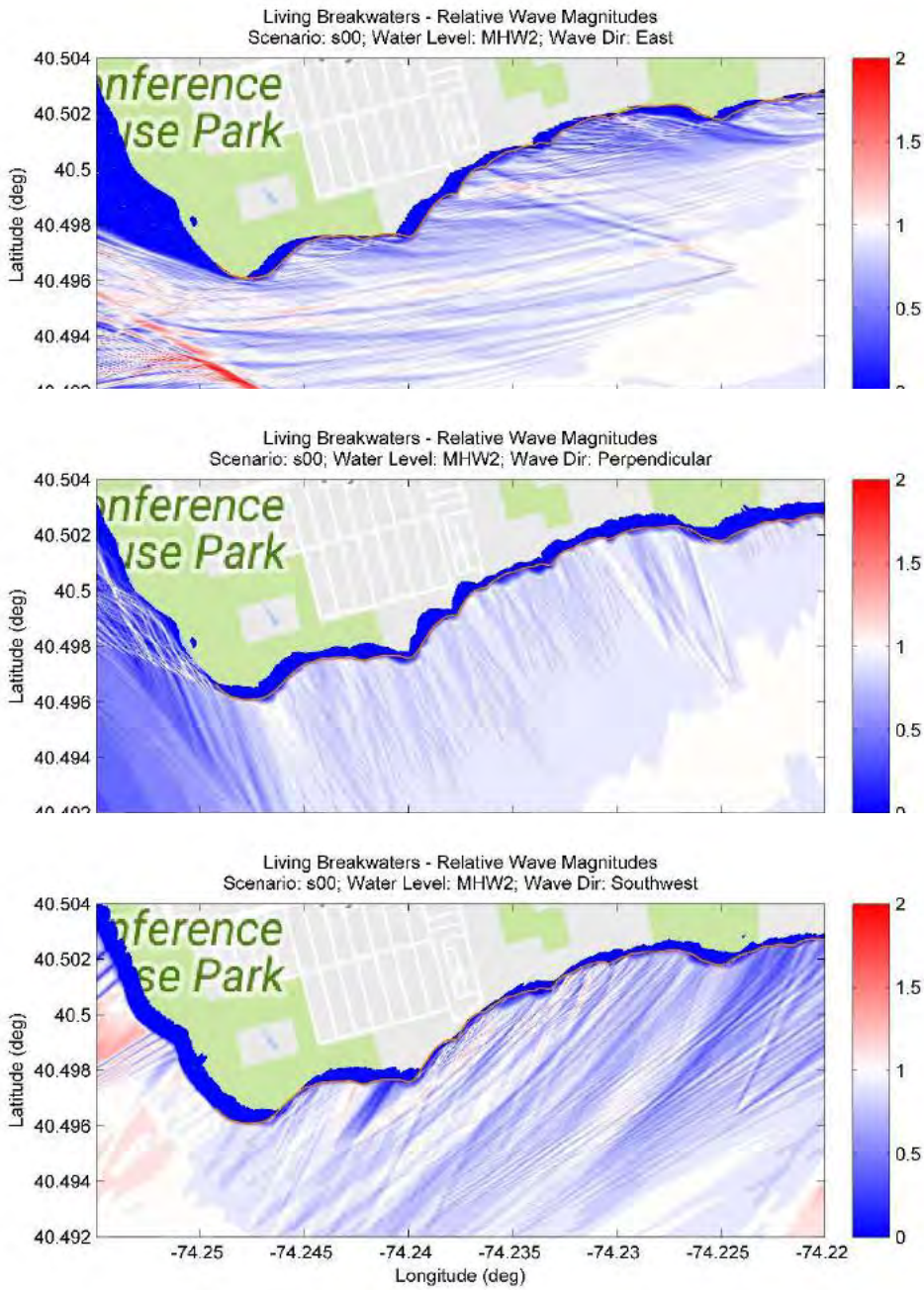


Figure 30. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. Baseline simulations (without-project) for an incoming wave height of 3 feet, wave period of 3 seconds, and water level at mean high water (2.08' NAVD88). Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

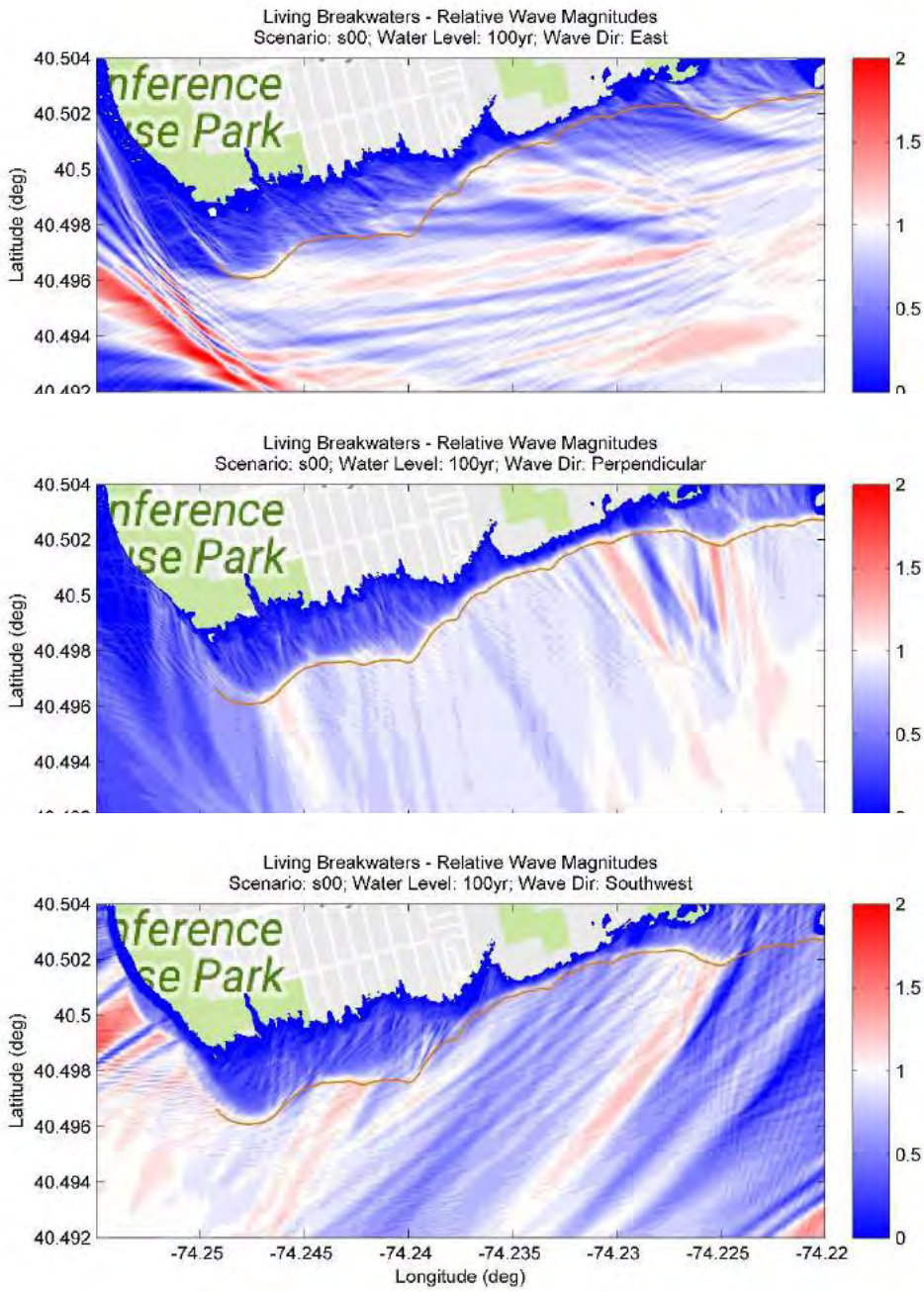


Figure 31. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. Baseline simulations (without-project) for an incoming wave height of 5.3 feet, wave period of 5 seconds, and the 1%-annual-chance FEMA PFIRM water elevation (12.9' NAVD88). Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

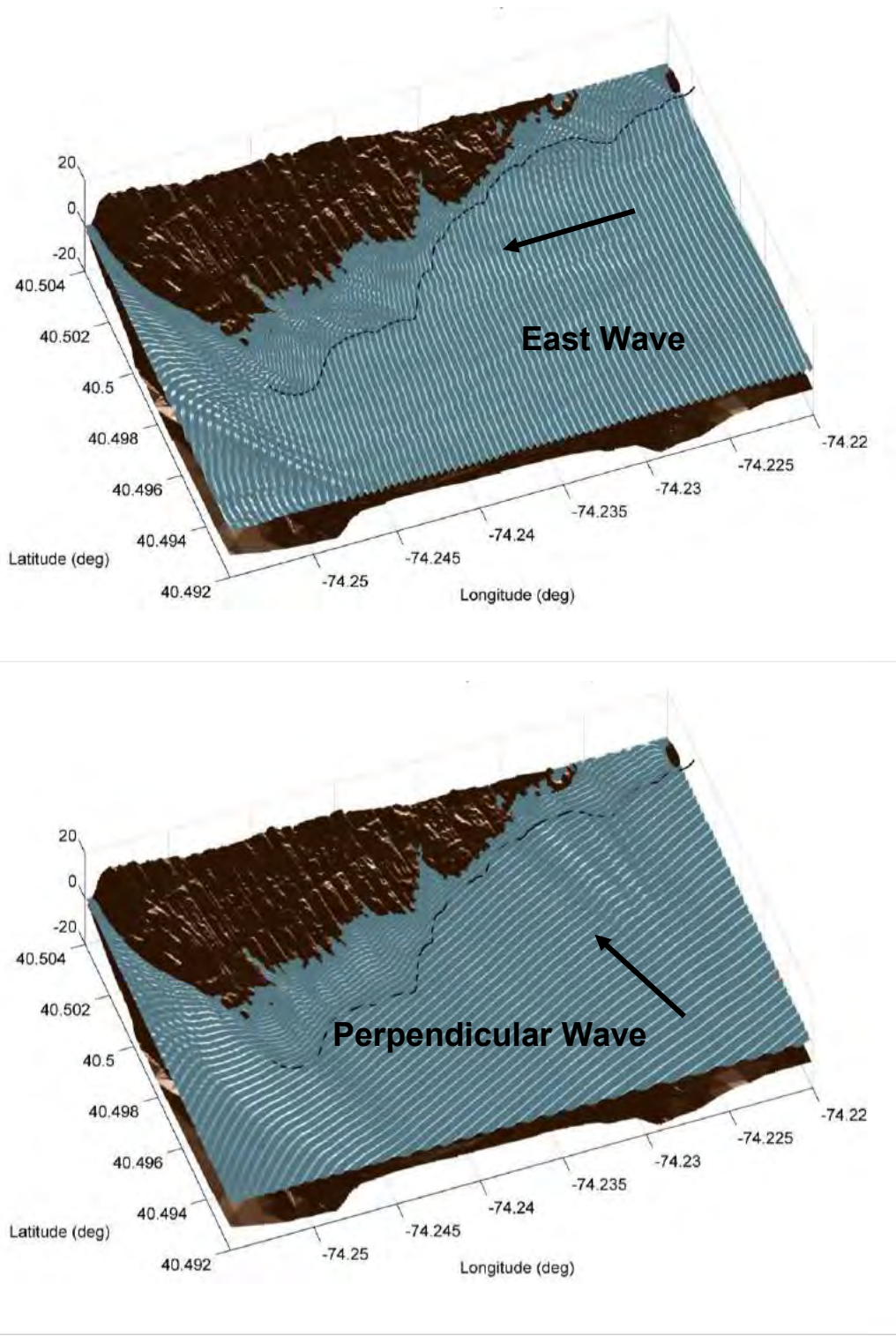


Figure 32. Wave crests and troughs near the potential Living Breakwaters alignment. Baseline simulations (without-project) for an imposed wave height of 5.3 feet, wave period of 5 seconds, and the 1%-annual-chance FEMA PFIRM water elevation. Top Image: east wave. Bottom image: wave perpendicular to shoreline.

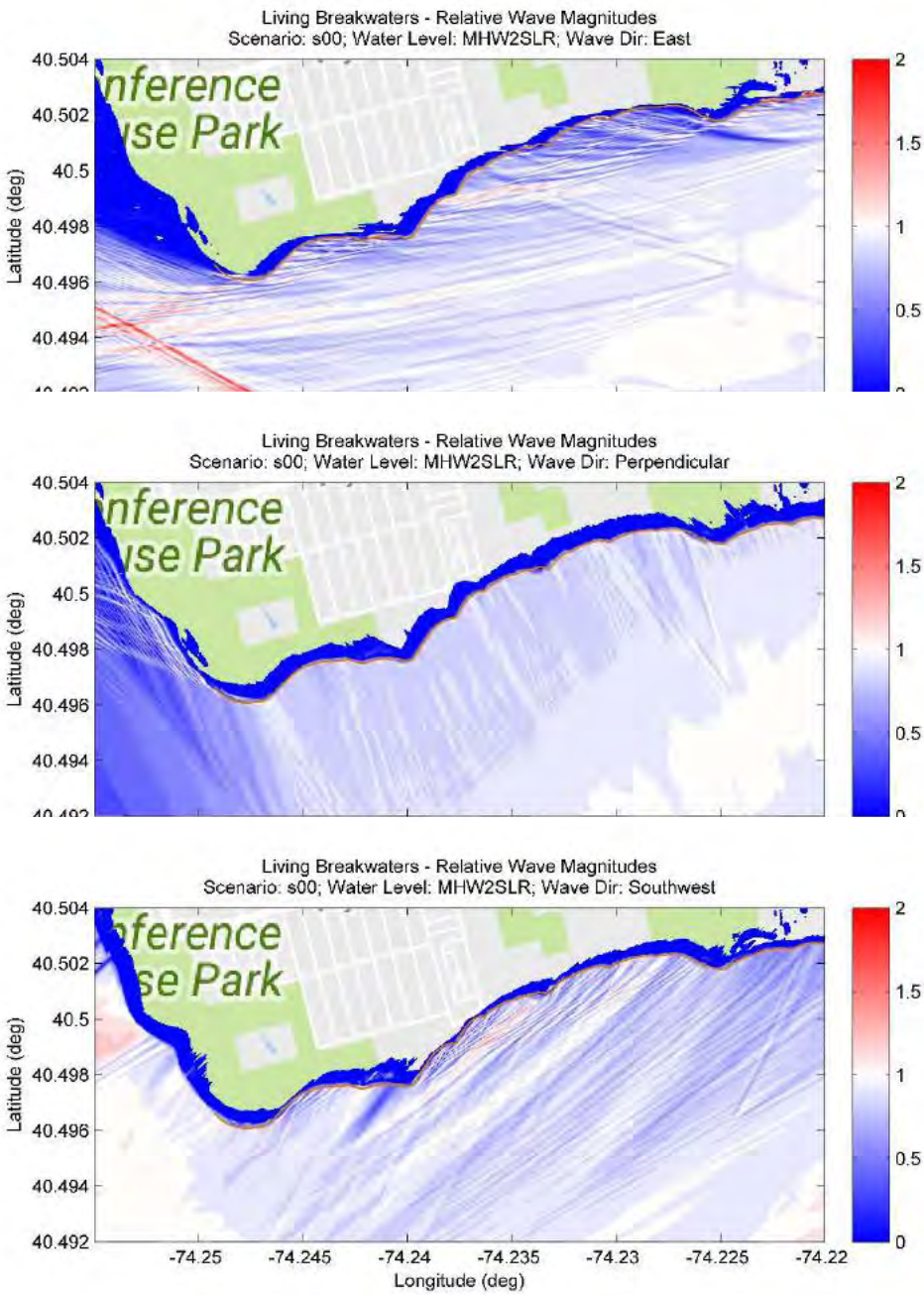


Figure 33. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. Baseline simulations with SLR, without-project, for an incoming wave height of 3 feet, wave period of 3 seconds, and mean high water. Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

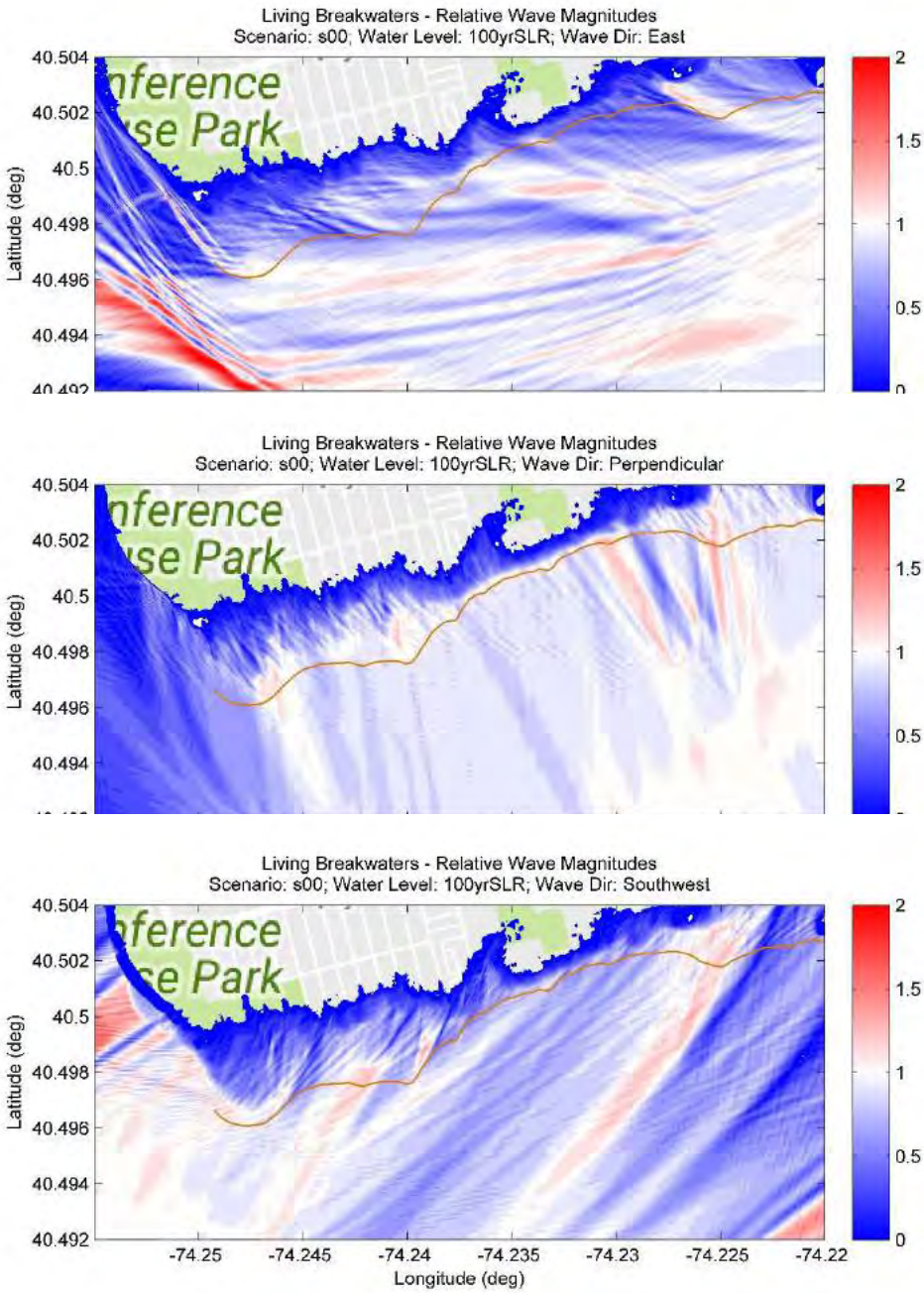


Figure 34. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. Baseline simulations with SLR, without-project, for an incoming wave height of 5.3 feet, wave period of 5 seconds, and the 1%-annual-chance FEMA PFIRM water elevation. Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

30% DESIGN SIMULATIONS

The 30% design simulation, including breakwaters and shoreline restoration, is summarized by relative wave height (wave height divided by incoming wave height imposed at the boundary) plots for each of the three wave approach directions on Figure 35 and Figure 36. Figure 35 shows the mean high water event with an imposed wave height of 3 feet and a wave period of 3 seconds. Figure 36 shows the FEMA PFIRM 1%-annual-chance event with an imposed wave height of 5.3 feet, and a wave period of 5 seconds.

Each image illustrates wave shadow areas created by breakwaters, wave penetration, and diffraction through the edge and gaps of breakwaters. The images also include a noticeable wave breaking line close to the shoreline, indicated by dark blue relative wave heights (close to zero). The breaker line advances landward for the increased water levels associated with the 1%-annual-chance event shown on Figure 36. Wave shoaling, refraction, and diffraction are also clearly observed from the propagation, crossing, and dissipation of wave rays at nearshore areas and around the breakwaters.

Design simulations were also run for the MHW with 30” of SLR and the 1% annual chance storm event with 30” of SLR (See Figure 37 and Figure 38). For these simulations, it was assumed that SLR would generate elevated water levels (stillwater elevations) but would not affect the storm wave height and period. The SLR simulations show the further penetration of waves and higher wave heights.

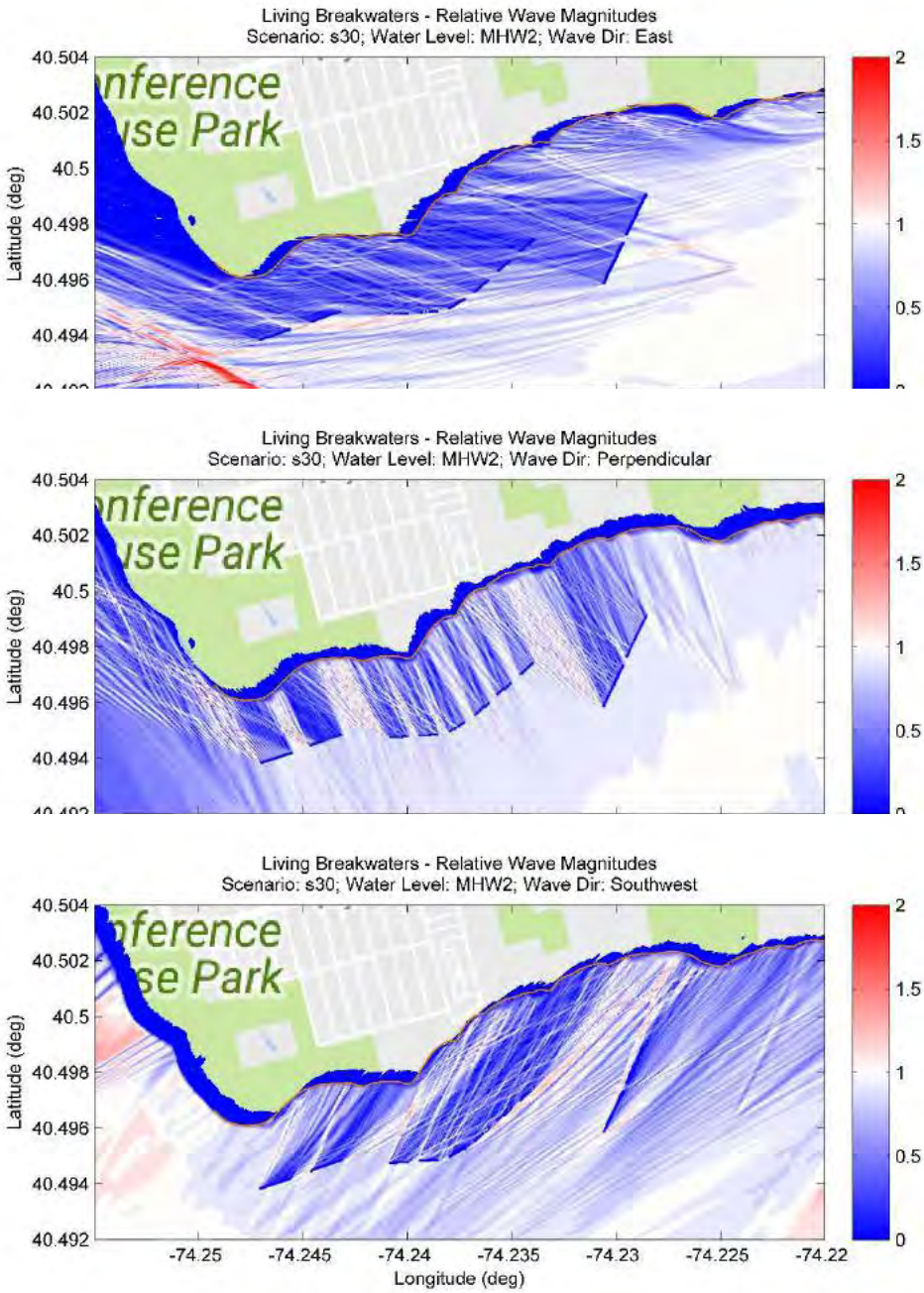


Figure 35. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. 30% design simulations for an incoming wave height of 3 feet, wave period of 3 seconds, and mean high water. Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

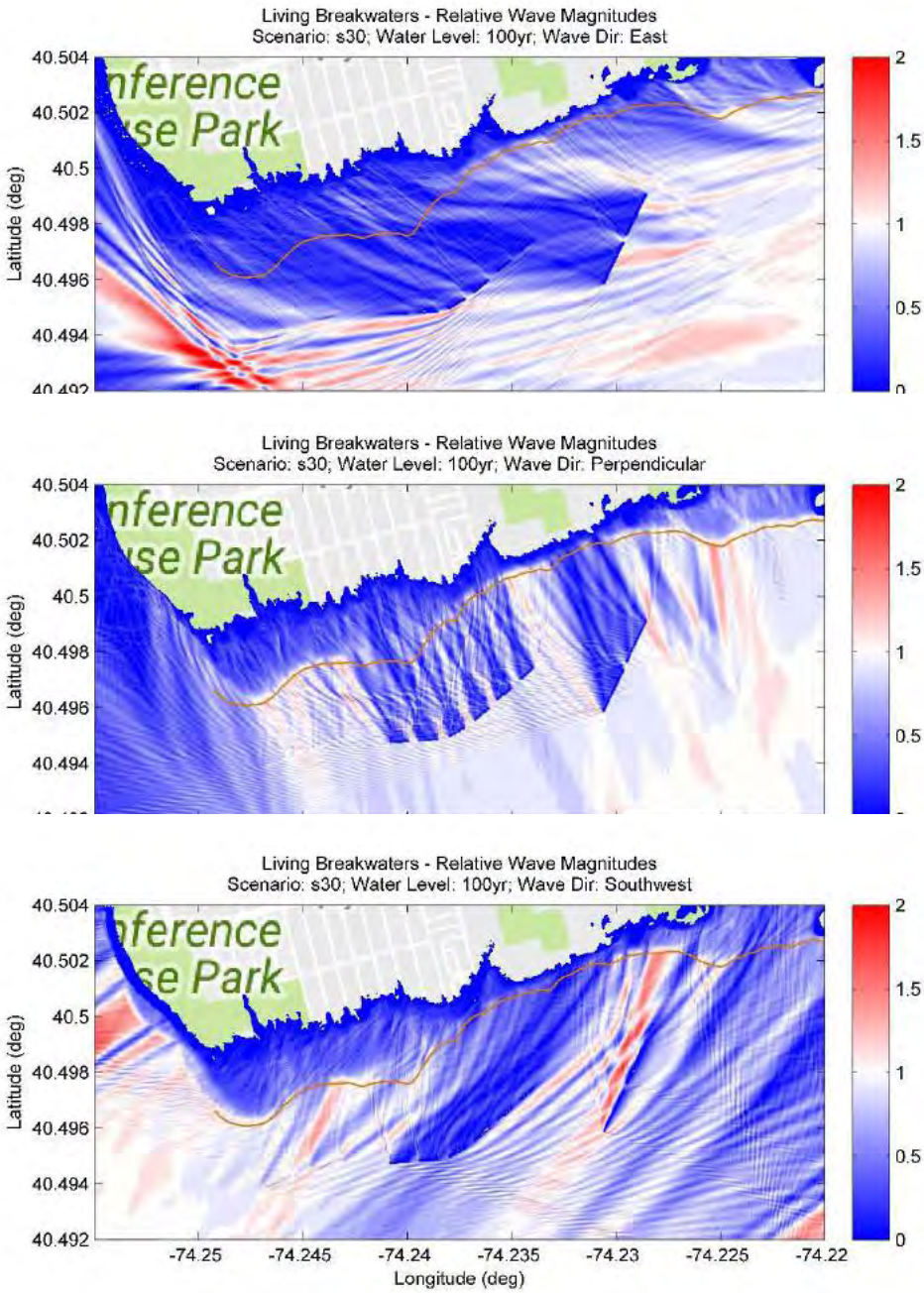


Figure 36. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. 30% design simulations for an incoming wave height of 5.3 feet, wave period of 5 seconds, and the 1%-annual-chance FEMA PFIRM water elevation. Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

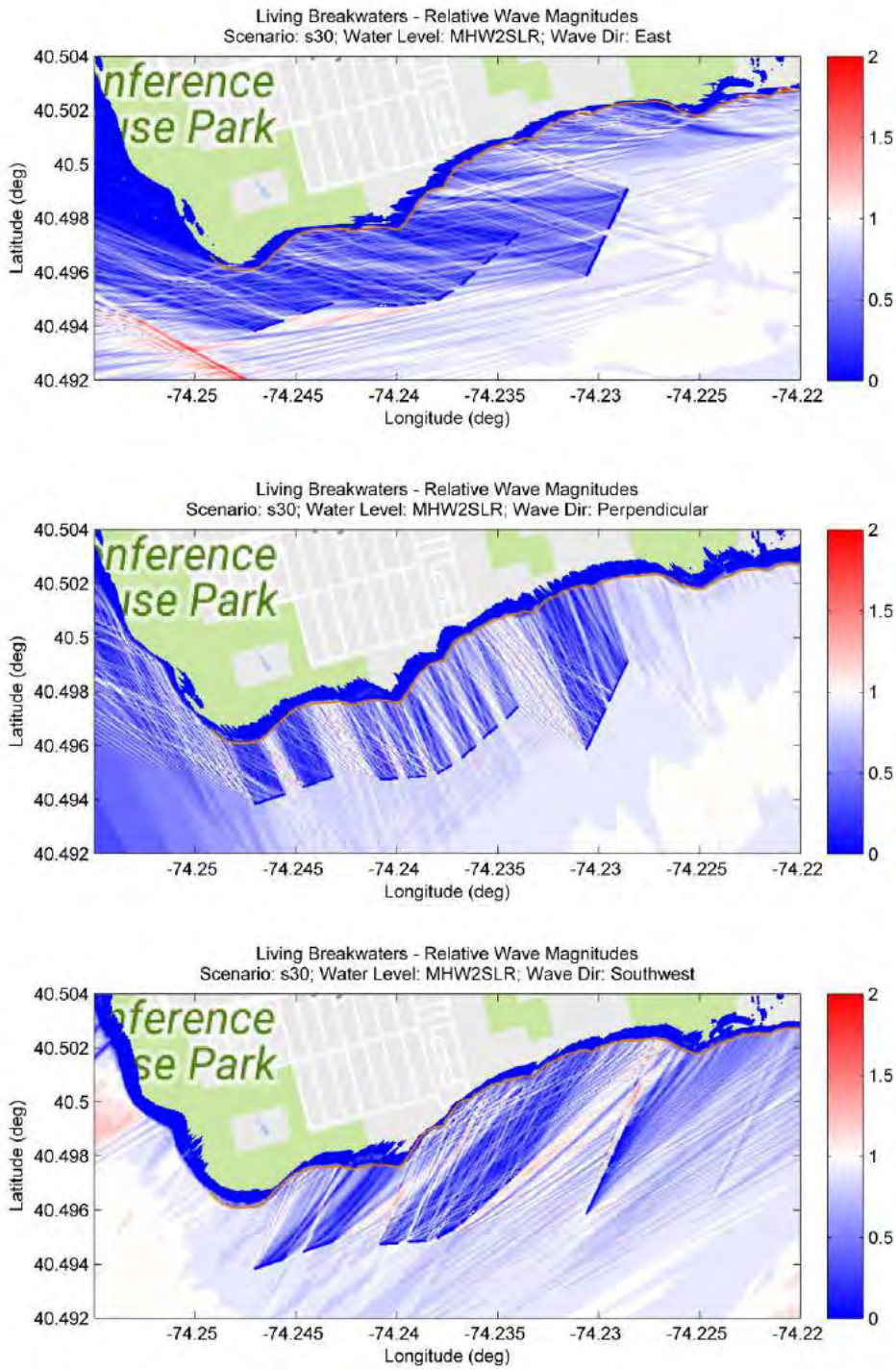


Figure 37. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. 30% design simulations for an incoming wave height of 3 feet, wave period of 3 seconds, and mean high water with SLR. Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

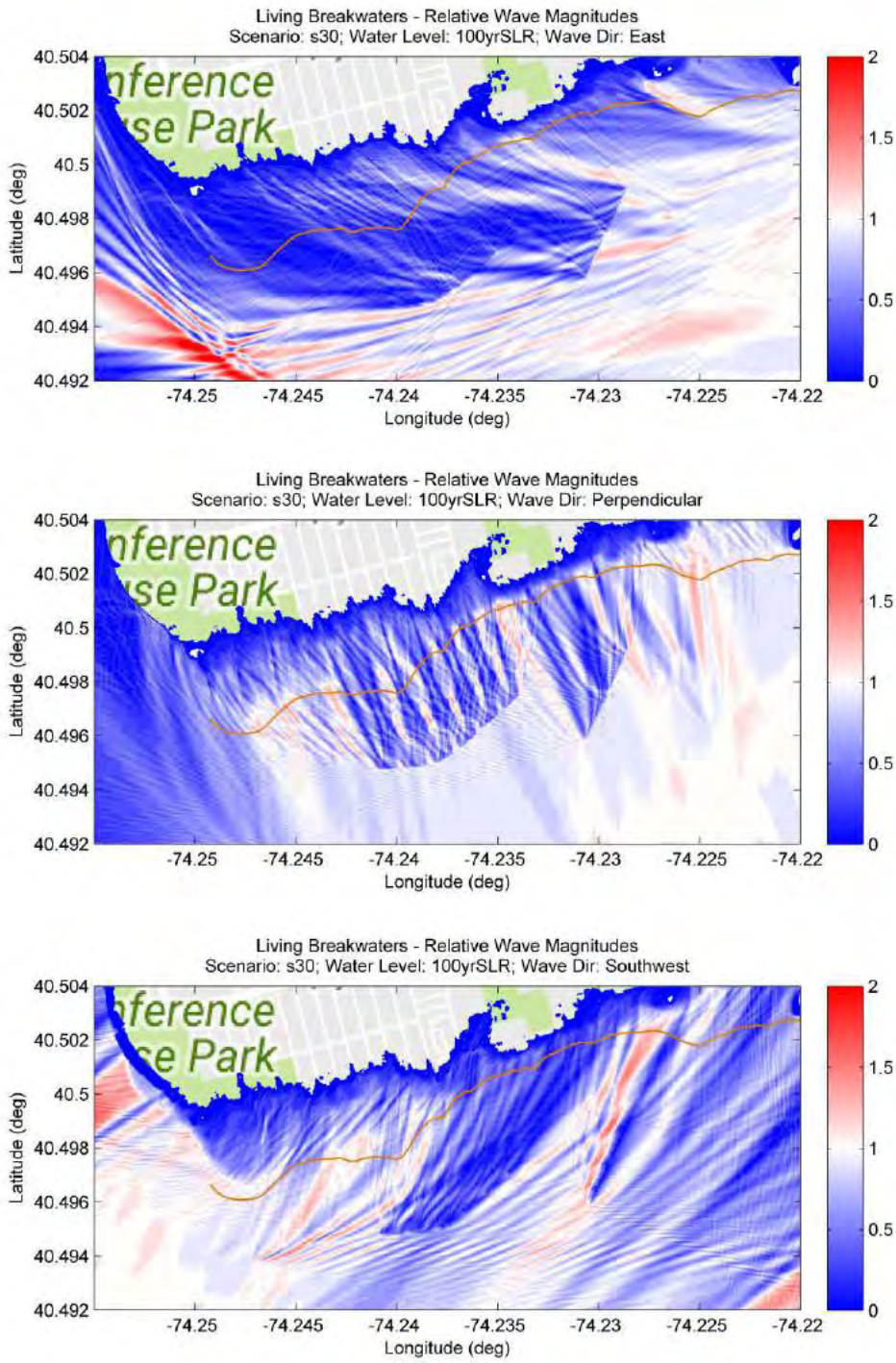


Figure 38. Relative wave heights in the vicinity of the potential Living Breakwaters alignment. 30% design simulations for an incoming wave height of 5.3 feet, wave period of 5 seconds, and the 1%-annual-chance FEMA PFIRM water elevation with SLR. Top Image: east wave. Middle image: wave perpendicular to shoreline. Bottom image: southwest wave. Orange line is shoreline.

ANALYSIS OF RESULTS

In order to better understand and preliminarily quantify the influence of the breakwaters on wave heights, average relative wave heights (or the percentage of incident wave height remaining) were calculated for regions near the project area. The locations of these regions are represented by the polygons shown on Figure 39. They were selected based on beach profile survey transect locations, breakwater layout, and cross shore beach change analysis locations.

Figure 39. Locations of polygons, transects, and relative wave heights for wave reduction calculation.

The average relative wave heights were calculated for each of the polygons shown in Figure 39 by averaging the relative wave heights located inside the polygons for each of the simulations run. The change in relative wave heights between the results with and without the project reflect the wave attenuation (wave height reduction) due to the breakwaters. The results of this analysis are presented in the tables on the following pages. Table 9, Table 10, and Table 11 present the wave reductions for each polygon along three incident wave directions for MHW both today and with 30" of sea level rise (SLR). It can be seen that the existing bathymetry reduces the incoming wave heights slightly (Table 9) and the addition of the breakwaters cause further reductions (Tables 10 and 11). Table 12, Table 13, and Table 14 present the same for the FEMA PFIRM 1%-annual-chance (100 year) event with an imposed wave height of 5.3 feet and a wave period of 5 seconds both with and without SLR. In each table the "relative wave height" is presented as the decimal percent of the wave height inputted at the model boundary. It should be noted that the project places greater focus on the area represented by polygon E for storm wave height reduction, as this is the zone within the project area with vulnerable on-shore assets in the FEMA PFIRM V zone and LiMWA. In other locations, while the shoreline has been subject to erosion, structures and infrastructure are

currently outside the FEMA PFIRM high energy wave zones. Only those polygons where wave height reductions were targeted or within the influence of the breakwaters are included in the summary below.

Wave Reduction Results at Mean High Water Level and 3 foot Wave Height

Table 9. Relative wave heights for baseline simulations (MHW).

Polygon	Associated Transects	Relative Wave Height Today (MHW=2.08 NAVD88)			Relative Wave Height with 30" SLR (MHW=4.58 NAVD88)		
		East	Perpendicular	Southwest	East	Perpendicular	Southwest
C	6, 7, 8	0.94	0.93	0.97	0.91	0.87	0.95
D	9	0.95	0.91	0.74	0.94	0.88	0.81
E	10, 11, 12, 13	0.87	0.91	0.92	0.9	0.9	0.9
F	14, 15, 16	0.84	0.9	0.89	0.91	0.89	0.94
G	17, 18	0.9	0.93	0.83	0.92	0.91	0.88
H	19, 20	0.8	0.91	0.8	0.82	0.89	0.85

Table 10. Wave reductions for 30% design simulations (MHW).

Polygon	Associated Transects	Relative Wave Height			Average Change from Baseline
		East	Perpendicular	Southwest	
C	6, 7, 8	0.4	0.52	0.73	-42%
D	9	0.36	0.92	0.39	-36%
E	10, 11, 12, 13	0.45	0.66	0.56	-38%
F	14, 15, 16	0.52	0.94	0.48	-27%
G	17, 18	0.74	0.59	0.91	-15%
H	19, 20	0.8	0.91	0.71	-4%

Table 11. Wave reductions for 30% design simulations with SLR (MHW + 30").

Polygon	Associated Transects	Relative Wave Height			Average Change from Baseline	Average Change From 30% Design with no SLR
		East	Perpendicular	Southwest		
C	6, 7, 8	0.36	0.49	0.73	-42%	0%
D	9	0.43	0.9	0.35	-36%	0%
E	10, 11, 12, 13	0.46	0.64	0.61	-37%	1%
F	14, 15, 16	0.59	0.93	0.38	-30%	3%
G	17, 18	0.78	0.48	0.88	-21%	6%
H	19, 20	0.82	0.89	0.74	-4%	0%

Wave Reduction Results at 1% Annual Chance Water Level and Wave Height

Table 12. Wave reductions for baseline simulations (100 year).

Polygon	Associated Transects	Relative Wave Height			Relative Wave Height (with 30" SLR)		
		East	Perpendicular	Southwest	East	Perpendicular	Southwest
C	6, 7, 8	1.04	0.93	1.08	1.05	0.93	1.06
D	9	1.14	0.91	0.95	1.12	0.93	0.96
E	10, 11, 12, 13	0.96	0.94	0.77	0.96	0.94	0.81
F	14, 15, 16	0.75	0.93	0.70	0.81	0.94	0.75
G	17, 18	0.99	0.99	0.83	1	0.98	0.83
H	19, 20	0.85	0.86	1.04	0.83	0.88	1.01

Table 13. Wave reductions for 30% design simulations (100 year).

Polygon	Associated Transects	Relative Wave Height			Average Change from Baseline
		East	Perpendicular	Southwest	
C	6, 7, 8	0.5	0.92	1	-20%
D	9	0.23	0.94	0.88	-28%
E	10, 11, 12, 13	0.29	0.56	0.43	-51%
F	14, 15, 16	0.34	1	0.29	-35%
G	17, 18	0.76	0.43	0.9	-24%
H	19, 20	0.85	0.87	0.83	-6%

Table 14. Wave reductions for 30% design simulations with SLR (100 year + 30").

Polygon	Associated Transects	Relative Wave Height			Average Change from Baseline	Average Change From 30% Design with no SLR
		East	Perpendicular	Southwest		
C	6, 7, 8	0.43	0.94	1.03	-20%	0%
D	9	0.25	0.96	0.92	-26%	2%
E	10, 11, 12, 13	0.29	0.6	0.47	-49%	2%
F	14, 15, 16	0.73	1.02	0.23	-24%	11%
G	17, 18	0.8	0.57	0.9	-18%	6%
H	19, 20	0.83	0.87	0.76	-9%	-2%

CONCLUSIONS

The REFDIF wave transformation model was used to examine the wave climate in the nearshore region close to the proposed Living Breakwaters alignments. While breakwaters cannot lower the storm surge elevations, they can dramatically reduce the waves acting on the shoreline, which damage shoreline structures and are the driving force for erosion.

Comparing model results for relative wave heights with- and without Living Breakwaters demonstrate average wave height reductions of up to 51%. The largest wave reductions were in the region targeted for storm wave attenuation (polygon E) due to the concentration of residential infrastructure there. The effectiveness of the breakwaters is reduced with 30 inches of sea level rise allowing 2-11% increases in wave height but the Living Breakwaters still reduce wave heights up to 49%.

STORM INDUCED PROFILE RESPONSE MODELING

In addition to the long term shoreline change, shorter term storm-induced changes to the beach profile were investigated. Tropical and extratropical storms influence the beach profile over these short time frames, requiring a modified approach from the long term shoreline modeling described previously. For consistency with the TSPP team's approach, the SBEACH model (Larson, 1990) was first used to evaluate storm-induced beach profile changes.

However, as described in the following sections, calibration efforts demonstrated that SBEACH was not capable of accurately reproducing the beach profile response observed during the Hurricane Sandy event. As a result, an alternative storm-induced shoreline change model, CSHORE (Johnson, 2012), was evaluated as well. CSHORE performed significantly better than SBEACH at reproducing the observed Hurricane Sandy profile response. As a result, CSHORE was used for the full analysis of with- and without-project storm-induced beach profile change simulations. The results of these simulations are described in the following sections. Note that storm induced beach profile change was only modeled for areas outside the TSPP project area. The TSPP team is modeling and analyzing transects within the TSPP project area. .

SBEACH AND CSHORE MODEL OVERVIEW

Cross shore changes in the shoreline/beach profile due to a single storm event can be significant. Both the Storm-induced BEAch CHange beach erosion model (SBEACH) and the Cross-SHORE beach erosion model (CSHORE) were used to assess storm event response and changes to the beach profile. The models simulate cross-shore beach, berm, and dune erosion produced by storm waves and water levels. The models require the following inputs:

- Beach Profile Transects
- Wave Conditions
- Water Levels
- Sediment Characteristics

These inputs are discussed further in the following sections.

BASELINE MODEL INPUTS

BEACH PROFILE TRANSECTS

Simulations were performed at the transect locations shown on Figure 40. The location map shows 23 beach profile transects which are categorized as either inside or outside the TSPP limits, shown in purple. The analysis described herein focuses on the 10 beach profile transects (1-7 and 21-23) outside the TSPP.

Figure 40. Transect location map.

Transect surveys were performed in Fall 2015 and Spring 2016 (MFS, 2015). Both surveys ranged from -50 to +10 feet NAVD88 for all transects, and the seasonal differences at each transect were minimal. Given the high degree of overlap and similarity between the two sets of transects, running a separate analysis for Fall and Spring was not necessary. As a result, only the Fall 2015 transect profiles were used in the analysis. Transect surveys were combined with 2010 LiDAR (NYC, 2012) to supplement onshore topography to the inland extent of storm tide.

The ten combined transects have lengths between 1,000 and 4,000 feet. The transects begin offshore at a depth of -50 to -40 feet NAVD88 and extend onshore to an elevation of 10 to 40 feet NAVD88. Beach berm widths are

approximately 100 feet for most transects. Transects 1, 4, 21, and 23 have foredune features at an approximate elevation of 7 feet NAVD88. Transects 4 through 23 generally have dune features at approximately 10 feet NAVD88. Figure 41 shows the beach profile at transect 1, with all other profiles shown in Appendix B.

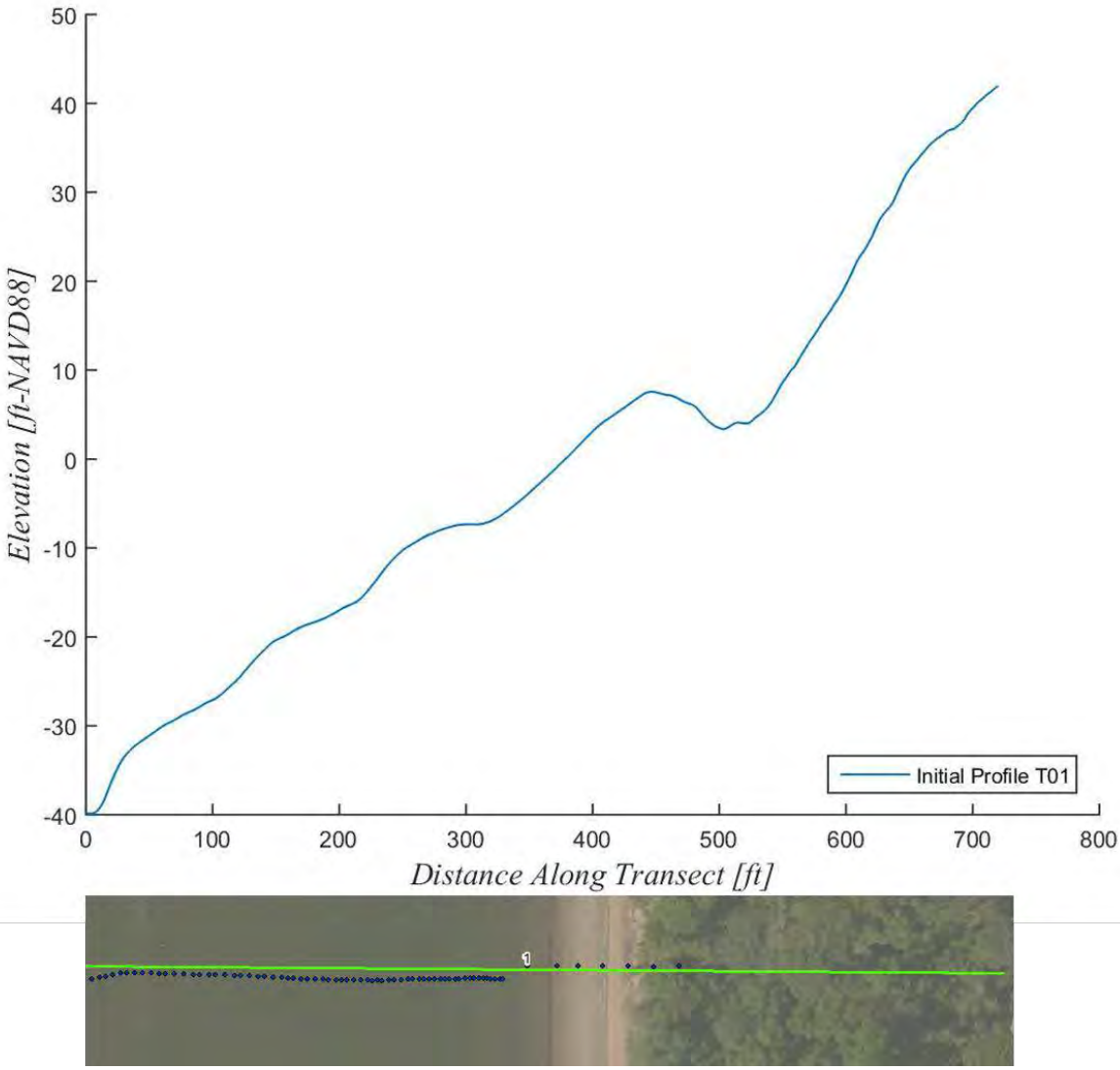


Figure 41. Beach profile at transect 1. Profiles supplemented with pre-Sandy LiDAR Onshore of the Fall 2015 transect survey. Recent orthoimagery at the transect shown for reference.

WATER LEVELS AND WAVE CONDITIONS

Storms representing the 10-, 25-, 50-, and 100-year FEMA PFIRM return period events and Hurricane Sandy were selected to be simulated. The four FEMA storms were selected from the full suite of 189 storms used by FEMA to develop the 2013 PFIRM (FEMA 2015). The individual storms that best matched the published FEMA PFIRM return period stillwater elevations were selected for analysis. Historical extratropical storms best represent the 10- and 25-year storm events, and synthetic tropical storms best represent the 50- and 100-year storm events, as shown in Table 15.

Using the FEMA PFIRM model inputs for these storms, each event listed in Table 15 was simulated in ADCIRC/SWAN to provide wave conditions and water levels during the storms that were used as inputs into the profile response modeling. The time series inputs provided by ADCIRC/SWAN include water levels, significant wave heights, and peak wave periods at regular time intervals for the full storm duration at the project site. For the Hurricane Sandy storm, the FEMA PFIRM ADCIRC/SWAN bathymetric grid was refined and simulated with available wind field and water level forcing conditions observed during the hurricane (City of New York, 2013). Simulation outputs were found to compare well with observed high water marks and time series of storm tides collected by the USGS in New York Harbor, including adjacent to the Living Breakwaters.

Table 15. Simulation events, their names, and associated peak stillwater elevation.

Event	Peak Stillwater Elevation (feet NAVD88)	Storm Name
10-Year	8.1	FEMA PFIRM “19620306”
25-Year	9.3	FEMA PFIRM “19921211”
50-Year	11.3	FEMA PFIRM “NJB_0003_012”
100-Year	12.7	FEMA PFIRM “NJB_0001_010”
Hurricane Sandy	12.9	Hurricane Sandy

To match each storm to a given return period event, the time series data of ADCIRC/SWAN model results were extracted from a nearshore location close to the project area (Figure 42). The extracted water level and wave height time series are shown on Figure 43 through Figure 47. The peak surge elevation from each storm is then compared to return surge elevations at the sample locations. Storms that most closely match the 10-, 25-, 50-, and 100-year return surge elevations were then selected. From the selected storms, wave and water level time series were extracted at locations near the offshore ends of the transects, shown on Figure 40. These wave and water level time series from the offshore transect location were propagated along the transect using the SBEACH and CSHORE profile response modeling.

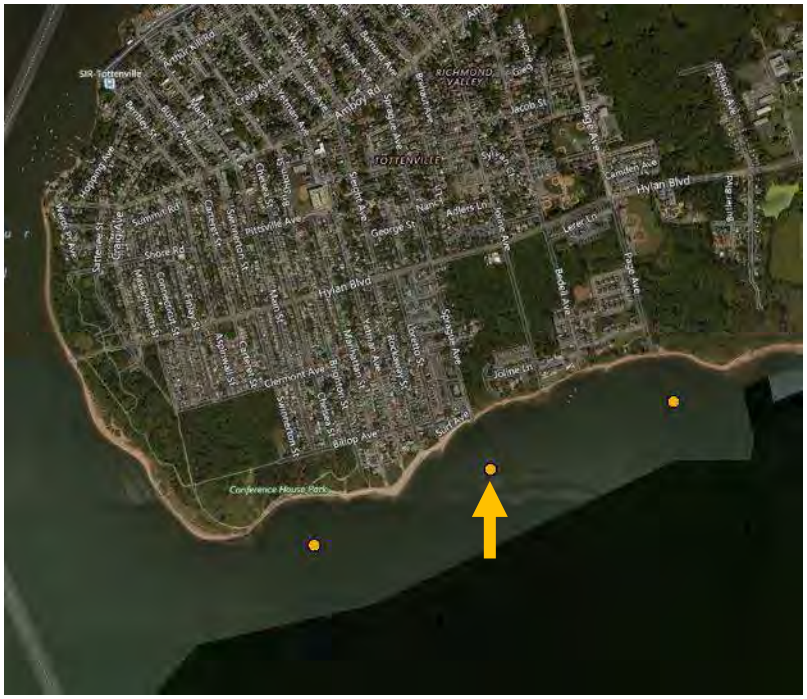


Figure 42. Nearshore extraction location, close to the project area, indicated by the arrow.

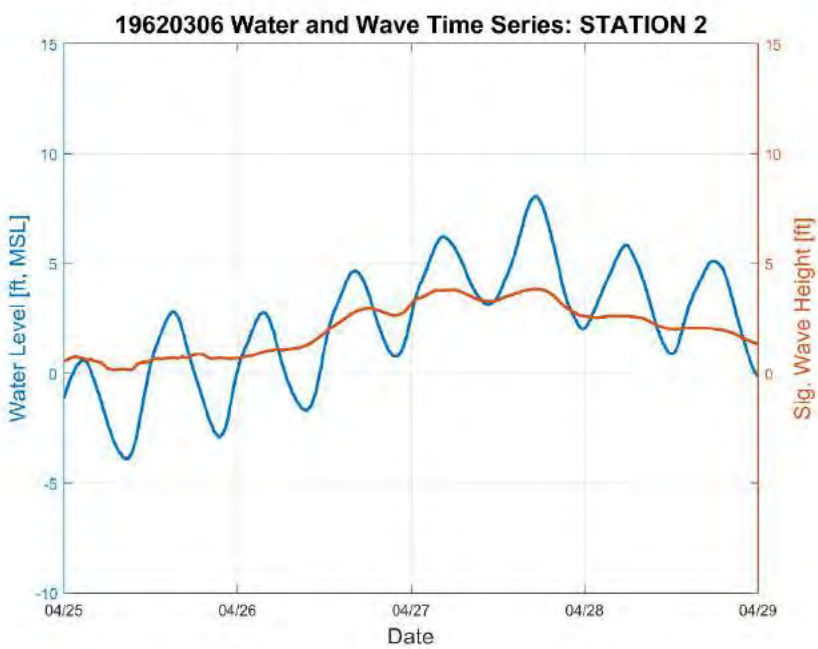


Figure 43. 10-year event storm tide and wave height time series.

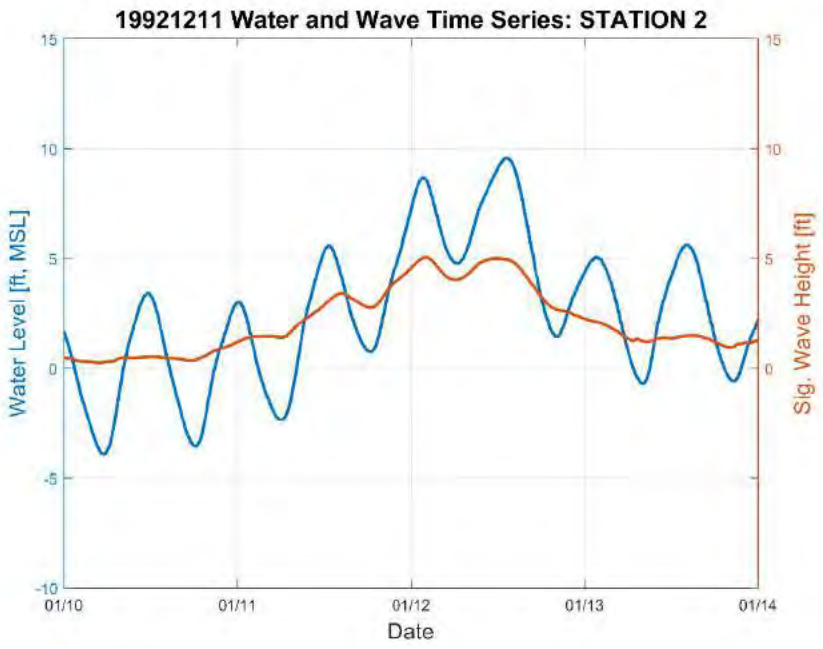


Figure 44. 25-year event storm tide and wave height time series.

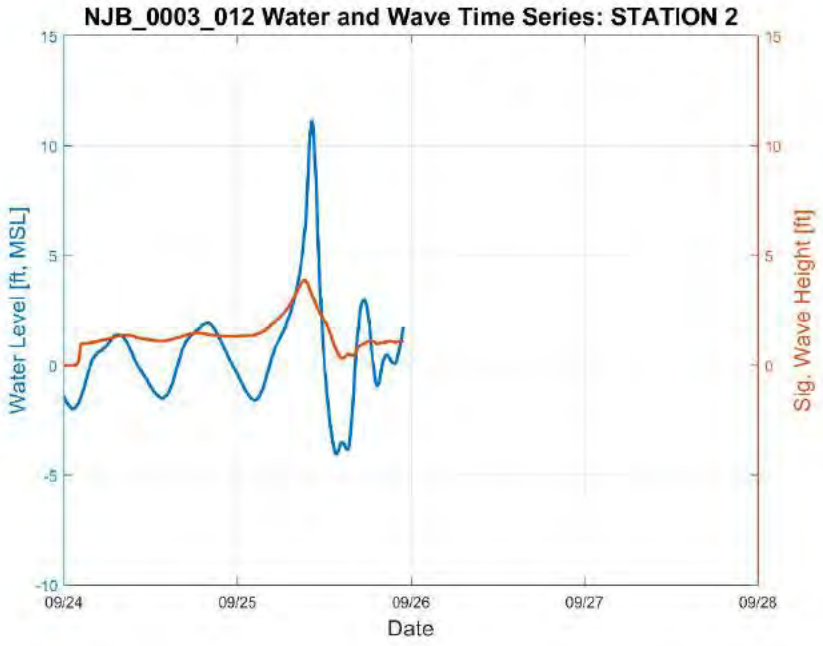


Figure 45. 50-year event storm tide and wave height time series.

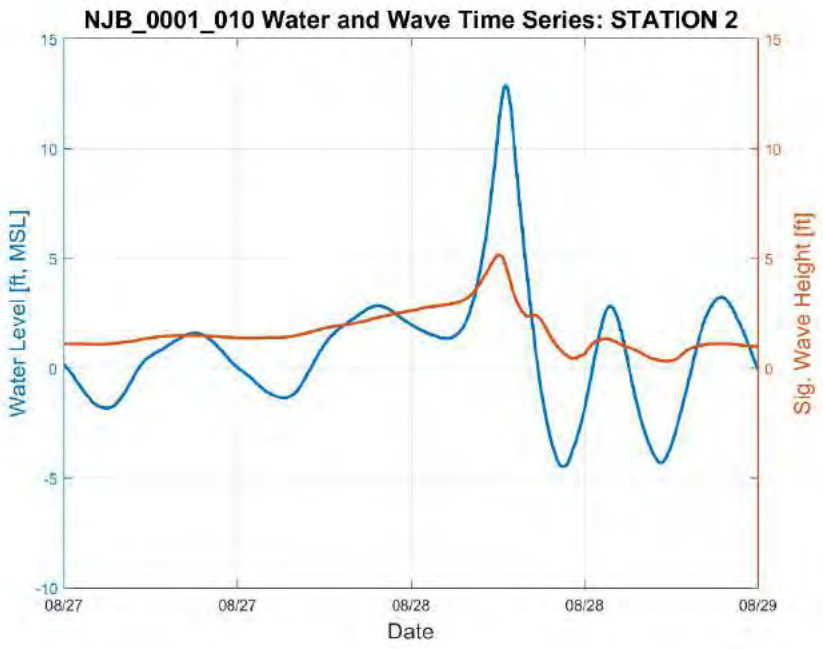


Figure 46. 100-year event storm tide and wave height time series.

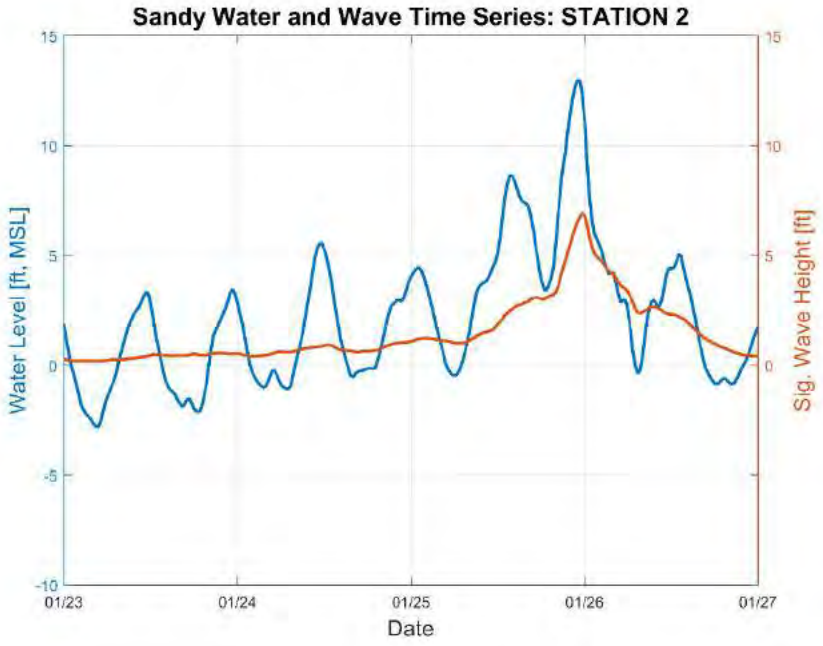


Figure 47. Hurricane Sandy storm tide and wave height time series.

SEDIMENT CHARACTERISTICS

Sediment surveys were completed throughout the project area during Summer 2015, Fall 2015, and Spring 2016 (MFS, 2015). The specific sediment surveys utilized in this analysis were:

- Fall 2015 Nearshore (MFS 11/15)
- Summer 2015 Offshore (Hill International 6/15)
- Spring 2016 Nearshore (MFS 5/16)
- Spring 2016 Offshore (Prudent Engineering 4/16)

Figure 48 shows an overview of sediment size from the Summer and Fall 2015 surveys, and Figure 49 shows the same overview of the Spring 2016 surveys. The average D_{50} measurement for both sets of surveys is 0.94 millimeters. However, this average D_{50} is influenced by surveys taken near the MLLW elevation in the surf zone where the sediment is considerably coarser. The average D_{50} for these MLLW measurements is 2.15 millimeters. The average D_{50} is 0.61 millimeters when you exclude those measurements and only include the offshore surveys and the beach surveys inland of MLLW. These average sediment sizes informed a range of D_{50} values that were tested during the calibration phase. Table 16 includes a summary of the sediment data.

Table 16. Summary of sediment survey data.

Location	Sediment Size (mm)		
	Fall	Spring	Average
Average MLLW	2.24	2.06	2.15
Average Nearshore including MLLW	1.05	1.07	1.06
Average Nearshore without MLLW	0.53	0.71	0.62
Average All	0.95	0.93	0.94
Average All without MLLW	0.56	0.67	0.61

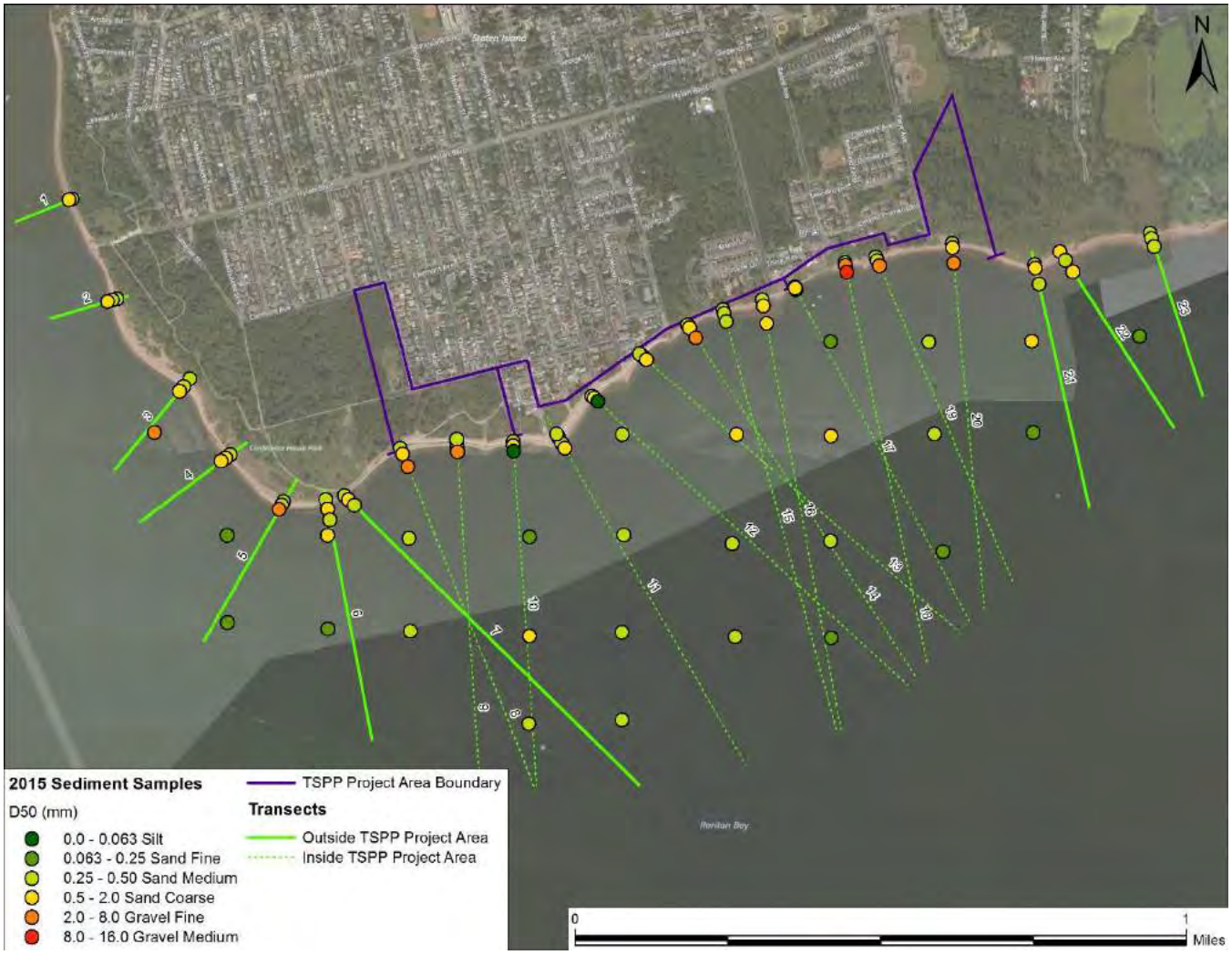


Figure 48. Summer and Fall 2015 sediment surveys.

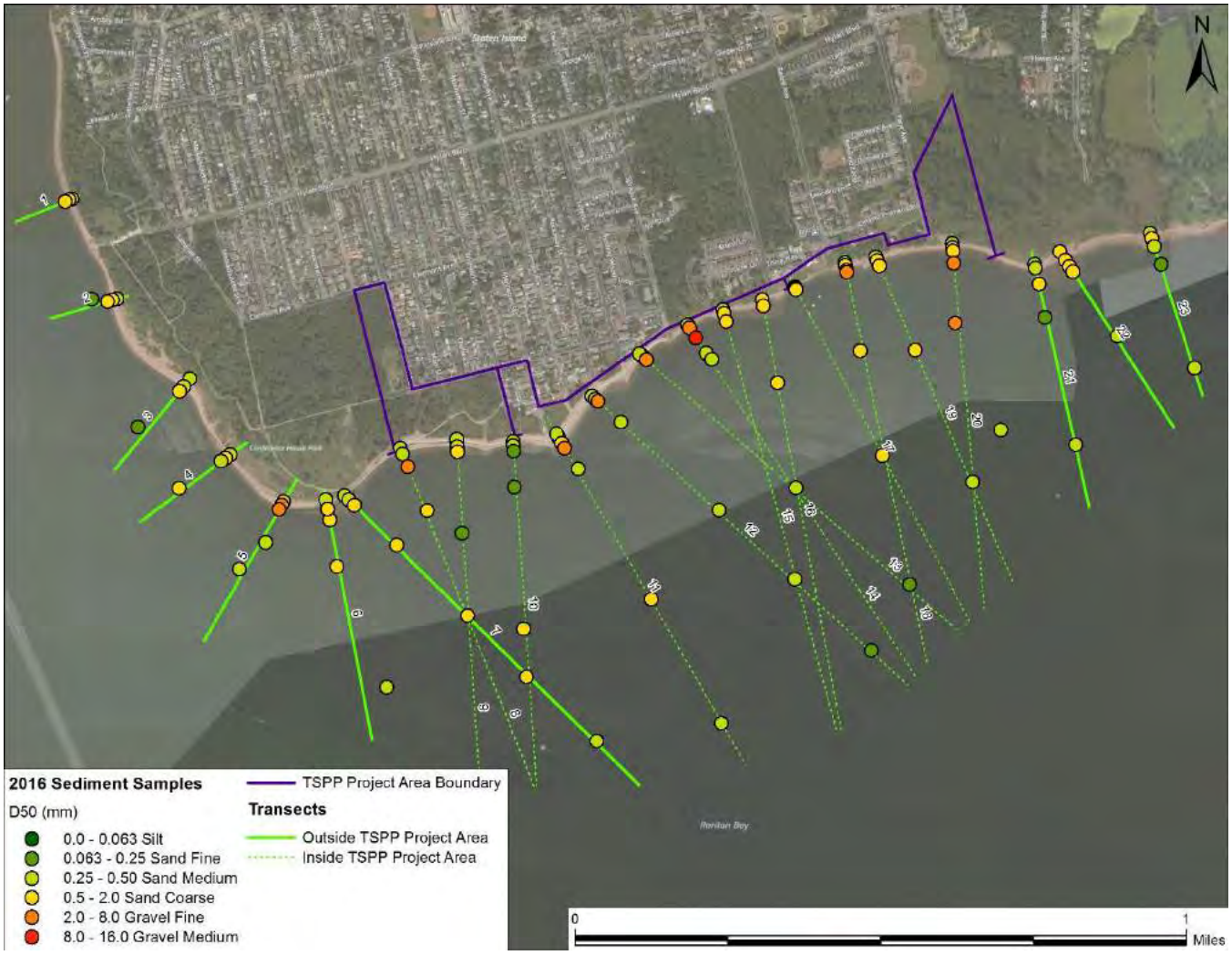


Figure 49. Spring 2016 sediment survey.

BASELINE SIMULATIONS

MODEL CALIBRATION

With no pre- and post-storm event beach surveys in the region available, data from Hurricane Sandy was used for calibration of the model. LiDAR pre-and post-Sandy were used in the analysis (USGS 2010; USGS 2014). Pre-Sandy LiDAR surveys were collected in Spring 2010. Hurricane Sandy made landfall on October 29, 2012, and Post-Sandy LiDAR surveys were completed two weeks later on November 16, 2012.There is a significant time between the pre- and post-storm LiDAR data, which is a possible source of error, but it represents the best available data. These transects are located throughout an undeveloped beach environment where beach profiles are not affected by man-made structures. Without outside influence, it is assumed that the change in the beach profiles is due to Hurricane Sandy. Given local MHW is 2.08 feet NAVD88, only LiDAR information above 2 feet NAVD88 was used due to interference from the water. Figure 50 shows the pre- and post-Sandy Lidar used for this analysis.

Pre- and post-Sandy orthoimagery collected by NOAA was also reviewed. These images provide detail regarding the extent of overwash caused by the storm. In most places the imagery shows where the beach sediment was carried onshore. The orthoimagery was compared to the LiDAR surveys to verify the changes observed between pre- and post-Sandy observations. The orthoimagery at each transect show some degree of sand overwash that is also evident when comparing pre- and post-Sandy LiDAR. However, LiDAR surveys for transects 5, 6, 7, and 23 also show some scour along the backshore region. And, orthoimagery for these scour areas look similar to the overwash areas. In both cases the orthoimagery show more sediment and less vegetation which can be caused by overwash covering the vegetation or by the loss of vegetation due to scour. As a result, orthoimagery can be used to confirm a change occurred, but is not reliable at predicting whether that change was a gain or loss of sediment. Figure 50 and Figure 51 show an example of the aerial imagery comparison done at the project site.

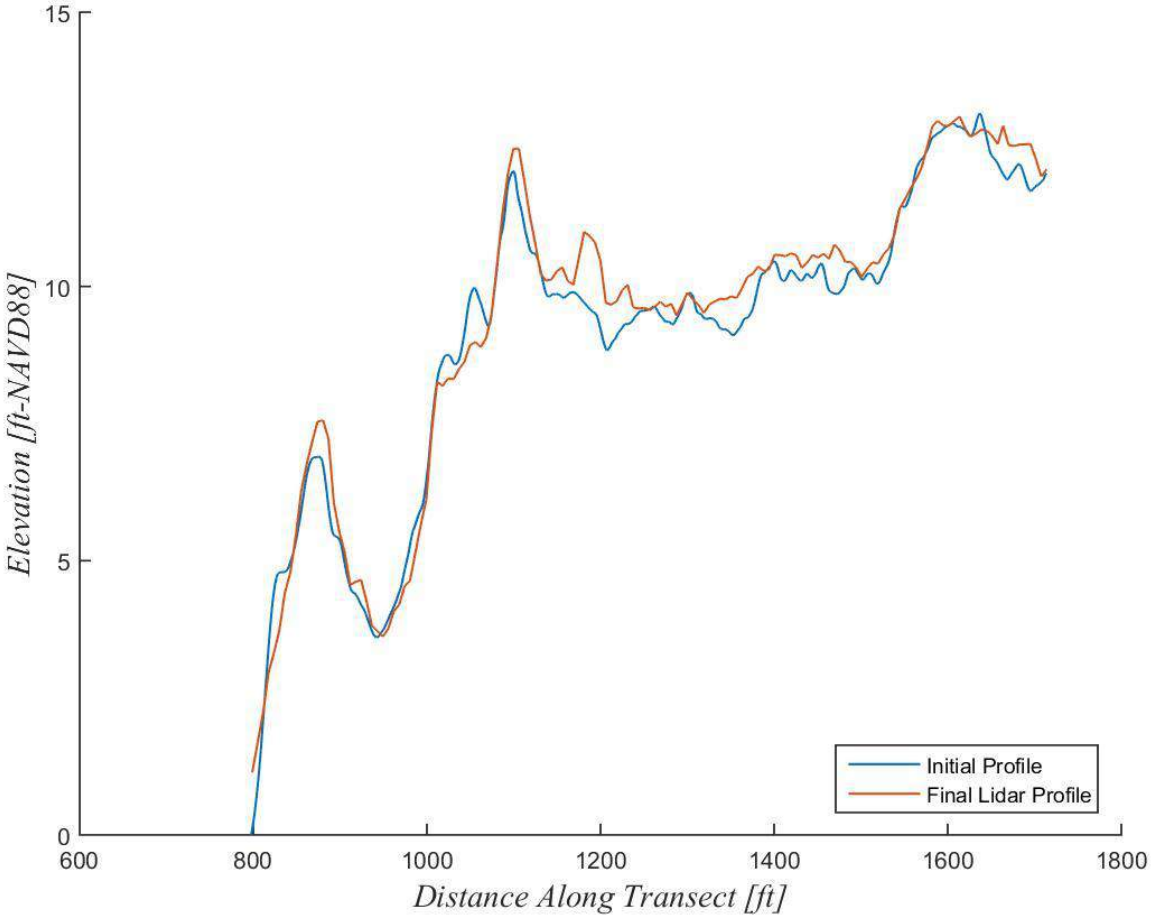


Figure 50. Pre- and post-Sandy comparison at transect 4. Line plot shows the initial (pre-Sandy) profile compared to the final (post-Sandy) profile. Underneath the line plot, the images include pre-Sandy orthoimagery (top) compared to post-Sandy orthoimagery (bottom). Comparison of the imagery shows some sand overwash covering the road in the middle of the image. The line plot shows that this change was indeed caused by additional sediment accumulation along the entire profile.

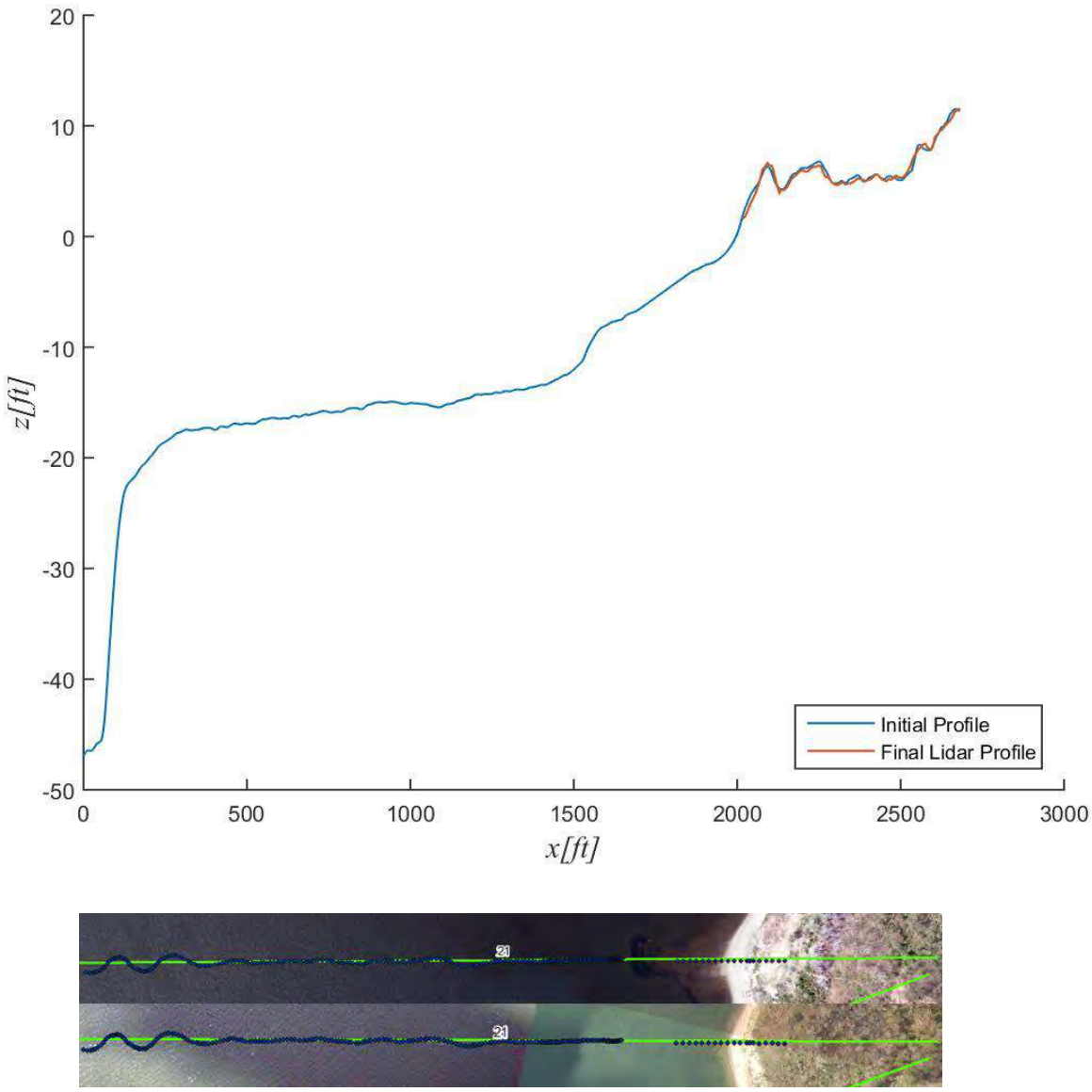


Figure 51. Pre- and post-Sandy comparison at transect 21. Line plot shows the initial (pre-Sandy) profile compared with the final (post-Sandy) profile. Underneath the line plot, the images pre-Sandy orthoimagery (top) compared to post-Sandy orthoimagery (bottom). Comparison of the imagery shows noticeable sand overwash caused by the storm. The line plot shows some erosion inland of the beach which is not immediately evident from the imagery.

The Hurricane Sandy storm and waves time series inputs were simulated for each of the 10 beach profile transects outside the TSPP project limits. When simulating results in SBEACH, the beach profiles, especially at dune features, showed more erosion than the post-Sandy Lidar surveys. Figure 52 and Figure 53 show the SBEACH results of the Hurricane Sandy event simulations at transects 4 and 21.

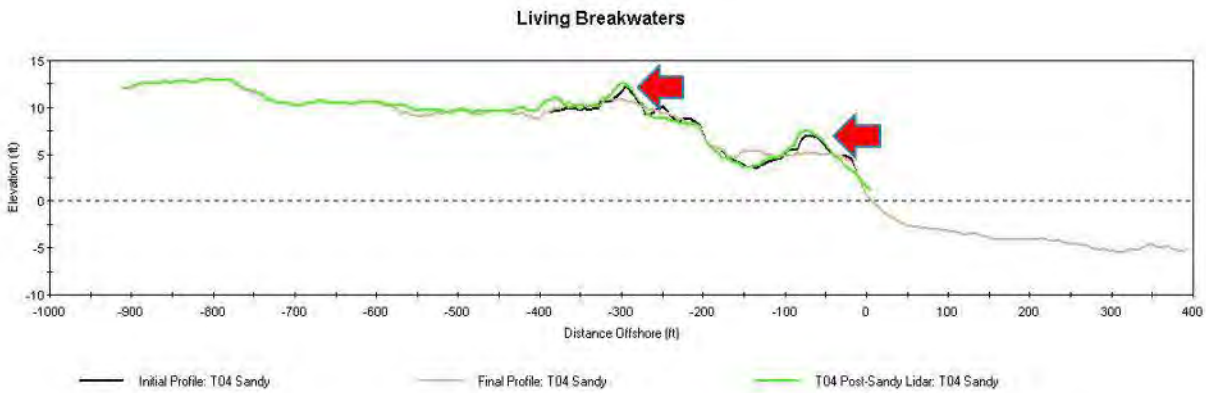


Figure 52. SBEACH model results for Hurricane Sandy at transect 4. Initial pre-Sandy profile shown in red. Final SBEACH profile shown in gray. Post-Sandy Lidar survey shown in green. Arrows point to large dunes where SBEACH results show considerable erosion relative to post-Sandy LiDAR.

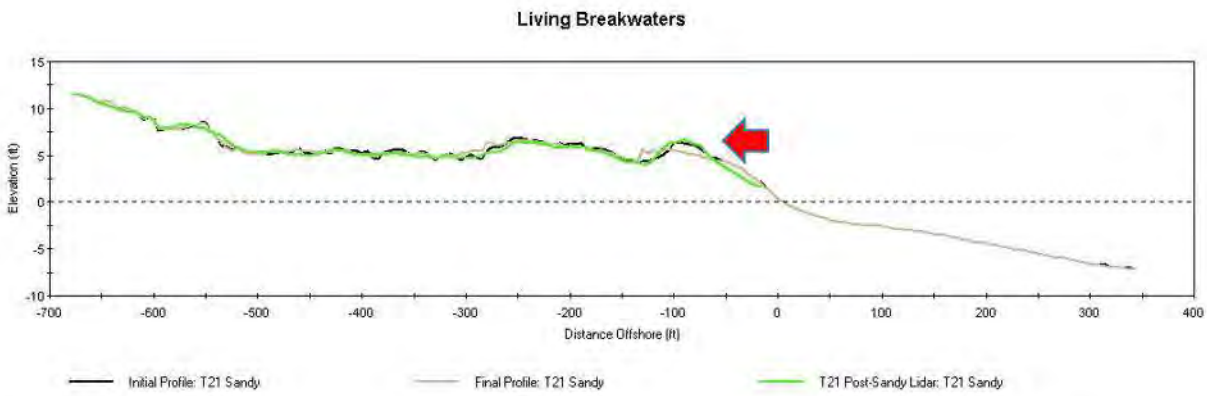


Figure 53. SBEACH model results for Hurricane Sandy at transect 21. Initial pre-Sandy profile shown in red. Final SBEACH profile shown in gray. Post-Sandy Lidar survey shown in green. The arrow points to a dune where SBEACH results show considerable erosion relative to post-Sandy LiDAR.

Multiple rounds of model calibration were completed to reduce the high degree of erosion created in the SBEACH simulations that did not match the observed events. Table 17 lists the default parameter values in SBEACH, and the parameter values that produced results most similar to the post-Sandy Lidar survey results shown on Figure 52 and Figure 53. The model results were most sensitive to the D_{50} and the maximum slope prior to avalanching parameters. A full range of D_{50}'s and avalanching parameters was tested, and the parameters that produced results most similar to the post-Sandy profiles are shown in Table 17. Even with these calibrated parameters, the best attainable results with the SBEACH model, shown on Figure 52 and Figure 53, do not match the dune response during the Hurricane Sandy event. In an attempt to achieve better calibration, the CSHORE model was used to simulate the Sandy event as well (USGS, 2014). This alternative was included because the CSHORE model has a more detailed description of storm-event physics and has more recent updates from the experimental literature.

Also, the model was used extensively for dune erosion in the NYC region as part of the most-current FEMA PFIRM study (FEMA 2015).

Table 17. SBEACH Parameters. Default values were used except where alternative values yielded results closer to physical observations during calibration tests.

Parameter Name	Default Value	Calibrated Value
Transport Rate Coefficient (K)	1.75×10^{-6} m^4/N	1.75×10^{-6} m^4/N
Overwash Transport Parameter	0.005	0.005
Coefficient for Slope-Dependent Term (E)	0.002 m^2/s	0.002 m^2/s
Transport Rate Decay Coefficient Multiplier (λ)	0.5	0.5
Water Temperature	20 C	20 C
Effective Grain Size	0.35 mm	1.0 mm
Maximum Slope Prior to Avalanching	45 deg	30 deg

* Further description of the parameters can be found in the SBEACH documentation (Larson 1990)

The Hurricane Sandy event was simulated in CSHORE model using adjustments from the default input parameters where needed. Table 18 summarizes the default and calibrated parameters in CSHORE, highlighting the sensitivity to D_{50} and Suspension Efficiency Due to Breaking. The CSHORE and SBEACH results for transects 4 and 21 during the Hurricane Sandy event are shown on Figure 54 and Figure 55, clearly indicating the improved response of CSHORE relative to SBEACH, especially at dune features. The results for the remaining transects can be found in Appendix C. With these results, CSHORE was advanced for all simulations using the calibrated parameters shown in Table 18.

Table 18. CSHORE Parameters. Default values were used with some exceptions where alternative values yielded results closer to physical observations during calibration tests.

Parameter Name	Default Value	Calibrated Value
Shallow Water Wave Breaking Parameter	0.8	0.8
Sediment Porosity	0.4	0.4
Average Sediment Size (D_{50})	0.3	0.61
Specific Gravity	2.65	2.65
Suspension Efficiency due to Breaking	0.005	0.002
Suspension Efficiency due to Friction	0.01	0.01
Suspended Load Parameter	0.5	0.5
Overtopping Suspended Load Parameter	0.1	0.1
Sediment Friction Angle Tangent	0.630	0.630
Bedload Parameter	0.001	0.001
Bottom Friction Parameter	0.015	0.015

* Further description of the parameters can be found in the CSHORE documentation (Johnson 2012)

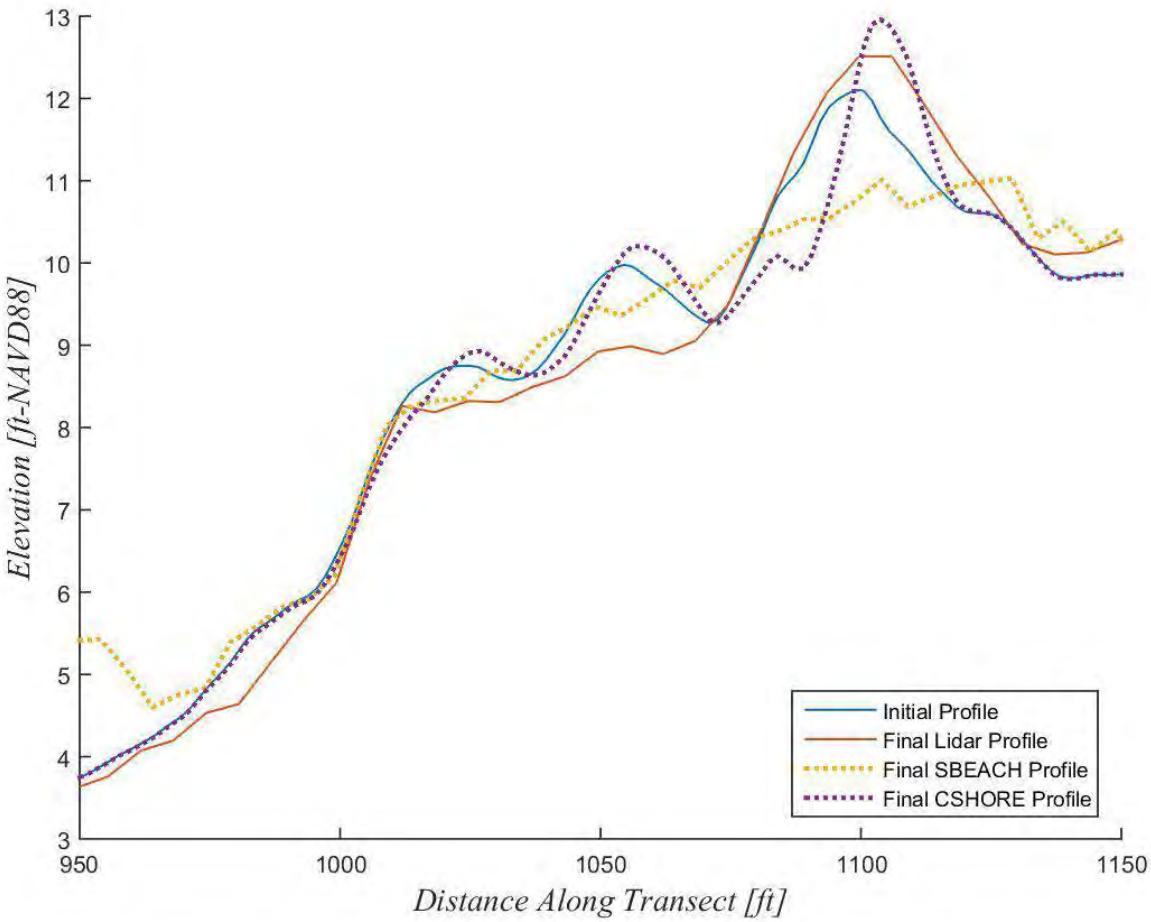


Figure 54. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 4. Final CSHORE Profile is much closer to Final Lidar Profile relative to SBEACH results.

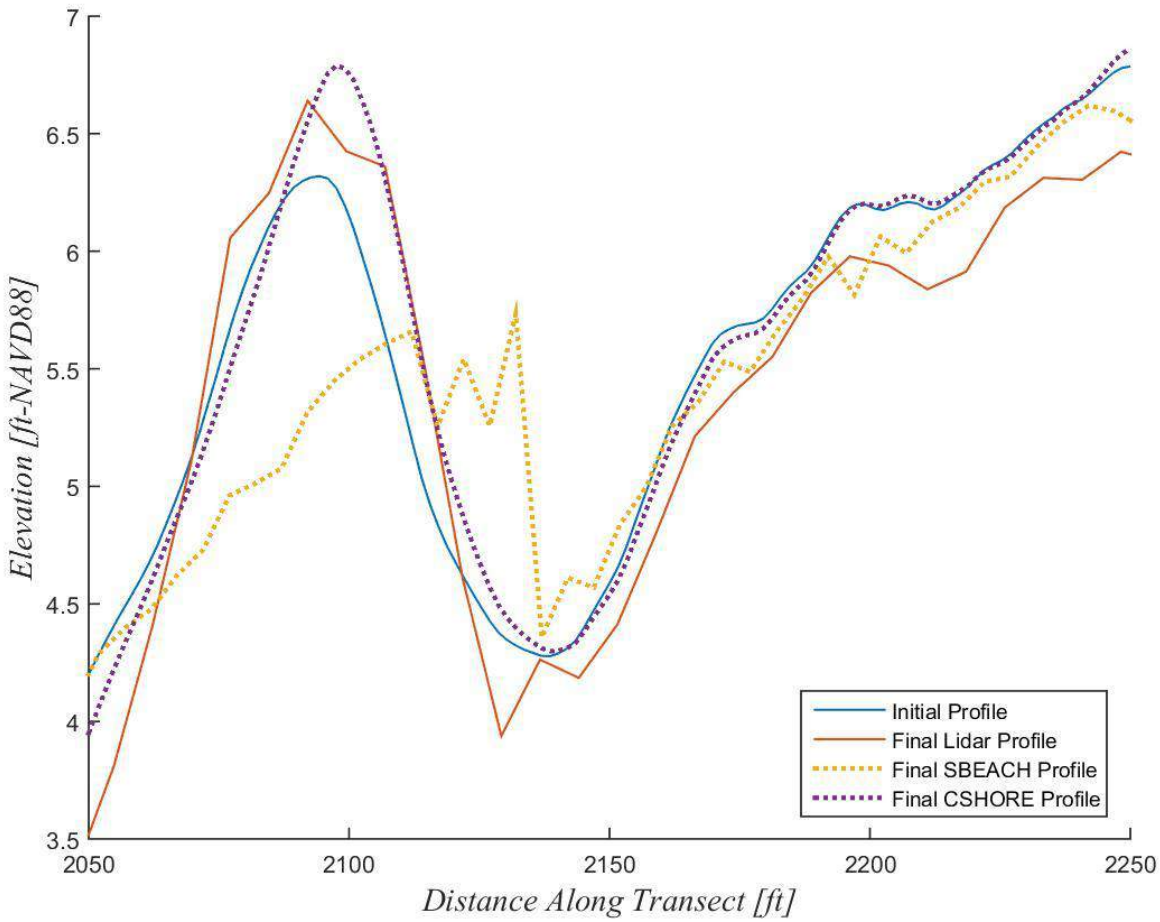


Figure 55. CSHORE and SBEACH model results for Hurricane Sandy at transect 21. Final CSHORE Profile is much closer to Final Lidar Profile relative to SBEACH results.

SIMULATION RESULTS – WITHOUT-PROJECT

Figure 56. Location map of beach profile transects. Transects 1-7 and 21-23 were modeled in CSHORE.

In addition to Hurricane Sandy, the CSHORE model was run for all four FEMA storms at the ten beach profile transects outside the TSPP project limits. The results for transects 1 through 5 show little or no change to the beach profile for any of the four FEMA storms. These transects are sheltered from the most direct wave exposure, explaining their muted shoreline response. Only during the Sandy simulations did these transects change noticeably due to the storm event.

Transects 6, 7, and 21 are more exposed and have more pronounced dune crests. These transects show increased erosion for most storms. In the CSHORE model, high frequency events (10- and 25-year storms) had lower surge elevations which allowed the wave activity to hit the beach directly and cause erosion. Low frequency events (50- and 100-year storms) had higher surge elevations which carried the wave activity over the beach region, leaving it unchanged. These results suggest higher frequency storms pose a greater risk to the beach region while lower frequency storms pose a greater risk to inland areas. And Hurricane Sandy, which had the greatest wave activity of the storm set, caused erosion along the beach despite the high surge elevation. Figure 57 shows the results for the four FEMA PFIRM events at transect 6. Figure 58 shows evolution of Transect 6 at four snapshots in time during the 25-year storm, demonstrating the influence of water level on the erosion of the dune features.

Transects 22 and 23 lack a pronounced dune crest, which is one of the more fragile parts of a beach profile. These dune crests get built up during calm periods, but are not able to withstand elevated surge and wave activity during storms. Without a large dune crest, transects 22 and 23 show a reduced storm response during the FEMA PFIRM storm event simulations as well as during the Hurricane Sandy simulation. Appendix D shows the results for the four FEMA PFIRM events at all the modeled transects.

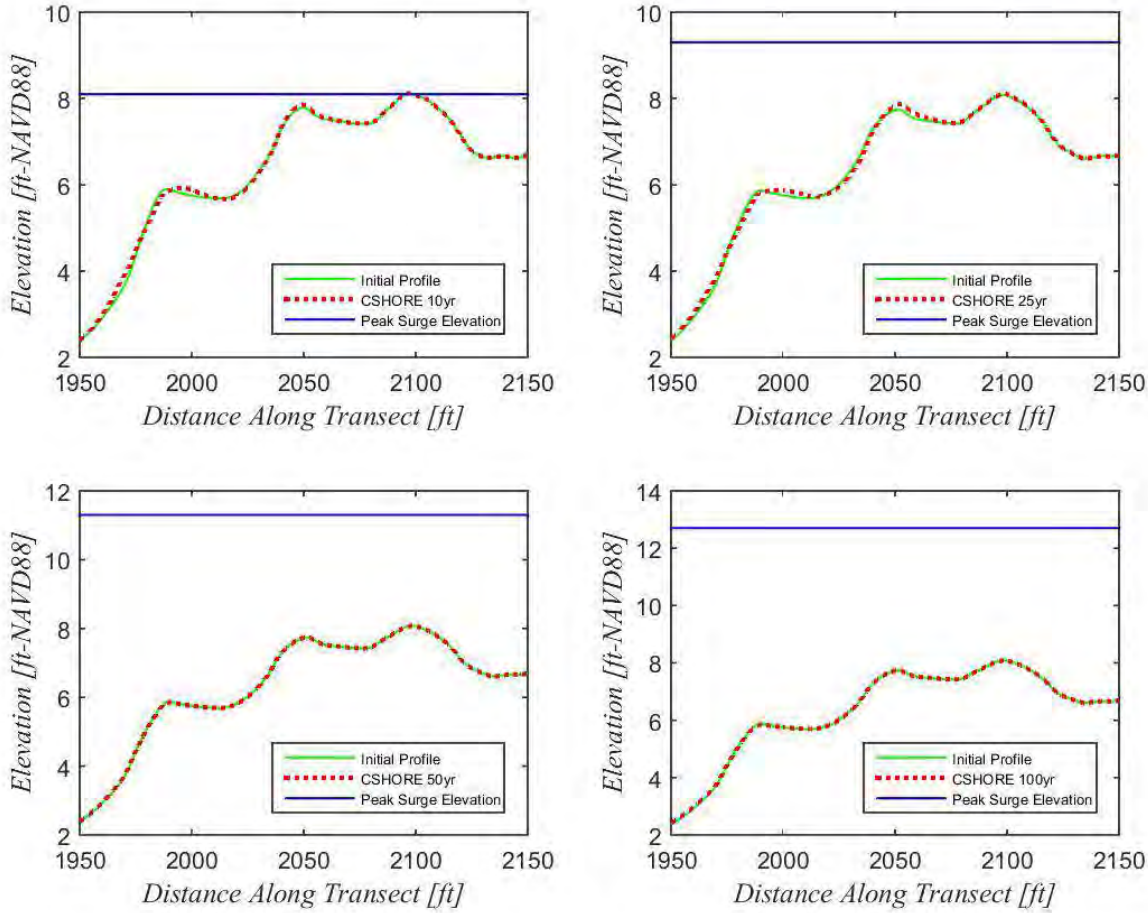


Figure 57. CSHORE results for 10-, 25-, 50-, and 100-year storm events at transect 6.

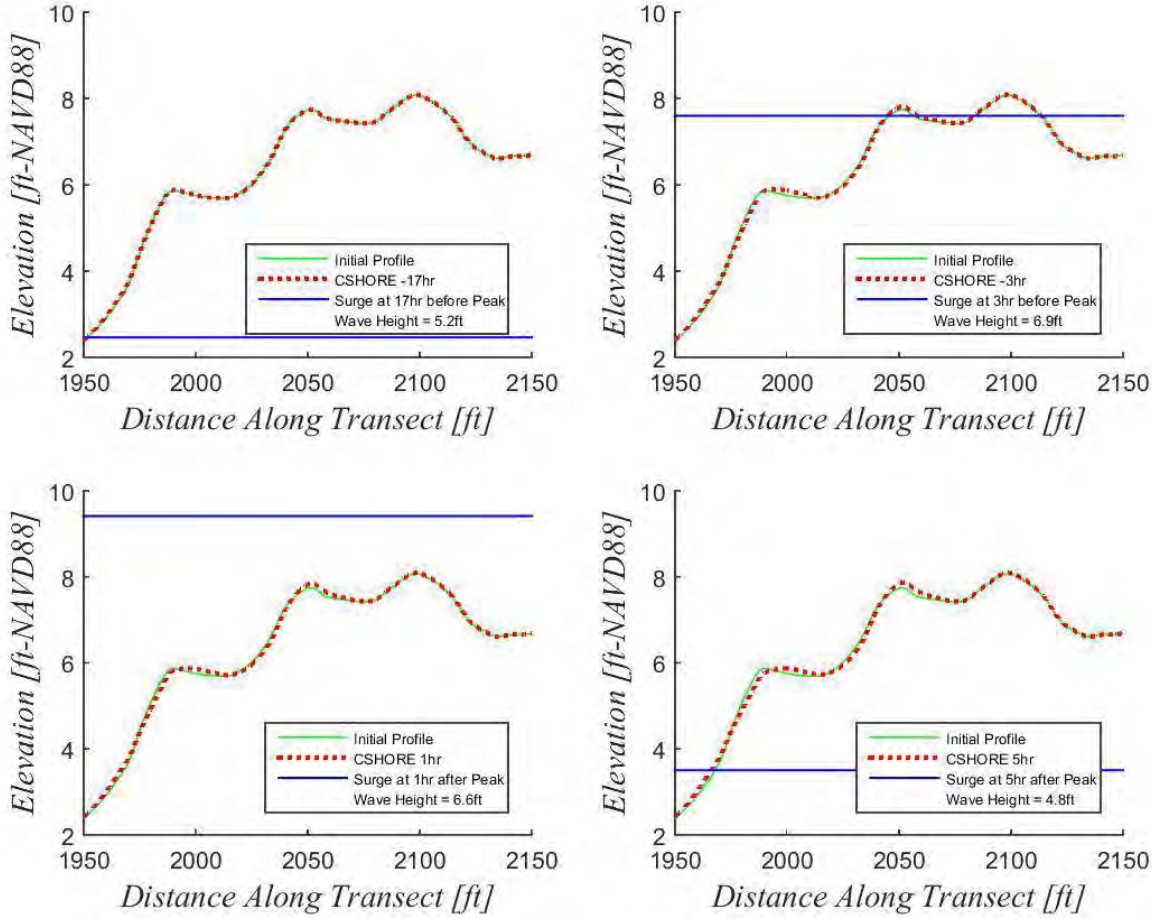


Figure 58. CSHORE results for 25-year storm event at Transect 6 at four times during the storm event.

30% DESIGN SIMULATIONS

CSHORE simulations were performed with the wave height reduction estimates from the REFDIF 30% design simulations with the Living Breakwaters for the 100-year FEMA PFIRM event. The reduction factor of 0.5 was applied for waves from the east at Transects 6 and 7 as shown in Table 11 (see RefDif Section). Other transects described in this section, transects 1-5 and 21-23, were not in the shadow zone of the Living Breakwaters so were not included in the with-project analysis.

The wave direction time series for the 100-year event was reviewed demonstrating that the majority of the storm waves approached from the east, allowing the reduction factor to be applied during most of the event. For wave approach directions within ±45 degrees from east, the reduction factor was linearly interpolated between 0.5 and 1.0 (i.e 0.5 at 0 degrees from east 0.75 at 22.5 degrees from east, and 1.0 at 45 degrees from east). Figure 59 shows the reduced wave height inputs used for the with-project simulations. Also note that these wave height inputs correspond to storm data at the offshore end of transects 6 and 7 (see Figure 40), and are therefore different from Figure 43 through Figure 47 which correspond to storm data closer to shore.

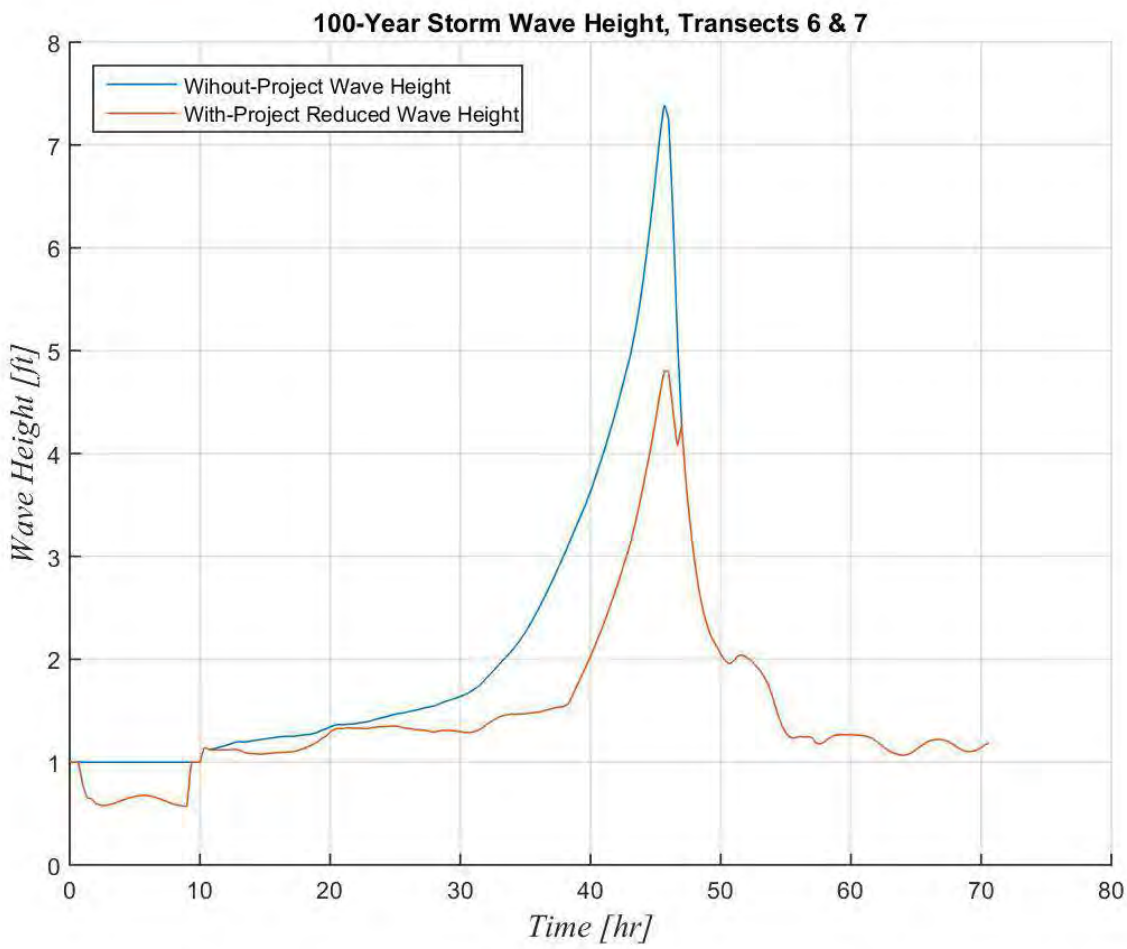


Figure 59. With-project (reduced) wave height compared to without-project (original) wave height for the 100-year storm event at transects 6 and 7.

Figure 60 shows transect 6 with-project results for the 100-year storm event, demonstrating a similar response to the without-project profile shown on Figure 57. The similar response with- or without-project is likely due to the fact that the storm tide elevation is significantly higher than the dune crest elevations. It is expected that the wave reductions resulting from the Living Breakwaters will have the most benefit to beach transects in the TSPP project area, which is outside the scope of this analysis.

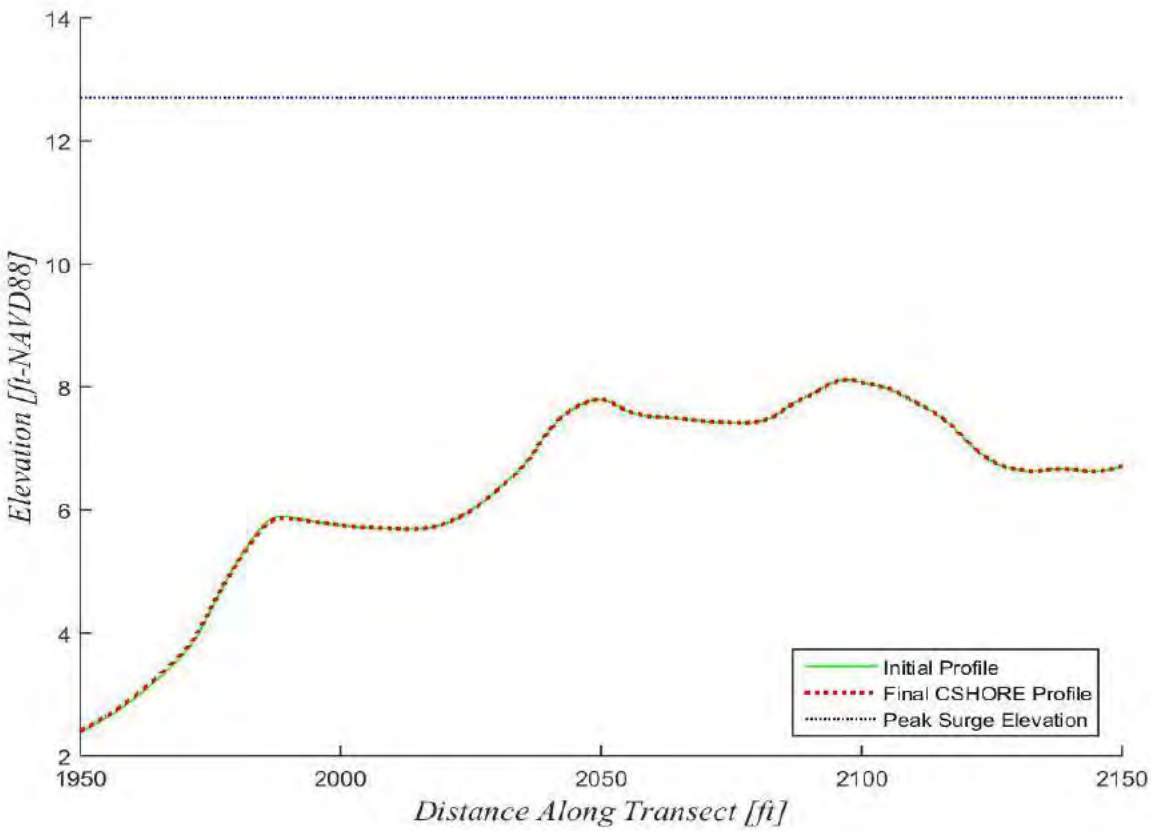


Figure 60. CSHORE results for transect 6 after the 100-year storm event using with-project (reduced) wave heights. No change was found along the profile because the high surge levels carried the wave activity above the beach profile.

CONCLUSIONS

In summary, the CSHORE model was used to simulate with- and without-project beach profile changes during the FEMA PFIRM 10-, 25-, 50-, and 100-year events at transects 1-7 and 21-23. The model parameters were based on a calibration effort using limited available data measured during Hurricane Sandy. The calibration effort also demonstrated that SBEACH was not capable of reproducing Hurricane Sandy response at the dune crests, requiring the use of CSHORE for all simulations. The limited availability of calibration data requires caution in the interpretation of the results presented in this section.

However, the current calibration results suggest that the beach profile does not respond significantly to large storm tide events outside of the TSPP project area, which is what was observed during Hurricane Sandy. These muted responses may be attributed to a large effective sand grain size and significant amounts of vegetation cover on the dunes and landward of the dunes. These results may also vary from results within the TSPP project area which may be more at risk of event based erosion.

WATER CIRCULATION MODELING

In studying alternatives for the Living Breakwater off the coast of Staten Island, it is important to recognize the effect such a structure would have on residence time and flushing of water and potential pollutants between the breakwater and the shore. In order to evaluate the potential impacts of the breakwater system on water quality, the time required for tidal flushing, or residence time, with and without Living Breakwaters was modeled using Delft3D-FLOW, a finite volume hydrodynamics model, and Delft3D-WAQ, a multidimensional water quality framework. This section describes the setup of the Delft3D-FLOW and Delft3D-WAQ models, the model validation procedures, and the influence of the Living Breakwaters on tidal flushing.

DELFT3D MODEL OVERVIEW

Delft3D is a globally-applied robust model used to assess hydrodynamics, water quality, and morphology. In this phase of design, it was used to simulate tidal currents and assess potential changes in flushing time. The movement of a conservative tracer was introduced in the lee of the living breakwaters and the flushing time was quantified with and without living breakwaters.

BASELINE MODEL INPUTS

The Delft3D-FLOW model bathymetry is shown on Figure 61 and was developed from the same bathymetric and survey information used in the wave transformation modeling. The grid is composed of regularly spaced 20 by 20-foot regular grid cells.

Three boundary conditions are applied at the open ocean to the east, the Raritan River, and Arthur Kill. Both the Raritan River and Arthur Kill use a zero-gradient Neumann boundary condition allowing for water to flow in and out. The eastern boundary is forced with water surface elevations extracted from simulations conducted using the FEMA ADCIRC model forced with tidal constituents from the 2001 ADCIRC harmonics database (FEMA, 2014b).

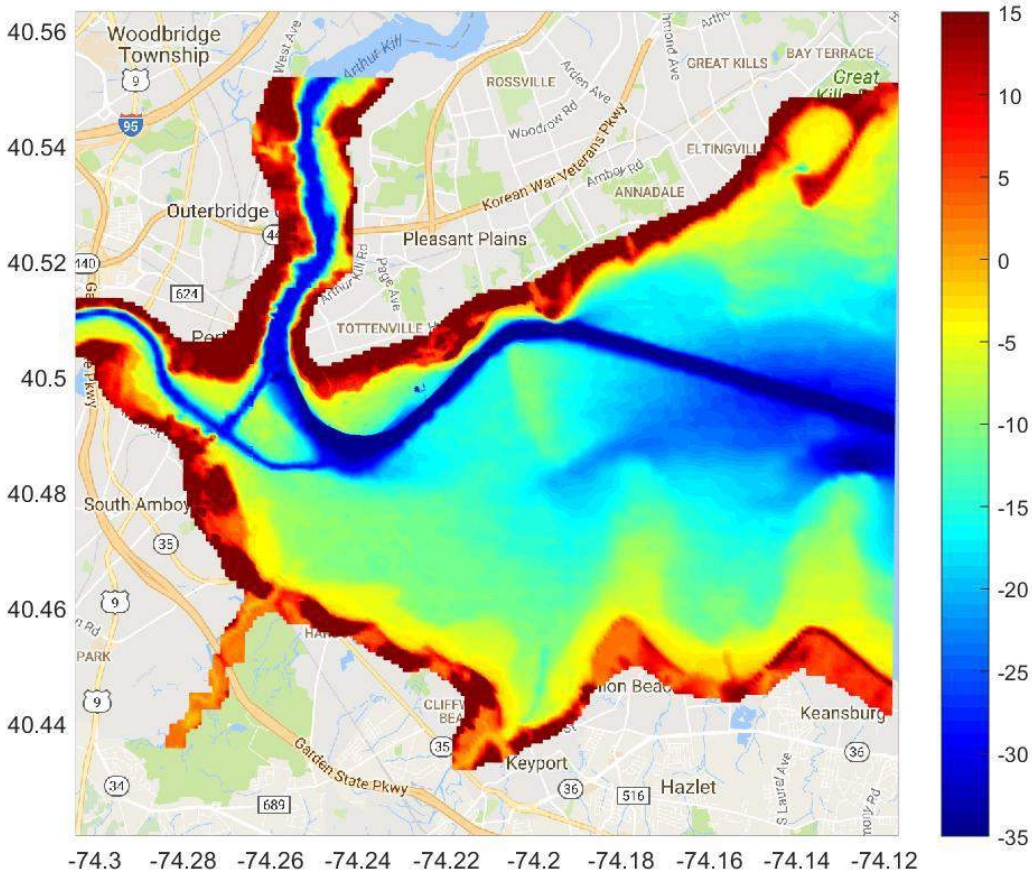


Figure 61. Delft3D model domain and bathymetric contours (feet NAVD88).

MODEL VALIDATION

To ensure the Delft3D-FLOW model was generating reasonable results, a series of validation exercises were conducted to compare computed water surface elevations and velocities to observations.

Unfortunately, only limited long term gage data is available throughout the region, so water surface elevation validation has been conducted using harmonics derived for NOAA subordinate stations, which can be converted to a time series of water surface elevations. Figures 62 through 67 show the comparison of water surface elevations between NOAA subordinate station computed elevations, ADCIRC, and Delft3D-FLOW. Comparisons are generally good in both phase and amplitude with only minor deviations. The largest deviations come during the neap tides while spring tides show excellent agreement.

In order to show that the velocities predicted by the model are reasonable, modeled output was compared to those measured by the deployed ADCP1. Figure 68 shows the comparison of surface velocities at ADCP1. Though Delft3D-FLOW is run in the two-dimensional depth averaged mode, an approximation to surface velocity can be made for comparison to the ADCP. Since wind forcing is not included in the model, an exact match is not expected and results are checked to ensure that reasonable velocities are modeled and that differences can be

understood. A plot of wind speed observations at Sandy Hook is provided to give reference for the discrepancy between the modeled and observed surface velocities. When taken in total, when the wind speeds are greater, the discrepancy between observed and modeled surface velocities is larger while when wind speeds are low, the discrepancy is generally much smaller, particularly on June 11, 2016.

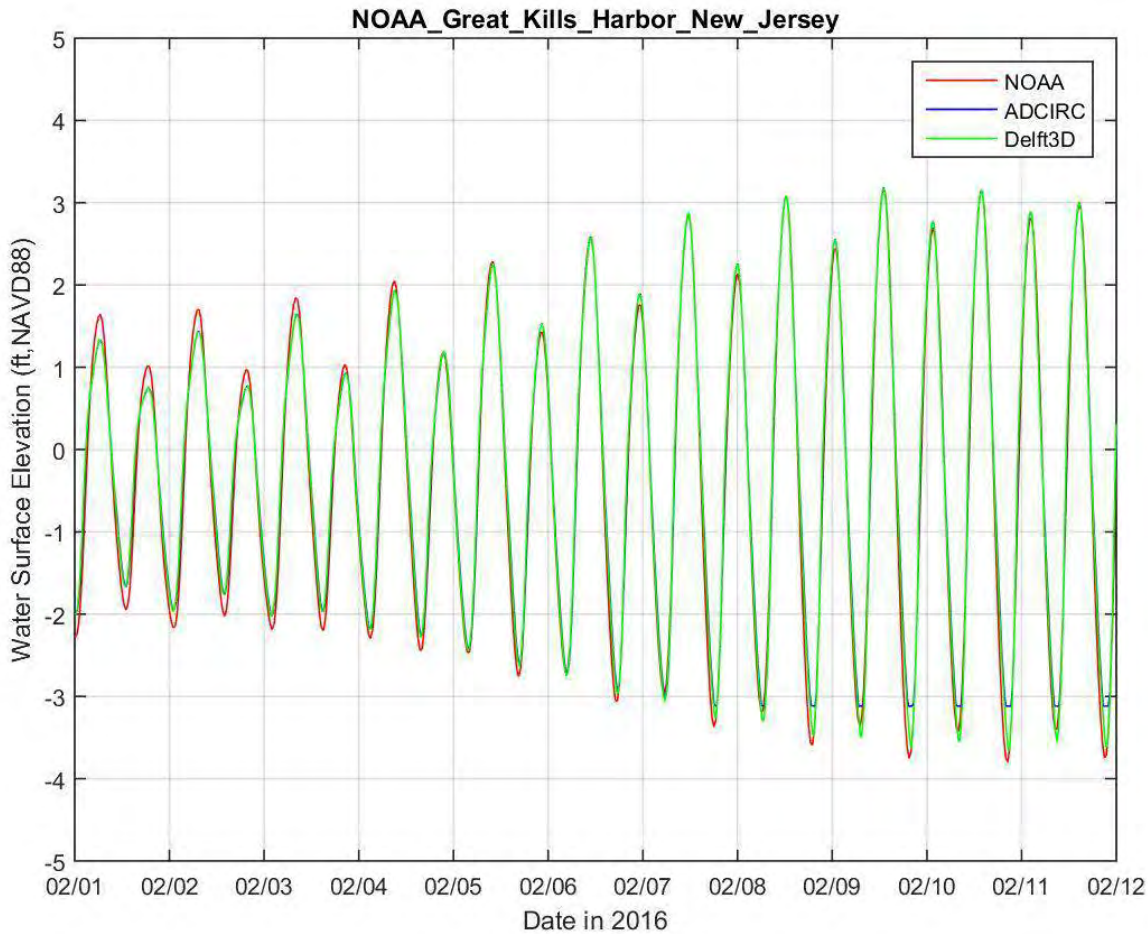


Figure 62. Comparison of water surface elevations (feet NAVD88) in Great Kills Harbor for February 2016 between the harmonics database, the FEMA ADCIRC model, and the Delft3D-FLOW model.

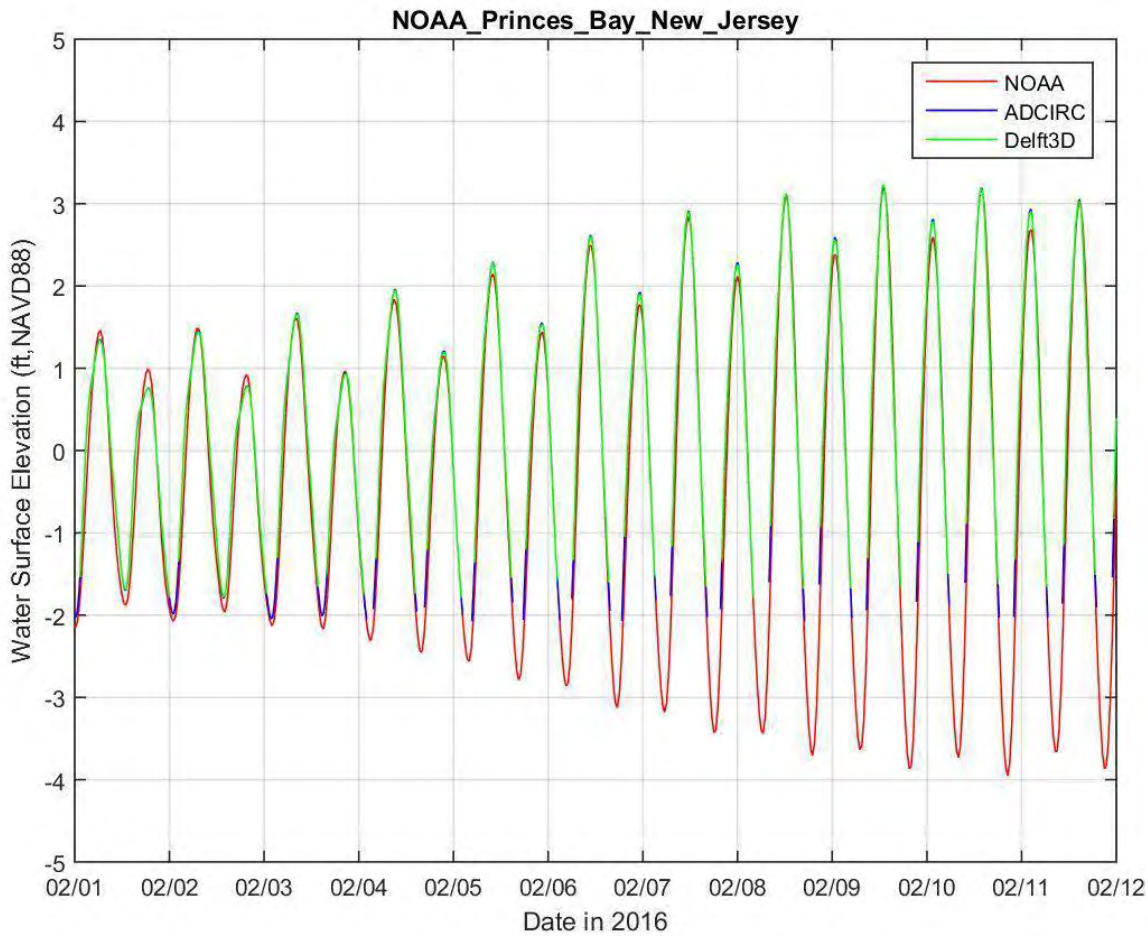


Figure 63. Comparison of water surface elevations (feet NAVD88) in Prince's Bay for February 2016 between the harmonics database, the FEMA ADCIRC model, and the Delft3D-FLOW model.

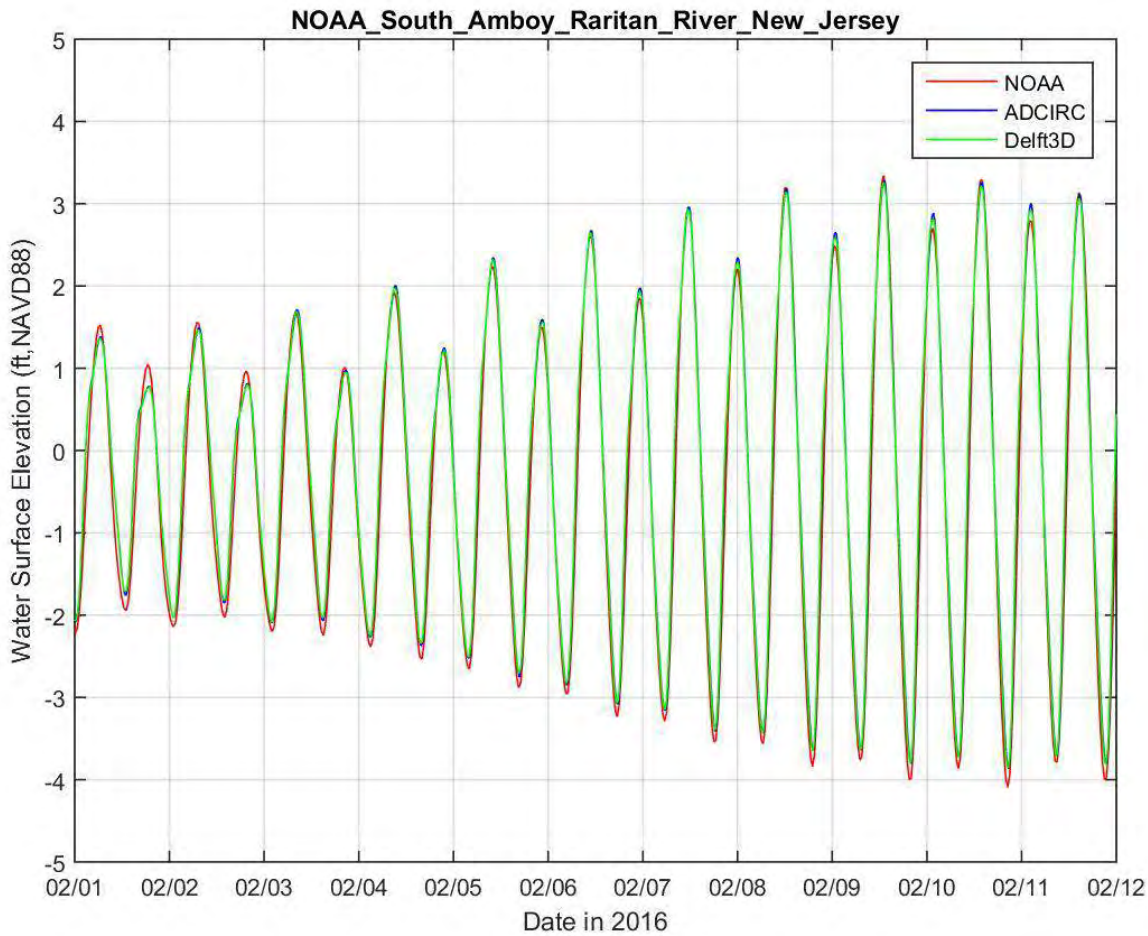


Figure 64. Comparison of water surface elevations (feet NAVD88) in the Raritan River for February 2016 between the harmonics database, the FEMA ADCIRC model, and the Delft3D-FLOW model.

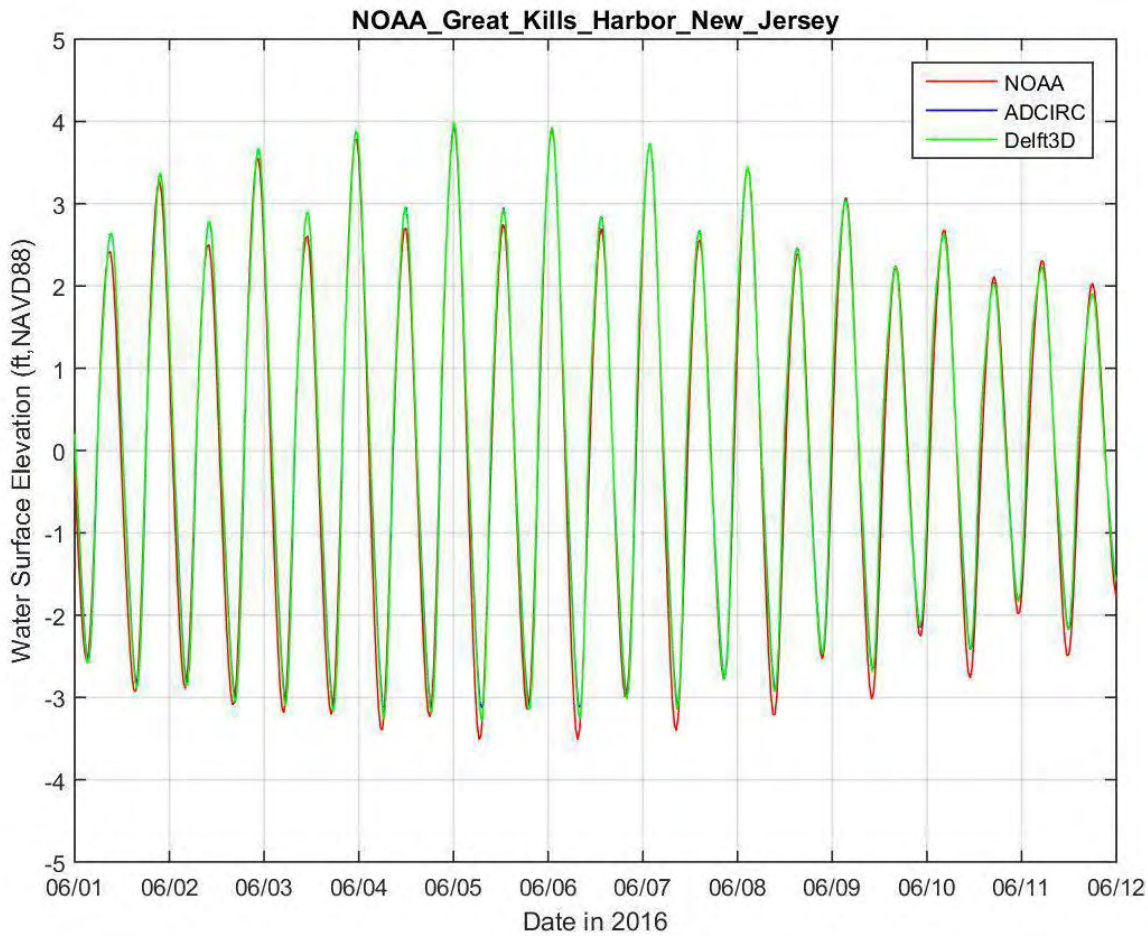


Figure 65. Comparison of water surface elevations (feet NAVD88) in Great Kills Harbor for June 2016 between the harmonics database, the FEMA ADCIRC model, and the Delft3D-FLOW model.

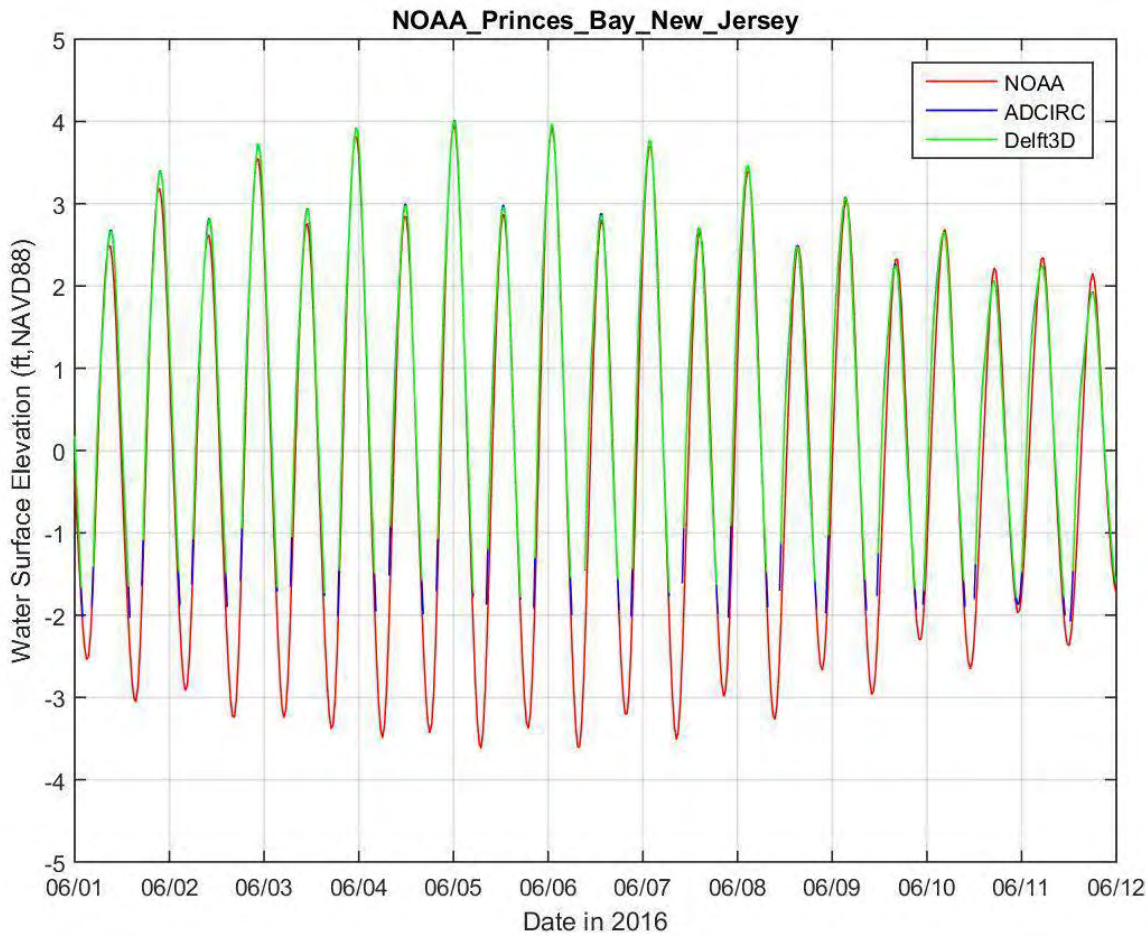


Figure 66. Comparison of water surface elevations (feet NAVD88) in Prince's Bay for June 2016 between the harmonics database, the FEMA ADCIRC model, and the Delft3D-FLOW model.

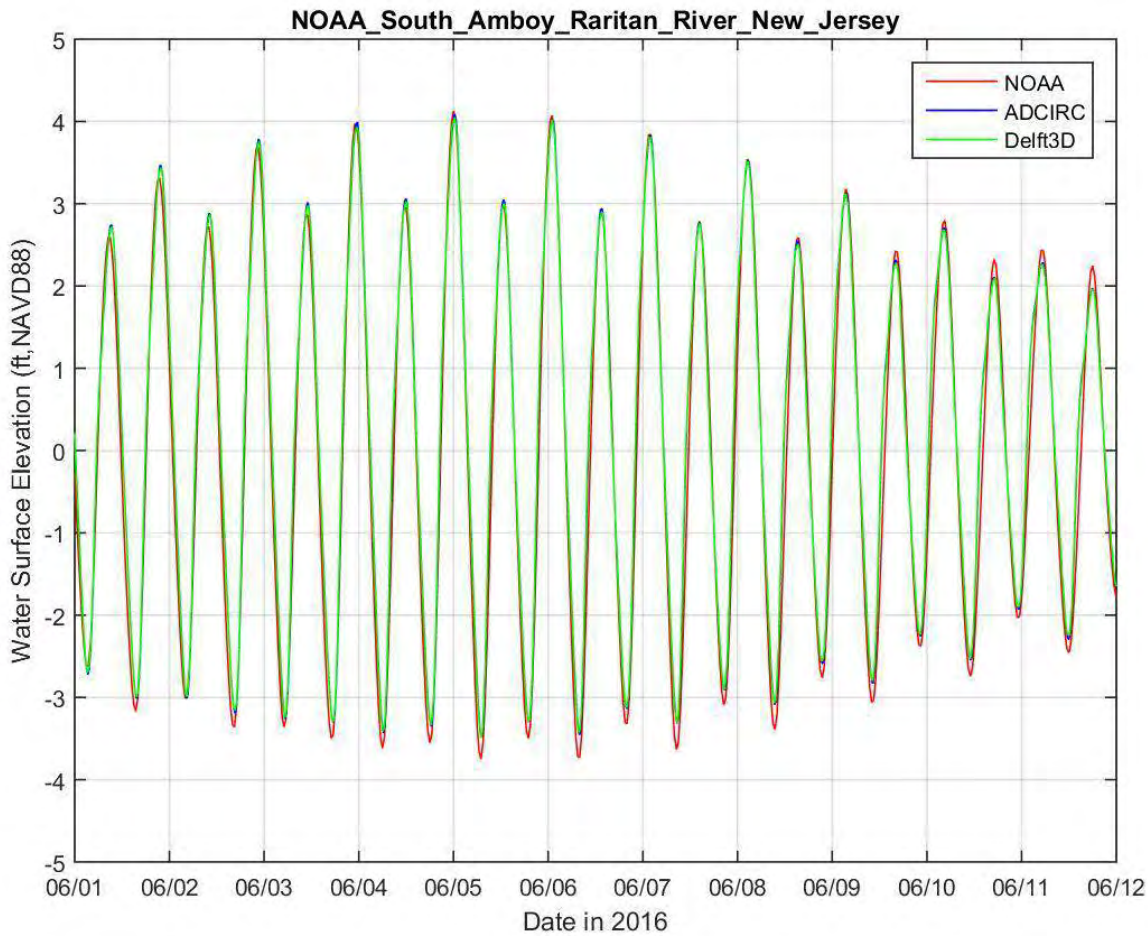


Figure 67. Comparison of water surface elevations (feet NAVD88) in the Raritan River for June 2016 between the harmonics database, the FEMA ADCIRC model, and the Delft3D-FLOW model.

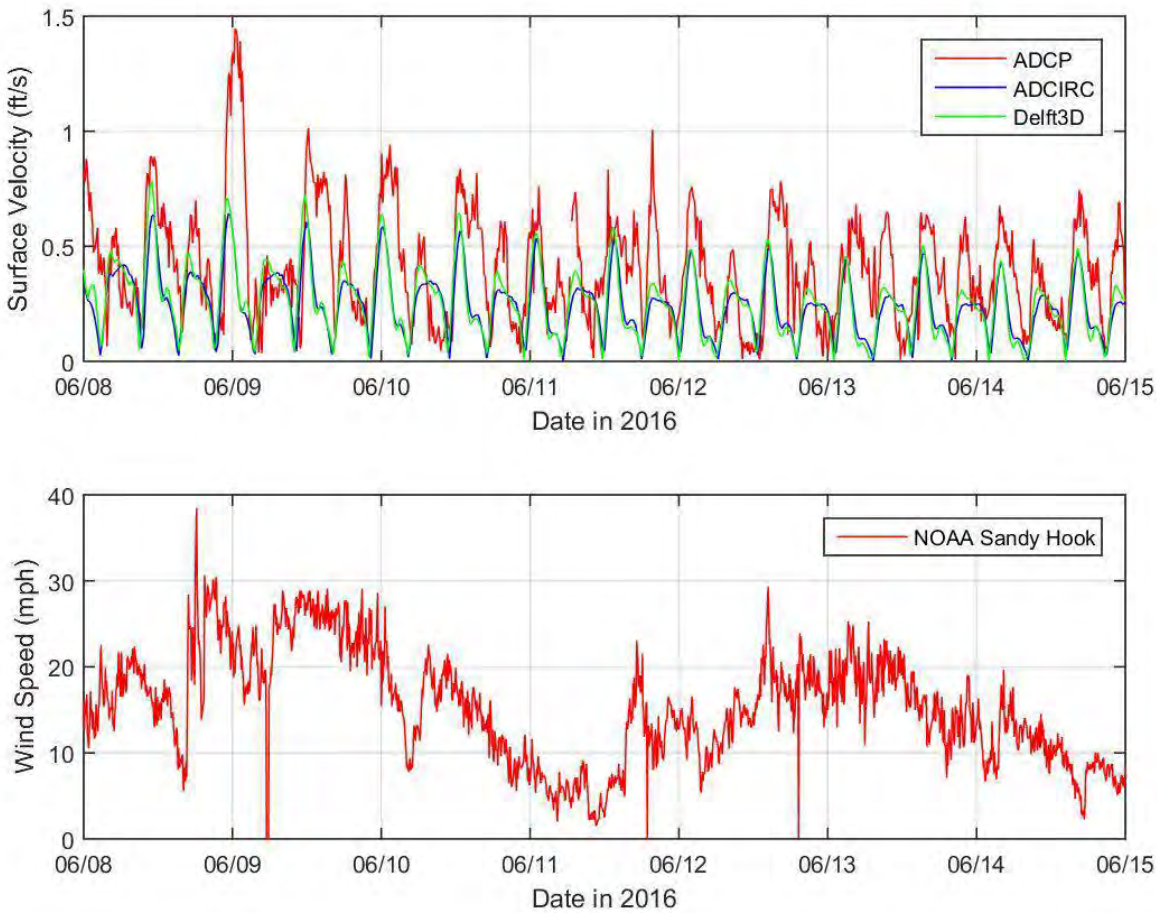


Figure 68. Comparison of observed and modeled surface velocities (top) and wind speed observations at Sandy Hook, NJ (bottom).

RESIDENCE TIME MODELING SETUP

Hydrodynamics were computed for both February 2016 and June 2016 with and without the living breakwaters. These time periods were chosen since they corresponded to times when ADCP data were available. Also, one is the start of a neap tide cycle and the other a spring tide cycle. These hydrodynamic results are used to force the Delft3D-WAQ water quality simulation. It is assumed that the validated hydrodynamics are adequate predictors of tracer movement in the absence of data to validate the water quality model. A conservative tracer is placed into hydrodynamic simulations that have been running for 30 days, which allows the model to reach a dynamic steady state. Besides the movement of the tracer due to the water velocities, molecular diffusion is also included in the model to advect tracer.

Figure 69 shows the initial placement of the tracer slug. The slug is placed so that it encompasses the entire area enclosed by the breakwaters. The tracer is allowed to move throughout and exit the domain over the next 30 days of simulation. Flushing estimates are made by computing the mass of tracer remaining within the area originally defined on Figure 69. The time required to reach 50%, 37%, and 10% remaining concentration are reported in this

analysis, i.e. t_{50}, t_{37}, and t_{10}. The time required to reach 37% of the remaining concentration is used to represent the flushing time in the system. (Monsen, 2002)

Figure 69. Location of initial tracer slug (yellow hatch) relative to 30% design Living Breakwaters layout (red).

RESIDENCE TIME SIMULATION RESULTS

Figures 70 through 74 show snapshots of the tracer's movement in June 2016 over 5 days. Each left pane shows the simulation without breakwaters and each right pane shows the simulation with breakwaters. The tracer can be seen moving through and around the breakwaters. By day 5, the plume with and without breakwaters is very similar and most of the concentration has moved out of the study area in both cases.

Figure 75 and Figure 76 show the concentration of tracer in time as a percentage of its mass remaining in the study area. In general, the addition of breakwaters does not significantly change the flushing of the tracer and most of the substance leaves rather quickly. The changes to residence time are on the order of only a few hours. This information is summarized in Table 19.

Table 19. Summary of residence times computed by the water quality model.

	Feb-16			Jun-16		
Residence Time Metric (%)	Without Breakwaters (days)	With Breakwaters (days)	Change in Residence Time (hr)	Without Breakwaters (days)	With Breakwaters (days)	Change in Residence Time (hr)
t_{50}	1.26	1.35	2.16	0.33	0.49	3.84
t_{37}	1.88	1.82	-1.44	0.79	0.93	3.36
t_{10}	4.49	4.42	-1.68	1.97	1.99	0.48

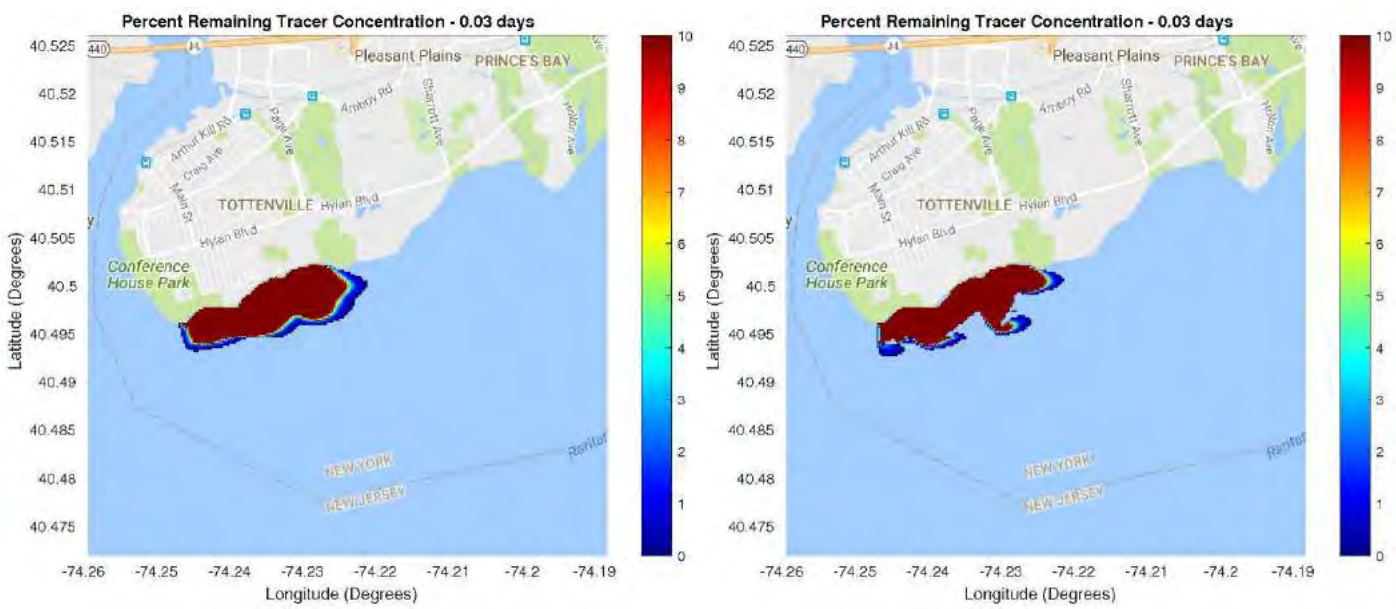


Figure 70: Water quality simulation of conservative tracer in June 2016, 0.03 days into simulation. Left pane without breakwaters and right pane with breakwaters.

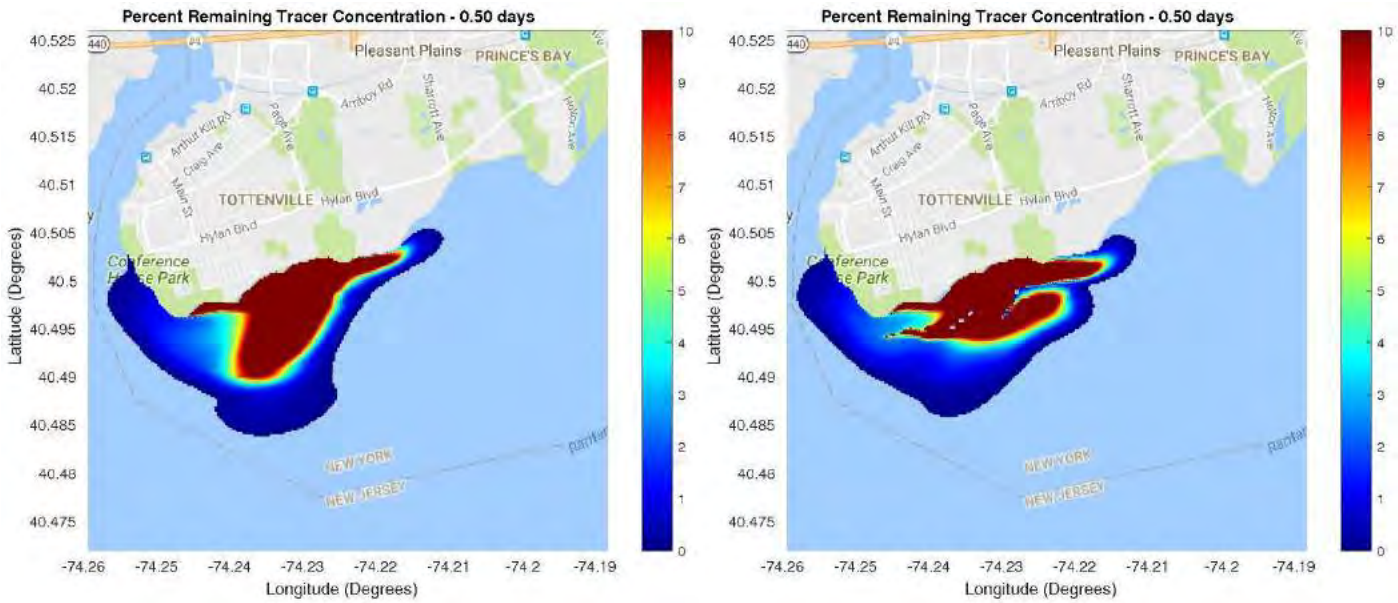


Figure 71. Water quality simulation of conservative tracer in June 2016, 0.50 days into simulation. Left pane without breakwaters and right pane with breakwaters.

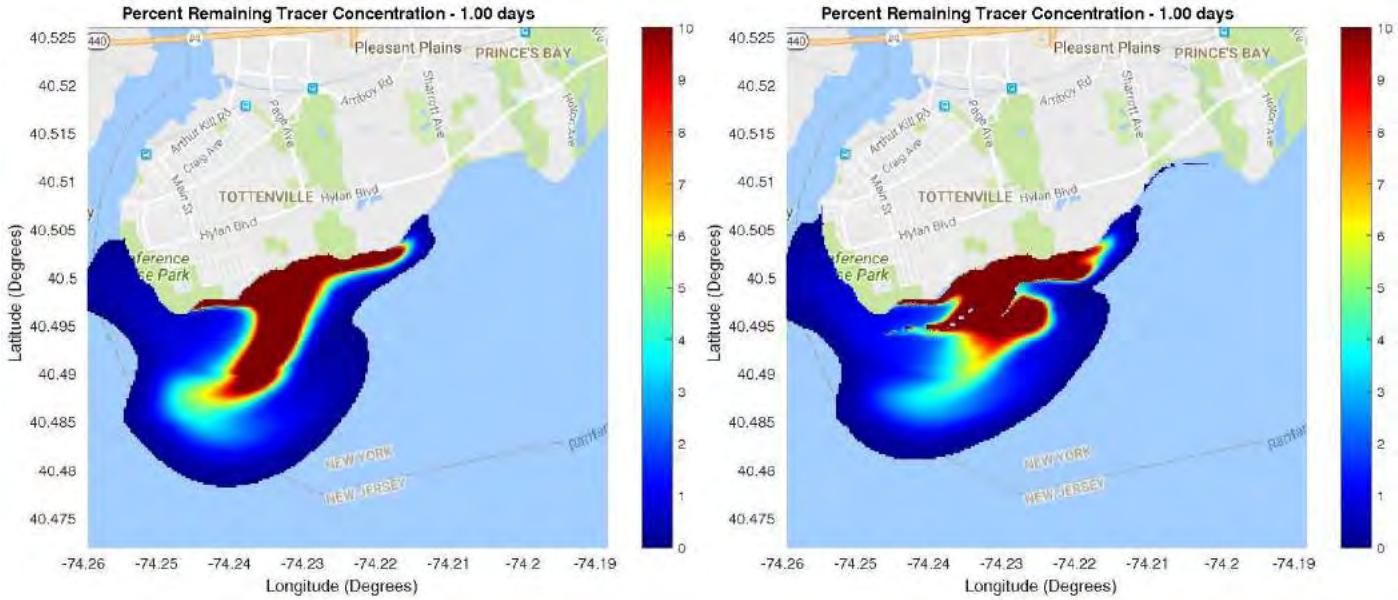


Figure 72. Water quality simulation of conservative tracer in June 2016, 1.00 days into simulation. Left pane without breakwaters and right pane with breakwaters.

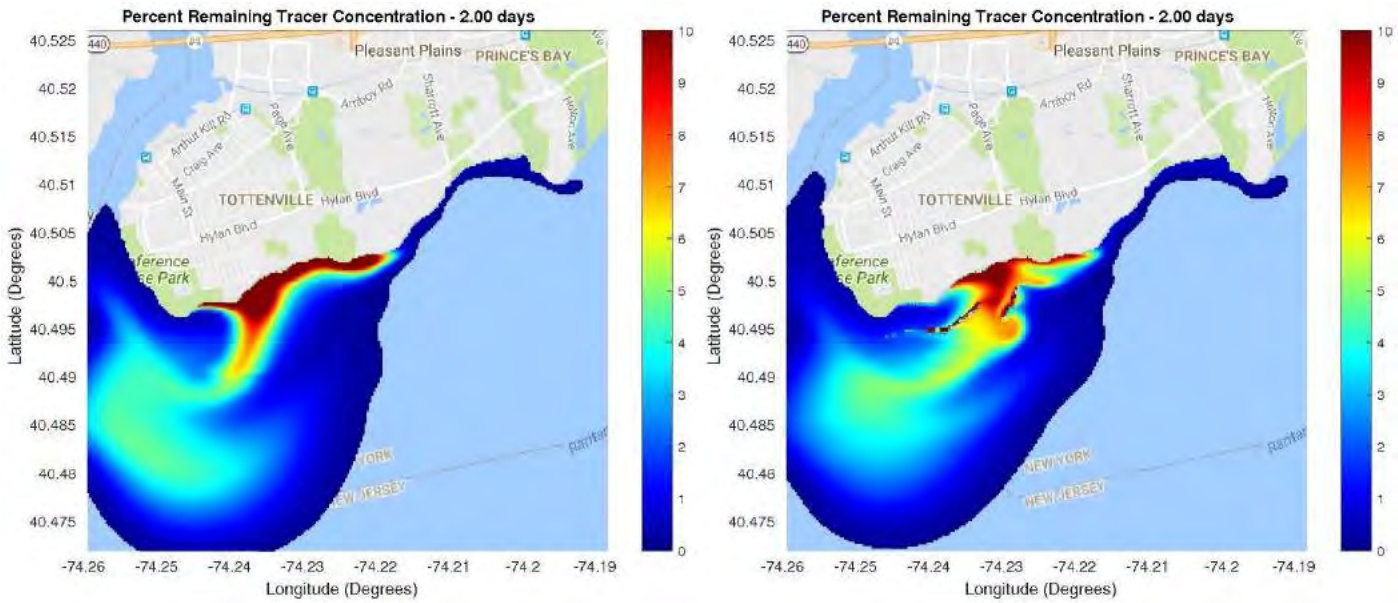


Figure 73. Water quality simulation of conservative tracer in June 2016, 2.00 days into simulation. Left pane without breakwaters and right pane with breakwaters.

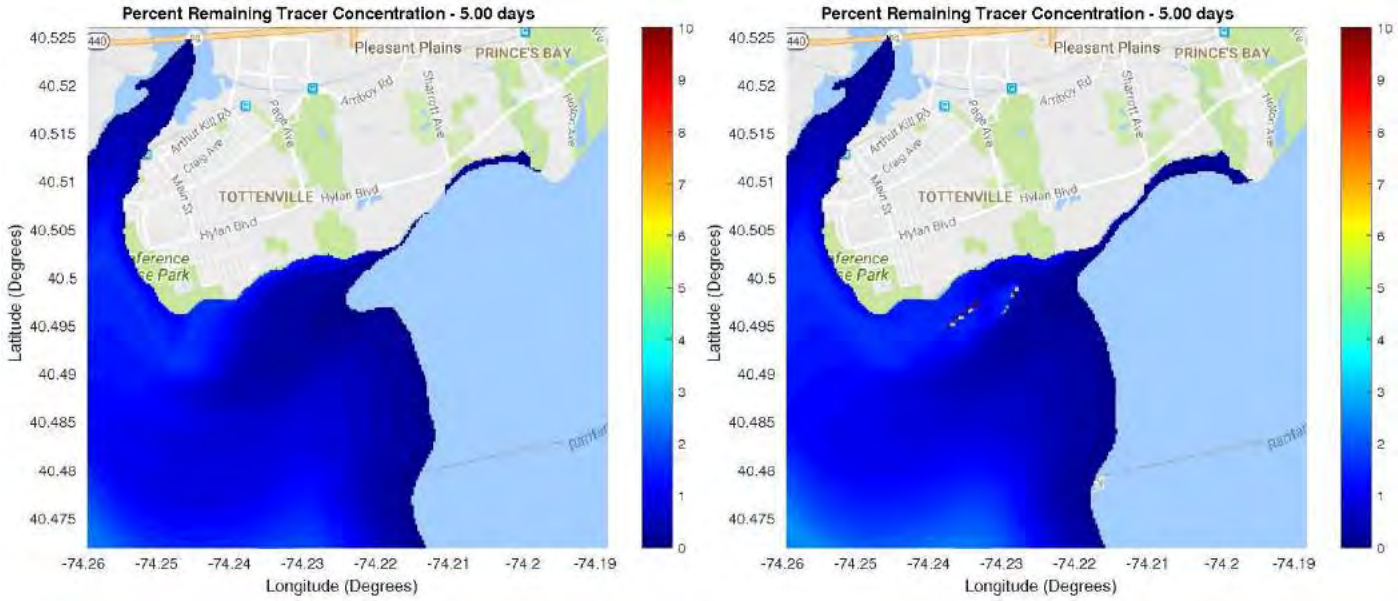


Figure 74. Water quality simulation of conservative tracer in June 2016, 5.00 days into simulation. Left pane without breakwaters and right pane with breakwaters.

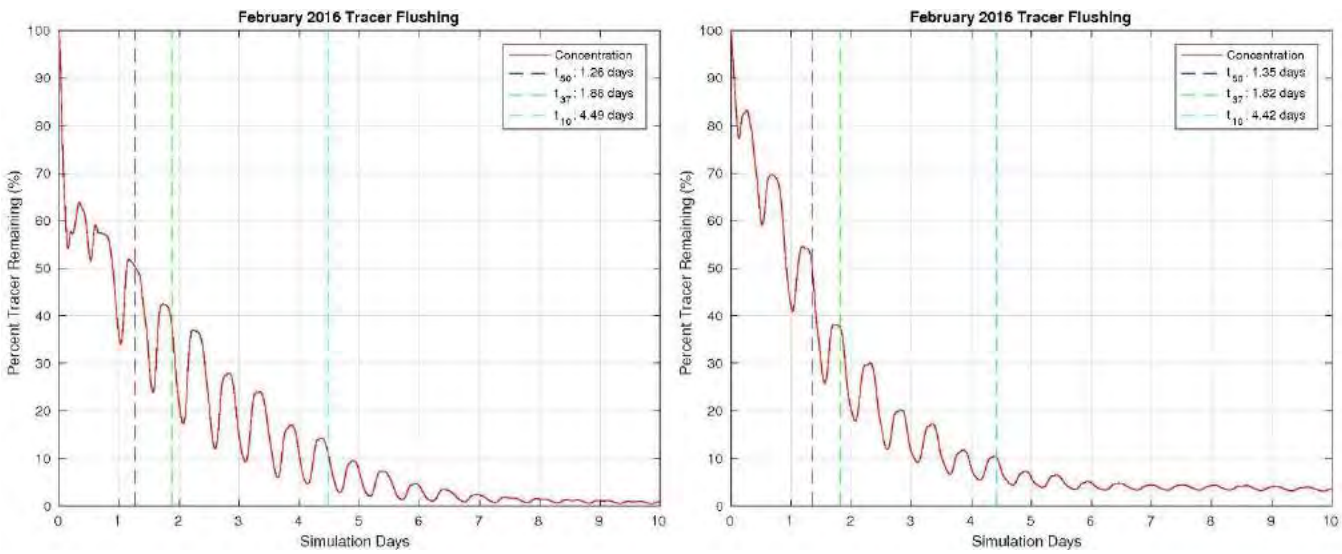


Figure 75. Comparison of concentration remaining in study area without breakwaters (left) and with breakwaters (right) for the February 2016 simulation.

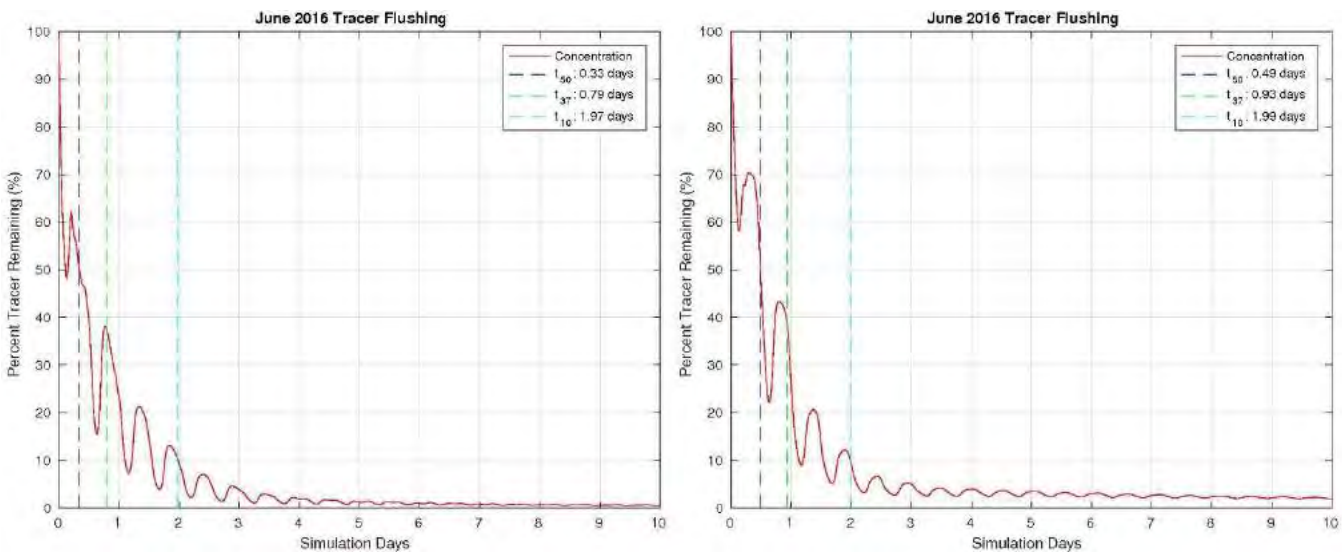


Figure 76. Comparison of concentration remaining in study area without breakwaters (left) and with breakwaters (right) for the June 2016 simulation.

CONCLUSIONS

Simulations indicate the concentration of tracer was less than 50% after less than 1.5 days and less than 10% remaining after 4.5 days for both the with- and without-project conditions. The results of the Delft3D water circulation model indicate minimal differences in the overall flushing times due to the presence of the breakwaters. Changes in residence times (time water remains in area shoreward of proposed breakwaters) were modeled as less than a few hours. Based on the modeling, the proposed breakwater design should have negligible, if any, impact on water quality in the project area relative to the existing conditions.

SUMMARY AND CONCLUSIONS

In support of 30% design of the Living Breakwaters modeling was performed to estimate project goals related to shoreline change, wave energy reduction, and maintained water quality flushing time. Wave transformation, shoreline change, storm induced beach profile response (cross shore change), and water circulation modeling were conducted.

Shoreline change modeling requires long-term wave data to achieve reasonable estimates. Since long-term wave data was not available in the immediate vicinity of the Living Breakwaters, a SWAN wave model was used to develop a 30-year (1982-2012) wave hindcast. This modeling transformed the offshore USACE WIS station wave hindcast available east of Sandy Hook together with local wind data and was validated with available wave measurement records in Raritan Bay.

Using this project vicinity wave hindcast data, shoreline change modeling was performed using the GENESIS model. The model was calibrated/validated using orthoimagery-based observed shoreline changes from 1978-2012. GENESIS was the primary tool to perform “what if” scenario evaluations of varying breakwater layouts allowing assessment of the potential impacts on shoreline change to help achieve the intended shoreline response goals of the project. The shoreline change model results demonstrated that the Living Breakwaters could be aligned to effectively reduce historical erosion rates and maintain the beach.

In addition to maintaining the beach, wave reduction is another goal of the Living Breakwaters. The REFDIF wave model was used to demonstrate the breakwaters were effective in attenuating wave energy and that a desired balance of shoreline change and wave protection to meet project goals could be achieved. Average wave height reductions of 38% to 51% were seen at the critical residential areas. Resiliency to sea level rise was also demonstrated with average wave height reductions in the same region ranging from 37% to 49% when including 30 inches of sea level rise.

Short-term shoreline response modeling during storms of significance was also performed. Limited LiDAR, wave, and water level data during Hurricane Sandy was used to calibrate the model. The calibration effort demonstrated that the SBEACH model was not capable of reproducing observed dune response during Hurricane Sandy. However, the CSHORE model was capable of reproducing dune response during Hurricane Sandy and was adopted for this analysis. Observed short-term shoreline response was muted during Hurricane Sandy, perhaps due to a relatively large effective sand grain size and/or due to the significant vegetation cover on and landward of dunes. CSHORE results with and without the Living Breakwaters each showed a muted response of the beach and dune features during the FEMA PFIRM 100-year event. This is consistent with the Hurricane Sandy response, which has characteristics similar to the FEMA PFIRM 100-year event. The CSHORE modeling was focused on shoreline areas outside of the TSPP project area, with the expectation that the TSPP team will perform similar short-term shoreline response modeling in the vicinity of the TSPP project area. Additional benefits of the Living Breakwaters on the TSPP project area may result from these simulations.

Flushing time behind the Living Breakwaters was evaluated with the Delft3d model. Simulations were performed during two months for which ADCP measurements were available to support model validation. Conservative tracer was released at the beginning of the each month in the lee of the Living Breakwaters and flushing time was

evaluated with and without Living Breakwaters. Results revealed no significant change in the residence time or tidal flushing with the Living Breakwaters in place.

In summary, the model simulations have demonstrated that the Living Breakwaters are effective at achieving the overall project goals to reduce historical erosion shoreline, maintain the shoreline and reduce wave energy in front of residential areas, and not have impacts on water quality flushing time. Although the modeling performed for 30% design was comprehensive for the current level of detail required, additional numerical and/or physical modeling with further physical detail will be performed at 60% design to further confirm the Living Breakwaters layout that achieves shoreline change, wave reduction, and habitat benefits without sacrificing water quality flushing times.

REFERENCES

CERC. 2001. Wave Statistics for Lower New York Bay – Dredged Material Management Plan.

City of New York. 2013. *plaNYC: A Stronger, More Resilient New York.*

FEMA. 2014a. Region II Storm Surge Project – Coastal Terrain Processing Methodology. September.

FEMA. 2014b. Region II Storm Surge Project – Model Calibration and Validation. September.

FEMA. 2015. Preliminary Flood Insurance Study for the City of New York. December.

Hanson, Hans. 1989. Genesis – A Generalized Shoreline Change Numerical Model.

Hill International. 2015. Mutlibeam Bathymetric Survey Fall 2015.

Jensen, Robert. 2010. USACE Coastal and Hydraulics Laboratory Engineer Research and Development Center, Wave Information Studies, Project Documentation.

Kirby, James T., and Robert A. Dalrymple. 1994. REF/DIF 1 Version 2.5 Documentation and User's Manual. Center for Applied Coastal Research, University of Delaware. Newark, DE.

MFS Consulting Engineers, LLC. 2015. Fall 2015 Shoreline Structures Survey and Beach Profile Transect Surveys.

Monsen, Nancy, Cloern, James, Lucas, Lisa, and Monismith, Stephen, A Comment on the use of Flushing Time, Residence Time, and Age as Transport Time Scales, Limnology and Oceanography Volume 47 Issue 8, September 2002.

NOAA. 2012. *Hurricane Sandy: Rapid Response Imagery for the Surrounding Regions.*

Nordstrom, Karl F., Nancy L. Jackson, and John P. Tiefenbacher. 1990. Threats to Beach Resources and Park Boundaries Caused by Shoreline Migration in an Urban Estuarine Park.

NYCDOITT. 2012. Digital Elevation Model (DEM), 2010, New York City – Improved Shoreline.

NYSDEC. 1988. Coastal Erosion Hazard Area Map, Staten Island, Richmond County, New York.

Roarty, Hugh. 2016. Personal Communications Regarding ADCP Measurements in Raritan Bay by the Center for Ocean Observing, Rutgers University.

Simiu, E., P. Vickery, and A. Kareen. 2007. Relation between Saffir-Simpson Hurricane Scale Wind Speeds and Peak 3-s Gust Speeds over Open Terrain.

Stockdon, Hillary F., Rob A. Holman, Peter A. Howd, and Asbury H. Sallenger, Jr. 2006. Empirical Parameterization of Setup, Swash, and Runup.

SWAN. 2006. SWAN Technical Documentation. SWAN Cycle III Version 40.51.

USACE. 1984. Shore Protection Manual.

USACE. 2015a. Raritan Bay and Sandy Hook Bay, New Jersey Combined Erosion Control and Coastal Storm Risk Management Project Borough of Highlands Feasibility Study. July.

USACE. 2015b. South Shore of Staten Island, New York, Phase , Great Kills to Tottenville Bach Coastal Storm Risk Management Project Preliminary Alternative Analysis.

USGS. 2010. National Assessment of Shoreline Change: Historical Shoreline Change along the New England and Mid-Atlantic Coasts.

USGS. 2014. 2013-2014 U. S. Geological Survey CMGP LiDAR: Post Sandy (New York City).

APPENDIX A – 30% DESIGN MODELING RESULTS REPORT

LIVING BREAKWATERS

30% DESIGN MODELING RESULTS REPORT

Modeled Scenarios & Results (GENESIS, REFDIF, DELFT3D)

Date: 10/07/2016
Prepared by: ARCADIS
Reviewed by: **SCAPE**

VERSION	DATE	NOTES
1.0	08.01.2016	FIRST VERSION SUBMITTED FOR CLIENT REVIEW. THIS DRAFT ONLY INCLUDES RESULTS COMPLETED THROUGH 07.30.2016
2.0	10.12.2016	VERSION SUBMITTED AS APPENDIX TO 30% DESIGN MODELING REPORT

NAME	ORGANIZATION	DATE	COMMENTS PROVIDED?	COMMENTS INCORPORATED?

CONTENTS

INTRODUCTION 3

Overview

HISTORIC ANALYSIS AND EXISTING INFORMATION 6

Historic shoreline change and FEMA pFIRMs

BASELINE (FUTURE WITHOUT PROJECT) 11

00: Baseline (future without project)

DESIGN SCENARIOS 17

SCENARIO 01: “HOLD THE SHORELINE”

SCENARIO 02: “STORM WAVE ATTENUATION”

SCENARIO 03: “TESTING FOR A TOMBOLO”

SCENARIO 04: “LEARNING FROM ROUND ONE

SCENARIO 05: “MODIFIED SCENARIO 4”

SCENARIO 06: “MINIMALIST APPROACH”

SCENARIO 07: “MINIMALIST APPROACH WITH SHORELINE RESTORATION”

SCENARIO 09

SCENARIO 10

SCENARIO 11

SCENARIO 12

SCENARIO 13

SCENARIO 14

SCENARIO 15

FINAL 30% DESIGN SCENARIO 66

Final 30% Design Scenario

Overall Take-Aways

INTRODUCTION

OVERVIEW

This document summarizes the numerical modeling performed to date on the Living Breakwaters breakwater design scenarios during 30% Design. The current version of this report and provides a summary of scenarios modeled and model results completed through 30% Design.

Numerical modeling performed to date has been for long-term shoreline change (using the GENESIS model),wave refraction and diffraction (using the REFDIF model), storm-induced profile response (using SBEACH and CSHORE models), and water circulation (using Delft3D model).

SUMMARY OF MODEL RESULTS (AS OF 10.06.2016)

- Modeling efforts have focused on advancing the breakwater layout for the selection of a 30% design preferred scenario. Initial efforts examined scenarios designed to evaluate the impact of breakwater length, spacing, and distance from shore on long-term shore change (erosion and accretion) and the wave climate in the lee of the breakwaters.
- Additional modeling simulations were performed on potential breakwater system configurations to determine system performance and evaluate various layout options at achieving project goals.
- The without project (baseline) and project (30% design) have been simulated with all models. For some models (GENESIS and REFDIF) multiple scenarios were simulated in the screening and development of the preferred scenario.
- The preferred layout is shown to advance and refine beyond 30% design.

MODEL ASSUMPTIONS AND STANDARDS

- Modeling Assumptions and Standards are outlined in the Project Assumptions and Standards Memo (currently being updated in collaboration with Stantec / RACE) and the 30% Design Modeling Report.
- Shoreline change modeling was performed using the GENESIS model and the wave climate assessed in the lee of the breakwaters using the REFDIF model. Storm induced beach profile change for the shoreline areas outside of the Tottenville Shoreline Protection Project area were assessed using the SBEACH and CSHORE models and water circulation/preliminary water quality were evaluated using the Delft3D model.

Living Breakwaters 30% Design
Summary scenarios modeled

Scenrio

Sc. #	Scenario name (if provided)	GENESIS	REFDIF MHW	REFDIF MHW +30" SLR	REFDIF 100yr	REFDIF 100yr + 30" SLR	Delft 3D	SBEACH	CSHORE
00	No Action	X	X		X		1	1	1
01	Hold the Shoreline	X	X		X				
02	Storm Wave Reduction	X	X		X				
03	Test for Tombolo	X	X		X				
04	"Dream Scenario"	X	X		X				
05	sc05	X							
06	sc06	X							
07	sc07	X							
08	"Permitting" Scenario								
09	sc09	X							
10	sc10	X							
11	sc11	X							
12	sc12	X							
13	sc13	X							
14	Preliminary Preferred Scenario	X	X		X				
15	Revised 30% Design Scenario	X	X		X				
-	30% Design Scenario (including shoreline restoration)	X	X	X	X	X	1		1

Notes & assumptions

water level used for all GENESIS Runs @ MHW was	2.08
water level used for all GENESIS Runs w/ SLRwas	4.58
MHW used for typical tides RefDif runs	2.10
Incident wave height for typical tides RefDif runs	3.00
Stillwater elevation for 100yr storm RefDif runs	12.90
Incident wave height for 100yr storm RefDif runs	5.30

RefDIF runs model only single wave directions at a time, the following wave directions (degrees from N) were modeled: E (90); Perpendicular to Shore (150); SW (225)
SBEACH / CSHORE were performed for 5 storm series (10, 25, 50, 100, Sandy); hydrographs were selected by ARCADIS based on FEMA storms and share with TSPP team
SBEACH / CSHORE are used to model event-based change at the shoreline and so only locations outside the TSPP project area were modeled; 7 transects:

HISTORIC ANALYSIS AND EXISTING INFORMATION

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW SPRING 2012

MHW 1978

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

OBSERVED HISTORIC SHORELINE CHANGE

1978 - SPRING 2012 (PRE-SANDY)

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SPRING 2012 MHW (PRE-SANDY)

FALL 2012 MHW (POST-SANDY)

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

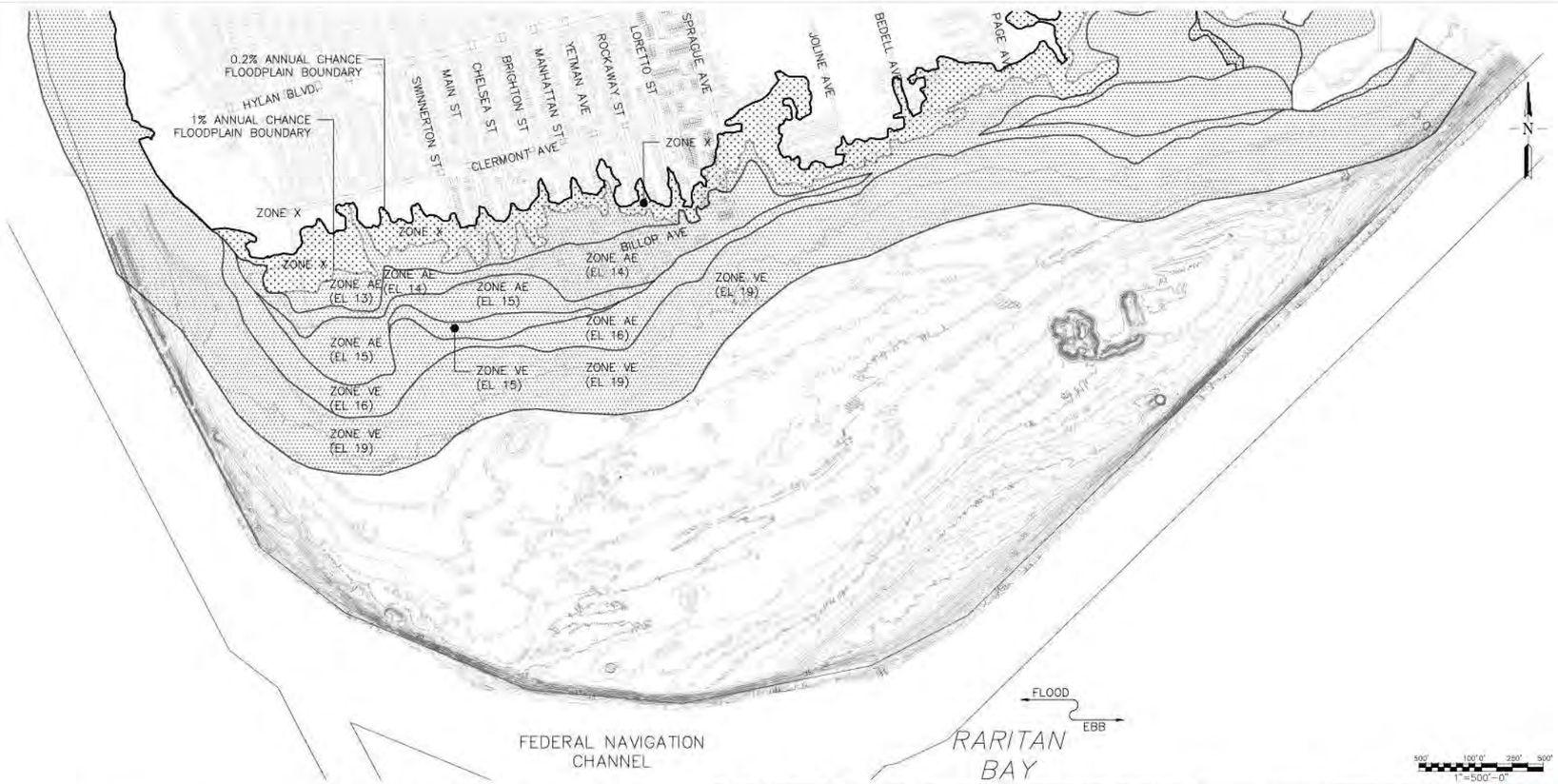
OBSERVED EVENT BASED SHORELINE CHANGE

SPRING 2012 (PRE-SANDY) - FALL 2012 (POST SANDY)

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING



1 G-100 FEMA FLOOD INSURANCE RATE PLAN

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS
OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% annual chance floodplain boundary
0.2% annual chance floodplain boundary
Floodway boundary
Zone D boundary
CBRS and OPA boundary
Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
Limit of Moderate Wave Action
513 — Base Flood Elevation line and value; elevation in feet*
(EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*
* Referenced to the North American Vertical Datum of 1988
15 — 15 Cross section line
23 — 23 Transect line
Culvert, Flume, Penstock or Aqueduct
Road or Railroad Bridge
Footbridge
87°07'45", 32°22'30" Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
4076000 N 1000-meter Universal Transverse Mercator grid values, zone 19
600000 FT 5000-foot grid values: New York State Plane coordinate system, Long Island zone (FIPSZONE 3104), Lambert Conformal Conic projection
DX5510 × Bench mark (see explanation in Notes to Users section of this FIRM panel)
● M1.5 River Mile

2 G-100 FIRM LEGEND N.T.S.

3 G-100 PRELIMINARY FLOOD INSURANCE RATE MAP

30% DESIGN SUBMISSION
NOT FOR CONSTRUCTION

FEMA PFIRM MAP

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

HISTORIC SHORELINE CHANGE AND FEMA PFIRMS

Historic shoreline change analysis was performed based on orthoimagery available between 1978 and 2012, for a period covering the range of the wave hindcast data (1982 to 2012).

The rates of shoreline change exceed 1 foot per year mostly adjacent to Conference House Park west of Brighton Street, with the greatest shoreline erosion rate at 3.5 feet per year (±0.4 feet per year).

Most of the shoreline change rates moving to the northeast from Brighton Street along the shoreline are less than 1 foot per year. An exception is shown between Manhattan and Rockaway Streets where the rate is estimated at 1.7 feet per year (±0.4 feet per year) and between Page Avenue and Richard Avenue where the long-term erosion rate is estimated at 2.4 feet per year (±0.4 feet per year). This area is downdrift of an L-shaped timber pile groin structure, which may have been a historic pier.

Areas of the most pronounced localized shoreline change are downdrift of existing groin structures.

BASELINE (FUTURE WITHOUT PROJECT)

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

BASELINE, FUTURE WITHOUT PROJECT

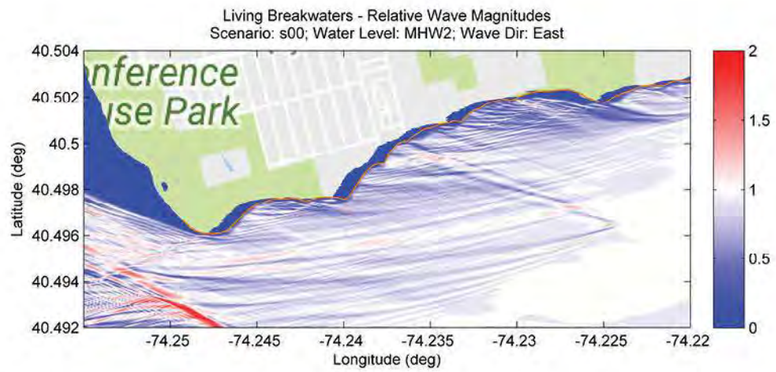
GENESIS RESULTS

NY RISING

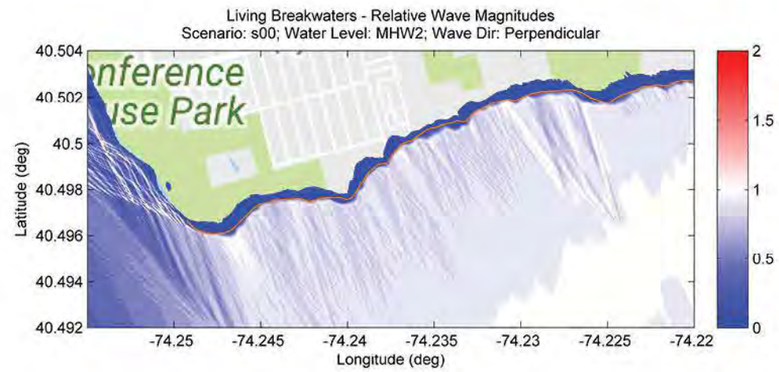
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

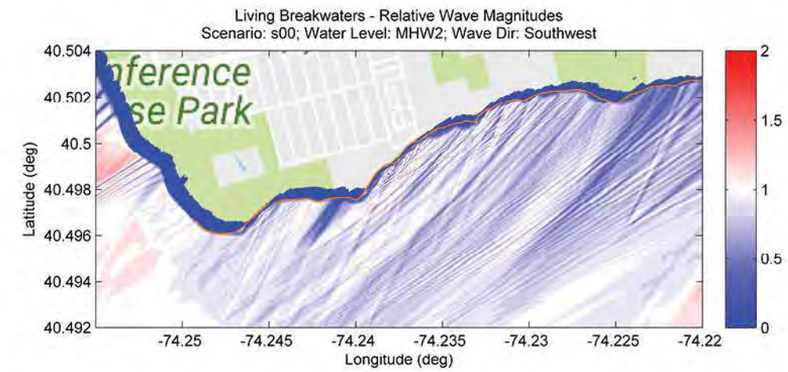
MHW | Input Wave Height of 3 feet | Waves from East



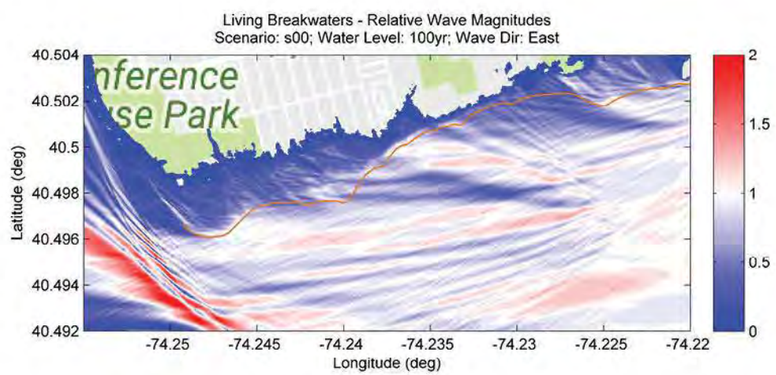
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



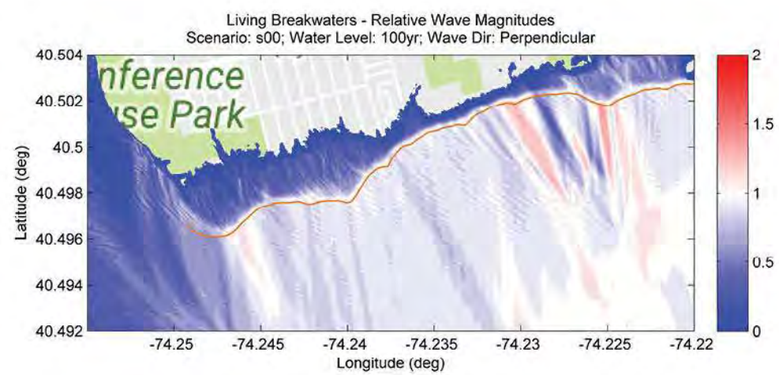
MHW | Input Wave Height of 3 feet | Waves from Southwest



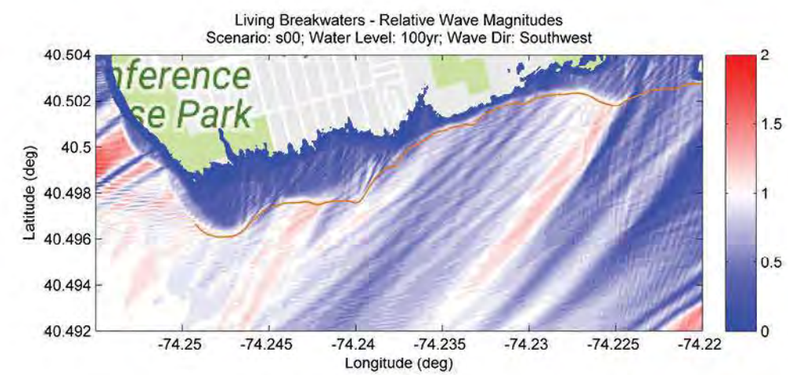
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

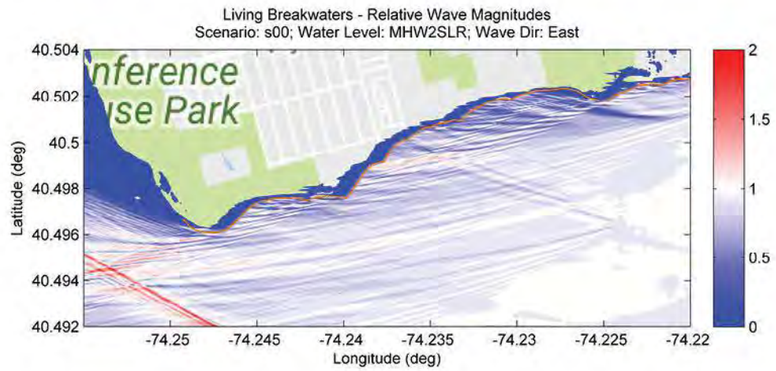


100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



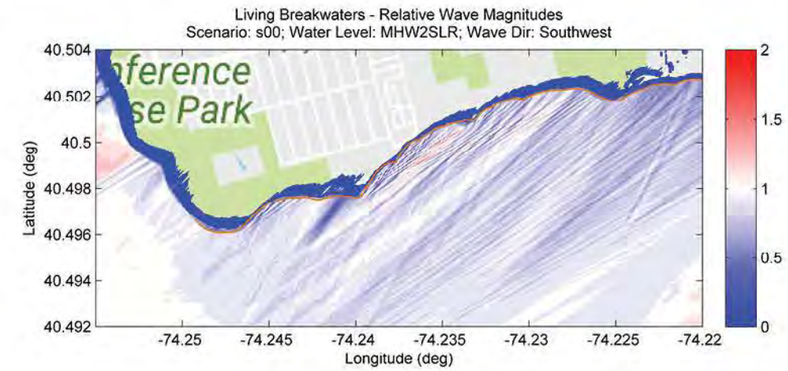
WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).

MHW + 30" SLR | Input Wave Height of 3 feet | Waves from East

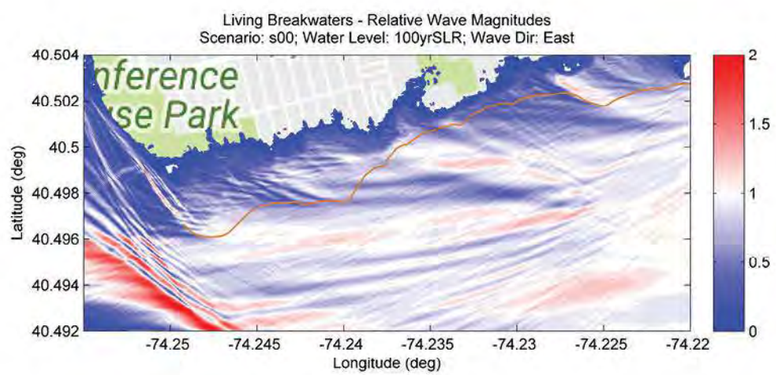


MHW + 30" SLR | Input Wave Height of 3 feet | Waves Perpendicular to Shore

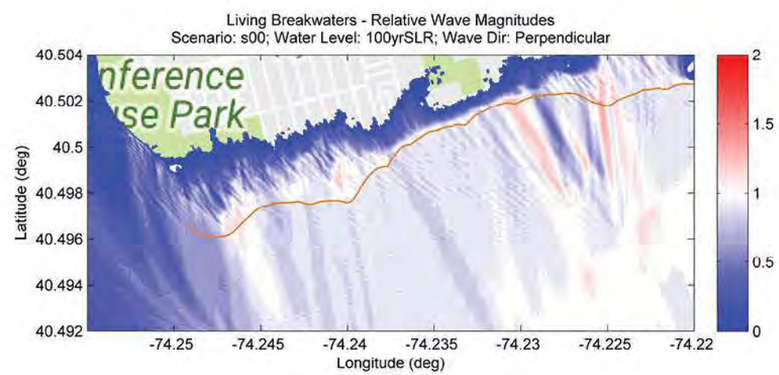
MHW + 30" SLR | Input Wave Height of 3 feet | Waves from Southwest



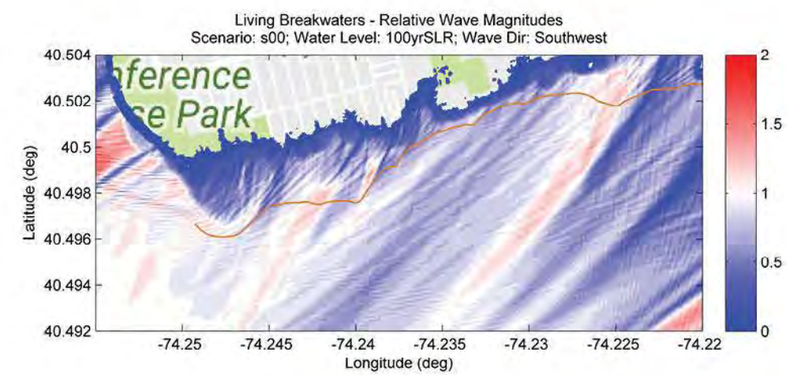
100 Year + 30" SLR | Input Wave Height of 5.3 feet | Waves from East



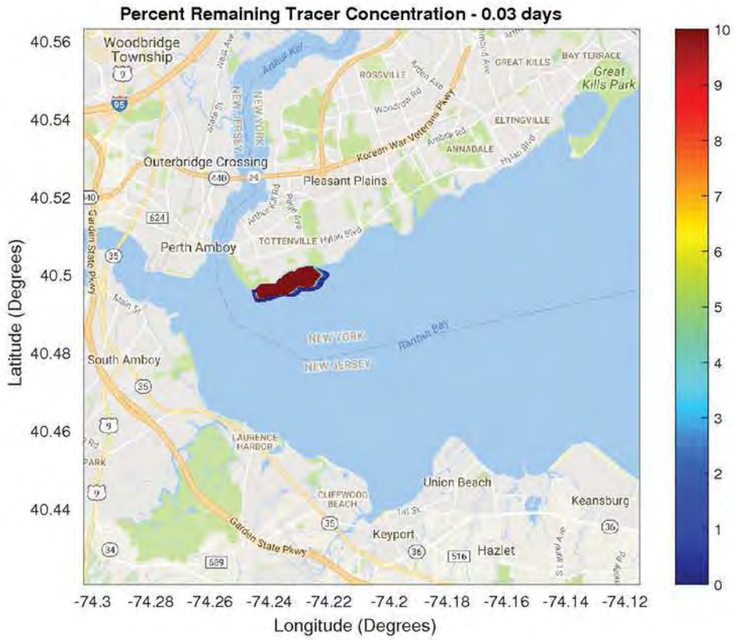
100 Year + 30" SLR | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

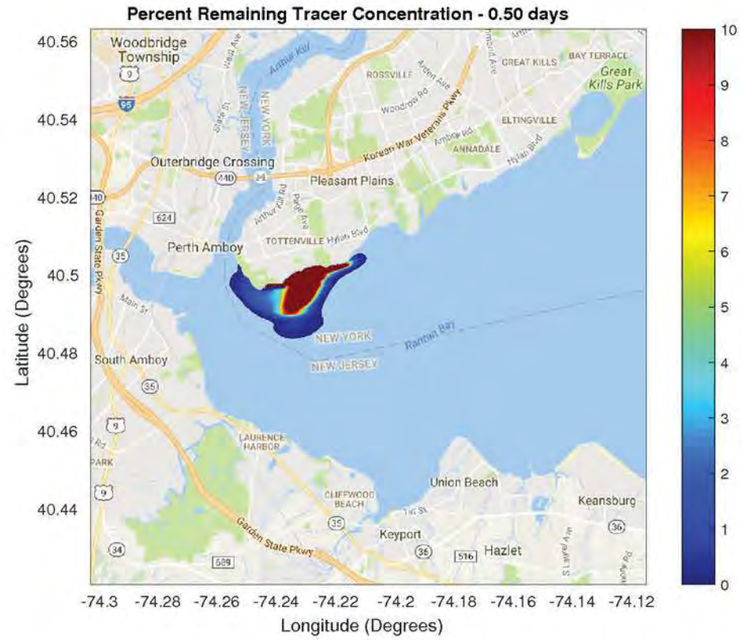


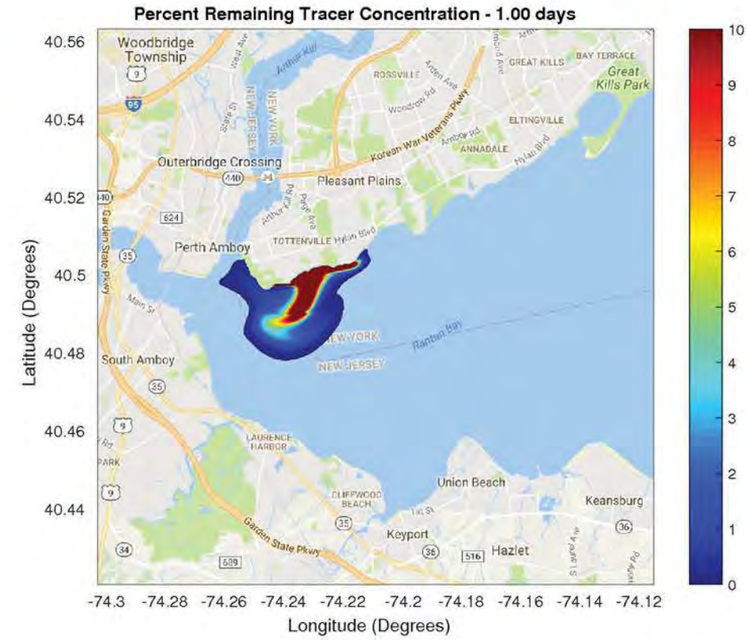
100 Year + 30" SLR| Input Wave Height of 5.3 feet | Waves from Southwest

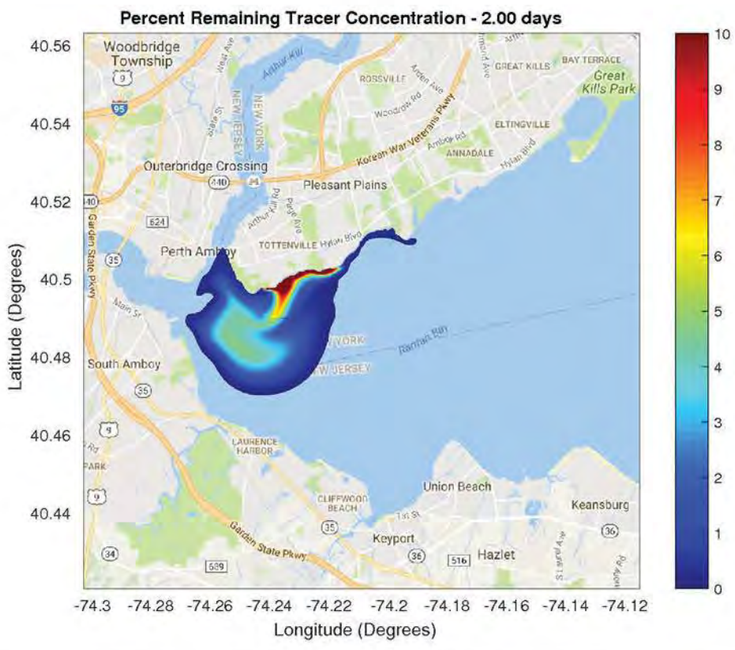


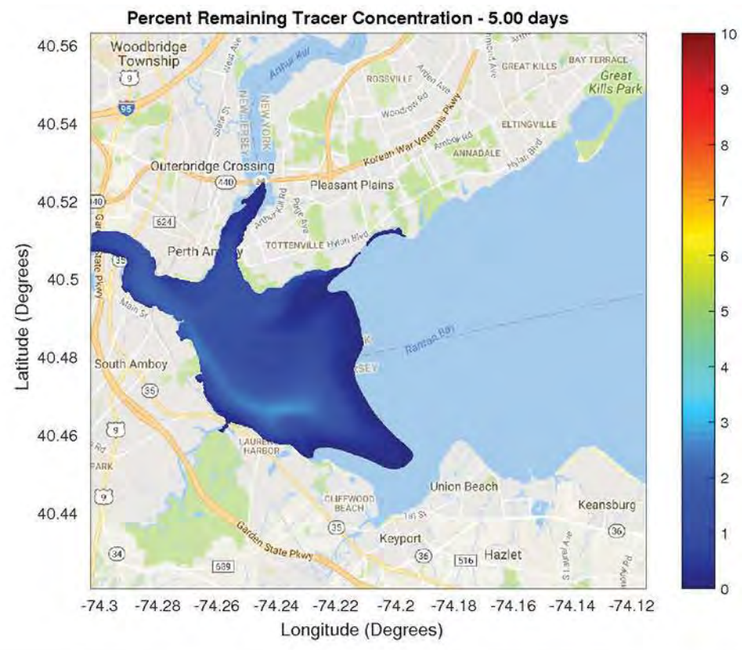
WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).











BASELINE, FUTURE WITHOUT PROJECT

DELFT-3D RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

00: BASELINE (FUTURE WITHOUT PROJECT)

ASSUMPTIONS: SHORELINE CONDITIONS

- 2015 shoreline (which was a compilation of the 2015 TSPP survey, 2014 LiDAR in areas outside the survey, and the 2015 structures survey supplemented with aerial information) was used as starting point / baseline for shoreline change of the preferred alternative.
- Initial model simulations used the pre-Sandy 2012 shoreline developed from aerial photography as the initial shoreline based on the shorelines used in the calibration process and the data available at the start of the scenario modeling process (this initial shoreline was used for consistency of comparison until the preferred scenario was selected).
- Shoreline structures / conditions assumed to be as surveyed in fall 2015; baseline model results assume no alteration of existing shoreline structures.
- The shoreline is the surveyed MHW line defined as 2.08 ft. NAVD88 tidal datum at Sandy Hook. Outside the survey limits, MHW was delineated from post-Sandy USGS LiDAR(August 2014).

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- The overall trends in shoreline change remain similar. Southwest of Sprague Avenue, the future without scenario showed shoreline change rates for the next 20 years consistent with the severe (>1') rates seen over the past 30 years. Northeast of Sprague Avenue, the future without scenario showed somewhat reduced rates shoreline change for the next 20 years relative to the rates seen over the past 30 years.
- The complex (wavey) nature of this shoreline and large number of structures on the shoreline likely complicates shoreline change processes, making results more varied
- Changes in sea levels may also play a factor in the response of the shoreline. Currently the model simulation have used current mean sea level. This allowed for comparison between scenarios but the effects of varying sea level will be tested once the preferred scenario is advanced in the next phase of design. Simplified shoreline change models, such as GENESIS, are effective at evaluating trends in shoreline changes and impacts of shoreline and nearshore structures but do not fully represent the cross shore processes that are impacted by sea level rise. Sea level rise influences are further evaluated in this phase of modeling in REFDIF.

WAVE ACTION

- Both the channel and the northern depth anomaly (the hole), impact wave refraction and diffraction and can result in some increased wave heights.
- The beach itself is one of the best attenuators of storm waves (building beach and complimentary on-shore interventions may have best storm wave reduction benefits)

WATER QUALITY

- The tracer plume originating from the project area dissipates to less than a few percent concentration in less than 5 days.

DESIGN SCENARIOS

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 01

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW 2012

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 01

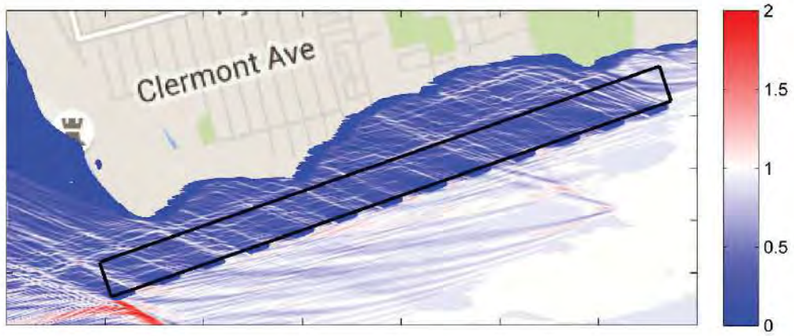
SCENARIO LAYOUT

NY RISING

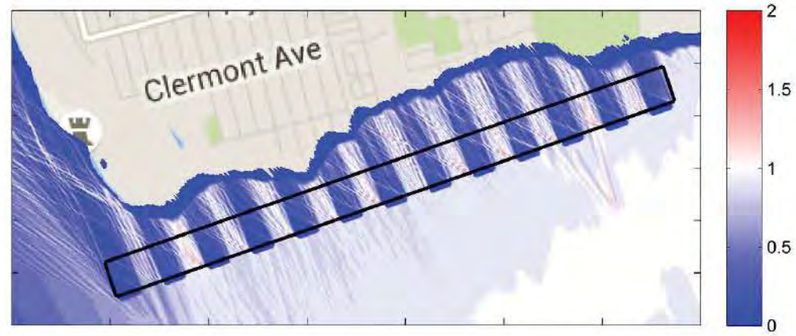
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

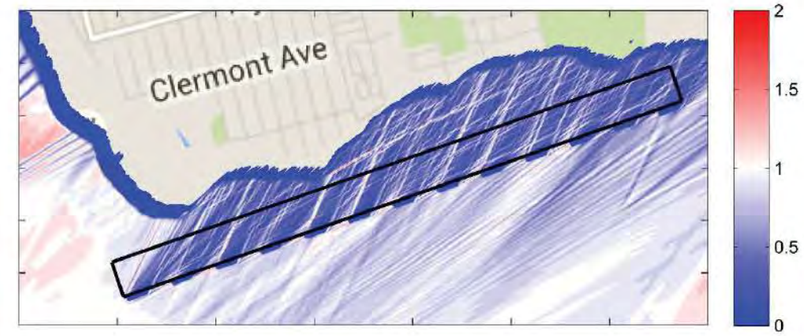
MHW | Input Wave Height of 3 feet | Waves from East



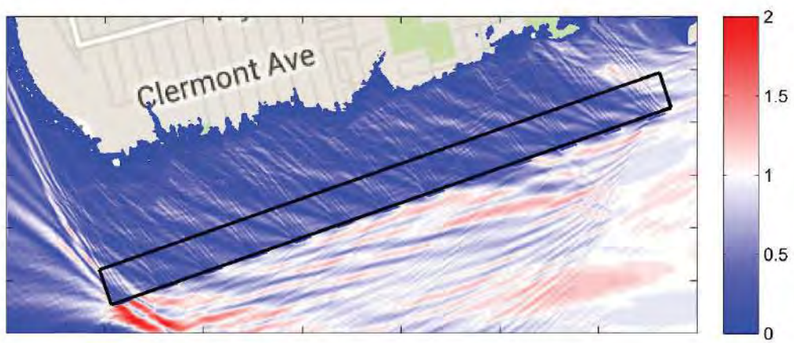
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



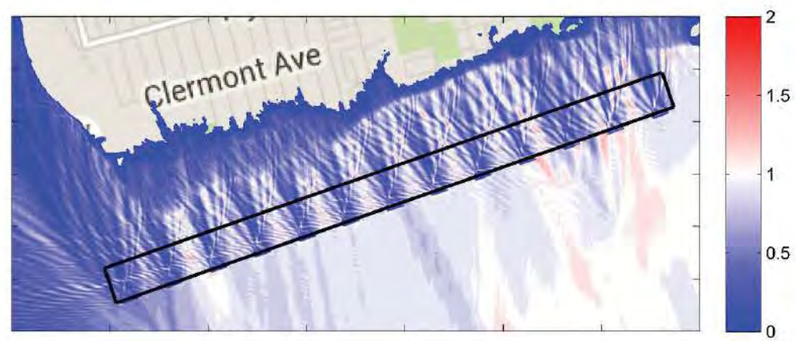
MHW | Input Wave Height of 3 feet | Waves from Southwest



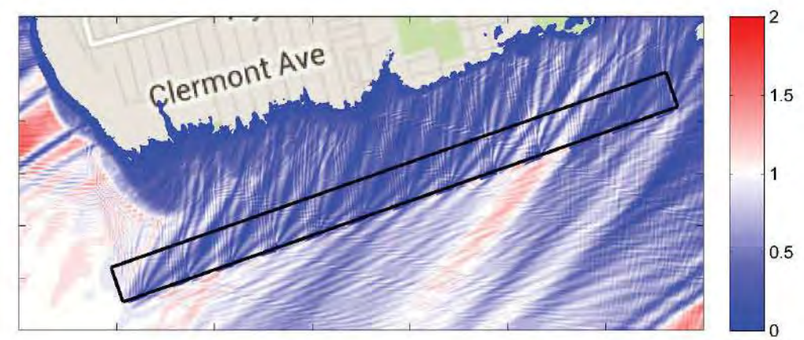
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



Wave heights shown are relative wave heights (modeled wave height/incoming offshore wave height).

SCENARIO 01: “HOLD THE SHORELINE”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- System provided effective shoreline stabilization in almost all areas.
- Limited effect at furthest distance to shore (x=1,300 feet, L/x=.25, where x is distance from shore and L is breakwater length) Trapping of greater amounts of sediment ‘upstream’ appears to limit potential of sediment capture downstream, suggesting that this is not a high sediment system.
- Salient response at north end was surprisingly strong; may be the salient itself beginning to act to trap sediment behind it. => may not need to extend breakwaters all the way north to get salient effect there.

WAVE ACTION

- The wave shadow zone (area where we see wave height reduction) is larger when waves are oblique rather than head-on in relation to breakwater orientation

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
AREADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 02: "STORM WAVE ATTENUATION"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 02: "STORM WAVE ATTENUATION"

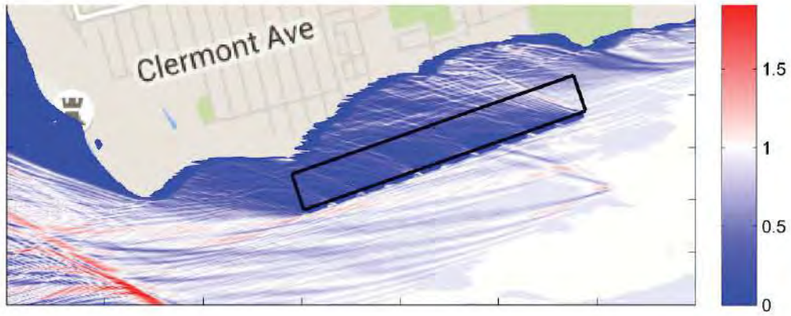
GENESIS RESULTS

NY RISING

SCAPE TEAM

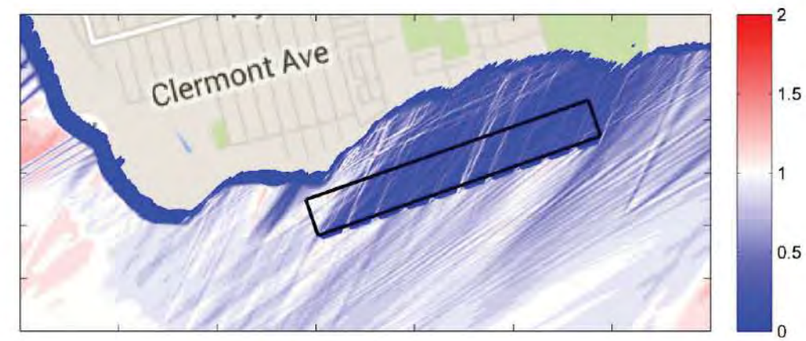
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW | Input Wave Height of 3 feet | Waves from East

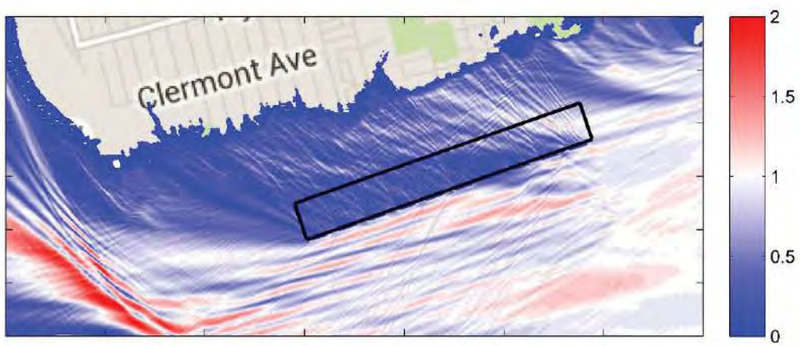


MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore

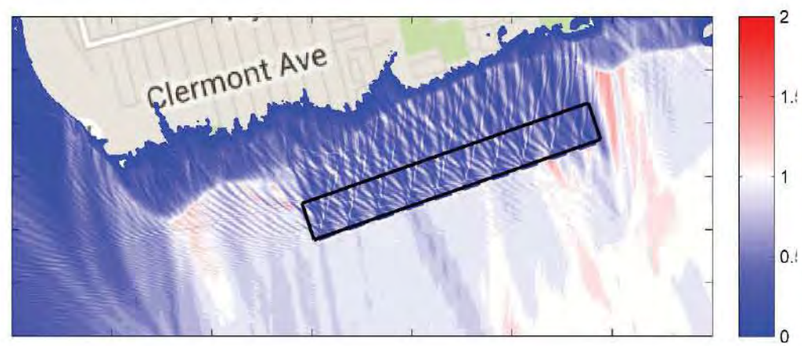
MHW | Input Wave Height of 3 feet | Waves from Southwest



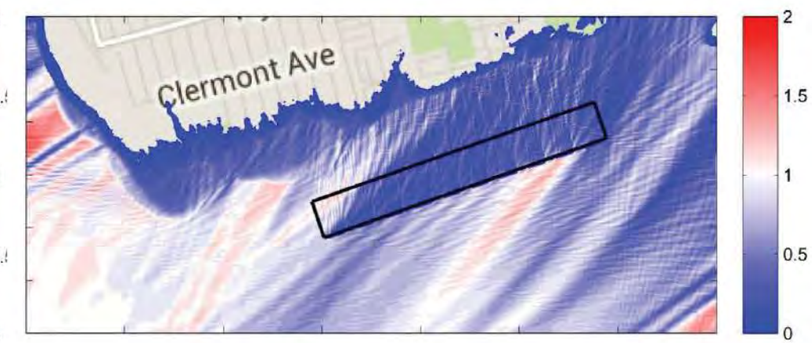
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 02: "STORM WAVE ATTENUATION"

REF DIF RESULTS

SCENARIO 02: "STORM WAVE ATTENUATION"

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Breakwaters acted as a single unit in how they impacted shoreline change => Breakwaters with small gap width (30') or Wg/(L+Wg) (1/4) act like a single unit in salient formation
- If sediment is trapped 'upstream', but if nothing is done at the southern end, this could exacerbate erosion in Conference House Park => breakwater system will need to extend to the southwestern edge of Zone 2 to avoid further erosion in this zone.

WAVE ACTION

- Smaller gap widths allow fewer / lower waves to pass through.
- Again, the wave shadow zone (area where we see wave height reduction) is larger when waves are oblique rather than head-on in relation to breakwater orientation

SCENARIO 02: "STORM WAVE ATTENUATION"
MODEL TAKE-AWAYS AND LESSONS LEARNED

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 03: "TESTING FOR TOMBOLO"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 03: "TESTING FOR TOMBOLO"

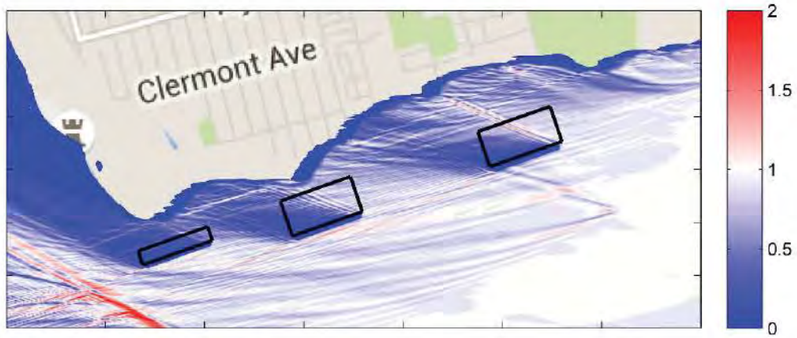
GENESIS RESULTS

NY RISING

SCAPE TEAM

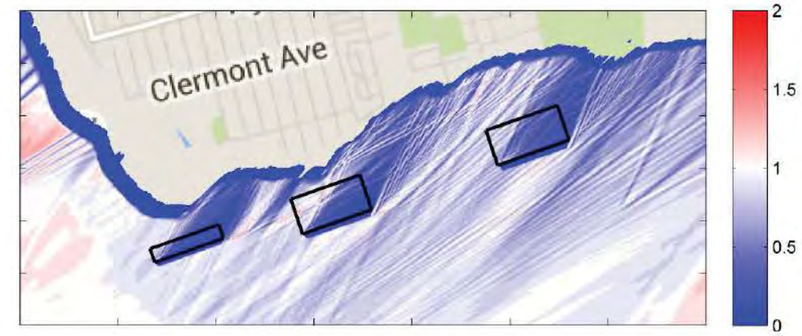
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW | Input Wave Height of 3 feet | Waves from East

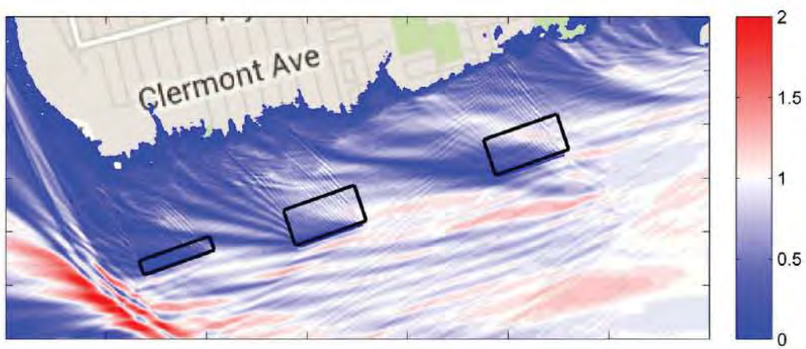


MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore

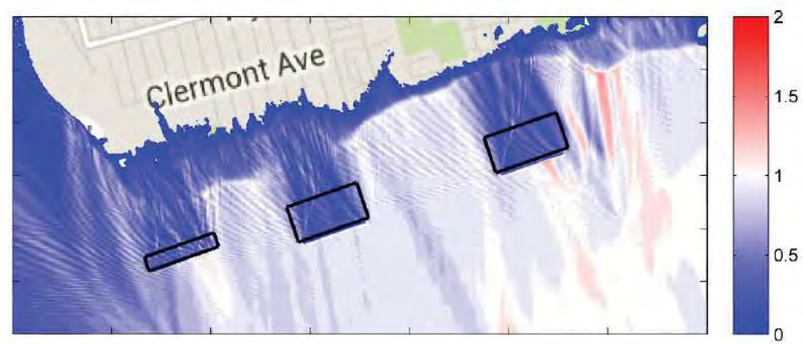
MHW | Input Wave Height of 3 feet | Waves from Southwest



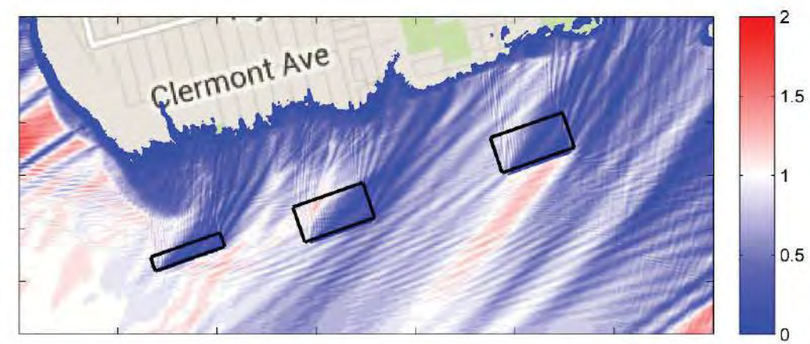
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 03: "TESTING FOR A TOMBOLO"

REF DIF RESULTS

SCENARIO 03: "TESTING FOR A TOMBOLO"

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- The long breakwaters all show significant salient response.
- Shoreline response is not proportional to distance to shore (X) or the ratio of breakwater segment length to distance to shore (L/X), suggesting that other factors influence the scale of salient formation, including but not limited to amount of sediment in the system, amount of sediment trapped upstream, shape of shoreline, and existing coastal structures.
- It may be possible to create a tombolo, which would act like a terminal groin at the end of the system.

WAVE ACTION

- The wide spacing between breakwater segments means that there is little wave reduction in the gaps between them.
- The breakwaters themselves are effective wave attenuators.

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
HARSON'S BRANCKEBROOK
AREADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

2012 MHW

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 04: "LEARNING FROM ROUND ONE"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 04: "LEARNING FROM ROUND ONE"

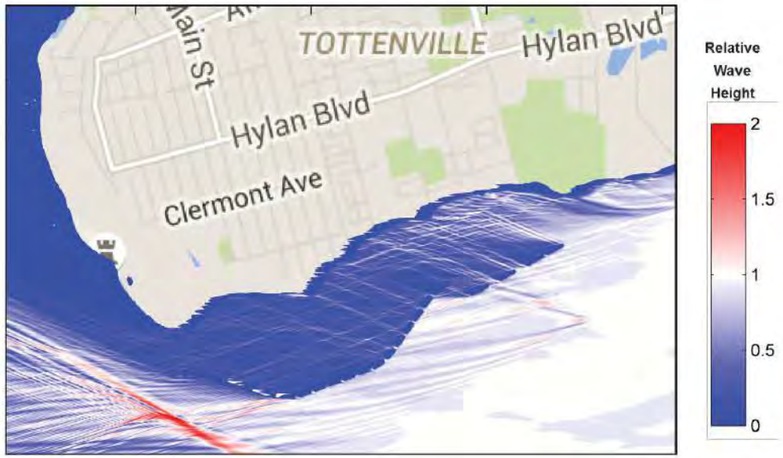
GENESIS RESULTS

NY RISING

SCAPE TEAM

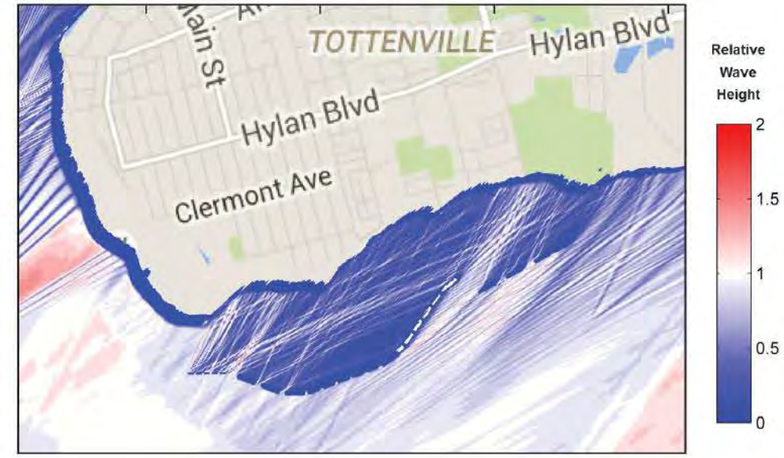
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW | Input Wave Height of 3 feet | Waves from East

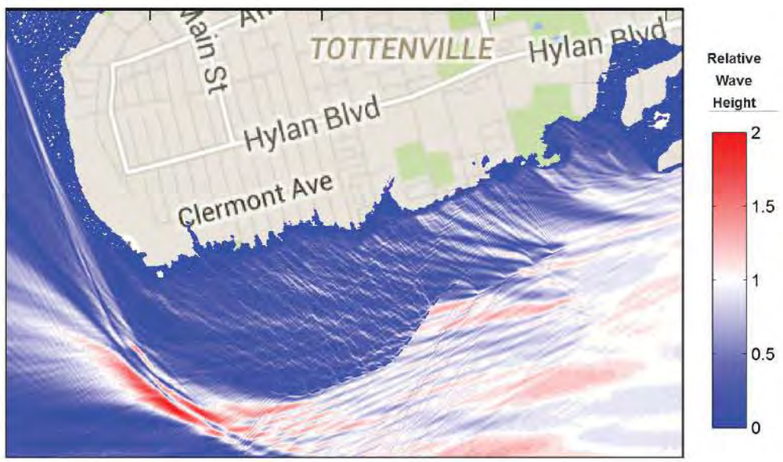


MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore

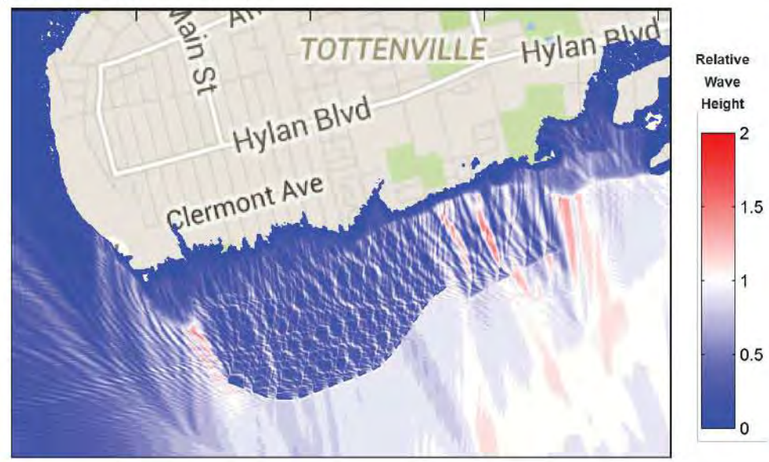
MHW | Input Wave Height of 3 feet | Waves from Southwest



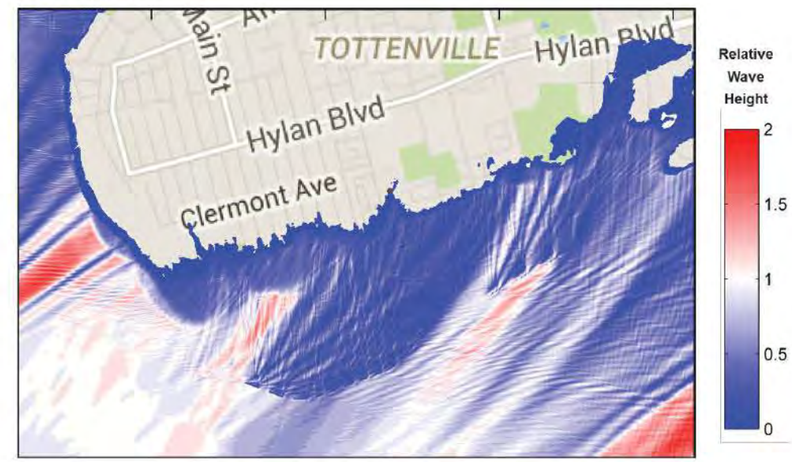
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 04: "LEARNING FROM ROUND ONE"

REF DIF RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 04: "LEARNING FROM ROUND ONE

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Shoreline is stabilized along length
- Limited longshore sediment supply is trapped along northeast shoreline and does not reach Zones 2 and 3 where accretion is desired
- Varying breakwater layout for desired goals by region appears to have merit

WAVE ACTION

- Effective wave shadow zone throughout most of the project area (area where we see wave height reduction)
- Lower crested breakwaters on western edge show limited effectiveness in attenuating waves under higher water levels

OTHER

- Large footprint = costly, high impact

SCENARIO 04: "LEARNING FROM ROUND ONE"
MODEL TAKE-AWAYS AND LESSONS LEARNED

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED
SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 05: "MODIFIED SCENARIO 04"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 05: "MODIFIED SCENARIO 04"

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 05: “MODIFIED SCENARIO 4”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Shoreline is stabilized along much of its length
- Significant accretion between Manhattan St and Page Ave
- Some erosion continued in Zone 2
- Removing northeastern breakwaters allowed more sediment to move farther west along the shoreline
- Bringing breakwaters closer to shore increased shoreline accretion and wave protection

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 06: "MINIMALIST APPROACH"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 06: "MINIMALIST APPROACH"

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 06: “MINIMALIST APPROACH”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Northeastern breakwaters were effective in retaining sediment and causing shoreline accretion
- Removal and lowering of southwestern breakwaters resulted in loss of protection and considerable erosion in conjunction with sediment trapping up drift

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 07: "MINIMALIST APPROACH WITH SHORELINE RESTORATION"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 07: "MINIMALIST APPROACH WITH SHORELINE RESTORATION"

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 07: “MINIMALIST APPROACH WITH SHORELINE RESTORATION”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Shoreline restoration shifted shoreline outward in region of fill
- Shoreline restoration was relatively well retained
- Erosion of western part of shoreline was slightly reduced but still significant as in previous scenario (same breakwater layout sc06)

SCENARIO 07: “MINIMALIST APPROACH WITH SHORELINE RESTORATION”

MODEL TAKE-AWAYS AND LESSONS LEARNED

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 09

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 09

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 09

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Moving the western and central breakwaters closer to shore enhanced shoreline protection.
- Having a breakwater in the middle of the western bay at the park reduced erosion of that region.
- Removal of southwestern breakwaters resulted in loss of protection and considerable erosion of Ward's Point in conjunction with sediment trapping up drift.

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0′ 500′ 1000′ 2000′

SCENARIO 10

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 10

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 10

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Repositioning of the central breakwaters improved shoreline shape and moving farther offshore into deeper water is likely to aid constructability without any noticeable loss in shoreline retention in the simulation.
- Moving of the southwestern breakwater resulted in accretion at the western point (Ward's Point) but significant erosion continued in the adjacent embayment.

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 11

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 11

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 11

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Reducing the number of breakwaters in the central portion and moving the southwestern breakwater increased erosion especially in the adjacent embayment.
- Significant accretion at Ward's Point and between Manhattan St and Bedell Ave

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 12

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 12

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 12

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Splitting the southwestern breakwater into two to provide protection to the point and embayment reduced erosion in the region, but erosion continued.
- Adding back a breakwater to the central section improved shoreline retention and protection between Bedell St and Page Ave
- Retained accretion between Manhattan St and Bedell St

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 13

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 13

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 13

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Moving the southwestern breakwaters and lengthening the breakwater at the southwestern point improved the modeled shoreline response shape; almost eliminated erosion in Zone 2
- Consistent beach accretion between Yettman St and Page Ave

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
HPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 14

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 14

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 14 (2015 MHW)

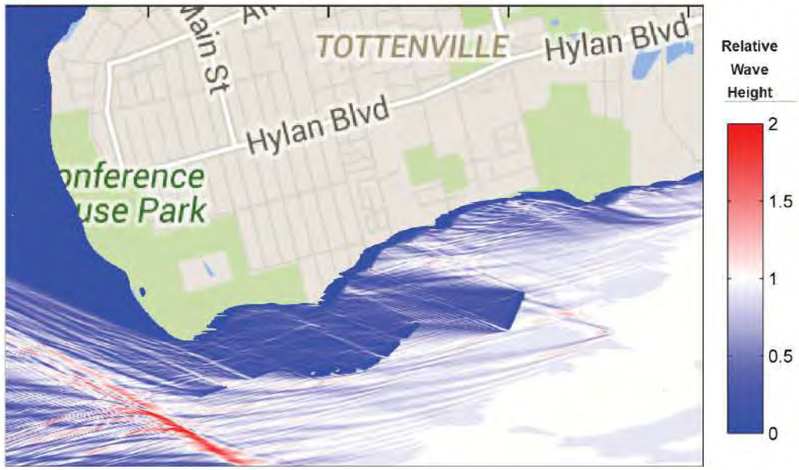
GENESIS RESULTS

NY RISING

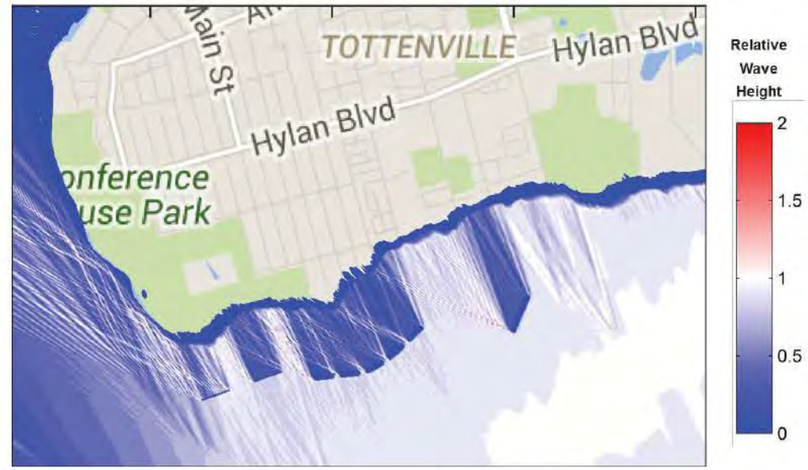
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

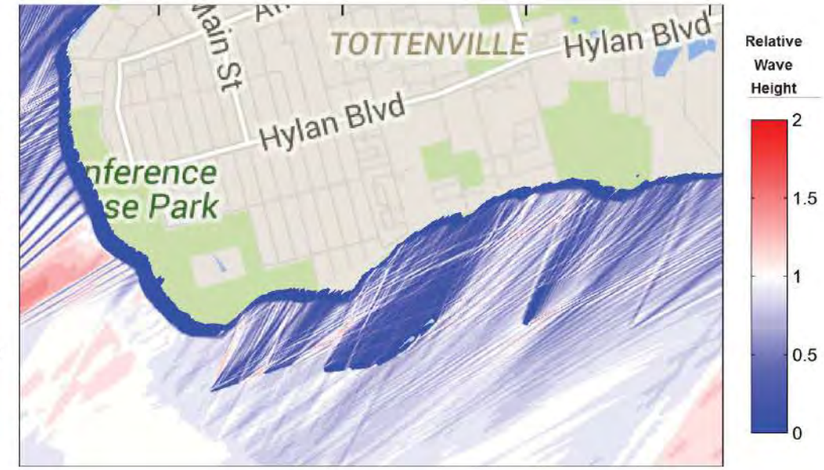
MHW | Input Wave Height of 3 feet | Waves from East



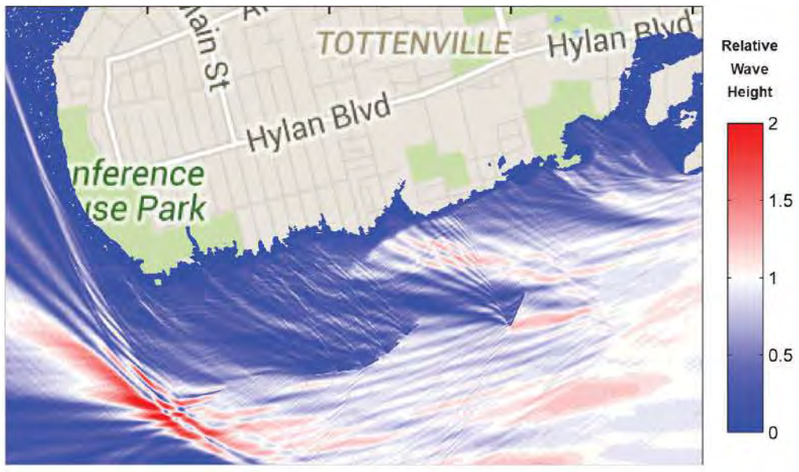
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



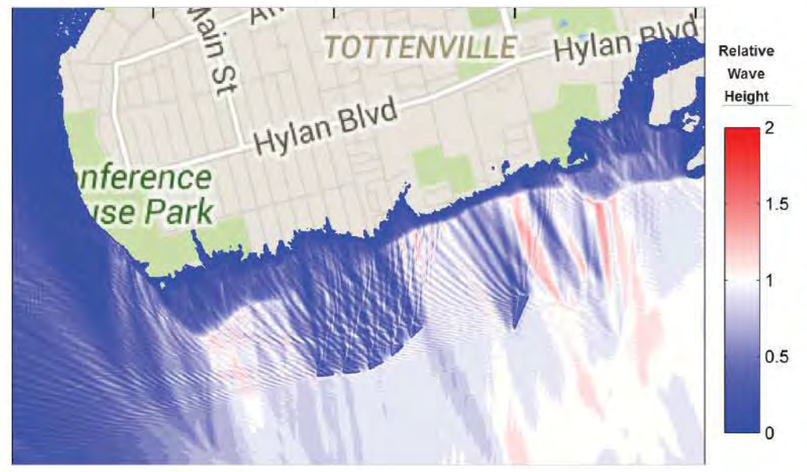
MHW | Input Wave Height of 3 feet | Waves from Southwest



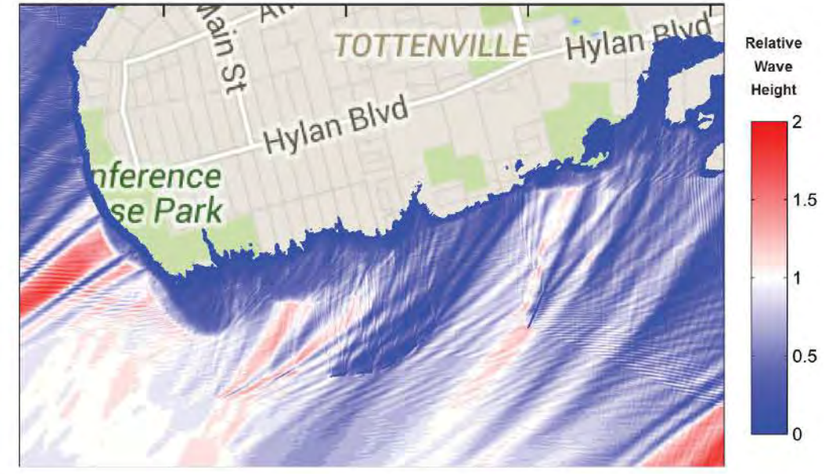
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 14

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Similar to Scenario 13, refinement of southwestern breakwater location and lengthening of these breakwater segments improved modeled shoreline response, shoreline shape, sediment accretion, and sediment retention at the southwestern point and adjacent embayment.

WAVE ACTION

- Breakwaters provide effective wave shadow zones in their lee for area between Brighton St. and Sprague Ave. where vulnerable locations / assets are located for most wave directions. Some additional study may be required for waves from the east.
- Lower crested southwestern breakwaters show reduced effectiveness in attenuating waves under higher water levels. Note that storm wave attenuation has not been identified as a priority for this area, as vulnerable assets are not located in this area.
- Increased wave exposure in gap between northeastern and central breakwaters: the increased spacing and reduction of number of northeastern breakwaters was to attempt to balance between wave attenuation and sediment trapping. Further refinement of breakwater alignment may be required if storm wave attenuation for the northeastern area of the project area is a greater priority.

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
HARSON'S MANCKEBACH
ARCADIS
BEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 15

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 15

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 15

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Similar to Scenario 14, addition of one more central breakwater and eastern breakwater to balance shoreline response with improved wave protection.
- Additional accretion to the northern eastern portion of the project shoreline due to the additional breakwaters. Some reduction in sediment available and accretion farther down the shore.

WAVE ACTION

- Breakwaters provide effective wave shadow zones in their lee for area between Brighton St. and Sprague Ave. where vulnerable locations / assets are located for most wave directions. Additional protection from waves from the east afforded by the additional breakwaters.
- Lower crested southwestern breakwaters show reduced effectiveness in attenuating waves under higher water levels. Note that storm wave attenuation has not been identified as a priority for this area, as vulnerable assets are not located in this area.

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
HARSON'S MANCKERMAN
AREADIS
BEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

FINAL 30% DESIGN SCENARIO

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

2015 MHW

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

30% DESIGN SCENARIO

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

30% DESIGN SCENARIO

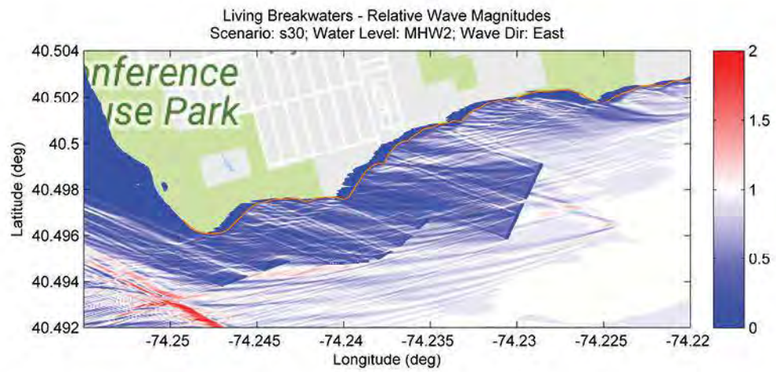
GENESIS RESULTS

NY RISING

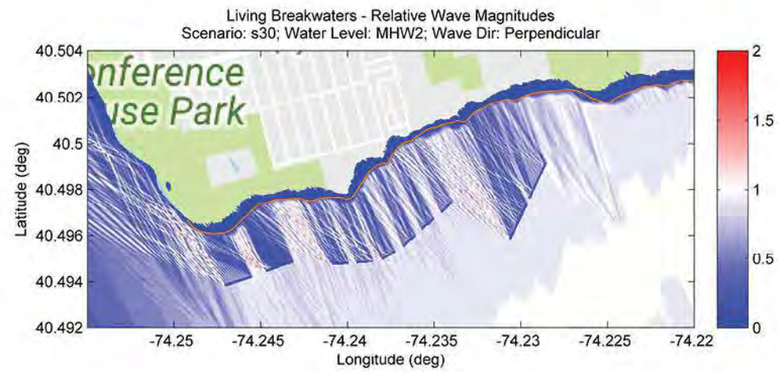
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

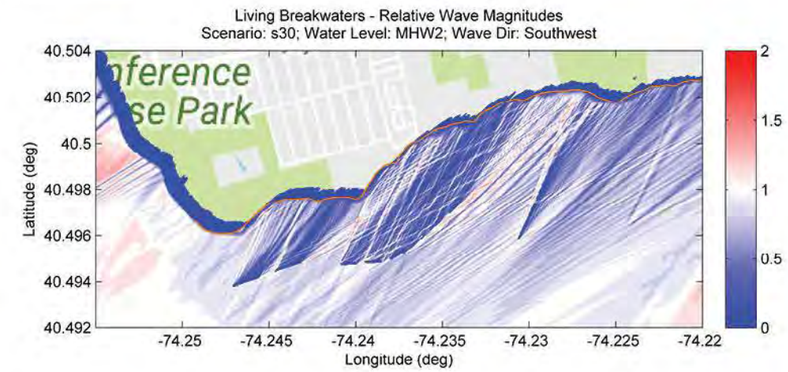
MHW | Input Wave Height of 3 feet | Waves from East



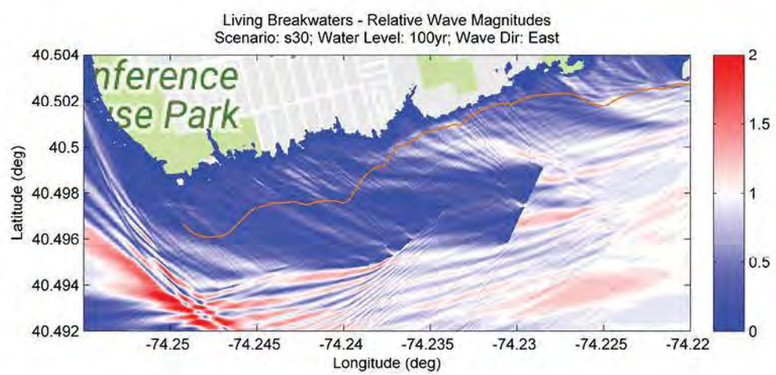
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



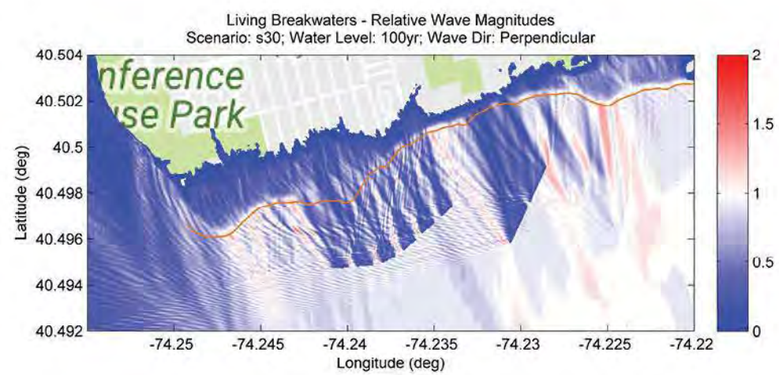
MHW | Input Wave Height of 3 feet | Waves from Southwest



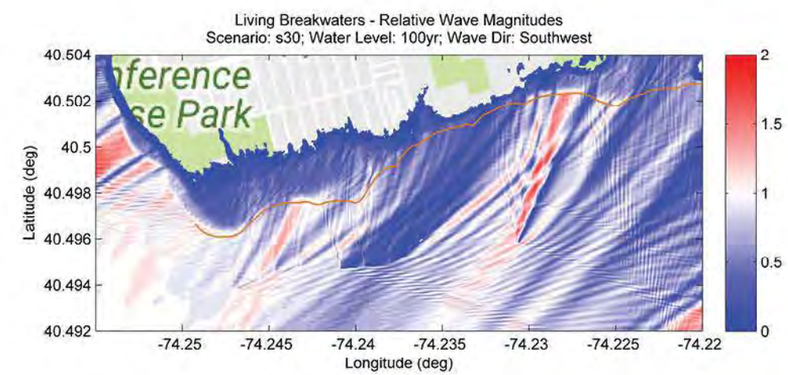
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

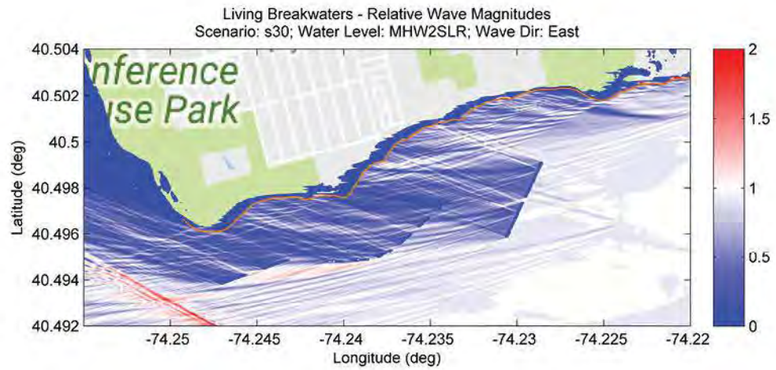


100 Year | Input Wave Height of 5.3 feet | Waves from Southwest

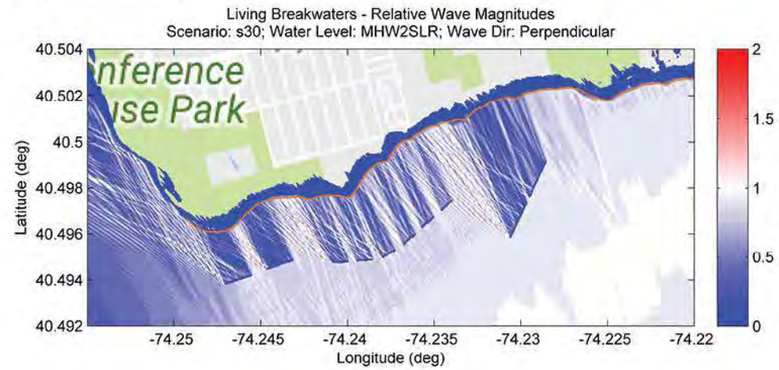


WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).

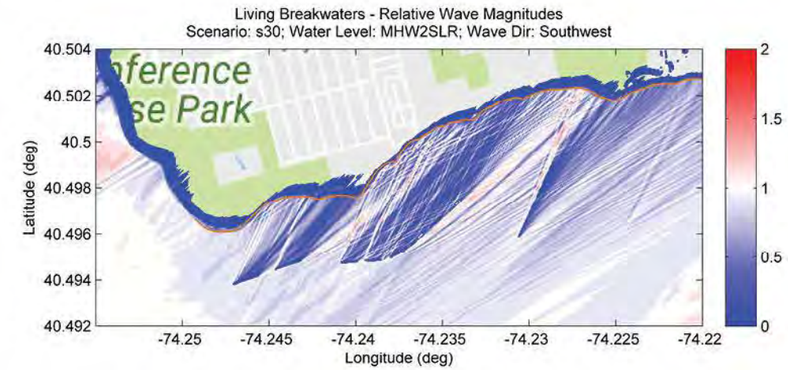
MHW + 30" SLR | Input Wave Height of 3 feet | Waves from East



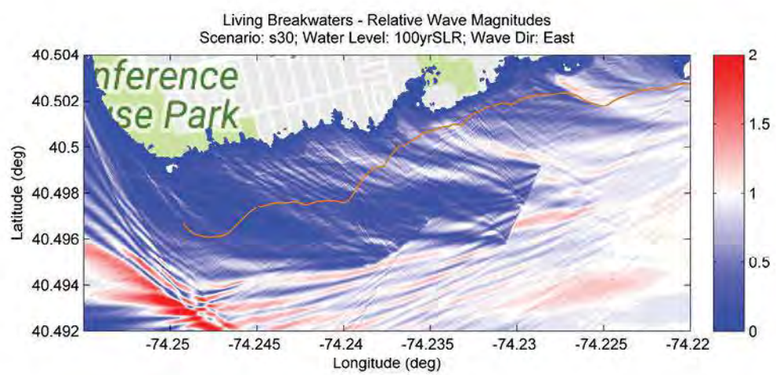
MHW + 30" SLR | Input Wave Height of 3 feet | Waves Perpendicular to Shore



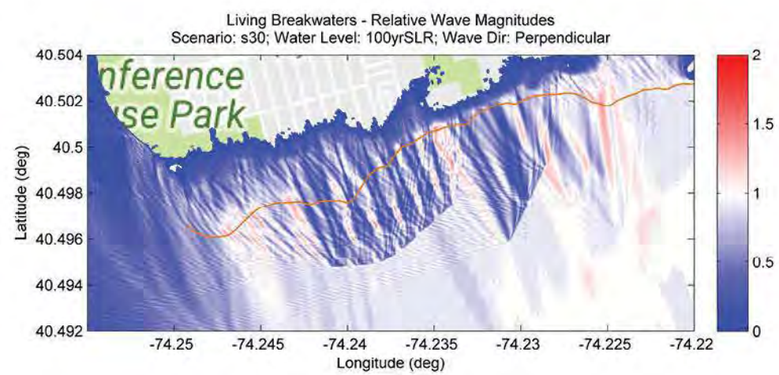
MHW + 30" SLR | Input Wave Height of 3 feet | Waves from Southwest



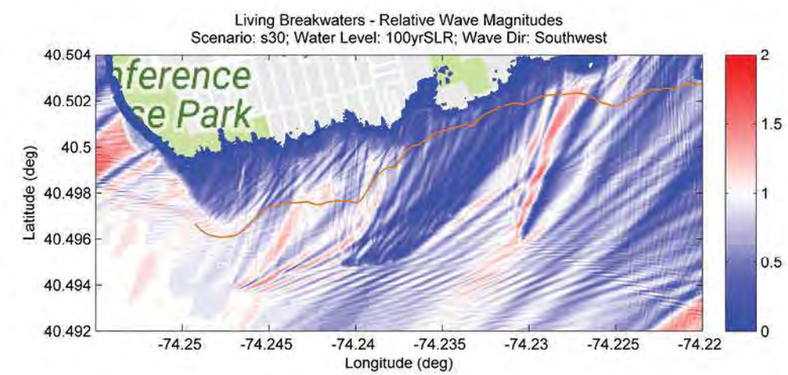
100 Year + 30" SLR | Input Wave Height of 5.3 feet | Waves from East



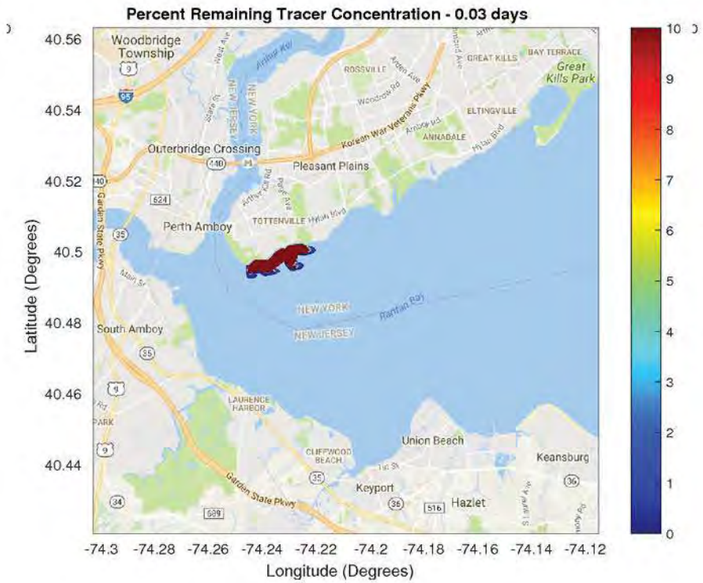
100 Year + 30" SLR| Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

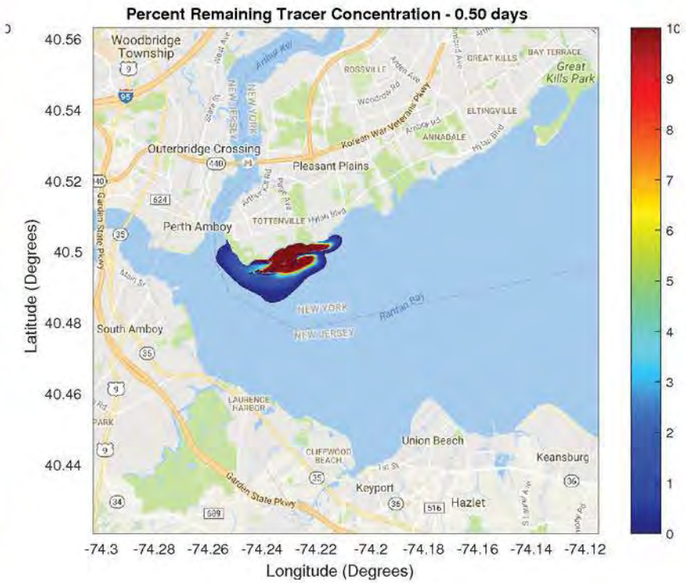


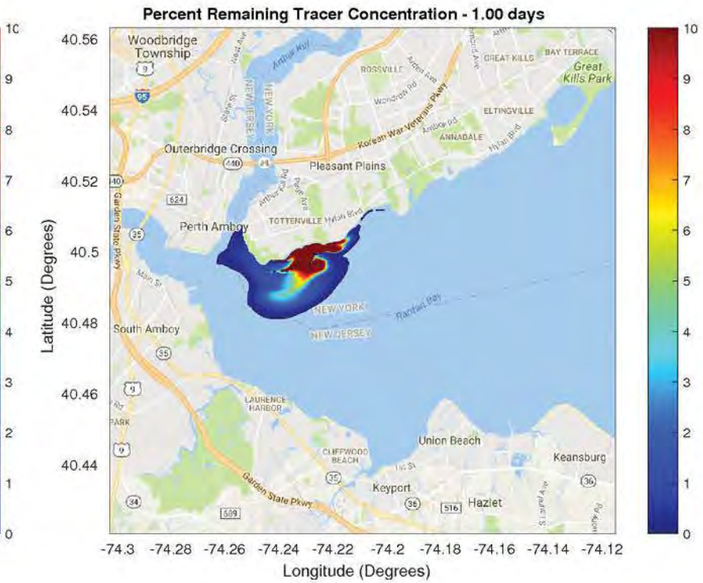
100 Year + 30" SLR| Input Wave Height of 5.3 feet | Waves from Southwest

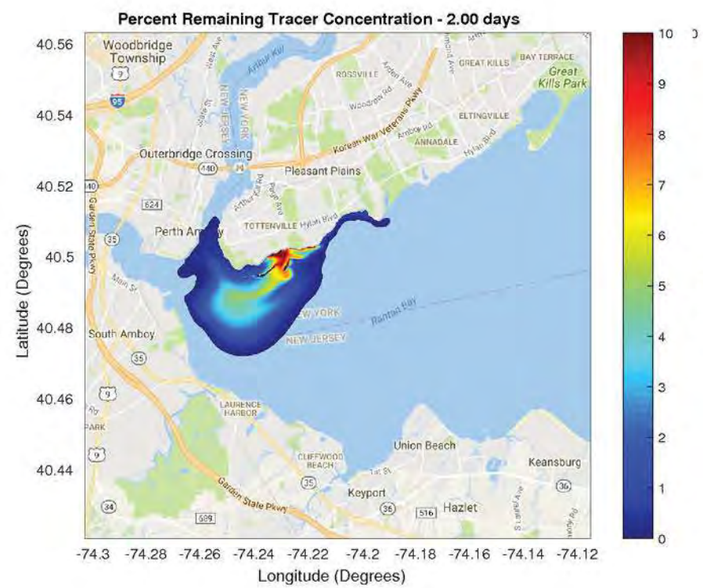


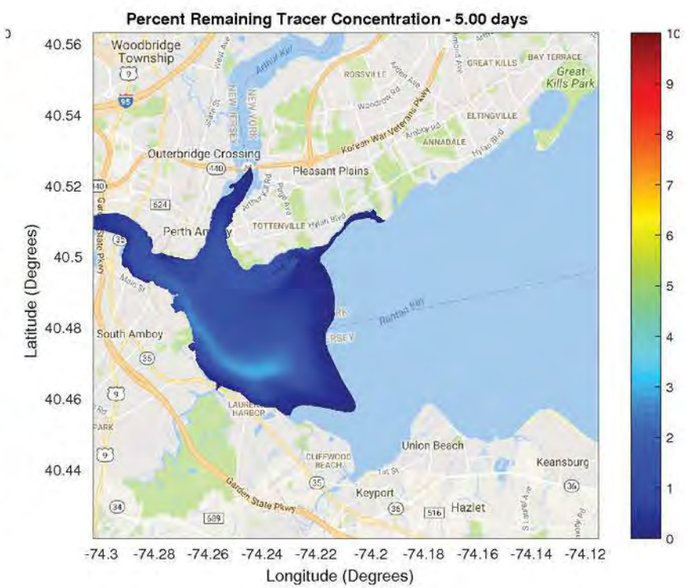
WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).











30% DESIGN SCENARIO

DELFT-3D RESULTS

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

FINAL 30% DESIGN SCENARIO

SUMMARY OF MODEL RESULTS

SHORELINE CHANGE

- Same as Scenario 15 with the addition of some shoreline restoration
- Beach is well retained and provides increased beach width over critical area of the shoreline
- Balance of shoreline response and wave protection

WAVE ACTION

- Same as Scenario 15.

WATER QUALITY

- No significant changes in residence time due to breakwaters

OVERALL TAKE-AWAYS

SHORELINE CHANGE

- Living Breakwaters spacing, gap width, distance to shoreline, and alignment iteratively tested to develop a preferred scenario.
- Living Breakwater System can provide effective shoreline stabilization in almost all areas.
- Breakwater distance from shore, length, gap width, and the relative ratios between them influence the shoreline behavior. Other factors influence the scale of salient formation, including but not limited to amount of sediment in the system, amount of sediment trapped upstream, shape of shoreline, and existing coastal structures.
- Trapping of greater amounts of sediment 'upstream' appears to limit potential of sediment capture downstream.
- "Opening" northeast breakwater area was required to allow updrift sediment to transport to zone 2 / zone 3.
- Southwestern breakwaters are required to stabilize historical erosion at Conference House Park.

WAVE ACTION

- With enough properly spaced breakwaters an effective wave shadow zone (area where we see wave height reduction) throughout most of the project area can be created.
- Smaller gap widths allow fewer / lower waves to pass through.
- Wide spacing between breakwater segments results in little wave reduction in the gaps between them.
- Use of lower crested breakwaters on western edge show limited effectiveness in attenuating waves under higher water levels, so are only being recommended where storm wave attenuation is not a priority (southeastern end of the project area)

WATER QUALITY

- No significant changes in residence time due to breakwaters

SHORELINE RESTORATION

- Shoreline restoration shifted shoreline outward in region of fill.
- Shoreline restoration was relatively well retained.

APPENDIX B - SBEACH AND CSHORE SIMULATIONS

INITIAL BEACH PROFILE TRANSECTS

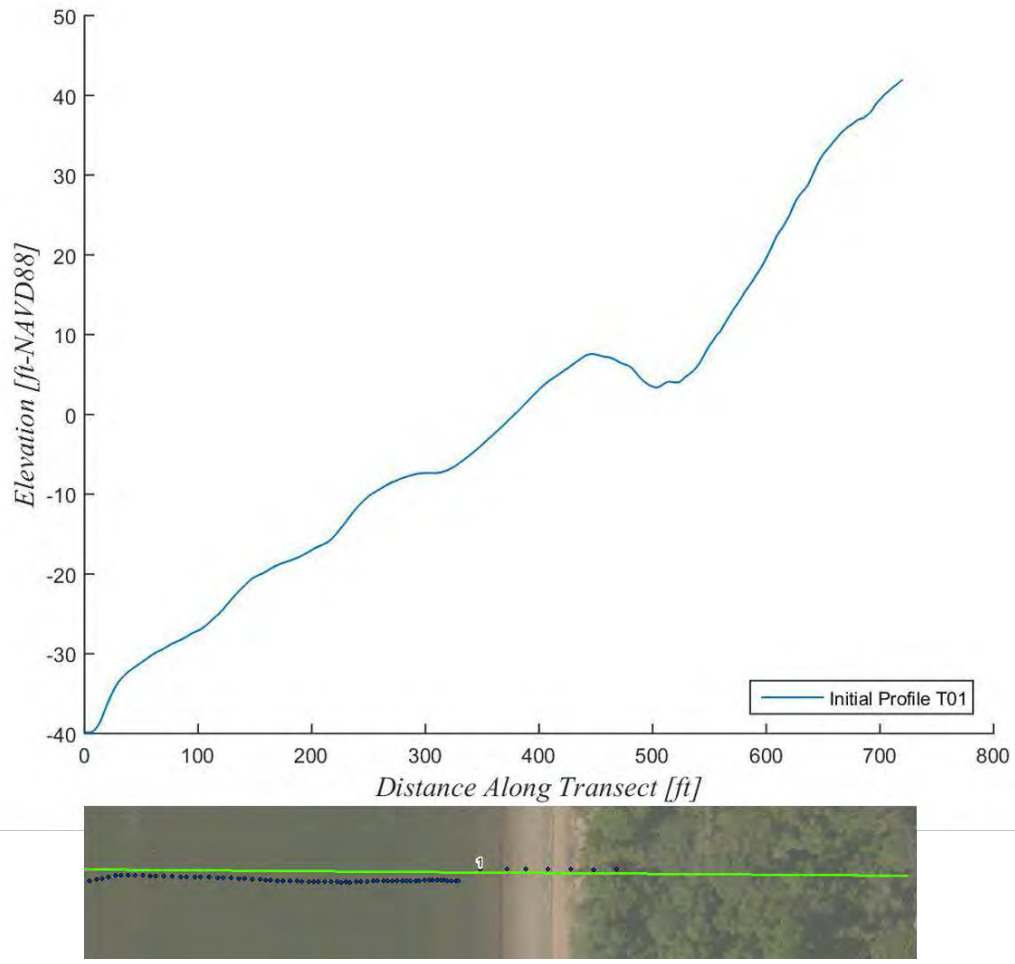


Figure 1. Initial beach profile and recent orthoimagery for transect 1.

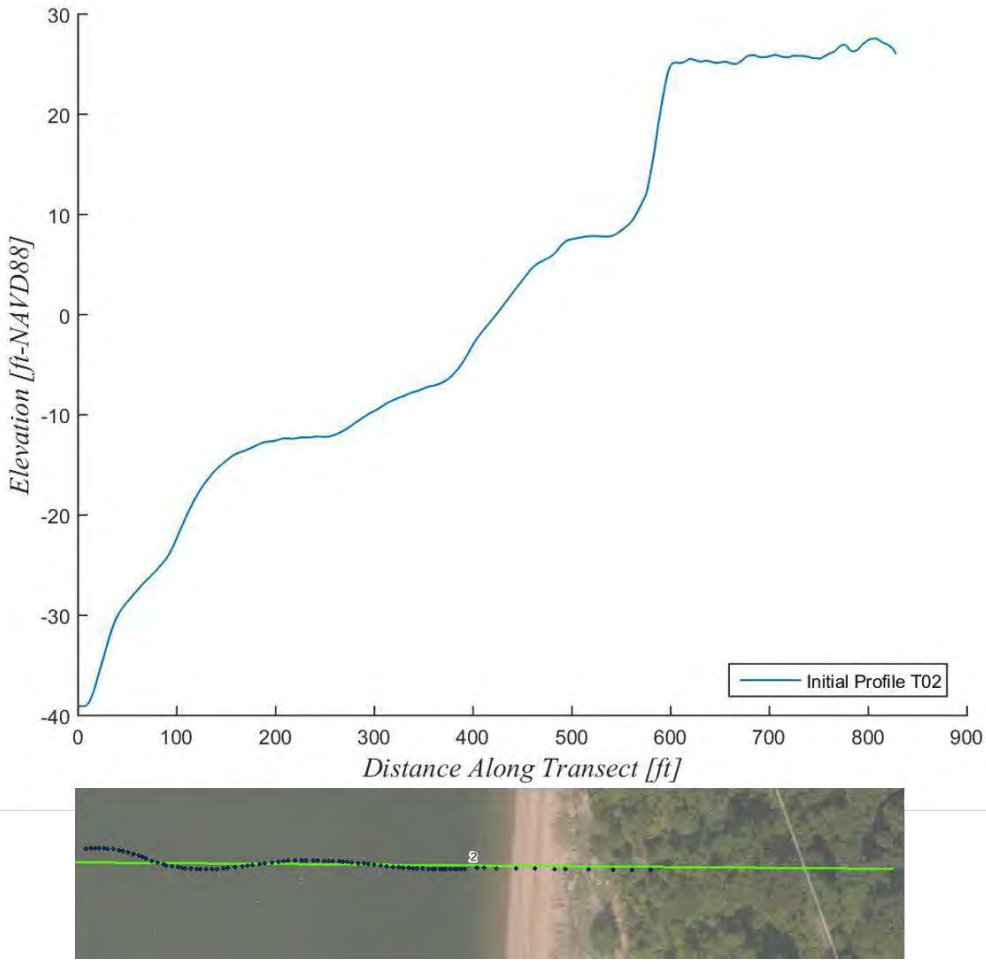


Figure 2. Initial beach profile and recent orthoimagery for transect 2.

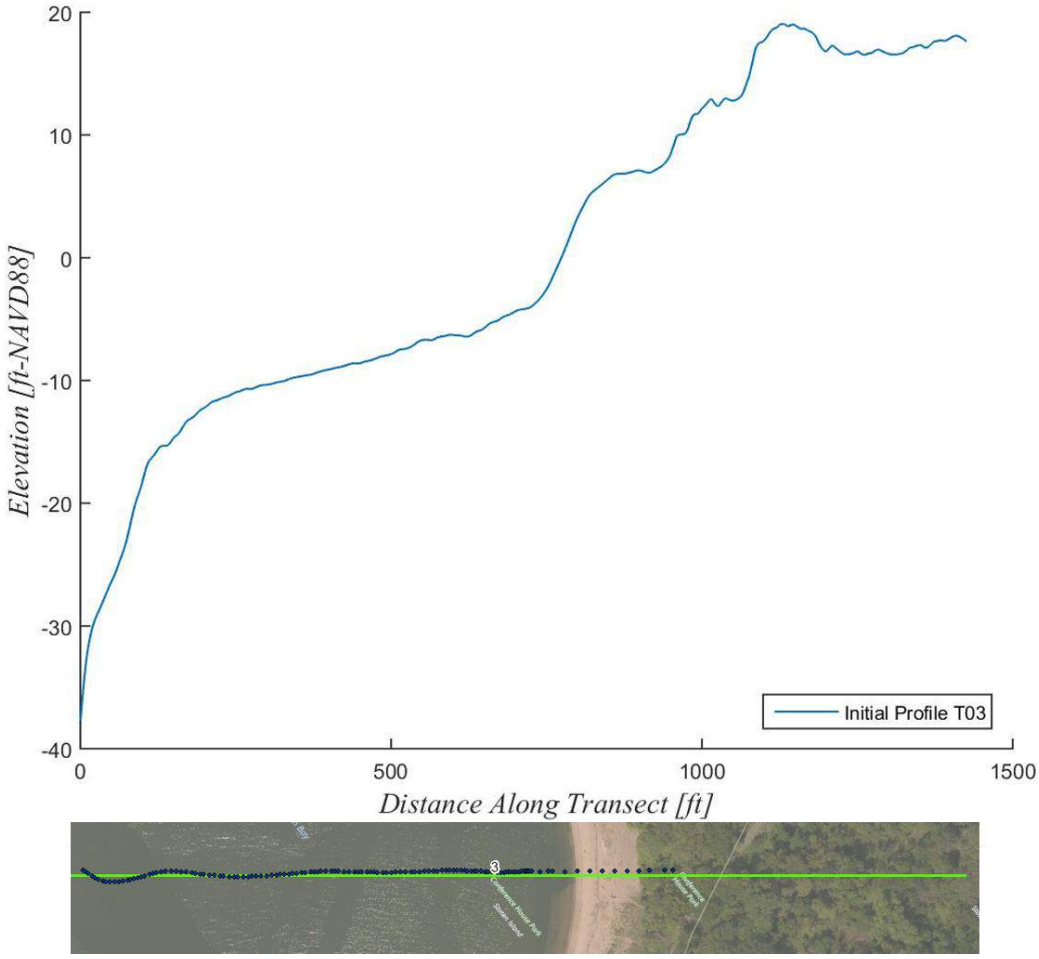


Figure 3. Initial beach profile and recent orthoimagery for transect 3.

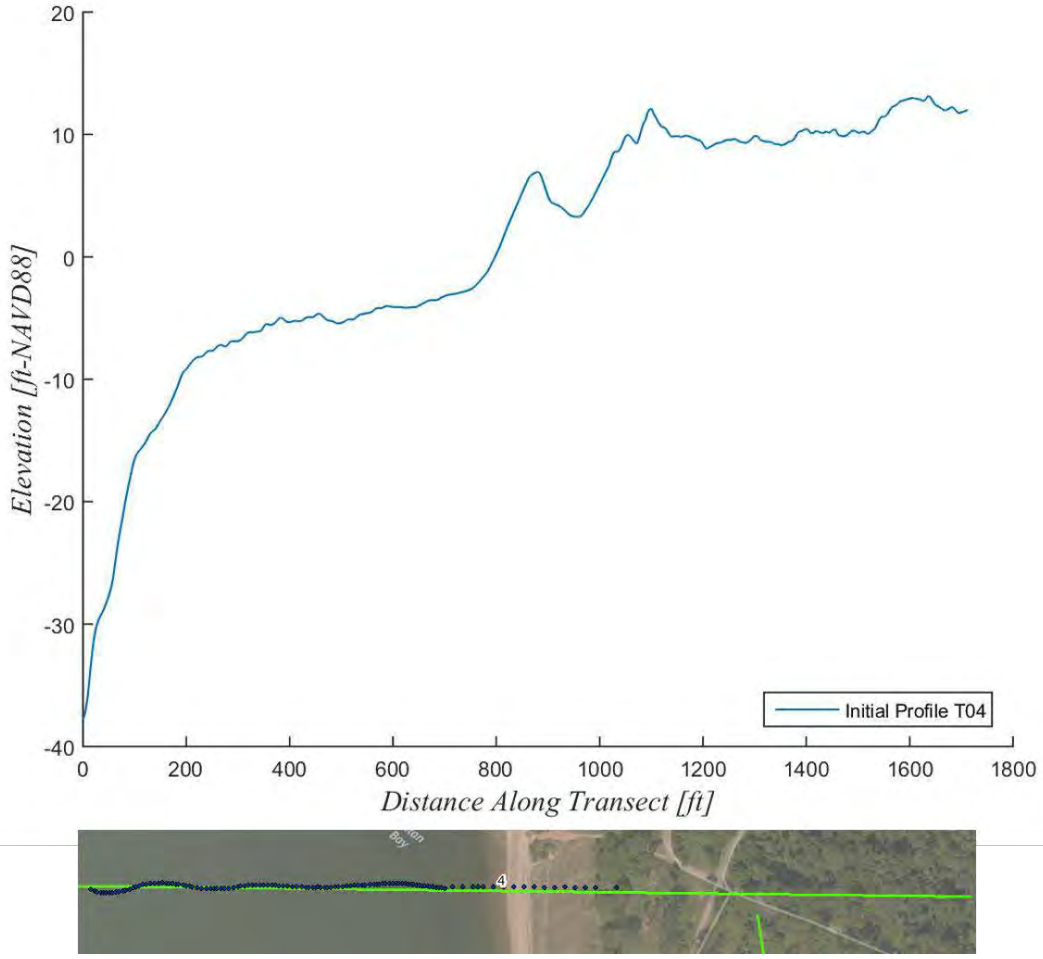


Figure 4. Initial beach profile and recent orthoimagery for transect 4.

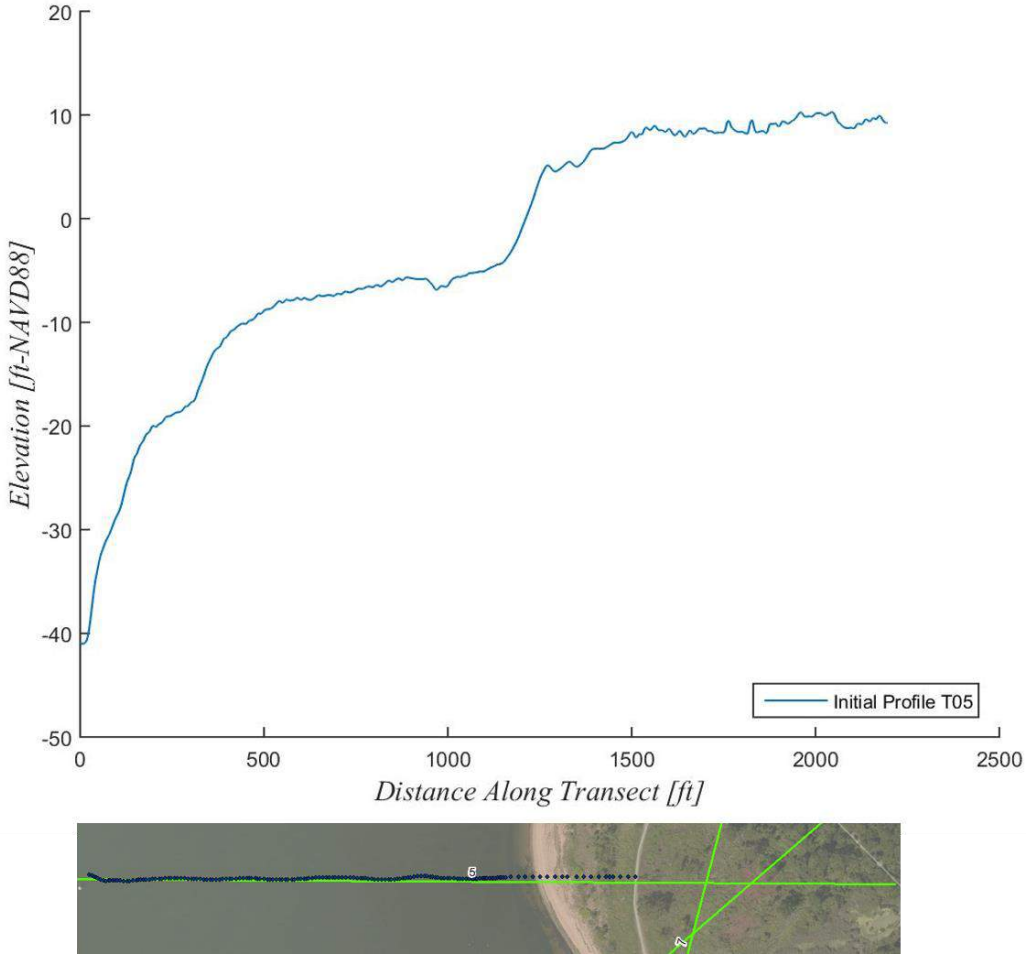


Figure 5. Initial beach profile and recent orthoimagery for transect 5.

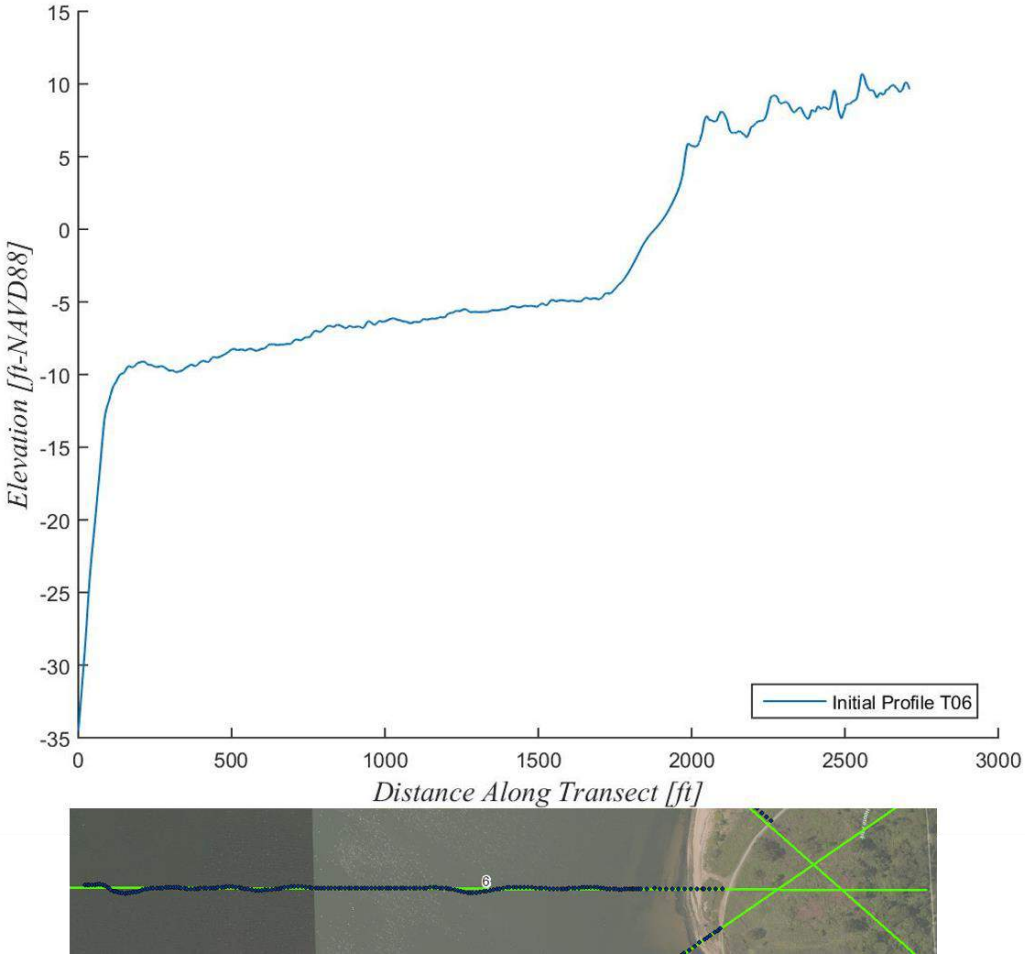


Figure 6. Initial beach profile and recent orthoimagery for transect 6.

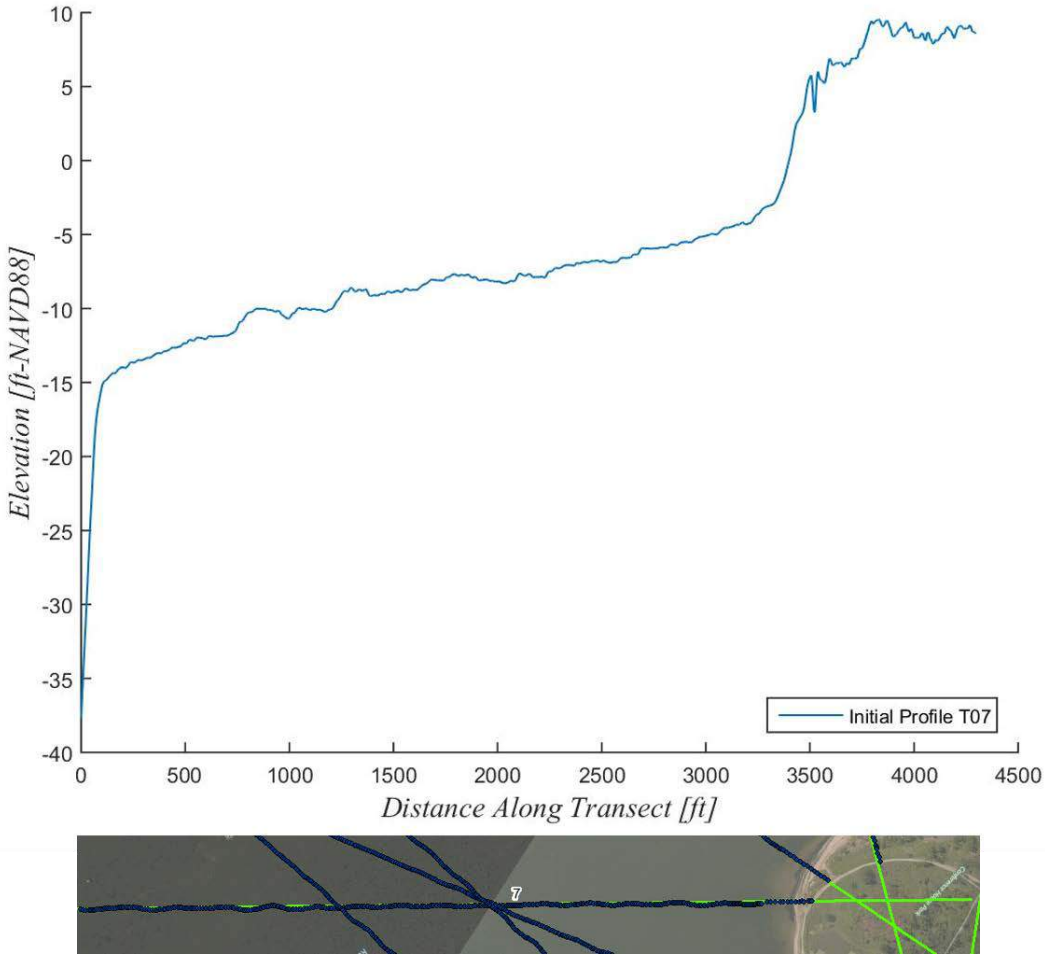


Figure 7. Initial beach profile and recent orthoimagery for transect 7.

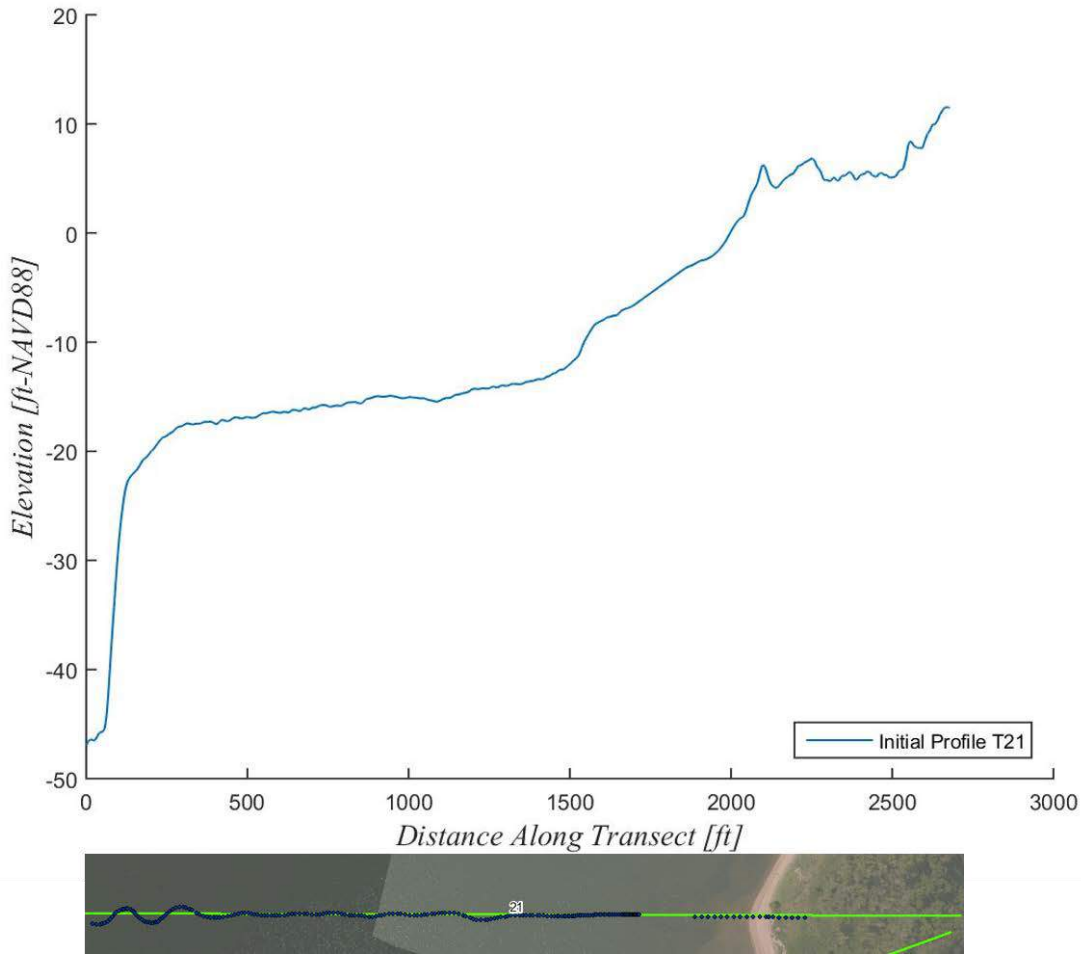


Figure 8. Initial beach profile and recent orthoimagery for transect 21.

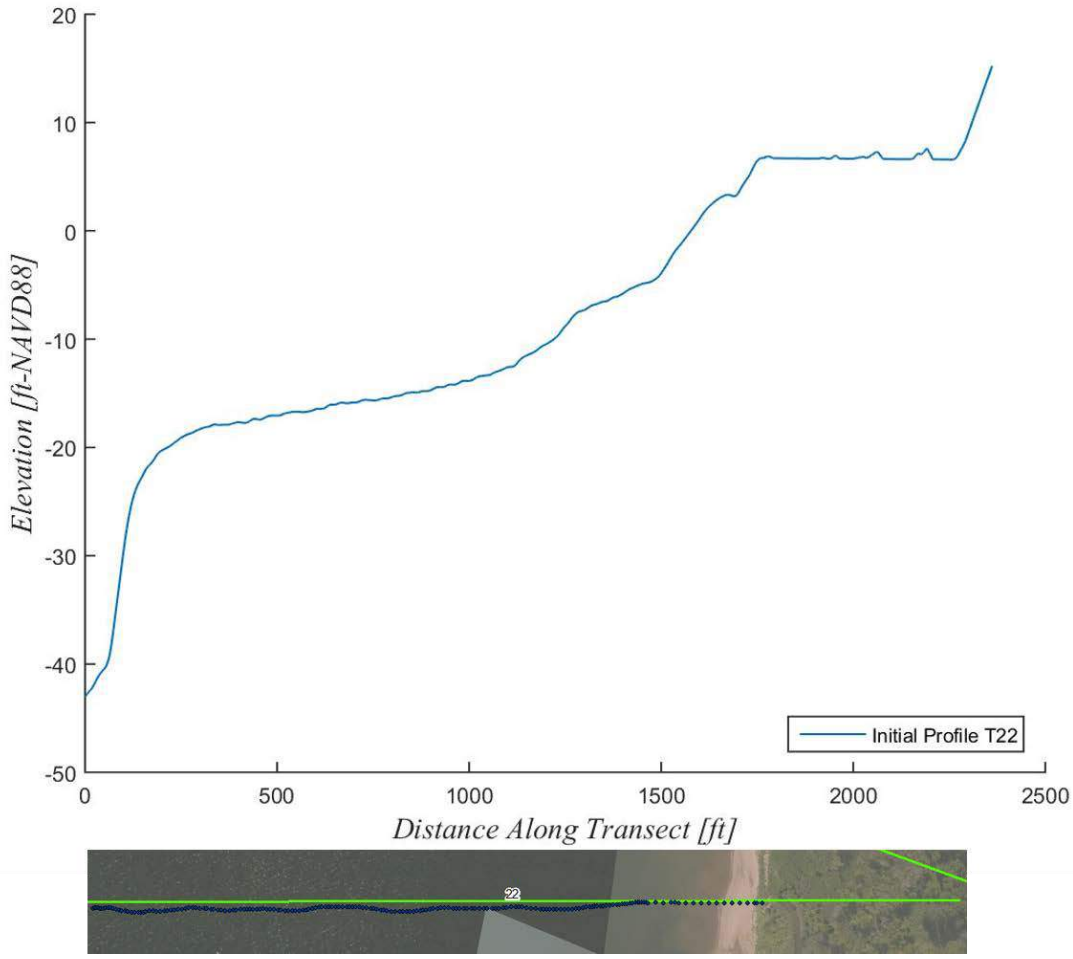


Figure 9. Initial beach profile and recent orthoimagery for transect 22.

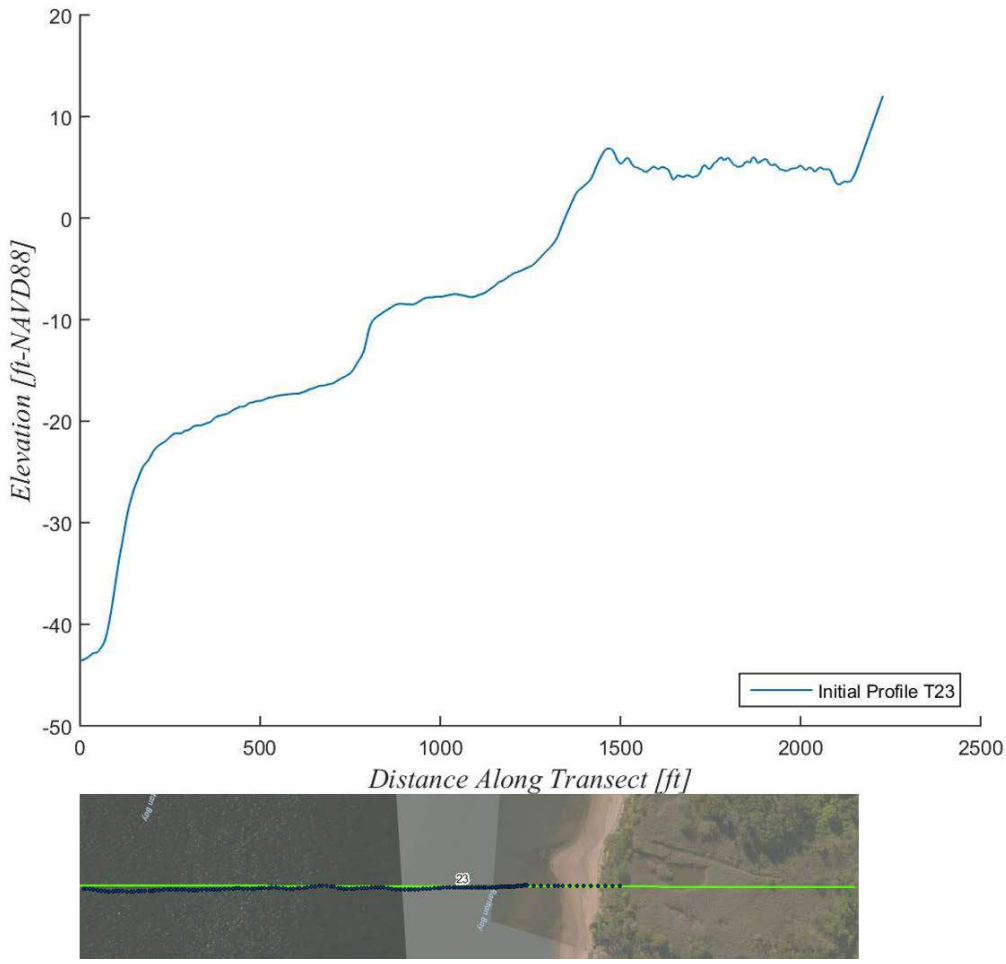


Figure 10. Initial beach profile and recent orthoimagery for transect 23.

SBEACH AND CSHORE SIMULATIONS WITH HURRICANE SANDY

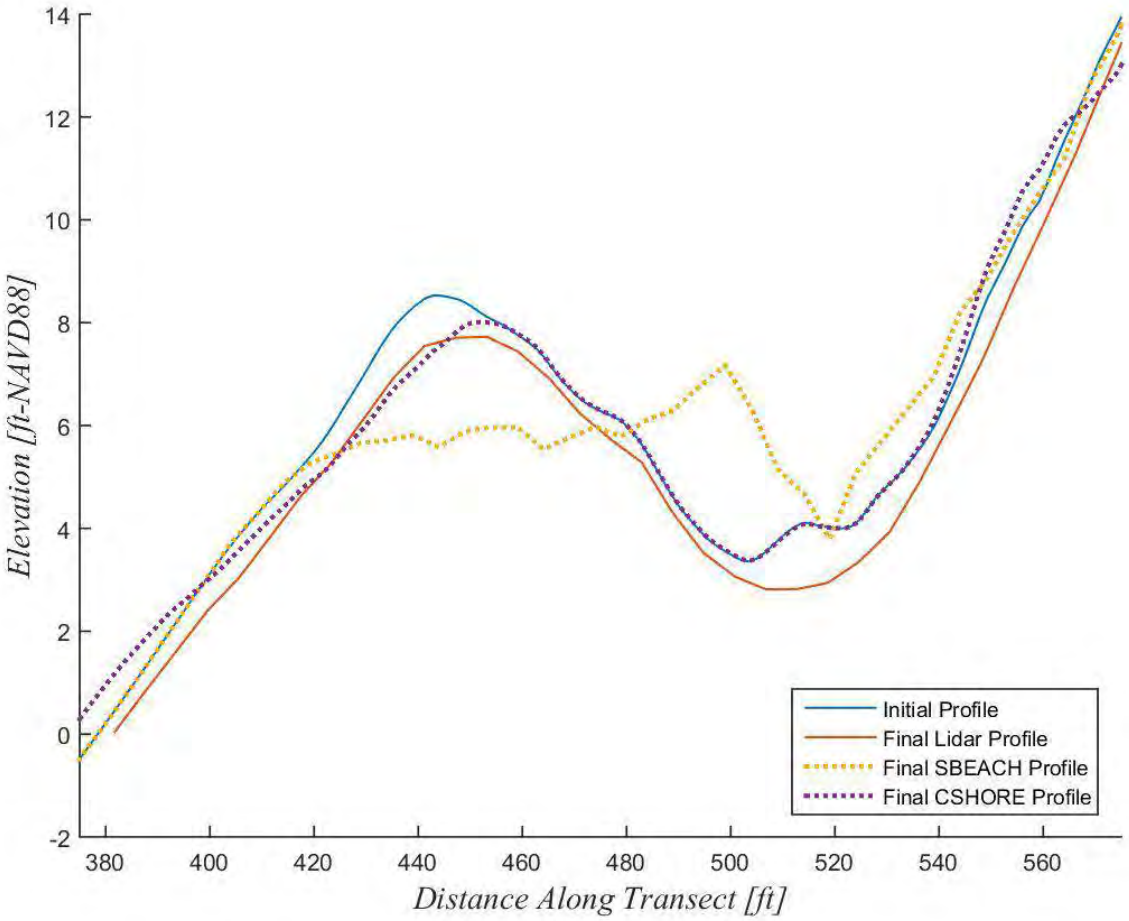


Figure 11. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 1.

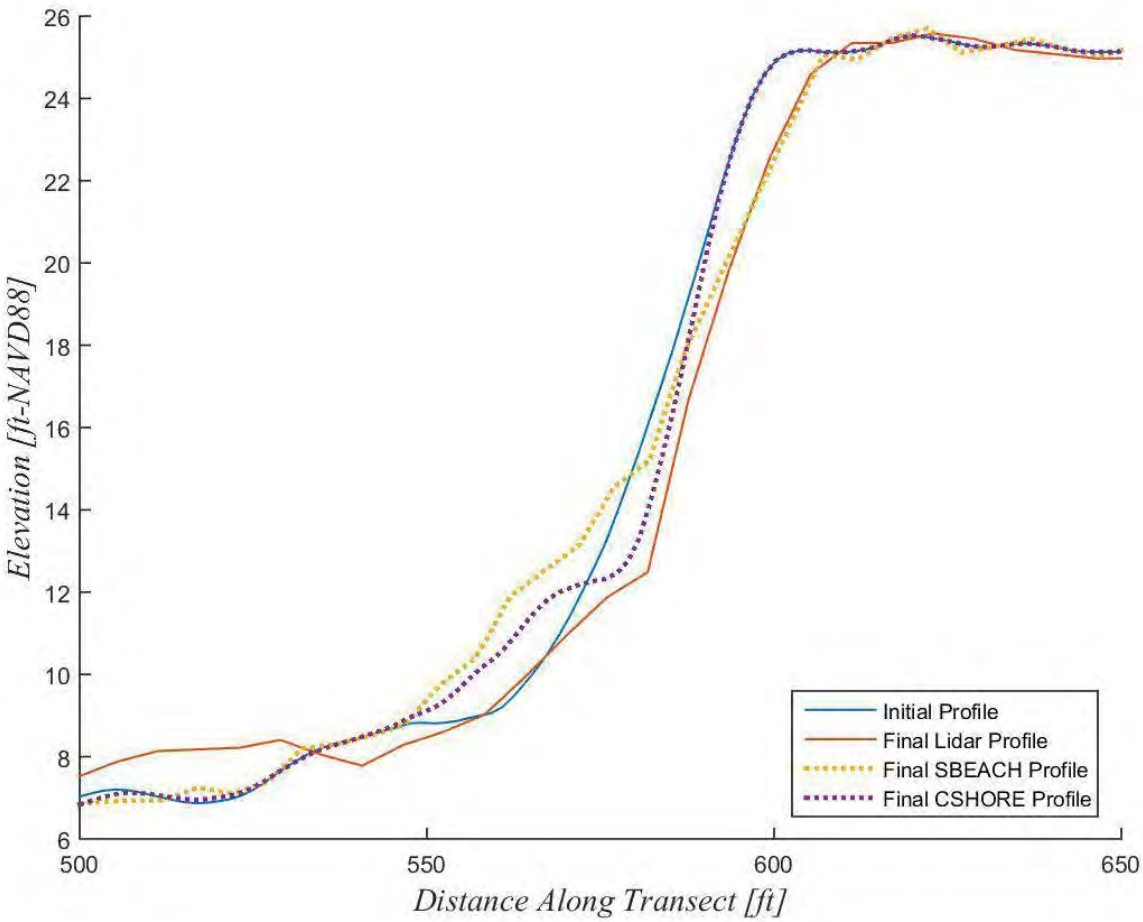


Figure 12. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 2.

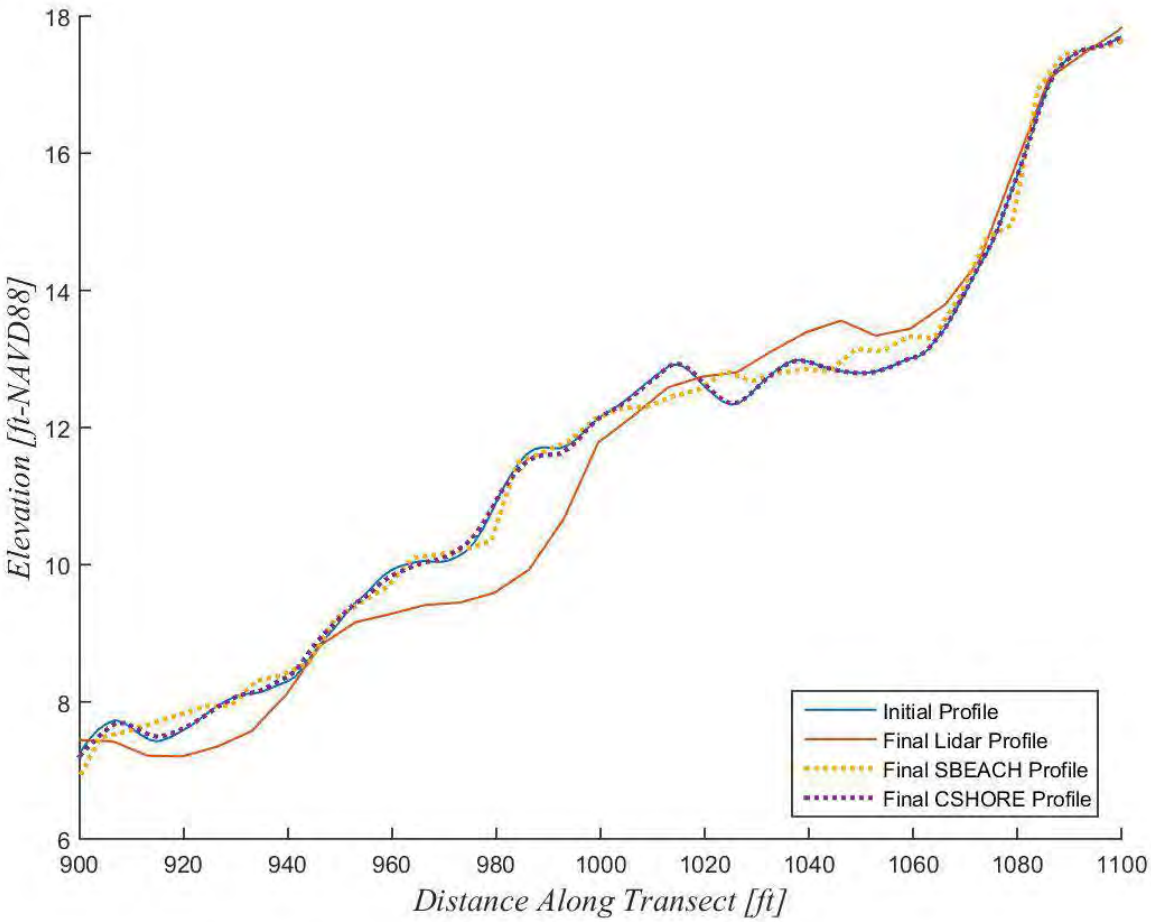


Figure 13. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 3.

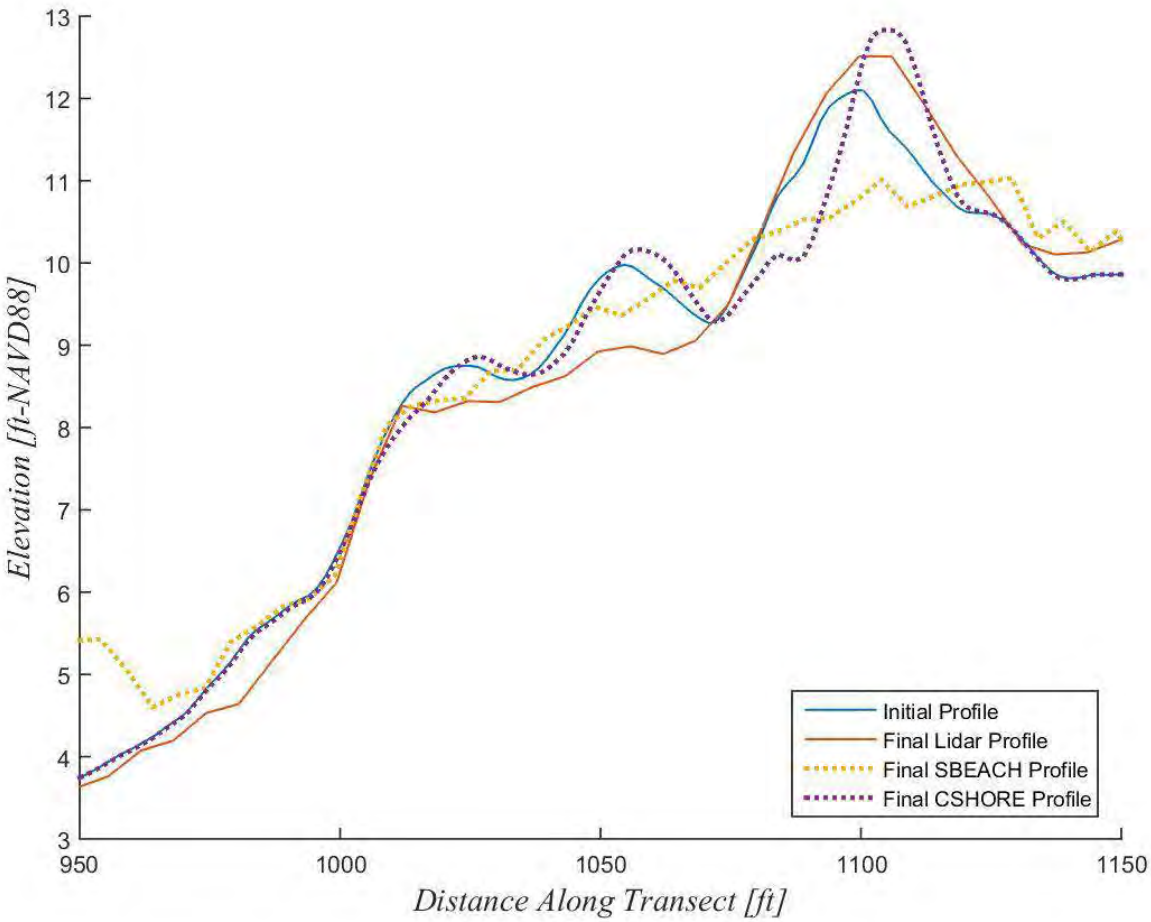


Figure 14. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 4.

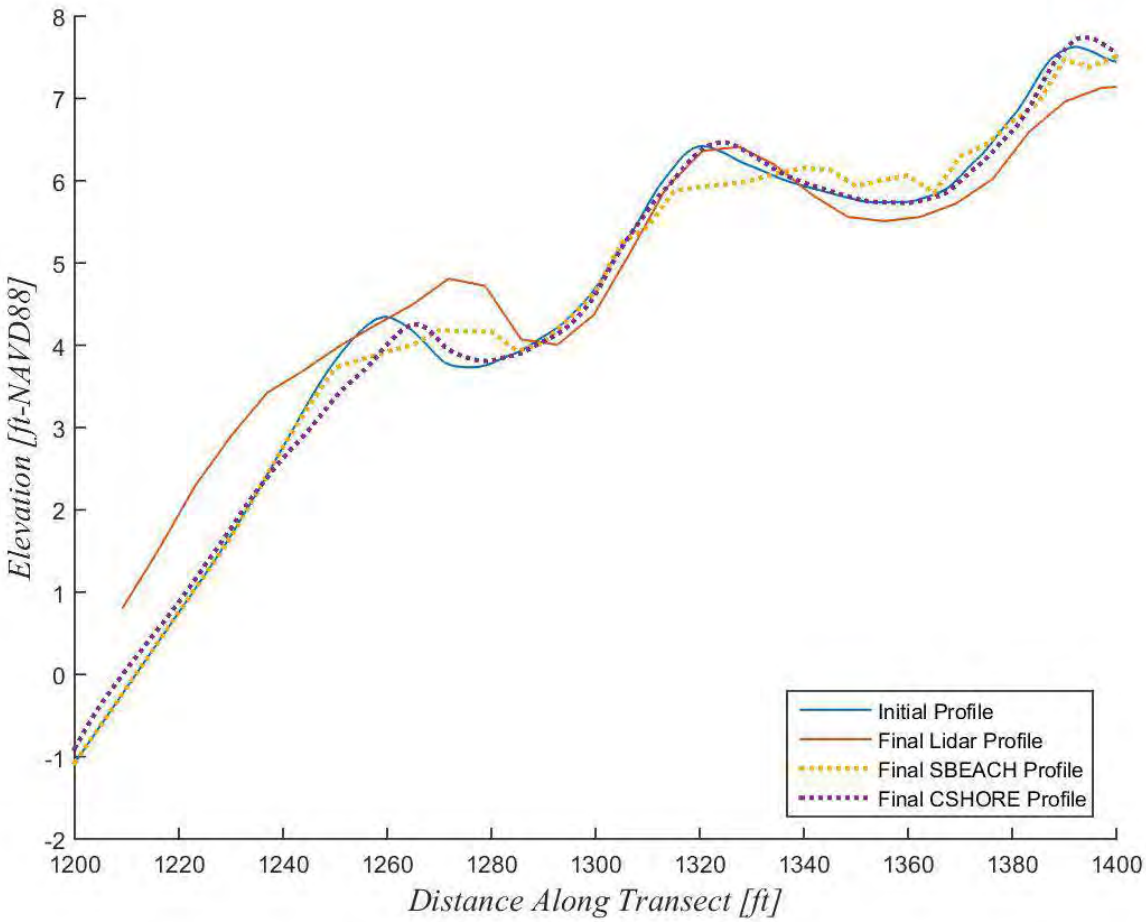


Figure 15. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 5.

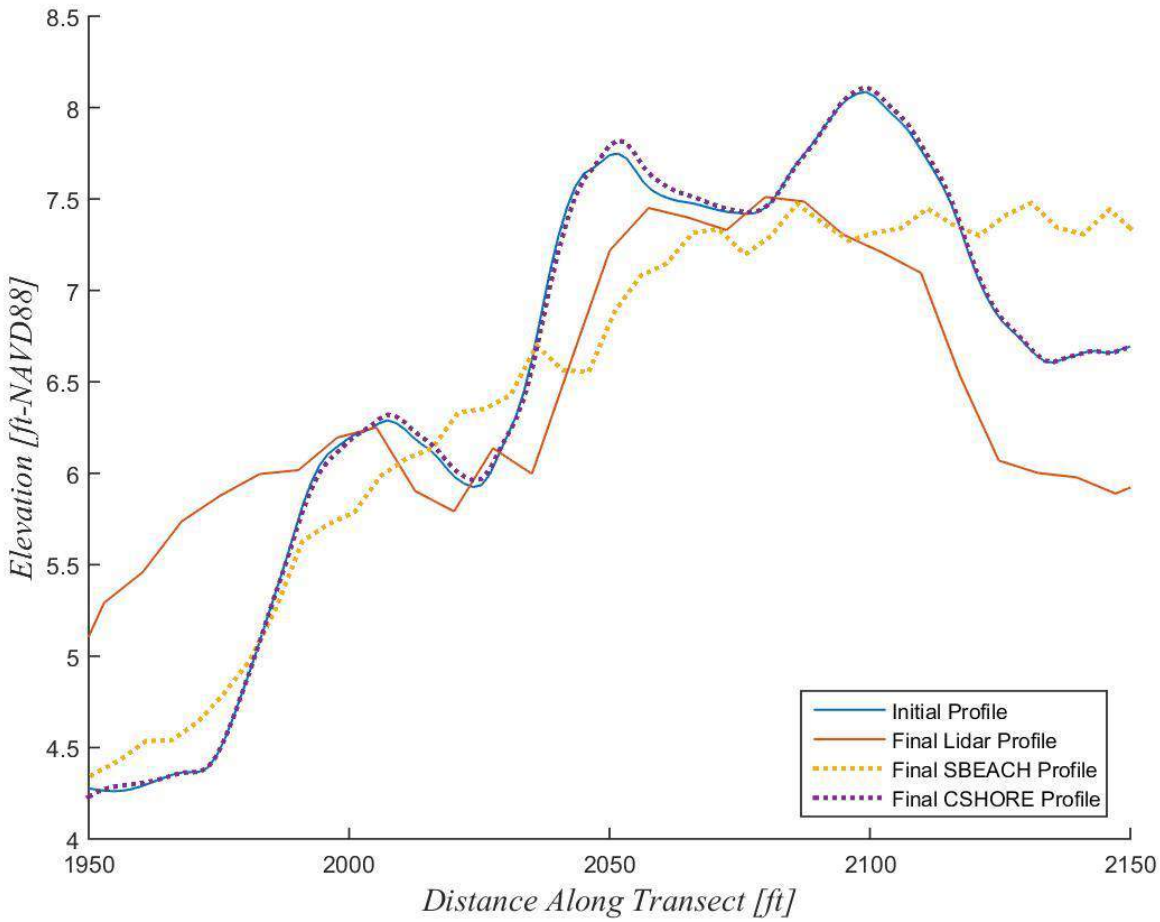


Figure 16. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 6.

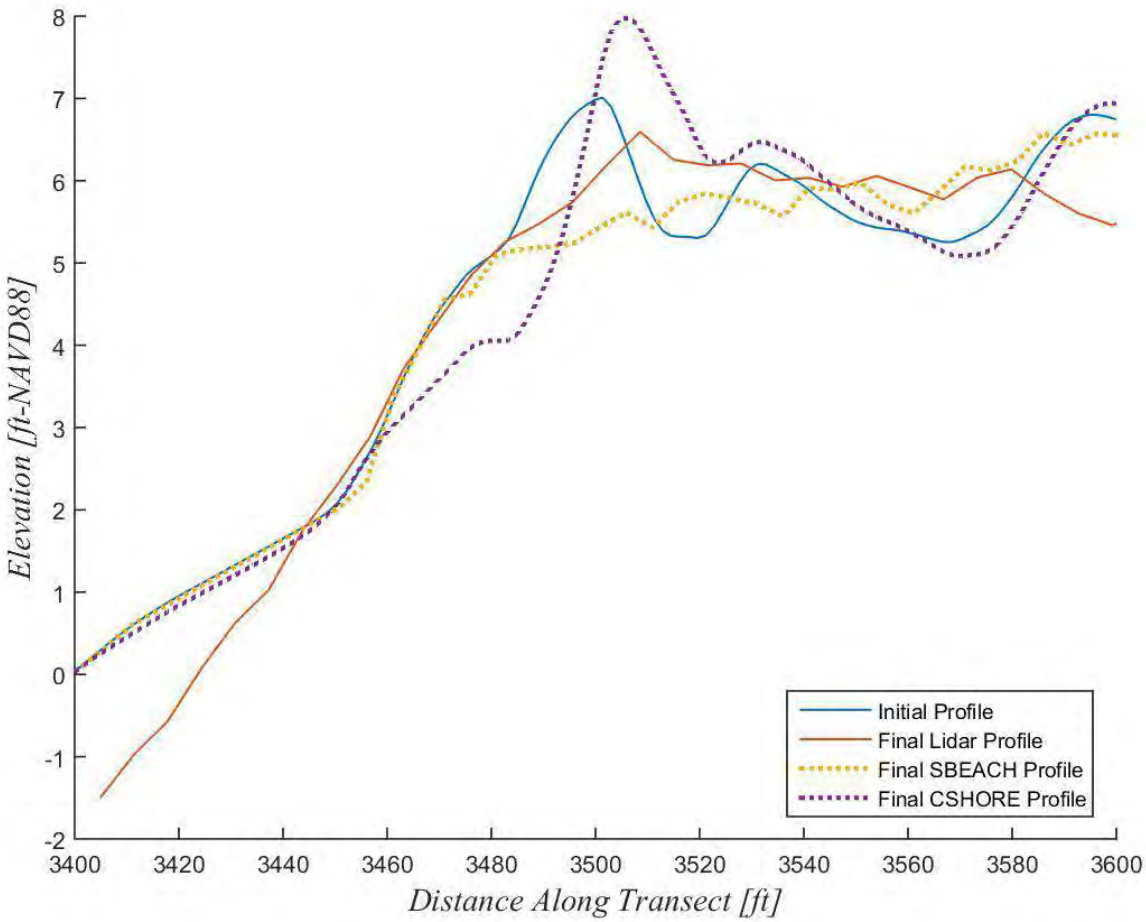


Figure 17. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 7.

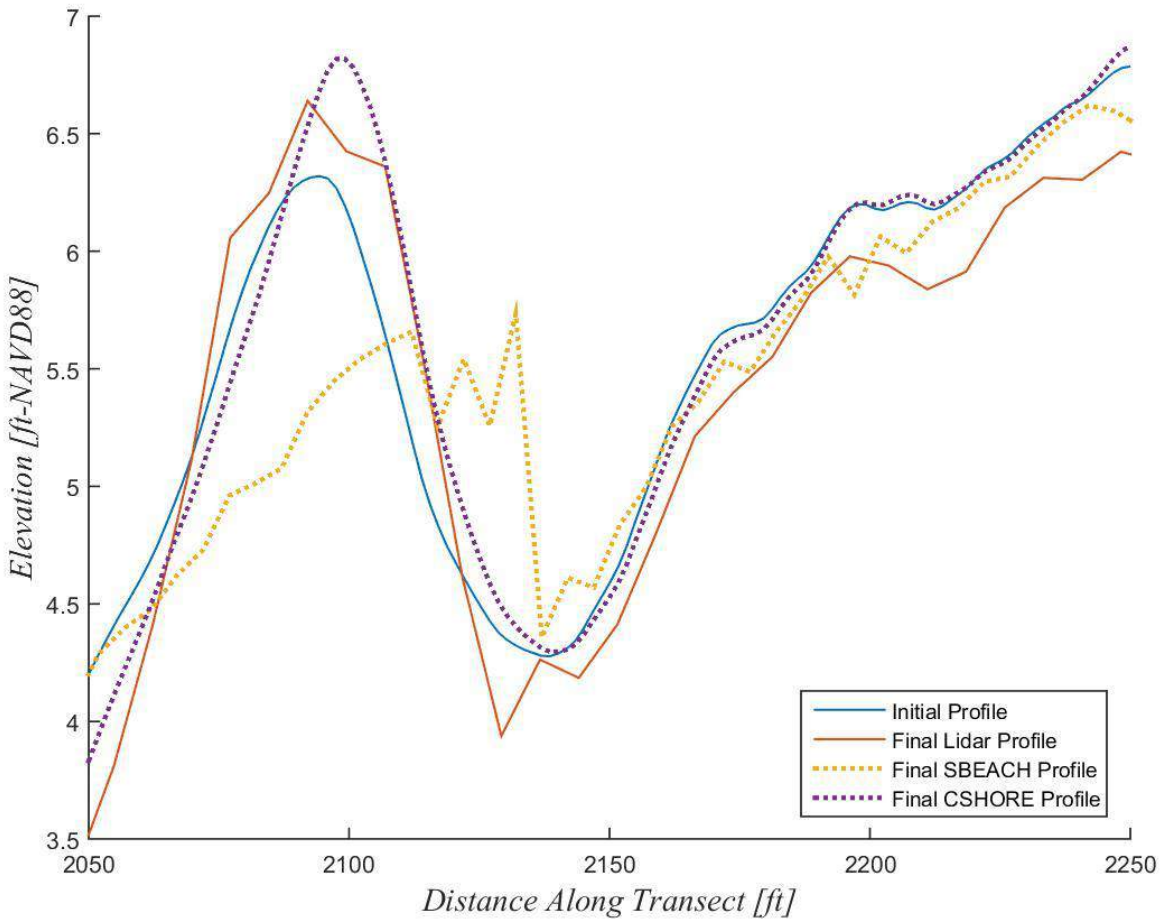


Figure 18. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 21.

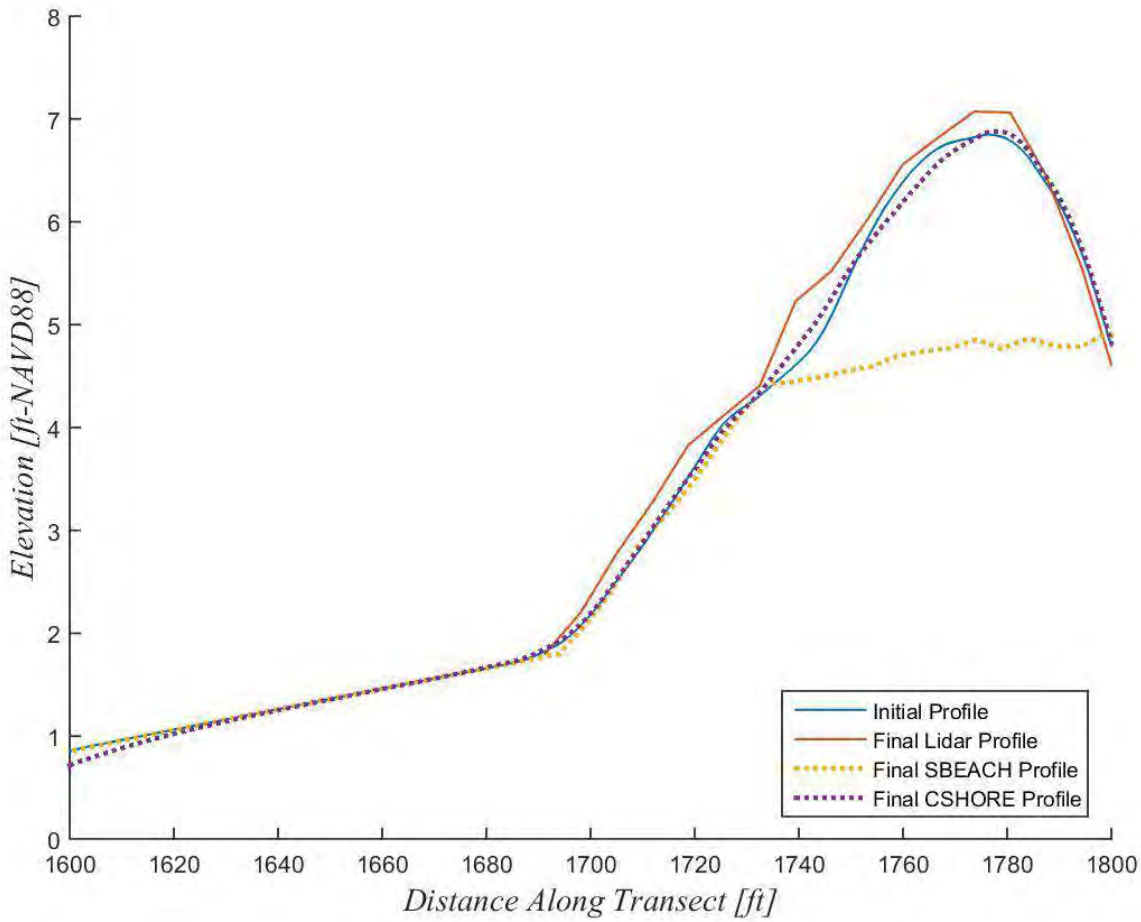


Figure 19. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 22.

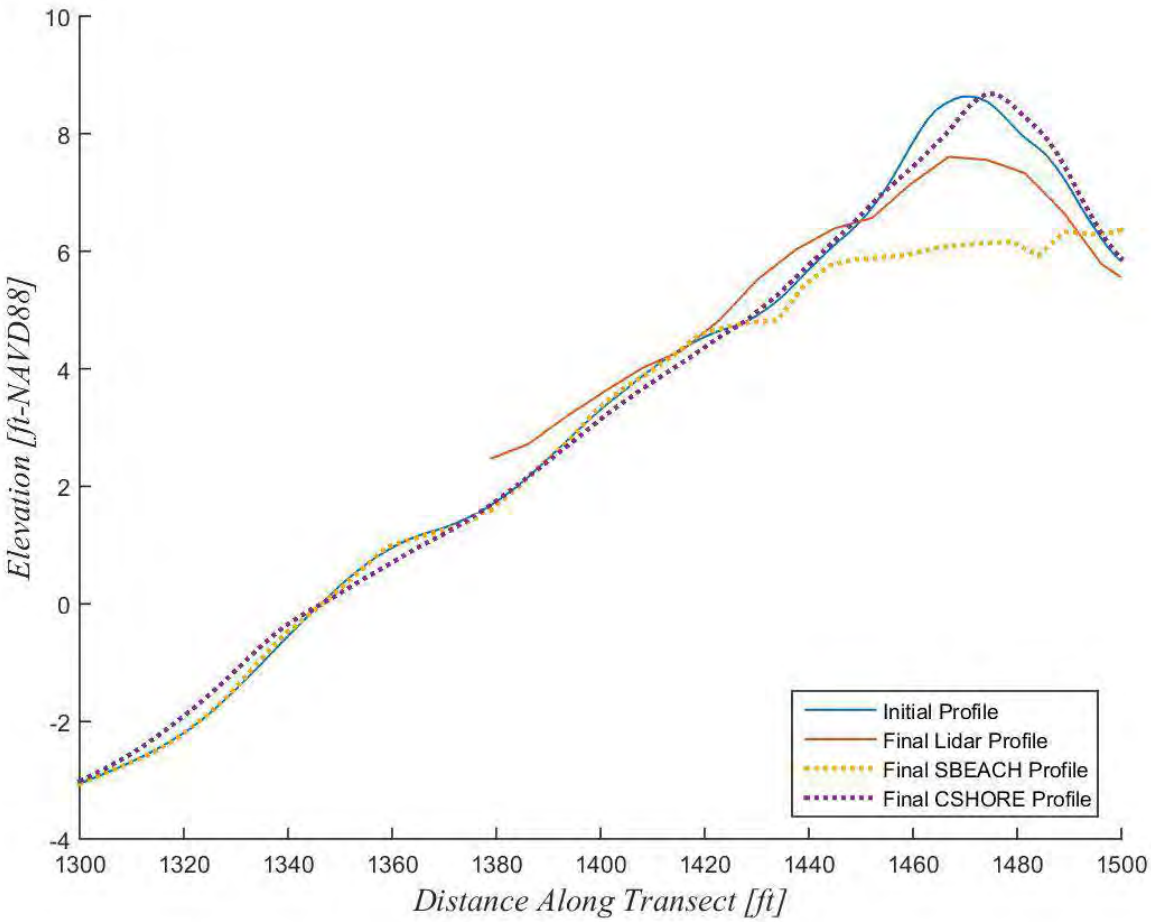


Figure 20. Comparison of CSHORE and SBEACH model results for Hurricane Sandy at transect 23.

CSHORE SIMULATIONS WITH FEMA PFIRM STORMS

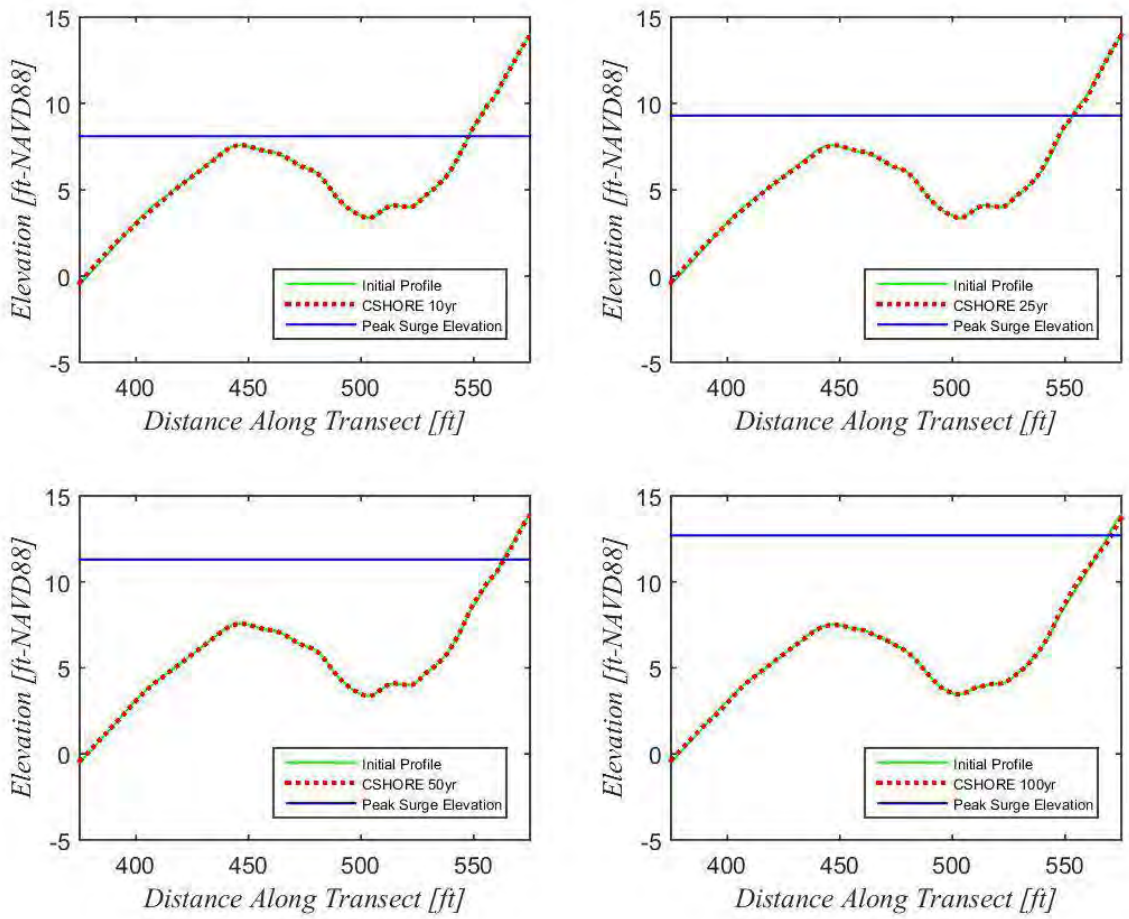


Figure 21. CSHORE results for 10-, 25-, 50-, and 100-year storm events at transect 1.

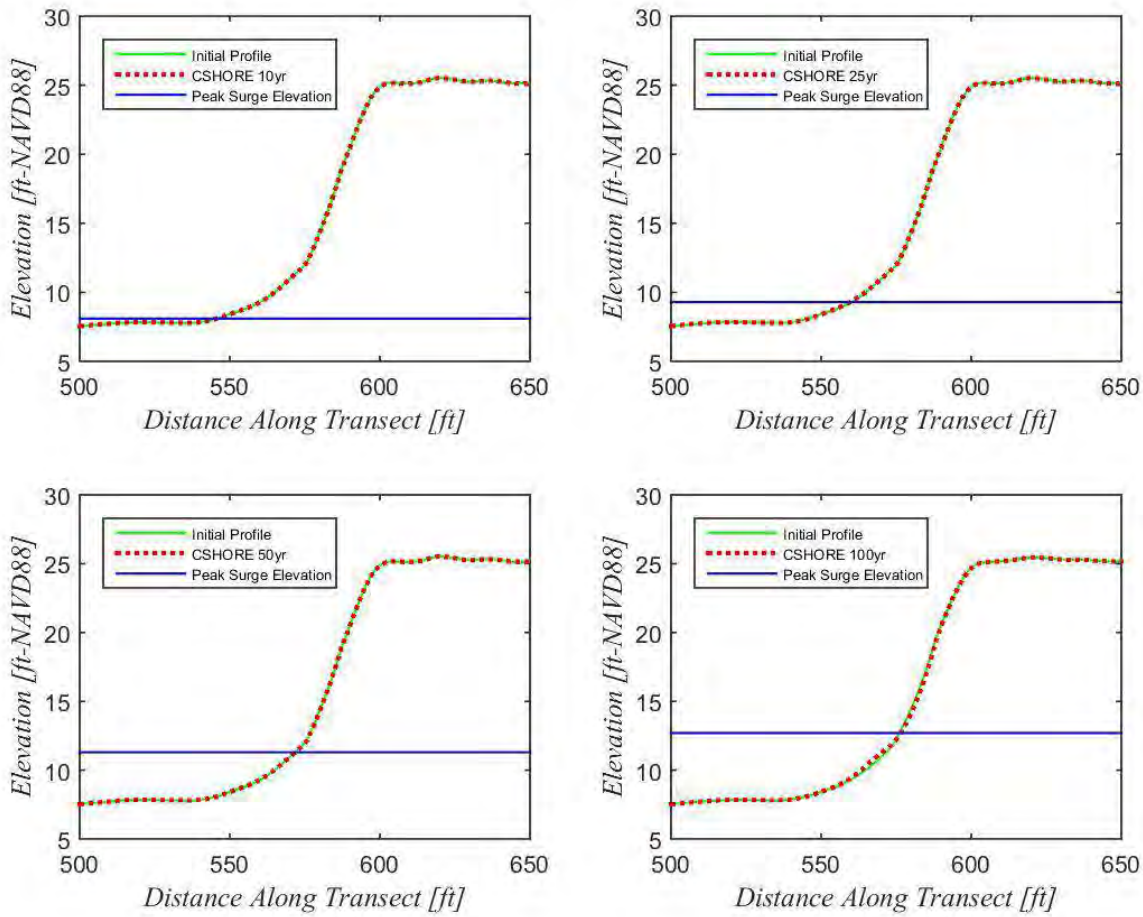


Figure 22. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 2.

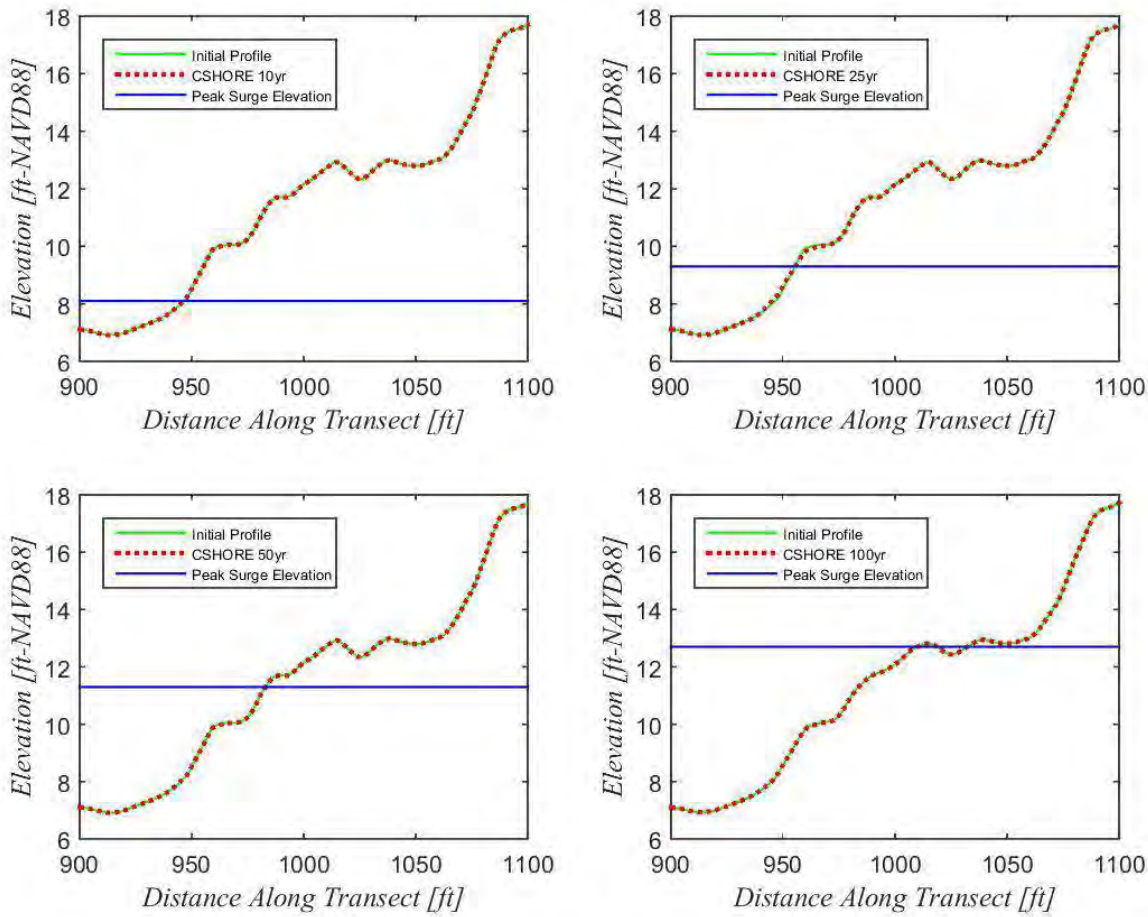


Figure 23. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 3.

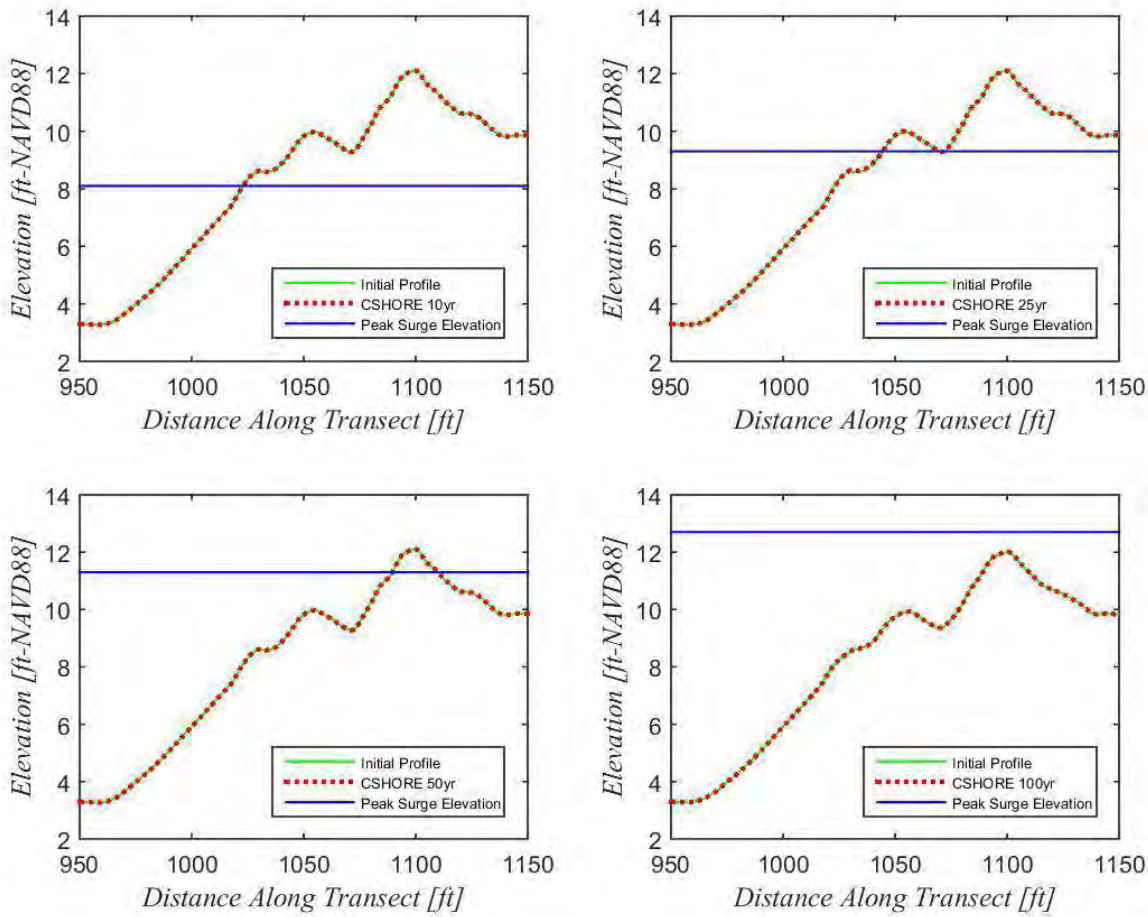


Figure 24. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 4.

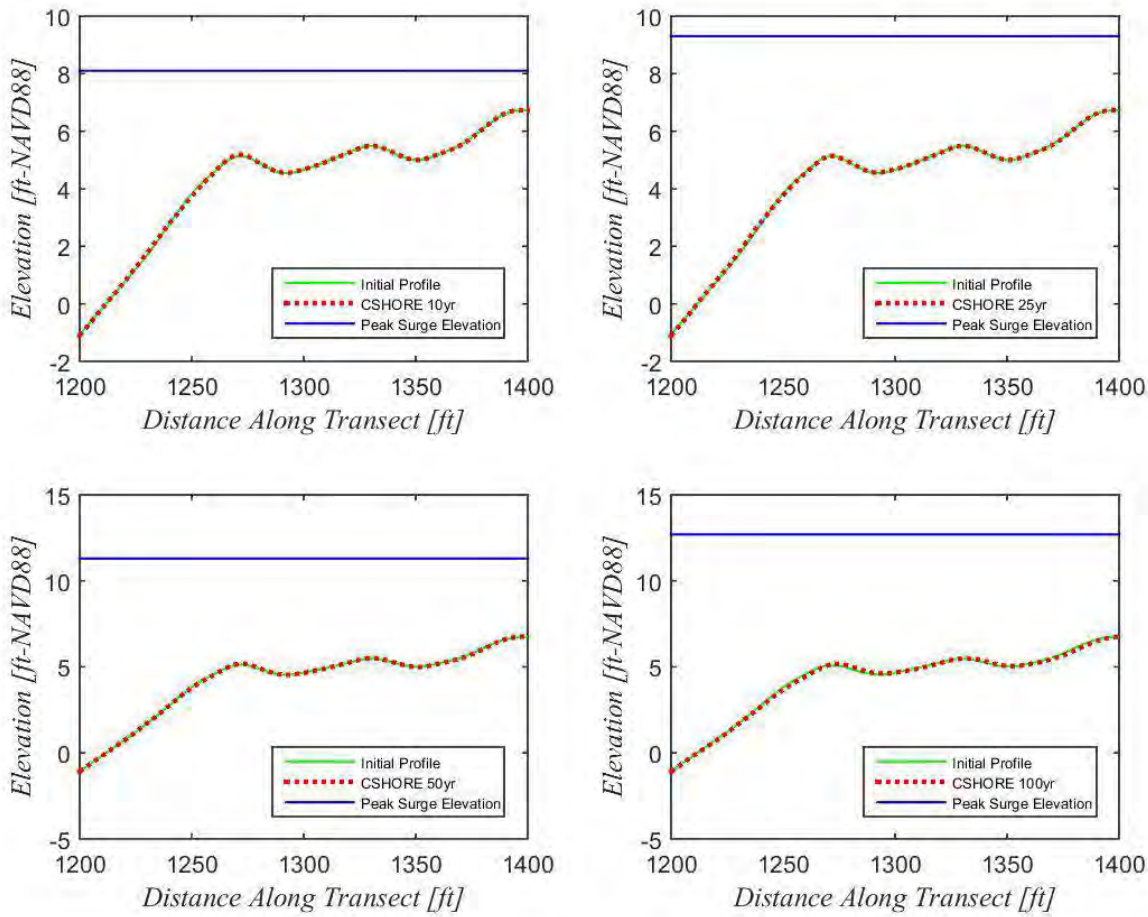


Figure 25. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 5.

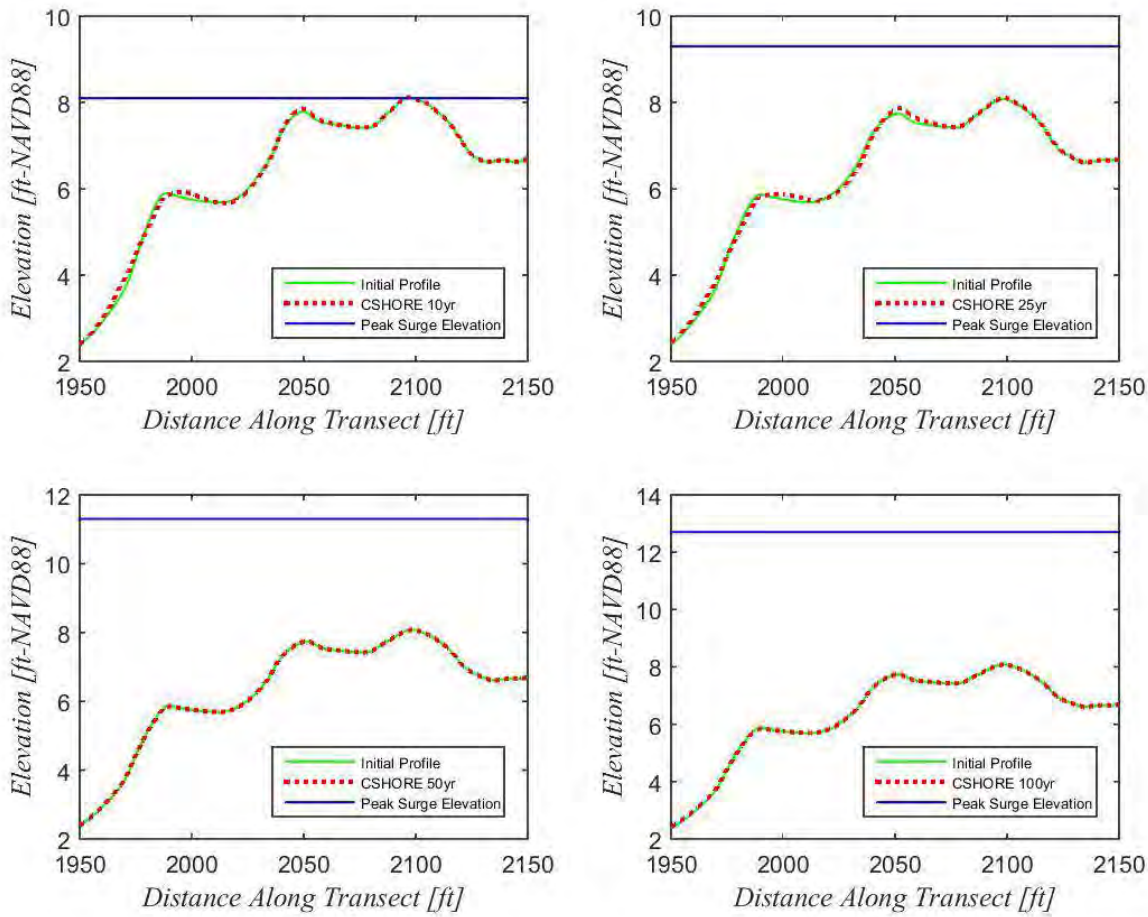


Figure 26. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 6.

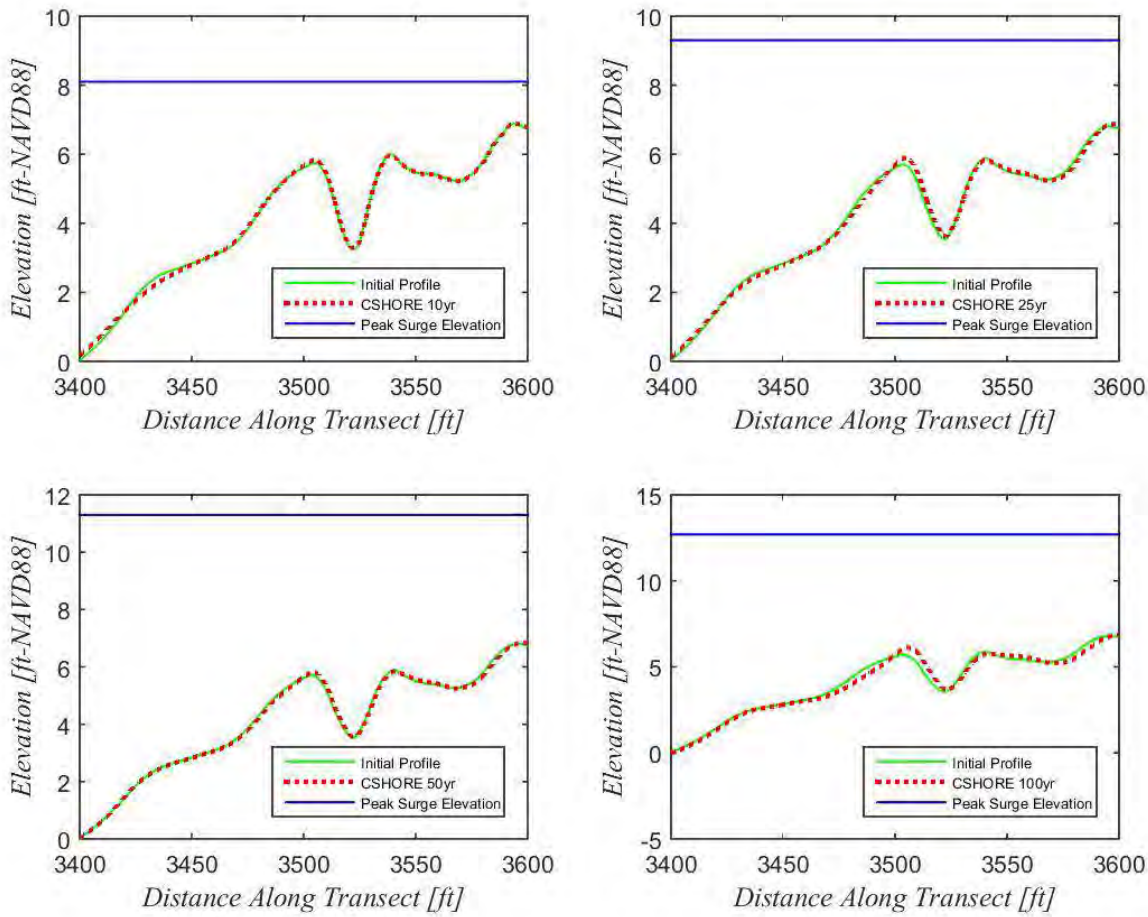


Figure 27. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 7.

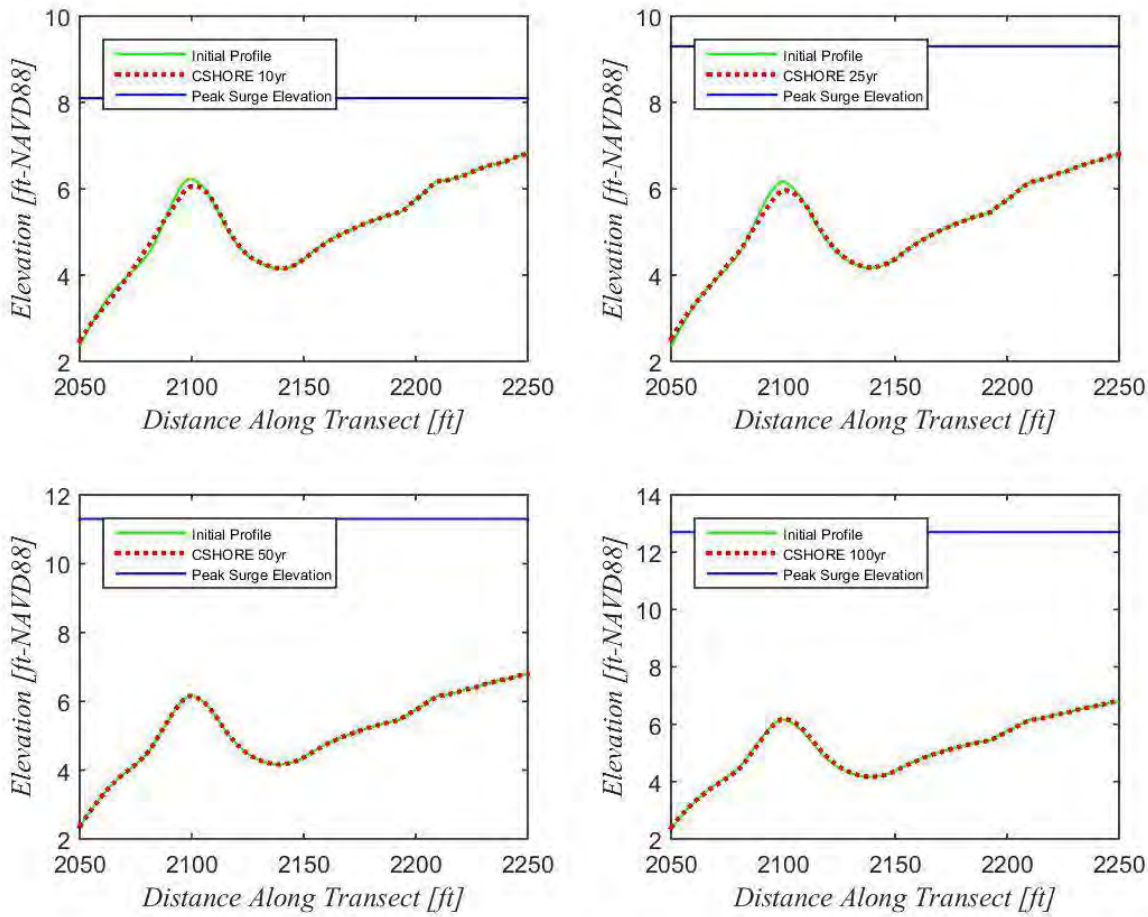


Figure 28. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 21.

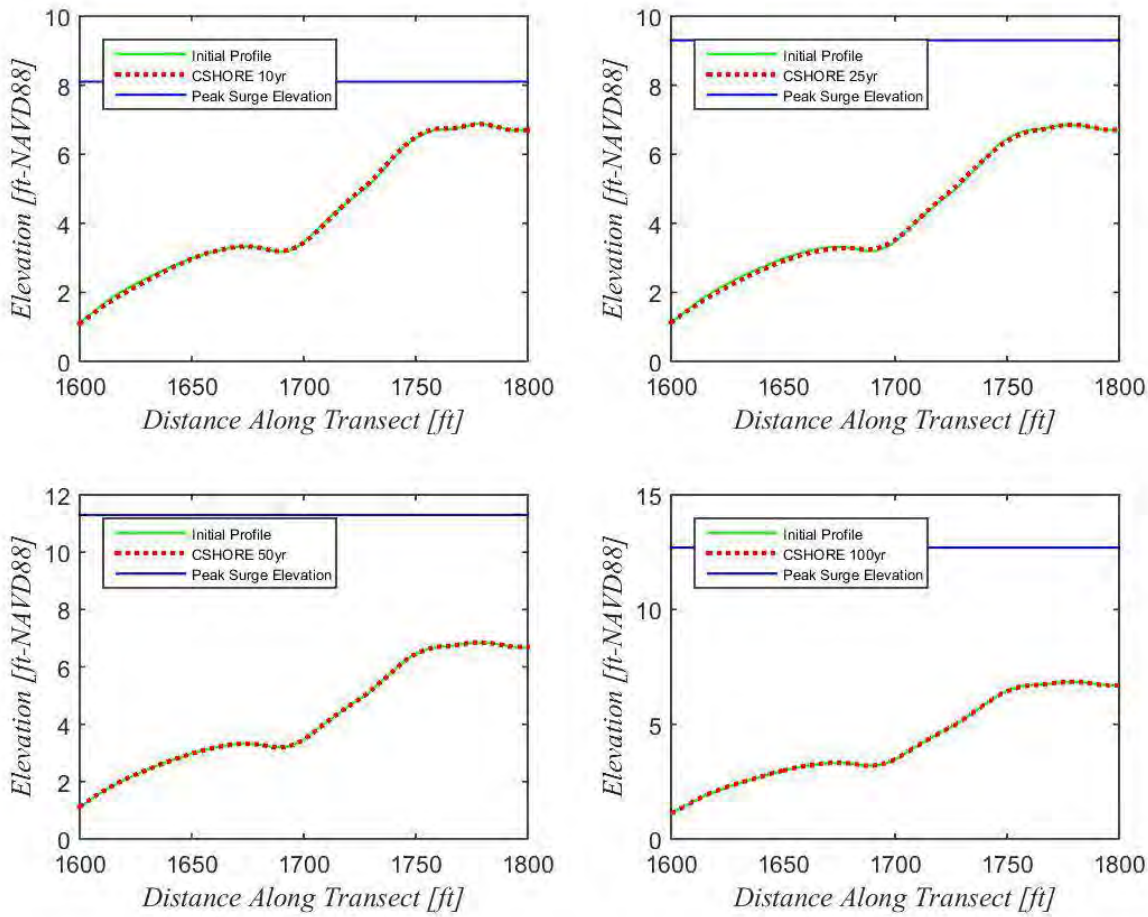


Figure 29. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 22.

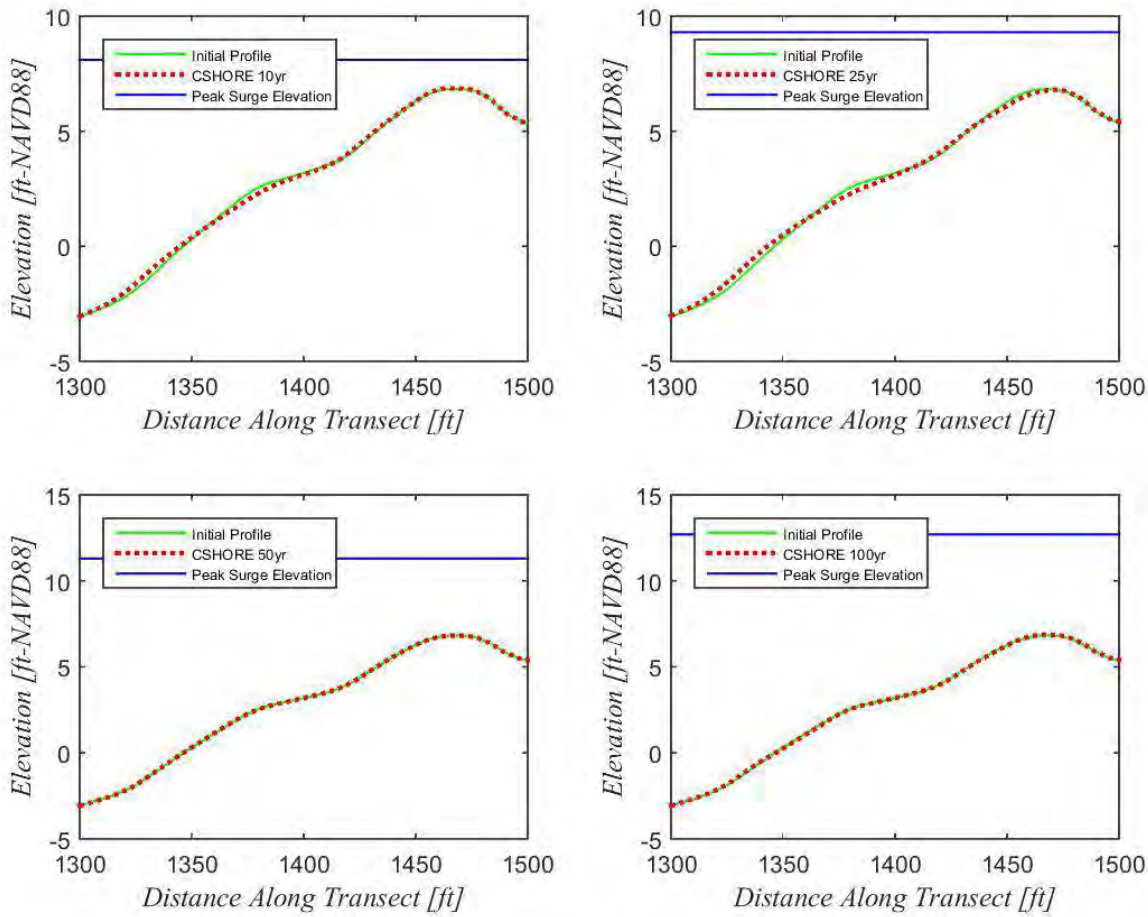


Figure 30. CSHORE results for 10-, 25-, 50-, and 100-year storm events at Transect 23.

LIVING BREAKWATERS

30% DESIGN MODELING RESULTS REPORT

Modeled Scenarios & Results (GENESIS, REFDIF, DELFT3D)

Date: 02/10/2017
Prepared by: ARCADIS
Reviewed by: **SCAPE**

VERSION	DATE	NOTES
1.0	08.01.2016	FIRST VERSION SUBMITTED FOR CLIENT REVIEW. THIS DRAFT ONLY INCLUDES RESULTS COMPLETED THROUGH 07.30.2016
2.0	10.12.2016	VERSION SUBMITTED AS APPENDIX TO 30% DESIGN MODELING REPORT
3.0	02.10.2017	UPDATED VERSION FOR REVISED 30% DESIGN MODELING REPORT

NAME	ORGANIZATION	DATE	COMMENTS PROVIDED?	COMMENTS INCORPORATED?

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

CONTENTS

INTRODUCTION 3

Overview

HISTORIC ANALYSIS AND EXISTING INFORMATION 6

Historic shoreline change and FEMA pFIRMs

BASELINE (FUTURE WITHOUT PROJECT) 11

00: Baseline (future without project)

DESIGN SCENARIOS 17

SCENARIO 01: “HOLD THE SHORELINE”

SCENARIO 02: “STORM WAVE ATTENUATION”

SCENARIO 03: “TESTING FOR A TOMBOLO”

SCENARIO 04: “LEARNING FROM ROUND ONE

SCENARIO 05: “MODIFIED SCENARIO 4”

SCENARIO 06: “MINIMALIST APPROACH”

SCENARIO 07: “MINIMALIST APPROACH WITH SHORELINE RESTORATION”

SCENARIO 09

SCENARIO 10

SCENARIO 11

SCENARIO 12

SCENARIO 13

SCENARIO 14

SCENARIO 15

FINAL 30% DESIGN SCENARIO 66

Final 30% Design Scenario

Overall Take-Aways

INTRODUCTION

OVERVIEW

This document summarizes the numerical modeling performed to date on the Living Breakwaters breakwater design scenarios during 30% Design. The current version of this report and provides a summary of scenarios modeled and model results completed through 30% Design.

Numerical modeling performed to date has been for long-term shoreline change (using the GENESIS model),wave refraction and diffraction (using the REFDIF model), storm-induced profile response (using SBEACH and CSHORE models), and water circulation (using Delft3D model).

SUMMARY OF MODEL RESULTS (AS OF 10.06.2016)

- Modeling efforts have focused on advancing the breakwater layout for the selection of a 30% design preferred scenario. Initial efforts examined scenarios designed to evaluate the impact of breakwater length, spacing, and distance from shore on long-term shore change (erosion and accretion) and the wave climate in the lee of the breakwaters.
- Additional modeling simulations were performed on potential breakwater system configurations to determine system performance and evaluate various layout options at achieving project goals.
- The without project (baseline) and project (30% design) have been simulated with all models. For some models (GENESIS and REFDIF) multiple scenarios were simulated in the screening and development of the preferred scenario.
- The preferred layout is shown to advance and refine beyond 30% design.

MODEL ASSUMPTIONS AND STANDARDS

- Modeling Assumptions and Standards are outlined in the Project Assumptions and Standards Memo (currently being updated in collaboration with Stantec / RACE) and the 30% Design Modeling Report.
- Shoreline change modeling was performed using the GENESIS model and the wave climate assessed in the lee of the breakwaters using the REFDIF model. Storm induced beach profile change for the shoreline areas outside of the Tottenville Shoreline Protection Project area were assessed using the SBEACH and CSHORE models and water circulation/preliminary water quality were evaluated using the Delft3D model.

Living Breakwaters 30% Design
Summary scenarios modeled

Scenrio

Sc. #	Scenario name (if provided)	GENESIS	REFDIF MHW	REFDIF MHW +30" SLR	REFDIF 100yr	REFDIF 100yr + 30" SLR	Delft 3D	SBEACH	CSHORE
00	No Action	X	X		X		1	1	1
01	Hold the Shoreline	X	X		X				
02	Storm Wave Reduction	X	X		X				
03	Test for Tombolo	X	X		X				
04	"Dream Scenario"	X	X		X				
05	sc05	X							
06	sc06	X							
07	sc07	X							
08	"Permitting" Scenario								
09	sc09	X							
10	sc10	X							
11	sc11	X							
12	sc12	X							
13	sc13	X							
14	Preliminary Preferred Scenario	X	X		X				
15	Revised 30% Design Scenario	X	X		X				
-	30% Design Scenario (including shoreline restoration)	X	X	X	X	X	1		1

Notes & assumptions

water level used for all GENESIS Runs @ MHW was	2.08
water level used for all GENESIS Runs w/ SLRwas	4.58
MHW used for typical tides RefDif runs	2.10
Incident wave height for typical tides RefDif runs	3.00
Stillwater elevation for 100yr storm RefDif runs	12.90
Incident wave height for 100yr storm RefDif runs	5.30

RefDIF runs model only single wave directions at a time, the following wave directions (degrees from N) were modeled: E (90); Perpendicular to Shore (150); SW (225)
SBEACH / CSHORE were performed for 5 storm series (10, 25, 50, 100, Sandy); hydrographs were selected by ARCADIS based on FEMA storms and share with TSPP team
SBEACH / CSHORE are used to model event-based change at the shoreline and so only locations outside the TSPP project area were modeled; 7 transects:

HISTORIC ANALYSIS AND EXISTING INFORMATION

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW SPRING 2012

MHW 1978

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

OBSERVED HISTORIC SHORELINE CHANGE

1978 - SPRING 2012 (PRE-SANDY)

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SPRING 2012 MHW (PRE-SANDY)

FALL 2012 MHW (POST-SANDY)

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

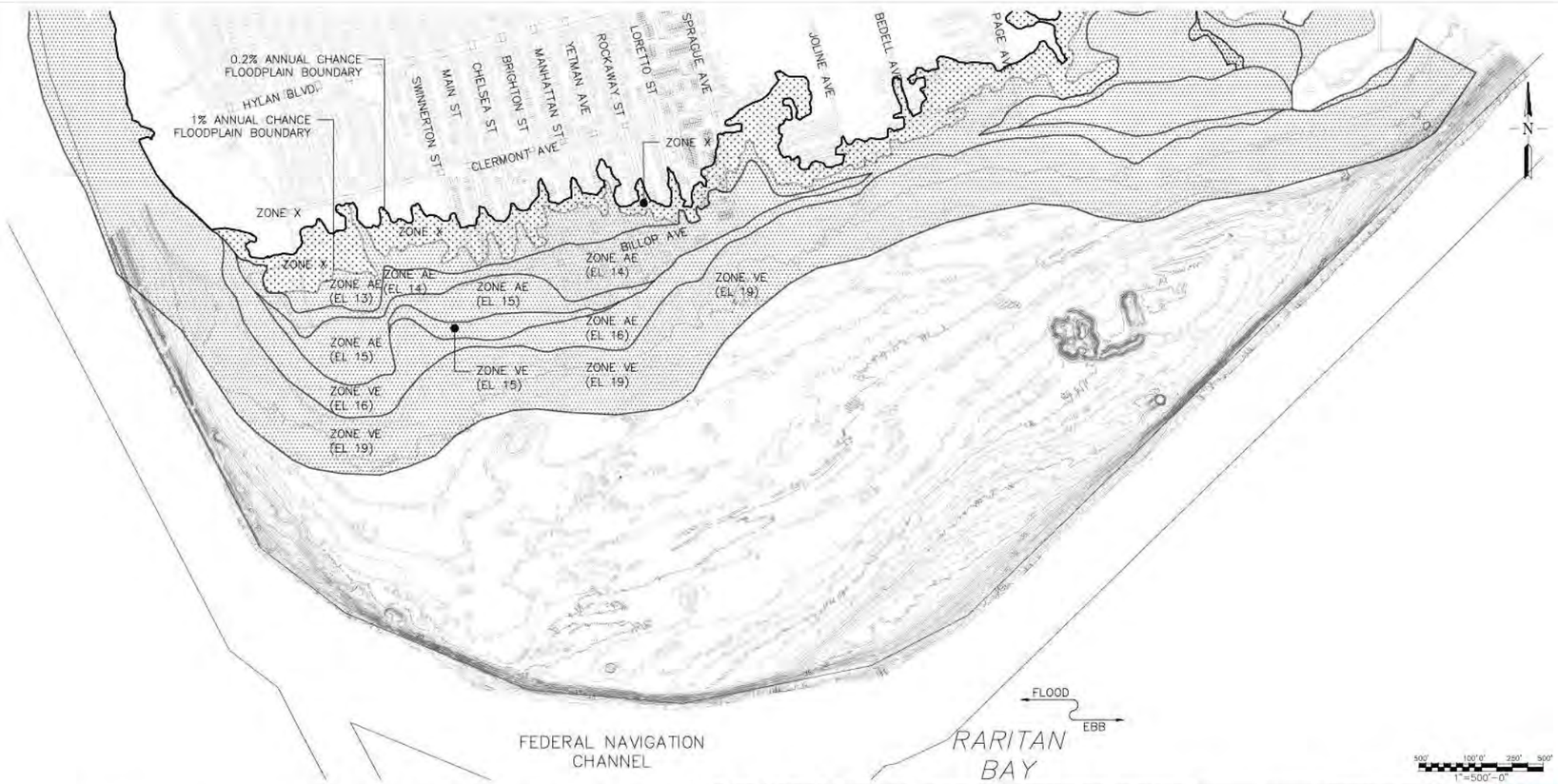
OBSERVED EVENT BASED SHORELINE CHANGE

SPRING 2012 (PRE-SANDY) - FALL 2012 (POST SANDY)

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING



1 G-100 FEMA FLOOD INSURANCE RATE PLAN

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS
OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% annual chance floodplain boundary
0.2% annual chance floodplain boundary
Floodway boundary
Zone D boundary
CBRS and OPA boundary
Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
Limit of Moderate Wave Action
513 — Base Flood Elevation line and value; elevation in feet*
(EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*
* Referenced to the North American Vertical Datum of 1988
15 — 15 Cross section line
23 — 23 Transect line
Culvert, Flume, Penstock or Aqueduct
Road or Railroad Bridge
Footbridge
87°07'45", 32°22'30" Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
4076000 N 1000-meter Universal Transverse Mercator grid values, zone 19
600000 FT 5000-foot grid values: New York State Plane coordinate system, Long Island zone (FIPSZONE 3104), Lambert Conformal Conic projection
DX5510 × Bench mark (see explanation in Notes to Users section of this FIRM panel)
● M1.5 River Mile

2 G-100 FIRM LEGEND N.T.S.

3 G-100 PRELIMINARY FLOOD INSURANCE RATE MAP

30% DESIGN SUBMISSION
NOT FOR CONSTRUCTION

FEMA PFIRM MAP

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

HISTORIC SHORELINE CHANGE AND FEMA PFIRMS

Historic shoreline change analysis was performed based on orthoimagery available between 1978 and 2012, for a period covering the range of the wave hindcast data (1982 to 2012).

The rates of shoreline change exceed 1 foot per year mostly adjacent to Conference House Park west of Brighton Street, with the greatest shoreline erosion rate at 3.5 feet per year (±0.4 feet per year).

Most of the shoreline change rates moving to the northeast from Brighton Street along the shoreline are less than 1 foot per year. An exception is shown between Manhattan and Rockaway Streets where the rate is estimated at 1.7 feet per year (±0.4 feet per year) and between Page Avenue and Richard Avenue where the long-term erosion rate is estimated at 2.4 feet per year (±0.4 feet per year). This area is downdrift of an L-shaped timber pile groin structure, which may have been a historic pier.

Areas of the most pronounced localized shoreline change are downdrift of existing groin structures.

BASELINE (FUTURE WITHOUT PROJECT)

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

BASELINE, FUTURE WITHOUT PROJECT

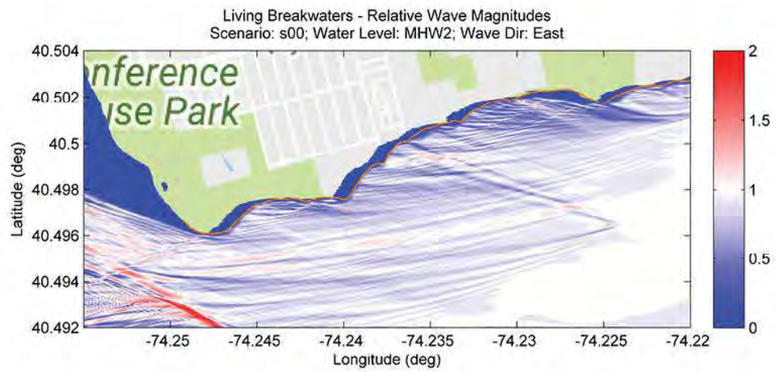
GENESIS RESULTS

NY RISING

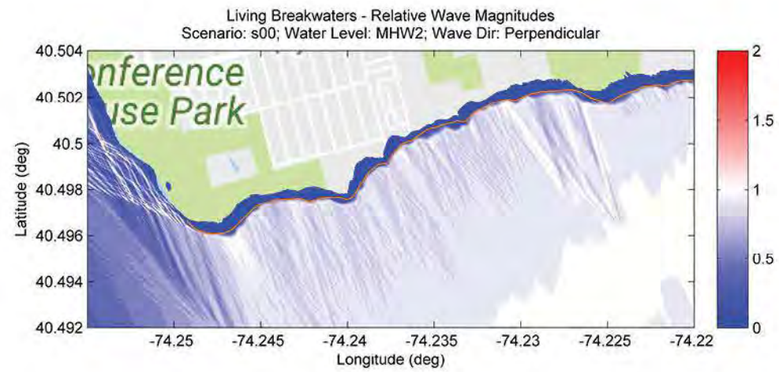
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

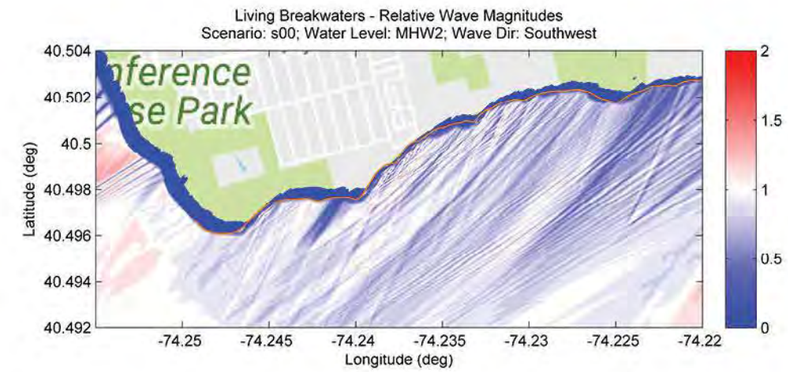
MHW | Input Wave Height of 3 feet | Waves from East



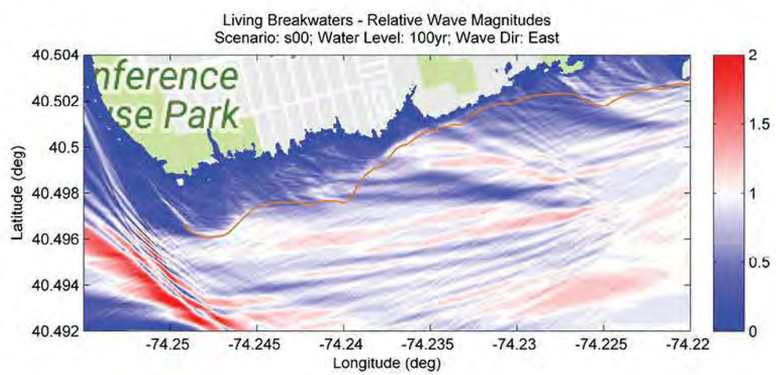
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



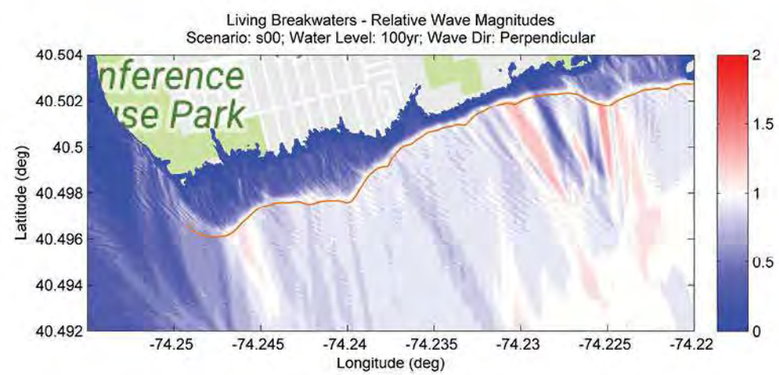
MHW | Input Wave Height of 3 feet | Waves from Southwest



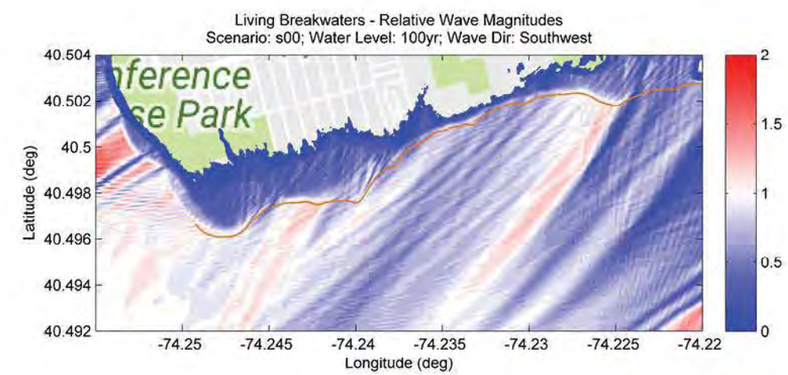
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

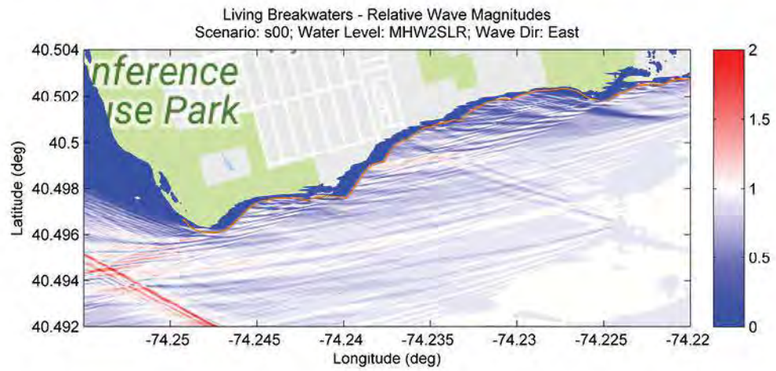


100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



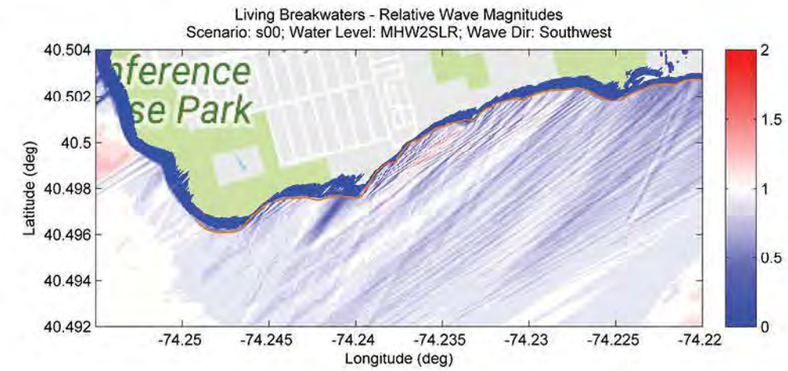
WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).

MHW + 30" SLR | Input Wave Height of 3 feet | Waves from East

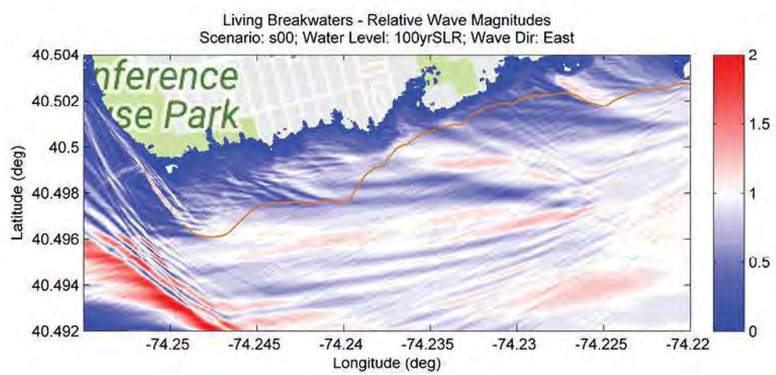


MHW + 30" SLR | Input Wave Height of 3 feet | Waves Perpendicular to Shore

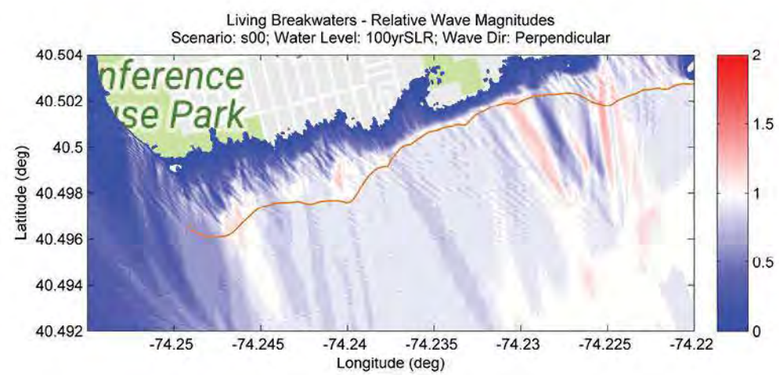
MHW + 30" SLR | Input Wave Height of 3 feet | Waves from Southwest



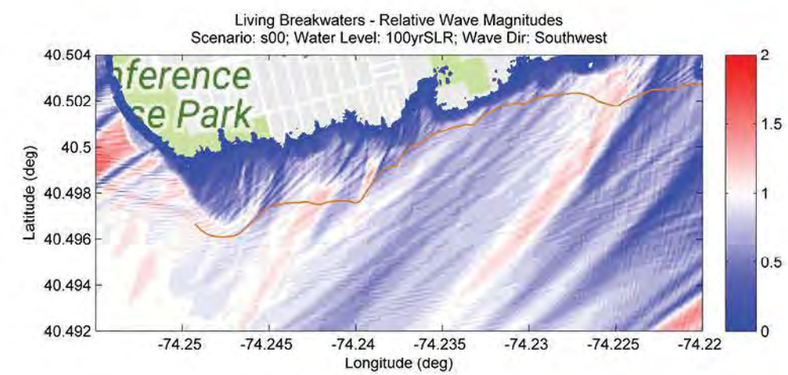
100 Year + 30" SLR | Input Wave Height of 5.3 feet | Waves from East



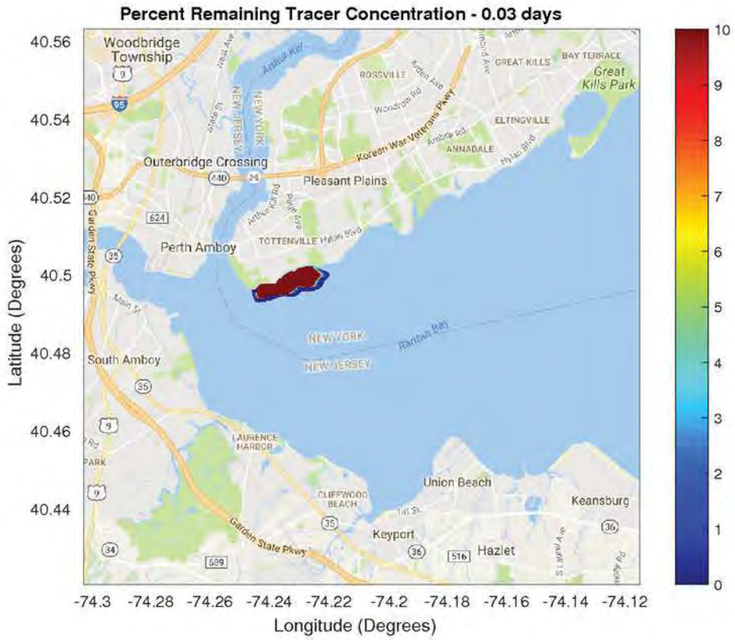
100 Year + 30" SLR | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

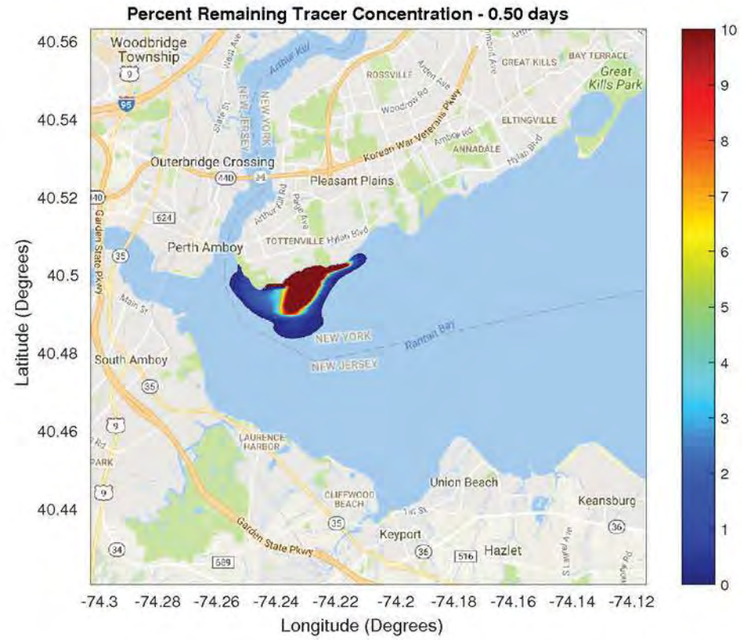


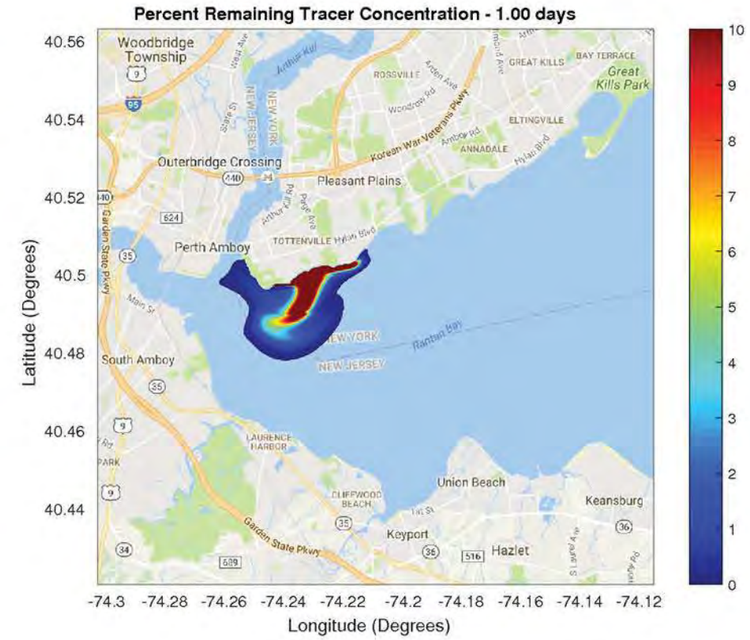
100 Year + 30" SLR| Input Wave Height of 5.3 feet | Waves from Southwest

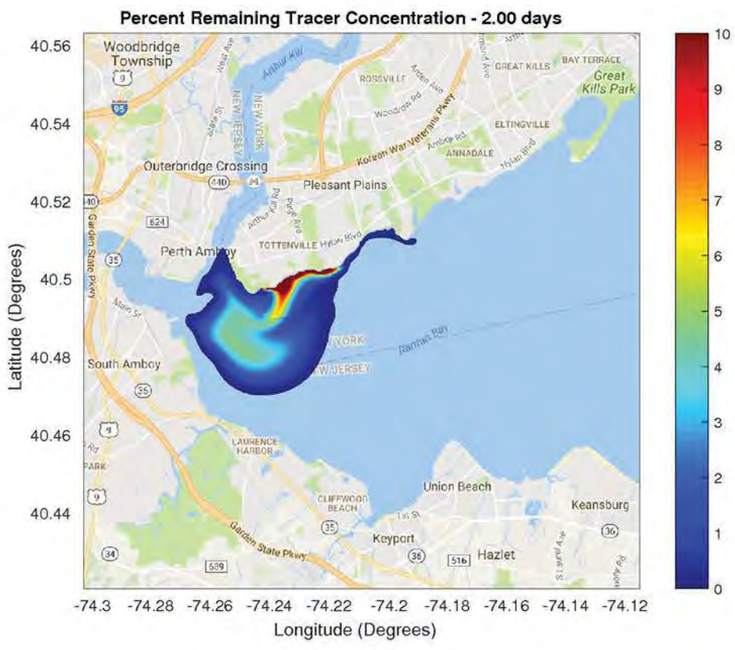


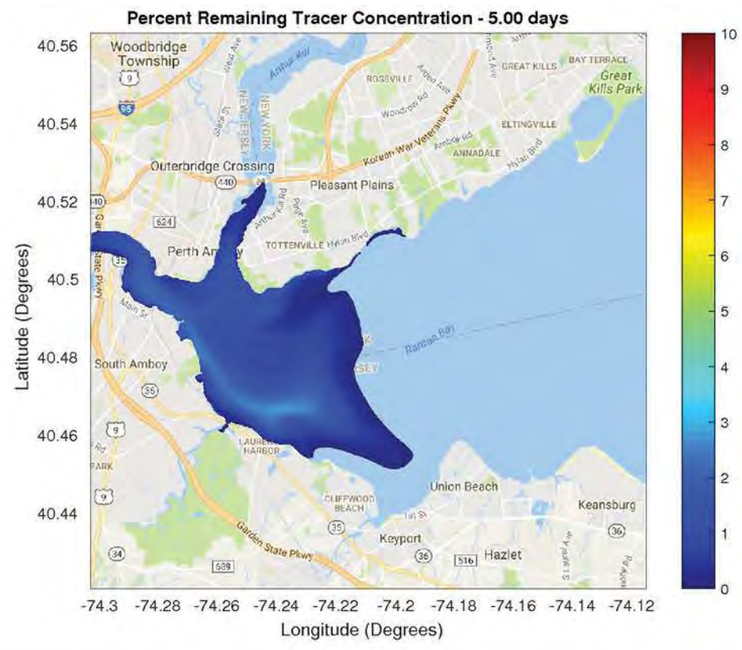
WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).











BASELINE, FUTURE WITHOUT PROJECT

DELFT-3D RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

00: BASELINE (FUTURE WITHOUT PROJECT)

ASSUMPTIONS: SHORELINE CONDITIONS

- 2015 shoreline (which was a compilation of the 2015 TSPP survey, 2014 LiDAR in areas outside the survey, and the 2015 structures survey supplemented with aerial information) was used as starting point / baseline for shoreline change of the preferred alternative.
- Initial model simulations used the pre-Sandy 2012 shoreline developed from aerial photography as the initial shoreline based on the shorelines used in the calibration process and the data available at the start of the scenario modeling process (this initial shoreline was used for consistency of comparison until the preferred scenario was selected).
- Shoreline structures / conditions assumed to be as surveyed in fall 2015; baseline model results assume no alteration of existing shoreline structures.
- The shoreline is the surveyed MHW line defined as 2.08 ft. NAVD88 tidal datum at Sandy Hook. Outside the survey limits, MHW was delineated from post-Sandy USGS LiDAR(August 2014).

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- The overall trends in shoreline change remain similar. Southwest of Sprague Avenue, the future without scenario showed shoreline change rates for the next 20 years consistent with the severe (>1') rates seen over the past 30 years. Northeast of Sprague Avenue, the future without scenario showed somewhat reduced rates shoreline change for the next 20 years relative to the rates seen over the past 30 years.
- The complex (wavey) nature of this shoreline and large number of structures on the shoreline likely complicates shoreline change processes, making results more varied
- Changes in sea levels may also play a factor in the response of the shoreline. Currently the model simulation have used current mean sea level. This allowed for comparison between scenarios but the effects of varying sea level will be tested once the preferred scenario is advanced in the next phase of design. Simplified shoreline change models, such as GENESIS, are effective at evaluating trends in shoreline changes and impacts of shoreline and nearshore structures but do not fully represent the cross shore processes that are impacted by sea level rise. Sea level rise influences are further evaluated in this phase of modeling in REFDIF.

WAVE ACTION

- Both the channel and the northern depth anomaly (the hole), impact wave refraction and diffraction and can result in some increased wave heights.
- The beach itself is one of the best attenuators of storm waves (building beach and complimentary on-shore interventions may have best storm wave reduction benefits)

WATER QUALITY

- The tracer plume originating from the project area dissipates to less than a few percent concentration in less than 5 days.

DESIGN SCENARIOS

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 01

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW 2012

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 01

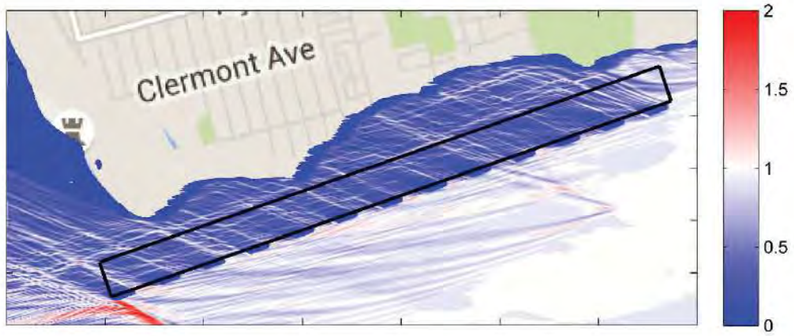
SCENARIO LAYOUT

NY RISING

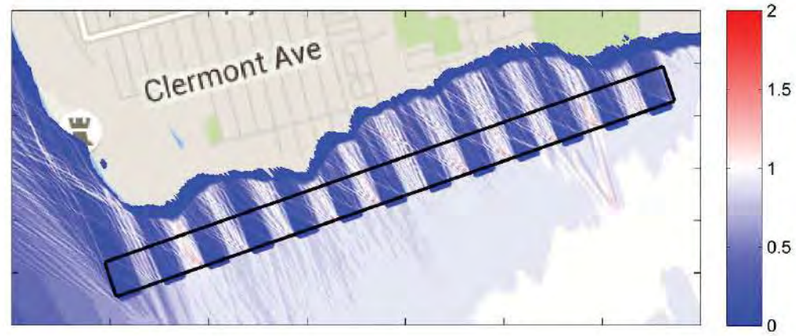
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

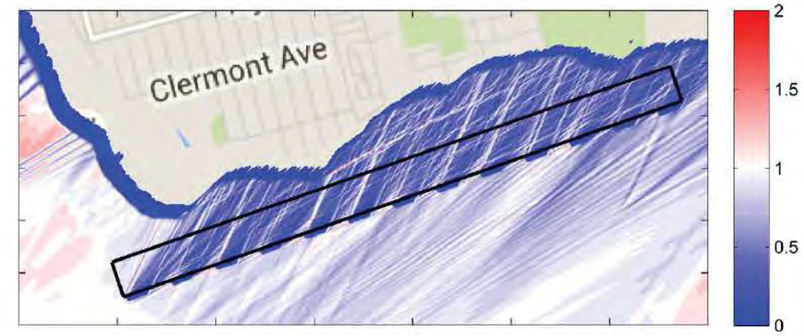
MHW | Input Wave Height of 3 feet | Waves from East



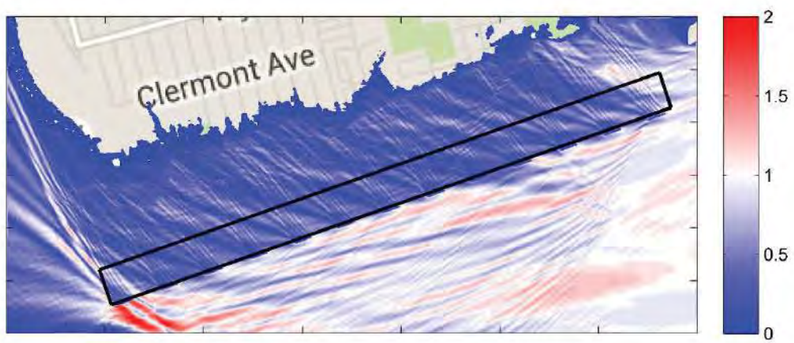
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



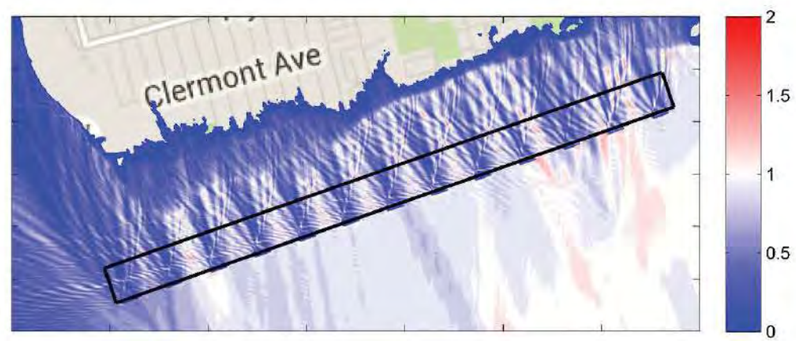
MHW | Input Wave Height of 3 feet | Waves from Southwest



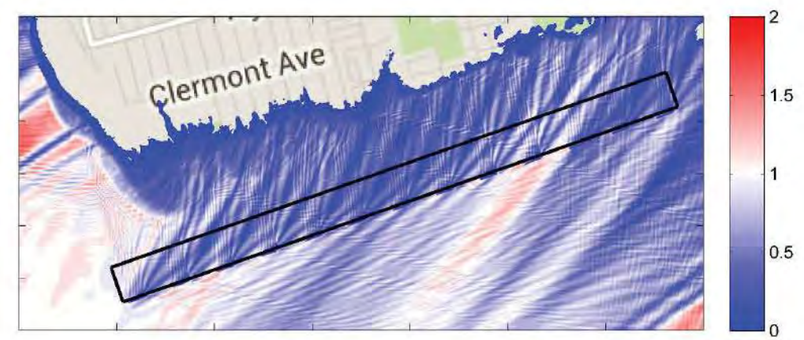
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



Wave heights shown are relative wave heights (modeled wave height/incoming offshore wave height).

SCENARIO 01: “HOLD THE SHORELINE”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- System provided effective shoreline stabilization in almost all areas.
- Limited effect at furthest distance to shore (x=1,300 feet, L/x=.25, where x is distance from shore and L is breakwater length) Trapping of greater amounts of sediment ‘upstream’ appears to limit potential of sediment capture downstream, suggesting that this is not a high sediment system.
- Salient response at north end was surprisingly strong; may be the salient itself beginning to act to trap sediment behind it. => may not need to extend breakwaters all the way north to get salient effect there.

WAVE ACTION

- The wave shadow zone (area where we see wave height reduction) is larger when waves are oblique rather than head-on in relation to breakwater orientation

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
AREADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 02: "STORM WAVE ATTENUATION"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 02: "STORM WAVE ATTENUATION"

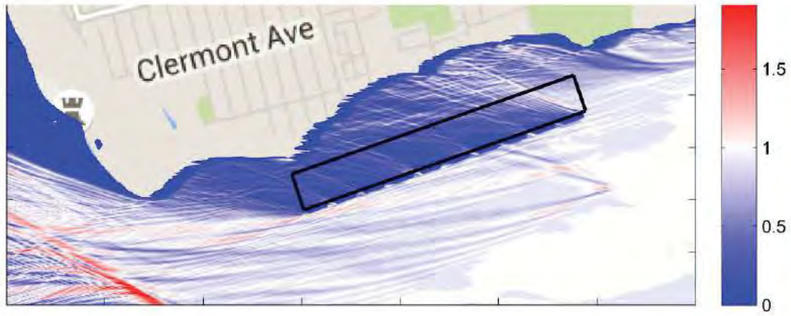
GENESIS RESULTS

NY RISING

SCAPE TEAM

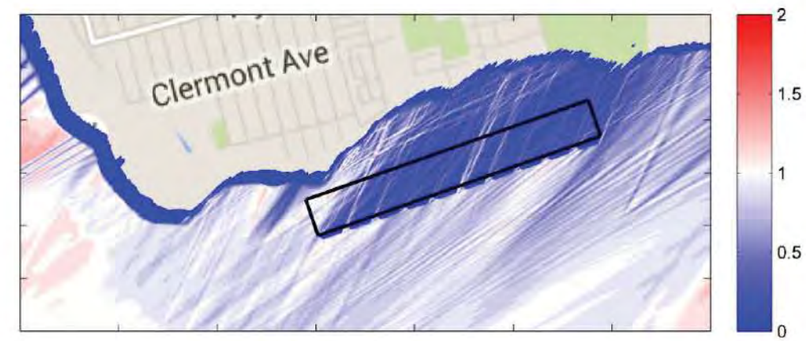
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW | Input Wave Height of 3 feet | Waves from East

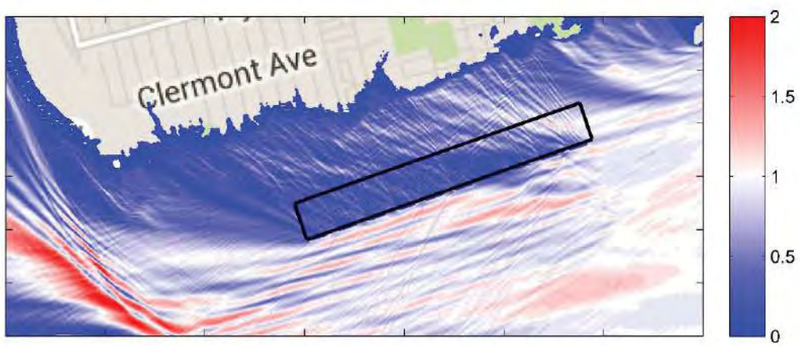


MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore

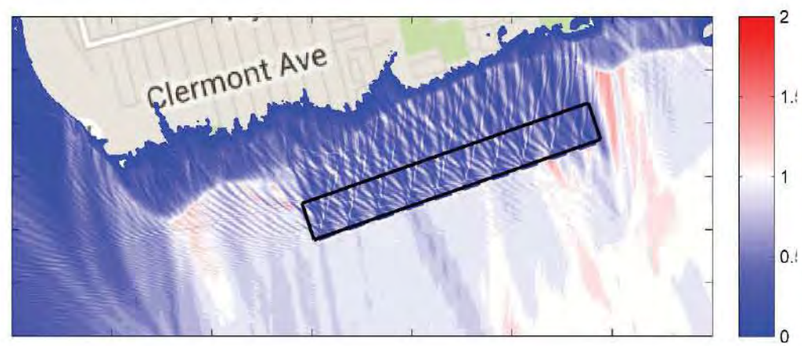
MHW | Input Wave Height of 3 feet | Waves from Southwest



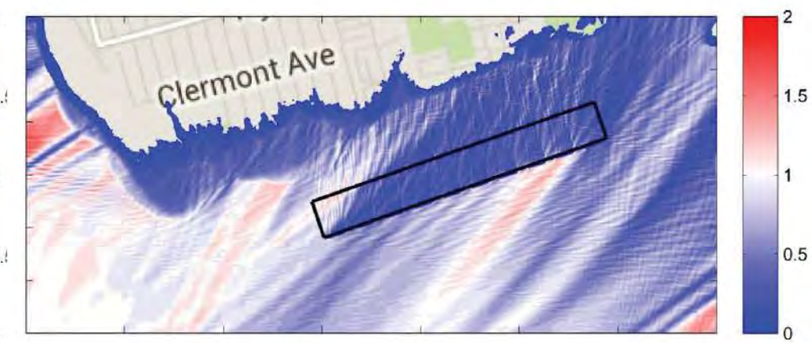
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 02: "STORM WAVE ATTENUATION"

REF DIF RESULTS

SCENARIO 02: "STORM WAVE ATTENUATION"

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Breakwaters acted as a single unit in how they impacted shoreline change => Breakwaters with small gap width (30') or Wg/(L+Wg) (1/4) act like a single unit in salient formation
- If sediment is trapped 'upstream', but if nothing is done at the southern end, this could exacerbate erosion in Conference House Park => breakwater system will need to extend to the southwestern edge of Zone 2 to avoid further erosion in this zone.

WAVE ACTION

- Smaller gap widths allow fewer / lower waves to pass through.
- Again, the wave shadow zone (area where we see wave height reduction) is larger when waves are oblique rather than head-on in relation to breakwater orientation

SCENARIO 02: "STORM WAVE ATTENUATION"
MODEL TAKE-AWAYS AND LESSONS LEARNED

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 03: "TESTING FOR TOMBOLO"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 03: "TESTING FOR TOMBOLO"

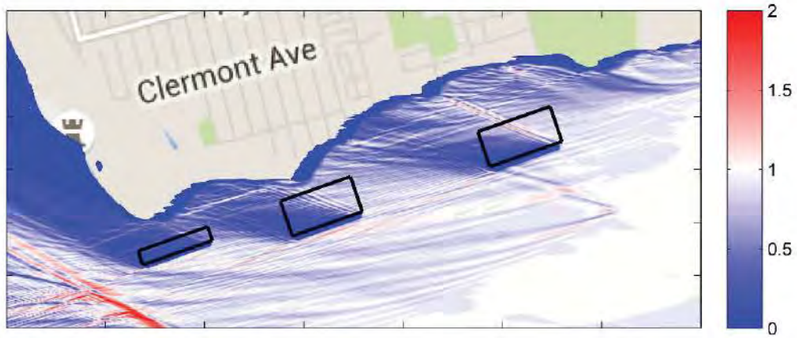
GENESIS RESULTS

NY RISING

SCAPE TEAM

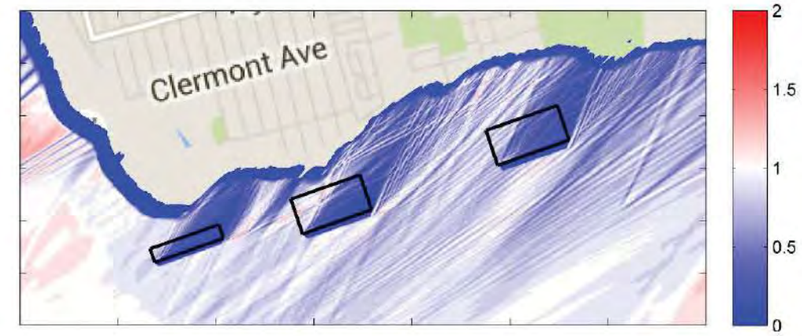
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW | Input Wave Height of 3 feet | Waves from East

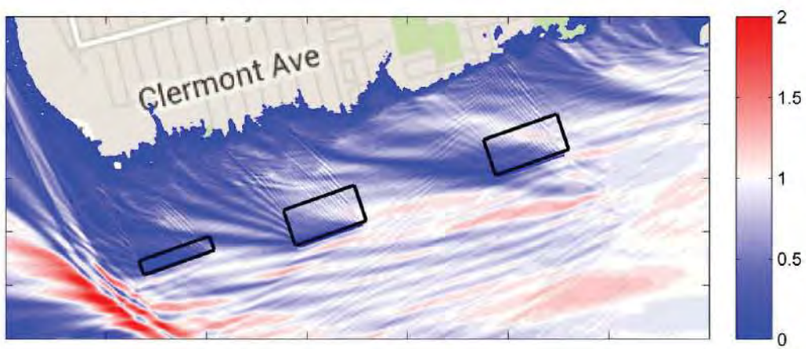


MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore

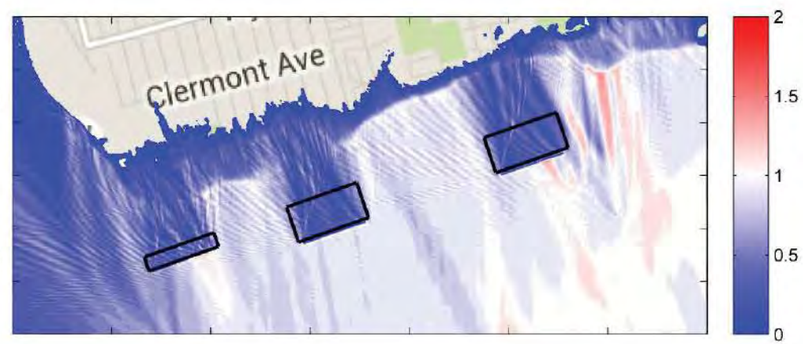
MHW | Input Wave Height of 3 feet | Waves from Southwest



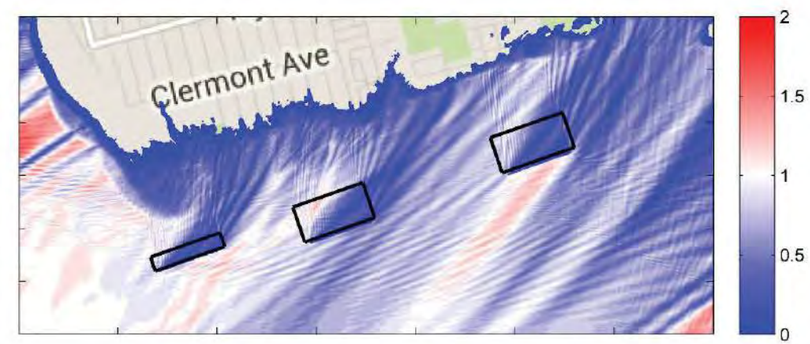
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 03: "TESTING FOR A TOMBOLO"

REF DIF RESULTS

SCENARIO 03: "TESTING FOR A TOMBOLO"

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- The long breakwaters all show significant salient response.
- Shoreline response is not proportional to distance to shore (X) or the ratio of breakwater segment length to distance to shore (L/X), suggesting that other factors influence the scale of salient formation, including but not limited to amount of sediment in the system, amount of sediment trapped upstream, shape of shoreline, and existing coastal structures.
- It may be possible to create a tombolo, which would act like a terminal groin at the end of the system.

WAVE ACTION

- The wide spacing between breakwater segments means that there is little wave reduction in the gaps between them.
- The breakwaters themselves are effective wave attenuators.

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
HARSON'S BRANCKEBROOK
AREADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

2012 MHW

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 04: "LEARNING FROM ROUND ONE"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 04: "LEARNING FROM ROUND ONE"

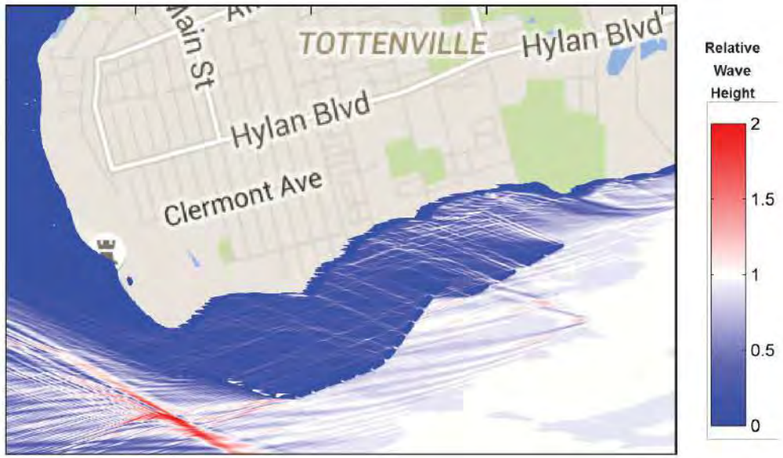
GENESIS RESULTS

NY RISING

SCAPE TEAM

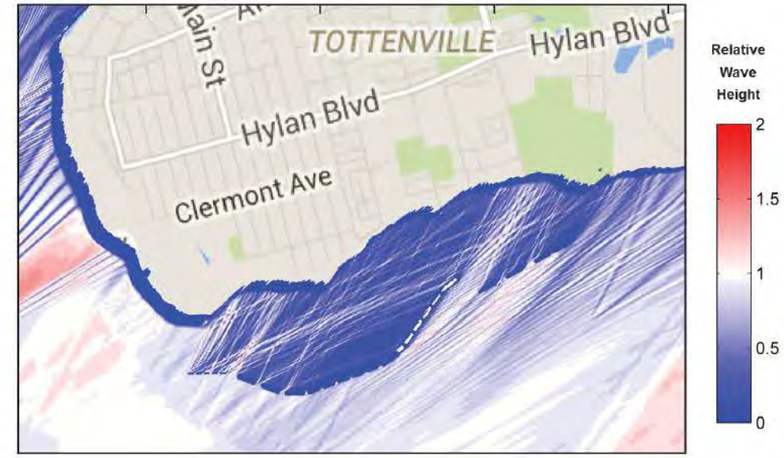
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW | Input Wave Height of 3 feet | Waves from East

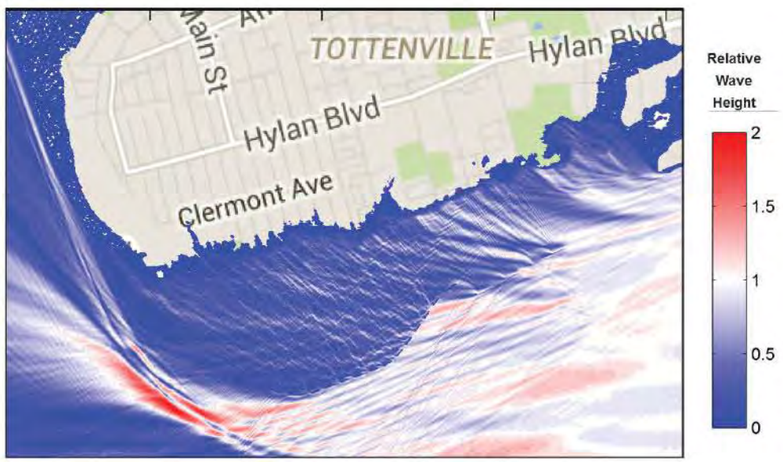


MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore

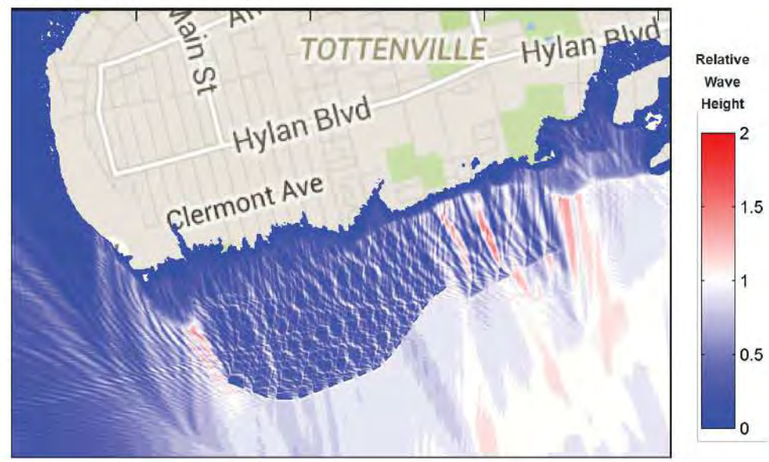
MHW | Input Wave Height of 3 feet | Waves from Southwest



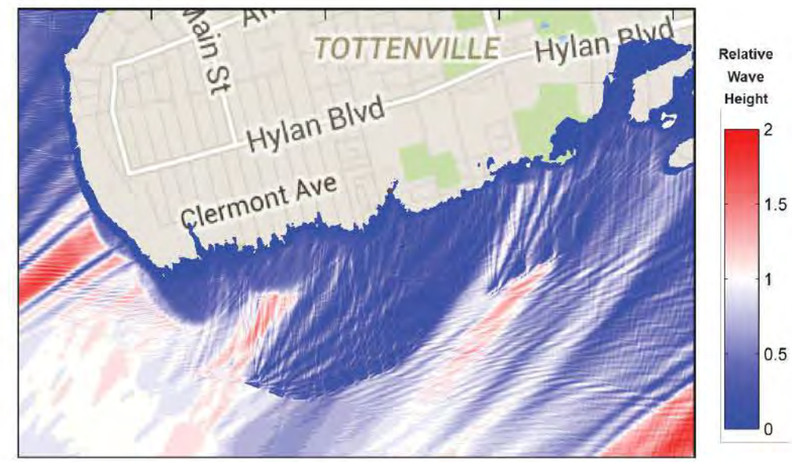
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 04: "LEARNING FROM ROUND ONE"

REF DIF RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 04: "LEARNING FROM ROUND ONE

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Shoreline is stabilized along length
- Limited longshore sediment supply is trapped along northeast shoreline and does not reach Zones 2 and 3 where accretion is desired
- Varying breakwater layout for desired goals by region appears to have merit

WAVE ACTION

- Effective wave shadow zone throughout most of the project area (area where we see wave height reduction)
- Lower crested breakwaters on western edge show limited effectiveness in attenuating waves under higher water levels

OTHER

- Large footprint = costly, high impact

SCENARIO 04: "LEARNING FROM ROUND ONE"
MODEL TAKE-AWAYS AND LESSONS LEARNED

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED
SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 05: "MODIFIED SCENARIO 04"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 05: "MODIFIED SCENARIO 04"

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 05: “MODIFIED SCENARIO 4”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Shoreline is stabilized along much of its length
- Significant accretion between Manhattan St and Page Ave
- Some erosion continued in Zone 2
- Removing northeastern breakwaters allowed more sediment to move farther west along the shoreline
- Bringing breakwaters closer to shore increased shoreline accretion and wave protection

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 06: "MINIMALIST APPROACH"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 06: "MINIMALIST APPROACH"

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 06: “MINIMALIST APPROACH”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Northeastern breakwaters were effective in retaining sediment and causing shoreline accretion
- Removal and lowering of southwestern breakwaters resulted in loss of protection and considerable erosion in conjunction with sediment trapping up drift

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 07: "MINIMALIST APPROACH WITH SHORELINE RESTORATION"

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 07: "MINIMALIST APPROACH WITH SHORELINE RESTORATION"

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 07: “MINIMALIST APPROACH WITH SHORELINE RESTORATION”

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Shoreline restoration shifted shoreline outward in region of fill
- Shoreline restoration was relatively well retained
- Erosion of western part of shoreline was slightly reduced but still significant as in previous scenario (same breakwater layout sc06)

SCENARIO 07: “MINIMALIST APPROACH WITH SHORELINE RESTORATION”

MODEL TAKE-AWAYS AND LESSONS LEARNED

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 09

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 09

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 09

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Moving the western and central breakwaters closer to shore enhanced shoreline protection.
- Having a breakwater in the middle of the western bay at the park reduced erosion of that region.
- Removal of southwestern breakwaters resulted in loss of protection and considerable erosion of Ward's Point in conjunction with sediment trapping up drift.

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0′ 500′ 1000′ 2000′

SCENARIO 10

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 10

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 10

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Repositioning of the central breakwaters improved shoreline shape and moving farther offshore into deeper water is likely to aid constructability without any noticeable loss in shoreline retention in the simulation.
- Moving of the southwestern breakwater resulted in accretion at the western point (Ward's Point) but significant erosion continued in the adjacent embayment.

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 11

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 11

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 11

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Reducing the number of breakwaters in the central portion and moving the southwestern breakwater increased erosion especially in the adjacent embayment.
- Significant accretion at Ward's Point and between Manhattan St and Bedell Ave

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 12

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 12

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 12

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Splitting the southwestern breakwater into two to provide protection to the point and embayment reduced erosion in the region, but erosion continued.
- Adding back a breakwater to the central section improved shoreline retention and protection between Bedell St and Page Ave
- Retained accretion between Manhattan St and Bedell St

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 13

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 13

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 13

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Moving the southwestern breakwaters and lengthening the breakwater at the southwestern point improved the modeled shoreline response shape; almost eliminated erosion in Zone 2
- Consistent beach accretion between Yettman St and Page Ave

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
HPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 14

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2032 MHW

MHW SPRING 2012

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUIÑONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 14

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 14 (2015 MHW)

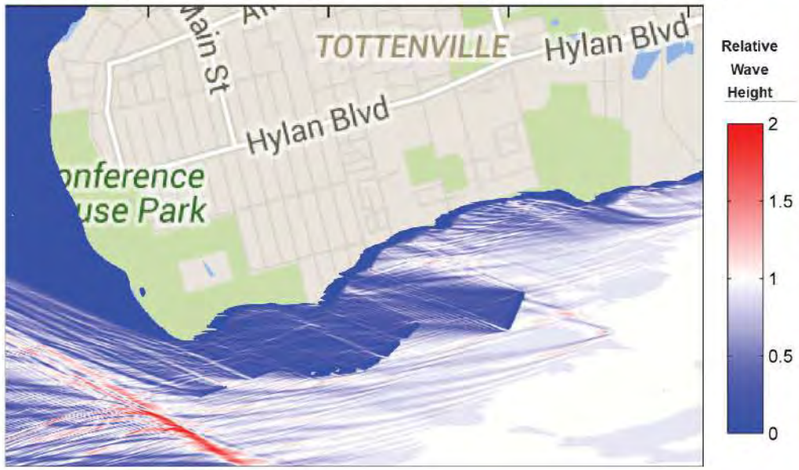
GENESIS RESULTS

NY RISING

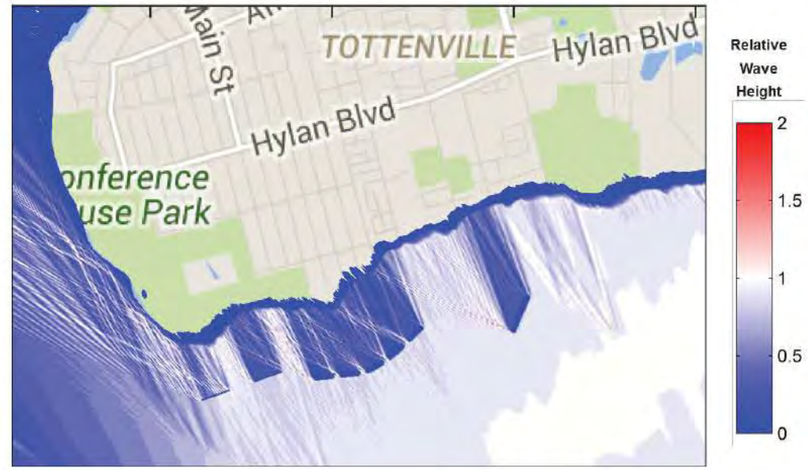
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

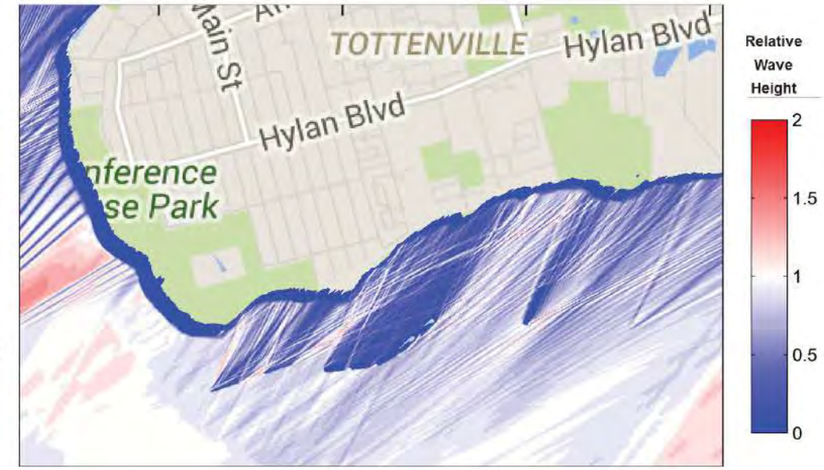
MHW | Input Wave Height of 3 feet | Waves from East



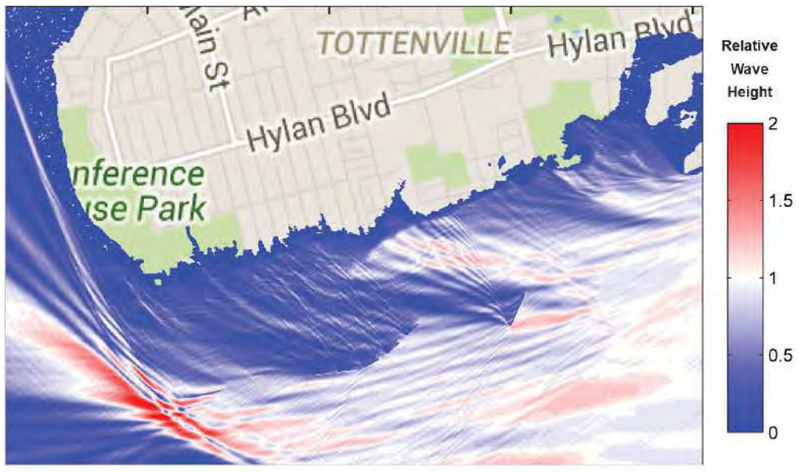
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



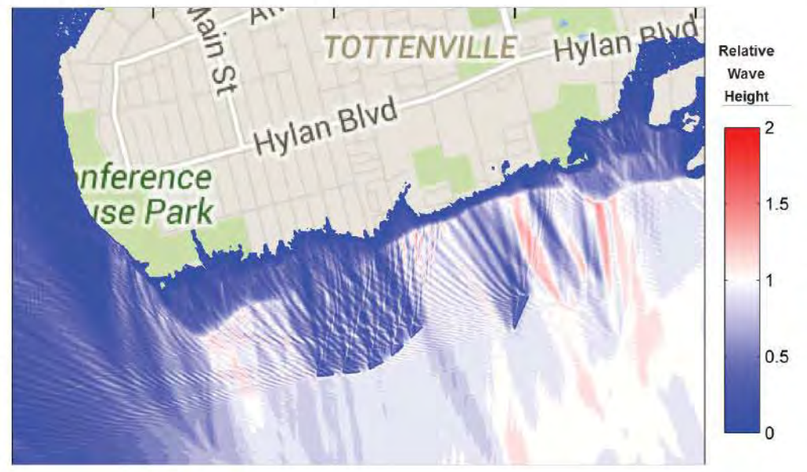
MHW | Input Wave Height of 3 feet | Waves from Southwest



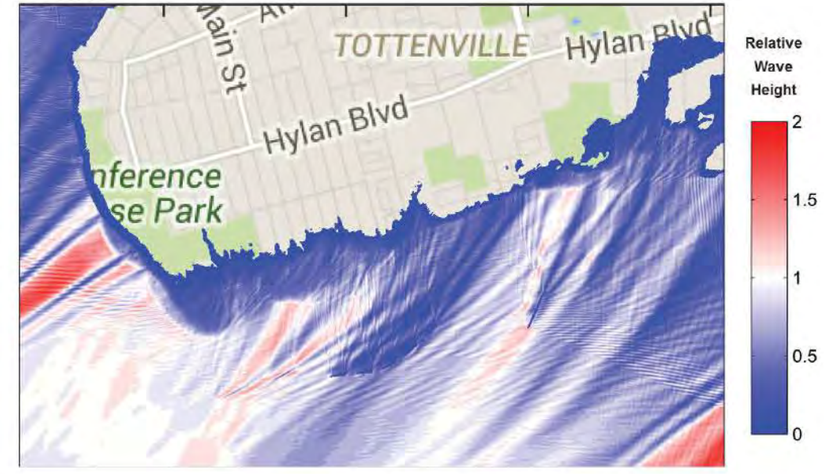
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore



100 Year | Input Wave Height of 5.3 feet | Waves from Southwest



SCENARIO 14

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Similar to Scenario 13, refinement of southwestern breakwater location and lengthening of these breakwater segments improved modeled shoreline response, shoreline shape, sediment accretion, and sediment retention at the southwestern point and adjacent embayment.

WAVE ACTION

- Breakwaters provide effective wave shadow zones in their lee for area between Brighton St. and Sprague Ave. where vulnerable locations / assets are located for most wave directions. Some additional study may be required for waves from the east.
- Lower crested southwestern breakwaters show reduced effectiveness in attenuating waves under higher water levels. Note that storm wave attenuation has not been identified as a priority for this area, as vulnerable assets are not located in this area.
- Increased wave exposure in gap between northeastern and central breakwaters: the increased spacing and reduction of number of northeastern breakwaters was to attempt to balance between wave attenuation and sediment trapping. Further refinement of breakwater alignment may be required if storm wave attenuation for the northeastern area of the project area is a greater priority.

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
HARSON'S MANCKEBACH
ARCADIS
BEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 15

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

SCENARIO 15

GENESIS RESULTS

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

SCENARIO 15

MODEL TAKE-AWAYS AND LESSONS LEARNED

SHORELINE CHANGE

- Similar to Scenario 14, addition of one more central breakwater and eastern breakwater to balance shoreline response with improved wave protection.
- Additional accretion to the northern eastern portion of the project shoreline due to the additional breakwaters. Some reduction in sediment available and accretion farther down the shore.

WAVE ACTION

- Breakwaters provide effective wave shadow zones in their lee for area between Brighton St. and Sprague Ave. where vulnerable locations / assets are located for most wave directions. Additional protection from waves from the east afforded by the additional breakwaters.
- Lower crested southwestern breakwaters show reduced effectiveness in attenuating waves under higher water levels. Note that storm wave attenuation has not been identified as a priority for this area, as vulnerable assets are not located in this area.

NY RISING
SCAPE TEAM
SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
HARSON'S MANCKERMAN
AREADIS
BEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
RPS CONSULTING ENGINEERS
PRUDENT ENGINEERING

FINAL 30% DESIGN SCENARIO

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

2015 MHW

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

30% DESIGN SCENARIO

SCENARIO LAYOUT

NY RISING

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

MODELED 2035 MHW

MHW 2015

ANTICIPATED BEACH GROWTH

ANTICIPATED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
CONTOUR BATHYMETRY GENERATED BY HILL

0' 500' 1000' 2000'

30% DESIGN SCENARIO

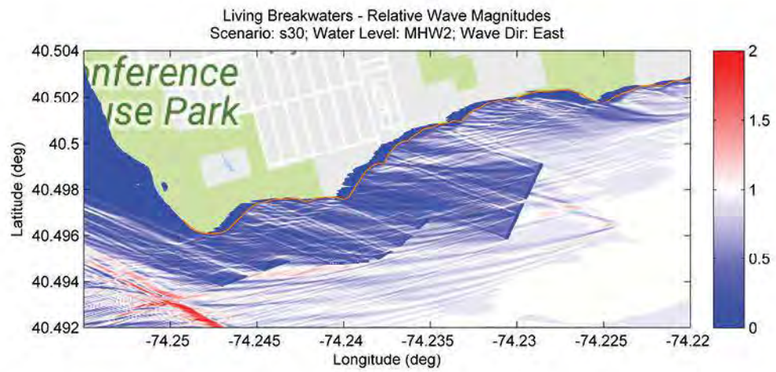
GENESIS RESULTS

NY RISING

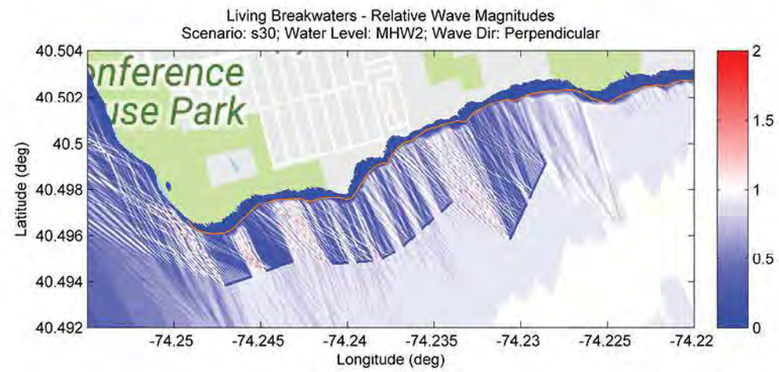
SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

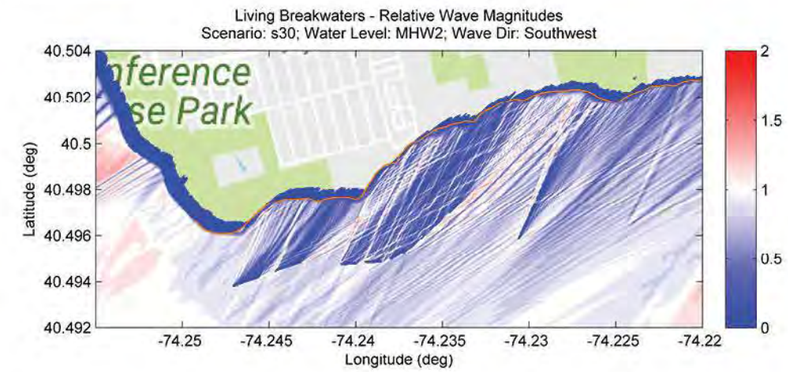
MHW | Input Wave Height of 3 feet | Waves from East



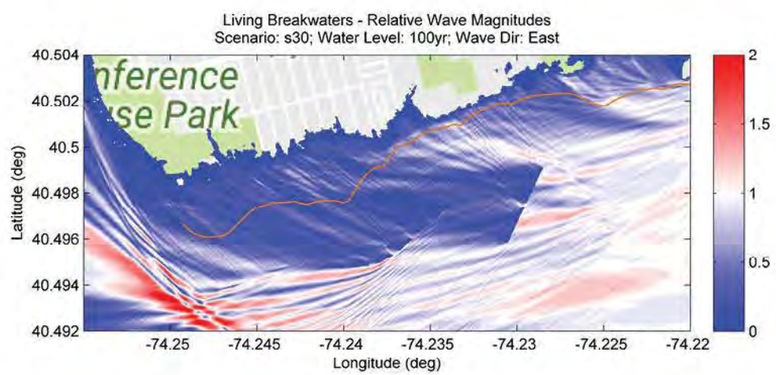
MHW | Input Wave Height of 3 feet | Waves Perpendicular to Shore



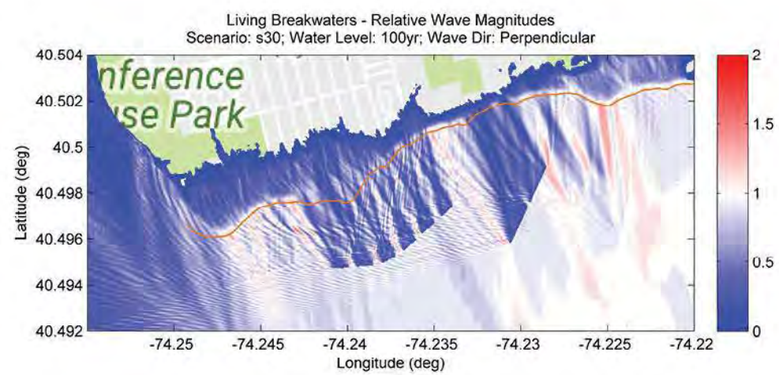
MHW | Input Wave Height of 3 feet | Waves from Southwest



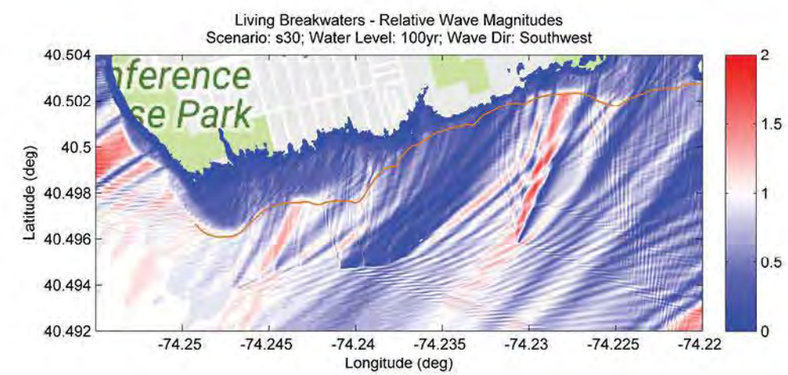
100 Year | Input Wave Height of 5.3 feet | Waves from East



100 Year | Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

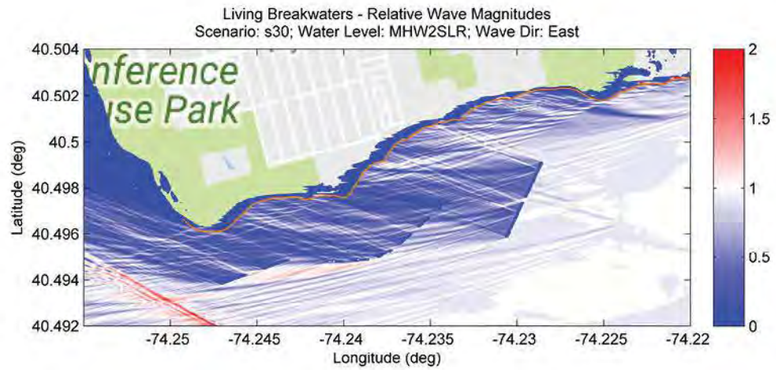


100 Year | Input Wave Height of 5.3 feet | Waves from Southwest

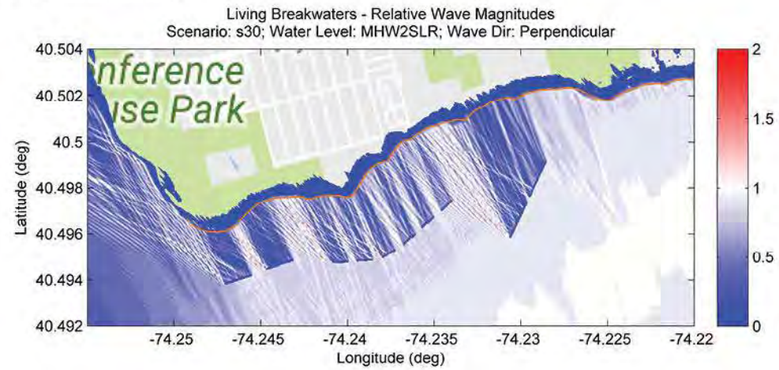


WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).

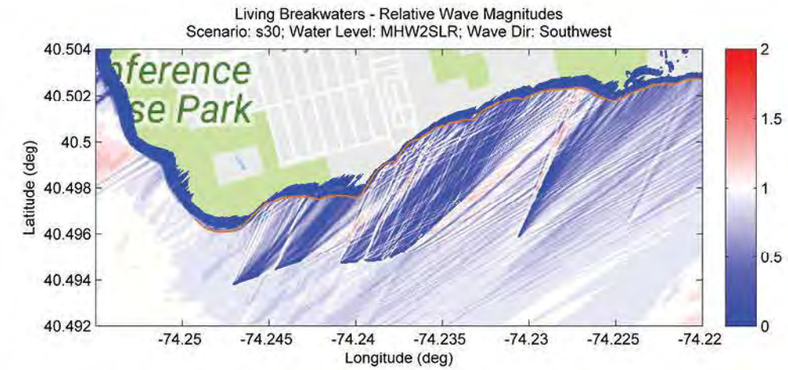
MHW + 30" SLR | Input Wave Height of 3 feet | Waves from East



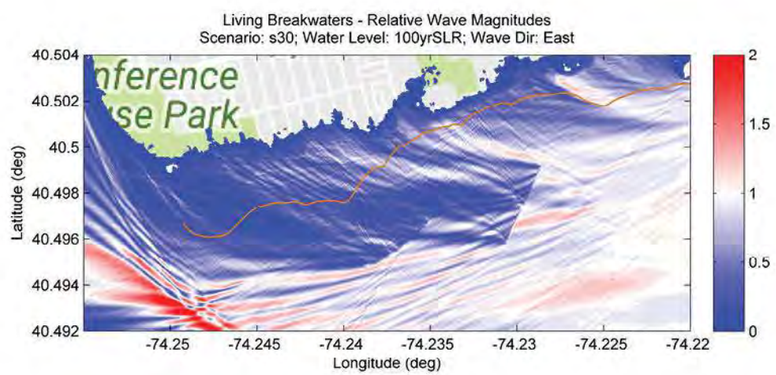
MHW + 30" SLR | Input Wave Height of 3 feet | Waves Perpendicular to Shore



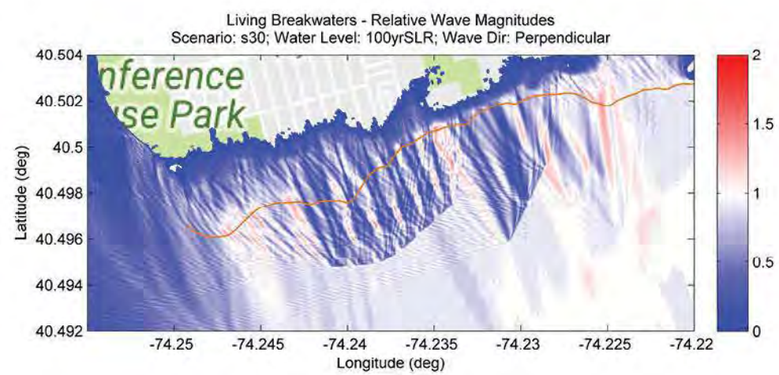
MHW + 30" SLR | Input Wave Height of 3 feet | Waves from Southwest



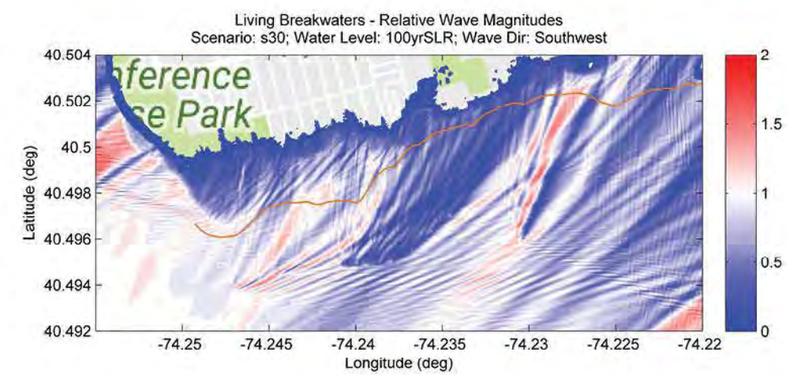
100 Year + 30" SLR | Input Wave Height of 5.3 feet | Waves from East



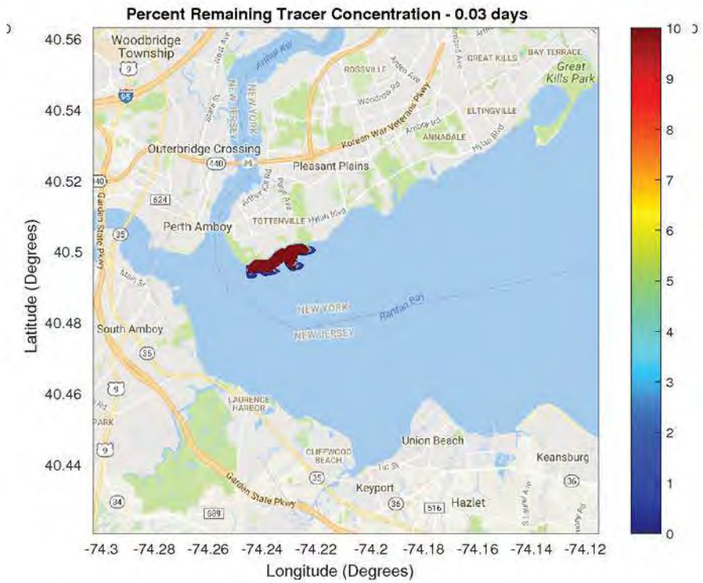
100 Year + 30" SLR| Input Wave Height of 5.3 feet | Waves Perpendicular to Shore

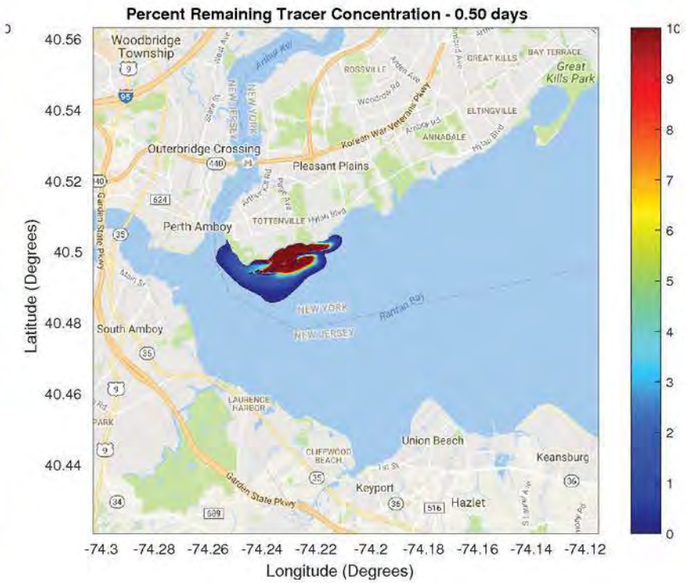


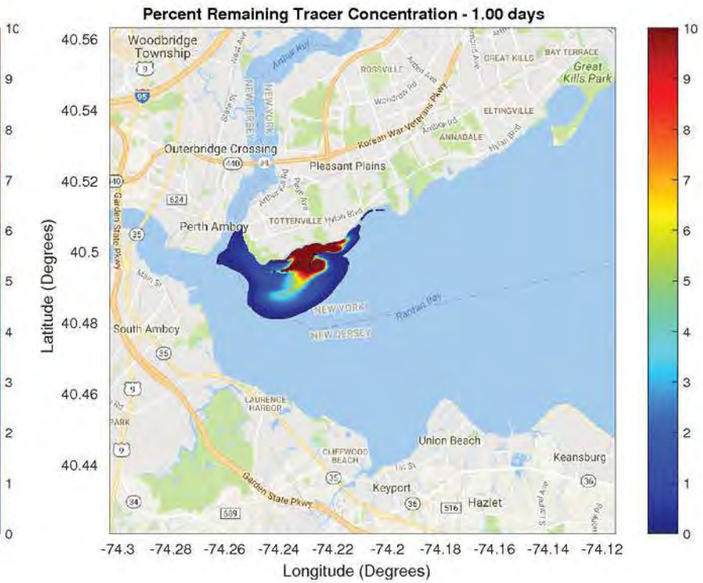
100 Year + 30" SLR| Input Wave Height of 5.3 feet | Waves from Southwest

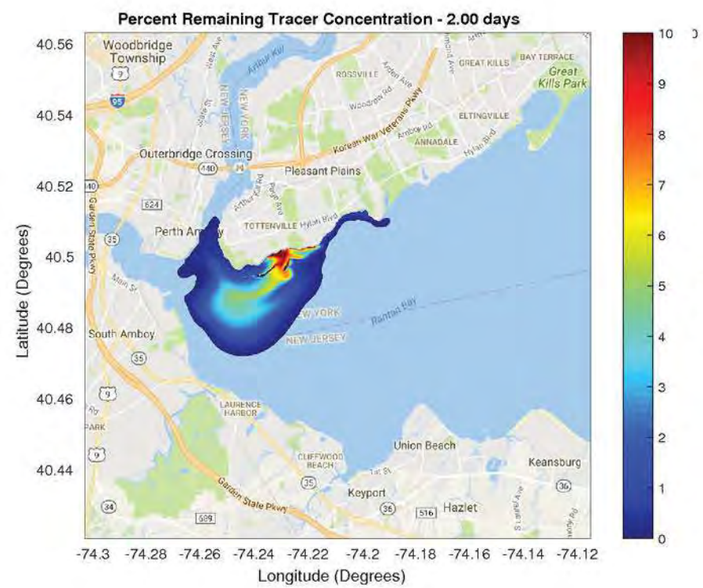


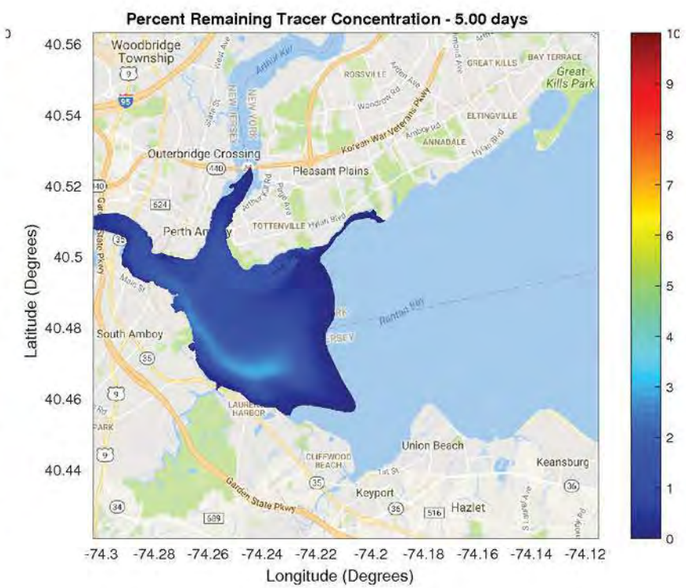
WAVE HEIGHTS SHOWN ARE RELATIVE WAVE HEIGHTS (MODELED WAVE HEIGHT/INCOMING OFFSHORE WAVE HEIGHT).











30% DESIGN SCENARIO

DELFT-3D RESULTS

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
LOT-EK ARCHITECTURE
MFS CONSULTING ENGINEERS
PRUDENT ENGINEERING

FINAL 30% DESIGN SCENARIO

SUMMARY OF MODEL RESULTS

SHORELINE CHANGE

- Same as Scenario 15 with the addition of some shoreline restoration
- Beach is well retained and provides increased beach width over critical area of the shoreline
- Balance of shoreline response and wave protection

WAVE ACTION

- Same as Scenario 15.

WATER QUALITY

- No significant changes in residence time due to breakwaters

OVERALL TAKE-AWAYS

SHORELINE CHANGE

- Living Breakwaters spacing, gap width, distance to shoreline, and alignment iteratively tested to develop a preferred scenario.
- Living Breakwater System can provide effective shoreline stabilization in almost all areas.
- Breakwater distance from shore, length, gap width, and the relative ratios between them influence the shoreline behavior. Other factors influence the scale of salient formation, including but not limited to amount of sediment in the system, amount of sediment trapped upstream, shape of shoreline, and existing coastal structures.
- Trapping of greater amounts of sediment 'upstream' appears to limit potential of sediment capture downstream.
- "Opening" northeast breakwater area was required to allow updrift sediment to transport to zone 2 / zone 3.
- Southwestern breakwaters are required to stabilize historical erosion at Conference House Park.

WAVE ACTION

- With enough properly spaced breakwaters an effective wave shadow zone (area where we see wave height reduction) throughout most of the project area can be created.
- Smaller gap widths allow fewer / lower waves to pass through.
- Wide spacing between breakwater segments results in little wave reduction in the gaps between them.
- Use of lower crested breakwaters on western edge show limited effectiveness in attenuating waves under higher water levels, so are only being recommended where storm wave attenuation is not a priority (southeastern end of the project area)

WATER QUALITY

- No significant changes in residence time due to breakwaters

SHORELINE RESTORATION

- Shoreline restoration shifted shoreline outward in region of fill.
- Shoreline restoration was relatively well retained.

Appendix E-6
Target Species Rationale

A. INTRODUCTION AND BACKGROUND

The design, construction, and operation of the Breakwaters Project would result in the creation of ecologically-designed, three-dimensional reef-like habitat that would increase the diversity of the aquatic habitats available for plant and invertebrate species that provide or create habitat (habitat forming plants and invertebrates) found in Raritan Bay (e.g., brown algae and local shellfish like mussels, barnacles, and oysters). As habitat forming species recruit and mature on the Breakwaters Project structures, the newly enhanced matrix of physical and biogenic structures should facilitate recruitment and retention of resident and transient fishes, crabs, bivalves, small invertebrate, and plankton (e.g., Nestlerode 2004; Burt et al. 2012; Firth et al. 2014; Perkol-Finkel and Sella. 2014, 2015; Sella and Perkol-Finkel 2015). The Breakwaters Project would diversify existing nearshore benthic habitats in Raritan Bay by providing substitute structured habitat for long absent oyster populations, while achieving its primary ecosystem service of wave-attenuation and shoreline risk reduction that would be achieved in conjunction with the Tottenville Shoreline Protection Project (Shoreline Project). Together, these projects aim to reduce wave action and coastal erosion along the shoreline in Tottenville, while enhancing ecosystems and shoreline access, use and stewardship. The Breakwaters Project not only aims to meet its primary goal of storm wave attenuation and prevention or reversal of shoreline erosion, but the creation of reef-like habitat contributes to larger-scale efforts in the Hudson-Raritan Bay to improve water quality and restore ecosystem functions, including historically abundant shellfish communities.

Design considerations for the Breakwaters Project's structures explicitly incorporate materials and methods that would facilitate the attraction of several functional groups and species (i.e., target groups), by using a combination of materials and structures engineered to recruit and retain habitat forming species (e.g., ecological design) of the breakwater structures (e.g., number, slopes, orientation, reef-fingers, and reef streets), and placement of ecologically-enhanced structural units. The key ecological relationships (e.g., predator-prey, competition, facilitation, recruitment, reproduction) expected from successful reef-like habitats would be more likely to occur on the Breakwaters Project than standard breakwaters because the design process considers the specific ecological needs of the local estuarine flora and fauna – particularly those of ecosystem engineers[1] like oysters and other bivalves, polychaetes, and encrusting organisms (Bruno et al. 2003; Browne and Chapman 2011). The total amount of inshore habitat in Raritan Bay and Sandy Hook Bay is approximately 33,500 acres, of which the Breakwaters Project study area would comprise 610 acres. The maximum projected footprint of the breakwater segments would cover approximately 12.7 acres or 2 percent of existing bottom habitat within the study area. Within the Hudson Raritan Estuary, the footprint of the breakwater

[1] Ecosystem engineer— species that affect the physical space in which other species live and their direct effects can last longer than the lifetime of the organism (Hastings et al. 2007).

segments represents an even smaller percentage of the available benthic habitat. Thus, while construction of the Breakwaters Project would displace existing sand and gravel benthic habitats in the study area, it would add structured habitat that has been identified as a restoration priority for the greater Hudson River Estuary, adds to the "mosaic" of available habitats, and promotes the development of a productive and diverse local ecological community (USACE 2016a).

The unpredictability of fish and invertebrate recruitment and community assembly processes precludes precise prediction of the abundance of a particular species or taxa that would result from habitat modification. Thus, while the potential increase in local productivity associated with the diversity of structured habitats resulting from the Breakwaters Project would provide increased ecological niche space, the success of any particular species (e.g., oysters) at any time or place on the Breakwaters Project structures or in their vicinity is challenging to predict with acceptable confidence. Because the benefits of the new structured habitat are expected to accrue to several species and functional groups of Raritan Bay (e.g., fish, benthic invertebrates, plants, and plankton), metrics of ecosystem functioning on the associated reef-like habitat should consider the broad suite of species groups likely to benefit from the project in terms of their representative ecological functions, as well as their social and economic value. Adopting this perspective lends to a more holistic view that considers restoring ecosystem functions to an ecologically degraded region rather than pinning success on the presence of any single species that, for external factors unrelated to the Breakwaters Project, may not successfully colonize to the study area.

While ecologically-enhanced breakwater structures and man-made reefs generally increase productivity, species diversity, or both and reduce the ratio between invasive to local species compared to areas without structured habitat and low-complexity breakwaters (Burt et al. 2012; Wen et al. 2013; Aguilera et al. 2014; Firth et al. 2014, Sella and Perkol-Finkel, 2015), ecological caveats to consider in the design, construction, and operation of breakwaters include the potential for introducing invasive species (Glasby et al. 2007; Dafforn et al. 2012).

The following sections review the ecological functions of selected targeted functional groups, design considerations relevant to each group, and provide suggested metrics of ecosystem function. Such metrics of enhancement and restoration progress should consider the duration of the enhancement and spatial context that reflect progress on a species group level and across species groups (e.g., how many species groups show progress toward an enhanced or restored state). The sections below provide an overview of target species groups expected to benefit from the installation of the Breakwaters Project off the southeast coast of Staten Island. The groups and the species included in each group are based on historical surveys and the recent surveys conducted by the project team to document existing biological and ecological conditions in the study area (Normandeau 2015 a,b,c,d; SeArc 2015).

Historically, Raritan Bay and the larger Hudson-Raritan estuary was an extremely productive estuarine system and supported at least 338 fish species of resident, migratory, and transitory fish species (Berg and Levinton 1985; MacKenzie 1990; Briggs and Waldman 2002). Although the fish diversity remains high in Raritan Bay, the productivity of the system is depleted compared to historical levels (MacKenzie 1990). The reduction in fish productivity has been attributed to overharvesting, loss and degradation of habitat, and pollution (MacKenzie 1990). These recent surveys documenting existing conditions of the study area used beach seines, otter and beam trawls, fish traps, and visual surveys to collect a comprehensive sample of the current fish community in the study area. Catches in seines were dominated by Atlantic silversides, but Atlantic menhaden and striped killifish were also very common. Other species caught in seines

included tautog, northern kingfish, bay anchovy, white mullet, bluefish, winter flounder, mummichog, and American eel. Bay anchovy were most common in trawl catches, with Atlantic silversides and Atlantic menhaden also common. One summer flounder and one winter flounder were also caught. Few fish were caught using traps, where only black sea bass, northern pipefish, and scup were found.

Over the last half-century, several research surveys documented the evolution of the benthic community composition in Raritan Bay. While the observed benthic community fauna fluctuated over these sampling events, the overall structure of the species composition has been consistent in surveys conducted beginning in the 1950s to recent years with some of the observed variability associated with different sampling protocols (Normandeau 2015 a,b,c,d; SeArc 2015). Previous surveys of the New York Harbor estuary's benthic invertebrate fauna, has identified 328 total species with the dominant taxonomic groups comprising polychaetes (43%), crustaceans (31%), and mollusks (17%) (Cerrato 2006). More broadly, taxa present in the system include aquatic earthworms (oligochaetes), segmented worms (polychaetes), snails (gastropods), bivalves (e.g., soft shell clam, dwarf surf clam, blue mussel, ribbed mussel and oyster), barnacles, amphipods, isopods, crabs, and shrimp. Surveys conducted to document existing conditions for the Breakwaters Project study area found 184 taxa in benthic grab samples collected from soft bottom habitat (sand, mud, and gravel), while concurrent sampling of hard bottom habitat identified 115 epifaunal taxa (Normandeau 2015 a,b,c,d; SeArc 2015).

Surveys of the existing conditions in soft sediments (e.g., sand, gravel, mud) identified distinct epibenthic and benthic invertebrate communities (i.e., small animals living in and on the sediment) residing in the different sediment types found in the study area (Normandeau 2015 a,b,c,d;). Soft bottom surveys identified distinct differences in communities between sites with different substrates. Sand and gravel substrates were most common throughout the study area, with sand substrates only occurring at western sites near locations with hard substrates. While both substrate types contained similar taxonomic groups, sample sites with sand and gravel substrates had higher densities compared to those with only sand substrates. The exception to this observation was that sand sites contained higher densities of small gem clams. Hard bottom benthic surveys found that gastropods, amphipods and polychaete worms comprised the majority of the hard-bottom epibenthic assemblage at all five hard-bottom sites, with amphipods the numerically dominant invertebrate. Nearby artificial structures contained 43 taxa of algae, invertebrates, fish, and birds where the shallower areas were dominated by algae and polychaetes were most common in deeper water sites (SeArc 2015).

Because the Breakwaters Project would add high-quality, spatially-complex reef-like habitat to the study area that should attract habitat forming species as well as fish and benthic invertebrate species, the initial benefits to the local ecological community would reflect early-stage colonization processes. Because few oysters were found in the vicinity of the study area in surveys of nearby artificial structured habitat (SeArc 2015), the extent that oysters would successfully recruit to the Breakwaters Project system depends on the success of planned, efforts to seed the breakwater segments with oysters and develop nearby spat nurseries. To increase chances for success, several different seeding methods and substrates are proposed: spat on shell or disk on bio-enhancing concrete units; spat on shell in oyster gabions; dispersal of loose spat on shell; and nearby spat nurseries. The prospect of a self-sustaining oyster reef network in the region, would depend on the collective oyster restoration efforts throughout the New York Harbor (e.g., New York-New Jersey Harbor & Estuary Program; Billion Oyster Project) to ensure sufficient adult oyster densities over broader spatial scales to overcome the vagaries of

the natural oyster larvae supply from this comparatively small project (i.e., year to year variability in oyster gamete production and self-retention of locally produced larvae).

Other habitat forming benthic invertebrates (e.g., mussels, barnacles, tunicates, and bryozoans) and algae (encrusting algae and macroalgae) found during the survey would be expected to recruit to the breakwaters structures (Normandeau 2015 a,b,c,d; SeArc 2015; Ferrario et al. 2016; Firth et al. 2016). In addition, structured habitat with viable populations of habitat forming bivalves and other invertebrates could provide increased feeding opportunities for juvenile and adult fish, potentially attracting juvenile recruits to suitable nursery habitat and contributing to improved productivity in local populations (Mann and Harding 1997, 1998; Coen and Grizzle 2007). Thus, the developing ecological community would be shaped not only by the oyster seed supplied, but by the larger species pool and the larvae it would supply. Additional ecological interactions such as competition, predation, and facilitation would influence both the development of the local community and the potential for oyster colonization and persistence in the study area enhancement efforts (details described below) (e.g., Bruno et al. 2001, Mitcheli et al., 2005; Mann and Harding 1997, 1998; Coen and Grizzle 2007).

Fish species would likely derive benefits from the Breakwaters Project depending on their preference (and their prey's preference) for reef-like habitat and adjoining waters at their different life stages (Mann and Harding 1997, 1998; Nestlerode 2004). Fish that are strongly linked to structure for shelter and food should be most tightly coupled with development of the breakwaters structures (e.g., structure-oriented target species groups below), while the increased productivity associated with these structures and the mosaic of transitional habitats created should provide attractive habitat to both pelagic forage species and ecologically and economically important transient species using the newly created habitat (e.g., Jones and Andrews 1992; Coen and Grizzle 2007; Burt et al. 2012).

Expectations regarding the long-term ecological community that would inhabit the Breakwaters Project study area should recognize that it would differ from the current one in terms of the number of species, the relative abundance of those species, the species groups present, and the ecological functions and ecosystem services provided. Not only would the newly created reef-like structures differ from historical conditions, they would differ from expectations for hypothetical "natural" reef community in the same site, because, in part, of the different substrates, the duration of active seeding and monitoring effects, and the reduced abundance of resident species compared to historical levels (Burt et al. 2011, 2012). Because the Breakwaters Project reflect active efforts to incorporate ecological processes that support the recruitment and persistence of structure-oriented and habitat forming organisms, the structure should facilitate recruitment of an ecological community representative of the native diversity of species of the region.

The use of bio-enhancing concrete armor units, in conjunction with careful design of each Living Breakwater structure and the entire system of ecologically-enhanced breakwaters, would encourage the recruitment of several different species and life stages from several functional species groups to the study area, while meeting the primary goal of shoreline stabilization. Because newly created subtidal and intertidal reef-like habitat would be created that displaces 12.7 acres of existing sand and gravel bottom habitat, it would be necessary to first demonstrate that impacts of the Breakwater Project would not result in significant adverse impacts to the existing ecological communities. This could be done by confirming the continued presence of taxa historically present in the study area. Thus, monitoring studies should be designed to document the continued presence of those species groups currently and historically found in the

study area, while also tracking trends in the distribution and relative absence of non-native invasive species. Additional ecological enhancements to the community would be demonstrated by evidence of increased species richness (i.e., more species) in the study area, presence of habitat forming groups on and near the breakwaters (e.g., oysters, mussels, barnacles, clams, tubeworms, macroalgae), colonization of bio-enhancing concrete structures by target species groups, increased productivity and abundance of species groups, evidence of new trophic interactions (e.g., predatory fish consuming forage fish associated with the new structures or crabs consuming habitat forming benthic invertebrates), and, finally, in the longer term, perhaps self-sustaining oyster populations in the study area. The latter metric, in particular, is likely dependent on larger scale oyster restoration and larger scale, ongoing water quality improvement efforts in the Hudson-Raritan Estuary. Considering a range of species groups, rather than focusing on a limited number of species and ecosystem functions, expands the range of possible outcomes that include desirable ecological functions and ecosystem services (e.g., increased species richness, increased community resilience, greater biogenic structure and habitat complexity). This approach accounts for the multiple pathways that colonization of the breakwaters structures could take in delivering the functions representative of a robust ecological community over time, across the Breakwaters Project system, and among neighboring estuarine habitats (Zedler 2005; Micheli and Halpern 2005).

B. FUNCTIONAL GROUPS

The functional groups described below aggregate species that share similar ecological roles in the Hudson River Estuary to emphasize the importance of a functionally diverse ecosystem rather than the presence of a few particular species. This is particularly important in highly variable environments exemplified by temperate estuaries like Raritan Bay and the larger Hudson-Raritan estuary. In these ecosystems, fluctuations in recruitment or changes in migratory patterns may result in high variability in the abundance of local populations of each species that, alone, do not reflect the state of the ecosystem. Environmental conditions (e.g., salinity, water temperature, sea level) in temperate estuaries vary over ecologically relevant ranges at many temporal and spatial scales. For example, salinity and temperature change with the ebb and flow of the daily tidal cycle, which is further influenced by the freshwater inputs from Hudson River and other tributaries in the watershed. At larger time scales, seasonal variability in temperate estuaries between winter and summer conditions means that for many species the estuary provides suitable habitat for only part of the year; thus, the typical community composition changes throughout the year. In addition, year-to-year variability in the form of dry and wet years or winter and tropical storms impart strong signals that influence both the environmental conditions and the species occupying the estuary. In some cases, species groups also reflect common economic (e.g., commercial or recreational fisheries) or social (e.g., conservation of protected species) values. While this classification scheme is not a perfect system, the proposed groups encompass several desirable ecological characteristics expected of newly created reef-like ecosystems, while considering the effects of the variability of environmental and ecosystem conditions characteristic of the study area. Consideration of the latter point is important. Because the Breakwaters Project would create new structured habitat that would likely be colonized both by species present in the study area before construction and, potentially, by those not currently present (e.g. oysters), it would be important to ensure that species groups present before the project continue to occupy the study area – either on or along Breakwaters Project structures or in nearby waters).

The functional roles of species found in the study area encompass habitat creators, structure-oriented fish and invertebrates, and transient species attracted by the new structured habitat. These functional roles can be refined to include groups of species that ensure that different ecological functions (e.g., habitat forming) are spread across these groups. This approach hedges against the potential absence of a function because of the absence of a particular species or species group by spreading ecological functions across species within and across functional groups. Below each target species group is described in terms of its representative species, ecological roles in both existing estuarine and the newly created reef-like habitats of the Breakwaters Project, and design considerations, and other relevant factors for developing the expected range of possible outcomes from the construction of the Breakwaters Project. Representative taxa comprising each functional group described below were chosen because of their commonness, important ecological role (e.g., keystone species, habitat-formers, or filter-feeder), economic importance (i.e., commercial and recreational fisheries), or conservation status. The taxa listed provide examples of several common or well-known species that provide the services and roles descriptive of each functional group. The functional groups are defined in terms of representative species and taxa; hence, taxa not included in the functional groups described below are not precluded from being included in any of these groups.

HABITAT FORMING AUTOTROPHS

Habitat forming autotrophs would contribute to the base of the Breakwaters Project food web. This group consists of macroalgae species (i.e., seaweed) found on hard substrates throughout the study area and represents the primary producers most likely to colonize the Breakwaters Project. This distinction between habitat-forming autotrophs and phytoplankton was made to emphasize the Breakwaters Project's importance as substrate for habitat formers. Historically common macroalgae species in the Hudson-River Estuary include brown algae (*Fucus* sp.) and green algae (*Ulva lactua*) (Perlmutter 1971). Recent surveys in the study area found that red branching algae (*Agardhiella* spp.), *U. lactuca*, and red filamentous algae were the most common macroalgae sampled. Green algae, however, when found in great abundance may be considered a nuisance species.

Habitat forming macroalgae provide several ecological functions in estuarine systems: primary production/food; nursery, foraging, and spawning habitat for fish and benthic invertebrates; water flow modulation; and nutrient cycling. In addition, seagrass beds could contribute to sediment stabilization in the study area, should they become established in the long-term. Macroalgae require suitable hard substrates and tend to stratify by type and species across the rocky coastlines where they are present, with green algae common in along the shorelines, brown algae in the mid-intertidal zone to sub-tidal waters, and red algae occurring in the lower intertidal waters. Habitat complexity (e.g., the presence of tidal pools, crevices, textured bio-enhanced concrete armoring units) also appears to contribute to macroalgae species diversity (and the benthic community as a whole); thus, Breakwaters Project design considerations such as deploying settlement structures (e.g., tidal pools) throughout the water column would encourage their recruitment and retention (Firth et al. 2014; Evans et al. 2016). The habitat provided by macroalgae and, potentially seagrass beds, could also serve as fish habitat for economically important species at different life stages (e.g., black sea bass, red hake, summer flounder, windowpane, winter flounder, clearnose skates, little skate, winter skate, and striped bass) in the study area. Canopy-forming macroalgae on man-made structures may be subjected to increased grazing pressure by herbivores species on one hand, and damaged by handling and clipping interactions from a wide range of species on the other hand. (Ferrario et al. 2016).

Another benefit of canopy-forming algae is that it can cool tidal pool temperatures by 25%, stabilizing microclimate reducing both weathering and ecological stress (Coombes et al. 2003).

The percent cover, species richness, distribution, and canopy size (e.g., mean stipe length) of macroalgae patches on different Breakwater Project components (waveside and leeside of the core structure, reef streets and fingers, emergent areas, reef ends) and other locations in the study area (neighboring sediments), as well as quantification of the fish and benthic invertebrate community residing in those patches would provide insight into the ecosystem services provided by habitat forming autotrophs. While the presence of seagrass beds provides insight into ecosystem health, they are not expected to benefit directly or immediately from the creation of the breakwaters and should not be considered a target species for the Breakwaters Project, but could be considered in the context of long-term restoration goals for the region set in the Hudson-Raritan Estuary Comprehensive Restoration Plan (USACE 2016a).

BIVALVE HABITAT FORMING SESSILE INVERTEBRATES

The Breakwaters Project would provide structured reef-like habitat designed to attract and retain habitat forming bivalve mollusk species like oysters and mussels. While historically abundant in the Hudson-Raritan Estuary, oysters are rare in the system and the study area (Kurlansky 2007; USACE 2016a; Normandeau 2015 a,b,c,d; SeArc 2015). Because oyster reefs provide important ecological functions in estuarine systems and are indicative of ecosystem health, oysters are the focus of large-scale ecological restoration efforts in the Hudson River Estuary (USACE 2016a). Each segment of the Breakwaters Project would incorporate features that promote oyster recruitment and retention. In addition, the waters over much of the study area (i.e., the Lower Bay region of the Hudson Raritan Estuary) meet water quality criteria for four key parameters linked to oyster egg and larval survival – salinity range, dissolved oxygen, total suspended solids, and bathymetry (USACE 2016a).

Growth of oysters on the Living Breakwater segments would be encouraged through the combination of site selection, use of bio-enhanced concrete units constructed using special concrete admixtures with textured surfaces, multiple sizes of primary granite/rock substrate, gabions filled with spat on shell, and use of several methods to seed each breakwaters segment with oyster spat. Several types of bio-enhancing concrete units would be used including fish hubs; oyster shell containers; tidal planters; oyster hatchery units; and tidal pool units. In addition to oysters, these structures would promote the attraction and retention of macroalgae and other habitat forming invertebrates, as well as fish and benthic invertebrates benefitting from the expected increases in refuge habitat and foraging opportunities. Active oyster restoration techniques on or adjacent to the breakwaters would include: incorporation of spat placement into a small percentage of the bio-enhancing concrete units, the use of oyster shell gabions, spat on shell, oyster nurseries, and in-situ setting pilots. These techniques would draw upon experiences with oyster restoration projects associated with the Hudson Raritan Estuary Comprehensive Restoration Plan, the Hudson River Foundation Oyster Restoration Research Project, and the Billion Oyster Project (USACE 2016a; http://www.hudsonriver.org/?x=orrp; https://www.billionoysterproject.org/).

In addition, not only would creation of viable oyster populations be contingent upon significant labor and capital intensive hatchery and seed planting efforts, but self-sustaining populations also would require continued levels of acceptable water quality, protection from excessive mortality (e.g., poaching, disease), and a network of sufficiently dense breeding populations in the Hudson-Raritan Estuary to ensure a consistent larval supply. Initially, even without the desired outcome of persistent oyster populations on the Breakwaters Project structures,

ecosystem benefits associated with the Breakwaters Project should be similar to those expected from a healthy, artificial oyster reef. Ecologically-designed reef-like structures generally attract other primary habitat forming sessile invertebrates (e.g., barnacles, mussels) and have been shown to support ecological communities that function similarly to restored oyster reef systems (e.g., Grabowski 2005; Luckenback et al. 2005; Gregalis et al. 2008).

Competitive dominant habitat forming species would reduce the space for other primary space holders, but their presence would increase the available niche space for other species including secondary habitat formers (refer to studies cited in Bruno et al. 2003). In other cases, some primary habitat forming species could facilitate the settlement of other primary habitat formers. For example, the presence of mussel beds and barnacles may promote settlement of oyster larvae (Osman 1989). However, other sessile invertebrates, such as bryozoans, ascidians, and boring sponges, negatively impacted oyster larvae settlement (Osman 1989; Barnes 2008).

Beneficial ecosystem functions associated with the establishment of primary habitat forming invertebrates augment many of those associated with creating reef-like habitat. These functions include stabilization of benthic or intertidal habitat, nursery and spawning habitat for fishes, predator refuges for forage fish and juvenile fish and shellfish, and the modification of local currents that may enhance delivery of planktonic food particles to filter-feeding species (Grabowski et al. 2007). In addition, the presence of a healthy population of habitat forming shellfish provide increased forage for fish and other shellfish (e.g., oyster drills and blue crabs), increased opportunities for secondary habitat formers (as reviewed in Bruno et al. 2003), increased benthic-pelagic coupling (filter-feeding and subsequent excretion that transfers energy and biomass from the water column to the neighboring sediments) (e.g., Mann and Harding 1997, 1998; Coen et al. 2007). Studies have also shown that unstructured habitat areas adjoining reefs are associated with increased abundance and species diversity over more isolated unstructured habitat (edge-effects) (Scyphers et al. 2011, 2015).

Several of the considerations for designing a reef-like system amenable to colonization and establishment of populations of oysters and other habitat forming shellfish were discussed above. The construction of the Breakwaters Project, however, must avoid adverse impacts to the existing functioning of the local community, including no adverse impacts to protected species and critical habitat, as well as avoid significant adverse impact to areas of essential fish habitat. Monitoring efforts, therefore, would need to assess that community composition has not notably lost representative taxa or species groups as a result of the construction of the Breakwaters Project (i.e., continued occurrence of species groups observed in existing conditions surveys). The materials used to construct the breakwaters structures and the rugosity, height, length, width, and slope of the structures all influence the settlement of primary habitat forming shellfish. Competition among primary habitat formers might be expected, but presence of one species could facilitate settlement of another (Barnes 2008). Finally, the local abundance of predators and competitors (e.g., boring sponges, *Cliona* sp.) may preclude veliger settlement or facilitate predation by other species (Barnes 2008).

Monitoring studies should characterize the number of different species present and their relative performance. Other useful metrics include density, spatial coverage, growth, and survival of key species (e.g., oysters, mussels, and barnacles) on each breakwater and the different habitat types on each breakwater (e.g., lee vs wave sides). The Breakwaters Project also provides an opportunity to evaluate how colonization by barnacles, mussels, and oysters could facilitate recruitment of other species to the different Breakwaters Project and how those relationships vary at different depths and locations along the breakwaters structures. Measuring water clarity

would provide insight into potential improvements to local water quality attributable to local filter feeding organisms. Measuring the diversity of secondary habitat formers on structures seeded with oysters and on other areas of the each breakwater segment would enable comparison of the effectiveness among areas of actively managed oyster seeding, natural oyster settlement, and on areas initially colonized by mussels and barnacles. These data would quantify key interactions that influence the local ecology and water quality.

NON-BIVALVE HABITAT FORMING SESSILE INVERTEBRATES

Biogenic habitat created by other benthic invertebrates provides additional structural complexity to that associated with the breakwaters structures themselves, while concomitantly increasing the potential for ecosystem functions ranging from filter-feeding, to providing food for local grazers and predators, to creating additional habitat and increasing habitat complexity for fish and other benthic invertebrates, to sequestering carbon, to bioprotection, and to contributing to local biodiversity (Ostroumov 2005; Coen et al. 2007; Aguilera 2014). Bioprotection describes processes by which organisms protect the surfaces they colonize from weathering and erosion. Here the build-up of a biogenic calcium carbonate layer over the Living Breakwater structure would increase both the availability of heterogeneous habitat while contributing to the stability and longevity (Risinger 2012, Coombes et al. 2013). The concepts and approaches used to monitor bivalve habitat formers could be used for this group as well.

Members of this diverse group found in the study area during surveys documenting existing conditions included barnacles, bryozoans, hydroids, tunicates, encrusting sponges, sea anemones, and tube worms (Normandeau 2015 a,b,c,d; SeArc 2015). Species in this group are primarily filter-feeders, but also includes predatory sea anemones. Similar to primary habitat-formers, many members of this species group function as ecosystem engineers that transform their physical environment by accreting biogenic structures that typically outlast the lifespans of the individual organisms, but these structures typically have a smaller spatial scale than, for example, the hard structures associated with oyster reefs or mussel beds (Gutierrez and Jones 2003; Hastings et al. 2007). Note that anemones, tunicates, and sponges do not accrete calcium carbonate and, therefore, do not leave behind the long-lasting structures associated with oysters, mussels, barnacles, or tubeworms. The additional fine-scale habitat complexity created by these habitat formers provides alternative predator refuges and foraging opportunities available to small, mobile invertebrates (Sella and Perkol-Finkel 2015).

While taxa in this group provide similar services, each taxon would occupy different regions of the Breakwaters Project and make distinct contributions to habitat creation, filter-feeding, and other ecosystem services provided by this group. Barnacles inhabit the intertidal zone, but species differ in their preferred elevation band along the intertidal region. These filter-feeders consume plankton and detritus and produce shells composed of calcium carbonate. Barnacles prey for fish, larger crustaceans, and worms. Bryozoans are colonial organisms that form three dimensional aggregations that often encrust hard substrates and algae. These “moss animals” are suspension feeders that consume plankton and detritus. Encrusting bryozoans secrete calcium carbonate and chitin (a polysaccharide that also forms the shells of insects, crabs, and other arthropods) sheets over hard substrate that adds additional relief to hard substrates (i.e., ECOncrete armor units and tide pools, standard armor units, and oyster shell gabions). Bryozoans and their pelagic larvae are prey for nudibranchs, fish, crustaceans, and echinoderms (Lidgard 2008). Taxa found in the existing conditions surveys included *Schizoporella*, *Watersipora* sp., and *Membranipora* (Normandeau 2015 a,b,c,d; SeArc 2015). Tunicates are filter feeders that live as solitary individuals or as colonies and may be sessile or planktonic.

Because tunicates do not produce a durable calcium carbonate skeletal structure that would persist long after the death of a tunicate, they are not considered ecosystem engineers; however, they do add habitat complexity at finer spatial scales and are prodigious filter-feeders. Polychaetes are another important member of the benthic invertebrate community in the Hudson-Raritan estuary system that secretes calcium carbonate tubes around their bodies; this structure provides both protection to these filter-feeding tubeworms and habitat to small fish and benthic invertebrates. Sponges, the simplest of multi-cellular animals, are sessile organisms and efficient filter feeders - capturing particles as small as bacteria. Sponges have different forms, which influences their role as habitat forming species. Encrusting sponges cover the surface of hard substrates, with some local taxa of boring sponge (e.g., *Cliona* sp.) able to influence the local benthic invertebrate community by drilling into accreted calcium carbonate substrate and shells (Barnes 2008). Like tunicates, sponges are neither important prey items nor do they deposit calcium carbonate structures that create and augments local biogenic habitat. Thus, sponges are not considered ecosystem engineers. These habitat forming filter feeders contribute to local habitat complexity on the scale of centimeters to meters and provide additional benthic pelagic coupling. Sponges found in the existing conditions surveys included *Microciona prolifera* and *Halichondria bowerbanki* and the boring sponge (*Cliona* sp.).

The existing conditions surveys found several members of this group are present in the study area and nearby artificial habitat structures: barnacles (e.g., *Amphibalanus* sp., *Chthamalus fragilis*), tube-forming polychaete worms (e.g., *Sabellaria vulgaris*, Serpulidea), sponges (e.g., *Microciona prolifera*, *Halichondria bowerbanki*), anemones (e.g., *Diadumene leucolena*, *D. lineata*, *Metridium senile*), and tunicates (e.g., *Molgula manhattansis*) (Normandeau 2015 a,b,c,d; SeArc 2015).

CRYPTIC FISH

The rocky, reef-like habitat formed by the Breakwaters Project structures would create habitat not currently present in the study area that is suitable for small, structure-oriented, benthic fish species (Normandeau 2015 a,b,c,d; SeArc 2015). Examples of these “cryptic” fish species found in coastal and estuarine waters of New York include gobies (naked, seaboard, and highfin), blennies (feather and freckled), rock gunnel, skilletfish, and oyster toadfish. Recruitment of cryptic fish to the Breakwaters Project would indicate added complexity to the existing food web, because these fish are prey for several fish species, blue crabs, and other invertebrates during foraging forays at the Breakwaters Project (e.g., Mann and Harding 1997, 1998). In additions, these target species group feeds on small benthic invertebrates (e.g., tube worms, amphipods, isopods) (D'Aguillo et al. 2014. Note that while oyster toadfish are included in this group because they use rocky habitats, they are primarily piscivores with few natural predators. Of the species in this group, only oyster toadfish were collected in the study area during seine, trawl, and trap surveys conducted in 2015 to characterize existing biological conditions (Normandeau 2015 a,b,c,d; SeArc 2015). The relative absence of this group in the existing conditions surveys is consistent with the lack of abundant, structured habitat. This group should benefit from the ecological design considerations discussed above, because these fish would be attracted to productive reef-like structures and the protection they offer from predators and foraging opportunities. Thus, features designed to attract habitat forming invertebrates and the resultant community of benthic and epibenthic invertebrates would ultimately attract these cryptic fish species. Specifically, ECOncrete attracted cryptic fish (blennies and gobies) that were not found in non-ecologically designed structural armoring units (Sella and Perkol-Finkel

2015). These fish would use the Breakwaters Project structure for refuge and breeding and rarely occur more than a few feet from structured habitat.

Efforts to monitor cryptic fish relative abundance and distribution on the breakwaters structures would entail either dive or fine-mesh trap studies. These studies would enable the characterization of number of species present and their density, spatial coverage, and preferred habitats. The Breakwaters Project would provide an opportunity measure the colonization rate of these species and to assess their role as forage in higher trophic level organisms. Providing a key link in the trophic system is important because the presence of prey for game fish should attract predators like weakfish and striped bass. Long-term diet studies of these species and their predators would provide important insights into the energetic transfers on the Breakwaters and organisms occupying neighboring habitats.

STRUCTURE-ORIENTED FISH

Natural and man-made reefs and reef-like structures provide the primary habitat for many economically and ecologically important structure-oriented fish species. The use of structured habitat for each of these species varies by life-stage and season, but this group use structured habitat and its surroundings for refuge and feeding at different life stages. The body shape and jaw structure of these species (e.g., tautog, *Tautoga onitis*, black sea bass, *Centropristis striata*; and cunner, *Tautogolabrus adspersus*) are well-suited for navigating highly-structured habitat to consume sessile benthic invertebrates or capturing motile prey. Both tautog and black sea bass are managed along their range in U.S. mid-Atlantic coast and their structure-oriented, non-migratory behaviors has led to population assessments and management efforts at regional to state-by-state scales. Each of the species mentioned have active recreational fisheries in New York, with an average total catch of 2,513,318 black seabass, 1,178,639 tautog, and 36,244 cunner from 2014 to 2015 (Marine Recreational Information Program online query, November 20, 2016; http://www.st.nmfs.noaa.gov/recreational-fisheries/data-and-documentation/queries/index).

Commercial landings of black sea bass in New York averaged 187,085 pounds from 2014 to 2015; over the same period commercial landings of tautog and cunner averaged 116,521 pounds and 3,485 pounds, respectively (https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index, online query November 20, 2016). The most recent stock assessment available for black sea bass reports that the stock is neither overfished nor is it experiencing overfishing (NEFSC 2012). The most recent tautog stock assessment employed regional approach to defining management units rather than assessing the status coast wide and found that the tautog population in New York-New Jersey is currently overfished (ASMFC 2015c).

Because these fish are strongly associated with structure, monitoring their distribution and relative abundance would likely require dive-based surveys (juveniles and adults) and trap surveys (adults – depending on trap mesh size) similar to those employed to monitor the development on the cryptic fish target species group. Because species this group prey on organisms found both on the breakwaters structures and in surrounding waters diet studies would provide information on trophic linkages and energy transfers between the Breakwaters and neighboring habitats.

TRANSIENT/PELAGIC FORAGE FISH

While cryptic fish are important prey for fish feeding on and around structured habitat, pelagic forage fish like anchovies, silversides, and herring are among the most abundant fish in the

coastal ocean and are consumed by just about every piscivorous species where they are found. Recent actions of U.S. Atlantic Coast fisheries management regulators reflect the ecological role of forage fish in supporting higher trophic levels fish species in the ecosystem. In August 2016, the Mid-Atlantic Fishery Management Council approved its Ecosystem Approach to Fisheries Management and passed an amendment to protect forage fish species in Mid-Atlantic that do not have fishery management plans (http://www.mafmc.org/actions/unmanaged-forage). In addition, ecosystem considerations (e.g., trophic interactions) are also a common, if not required component, in federal and interstate fishery management plans and stock assessments (e.g., Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. §§1801 *et seq.*; ASMFC 2016a).

Several species of forage fish can be found in Raritan Bay and neighboring waters, including, but not limited to American shad, Atlantic menhaden, Atlantic herring, killifish, mummichog, river herring (alewife and blueback herring), silversides (Atlantic, inland, rough, and brook), and white mullet. Other forage fish that may be found in the study area include sand lance, sticklebacks, spot, and butterfish. Atlantic silversides, Atlantic menhaden, bay and striped anchovies, mummichog, striped killifish, and white mullet comprised the forage fish found in the study area during existing conditions surveys conducted in June, July, and September 2015. Some of these forage fish support noteworthy fisheries, with Atlantic menhaden supporting the second largest commercial fishery in the U.S. by landings (1,256,192, 000 lbs. in 2014, SEDAR 2015), while the numerical dominance of bay anchovy and silversides in research survey catch as well as their common occurrence in predatory fish (e.g., striped bass, weakfish, bluefish, and summer flounder) stomach contents of supports their key role in the coastal food web dynamics (Houde and Zastrow 1991; Steimle et al. 2000; Bonzek el al. 2014). Many of these forage species are filter feeders, a mechanism often associated with the potential for improving water quality via the net uptake of excess nutrients. In a study investigating the potential for increasing water quality by the filter-feeding of Atlantic menhaden in the Chesapeake Bay suggested that this mechanism had little effect, in part because the uptake of phytoplankton by menhaden was size limited as only Young Of the Year (YOY) fish effectively graze particles the size of phytoplankton (Lynch et al. 2010). Species in this target species group generally consume phytoplankton, zooplankton, and small benthic invertebrates. While all use the Hudson Raritan Estuary, the presence of a particular taxon primarily depends on season and life stage. For example, Atlantic menhaden occur in estuaries during warmer months, but are found offshore during the winter when spawning occurs (SEDAR 2015).

Many of these fish occur in nearshore waters sufficiently removed from structured habitat, so beach seines are effective tools for sampling the relative abundance of these species in the study area. For fish more distant from the shoreline, small otter trawls could be used as well (note that beam trawls used during the existing conditions survey were largely ineffective at sampling fish and macroinvertebrate species). If dive surveys are used to enumerate benthic invertebrates, structure-oriented fish, and cryptic forage fish, then these surveys could also include counts of this target species group and make notes on their use of structured habitat and interactions with other target species groups. Diet studies of higher trophic level of structure-oriented fish and upper trophic level transient fish would provide insight into patterns of prey consumption by higher trophic level fish (e.g., do these transient species tend to eat pelagic forage fish or cryptic forage fish associated with the breakwaters structures?).

UPPER TROPHIC LEVEL TRANSIENT FISH

This group consists of pelagic species that may occasionally forage near structured-habitats to feed on locally abundant forage fish or benthic invertebrates (Mann and Harding 1997, 1998, Scyphers et al. 2011, 2015). These species include popular recreational and commercial fish such as striped bass (*Morone saxitilis*), white perch (*M. americana*), bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), black drum (*Pogonias cromis*), red hake (*Urophycis chuss*), summer flounder (*Paralythis dentatus*), windowpane flounder (*Scopthalmus aquosus*), and winter flounder (*Pseudopleuronectes americanus*) that are likely to forage at the Breakwaters Project or in nearby waters. While Atlantic sturgeon (*Acipenser oxyrhynchus*) are a protected species, they are included in this group because they could occur on the study area during migrations during different life stages.

The species in this target species group constitute some of the most popular recreational and commercial fisheries in New York and along the U.S. mid-Atlantic coast. In New York, the average commercial landing of summer flounder for 2014 and 2015 was 830,881 pounds, while recreational anglers caught 4,484,971 fish on average during the same period. The current stock assessment update found that while the stock currently experiences overfishing, it is not currently overfished; the spawning population abundance is well below the target and has declined in recent years to the lowest levels since the late 1990s (Tercerio 2015). Bluefish commercial landings averaged 949,979 pounds from 2014 to 2015 in New York, while a total of 2,264,921bluefish were caught recreationally during the same period. While the bluefish stock is not currently overfished and is not experiencing overfishing, its estimated abundance has consistently been below the target biomass reference since the early 1990s (NEFSC 2015). In fisheries management, target biomass levels denote the abundance should, on average, be equally likely to be above or below that abundance level; thus, while bluefish are not overfished their abundance levels have consistently fallen below management goals. New York's striped bass commercial landings averaged 510,189 pounds over 2014 to 2015, while the state's recreational fishery caught an average of 920,513 fish each year over the same period. Currently, the coast wide striped bass stock is neither overfished nor is overfishing occurring. Recruitment in the Hudson River declined from 2007 to 2011; however, the 2014 cohort appears strong (ASMFC 2015a). The coast wide weakfish stock abundance is considered low relative to recent decades and the population has experienced high levels of mortality for much of the last 15 years (i.e., total mortality rates exceeding the threshold level) (ASMFC 2016b). In 2014 and 2015, annual commercial landings averaged 28,868 pounds in New York while recreation catch averaged 2,698 fish each year.

New York DOS has declared portions of the Hudson River as "significant coastal fish and wildlife habitat" for striped bass as a protective measure against the year-to-year variability in environmental conditions and harvest levels. In addition, the elasmobranchs clearnose skate, little skate, and winter skate also may forage for benthic fish and invertebrates attracted to the Breakwaters Project. Because many of these fish are managed and have a long history of harvest, estimates of population health are available for several of these species and for some essential fish habitat has been designated for those fish falling under the purview of the federal government. While the construction of the Breakwaters Project would transform some existing soft and hard bottom sediments into ecologically-designed reef-like habitat, the area lost is minimal (2%) of habitat available in the study area and would not be lost all at once but sequentially as each breakwater segment is constructed. Additional foraging opportunities are expected from the construction of the Breakwaters Project, so an increased supply of forage fish and benthic invertebrates would help ensure presence of this group. It is likely that juveniles of

some of these species may also use the Breakwaters Project as predatory refugia during their early life stages. Existing conditions beach seine, trawl, and pot surveys collected bluefish, winter flounder, American eel, weakfish, silver hake, and scup in the study area.

Juveniles of some fish in this target group occur in nearshore waters that are best sampled using beach seines, while otter trawls are better sampling tools for larger fish in the study area. Dive surveys used to enumerate benthic invertebrates, structure-oriented fish, and cryptic forage fish could also include counts of this target species group and make notes on their use of structured habitat and interactions with other target species groups. Diet studies of this higher trophic level group provide insight into patterns of prey consumption at the Breakwaters Project.

BENTHIC MACROINVERTEBRATES

This group spans a diverse group of taxa including crustaceans (e.g., crabs, hermit crabs, lobster), mollusks (e.g., snails, whelks, limpets), and horseshoe crabs. Collectively, these species contribute to a broad range of ecological services in the form of predator-prey interactions (e.g., food for protected shorebirds, detritus consumers) and also support diverse commercial, recreational, and, for horseshoe crabs, biomedical fisheries. Because the ecologically-designed and fully constructed Breakwaters Project would provide both refuge and foraging habitat for the members of this assemblage, benthic macroinvertebrates would likely constitute an important species group on the structure and the surrounding waters (Coen et al. 2007). Many of the species in this group, such as economically important blue crabs, American lobsters, knobbed whelks, and horseshoe crabs, are well-known. Other members of the Raritan Bay benthic invertebrate community (e.g., rock crabs, lady crabs, and oyster drills) are less well-known and do not support large fisheries or venture onto shorelines to spawn (USACE 2016a; Normandeau 2015 a,b,c,d; SeArc 2015). The benthic habitat and fish surveys conducted in the summer and fall of 2015 to document existing biological conditions caught Say mud crabs, blue crabs, lady crabs, portly spider crabs, longwrist hermit crabs, horseshoe crabs, oyster drills, and other species.

Although many of the large crustaceans in this group are opportunistic scavengers or predators, these taxa are preyed upon by other invertebrates, as well as fish (e.g., red drum, croaker) and seabird species. The shellfish species also comprise part of the diet of the two sea turtle species that could occur in the study area (Kemp's Ridley and loggerheads). One highly visible ecosystem service provided by this group is that horseshoe crab eggs deposited on sandy beaches are an important food source for migratory shorebirds including the threatened red knot (*rufa* subspecies). While horseshoe crabs would likely benefit from increased foraging opportunities afforded by the reef-like structure, horseshoe crabs could also benefit from improved shorelines that would serve as spawning habitat. They require access to open, undisturbed sand/pebble beaches in calmer waters, where a portion of the beach is at or above MHW level for egg laying and larval development. Because such habitat is a bottleneck (i.e., a habitat limitation) for this species, it is important to ensure adequate shoreline habitat for nesting and egg/larvae development (ASMFC 2015b). In addition, horseshoe crabs support two commercial fisheries, a bait-fishery and a biomedical fishery that harvests horseshoe crab blood to produce Limulus amoebocyte lysate (LAL) – the most sensitive test available to detect human pathogens in hospitals. Thus, horseshoe crabs are an ecologically and economically important species in the Hudson River Estuary.

The use of ECOncrete® bio-enhancing armor units and the bio-active tide pool units should help to attract and retain habitat forming species. These habitat forming species would then serve as refuge for either benthic macroinvertebrates or their prey, as would the wide range of rock sizes

and different habitats found on the Breakwaters Project segments (waveside and leeside Breakwater cores, reef streets and fingers, emergent areas, reef ends, and adjoining sediments). Macroinvertebrate monitoring programs tracking their spatial and temporal distribution and relative abundance should use multiple methods (e.g., trap, visual, and destructive surveys) to help reduce potential impacts from selectivity and avoidance behaviors. Horseshoe crab spawning surveys can identify areas of beach used and provide insight into areas preferred by spawning adults (i.e., do horseshoe crabs use the restored areas of the beach?).

PROTECTED SPECIES

A final target species group to consider includes protected species that could occur in the study area and are known to use the Hudson River Estuary and neighboring coastal waters. This group includes federally-listed species that have the potential to occur in Raritan Bay, near the project site (NMFS 2015). While endangered Atlantic sturgeon (*Acipenser oxyrhynchus*; New York Bight Distinct Population Segment and others, endangered) occur in the Hudson River Estuary, they are included in the *Upper trophic level transient fish* functional group and discussed there. Hence, species in this target group include sea turtle species that may occur in the study area: loggerhead sea turtle (*Caretta caretta*; threatened), green sea turtle (*Chelonia mydas*; threatened), and Kemp's ridley sea turtle (*Lepidochelys kempi*; endangered) (NMFS 2015). Monitoring efforts for other species, such as the harbor seal (*Phoca vitulina*) should note the presence (and estimated) number of any protected species observed in the study area and cooperate with ongoing regional efforts to monitor these species.

C. REFERENCES

Aguilera, M. A., B. R. Broitman, M. Thiel. 2014. Spatial variability in community composition on a granite breakwater versus natural rocky shores: Lack of microhabitats suppresses intertidal biodiversity. Marine Pollution Bulletin 87: 257-268.

ASMFC. 2015a. Atlantic Striped Bass Stock Assessment Update 2015. Atlantic States Marine Fisheries Commission, Arlington, Virginia. 100 pp.

ASMFC. 2015b. Habitat Bottlenecks and Fisheries Management. Atlantic States Marine Fisheries Commission. Prepared by the ASMFC Habitat Committee, November 2015. Arlington, Virginia. 11 pp.

ASMFC. 2015c. Tautog Benchmark Stock Assessment and Peer Review Reports. Accepted for Management Use February 2015. Atlantic States Marine Fisheries Commission, Arlington, Virginia. 250 pp.

ASMFC. 2016a. Technical Support Group Guidance and Benchmark Stock Assessment Process. Atlantic States Marine Fisheries Commission, Arlington, Virginia. February 2016. 56 pp.

ASMFC. 2016b. Weakfish Benchmark Stock Assessment and Peer Review Report. Atlantic States Marine Fisheries Commission, Arlington, Virginia. 263 pp.

Barnes, B. B. 2008. Interspecific interactions in oyster reef communities: the effect of established fauna on oyster larval recruitment. M. S. Thesis, College of William and Mary. 123 pp.

Berg, D. L. and J. S. Levinton. 1985. The biology of the Hudson-Raritan estuary, with emphasis on fishes. NOAA Technical Memorandum NOS OMA 16. Rockville, MD. April 1985. 180 pp.

Bonzek, C. F., J. Gartland, D. J. Gauthier and R. J. Latour. 2014. Data collection and analysis in support of single and multispecies stock assessments in the Mid-Atlantic: Northeast Area Monitoring

and Assessment Program Near Shore Trawl Survey (NEAMAP). Award Number: NA14NMF4540004. Annual Data Report to the National Oceanographic and Atmospheric Administration, National Marine Fisheries Service - Northeast Fisheries Science Center and the Mid-Atlantic Fishery Management Council. Virginia Insitute of Marine Science, Gloucester Point, VA. 329 pages.

Briggs, P. T. and J. R. Waldman. 2002. Annotated list of fishes reported from the marine waters of New York. Northeastern Naturalist. 9: 47-80.

Browne, M. A. and M. G. Chapman. 2011. Ecologically Informed Engineering Reduces Loss of Intertidal Biodiversity on Artificial Shorelines. Environmental Sciences and Technology 45: 8204–8207.

Bruno, J. F., J. J. Stachowicz, and M. D. Bertness. 2003. Inclusion of facilitation into ecological theory. Trends in Ecology and Evolution. 18: 119-125.

Burt., J., A. Bartholomew, and P. F. Sale. 2011. Benthic community development on large-scale engineered reefs: A comparison of communities among breakwaters of different age and natural reefs. Ecological Engineering 37: 191-198.

Burt, J. A., D. A. Feary, G. Calvalcante, A. G. Bauman, P. Usseglio. 2012. Urban breakwaters as reef fish habitat in the Persian Gulf. Marine Pollution Bulletin 72: 342-350.

Cerrato, R.M. 2006. Long-term and large-scale patterns in the benthic communities of New York Harbor. Pp. 242-265 in: The Hudson River Estuary (J. Levinton and J. Waldman, eds.). Cambridge University Press.

Christiansen, C., H. Christoffersen, J. Dalsgaard, and P. NØrnberg. 1981. Coastal and near-shore changes correlated with die-back in eel-grass (*Zostera marina*, L.). Sedimentary Geology 28:163-173.

Coen, L. D. and R. E. Grizzle. 2007. The Importance of Habitat Created by Molluscan Shellfish to Managed Species along the Atlantic Coast of the United States. Habitat Management Series #8, Atlantic States Marine Fisheries Commission, Washington, D. C. 108 pp.

Coombes M. A., L. A. Naylor, H. A. Viles, and R. C. Thompson. 2003. Bioprotection and disturbance: Seaweed, microclimatic stability and conditions for mechanical weathering in the intertidal zone. Geomorphology 202: 4-14.

Dafforn K. A., T. M. Glasby, and E. L. Johnston. 2012. Comparing the Invasibility of Experimental ‘‘Reefs’’ with Field Observations of Natural Reefs and Artificial Structures. PLoS ONE 7: e38124. doi:10.1371/journal.pone.0038124

D'Aguillo, M. C., A. S. Harold, T. L. Darden. 2014. Diet composition and feeding ecology of the naked goby *Gobiosoma bosc* (Gobiidae) from four western Atlantic estuaries. Journal of Fish Biology 85: 355-73.

Evans A. J., L. B. Firth, S. J. Hawkins, E. S. Morris, H. Goudge, and P. J. Moore. 2016. Drill-cored rock pools: an effective method of ecological enhancement on artificial structures. Marine and Freshwater Research 67: 123–30.

Ferrario, F., L. Iveša, A. Jaklin, S. Perkol-Finkel, and L. Airoldi. 2016. The overlooked role of biotic factors in controlling the ecological performance of artificial marine habitats. Journal of Applied Ecology. 53: 16–24.

Firth, L.B., M. Schofield, F. J. White, M. W. Skova, S. J. Hawkins. 2014. Biodiversity in intertidal rock pools: Informing engineering criteria for artificial habitat enhancement in the built environment. Marine Environmental Research 102: 122-130.

Fonseca, M. S., and J. S. Fisher. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration. Marine Ecology Progress Series 29.

Glasby, T. M., S. D. Connell, M. G. Holloway, and C. L. Hewitt. 2007. Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions? Marine Biology 151: 887-895.

Grabowski, J. H., C. H. Peterson, K. Cuddington, J. Byers, W. Wilson, and A. Hastings. 2007. Restoring oyster reefs to recover ecosystem services. Ecosystem engineers: plants to protists:281-298.

Gregalis, K. C., S. P. Powers, and K. L. Heck, Jr. 2008. Restoration of oyster reefs along a bio-physical gradient in Mobile Bay, Alabama. Journal of Shellfish Research 27: 1163-1169.

Gutierrez J. L., C. G. Jones, D. L. Strayer, and O. O Iribarne. 2003. Mollusks as ecosystem engineers. Oikos 101: 79-90.

Hastings, A. M., J. E. Byers, J. A. Crooks, K. Cuddington, C. G. Jones, J. G. Lambrinos, T. S. Talley, and W. G. Wilson. 2007. Ecosystem engineering in time and space. Ecology Letters 10: 153-164.

Houde, E. D. and C. E. Zastrow, C.E. 1991. Bay anchovy, *Anchoa mitchilli*. In: Funderburk, S.L., Jordan, S.J., Mihursky, J.A., Riley, D. (Eds.), Habitat Requirements for Chesapeake Bay Living Resources. Chesapeake Bay Program, Annapolis, MD, pp. 8-1e8-14.

Jones, C. G., J. H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. Oikos 69:373-386.

Kurlansky, M. 2006. The Big Oyster: History on the Half Shell. Ballantine Books, New York. 336 pp.

Lidgard, S. 2008. Predation on marine bryozoan colonies: taxa, traits and trophic groups. Marine Ecology Progress Series 359: 117-131.

Luckenbach, M. W., L. D. Coen, P. G. Ross, Jr., and J. A. Stephan. 2005. Oyster reef habitat restoration relationships between oyster abundance and community development based on two studies in Virginia and South Carolina. Journal of Coastal Research 40: 64-78.

Lynch, P. D., M. J. Brush, E. D. Condon, R.J. Latour. 2010. Net removal of nitrogen through ingestion of phytoplankton by Atlantic menhaden *Brevoortia tyrannus* in Chesapeake Bay. Marine Ecological Progress Series 401: 195-209.

MacKenzie, C. L. 1990. History of the Fisheries of Raritan Bay, New York and New Jersey. Marine Fisheries Review 52: 1-45.

Mackenzie, C., and L. Stehlik. 1988. Past and present distributions of soft clams and eelgrass in Raritan Bay. Bulletin of the New Jersey Academy of Sciences 33: 61-62.

Mann, R. and J. Harding. 1997. Trophic studies on constructed “restored” oyster reefs. Grant Report to U. S. Environmental Protection Agency, Chesapeake Bay Program Office, Grant No. CB993267-02-1 awarded to the Virginia Institute of Marine Science, Gloucester Point, Virginia. August 1997. 35 pp.

Mann, R. and J. Harding. 1998. Continuing trophic studies on constructed “restored” oyster reefs. Grant Report to U. S. Environmental Protection Agency, Chesapeake Bay Program Office, Grant No.

CB993267-03 awarded to the Virginia Institute of Marine Science, Gloucester Point, Virginia. June 1998. 71 pp.

Micheli, F., B. S. Halpern. 2005. Low functional redundancy in coastal marine assemblages. Ecology Letters. 8: 391-400.

NMFS. 2015. Letter from M. Murray-Brown, NMFS, to C. Seewagen, AKRF, re Living Breakwaters and Tottenville Dune Projects in Richmond County, New York. May 14, 2015.

Nestlerode, J. A. 2004. Evaluating Restored Oyster Reefs in Chesapeake Bay: How Habitat Structure Influences Ecological Function. Ph.D. Dissertation, Virginia Institute of Marine Science, College of William and Mary. 262 pp.

Normandeau Associates. 2015a. Assessment of Existing Condition of Benthic and Fish Communities for the Living Breakwaters and Tottenville Dune Projects: July 2015 Survey Results. 12 pp.

Normandeau Associates. 2015b. Assessment of Existing Condition of Benthic and Fish Communities for the Living Breakwaters and Tottenville Dune Projects: July and September 2015 Benthic Survey Results. 46 pp.

Normandeau Associates. 2015c. Assessment of Existing Condition of Benthic and Fish Communities for the Living Breakwaters and Tottenville Dune Projects: June 2015 Survey Results. 22pp.

Normandeau Associates. 2015d. Assessment of Existing Condition of Benthic and Fish Communities for the Living Breakwaters and Tottenville Dune Projects: September 2015 Fish Survey Results. 12 pp.

Northeast Fisheries Science Center (NEFSC). 2012. 53rd Northeast Regional Stock Assessment Workshop (53rd SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 12-05; 559 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://nefsc.noaa.gov/publications/

Northeast Fisheries Science Center (NEFSC). 2015. 60th Northeast Regional Stock Assessment Workshop (60th SAW) Assessment Report. U. S. Department of Commerce, Northeast Fisheries Science Center Reference Document. 15-08; 870 p. doi: 10.7289/V5W37T9T

Osman, R. W., R. B. Whitlatch, and R. N. Zajac. 1989. Effects of resident species on recruitment into a community: larval settlement versus post-settlement mortality in the oyster *Crassostrea virginica*. Marine Ecology Progress Series 54: 61-73.

Ostroumov, S. A. 2005. Some aspects of water filtering activity of filter-feeders. Hydrobiologia 542: 275-286.

Perkol-Finkel, S., and I. Sella. 2014. Ecologically Active Concrete for Coastal and Marine

Infrastructure: Innovative Matrices and Designs. *In*: Allsop, W., Burgess, K. (Eds.), From Sea to Shore – Meeting the Challenges of the Sea. ICE Publishing, pp. 1139–1149.

Perkol-Finkel, S., and I. Sella. 2015. Harnessing urban coastal infrastructure for ecological enhancement. Pages 102-110 in Proceedings of the Institution of Civil Engineers-Maritime Engineering. Thomas Telford Ltd.

Perlmutter. 1971. Ecological Studies Related to the Proposed Increase in Generating Capacity at the Astoria Power Station of Consolidated Edison. Report prepared for the Consolidated Edison Company of New York, Inc.

Risinger, J. D. 2012. Biologically dominated engineered coastal breakwaters. Ph.D. Dissertation, Interdisciplinary Programs in Engineering Science, Department of Biological and Agricultural Engineering. 139 pp.

Scyphers, S. B., S. P. Powers, K. L. Heck Jr., and D. Byron . 2011. Oyster Reefs as Natural Breakwaters Mitigate Shoreline Loss and Facilitate Fisheries. PLoS ONE 6(8): e22396. doi:10.1371/journal.pone.0022396

Scyphers, S. B., S. P. Powers, and K. L. Heck Jr. 2015. Ecological Value of Submerged Breakwaters for Habitat Enhancement on a Residential Scale. Environmental Management 55: 383–391.

SeArc – Ecological Marine Consulting, Ltd. (SeArc). 2015. Adjacent Artificial Habitat Survey Report Tottenville, Southern Waterfront. Prepared for the Governor's Office of Storm Recovery. December 9, 2015. 31pp.

Sella. I and S. Perkol-Finkel. 2015. Blue is the new green – Ecological enhancement of concrete based coastal and marine infrastructure. Ecological Engineering 84: 260-272.

Short, F., and C. Short. 1984. Seagrass Filter: Purification of Estuarine and Coastal Waters. The Estuary as a Filter, Academic Press, Orlando FL. 1984. p 395-413.

Southeast Data, Assessment, and Review (SEDAR). 2015. SEDAR 40 – Atlantic Menhaden Stock Assessment Report. SEDAR, North Charleston SC. 643 pp.

Steimle, F. W., R. A. Pikanowski, D. G. McMillan, C. A. Zetlin, and S. J. Wilk. 2000. Demersal Fish and American Lobster Diets in the Lower Hudson - Raritan Estuary. NOAA Technical Memorandum NMFS-NE-161. 118 p.

Terceiro M. 2015. Stock assessment update of summer flounder for 2015. U. S. Department of Commerce, Northeast Fisheries Science Center Reference Document. 15-13; 18 p. doi: 10.7289/V57D2S4G

USACE. 2016. Hudson-Raritan Estuary Comprehensive Restoration Plan: Version 1.0. U.S. Army Corps of Engineers, New York District, New York, NY. Contributing authors: U. S. Army Corps of Engineers, HDR, Inc., URS Corporation, The Port Authority of NY & NJ, New York – New Jersey Harbor & Estuary Program, and Hudson River Foundation. 222 pp.

Ward, L. G., W. M. Kemp, and W. R. Boynton. 1984. The influence of waves and seagrass communities on suspended particulates in an estuarine embayment. Marine Geology 59:85-103.

Wen, C. K.-C., K.-S. Chen, H. J. Hsieh, C.-M. Hsu, C. A. Chen. 2013. High coral cover and subsequent high fish richness on mature breakwaters in Taiwan. Marine Pollution Bulletin 72: 53-63.

Zedler, J. B. 2005. Ecological Restoration: Guidance from Theory. San Francisco Estuary and Watershed Science 3: http://escholarship.org/uc/item/707064n0.

Appendix E-7
Tottenville Shoreline Protection Project –
Wetland Delineation

AKRF

Environmental and Planning Consultants

440 Park Avenue South
7th Floor
New York, NY 10016
tel: 212 696-0670
fax: 212 213-3191
www.akrf.com

Memorandum

To: Governor's Office of Storm Recovery (GOSR)

From: Jesse Moore, AKRF

Date: December 15, 2016

Re: Tottenville Shoreline Protection Project – Wetland Delineation

cc: Sandy Collins, AKRF

INTRODUCTION

The Governor's Office of Storm Recovery (GOSR) is proposing the Tottenville Shoreline Protection project (Shoreline Project), a series of shoreline protection measures, including an earthen berm, eco-revetment, hybrid dune system, and raised edge (revetment with trail) with revetment, along with wetland enhancements, and landscaping with native coastal plant species, from approximately west of the intersection of Swinnerton Street and Billop Avenue to Page Avenue (**Figure 1**).

In August 2016, AKRF delineated one wetland (Wetland F) in the Study Area and two wetlands (Wetlands AB and G) off site for purposes of identifying any freshwater wetland buffer areas. This memorandum outlines the details of the wetland delineation.

METHODOLOGY

Prior to the wetland delineation, United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) (see **Figure 2**) and New York State Department of Environmental Conservation (NYSDEC) (see **Figure 3**) maps were reviewed to determine locations of state-mapped and/or NWI-mapped wetlands on and in the vicinity of the Study Area. The Natural Resources Conservation Service (NRCS) soils maps (see **Figure 4**) were also reviewed to determine soil types within the Study Area, particularly with respect to soil series identified as hydric. AKRF wetland scientists conducted a wetland delineation of the Study Area on August 8, 2016 and August 10, 2016, using the United States Army Corps of Engineers (USACE) wetland delineation methodology.[1] Methodology pertaining to the three USACE wetland indicators (i.e., hydrology, soils, and hydrophytic vegetation) is described below. The

[1] Environmental Laboratory. 1987. "Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss; U.S. Army Corps of Engineers. 2011. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (version 2.0), ed. J.S. Wakeley, R.W. Lichvar, C.V. Noble, and J.F. Berkowitz. ERDC/EL TR-12-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

USACE *Wetland Determination Data Form – Northcentral and Northeast Region* (2012) was used to document the wetlands observed on the Study Area. Photographs were also taken of the delineated wetlands (see **Figures 5** and **6**).

HYDROLOGY AND SOILS

The hydrology of the Study Area was characterized using aerial photographs, site observations, and an auger to determine soil saturation and/or a high water table. Soils were characterized with the use of an auger and a Munsell Soil Color Chart. During the wetland delineation, both hydrology and soils observations were made during a period of dry weather.

VEGETATION

The USACE *Northcentral and Northeast 2014 Regional Wetland Plant List* was used to determine the wetland/upland status[2] of the plant species identified on the Study Area. Percent cover was documented in the tree, woody vine, sapling/shrub, and herbaceous strata. In most instances, a 30-foot (ft) radius plot was established to document plant species percent cover in the tree and vine strata. Within this 30-ft plot, a 15-ft radius plot was established for the measurement of percent cover of shrubs and saplings. For species in the herbaceous stratum, a 5-ft radius plot was established within the 30-ft radius plot.

EXISTING CONDITIONS

MAPPING

National Wetlands Inventory-Mapped Wetlands

NWI wetland maps indicate that one freshwater wetland and six tidal wetlands occur within the vicinity of the Study Area, and two freshwater wetlands occur offsite and were delineated for purposes of assessing whether the New York State Department of Environmental Conservation (NYSDEC) freshwater wetland buffer was within the Study Area (see **Figure 2**). The NWI-mapped freshwater wetland within the vicinity of the Study Area is a palustrine unconsolidated bottom/scrub-shrub wetland with broad-leaved deciduous vegetation that is semi-permanent-tidal (PUB/SS1T). The NWI-mapped tidal wetlands include: an estuarine intertidal wetland dominated by emergent persistent vegetation that is irregularly flooded (E2EM1P), an estuarine intertidal wetland with an unconsolidated sand shore that is irregularly flooded (E2US2P), an estuarine intertidal wetland with an unconsolidated sand shore that is regularly flooded (E2US2N), an estuarine subtidal wetland with an unconsolidated bottom that is permanently flooded and oligohaline (E1UBL6), an estuarine intertidal wetland with emergent persistent vegetation that is irregularly flooded and oligohaline (E2EM1P6), and an estuarine intertidal wetland with emergent *Phragmites australis* dominated vegetation that is irregularly flooded and oligohaline (E2EM5P6). The two offsite NWI-mapped freshwater wetlands include: a palustrine forested wetland with broad-leaved deciduous vegetation that is seasonally flooded and/or saturated (PFO1E) and a palustrine wetland with emergent *Phragmites australis* dominated vegetation that is seasonally flooded and/or saturated (PEM5E). Site inspection confirms wetland type and approximate locations of the E2US2P, E2US2N, E2EM5P6, E2EM1P6, E1UBL6, PFO1E, and PEM5E wetlands. However, site inspection does not confirm the presence of the E2EM1P and PUB/SS1T wetlands.

New York State Department of Environmental Conservation-Mapped Wetlands

NYSDEC tidal wetland maps indicate littoral zone tidal wetlands (LZ) occur within the vicinity of the Study Area (see **Figure 3**). LZ wetlands are the tidal wetland zone that is permanently flooded by no

[2] Wetland/upland statuses for plant species include Obligate (OBL; occurring in wetlands greater than or equal to 99 percent of the time), Facultative Wetland (FACW; occurring in wetlands between 67 and 99 percent of the time), Facultative (FAC; occurring in wetlands between 34 and 66 percent of the time), Facultative Upland (FACU; occurring in wetlands between 1 and 33 percent of the time), and Upland (UPL; occurring in wetlands less than or equal to 1 percent of the time). Dominant species indicative of wetlands include species rated as OBL, FACW, and FAC.

more than 6 feet of water at mean low water (MLW) and is not included in any other wetland category. Site inspection confirms these mapped wetland types and approximate locations. There are two NYSDEC-mapped freshwater wetlands within the vicinity of the Study Area, AR-22 to the west of the Study Area and AR-15 to the east of the Study Area (see **Figure 3**). The two NYSDEC-mapped freshwater wetlands are located more than 100 feet from the Study Area, thus the Study Area is not within the NYSDEC-regulated freshwater wetland adjacent area for AR-15 or AR-22.

Natural Resources Conservation Service -Mapped Soils

Within the Study Area soils are mapped as "Be – Beaches," "BtA – Boonton loam, 0 to 3 percent slopes," "CaA – Catden muck, 0 to 2 percent slopes," "FrA – Fortress fine sandy loam, 0 to 3 percent slopes," "GUA – Greenbelt-Urban land complex, 3 to 8 percent slopes," "GUB – Greenbelt-Uban land complex, 3 to 8 percent slopes," "HHA – Haledon-Hasbrouck complex, 0 to 3 percent slopes, frequently ponded," "NoA – North Meadow sandy loam, 0 to 3 percent slopes," "PkA – Preakness mucky silt loam, 0 to 3 percent slopes," "PvA – Preakness silt loam, 0 to 3 percent slopes, frequently ponded," "UGA – Urban land-Greenbelt complex, 0 to 3 percent slopes," "ULA – Urban land-Laguardia complex, 0 to 3 percent slopes," and "WbA – Westbrook mucky peat, sandy substratum, 0 to 1 percent slopes, very frequently flooded" by NRCS (see **Figure 4**). The NRCS lists five of the series mapped for the Study Area as hydric: CaA, HHA, PkA, PvA, and WbA. Hydric soil is one of the three parameters that define a wetland according to the USACE methodology.

ONSITE DELINEATION

One wetland (Wetland F) was delineated within the Study Area and two wetlands (Wetlands AB and G) were delineated in the vicinity of the Study Area in August 2016 (see **Surveyed Wetland Drawings**). These wetlands were flagged as follows:

- Wetland AB: A-1 to A-9, B-1 to B-19;
- Wetland F: F-1 to F-37; and
- Wetland G: G-1 to G-19.

Wetland AB

Wetland AB is a freshwater emergent wetland located in the vicinity of the eastern portion of the Study Area, east of Page Avenue in Butler Manor Woods (see **Figure 6a, Photographs 1 and 2**). The soils, hydrology, and hydrophytic vegetation of Wetland AB are described below.

The Data Form for Wetland AB depicts the dominant species associated with this wetland. These species include pin oak (*Quercus palustris*) (FACW) and red maple (*Acer rubrum*) (FAC) in the tree layer, common reed (*Phragmites australis*) (FACW) for the herbaceous layer and poison ivy (*Toxicodendron radicans*) (FAC) for the woody vine layer.

Soils of this wetland meet the criteria of "F6 Redox Dark Surface." The primary hydrology indicators are "B7 Inundation Visible on Aerial Imagery," "B8 Sparsely Vegetated Concave Surface," and "B9 Water-stained Leaves." The secondary hydrology indicator is "B16 Moss Trim Lines" (see Data Form Wetland AB).

Upland AB

This upland area is located between to Wetland AB and a walking trail to the west. The dominant species associated with the upland area are sweetgum (*Liquidambar styraciflua*) (FAC) and pin oak (FACW) in the tree layer, hackberry (*Celtis occidentalis*) (FAC) in the sapling/shrub layer, common mugwort (*Artemisia vulgaris*) (UPL) in the herb layer, and poison ivy (FAC) in the woody vine layer. The soils and hydrology of this area do not meet the USACE criteria for a wetland. For these reasons, this area was documented as upland (see Data Form for Upland AB).

Wetland F

Wetland F is a tidal emergent wetland located in the western portion of the Study Area, south of Billop Avenue and west of Manhattan Street (see **Figure 6b, Photographs 3 and 4**). The soils, hydrology, and hydrophytic vegetation of Wetland F are described below.

The Data Form for Wetland F depicts the dominant species associated with this wetland. These species include common reed (FACW) in the herbaceous layer.

Soils of this wetland meet the criteria of "S1 Sandy Mucky Mineral." The primary hydrology indicators are "A2 High Water Table" at 7 inches depth, "A3 Saturation" at the surface, and "B1 Water Marks." The secondary hydrology indicators are "B10 Drainage Patterns" and "D2 Geomorphic Position" due to its location in a depression adjacent to tidal waters with a connection to these tidal waters via a culvert (see Data Form Wetland F).

Upland F

This upland area is located south of Wetland F along the maritime dune. The maritime dune is unvegetated. The vegetation, soils, and hydrology of this area do not meet the USACE criteria for a wetland. For these reasons, this area was documented as upland (see Data Form for Upland F).

Wetland G

Wetland G is a freshwater/tidal emergent wetland complex located in the vicinity of the western portion of the Study Area, in Conference House Park (see **Figure 6c, Photographs 5 and 6**). The soils, hydrology, and hydrophytic vegetation of Wetland G are described below.

The Data Form for Wetland G lists the dominant species associated with this wetland. These species include buttonbush (*Cephalanthus occidentalis*) (OBL) in the sapling/shrub layer and arrow arum (*Peltandra virginica*) (OBL) in the herbaceous layer.

Soils of this wetland meet the criteria of "S1 Sandy Mucky Mineral." The primary hydrology indicators are "A1 Surface Water" at over 6 inches deep, "A2 High Water Table" at 9 inches below surface, "A3 Saturation" observed at the surface, "B7 Inundation Visible on Aerial Imagery," "B13 Aquatic Fauna," and "B9 Water-stained Leaves." (see Data Form Wetland G).

Upland G

This upland area is located east of Wetland G. The dominant species associated with the upland area are pin oak (FACW) in the tree layer, pokeweed (*Phytolacca americana*) (FACU) and wineberry (*Rubus phoenicolasius*) (FACU) in the herbaceous layer. The vegetation, soils, and hydrology of this area do not meet the USACE criteria for a wetland. For these reasons, this area was documented as upland (see Data Form for Upland G).

CONCLUSIONS AND RECOMMENDATIONS

As described above, one vegetated freshwater emergent wetland (Wetlands AB) within the Study Area one wetland containing both freshwater and tidal emergent areas (Wetland G) within the vicinity of the Study Area, and one vegetated tidal emergent wetland (Wetlands F) within the Study Area were delineated, as per the USACE wetland delineation methodology. Any impacts to federally- or state-mapped wetlands are subject to Section 401 and 404 permits under the Clean Water Act and Tidal Wetland permits under Article 25 and Freshwater Wetland permits under Article 24 of the Environmental Conservation Law.

Figures:

1. USGS Topographic Map
2. NWI Wetlands
3. NYSDEC Tidal Wetlands
4. NRCS Soils

5. Photograph Key
6. Representative Site Photographs

Attachments:

Surveyed Wetland Drawings

USACE Wetland Determination Forms

2/10/2017

Source: USGS Topo base map service from The National Map

Proposed Breakwater Features

Proposed Shoreline Restoration Area

Approximate Location of Proposed Water Hub and Accessory Seasonal Boat Launch (exact location to be determined)

Proposed Shoreline Project Elements

Proposed Floating Dock and Oyster Nursery

0 1,000 FEET

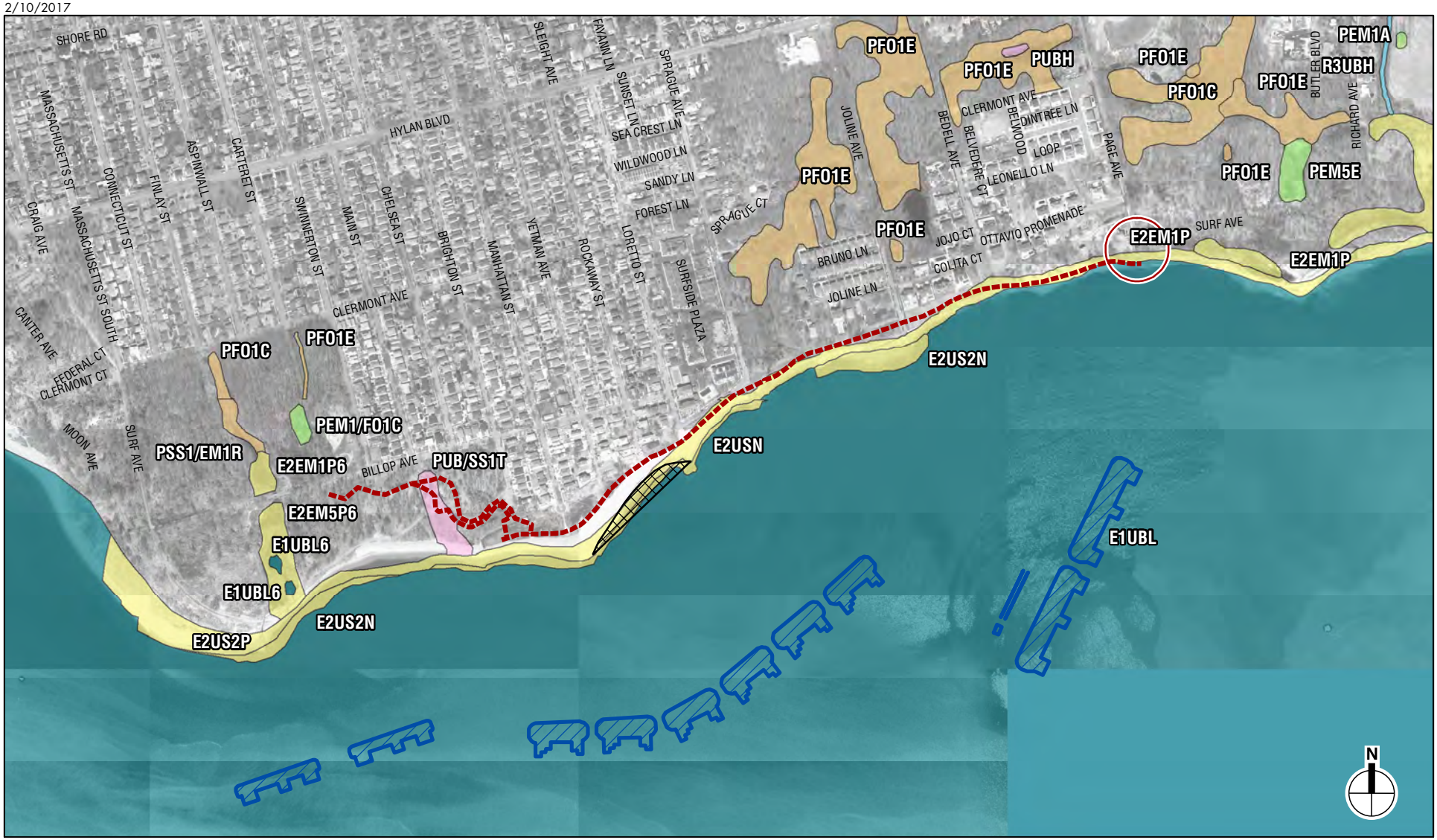
Approximate coordinates of Project Site:
74°14'13"W 40°29'59"N

USGS 7.5 Minute Topographic Map
Arthur Kill Quad

Coastal and Social Resiliency Initiatives for Tottenville Shoreline

Figure 1

2/10/2017



Proposed Breakwater Features

Proposed Shoreline Restoration Area

Proposed Floating Dock and Oyster Nursery

Proposed Shoreline Project Elements

Approximate Location of Proposed Water Hub and Accessory Seasonal Boat Launch (exact location to be determined)

Freshwater Forested/Shrub Wetland (PFO, PSS)

Freshwater Emergent Wetland (PEM)

Freshwater Pond (PUB, PAB)

Estuarine and Marine Wetland (E2, M2)

Riverine (R)

Estuarine and Marine Deepwater (E1, M1)

0 1,000 FEET

U.S. Fish and Wildlife Service
National Wetlands Inventory

Coastal and Social Resiliency Initiatives for Tottenville Shoreline

Figure 2

2/10/2017

Proposed Breakwater Features

Proposed Shoreline Restoration Area

Proposed Floating Dock and Oyster Nursery

Proposed Shoreline Project Elements

Approximate Location of Proposed Water Hub and Accessory Seasonal Boat Launch (exact location to be determined)

NYSDEC Tidal Wetlands (1974)

Littoral Zone (LZ)

State-regulated freshwater wetlands

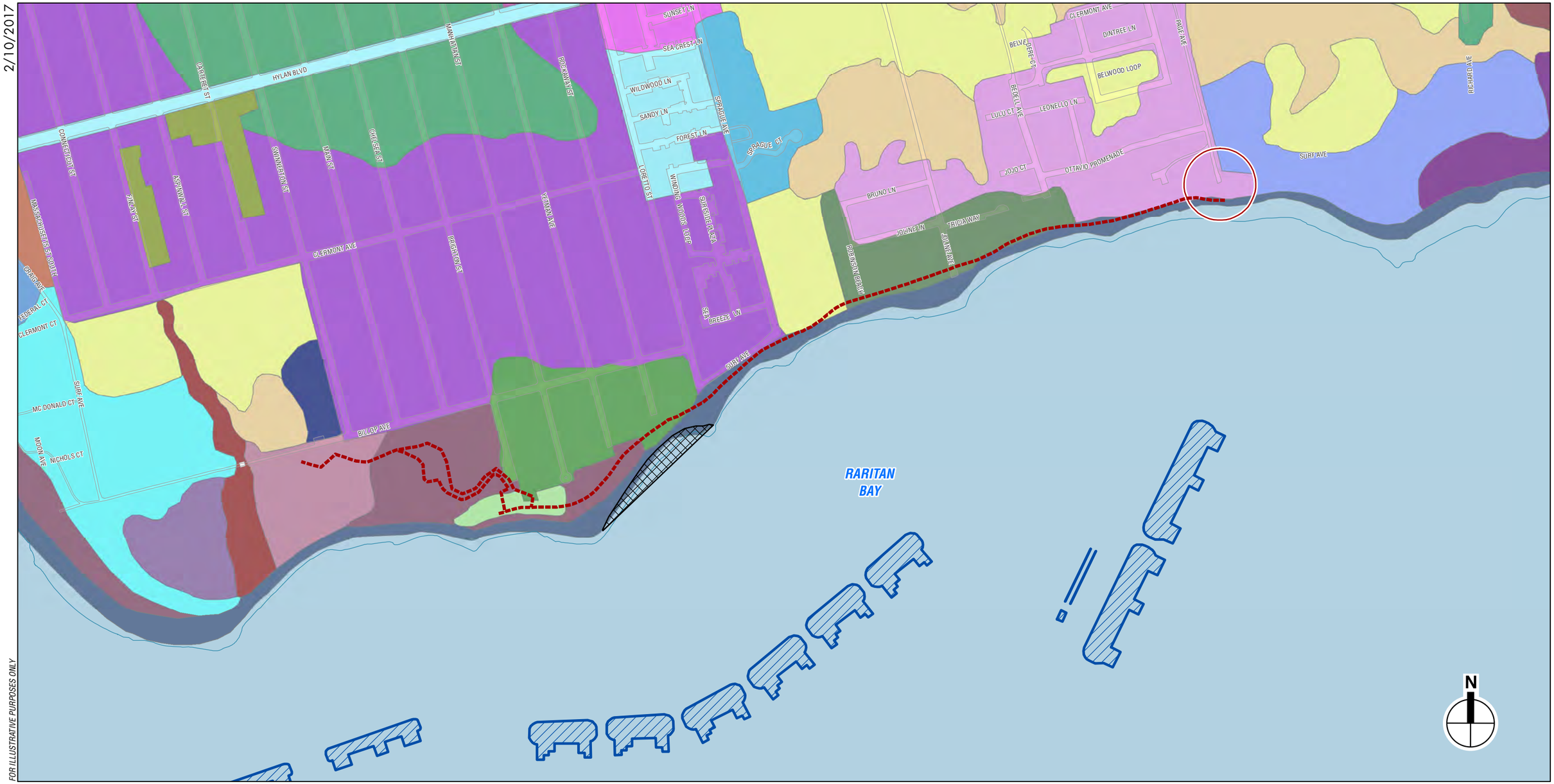
0 2,000 FEET

NYSDEC Freshwater Wetlands

Coastal and Social Resiliency Initiatives for Tottenville Shoreline

Figure 3

2/10/2017



FOR ILLUSTRATIVE PURPOSES ONLY

Proposed Breakwater Features

Proposed Shoreline Restoration Area

Proposed Shoreline Project Elements

Approximate Location of Proposed Water Hub and Accessory Seasonal Boat Launch (exact location to be determined)

Proposed Floating Dock and Oyster Nursery

BHBu	ELUA	HHA	PvA	UVBl
Be	FrA	HaA	UGA	UsA
BtA	GUA	IwA	UGAl	UtA
BtB	GUB	NoA	UGB	WbA
CaA	GbA	PkA	ULA	WiC

0 1,000 FEET

Soils Map
Figure 4

Coastal and Social Resiliency Initiatives for Tottenville Shoreline

2/10/2017

FOR ILLUSTRATIVE PURPOSES ONLY

Proposed Breakwater Features

Proposed Shoreline Restoration Area

Proposed Shoreline Project Elements

Approximate Location of Proposed Water Hub and Accessory Seasonal Boat Launch (exact location to be determined)

Proposed Floating Dock and Oyster Nursery

Photograph View Direction and Reference Number

0 1,000 FEET

Natural Resources
Key to Photographs

Coastal and Social Resiliency Initiatives for Tottenville Shoreline

Figure 5

View of Wetland AB, facing southeast **1**

View of Wetland AB, facing west **2**

Natural Resources
Photographs
Figure 6a

View of Wetland F, facing east **3**

View of Wetland F, facing north **4**

Natural Resources
Photographs
Figure 6b

View of Wetland G, facing north **5**

View of Wetland G, facing south **6**

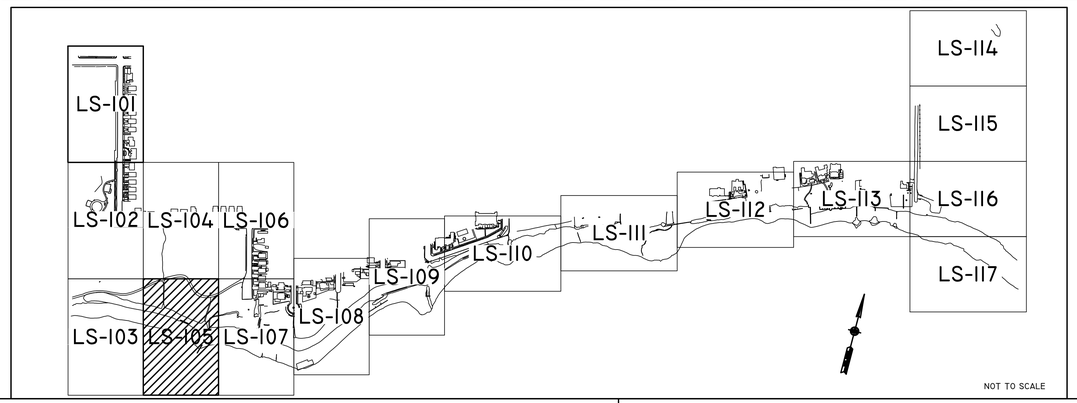
Natural Resources
Photographs
Figure 6c

MATCH LINE SEE SHEET LS-107

MATCH LINE SEE SHEET LS-103

20' 0 10' 20' 40' 80'

GRAPHIC SCALE



30% DESIGN DEVELOPMENT
NOT FOR CONSTRUCTION

CITY OF NEW YORK
PARKS & RECREATION
OLMSTED CENTER
FLUSHING MEADOWS CORONA PARK
FLUSHING, NEW YORK 11368

PROJECT TITLE
TOTTENVILLE SHORELINE PROTECTION PROJECT

DRAWING TITLE
TOPOGRAPHIC SURVEY - SHEET 5 OF 17

DESIGNED BY X. XXXX	DRAWN BY P.POZNANSKI	CHECKED BY C.MEE
REVIEWED-TEAM LEADER X. XXXX	FORESTRY X. XXXX	APPROVED-DIRECTOR X. XXXX
APPROVED DEPUTY CHIEF OF DESIGN X. XXXX	APPROVED-CHIEF ENGINEER X. XXXX	CONTRACT NO. XXXXXXX
DATE: MONTH DD, YYYY	B-SCAN	SCALE 1" = 20'-0"
BLOCK NNNN		DRAWING NO. LS-105
LOT LLL		DATE 06/15/2016

Naik GROUP
253 WEST 30TH STREET NEW YORK, NY 10001
Ph: 212.575.2701

SHEET No. 13 OF 114 SHEETS

MATCH LINE SEE SHEET LS-106

MANHATTAN STREET

MATCH LINE SEE SHEET LS-108

MATCH LINE SEE SHEET LS-105

BLOCK 7881

BLOCK 7857

#460 3 STY. BRICK & FRAME 16

#464 3 STY. BRICK & FRAME 18

#463 2 STY. BRICK & FRAME 46

#469 3 ½ STY. FRAME 43

POOL

DECK

STEPS

PAVED DRIVE

CONC.

GRASS

1' BR.WALL

LANDSC.

3'H STONE WALL

PLANTERS

STONE C.

PRIVATE PROPERTY

ELEVATED WOODEN DECK

CONC. WALK (G)

ASPHALT PVMT. (G)

GRAVEL

VEGETATION LINE

SAND LINE

DENSE TREE COVER

DENSE BRUSH COVER

PHRAGMITES

DITCH WETLAND AREA

DITCH BOTTOM LINE

DITCH

WETLAND LINE

SWAMP

SAND DUNES

DUNE FABRIC

SAND

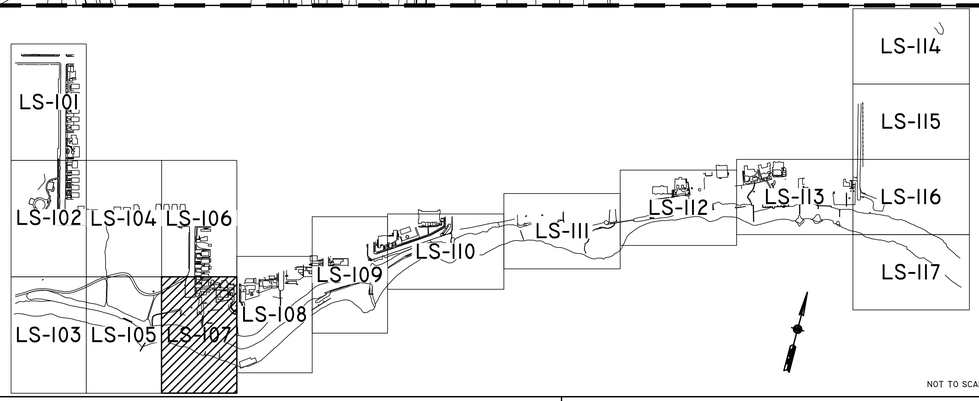
WOODEN DOCK RUINS

RARITAN BAY

TIDE NORTH

20' 0 10' 20' 40' 80'

GRAPHIC SCALE



NOT TO SCALE

30% DESIGN DEVELOPMENT
NOT FOR CONSTRUCTION

CITY OF NEW YORK
PARKS & RECREATION
OLMSTED CENTER
FLUSHING MEADOWS CORONA PARK
FLUSHING, NEW YORK 11368

PROJECT TITLE
TOTTENVILLE SHORELINE PROTECTION PROJECT

DRAWING TITLE
TOPOGRAPHIC SURVEY - SHEET 7 OF 17

DESIGNED BY X. XXXX	DRAWN BY P.POZNANSKI	CHECKED BY C.MEE
REVIEWED-TEAM LEADER X. XXXX	FORESTRY X. XXXX	APPROVED-DIRECTOR X. XXXX
APPROVED DEPUTY CHIEF OF DESIGN X. XXXX	APPROVED-CHIEF ENGINEER X. XXXX	CONTRACT NO. XXXXXXX
B-SCAN	SCALE 1" = 20'-0"	DRAWING NO. LS-107
	DATE 06/15/2016	SHEET No. 15 OF 114 SHEETS

DATE: MONTH DD, YYYY
BLOCK NNNN
LOT LLL

Naik GROUP
253 WEST 35TH STREET NEW YORK, NY 10001
Ph: 212.575.2701

WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: Living Breakwaters City/County: Richmond County Sampling Date: 08/08/2016

Applicant/Owner: Governor's Office of Storm Recovery (GOSR) State: NY Sampling Point: Wetland AB

Investigator(s): Jesse Moore, Teresa Cannone, AKRF, Inc. Section, Township, Range: Tottenville

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): ____

Subregion (LRR or MLRA): MLRA 149B of LRR S Lat: 40.503870 Long: -74.224968 Datum: ____

Soil Map Unit Name: PkA – Preakness mucky silt loam 0 to 3 percent slopes NWI classification: PEM5E

Are climatic/hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation N, Soil N, or Hydrology N naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X No ____	**Is the Sampled Area within a Wetland?**	**Yes** X **No** ____
Hydric Soil Present?	Yes X No ____	If yes, optional Wetland Site ID:	
Wetland Hydrology Present?	Yes X No ____		

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ____ Surface Water (A1)
- ____ High Water Table (A2)
- ____ Saturation (A3)
- ____ Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- X Inundation Visible on Aerial Imagery (B7)
- X Sparsely Vegetated Concave Surface (B8)
- X Water-Stained Leaves (B9)
- ____ Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- ____ Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- ____ Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- ____ Drainage Patterns (B10)
- X Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- ____ Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present?	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** X **No**

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION – Use scientific names of plants. Sampling Point: Wetland AB

Tree Stratum (Plot size: 30' radius)	Absolute % Cover	Dominant Species?	Indicator Status
1. *Quercus palustris*	20	Y	FACW
2. *Acer rubrum*	15	Y	FAC
3. *Liquidambar styraciflua*	7	N	FAC
4.			
5.			
6.			
7.			
	42	=Total Cover	
Sapling/Shrub Stratum (Plot size: 15' radius)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	0	=Total Cover	
Herb Stratum (Plot Size: 5' radius)			
1. *Phragmites australis*	85	Y	FACW
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9..			
10.			
11.			
12.			
	85	=Total Cover	
Woody Vine Stratum (Plot size: 30' radius)			
1. *Toxicodendron radicans*	5	Y	FAC
2.			
3.			
4.			
	5	=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index Worksheet:

Total % Cover of:		Multiply by	
OBL species		x1=	
FACW species		x2=	
FAC species		x3=	
FACU species		x4=	
UPL species		x5=	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ___ 1 – Rapid Test for Hydrophytic Vegetation
- X 2 – Dominance Test is >50%
- ___ 3 – Prevalence Index is #3.0[1]
- ___ 4 – Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and creater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Wetland AB

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Redox Features Type[1]	Redox Features Loc[2]	Texture	Remarks
0-2	7.5YR 3/2	100					Organic matter	
2-11	10YR 3/2	75	5YR 3/4	5	C	M	Silty clay	
	10YR 8/6	10						
	10YR 2/1	10						
11-24	10YR 3/2	85	7.5YR 5/8	15	C	M	Silty clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ____ Histosol (A1)
- ____ Histic Epipedon (A2)
- ____ Black Histic (A3)
- ____ Hydrogen Sulfide (A4)
- ____ Stratified Layers (A5)
- ____ Depleted Below Dark Surface (A11)
- ____ Thick Dark Surface (A12)
- ____ Sandy Mucky Mineral (S1)
- ____ Sandy Gleyed Matrix (S4)
- ____ Sandy Redox (S5)
- ____ Stripped Matrix (S6)
- ____ Dark Surface (s7) (**LRR, MLRA, 149B**)
- ____ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ____ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ____ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ____ Loamy Gleyed Matrix (F2)
- ____ Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ____ Depleted Dark Surface (F7)
- ____ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ____ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ____ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ____ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ____ Dark Surface (S7) (**LRR, K, L**)
- ____ Polyvalue Below Surface (S8) (**LRR K, L**)
- ____ Thin Dark Surface (S9) (**LRR K, L**)
- ____ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ____ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ____ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- Red Parent Material (F21)
- ____ Very Shallow Dark Surface (TF12)
- ____ Other (explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Field Observations:
Type: _____
Depth (inches): _____

Hydric Soil Present? **Yes** X **No**

Remarks:

WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: Living Breakwaters City/County: Richmond County Sampling Date: 08/10/2016

Applicant/Owner: GOSR State: NY Sampling Point: Wetland F

Investigator(s): Jesse Moore, Teresa Cannone, AKRF, Inc. Section, Township, Range: Tottenville

Landform (hillslope, terrace, etc.): Depression Local relief (concave, convex, none): Concave Slope (%): ____

Subregion (LRR or MLRA): MLRA 149B of LRR S Lat: 40.498005 Long: -74.240877 Datum: ____

Soil Map Unit Name: ULA NWI classification: None

Are climatic/hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation N, Soil N, or Hydrology N naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X No ____	**Is the Sampled Area within a Wetland?**	**Yes** X **No** ____
Hydric Soil Present?	Yes X No ____	If yes, optional Wetland Site ID:	
Wetland Hydrology Present?	Yes X No ____		

Remarks: (Explain alternative procedures here or in a separate report.)

A berm separates wetland F into two sections which are connected by a culvert.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ____ Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- X Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- ____ Inundation Visible on Aerial Imagery (B7)
- ____ Sparsely Vegetated Concave Surface (B8)
- ____ Water-Stained Leaves (B9)
- ____ Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- ____ Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- X Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- X Drainage Patterns (B10)
- ____ Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- X Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes X	No ____	Depth (inches): 7"
Saturation Present?	Yes X	No ____	Depth (inches): Surface

Wetland Hydrology Present? **Yes** X **No**

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION – Use scientific names of plants.

Sampling Point: Wetland F

Tree Stratum (Plot size: 30' radius)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	0	=Total Cover	

Sapling/Shrub Stratum (Plot size: 15' radius)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	0	=Total Cover	

Herb Stratum (Plot Size: 5' radius)			
1. *Phragmites australis*	85	Y	FACW
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9..			
10.			
11.			
12.			
	85	=Total Cover	

Woody Vine Stratum (Plot size: 30' radius)			
1.			
2.			
3.			
4.			
	0	=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 1 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index Worksheet:

Total % Cover of:		Multiply by	
OBL species		x1=	
FACW species		x2=	
FAC species		x3=	
FACU species		x4=	
UPL species		x5=	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ___ 1 – Rapid Test for Hydrophytic Vegetation
- X 2 – Dominance Test is >50%
- ___ 3 – Prevalence Index is #3.0[1]
- ___ 4 – Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and creater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Wetland F

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-7	5Y 2.5/1	10	10YR 5/6	5	C	M	Mucky sandy silt	
	2.5Y 3/2	85						
7-19	10YR 3/2	100					Silty clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ____ Histosol (A1)
- ____ Histic Epipedon (A2)
- ____ Black Histic (A3)
- ____ Hydrogen Sulfide (A4)
- ____ Stratified Layers (A5)
- ____ Depleted Below Dark Surface (A11)
- ____ Thick Dark Surface (A12)
- X Sandy Mucky Mineral (S1)
- ____ Sandy Gleyed Matrix (S4)
- ____ Sandy Redox (S5)
- ____ Stripped Matrix (S6)
- ____ Dark Surface (s7) (**LRR, MLRA, 149B**)
- ____ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ____ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ____ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ____ Loamy Gleyed Matrix (F2)
- ____ Depleted Matrix (F3)
- ____ Redox Dark Surface (F6)
- ____ Depleted Dark Surface (F7)
- ____ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ____ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ____ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ____ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ____ Dark Surface (S7) (**LRR, K, L**)
- ____ Polyvalue Below Surface (S8) (**LRR K, L**)
- ____ Thin Dark Surface (S9) (**LRR K, L**)
- ____ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ____ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ____ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- Red Parent Material (F21)
- ____ Very Shallow Dark Surface (TF12)
- ____ Other (explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Field Observations:
Type: _____
Depth (inches): _____

Hydric Soil Present? **Yes** X **No**

Remarks:

WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: Living Breakwaters City/County: Richmond County Sampling Date: 08/10/2016

Applicant/Owner: GOSR State: NY Sampling Point: Wetland G

Investigator(s): Jesse Moore, Teresa Cannone, AKRF, Inc. Section, Township, Range: Tottenville

Landform (hillslope, terrace, etc.): None Local relief (concave, convex, none): None Slope (%): ____

Subregion (LRR or MLRA): MLRA 149B of LRR S Lat: 40.498934 Long: -74.246452 Datum: ____

Soil Map Unit Name: CaA, HaA NWI classification: None

Are climatic/hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation N, Soil N, or Hydrology N naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X No ____	**Is the Sampled Area within a Wetland?**	**Yes** X **No** ____
Hydric Soil Present?	Yes X No ____	If yes, optional Wetland Site ID:	
Wetland Hydrology Present?	Yes X No ____		

Remarks: (Explain alternative procedures here or in a separate report.)

Sampling point near wetland flag G19.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- ____ Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- X Inundation Visible on Aerial Imagery (B7)
- ____ Sparsely Vegetated Concave Surface (B8)
- X Water-Stained Leaves (B9)
- X Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- ____ Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- ____ Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- ____ Drainage Patterns (B10)
- ____ Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- ____ Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes X	No ____	Depth (inches):	6+"
Water Table Present?	Yes X	No ____	Depth (inches):	9"
Saturation Present?	Yes X	No ____	Depth (inches):	Surface

Wetland Hydrology Present? **Yes** X **No**

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Aquatic fauna is small fish species

VEGETATION – Use scientific names of plants.

Sampling Point: Wetland G

Tree Stratum (Plot size: 30' Radius)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	0	=Total Cover	
Sapling/Shrub Stratum (Plot size: 15' Radius)			
1. *Cephalanthus occidentalis*	10	Y	OBL
2.			
3.			
4.			
5.			
6.			
7.			
	10	=Total Cover	
Herb Stratum (Plot Size: 5' Radius)			
1. *Peltandra virginica*	15	Y	OBL
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9..			
10.			
11.			
12.			
	15	=Total Cover	
Woody Vine Stratum (Plot size: 30' Radius)			
1.			
2.			
3.			
4.			
	0	=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100 (A/B)

Prevalence Index Worksheet:

Total % Cover of:		Multiply by
OBL species		x1=
FACW species		x2=
FAC species		x3=
FACU species		x4=
UPL species		x5=
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ___ 1 – Rapid Test for Hydrophytic Vegetation
- X 2 – Dominance Test is >50%
- ___ 3 – Prevalence Index is #3.0[1]
- ___ 4 – Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and creater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Wetland G

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-7	10 YR 2/1	100					Mucky silt	Organic matter
7-12	7.5 YR 4/2	100					Sandy clay	Gravel
12-20	7.5 YR 4/2	100					Silty clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- X Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (s7) (**LRR, MLRA, 149B**)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Dark Surface (S7) (**LRR, K, L**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- Red Parent Material (F21)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Field Observations:
Type: _____
Depth (inches): _____

Hydric Soil Present? **Yes** X **No**

Remarks:

WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: Living Breakwaters City/County: Richmond County Sampling Date: 08/08/2016

Applicant/Owner: GOSR State: NY Sampling Point: Upland AB

Investigator(s): Jesse Moore, Teresa Cannone, AKRF, Inc. Section, Township, Range: Tottenville

Landform (hillslope, terrace, etc.): Terrace Local relief (concave, convex, none): None Slope (%): 0

Subregion (LRR or MLRA): MLRA 149B of LRR S Lat: 40.502875 Long: -74.225109 Datum: ____

Soil Map Unit Name: PkA NWI classification: None

Are climatic/hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation N, Soil N, or Hydrology N naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No ____	**Is the Sampled Area within a Wetland?** **Yes** ____ **No** X
Hydric Soil Present?	Yes ____	No X	If yes, optional Wetland Site ID:
Wetland Hydrology Present?	Yes ____	No X	

Remarks: (Explain alternative procedures here or in a separate report.)

Sampling point is located on the trail traversing Wetland AB

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ____ Surface Water (A1)
- ____ High Water Table (A2)
- ____ Saturation (A3)
- ____ Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- ____ Inundation Visible on Aerial Imagery (B7)
- ____ Sparsely Vegetated Concave Surface (B8)
- ____ Water-Stained Leaves (B9)
- ____ Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- ____ Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- ____ Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- ____ Drainage Patterns (B10)
- ____ Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- ____ Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present?	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION – Use scientific names of plants.

Sampling Point: Upland AB

Tree Stratum (Plot size: 30' radius)	Absolute % Cover	Dominant Species?	Indicator Status
1. *Liquidambar styraciflua*	70	Y	FAC
2. *Quercus palustris*	40	Y	FACW
3.			
4.			
5.			
6.			
7.			
	110	=Total Cover	
Sapling/Shrub Stratum (Plot size: 15' radius)			
1. *Celtis occidentalis*	30	Y	FAC
2. *Liquidambar styraciflua*	7	N	FAC
3. *Rosa multiflora*	3	N	FACU
4.			
5.			
6.			
7.			
	0	=Total Cover	
Herb Stratum (Plot Size: 5' radius)			
1. *Artemisia vulgaris*	95	Y	UPL
2. *Lonicera japonica*	15	N	FACU
3. *Parthenocissus quinquefolia*	5	N	FACU
4. *Smilax rotundifolia*	3	N	FAC
5.			
6.			
7.			
8.			
9..			
10.			
11.			
12.			
	118	=Total Cover	
Woody Vine Stratum (Plot size: 30' radius)			
1. *Toxicodendron radicans*	30	Y	FAC
2.			
3.			
4.			
	30	=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 80 (A/B)

Prevalence Index Worksheet:

Total % Cover of:		Multiply by
OBL species		x1=
FACW species		x2=
FAC species		x3=
FACU species		x4=
UPL species		x5=
Column Totals:	(A)	(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ___ 1 – Rapid Test for Hydrophytic Vegetation
- X 2 – Dominance Test is >50%
- ___ 3 – Prevalence Index is #3.0[1]
- ___ 4 – Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and creater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Upland AB

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Redox Features Type[1]	Redox Features Loc[2]	Texture	Remarks
0-20	10 YR 4/4	100					Loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

____ Histosol (A1)
____ Histic Epipedon (A2)
____ Black Histic (A3)
____ Hydrogen Sulfide (A4)
____ Stratified Layers (A5)
____ Depleted Below Dark Surface (A11)
____ Thick Dark Surface (A12)
____ Sandy Mucky Mineral (S1)
____ Sandy Gleyed Matrix (S4)
____ Sandy Redox (S5)
____ Stripped Matrix (S6)
____ Dark Surface (s7) (**LRR, MLRA, 149B**)

____ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
____ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
____ Loamy Mucky Mineral (F1) (**LRR K, L**)
____ Loamy Gleyed Matrix (F2)
____ Depleted Matrix (F3)
____ Redox Dark Surface (F6)
____ Depleted Dark Surface (F7)
____ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

____ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
____ Coast Prairie Redox (A16) (**LRR K, L, R**)
____ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
____ Dark Surface (S7) (**LRR, K, L**)
____ Polyvalue Below Surface (S8) (**LRR K, L**)
____ Thin Dark Surface (S9) (**LRR K, L**)
____ Iron-Manganese Masses (F12) (**LRR K, L, R**)
____ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
____ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
Red Parent Material (F21)
____ Very Shallow Dark Surface (TF12)
____ Other (explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Field Observations:
Type: _____
Depth (inches): _____

Hydric Soil Present? **Yes** **No** X

Remarks:

WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: Living Breakwaters City/County: Richmond County Sampling Date: 08/10/2016

Applicant/Owner: GOSR State: NY Sampling Point: Upland F

Investigator(s): Jesse Moore, Teresa Cannone, AKRF, Inc. Section, Township, Range: Tottenville

Landform (hillslope, terrace, etc.): Dune Local relief (concave, convex, none): None Slope (%): 0

Subregion (LRR or MLRA): MLRA 149B of LRR S Lat: 40.497798 Long: -74.241416 Datum: ____

Soil Map Unit Name: FrA NWI classification: None

Are climatic/hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation N, Soil N, or Hydrology N naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No X	**Is the Sampled Area within a Wetland?**	**Yes** ____ **No** X
Hydric Soil Present?	Yes ____	No X	If yes, optional Wetland Site ID:	
Wetland Hydrology Present?	Yes ____	No X		

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ____ Surface Water (A1)
- ____ High Water Table (A2)
- ____ Saturation (A3)
- ____ Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- ____ Inundation Visible on Aerial Imagery (B7)
- ____ Sparsely Vegetated Concave Surface (B8)
- ____ Water-Stained Leaves (B9)
- ____ Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- ____ Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- ____ Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- ____ Drainage Patterns (B10)
- ____ Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- ____ Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present?	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION – Use scientific names of plants.

Sampling Point: Upland F

Tree Stratum (Plot size: 30' radius)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	0	=Total Cover	

Sapling/Shrub Stratum (Plot size: 15' radius)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	0	=Total Cover	

Herb Stratum (Plot Size: 5' radius)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9..			
10.			
11.			
12.			
	0	=Total Cover	

Woody Vine Stratum (Plot size: 30' radius)			
1.			
2.			
3.			
4.			
	0	=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 0 (A)

Total Number of Dominant Species Across All Strata: 0 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 0 (A/B)

Prevalence Index Worksheet:

Total % Cover of:		Multiply by	
OBL species		x1=	
FACW species		x2=	
FAC species		x3=	
FACU species		x4=	
UPL species		x5=	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ____ 1 – Rapid Test for Hydrophytic Vegetation
- ____ 2 – Dominance Test is >50%
- ____ 3 – Prevalence Index is #3.0[1]
- ____ 4 – Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ____ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and creater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** ____ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Upland F

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Redox Features Type[1]	Redox Features Loc[2]	Texture	Remarks
0-21	10 YR 6/4	100					Sand	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

- ____ Histosol (A1)
- ____ Histic Epipedon (A2)
- ____ Black Histic (A3)
- ____ Hydrogen Sulfide (A4)
- ____ Stratified Layers (A5)
- ____ Depleted Below Dark Surface (A11)
- ____ Thick Dark Surface (A12)
- ____ Sandy Mucky Mineral (S1)
- ____ Sandy Gleyed Matrix (S4)
- ____ Sandy Redox (S5)
- ____ Stripped Matrix (S6)
- ____ Dark Surface (s7) (**LRR, MLRA, 149B**)
- ____ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ____ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ____ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ____ Loamy Gleyed Matrix (F2)
- ____ Depleted Matrix (F3)
- ____ Redox Dark Surface (F6)
- ____ Depleted Dark Surface (F7)
- ____ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ____ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ____ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ____ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ____ Dark Surface (S7) (**LRR, K, L**)
- ____ Polyvalue Below Surface (S8) (**LRR K, L**)
- ____ Thin Dark Surface (S9) (**LRR K, L**)
- ____ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ____ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ____ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- Red Parent Material (F21)
- ____ Very Shallow Dark Surface (TF12)
- ____ Other (explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Field Observations:
Type: _____
Depth (inches): _____

Hydric Soil Present? **Yes** **No** X

Remarks:

WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: Living Breakwaters City/County: Richmond County Sampling Date: 08/10/2016

Applicant/Owner: GOSR State: NY Sampling Point: Upland G

Investigator(s): Jesse Moore, Teresa Cannone, AKRF, Inc. Section, Township, Range: Tottenville

Landform (hillslope, terrace, etc.): None Local relief (concave, convex, none): None Slope (%): 0

Subregion (LRR or MLRA): MLRA 149B of LRR S Lat: 40.498413 Long: -74.245876 Datum: ____

Soil Map Unit Name: BtA NWI classification: None

Are climatic/hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation N, Soil N, or Hydrology N significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation N, Soil N, or Hydrology N naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No X	**Is the Sampled Area within a Wetland?**	**Yes** ____ **No** X
Hydric Soil Present?	Yes ____	No X	If yes, optional Wetland Site ID:	
Wetland Hydrology Present?	Yes ____	No X		

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ____ Surface Water (A1)
- ____ High Water Table (A2)
- ____ Saturation (A3)
- ____ Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- ____ Inundation Visible on Aerial Imagery (B7)
- ____ Sparsely Vegetated Concave Surface (B8)
- ____ Water-Stained Leaves (B9)
- ____ Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- ____ Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- ____ Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- ____ Drainage Patterns (B10)
- ____ Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- ____ Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present?	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

VEGETATION – Use scientific names of plants. Sampling Point: Upland G

Tree Stratum (Plot size: 30' radius)	Absolute % Cover	Dominant Species?	Indicator Status
1. *Quercus palustris*	85	Y	FACW
2. *Sassafras albidum*	10	N	FACU
3.			
4.			
5.			
6.			
7.			
	95	=Total Cover	
Sapling/Shrub Stratum (Plot size: 15' radius)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	0	=Total Cover	
Herb Stratum (Plot Size: 5' radius)			
1. *Phytolacca americana*	15	Y	FACU
2. *Rubus phoenicolasius*	10	Y	FACU
3. *Toxicodendron radicans*	5	N	FAC
4.			
5.			
6.			
7.			
8.			
9..			
10.			
11.			
12.			
	30	=Total Cover	
Woody Vine Stratum (Plot size: 30' radius)			
1.			
2.			
3.			
4.			
	0	=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 33 (A/B)

Prevalence Index Worksheet:

Total % Cover of:		Multiply by	
OBL species		x1=	
FACW species		x2=	
FAC species		x3=	
FACU species		x4=	
UPL species		x5=	
Column Totals:	(A)		(B)

Prevalence Index = B/A =

Hydrophytic Vegetation Indicators:

- ____ 1 – Rapid Test for Hydrophytic Vegetation
- ____ 2 – Dominance Test is >50%
- ____ 3 – Prevalence Index is #3.0[1]
- ____ 4 – Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ____ Problematic Hydrophytic Vegetation[1] (Explain)

[1] Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and creater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** ____ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL Sampling Point: Upland G

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Redox Features Type[1]	Redox Features Loc[2]	Texture	Remarks
0-6	10 YR 2/1	50					Loam	
	10 YR 3/3	50					Loam	
6-24	10 YR 5/4	100					Loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix

Hydric Soil Indicators:

____ Histosol (A1)
____ Histic Epipedon (A2)
____ Black Histic (A3)
____ Hydrogen Sulfide (A4)
____ Stratified Layers (A5)
____ Depleted Below Dark Surface (A11)
____ Thick Dark Surface (A12)
____ Sandy Mucky Mineral (S1)
____ Sandy Gleyed Matrix (S4)
____ Sandy Redox (S5)
____ Stripped Matrix (S6)
____ Dark Surface (s7) (**LRR, MLRA, 149B**)

____ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
____ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
____ Loamy Mucky Mineral (F1) (**LRR K, L**)
____ Loamy Gleyed Matrix (F2)
____ Depleted Matrix (F3)
____ Redox Dark Surface (F6)
____ Depleted Dark Surface (F7)
____ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

____ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
____ Coast Prairie Redox (A16) (**LRR K, L, R**)
____ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
____ Dark Surface (S7) (**LRR, K, L**)
____ Polyvalue Below Surface (S8) (**LRR K, L**)
____ Thin Dark Surface (S9) (**LRR K, L**)
____ Iron-Manganese Masses (F12) (**LRR K, L, R**)
____ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
____ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
Red Parent Material (F21)
____ Very Shallow Dark Surface (TF12)
____ Other (explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Field Observations:
Type: _____
Depth (inches): _____

Hydric Soil Present? **Yes** **No** X

Remarks:

Appendix E-8
Sediment Chemistry Data

Appendix E-8: Sediment Chemistry Data

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		West											
		Class B	Class C	Unrestricted Use	Protection of Groundwater	2012_9		2013_28		2014_19		2071_12		HB06_11		HB06_12	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/21/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015	
1,1,1-Trichloroethane	(mg/kg)			0.68	0.68	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,1-Dichloroethane	(mg/kg)			0.27	0.27	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,1-Dichloroethene	(mg/kg)			0.33	0.33	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,2,4-Trimethylbenzene	(mg/kg)			3.6	3.6	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,2-Dichlorobenzene	(mg/kg)			1.1	1.1	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,2-Dichloroethane	(mg/kg)			0.02	0.02	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,3,5-Trimethylbenzene	(mg/kg)			8.4	8.4	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,3-Dichlorobenzene	(mg/kg)			2.4	2.4	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,4-Dichlorobenzene	(mg/kg)					0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
1,4-Dioxane	(mg/kg)			0.1	0.1	0.0625	U	0.0625	U	0.059	U	0.056	U	0.03675	U	0.055	U
2,4,5-TP	(mg/kg)			0.1	0.1	0.06	U	0.0555	U	0.0545	U	0.056	U	0.054	U	0.054	U
2-Butanone	(mg/kg)					0.00835	U	0.00835	U	0.00785	U	0.00745	U	0.0049	U	0.00735	U
4,4'-DDD	(mg/kg)			0.0033	17	**0.01385**	U	**0.0137**	U	**0.01275**	U	**0.01345**	U	**0.0052**	J	**0.01315**	U
4,4'-DDE	(mg/kg)			0.0033	136	**0.01385**	U	**0.0137**	U	**0.01275**	U	**0.01345**	U	**0.0064**	J	**0.0064**	J
4,4'-DDT	(mg/kg)			0.0033	14	**0.01385**	U	**0.0137**	U	**0.01275**	U	**0.01345**	U	**0.01275**	U	**0.01315**	U
Acenaphthene	(mg/kg)			20	98	0.0875	U	0.082	U	0.0805	U	0.0855	U	0.08	U	0.078	U
Acenaphthylene	(mg/kg)			100	107	0.0529	J	0.045	J	0.0805	U	0.0855	U	0.08	U	0.0683	J
Acetone	(mg/kg)			0.05	0.05	0.0105	J	0.00835	U	0.0119	J	0.0153		0.0083	J	0.00735	U
Aldrin	(mg/kg)			0.005	0.19	**0.00715**	U	**0.00705**	U	**0.00655**	U	**0.00695**	U	**0.00655**	U	**0.0068**	U
alpha-BHC	(mg/kg)			0.02	0.02	0.00715	U	0.00705	U	0.00655	U	0.00695	U	0.00655	U	0.0068	U
alpha-Chlordane	(mg/kg)			0.094	2.9	0.00715	U	0.00705	U	0.00655	U	0.00695	U	0.00655	U	0.0068	U
Anthracene	(mg/kg)			100	1000	0.119	J	0.0847	J	0.0844	J	0.115	J	0.143	J	0.0829	J
Aroclor-1016	(mg/kg)					0.0275	U	0.0275	U	0.0255	U	0.027	U	0.0255	U	0.0265	U
Aroclor-1221	(mg/kg)					0.0275	U	0.0275	U	0.0255	U	0.027	U	0.0255	U	0.0265	U
Aroclor-1232	(mg/kg)					0.0275	U	0.0275	U	0.0255	U	0.027	U	0.0255	U	0.0265	U
Aroclor-1242	(mg/kg)					0.0275	U	0.0275	U	0.0255	U	0.027	U	0.0255	U	0.0265	U
Aroclor-1248	(mg/kg)					0.0275	U	0.0275	U	0.0255	U	0.027	U	0.0255	U	0.0265	U
Aroclor-1254	(mg/kg)					0.029	J	0.024	J	0.024	J	0.021	J	0.037	J	0.039	J
Aroclor-1260	(mg/kg)					0.0275	U	0.0275	U	0.0255	U	0.027	U	0.0255	U	0.0265	U
Arsenic, Total	(mg/kg)	8.2	53	13	16	4.1		4.9		**15.5**		4.2		10.4		8.9	
Barium, Total	(mg/kg)			350	820	14		18.3		20.6		16.6		29.6		23.3	
Benzene	(mg/kg)			0.06	0.06	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Benzo(a)anthracene	(mg/kg)			1	1	0.211		0.316		0.142	J	0.143	J	0.213		0.286	
Benzo(a)pyrene	(mg/kg)			1	22	0.237		0.348		0.177		0.162	J	0.219		0.343	
Benzo(b)fluoranthene	(mg/kg)			1	1.7	0.303		0.454		0.203		0.215		0.274		0.428	
Benzo(g,h,i)perylene	(mg/kg)			100	1000	0.151	J	0.234		0.108	J	0.112	J	0.14	J	0.231	
Benzo(k)fluoranthene	(mg/kg)			0.8	1.7	0.115	J	0.082	U	0.0849	J	0.0855	U	0.104	J	0.156	J

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		West											
		Class B	Class C	Unrestricted Use	Protection of Groundwater	2012_9		2013_28		2014_19		2071_12		HB06_11		HB06_12	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/21/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015	
Beryllium, Total	(mg/kg)			7.2	47	0.4	U	0.3	J	0.38	J	0.27	J	0.45	J	0.42	J
beta-BHC	(mg/kg)			0.036	0.09	0.00715	U	0.00705	U	0.00655	U	0.00695	U	0.00655	U	0.0068	U
Cadmium, Total	(mg/kg)	1.2	9.5	2.5	7.5	0.42	J	0.48	J	1		0.44	J	1		0.99	
Carbon Tetrachloride	(mg/kg)			0.76	0.76	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Chlorobenzene	(mg/kg)			1.1	1.1	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Chloroform	(mg/kg)			0.37	0.37	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Chromium, Total	(mg/kg)			1	19	**15.7**		**18.4**		***28.5***		**16.2**		***33***		***31.1***	
Chrysene	(mg/kg)			1	1	0.218		0.334		0.124	J	0.154	J	0.215		0.296	
cis-1,2-Dichloroethene	(mg/kg)			0.25	0.25	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Copper, Total	(mg/kg)	33	270	50	1720	28.9		32.8		**56.8**		27.6		**63**		**61.4**	
Cyanide, Total	(mg/kg)			27	40	0.215	U	0.215	U	0.2	U	0.215	U	0.195	U	0.205	U
delta-BHC	(mg/kg)			0.04	0.25	0.00715	U	0.00705	U	0.00655	U	0.00695	U	0.00655	U	0.0068	U
Dibenzo(a,h)anthracene	(mg/kg)			0.33	1000	0.0875	U	0.0647	J	0.0805	U	0.0855	U	0.08	U	0.0695	J
Dibenzofuran	(mg/kg)			7	210	0.0875	U	0.082	U	0.0805	U	0.0855	U	0.08	U	0.078	U
Dieldrin	(mg/kg)	0.11	0.48	0.005	0.1	**0.01385**	U	**0.0137**	U	**0.01275**	U	**0.01345**	U	**0.01275**	U	**0.01315**	U
Endosulfan I	(mg/kg)			2.4	102	0.00715	U	0.00705	U	0.00655	U	0.00695	U	0.00655	U	0.0068	U
Endosulfan II	(mg/kg)			2.4	102	0.01385	U	0.0137	U	0.01275	U	0.01345	U	0.01275	U	0.01315	U
Endosulfan Sulfate	(mg/kg)			2.4	1000	0.01385	U	0.0137	U	0.01275	U	0.01345	U	0.01275	U	0.01315	U
Endrin	(mg/kg)			0.014	0.06	0.01385	U	0.0137	U	0.01275	U	0.01345	U	0.01275	U	0.01315	U
Ethylbenzene	(mg/kg)			1	1	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Fluoranthene	(mg/kg)			100	1000	0.327		0.602		0.219		0.247		0.339		0.516	
Fluorene	(mg/kg)			30	386	0.0875	U	0.082	U	0.0805	U	0.0855	U	0.08	U	0.078	U
gamma-BHC	(mg/kg)			0.1	0.1	0.00715	U	0.00705	U	0.00655	U	0.00695	U	0.00655	U	0.0068	U
Heptachlor	(mg/kg)			0.042	0.38	0.00715	U	0.00705	U	0.00655	U	0.00695	U	0.00655	U	0.0068	U
Hexachlorobenzene	(mg/kg)			0.33	3.2	0.0875	U	0.082	U	0.0805	U	0.0855	U	0.08	U	0.078	U
Hexavalent Chromium	(mg/kg)					1.75	U	1.7	U	1.6	U	1.7	U	1.6	U	1.7	U
Indeno(1,2,3-cd)pyrene	(mg/kg)			0.5	8.2	0.176		0.274		0.115	J	0.12	J	0.154	J	0.226	
Lead, Total	(mg/kg)	47	218	63	450	30.7		33.6		54		30.6		**65.7**		61.5	
Manganese, Total	(mg/kg)			1600	2000	102		119		200		111		186		193	
Mercury, Total	(mg/kg)	0.17	1	0.18	0.73	**0.4**		**0.36**		**0.46**		**0.38**		**0.49**		**0.57**	
Methyl t-Butyl Ether	(mg/kg)			0.93	0.93	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Methylene Chloride	(mg/kg)			0.05	0.05	0.0326		0.0295		0.0298		0.0245		0.0193		0.0266	
Moisture	%					44.2		40.9		38.6		42.2		38.5		39.7	
mp-Cresol	(mg/kg)			0.33	0.33	0.2355	U	0.221	U	0.217	U	0.2305	U	0.2165	U	0.211	U
Naphthalene	(mg/kg)			12	12	0.0875	U	0.082	U	0.0805	U	0.0855	U	0.08	U	0.078	U
n-Butylbenzene	(mg/kg)			12	12	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Nickel, Total	(mg/kg)			30	130	8.3		9.7		14.7		8.5		15.8		15.7	

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		West											
		Class B	Class C	Unrestricted Use	Protection of Groundwater	2012_9		2013_28		2014_19		2071_12		HB06_11		HB06_12	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/21/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015	
n-Propylbenzene	(mg/kg)			3.9	3.9	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
o-Cresol	(mg/kg)			0.33	0.33	0.2355	U	0.221	U	0.217	U	0.2305	U	0.2165	U	0.211	U
Pentachlorophenol	(mg/kg)			0.8	0.8	0.1745	U	0.1635	U	0.1605	U	0.171	U	0.1605	U	0.1565	U
Phenanthrene	(mg/kg)			100	1000	0.116	J	0.258		0.0834	J	0.113	J	0.141	J	0.198	
Phenol	(mg/kg)			0.33	0.33	0.2355	U	0.221	U	0.217	U	0.2305	U	0.2165	U	0.211	U
Pyrene	(mg/kg)			100	1000	0.305		0.488		0.237		0.23		0.349		0.493	
sec-Butylbenzene	(mg/kg)			11	11	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Selenium, Total	(mg/kg)			3.9	4	2	U	2	U	1.3	J	1.95	U	1.7	J	2.4	J
Silver, Total	(mg/kg)			2	8.3	0.8	U	0.8	U	0.83	J	0.8	U	0.99	J	0.94	J
tert-Butylbenzene	(mg/kg)			5.9	5.9	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Tetrachloroethene	(mg/kg)			1.3	1.3	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Toluene	(mg/kg)			0.7	0.7	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Total Polychlorinated Biphenyl	(mg/kg)	0.1	1	0.1	3.2	0.0275	U	0.0275	U	0.0255	U	0.027	U	0.0255	U	0.0265	U
Total Solids	%					55.8		59.1		61.4		57.8		61.5		60.3	
Total Xylenes	(mg/kg)			0.26	1.6	0.005	U	0.005	U	0.0047	U	0.00445	U	0.00295	U	0.0044	U
trans-1,2-Dichloroethene	(mg/kg)			0.19	0.19	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Trichloroethene	(mg/kg)			0.47	0.47	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Trivalent Chromium	(mg/kg)					15.7		18.4		28.5		16.2		33		31.1	
Vinyl Chloride	(mg/kg)			0.02	0.02	0.00165	U	0.00165	U	0.00155	U	0.0015	U	0.001	U	0.00145	U
Zinc, Total	(mg/kg)			109	2480	77.8		85.3		**136**		79		**141**		**151**	
Σ DDT, Calculated	(mg/kg)	0.003	0.03			0		0		0		0		0.0116		0.0064	
Total PAH, Calculated	(mg/kg)	4	45			2.3309		3.5024		1.5777		1.611		2.291		3.3937	
Total BTEX, Calculated	(mg/kg)	0.96	5.9			0		0		0		0		0		0	

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		Southwest											
		Class B	Class C	Unrestricted Use	Protection of Groundwater	1129_20		1363_24		1364_6		1438_23		1439_20		1440_8	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/24/2015		9/21/2015		9/24/2015		9/21/2015		9/24/2015		9/24/2015	
1,1,1-Trichloroethane	(mg/kg)			0.68	0.68	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,1-Dichloroethane	(mg/kg)			0.27	0.27	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,1-Dichloroethene	(mg/kg)			0.33	0.33	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,2,4-Trimethylbenzene	(mg/kg)			3.6	3.6	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,2-Dichlorobenzene	(mg/kg)			1.1	1.1	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,2-Dichloroethane	(mg/kg)			0.02	0.02		U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,3,5-Trimethylbenzene	(mg/kg)			8.4	8.4	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,3-Dichlorobenzene	(mg/kg)			2.4	2.4	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,4-Dichlorobenzene	(mg/kg)						U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
1,4-Dioxane	(mg/kg)			0.1	0.1	0.04955	U	0.03715	U	0.0505	U	0.04365	U	0.0485	U	0.0515	U
2,4,5-TP	(mg/kg)			0.1	0.1	0.04295	U	0.04435	U	0.0435	U	0.057	U	0.04195	U	0.0454	U
2-Butanone	(mg/kg)					0.0066	U	0.00495	U	0.00675	U	0.0058	U	0.00645	U	0.00685	U
4,4'-DDD	(mg/kg)			0.0033	17	**0.01025**	U	**0.01135**	U	**0.0105**	U	**0.01325**	U	**0.0102**	U	**0.01065**	U
4,4'-DDE	(mg/kg)			0.0033	136	**0.01025**	U	**0.01135**	U	**0.0105**	U	**0.01325**	U	**0.0102**	U	**0.01065**	U
4,4'-DDT	(mg/kg)			0.0033	14	**0.01025**	U	**0.01135**	U	**0.0105**	U	**0.01325**	U	**0.0102**	U	**0.01065**	U
Acenaphthene	(mg/kg)			20	98	0.0615	U	0.066	U	0.067	U	0.084	U	0.064	U	0.066	U
Acenaphthylene	(mg/kg)			100	107	0.0615	U	0.066	U	0.067	U	0.0655	J	0.064	U	0.066	U
Acetone	(mg/kg)			0.05	0.05	0.0066	U	0.00495	U	0.00675	U	0.0074	J	0.007	J	0.00685	U
Aldrin	(mg/kg)			0.005	0.19	**0.0053**	U	**0.00585**	U	**0.0054**	U	**0.0068**	U	**0.00525**	U	**0.0055**	U
alpha-BHC	(mg/kg)			0.02	0.02	0.0053	U	0.00585	U	0.0054	U	0.0068	U	0.00525	U	0.0055	U
alpha-Chlordane	(mg/kg)			0.094	2.9	0.0053	U	0.00585	U	0.0054	U	0.0068	U	0.00525	U	0.0055	U
Anthracene	(mg/kg)			100	1000	0.0615	U	0.066	U	0.067	U	0.104	J	0.064	U	0.066	U
Aroclor-1016	(mg/kg)					0.0205	U	0.0225	U	0.021	U	0.0265	U	0.0205	U	0.0215	U
Aroclor-1221	(mg/kg)					0.0205	U	0.0225	U	0.021	U	0.0265	U	0.0205	U	0.0215	U
Aroclor-1232	(mg/kg)					0.0205	U	0.0225	U	0.021	U	0.0265	U	0.0205	U	0.0215	U
Aroclor-1242	(mg/kg)					0.0205	U	0.0225	U	0.021	U	0.0265	U	0.0205	U	0.0215	U
Aroclor-1248	(mg/kg)					0.0205	U	0.0225	U	0.021	U	0.0265	U	0.0205	U	0.0215	U
Aroclor-1254	(mg/kg)					0.0205	U	0.0225	U	0.021	U	0.026	J	0.0205	U	0.0215	U
Aroclor-1260	(mg/kg)					0.0205	U	0.0225	U	0.021	U	0.0265	U	0.0205	U	0.0215	U
Arsenic, Total	(mg/kg)	8.2	53	13	16			3.5		2.3		4.4		1.5		3	
Barium, Total	(mg/kg)			350	820			7.3		5.1		18.6		2.8		5.4	
Benzene	(mg/kg)			0.06	0.06	0.0013	U	0.001	U	0.00135	U	0.00115	U	0.0013	U	0.00135	U
Benzo(a)anthracene	(mg/kg)			1	1	0.0615	U	0.066	U	0.067	U	0.357		0.064	U	0.066	U
Benzo(a)pyrene	(mg/kg)			1	22	0.0615	U	0.066	U	0.067	U	0.394		0.064	U	0.066	U
Benzo(b)fluoranthene	(mg/kg)			1	1.7	0.0421	J	0.066	U	0.067	U	0.494		0.064	U	0.066	U
Benzo(g,h,i)perylene	(mg/kg)			100	1000	0.0615	U	0.066	U	0.067	U	0.244		0.064	U	0.066	U
Benzo(k)fluoranthene	(mg/kg)			0.8	1.7	0.0615	U	0.066	U	0.067	U	0.178		0.064	U	0.066	U

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		Southwest					
		Class B	Class C	Unrestricted Use	Protection of Groundwater	1129_20	1363_24	1364_6	1438_23	1439_20	1440_8
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/24/2015	9/21/2015	9/24/2015	9/21/2015	9/24/2015	9/24/2015
Beryllium, Total	(mg/kg)			7.2	47	U	0.345 U	0.28 U	0.29 J	0.215 U	0.335 U
beta-BHC	(mg/kg)			0.036	0.09	0.0053 U	0.00585 U	0.0054 U	0.0068 U	0.00525 U	0.0055 U
Cadmium, Total	(mg/kg)	1.2	9.5	2.5	7.5	U	0.345 U	0.28 U	0.57 J	0.215 U	0.335 U
Carbon Tetrachloride	(mg/kg)			0.76	0.76	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Chlorobenzene	(mg/kg)			1.1	1.1	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Chloroform	(mg/kg)			0.37	0.37	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Chromium, Total	(mg/kg)			1	19		**9.5**	**8.8**	***19.3***	**6**	**10.1**
Chrysene	(mg/kg)			1	1	0.0615 U	0.066 U	0.067 U	0.375	0.064 U	0.066 U
cis-1,2-Dichloroethene	(mg/kg)			0.25	0.25	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Copper, Total	(mg/kg)	33	270	50	1720		8.6	8.8	34.5	5.9	10.5
Cyanide, Total	(mg/kg)			27	40	U	0.18 U	0.175 U	0.205 U	0.16 U	0.17 U
delta-BHC	(mg/kg)			0.04	0.25	0.0053 U	0.00585 U	0.0054 U	0.0068 U	0.00525 U	0.0055 U
Dibenzo(a,h)anthracene	(mg/kg)			0.33	1000	0.0615 U	0.066 U	0.067 U	0.0628 J	0.064 U	0.066 U
Dibenzofuran	(mg/kg)			7	210	0.0615 U	0.066 U	0.067 U	0.084 U	0.064 U	0.066 U
Dieldrin	(mg/kg)	0.11	0.48	0.005	0.1	**0.01025** U	**0.01135** U	**0.0105** U	**0.01325** U	**0.0102** U	**0.01065** U
Endosulfan I	(mg/kg)			2.4	102	0.0053 U	0.00585 U	0.0054 U	0.0068 U	0.00525 U	0.0055 U
Endosulfan II	(mg/kg)			2.4	102	0.01025 U	0.01135 U	0.0105 U	0.01325 U	0.0102 U	0.01065 U
Endosulfan Sulfate	(mg/kg)			2.4	1000	0.01025 U	0.01135 U	0.0105 U	0.01325 U	0.0102 U	0.01065 U
Endrin	(mg/kg)			0.014	0.06	0.01025 U	0.01135 U	0.0105 U	0.01325 U	0.0102 U	0.01065 U
Ethylbenzene	(mg/kg)			1	1	U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Fluoranthene	(mg/kg)			100	1000	0.0467 J	0.066 U	0.067 U	0.663	0.064 U	0.066 U
Fluorene	(mg/kg)			30	386	0.0615 U	0.066 U	0.067 U	0.084 U	0.064 U	0.066 U
gamma-BHC	(mg/kg)			0.1	0.1	0.0053 U	0.00585 U	0.0054 U	0.0068 U	0.00525 U	0.0055 U
Heptachlor	(mg/kg)			0.042	0.38	0.0053 U	0.00585 U	0.0054 U	0.0068 U	0.00525 U	0.0055 U
Hexachlorobenzene	(mg/kg)			0.33	3.2	0.0615 U	0.066 U	0.067 U	0.084 U	0.064 U	0.066 U
Hexavalent Chromium	(mg/kg)					U	1.35 U	1.35 U	1.75 U	1.25 U	1.35 U
Indeno(1,2,3-cd)pyrene	(mg/kg)			0.5	8.2	0.0615 U	0.066 U	0.067 U	0.268	0.064 U	0.066 U
Lead, Total	(mg/kg)	47	218	63	450		14	11.5	37	7.7	13.8
Manganese, Total	(mg/kg)			1600	2000		168	222	108	66.1	215
Mercury, Total	(mg/kg)	0.17	1	0.18	0.73		0.069 J	0.048 J	**0.48**	0.058	0.055 J
Methyl t-Butyl Ether	(mg/kg)			0.93	0.93	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Methylene Chloride	(mg/kg)			0.05	0.05	0.0124	0.0199	0.0153	0.0192	0.0097	0.0145
Moisture	%						27.9	25.5	41.6	22.2	26.4
mp-Cresol	(mg/kg)			0.33	0.33	0.1655 U	0.179 U	0.181 U	0.2265 U	0.1725 U	0.179 U
Naphthalene	(mg/kg)			12	12	0.0615 U	0.066 U	0.067 U	0.084 U	0.064 U	0.066 U
n-Butylbenzene	(mg/kg)			12	12	U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Nickel, Total	(mg/kg)			30	130		7.1	5.6	10.2	3.2	5.5

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		Southwest					
		Class B	Class C	Unrestricted Use	Protection of Groundwater	1129_20	1363_24	1364_6	1438_23	1439_20	1440_8
Analyte	**Units**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**9/24/2015**	**9/21/2015**	**9/24/2015**	**9/21/2015**	**9/24/2015**	**9/24/2015**
n-Propylbenzene	(mg/kg)			3.9	3.9	U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
o-Cresol	(mg/kg)			0.33	0.33	0.1655 U	0.179 U	0.181 U	0.2265 U	0.1725 U	0.179 U
Pentachlorophenol	(mg/kg)			0.8	0.8	0.1225 U	0.1325 U	0.134 U	0.168 U	0.1275 U	0.1325 U
Phenanthrene	(mg/kg)			100	1000	0.0615 U	0.066 U	0.067 U	0.302	0.064 U	0.066 U
Phenol	(mg/kg)			0.33	0.33	0.1655 U	0.179 U	0.181 U	0.2265 U	0.1725 U	0.179 U
Pyrene	(mg/kg)			100	1000	0.0615 U	0.066 U	0.067 U	0.592	0.064 U	0.066 U
sec-Butylbenzene	(mg/kg)			11	11	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Selenium, Total	(mg/kg)			3.9	4	U	1.75 U	1.4 U	2.05 U	1.1 U	1.65 U
Silver, Total	(mg/kg)			2	8.3	U	0.7 U	0.55 U	0.8 U	0.435 U	0.65 U
tert-Butylbenzene	(mg/kg)			5.9	5.9	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Tetrachloroethene	(mg/kg)			1.3	1.3	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Toluene	(mg/kg)			0.7	0.7	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Total Polychlorinated Biphenyl	(mg/kg)	0.1	1	0.1	3.2	0.0205 U	0.0225 U	0.021 U	0.0265 U	0.0205 U	0.0215 U
Total Solids	%						72.1	74.5	58.4	77.8	73.6
Total Xylenes	(mg/kg)			0.26	1.6	0.00395 U	0.00295 U	0.00405 U	0.0035 U	0.0039 U	0.0041 U
trans-1,2-Dichloroethene	(mg/kg)			0.19	0.19	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Trichloroethene	(mg/kg)			0.47	0.47	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Trivalent Chromium	(mg/kg)						9.5	8.8	19.3	6	10.1
Vinyl Chloride	(mg/kg)			0.02	0.02	0.0013 U	0.001 U	0.00135 U	0.00115 U	0.0013 U	0.00135 U
Zinc, Total	(mg/kg)			109	2480		41.4	38.6	97.3	23.6	41.8
Σ DDT, Calculated	(mg/kg)	0.003	0.03			0	0	0	0	0	0
Total PAH, Calculated	(mg/kg)	4	45			0.0888	0	0	4.0993	0	0
Total BTEX, Calculated	(mg/kg)	0.96	5.9			0	0	0	0	0	0

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		Southwest									
		Class B	Class C	Unrestricted Use	Protection of Groundwater	986_26		HB02_1		HB02_2		HB07_13		HB07_14	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/24/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015	
1,1,1-Trichloroethane	(mg/kg)			0.68	0.68	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,1-Dichloroethane	(mg/kg)			0.27	0.27	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,1-Dichloroethene	(mg/kg)			0.33	0.33	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,2,4-Trimethylbenzene	(mg/kg)			3.6	3.6	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,2-Dichlorobenzene	(mg/kg)			1.1	1.1	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,2-Dichloroethane	(mg/kg)			0.02	0.02	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,3,5-Trimethylbenzene	(mg/kg)			8.4	8.4	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,3-Dichlorobenzene	(mg/kg)			2.4	2.4	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,4-Dichlorobenzene	(mg/kg)					0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
1,4-Dioxane	(mg/kg)			0.1	0.1	0.04875	U	0.04655	U	0.04655	U	0.03885	U	0.03725	U
2,4,5-TP	(mg/kg)			0.1	0.1	0.0426	U	0.04455	U	0.04675	U	0.0463	U	0.04695	U
2-Butanone	(mg/kg)					0.0065	U	0.0062	U	0.0062	U	0.0052	U	0.00495	U
4,4'-DDD	(mg/kg)			0.0033	17	**0.0104**	U	**0.0112**	U	**0.01145**	U	**0.01165**	U	**0.01125**	U
4,4'-DDE	(mg/kg)			0.0033	136	**0.0104**	U	**0.0112**	U	**0.01145**	U	**0.01165**	U	**0.01125**	U
4,4'-DDT	(mg/kg)			0.0033	14	**0.0104**	U	**0.0112**	U	**0.01145**	U	**0.01165**	U	**0.01125**	U
Acenaphthene	(mg/kg)			20	98	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Acenaphthylene	(mg/kg)			100	107	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Acetone	(mg/kg)			0.05	0.05	0.0088	J	0.0062	U	0.0062	U	0.0055	J	0.00495	U
Aldrin	(mg/kg)			0.005	0.19	**0.00535**	U	**0.0058**	U	**0.0059**	U	**0.006**	U	**0.0058**	U
alpha-BHC	(mg/kg)			0.02	0.02	0.00535	U	0.0058	U	0.0059	U	0.006	U	0.0058	U
alpha-Chlordane	(mg/kg)			0.094	2.9	0.00535	U	0.0058	U	0.0059	U	0.006	U	0.0058	U
Anthracene	(mg/kg)			100	1000	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Aroclor-1016	(mg/kg)					0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Aroclor-1221	(mg/kg)					0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Aroclor-1232	(mg/kg)					0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Aroclor-1242	(mg/kg)					0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Aroclor-1248	(mg/kg)					0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Aroclor-1254	(mg/kg)					0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Aroclor-1260	(mg/kg)					0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Arsenic, Total	(mg/kg)	8.2	53	13	16	4		2.5		2.1		3.6		3.7	
Barium, Total	(mg/kg)			350	820	11.3		5.7		7		10		10.4	
Benzene	(mg/kg)			0.06	0.06	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Benzo(a)anthracene	(mg/kg)			1	1	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Benzo(a)pyrene	(mg/kg)			1	22	0.0345	J	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Benzo(b)fluoranthene	(mg/kg)			1	1.7	0.0491	J	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Benzo(g,h,i)perylene	(mg/kg)			100	1000	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Benzo(k)fluoranthene	(mg/kg)			0.8	1.7	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		Southwest									
		Class B	Class C	Unrestricted Use	Protection of Groundwater	986_26		HB02_1		HB02_2		HB07_13		HB07_14	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/24/2015		9/21/2015		9/21/2015		9/21/2015		9/21/2015	
Beryllium, Total	(mg/kg)			7.2	47	0.23	J	0.285	U	0.335	U	0.35	U	0.22	J
beta-BHC	(mg/kg)			0.036	0.09	0.00535	U	0.0058	U	0.0059	U	0.006	U	0.0058	U
Cadmium, Total	(mg/kg)	1.2	9.5	2.5	7.5	0.2	J	0.285	U	0.335	U	0.35	U	0.24	J
Carbon Tetrachloride	(mg/kg)			0.76	0.76	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Chlorobenzene	(mg/kg)			1.1	1.1	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Chloroform	(mg/kg)			0.37	0.37	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Chromium, Total	(mg/kg)			1	19	**12.7**		**9.7**		**7.6**		**11**		**12**	
Chrysene	(mg/kg)			1	1	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
cis-1,2-Dichloroethene	(mg/kg)			0.25	0.25	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Copper, Total	(mg/kg)	33	270	50	1720	12.9		7.9		7.4		13.1		15	
Cyanide, Total	(mg/kg)			27	40	0.16	U	0.165	U	0.185	U	0.18	U	0.175	U
delta-BHC	(mg/kg)			0.04	0.25	0.00535	U	0.0058	U	0.0059	U	0.006	U	0.0058	U
Dibenzo(a,h)anthracene	(mg/kg)			0.33	1000	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Dibenzofuran	(mg/kg)			7	210	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Dieldrin	(mg/kg)	0.11	0.48	0.005	0.1	**0.0104**	U	**0.0112**	U	**0.01145**	U	**0.01165**	U	**0.01125**	U
Endosulfan I	(mg/kg)			2.4	102	0.00535	U	0.0058	U	0.0059	U	0.006	U	0.0058	U
Endosulfan II	(mg/kg)			2.4	102	0.0104	U	0.0112	U	0.01145	U	0.01165	U	0.01125	U
Endosulfan Sulfate	(mg/kg)			2.4	1000	0.0104	U	0.0112	U	0.01145	U	0.01165	U	0.01125	U
Endrin	(mg/kg)			0.014	0.06	0.0104	U	0.0112	U	0.01145	U	0.01165	U	0.01125	U
Ethylbenzene	(mg/kg)			1	1	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Fluoranthene	(mg/kg)			100	1000	0.052	J	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Fluorene	(mg/kg)			30	386	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
gamma-BHC	(mg/kg)			0.1	0.1	0.00535	U	0.0058	U	0.0059	U	0.006	U	0.0058	U
Heptachlor	(mg/kg)			0.042	0.38	0.00535	U	0.0058	U	0.0059	U	0.006	U	0.0058	U
Hexachlorobenzene	(mg/kg)			0.33	3.2	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Hexavalent Chromium	(mg/kg)					1.3	U	1.4	U	1.45	U	1.35	U	1.35	U
Indeno(1,2,3-cd)pyrene	(mg/kg)			0.5	8.2	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Lead, Total	(mg/kg)	47	218	63	450	18.6		10.9		10.8		18.1		19.2	
Manganese, Total	(mg/kg)			1600	2000	164		179		252		203		291	
Mercury, Total	(mg/kg)	0.17	1	0.18	0.73	0.054	J	0.074		0.072		0.089		0.098	
Methyl t-Butyl Ether	(mg/kg)			0.93	0.93	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Methylene Chloride	(mg/kg)			0.05	0.05	0.0109		0.0265		0.0255		0.0244		0.0216	
Moisture	%					22.1		27.4		29.7		29.5		28.7	
mp-Cresol	(mg/kg)			0.33	0.33	0.171	U	0.1745	U	0.1845	U	0.1855	U	0.1855	U
Naphthalene	(mg/kg)			12	12	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
n-Butylbenzene	(mg/kg)			12	12	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Nickel, Total	(mg/kg)			30	130	7.5		4.9		4.7		6.5		6.8	

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		Southwest									
		Class B	Class C	Unrestricted Use	Protection of Groundwater	986_26		HB02_1		HB02_2		HB07_13		HB07_14	
Analyte	**Units**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**9/24/2015**		**9/21/2015**		**9/21/2015**		**9/21/2015**		**9/21/2015**	
n-Propylbenzene	(mg/kg)			3.9	3.9	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
o-Cresol	(mg/kg)			0.33	0.33	0.171	U	0.1745	U	0.1845	U	0.1855	U	0.1855	U
Pentachlorophenol	(mg/kg)			0.8	0.8	0.1265	U	0.129	U	0.137	U	0.1375	U	0.1375	U
Phenanthrene	(mg/kg)			100	1000	0.0635	U	0.0645	U	0.0685	U	0.0685	U	0.0685	U
Phenol	(mg/kg)			0.33	0.33	0.171	U	0.1745	U	0.1845	U	0.1855	U	0.1855	U
Pyrene	(mg/kg)			100	1000	0.0484	J	0.0645	U	0.0685	U	0.0685	U	0.0685	U
sec-Butylbenzene	(mg/kg)			11	11	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Selenium, Total	(mg/kg)			3.9	4	0.84	J	1.45	U	1.7	U	1.75	U	1.55	U
Silver, Total	(mg/kg)			2	8.3	0.42	U	0.55	U	0.65	U	0.7	U	0.6	U
tert-Butylbenzene	(mg/kg)			5.9	5.9	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Tetrachloroethene	(mg/kg)			1.3	1.3	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Toluene	(mg/kg)			0.7	0.7	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Total Polychlorinated Biphenyl	(mg/kg)	0.1	1	0.1	3.2	0.021	U	0.0225	U	0.023	U	0.0235	U	0.0225	U
Total Solids	%					77.9		72.6		70.3		70.5		71.3	
Total Xylenes	(mg/kg)			0.26	1.6	0.0039	U	0.0037	U	0.0037	U	0.0031	U	0.003	U
trans-1,2-Dichloroethene	(mg/kg)			0.19	0.19	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Trichloroethene	(mg/kg)			0.47	0.47	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Trivalent Chromium	(mg/kg)					12.7		9.7		7.6		11		12	
Vinyl Chloride	(mg/kg)			0.02	0.02	0.0013	U	0.00125	U	0.00125	U	0.00105	U	0.001	U
Zinc, Total	(mg/kg)			109	2480	52.9		34.3		33.2		49.3		57.2	
Σ DDT, Calculated	(mg/kg)	0.003	0.03			0		0		0		0		0	
Total PAH, Calculated	(mg/kg)	4	45			0.184		0		0		0		0	
Total BTEX, Calculated	(mg/kg)	0.96	5.9			0		0		0		0		0	

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		South											
		Class B	Class C	Unrestricted Use	Protection of Groundwater	1217_42		1374_22		1787_44		2146_25		654_9		659_7	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/24/2015		9/24/2015		9/24/2015		9/24/2015		9/24/2015		9/24/2015	
1,1,1-Trichloroethane	(mg/kg)			0.68	0.68	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,1-Dichloroethane	(mg/kg)			0.27	0.27	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,1-Dichloroethene	(mg/kg)			0.33	0.33	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,2,4-Trimethylbenzene	(mg/kg)			3.6	3.6	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,2-Dichlorobenzene	(mg/kg)			1.1	1.1	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,2-Dichloroethane	(mg/kg)			0.02	0.02	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,3,5-Trimethylbenzene	(mg/kg)			8.4	8.4	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,3-Dichlorobenzene	(mg/kg)			2.4	2.4	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,4-Dichlorobenzene	(mg/kg)					0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
1,4-Dioxane	(mg/kg)			0.1	0.1	0.0495	U	0.04855	U	0.054	U	0.0505	U	0.0485	U	0.04895	U
2,4,5-TP	(mg/kg)			0.1	0.1	0.0435	U	0.04275	U	0.0474	U	0.0438	U	0.0419	U	0.04235	U
2-Butanone	(mg/kg)					0.0066	U	0.0065	U	0.0072	U	0.0068	U	0.00645	U	0.00655	U
4,4'-DDD	(mg/kg)			0.0033	17	**0.0105**	U	**0.01**	U	**0.01135**	U	**0.0107**	U	**0.01065**	U	**0.01045**	U
4,4'-DDE	(mg/kg)			0.0033	136	**0.0105**	U	**0.01**	U	**0.01135**	U	**0.0107**	U	**0.01065**	U	**0.01045**	U
4,4'-DDT	(mg/kg)			0.0033	14	**0.0105**	U	**0.01**	U	**0.01135**	U	**0.0107**	U	**0.01065**	U	**0.01045**	U
Acenaphthene	(mg/kg)			20	98	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U
Acenaphthylene	(mg/kg)			100	107	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U
Acetone	(mg/kg)			0.05	0.05	0.0081	J	0.0065	U	0.0089	J	0.0068	U	0.00645	U	0.0076	J
Aldrin	(mg/kg)			0.005	0.19	**0.0054**	U	**0.00515**	U	**0.00585**	U	**0.0055**	U	**0.0055**	U	**0.0054**	U
alpha-BHC	(mg/kg)			0.02	0.02	0.0054	U	0.00515	U	0.00585	U	0.0055	U	0.0055	U	0.0054	U
alpha-Chlordane	(mg/kg)			0.094	2.9	0.0054	U	0.00515	U	0.00585	U	0.0055	U	0.0055	U	0.0054	U
Anthracene	(mg/kg)			100	1000	0.063	U	0.0627	J	0.07	U	0.0665	U	0.062	U	0.064	U
Aroclor-1016	(mg/kg)					0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Aroclor-1221	(mg/kg)					0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Aroclor-1232	(mg/kg)					0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Aroclor-1242	(mg/kg)					0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Aroclor-1248	(mg/kg)					0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Aroclor-1254	(mg/kg)					0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Aroclor-1260	(mg/kg)					0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Arsenic, Total	(mg/kg)	8.2	53	13	16	2.6		1.6	J	2.2		3.3		2.8		3.5	
Barium, Total	(mg/kg)			350	820	6.3		2.6	J	6.4		5.1		9.5		9	
Benzene	(mg/kg)			0.06	0.06	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Benzo(a)anthracene	(mg/kg)			1	1	0.063	U	0.103	J	0.07	U	0.0665	U	0.062	U	0.064	U
Benzo(a)pyrene	(mg/kg)			1	22	0.063	U	0.0816	J	0.07	U	0.0665	U	0.062	U	0.064	U
Benzo(b)fluoranthene	(mg/kg)			1	1.7	0.0435	J	0.0976	J	0.07	U	0.0665	U	0.062	U	0.064	U
Benzo(g,h,i)perylene	(mg/kg)			100	1000	0.063	U	0.051	J	0.07	U	0.0665	U	0.062	U	0.064	U
Benzo(k)fluoranthene	(mg/kg)			0.8	1.7	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		South											
		Class B	Class C	Unrestricted Use	Protection of Groundwater	1217_42		1374_22		1787_44		2146_25		654_9		659_7	
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/24/2015		9/24/2015		9/24/2015		9/24/2015		9/24/2015		9/24/2015	
Beryllium, Total	(mg/kg)			7.2	47	0.295	U	0.27	U	0.33	U	0.28	J	0.24	J	0.34	J
beta-BHC	(mg/kg)			0.036	0.09	0.0054	U	0.00515	U	0.00585	U	0.0055	U	0.0055	U	0.0054	U
Cadmium, Total	(mg/kg)	1.2	9.5	2.5	7.5	0.295	U	0.27	U	0.33	U	0.305	U	0.275	U	0.28	U
Carbon Tetrachloride	(mg/kg)			0.76	0.76	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Chlorobenzene	(mg/kg)			1.1	1.1	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Chloroform	(mg/kg)			0.37	0.37	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Chromium, Total	(mg/kg)			1	19	**8.9**		**4.4**		**9.5**		**11.2**		**9.6**		**11.8**	
Chrysene	(mg/kg)			1	1	0.063	U	0.0799	J	0.07	U	0.0665	U	0.062	U	0.064	U
cis-1,2-Dichloroethene	(mg/kg)			0.25	0.25	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Copper, Total	(mg/kg)	33	270	50	1720	10		5		8.9		11.3		9.8		12.9	
Cyanide, Total	(mg/kg)			27	40	0.165	U	0.165	U	0.175	U	0.17	U	0.155	U	0.155	U
delta-BHC	(mg/kg)			0.04	0.25	0.0054	U	0.00515	U	0.00585	U	0.0055	U	0.0055	U	0.0054	U
Dibenzo(a,h)anthracene	(mg/kg)			0.33	1000	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U
Dibenzofuran	(mg/kg)			7	210	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U
Dieldrin	(mg/kg)	0.11	0.48	0.005	0.1	**0.0105**	U	**0.01**	U	**0.01135**	U	**0.0107**	U	**0.01065**	U	**0.01045**	U
Endosulfan I	(mg/kg)			2.4	102	0.0054	U	0.00515	U	0.00585	U	0.0055	U	0.0055	U	0.0054	U
Endosulfan II	(mg/kg)			2.4	102	0.0105	U	0.01	U	0.01135	U	0.0107	U	0.01065	U	0.01045	U
Endosulfan Sulfate	(mg/kg)			2.4	1000	0.0105	U	0.01	U	0.01135	U	0.0107	U	0.01065	U	0.01045	U
Endrin	(mg/kg)			0.014	0.06	0.0105	U	0.01	U	0.01135	U	0.0107	U	0.01065	U	0.01045	U
Ethylbenzene	(mg/kg)			1	1	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Fluoranthene	(mg/kg)			100	1000	0.0479	J	0.245		0.0534	J	0.0665	U	0.062	U	0.064	U
Fluorene	(mg/kg)			30	386	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U
gamma-BHC	(mg/kg)			0.1	0.1	0.0054	U	0.00515	U	0.00585	U	0.0055	U	0.0055	U	0.0054	U
Heptachlor	(mg/kg)			0.042	0.38	0.0054	U	0.00515	U	0.00585	U	0.0055	U	0.0055	U	0.0054	U
Hexachlorobenzene	(mg/kg)			0.33	3.2	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U
Hexavalent Chromium	(mg/kg)					1.3	U	1.3	U	1.4	U	1.35	U	1.3	U	1.25	U
Indeno(1,2,3-cd)pyrene	(mg/kg)			0.5	8.2	0.063	U	0.0533	J	0.07	U	0.0665	U	0.062	U	0.064	U
Lead, Total	(mg/kg)	47	218	63	450	13.3		4		12.7		8.8		10.7		11.5	
Manganese, Total	(mg/kg)			1600	2000	96.6		45.4		125		130		124		131	
Mercury, Total	(mg/kg)	0.17	1	0.18	0.73	0.05	J	0.0325	U	0.056	J	0.027	J	0.037	J	0.028	J
Methyl t-Butyl Ether	(mg/kg)			0.93	0.93	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Methylene Chloride	(mg/kg)			0.05	0.05	0.0079		0.0094		0.0146		0.0123		0.0109		0.0134	
Moisture	%					23.5		22.6		30		25		22.6		22.2	
mp-Cresol	(mg/kg)			0.33	0.33	0.1695	U	0.1655	U	0.189	U	0.18	U	0.168	U	0.1725	U
Naphthalene	(mg/kg)			12	12	0.063	U	0.0615	U	0.07	U	0.0665	U	0.062	U	0.064	U
n-Butylbenzene	(mg/kg)			12	12	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Nickel, Total	(mg/kg)			30	130	5.5		3.7		5.6		9.7		7.5		8.9	

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		South											
		Class B	Class C	Unrestricted Use	Protection of Groundwater	1217_42		1374_22		1787_44		2146_25		654_9		659_7	
Analyte	**Units**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**9/24/2015**		**9/24/2015**		**9/24/2015**		**9/24/2015**		**9/24/2015**		**9/24/2015**	
n-Propylbenzene	(mg/kg)			3.9	3.9	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
o-Cresol	(mg/kg)			0.33	0.33	0.1695	U	0.1655	U	0.189	U	0.18	U	0.168	U	0.1725	U
Pentachlorophenol	(mg/kg)			0.8	0.8	0.1255	U	0.1225	U	0.14	U	0.1335	U	0.1245	U	0.1275	U
Phenanthrene	(mg/kg)			100	1000	0.063	U	0.235		0.07	U	0.0665	U	0.062	U	0.064	U
Phenol	(mg/kg)			0.33	0.33	0.1695	U	0.1655	U	0.189	U	0.18	U	0.168	U	0.1725	U
Pyrene	(mg/kg)			100	1000	0.063	U	0.198		0.0543	J	0.0665	U	0.062	U	0.064	U
sec-Butylbenzene	(mg/kg)			11	11	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Selenium, Total	(mg/kg)			3.9	4	1.5	U	1.35	U	1.65	U	1.1	J	1.35	U	1.1	J
Silver, Total	(mg/kg)			2	8.3	0.6	U	0.55	U	0.65	U	0.6	U	0.55	U	0.55	U
tert-Butylbenzene	(mg/kg)			5.9	5.9	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Tetrachloroethene	(mg/kg)			1.3	1.3	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Toluene	(mg/kg)			0.7	0.7	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Total Polychlorinated Biphenyl	(mg/kg)	0.1	1	0.1	3.2	0.021	U	0.02	U	0.0225	U	0.0215	U	0.0215	U	0.021	U
Total Solids	%					76.5		77.4		70		75		77.4		77.8	
Total Xylenes	(mg/kg)			0.26	1.6	0.004	U	0.0039	U	0.0043	U	0.0041	U	0.0039	U	0.0039	U
trans-1,2-Dichloroethene	(mg/kg)			0.19	0.19	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Trichloroethene	(mg/kg)			0.47	0.47	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Trivalent Chromium	(mg/kg)					8.9		4.4		9.5		11.2		9.6		11.8	
Vinyl Chloride	(mg/kg)			0.02	0.02	0.0013	U	0.0013	U	0.00145	U	0.0014	U	0.0013	U	0.0013	U
Zinc, Total	(mg/kg)			109	2480	40.2		16.4		39.1		37.1		38.5		40.8	
Σ DDT, Calculated	(mg/kg)	0.003	0.03			0		0		0		0		0		0	
Total PAH, Calculated	(mg/kg)	4	45			0.0914		1.2071		0.1077		0		0		0	
Total BTEX, Calculated	(mg/kg)	0.96	5.9			0		0		0		0		0		0	

Appendix E-8: Sediment Chemistry Data (continued)

		NYSDEC TOGS 5.1.9		NYSDEC Part 375		South						
		Class B	Class C	Unrestricted Use	Protection of Groundwater	714_40	717_59	720_16	HB04_6	HB04_7	HB05_8	HB05_9
Analyte	Units	mg/kg	mg/kg	mg/kg	mg/kg	9/24/2015	9/24/2015	9/24/2015	9/21/2015	9/21/2015	9/21/2015	9/21/2015
1,1,1-Trichloroethane	(mg/kg)			0.68	0.68	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,1-Dichloroethane	(mg/kg)			0.27	0.27	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,1-Dichloroethene	(mg/kg)			0.33	0.33	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,2,4-Trimethylbenzene	(mg/kg)			3.6	3.6	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,2-Dichlorobenzene	(mg/kg)			1.1	1.1	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,2-Dichloroethane	(mg/kg)			0.02	0.02	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,3,5-Trimethylbenzene	(mg/kg)			8.4	8.4	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,3-Dichlorobenzene	(mg/kg)			2.4	2.4	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,4-Dichlorobenzene	(mg/kg)					0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
1,4-Dioxane	(mg/kg)			0.1	0.1	0.0477 U	0.0482 U	0.04945 U	0.04735 U	0.0482 U	0.03755 U	0.0409 U
2,4,5-TP	(mg/kg)			0.1	0.1	0.041 U	0.0414 U	0.0438 U	0.0469 U	0.04905 U	0.04705 U	0.04645 U
2-Butanone	(mg/kg)					0.0064 U	0.0065 U	0.0066 U	0.0042 J	0.00645 U	0.0064 J	0.00545 U
4,4'-DDD	(mg/kg)			0.0033	17	**0.0099** U	**0.0099** U	**0.0104** U	**0.01145** U	**0.01185** U	**0.0115** U	**0.0115** U
4,4'-DDE	(mg/kg)			0.0033	136	**0.0099** U	**0.0099** U	**0.0104** U	**0.01145** U	**0.01185** U	**0.0115** U	**0.0115** U
4,4'-DDT	(mg/kg)			0.0033	14	**0.0099** U	**0.0099** U	**0.0104** U	**0.01145** U	**0.01185** U	**0.0115** U	**0.0115** U
Acenaphthene	(mg/kg)			20	98	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Acenaphthylene	(mg/kg)			100	107	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Acetone	(mg/kg)			0.05	0.05	0.0062 J	0.0085 J	0.0066 J	0.0099 J	0.0083 J	0.0149	0.00545 U
Aldrin	(mg/kg)			0.005	0.19	**0.0051** U	**0.0051** U	**0.00535** U	**0.0059** U	**0.0061** U	**0.00595** U	**0.00595** U
alpha-BHC	(mg/kg)			0.02	0.02	0.0051 U	0.0051 U	0.00535 U	0.0059 U	0.0061 U	0.00595 U	0.00595 U
alpha-Chlordane	(mg/kg)			0.094	2.9	0.0051 U	0.0051 U	0.00535 U	0.0059 U	0.0061 U	0.00595 U	0.00595 U
Anthracene	(mg/kg)			100	1000	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Aroclor-1016	(mg/kg)					0.02 U	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Aroclor-1221	(mg/kg)					0.02 U	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Aroclor-1232	(mg/kg)					0.02 U	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Aroclor-1242	(mg/kg)					0.02 U	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Aroclor-1248	(mg/kg)					0.02 U	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Aroclor-1254	(mg/kg)					0.47	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Aroclor-1260	(mg/kg)					0.02 U	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Arsenic, Total	(mg/kg)	8.2	53	13	16	1.9	2	1.9	3.8	5.8	3.9	4.7
Barium, Total	(mg/kg)			350	820	8.1	4.6	5.8	11.2	21.4	11.3	9.9
Benzene	(mg/kg)			0.06	0.06	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Benzo(a)anthracene	(mg/kg)			1	1	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Benzo(a)pyrene	(mg/kg)			1	22	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Benzo(b)fluoranthene	(mg/kg)			1	1.7	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Benzo(g,h,i)perylene	(mg/kg)			100	1000	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Benzo(k)fluoranthene	(mg/kg)			0.8	1.7	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U

Appendix E-8: Sediment Chemistry Data (continued)

Analyte	Units	NYSDEC TOGS 5.1.9 Class B mg/kg	NYSDEC TOGS 5.1.9 Class C mg/kg	NYSDEC Part 375 Unrestricted Use mg/kg	NYSDEC Part 375 Protection of Groundwater mg/kg	South 714_40 9/24/2015		South 717_59 9/24/2015		South 720_16 9/24/2015		South HB04_6 9/21/2015		South HB04_7 9/21/2015		South HB05_8 9/21/2015		South HB05_9 9/21/2015	
Beryllium, Total	(mg/kg)			7.2	47	0.2	J	0.24	J	0.305	U	0.33	U	0.3	J	0.26	J	0.25	J
beta-BHC	(mg/kg)			0.036	0.09	0.0051	U	0.0051	U	0.00535	U	0.0059	U	0.0061	U	0.00595	U	0.00595	U
Cadmium, Total	(mg/kg)	1.2	9.5	2.5	7.5	0.235	U	0.27	U	0.305	U	0.34	J	0.5	J	0.295	U	0.31	U
Carbon Tetrachloride	(mg/kg)			0.76	0.76	0.0013	U	0.0013	U	0.0013	U	0.00125	U	0.0013	U	0.001	U	0.0011	U
Chlorobenzene	(mg/kg)			1.1	1.1	0.0013	U	0.0013	U	0.0013	U	0.00125	U	0.0013	U	0.001	U	0.0011	U
Chloroform	(mg/kg)			0.37	0.37	0.0013	U	0.0013	U	0.0013	U	0.00125	U	0.0013	U	0.001	U	0.0011	U
Chromium, Total	(mg/kg)			1	19	**9.8**		**11**		**7.5**		**14.7**		***20.4***		**14**		**13.2**	
Chrysene	(mg/kg)			1	1	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
cis-1,2-Dichloroethene	(mg/kg)			0.25	0.25	0.0013	U	0.0013	U	0.0013	U	0.00125	U	0.0013	U	0.001	U	0.0011	U
Copper, Total	(mg/kg)	33	270	50	1720	9.4		15.8		7.3		20.1		25.2		8.4		9.2	
Cyanide, Total	(mg/kg)			27	40	0.155	U	0.155	U	0.17	U	0.18	U	0.19	U	0.18	U	0.17	U
delta-BHC	(mg/kg)			0.04	0.25	0.0051	U	0.0051	U	0.00535	U	0.0059	U	0.0061	U	0.00595	U	0.00595	U
Dibenzo(a,h)anthracene	(mg/kg)			0.33	1000	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
Dibenzofuran	(mg/kg)			7	210	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
Dieldrin	(mg/kg)	0.11	0.48	0.005	0.1	**0.0099**	U	**0.0099**	U	**0.0104**	U	**0.01145**	U	**0.01185**	U	**0.0115**	U	**0.0115**	U
Endosulfan I	(mg/kg)			2.4	102	0.0051	U	0.0051	U	0.00535	U	0.0059	U	0.0061	U	0.00595	U	0.00595	U
Endosulfan II	(mg/kg)			2.4	102	0.0099	U	0.0099	U	0.0104	U	0.01145	U	0.01185	U	0.0115	U	0.0115	U
Endosulfan Sulfate	(mg/kg)			2.4	1000	0.0099	U	0.0099	U	0.0104	U	0.01145	U	0.01185	U	0.0115	U	0.0115	U
Endrin	(mg/kg)			0.014	0.06	0.0099	U	0.0099	U	0.0104	U	0.01145	U	0.01185	U	0.0115	U	0.0115	U
Ethylbenzene	(mg/kg)			1	1	0.0013	U	0.0013	U	0.0013	U	0.00125	U	0.0013	U	0.001	U	0.0011	U
Fluoranthene	(mg/kg)			100	1000	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
Fluorene	(mg/kg)			30	386	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
gamma-BHC	(mg/kg)			0.1	0.1	0.0051	U	0.0051	U	0.00535	U	0.0059	U	0.0061	U	0.00595	U	0.00595	U
Heptachlor	(mg/kg)			0.042	0.38	0.0051	U	0.0051	U	0.00535	U	0.0059	U	0.0061	U	0.00595	U	0.00595	U
Hexachlorobenzene	(mg/kg)			0.33	3.2	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
Hexavalent Chromium	(mg/kg)					1.2	U	1.3	U	1.3	U	1.4	U	1.4	U	1.45	U	1.35	U
Indeno(1,2,3-cd)pyrene	(mg/kg)			0.5	8.2	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
Lead, Total	(mg/kg)	47	218	63	450	7.6		7.1		8.2		24.5		36.2		19		20.1	
Manganese, Total	(mg/kg)			1600	2000	78.3		80.8		84.3		335		490		298		282	
Mercury, Total	(mg/kg)	0.17	1	0.18	0.73	0.022	J	0.0275	U	0.028	J	0.17		**0.22**		0.066	J	0.07	
Methyl t-Butyl Ether	(mg/kg)			0.93	0.93	0.0013	U	0.0013	U	0.0013	U	0.00125	U	0.0013	U	0.0005	J	0.0011	U
Methylene Chloride	(mg/kg)			0.05	0.05	0.0133		0.0141		0.0107		0.0261		0.0267		0.023		0.0219	
Moisture	%					20.2		21.4		23.6		31.1		33		29.7		29.3	
mp-Cresol	(mg/kg)			0.33	0.33	0.1615	U	0.163	U	0.173	U	0.1895	U	0.2015	U	0.1885	U	0.191	U
Naphthalene	(mg/kg)			12	12	0.06	U	0.0605	U	0.064	U	0.0705	U	0.0745	U	0.0695	U	0.0705	U
n-Butylbenzene	(mg/kg)			12	12	0.0013	U	0.0013	U	0.0013	U	0.00125	U	0.0013	U	0.001	U	0.0011	U
Nickel, Total	(mg/kg)			30	130	8.8		7.7		5.9		8.4		10.7		9.3		9	

Appendix E-8: Sediment Chemistry Data (continued)

Analyte	Units	NYSDEC TOGS 5.1.9 Class B mg/kg	NYSDEC TOGS 5.1.9 Class C mg/kg	NYSDEC Part 375 Unrestricted Use mg/kg	NYSDEC Part 375 Protection of Groundwater mg/kg	South 714_40 9/24/2015	South 717_59 9/24/2015	South 720_16 9/24/2015	South HB04_6 9/21/2015	South HB04_7 9/21/2015	South HB05_8 9/21/2015	South HB05_9 9/21/2015
n-Propylbenzene	(mg/kg)			3.9	3.9	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
o-Cresol	(mg/kg)			0.33	0.33	0.1615 U	0.163 U	0.173 U	0.1895 U	0.2015 U	0.1885 U	0.191 U
Pentachlorophenol	(mg/kg)			0.8	0.8	0.1195 U	0.121 U	0.128 U	0.1405 U	0.1495 U	0.1395 U	0.1415 U
Phenanthrene	(mg/kg)			100	1000	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
Phenol	(mg/kg)			0.33	0.33	0.1615 U	0.163 U	0.173 U	0.1895 U	0.2015 U	0.1885 U	0.191 U
Pyrene	(mg/kg)			100	1000	0.06 U	0.0605 U	0.064 U	0.0705 U	0.0745 U	0.0695 U	0.0705 U
sec-Butylbenzene	(mg/kg)			11	11	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Selenium, Total	(mg/kg)			3.9	4	0.97 J	0.98 J	1.5 U	1.65 U	1.2 J	1.5 U	1.55 U
Silver, Total	(mg/kg)			2	8.3	0.475 U	0.55 U	0.6 U	0.65 U	0.75 U	0.6 U	0.6 U
tert-Butylbenzene	(mg/kg)			5.9	5.9	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Tetrachloroethene	(mg/kg)			1.3	1.3	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Toluene	(mg/kg)			0.7	0.7	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Total Polychlorinated Biphenyl	(mg/kg)	0.1	1	0.1	3.2	**0.47**	0.02 U	0.021 U	0.023 U	0.0235 U	0.023 U	0.023 U
Total Solids	%					79.8	78.6	76.4	68.9	67	70.3	70.7
Total Xylenes	(mg/kg)			0.26	1.6	0.0038 U	0.0039 U	0.00395 U	0.0038 U	0.00385 U	0.003 U	0.00325 U
trans-1,2-Dichloroethene	(mg/kg)			0.19	0.19	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Trichloroethene	(mg/kg)			0.47	0.47	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Trivalent Chromium	(mg/kg)					9.8	11	7.5	14.7	20.4	14	13.2
Vinyl Chloride	(mg/kg)			0.02	0.02	0.0013 U	0.0013 U	0.0013 U	0.00125 U	0.0013 U	0.001 U	0.0011 U
Zinc, Total	(mg/kg)			109	2480	27.2	28.3	29.7	68.9	87.4	58.5	59
Σ DDT, Calculated	(mg/kg)	0.003	0.03			0	0	0	0	0	0	0
Total PAH, Calculated	(mg/kg)	4	45			0	0	0	0	0	0	0
Total BTEX, Calculated	(mg/kg)	0.96	5.9			0	0	0	0	0	0	0

Note:
Below detection values reported at 0.5 * reporting limit for individual parameters, reported as 0 when comparing against summed values.

NYSDEC TOGS 5.1.9 - Class B Exceedance
NYSDEC TOGS 5.1.9 - Class C Exceedance
NYSDEC Part 375 Unrestricted Use Exceedance
NYSDEC Part 375 Protection of Groundwater Exceedance

Appendix E-9
Existing Conditions Site Photographs

PHOTO 1 - VIEW OF THE BEACH AND FORESTED UPLANDS ON THE NORTHEASTERN PORTION OF THE STUDY AREA, FACING SOUTH.

PHOTO 2 - VIEW OF THE BEACH AND ARTIFICIAL TEMPORARY WITHIN THE STUDY AREA, FACING SOUTH.

PHOTO 3 - VIEW FROM THE TOP OF THE ARTIFICIAL TEMPORARY DUNES, BEACH, AND VEGETATED UPLAND, FACING NORTH.

PHOTO 4 - VIEW OF THE UNMAPPED COMMON REED (*PHRAGMITES AUSTRALIS*) DOMINATED MARSH WITHIN THE STUDY AREA, FACING WEST.

PHOTO 5- VIEW OF THE BEACH AND VEGETATED DUNES WITHIN THE STUDY AREA, FACING EAST.

PHOTO 6 - VIEW OF THE VEGETATED DUNES AND FORESTED UPLANDS ON THE SOUTHERN PORTION OF THE STUDY AREA, FACING WEST.

PHOTO 7 - VIEW OF THE SOUTHERN SUCCESSIONAL HARDWOOD COMMUNITY FROM THE BEACH, FACING WEST.

Appendix E-10
Calculation of Available Surface Area and Marine Habitat Generated for Living Breakwaters—Memo

MEMO

Date: November 28, 2016
From: SCAPE, OCC, SEARC
To: AKRF, GOSR
Cc:
Re: **Calculation of Available Surface Area and Marine Habitat Generated for Living Breakwaters**

The Living Breakwaters team has calculated the amount of marine habitat generated and displaced by the project, taking into consideration both the breakwater structures and the potential beach fill proposed. This memo defines the habitats considered and describes the methods used for calculating the approximate areas of each of these habitats created and displaced by the project. Back up documentation and summary areas are provided in the attachments.

SUMMARY OF TYPES OF HABITAT DISPLACED AND CREATED

The elements of the project included in this estimation of habitat created and displaced include in-water surface piercing breakwaters constructed of a combination of rock and bio-enhancing concrete units, and a single stretch of beach fill consisting of sand.

The existing habitats in the locations where the project elements (breakwaters and beach fill) will be located consist largely of small and large grain (sand and gravel) subtidal and intertidal habitat.

The **breakwaters** will replace existing subtidal small and large grained bottom habitat with subtidal, intertidal, and emergent hard / rocky habitat, comprised of rock and bio-enhancing concrete of varying sizes depending on their function and location on the breakwater.

The **beach fill** will replace subtidal and intertidal small and large grained habitat (sand, gravel and pebbles) with subtidal, intertidal, and emergent small grained habitat (sand).

Habitat Type Definitions

As described in the Living Breakwaters 30% Design Report, habitat types have been defined by (1) their substrate or grain size and (2) their location within the tidal column.

Substrate / Grain Size Definitions:

- **Hard / rocky bottom:** Greater than 64mm (2.5”). Substrate includes small cobbles to boulders. The breakwater structures are considered to be hard / rocky bottomed

habitat. Habitats are observed or will occur in emergent, intertidal, and subtidal conditions.

- **Large grain:** 64mm (2.5”) to 2mm (.07”). Substrates in this category include gravel, pebbles, and shells. Habitats are observed or will occur in intertidal and subtidal conditions.
- **Small grain:** 2mm (.07”) to .063mm (.002”). Substrate includes sand. This includes existing sandy bottomed habitats. Habitats are observed or will occur in emergent, intertidal, and subtidal conditions.
- **Fine grain:** Less than .063mm (.002”). Substrate in this category include silt and clay and is characterized by generally cohesive material. This condition is not observed in the area where breakwaters are proposed, nor is it anticipated to be generated by the breakwaters’ interactions with their surroundings.
- **Vegetated:** This habitat includes submerged aquatic vegetation (SAV) and intertidal vegetation, usually occurring in small to fine grained conditions. While this habitat may form over time as a result of the project, it is not being directly constructed as part of the project.

Location in the Tidal Column Definitions:

- **Emergent:** above mean high water (MHW), includes the supra-littoral zone (an area above MHW which is mostly effected by sea-spray and gets water cover, by surge or waves, only in storms).
- **Intertidal:** An area of tidal amplitude, between mean low water (MLW) and MHW. Organisms in this area are most effected by waves and tidal fluctuations, as their level of water coverage varies. Also “littoral”.
- **Subtidal:** An area below low tide, below MLW. This area is always covered with water, and if exposed, only for a very short time period. Also “sublittoral”.

For a more detailed description of the habitats types and the species they may serve, refer to the 30% Design Report Appendix M: Target Functional Groups and Habitats.

Due to the specificity of existing habitat surveys, it is not possible to determine the specific extents and areas of small grained (sand) versus large grained (gravel and pebbles) habitat, so for the purposes of this habitat quantification process, these two habitat types have been combined.

APPROACH TO QUANTIFYING HABITATS DISPLACED AND CREATED

Habitats Included / Excluded From These Calculations

For the purpose of these calculations, only marine (intertidal and subtidal) habitat has been quantified. Neither the emergent habitat created by the breakwaters and beach fill, nor any emergent habitat displaced by the beach fill are included. No emergent habitat will be displaced by the breakwaters. Though the emergent areas of the breakwaters will provide habitat potential (such as seal haul out areas or bird roosts), it is not directly related to surface area and is not inhabited in the same way that the niches and crevices created by the subtidal and intertidal rocks and bio-enhancing armor units will be. As the productive surface area is less easily quantifiable and function differently than the subtidal and intertidal habitats, their benefits will be noted qualitatively, but they are excluded from these quantitative calculations.

Method Used For Calculating Breakwater Habitat Created

The breakwaters will create hard / rocky habitat consisting of rock and bio-enhancing concrete units ranging from 12” to 40” in diameter. Given their size relative to the target species / functional groups, these materials will create niches and crevices between individual units that are usable by the target species / functional groups, thus generating habitat area significantly greater than the planar surface area of the simple breakwater structure.

In order to estimate the actual area of hard / rock subtidal and intertidal habitat created by the breakwaters, an approximation of Accessible Surface Area (ASA) was developed.

In order to calculate the Accessible Surface Area (ASA), and from it the available habitat generated by the various areas of the breakwater, the following methodology was used:

1. Calculate the total volume of the material in the identified portion of the breakwater using geometric approximation (see below for assumptions made regarding the geometry of materials for different areas of the breakwaters).
2. Calculate the volume of the voids within the total volume using porosity for rough, random placement of the units.
3. Calculate the total number of units using the volume of a sphere to idealize a single unit.
4. Calculate the Available Surface Area (ASA) by multiplying the number of units by the surface area of the idealized unit.
5. Calculate the Available Habitat by multiplying the ASA by 70%

Using this methodology, the areas created by the main breakwater segment and the reef ridges / streets were calculated separately and combined to generate an estimation of the total ASA of hard / rocky intertidal and subtidal habitat created by the breakwaters.

A number of assumptions and geometric approximations were required to use this methodology:

- The shape of the stones or bio-enhancing concrete units (regardless of size) comprising the different parts of the breakwater is a sphere with a constant diameter equal to the median stone size (D_{50}).
- A simplified geometry (length, width, thickness) is used to calculate the volume, which negates irregularities due to stone/unit placement.
- The porosity is based on values given in Table VI-5-51 of the Coastal Engineering Manual (USACE EM 1110-2-1100) for a two-layer, randomly placed rough quarry stone.
- The available habitat created is dependent on different factors, which vary with the penetration into the subsurface such as grain/stone size, dissolved oxygen, nutrient flux, light, temp, etc. These factors dictate the actual percentage of the ASA, which can be regarded as the available habitat. Since it is difficult to quantify the above-mentioned variables at this point in the design process, we recommend calculating the available habitat using a conservative assessment of 70% of the ASA as a rule of thumb. This number will present the available habitat as the area of the ASA not effected by limiting or overloading environmental factures, which can be considered as an Essential Fish Habitat. Thus, this will provide habitat for a diversity of sessile and algae species which serve as food and cover for fish and other foraging organisms (NOAA Fisheries Greater Atlantic Region).

In addition, the following assumptions regarding material composition and size were made:

- For the main breakwater segment:
    - To calculate the ASA for the armored portion of the main breakwaters and average geometric approximation of both armor and toe armor units (both rock and bio-enhancing concrete) was made; units were assumed to have an average diameter of 30” and be present at a consistent thickness of two layers for all breakwater types.
    - The ASA of the scour apron, where it extended beyond the armored portion of the main breakwater, was calculated separately from the armor portion; units of the

scour apron were assumed to consist of bedding stone with an average diameter of 12” and thickness of one layer of stone for all breakwater types.

- For the reef ridges & streets:
  - To calculate the ASA for the armored portion of the main breakwaters and average geometric approximation of the various materials comprising the reef streets—riprap and toe armor units (both stone and bio-enhancing concrete)—was made; units were assumed to have an average diameter of 30” and thickness was assumed to vary by breakwater type.
  - The ASA of the scour apron, where it extends between (reef streets) and beyond the reef ridges was calculated separately from the riprap and armor units of the reef ridges; units of the scour apron were assumed to consist of bedding stone with an average diameter of 12” and thickness of one layer of stone for all breakwater types.

The above method and assumptions were used to calculate the ASA of the intertidal and subtidal hard / rocky marine habitat generated by the living breakwaters. The backup calculations prepared to estimate the habitat surface area created by the breakwaters are provided in *Table 2: Volume, Void, and Surface Area Backup Calculations*.

As the design is further refined, additional factors such as surface texture / roughness can be considered as part of the habitat creating factors for more detailed habitat quantity estimates.

Method for Calculating Beach Fill Habitat Created

It is assumed that the beach fill will consist of sand (small grained habitat, grain sizes will range between 2mm (.07”) to .063mm (.002”)). Thus, for the beach fill habitat area calculations, a planar area (square footage) was calculated to estimate the area of small grained habitat created by the beach fill as the void between grains are too small to appreciably influence the ASA of the habitat created by small grained material.

Method for Calculating Habitat Displaced

All of the habitat displaced is small and large grained habitat (grain size between .063mm (.002”) and .64mm (2.5”)). Thus, for these habitat area calculations a planar area (square footage) was calculated to estimate the area of small grained habitat displaced as the void between grains are too small to appreciably influence the ASA of the habitat created by small and large grained material.

SUMMARY

Table 1: Summary of Habitat Displaced and Created by the Living Breakwaters (attached) contains a summary of the marine habitat that is anticipated to be displaced and created by the project, according to the methodology outlined above. The overall totals according to this methodology show that a net change of +27.2 acres of marine habitat will be created below the MHW line (subtidal and intertidal). Table 1 includes a summary of the surface area of intertidal and subtidal habitat displaced and created (small/large grained habitat and hard/rocky habitat). This estimate includes habitat created and displaces by both the breakwater structures (inclusive of reef streets) and the beach fill.

SUPPORTING CALCULATIONS AND DOCUMENTATION (ATTACHED)

Table 1. Summary of Habitat Displaced and Created by the Living Breakwaters (30% Design Scenario)

Table 2: Volume, Void, and Surface Area Backup Calculations

Figure 1. Breakwater Habitat Types

Figure 2. Breakwater Materials and their Sizes

Figure 3. Breakwater Habitat Areas and Available Surface Area (ASA) Calculation Method

TABLE 1: SUMMARY OF HABITAT DISPLACED AND CREATED BY LIVING BREAKWATERS (30% DESIGN SCENARIO)

	Habitat Areas [squre feet]			Habitat Areas [acres]			Beach Fill [square feet]			Breakwater Core [square feet]			Reef Streets [square feet]		
	Displaced	Created	NET change	Displaced	Created	NET change	Displaced	Created	NET change	Displaced	Created	NET change	Displaced	Created	NET change
intertidal small and large grained (sand and gravel)*	39,091	56,984	17,893	0.9	1.3	0.4	39,091	56,984	17,893	0	0	0	0	0	0
subtidal small and large grained (sand and gravel)*	654,383	30,991	-623,392	15.0	0.7	-14.3	103,289	30,991	-72,298	429,779	0	-429,779	121,315	0	-121,315
hard / rocky (hard bottom) intertidal	0	564,837	564,837	0.0	13.0	13.0	0	0	0	0	492,199	492,199	0	72,638	72,638
hard / rocky (hard bottom) subtidal	0	1,231,626	1,231,626	0.0	28.3	28.3	0	0	0	0	599,803	599,803	0	631,822	631,822
total below MHW (subtidal & intertidal)	**693,474**	**1,884,437**	**1,190,963**	**15.9**	**43.3**	**27.3**	**142,380**	**87,975**	**-54,405**	**429,779**	**1,092,002**	**662,223**	**121,315**	**704,460**	**583,145**

	BW TOTAL (core + reef street)		
	Displaced	Created	NET change
intertidal small and large grained (sand and gravel)*	0	0	0
subtidal small and large grained (sand and gravel)*	551,094	0	-551,094
hard / rocky (hard bottom) intertidal	0	564,837	564,837
hard / rocky (hard bottom) subtidal	0	1,231,626	1,231,626
total below MHW (subtidal & intertidal)	551,094	1,796,463	1,245,368

TABLE 2: VOLUME, VOID, AND SURFACE AREA BACKUP CALCULATIONS (1 OF 2)

INTERTIDAL CALCULATIONS

location	material	BW type	Length of Armor Layer per Breakwater (A)	Armor Layer Thickness (B)	Armor Layer Height (C)	Total Volume (A)*(B)*(C) /sin Θ (D)	Porosity n=Vvoid/Vtotal (E)	Volume of Voids Vvoid=Vtotal*n (D)*(E) (F)	Volume of Armor Units (D)-(F) (G)	Volume of Idealized Armor Unit Sphere of diameter 3.3' V=4/3*PI*(ø/2)^3 (H)	Number of Units Possible within Volume (G)/(H) (I)
Main Breakwater	both stone and bio-enhancing concrete armor units and toe armor units, D50=30"	Type 'A'	990.00	6.60	4.70	67,644.15	0.37	25,028.33	42,615.81	18.82	2,264.80
		Type 'B'	724.00	6.60	4.70	49,469.05	0.37	18,303.55	31,165.50	18.82	1,656.28
		Type 'C'	1,330.00	6.60	4.70	90,875.47	0.37	33,623.92	57,251.55	18.82	3,042.61

location	material		Length of Ridges per Breakwater (A)	Ridge Section Area at Core (B)	Ridge Section Area at End (C)	Total Volume (A)* [(B)+(C)]/2 (D)	Porosity n=Vvoid/Vtotal (E)	Volume of Voids Vvoid=Vtotal*n (D)*(E) (F)	Volume of Reef Units (D)-(F) (G)	Volume of Idealized Reef Unit Sphere of diameter 2.5' V=4/3*PI*(ø/2)^3 (H)	Number of Units Possible within Volume (G)/(H) (I)
Reef Ridges & Streets (reef ridge)	Rip Rap (#1 & 2) and Toe Armor Units; D50=30"	Type 'A'	520.00	35.00	0.00	9,100.00	0.37	3,367.00	5,733.00	8.18	700.75
		Type 'B'	410.00	32.00	0.00	6,560.00	0.37	2,427.20	4,132.80	8.18	505.16
		Type 'C'	410.00	27.00	0.00	5,535.00	0.37	2,047.95	3,487.05	8.18	426.23

SUBTIDAL CALCULATIONS

location	material	BW type	Length of Armor Layer per Breakwater (A)	Armor Layer Thickness (B)	Armor Layer Height (C)	Total Volume (A)*(B)*(C) /sin Θ (D)	Porosity n=Vvoid/Vtotal (E)	Volume of Voids Vvoid=Vtotal*n (D)*(E) (F)	Volume of Armor Units (D)-(F) (G)	Volume of Idealized Armor Unit Sphere of diameter 3.3' V=4/3*PI*(ø/2)^3 (H)	Number of Units Possible within Volume (G)/(H) (I)
Main Breakwater	both stone and bio-enhancing concrete armor units and toe armor units, D50=30"	Type 'A'	990.00	6.60	1.38	19,861.47	0.37	7,348.74	12,512.73	18.82	664.98
		Type 'B'	724.00	6.60	3.38	35,575.62	0.37	13,162.98	22,412.64	18.82	1,191.11
		Type 'C'	1,330.00	6.60	6.38	123,358.62	0.37	45,642.69	77,715.93	18.82	4,130.19

location	material	BW type	Length of Apron per Breakwater (A)	Avg. Apron Layer Width (B)	Apron Layer Height (C)	Total Volume (A)*(B)*(C) (D)	Porosity n=Vvoid/Vtotal (E)	Volume of Voids Vvoid=Vtotal*n (D)*(E) (F)	Volume of Reef Units (D)-(F) (G)	Volume of Idealized Apron Stone Sphere of diameter 1.0' V=4/3*PI*(ø/2)^3 (H)	Number of Stones Possible within Volume (G)/(H) (I)
Main Breakwater (scour apron)	bedding stone; D50=12"	Type 'A'	838.00	10.00	1.00	8,380.00	0.37	3,100.60	5,279.40	0.52	10,082.91
		Type 'B'	594.00	10.00	1.00	5,940.00	0.37	2,197.80	3,742.20	0.52	7,147.08
		Type 'C'	1,140.00	10.00	1.00	11,400.00	0.37	4,218.00	7,182.00	0.52	13,716.61

location	material	BW type	Length of Ridges per Breakwater (A)	Ridge Section Area at Core (B)	Ridge Section Area at End (C)	Total Volume (A)*[(B)+(C)] /2 (D)	Porosity n=Vvoid/Vtotal (E)	Volume of Voids Vvoid=Vtotal*n (D)*(E) (F)	Volume of Reef Units (D)-(F) (G)	Volume of Idealized Reef Unit Sphere of diameter 2.5' V=4/3*PI*(ø/2)^3 (H)	Number of Units Possible within Volume (G)/(H) (I)
Reef Ridges & Streets (reef ridge)	Rip Rap (#1 & 2) and Toe Armor Units; D50=30"	Type 'A'	520.00	18.00	18.00	9,360.00	0.37	3,463.20	5,896.80	8.18	720.77
		Type 'B'	410.00	85.00	85.00	34,850.00	0.37	12,894.50	21,955.50	8.18	2,683.64
		Type 'C'	410.00	216.00	216.00	88,560.00	0.37	32,767.20	55,792.80	8.18	6,819.61

location	material	BW type	Length of Apron per Breakwater (A)	Avg. Apron Layer Width (B)	Apron Layer Height (C)	Total Volume (A)*(B)*(C) (D)	Porosity n=Vvoid/Vtotal (E)	Volume of Voids Vvoid=Vtotal*n (D)*(E) (F)	Volume of Reef Units (D)-(F) (G)	Volume of Idealized Apron Stone Sphere of diameter 1.0' V=4/3*PI*(ø/2)^3 (H)	Number of Stones Possible within Volume (G)/(H) (I)
Reef Ridges & Streets (scour apron)	bedding stone; D50=12"	Type 'A'	1,192.00	4.00	1.00	4,768.00	0.37	1,764.16	3,003.84	0.52	5,736.91
		Type 'B'	950.00	8.40	1.00	7,980.00	0.37	2,952.60	5,027.40	0.52	9,601.63
		Type 'C'	1,010.00	9.60	1.00	9,696.00	0.37	3,587.52	6,108.48	0.52	11,666.34

notes / assumptions

Scour apron length only includes exposed areas (not covered by reef ridge or armor layer)
Scour apron width includes slope and flat
Ridge layer width = Width at base + (2) 40" toe units
Ridge layer assumes 30" average unit size. Toe unit D50=40", Riprap Stone 1 D50=30", Riprap stone 2 D50 = 24"

TABLE 2: VOLUME, VOID, AND SURFACE AREA BACKUP CALCULATIONS (2 OF 2)

INTERTIDAL CALCULATIONS 564,837

location	material	BW type	Surface Area of Armor Unit SA=4*PI*(ø/2)^2 (J)	Total Surface Area of All Armor Units (Accessable Surface Area) (I)*(J) (K)	Available Habitat 70% of ASA (K)*0.7 (L)	Number of Breakwaters (M)	Total Available Habitat [sf] (L)*(M) (N)
Main Breakwater	both stone and bio-enhancing concrete armor units and toe armor units, D50=30"	Type 'A'	34.21	77,483.30	54,238.31	2	108,477
		Type 'B'	34.21	56,664.55	39,665.19	6	237,991
		Type 'C'	34.21	104,093.72	72,865.60	2	145,731
						Total [sf]	492,199

location	material		Surface Area of Reef Unit SA=4*PI*(ø/2)^2 (J)	Total Surface Area of All Reef Units (Accessable Surface Area) (I)*(J) (K)	Available Habitat 70% of ASA (K)*0.7 (L)	Number of Breakwaters (M)	Total Available Habitat [sf] (L)*(M) (N)
Reef Ridges & Streets (reef ridge)	Rip Rap (#1 & 2) and Toe Armor Units; D50=30"	Type 'A'	19.63	13,759.20	9,631.44	2	19,263
		Type 'B'	19.63	9,918.72	6,943.10	6	41,659
		Type 'C'	19.63	8,368.92	5,858.24	2	11,716
						Total [sf]	72,638

SUBTIDAL CALCULATIONS 1,231,626

location	material	BW type	Surface Area of Armor Unit SA=4*PI*(ø/2)^2 (J)	Total Surface Area of All Armor Units (Accessable Surface Area) (I)*(J) (K)	Available Habitat 70% of ASA (K)*0.7 (L)	Number of Breakwaters (M)	Total Available Habitat [sf] (L)*(M) (N)
Main Breakwater	both stone and bio-enhancing concrete armor units and toe armor units, D50=30"	Type 'A'	34.21	22,750.41	15,925.29	2	31,851
		Type 'B'	34.21	40,750.25	28,525.18	6	171,151
		Type 'C'	34.21	141,301.69	98,911.18	2	197,822
						Total [sf]	400,824

location	material	BW type	Surface Area of Apron Stone SA=4*PI*(ø/2)^2 (J)	Total Surface Area of All Reef Units (Accessable Surface Area) (I)*(J) (K)	Available Habitat 70% of ASA (K)*0.7 (L)	Number of Breakwaters (M)	Total Available Habitat [sf] (L)*(M) (N)
Main Breakwater (scour apron)	bedding stone; D50=12"	Type 'A'	3.14	31,676.40	22,173.48	2	44,347
		Type 'B'	3.14	22,453.20	15,717.24	6	94,303
		Type 'C'	3.14	43,092.00	30,164.40	2	60,329
						Total [sf]	198,979

location	material	BW type	Surface Area of Reef Unit SA=4*PI*(ø/2)^2 (J)	Total Surface Area of All Reef Units (Accessable Surface Area) (I)*(J) (K)	Available Habitat 70% of ASA (K)*0.7 (L)	Number of Breakwaters (M)	Total Available Habitat [sf] (L)*(M) (N)
Reef Ridges & Streets (reef ridge)	Rip Rap (#1 & 2) and Toe Armor Units; D50=30"	Type 'A'	19.63	14,152.32	9,906.62	2	19,813
		Type 'B'	19.63	52,693.20	36,885.24	6	221,311
		Type 'C'	19.63	133,902.72	93,731.90	2	187,464
						Total [sf]	428,588

location	material	BW type	Surface Area of Apron Stone SA=4*PI*(ø/2)^2 (J)	Total Surface Area of All Reef Units (Accessable Surface Area) (I)*(J) (K)	Available Habitat 70% of ASA (K)*0.7 (L)	Number of Breakwaters (M)	Total Available Habitat [sf] (L)*(M) (N)
Reef Ridges & Streets (scour apron)	bedding stone; D50=12"	Type 'A'	3.14	18,023.04	12,616.13	2	25,232
		Type 'B'	3.14	30,164.40	21,115.08	6	126,690
		Type 'C'	3.14	36,650.88	25,655.62	2	51,311
						Total [sf]	203,234

notes / assumptions

FIGURE 1: BREAKWATER HABITAT TYPES

NY RISING SCAPE TEAM

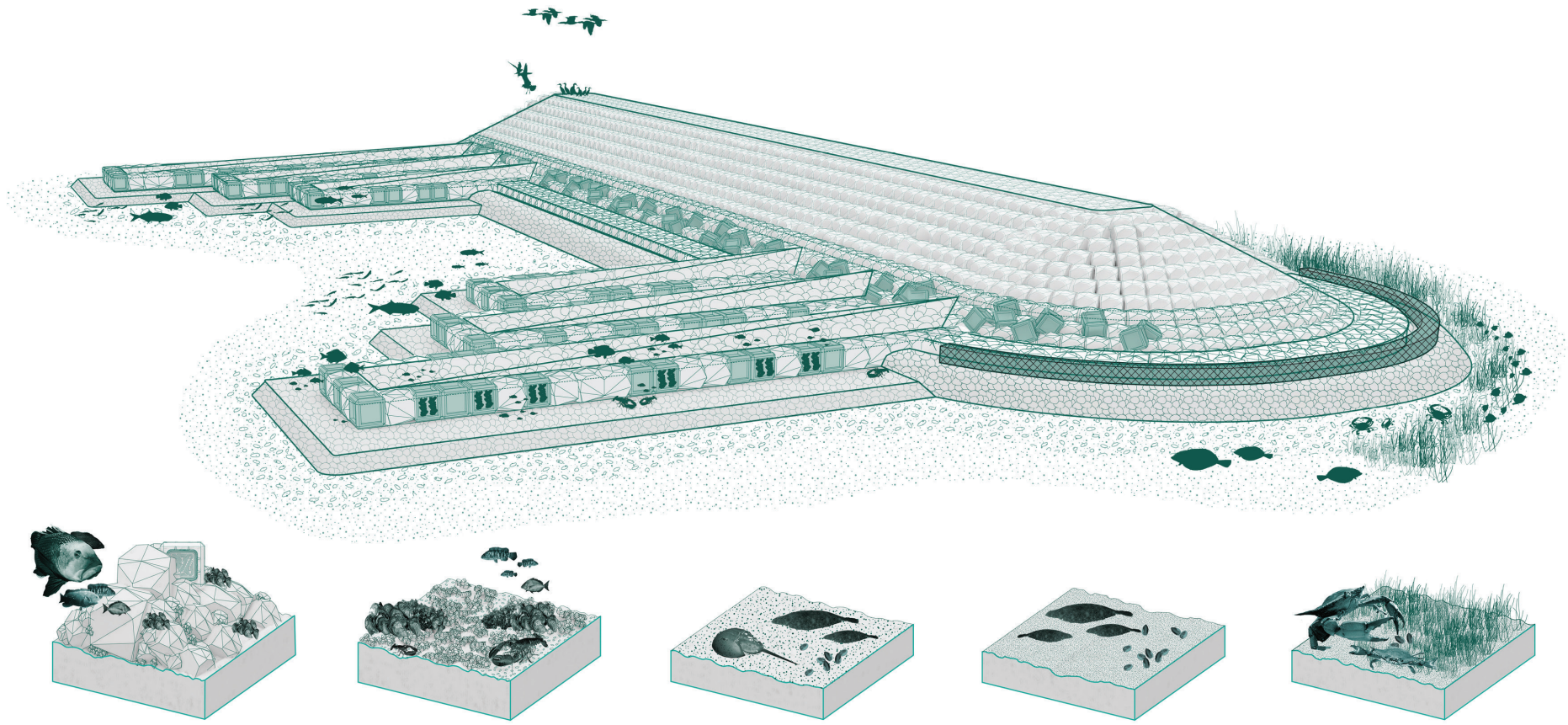


FIGURE 2: BREAKWATER MATERIALS AND THEIR SIZES

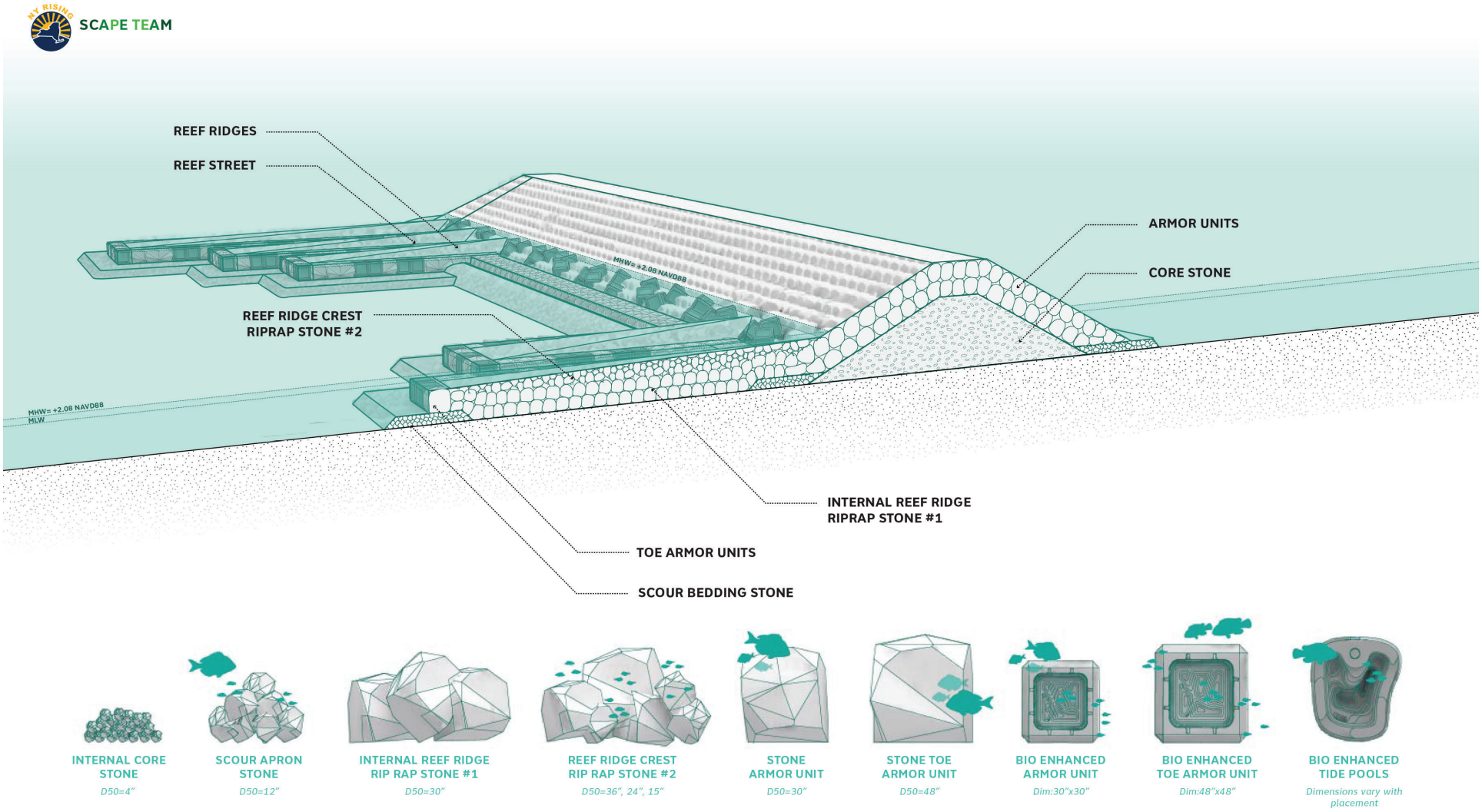
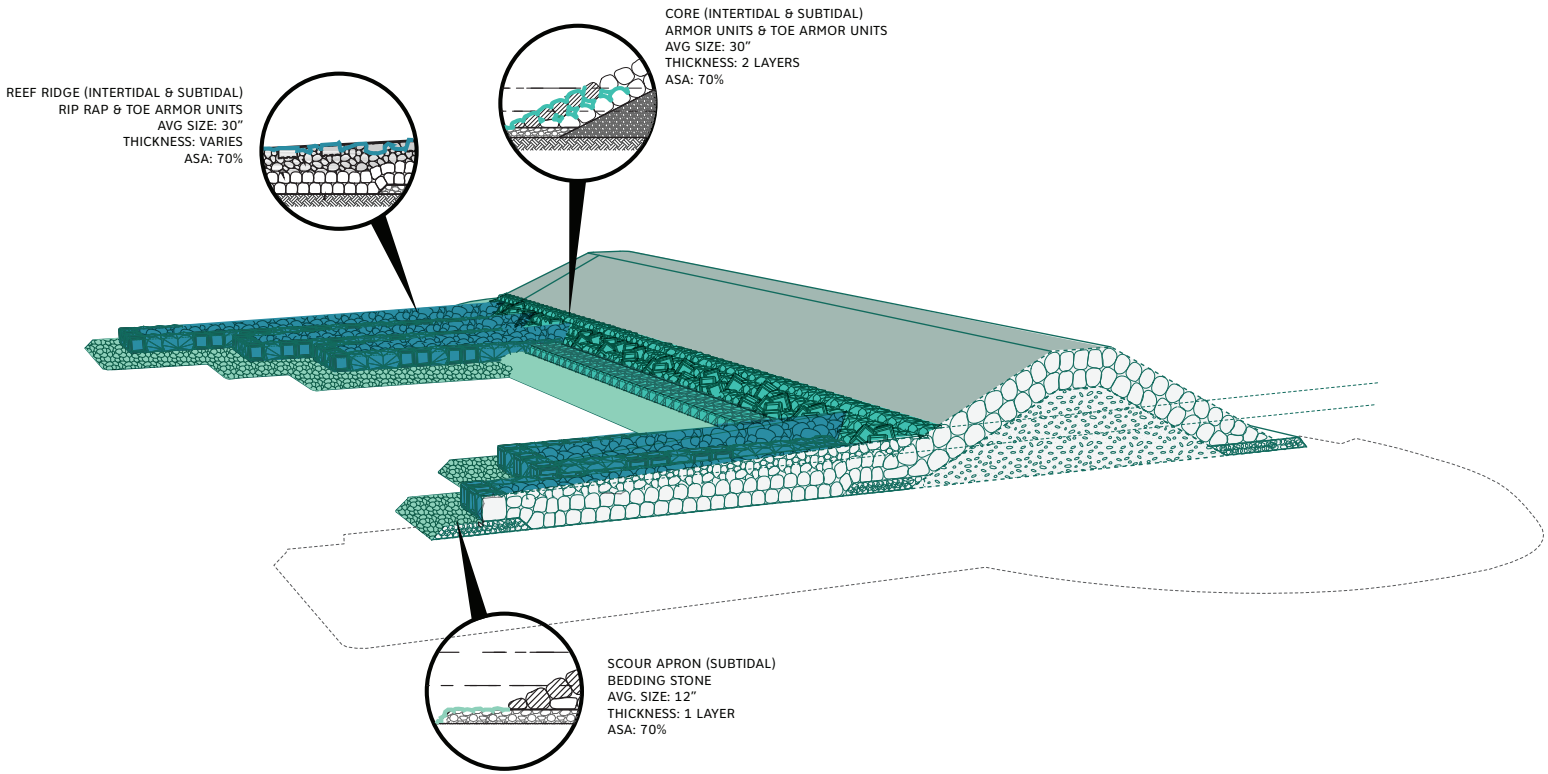
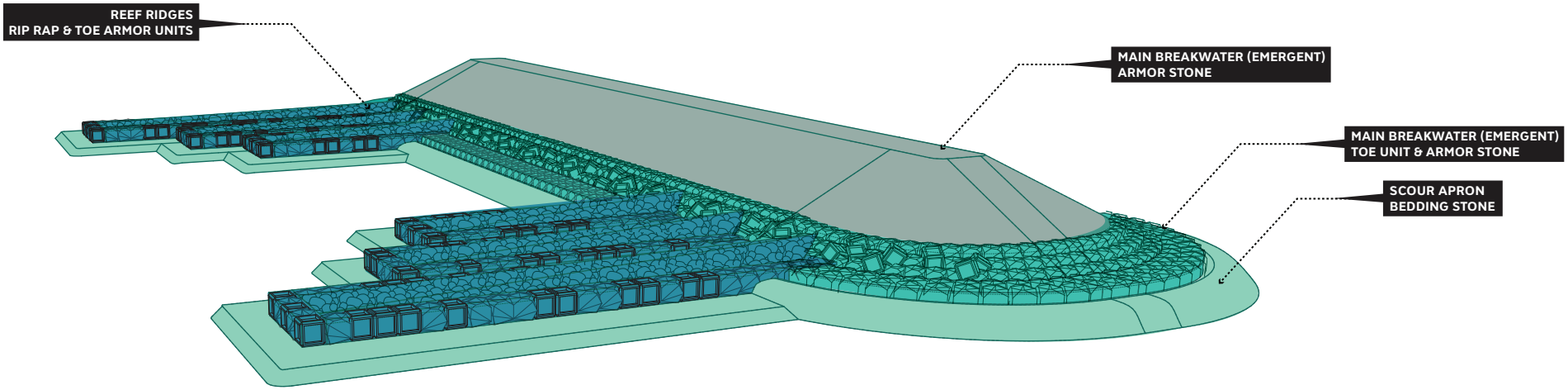


FIGURE 3: BREAKWATER HABITAT AREAS AND AVAILABLE SURFACE AREA (ASA) CALCULATION METHOD





Appendix E-11
Essential Fish Habitat

NOAA FISHERIES
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
Essential Fish Habitat (EFH) Consultation Guidance
EFH ASSESSMENT WORKSHEET

Introduction:

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) mandates that federal agencies conduct an essential fish habitat (EFH) consultation with NOAA Fisheries regarding any of their actions authorized, funded, or undertaken that may adversely affect EFH. An adverse effect means any impact that reduces the quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components. Adverse effects to EFH may result from actions occurring within EFH or outside of EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

This worksheet has been designed to assist in determining whether a consultation is necessary and in preparing EFH assessments. This worksheet should be used as your EFH assessment or as a guideline for the development of your EFH assessment. At a minimum, all the information required to complete this worksheet should be included in your EFH assessment. If the answers in the worksheet do not fully evaluate the adverse effects to EFH, we may request additional information in order to complete the consultation.

An expanded EFH assessment may be required for more complex projects in order to fully characterize the effects of the project and the avoidance and minimization of impacts to EFH. While the EFH worksheet may be used for larger projects, the format may not be sufficient to incorporate the extent of detail required, and a separate EFH assessment may be developed. However, regardless of format, the analysis outlined in this worksheet should be included for an expanded EFH assessment, along with additional information that may be necessary. This additional information includes:

- the results of on-site inspections to evaluate the habitat and site-specific effects
- the views of recognized experts on the habitat or the species that may be affected
- a review of pertinent literature and related information
- an analysis of alternatives to the action that could avoid or minimize the adverse effects on EFH.

Your analysis of adverse effects to EFH under the MSA should focus on impacts to the habitat for all life stages of species with designated EFH, rather than individual responses of fish species. Fish habitat includes the substrate and benthic resources (e.g., submerged

aquatic vegetation, shellfish beds, salt marsh wetlands), as well as the water column and prey species.

Consultation with us may also be necessary if a proposed action results in adverse impacts to other NOAA-trust resources. Part 6 of the worksheet is designed to help assess the effects of the action on other NOAA-trust resources. This helps maintain efficiency in our interagency coordination process. In addition, further consultation may be required if a proposed action impacts marine mammals or threatened and endangered species for which we are responsible. Staff from our Greater Atlantic Regional Fisheries Office, Protected Resources Division should be contacted regarding potential impacts to marine mammals or threatened and endangered species.

Instructions for Use:

Federal agencies must submit an EFH assessment to NOAA Fisheries as part of the EFH consultation. Your EFH assessment must include:

1) A description of the proposed action.
2) An analysis of the potential adverse effects of the action on EFH, and the managed species.
3) The federal agency's conclusions regarding the effects of the action on EFH.
4) Proposed mitigation if applicable.

In order for this worksheet to be considered as your EFH assessment, you must answer the questions in this worksheet fully and with as much detail as available. Give brief explanations for each answer.

Federal action agencies or the non-federal designated lead agency should submit the completed worksheet to NOAA Fisheries Greater Atlantic Regional Fisheries Office, Habitat Conservation Division (HCD) with the public notice or project application. Include project plans showing existing and proposed conditions, all waters of the U.S. on the project site, with mean low water (MLW), mean high water (MHW), high tide line (HTL), and water depths clearly marked and sensitive habitats mapped, including special aquatic sites (submerged aquatic vegetation, saltmarsh, mudflats, riffles and pools, coral reefs, and sanctuaries and refuges), hard bottom habitat areas and shellfish beds, as well as any available site photographs.

For most consultations, NOAA Fisheries has 30 days to provide EFH conservation recommendations once we receive a complete EFH assessment. Submitting all necessary information at once minimizes delays in review and keeps review timelines consistent. Delays in providing a complete EFH assessment can result in our consultation review period extending beyond the public comment period for a particular project.

The information contained on the HCD website (http://www.greateratlantic.fisheries.noaa.gov/habitat/) will assist you in completing this worksheet. The HCD website contains information regarding: the EFH consultation process; Guide to EFH Designations which provides a geographic species list; Guide to EFH Species Descriptions which provides the legal description of EFH as well as important ecological information for each species and life stage; and other EFH reference documents including examples of EFH assessments and EFH consultations.

Our website also includes a link to the NOAA EFH Mapper (http://www.habitat.noaa.gov/protection/efh/efhmapper/index.html). We would note that the EFH Mapper is currently being updated and revised. Should you use the EFH Mapper to identify federally managed species with designated EFH in your project area, we recommend checking this list against the Guide to Essential Fish Habitat Designations in the Northeast (http://www.greateratlantic.fisheries.noaa.gov/hcd/index2a.htm) to ensure a complete and accurate list is provided.

EFH ASSESSMENT WORKSHEET FOR FEDERAL AGENCIES (modified 3/2016)

PROJECT NAME: Coastal & Social Resiliency Initiatives for Tottenville Shoreline

DATE: February 2017

PROJECT NO.:

LOCATION (Water body, county, physical address):
Raritan Bay, Richmond County, Staten Island

PREPARER: AKRF, Inc.

Step 1: Use the Habitat Conservation Division EFH webpage's Guide to Essential Fish Habitat Designations in the Northeastern United States to generate the list of designated EFH for federally-managed species for the geographic area of interest (http://www.greateratlantic.fisheries.noaa.gov/hcd/index2a.htm). Use the species list as part of the initial screening process to determine if EFH for those species occurs in the vicinity of the proposed action. The list can be included as an attachment to the worksheet. Make a preliminary determination on the need to conduct an EFH consultation.

1. INITIAL CONSIDERATIONS		
EFH Designations	**Yes**	**No**
Is the action located in or adjacent to EFH designated for eggs? **List the species:** See Table 1	X	
Is the action located in or adjacent to EFH designated for larvae? **List the species:** See Table 1	X	
Is the action located in or adjacent to EFH designated for juveniles? **List the species:** See Table 1	X	

Is the action located in or adjacent to EFH designated for adults or spawning adults? **List the species:** See Table 1	X	
If you answered no to all questions above, then EFH consultation is not required - go to Section 5. If you answered yes to any of the above questions proceed to Section 2 and complete remainder of the worksheet.		

<u>Step 2</u>: In order to assess impacts, it is critical to know the habitat characteristics of the site before the activity is undertaken. Use existing information, to the extent possible, in answering these questions. Identify the sources of the information provided and provide as much description as available. These should not be yes or no answers. Please note that there may be circumstances in which new information must be collected to appropriately characterize the site and assess impacts. Project plans that show the location and extent of sensitive habitats, as well as water depths, the HTL, MHW and MLW should be provided.

2. SITE CHARACTERISTICS

Site Characteristics	Description
Is the site intertidal, sub-tidal, or water column?	The site comprises intertidal, subtidal, and water column habitats.
What are the sediment characteristics?	The sediments at the project site are primarily small grained (i.e., sand) mixed with large grained (i.e., gravel) material. Smaller areas of finer silty sand and mud exist near the navigation channel of Raritan Bay.
Is there submerged aquatic vegetation (SAV) at or adjacent to project site? If so describe the SAV species and spatial extent.	There is no submerged aquatic vegetation at or adjacent to the project site.
Are there wetlands present on or adjacent to the site? If so, describe the spatial extent and vegetation types.	A 0.8-acre tidal emergent wetland dominated by phragmites is located on landward side of MHW within Conference House Park. NWI maps Raritan Bay as E1UBL wetland (deepwater tidal habitats along low-energy coastlines with continuously submerged substrates and less than 30% vegetative cover).
Is there shellfish present at or adjacent to the project site? If so, please describe	Hard clam, horseshoe crab, blue crab, lady crab, say mud crab, portly spider crab, and hermit crabs have been found at the project site. Other shellfish known to occur in Raritan Bay

the spatial extent and species present.	but which were not collected at the project site include: other crab species, shrimp, soft shell clam, dwarf surf clam, blue mussel, ribbed mussel, and oysters.
Are there mudflats present at or adjacent to the project site? If so please describe the spatial extent.	There are no mudflats at or adjacent to the project site.
Is there rocky or cobble bottom habitat present at or adjacent to the project site? If so, please describe the spatial extent.	Yes. Occasional pockets of rock/cobble can be found at the project site, but the majority of the substrate is sand and gravel.
Is Habitat Area of Particular Concern (HAPC) designated at or near the site? If so for which species, what type habitat type, size, characteristics?	There are no HAPCs designated at or near the project site.
What is the typical salinity, depth and water temperature regime/range?	Based on NYCDEP water quality data from 1999-2014, salinity ranges from 7 to 29 ppt in the project area, depending on tidal direction and amount of freshwater inflow. Temperature typically ranges from 34 to 82 degrees Fahrenheit.
What is the normal frequency of site disturbance, both natural and man-made?	The existing underwater environment experiences disturbance from recreational boat traffic, as well as natural disturbance from tidal action. Due to the level of existing shoreline development in the area, human activity along the shoreline is common. Major natural disturbances are infrequent, in the form of periodic extreme storm events.
What is the area of proposed impact (work footprint & far afield)?	See Attachment 1. Breakwaters will occupy approx. 3,900 linear feet 500 to 2,100 ft offshore of the Tottenville shoreline of Staten Island in waters 2-10 feet deep. The breakwaters will be placed on a 12.7 acre footprint of sand/gravel bottom, and will provide about 41.2 acres of diverse in-water rocky habitat.

<u>Step 3</u>: This section is used to describe the anticipated impacts from the proposed action on the physical/chemical/biological environment at the project site and areas adjacent to the site that may be affected.

3. DESCRIPTION OF IMPACTS

Impacts	Y	N	Description
Nature and duration of activity(s). Clearly describe the activities proposed and the duration of any disturbances.	X		See Attachment 2 for a detailed description of the Proposed Actions.
Will the benthic community be disturbed? If no, why not? If yes, describe in detail how the benthos will be impacted.	X		As described in Attachment 2, there will be a permanent loss of benthos within the 12.7-acre footprint of the breakwaters.
Will SAV be impacted? If no, why not? If yes, describe in detail how the SAV will be impacted. Consider both direct and indirect impacts. Provide details of any SAV survey conducted at the site.		X	There is no submerged aquatic vegetation in the study area.
Will salt marsh habitat be impacted? If no, why not? If yes, describe in detail how wetlands will be impacted. What is the aerial extent of the impacts? Are the effects temporary or permanent?	X		0.24 acres within the 0.8-acre delineated tidal wetland located landward of Raritan Bay MHW due to construction of hybrid dune, transition node structure to provide shoreline access, and trail.
Will mudflat habitat be impacted? If no, why not? If yes, describe in detail how mudflats will be impacted. What is the aerial extent of the impacts? Are the effects temporary or permanent?		X	There is no mudflat habitat in the study area.
Will shellfish habitat be impacted? If so, provide in detail how the shellfish habitat will be impacted. What is the aerial extent of the impact?	X		See Attachment 2. The project site is within a NYSDEC uncertified shellfish land area. As a result of the Proposed Actions, 12.7 acres of sand/gravel substrate will be replaced with a diverse rocky habitat that will provide habitat for shellfish.

Provide details of any shellfish survey conducted at the site.			
Will hard bottom (rocky, cobble, gravel) habitat be impacted at the site? If so, provide in detail how the hard bottom will be impacted. What is the aerial extent of the impact?	X		See Attachment 2. No rock or cobble habitat will be impacted. The Proposed Actions will replace 12.7 acres of sand/gravel substrate with diverse rocky habitat that will provide about 3.3 times the amount of habitat being displaced.
Will sediments be altered and/or sedimentation rates change? If no, why not? If yes, describe how.	X		Yes, see Attachment 2. Sediment characteristics and sedimentation rates will be altered within the immediate vicinity of the breakwater segments and along beach areas.
Will turbidity increase? If no, why not? If yes, describe the causes, the extent of the effects, and the duration.	X		Yes, see Attachment 2. There may be a temporary increase in turbidity during construction of the breakwaters, but effects would be minimized. Any turbidity increase would be temporary and localized and would not result in long term impacts to EFH.
Will water depth change? What are the current and proposed depths?		X	The Proposed Actions will not affect water depths outside the footprint of the breakwater segments and the 2.0 acres of sand placement below mean high water in the area of shoreline restoration.
Will contaminants be released into sediments or water column? If yes, describe the nature of the contaminants and the extent of the effects.	X		Sediments within the study area generally have low levels of contamination. Sediment resuspension during construction is expected to be minimal and to dissipate quickly.
Will tidal flow, currents, or wave patterns be altered? If no, why not? If yes, describe in detail how.	X		Yes, see Attachment 2. The breakwaters will attenuate wave height and result in small changes in currents around their edges. The Proposed Actions will not adversely affect water circulation or tidal flushing of Raritan Bay.
Will ambient salinity or temperature regime change? If no, why not? If yes, describe in detail how and the effects of the change.		X	The Proposed Actions will not adversely affect tidal flushing of Raritan Bay, and therefore, will not affect salinity or temperature regimes.

Will water quality be altered? If no, why not? If yes, describe in detail how. If the effects are temporary, describe the duration of the impact.	X		See Attachment 2. The Proposed Actions have the potential to result in temporary localized increases in suspended sediment during construction. The Proposed Actions will not adversely affect tidal flushing and therefore, will not result in long-term impacts to water quality.
Will ambient noise levels change? If no, why not? If yes, describe in detail how. If the effects are temporary, describe the duration and degree of impact.		X	The Proposed Actions will not affect ambient noise levels.
Does the action have the potential to impact prey species of federally managed fish with EFH designations?	X		See Attachment 2. Benthic organisms in the footprint of the breakwaters will be lost; however, the Proposed Actions will improve overall habitat diversity and aquatic community structure and provide habitat for encrusting organisms and provide additional forage for EFH species.

<u>Step 4</u>: This section is used to evaluate the consequences of the proposed action on the functions and values of EFH as well as the vulnerability of the EFH species and their life stages. Identify which species (from the list generated in Step 1) will be adversely impacted from the action. Assessment of EFH impacts should be based upon the site characteristics identified in Step 2 and the nature of the impacts described within Step 3. The Guide to EFH Descriptions webpage (<u>http://www.greateratlantic.fisheries.noaa.gov/hcd/list.htm</u>) should be used during this assessment to determine the ecological parameters/preferences associated with each species listed and the potential impact to those parameters.

4. EFH ASSESSMENT			
Functions and Values	**Y**	**N**	**Describe habitat type, species and life stages to be adversely impacted**
Will functions and values of EFH be impacted for:			
<u>Spawning</u> **If yes, describe in detail**		X	Spawning winter flounder may be present during January-April. The project will comply with in-water restrictions from NMFS to protect winter flounder

how, and for which species. Describe how adverse effects will be avoided and minimized.			spawning EFH at the site (Jan 15 to May 31). The footprint of the breakwaters represents only 2% of the inshore habitat in the study area, therefore, spawning habitat will be available in the vicinity.
<u>Nursery</u> **If yes, describe in detail how and for which species. Describe how adverse effects will be avoided and minimized.**	X		Temporary effects on windowpane and winter flounder larvae could occur. The Proposed Actions will have an overall beneficial impact on nursery habitat. See Attachment 3.
<u>Forage</u> **If yes, describe in detail how and for which species. Describe how adverse effects will be avoided and minimized.**	X		Temporary effects on juvenile and adult windowpane, summer flounder, winter flounder, and clearnose, little, and winter skate foraging could occur. The Proposed Actions will have an overall benefit on foraging habitat. See Attachment 3.
<u>Shelter</u> **If yes, describe in detail how and for which species. Describe how adverse effects will be avoided and minimized.**		X	The Proposed Actions will improve shelter habitat for EFH species. See Attachment 3.
Will impacts be temporary or permanent? Describe the duration of the impacts.			The Proposed Actions will have both temporary and permanent effects. See Attachment 3.
Will compensatory mitigation be used? If no, why not? Describe plans for mitigation and how this will offset impacts to EFH. Include a conceptual compensatory mitigation plan, if applicable.	X		Yes, see Attachment 3. A number of mitigation measures will be included as part of the project.

Step 5: **This section provides the federal agency's determination on the degree of impact to EFH from the proposed action. The EFH determination also dictates the type of EFH consultation that will be required with NOAA Fisheries.**

Please note: if information provided in the worksheet is insufficient to allow NOAA Fisheries to complete the EFH consultation additional information will be requested.

5. DETERMINATION OF IMPACT

	/	Federal Agency's EFH Determination
Overall degree of adverse effects on EFH (not including compensatory mitigation) will be: **(check the appropriate statement)**		**There is no adverse effect on EFH or no EFH is designated at the project site.** **EFH Consultation is not required**
	X	**The adverse effect on EFH is not substantial.** **This means that the adverse effects are either no more than minimal, temporary, or that they can be alleviated with minor project modifications or conservation recommendations.** **This is a request for an abbreviated EFH consultation.**
		The adverse effect on EFH is substantial. **This is a request for an expanded EFH consultation**

Step 6: Consultation with NOAA Fisheries may also be required if the proposed action results in adverse impacts to other NOAA-trust resources, such as anadromous fish, shellfish, crustaceans, or their habitats as part of the Fish and Wildlife Coordination Act Some examples of other NOAA-trust resources are listed below. Inquiries regarding potential impacts to marine mammals or threatened/endangered species should be directed to NOAA Fisheries' Protected Resources Division.

6. OTHER NOAA-TRUST RESOURCES IMPACT ASSESSMENT	
Species known to occur at site (list others that may apply)	**Describe habitat impact type (i.e., physical, chemical, or biological disruption of spawning and/or egg development habitat, juvenile nursery and/or adult feeding or migration habitat). Please note, impacts to federally listed species of fish, sea turtles, and marine mammals must be coordinated with the GARFO Protected Resources Division.**
alewife	See Attachment 4
American eel	See Attachment 4
American shad	See Attachment 4
Atlantic menhaden	See Attachment 4
blue crab	See Attachment 4
blue mussel	See Attachment 4
blueback herring	See Attachment 4
Eastern oyster	See Attachment 4
horseshoe crab	See Attachment 4
quahog	See Attachment 4
soft-shell clams	See Attachment 4
striped bass	See Attachment 4
other species:	Impacts to sturgeon and sea turtles are included in Attachment 4.

Useful Links

National Wetland Inventory Maps
http://www.fws.gov/wetlands/

EPA's National Estuaries Program
http://www.epa.gov/nep/information-about-local-estuary-programs

Northeast Regional Ocean Council (NROC) Data Portal
http://www.northeastoceandata.org/

Mid-Atlantic Regional Council on the Ocean (MARCO) Data Portal
http://portal.midatlanticocean.org/

Resources by State:

Maine
Eelgrass maps
http://www.maine.gov/dmr/rm/eelgrass/
Maine Office of GIS Data Catalog
http://www.maine.gov/megis/catalog/
Casco Bay Estuary Partnership
http://www.cascobayestuary.org/
Maine GIS Stream Habitat Viewer
http://mapserver.maine.gov/streamviewer/index.html

New Hampshire
New Hampshire's Statewide GIS Clearinghouse, NH GRANIT
http://www.granit.unh.edu/
New Hampshire Coastal Viewer
http://www.granit.unh.edu/nhcoastalviewer/

Massachusetts
Eelgrass maps
http://maps.massgis.state.ma.us/images/dep/eelgrass/eelgrass_map.htm
MADMF Recommended Time of Year Restrictions Document
http://www.mass.gov/eea/docs/dfg/dmf/publications/tr-47.pdf
Massachusetts Bays National Estuary Program
http://www.mass.gov/eea/agencies/mass-bays-program/
Buzzards Bay National Estuary Program
http://buzzardsbay.org/
Massachusetts Division of Marine Fisheries
http://www.mass.gov/eea/agencies/dfg/dmf/
Massachusetts Office of Coastal Zone Management
http://www.mass.gov/eea/agencies/czm/

Rhode Island
Eelgrass maps
http://www.savebay.org/file/2012_Mapping_Submerged_Aquatic_Vegetation_final_report_4_2013.pdf
Narraganset Bay Estuary Program

http://www.dem.ri.gov/programs/benviron/water/wetlands/wetldocs.htm
Rhode Island Division of Marine Fisheries
http://www.dem.ri.gov/
Rhode Island Coastal Resources Management Council
http://www.crmc.ri.gov/

Connecticut
Eelgrass Maps
https://www.fws.gov/northeast/ecologicalservices/pdf/wetlands/2012_CT_Eelgrass_Final_Report_11_26_2013.pdf
Long Island Sound Study
http://longislandsoundstudy.net/
CT GIS Resources
http://www.ct.gov/deep/cwp/view.asp?a=2698&q=323342&deepNav_GID=1707
CT DEEP Office of Long Island Sound Programs and Fisheries
http://www.ct.gov/deep/
CT Bureau of Aquaculture Shellfish Maps
http://www.ct.gov/doag/cwp/view.asp?a=3768&q=451508&doagNav=
CT River Watershed Council
http://www.ctriver.org/

New York
Eelgrass report
http://www.dec.ny.gov/docs/fish_marine_pdf/finalseagrassreport.pdf
Peconic Estuary Program
http://www.peconicestuary.org/
NY/NJ Harbor Estuary
http://www.harborestuary.org/

New Jersey
Submerged Aquatic Vegetation mapping
http://crssa.rutgers.edu/projects/coastal/sav/
Barnegat Bay Partnership
http://bbp.ocean.edu/pages/1.asp

Delaware
Partnership for the Delaware Estuary
http://www.delawareestuary.org/
Center for Delaware Inland Bays
http://www.inlandbays.org/

Maryland
Submerged Aquatic Vegetation mapping
http://data.imap.maryland.gov/datasets/da64df6bd4124ce9989e6c186a7906a7_0
MERLIN
http://geodata.md.gov/imaptemplate/?appid=a8ec7e2ff4c34a31bc1e9411ed8e7a7e
Maryland Coastal Bays Program
http://www.mdcoastalbays.org/

Virginia
Submerged Aquatic Vegetation mapping
http://web.vims.edu/bio/sav/maps.html

Table 1
Essential Fish Habitat Designations—Raritan Bay

Species	Eggs	Larvae	Juveniles	Adults
Red hake (*Urophycis chuss*)		X	X	X
Redfish (*Sebastes fasciatus*)	n/a			
Winter flounder (*Pleuronectes americanus*)	X	X	X	X
Windowpane flounder (*Scopthalmus aquosus*)	X	X	X	X
Atlantic sea herring (*Clupea harengus*)		X	X	X
Bluefish (*Pomatomus saltatrix*)			X	X
Long finned squid (*Loligo pealei*)	n/a	n/a		
Short finned squid (*Illex illecebrosus*)	n/a	n/a		
Atlantic butterfish (*Peprilus triacanthus*)		X	X	X
Atlantic mackerel (*Scomber scombrus*)			X	X
Summer flounder (*Paralicthys dentatus*)		X	X	X
Scup (*Stenotomus chrysops*)	X	X	X	X
Black sea bass (*Centropristus striata*)	n/a		X	X
Surf clam (*Spisula solidissima*)	n/a	n/a		
Ocean quahog (*Artica islandica*)	n/a	n/a		
Spiny dogfish (*Squalus acanthias*)	n/a	n/a		
King mackerel (*Scomberomorus cavalla*)	X	X	X	X
Spanish mackerel (*Scomberomorus maculatus*)	X	X	X	X
Cobia (*Rachycentron canadum*)	X	X	X	X
Sandbar shark (*Carcharhinus plumbeus*)		X[(1)]		X
Clearnose skate (*Raja eglanteria)*			X	X
Little skate (*Leucoraja erinacea*)			X	X
Winter skate (*Leucoraja ocellata*)			X	X

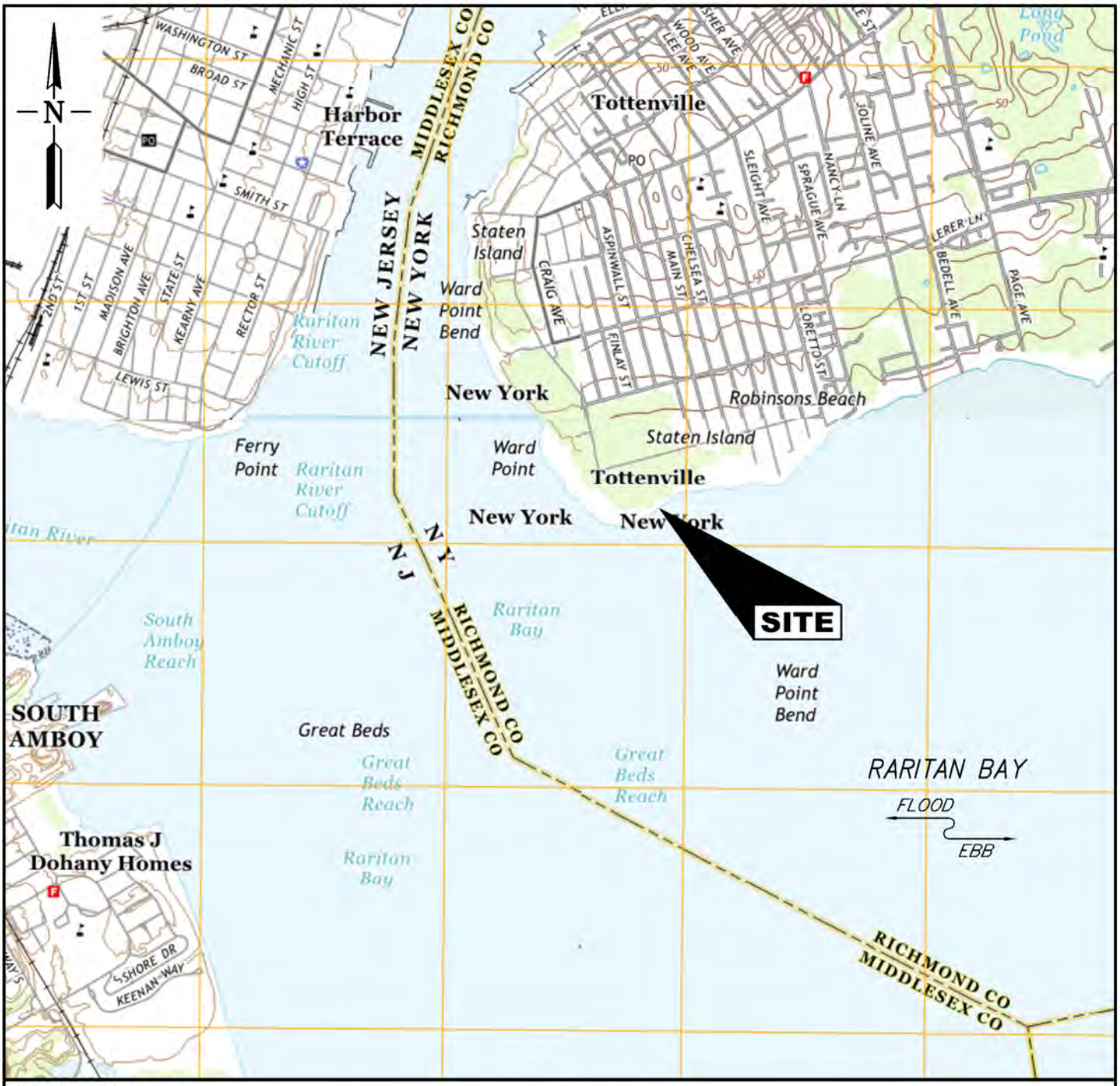
X = EFH has been designated within the square for a given species and life stage.

n/a = Either there is no data available for the designated life stages for that species or those life stages are not present in the species' reproductive cycle.

[(1)] = This species does not have a free-swimming larval stage; rather they are live bearers that give birth to fully formed juveniles. For the purpose of this table, "larvae" for sandbar shark refers to neonates and early juveniles.

Sources: Summary of Essential Fish Habitat (EFH) Designations from http://www.greateratlantic.fisheries.noaa.gov/hcd/STATES4/new_jersey/40207410.html

ATTACHMENT 1



TAKEN FROM MULTIPLE USGS MAPS:
ARTHUR KILL, PERTH AMBOY, SOUTH AMBOY, & KEYPORT QUADRANGLE
NEW JERSEY–NEW YORK
7.5 MINUTE SERIES

VICINITY MAP

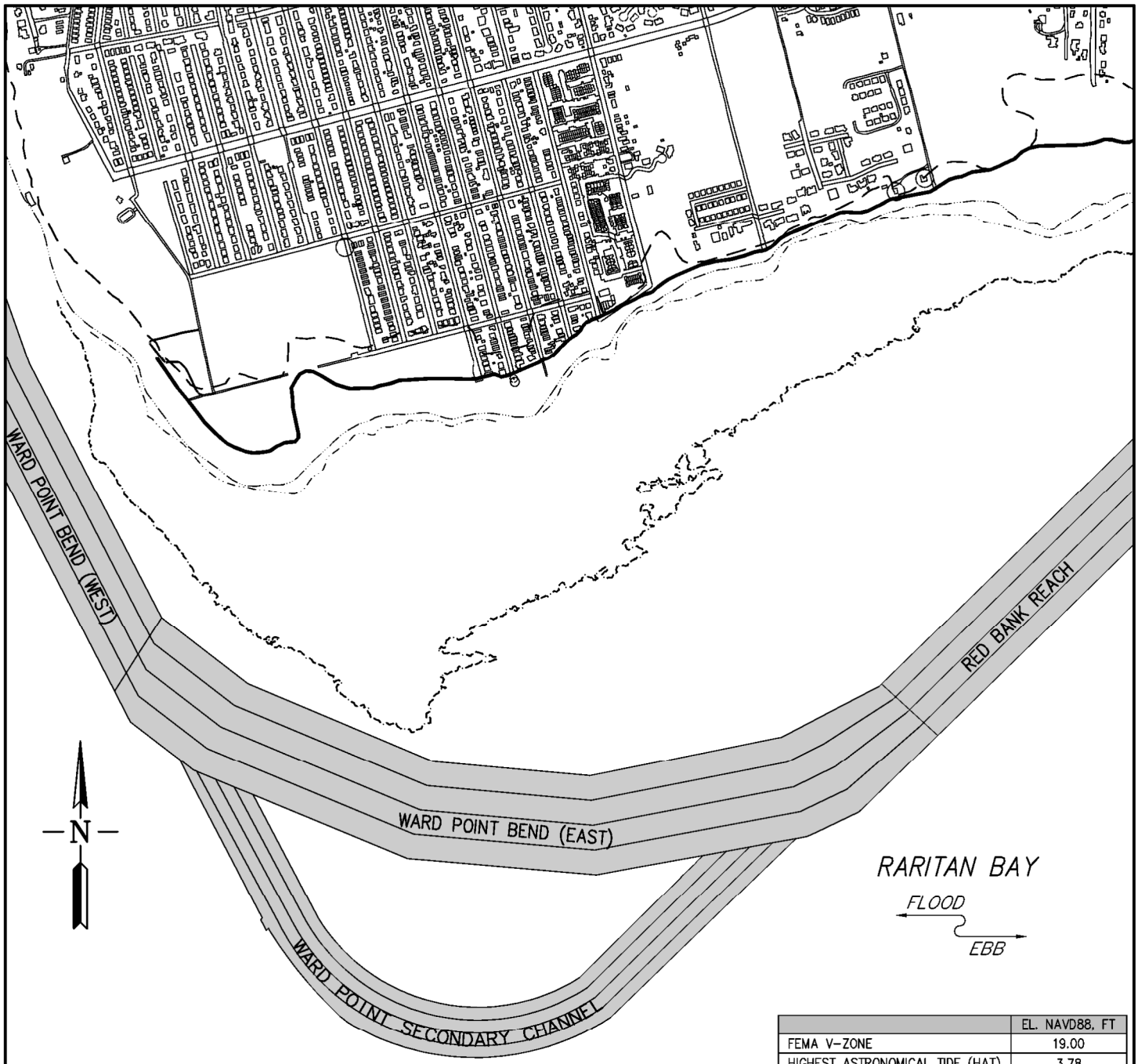
0 2000 4000 FT.

SCALE 1"=2000'–0"

FOR PERMIT USE ONLY NOT FOR CONSTRUCTION	DATUM: N.A.V.D. 88 APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY APPLICATION NO.: AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.	PROPOSED CONSTRUCTION OF LIVING BREAKWATERS WARD POINT BEND, RARITAN BAY TOTTENVILLE, STATEN ISLAND COUNTY OF RICHMOND STATE OF NEW YORK DATE: 01/20/2017 SHEET 1 OF 15

\\cowi.net\projects\A065000\A068233\CAD\A068233.2\Phase 3\Task 2\30pct Permit CAD\Permit 01.dwg Permit 01 Rey Buzeta Fri, 20 Jan 2017 – 4:09pm

ATTACHMENT 1



EXISTING OVERALL SITE PLAN

0 1200 2400 FT.

SCALE 1"=1200'-0"

	EL. NAVD88, FT
FEMA V-ZONE	19.00
HIGHEST ASTRONOMICAL TIDE (HAT)	3.78
MEAN HIGHER HIGH WATER (MHHW)	2.41
MEAN HIGH WATER (MHW)	2.08
NAVD88	0.00
MSL	-0.24
MEAN LOW WATER (MLW)	-2.62
MEAN LOWER LOW WATER (MLLW)	-2.82
LOWEST ASTRONOMICAL TIDE (LAT)	-4.19

LIVING BREAKWATERS TIDAL DATA (BASED ON NOAA STATION NO. 8531680, SANDY HOOK, NJ)

LEGEND

- MEAN HIGH WATER
- MEAN LOW WATER
- FEMA V-ZONE
- LiMWA
- FEDERAL NAVIGATION CHANNEL
- -6' MLW (NAVD88 EL. -8.62)

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

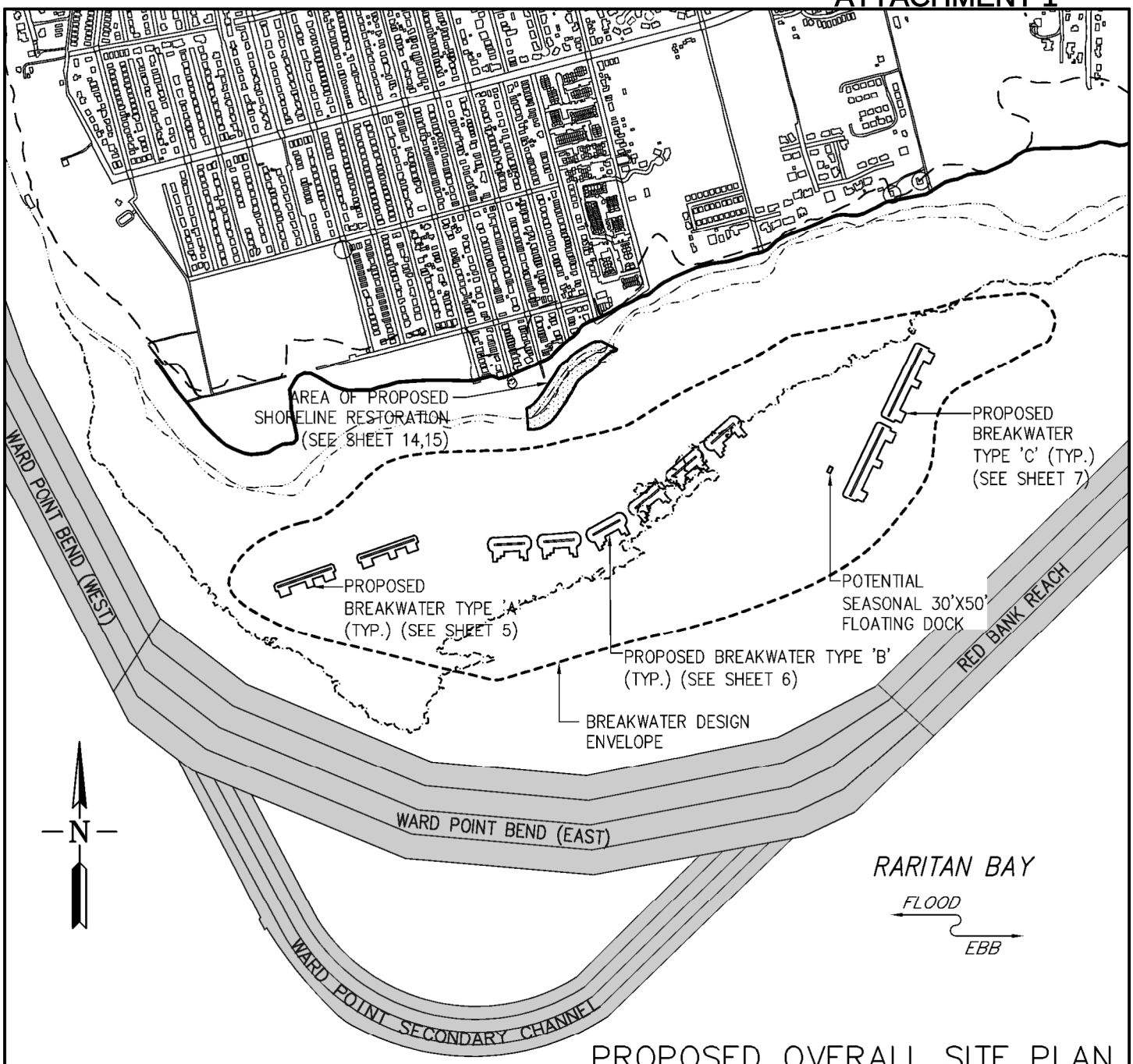
WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

SHEET 2 OF 15

\\cowi.net\projects\A065000\A068233\CAD\A068233.2\Phase 3\Task 2\30pct Permit CAD\Permit 02.dwg Permit 02 Rey Buzeta Fri, 20 Jan 2017 - 4:07pm

ATTACHMENT 1



PROPOSED OVERALL SITE PLAN

0 1200 2400 FT.

SCALE 1"=1200'-0"

NOTE: MINIMUM DISTANCE FROM BREAKWATER DESIGN ENVELOPE TO FEDERAL NAVIGATION CHANNEL IS APPROXIMATELY 493 FEET.

LEGEND

- MEAN HIGH WATER
- MEAN LOW WATER
- FEMA V-ZONE
- LiMWA
- FEDERAL NAVIGATION CHANNEL
- BREAKWATER DESIGN ENVELOPE
- -6' MLW (NAVD88 EL. -8.62)
- PROPOSED MHW

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

SHEET 3 OF 15

\\cowi.net\projects\A065000\A068233\CAD\A068233.2\Phase 3\Task 2\30pct Permit CAD\Permit 03_04.dwg Permit 03 Rey Buzeta Tue, 24 Jan 2017 - 5:34pm

TYPE	NUMBER OF SEGMENTS	TOTAL LENGTH AT EL. 0 NAVD88 (LF)	TOTAL FOOTPRINT (SF)	TOTAL FOOTPRINT (ACRES)	FOOTPRINT SHALLOWER THAN −6' MLW	TOTAL VOLUME (CF)	TOTAL VOLUME BELOW MHW (CF)
A	2	900	88,327	2.0	2.0	498,752	450,789
B	6	1,800	277,881	6.4	3.0	2,654,720	1,947,097
C	2	1,200	184,886	4.2	0.0	2,169,968	1,670,614
TOTAL	10	3,900	551,094	12.7	5.0	5,323,440	4,068,501

BREAKWATER TYPES AND QUANTITIES

	AVERAGE CROSS SECTIONAL AREA (FT^2/FT)	PLAN AREA (FT^2)	LENGTH (FT)	VOLUME (FT^3)	VOLUME (YD^3)
TOTAL SHORELINE RESTORATION CONSIDERED	203.1	142,380	806	558,921	20,701
TOTAL SHORELINE RESTORATION BELOW M.H.W.	109.2	103,289	806	414,969	15,369

PROPOSED SHORELINE RESTORATION QUANTITIES

TYPE	NUMBER OF SEGMENTS	TOTAL LENGTH AT EL. 0 NAVD88 (LF)	TOTAL FOOTPRINT (SF)	TOTAL FOOTPRINT (ACRES)
POTENTIAL SEASONAL FLOATING DOCK	1	50	1,500	0.0

TEMPORARY SEASONAL DOCK QUANTITIES

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

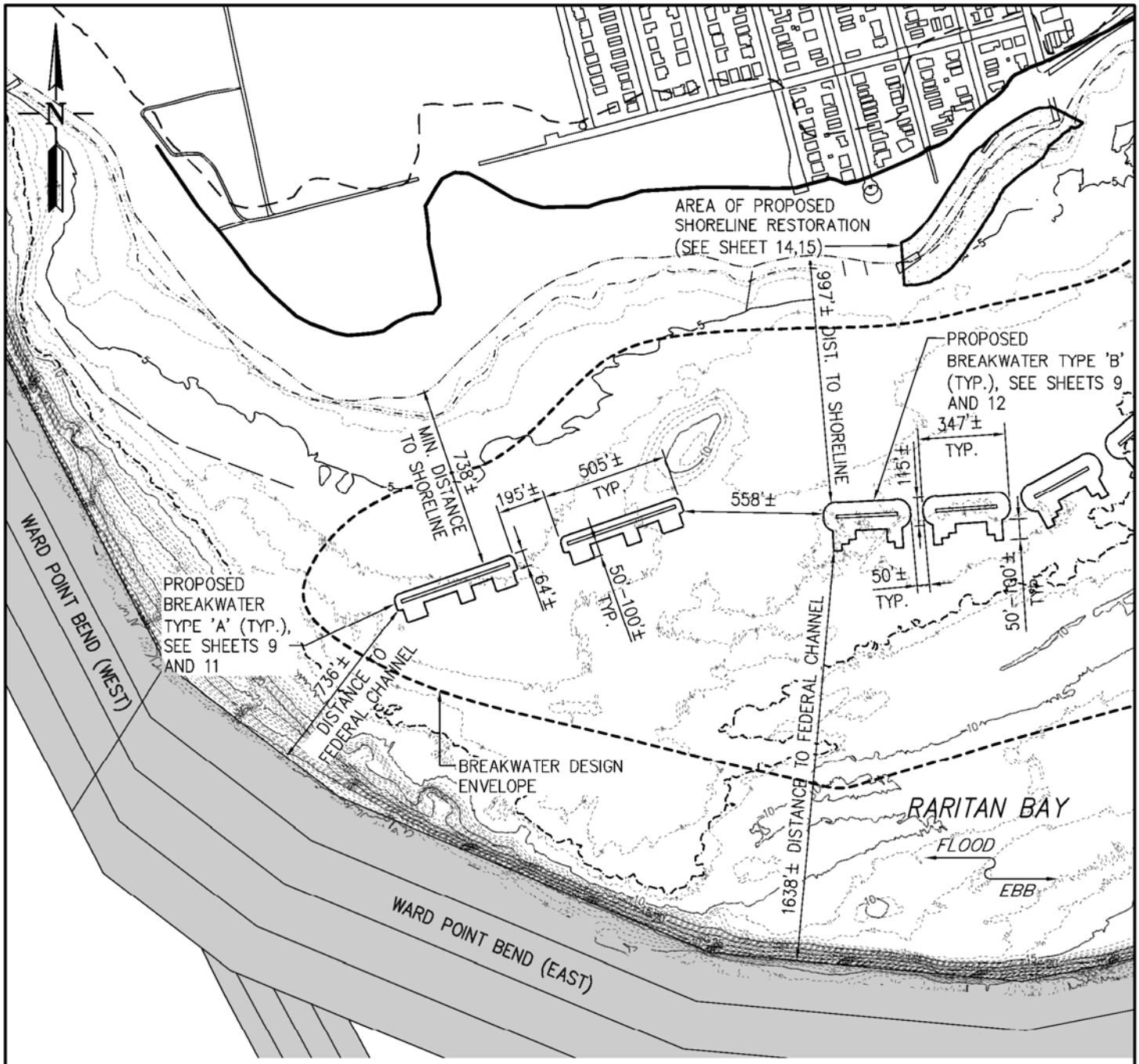
AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

ATTACHMENT 1



PROPOSED PARTIAL SITE PLAN

0 600 1200 FT.

SCALE 1"=600'-0"

LEGEND

- MEAN HIGH WATER
- FEMA V-ZONE
- FEDERAL NAVIGATION CHANNEL
- PROPOSED MEAN HIGH WATER
- MEAN LOW WATER
- LiMWA
- BREAKWATER DESIGN ENVELOPE
- MAJOR CONTOUR
- MINOR CONTOUR
- -6' MLW (NAVD88 EL. -8.62)

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

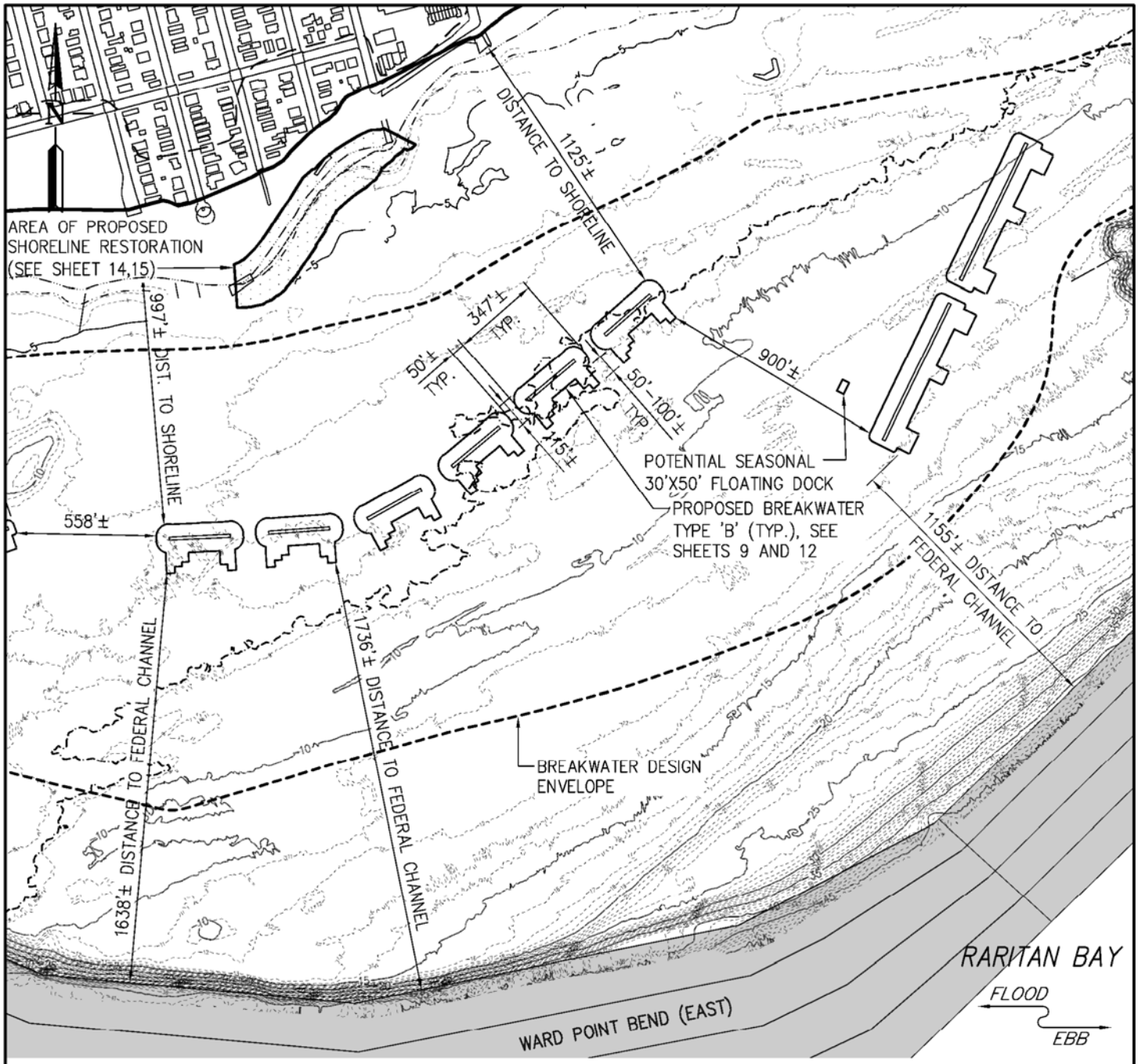
PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

SHEET 5 OF 15

\\cowi.net\projects\A065000\A068233\CAD\A068233.2\Phase 3\Task 2\30pct Permit CAD\Permit 05_07.dwg Permit 05 Rey Buzeta Tue, 24 Jan 2017 - 5:45pm



PROPOSED PARTIAL SITE PLAN

0 600 1200 FT.

SCALE 1"=600'-0"

LEGEND

- MEAN HIGH WATER
- FEMA V-ZONE
- FEDERAL NAVIGATION CHANNEL
- PROPOSED MEAN HIGH WATER
- MEAN LOW WATER
- LiMWA
- BREAKWATER DESIGN ENVELOPE
- MAJOR CONTOUR
- MINOR CONTOUR
- -6' MLW (NAVD88 EL. -8.62)

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

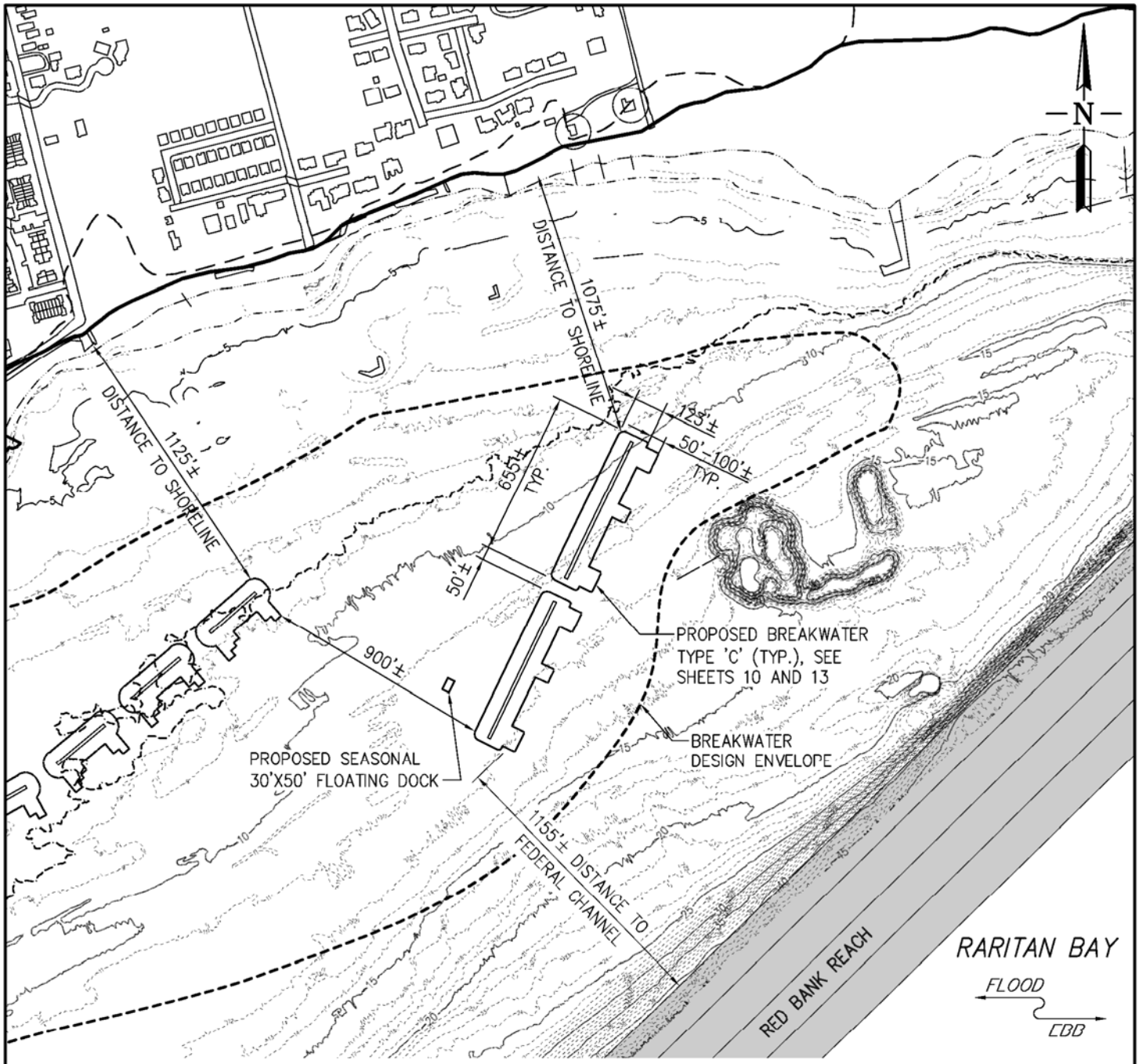
PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

\\cowi.net\projects\A065000\A068233\CAD\A068233.2\Phase 3\Task 2\30pct Permit CAD\Permit 05_07.dwg Permit 06 Rey Buzeta Tue, 24 Jan 2017 - 5:47pm

ATTACHMENT 1



PROPOSED PARTIAL SITE PLAN

0 600 1200 FT.

SCALE 1"=600'-0"

LEGEND

- MEAN HIGH WATER
- FEMA V-ZONE
- FEDERAL NAVIGATION CHANNEL
- PROPOSED MEAN HIGH WATER
- MEAN LOW WATER
- LiMWA
- BREAKWATER DESIGN ENVELOPE
- MAJOR CONTOUR
- MINOR CONTOUR
- -6' MLW (NAVD88 EL. -8.62)

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

SHEET 7 OF 15

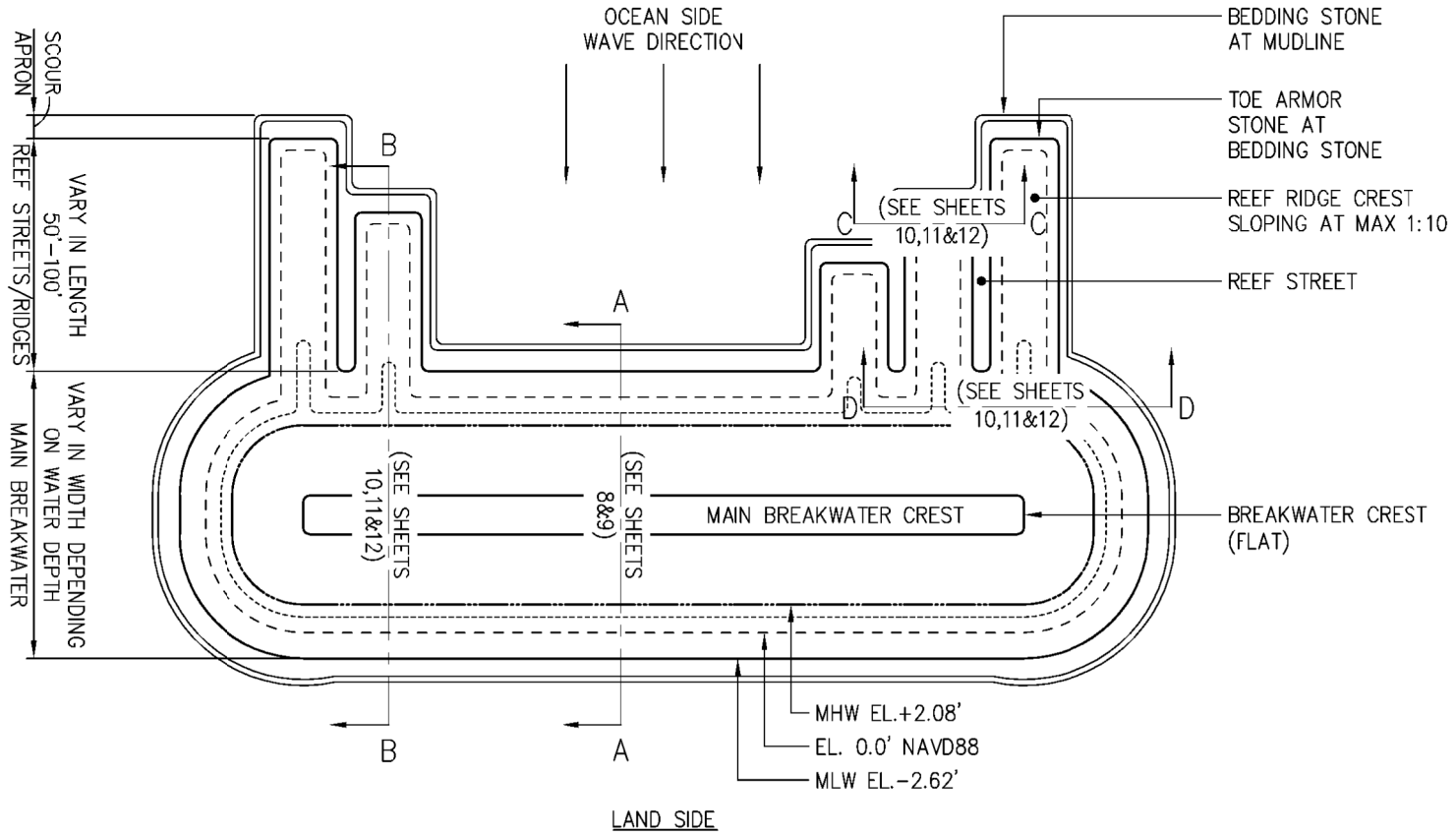
\\cowi.net\projects\A065000\A068233\CAD\A068233.2\Phase 3\Task 2\30pct Permit CAD\Permit 05_07.dwg Permit 07 Rey Buzeta Tue, 24 Jan 2017 - 5:49pm

FILL VOLUME PER TYPE 'A' BREAKWATER SEGMENT		
MATERIAL	QUANTITY*	UNITS
STONE ARMOR UNITS	136,782	CF
BIO-ENHANCED CONCRETE ARMOR UNITS (ALL TYPES)	14,575	CF
BIO-ENHANCED CONCRETE TIDEPOOL UNITS	3,118	CF
OTHER GRADED EXTERIOR STONE	651	CF
CORE STONE	33,621	CF
BEDDING STONE/SCOUR MATERIAL	70,280	CF
GEOTEXTILE	57,309	SF

FILL VOLUME PER TYPE 'B' BREAKWATER SEGMENT		
MATERIAL	QUANTITY*	UNITS
STONE ARMOR UNITS	225,392	CF
BIO-ENHANCED CONCRETE ARMOR UNITS (ALL TYPES)	12,194	CF
BIO-ENHANCED CONCRETE TIDEPOOL UNITS	3,759	CF
OTHER GRADED EXTERIOR STONE	6,407	CF
CORE STONE	193,515	CF
BEDDING STONE/SCOUR MATERIAL	50,284	CF
GEOTEXTILE	74,364	SF

FILL VOLUME PER TYPE 'C' BREAKWATER SEGMENT		
MATERIAL	QUANTITY*	UNITS
STONE ARMOR UNITS	486,177	CF
BIO-ENHANCED CONCRETE ARMOR UNITS (ALL TYPES)	26,748	CF
BIO-ENHANCED CONCRETE TIDEPOOL UNITS	8,834	CF
OTHER GRADED EXTERIOR STONE	22,034	CF
CORE STONE	514,069	CF
BEDDING STONE/SCOUR MATERIAL	80,638	CF
GEOTEXTILE	151,934	SF

*NOTE: THE ABOVE QUANTITIES REPRESENT A BIO-ENHANCED CONCRETE AND TIDEPOOL INCLUSION RATE OF 30% OF THE TOTAL AVAILABLE SUBTIDAL AND INTERTIDAL BREAKWATER SURFACE AREA.



PROPOSED TYPICAL BREAKWATER PLAN

SCALE: N.T.S.

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S
OFFICE OF STORM RECOVERY

APPLICATION NO.:

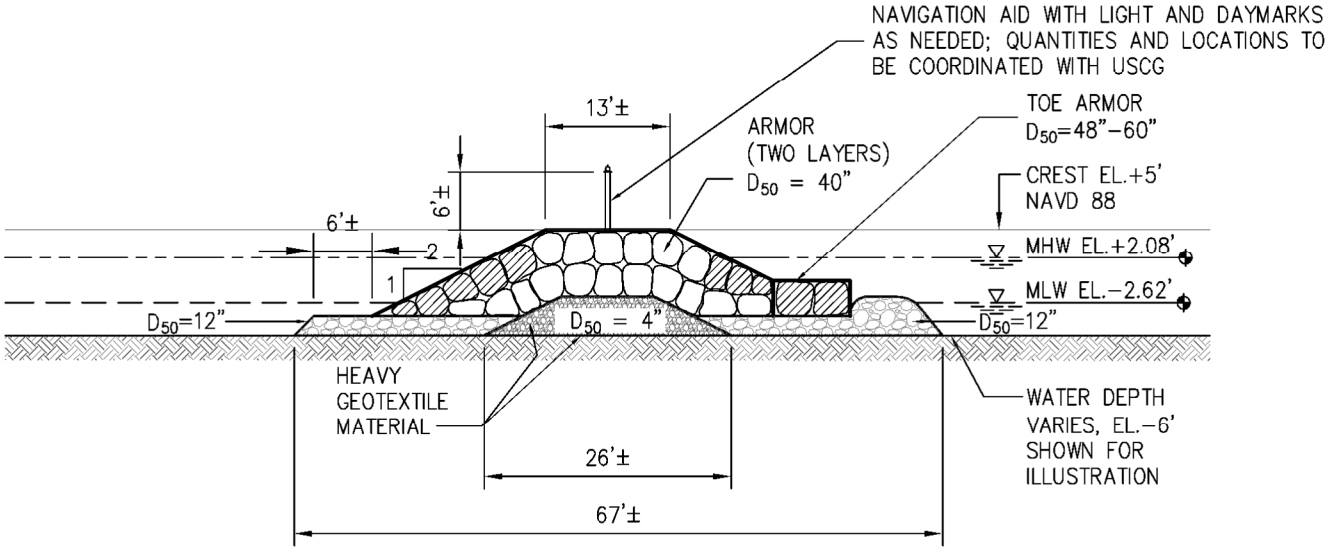
AGENT: OCEAN & COASTAL CONSULTANTS
ENGINEERING, P.C.

PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

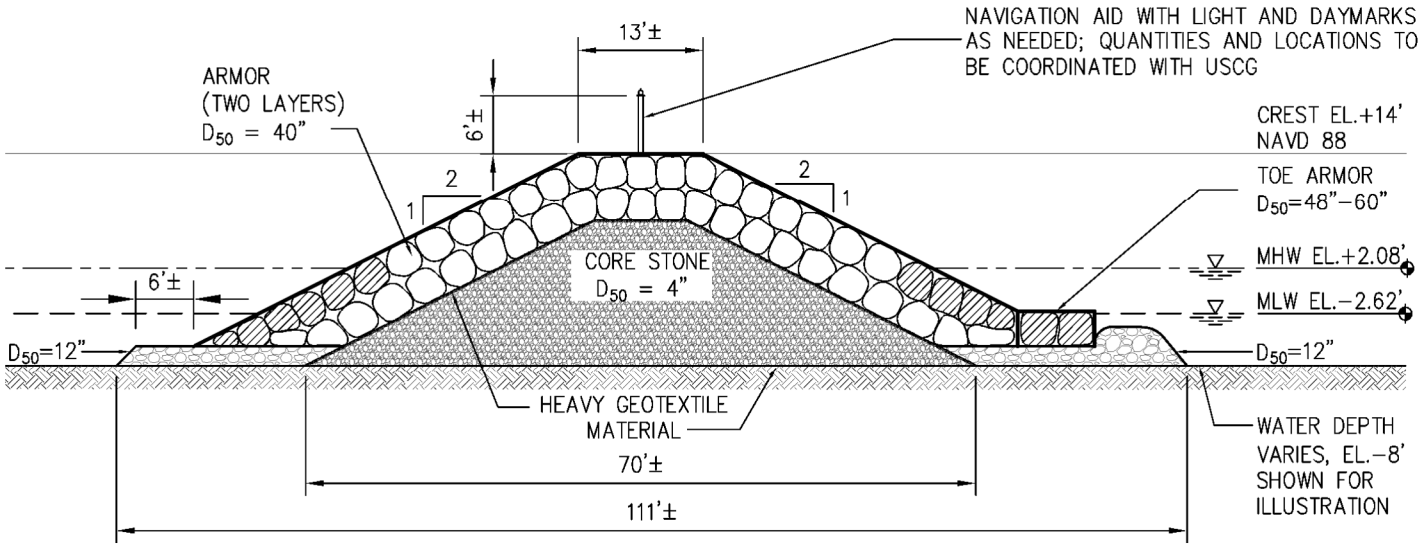
WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

ATTACHMENT 1



TYPICAL BREAKWATER TYPE 'A'
PROPOSED SECTION A–A



NOTE:
1. WHERE POTENTIAL BIO–ENHANCING CONCRETE UNITS ARE INDICATED, ARMOR STONE WILL BE REPLACED WITH BIO–ENHANCING CONCRETE UNITS AT A RATE OF 30%; IN ALL OTHER LOCATIONS, ARMOR AND TOE UNITS WILL BE STONE OF THE SIZE INDICATED.
2. REFER TO SHEET 8 FOR BREAKWATER VOLUME SUMMARY.

TYPICAL BREAKWATER TYPE 'B'
PROPOSED SECTION A–A

0 20 40 FT.
SCALE 1"=20'–0"

LEGEND	
POTENTIAL LOCATION FOR BIO–ENHANCING CONCRETE UNITS	
POTENTIAL LOCATION FOR TIDE POOL UNITS	

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

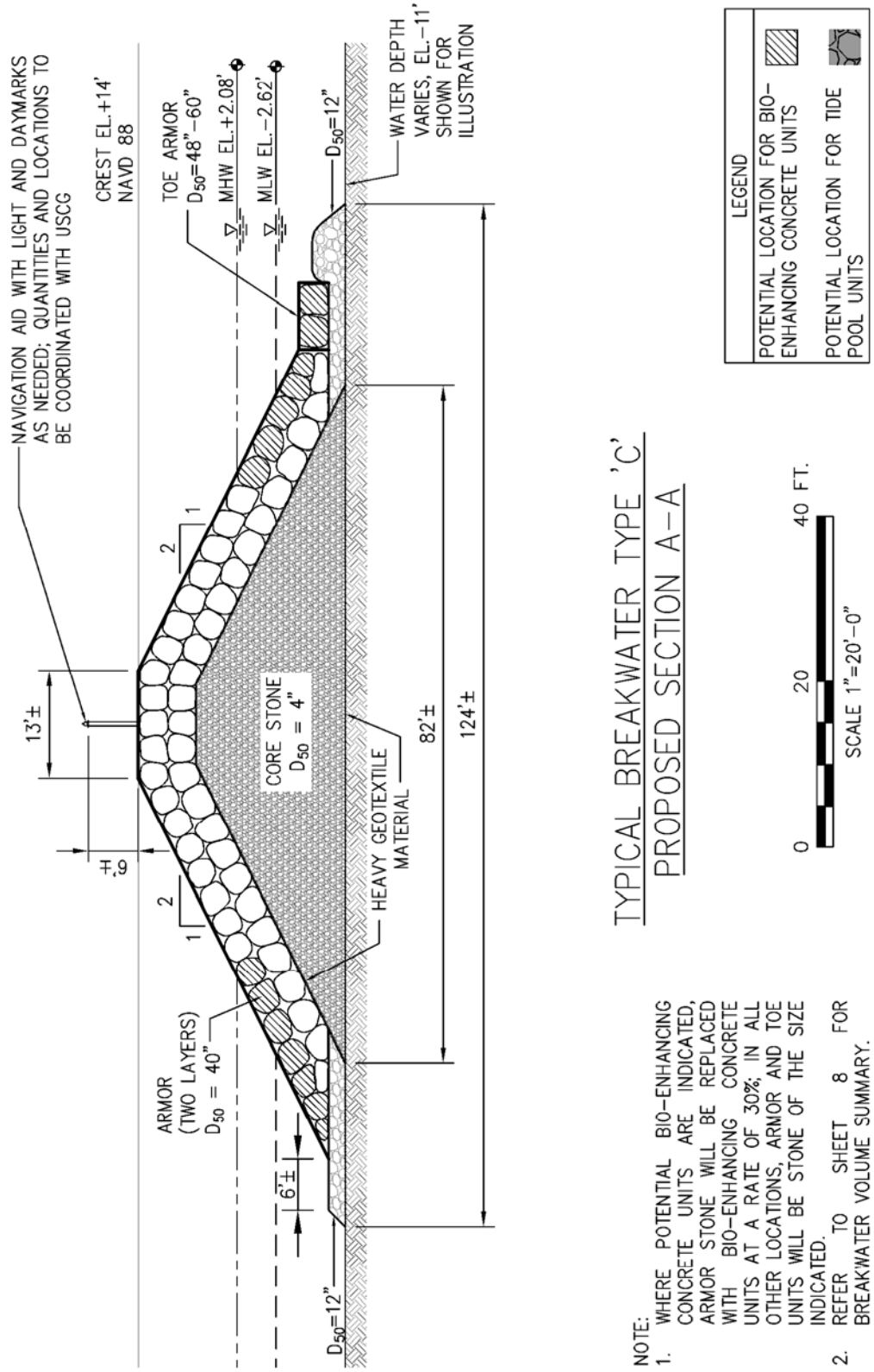
APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017



TYPICAL BREAKWATER TYPE 'C'
PROPOSED SECTION A-A

NOTE:
1. WHERE POTENTIAL BIO-ENHANCING CONCRETE UNITS ARE INDICATED, ARMOR STONE WILL BE REPLACED WITH BIO-ENHANCING CONCRETE UNITS AT A RATE OF 30%; IN ALL OTHER LOCATIONS, ARMOR AND TOE UNITS WILL BE STONE OF THE SIZE INDICATED.
2. REFER TO SHEET 8 FOR BREAKWATER VOLUME SUMMARY.

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

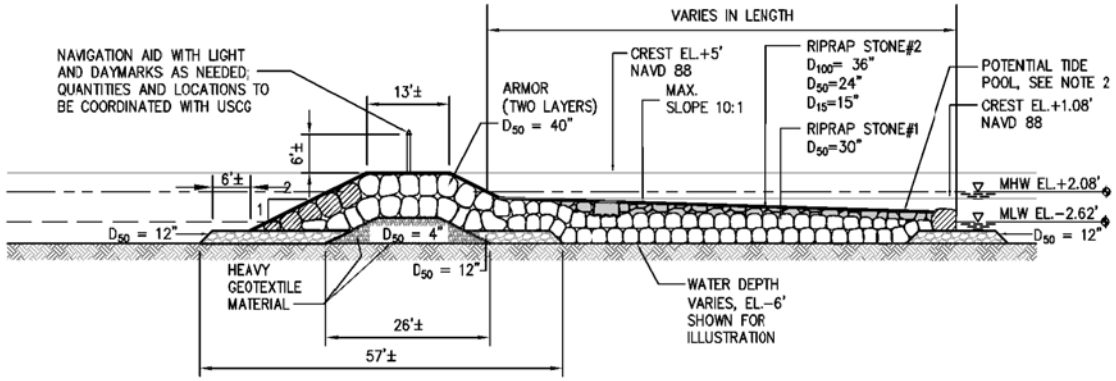
APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

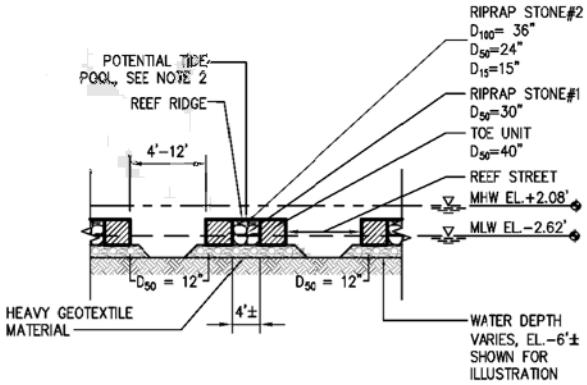
PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

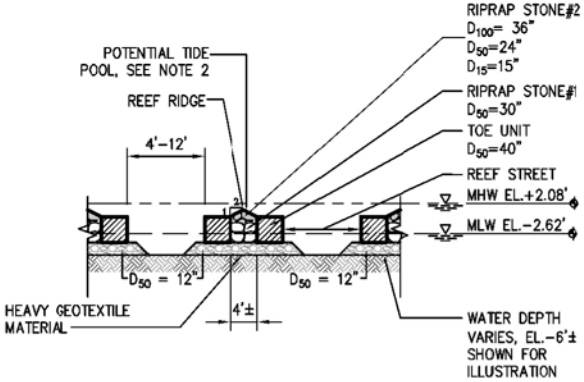
DATE: 01/20/2017



TYPICAL BREAKWATER TYPE 'A'
PROPOSED SECTION B-B



TYPICAL BREAKWATER TYPE 'A'
REEF RIDGE/STREET SECTION C-C
(AT END OF RIDGE)



TYPICAL BREAKWATER TYPE 'A'
REEF RIDGE/STREET SECTION D-D
(AT BREAKWATER)

LEGEND	
POTENTIAL LOCATION FOR BIO-ENHANCING CONCRETE UNITS	
POTENTIAL LOCATION FOR TIDE POOL UNITS	

0 30 60 FT.

SCALE 1"=30'-0"

NOTE:
1. WHERE POTENTIAL BIO-ENHANCING CONCRETE UNITS ARE INDICATED, ARMOR STONE WILL BE REPLACED WITH BIO-ENHANCING CONCRETE UNITS AT A RATE OF 30% IN ALL OTHER LOCATIONS, ARMOR AND TOE UNITS WILL BE STONE OF THE SIZE INDICATED.
2. WHERE POTENTIAL TIDE POOLS ARE INDICATED, RIPRAP STONE WILL BE REPLACED WITH TIDE POOL UNITS AT A RATE OF 30% IN ALL OTHER LOCATIONS, RIPRAP WILL BE STONE OF THE SIZE INDICATED.
3. REFER TO SHEET 8 FOR BREAKWATER VOLUME SUMMARY.

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

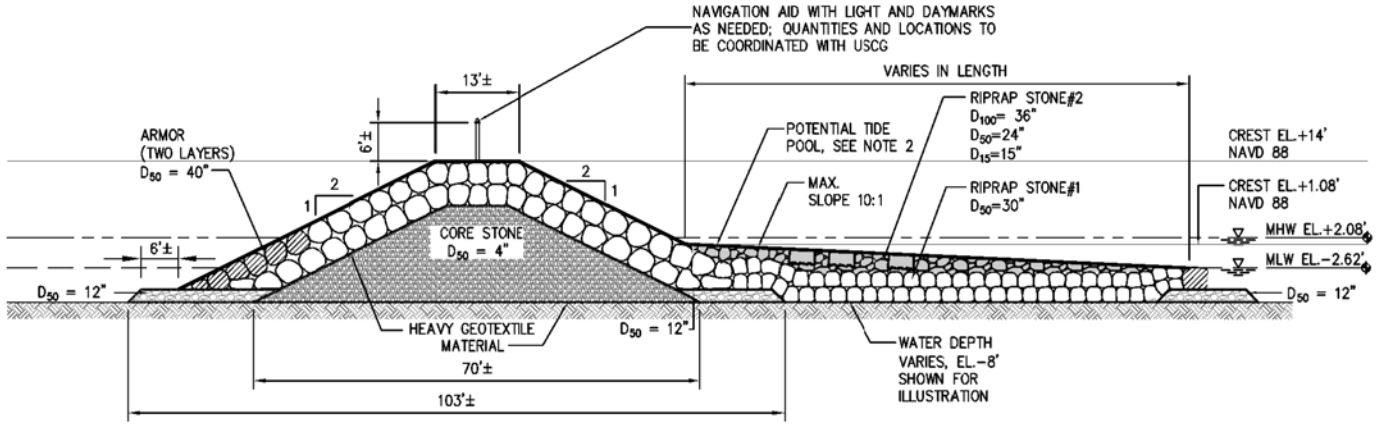
PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

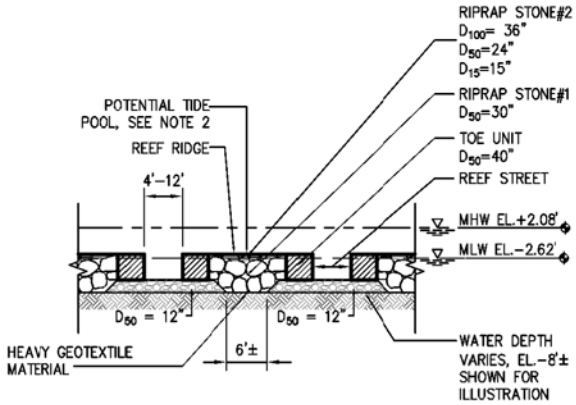
DATE: 01/20/2017

SHEET 11 OF 15

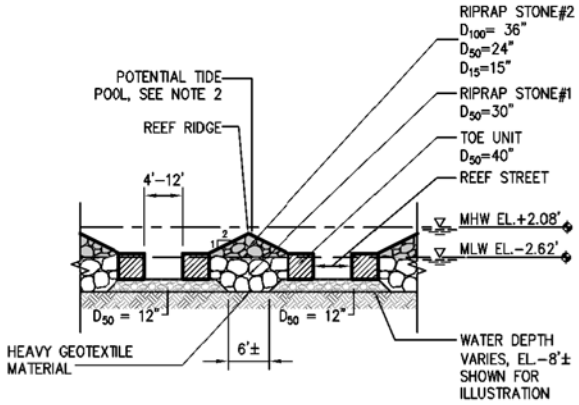
ATTACHMENT 1



TYPICAL BREAKWATER TYPE 'B'
PROPOSED SECTION B-B



TYPICAL BREAKWATER TYPE 'B'
REEF RIDGE/STREET SECTION C-C
(AT END OF RIDGE)



TYPICAL BREAKWATER TYPE 'B'
REEF RIDGE/STREET SECTION D-D
(AT BREAKWATER)

LEGEND	
POTENTIAL LOCATION FOR BIO-ENHANCING CONCRETE UNITS	
POTENTIAL LOCATION FOR TIDE POOL UNITS	

0 30 60 FT.

SCALE 1"=30'-0"

NOTE:
1. WHERE POTENTIAL BIO-ENHANCING CONCRETE UNITS ARE INDICATED, ARMOR STONE WILL BE REPLACED WITH BIO-ENHANCING CONCRETE UNITS AT A RATE OF 30% IN ALL OTHER LOCATIONS, ARMOR AND TOE UNITS WILL BE STONE OF THE SIZE INDICATED.
2. WHERE POTENTIAL TIDE POOLS ARE INDICATED, RIPRAP STONE WILL BE REPLACED WITH TIDE POOL UNITS AT A RATE OF 30% IN ALL OTHER LOCATIONS, RIPRAP WILL BE STONE OF THE SIZE INDICATED.
3. REFER TO SHEET 8 FOR BREAKWATER VOLUME SUMMARY.

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

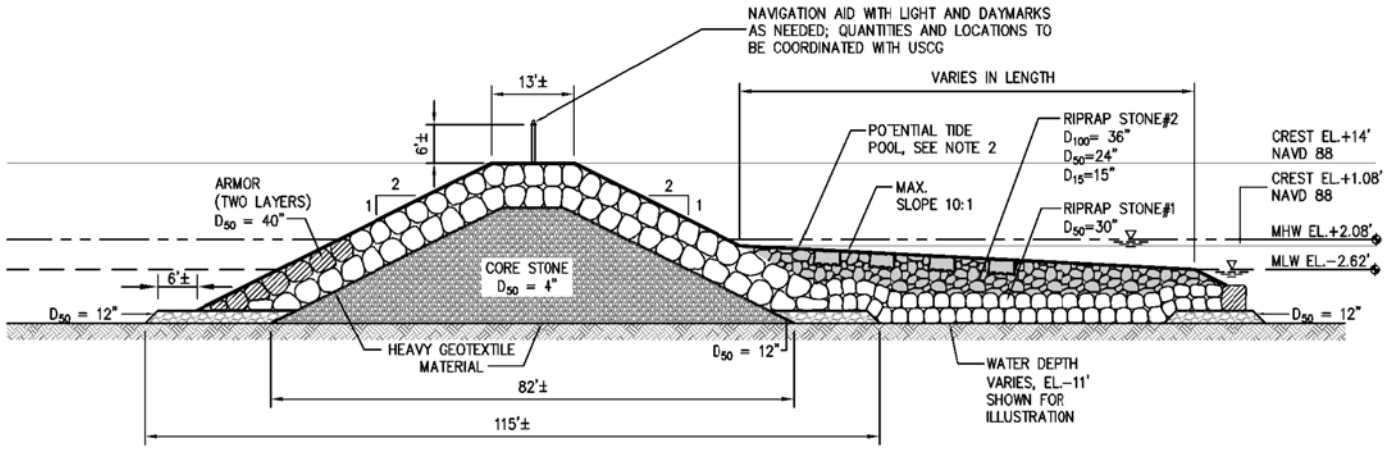
PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

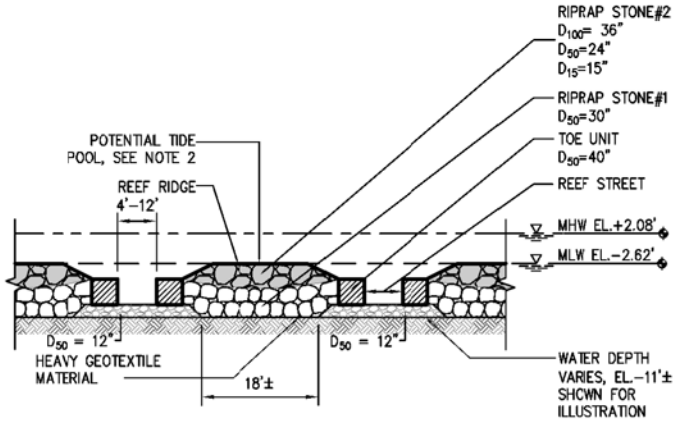
DATE: 01/20/2017

SHEET 12 OF 15

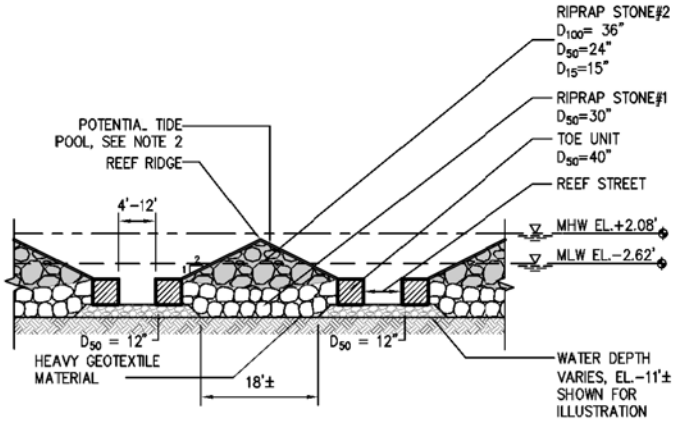
ATTACHMENT 1



TYPICAL BREAKWATER TYPE 'C'
PROPOSED SECTION B-B



TYPICAL BREAKWATER TYPE 'C'
REEF RIDGE/STREET SECTION C-C
(AT END OF RIDGE)



TYPICAL BREAKWATER TYPE 'C'
REEF RIDGE/STREET SECTION D-D
(AT BREAKWATER)

LEGEND	
POTENTIAL LOCATION FOR BIO-ENHANCING CONCRETE UNITS	
POTENTIAL LOCATION FOR TIDE POOL UNITS	

0 30 60 FT.

SCALE 1"=30'-0"

NOTE:
1. WHERE POTENTIAL BIO-ENHANCING CONCRETE UNITS ARE INDICATED, ARMOR STONE WILL BE REPLACED WITH BIO-ENHANCING CONCRETE UNITS AT A RATE OF 30%; IN ALL OTHER LOCATIONS, ARMOR AND TOE UNITS WILL BE STONE OF THE SIZE INDICATED.
2. WHERE POTENTIAL TIDE POOLS ARE INDICATED, RIPRAP STONE WILL BE REPLACED WITH TIDE POOL UNITS AT A RATE OF 30%; IN ALL OTHER LOCATIONS, RIPRAP WILL BE STONE OF THE SIZE INDICATED.
3. REFER TO SHEET 8 FOR BREAKWATER VOLUME SUMMARY.

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

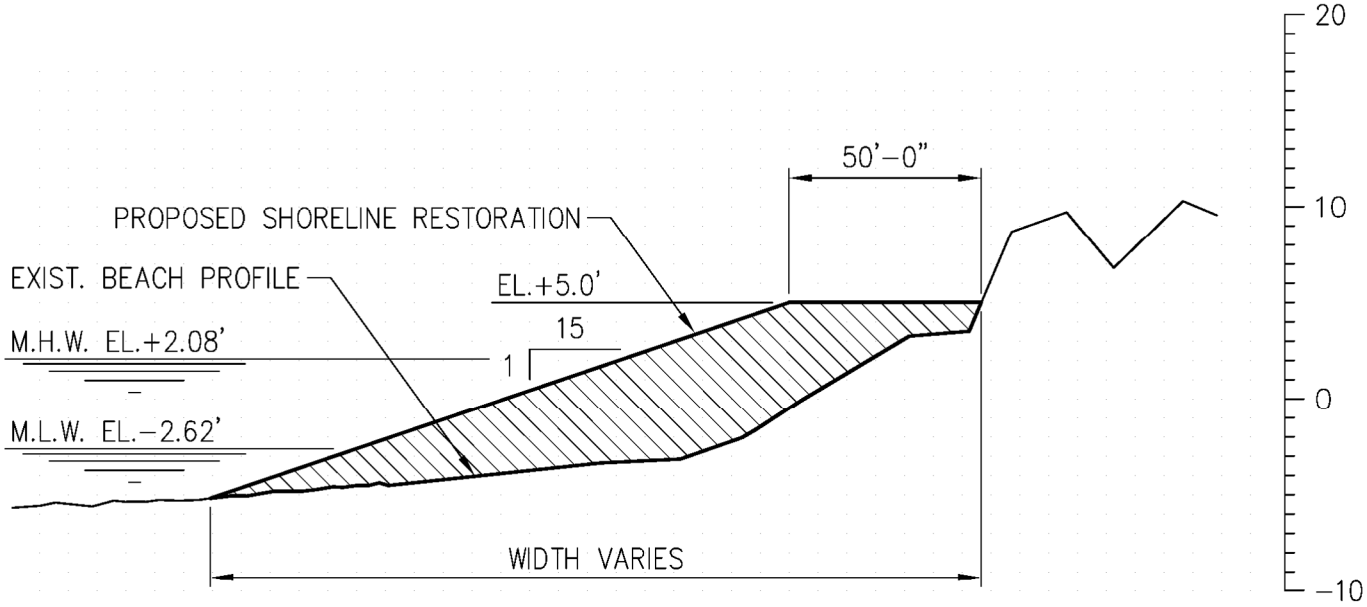
PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

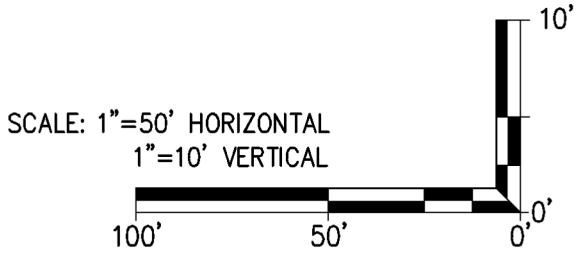
DATE: 01/20/2017

SHEET 13 OF 15

ATTACHMENT 1

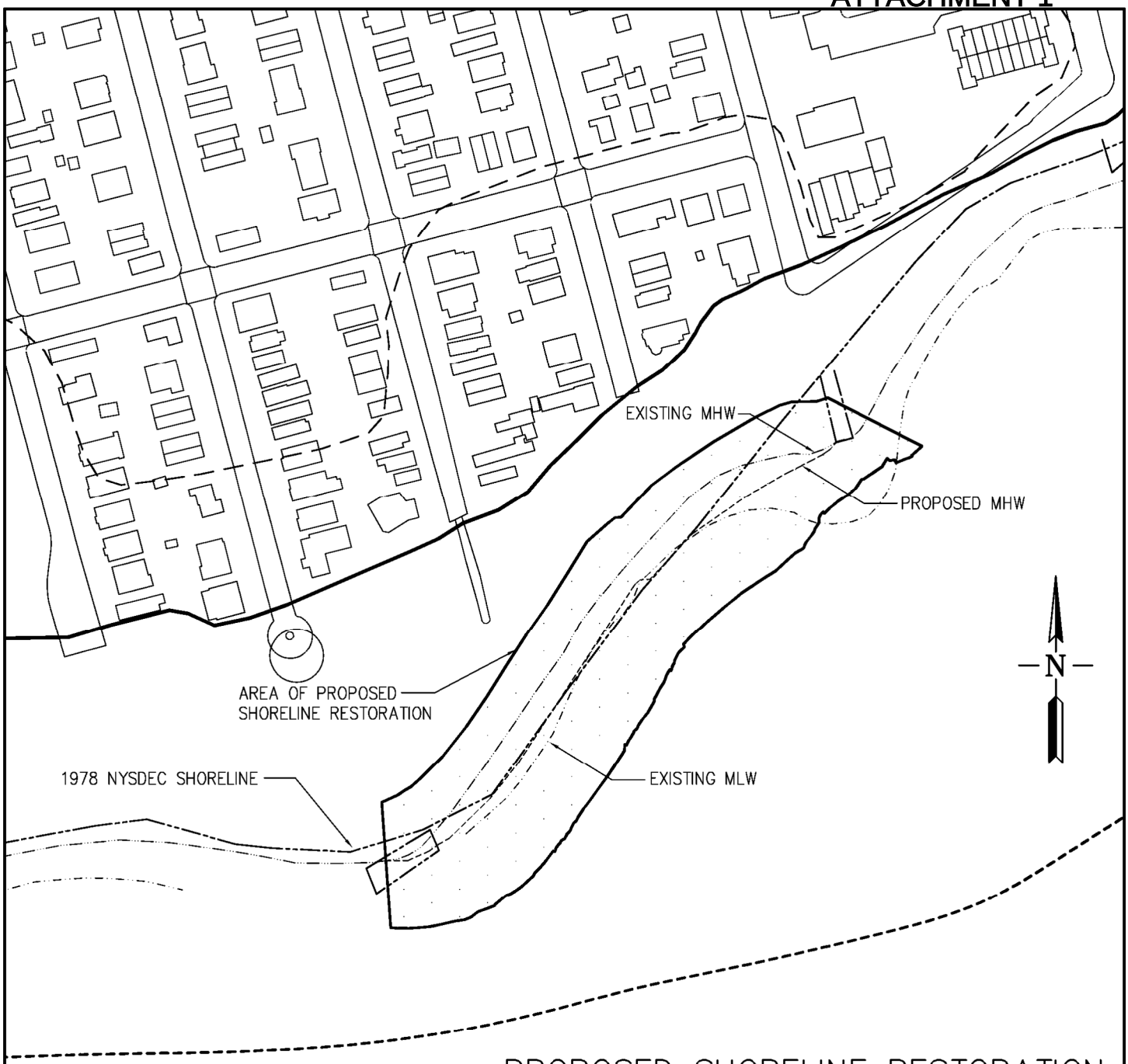


PROPOSED SHORELINE RESTORATION SECTION



FOR PERMIT USE ONLY NOT FOR CONSTRUCTION	DATUM: N.A.V.D. 88 APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY APPLICATION NO.: AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.	PROPOSED CONSTRUCTION OF LIVING BREAKWATERS WARD POINT BEND, RARITAN BAY TOTTENVILLE, STATEN ISLAND COUNTY OF RICHMOND STATE OF NEW YORK DATE: 01/20/2017 SHEET 14 OF 15

ATTACHMENT 1



PROPOSED SHORELINE RESTORATION PART PLAN

LEGEND

- MEAN HIGH WATER
- MEAN LOW WATER
- FEMA V-ZONE
- 1978 NYSDEC SHORELINE
- LiMWA
- BREAKWATER DESIGN ENVELOPE
- PROPOSED MHW

0 200 400 FT.

SCALE 1"=200'-0"

FOR PERMIT USE ONLY
NOT FOR CONSTRUCTION

DATUM: N.A.V.D. 88

APPLICATION BY: GOVERNOR'S OFFICE OF STORM RECOVERY

APPLICATION NO.:

AGENT: OCEAN & COASTAL CONSULTANTS ENGINEERING, P.C.

PROPOSED CONSTRUCTION OF LIVING BREAKWATERS

WARD POINT BEND, RARITAN BAY
TOTTENVILLE, STATEN ISLAND
COUNTY OF RICHMOND
STATE OF NEW YORK

DATE: 01/20/2017

SHEET 15 OF 15

\\cowi.net\projects\A065000\A068233\CAD\A068233.2\Phase 3\Task 2\30pct Permit CAD\Permit 15.dwg Permit 15 Rey Buzeta Tue, 24 Jan 2017 - 6:01pm

Attachment 2 Description of Impacts—Additional Information

The following information is provided in response to certain questions listed under Step 3 "Description of Impacts" of the EFH Assessment Worksheet.

Nature and duration of activity(s). Clearly describe the activities proposed and the duration of any disturbances.

The Proposed Actions consists of the implementation of two individual projects: the Living Breakwaters Project ("Breakwaters Project") and the Tottenville Shoreline Protection Project ("Shoreline Project"), as described below, as a layered strategy that will increase the overall resiliency of the Tottenville shoreline. The South Shore of Staten Island is vulnerable to both event-based and gradual coastal erosion and land loss. Consistent with the City's Coastal Protection Initiatives and planning studies for the Tottenville area, the goal of the Proposed Actions is to reduce wave action and coastal erosion along the shoreline in Tottenville, while enhancing ecosystems and shoreline access, use and stewardship. This goal would be achieved using a layered approach that would address wave action, impacts of coastal flooding and event-based (i.e., short-term/storm-related) and gradual (long-term) shoreline erosion, while restoring and enhancing ecosystems, improving waterfront access and engaging with the community through educational and stewardship programs directly related to the coastal resiliency actions. In other words, it is highly important that the actions both provide coastal protection and ecological enhancement, and at the same time serve as a means to engage and educate the public on local ecosystems and innovative coastal resiliency strategies in an era increasingly affected by climate change.

The following sections describe the Breakwaters Project and Shoreline Project.

Breakwaters Project

The Breakwaters Project, as presented in **Attachment 1**, comprises the ecologically enhanced breakwater system, which will include approximately 10 breakwater segments of varying size, the proposed area of shoreline restoration, the proposed seasonally placed floating dock and boat launch, the Water Hub, and the oyster nursery. The proposed area of one-time sand placement in the area of shoreline restoration includes 163,820 square feet (3.8 acres), of which 87,975 square feet (2.0 acres) is below mean high water (MHW). The proposed beach fill will extend along approximately 806 feet of shoreline between Manhattan Street and Loretto Street. About 20,701 cubic yards (CY) of sand, approximately 15,369 CY of which will be below MHW, will be placed in this location to establish a beach berm and in what is currently a narrow and erosion-prone section of the beach. This 3.8-acre area was selected for one-time beach fill because of high historic and projected erosion rates, narrow beach width and the presence of adjacent vulnerable assets (tidal wetlands and homes) in the FEMA V and Limit of Moderate Wave Action zones. The shoreline restoration will extend the beach at an elevation of +5.0 NAVD88 to a width of 50 feet. The use of this one-time shoreline restoration will be stabilized by the breakwaters. It will augment the accretion potential that can be provided by the breakwaters and

add sediment to the overall system, particularly contributing to the most erosion-prone areas in the southwestern portion of the site and generally enhancing overall beach growth potential.

A temporary seasonal floating dock measuring about 30 feet by 50 feet, with a total area of 1,500 square feet, will be installed as part of the Water Hub portion of the Breakwaters Project to provide water-based access to the Living Breakwaters for observations, monitoring, maintenance and stewardship, including specifically, for vessels operated by the Billion Oyster Project and any other anticipated project stewards. Active oyster restoration is planned for areas on and adjacent to the breakwaters via several techniques: bio-enhancing concrete armor units containing oysters, oyster gabions, in-situ oyster setting on a trial basis, spat-on-shell, and an oyster spat nursery. Approximately 5 acres of spat-on-shell will be placed in "reef streets," or rocky interspaces on the breakwaters, and potentially adjacent to the breakwater structures. A floating nursery structure comprising a series of floating oyster trays housing spat-on-shell, most likely arranged as two 300-foot-long by 10-foot-wide segments totaling approximately 6,000 square feet (0.2 acres) will also be located in the lee of the breakwaters.

At the Water Hub, access to the water from the shore will be provided by means of a seasonally deployed temporary floating boat launch. Anchored about a foot above MHW, the approximately 8-foot-wide temporary boat launch will extend approximately 210 feet and will provide a separation of approximately 18 inches between the bottom of a vessel located at the end of the launch and the bay bottom at mean low water (MLW). The approximately 4 to 5-foot deep water depths at MLW will be sufficient for docking of a shallow draft research vessel.

The proposed breakwaters will have a total length of approximately 3,900 linear feet within Raritan Bay and will be located between 500 and 2,100 feet from the shoreline. Additionally, the vast majority of the breakwater structures would be located more than 1,500 feet from the Federal Navigation Channel with one breakwater segment located more than 700 feet from the channel. The breakwater structures will occupy approximately 551,094 square feet (12.75 acres) on the bottom of Raritan Bay and result in the placement of 197,164 CY of rock and ecologically enhanced concrete within Raritan Bay, approximately 150,685 CY of which will be placed below MHW. Each breakwater structure will incorporate the reef street and ridge components (rocky protrusions [reef ridges] and the narrow spaces between them [reef streets] on the ocean-facing side of the breakwaters) to create additional complex hard/rocky structured habitat extending out along the bottom. The breakwaters will be positioned and designed to optimize reduction in both wave height and shoreline erosion, while enhancing habitat and minimizing habitat displacement and navigational impacts.

Three types of breakwaters, defined largely by their differences in crest elevation (in NAVD88) and overall height, will be constructed: Type A, Type B, and Type C (**Attachment 1)**, all of which will extend some height above MHW. Two segments of Type A breakwaters will be installed in the western portion of the project site near Ward's Point. These breakwaters have a crest elevation of +5 feet NAVD88 and an overall height of 11 feet. Together the two segments will be approximately 900 feet long, and result in the placement of 18,472 CY in the bay, of which 16,696 CY will be below MHW within a 2.0-acre footprint. In the middle portion of the project site, offshore of the beach fill area, six segments of Type B breakwaters will be installed. Together these segments will be approximately 1,800 feet long, with a crest elevation of +14 feet NAVD88, an overall height of 22 feet, and result in the placement of approximately 98,323 CY in the bay, of which 72,115 CY will be below MHW within a 6.4-acre footprint. Two Type C breakwaters will be installed offshore from the Water Hub location in the eastern portion of the project site. Together, these segments will be approximately 1,200 feet long, with a crest

elevation of +14 feet NAVD88, an overall height of 25 feet, and result in the placement of approximately 80,369 CY within the bay, of which approximately 61,875 CY will be below MHW within a 4.2-acre footprint. The oyster nursery and seasonal floating dock will be located on the shore side of the Type C breakwater farthest from shore.

Breakwater crest elevations and locations were based on the relative need for storm wave attenuation along the shoreline, the intent to stabilize shoreline change across the project area, and to promote shoreline accretion in key locations. Type B and C breakwaters, which each have a crest elevation of +14 feet NAVD88, were designed to protect the most vulnerable assets near the shoreline from storm wave action. Considering up to 30 inches sea level rise, these breakwaters are designed to reduce wave heights to less than 3 feet in a 100-year storm event, thereby reducing wave energy at the shoreline and structural damage to onshore assets previously exposed to storm wave action. Preliminary modeling indicates that these high-crested breakwaters will be capable of reducing storm wave heights by 50 percent or more, reducing storm wave exposure of the southwestern shore of Staten Island. The Type A breakwaters, with crest elevations of +5 feet NAVD88, will be placed where there are not assets vulnerable to storm wave energy along the shoreline. These breakwaters will remain above MHW with up to 30 inches of sea level rise, and thus would still reduce or reverse long-term erosion.

Wave attenuation provided by the breakwaters on a day-to-day basis will help to maintain beach conditions by reducing long term beach erosion rates, reducing exposure of shoreline structures to erosion, and encouraging accretion in priority beach zones where the existing beach is narrow and/or projected rates of erosion are high. The breakwater system is designed and located to maintain and restore the beach while minimizing down-drift impacts. The breakwaters will attenuate waves and alter the sediment transport along the shore for this purpose. Local sediment transport rates and accretion will be altered, but the natural processes will not be blocked as there will still be sediment transport along the shore and tidal circulation around the breakwaters. At the western tip of the study area near Ward's Point, the breakwaters will reduce sand migration from the northeast into the Federal Navigation Channel. The breakwaters were also designed to encourage shoreline growth, or accretion, in places where the beach is most narrow and/or projected erosion rates are high. One-time shoreline restoration proposed for the narrow section of shoreline between Loretto Street and Manhattan Street will augment the accretion potential that could be provided the breakwaters.

The installation of the breakwater structures will result in the replacement of 12.7 acres of subtidal sand and gravel habitat with subtidal, intertidal and emergent hard/rocky habitat composed of rock and bio-enhancing concrete of varying sizes. The inshore sandy/gravel habitat displaced by the breakwaters constitutes only 2 percent of the approximately 610 acres of available inshore habitat within the study area in Raritan Bay. This 2 percent loss of sand/gravel habitat will occur sequentially as the breakwaters are constructed over an approximately 18-month period. The breakwaters have been designed to include varying levels of elevation and inclination, along with bio-enhancing materials and a variety of textures and grain sizes in order to create: sheltered habitats for fish, confined waterbodies at the intertidal zone, recruitment capabilities for shellfish, and structural complexity to accommodate a diverse biotic community. On the ocean side of the breakwaters, rocky protrusions (reef ridges) and narrow spaces between them (reef streets) will create interspaces of narrow rocky conditions within the intertidal and subtidal zones to allow for a diversity of habitat characteristics and ecological enhancement (see **Attachment 1**). Crevices and void space created in the breakwater structures will provide refuge for fish and epibenthic invertebrates and foraging habitat for larger pelagic fish species.

Based on surveys of the adjacent structured habitat in the study area and engineering design principles of breakwater structures, it is estimated that 70 percent of the exposed surface area of the armor units will be available as habitat for local aquatic biota. The surface area that will result from placement of the armor units and bio-enhancing concrete units within the breakwater will provide an estimated 1,796,463 square feet (41.2 acres) of habitat (12.9 acres intertidal and 28.3 acres subtidal) available to encrusting habitat forming organisms identified in **Table 1**, which were observed on and near the rocky substrates sampled within the study area and on adjacent artificial rocky habitat. This area of available habitat will represent a net increase in available habitat of about 1,243,251 square feet (28.5 acres) when compared to the 12.7 acres of sand and gravel habitat that will be displaced by the breakwater structure. Thus, the structured habitat resulting from the breakwaters segments will provide approximately 3.3 times that amount of available habitat when compared to the sand and gravel area displaced. In addition, crevices and void space created in the breakwater structures will provide refuge and forage area for EFH and other fish and epibenthic invertebrates. Even assuming that only 50 percent of the exposed surface area will be available to encrusting organisms, the breakwater construction will still result in an increase in available habitat of 31.5—a net increase in usable habitat of 16.8 acres or approximately 2.3 times the area of Raritan Bay bottom displaced by the Breakwaters Project. The breakwaters will also create microhabitat changes along the edges and between the breakwater structures associated with the change in sediment transport from the erosion control services of the Proposed Actions, and small changes in flow patterns around the structures associated with their wave attenuation capabilities. The complex rocky surface of the breakwaters, along with the bio-enhancements, will increase habitat diversity in Raritan Bay and provide increased availability of sheltering and foraging habitat for EFH species.

Table 1
Target Species Group Descriptions

Characteristic Groups	Ecological Roles and Societal Value	Representative Taxa	Existing Conditions	Essential Fish Habitat	Recreational or Commercial Value
Habitat-forming autotrophs	Primary producers; foraging/ refuge/nursery habitat; coastal protection	Eelgrass	-	-	-
		Red branching algae	Yes	-	-
		Red filamentous algae	Yes	-	-
		Green algae	Yes	-	-
		Brown algae	-	-	-
Bivalve habitat-forming sessile invertebrates	Refuge and substrate for primary producers, benthic and epibenthic invertebrates, and fish; filter-feeding (benthic-pelagic coupling); shoreline protection	Eastern oyster	-	-	Yes
		Blue mussel	Yes	-	Yes
Non-bivalve habitat-forming sessile invertebrates	Forage; filtering (benthic-pelagic coupling; increased habitat rugosity)	Barnacles	Yes	-	-
		Bryozoans	Yes	-	-
		Tunicates	Yes	-	-
		Tubeworms	Yes	-	-
		Clams	Yes	-	-
		Sponges	Yes	-	-
Cryptic fish	Forage for higher trophic-level fish, seabirds; eggs adhere to structure; use structure for refuge; wide range of prey from algae to plankton to crustaceans, mollusks, other benthic invertebrates	Gobies	-	-	-
		Blennies	-	-	-
		Rock gunnel	-	-	-
		Oyster toadfish	-	-	-
Structure oriented reef fish	Consume benthic invertebrates and fish near structured habitat; commercial and recreational fisheries	Tautog	Yes	-	-
		Black sea bass	Yes	Yes	Yes
		Cunner	Yes	-	Yes
Transient/pelagic forage fish	Forage for higher trophic-level fish, shorebirds; consume zooplankton and planktonic fish and macroinvertebrate larvae	American sandlance	-	-	-
		Atlantic herring	-	Yes	Yes
		Atlantic menhaden	Yes	-	Yes
		Atlantic silversides	Yes	-	-
		Bay anchovy	Yes	-	-
		Inland silverside	-	-	-
		Fundulus sp.	Yes	-	-
		Rainbow smelt	-	-	-
		Sheepshead minnow	Yes	-	-
		Spot	Yes	-	Yes
		Sticklebacks	Yes	-	-

Table 1
Target Species Group Descriptions

Characteristic Groups	Ecological Roles and Societal Value	Representative Taxa	Existing Conditions	Essential Fish Habitat	Recreational or Commercial Value
		Striped anchovy	-	-	-
		Tidewater silverside	-	-	-
		Tomcod	-	-	-
Upper trophic level reef-transient fish	Predatory fish that feed on forage fish linked to or associated with (oyster) reef habitat; commercial and recreational fisheries	American eel	Yes	-	Yes
		Atlantic butterfish	-	Yes	Yes
		Atlantic cod	-	Yes	Yes
		Atlantic mackerel	-	Yes	Yes
		Atlantic striped bass	Yes	-	Yes
		Bluefish	Yes	Yes	Yes
		Monkfish	-	Yes	Yes
		Red hake	-	Yes	Yes
		Scup	-	Yes	Yes
		Silver hake	-	Yes	Yes
		Summer flounder	Yes	Yes	Yes
		Weakfish	Yes	-	Yes
		Windowpane	Yes	Yes	Yes
		Witch flounder	Yes	Yes	Yes
		Winter flounder	-	Yes	Yes
		Yellowtail flounder	-	Yes	Yes
Benthic macroinvertebrates	Consumers of small fish and epibenthic invertebrates; horseshoe crab eggs prey for shore birds; important prey and predators of estuarine systems	Blue crab	Yes	-	Yes
		Other crabs	Yes	-	-
		Horseshoe crab	Yes	-	Yes
		Lobsters	-	-	Yes

To construct the breakwater segments, geotextile panels will be floated out to its final location, and then lowered to the bottom by the weight of large rocks to minimize sediment resuspension. Bedding stone (scour apron), core stone, rip rap stone, and armor units made of stone or bio-enhancing concrete, will be placed on top of the geotextile in various configurations depending on the type of breakwater being constructed (**Attachment 1**). These materials will be "clean" to further minimize the potential for release of suspended material into the water column. Barges carrying construction materials will make an average of less than one trip per day over the entire construction period. It is anticipated that crane barges will be continually moved during construction to create the best lifting angles and shortest lifting distances to install the breakwater segments. Barges will be located to maintain a separation of at least 2 feet between the bottom of the barge and the mudline. Construction will last approximately 8-9 months per year for two years, or up to 18 months in total.

Construction of the breakwater segments will result in temporary and localized sediment resuspension and permanent loss of sandy/gravel bottom habitat. There may be a temporary

increase in vessel traffic and noise during the construction period, but noise levels will not be outside the range of typical vessel activity in Raritan Bay. Construction barges will result temporary shading where they are moored, and the floating dock and boat launch will result in temporary shading on a seasonal basis. Construction vessels, including barges, will maintain at least 2 feet of clearance with the bottom of the bay to minimize additional sediment resuspension from vessel movement.

Shoreline Project

The proposed Shoreline Project will consist of a series of shoreline protection measures that will include an earthen berm, hybrid dune system, eco-revetment, and a raised edge with a revetment along with wetland enhancements, and landscaping with coastal plant species, as described in greater detail below. All of these structures will be above MHW (+2.08 NAVD88). The Shoreline Project will extend from approximately west of the intersection of Swinnerton Street and Billop Avenue to Page Avenue. Along the length of the Shoreline Project, additional shoreline treatments will be implemented, such as wetland enhancements and additional shoreline plantings. Green infrastructure will be implemented wherever possible and permeable path materials will be used throughout the project. All elements of the Shoreline Project will be constructed on land. Water-based delivery of material is unlikely for the Shoreline Project but would be explored as design progresses. The Shoreline Project will take approximately 21 months to complete. The Shoreline Project has limited potential to adversely affect EFH. Erosion and sediment control measures implemented in accordance with a Stormwater Pollution Prevention Plan ("SWPPP") prepared as required under the New York State Pollutant Discharge Elimination System ("SPDES") General Permit GP-0-15-002 for Stormwater Discharges from Construction Activity will minimize discharge of sediment to Raritan Bay during construction of the Shoreline Project.

The hybrid dune system and wetland bridge within the transition between the earthen berm and hybrid dune, and a portion of the proposed path would be constructed within the 0.8-acre delineated tidal wetland. The area of this delineated tidal wetland that would be affected by the Shoreline Project elements would include approximately 7,358 square feet (0.17 acres) due to the hybrid dune, 1,608 square feet (0.04 acres) due to the path, and 1,245 square feet (0.03 acres) due to the transition node structure. Permanent impacts to the tidal wetland would be primarily within the portion of the wetland dominated by common reed and while the loss of a portion of the wetland would be an adverse effect, it would be offset by the enhancement of the tidal wetland plant community that would result from the proposed modification of the inlet to Raritan Bay to increase tidal exchange within this wetland. The portion of the path that crosses through the wetland would be designed in consultation with the NYSDEC and USACE to allow access across the wetland while minimizing adverse effects to the tidal wetland. Temporary impacts would be minimized through the use of measures such as marsh mats or low ground-pressure equipment within the wetland, and installation of erosion and sediment control measures in accordance with the SWPPP" prepared as required under the SPDES General Permit GP-0-15-002 for Stormwater Discharges from Construction Activity. Portions of the wetland disturbed during dune and wetland bridge construction would be restored as necessary (e.g., repair of ruts, stabilization of soil). Wetland vegetation would be planted to replace vegetation temporarily disturbed during construction. With these measures in place temporary impacts to wetlands during construction and the permanent loss of a small portion of the wetland due to the placement of the hybrid dune and transition node structure would not result in significant adverse impacts to wetland resources.

Will the benthic community be disturbed? If no, why not? If yes, describe in detail how the benthos will be impacted.

Construction of the breakwater segments will have the potential to result in temporary localized increases in suspended sediment which will dissipate upon completion of sediment disturbing activities. Materials used to build the breakwaters will be "clean" to minimize release of suspended materials into the water column. The 2 feet of clearance maintained by construction vessels will ensure that no further benthic effects will result during construction of the proposed project.

The construction of the breakwater segments will result in the permanent of 12.7 acres of subtidal sandy/gravel bottom habitat and associated invertebrates within this footprint. This loss will be more than offset by the 1,231,626 square feet (28.3 acres) of available subtidal hard rocky habitat and 564,837 square feet (12.9 acres) of available intertidal hard rocky habitat, for a total of 41.2 acres that will be available below MHW. The breakwater structures will represent a net increase in available habitat of about 28.5 acres, or 3.3 times the amount of available habitat when compared to the sand and gravel area There will also be a permanent loss of 2.0 acres of sandy bottom in the intertidal zone where 15,369 CY of sand will be placed below MHW.

Long-term changes to benthic habitat in the vicinity of the breakwater segments will likely include the accumulation of sandy and coarse-grained substrate near the structures, with the potential for additional accumulation of broken shells or other calcium carbonate materials originating from sessile and encrusting marine organisms, which could provide additional habitat for benthic organisms. An oyster nursery system will be deployed, including the setting of live spat on oyster gabions and selected bio-enhancing concrete units among the breakwater segments. Large-scale design features of the breakwaters (i.e., number, size, shape, spatial distribution, composition, and orientation) will contribute to the diversity of habitats created by the Breakwaters Project and could result in a benthic community anchored by a healthy population of habitat-forming species that includes mussels, native oysters, hard clams, macro algae, barnacles, bryozoans, tunicates, tubeworms, and sponges.

Will shellfish habitat be impacted? If so, provide in detail how the shellfish habitat will be impacted. What is the aerial extent of the impact? Provide details of any shellfish survey conducted at the site.

In accordance with 6 NYCRR Part 41: Sanitary Condition of Shellfish Lands, all shellfish lands in Richmond County are in such a sanitary condition that the shellfish are not to be taken for use as food and the waters off Richmond County are designated as uncertified. Soft- and hard-bottom surveys were conducted between June and September 2015 in the project location to characterize the benthic invertebrate community. The survey indicated that there are two distinct benthic assemblages in the study area, one occurring in mud and sand/gravel substrate throughout the project location and a second, less widely distributed group associated with sandy substrate near the mouth of the Arthur Kill. Shellfish found in sand/gravel substrates included the bivalve mollusk *Crepidula fornicata* and gastropod snail *Boonea bisuturalis*. Hard clam (*Mercenaria mercenaria*) was most abundant in mud, but also occurred in sand/gravel and scattered hard bottom areas. Shellfish found in sand substrate included *C. fornicata* and the bivalve clam *Gemma gemma*. Hard clam, horseshoe crab (*Limulus polyphemus*), blue crab (*Callinectes sapidus*), lady crab (*Ovalipes ocellaus*), say mud crab (*Dyspanopeus sayi*), portly spider crab (*Libinia emarginata*), and hermit crabs (Paguroidea) have been found at the project

site. Other shellfish known to occur in Raritan Bay include soft shell clam (*Mya arenaria*), dwarf surf clam (*Mulinia lateralis*), blue mussel (*Mytilus edulis*), ribbed mussel (*Aulacomya atra*), and oysters (*Crassostrea virginica*).

Shellfish habitat may be affected by localized increased turbidity from sediment resuspension by placement of the breakwater materials and movement of construction vessels; however, this effect will be temporary and below the thresholds that could adversely impact susceptible benthic invertebrates, and sediments will dissipate upon cessation of sediment disturbing construction activities. There will be a permanent loss of 12.7 acres of sandy/gravel bottom habitat and associated infaunal and non-motile shellfish. The 12.7 acres of sand/gravel habitat represents only 2 percent of the available inshore habitat in the study area within Raritan Bay, and the expected accumulation of sand and gravel will re-establish suitable habitat for burrowing organisms in the direct vicinity of the breakwaters. While the area within this footprint will no longer be suitable for burrowing shellfish, the net increase of 28.5 acres of high-relief rocky habitat along with interstitial habitat and crevices will create suitable refugia for encrusting shellfish. Additionally, live oyster spat will be added to selected locations among the breakwaters and deployed in a nursery system (floats, anchors, and oyster trays) in an attempt to establish a viable population of oysters in Raritan Bay. The proposed breakwater structures will substantially increase the availability of hard substrate for oysters and other epifauna on the bottom of Raritan Bay, thereby improving habitat suitable for shellfish in the study area.

Will hard bottom (rocky, cobble, gravel) habitat be impacted at the site? If so, provide in detail how the hard bottom will be impacted. What is the aerial extent of the impact?

There are currently small pockets of hard bottom habitat throughout Raritan Bay, including within the study area, but the footprint of the breakwaters mainly comprises sand and sand/gravel bottom habitat. Installation of the breakwaters will result in a gain of 41.2 acres of hard bottom habitat in the subtidal and intertidal zones in the study area, representing a net gain of 28.5 acres of hard bottom habitat. The composition of the breakwaters will include hard surface reef ridges, bio-enhancing concrete units, and interstitial spaces between armor units, adding to the diversity of available habitat in the study area.

Will sediments be altered and/or sedimentation rates change? If no, why not? If yes, describe how.

Sediments will be altered within the 12.7-acre footprint of the breakwaters from sandy/gravel bottom to 41.2 acres (total surface area) of hard features including rock substrates of various texture and grain size, as well as bio-enhancing concrete units. The Breakwaters Project has been designed to reduce or reverse coastal erosion and grow the shoreline where the beach is most narrow and/or where projected erosion rates are high. The breakwater system is designed and located to maintain and restore the beach while minimizing down-drift impacts. The breakwaters will attenuate waves and alter the sediment transport along the shore for this purpose. Local sediment transport rates and accretion will be altered, but the natural processes will not be blocked, as there would still be sediment transport along the shore and tidal circulation around the breakwaters. As such, the Proposed Actions are expected to reduce long-term erosion and encourage accretion close to and along parts of the shoreline, and small amounts of deposition and scour are expected to occur at the edges of the breakwater structures. It is anticipated that coarse-grained and sandy material similar to that already found in Raritan Bay will accumulate around the breakwaters consistent with tide and current patterns in the area. Sediment quality will not be altered in areas of either accretion or scour around the breakwaters, as sediments in the area were found to contain low levels of contaminants.

Additionally, approximately 163,820 square feet (3.8 acres) of sand will be placed as part of the shoreline restoration between Loretto Street and Manhattan Street in order to augment the accretion potential of the breakwaters along this narrow section of beach. Only 87,975 square feet (2.0 acres) will be below MHW. About 20,701 cubic yards of sand, approximately 15,369 cubic yards of which will be below MHW, will be placed in this location. The proposed shoreline restoration is intended to increase the overall amount of sediment available in the system, enhance the overall beach growth along the south shore of Staten Island, and reduce erosion risk to the dunes along this especially vulnerable stretch of the shore. It will augment the accretion potential that can be provided by the breakwater system.

Will turbidity increase? If no, why not? If yes, describe the causes, the extent of the effects, and the duration.

During construction, the Breakwaters Project has the potential to result in minimal resuspension of bottom sediment and temporary increases in turbidity in the immediate vicinity of construction activities. Temporary sediment resuspension may occur during lowering of the geotextile panels that will underlay the breakwaters on the bottom of the Bay, movement of construction vessels, and seasonal placement of the floating dock and boat launch. Any increased turbidity or resuspension of contaminants caused by these activities will be temporary and localized, and sediments are expected to settle quickly upon cessation of sediment disturbing activities. Rocks used for armoring and to construct the breakwaters will be made of "clean" materials to further minimize the potential for release of suspended material into the water column.

Will tidal flow, currents, or wave patterns be altered? If no, why not? If yes, describe in detail below.

The Breakwaters Project will ultimately alter wave patterns by reducing wave height and energy in order to reduce or reverse erosion and lower coastal storm risk along the Tottenville shoreline of the South Shore of Staten Island. At lower water levels when the breakwaters are visible above the water line, waves will break on the ocean side of the structures. As waters rise over time (i.e., up to 30 inches of sea level rise) the breakwaters will be fully submerged and waves will move beyond the breakwaters, but at much lower height and intensity. Considering up to 30 inches of sea level rise, the breakwaters are designed to reduce wave heights to less than 3 feet in a 100-year storm event, thereby reducing wave energy at the shoreline and structural damage to onshore assets previously exposed to storm wave action. As a system, the breakwaters will be capable of reducing storm waves by 50% or more. The use of multiple structures of varying size, rather than one continuous breakwater, along with their placement at least 500 feet from the shoreline will allow for continuous water exchange through the study area with little obstruction. The breakwaters will create small changes in flow directly surrounding the structures, but will not significantly disrupt existing currents in Raritan Bay.

Will water quality be altered? If no, why not? If yes, describe in detail how. If the effects are temporary, describe the duration of the impact.

As described above, there is the potential for temporary sediment resuspension and localized increases in turbidity during construction; however, these effects will be minimized and will not adversely affect water quality. The Breakwaters Project was designed to maximize water circulation and maintain sufficient flushing conditions in the study area. The use of multiple breakwater segments of varying size, rather than one continuous breakwater, along with their placement at least 500 feet from the shoreline, will allow for continuous water exchange and

flushing throughout the study area to avoid impacts to water quality resulting from stagnant water conditions. Therefore, no long-term adverse impacts to water quality are expected to occur as a result of the Proposed Actions.

Does the action have the potential to impact prey species of federally managed fish with EFH designations?

The Breakwaters Project will have both temporary and permanent impacts to prey species of EFH fish. Construction activities have the potential to result in temporary impacts to fish and macroinvertebrates due to temporary increases in suspended sediment, loss of benthic habitat in the 12.7-acre footprint of the breakwaters, movement of construction vessels and breakwater materials through the water column, and associated underwater noise. Multiple measures will be used to minimize the effects of temporary sediment suspension, as described above. Fish and motile benthic macroinvertebrates will be able to avoid the study area during construction of the breakwaters and will not be affected by temporary increases in suspended sediment. Elevated suspended sediment concentrations will dissipate via dispersion by tidal currents of Raritan Bay upon cessation of sediment disturbing activities.

The Proposed Actions will result in a loss of non-motile benthic organisms, which may serve as prey for EFH species, within the 12.7 acres of sand and sand/gravel bottom where the breakwaters will be placed. While burrowing shellfish will no longer be available to predators within this footprint, this area represents only 2 percent of the available inshore habitat in the 610-acre study area within Raritan Bay and will not be lost all at once but sequentially as breakwater segments are constructed. Burrowing shellfish will continue to be available as prey to EFH species in the vicinity and will likely reestablish in the sand/gravel areas immediately surrounding the breakwaters. Additionally, the 41.2 acres of rocky surface created by the breakwaters will provide suitable substrate for encrusting shellfish and other epibenthic macroinvertebrates, which will in turn provide a source of prey for federally managed fish that consume these species. The rocky, high-relief reef-like habitat of the breakwater structures will create habitat well-suited to small, structure-oriented fish species along with pelagic forage fish which serve as prey to EFH species. The increase of available rocky habitat, along with the crevices and void space between and among the breakwaters, is expected to support a diverse benthic community, including encrusting organisms that can serve as prey for EFH species, and provide additional foraging habitat for fish.

Attachment 3 EFH Assessment—Additional Information

The following information is provided in response to certain questions listed under Step 4 "EFH Assessment" of the EFH Assessment Worksheet.

***Nursery*: If yes, describe in detail how and for which species. Describe how adverse effects will be avoided and minimized.**

Windowpane and winter flounder larvae are initially planktonic, but quickly become bottom-oriented and could be affected by in-water work if they are present at the project site. Any pelagic larvae that may occur in the study area will be less susceptible to effects from the in-water work, as they are able to move away from the construction area to suitable habitat in the vicinity. Larvae in the study area could be temporarily impacted by minor increases in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels prior to lowering of the breakwater stones and bio-enhancing concrete units. In-water construction activities will likely be restricted between early January and late May to protect spawning winter flounder, which will also protect any larvae present in the study area during that time.

The additional ecological enhancements to the study area resulting from the Breakwaters Project (e.g., eco-enhancing concrete armor units, reef streets and ridges, interstitial habitat creation) will create a mosaic of high-relief habitat across different elevations, inclinations, and orientations, expanding the niche space available for larvae associated with the bottom and for structure-oriented species. The 12.7-acre loss of sandy/gravel benthic habitat within Raritan Bay associated with placement of the breakwaters will not result in significant adverse impacts to nursery habitat for EFH species, as the estimated 41.2 acres of complex rocky habitat surface, with crevices and void space among and between the breakwaters, will provide refugia and potential nursery habitat for aquatic species which is currently limited within the study area.

***Shelter*: If yes, describe in detail how and for which species. Describe how adverse effects will be avoided and minimized.**

The project will not adversely impact sheltering habitat for EFH species. In fact, the breakwaters will provide a benefit by providing sheltering opportunities for EFH species such as black sea bass, bluefish, and red hake, which are limited within the portion of Raritan Bay within the study area. The breakwater structures will result in an estimate 41.2 acres of high relief rocky habitat surface area, a net increase in habitat of about 28.5 acres when compared to the 12.7 acres of sand/gravel habitat that will be displaced by the breakwater segments. It will incorporate interstitial habitats specifically designed to provide shelter for fish and shellfish in addition to the crevices and void space among and between the breakwaters. The breakwater segments have been designed to have varying levels of elevation, inclination, bio-enhancing materials, textures, interstitial spaces, and grain sizes in order to create a diversity of habitat characteristics and sheltering opportunities for aquatic biota. Reef ridges and reef streets incorporated into the breakwater layout will create interspaces of narrow rocky conditions, providing niche spaces for

sheltering fish. Aquatic species will have sheltering opportunities within the spaces created by these features over the entirety of the breakwater structures and among the segments themselves.

***Forage*: If yes, describe in detail how and for which species. Describe how adverse effects will be avoided and minimized.**

Red hake and bluefish are structure-oriented foragers, and juvenile and adult windowpane, summer flounder, winter flounder, and clearnose, little, and winter skate are benthic feeders. Other EFH species also feed on benthic organisms, although not exclusively. The Breakwaters Project will result in a minor temporary increase in suspended sediment and localized increases in turbidity during construction which could impact bottom dwelling foraging species; these effects will be minimized through the careful placement of geotextile panels and breakwater materials. During construction, species that feed on benthic organisms are expected to relocate to available foraging habitat in the vicinity during the construction period, and return upon completion of the work. The conversion from 12.7 acres of sandy/gravel bottom to 41.2 acres of hard surface habitat within Raritan Bay associated with the breakwater placement will not result in significant adverse impacts to foraging habitat for EFH species. In fact, the high-relief rocky and bio-enhancing concrete surfaces comprising the breakwater segments which will provide habitat for encrusting and shelter-oriented organisms, and the spaces created by the reef ridges, reef streets, and armor units, will provide additional forage habitat. Local, small-scale changes in water circulation, water quality, and sediment transport resulting from the Breakwaters Project could increase local retention of planktonic invertebrates and fish larvae and their subsequent recruitment to the breakwaters, in turn influencing the local fish community and its forage base.

Will impacts be temporary or permanent? Describe the duration of the impacts.

The Breakwaters Project will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, and maintaining at least 2 feet of clearance from the bottom of the Bay. The 12.7-acre footprint of the breakwaters represents only 2 percent of the available inshore habitat within the approximately 610 acres of similar habitat in Raritan Bay within the study area for the project. This 2 percent loss of sand/gravel habitat will occur sequentially over the 18-month construction period for the breakwaters, rather than all at one time. As the breakwaters are constructed, motile organisms will be temporarily displaced to other suitable habitat in the area, but are expected to return to the project site upon completion of the breakwater installation. There may be a temporary increase in vessel traffic and noise during the construction period, along with shading by anchored barges, but these actions will not be outside the range of typical vessel activity within the study area in Raritan Bay, which is a region of high commercial vessel traffic. This temporary increase in vessel traffic will not result in significant adverse impacts to benthic invertebrates or fish community in the study area. Seasonal shading by the temporary floating dock, accessory seasonal dock, and temporary shading by construction barges will not result in significant impacts to EFH species because the size of these vessels and structures will allow some light to penetrate to the aquatic habitat beneath during periods of the day. Construction is expected to last approximately 18 months (8-9 months per year for two years).

Placement of the breakwater structures will result in the permanent loss of 12.7 acres of sandy/gravel bottom habitat in Raritan Bay, along with non-motile organisms within this footprint. However, this loss will be more than offset by the approximately 3 times greater area of rocky and bio-enhancing concrete surface habitat that will be provided by the breakwater segments, resulting in an increase in habitat complexity and diversity that will benefit EFH

species. Additional long-term beneficial effects will likely accrue to the local benthic invertebrate and fish community from the increased habitat diversity and water quality improvements from the establishment of a self-sustaining, viable mollusk population on the hard substrate of the breakwater system.

Will compensatory mitigation be used? If no, why not? Describe plans for mitigation and how this will offset impacts to EFH. Include a conceptual compensatory mitigation plan, if applicable.

The proposed project would have the potential to affect EFH due to the loss of 12.7 acres of sand and gravel habitat but the adverse effect on EFH is not substantial and would have the potential to result in improved habitat for EFH. The breakwater structures that will replace the sand and gravel habitat will incorporate bio-enhancement features including varying levels of elevation and inclination, bio-enhancing materials, multiple textures, different grain sizes, and creation of rocky interspaces. The features composing the breakwaters are designed to create sheltered habitats and structural complexity for fish and benthic organisms, create confined waterbodies (i.e., tide pools) at the intertidal zone, and promote recruitment capabilities for shellfish in order to accommodate a diverse biotic community. The textured surfaces in particular are designed to promote biogenic accretions and micro-habitat and community development. Aquatic organisms can use the high-relief, hard substrate and rocky interspaces for attachment, shelter, and foraging, thus improving the ecological function of what was previously sandy/gravel bottom.

Based on surveys of adjacent structured habitat in the study area and engineering design principles of breakwater structures, it is estimated that 70 percent of the surface area of the armor units will be available as habitat for local aquatic biota. According to calculations of surface area for the Breakwaters Project, the 41.2 acres of rocky habitat surface created by the breakwaters will represent a net increase in available habitat of about 28.5 acres when compared to the 12.7 acres of sand and gravel habitat that will be displaced, and will provide the crevices and void space that will provide refuge and forage area for fish and epibenthic invertebrates. Even assuming that only 50 percent of the surface area will be available to encrusting organisms, the breakwaters will result in an increase in available habitat of 29.5 acres, representing a net increase in usable habitat of 16.8 acres when compared to the 12.7 acres of sand and gravel habitat displaced.

In addition to direct aquatic habitat improvements, the project incorporates measures undertaken as part of the Shoreline Protection component of the Layered Strategy, which will ultimately improve aquatic habitat for EFH species. These measures will include removal of sand filled barrier bags that comprise the man-made temporary dune within Conference House Park and removal of 7,680 CY of unpermitted fill (13 CY below MHW) from the shoreline of Conference House Park near Tricia Way, restoring beach habitat in these locations. Shoreline stabilization measures will include planting of native coastal vegetation at the hybrid dune, earthen berm, eco-revetment, raised pathway, and transition nodes of the Shoreline Protection component of the Layered Strategy. The shoreline stabilization elements will reduce erosion and improve soil conditions by establishing native vegetation, which will ultimately help minimize the effects of stormwater runoff on water quality in the project area by improving infiltration, subsequently improving aquatic habitat for fish and benthic macroinvertebrates. Shoreline stabilization efforts are also expected to improve beach habitat for horseshoe crabs.

The improvement in tidal flushing within the 0.8-acre delineated tidal wetland as enhancement for the 0.24 acres of impacts due to establishment of the hybrid dune, transition node structure and trail, will provide additional estuarine habitat for forage species. ✷

Attachment 4 Other NOAA-Trust Resources Impact Assessment

The following information is provided in response to Step 6 "Other NOAA-Trust Resources Impact Assessment" of the EFH Assessment Worksheet.

Describe habitat impact type (i.e., physical, chemical, or biological disruption of spawning and/or egg development habitat, juvenile nursery and/or adult feeding or migration habitat). Please note, impacts to federally listed species of fish, sea turtles, and marine mammals must be coordinated with the GARFO Protected Resources Division.

Alewife

Alewife (*Alosa pseudoharengus*) is a pelagic species that can occur in Raritan Bay from spring to fall and were observed during sampling in the study area in 2015. During the spring months, this species migrates through Raritan Bay to spawning grounds in the Hudson, Raritan, and Navesink Rivers, where eggs are deposited in slow-flowing water over a variety of substrates (Mackenzie 1990, Pardue 1983). Peak abundance of larval alewife in estuaries occurs in waters with salinities of 1-5 parts per thousand (ppt) at the surface and 1-15 ppt at the bottom (Locke and Courtenay 1995). Most juveniles emigrate from freshwater estuarine nursery habitats in the rivers where they were spawned between June and November of their first year (Pardue 1983). Adult alewife school in open waters and occupy a variety of inshore ocean, estuarine, and freshwater habitats depending on the season (Hildebrand 1963). They are only associated with bottom structure or substrate during spawning, which occurs in rivers and tributaries. Larval and juvenile alewife feed on small invertebrates, and adults feed on fish eggs, insects, crustacean eggs and larvae, and smaller fish.

Given that alewife are pelagic, and neither spawning nor nursery habitat occurs within Raritan Bay, the Proposed Actions will not adversely affect this species. Once installed, the breakwaters may provide habitat for prey species of alewife, improving foraging habitat for alewife in the study area. The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and a requirement for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay. Any temporary increases in suspended sediments will dissipate upon the cessation of sediment disturbing activities. Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact habitat for alewife.

American Eel

American eel (*Anguilla rostrata*) can occur in Raritan Bay year-round and were observed during sampling in the study area in 2015. This species is catadromous, spending most of its life in fresh water and spawning in salt water. They occur in streams and rivers with continuous flow over muddy or silty substrate (Scott and Scott 1988). During the day they tend to rest in undercut banks and deep pools near logs or boulders (Fischer 1978). At sexual maturity, adults migrate from the Hudson, Raritan, and Navesink Rivers and their tributaries to spawning grounds in the Sargasso Sea (Mackenzie 1990). American eels have several life stages: egg, glass, elver, yellow, and silver. Eggs hatch on the ocean surface in the Sargasso Sea and drift with currents for about a year as they develop into larvae before reaching the Atlantic coast (USFWS 2015). Glass eels, or larvae, are about 2-3 inches long by the time they reach the coast, and metamorphose into elvers, or juveniles, in nearshore areas of estuaries and tidal rivers (USFWS 2015, Fischer 1978). Elvers transform into yellow eels, which are sexually immature adults, and can spend up to 40 or more years living in freshwater habitats before they mature into silver eels and migrate to the Sargasso Sea to spawn; eels that remain in brackish waters tend to mature earlier than those in freshwater (USFWS 2015). American eels feed on a variety of things, including insects, fish, fish eggs, crabs, worms, clams, and frogs (USFWS 2011).

Given that neither spawning nor nursery habitat for American eel occurs within Raritan Bay, the Proposed Actions will not adversely affect this species. The rocky interspaces created by the breakwater segments may offer sheltering habitat for American eels. Installation of the breakwaters will also create suitable habitat for forage fish that are associated with reef habitat, potentially increasing the presence of prey species for American eels in the study area. The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and a requirement for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate upon the cessation of sediment disturbing activities. Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact habitat for American eel.

American Shad

American shad (*Alosa sapidissima*) is a schooling pelagic species that can occur in Raritan Bay year-round and were observed during sampling in the study area in 2015. This species migrates from offshore waters to spawning grounds in the tidal areas of the Hudson River; they can tolerate moderate salinity but spawn in lower salinity waters over sand and gravel (Leggett 1976, Walberg and Nichols 1967). Spawning occurs over a variety of substrates, but preferably over sand and gravel bottom with sufficient water movement to eliminate silt deposits (Stier and Crance 1985). Larvae prefer brackish waters with salinities of 7 ppt or less (Leim 1924). Larvae and juveniles start to migrate into the open ocean during the fall, and adults spend most of their lives in offshore ocean waters. Larval and juvenile shad feed mainly on aquatic insects and crustaceans, and adults are primarily plankton feeders (Stier and Crance 1985).

Given that American shad are pelagic, and neither spawning nor nursery habitat occurs within Raritan Bay, the Proposed Actions will not adversely affect this species. The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and a requirement

for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate upon the cessation of sediment disturbing activities. Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact habitat for American shad.

Atlantic Menhaden

Atlantic menhaden (*Brevoortia tyrannus*) can occur in Raritan Bay year-round and were observed during sampling in the study area in 2015. This species migrates seasonally along the Atlantic coast, moving north through the Mid-Atlantic Bight during spring, and south to Cape Hatteras during the fall (Able and Fahay 1998). Adults are found near surface waters, typically in shallow areas overlying the continental shelf, and they occur in greatest abundance adjacent to major estuaries (Jones et al. 1978). They move inshore during the summer and into deeper waters in the winter. Spawning occurs in continental shelf waters and in the lower reaches of estuaries and coastal bays in waters up to 10 meters deep (Dovel 1971, Rogers and Van Den Avyle 1989). Larvae and juveniles use estuaries during the summer before migrating offshore in the fall (Dovel 1971). Concentrations of young menhaden occur in inshore estuarine waters along the entire Atlantic coast (Rogers and Van Den Avyle 1989). Larvae feed on plankton, and juveniles and adults are filter feeders.

Given that Atlantic menhaden are pelagic, and neither spawning nor nursery habitat occurs within Raritan Bay, the Proposed Actions will not adversely affect this species. The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and a requirement for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay; suspended sediments will dissipate upon the cessation of sediment disturbing activities. Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact habitat for Atlantic menhaden.

Blue Crab

Blue crab (*Callinectes sapidus*) can occur in Raritan Bay year-round and were observed during sampling in the study area in 2015. Mating season occurs from May through October in the mid-Atlantic in the upper areas of estuaries and lower portions of rivers (Hill et al. 1989). Females generally spawn in high salinity waters between 2 and 9 months after mating (Hill et al. 1989). Eggs are deposited as a cohesive mass that remains attached to the female until larvae, called zoeae, emerge (Hill et al. 1989). Zoeae molt multiple times over the course of about 1-1.5 months, transforming into megalops, or the second larval stage, which is crablike in appearance; development into the juvenile “first crab” stage is characterized by adult proportions and appearance after 6-20 additional days (Hill et al. 1989). Areas of submerged aquatic vegetation in high salinity estuarine waters are used as nursery areas (Heck and Thoman 1984). Juveniles gradually migrate into shallower, less saline waters of upper estuaries and rivers, where they grow and mature into adults through a series of molt and intermolt phases over the course of about 12-18 months (Hill et al. 1989). Blue crabs move from shallow areas and tributaries in the summer to deeper areas in the eastern part of Raritan Bay in the fall (Mackenzie 1990). When not mating, small blue crabs prefer shallow, high salinity waters over substrates of soft detritus, mud, or mud-shell; larger crabs generally prefer deeper estuarine waters with hard bottom

substrates (Hill et al. 1989). As detritivores and scavengers, blue crabs feed on a variety of phytoplankton, invertebrates, fish, and other crabs.

The breakwater structures will provide shelter and foraging habitat for larger crabs. The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and a requirement for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay; suspended sediments will dissipate upon the cessation of sediment disturbing activities. Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact EFH for blue crab. Blue crabs are motile and are not expected to be adversely impacted by project activities.

Blue Mussel

Blue mussel (*Mytilus edulis*) is a valuable commercial species and is widely distributed and locally abundant in the north and mid-Atlantic regions; it can occur in the deeper waters of Raritan Bay year-round and was observed during sampling in the study area in 2015. This species is a bivalve mollusk that filter-feeds on phytoplankton and particulate detritus from the water (Rice 2010). Adult mussels typically reach shell lengths of about 4 inches and attach to hard surfaces, including large boulders, pebbles, and other mussels (Rice 2010, Newell 1989). Eggs are released into the water column for fertilization and hatch after about 5 hours (Newell 1989). Blue mussels go through several larval stages lasting between 15 days and 6 months after hatching. After about 6 months, the mussel temporarily attaches to filamentous substrates and develops as a juvenile for up to 2 years (Newell 1989). Juveniles grow to approximately 1.5 mm while attached to filamentous algae, and then are carried by currents until they reattach to a hard substrate (Newell and Moran 1989). Following the juvenile stage, adults live in habitats ranging from flat intertidal shores to vertical surfaces subject to wave splash (Newell 1989). They are typically found in subtidal and intertidal environments over a wide range of salinities (5-35 ppt) and depths ranging from 16 to 32 feet (Zagata et al. 2008).

The study area is largely composed of sandy substrate, but there may be some blue mussels present in isolated areas of hard bottom. Any mussels in the footprint of the breakwaters will be lost with the installation of the breakwater structures. This loss will be more than offset by the estimated 41.2 acres of hard surface area resulting from the Proposed Actions suitable for blue mussel colonization. Temporary and localized increases in suspended sediment and turbidity during construction will be minimized through the careful placement of the geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and the requirement that construction vessels maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate with the cessation of sediment disturbing activities and will not adversely impact blue mussel populations in Raritan Bay.

Blueback Herring

Blueback herring (*Alosa aestivalis*) is a schooling pelagic species that can occur in Raritan Bay, however, this species was not observed during sampling in the study area. Blueback herring adults spend much of their lives in salt water and return to freshwater tributaries to spawn over gravel and sand substrates (Loesch 1969) and would likely only occur in the Raritan Bay between April and June during migrations into freshwater spawning habitats and back into inland coastal waters post-spawn. Spawning occurs in swift-flowing, deeper stretches of rivers

over hard substrate, and in slower-flowing tributaries and flooded areas with soft substrates (Pardue 1983). Eggs adhere to vegetation, rocks, and debris in fresh water where they are deposited. Blueback herring remain in freshwater habitats as larvae and migrate to low salinity estuarine water as juveniles, generally between June and November of their first year (Loesch 1969, Pardue 1983). Larval and juvenile blueback herring feed on small invertebrates, and adults feed on fish eggs, insects, crustacean eggs and larvae, and smaller fish.

Given that blueback herring are pelagic, and neither spawning nor nursery habitat occurs within Raritan Bay, the Proposed Actions will not adversely affect this species. The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and a requirement for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate upon the cessation of sediment disturbing activities. Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact habitat for blueback herring.

Eastern Oyster

Eastern oyster (*Crassostrea virginica*) can occur in the deeper waters of Raritan Bay year-round, however, this species was not observed during sampling in the study area in 2015. There are no known oyster beds currently present in Raritan Bay. Adult oysters are non-motile and typically live in clumps, or beds. In mid-Atlantic waters, they prefer water depths ranging from 2 to 16 feet (MacKenzie, Jr. 1996). Spawning occurs via release of eggs into the water, where they are fertilized; eggs and young larvae remain in the water column for 2-3 weeks (Stanley and Sellers 1986). Juveniles, or spat, develop in the water column and attach to hard surfaces such as stones or other oyster shells, usually in established oyster beds, about 2-3 weeks after spawning. This species tolerates a wide range of salinity, generally between 5 and 32 ppt. Sufficient water currents are necessary to flush suspended sediments, remove debris, and transport food over oyster beds. Oyster larvae feed largely on plankton, while adult oysters filter-feed on diatom plankton, dinoflagellates, ostracods, small eggs, and anything else in the water that is 3-4 micrometers in size, including bacteria (Stanley and Sellers 1986).

Installation of the breakwater structures and incorporation of bio-enhancing concrete units will substantially increase the availability of hard substrate habitat for oysters, replacing the 12.7 acres of sand and gravel substrate with an estimated 41.2 acres of available high-relief hard surface that will provide habitat suitable for encrusting organisms like eastern oyster. Active oyster restoration is planned for areas on and adjacent to the breakwaters via several techniques: bio-enhancing concrete armor units containing oysters, oyster gabions, in-situ oyster setting on a trial basis, spat-on-shell, and an oyster spat nursery. Approximately 5 acres of spat-on-shell would be placed in “reef streets,” or rocky interspaces on the breakwaters, and potentially adjacent to the breakwater structures. A floating nursery structure comprising a series of floating oyster trays housing spat-on-shell, most likely arranged as two 300-foot long segments totaling approximately 6,000 square feet (0.2 acres), will also be located in the lee of th ebreakwaters. This restoration effort is also expected to enhance benthic habitats for northern quahog, blue mussels, and other crustacean species, which can attach to or burrow beneath the oyster shells.

The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the

breakwaters, and a requirement for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate upon the cessation of sediment disturbing activities. Live oysters will not be added until construction is complete, and will not be affected by these construction activities.

Horseshoe Crab

Horseshoe crab (*Limulus polyphemus*) can occur in Raritan Bay and were observed during sampling in the study area in 2015. Horseshoe crabs are known to spawn along portions of the beach at Staten Island's southern shoreline. Adult horseshoe crabs migrate from deep offshore waters from April to July to spawn. Eggs are deposited on beaches in the upper portion of the intertidal zone and below the feeding zone of shorebirds (USACE 2009). Spawning habitat depends on ready access to open and undisturbed sandy beaches in relatively calm waters, with a portion of the beach at or above Mean High Water where eggs are laid and larvae develop (Baine et al. 2007). Beach quality, including slope, width, and sediment grain size, can influence spawning activity (Baine et al. 2007); beach slope between 7 and 10° is thought to be optimal for horseshoe crab spawning habitat (USACE 2009). Females make several nests during one beach trip and often return on successive tides to lay more eggs (MDNR 2016). After about one month, the eggs hatch and larvae remain in the intertidal flats or shoal waters where they were spawned until settling to the bottom to molt (USACE 2009, MDNR 2016). During its first 2-3 years, the horseshoe crab molts several times per year, and then about once annually until it reaches sexual maturity around 9-11 years in age (MDNR 2016). Adults remain in deep offshore habitats during most of the year, except during the spawning season. Horseshoe crabs feed mainly on marine worms and shellfish, and serve as an important food source to shorebirds and juvenile sea turtles. Migratory shorebirds rely on horseshoe crab eggs to survive their journey to breeding grounds (MDNR 2016). Horseshoe crab eggs and larvae are also a food source for a variety of species including crabs, whelks, striped bass, white perch, American eel, killifish, silver perch, weakfish, kingfish, silversides, summer flounder, and winter flounder (MDNR 2016).

The proposed one-time sand placement over 3.8 acres as part of the shoreline restoration between Manhattan Street and Loretto Street will comply with construction windows to protect horseshoe crab spawning activities, and will not occur during the species' peak spawning season (late May to early June). Placement of the 15,369 cubic yards of sand that would fall below MHW will likely also be restricted during the spawning season for winter flounder (early January through late May), which has some overlap with the timing of horseshoe crab spawning. As horseshoe crabs move inshore from deep offshore waters only during spawning periods, placement of the breakwaters will not adversely affect this species, as they would likely be moving inshore during period when in-water construction activities are restricted to protect winter flounder.

Temporary and localized increases in suspended sediment and turbidity during construction will be minimized through the careful placement of the geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and the requirement that construction vessels maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate with the cessation of sediment disturbing activities and will not adversely impact horseshoe crab populations in Raritan Bay.

Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact habitat for horseshoe crabs. Once installed, the breakwaters may provide shelter for larval and juvenile horseshoe crabs while they molt in the intertidal zone following the spawning period.

Additionally, increased shoreline stability resulting from the reduced or reversed shoreline erosion by the breakwaters, the one-time shoreline restoration, and other stabilization activities of the Shoreline Project will likely benefit spawning horseshoe crabs by providing suitable beach habitat along the south shore of Staten Island. While the shoreline restoration will alter the slope of the beach at varying levels, horseshoe crabs were observed outside this area and are expected to continue spawning at other suitable locations along the beach.

Quahog

Northern quahog (*Mercenaria mercenaria*), also known as hard clams, can occur in the deeper waters of Raritan Bay year-round and were observed during sampling in the study area in 2015. Hard clams are found in the intertidal and subtidal zones of bays and estuaries in waters up to 15 meters deep, most often in higher salinity waters (Stanley and DeWitt 1983). They can be found in all sediment types, but prefer sediments that are a mixture of sand and mud with some coarse material. Adults burrow an average of 2 centimeters into sand, and an average of just one centimeter into softer substrates; adults can escape 10-50 cm of overburden if buried and can re-burrow if removed from the substrate (Stanley and DeWitt 1983). Eggs are released into the water column for fertilization and are carried by tidal and coastal currents for about 10 hours before hatching. Larvae develop 12-14 hours after hatching and drift up and down through the water column until they reach about 2-3 millimeters in length. At this time, the shell begins to thicken and larvae transform into seed clams, which begin a final migration to their ultimate habitat, settling as adults in their second summer (Stanley and De Witt 1983). Adult clams filter plankton and microorganisms from the water that are carried close to the bottom by currents.

As hard clams were found during benthic surveys in the study area, some will likely be lost within the 12.7-acre footprint of the breakwater structures. In the 2015 shellfish survey at the project location, hard clams were found to be widely distributed throughout the study area and were most abundant in muddy substrates. As the footprint of the breakwaters represents only 2 percent of the approximately 610 acres of available inshore habitat in the study area within Raritan Bay, hard clams are expected to continue to colonize or recolonize in suitable habitat surrounding the breakwater structures. Temporary and localized increases in suspended sediment and turbidity during construction will be minimized through the careful placement of the geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and the requirement that construction vessels maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate with the cessation of sediment disturbing activities and will not adversely impact hard clam populations in Raritan Bay.

Soft-shell Clams

Soft-shell clams (*Mya arenaria*) can occur in Raritan Bay year-round and were observed during sampling in the study area in 2015. This species inhabits sandy, sand-mud, or sandy clay bottoms of inlets and bays, typically at water depths of 3-4 meters and salinities no less than 4-5 ppt (Abraham and Dillon 1986). Adults burrow up to 30 centimeters into the substrate, with siphons extending to the sediment surface to feed on detritus and plankton suspended in the water (Abraham and Dillon 1986). Soft-shell clams spawn biannually based on water temperatures, once in spring at 10-20°C and once in fall when temperature falls to 20°C. Eggs are broadcast into the water and develop into planktonic larvae about 12 hours after fertilization; after about 4-6 weeks, larvae settle to the bottom (Abraham and Dillon 1986). Juveniles are able to move to more favorable locations, usually sandy bottoms with less than 50% silt content, before burrowing into the substrate as adults (Abraham and Dillon 1986).

As soft-shell clams were found during benthic surveys in the study area, some will likely be lost within the 12.7-acre footprint of the breakwater structures. As the footprint of the breakwaters represents only 2 percent of the approximately 610 acres of available inshore habitat in the study area within Raritan Bay, soft-shell clams are expected to continue to colonize or recolonize in suitable substrate around the breakwaters. Temporary and localized increases in suspended sediment and turbidity during construction will be minimized through the careful placement of the geotextile panels, the use of clean materials to build the breakwaters, and the requirement that construction vessels maintain at least 2 feet of clearance with the bottom of the Bay; suspended sediments will dissipate with the cessation of sediment disturbing activities and will not adversely impact soft-shell clam populations in Raritan Bay.

Striped Bass

Striped bass (*Morone saxatillis*) can occur in Raritan Bay from spring to fall and were observed during sampling in the study area in 2015. Striped bass can be found in Raritan Bay during spawning migrations from coastal waters into freshwater spawning grounds between May and June, and back to coastal waters post-spawn in the fall (CHG&E et al. 1999). Larvae drift with the current, but remain in low salinity river waters; juveniles begin to move into higher salinity waters as they grow. Juveniles could be found in the New York Harbor, including Raritan Bay, by late summer (CHG&E et al. 1999, Dunning et al. 2009). Outside of spawning periods, adult striped bass migrate along the Atlantic coast and would not likely be found in Raritan Bay. When they are present, they generally occur in open water, inter-pier, and semi-enclosed basin areas, especially offshore from sandy beaches or rocky shores where prey species are most abundant. Larvae feed mainly on copepods and chironomid larvae, adding larger aquatic invertebrates and small fishes to their diet as they grow (Fay et al. 1983). Larger striped bass begin to school while foraging and feed primarily on clupeids, including bay anchovy and Atlantic menhaden, but also continue to feed on invertebrates (Fay et al. 1983).

Given that striped bass are pelagic, and neither spawning nor nursery habitat occurs within Raritan Bay, the Proposed Actions will not adversely affect this species. Installation of the breakwaters will create suitable habitat for forage fish that are associated with reef habitat, increasing the availability of prey species for striped bass in the study area within Raritan Bay. Juvenile striped bass may also use the breakwater segments for refugia and foraging. The Proposed Actions will result in a temporary increase in suspended sediment and localized increases in turbidity during construction, which will be minimized through the careful placement of geotextile panels and breakwater materials, the use of clean materials to build the breakwaters, and a requirement for construction vessels to maintain at least 2 feet of clearance with the bottom of the Bay. Suspended sediments will dissipate upon the cessation of sediment disturbing activities. Temporary increases in vessel noise, traffic, and shading during the construction period will be within the range of typical vessel activity in Raritan Bay and will not impact habitat for striped bass.

Atlantic Sturgeon

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*; endangered) can occur in Raritan Bay and may be present in the study area (NMFS 2015). No individuals of this species were observed during sampling in the study area in 2015. Atlantic sturgeon is a bottom-dwelling fish that inhabits large freshwater rivers when spawning and primarily marine waters when not breeding. They can also be found in bays, river mouths, and estuaries. While they are not expected to occur in significant numbers in the study area, transient adults and sub-adults may be present as the move through shallower marine waters along the Atlantic coast; early life stages are

relatively intolerant of salinity. Atlantic sturgeon prefer deeper waters than those in the study area, with the majority occurring in waters between 10 and 15 meters (32 and 49 feet) in depth (Dunton et al. 2010), and transient individuals that may occur in Raritan Bay would be expected to avoid the shallow waters of the study area in favor of more suitable habitat. Nonetheless, adult and sub-adult Atlantic sturgeon may use portions of the study area for foraging; these life stages are benthic feeders, and placement of the breakwaters could temporarily disturb foraging habitat. However, the 12.7-acre footprint of the breakwaters will represent only about 2 percent of the available inshore habitat of Raritan Bay, and sturgeon will be able to avoid the construction area in favor of suitable habitat nearby. Once the one-time sand placement and construction of the breakwaters is complete, sturgeon will be able to forage for benthic fish and invertebrates along the reef streets and ridges of the breakwaters and in the crevices and void space between and among the structures.

Sea Turtles

While no sea turtles were observed during sampling in the study area in 2015, New York and New Jersey waters may be warm enough to support loggerhead (*Caretta caretta*; federally threatened, state endangered) and Kemp's ridley (*Lepidochelys kempi*; endangered) turtles from May through mid-November, and green sea turtles (*Chelonia mydas*) from June through October; those that do occur in these waters are typically small juveniles (NMFS 2015). Leatherback sea turtles (*Dermochelys coriacea*; endangered) may be found in the waters off New York and New Jersey during the warmer months, but this species generally prefers deep, pelagic waters over shallow, nearshore waters, and would not be expected in the vicinity of the study area. The New York-New Jersey Harbor complex of which Raritan Bay is a part is considered to be of marginal or lower quality sea turtle habitat, and observations of these species are infrequent (Ruben and Morreale 1999, USACE 2001). During a 2015 vegetation survey for the project, a deceased unidentified sea turtle was observed on the beach within Conference House Park, in the western part of the study area at the mouth of the Arthur Kill. No other sea turtles have been observed during surveys within the project site. Overall, sea turtles have the potential to occur within the study area on rare occasions, and only as transient individuals, rather than for long-term occupation for breeding, wintering, or growth and development.

References

Able, K.W., and F.P. Fahay. 1998. The first year in the life of estuarine fishes in the Middle Atlantic Bight. Rutgers University Press, New Brunswick, New Jersey. 400 pp.

Baine, M., J. Lodge, D.J. Suszkowski, D.B. Botkin, R.J. Diaz, K. Farley, J.S. Levinton, F. Steimle, and P. Wilber. 2007. Target ecosystem characteristics for the Hudson Raritan Estuary: technical guidance for developing a comprehensive ecosystem restoration plan. A report to the Port Authority of NY/NJ, pp. 1-112.

Central Hudson Electric and Gas Corp. (CHG&E), Consolidaetd Edison Company of New York Inc., New York Power Authority, and Southern Energy New York. 1999. Draft Environmental Impact Statement for State Pollution Discharge Elimination System Permits for Bowline Point, Indian Point 2&4, and Roseton Steam Electric Generating Stations.

Dovel, W.L. 1971. Fish eggs and larvae of the upper Chesapeake Bay. University of Maryland. Natural Resources Institute Special Report 4:1-71.

Dunning, D.J., Q.E. Ross, K.A. McKown, and J.B. Socrates. 2009. Effect of striped bass larvae transported from the Hudson River on juvenile abundance in Western Long Island Sound. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:343-353.

Dunton, K.J., A. Jordaan, K.A. McKown, D.O. Conover, and M.G. Frisk. 2010. Abundance and distribution of Atlantic sturgeon (*Acipenser oxyrinchus*) within the Northwest Atlantic Ocean, determined from five fishery-independent surveys. Fisheries Bulletin 108:450-465.

Fay, C.W., R.J. Neves, and G.B. Pardue. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) – striped bass. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.8. U.S. Army Corps of Engineers, TR EL-82-4. 36 pp. October 1983.

Fischer, W. 1978. FAO species identification sheets for fishery purposes. Western Central Atlantic (fishing area 31). Food and Agriculture Organization of the United Nations.

Heck, K.L., and T.A. Thoman. 1984. The nursery role of seagrass meadows in the upper and lower reaches of the Chesapeake Bay. Estuaries 7: 70-92.

Hildebrand, S.F. 1963. Family: Clupeidae. In: Fishes of the Western North Atlantic, pp. 152-249. Memoir, Sears Foundation for Marine Research 1:1-630.

Hill, J., D.L. Fowler, and M.J. Van Den Avyle. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates Mid-Atlantic) – Blue Crab. U.S. Fish and Wildlife Service Biological Report 82(11.100). U.S. Army Corps of Engineers, TR EL-82-4. 18 pp. March 1989.

Jones, W.P., D.F. Martin, and J.D. Hardy. 1978. Development of fishes of the Mid-Atlantic Bight. An atlas of egg, larval and juvenile stages. Fish and Wildlife Service.

Leggett, W.C. 1976. The American shad with special reference to its migration and population dynamics in the Connecticut River. In: D. Merriman and L.M. Thorpe (eds.), The Connecticut River Ecological Study: The Impact of Nuclear Power Plant, pp. 169-225. American Fishery Society Monograph 1:169-225.

Leim, A.H. 1924. The life history of the shad *Alosa sapidissima*, (Wilson) with special reference to factors limiting its abundance. Contributions to Canadian Biology of Fisheries 2:161-284.

Locke, A., and S.C. Courtenay. 1995. Effects of environmental factors on ichthyoplankton communities in the Miramichi estuary, Culf of St. Lawrence. Journal of Plankton Research 17:333-349.

Loesch, J.L. 1969. A study of blueback herring, *Alosa aestivalis* (Mitchill), in Connecticut waters. PhD Thesis, University of Connecticut, Storrs, CT. 78pp.

MacKenzie, Jr., C.L. 1990. History of the fisheries of Raritan Bay, New York and New Jersey. Marine Fisheries Review 52: 1-45.

MacKenzie, Jr., C.L. 1996. History of oystering in the United States and Canada, featuring the eight greatest oyster estuaries. Marine Fisheries Review 58: 1-79.

Maryland Department of Natural Resources (MDNR). 2016. Horseshoe crab life history. Available http://dnr2.maryland.gov/fisheries/Pages/horseshoe-crab.aspx. Accessed September 2, 2016.

National Marine Fisheries Service (NMFS). 2015. Letter from M. Murray-Brown, NMFS, to C. Seewagen, AKRF, re Living Breakwaters and Tottenville Dune Projects in Richmond County, New York. May 14, 2015.

Newell, R.I.E. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North and Mid-Atlantic) – Blue Mussel. U.S. Fish and Wildlife Service Biological Report 82(11.102). U.S. Army Corps of Engineers, TR El-82-4. 25 pp. June 1989.

Newell, R.I., and D. Moran. 1989. Sepcies profiles: Life histories and environmental requirements of coastal fishes and invertebrates (North and Mid-Atlantic) blue mussel. Biological Report 82(11.102). Fish and Wildlife Service, U.S. Department of the Interior.

Pardue, G.B. 1983. Habitat suitability index models: alewife and blueback herring. U.S. Fish and Wildlife Service FWS/OBS-82/10.58. 22 pp. September 1983.

Rice, M.A. 2010. Cultured mussels of the Northeast. Northeastern Regional Aquaculture Center, NRAC Publication No. 210-2010.

Rogers, S.G., and M.J. Van Den Avyle. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) – Atlantic menhaden. U.S. Fish and Wildlife Service Biological Report 82(11.108). U.S. Army Corps of Engineers TR EL-82-4. 23 pp. August 1989.

Ruben, H.J., and S.J. Morreale. 1999. Draft Biological Assessment for Sea Turtles in New York and New Jersey Harbor Complex. Unpublished Biological Assessment submitted to National Marine Fisheries Service.

Scott, W., and M. Scott. 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Science, 219. University of Toronto Press, Toronto, Canada.

Stanley, J.G., and R. DeWitt. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic) – hard clam. U.S. Fish and Wildlife Service FWS/OBS-82/11.18. U.S. Army Corps of Engineers, TR EL-82-4. 19 pp. October 1983.

Stanley, J.G., and M.A. Sellers. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) – American Oyster. U.S. Fish and Wildlife Service Biological Report 82(11.65). U.S. Army Corps of Engineers, TR EL-82-4. 25 pp. July 1986.

Stier, D.J., and J.H. Crance. 1985. Habitat suitability index models and instream flow suitability curves: American shad. U.S. Fish and Wildlife Service Biological Report 82(10.88). 34 pp. June 1985.

United States Army Corps of Engineers (USACE). 2001. Beach Renourishment and Offshore Borrowing in the Raritan Bay Ecosystem: A Biological Assessment for Sea Turtles.

United States Army Corps of Engineers (USACE). 2009. Delaware River main stem and channel deepening project. Draft Essential Fish Habitat evaluation. February 2009.

United States Fish and Wildlife Service (USFWS). 2011. The American Eel. Available http://www.fws.gov/northeast/newsroom/facts.html. Updated December 21, 2011.

United States Fish and Wildlife Service (USFWS). 2015. American eel, *Anguilla rostrata*. October 2015.

Walberg, C.H., and P.R. Nichols. 1967. Biology and management of the American shad and status of the fisheries. Atlantic coast of the United States, 1960. U.S. Fish and Wildlife Service, Special Science Report, Fisheries, 550. 105pp.

Zagata, C., C. Young, J. Sountis, and M. Kuehl. 2008. *Mytilus edulis*. Available http://animal.diversity.ummz.umich.edu/site/accounts/informatino/Mytilus_edulis.html.