Machicomoco State Park
Shoreline Management Plan

May 2022

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Executive Summary

Machicomoco State Park is located in Gloucester County, Virginia, along the York River. It is bordered by Cedarbush Creek to the northwest, Timberneck Creek to the east, and the Catlett Islands and Poplar Creek to the south. It is an important historical and archaeological site, as it has been inhabited by humans as far back as the Middle Woodland Period, during the time of the Powhatan. It was later settled by English colonists, whose descendants remained in possession of the property until it was given to the Virginia Department of Conservation and Recreation (DCR) in October of 2020. Construction of the park had already begun in 2018, and was completed and opened to the public in April of 2021.

The park is 645 acres with approximately 2.5 miles of shoreline. Several structures presently exist along the shoreline, including a pier and floating boat docks, as well as living shoreline protection structures consisting of a single stone sill adjacent to the pier and a gapped stone sill living shoreline system. The Shoreline Studies Program of the Virginia Institute of Marine Science (VIMS) was tasked with surveying Machicomoco in order to develop a shoreline management plan to protect the park's shoreline from erosion, storm surges, and sea level rise. Two surveys of the park were conducted to assess the current condition of the shoreline, collect elevation data, and determine where additional shoreline protection structures should be placed.

Currently, the outlying Catlett Islands, which are not park of the park, protect the park's southern shoreline and provide a glimpse into the future of the park's shorelines. The Islands are experiencing the highest amounts of erosion and shoreline change. With regards to the park itself, the shorelines along Cedarbush and Timberneck Creek are experiencing low amounts of erosion, while the shoreline on Poplar Creek behind the Catlett Islands and the shoreline around the sill system largely remain stable. Based on the surveys and shoreline change data, a living shoreline sill system is proposed between the boat dock and existing gapped sill system to protect the vulnerable recreationally and archaeologically important areas there. A system of 3 rock sills with sand fill and marsh plants is recommended.

The proposed living shoreline utilizes rock, sand and plants to protect the shoreline and reduce erosion of the upland bank. Along other areas of the park, suggested management strategies are primarily to plant marsh grasses in existing substrate and trim back the upland vegetation to provide adequate sunlight for the marsh, create oyster habitat to protect existing marsh fringes, and in areas with slightly more erosion, additional rock sill living shoreline systems.

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1 Introduction

Machicomoco State Park (MSP) is located along the York River in Gloucester County, Virginia, between Cedarbush Creek and Timberneck Creek (Figure 1). Figures are shown in Appendix A. Archaeological evidence dating to the Middle and Late Woodland Periods (200 BCE – 1000 CE) strongly suggests that the area is associated with Tsenacommacah and the Powhatan's chiefdom (DCR, 2021). The site was primarily used as a base for hunting, fishing, and oystering activities. The area was later settled by English colonists around 1639, and was eventually sold to John Catlett in 1792, where it remained in the Catlett family's possession for over 200 years (DCR, 2021).

In recent years, a development company began constructing infrastructure, including roads and individual lot aprons, for the Timberneck subdivision. However, the subdivision was not completed, and the 645-acre area was purchased by the Conservation Fund as part of the Surry-Skiffes Creek Transmission Line Project memorandum of agreement. The park was designed and developed by Nelson Byrd Woltz Landscape Architects, who began construction in March of 2018. The area was transferred to the Virginia DCR in October of 2020 (DCR, 2021). Today, the park is open to the public and includes camping and picnic areas, walking trails, piers, and a boat dock. Not including the upland areas adjacent to the Catlett Islands, Machicomoco has approximately 2.5 miles of shoreline: approximately 0.4 miles along Poplar Creek, 1.5 miles along Timberneck Creek, and 0.6 miles along Cedarbush Creek (Figure 2).

The goals of this project were to 1) utilize existing data as well as a visual inspection by boat of the park's shoreline to make management recommendations, and 2) to develop a site-specific living shoreline plan to address erosion in the vicinity of the boat dock at the park. The design is a "shovel-ready" project that contains the information in sufficient detail to permit the project including estimated quantities and costs. These tasks will provide protection for the archaeological and cultural sites and can accommodate any future improvements that will be made to the park.

2 Existing Conditions

2.1 Physical Setting

2.1.1 Physical Parameters

MSP is located in the lower estuarine reaches of the York River and has shoreline along Cedarbush, Timberneck, and Poplar Creek. It is located adjacent to the Catlett Islands which are two subaerial, stratigraphic depositional sequences separated by Poplar Creek. The upriver northwest island and the downriver southeast island both consist of forested upland ridges and low-lying tidal saltmarshes (Figure 2). Most of the Catlett Islands are part of the Chesapeake Bay National Estuarine Research Reserve (CBNERR).

The upland area of Machicomoco ranges from +30 ft to +3 ft above North American Vertical Datum 1988 (NAVD88) (Figure 3). The marshy areas are less than +3 ft NAVD88. At

Machicomoco, NAVD88 is 1.3 ft above mean low water (MLW) (Hardaway et al., 2021). Much of the MSP shoreline has a high bank that is eroding or undercut in many places as the heavily forested areas along the shoreline shade out the fringe marsh (Figure 4A). Small, lower pocket marshes, visible on Figure 3, occur between the higher forested points of land that extend farther into the Creeks (Figure 4B). Bank height affects the nature of erosion. Though waves impact the base of any eroding bank, the long-term fate of the bank slope will depend on bank height and composition. During severe storms, the waves may overtop lower banks or directly act on the bank face of a higher bank.

The nearshore of Timberneck and Cedarbush Creeks is relatively shallow (Figure 5). Bathymetry data collected for another project was used to assess the nearshore depths adjacent to the park. The data collection methodology can be found in Hardaway et al. (2020b) and Milligan et al. (2021). Generally, Timberneck Creek is deeper than Cedarbush Creek. Whereas Cedarbush has a shallow shoal across its mouth, Timberneck has a defined channel with slightly deeper pockets within. One of the largest and deepest pockets is adjacent to the large pier and floating docks at the park at a depth of between -6 and -7 ft mean lower low water (MLLW). Another deeper pocket occurs adjacent to the existing sill at the tip of the property on Timberneck.

At its mouth, Cedarbush Creek has a longest fetch of 3.3 miles to the southwest, the shoreline along Poplar Creek has a longest fetch of about 2.2 miles to the south, and the park shoreline at the mouth of Timberneck Creek has a longest fetch of about 2.4 miles to the south. The fetches are much smaller up the creeks, less than 1 mile.

2.1.2 Existing Structures and Shore Change

Over time, several structures have been built along the shoreline to mitigate erosion or for recreational purposes. One 210 ft pier exists along the southern shore of the park in Poplar Creek and provides car-top launch access, and two more piers, one west of the southeast point and approximately 115 ft long is suitable for nature viewing; the other, which also includes a floating boat dock, is approximately 518 ft long occurs along the southeastern shore in Timberneck Creek (Figure 2). Permitted by Timberneck, LLC, designed by Williamsburg Environmental Group, and constructed by Coastal Design & Construction, Inc. of Gloucester, Virginia, a gapped sill system along the southeastern point in early 2011, the first one measuring 120 ft and the second measuring 265 ft in length, and each ranging in height from +5 ft MLW on the ends to +3.5 ft MLW in the center (Figure 6) More details on the project are shown in Appendix B. The same company also constructed a single sill measuring 85 ft long and +3.5 ft MLW high just north of the largest pier and boat dock (Figure 7).

Using existing data from the Shoreline Studies Program Shore Change Database, the long-term change rates were determined between 1937 and 2019 (Figure 8). The shorelines of the Catlett Islands along the York River have mostly experienced low to high rates of erosion. The interior shorelines at Catlett generally have very low erosion rates with a few areas of very low accretion (Figure 8). Along Timberneck and Cedarbush Creeks most of the shorelines are experiencing very low to low erosion. More detailed shore change is shown in Appendix C.

The digitized shorelines from 2007 and 2019 were compared to determine shore change. The area between the shorelines was converted to polygons in Esri ArcMap to show the gain and loss along the shore at MSP and at Catlett (Figure 9). Since 2007, there was an overall loss of 21.1 acres of shoreline from erosion and an overall gain of 1.2 acres, with most of the loss occurring on the Catlett Islands and most of the gains occurring behind the sills (Figure 9).

In addition to changes in the shorelines of the area, vegetation zones also experienced shifts from 2007 to 2019. On the Catlett Islands, there was an overall conversion of 22 acres of ghost trees/maritime forest upland zone to high marsh (Figure 10). As sea level has risen, the marsh migrates to higher elevations. Around the fringes of the Islands, the ghost forest/maritime forest habitats are being lost to erosion. Catlett is generally much lower than MSP's shoreline which is backed by a high bank. As a result, it is much more susceptible to higher water levels. However, as sea-level continues to rise, MSP will begin to be affected, particularly in the lower, pocket marshes and along the lower shoreline directly adjacent to the Islands.

2.1.3 Archaeology

In keeping with its habitation for at least 2 millennia, cultural resources have been found in many areas of MSP and Catlett Islands. Though not mapped for this report, archaeological resources are mapped in the Virginia Department of Historic Resources, Virginia Cultural Resource Information System (V-CRIS). Those resources shown typically occur closer to the shoreline than in the middle portion of the park. This is in keeping with the area being used by Native Americans as a hunting and fishing area. In addition, most areas of the park have been farmed since the colonial area. However, not all of the park has been mapped (D. Brown, personal communication, October 27, 2021). Dr. Brown has suggested that additional sites likely will be found if other areas are surveyed. In addition, no surveys for cultural resources have been done along the shorelines of Timberneck and Cedarbush Creeks (D. Brown, personal communication, October 27, 2021).

2.2 Tide Range and Sea-Level Rise

Mean tide range is 2.5 ft MLW at MSP. Storm surge frequencies for the 10, 50, and 100-year events are 6.2 ft MLW, 7.3 ft MLW, and 7.8 ft MLW, respectively (FEMA, 2021).

Sea level rise was calculated to be 4.9 mm/yr (NOAA Tides and Currents, 2021). Based on this rate of change, mean sea level has increased vertically by 0.2 ft since 2007. Though this seems like a small amount of water, over the gradual slopes in the marsh, it can affect a large area horizontally. This accounts for the internal conversion of the upland forests to marsh shown in Figure 10.

By 2050, nearly an additional 0.5 ft of sea level rise will occur vertically. In about 60 years, sea level will be at least 1 ft higher. NOAA's Sea Level Rise and Coastal Flooding Impacts (NOAA, 2021) interactive mapping tool shows the extent of horizontal flooding due to a specified amount of sea level rise. The viewer presents data relative to mean higher high water (MHHW) which is about 0.2 ft above MHW. Shown in Figure 11A, the extent of an additional 1 ft of water relative to MHHW, indicates that much of the marsh at Catlett will be lost with only the maritime forests still emergent. Due to its higher elevation, much of MSP is unaffected. Generally, the low marshes and the Catlett Islands are the areas that will be impacted most by sea level rise. With 1 foot of sea level rise, all of the low-lying marshes of the Catlett Islands will be underwater, as will some of the low-lying marshes and current shoreline at Machicomoco. With +5 ft of sea level rise (Figure 11B), the Catlett Islands will completely disappear, as will all of the low-lying marshes at Machicomoco, thereby drastically increasing the effects on the park shoreline. The high upland areas will not be flooded under normal conditions; however, the additional water level will increase wave action acting directly on the bank, causing further erosion and instability.

2.3 Marine Resources

The Submerged Aquatic Vegetation (SAV) Program at the Virginia Institute of Marine Science has not documented any SAV in the waters around Machicomoco since they began monitoring SAV in the Chesapeake Bay in 1987 (VIMS, 2021).

At the survey site along Timberneck Creek, six private oyster grounds exist within the creek (Figure 12), and several others exist further out into the York River; however, all of the leases in Timberneck Creek currently lie within a shellfish condemnation zone, with the exception of one plot that extends just out of the condemnation zone (VMRC, 2021). In addition, oysters naturally inhabit the shoreline in areas of the park where there is a wide intertidal zone such as in the area of the pier and boat slips on Timberneck Creek (Figure 4C).

The benthic community in the York River has been assessed using the Index of Biological Integrity. This index ranks the relative value of bottom communities around Chesapeake Bay on a scale of 0-100% by comparing values of key benthic community attributes (“metrics”) to reference values expected under non-degraded conditions in similar habitat types. It is therefore a measure of deviation from reference conditions. As a whole, the York River benthic community was listed as being in good health (72%) in 2020 (EcoHealth, 2021).

The York River system is home to a diversity of fish species, some of which are year-round residents while others use the river during a particular season or life stage (Hewitt et al., 2009). More than 130 species of fish have been observed in the York. These species include top predators such as sharks to plankton feeders such as bay anchovies. The diversity represented by fish fauna includes members of the shad and herring family, drums, flatfishes, temperate basses, catfishes, sharks, skates, rays, and numerous smaller fishes that serve as forage such as bay anchovy, Atlantic menhaden, and killifish. Historically, fisheries for blue crabs, American shad, striped bass, and Atlantic sturgeon thrived in the Chesapeake Bay region, but in recent times, and with the exception of striped bass, these fisheries have declined (Hewitt et al., 2009). Fishes in the York have varying life history patterns, from fast growing species such as alewife, to slow growing, late maturing species such as Atlantic sturgeon. The young of many species use the York River system as a nursery area and depend on the high productivity of this estuary, particularly its marshes, for conferring fast growth and high survival during the first year of life. However, areas of SAV are needed for settlement and protection, and the areas around Machicomoco have no SAV. Overall, the York River had poor ecosystem health (graded as a

“D”) in 2020 according to the Index of Biological Integrity. Many of the improvements made in 2019 were reversed in 2020 as overall health dropped from 37% to 32% between 2019 and 2020. Scores dropped for dissolved oxygen, nitrogen, phosphorus, chlorophyll a, and water clarity. Benthic community and aquatic grasses were the only scores that increased (EcoHealth, 2021).

In addition to the boat slips for the park, there is also a working waterfront across Timberneck Creek from MSP (Figure 2). Williams Landing is a public working waterfront that consists of a pier and boat ramp, and provides access for both recreational and commercial use.

3 Methods

Machicomoco State Park was surveyed by boat traveling at a slow speed along the shoreline. During this survey on 24 August 2021, GPS-tagged photographs (Figure 13) were taken along the entire park shoreline, and Virginia Geographic Information Network (VGIN) imagery field maps were used to document shore conditions. These conditions were categorized as shown in Table 1. The bank face and base of the bank were categorized as erosional, transitional/undercut, and stable. The width of the fringe marsh adjacent to the shoreline was estimated. The existing structures also were assessed. Only Timberneck and Cedarbush Creeks were assessed by boat because Poplar Creek was too shallow to access. It was assessed remotely using VGIN imagery and other imagery.

After the initial boat survey, the photographs and field notes taken of the shore conditions were used to map the shore conditions of the entire Machicomoco shoreline in Esri ArcMap (Appendix D). These data were then used to assess which areas of the park were most in need of stabilization and erosion mitigation. From that information, the best strategies to use on all the shorelines were determined. This data is mapped in Appendix E. One of the most visible areas of erosion was determined to be adjacent to the pier on Timberneck Creek. This area was selected for the site-specific living shoreline design.

A shore elevation survey was conducted later on 1 November 2021. The survey was planned to be conducted once the vegetation had started to die back to make accessing the site and collecting data easier due to coverage on the upland bank. This survey consisted of setting up two real-time kinematic positioning (RTK) base stations (Trimble R8 GNSS), one on the sill system and one on the large pier/boat dock to collect 2-hr global positioning system (GPS) elevation data of the benchmarks. The 2-hr occupation data was processed through the National Geodetic Survey (NGS) Online Positioning User System (OPUS) to get the horizontal coordinates and vertical elevations of the benchmarks. A Trimble total station was set up on the large pier to collect elevation points from an optical tracking prism atop a stadia rod. The area between the boat dock and sills were surveyed this way, as it was decided that this was the area where a new living shoreline system would be designed (Figure 14). Due to tree cover along the shoreline, the base of bank could not be reached. In addition, the top of the bank was not surveyed. Therefore, the shore survey was supplemented with several points from the NGS 2019 Lidar data where necessary.

With the exception of the maps of predicted sea level rise, all maps were created in GIS. Elevation maps were created using data collected in the field and lidar data from NOAA/NGS. Shore condition maps were created using on-site observations and GPS-linked photos taken during surveys, which were then digitized into GIS.

Findings were discussed with DCR staff in order to recommend what action should be taken and where, as well as to get feedback from park staff as to which areas they felt were most important for recreational, cultural, and archeological purposes.

Table 1. Shore condition categories used in the assessment.

Condition	Description
Bank Face	Condition of the visible vertical side of the bank between its top and base
Erosional	The bank face is actively being worn away by water, wind, or other factors; usually visible as scarped and non-vegetated.
Transitional	The bank face is partially stable, but beginning to show signs of erosion.
Stable	The bank face is stable and not actively being worn away. Usually a marsh fringe fronts the shoreline.
Base of Bank	Condition of the bottom of the bank where it meets the shore or water
Erosional	The bank base is actively being worn away by water, wind, or other factors; usually visible as scarped and non-vegetated.
Undercut	The bank base has been worn away to the point that it is concave; the bank face and/or top of the bank extends further out than the base.
Stable	The bank base is stable and not actively being worn away. Usually a marsh fringe fronts the shoreline.
Marsh Width	Width of the marsh from the landward side at the base of the bank to the seaward/channel side
<5 ft	The width of the marsh is less than 5 feet wide.
5-10 ft	The width of the marsh is between 5 and 10 feet wide.
10-50 ft	The width of the marsh is between 10 and 50 feet wide.
50-100 ft	The width of the marsh is between 50 and 100 feet wide.
>100 ft	The width of the marsh is greater than 100 feet wide.

4 Shoreline Management Strategies

4.1 Overall Park Management Planning

4.1.1 Shore Types and Preferred Strategies

Using information from the on-site surveys and the maps created in GIS, the entire shoreline of Machicomoco was analyzed and assessed to determine which areas were most stable, which were most vulnerable, and which were most valuable to the park both recreationally and archaeologically (Appendix D). Based on this information, an overall management plan was created for the park to determine what actions should be taken for specific areas of shoreline (Appendix E).

To discuss the shore conditions and management recommendations, the shoreline was divided into six reaches based on location and whether or not the area contained any protective shoreline structures to assess specific areas' conditions and erosion or accretion rates from 1937 to 2019 in order to determine management strategies for each area (Figure 15). Each reach consists of individual plates (Figure 16) that display data at a scale that is easily readable for both the shore conditions (Appendix D) and the management recommendations (Appendix E).

The base of bank condition is the key. If it is erosive, undercut, scarped or slumping then the potential exists for bank face instability. The bank face condition reflects the seriousness of the problem. When shoreline erosion control strategies are applied, the interface with the riparian edge also must be considered. If the bank face is relatively stable, the riparian edge might remain as is, but if the bank face is fully exposed and actively eroding, then bank grading might be preferred. However, as this is state property and cultural resources are known to exist along the upland close to the shore, bank grading will generally not be recommended at this site. The site shoreline management recommendations are summarized in Table 2.

Because most of MSP's shoreline has relatively low fetch and low erosion rates, four different types of management strategies are recommended. The low rock sill is used along higher banks that are actively eroding. This strategy has been employed successfully at the park in two locations (Appendix B). It consists of an engineered trapazoidal rock structure placed in the nearshore. The structure is generally not continuous but has gaps to allow fauna to access the system. Sand is placed behind the structure on a gradual slope to the bank and is planted with high and low marsh grasses. The size of the structure (both width and height) depend on the hydrodynamics of the shore reach. Larger fetches and deeper water requires larger structures, and smaller fetches can use lower, smaller living shorelines. The rock sills recommended in this report should be sized similarly to the existing systems at the site.

The oyster sill is a structure that is designed to allow oyster spat to attach to it, thereby creating a reef. Forms often made out of concrete are used to create the structure that are placed along the shoreline. The oyster sill has some height to it so that it can help mitigate waves impacting the bank. Sand can be placed behind the structures, but it is not required because they are often positioned in areas where it would be difficult to bring it in to the shoreline. However, marsh grasses could be planted in existing substrated. Many different types of concrete forms exist; several are mentioned here. Some forms are proprietary so no specific recommendations will be made in this document. However, any of these types of forms can effectively be used to create an oyster sill along the shoreline. The advantage of these types of structures is that they can often be built by hand with volunteers drastically reducing the cost. These structures perform better in areas with large oyster populations because they require spat to be successful. MSP has plenty of oysters along its shoreline. This is not a complete list of the many types of structures that have been placed along the shoreline as oyster reefs. However, these are the ones that the authors have experience with and will likely perform well.

- Mesh bags filled with oyster shell that are stacked along the shoreline (Figure 17). The bags are usually 18 inches x 8 inches x 6 inches and can be stacked in several types of configuration. (Milligan et al., 2018). These bags are relatively inexpensive and easy to install. However, one concern is the use of the plastic mesh bag due to the increased concern about microplastics in the Bay.
- Oyster castles are pre-formed concrete structures that are stacked together (Figure 18). Oysters grow on the many sides of the structure essentially gluing the blocks together (https://blogs.ubc.ca/royaloysters/2014/11/25/oysters-thriving-on-man-made-castles-installed-on-south-carolinas-shores/; https://www.delmarvanow.com/story/news/local/virginia/2017/08/28/concrete-castles-oysters-erosion/587651001/)
- Diamond and X-Reefs are two shapes of pre-cast concrete that have shells embedded in the structure (Figure 19). Oyster spat may prefer to attach to oyster shells so these forms have the ease of pre-cast concrete but could allow for better spat settlement. These structures are larger than the previous two and require equipment for installation (https://www.dailypress.com/news/dp-nws-evg-biogenic-water-reefs-20170630-story.html).
- Natrx using 3D printing technology to design pre-cast concrete structures specifically for a shoreline (https://natrx.io/). The company has recently moved to the Hampton Roads area and a project with their structures has been designed and is in the permitting process.

For many areas of MSP, the recommended shore strategy is to trim trees, plant marsh, and/or intertidal oysters. The areas of the park that is heavily wooded along the shoreline shades the marsh. In many cases, this has resulted in the loss of the marsh completely or it has been reduced to less than 5 ft and is intermittent. This allows waves to impact the upland bank directly causing erosion. The trim trees recommendation is to allow light to get to the shoreline. If marsh exists, this would enhance it and potentially allow it to grow larger. However, in some areas where the marsh is non-existent, it could be useful to plant the existing substrate with marsh grass. To protect the marsh grasses, a temporary coir log can be staked in front of the planted grasses. More recently, grasses are planted in the coir log as well (https://coirgreen.com/using-coir-logs/). Another option is to use an oyster form in front of the marsh or the eroding bank. The same oyster bags and pre-cast forms can be used, but they can be smaller, lower, and less continuous than oyster sills. The idea is to provide substrate for oyster spat to settle thereby creating small reefs along the shoreline like what occurs naturally at MSP (Figure 4C). The oyster substrate is placed in the intertidal zone.

This same idea applies to the intertidal oysters recommendation. This strategy is separate from the previous category because there are no trees to trim or marsh to plant. It is recommened along wide marshes that are eroding, but no imminent threat to the upland is occuring. Low, small structures such as oyster bags, oyster castles or even granite can be placed against the eroding marsh edge. This only works for marsh that are eroding on the outside edge. This does not alleviate the issues marshes have with sea-level rise.

Table 2. Summary of site shoreline management recommendations.

Site Num.	Water Body	Length (ft)	Bank Face	Base of Bank	Marsh Width (ft)	Recommendation
1	Timberneck	471	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
2	Timberneck	820	Stable	Undercut/ Stable	5-10	Trim Trees, Plant Marsh, Intertidal Oysters
3	Timberneck	599	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
4	Timberneck	1,390	Transitional	Erosional	<5	Trim Trees, Plant Marsh, Intertidal Oysters
5	Timberneck	494	Stable/ Erosional	Erosional/ Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
6	Timberneck	223	Erosional	Erosional	<5	Oyster Sill
7	Timberneck	244	Erosional	Erosional	<5	Oyster Sill
8	Timberneck	365	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
9	Timberneck	213	Erosional	Undercut	<5	Oyster Sill
10	Timberneck	455	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
11	Timberneck	273	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
12	Timberneck	657	Transitional	Erosional	5-10	Low Rock Sill
13	Timberneck	1,804	Stable	Stable	10-100	Intertidal Oysters
13	Poplar	3,596	Stable	Stable	10-50	Intertidal Oysters
14	Cedarbush	291	Stable	Stable	>100	Oyster Sill
15	Cedarbush	406	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
16	Cedarbush	750	Transitional	Erosional/ Undercut	5-10	Low Rock Sill
17	Cedarbush	555	Transitional	Erosional	<5	Low Rock Sill
18	Cedarbush	571	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters
19	Cedarbush	1,005	Stable	Undercut	<5	Trim Trees, Plant Marsh, Intertidal Oysters

4.1.2 Reach Management

<u>*Timberneck Creek*</u>

Reach 1, Appendix E, the area of Timberneck Creek north of the single sill, is shown on Plates 1-4 and has 10 shore recommendation sites. It has primarily stable bank faces, erosional or undercut bank bases, and a very narrow marsh fringe (<5 ft). Several of the bank headlands are eroding, and the shorelines have an average long-term (1937-2019) erosion rate of -0.3 ft/yr. The most northern section of Reach 1 has the least amount of shore change, but Plates 3 and 4 show that some areas of marsh have eroded since 2007, particularly in the pocket beaches. Sites 1-5, 8 and 10 (Appendix E) has a recommendation to trim trees, plant marsh, and intertidal oysters.

However, the shoreline within each of these sites is highly variable. Adjacent shorelines can have varying widths of marsh and one section of upland bank can be relatively stable while the one next to it has an eroding scarp (Figure 20). Sites 6, 7 and 9 have exposed bank faces that are are actively eroding. For the upland to become stable, an oyster sill is recommended. Fallen trees will need to be removed from these sites before the oyster sills are installed. If marsh exists, the sill should be placed in front of it. Trimming trees and planting marsh could also help stabilize the shoreline behind the sills.

Reach 2, extends from the small single existing sill to the southeast point of the park. It has primarily stable or transitional bank faces, erosional or undercut base of bank, and an average long-term (1937-2019) erosion rate of -0.4 ft/yr. The location of the existing sill shows as long-term accretion. Reach 2 is shown on Plate 4 and has 2 management recommendation sites. Site 11 is located behind the floating pier. It has a stable bank face because the wave impacts are limited due to the pier. The base of bank is undercut in some areas and the marsh is narrow (< 5ft). Site 12 has a transitional bank face with some areas scarped even as others are protected by a wider marsh. The base of bank is erosional and though the marsh width is shown as 5-10 ft, in truth it is variable along the site. Some areas do have a nice wide marsh with low and high marsh and even some scrub shrub, whereas other areas have an exposed base of bank and bank face. This section of shore is one of the most visible in the park due to the pier and has an erosion issue that should be addressed. The upland adjacent to this area has a several areas where cultural resources have been mapped. For these reasons, this site was chosen for the site-specific living shoreline design.

Reach 3 is the area of Timberneck Creek directly behind the exisiting sill system. It has a stable bank face and base, and an average long-term (1937-2019) accretion rate of +0.3 ft/yr due to the construciton of the sill. This site has been addressed so no recommendations were made. However, the longer sill was designed to be higher on the ends (+5 ft MLW) and lower in the middle (+3.5 ft MLW). This section of shoreline should be monitored to ensure that marsh is not being lost behind the center part of the structure due to sea-level rise.

Reach 4 is shown on Plates 5 and 6 and has one site (13). It is located adjacent to the sill system west of the point. It has a stable bank face and base, and an average long-term (1937-2019) erosion rate of -0.16 ft/yr. Though the marshes are relatively wide along this reach (Figure 21) (Appendix D), some sections of marsh are eroding (Appendix C). For that reason, the management recommendation is to use intertidal oysters in front of the marsh. Some areas of the marsh are thinner than others such that overhanging trees may be an issue. If so, they can be trimmed. If areas appear to be eroding more quickly, a slightly higher intertidal oyster structure can be used, particularly in the vicinity of the pier (Figure 21). Sea-level rise is beginning to impact this area as evidenced by the ghost trees in the marsh.

Poplar Creek

Reach 5 is shown on Plates 7 and 8 and has one site, which is actually a continuation of Site 13 because it also has wider marshes that protect the upland bank. Along Poplar Creek, the bank face and base are stable, and the shorelines have an average long-term (1937-2019) erosion rate of -0.68 ft/yr. The marshes have lost acreage since 2007. The recommendation for this section of shoreline is intertidal oysters to help reduce erosion along the front of the marsh.

Cedarbush Creek

Reach 6 occurs along Cedarbush Creek and is shown on Plates 9-11. Sites 14-19 are along this stretch of shoreline. Overall, the reach has primarily stable bank faces, erosional and undercut bank bases, and an average long-term (1937-2019) erosion rate of -0.33 ft/yr. Site 14 fronts an extensive marsh that is eroding. For this site, an oyster sill is recommended.

Sites 16 and 17 have transitional bank faces and eroding or undercut base of bank with narrow marshes. These shorelines are in front of the camping area and steep eroding banks and fallen trees are safety hazards. As such, a low rock sill living shoreline would be a good demonstration area. In addition, recreational access could be built into the design while protecting the shoreline. Sites 15, 18 and 19 have stable bank faces, undercut bases of bank, and narrow marshes. The recommendation along these shorelines is to trim trees and install intertidal oyster structures and plant marsh grass.

4.2 Living Shoreline Plan

Living Shorelines are a preferred management practice that address erosion and enhance ecosystem services by providing long-term protection, restoration, or enhancement of vegetated shoreline habitats through strategic placement of plants, stone, sand fill and other structural or organic materials (Hardaway et al., 2021). Living Shorelines is the overarching guide for the recommended management strategies along Machicomoco because they are effective shore protection and will protect archaeology while establishing a marsh edge at the site and recreating habitat that existed during the time of the Powhatan.

At Machicomoco, two living shoreline systems already exist. Both the gapped sill system and the single sill next to the large pier with floating docks in Timberneck Creek are living shoreline systems, as they consist of stone structures that have been filled in behind by native saltmarsh grasses (Figures 6 and 7). The site-specific design for Site 12 is similarly sized to these existing structures.

4.2.1 Design

A living shoreline system design must include managing and restoring riparian vegetation as well as minimizing nearshore impacts and increases marsh area. For Site 12 at MSP, 3 stone sills will be built along the shoreline between the existing stone sill system at the point and the shoreline behind the boat dock (Figure 22). Stone sills are trapezoidal structures often consisting of a central core of smaller stones covered with filter fabric, which is then covered by larger armor stones that usually extend out in an "apron" on the front side facing the water. The area behind the sill is then filled with sand and graded, and native marsh grasses, in this case *Spartina patens* and *Spartina alterniflora*, are planted in the sand. Goose fencing then temporarily placed over the marsh grasses to protect them from grazing animals such as ducks and geese until they have established themselves. Overhanging tree limbs should be trimmed, and trees that are on the bank and leaning should be removed. Also, fallen dead trees need to be removed.

The sills are placed about 30 feet offshore from the bank. Sill 1 is 192 ft long, Sill 2 is 300 ft long, and Sill 3 is 147 ft long. The crest elevation is +4 ft MLW and is 3 ft wide. The overall structure width is 14 ft. The sand fill extends about 20 feet landward from the back of the sill and will be planted with *Spartina patens* and *Spartina alterniflora*. The sand fill intersects the structure at +2 ft MLW and extends landward 10 ft to MHW. From there, it has a steeper slope to +4 ft MLW where it intercepts the bank face. Two gaps, 8 ft and 21 ft wide occur between the structures. In the past, the recommendation has been for the sand to intersects at mean tide level. However, tide data was collected by CBNERR on the pier at MSP indicated an increase in water levels on a regular basis. About 1.5 years of water level data taken every minute (6/1/2020-12/1/2021) was plotted relative to MLW and analyzed for general elevation trends (Figure 23). The data showed that in that time, MHW was exceeded for 2,621 hours. Water levels were higher than 3.5 ft MLW for 287 hours, and for 7 hours it exceeded 4.5 ft MLW. The highest water level recorded was about +5 ft MLW on 29 May 2021. Because marsh vegetation is tolerant to certain habitats, these high-water levels will impact how well the grasses maintain themselves over time.

Though much of the shoreline has exposed eroding bank, some sections of shore have marshes with scrub shrub and some have no marsh with exposed eroding bank. Figure 24 shows the habitats that the sand fill will impact. It varies behind each structure. It's important to note that because of the variability, the typical profiles do not represent all the areas behind the structures. Figures 25-29 show photos and typical cross-section for the profile associated with the sill or gap. These also highlight the variability of the marsh fringe. It is important to note that in areas with marsh fringe, the base of the bank is still erosional and the bank face transitional.

Access to the site can be through area where the elevation drops gradually which will make it easier to move the construction equipment to the shoreline (Figure 22). A stockpile is shown adjacent. Presently, no cultural resources have been mapped in this area. In order to protect known and potential archeological sites in the construction and access areas, logging mats will be placed along the access route in order to disperse the weight of trucks bringing construction materials and supplies to the site. The draft joint permit application is in Appendix F for this project. The estimated cost for sand and rocks is about $455 per foot installed. The living shoreline covers about 670 ft. An additional 20% should be added for mobilization, demobilization, and site work was well as for plants and planting supplies. This results in an approximate cost of $365,800 to construct this project. However, this is just an estimate. Final costs will depend on materials and installation costs at the time of construction.

4.2.2 Monitoring, Maintenance, and Resiliency

Because Machicomoco State Park is such a valuable area both recreationally and culturally, it is important that the site continue to be monitored to ensure that the shoreline structures remain in good condition and are protecting the park and potential archaeological sites from erosion and sea level rise. This can be done via lidar or by an in-person assessment and survey of the area. Additionally, it will be important to monitor the progress and health of the existing, both natural and constructed, and newly-created marshes, as they are vital to protecting the shorelines from erosion.

A monitoring protocol was developed for the Leesylvania State Park living shoreline and is applicable at this site as well (Milligan et al., 2019). It included easy to use metrics for determining if the living shoreline system is meeting the goals set forth in the management strategy. The metrics include visually determining changes in topography, vegetation coverage, and tidal inundation. These are the three main factors affecting the success of a living shoreline project. Other considerations include watching plant types in the marsh. *Phragmites australis* is a highly invasive plant. If *P. australis* gets a foothold in the system, it should be controlled as quickly as possible (NRCS, no date).

Additional maintenance to the sill systems may be necessary over time. If debris floats into the marsh, it should be removed before it kills the marsh. Trees will be limbed as part of the project construction to avoid overhang and shading of the marsh. However, over time, the trees will regrow and should be periodically limbed to ensure the marsh has enough sunlight to continue to grow. After storms, additional sand and grass plantings may be necessary.

Resiliency was a consideration in the design of the living shoreline project. The rocks have a little higher elevation than the existing sill immediately up the creek from this site. Typically, low marsh (*S. alterniflora*) grows from mid-tide level to MHW. In the past, the system was designed to intersect the sand with the back of the sill at mid-tide. However, due to extended hours of inundation higher the MHW, the sand in the living shoreline intersects just 0.5 ft below MHW. This gives the *S. alterniflora* better chances of survival with more frequent inundation. Over the long-term, the marsh should be monitored to ensure that it is migrating with the increased water level. Due to the high bank at this site, the marsh will not be able to migrate laterally so it will need to migrate upward to maintain itself. Designing the system so that the marsh platform starts closer to existing high water will increase its ability to maintain itself. However, additional rock and sand can be added as needed in the future.

5 Summary

As the newest state park in Virginia, Machicomoco has become a cultural resource; both as a recreational area, and as a historic and archeological site. It has almost 4 miles of shoreline that spans the coast of three creeks, and is protected along the York River by the outlying Catlett Islands. While the Catlett Islands are quickly eroding away, the park area behind them is, for the time being, mostly stable; though the shoreline along Poplar Creek is retreating from sea level rise. Machicomoco's other shorelines in Cedarbush and Timberneck Creek are more stable, and are experiencing low erosion rates. The areas of park shoreline behind the current living shoreline systems remain stable after 10 years, which is why the Shoreline Studies Program has advised for the construction of another living shoreline system in the area between the boat dock and existing sills to further stabilize the shoreline. Other recommendations for the park shoreline include trimming trees that overhang the shoreline shading out the marsh, planting marsh is in existing substrate, and using oyster bags and pre-cast concrete forms to create oyster sills and enhance the intertidal area. Several other low rock sills are recommended along both Cedarbush Creek. It is the hope that these systems will continue to protect the shoreline of the park from erosion, storm surges, and sea level rise so that people will be able to enjoy this important cultural area for years to come.

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Appendix A

Project Location &

Existing Shoreline

Conditions Overview

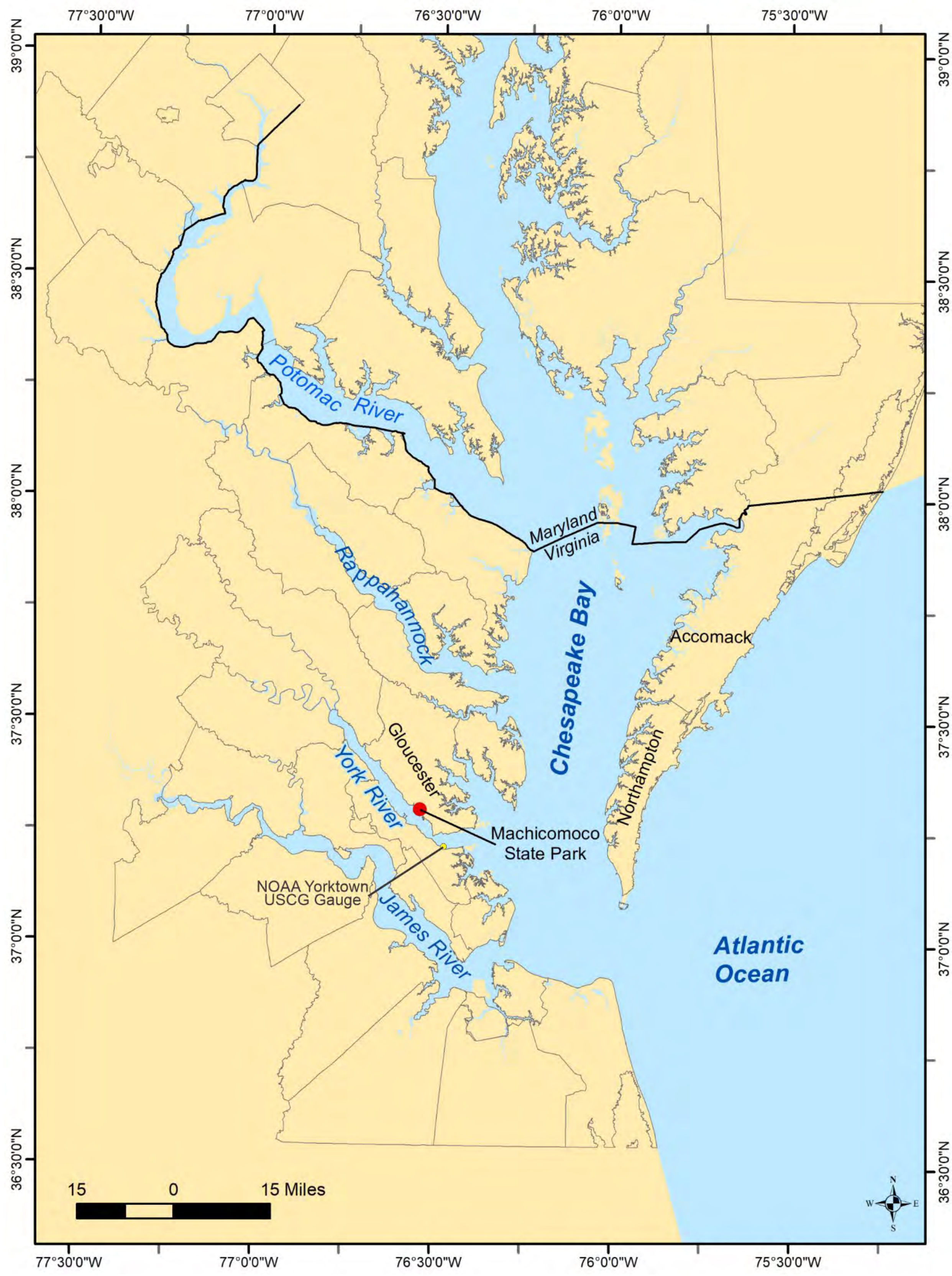


Figure 1. Location of Machicomoco State Park within the Chesapeake Bay estuarine system. Lat/long location: 37.307279°, -76.541560°.

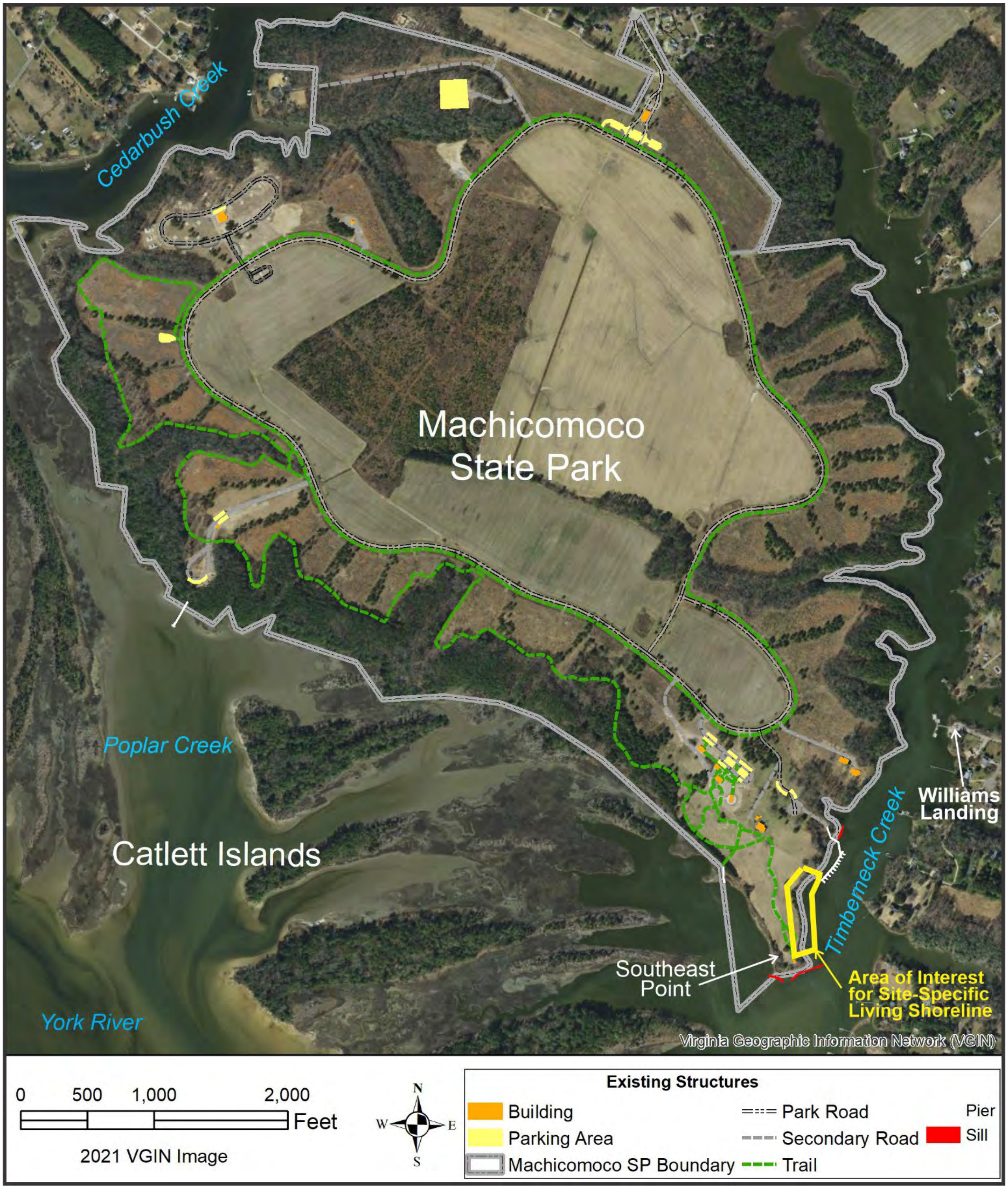


Figure 2. Physical and hydrodynamic boundaries of Machicomoco State Park with existing park infrastructure and shoreline structures.

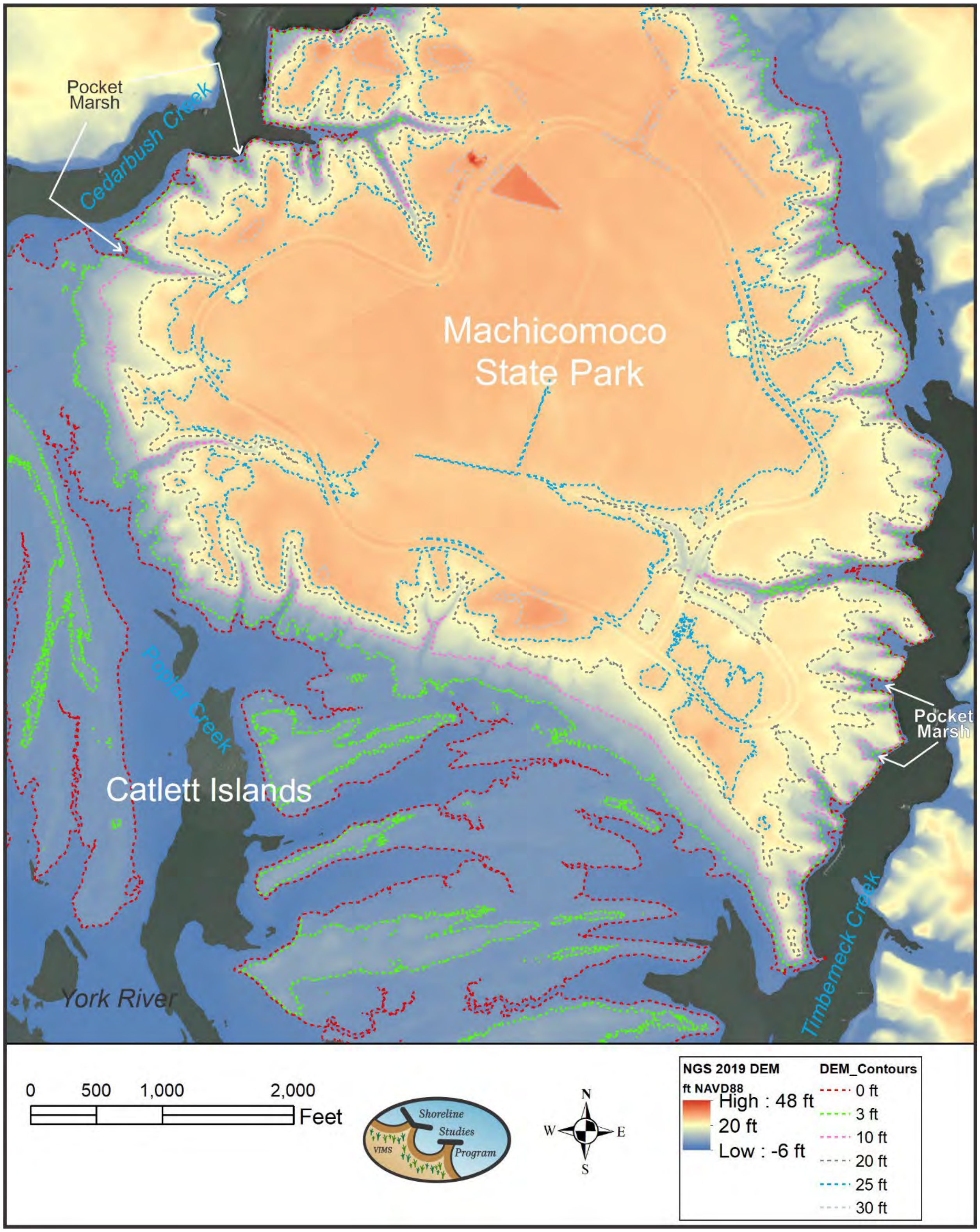


Figure 3. Digital elevation model and elevation contour lines, relative to NAVD88, from the 2019 National Geodetic Survey Lidar data for Machicomoco State Park. Several examples of pocket marshes are identified along the creeks.

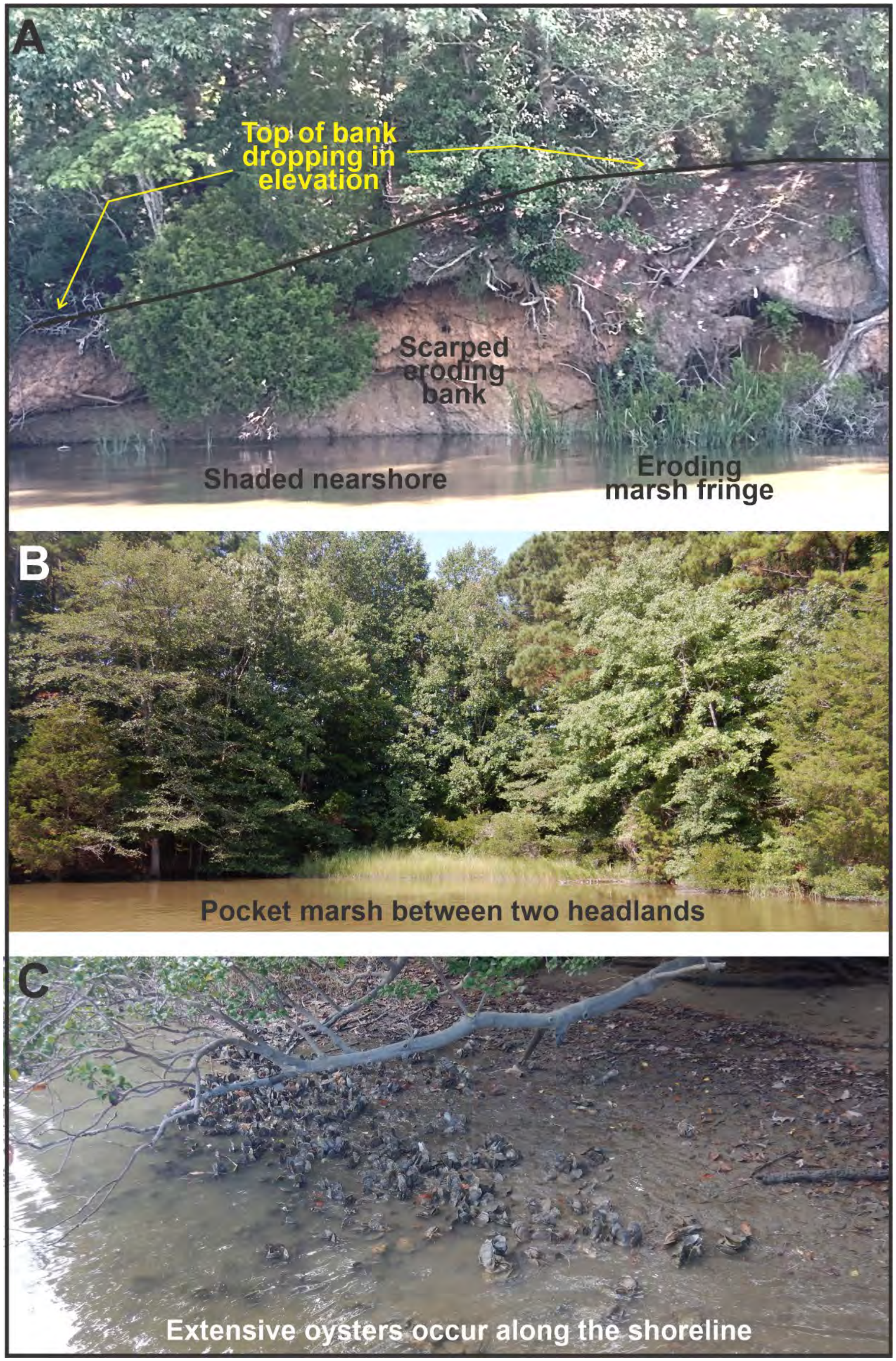


Figure 4. Photos taken of the MSP shoreline in 2021 showing A) an eroding bank face, B) a pocket marsh, and C) oysters along the shoreline.

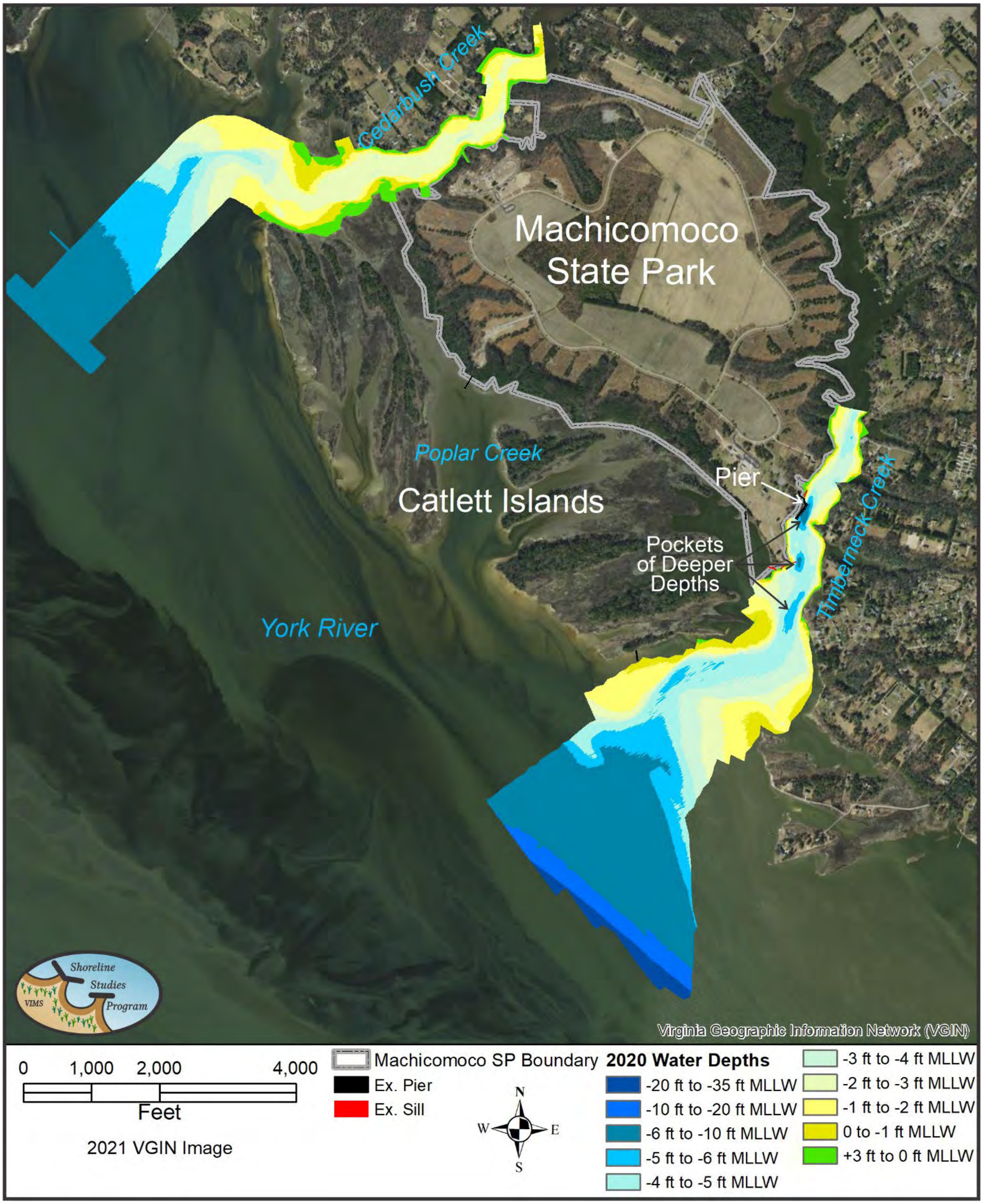


Figure 5. Bathymetric digital elevation model data of Timberneck and Cedarbush Creeks.

Figure 6. Sill constructed at the southeastern tip of the park on Timberneck Creek in 2011. Photo date 24 Aug 2021. Lat/long location: 37.294578°, -76.534841°

Figure 7. Sill constructed adjacent to the pier on Timberneck Creek. Photo Date 1 Nov 2021. Lat/long location: 37.297472°, -76.533842°

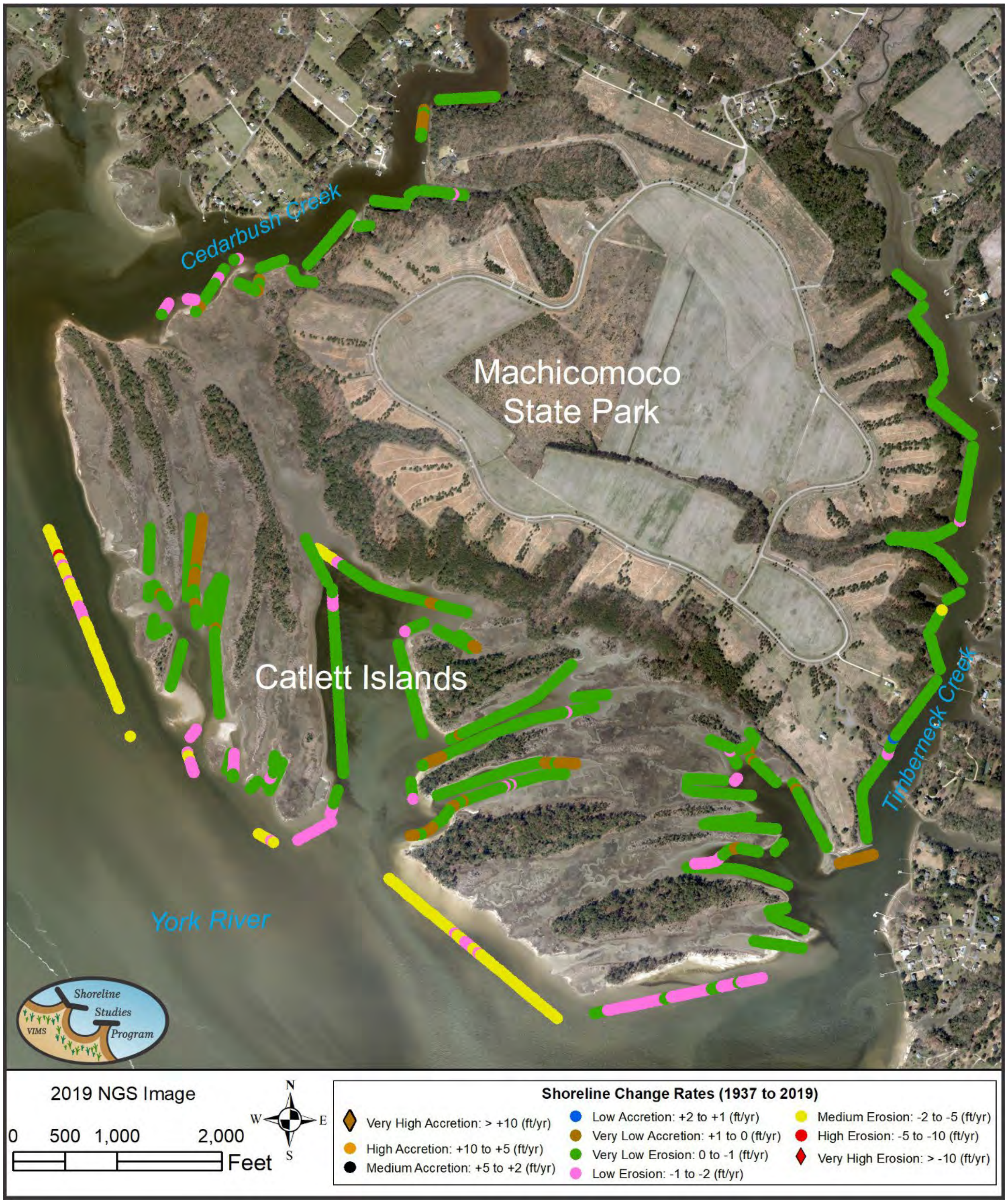


Figure 8. Long-term shore change at Machicomoco State Park and Catlett Islands from the Shoreline Studies Program Shore Change Database.

Figure 9. Shore loss and gain at Machicomoco State Park and Catlett Islands from the Shoreline Studies Program Shore Change Database.

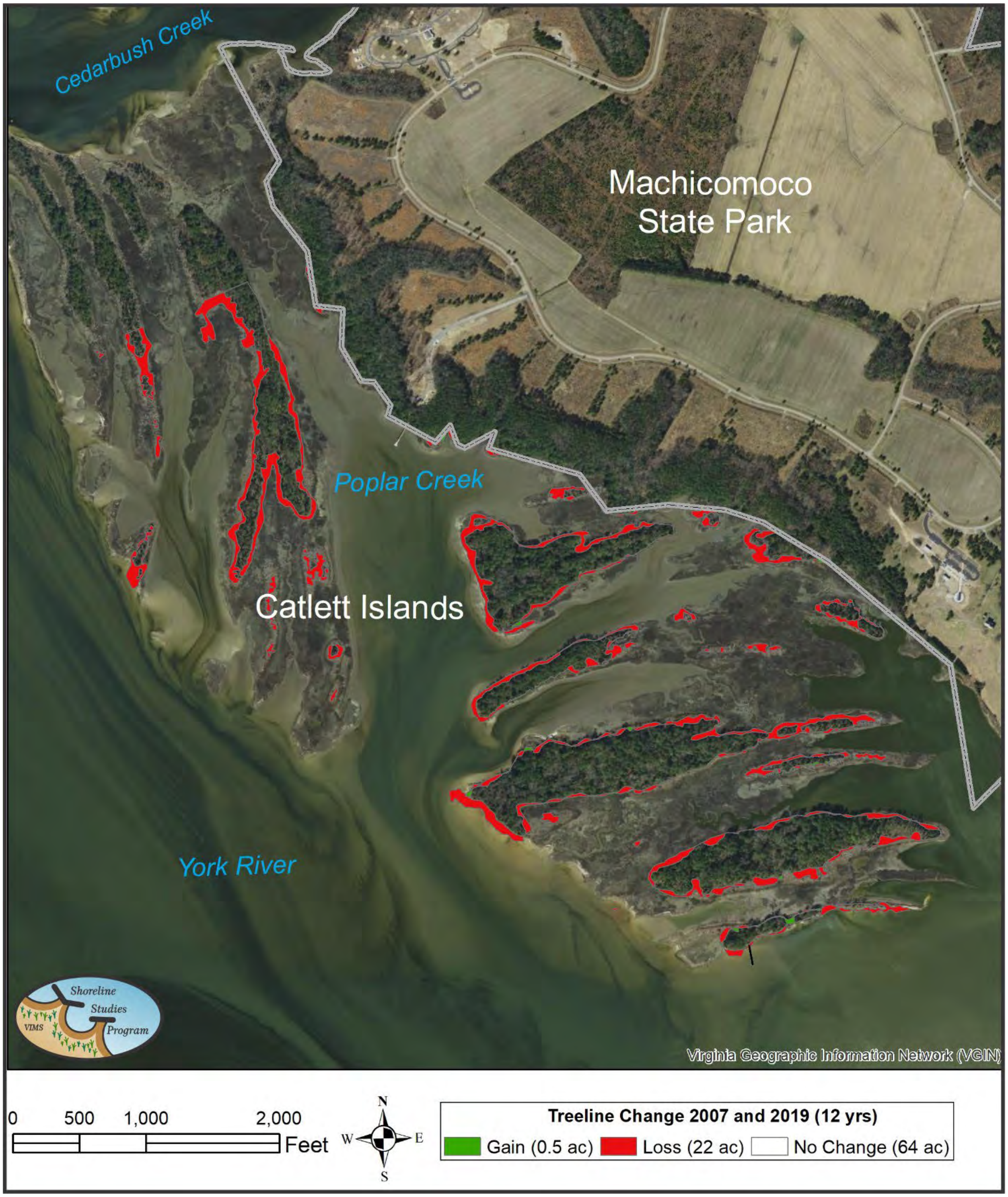


Figure 10. Loss of upland trees at Catlett. Due to sea-level rise, the tree line is being converted to marsh as it migrates higher in elevation.

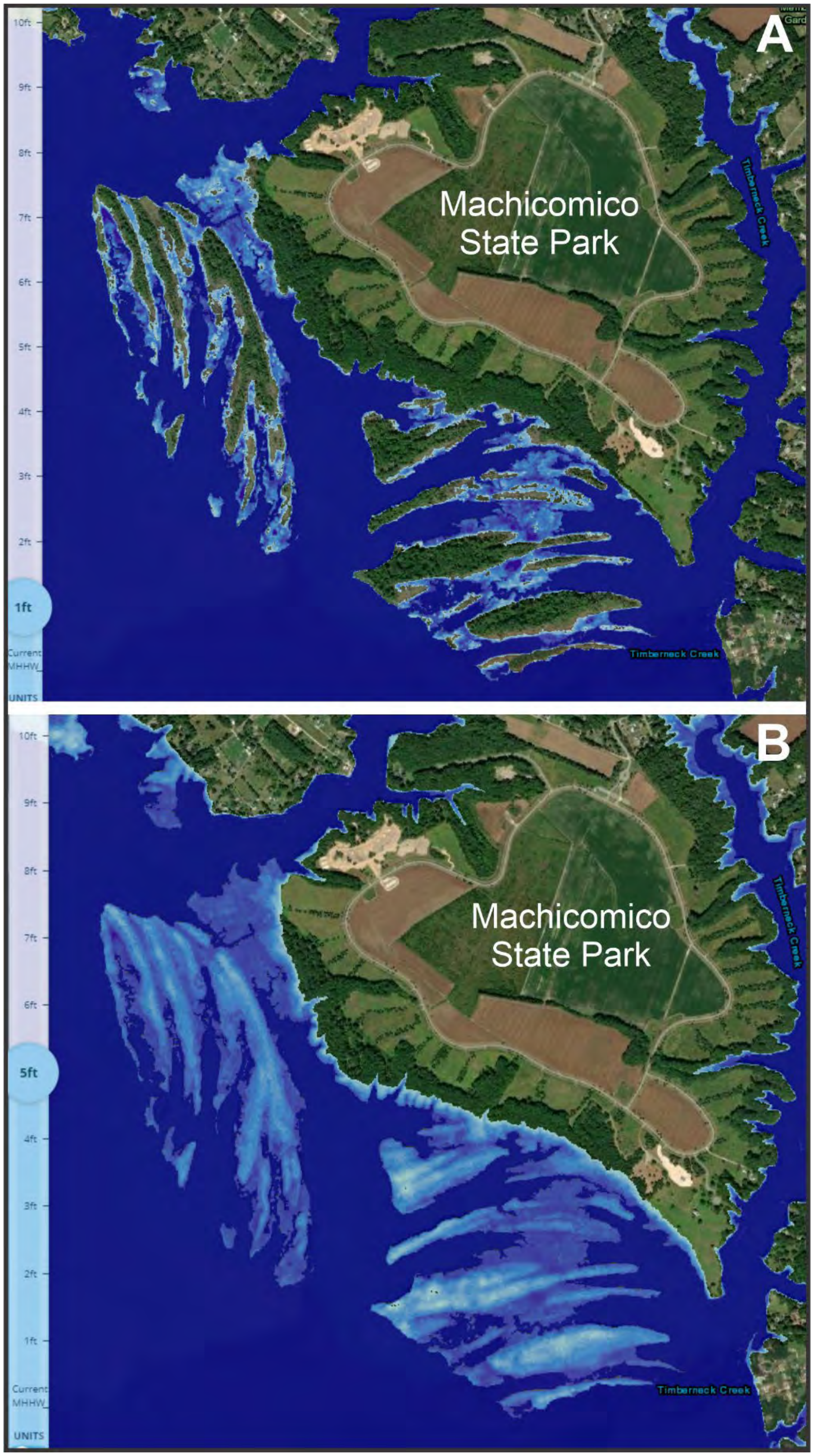


Figure 11. NOAA's sea-level rise viewer Machicomoco and Catlett Islands. A) shows +1 ft mean higher high water, and B) shows +5 ft mean higher high water. [*https://coast.noaa.gov/slr/#/layer/slr*](https://coast.noaa.gov/slr/#/layer/slr)

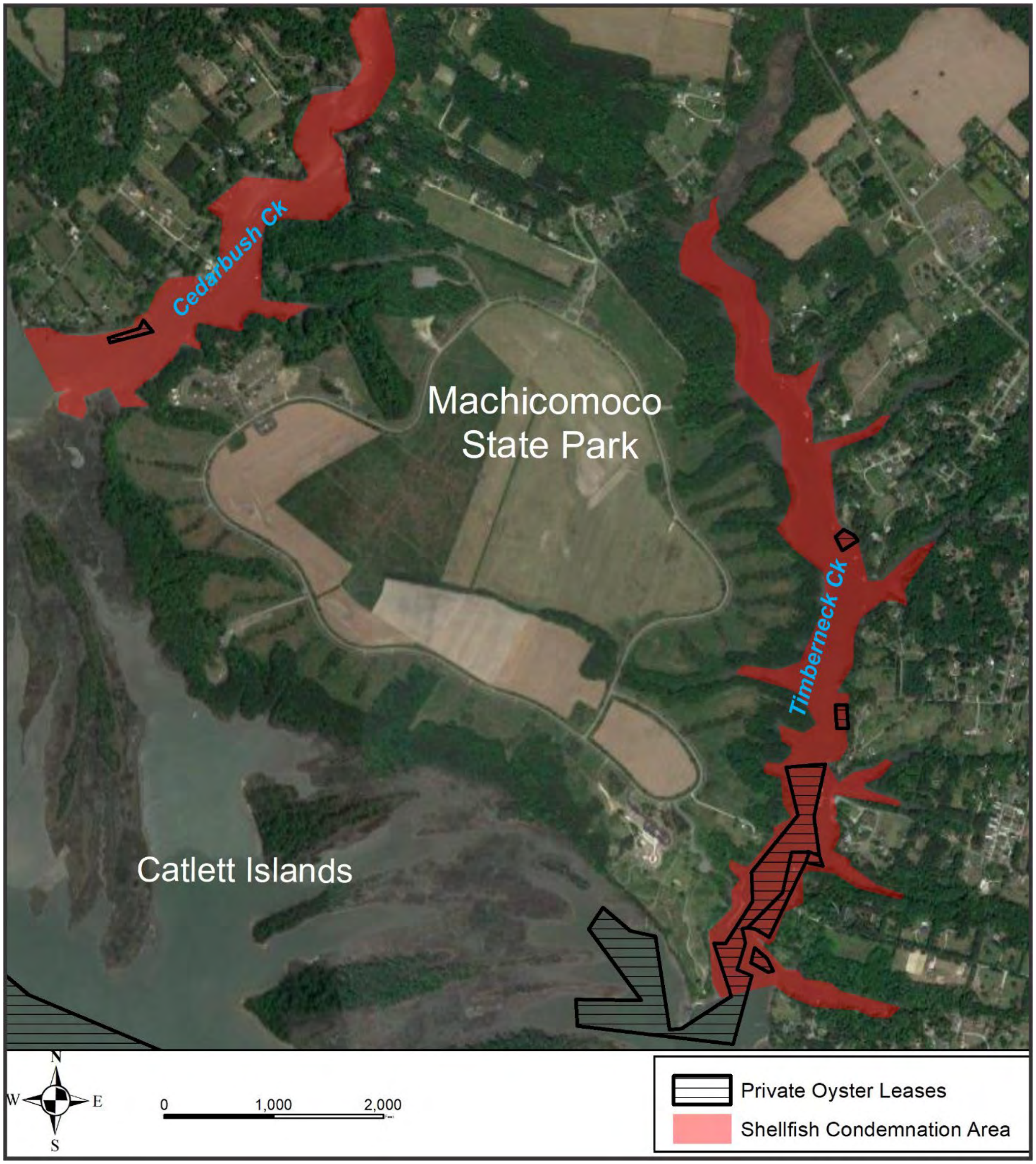


Figure 12. Private oyster leases from the Virginia Marine Resource Commission's database and shellfish condemnation areas from the Virginia Department of Health in Timberneck and Cedarbush Creeks.

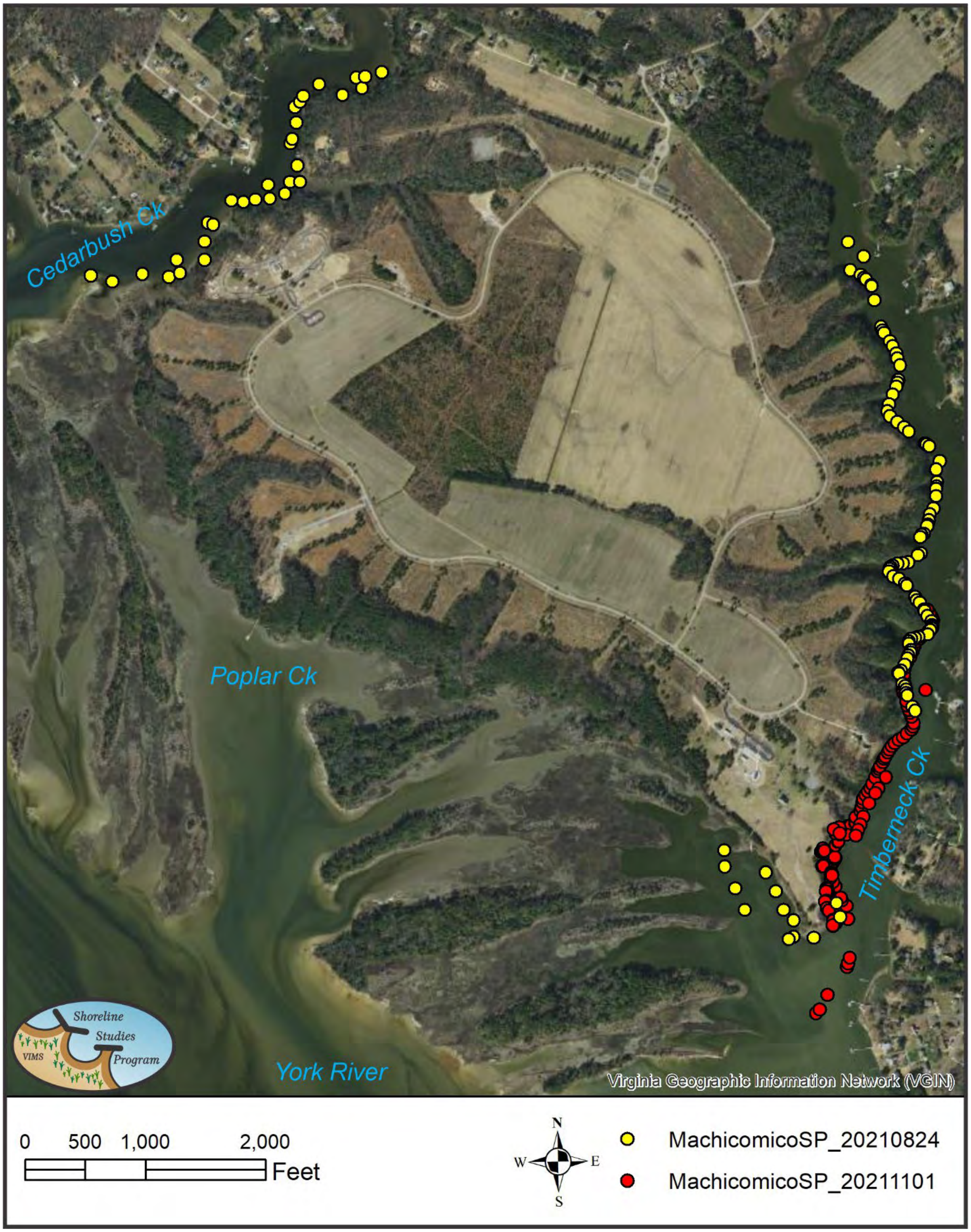


Figure 13. Locations of geo-tagged photographs taken during the boat and elevation surveys.

Figure 14. Elevation survey (1 Nov 2021) of the area chosen for the site-specific living shoreline design.

Figure 15. Reach designations for Machicomoco's shorelines.

Figure 16. Plate index for shore conditions and management strategy recommendations.

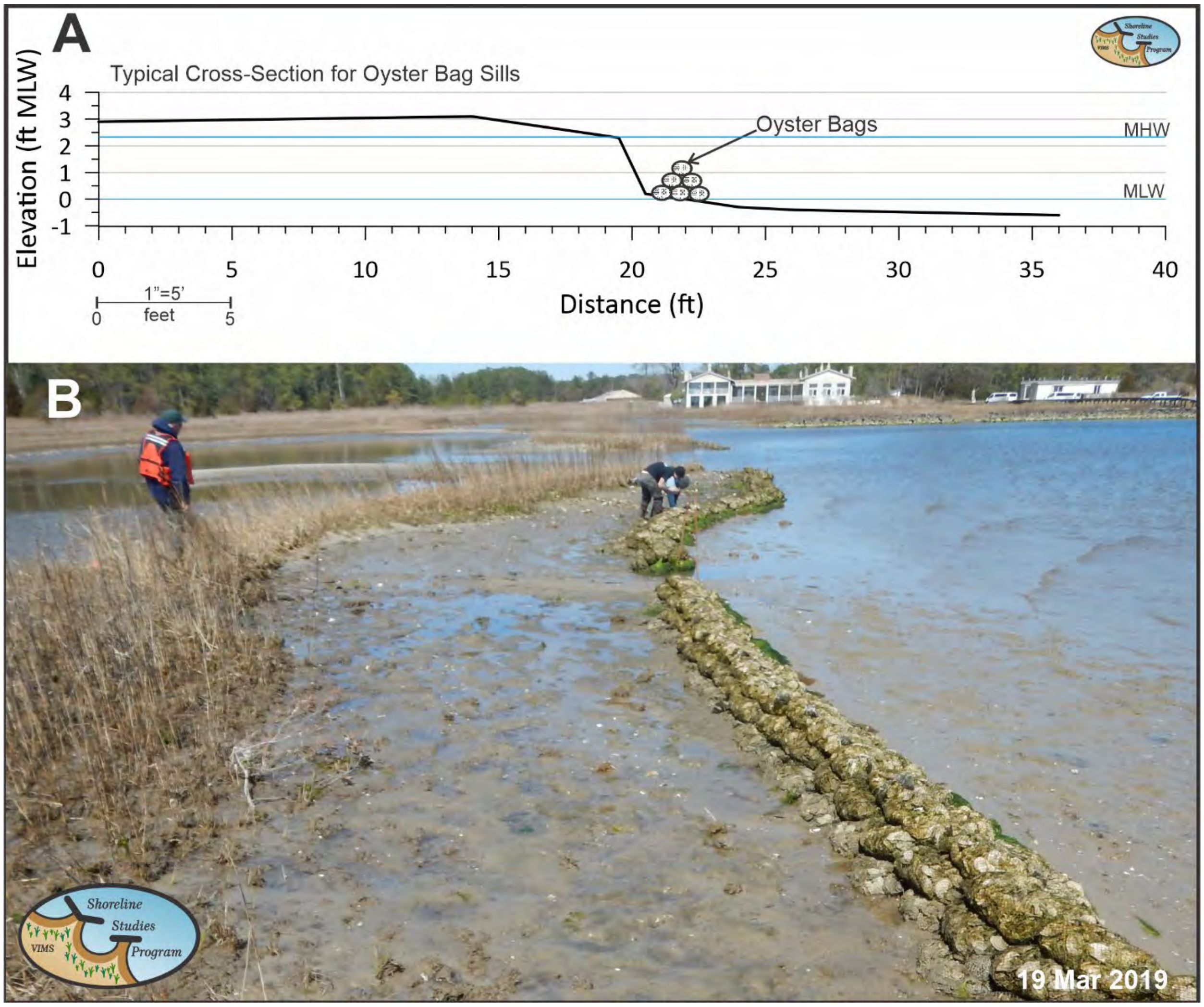


Figure 17. A) A typical oyster bag sill cross-section from Hardaway et al. (2020a); and B) a six-bag oyster bag sill one year after installation at Captain Sinclair's Recreational Area (Milligan et al., 2018).

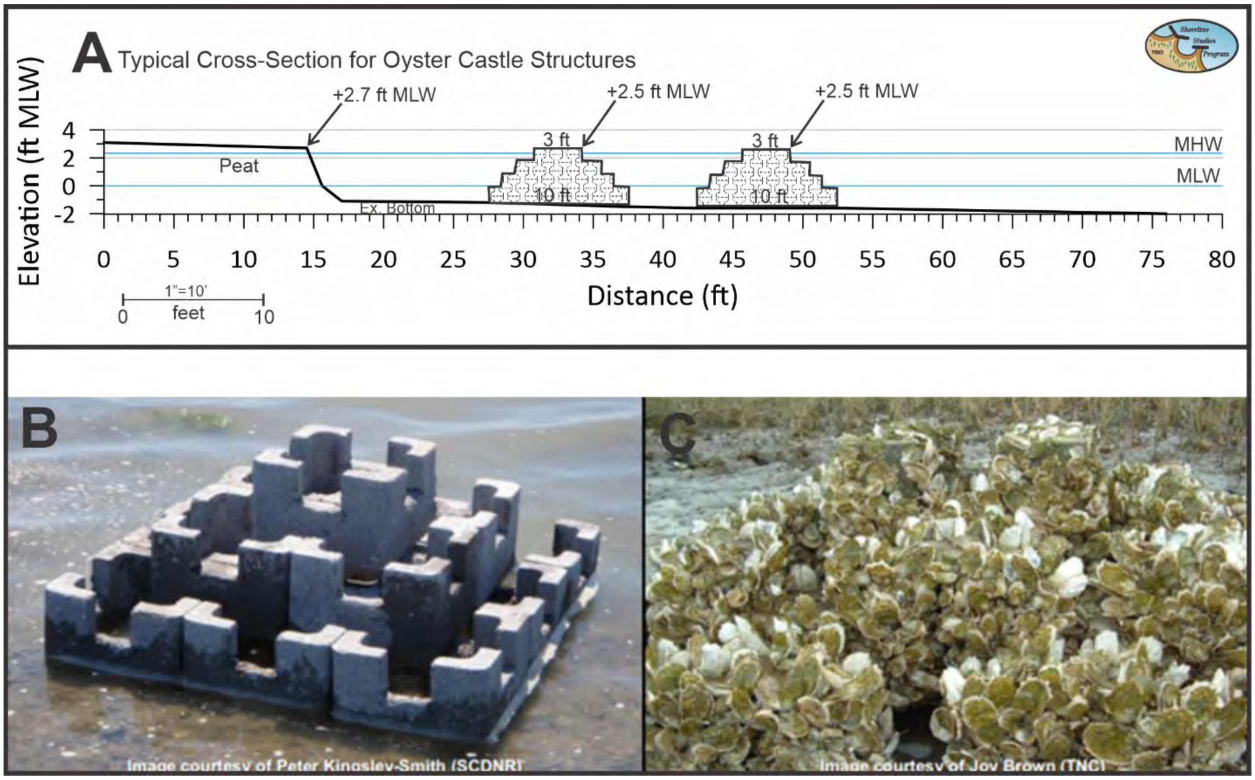


Figure 18. A) A typical oyster castle cross-section from Hardaway et al., (2020a) and B) images of the oyster castles just after installation, and C) after oysters have grown. Images obtained from https://blogs.ubc.ca/royaloysters/2014/11/25/oysters-thriving-on-man-made-castles-installed-on-south-carolinas-shores/.

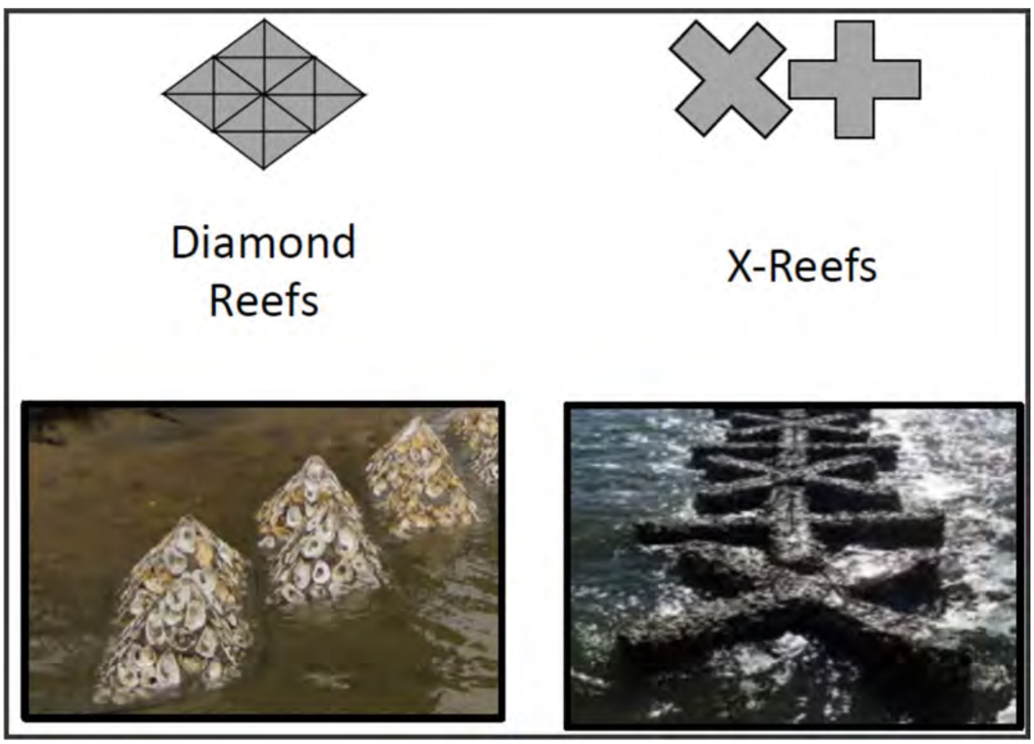


Figure19. Configuration of diamond reefs and X-reefs along with photos of their installation. Courtesy of R. Burke (CNU).

Figure 20. Photos taken along Reach 1 in Timberneck Creek. The two sites are directly adjacent to one another. The scarped bank would require more work to become stable.

Figure 21. Photos of the shoreline at Site 13 west of the point. Photos courtesy of the Virginia Department of Parks and Recreation.

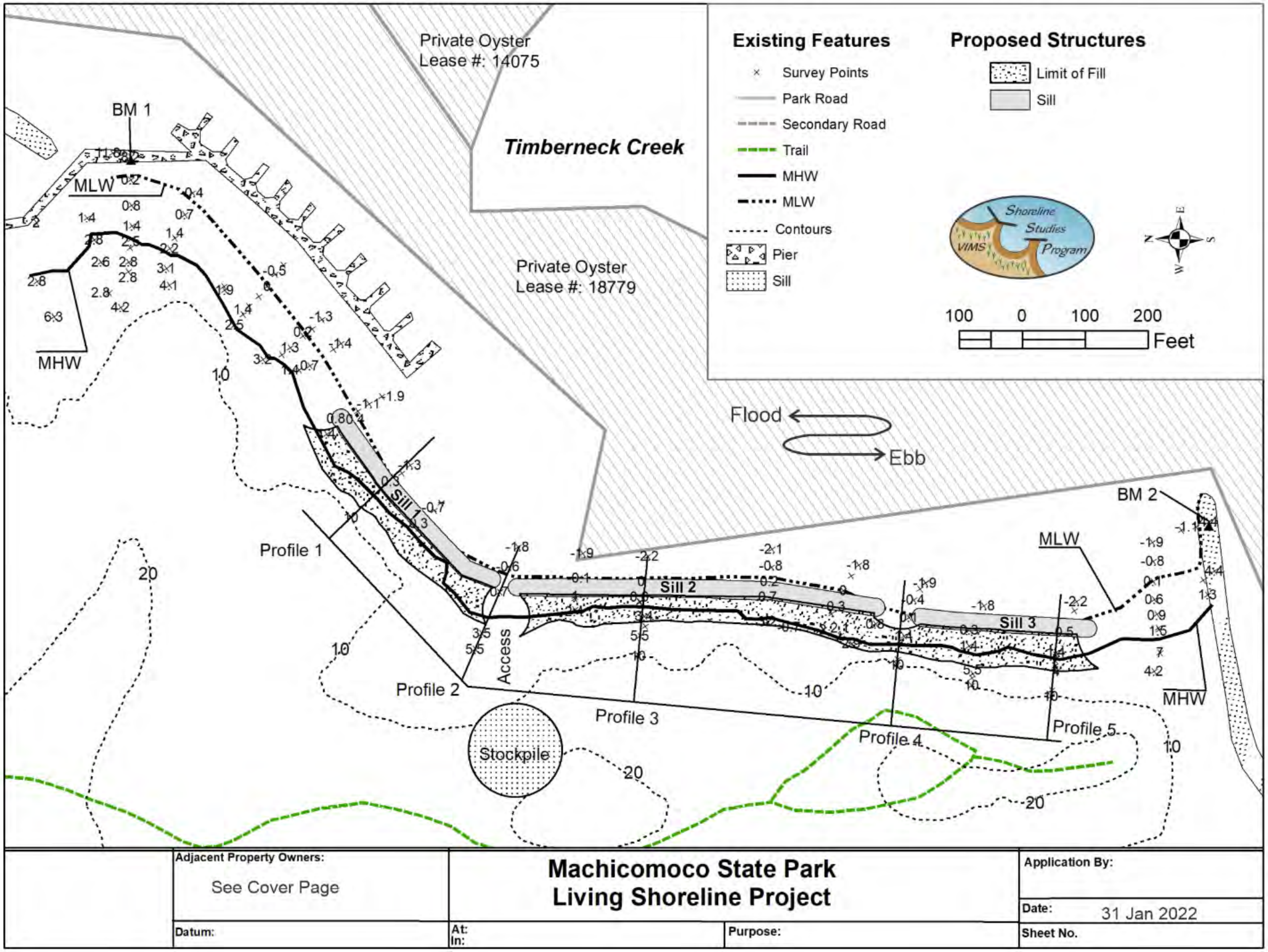


Figure 22. Planform for the living shoreline design for Site 12.

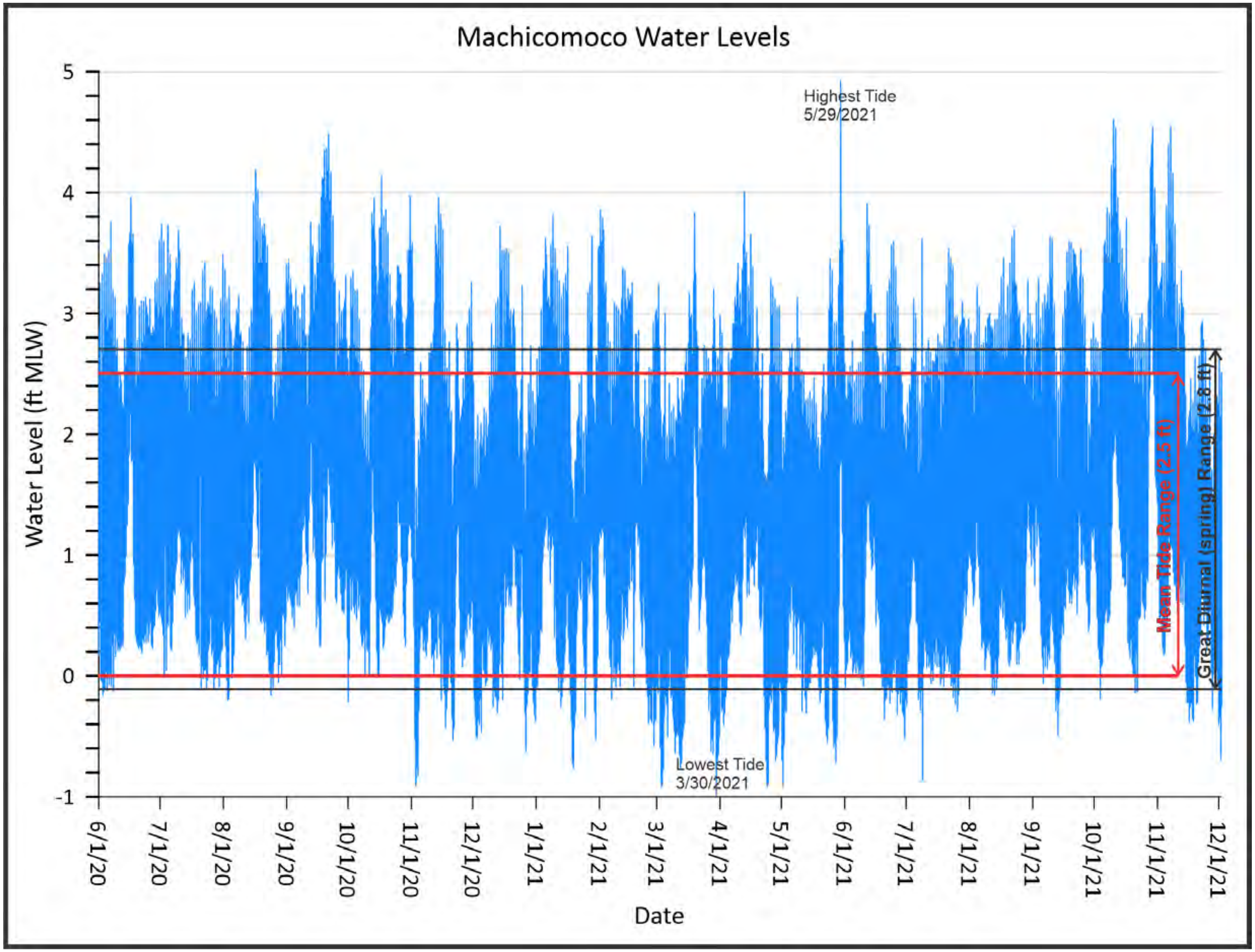


Figure 23. Water levels taken every minute for 1.5 years by CBNERR at MSP plotted relative to MLW. The MHW and MHHW water lines are shown on the plot.

Figure 24. Planform showing the impact of the sand fill on the existing habitats. The shoreline along this reach varies between marsh fringe and no marsh fringe with a scarped, eroding bank.

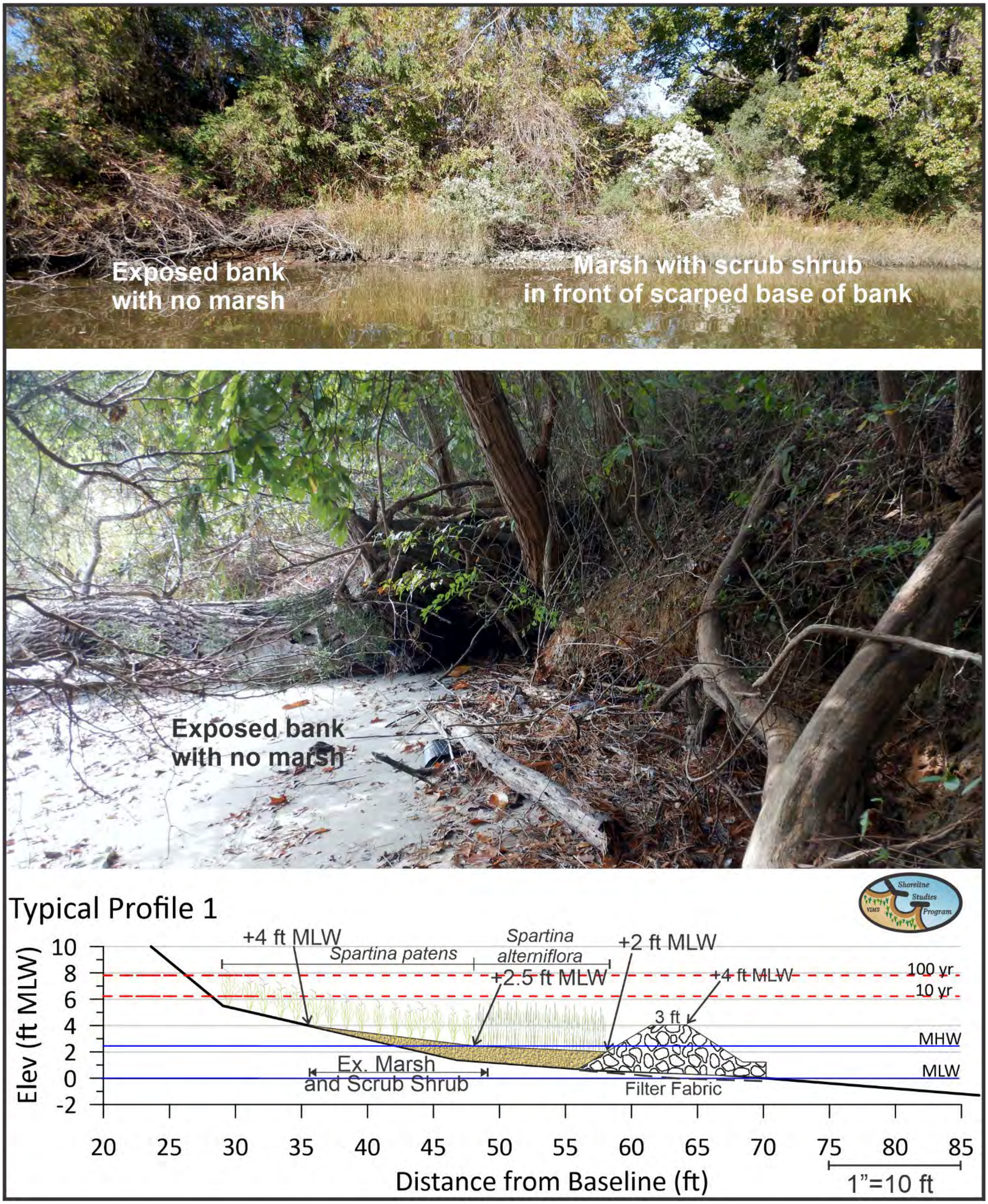


Figure 25. Photos showing the (top) northern section of sill 1 with its marsh and scrub shrub and (middle) the southern section of sill 1 where no marsh exists. The bottom is the typical profile of sill 1. However, it shows the northern section, not the southern section.

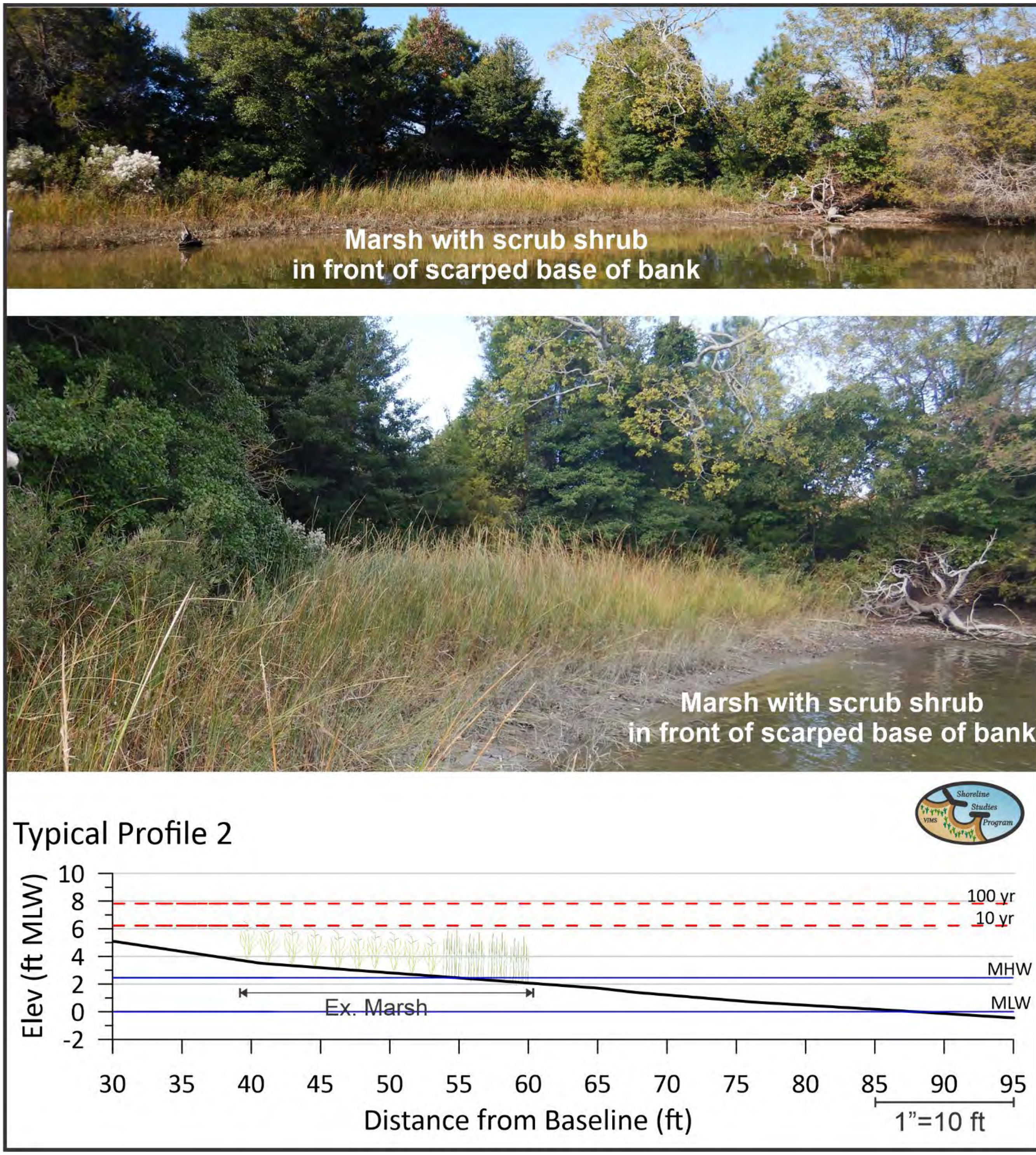


Figure 26. Photos showing the gap between sills 1 and 2. A wide marsh with a gentle slope exists here. The typical profile shows that no additional sand is needed.

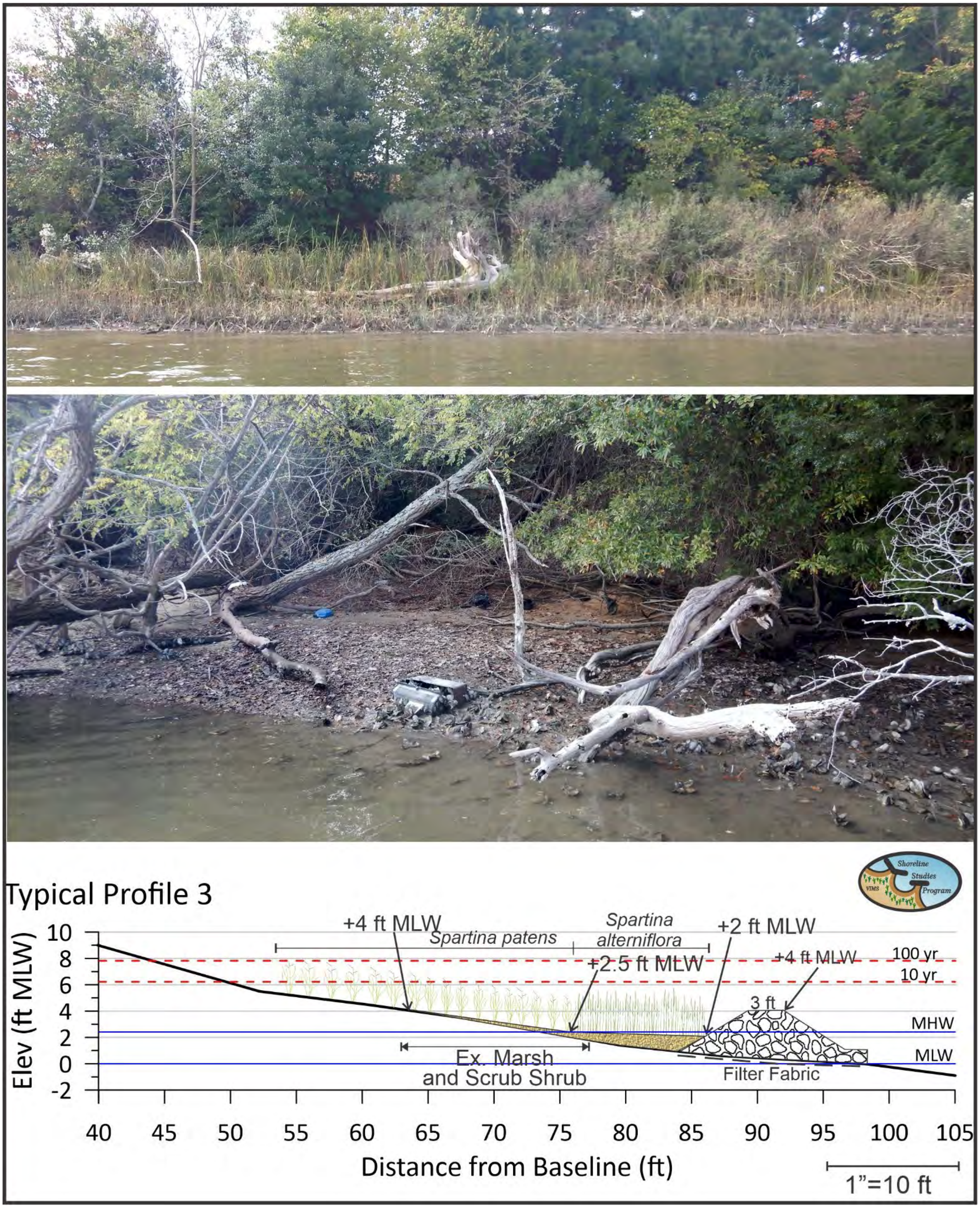


Figure 27. Photos showing the (top) northern section of sill 2 with its marsh and scrub shrub and (middle) the southern section of sill 2 where no marsh exists. The bottom is the typical profile of sill 2. However, it shows the northern section, not the southern section.

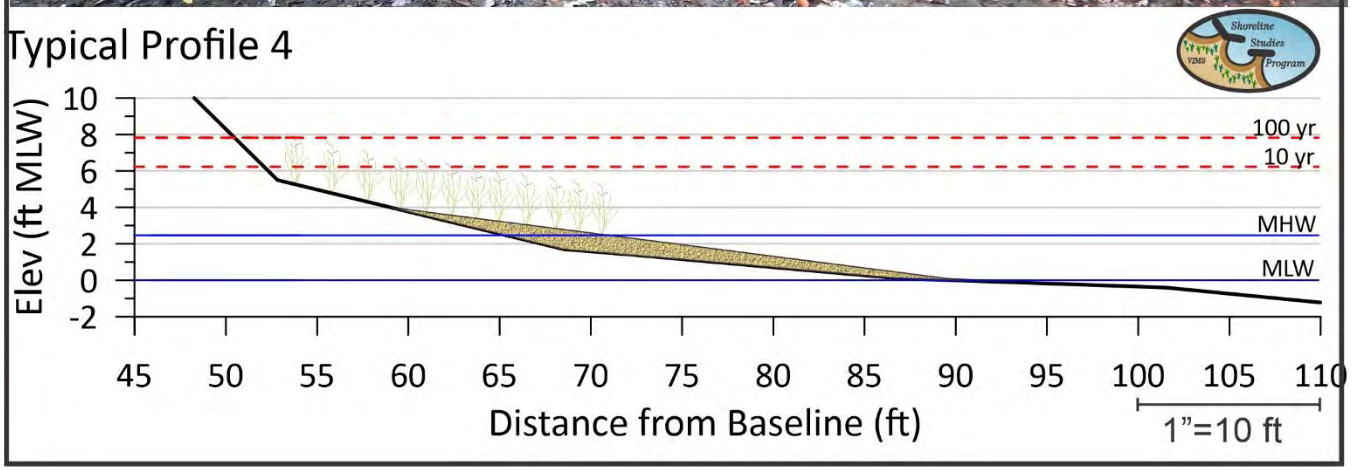


Figure 28. Photos showing the gap between sills 2 and 3. This profile has no marsh and an exposed bank. The typical profile shows that sand and plants are needed.

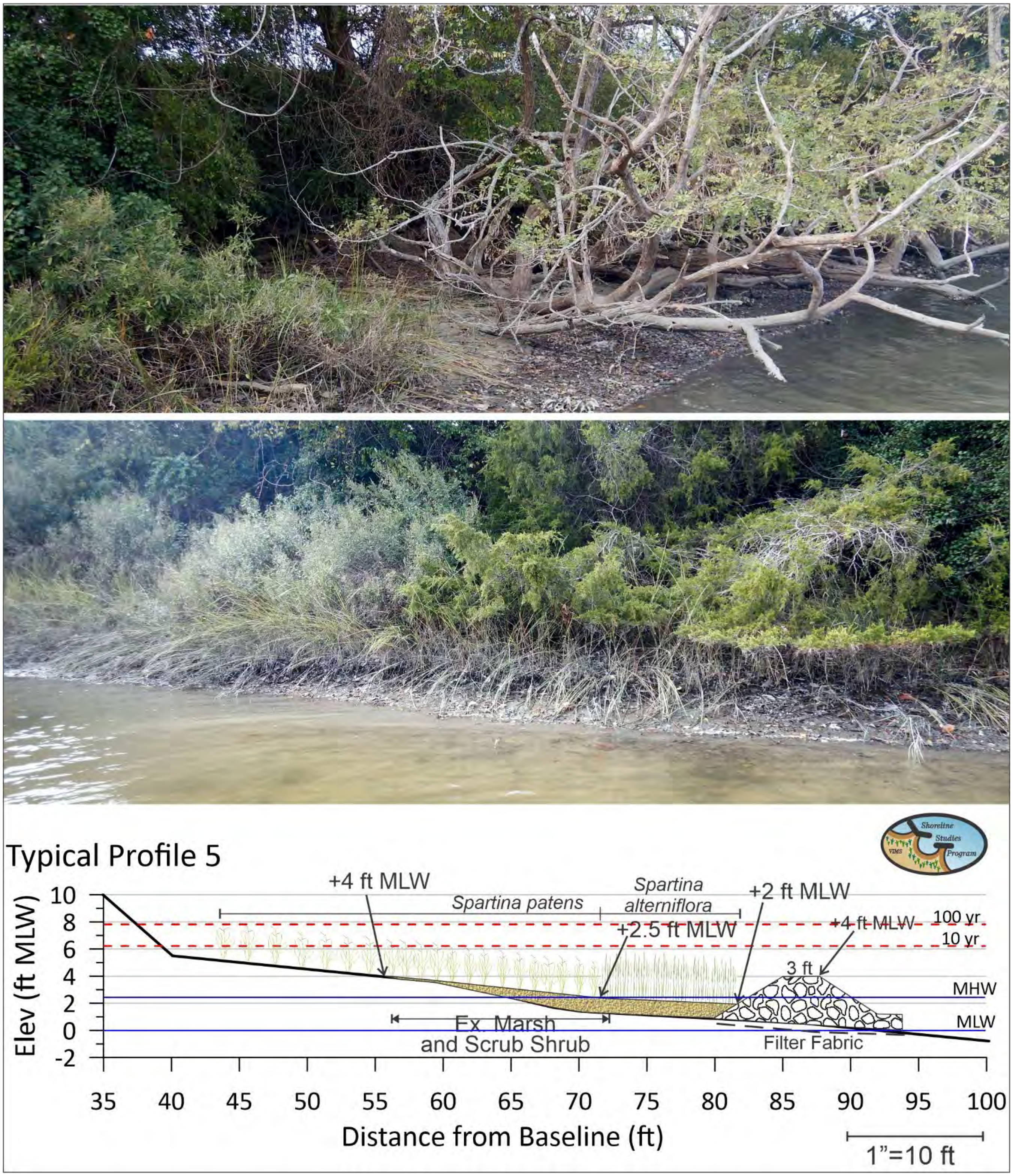
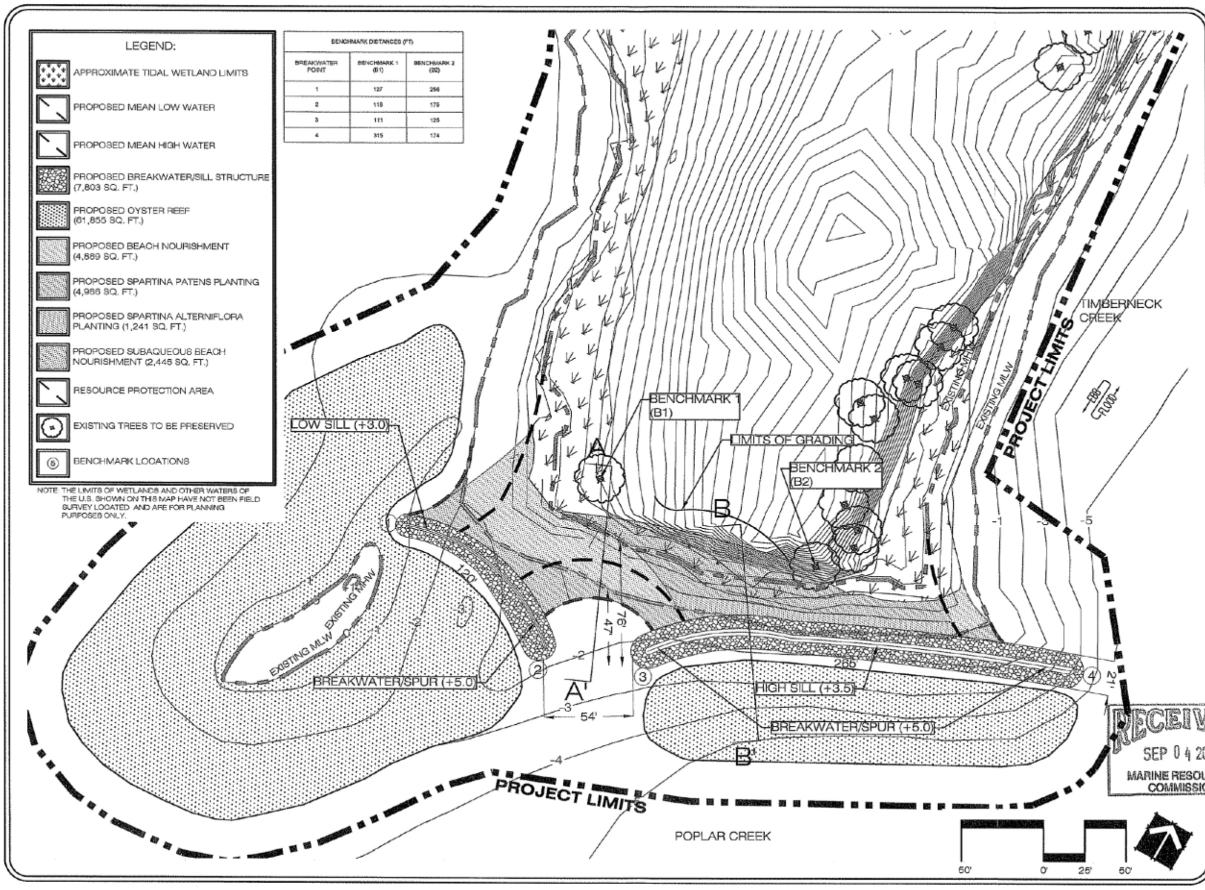


Figure 29. Photos showing the (top) northern section of sill 3 where no marsh exists and (middle) the southern section of sill 3 with its marsh and scrub shrub. The bottom is the typical profile of sill 3. However, it shows the southern section, not the northern section.

Appendix B

Previous Shoreline

Plans & Conditions



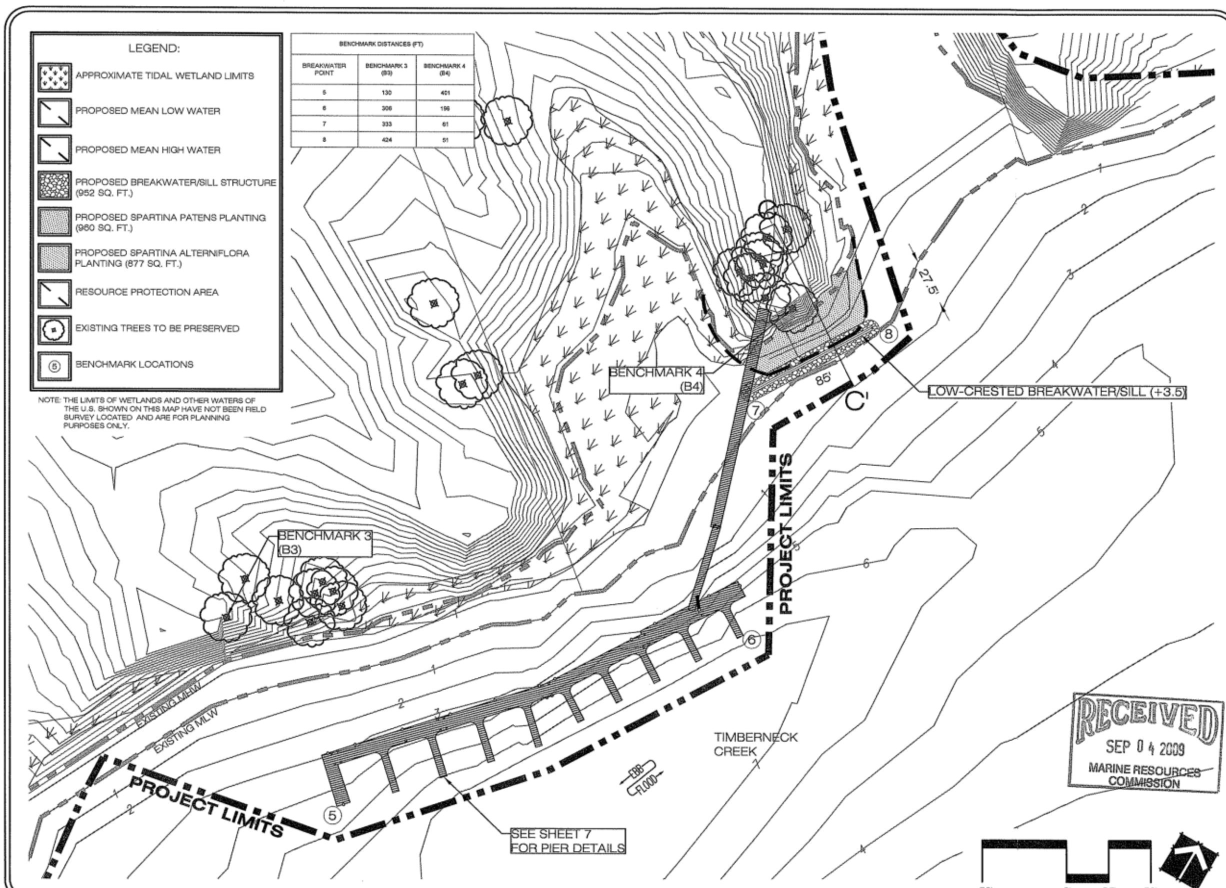
BENCHMARK DISTANCES (FT)		
BREAKWATER POINT	BENCHMARK 1 (B1)	BENCHMARK 2 (B2)
1	127	256
2	118	175
3	111	125
4	315	174

WILLIAMSBURG ENVIRONMENTAL GROUP, INC.
Environmental Consultants

SHORELINE STABILIZATION PLAN
TIMBERNECK FARM
GLOUCESTER COUNTY, VIRGINIA

RECEIVED
SEP 04 2009
MARINE RESOURCES COMMISSION

SHEET: 2 OF 7



BENCHMARK DISTANCES (FT)		
BREAKWATER POINT	BENCHMARK 3 (B3)	BENCHMARK 4 (B4)
5	130	401
6	306	196
7	333	61
8	424	51

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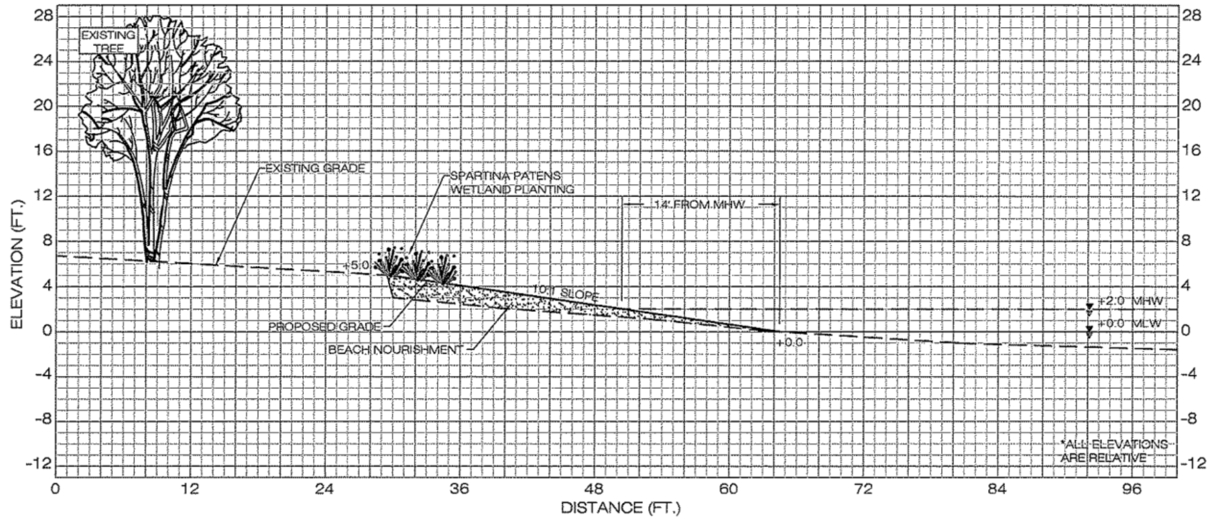
Environmental Consultants

SHORELINE STABILIZATION AND PIER
TIMBERNECK FARM
GLOUCESTER COUNTY, VIRGINIA

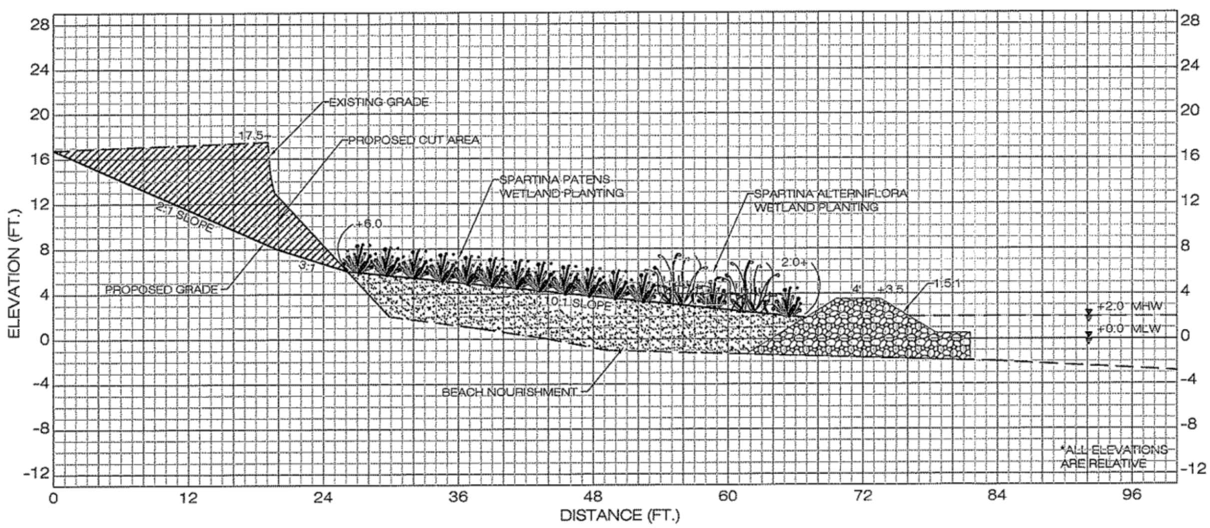
RECEIVED
SEP 04 2009
MARINE RESOURCES COMMISSION

SHEET: 3 OF 7



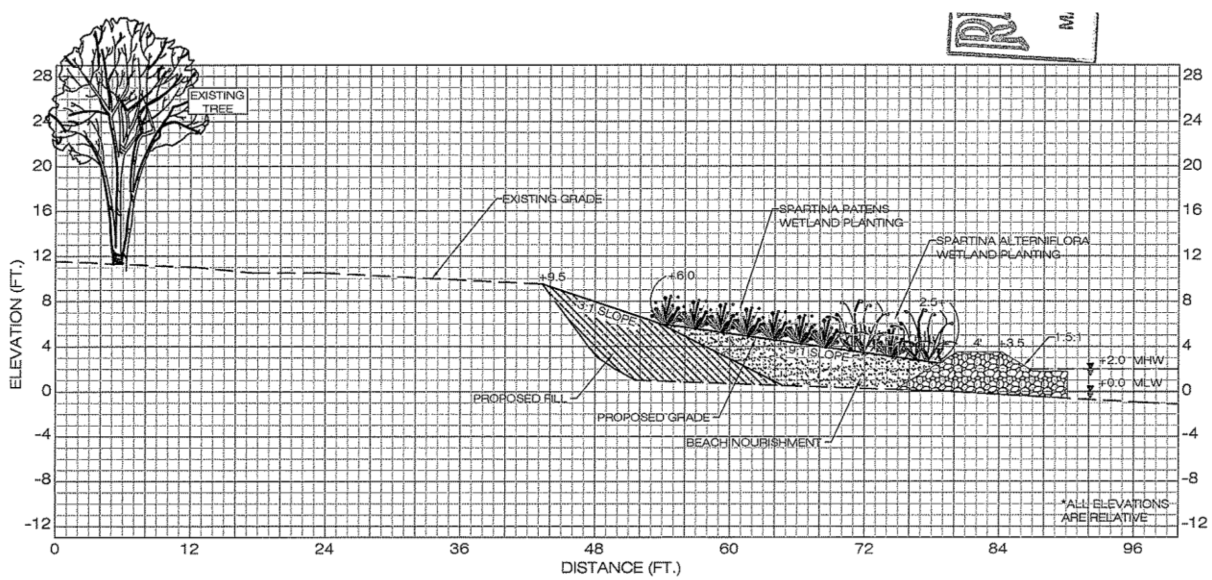
CROSS-SECTION A-A': TYPICAL BEACH FILL

SCALE: HORIZONTAL 1 INCH = 12 FEET, VERTICAL 1 INCH = 12 FEET



CROSS-SECTION B-B': TYPICAL BREAKWATER

SCALE: HORIZONTAL 1 INCH = 12 FEET, VERTICAL 1 INCH = 12 FEET



CROSS-SECTION C-C': TYPICAL BREAKWATER

SCALE: HORIZONTAL 1 INCH = 12 FEET, VERTICAL 1 INCH = 12 FEET

Sill at the Point Before, During and 10 Years Later

Photo date: 26 Sep 2010
Eroding upland bank, no marsh fringe
Photo credit: VMRC Project Report dated 4 Sep 2009

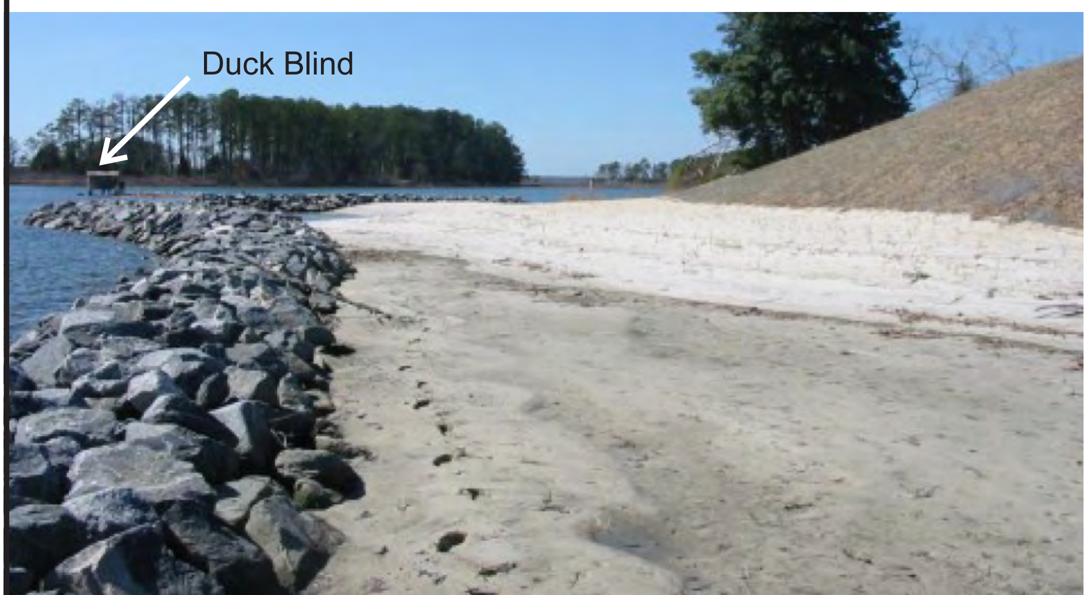


Photo date: 4 Mar 2011
New sill, placed sand nourishment,
marsh grass planted,
graded bank
Photo credit: VMRC Project Report dated 4 Sep 2009

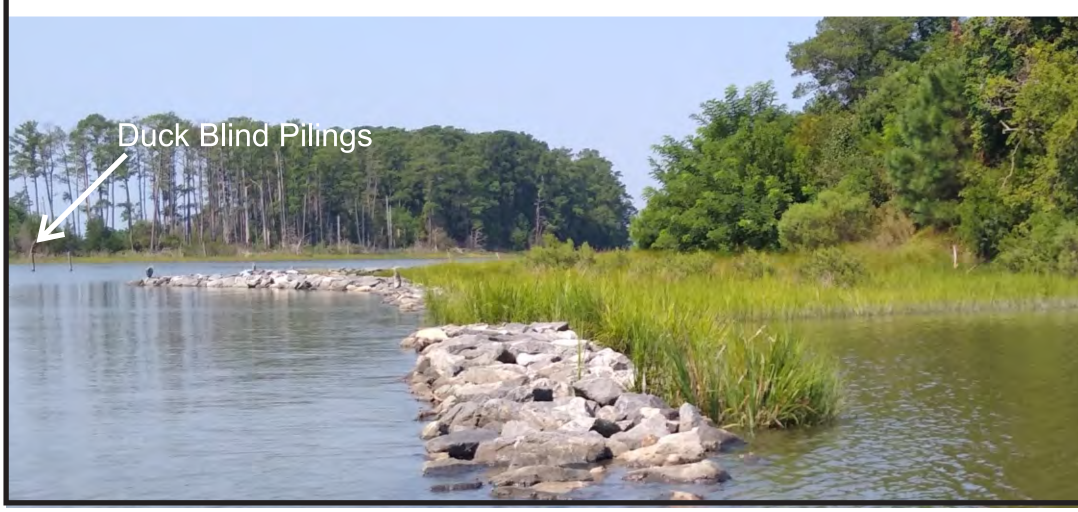


Photo date: 24 Aug 2021
The marsh sill 10 years after construction.
Photo credit: VIMS Shoreline Studies Program

Sill at the Point 10 years after construction

The ends of the sills are designed to be higher than at the center.
Below, the panoramic image shows that the center section is barely above high water though the ends are higher.

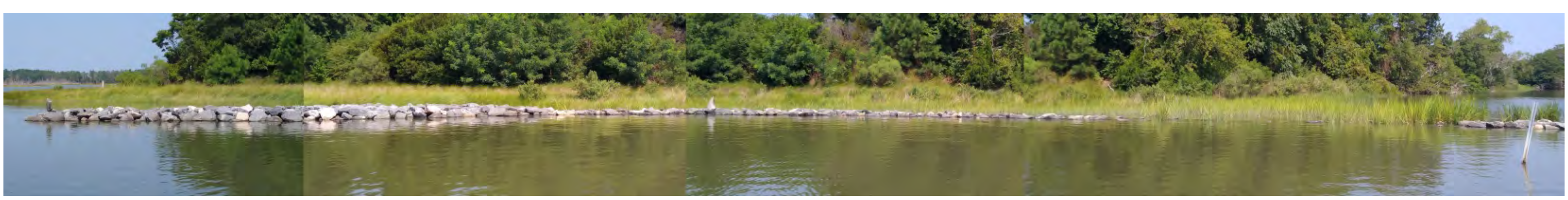


Photo taken 26 Sep 2010
Steep eroding upland bank, no marsh fringe.
Photo credit: VMRC Project Report dated 4 Sep 2009

Photo taken 4 Mar 2011 1258
New sill, placed sand nourishment, marsh grass planted, fill placed over bank instead of grading it.
Photo credit: VMRC Project Report dated 4 Sep 2009

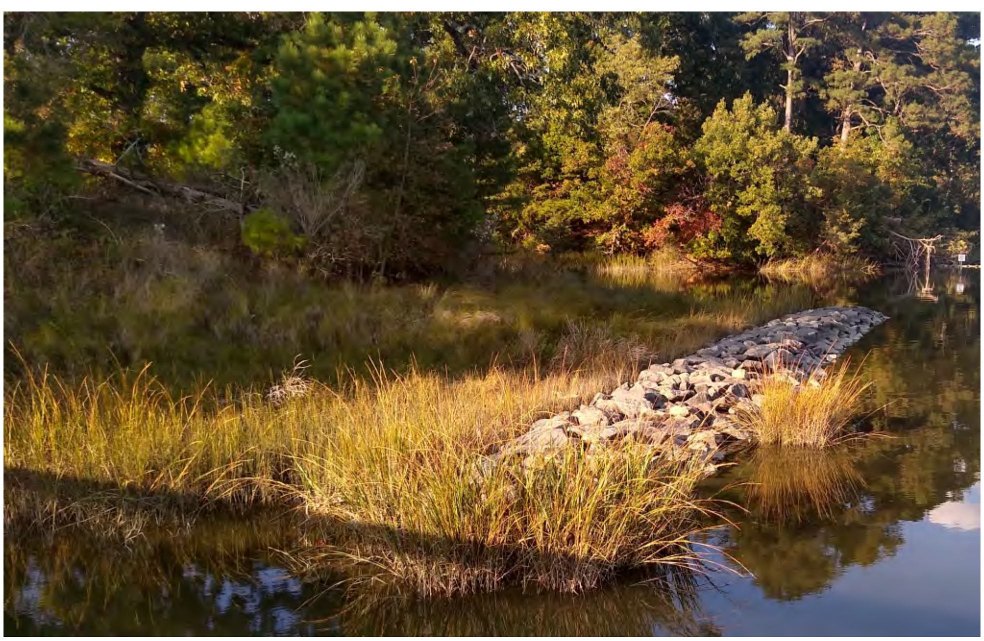
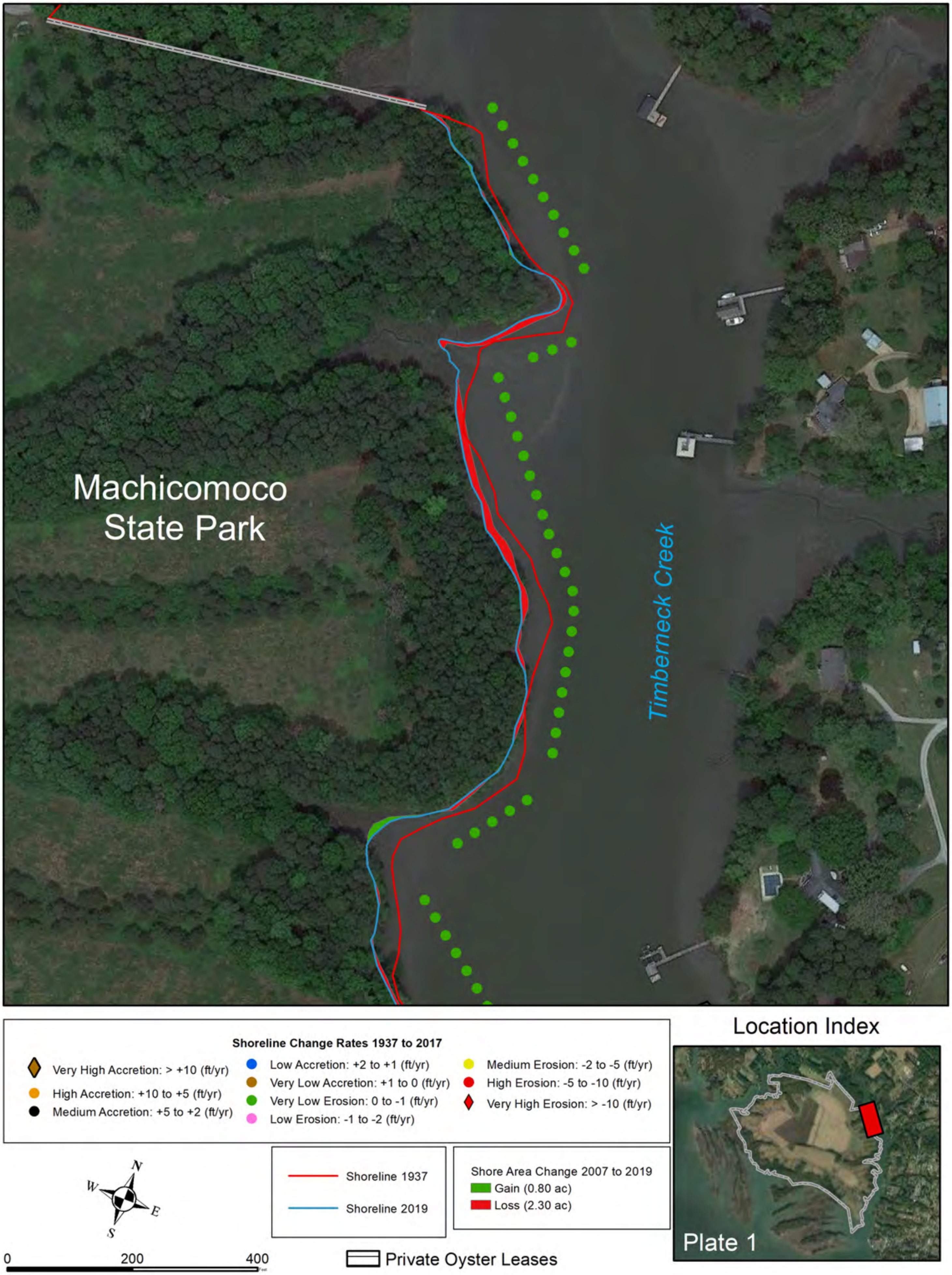


Photo taken 1 Nov 2021
Photo credit: VIMS Shoreline Studies Program

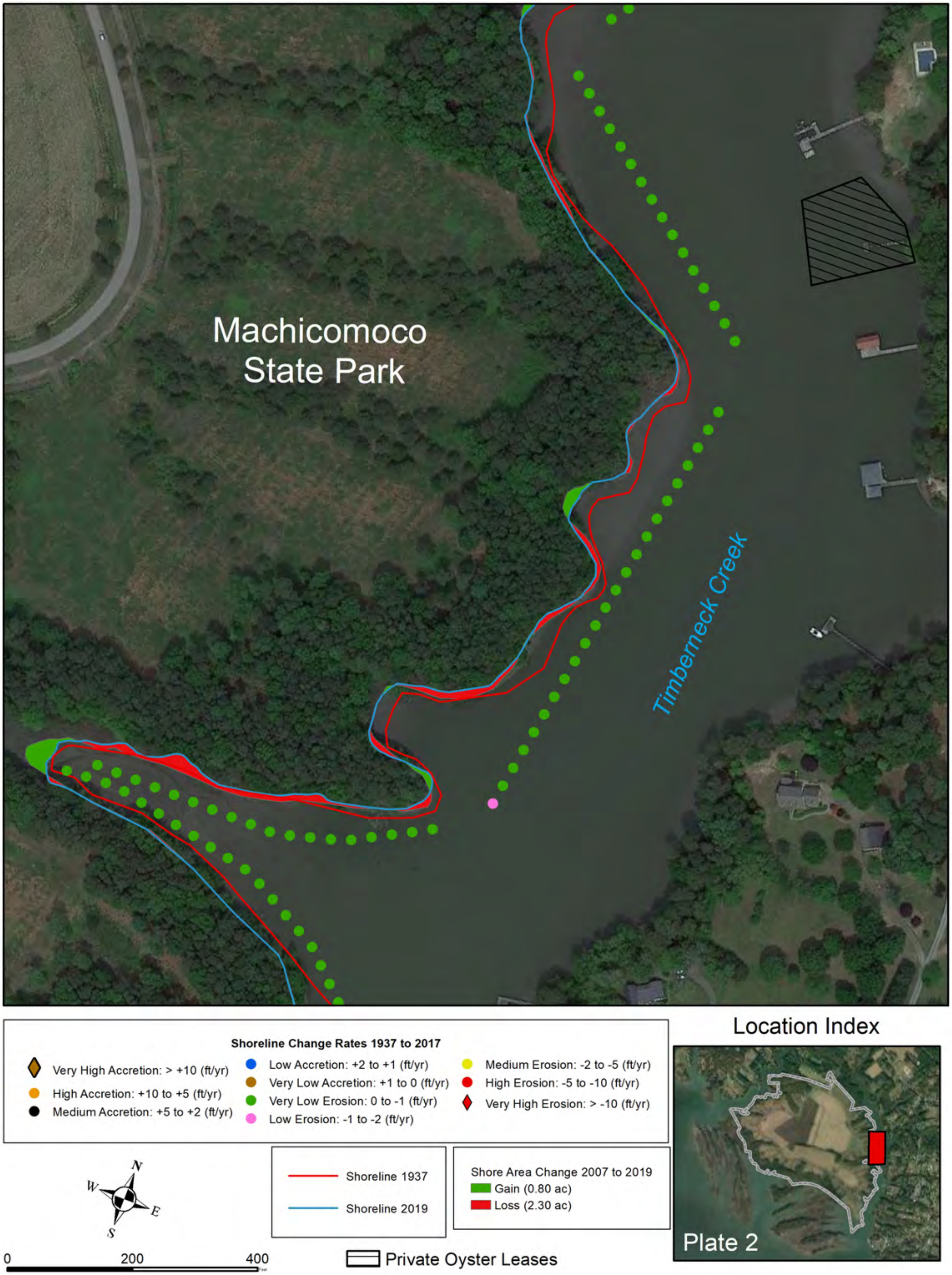
Appendix C

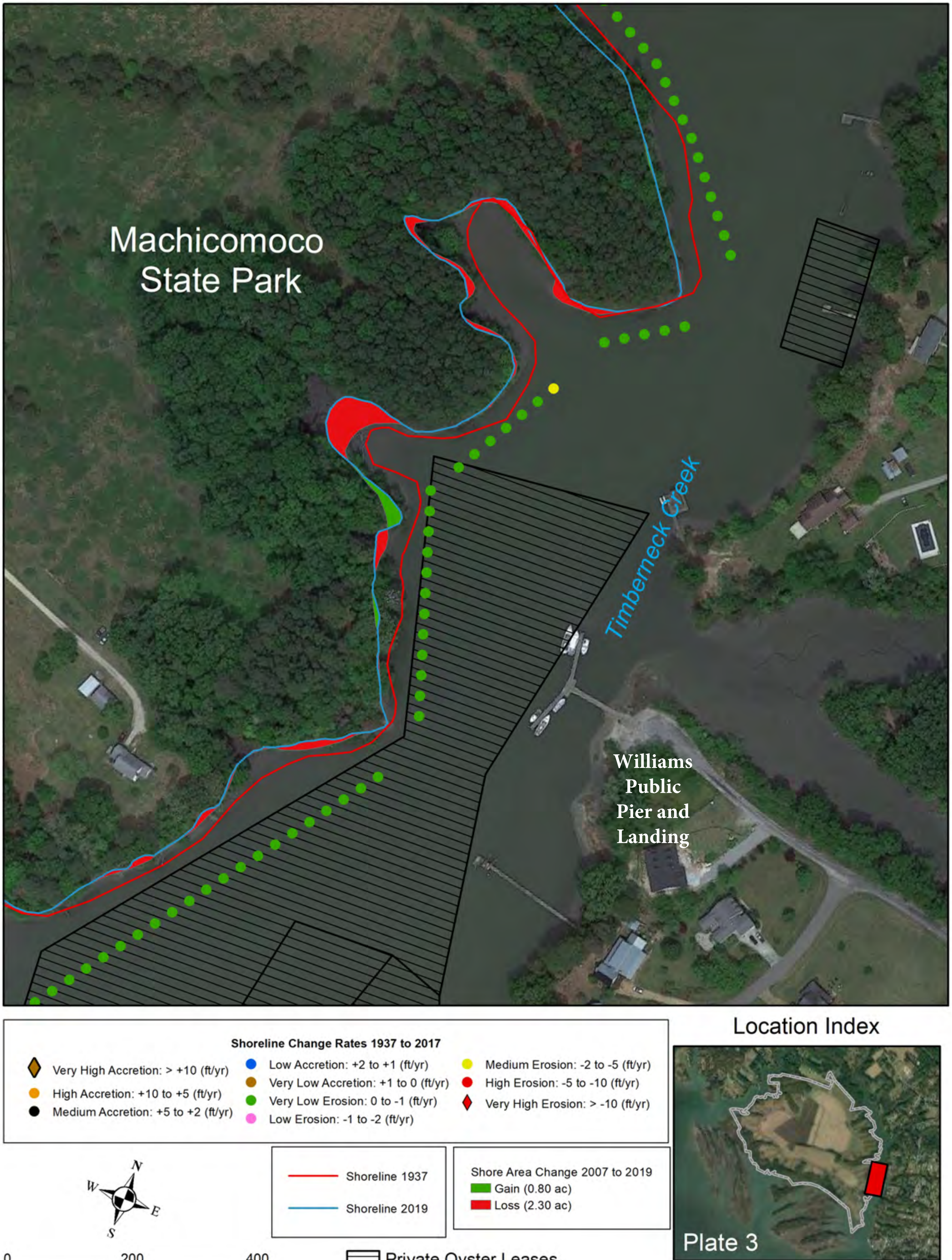
Shore Change

2021 VGIN Image



Machicomoco State Park
Timberneck Creek
Shoreline Change Rates 1937 to 2017
Very High Accretion: > +10 (ft/yr)
High Accretion: +10 to +5 (ft/yr)
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: > -10 (ft/yr)
Location Index
Plate 1
N
W
E
S
Shoreline 1937
Shoreline 2019
Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)
0
200
400
Private Oyster Leases


Machicomoco State Park
Timberneck Creek
Shoreline Change Rates 1937 to 2017
Very High Accretion: > +10 (ft/yr)
High Accretion: +10 to +5 (ft/yr)
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: > -10 (ft/yr)
Location Index
Plate 2
N
W
E
S
0
200
400
Shoreline 1937
Shoreline 2019
Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)
Private Oyster Leases



Machicomoco
State Park
Timberneck Creek
Williams
Public
Pier and
Landing
Shoreline Change Rates 1937 to 2017
Very High Accretion: > +10 (ft/yr)
High Accretion: +10 to +5 (ft/yr)
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: > -10 (ft/yr)
Location Index
Shoreline 1937
Shoreline 2019
Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)
Plate 3
N
W
E
S
0
200
400
Private Oyster Leases

Shoreline Change Rates 1937 to 2017

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: > -10 (ft/yr)

Shoreline 1937

Shoreline 2019

Shore Area Change 2007 to 2019
- Gain (0.80 ac)
- Loss (2.30 ac)

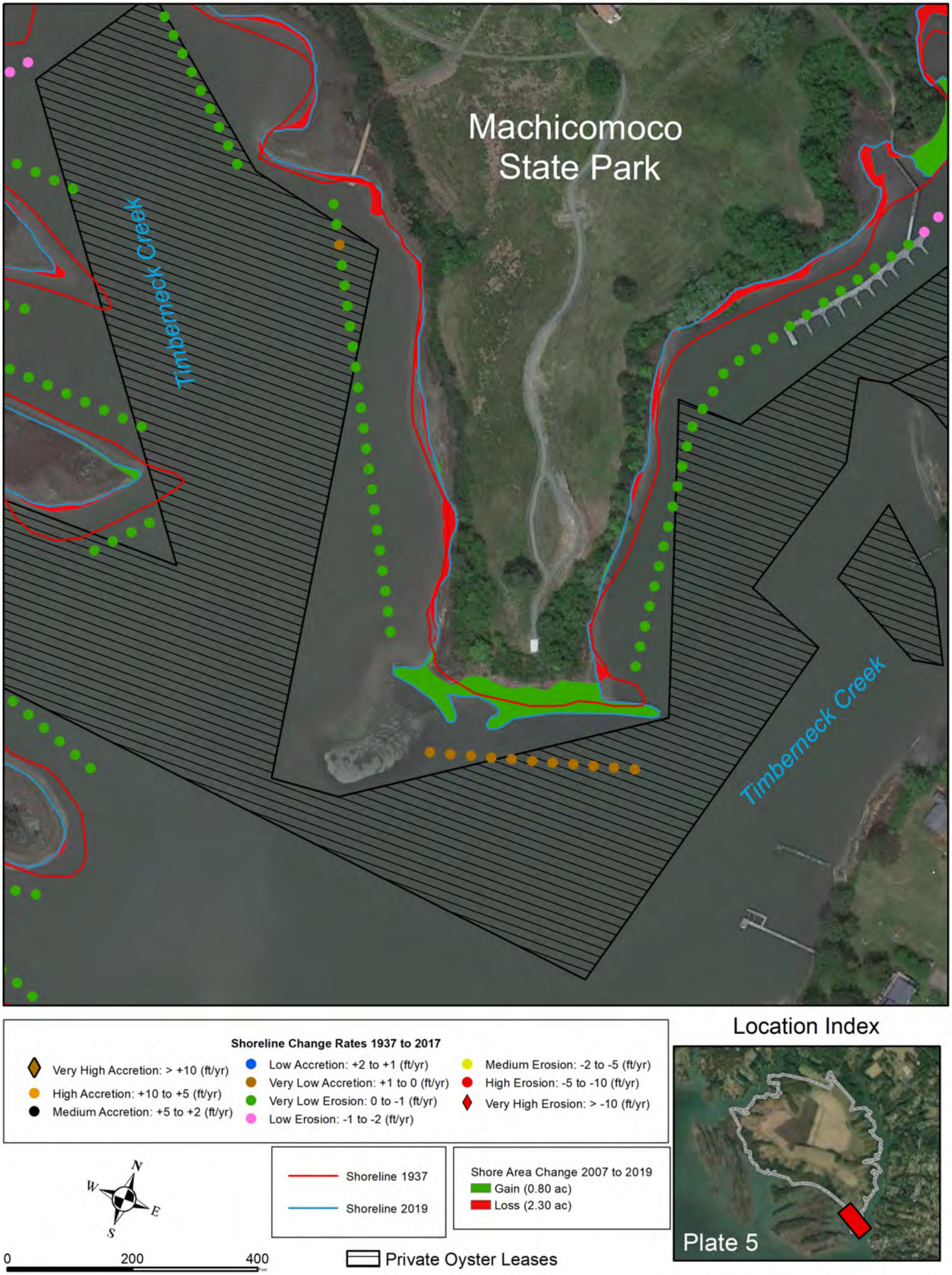
N W E S

0 200 400 Feet

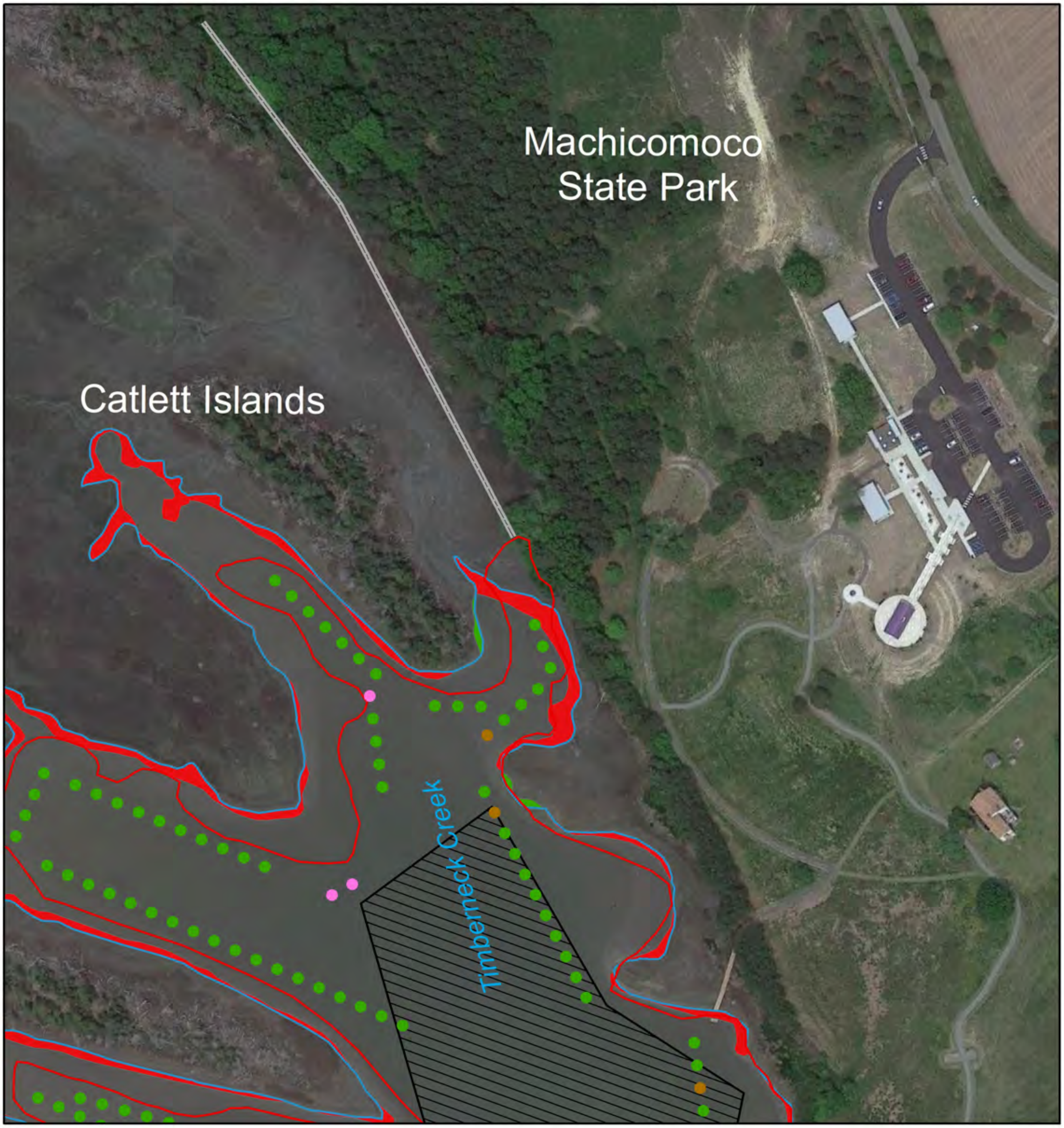
Private Oyster Leases

Location Index

Plate 4



Machicomoco
State Park
Timberneck Creek
Timberneck Creek
Shoreline Change Rates 1937 to 2017
Very High Accretion: > +10 (ft/yr)
High Accretion: +10 to +5 (ft/yr)
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: > -10 (ft/yr)
Location Index
Plate 5
N
W
E
S
0
200
400
Shoreline 1937
Shoreline 2019
Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)
Private Oyster Leases



Shoreline Change Rates 1937 to 2017

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: > -10 (ft/yr)

Shoreline 1937
Shoreline 2019

Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)

N W E S

0 200 400

Private Oyster Leases

Location Index

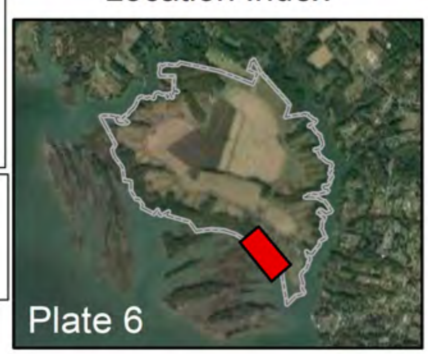
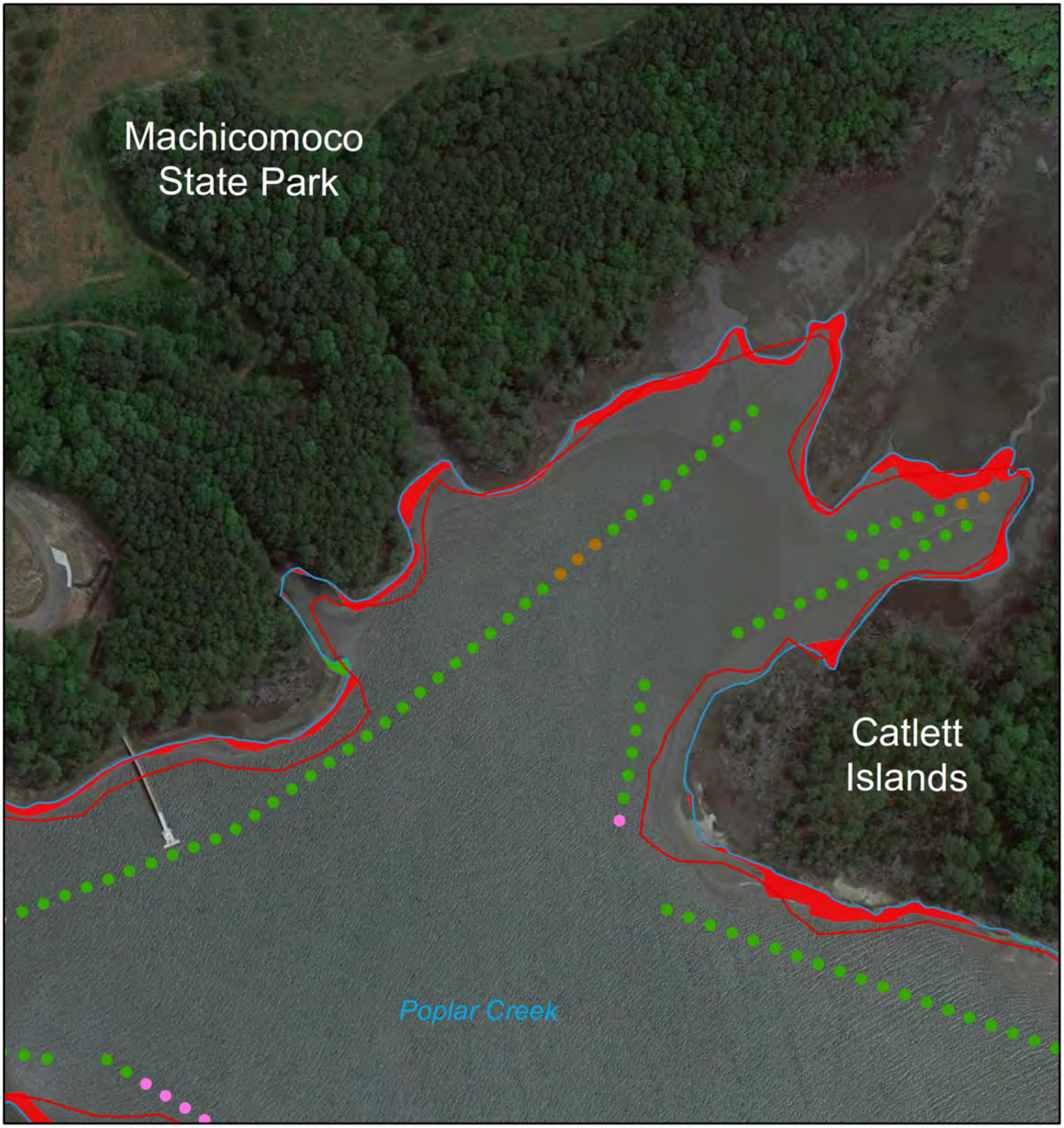


Plate 6



Shoreline Change Rates 1937 to 2017

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: > -10 (ft/yr)

Shoreline 1937
Shoreline 2019

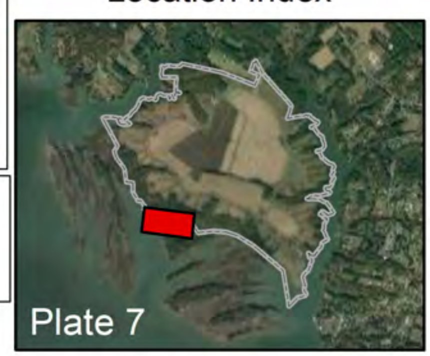
Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)

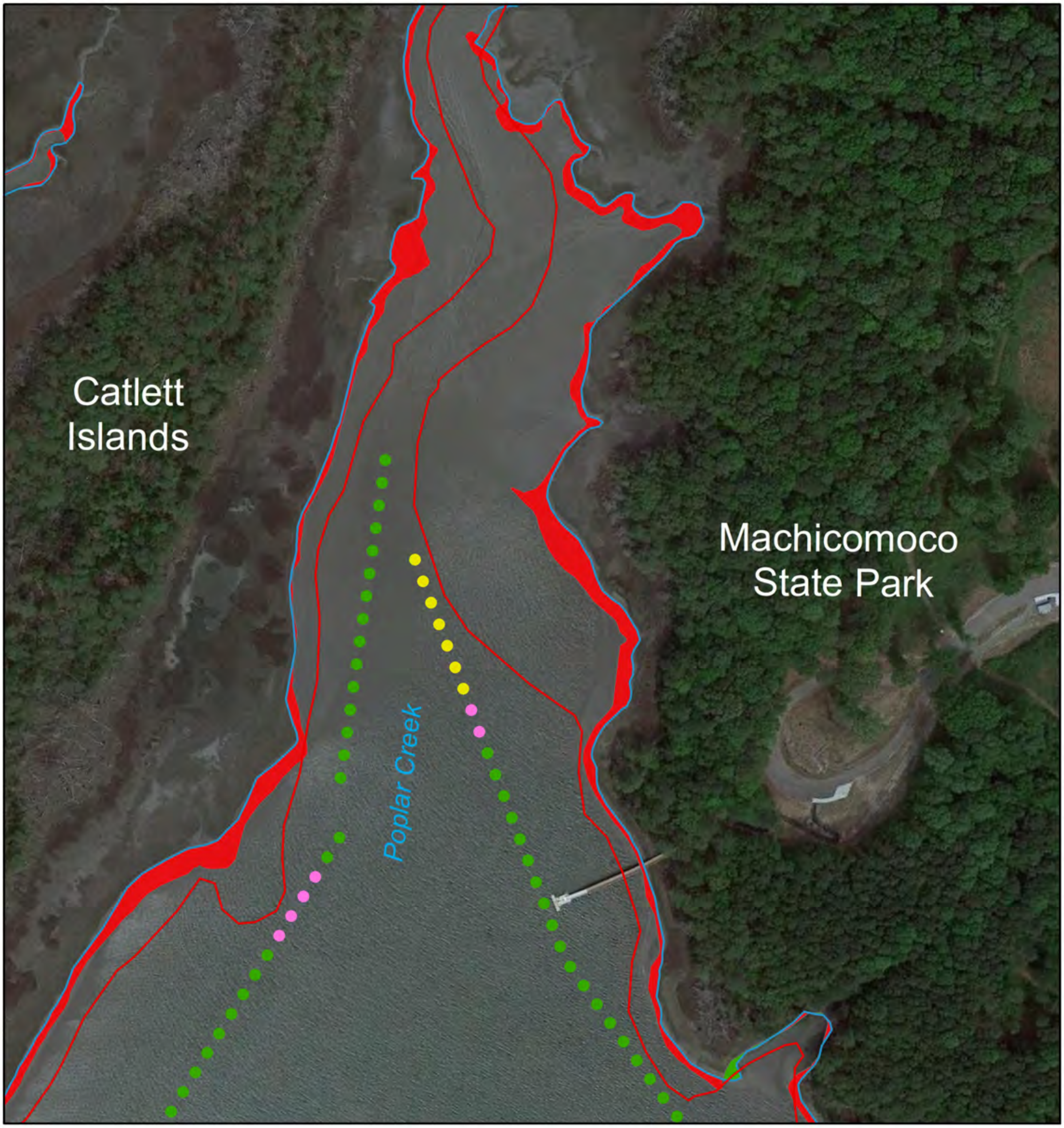
N E S W

0 200 400

Private Oyster Leases

Location Index





Shoreline Change Rates 1937 to 2017

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: > -10 (ft/yr)

Shoreline 1937

Shoreline 2019

Shore Area Change 2007 to 2019

Gain (0.80 ac)

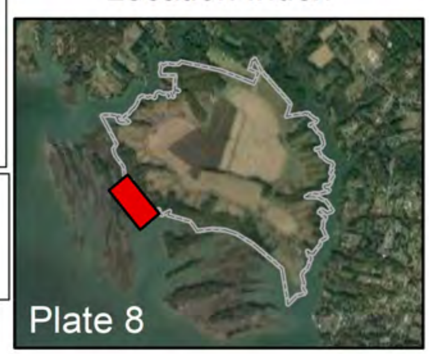
Loss (2.30 ac)

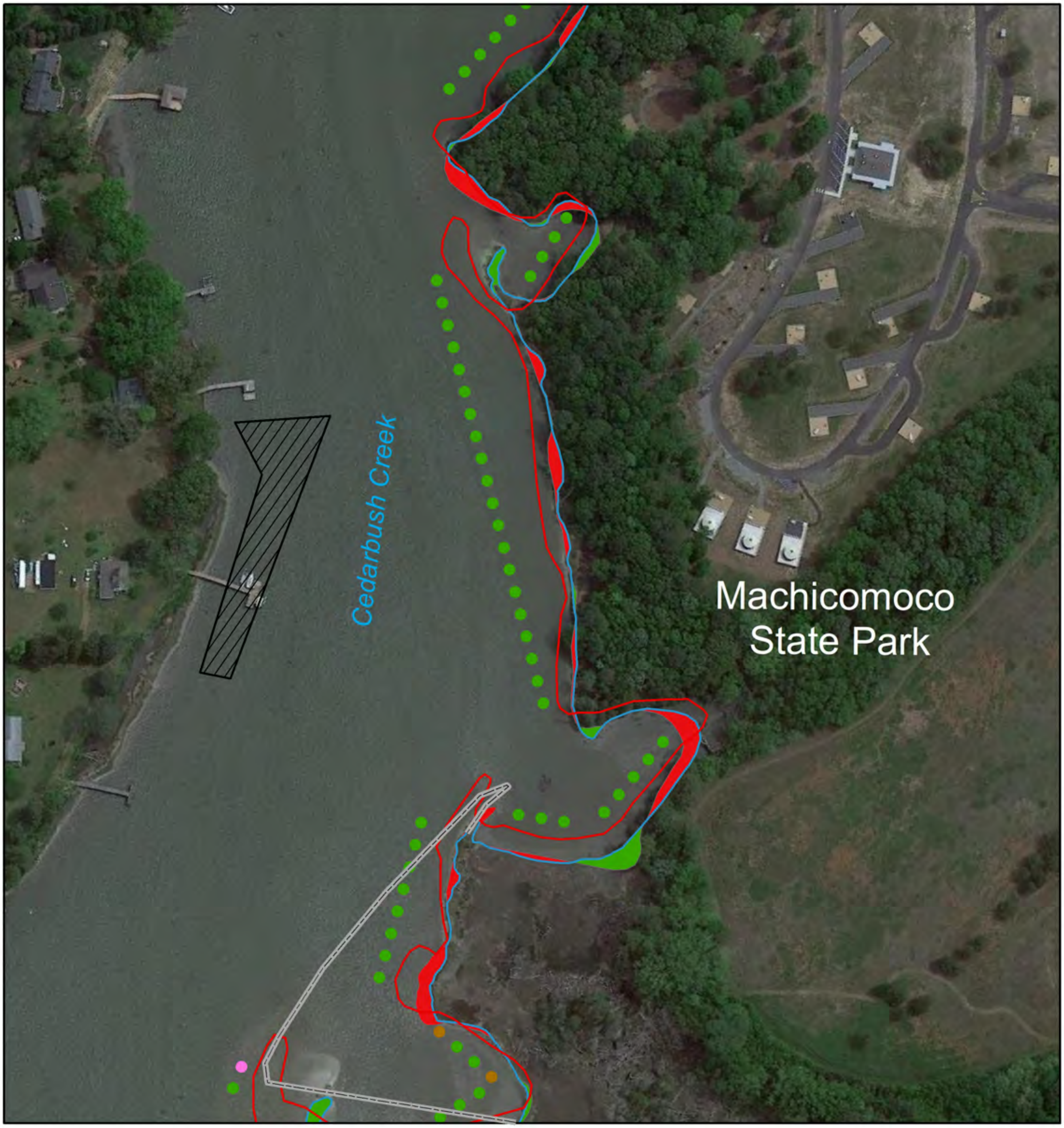
N W E S

0 200 400

Private Oyster Leases

Location Index





Shoreline Change Rates 1937 to 2017

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: > -10 (ft/yr)

Shoreline 1937
Shoreline 2019

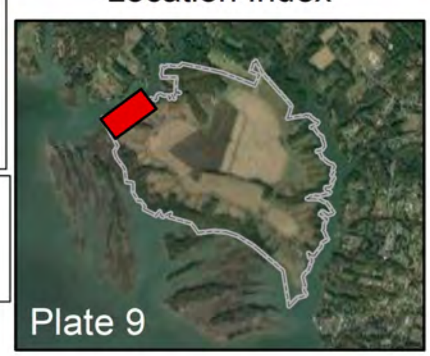
Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)

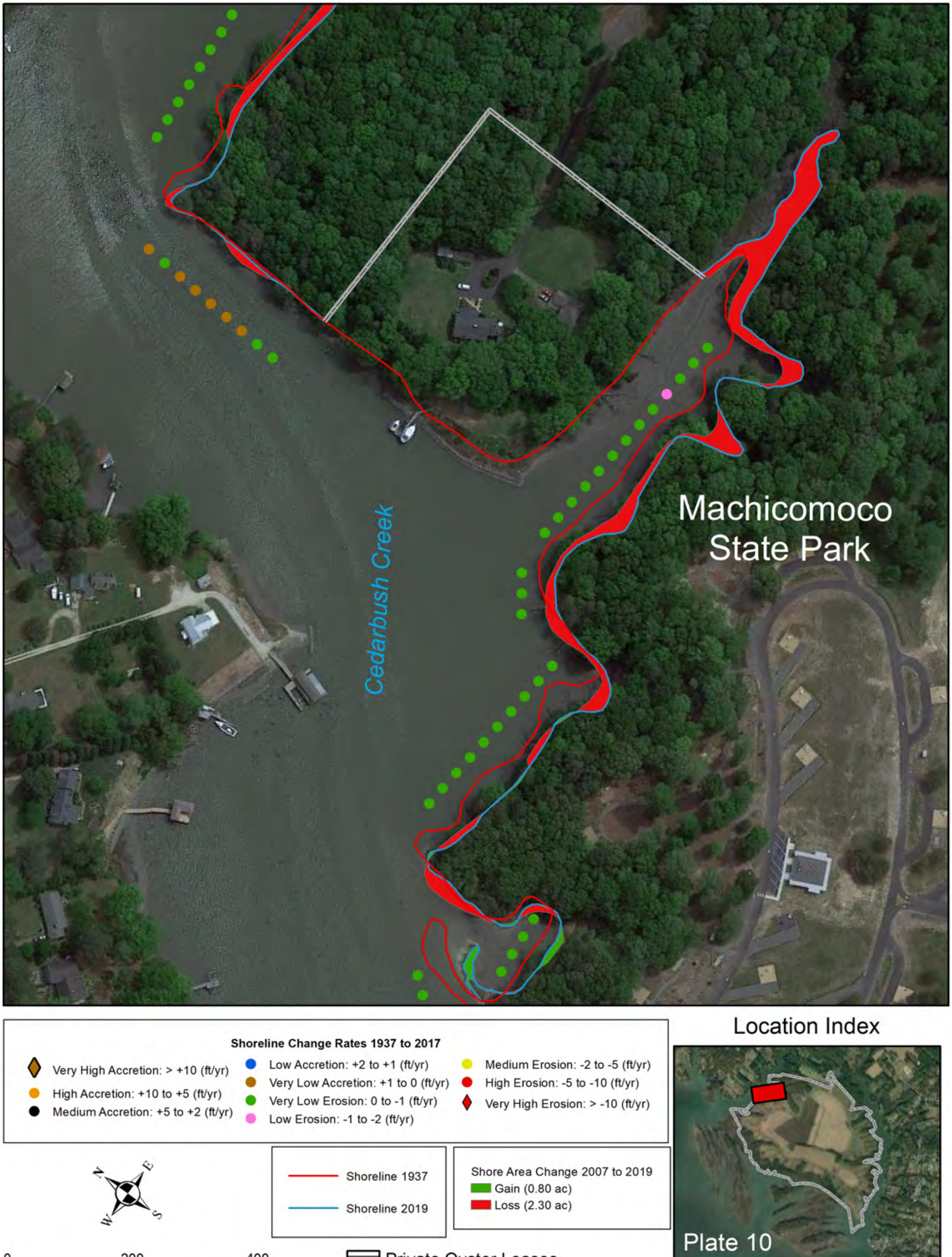
N E S W

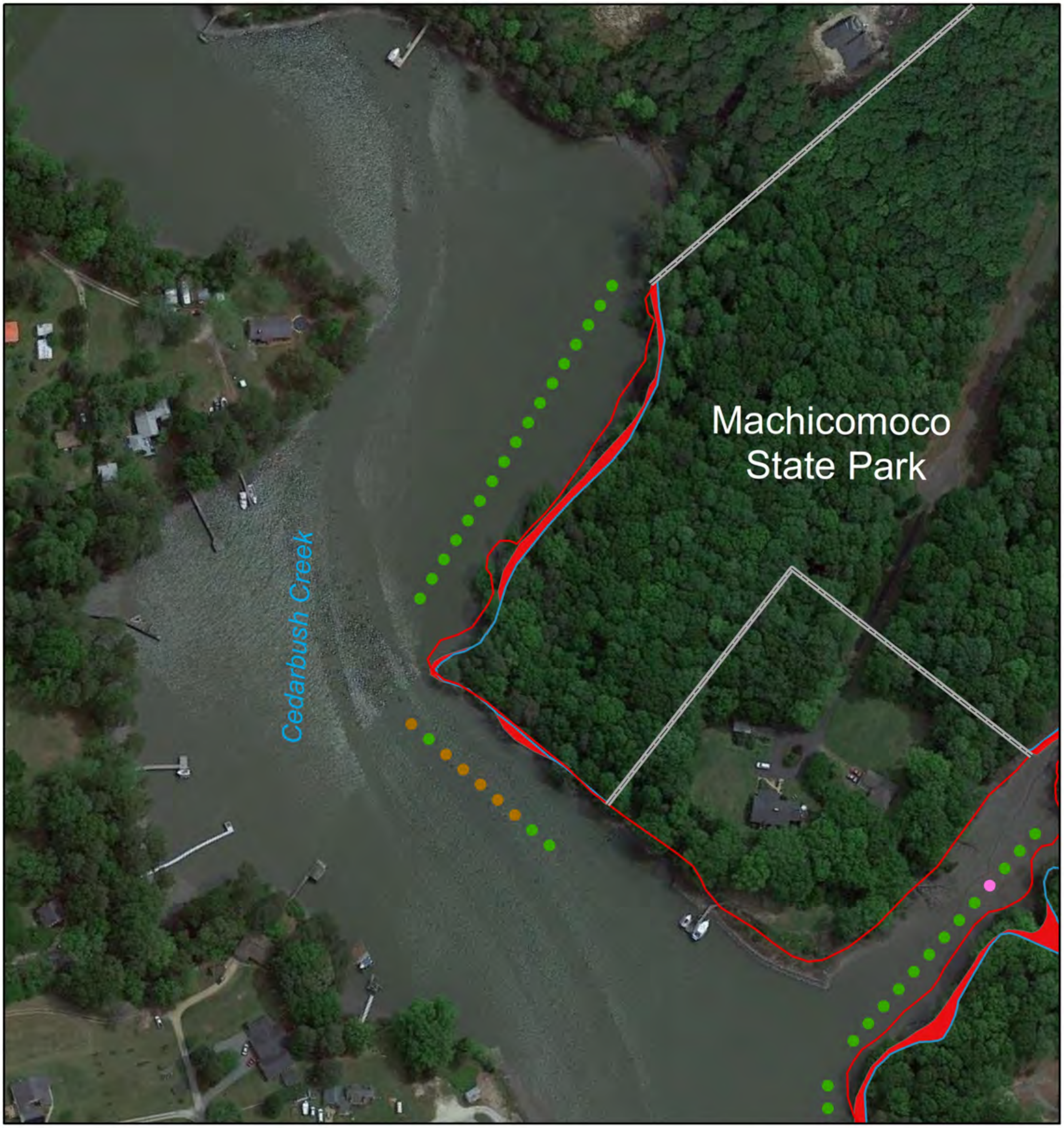
0 200 400

Private Oyster Leases

Location Index




Machicomoco State Park
Cedarbush Creek
Shoreline Change Rates 1937 to 2017
Very High Accretion: > +10 (ft/yr)
High Accretion: +10 to +5 (ft/yr)
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion: +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: > -10 (ft/yr)
Location Index
Shoreline 1937
Shoreline 2019
Shore Area Change 2007 to 2019
Gain (0.80 ac)
Loss (2.30 ac)
N E S W
0 200 400
Private Oyster Leases
Plate 10



Shoreline Change Rates 1937 to 2017

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion: +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: > -10 (ft/yr)

Shoreline 1937

Shoreline 2019

Shore Area Change 2007 to 2019

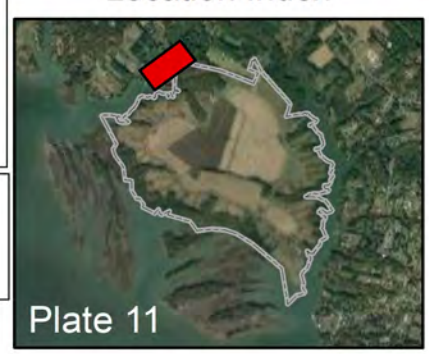
- Gain (0.80 ac)
- Loss (2.30 ac)

Private Oyster Leases

N E S W

0 200 400

Location Index

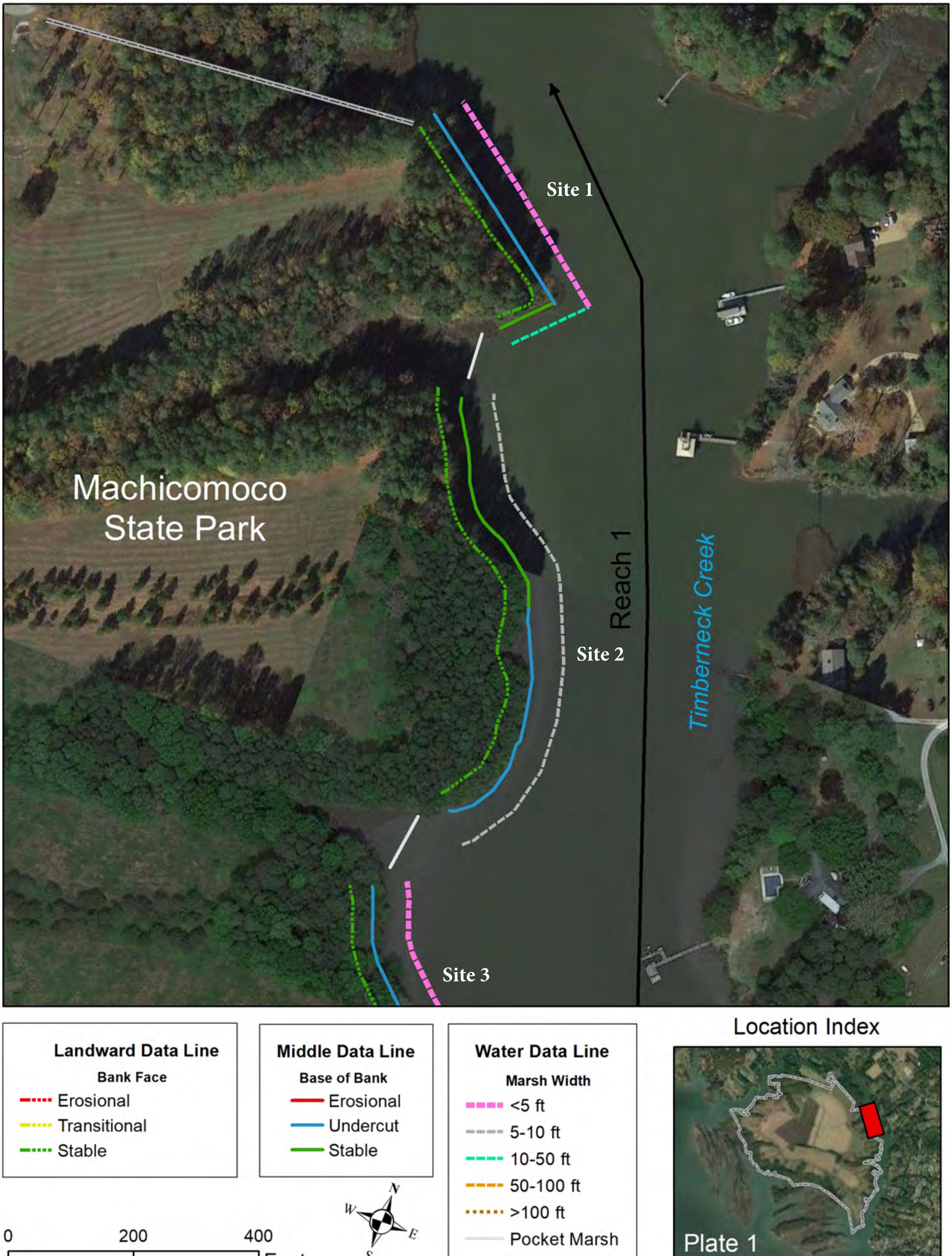


Appendix D

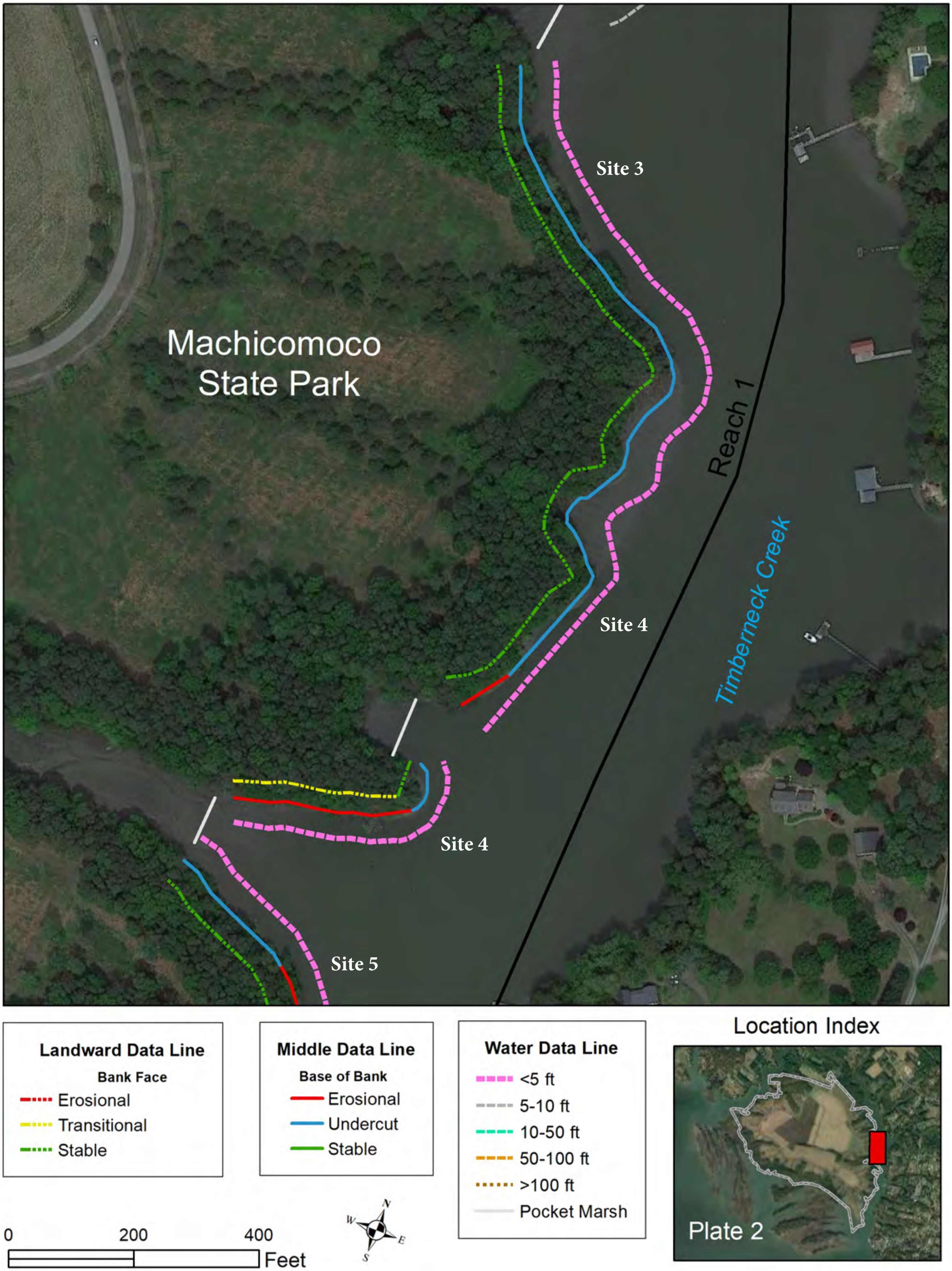
Detailed Existing

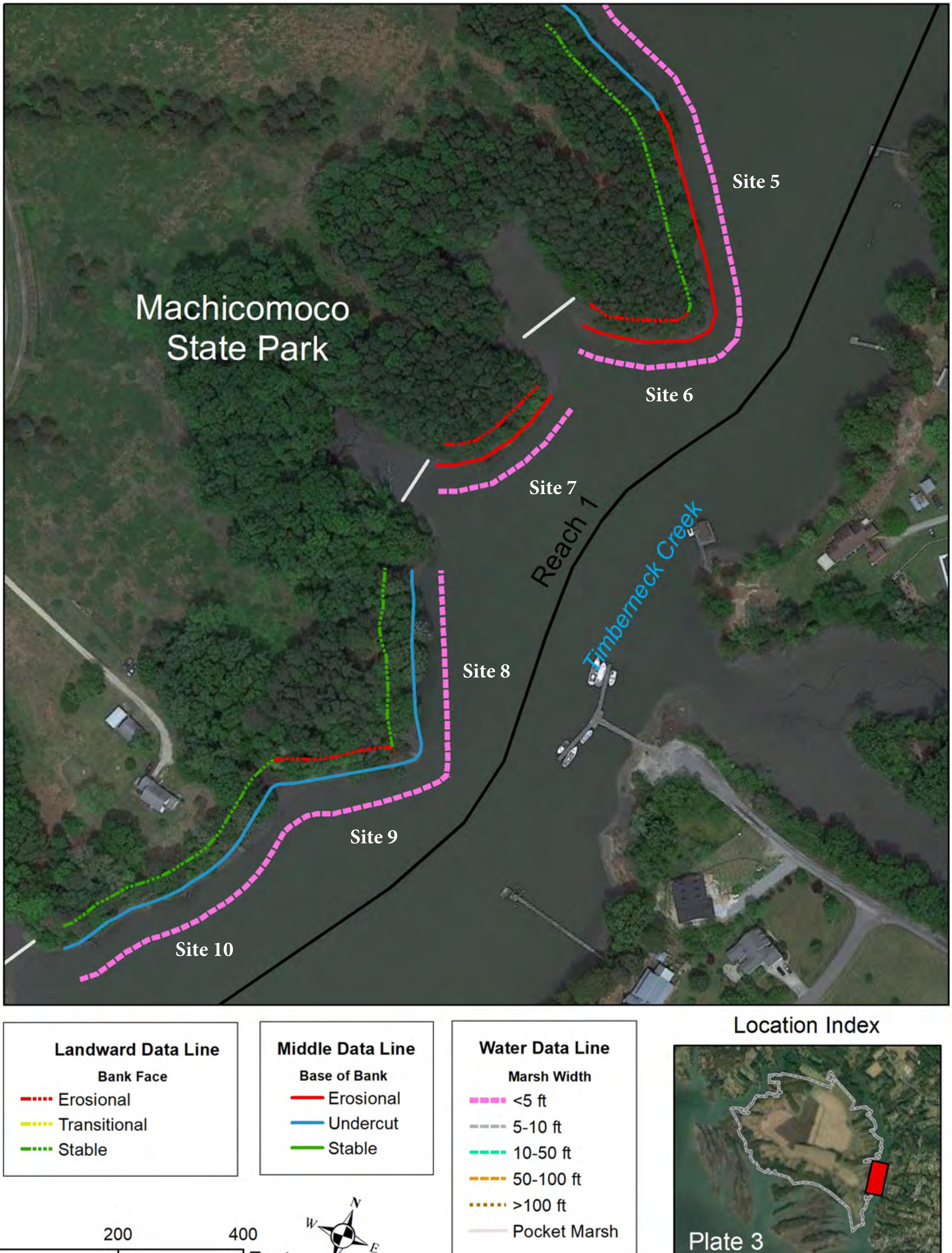
Shoreline Conditions

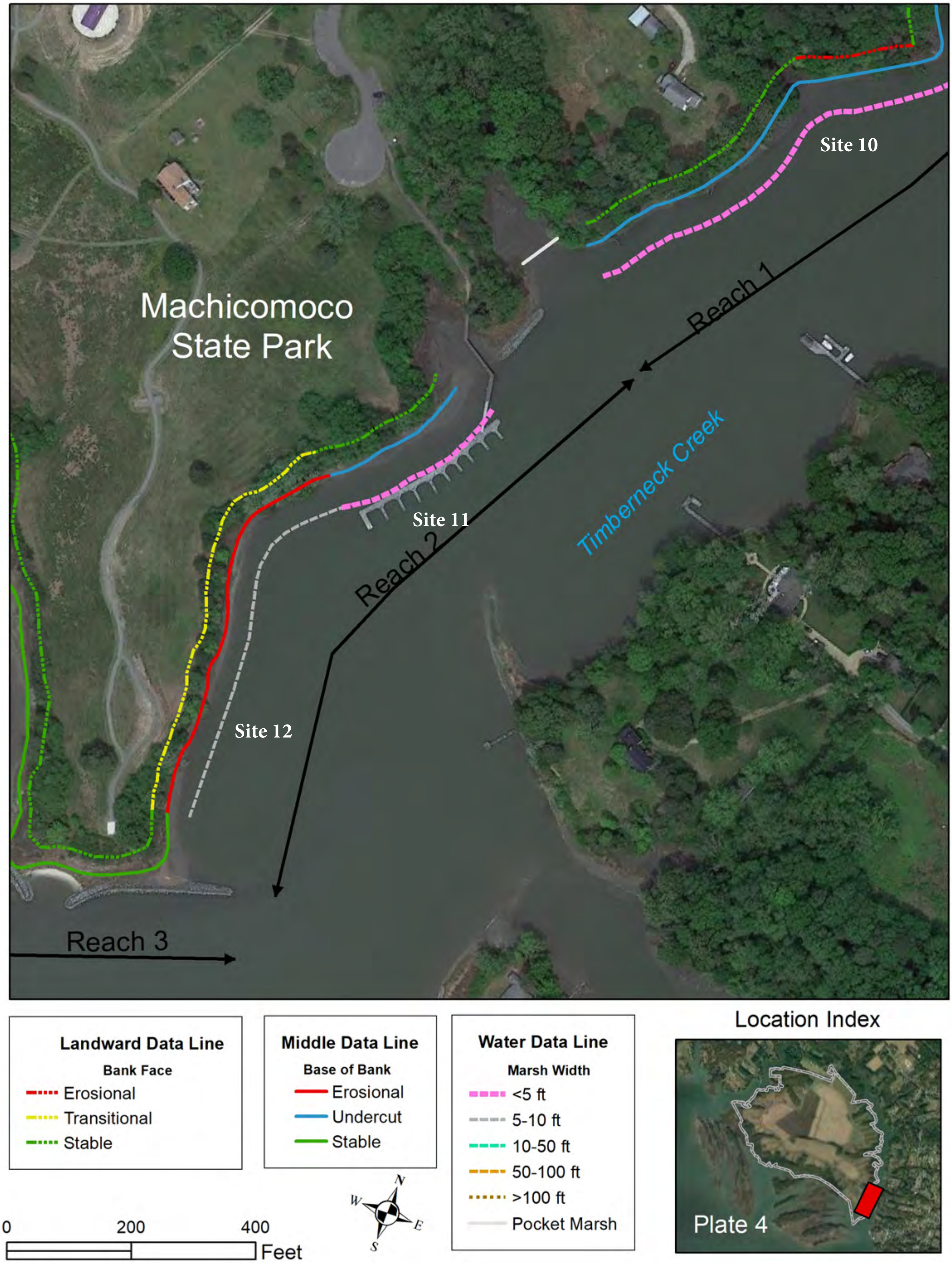
11
10
9
Cedarbush Creek
Machicomoco
State Park
1
2
3
4
5
6
7
8
Catlett
Poplar Creek
Islands
Timberneck Creek
York River
Virginia Geographic Information Network (VGIN)
N
S
E
W
0
500
1,000
2,000
Feet
2021 VGIN Image



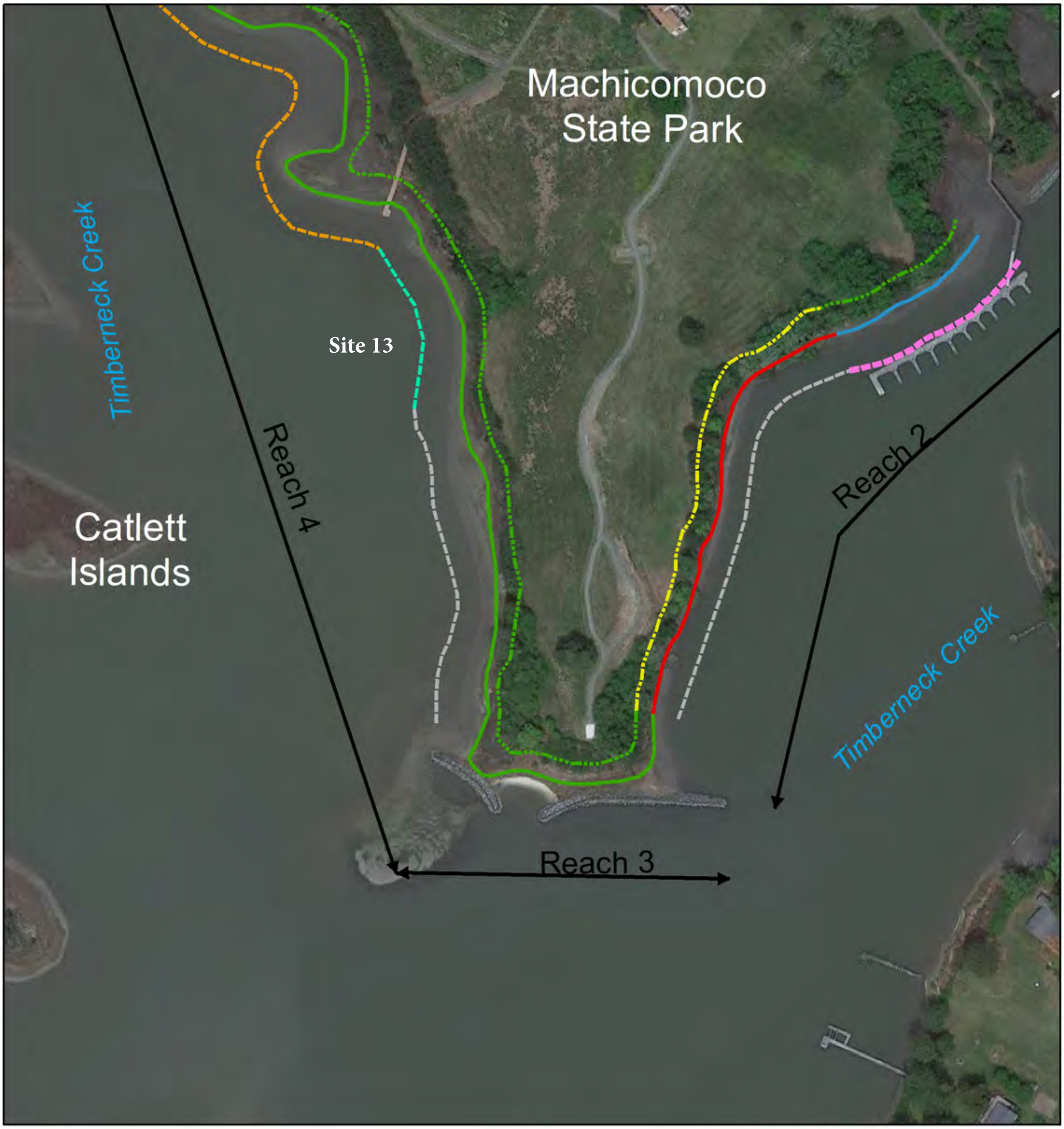
Site 1
Machicomoco
State Park
Reach 1
Timberneck Creek
Site 2
Site 3
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
Location Index
Plate 1
0
200
400
Feet
N
E
S
W


Machicomoco
State Park
Site 3
Reach 1
Site 4
Timberneck Creek
Site 4
Site 5
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
0
200
400
Feet
N
W
E
S
Location Index
Plate 2


Machicomoco State Park
Site 5
Site 6
Site 7
Site 8
Site 9
Site 10
Reach 1
Timberneck Creek
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
Location Index
Plate 3
0
200
400
Feet
N
E
S
W



Site 10
Reach 1
Machicomoco
State Park
Timberneck Creek
Site 11
Reach 2
Site 12
Reach 3
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
Location Index
Plate 4
0
200
400
Feet
N
E
S
W



Landward Data Line

Bank Face

- Erosional
- Transitional
- Stable

Middle Data Line

Base of Bank

- Erosional
- Undercut
- Stable

Water Data Line

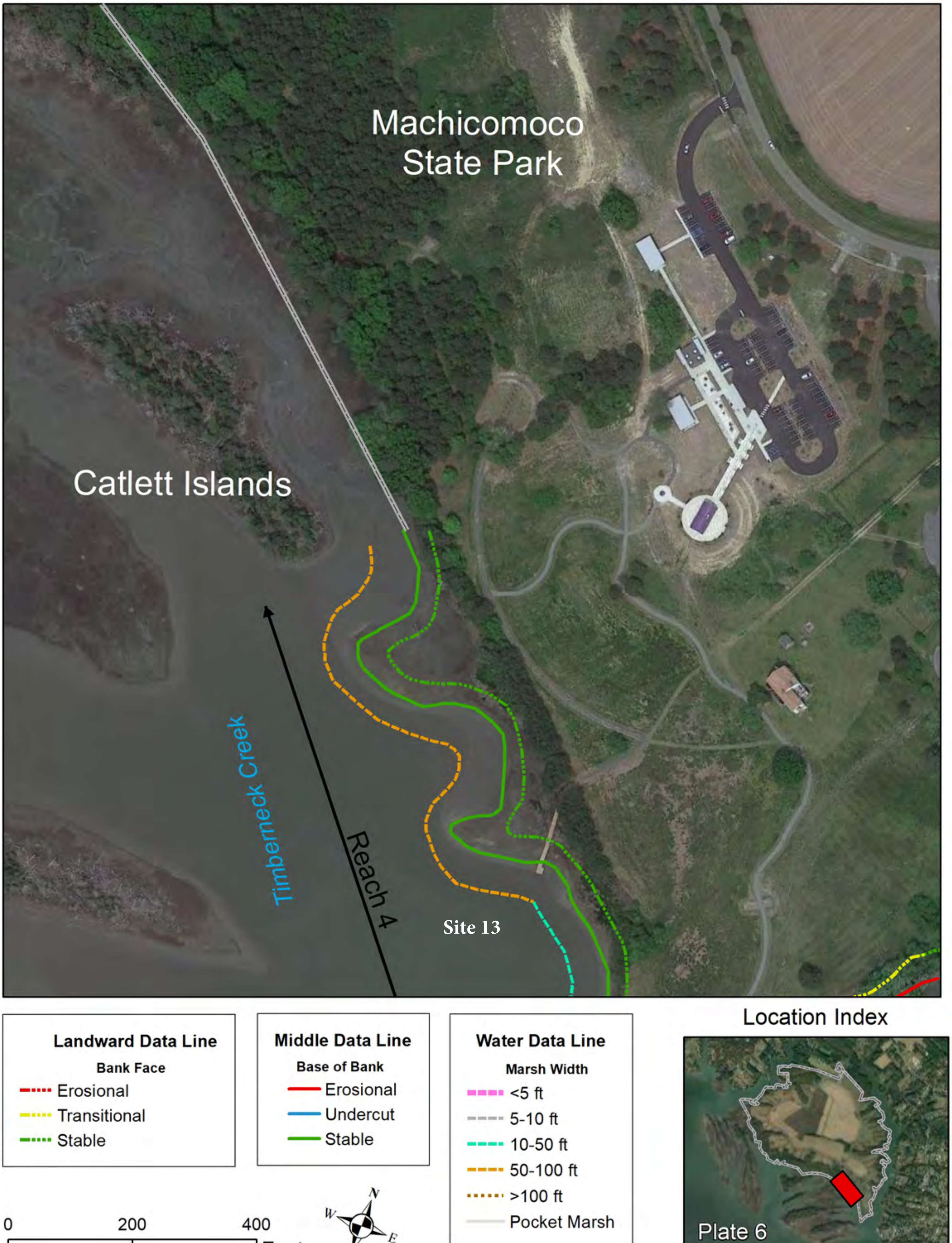
Marsh Width

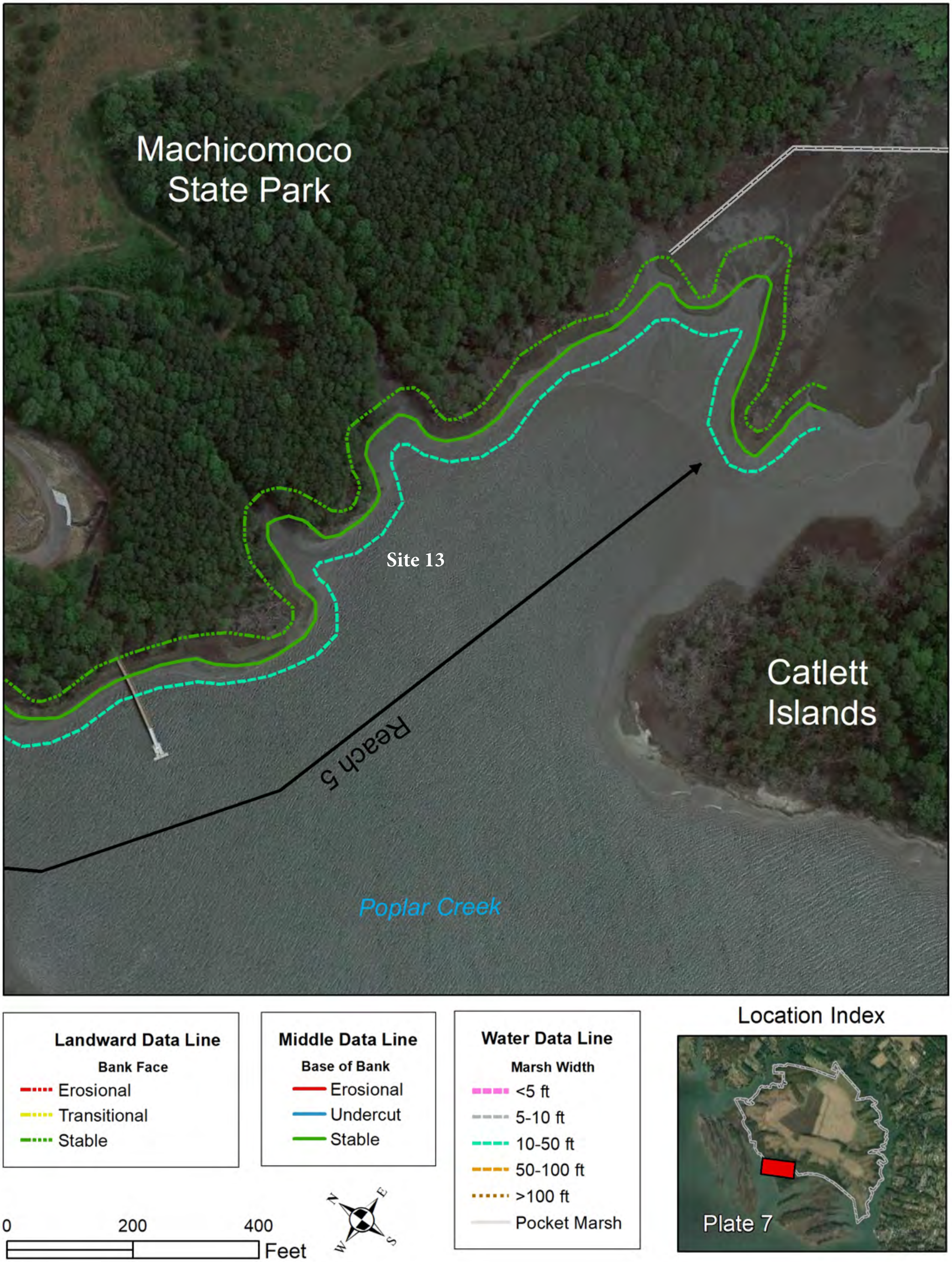
- <5 ft
- 5-10 ft
- 10-50 ft
- 50-100 ft
- >100 ft
- Pocket Marsh

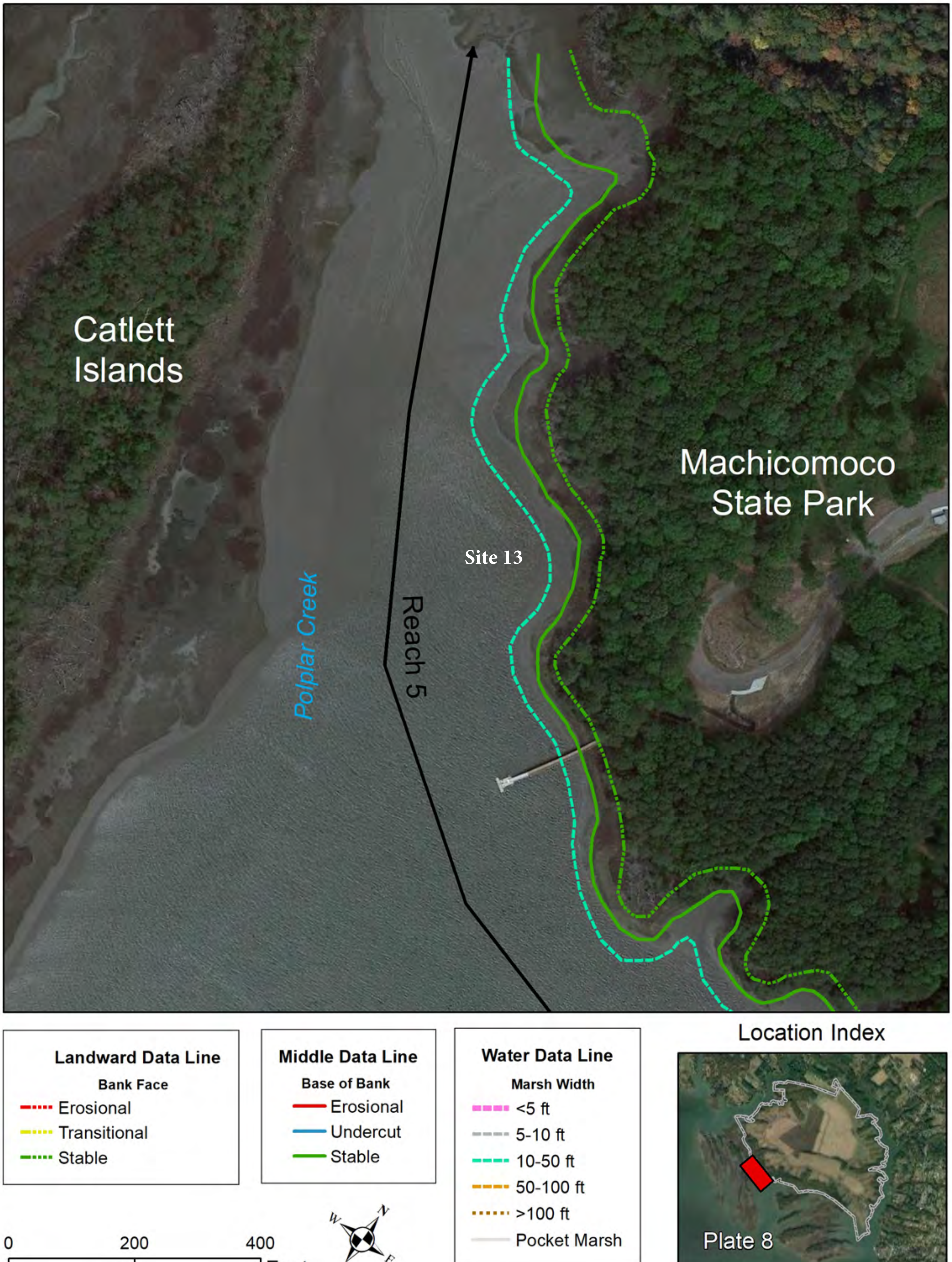
Location Index

0 200 400 Feet

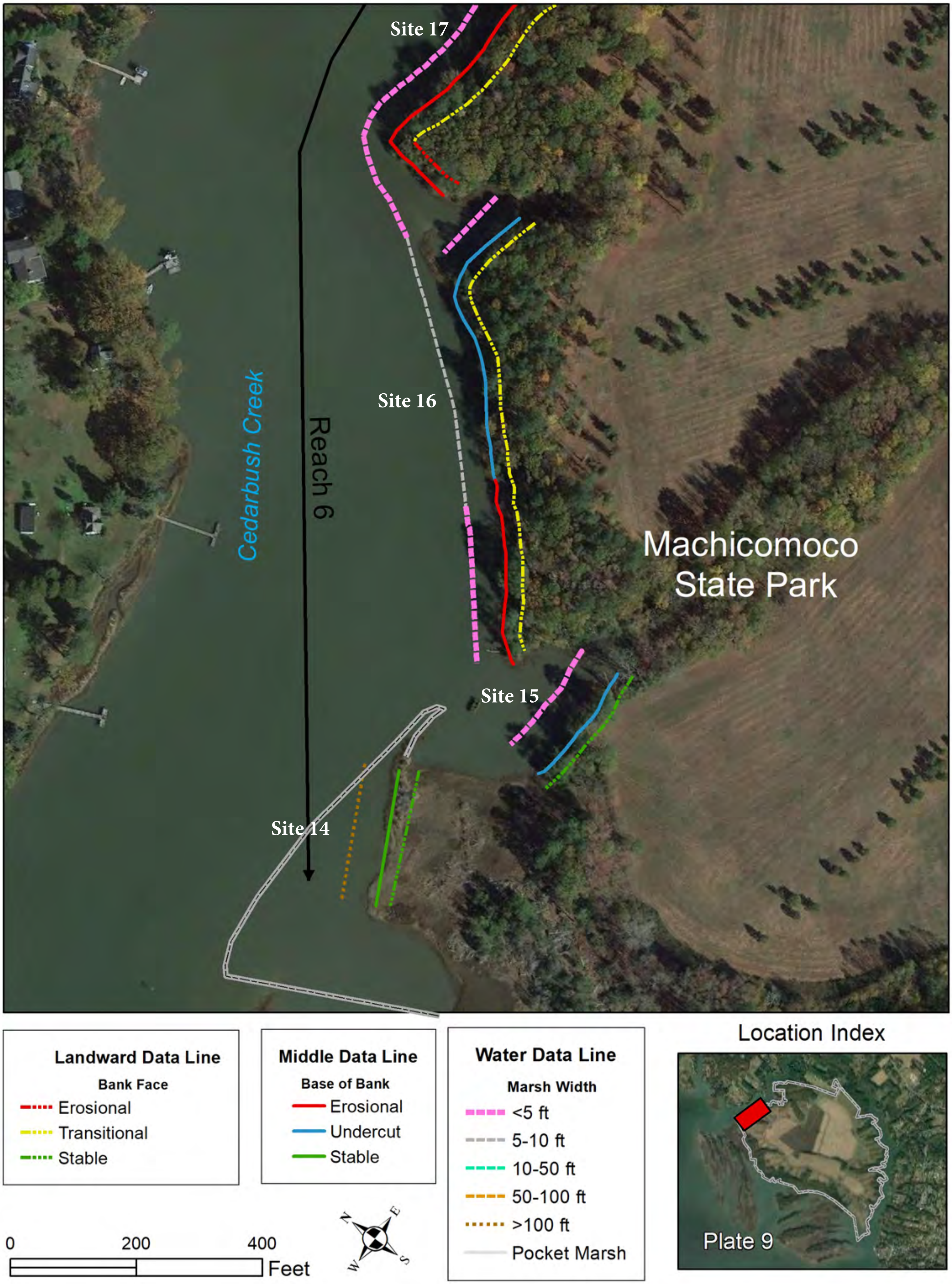
N E S W

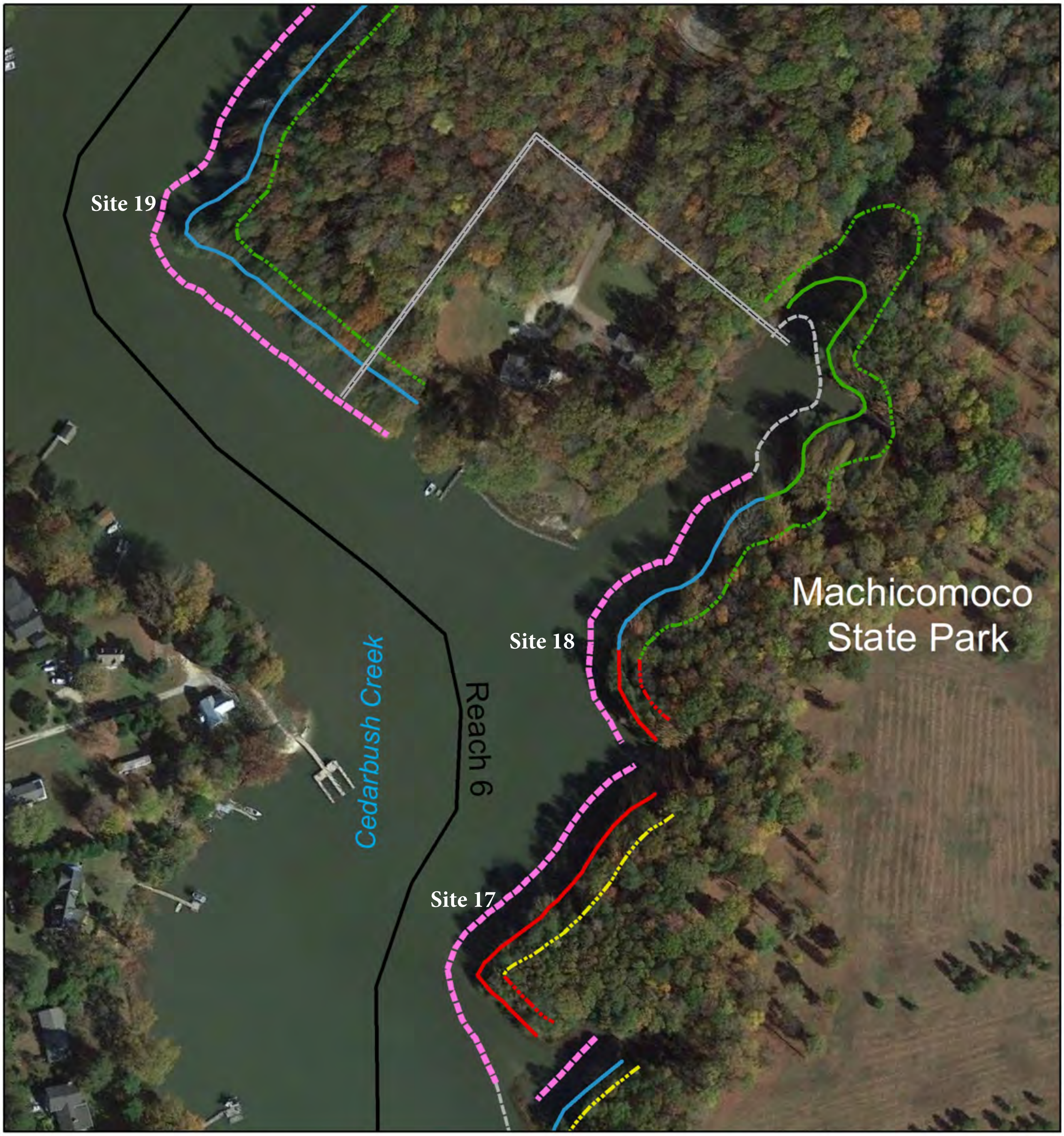

Machicomoco State Park
Catlett Islands
Timberneck Creek
Reach 4
Site 13
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
0
200
400
Feet
N
W
E
S
Location Index
Plate 6


Machicomoco
State Park
Site 13
Reach 5
Catlett
Islands
Poplar Creek
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
Location Index
Plate 7
0
200
400
Feet
N
E
S
W



Catlett
Islands
Machicomoco
State Park
Site 13
Polpiar Creek
Reach 5
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
Location Index
Plate 8
0
200
400
Feet
W
N
S
E


Site 17
Site 16
Site 15
Site 14
Cedarbush Creek
Reach 6
Machicomoco State Park
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
Location Index
Plate 9
0
200
400
Feet
N
E
S
W



Landward Data Line

Bank Face

- Erosional
- Transitional
- Stable

Middle Data Line

Base of Bank

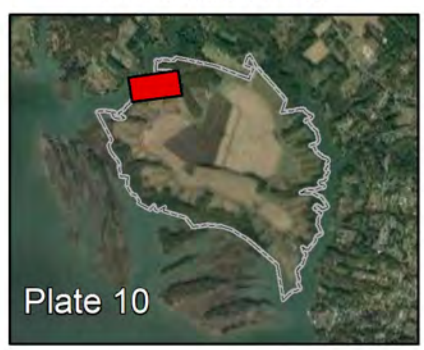
- Erosional
- Undercut
- Stable

Water Data Line

Marsh Width

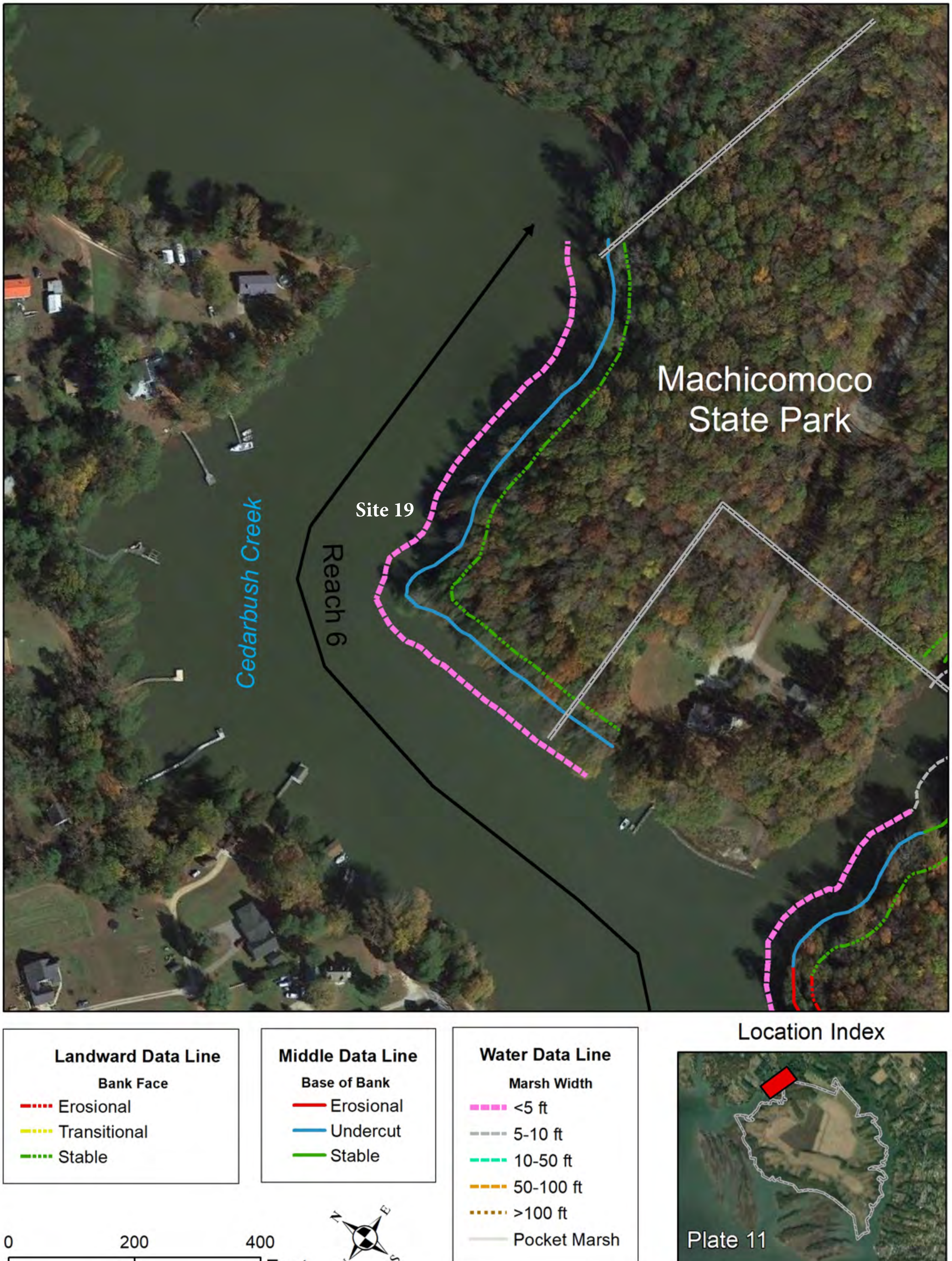
- <5 ft
- 5-10 ft
- 10-50 ft
- 50-100 ft
- >100 ft
- Pocket Marsh

Location Index



0 200 400 Feet

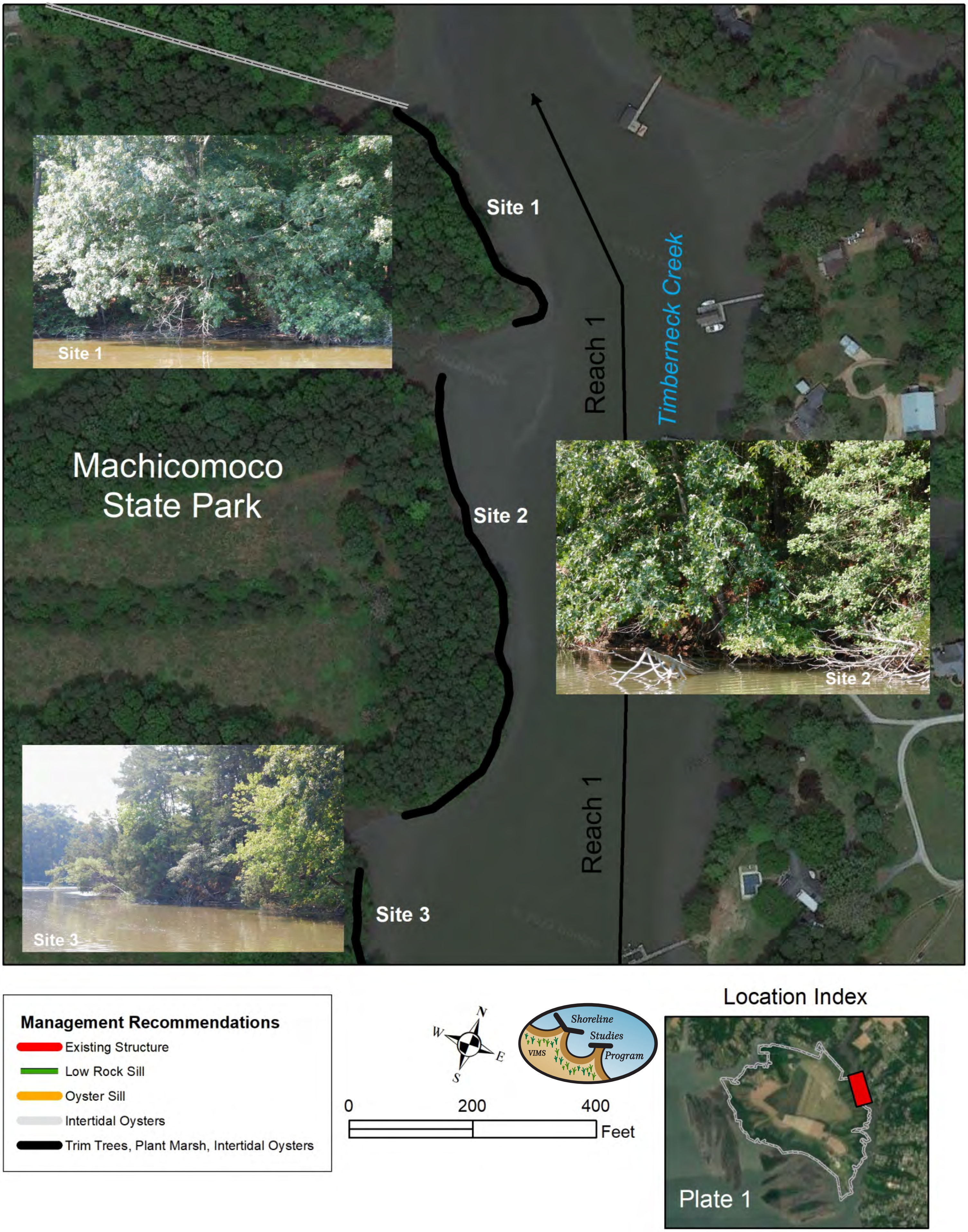
N E S W



Machicomoco
State Park
Site 19
Reach 6
Cedarbush Creek
Landward Data Line
Bank Face
Erosional
Transitional
Stable
Middle Data Line
Base of Bank
Erosional
Undercut
Stable
Water Data Line
Marsh Width
<5 ft
5-10 ft
10-50 ft
50-100 ft
>100 ft
Pocket Marsh
Location Index
Plate 11
0
200
400
Feet
N
E
S
W

Appendix E
Shoreline Management
Recommendations

Cedarbush Creek
Machicomoco
State Park
Catlett
Poplar Creek
Islands
York River
Timberneck Creek
1
2
3
4
5
6
7
8
9
10
11
Virginia Geographic Information Network (VGIN)
N
S
E
W
0
500
1,000
2,000
Feet
2021 VGIN Image

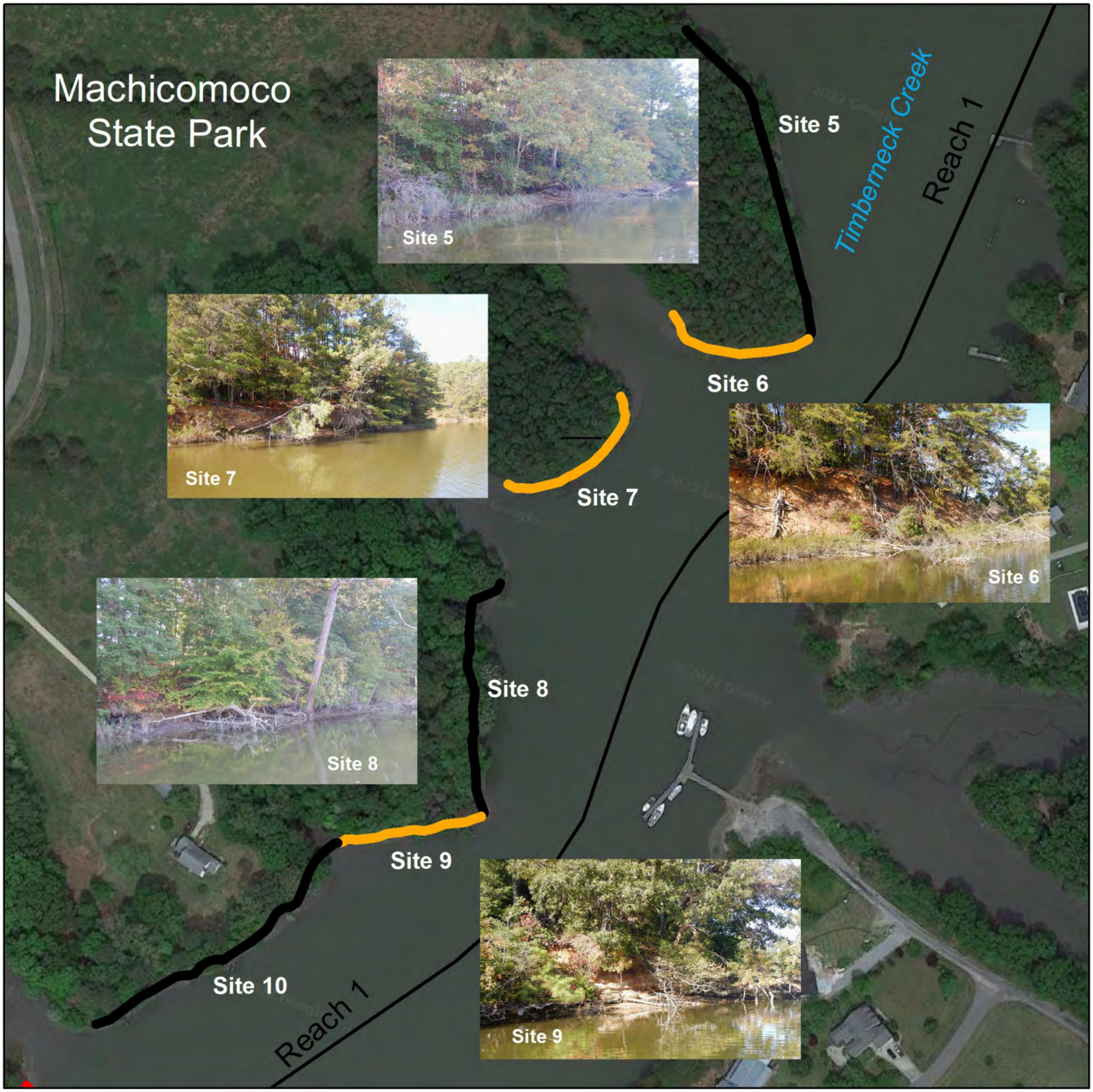

Site 1
Site 1
Reach 1
Timberneck Creek
Machicomoco
State Park
Site 2
Site 2
Reach 1
Site 3
Site 3
Management Recommendations
Existing Structure
Low Rock Sill
Oyster Sill
Intertidal Oysters
Trim Trees, Plant Marsh, Intertidal Oysters
N
W
E
S
Shoreline
Studies
Program
VIMS
0
200
400
Feet
Location Index
Plate 1

Management Recommendations

- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters

0 200 400 Feet

Location Index



Management Recommendations

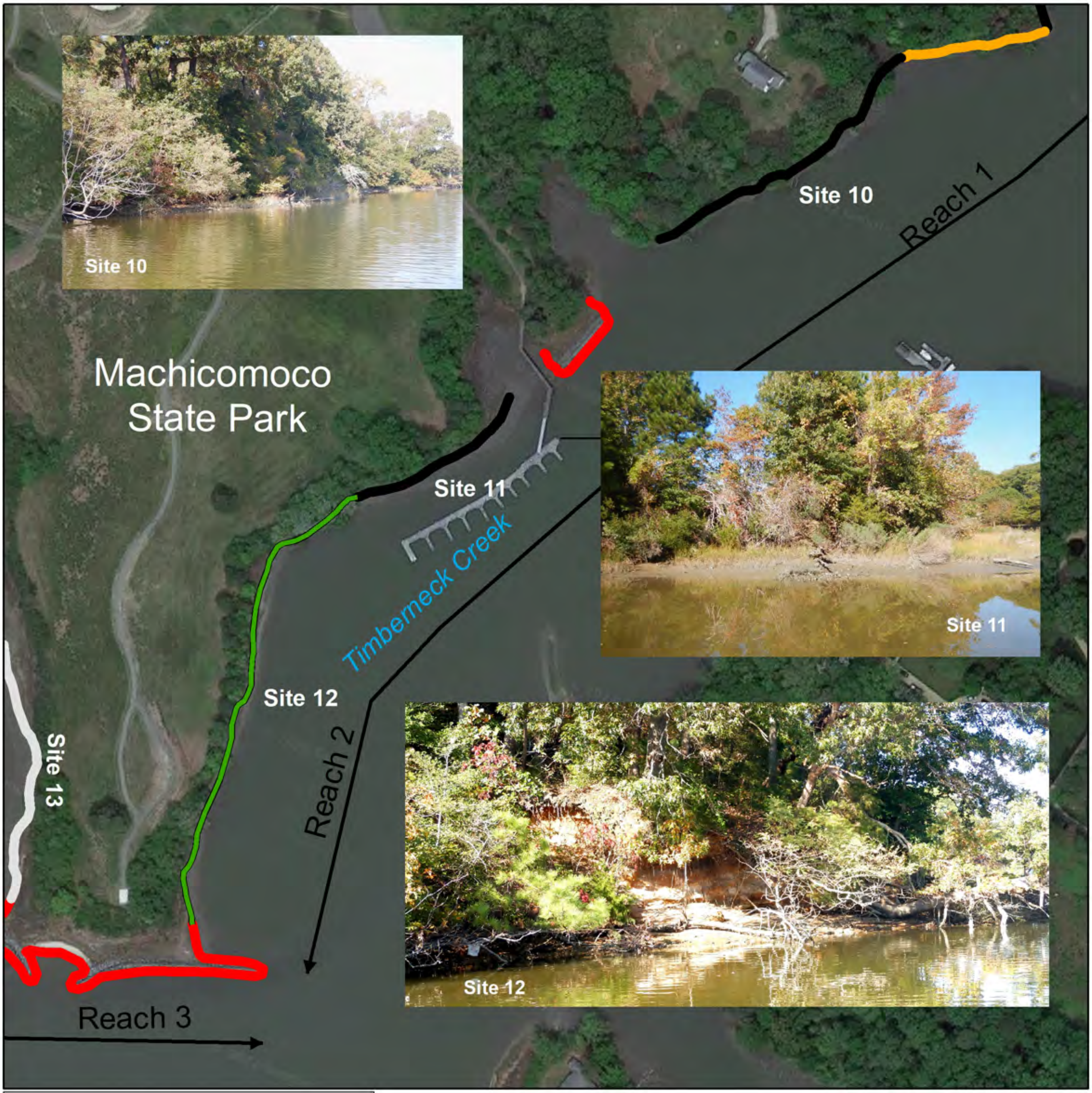
- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters

N W E S

0 200 400 Feet

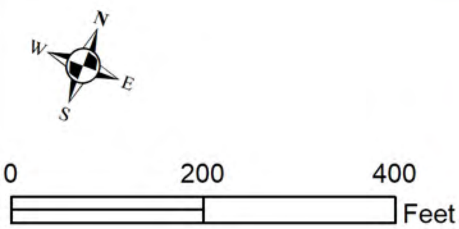
Shoreline Studies Program VIMS

Location Index

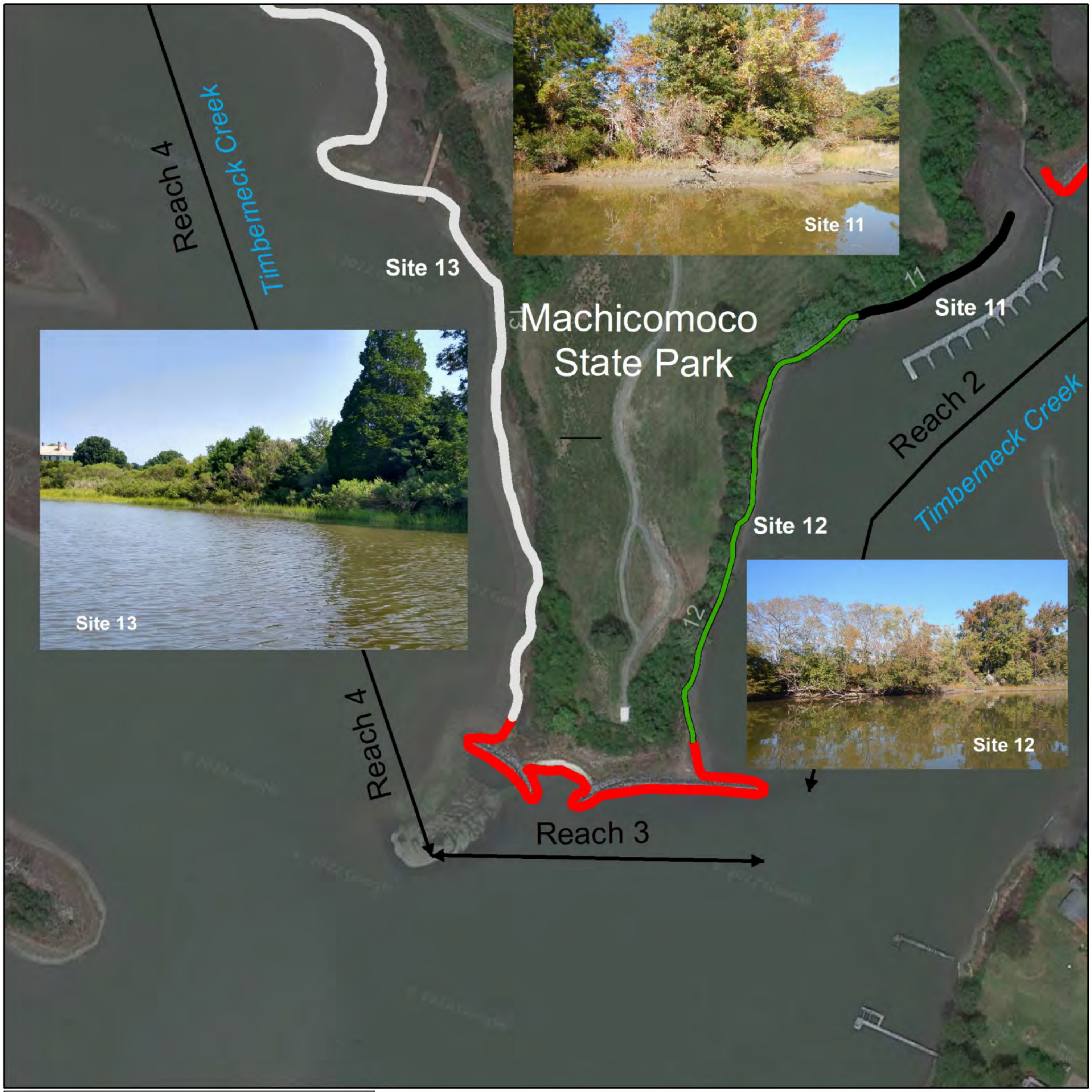


Management Recommendations

- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters



Location Index



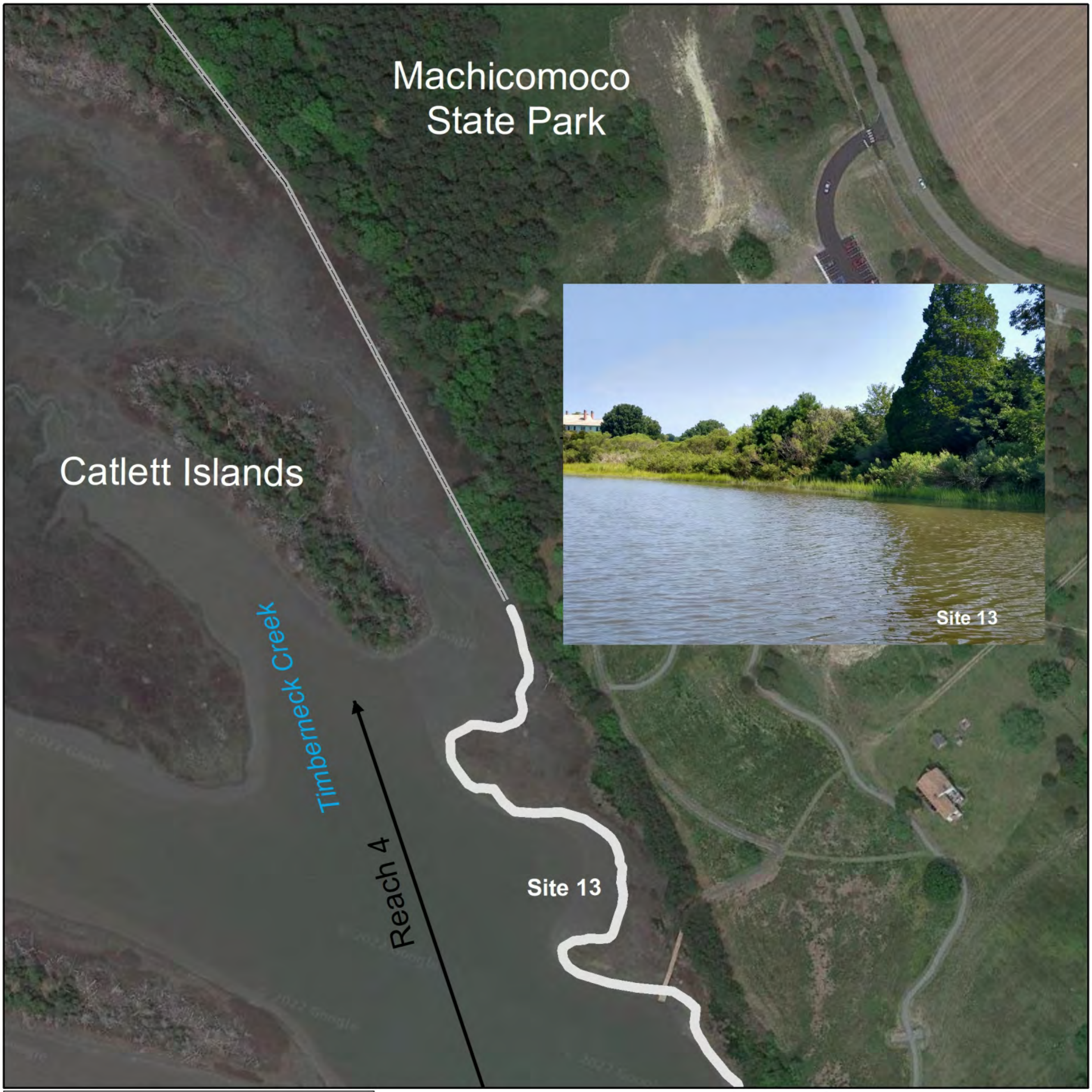
Management Recommendations

- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters

0 200 400 Feet

Shoreline Studies Program VIMS

Location Index



Management Recommendations

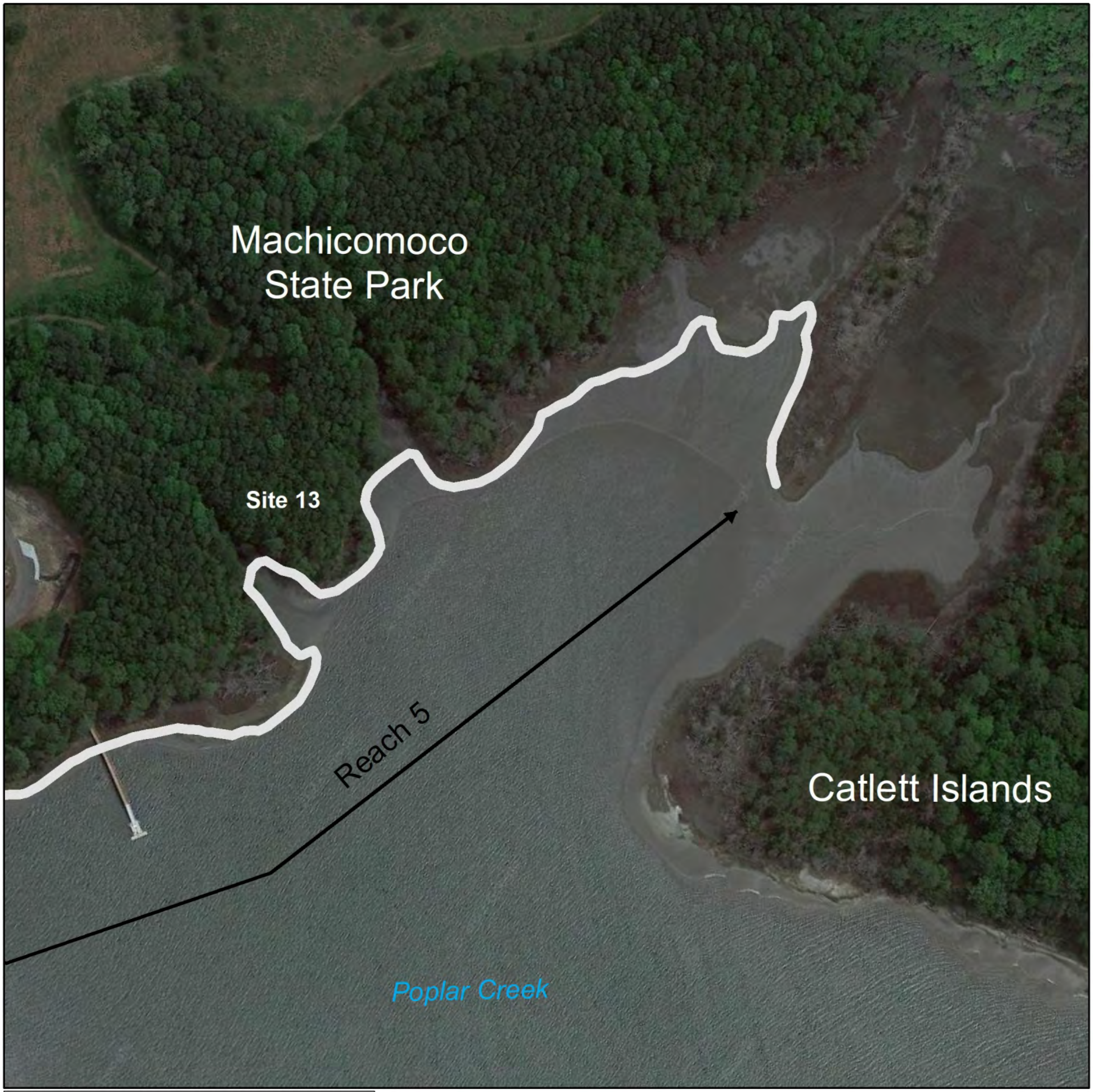
- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters

N W E S

Shoreline Studies Program VIMS

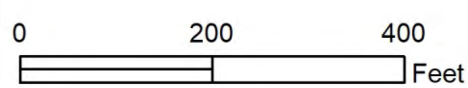
0 200 400 Feet

Location Index

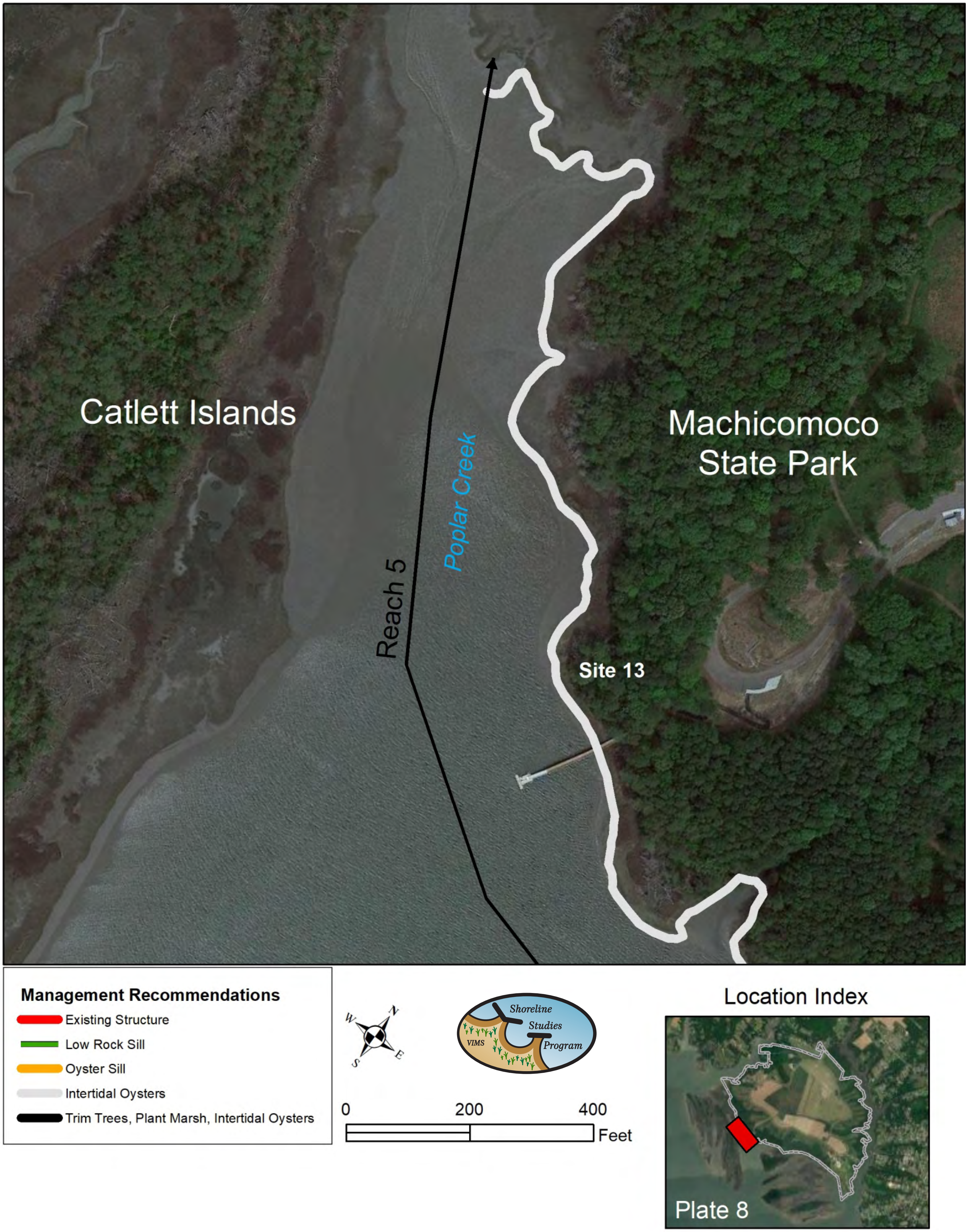


Management Recommendations

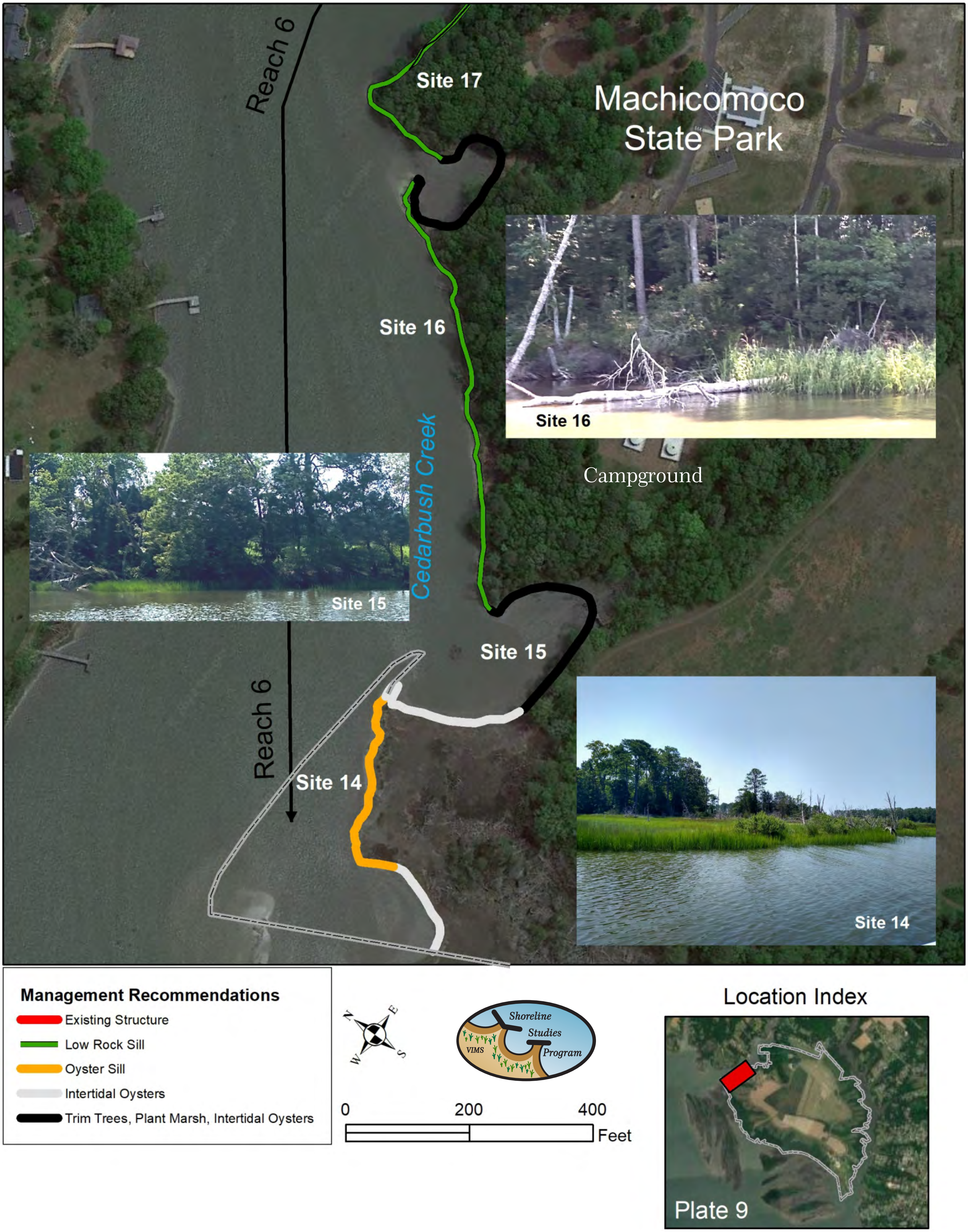
- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters

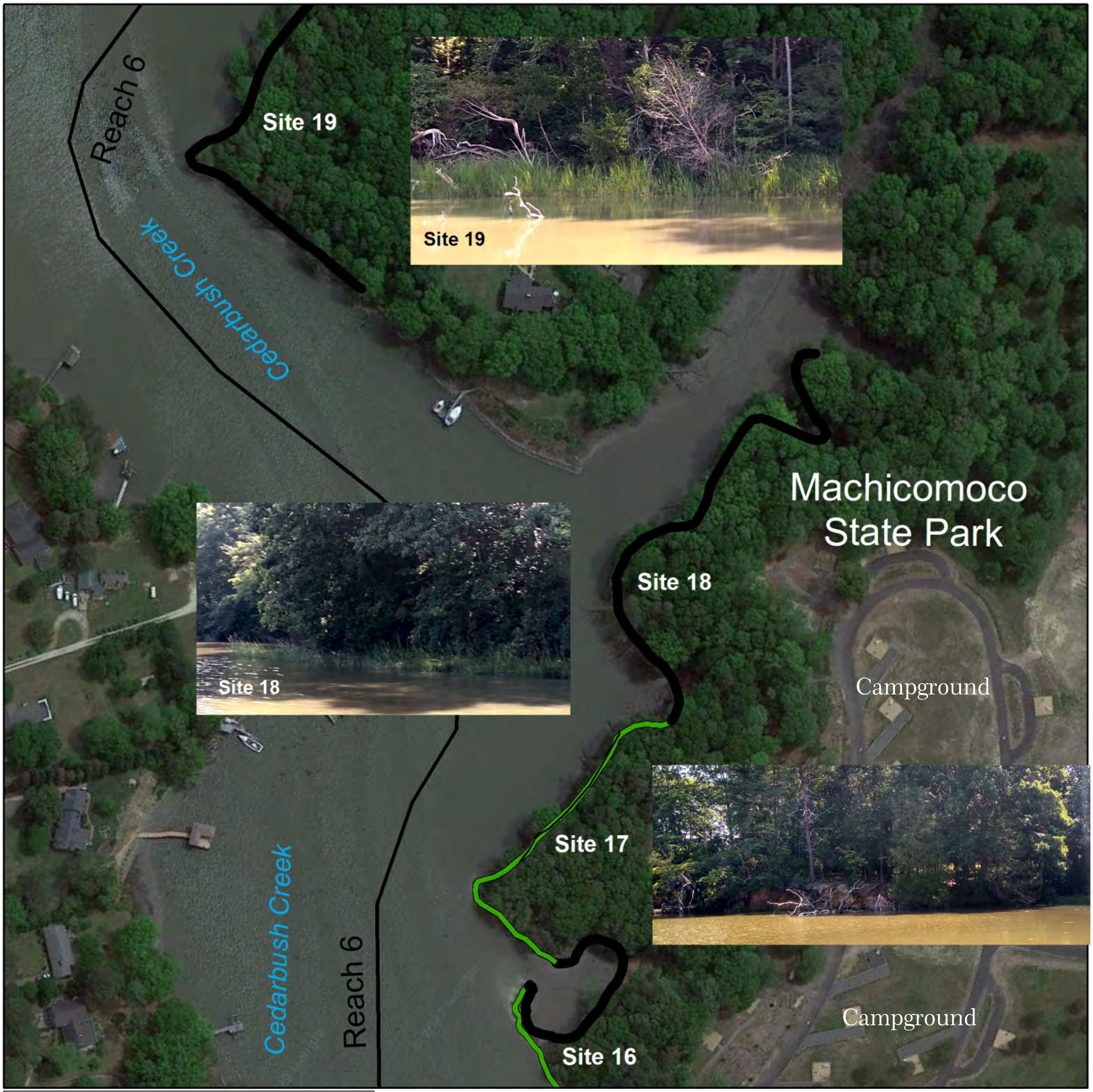


Location Index



Catlett Islands
Machicomoco
State Park
Poplar Creek
Reach 5
Site 13
Management Recommendations
Existing Structure
Low Rock Sill
Oyster Sill
Intertidal Oysters
Trim Trees, Plant Marsh, Intertidal Oysters
W
N
S
E
Shoreline
Studies
Program
VIMS
0
200
400
Feet
Location Index
Plate 8


Reach 6
Site 17
Machicomoco
State Park
Site 16
Site 16
Cedarbush Creek
Campground
Site 15
Site 15
Reach 6
Site 14
Site 14
Management Recommendations
Existing Structure
Low Rock Sill
Oyster Sill
Intertidal Oysters
Trim Trees, Plant Marsh, Intertidal Oysters
N
E
S
W
Shoreline
Studies
Program
VIMS
0
200
400
Feet
Location Index
Plate 9



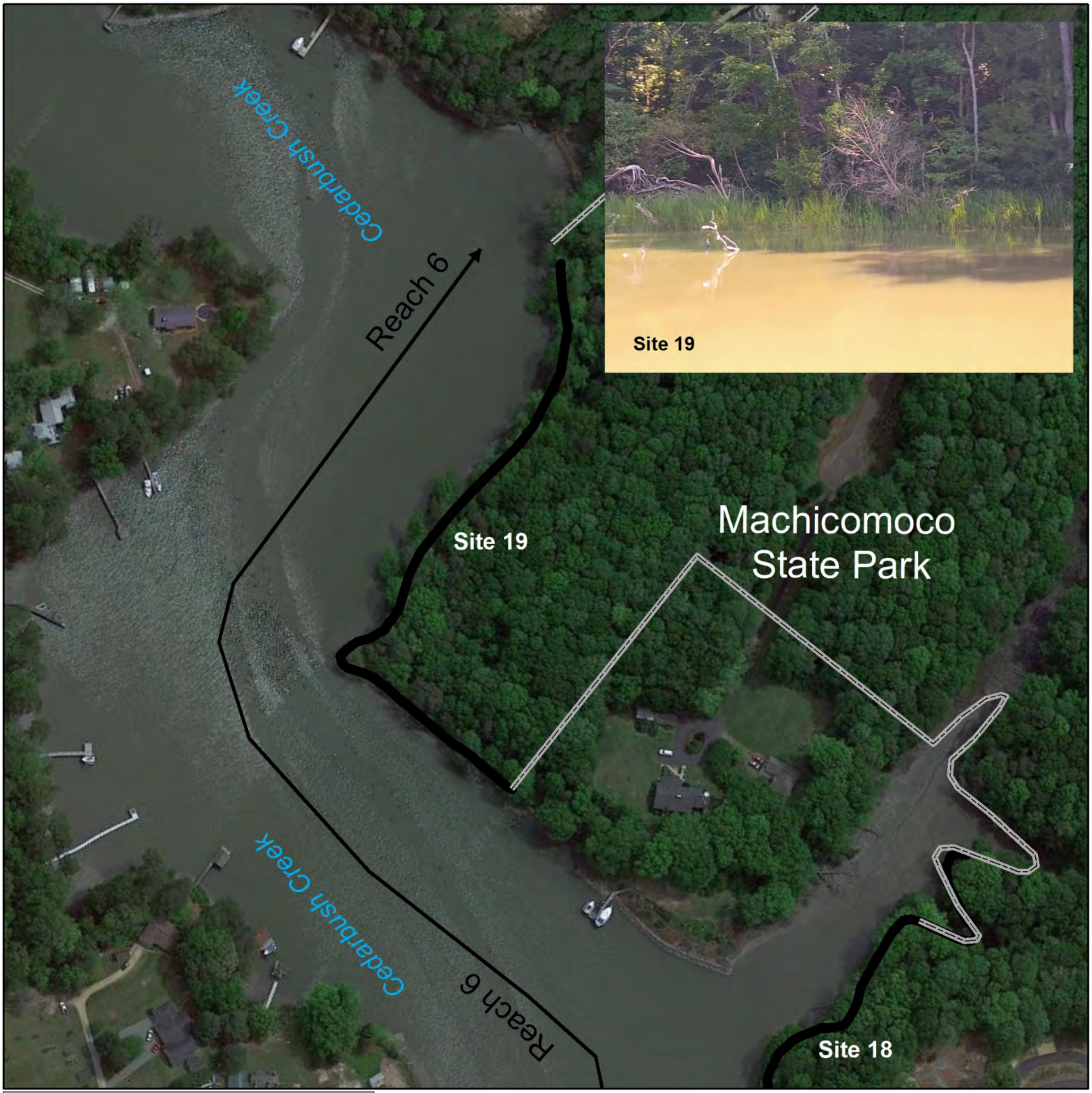
Management Recommendations

- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters

Shoreline Studies Program VIMS

0 200 400 Feet

Location Index



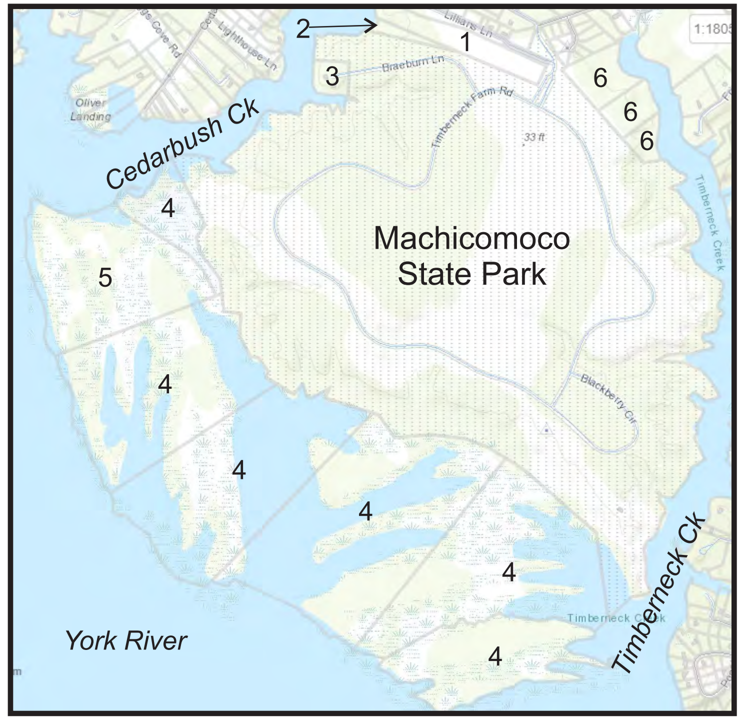
Management Recommendations

- Existing Structure
- Low Rock Sill
- Oyster Sill
- Intertidal Oysters
- Trim Trees, Plant Marsh, Intertidal Oysters

0 200 400 Feet

Location Index

Appendix F
Draft Joint Permit
Application



Adjacent Property Owners

Number	RPC	Name
1	13963	William Woodward, Jr.
2	31120	Shawn and Dawn Lemon
3	13933	Christy and Eric Baldwin
4	13939, 43115, 16918, 29971, 43120, 29788	College of William & Mary, Virginia Institute of Marine Science
5	20212	Ablowich Family Joint Trust
6	10967, 18059, 32448	Williams Revocable Trust

VIMS Shoreline Studies Program

Adjacent Property Owners

Hog Island Living Shoreline

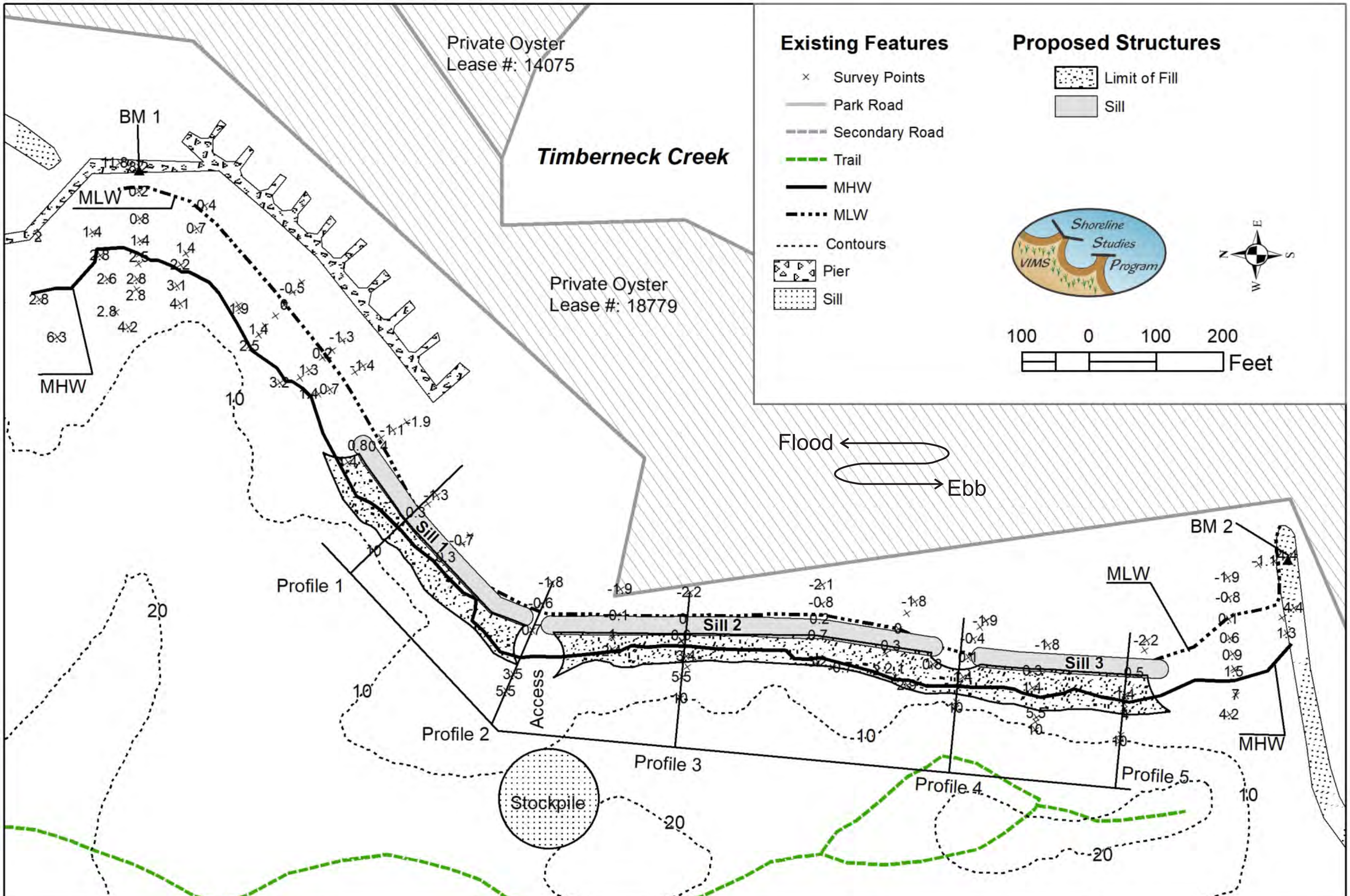
Application By:

Datum: MLW

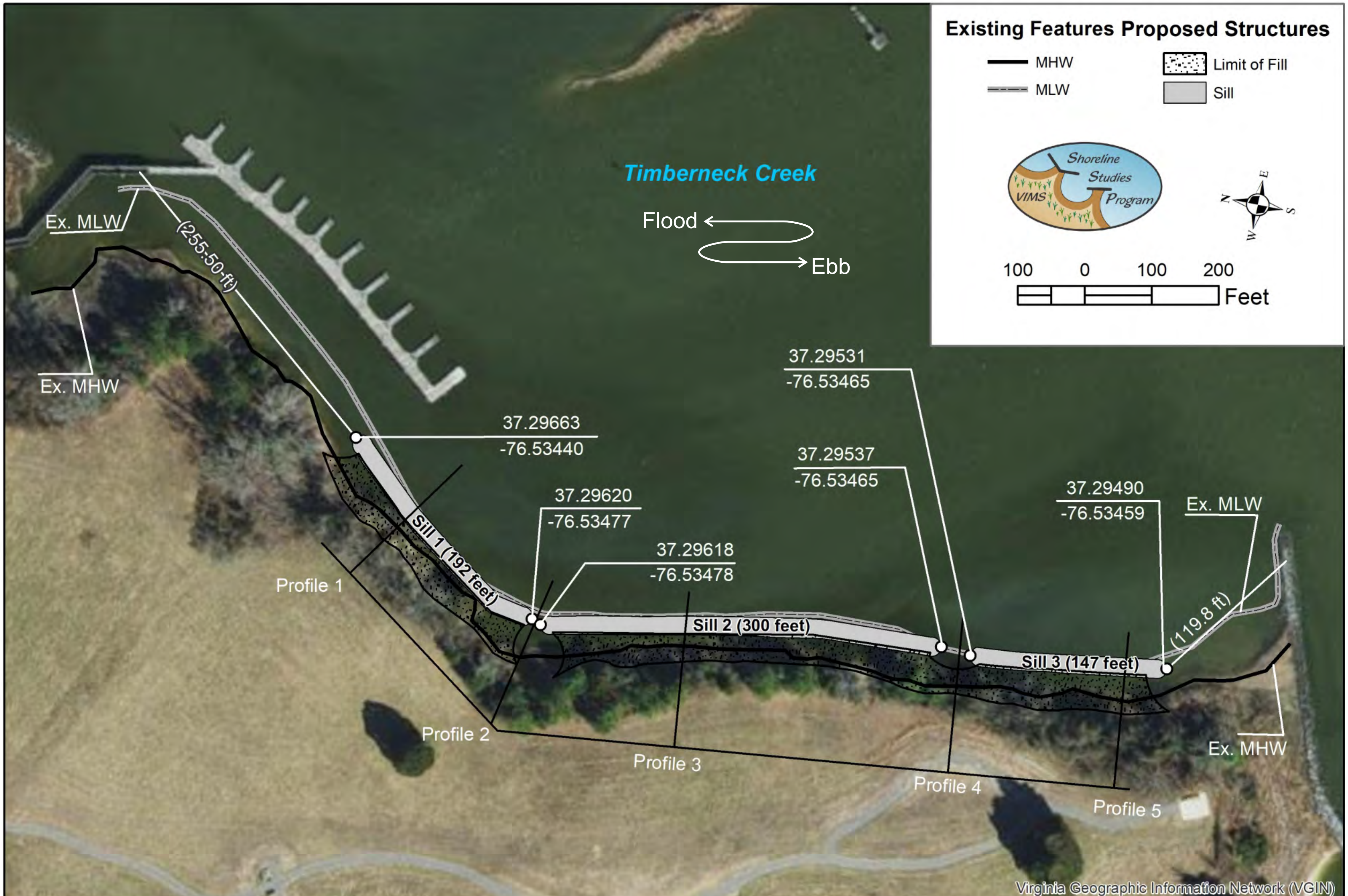
At:
In:

Purpose: Shore Protection

Date: 31 Jan 2022
Sheet: 1 of 6

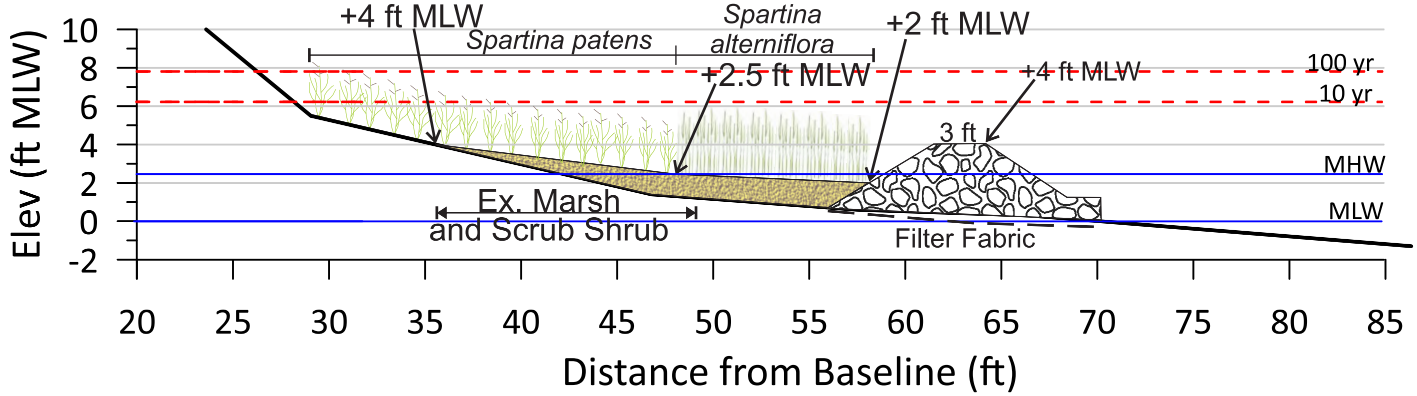


	Adjacent Property Owners: See Cover Page	**Machicomoco State Park Living Shoreline Project**	**Application By:**
			Date: 31 Jan 2022
	Datum:	**At:** **In:** / **Purpose:**	**Sheet No.**

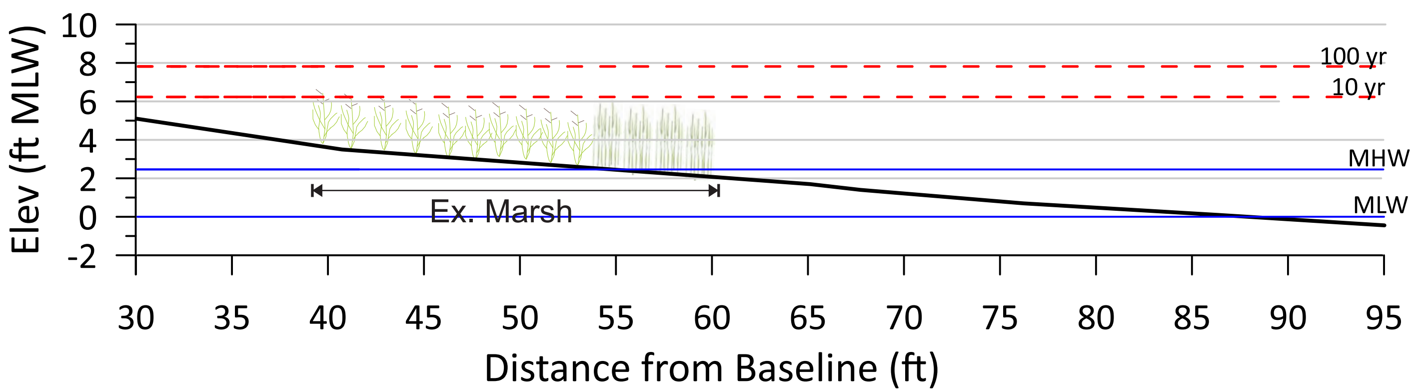


Adjacent Property Owners: See Cover Page	**Machicomoco State Park Living Shoreline Project**	Application By:
		Date: 31 Jan 2022
Datum:	At: In: / Purpose:	Sheet No.

Typical Profile 1



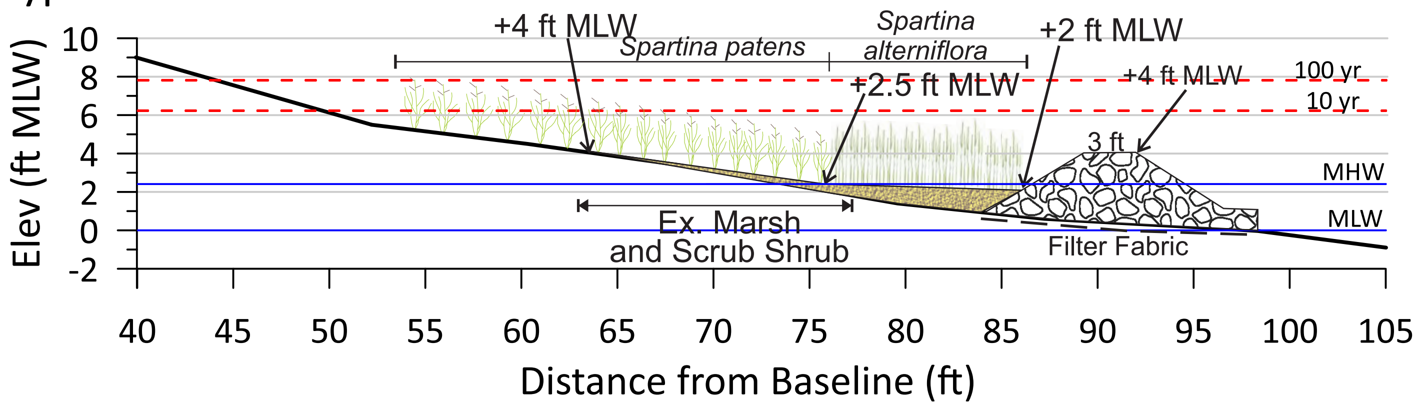
Typical Profile 2



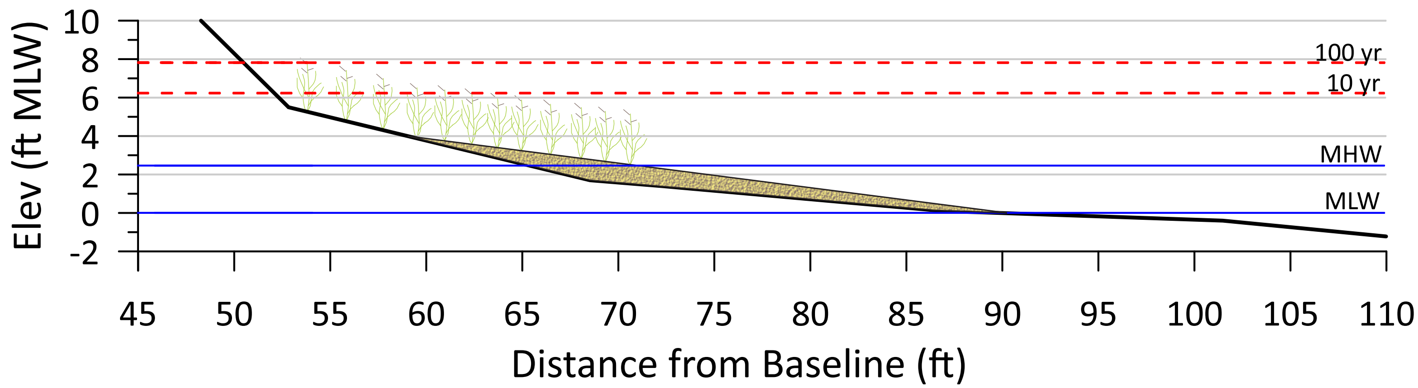
1"=10 ft

Shoreline Studies Program VIMS	Adjacent Property Owners	Machicomoco State Park Living Shoreline		Application By:
	Datum: MLW	At: In:	Purpose: Shore Protection	Date: 31 Jan 2022 Sheet:

Typical Profile 3



Typical Profile 4



1"=10 ft

Shoreline Studies Program VIMS

Adjacent Property Owners

Machicomoco State Park Living Shoreline

Application By:

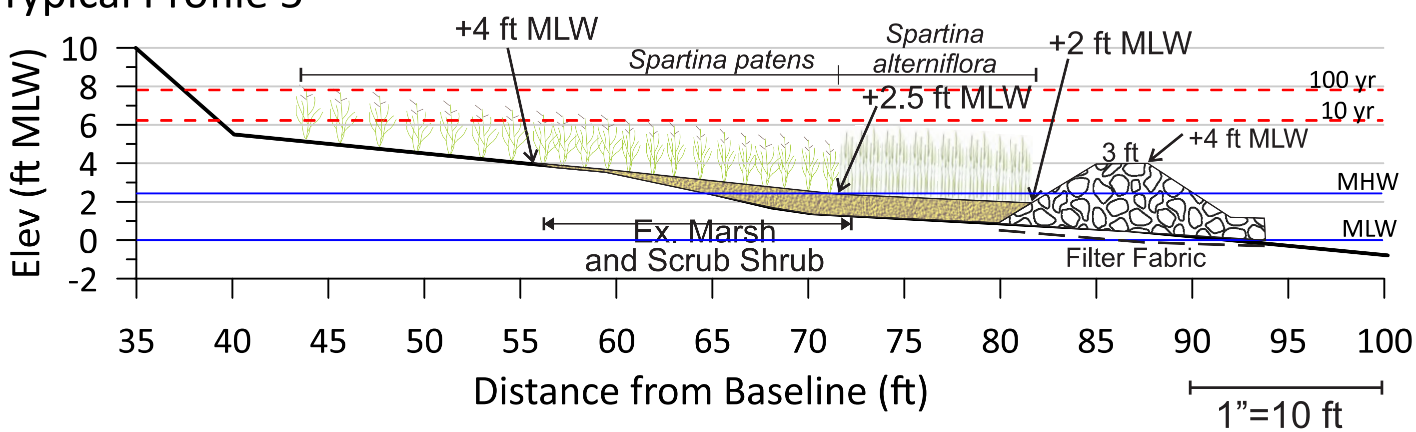
Datum: MLW

At:
In:

Purpose: Shore Protection

Date: 31 Jan 2022
Sheet:

Typical Profile 5



Shoreline Studies Program, VIMS	Adjacent Property Owners	Machicomoco State Park Living Shoreline	Application By:
	Datum: MLW	At: In: / Purpose: Shore Protection	Date: 31 Jan 2022 / Sheet: