

Preserving Coastal Parklands

ASSATEAGUE ISLAND NATIONAL SEASHORE



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Table of Contents

Executive Summary **01**

Our Approach 08

Design Concepts **27**

Bayside: Natural Wood Reef 28

Dune Fencing: Directed Overwash 64

References **108**

Appendix **113**

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Executive Summary

Coastal parklands are culturally significant landscapes where unique natural and historical forms and forces are affected directly by marsh migration, coastal erosion, intense storm events, and habitat loss. Nature-based solutions (NBS) work with natural forms and processes to produce desirable effects such as slowing erosion, building habitat, protecting critical infrastructure, and directing dune evolution while improving habitat and human experiences of the landscape over time. Because they work with the natural qualities of a landscape, the implementation of NBS to combat subsidence, flooding, erosion, and increasingly strong and frequent storms in coastal parklands is both imperative and a unique challenge requiring an innovative approach.

Today, Assateague Island National Seashore (ASIS) is one of the 25 national parks most at risk from accelerated erosion, higher water levels, and more extreme storms [1]. While it has always been a fluid landscape shaped by oceanic forces, these new environmental dynamics will require rebuilding and relocating infrastructure, bolstering island ecological resilience, and reimagining public use of the Park. The philosophy around adaptation at the park makes ASIS unique: according to the Park's foundation document, a central goal is to "allow the island to continue to be shaped predominantly by natural coastal processes'' [2]. At Assateague Island, the general approach of the National Park Service (NPS) is to accept new hydrological, ecological, and meteorological conditions and work with them to enhance human experience and habitat values instead of resisting them. It is an adaptive approach that creates much opportunity for the design of resilient nature-based landscapes and can inform the adoption of innovative practices in coastal parklands along the East and Gulf Coasts.

In this context, our team attempted to build on the good work already underway and to develop additional concepts and approaches that might enhance the Park's goals in keeping with their mission. This entailed first documenting and analyzing current practices and their effects, including dune management, restoration of marshes that have extensive mosquito ditching, and implementing flexible recreation

Executive Summary

infrastructure and amenities. This analysis was part of our research process to generate new concepts and approaches suited to the place, but also may serve to help disseminate information about the innovations and best practices already in place at Assateague. Second, we worked with NPS partners to identify two focus areas– the managed dune area and Bayside Peninsula– where important dynamics and needs existed that called for additional research into new forms of NBS.

This research took place between January 2023 and January 2024 and was divided into four stages: 1) site investigation by researchers and collaborators at Assateague Island National Seashore to identify needs and opportunities and understand the historical and natural context of the Park (Figure 1); 2) a design workshop held at the University of Virginia to collaboratively discuss design opportunities; 3) development of natural infrastructure concepts framed in the workshop; and 4) concept review and refinement, incorporating comments from ASIS leadership. The multi-disciplinary team brings together landscape architectural and history expertise from the University of Virginia, social science and conservation expertise from The Nature Conservancy, and large-scale resilience and institutional coordination expertise from NPS and EA Engineering, Science, and Technology Inc, PBC. Our approach leverages the tools of our team to investigate what is particular about this landscape, and how its specific qualities can play a role in generating more resilient and meaningful landscapes over time. This document outlines the team's approach to nature-based solutions in the Park and describes design concepts for the Bayside peninsula and key dune sites in the more intensively managed Developed Area of the park.



Figure 1. Site visit in April 2023

Bayside

On the Bayside peninsula the design concept is a natural wood reef which would use wind-driven erosion of an existing parking area at the end of the peninsula to build a beach strand and protect tidal marsh (Figure 2). The western point of the landform is rapidly eroding, losing almost twenty feet per year. This proposal brings together both natural forces - erosion and sediment transport - and anthropogenic forces – trees felled for the retreat of recreational infrastructure – to generate habitat on the northern edge of the peninsula.



Figure 2. Aerial illustration of proposed NBS at Bayside

Dunes

We propose the establishment of strategic dune overwash zones that would allow for additional overwash in the developed area of the national seashore by lowering foredune crest height while maintaining or increasing sand volume in the dune system. ASIS already allows for larger overwash events as a means of permitting the island to adapt to more frequent, larger storms and higher water levels with minimal disturbance to maintenance and human use. By diversifying the fencing practices already in place, our research suggests that in key locations within the developed area it is possible to achieve greater dune diversity with less maintenance requirements to enhance island resiliency over time (Figure 3). Our study focuses on a site north of North Ocean Beach, but the overwash zones would also be appropriate at other locations as well (e.g. walk-in campgrounds).



Figure 3. Diversifying dune fencing in different contexts across ASIS.





1.1

Our Approach

Assateague Island National Seashore is a NPS and state-owned barrier island that formed about 5,000 years ago; a constantly changing landform lying on the edge of the Atlantic. Over its lifetime the sandy island has been worked and reworked by dynamic coastal processes including storm-driven overwash, dune formation, and sediment transport driven by waves and wind [3] as well as by the values and needs of the people who have lived on and managed Assateague. For centuries, Assateague had been the ancestral home of the Chincoteague and Pocomoke-Assateague Nations, for whom the island is now named [4], as well as home to a few sparse but sturdy English settlements and villages [5]. Assateague Island extends over two states, Virginia and Maryland, with the northern half of the island used as a nature-based recreational park that is co-managed by NPS and the State of Maryland, and the southern end of the island managed by the U.S. Fish & Wildlife Service as Chincoteague National Wildlife Refuge.

The island is constantly in the process of being reshaped by the forces of water and wind, which has long frustrated large-scale plans for development [6]. It is clear from looking back at the history of human settlement, which has left only traces in the sands and marshes of the island [7], that to occupy Assateague is to live with this constancy of movement and sense of impermanence. While loss and erasure may seem counter to a conservation mindset, the National Park Service has embraced these natural processes as a key feature, as evidenced by this excerpt from the purpose statement of their Foundation document, “to preserve the outstanding Mid-Atlantic coastal resources of Assateague Island and its adjacent waters and the natural processes upon which they depend.” [8]

The natural forces that shape the Park are growing faster and larger, subjecting the island to changes that park environments and infrastructures can’t keep up with in perpetuity. Assateague Island faces increasing storm impacts and changing water levels, as well as rapid shoreline evolution and disturbance. These forces will introduce uncertainty that will necessitate a transition in the way the Park is managed. Therefore, in 2016, NPS prepared a General Management Plan [9] to guide ASIS managers for the next twenty years. The plan outlines four alternatives. The first alternative involves NPS continuing to manage resources and visitor use as it does today, the second sees management concentrating conventional beach recreation into a high density and highly managed developed zone, the third (preferred) alternative calls for shifting visitor and recreational resources and locations to adapt to changing hydrodynamic conditions, and the fourth completely allows natural processes to overtake existing resources.

Using the third alternative as a guideline to manage the Park preserves most of the existing recreational uses of the island. It also necessitates adaptive design and maintenance, as well as a long-term strategy for shifting vulnerable assets. The design concepts discussed here were developed to work with this vision and complement the work already being done at ASIS.



1.2

Islands within the Island

Assateague is part of a larger system of barrier islands stretching along the Atlantic coast, all stitched together by longshore transport (fig. 4). Much of this barrier island system has been heavily developed, limiting or obstructing natural island movement. Jetties and groins meant to lock specific beaches or inlets in place end up robbing sediment from islands downshore.

Assateague represents one of the most extensive stretches of unrestrained barrier island in this system. Left to migrate and evolve more naturally, Assateague offers a unique opportunity to observe barrier island change over time. Traces of overwash fans and footprints of historic inlets are clearly visible in the morphology and vegetation of the island today, leaving us with a picture of islands within the island (fig. 5), each with its own history and dynamic.

Overwash, breaches, and inlets are a natural and ultimately beneficial part of island change. Overwash drives island migration in reponse to storm events and changing water levels by transporting sand from the beach to the island interior. This migration means that barrier islands are able to retreat, which has allowed them to adapt to rising sea levels over time, though there is a potential threshold for this adaptation. Sometimes overwashing flows breach the island during large storms, creating channels between the ocean and the bay. Most breaches are short-lived and are naturally closed by longshore transport.

Net annual longshore transport is between 115,000 and 214,000 cubic meters per year (4 million - 7.5 million cubic feet) [10]. Though gentle, consistent wind from the southeast drives sand northward in the summer, sediment transport is predominantly southward due to strong nor'easters. The island is comprised of four major zones: 1) the rapidly-shifting northern end, 2) the "held" but narrowing developed zone, 3) the mid-island backcountry, where wider and more heterogeneous island features remain stable, and 4) the accretionary southern tip (fig. 6). These four zones have important implications for how visitors experience and understand the island, as well as for different strategies for park infrastructure design and land management. The sections on the following pages (figs. 7 and 9) describe these zones and how they have changed over the last twenty years. The northern end is relatively low and narrow. The narrow active beach fronts a large washover sandflat (fig 7, Section 1). Beach erosion over time is clear and significant. The dune crest, however, has maintained its position for the last 15 years and has grown significantly.

Sections 2 and 3 in Figure 7 describe two management styles: active, in the State Park (2), and passive in the National Park (3). In

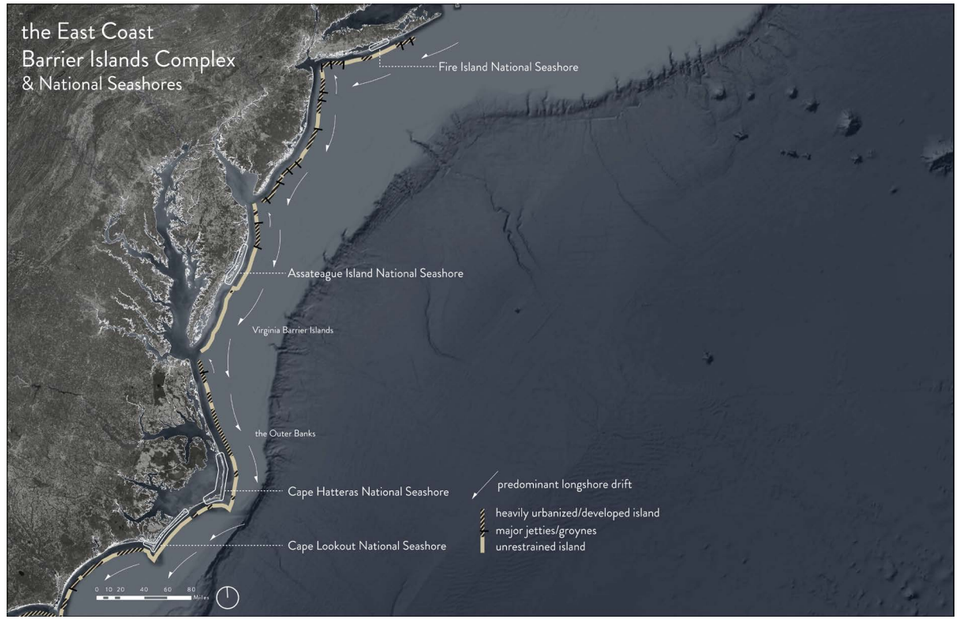


Figure 4. East Coast Barrier Islands. Assateague Island National Seashore represents one of the longest stretches of unrestrained barrier islands along the East Coast.

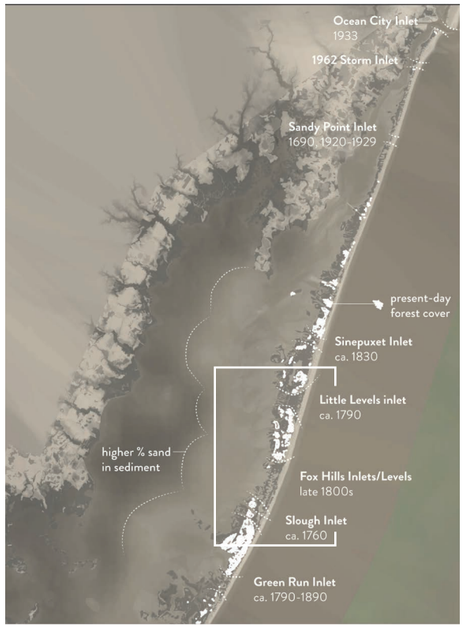


Figure 5. Islands within the Island, shaped by historical inlets

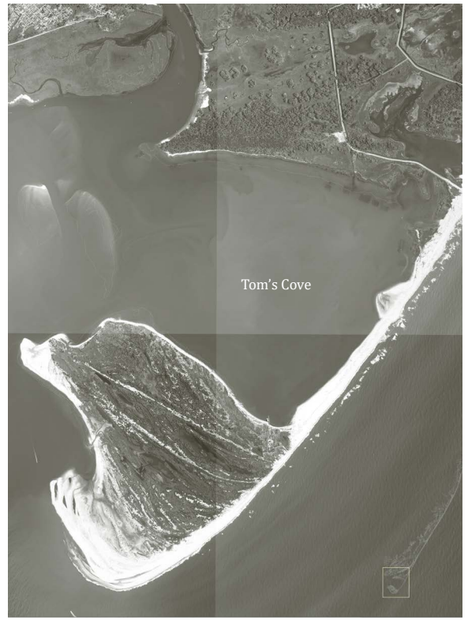


Figure 6. Tom's Cove, the southern tip of Assateague Island

1.2 Islands within the Island



Section Cut Line

Section Line without vertical exaggeration

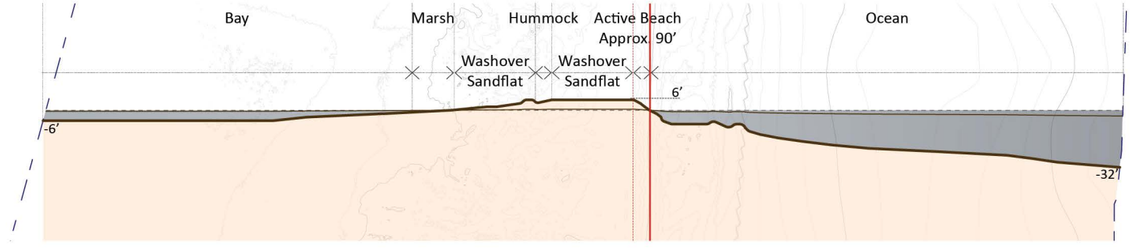
Section Line with 10x vertical exaggeration

MHW- 0'

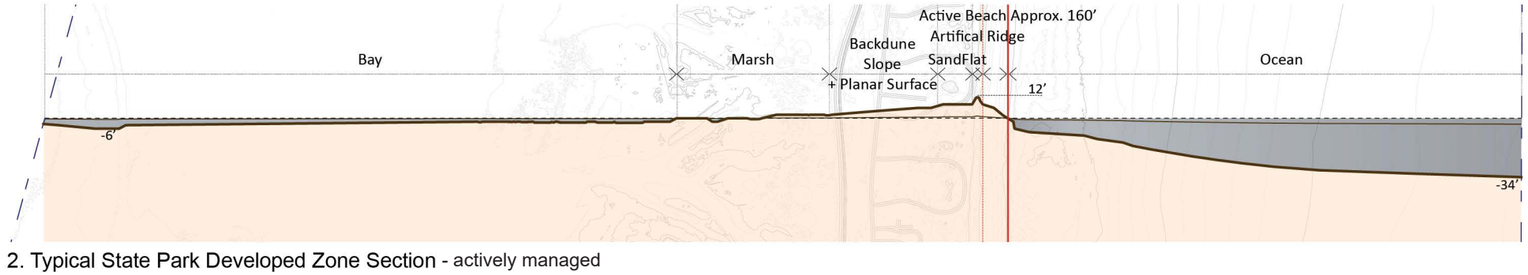
Active Beach width

ASIS Boundary

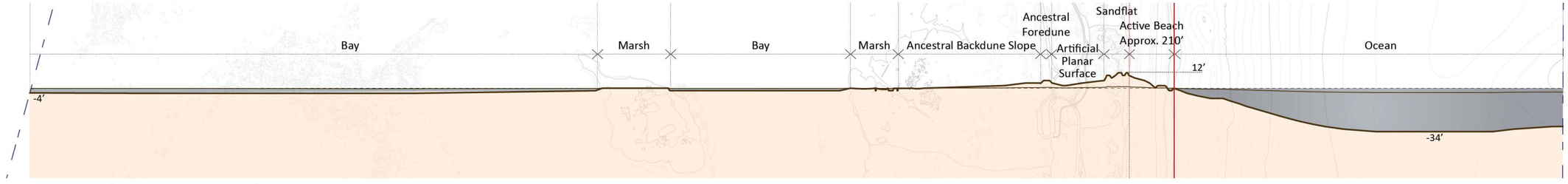
Infrastructure



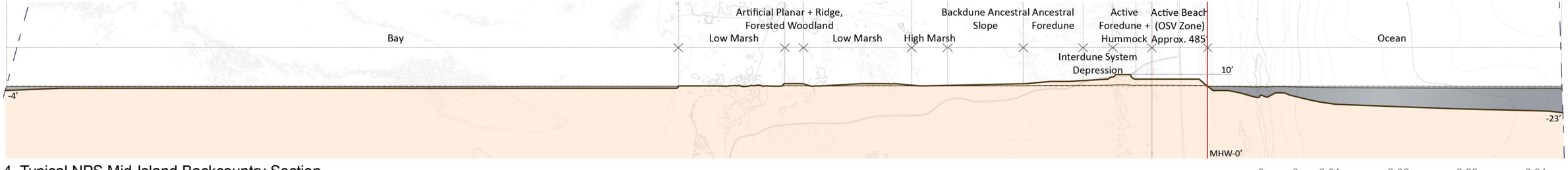
1. Typical North Beach Overwash Section



2. Typical State Park Developed Zone Section - actively managed



3. Typical NPS Developed Zone Section - passively managed



4. Typical NPS Mid-Island Backcountry Section

Typical Island-Scale Sections

0 0 0.01 0.02 0.03 0.04 Miles

Figure 7. Four sections through Assateague Island, illustrating different natural dynamics and different management styles.

1.2 Islands within the Island

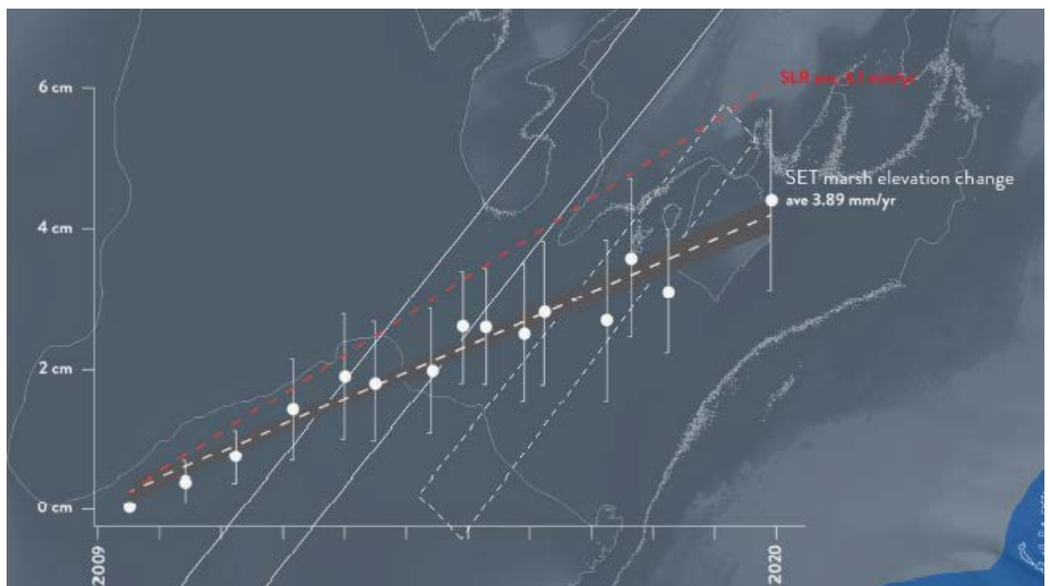


Figure 8. Surface Elevation Table (SET) marsh elevation over time at ASIS, which has begun to be outpaced by sea level.

the State Park, where the dune is actively maintained with machinery, we see a very narrow beach but a stable and extremely large protective dune. Because this dune maintenance holds its line and restricts the natural forces pushing the island bayward, the infrastructure behind the dune is kept safe and the beach in front of the dune erodes.

Figure 7, Section 3 characterizes the portion of the developed zone managed by NPS, which was the focus of our research. Dunes are passively managed, meaning fencing is placed and left to accrete sand. When the active beach area starts to shrink, the dune fences are shifted bayward to maintain a wide beach. The passively managed dune is flattening, migrating, and complexifying over time (GPS 7.0, fig.9). In 2020, as compared to 2005, the dune crest is much lower but the volume looks stable. The marsh hasn't seen much change over 15 years. Without replenishment this marsh will potentially drown if sea level rises (see fig. 8).

Figure 7 Section 4 characterizes the backcountry area, where the dune crest has been displaced 64m inland (GPS 11.0, fig. 9). Over the last fifteen years, marsh elevation here has kept pace with sea level.

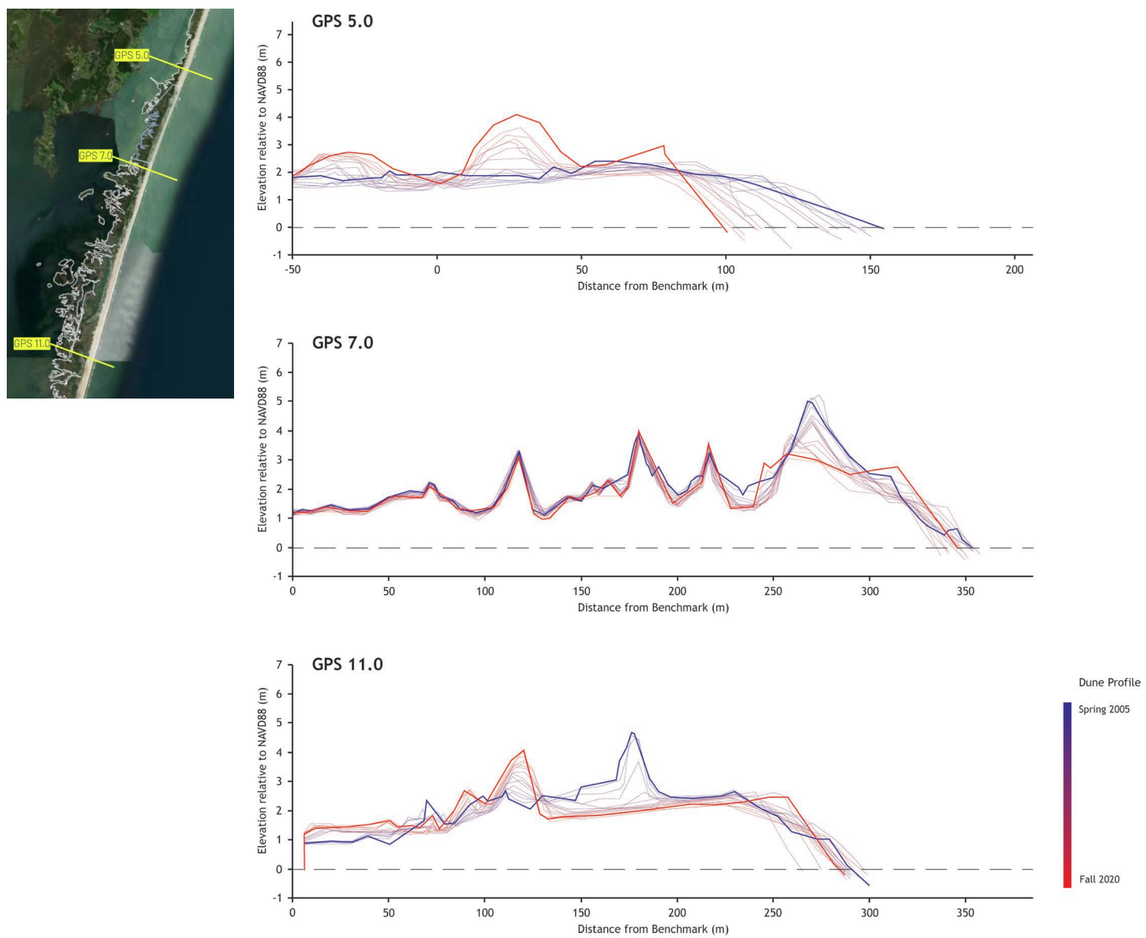


Figure 9. Three sections taken through Assateague Island, showing profile change over time from Spring 2008 to Fall 2020. Beach is right, Bay is left. Redrawn from *Shoreline Position and Coastal Topographical Change Monitoring at Assateague Island National Seashore 2005–2020 Trend Report* https://irma.nps.gov/DataStore/DownloadFile/672261

1.3 Barrier Island as a Whole System

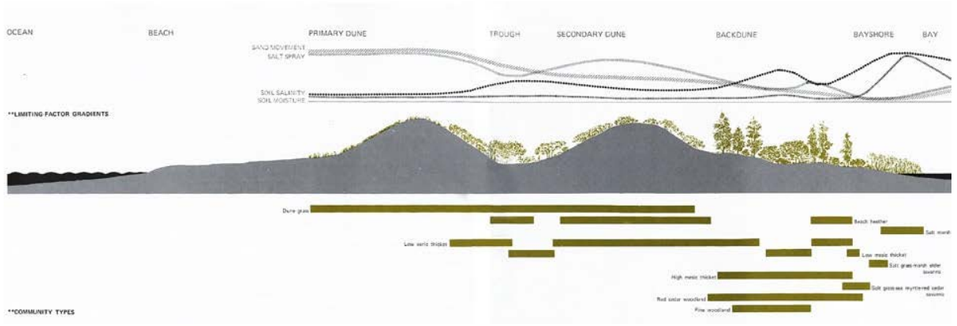


Figure 10. Ian McHarg's drawing of dune succession from Design With Nature (1969). Beach left, Bay right.

Migration is the means by which barrier islands resist the obliterating effects of severe storm events. As overwash pushes sand from the beach into the island interior, it replenishes the island backmarshes, which form the leading edge of the westward rollover of the barrier island system. The health and long-term survival of the barrier island therefore rests on the health and mobility of its backmarshes.

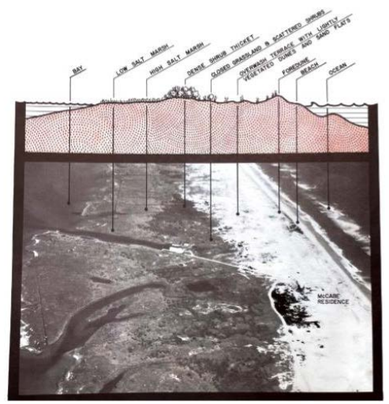


Figure 11. Atlas of Environmental Dynamics (1977) characterization of island morphology

Connections between the sandy foredune and the wetlands of the back marsh have been illustrated over time, as seen in Ian McHarg's drawing of dune succession in his landmark 1969 text, Design with Nature, (fig. 10) and observed at Assateague by Dolan et. al in their 1977 Atlas of Environmental Dynamics (fig. 11). Sediment from the foredune is moved by aeolian transport up the foredune and is trapped by vegetation growing in the grassy uplands. During large storm events, sand is pushed further back into the marshes, accreting and aiding in the growth and stabilization of the wetlands, essentially allowing the barrier island to march backwards and reconstruct itself from overwash and storm surge events.

Gazing out across the marshes, which begin in the lower elevations of Assateague's leeward side and wend their way into the brackish waters of Sinepuxent Bay, one could be forgiven for believing them to be a homogenous plane



Figure 12. Photo of Assateague marshes

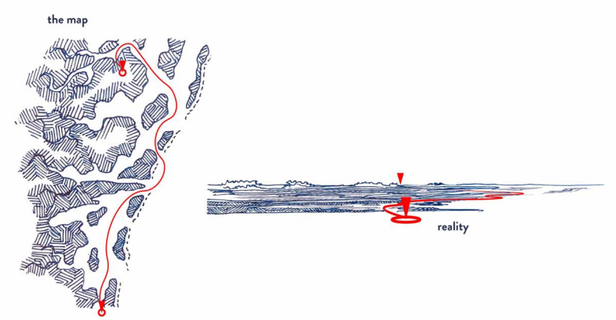


Figure 13. Sketches illustrating the difference between a perspective of the marshes from the air vs. on the ground.

of flat grasslands (fig. 12). However the subtle topographical changes soon begin to reveal their logic - salt marshes occupy the narrow topographic band between mean sea level (MSL) and mean higher high water (MHHW) [11]. At Assateague, the difference between the two is about 14 inches [12], and this critical vertical band is dominated by cattails (*Typha angustifolia*), needlerush (*Juncus roemerianus*), and saltwater cordgrass (*Spartina alterniflora*) [13].

Changes in the marshes have historically been difficult to mark and track. Maps and charts of the area have had to determine where the line between water and land lies (fig. 13). On the constantly moving landscape of Assateague, cartographers used a dashed line to demarcate the liminal zone between water and land along with a few hatch marks to indicate marshes and swamps [14]. Given the tidal differences, this must have been no easy feat, also considering the influence

1.3 Barrier Island as a Whole System

of freshwater rivers and the saltwater intrusions from changing sea levels and the intermittent washovers from sudden inlet openings.

In the marshes, wildfowl hunters are particularly attuned to the changes over time in the back marshes. From the Assateague Island Oral Histories Collection at the Nabb Center, there are records of hunters and craftsmen having kept annual records of the numbers, diversity, and health of the birds that feed and nest in the grasses [15]. From the recollections of Miles Hancock and Tom and Cob Reed, the ducks and waterfowl that once nested in the marshes have long dropped off in numbers, perhaps due to agricultural runoff, perhaps due to other factors affecting marsh health [16].

However, the health of the marshes have also been affected by decades of drainage programs, meant to improve the health of those who live and farm near the lowlands by draining mosquito breeding areas [17]. Mosquito control hit a fever pitch during the Works Progress Administration (WPA) years of the 1930s and 40s as the difficult and arduous work was taken on by crews of young men in need of work (fig. 15). In the state of Delaware, at the northernmost end of the Delmarva peninsula, mosquito control was the largest Civilian Conservation Corps (CCC) activity, with one third of all CCC companies in the state operating as mosquito control units [18]. Camps at Snow Hill Landing and Berlin were mobilized to dig a grid of drainage canals all along the Maryland coast, bringing Cartesian logic to the marsh. The CCC workers dug parallel ditches 10-20” wide, up to 30” deep, and spaced 150’ throughout the marsh [19]. As shown in the section right, these ditches have scoured and enlarged over time; and the interior marshes have subsided. Today, the ditches are still visible. NPS has worked to restore salt marshes at Assateague using sand fill and planting with native vegetation [20].

In support of ASIS management’s ongoing work to fill the ditches, we documented their current process (figs. 14, 15) and performed a suitability analysis of the marshes, corresponding ecological processes, and nearby amenities. This analysis supports the NPS marsh prioritization framework [21] by describing two sets of goals: one aimed at supporting habitats in imminent danger of loss that are near park roads, structures, and campsites (fig. 16); and the other aimed at supporting marshes with potential for migration (fig. 17). The potential for migration was approximated in the GIS-based suitability analysis through a model which synthesized elevation (CoNED), soil type (prioritizing peat/ muck soils, via NPS Sediment Classification Map), and sea grass proximity (NPS Submerged Marine Habitat Mapping).

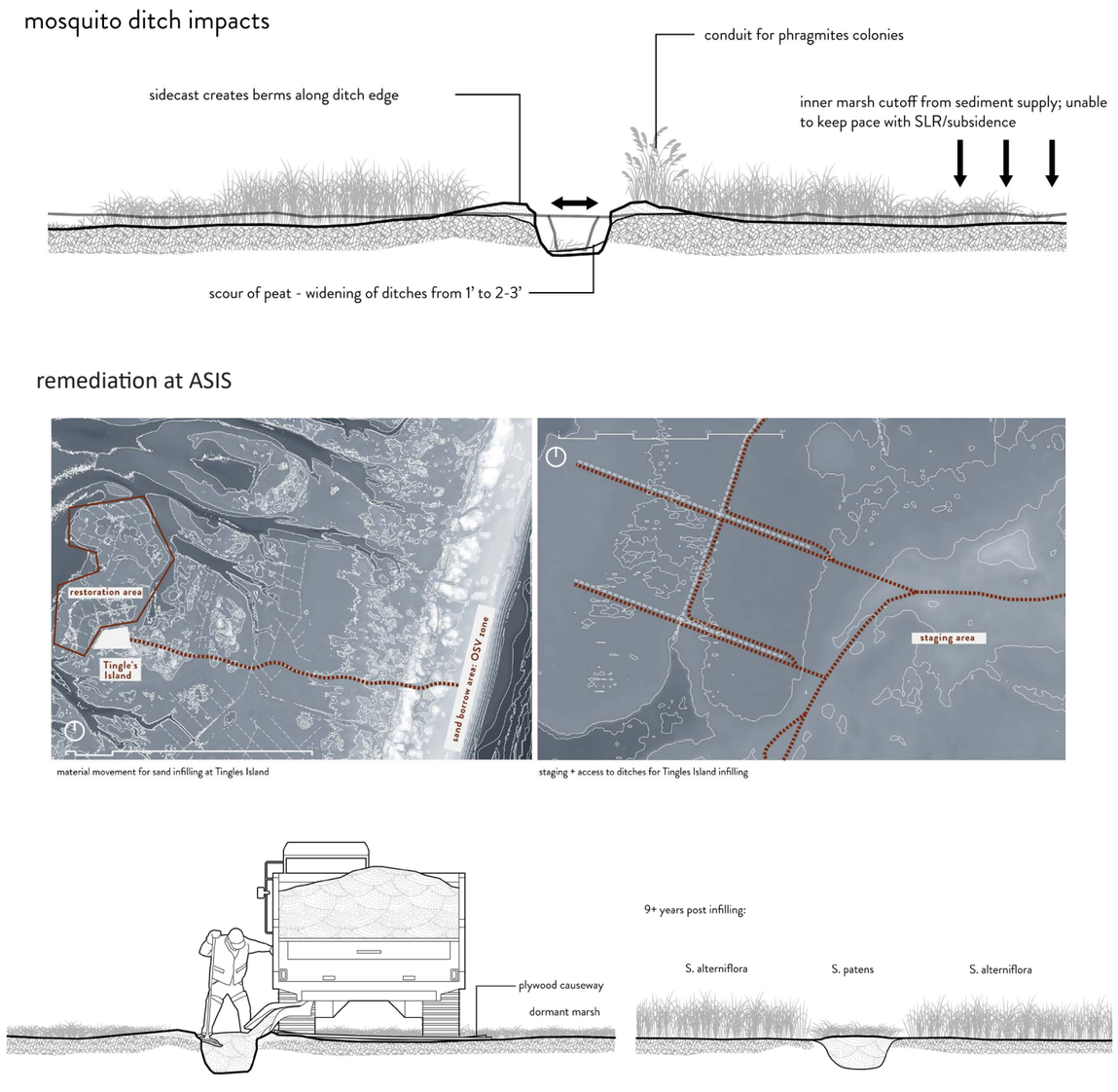
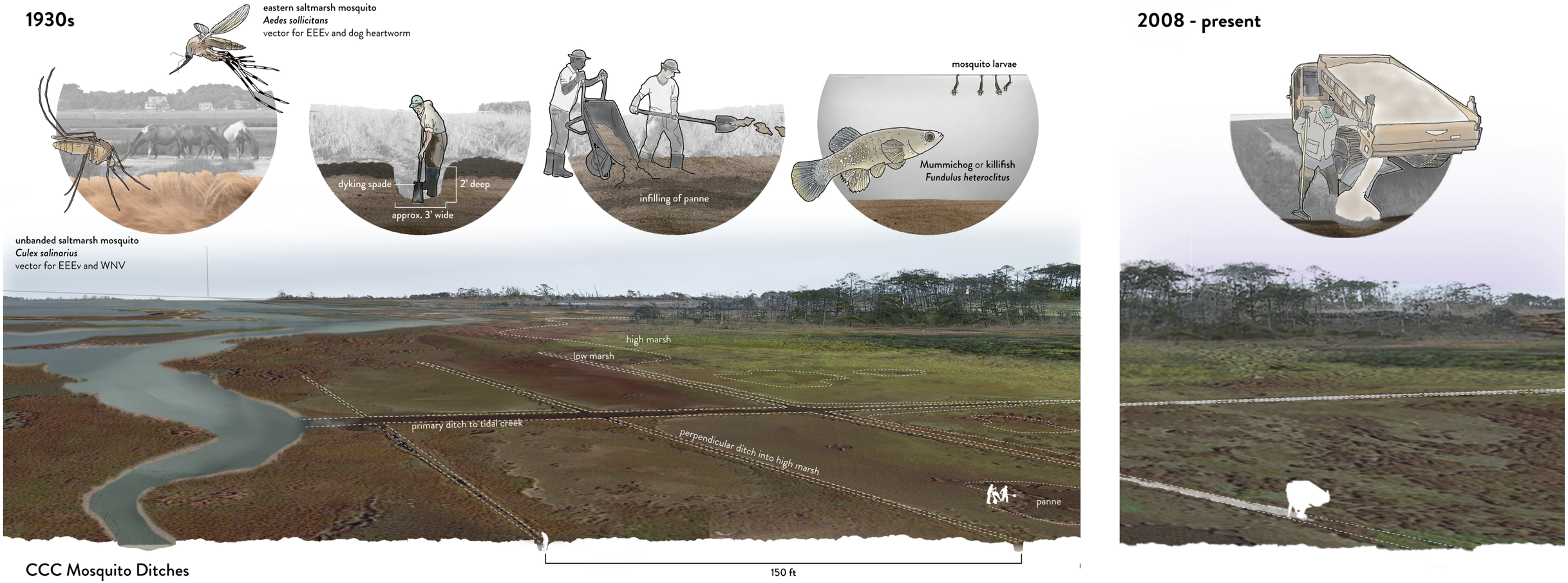


Figure 14. Details of marsh ditch filling at ASIS.

1.3 Barrier Island as a Whole System



CCC Mosquito Ditches

Beginning in the 1930s, the **Civilian Conservation Corps** hand-dug an estimated **87 miles of "grid ditches"** in the salt-marshes on Assateague Island. The intention was to drain standing-water depressions (panne) in the high marsh, where wet-dry cycles make ideal mosquito breeding habitat. CCC ditches tended to be narrow (approx. 3') and of varying depth (>2') with vertical banks, with primary ditches connecting to tidal creeks and perpendicular ditches into the high marsh, spaced regularly at 150' apart.

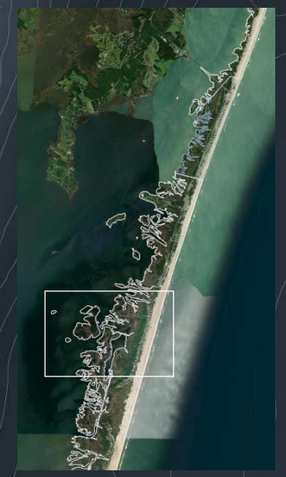
Ultimately, mosquito ditching has had a huge negative impact on the ecological health of coastal marshlands nationally. By eliminating landscape features such as panne that slow and hold water, the ditches homogenized marsh hydrology and reduced critical habitat for birds, insects, and crustaceans - including species like **mummichog** that feed on mosquito larvae.

Since 2008, the National Seashore has undertaken a novel approach to mosquito ditch restoration, filling in ditches with beach sand as a proxy of the natural process of overwash. Operating in the winter months and using temporary road structures, construction vehicles are able to work over the dormant marsh with minimal negative impacts. So far, over 400 acres of marsh have been restored using this method.

Figure 15. Marsh ditches through time at ASIS: from the CCC to current-day remediation.



Figure 16. Marsh prioritization framework aimed at supporting habitats near park amenities in imminent danger of loss, with high suitability marshes in purple. Ditches illustrated in orange are most suitable for filling.



Ditches most suitable for infill

Suitability

Low — High

ft

500 1000 2000

NAVD88 (ft)

30

25

-20

Figure 17. Marsh prioritization framework aimed at supporting habitats with potential for migration, with high suitability marshes in purple. Ditches illustrated in orange are most suitable for filling.

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Design Concepts

TWO CONCEPTS FOR THE DEVELOPED ZONE

In keeping with ASIS management philosophy, these design concepts aim to steer environmental dynamism rather than prevent it. The design concepts described here attempt to increase resilience to natural hazard events by using natural processes to drive complexity of island edges and in turn strengthen the island interior. The Bayside natural wood reef captures sediment eroding from the peninsula to build a beach, direct sand spit evolution, and protect existing marsh. The dune overwash zone concept allows overwash to feed the island interior from the ocean side and builds complexity in the backdune system.



Figure 18. Key map showing locations of design concepts

2.1 Bayside: Natural Wood Reef

On the Bayside peninsula the design concept is a natural wood reef which would use wind-driven erosion to build a beach, direct sand spit evolution, and protect existing marsh. The western point of the landform is rapidly eroding, losing almost twenty feet per year. This proposal brings together both natural forces - erosion and sediment transport - and anthropogenic forces – trees felled for the retreat of recreational infrastructure – to generate habitat on the northern edge of the peninsula.

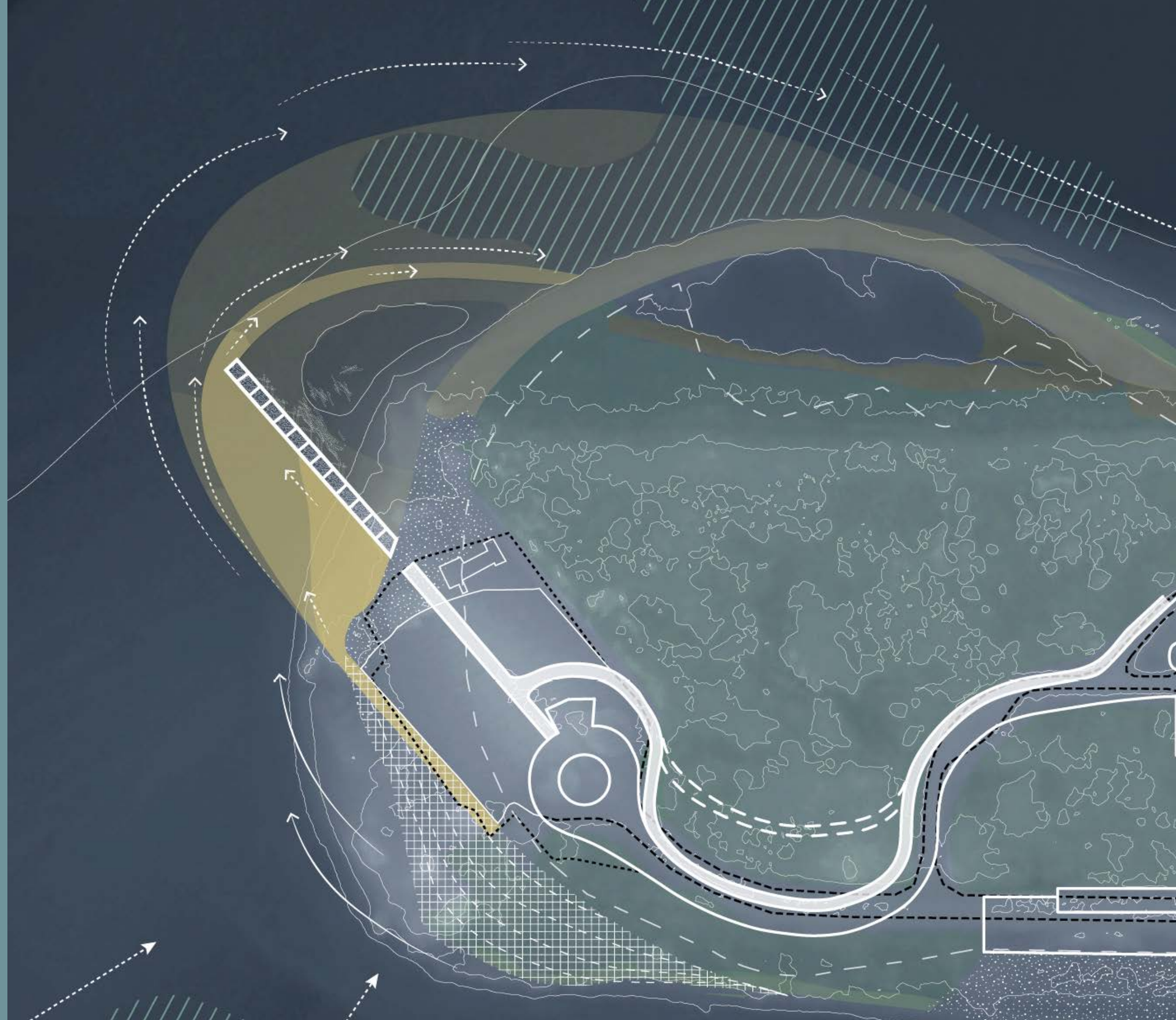


Figure 19. A plan diagram of Bayside Peninsula illustrating the Natural Wood Reef in white, with projected sediment accretion in yellow.

2.1 Bayside: Natural Wood Reef

The area where Bayside is now set was previously marsh and shoals, as can be seen in 19th and early 20th century nautical charts [22]. This area is located at the leeward side of the North Beach Coast Guard Station, which was built and conveyed in 1883 [23]. From a U.S. Coastguard North Beach Station photograph Scrapbook kept at the Nabb Research Center at Salisbury University, we can see that the men stationed here used the back marshes as hunting ground for sport while waiting to rescue ships in distress (fig. 20). Following North Beach Station's decommission in 1952 [24] and the subsequent purchase of beach lots, the bayside area was filled with sand and flattened with construction equipment, forming the long, rounded peninsula that sticks out in blaring white in historic aerials (fig. 21).

No one would mistake Bayside as a natural feature of Assateague Island - the Bayside peninsula juts into Sinepuxent Bay in a manner uncharacteristic of a barrier island. To the north and south, the leeward side is ragged with a mixture of small islands, marshes, and hardwood hammocks that is more typical of Assateague's geomorphology.

Aerial images taken of Worcester County, MD from 1957 to 1962 [25], show that the peninsula was created during the construction of Leon Ackerman's ill-fated mid-century development, Ocean Beach (fig. 21). The site was initially intended to serve as the grounding point for a bridge [26] that would improve access to the island from the mainland for the over 9,000 building lots, 130 side streets, and 15 miles of paved road which constituted the new development (Ocean Beach plat). Initially, the bridge was funded by private interests, though the expenses led Ackerman to donate 540 acres to the State of Maryland to finish construction [27]. However, hopes for the Ocean Beach bridge were dashed by the 1962 Ash Wednesday Storm, which like many previous nor'easters and hurricanes, had re-constituted the island. The Storm wiped out the already battered dunes, filling the back marshes with sand, and destroying the newly constructed roads and buildings [28]. Plans for Ocean Beach were abandoned and all that remains of its bridge construction is today's Bayside Peninsula.

Since acquisition by NPS, Bayside has served as a ferry landing, a campground, concessions stand, boat launch, picnic area, and as a popular spot for birdwatchers to observe the many bird species that this critical barrier island ecosystem supports. The parking lot at the



Figure 20. Hunting in the back marshes while waiting to rescue ships in distress. Photograph from the U.S. Coastguard North Beach Station photograph scrapbook kept at the Nabb Research Center at Salisbury University.

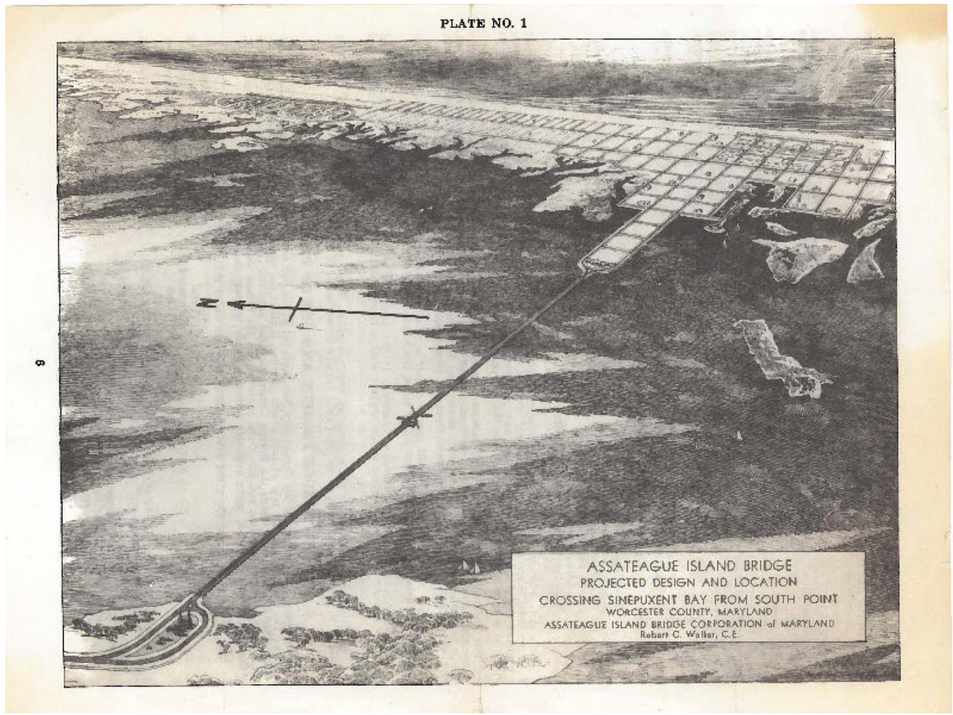


Figure 21. Assateague Island Bridge Projected Design and Location, illustrating the Bayside Peninsula's original intended purpose

2.1 Bayside: Natural Wood Reef

end of the road shows unparalleled views of Sinepuxent Bay as well as the marks of constant erosion –fallen trees, cleaved land. The sandy landmark has been overtaken by marsh and shrubs (fig. 22), and has begun to take on a form carved by the processes of wind and water, rather than by backhoe and bulldozers.

Background

Situated along Sinepuxent Bay, the western portion of Bayside is severely threatened by wind-driven erosion - note the wide fetch zone to the southwest of the peninsula (fig. 32). Almost twenty feet of land is lost per year: in the 1990s, the parking lot was two to three times larger than it is now and there used to be a boardwalk circling the peninsula

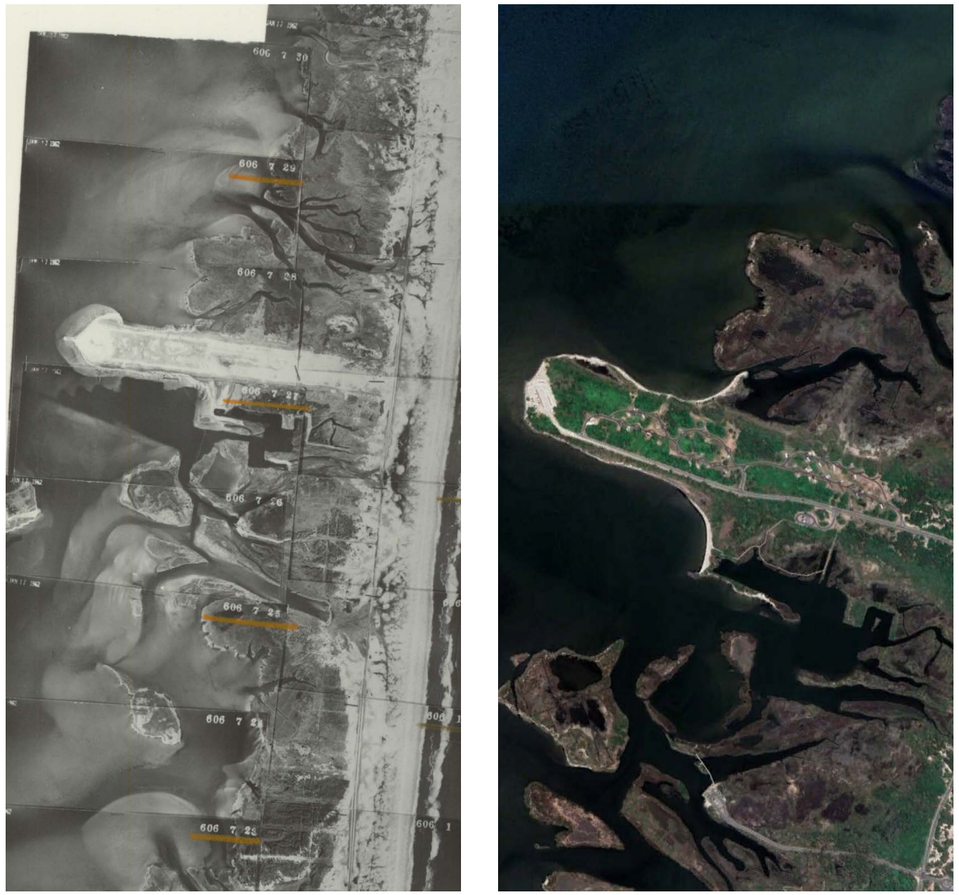


Figure 22. Left shows Bayside peninsula in 1962, right is an aerial from present day

(fig. 22). But the erosion was not only destructive – it also created sandy beaches with shallow, warm water and no waves: the western point is currently a prime recreational area for swimming, paddling, and kayaking. The southern edge of the peninsula, located along a deep dredge borrow area, is more like a sheltered cove. Similar to the western point, the southern edge has sandy shores but it is protected from wind erosion by Great Egging Island and the presence of sub-aquatic vegetation (SAV) (fig. 32). NPS has plans to retreat its recreational infrastructure to the east and south and has gone through a planning process to design new parking lots, a new kayak concession location, new boardwalks, new campground areas and a new picnic area with a trail to the existing beach (fig. 34).

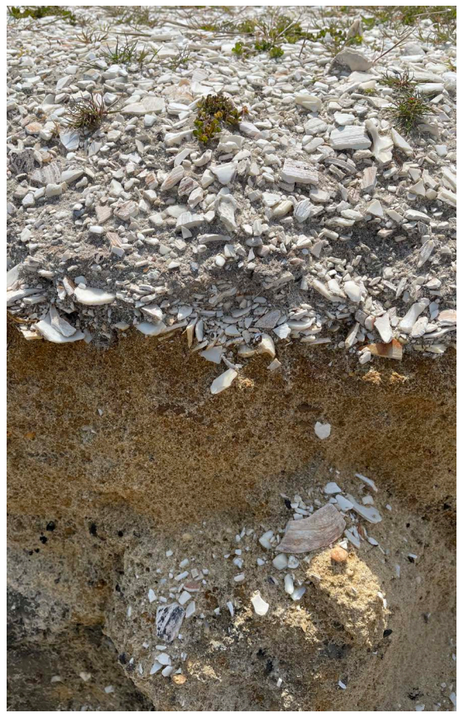
As Bayside is a fully anthropogenic feature, the peninsula is highly managed and is already the site of innovative design features, including clamshell paving and floating mats for accessible parking.

The high level of erosion and deposition around Bayside means that hunks of asphalt eroded from the old parking lot still wash up on the beach. In anticipation of these natural dynamics, the parking lot is now paved with a mixture of clamshell, clay, and sand (fig. 24). The clamshell feature has to be brushed twice per week in exposed areas near an active beach and additional material is added annually after storm events [29]. In keeping with this existing work with natural processes, and in support of the retreat of Bayside's recreational infrastructure, we documented existing practices at ASIS on the next two spreads (figs. 24 and 25) and have developed a design for a shallow wood reef.



Figure 23. Existing conditions and amenities at Bayside

2.1 Bayside: Natural Wood Reef



1. Clamshell paving detail at eroding parking lot, exposing the layers of clay and sand under the clamshell surface

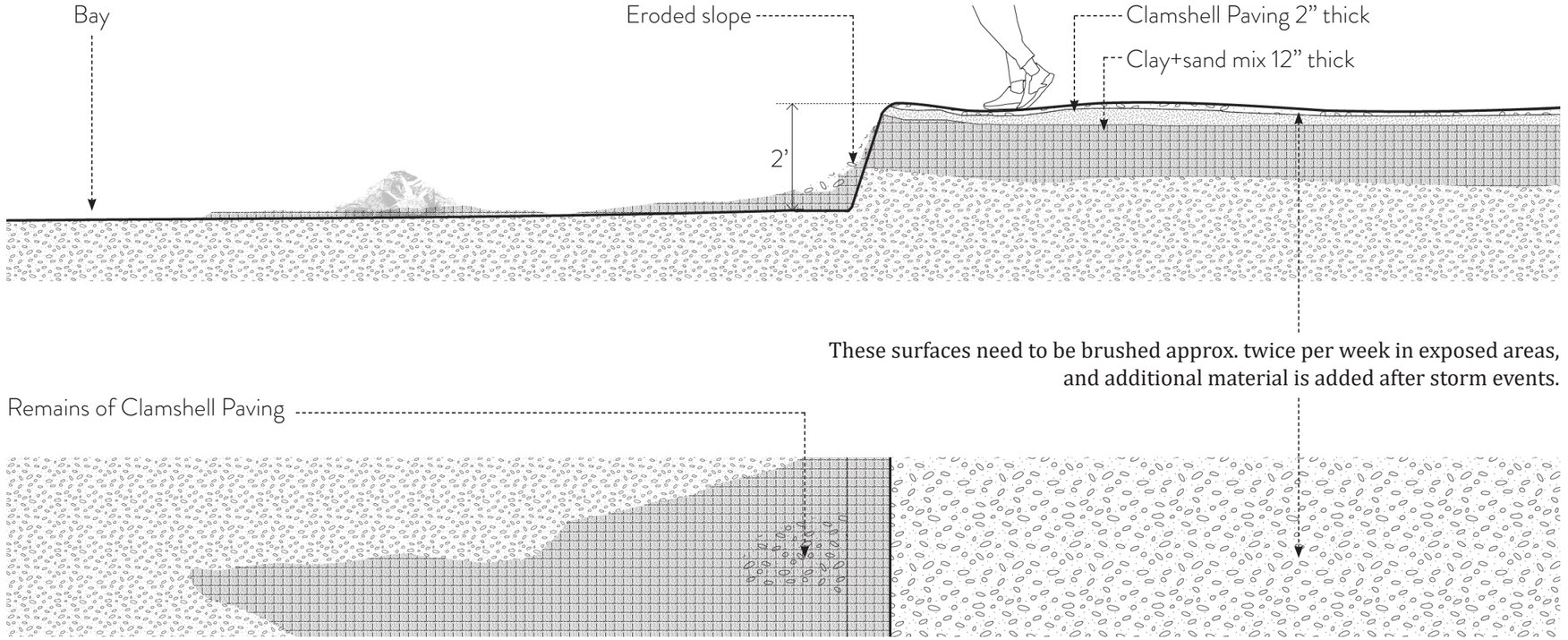




Figure 24

2.1 Bayside: Natural Wood Reef



2. Mat for Accessible Parking. These mats are required to accommodate light and medium vehicles traffic on unstable ground

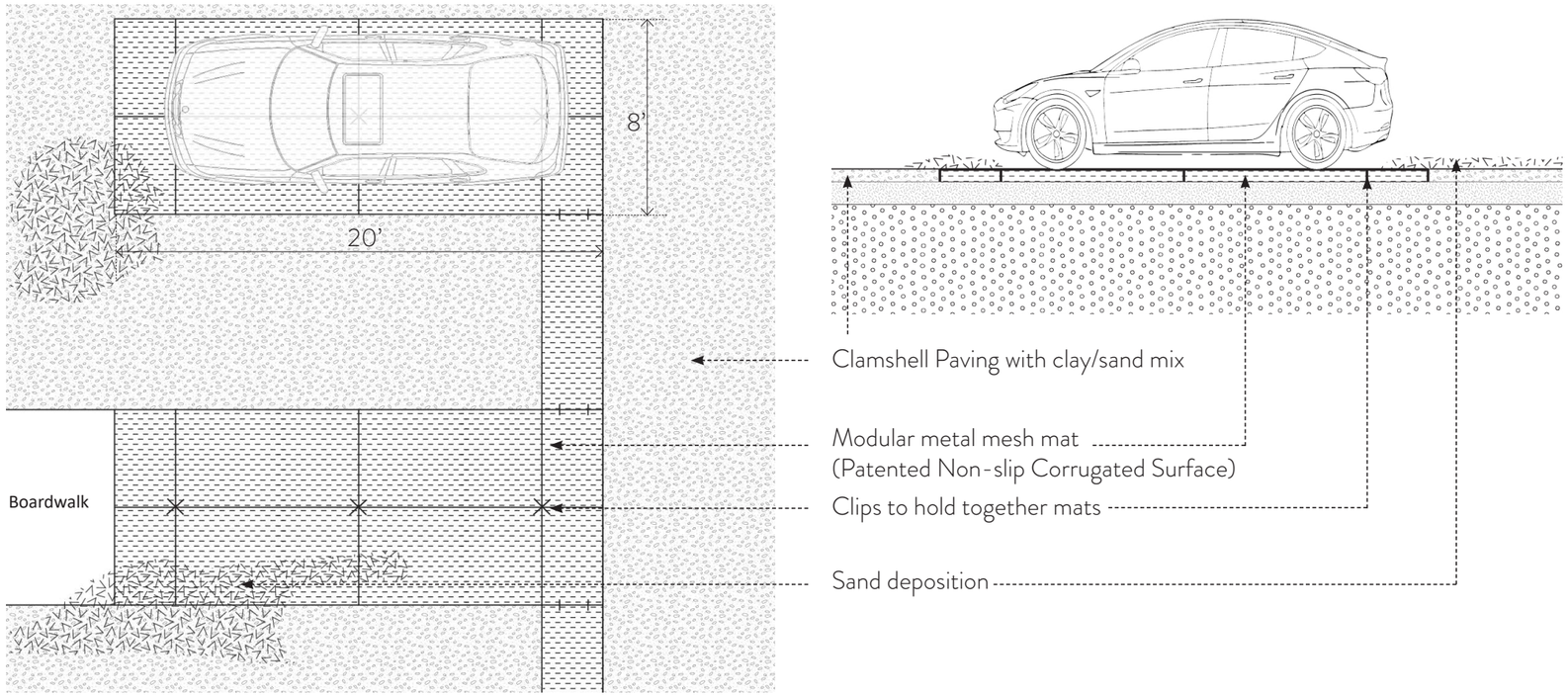


Figure 25



2.1 Bayside: Natural Wood Reef



Figure 26. A photo taken at the eroding Bayside Peninsula beach. On the right, the clamshell paving is visible atop the clay and sand mix.

2.1 Bayside: Natural Wood Reef

The direction of most severe wave attack is from the southwest due to the significantly larger fetch in that direction. Analysis of a wave model and historical aerial photographs shows that the sand from the peninsula tends to erode from the western edge and accrete on the northern edge, then track back east with currents and waves. Over time this has produced the small spit, lagoon, and thin beach along the north edge. This spit complex is growing into the marsh to the east. Figure 27 illustrates this western erosion and northern accumulation over the last 30 years.

Design Concept: Natural Wood Reef

The proposed design for Bayside supports the planned retreat from the eroding tip, which will require clearing existing trees. The natural wood reef utilizes these trees (fig. 28) and the erosive forces hitting the western tip of the peninsula to build marsh on the northern edge. The main goals of the design concept are to:

- Work with the natural processes of longshore sediment transport and tree fall to stabilize the shoreline over time, and enrich the experiences and habitats of the landscape
- Guide sediment movement from the eroding western tip so that it forms a beach aligned with the most impactful waves and enhances the spit on the north side of the island.
- Maintain the beauty and drama of visitor views across Sinepuxent Bay
- Enrich and protect birding habitat along the northern edge of the peninsula

Traditional shoreline protection strategies (breakwater, riprap revetment, or groins) are not desirable in this location because they would degrade the recreational experience of nature here and interrupt the natural processes of sediment movement with materials foreign to the island. Through conversations with NPS staff we understand there is a desire to avoid heavy construction equipment on Bayberry Drive. And the extremely wide, shallow condition of the nearshore prevents easy access by barge.

A circular process of 1) collecting fallen trees and trees recovered from the construction of a new parking lot), 2) sorting them, and 3) placing them in a sill on the north side of the peninsula could address issues of vulnerability, access, and construction limitations. The reef we researched was approximately 25’ wide, 225’ long, and 4’ tall from bay bottom (crest height near MHW): low enough to protect the compelling visual character of the landscape, small enough to be easily constructible, and large enough to make a significant impact on wave dissipation and sediment movement. We anticipate needing between 100 and 200 trees, utilizing different kinds of trees and tree parts for different parts of the feature (figs. 28-31).

The orientation of the Natural Wood Reef responds to existing nearshore morphology. We anticipate that the immediate effect would be further erosion of the peninsula tip whose sediment would be pulled into a leeward curve around the sill. The longer-term effect would be an extension of the existing marsh-lagoon-spit complex along

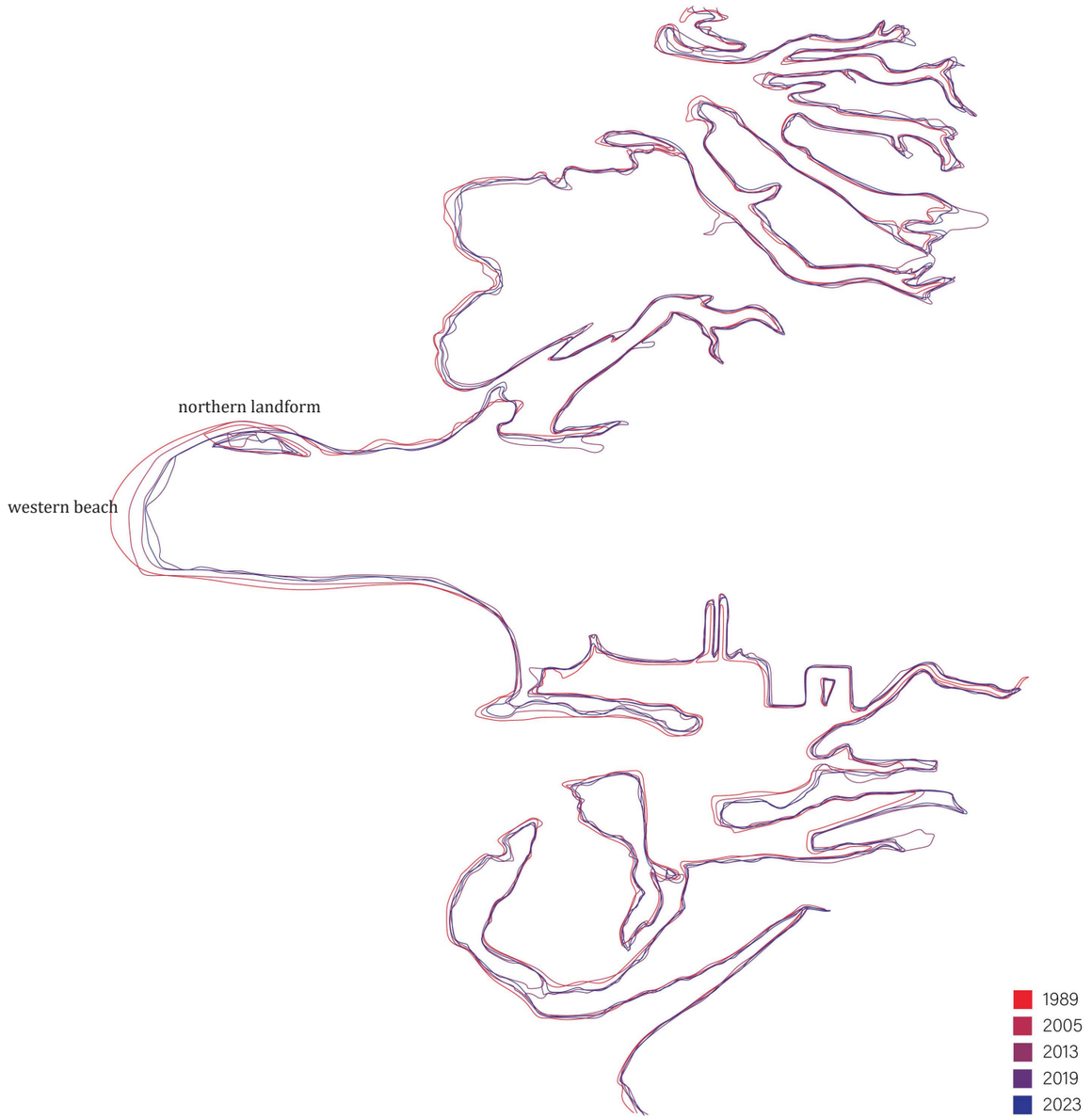


Figure 27. Bayside Peninsula change over time. We can see the relatively dramatic erosion of the western beach, and the subsequent growth of the northern landform. We are exaggerating and directing this dynamic relationship between erosion and land building with the Natural Wood Reef.

2.1 Bayside: Natural Wood Reef

the shallow northern shore (fig. 35). The northern edge of Bayside is prime recreational birdwatching territory, and there is an extremely active community of birders at ASIS. We anticipate the Natural Wood Reef will expand and enrich this well-loved habitat.

Analysis

Our team worked with EA Engineering, Science, and Technology Inc. PBC as they developed a numerical model of the bay and peninsula to evaluate the potential impacts of promising concepts in relation to wave attenuation and current velocity under different, relevant conditions (see Appendix for full memorandum). Three event conditions were modeled: typical conditions, a 1-year storm, and a 10-year storm. The events were generated by updating water levels and modeling wind-generated waves from a single annually characteristic wind direction. Each event condition was run under existing conditions (without a reef) and with the reef design.The model results give wave height and direction and indicate the breakwater's effectiveness:

- Typical conditions—50-60% reduction in wave height
- 1-year storm—50-60% reduction in wave height
- 10-year storm—10-50% reduction in wave height

The feature consistently creates a low-energy zone to the east. When combined with an extension of the existing sand spit and longshore transport is redirected around the reef, we anticipate fine sediments would move through and around the reef before depositing on the lee side where they are protected by the reef and future sand spit. The model results are limited in two key ways: 1) by using more generic wind rose inputs, it overemphasizes NW event conditions and does not adequately take into account the large, erosive SW events that occur due to longer fetch and 2) because the

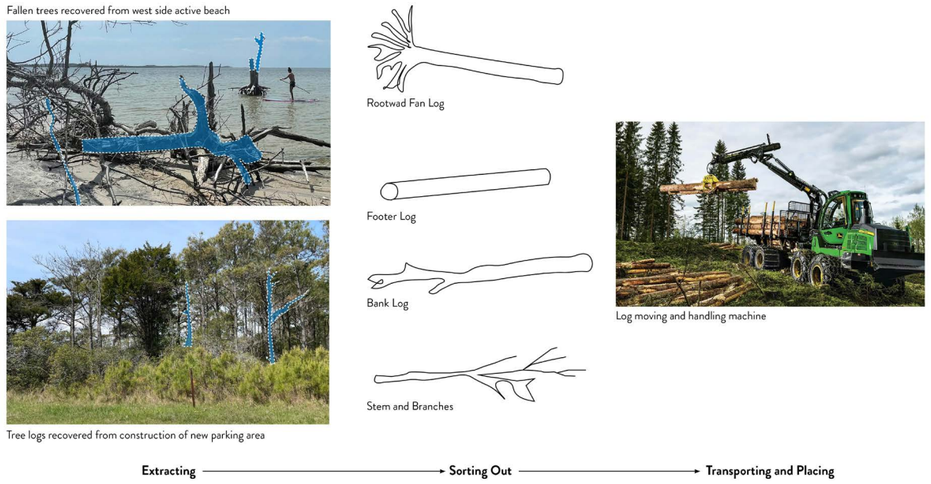


Figure 28. Tree sourcing and sorting

structure is inserted and tested using existing topography, the model does not speak to the deposition of sediment. While the model results are relevant, and preliminary results indicate that the reef will reduce up to 60% incident wave height during typical conditions and minor storm events with effectiveness decreasing as water levels rise during larger events with higher storm surge, the geometry of the design feature as proposed also 1) accounts for both the large events from the SW (as described in discussions with park management, illustrated in aerials over time, and evinced by the large fetch and debris patterning on site) and 2) is meant to work with and guide the deposition of sediment over time. The model should only be used for costing and concept design in future efforts.

Installation and maintenance

The starting point for placing linear tree sill would be set back 25' from the edge of the parking lot, . We anticipate laying felled trees in approximately 3'-6' of water, allowing enough depth to anchor 4"-6" wide, 15'-20' long wooden stakes manually first. The felled trees would interlink with each other like jacks, and the 6" stakes would pin them more firmly into place (fig. 30, 31). As the parking lot area continues to erode, we anticipate around 3900 cubic yards (+/- 3900 y3) of sediment will be displaced. The proposed structure will reduce wave energy, which would result in this sediment accreting in the lee of the structure. If nothing is done, the peninsula will continue to erode 10-20 ft per year. A comparison between existing and proposed conditions indicates that the proximal SAV will see a minor impact. SAV location and impact would have to be confirmed on site, and compared not simply to existing conditions (as modeled here), but rather to a future condition in which the parking lot has eroded and that sediment is distributed around the peninsula.

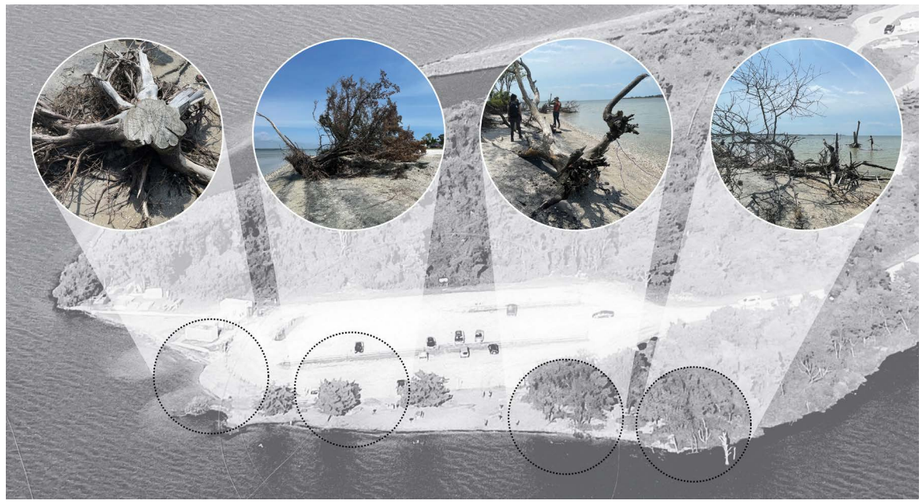


Figure 29. Photographs of fallen trees keyed to their locations on Bayside Peninsula.

2.1 Bayside: Natural Wood Reef

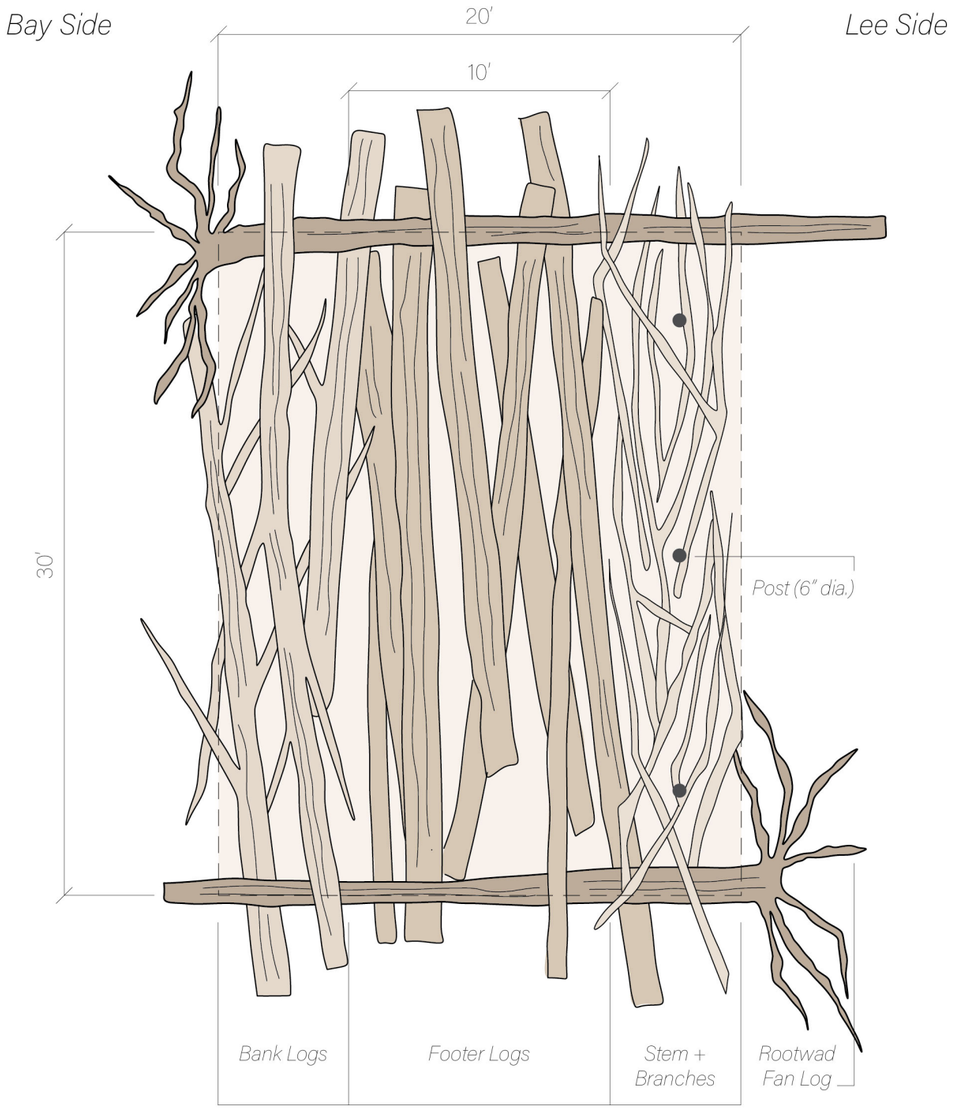


Figure 30. A plan view of a section of the wood reef, highlighting the orientation of different tree types.

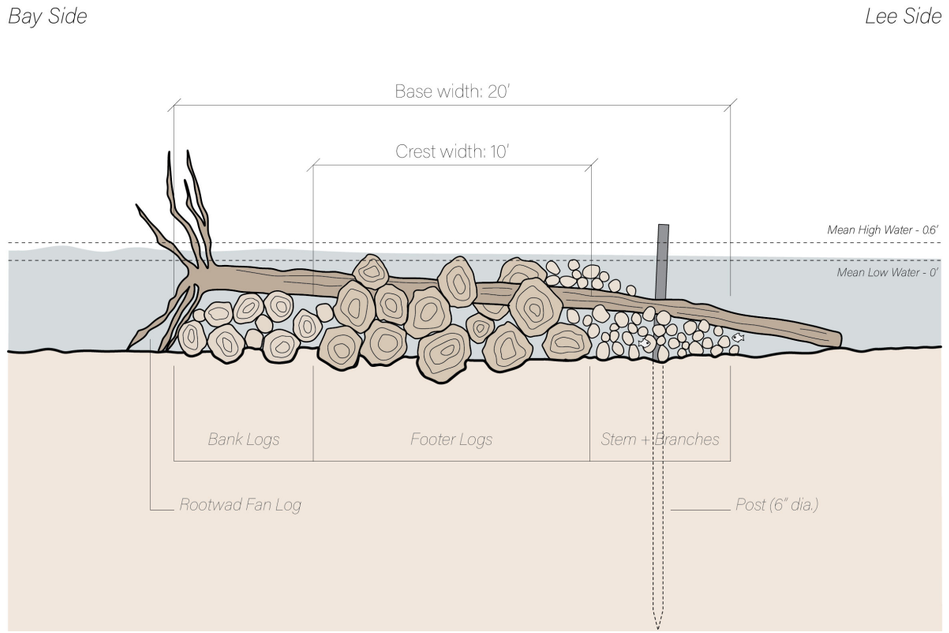


Figure 31. A section view of the Natural Wood Reef

2.1 Bayside: Natural Wood Reef

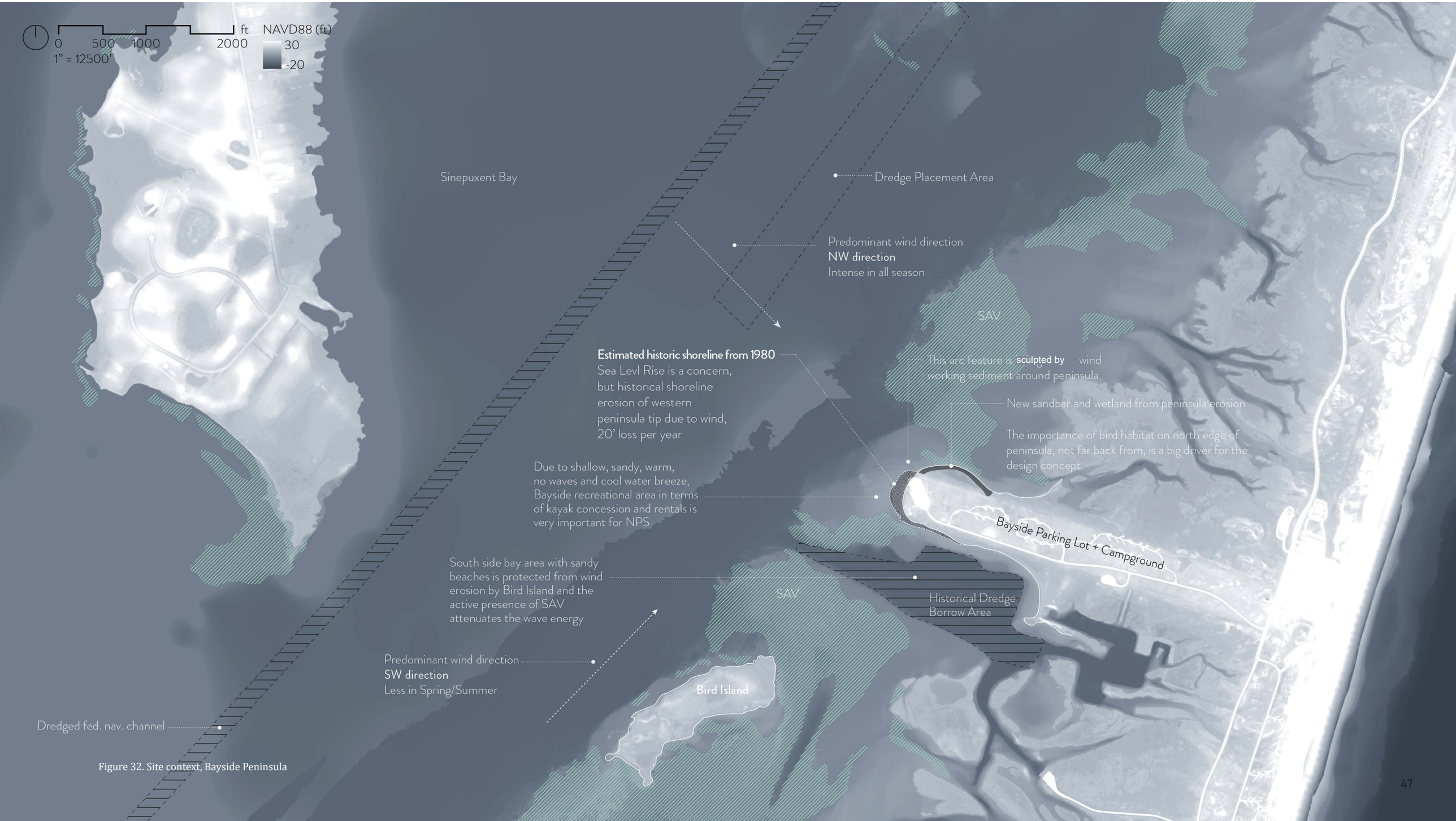


Figure 32. Site context, Bayside Peninsula

2.1 Bayside: Natural Wood Reef



Figure 33. Wind-driven erosion of Bayside point shown in relation to other site features

2.1 Bayside: Natural Wood Reef

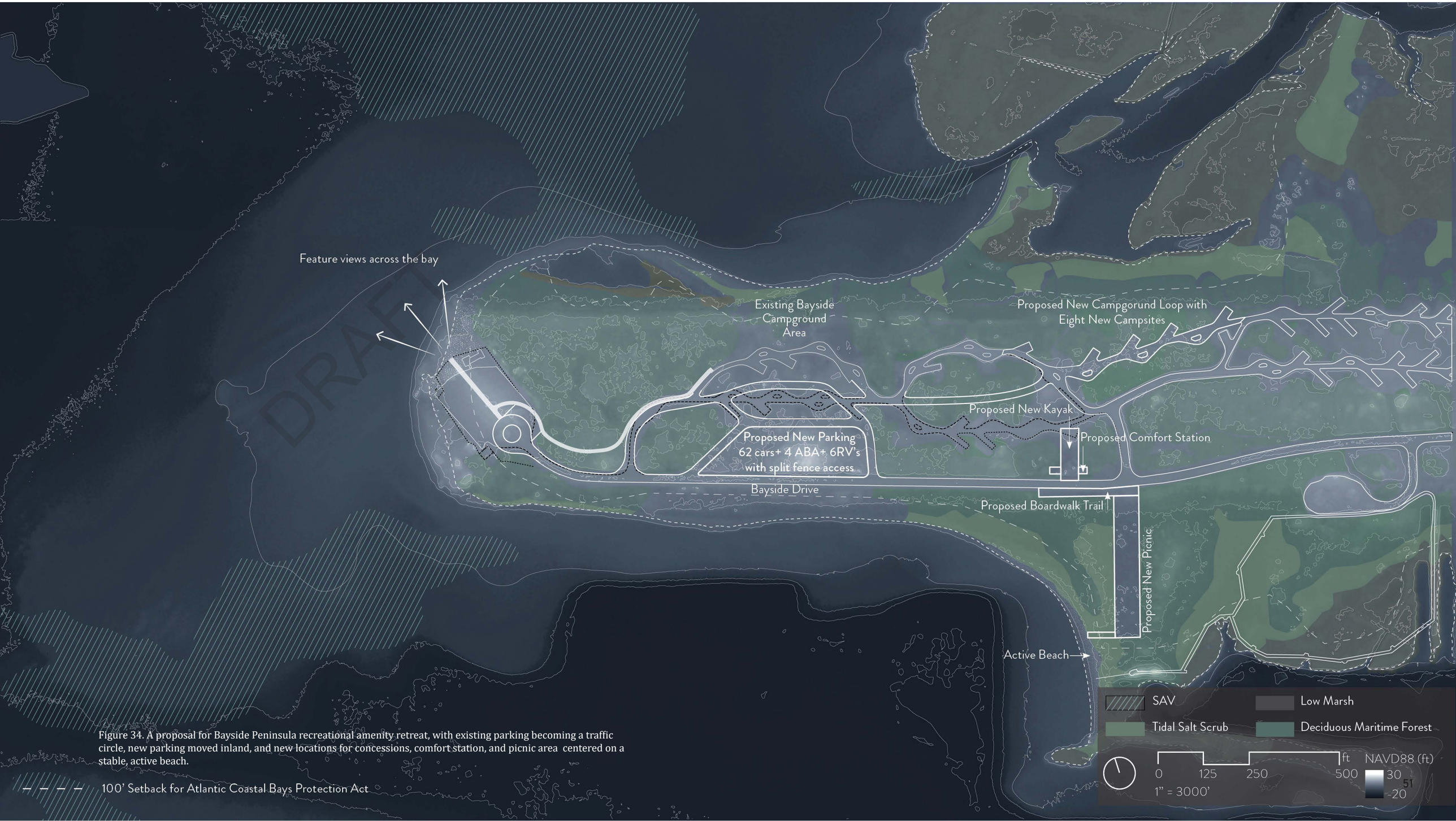


Figure 34. A proposal for Bayside Peninsula recreational amenity retreat, with existing parking becoming a traffic circle, new parking moved inland, and new locations for concessions, comfort station, and picnic area centered on a stable, active beach.

2.1 Bayside: Natural Wood Reef

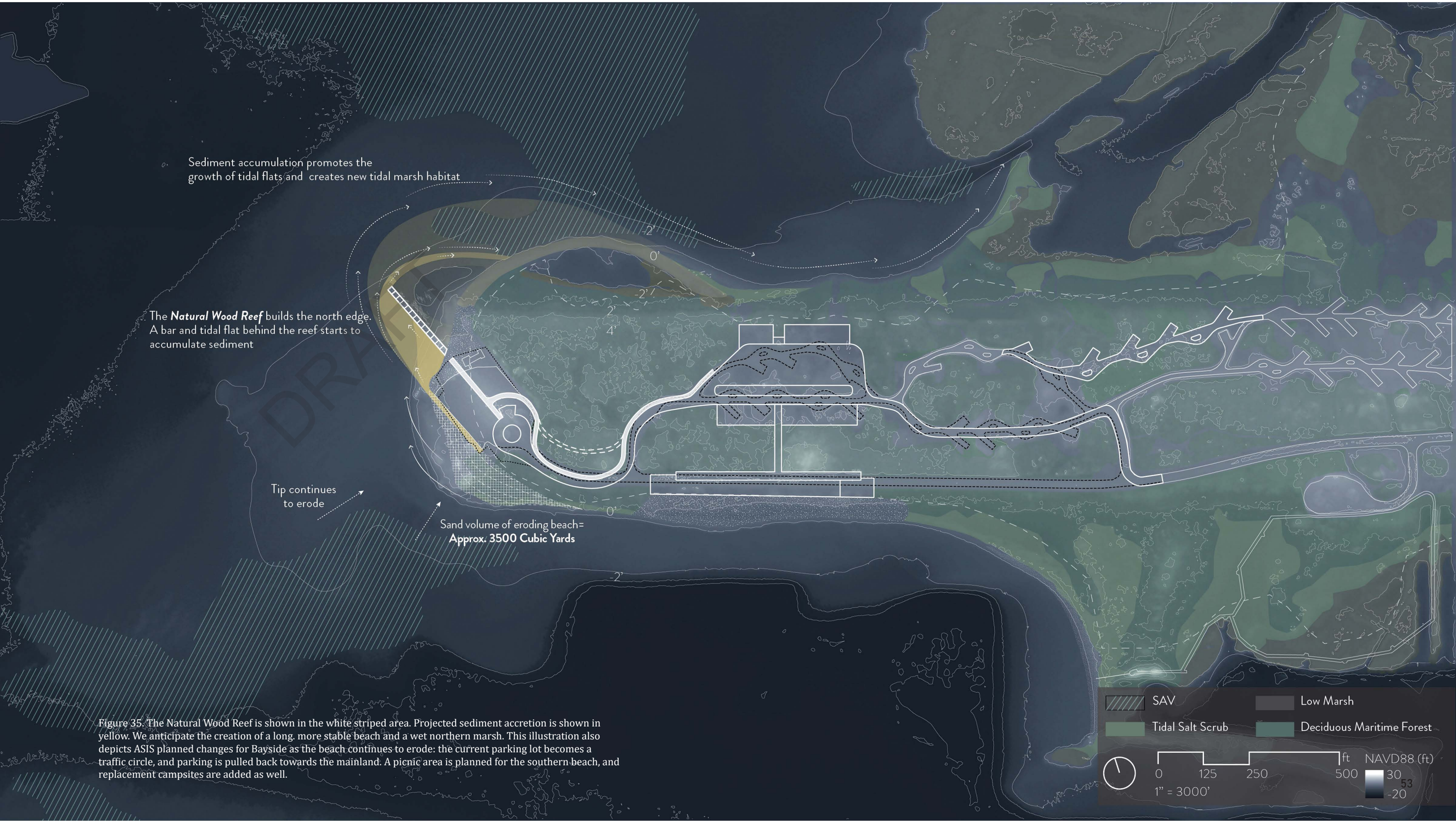


Figure 35. The Natural Wood Reef is shown in the white striped area. Projected sediment accretion is shown in yellow. We anticipate the creation of a long. more stable beach and a wet northern marsh. This illustration also depicts ASIS planned changes for Bayside as the beach continues to erode: the current parking lot becomes a traffic circle, and parking is pulled back towards the mainland. A picnic area is planned for the southern beach, and replacement campsites are added as well.

2.1 Bayside: Natural Wood Reef

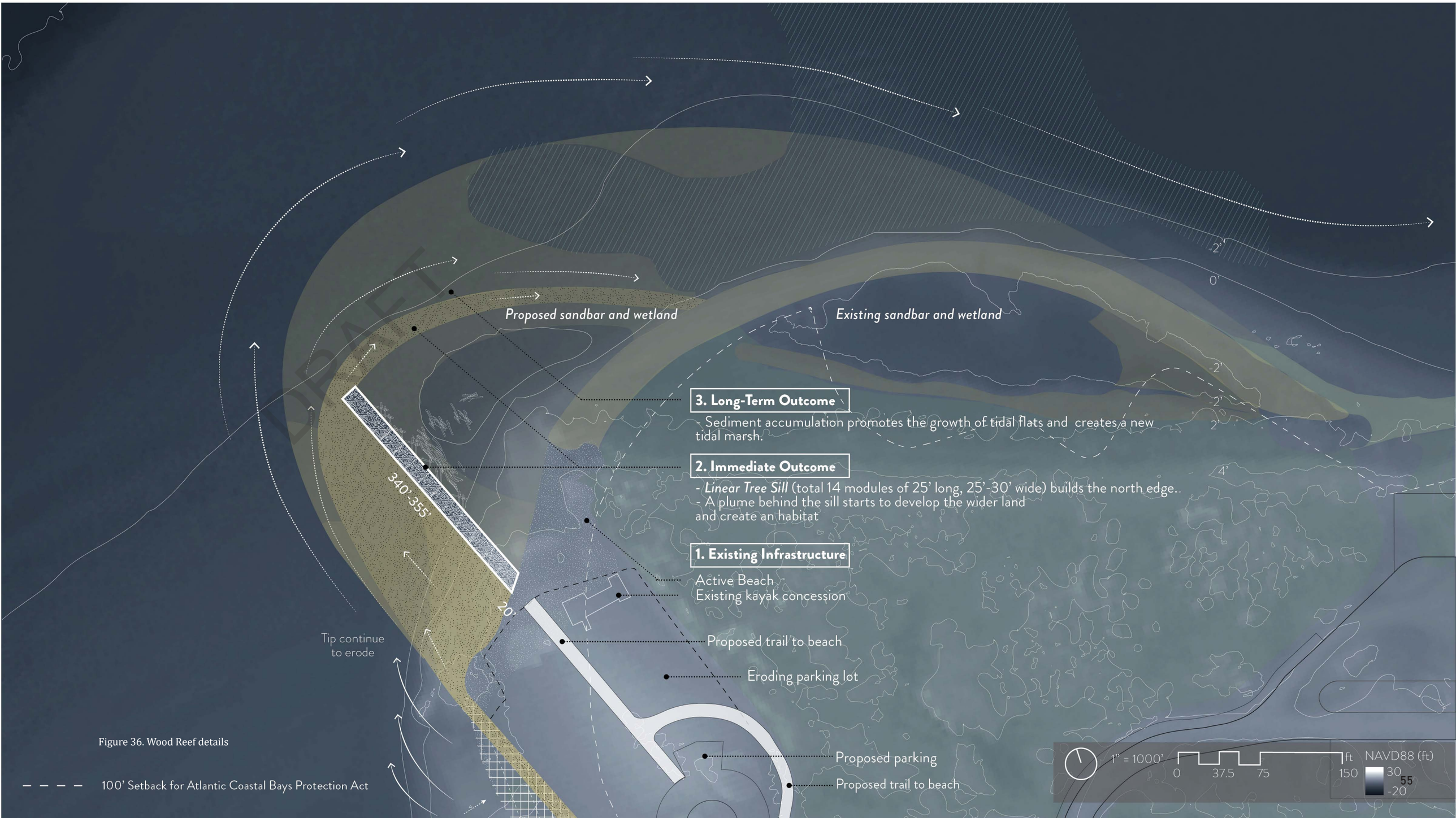


Figure 36. Wood Reef details

2.1 Bayside

Spit evolution

Lagoon

Natural Wood Reef

Figure 37. An aerial of Bayside Peninsula showing projected change over time after installation of the natural wood reef



Figure 38. An aerial image describing temporary measures for Bayside Peninsula, using felled and fallen trees and dredged sand to shore up the edge

Temporary measures

A related concept for short-term stabilization of the shoreline draws from the large woody debris found along bayside shorelines of the island as forests fall in or logs are carried by the rivers to the bays. We used the wrack line—a line of debris found along the highwater mark during storms or high tide events (Fig. 39) —to locate the woody materials and create a shoreline stabilization feature.

This concept arranges large wood trunks along the shoreline in a triangular form, with the shoreline forming one side of the triangle. The form is then filled with 10-20 cubic yards of sand. The wood is set in several feet from mean high water, but in front of the parking area scarp that is attacked by high waves out of the southwest. The long leg of the triangle is aligned perpendicular to the nearshore direction of these larger incoming waves, while the short leg is perpendicular to the waves out of the northeast. This alignment should reduce erosion and offer some stability to the structures during wave events. The construction technique is similar to a crib wall, albeit using a small number of large diameter members, roughly placed. The logs are approximately 18”-30” in diameter, with two stacked to create the long leg, and only one used for the short leg,



Figure 39. Wrack line at Bayside, existing condition

2.1 Bayside

sandwiched between the other two at the tip. The tip is pinned in place with four large logs, approximately 10’ long and driven in to about 5-6’ depth (see Figs. 38, 42).

Each triangle is thought of as a cell, with a space of equal distance along the shoreline understood to be a functional part of the feature, acting to receive sand that is winnowed from the triangle and offer a gentler gradient between mean high water and the higher elevation parking area. The triangles could be nourished as winnowing occurred to provide additional protection and extend the life of the temporary measure. Wood posts are driven into the ground near the shore-side of the logs to help pin them into place. The feature is repeatable, with four currently installed to protect the entire bayside tip.

The temporary measures use only trees and sand cleared from the parking areas on the ocean side of the island (Fig. 40). The concept is inspired by the tree-fall pattern observed on site along the wrack line and common to bayside shorelines along the Atlantic and Gulf Coasts (Fig. 39). Moreover, it is implementable with equipment and knowledge already available within the park. The first phase of the installation took about two weeks to construct all four features (Fig. 41). Based on patterns observed in aerials and wave modeling undertaken we expect much of the sand to move to the northern side of the peninsula and to track back east to nourish wetlands on the backside of the island through longshore sediment transport and small-scale overwash.

The features are expected to affect the visitor experience, but not to impair it in the way that a rock or sandbag revetment would. They may even make it easier and more interesting to access and use this recreational shoreline by providing informal seating and gentler slopes from the parking areas onto the beach and nearshore. In the first week after their installation, the shoreline was full of people setting up chairs and paddling kayaks, suggesting it is not an impediment at all.

The temporary measures will be monitored for the next three to five years to track changes in topography and nearshore bathymetry as well as amount of sand placed, and any displacement of the wooden structures themselves. There should eventually be some decay of the logs, leading to their collapse or displacement, though by that time vegetation may have taken hold in the triangles to help hold sand in place and the replacement of the temporary structures may not be immediately needed.

This concept is an outcome of the research from the Coastal Parklands team and the ingenuity of the Assateague operations managers and staff. As a temporary measure that uses all natural materials, practices and equipment on site, and works with natural processes to enhance landscapes beyond its immediate footprint, the temporary measure offers an alternative to stone revetment or sandbags for property owners and land managers confronting erosion. While not intended to last forever, it should enrich the landscape while affording protection and buying time, either to be remade, or for a new approach to be developed.



Figure 40. Felled or fallen logs are being used as natural infrastructure materials



Figure 41. Excavation creating a base to place logs into

2.1 Bayside



Figure 42. Construction of temporary stabilization measure. This image shows the longer 30” log detail, perpendicular to prevailing wind and waves, pinned into place with smaller logs.

2.2 Dune Overwash Zones

We propose a diversification of dune management strategies across the developed zone based on public uses and infrastructure, historic geomorphology, and future shorelines. Adjustments to the layout of dune fencing may enhance dune complexity and resilience while reducing required maintenance. In some areas, we recommend maintaining existing fencing to protect critical infrastructure. In others, we recommend adjusting fencing to inject sand further into the natural dune system. There are also points where we suggest allowing for productive overwash events. Together, these strategies would contribute to a more heterogeneous coastline and a more resilient island interior.

The design process described here focuses on directed overwash at North Ocean Beach. Maintaining sand volume while lowering continuous crest height in some areas offers a means to building up the dune system and adjacent wetlands through overwash while minimizing the risks of inlet formation inherent in overwash events. This is achieved through what we call Dune Overwash Zones. The following section describes our methodology for locating and sizing these zones, and for adapting the existing maintenance practice of dune fencing to work with aeolian transport and periodic overwash events to achieve these aims.

Figure 38. Digital Elevation Model of ASIS showing the long, linear foredune in the Developed Zone (in white)

2.2 Dune Fencing

Background

All along Assateague, the dunes trace the edge of the beach. Dunes on a barrier island are primarily responsible for land stabilization, which had been at issue for Assateague since Frederick Law Olmsted Jr. 's 1941 flight over the island [30]. The flight was in the service of a study to determine future National Seashore sites and Olmsted had remarked that Assateague had potential but would require stabilization through building up dunes to help protect against overwash events [31]. Here, Olmsted was perhaps referring to the 1933 Hurricane (fig. 39) that had breached the low foredunes to create the Ocean City Inlet, which had severed Assateague from the growing resort town and further isolated the beach from anything but boat access [32].

However, constructing dunes and stabilizing the landscape for recreation has come at the expense of some of Assateague's natural processes. Olmsted himself had commented that he did not think it possible to "permit relatively intensive use of a good bathing beach for popular bathing and related popular beach activities without de-naturalizing and rather completely sophisticating the immediately adjoining hinterland" [33]. While overwash events can be unpredictable and destructive to anything that is constructed in their paths, overwash is a natural process of barrier islands. These areas of historic overwash can be identified by their unique fanned forms and seen from what is absent - sparse vegetation patterns and lack of marshes (fig. 40) [34]. Overwash is critical to create the variability in geomorphic



Figure 39. An aerial photo of the Ocean City Inlet, created 1933. https://www.nab.usace.army.mil/Media/Images/igphoto/2001878700/

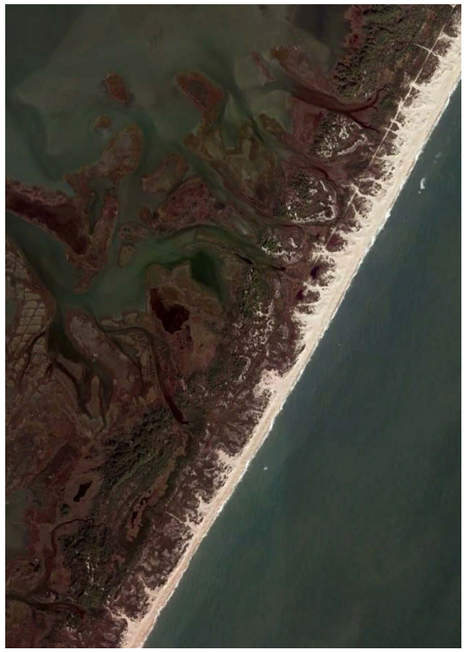


Figure 40. Overwash fans visible in an ASIS aerial



Figure 41. Visitors at ASIS playing on the dunes

and vegetative communities that have made Assateague Island a rich, diverse ecosystem [35].

Dunes are primarily constructed through the daily and annual movement of sand through aeolian transport. These processes are complicated by erosion and overwash from storm events as well as heavy recreational beach use. Standing on the beach and gazing out towards the dunefield, one can observe the tops of sand-fences that have been swallowed by dune migration. Those who choose to camp on the foredunes experience firsthand the power of movement generated by the aeolian forces that send granules of sand across the island. And while dunes are subject to further destabilization through use, the need for conservation is balanced against the desire for recreation. One can observe children at play (fig. 41), traipsing over the dunes, as well as, on the southern end of the Park, the oversand vehicle zone (OSV) allows a limited number of 4-wheel drive vehicles to adventure through the quiet, remote beaches despite the controversy surrounding its usage [36].

This balance, or tension of conservation and recreation, is played out daily in the maintenance of park infrastructure. The paved parking lots and roads that lie

2.2 Dune Fencing

behind these dunes are always at risk of being overtaken after major storms, reclaimed by the shifting sands, and require movement and replacement [37]. Restrooms, concession stands, and comfort stations are built so that they can be packed away if a major storm is forecast for the region [38]. Annual campers have trouble recognizing their favorite spots, realizing that the beach that they left behind is no longer the same as the one to which they have returned. Historically, the villages and remote settlements that built on these unstable soils held change and loss as a matter of fact [39]. Attempts by developers to plat this landscape, and by the military to bury old ordinance in the back dunes [40] were not successful and have left a legacy that the park and its users adapt to today. From time to time, locals and beachcombers will uncover relics from the past and will be reminded of Assateague's rich human history amongst the undulating landforms.

Dune fencing

Various configurations of dune fencing (fig. 42) are employed in dune management; relating to existing conditions, ease of construction, available materials, cost, and aesthetic values. Research indicates that double-line straight wood-slat fencing, popular on U.S. coasts, is a cost-effective way to promote



Figure 42. Photograph of dune fencing, illustrating materiality and dimensions up close. Wood and wire is a more sustainable use of materials than plastic (note relict orange fencing).

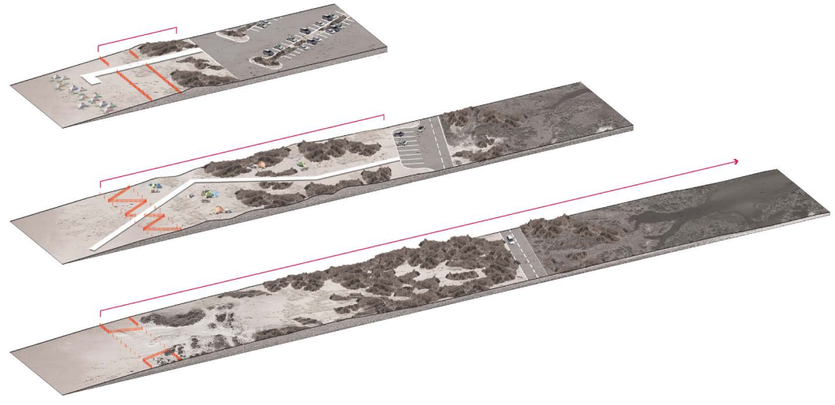


Figure 43. Proposed diversification of dune fencing in different contexts across ASIS. Top represents current practice.

dune growth [41]. Other configurations with greater porosity and more shore-perpendicular elements may be less effective at maintaining an existing dune line but can be beneficial in injecting sand deeper into the dune system and promoting migration and overwash.

The existing dune fencing strategy at ASIS is uniform across the developed zone – double-line fencing parallel to the shore (fig. 44). The management paradigm is passive, meaning fencing is put in place and the resulting dune is left to accrete and erode until the next fence install period (fig. 45). Because sand moves constantly, this means the dune crest rises and falls within envelopes around 6' regularly throughout a year [42]. The target elevation is the average dune height on natural portions of the beach. The primary goal for the existing fencing is to protect the adjacent visitor use infrastructure (roads, parking areas, campground). To do this, the existing fences are installed in such a way as to 1) preserve beach width by moving fences back as the shoreline erodes and 2) prevent regular, nuisance overwash while allowing for larger, productive overwash events.

We propose a diversification of dune management strategies (figs. 43, 46, 47) across the developed zone based on public uses and infrastructure, historic geomorphology, and future shorelines. This diversification would contribute to a more heterogeneous and resilient coastline at multiple scales: from the scale of the dune, to the scale of park programming, to the scale of the island. Altering fence configuration can inject sand into eroding dunes; promote faster dune migration and more varied and interesting visitor experience in lower density zones (i.e. walk-in campsites); and create intentional overwash areas in strategic locations to benefit cross-island processes with minimal impacts to access

2.2 Dune Fencing

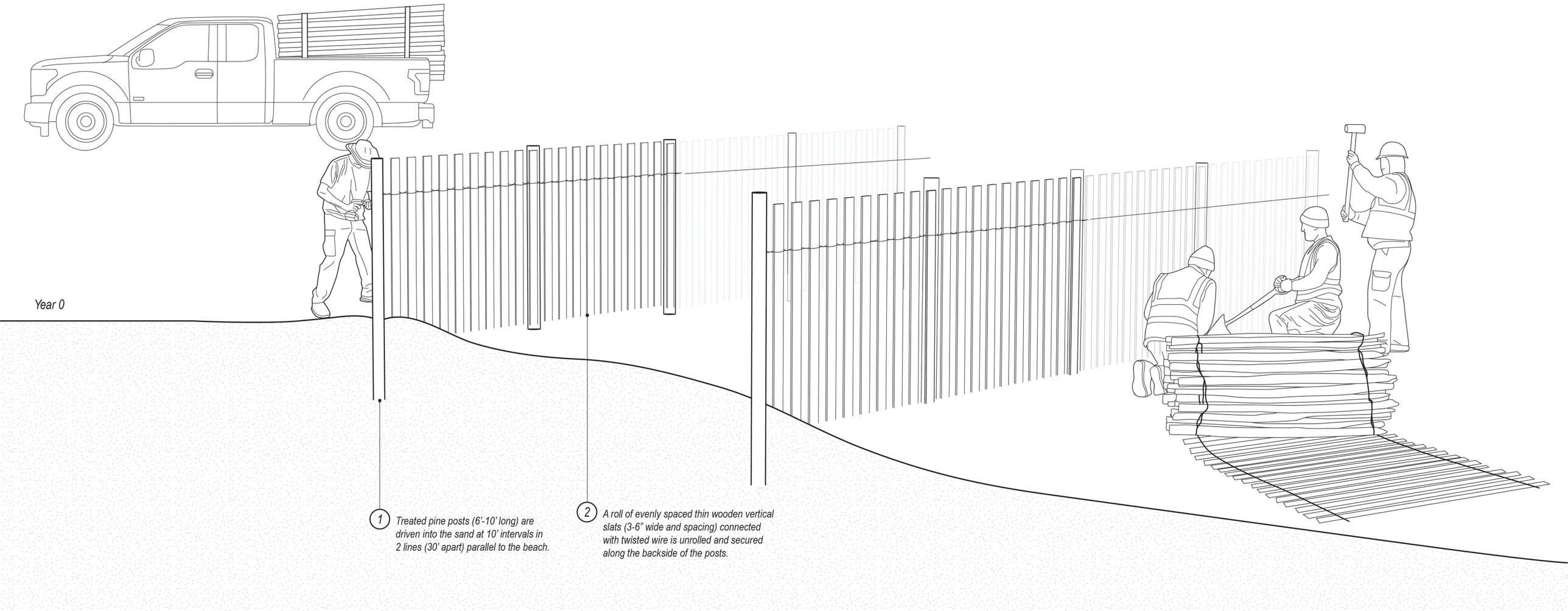


Figure 44. Existing dune fencing practice at ASIS, which passively manages their dunes with a double-line of fencing that captures sand moved by natural processes.

2.2 Dune Fencing

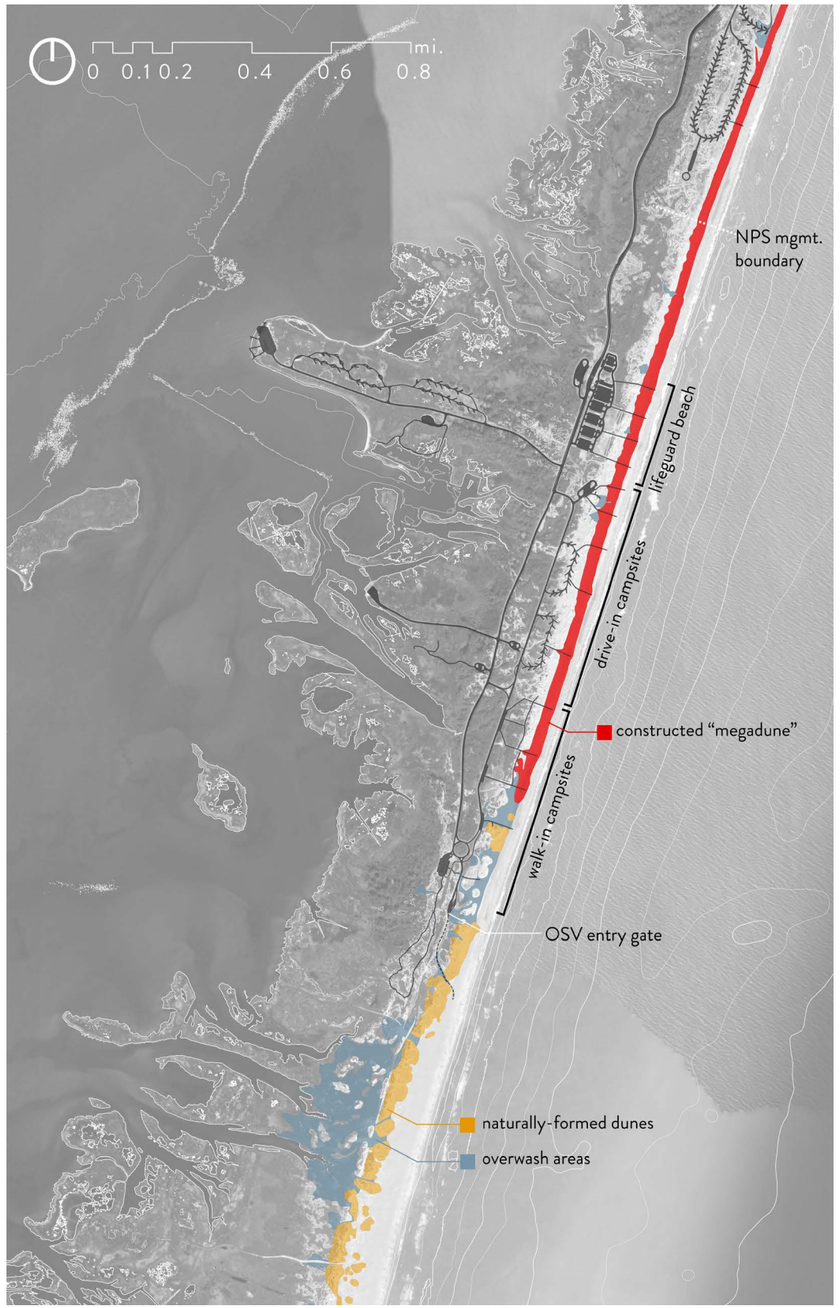


Figure 46. Existing context of fencing and resultant dune structure at ASIS

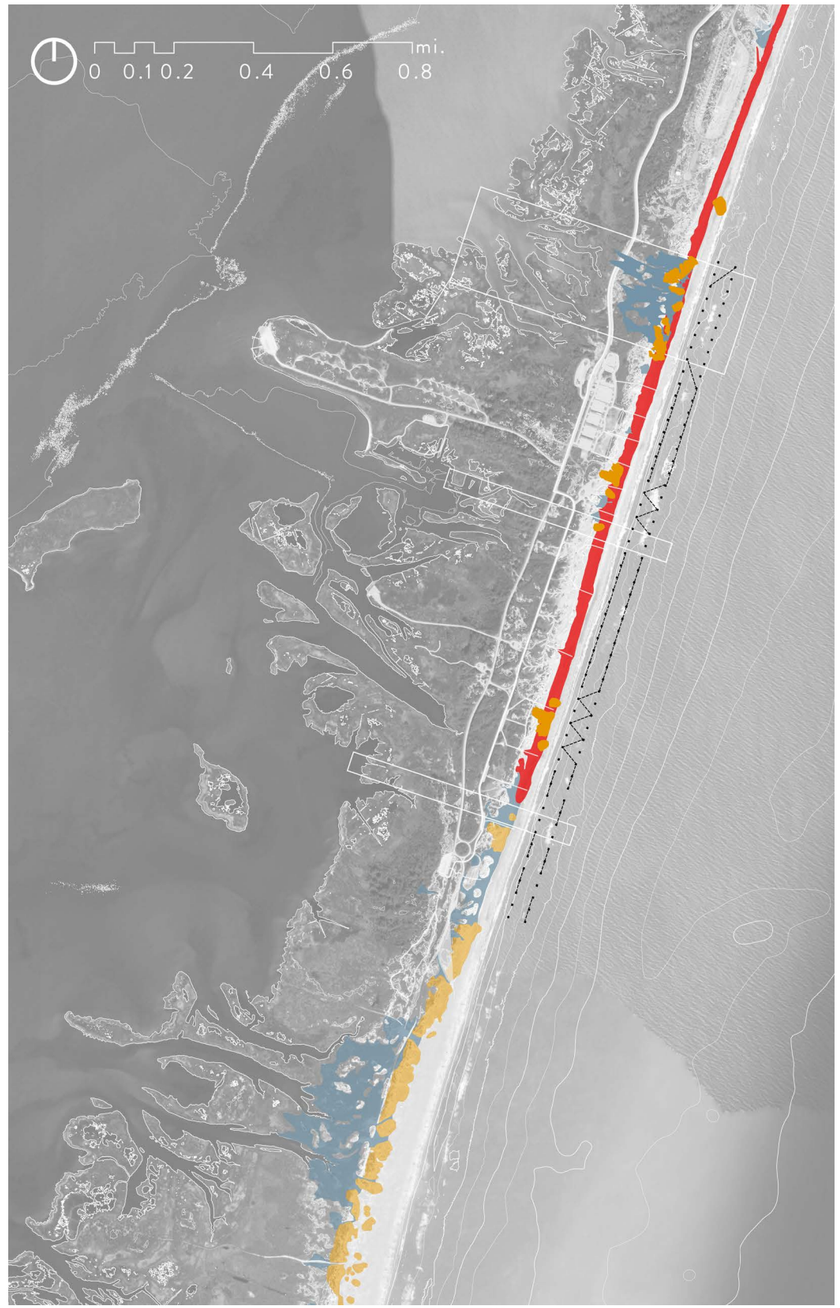


Figure 47. Proposed fencing diversification and projected dune structure change

and infrastructure. Focusing on fencing as the means by which park management continues to engage the natural working of sediment by wind and waves minimizes labor and cost because it simply modifies an existing practice. It also makes room for further experimentation and adaptive management as fencing is typically replaced every three years [43].

The diversification we recommend entails identifying areas where dune overwash is allowable with minimal risk and to enhance recreation and habitat functions and processes, and secondly to identify fencing geometry (spacing, lengths, and orientation) that would help achieve the project goals. For the design concept we recommend (pp. 83 - 95), this means removing a section of fencing to allow more overwash events to push sand into the island interior; reducing and realigning the fencing from a double-straight line to a new alignment. This will create a more heterogenous dune field and raise the base elevation after overwash, while maintaining or increasing sand volumes in order to minimize the risk of inlet formation. Encouraging natural processes like overwash and aeolian transport is not only in keeping with park practices, values, and goals for visitor experience; we argue this will also make the island more resilient to the effects of both long-term human use (degraded and fragmented beach, dune, and marsh ecologies) as well as larger storm events and higher water levels.

One of the effects of management for human use in the developed area is sediment starvation behind the foredune. Because the double-line fence is so effective at capturing sand and protecting the infrastructure behind it, areas like North Ocean Beach have low, wet backdune areas. Elevational data confirms this field observation, but it is a broadly observed phenomenon [44]. As the beach migrates westward, toward the bay, relocating park facilities and recreation bayward will be more difficult in these starved zones. If left as they are, these zones will also lack backdune vegetation to help smooth the ecological transition. Working with natural processes to strategically raise these areas now will help facilitate the impending beach and infrastructure migration that will have to happen in the near future.

Adjusting existing management practices will also make the island more resilient to increasingly common storm events. The way the existing managed foredune works to protect against storms is to keep out waves and the energy associated with them for more regular events. But natural dune systems are less uniform – their volume is more spread out, and there are dips and gaps. This means they can accept more waves and sand that the waves carry, allowing deposition to occur while simultaneously dissipating wave energy. The Dune Overwash Zone concept works with the principle that sand volume is one of the primary ways of mitigating risk of inlet formation from overwash events. This means that dune volume (rather than height) is the metric by which protection against events should be measured. Dune geometry, then, becomes a useful design variable as long as volume remains constant or increases.

To illustrate the value of geometric variation in dunes at ASIS, we compared dune volume and distribution at three sites representing managed, previously managed, and natural dune systems. These sites were, respectively, North Ocean Beach, Developed Zone South,

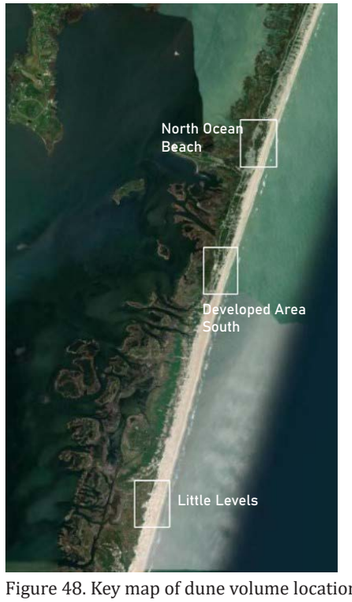


Figure 48. Key map of dune volume locations

Table 1. Dune Volume per beach-parallel section (m3)

Section	North Ocean Beach	Developed Area South	Little Levels
1	86272	89065	79098
2	104003	97809	81089
3	103895	94678	85383
4	109866	100300	85968
5	114880	112941	85973
6	110814	121018	95531
7	112169	133659	97607
8	98759	140614	105876
9	98426	137035	128090
10	97925	116089	179354
11	105750	116269	194382
12	89595	125366	235248
13	99067	120191	301860
14	121982	144210	314623
15	157616	151896	271308
16	189712	178222	258770
17	199779	194876	233012
18	220059	243340	239379
19	245937	282449	234769
20	428863	300316	231519
21	356454	297948	242772
22	250529	243667	240783
23	208179	198398	214014
24	201316	145102	190090
25	78213	55213	54735

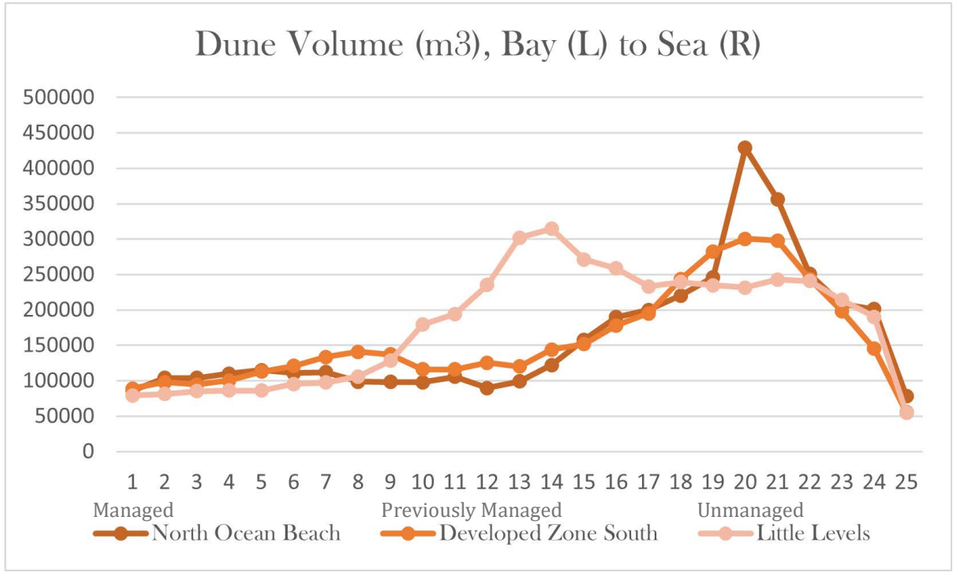


Figure 49. Graph illustrating dune section area at three sites. The ocean is right, the bay is left.

and Little Levels (see map fig 48). To calculate dune volume, 25 sections parallel to the beach were taken in each area, 50 meters apart. Each of the volumes in Table 1 and Figure 49 represents one of these 50-meter-thick slices of sand. We can see the sharp spike in volume at North Ocean Beach, which represents the managed foredune, and the dropoff behind. At Developed Zone South, note the foredune has eroded but remains in a similar position. This is in keeping with contemporary dune morphology research, which suggests that fenced dune systems "can erode but do not recover over inter-annual time scales" [45]. At Little Levels, the volume is distributed more evenly between the fore and backdunes. The overall volume is also 12% greater than at the managed and historically managed sites. The total volume at North Ocean Beach is 3,990,060 cubic meters, the total volume at Developed Zone South is 3,940,672 cubic meters, and the total volume at Little Levels is 4,481,230 cubic meters.

Further study would sample more managed, previously managed, and natural sites at ASIS to validate these initial findings and could lead to higher confidence in causally linking natural dune variation with increased coastal resilience. But this small exploration, for us, helps to at least illustrate two larger points: that the more distributed dune geometry found in natural areas 1) does not lead to increased risk, and 2) can in fact be associated with higher overall dune volume. This understanding of the way natural dune morphology works at ASIS led to a design process that prioritized the creation of both foredune gaps and backdune sand traps.

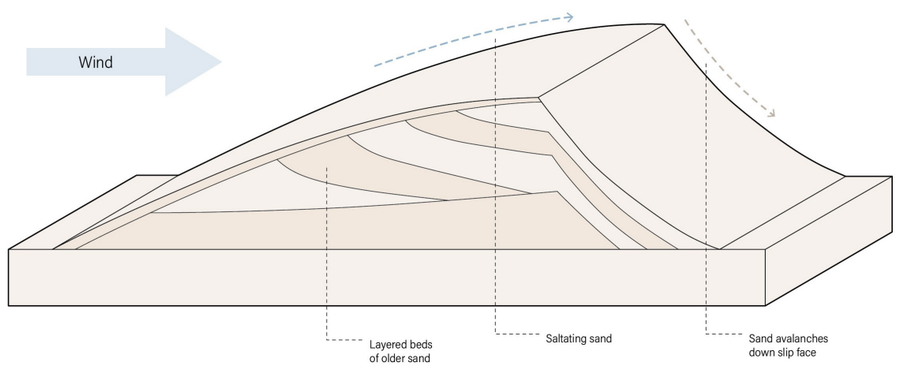


Figure 50. A simple diagram of wind-blown sand deposition, illustrating layers of sand forming over time

Fence pattern exploration

We explored a variety of potential fence patterns, each producing a different kind of dune. Generally, these dunes are formed when fences, or vegetation, or other structures create a wind shelter zone, slowing wind-blown sand enough to make it drop down. More specific features of dune form depend on environmental conditions like wind direction and velocity, as well as fence height, porosity, orientation, and maintenance (Figure 50).

Wind velocity, fence porosity, and fence height determine the size of the shelter area. For instance, with 10 mph winds, a 6-foot-high porous fence will produce minimum velocity 10 feet downwind from the fence. When the wind is 20 mph, the minimum velocity point will be 65 feet from the fence; and at 30 mph, the area protected is about 90 feet downwind. As a general rule, wind protection is usually adequate for a distance equal to about 20 times the fence height, whereas the major material drop is in an area downwind equal to about 10 times the fence height [46].

Wind direction and fence orientation determine the shape of the shelter area. Common fencing patterns include shore parallel, to protect the beach from onshore wind; perpendicular, to capture crosswind sand and protect existing dunes from foot traffic; and oblique. The Cape Hatteras Sediment Management Framework, set at Cape Hatteras, about 300 miles to the south of ASIS, cites a U.S. Fish and Wildlife Service Biological Opinion which stipulates that fencing should always be placed no less than 45 degrees relative to shoreline, which seems to be the standard practice in North Carolina [47] . A 2019 in-situ study at Brogue Banks, NC suggests that sand fencing the foredune may not always be the best singular management action, namely because they may prevent sand deposition to natural dune systems further behind the fence and reduce the vertical growth of the natural dune [48]. ASIS manages their dune contour to achieve a continuous crest height that will eliminate nuisance overwash that can increase maintenance or impact recreational uses, while allowing larger overwash events through.

Maintenance over time determines the fate of the dune. A sand fence is only operational until it reaches its carrying capacity; this is why fences and posts are relaid over time. We propose implementing alternative fence patterns in target areas to complexify dune morphology and encourage natural processes to play a productive role in shaping the island. This continues the tradition of ASIS protecting coastal processes over static features. In areas of less-concentrated public use and minimal adjacent pavement, breaking up the double-line fence could promote wider and more heterogeneous dune systems.

2.2 Dune Fencing

Geomorphic complexity lends itself to a more naturalistic experience of the dune system, but is also correlated with more varied vegetation composition, dune migration, and healthier backdune and marsh habitats.

It is important to note that site-specific evidence, which can only come from testing patterns at ASIS, is more valuable than research from other locations. There is precedent research indicating that fencing changes do not decrease the accumulation of sand over time. This means that although the dune geometry would change, dune volume and therefore dune protection would not. A three-year study comparing parallel, oblique, and perpendicular sand fencing on Santa Rosa Island, a barrier island in Florida, concluded that different sand fence configurations do not lead to significantly different volumes of sand accumulated [49]. Another study on Timbalier Island, Louisiana, also reported no difference in accumulated volume across fence types [50]. Our design concept capitalizes on the ability to alter dune geometry, and proposes a non-continuous dune system. We believe this will let more sand into the dune system, both through overwash and aeolian transport. This is supported by the dune volume calculations taken at ASIS (Figure 49).

The following drawings (Figures 52-58) explore alternative fences and resulting dune geometries; pulling from precedent and the study of existing topography.

Every exploration has the same or less linear feet of fencing as the existing Double Line fence practice.

The most promising sketch concepts were tested on a wind table built at the University of Virginia, with the specific goal of qualitatively understanding the impacts of different fences on dune geometry (and subsequently risk reduction, vegetation, and human experience) in more depth (Figures 59-61). These results were refined into a final design concept using drawings, comparing with analogues on the island, and through geometric analysis. This final concept could undergo quantitative analysis or could be field tested. As discussed in the next section, we recommend field testing at North Ocean Beach. Given complex and highly variable wind conditions, sand supply, and existing dune geometry at ASIS at any point in time, quantitative analyses here would not only be costly but also be associated with a very high degree of uncertainty.

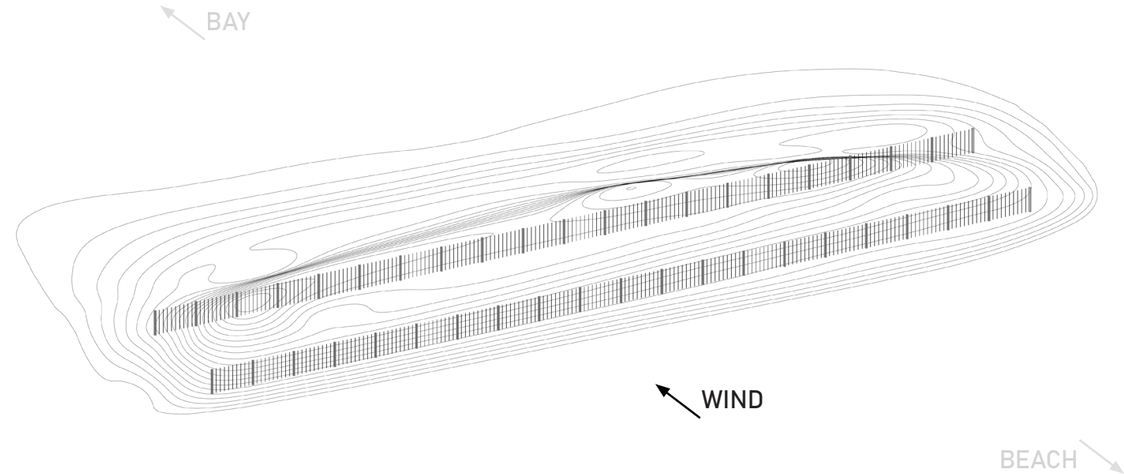


Figure 52.

Double line: The existing double fencing strategy is likely the most effective for maintaining existing foredunes. Best used adjacent to paved access areas, like the Lifeguard Beach and drive-in campgrounds.

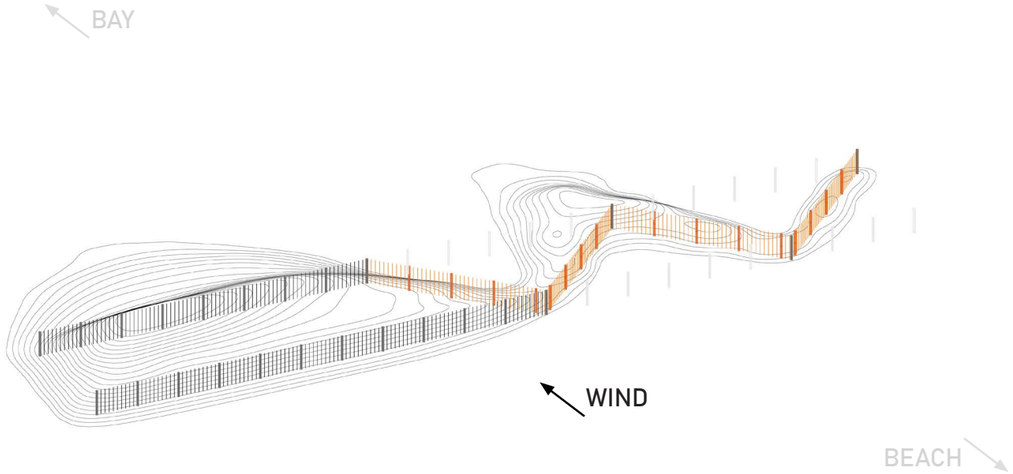


Figure 53.

Zig zag: In areas of less-concentrated public use and minimal adjacent pavement (i.e. walk-in campsites), a single zig-zag fence is a generalizable pattern that could promote a wider and more heterogeneous dune system and promote dune migration.

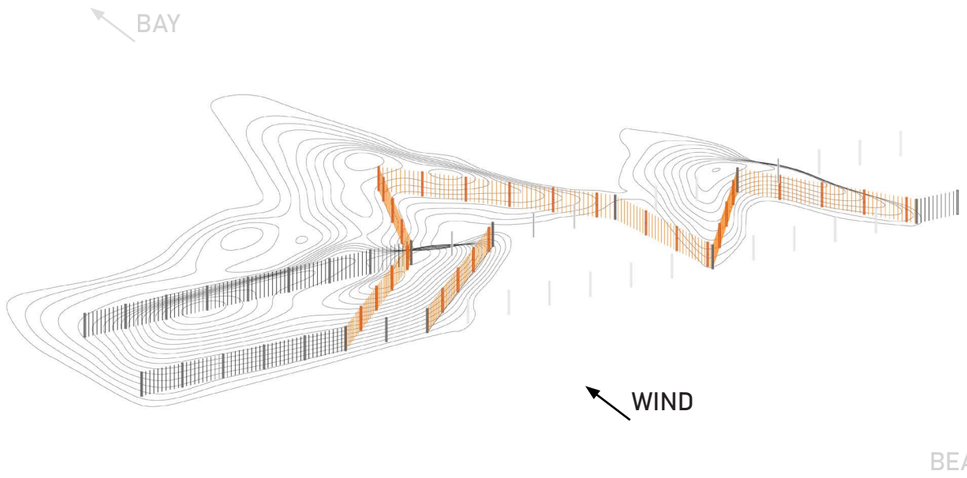


Figure 54.

Freehand zig zag: Fencing is laid in response to existing dunes on site.

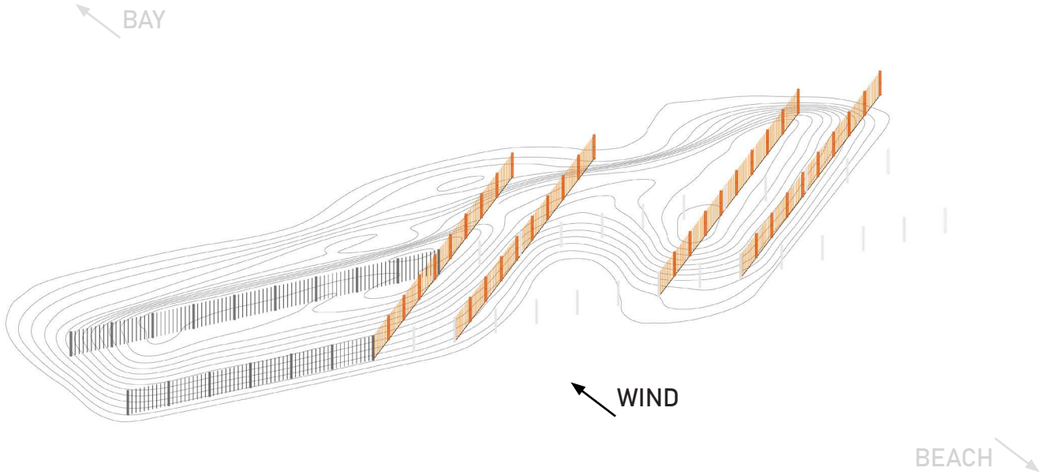


Figure 55.

Wind-perpendicular: Double-line fencing set perpendicular to prevailing winds - see wind roses (fig. 35). Increases volume capture while utilizing efficiency of double-line fencing. Pairs this increased volume with non-linear, staggered form associated with natural dunes.

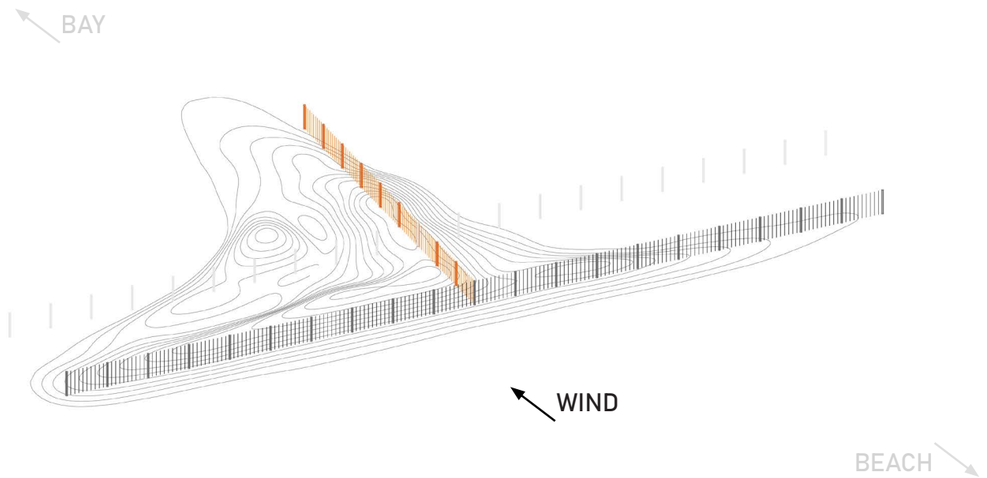


Figure 56.

Shore-perpendicular: Promotes a less linear dune shape, injects sand deeper into the dune system. Widely used in US coastal parks.

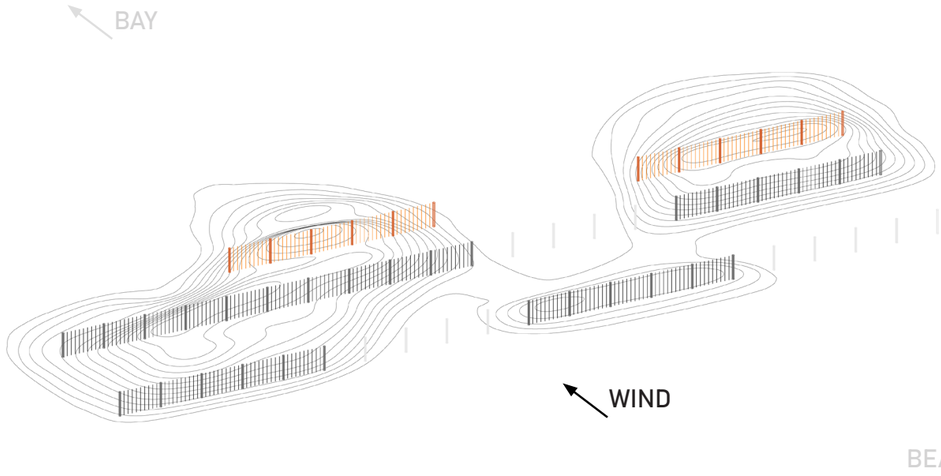


Figure 57.

Offset horizontals: Preserves linear feet of fencing. Breaks up linearity of the existing double-line dune. Straightforward and specific method for planting a small dune field.

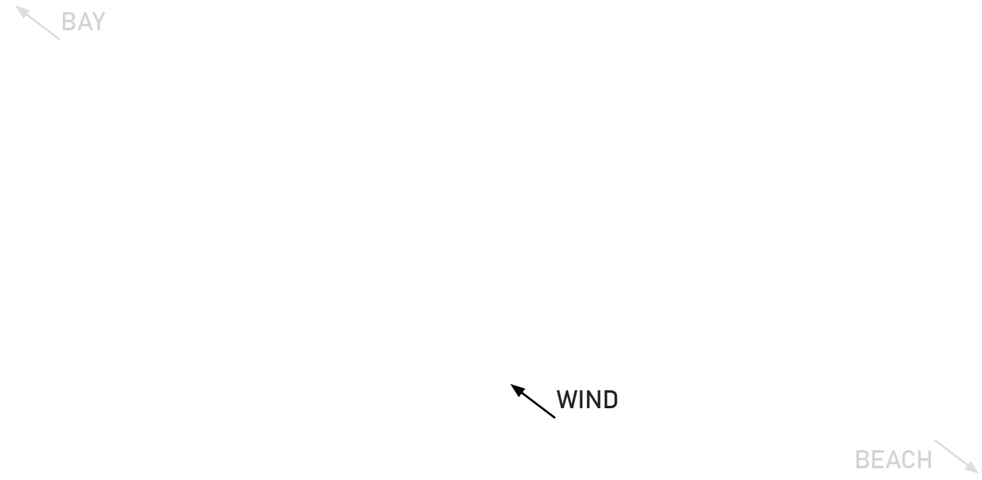


Figure 58.

Overwash gap: In strategic areas (minimal infrastructure + high overwash potential + impaired marshes), gap/"funnels" in dune fencing could permit productive overwash to benefit cross-island processes with minimal impacts to access and infrastructure.

Staggered shore parallel
Pattern 1

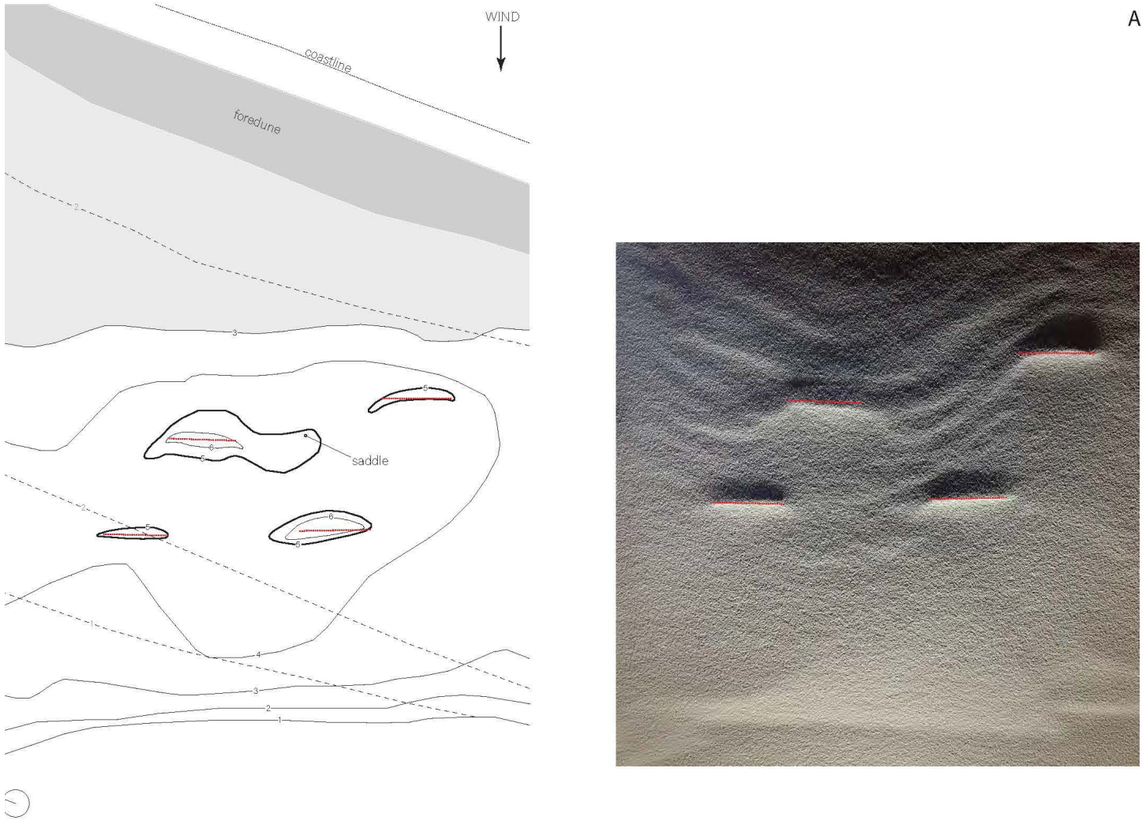


Figure 59. Staggered shore-parallel fence pattern tested on the wind table

Staggered chevrons
Pattern 2

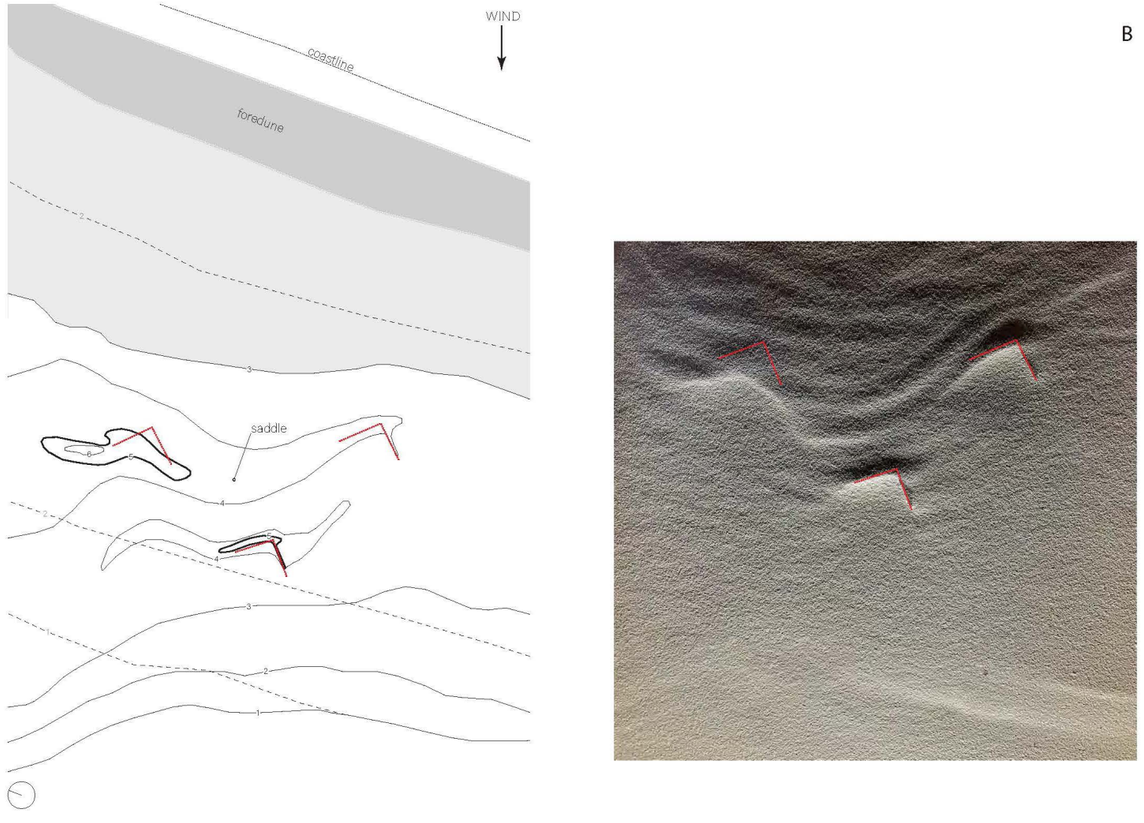
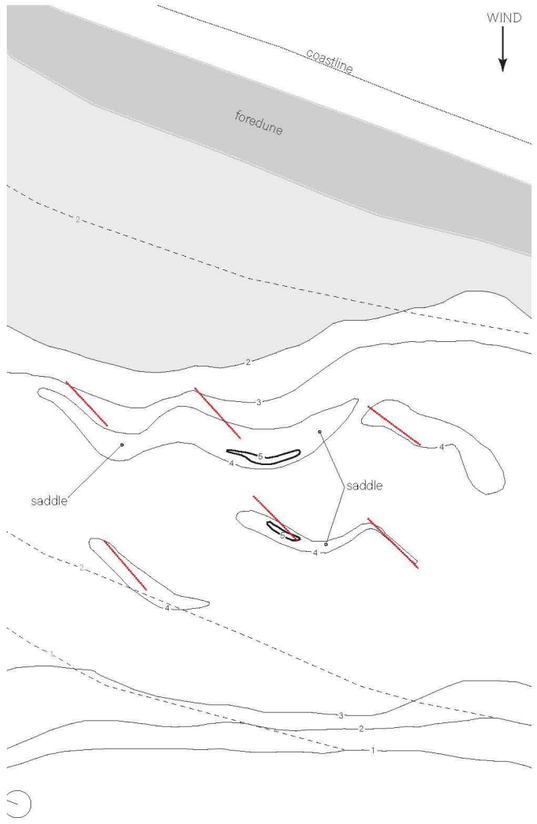


Figure 60. Staggered chevron pattern tested on the wind table

Offset oblique
Pattern 3



C

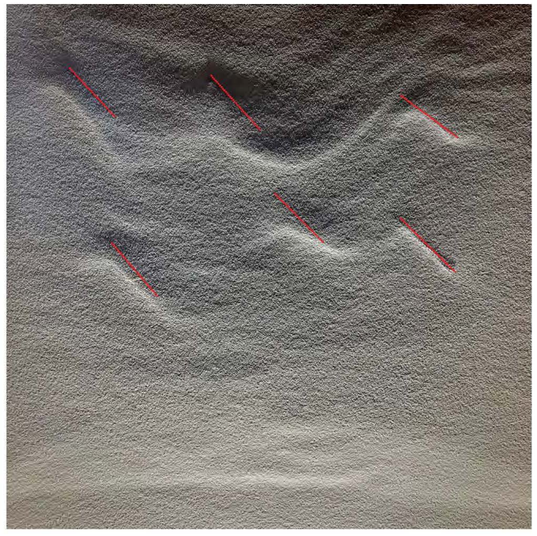


Figure 61. Offset Oblique fence pattern tested on the wind table

Design Concept: Dune Overwash Zone

We recommend creating an overwash zone directly to the north of the North Ocean Beach Lifeguard area. The site has an existing break in the backdune and has evidence of a historic inlet, meaning it has a higher overwash probability [51]. Nearshore bathymetry also suggests high overwash potential (fig. 63). The site's backdune system is also starved for sediment and is not proximal to sensitive infrastructure.

Overwash generally breaks through gaps in the foredune crest line [52]; so our design concept entails creating an intentional gap in the foredune by removing some of the double-line fencing. We also suggest placing smaller, distributed fence lines in the backdune.

This design concept is a combination of the sketches in Figures 57 and 58, and the wind table test illustrated in Figure 61. The smaller distributed fencing is a means to collect sand in the backdune zone and build both volume and geometric complexity through aeolian transport. This will have the effect of increasing habitat and varying human experience, but will also minimize the risk of inlet formation while allowing for overwash. In a storm scenario, we anticipate that the gap and stepped-back fencing would encourage overwashed sediment into the backdune area, increasing island stability by increasing interior island elevation.

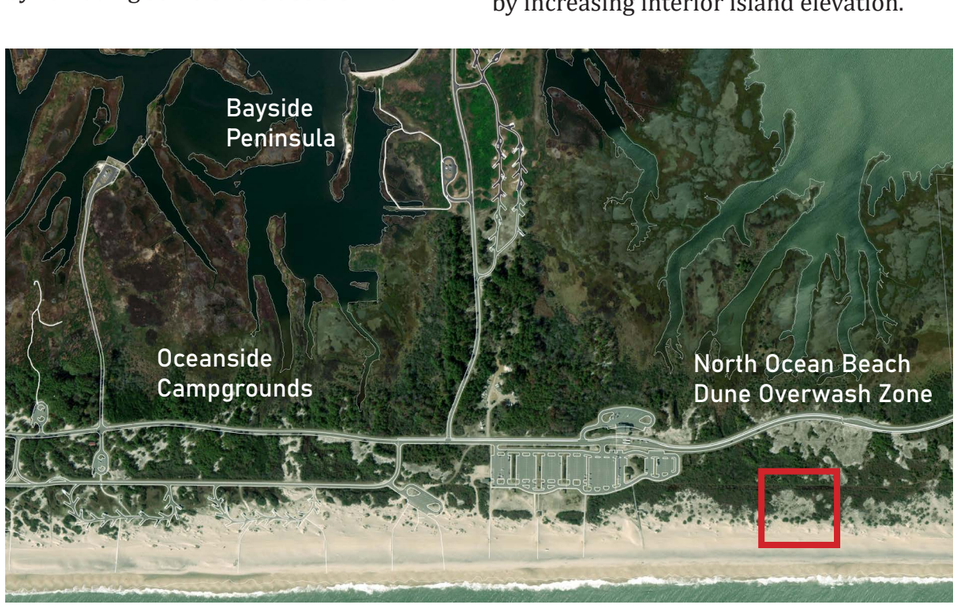


Figure 62. Key map of North Ocean Beach Dune Overwash Zone concept

2.2 Dune Fencing

Storms in the Developed Zone at ASIS can cause overwash that penetrate island interior at elevations up to 2.2 m (NAVD88). The frequency and intensity of overwash is controlled by wind and significant wave height, water level, storm surge, storm duration, and nearshore bathymetry, but also by beach topography [53], berm width, and beach volume [54]. The design concept discussed here works with these last three overwash controls.

At ASIS, “92% of wave heights are less than 1.4 m, but wave heights of up to 3.5 m height occur about once every 10 years, and up to 4.5 m once every 50 years” [55]. Existing dune management at ASIS aims to limit nuisance, erosional wave events, but promote overwash during larger-scale events. Our field walks and topographic analysis suggests that many areas in the developed zone aren’t getting as much overwashed sediment as they could. We aim to complexify appropriate areas to let more overwash through. These more complex dune geometries will slow larger overwash events and encourage more sediment to drop, as opposed to letting the overwash cut right across the island. The North Ocean Beach site can serve as a test site for the practice of complexifying the backdune and opening up the double-line.

Overwash restoration has precedent on Assateague Island, north of the developed zone. An artificial foredune was constructed in 1998 north of the State Park to protect the island from the threat of erosion and breaching caused by the Ocean City inlet jetty. The foredune prevented all overwash and wind from passing through which had unintended effects, including converting the beach community to herbaceous and shrub communities and reducing the habitat of shorebirds like the Piping Plover. In 2009, notches were cut through the dune to re-establish overwash [56]. The geomorphological metric of success for this project was one overwash event per year, if overwash occurred elsewhere on the island, and the project worked. Additionally, none of the notches widened or deepened. The researchers took this to indicate that the notches did not increase the risk of island breach [57].

Our proposed design reorganizes dune shape to accept productive overwash. We identified a site at North Ocean Beach where a number of factors contribute to high overwash potential, which coupled with minimal infrastructure and relatively vulnerable marsh in the island interior, (fig. 47) led to the conceptualization of a beneficial overwash gap in the foredune.

This gap would be created by removing 50-60m of fencing from the existing double-line (fig. 51, total removed fencing 100-120m). Removing the fencing would enable dunes to develop over time via aeolian transport (in contrast to the Schupp notches). According to Schupp et al. 2013, the 50-60m gap as proposed would be far enough from any foredune edges to put the foredune at risk (Schupp et al. [58] recommend gaps at least 200m from the N and S edges of the foredune). Sand slumping is anticipated to extend 5-10 m from each side. The resulting dune gap would be 30-50 m. Some of the removed fencing would then be placed in the backdune (60 m) in shorter runs.

The smaller runs of fencing are designed to retain sand in the backdune area in keeping with existing morphology. We analyzed the context by isolating high points of the proximal backdune system, and using a minimum spanning tree algorithm to isolate clusters and determine the range of distances between backdune peaks (fig. 54). The analysis informed fence run length and spacing.

This overwash proposal is intended to create the ideal overwash profile described in the previous overwash restoration project [59], which had a peak elevation of 2.16 m (NAVD88) and a 1% slope westward through the foredune’s expanded flanks to a backshore elevation of 1.48 m (NAVD88). The desired effect is the creation of overwash fans similar to ones found elsewhere on the island, like at Little Levels (fig. 46, 47). At the Little Levels comparison site, smaller fans have a 20m wide channel that runs through the foredune and fans out into a 50 m arc; larger fans have closer to a 130 m crown. If we assume that overwash fans at North



Figure 63. Overwash fans at Little Levels, a comparison site, are 150-400’ wide with 60’ channels.

2.2 Dune Fencing

Ocean Beach will be a similar size to the Little Levels site, overwash fans should not get large enough to have any effect on non-moveable infrastructure (e.g. the ranger station and fee booths at Site 2). To get a better sense of the size of storms that might create our comparison site fans, the 1992 storm that likely created the Little Levels fans pictured in Figure 46 had a surge height of 0.97m, peak water level of 1.4m, and a return period of 7-9 years [60].

A better proxy for understanding the likely effect of a fence gap is the sand accumulation around the parking lot boardwalk at North Ocean Beach, which cuts inland through a large gap in the double-line fencing (figs. 64, 65). The design concept we recommend is pictured in the next sets of spreads (figs. 66, 68). During our January field visit, in situ discussion confirmed the selection of the North Ocean Beach site as the best place to test the dune overwash concept, given the gap proxy described above as well as the low risk of infrastructure compromise and obvious sediment starvation in the backdune, evidenced by elevation data and observed Phragmites stand on site.

Metrics of success for this concept, if tested in the field, would be increased volume in the backdunes, increased geometric complexity of the dunes, and increased dune vegetation. Drone surveys would be a good method for assessing these metrics, as they would enable plant identification as well as topographic change and geometric complexity. Using the SET transect method already taking place at ASIS would be a good way to assess volumetric change, but in order to understand anything about dune geometry the transects would have to be taken at a tighter N-S interval than they are currently. For any monitoring method, being able to collect data before and soon after major storm events, as well as through the seasons (wind strength and direction is seasonal), would be incredibly valuable.



Figure 64. A photo of the boardwalk leading from North Ocean Beach to the parking lot, illustrating the dunes that form without the double-line fence to trap sand into the large linear foredune. This photo also illustrates that a gap here does not cause significant foredune destabilization.



Figure 65. Perspective of the proposed dune overwash zone, illustrating dune gap by the ocean and backdune fencing in the foreground

2.2 Dune Fencing

In this figure, white represents the ideal overwash elevation of 2.16m NAVD88. Existing landscape characteristics leading to the selection of this site include low nearshore bathymetry, a significant break in the backdune, a low marshy backdune area, evidence of a historic inlet (see Appendix pg. 114), a low probability of any disruption to current operations or damage to critical infrastructure, and vulnerable marsh beyond Bayberry Drive that would benefit from increased overwash in the far future. The combination of all of these characteristics led our team to imagine this area as a protoypical beneficial overwash corridor.



Figure 66.

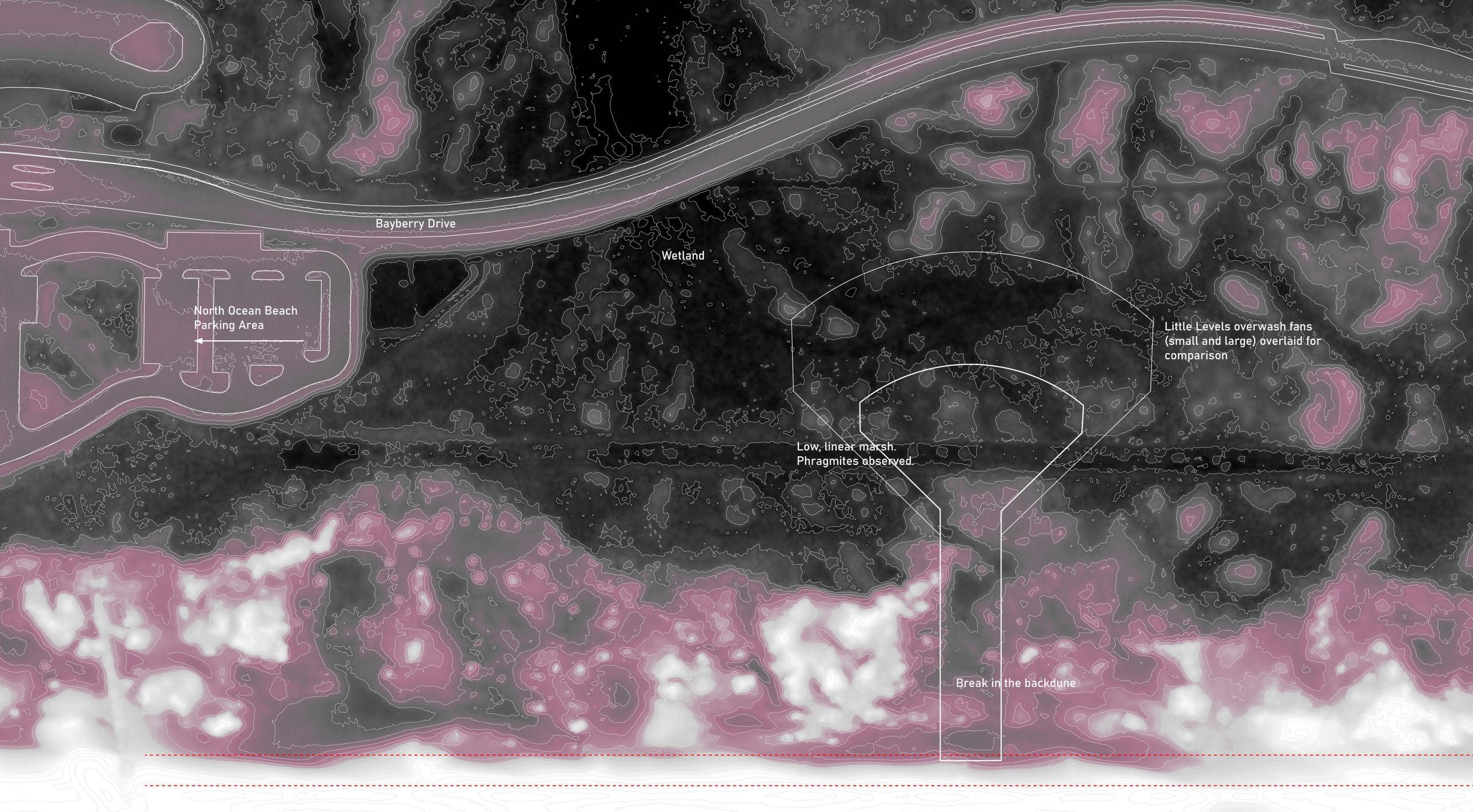


Figure 67. Existing conditions. The water's edge is the bottom of the page. Fencing is shown in dashed red. The overwash elevation window 1.90 to 2.50m (2.16m is ideal overwash elevation) is shown in pink. Currently, the double-line-fenced foredune (large white horizontal swath) prevents the backdune from receiving overwash.

2.2 Dune Fencing

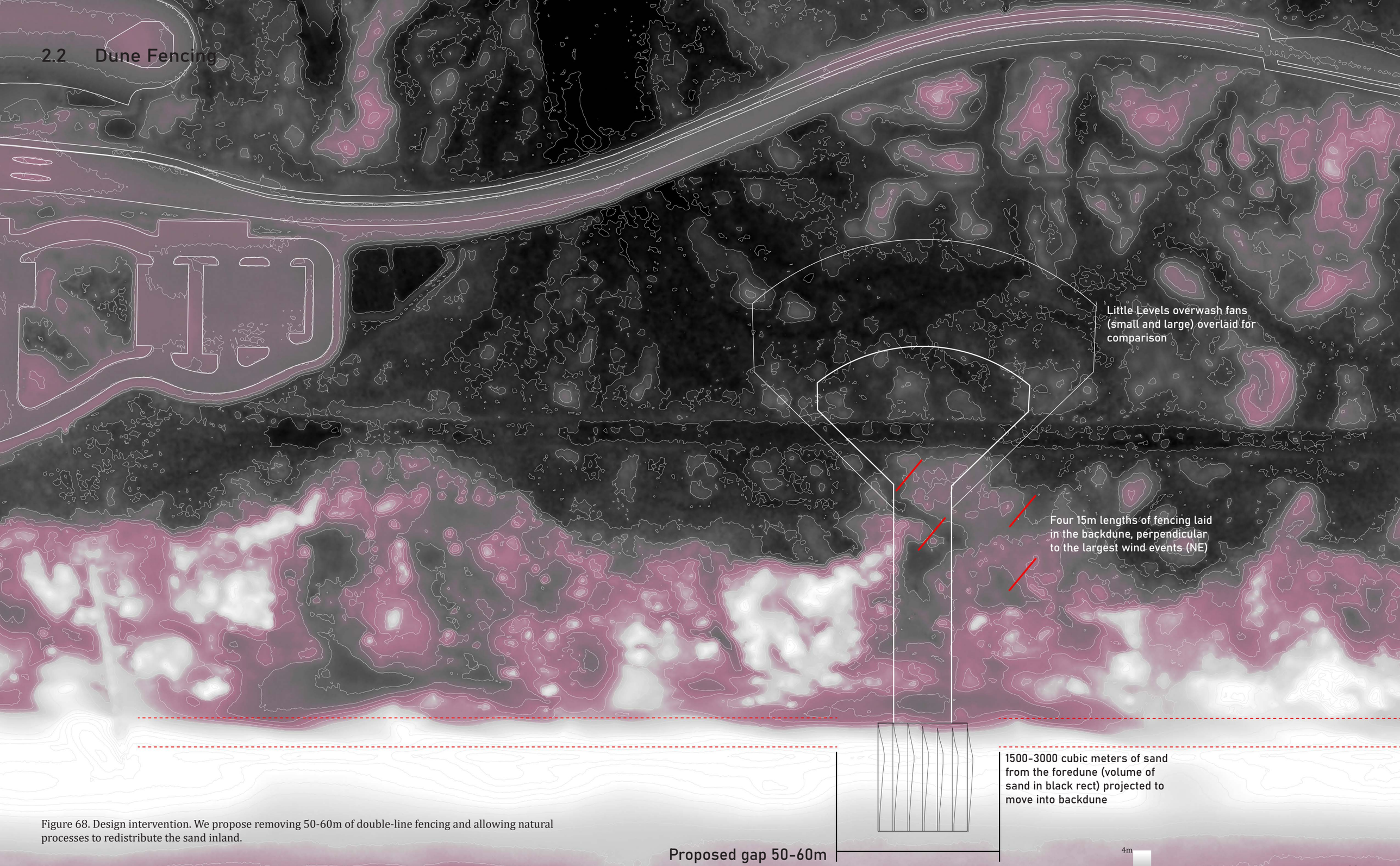


Figure 68. Design intervention. We propose removing 50-60m of double-line fencing and allowing natural processes to redistribute the sand inland.

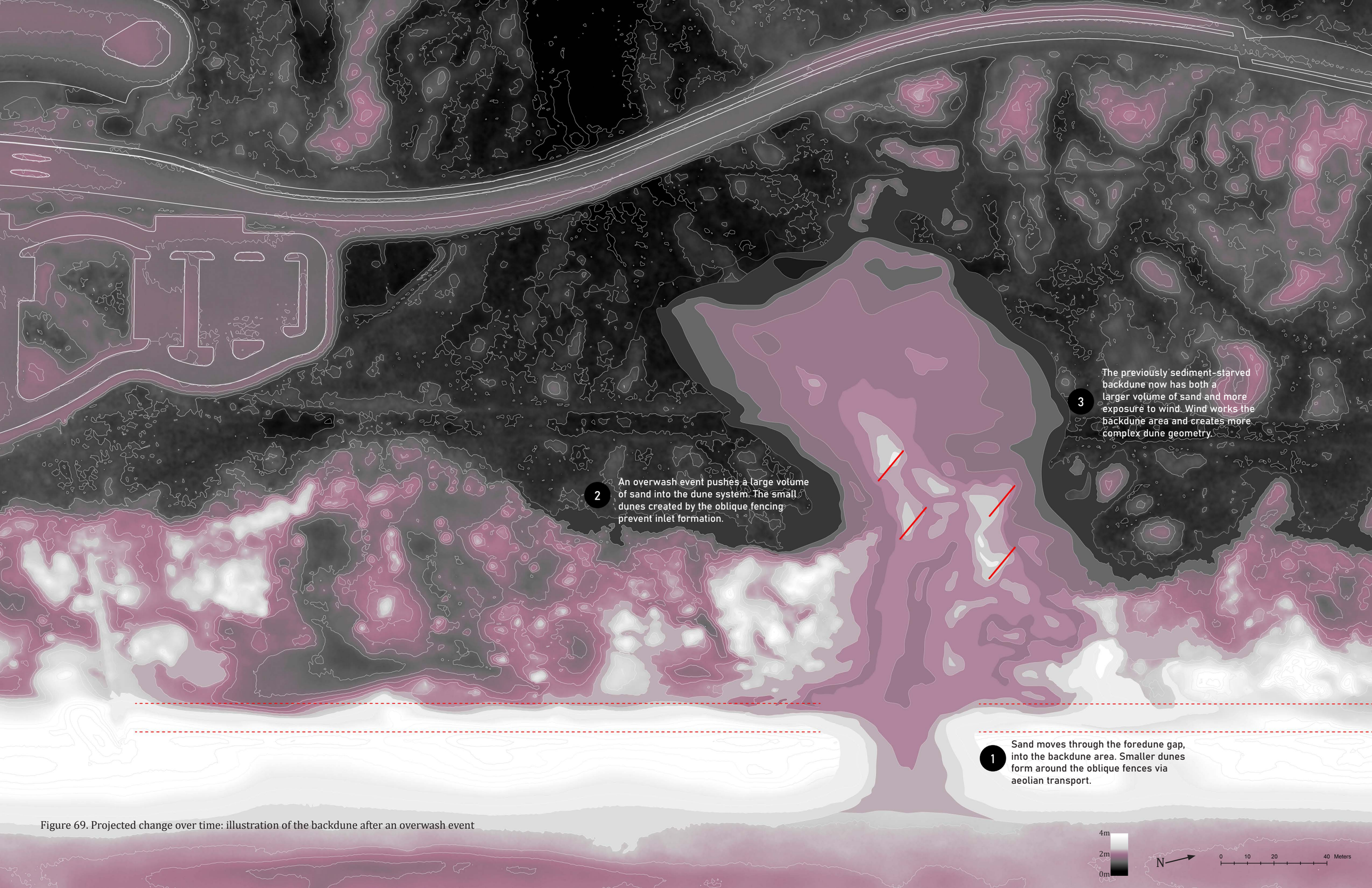


Figure 69. Projected change over time: illustration of the backdune after an overwash event

2.2 Dune Fencing

The analysis illustrated in Figures 70 and 71 (full analyses in Appendix) distills geometric parameters from the existing dunes in the three study areas (Tables 2 and 3). These parameters were used to help us define the dimensions for our backdune fencing such that it would integrate into its context. This integration enables relatively natural dune migration dynamics, and attempts to avoid the creation of atypical sand dynamics in the landscape. High points were located and connected into dune graphs using a Kruskal's minimum spanning tree algorithm with a cutoff of 15 meters. This means that if a high point is closer than 15 meters away from another, it is connected into one dune. A fit line was drawn through each set of high points, and both the length and angle were design referents for us. Table 2 provides summary statistics for the managed, previously managed, and unmanaged zones. One of the more interesting differences between these sites were the ranges of dune sizes: the managed site had very similar-sized dunes, the previously managed site had a larger size range, and the unmanaged site had the largest range of sizes. This helped frame the goal for increased heterogeneity, which in the design means that even though we propose to seed dunes with context-specific angles and lengths in the near term, these dune fences are placed such that over longer periods of time, some of the dunes are intended to merge and in so doing, to widen the local range of dune lengths.

Table 2. Summary statistics from dune analysis across three sites

	Avg fit line length (m)	Hi Pt Distance Avg	# Hi Pts per fit line	# Hi Pt range	Hi Pt Dist range
North Ocean Beach	30.6	10.5	5.9	11	10.2
Developed Zone South	50.3	9.7	10.9	21	10.4
Little Levels	33.1	9.8	7.1	36	11.1

Table 3. North Ocean Beach Dunes

Dune	Fit line length (m)	Angle	# Hi Pt	Avg Hi Pt Distance
N1	29	353	7	7.8
N2	39	329	5	11.5
N3	32	306	6	12.0
N4	26	81	6	9.4
N5	25	356	6	9.2
N6	36	45	7	10.0
N7	34	32	8	10.3
N8	68	39	14	12
N9	15	358	3	8
N10	13	15	3	7.5
N11	38	357	7	12
N12	29	285	5	11.3
N13	21	286	3	11
N14	23	277	3	12

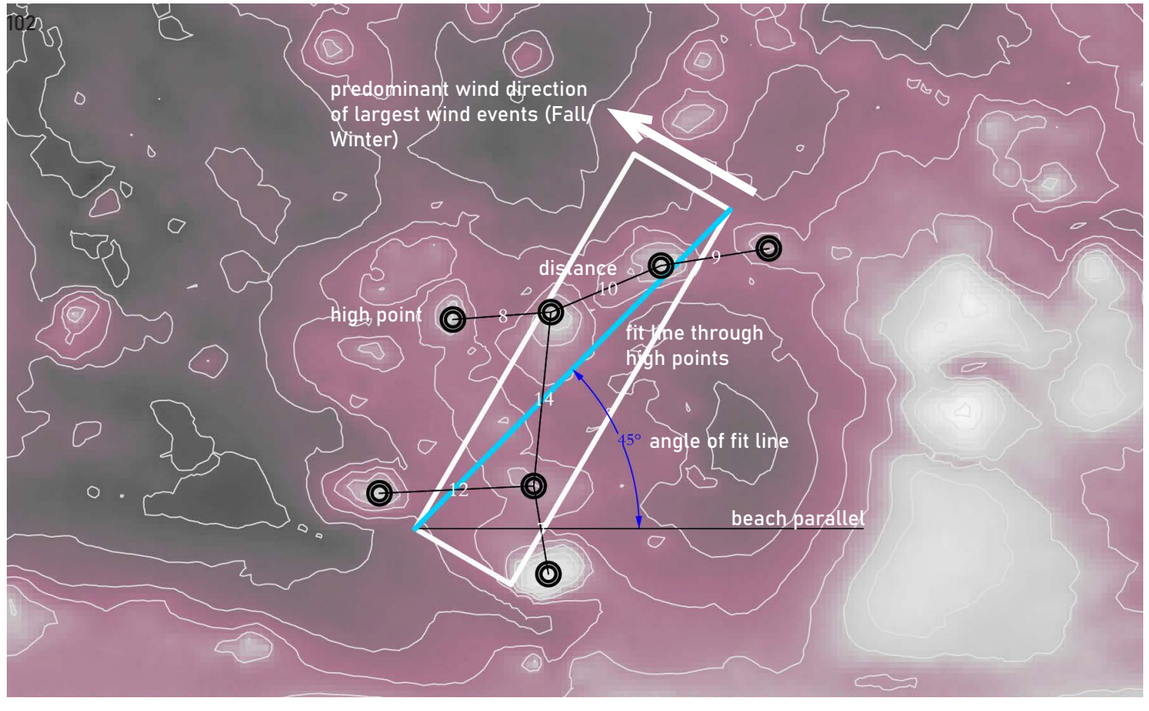


Figure 70. A key for the dune analysis drawings.

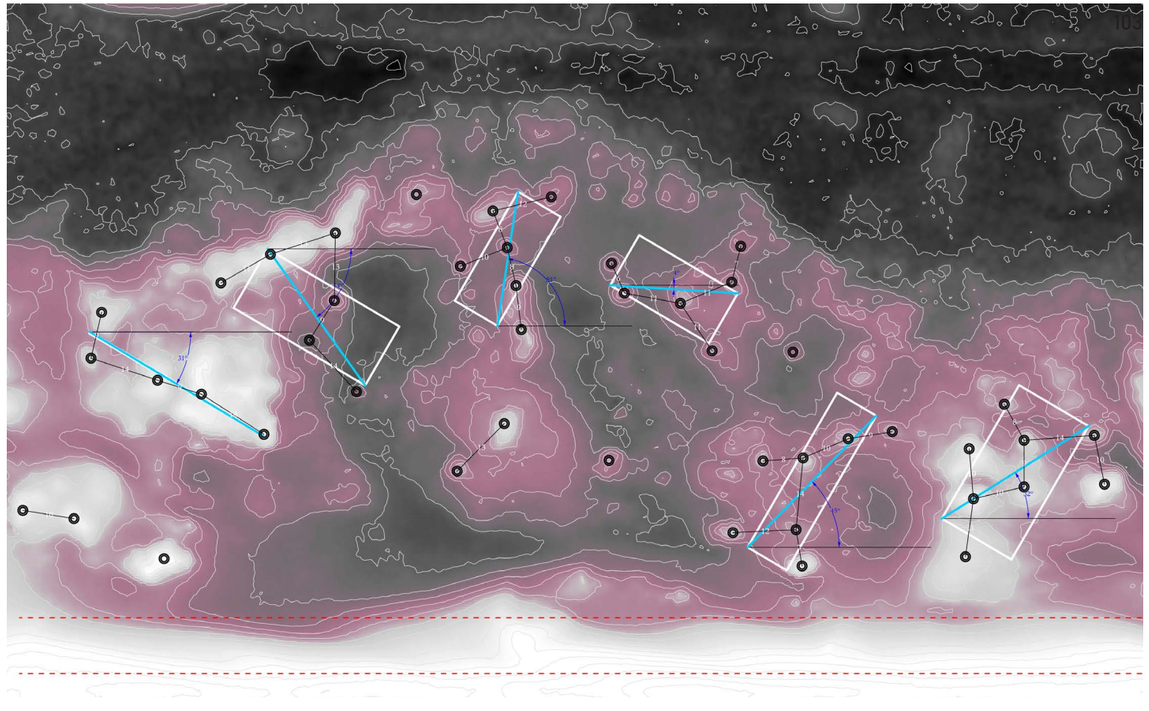


Figure 71. A detail from the dune analysis at North Ocean Beach.

2.2 Dune Fencing



Figure 72. Rendering of dune overwash zone concept, with new fencing called out in orange.. Pictured here are figures on the North Ocean Beach boardwalk, looking at a new overwash fan starting to be colonized by dune vegetation.



Conclusion

The design research here explores the role of natural infrastructure in a highly dynamic place. At Assateague Island, NPS works with natural processes to enhance human experience and habitat values. An important part of our work here was describing the innovative work Assateague Island National Seashore has been doing already, including passive dune management, marsh restoration in areas with extensive mosquito ditching, and the implementation of flexible recreation infrastructure and amenities. This documentation was part of our research process to generate new concepts and approaches suited to the place but also may serve to help disseminate information about the innovations and best practices already in place at Assateague.

Our proposed design concepts fit into the park's approach to adaptive management by choreographing cross-island sediment transport with maintenance and recreation. This choreography is critical to living with barrier islands now and to ensuring they have a healthy future. The design concepts we proposed illustrate how we can achieve these goals mechanically, by placing sediment and protecting the shoreline on Bayside, and hydraulically, through the creation of dune overwash zones for targeted sand accumulation.

On the Bayside peninsula, the design concept is a natural wood reef which would use wind-driven erosion of an existing parking area at the end of the peninsula to build a beach strand and protect tidal marsh. We also designed temporary shoreline stabilization measures using woody debris and sand cleared from the parking lot. These were implemented in 2024 and will be monitored for three to five years. On the ocean side, we propose the establishment of strategic dune overwash zones that would allow for additional overwash in the developed area of the national seashore by lowering foredune crest height while maintaining or increasing sand volume in the dune system.

These concepts were designed in alignment with the way that Assateague Island National Seashore works already, through maintenance and monitoring. Barrier islands are the most geomorphologically active landscapes in the world. In a context like this, the park's approach to management, through the enhancement of natural processes with flexible maintenance, is especially instructive. It illustrates the opportunity for new kinds of forms and practices that can meet future challenges while celebrating the history and dynamism of the shore.

References

[1] Foundation Document: Assateague Island National Seashore. US Department of the Interior, National Park Service, March 2018, https://www.nps.gov/asis/learn/management/upload/ASIS_FD_2018_508-web.pdf, p. 7.

[2]Ibid., p. 3.

[3] Schupp, Courtney A. Assateague Island National Seashore: geologic resources inventory report. US Department of the Interior, National Park Service, Natural Resource Program Center, 2013.

[4] “Pocomoke-Assateague.” Native Land. 8 Oct. 2021, native-land.ca/.

[5] Bearrs, Edwin C. General Background Study and Historical Base Map: Assateague Island National Seashore, Maryland-Virginia. Washington, Division of History, Office of Archaeology and Historic Preservation, 1968, p. 17.

[4] Bearrs, Edwin C. General background study and historical base map: Assateague Island National Seashore, Maryland-Virginia. Washington, Division of History, Office of Archaeology and Historic Preservation, 1968, p. 84.

[5] United States, National Park Service, U.S. Department of the Interior. Foundation document: Assateague Island National Seashore, Maryland and Virginia. March 2018, p. 4.

[6]

[7] “General Management Plan: Assateague Island National Seashore, MD, VA.” National Park Service, U.S. Department of the Interior, 25 Apr. 2020, www.nps.gov/asis/learn/management/general-management-plan.htm.

[8] Foundation Document: Assateague Island National Seashore. US Department of the Interior, National Park Service, March 2018, https://www.nps.gov/asis/learn/management/upload/ASIS_FD_2018_508-web.pdf, p. 4.

[9]“General Management Plan: Assateague Island National Seashore, MD, VA.” National Park Service, U.S. Department of the Interior, 25 Apr. 2020, www.nps.gov/asis/learn/management/general-management-plan.htm.

[10] Schupp, Courtney A. Assateague Island National Seashore: geologic resources inventory report. US Department of the Interior, National Park Service, Natural Resource Program Center, 2013. p. vii

[11] Morris, J. T., and K. A. Renken. “The impact of sea-level rise on saltmarsh condition and resiliency: Assateague Island National Seashore, Cape Cod National Seashore, Fire Island National Seashore, and Gateway National Recreation Area.” Natural Resource Report NPS/NCBN/NRR—2019/1974. National Park Service, Fort Collins, Colorado (2019).

[12] “Datums for 8570283, Ocean City inlet MD.” Tides & Currents, National Oceanic and Atmospheric Administration, 22 Apr. 2020, tidesandcurrents.noaa.gov/.

[13] “Grasses: Assateague Island National Seashore, MD, VA.” National Park Service, U.S. Department of the Interior, 6 Feb. 2017, www.nps.gov/asis/learn/nature/grasses.htm.

[14] United States, National Oceanic and Atmospheric Administration and National Geospatial-Intelligence Agency, Department of Commerce and Department of Defense. U.S. chart no. 1: symbols, abbreviations, and terms used on paper and electronic navigational charts. 15 April 2019.

[15] “Assateague Island Oral History Collection, 1978-2004.” Edward H. Nabb Research Center for Delmarva History and Culture, Salisbury University, Salisbury, Maryland, 2019.

[16] Reed, Tom, and Reed, Cob. “Assateague Island Oral History Collection, 1978-2004.” Edward H. Nabb Research Center for Delmarva History and Culture, Salisbury University, Salisbury, Maryland, 2019.

[17] “Crystal clear: restoring the salt marsh at Assateague Island.” National Park Service, U.S. Department of the Interior, 9 Apr. 2023, www.nps.gov/articles/restoring-the-salt-marsh-at-assateague-island.htm.

[18] Mayer, Robert W. Creation of a legacy: the story of the Civilian Conservation Corps at Bombay Hook – 1938 to 1942. n.d. npshistory.com/brochures/nwr/bombay-hook-ccc.pdf?ref=andrewsharp.net.

[19] Mayer, Robert W. Creation of a legacy: the story of the Civilian Conservation Corps at Bombay Hook – 1938 to 1942. n.d. npshistory.com/brochures/nwr/bombay-hook-ccc.pdf?ref=andrewsharp.net.

[20] “Crystal clear: restoring the salt marsh at Assateague Island.” National Park Service, U.S. Department of the Interior, 9 Apr. 2023, www.nps.gov/articles/restoring-the-salt-marsh-at-assateague-island.htm.

[21] National Park Service. The Impact of Sea-level Rise on Saltmarsh Condition and Resiliency: Assateague Island National Seashore, Cape Cod National Seashore, Fire Island National Seashore, and Gateway National Recreation Area. Natural Resource Report NPS/NCBN/NRR—2019/1974. U.S. Department of the Interior, 2019.

[22] U.S. Coast and Geodetic Survey. Assateague and Chincoteague (T8128). 1942.

[23] “U.S. Coastguard North Beach Photograph Scrapbook, 1915, 1919.” Edward H. Nabb Research Center for Delmarva History and Culture, Salisbury University, Salisbury, Maryland, 2014.

[24] “Life-Saving Station Historical Marker near Berlin in Worcester County, Maryland.”

The Historical Marker Database, 18 Sept. 2022, www.hmdb.org/m.asp?m=8143.

[25] Aero Service Corp. & Maps, Inc. . “Aerial Photography – Ocean City (1952-1964).” Johns Hopkins Libraries, Maryland State Roads Commission, 2011, jscholarship.library.jhu.edu/items/7771e421-ff74-459a-a30a-ae7505c3b438.

[26] “Life of the Dunes.” Assateague Island National Seashore. National Park Service. N.d. asis.stqry.app/story/229741.

[27] Mackintosh, Barry. “The becoming of the seashore.” Assateague Island National Seashore: an administrative history. History Division, National Park Service, U.S. Department of the Interior, 1982, npshistory.com/publications/asis/adhi/chap1.htm.

[28] Kotlowski, Dean. “The last lonely shore: nature, man, and the making of Assateague Island National Seashore.” Maryland Historical Magazine. 2004.

[29] “Natural parking lots at Assateague Island National Seashore.” National Park Service, U.S. Department of the Interior, 19 Jan. 2017, www.nps.gov/articles/natural-parking-lots-at-assateague-island-national-seashore.htm

[30 - 32] Mackintosh, Barry. “The becoming of the seashore.” Assateague Island National Seashore: an administrative history. History Division, National Park Service, U.S. Department of the Interior, 1982, npshistory.com/publications/asis/adhi/chap1.htm.

[33] Diamont, Rolf, Carr, Ethan, and Meier, Lauren. United States, Organization of American Historians, National Park Service, U.S. Department of the Interior. The Olmsteds and the National Park Service: historic resource study. 2020, p. 173.

[34 - 35] Schupp, Courtney A., et al. “Restoration of overwash processes creates piping plover (Charadrius melodus) habitat on a barrier island (Assateague Island, Maryland).” Estuarine, Coastal and Shelf Science 116 (2013): 11-20.

[36] Mackintosh, Barry. “For public outdoor recreation use and enjoyment.” Assateague Island National Seashore: an administrative history. History Division, National Park Service, U.S. Department of the Interior, 1982, www.nps.gov/parkhistory/online_books/asis/adhi8.htm.

[37] Rush, Don. “Two parking lots move inland at Assateague Island National Seashore.” Delmarva Public Media, 9 Sept. 2013, www.delmarvapublicmedia.org/local-news/2013-09-09/two-parking-lots-move-inland-at-assateague-island-national-seashore.

[38] “Moveable restrooms at Assateague Island National Seashore.” National Park Service, U.S. Department of the Interior, 19 Jan. 2017, https://www.nps.gov/articles/movable-restrooms-at-assateague-island-national-seashore.htm.

[39] Phillips, Robert and Hall, Calvin. “Assateague Island Oral History Collection, 1978-2004.” Edward H. Nabb Research Center for Delmarva History and Culture, Salisbury University, Salisbury, Maryland, 2019.

[40] Soper, Shawn. “Safety reminders issued after another military ordnance found on Assateague.” Maryland Coastal Dispatch, 29 July 2022, mdcoastdispatch.com/2022/07/29/safety-reminders-issued-after-another-military-ordnance-found-on-assateague/.

[41] Eichmanns, Christiane, et al. “Sand trapping fences as a nature-based solution for coastal protection: An international review with a focus on installations in Germany.” Environments 8.12 (2021): 135.

[42 - 43] Preserving Coastal Parklands Site Visit. Conversation with Bill Hulslander, Chief of Resource Mgt, and Eric Sherry, Chief of Maintenance. April 27, 2023.

[44 -45] Itzkin, M., Moore, L. J., Ruggiero, P., & Hacker, S. D. (2020). The effect of sand fencing on the morphology of natural dune systems. Geomorphology, 352, 106995.

[46] Jones, Don D., and William H. Friday. “Wind and Snow Control around the Farm.” Purdue University Cooperative Extension Service, Purdue University, www.extension.purdue.edu/extmedia/ncr/ncr-191.html. Accessed 1 Sept. 2023.

[47] “Cape Hatteras National Seashore Sediment Management Framework” Cape Hatteras National Seashore North Carolina, National Park Service, US Department of the Interior, Mar. 2021, npshistory.com/publications/caha/sediment-mgt-eis-2021.pdf.

[48] Itzkin, M., Moore, L. J., Ruggiero, P., & Hacker, S. D. (2020). The effect of sand fencing on the morphology of natural dune systems. Geomorphology, 352, 106995.

[49] Miller, Deborah L., Mack Thetford, and Lisa Yager. “Evaluation of sand fence and vegetation for dune building following overwash by Hurricane Opal on Santa Rosa Island, Florida.” Journal of Coastal Research (2001): 936-948.

[50] Mendelssohn, Irving A., et al. “Experimental dune building and vegetative stabilization in a sand-deficient barrier island setting on the Louisiana coast, USA.” Journal of Coastal Research (1991): 137-149.

[51] Reducing Vulnerability in Five North Carolina Coastal Communities: A Model Approach for Identifying, Mapping, and Mitigating Coastal Hazards, Duke University Program for the Study of Developed Shorelines. Prepared for North Carolina Division of Emergency Management , Aug. 2001, www.wcu.edu/webfiles/pdfs/psds_reducing_1991.pdf.

[52]

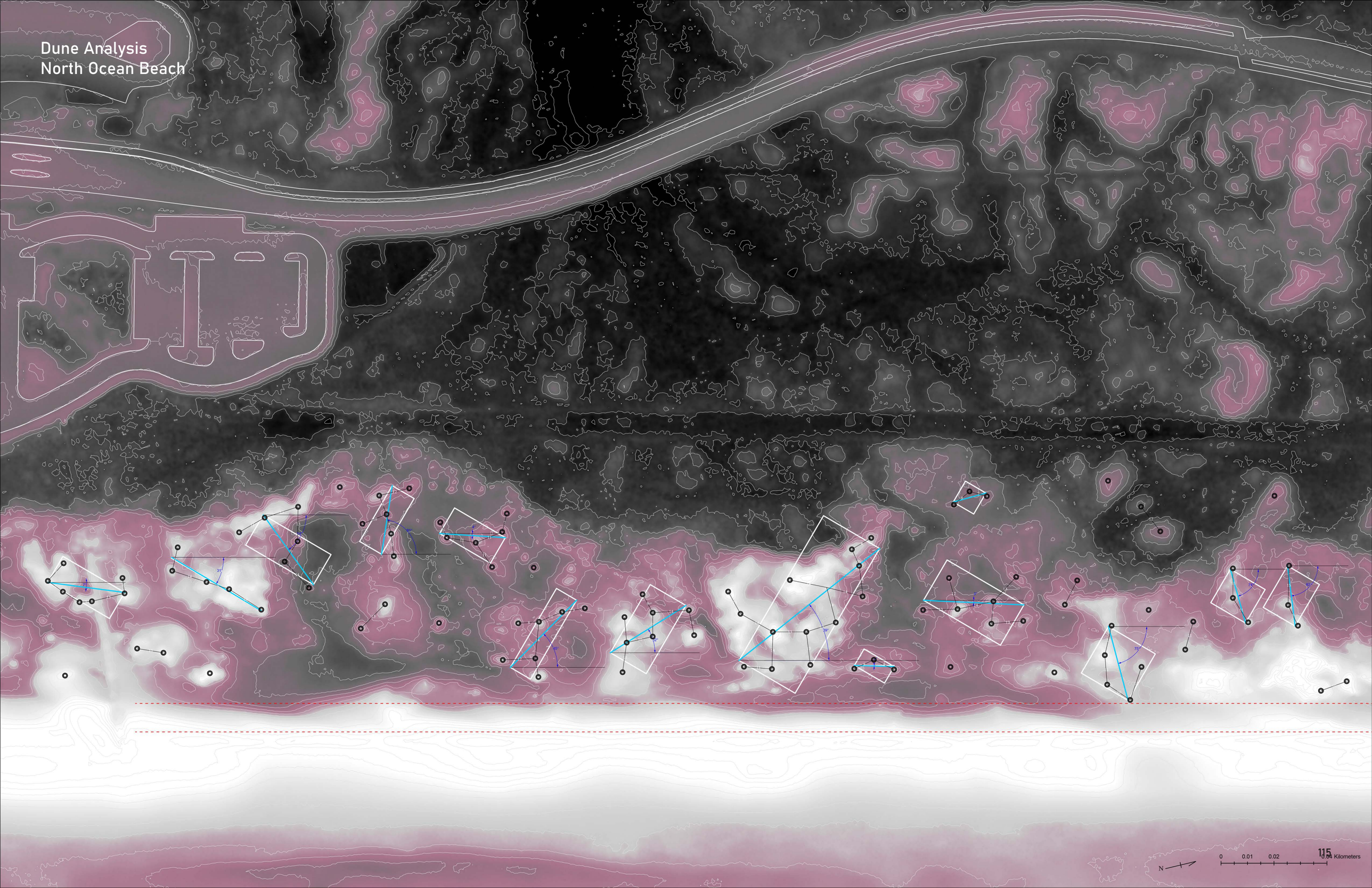
[53 -59] Schupp, Courtney A., et al. “Restoration of overwash processes creates piping plover (Charadrius melodus) habitat on a barrier island (Assateague Island, Maryland).” Estuarine, Coastal and Shelf Science 116 (2013): 11-20.

[60] Munger, Sophie, and Nicholas C. Kraus. “Frequency of extreme storms based on beach erosion at Northern Assateague Island, Maryland.” Shore & beach 78.2 (2010): 3-11.

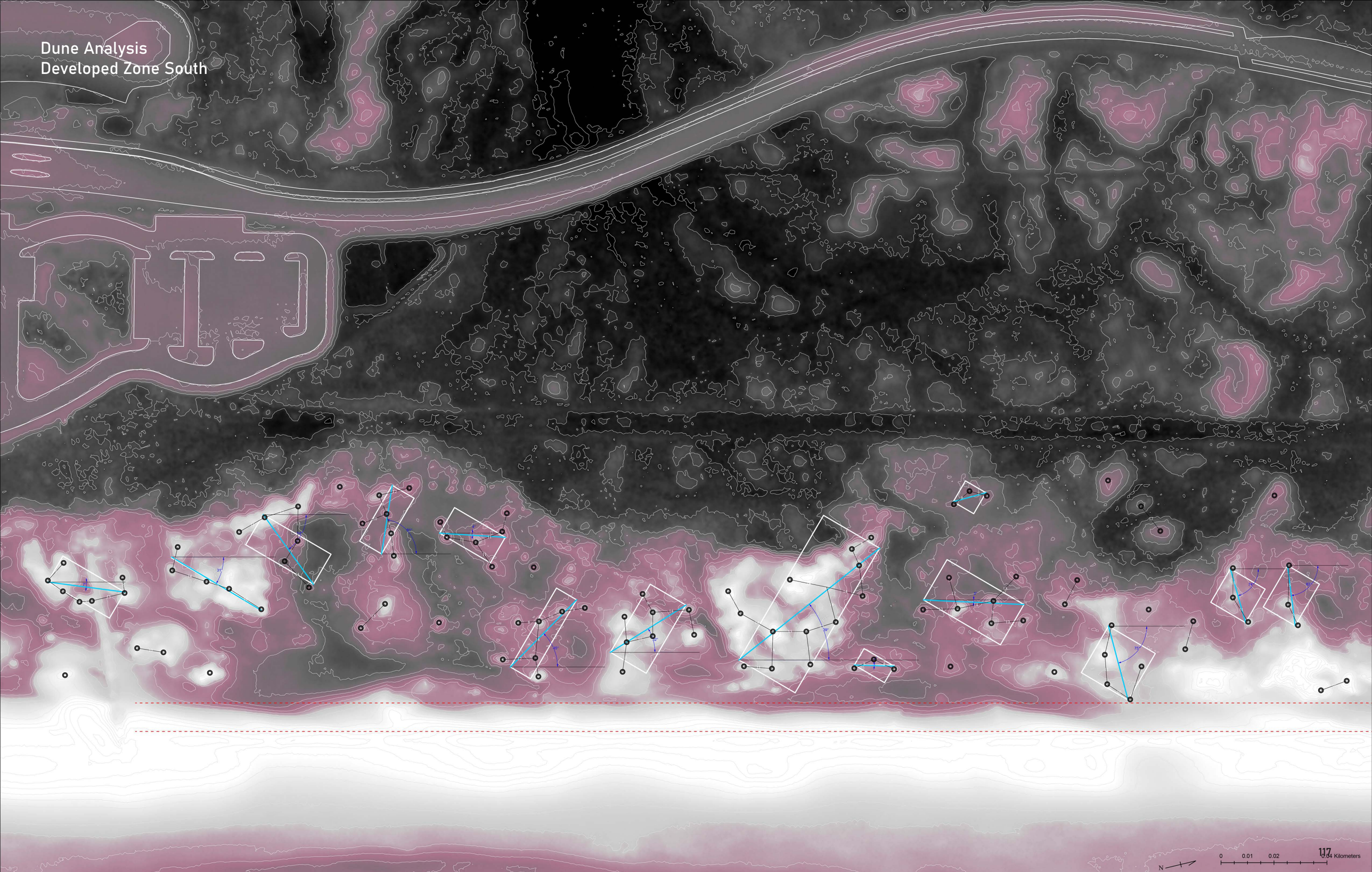
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Appendix

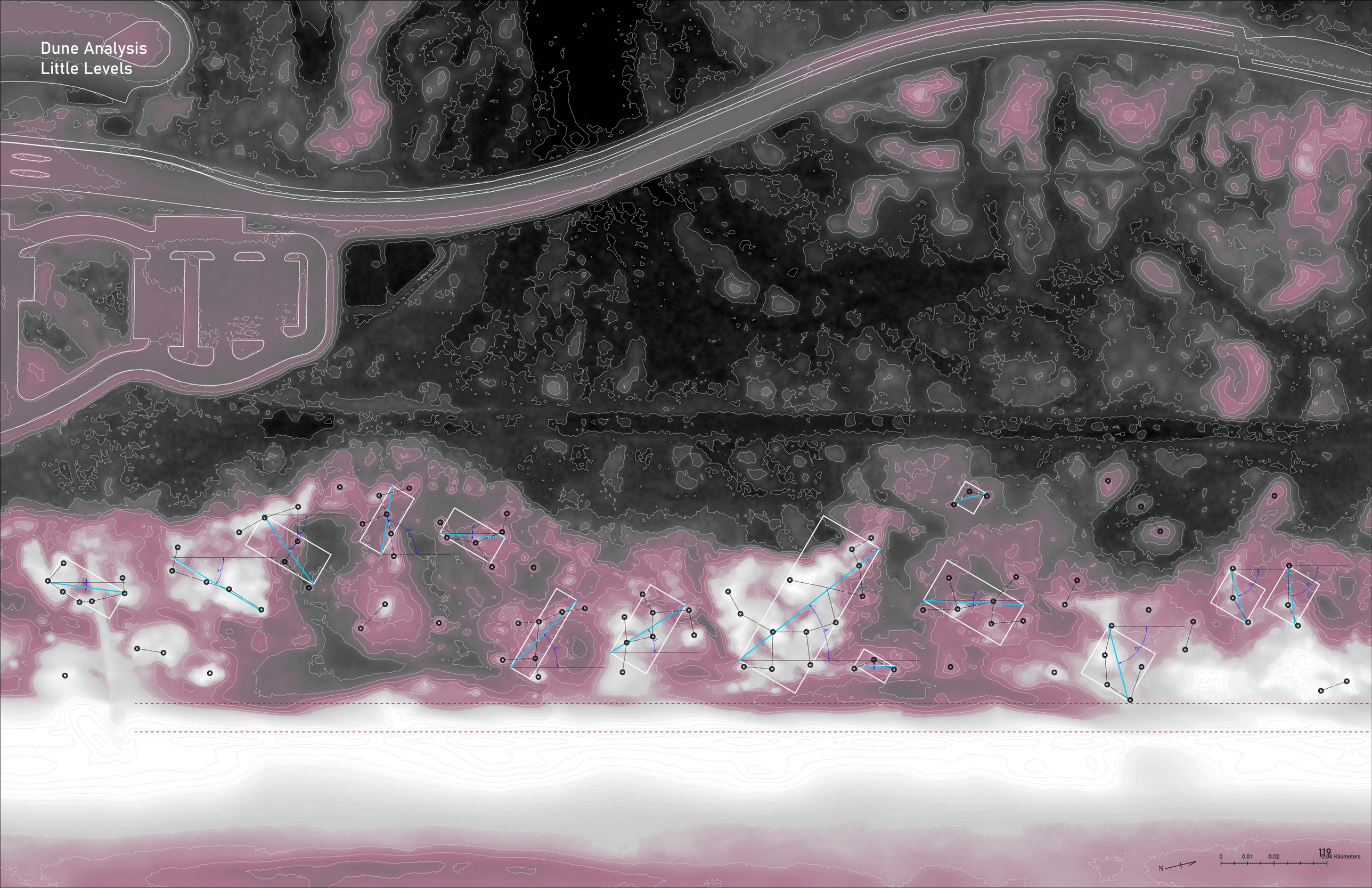
Dune Analysis
North Ocean Beach



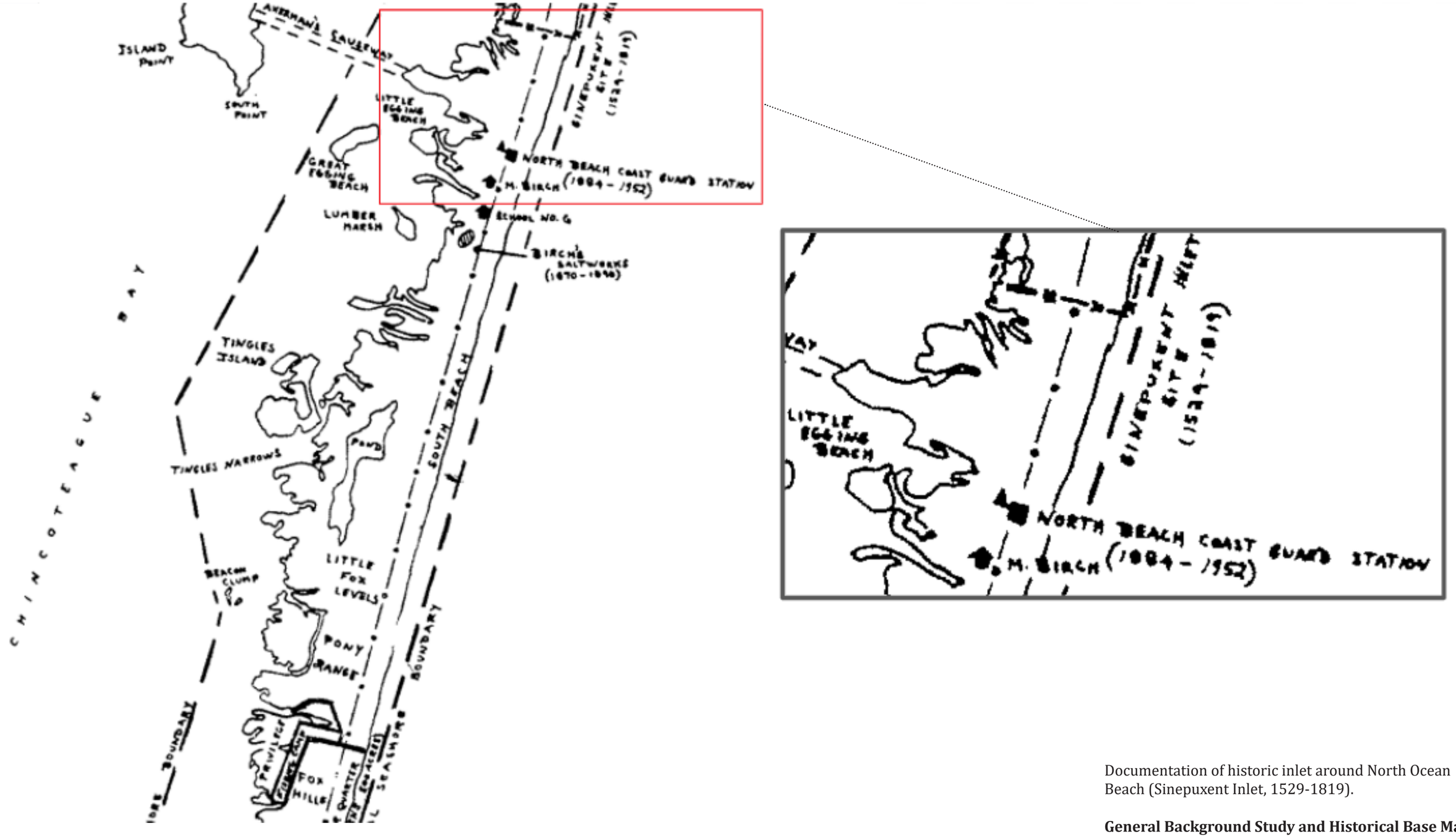
Dune Analysis
Developed Zone South



Dune Analysis
Little Levels



2.2 Dune Fencing



Documentation of historic inlet around North Ocean Beach (Sinepuxent Inlet, 1529-1819).

General Background Study and Historical Base Map
Edwin C Bearss, 1968. Page 154.
http://npshistory.com/publications/asis/gbs-hbm.pdf

Memorandum – CMSWave Modeling

PROJECT SUMMARY

The University of Virginia (UVA), in partnership with the U.S. Army Corps of Engineers (USACE) Engineering with Nature (EWN) program, the National Park Service, The Nature Conservancy (TNC), and ETZ Strategies, is undertaking a three-year site-based research project to develop and assess Nature-Based Solutions (NBS). The team is reviewing NBS opportunities for three coastal national parks in the Chesapeake Bay region under funding support from the EWN program, including Assateague Island National Seashore (the seashore).

The UVA team has developed a preliminary NBS design to address flood control and landscape management needs at the seashore's Bayside Camping Area (**Figure 1**). This design consists of a wooden reef breakwater structure (reef) located to the west of the Bayside Camping Area near the Bayside Rental Stand and parking area. The parking area has been experiencing erosion. As a result, the seashore has had to reduce the number of parking spots available over the years. The reef will be constructed with woody debris. It is anticipated that this debris will be from tree removal set to take place in and around the camping areas.

As part of the project team, EA Engineering, Science, and Technology, Inc., PBC (EA) is assisting in analyzing the proposed reef design at this site. It is EA's understanding that this project seeks to address research questions related to how to implement natural infrastructure to provide benefits in these parks and in other coastal parklands within the Mid-Atlantic region. In support of this project, EA has developed a numerical model using the two-dimensional wave spectral transformation model, CMSWave, within the Surface-water Modeling System (SMS) Version 12.2 to evaluate the proposed reef's impact to wave conditions in the vicinity of the structure.

Figure 1. Bayside Campground Site Map



Model Summary and EA Feedback

- EA modeled three event conditions:
  - typical conditions
  - 1-year storm
  - 10-year storm
- The events were generated by updating water levels and modeling wind-generated waves from a single annually characteristic wind direction.
- Each event condition was run under existing conditions (without a reef) and with the reef design provided by UVA.
- The model has the following limitations:
  - The selected wind direction is the dominant annual wind direction but not representative of seasonal variation in wind direction or event-specific wind direction.
  - The model does not include sediment analysis and cannot show how the reef may impact morphology or sediment transport.
  - The model was validated with empirical literature data and should only be used for a 10% design.
- The model results give wave height and direction and indicate the reef's effectiveness:
  - Typical conditions—50-60% reduction in wave height
  - 1-year storm—50-60% reduction in wave height
  - 10-year storm—10-50% reduction in wave height
- EA recommends consideration of alternative reef orientations. Investigation of the seasonal wind roses indicate that although the primary annual wind direction comes from the southwest, event conditions may come from the northwest, which the UVA reef design orientation would not serve to protect. An alternative orientation would place the reef parallel to the shoreline, shifting southwest, in line with the tip of the peninsula. **though these conclusions seem to run counter to the proposed reef, see pages 42-43 for discussion*

Model Domain

Two grids were established to evaluate the wave conditions at the site. The first grid had a resolution of 10 meters (m) and was used to generate wind driven waves. Wave data was extracted from this low-resolution model and input into a model with a 1 m resolution, such that the reef could be appropriately analyzed. The larger domain is shown below in **Figure 2** and the smaller domain is shown in **Figure 3**.

Figure 2. Model Domain (10 m Grid Size)

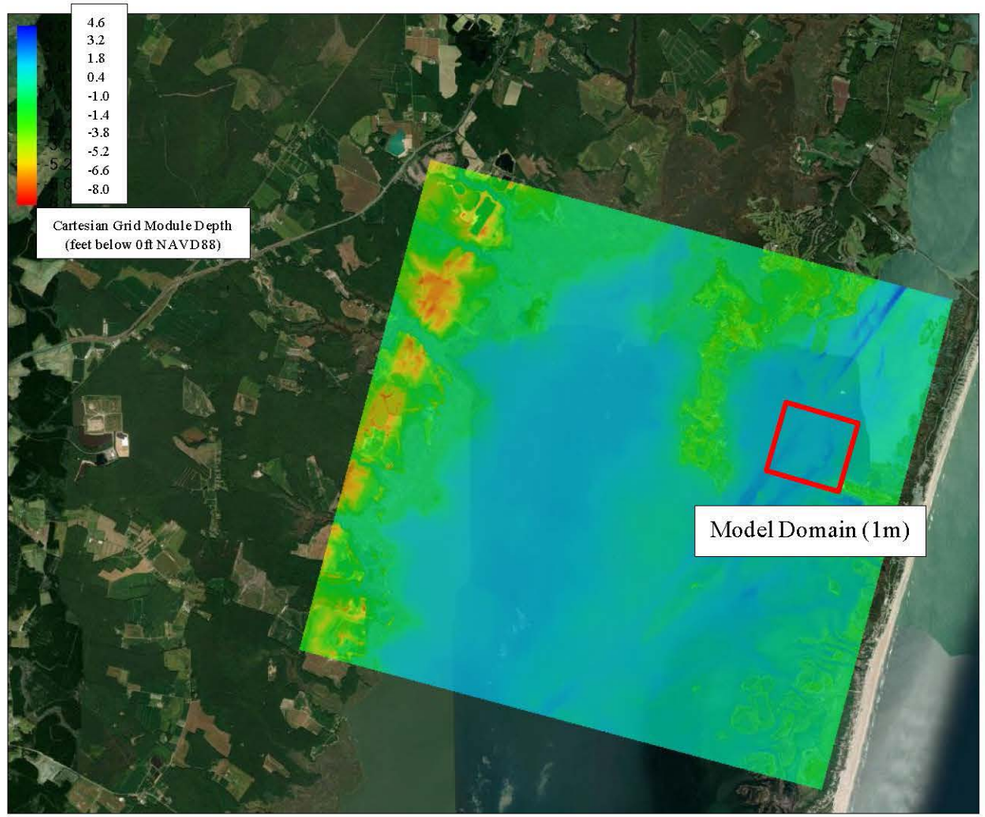
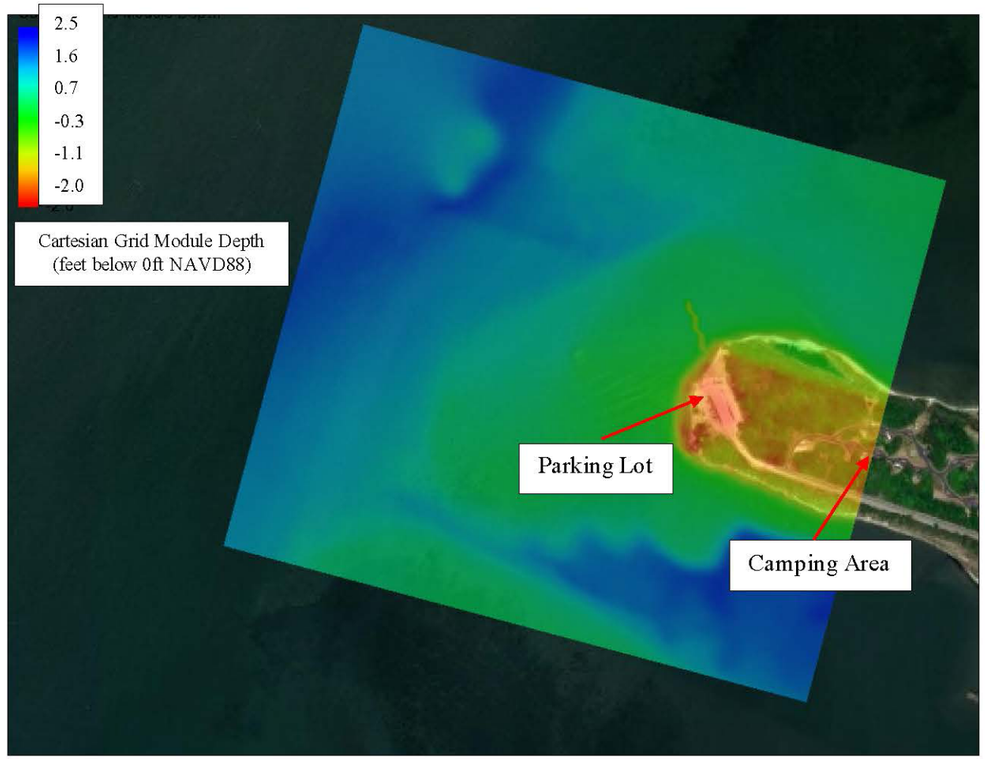


Figure 3. Model Domain (1 m Grid Size)



Existing Conditions

Bathymetry

The model was generated with bathymetry data from the Continuously Updated Digital Elevation Model (CUDEM) - 1/9 Arc-Second Resolution Bathymetric-Topographic Tiles. This data is sufficient for the preliminary analysis conducted herein; however, no quantitative vertical accuracy analysis has been performed (Cooperative Institute for Research in Environmental Sciences [CIRES] 2014). As such, it is recommended that site specific data be collected if the design is to be advanced.

Wind and Water Level Conditions

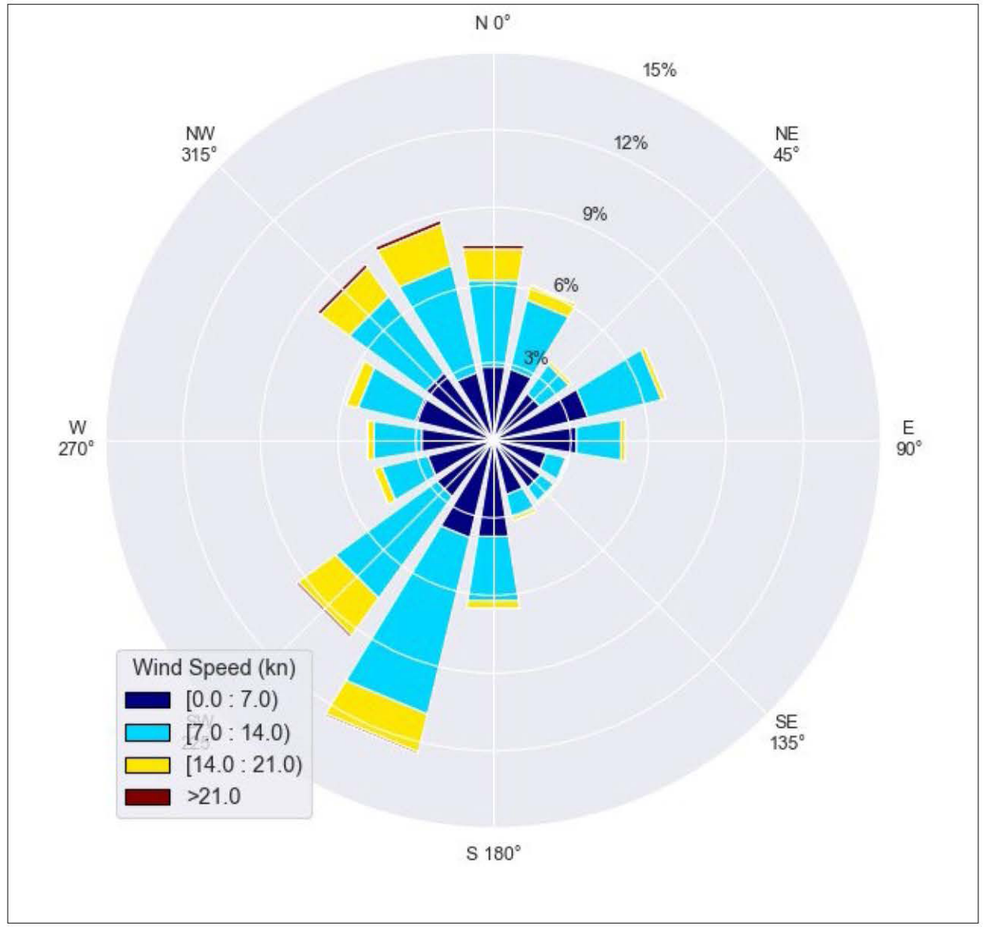
The model was run under three different condition states: typical conditions, a 1-year storm event, and a 10-year storm event. For each condition state, wind and water levels were inputted in the large, low-resolution grid, and the same wind and water levels, along with the model-generated wave climate, were inputted in the high-resolution grid to simulate event conditions that would impact the reef. Typical condition wind was estimated from a wind rose generated from the National Oceanic and Atmospheric Administration's (NOAA) Ocean City Inlet, Maryland station (8570283) (NOAA 2023) from 2008-2023,

showing dominant winds coming from the south-southwest at windspeeds ranging from 2-20+ miles per hour (mph) (**Figure 4**). The wind was modeled to start at a light breeze (5 mph) and steadily increase to a strong breeze (25 mph) over 24 hours. This was done for two reasons:

1. To investigate the typical wind-driven wave conditions at the site.
2. By gradually increasing the winds over the 24-hour period, one can check that the model is functioning as expected. As the winds increase, wave heights should increase as well.

Figure 4 shows that the highest windspeeds come from the northeast during nor'easter events in the fall in winter. However, the short fetch between the shore and the bayside peninsula limits wind-wave generation from that direction, so the south-southwest was selected as the wind direction for all event conditions.

Figure 4. Ocean City Inlet, MD (Station No. 8570283) 2008-2023 Wind Rose



Typical water levels were taken from hourly tidal water levels for a characteristic day from the Ocean City Inlet NOAA Station with a tidal range of -0.2-0.4 m North American Vertical Datum of 1988 (NAVD88).

For the 1-year and 10-year events, wind data was taken from the American Society of Civil Engineers (ASCE) 7 Hazards Report (ASCE 2023). The highest astronomical tide (HAT) from the Ocean City Inlet NOAA Station was used for the 1-year event Stillwater level (SWL), and the 10-year event SWL was taken from the FEMA Flood Insurance Study for Worcester County, MD (2015) for coordinates N 38.2 W -75.2, corresponding to a 10-year Stillwater elevation of 0.98 m NAVD88. With the wind and SWL values, characteristic tide and surge elevations were generated for synthetic storm events using the Larson, Kraus, and Byrnes (1990) formulation outlined in Coastal Engineering Research Center Technical Report (TR-CERC-89-9). The sum of the generated tidal water levels, predicted from tidal datums from the Ocean City Inlet NOAA station, and predicted storm surge values gave the 1-year and 10-year event water levels. The typical conditions were modeled over 24 hours with hour-long time steps, while the 1-year and 10-year events were modeled over 56 hours with hour-long time steps. For the 1- and 10-year events, the peak surge occurred at high tide, showing the worst possible event condition. The wind, water level, tidal range, and event duration inputs for each condition state are summarized in **Table 1**.

Table 1. Model Condition State Inputs

Condition State	Wind Speed meters/second (m/s)	Wind Direction	Water Level	Tidal Range (NAVD88)	Model Duration
Typical Conditions	2.2 – 11.1 m/s (5 – 25 mph)	South-southwest (210° meteorologic)	-0.2 – 0.4 m NAVD88	-0.2 – 0.4 m	24 hours
1-Year Event	27 m/s (60 mph)	South-southwest (210° meteorologic)	-0.5 – 0.8 m NAVD88	-1.6 – 0.5 m	56 hours
10-Year Event	35 m/s (78 mph)	South-southwest (210° meteorologic)	-0.5 – 1.8 m NAVD88	-1.6 – 0.5 m	56 hours

Proposed Conditions

UVA provided EA with the layout and elevation of the proposed reef. The structure starts 25 m offshore, in line with the peninsula's northwest tip, at a 50-degree angle with the peninsula to the north of it, as seen in **Figure 5a**. A digital elevation model (DEM) was incorporated into the model (**Figure 5c)** by assigning 33 cells an elevation of 0.5 m NAVD88, spanning water depths 0-0.64 m NAVD88, represented by the color gradient shown in **Figure 5c**. The reef cells are shown in **Figure 5b** as brown points.

Figure 5. Modeled Reef



Results

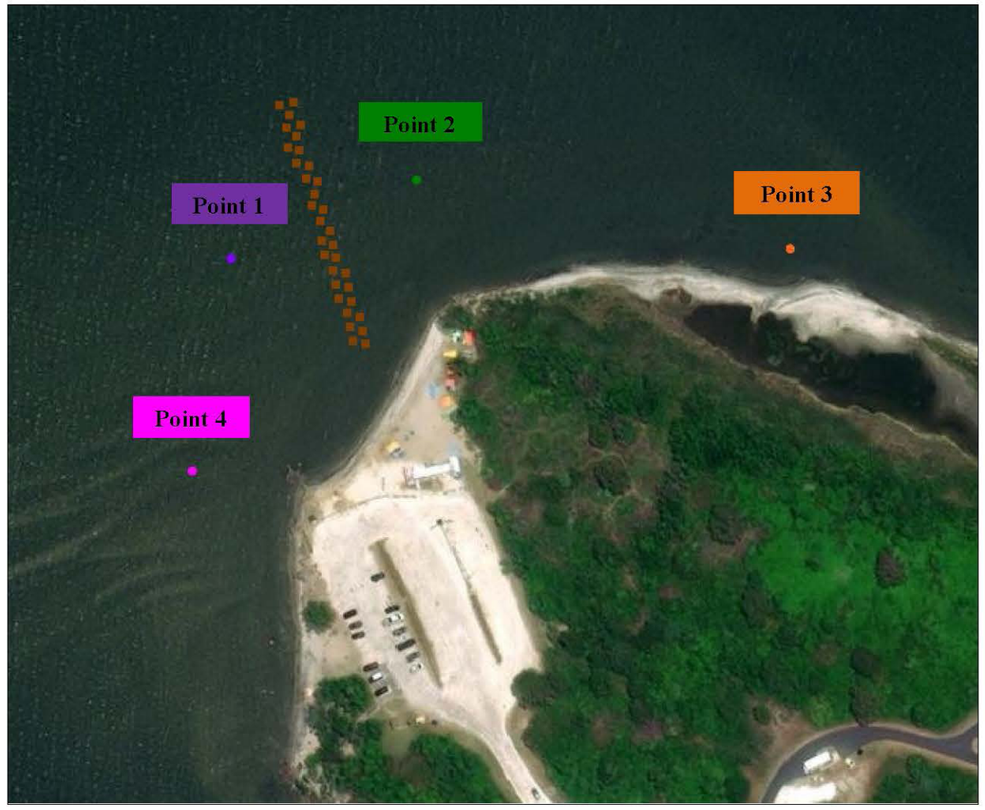
Observation Points

Four observation points were incorporated into the model to record wave heights at key areas of interest:

- Point 1 (red): Reef-Seaward
- Point 2 (green): Reef-Landward
- Point 3 (blue): Sand Spit
- Point 4 (pink): Parking Lot Tip

The location of these points is shown in **Figure 6**.

Figure 6. Observation Points

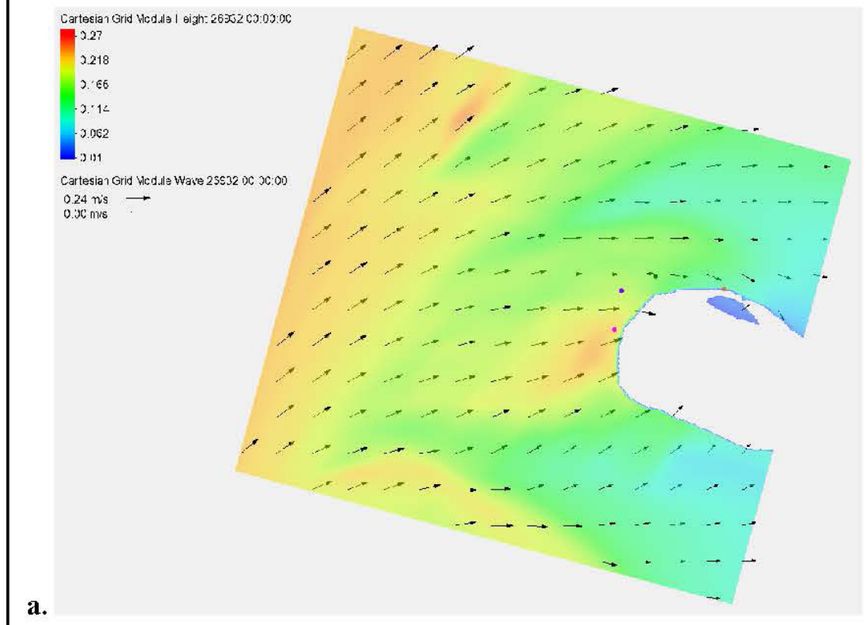


Figures 7-9 give the model results for the typical, 1-year, and 10-year events:

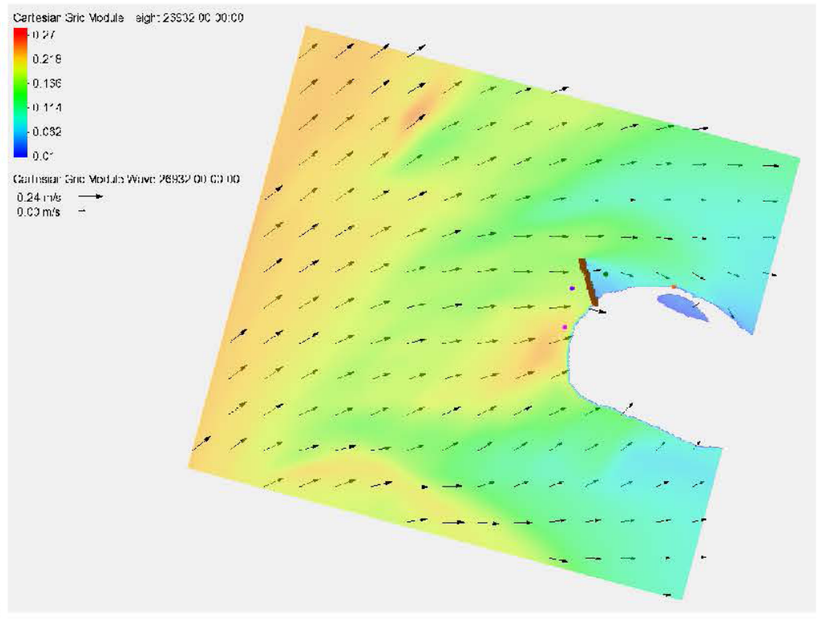
- **Figures 7-9a** show the modeled existing wave height time series at observation points 1 and 2.
- **Figures 7-9b** show the modeled proposed wave height time series at observation points 1 and 2.
- **Figures 7-9c** show the time series maximum wave heights for modeled existing conditions.
- **Figures 7-9d** show the time series maximum wave heights for modeled proposed conditions.

The wave heights at observation points 3 and 4 had minimal to no difference between the existing and proposed case, so they were not shown in the following figures. **Table 2** shows the maximum wave height reduction between the existing and proposed conditions for each of the observation points.

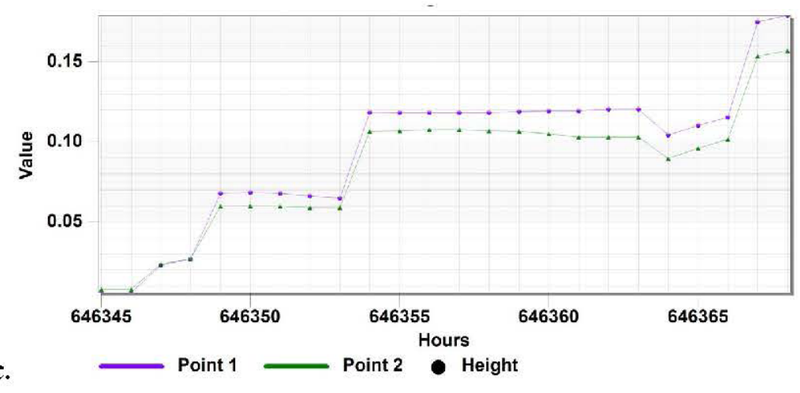
Figure 7. Existing (left) vs. Proposed Wave Conditions (right) during typical conditions. Top panel panels show wave height by color in meters and direction with arrows; bottom panels show wave heights observed at observation points 1 and 2 (shown in Figure 6).



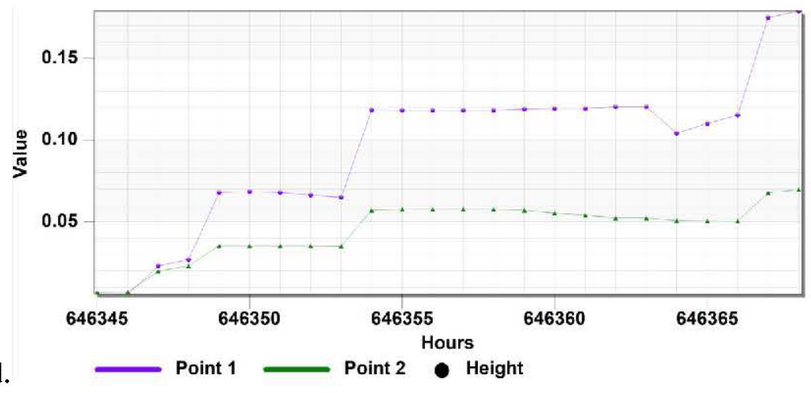
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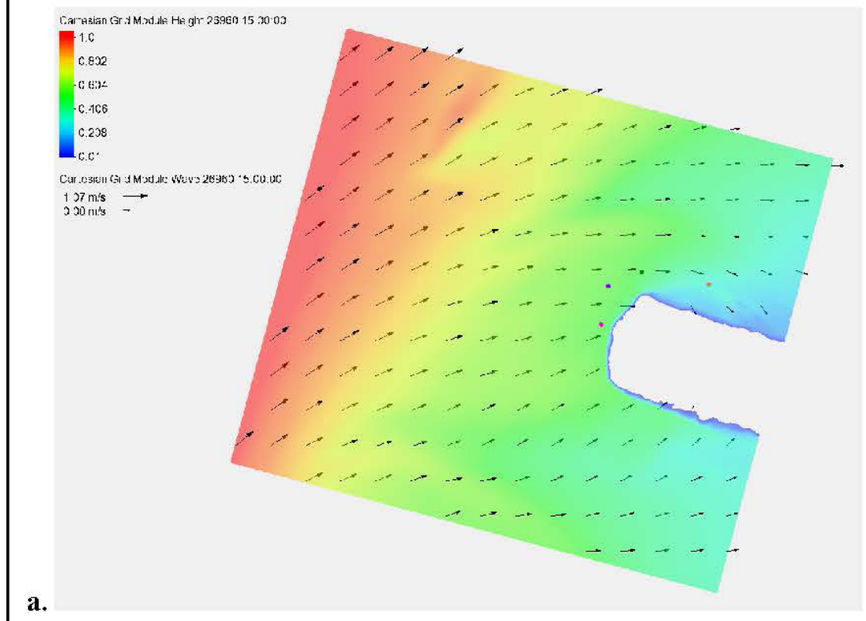


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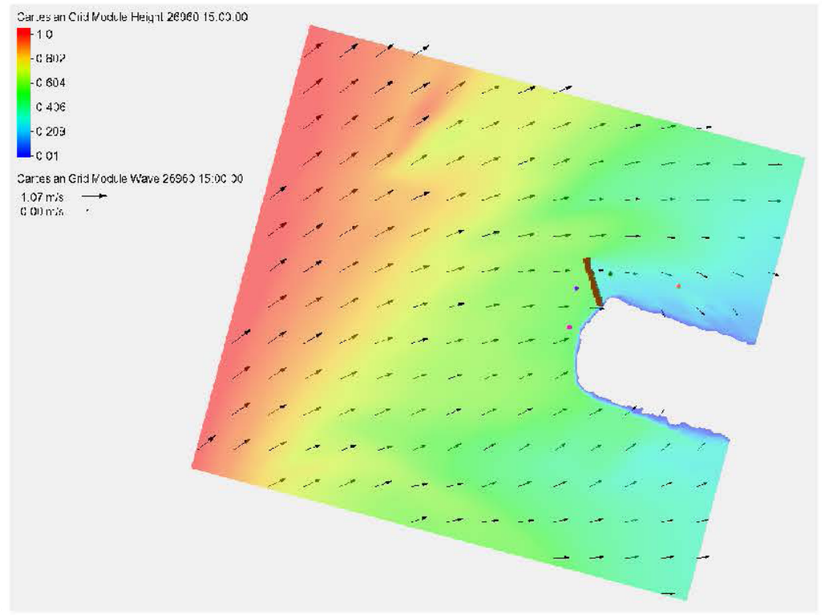


d.

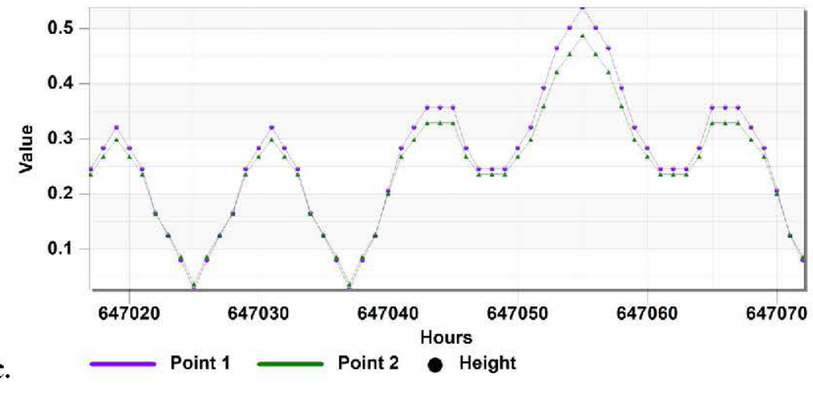
Figure 8. Existing (left) vs. Proposed Wave Conditions (right) during a 1-year storm. Top panel panels show wave height by color in meters and direction with arrows; bottom panels show wave heights observed at observation points 1 and 2 (shown in Figure 6).



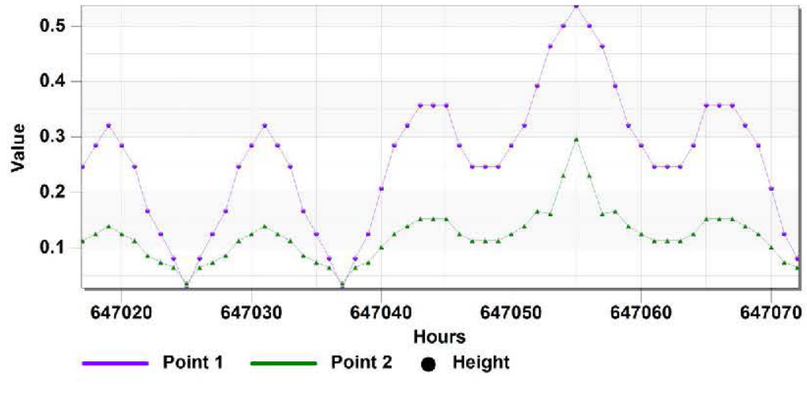
a.



b.



c.



d.

Figure 9. Existing (left) vs. Proposed Wave Conditions (right) during a 10-year storm. Top panel panels show wave height by color in meters and direction with arrows; bottom panels show wave heights observed at observation points 1 and 2 (shown in Figure 6).

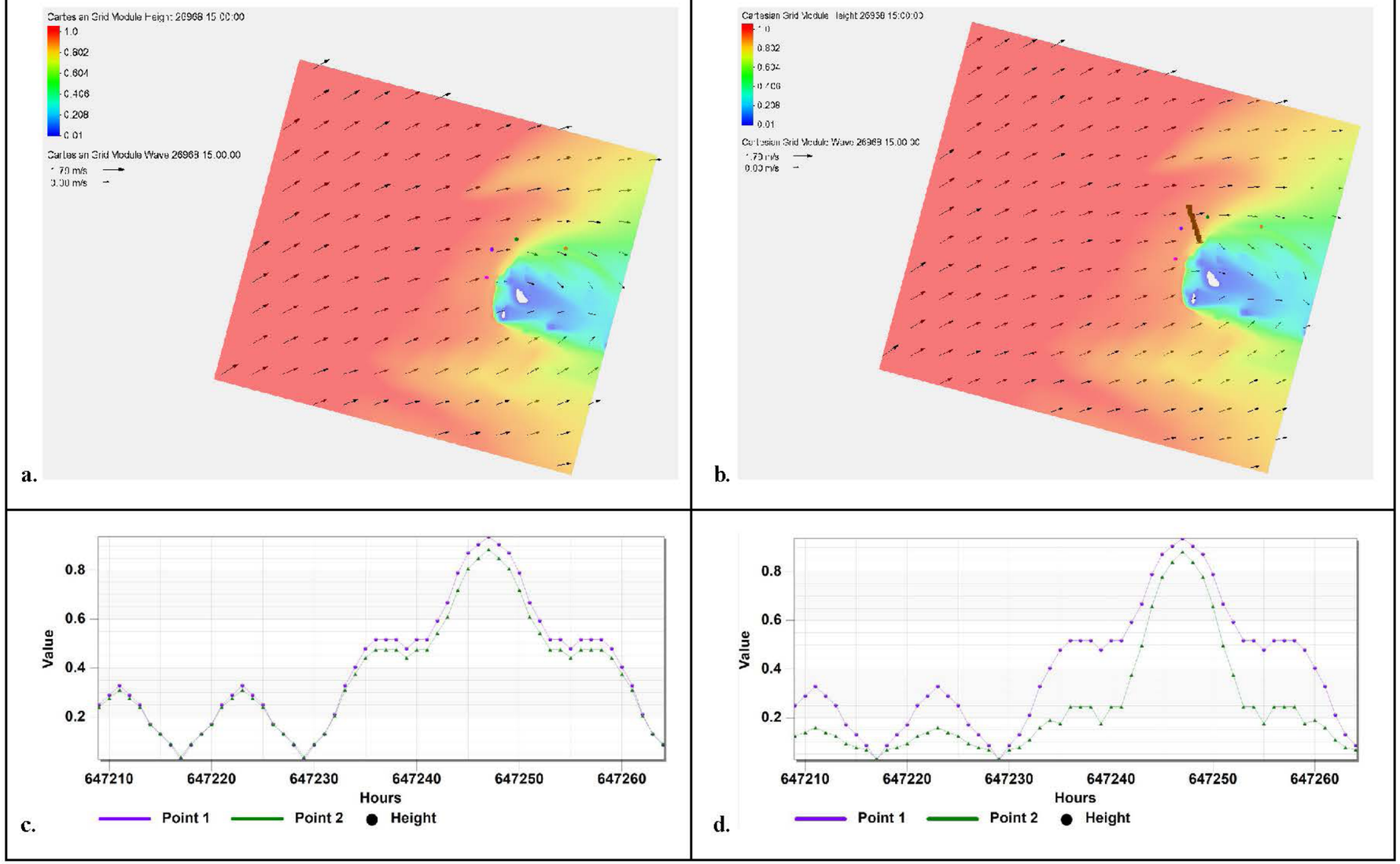


Table 2. Maximum Wave Height Reduction of Proposed vs. Existing Conditions

Condition State	Observation Point 1	Observation Point 2	Observation Point 3	Observation Point 4
Typical Conditions	0%	50%	10%	0%
1-Year Event	0%	50%	20%	0%
10-Year Event	0%	50%	10%	0%

Figures 7-9 indicate the proposed conditions reduce wave heights in the lee of the structure. **Table 2** shows wave height reductions of up to 50% occur at observation point 2, directly behind the reef, while at observation point 3, in the sand spit, wave heights reduced 10-20%. No wave height reductions were observed at observation point 4, at the tip of the peninsula nor on the seaward side of the reef.

To validate the model results, the reef was modeled in an iterative process, comparing the transmission coefficient (K_T) of the modeled reef to those results with literature data. The transmission coefficient is the ratio of the transmitted wave height over the incident wave height. Taking results at observation point 1 as the incident wave height and point 2 as the transmitted, K_T values can be calculated using the results displayed in **Figures 7-9d** and are summarized below in **Table 3**. **Table 3** also presents the corresponding maximum water depths, calculated from the sum of the maximum water level elevation and the peak of the reef at 0.6m NAVD88.

Table 3. Proposed Model Transmission Coefficients

	Typical Conditions	1-Year Event	10-Year Event
Transmission Coefficient	0.4 – 0.5	0.4 – 0.5	0.5 – 0.9
Maximum Depth (m)	1.0	1.4	2.4

The K_T values for typical conditions align well with Boumans et al. (1997) study of a large-scale Christmas tree project in Louisiana, which found an average transmitted wave induced pressure (directly related to wave height) of 0.5 at similar water depths to those around the proposed reef. Maynord et al. (2006) found slightly higher K_T values, ranging 0.63-0.93 (0.63 for non-overtopping conditions) for a branch box breakwater. The water level for this experiment was deeper and the K_T values align more closely with the modeled 10-year event, suggesting at deeper water levels, similar structures have a lower capacity to reduce incident wave heights, especially if overtopping occurs. It can be seen in **Figure 9d**, that the 10-year event maximum water level is the point when the reef stops reducing wave heights. This is likely because the water elevation at the peak of the 10-year event is high enough above the reef that it no longer influences the waves.

There is also a relationship between wave height and sedimentation. Wave energy is proportional to the wave height squared, so as wave height decreases, so does wave energy at a larger factor (Seenipandi et al. 2021). Wave energy is responsible for sediment transport, driving erosion and sedimentation processes. With reduced wave energy, there is reduced transport. Due to the lack of site-specific data, these results are limited as they cannot be calibrated with actual site conditions. As such, the results presented should only be used for preliminary (10% level) conceptual design.

Conclusions

These preliminary results indicate that the reef will reduce up to 60% incident wave height during typical conditions and minor storm events, but the effectiveness of the reef decreases as water levels rise during larger events with higher storm surge. Detached structures, like the proposed reef, protect the shore by dissipating wave energy, which generally results in sediment accretion in the lee of the structure.

It is anticipated that this will result in a reduction in sediment transport in the lee of the reef. The area of reduced wave heights is limited to the lee side of the reef. In its current position, the reef does not significantly reduce wave heights at the parking area or sand spit. Realignment of the structure may better protect these areas. It is noted that these model results are based on limited site-specific data and should only be used for 10% level conceptual design. This analysis only considered waves generated from a storm with south-southwest wind. The selected wind direction is the dominant annual wind direction (**Figure 4**) but not representative of seasonal variation in wind direction or strength/speed. Additional analysis should be completed to evaluate storms with northeast winds that are common in fall and winter. However, it is anticipated that the limited fetch from these directions will limit wave heights.

**though these conclusions seem to run counter to the proposed reef, see pages 42-43 for discussion*

References

American Society of Civil Engineers (ASCE). 2023. *ASCE 7 Hazards Report.* Available [online]: https://asce7hazardtool.online/. Accessed 11 October 2023.

Boumans, R.M., Day, J.W., Kemp, G.P. and Kilgen, K. 1997. The effect of intertidal sediment fences on wetland surface elevation, wave energy, and vegetation establishment in two Louisiana coastal marshes. *Ecological Engineering* 9, 37-50.

Cooperative Institute for Research in Environmental Sciences (CIRES). 2014. Continuously Updated Digital Elevation Model (CUDEM) - 1/9 Arc-Second Resolution Bathymetric-Topographic Tiles. [Maryland]. NOAA National Centers for Environmental Information. University of Colorado, Boulder. Available [online]: https://doi.org/10.25921/ds9v-ky35. Accessed 20 September 2023.

Larson, M., Kraus, N,.C., and Byrnes, M.R. 1990. *SBEACH: Numerical Model for Simulating Storm-Induced Beach Change.* Report 2, Numerical Formulation and Model Tests. Vicksburg, Mississippi: U.S. Army Engineer Research and Development Center (ERDC) (Technical Report, CERC-89-9 rept.2).

Maynord, S.T., Winkler, M.F. and Demco, D.E. 2006. *Branchbox breakwater design at Pickleweed Trail, Martinez, CA, Section 227 Demonstration Project.* ERDC/CHL CHETN-VI-42, U.S. Army Engineer Research and Development Center, Vicksburg, MS. Available [online]: https://erdc-library.erdc.dren.mil/jspui/bitstream/11681/2020/1/CHL-CHETN-VI-42.pdf. Accessed 19 January 2023

National Oceanic and Atmospheric Administration (NOAA). 2023. Ocean City Inlet, MD - Station ID: 8570283. Tides & Currents. Available [online]: https://tidesandcurrents.noaa.gov/stationhome.html?id=8570283. Accessed 19 January 2023.

Seenipandi, K., Ramachandran, K.K., and Chandrasekar, N. 2021. *18 - Modeling of coastal vulnerability to sea-level rise and shoreline erosion using modified CVI model.* Earth Observation, Remote Sensing of Ocean and Coastal Environments, Elsevier. (315-340). ISBN 9780128196045. https://doi.org/10.1016/B978-0-12-819604-5.00018-4.