SHORELINE PROTECTION OF HISTORIC AND COASTAL RESOURCES AT BRUNSWICK TOWN/ FORT ANDERSON

Phillip C. Todd,[1] Devon Eulie, PhD.[2]

ABSTRACT

The shoreline at the State of North Carolina's historic site, Brunswick Town/ Fort Anderson (BTFA), was in need of protection from constant tide forces and dynamic wave action. Colonial-era wharves are being destroyed, and precious artifacts from these buried colonial-era wharves are being washed into the Cape Fear River. The Civil War-era batteries are being undermined. Additionally, valuable *Spartina alterniflora* marsh platforms were being eroded. The NC Department of Natural and Cultural Resources (NCDNCR) seeks to halt the shoreline erosion in order to prevent the destruction of and additional wash of these buried colonial-era wharves, the Civil War-era batteries and the destruction of three other colonial era wharf sites.

Erosion on the banks of BTFA was first noted in 2008. In 2012, the NCDNCR attempted to arrest the shoreline erosion. The initial attempt was unsuccessful in arresting the erosion, and the NCDNCR struggled to protect these sensitive and historically significant resources from the adjacent high energy wave environment.

The Reefmaker (RM) concept was identified as a potential solution for the shoreline erosion in place of a traditional breakwater structure. The Reefmaker product provides several ecoservices and works in horizontally limited area whereas the breakwater structure does not provide these services nor would have worked in horizontally limited areas.

In summer 2017, Phase 1 was implemented involving 220 feet of RM along the highest eroded area of BTFA. Construction for Phase 2 (240 feet) was completed in early August 2018, prior to Hurricane Florence battering the project area for several days. The shoreline in these areas has been stabilized, and a new shoreline is being formed as the Reefmaker structure disrupts wave energy and allows for flushing which enables accretion.

The University of North Carolina Wilmington (UNCW) conducts project monitoring for the State of NC. Monitoring components include sediment accretion, vegetation establishment and wave energy measurements; including the approaching wave, wave transmission through the structure and reflected wave energy. UNCW established the project's baseline documentation in 2016, and began monitoring Phase 1 in August 2017. Quarterly monitoring reports are being generated by UNCW through summer 2018.

This paper will describe past stabilization methods of the historic site, document why the Reefmaker concept was the best solution for the BTFA site over a rock breakwater structure, note Phase 2 adjustments from lessons learned on Phase 1 and describe the monitoring results of the project to date.

INTRODUCTION

Brunswick Town/Fort Anderson (BTFA) is a state-owned historic site located on the west bank of the lower Cape Fear River in Brunswick County, North Carolina. The area has a historical interest related to colonial life in North Carolina as well as a Confederate fortification during the Civil Water. This protect historic site is administered by the North Carolina Department of Natural and Cultural Resources (DNCR) Division of State Historic Sites and Properties.

Erosion of the shoreline, including coastal marsh at BTFA, was first noted in 2008. DNCR sought to arrest the erosion to save the valuable natural and cultural resources from destruction and wash into the Cape Fear River.

To protect the cultural and natural resources of the BTFA state historic site, DNCR ultimately plans to control the erosion along the full shoreline of their property, approximately 4,925 feet of shoreline. Funding limitations has caused

[1] Project Development Coordinator; PO Box 10339 Wilmington, NC; 919-971-5641; p.todd@atlanticreefmaker.com
[2] Assistant Professor; 601 South College Road Wilmington NC 28403-5949; (910) 962-3230; eulied@uncw.edu

stabilization to occur in phases. The phasing of shoreline protection has been prioritized based on vulnerability of historic resources, and phases are implemented when funding becomes available.

HISTORICAL SIGNIFICANCE

Brunswick Town was established in 1726. The town was the first successful British settlement in the Cape Fear area of North Carolina. The town thrived as a major British port. Brunswick Town was the place of governance for two provincial governors. In 1776, during the American Revolutionary, the British raided the town and destroyed it. It was never re-built.

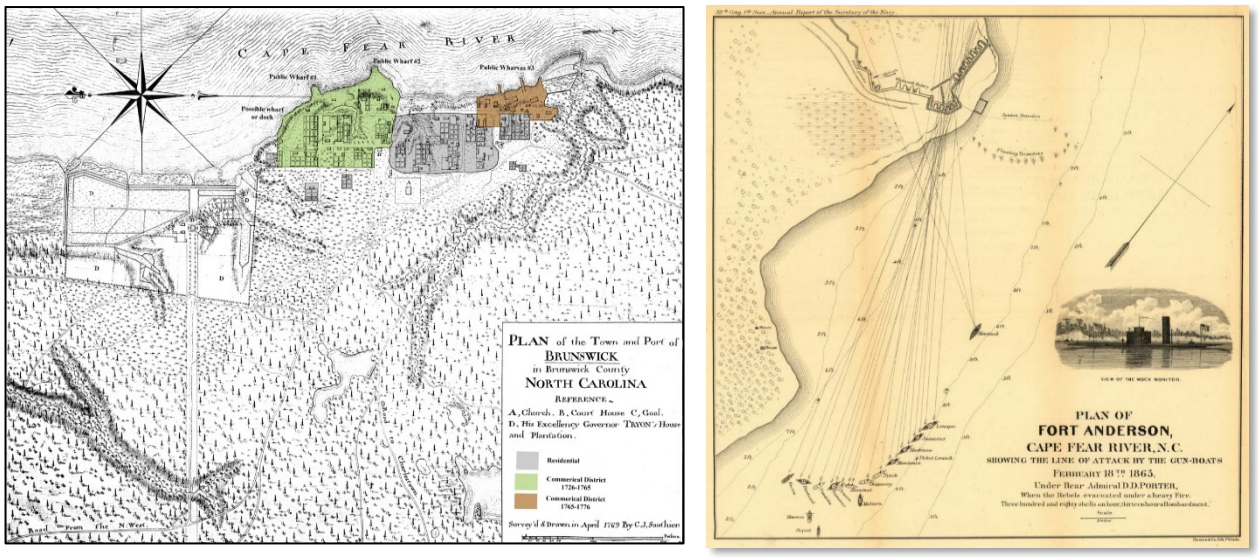

Figure 1. Historic Imagery of Brunswick Town/ Fort Anderson.

Construction of Fort Anderson began in March 1862 on top of the old Brunswick Town village. Fort Anderson was the northern most fort of a series of fortifications constructed by the Confederates along the Cape Fear. Their goal was to protect Wilmington, NC, a vital port during the Civil Water and located 10 miles upriver from Fort Anderson. The fort fell to the Union soldiers on February 17, 1865.

SHORELINE EROSION at BTFA

In spring 2008, BTFA staff noticed an increase in erosion along the site's river shoreline and coastal resources. The coastal erosion is accelerating and is quickly uncovering the colonial-era wharves and batteries. Many other historical archaeological artifacts, like colonial shoe buckles and Spanish clothing for example, are constantly being uncovered and lost.

DNCR sought to protect the historic resources and the site's valuable natural resources, *Spartina alterniflora* marsh platforms, which exist along the shoreline, from rapid shoreline erosion resulting from constant tidal forces and dynamic wave action (ship's displacement wave) at the BTFA historic site. The impacts of these constant tidal forces and wave action have resulted in the loss of 75-120 feet in tidal marsh since 2008. On-going shoreline erosion had exposed a buried colonial-era wharf that is rapidly being destroyed, was undermining Civil War-era earthwork batteries and threatening three other colonial era wharf sites and washing away the marsh grass.

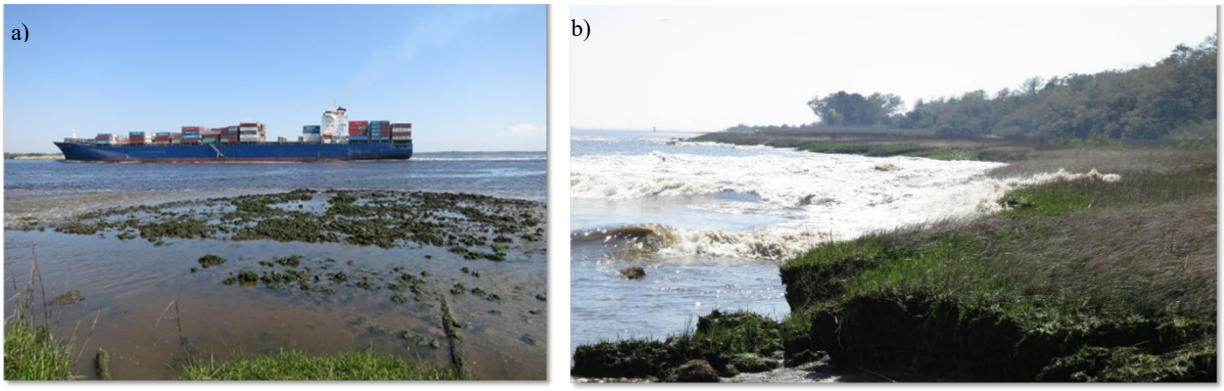

Figure 2. Cargo ship going into port (a) and picture of associated waves striking the escarped shoreline (b).

Research by archaeologist Stanley South identified at least four colonial wharves and two five-gun batteries along the BTFA shoreline. The continued existence of these wharves and batteries was, and continues to be, under grave threat without appropriate shoreline protection.

River Channel Modifications

In 2006, the United States Army Corps of Engineers (USACE) completed the task of deepening and widening the Cape Fear River from Wilmington to the Atlantic Ocean. The river adjustments were made to accommodate large vessel access to the Port of Wilmington, NC and created ship passing lanes directly in front of the BTFA Historic Site.

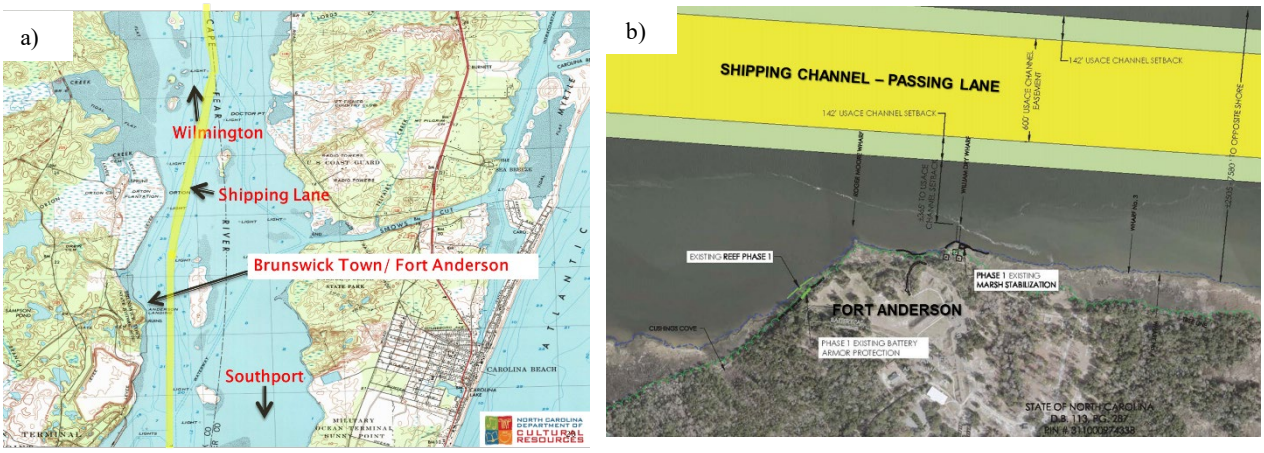

Figure 3. Vicinity map showing project location and shipping lane (a) and shipping lane relative to BTFA (b).

Emergency stabilization efforts

Emergency stabilization efforts were undertaken on July 30, 2012. The stabilization efforts were focused in the most critical areas of erosion threatening the known features of historical significance. The temporary efforts consisted of the installation of ~279 feet (one 179-foot section and one 100-foot section) of a rip rap revetment at the toe of (Civil War Fort earthen) Battery "A" and 500 feet of "Triton Marine Mattresses" as toe of marsh revetments along the shoreline near Colonial William Dry Wharf. The rip rap revetments and marine mattresses have helped abate some of the wave action along a section of the shoreline, but, overall, these protections are having limited success, and erosion was continuing.

Around William Dry Wharf, the marine mattresses followed the original scoured shoreline per local (Coastal Area Management Act [CAMA], the state's Coastal Zone Management Act agency, General Permit) NC coastal permit requirements. This installation created a section of the mattresses that were at a right angle. The orientation of shoreline protection concentrated wave energy along the William Dry Wharf timber area where a scour pool formed, accelerating the wharf timber exposure.

Waves overtopping the mattresses have scoured material in many areas from between the revetment and the marsh escarpment. Erosion was continuing unabated in areas without protection. The gap between the rip rap revetments at the toe of Battery "A" continued to experience erosion.

Planning Efforts for Permanent Stabilization Effort

The initial plan to protect BTFA involved a rock sill living shoreline. The USACE were consulted, and their engineers stated that a rock sill would have to be a minimum riverbed base footprint of 45 feet to handle the wave energy being confronted at the BTFA shoreline.

This type of shoreline protection would have worked along the Battery A shoreline, but there was not sufficient horizontal area to accommodate such a large rock breakwater at the historic wharfs where the original, natural river channel occurred (see Figure 4 and 5). At the wharfs, the river has a natural drop off, and the installation of a rock sill would have covered the coastal resources which DNCR sought to also save.

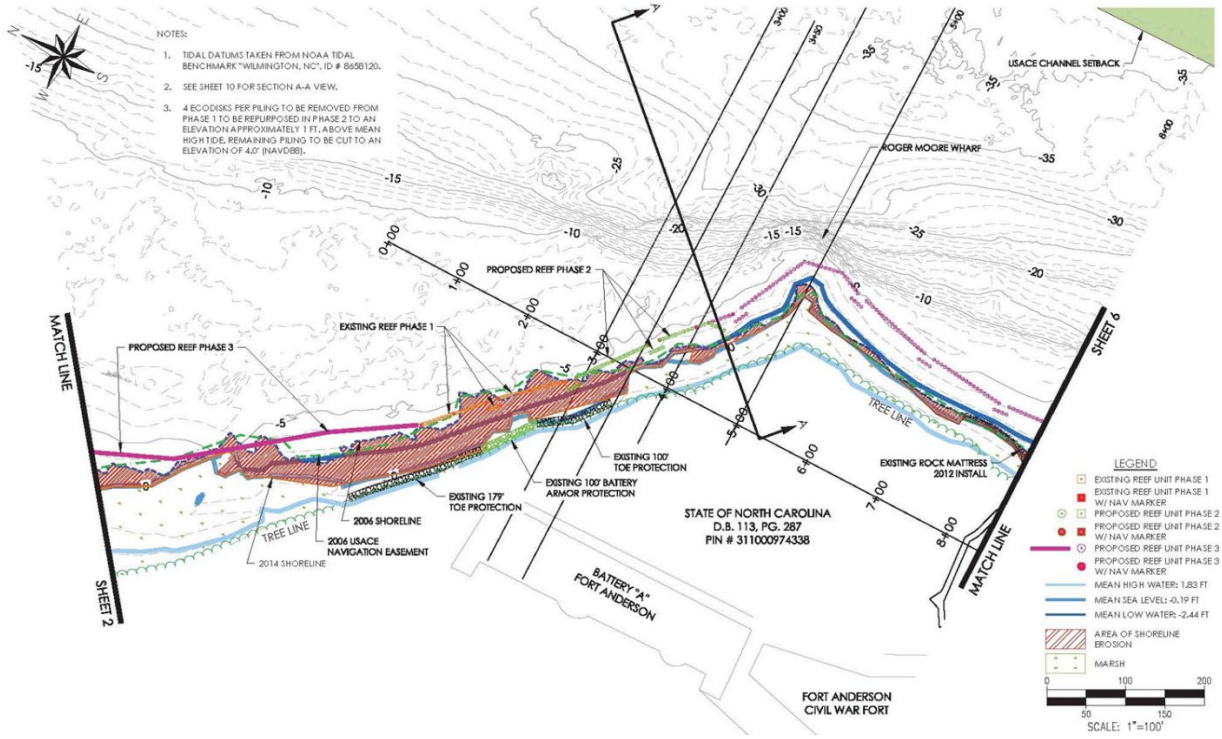

Figure 4. Bathymetric data and cross section locations.

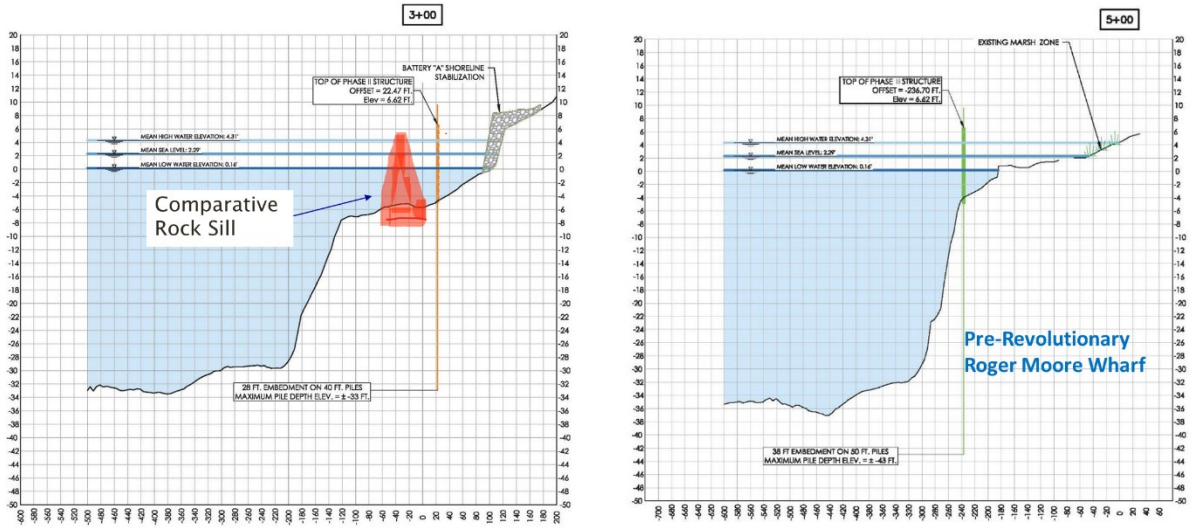

Figure 5. Cross Section 3+00 and 5+00 noting horizontally limited areas for rock sill & natural wharf.

Confronted with an emergency and limited time, Mr. Randy Boyd, currently working with Scenic Consulting Group, looked at adapting existing technologies and structures to solve the wave attenuation problem. It was quickly identified that passing ship's displacement, based on its tonnage and combined with its speed, was the primary source of the damaging waves. Requesting ships to just slowdown was not an option, as the BTFA's waterfront sits along the main channel's passing lane enables shipping traffic the ability to speed up and pass other slower moving traffic (see Figure 3).

While watching an episode of "Reef Wranglers", a Weather Channel television series, Mr. Boyd observed a potential solution to DNCR's problem as Walter Marine constructed an artificial reef structure in Florida. Within a couple of weeks, Mr. Boyd and a DNCR representative visited Walter Marine's facilities in Alabama. They quickly realized that Walter Marine's Reefmaker (RM) Ecosystem could be altered and engineered to dissipate high energy waves. However, Walters Marine had minimal engineering calculations or construction specifications to ensure that the system could handle a high energy wave environment.

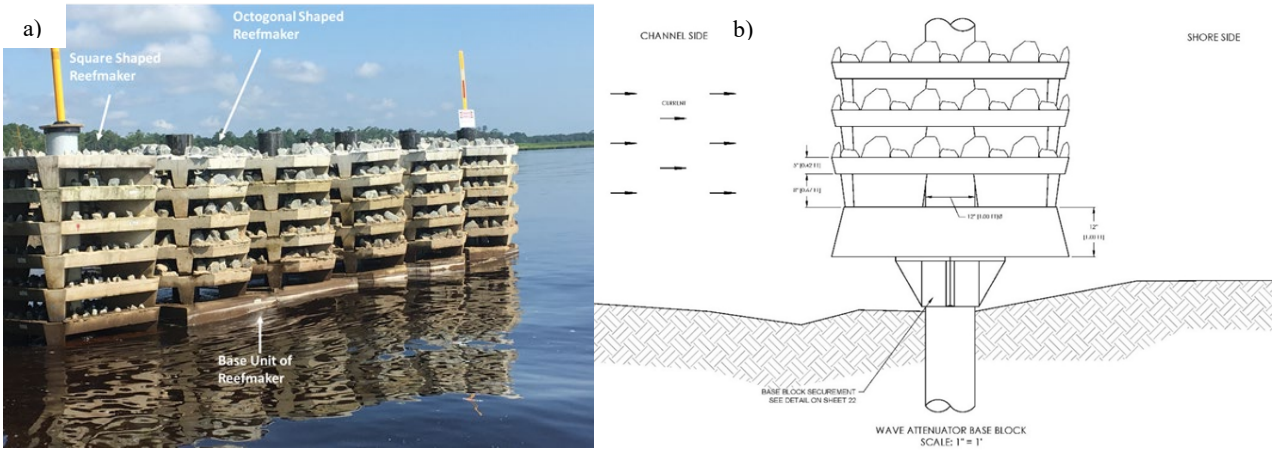

Figure 6. Photograph of Reefmaker (a) (square and octagonal) and image of structure from design plans (b)

Following six months of complex wave energy analysis, material strength analysis, geotechnical borings and design, pre-cast concrete design, concrete mix design and reinforcement considerations for saltwater environments, staff prepared drawings and specifications for a new high energy wave Reefmaker Ecosystem design. The plan drawings

and specifications were submitted to the NC State Construction Office for an extensive review by their structural engineering section. Following several engaging discussions, the NC State Construction Office's engineers approved the design for construction and commented on its ingenuity and innovated design as compared to conventional rock sill structures.

How the Reefmaker Concept Works

The Reefmaker RM concept includes individual ecodisks made of concrete that are stacked on a 12" diameter fiberglass pile. The Reefmaker concept is a water flow through wave attenuation system. The legs on the 'water front' side, or open water/river side of the structure, of the ecodisk tray direct water to the fiberglass piling. The piling speeds up the wave energy speed, and when the water reaches the 'landward' side of the structure, then the water exits the structure. The wave energy dissipates because the flow is no longer concentrated, and sediment in the water column drops out, accreting on the shoreline.

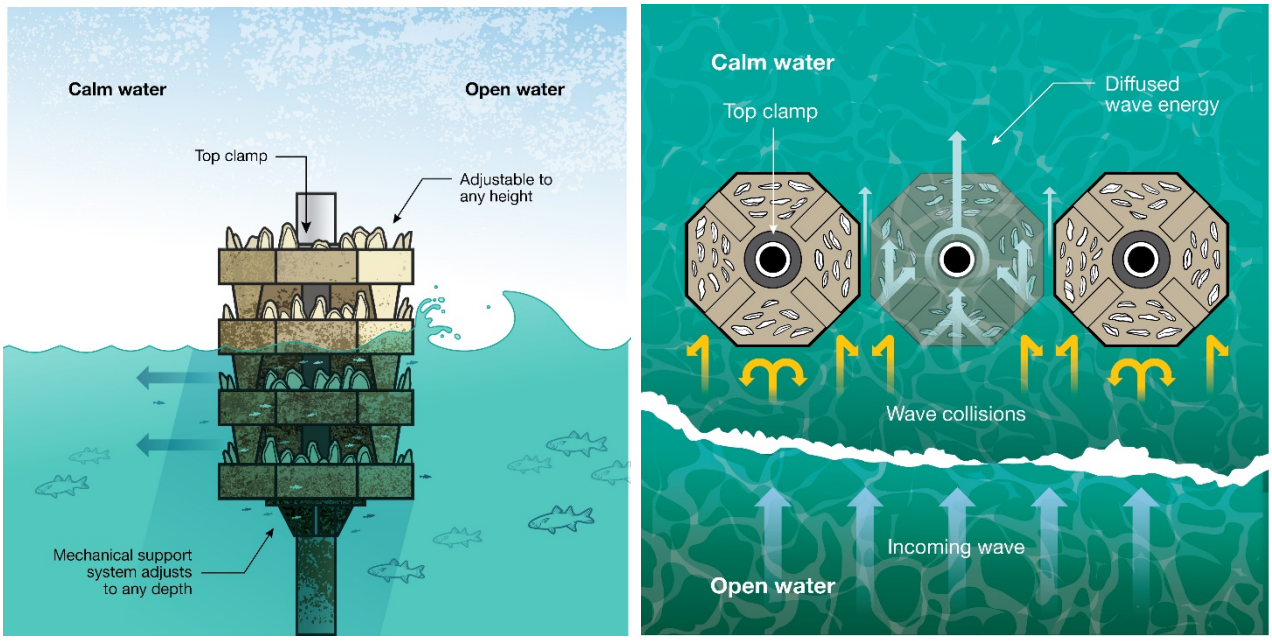

Figure 7. How the Reefmaker concept dissipates wave energy.

Why the Reefmaker instead of a Rock Breakwater Structure

The Reefmaker product provides several ecoservices and works in horizontally limited area whereas the breakwater structure does not provide these services nor would have worked in horizontally limited areas. Therefore, the Reefmaker system was selected as shoreline stabilization method for implemented and protection of BTFA.

There are other benefits to the Reefmaker in addition to its ability to be located in horizontally challenged areas. These benefits include:

- dissipation of destructive wave energy while allowing for tidal influence of the shoreline
- serving as ideal habitat for marine life
- sitting off of the substrate as the RM system is constructed on a fiberglass pile. Because the RM product is not constructed on the substrate,
    - it minimizes scour of the substrate in proximity to the structure; and,
    - it minimizes sand redistribution because the sand is allowed to flow through the product and along the substrate;
- flushing along the entire shoreline because the wave energy is allowed to flow through the RM product
- being designed to perform in high energy environments
- minimizing the project related 'foot print' to substrate. The impact to the substrate is from the 12" diameter fiber glass piling (0.785 ft^2/pile). Comparing the foot print impact of RM concept versus a rock breakwater structure, which are assumed to be 500' long:
    - a Reefmaker structure (~100 piles) would impact 78.5 ft^2
    - a Rock breakwater that is 500 feet long with 2:1 slopes would impact 10,000 ft^2
- allowing for modular construction, and therefore easy product expandability to accommodate sea level rise (SLR) and eliminate the need for any future environmental permitting as there would be no environmental impacts.

PHASE 1 STABILIZATION

Phase 1 stabilization at the BTFA shoreline involved 220 feet of the Reefmaker system and the installation of 200 feet of rip rap slope protection between two areas previously stabilized with rip rap. After Hurricane Matthew in 2016, the Reefmaker structure was positioned to protect Battery A which was deemed the most vulnerable area of the historic site. Construction began in July 2017, and it was completed in August 2017.

Figure 8. Phase 1 installation with ecodisks stacked to 2' above mean highest high tide.

The initial Phase 1 structure was installed with extra ecodisks. These disks were installed to the noted height, originally set to 2 feet above mean highest high tide, with the understanding that these extra ecodisks would be removed and re-purposed for Phase 2. Therefore, in the corresponding pictures, the structure height of the Phase 1 structure is substantially greater than ordinary high tide. Later photos show the structure height being set to the appropriate height, which is 1-foot above ordinary high water.

Lessons learned from Phase 1

After construction of Phase 1, staff with Atlantic Reefmaker made regular site visits to asses the effects of the product after its installation. Land and aerial photos of the structure and surrounding area were taken, and several changes were noted. One change involved the accretion of material between the Reefmaker structure and shore. The accretion in one area behind the structure grew to about 1 meter in height over the time of August 2017 to August 2018.

Perhaps the most telling part of the visits was from the drone videos of boat wakes associated with vessel traffic along the Cape Fear River. These videos showed how varied the interaction of wave energy from port bound and sea bound vessels was with the shoreline due to the orientation of the shipping channel relative to the shoreline (drone video of wave attenuation, sea bound vessels, https://drive.google.com/file/d/1HNPDp8ZwGIKjyHtmr_1j6V2-bboaf-1X/view from December 2017). Wave energy from sea bound vessels had a 'direct hit' on the Reefmaker structure. However, wave energy from the port bound vessels sent wave energy parallel to the shoreline and to the Reefmaker structure. The Phase 1 Reefmaker location rendered the structure ineffective from port bound vessels, and this resulted in the accreted material behind the Phase 1 structure being washed northward to its resting position between the northern section of the Reefmaker to the base of the north marsh platform. Staff with CAMA realized the problem, and allowed DNCR to install ecodisks that tied into the shoreline for Phase 2.

The understanding of wave energy hitting the shore and Reefmaker structure from variable angles led to an alignment adjustment. Instead of having the terminal end continue to be parallel to the shoreline, the decision was made to have the structure's terminal end at the south marsh platform be 'flared' back toward the shoreline. By flaring the structure toward the shoreline, the positioned Reefmaker would dissipate waves from port bound vessels and eliminate the wash of sediment upriver from behind the structure.

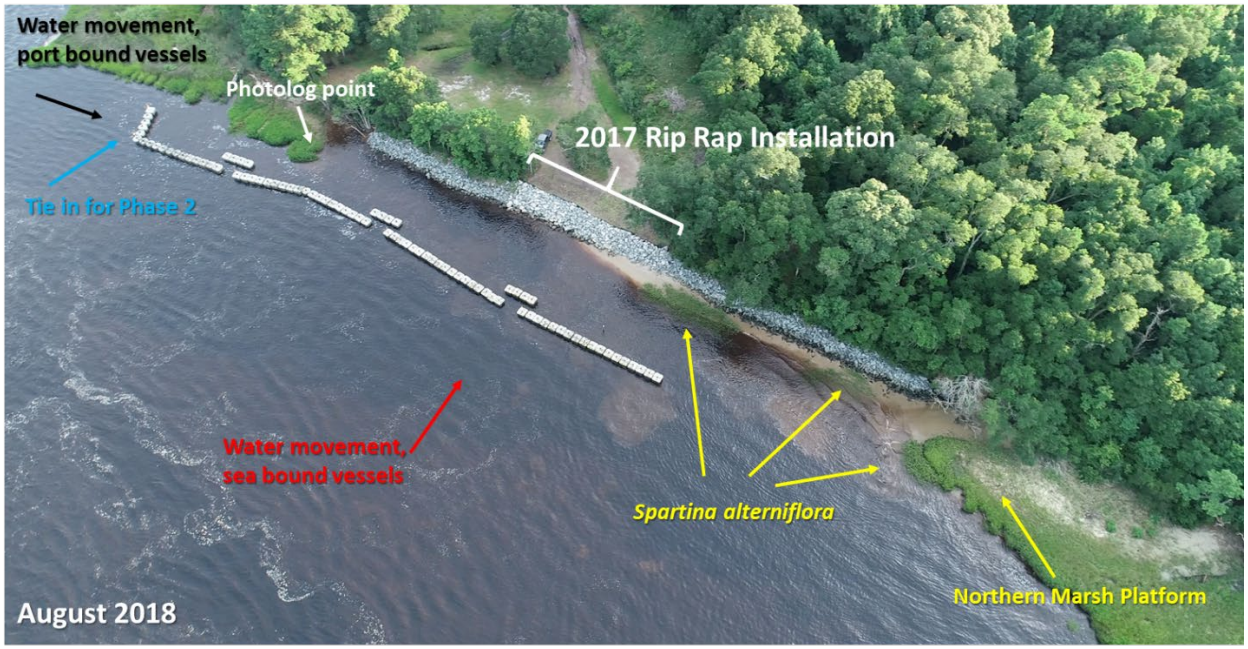

Figure 9. Aerial perspective of BTFA (Phase 1 & 2) with notations of interest.

Improving the Reefmaker Structure

After Phase 1, staff at Atlantic Reefmaker considered changes to the design of the product. The original design was a squared shaped ecodisk tray, and it weighed 1,600 pounds/ tray. An octagonal shape was developed, and the new tray weighs 1,300 pounds/tray. Additionally, the rebar scheduled was updated to accommodate the shape change and provide the required strength to handle wave energy from these ocean vessels. The updated octagonal shaped ecodisk tray does several things: it decreases the amount of required material to create an ecodisk, thereby reducing the product costs; it allows for wave energy dissipation from ship waves that approach the structure at different angles and for

these waves to be reflected back to the open water; and it enables unlimited geometric alignment configurations along the shoreline, eliminating a 'straight line' effect (a visual improvement) and channel scouring.

PHASE 2 STABILIZATION

Phase 2 involved 240 feet of RM installation. Construction began in June 2018, and it was completed in late July 2018. During implementation, the extra ecodisks from the Phase 1 structure were moved and installed for the Phase 2 structure, being set at height of 1-foot above ordinary high water. The ecodisk trays at the lower end of Phase 2 structure were octagonal shaped. The alignment at the Phase 2 structure terminus involved constructing the structure to flare toward the shoreline to dissipate wave energy from port bound vessels (see Figure 9).

Figure 10. Phase 2 installation with ecodisks from Phase 1 re-purposed for Phase 2

MONITORING

Past Storm Events

The Reefmaker structure at BTFA has experienced several storm events. There were no significant storm events in 2017, but 2018 was a different story. The structure was tested as it withstood the several high tides with pounding storm surges and flooding associated with Hurricane Florence's landing in September 2018. The structure sustained no damage from the storm event, and the accreted sediments appeared to remain behind the structure even after the 3 weeks of flooding along the Cape Fear River.

Figure 11. Photograph of Phase 1 structure and accreted area

Changes noted after Phase 1 stabilization

After completion of Phase 1 (220 feet of Reefmaker structure), staff at BTFA and Atlantic Reefmaker noted how the structure immediately attenuated shipping traffic's displacement wave energy and stabilized the shoreline directly behind the structure. Within 3 months after Phase 1's completion, accretion was noted behind the structure. A photopoint was established in October 2017, and, on a regular basis, photographs are being taken to note the changes behind the structure.

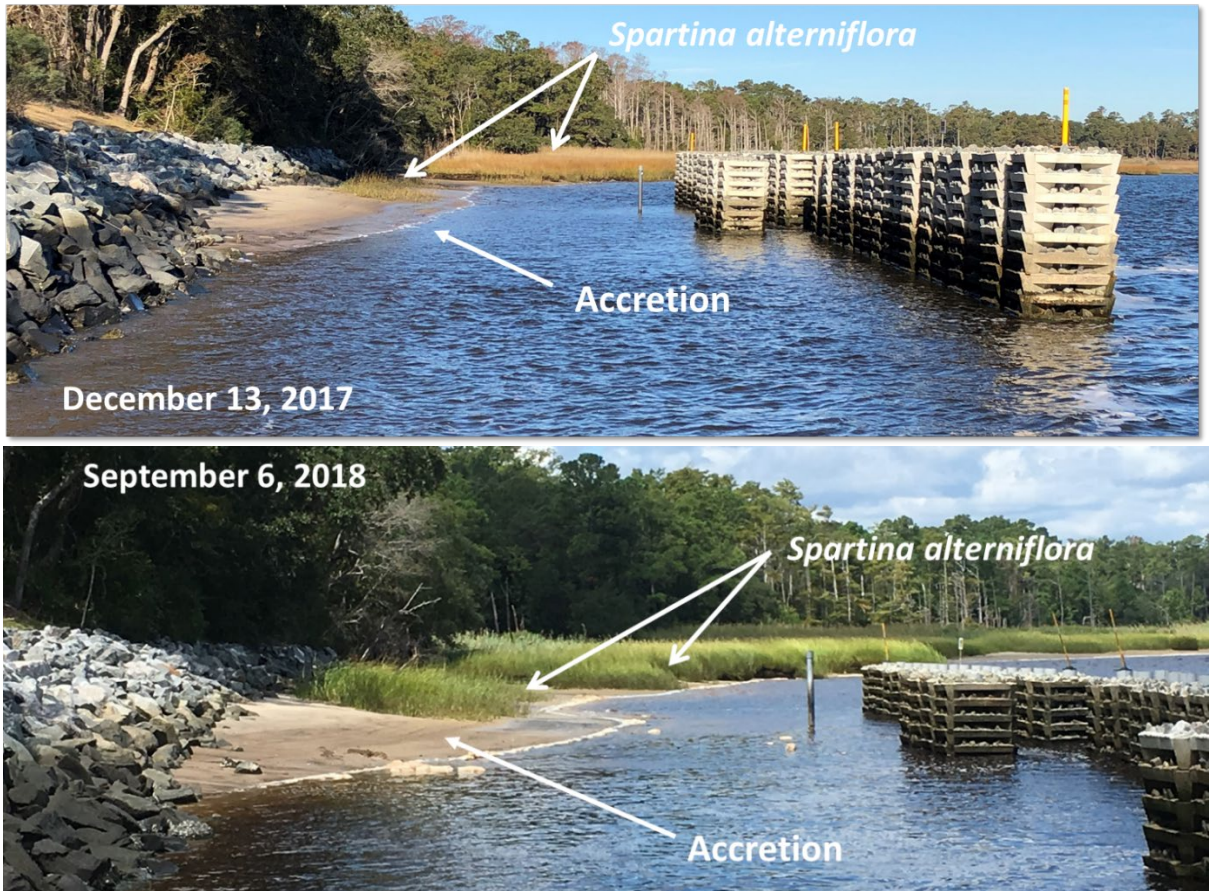

Figure 12. Photolog of accretion behind the Phase 1 structure.

Photographs of the project area also capture changes in *Spartina alterniflora* populations behind the structure.

Figure 13. Photographs of *Spartina alterniflora* over time at the project site – March 2016 to September 2018.

Changes noted after Phase 2 stabilization

Since completion of Phase 2 (240 feet of Reefmaker with flank tie in) in late July 2018, there has been several noted changes regarding accretion. The sediment captured on the north end of the project, corresponding primarily to Phase 1, has become more distributed behind the structure.

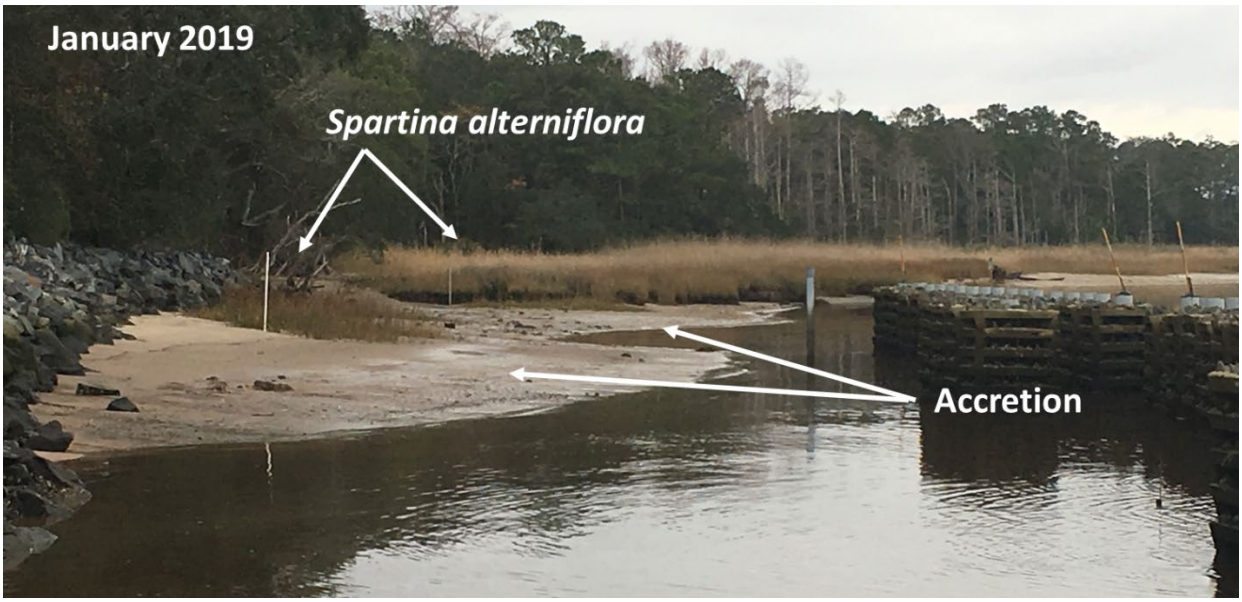

Figure 14. Greater distribution of accretion behind Phase 1 structure.

There has been accretion behind the area of Phase 2 installation. Without a flank associated with Phase 1, a scour area developed on the southern side of the Phase 1 structure. This area has been accreting after the construction of Phase 2 because wave energy from port bound vessels is not scouring the area.

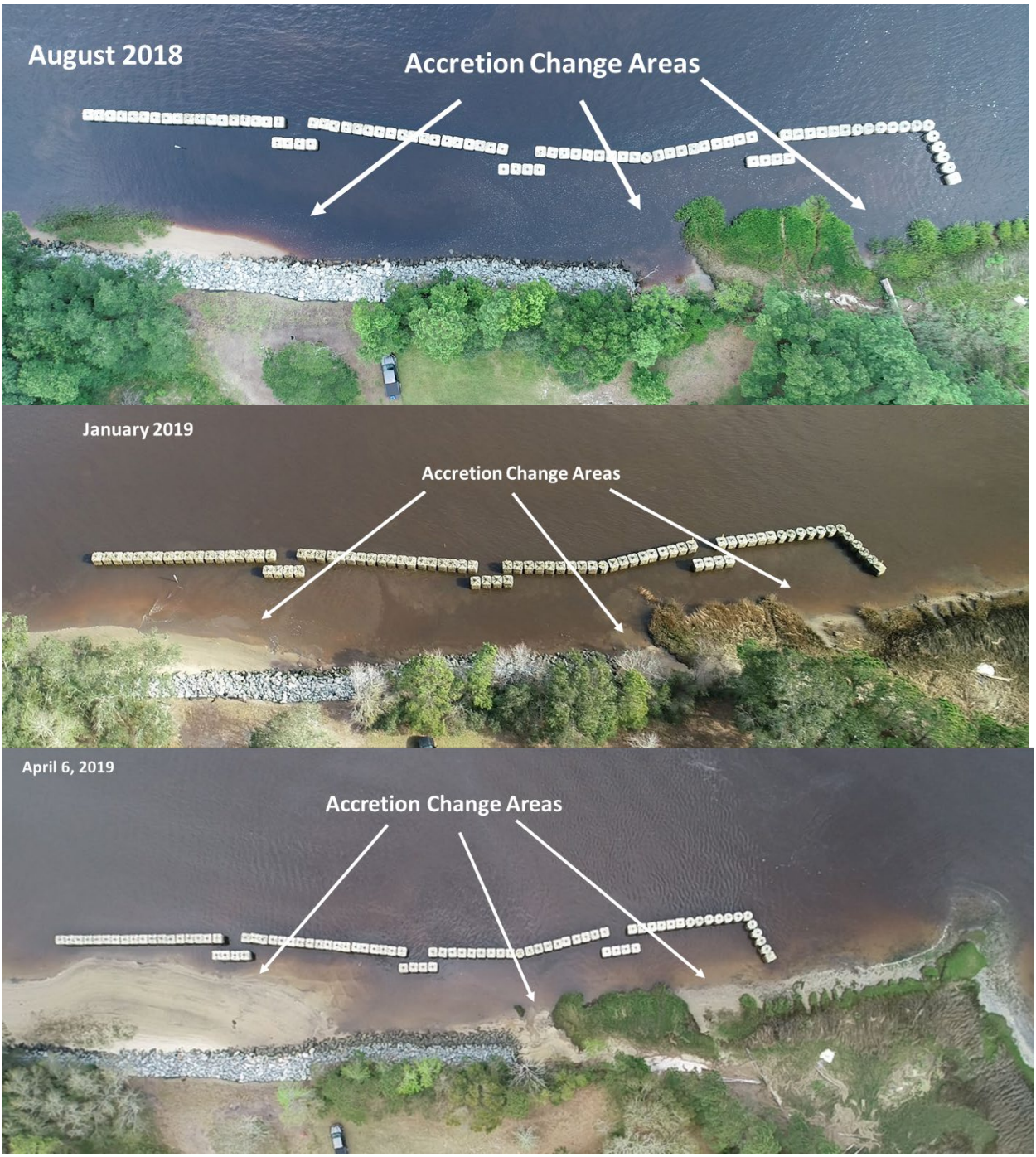

Figure 15. Accretion changes after completion of Phase 2.

Mapping of shoreline changes

The following images note how the shoreline has changed at BTFA.

Figure16. Shoreline change from July 2017 to April 2019.

Figure 17. Presence/absence of wetness from ship wake

Habitat for marine fauna

Staff at BTFA have noted a greater number and abundance of marina fauna since installation of the Reefmaker structure. Structure has become a premier fishing spot on lower Cape Fear River attracting schools of striped mullet and creating ideal habitat for flounder, channel bass, striped bass, and blue crab populations.

Figure 18. View of structure at high tide. Phase 1 is furthest away in this picture.

Figure 19. Sessile fauna recruitment to the structure.

Future monitoring

As part of the Phase 2 grant, money was set aside for monitoring the structure and its effects upon the shoreline at BTFA. The University of North Carolina Wilmington (UNCW) conducts project monitoring for the State of NC. Monitoring components include sediment accretion, vegetation establishment and wave energy measurements; including the approaching wave, wave transmission through the structure and reflected wave energy. UNCW established the project's baseline documentation in 2016, and began monitoring Phase 1 in August 2017. UNCW conducts quarterly monitoring of the site. The current funding of the site monitoring extends through early summer 2018.

CONCLUSIONS

The Atlantic Reefmaker has stabilized the shoreline at Brunswick Town/ Fort Anderson. The natural and historic resources are no longer being washed away in areas where the Reefmaker has been installed, and shoreline in these areas is no longer being pummeled by constant tidal forces and dynamic wave action. The shoreline at BTFA is accreting, and marina fauna are using the structure as habitat.