

The Town of Nags Head

Estuarine Shoreline Management Plan



Acknowledgments

This document synthesizes input and work by dedicated people and organizations who guided its development: Town of Nags Head Board of Commissioners (TONH), Planning Board, and staff; the Estuarine Shoreline Management Plan (ESMP) Advisory Council and Technical Team, especially Coastal Studies Institute, The Nature Conservancy, and North Carolina Coastal Federation; residents who attended meetings and hosted site tours; and the consultant team of Biohabitats and Moffat & Nichol. The Town would like to thank the National Fish and Wildlife Foundation (NFWF) for funding a portion of this project, and for providing much needed funds for resilience projects nationally. We also thank all participants in the August public workshop for lending their time and perspectives.



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Introduction

The Town of Nags Head is affected by impacts from coastal hazards like hurricanes, nor'easters, and sea level rise. The negative impacts of these hazards affect private and public property as well as key infrastructure and natural resources. Mitigating the impacts of these hazards to preserve the community's distinctive heritage and unique lifestyle, critical natural resources, and coastal ecosystem is important to the Town and its economy, as reflected in the Town's vision. The Town of Nags Head Estuarine Shoreline Management Plan (Plan) is an essential step in mitigating the impacts of flooding, storm

surge, erosion, and wave action on the estuarine shoreline. The Plan is a comprehensive effort to address the management of 17 miles of estuarine shoreline in the Town while balancing land use, ecosystem health, public health, and recreational opportunities. This Plan characterizes the existing shoreline and its historical changes; identifies shoreline best management practices, uses, and policy; explores the legal and regulatory impacts on shoreline management and nature-based solutions; and considers the impacts of coastal hazards.



The Planning Opportunity

Widely recognized for thought-leadership on coastal management issues, the Town of Nags Head is well-positioned to advance projects that could establish precedent in estuarine shoreline management. Future generations will look back on this time as the early days of collaborative coastal resilience, but the need is already urgent, and there are well-resourced entities in search of new and big ideas on preparing communities for change. If Nags Head chooses to remain at the fore of resilience planning by acting together, leveraging its partnerships, and harnessing the current flush of funding for nature-based solutions, it has the opportunity to safeguard assets that are quickly degrading.

STUDY PURPOSE & GOALS

The principal purpose of the Plan, in accordance with its grant deliverables for its National Fish and Wildlife Foundation funding, is to develop strategies that will prioritize living and nature-based shoreline management projects appropriate for each segment of the Town's estuarine shoreline.

The goals of the Town of Nags Head planning staff and volunteer members of the Advisory Committee were to work together to:

- Identify strategies and sites where Nags Head's estuarine shoreline can be managed to safeguard critical structures, enhance habitat values, and provide aesthetic and community benefits
- Build public awareness of the risks to the current estuarine shoreline from sea level rise and storm events
- Describe regulatory barriers and pathways to implementation of nature-based solutions
- Preserve or enhance recreational access to the sound

PUBLIC ENGAGEMENT

Public input collected via an appointed advisory committee, a volunteer technical committee, small group and stakeholder conversations, surveys, and public workshops is woven throughout this Plan. The complete timeline and a list of engagement events is summarized in the final section.



Foundational Plans & Policies

Nags Head has demonstrated leadership in planning for complex coastal issues, so this Plan advances a body of work that has been supported by decision-makers and community input. A few of the most important documents that serve as foundation to this plan are the TONH Comprehensive Plan, the Nags Head Vulnerability Consequences and Adaptation Planning Scenario (VCAPS), and recent regulatory changes that smooth the approval pathways for nature-based coastal protection.

FOCUS NAGS HEAD COMPREHENSIVE & CAMA LANDUSE PLAN

In order to better plan for the future, Nags Head initiated a comprehensive planning process in 2015, known as FOCUS Nags Head. The FOCUS Plan was adopted in 2017 and its revision was recertified in 2022. The plan includes policies and actions that require continued commitment to examine how sea level rise and climate change will impact the Town and what the Town and its citizens can do to protect

vital infrastructure, preserve community character, and maintain a thriving local economy.

VULNERABILITY CONSEQUENCES AND ADAPTATION PLANNING SCENARIO (VCAPS)

Nags Head contacted North Carolina Sea Grant to conduct an extension project to provide Nags Head with the data, legal, and policy analysis it needs to understand its vulnerabilities and more effectively plan for the future. North Carolina Sea Grant utilized the Vulnerability Consequences and Adaptation Planning Scenario (VCAPS) process in the summer of 2015. Background research and semi-structured interviews were conducted during the summer, and a public VCAPS workshop was held on December 7-8, 2015. One of the top priorities emerging from that process was to develop a management plan that establishes policies, procedures, and an overall management strategy for the Town's estuarine shoreline.



Foundational Plans & Policies

US ARMY CORPS OF ENGINEERS NATIONWIDE PERMIT 54 & NC

In 2017, the U.S. Army Corps of Engineers authorized its first Nation Wide Permit for Living Shorelines to address the construction and maintenance of erosion prevention projects are built with nature-based structural and organic materials, such as plants, submerged aquatic vegetation, wood and stone. In 2019, the NC Coastal Resources Commission followed suit, establishing a permitting pathway for living shorelines under 500 linear feet in length. These two regulatory changes set the stage for advancing nature-based solutions on the NC coast.

ALBEMARLE-PAMLICO NATIONAL ESTUARY PARTNERSHIP COMPREHENSIVE CONSERVATION AND MANAGEMENT PLAN

In 2012, Albemarle-Pamlico National Estuary Partnership (APNEP) adopted a 10-year plan outlining management actions identified in five general components (Identify, Protect, Restore, Engage, Monitor), which together address the major challenges to understanding, protecting, and restoring ecosystem health and function while embracing the new systems-based approach to managing the Albemarle-Pamlico region.





System Dynamics

Long-time residents and historians know how much the estuarine context of Nags Head has changed. Roanoke sound was broader and deeper before the mid 1700s, when the Roanoke inlet closed and forced more water through the historically shallow Croatan sound. Recent land-loss has been visible to long-term residents. This section examines the changes and trajectory of the estuarine shoreline along Nags Head and tries to understand how the sound and its marsh and seagrass beds have changed and on what pathway they will progress.

NAGS HEAD AS A BARRIER ISLAND

Geomorphology of Roanoke Sound

Barrier islands require three conditions to form: a gradually rising sea level, a surplus of sand, wind and waves large and strong enough to move the sand. The northern province of North Carolina's barrier island system (i.e. north of Cape Lookout) is characterized by a Pliocene-quaternary geologic framework and dominated by sediment, which shapes its gentle slopes. The rivers that drain the piedmont watersheds into this area are brown-water rivers with high loads of sediment. Because its barrier islands are long and have few inlets, there is little effect of astronomical tides, and the water levels and wave energy are instead predominantly wind driven. The system is also relatively fresh, such that oysters do not thrive north of Whalebone Junction.

Inlets have historically formed and filled along the Outer Banks. Between 2-5 inlets used to perforate the barrier island system above Nags Head, the last disappearing close to 1800. These breaks in the barrier island were an important source for the surplus of sand to move into the estuary and accumulate along its shoreline.

Wind has also shaped the land. Nags Head is a "complex" barrier island, with high areas created from old beach ridges and prodigious movement of sand by wind. In many places, the barrier dune ridges creating the higher parts of the island have long prevented regular overwash from the ocean side, though overwash typically provides sand to estuaries bordered by low and narrow segments of the Outer Banks. But even without large overwash fans from big storms, pre-development Nags Head moved a lot of sand to the estuarine side of the island. The obvious marker of this is Jockey's Ridge, which grew 20 feet in height from 1915 to 1953 but has not accumulated more sand since then. Instead, it has eroded, mostly by wind that drives the sand steadily south.

Today the northern inlets have closed and urban development both prevents overwash along the island and limits the movement of sand by wind. As a result, the sediment supply to the estuarine shoreline of Nags Head is severely limited to sand eroding from Colington Island and Jockeys Ridge along with what material is carried down the rivers from upland sources.

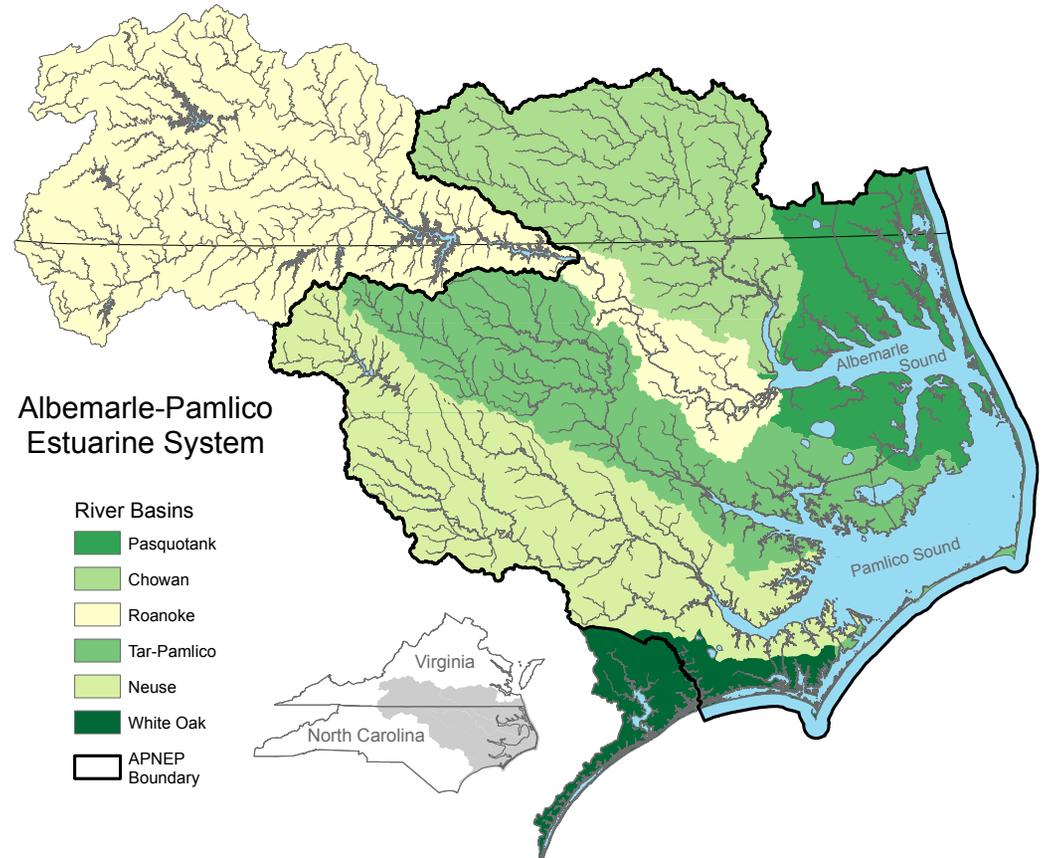


System Dynamics: Upstream Watershed Change

Lands and Dams

According to the 2012 APNEP Ecosystem Assessment, most estuarine shorelines in Albemarle-Pamlico Estuarine System are eroding in response to the interaction of storms and sea level rise. However, previous studies indicate that shoreline erosion is locally variable even over short distances. Mainland marsh and low sediment bank have the overall highest average rates of estuarine shoreline recession.

The water that passes along Nags Head's estuarine shore comes from large upstream watersheds where land use has been changing and impervious surface has been added. The changes to the water volume, sediment load, and water quality are known to be significant.



Map Credit: Tim Ellis



System Dynamics: Benefits at the Shoreline

Where Land Meets Water

Because estuaries (or “sounds”) are under the influence of both terrestrial watersheds and the ocean, they are highly productive, full of plants and animals, and extremely rich in nutrients. Within estuaries, salt marshes and sea grass beds are some of the most productive ecosystems in the world. They provide essential food, refuge, and nursery habitats for more than 75% of fisheries species and an even higher proportion of recreational fishing catch, including shrimp, blue crabs and many finfish. For Nags Head, aesthetic and recreational functions of the estuarine shoreline are prized by visitors and residents.

In urbanized areas, they can also serve critical functions in improving water quality, as toxic chemicals and nutrients, especially phosphorous, adhere to the wetland soil (Deaton et al 2010). Finally, a gentle, sloping shoreline that is covered in vegetation dissipates wave energy and minimizes erosion or may even accrete sediment when water is still. Coastal wetlands dampen storm surge and wind impacts, reducing property damage in storm events. An economic study from 2020 (Sun and Carson) valued the storm protection offered by Dare County wetlands at \$618,000 per km² over a 30-year horizon. This protection depends on the persistence of marsh habitats.

	Very Important (1)	Somewhat Important (2)	Neutral (3)	Not Very Important (4)	Not Important (5)	Weighted Average
Ecological: Habitat and water quality, absorbing wave energy	26	8	2	0	0	1.33
Cultural: Viewsheds, open character, natural vistas	19	11	5	0	0	1.6
People: Preventing injuries and/or loss of life	19	11	2	0	2	1.68
Infrastructure: Preventing damage/loss of roads, bridges, utilities	19	12	2	0	2	1.69
Recreational: Water access, gathering place	18	10	4	1	1	1.74
Personal Property: Protection of property adjacent to shore	16	11	5	1	2	1.91

Respondents to a public survey in May 2022 prioritized ecological functions of habitat, water quality, and wave attenuation as the most important estuarine shoreline benefits.



Today's Estuarine Shoreline

Feasible design recommendations rely on a high-level understanding of the coastal conditions, so the consultant team undertook a preliminary engineering assessment and developed a model to clarify the typical range of values for the parameters that are most important to shoreline design: wave energy, erosion rates, shoreline character, shoreline slope, and presence of marsh. Additional key considerations at the site scale include land use and ownership as well as the proximity or vulnerability of soundside infrastructure. The complete engineering report and geospatial database of the variables considered are described in the appendix and briefly summarized here.



Erosion along unprotected segments of the estuarine shoreline has reached more than 400 ft in some areas.

SUMMARY OF KEY SHORELINE CHARACTERISTICS

Exposed vs Protected Shoreline

- maximum Hs >.5ft during normal conditions
- maximum Hs >.5ft during storm events only

Erosion Rate

- Continuous variable

Shoreline Condition

- Marsh
- Miscellaneous
- Modified (bulkhead, riprap, etc)
- Sediment bank
- Swamp forest

Bank Slope (measured from bottom of low marsh to top of bank)

- steeper than 33%
- between 33-20%
- shallower than 20%

Low Marsh Zone Width (width of low marsh elevation range)

- absent low marsh zone
- less than 6ft
- greater than 6ft

Distance to Infrastructure (structures, roads, utilities, etc)

- less than 15ft
- between 15-30ft
- greater than 30ft

Sea Level Rise (SLR) Vulnerability/Marsh Migration

- 2 ft rise
- 3 ft rise
- 4 ft rise

Today's Estuarine Shoreline

WIND, WAVES, AND WATER LEVEL

In the spring of 2022, Moffat & Nichol developed a local Wave Exposure Model to document the baseline condition of the estuarine shoreline. The consultant team worked with East Carolina University's Coastal Studies Institute to collect bathymetry data along Nags Head to supplement the existing federal data. The purpose of the study was to characterize the water levels and wave climate at the project site and use statistical analysis of these environmental parameters to inform the design of shoreline treatments to meet the goals of the shoreline management plan.

To identify the dominant wind directions with large magnitudes at the project site, wind data were analyzed from two sources - Meteorological Terminal Air Reports data located at airports and data from the National Oceanic and Atmospheric Administration's (NOAA) Center for Operational Oceanographic Products and Services. Analysis of the windspeed and direction confirms the seasonal shift in wind direction, with prevalent wind energy coming from the southwest or north/northeast depending on the time of year.

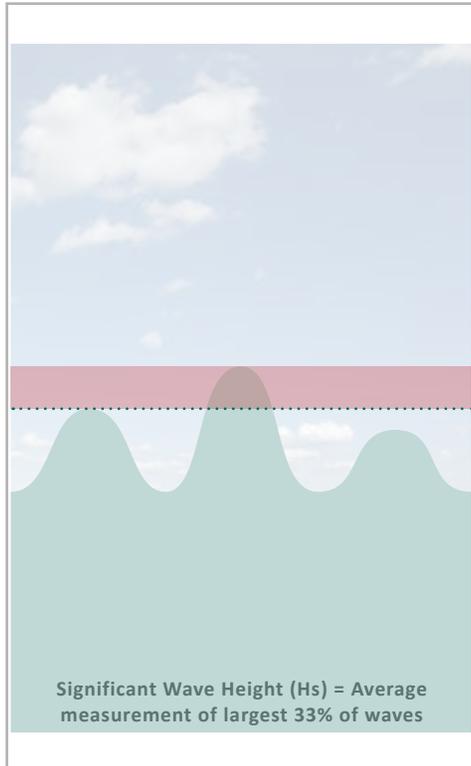
The amount of wave energy hitting the shore depends on the fetch, or extent of open water in the dominant wind direction for any given site. Differences in wind direction and intensity and the fetch in the dominant wind direction create variability in the amount of erosion due to quotidian wave attack, though episodic large storm events have a strong influence on the coastal landforms. Some of the Town's shoreline was well protected by angle and orientation, so the average wave height is low. Other sections of estuarine shoreline are exposed.

As a general rule of thumb, we set the conceptual threshold of "allowable" wave height as 0.5 feet below the elevation where marsh plants can survive. As wave height and energy varies along the shore, the height requirements for a breakwater to reduce wave attack vary.

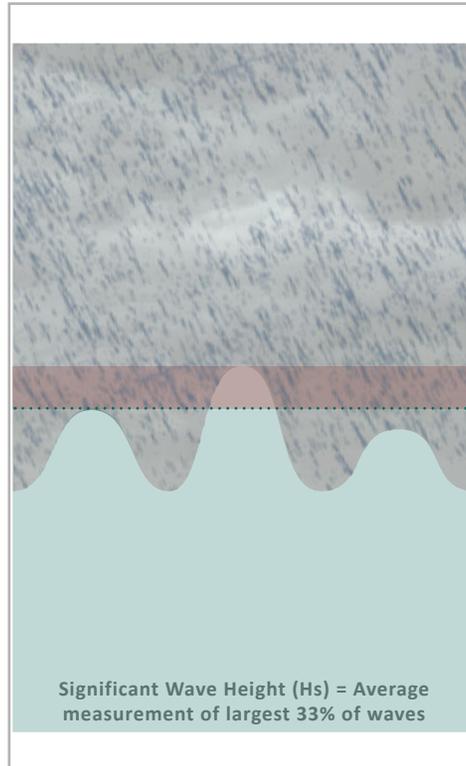


WIND WAVES

The wind wave category seeks to differentiate locations that maintain a highly erosive energy during normal conditions from those that are highly erosive during infrequent storm events. A Significant Wave Height (H_s) is the average wave height of the largest 33% of incoming waves. A max H_s greater than 6in is a threshold above which has been shown to be erosional to marsh communities.



H_s greater than 6in during normal conditions



H_s greater than 6in during storm events

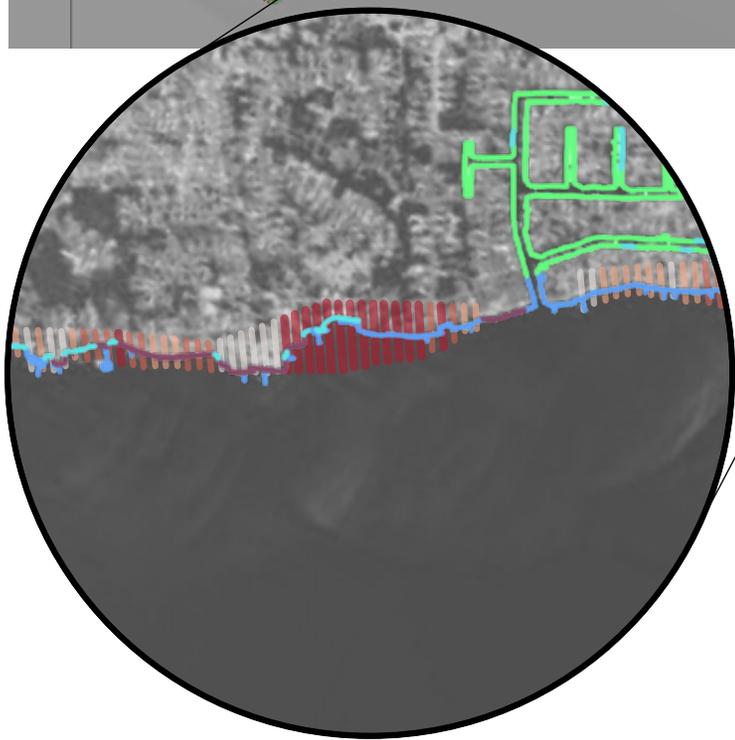
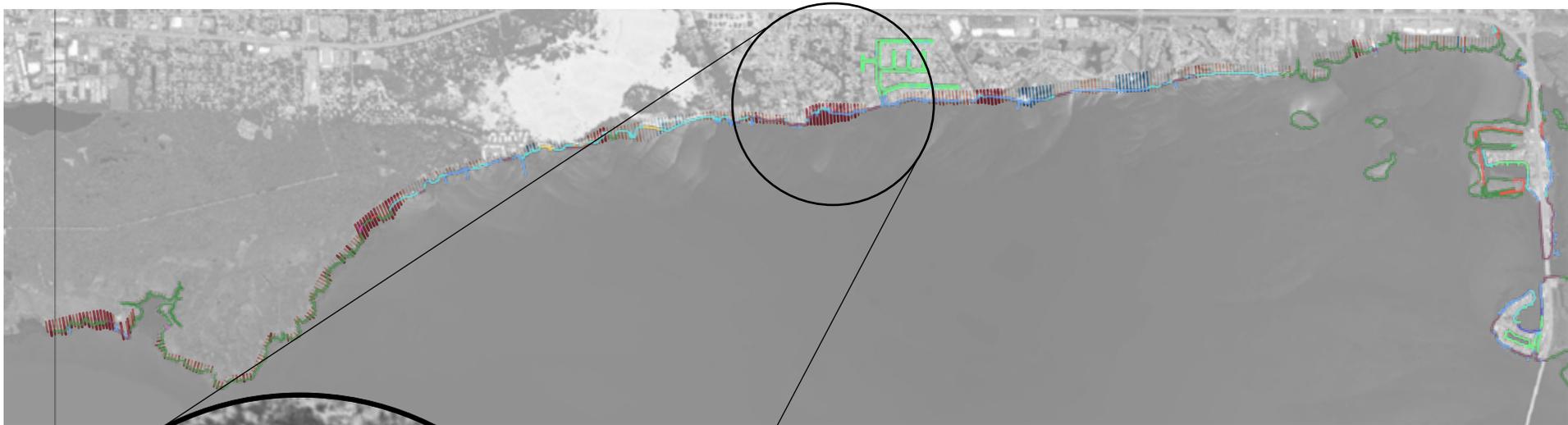


Engineering Report - Analysis point locations

Significant H_s greater than 6in during normal conditions: Consistently erosive conditions will require heavier breakwater protection to maintain marsh edge.

Significant H_s greater than 6in during storm events: Infrequently erosive conditions would benefit from moderate/light breakwater protection.



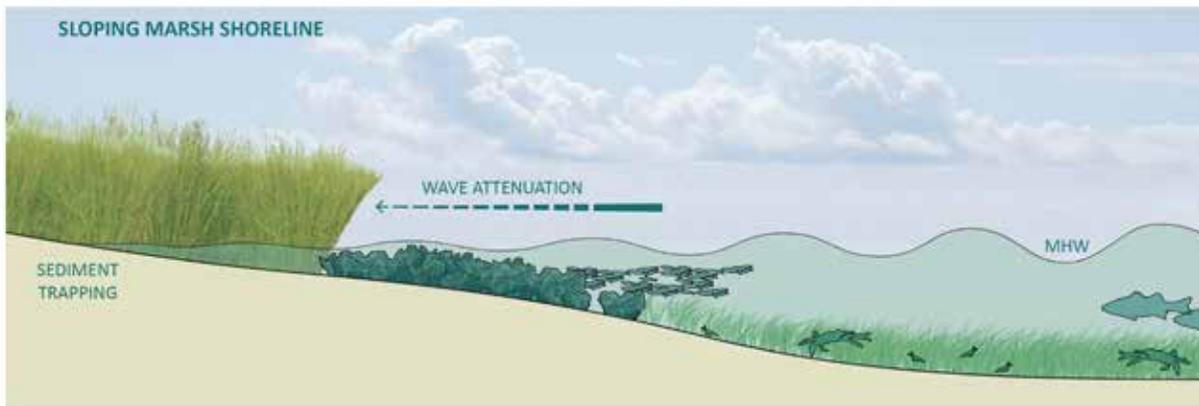


Each perpendicular line in this figure is a transect that extends offshore to the known extent of the former shoreline.

SHORELINE EROSION RATE AND LAND LOSS

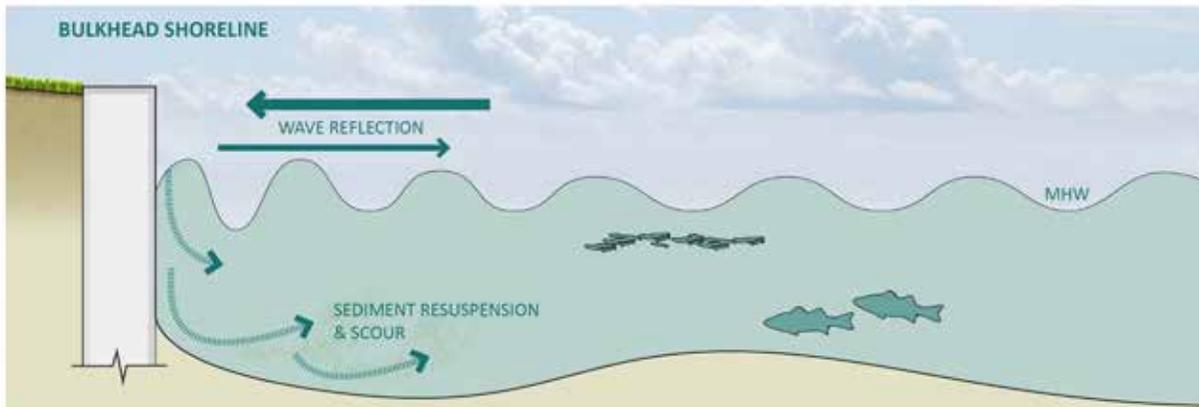
Sections of Nags Head's estuarine shoreline have lost over 400 linear feet of land since the reliable mapping in 1949. Although erosion and sediment transport are natural processes and can be beneficial to coastal systems, some of the erosion in Nags Head is ultimately caused by human modifications to the upstream watersheds and shoreline. The USGS Digital Shoreline Analysis System (DSAS) software established shoreline erosion rates along the estuarine shoreline of Nags Head by comparing historic shorelines and recent shoreline measurements by East Carolina University. DSAS allows analysts to calculate rate-of-change statistics from multiple historical shoreline positions as related to a common, inland baseline. Erosion rates in the Town range from stable conditions to loss of over 400 linear feet in land over the last 70 years. Because the DSAS analysis does not incorporate shoreline character, historical erosion rates are sometimes a poor predictor of future ones. For example, a homeowner experiencing rapid land loss might have installed a bulkhead and no longer be experiencing high rates of loss.





TOWN'S NATURAL SHORELINE

Salt- and brackish-water marshes	49,566 lf
Sheltered, vegetated low banks	14,232 lf
Scrub-shrub wetlands	5,060 lf
Fine- to medium-grained sand beaches	1,420 lf
<u>Swamps</u>	<u>211 lf</u>
	70,489 lf



TOWN'S MAN-MADE SHORELINE

Exposed, solid man-made structures	20,160 lf
Sheltered, solid man-made structures	18,853 lf
Exposed riprap	10,314 lf
<u>Sheltered riprap</u>	<u>761 lf</u>
	50,088 lf

Natural and armored shorelines reflect wave energy differently. Natural shorelines (above) can absorb the wave energy that bounces off of bulkheads (below), creating scour and deepening the nearshore environment.

SHORELINE CHARACTER

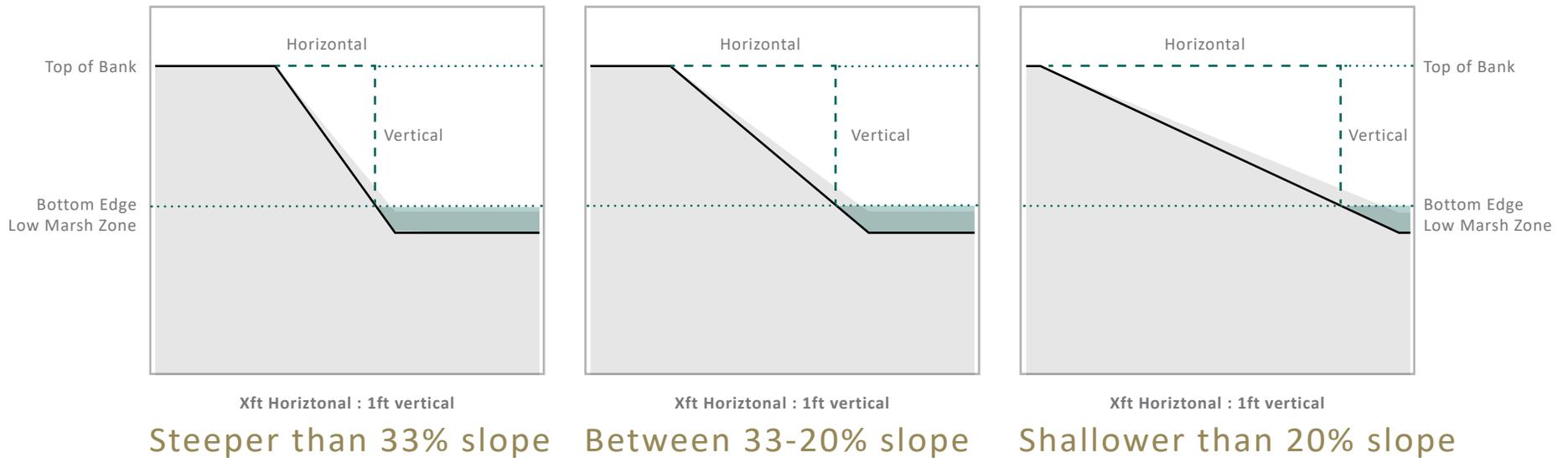
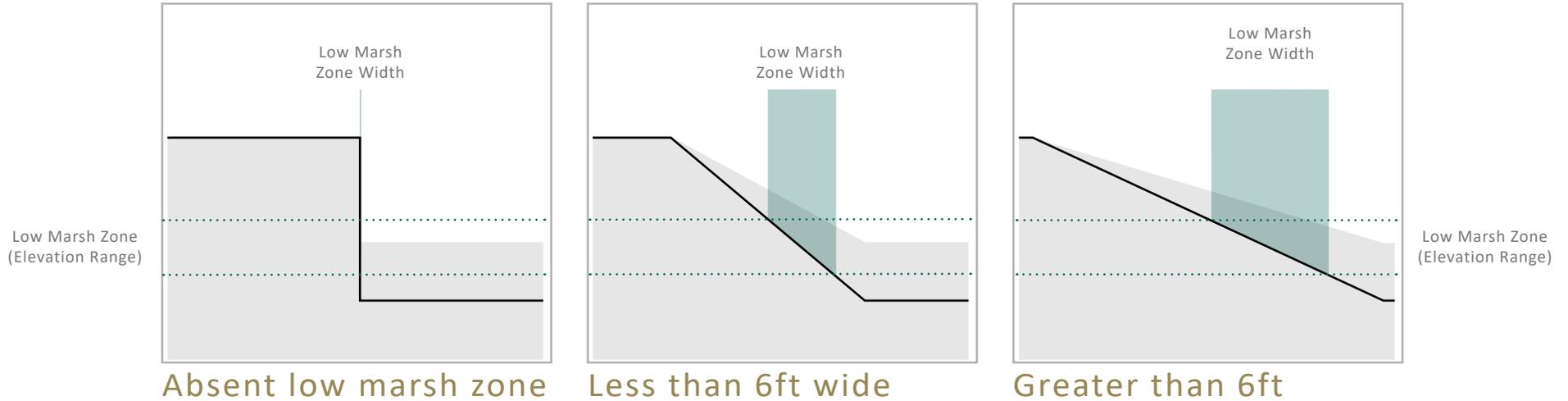
In the face of mounting erosion pressure and dwindling accumulation of sediment to bolster the shoreline, many property owners have chosen to fortify or armor their waterfront properties. Stabilization

strategies include riprap and bulkheads made from a variety of materials, including wood, vinyl, and masonry materials.



WIDTH OF MARSH ZONE AND BANK SLOPE: ATTRIBUTES OF EXISTING CONDITIONS

Low Marsh Zone (LMZ) Width



OWNERSHIP AND LAND USE

Outside the large pieces of shoreline owned by the Nature Conservancy (Nags Head Woods), the State (Jockey’s Ridge) and a large single landholder (Nags Head Golf Links), most of the shoreline is

comprised of 140 individual residential owners. Additional sectors of ownership are labeled by shoreline segment in the figure below.



Climate Change and Resilience

Future management of the Town's shoreline must be understood in light of climate change. Even if greenhouse gas emissions were eliminated today, continued warming and sea level rise would occur due to the current accumulation of emissions. Climate change is also changing rainfall patterns to favor more intense storm events, with more precipitation coming quickly, and an increased frequency and intensity of hurricanes and similar storms. These major storm events move enough sand to strongly influence coastline conditions.

This plan accounts for the change in sea level between 1992 and 2022 by assuming a combination of the historic rates and the projections reported by NOAA. This results in an increase in all water levels of 6.7 inches (or 0.56 ft) between 1992 and 2022 resulting in an assumed MSL in 2022 of +0.14 ft-NAVD.

The projections labeled "K14" are based on Kopp et al. (2014), which relies on the expert elicitation work of Bamber and Aspinall (2013) for characterizing the contribution to sea level rise from ice sheets. The likely ranges for the K14 projections published in Kopp et al. (2017) present comparable results to other projections. The K14 projections represent the best available projections for local sea level change in North Carolina and were used for this study. The K14 projections for relative sea level change for Duck, NC serve as a useful indicator of anticipated changes in Nags Head.



SEA LEVEL RISE VULNERABILITY

One important shoreline characteristic is its vulnerability to sea level rise, which varies widely depending on topography and the location of infrastructure. It is possible to index vulnerability to the percentage of a parcel that is projected to be underwater under future scenarios and also to score the site's potential for marsh migration. Marsh migration refers to an existing marshes ability to adapt to SLR by moving to higher elevations. SLR information informs cost/benefit calculations and potential longevity of proposed interventions. Unfortunately, SLR projections are widely variable and depend on our collective response in addressing climate change. Timeframes described below assumes an intermediate emissions pathway.



2ft rise



3ft rise



4ft rise

2ft SLR: A rise of 2ft and presumed location of mean sea level (MSL). Estimated timeframe is 30 years (2052 a.d.)

3ft SLR: A rise of 3ft and presumed location of mean sea level (MSL). Estimated timeframe is 50 years (2072 a.d.)

4ft SLR: A rise of 4ft and presumed location of mean sea level (MSL). Estimated timeframe is 70 years (2092 a.d.)

Key Management Challenges

Water quality, loss of marsh, land loss, and preserving the visual character are among the most important management challenges along Town’s estuarine shore. Flood risk is compounded by the various sources of water: wind tide flooding that can occur when winds blow persistently in one direction for multiple days; storm surges creating major coastal flooding events caused by gales, northeasters, tropical storms, and hurricanes; and rainfall flooding exacerbated by higher tide elevations that reduce or block drainage.

Together with public opinion from a May 2022 survey, the data on existing conditions presented here confirms what The Town knows: the marsh is disappearing and Nags Head is losing land. In order to organize the potential solutions, this Plan uses a typological approach to categorize the type of existing conditions at any site. This typological approach allows us to link the solutions in the next section to the existing conditions as described here.

	Very Important (1)	Somewhat Important (2)	Neutral (3)	Not Very Important (4)	Not Important (5)	Weighted Average
Water Quality in the sound	28	8	0	0	0	1.22
Loss of marsh habitat	23	10	1	1	1	1.53
Land loss along the estuarine-shoreline	20	12	1	1	1	1.6
Preserve visual character of vegetated shoreline	18	14	2	1	0	1.6
Stormwater system overwhelmed in extreme events	12	20	0	1	0	1.70
Improving bulkheads/riprap	18	10	6	0	1	1.74
Providing recreational access	13	16	2	2	2	1.97
Flooding from the estuarine side	9	21	3	1	1	1.97
Turbulence from waves rebounding from hard shoreline	12	15	5	2	1	2.00
Bridges/roads flooding or being blocked	9	16	6	1	1	2.06

Respondents to a public survey in May 2022 prioritized land loss and visual appearance & character as important management challenges.



Shoreline Typologies: Exposed, Hardened Conditions



EXPOSED, SOLID BULKHEAD STRUCTURES

- Slopes >33%
- **Absent Low Marsh Zone (LMZ)**
- Public, Private and Vacant ownership
- Wind Waves- Hs normal & storm
- Distance to infra. >30ft



EXPOSED RIPRAP

- Slopes 20-33 & >33%
- **Absent LMZ**
- Public & Private ownership
- Wind Waves- Hs storm
- Distance to infra. mixed



EXPOSED, SOLID BULKHEAD STRUCTURES WITH LOW MARSH ZONE

- Slopes >33%
- **LMZ > 6ft**
- Private ownership
- Wind Waves- Hs normal & storm
- Distance to infra. mixed

Shoreline Typologies: Exposed, Softer Edges



EXPOSED, FAILING, VEGETATIVE BANKS

- Slopes >33%
- LMZ > 6ft
- Public & Private ownership
- Wind Waves- Hs normal
- Distance to infra. >30ft



EXPOSED, LOW BANK & BEACHES

- Slopes <20%
- LMZ > 6ft
- Public & Private ownership
- Wind Waves- Hs normal & storm
- Distance to infra. >30ft



EXPOSED SALT & BRACKISH-WATER MARSHES

- Slopes <20%
- LMZ > 6ft
- Public, Private
- Wind Waves- Hs normal & storm
- Distance to infra. >30ft

Shoreline Typologies: Mixed Sheltered Conditions



SHELTERED, SOLID BULK- HEAD STRUCTURES

- Slopes >33%
- Absent LMZ
- Private ownership
- Sheltered from Wind Waves
- Distance to infra. mixed



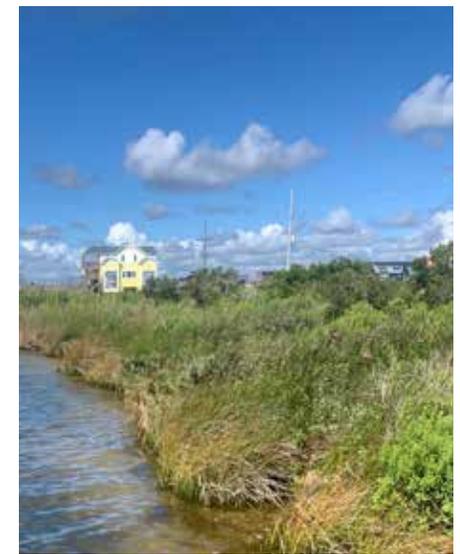
SHELTERED RIPRAP

- Slopes >33%
- **Absent LMZ**
- Private, Vacant Private
- Sheltered from Wind Waves
- Distance to infra. >30ft



SHELTERED, VEGETATED LOW BANKS

- Slopes 20-33%
- **Absent LMZ**
- Private, Vacant Private
- Sheltered from Wind Waves
- Distance to infra. >30ft



SHELTERED, SCRUB- SHRUB/WETLANDS

- Slopes 20-33%
- **Absent LMZ**
- Private, Vacant Private
- Sheltered from Wind Waves
- Distance to infra. >30ft





RESTORING THE SHORE: SOLUTIONS



Thinking Big

The large-scale processes such as upland water flow and overwash from the ocean that once fed sediment and sand into the barrier island system to build and maintain its form have been disrupted by human modifications of Nags Head. Therefore, there is a mismatch in the scale of the problem versus the solutions if we look only at management options whereby an individual landowner protects their own shoreline. Although a coordinated large-scale effort is daunting in terms of human collaboration, it may be the requisite response to the existential threat to the Town. Local conditions are favorable for interventions at scale, in part because we know there is a large-scale movement of sand and sediment along the estuary. The primary plume of sand, originating from Jockey's Ridge, is observable in

satellite imagery, while the sound's bathymetry also offers evidence of large-scale movement that settles in underwater ridges. However, it appears that the preponderance of the sand escapes down Croaton Sound or simply resuspends and resettles constantly. If this material can be harnessed and established with vegetation, the estuarine shoreline will be more resilient to future change and increasing severity and duration of storms. Therefore, while the menu of restorative approaches to estuarine management includes smaller-scale responses such as bulkheads and living shorelines, energetically evaluating the feasibility of coordinated action is the primary recommendation of this Plan.

Waves of Sand Present an Opportunity



Green Bulkhead Enhancements



Vertical - Vinyl/Timber Bulkhead

SUITABLE TYPOLOGIES

- Sheltered, Solid Bulkhead Structures
- Sheltered Riprap
- Exposed, Solid Bulkhead Structures
- Exposed Riprap

IMPORTANT FUNCTIONS

- Attenuation of wave energy
- Reduction of scour
- Habitat

Where bulkheads have already been placed or are seen as preferential based on site limitations, design techniques can be utilized to soften their erosive and scouring impacts, while enhancing their ecosystem service value. A small scale and low-cost enhancement, such as Habitat Baskets or bulkhead façade treatments, attaches directly to the bulkhead face and adds habitat complexity. Wetland Baskets are another option that can be attached directly to the bulkhead structure. As pictured on the next page, this technique involves Hesco baskets, filled with a sand media and planted with wetland vegetation, to reestablish a wetland edge. Depending on site characteristics, the new wetland edge could reconnect the upland to the water's edge or just provide low marsh habitat. Intertidal Habitat Structures could be implemented within the intertidal zone along the base of the bulkhead (given suitable conditions), to disrupt and attenuate incoming wave energies, interrupt the typical scouring impacts, and provide habitat complexity within the intertidal zone.

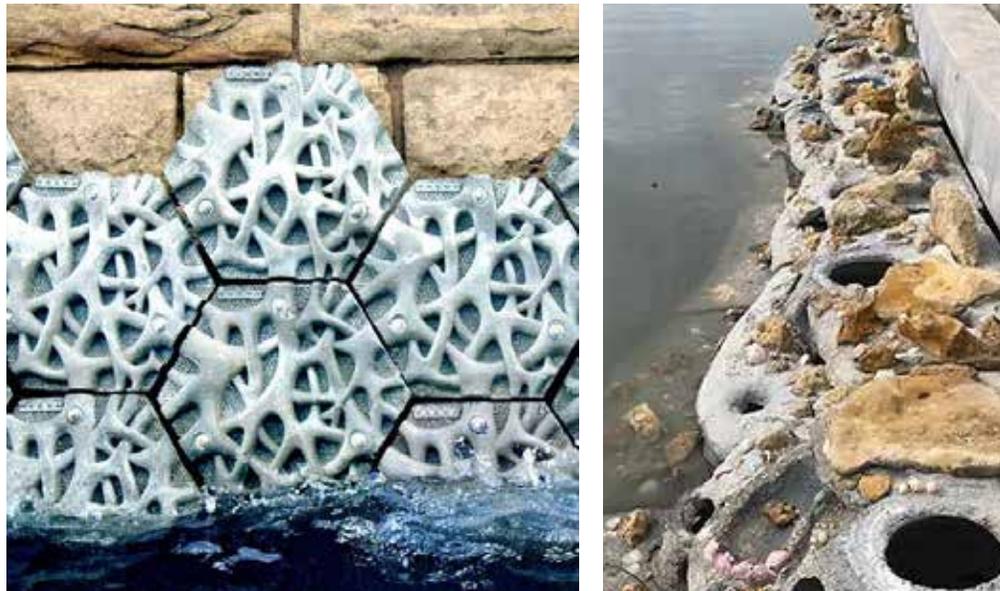
Bulkheads with a riprap edge condition provides an opportunity for Vegetative Enhancement. This option aims to provide vegetative cover by installing sand media pockets within the aggregate for woody material, or establishing herbaceous cover through media import, seeded mat covers, or a combination of the two. The vegetative enhancement technique could be retrofitted into an existing riprap edge or added into the design of a new riprap edge installation. The above techniques are a vital component of a complete shoreline management strategy, because so much of the Town's estuarine shoreline has already been armored.



Green Bulkhead Enhancements



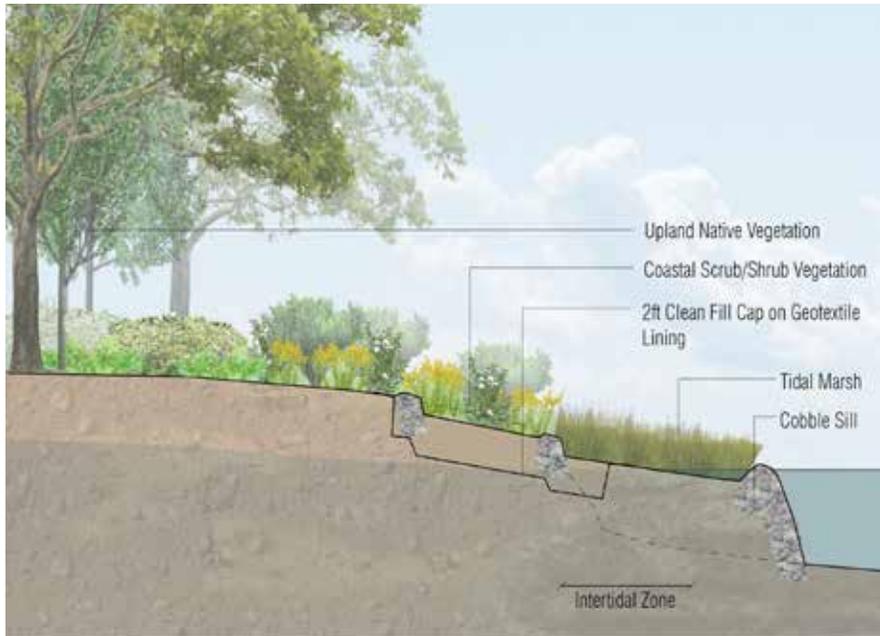
In this innovative Nature Conservancy project along Alabama’s Fowl River, designers used gabion baskets attached to an existing, but failing, bulkhead. The bulkhead remained in place to save the cost of removal and reduce property loss. The gabion baskets were planted with native marsh grasses to create a tiered structure that mimics the slope of a natural shoreline.



The least intrusive way to modify an existing bulkhead to improve its wave energy attenuation and habitat benefits is to affix materials with more complex structures to its face. The tiles at left offer a surface suitable for small marine organisms and larval shellfish. The EcoRap Living Seawall modules at right diminish rather than reflect wave energy. They also provide escape habitat for juvenile fish, which is a critical function of shallow nearshore habitats.

Resiliency Terraces

PROPOSED TREATMENTS



SUITABLE TYPOLOGIES

- Exposed Riprap
- Exposed Solid Bulkhead Structures with Low Marsh Zone
- Exposed, Failing, Vegetated Banks
- Exposed Salt & Brackish-Water Marshes
- Exposed Low Bank and Beaches

Resiliency Terraces

Where space permits, an option to counter loss of shoreline protection is the use of terracing, which can allow for a limited amount of marsh migration and vegetative & habitat diversity. Suitable locations would offer a combination of horizontal depth from the existing shoreline and appropriate vertical height to be able to pull back the land and regrade into a more consistent slope. Terracing is a critical component that allows a flatter horizontal grade, while stepping up to meet the slope requirements. Migration ramps are graded in

between the terraces to provide connection and migration potential between cells. The diagrams below show a barrier (retention feature) at every elevational change.

Resiliency terraces are a hybrid option in shoreline management and may be suited to places that have already been partially altered. They merge providing some of the stabilization benefits of bulkheads with some habitat value and managed plantings.

Living Shorelines

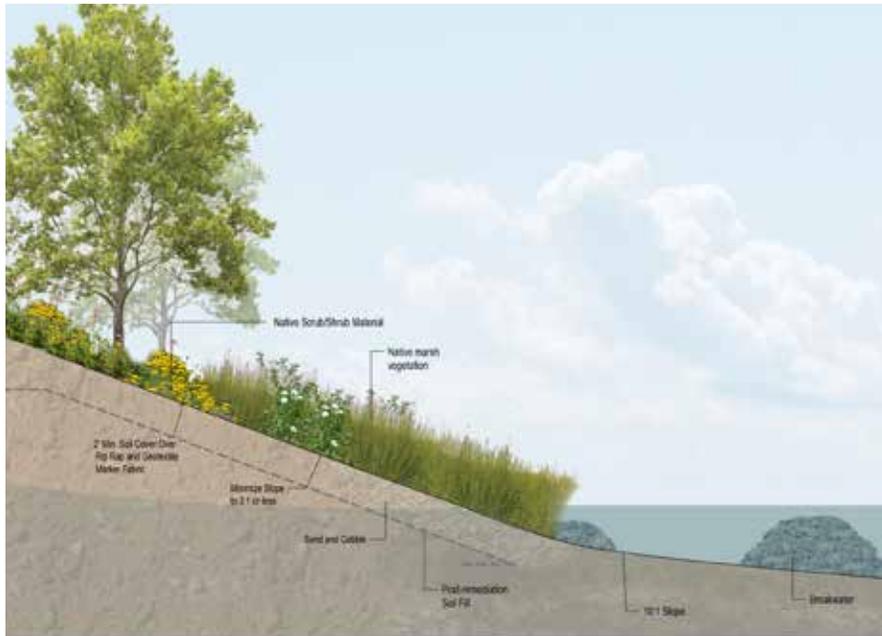
Living shoreline are a method of shoreline stabilization using plants and natural materials to reduce erosion and slow the wave energy associated with storms. Rather than creating a barrier between the shore and water, as with conventional bulkheads and seawalls, a living shoreline allows for a natural transition. The shoreline can thus provide erosion protection while still performing valuable ecosystem services and maintaining aesthetic character.

One of the best examples of a living shoreline in North Carolina protects the shore and is accreting land just off of Jockey's Ridge. The Coastal Federation and NC State Park have created a design that traps the material eroding from the dune, restoring eroded shoreline.



Living Shorelines

PROPOSED TREATMENTS



SUITABLE TYPOLOGIES

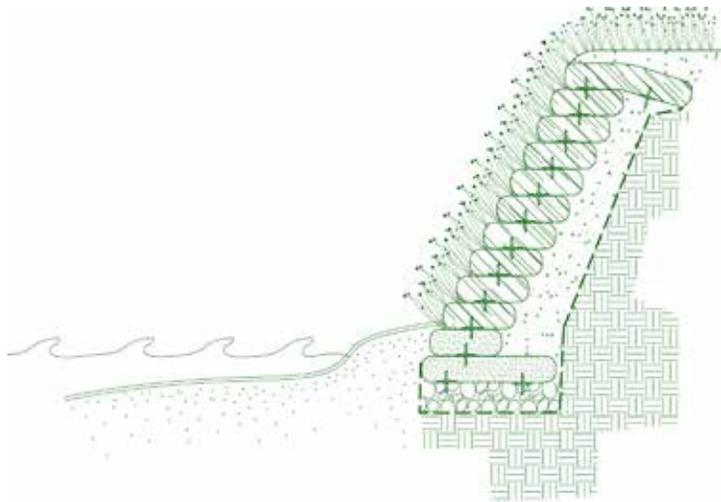
- Exposed, Solid Bulkhead Structures with Low Marsh Zone
- Exposed, Failing, Vegetated Banks
- Exposed Salt & Brackish-Water Marshes
- Exposed, Low Banks & Beaches



Geotextile Tubes

PROPOSED TREATMENTS

Strong geotextiles filled with local material have been used for shore protection in several different configurations (Lim and Siew 2022). In sheltered locations with natural shorelines, they can reduce erosion in a function similar to bulkheads with moderately more energy absorption and less rebound. Without an offshore wavebreak component, such systems cannot diffuse much wave energy and can degrade in extreme events. Some vendors sell systems designed to recruit vegetation that will continue to stabilize shorelines over time, which can be effective with sufficient sunlight.

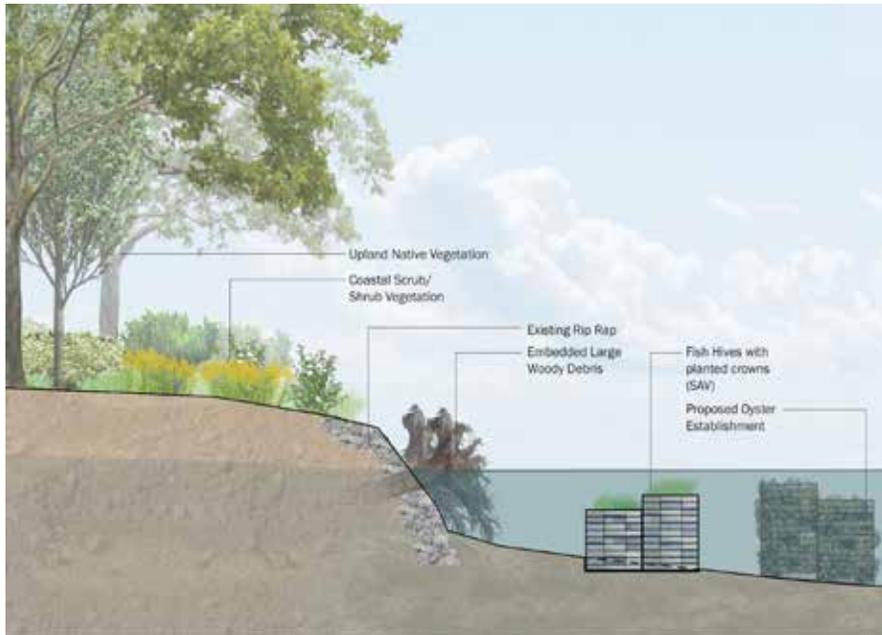


Envirolok's geobag system is designed to stabilize shorelines that do not experience extreme wave energy and allow plant recruitment. Installed on Kiawah Island, SC at right. Images:Envirolok



Embedded Large Woody Debris

PROPOSED TREATMENTS



SUITABLE TYPOLOGIES

- Exposed Riprap
- Exposed, Failing, Vegetated Banks
- Exposed Salt & Brackish-Water Marshes
- Exposed, Low Bank and Beaches



Embedded Large Woody Debris

An extension of the living shoreline concept, this approach uses natural materials to enhance habitat complexity and nutrient cycling. It is particularly noteworthy in places such as Nags Head, where the oysters that are often key to living shoreline design cannot thrive. If installed below the mean sea level, the consistent saturation of the woody material limits aerobic decomposition and allows the structures to remain for many decades.

Another benefit of this type of approach is the diversion of woody material from the landfill or other waste facilities. If coupled with a site clearing project, where trees and woody material are removed, much of the material can be supplied for minimal cost. The stockpiling of Christmas trees for use in these structures is an ideal application because of the dense branching matrix and smaller size, which facilitates placement by volunteers.

Reef Balls and Oyster Alternatives

Oyster reefs are the natural model for the small-scale breakwaters required by living shorelines. Breakwater alternatives that are not dependent on oysters such as Reef Balls or EConcrete products are widely used in places like Nags Head where oysters do not thrive. Since these materials and designs began to be adopted more broadly, there has been a substantive body of literature developed on anchoring them securely through intense storms while making sure that breakwater designs are compatible with recreational boating and other popular water sports. Since good designs attract fish, they tend to be popular with anglers. Such materials can be deployed in Nags Head's estuarine shore (e.g. Harvey Event Site concept, p 42).



Paddleboarding over reef balls in Turks & Caicos, credit: reefbeach.com.



Open-Water Design Strategies: Breakwaters Reimagined

Working on large-scale modifications and living breakwaters out in the open water zone is a more ambitious and holistic effort to respond to the scale of the disrupted processes and seek to restore more natural habitat to the sound. These strategies can be implemented together with the forgoing, smaller-scale solutions focused on the shoreline itself.

Living breakwater creation involves the placement of material offshore to create islands with engineered hardened edges to protect against erosion, while simultaneously acting as a wave break for the shoreline. The landward facing edges of these structures can be designed to establish heterogeneous marsh habitat zones that are not

subject to high fetch wave impacts. Location of submerged habitats, including Submerged Aquatic Vegetation (SAV) and mussel colonies, is critical to survey for final island placement.

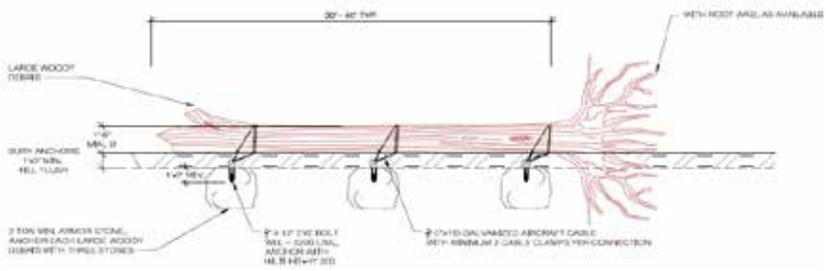
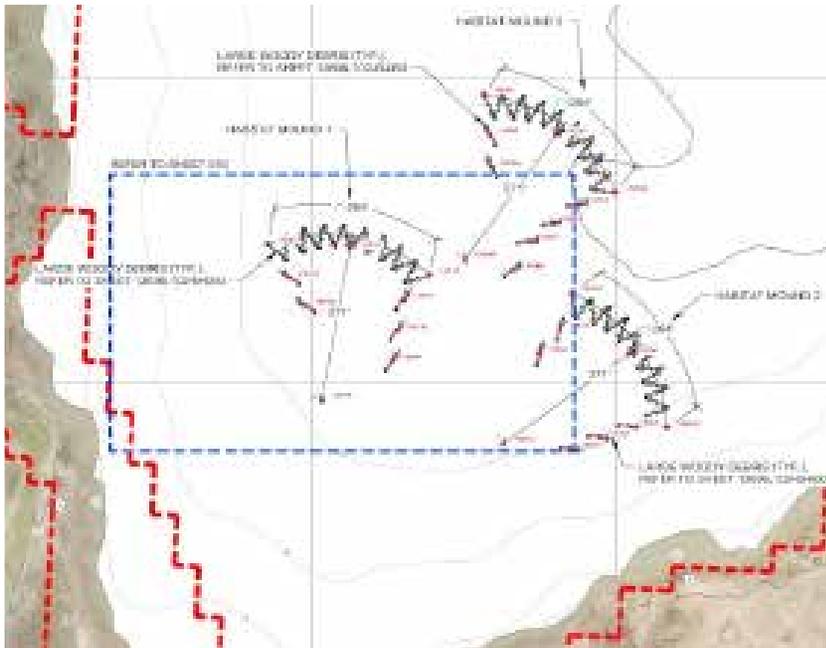
These living breakwater structures can also be incorporated in a systems thinking approach, whereby sediment flows can be harnessed for land building. Orientation of the islands along the predominant/seasonal sediment flows can encourage the deposition of this material in selective areas. Sediment accumulation could potentially support and expand the breakwater islands or contribute material to the waters between the island structures and the Town shoreline.



NC State's Coastal Dynamics Design Lab developed renderings of living breakwaters for Nags Head's Estuarine Shoreline. Like the concepts in this plan, these concepts used reef balls rather than oysters, which cannot thrive in Roanoke Sound's low salinity. Credit: NCSU Coastal Dynamics

Open-Water Design Strategies: Breakwaters Reimagined

PROPOSED TREATMENTS



TERRACES PROVIDE HABITAT FOR A VARIETY OF SPECIES



Images courteous of the City of Virginia Beach & Ducks Unlimited

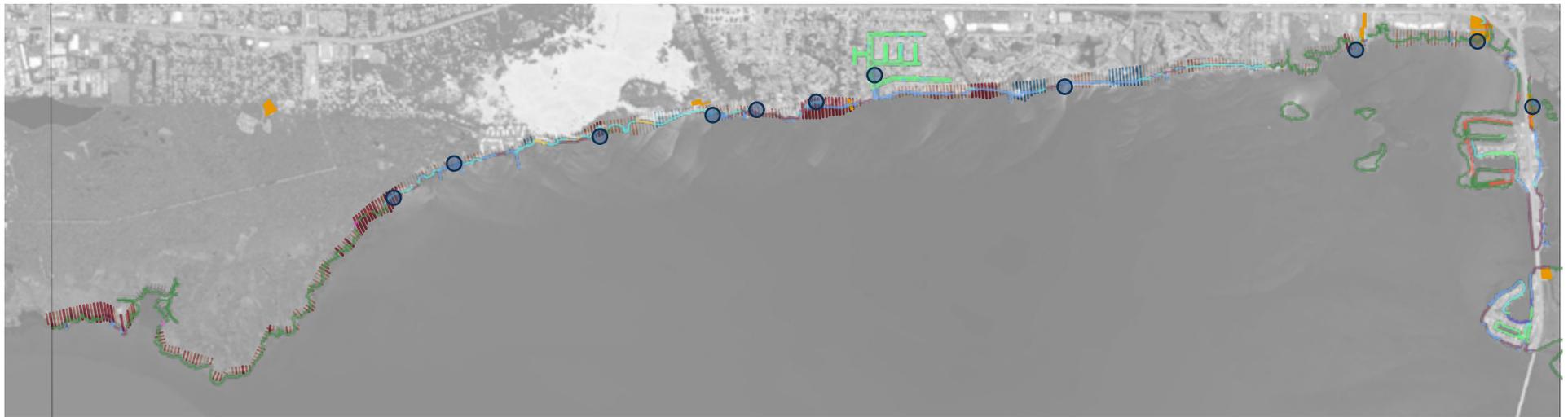
PILOT SITE CONCEPTS



Pilot Site Selection

In August of 2022, Town staff, the Advisory Committee, and the Technical Partners worked through a prioritization exercise centered around 11 potential sites that varied by location, ownership, physical characters, and modification history. A survey was deployed to solicit input from those unable to attend the workshop. After examining

the ranked selection criteria and collecting feedback on the menu of solutions, the planning team decided to prioritize large-scale and holistic approaches at three sites, some of which encompassed more than one of the 11 indicated by blue circle in the figure below.



Nags Head Woods and Villa Dunes Drive

CHALLENGE

The first concept site encompasses two distinctly different typological conditions: Steep, highly eroded banks and Exposed bulkhead structures with and without low marsh zone. In this higher-energy, northernmost site, erosion is advancing rapidly and threatening a Town owned residential road (Villa Dunes Drive) perched on a steep, eroding bluff in Nags Head Woods. The Town has moved the road in the Eastward direction two times in order to protect its integrity. The area is a dedicated nature preserve, and home to an old growth stand of Live oak, Atlantic red cedar, American holly and American beech. Residents remember swinging on ropes from the pictured Live oak tree, which collapsed into the water as the bluff eroded. Just to the South, residential properties dot the shoreline and have approached erosion and land loss with a variety of bulkheads and strategies but are keenly interested in a collaborative approach.

PROPOSED APPROACH

The core element of this pilot site is a series of Living Breakwaters that can provide a multi-faceted, nature-based approach for the Town. Positioned a minimum one hundred feet offshore, the living breakwater structures have a sound facing hardened edge and a softer, low slope landward facing side for marsh/habitat establishment. Although these structures will be placed within the viewshed, the landward facing marsh edge will be the primary viewpoint and not

the hardened edge. The breakwater structures are limited in location by the private docks and will only occur landward of the dock extents to minimize navigational hazards.

Additionally, seasonal sediment flows, originating at Jockey's Ridge and moving in the northern direction, have been observed. Placement of these breakwater structures along this sediment flow pathway anticipates an accumulation of this material along the breakwater edges. Over time, this may result in sand bar formations that could provide habitat or further contribute sand material into the littoral zone. Along with providing the necessary protection from wave energy, the Living Breakwater provides ecological, recreational, and economic benefits, including:

- Engineered rock formations provide escape and refuge for fish
- Concrete-coated material encourages colonization by marine organisms
- Sediment or dredge material can be beneficially used to enhance protection and habitat
- Landward facing, tidal wetlands provide shelter for crabs, shrimp and fish larvae, and marsh birds
- Birding, nature education, kayaking & canoing, stewardship
- Woody debris aggradation structures could be used to encourage sand accumulation



Nags Head Woods Preserve & Villa Dunes Drive

Nags Head, NC

HEAVILY ERODED BANK AND HIGH HISTORICAL EROSION HISTORY. LIVING BREAKWATER POSITIONED TO ACCRETRE SAND BEING TRANSPORTED IN A NORTHERN DIRECTION.

Private Drive

Villa Dunes Drive

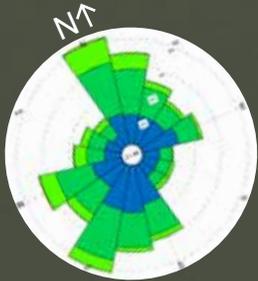
SECTION

Nags Head Shoreline (1949)

LIMITING INTERVENTIONS TO BEHIND BOATHOUSES/ BOARDWALK POINT TO REDUCE NAVIGABLE HAZARDS

LIVING BREAKWATERS ORIENTED TO ENCOURAGE THE ACCRETION OF SUSPENDED SANDS MOVING NORTH. HARDENED WATERWARD EDGE PROTECTS BREAKWATER AND SHORELINE FROM WAVE DAMAGE.

Seasonal Sediment Movements North



West Soundside Road

CHALLENGE

Challenge: This priority site for Town stormwater management has a mix of shoreline conditions and homeowner/municipal strategies to prevent further erosion. The Town owns a stormwater discharge point to the South of the state park. The Town owned neighborhood access road (West Soundside Road) is under constant threat from erosion and flooding. A riprap edge along the right-of-way was installed to offset any additional shoreline losses; however, the roadway is frequently flooded during storm events due to a low roadway elevation. Frequent private docks hamper the ability to work offshore and raise concerns about navigation and access needs.

PROPOSED APPROACH

Along this complex stretch of shoreline, the proposed solutions blend the living breakwater approach where there is adequate space, with shoreline conversion from a hardened edge condition to one that provides stability and vegetation/habitat value. This stretch of shore-

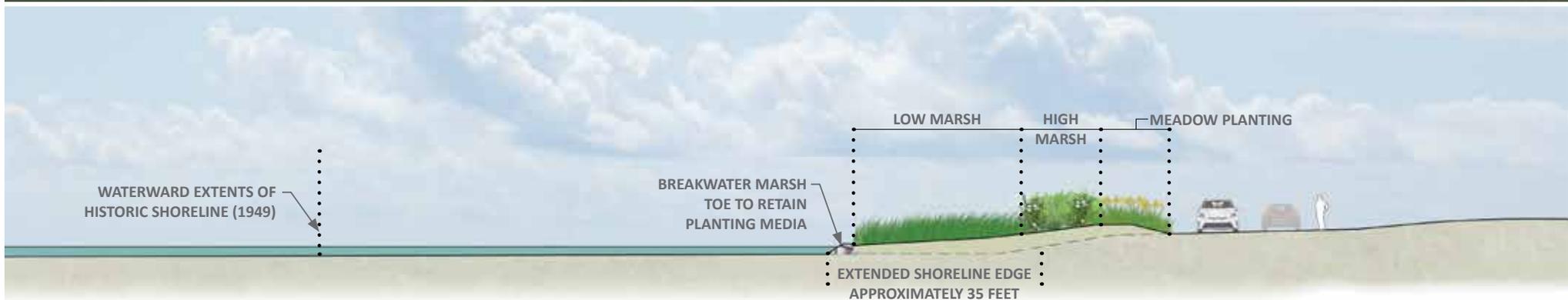
line is located south of Jockey's Ridge and, like the Nags Head Woods concept, is designed to harness the seasonal (southerly) sand flows using the Living Breakwaters. The breakwater structures are limited in location by the private docks and will only occur landward of the dock extents to minimize navigational hazards.

The areas that are reinforced with a riprap embankment will be converted (resiliency terracing) to a softer condition that can resist erosion, while providing habitat value. When applicable, material will be imported to extend the shoreline waterward and armored on the front edge with the stone aggregate. Multiple terrace plateaus to provide low slope heterogeneous habitat zones. Riser retention structures separate plateaus, while media ramp connections allow for migration between cells. In cases where stormdrain outfalls cause a conflict, either the resiliency terrace will be shortened, or the outfall infrastructure will be extended to meet terrace front edge.



West Soundside Road

Nags Head, NC



Harvey Sound Access

CHALLENGE

Because they are publicly owned, the event site that is shared by Dare County Tourism Board and the Town of Nags Head and the adjacent Town-owned Harvey site may be the logical first project to pursue. A new boardwalk network and upland pathway enhancement has been proposed for the area, by the Dare County Tourism Board, the major owner of the Event Site parcel. There are existing issues on site that include unregulated water access and trampling of the marsh leading to erosion, as well as some stormwater drainage impacts that appear to be hastening erosion. In addition, the eroding marsh adjacent to a local restaurant (Miller's Waterfront Restaurant) has been used for informal boat parking for patrons. Although this may hasten erosion, it is a cherished feature of the restaurant for many.

PROPOSED APPROACH

At this site, where public access is a critical feature, the management goals are to balance the availability of public access with restoring and sustaining a healthy marsh habitat. To accommodate this, a new boardwalk pathway that runs along the shoreline and connects the proposed boardwalk network plan with the Harvey Sound Park and

Miller's Waterfront Restaurant. A portion of the shoreline will be converted to a sandy beach to facilitate access, setup, and resting space for kite boarders and will be accessed via the new boardwalk connection. Even though the boardwalk is running along the shoreline, it can provide wetland benefits by attenuating incoming wave energy that accelerates erosion, in addition to reducing human compaction along the wetland edge. A final element will be the expansion of the sandy beach used for informal boat parking.

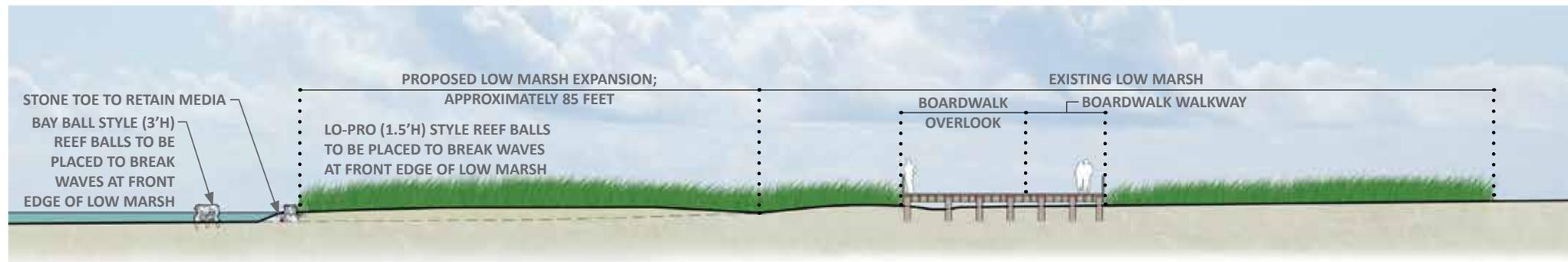
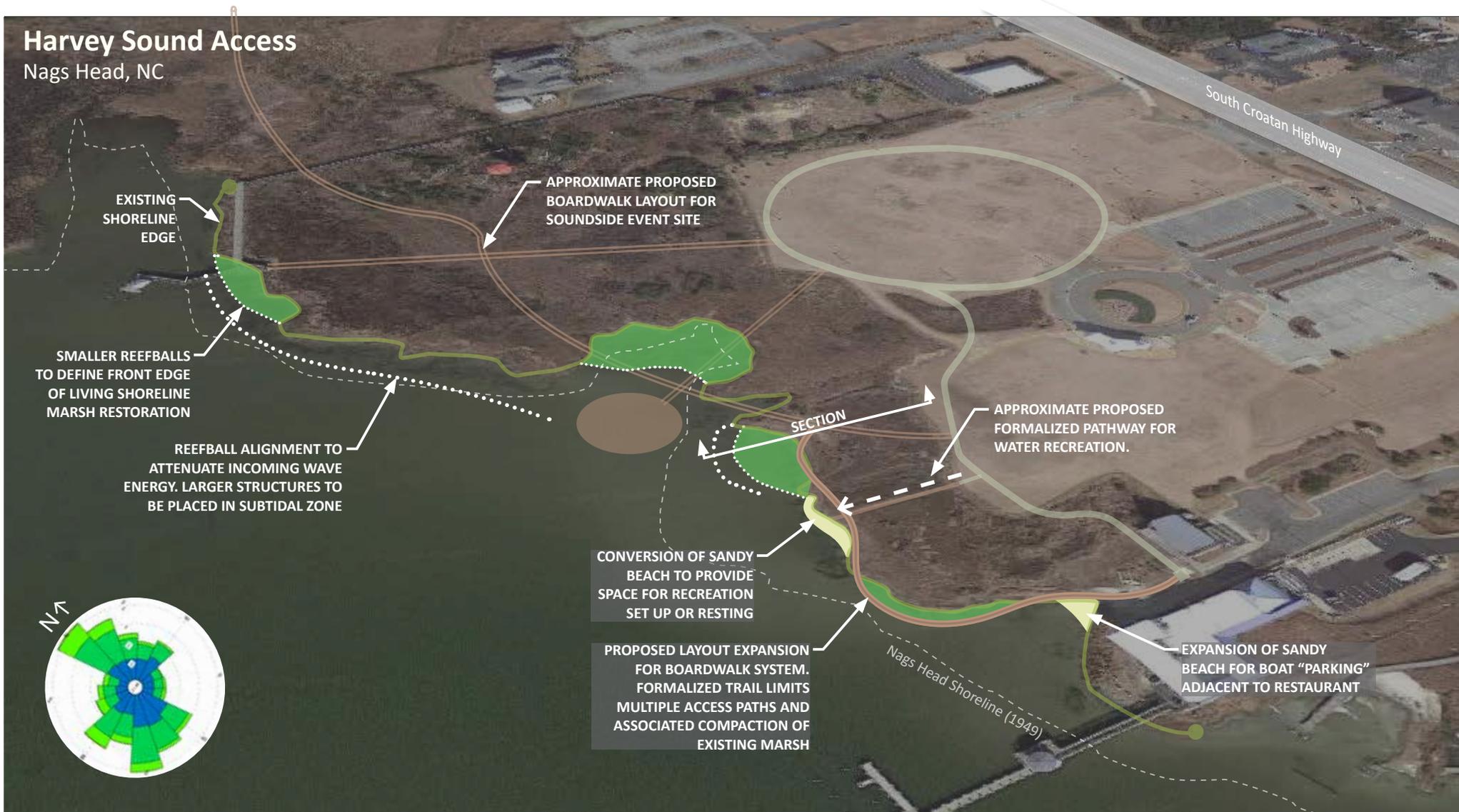
Several wetland areas along the shoreline have receded due to erosion and will be targeted for wetland restoration. Establishing a living shoreline will involve the import of fill material to achieve the desired elevations needed for marsh establishment. The design will implement a stone sill to retain the fill material, as well as wave attenuation structures, proposed as two different reef ball sizes, to protect against wave generated erosion and help potentially accumulate sand behind the structures.

A complex, highly visible restoration and access project here would also provide an opportunity for education and interpretation ranging from signage for visitors to interactive programs with local schools.



Harvey Sound Access

Nags Head, NC





IMPLEMENTATION



Implementation: Data & Design Process

WHERE WE ARE AND WHERE TO GO

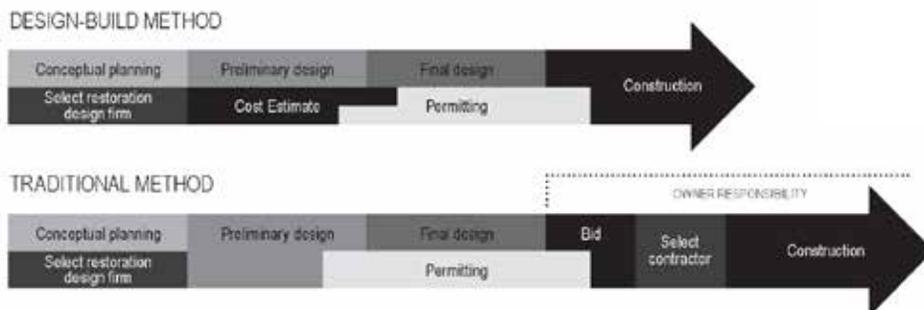
This Plan provides an overview of the threats and considerations for the Town's estuarine shoreline management, gives a menu of shoreline treatment options, and elevates three pilot sites where large-scale interventions could be facilitated by the Town. The pilot site concepts and supporting materials provide a strong basis for marshalling the resources and writing grants to move into the next phase of work. Once funding is secured, approved concepts can advance to the design phase, which will require additional site-specific detail and data collection, local wave energy models, survey, and some additional measurement of the key system parameters such as seasonal variation and local sediment load. The design phase will answer several of the questions posed here: exactly how much will it cost to build? What elements of the concept should be modified to obtain permits?

For smaller-scale treatments, such as a single-owner living

shoreline applications, the permitting pathway may be straightforward or allow a design-build approach (see diagram) where the permits are obtained by the contractors who finalize the design and take responsibility for construction. A traditional design-bid-build delivery method will be required for large and complex projects as outlined for the pilot sites, where design process is long and may need to be adjusted to meet permitting requirements.

In November 2022, the Town requested a scoping meeting with multiple regulatory agencies to share the fundamental approach of the ESMP and review their concerns about advancing the projects. Key items of feedback included:

- the Town should lead a joint application for permitting and the important coordination among property owners,
- riparian and navigational rights must be secure,
- carefully consider silt material, shellfish harvest, and plant material, and
- projects should minimize damage to protected submerged aquatic vegetation.



Implementation: Funding

COST ESTIMATES FOR COMPARABLE PROJECTS

Funding is a key factor in advancing any of the concepts or solutions in this plan, and estimates are difficult to produce because they vary widely by designer and inflation has destroyed the usefulness of previous experience. Additional local factors such as delivery of material to a site and ability to work from shore or barge can vary widely. For example, recent estimates for just the rock breakwaters for living shoreline range 300% from \$500-1500/linear foot.

Nevertheless, we can be certain that this is a propitious time for large-scale coastal protection efforts, with new local resilience funding coming online every year. Unfortunately there are also more municipalities competing for those funds than ever before. A coordinated plan and wide public support are competitive advantages in the funding landscape, as are nature-based solutions and innovative strategies.



Permitting

PERMITTING CONSIDERATIONS FOR ESMP

The NC Division of Coastal Management carries out the state’s Coastal Area Management Act (CAMA), the Dredge and Fill Law in North Carolina’s 20 coastal counties. They make permit decisions after considering agency and public comments, and after determining whether a proposed project meets CRC rules and the enforceable policies of the local government’s land-use plan.

The CAMA permit system is divided into major and minor permits. Major permits are necessary for activities that require other state or federal permits. Applications for major permits are reviewed by up to 10 state and four federal agencies before a decision is made. ESMP projects could also fall under general permits, which involve less agency scrutiny and are for less complicated and more repetitive types of projects.

Management Technique	Additional Information	Permitting*
Living Shorelines	<ul style="list-style-type: none"> Allows natural connections between aquatic environment and adjacent upland; preserves tidal exchange, sediment conservation, allows for marsh migration. Best for medium/low energy shorelines. 	General Permit <ul style="list-style-type: none"> Streamlined permits for routine projects. Issued by DCM field staff Permit issuance averages 5-14 days Projects that exceed general permit use standards may still be permitted through Major Permit process.
Bulkheads/Sea Wall	Hard armoring of the shoreline. <ul style="list-style-type: none"> A wall is created at the upland/marsh or upland/water interface and backfilled to raise upland. Holds the shoreline, keeping it static and may be best fit for high wave energy. Can cause erosion on subject & neighboring property Disrupt sediment movement and transport patterns. 	General Permit <ul style="list-style-type: none"> Streamlined permits for routine projects. Issued by DCM field staff. Permit issuance averages 5-14 days.
More complex projects that trigger additional permits	Serves as the application for other state and federal permits. <ul style="list-style-type: none"> The dredging and filling of water and/or wetlands fall into this category. DCM will issue a major permit if the project complies with the CRC’s standards for development in AECs, the local CAMA land use plan, and local development regulation. 	Major Permit <ul style="list-style-type: none"> NC DCM CAMA Major Permit. Permit application reviewed by 10 state and 4 federal agencies, involves DCM and USACE permit coordination. DCM provides coordination with other agencies on behalf of the applicant. USACE can use their USACE Programmatic General Permit 291 for CAMA Major Permits. Permit issuance averages 75-90 days.



Considerations for Future Opportunities

RESOURCES AND NEEDS

As we look to the future of estuarine shoreline management for the Town of Nags Head, several considerations and steps rise to the fore. Distribution and dissemination of this document and its supporting materials is important to the second goal of building public awareness of the risks to the current estuarine shoreline from sea level rise and storm events. The Town is acting to make this document widely available and present its findings at fora such as the North Carolina Beach and Inlet Waterway Association.

The National Fish and Wildlife Foundation, which funded this effort, has a funding structure designed to help communities work through a process that starts with plans, moves into design, and leads to implementation. In order to take advantage of the next opportunities, Nags Head will need to adopt the plan and open a conversation about staffing or match resources for future phases.

Building on the momentum of this work and the partnerships created will involve continuing to work with some of the key partners to understand data needs and fill gaps in our understanding. It will also mean starting to try to understand public sentiment on its proposed concepts. To position the town as a proactive leader with shovel-ready ideas and increase advantage in the funding competitions, the Town can begin to plan site-scale engineering and design development for sites of interest.

Finally, the Town and residents would benefit from a shared understanding of the regulatory opportunities around shoreline management, which are beyond the scope of this document. Widespread tools such as incentives for voluntary development setbacks, buffer regulations for estuarine shoreline properties, or bulkhead ordinances can be examined for feasibility and applicability in Nags Head.



Engagement Summary

ADVISORY COMMITTEE, TECHNICAL PARTNERS, AND PUBLIC INPUT

The Estuarine Shoreline Management Plan Advisory Committee was selected by the Board of Commissioners to represent resident, business owner, and land management interests along Nags Head’s estuarine shoreline. They provided guidance and feedback to Town staff and the Consultant Team on the development of the Plan. A variety of stakeholder engagement methods solicited feedback from the advisory group on overall long-term goals for estuarine shoreline management, stakeholders that should be engaged, education and outreach opportunities, criteria for project prioritization, identifying future land use concerns, policy and land use objectives, and managing public access. Meeting in tandem with the Advisory Committee and upon occasion for special concept review, the technical partners

included representation from Eastern Carolina University and the NC Coastal Federation.

INPUT TIMELINE

- 5 advisory committee meetings at plan development milestones
- May 2022: Initial public survey
- August 2022: Public workshop & survey II for pilot site selection
- Draft Plan Review & Adoption

ADVISORY COMMITTEE MEMBERS

Ralph Buxton

Ann Daisey

Bob Sanders, BOC Liaison

Joy Greenwood, Jockey’s Ridge State Park

Adnan Jalil

Cola Vaughan

Reide Corbett, ECU

Lee Nettles, OB Visitors Bureau

Randy Blanton

Molly Harrison

Lora Eddy, TNC

Diane Bognich, OB Visitors Bureau

Robert Netsch

Mike Kelly

Aaron McCall, TNC

Louisa Farr

Mike O’Steen

John Mebane, The Links



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Photo Credit: villagerealtyobx.com