Living Shorelines along the Georgia Coast

A summary report of the first Living Shoreline projects in Georgia

GEORGIA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESOURCES DIVISION

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Living Shoreline
Summary Report

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The Project Team responsible for the guidance, direction, and implementation of the living shorelines projects described in this document consisted of: Jan Mackinnon, Georgia Department of Natural Resources, Coastal Resources Division, Biologist; Christi Lambert, The Nature Conservancy, Georgia Marine and Freshwater Conservation Director; Dorset Hurley, Sapelo Island National Estuarine Research Reserve. Research Coordinator, Senior Marine Biologist; Fred Hay, GADNR: Wildlife Resources Division, Sapelo Island Manager; Scott Coleman, Ecological Manager, Little St. Simons Island; Tom Bliss, University of Georgia Marine Extension Service;Conservancy; Alan Power, PhD, University of Georgia; These projects and this report have been made possible by their significant contributions and energies.

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LIVING SHORELINES

Introduction

A living shoreline is a sloped, erosion control technique built to protect an embankment which: mimics natural habitat; provides increased opportunities for species diversity and productivity; and can serve to improve water quality and the ecological integrity of the area.

Generally, sloped erosion control techniques use hard materials placed in such a way as to absorb the energy of incoming water and reduce erosion. The intent of living shorelines is to use materials, such as oyster shells, that do not serve as a barrier to native species but rather encourage the recruitment and growth of such species. The proliferation of these species, such as living oysters, can, in turn, further aid in the stabilization of the shoreline through the natural cements created by the organisms as they adhere to one another and to the embankment. Living shorelines also incorporate native plant species, such as marsh grass (*Spartina*, sp.), which establish extensive root systems and further aid in the stabilization of the embankment soils and the formation of habitat. Some predict that the self-perpetuating adhesion, root systems, and plasticity of living shorelines will allow them to be more permanent than traditional walls and to adapt more effectively to changing sea levels and storms.

Through the promotion of native species and habitats, living shorelines can preserve and enhance the ecological integrity of the coastal environment. In general, these environments provide essential water filtration, habitat, and recreational and commercial opportunities in coastal Georgia. Oyster reefs, such as those created by living shorelines for example, provide up to $100,000/hectare through water filtration, habitat, bank stabilization, and harvesting potential (Grabowski 2012). A study in 2011 also indicated a 38% increase in fish abundance at a constructed oyster reef site as compared to a control site. Marsh grasses have been shown to reduce nutrient pollution by >90% and provide over $6,000 in nutrient reduction services per acre per year in eastern Florida. Together, these coastal marsh environments comprise one of the most productive ecosystems on earth, accounting for the production of 10 tons of dry organic material per acre per year (Odum 1961). The aesthetic appeal of these environments and their opportunities for recreation also draws millions of tourists each year and help to bring $1.9 billion to coastal Georgia each year.

This guidance document will focus primarily on the design, methods, application, viability, and effects of living shorelines in coastal Georgia, with specific reference to the construction and monitoring of living shorelines on Sapelo Island and Little St Simons Island.

Background

The discovery of Georgia's unique coastal resources has driven explosive population growth in its six coastal county area since the 1990's. Bryan and Camden counties located on the Georgia coast were among the fastest growing in the nation from 1990 to 2000, more than doubling in population, and McIntosh and Liberty counties grew at fourteen percent during that same period. Additional growth will continue over the next two decades, increasing the coastal population to about 844,000 people, according to a report produced by Georgia Tech's Center for Quality Growth and Regional Development (Georgia Institute of Technology 2006).

Tourism has also increased significantly in recent decades as the nation's population and its interest in coastal Georgia have grown. In 1997 the Georgia Department of Industry, Trade and Tourism reported more than $1.9 billion was generated by tourism in the state's Region 9 (which includes the coastal counties), making tourism the region's second largest economic driver (behind import/export trade). Sport fishing remains an important component of tourism revenue according to the Brunswick and Golden Isles of Georgia Visitors Bureau. According to the Fish &Wildlife Service in its 2006 National Survey more than 87% of outdoor recreation activity revenues come from sources other than hunting and fishing, such as bird watching, boating, and hiking (USFWS 2006).

In addition to the aesthetic appeal of coastal Georgia's natural landscapes, commercial fishing, crabbing, and oyster harvesting have also provided an economic base for coastal communities. In 1908, for example, 8 million pounds of oyster meat was harvested in Georgia (Grabowski *et al*, 2012). Currently, the shrimping and shellfish industries combined are multi-million dollar industries in Georgia.

Coastal Georgia's natural resources also provide tremendous value in ways that are less obvious to the general public such as water filtration, bank stabilization, and by serving as the backbone of the eco-system. Totaling 368,521 acres, Georgia's coastal marshes represent almost one third of all the remaining salt-marsh along the east coast of the United States and are among the most the extensive and productive in the country (GA DNR 2012). Marsh edge habitat is critical to benthic crabs as molting and spawning refuge, for shrimp as foraging habitat, and for oysters for optimal settlement, recruitment and growth. Oyster reefs found within marsh edge habitat are also considered essential fish habitats and in turn support birds, marine mammals, and other wildlife. Additionally, each adult oyster filters approximately 48 gallons of water per day and each hectare of oysters can reduce water treatment costs that would otherwise be borne by state and local governments by $6,000 to $10,000. Through natural cementing, wave dissipation, and erosion reduction, each hectare of oysters can also provide shoreline stabilization services of approximately $90,000 (Grabowski *et al*, 2012).

Real estate development accounts for a significant portion of GA annual Gross Domestic Product; ecotourism draws millions of people to the coast and billions of dollars in tourism-related revenues each year; fishing and crabbing opportunities directly employ many thousands and support an active sport fishing industry; and salt marshes provide inestimable water filtration and treatment services for dozens of major rivers that drain most of Georgia.

But, in spite of the invaluable commercial, aesthetic, and environmental services provided by natural shorelines, these environments have been threatened and, at times, severely damaged by human activities (such as pollution and habitat loss) and the increased erosional effects of sea level rise in

Georgia. The earning potential of the commercial oyster industry, for example, was decimated in the early part of the 19th century when overharvesting reduced populations by over 85%. Only 21,842 pounds of oyster meat was harvested in Georgia in 2012, compared to eight million pounds of oyster meat harvested in Georgia 1908. In 1910, three million pounds of oyster meat was harvested in Georgia. (Harris 1980) (CRD)

CRD is interested in studying living shorelines in an effort to learn more about how they stabilize tidal creek banks as well as the biological communities that they support. While traditional bulkheads and revetments may be effective at reducing erosion and upland loss, they often times minimize habitats that are essential to shorebirds, fish, and shellfish. Hardened shorelines have been identified as priority threats to marine system habitats in the St. Mary's-Satilla-Cumberland Island Estuarine Complex through work conducted by The Nature Conservancy (DeBlieu *et. al.* 2005). There are varying opinions regarding the effectiveness of these structures to effectively absorb wave energy due to their hard and sometimes vertical nature, which may cause increased erosion of lower or adjacent embankments. This deflected wave energy and erosion in some locations has also been shown to eventually undermine the structures themselves and result in structural failure and amplified upland loss (Alexander 2010, Berman 2005 and Byrne 1995).

One of the most effective means of reversing these trends and improving the natural and economic health of Georgia's coast may be through the implementation of living shorelines and their associated restoration of oyster and marsh habitat. Some of the benefits of living shoreline compared to traditional stabilization methods are listed below in Table 1.

Table 1. Comparison of Traditional Shoreline Stabilization and Living Shorelines

Traditional Armored Shoreline Stabilization	**Living Shoreline**
Bulkheads, rip rap, revetments, jetties	Marsh plants, oyster shell, (recycled) rip rap
Deflects wave energy, shift erosional forces	Absorbs wave energy, reduces erosional forces
Reduces availability of intertidal habitat niches	Provides a robust intertidal habitat platform for colonization and enhanced biodiversity
Provides minimal filtering properties	Filters pollutants and nutrients
Obstructs water- to-land faunal migration	Provides a faunal-friendly slope for trans-ecozone migration

TNC, 2013

"Living shorelines are crucial to habitat development and to the conservation of fish, birds and other wildlife. We must continue to promote these kinds of restoration activities as they are vital to sustaining the delicate ecological system."

-Tom Kelsch, Director of Conservation Programs for the National Fish and Wildlife Foundation

Pre-construction. 2009. Sapelo.

Post-construction. 2010. Sapelo

Post-construction. 2013. Sapelo

"Living shorelines provide erosion protection benefits and essential habitat for living resources ."

-Keith Campbell, Foundation for the Environment:

Objectives

In response to an increasing demand for shoreline stabilization and to help Georgia meet the ongoing challenge of protecting and enhancing its living estuarine resources, the partners established the following goals.

- To test a number of potential living shoreline methods in the interest of identifying an optimal shoreline stabilization method that does not rely on conventional hard armoring practices.
- To develop an erosion control technique that effectively protects the intended embankment and: mimics natural habitat; provides opportunities for increased species diversity and productivity; and can serve to improve the water quality and ecological integrity in the area.
- To establish living shoreline demonstration sites that would provide opportunities for education, promotion and dissemination of the living shoreline study results.
- To quantify ecological results from different treatments of living shoreline types.
- To explore and communicate effective techniques for shoreline stabilization and the benefits of living shorelines in Georgia.
- To positively affect policy regarding coastal shoreline stabilization by applying verifiable scientific evaluation methods to a recognized policy need.
- To build capacity through partnerships and stakeholder involvement for shoreline habitat enhancement.

In order to achieve the above goals, the Georgia Department of Natural Resources sought and received funding from EPA in 2006 to design, construct, and study two living shorelines on Sapelo Island. Also during this time, The Nature Conservancy received funding from NOAA to investigate living shorelines in coastal Georgia. Together DNR and TNC formed a partnership with other entities to plan living shoreline demonstration projects for coastal Georgia.

LIVING-SHORELINE DEMONSTRATION PROJECTS

Overview

In order to achieve the objectives listed above, a living shoreline demonstration project on Sapelo Island was planned and designed from 2006-2009, and implemented from 2010- 2011. The project includes living shoreline applications along two reaches of eroding shoreline along Upper and Lower Post Office Creek. The northern site, known as the Ashantilly Site, spans 370 linear feet, and the southern site, known as the Long Tabby Site, spans 270 linear feet. The final project designs included combinations of: gabions filled with oyster shell, oyster shell bags, and stone; loose stone and oyster shell bags; and appropriate coastal wetlands and native plantings. Additional information regarding the methodology is included in following sections.

The project included a three year pre- and post- construction monitoring component, designed and conducted by the University of Georgia, Marine Extensive Service (MAREX) and the Sapelo Island National Estuarine Research Reserve (SINERR). The scientific data generated quantifies the ecological effects and efficacy of the various experimental engineering approaches used.

The Sapelo Island project was funded in part by the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the Coastal and Wildlife Resources Divisions of the Georgia Department of Natural Resources, The Nature Conservancy, and the Sapelo Island National Estuarine Research Reserve.

In 2013, a living shoreline project was also completed on Little St Simons Island in cooperation with the owners of Little St Simons Island, the University of Georgia Marine Extension Service, The Nature Conservancy, and the Coastal Resources Division of the Georgia Department of Natural Resources. The project involved the removal of a failing bulkhead and the installation of a living shoreline. Principals and findings of the Sapelo project were incorporated in the design and construction, as were novel approaches that were specific to the new site and intended to improve on the previous methods used on Sapelo. The project was funded by the Southeast Aquatic Research Partnership, NOAA, and the owners of Little St Simons Island.

The completed stabilization projects provide information regarding living shoreline design and construction considerations, cost estimates for project materials and construction, and case studies for physical and biological monitoring. The project also provides information for coastal resource managers and private property owners about stabilization methods that can achieve a balance between property protection and ecosystem conservation, enabling improved planning and decision making.

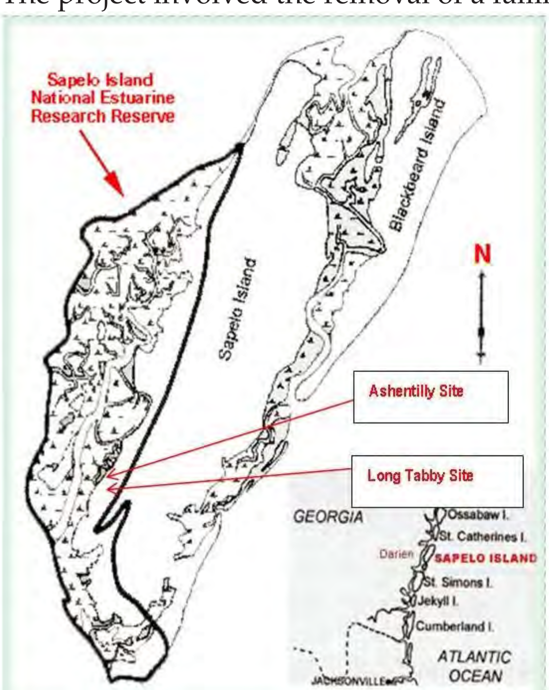


Figure 1. Site map showing experimental site locations. Ashantilly and Long Tabby.

Planning and Design

Initial steps in the planning and design of the living shorelines involved: 1) the selection of the appropriate sites; 2) the evaluation of appropriate stabilization techniques; and 3) the design of the living shoreline plans.

Site Selection

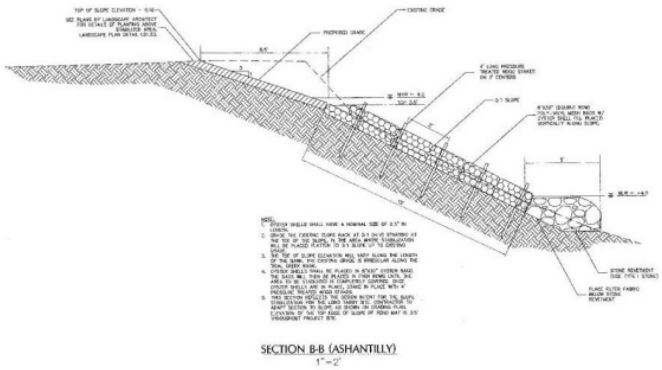
On Sapelo Island, two locations were selected for restoration and experimentation along the western edge of the island where Post Office Creek directly contacts the upland. These locations were selected due to the high rate of upland erosion that was occurring at each site and the proximity of valuable infrastructure and buildings to the active erosion. The sites were generally characterized by sheer banks with little to no marsh vegetation and an average tidal range of 8'. The Living Shoreline Partners team determined that the location of the embankment within the intertidal range and the presence of sufficient living oysters indicated the feasibility of the project with respect to its intended oyster reef establishment. These sites were also selected based on their significant exposure to island guests and educational potential.

On Little St Simons Island, a location was selected at the primary access point to the island along Mosquito Creek due to the fact that the existing bulkhead was failing and in need of significant repair or replacement. The site was also selected as a result of its significant exposure to island guests and its educational potential.

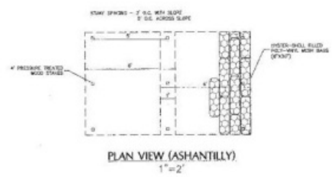
Stabilization Techniques

Shoreline stabilization techniques in Georgia, South Carolina, and North Carolina were examined for feasibility. These techniques included conventional hard-armoring methods such as bulkheads and stone revetments, as well as potential living shoreline designs. Conventional methods were found to be inappropriate for ecological, structural, aesthetic, and educational reasons.

Design - Ashantilly Site - Sapelo Island (See Appendix A for larger construction drawings)



Detail of Ashantilly Site plan including oyster bags, stake, geotextile, and rip rap placement (See Appendix C for larger plan)



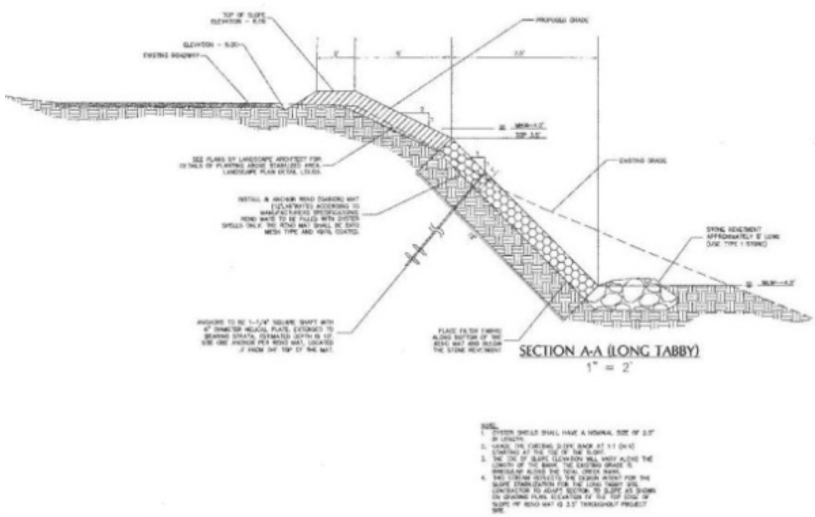
The design selected at the Ashantilly site on Sapelo Island involved the application of "soft" armoring techniques consistent with the funding requirements of the EPA and the guidance on living shorelines from NOAA. The plan involved the shaping of the embankment to a slope with a 2:1 run over rise and placement of two layers of bagged oyster shell on the embankment. The slope is essential in most locations to create the proper zone for oysters and vegetation. The oyster bags consisted of loose oyster shell placed in poly-vinyl mesh bags measuring approximately 8 inches in diameter and 20 inches in length. On the bottom layer, bags were oriented horizontally to the slope gradient, in the second (top) layer the bags were placed perpendicular to first layer in order to create zones to enhance oyster spat settlement. Stakes measuring 2" by 2" wide and 36" long were driven into the embankment every 3 to 5 feet in order to help prevent the downward migration of the oyster bags.

Ashantilly site construction photo

Detail of Ashantilly site oyster bag placement

Geotextile fabric (an extremely durable woven plastic fabric) was installed on the lower embankment and a five foot wide area of surge stone was placed on the geotextile. Surge stone, also known as #1 rip rap, consists of large granite stone weighing approximately 125 pounds each and measuring 24" in diameter. The design included plantings at the top of the embankment of low and high marsh vegetation, as well as appropriate native upland grasses and shrubs.

Design **-** Long Tabby Site - Sapelo Island (See Appendix A for construction drawings)



Detail of Long Tabby Site plan including rock toe, geotextile, and gabion placement (See Appendix C for larger plan)

The design at the Long Tabby site involved the shaping of the embankment and the application of reno-mattresses, large granite stones, and native plantings.

The plans called for the embankment to be graded to a 1:1 slope at the northern end of the project and to a 2:1 slope at the southern end. The steeper slope was recommended on the northern end because the proximity of the embankment to an existing road would make it impossible to achieve a more moderate slope. A small berm was included at the top of the embankment at the southern end of the project in the interest of redirecting storm water away from the protected shoreline and preventing concentrated erosion.

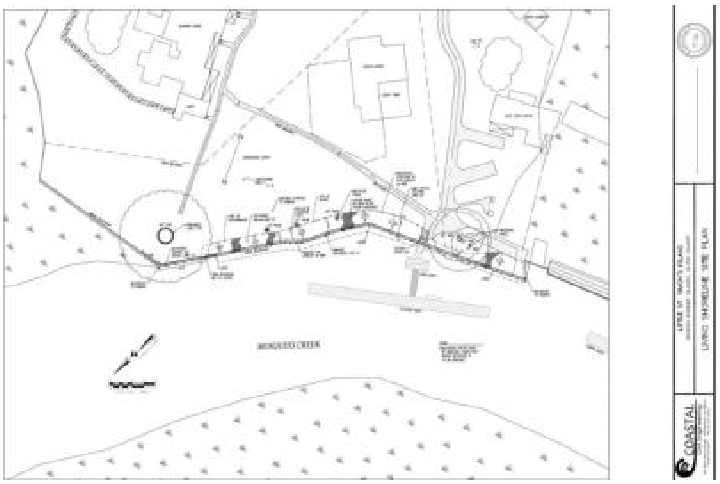
Figure 1. Gabion basket filled with granite and a bagged shell laminate.

Figure 2. Gabion with anchor and rock toe.

The specified reno-mattresses were constructed of welded steel wire, and measured 6' wide by 12' long by 1' thick (figure 1). Each mattress was to be placed vertically on the embankment and secured with a square shaft metal anchor with a 6" plate to a depth of 10' (figure 2). The reno-mattresses were recommended by the engineering firm because the slope of the embankment was thought to be too steep for oyster bags. Reno-mattresses are conventionally considered a hard-armoring technique, however, three types of materials were prescribed by the project team as fill-material in the interest of promoting oyster growth and habitat: 1) bagged oyster shells on top of granite rocks, 2) loose oyster shells on top of granite rocks, and 3) granite rocks only. Three types of fill-material were also prescribed in the interest of experimentally determining which material serves as a more effective growth medium for oysters.

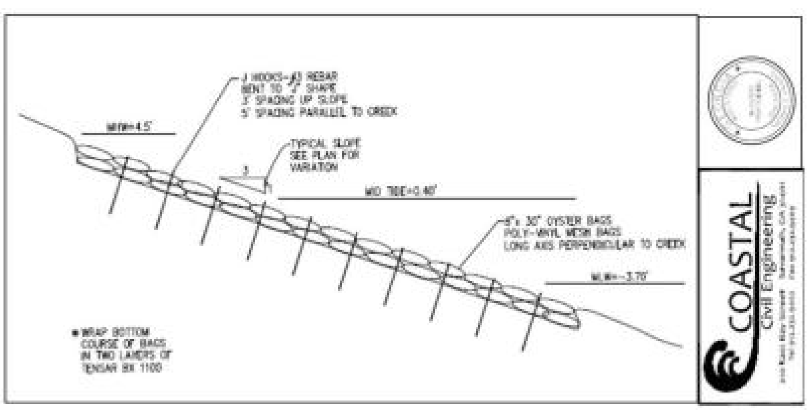
Geotextile fabric was installed on the lower embankment and a five foot wide area of surge stone was placed on the geotextile. The design included plantings at the top of the embankment for low and high marsh vegetation, with appropriate native upland grasses, and shrubs. The overall plan was designed to fit within the definition of living shorelines and conform to the funding requirements of NOAA.

Design **-** Little St. Simons Island (see Appendix A for larger construction drawings)



Little St. Simons Island Site plan.

The design at Little St. Simons Island (LSSI) involved a compromise between the "hard" and "soft" armoring methods that were used on Sapelo Island. This hybrid design was similar to the design used at the Ashantilly Site and involved the shaping of the embankment and the application of oyster bags, recycled concrete, and native plants; however, the plan also involved encasing the first layer of oyster bags in geogrid (an extremely durable mesh that is a structural component in road construction) in order to create flexible cohesion and structural integrity. The geogrid was designed to be anchored into the embankment in order to prevent the downward subsidence of materials.



Detail of Little St. Simons Island Site plan including oyster bags, anchors, and geogrid. See Appendix A for larger drawings.

The bank at LSSI was graded at a 2:1 slope and a 3:1 slope along most of the length of the project in order to reduce the erosional and gravitation forces on the bank, and at a 1.5:1 slope in certain areas to protect existing trees. No areas on the bank were to be graded to a 1:1 slope as it was felt that this would be unnecessary and more prone to failure. It was decided that the existing bulkhead would remain and be repaired at the western end of the project so as not to disturb the root system of a large Live Oak tree and threaten its survival. The living shoreline embankment was designed to tie into the bulkhead at the west end by curving the slope behind the bulkhead and trimming the bulkhead to match the slope in that area.

Bottom course of oyster bags wrapped in geogrid.
Little St. Simons Island, GA

Bottom course of oyster bags wrapped in geogrid after bulkhead removal.
Little St. Simons Island, GA.

Recycled concrete was used at the toe of the slope in order to reduce the transportation and ecological costs associated with the granite stones. The oyster bags were to be placed along the bank from -4' below mean tide elevation at the bottom the bank to 4.5' above mean tide elevation at the top of bank. The upper elevation of the oysters bags on LSSI was designed to be 0.5' higher than on Sapelo in order to better protect the top of bank from erosion associated with high tides and storm water runoff. Plans for native plants were much more extensive at the top of bank than they were at Sapelo Island due to funding availability and included some areas in the intertidal zones as well.

Construction Methods

Construction Methods Narrative

The methods employed in the construction of each living shoreline generally involved the following steps and elements. These methods have been summarized in the active tense so as to serve as instructions for future living shoreline projects.

The first step in the construction of each living shoreline is to “ground-truth” and reconcile the proposed design with the actual site conditions. This is accomplished by identifying benchmarks and fixed points, such as docks or buildings, in the plans and measuring the distance from those points to the relevant features of embankment and proposed site work. These features may include the limits of disturbance, the staging areas, and the vegetation to be removed. Once the relevant features and limits of disturbance have been located it is also important to conspicuously mark or flag those elements in order to provide the construction and project teams with visual perspective of the dimensions and proposed changes to the project.

The next step in the construction process involves the identification of existing elevations and drainage patterns. This step should be accomplished with a surveyor's transit or similar equipment. Generally, a laser transit is positioned within 400' of a benchmark with a known elevation. The surveying rod is then placed on the benchmark and adjusted until the top of the rod is even with the top of the transit, and the height of the rod is measured in inches. By adding the height of the rod to the elevation of the benchmark, the elevation of the transit can be established. Any elevation on the site can then be established by adjusting the top of the rod to the same height as the top of the transit and subtracting the height of the rod from the known elevation of the transit. Once these elevations are established it is important to create a plan for the movement of soils and shaping of bank so that the desired changes can be accomplished as efficiently as possible.

The third step is to assess the soil conditions, the tidal variance, and the tidal predictions for the days during which construction will take place. Soil conditions and characteristics will affect the way in which the embankment can be shaped; for example, soils with a high clay content have a steeper angle of repose than those with high sand content and they are less susceptible to liquefaction and erosion. Tidal variance will determine which time of day the bank will be exposed and which time of day to perform the various functions of the job.

Once these elements have been identified and assessed, the contractor should develop a comprehensive construction plan and communicate that plan with the construction and project teams. Any discrepancies between the plans or intent of the project and the site conditions or viability of the project should be addressed and amended with the owner. Written documentation of any amendments to the plan should be obtained by the contractor, the project team, owner, and engineer (if applicable) in order to better modify future living shoreline design.

The next step in the construction process involves the preparation of the site and the removal of all necessary vegetation, debris, and appropriate obstructions. On Sapelo Island, for example, the construction team removed several trees that were at risk of falling into the marsh and several trees that had already fallen in. A large excavator was used to remove the tree trunks and root systems and a chainsaw was used to cut the material into pieces that could be loaded into a dump truck for disposal.

Once the site has been cleared and prepped, the construction team may begin grading and shaping the embankment to the appropriate slope using a large excavator. Generally, a 40,000 lb.-50,000 lb. excavator is preferable because the size of the boom and bucket and the weight of the machine provide sufficient reach and lifting capabilities. Throughout the grading process, the contractor must confirm that the proper elevations and gradients are achieved. For example, a transit should be used to confirm the elevation of the toe-of-slope, and a 4' level should be used to confirm the rise and run of the slope. Once the toe-of-slope is established, the contractor should install the geotextile along the bottom portion of the embankment and place the rip rap on top of the geotextile at the appropriate dimensions, locations, and elevations.

Oyster bags or reno-mattresses (or other specified stabilization method) should be installed immediately after the placement of the rip rap in order to avoid additional erosion at the site. Oyster bags should be installed manually and if geogrid is specified, a layer of geogrid should be installed above and below the bottom lay of oyster bags. Proper coverage of the embankment is essential and the contractor should consider immediate and long-term stability of the bank with respect to storm water run-off and tidal variations. Stabilizing stakes or anchors should be installed according to the plans; stakes may be installed manually but anchors may require mechanical installation.

The reno-mattresses are delivered unassembled and the contractor must properly wire the reno-mattresses together on-site. They may be filled with aggregate before or after installation on the bank; however, pre-filled mattresses should be installed on steep embankments for greater control. In either case, reno-mattresses should be mechanically installed with an excavator per the manufacturer's recommendations. The top elevation of the oyster bags may be adjusted to conform to the plans after the placement of stakes by adding or removing bags; however, the proper top elevation of the reno-mattresses must be obtained prior to installation of the anchors. A transit should be used to confirm these elevations, and masonry string may be used to provide a visual aid.

Once all of the bags or mattresses have been properly placed, the contractor should shape the top of bank according to the plans and create a transition between the upland elevations and the top of the bank. This transition should be above the mean high water elevation; however, it should be stabilized with erosion control blankets in order to protect the bank from extreme tides, rain, and storm water runoff. These blankets dissipate the energy of water, provide improved growing conditions for plants, and are typically made of straw, wood, or coconut fibers encased in poly-vinyl mesh. They are particularly important in the stages immediately following construction as they help to hold the soil in place while plants and root systems become established.

Final steps in the construction process involve replacement of the dock (if applicable), installation of plants, and jobsite clean-up. Native grasses, shrubs, and trees should be installed along the bank adjacent to the oyster bags to mimic a natural shoreline. At the Ashantilly site, for example: *Spartina alterniflora* were planted in a grid pattern on 1.5' centers in offset rows; *Borrichia frutescens*, *Muhlenbergia filipes*, and *Distichlis spicata* were planted on 2' centers in offset rows; and shrubs and trees (*Juniperus virginiana, Quercus virginiana, Ilex vomitoria*, and *Morella cerifera*) were planted along the shoreline in a non-structured manner. Once the job-site has been cleaned of all construction related debris and the dock has been replaced, the contractor should meet with project team to inspect the site, explain the as-built conditions, address any concerns or questions, and take any final corrective action needed.

A long-term maintenance plan should be produced and implemented by the project team in cooperation with the construction team and the owner. The plan should include: watering of plants; and monitoring plans for stability, oyster habitat and associated fauna, vegetation, water quality, erosion, invasive species, and fish and crustacean habitat usage. An outline of construction and monitoring methods are described in greater detail in the following sections.

Construction Methods Outline

1. Planning
    a. Measurement of the embankment and determination of the limits of disturbance.
    b. Identification of existing elevations, soil conditions, drainage patterns, tidal variance and predictions, staging areas, and vegetation to be removed.
    c. "Ground-truthing" and reconciliation of proposed work-site with actual conditions.
    d. Establishment of benchmarks and flagging of all appropriate features.
    e. Creation of a construction plan, communication of the plan, discussion of any necessary modifications with project team and owner, and adaptation of plans accordingly.

    Tools used: Surveying equipment; measuring tape.
2. Prepping
    a. Clearing of necessary vegetation.
    b. Removal of necessary tree material from upland and embankment within the limits of disturbance.

    Tools used: chainsaw; 50,000 lb. excavator; dump truck.
3. Constructing
    a. Grading of embankment to required slope and confirmation of proper grade.
    b. Installation of geotextile and rip rap, and confirmation of rip rap elevations.
    c. Installation of oyster bags, reno-mattresses, and/or stabilization method and confirmation of proper elevations.
    d. Installation of stakes and/or anchors.

    Tools used: transit; 4' level; measuring tape; 50,000 lb. excavator; masonry string.
4. Finalizing
    a. Finish grading the top of bank.
    b. Installation of erosion control blanket.
    c. Cleanup of site.
    d. Replacement of dock.

    Tools used: skidsteer loader; dump truck; circular saw; wrenches; power drill; saws-all.

Ashantilly Living Shoreline Construction Methods

Biological Monitoring Methods

Oysters and other fixed benthic faunal species

Several types of monitoring took place to capture species presence and diversity along the living shoreline projects. The following data were collected:

- Areal Extent of Oyster Reef Habitat
- Fixed Benthic Faunal Composition
- Oyster Recruitment Availability

Pre-construction: The spatial extent of existing oyster reefs was mapped before construction. To determine the oyster density and shell length of oyster beds identified a 0.25 m^2 quadrant was randomly placed within each bed. At Ashantilly there was one small oyster reef present (1 quadrant), and nine oyster beds were mapped (10 quadrants) at Long Tabby.

Post-construction: Nine individual transects were established at each project site. Three 0.25 m^2 quadrats sites were selected on each transect to cover the three tidal zones (low, medium, high) and the number of living and recently dead oysters was counted in each quadrant. Each sampling station was permanently marked to enable assessments in subsequent years. A mean oyster size per reef was calculated by measuring 30 randomly selected oysters within each quadrat with Vernier calipers to the nearest mm and then used to construct a size frequency distribution for all oysters at each site. These linear measurements were converted to biomass (grams dry weight per meter squared) according to Dame (1972). A control (reference site) equal to the length to the two experimental sites was established to provide non-biased perspective on perceived changes at all locations.

The pre-existing spatial extent and distribution of all intertidal oysters within the boundaries of the projects was digitally mapped prior to construction of the living shorelines. The maps were then used to calculate the pre-existing area of oysters and oyster reef habitat in square meters. After the construction of the living shorelines the scientific team re-mapped the distribution of the oysters (by species). Spatial patterns of oyster populations were examined along the length of the delineated study area shorelines in relation to: the location of each stabilization method; and intertidal zonation. The total area of exposed hard surface was also mapped, which enabled to the team to compare successful and potential oyster habitat to the loss of potential oyster habitats resulting from sedimentation or disturbance. This monitoring was conducted in September 2010 and again in September 2011; see figure 5 for the final mapping of these resources.

The number of other sessile macro-fauna (e.g. mussels and barnacles) was also monitored annually through 2011 to gauge the success of the reef and shoreline stabilization associated with the recruitment of other shellfish. If present during the sampling, exotic species were identified and monitored.

Equipment used included an Archer handheld field PC with Trimble Pathfinder Pro XC GPS receiver (2-5 m accuracy), ArcPad GPS software with a customized data entry form and captured still images using a Ricoh 500SE GPS-ready digital camera.

Vegetation

The spatial extent of existing Spartina alterniflora was mapped prior to construction. To determine the density and height of Spartina three 0.25 m^2 quadrants were used within each stand identified. At Ashantilly six stands of Spartina (18 quadrants), and at Long Tabby four stands of Spartina (12 quadrants) were observed. Other vegetation was mapped and identified but density was not determined. The project team mapped the distribution of any native vegetation within each site (Long Tabby and Ashantilly) and calculated the pre-existing composition and area of habitat in square meters by species. A control (reference site) of equal length to the two experimental sites was established to provide non-biased perspective on perceived changes at all locations.

After the emplacement of the living shoreline stabilization methods, the removal of all construction equipment, and the completion of native vegetation plantings the scientific team digitally mapped the distribution of the new plantings. Additional plant surveys, maps, and calculations were completed through fall 2011.

Technology used in the sampling included an Archer handheld field PC with Trimble Pathfinder Pro XCGPS receiver (2-5 m accuracy), ArcPad GPS software with a customized data entry form and captured still images using a Ricoh 500SE GPS-ready digital camera.

Water Quality

Water quality near the project sites was monitored from June 2009- 2012 using the Sapelo Island National Estuarine Research Reserve's System-Wide Monitoring Program (SWMP) personnel, equipment and protocols. Six parameters (Dissolved Oxygen, Turbidity, pH, Tidal Amplitude, Water Temperature and Salinity) were acquired on 15 minute intervals, 365 days/ year at two sites (Upper Duplin River and Lower Duplin River) near the experimental treatments.

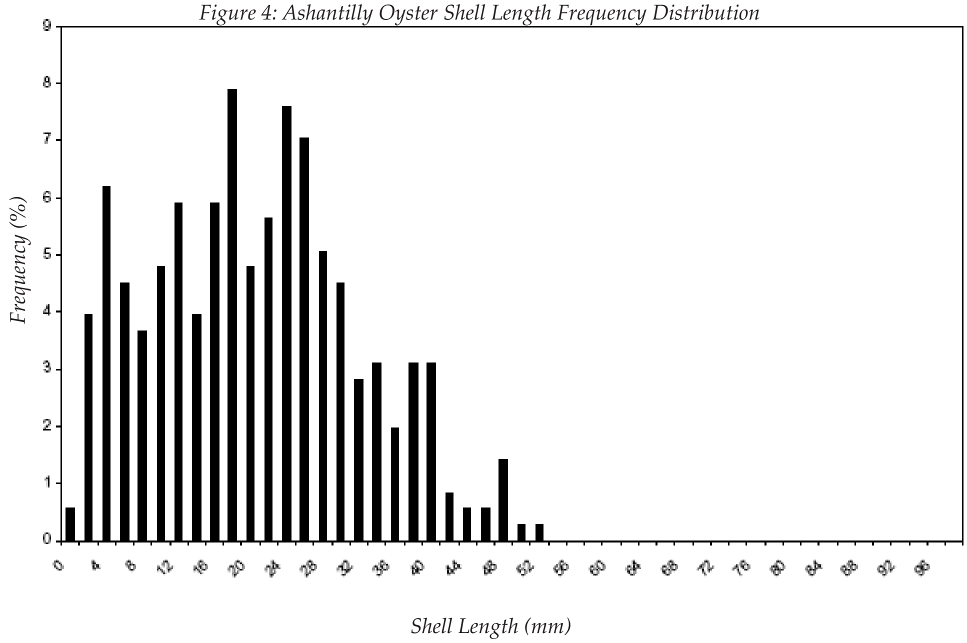
Water quality was considered an essential monitoring component, as hydrology and water chemistry have profound effects upon the biological indicators of the project's success including species abundance, diversity and health among sites and experimental treatments.

Results

Data and Visual Analysis

Preliminary results obtained one year after the completion of the project included a size-frequency distribution graph, which could be used to compare oyster growth at the Ashantilly site (Figure 4). Maps of vegetative coverage were also created which could be used to determine the percent coverage and location at the intertidal, transitional and supra tidal zones (Figure 5). This document may be amended with updates as analysis continues. Scientific results generated by the annual assessments will be amended and presented chronologically and thematically in future versions of this document.

Figure 4: Ashantilly Oyster Shell Length Frequency Distribution



Ashantilly site oyster size (mm) frequency distribution used in estimating total oyster biomass and for a comparative efficacy metric against the Long Tabby site.

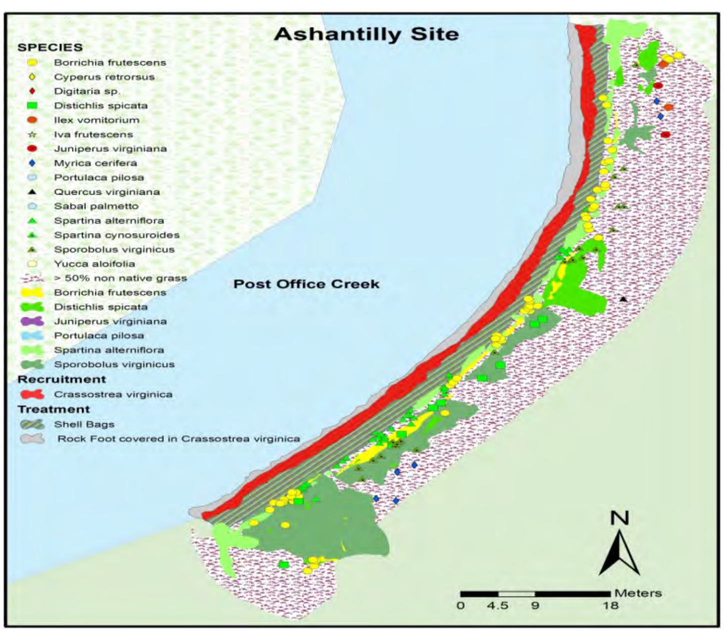


Figure 5: GPS qualitative mapping of the Ashantilly site showing supra-tidal vegetation groundcover, extent of primary natural oyster colonization (red).

Ashantilly Living Shoreline pre-construction in 2009 (left) and post-construction in 2010 (right)

Long Tabby Living Shoreline pre-construction in 2009 (left) and post-construction in 2010 (right)

Ashantilly and Long Tabby Sites on Sapelo Island – 2013

Cost Comparisons

Costs have been identified as being one of the motivating factors for property owners in determining the appropriate bank stabilization technique for them. In order to address costs, throughout the planning, construction and monitoring of the Sapelo and Little St. Simons Island projects, material and construction expenses were tracked in order to determine overall project costs.

Given that most traditional bank stabilization projects are either rip-rap revetments or various types of bulkheads, it was logical to provide cost comparisons for these traditional methods and compare those with Living Shoreline costs. The outcome for this analysis is a Cost Comparison table of various types of bulkheads and revetments compared with those costs of the materials and construction costs for the three Living Shorelines, 2010 for Sapelo Island and 2013 for Little St. Simons Island.

For each Living Shoreline project site, a comparison is made between the real costs and the projected costs of installing a bulkhead or revetment at the same location. For these purposes, bulkheads are divided into 1) vinyl bulkheads with toe protection, 2) wooden bulkhead with toe protection, and 3) concrete bulkhead with toe protection. Revetments are separated into three types as well: 1) Granite Type 1 rip rap with Type 1 toe protection, 2) Granite Type 3 with Type 1 toe protection, or 3) Granite Type 3 with Type 3 toe protection. The above types of traditional methods were selected based on their frequency of use in coastal Georgia tidal creek systems.

It is important to note that the estimated costs do not include the cost to barge materials to the barrier islands. Costs also do not include housing for contractors on the barrier islands. It is also important to note that all Living Shoreline costs include planting costs for marsh and upland transitional plants, an important component of this technique.

The following tables lay out the Living Shoreline costs along with the traditional technique costs.

Bank Stabilization Cost Estimates

- Ashantilly Site, Sapelo Island, GA -

<u>Bulkheads</u>: A bulkhead is any shore-parallel vertical structure or wall designed to prevent erosion of the land.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Vinyl bulkhead w/toe protection	Linear Foot	$283	$656

A vinyl bulkhead is a vertical sea wall constructed of rigid, interlocking vinyl sections. Each section is 18" wide on average, has tongue and groove type edges which lock together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Wooden bulkhead w/toe protection	Linear Foot	$241	$606

A wooden bulkhead is a vertical sea wall constructed of pressure-treated wood sections. Each section is 12" wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Concrete bulkhead w/toe protection	Linear Foot	$476	$977

A concrete bulkhead is a vertical sea wall constructed of concrete sections. Each section is 18"-36" wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

All costs based on heights of 8' of exposed sea wall plus toe protection

Total Length of Embankment = 300 Linear Feet

Installation Costs include the cost to: extend old dock ramp to meet the new top of bank; backfill; and finish grade.

Estimated costs do not include the cost to barge the material to the island or island housing

Sloped Revetments ***: Sloped revetments are constructed features made of hard materials placed on banks in such a way as to absorb the energy of incoming water. Revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion.***

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 1 Rip Rap w/ Type 1 toe protection	Linear Foot	$164	$439

Granite Type 1 Rip Rap, also known as "surge stone," is comprised of granite stones, each weighing approximately 125 lbs on average and measuring 18" to 24" in diameter. It is used in areas where larger stones are needed for stability or to resist the forces of strong currents or wave action. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 1 toe protection	Linear Foot	$155	$413

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on the upper portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss. Granite Type 1 Rip Rap is used to provide additional stability on the lower portion of the bank.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 3 toe protection	Linear Foot	$152	$410

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on all portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Living Shoreline – A living shoreline is a sloped erosion control technique that mimics natural, native habitat, provides increased opportunities for species diversity and productivity, and can serve to improve water quality and the ecological integrity of the area.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Oyster bags w/ Type 1 Rip Rap Toe Protection (including all real costs)	Linear Foot	$115	$332

Oyster bags are plastic mesh bags that are filled with loose oyster shells. Each bag is approximately 10 inches in diameter and weighs 10 lbs on average. Oyster bags are used instead of rip rap to reduce the energy of water currents and also to provide habitat and a growing medium for living oysters. The living oysters in time provide water filtration and natural cementation and structural integrity to the embankment. Native plants are used at the top of the bank to further reduce erosion and provide habitat and water filtration. Granite Type 1 Rip Rap is used on the bottom portion of the bank for additional stability.

Bank Stabilization Cost Estimates

- Long Tabby Site, Sapelo Island, GA -

***<u>Bulkheads:</u>* A bulkhead is any shore-parallel vertical structure or wall designed to prevent erosion of the land.**

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Vinyl bulkhead w/toe protection	Linear Foot	$283	$671

A vinyl bulkhead is a vertical sea wall constructed of rigid, interlocking vinyl sections. Each section is 18" wide on average, has tongue and groove type edges which lock together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Wooden bulkhead w/toe protection	Linear Foot	$241	$621

A wooden bulkhead is a vertical sea wall constructed of pressure-treated wood sections. Each section is 12" wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Concrete bulkhead w/toe protection	Linear Foot	$476	$1007

A concrete bulkhead is a vertical sea wall constructed of concrete sections. Each section is 18"-36" wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

All costs based on heights of 8' of exposed sea wall plus toe protection

Total Length of Embankment = 300 Linear Feet

Installation Costs include the cost to: extend old dock ramp to meet the new top of bank; backfill; and finish grade.

Estimated costs do not include the cost to barge the material to the island or island housing

Sloped Revetments ***: Sloped revetments are constructed features made of hard materials placed on banks in such a way as to absorb the energy of incoming water. Revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion.***

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 1 Rip Rap w/ Type 1 toe protection	Linear Foot	$164	$454

Granite Type 1 Rip Rap, also known as "surge stone," is comprised of granite stones, each weighing approximately 125 lbs on average and measuring 18" to 24" in diameter. It is used in areas where larger stones are needed for stability or to resist the forces of strong currents or wave action. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 1 toe protection	Linear Foot	$155	$428

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on the upper portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss. Granite Type 1 Rip Rap is used to provide additional stability on the lower portion of the bank.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 3 toe protection	Linear Foot	$152	$425

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on all portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Living Shoreline ***– A living shoreline is a sloped erosion control technique that mimics natural, native habitat, provides increased opportunities for species diversity and productivity, and can serve to improve water quality and the ecological integrity of the area.***

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Oyster bags w/ Type 1 Rip Rap Toe Protection (including all real costs)	Linear Foot	$150	$346

Oyster bags are plastic mesh bags that are filled with loose oyster shells. Each bag is approximately 10 inches in diameter and weighs 10 lbs on average. Oyster bags are used instead of rip rap to reduce the energy of water currents and also to provide habitat and a growing medium for living oysters. The living oysters in time provide water filtration and natural cementation and structural integrity to the embankment. Native plants are used at the top of the bank to further reduce erosion and provide habitat and water filtration. Granite Type 1 Rip Rap is used on the bottom portion of the bank for additional stability.

Bank Stabilization Cost Estimates

- Little St Simons Island, GA -

***<u>Bulkheads:</u>* A bulkhead is any shore-parallel vertical structure or wall designed to prevent erosion of the land.**

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Vinyl bulkhead w/toe protection	Linear Foot	$283	$686

A vinyl bulkhead is a vertical sea wall constructed of rigid, interlocking vinyl sections. Each section is 18″ wide on average, has tongue and groove type edges which lock together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Wooden bulkhead w/toe protection	Linear Foot	$241	$652

A wooden bulkhead is a vertical sea wall constructed of pressure-treated wood sections. Each section is 12″ wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Concrete bulkhead w/toe protection	Linear Foot	$476	$1022

A concrete bulkhead is a vertical sea wall constructed of concrete sections. Each section is 18″-36″ wide on average, has tongue and groove type edges which fit together with adjacent sections, and is driven into the ground for stability. Additional stability is provided by tie-backs which extend from the exposed face of the wall into the embankment to a fixed anchor. The toe, or the embankment below the bulkhead that is exposed to the water, is protected from currents and waves by large granite rocks called rip-rap.

All costs based on heights of 8′ of exposed sea wall plus toe protection

Total Length of Embankment = 300 Linear Feet

Installation Costs include the cost to: extend old dock ramp to meet the new top of bank; backfill; and finish grade.

Estimated costs do not include the cost to barge the material to the island or island housing

Sloped Revetments ***: Sloped revetments are constructed features made of hard materials placed on banks in such a way as to absorb the energy of incoming water. Revetments are usually built to preserve the existing uses of the shoreline and to protect the slope, as defense against erosion.***

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 1 Rip Rap w/ Type 1 toe protection	Linear Foot	$164	$469

Granite Type 1 Rip Rap, also known as "surge stone," is comprised of granite stones, each weighing approximately 125 lbs on average and measuring 18" to 24" in diameter. It is used in areas where larger stones are needed for stability or to resist the forces of strong currents or wave action. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 1 toe protection	Linear Foot	$155	$443

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on the upper portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss. Granite Type 1 Rip Rap is used to provide additional stability on the lower portion of the bank.

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Granite Type 3 w/ Type 3 toe protection	Linear Foot	$152	$440

Granite Type 3 Rip Rap is comprised of granite stones, each weighing approximately 15 lbs on average and measuring 6" to 8" in diameter. It is used to reduce the velocity and energy of water currents on all portions of the bank. Geotextile, a woven nylon fabric, is placed under the rip rap to further reduce the energy of the water on the soil and further prevent soil loss.

Living Shoreline ***– A living shoreline is a sloped erosion control technique that mimics natural, native habitat, provides increased opportunities for species diversity and productivity, and can serve to improve water quality and the ecological integrity of the area.***

Type	Unit	Materials Cost Only ($/Unit)	Installed Cost ($/Unit)
Oyster bags w/ Recycled Concrete Toe Protection	Linear Foot	$126	$367

Oyster bags are plastic mesh bags that are filled with loose oyster shells. Each bag is approximately 10 inches in diameter and weighs 10 lbs on average. Oyster bags are used instead of rip rap to reduce the energy of water currents and also to provide habitat and a growing medium for living oysters. The living oysters in time provide water filtration and natural cementation and structural integrity to the embankment. Native plants are used at the top of the bank to further reduce erosion and provide habitat and water filtration. Granite Type 1 Rip Rap is used on the bottom portion of the bank for additional stability.


Little St. Simons Island shoreline progress 2012 (left) and 2013 (right)

Discussion

The use of different methodologies at two similarly impacted locations on Sapelo Island created a unique opportunity to combine the NOAA and EPA funding, to compare the different techniques, and to learn which one would provide a greater ecological and structural benefit to the shoreline. The construction of a living shoreline demonstration site on LSSI created an opportunity to apply the lessons learned on Sapelo Island and to advance living shoreline technologies.

Ashantilly Site –

The placement of shell bags directly on the embankment at the Ashantilly site was the easiest stabilization method for the contractor to employ because the placement of the bags could be accomplished by unskilled manual laborers. The method also enabled the contractor to establish complete and uniform coverage of the embankment due to the modular aspect of the bags. Additional oyster bags could be placed on the bank as needed for example, and the bottom elevation of bags could be adjusted to conform to irregularities in the toe. Oyster bags that were placed erroneously or unnecessarily could also be easily removed or repositioned.

As of 2013, the living oyster reef at the Ashantilly site has become far more extensive than the population of oysters at the Long Tabby site. The difference in oyster recruitment and success may be attributable to a “preference” for bagged oyster shell and a “dislike” for reno-mattresses; however, sedimentation at the Long Tabby site may also have contributed by covering up and making unavailable potential oyster substrate (also known as cultch). Potential causes of the sedimentation are discussed in more detail in the following section. In any event, the constructed reef at the Ashantilly site was considered more aesthetically appealing than the Long Tabby reef and it continues to have a more natural and congruent appearance.

In 2012, two years after the completion of the project, localized subsidence occurred at the northern end of the Ashantilly site. The localized area was effectively recovered with new oyster bags and no upland was lost. The exact cause of the subsidence is unknown, however it may have been a result of one, or a combination, of the following factors: erosion of the embankment may have occurred below the rip rap at the toe of slope and undermined the soils beneath the oyster reef; the oyster bags were not enclosed in any larger wire or plastic Igrid and did not benefit from the holistic integrity of such a system; the bags were not anchored to the bank with large anchors; and the 2" x 2" stakes that had been used to help prevent subsidence had rotted or were removed. The stakes had been removed because it was thought that they contributed to the collection of dead marsh grass (wrack) which would prevent effective oyster colonization. Steel "J" hooks may be more effective in future projects as they are less susceptible to rotting and may be inserted to the level of the oyster bags.

Native plants were extensively installed at the top of the bank and ultimately became well established; however, the success of the plants was effectively delayed by low rainfall, inadequate watering hoses and schedules, and accidental mowing. Future projects should obtain sufficient hoses, soaker hoses, and sprinklers prior to planting at each site, and create a watering schedule. In coastal GA, it would be best to also plan to have the plantings in the ground by mid-March to avoid the heat of the summer. Completion of the earthmoving sections of the project by late February may be a factor in the success of the spring vegetation plantings. Since native plants should not be mowed, future project management teams should generate awareness and "buy-in" with those interested in maintaining the landscape. The following factors may have initially contributed to native plant mortality: lack of understanding of plant requirements, resistance to natural landscapes, improper signage, markers, or inter-staff communication.

Long Tabby Site –

The reno-mattresses and 10' anchors used at the Long Tabby site provided greater support and integrity than did the loose oyster bags and stakes used at Ashantilly; however, the size and dimensions of the mattresses created installation and habitat challenges. Each filled mattress, for example, weighed 8,000 lbs. and a sophisticated system of steel beams and rigging was required to lift them and set them in place. Once placed on the embankment, intentional adjustments were difficult; however, the contractor had to maintain the proper elevation of the mattress at the top of bank until the anchors were installed.

No adjustments could be made to the dimensions of the mattresses, but the dimensions of the bank varied with its slope. The slope at the southern end of the site, for example, was 2:1 and 18' long, which was 6' longer than the mattresses. Additional oyster bags and rip rap were therefore required to protect areas that could not be covered by the mattress at the top and toe of slope, especially when the run over rise was greater than 1:1.

As of 2011, during the last post-monitoring event, oyster populations were not as extensive at the Long Tabby site as they were at the Ashantilly site. The difference in oyster recruitment and success may be attributable to a "preference" for bagged oyster shell and a "dislike" for reno-mattresses; however, sedimentation at the Long Tabby site may also have contributed by covering up and making unavailable potential oyster substrate. Potential causes of the sedimentation were: increased potential for sediment entrapment in mattresses; potentially reduced water velocity; increased erosion at the top of bank.

Extensive erosion at the top of the bank occurred at the Long Tabby site due to the fact that an erosion control blanket was not initially installed. Living shoreline designs should always include the installation of erosion control blankets at the top of the bank. Erosion control blankets and additional oyster bags were successfully installed to maintain a tidally resistant barrier while these areas colonized with vegetation. In 2013, however, horseshoe crab spawning activity at Long Tabby exacerbated erosion and installation of additional erosion control products (such as oyster bags, rip rap, and blanket) may be required.

Dry conditions negatively affected plant success but *S. alterniflora* was successfully replanted in the upper intertidal zone of the site. *S. alterniflora* was less successful at the southern end of the site due to the fact that the plantings were topographically above the plants' natural inundation zone. An alternative such a *Spartina patens* would have been a better choice because it naturally grows at higher elevations. A small berm was placed several feet from the edge of the shoreline in order to help control upland stormwater runoff. The berm has proven successful in redirecting storm water runoff and was later stabilized by re-colonizing grasses. A few horseshoe crabs became stuck in gaps in the reno-mattresses and the large rocks and became stranded at low tide. Future consideration should be given to appropriate methods for horseshoe crab spawning sites so as to minimize negative impacts to this species. In addition, regardless of horseshoe spawning conditions, routine maintenance for reno-mattresses is needed in order to assure that all wires remain attached and that no openings are created for fish and invertebrate trapping, or human hazards.

Little St. Simons Island –

The encasement of the bottom layer of oyster bags in geogrid provided a more comprehensive integrity to the embankment than did the application of oyster bags alone at the Ashantilly site. The geogrid encasement effectively created a whole unit that was greater than the sum of its parts. The oyster bag 'units' were then supported by the anchors in the embankment and the success of the method did not rest entirely on the success of the rip rap toe. The reno-mattresses at the Long Tabby site created a similar integral unit which could be anchored; however, the plasticity of the geogrid allowed the contractor to match the dimensions of the stabilization method to those of the embankment.

The top layer of bags was not encased on LSSI, as they were at the Long Tabby site in the mattresses, as it was felt that the exposed surface of the bags would be more conducive to oyster recruitment and growth. The bottom portions of the bank at LSSI have, however, been extensively covered with sediment, which may negatively affect recruitment. The project team at LSSI will continue to monitor the sedimentation and recruitment rates and may place additional bags in the spring to provide supplemental cultch material as needed. Once living oysters become established, the growth of the oysters should out-pace the rate of sedimentation.

The removal of the old bulkhead was more time intensive than the contractor anticipated as each piling had to be individually wrapped with a chain, removed with the excavator, and loaded into a dump truck. The wall also had to be removed in small section using the same method. In general, half as much embankment could be stabilized with oyster bags each day on LSSI as was at the Ashantilly site.

The sandy soils at LSSI were less cohesive than the clayey soils on Sapelo, had a reduced angle of repose, and had a greater susceptibility to liquefaction. Geotextile was incorporated in the lower portions of the bank, which helped prevent soil subsidence, but it did not extend to the upper portions of the embankment as it was thought that it would inhibit plant roots and success. In future projects, geotextile should extend to the top of bank in the interest of embankment stability and be covered with oyster bags, soil, and native plants where appropriate.

Minor erosion occurred at the top of bank at LSSI, as it did at the Sapelo sites, due to rain and storm water runoff, but it was not extensive and was easily repaired. Additional oyster bags, soil, and erosion control blankets were placed and monitoring will continue. The potential for erosion of these areas should be eliminated as native plants and their root systems become more established. The plans specified the placement of bags up to 4.5' above mean tide on LSSI, which is 0.5' higher than the top of bags at Sapelo, but did not extend further in consideration of the planting designs. In future projects, oyster bags (or approved alternative) should be placed higher on the embankment and then covered with soils and plants and erosion control blankets as required. The additional bags, while ineffective as cultch material and invisible, would eliminate the potential for extensive gullies which could compromise the integrity of the bank from within.

Native plants, such as *Spartina alterniflora*, were successfully planted on middle and upper portions of the embankment. The embankment soils in these areas have not eroded, but will need to be monitored to confirm persistence and sufficiency over time. This method is not recommended for areas with high tidal velocities, such as those at the Ashantilly site.

Native plants were installed extensively along a 20 to 25' buffer above the embankment. Ideal growing conditions, including daily rain events and “mild” summer temperatures, as well as intensive maintenance plans facilitated rapid and robust growth of the plantings. The diversity and abundance of the species was intended to enhance the stability and aesthetic appeal of the project. Deer foraging did initially impact the growth of some species, but did not result in any plant mortality. A “viewing area” was also built using additional bags at the top of bank at the request of the landscape architect. The area successfully allows guests and visitors to overlook the living shoreline and gain an enhanced perspective of the oysters, but may not have long term stability.

Juvenile oyster populations have been recorded, but adult oysters are not yet visible at the site.

Sapelo Project Timeline

2008

April. DNR Engineering engaged a firm to plan and design the living shoreline construction methods. Data was gathered from hydrological and topographical surveys. A monitoring plan was drafted by the project team, in which key metrics and monitoring agencies were identified. Planting Schematics and Engineering Plans were drafted (Appendices C).

May. Several sites in NC were visited by project team members. Team members were accompanied by the Senior Scientist of the North Carolina Coastal Federation, Wilmington, NC. Survey work began at the proposed site. Plant vendors were contacted.

September. Plans for the two sites were re-evaluated by the project team based on funding constraints, engineering constraints, and locality constraints. Oyster shell vendors were also contacted.

2009

January. A second set of engineering plans was evaluated by the project team.

March. Adjustments and revisions to the plans were discussed with engineering firm and the firm was engaged to produce a final set of plans. The project team met with representatives of the EPA and the engineering firm, as well as the Senior Scientist of the North Carolina Coastal Federation at the project sites on Sapelo Island. A living shoreline workshop was held during the site visit and strategies and goals were discussed. Monitoring plans that met both EPA and NOAA standards were developed and finalized.

May. DNR-CRD permitting staff visited the site and identified the Coastal Marshlands Protection Act jurisdictional lines for the project. Oyster spat settlement substrate was placed at the Ashantilly shoreline and three other reference sites around Sapelo Island, GA.

July. DNR received final construction plans from the engineering firm and developed a bid package for construction. Don Benz, retired Landscape Architect, finalized landscape plan for Ashantilly and Long Tabby.

August. WRD secured all permits for both project sites including the DNR Environmental Protection Division Buffer Variances, the Request for Revocable License through the DNR Coastal Resources Division, Federal Consistency through the Coastal Zone Management Program, and Nationwide 13 permits from the U.S. Army Corps of Engineers. Project team members secured NEPA clearance with EPA and NOAA.

September. Pre-construction monitoring of vegetation, invasive/non-native species, oysters, and reef fauna began. Construction plans were sent out for public bidding. Supplies and materials were purchased, including oyster shells, mesh bag material, bagging equipment, plants, and tools. The project team determined that DNR would manage on-site construction. The sub-award contract was prepared for DNR. A pre-bid meeting was held on November 13th, and thirty contractors participated. Eight bids were submitted. Hoffman Environmental Services (HES) was selected and awarded the contract.

December. Oyster shells were transported to the Sapelo Island Visitor Center in Meridian, GA. Note: the visitor center provided a mainland shell storage site and a location to convene shells bagging efforts throughout the project. Shell bags were transported via barge to Sapelo Island by DNR.

2010

February. Construction set-up, equipment staging, and groundbreaking began. Team members attended a Living Shoreline Workshop in March in Yulee, FL to share information and to learn about other projects. Team member Daniel Harris, presented the Sapelo Living Shoreline Project at the workshop. The project team started meeting with the regulatory staff of DNR to provide information about living shoreline stabilization methods, discuss the importance and advantages of living shorelines, discuss future implementation, and gain feedback.

March. The Coastal Resource Division and the Environmental Protection Division of the Georgia Department of Natural Resources regulatory staff met on Sapelo Island and visited the project sites. Both divisions indicated a great interest in the living shoreline project and its underlying concepts and expressed desire to communicate the value of the project with other agencies and to encourage them to consider it as a future alternative. Project team members expressed interest in selecting and continuing to work on additional Living Shoreline Pilot Project sites.

Volunteers filled mesh bags with oyster shells. Hoffman Environmental Services graded embankments and installed geotextile, rip rap, oyster bags, reno-mattresses, and anchors. (See Appendix C for construction details). HES rebuilt sections of docks at both of the Sapelo sites that had been removed to accommodate construction of the Living Shoreline. Construction work was then inspected and approved by Buddy Harrison (GADNR Construction and Engineering).

April. Native grasses, shrubs, and trees were installed along the bank adjacent to the oyster bags to mimic a natural shoreline. *Spartina alterniflora* was planted in a grid pattern on 1.5' centers in offset rows. *Borrichia frutescens*, *Muhlenbergia filipes*, and *Distichlis spicata* were planted on 2' centers in offset rows. Shrubs and trees (*Juniperus virginiana, Quercus virginiana, Ilex vomitoria*, and *Morella cerifera*) were planted along the shoreline in a non-structured manner. Slow-release fertilizer (~1 oz. per plant) was placed into the soil. Landscaping was completed at both shoreline sites, by volunteers with Coastal Wildscapes, a community based group that works to protect and restore native upland and wetland habitats, and Friends of Sapelo, a non-profit volunteer organization that supports the research, education and outreach mission of the Sapelo Island National Estuarine Research Reserve.

Long-term monitoring plans were produced and implemented, to include the assessment of oyster habitat and associated fauna, vegetation, water quality, erosion, invasive species, and fish and crustacean habitat usage. Pre-construction elevations, monitoring and biological monitoring of oyster spat settlement were conducted by the University of Georgia Marine Extension Service (UGA MAREX).

An erosion control blanket was installed above the reno-mattresses at the top of the embankment at the Long Tabby site to: prevent soil loss from high tidal events and storm water runoff; and to aid in the establishment of native plants and root systems. The 8' wide blanket 8' consisting of straw and plastic fibers, was cut in half and rolled along a 4' wide section above the reno-mattresses. Salt-tolerant grasses and marsh plants were seeded and installed beneath and through the blanket. A wooden railing was also built along the road at Long Tabby to protect the shoreline from vehicle traffic. Members of the Friends of Sapelo made the railing out of recycled wood. A Living Shoreline Assistant position was created and hired by TNC for the project coordination.

November. Jan Mackinnon presented the Sapelo Living Shoreline projects at the Restore America's Estuaries Conference in Texas.

2011

On May 23, partners hosted and facilitated a meeting on Sapelo Island with the Army Corps of Engineers Savannah District, NOAA Fisheries out of Charleston and NOAA Habitat Conservation out of St. Augustine, EPD staff and and Coastal Zone Management Federal Consistency coordinator. The purpose of this meeting was to engage additional regulatory staff to introduce the projects and discuss the history, planning, implementation and future steps of the Living Shoreline sites on Sapelo Island. Agencies that were unable to attend due to travel restraints or other commitments were the USFWS and EPA. Project team members attended several additional meetings and workshops at which site monitoring and results were analyzed.

October. TNC volunteers assisted Sapelo Island National Estuarine Research Reserve staff with the removal of wooden stakes from the Living Shoreline that were used as a temporary mechanical stabilization component for the oyster shell filled bags. This helped create a stable substrate where oysters could generate a contiguous, long-term, bio-stabilization solution and improved habitat. All exposed stakes were cut off at the level of the bags and removed from the shoreline.

Sapelo Community Involvement

The living shoreline demonstration project received strong support from local, state and regional community members and organizations. Volunteers from local and state businesses, including the Darien Telephone Company and Georgia Power participated. Volunteers contributed significantly to the creation and transport of bagged oyster shells, the planting of native vegetation and construction and maintenance. Twenty-five volunteer events were conducted and more than 437 volunteers participated and contributed in 1573 volunteer hours. Volunteer groups included Friends of Sapelo, McIntosh County Academy high school, and Alternative Spring Breaks from Grand Valley State University in Michigan. McIntosh County Academy Student Conservation Club promoted the project and helped encourage volunteerism. Coastal Wildscapes, a local volunteer organization helped to recruit volunteers to support the project and organized a weekend event to plant native vegetation. Eleven student volunteers from Grand Valley State University assisted with site maintenance and oyster shell bag production. This is the second year this college program supported the Living Shoreline in Georgia. A portion of the oyster shells used for the project was donated to DNR community shell recycling centers in the area.

Emplacement of tidal and supra-tidal native plantings by volunteers.

Public participation in bagging efforts contributed over 1500 volunteer hours.

Sapelo Outreach Activities

The Living Shoreline Team conducted numerous public and group outreach events and presentations. The project was featured at public festivals, partner meetings and in newspapers, partner newsletters and websites.

- The EPA/NOAA GA Living Shoreline Restoration project was featured in the Darien News on January 2010 and the article: Native plants and oyster shells installed as an erosion measure on Sapelo Island was featured on April 15, 2010.
- Project highlights and updates of the EPA/NOAA GA Living Shoreline Restoration project were presented to the Georgia TNC Board of Trustees, the SINERR Advisory Council, Georgia Oyster Restoration meeting, and the EPA Climate Adaptation Clinic.
- TNC Marketing Resource Center (MRC) staff filmed the project and interviewed staff for inclusion in a national oyster restoration production.
- GA DNR, CRD and TNC's website will be used for additional productions and products. TNC also worked with the MRC to include the Living Shoreline in a flash graphics production focusing on oysters.
- Volunteers from Coastal Wildscapes, Friends of Sapelo, and AmeriCorps, along with project partners, planted native vegetation on April 1, 2010.
- Spring 2010 – GA DNR Coastal Resources Division published an article in the Georgia Sound Newsletter highlighting the state's first Living Shoreline projects.
- A Volunteer Appreciation Day tour was given by Sapelo Island Manager, Fred Hay, on April 9, 2010 so oyster bagging participants from the community could see the results of their work.
- Cadets from the Youth Challenge Academy of Fort Stewart U.S. Army Post bagged oyster shells at Meridian on April 13, 2010.
- Interns from the Georgia Teen Work Program bagged shells from April 15th – June 1st, 2010.
- A railing along the shoreline at Long Tabby was built by Friends of Sapelo volunteers in May, 2010 using recycled wood.
- TNC staff attended the Coastal Georgia Audubon Society meeting on April 20, 2010 and discussed the Living Shoreline project and associated volunteer opportunities on Sapelo Island.
- A Brunswick News article in July 2010 promoted TNC's Leaders in Environmental Action for the Future (LEAF), a group of 3 high school interns from New York City who worked on nature preserves in Georgia. The LEAF group worked on the Living Shoreline Projects on Sapelo Island.
- The Little St. Simons Island Ecological and Operations Managers visited the Sapelo Island Living Shoreline on July 16, 2010 and met with project team members from TNC and DNR.
- Members of the Institute for Georgia Environmental Leadership visited the site on Sapelo on September 13, 2010 for a presentation on the Living Shoreline.
- A presentation on Living Shorelines was given to the TNC GA Board of Trustees on September 28, 2010.
- A Living Shoreline presentation and meeting for interested guests on Little St. Simons Island was given on October 7, 2010.

- The living shoreline project and was presented at two coastal conferences: Restore America's Estuaries 5th National Conference on Coastal and Estuarine Habitat Restoration Preparing for Climate Change: Science, Practice, and Policy (Galveston, TX 2010) and the International Conference of Shellfish Restoration (Charleston, SC 2010).
- In October 2011 approximately 20 staff from the GA EPD, NOAA, and Corp of Engineers attended a Living Shoreline site visit and workshop on Sapelo hosted by the Project Team and the Sapelo Island Coastal Training Program.
- Two posters were presented, one in Memphis, TN at the ACE 5th National Partnership Conference and the second at Ponte Vedra, FL, NERR national conference (Hurley et. al, 2011).

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Daniel Harris – University of Georgia Marine Extension Service

Amanda Wrona Meadows, PhD – The Nature Conservancy

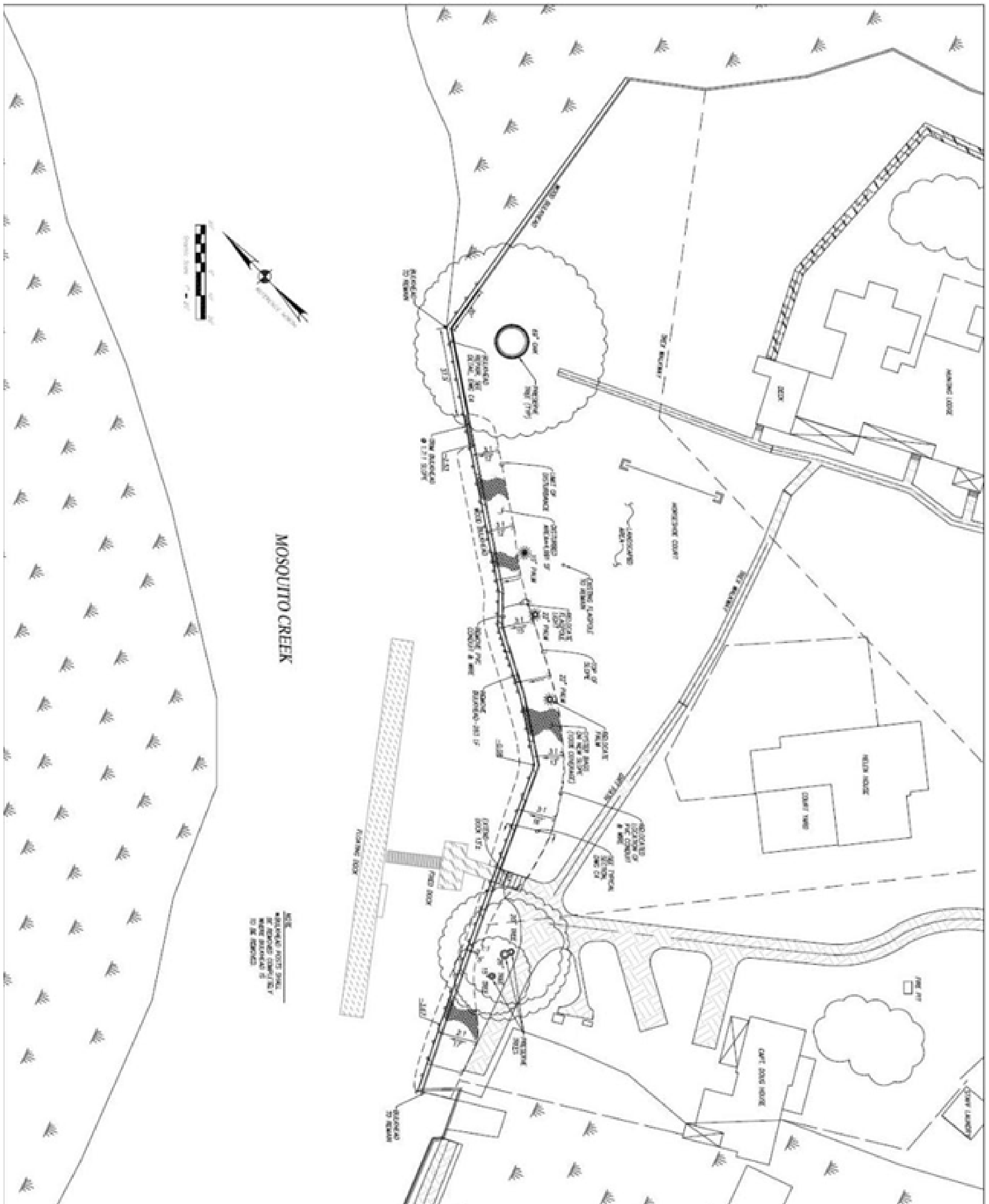
Alan Power, PhD – University of Georgia

Permits secured for project:

Request for Revocable License through the DNR Coastal Resources Division
Buffer Variances through the DNR Environmental Protection Division
Federal Consistency through the Coastal Zone Management Program
Nationwide 13 permits from the U.S. Army Corps of Engineers
National Environmental Policy Act authorization

Appendix A – Construction Documents

Living Shoreline Site Plan for Little St Simons Island

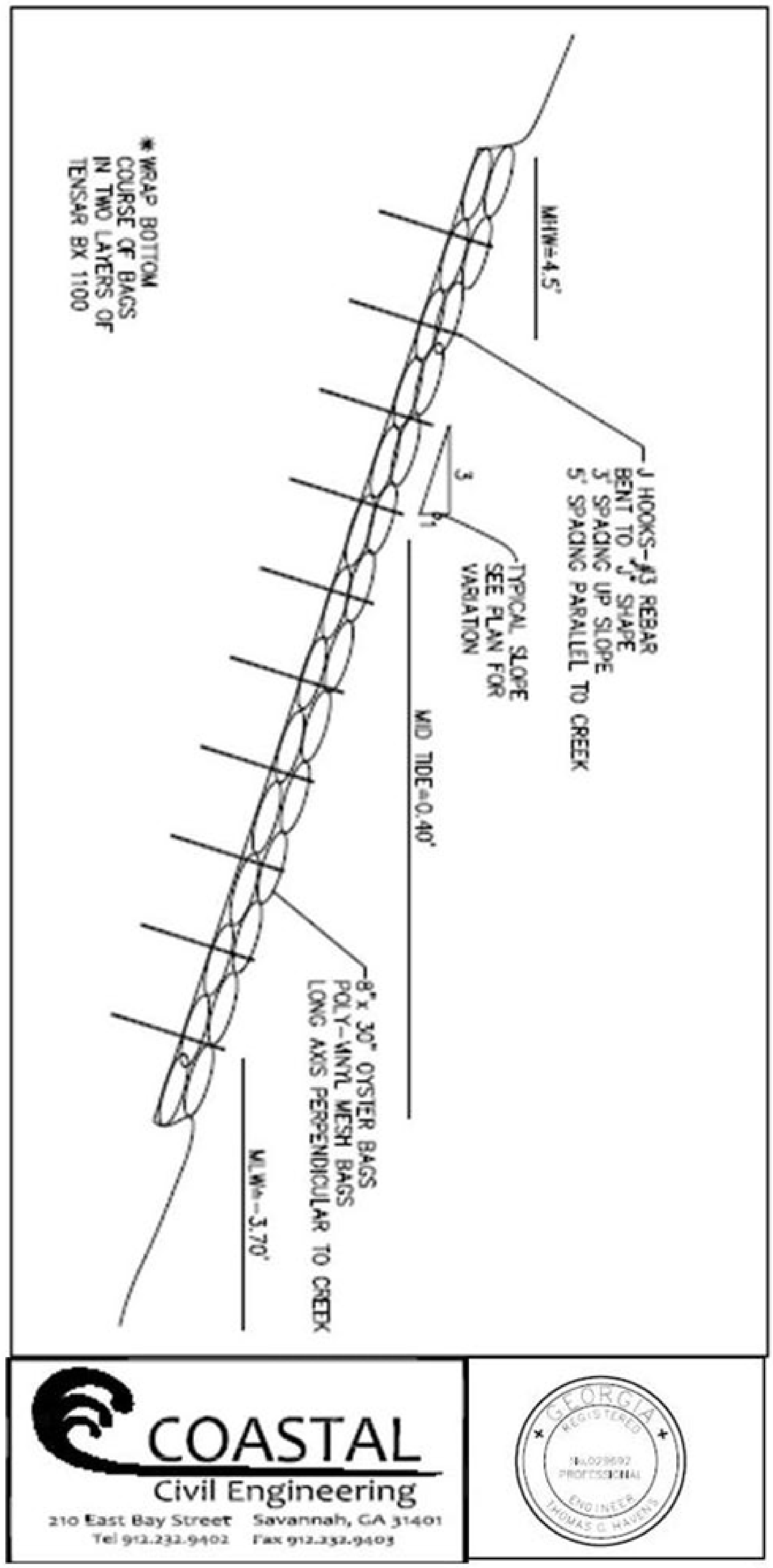


COASTAL Civil Engineering

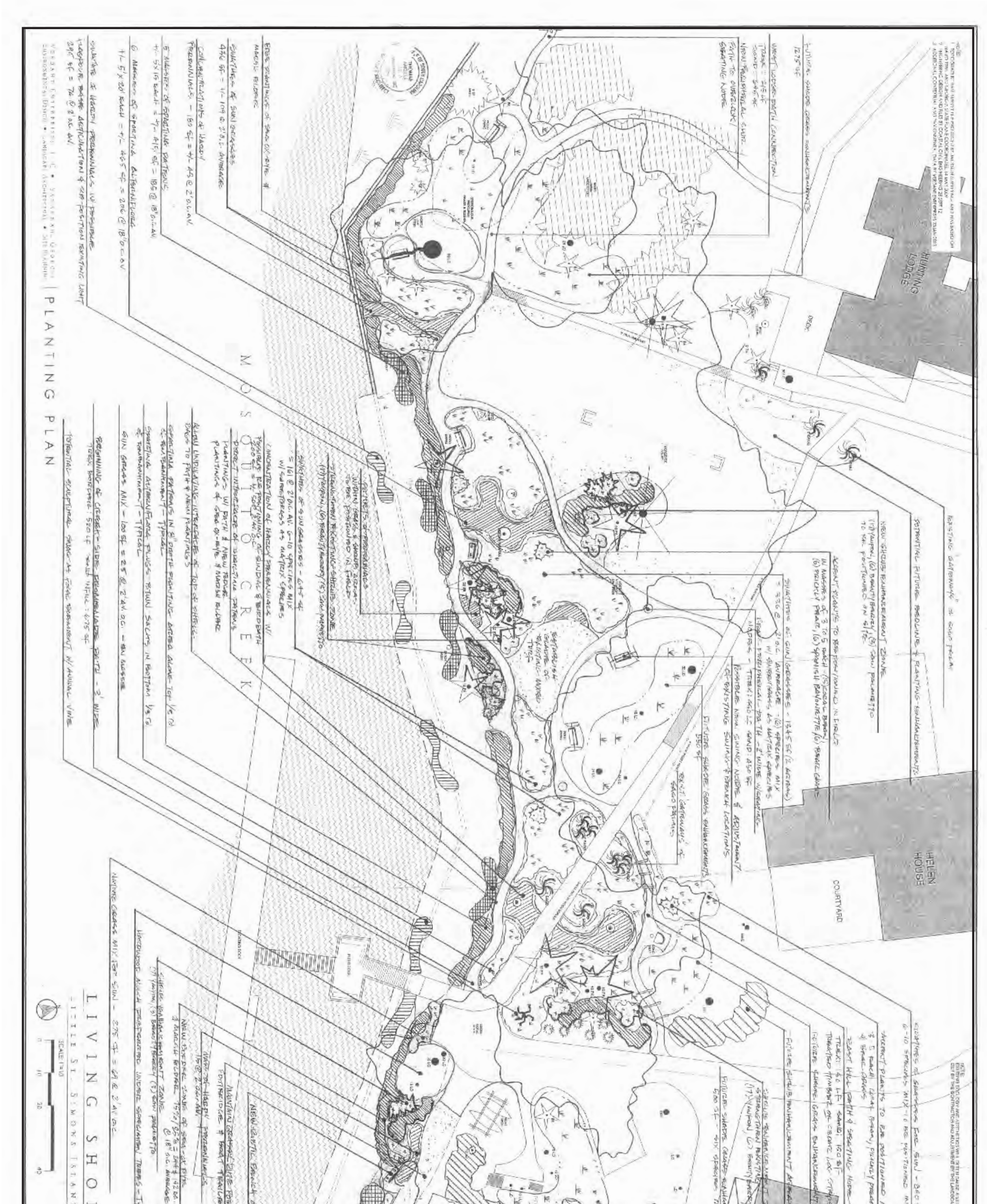
LITTLE ST. SIMON'S ISLAND
GEORGIA BARRIER ISLANDS, GLYNN COUNTY

LIVING SHORELINE SITE PLAN

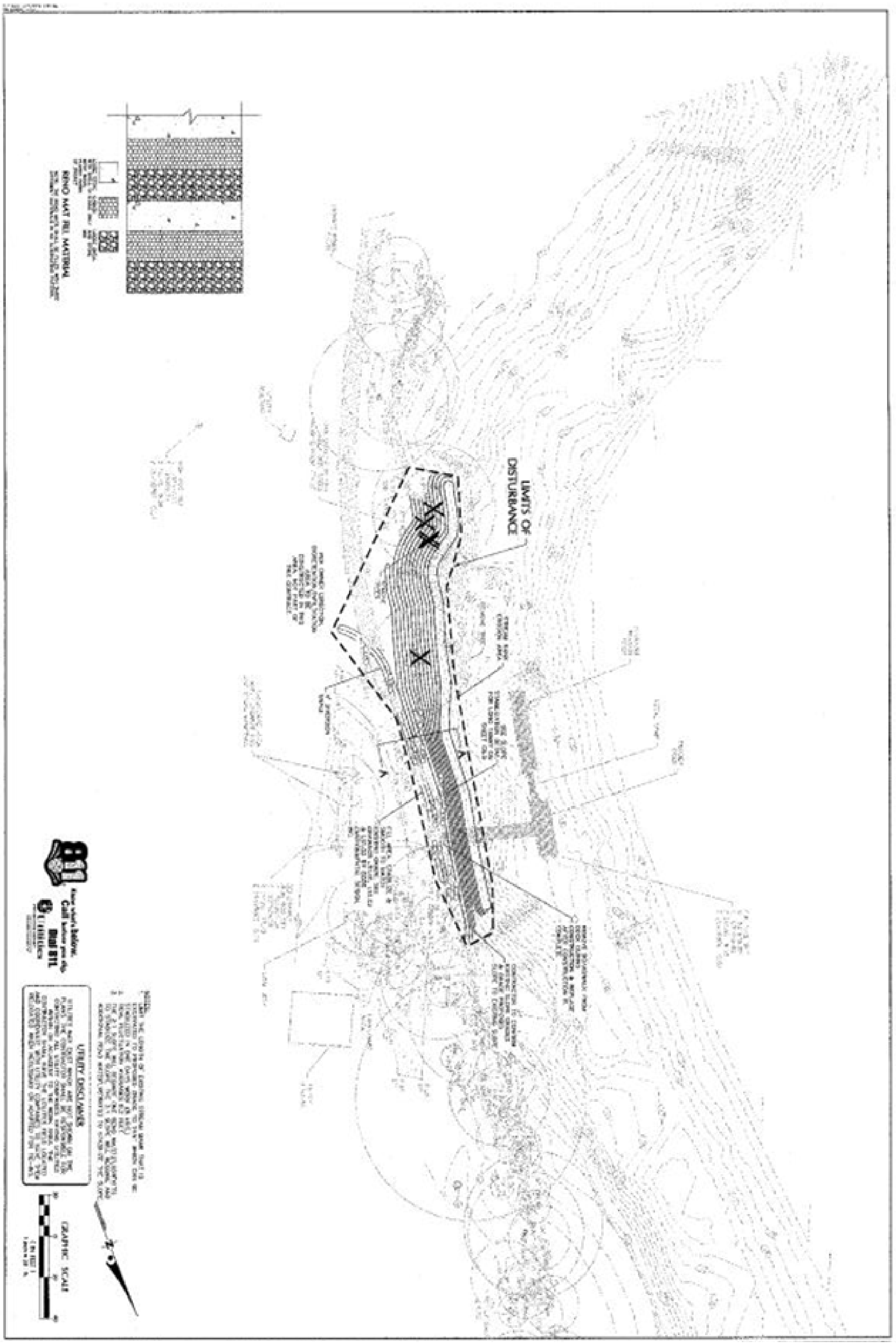
Living Shoreline Construction Detail for Little St Simons Island



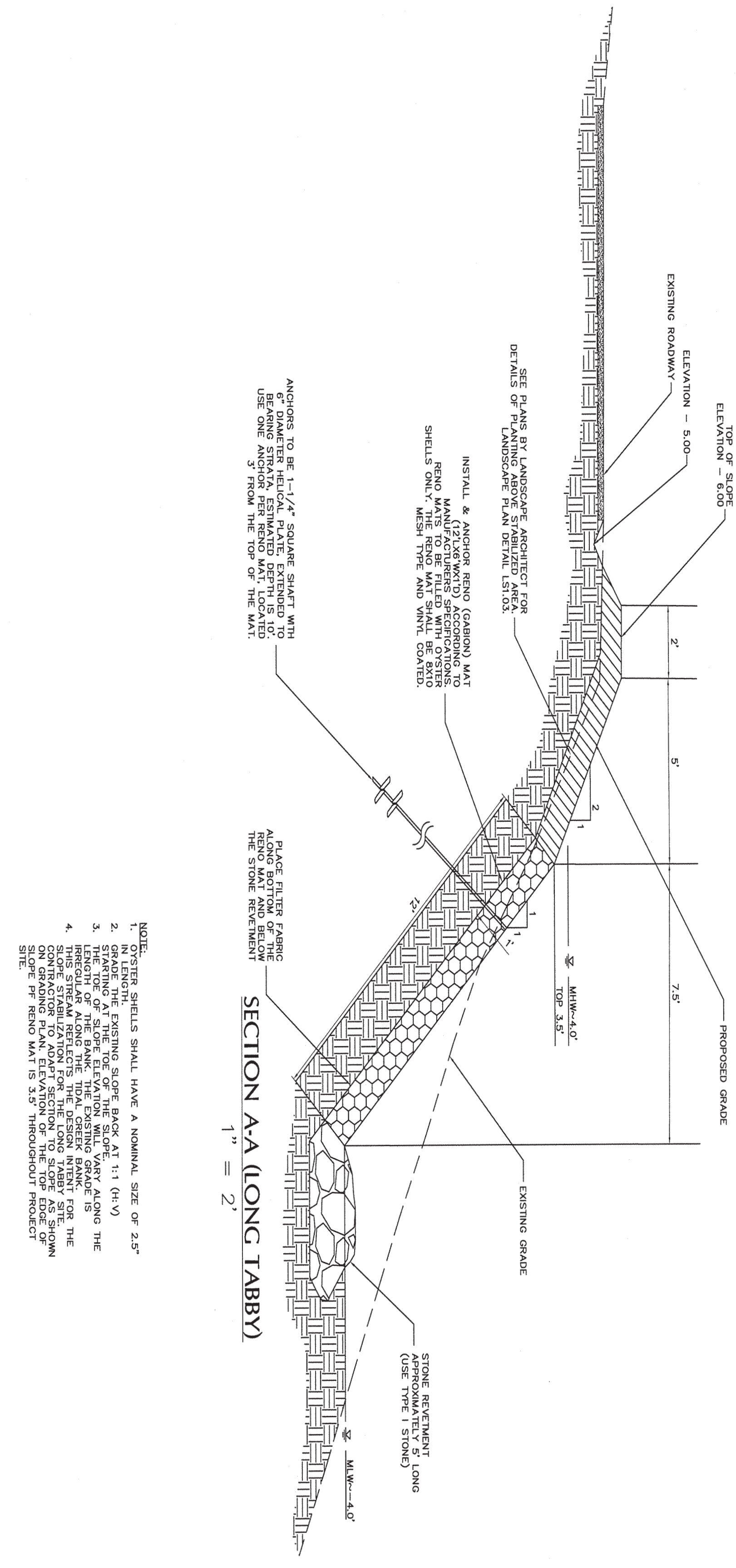
Long Tabby Construction Detail



Long Tabby Site Plan



Long Tabby Construction Detail



Ashantilly Construction Detail