Mordecai Island
Beach Haven, New Jersey
Project Modification for
Ecosystem Restoration (Section 1135)
Feasibility Study and Integrated
Environmental Assessment

February 7, 2022
DRAFT FEASIBILITY REPORT

U.S. Army Corps of
Engineers
Philadelphia District

New Jersey
Department of
Environmental
Protection

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FINDING OF NO SIGNIFICANT IMPACT
MORDECAI ISLAND, BEACH HAVEN, NEW JERSEY
ECOSYSTEM RESTORATION FEASIBILITY STUDY
AND INTEGRATED ENVIRONMENTAL ASSESSMENT

The U.S. Army Corps of Engineers, Philadelphia District (Corps) has conducted an environmental analysis in accordance with the National Environmental Policy Act of 1969, as amended. Based on when NEPA was initiated, this Environmental Assessment (EA) was developed in accordance with the applicable regulations, policies, and procedures, including the Corp's NEPA regulations in Engineers Regulation (ER) 200-2-2 and the previous CEQ NEPA regulations at 40 CFR Part 1500 (NEPA Implementing Regulations). The draft integrated Feasibility Report and Environmental Assessment (IFR/EA) addresses ecosystem restoration opportunities and feasibility at Mordecai Island, Beach Haven, New Jersey.

The draft EA, incorporated herein by reference, evaluated various alternatives for ecosystem restoration to address habitat loss due to erosion at Mordecai Island. The recommended plan is the National Ecosystem Restoration (NER) Plan, and includes:

- A rubble mound breakwater at Alignment A that extends approximately 3000 linear feet on the western side of Mordecai Island, the placement of approximately 30,000 cubic yards of sand dredged from the NJIWW and planting marsh vegetation on approximately 11 acres of restored intertidal marsh habitat.

In addition to a "no action" plan, 6 other alternatives were evaluated. The alternatives consisted of a variety of restoration and protection measures including different alignments of the rubble mound structure and Wave Attenuation Devices (WADs) which are described in Section 5.4 of the EA.

For all alternatives, the potential effects were evaluated, as appropriate. A summary assessment of the potential effects of the recommended plan are listed in Table 1:

Table 1: Summary of Potential Effects of the Recommended Plan

	Insignificant effects	Insignificant effects as a result of mitigation*	Resource unaffected by action
Aesthetics	☒	☐	☐
Air quality	☒	☐	☐
Aquatic resources/wetlands	☒	☐	☐
Invasive species	☐	☐	☒

	Insignificant effects	Insignificant effects as a result of mitigation*	Resource unaffected by action
Fish and wildlife habitat	☒	☐	☐
Threatened/Endangered species/critical habitat	☒	☐	☐
Historic properties	☐	☐	☒
Other cultural resources	☐	☐	☒
Floodplains	☐	☐	☒
Hazardous, toxic & radioactive waste	☐	☐	☒
Hydrology	☐	☐	☒
Land use	☒	☐	☐
Navigation	☒	☐	☐
Noise levels	☐	☐	☒
Public infrastructure	☐	☐	☒
Socio-economics	☐	☐	☒
Environmental justice	☐	☐	☒
Soils	☒	☐	☐
Tribal trust resources	☐	☐	☒
Water quality	☒	☐	☐
Climate change	☐	☐	☒

All practicable and appropriate means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. Best management practices (BMPs) as detailed in the EA will be implemented, if appropriate, to minimize impacts. Avoidance and minimization measures to be taken include a seasonal dredging restriction from January 1st through May 31st, SAV monitoring, and water-based construction of the breakwater. These measure are discussed in more detail in Section 6 of the EA.

Since this is an ecosystem restoration project, no compensatory mitigation is required as part of the recommended plan.

Public review of the draft IFR/EA and FONSI is currently being conducted. All comments submitted during the public review period will be responded to in the Final IFR/EA and FONSI.

Pursuant to Section 7 of the Endangered Species Act of 1973, as amended, the U.S. Army Corps of Engineers determined that the recommended plan may affect but is not likely to adversely affect the following federally listed species or their designated critical habitat: piping plover, red knot, Atlantic sturgeon and roseate tern.

Pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended, the U.S. Army Corps of Engineers determined that the recommended plan has noeffect on historic properties.

Pursuant to the Clean Water Act of 1972, as amended, the discharge of dredged or fill material associated with the recommended plan has been found to be compliant with section 404(b)(1) Guidelines (40 CFR 230). The Clean Water Act Section 404(b)(1) Guidelines evaluation is found in Appendix B of the IFR/EA.

A water quality certification pursuant to section 401 of the Clean Water Act will be obtained from the NJDEP prior to construction. All conditions of the water quality certification shall be implemented in order to minimize adverse impacts to water quality.

A determination of consistency with the New Jersey Coastal Zone Management program pursuant to the Coastal Zone Management Act of 1972 will be obtained from the NJDEP prior to construction. All conditions of the consistency determination shall be implemented in order to minimize adverse impacts to the coastal zone.

All applicable environmental laws have been considered and coordination with appropriate agencies and officials is ongoing with the public review of this IFR/EA. An Essential Fish Habitat (EFH) assessment was completed (sections 3.71 and 6.2.5.1 in the IFR/EA) and is being coordinated with NOAA Fisheries/National Marine Fisheries Service.

Technical, environmental, and cost effectiveness criteria used in the formulation of alternative plans were those specified in the Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on this report, the reviews by other Federal, State and local agencies, Tribes, input of the public, and the review by my staff, it is my determination that the recommended plan would not cause significant adverse effects on the quality of the human environment; therefore, preparation of an Environmental Impact Statement is not required.

____________________________ _______________________________________

Date	Ramon Brigantti Lieutenant Colonel, Corps of Engineers District Engineer

Executive Summary

Study Information

The intent of the Mordecai Island, Beach Haven, New Jersey, Ecosystem Restoration Feasibility Study and Integrated Environmental Assessment is to evaluate potential options to address habitat loss due to erosion of the western side of the island.

Authorization is provided by Section 1135 of the Water Resources Development Act of 1986. Section 1135 authorization enables the U.S. Army Corps of Engineers (Corps) to partner with a non-Federal sponsor to plan, design and build modifications to existing Corps projects, or areas degraded by Corps projects, to restore aquatic habitats for fish and wildlife. In the case of this study, the degraded area is Mordecai Island in New Jersey (see Figures ES.1 and ES.2) and the source of degradation is the adjacent Federal navigation channel, the New Jersey Intracoastal Waterway (NJIWW).

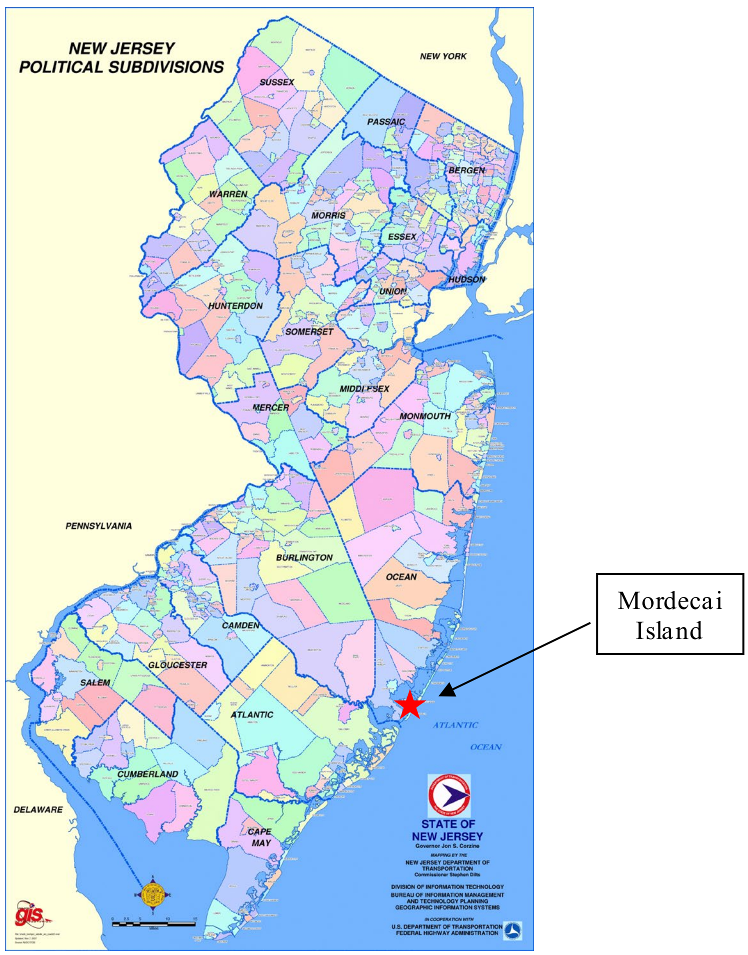
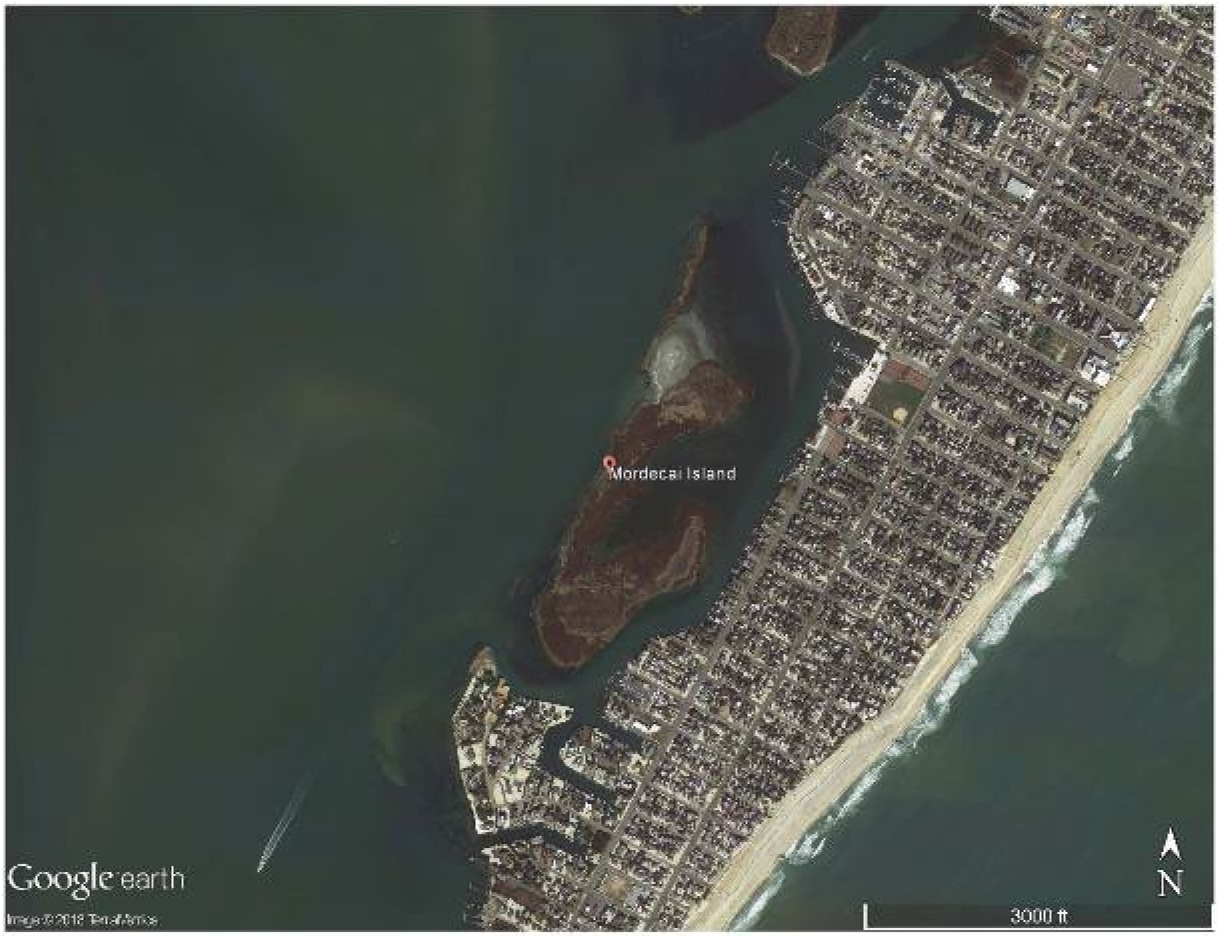


Figure ES.1: Location of Mordecai Island in New Jersey



Problem

Habitat loss is occurring on the western edge of Mordecai Island due to erosion of the marsh by waves and vessel wakes associated with the NJIWW. There is insufficient suspended material moving within the system to deposit and cause substantial accretion in the eroded areas.

Plan Formulation

The goal of the study is to address erosion and habitat loss on the western side of Mordecai Island from the northern tip of the island to the northern end of existing erosion management features installed by Mordecai Land Trust (MLT), owners of the island.

Study objectives are as follows:

1. Protect Mordecai Island from erosive forces on the western shore, extending from the northern tip of the island to the northern end of the MLT erosion management features, and limit further loss of land mass through 2080.

2. Restore Mordecai Island shorebird (e.g. least tern) and diamondback terrapin habitat through 2080.
3. Restore Mordecai Island low saltmarsh (e.g. *Spartina alterniflora* dominated saltmarsh) through 2080.

The following measures were considered as part of a solution to address the planning objectives above:

<u>Onshore Measures</u>

1. Shoreline grading and high performance turf reinforcement mat (TRM) with fill on top of mat and seeding
2. Shore slope stone revetment, with or without fill and planting
3. Articulated open cell concrete mat with fill in cells and planting
4. Biologs, with or without fill
5. Steel sheet pile bulkhead, no fill

<u>Offshore Measures</u>

6. Near shore stone sill, with or without fill and planting
7. Geotubes® with armor layer, with or without fill
8. Oyster castles®, with or without fill
9. Offshore breakwaters, with or without fill
10. Precast concrete structures (e.g. Beach Prisms™ or WADs®) as sills or breakwaters, with or without fill

<u>Other Measures</u>

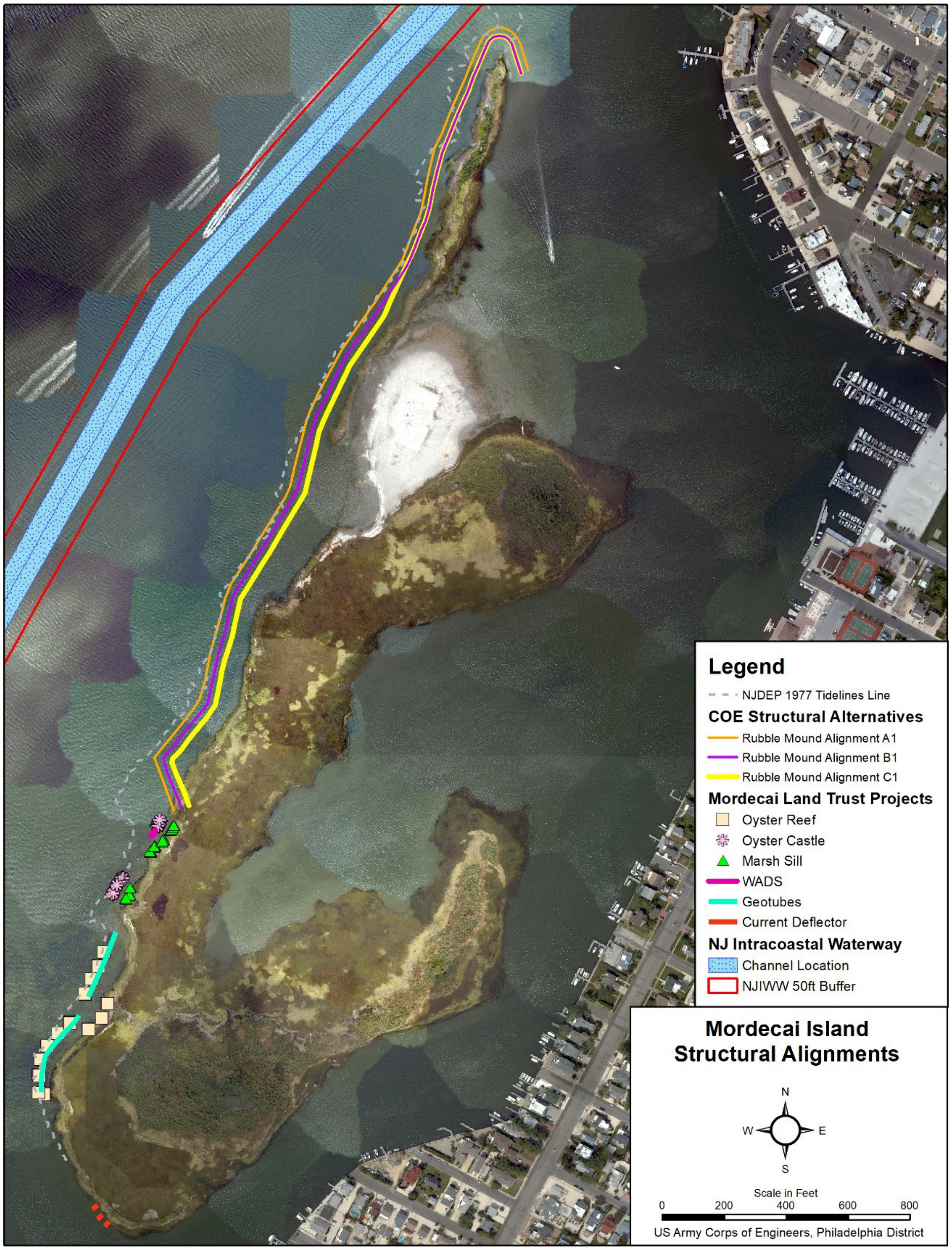
11. Floating wave attenuators
12. Move No Wake Zone markers closer to the New Jersey Intracoastal Waterway (NJIWW) channel
13. Move NJIWW farther away from Mordecai Island

The measures were subjected to multiple iterations of assessment, with a rubble mound breakwater with fill behind it ultimately being determined to be the most viable option to best meet the goal and objectives. A recommendation will also be made to move No Wake Zone markers closer to the NJIWW channel.

Alternative Plans Considered

Based on the above referenced in-depth analysis, the remaining alternatives (see Figure ES.3) were as follows:

Alternative 1: No Action
Alternative 2: Rubble mound breakwater with fill from NJIWW at Alignment A1
Alternative 3: Rubble mound breakwater with fill from NJIWW at Alignment B1
Alternative 4: Rubble mound breakwater with fill from NJIWW at Alignment C1


Legend
NJDEP 1977 Tidelines Line
COE Structural Alternatives
Rubble Mound Alignment A1
Rubble Mound Alignment B1
Rubble Mound Alignment C1
Mordecai Land Trust Projects
Oyster Reef
Oyster Castle
Marsh Sill
WADS
Geotubes
Current Deflector
NJ Intracoastal Waterway
Channel Location
NJIWW 50ft Buffer
Mordecai Island
Structural Alignments
N
W
E
S
Scale in Feet
0
200
400
600
800
US Army Corps of Engineers, Philadelphia District

Rubble mound breakwaters were considered at three different depths providing similar levels of erosion protection, with the 1977 Tidelands line generally representing the greatest depth (Alignment A1) and two other alternatives (Alignments B1 and C1) approximately 25 ft. apart in successively shallower water toward the western shore of the island. Alignments A1, B1 and C1 average -4', -3.5' and -3' NAVD88 in depth, respectively, and converge at the northern tip of the island as they draw closer to the channel. The northern half of Alignment C1 follows the same layout as the northern half of Alignment B1, since a landward offset of Alignment C1 in this area would place the structure on the island and act as a shoreline slope revetment, a measure which was screened out prior to alternative plan formulation. Alignment A1 would extend for 3,000 linear ft. and have an average height of 7.6 ft. from the bay bottom. Structures along Alignment B1 would extend for 2,900 linear ft. and have an average height of 7.1 ft. Structures along Alignment C1 would also be 2,900 linear ft. in length and would have an average height of 6.6 ft. The average heights are the initial construction heights of the structure and factor in one foot of over-build for potential settlement. Settlement will be further evaluated in more detail during the next phase of the study.

Wind generated waves were determined to be relatively small for Mordecai Island. Boat driven waves are most likely the main driver of erosion and were therefore used as the design wave for the breakwater. Based on potential boat generated waves, as well as use of STWAVE nearshore model, the minimum crest elevation for the breakwater was determined to be +2.6 ft. NAVD88. To account for potential settlement, the initial construction was estimated to be +3.6 ft. NAVD88 (1foot of overbuild). A geocomposite will be placed between the bottom of the structure and the existing ground.

The crest width of the trapezoidal breakwater, a function of the rock size and design wave height, was determined to be 3 ft. Side slopes of 2H:1V were chosen as the steepest allowable slope based on both economics and design. A continuous breakwater was selected for the development of alternative plans due to a greater potential to protect existing and placed material behind the structure. Sill vents, or lower sections of breakwater, were designed into the structure to promote intertidal flushing in order to maintain water quality. The sill vents are approximately 40 ft. long and have a crest elevation at the MLW line to allow water to flow through the breakwater during the entire tide cycle. There is approximately 160 linear ft. of breakwater between each sill vent. The northern tip of Mordecai Island is the most vulnerable area to waves due to its proximity to the NJIWW. For this reason, there are no sill vents in the northern tip of the breakwater.

All three breakwater alignment alternatives also included the placement of fill behind the breakwater and Mordecai Land Trust structures to regain lost wetlands and to transition the existing wetland edge from a vertical scarp to a gradual slope. Alignment A1 would include the addition of approximately 11.5 acres of restored marsh, Alignment B1 would add approximately 9 acres of restored marsh and Alignment C1 would add approximately 8 acres of restored marsh to the island footprint. In addition, all alignments included the addition of sand on approximately 3.7 acres of previously placed fill to increase the elevation for beach nesting birds.

Tentatively Selected Plan

Alternative 2: Rubble mound breakwater with fill from NJIWW at Alignment A1, along with No Wake buoys being moved closer to the NJIWW channel is the Tentatively Selected Plan (TSP).

Alignment A1 generally follows the 1977 Tidelands line, approximately parallel to the west side of Mordecai Island in the nearshore area. (See Figure ES.1.4.) The rubble mound breakwater along Alignment A1 will extend for 3,000 linear ft. and have an average height of 7.6 ft. from the bay bottom. The average height is the initial construction height of the structure and factors in one foot of over-build for potential settlement. Settlement will be further evaluated in more detail during the next phase of the study. To account for potential settlement of one foot, the initial construction is estimated to be +3.6 ft. NAVD88 (1 foot of overbuild). Settlement will be further evaluated in more detail during the next phase of the study. The rubble mound breakwater will have a crest width of 3 feet and 2H:1V side slopes. Sill vents, at a crest elevation matching Mean Low Water (MLW), will be placed every 160 feet along the structure to allow for water flow and circulation behind the structure during the full tidal cycle. Each sill vent will be 40 feet long. A geocomposite will be placed between the bottom of the structure and the existing ground (see Geotechnical Section of the Engineering Technical Appendix).

Approximately 30,000 cy of sand will be obtained from normal maintenance dredging of the NJIWW and placed behind the structure to restore 11.5 acres of lost intertidal marsh habitat and raise the elevation of approximately 3.7 acres of beach nesting bird habitat. The restored marsh habitat will be planted with elevation appropriate wetland vegetation. In addition to the marsh acres restored, the TSP will protect approximately 22 acres of island habitat that are projected to be lost by 2080 due to future erosion.

In order to determine the ecological uplift and NER benefits associated with the TSP, habitat values for the project area were calculated using the New England Salt Marsh Model. The results of the analysis shows that the TSP will provide 285 Average Annual New England Salt Marsh Model (NESMM) Units over the No Action plan. A Cost Effectiveness and Incremental Cost Analysis (CE/ICA) was also completed and the results can be found in Section 5.5.3.

As part of the TSP, it is also recommended that existing No Wake buoys be moved closer to the NJIWW channel to promote visibility of the buoys and, indirectly, reduce boat wakes. Relocation of the buoys would be at no cost to this project.

Table ES.1: Tentatively Selected Plan Projected Cost

Feature	Cost	Contingency	Total
01 Lands and Damages	$54,000	$14,000	$68,000
02 Relocations	$15,000	$3,000	$18,000
06 Fish and Wildlife Facilities	$987,000	$188,000	$1,175,000
10 Breakwaters and Seawalls	$3,339,000	$931,000	$4,270,000
30 Planning, Engineering & Design	$885,000	$229,000	$1,114,000
31 Construction Management	$563,000	$146,000	$709,000
TOTAL	$5,843,000	$1,510,000	**$7,354,000**

Price Level: December 2021 Discount Rate: 1.125

Table ES.2: Projected Cost of TSP, Environmental Monitoring, Adaptive Management

Item	Quantity	Cost	Total
Tentatively Selected Plan	1	$7,354,000	$7,354,000
Environmental Monitoring	5	$100,680	$503,400
Adaptive Management	1	$94,388	$94,388
TOTAL			**$7,951,788**

Price Level: December 2021 Discount Rate: 1.125
(Note: Environmental Monitoring is assumed to occur for five years. Adaptive Management is assumed to occur in year four.)

Table ES.3: Federal/Non-Federal Cost Share Breakdown

Item	Total Cost	Federal 75%	Non-Federal 25%
Tentatively Selected Plan	$7,354,000	$5,515,500	$1,838,500
Environmental Monitoring	$503,400	$377,550	$125,850
Adaptive Management	$94,388	$70,791	$23,597
TOTAL	**$7,951,788**	**$5,963,841**	**$1,987,947**

Price Level: December 2021 Discount Rate: 1.125

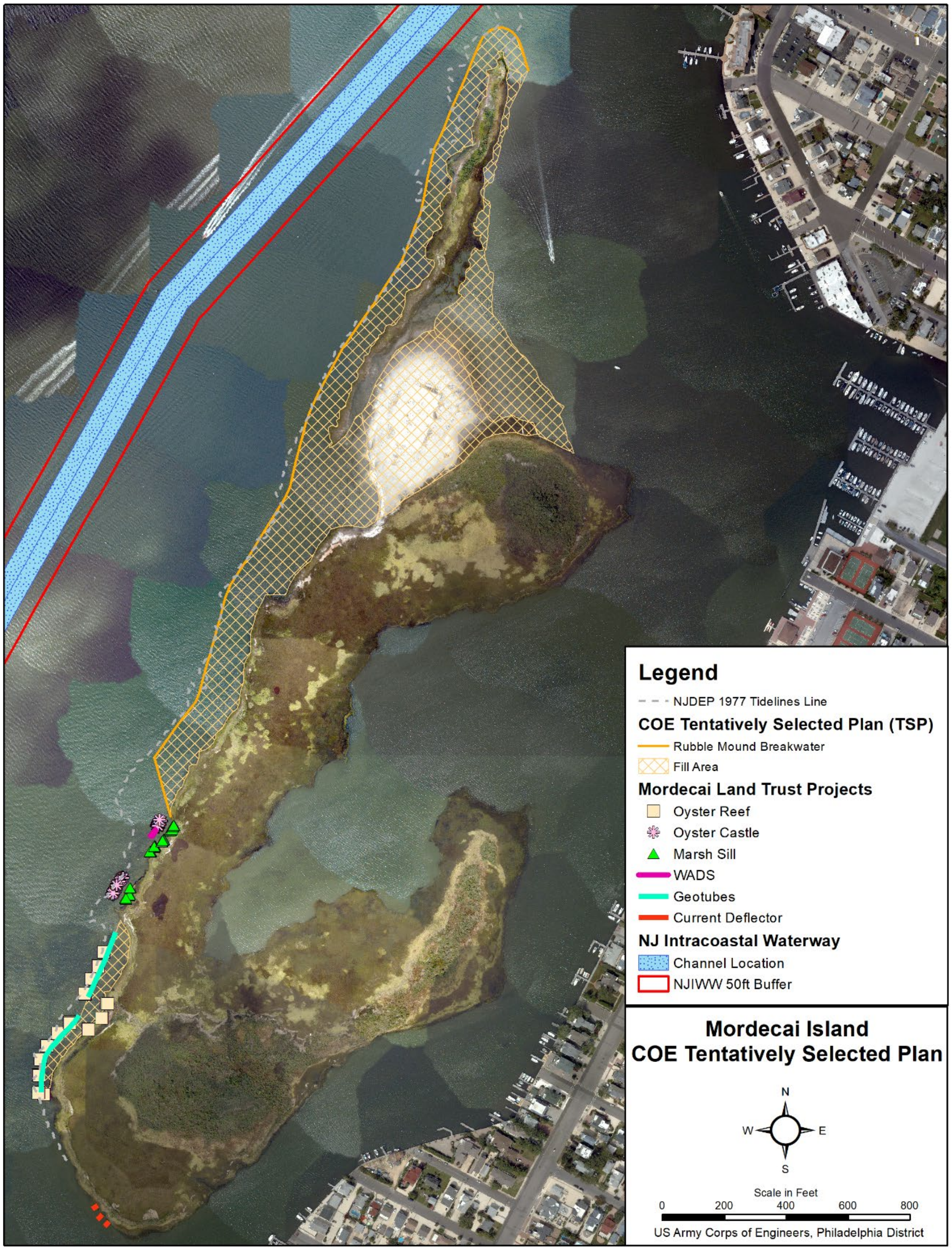


Figure ES.4: Tentatively Selected Plan

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*Section headings in this document marked with an asterisk indicate consistency with requirements of National Environmental Policy Act (NEPA) Environmental Impact Statements.

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

1 Introduction

1.1 Study Authority*

This study was conducted under the authority of Section 1135 of the Water Resources Development Act of 1986. Under this authority the United States Army Corps of Engineers (Corps) may plan, design and build modifications to existing Corps projects, or areas degraded by Corps projects, to restore aquatic habitats for fish and wildlife. In the case of this study, the degraded area is Mordecai Island in New Jersey and the source of degradation is the adjacent Federal navigation channel, the New Jersey Intracoastal Waterway (NJIWW).

1.2 Study Area

The study area is the approximately 47 acres of Mordecai Island, and surrounding features affecting, or affected by, Mordecai Island (Figure 1.1). Mordecai Island is located near Beach Haven Borough in Barnegat Bay, Ocean County, New Jersey and, as noted above, is adjacent to the NJIWW (Figure 1.2).

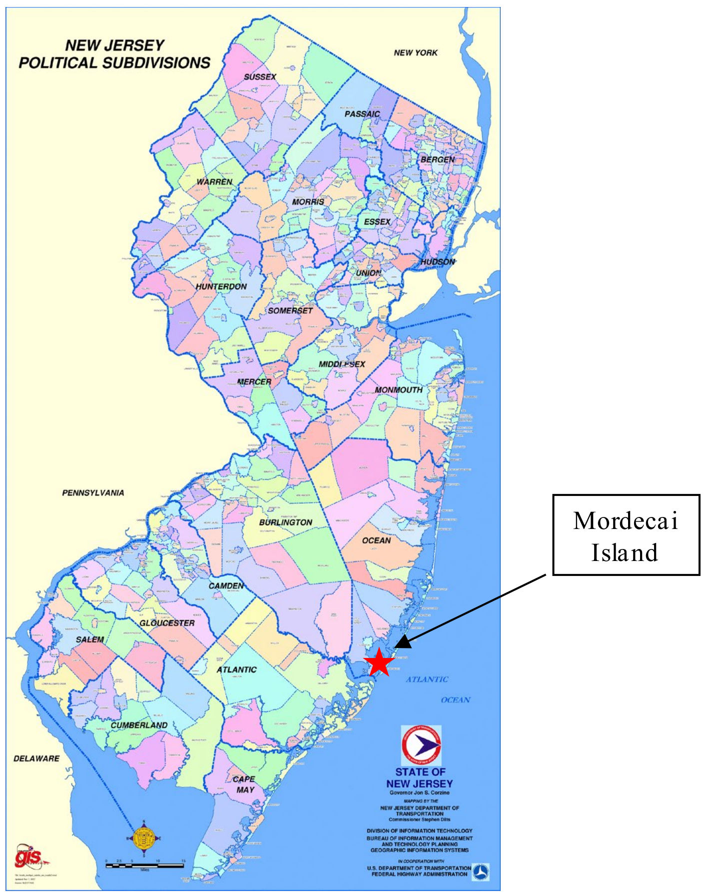


Figure 1.1: Location of Mordecai Island in New Jersey

Figure 1.2: Mordecai Island and Surrounding Area

1.3 Purpose and Need for Action*

The purpose of the feasibility study was to investigate and recommend an implementable solution to the identified problems at Mordecai Island. Saltwater marshes on the New Jersey coastline have been disappearing over the past hundred years due to factors such as sea level rise, lower accretion rates, and higher rates of anthropogenic erosion. In the Mordecai Island study area alone, it is estimated that over 11 acres of coastal marsh have been lost on the island since 1977, with an average loss of 2-4' per year along the western edge of the island. As sea levels continue to rise and storms become more frequent and intense, salt marshes that cannot keep pace with sea level rise will ultimately be lost, along with the ecosystem services they provide to coastal communities and the coastal economy. Furthermore, salt marshes provide habitat for economically and ecologically important fish, crabs, and shellfish; nesting and foraging habitat for migratory and resident birds; and improved water quality through de-nitrification and sediment removal. Ecosystem restoration projects like the one proposed for Mordecai Island will create a regional uplift in ecosystem functions, services and resiliency—including increased buffering capacity against storm and flood damage, significant regional uplift in water quality, and the enhancement and creation of fish, shellfish, wading bird, and waterfowl habitat. The uplift in ecosystem services will have a significant, positive impact on dependent local and regional economies, including tourism, hunting, fishing, recreation, and avoided storm damage costs.

This report documents the analysis of existing conditions, without-project conditions, plan formulation, and development of the National Ecosystem Restoration (NER) plan for the study area. The evaluations were based on site-specific technical information developed during the course of the study. These evaluations included surveys, hydraulic and economic evaluations, geotechnical investigations and environmental and cultural resources inventories. This report will detail the following:

a. Problems and potential solutions for the study area

b. Costs, benefits, environmental and social impacts of potential solutions

c. The optimized NER plan and results of the Cost Effectiveness/Incremental Cost Analysis (CE/ICA)

d. Project Partnership Agreement (PPA) responsibilities of the Non-Federal Sponsor

1.4 Report Organization

This document has been organized in a manner consistent with Corps requirements for feasibility reports. The main report summarizes the results of feasibility studies, and the technical appendices present the details of the technical investigations conducted for the Mordecai Island, Beach Haven, New Jersey, Ecosystem Restoration Feasibility Study and Integrated Environmental Assessment.

Chapter 2 of this study provides a summary of Federal and local participation in previous studies or projects within the bounds of, or affecting, the study area.

Chapter 3 of this study reviews the existing site conditions pertinent to quantifying the “with” and “without” project consequences.

Chapter 4 of this study provides inventoried and forecast without project conditions in terms of erosion and habitat loss.

Chapter 5 provides an overview of the step-by-step process leading up to the identification of the Tentatively Selected Plan.

Chapter 6 describes the components, impacts, economics, risks and uncertainties of the Tentatively Selected Plan.

Chapter 7 lists compliance with applicable environmental laws and regulations.

Chapter 8 reviews the implementation process, schedule and the cost-sharing agreement for the Recommended Plan.

Chapter 9 briefly describes the monitoring plan that will be implemented to track progress of the ecosystem restoration project and the adaptive management plan that will be implemented in the event that future changes are needed to improve ecosystem restoration onsite.

Chapter 10 includes information on the public review process.

Chapter 11 contains the outcome of this study recommended by the District Engineer.

Chapter 12 provides a comprehensive list of those involved in producing the analyses, documentation and decisions contained herein.

Chapter 13 lists the sources referenced throughout the report.

Note: Reference in this report to trademarked names and products is not intended to imply support or endorsement of the Corps' study or the recommended plan by the manufacturer/trademark holder.

2 Prior Studies and Actions

2.1 Corps of Engineers

2.1.1 Breach Fill

In 2015 the Philadelphia District's Operations Division began a beneficial use of dredged material project on Mordecai Island using materials from shoaling in the adjacent Intracoastal Waterway. The overarching goal of this project was to increase the long-term resilience of Mordecai Island, which protects the developed shoreline of neighboring Long Beach Island from wave energy generated in Barnegat Bay.

In November 2015, the Corps used approximately 25,000 cubic yards of sediment dredged from the NJIWW to fill in an erosional gap that had effectively split Mordecai Island in two (see Figure 2.1). A thick mound (~3ft deep) of sediment was placed in the gap, to rejoin the two remaining lobes of the island. Planting of the filled area was completed in May 2016. The lowest zone of the fill area was planted with saltmarsh cordgrass (*Spartina alterniflora*). The next highest zone was planted with saltmeadow hay (*Spartina patens*) and salt grass (*Distichlis spicata*). The third zone, the highest zone above the intertidal influence, was originally planned to receive coastal shrub plantings, however, this zone, along with the shell cover, developed into beach nesting bird habitat. Therefore, this zone was left unvegetated to provide habitat for beach nesting birds.

A turbidity curtain was installed on the northeastern edge of the fill area to contain sediment. The result has been significant accretion behind the curtain and creation of a sandy beach area providing a foraging, roosting and courtship area for avian species. The success and benefits of the turbidity curtain led to a joint decision by the Corps and NJDEP to leave it in place.

Monitoring of the project was conducted through site visits and surveys by the Philadelphia District, the Corps Engineer Research and Development Center (ERDC), and the National Oceanic and Atmospheric Administration (NOAA). The National Centers for Coastal Ocean Science (NCCOS) at NOAA was tasked with establishing both baseline data and developing a monitoring program to determine the ecological implications of both the sediment placement and shoreline stabilization efforts and to track evolution of the project over time. The field work was conducted for three years, from 2017 through 2019. Several bird species were observed utilizing the habitat: Black Skimmers, Least Terns and American Oystercatchers. In addition, the fill provided nesting habitat for Northern Diamondback Terrapins. Additional results are provided in Section 3.5 of the Baseline Conditions.

The nesting portion of the filled area flooded, so the Philadelphia District added more material in December 2017 to raise the elevation of the habitat.

Figure 2.1: Location of Corps Breach Fill Project

2.2 Mordecai Land Trust (MLT)

2.2.1 Coir Log Installation

In 2006, as Phase I of a Southwest Mordecai Ecosystem Restoration (SWMER) project, United States Fish and Wildlife Service (USFWS)/Mordecai Land Trust installed biodegradable coir logs, also known as biologs, on the edge of part of Mordecai Island and planted *Spartina alterniflora* in the landward, protected side of the biologs (see Figure 2.2). A 2008 inspection determined that "In general, biologs placed in the high energy environment of the island's western side were missing and marsh erosion has continued. Some biologs placed along the calmer eastern side of the island are still present, but the coir fibers have no remaining strength…Overall observations of the accretion and erosion rates (inches/month) of Mordecai Island before and after the biolog installation show no discernable differences…Further observations comparing the yearly-month rates of accretion/erosion for those area sheltered by a biolog versus those areas without biologs also show no discernable difference ... The conclusion that the biologs have very little to no effect on the accretion/erosion rates of the island can be reached by combining the two sets of observed data. None of the *Spartina alterniflora* that was planted in the biologs in 2006 survived…it is recommended that biologs, if installed in low energy areas, be secured with wire rope. Biologs should not be installed in areas of high or moderate wave energy.”[1]

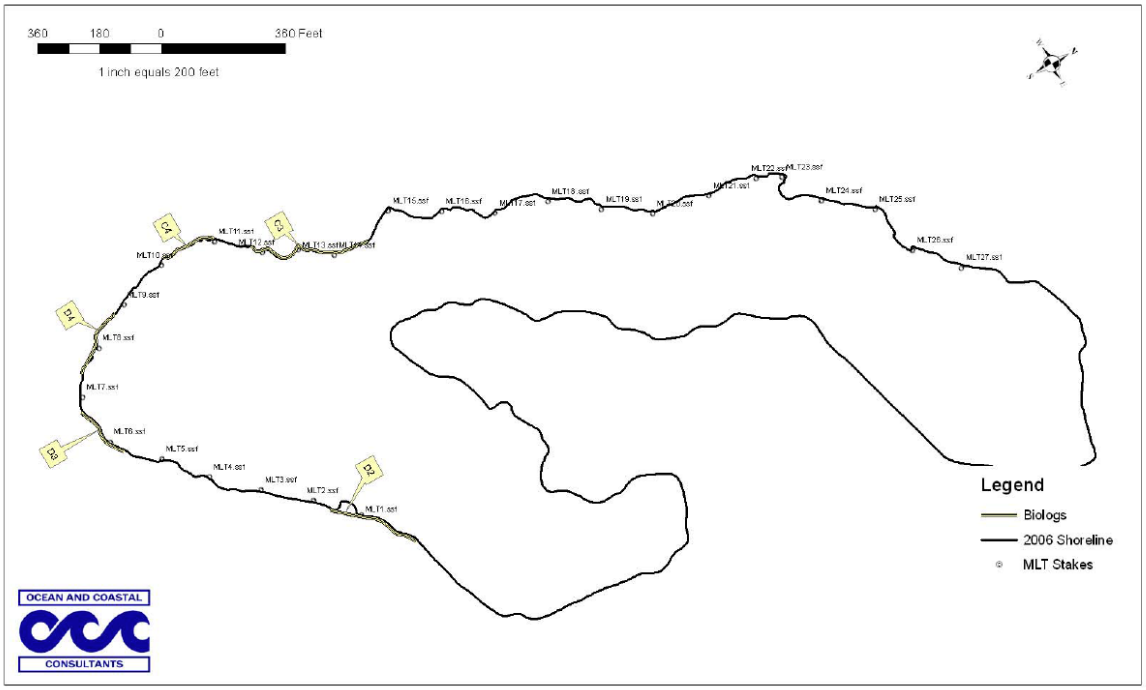


Figure 2.2: Locations of MLT Coir Logs

[1] *“South West Mordecai Ecosystem Restoration (SWMER) Phase I Biolog Performance Review, OCC Project No. 204124.3,” from Ocean and Coastal Consultants to Mordecai Land Trust, Letter Report, August 20, 2008.*

2.2.2 Geotube® Installation

In 2010 USFWS conducted Phase II of the SWMER project with placement of 570 linear ft. of polypropylene geotextile tube sill offshore of the southwestern portion of the island, as shown in Figures 2.3 through 2.6. The specifications called for the geotextile tubes to be designed to reach a tube height of 3.5 ft. above the bay floor for the entire length of the tubes. The sill was specified to be placed on a scour apron. The Geotubes® by TenCate Geosynthetics North America are unarmored.

Phase II of the project also called for a series of three current deflectors to be installed along Mordecai Island’s southern edge at Liberty Thorofare. The current deflectors were specified to be coir logs made with synthetic netting and set on a scour protection mat made of woven coir fabric and a backing mat.

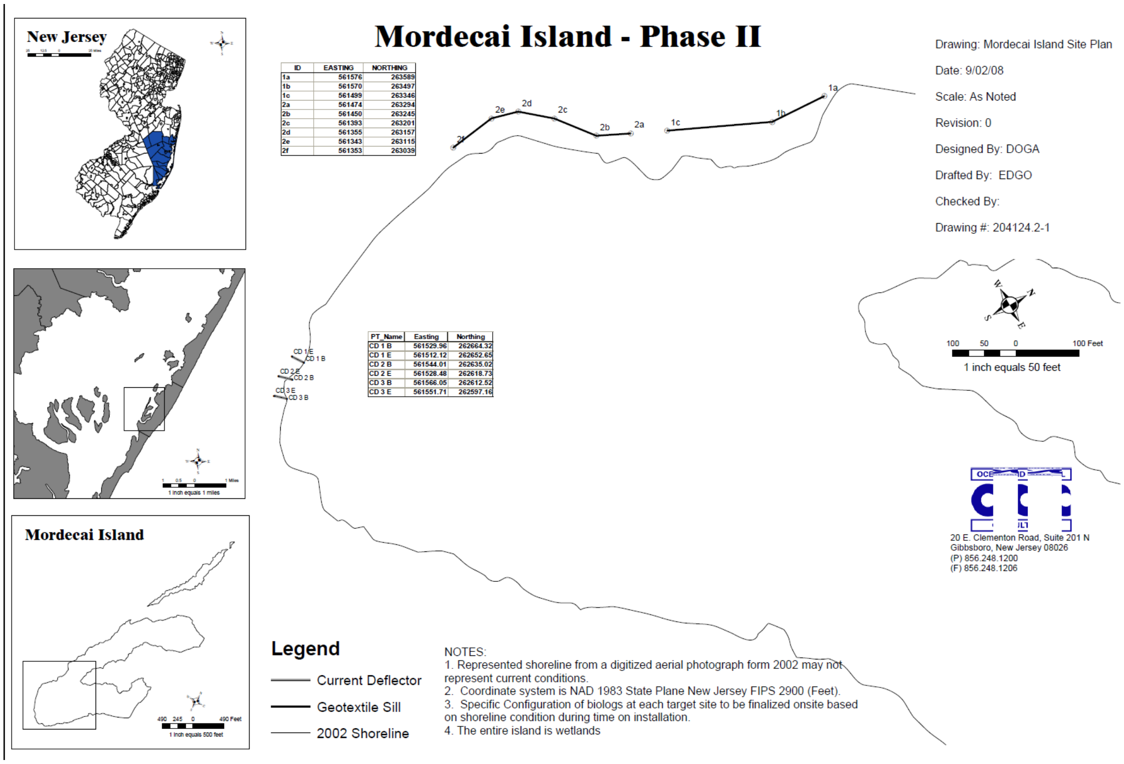


Figure 2.3: Locations of MLT Geotubes®

Although there has not been scientific monitoring of the effectiveness of the Geotubes®, the following Google Earth image confirms that they were still in place in July 2018 and a Corps field trip in August 2018 confirmed their continued existence. In August 2016 MLT noted on their website that over the past 5 years an intertidal land bridge had been established between the tubes and the island. This is also visible on aerial photos and from the shoreline at low tide. The Land Trust intends to plant clumps of ribbed mussels and *Spartina* together. The stated goal is to have sediment accrete faster and hasten island growth toward the tubes. A site visit was made by the Corps on August 17, 2018 and it was noted that the tubes' intertidal surfaces are covered with bladderwrack seaweed and barnacles, with accompanying periwinkles and small forage fish. One of the tubes had broken open at the end but had been effectively closed off by having bags of oyster shells piled onto the flaps of the open end.

Figure 2.4: Aerial View of Installed MLT Geotubes®

Figure 2.5: Tombolos Behind MLT Geotubes®

Figure 2.6: MLT Geotubes®

2.2.3 Osprey Platform Replacement

An osprey platform was installed next to Mordecai Island in the 1990s. The structure decayed and was prone to predator invasion. In 2016 MLT replaced the osprey platform in the eastern cove area of Mordecai Island. (See Figure 2.7) In 2017 an unattached male was observed defending the platform and in 2018 a nesting pair with one chick was seen on the platform. The nesting pair returned and had successful breeding in 2019.

Figure 2.7: MLT Osprey Platform

2.2.4 Oyster Castle® Installation

In August of 2017 MLT, with the help of ReClam the Bay, another local nonprofit organization, installed four experimental sets of Allied Concrete Company's Oyster Castles® on the western side of the island just north of the previously installed Geotubes®. The installation included blocks with and without oyster spat introduced onto them.

The first array of Oyster Castles® is six tiers high, with spat laden blocks from bottom to top. The purpose of this array is to determine the natural elevation for optimal oyster growth. MLT is observing for habitat creation, as well as structural stability and wave attenuation.

The second array of Oyster Castles® is formed in an arrowhead shape pointing west, into the waves and boat wakes. The goal of this array is to provide information on the structural integrity of the arrowhead formation. In addition, bags of oyster spat on shell were placed on the leeward, or sheltered, side of the array to encourage growth of oysters and other marine organisms.

The third array is being observed for effectiveness of wave attenuation and the fourth array is being watched for habitat creation. In addition, the remaining Oyster Castles® were laid out near the island shoreline in an attempt to lessen erosion.

In June 2018 a second series of Oyster Castles® were put in place on the western side of the island. The largest array is about six times the size of the biggest array placed in 2017. At 22 castles in length by 9 castles in width, it covers about a 1000 square ft. of bay bottom. Five smaller arrays were also placed closer to shore. In addition, more Oyster Castles® were added to the northernmost 2017 structure, thereby doubling its size to enable wave measurement and transmissivity comparison to the large 2018 structure. (See Figures 2.8 through 2.11.)

During a July 2018 visit to the castles, MLT members noted that spat on the 2017 castles had matured and submerged aquatic vegetation around the castles had grown significantly. It was also observed that the small near-shore sills from both 2017 and 2018 had tombolos of accreted material forming to join them to the island. (See Figure 2.9.)

Figure 2.8: MLT Oyster Castle® Arrays

On November 6, 2019 Stockton University Coastal Research Center conducted a survey of the Oyster Castle® array installed in 2018. The survey compared elevation points with some collected in September 2018. Structure settlement was between -0.10 and -0.58 ft. across the array, with an average of -0.26 ft.. Settlement was slightly greater (-0.31 ft.) on the western side of the array, than on the eastern side (-0.19 ft.). (See Figure 2.11.) The survey concluded that the Oyster Castle® array has maintained its as-built design and orientation and settlement has been slightly higher on the side exposed to direct wave energy.

Figure 2.9: Tombolo Creation at Oyster Castle® Array on Mordecai Island

Figure 2.10: Growth of Biota on Mordecai Island Oyster Castle®

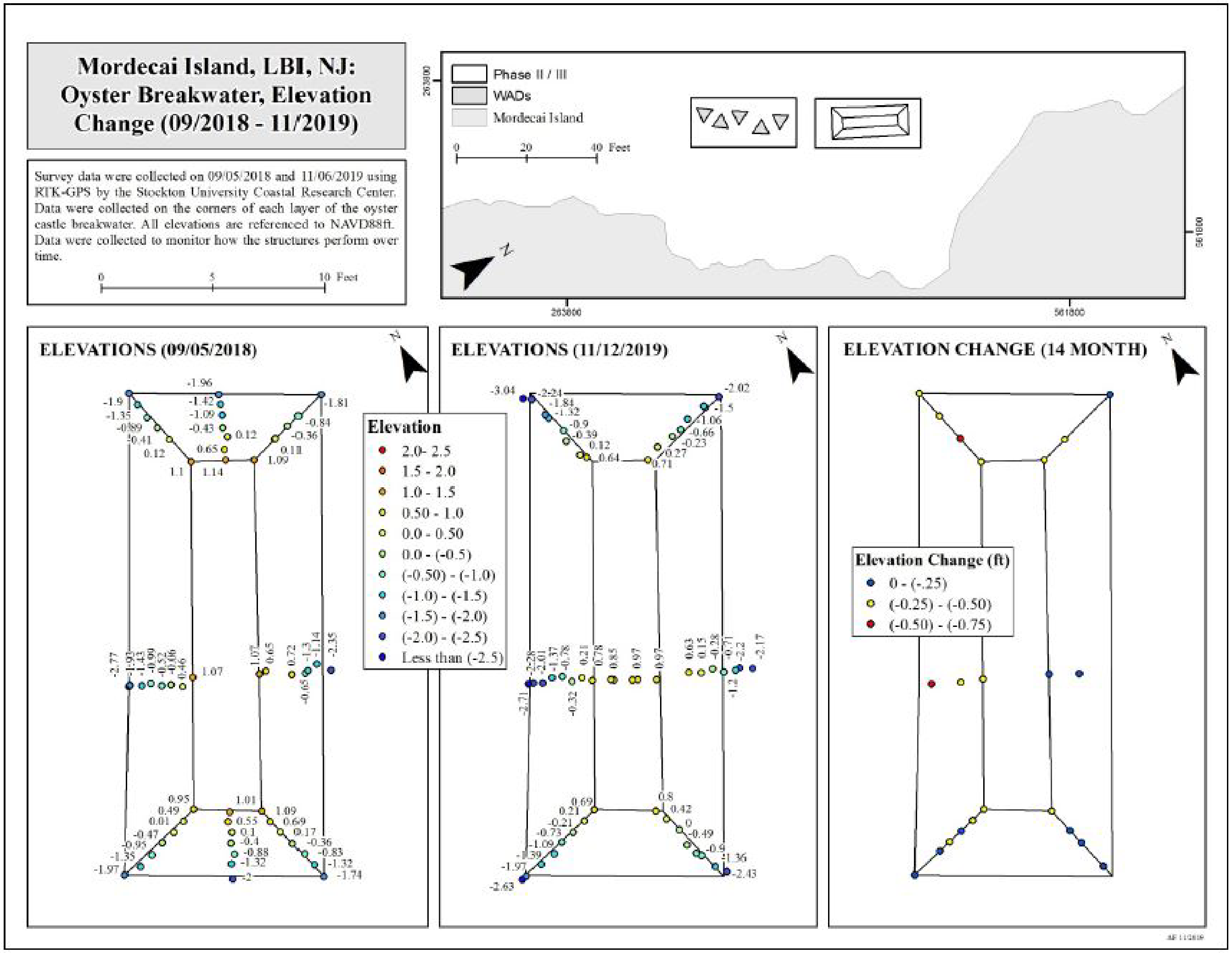


Figure 2.11: Elevation Changes Across the MLT 2018 Oyster Castle® Array

2.2.5 Northern Diamondback Terrapin Nest Relocation

Diamondback terrapins have been observed swimming in Mordecai Island's eastern cove and basking on the shore. MLT developed an interest in helping the protected New Jersey species establish nests on Mordecai Island. A sandy area of slightly higher ground on the southwest corner of the island was cleared of vegetation in 2016 and coined "Terrapin Garden." Diamondback terrapin hatching success rate in 2016 is unknown. On June 25, 2017, three Northern Diamondback Terrapin clutches totaling 38 eggs were transported to Mordecai for renesting (Budd 2017). The site was revealed to be less than optimal for natural nesting and required significant care and maintenance. Due to an abundance of spring rains, the prospective nesting site became overgrown with vegetation and there was evidence of flooding. The site was also subject to high predation. With extensive human assistance, there was a 68% hatchling success rate (Budd 2017).

In 2018, lessons learned were applied and more suitable nesting sites were selected by MLT. Six clutches, totaling 77 eggs, were relocated and enclosed on sand mounds on the western side of the island, but monitoring was completed prior to hatching and the success rate is unknown (Budd pers. comm.).

Terrapin Garden habitat improved as a result of the accretion associated with the 2018 installation of oyster castles as described in Section 2.2.4. A total of 30 eggs were relocated from Holgate to Terrapin Garden with an 80% success rate and no predation (i.e., eggs were in exclosures). Wild nests at Terrapin Garden had a 33% success rate, with failure attrributed to predation. The total combined success rate was 71% (Budd 2019a).

2.2.6 Shell Bag Installation

As of July 2018, MLT and ReClam the Bay had installed over 200 shell bags in several locations along Mordecai Island. The bags contain clam shells that have oyster spat growing on them. The purpose of bag placement is to provide living protective structures. Bags have been placed on the Geotubes® to close off a hole, as well as near the Geotubes® to create a protective reef. MLT is looking into adding ribbed mussels to this protective effort. Shell bags have also been placed close to the edge of the marsh in an effort to slow erosion of the island. (See Figure 2.12.) In addition, shell bags were placed as a protective barrier along the western side of the Corps fill project location. This last placement has contributed to creation of tide pools and a mud flat. In September 2018 Spartina was observed growing through the shell bags.

Figure 2.12: MLT Shell Bags at the Edge of Mordecai Island

2.2.7 Wave Monitoring at One Oyster Castle® Breakwater

From September 17, 2018 to October 5, 2018 MLT conducted a wave monitoring program at Oyster Castle® array #6. The purpose of the effort was to evaluate the wave attenuation ability of the Oyster Castle® structure. Wave data was collected by a gauge on the seaward side of the structure and a gauge on the landward side of the structure. Weather data was also collected throughout the study period. No major storms were recorded.

Wave height attenuation was higher when the Oyster Castle® array was emergent. Waves from the northwest and southwest were observed bypassing the array, implying that the face of the structure was not perpendicular to the incoming wave direction during the study. Waves coming in perpendicular to the structure were observed wrapping around the array, indicating that it needs to be longer. Data also suggested that wave energy was propagating landward of the structure. Recommendations were made for alterations to the Oyster Castle® array. In addition, further monitoring is needed to expand the data sets and include a range of conditions.

Two boat wake tests were also performed during the study period, with one resulting in observable data. The Oyster Castle® array was emergent during the data bursts. The waves approached the structure perpendicularly. The array effectively reduced wave height from the boat wake test at mid-tide, with winds from the south at 7.9 mph. Further field tests are needed to obtain more data.

Also of note, during the study period observed water levels were found to be higher than predicted.

2.2.8 Installation of Wave Attenuation Devices

As Phase 3 of their demonstration projects (see Figure 2.16), on September 17, 2019 Mordecai Land Trust installed five of Living Shoreline Solution, Inc.'s Wave Attenuation Devices, also known as WADs®. (See Figure 2.13.) WADs® are hollow poured concrete pyramids that are designed to site conditions. (See Figure 2.14.) The purpose of the WADs® is to break wave energy, while also promoting growth of biota. MLT's WAD® array is laid out in a staggered arrangement along the western shore of the island, in a northeast to southwest direction. Each of the WADs® is 60 inches high, with a base of 113 inches. MLT installed both corrugated and smooth surfaced WADs® to compare performance and biological growth patterns. Two different hand probes were used to consider firmness of the bay bottom. It was determined that no geotextile or geocomposite base was needed for the WADs®. Therefore, they were set directly onto the bay bottom.

On November 6, 2019 Stockton University Coastal Research Center conducted a survey to determine as-built elevations of the WADs®. (See Figure 2.15.) Ground elevations around the array were between -2.5 and -4.0 NAVD88, with all of the deeper areas (>-3.0 NAVD88) occurring around the western edge of the three southernmost WADs®, WADs® 3 through 5). Corner surface elevations at WAD® 1 and WAD® 2 were consistent with variations in elevations of 0.12 ft. and 0.17 ft., respectively. Corner surface elevations at WADs® 3 through 5 were consistently lower along the western edges. Data indicates that the western edges of the southern three WADs® are being scoured, causing uneven settlement of the WADs®.

Figure 2.13: MLT Wave Attenuation Devices

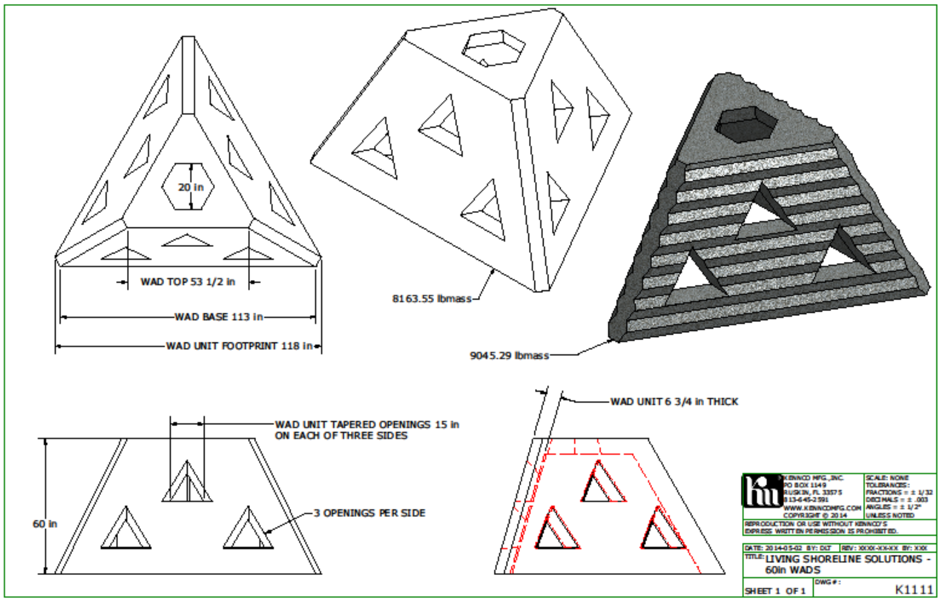


Figure 2.14: WAD® Details

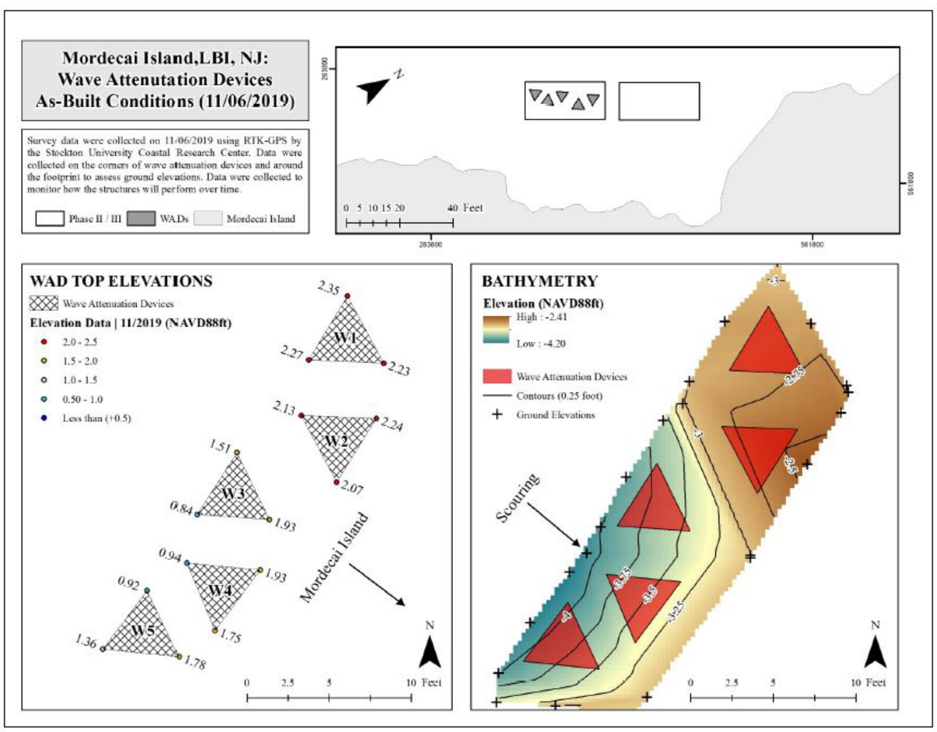
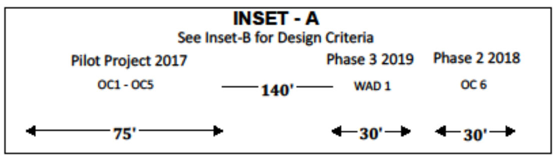
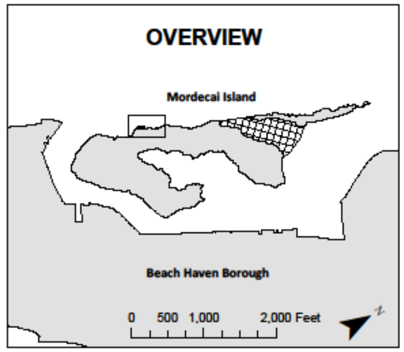


Figure 2.15: November 6, 2019 Elevation Conditions of MLT WADs®

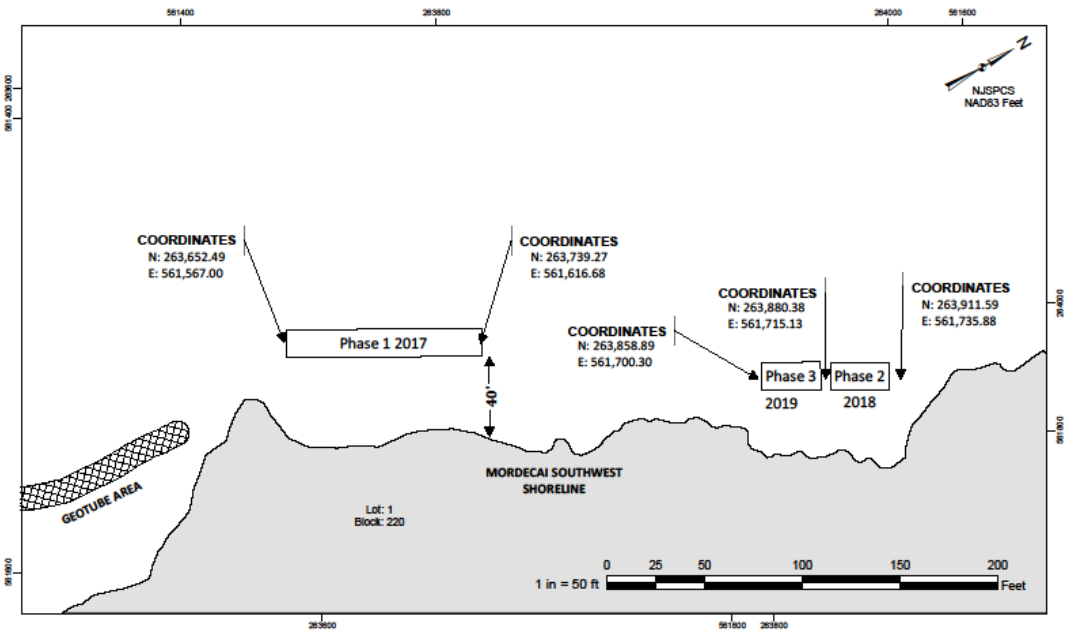
Datum	MLLW (feet)	NAVD88ft
Source	NOAA Station #85334208 Beach Haven,NJ	Conversion of NOAA Gauge value to NAVD88ft (VDATUM)
HTL	-	-
MHHW	2.54	1.2
MHW	2.26	0.92
NAVD88ft	1.34	0
MTL	1.19	-0.15
MLW	0.11	-1.23
MLLW	0	-1.34





INSET-B: DESIGN CRITERIA

BREAKWATERS	Name	OC1	OC2	OC3	OC4	OC5	OYSTER CASTLE BREAKWATER 6		WAD BREAKWATER 7	
	Year	2017	2017	2017	2017	2017 - 2018	2018		2019	
	Mode	Demo Habitat	Demo Structures	Demo Structures	Demo Structures	Demo Measure	Structural Wave Measurement		Structural Wave Measurement	
	# Castles	130	35	47	47	130	826		5 WADS	
	# Tiers	5	4	4	3	5	7		NA	
	Footprint	6x8	4x4	3x6	4x6	6x8	9 x 22		10 x 30	
MARSH SILLS	Name	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10
	Year	2017	2017	2017	2018	2018	2018	2018	2018	2019	2019
	# Castles	8	5	5	8	33	62	32	43	33	32
	# Tiers	2	1	2	2	2	3	3	2	3	3
	Footprint	2 x 3	2 x 2	2 x 2	2 x 3	3 x 7	3 x 11	3 x 6	3 x 9	4 x 10	3 x 7



"This plan is intended for permitting only

•The project complies with NJDEP General Permits 1503-04-0012.2 CZM 17001and 18001. USACE Nationwide Permit CENAP-OP-2017-00191, File 1503-04-0012.2 CZM 190001, and NJ Bureau of Tidelands Management License File # 1503-04-0012.2 TDI 170001

•The breakwater is a structural component intended to reduce wave energy.

•Specific construction of each breakwater structure to be finalized by project design team.

•Map coordinates are in North American Datum of 1983 (NAD83), New Jersey State Plane Coordinate System US feet (NJSPCS).

•Map coordinates, construction as-built dimensions and elevations for all breakwaters and marsh sills are shown on ArcGIS Pro drawing http://arcg.is/1GrDLO0

MORDECAI ISLAND

LIVING BREAKWATER
PILOT, PHASE II AND PHASE III
FACILITY

LAYOUT AND DESIGN
CRITERIA

MORDECAI LAND TRUST
BEACH HAVEN, N.J.

BY: Jim P. Dugan, Mordecai Island Land Trust

DATE: 11/14/2019

REVISION: VERSION 5

DRAWN BY: A.Ferencz - Stockton University, Coastal Research Center

REVISION 2 : Added Phase II 2018 Breakwater
REVISION 3: Added Marsh Sill Notes For Phase II
REVISION 4: Added as Built Dimensions For Phase II. Added location and changed notes for Phase III Breakwater
REVISION 5: Changed inset-b and Phase III coordinates on map

Figure 2.16: MLT Oyster Castle® and WAD® Information

3 Baseline Conditions/Affected Environment*

3.1 Air Quality

As required by the Clean Air Act, the EPA sets National Ambient Air Quality Standards (NAAQS) for six (6) common air pollutants known as "criteria pollutants." After the EPA sets the NAAQS, it determines which areas of the country meets those standards. If the air quality in a geographic area meets or is cleaner than the standard, it is called an attainment area. Areas that do not meet a standard are called nonattainment areas.

The project site is within the Philadelphia-Wilmington-Atlantic City, PA- NJ-MD-DE nonattainment area for the 8-hour ozone NAAQS and is classified as "marginal." "Marginal" is the lowest classification, meaning that the ozone levels in this area are closer to the standard than in those areas with a higher classification. As required by the Clean Air Act, the State of New Jersey has a State Implementation Plan (SIP) in place describing how the 8-hour ozone NAAQS will be achieved and maintained in nonattainment areas

General Conformity is a process to implement Section 176(c) of the Clean Air Act to ensure actions conducted or sponsored by Federal agencies in nonattainment or maintenance areas are consistent with the SIP. General Conformity requires that reasonably foreseeable emissions from Federal actions will not cause or contribute to new violations of a NAAQS, increase the frequency or severity of existing NAAQS violations, or delay timely attainment of the NAAQS or any interim milestone towards achieving attainment. However, a General Conformity determination is not required if the emissions from the federal action will fall below the de minimis levels set forth in the Clean Air Act regulations.

The *de minimis* emission threshold for a Marginal ozone nonattainment area is 100 tons/year of NOx or 50 tons/year VOC.

3.2 Water Quality

Water quality is a primary determinant of habitat quality for fish and wildlife, and also affects recreational opportunities in and the overall aesthetics of a water body. Water quality within the coastal waters of New Jersey is comparable to that of similar coastal water bodies along the New York Bight and is indicative of similar coastal tidal river and estuary complexes along the Mid-Atlantic coast (USFWS, 1997). The quality of water in this coastal region is dependent largely on the influence of the major coastal freshwater rivers that flow into the bays including the Mullica River, Absecon Creek, Patcong Creek and the Great Egg Harbor River. Other factors that influence water quality over time include tides, season, ocean current fluctuations, nutrient enrichment, water depth, biotic communities, and other temporal and spatial variables.

Studies conducted on the bays and estuaries in the vicinity of Mordecai Island and the NJIWW indicate that water quality has historically been impacted by pollutants such as nutrients, pathogens, heavy metals and fecal coliform bacteria. As a result, habitat for fish and wildlife has been degraded in many areas relative to historical pre-developed conditions. Barnegat Bay-Little Egg Harbor and New Jersey's more southerly inland bays from Great Bay (at the mouth of the

Mullica River) south to Cape May are considered by the National Oceanic and Atmospheric Administration (NOAA) to be highly eutrophic – meaning that they are susceptible to nutrient-fueled algae blooms that harm aquatic ecosystems and have the potential to deprive waterways of oxygen. NOAA projects that nutrient related symptoms in the southern coastal bays are likely to worsen in the years to come.

3.3 Physical Setting

3.3.1 Physiography

The New Jersey shoreline can be divided into those sections where the sea meets the mainland, at the northern and extreme southern ends of the State, and where the sea meets the barrier islands, in the central to southern portion of the State. The barrier islands extend from Bay Head, down the coast for approximately 90 miles (145 km), to just north of Cape May Inlet and are generally continuous, except for the interruption by 10 inlets. Mordecai Island is a land mass of approximately ¾ -mile long and ¼ -mile wide and is situated in Barnegat Bay adjacent to Long Beach Island near Beach Haven Borough, Ocean County, New Jersey.

3.3.2 Topography/Bathymetry

There have been several topographic and bathymetric surveys conducted at Mordecai Island since 2008.

Table 3.1: Surveys of Mordecai Island Area

Date	Surveyor	Notes
January 2019	Corps Philadelphia District	Island and offshore, including channel
April 2018	Corps Philadelphia District	Island and offshore
December 2017	Corps Philadelphia District	Breach area
February 2016	Corps Philadelphia District	Breach area
December 2015	Corps Philadelphia District	Breach area
August 2015	Corps Philadelphia District	Breach area
April 2013	Stockton University	Western shoreline assessment
October 2012	Stockton University	Western shoreline assessment
May 2011	Corps Philadelphia District	Island and offshore, largest and most comprehensive
June 2008	Corps Philadelphia District	Island and offshore

Topography of Mordecai Island primarily consists of widespread areas of high and low salt marsh with some exposed sod and grass-covered sloped areas. There are areas of common reed and a small amount of elevated regions colonized by bayberry, winged sumac, and token eastern red cedar. The peak elevation from the January 2019 survey on the island was +4.6 ft. NAVD88, located in the northeast portion of the island across from Berkeley Ave.

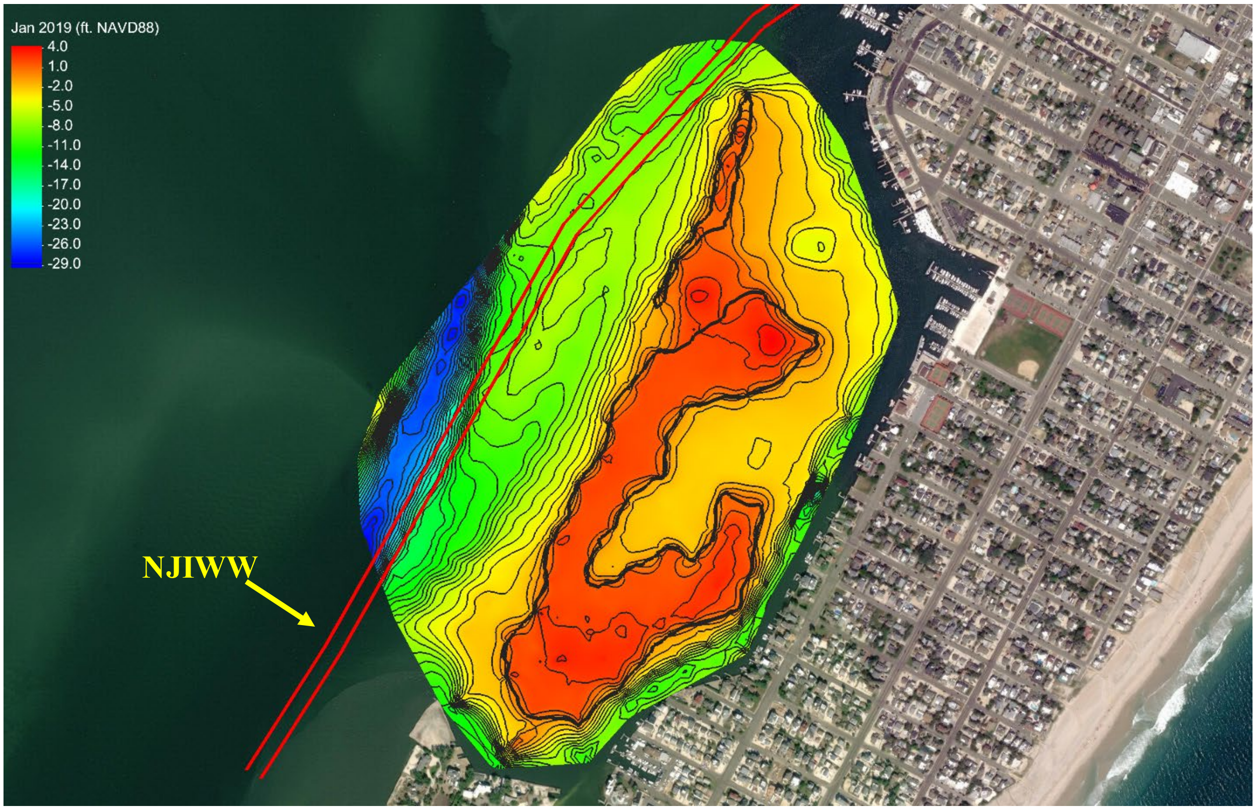


Figure 3.1: January 2019 Bathymetry and Topography

3.3.3 Subsurface Geology

Based on the Bedrock Geologic Map of New Jersey, dated 2014, the project site lies within the outer Coastal Plain Physiographic Province. (A physiographic province is a geographic region with distinct landscape characteristics and commonly distinct rock types.) The Coastal Plain Province is characterized by the Kirkwood formation, Belleplain Member (middle Miocene) which consist of gray to white, fine to medium grained, micaceous sand, wood and shell fragments. The lower part consists of gray-brown, laminated silty clay, diatoms and shell fragments.

3.3.4 Surficial Deposits

Based on the soil survey of Ocean County (NRCS Web Soil Survey: "Custom Soil Resource Report for Ocean County, New Jersey," United States Department of Agriculture and Natural Resources Conservation Service, dated May 20, 2019), the typical soils found within the approximate project limits consist of Appoquinimink-Transquaking-Mispillion complex (AptAv), Psammaquents, sulfidic substratum, (PstAt), Dredge Channel (WDC4A), Indian River sand flat (WIr1) and Indian River sand tidal inlet (WIr3). (See Figure 3.2 and Table 3.2.)

Figure 3.2: Mordecai Island Soils Map 5455

Table 3.2: Soil Types and Characteristics

Type of Soil	Characteristics
Appoquinimink-Transquaking-Mispillion complex (AptAv)	• Appoquinimink - mucky silt loam (0-12 inches) underlain by silt loam (12 to 30 inches) and mucky peat (30 to 80 inches) ; • Transquaking - mucky peat (0 to 14 inches) underlain by muck (14 to 60 inches) and silty clay (60 to 90 inches); • Mispillion - mucky peat (0 to 10 inches) underlain by muck (10 to 26 inches) and silt loam (26-90 inches). • The soils develop along tidal marshes with 0 to 1 percent slopes and are derived from loamy fluviomarine deposits over herbaceous organic material. The soils are very poorly drained, very frequently flooded and havestrong saline content.
Psammaquents, sulfidic substratum, (PstAt)	• Includes coarse sand (0 to 12 inches) underlain by gravelly sand (12 to 36 inches) and mucky peat (36 to 80 inches). • The soils develop along flats with 0 to 2 percent slopes and are derived from sandy lateral spread of deposits over organic material.

	• The soils are very poorly drained, frequently flooded and have very slightly saline to strong saline content
Dredge Channel (WDC4)	Encompasses approximately 3.3 to 13.1 ft. of water depth
Indian River (Wlr1)	• Includes sand from approximately 0 to 79 ft.. • The soils along the Indian River develop along flood-tidal delta flats with 0 to 3.3 ft. of water depth. • The Indian River sandis frequently flooded, very frequently flooded and has strong saline content
Indian River (Wlr3)	• Includes sand from approximately 0 to 70 ft.. • The soil develops along sandy flood-tidal delta lagoon deposits with 6.5 to 16.4 ft. of water depth. • The soil is very frequently flooded, contains 5 percent calcium carbonate and has strong saline content

A site-specific geotechnical investigation was performed for the Corps Philadelphia District by Schnabel Engineering, Inc. The work included the advancement of three (3) geotechnical borings drilled from the water adjacent to Mordecai Island. The geotechnical borings extended to depths of 50 ft. below the mud line and indicated that the surficial soils are comprised of loose to medium dense sand underlain by a layer of soft, silty clay and peat. Underlying the clay and peat stratum, sandy soils were present to the termination depths of the borings. See Appendix A: Engineering Technical Appendix for the results of the subsurface investigation within the project area.

3.3.5 Sediment Characteristics

In addition to the above-mentioned borings, sediment samples were separately collected from three (3) core locations (MOR-01 through MOR-03) in the NJIWW channel adjacent to the western side of Mordecai Island. Samples were analyzed for grain size; TOC; Target Compound List (TCL) volatile organics (VOCs) and semi-volatile organics (SVOCs); TCL pesticides; Target Analyte List (TAL) inorganics, including total cyanide and total mercury; polychlorinated biphenyl (PCB) arochlors and PCB congeners/dioxins and furans. VOC fractions were collected directly from the sediment cores.

The sediment cores ranged from 8.5 to 9.5 ft. below the mudline and consisted of 75 to 86% fine and medium sand, with varying amounts of silt. The sediment analytical results were compared to NJDEP residential and non-residential direct contact cleanup criteria. There were no contaminant parameters detected in Mordecai Island sediment that exceeded New Jersey residential or non-residential soil cleanup criteria.

For site specific biological and environmental information see the report by Tetra Tech, Inc. titled “Sediment Quality Analysis for Maintenance Dredging and Beneficial Use of Dredged Material within the New Jersey Intracoastal Waterway (Mordecai Island, Avalon, and Stone Harbor)” in Appendix A: Engineering Technical Appendix.

3.4 Coastal Processes

A number of coastal hydraulic processes affect Mordecai Island. Drivers of shoreline erosion at Mordecai Island include wind, wind and boat-generated waves, tides, tidal currents, sea level change, and sediment transport. These critical elements along with other coastal processes are described below.

3.4.1 Climate

The climate in the study area is principally continental in character. However, the moderating influence of the Atlantic Ocean is apparent throughout the year. As a result, summers are relatively cooler and winters relatively milder than elsewhere at the same latitude. The mean temperature during the summer months varies from the mid 60’s to the mid 70’s. Precipitation is moderate and well distributed throughout the year, with June the driest month and August the wettest, on average. Tropical storms and hurricanes occasionally bring excessive rainfall to the area. The bulk of winter precipitation results from storms that move northeastward along the east coast of the United States.

3.4.2 Winds

Long-term systematic wind and climate data are available from two nearby locations; the Coast Guard Facility located 15 miles south in Atlantic City, NJ and the Jacques Cousteau National Estuarine Research Reserve located 11 miles west of Mordecai Island in Tuckerton, NJ. An analysis of local wind directions and speed was done using data collected from October 2002 to October 2018 at the Jacques Cousteau National Estuarine Research facility by ERDC for purposes of developing a STeady-state WAVE (STWAVE) wind-wave model for the study area, as summarized in Section 3.4.3.

The record used consisted of 15 minute intervals of wind speed and direction. Winds were subset by seasons for purposes of comparison, e.g. winter was the months of December, January, and February. Wind roses showing the frequency of magnitude and direction associated with each season are provided in Figure 3.3. (A wind rose is a graphical chart that characterizes the speed and direction of winds at a location.)

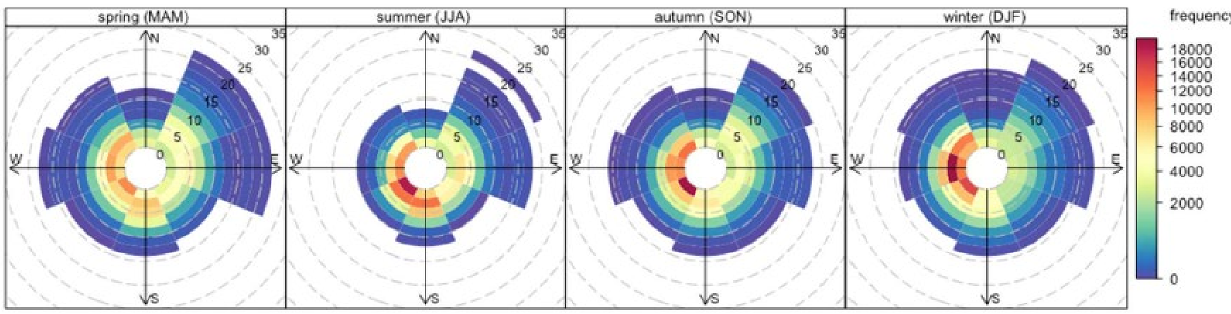


Figure 3.3: Seasonal Wind Frequency Plots

Three major hurricane landfall events were also used as subsets to determine major storm winds and estimate their wave generation. The selected storms were hurricanes Isabel, Irene, and Sandy with landfall dates of September, 13 2003, August 27, 2011, and October 29, 2012, respectively. The corresponding subset included the 24 hours pre- and post-landfall. A wind rose showing the wind conditions associated with these storms is provided in Figure 3.4. Based on their frequency of occurrence, the seasonal and storm wind conditions in Table 3.1 were selected for modeling.

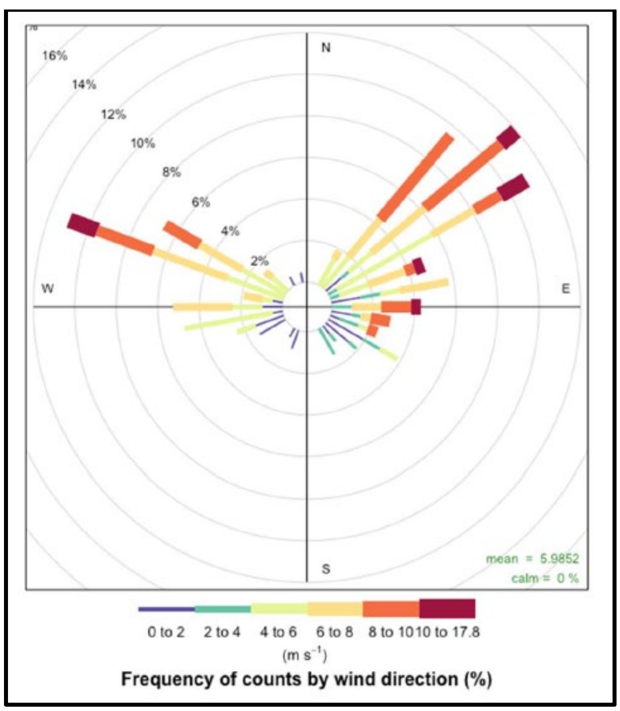


Figure 3.4: Wind Rose of Storm Events

Table 3.3: Modeled Wind Conditions

Event	Condition Description	Wind Speed (mph)	Wind Direction (deg.)
Spring	Average	4.5	220.0
	High	26.8	60.0
Summer	Average	4.5	230.0
	High	17.9	60.0
Fall	Average	4.5	230.0
	High	22.4	40.0
Winter	Average	6.7	270.0
	High	11.2	190.0
Storm	From West	22.4	290.0
	From Northeast	17.9	60.0

3.4.3 Waves

Wind Waves: Waves within the study area can be either wind-generated or caused by boat wakes. ERDC conducted a wave assessment for Mordecai Island and vicinity. The purpose of the assessment was to determine the wave heights near Mordecai Island that could be accounted for by wind moving across the large fetch to the west of the island across Barnegat Bay. The STWAVE model (Massey et al. 2011), which is a phase-averaged spectral model for wave generation, propagation and transformation, was used to estimate the local wind-wave climate.

In order to capture the wind fetch lengths to which Mordecai Island is exposed, a STWAVE grid was developed to encompass the entire southern complex of Barnegat Bay. The topography and bathymetry data to populate the STWAVE domain was obtained from two sources, the 2015 United States Geologic Survey (USGS) CoNED Topobathymetric Model (1888-2014) and the 2017 Corps National Coastal Mapping Program (NCMP) Topobathy Lidar Digital Elevation Model (DEM). The USGS CoNED model was resampled to a 10-m resolution and served as the base elevation data because of its comprehensive coverage of the entire model domain. Bathymetry and topography, including that of Mordecai Island, were then updated with the resampled 5-m Corps NCMP Lidar DEM. The STWAVE domain and inset of Mordecai Island, including the ten points where wave height, peak wave period, and mean wave direction output were saved along its western edge, is shown overlaid on aerial imagery in Figure 3.5.

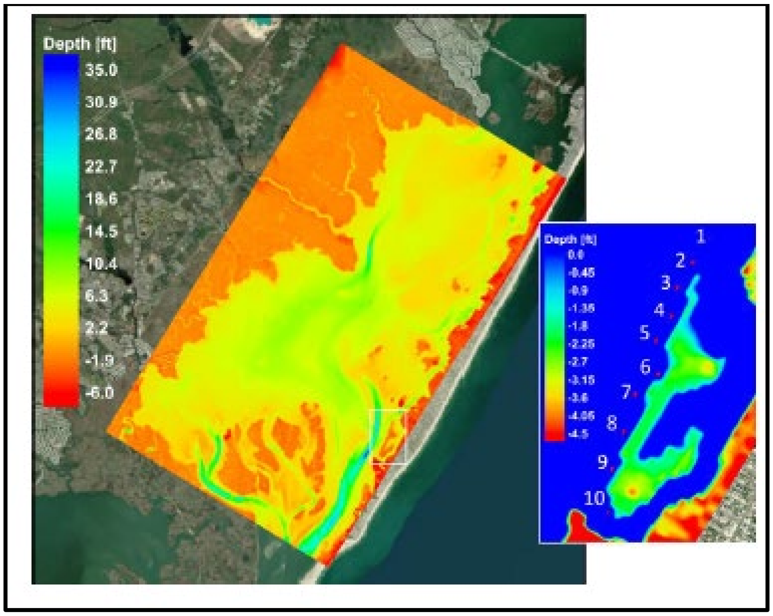


Figure 3.5: STWAVE Domain and Output Locations

The STWAVE model results showed that the average wind conditions for the Spring, Summer, and Fall produced nearly calm wave conditions characterized by wave heights less than 0.2 ft. in the vicinity of Mordecai. The peak wave periods throughout the domain were very short, less than 1.5 sec, and were near or at the minimum frequency resolved by the model. The average wind condition for the Winter yielded slightly larger waves than the average winds for the Spring, Summer, and Fall because of the slightly higher wind magnitude and a wind direction more directed at the island. For the Winter average wind, waves just offshore of northern Mordecai were less than 0.5 ft., with smaller wave heights along the south of Mordecai due to sheltering by the islands to its west. Again, wave periods were short, around 1.5 sec. It is important to note that the wave energy in sheltered areas can be underestimated because wave diffraction is not included in STWAVE.

The Spring high, Summer high, and Fall high are all wind conditions blowing out of the northeast. Model results showed that northeastern winds grew the largest waves, ranging from 1.0 to 1.6 ft. and periods up to 3.5 sec, depending on the wind magnitude, in the southwestern bay due to the uninterrupted fetch. However, waves along the western edge of Mordecai Island were computed to be smaller due to the wind direction blowing away from the island and sheltering by islands to the its north. The wave heights offshore of Mordecai Island were computed to be less than 0.7 ft., with peak periods of less than 2.0 sec. The Winter high wind condition produced smaller wave heights than the Spring, Summer, and Fall high wind conditions due to its smaller wind magnitude and direction out of the southeast; wave heights and peak periods in the vicinity of Mordecai Island were computed in the model to be less than 0.3 ft. and 1.5 sec, respectively.

The storm wind conditions simulated in the wave modeling generated a more energetic wave climate near Mordecai Island than the seasonal wind conditions. Whereas the storm wind condition from the northeast generated wave heights and peak periods of approximately 0.3 ft. to 0.5 ft. and 1.5 sec, respectively, the storm wind condition from the west grew waves along an uninterrupted fetch against the western coast of Mordecai Island. This condition resulted in the largest waves, considering all the simulations with maximum wave heights of approximately 1.5 ft. and peak periods of 2.0 – 2.5 sec.

In summary, the wave energy in the vicinity of Mordecai Island was found to be low for the seasonal wind simulations due to low wind magnitudes and directions generally along the north-south axis of the bay (e.g., waves are travelling roughly parallel to or away from the island, sheltering from other island groups). The southern portion of Mordecai Island is sheltered by the islands to its west. Again, the wave energy in sheltered areas can be underestimated because STWAVE does not account for diffraction. The largest waves, those exceeding 1.0 ft., were generated by the storm condition of 22.4 mph blowing directly at the island from the west over the uninterrupted fetch of the bay.

Boat Wakes: Wave characteristics generated from vessels traveling in the adjacent NJIWW were also examined. Unlike for wind-generated waves, no detailed modeling was done to simulate the potential wave climate from vessels travelling adjacent to Mordecai Island in the NJIWW or surrounding waters. Nor did study resources allow for a high-resolution recreational boating traffic study to be done that could have tracked the number of boats that pass by Mordecai Island on an average day, boat types, speed, and traffic patterns. Instead, an online literature review was done to ascertain typical wave heights generated by vessels that are common to the area.

Wakes from boats have been shown to have erosive effects on shorelines located near heavy traffic areas. Wave heights generated from boat traffic are a function of the boat length, hull type, water depth, and boat speed. The best predictor of the size of a boat-generated wave is the speed at which the boat travels (Sorenson, 1973). The maximum boat wake is produced at the point just before it transitions to planing. Several reports from the online literature review were found that related boat size and speed to wave heights.

Table 3.2 is a summary of wave heights from various types of boats and speeds and was taken from a 2017 report entitled. "*Review of Boat Wake Wave Impacts on Shoreline Erosion and Potential Solutions for the Chesapeake Bay*" done by the Scientific and Technical Advisory Committee for Chesapeake Bay Program. The table is originally from a 1973 American Society of Civil Engineers Waterways Harbors and Coastal Engineering journal article entitled "*Water Waves Produced by Ships*" by Sorenson.

Table 3.4: Typical Wave Heights from Various Boat Types and Speeds

Type of Boat	Distance from Sailing Line (ft.)	Speed of Boat (knots)	Maximum Wave Height (ft.)
26 ft. Uniflight (Planing Hull)	330	10	1.33
	330	26	1.00
	490	10	1.25
	490	27	0.75
16 ft. Boston Whaler (Planning Hull)	164	10	0.75
	164	24	0.50
	490	12	0.50
	490	27	0.25
45 ft. Tugboat (Displacement Hull)	98	6	0.75
	98	10	1.50
	490	6	0.20
	490	10	1.00

In addition to the Chesapeake Bay Boat Wake Analysis, another report from NOAA in 2012 entitled "*Boat Wakes and Their Influence on Erosion in the Atlantic Intracoastal Waterway, North Carolina*" was reviewed for applicable information. The analysis was done per request of the Wilmington District of the Corps of Engineers in order to develop a prototype boat wake model that could predict wave conditions and potential seafloor erosion zones and shear stresses at Snow Cut, NC based upon input of a boat hull type, length, speed, and sailing line. Wave data and a detailed boat traffic study was collected in order to test and validate the results from the boat wake model. Two different boat lengths (23 ft. and 53 ft.) at three different speeds (3, 10, and 20 knots) were used for the model based upon typical small and large boats that are common to the area. Maximum boat-generated wave heights varied from 0.25 ft. for the 23 ft. boat travelling at 3 knots to 1.5 ft. for the 53 ft. boat travelling 10 knots.

In summary, the literature review of boat-generated wave heights indicated that for boats common to the Mordecai Island study area, typical maximum wave heights varied from 0.25 ft. to 1.5 ft. Given the results of ERDC's STWAVE wave model of wind-generated waves, boat-generated wave heights can be expected to be at the same level of magnitude or slightly larger than the wind-generated waves impacting Mordecai Island on a day-to-day basis.

3.4.4 Tides

The tides affecting the study area are semi-diurnal with two nearly equal high tides and two nearly equal low tides per day. The average tidal period is 12 hours and 25 minutes, such that two full tide cycles require slightly more than one day, or 24 hours and 50 minutes. Therefore, high and low tides occur almost one hour later than the previous day.

The tidal benchmarks adopted for the study area were taken from NOAA station 8534208 (Beach Haven Coast Guard Station), which is just south of Mordecai Island. NOAA's "VDatum" program was used to transform the tidal datums to NAVD88 at Mordecai Island. Table 3.5

summarizes the 1983 – 2001 tidal epoch datums relative to MLLW and NAVD88 from NOAA's web page https://tidesandcurrents.noaa.gov/stationhome.html?id=8534208

Table 3.5: Mordecai Island Tidal Datums

Datum	Description	Elevation (ft. MLLW)	Elevation (ft. NAVD88)
MHHW	Mean Higher-High Water	2.54	1.35
MHW	Mean High Water	2.26	1.07
MTL	Mean Tide Level	1.19	0.00
MLW	Mean Low Water	0.11	-1.08
MLLW	Mean Lower-Low Water	0.00	-1.19

The USGS operates several tidal stations in Barnegat Bay. The two closest stations to Mordecai Island are USGS Station 01409335, Little Egg Inlet near Tuckerton, NJ and USGS Station 01409146, East Thorofare at Ship Bottom, NJ. These stations are located five miles south and seven miles north of Mordecai Island respectively. Figure 3.6 shows tides during typical non-storm conditions (Oct. 6-9, 2018) for NOAA's Atlantic City open coast station and for the two USGS tidal stations in the vicinity of Mordecai Island.

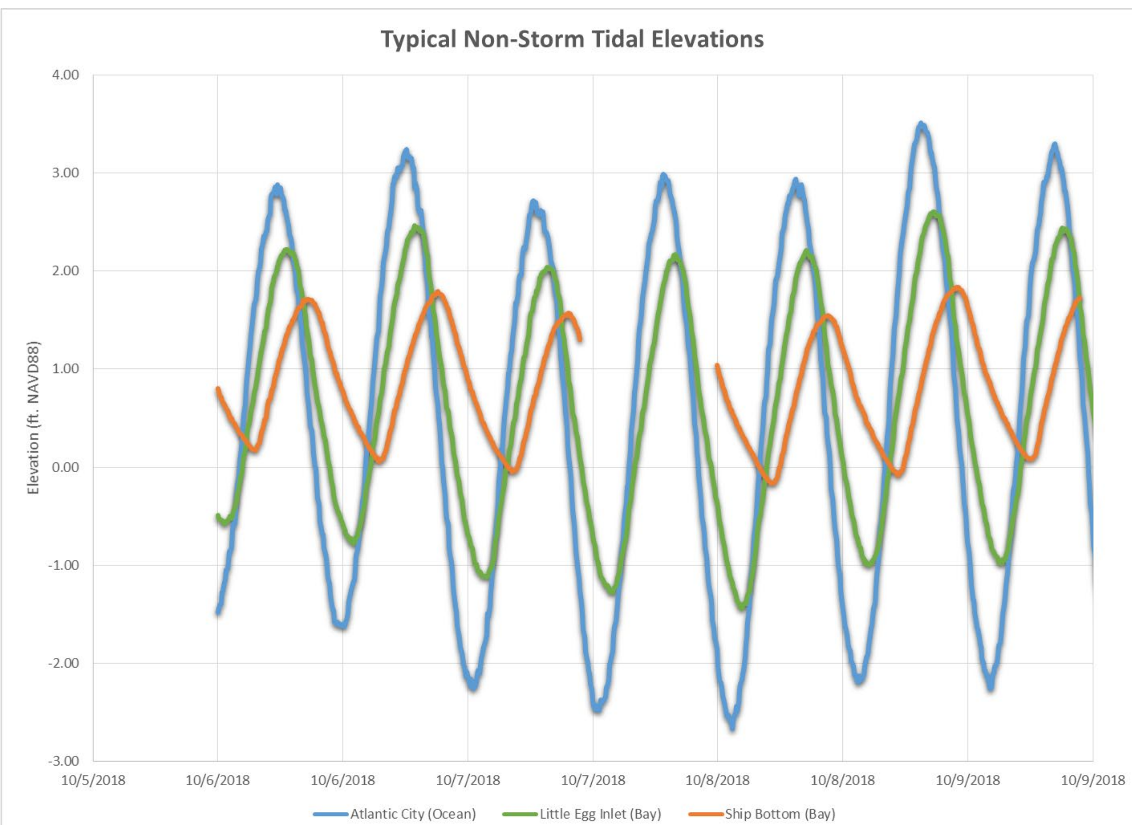


Figure 3.6: Typical Non-Storm Tidal Elevations in Vicinity of Mordecai Island

The figure shows that the tidal range in Barnegat Bay, including at Mordecai Island, is greatly influenced by the geography, the hydraulic resistance of the marshes and both Little Egg Inlet and, to a lesser extent due to it being further away, Barnegat Inlet. All these factors result in time lags and dampened tide heights compared to tides at the open coast like at Atlantic City.

3.4.5 Tidal Currents

Tidal current information was obtained from NOAA Tidal Current Tables. They are generally reported for subordinate stations at select inlets and bay bridge crossings. Information within the study area at Mordecai Island itself in Barnegat Bay is sparse. The closest inlets to Mordecai Island are Little Egg Inlet, which is approximately five miles south, and Barnegat Inlet, which is approximately sixteen miles north. Little Egg Inlet is not a subordinate station location but Barnegat Inlet is. NOAA also has a subordinate station located at the Manahawkin Drawbridge in Barnegat Bay, which is seven miles north of Mordecai Island. Currents are highly variable and are related to the hydraulic coupling of Little Egg and Barnegat Inlets as well as interaction with waves. At Barnegat Inlet the maximum flood current is 2.2 knots and the maximum ebb current is 2.5 knots. At the Manahawkin Drawbridge in Barnegat Bay the maximum flood and ebb currents are understandably less, given its location relative to the inlets, at 1.1 and 0.9 knots respectively. Tidal currents at Mordecai Island would be expected to be similar or slightly larger than the currents at the Manahawkin Drawbridge given that Mordecai Island is closer to Little Egg Inlet.

3.4.6 Storm Surge

Storm surge is the increased water level above the predicted astronomical tide due to storm winds over the bay and the resultant wind stress on the bay surface. The magnitude of the storm surge is calculated as the difference between the predicted astronomic tidal elevation and the actual water surface elevation at any time. These components of water level and current must be added to the ambient sources of currents and wave set-up to determine the cumulative conditions at a given location.

Storms of two basic types present a significant threat to the study area; tropical cyclones (i.e., hurricanes) or extra-tropical cyclones (“nor’easters”). Both types can cause erosion due to high tides and increased wave heights as well as deposition of sediment within channels. Although the meteorological origins of the two types of storms differ, both can generate large, low-pressure atmospheric systems with intense wind fields that rotate counter-clockwise (in the northern hemisphere).

3.4.7 Sea Level Change

In accordance with Corps Engineering Regulation (ER) 1100-2-8162, potential effects of sea level change (SLC) were analyzed over a 50-yr economic analysis period and a 100-yr planning horizon. Research by climate science experts predict continued or accelerated climate change for the 21st century and possibly beyond, which would cause a continued or accelerated rise in global mean sea level. ER 1100-2-8162 states that planning studies will formulate alternatives over a range of possible future rates of SLC and consider how sensitive and adaptable the alternatives are to SLC. ER 1100-2-8162 requires that planning studies and engineering designs consider three future sea level change scenarios: low, intermediate, and high. The historic rate of

SLC represents the "low" rate. The "intermediate" rate of SLC is estimated using the modified National Research Council (NRC) Curve I. The "high" rate of SLC is estimated using the modified NRC Curve III. The "high" rate exceeds the upper bounds of Intergovernmental Panel on Climate Change (IPCC) estimates from both 2001 and 2007 to accommodate the potential rapid loss of ice from Antarctica and Greenland, but it is within the range of values published in peer-reviewed articles since that time.

Historical SLC adopted for Mordecai Island (4.07 mm/yr) is based on NOAA tidal records at Atlantic City, NJ. Figure 3.7 shows historical SLC at Atlantic City from 1992 to 2019. Several metrics for sea level are presented, the monthly mean sea level (light blue), 5-year moving average (orange), and 19-year moving average (dark blue). It is apparent that over longtime scales (19 years) mean sea level is steadily increasing. However, over shorter time scales mean sea level may increase or decrease.

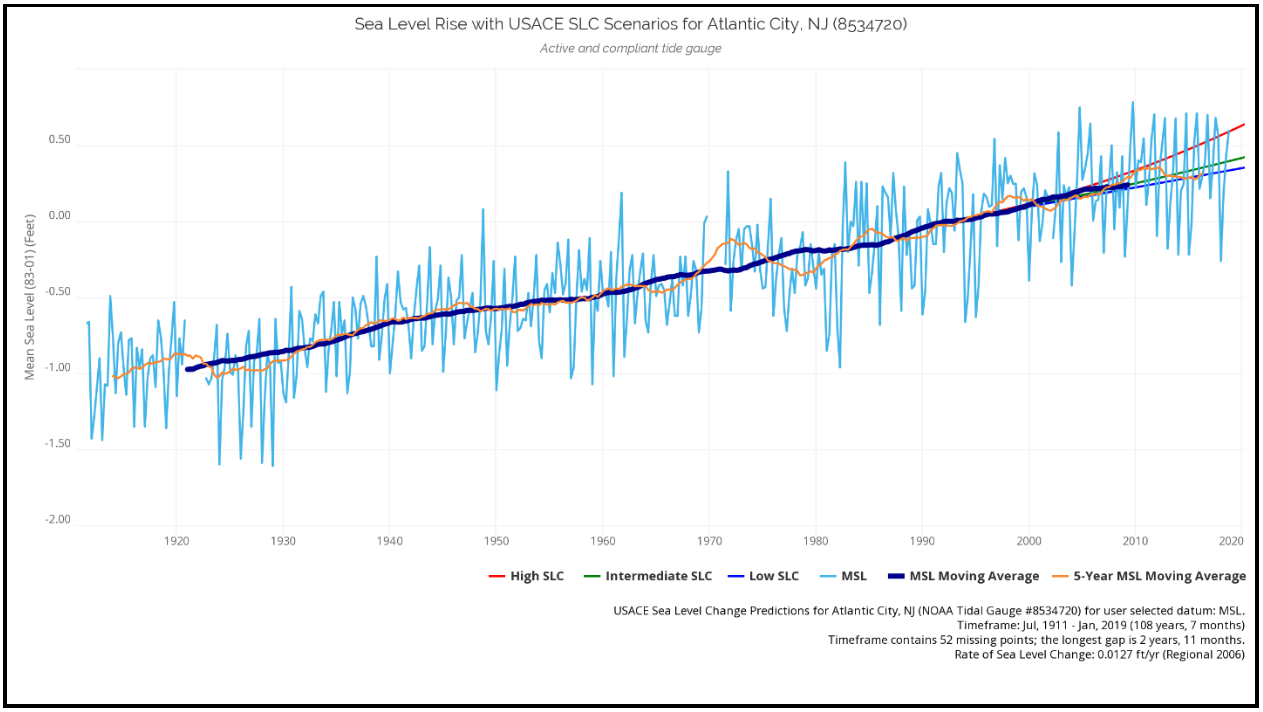


Figure 3.7: Historic Relative Sea Level Change at Atlantic City, NJ

The monthly mean sea level, light blue line in Figure 3.7, appears to go up and down every year, capturing the seasonal cycle in mean sea level. The 5-year moving average, orange line in Figure 3.7, captures the inter-annual variation (2 or more years) of sea level.

Corps low, intermediate, and high SLC scenarios over the 100-yr planning horizon derived from Atlantic City, NJ are presented in Table 3.4 and Figure 3.8. Water level elevations at year 2030 are expected to be between 0.5 and 1.0 ft. higher than the current National Tidal Datum Epoch (NTDE) of 1983-2001. Water elevations at year 2080 are expected to be between 1.15 and 4.02 ft. higher than the current NTDE. Future water levels are determined by adding the SLC values in Table 3.4. For example, a water level elevation of 10 ft. NAVD88 based on the current NTDE, will have an elevation in the year 2080 of 11.15, 11.84, and 14.02 ft. NAVD88 under the Corps low, intermediate, and high SLC scenarios respectively.

Table 3.6: Corps Sea Level Change Scenarios (Derived from Atlantic City, NJ)

Year	Corps Low (ft. NAVD88)	Corps Intermediate (ft. NAVD88)	Corps High (ft. NAVD88)
1992	0.00	0.00	0.00
2000	0.11	0.11	0.13
2019	0.35	0.42	0.62
2030	0.50	0.63	1.03
2040	0.63	0.83	1.48
2050	0.76	1.06	2.01
2060	0.89	1.30	2.60
2070	1.02	1.56	3.28
2080	1.15	1.84	4.02
2090	1.28	2.14	4.84
2100	1.41	2.44	5.74
2110	1.55	2.78	6.71
2120	1.68	3.13	7.75
2130	1.81	3.50	8.87
Difference 2019 - 2080	0.80	1.42	3.40

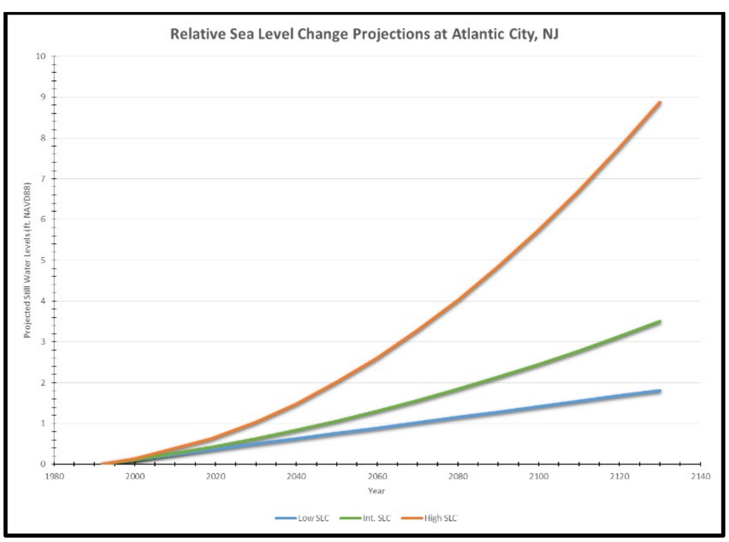


Figure 3.8: Relative Sea Level Change Projections at Atlantic City, NJ

3.4.8 Sediment Transport

Sediment offshore of Mordecai Island can be from several sources:

- Natural long-term erosion/weathering of Mordecai Island itself
- Overtopping of Mordecai Island by waves during severe storms.
- Weathering of nearby islands in Barnegat Bay and transported offshore of Mordecai Island by tidal currents
- Upland sediment sources transported down the rivers of Barnegat Bay Watersheds

An offshore bathymetric change analysis was conducted off the western coastline of Mordecai Island to see if there has been any significant natural scouring or deposition in the nearshore from Mordecai Island erosion itself or from other sources. Bathymetric survey data collected in 2003, 2008, 2011, and 2019 was used in the analysis and the extent of the analysis was limited to the offshore area where coverage from all five survey dates overlapped. Digital elevation models were created from each survey as shown in the contour plots of Figure 3.9 to Figure 3.12.

Figure 3.9: July 2003 Offshore Bathymetry

Figure 3.10: June 2008 Offshore Bathymetry

Figure 3.11: May 2011 Offshore Bathymetry

Figure 3.12: January 2019 Offshore Bathymetry

As Figures 3.9 to 3.12 show, offshore bathymetry within the mapped boundaries varied between -3.0 ft. NAVD88 close to Mordecai Island to -13.0 ft. NAVD88 further offshore at the NJIWW. Even though the minimum and maximum depths did not change much between 2003 and 2019, the contours show that there has been some sediment movement offshore of Mordecai Island.

Volumetric changes within the boundaries of the offshore bathymetric surfaces were quantified and compared for each survey year to see if there were any volumetric trends and to quantify annualized offshore deposition and scour rates (Table 3.7).

Table 3.7: Offshore Volumetric Change Summary

Date	Min. Depth (ft. NAVD88)	Max. Depth (ft. NAVD88)	Avg. Depth (ft. NAVD88)	Water Column Volume (cu yd.)	Total Volume Change (cu yd.)	Annual Volume Change (cu yd.)	Trend
July 2003	-11.00	-2.80	-7.20	394,153			
					-89,169	-17,834	Overall Scouring
June 2008	-12.70	-4.80	-8.90	483,322			
					78,281	26,094	Overall Deposition
May 2011	-10.80	-3.50	-7.40	405,041			
					-28,653	-3,820	Overall Scouring
Jan 2019	-12.70	-3.80	-8.00	433,694			
TOTAL 2003 – 2019					-39,541	-2,551	Overall Scouring

As Table 3.5 shows, offshore of Mordecai Island goes through periods of scouring and deposition with the net difference basically cancelling each other out. Minimum, maximum and average depths remained relatively stable from 2003 to 2019, also the annual volume change (scour) is relatively small at 2,551 cu yd. per year.

Visualization of the difference between 2003 and 2019 was done by subtracting the bathymetric surface DEM from the Jan. 2019 survey from the July 2003 bathymetric surface DEM as shown in Figure 3.13. The figure shows where offshore are areas of deposition (positive) and areas of scour (negative).

Figure 3.13: Changes in Offshore Bathymetry 2003 - 2019

Figure 3.13 shows that over the past 16 years there have been scour areas up to 4.0 ft. off the southwest portion of the island and in the northwest portion adjacent to the NJIWW channel. Only one area adjacent to the island showed deposition over the 16 years and it is located west of the breach where sand was placed as part of the 2015 beneficial use of dredged material project by Philadelphia District Operations Division.

Even though the western shoreline of Mordecai Island has been retreating and eroding (refer to Section 4.2.2), there is no indication that within the boundaries of this bathymetric analysis there is a significant accumulation of material which would result in shallower depths. This analysis also shows that there does not appear to be a large influx of material coming from elsewhere to offshore of Mordecai Island's western shoreline. This information is useful to know to evaluate potential natural sediment accumulation that could occur in the future leeward of an offshore breakwater, for example, and if an initial fill leeward of such a structure should be considered.

However, this analysis does not include the area immediately offshore the western shoreline of the island (above elevation -3.0 ft. NAVD88) due to lack of survey coverage because of depths being too shallow for a survey boat. The analysis of this nearshore area had to be limited to a cross-section analysis of the May 2011 and January 2019 surveys and is discussed in the Section 4.2.2.

3.5 Vegetation

3.5.1 Subtidal Vegetation (Submerged Aquatic Vegetation and Algae)

Submerged aquatic vegetation (SAV) are rooted vascular flowering plants that exist within the water column and are exposed to sunlight in subtidal waters (below the low tide line) of the study area. SAV provide important food and cover resources for a variety of species including threatened and endangered sea turtles, small fish, shellfish, and other invertebrates. Lacey (2016) concluded that underwater vegetated habitat in Barnegat Bay has been declining since the early 2000s (as cited in Kennish et al. [2008, 2010, 2012] and Fertig et al. [2013]). SAV surveys were conducted in the waters surrounding Mordecai Island in 2003, 2018, and 2019 (Versar 2004, Davis and Gianneli 2018, Davis per. Comm., USFWS pers. Comm 2019).

In 2003, a comprehensive survey of SAV and potential SAV habitat was conducted using aerial photography in the shallow waters surrounding the island. Approximately 64.5 acres of SAV beds were identified and delineated by photointerpretation of the SAV signatures on film around the periphery of Mordecai Island. Figure 3.14 provides a map of the aerial survey results for SAV in the vicinity of Mordecai Island. Only one SAV species, *Zostera marina* (eelgrass), was present. A total of 30.7 % of the SAV cover was categorized as sparse, followed by moderate (27.1%), dense (26.7%), and very sparse (15.5%). Areas with the least dense SAV beds were generally found in deeper water and in areas that experience substantial boat traffic and other disturbances. SAV cover around the western periphery of Mordecai Island was mapped as sparse and moderately dense in most areas; most of which was in a 50 to 60-ft.-wide band. The densest SAV was mapped in one large irregularly shaped parcel on the eastern side of the island (Versar 2004).

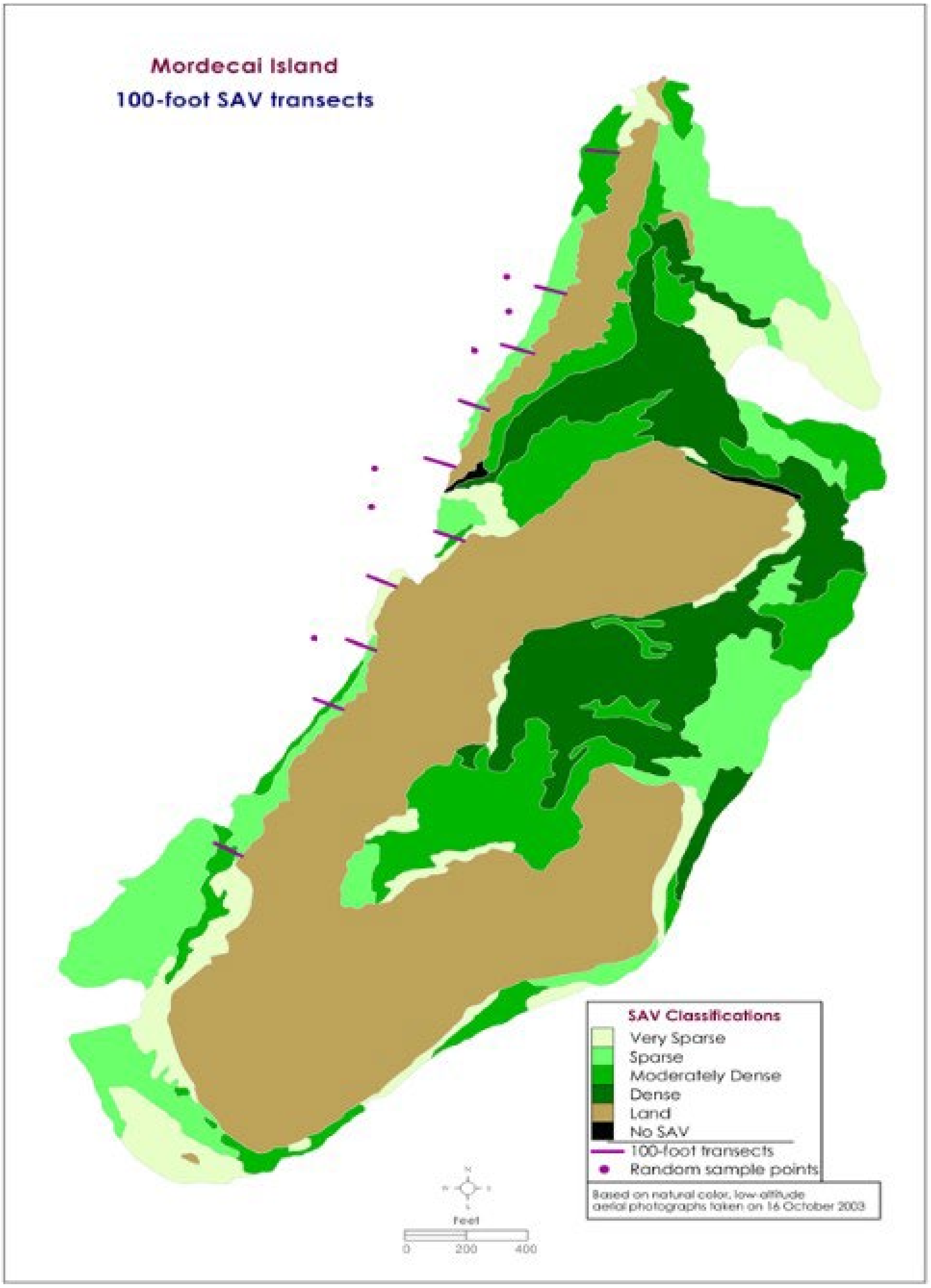


Figure 3.14: 2003 Aerial SAV Survey Results in the Vicinity of Mordecai Island (Versar 2004)

Additional SAV surveys were conducted by NOAA-NCCOS in 2018 and 2019 as part of a program to monitor changes associated with Corps and MLT 2015 restoration efforts (which are described in Section 2 of this report). In 2018, NOAA-NCCOS used "drop-camera" underwater photography and stratified random sampling to sample SAV around Mordecai Island (Davis and Gianneli 2018). SAV were only present with algae at 5 of the 60 stations sampled, while only brown and green algae were present at 18 stations (Davis and Gianneli 2018). Vegetation was present at 22 stations but type “undeterminable” based on the quality of the image (but hypothesized to be algae, which was supported by benthic grab samples). “Image quality was too low to verify the presence or absence of vegetation and 5 stations were uninterpretable.” Three sites were unvegetated; these occurred on the west side of the island south of the Corps sediment placement in water depths of 3 to 6 ft (Davis and Gianneli 2018). Figure 3-15 summarizes these results. *Zostera marina,* which is known to be the dominant seagrass in the area, “appeared to be present” (Davis and Gianneli 2018).

In 2019, NOAA-NCCOS modified their methods and use a towed, sled-mounted camera at randomly selected locations and “concentrated their efforts in the nearshore waters on the west side of the island.” These results indicate that, “macroalgae was generally more abundant than SAV. Total percent cover of both algae and SAV dropped off dramatically with distance from shore.” (Davis pers. comm.).

Figure 3.15: 2018 and 2019 NOAA-NCCOS Subtidal Vegetation Survey Results (NOAA-NCCOS pers. comm.)

Additionally, USFWS and MLT conducted a SAV survey via snorkeling in 2018. During the survey, the team collected depth and percent cover of SAV, macroalgae, and sediment in 1-square meter quadrats along 10 transects. The results of this survey are presented in Figure 3.16. Incidental observations conducted after the survey found the densest SAV beds near the oyster castles (Mcculloch, pers. comm.).

Figure 3.16: 2018 USFWS and MLT SAV Survey Results

3.5.2 Upland Vegetation

The primary upland wildlife vegetated habitat present within the Mordecai Island study area is scrub/shrub. Scrub shrub habitat is commonlyfound at the transition from high marsh to uplands in the New Jersey coastal environment. Only a small portion (approximately 6 acres) of Mordecai Island is composed of scrub/shrub upland habitat. Vegetation in these areas includes switchgrass (*Panicum virgatum*), bayberry (*Myrica pensylvanica)*, eastern red cedar (*Juniperus virginiana*), winged sumac (*Rhus copallina*), and common reed (*Phragmites australis*). Scrub shrub communities are an important component of the open water/tidal marsh/upland transition, providing habitat for numerous species of birds and mammals that utilize these areas. As described in Section 2.1.1, the highest zone of the 2015 breach fill placement area on Mordecai Island was originally planned to be planted with native scrub shrub habitat but was being utilized by beach nesting birds. As a result, no shrubs were planted and it has since transitioned into habitat for beach nesting birds and diamond back terrapins. The Mordecai Land Trust has also reported the presence of *Phragmites australis* in this area.

3.6 Intertidal Vegetation and Wetlands

Wetlands play a vital role in the overall well-being of coastal ecosystems. Wetland habitats within the study area include the following:

- bay and mudflats,
- low saltmarsh,
- high saltmarsh,
- common reed or phragmites(tidal/upland).

Many plants and animals depend on wetlands and intertidal vegetated habitat for survival, including threatened and endangered species. Wetlands provide a nursery habitat for many commercially and recreationally important fish species that are harvested outside the wetland. Wetlands also play an important role in flood protection. The roots of wetland plants help bind the shoreline together, resisting erosion by wind and waves and providing a physical barrier that slows down storm surges and tidal waves, thereby reducing their height and destructive power. The wetland areas around Mordecai Island consist of approximately 40 acres of high and low salt marsh composed of mixed salt marsh vegetation (*Spartina alterniflora*, *Spartina patens*, *Distichlis spicata*, *Salicornia bigelovi*, etc.) and additional tidal mudflats. NOAA-NCCOS 2017 and 2018 sampling on Mordecai Island indicates that “the intertidal vegetative community of Mordecai Island is typical of U.S. east coast salt marshes” (Davis and Dubick 2017, Davis et al. 2018).

Low saltmarsh habitats are generally dominated by saltmarsh cordgrass (*Spartina alterniflora*), the dominant saltmarsh plant species in the northeastern United States (Mitsch and Gosselink, 1993). This is also the case with Mordecai Island, although bladder wrack (*Fucus vesiculosis*) is also present where mussels were present (Davis et al. 2018). These species grow in the intertidal zone between low and high tide line and are subject to daily tidal inundation. Wildlife species utilizing the low saltmarsh habitats include birds such as clapper rails (*Rallus longirostris*), waterfowl, and other species that feed on insects, crabs and other invertebrates that this community supports. The low marsh and tidal channel complex provides significant habitat for numerous fish species that depend on estuaries for nursery and spawning grounds, as well as smaller resident fish such as mummichog, killifish and silversides (Mitsch and Gosselink, 1993; Tiner, 1985).

The high saltmarsh at Mordecai Island is also a typical high saltmarsh community with *Spartina alterniflora* reduced compared to the low saltmarsh (Davis et al. 2018). High saltmarsh habitats are generally found near the mean high tide level, and are generally dominated by saltmarsh hay (*Spartina patens*) and seashore saltgrass (*Distichlis spicata*). High saltmarsh provides habitat for many of the same species found in the low tidal marsh areas. However, since high saltmarsh is inundated far less regularly than the low saltmarsh, waterfowl such as black ducks (*Anas rubripes*) and mallards (*Anas platyrhynchos*) may breed within this habitat.

3.7 Fisheries

The coastal waters of New Jersey are reported to support up to 107 species of fish during part or all of their life cycle (BBEP, 2001; Tatham et. al., 1984). Of these, 61 species have been studied extensively regarding their role and presence in estuarine habitats (Able and Fahey, 1998). The great diversity of fish fauna found in estuarine habitats includes both resident and transient species. Species habitat use is best understood in terms of life history, as many fish species occupy estuarine habitats only during certain life stages. Several fish species are continuously present in coastal habitats, while others are present only during certain periods (e.g. during spring many fish species use specific habitats for spawning). Thus, the distribution and abundance of important indicator fish species vary both temporally and spatially. Estuarine environments are extremely important to wide number of fish species because of the multitude of niche environments available to fish. Certain fish species utilize shallow water vegetated habitats for spawning while others migrate out to open water to distribute their eggs as planktonic forms. Similarly, some larval fish species migrate from open water as they develop and enter highly productive estuarine environments to grow and develop into juvenile stages. In this respect estuaries provide ample amounts of both food and protection for larval and juvenile stages of fish (Able and Fahey, 1998). Fish species identified in the study area by sampling conducted by Richard Stockton College in 2001 (Stockton 2001 pers. comm.) included: tautog (*Tautoga onitis*), northern puffer (*Sphoeroides maculatus)*, northern pipefish (*Syngnathus fuscus*), winter flounder (*Pseudopleuronectes americanus*), summer flounder (*Paralichthys dentatus*), Atlantic silverside (*Menidia menidia*), cunner (*Tautogolabrus adspersus*), threespine stickleback (*Gasterosteus aculeatus*), striped killifish (*Fundulus majalis*), mummichog (*Fundulus heteroclitus*), alewife (*Alosa pseudoharengus*), weakfish (*Cynoscion regalis*), bay anchovy (*Anchoa mitchilli*), American eel (*Anguilla rostrata*), northern sennet (*Sphyraena borealis*), striped burrfish (*Chilomycterus schoepfi*), and bluefish (*Pomatomus saltatrix*).

3.7.1 Essential Fish Habitat

Under provisions of the Magnuson-Stevens Act, areas along the Atlantic coast, including the proposed study area are designated as Essential Fish Habitat (EFH) for species with Fishery Management Plans (FMPs). A query of the NMFS EFH Mapper was conducted to determine the species and life stages with EFH designated in the study area (NMFS 2020a). This list was further refined by excluding all species and life stages that did not have EFH designated within bays, estuaries, or inshore waters. The study area contains EFH for various life stages for 21 species of managed fish. Table 3-8 presents the managed species and their life stage that EFH is identified for the Mordecai Island (Barnegat Bay) study area. Table 3-9 presents habitat utilization of identified EFH species in the Mordecai Island study area.

Table 3.8: Summary of Essential Fish Habitat (EFH) Designation for Mordecai Island Project, Barnegat Bay Area

Species	Eggs	Larvae	Juveniles	Adults
Red hake (*Urophycis chuss*)	X	X	X	
Winter flounder (*Pleuronectes americanus*)	X	X	X	
Little skate (*Leucoraja erinacea*)	n/a	n/a	X	X
Ocean pout (*Zoarces americanus*)	X			X
Windowpane flounder (*Scophthalmus aquosus*)	X	X	X	X
Atlantic herring *(Clupea harengus)*			X	X
Silver hake (*Merluccius bilnearis*)	X	X		
Winter skate (*Leucoraja ocellata*)			X	X
Clearnose skate (*Raja eglanteria*)			X	X
Spiny dogfish (*Squalus acanthias*)			Sub-adult female	X
Bluefish (*Pomatomus saltatrix*)			X	X
Atlantic butterfish (*Peprilus triacanthus*)			X	X

Longfin inshore squid (*Doryteuthis pealeii*)	X		X	X
Summer flounder (*Paralichthys dentatus*)		X	X	X
Summer flounder (*Paralichthys dentatus*)			HAPC	
Scup (*Stenotomus chrysops*)	n/a	n/a	X	X
Black sea bass (*Centropristis striata*)	n/a	n/a	X	X
Smoothhound shark complex (Atlantic stock)		X	X	X
White shark (*Carcharodon car*charias)		X		
Sand tiger shark (*Odontaspis taurus*)			X	
Dusky shark (*Carcharhinus obscurus*)		X		
Sandbar shark (*Carcharhinus plumbeus*)		X	X	X

HAPC=Habitat Areas of Particular Concern; Source: NMFS 2020a.

Table 3.9: Habitat Utilization of Identified EFH Species Identified in the Mordecai Island Study Area (Barnegat Bay)

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
Red hake (*Urophycis chuss*)	Surface waters. Temps <10 C <25% salinity	Surface waters. Temps <19 C <25% salinity	Bottom habitats with shell fragments Temps <16 C 31-33% salinity	EFH for this life stage not designated in the study area

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
Winter flounder (*Pleuronectes americanus*)	Bottom habitats (muddy sand, sand, gravel). Temps <10 C 10-30% salinity <6 m depth	Pelagic and bottom waters. Temps <15 C 4-30% salinity <6 m depth	Bottom habitats (mud or fine grained sand) Temps <25 C 10-30% salinity 1-50 m depth	EFH for this life stage not designated in the study area
Little skate (*Leucoraja erinacea*)	N/A	N/A	Intertidal and subtidal sand, gravel, and mud in high salinity zones in bays and estuaries	Intertidal and subtidal sand, gravel, and mud in high salinity zones in bays and estuaries
Ocean pout (*Zoarces americanus*)	Sheltered nests, holes, or rocky crevices in high salinity zones in bays and estuaries	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area	Mud and sand, particularly in association with structure forming habitat types (i.e. shells, gravel, or boulders) in high salinity zones in bays and estuaries
Windowpane flounder (*Scophthalmus aquosus*)	Surface waters. Temps <20 C <70 m depth	Pelagic waters. Temps <20C <70 m depth	Bottom habitats (mud or fine grained sand) Temps <25 C 5.5-36% salinity 1-100 m depth	Bottom habitats (mud or fine grained sand) Temps <26.8 C 5.5-36% salinity 1-100 m depth
Atlantic herring *(Clupea harengus)*	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area	Pelagic waters and bottom habitats Temps <10 C 26-32% salinity 15-135 m depth	Pelagic waters and bottom habitats Temps <10 C >28% salinity 20-130 m depth
Silver hake (*Merluccius bilnearis*)	Surface waters year round. Temps <20 C >50 m depth	Surface waters year round. Temps <20 C >15 m depth	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area
Winter skate (*Leucoraja ocellata*)	N/A	N/A	Sand, gravel, and mud in high salinity zones in bays and estuaries	Sand, gravel, and mud in high salinity zones in bays and estuaries

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
Clearnose skate (*Raja eglanteria*)	N/A	N/A	Mud, sand, gravel and rock in high salinity zones in bays and estuaries	Mud, sand, gravel and rock in high salinity zones in bays and estuaries
Spiny dogfish (*Squalus acanthias*)	N/A	N/A	Female subadults: pelagic and epibenthic waters, in full salinity (32-35 ppt) typically lower water temperature (7 - 15 C) in winter and spring. Male subadults: pelagic and epibenthic waters, in full salinity (32-35 ppt) typically lower water temperature (7 - 15 C) in winter and spring; found in deeper water than females.	Female subadults: pelagic and epibenthic waters, in full salinity (32-35 ppt) typically lower water temperature (7 - 15 C) in winter and spring. Male subadults: pelagic and epibenthic waters, in full salinity (32-35 ppt) typically lower water temperature (7 - 15 C) in winter and spring.
Bluefish (*Pomatomus saltatrix*)	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area	Pelagic waters. Temps 19-24 C 23-36% salinity	Pelagic waters. Temps 14-16 C >25% salinity
Atlantic butterfish (*Peprilus triacanthus*)	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area	Pelagic waters. Temps 3-28 C 3-37% salinity 10-360 m depth (most <120)	Pelagic waters.
Longfin inshore squid (*Doryteuthis pealeii*)	Bottom habitat (e.g., shells, lobster pots, piers, fish traps, boulders, and rocks, SAV and	N/A	Pre-recruits: pelagic habitats bottom depths between 6 and 160 meters where bottom water temperatures are 8.5-	Recruits: pelagic habitats over bottom depths between 6 and 200 meters where bottom water temperatures are 8.5-14°C and salinities are 24-36.5 ppt.

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
	macroalgae, sand, and mud) with water temperatures are between 10°C and 23°C, salinities are between 30 and 32 ppt, and depth is less than 50 meters		24.5°C and salinities are 28.5-36.5 ppt	
Summer flounder (*Paralichthys dentatus*)	EFH for this life stage not designated in the study area	Pelagic waters. Temps 9-12 C 23-33% salinity 10-70 m depth	Demersal waters (mud and sandy substrate). Temps >11 C 10-30% salinity 0.5-5 m depth	Demersal waters (mud and sandy substrate). 0-25 m depth
Summer flounder (*Paralichthys dentatus*)	No HAPC designated for this life stage	No HAPC designated for this life stage	HAPC= all native species of macroalgae, seagrasses, and freshwater and tidal macrophytes in any size bed, as well as loose aggregations	No HAPC designated for this life stage
Scup (*Stenotomus chrysops*)	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area	Demersal waters. Temps >7 C >15% salinity 0-38 m depth	Demersal waters and inshore estuaries. Temps >7 C >15% salinity 2-185 m depth
Black sea bass (*Centropristis striata*)	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area	Demersal waters over rough bottom, shellfish and eelgrass beds. Temps >6 C >18% salinity 1-38 m depth	Demersal waters over structured habitat (natural and man-made) Temps >6 C >20% salinity 20-50 m depth
Smoothhound shark complex (Atlantic stock):	N/A	Inshore bays and estuaries.	Inshore bays and estuaries.	Inshore bays and estuaries.

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
smooth dogfish (*Mustelus canis*)				
White shark (*Carcharodon carcharias)*	N/A	Inshore waters	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area
Sand tiger shark (*Odontaspis Taurus*)	N/A	EFH for this life stage not designated in the study area	Shallow coastal waters to the 25 m isobath	EFH for this life stage not designated in the study area
Dusky shark (*Carcharhinus obscurus*)	N/A	Shallow coastal waters, inlets, and estuaries <25 m depth	EFH for this life stage not designated in the study area	EFH for this life stage not designated in the study area
Sandbar shark (*Carcharhinus plumbeus*)	N/A	Shallow coastal waters <25 m depth	Shallow coastal waters <25 m depth	Shallow coastal waters <50 m depth

Source: NMFS 2020a

The above-listed fish species are not estuarine resident species and therefore only utilize this area on a seasonal basis, primarily in the warmer summer months. During the summer months, the estuary is typically utilized as a forage area for juveniles and adults and as a nursery area for larvae and juveniles.

3.8 Wildlife Resources

Mordecai Island is an important haven for wildlife in Barnegat Bay. As described in Section 2.2.5, Mordecai Island provides habitat for the diamondback terrapin (*Malaclemys terrapin terrapin*). MLT has conducted diamondback terrapin relocation studies and has managed habitat on the island for terrapins (Budd 2019a). Mordecai Island is especially important for birds, most notably migratory shorebirds. The habitats on Mordecai Island provide breeding, foraging, nesting and resting areas for many species of migratory birds, including shorebirds, wading birds, raptors and waterfowl. More than 70 species of birds have been observed on Mordecai Island between 2017 and 2020 (Budd 2018, Budd 2019b, Budd 2020). Nine of these species, the black skimmer, least tern, bald eagle, osprey, yellow-crowned night heron, black-crowned night heron, red knot, and piping plover are included on the NJDEP state endangered and threatened species lists (Budd 2019b). The piping plover and red knot are also listed as Federally threatened.

Migratory bird species frequently observed in the Mordecai Island study area include (but are not limited to): great blue heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta* *thula*), common tern (*Sterna hirundo*), herring gull (*Larus argentatus*), great black-backed gull (*Larus marinus*), laughing gull (*Larus atricilla*), double-crested cormorant *(Phalacrocorax auritus*), belted kingfisher (*Ceryle alcyon*), American oystercatcher (*Haematopus palliatus*), mallard duck (*Anas platyrhynchos*), barn swallow (*Hirundo rustica*), red-winged blackbird (*Agelaius phoeniceus*), and American crow (*Corvus brachyrhynchos*) (Budd 2018, Budd 2019b).

Rodents such as white-footed mice (*Peromyscus leucopus*) and meadow voles (*Microtus pennsylvanicus*) may use high marsh habitat on Mordecai Island. Because of the proximity to the barrier island, mammalian predators occasionally make their way to Mordecai Island (Burger and Gochfeld 1991). In 2017, there was evidence of a mink predating diamondback terrapin nests (Budd 2017). In 2019, MLT observed a raccoon and an otter during biological sampling at the island (Budd 2019b).

Marine macroinvertebrates identified in the study area include: horseshoe crabs (*Limulus polyphemus*), fiddler crabs (*Uca sp.*), hard clam (*Mercenaria mercenaria*), hermit crab, grass shrimp (*Palaemonetes pugio*), sand shrimp (*Crangon septemspinosa*), mud dog whelk (*Nassarius obsoletus)*, blue crab (*Callinectes sapidus*), blue mussel (*Mytilus edulis*), oysters *(Crassostrea virginica*), ribbed mussels (*Geukensia demissa*), mud snail, isopods, amphipods, and tube worms (Stockton pers. comm., Budd 2018, Budd 2019b). Davis et al. (2018) monitored benthic infauna (invertebrates living in the sediments) in 2017, 2018, and 2019. Benthic infauna were more dense in the soft sediments than the sandy sediments surrounding the island. The soft sediments were dominated by tube-building gammarid amphipods (*Ampelisca* spp.) and the opportunistic polychaete, *Streblospio benedicti*. Benthic infauna was less dense, but the species were more diverse in the sandy sediments (Davis et al. 2018).

3.9 Threatened and Endangered Species

The Endangered Species Act (ESA) provides a program for the conservation of threatened and endangered species and a means for conserving the ecosystems upon which those species depend. Section 7 (a)(2) of the ESA requires federal agencies to consult with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) to ensure their activities are not likely to jeopardize the continued existence of listed species or destroy or adversely modify their critical habitat. Under the ESA, an endangered species is in danger of extinction and a threatened species is likely to become endangered within the foreseeable future.

The New Jersey Endangered Species Act (NJESA) is designed to protect species whose survival in New Jersey is imperiled by loss of habitat, over-exploitation, pollution, or other impacts. Under the NJESA, endangered species are those whose prospects for survival in New Jersey are in immediate danger because of a loss or change of habitat, over-exploitation, predation, competition, or disease. Threatened species are those that may become endangered if conditions surrounding the species begin or continue to deteriorate.

The USFWS Information for Planning and Consultation (IPAC) and NMFS ESA Mapper websites were queried on 9 June 2020 to determine the potential occurrence of federally listed threatened, endangered, or candidate species within the Study Area (USFWS, 2020; NMFS, 2020b).

The piping plover (*Charadrius melodus*) is a Federally- and state-listed shorebird that breeds on sandy beaches along the Atlantic and Gulf coasts. The species was federally listed as threatened in 1986. In New Jersey piping plovers nest on coastal beaches in Ocean County generally between March 15 and August 31. Piping plovers are territorial birds that build their nests above the high tide line, usually on sandy ocean beaches and barrier islands, but also on gently sloping foredunes, blowout areas behind primary dunes, washover areas or in between dunes. While nesting habitat does not exist on Mordecai Island, piping plover were observed foraging on Mordecai Island in 2019 and 2020 (Budd 2020). Feeding areas include the intertidal zone, washover areas, mudflats, sandflats, wrack lines and along the shoreline of coastal ponds, lagoons and salt marshes. Piping plover adults and chicks feed on macroinvertebrates such as worms, fly larvae, beetles, and small crustaceans.

The roseate tern (*Sterna dougallii*) is a medium-sized tern that is primarily tropical but breeds in scattered coastal localities in the northern Atlantic temperate zone. It was Federally-listed as endangered in 1987 in the northeast region, including New Jersey. The roseate tern was state-listed in New Jersey initially as threatened in 1979 but reclassified as endangered in New Jersey in 1984. The New Jersey Natural Heritage Program considers the roseate tern to be a non-breeding species in the state and globally “very rare and local throughout its range” (NJDEP, Department of Fish and Wildlife). Roseate terns were not documented at Mordecai Island during the MLT 2017 through 2020 biological surveys (Budd 2018, Budd 2020).

The red knot (*Calidris canutus*) is listed as Federally threatened (2015) and state-listed as endangered (2007). Red knots are primarily found within the Delaware Bay shorelines, where they occur in large numbers during the spring (mid-May through early June) and fall (late July through November) migration periods. Red knots feed on invertebrates, especially horseshoe crab eggs during the spring migration. The NJDEP reports that both horseshoe crab and red knot numbers have declined by over 75 percent since the early 1990’s. Red knots were documented at Mordecai Island during the MLT 2020 biological surveys (Budd 2018, Budd 2019b, Budd 2020).

The eastern black rail (*Laterallus jamaicensis jamaicensis*) was listed as Federally threatened in October 2020. According to Conserve Wildlife New Jersey, the black rail occurs in coastal salt and brackish marshes where they often nest in areas of elevated marsh that are flooded only during extremely high tides. Nests are typically located in marshes dominated by salt hay. These marshes also may contain spike grass, black rush, or marsh elder. Marshes containing salt hay provide characteristically thick mats of overlapping vegetation, beneath which the rails traverse on pathways of flattened vegetation. Black rails may seek cover within vegetation in adjacent upland fields and meadows during high tides. Black rails occupy similar habitats throughout the year. In the past three decades, black rails have been observed along the Atlantic Coast during the nesting season. The black rail (*Laterallus* jamaicensis) is state-listed as endangered. The black rail has nested in emergent tidal marshes in the surrounding area, but was not observed on Mordecai Island during the 2017 through 2020 MLT biological surveys.

The salt marsh sparrow (*Ammodramus caudacutus*) is currently being evaluated by the USFWS to determine if listing under the ESA is warranted and it is listed as a species of Special Concern in the State of New Jersey. The salt marsh sparrow is a year-round resident in New Jersey, favoring coastal saltmash habitat. Nests consist of plant material and can be constructed directly on the ground or about 2 feet above the ground, among the stems of tall marsh grasses.

The bald eagle (*Haliaeetus leucocephalus*) nests in large wooded areas associated with marshes and other water bodies. The NJDEP reported that there were 190 active bald eagles nests within the state in 2019. Although the bald eagle was removed from the Endangered Species list in 2007, it is still protected by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. These laws prohibit killing, selling or otherwise harming eagles, their nests, or eggs. The bald eagle has remained a state-listed species in New Jersey. A bald eagle was observed at Mordecai Island during the MLT 2019 and 2020 biological survey (Budd 2020).

There are currently 34 bird species state-listed as endangered or threatened species in New Jersey. In addition to those already mentioned, black skimmer (*Rynchops niger*), least tern (*Sternula antillarum*), osprey, yellow-crowned night heron, and black-crowned night heron have also been observed on Mordecai Island. Osprey and black skimmer nest on Mordecai Island. Historically, the black skimmer nesting colony was one of the largest in Barnegat Bay, consisting of 302 adults, 168 nests, and 254 fledglings in 2003 (Pover, Personal Communication, 2003).

Four Federally-listed threatened or endangered sea turtles have the potential to occur in the study area. These include the endangered Kemp's ridley turtle (*Lepidochelys kempii*) and leatherback turtle (*Dermochelys coriacea*) and the threatened green (*Chelonia mydas*) and loggerhead *(Caretta caretta*) turtles (NMFS 2020b). All four species of sea turtles are also listed in the State of New Jersey and could potentially forage in the study area.

As described above, the northern diamondback terrapin (*Malaclemys terrapin*), considered a New Jersey species of Special Concern is known to nest on Mordecai Island. The diamondback terrapin occupies brackish tidal marshes and nests on sandy bay beaches. As discussed in Section 2.2.5, MLT has been conducting terrapin relocation studies and has been managing habitat for terrapins since 2016.

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) was listed as Federally endangered and threatened in 2012 and is listed as endangered in New Jersey. Atlantic sturgeon spawn in the freshwater regions of the Delaware River. By the end of their first summer the majority of young-of-the-year Atlantic sturgeon remain in their natal river while older subadults begin to migrate to the lower Delaware Bay or nearshore Atlantic Ocean. An acoustic tagging study conducted between 2008-2011 (Brundage and O'Herron, 2011 found a few subadults, tagged within the Delaware River, in the Hudson River, Potomac River and off Cape Hatteras in the second year of the study. Older subadult Atlantic sturgeon are known to undertake extensive marine migrations, returning to their natal river in the late spring, summer, and early fall months (Dovel and Berggren, 1983). Early (eggs, larvae, young-of-year) and juvenile life stages of Atlantic sturgeon will not be present in the study area as they are not able to tolerate the high salinity (NMFS pers. com.). While sub-adult and adult Atlantic sturgeon use of marine habitat is not completely understood, they are known to use nearshore coastal waters for their marine migration (NOAA Fisheries 2020); therefore, it is unlikely that Atlantic sturgeon would occur in the study area.

The harbor porpoise (*Phocoena phocoena*) and the bottlenose dolphin (*Tursiops truncatus*) are New Jersey species of special concern. These species, as are all marine mammals, are protected under the Marine Mammal Protection Act. While mid-Atlantic waters are the southern extreme of their distribution, stranding data indicate a strong presence of harbor porpoise off the coast of New Jersey, predominately during spring. Both species have the potential to occur in the marine portions of the study area, especially from spring through late summer (BBEP 2001).

3.10 Cultural Resources

The NJIWW is a 117-mile section of the 3000-mile Intracoastal Waterway (ICW) stretching along the Atlantic and Gulf coasts of the United States. The NJIWW was conceived in 1808 and constructed in sections during the late 1800s and 1900s, and serves as a protected navigation route for private, commercial and military vessels. The section of the NJIWW within the Area of Potential Effect is not listed on the National Register of Historic Places.

Mordecai Island is a 47-acre uninhabited coastal salt marsh island within the Barnegat Bay complex. No cultural resource investigation has been conducted on Mordecai Island; however, its marshy habitat makes it of moderate to low probability for intact Native American archaeological sites eligible for listing on the National Register of Historic Places.

3.11 Socioeconomics

Mordecai Island is located next to the Borough of Beach Haven in Ocean County, NJ. Beach Haven is a 0.978 square mile borough with an estimated population of 1,102. The population has declined from 2010, and it has been declining over the past 2 decades. On average, the rest of the country has seen a modest population increase. Table 3.10 shows that the proportion of the population under 18 is 8.5% and over 65 years old is 37.7%. Combined, the proportion of young and old make up 46.2%. This proportion is higher than the state and national averages and indicates a significant population of retirees. The median age of 59.5 in Beach Haven is much higher than the county, state, and national averages. This further reflects the high number of retirees and near-retirees.

Table 3.10: Population

Category	Beach Haven	Ocean County	New Jersey	United States
Population	1,102	589,699	8,960,161	321,004,407
% Change from 2010-2017	-6.17%	2.28%	0.19%	3.97%
Persons Under 18	8.50%	23.60%	22.30%	22.90%
Persons Over 65	37.70%	22.10%	15.10%	14.90%
Median Age	59.5	42.9	39.6	37.8

Population demographics given in the 2017 census statistics estimate that Beach Haven's population is 96% white, 1.4% black, 0.2% American Indian, 1% Asian, 1.1% Hispanic, and 0.3% Other. Beach Haven has a higher percentage of white people and is less diverse than the county, state, and national averages. Table 3.11 shows the population demographics for Beach

Haven, Ocean County, New Jersey, and the United States. Overall, New Jersey is a racially diverse state, but within Ocean County, there is less racial diversity.

Table 3.11: Population Demographics

Category	Beach Haven	Ocean County	New Jersey	United States
White	96%	84.90%	56.10%	61.50%
Black	1.40%	2.80%	12.70%	12.30%
American Indian	0.20%	0%	0.10%	0.70%
Asian	1%	1.90%	9.40%	5.30%
Hispanic	1.10%	9%	19.70%	17.60%
Other	0.30%	1.40%	2%	2.60%

Table 3.12 shows the educational attainment of the local, state, and national populations. Beach Haven is a well-educated community, with only 0.7% of the borough having less than a high school education. The proportion of Beach Haven with a Bachelor's degree or higher is 56.5%, significantly higher than that of the county, state, and national education rates.

Table 3.12: Educational Attainment

Category	Beach Haven	Ocean County	New Jersey	United States
Less than high school	0.70%	8%	9.40%	10.80%
High school	21.90%	31.80%	25.50%	24.80%
Some College	23.70%	29.70%	24.40%	31.10%
Bachelor's or higher	56.50%	30.50%	40.70%	33.40%

Table 3.13 summarizes key economic characteristics across Beach Haven, Ocean County, New Jersey, and the United States. Beach Haven has a labor force of only 495, and the unemployment rate is 4.1%. The unemployment rate is about on par with the county, state, and national unemployment rates. Beach Haven has a median household income of $86,705 and is higher than the median household incomes at the county, state, and national levels. In addition, Beach Haven has a per capita income of $61,903, far exceeding the county, state, and national per capita incomes. Beach Haven has 565 occupied housing units. The labor force being smaller than the number of occupied houses indicates a large retiree population and/or a relatively wealthy community. Beach Haven's poverty level is lower than the county, state, and national poverty rates.

Table 3.13: Economic Characteristics

Category	Beach Haven	Ocean County	New Jersey	United States
Labor Force	495	272,287	4,724,242	162,184,325
Unemployment Rate	4.10%	3.90%	4.60%	4.10%

Median Household Income	$86,705	$65,771	$76,475	$57,652
Per Capita Income	$61,903	$33,312	$39,069	$31,177
Occupied Housing Units	565	223,135	3,199,111	118,825,921
People Below Poverty Level	6.50%	10.90%	10.70%	14.60%

3.12 Hazardous, Toxic and Radioactive Waste

As part of the earlier New Jersey Intracoastal Waterway Ecosystem Restoration Feasibility Study (May 2009), the Corps conducted Environmental Data Research (EDR) searches for an extensive area on the NJIWW. The EDRs searches included numerous Federal and state environmental databases for permits, incident reports, historical and cultural locations, closure reports, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, better known as Superfund) and Resource Conservation and Recovery Act (RCRA) sites within a one mile radius of a provided address. The results of the database searches were detailed in *New Jersey Intracoastal Waterway Ecosystem Restoration Feasibility Report, May 2009.*

There are no known Hazardous, Toxic, Radiological Wastes (HTRW) sites within the Mordecai Island study area, including the island portion and the potential borrow source area (NJIWW). Therefore, no significant source of chemical contamination at the island or the potential borrow source area is likely.

No additional studies or sediment sampling was conducted during this phase of the study. Sediment sampling may be conducted later to support borrow source selection, if appropriate. The sediment samples would be analyzed for chemical contamination, as well as for geotechnical parameters.

4 Inventoried and Forecast Without Project Conditions

4.1 Sources and Nature of Erosion

Wave heights from 1.5 ft. to 3 ft. from either wind-generated storm events or from boat wakes are frequently encountered at Mordecai Island and are responsible for the long-term erosion occurring to the island. Waves are impacting the island by undermining of the bank, which in turn is producing episodic retreat along the western shoreline. Undermining, as opposed to overtopping, appears to be a stronger driver of historic island erosion.

4.2 Historical Island and Nearshore Change Analysis

Three different methods were used to track historical Mordecai Island erosion. The first method involved cutting cross-sections from the island to 400 to 600 ft. offshore of the western shoreline from the 2011 and 2019 topographic and bathymetric DEMs. The second method looked at changes in area of the island's footprint based upon aerial photography between 1977 and 2017. The third method examined changes to the digitized footprints of the island in more detail by using transects every 200 ft. around the perimeter in order to quantify the variability of island erosion which could be used as a predictor of future island footprints under both "without" and "with" project conditions.

Cross-Section Method: DEMs were developed for the May 2011 and January 2019 topographic and bathymetric surveys and six cross-sections were cut (Figure 4.1) perpendicular to the western shoreline in order to track and visualize topographic and bathymetric changes in the nearshore during that eight year period as shown in Figure 4.2 and Figure 4.3.

Figure 4.1: Mordecai Island Cross-Section Locations

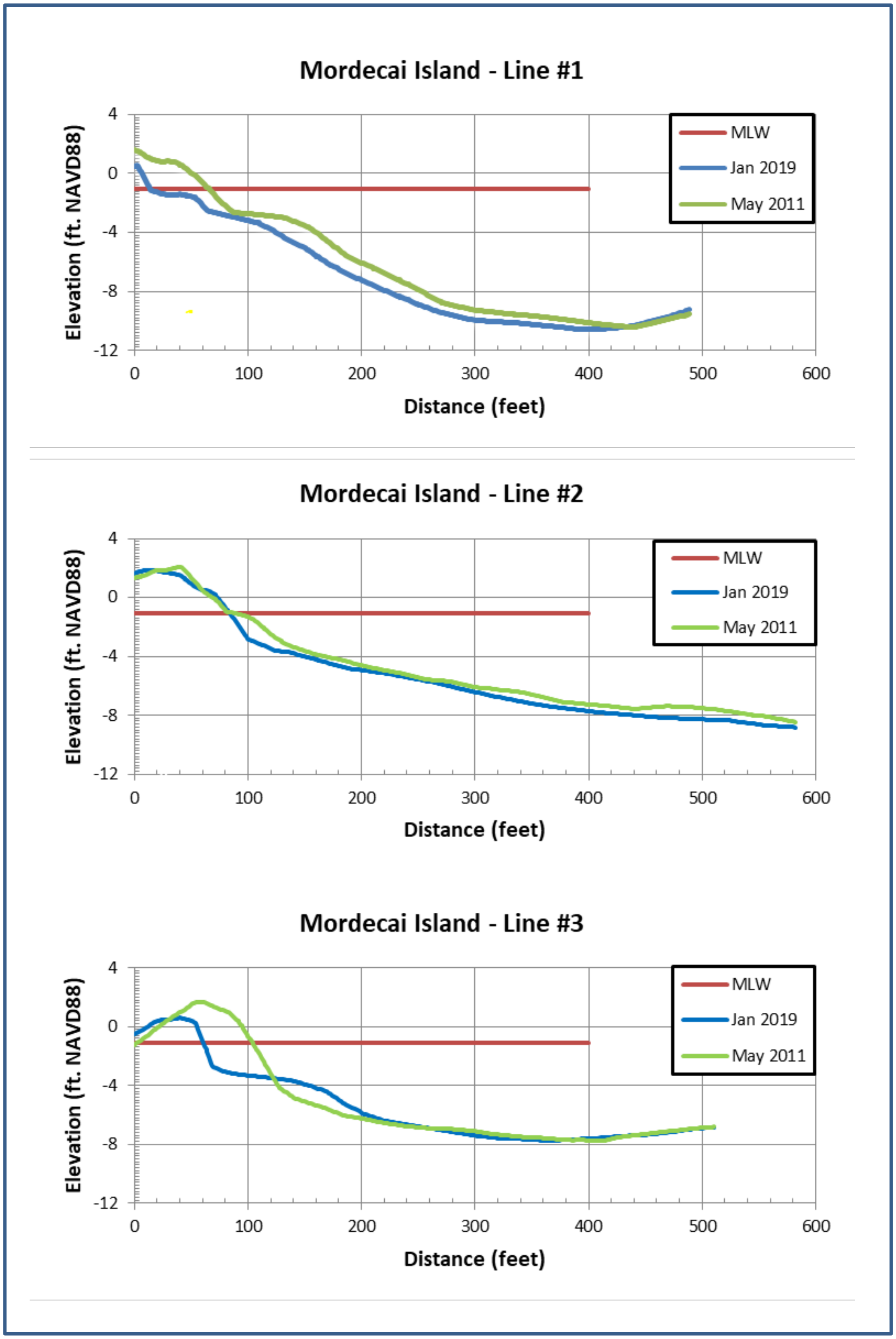


Figure 4.2: Mordecai Island 2011 and 2019 Cross-Sections 1-3

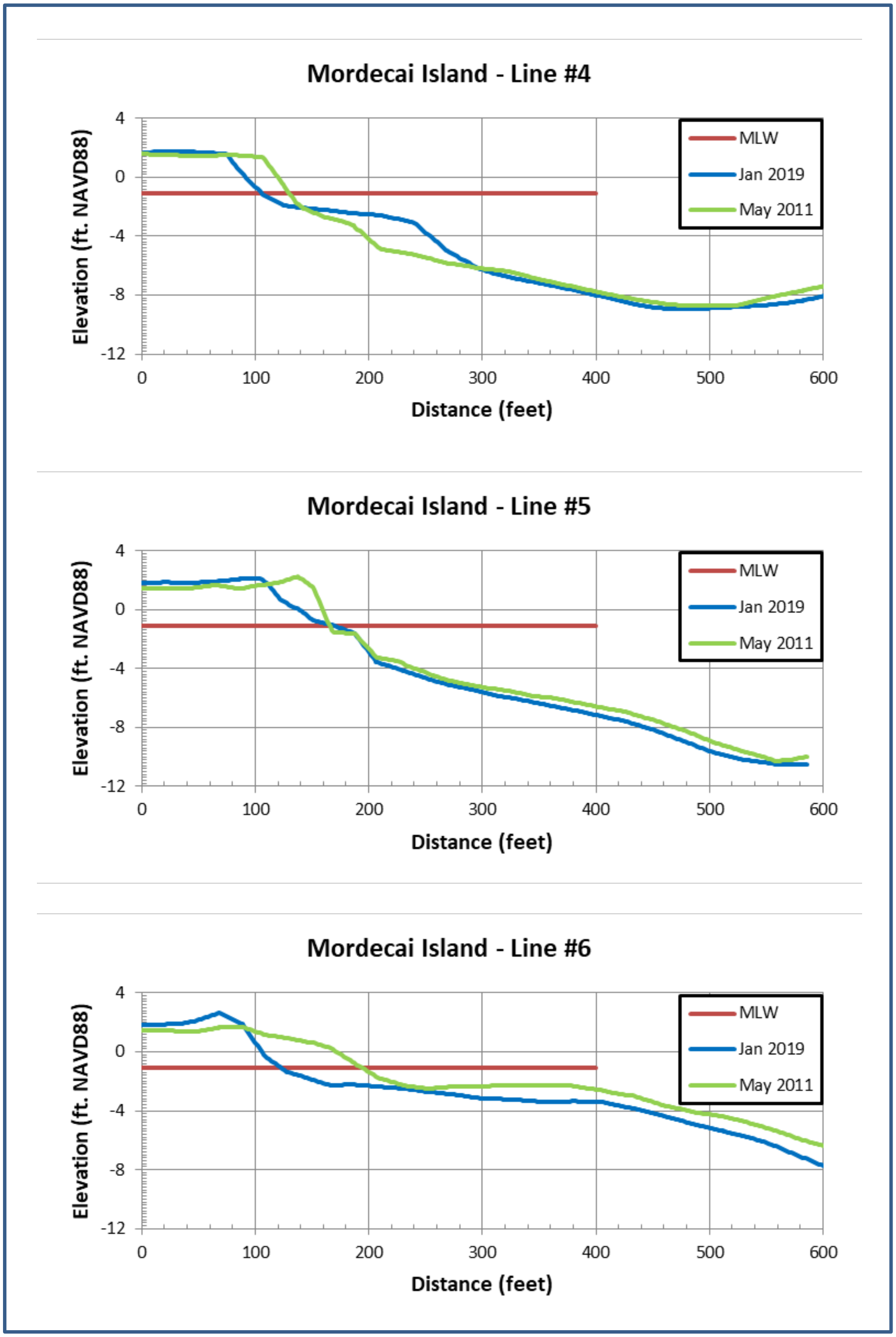


Figure 4.3: Mordecai Island 2011 and 2019 Cross-Sections 4-6

Area changes between the May 2011 and January 2019 surveys were quantified above MLW (-1.08 ft. NAVD88) and changes in the location of the MLW contour for each cross-section is summarized in Table 4.1.

Table 4.1: Cross-Sectional Area Changes Above and Below MLW

Cross Section	2011 – 2019 Area Change Above MLW (cu. yd. / ft.)	2011 – 2019 Area Change Below MLW (cu. yd. / ft.)	2011 – 2019 Change of MLW Contour (ft.)
Line 1	-3.45	-11.93	-52.14
Line 2	-0.12	-9.62	-6.19
Line 3	-3.38	+1.40	-42.81
Line 4	-2.08	+2.13	-24.56
Line 5	-1.26	-6.90	3.61
Line 6	-2.97	-15.20	-71.13
Average	-2.21	-6.69	-32.2
Average Annual Change	-0.27	-0.81	-3.90

Figures 4.2 to 4.3 and Table 4.1 clearly shows the loss in area and the retreat of the western shoreline above MLW between 2011 and 2019. Average loss of area was 2.21 cubic yards per foot and the average retreat distance at MLW was 32.2 ft. The cross-sections and Table 4.1 also show some deposition of material in the nearshore area below MLW from what was eroded above MLW for Line #3 and Line #4. The retreat from May 2011 to January 2019 both above and below MLW for Lines #1, 2, 5 and 6 indicate that material lost could have been transported into the breach area from Lines #1 and #2 or south away from the island in the case for Lines #5 and #6.

<u>Footprint Method</u>: Geo-referenced aerial photography of Mordecai Island from the years of 1977, 1995, 2002, 2007, 2012, 2015, and 2017 was obtained from various sources and digitized in order to quantify historical erosion rates on a footprint basis. The island footprint was digitized in ArcGIS for each aerial date and they were plotted against each other as shown in Figure 4.4. Also, a map was prepared that shows erosion and accretion areas around the perimeter of the island from the 1977 and 2017 aerials, as shown in Figure 4.5. It should be noted that the digitized shorelines representing the island footprint for each aerial photograph should not be considered necessarily as either the MHW or MLW line. They are just representations of the land/water interface and their locations are subject to the resolution and quality of the aerial photograph.

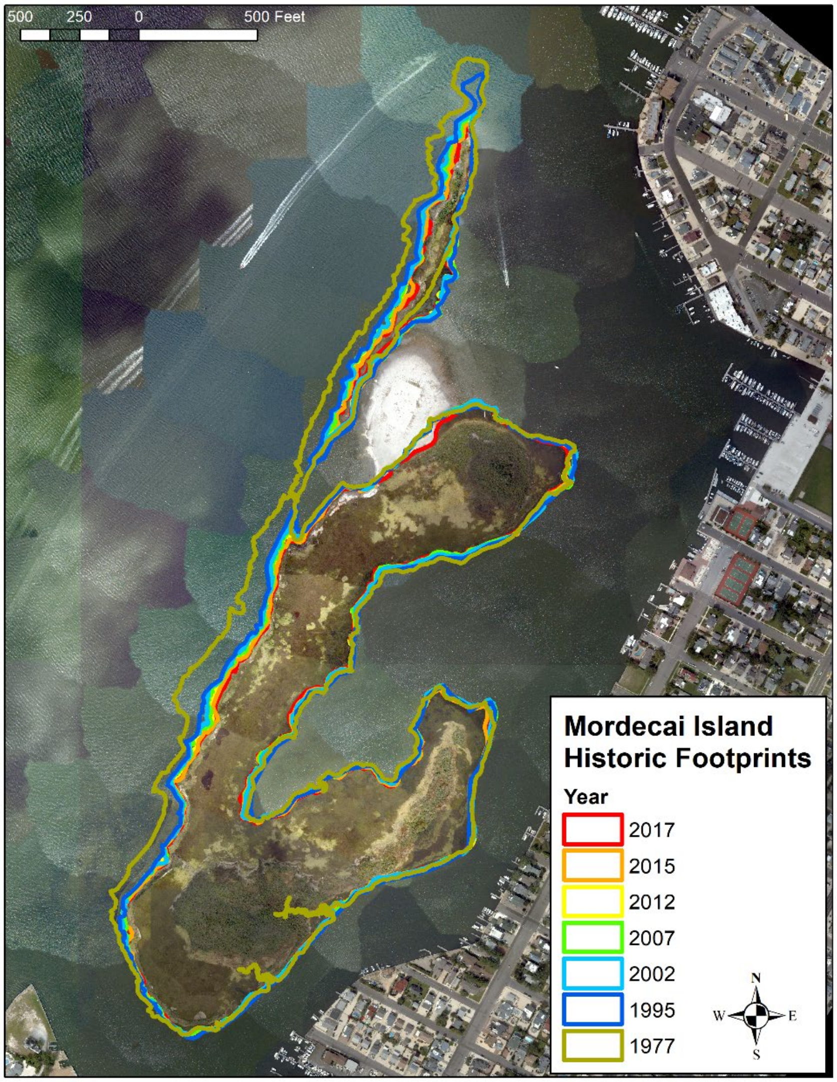


Figure 4.4: Historical Mordecai Island Footprint Areas 1977 - 2017

Figure 4.5: Mordecai Island 1977 Footprint vs. 2017 Footprint

As Figure 4.5 shows, the western shoreline has retreated to the east while other parts of the island have remained relatively stable during the 40 year time period. The separate islands were conjoined in 1977, but in the early 1980s the island was breached and has been split into a "north" and "south" island ever since. The mechanical placement of sand in 2015 and 2017 in the breach area as part of the beneficial use of dredge material project was ignored for this analysis as it was not natural accretion. Remaining and eroded areas from each year were tabulated and compared against the 1977 island footprint in ArcGIS and are summarized in Table 4.2 and Table 4.3 for the "south" and "north" island respectively.

Table 4.2: Historical Mordecai South Island Footprint Changes

Year	South Island Area (acres)	Total Eroded Area (acres)	Annual Eroded Area (acres)	Percent Area Lost Since 1977
1977	47.69			
		3.51	0.18	7.36
1995	44.18			
		1.09	0.14	9.65
2002	43.09			
		0.28	0.05	10.24
2007	42.81			
		0.54	0.09	11.37
2012	42.27			
		0.91	0.23	13.28
2015	41.36			
		0.74	0.25	14.82
2017	40.62			
Acres Lost 1977 - 2017		7.07		
Avg. Acres Lost / Year		0.17		

Table 4.3: Historical Mordecai North Island Footprint Changes

Year	North Island Area (acres)	Total Eroded Area (acres)	Annual Eroded Area (acres)	Percent Area Lost Since 1977
1977	6.13			
		1.74	0.09	28.35
1995	4.39			
		0.95	0.12	43.84
2002	3.44			
		0.02	0.00	44.14
2007	3.42			
		0.25	0.04	48.30
2012	3.17			
		0.31	0.08	53.42
2015	2.86			
		0.42	0.14	60.24
2017	2.44			
Acres Lost 1977 - 2017		3.69		
Avg. Acres Lost / Year		0.09		

As Tables 4.2 and 4.3 show, there has been significant reduction in Mordecai Island's footprint since 1977. The larger southern island has lost almost 15% of its 1977 footprint area while the smaller northern island has lost 60% of its 1977 footprint area. Annual footprint erosion rates for the southern island have more than doubled since 2012, compared to the early 2000s, and there has been a steady increase in the annual footprint erosion rates since 2002 for the northern island.

Transect Method: A more refined erosion analysis was done along individual transects spaced 200 ft. apart around the perimeter of the island. The transect analysis was done in order to quantify and distinguish higher versus lower historical erosion rates that could be used to evaluate benefits of potential ecosystem restoration alternatives. Just like with the footprint analysis, the mechanical placement of sand in the breach area from the beneficial use of dredge material project was ignored. Figure 4.6 shows the variable annual erosion rate every 200 ft. around the perimeter of Mordecai Island that has occurred between 1977 and 2017.

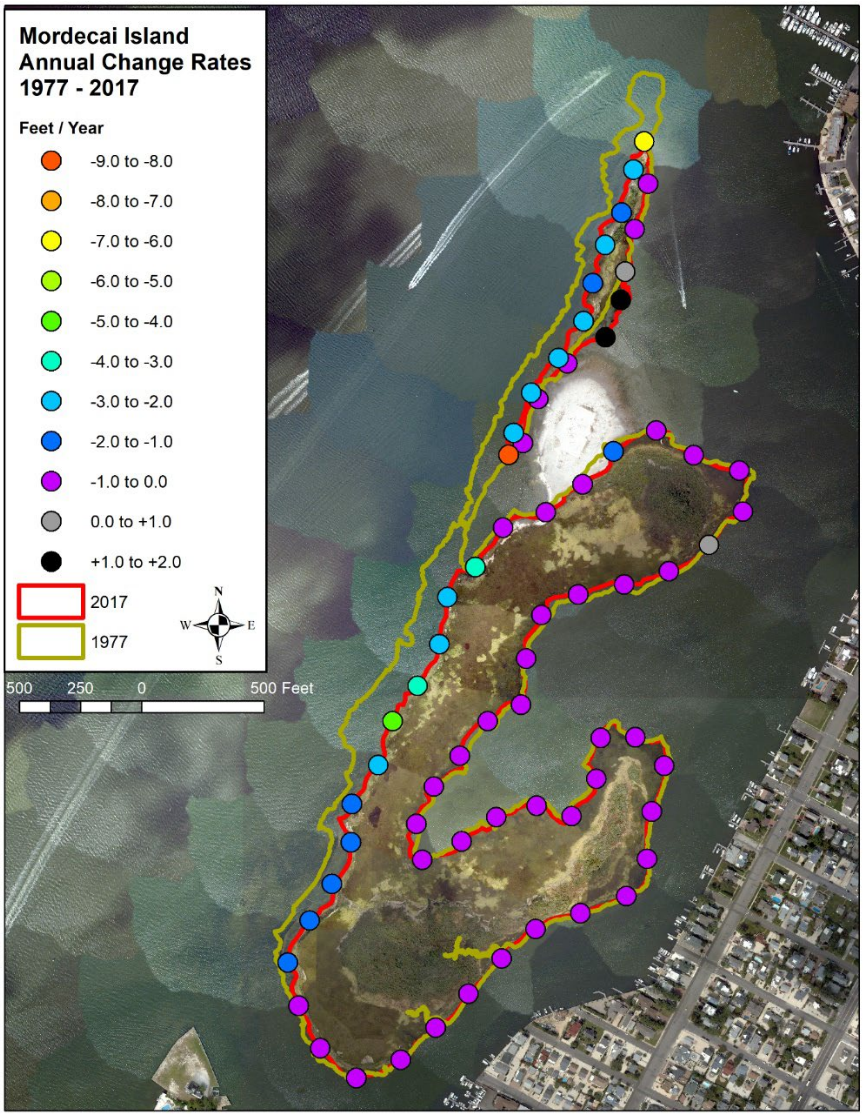


Figure 4.6: Mordecai Island Annual Change Rates from 1977 to 2017 by Transect

Results of the analysis indicate that the western shoreline of Mordecai Island has been retreating on average between 2 – 4 ft. per year, with some pocket areas showing retreat as high as 5 ft. per year. The retreat in the southwest portion of the island was lower, around 1 – 2 ft. per year. These results are consistent with what the cross-sections and aerials showed in the previous analyses. There are several factors related to why the southwest portion has retreated less than other portions of the western shoreline. The 2010 Geotubes® installation appears to show signs of slowing down island retreat in the area. In addition, there is less exposure to the predominate direction of wind driven waves that come out of the northeast, and the location of the NJIWW channel is further away from the southwest portion of the island. All these factors have contributed to lower retreat rates. Figure 4.6 also shows that the largest retreat rates since 1977 have occurred at the northern tip of Mordecai Island, which is where the NJIWW is located the closest to the island and at the vulnerable breach area where the island split into two in the early 1980s.

Strong tidal currents and waves that develop over a large fetch have contributed to severe shoreline erosion along Mordecai Island. Over the past 100 years, half the island has been lost through erosion. The western edge, adjacent to the NJIWW, has receded at a rate on the order of 2 to 4 feet per year. Additionally, since shoaling exists in the marked NJIWW channel but deeper water exists adjacent to the island, the wakes of vessels are now contributing to increased wave action in the vicinity of the eroding Mordecai Island shoreline. These erosion rates have led to the loss of approximately 11 acres of island habitat over the 40-year period of analysis. The severe erosion that has taken place has resulted in the loss of high and low marsh habitat as well as sandy intertidal areas adjacent to the shoreline. The erosion has lead to the loss of gradual habitat transitions within the intertidal zone as much of the island edge is currently steep edges which limit species use in the area.

4.3 Future Without-Project Conditions

In the future, approximately 22 acres of Mordecai Island could be eroded by the year 2080, as shown in Figure 4.7. Separate analyses were conducted that projected a future Mordecai Island footprint in the year 2080 based upon historical erosion rates, future accelerated sea level change, and a combination of both. The historical annual erosion rates developed using the transect method described in Section 4.2 were the basis to determine what the size and shape of Mordecai Island could look like in the year 2080. At the onset of the analysis it was determined that having transects spaced every 200 ft. was not dense enough to adequately determine the size and shape of the island. The ArcGIS tool called “Digital Shoreline Analysis System” (DSAS) published by the USGS was used to take the rates developed every 200 ft. and refine them to a much closer spacing. The DSAS tool automates the process of taking multiple shoreline positions and calculating erosional changes out into the future.

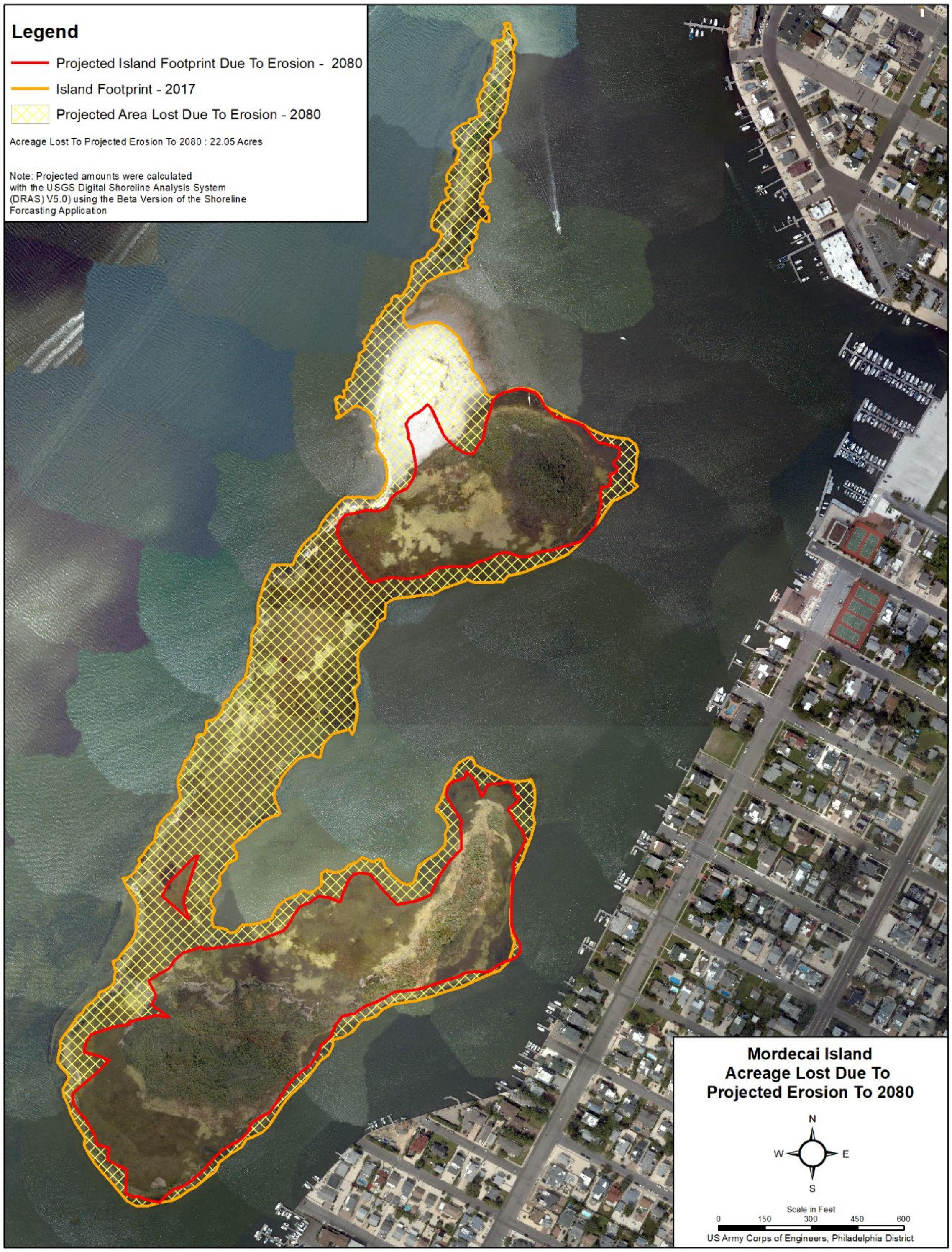


Figure 4.7: Future Without Project Condition - Projected Acreage Lost to Erosion by 2080

It should be noted that neither the tool nor the analysis assumed topographic changes in the island's elevation would impact future erosional rates. They basically treated the island as a flat surface with a constant elevation. This is a conservative assumption because as elevation increases away from the island's edge, it can be expected that historical erosion rates will not be the same but be less. It was also assumed that no future placement of sand would be happening from the beneficial use of dredge material project that was started in year 2015 by the Philadelphia District Operations Division. Lastly, it was assumed that the future erosional rates of the island are not impacted by future accelerated sea level change, that they are independent of one another and can be examined independently at first and then combined to come up with a composite future island size and shape. The relationship of future island erosion as sea level changes is a complex process that would be very difficult to predict given the dynamics of the environment.

Another projection of what the island's size and shape could be in year 2080 was calculated by analyzing the loss in acreage due to sea level change alone. A DEM of the island's topographic elevations based upon the recent 2018 and 2019 surveys was created in ArcGIS and used as the basis for the analysis. Projection of the island's potential future footprint in the year 2080 used those topographic elevations and the projected elevations along the intermediate sea level change curve as shown previously in Figure 3-8. Based upon the analysis it was determined that approximately 33 acres could be submerged by year 2080. It should be noted that these calculations do not take into account any marsh accretion.

Projection of the future island footprint based upon sea level change included some assumptions. One assumption was that potential future island footprints due to just sea level change alone are not impacted by future island erosion, and these processes are independent of one another. Another assumption made is that there would be no changes in island elevations from the 2018/19 surveys to 2080 and that the DEM developed based upon those island surveys is still applicable in the future. The island's marshes' adaptability to potentially rise in elevation in conjunction with sea level change was not considered. The MLT projects identified in Chapter 2 of this feasibility report are not included in the calculations of erosion because they are experimental in nature, thus subject to alteration, and no data is available to predict their performance to reduce erosion in the future. Lastly, it was assumed that no additional fill from the Federal navigation project would be placed in the breach area.

The results of both the future erosion and sea level change footprints were superimposed to derive a worse-case scenario of what the island's size and shape could be in year 2080, as shown in Figure 4.8 without and with topographic elevations from the recent 2018/19 island surveys.

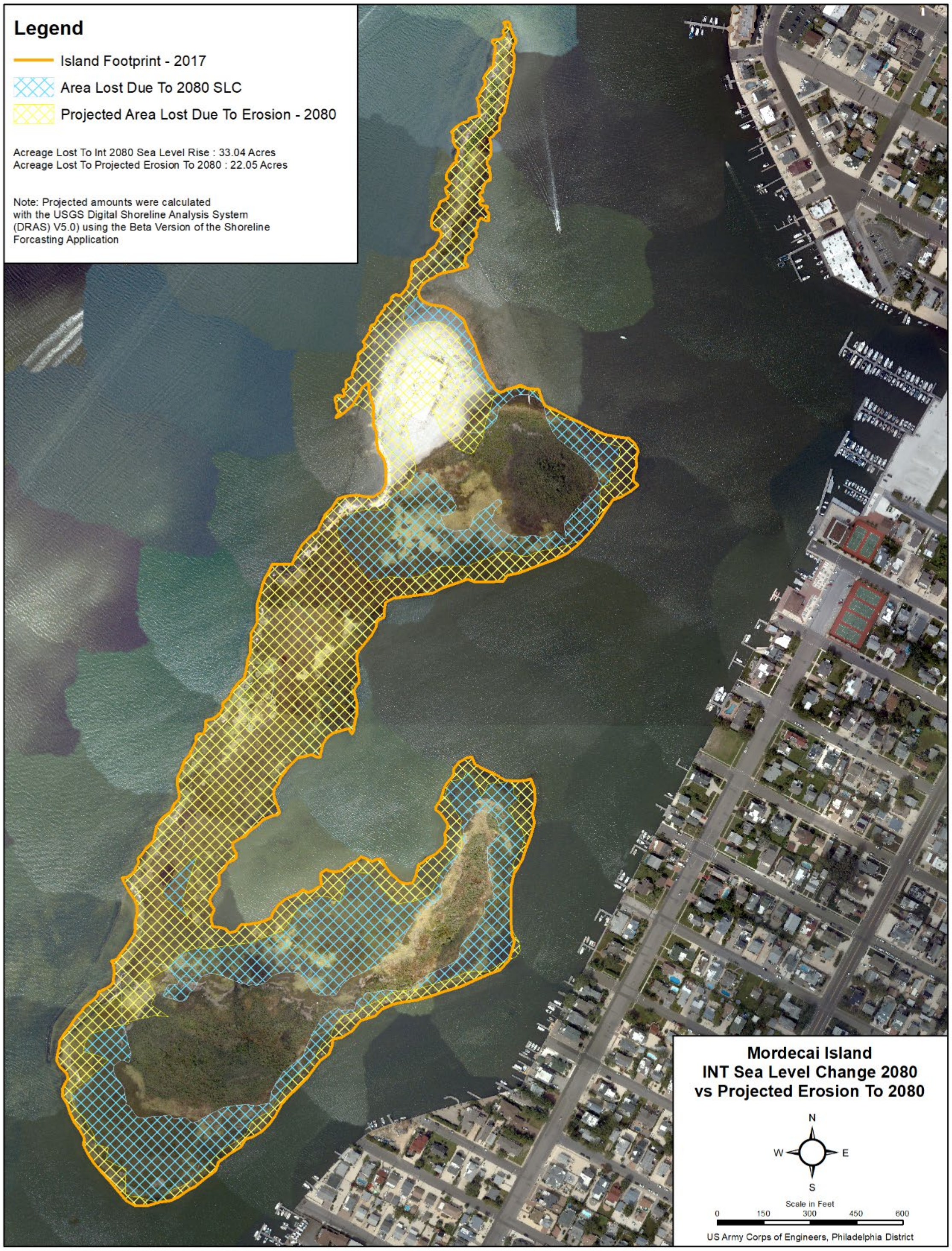


Figure 4.8: Future Without Project Condition - Combined Projected Acreage Lost to Erosion and Sea Level Rise by 2080

As reported in USACE (2014), New Jersey's coastal wetlands and tidal mudflats are highly susceptible to the effects of sea level rise. Tidal mudflats would experience increased inundation and/or their tidal regimes changed from intertidal to subtidal. Coastal wetlands can adapt and keep pace with sea level rise through vertical accretion and inland migration but must remain at the same elevation relative to the tidal range and have a stable source of sediment. Cooper et al. (2005) reported that coastal wetlands in New Jersey will generally be unable to accrete at a pace greater or equal to relative sea level rise (3.53 mm/year) and are extremely susceptible to permanent inundation. According to Lathrop and Love (2007), New Jersey's salt marshes appear to have been able to keep pace with historical rates of sea level rise, but if sea level rises faster than marsh accretion, tidal marshes could eventually be drowned and replaced by open water. Strange (2008) reported that New Jersey's tidal salt marshes are keeping pace with current local rates of sea level rise of 4 mm/yr but will become marginal with a 2 mm/yr acceleration and will be lost with a 7 mm/yr acceleration except where they are near local sources of sediments (e.g., rivers such as the Mullica and Great Harbor rivers in Atlantic County). Coastal wetlands are forced to migrate inland due to a combination of sea level rise and vertical accretion forcing the saline marshes on the coastline to drown or erode and the upslope transitional brackish wetlands to convert to saline marshes. A significant portion of New Jersey's coastal wetlands are adjacent to human development or seawalls that block natural wetland migration paths and increase the likelihood of wetland loss from inundation (Cooper et al. 2005). For Mordecai Island, the website https://maps.coastalresilience.org/newjersey/# shows relatively minor changes in the acreage of the island under SLC of one or two feet when predicted marsh accretion is taken into account (Figures 4.9 and 4.10).

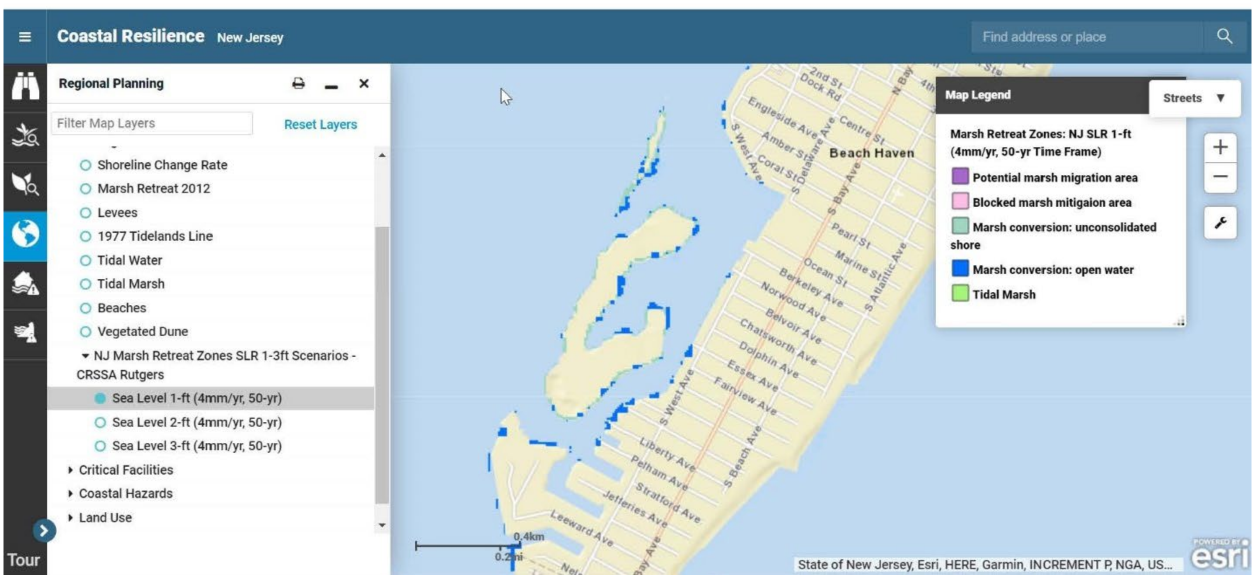


Figure 4.9: Predicted Island Footprint with 1 foot Sea Level Rise

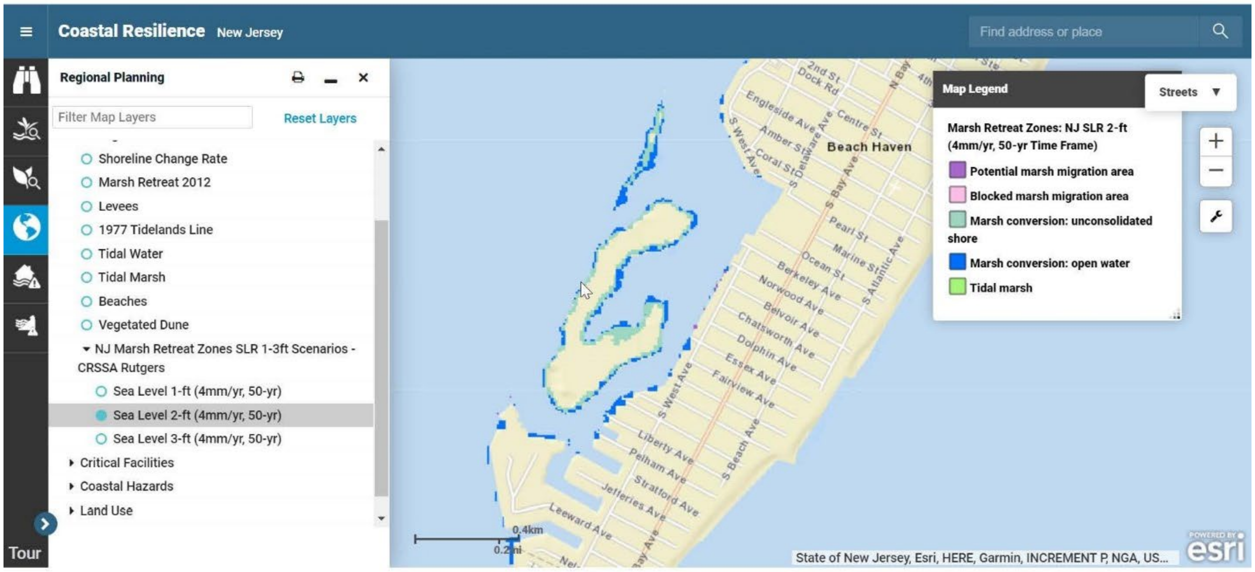


Figure 4.10: Predicted Island Footprint with 2 Foot Sea Level Rise

5 Plan Selection Process

5.1 Problems and Opportunities*

5.1.1 Problem Statement

Coastal intertidal marsh habitat loss is occurring on the western edge of Mordecai Island due to erosion of the marsh by waves and vessel wakes associated with the NJIWW. There is insufficient suspended material moving within the system to deposit and cause substantial accretion in the eroded areas. Between 1977 and 2017, approximately 11 acres of valuable marsh habitat was lost on Mordecai Island. The severe erosion also led to a breach in the island, splitting it into two pieces. Mordecai island supports a variety of species, including Federal and State-listed species and provides valuable nesting habitat to several beach nesting and marsh birds as well as diamondback terrapins.

5.1.2 Opportunities

1) Reduce habitat loss, including for NJ State listed threatened and endangered species.
2) Restore lost habitat, including for NJ State listed threatened and endangered species.
3) Complement existing erosion management and restoration efforts by other parties (see Chapter 2.0 of this report) to synergistically increase the collective benefits.

5.2 Goal and Objectives

5.2.1 Goal Statement*

Address erosion and habitat loss on the western side of Mordecai Island from the northern tip of the island to the northern end of the MLT erosion management features.

5.2.2 Objectives*

5.2.2.1 Habitat Protection

1) Protect Mordecai Island salt marsh from erosive forces on the western shore, extending from the northern tip of the island to the northern end of the MLT erosion management features, and limit further loss of land mass through 2080.

5.2.2.2 Habitat Restoration

2) Restore Mordecai Island shorebird (e.g. least tern) and diamondback terrapin habitat through 2080.
3) Restore Mordecai Island saltmarsh (e.g. *Spartina alterniflora* dominated saltmarsh*)* through 2080.

5.3 Constraint and Considerations

5.3.1 Constraint

1) Structures cannot be placed within 50’ of the NJIWW channel. See Figure 5.1.

The 50’ buffer area requirement for the NJIWW and other coastal federal navigation channels was determined at the discretion of the Philadelphia District, Operations Division. The buffer area is intended to allow the Corps and its contractors adequate space and maneuverability to perform maintenance dredging throughout the federal navigation channel. Additionally, it provides vessel traffic a safety margin, aims to account for the width of moored vessels, as well as protect nearby vessels and structures from waves.

5.3.2 Considerations

1) Ongoing local erosion control efforts need to be taken into consideration. See Figure 5.2.
2) Tidelands are all lands that are currently and formerly flowed by the mean high tide of a natural waterway. A project can be implemented within the boundary of the 1977 tidelands line. NJDEP Division of Land Use Regulation can more easily issue permits within the 1977 tidelands line. See Figure 5.1.

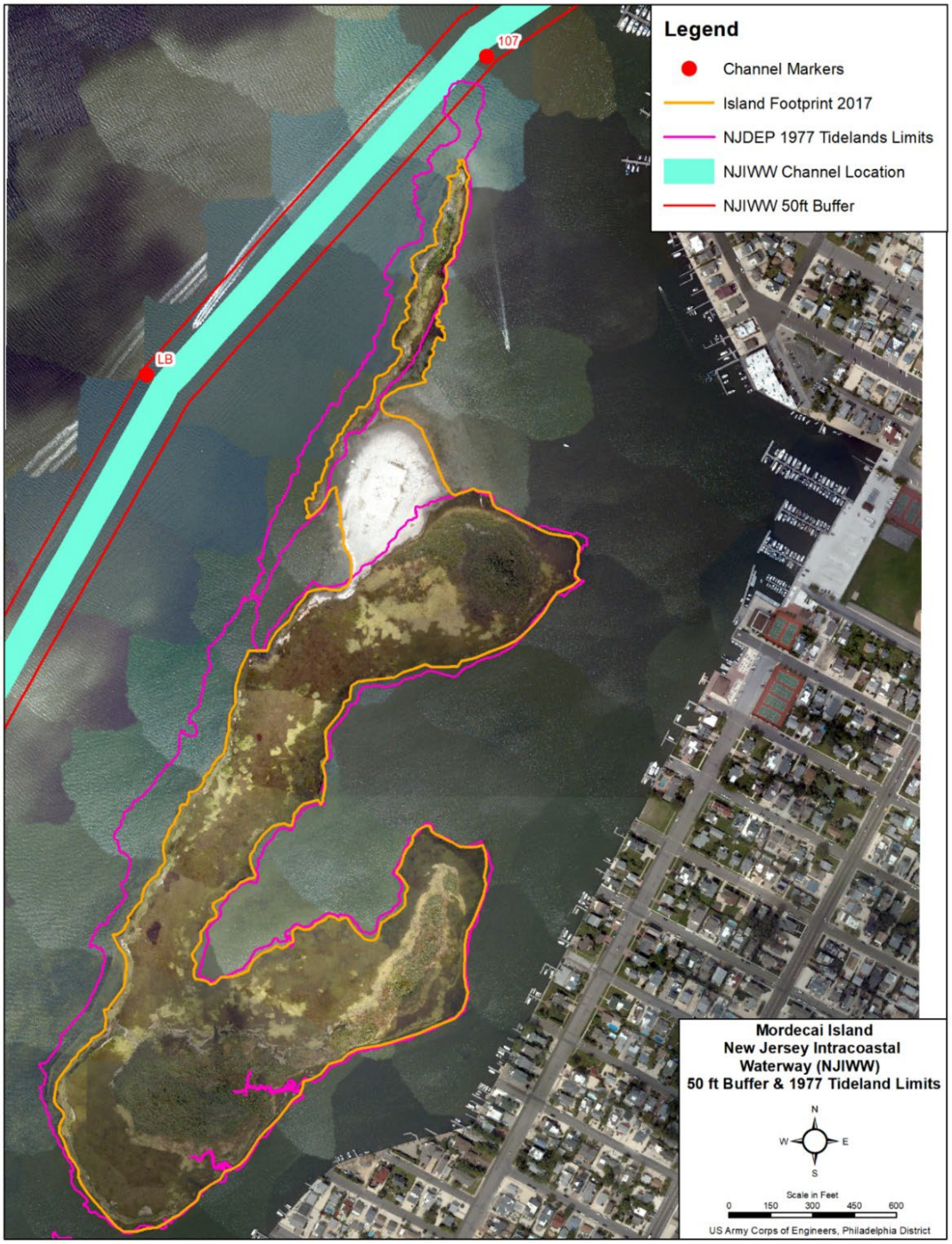


Figure 5.1: NJIWW Channel, 50' Channel Buffer, Channel Markers, 1977 Tidelands Line

Figure 5.2: MLT Erosion Control Features

5.4 Formulation of Alternative Plans

Formulation of alternative plans began with identification of potential measures, followed by screening of those measures to determine how well they met evaluation criteria. Applicable measures were then combined into alternative plans and screened for how well they met the desired objectives of habitat protection and restoration.

Based upon the wave analysis done, as summarized in Section 3.4.3, a design wave height of 2.0 ft. was selected. This wave height is not a representation of storm conditions because during extreme storms submergence of Mordecai Island is probable, as the highest elevation on the island is approximately +4.0 ft. NAVD88. The design wave height is representative of more frequently encountered conditions at Mordecai Island. To account for some of the uncertainty associated with picking a single wave height for design purposes and due to a lack of any boat traffic study, modeling, or analysis within the study area, a sensitivity analysis was done using wave heights from 1.5 to 4.0 ft. in order to gage how sensitive design elements (size, configuration, crest elevation, etc.) were to varying wave heights.

Plans to address the needs in the study area must be formulated to do the best job possible to provide a complete, effective, efficient, and acceptable plan to meet the project goal and objectives. These criteria impose general planning constraints within any study area.

Completeness: The extent to which the alternative plans provide and account for all necessary investments or other actions to ensure the realization of the planning objectives, including actions by other Federal and non-Federal entities. Measures and alternatives were considered for whether they will achieve the planned outputs.

Effectiveness: The extent to which the alternative plans contribute to achieving the planning objectives. Measures and alternatives were considered for the extent/significance of their contribution to addressing the restoration problem or opportunities. Effectiveness was the primary criterion considered during evaluation of measures. If a measure would not effectively contribute to addressing the project objectives, it became less important to consider in depth whether it was complete or acceptable.

Efficiency: The extent to which an alternative plan is the most cost effective means of achieving the objectives. This criterion was not applied to measures during the first screening because it became clear that many measures would be eliminated from consideration due to the other, more qualitative, criteria. Development of parametric costs would not change the outcome. Alternatives were considered for their relative cost to each other and the project cost limit. Efficiency was evaluated in the final step of the planning process through the Cost Effectiveness/Incremental Cost Analysis (CE/ICA).

Acceptability: The extent to which the measures and alternative plans are acceptable in terms of applicable laws, regulations and public policies. For the screening of measures best professional judgment was applied based on existing knowledge of applicable regulations and experience in their application. Screening of alternatives involved actively engaging with resource agencies to determine the level of acceptability.

5.4.1 Measures

5.4.1.1 Potential Onshore Measures

Onshore measures can potentially provide protection of existing marsh, but do not contribute to restoration of new marshland. Onshore measures are often not combinable with offshore measures due to the onshore measure's negative effect on habitat in transition zones. A notable exception is in the case of biologs being used to stabilize the shoreline until fill and plantings mature and provide stabilization. Some onshore measures are combinable with each other, involving use of different measures in areas with different features, such as varying slope. Onshore measures include the following:

1) Shoreline grading and high performance turf reinforcement mat (TRM) with fill on top of mat and seeding
2) Shore slope stone revetment, with or without fill and planting
3) Articulated open cell concrete mat with fill in cells and planting
4) Biologs, with or without fill
5) Steel sheet pile bulkhead, no fill

5.4.1.2 Potential Offshore Measures

Offshore measures can provide varying degrees of protection of existing marsh and contribute to restoration of new marshland. Certain offshore measures may be combined. Offshore measures include the following:

6) Near shore stone sill, with or without fill and planting
7) Geotubes® with armor layer, with or without fill
8) Oyster castles®, with or without fill
9) Offshore breakwaters, with or without fill
10) Precast concrete structures (e.g. Beach Prisms™ or WADs®) as sills or breakwaters, with or without fill

5.4.1.3 Other Measures

11) Floating wave attenuators
12) Move No Wake Zone markers closer to the NJIWW channel
13) Move NJIWW farther away from Mordecai Island

5.4.2 Description and Evaluation of Measures

1) **Shoreline grading and high performance turf reinforcement mat (TRM) with fill on top of mat and seeding**

Turf reinforcement mats (see Figures 5.3 and 5.4) can be biodegradable or non-biodegradable. Based on the following information from ERDC 2014, only non-biodegradable material was considered as a potential erosion control measure for Mordecai Island.

Figure 5.3: Installation of Turf Reinforcement Mat

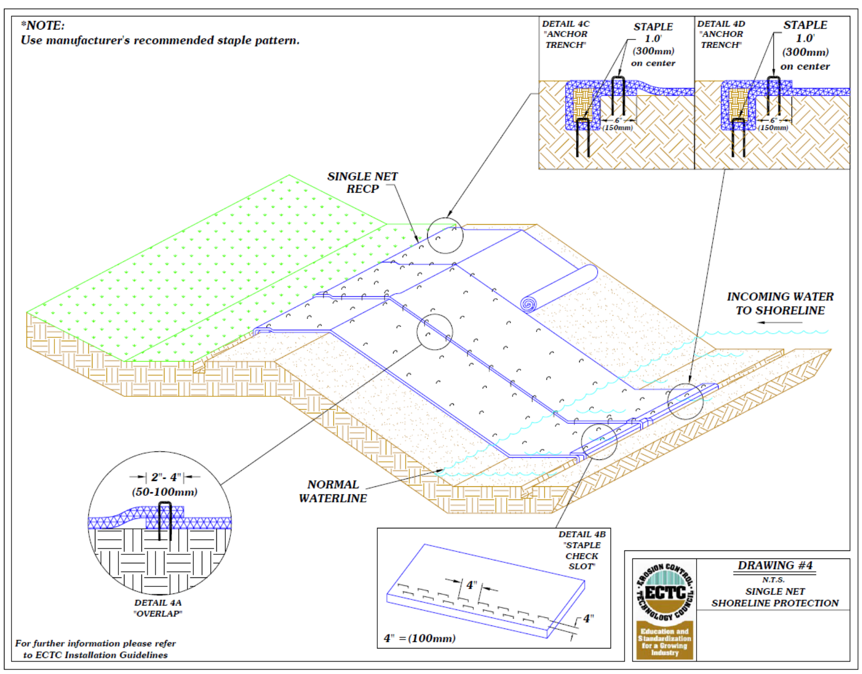


Figure 5.4: Drawing of Turf Reinforcement Mat

Analysis

Completeness: This measure would completely achieve Objective #1 by protecting existing habitat and preventing future loss of habitat. The measure would not achieve Objectives #2 and #3 of restoring lost habitat.

Effectiveness: "Considering the high energy environment, high visibility and multiple goals of the Mordecai Island restoration, use of a biodegradable rolled erosion control product (RECP) may not be sufficient, even with offshore breakwaters or sills. Current conditions, as well as previously implemented and failed "soft" approaches show that vegetation alone will not hold these shorelines in place – even if a degradable TRM is used successfully initially, once it degrades, an unchanged energy environment will result in the same long-term erosion patterns.

In those areas with persistent shoreline erosion, particularly where conditions limit additional stabilization methods or there is other reason to expect continuing erosive conditions, a nondegradable, High Performance TRM (HPTRM) is a good long-term solution if installed correctly. All TRMs need to be anchored to the ground, which can be accomplished with stakes, staples or percussion-driven tendon anchors. Additionally, these materials can be installed without the need for heavy equipment, which may be a distinct advantage for the Mordecai Island environment."[2]

[2] *Memorandum from ERDC to CENAP, "Mordecai Island Coastal Wetlands Restoration Project, Section 1135 – Ocean County, New Jersey) Water Operations Technical Support Request Number 2013-027." 24 March 2014.*

This measure might be effective at contributing to the objective of protecting the existing habitat and preventing future loss. However, there appears to only be information available about the use of such materials pertains to use on stream banks, not on marsh edges. It is unknown whether the Mordecai Island marsh substrate is sufficient to hold the necessary anchors, but visual observation indicates that it is unlikely.

Acceptability: This measure would likely be marginally acceptable to the resource agencies since without it the island is likely to eventually erode to a much smaller size and there would be loss of habitat. However, hardened shorelines (even with seeding/planting on surface) typically are not acceptable to resources agencies and they are likely to provide more support for a greener solution. There could be substantial temporary and/or permanent impacts to the island during construction of this measure.

2) Shore slope stone revetment, with or without fill and planting

With planting, this measure is also known as a joint planted revetment (see Figure 5.5). Per Stevens Institute of Technology 2016, "Revetments are shore-attached structures built along the shoreline to prevent erosion of the bank. Revetments are typically constructed from rock or concrete armor units, although alternative materials such as gabion baskets, rubble/debris, and even felled trees can also be used. Revetments are designed to armor the existing bank and to dissipate the incident wave energy on their sloping face. Revetments can be used at both open coastal locations and on lower energy sheltered coasts. Revetments differ from rip-rap covered slopes in that revetments are typically designed more rigorously and have more clearly defined layers and stone sizes. As part of a living shorelines strategy, the interstitial spaces in a traditional revetment can be planted. Incorporating vegetation within the revetment can provide valuable ecological benefits and help to stabilize the soil under the revetment."

Figure 5.5: Stone Revetment with Planting

"Revetments are typically constructed on a 1Vertical: 2Horizontal slope. Riprap/Stone can move during storms or wave action and as such the stone used needs to be heavy enough to remain in place. Revetments are very long lasting, durable structures which usually do not need any maintenance after construction. Revetments, when designed to, can withstand a wide range of wave energies from very little to large wave action. Although revetments cause a loss of soft bottom habitat, it causes less habitat destruction and loss than bulkheads and also creates fisheries habitat." (See Figure 5.6.)

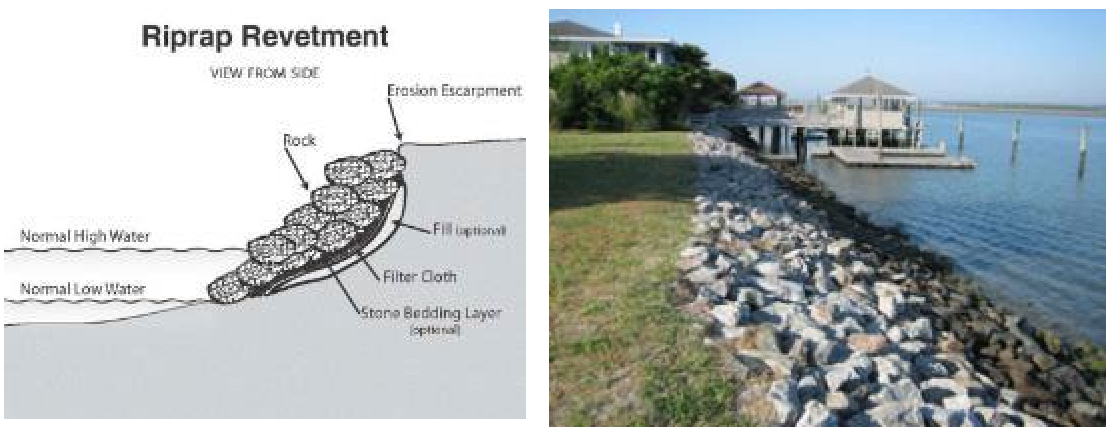


Figure 5.6: Stone Revetments

According to the Virginia Institute of Marine Science's *Design Guidelines for Shore Protection*, "Marsh Toe Protection Revetments (a.k.a.: riprap at the waterward toe of a marsh) are a shore-parallel, sloping structure constructed against a marsh escarpment to protect the marsh wetland roots from undermining. Placing riprap or stone on the waterward edge of the marsh helps to stabilize or reestablish the marsh vegetation. Marsh grasses dissipate wave energy and wave height through friction and drag, and thus help to reduce erosion further inland (usually on the high ground). Marsh vegetation also increases the marsh habitat and provides food for the lower organisms such as algae and seaweeds, finfish and shellfish, mammals and shorebirds."

"These marsh toe revetments can be used where existing marshes have eroding edges and scarps, or where upland bank erosion is present in spite of the marsh being present... These are low stone structures placed near the channelward marsh edge. The stone height can be near mean high water in low energy settings or if the marsh is already more than 15 ft wide. The height can be raised 1 foot above mean high water in moderate energy settings. Marsh toe revetments should be offset from the existing marsh edge near or channelward from mean low water. They should not be placed immediately next to or directly on the marsh surface. The low marsh zone between the marsh edge and mean low water should not be completely covered with stone. Tidal gaps can be strategically placed at natural marsh channels or where the total length of marsh toe revetment is greater than 100 ft."

Analysis

Completeness: A revetment would achieve Objective #1 by protecting existing habitat and preventing future loss of habitat, as it would stop erosion where the edge of the marsh is located during construction. Use of a revetment does not allow for restoration of marsh habitat where it has already eroded away, unless the revetment is part of a larger plan including fill or accretion in front of it.

Effectiveness: Revetments can be useful where the slope is too steep for a softer approach to work. This measure is effective at contributing to the objective of protecting the existing habitat from erosive forces. This measure would not contribute to restoration of habitat, except through temporary habitat gain if fill is placed in front of it.

Acceptability: Joint Planted Revetment is one of the measures presented in the 2016 Stevens Institute of Technology's "*Living Shorelines Engineering Guidelines,*" thus implying some level of acceptance. However, typically, hardened shorelines (even with seeding/planting on top portion) are not acceptable to some of the relevant resource agencies and they are likely to prefer a greener solution. There would likely be substantial temporary and/or permanent impacts to the island during construction of this measure. A stone revetment also disconnects the island habitat from the bay and likely would act as a barrier for species (e.g., diamondback terrapin) to access the island wherever there is riprap.

3) **Articulated open cell concrete mat with fill in cells and planting**

Articulated concrete mats consist of a flexible, interlocking matrix of cellular concrete blocks of uniform size, shape, and weight used for hard armor erosion control. (See Figure 5.7.) The concrete blocks can be solid or have openings in them. For Mordecai Island, open celled blocks were considered in order to support growth of marsh vegetation.

Analysis

Completeness: An articulated concrete mat would stop erosion where the edge of the marsh is located during construction. However, use of a mat does not allow for restoration of marsh habitat where it has already eroded away, unless the mat is part of a larger plan including fill or accretion in front of it. This measure would achieve Objective #1 by protecting existing habitat and limiting future loss of habitat. A benefit is that vegetation can grow in the voids of the concrete.

Figure 5.7: Articulated Concrete Mat Installation and Planted

Effectiveness: In theory, this measure would be effective at contributing to the objective of protecting the existing habitat and preventing future loss. A search for information indicated that an articulated concrete mat is typically used for stabilization of stream banks, rather than to protect against erosion of marshes. Therefore, effectiveness on Mordecai Island is unpredictable. On its own, the measure would not contribute to the restoration objectives.

Acceptability: This measure would likely be marginally acceptable to the resource agencies. They would probably accept it since without it the island is likely to eventually erode to a much smaller size and there would be loss of habitat. However, hardened shorelines (even with seeding/planting on surface) typically are not acceptable to resources agencies and they are likely to prefer a greener solution. Use would require excavation of the shoreline. There could be substantial temporary and/or permanent impacts to the island during construction of this measure.

4) Biologs, with or without fill

Biologs are tubes typically made with polyethylene or coir twine material on the outside and packed coconut fiber on the inside. According to Austin, Texas, Watershed Protection Department, “Coir is anchored in areas with loose soils that need stabilization including stream banks, wetlands and construction sites. The advantage of using coir logs for erosion control (rather than rocks or bulkheads) is that the coir allows vegetation to grow within it as it slowly biodegrades becoming part of the matrix of the soil. When the coir has finally biodegraded (years later), the roots of the vegetation then provide the long-term stability of the soil which provides natural and beneficial integrity to the land and water.” (See Figures 5.8 and 5.9.)

Figure 5.8: Installation of Biologs

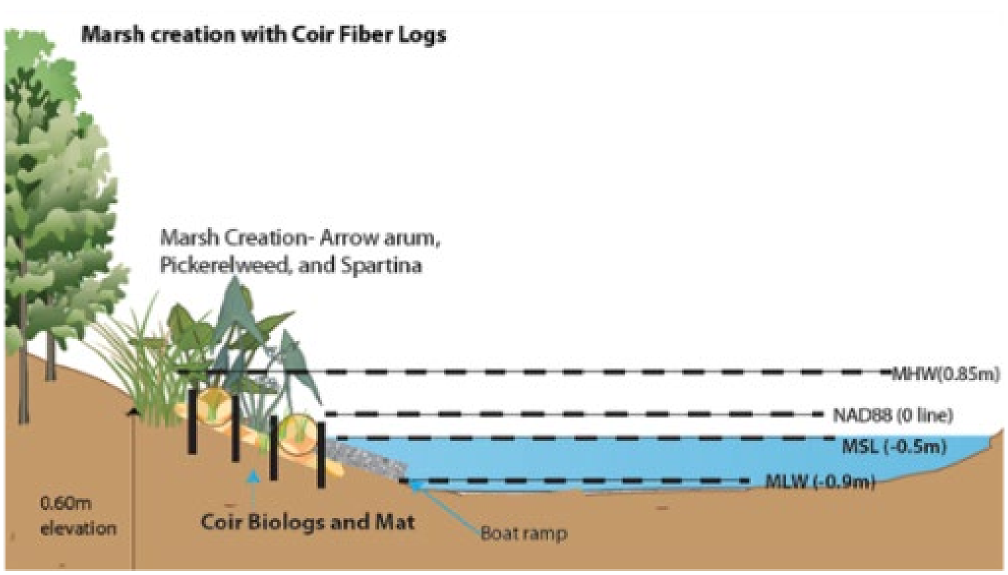


Figure 5.9: Relative Positioning of Biologs

Analysis

Completeness: Coir logs might marginally protect the existing habitat and prevent future loss, consistent with Objective #1. However, the benefit is likely to be short term. In addition, the measure does not meet the restoration objectives. This measure may be better combined with other measures (e.g., marsh sill) to be more complete.

Effectiveness: A drawback of coir logs is that they have a short lifespan and thus, in a high energy environment, would not adequately protect the island from erosion. They are biodegradable and have a low profile. This measure could, in theory, be effective at contributing to the objective of protection of existing habitat and limiting future loss. However, past use on Mordecai Island was ineffective. (See Section 2.2.1 of this feasibility report.) Coir logs are likely to work better in tandem with another, longer term, measure (e.g., marsh sill).

Acceptability: This measure would likely be acceptable to the resource agencies in terms of environmental impact; however, the agencies might question its long term effectiveness. The Mordecai Land Trust is likely to question the use of coir logs without accompanying measures, due to the Land Trust's experience described in Section 2.2.1 of this feasibility report.

5) Steel sheet pile bulkhead, no fill

According to the North Carolina DEQ *Estuarine Shoreline Stabilization Options*, "A bulkhead (a.k.a.: Vertical Structure, Seawall) is any shore-parallel vertical structure designed to prevent erosion, overtopping, flooding, or sliding of the land. Bulkheads are usually placed along an eroding bank or escarpment to hold back the land from the water and prevent erosion. Bulkheads are a long lasting, durable structure that can stand up to moderate to high wave energy; but they also prevent the natural migration of wetland vegetation." (See Figure 5.10.)

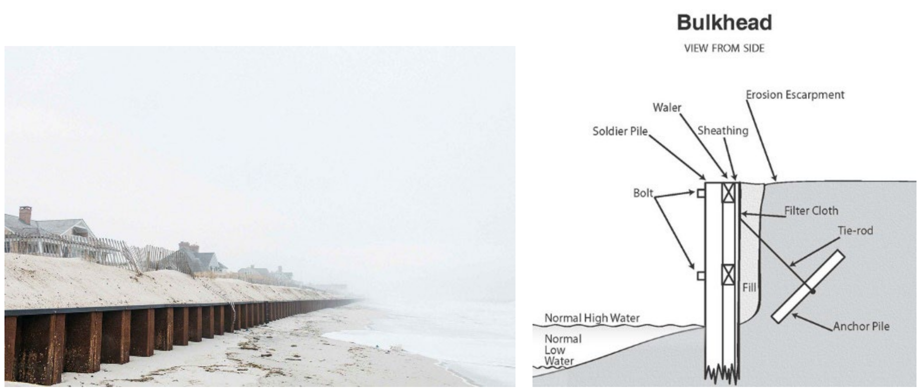


Figure 5.10: Bulkhead Design

Analysis

Completeness: A bulkhead would stop erosion where the edge of the marsh is located during construction, but would not allow for restoration of marsh habitat where it has already eroded away. Use of a bulkhead would require planning for possible wave reflection and scour and likely require addition of a mat or other hardening in front of the bulkhead.

Effectiveness: This measure would be effective at contributing to the objective of protecting the existing habitat and limiting future loss.

Acceptability: Use of a bulkhead would involve loss of transitional habitat and there would be environmental impact during construction. This measure would likely not be acceptable to the resource agencies. Typically, hardened shorelines are not acceptable to resources agencies and they are likely to encourage a greener solution. There would likely be substantial temporary and/or permanent impacts to the island during construction of this measure. A bulkhead also disconnects the island habitat from the bay and likely would act as a barrier for species (e.g., diamondback terrapin) to access the island wherever there is a bulkhead built.

6) Nearshore stone sill, with or without fill and planting

"Sills are low-elevation, typically stone structures that are constructed in the water parallel to the existing shoreline. Sills are often used as armoring for fringe marshes or wetlands that require a higher degree of protection. Sills dissipate wave energy and reduce bank erosion, causing waves to break on the offshore structure, rather than upon the natural, more fragile shore. The quiescent area of water that is created by the sill often allows sand and sediment to accumulate between the structure and the shoreline. With time this process can eventually raise the elevation of the bottom and create a perched beach. This unique effect not only serves to further stabilize the shoreline or marsh behind the sill but replaces lost and eroded land. Often the area between the sill and the shoreline is filled during construction to accelerate the development of the perched beach. Marsh plantings are often added to further stabilize the reclaimed land."[3] (See Figure 5.11.)

Figure 5.11: Nearshore Stone Sill

[3] *Stevens Institute of Technology. Living Shorelines Engineering Guidelines. New Jersey Department of Environmental Protection, February 2016.*

Sills are smaller than breakwaters. Sills are low height structures that are often below water. Their primary purpose is to interrupt transport of sediment from onshore to offshore and allow for sediment buildup onshore.

According to the 2016 *Living Shorelines Engineering Guidelines*, "A properly designed sill will contain windows or gaps along the structure to allow for circulation. While it is possible for water to access a marsh bordered by a living reef through overtopping or the macro-pores or spaces in the reef, gaps should always be included along larger projects to allow access for marine fauna (i.e. fish and turtles). Limited research has been performed to determine optimum gap width and frequency, but a general empirical guide recommends windows at least every 100 ft. along the length of the project (Hardaway, et al., 2010). Factors that influence window spacing include drainage, elevation change, recreational access, and bends in the project. Scour is generally observed along the shoreline behind the windows as waves are allowed to penetrate into this area." (See Figure 5.12.)

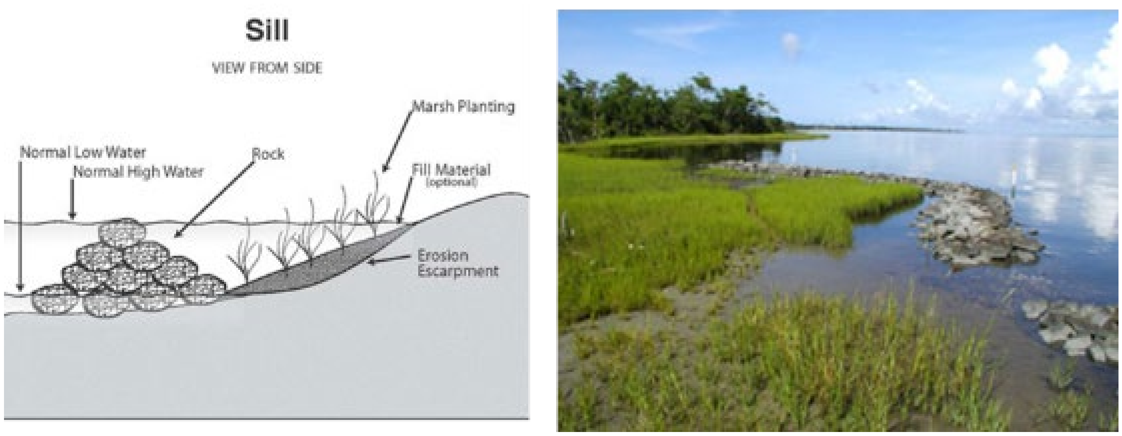


Figure 5.12: Nearshore Stone Sill Design

State of North Carolina Department of Environmental Quality. "Stabilization Options: Estuarine Shoreline Stabilization Options". https://deq.nc.gov/about/divisions/coastal-management/coastal-management-estuarine-shorelines/stabilization/stabilization-options (accessed May 1, 2019).

Analysis

Completeness: A sill could help break some wave and wake energy and, thus, contribute to the objective of protecting existing habitat and limiting future loss. However, sills are designed to be primarily located underwater and, therefore, would not sufficiently break the 2' design wave. Sills could be a complementary feature to larger structures if waves are likely to reform landward of the larger structure. Fill placed between the sill and the island would also contribute to meeting the restoration objectives. Without added fill at the time of construction, accretion would be slow and the restoration objectives would not be met until later.

Effectiveness: Sills are appropriate at sites with a low-moderate erosion rate. (Stevens Institute, 2016) A sill would be moderately effective at stabilizing the shoreline and would likely need to be combined with other measures to increase the effectiveness in the higher energy study area. This measure is effective at contributing to the protection of existing habitat and preventing future loss. Sills would also contribute to the restoration of lost habitat, especially if they are combined with landward fill material and planting.

Acceptability: The logistics of construction could be challenging, but there are likely to be acceptable options available. Because sills are smaller than breakwaters and do not require alteration of the marsh edge as with mats or revetments, they are likely to be more environmentally acceptable. A sill can contribute to the environment by functioning like a reef. There is potential for erosion on either side of the sill.

Marsh sills have generally been accepted by resource agencies for their use in living shorelines. In addition, since NJDEP has an approved use of living shorelines under the Coastal Zone Management Act, it's likely this measure would be acceptable.

7) Geotubes® with armor layer, with or without fill

Geotubes® are sediment-filled permeable, but soil-tight, sleeves of geotextile fabric. When used for erosion control they are usually large, often with a circumference of 15 – 60 or more ft. and lengths of 50 – 200 or more ft. (See Figure 5.13.)

Figure 5.13: Corps Installation of Geotubes® at Nelson Lagoon, Alaska

Analysis

Completeness: Geotubes® with an armor layer could achieve Objective #1 landward of the individual Geotubes® by protecting existing habitat and limiting future loss of habitat. If material accretes landward of the Geotube® or fill is deposited during construction, the approach would be more complete due to restoration of habitat, which is another project objective. However, as noted in Section 3.4.8 of this feasibility report, there does not appear to be a large influx of material coming from elsewhere to offshore of Mordecai Island's western shoreline, thereby limiting potential for natural accretion. Relocation of the NJIWW could provide a potential source of fill material.

Effectiveness: The covering of the Geotube® is susceptible to wear and being torn, as evidenced by MLT's experience with Geotubes® off the western shore of Mordecai Island. Geotubes® with an armor layer of dolos (concrete block in a complex geometric shape), or similar covering, would effectively serve as a breakwater. This measure is effective at contributing to the protection of existing habitat and preventing future loss. If material accretes between the island and the Geotube® or fill is used, it would be more effective by restoring habitat, thereby addressing two other project objectives. Geotubes could potentially also be combined with other measures to be more effective. As sea level rises, effectiveness would become more limited, unless the Geotubes® were replaced with increasingly larger Geotubes®.

Acceptability: Use would cause environmental impact on shallow water habitat. There is potential for accretion landward of the Geotubes®, although there is limited available sediment in the system. Geotubes® have generally been acceptable to the public and resource agencies. The long-term viability of the structure may be questioned by the resource agencies. Geotubes® have been known to tear, as an existing one at Mordecai Island has done (see Section 2.2.2 of this feasibility report) and the armoring layer could both protect and add stress to the Geotube® fabric.

8) Oyster Castles ®, with or without fill

"Oyster Castles ® are prefabricated concrete blocks specifically designed to attract and foster oyster settlement and are manufactured by Allied Concrete Company in Charlottesville, Virginia. Each Oyster Castle® is 1 foot by 1 foot, 8 inches high, and 2 to 3 inches thick... The structures are hollow on the inside with a notch cut into each side to allow the blocks to lock together."[4] (See Figure 5.14.)

[4] United States Fish and Wildlife Service. Final Environmental Assessment for the Gandy's Beach/Money Island Living Shoreline Project, 2015.

Oyster Castles® are designed to be connected into arrays of various sizes. Shoreline remediation and salt marsh preservation are by-products of the effort geared toward oyster restoration.

Figure 5.14: Oyster Castles®

Source of photos: Allied Concrete Company. http://www.alliedconcrete.com

Analysis

Completeness: Preliminary information indicates that Oyster Castles® alone would not sufficiently address the objectives of this study. Oyster Castles® could potentially help break some wave and wake energy and, thus, contribute to the objective of protecting existing habitat and limiting future loss. However, Oyster Castles® are designed to be primarily located underwater and, therefore, would not sufficiently break the 2' design wave. This measure may be best combined with other measures to be more complete.

Effectiveness: Preliminary observations of Oyster Castles® already installed next to Mordecai Island indicate that they are effectively creating viable habitat and tombolos are developing out from the shore toward Oyster Castle® arrays. (See Section 2.2.4 of this feasibility report.) The primary purpose of Oyster Castles® is restoration of oysters to a water body. Shoreline protection and marsh restoration are potential by-products. Pursuit of these by-products appears to work best in lower to moderate energy environments. It is unlikely that oyster castles alone would serve well in the higher energy environment of the study area and there are more efficient ways to address a 2' design wave. This measure may be best combined with other measures to be more effective.

Acceptability: Oyster Castles® have generally been acceptable to the resource agencies. The long-term viability of the structure may be questioned by the resource agencies.

9) Offshore breakwaters, with or without fill

(See also, **Geotubes® with armor layer** and **Precast concrete structures**) Per Stevens Institute of Technology (2016), "Breakwaters are coastal engineering structures typically constructed parallel to the shoreline that are designed to reduce the amount of wave energy experienced by the area directly behind them. Breakwaters are frequently used in marinas and harbors as well as along open coasts. When utilized as a part of a living shorelines project, breakwaters are designed to reduce the wave energy to acceptable levels to allow the establishment of a beach or vegetated (typically marsh) shoreline in its lee. Breakwaters are distinguished from sills in that they are typically constructed in deeper water, further from shore, in more energetic wave climates, and tend to be slightly larger."

Figure 5.15: Stone Breakwaters

Breakwaters can be continuous or have breakwater gaps as seen on the right and left, respectively in Figure 5.15. Breakwater gaps help promote sediment accretion behind the structure in sediment rich environments. In some areas, where there is not enough sediment in the system to naturally accrete, a continuous breakwater may be more advantageous. A continuous breakwater has a greater potential to protect material placed behind the structure. Instead of breakwater gaps, sill vents can be designed into a continuous breakwater by reducing the crest height in some areas of the structure to promote intertidal flushing while still protecting the habitat behind the structure. (See Figure 5.16.)

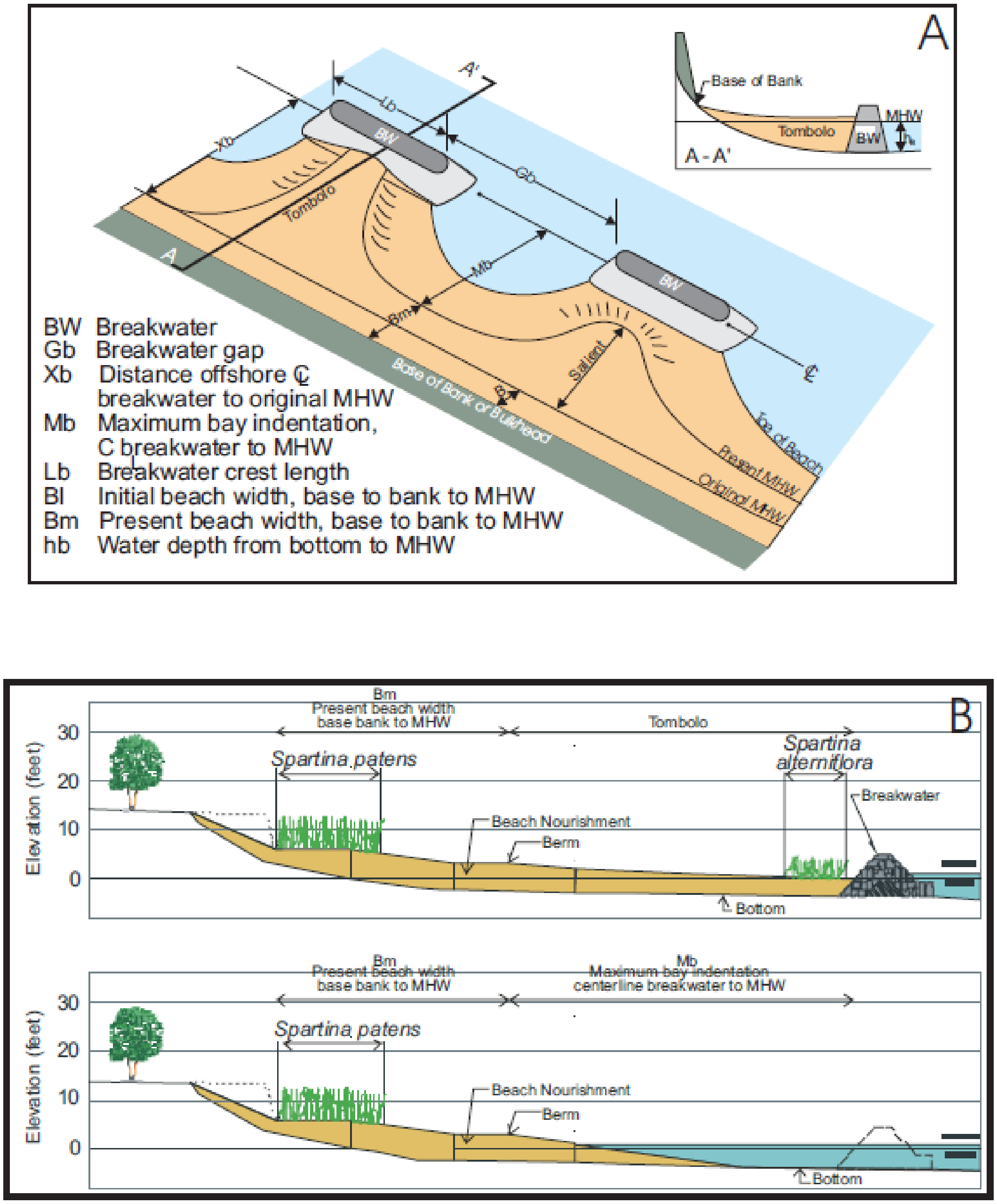


Figure 5.16: A) Breakwater Design Parameters and B) Typical Tombolo with Breakwater and Bay Beach Cross Section (after Hardaway and Byme, 1999)

Analysis

Completeness: A breakwater would achieve Objective #1 by protecting existing habitat and limiting future loss of habitat. If fill is used, it would provide more completeness by restoring habitat, which is another project objective. Habitat restoration could also occur over time without fill but, given the limited amount of sediment available in the system, accretion and, thus, restoration would be very slow.

Effectiveness: This measure could be effective at protecting existing habitat and limiting future loss. Effective erosion control could occur, but accretion would be slow without added fill. If fill is used, it would be more effective at restoring habitat, thereby contributing to all the project objectives. Effectiveness can be maintained with sea level rise by adding more rock to raise the height of breakwater. Increased bottom width would be necessary to support increased height.

Acceptability: Breakwaters would have a large environmental footprint on the bay bottom and potentially present a boating hazard, though proper signage could help address the risk. Despite the large environmental footprint, in the case of Mordecai Island, this measure may be acceptable to resource agencies due to its effectiveness. Placement of breakwaters would also need to take into consideration the 1977 Tidelands Claim Line as the acceptable waterward limit of structures. In addition, placement of breakwaters would need to take into consideration any limits placed on reflection of waves into the NJIWW.

10) Precast concrete structures (e.g. Beach Prisms™ or WAD® - Wave Attenuation Device), with or without fill

Easi-Set® Worldwide's Beach Prisms™ are triangular pre-cast concrete structures that are designed to limit shoreline erosion in riverine and bay environments (see Figure 5.17). The structures have slots in them to allow water through while breaking wave energy. Each section is 3-4' in height and 10' in length, making them most appropriate to a near shore shallow environment. The size limit appears to limit opportunities for adaptation to sea level rise. Beach Prisms™ have been used in the Toms River off of Barnegat Bay, north of Mordecai Island.

Figure 5.17: Beach Prisms™ Prior to Installation

Beach Prisms™ (weighing about 10,000 pounds each) before installation roughly 50 ft. away from the beach in the Toms River in Ocean Gate, NJ. *(Photo by: FEMA/Rosanna Arias, https://www.fema.gov/media-library/assets/images/85964* (accessed May 1, 2019)

As previously described in Section 2.2.8 of this report, Living Shoreline Solutions, Inc.'s WADs® are poured concrete pyramids of varying heights that are designed to site conditions. The structures are hollow to allow water and biota to pass through, while reducing wave energy. They are often placed in overlapping rows. The system is not anchored to the bottom and is therefore portable in the event of needed modification. Rising water levels can be addressed by sliding another WAD® unit on top of an existing one, or by adding a higher row of WADs®. As shown in the Figures 5.18 and 5.19, the Corps has placed WADs® for a living shoreline project at Bayou Caddy in Biloxi, Mississippi.

Figure 5.18: WADs® Placement at Bayou Caddy in Biloxi, MS

Figure 5.19: WADs® in Place at Bayou Caddy in Biloxi, MS

Analysis

Completeness: These measures could contribute to achieving Objective #1 by protecting existing habitat and limiting future loss of habitat. However, there are not enough examples of Beach Prisms™ to demonstrate the longevity and adaptability of this measure. WADs® are designed to be adaptable to future conditions. This adaptability could be important as sea level rise progresses. Both structures could contribute to Objective #2 through promotion of accretion for habitat restoration. However, there is limited material available in the system for accretion, so accretion would likely take a long time. The use of precast concrete structures would be a more complete approach with the addition of fill material between the island and the structures.

Effectiveness: "Beach prisms are typically used in beach protection applications specifically for that purpose, in the nearshore area where stone sills would be placed. These structures may be sufficient in one or more of the lower energy zones, but they are limited by water depth as they are a single size, may require footing with other stone material, and may be difficult to maintain if individual sections shift around. Other drawbacks include lack of resiliency, lack of modification capability in the event of sea level rise or adaptive management (i.e., stone sills can easily be elevated or lowered by adding or removing rock materials), spot repair, widening or narrowing gaps by less than the width of a single section."[5]

[5] Memorandum from ERDC to CENAP on "Water Operations Technical Support; Request Number 2013-027, Mordecai Island Coastal Wetlands Restoration Project, Section 1135 – Ocean County, New Jersey." 24 March 2014.

WADs® are designed to specific site conditions and can be cast in varying sizes, with varying features. WADs® can be modified by addition of further WADs®, removal of existing WADs®, or relocation of existing WADs®, thereby making them more effective than Beach Prisms™.

Acceptability: "[Beach Prisms™] would provide some refugia for fish and some substrate for colonization by shellfish, though would not provide any opportunity for interplanting SAV."[6]

[6] Memorandum from ERDC to CENAP on "Water Operations Technical Support; Request Number 2013-027, Mordecai Island Coastal Wetlands Restoration Project, Section 1135 – Ocean County, New Jersey." 24 March 2014.

Unlike Beach Prisms™, WADs® are hollow, with openings in the pyramid walls and often at the bottom, providing greater substrate surface area and potentially greater refugia opportunities.

Both structures require a crane for them to be raised and lowered into place. MLT has successfully placed WADs® using a barge adjacent to Mordecai Island.

Both structures would have an environmental footprint on the bay bottom and potentially present a boating hazard, though proper signage could help address the risk. Despite the environmental footprint, in the case of Mordecai Island, WADs® may be acceptable to resource agencies due to WADs'® effectiveness and adaptability. Placement of these measures would also need to take into consideration the 1977 Tidelands Claim Line as the acceptable waterward limit of structures.

11) Floating wave attenuator

In a marine environment, wave attenuators (sometimes known as floating breakwaters) are large floating structures used to reduce wave energy, often at marinas. They can be made with a variety of materials and are anchored to the seabed.

Analysis

Completeness: This measure is not likely to protect the existing habitat and limit future loss of habitat. Nor will it contribute to restoration of lost habitat.

Effectiveness: "Considering both the generally high wave energy environment with the sporadic heavy boat traffic and associated vessel wakes, a floating wave attenuator is not recommended. These structures are effective in some settings, though can be a maintenance burden with debris or ice. Additionally, wave attenuators are designed with that single goal and generally do not provide substrate, cover or other habitat benefits."[7]

[7] *Memorandum from ERDC to CENAP on "Water Operations Technical Support; Request Number 2013-027, Mordecai Island Coastal Wetlands Restoration Project, Section 1135 – Ocean County, New Jersey." 24 March 2014.*

This measure is not likely to be effective at the protection of existing habitat and preventing future loss of habitat.

Acceptability: Depending on the design of the wave attenuator, it would likely be accepted by resource agencies, but could be considered a potential navigation hazard and aesthetically displeasing.

12) Move No Wake Zone markers closer to the NJIWW channel

A No Wake Zone is a designated area where boats are prohibited from producing wakes. No Wake Zone markers are present between Mordecai Island and the NJIWW channel, but they are reportedly not often noticed by boaters.

Analysis

Completeness: Since energy from boat wakes contributes to the erosion of Mordecai Island, a noticeable No Wake Zone for the nearby Intracoastal Waterway would be helpful if boaters observe it. However, it would not fully eliminate erosion or contribute to habitat restoration. A respected No Wake Zone would work well in tandem with other measures.

Effectiveness: On its own, this measure is likely to be minimally effective at the protection of existing habitat and limiting future loss of habitat. It could be very effective when combined with other measures and effectiveness of other measures would benefit from reduced wake energy.

Acceptability: A re-marking of the No Wake Zone would likely be accepted by resource agencies.

13) Move NJIWW channel farther away from the island

NJIWW channel marker LB west of Mordecai Island, at 39° 33.745' N, 74° 15.191' W, cannot be moved, but it is possible that the channel of the New Jersey Intracoastal Waterway can be moved to the other side of the buoy and the channel indicators on the marker can be changed from red to green.

Analysis

Completeness: Since energy from boat wakes contributes to the erosion of Mordecai Island, moving the nearby NJIWW channel farther from the island would be helpful. The effort would move the channel farther away from much of the island study area, however, the channel would continue to be relatively close to the island at the northern tip where it passes channel marker 107 north of the island. In this instance, the channel marker is already on the island side of the channel. Where feasible, moving the NJIWW channel would not fully eliminate erosion or contribute to habitat restoration. Moving the channel would work well in tandem with other measures. Relocating the channel could contribute to the overall completeness of the project as it would necessitate dredging of a shoal, thereby providing fill material to be placed behind an erosion control structure and enhancing the restoration aspect of the project.

<u>Effectiveness:</u> On its own, this measure is likely to be minimally effective at the protection of existing habitat and limiting future loss of habitat. It could be very effective when combined with other measures and effectiveness of other measures would benefit from reduced boat wake energy.

<u>Acceptability:</u> The shoal to the west of the existing location of the NJIWW channel has been in place at least since the late 1800s. Digging into it is likely to destabilize it and cause infilling of a relocated channel. The channel is the responsibility of the Corps Philadelphia District and moving the channel is not acceptable within the District due to the likely effect on the channel.

5.4.3 Summary of Evaluation of Measures

Table 5.1 depicts the screening results for the measures. Where evaluations appear to be similar, the Notes section provides information on considerations that distinguish one measure from another.

Table 5.1: Measures Screening

		CRITERIA			
MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Shoreline grading and high performance turf reinforcement mat (TRM) with fill on top of mat and seeding	Protection: High Restoration: Low	Low	Low	No	1. Sufficiency of substrate for anchoring unknown, but unlikely. 2. Technique typically used on streambanks. 3. Potential negative impact to island during construction.
Shore slope stone revetment, with fill	Protection: High Restoration: Low	Protection: High Restoration: Low	Medium	No	1. Weight could cause further marsh calving. 2. Fill vulnerable to being washed away. 3. Potential negative impact to island during construction. 4. Negatively impact transitional habitat zone. 5. NJDEP has implied potential acceptance.
Shore slope stone revetment, without fill	Protection: High Restoration: Low	Protection: High Restoration: Low	Medium	No	1. Weight could cause further calving of the island. 2. Potential negative impact to island during construction. 3. Negatively impact transitional habitat zone.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Articulated open cell concrete mat with fill in cells and planting	Protection: High Restoration: Low	Protection: Medium Restoration: Low	Medium	No	1. Technique typically used on streambanks, not marsh islands. 2. Weight could cause further calving. 3. Potential negative impacts to the island during construction.
Biologs, with fill	Protection: Low Restoration: Low	Low	Medium	No	1. Fill vulnerable to being washed away. 2. Very poor prior performance on Mordecai Island. 3. Minimal negative impact on habitat.
Biologs, without fill	Protection: Low Restoration: Low	Low	Medium	No	1. Very poor prior performance on Mordecai Island. 2. Minimal negative impact on habitat.
Steel sheet pile bulkhead, no fill	Protection: High Restoration: Low	High	Low	No	1. Loss of connectivity between the marsh platform and subtidal habitats. 2. Elimination of transitional habitat. 3. Impact to island during construction. 4. Limit access to island for some species.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Near shore stone sill, with fill and planting	Low	High	High	Yes	1. Would need to be combined with a higher structure to sufficiently break the wave/wake energy. 2. Fill could help promote habitat restoration earlier than waiting for only accretion. 3. Amenable to modification over time. 4. Potential construction challenges.
Near shore stone sill, without fill and planting	Low	Medium	High	Yes	1. Would need to be combined with a higher structure to sufficiently break the wave/wake energy. 2. Amenable to modification over time. 3. Potential construction challenges.
Geotubes® with armor layer, with fill	High	Medium	Medium	No	1. Armor layer may be modifiable after installation. Geotubes® would not be readily modifiable. 2. May impact shallow water habitat. 3. Long term viability of Geotube® material is likely to be a major issue. 3. Fill could help promote habitat restoration earlier than waiting for only accretion.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Geotubes® with armor layer, without fill	Medium	Medium	Medium	No	1. Armor layer may be modifiable after installation. Geotubes® would not be readily modifiable. 2. May impact shallow water habitat. 3. Long term viability of Geotube® material is likely to be a major issue.
Oyster Castles®, with fill	Low	Medium	High	Yes	1. Would need to be combined with a higher structure to sufficiently break the wave/wake energy. 2. Preliminary information from existing Oyster Castles® indicates potential to increase habitat lift. 3. Fill could help promote habitat restoration earlier than waiting for only accretion. 4. Amenable to modification over time.
Oyster Castles®, without fill	Low	Medium	High	Yes	1. Would need to be combined with a higher structure to sufficiently break the wave/wake energy. 2. Preliminary information from existing Oyster Castles® indicates potential to increase habitat lift. 3. Waiting for accretion would take longer to realize restoration benefits than if fill is provided. 4. Amenable to modification over time.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Offshore breakwaters, with fill	High	High	High	Yes	1. Depending on construction materials and design, may be amenable to modification. 2. Depending on distance from the island shore, can sufficiently break wave and wake energy. 3. Depending on distance from the island shore, might need a secondary structure closer to the shore to keep waves from reforming. 4. Placement would need to consider the 1977 tidelands line. 5. Placement and design would need to consider potential reflection of wave energy toward the channel. 6. Fill could help promote habitat restoration earlier than waiting for only accretion. 7. Would be perpetually visible. 8. Depending on materials and design, bird habitat can be encouraged on top of the structure. 9. Relatively shallow bathymetry would need to be considered for construction access.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Offshore breakwaters, without fill	Protection: High Restoration: Low	Protection: High Restoration: Low	High	Yes	1. Depending on construction materials and design, may be amenable to modification. 2. Depending on distance from the island shore, can sufficiently break wave and wake energy. 3. Depending on distance from the island shore, might need a secondary structure closer to the shore to keep waves from reforming. 4. Placement would need to consider the 1977 tidelands line. 5. Placement and design would need to consider reflection of wave energy toward the channel. 6. Waiting for accretion would take longer to realize restoration benefits than if fill is provided. 7. Would be perpetually visible. 8. Depending on materials and design, bird habitat can be encouraged on top of the structure. 9. Relatively shallow bathymetry would need to be considered for construction access.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Precast concrete structures/Beach Prism™, with fill	Low	Unknown	High	No	1. Would need to be combined with a higher structure to sufficiently break the wave/wake energy. 2. Not amenable to modification. 3. Not enough examples of use to determine longevity. 4. Fill could help promote habitat restoration earlier than waiting for only accretion.
Precast concrete structures/Beach Prism™, without fill	Low	Unknown	High	No	1. Would need to be combined with a higher structure to sufficiently break the wave/wake energy. 2. Not amenable to modification. 3. Not enough examples of use to determine longevity. 4. Waiting for accretion would take longer to realize restoration benefits than if fill is provided.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Precast concrete structures/WAD®, with fill	High	High	High	Yes	1. Amenable to modification. 2. Depending on distance from the island shore, can sufficiently break wave and wake energy. 3. Depending on distance from the island shore, might need a secondary structure closer to the shore to keep waves from reforming. 4. Placement would need to consider the 1977 tidelands line. 5. Fill could help promote habitat restoration earlier than waiting for only accretion. 6. Would be perpetually visible. 7. Limited impact on bay bottom. 8. Provides fish refuge and is supportive of other biota. 9. Relatively shallow bathymetry would need to be considered for construction access.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Precast concrete structures/WAD®, without fill	Protection: High Restoration: Low	Protection: High Restoration: Low	High	Yes	1. Amenable to modification. 2. Depending on distance from the island shore, can sufficiently break wave and wake energy. 3. Depending on distance from the island shore, might need a secondary structure closer to the shore to keep waves from reforming. 4. Placement would need to consider the 1977 tidelands line. 5. Would be perpetually visible. 6. Limited impact on bay bottom. 7. Provides fish refuge and is supportive of other biota. 8. Relatively shallow bathymetry would need to be considered for construction access.
Floating wave attenuator	Low	Low	High	No	1. Minimal contribution to habitat protection or restoration.
Move No Wake Zone markers closer to the channel	Low	Medium	High	Yes	1. Coordination would be needed with the US Coast Guard. 2. Moderately effective on its own; very effective in combination with other measures. 3. Would help other measures be more effective.

MEASURES	Completeness	Effectiveness	Acceptability	Conduct Further Analysis (Y/N)	Notes
Move NJIWW channel farther away from the island	Low	Medium	High	Yes	1. Would reduce impact on the island from the primary source of wake-driven energy. 2. Moderately effective on its own; very effective in combination with other measures. 3. Would provide a source of sediment to fill landward of any wave-breaking structures. 4. Would help other measures be more effective. 5. Would destabilize a shoal and cause channel infill.

In summary, the measures carried forward in plan formulation include the following:

Primary Measures

1. Offshore breakwaters, with fill
2. Offshore breakwaters, without fill
3. Wave Attenuation Devices®, with fill
4. Wave Attenuation Devices®, without fill

Supplemental Measures

5. Near shore stone sill, with fill and planting
6. Near shore stone sill, without fill and planting
7. Oyster Castles®, with fill
8. Oyster Castles®, without fill
9. Move No Wake Zone markers closer to the channel
10. Move NJIWW channel farther away from the island

For each of the structural options, providing fill and planting on the landward side of the structure would be a more comprehensive response to the project objectives, although depending exclusively on natural accretion is an option that has some limited potential to eventually address the objectives.

Both near shore stone sills and Oyster Castles® are designed to be primarily located underwater and, therefore, would not sufficiently break the 2' design wave. If used, both measures would need to be combined with a higher structure and could serve to keep waves from reforming landward of the higher structure, if the design process demonstrates that there will be a problem with wave reformation. There is also potential that the smaller structures, such as Oyster Castles®, could serve to divert flow at the northern end of a larger structure, or limit sediment transport away from the southern end.

Moving the No Wake Zone markers closer to the channel also has potential to reduce the impact of boat wakes, which would benefit every alternative plan and otherwise not impact them. Therefore, moving the No Wake Zone markers is an aspect of each alternative plan moving forward.

Moving the nearby NJIWW channel could reduce the impact of boat wakes and it could also provide a source for some construction fill material. Philadelphia District, Operations Division, could move the NJIWW channel farther away from the island, and doing so would provide material from a current shoal where the new channel would be located. It is estimated that approximately 30,000 cubic yards of material would then be available from maintenance dredging every ten years. The channel could be moved as part of this project; Operations Division does not have plans to move the channel for any other purpose. Other sources of readily available suitable material do not exist in the area.

5.4.4 Further Evaluation of Measures

It was determined that given the location of the limiting 1977 Tidelands line, waves are not likely to reform landward of the structure. Therefore, a supplemental sill would not be effective. Supplemental structures, such as Oyster Castles®, at the northern and southern ends of a structural measure will be considered as part of the overall design process, where needed.

Further discussion with resource agencies revealed that impacts to SAV could be considered part of a trade-off analysis with benefits realized for ecosystem restoration projects within the 1977 Tidelands line. This is within the area covered by NJDEP's living shorelines regulations and therefore not a major constraint to project planning.

5.4.5 Development of Alternative Plans

Erosion of the western side of Mordecai Island, as well as any habitat protection and habitat restoration, needs to be considered as a system and not leave vulnerable areas. Therefore, each alternative needs to extend from the northern tip of the island southward to the northern end of the MLT features described in Chapter 2 of this report.

Both wave attenuation structures (e.g., WAD®) and rubble mound breakwaters, with and without fill, were considered at three different depths providing similar levels of erosion protection, with the 1977 Tidelands line generally representing the greatest depth (Alignment A) and two other alternatives (Alignments B and C) approximately 25 ft. apart in successively shallower water toward the western shore of the island. (See Figure 5.20.)

Alignments A, B and C average -4', -3.5' and -3' NAVD88 in depth, respectively, and converge at the northern tip of the island as they draw closer to the channel. The northern half of Alignment C follows the same layout as the northern half of Alignment B, since a landward offset of Alignment C in this area would place the structure on the island and act as a shoreline slope revetment, a measure which was screened out prior to alternative plan formulation.

Both a rubble mound breakwater and wave attenuation structures along Alignment A would extend for 3,000 linear ft. and have an average height of 7.6 ft. from the bay bottom. Structures along Alignment B would extend for 2,900 linear ft. and have an average height of 7.1 ft.. Structures along Alignment C would also be 2,900 linear ft. in length and would have an average height of 6.6 ft. The average heights are the initial construction heights of the structure and factor in one foot of over-build for potential settlement. Settlement will be further evaluated in more detail during the next phase of the study.

As noted above, both rubble mound breakwater and wave attenuation structures would be placed approximately parallel to the west side of Mordecai Island in the nearshore area. Specific design considerations and assumptions for the breakwater and the wave attenuation structures can be found in the Engineering Technical Appendix. Designs and quantities are preliminary in order to compare alternatives through a cost effectiveness/incremental cost analysis. Specific design features can be optimized in the next phase of the study.

Wind generated waves were determined to be relatively small for Mordecai Island (see Section 3.4.3). Boat driven waves are most likely the main driver of erosion and were therefore used as the design wave for the breakwater and wave attenuation structures. Based on potential boat generated waves, as well as use of the STWAVE nearshore model, the minimum crest elevation for both structures was determined to be +2.6 ft. NAVD88. To account for potential settlement, the initial construction of both structures was estimated to be +3.6 ft. NAVD88 (1foot of overbuild). Both structures require a geocomposite between the bottom of the structure and the existing ground (see Geotechnical Section of the Engineering Technical Appendix).

The crest width of the trapezoidal breakwater, a function of the rock size and design wave height, was determined to be 3 ft. Side slopes of 2H:1V were chosen as the steepest allowable slope based on both economics and design. As described in Section 5.2.2, there are two types of breakwater structures; gapped and continuous. Based upon historic erosion and accretion rates, there may not be enough sediment in the system to naturally accrete behind gapped breakwaters. A continuous breakwater was selected for the development of alternative plans due to a greater potential to protect existing and/or placed material behind the structure. Some water can transport through the breakwater voids, however this transport may not be enough to promote water quality behind the structure. Therefore, sill vents, or lower sections of breakwater, were designed into the structure to promote intertidal flushing in order to maintain water quality. The sill vents are approximately 40 ft. long and have a crest elevation at the MLW line to allow water to flow through the breakwater during the entire tide cycle. There is approximately 160 linear ft. of breakwater between each sill vent. The northern tip of Mordecai Island is the most vulnerable area to waves due to its proximity to the NJIWW. For this reason, there are no sill vents in the northern tip of the breakwater.

The wave attenuation structures are poured concrete pyramids (except flat on the top) aligned in a double row to more effectively attenuate wave energy. Water can move between each wave attenuation structure and through the six triangle openings located on each wave attenuation structure face. Water quality is not a factor and sill vents or gaps between the wave attenuation structures are not needed. Wave attenuation structure dimensions are outlined in the Engineering Technical Appendix.

In addition to the structural alternatives, fill to the 1977 Tidelands line without a hardened structure, as well as No Action, rounded out the alternatives considered. It was still assumed that relocating the channel could provide a source of fill material. Each alternative except No Action included moving the No Wake Zone markers closer to the channel.

In summary, alternatives at this stage of plan formulation included the following:

1. No Action (the alternative to which all others are compared to determine effects)
2. Wave attenuation structures at alignments A, B and C, all with fill material
3. Rubble mound breakwater at alignments A, B and C, all with fill material
4. Wave attenuation structures at alignments A, B and C, all without fill material
5. Rubble mound breakwater at alignments A, B and C, all without fill material
6. Fill material without a structure

Structural alignments A, B, and C can be found in Figure 5.20. Fill material without a structure can be found in 5.21. Sample typical cross sections can be found in Figure 5.22 through Figure 5.27. Cross sections are not shown with fill because the amount of fill will vary throughout the placement area and throughout time. Depending upon the quantity of sand available from the maintenance dredging and the island conditions at the time of construction, it is estimated that between 1 and 1.5 feet of sand will be placed in the fill areas. Behind the breakwater and MLT structures, the sand will be graded in a natural slope that will eliminate the steep edges and mimic healthy intertidal habitat. Fill will not extend beyond the rubble mound structure.

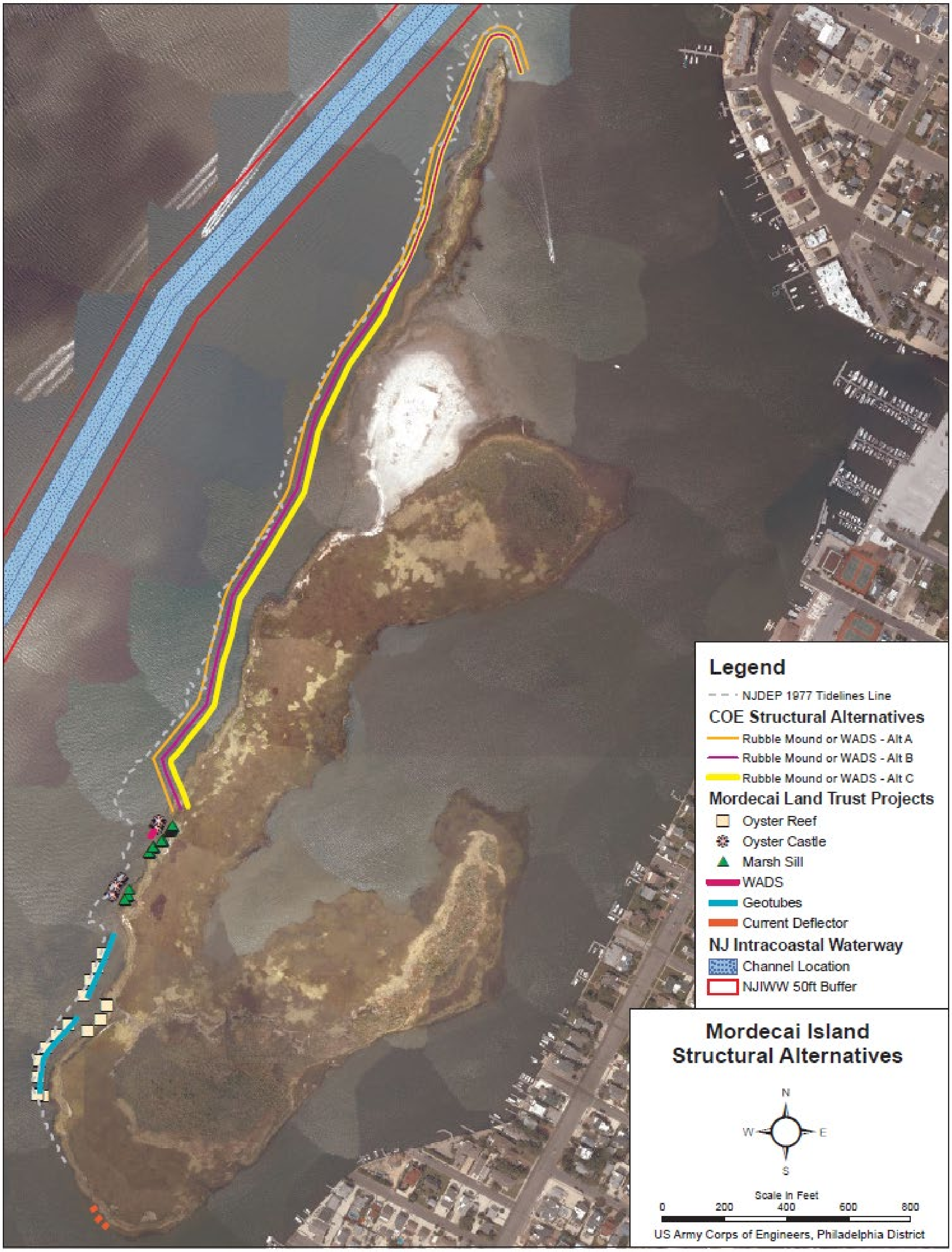


Figure 5.20: Plan View of Structural Alternatives

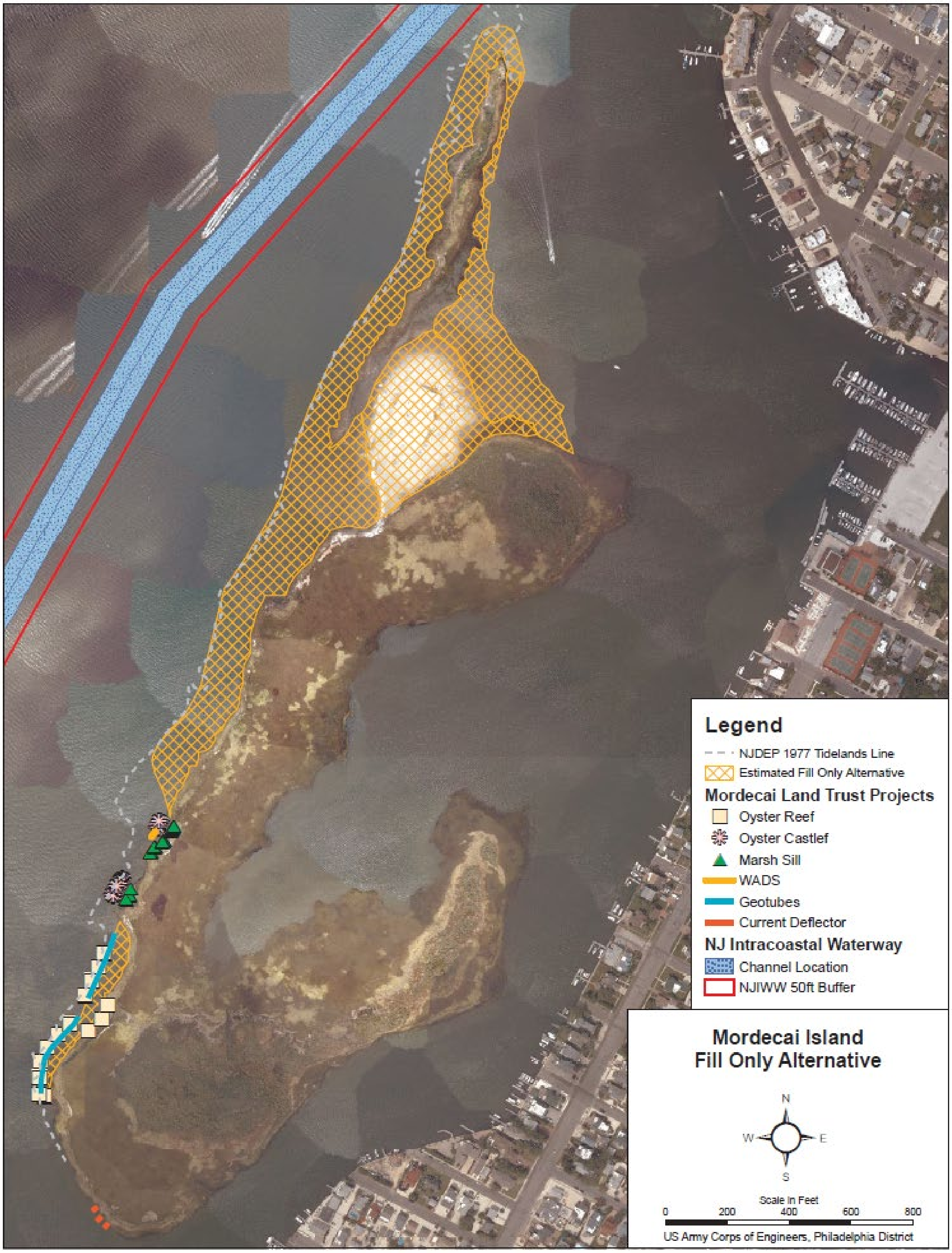


Figure 5.21: Plan View of Fill Only Alternative

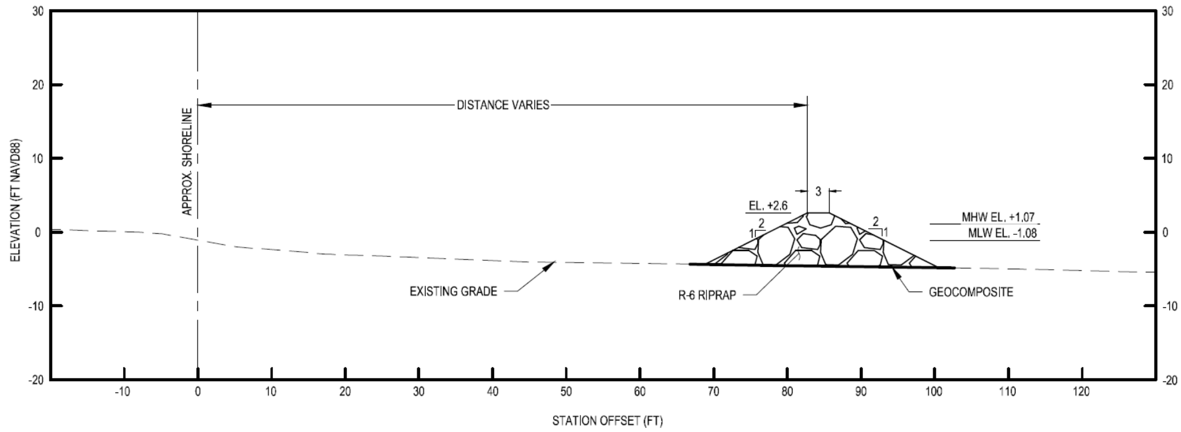


Figure 5.22: Typical Section of a Rubble Mound Breakwater at Alignment A

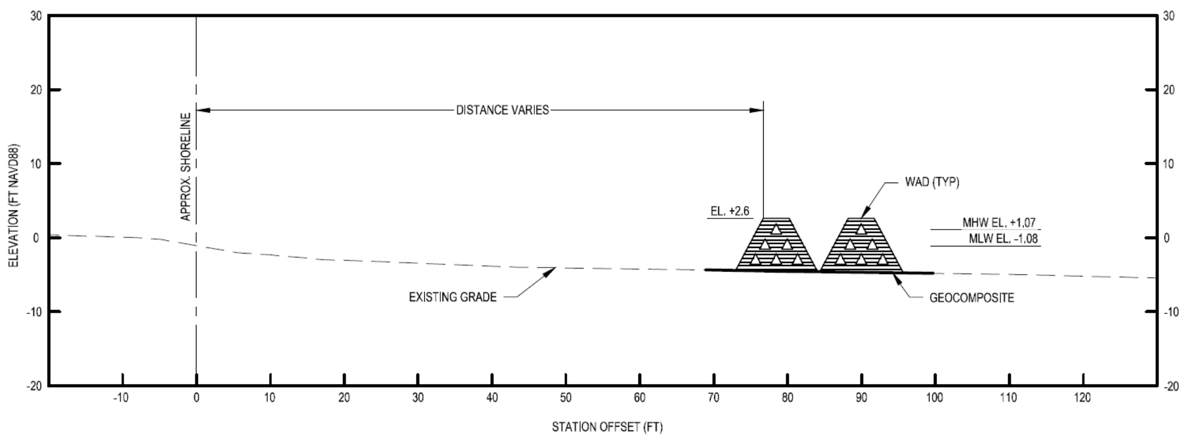


Figure 5.23: Typical Section of a Wave Attenuation Structure at Alignment A

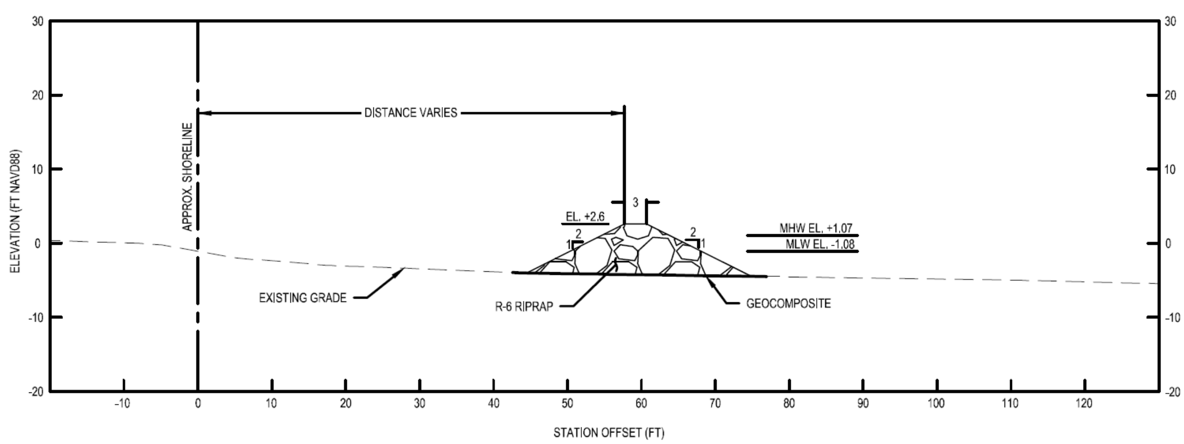


Figure 5.24: Typical Section of a Rubble Mound Breakwater at Alignment B

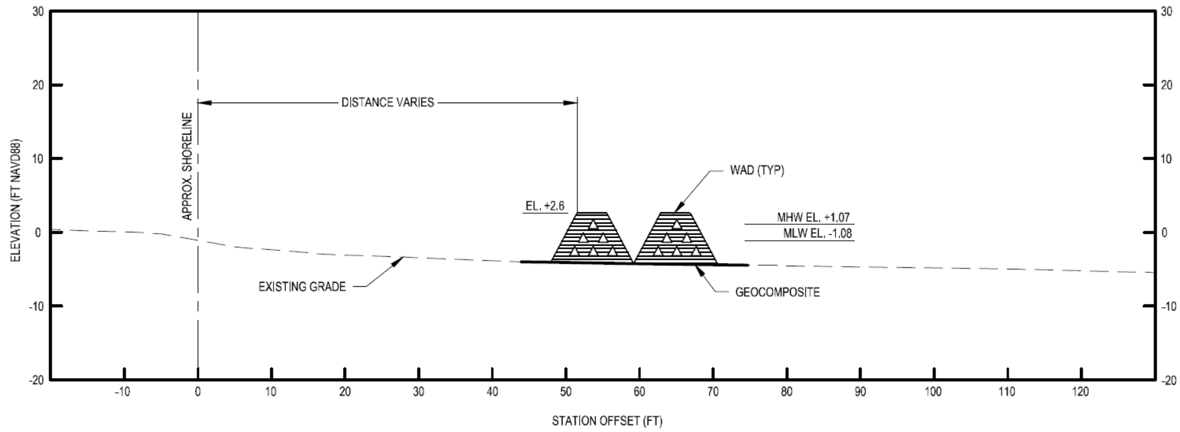


Figure 5.25: Typical Section of a Wave Attenuation Structure at Alignment B

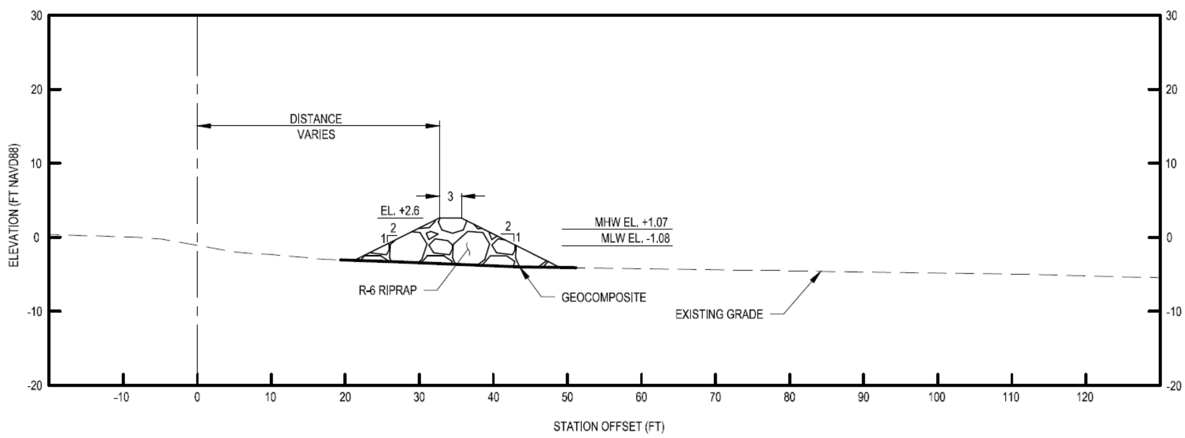


Figure 5.26: Typical Section of a Rubble Mound Breakwater at Alignment C

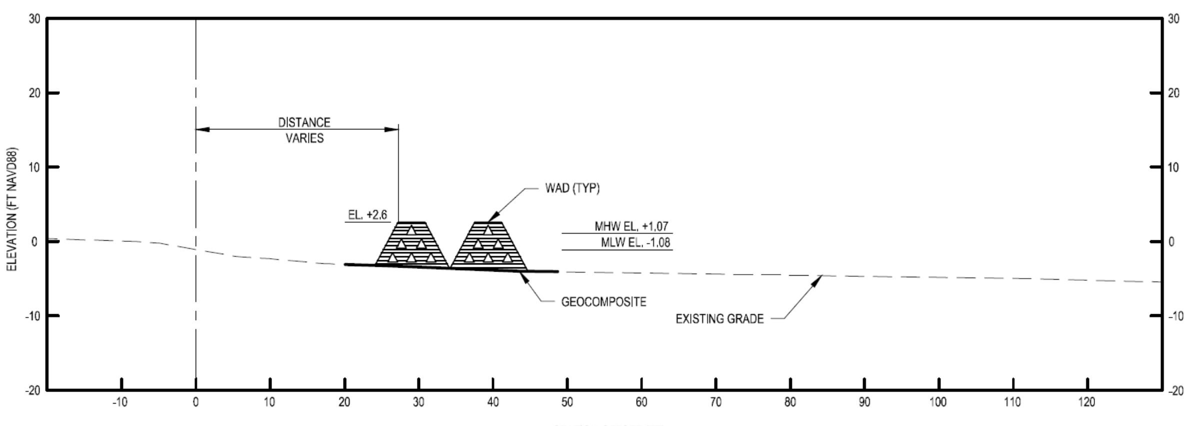


Figure 5.27: Typical Section of a Wave Attenuation Structure at Alignment C

Costs for each alternative were as follows:

Table 5.2: Alternatives Cost Comparison

Alternative	Alignment A	Alignment B	Alignment C	Fill Only
No Action	$0	$0	$0	$0
WADs® w/Fill	$8,475,000	$7,979,000	$7,838,000	N/A
Rubble w/Fill	$8,358,000	$7,472,000	$6,994,000	N/A
WADs® w/out Fill	$5,557,000	$4,969,000	$4,814,000	N/A
Rubble w/out Fill	$5,428,000	$4,408,000	$3,879,000	N/A
Fill Only	N/A	N/A	N/A	$3,546,000

Price Level: May 2019 Discount Rate: 2.75%

5.4.6 Refinement of Alternative Plans

At this point in plan formulation further coordination and more in-depth analysis was conducted and the following information was revealed.

A non-Federal project cost limit of $1.7 million for Design & Implementation (D&I) phase (the project phase after this feasibility study) was identified at this time. Given a 75% Federal contribution to D&I cost and a non-Federal contribution of 25%, this resulted in a total D&I phase cost not to exceed $6.8 million.

As shown in Table 5.2 above, WADs® were found to consistently cost more than equivalent rubble mound breakwater structures. Additionally, benefits from WADs® and rubble mound breakwaters were projected to be the same. Therefore, WADs® were eliminated from further consideration.

Close examination of historic navigation maps indicated that the shoal to the west of the current NJIWW location has been present as far back as at least the late 1800s, indicating that it is a relatively stable natural feature. Removing material in order to relocate the NJIWW channel into the shoal could destabilize it and cause increased infilling of the channel, thereby shortening the length of time of the dredging cycle. This risk was found to not be acceptable within the Corps Philadelphia District, which is responsible for dredging the channel. Thus, this measure was removed from further consideration.

Use of dredged material from the current location of the NJIWW entered into the analysis. The channel west of Mordecai Island was dredged by the Corps Philadelphia District in 2015, resulting in 30,000 cubic yards of dredged material. Placement of the material in the breach at Mordecai Island was found to be the Federal Standard for this operation. It is the District's best professional judgment that a similar amount of material will accumulate in the channel over 10 years and be available for placement at Mordecai Island.

Plan formulation analysis found that in terms of completeness, using material from the channel would work well in tandem with other measures. Material from the channel could contribute to the overall completeness of the project as it would provide fill material to be placed behind an erosion control structure and enhance the restoration aspect of the project. If a lag occurred between implementation of other components of the restoration project and dredging, benefits would still be realized. On its own, this measure is likely to be minimally effective at the protection of existing habitat and limiting future loss of habitat. It could be very effective when combined with other measures. Use of material from planned dredging of the NJIWW by Philadelphia District, Operations Division, adds significant efficiency to this restoration project, as the cost of dredging and material placement would be borne by the dredging operation, rather than this project. In terms of acceptability, the channel is the responsibility of the Corps Philadelphia District and placement of material from the channel at Mordecai Island is acceptable within the District. Coordination with other agencies would occur as is typical with dredging projects and is not expected to be an issue.

A set of assumptions accompanied the above analysis of use of the NJIWW channel for fill material. As previously noted, it is the District's best professional judgment that, based on the 2015 channel dredging, approximately 30,000 cubic yards of material will have accumulated in the channel over a 10 year period and be available for placement at Mordecai Island. Breakwater construction and fill placement will be in tandem, with breakwater construction up to one year ahead of dredging and filling. An assumption was made that design and breakwater construction will take two years, perhaps 2023 and 2024. The fill would then happen in 2025. That would place it 10 years after the 2015 dredging of the NJIWW channel. If the channel shoals and is dredged before construction of the restoration project, a structural restoration project will still create benefits. The project is not technically a failure if there is less than 30,000 cubic yards during the first deposition of material. There will still be benefits and there will still be better habitat conditions than prior to project implementation.

Given that relocation of the channel was removed from further consideration and that the channel will remain at its current location relatively close to Mordecai Island, placement of fill material from the NJIWW channel without an accompanying wave-breaking structure would introduce a risk of the material re-entering the channel. This risk was found to not be acceptable within the Corps Philadelphia District, which is responsible for dredging the channel. In addition, engineering judgment that the sand would not stay in place indicated that restoration goals would not be met. Thus, the fill only measure was removed from further consideration.

Based on the above coordination and in-depth analysis, the remaining alternatives (see Figure 5.28) were as follows:

Alternative 1: No Action
Alternative 2: Rubble mound breakwater with fill from NJIWW at Alignment A1
Alternative 3: Rubble mound breakwater with fill from NJIWW at Alignment B1
Alternative 4: Rubble mound breakwater with fill from NJIWW at Alignment C1

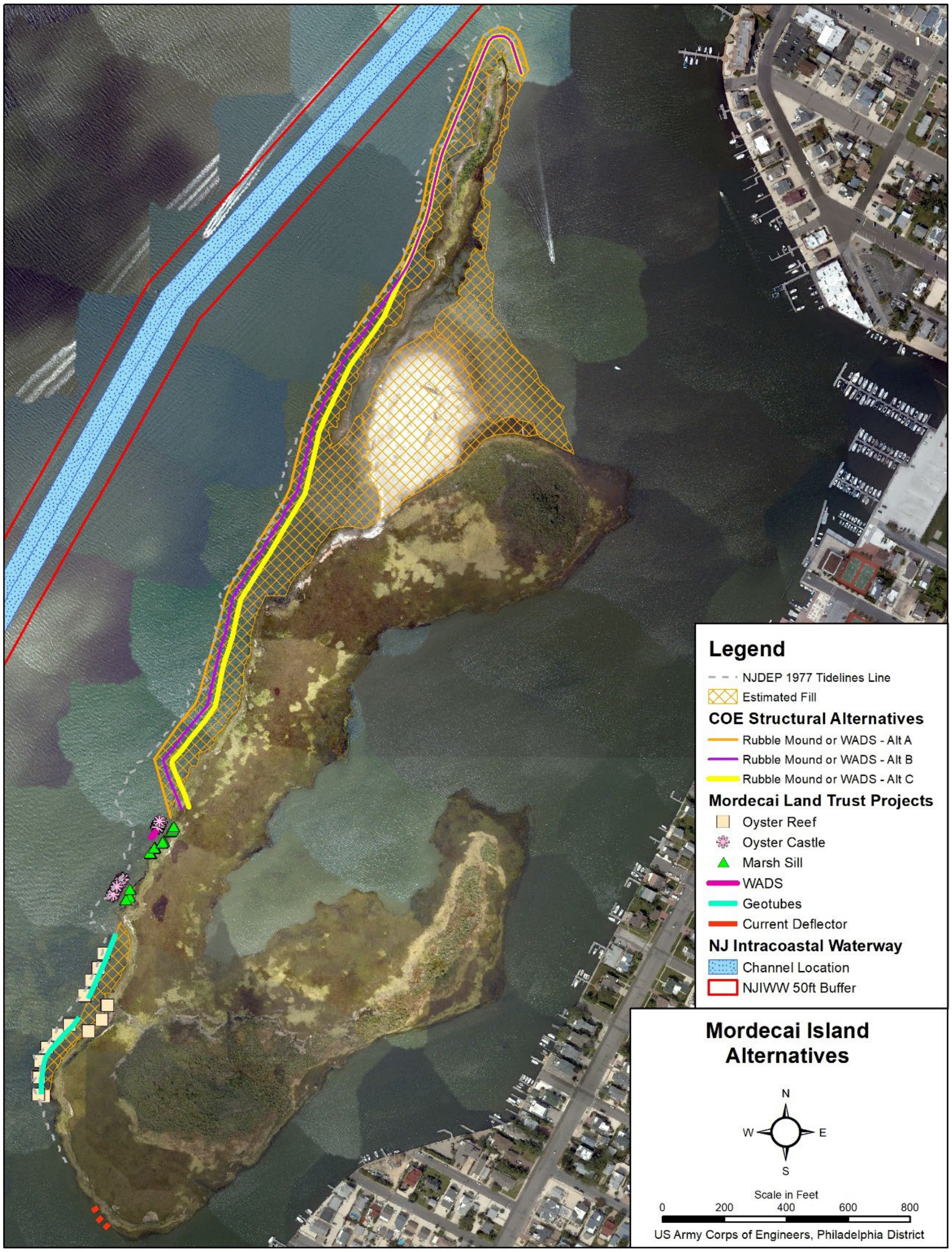


Figure 5.28: Mordecai Island Alternatives

Description of rubble mound breakwater design remained the same as in Section 5.2.4 of this report. Alignments remained the same as in Figure 5.20 and are shown again in Figure 5.28. Cross sections remained the same as in Figures 5.22, 5.24 and 5.26. Each of the alternatives includes a recommendation to move No Wake Zone markers closer to the channel, at no cost to the project.

Costs for each alternative were as follows:

Table 5.3: Updated Alternatives Cost Comparison

	Alignment A1	Alignment B1	Alignment C1
No Action	$0	$0	$0
Rubble w/Fill	$4,977,000	$4,101,000	$3,629,000

Price Level: May 2019 Discount Rate: 2.75%

5.5 Evaluation of Alternative Plans

5.5.1 Future With Project Island Footprint Projections

The same methodology used to project future island footprint size and shape for the without project conditions was also done for the offshore structure Alignment A1 under consideration. Given that Alignments A1, B1, and C1 are the same elevation and are of similar length, only one analysis was necessary. The erosion analysis would not produce different results for the different distances of the alignments offshore. The same without project annualized projections of historical erosion rates derived from the DSAS tool in ArcGIS were used first from 2017 to 2030 and then for the parts of the island that are not leeward of the offshore breakwater alignment to year 2080. The portion of the island being sheltered by each of the three alignments was assumed to have negligible future erosion from 2030 to 2080 for purposes of this analysis. Computation of reduced erosion rates along the portion of the island being protected would be a very complicated process given the dynamics of the environment and all the factors that would come into play to compute an accurate estimate. Such an analysis would be beyond the scope of this study. The MLT projects identified in Chapter 2 of this feasibility report are not included in the calculations of erosion because they are experimental in nature, thus subject to alteration, and no data are available to predict their performance to reduce erosion in the future. It was also assumed that there would be no difference to the island's future size and shape for each of the three offshore breakwater alignments due to sea level change since crest elevations of the different alignments were the same and that none of the alignments being considered fully encloses the island in order to "protect" it from sea level change in the future. Future with project habitat values were projected based on normal habitat succession and SLC estimates since, as discussed above, the rubble mound structures were assumed to essentially eliminate the erosion behind the structure.

5.5.2 Evaluation of Environmental Benefits

The Corps used the Assessment of Wildlife Habitat Value of New England Salt Marsh Model (NESMM) to quantify the ecological benefits gained from ecosystem restoration activities at Mordecai Island. The model was used to evaluate the habitat value of salt marsh protection and restoration associated with the installation of an offshore rubble mound breakwater and the placement of sand to restore lost wetland habitat. The model looked at with and without project habitat changes over a 50-year period (2030 to 2080) including predicted habitat responses to sea level change (SLC).

As discussed previously, 3 different rubble mound alignments were evaluated to protect Mordecai Island from further erosion. Each alignment was placed in a different depth of water and resulted in a range of acreages of wetlands restored due to the different distances from shore. Each alignment was designed to significantly reduce the erosion along the western edge of the island. The placement of sand behind the structures will allow for the restoration of between 8 and 11.5 acres of high and low marsh, as well as increasing the elevation of the previous fill area which is currently used by beach nesting birds and diamondback terrapins.

5.5.2.1 Model Description

The NESMM is a marsh assessment tool that was developed by the U.S. Environmental Protection Agency (USEPA). This model is approved for use by the Corps Ecosystem Restoration Planning Center of Expertise. NESMM is a standalone assessment tool based on wildlife habitat values of coastal wetlands. The model quantifies salt marsh health and function through the valuation of marsh characteristics and the presence of habitat types. While other habitat evaluation tools use marsh functions as metrics (e.g., nutrient removal) to assess wetland sites, the NESMM focuses on marsh habitat types, marsh morphology, and landscape setting.

The marsh habitat type was chosen to be used as the framework for the environmental model for a number of reasons. First, providing wildlife habitat is one of the most important functions shared by all marshes. Salt marshes are thought to be amongst the most productive ecosystems in the world, providing substantial biodiversity, supporting numerous species from all of the major groups of organisms, and providing both seasonal and year around habitat for many terrestrial and aquatic species. Of particular importance are wetlands that provide habitat for threatened and endangered species. Second, the area of available habitat within a marsh is a metric that is well suited for assessment. Aerial photographic interpretation of the habitat types in the marsh system coupled with ground-truthing can be accomplished easily. Additionally, forecasts of types of habitats in restored and/or created marsh are typically planned out in restoration efforts, so the applicable data is available.

The NESMM quantifies habitat values based on marsh characteristics and the presence of habitat types that contribute to use by terrestrial species. The model's developers identified 79 birds, 20 mammals, and 6 amphibian and reptile species that utilize New England salt marsh habitat at some life stage. Habitat requirements of these species were determined through a search of published literature, unpublished reports, anecdotal information from wetland ecologists and personal observations of the model's creators. From the available information, the developers identified common habitat types associated within salt marshes, or those that were reported as being used by at least 3 bird or mammal species. These habitat types, as well as the habitat requirements of salt marsh fauna, form the basis of the salt marsh assessment model.

The model consists of eight wetland and landscape components that are used to assess and evaluate salt marsh wildlife habitat values (Table 5.4). Several of the components are directly based on the different habitat types found in and around marshes or ecosystems that are linked to salt marshes. Other components reflect the anthropogenic alteration of these habitats. The remaining components take into account the size, morphology, and landscape positions of the marsh, which may be important to territorial species and those that require adjacent upland habitats. The eight components are (1) marsh habitat types, (2) marsh morphology, (3) marsh size, (4) degree of anthropogenic modification, (5) vegetative heterogeneity, (6) surrounding land use, (7) connectivity, and (8) vegetation types. Each component, in turn, consists of several categories. For example, the "Habitat Type" component consists of ten categories including shallow open water, tidal flats, pannes, wooded islands, and low marsh. A complete description of each habitat component and the overall framework of this model are included in McKinney and Wigand (2006).

The model user assigns a rating of low, moderate, high or absent to each model category. The rating is given a numerical score and a weighting factor to reflect faunal habitat requisites, which can be found in Table 5.5. For example, one category of the habitat component involves the presence of shallow water. If open shallow water habitat makes up >20% of the marsh, the category is given a numeric score of "5". If open shallow water habitat is absent from a salt marsh, the category is given a "0". The value of each category is multiplied by a weighting factor. The output produced by the USEPA model is a numerical score, an overall relative wildlife habitat assessment score for the marsh, which is calculated by summing subtotals for each of eight habitat components of the model. The values and weighting factors assigned to each model component are shown in Table 5.5 (McKinney et al. 2009).

Table 5.4: New England Salt Marsh Model wetland assessment components and their associated categories

Component	Categories	Criteria
I. Salt Marsh Size Class	Very small (under 5 ha) Small (5 – 25 ha) Medium-sized (26 – 125 ha) Large (126 – 200 ha) Very large (over 200 ha)	Marsh area
II. Salt Marsh Morphology	Salt meadow marsh Meadow / fringe marsh Wide fringe marsh Narrow fringe marsh Marine fringe marsh	Marsh morphology
III. Salt Marsh Habitat Types	Shallow open water Tidal flats Low marsh Trees overhanging water High marsh Pools Pannes Wooded islands Marsh-upland border Phragmites	Presence or abundance
IV. Extent of Modification	Little to no ditching Moderate ditching Severe ditching Little to no tidal restriction Moderate tidal restriction Severe tidal restriction	Degree of modification
V. Salt Marsh Vegetation	Aquatic plants Emergents Shrubs Trees /Vines	Presence or abundance
VI. Vegetative Heterogeneity	High heterogeneity Moderate heterogeneity Low heterogeneity	Number of habitat edges
VII. Surrounding Land Cover	Open water Natural land Maintained open land Developed land	Presence or area
VIII. Connectivity	Sand or cobble beach Coastal dunes or overwash Other salt marsh wetland Brackish wetland or pond Freshwater wetland or pond Upland meadow Upland forest	

Table 5.5: Values and weighting factors associated with each habitat category in the New England Salt Marsh Model

a) Pre-classification components

Component	Category	Weighting factor	Criteria (value) High (5)	High/mod. (4)	Moderate (3)	Mod./low (2)	Low (1)
Size class	–	10	> 200 ha	126–200 ha	26–125 ha	5–25 ha	< 5 ha
Morphology	–	10	Salt meadow	Meadow/fringe	Wide or marine fringe	–	Narrow fringe

b) Assessment components

Component	Category	Weighting factor	Criteria (value) High (5)	Moderate (3)	Low (1)	Absent (0)
Habitat type	shallow open water	7	>20% of marsh unit	10–20% of marsh unit	<10% of marsh unit	absent
	tidal flats	8	>30% of marsh unit	5–30% of marsh unit	<5% of marsh unit	absent
	low marsh	8	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	trees overhanging water	5	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	high marsh	8	>40% of marsh unit	5–40% of marsh unit	<5% of marsh unit	absent
	wooded islands	6	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	phragmites	4	>3% of marsh unit	1–3% of marsh unit	<1% of marsh unit	absent
	pools	8	>10 pools/ha	2–10 pools/ha	<2 pools/ha	absent
	pannes	5	>10 pannes/ha	2–10 pannes/ha	<2 pannes/ha	absent
	marsh-upland border[a]	8				
	width		width >8 m	width 2–8 m	width <2 m	–
	length		>65% of perimeter	50–65% of perimeter	<50% of perimeter	–
	composition		>70% shrubs	50–70% shrubs	<50% shrubs	–
Anthropogenic modification	ditching	9	little to no ditching	moderate ditching	severe ditching	–
	tidal restriction	7	little to no restriction	moderate restriction	severe restriction	–
Vegetation	aquatic plants	2	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	emergents	3	>90% of marsh unit	75–90% of marsh unit	<75% of marsh unit	absent
	shrubs	3	>20% of marsh unit	5–20% of marsh unit	<5% of marsh unit	absent
	trees	4	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
	vines	1	>15% of marsh unit	5–15% of marsh unit	<5% of marsh unit	absent
Vegetative heterogeneity	–	6	5 edge habitats	3–4 edge habitats	1 or 2 edge habitats	–
Surrounding land use	open water	6	>35% of buffer[b]	25–35% of buffer	<25% of buffer	–
	natural land	9	>25% of buffer	10–25% of buffer	<10% of buffer	–
	maintained open	5	<5% of buffer	5–15% of buffer	>15% of buffer	–
	developed land	9	<5% of buffer	5–35% of buffer	>35% of buffer	–
Connectivity[c]		9				
	habitat types in buffer[d]		>4	3–4	1–2	–
	average size		>3 ha	1–3 ha	<1 ha	–
	proportion of buffer		>30% of buffer	15–30% of buffer	<15% of buffer	–

5.5.2.2 Application of the NESMM Model to Mordecai Island

The NESMM was used to calculate environmental benefits that would be derived from ecosystem restoration efforts at Mordecai Island using a 50-year period of analysis (2030-2080). The model was run under "without" project conditions as well as the 3 rubble mound alignments with sand fill using existing habitat and tidal conditions in the area and considering SLC.

Data used to quantify the future "without" project condition values were based on projected habitat changes over time using historic erosion rates and SLC estimates. Data used to quantify the future "with project" condition values were based upon projected habitat changes based on normal habitat succession and SLC estimates since it was assumed that any alignment of the rubble mound structures would essentially eliminate erosion behind the structure. The values for all scenarios were developed using anticipated site conditions once the rubble mound structure had been installed and marsh restoration efforts had been completed and are based upon the best professional judgment of Corps biologists. The inherent weakness of forecasting future conditions is that there is no way to guarantee what the future conditions will be at the site. This uncertainty can be mitigated with the establishment of monitoring and adaptive management programs, as is required by Corps policy and has been included in the Mordecai Island Feasibility Report and EA.

5.5.2.3 Benefit summary

To assess the ecological benefits gained from the ecosystem restoration project, the Corps used the NESMM to evaluate the habitat value of the island following the installation of a rubble mound structure and sand fill. Results are presented below in Table 5.6. These results show that there was no change in the NESMM score with the different rubble mound alignments since the same assumptions with regard to future habitat structure and value were used for all alignments. Some of these assumptions were:

1. Rubble mound structures at all alignments were assumed to essentially eliminate erosion behind the structure
2. An additional 22 acres of island habitat would be lost by 2080 with the No Action alternative
3. 20 acres of low marsh would be lost and converted to open water by 2080 with the No Action alternative
4. Low marsh that didn’t erode would convert to tidal flats as a result of erosion and SLC
5. High marsh will convert to low marsh as a result of erosion and SLC

The change in ecological output was realized with the addition of the sand behind the structures and the increase in habitat they provided. Since Alignment A was the furthest from shore, it allowed more wetland acreage to be restored, adding to the overall footprint of the island and increasing the overall ecological output. As a result, Alignment A resulted in the highest increase of Average Annual NESMM Units over the baseline conditions.

Table 5.6: Habitat value of Mordecai Island after installation of a rubble mound structure and sand fill

Plan/Target Year	NESMM Value (% of Maximum Score)	Acres	NESMM Score	Output Average Annual NESMM Units
Baseline 2030 (No Action)	.50	49.76	25	
Baseline 2080 (FWOP)	.46	24.4	11	468

Alignment A 2030	.50	61.18	31	
Alignment A 2080	.53	55.38	29	753 (**285 increase over baseline**)
Alignment B 2030	.50	58.94	30	
Alignment B 2080	.53	53.14	28	728 **(260 increase over baseline)**
Alignment C 2030	.50	57.89	29	
Alignment C 2080	.53	52.09	28	708 **(240 increase over baseline)**

5.5.3 Cost Effectiveness and Incremental Cost Analysis

In accordance with ER 1105-2-100 (U.S. Army Corps of Engineers, 2000), an incremental cost analysis was completed for this project. Cost effectiveness and incremental-cost analyses are an alternative to benefit-cost analysis used when the primary outputs/benefits of alternative plans are not measured in dollars. Cost effectiveness ensures that the least cost alternative is identified for each possible level of output, or NESMM units in this case. The incremental cost analysis reveals changes in costs as output score increase and allows an assessment of whether the increase in units is worth the additional cost. This process does not identify a unique optimal solution, rather it is a tool to help inform and support selecting an alternative.

Three restoration alternatives plus the no action alternative were evaluated in the cost effectiveness and incremental-cost analysis (CEICA) (see Table 5.7). The analysis of the plans shows that all three restoration plans (Alignment A1, Alignment B1 and Alignment C1), are cost-effective and best buy plans (economically justifiable) (see Figure 5.29).

Table 5.7: Cost effectiveness and incremental-cost analysis evaluation

Plan	Output AANESMM Score over Baseline	AA Cost	Incremental Cost	Incremental Cost/Output
Baseline/No Action	0	$0		
Alignment C1	240	$194,000	$194,000	$808
Alignment B1	260	$219,000	$25,000	$1,250
Alignment A1	285	$266,000	$47,000	$1,880

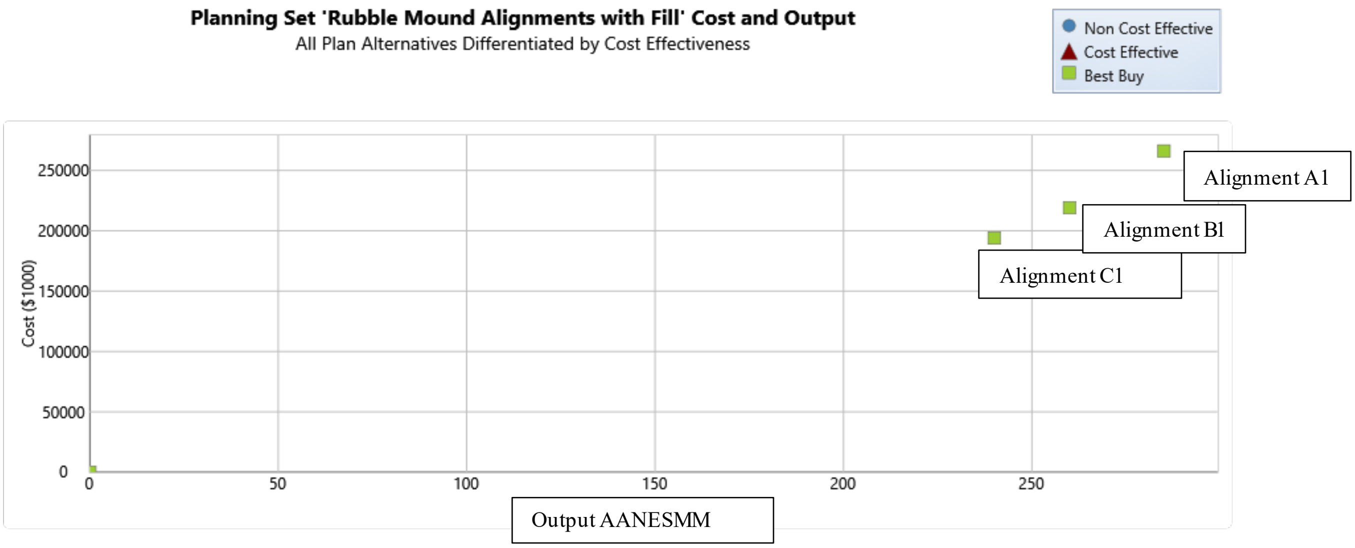


Figure 5.29: Cost effective and best buy plans

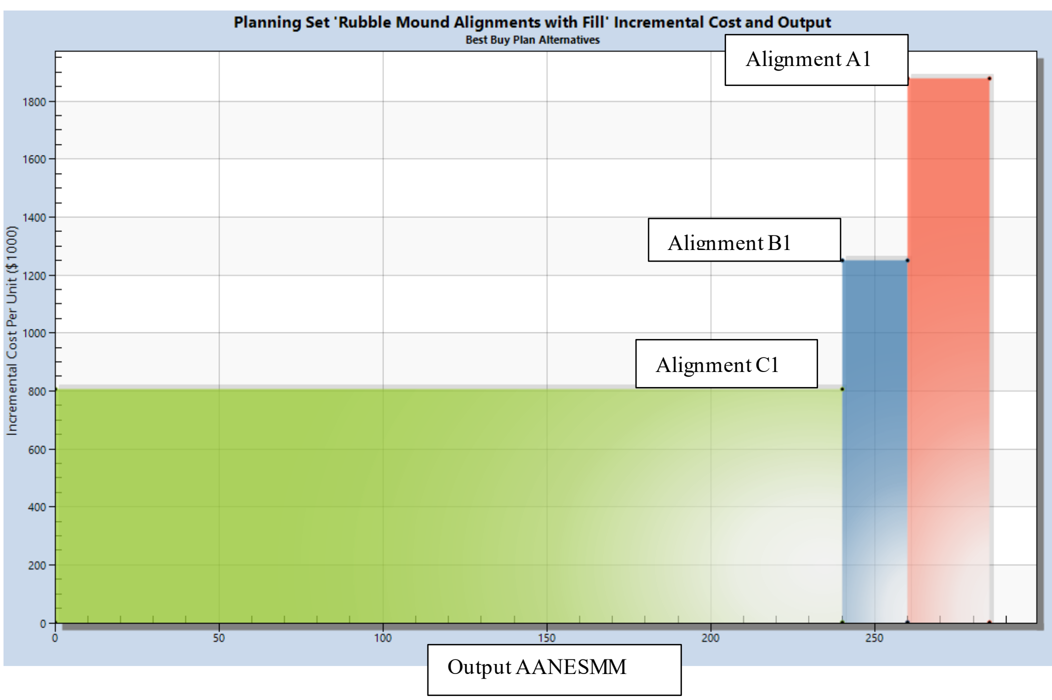


Figure 5.30: Habitat outputs and cost increases

Figure 5.30 shows how the habitat outputs and costs increase from Alignment C1 to Alignment B1 to Alignment A1. Since all three alternatives are cost effective and best buys under the CEICA analysis, all are justifiable choices for ecosystem restoration at Mordecai Island. As shown above, Alignment C would provide an additional 240 NESMM units over the No Action Alternative at a cost of $808 per unit. Alignment B would provide an additional 20 NESMM units over Alignment C at an incremental cost of $1,250 per NESMM unit. Alignment A would provide an additional 25 NESMM units over Alignment B at an incremental cost of $1,880 per unit. Although the incremental cost per unit of Alignment A is higher than going from the No Action Alternative to Alignment C, or for going from Alignment C to Alignment B, it is worth the increase to obtain the additional environmental benefits provide by Alignment A.

Alignment A is the recommended alternative and will result in the restoration of 11.5 acres of intertidal salt marsh habitat and the protection and additional 25 acres from future erosion (285 NESSM units) at an AA cost of $1,880/NESMM unit.

It should be noted that the overall cost for the alternatives increased after the CE/ICA was run. The cost increase was equal for all alternatives, so the increase does not alter the results of the CE/ICA as all alternatives increased by the same amount.

5.5.4 Significance of Ecosystem Outputs

The implementation of the proposed ecosystem restoration at Mordecai Island will create a regional uplift in ecosystem functions, services and resiliency—including increased buffering capacity against boat wakes, storm and flood damage, significant regional uplift in water quality, and the enhancement and creation of fish, shellfish, wading bird, and waterfowl habitat. The uplift in ecosystem services will have a significant, positive impact on dependent local and regional economies.

Salt marshes are highly productive habitats that contribute to the biodiversity of the coastal ecosystem. Salt marshes and islands such as Mordecai Island serve as spawning habitat and nurseries for many invertebrates and fish as well as nesting and feeding habitat for a variety of birds and mammals, including the Federal and State-listed species previously discussed. In addition to the valuable habitat provided by the island itself, Mordecai Island serves to protect SAV beds on the eastern side of the island from wave and storm activity. SAVs are an essential food for a number of waterfowl species, habitat for finfish, shellfish and other invertebrates, and provide sediment stabilization.

The Clean Water Act, Section 404(b)(1) Guidelines institutionally recognize salt marshes as Special Aquatic Sites. Salt marshes provide valuable nesting, spawning, nursery, cover, and foraging habitat for aquatic and semiaquatic animals, nutrient transformation functions, and aquatic productivity enhancement. The New Jersey Coastal Zone Management laws and regulations also recognize the importance of salt marsh and estuarine habitats.

6 Tentatively Selected Plan*

6.1 Description of the Tentatively Selected Plan

Alternative 2: Rubble mound breakwater with fill from NJIWW at Alignment A1, along with No Wake buoys being moved closer to the NJIWW channel is the Tentatively Selected Plan (TSP). This alternative will provide an increase of 285 Average Annual NESMM outputs over the without project conditions by protecting approximately 25 acres of the island from future erosion and the restoring 11.5 acres of saltmarsh habitat.

Alignment A1 generally follows the 1977 Tidelands line, approximately parallel to the west side of Mordecai Island in the nearshore area. (See Figure 6.1.) The rubble mound breakwater along Alignment A1 will extend for 3,000 linear ft. and have an average height of 7.6 ft. from the bay bottom. (See Figures 6.2 and 6.3.) The average height is the initial construction height of the structure and factors in one foot of over-build for potential settlement. Settlement will be further evaluated in more detail during the next phase of the study. To account for potential settlement of one foot, the initial construction is estimated to be +3.6 ft. NAVD88 (1 foot of overbuild). A geocomposite will be placed between the bottom of the structure and the existing ground (see Geotechnical Section of the Engineering Technical Appendix).

The crest width of the trapezoidal breakwater will be 3 ft. Side slopes will be 2H:1V. The breakwater will be continuous with sill vents, or lower sections of breakwater, designed to promote intertidal flushing to maintain water quality. The sill vents will be approximately 40 ft. long and have a crest elevation at the MLW line to allow water to flow through the breakwater during the entire tide cycle. There is approximately 160 linear ft. of breakwater between each sill vent. The northern tip of Mordecai Island is the most vulnerable area to waves due to its proximity to the NJIWW. For this reason, there are no sill vents in the northern tip of the breakwater. Specific design considerations and assumptions for the breakwater can be found in the Engineering Technical Appendix.

Following the installation of the rubble mound breakwater, sand obtained from maintenance dredging of the NJIWW will be placed behind the new breakwater and behind the existing MLT structures to restore lost wetland acreage. It is anticipated that approximately 30,000 cy of sand will be available every 10 years. Depending upon the island conditions and the available sand quantity at the time of construction, approximately 1 foot of sand will be added around the edge of the island (as depicted in Figure 6.1) to restore lost marsh habitat. It is anticipated that approximately 11.5 acres of wetland habitat will be restored as part of the restoration project. In addition to the wetland restoration, approximately 1.5 feet of sand will be added to the bird nesting area that currently exists in the previously filled breach area. Once the sand fill has been placed, wetland vegetation will be planted to help stabilize the shoreline. Figure 6.1 outlines the maximum potential extent of any sand fill for the project. An area larger than what is expected to be filled has been identified in order to allow for flexibility with sand placement based on available sand quantities and island conditions at the time of construction. This also allows for adaptive management of sand placement for future maintenance dredging cycles if needed.

As part of the TSP, it is also recommended that existing No Wake buoys be moved closer to the NJIWW channel to promote visibility of the buoys and, indirectly, reduced boat wakes. Relocation of the buoys would be at no cost to this project.

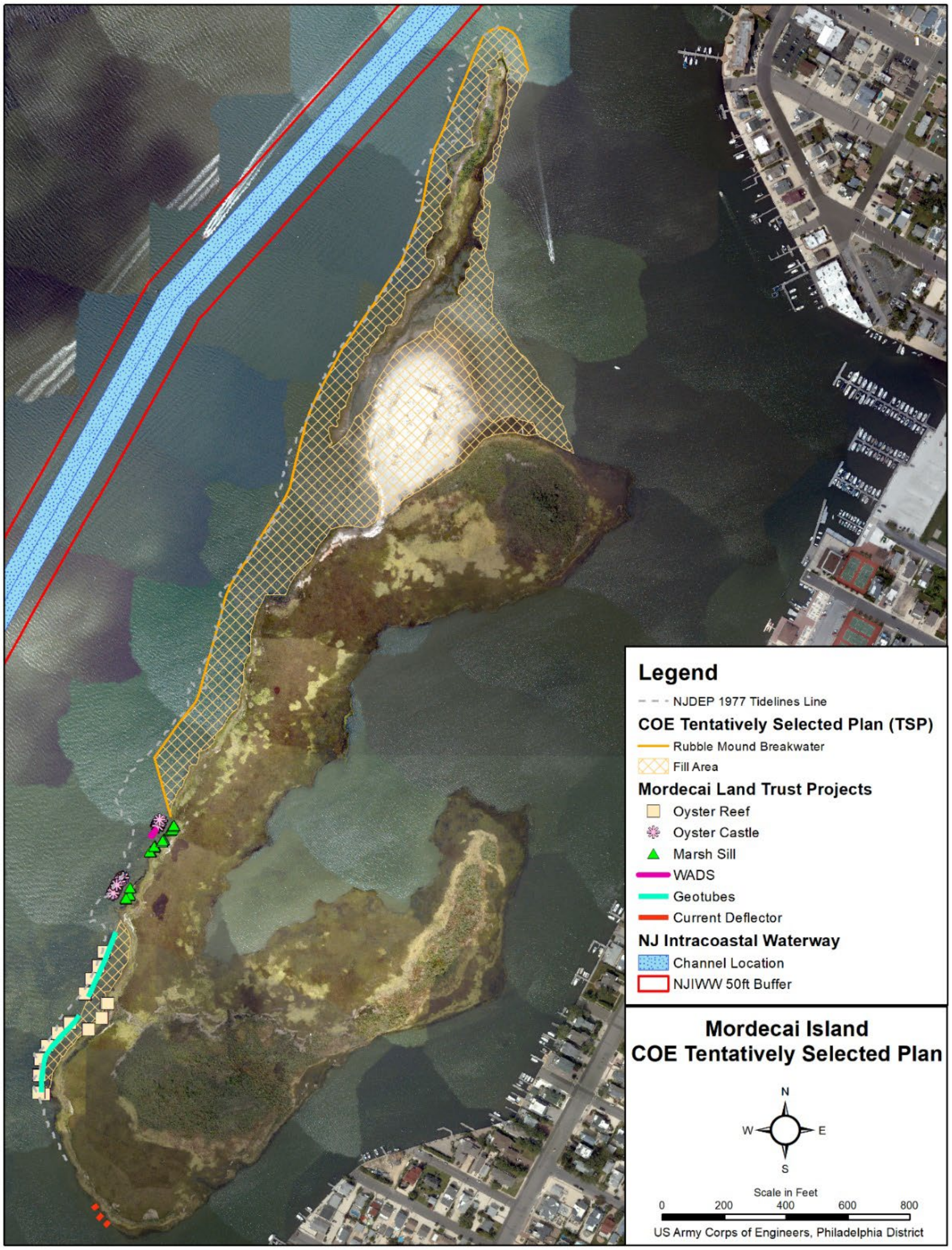


Figure 6.1: Tentatively Selected Plan

Figure 6.2: Tentatively Selected Plan Rubble Mound Plan View

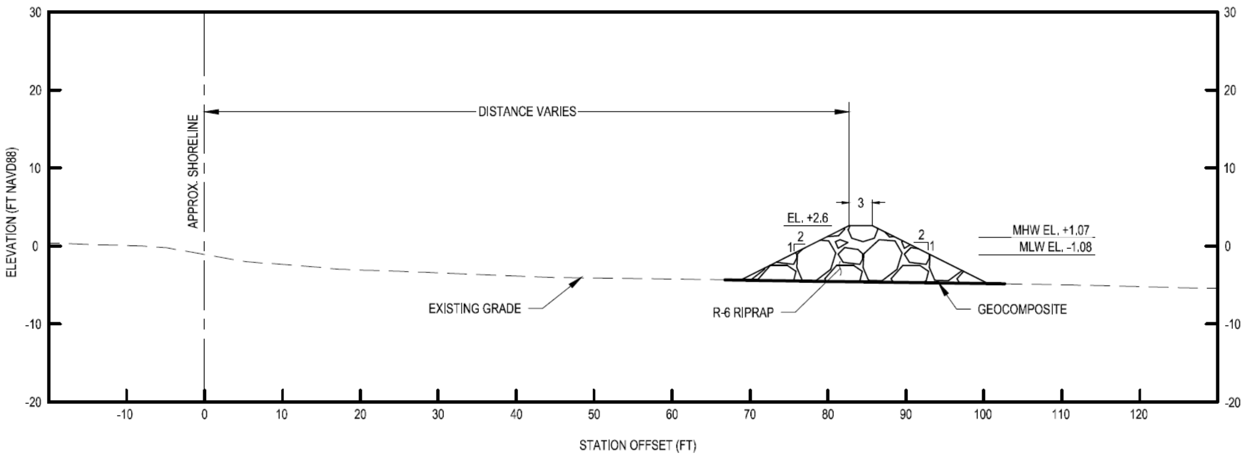


Figure 6.3: Tentatively Selected Plan Rubble Mound Cross Section at Alignment A

The cross section in Figure 6.3 does not show fill material because the amount of fill will vary throughout the placement area and throughout time. Depending upon the quantity of sand available from the maintenance dredging and the island conditions at the time of construction, it is estimated that between 1 and 1.5 feet of sand will be placed in the fill areas. Behind the breakwater and MLT structures, the sand will be graded in a natural slope that will eliminate the steep edges and mimic healthy intertidal habitat. Fill material will be placed landward of the rubble mound structure and tie into the elevation of the existing marsh edge to create a combination of low and high marsh habitat. Exact elevations and extent of fill will be based on the existing shoreline conditions at the time of construction and the amount of fill material available. Fill material will be planted with elevation appropriate wetland vegetation following placement.

6.2 Environmental Effects

6.2.1 Air Quality

This project would result in maintenance of existing regional conditions. There would be some minor, short-term effects on noise and air quality during construction of the breakwater. The island is not immediately adjacent to residential areas, and no long-term impacts are anticipated from the selected alternative. Air emissions for the project would be below the de minimis threshold for a marginal ozone nonattainment area (100 tons/year of NOx and 100 tons/year VOC). Therefore, a General Conformity determination is not required. The project is not considered regionally significant under 40 CFR 93.153 (i). See Appendix B for the Clean Air Act assessment calculations.

6.2.2 Water Quality

No significant effects to water quality are anticipated from implementation of any of the components of the selected plan. The design of the breakwater includes 40' long sill vents along the length of the structure to allow for substantial water flow between the breakwater and the island. These sills will be placed every 160' along the majority of the structure at an elevation to match the MLW line so water will flow through these vents at all cycles of the tide. Based on the design, no changes in water quality are anticipated from the installation of the rubble mound breakwater. Minor, short-term, temporary and localized impacts to water quality in the form of turbidity may occur from in-water construction activities during installation of the rubble mound breakwater, maintenance dredging and depositing sand behind the breakwater at Mordecai Island. The impacts of fill placement will be minimal since the material should settle out behind the breakwater before entering the open water. Any potential effects would be short-lived and localized and would be limited to the immediate vicinity of the dredging sites and the area that receives dredged material. Eventually tidal currents and bay circulation would negate any impacts from turbidity. Best Management Practices that are already in place for the approved maintenance dredging would be used to further minimize water quality impacts during project implementation. Therefore, no long-term adverse effects are anticipated. Overall, the project should have a positive impact on water quality around Mordecai Island. Since the project will be reducing the erosion of the island, less sediments will be released into the system, thereby reducing the turbidity in the immediate area of the island.

6.2.3 Topography and Soils

Under the no action alternative, erosion at Mordecai Island would continue and more wetland acreage would be lost. Without intervention, the western edge of the island will continue to erode and form steep edges that aren't conducive habitat for many marsh and intertidal species. The erosion also adds more turbidity into the area surrounding the island which has the potential to impact water quality and SAV's through burial of plants or reducing light available to plants.

Installation of the rubble mound breakwater will result in the conversion of approximately 2.3 acres of sandy bottom habitat into rocky habitat. While different from the sandy habitat, rocky habitat also provides important habitat for a variety of marine species and increases habitat diversity in the project area.

Placement of sand behind the breakwater and the MLT structures, as well as adding sand onto the previously filled area will result in changes to the current topography of the island. Depending upon the quantity of sand available from the maintenance dredging and the island conditions at the time of construction, it is estimated that between 1 and 1.5 feet of sand will be placed in the fill areas. Behind the breakwater and MLT structures, the sand will be graded in a natural slope that will eliminate the steep edges and mimic healthy intertidal habitat. These areas will also be planted with wetland vegetation to restore approximately 11.5 acres of previously lost acres of wetlands. Sand placed on the previously filled area will raise that elevation to be more suitable for beach nesting birds and diamondback terrapin nesting. Placing sand in these areas will also help to sustain the island habitat against future SLC. Overall, the project will result in positive ecological benefits to the regional salt marsh complex with the restoration of approximately 11.5 acres of intertidal marsh habitat and the protection of approximately 22 acres of marsh that was predicted to be lost to erosion by the year 2080.

Sand for the project will be obtained from future maintenance cycles of the NJIWW. The majority of the shoaling in this section of the NJIWW is usually between channel markers 107 and 109 so it is anticipated that the fill for the Mordecai restoration will come from this area. Future maintenance and shoaling may require dredging in other sections of the NJIWW over the life of the project. As such, dredging could occur anywhere between channel markers 102 to 110 (Figure 6.4).

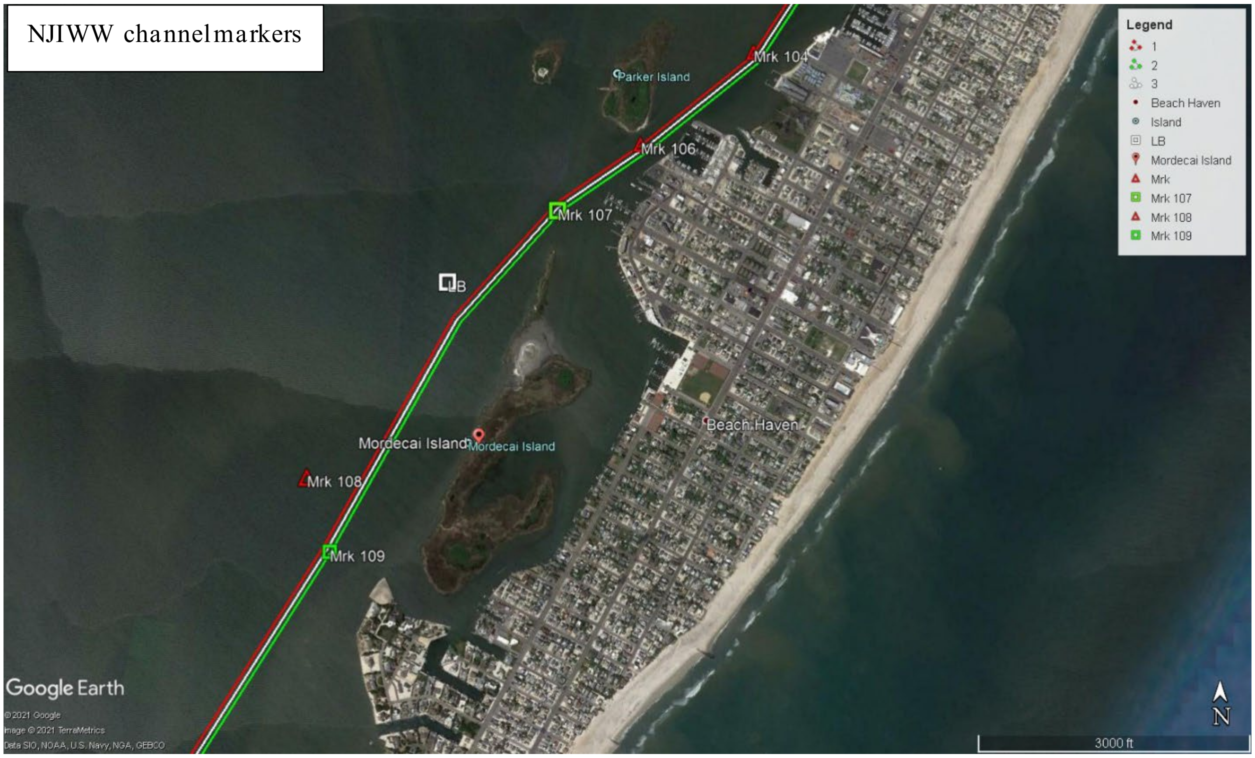


Figure 6.4: NJ Intracoastal Waterway (NJIWW) channel markers near Mordecai Island

As described in Section 3.3.5 of this report and in Appendix A: Engineering Technical Appendix, sediment cores were collected from the NJIWW in the vicinity of Mordecai Island (and 2 other locations not related to the project) in February and March of 2014 (Tetra Tech, 2014). Samples were analyzed for grain size; TOC; Target Compound List (TCL) volatile organics (VOCs) and semi-volatile organics (SVOCs); TCL pesticides; Target Analyte List (TAL) inorganics, including total cyanide and total mercury; polychlorinated biphenyl (PCB) arochlors and PCB congeners/dioxins and furans.

The overall conclusion from the report is that the sediment is considered clean with respect to chemical contamination and can be used for ecologically beneficial purposes. These sediments were subsequently used to fill the breach area at Mordecai Island as previously discussed. Impacts associated with the maintenance dredging of the NJIWW in the vicinity of Mordecai Island and placement of those sediments at Mordecai Island were previously discussed in an Environmental Assessment in USACE 2014.

6.2.4 Vegetation and Habitat

Marshes along the NJIWW provide important resting, feeding and nesting habitat to many migratory and resident species of birds. The implementation of the recommended ecosystem restoration plan at Mordecai Island will result in an ecological uplift by protecting the island from future erosion, raising the elevation of a portion of the island for birds and terrapins and restoring approximately 11.5 acres of previously eroded intertidal wetlands.

6.2.4.1 Subtidal Vegetation (SAVs and Algae)

The No Action alternative will result in the continued erosion of Mordecai Island. The continued erosion will add suspended sediments into the waters immediately surrounding the island, reducing the amount of sunlight available for SAVs and potential covering existing plants. Previous surveys have found minimal SAV utilization on the western side of the island and larger SAV beds on the eastern side of the island. Depending upon the extent of SAV beds at the time of construction, some SAV plants and macroalgae may be buried by the project through either the installation of the rubble mound structure of the placement of the sand fill. Based on the current SAV distribution in that area however, these impacts are expected to be minimal. Overall, the implementation of the proposed ecosystem restoration project is expected to have a beneficial impact on SAV beds and SAV habitat in several ways. The reduction in erosion of the island will reduce suspended sediments in the water column, making the area more suitable for SAV recruitment, growth and survival. The protection of the island from future erosion will also allow the island to continue to protect the SAV beds on the eastern side of the island. Projections of future erosion indicate the island will eventually breach, leaving the SAV beds on that side of the island vulnerable to higher wave action and additional sedimentation. In addition, the proposed project will also create an area of “calmer” wind and wave conditions behind the rubble mound breakwater which would be suitable for future SAV colonization.

6.2.4.2 Upland Vegetation

The No Action alternative would result in the continued loss of habitat at Mordecai Island due to erosion and the eventual loss of the upland vegetation on the island. No adverse effects are expected to upland vegetation with the proposed project. The placement of dredged material in and around marshes in New Jersey and other coastal regions have shown improved marsh health, function and resiliency with very short recovery times. Sand placement on the previously filled area of the island will provide improved habitat for beach nesting birds and diamondback terrapins. Overall, the project will result in positive ecological benefits to the upland habitat on the island by reducing future erosion.

6.2.4.3 Intertidal Vegetation and Wetlands

The No Action alternative would result in the continued loss of habitat at Mordecai Island due to erosion and the eventual loss of most of the intertidal vegetation and associated wetlands. The erosion that has occurred over the last 40 years has already resulted in the loss of approximately 11 acres of island habitat with the majority of the habitat associated with the intertidal wetlands. The erosion has left the wetlands fringing the island vulnerable to further erosion and has all but eliminated the gently sloping intertidal wetlands along most of the western side of the island. The implementation of the proposed ecosystem restoration project will restore approximately 11 acres of intertidal marsh to the island and protect the island and wetland habitat from future erosion. The restored acreage will be a combination of low and high marsh, depending upon conditions at the time of construction and the quantity of sand available from the maintenance dredging. The restored habitat will be planted with appropriate intertidal marsh vegetation and monitored to ensure proper coverage and survival of the vegetation. The return of the intertidal zone to a gentle slope, as opposed to the steep scarping that is currently occurring, will benefit a variety of fish, birds and other wildlife species utilizing the marsh area.

6.2.5 Fisheries

The project will have limited and short-term impact on finfish. With the exception of some small finfish, most bottom dwelling and pelagic fishes are highly mobile and should be capable of avoiding impacts associated with the construction of the rubble mound breakwater. The same will be true for the impacts associated with the sand placement. The primary impact to fisheries will be felt from the disturbance of benthic and epibenthic communities. The loss of benthos and epibenthos smothered as a result of construction of the rubble mound breakwater and sand placement may temporarily disrupt the food chain in the impacted areas. There will also be a transition of approximately 2.3 acres from subtidal sandy bottom habitat to rocky habitat which may have an impact on the type of fish and benthos utilizing those acres. Sandy habitat in the project area is not limiting however, so this transition will not represent a significant change to species in the area. Overall, the restoration project is expected to have a positive impact on finfish because of the reduced erosion and turbidity in the area and the return of proper intertidal slopes in the restored wetlands behind the breakwater. Based on the design elevations and expected settlement, the majority of the structure will be underwater at mean high tide and therefore still provide habitat to aquatic species.

6.2.5.1 Essential Fish Habitat

The no action alternative is not expected to have any significant changes on essential fish habitat within the project area from existing conditions. Continued erosion, especially along the western edge of the island would continue and would likely increase shallow open water essential fish habitat where some species may benefit while other species that depend on marsh habitats may be adversely affected. Continued erosion may negatively impact SAV beds around the island by adding excess sediment into the system, increasing water depths and decreasing light in the water column. EFH species utilizing SAV beds could be adversely affected.

The EFH worksheet submitted to the National Marine Fisheries Service (NMFS) is presented in Appendix B. Based on the previously listed habitat utilization by the designated EFH species, it appears that most of the species will not be found in the immediate project area, due to a depth requirement or the fact that they are migratory in nature (i.e., the sharks). There is the potential for a few species to be found in the project area and these include: winter flounder, windowpane flounder, summer flounder, scup, and black sea bass. Most of the above-listed fish species are not estuarine resident species and therefore only utilize this area on a seasonal basis, primarily in the warmer summer months. During the summer months, the estuary is typically utilized as a forage area for juveniles and adults and as a nursery area for larvae and juveniles. Since adults and juveniles of the above-listed species are mobile, it is expected that they will avoid the areas of disturbance regardless of season and therefore will not be impacted. In addition, the actual footprint of the in-water construction work is relatively small, so any impacts to demersal eggs and larvae of various species will be minor. The installation of the rubble mound breakwater will convert approximately 2.3 acres of subtidal sandy bottom habitat into subtidal and intertidal rocky habitat. While this represents a change in habitat type for some species, the rocky intertidal structure will still provide habitat for numerous estuarine species. Based on the design elevations and expected settlement, the majority of the structure will be underwater at mean high tide and therefore still provide habitat to aquatic species, in addition to adding rocky habitat in the water column. Sand placement around Mordecai Island may temporarily affect EFH for common prey species such as Atlantic silverside, mummichog, and sheepshead minnow. Burial of some benthic species will occur within the placement site, however, species in highly dynamic areas are typically R-selected species capable of recolonizing their populations rapidly through recruitment from neighboring areas. While turbidity will temporarily increase at the placement site, turbidity levels are typically naturally elevated in this area due to currents and wave action. Mobile species, such as fish and crabs in marine environments have been shown through video monitoring to leave an area of disturbance and elevated turbidity temporarily, returning shortly after placement operations cease. Turbidity that results from placement will dissipate quickly due to currents and the large grain size of the clean sandy material and will be largely confined behind the breakwater. The project may also have temporary minor impacts to the bottom habitat and demersal eggs/larvae of some species during sand placement. However, once the construction is completed it is likely that the bottom areas would quickly recolonize. Dredging in the NJIWW is not allowed from Jan 1st through May 31st of any given year so sand placement will occur during the allowable dredging window to further reduce the potential for impacting EHF species.

Potential indirect impacts to winter and summer flounder EFH include the removal and/or burial of benthic and epibenthic forage species habitat and the disruption and loss of forage species through increased turbidity and sediment re-suspension during dredging and the exclusion of some forage fish from the project area during construction. These indirect impacts are short-term as finfish prey species will return to the area immediately and benthic communities will begin to re-establish themselves within a few months following construction (Wilber and Clarke 2007). Moreover, adult flounder are opportunistic feeders and prey on a variety of on fish including sand lance, bay anchovy, and other flatfish (Klein-MacPhee 2002), while juveniles forage on sand shrimp and small fish. The loss of forage habitat would likely cause flounder to relocate from Mordecai Island to other nearby feeding habitats since the total aquatic habitat area impacted during the construction phase is a small fraction of the total estuary available to flounder and other EFH species.

Habitat Area of Particular Concern (HAPC) for summer flounder has been identified within SAV beds in the estuary. Depending on the location and density of SAVs around Mordecai Island at the time of construction, it is possible that there will be a temporary reduction in SAV habitat available for use by summer flounder. SAV surveys conducted in 2003, 2018 and 2019 identified varied densities of eelgrass and macroalgae on the western side of the island and higher densities on the eastern side of the island. The installation of the rubble mound breakwater could destroy some SAV beds within the footprint of the structure but the depth of the structure minimizes this potential as higher SAV densities were found in shallower water. It is also expected that once the breakwater is installed, it will create habitat more suitable for SAV colonization by reducing wave activity behind it. Sand placement, which will occur after the installation of the rubble mound breakwater, has the potential to temporarily impact existing SAVs. SAV surveys will be conducted prior to sand placement to minimize impacts to existing SAV beds to the greatest extent possible. Sand placement will also create additional areas suitable for SAV colonization and is expected to have an overall increase in SAV habitat. In addition, the restoration project will be protecting the island from erosion and protecting the high density SAV habitat on the eastern side of the island. During any construction activities, the dense SAV beds on the eastern side of the island will still be available for use by summer flounder. The Corps has concluded that the project will have a minimal direct effect on EFH and will be overall beneficial to EFH species and EFH habitat.

6.2.6 Wildlife Resources

Mordecai Island provides breeding, foraging, nesting and resting areas for many species of migratory birds, including shorebirds, wading birds, raptors and waterfowl. The No Action alternative would result in the continued loss of habitat at Mordecai Island due to erosion and the eventual loss of most of the habitat that currently exists on the island, thereby negatively impacting the species utilizing the island. The proposed project is intended to improve ecosystem functions, services and resiliency, including improvement in water quality, and the enhancement and creation of fish, shellfish, wading bird, and waterfowl habitat. The implementation of the proposed ecosystem restoration project will protect the existing island and restore approximately 11 acres of lost wetland habitat, all of which benefit the wildlife species living on and utilizing the island habitat. The addition of sand on approximately 4 acres of the previously filled breach area will raise the elevation of that area by approximately 1.5 feet, depending upon existing conditions at construction and the amount of sand available during maintenance dredging, and will benefit the beach nesting birds and diamondback terrapins utilizing the site. There will be some minor and temporary effects to wildlife species during the construction activities, but the majority of the island will not be affected during construction, and species can easily move to avoid the construction activities.

6.2.7 Threatened and Endangered and Other Protected Species

Due to the location of Mordecai Island, the project's potential effects on the Federally listed Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), piping plover (*Charadrius melodus*), roseate tern (*Sterna dougallii dougallii*), eastern black rail (*Laterallus jamaicensis*), and the red knot (*Calidris canutus*) have been considered. Piping plovers and red knots have recently been observed feeding and resting on Mordecai Island. While there may be some temporary disturbance to the bird species during construction activities, it is anticipated they will move away from construction activities since they are not nesting at the site. The resulting project will be beneficial to the listed species. Based on the available information, it has been determined that the proposed project is not likely to adversely affect the above listed threatened and endangered species. This determination is being coordinated with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service.

In addition, the project is expected to have no adverse effects on State-listed species of birds. The project is intended to protect and restore important resting, feeding and nesting habitat for these species. As previously mentioned, the addition of sand on the breach fill area will also improve nesting habitat for the diamondback terrapins on the island.

6.3 Cultural Impacts

The Area of Potential Effect (APE) would include the NJIWW as a source of sediment and the western shore and nearshore areas on Mordecai Island. Since the NJIWW will only be dredged to its previously authorized depth, and since the location of the rubble breakwater will be within the 1977 tideline footprint, and subsequent placement of dredged material will serve to stabilize the degraded marsh, the Corps has determined that the proposed action will have No Effect on historic properties eligible for or listed on the National Register of Historic Places pursuant to 36CFR800.4(d)(1).

On June 10, 2020 a No Effect determination letter was submitted electronically to the NJSHPO for review and concurrence. On June 25, 2020 a No Effect determination letter was submitted electronically to the Tribes for review and comment.

In a letter dated July 1, 2020 the Delaware Nation stated that the project as planned is acceptable, but if any unanticipated discoveries are encountered during construction they are requesting to be notified. No other Tribes responded.

In a letter dated July 8, 2020, the NJSHPO stated that, although the project setting is sensitive for archaeological sites, the undertaking only has a low potential to affect archaeological sites; therefore, the NJSHPO concurs with the finding that there will be no historic properties affected by the proposed undertaking within the APE (see Appendix B). No further Section 106 consultation is required unless additional resources are discovered during project implementation pursuant to 36CFR800.13.

6.4 Socioeconomic Conditions

National Economic Development (NED): As an ecosystem restoration study, NED benefits from coastal storm risk management are not quantified during the analysis. There may be incidental wave attenuation benefits for assets in the vicinity of Mordecai Island, but those benefits are not modeled and do not alter plan selection.

Regional Economic Development (RED): As with NED benefits, RED benefits are not quantified during the analysis. There may be incidental wave attenuation benefits which may reduce commercial service interruption during storm events, but this benefit stream is not modeled as part of an ecosystem restoration study and does not help inform plan selection.

Environmental Quality (EQ): EQ is the main benefit category for this study. Restoring 11.5 acres of marsh habitat on the island and mitigating future erosion would benefit the threatened natural habitats of intertidal marsh, bird nesting areas, exposed mud flats, shrub-dominated areas, and shallow water SAV beds. The project is expected to result in an increase of 285 AANESMMUs over the without project conditions.

Other Social Effects (OSE): The OSE account qualitatively assesses potential benefits of the project that are not picked up in economic development and environmental quality. Additional recreation may be a potential outcome of the Mordecai Island restoration. Bird watching conditions may improve, or there may be another environmental hobby that manifests itself. This project would provide a case study for researchers to study the potential of protecting the ecosystems of other areas. Also, an ecosystem restoration project near Beach Haven might strengthen community resiliency. Protecting the land in an area with such a small population shows commitment and may foster good spirits within the community.

6.4.1 Noise

The implementation of the proposed plan will result in minor temporary effects to noise in the area around Mordecai Island. These effects will be limited to the time of active construction and area not expected to be significantly greater than the background noise of boats and personal watercraft that frequent the NJIWW and surrounding area.

6.4.2 Environmental Justice

In accordance with Executive Order (Environmental Justice in Minority Populations) 12989 dated February 11, 1994, a review was conducted of the populations within the affected area. The Executive Order requires that "each Federal agency make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health and environmental effects of its programs, policies, and activities on minority populations and low-income populations." The U.S. Environmental Protection Agency definition for Environmental Justice is: "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." Based on a review of recent census data of the affected area, no impacts are expected to occur to any minority or low-income communities in the vicinity of Mordecai Island.

6.5 Real Estate

A Real Estate Planning Report is included as Appendix C. The report describes the interests required for project implementation and identifies the properties involved, their value, and ownership. The project is adjacent to the NJIWW, a Federal navigation channel. The project site is accessible by water and is subject to navigational servitude. Therefore, no estate acquisition is required for the project footprint. A Temporary Work Area Easement must be secured for all areas needed for access, docking, storing, and staging for construction equipment, materials, and operations. The Temporary Work Area Easement parcel is owned by the Borough of Beach Haven.

6.6 Projected Cost Revision

Following TSP selection, an Abbreviated Risk Assessment was conducted. It was determined that construction should be conducted from the water, rather than from Mordecai Island due to the risk of impacts to the island. This resulted in a revised TSP cost. (See Tables 6.1, 6.2 and 6.3 below.) Details of the cost calculation are located in Appendix A: Engineering Technical Appendix. The change in cost did not change identification of the TSP, given that the change from land-based to water-based construction was uniform across the alternatives. The non-Federal sponsor of the feasibility study is aware of the cost change.

Table 6.1: Tentatively Selected Plan - Projected Revised Cost

Feature	Cost	Contingency	Total
01 Lands and Damages	$54,000	$14,000	$68,000
02 Relocations	$15,000	$3,000	$18,000
06 Fish and Wildlife Facilities	$987,000	$188,000	$1,175,000
10 Breakwaters and Seawalls	$3,339,000	$931,000	$4,270,000
30 Planning, Engineering & Design	$885,000	$229,000	$1,114,000
31 Construction Management	$563,000	$146,000	$709,000
TOTAL	$5,843,000	$1,510,000	**$7,354,000**

Price Level: December 2021 Discount Rate: 1.125

Table 6.2: Projected Cost of TSP, Environmental Monitoring, Adaptive Management

Item	Quantity	Cost	Total
Tentatively Selected Plan	1	$7,354,000	$7,354,000
Environmental Monitoring	5	$100,680	$503,400
Adaptive Management	1	$94,388	$94,388
TOTAL			**$7,951,788**

Price Level: December 2021 Discount Rate: 1.125
(Note: Environmental Monitoring is assumed to occur for five years. Adaptive Management is assumed to occur in year four.)

Table 6.3: Federal/Non-Federal Cost Share Breakdown

Item	Total Cost	Federal 75%	Non-Federal 25%
Tentatively Selected Plan	$7,354,000	$5,515,500	$1,838,500
Environmental Monitoring	$503,400	$377,550	$125,850
Adaptive Management	$94,388	$70,791	$23,597
TOTAL	**$7,951,788**	**$5,963,841**	**$1,987,947**

Price Level: December 2021 Discount Rate: 1.125

7 Compliance with Environmental Statutes*

Compliance with applicable Federal Statutes, Executive Orders, and Executive Memoranda is ongoing and is presented in Table 7.1. This is a complete listing of compliance status relative to environmental quality protection statutes and other environmental review requirements.

The proposed ecosystem restoration through the installation of a rubble mound breakwater, sand placement and wetland plantings at Mordecai Island complies with and will be conducted in a manner consistent with New Jersey's requirements with regard to the Coastal Zone Management Act. A Federal Coastal Zone Consistency Determination is being requested with the circulation of this EA.

The ecosystem restoration activities described in this document is not expected to have significant changes in air quality impacts. A Clean Air Act Record of Non-Applicability (RONA) that demonstrates a typical emissions output during construction is presented in Appendix B that demonstrate that compliance will be met with Section 176(c)(1) of the Clean Air Act amendments of 1990.

Table 7.1: Compliance with Environmental Quality Protection Statutes and Other Environmental Review Requirements

FEDERAL STATUTES	COMPLIANCE STATUS
Archeological - Resources Protection Act of 1979, as amended	Full
Bald and Golden Eagle Protection Act	Full
Clean Air Act, as amended	Full
Clean Water Act of 1977	Partial
Coastal Barrier Resources Act	N/A
Coastal Zone Management Act of 1972, as amended	Partial
Endangered Species Act of 1973, as amended	Partial
Estuary Protection Act	Full
Federal Water Project Recreation Act, as amended	N/A
Fish and Wildlife Coordination Act	Partial
Land and Water Conservation Fund Act, as amended	N/A
Marine Protection, Research and Sanctuaries Act	Full
Magnuson-Stevens Fishery Conservation and Management Act	Partial
Migratory Bird Treaty Act	Full
National Historic Preservation Act of 1966, as amended	Full
National Environmental Policy Act, as amended	Partial
Rivers and Harbors Act	Full
Watershed Protection and Flood Prevention Act	N/A

FEDERAL STATUTES	COMPLIANCE STATUS
Wild and Scenic River Act	N/A
Executive Orders, Memorandums, etc.	
EO 11990, Protection of Wetlands	Full
EO12114, Environmental Effects of Major Federal Actions	Full
EO 12989, Environmental Justice in Minority Populations and Low-Income Populations	Full
EO 13045, Protection of Children from Environmental Health Risks and Safety Risks	Full
County Land Use Plan	Full

Full Compliance - Requirements of the statute, EO, or other environmental requirements are met for the current stage of review.
Partial Compliance - Some requirements and permits of the statute, E.O., or other policy and related regulations remain to be met.
Noncompliance - None of the requirements of the statute, E.O., or other policy and related regulations have been met.
N/A - Statute, E.O. or other policy and related regulations are not applicable.

8 Plan Implementation

The Non-Federal sponsors will be required to submit a Certification of financial capability for decision documents for the final report along with a Letter of support for the implementation of the project. After the final feasibility report is approved and signed by the Corps Philadelphia District Engineer, it is anticipated that a Project Partnership Agreement will be entered into between the Corps Philadelphia District, NJDEP and MLT and adequate funding will be put into place. The Design and Implementation phase of the project is anticipated to commence in 2023. During this phase the Corps will formalize plans and specifications and obtain regulatory permits for the project while NJDEP and MLT will confirm that the appropriate real estate instruments are in place to allow for construction. In addition, the project partners will develop a detailed monitoring plan.

Breakwater construction and fill placement will be consecutive, with breakwater construction up to one year ahead of dredging and filling. Design and breakwater construction will likely take two years, with fill placement from the NJIWW occurring during a third year. Lastly, the fill material will be planted with appropriate intertidal marsh vegetation. Construction will occur by barge from the water, with a staging area in Beach Haven on the barrier island. Dredging in the NJIWW is not allowed from January 1st through May 31st of any given year, so sand placement will occur during the allowable dredging window to further reduce the potential for impacting species using Essential Fish Habitat.

An initial monitoring event will occur immediately following completion of all site restoration activities in the form of post-construction monitoring under the construction contract. Long-term monitoring activities will be conducted annually for five years following completion of site restoration. Adaptive management will be implemented if specific restoration standards are not met or if it appears that actual conditions will diverge sufficiently far from the intended conditions to threaten the achievement of overall project goals. After five years the non-Federal partners will be solely responsible for the project, including monitoring and adaptive management.

9 Monitoring and Adaptive Management

The goal of the Mordecai Island Ecosystem Restoration Feasibility Study and Integrated Environmental Assessment is to preserve, protect and restore the island's diverse habitats by reducing shoreline erosion through the construction of a 3000 linear foot rubble mound breakwater, sand placement and wetland plantings which will result in an increase of 285 Average Annual NESMM units over the without project conditions.

In order to determine if the project has successfully met the project goals and that it is functioning properly, monitoring and adaptive management are included as part of the ecosystem restoration plan. Monitoring is necessary to determine if the rubble mound breakwater remains stable, reduces the rate of shoreline erosion and protects and enhances habitat. Monitoring of the sand placement and wetland plantings will also be conducted. Monitoring data will be used to provide feedback for future projects and to resource agencies and to inform the Corps if any adaptive management is necessary. A goal of the monitoring is also to provide the information necessary to improve the effectiveness of similar projects while minimizing the impact to the environment. A copy of the monitoring and adaptive management plan can be found in Appendix B.

10 Public Involvement*

Public involvement for the study has mostly been conducted with, and through, MLT. MLT is the nonprofit owner of Mordecai Island and members are the stakeholders most affected by the ecosystem restoration study. Coordination with MLT has been conducted by USACE and by NJDEP, the study's non-Federal sponsor. Communication has been through site visits, remote meetings, telephone calls and emails throughout the life of the study. Topics have included data sharing, plan formulation, the tentatively selected plan, MLT projects on the island, study schedule, future involvement of MLT in Design and Implementation phase of the restoration project, etc.

The Integrated Feasibility Report and Environmental Assessment will be available to the public for a 30 day review. The non-Federal sponsor, stakeholders, and the regulatory agencies will be consulted regarding the selection of the TSP.

11 Conclusions and Recommendations*

(To be finalized after review of the Tentatively Selected Plan.)

A rubble mound breakwater with fill from NJIWW along Alignment A is recommended, as is movement of No-Wake buoys closer to the channel.

The selected plan supports the recommended National Ecosystem Restoration (NER) Plan, which includes a rubble mound breakwater with fill and planting wetland vegetation. The selected plan will provide 285 Average Annual New England Salt Marsh Model Units (AANESMMUs) over the No Action plan. The breakwater generally follows the 1977 Tidelands line, approximately parallel to the west side of Mordecai Island in the nearshore area. The rubble mound breakwater will extend for 3,000 linear ft. and have an average height of 7.6 ft. from the bay bottom. To account for potential settlement of one foot, the initial construction is estimated to be +3.6 ft. NAVD88 (1 foot of overbuild). The rubble mound breakwater will have a crest width of 3 feet and 2H:1V side slopes. Sill vents, at a crest elevation matching Mean Low Water, will be placed every 160 feet along the structure to allow for water flow and circulation behind the structure during the full tidal cycle. Each sill vent will be 40 feet long. A geocomposite will be placed between the bottom of the structure and the existing ground (see Geotechnical Section of the Engineering Technical Appendix). Approximately 30,000 cubic yards of sand will be obtained from normal maintenance dredging of the NJIWW and placed behind the structure to restore lost intertidal low marsh habitat and beach nesting bird habitat. The restored marsh habitat will be planted with wetland vegetation. As part of the selected plan, it is also recommended that existing No Wake buoys be moved closer to the NJIWW channel to promote visibility of the buoys and, indirectly, reduced boat wakes. Relocation of the buoys would be at no cost to this project. The selected plan is compliant with all Federal environmental laws (see Table 7.1).

____________________________ _______________________________________

Date

Ramon Brigantti
Lieutentant Colonel, Corps of Engineers
District Engineer

12 List of Preparers*

Theresa Fowler – Project Management and Plan Formulation
Regina Kukola – Project Management and Plan Formulation
Jane Jablonski – Supervision and Plan Formulation
Mark Eberle – Environmental Resources
Beth Brandreth – Environmental Resources
Valerie Whalon – Environmental Resources
Nicole Minnichbach – Cultural Resources
Michael Kastner - Economics
William Welk – Cost Engineering
Jeff Sklencar – Cost Engineering
Robert Lowinski – Hydrology and Hydraulics
Samuel Weintraub – Civil Design
Mary Pakan – Civil Design
Melinda Eason – Geotechnical Engineering
William Harris – Geo-Environmental
Janay Dixon – Real Estate
Stephen Long – Geographic Information System Support
Linda Skale – Reference Librarian

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