
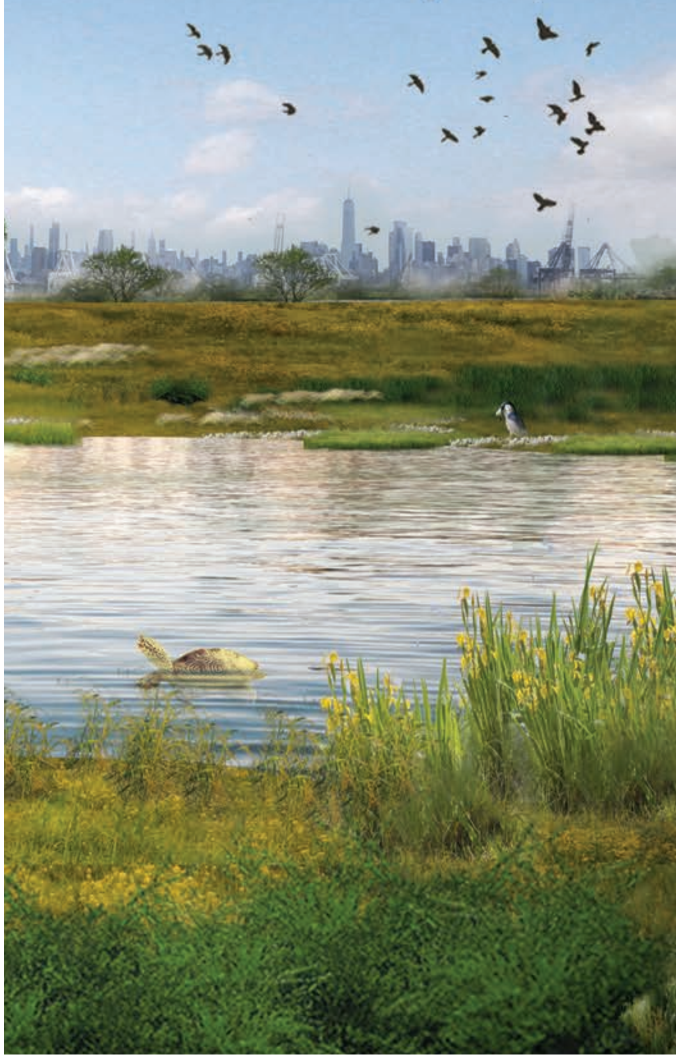
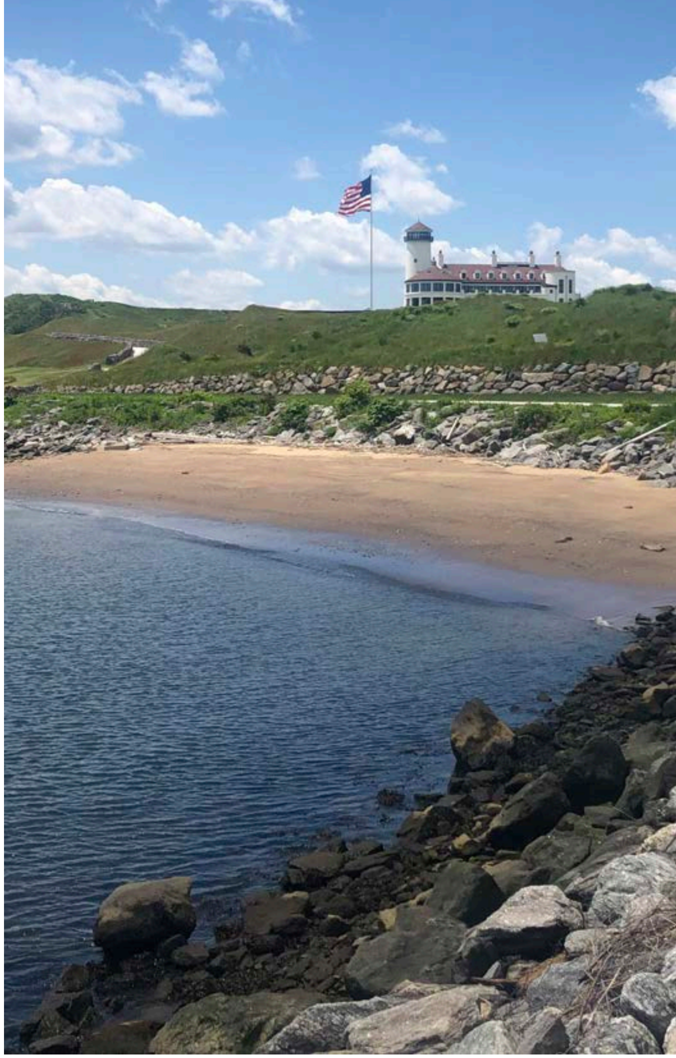

BAYONNE URBAN COASTAL DESIGN: AN INTEGRATED APPROACH

REPORT OF AUGUST 30, 2019

BAYONNE GOLF CLUB
New York Harbor

RUTGERS
CUES — Center for Urban Environmental Sustainability

STEVENS
INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

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BAYONNE URBAN COASTAL DESIGN: AN INTEGRATED APPROACH

Prepared for
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August 30, 2019

Prepared by
Rutgers Center for Urban Environmental Sustainability

With
The Stevens Institute of Technology

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I. EXECUTIVE SUMMARY

The City of Bayonne lies between New York and Newark Bays in the center of the Hudson-Raritan Estuary (HRE). The Bayonne Golf Club owns 309 acres of riparian lands located between the new residential development on the opposite shoreline that once housed the Marine Ocean Terminal Bayonne (MOTBY) and the club, at the Hudson River entrance to the Kill van Kull. These waters are located in the HRE Upper New York Bay planning region identified in the Comprehensive Restoration Plan (CRP) for the estuary. The Bayonne Urban Coastal Design (BUCD) project provides an opportunity to consider resiliency protections that will benefit this eastern portion of Bayonne, and at the same time, create desperately needed habitats that support the Target Ecosystem Characteristics (TECs) approved in the CRP.

Three design alternatives for coastal green infrastructure – Links Island, Bird Island, and Marine Terminal Island – were developed by Rutgers Center for Urban Environmental Sustainability (CUES), working collaboratively with Stevens Institute engineers. These designs are based on an analysis of detailed site and surrounding land use conditions, a review of relevant scientific literature, case studies that beneficially reused dredge material for coastal ecologic restoration projects, NOAA-FEMA projections of future sea level rise and storm surges predicted for 2050, and the TEC habitat needs identified in the CRP.

The island will convert approximately 175-acres of silty-clay mud sediments to shoreline and shallows (sand flats, dunes, mudflats, high and low marsh), transition grassland, and maritime forests that will serve as protection for the eastern Bayonne coastline. The island will add acreage that supports seven of the twelve identified TECs in the Comprehensive Restoration Plan. This installation will require engineered protections, such as breakwaters, revetments, and bulkheads, to mitigate erosive forces generated by wave, wind, and storm surge energies in the estuary.

Regulatory permits for a riparian installation would be required from the New Jersey Department of Environmental Protection and the U.S. Army Corps of Engineers. There are recent case studies, including marsh restoration in Jamaica Bay, NY, that offer precedents for this type of restoration activity that beneficially reuses dredge materials in coastal waters.

NOAA sea level rise projections for the region range from seven to sixteen feet by 2050. Due to the current uncertainties in these estimates, an adaptive management approach, based on consistent data collection, is recommended to ensure the island's sustainability and to maximize its protective and habitat values.

Figure 1. The Bayonne Urban Coastal Design (BUCD) site located between the Bayonne Golf Club and the MOTBY Channel. *Courtesy of CUES.*

II. INTRODUCTION

Urban Coastal Protection and the Hudson Raritan Estuary Comprehensive Restoration Plan

BACKGROUND

The Hudson-Raritan Estuary (HRE) was created by retreat of the Wisconsin Glacier 12,000 years ago. Post-glaciation the estuary was shallow, with water depths less than 20 feet at mean low tide (USACE 2016).[1] The estuary was covered by sandy beaches, marshes, and maritime forests. However, two centuries of human impacts have resulted in ecological degradation as urban and industrial expansion occurred at the expense of natural resources. Thousands of acres, more than 80% of HRE habitats, including coastal forests, wetlands, marshes, oyster reefs and tidal flats have been lost.

The area known as Bayonne was originally part of New Amsterdam, claimed by the Dutch after Henry Hudson explored NY-NJ harbor in 1609. The name Bayonne might have originated with Bayonne, France, where Huguenots settled for a year before the founding of New Amsterdam or from its location on the shores of two waterbodies, Newark and New York Bays.

The first record referring to the Bayonne area is dated March, 1646, when Jacob J. Roy, a gunner of Fort Amsterdam, received a land grant on the Kill van Col. The site was named Constapel's Hoeck (Gunner's Point), deriving its name from the occupation of its European owner. In 1654, grants were issued for land in the future Bayonne. A small group representing property owners arrived from New Amsterdam in 1655 and erected shelters, where they traded with Native Americans and probably cleared some land in preparation for building homes (Fig. 1).

However, in September 1655, the Amerindians (provoked by the killing of a native woman) attacked New Amsterdam. They then crossed the Hudson, attacked settlers on the western shore, and continued down through Bergen Neck (Bayonne) to Staten Island. The settlers fled to Manhattan. There is no record of when the Dutch returned to reclaim their Bergen Neck property, but in January 1658, a deed shows an Amerindian land sale to the Dutch. The settlement prospered after the arrival of more colonists.

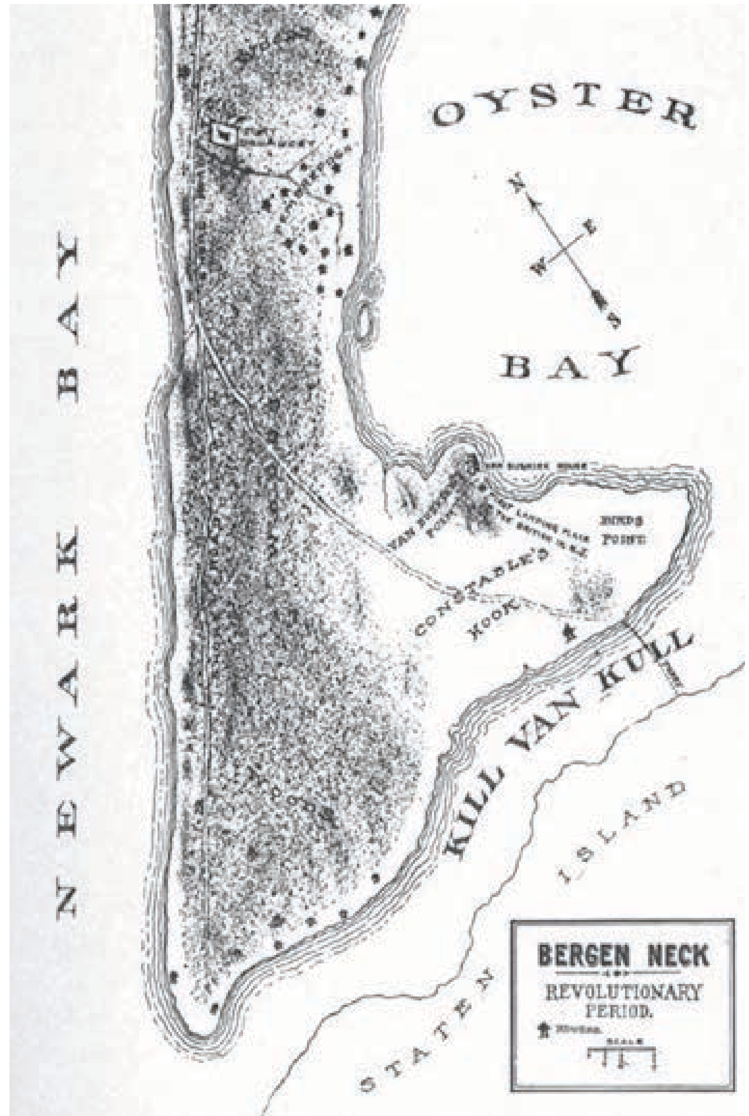

Figure 1. Constable's Hook location of the future City of Bayonne in the Revolutionary Period. *Courtesy of R. P. Whitcomb.*

Figure 2. Map of Bayonne in 1837. *Courtesy of R.P. Whitcomb.*

Figure 3. Aerial view of the industrial waterfront of Bayonne. Date unknown. *Courtesy of the Bayonne Public Library Digital Archives.*

The English, in 1664, captured all of New Netherlands from the Dutch. After English possession of New Amsterdam, Governor Nicolls gave five hundred acres to Samuel Edsall and Nicholas Johnson "for a Neck of Land lying at the mouth of Kill van Kul." This grant included part of Bergen Point (Constable's Hook). In November 1670, Johnson sold his interest to Edsall, who established a flourishing plantation and is credited with being the first settler of Bayonne in a brochure titled "The Model of the Government of the Province of East Jersey in America," published in Edinburgh in 1685.There were other small plantations to the east between the large plantation and a little village of twenty families. The recapture of New York by the Dutch in 1673, followed by their final surrender to the English the following year, had little effect on the Bayonne area.

Bergen Neck was an important territory during the Revolutionary War. In 1776, Lord Sterling, in command of the American forces at Bergen, undertook the defense of Bergen Neck where works were erected to prevent a British invasion from Staten Island. However, American troops evacuated the area in October 1776 after the British captured Manhattan.

Bayonne Township was created on April 1, 1861, from portions of Bergen Township. The City of Bayonne was incorporated by an act of the New Jersey Legislature in March 1869, including the communities of Bergen Point, Constable Hook, Centreville, Pamrapo and Saltersville. Bayonne had flourishing farms; workers in the fields; cows in the pastures, feeding; fields of waving corn, with a bay on either side; birds singing in the woods. The rattle of milk cans confronted travelers along the old Plank Road. Bergen Point was "the town," and the section north of Fourteenth Street, which was two-thirds woods, was the "country" where there were a few houses.[2]

Nineteenth Century Bayonne was known as a resort area inhabited by fisherman, farmers, and boat builders, but by the end of the century, development of oil refineries and oil-related infrastructure connected the City of Bayonne with the Texas oil fields.[3]

By 1920 Standard Oil in Bayonne was one of the largest oil refinery operations in the world.[2] During World War II the U.S. Navy opened a base at the Military Ocean Terminal at Bayonne (MOTBY) (Fig. 4). In 1967 MOTBY became a U.S. Army base and shipping terminal, which eventually closed in 1999.

The site that would become the future Bayonne Golf Club, owned by the U.S. government, was given to the State of NJ in 1869.[3] In 1912, the State sold the site's riparian rights to the R.G. Packard Company, and a portion of this riparian land was filled with dredge material.[3] The City of Bayonne sold the land to Public Service Electric & Gas Company in 1963 for the purpose of constructing a nuclear power plant, a plan that was ultimately abandoned.[3]

Figure 4. Aerial view of MOTBY in 1973. The site of the future Bayonne Golf Club is in the center background on the opposite side of the channel to the right of the oil tanks. *Courtesy of the Bayonne Public Library Digital Archives.*

Today, the Bayonne golf Club property (Fig. 5) includes 460 acres; approximately 309 are riparian acres below the Mean Low Tide line.[3]

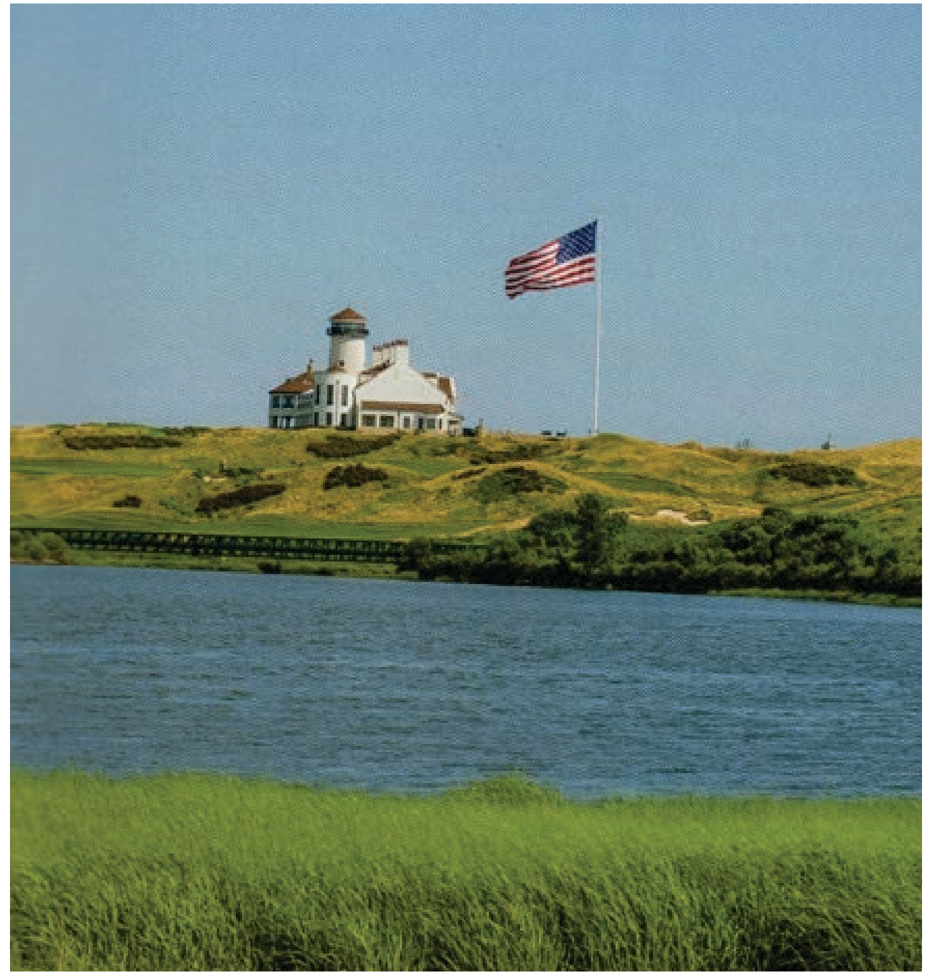

Figure 5. Bayonne Golf Club. *Courtesy of the Bayonne Golf Club.*

Figure 6. Designated planning regions within the Hudson-Raritan Estuary (HRE). *Courtesy of USACE.*

COMPREHENSIVE RESTORATION PLAN

Four hundred years after Henry Hudson's exploration, the HRE today is the most densely populated estuary in the U.S., with more than 20.1 million residents in the New York metropolitan area (USOMB 2015).[4] The HRE accommodates a robust port industry valued at roughly $53.5 billion annually, while also providing 336,600 industry-related jobs (NYSA 2015).[5]

In 1988, the HRE was designated as part of the National Estuary Program by the Federal government. The New York-New Jersey Harbor Estuary Program brought together the Federal government, the States of NY and NJ, academic institutions, and non-government organizations to improve HRE ecological conditions, leading the Harbor Estuary Program to release a Comprehensive Conservation and Management Plan in 1996. The Comprehensive Restoration Plan (CRP)[1] for the HRE (Fig. 6) was approved in 2016, providing goals and recommendations for protection and restoration of the estuary's habitats.

OPPORTUNITIES FOR RESTORATION AND RESILIENCY

Twelve Target Ecosystem Characteristics (TECs) that prioritize habitats needed to restore the HRE were approved for the CRP (Fig. 7). Over 300 HRE sites have been identified for priority restoration or habitat preservation. Currently the majority of these sites are located in New York, and only seven of the identified sites are in the Upper New York Bay Planning Region. However, ***New Jersey offers significant opportunities to expand the number of restoration sites and the potential to increase regional resiliency to respond to major storm events.***

Meeting TEC goals is a massive undertaking that will cost much more than is currently allocated, or reasonably expected, in Federal and/or state appropriations. Many projects involve physical alterations and re-creating upland, wetland, and aquatic habitats. Developing public-private funding sources will be crucial to reaching the TEC goals. ***The proposed Bayonne Urban Coastal Resiliency Project would support seven of the twelve approved TECS.***

THE BAYONNE GOLF CLUB

The Bayonne Golf Club, built in the spirit of the Old Course at Troon and other Scottish links courses, sits on a 38-acre municipal landfill and the low lying tract formerly owned by PSE&G (Fig. 8). In this privately financed restoration, the developers brought in about 7.5 million cubic yards of

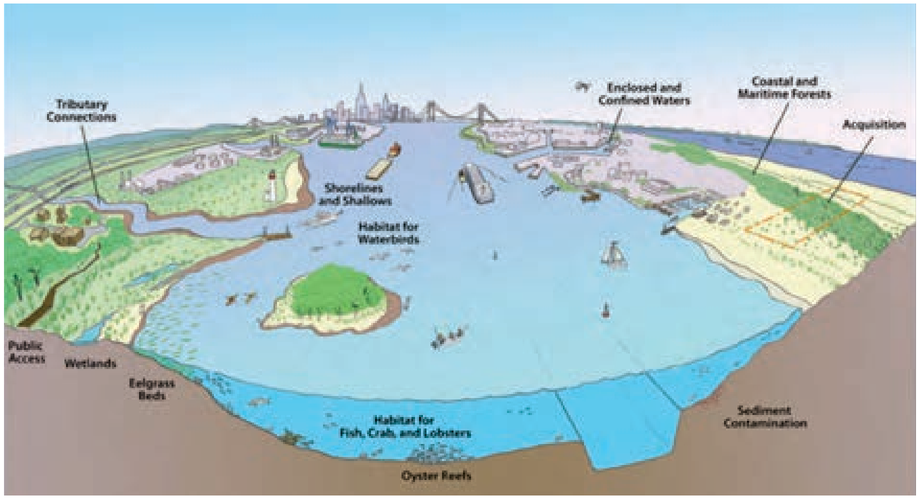

Figure 7. Illustration of the twelve approved Target Ecosystem Characteristics (TECs) in the Hudson-Raritan Estuary (HRE) Comprehensive Restoration Plan (CRP). *Courtesy of USACE.*

material from four harbor dredging projects according to the U.S. Army Corps of Engineers, the agency that oversaw the dredging, as well as other beneficially reused materials. The golf course, in the tradition of links courses worldwide, took the name of its host community.

The Bayonne course is visually striking, with no trees or cart paths on the steep rises and rough areas between its undulating fairways. The course offers views of the Statue of Liberty, Ellis Island, Manhattan, Brooklyn, the Verrazano-Narrows Bridge and Staten Island -- as well as some of the shipping cranes and scrap yards that are still in business around the harbor. The golf course contains a public walkway built on the perimeter of the course that creates an opportunity for Bayonne residents to experience the New York Harbor.

Across a small channel opposite the golf course is the former MOTBY (Fig. 8). The two-mile earthen pier was rechristened in 2002 as the Peninsula at Bayonne Harbor after being decommissioned by the Army and turned over to the City of Bayonne for redevelopment. Pier uses include a Royal Caribbean cruise ship port, plus film and television studio space. A 450-unit townhouse village is now under construction on the pier. The State Department of Environmental Protection characterized the course as a "very successful project" that "turned a brownfield into a greenfield." [6]

Figure 8. View of MOTBY from Bayonne Landfill/PSEG site before construction. *Courtesy of the Bayonne Golf Club.*

PROPOSED BAYONNE UPPER NEW YORK BAY RESTORATION SITE

The Bayonne Golf Club is the unique owner of 309 acres of subtidal riparian lands adjacent to the MOTBY Channel. This is the site of the proposed Bayonne Urban Coastal Design (BUCD) project, located in the Upper New York Bay planning region. The CRP identifies only seven sites in this region out of 296 total restoration opportunity sites in the NY-NJ harbor, the least of any HRE planning region.

Although natural shoreline is limited, the BUCD site is in close proximity to Liberty State Park, Ellis and Governors Islands (Fig. 9). A Stronger, More Resilient New York (2013), the NYC Special Initiative for Rebuilding and Resiliency, designated the Upper New York Bay planning region as appropriate for wetland, oyster reef, and living shorelines (including coastal and maritime forests). These habitats provide green infrastructure that can potentially minimize future damage from wave impacts and storm surges.

The BUCD project proposes a habitat complex consisting of intertidal and subtidal zones, shoreline and shallows, and maritime forests covering approximately 175 acres. The envisioned island installation would create both ecologically critical habitats, as well as green infrastructure, providing coastal storm protection for the eastern portion of the City of Bayonne and sections of interstate Route 440.

This multi-habitat project would support seven of the twelve TECs: Maritime Forests, Wetlands, Habitats for Waterbirds, Shorelines and Shallows, Habitat for Fish, Crabs, and Lobsters, Oyster Reefs, and Public Access (Fig. 10). The installation could potentially support the TEC for eelgrass beds, depending on continued water quality improvements provided by the project and eventual termination of Combined Sewer Overflow (CSO) discharges into the harbor.

Figure 9. Location of the proposed BUCD in the Upper Bay region of the NY Harbor Estuary. *Courtesy of CUES; data courtesy of ESRI.*

TARGET ECOSYSTEM CHARACTERISTICS OF THE BAYONNE URBAN COASTAL DESIGN PROJECT

Shorelines and Shallows

Create or restore shoreline and shallow sites with a vegetated riparian zone, an inter-tidal zone with a stable slope, and illuminated shallow water.

Habitat for Waterbirds

Restore and protect roosting, nesting, and foraging habitat (i.e. inland trees, wetlands, shallow shorelines) for long-legged wading birds.

Wetlands

Create and restore coastal and freshwater wetlands, at a rate exceeding the annual loss or degradation, to produce a net gain in acreage.

Oyster Reefs

Establish sustainable oyster reefs at several locations.

Coastal and Maritime Forests

Create a linkage of forests accessible to avian migrants and dependent plant communities.

Habitat for Fish, Crab, and Lobsters

Create functionally related habitats in each of the eight regions of the HRE.

Public Access

Improve direct access to the water and create linkages to other recreational areas, as well as provide increased opportunities for fishing boating swimming, hiking education, or passive recreation.

Figure 10. The BUCD project has the potential to support seven of the twelve Hudson-Raritan Estuary Comprehensive Restoration Plan TECs, including: Shorelines and Shallows; Habitat for Waterbirds; Wetlands; Oyster Reefs; Coastal and Maritime Forests; Habitat for Fish, Crab, and Lobsters; and Public Access. *Courtesy of CUES.*

To ensure the success of the BUCD project, the team reviewed the current scientific literature related to estuarine systems to ensure science-based design options. The literature review included estuarine ecologic attributes and discussions of sediment dynamics, vegetation and tidal influences, and wind effects on coastal islands.

Estuarine Management (and habitats)

Estuarine Management plans must be based on scientific data and have quantified goals to ensure their success (Morris et al., 2017,[7] Zedler 2017[8]). Estuaries are extremely variable and dynamic, and so management plans must be site specific. To achieve coastal resiliency & storm surge protection under urban conditions, hybrid designs that integrate natural and engineered protections may be the best option (nature-based infrastructure). Resiliency plans should minimally include a long term (100-year timeframe) to address a changing climate (Bilkovik et al., 2016[9]).

Sea Level Rise

Rising sea levels increase the base level of flood heights in the New York metropolitan region, increasing future flooding caused by hurricanes (Kemp et al., 2013[10]). Accelerated sea level rise will exacerbate historic trends of beach erosion and loss of highly productive coastal salt marshes (Gornitz et al., 2001[11]). These larger storms and higher storm surges will require changes in the regional landscape to ensure future resiliency.

Sedimentation Dynamics

Sediment dynamics are a key factor in estuarine ecosystems and essentially dictate typology and marsh survival (Reed et al., 2018[12]). Marsh failure is largely due to collapsing elevations caused by erosion, loss of vegetation, and sea level rise (Duvall et al., 2018[13]). Sediment dynamics and deposition rates must be understood and planned for in a comprehensive sediment plan (Ganju 2019[14]).

Vegetation

The presence of vegetation can reduce wave erosion, provide storm protection, and increase biodiversity (Costanza et al., 2008[15], Ajedegba et al., 2019[16], Reed et al., 2019[17]). Plant flexibility and height, as well as wave conditions and water depth, play an important role in determining how salt marsh vegetation interacts with waves (Rupprecht et al., 2017[18]). Vegetation can also enhance marsh deposition by trapping sediment when slowing flow velocities (Duvall et al., 2019[19]). Non-native plants have been shown to increase coastal resiliency, but they may outcompete native species. Therefore, trade-offs must be understood and evaluated when choosing vegetation for coastal resiliency (Charbonneau et al., 2017[20]). As with other conditions in estuarine systems, it is imperative to understand how vegetation behaves during storm events and include plants that are site-specific (Rupprecht et al., 2017[21]).

Wind Dynamics

Wind fetch effects marsh survival and must be considered when designing marsh protection features. Living shorelines are successful when fetch is <0.8 km, successful with light infrastructure when fetch is 0.8-1.6 km, and useless at fetch levels >1.6 km (Saleh & Weinstein 2016[22]). Due to the variability of estuaries, infrastructure should be based on site-specific fetch data.

Wave & Tidal Current Characteristics

Erosive effects attributable to waves and tidal current energies affect the size & width of marsh fringe structures and marsh morphology. These forces also determine ecologic pressures on plants and animals (Elliot & Whitfield 2011[23], Saleh & Weinstein 2016[24]).

Topography & Shore Morphology

For successful marsh survival it is vital to maintain marsh surface elevations (Cahoon et al., 2019[25]). Wider marshes may have greater wave attenuation capabilities and less horizontal erosion (Charbonneau et al., 2017[20]). Mounded topography creates niches that can increase both biodiversity and resilience (Diefenderfer et al., 2018[26]).

Oyster Reef

Oyster reefs with edge elevations close to mean sea level can reduce wave energy reaching marsh shorelines (Wiberg et al., 2019[27]). The addition of oysters to shoreline protection measures could increase wave mitigation properties (Coen et al., 2007[28]). This keystone species provides habitat enhancement and refugia for many other marine species. The constant filtration activity of subtidal oysters also contributes to water quality improvements through potential reduction of turbidity (Bertness 1999[29]).

CASE STUDIES

To ensure the long term sustainability of an offshore island and to increase resiliency and biodiversity in eastern Bayonne, NJ, four case studies were selected to inform the team about other constructed island projects (Fig. 11). The case studies selected were all island or marsh restoration or creation projects in the United States, built by the U.S Army Corp of Engineers (USACE). Theses case studies, which include Jamaica Bay, NY, Poplar Island, MD, Hamilton Wetlands Complex (CA), San Francisco, CA and Breton Island, LA, show the feasibility and permit-ability of projects incorporating beneficial reuse of dredge material.

For each case study, the pre-restoration site, the restoration process, the cost, and size of each project is included. This information gives valuable insight into the possible construction, permitting, and cost of the Bayonne Urban Coastal Design. The cost of these projects range from $38,000 per acre to over $400,000 per acre.

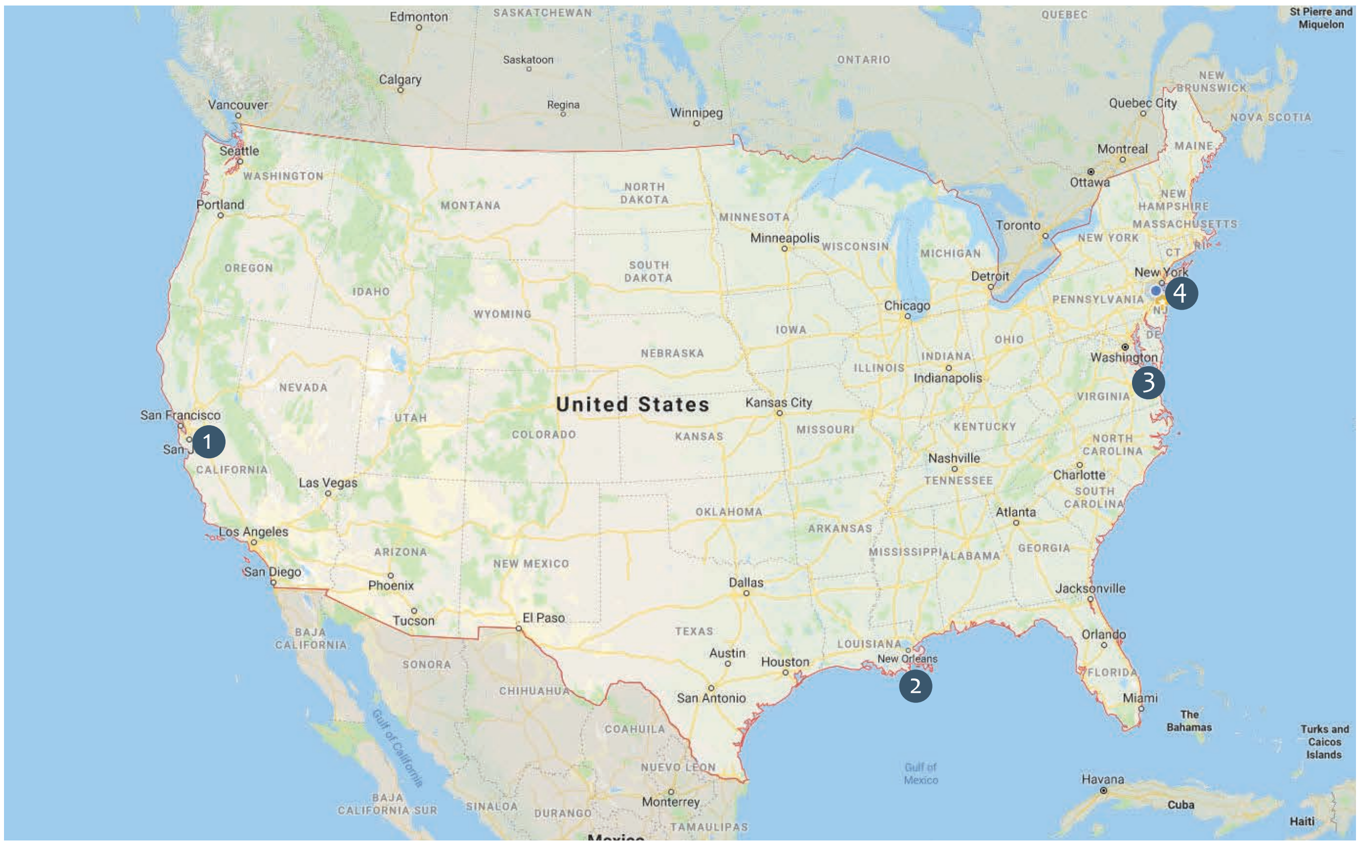

Figure 11. Map of the four case studies locations with select construction statistics. *Courtesy of CUES; aerial courtesy of Google Maps.*

1 Hamilton Wetlands Complex
Marin County, California
648 acres of restored wetlands
6 million cubic yards of dredge material used
Approximate cost: $286 million
$441,000 per acre

2 Breton Island
Plaquemines Parish, Louisiana
29 acres of restored island habitat
1.1 million cubic yards of dredge material used
Approximate cost: $1 million
$38,000 per acre

3 Poplar Island
Chesapeake Bay, Maryland
1,715 acres of restored island habitat
68 million cubic yards of dredge material used
Approximate cost: $667 million
$353,000 per acre

4 Elders Point East
Jamaica Bay, New York City, New York
40 acres of restored marshes
200,000 cubic yards of dredge material used
Approximate cost: $15 million
$375,000 per acre

Case Study 1: Hamilton Wetlands Complex, California

The Hamilton Wetlands Complex (Fig. 12), formerly the Hamilton Airfield, is located in Marin County, CA. This currently ongoing project is a wetland restoration using dredged material. Originally a wetland, this site was diked, drained, and transformed into an Air Base. The goals of the project were to breach the existing Bayfront levee and construct a new one, to restore former wetlands, and to provide lasting flood protection for the surrounding areas. In 2008, 6 million cubic yards of dredged sediment, primarily from the Port of Oakland's Harbor Deepening Project, was placed to create 648-acres of restored wetland. The total cost of the project as of 2019 is $2.86 million dollars, of which 25% is paid for by the State Coastal Conservancy and the remaining is funded by the USACE. The restored island includes intertidal marsh and mudflat, seasonal wetlands, and upland areas. The restoration is continuously monitored as part of an adaptive restoration plan. The wetlands provide habitat for migratory birds, salt marsh harvest mice, and includes a 2.7 mile trail for public access.[30]

Figure 12. Aerial view of the former Hamilton Air Force Base, now part of the Hamilton Wetlands Restoration Project, Novato, Marin County, California (2007). *Courtesy of U.S. Army Corps of Engineers.*

Case Study 2: Breton Island, Louisiana

Breton Island (Fig. 13) is a natural barrier island off the coast of southeastern Louisiana. The island's land mass was reduced from 180-acres to 125-acres after Hurricane George in 1998. The USACE placed 1.1 million cubic yards of dredged material from the Mississippi-Gulf Outlet to restore 29-acres of the island and 620-acres of shallow intertidal waters. The total project cost approximately 1 million dollars, of which 75% was federally funded and 25% was state funded. The island is now a part of a natural system that protects the coast of Louisiana and provides habitat for migratory birds and water fowl. It has been identified as a potential site for shallow water seagrass beds.[31]

Figure 13. Aerial view of Breton Island, Louisiana, with surrounding booms (2010). *Courtesy of Louisiana Sierra Club.*

Case Study 3: Poplar Island, Chesapeake Bay, Maryland

Poplar Island (Fig. 14), formerly known as the Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island, is located in Chesapeake Bay, Maryland. Poplar Island is a beneficial reuse option for placement of sediment dredged from the Baltimore Harbor, and a restoration project of the original 1,140-acre island. It has been called the "international model for the beneficial use of dredged material".[32] The USACE started the project in 1996 by installing dikes on the island's former boundaries and placing dredged sediment on the dikes. The project was approved for expansion in 2012. The final restoration will use 68 million cubic yards of dredge material to create 1,715-acres of habitat: 735-acres of wetland, 840-acres of upland, and 140-acres of embayment areas. The island provides habitats for over 200 species of bird and is a particularly important habitat for the diamondback terrapin. It is 100% Government funded, 25% from the Maryland Department of Transportation (MDOT) and 75% from the USACE.[33]

Figure 14. Aerial photo of Poplar Island, Chesapeake Bay, Maryland (2019). *Courtesy of Sled14.*

Case Study 4: Elders Point, Jamaica Bay, New York

Elders Point (Fig. 15) was originally a 132-acre wide island in Jamaica Bay, New York City. Due to erosion and loss of marshland the land mass was separated into two islands - Elders Point East and West, which are subtidally connected by a mudflat.[34] The USACE aimed to expand these islands through creation of salt marsh built on dredged sediment. The USACE used 200,000 cubic yards of dredged sediments from the NY-NJ Ambrose Channel to restore 40-acres of marshland and to replant *Spartina alterniflora*. The project cost is approximately 15 million dollars, with 65% of the cost paid by the federal government and 35% of the cost split between the State and City of New York.[35]

Figure 15. Marshes in Jamaica Bay, New York City, New York (2012). *Courtesy of Bjoertvedt.*

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Figure 9. Courtesy of CUES; data courtesy of ESRI.
Figure 11. Courtesy of CUES; data courtesy of Google Maps.
Figure 12. Aerial view of the former Hamilton Air Force Base, now part of the Hamilton Wetlands Restoration Project, Novato, Marin County, California (2007). Source: U.S. Army Corps of Engineers, photographer not specified or unknown [Public domain]
Figure 13. Aerial view of Breton Island, Louisiana, with surrounding booms (2010). Source: Louisiana Sierra Club [CC BY-ND 2.0 (https://creativecommons.org/licenses/by-nd/2.0/]
Figure 14. Aerial photo of Poplar Island, Chesapeake Bay, Maryland (2019). Source: Sled14 [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)]
Figure 15. Marshes in Jamaica Bay, New York City, New York (2012). Source: Bjoertvedt [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)]

III. ANALYSIS

Before designing an island in the riparian zone adjacent to the shoreline of the Bayonne Golf Club, understanding the existing conditions of the site was crucial to inform design decisions and to ensure the long term viability of proposed designs. The project site resides in a location susceptible to environmental factors driven by rising sea levels, and so it is critical to understand what the factors affecting an island placed in this location are. The BUCD team studied an array of scientific parameters to gain an understanding of the state of current coastal resiliency research and the specific site conditions in order to design within these parameters (Fig. 1).

The purpose of the analysis was to understand both the urban and the ecological context of the site. Land use and cover, impervious surface, and transit maps all provided an understanding of the urbanization of Bayonne. The flood, storm surge, fetch, sea-level rise, and sedimentation maps informed an analysis of the existing hydrological conditions at the site. These analyses were essential because they provided context, allowed for informed design decision-making, and provided data necessary to project potential future area needs.

The BUCD's analyses included collection of a series of data using a mix of desktop research, GIS-based mapping, and field data collection on site. To understand the project context within an expanded spatial scale, GIS-based desktop analysis included land use and land cover, transit, CSO locations, impervious surface, flood and storm surge data, and sea-level rise for the City of Bayonne. This data collection/analysis allowed the BUCD team to evaluate potential benefits for the city after installation of an island adjacent to the Bayonne Golf Course.

The base map used was the NJ DEP 2012 generalized land cover map. The BUCD team added the contract limit line to the base map and then using ArcMap combined various data with the base map. The data for land use and land cover, impervious surface, and transit was also from NJ DEP. Data related to potential flooding, storm surge, and sea-level rise was provided by NOAA. Fetch data was provided by Stevens Institute of Technology based on data collection at their Robins Reef monitoring site. Sedimentation data is from Coch's *Sediment Dynamics in the Upper and Lower Bays of New York Harbor* (2016).[1] Analysis of the data collected was a collaborative effort between Rutgers University and Stevens Institute of Technology.

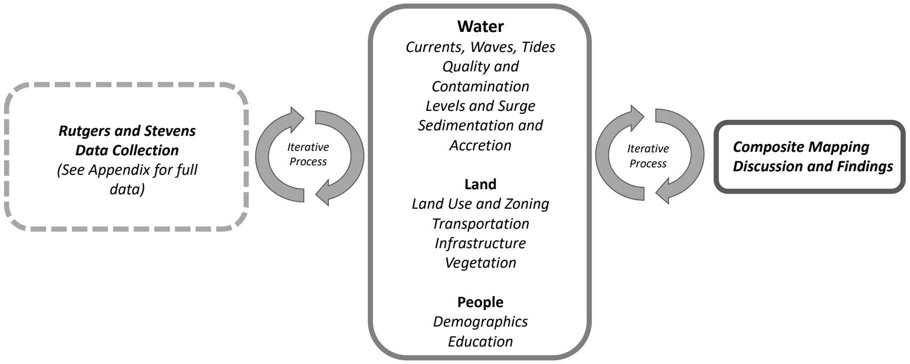


Figure 1. Diagram of the project's integrated design approach with data collection and analysis at its foundation. *Courtesy of CUES.*

LAND USE

Description:

Figure 4 shows the Land Use and Land Cover of the City of Bayonne, based on 2012 GIS data collected by NJ Department of Environmental Protection. During a site visit in June 2019, the team observed new residential construction located on the north side of the MOTBY Channel (Fig. 2), currently categorized as “transportation, commercial, utilities” (shaded grey).

Discussion:

The project site is located in a highly-mixed urban land use area, including residential, commercial, industrial, recreational, and other urban build-up.

Findings:

- There is highly-mixed urban context around the project site.
- There is recreational land use only within the Contract Limit Line (Fig. 3)
- The design needs to enhance and compliment the surrounding land use.
- The development of a natural preserve on the project site adds desperately needed open space within an intensely developed urban land, offseting some of the negative environmental impacts of an active mixed use area.
- The mixed urban land use provides sources for design context, allowing for a variety of formal expressions from grids to more natural landforms.

Figure 2. Abandoned building on MOTBY channel. *Courtesy of CUES.*

Figure 3. Bayonne Golf Club. *Courtesy of CUES.*

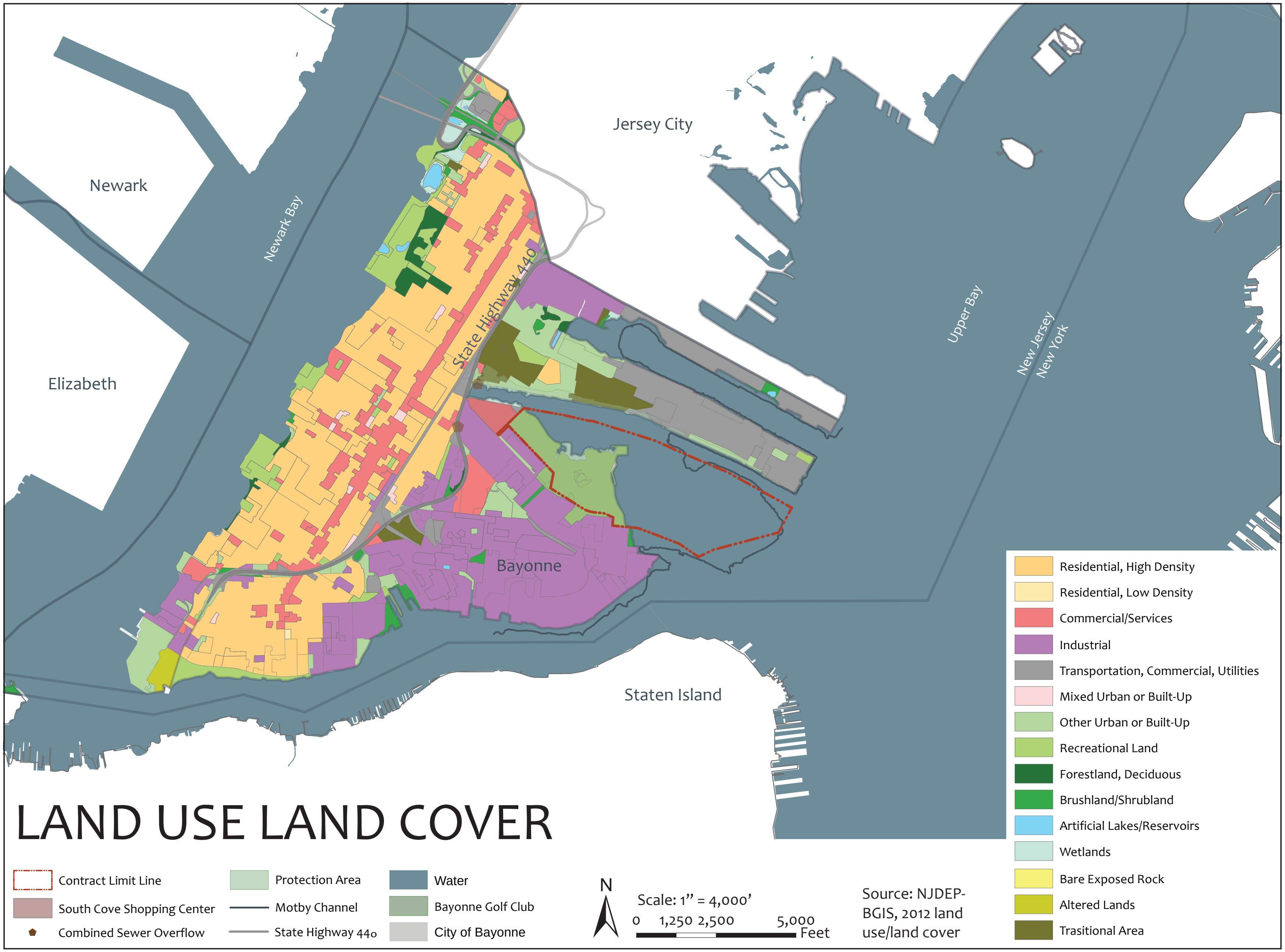


Figure 4. Land Use Land Cover map of the City of Bayonne. *Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NJDEP.*

TRANSIT

Description:

Figure 7 shows the current transportation system in Bayonne, part of Jersey City, Newark, and Elizabeth, including highways, local roads, ferry route, train railroads, and train stations. State Highway 440 is a major highway bisecting the City of Bayonne. There are 4 train stations in Bayonne as part of the Hudson-Bergen Light Rail system (Fig. 5).

A permit is pending at NJ DEP that if approved would allow construction of a marina and helipad landing site on the Bayonne Golf Course property adjacent to the proposed island. These facilities would be an amenity for golf course members. Should this installation be approved, the helipad would also be a component of emergency evacuation planning for the City of Bayonne and the NY-NJ Port Authority.

Discussion:

Most local roads are located west of State Highway 440 (Fig. 6), which corresponds to the location of residential land. A proposed NY-NJ Port Authority ferry route will pick-up/drop off on the new residential development side of MOTBY Channel, connecting to Pier A in Lower Manhattan.

Findings:

- Local roads have limited impact on the site.
- Ferry traffic could have a significant erosive impact on the site.
- Water transport along the estuary and channel will influence the type and function of protective structures.
- Transportation routes will be considered in determining areas of protection from floods and surge protection.

Figure 5. Train station and Light Rail in Bayonne. *Courtesy of CUES.*

Figure 6. State Highway 440. *Courtesy of CUES.*

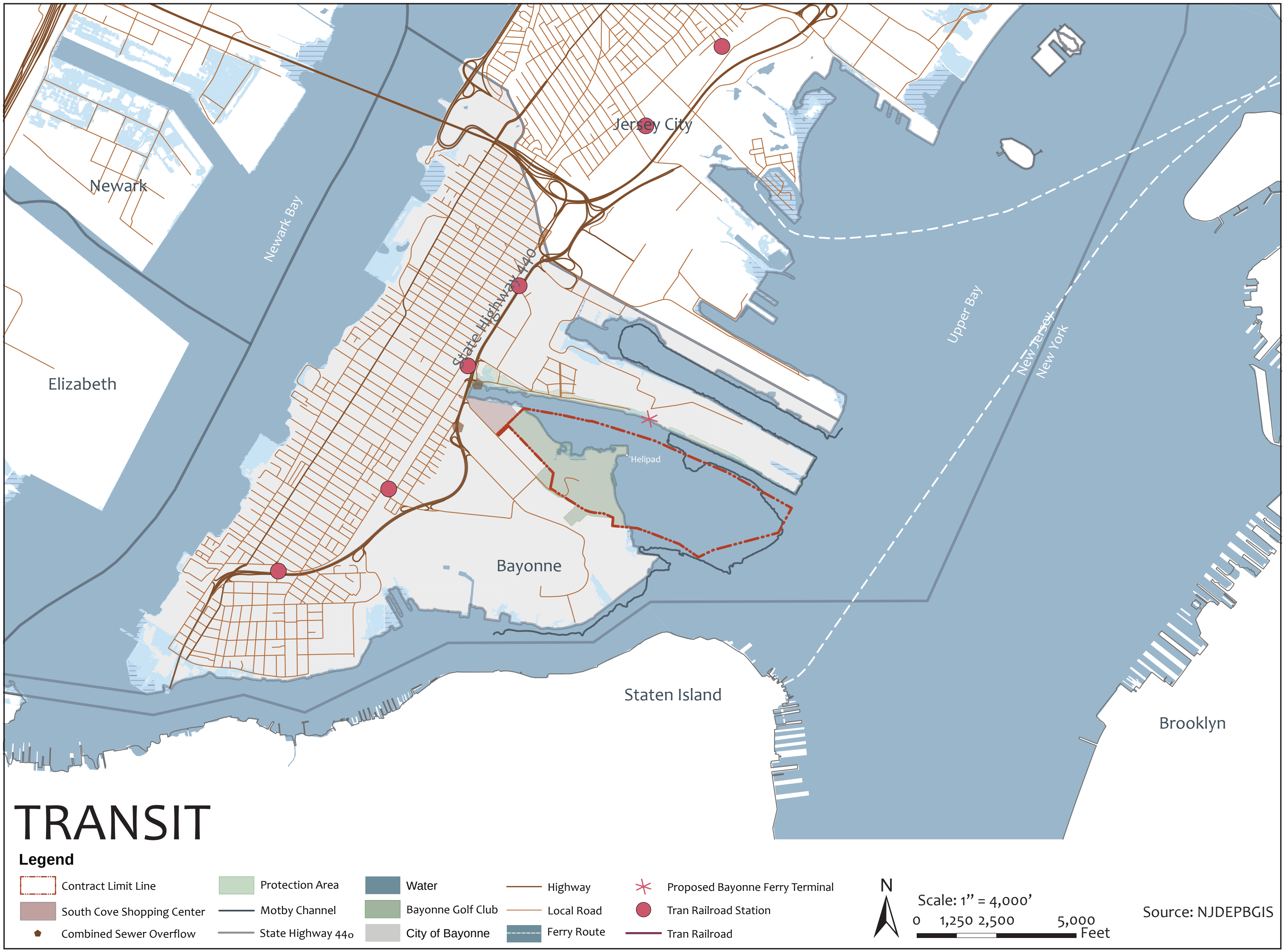


Figure 7. Map showing key terrestrial and maritime transit around the proposed BUCD site. *Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NJDEP.*

IMPERVIOUS SURFACES & COMBINED SEWER OVERFLOWS

Description:

Figure 10 shows the impervious surface and combined sewer overflow discharge points in Bayonne, Jersey City, Newark, and Elizabeth. The impervious surface is shown within a range of 0-100%. Combined Sewer Overflows (CSOs) are sewers that collect stormwater runoff, domestic sewage, and industrial wastewater in the same pipe and discharge into a local water body when volume exceeds capacity. The CSO points on the map indicate where the CSO discharges to a water body.

Discussion:

The map illustrates that the majority of land use around the Contract Limit Line has impervious surfaces, making the area more vulnerable in flooding events. The area and the percentage of the impervious surface will affect the volume of stormwater discharging from the CSOs.

Findings:

- The majority of land use land cover around the site contributes impervious surface (Fig. 8).
- Two CSOs discharge to the MOTBY Channel adjacent to the site (Fig. 9).
- Impervious surfaces and stormwater discharge calculations will be relevant to determine the impact of a 150-250 acre green space in the estuary.
- Increase of greenspace in the estuary will reduce impact of storm events and provide additional land for biodiversity and habitat.

Figure 8. Roadways and development adjacent to the project site. *Courtesy of CUES.*

Figure 9. Combined sewer overflow discharging upstream of the project site. *Courtesy of CUES.*

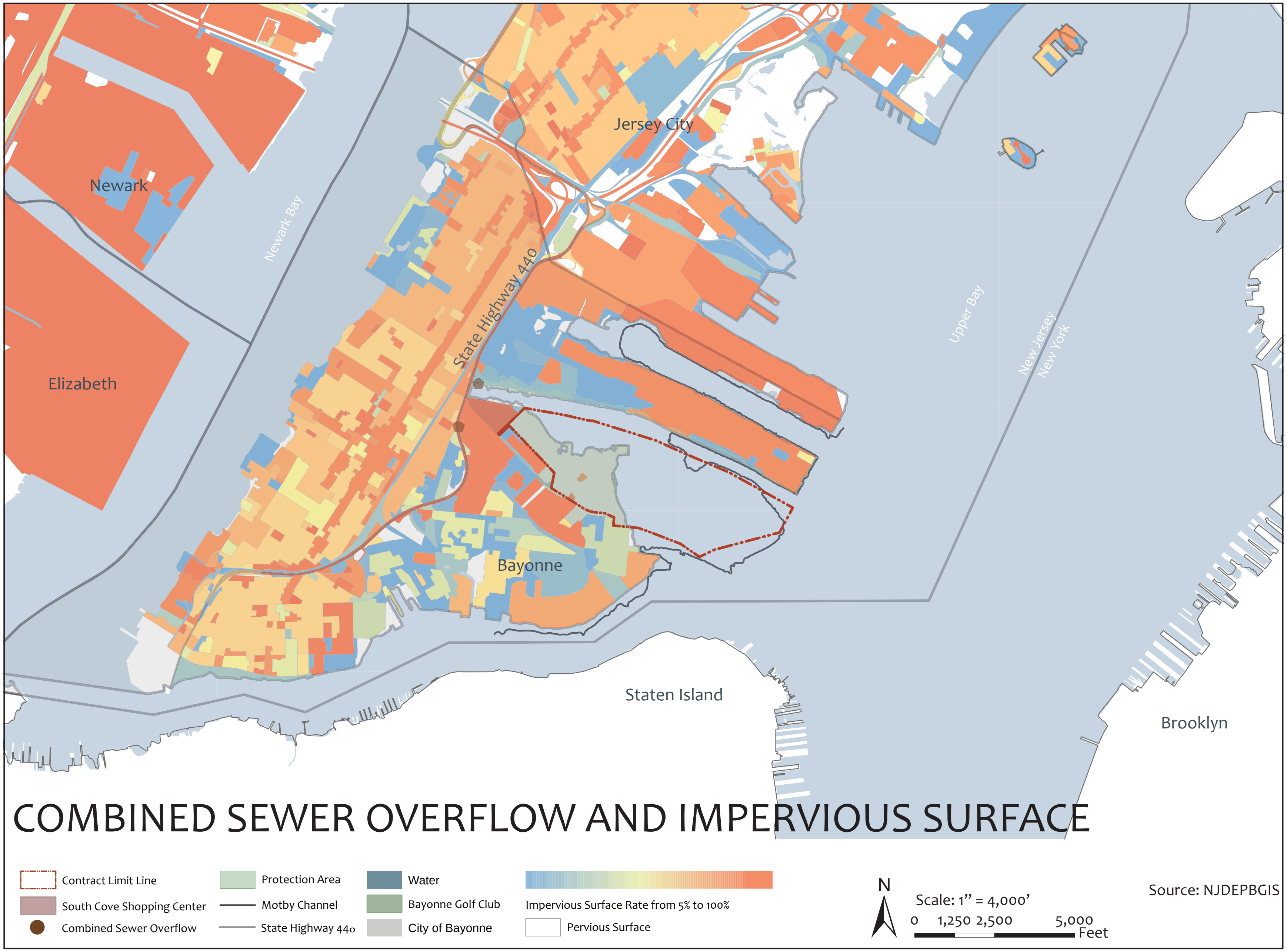


Figure 10. Map of Combined Sewer Overflows and impervious surfaces near the proposed BUCD site. *Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NJDEP.*

FLOODING & STORM SURGE

Description:
NOAA data is used by FEMA to determine the flood risks for various zones during a 100-year storm intensity (1% probability of occurring within a given year). The numbers in Figure 13 indicate the height of the floodwaters during a 100-year storm event. Pink areas are at highest risk of flooding compounded by a tidal storm surge. Blue areas inland are at risk of flooding, but are less affected by a tidal surge. Yellow areas are not at risk during a 100-year storm event, but would be flooded during a 500-year storm event (0.2% probability of occurring within a given year).

Discussion:
Figure 12 illustrates that the coastline of Bayonne is vulnerable to flooding (Figs. 11-12) and surge effects. The residential land to the north of MOTBY Channel, a portion of State Highway 440, and almost 50% of the Bayonne Golf Course is affected by 100-year storm flooding, the South Cove Shopping Mall is affected by 500-year storm flooding, and two CSOs would discharge during both storm events.

Findings:
- The map shows the proposed island would provide additional flood protection to portions of Eastern Bayonne adjacent to MOTBY and portions of Rt. 440.
- Increased protection of commercial zones from flood and storm surges represent a quantifiable economic impact in Bayonne.
- The construction of an island with varied protection structure types provides the opportunity to design and assess protection strategies.

Figure 11. Flooding on streets in Bayonne. *Courtesy of David Pfeffer.*

Figure 12. Flooding at the US Coast Guard Station in Bayonne. *Courtesy of Luke Clayton & U. S. Coast Guard.*

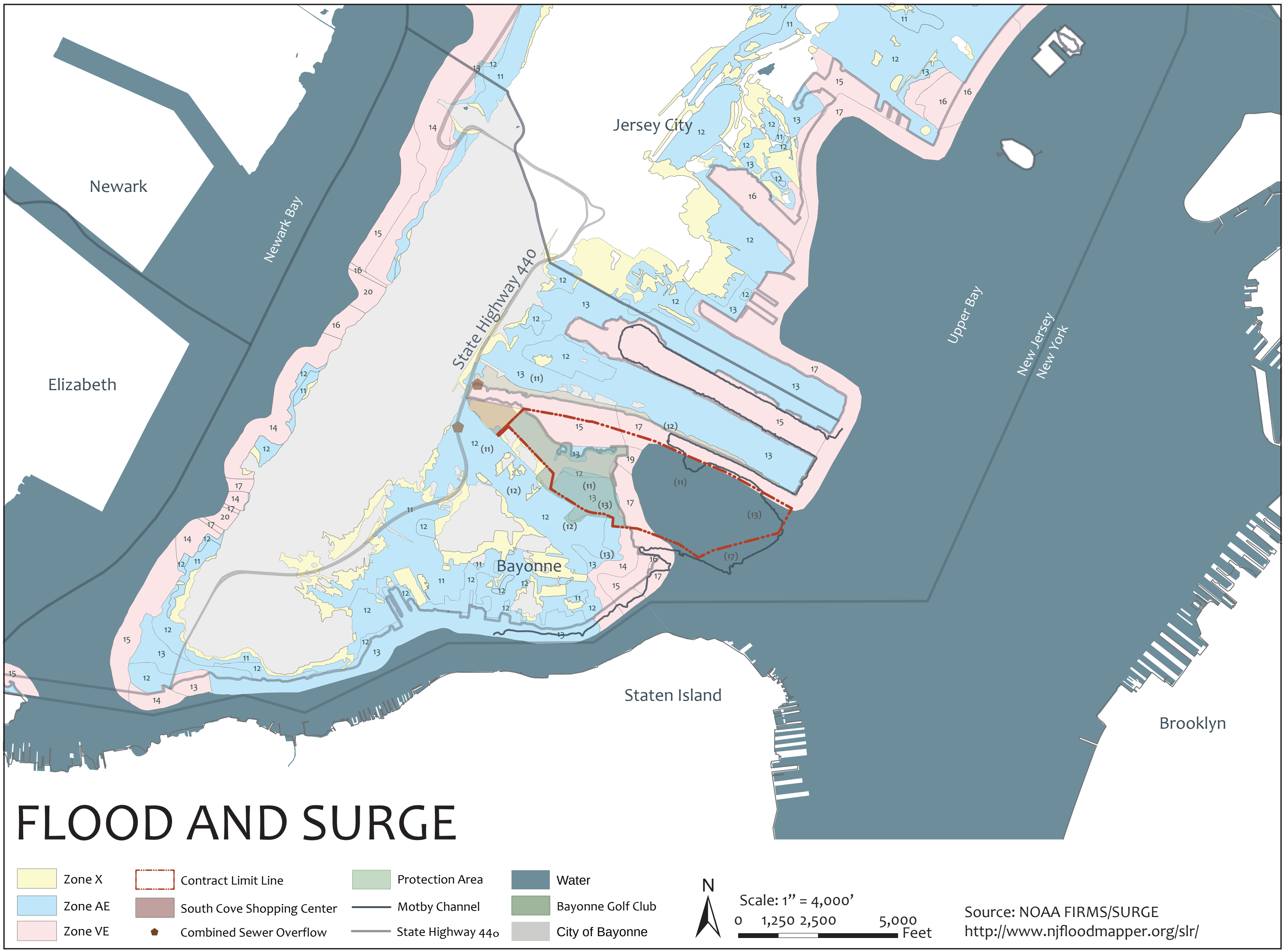


Figure 13. Map of 100-year and 500-year FEMA-designated flood zones in the City of Bayonne. *Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NOAA.*

FETCH

Description:
Fetch is the length of water over which a given wind has blown and is the main factor that creates storm surge, which leads to coastal erosion and flooding. The BUCD team considered wind frequency and speed data collected by the Stevens Institute at Robbins Reef lighthouse, a NOAA maintained monitoring station just outside the contract limit line, (Fig. 14), as well as wave data from passing ships (Fig. 15). This data was used to understand where wind and waves are the strongest and what parts of the proposed island would be most vulnerable to erosive energies.

Discussion:
For the map (Fig. 16), fetch distance from the easternmost point of the island was measured at 30-degree angles. This distance, coupled with wind strength, highlighted portions of the island that would be most susceptible to erosion. Appendix Section II includes data on wind speed and frequency.

Findings:

- The perimeter of the island facing the Hudson River would be most affected by fetch, storm surge, and wave energies.
- Protection is needed along the eastern perimeter to protect the island's substrate from erosion.
- This form of detailed data provides the information needed to devise a more accurate assessment of protection, protection structures, and habitats associated with changes in tidal and intertidal movements.

Figure 14. Stevens Institute collecting data at the proposed BUCD project site. *Courtesy of CUES.*

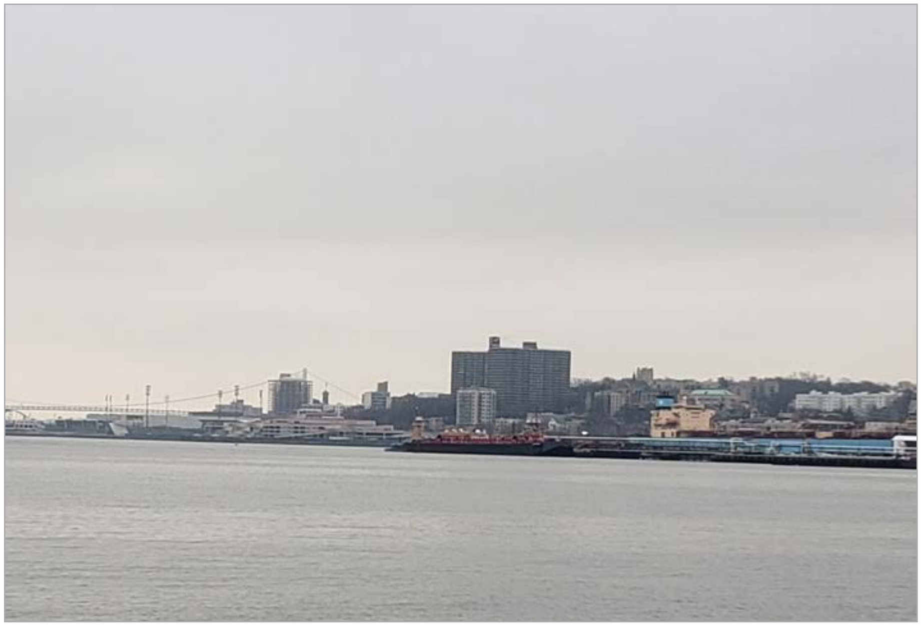


Figure 15. Shipping barge in the upper New York Bay. *Courtesy of Rutgers University praxis studio Spring 2019.*

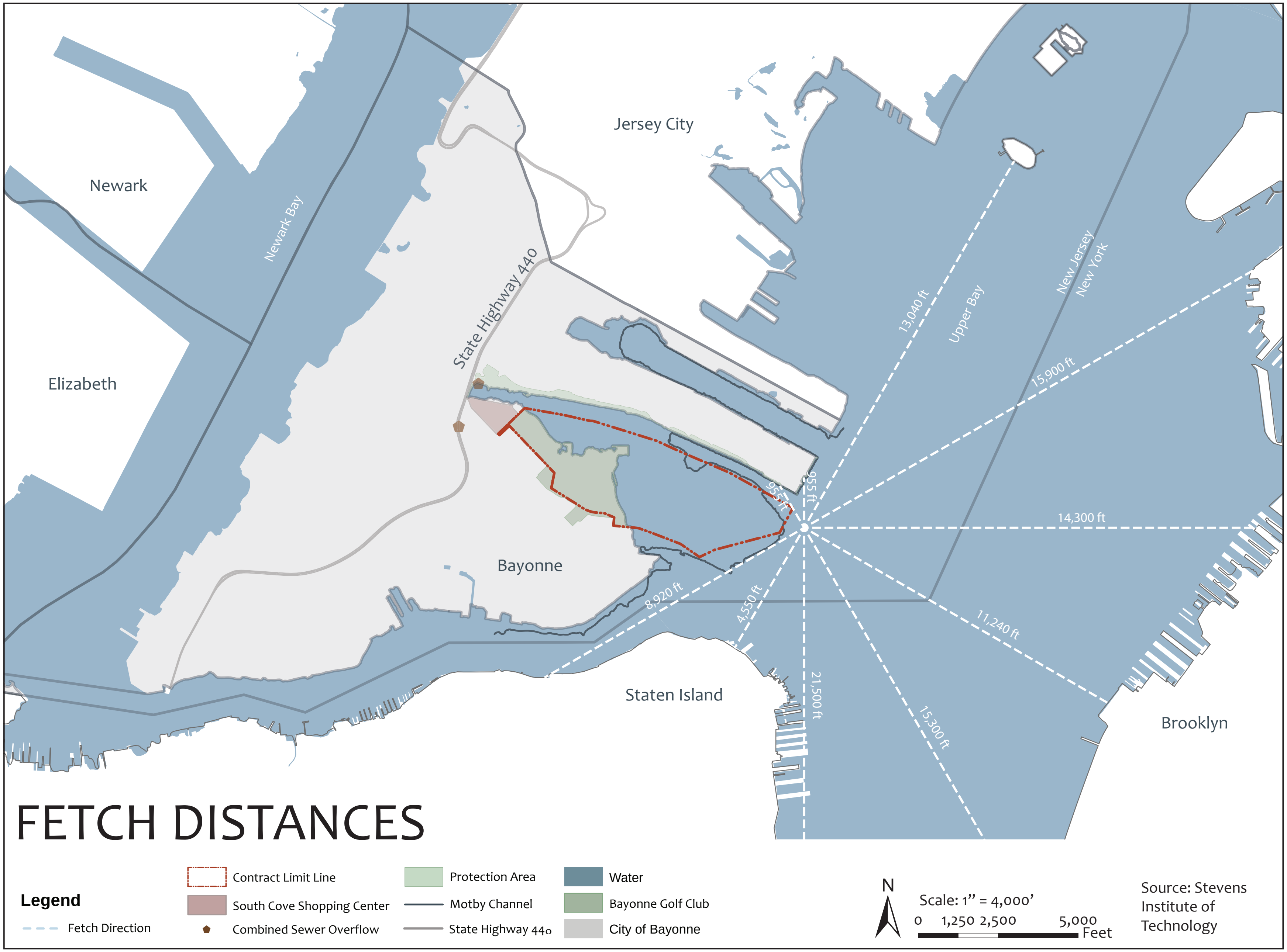


Figure 16. Fetch Distances Map. *Map courtesy of CUES; basemap courtesy of ESRI; fetch data courtesy of the Stevens Institute of Technology.*

SEA LEVEL RISE

Description:
Based on NOAA data, the map in Figure 19 shows the inundation at high tide if sea-level rose 3 feet and 5 feet.

Discussion:
Within the MOTBY area, the front of the South Cove shopping mall, the newly developed residential land, and a small portion of the Bayonne Golf Club will be inundated.

Findings:

- This map shows the vulnerability of eastern Bayonne as sea levels in the region rise.
- Sea level rise data will provide heights to assess amount of protection needed in this area.
- The amount of and extent of protection will be determined based on construction feasibility.

Figure 17. A seal sunbathing on a rock near South Cove Commons. *Courtesy of Rutgers University praxis studio Spring 2019.*

Figure 18. Sea-level rise on NJ coast. *Courtesy of YouTube.*

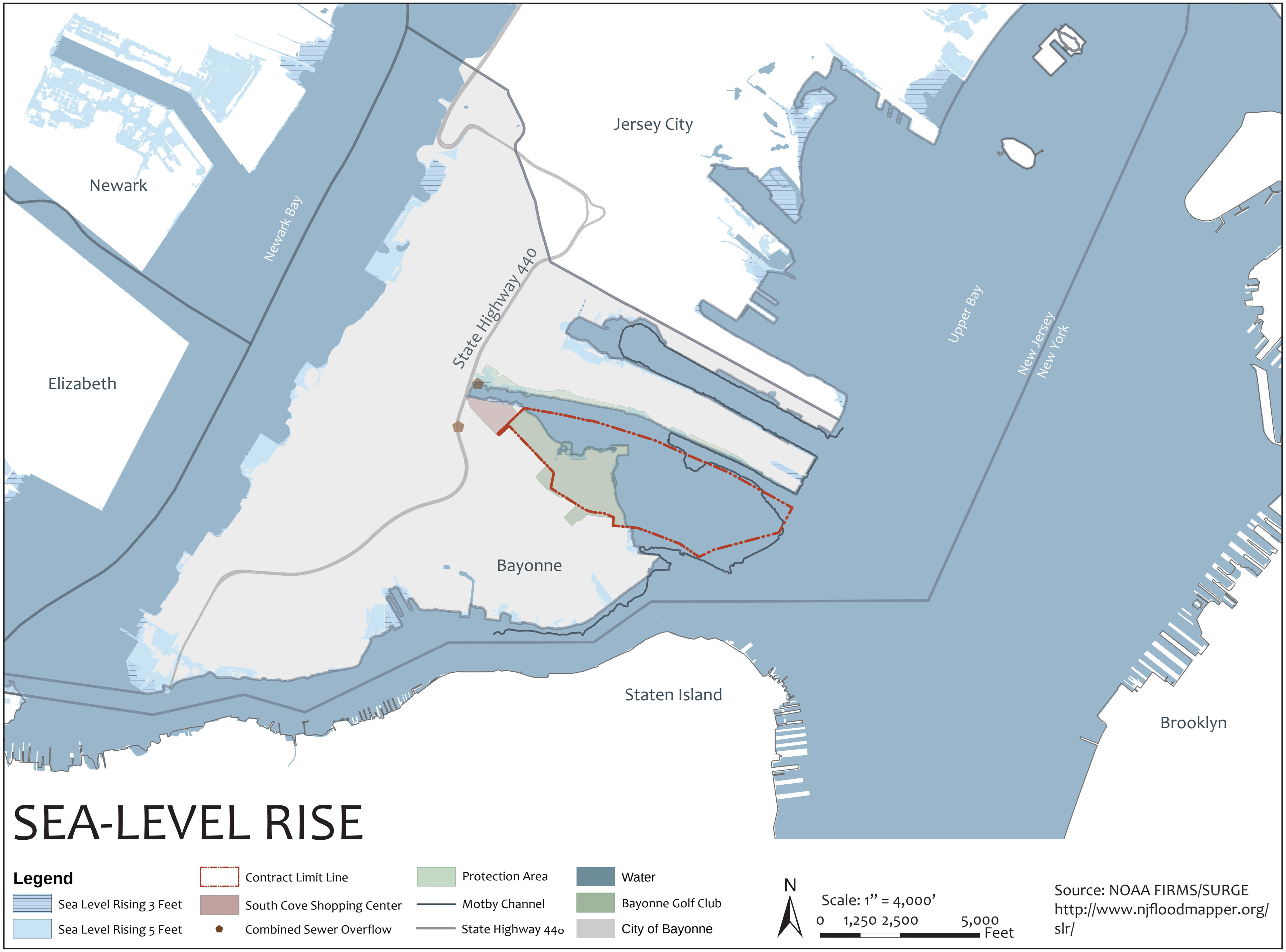


Figure 19. Map of projected sea level rise in Bayonne based on NOAA data. *Map courtesy of CUES; basemap courtesy of ESRI; sea level rise data courtesy of NOAA.*

SEDIMENTATION AND WATER QUALITY

Description:

The map in Figure 22 (adapted from Coch 2016)[2] shows major sediment deposition patterns in the Upper Bay Planning Region: western and northern shoreline (Hudson River dominated), eastern shorelines (ocean and river dominated), southern (ocean dominated). The composition of each sediment type differs. For instance, the western substrate includes sandy clayey silt, silty sand, and clayey silt sand. Sand is derived from ocean water, while silt and clay originate up river. The southern sand is deposited on incoming flood tides, while the silt and clay is deposited on outgoing ebb tides.

Stevens has analyzed sediment samples obtained from the project site, providing a baseline for sediment quality. These samples indicate elevated heavy metal concentrations at the P4-NE location. The proposed island could potentially serve as a cap to stabilize any existing pollution (see Appendix Section II for sediment data).

Water quality was also analyzed from 5 locations (Fig. 21). Several sampling events were performed: during high tide, during low tide, day, night, and after a storm event. Water quality data is presented in Appendix Section II. This study established the baseline water and sediment quality with spatial and temporal variations, which will be used as the reference point during and after the construction of the island.

Discussion:

Modeling of water flows would be required to determine affects the proposed designs would have on future sedimentation patterns.

Findings:

- The sediment in the project contract line appears to be derived from upriver, with silt and clay fractions combining with some sand (Fig. 20).
- Stevens initial analysis suggests that sediment deposition may be limited.
- The construction of the island may affect and impact sedimentation and accretion at a smaller scale, having some impact on tidal and subtidal habitat.
- The silt and clay fractions could potentially be concentrating sediment pollutants.

Figure 20. Sediment within the contract limit line is dominated by upriver silt and clay fractions. *Courtesy of CUES.*

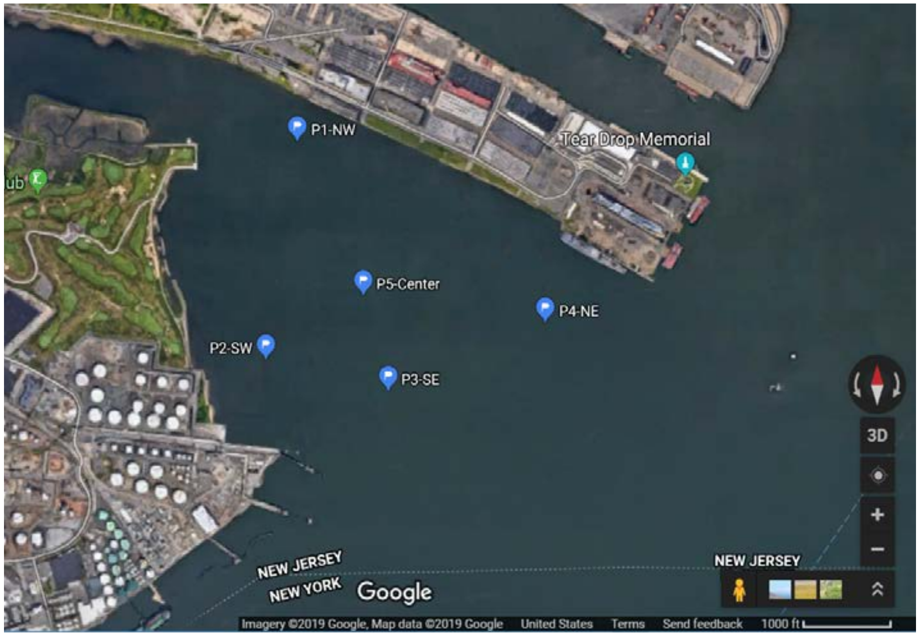


Figure 21. Sediment within the contract limit line is dominated by upriver silt and clay fractions. *Courtesy of the Stevens Institute of Technology, basemap by Google.*

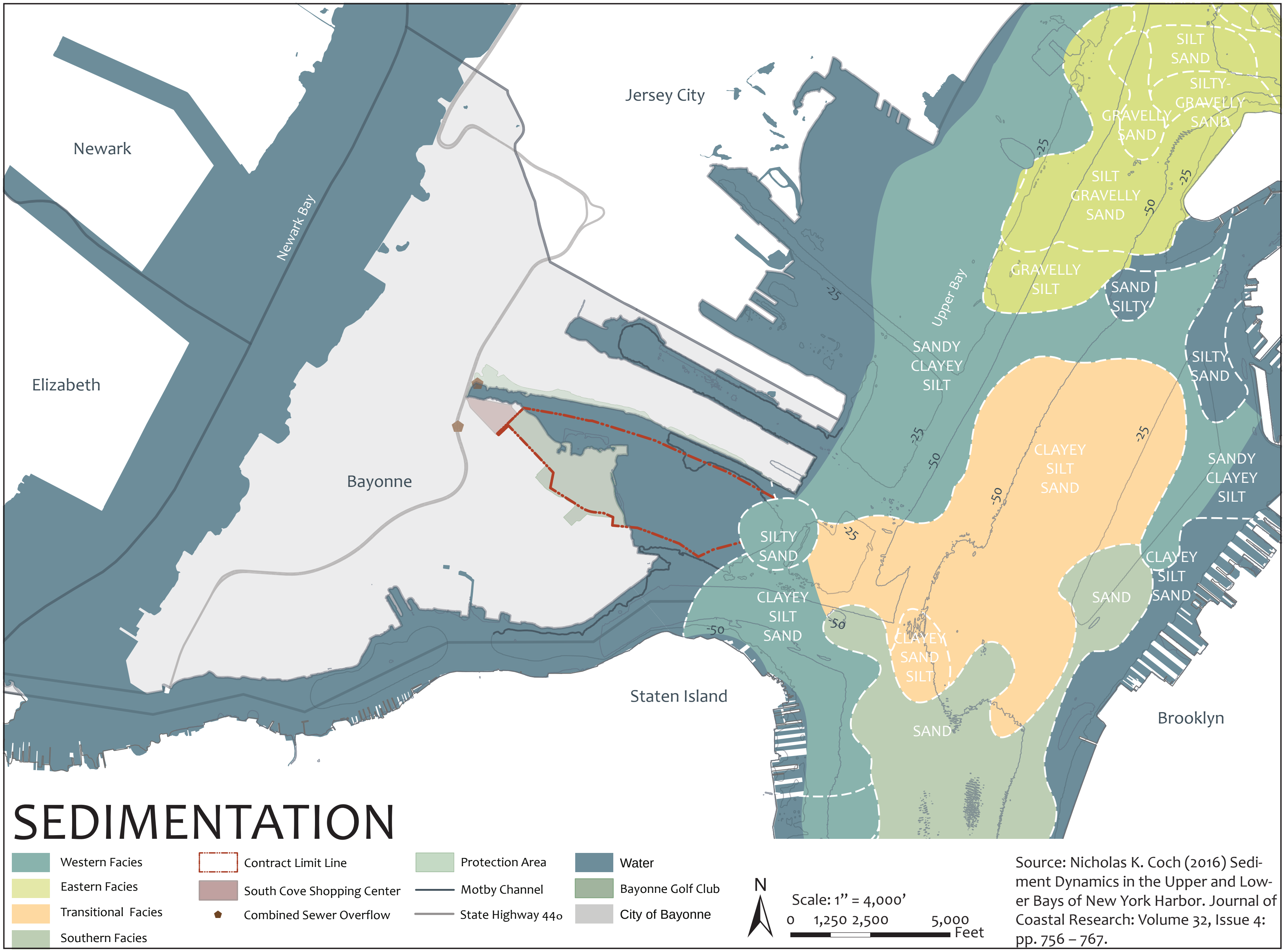


Figure 22. Map of sedimentation near the proposed BUCD site. *Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of Nicholas K. Coch, Sediment Dynamics in the Upper and Lower Bays of New York Harbor (2016).*

VEGETATION

CUES conducted a study of existing vegetation at the Bayonne Golf Course adjacent to the proposed design site in late May and early June 2019. The goal of the study was to document existing plant communities along the Bayonne Golf Club coastline in order to better understand which species might thrive on the proposed island under similar environmental conditions (wind, tidal fluctuations, elevation, etc.) (Fig. 23). An original planting plan for the Bayonne Golf Club perimeter areas was unfortunately not available to determine how much the plant assemblages have changed since the original planting installation.

Methods

Starting at the northwest corner of the Bayonne Golf Club, a sequence of transects was taken running east along the Hudson River Waterfront Walkway (Fig. 25). A transect point was placed every 100 meters along the walkway at the center of the path. At each point, two 10-meter transect lines were measured perpendicular to the path, (one going downhill and one going uphill), creating a 20 meter cross-section. Each plant growing along the transect line was identified and its location in relation to the path noted. To better understand plant exposure and tolerance to saltwater and salt spray, the mean high water mark was identified and its proximity to each downslope transect line was recorded.

This process was repeated along a private service path skirting the eastern boundary of the Bayonne Golf Club, where vegetation is subject to more direct wind exposure from the Upper Bay, yielding a total of 20 transect points.

Findings

Figure 24 is a list of vegetation identified along the transects. Some species were found on multiple transects, while others were only observed in one location. It should be noted that the transect plant list does not represent all species present on the golf course. Plant species that did not fall on a transect were not included and some grasses were not identifiable. Understanding existing plant communities thriving at the Bayonne Golf Club informed vegetation recommendations for the proposed island. See Appendix Section II for more detailed results of the transect study.

Figure 23. Vegetation on the proposed island will be exposed to similar conditions as existing plant communities studied along the Bayonne Golf Club shoreline. *Courtesy of CUES.*

Grasses
- American Beachgrass (*Ammophila breviligulata*)
- Switchgrass (*Panicum virgatum*)
- Common Glasswort (*Salicornia europaea*)
- Smooth Cordgrass (*Spartina alterniflora*)

Herbaceous plants
- White Snakeroot (*Ageratina altissima*)
- Common Milkweed (*Asclepias syriaca*)
- Cleavers (*Galium aparine*)
- Canada Goldenrod (*Solidago canadensis*)

Shrubs and trees
- Serviceberry (*Amelanchier arborea*)
- False Indigo Bush (*Amorpha fruticosa*)
- American Holly (*Ilex opaca*)
- Eastern Red Cedar (*Juniperus virginiana*)
- Northern Bayberry (*Myrica pensylvanica*)
- White Oak (*Quercus alba*)
- Post Oak (*Quercus stellate*)
- Staghorn Sumac (*Rhus typhina*)
- Black Locust (*Robinia pseudoacacia*)
- American Pussy Willow (*Salix discolor*)

Figure 24. Plant list of identified species at the Bayonne Golf Club growing along the transects (2019). *Courtesy of CUES.*

Figure 25. Map of transect point locations along the Hudson River Waterfront Walkway and Bayonne Golf Club service path. Vegetation at points T-13 through T-20 are exposed to more direct winds from the bay than points T-1 through T-12. *Courtesy of CUES; aerial image courtesy of ESRI.*

Figure 26. Collage of plants and plant communities observed during the 2019 existing vegetation study at the Bayonne Golf Club. *Courtesy of CUES.*

SOURCES

1) Nicholas K. Coch. (2016). Sediment Dynamics in the Upper and Lower Bays of New York Harbor. Journal of Coastal Research: Volume 32, Issue 4: pp. 756 – 767.

2) Nicholas K. Coch. (2016). Sediment Dynamics in the Upper and Lower Bays of New York Harbor. Journal of Coastal Research: Volume 32, Issue 4: pp. 756 – 767.

IMAGE SOURCES

Figure 4. Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NJDEP. [online] URL: https://gisdata-njdep.opendata.arcgis.com/datasets/land-use-land-cover-of-new-jersey-2012-download

Figure 7. Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NJDEP.

Figure 10. Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NJDEP. [online] URL: https://gisdata-njdep.opendata.arcgis.com/datasets/combined-sewer-overflow-cso-for-nj URL: https://gisdata-njdep.opendata.arcgis.com/datasets/impervious-surface-of-new-jersey-from-land-use-land-cover-2012-update

Figure 11. *Reference: [https://coastguard.dodlive.mil/2013/01/taking-care-of-our-own/] accessed on 8/1/19. CC BY 2.0*

Figure 12. *Reference: [https://www.flickr.com/photos/bytenik/463187728/] accessed on 8/1/19. Public domain photo*

Figure 13. Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of NOAA. [online] URL:

Figure 14. Courtesy of Stevens Institute of Technology.

Figure 15. Courtesy of Rutegrs University praxis studio Spring 2019.

Figure 16 Map courtesy of CUES; basemap courtesy of ESRI; fetch data courtesy of Stevens Institute of Technology.

Figure 17 Courtesy of Rutegrs University praxis studio Spring 2019.

Figure 18 Courtesy of YouTube. Reference: [https://www.youtube.com/watch?v=VMzsHbaspx8] accessed on 8/29/19.

Figure 19 Map courtesy of CUES; basemap courtesy of ESRI; sea level rise data courtesy of NOAA. [online] URL: https://coast.noaa.gov/slr/#/layer/slr/8/-8248153.641802779/4962289.829422/13/satellite/none/0.8/2050/interHigh/midAccretion

Figure 22 Map courtesy of CUES; basemap courtesy of ESRI; data courtesy of Nicholas K. Coch, Sediment Dynamics in the Upper & Lower Bays of New York Harbor (2016).

Figure 25 Courtesy of CUES; aerial image courtesy of ESRI.

IV. SYNTHESIS

The synthesis combines the analysis phase data to develop a baseline that underpins the proposed island design options (Fig. 1). The synthesis integrates various analysis maps and details critical aspects affecting the proposed island and its context within the Upper New York Bay Planning region. This synthesis provides an overview of environmental factors a landmass would encounter and provides a context for design process decisions.

Fetch and sea level data were combined to evaluate where the island requires the greatest protection from storm surge and erosive wave energies. The data analysis of existing natural vegetation on the shoreline of the Bayonne Golf Course and targeted habitat goals in the Hudson-Raritan Estuary Comprehensive Restoration Plan (CRP) were reviewed to inform design decisions related to potential habitat types. This information was used to determine opportunities for the island to maximize specific Target Ecosystem Characteristics (TECs) included in the CRP.

When embarking on building an offshore island, it is important to quantify the potential benefits from a project such as this one (Figure 2). The BUCD team wanted to understand if the island would meet its goal of protecting eastern Bayonne and what measureable benefits might be. The team estimated that the island would protect 4.75 miles of the Eastern Bayonne coastline. For the island's second goal of ecological diversity, the creation of an island would create 60 acres of maritime forest, the largest forest habitat in Hudson County, providing environmental benefits for wildlife and sequestration of carbon dioxide. Lastly, the island could be used as an educational resource for Bayonne students and local educational institutions.

The site analysis shown in Figure 3 combines many of the analysis maps from the previous chapter to give a diagrammatic understanding of the proposed island spaces. It illustrates the essential viewsheds, such as the ones from the golf course, the channel, the ferry, and the bay. It shows that the island size should be maximized for increased protection of Bayonne and to improve the island's resiliency.

The graphic demonstrates how the proposed island could protect Eastern Bayonne. Lastly, the site analysis map outlines what areas of the island are vulnerable to waves and storm surge energies. This image acts as an initial blueprint for the proposed island design and guides the habitat spaces that occur on the island.

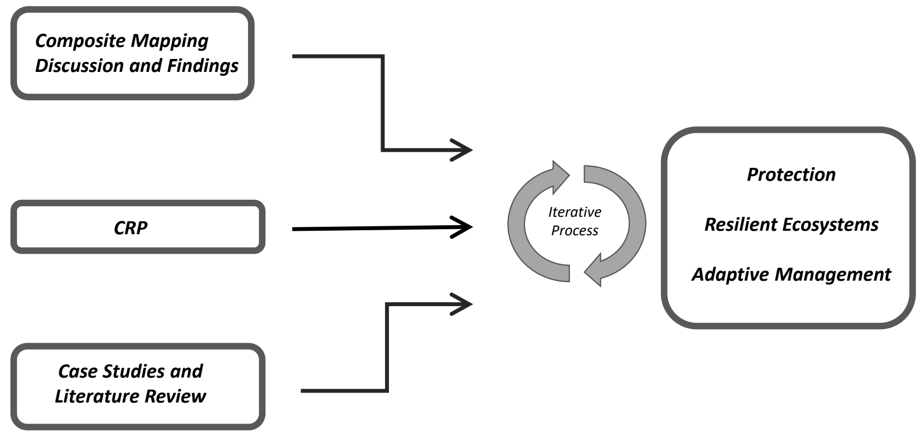


Figure 1. Diagram of the integrated approach to data synthesis that underpins the three conceptual designs presented in Chapter V. *Courtesy of CUES.*

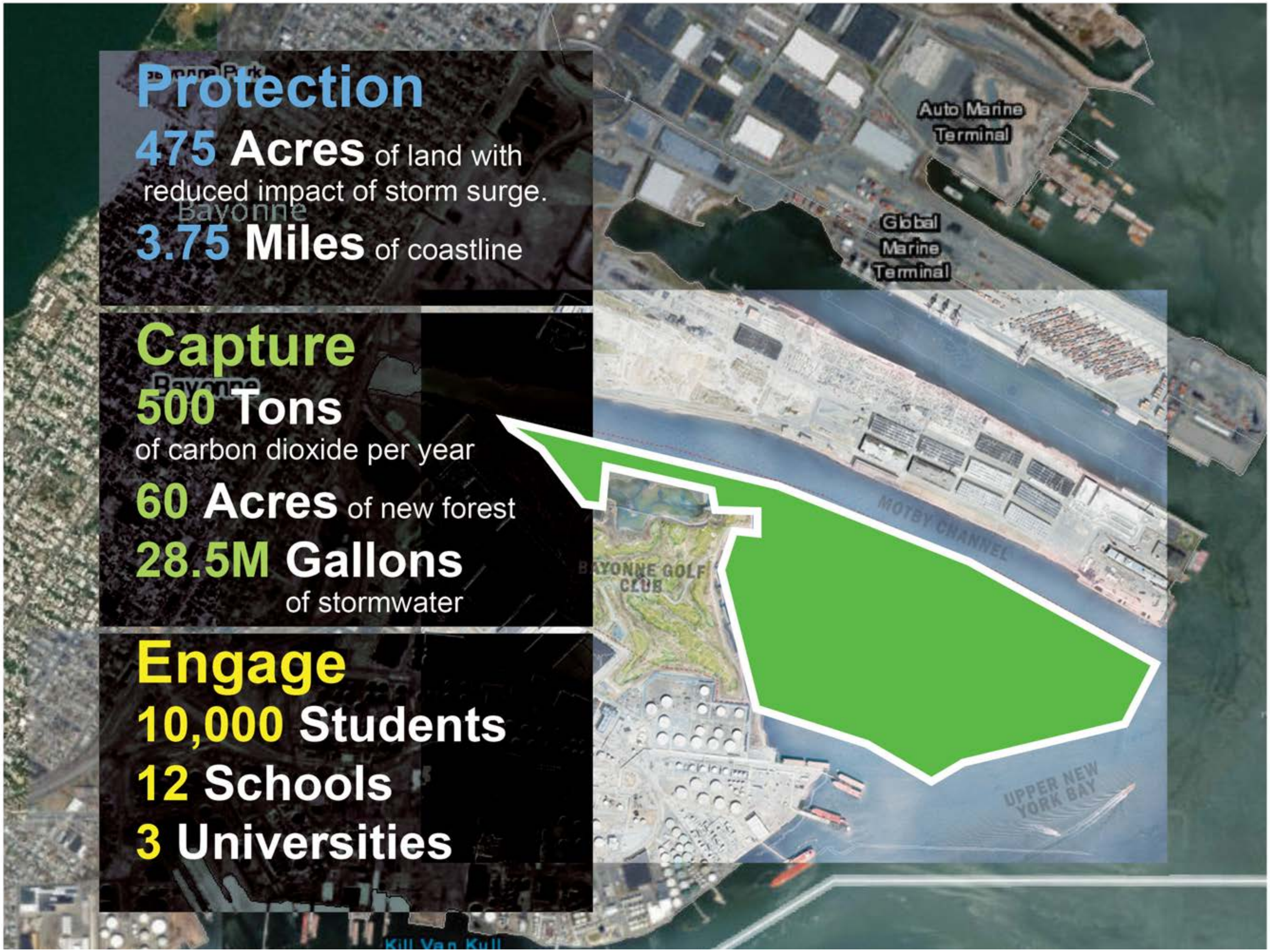


Figure 2. Potential benefits of constructing an island at the BUCD site. *Courtesy of CUES.*

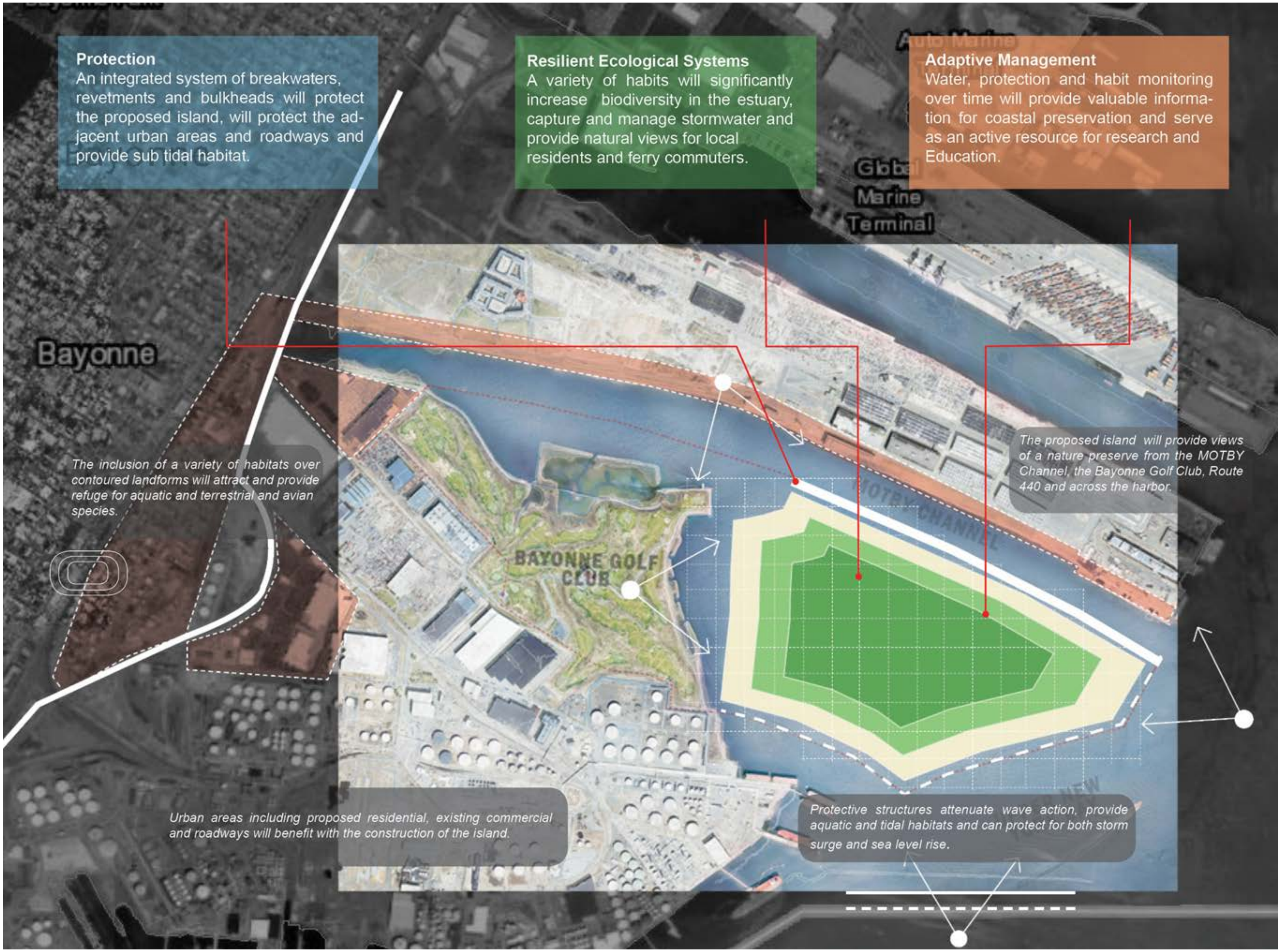


Figure 3. Site analysis diagram indicating: urban areas potentially protected from storm surge by creating an island; eastern areas of the island that will be exposed to most significant fetch and thus will require erosion protection; and key viewsheds from the golf course and new residential development on the opposite side of the channel. *Courtesy of CUES.*

TARGET ECOSYSTEM CHARACTERISTICS (TECs)

The proposed island site, located within the HRE, has a CRP that locates the project within the Upper New York Bay planning region. Due to this site's potential to provide critical ecological resources, the BUCD team examined the CRP to determine how this project could support HRE restoration goals. The CRP identified twelve TECs as achievable goals for restoration activities within the HRE (Table 1). The BUCD team used the TECs to guide the design process that will create habitats for target species.

The proposed island will support seven of the twelve TECs identified in the CRP (Fig. 4). The subtidal zone of the island creates shorelines and shallows that provide habitat for fish, crab, and lobster. The subtidal zone also includes living breakwaters that will create habitat for oysters. The island shoreline includes wetlands that create much-needed habitat for waterbirds and improve water quality. The upland portion of the island consists of coastal and maritime forests, an ecosystem that is severely lacking and under threat in the HRE.

Table 1. Description of the twelve approved Target Ecosystem Characteristics (TECs) in the Hudson-Raritan Estuary Comprehensive Restoration Plan (CRP). *Courtesy of USACE, The Waters We Share (2016) adapted by CUES.*

TEC	Target Statement
Wetlands	Create and restore coastal and freshwater wetlands, at a rate exceeding the annual loss or degredation, to produce a net gain in acreage.
Habitat for Waterbirds	Restore and protect roosting, nesting, and foraging habitat (i.e., inland trees, wetlands, shallow shorelines) for long-legged wading birds.
Coastal and Maritime Forests	Create a linkage of forests accessible to avian migrants and dependent plant communities.
Oyster Reefs	Establish sustainable oyster reefs at several locations.
Eelgrass Beds	Establish eelgrass beds at several location in the HRE study area.
Shorelines and Shallows	Create or restore shoreline and shallow sites with a vegetated riparian zone, an inter-tidal zone with a stable slope, and illuminated shallow water.
Habitat for Fish, Crab, and Lobsters	Create funtionally related habitats in each of the eight regions of the HRE.
Tributary Connections	Reconnect and restore freshwater streams to the estuary to provide a range of quality habitats to aquatic organisms.
Enclosed and Confined Waters	Improve or maintain water quality in all enclosed waterways and tidal creeks within the estuary to match or surpass the quality of their receiving waters.
Sediment Contamination	Isolate or remove one or more sediment zone(s) that is contaminated until such time as all HRE sediments are considered uncontaminated based on related water quality standards, related fishing / shellfishing bans or fish consumption advisories, and any newly-promulgated sediment quality standards, criteria or protocols.
Public Access	Improve direct access to the water and create linkages to other recreational areas, as well as provide increased opportunities for fishing, boating, swimming, hiking, education, or passive recreation.
Acquisition	Protect ecologically valuable coastal lands throughout the HRE from future development through land acquisition.

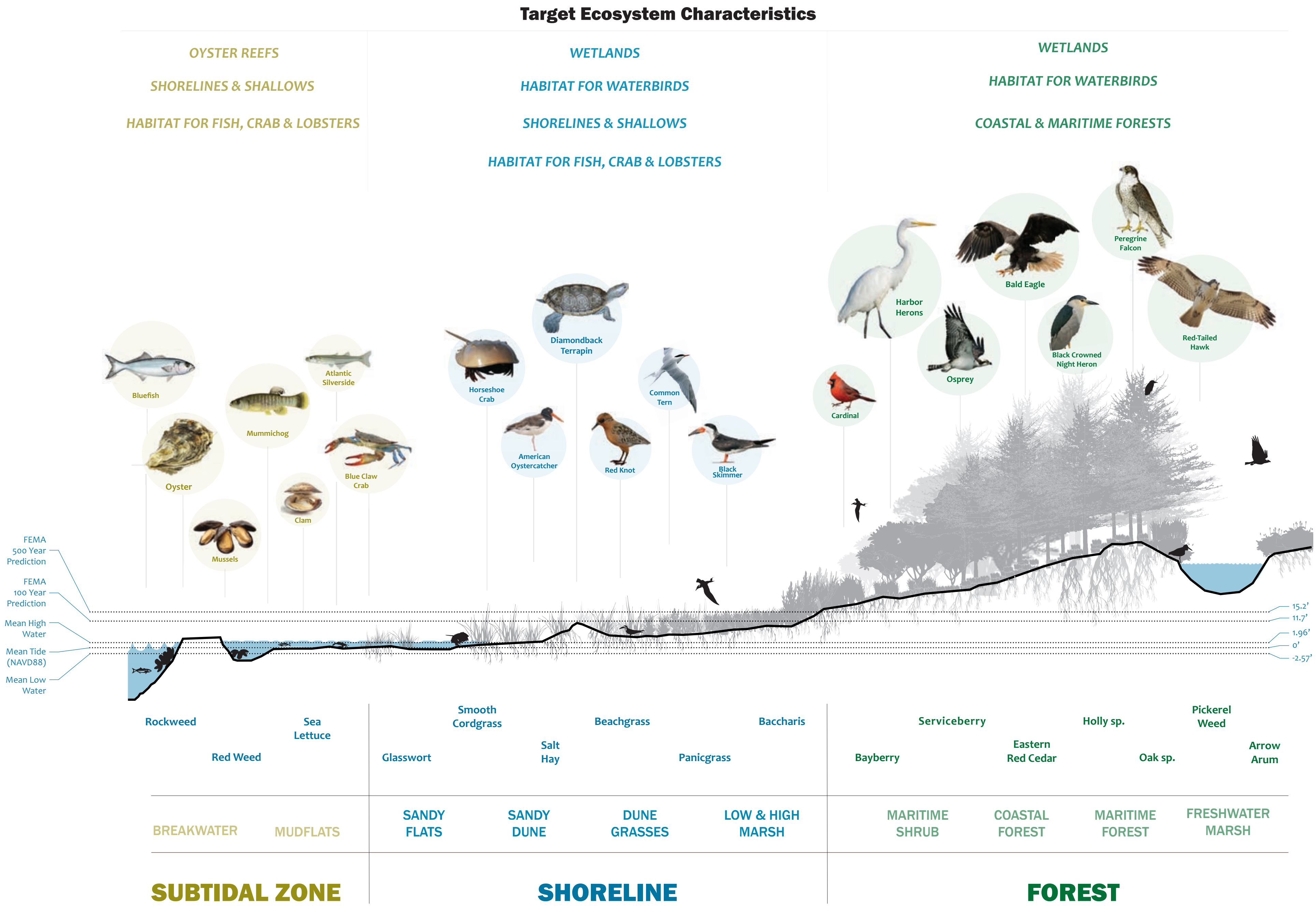


Figure 4. Diagram of seven of the twelve TECs from the approved 2016 Hudson-Raritan Estuary CRP that the three island design options support. Habitat types are shown in relation to tidal fluctuations and estimated flood heights, as well as to species of particular interest that could utilize the habitat for foraging or nesting. *Courtesy of CUES.*

Figure 5. Data collection will play a key role in an Adaptive Management approach to address sustainability issues of the proposed island. *Courtesy of CUES.*

FUTURE SITE MANAGEMENT

A Monitoring and Maintenance Plan (MMP) is included as a regulatory permitting condition. However, because green infrastructure resiliency applications in urban estuaries are relatively new, it is important to consider what data is needed to ensure long term sustainability of a restoration project. Therefore, we recommend the creation and use of an Adaptive Management Plan (AMP). This management approach is based on the understanding that ecosystems are complex dynamic resources that evolve unpredictably over time. Adaptive management is an iterative process requiring data collection followed by management actions taken in response to the actual data (Fig. 5).

Monitoring is required to evaluate the effects of erosive forces on the island and to determine the need for adaptive management interventions. A generalized monitoring plan can be adjusted to coordinate with educational research efforts. This monitoring should focus primarily on three main protective components:

1. Stability of the shoreline and elevation of the transitional area from intertidal beach to high marsh

2. Stability of designed wave attenuation structures

3. Performance of the installed wave attenuation structures

Should future design of the island incorporate items such as oyster castles, growth, subsidence, sedimentation, or degradation of these and other protective structures would also require annual monitoring. Data collected during these monitoring activities would provide valuable information for continuous evaluation of the health of the island.

A BACI (Before-After Control-Impact) Design should be employed to document and evaluate changes to the island boundaries over time. Monitoring of site conditions could include data collected using drone technology and/or traditional site survey techniques. This data will help managers and researchers better understand and respond to impacts from storm and surge events as well as sea level rise. Overall performance and stability of the shoreline wave attenuation structures (i.e. living breakwaters, revetments, etc.), sandy shores, mudflat areas, and marsh zones should be measured and analyzed to determine the most effective responses to changing conditions. Monitoring of flora and fauna present on and around the island should also be conducted to better understand habitat succession and wildlife habitat usage over time (Fig. 6-7).

Monitoring and adaptive managment provide opportunities for local outreach and education. The Hudson River National Estuarine Research Reserve, in collaboration with Stevens, developed a low-cost rapid protocol for monitoring the ecological and structural health of living shorelines that is particularly relevant for education. This protocol is available at: https://www.hrnerr.org/hudson-river-sustainable-shorelines/assessing-ecological-physical-performance. See Appendix Section III for more in-depth monitoring methods, timing recommendations and educational opportunities.

Figure 6. Ribbed mussels growing within the *Spartina alterniflora* root zone. Monitoring of site conditions will provide valuable information about the health and succession of floral and faunal communities on and around the island over time. *Courtesy of CUES.*

Figure 7. Monitoring of site conditions will provide important data about habitat use over time by wildlife, such as harbor herons. *Courtesy of CUES.*

V. DESIGN OPTIONS

Activities associated with industrialization have led to the alteration and contamination of many urban landscapes throughout the world, especially those within economically important harbor areas. For years these landscapes have been labelled biologically desolate, and devoid of any ecological value. Where a direct threat to human health was demonstrated, mitigation of the contaminated lands has normally been a priority. However, the question of appropriate adaptive land use after mitigation is often controversial.

Currently, innovative mitigation strategies and the reintroduction of legacy ecological systems have become plausible, driven by the need to increase coastal resiliency and reduce vulnerability in light of a changing climate. In fact, the NY-NJ Harbor Estuary Program, which includes the states of New York and New Jersey, has approved a Comprehensive Restoration Plan that calls for such efforts. The BUCD project represents such an opportunity.

The vision of the BUCD is to reclaim historic maritime habitats lost during the harbor's industrial development, while at the same time mitigating the impacts of documented rising sea levels within the estuary associated with climate change.

Planning Process

It is often helpful to illustrate actions that would fulfill project objectives in the form of various alternative designs. This produces a broad range of concepts for consideration and provides a context in which the ideas can be considered and evaluated. Three design alternatives described in the following pages were derived from objectives established at the onset of the project. We believe they have an internal consistency and logic. However, they should not be viewed as individual discrete proposals, but rather options from which a final plan evolves.

All of the alternatives present several methods for the dissipation of storm surge energy. In addition, since all three alternatives seek to establish maritime habitats, they include some similar ecological elements. However, each design has a specific focus, prioritizing different Target Ecosystem Characteristic (TEC) habitat types and species. The three alternatives include: The Links, Bird Island, and Estuary Terminal Island.

Figure 1. Image of the Bayonne Golf Club with the Military Ocean Terminal at Bayonne (MOTBY) in the distance. *Courtesy of Rutgers University praxis studio Spring 2019.*

DESIGN OPTION A: THE LINKS ISLAND

The Links Island design proposal (Fig. 2) aims to connect ("link") the island to the golf course through form and topography. This design includes both high and low saltmarsh systems in an attempt to recreate some of the dominate wetland systems that once existed throughout the harbor. As the topography moves upland the island is dominated by maritime and coastal forest. In addition, the change in topography creates a freshwater collection area unique to this design (Fig. 3). Stormwater capture capacity calculations are detailed in Appendix Section IV. Storm surge and erosion protection is provided by a combination of breakwaters and a bulkhead.

Figure 2. Plan view of the proposed Links Island. *Courtesy of CUES; basemap courtesy of ESRI.*

Figure 3. View of an ecologically vibrant freshwater collection area on the proposed Links Island. *Courtesy of CUES.*

DESIGN OPTION B: BIRD ISLAND

The Bird Island design (Fig. 4) was conceived with the intent of increasing habitat and biodiversity for as many species as possible. Similar to the Links Island design, there are marshes providing habitat for harbor herons and other wading birds. The Bird Island design also has sandy dune areas for species such as piping plovers, terns, skimmers, and horseshoe crabs. The upland areas contain maritime and coastal forests. This design includes the existing mudflats as additional areas for bird and foraging crabs. There is engineered protection from storm surge and wave erosion in the form of a revetment and breakwaters (Fig. 5).

Figure 4. Plan view of the proposed Bird Island. *Courtesy of CUES; basemap courtesy of ESRI.*

Figure 5. A revetment protects the northern edge of the the proposed Bird Island along the MOTBY channel. The island provides a rich visual amenity for pedestrians along the proposed MOTBY public walkway. *Courtesy of CUES.*

DESIGN OPTION C: ESTUARY TERMINAL ISLAND

The Estuary Terminal Island design approach (Fig. 6) is inspired by the historic Military Ocean Terminal Base and its current transition to a mixed use development. This design also integrates island form with protection of the mainland. This protection includes both a bulkhead and breakwaters, as well as a marsh area with a barrier dune. The island creates the succession from low marsh to high marsh to maritime and coastal forests using terraced steps (Fig. 7). In addition, this design incudes the potential for including alternative energy options (see Appendix Section IV), so the design addresses not only impacts of climate change, but also could contribute to generating green energy.

Figure 6. Plan view of the proposed Estuary Terminal Island. *Courtesy of CUES; basemap courtesy of ESRI.*

Figure 7. View of the proposed Estuary Terminal Island from the driving range at the Bayonne Golf Club. The island's terraced topography provides a diversity of habitats from barrier dune and low marsh to maritime and coastal forests. *Courtesy of CUES.*

DESIGN OPTION A: LINKS ISLAND SECTION CUT

DESIGN OPTION B: BIRD ISLAND SECTION CUT

DESIGN OPTION C: ESTUARY TERMINAL ISLAND SECTION CUT

Figure 8. Section cuts of the three design options showing the progression between each habitat to the breakwaters. Each section is approximately 1175’ long. *Courtesy of CUES.*

DESIGN OPTION A: LINKS ISLAND SECTION DETAIL

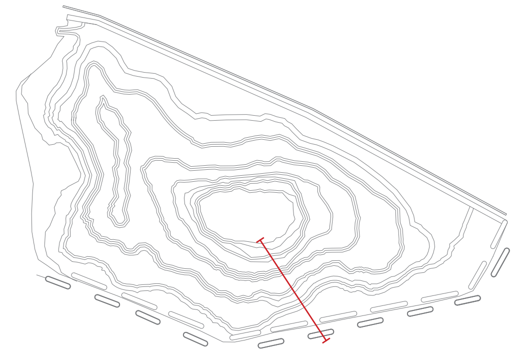
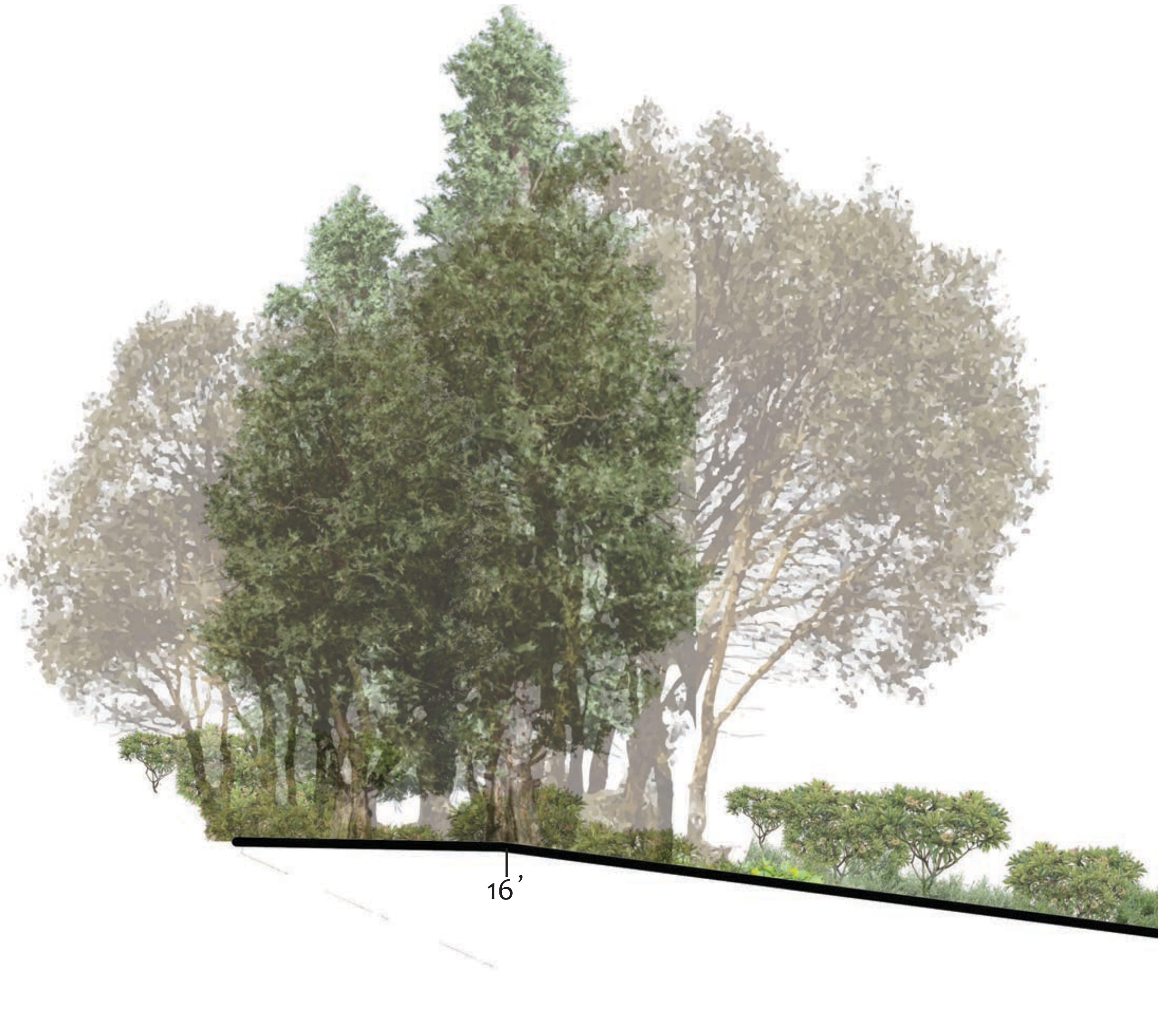


Figure 9b. Design location plan. *Courtesy of CUES.*

Figure 9a. Detailed callout of section cut reveals the progression from the proposed fresh water collection area to freshwater marsh to grasses and shrub. *Courtesy of CUES.*

DESIGN OPTION B: BIRD ISLAND SECTION DETAIL



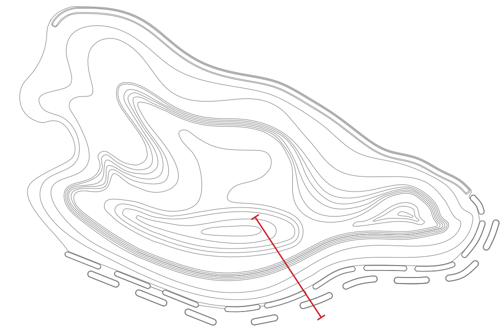


Figure 10b. Design location plan. *Courtesy of CUES.*

Figure 10a. Detailed callout of section cut reveals the sloped progression from maritime and costal forest (at elevation 16) to grass and shrubbery (at elevation 12). *Courtesy of CUES.*

DESIGN OPTION C: ESTUARY TERMINAL ISLAND SECTION DETAIL

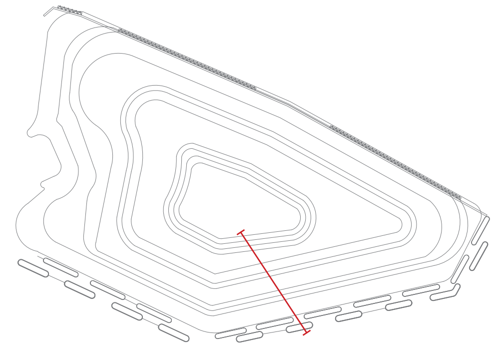


Figure 11b. Design location plan. *Courtesy of CUES.*

Figure 11a. Detailed callout of section cut reveals the terraced topography unique to the Estuary Terminal Island design. This specific detail focuses on the maritime and coastal forest habitat. *Courtesy of CUES.*

VI. DISCUSSION & RECOMMENDATIONS

Discussion

Integrated Approach

The project stressed the integration of current theory and research on coastal island construction with current regulatory determinations related to the site. The BUCD project team used an iterative design process to adhere spatial form to scientific data. The approach proved useful in providing specific design milestones to produce three options. The iterative design process facilitated the multi-discipline, multi-scale, multi-input discussion and represented engineering, ecological, social and economic factors spatially and graphically.

Academic Research

The devasting effects of extreme storm events and anticipation of higher sea levels has resulted in greater interest in projects that have the potential to increase the protection and resiliency of coastal communities. There is evidence that vegetation, marshes, barrier islands, oyster reefs – topographic forms that intercept energies associated with storm surge events – offer increased protection. However, it has not yet been clearly demonstrated how these green infrastructure options might be adapted for densely developed urban estuaries, and so pilot projects are desperately needed to evaluate green infrastructure effectiveness under urban conditions. The BUCD project represents an opportunity to document the impacts of climate change and to monitor the effectiveness of the proposed mitigation measures. Towards this end, it is recommended that collaborations with educational institutions and citizen scientists augment professional monitoring activities.

Design Research

The design research process used the data collected by Rutgers and the Stevens Institute (see Chapter III and Appendix Section II for a detailed description of data collected) to consider the spatial implications for island design and construction, the requirements for coastal protection, resilient habits, construction and post construction observation and management interventions.

The process scheduled specific design milestones: analysis, synthesis and design options. Each milestone refined the parameters and criteria used to propose solutions. The initial review and discussion of the site data and project goals identified three areas of interest: protection, resilient ecological systems, and future management adaptations. This allowed the data to be connected and to construct different design scenarios for discussion. For example, wave strength and fetch data were used to determine perimeter protection, and then as part of the discussion of a resilient ecological system, specifically the interphase between barrier, subtidal and shoreline habitats.

Each round of discussions in a specific design milestone phase represented a specific set of deliverables. Maps and charts consolidated information at the municipal scale in the analysis phase. These maps simplified the original data sets and maps, and then provided a new set of questions and parameters to discuss in the synthesis phase. Diagrams, plans, illustrative sections and case study photos summarized the synthesis phase and one consolidated diagram defined with specificity the location and characteristics associated with the protection and resilient ecological systems.

Finally, three design options were developed to represent feasible combinations and variations for coastal protection and natural habitats. The designs are a contextualized representation of the various elements that could be combined in a number of different ways. The iteration of data and spatial design were reinforced by case studies and research into the construction and economic feasibility of constructing the island.

Regulatory Framework

The regulatory agencies that would be involved in issuing permits for this unique project include the New Jersey Department of Environmental Protection (NJ DEP) and the U.S. Army Corps of Engineers (USACE). The Comprehensive Restoration Plan completed by the USACE for the Hudson-Raritan Estuary was approved in 2016. The State of New Jersey is a partner in, and signatory to, this plan. The project site is located in the Upper New York Bay Planning Region, where identified restoration opportunities are limited.

The proposed island would require installation of a base substrate placed in tidal waters. These activities would necessitate permits from the State of New Jersey and the USACE as required by the Clean Water Act, Section 404. These regulatory requirements were enacted to prevent unavoidable destruction of valuable wetland resources. However, the regulatory agencies do have the authority to issue the required permits, possibly with requirements to compensate for any habitat loss.

Case studies of similar projects beneficially using dredge and placement of fill material in tidal waters for restoration purposes (including in Jamaica Bay, NYC) provide recent precedents for this approach when used to achieve restoration goals that provide ecological benefits. Because the BUCD represents a novel project within the HRE that requires coordination between Federal and State regulatory agencies, it may be beneficial to consider bringing together representatives from each group.

Protection

1. Living Breakwaters

The dual layer of breakwaters (Fig. 1) provides protection to the island from wave, wind and tidal action. The top elevation of all protection structures were designed at 4' above Mean High Water (MHW), to accommodate free boarding. Additional water heights associated with 100 and 500-year storm events projected for 2050 were identified for future design discussion and refinement. The four tidal surfaces of the breakwaters increase available surface space for a variety of tidal and subtidal species to flourish (compared to a single face structure).

2. Revetments

Revetments (Fig. 2) are structures that absorb energy from incoming waves, and in this specific project's case, retain the fill base material for the construction of the island. They are similar to breakwaters in material and construction phasing, but are not specifically designated for habitat creation in our design options. The relative ease of construction allows for manipulation so revetment edges may be a straight or curved line.

3. Bulkheads

The bulkhead structure (Fig. 3)–either vinyl, metal or wood–is proposed as a hard edge wall to attenuate wave forces and specifically to retain construction material and maximize the available space for island construction. The construction of the bulkhead requires deep footings to stabilize the wall, material that withstands corrosion and long-term maintenance to secure the bulkhead's structural integrity.

While the suggestion of a continuous bulkhead along the northern boundary of the project is debatable, the engineering analysis does recommend that bulkheading at the north-western corner, the area directly exposed to wave action and fetch, is required to ensure stability.

4. Revetment-Bulkhead Hybrid

Some of the construction costs associated with the construction of a bulkhead can be offset by the construction of a revetment-bulkhead hybrid (Fig. 4). There are examples of these hybrid structures along the northeast coast. The bulkhead portion remains underwater and functions as the wall that holds back fill material along the MOTBY Channel. The revetment portion would be partially underwater and appear as a traditional revetment structure above water. In addition to lower costs there is an environmental benefit in creating a variety of spaces and surfaces for subtidal and tidal habitat.

In any option, breaking up linearity of the structural edge to provide more diversity of microhabitats would provide ecological benefits.

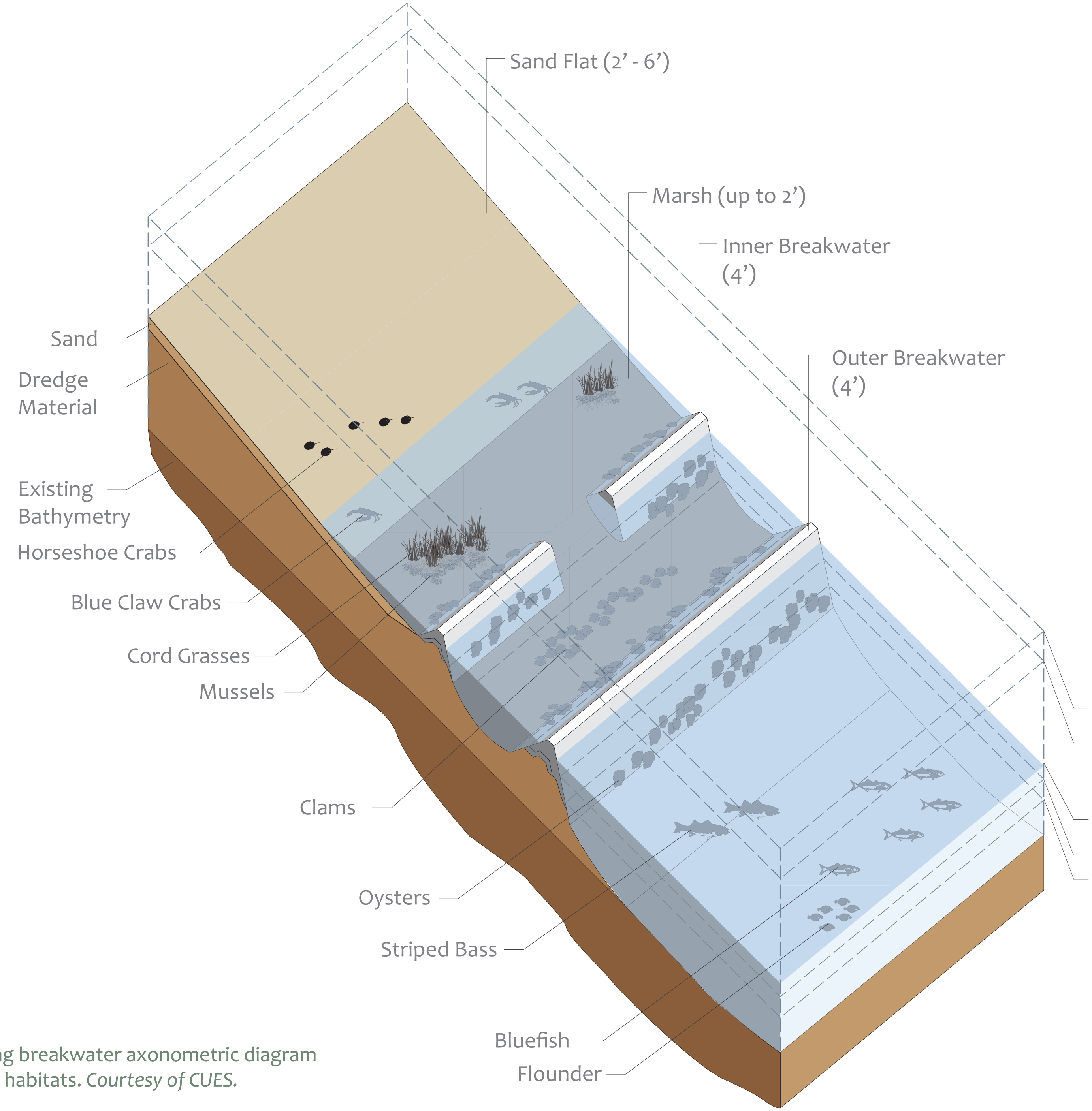


Figure 1. Living breakwater axonometric diagram with proposed habitats. *Courtesy of CUES.*

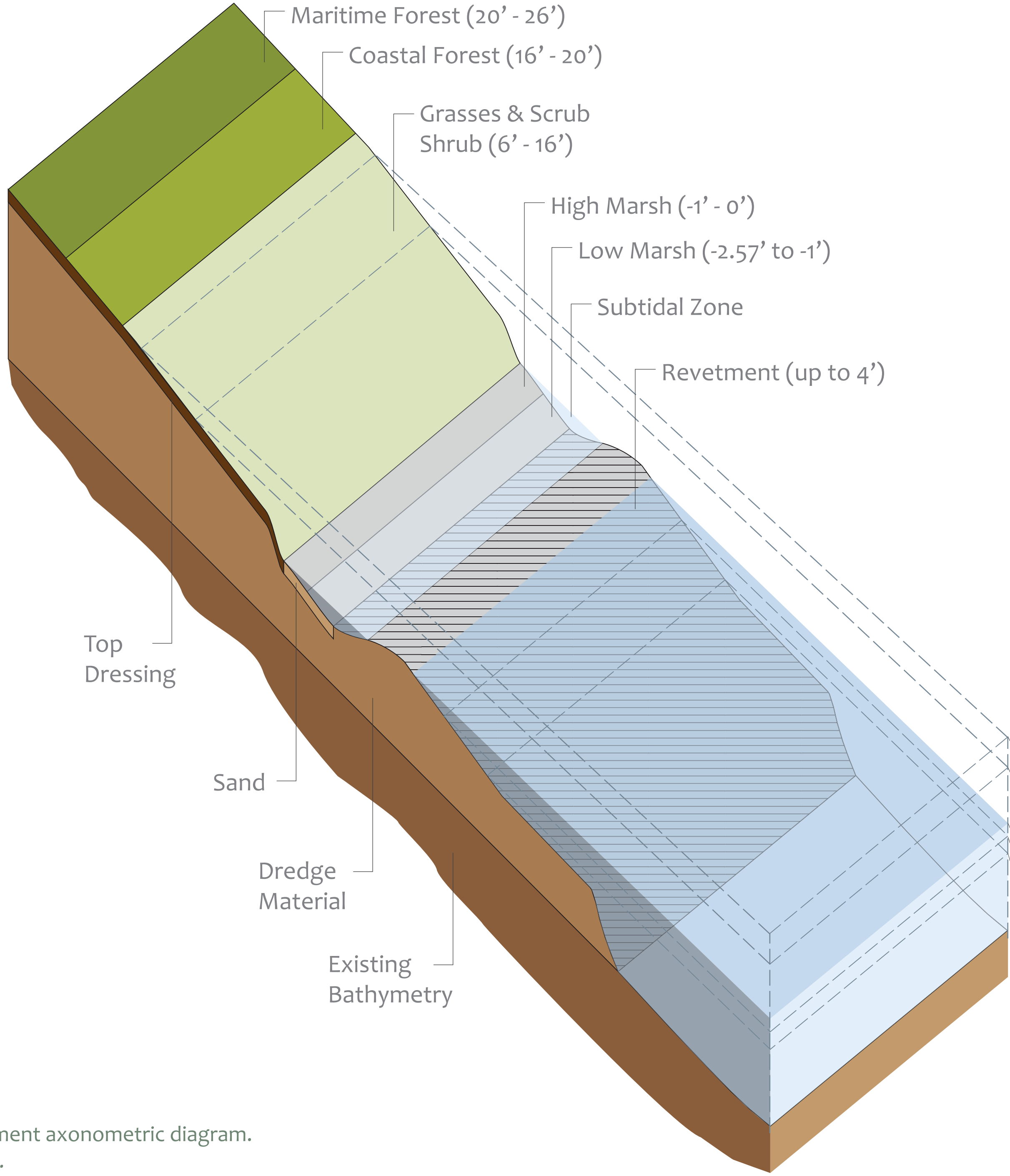


Figure 2. Revetment axonometric diagram.
Courtesy of CUES.

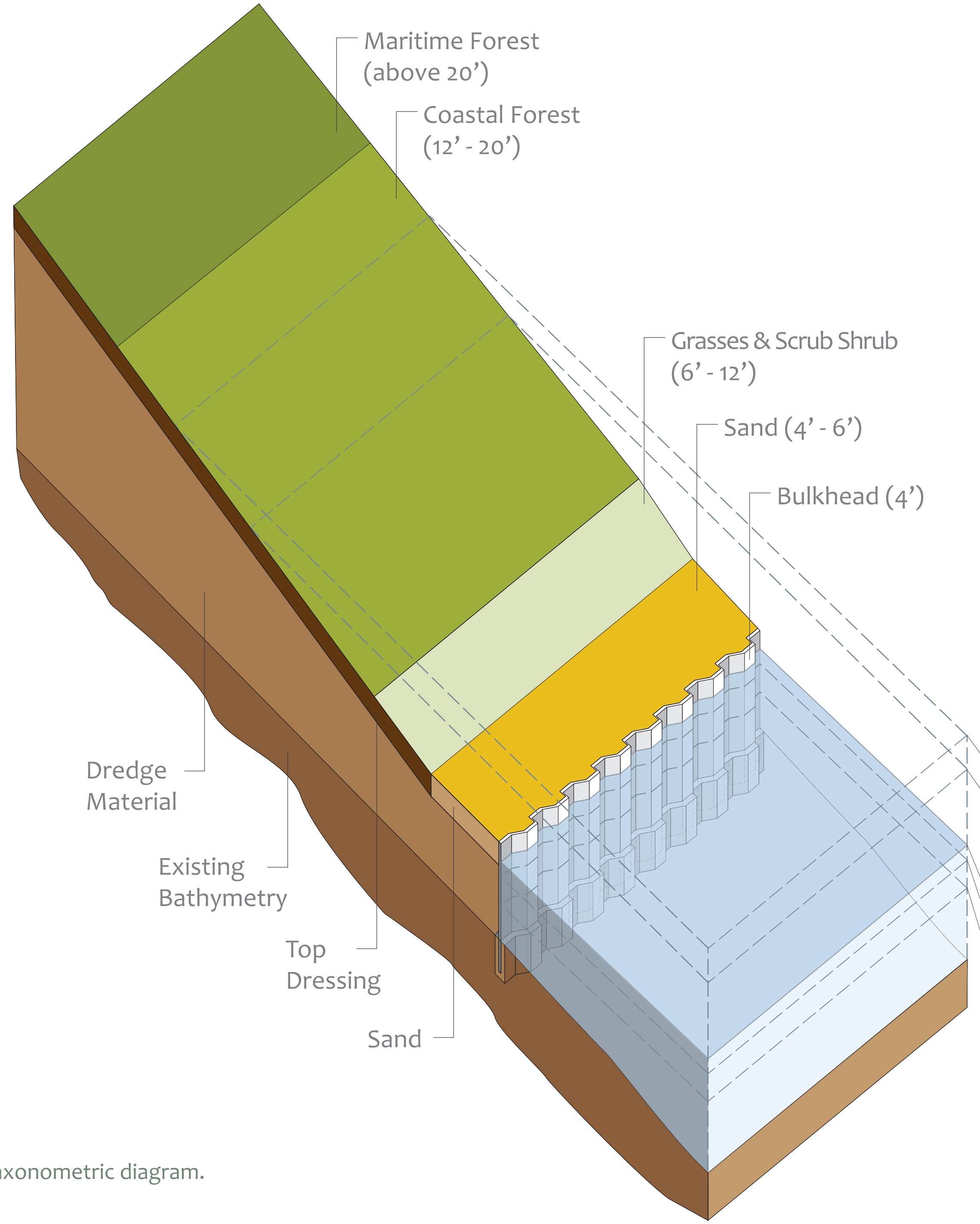


Figure 3. Bulkhead axonometric diagram.
Courtesy of CUES.

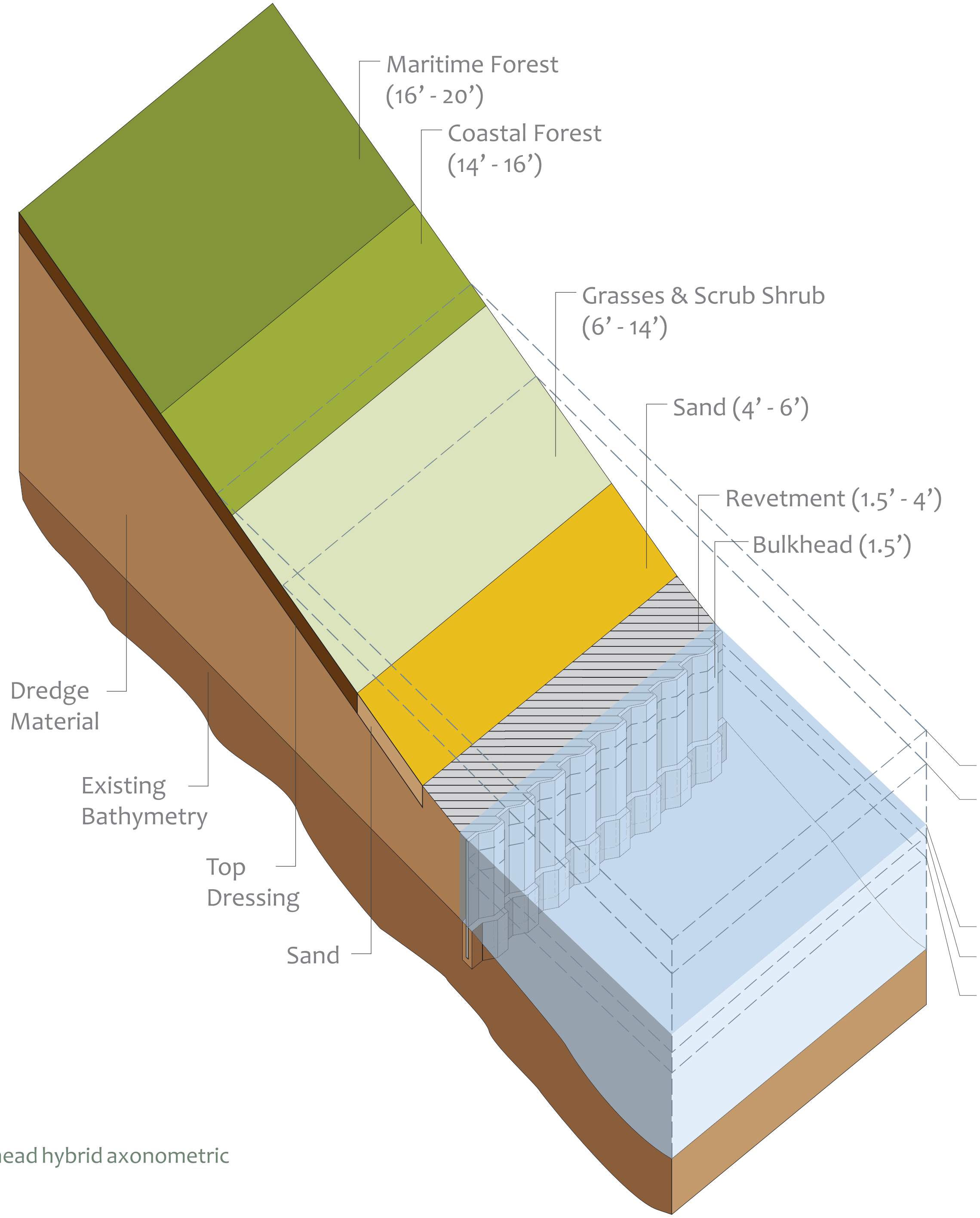


Figure 4. Revetment-Bulkhead hybrid axonometric diagram. *Courtesy of CUES.*

Resilient Ecological Systems

1. Tidal and Shoreline

The combination of wave/tidal energy and water chemistry shapes the physical bathymetry and the biological communities that inhabit the subtidal, intertidal, and shoreline areas. Tidal regions of the island provide topographic relief that is desperately needed in the HRE. Inclusion of the eastern oyster (considered a keystone species that "engineers" the marine environment) would add a living layer to the breakwater system that protects the Hudson River face of the island from erosion. The accretion of an oyster community could increase the strength of these structures, while contributing valuable filtration that benefits water quality and provides refugia for other marine species.

Mud and Sand Flats between the breakwaters and the beach area, in addition to shallow intertidal western island boundary, will provide enhanced habitat for many benthic species. With the extension and bulkheading of most of the Harbor's shoreline and deepening of the bay's main channel this type of habitat was mostly eliminated. However, just north of the BUCD site in Liberty State Park, 300 acres of mudflat was protected that serves as refuge for many marine species. The addition of the sand and mud flats at BUCD would further enhance these communities. While current velocities generally determine sediment deposition and grain size, intentionally varying the grain size during island construction could foster a greater diversity in the benthic community.

Sand flats and dunes contribute to dissipation of storm surge energies and provide a habitat that is currently absent from the majority of the Upper Bay region. Dune grasses stabilize the sand and help prevent erosion. Dune grasses such as black grass, and switchgrass and seaside goldenrod help to stabilize the dunes. This type of habitat along the shoreline is critical for many nesting shore bird species. The black skimmer and least tern, both endangered species in New Jersey, depend upon this type of habitat, and nest sporadically in the HRE.

Marsh vegetation within the tidal portion of the island would dissipate wave and surge energy, while aiding sediment deposition (Fig. 5). Root zones from marsh vegetation would stabilize sediments. Ribbed mussels growing within the *Spartina alterniflora* root zone would also enhance the stabilization of marsh sediments.

Maritime Shrub communities tolerate water deficit stress well and are salt tolerant. Such communities, consisting primarily of hightide bush, sea myrtle, and rose mallow are rare within the HRE. Their morphologies are often shaped by the salt spray, which tends to stunt the windward side. They provide valuable habitat for many avian and mammalian species as well as occasional reptiles and amphibians.

2. Forests

Maritime and coastal forests were once prevalent in the HRE, but remaining forest habitats are rare and the forests that do remain are extremely fragmented (Pralls, Shooters Islands, Sandy Hook, Liberty State Park). In addition, the composition of these forests often include many typically urban species rather than traditional maritime species. Forested islands dissipate wind energies associated with storm events and provide desperately needed habitat that supports resident and migratory avian species. To be sustainable, forest communities must be situated within a topography that provides protection from saltwater during storm surge events (14 feet above mean high tide or higher).

Figure 6 provides a sample list of recomended vegetation based on existing native vegetation near the site and suggested in the Hudson Raritan Estuarty Comprehensive Restoration Plan. Figure 7 compares the proportion of different habitat types and amounts of protective infrastructure included in the three design options.

Figure 5. The proposed island could contribute a diversity of habitats currently underrepresented in the Hudson Raritan Estuary. *Courtesy of CUES.*

SUGGESTED VEGETATION FOR PROPOSED ISLAND

Grasses
- American Beachgrass (*Ammophila breviligulata*)
- Switchgrass (*Panicum virgatum*)
- Common Glasswort (*Salicornia europaea*)
- Smooth Cordgrass (*Spartina alterniflora*)

Herbaceous plants
- White Snakeroot (*Ageratina altissima*)
- Common Milkweed (*Asclepias syriaca*)
- Cleavers (*Galium aparine*)
- Canada Goldenrod (*Solidago Canadensis*)

Shrubs and trees
- Serviceberry (*Amelanchier arborea*)
- False Indigo Bush (*Amorpha fruticose*)
- American Holly (*Ilex opaca*)
- Eastern Red Cedar (*Juniperus virginiana*)
- Northern Bayberry (*Myrica pensylvanica*)
- White Oak (*Quercus alba*)
- Post Oak (*Quercus stellate*)
- Staghorn Sumac (*Rhus typhina*)
- Black Locust (*Robinia pseudoacacia*)
- American Pussy Willow (*Salix discolor*)

Figure 6. Recommended plant list for proposed design options are influenced by existing vegetation adjacent to the site as well as the Hudson Raritan Estuary Comprehension Restoration Plan (HRE CRP). *Courtesy of CUES.*

Habitat Type	Links Island		Bird Island		Terminal Island	
	Acres	Percent	Acres	Percent	Acres	Percent
Sand flats/dunes	26	14%	24	13%	13	8%
Marsh	39	21%	62	35%	25	16%
Grasses & Scrub shrub	50	27%	36	20%	59	38%
Coastal/maritime forest	67	37%	56	31%	58	37%
Total Terrestrial	**181**	100%	**178**	100%	**155**	100%
Intertidal/Subtidal						
Revetment (feet)/Revetment-Bulkhead	4729		4525		4775	
Breakwaters (square feet)	187,640		220,464		204,552	
Breakwaters (acres)*	4		5		5	

***Note: 43,560 sq ft per acre**

Figure 7. Comparison of the acreage of habitat and protection types within the three proposed design options. *Courtesy of CUES.*

Recommendations

Protection

The review and comments on the three design options suggest that protection of the island should be a combination of the three proposed options (Fig. 8):

1. Double tier living breakwaters along the island's southern and eastern edge.
2. A short bulkhead along the north-west corner of the island to protect the island at the entrance to MOTBY channel from wave action and scouring.
3. A stone revetment along the northern edge of the island at MOTBY Channel.
4. All designs recommend a height of 4' above MHT
5. Designs to accommodate tidal and subtidal habitat can be incorporated into the revetment and bulkhead.

Ecological Systems

The proposed island installation converts approximately 175 acres of gravelly clay sediments that support a limited number of species and offer no storm protection into three critical ecosystems desperately needed in the restoration of the HRE that provide topographic protection from storm surge events. The island would add 175 acres of wetland and upland habitats that include:

1. Subtidal elements, which support benthic, bivalve, invertebrate, and finfish communities that reside in or migrate through the NY Bight area.
2. Shoreline and shallows, which add critical acreage needed for breeding and nursey habitat utilized by reptile, invertebrate, and finfish species.
3. Martime shrub and forest communities, which replace currently diminishing acreage of roosting and foraging habitat for threatened shorebird populations.

Adaptive Management

The protective design features (structures, marshes, dunes, forests) and ecologic communities of the island must be continually evaluated to determine responses to future sea level rise, changes related to erosive forces, and a warming climate. To ensure the sustainability of the island in light of an unpredictable future, an ongoing data collection and adaptive management process is a critical requirement. Issues that require regular data collection and potential future management action(s) include:

1. Sediment accretion rates: should sediment deposition rates fall below the rate of sea level rise, beneficial application of thin layer sediment or sand is a management option that would supplement natural deposition processes.
2. Erosion: should shoreline erosion occur, additional protective measures may be required. Erosion of higher elevation slopes may require modifications to the island topography or vegetation changes to stabilize specific areas.
3. Vegetation Communities: changes in vegetation will occur as successional communities replace the initial plantings. Species may need to be added or removed depending on future community composition.
4. Sea level rise: estimates for sea level rise in the HRE through 2050 range from 7 to 16 ft. Should the actual rise in sea level fall in the upper end of this range, the shoreline and shallows areas will become inter- and sub-tidal and the forested areas will become the shoreline. There is the strong potential that future decisions regarding increasing the height of the island will need to be addressed. Heights of protective structures (breakwaters, bulkheads, revetments, etc.) may also need to be adjusted over time or additional protections deployed due to sea level rise.

A proposed Adaptive Management Plan approach can be found in Appendix Section III.

Figure 8. Map of recommended protection infrastructure, habitat types and proportions, and management needs for the proposed island. *Courtesy of CUES.*

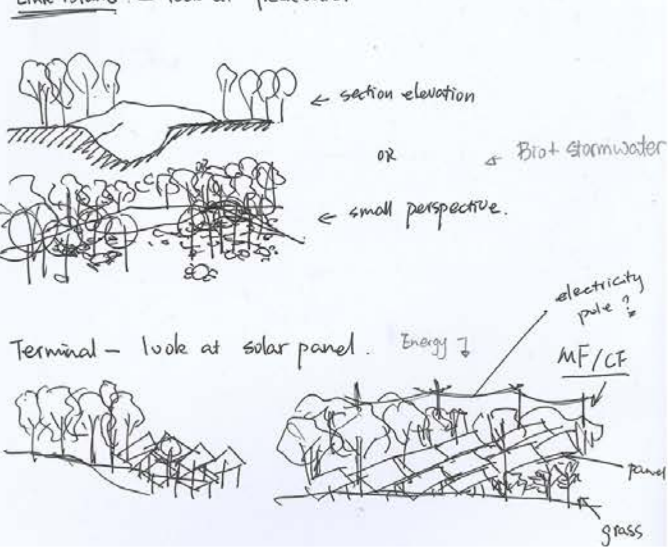
IMAGE SOURCES

Figure 1. Photo inset 1: Photographer, F.M.: NPS Photo by Steve Simon. 2012. Colonial National Historic Park, Virginia [digital image]. URL: https://www.nps.gov/articles/breakwaters-headlands-sills-and-reefs.htm; Photo inset 2: Photographer, F.M.: Jonathan Webb. 2015. Aerial hotograph of artificial reef offshore breakwater at Sea Palling on the Norfolk Coast [digital image]. Retrieved from URL: https://aeroengland.photodeck.com/media/191cc356-53bd-4be1-9c5d-139b95415063-aerial-photograph-of-artificial-reef-offshore-breakwater-at-s.

Figure 2. Photo inset 1: Photographer, F.M. Unknown. Date of publication unknown. Tauranga Sea Wall Rock Revetment - DuraForce™ - Cirtex Civil [digital image]. Retrieved from URL: https://cirtexcivil.co.nz/case_study/tauranga-sea-wall/; Photo inset 2: Photographer, F.M. (Photographer). 10/2017. Coastal Protection Revetment [digital image]. Retrieved from URL: https://twitter.com/envgovmv/status/920518668777410561.

Figure 3. Photo inset 1: Photographer, F.M.: Unknown. Date of Publication: Unknown. Bulkhead Installation Services [digital image]. Retrieved from URL: https://kngmarine.com/bulkhead-installation-services-manahawkin-nj/; Photo inset 2: Photographer, F.M.: Dale Gerhard. 03/2018. Bulkhead saves North Wildwood from disaster beyond beach erosion [digital image]. Retrieved from URL: https://www.pressofatlanticcity.com/news/breaking/bulkhead-saves-north-wildwood-from-disaster-beyond-beach-erosion/article_a421d450-9267-5a9d-bb41-6a0425735895.html.

Figure 4. Photo inset 1: Photographer, F.M.: Unknown. Date of Publication: Unknown. Residential Shoreline Protection [digital image]. Retrieved from URL: https://www.racecoastal.com/residential-shoreline-protection?lightbox=dataItem-io8wfpmy; Photo inset 2: Photographer, F.M.: Unknown. Date of Publication: Unknown. BREAK WATERS & ROCK REVETMENT [digital image]. Retrieved from URL: http://smcontracting.ae/new/architecture/.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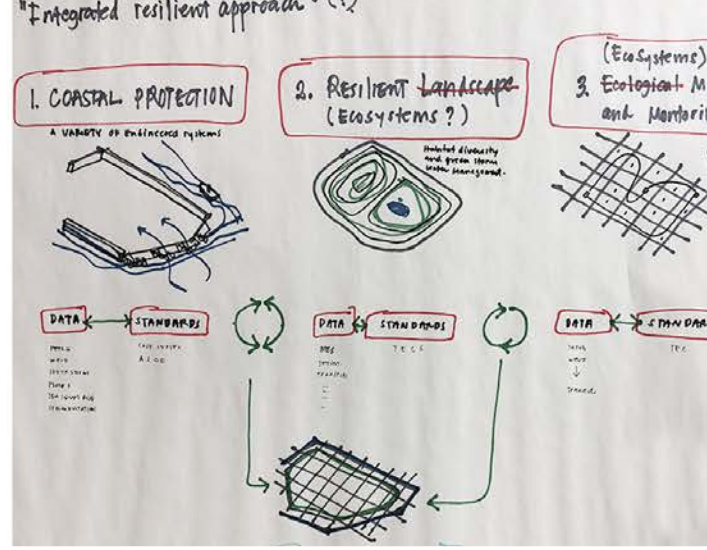
OR
small perspective.
electricity pole ?
Terminal – look at solar panel.
Energy
MF/CF
panel
grass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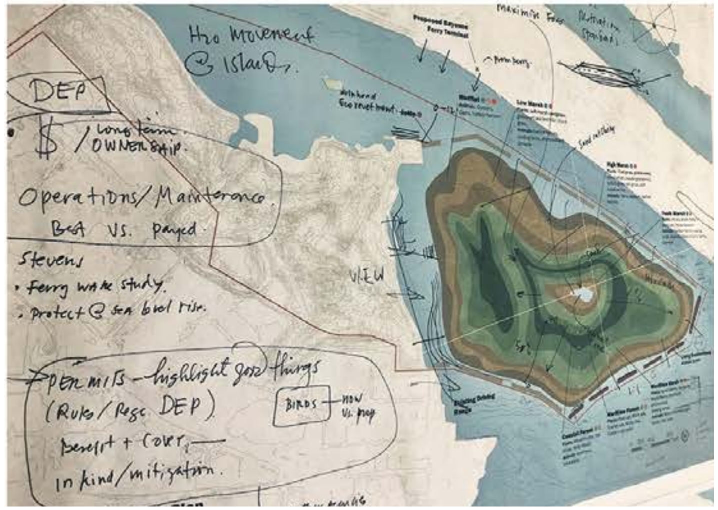
2. Resilient Landscape (Ecosystems ?)
DATA
STANDARDS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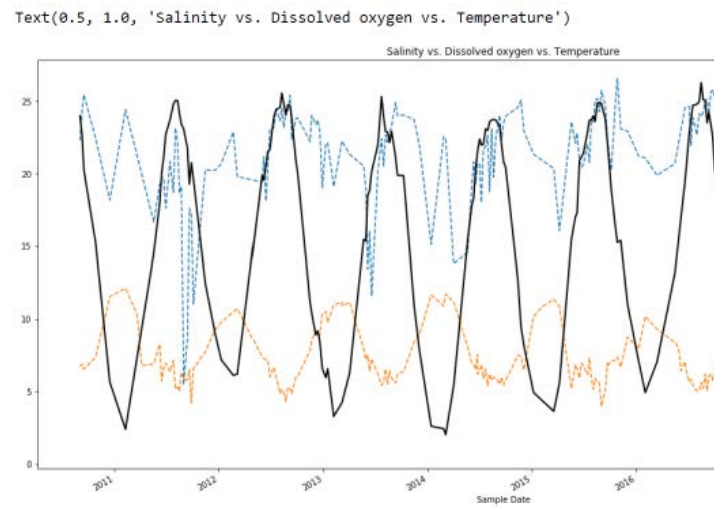
(Rules/Regs. DEP)
BIRDS
benefit + cover
in kind/mitigation
VIEW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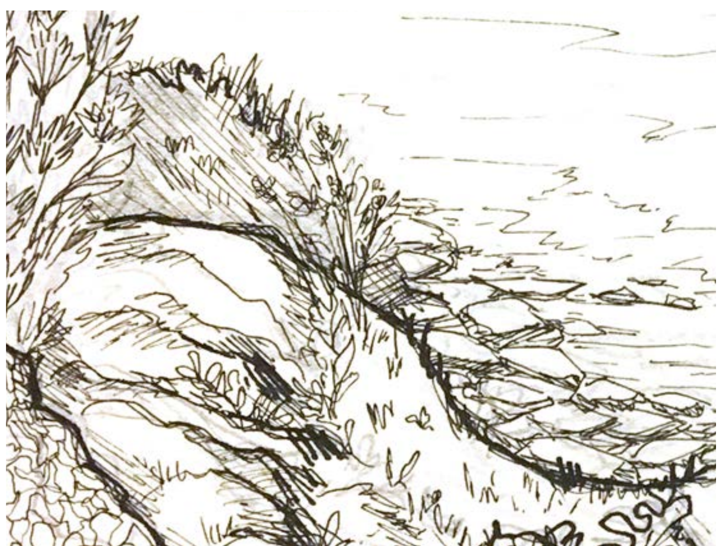
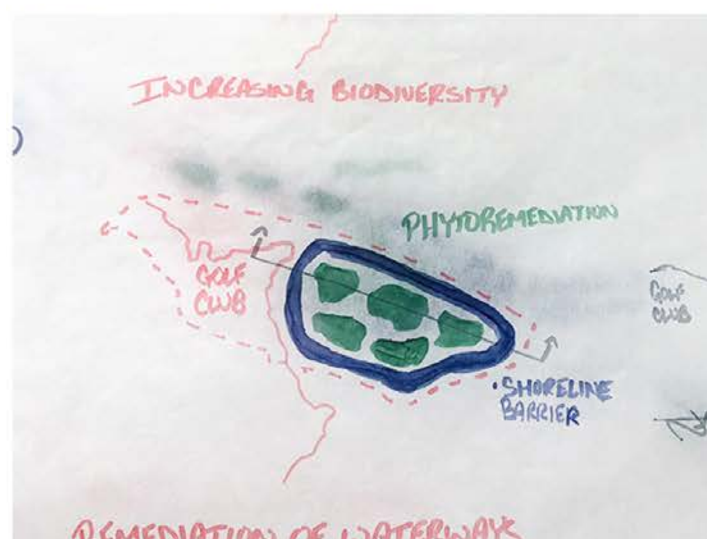
Sample Date


HARBOR SEALS

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