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Introduction

Living Shoreline Project

Leesylvania State Park is located along the Potomac River in Prince William County, Virginia (Figure 1). It is one of the most highly used state parks in Virginia with attendance topping 600,000 (Anne, 2017). The project shoreline occurs on the southeast-facing Potomac River shore north of the marina (Figure 2). This section of coast is very low and is exposed to long fetches across and down river. Prior to the project, the shoreline had a scarped bank, exposed tree roots, and falling trees which was unsafe for park visitors (Figure 3).

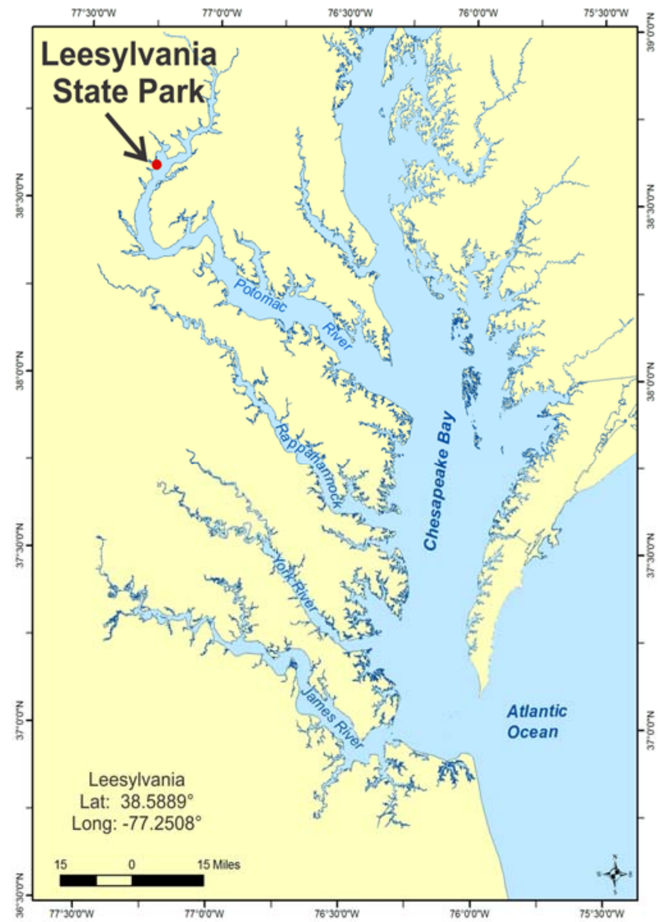

Figure 1. Location of Leesylvania State Park within the Chesapeake Bay estuarine system.

In 2011, the Shoreline Studies Program at the Virginia Institute of Marine Science (VIMS) performed a site assessment and developed the plan for a Living Shoreline demonstration project. The project consisted of four gapped rock sills with sand fill and marsh grass plantings (Figure 4). Project partners, Virginia State Parks, VIMS, Prince William County, and the Northern Virginia Regional Commission (NVRC) cooperated to obtain grant funding for construction.

Figure 2. Location of the Living Shoreline sill project at Leesylvania State Park.

Figure 3. Pre-project eroding Potomac River shoreline at Leesylvania State Park. The scarped bank, exposed roots, and fallen trees made the shoreline unsafe for visitors. Photo taken by Shoreline Studies Program, 21 March 2012.

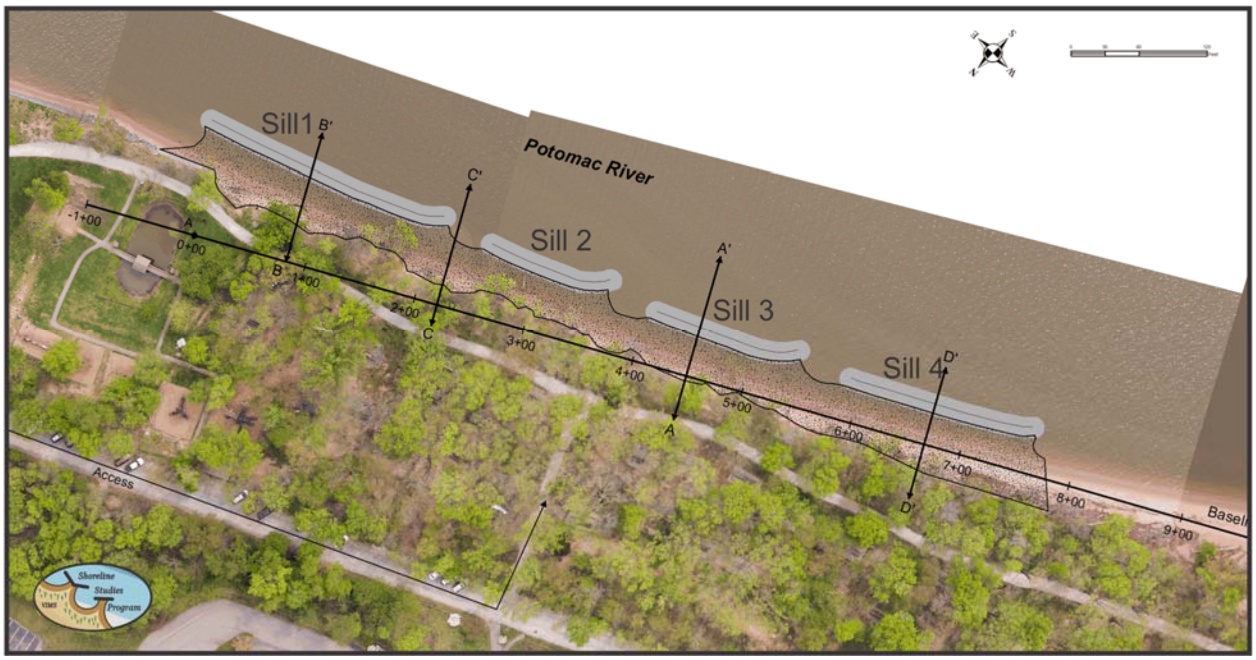

Figure 4. Living Shoreline sill project designed by Shoreline Studies Program, VIMS.

This project was funded, in part, through the Living Shorelines Initiative grant program, administered by the Chesapeake Bay Trust in conjunction with the National Oceanic and Atmospheric Administration (NOAA) Restoration Center and Maryland Department of the Environment. The first phase of the project was built in 2016 and included rocks sills 1, 2 and part of 3 along with sand fill (Figure 5A). The marsh grasses (*Schoenoplectus pungens* and *Panicum virgatum*) were planted, and exclusion fencing installed a month later (Figure 5B). A year later, the marsh grasses were well established (Figure 5C & D). The rest of the designed Living Shoreline project, the remainder of sill 3 and sill 4 was installed in 2018 (Figure 6).

Monitoring of the Living Shoreline project at Leesylvania was performed by the Shoreline Studies Program, VIMS and consisted of two elevation surveys using a Real-Time Kinematic Global Positioning System. The first survey took place just after installation for the

Figure 5. A) Rock sill 1 and sand fill after installation but before marsh planting (12Aug2016); B) Marsh grass planting and goose fence installation (1Sep2016); C) Sill 1 approximately one year after installation (23Oct2017); and D) high marsh grasses behind sill 1 after about one year (23Oct2017). Photos by Shoreline Studies Program, VIMS.

Figure 6. Google Earth image showing the installation of all four sills as designed. As of the photo date, sills 1 and 2 had been in place for about 1.75 years. The remainder of sill 3 and sill 4 had just recently been installed.

as-built survey in August 2016. The goal of this survey was to determine if the system had been built to design, and the survey occurred pre-planting. Typically, a Living Shoreline system is planted in late spring or early summer to provide a full season of marsh grass growth before the system is exposed to the stronger hydrodynamic conditions that occur during the winter. Grasses in August only have a fair probability of success while those planted in September have a poor probability of success because they typically do not develop the root stock to overwinter (Perry *et al*., 2001). Because the system was finished and the marsh grass planted in late summer, the second elevation survey occurred in March 2017 to determine how the system was maintained over the winter. At that time, the marsh grass was just starting to grow so no vegetation monitoring occurred for the system.

After this survey, no funding was available to continue monitoring the effectiveness of the Living Shoreline demonstration project. However, the project partners were concerned about the determining the status of the system on an ongoing basis. As a result, NVRC received funding to develop monitoring protocols for the site. With many types of monitoring plans and tools available, the Shoreline Studies Program, VIMS was tasked with defining the most useful way to monitor the efficacy of this Living Shoreline demonstration project at Leesylvania and other similar sites.

Monitoring Protocol Goals

Monitoring of shoreline stabilization projects with wetland restoration, like Living Shorelines, can be designed to accomplish many different tasks including information on their structural and functional aspects. Many monitoring plans are designed to determine if the project is similar to a reference area and how long it takes the project to reach parity in ecological function (Currin et al., 2008; Kreeger & Moody, 2014; Yepson, et al., 2016). These comparisons are very valid for scientific research but are not absolutely necessary to determine the success of a shoreline stabilization project. In fact, many eroding shorelines without wetlands vegetation do not have pertinent reference areas for any factor other than the erosion rate. However, if a natural shoreline with similar conditions of fetch and vegetation can be located nearby, it also can be sampled using this protocol for comparative purposes.

Natural resource managers and homeowners generally want to establish the effectiveness of their Living Shoreline for shoreline stabilization, not, necessarily, its parity with adjacent marshes. Therefore, the objective of this monitoring protocol is to use metrics that document sand retention, movement and elevation variability, tidal inundation, evaluate the success of the plantings and, where necessary, provide information for remedial actions. At the risk of being too simplistic, the data from these metrics are the information needed to answer the critical questions about the success of a Living Shoreline designed primarily for shoreline stabilization i.e. Are the measured parameters improving? staying the same? or deteriorating?

This monitoring protocol describes how to develop a monitoring plan for Living Shoreline projects that is applicable to the various types of shoreline protection systems that are installed throughout Chesapeake Bay. It is designed to be very simple and is aimed primarily at Virginia's natural resource managers and interested homeowners who do not have access to sophisticated equipment, laboratory facilities, or funding for a more extensive monitoring project as described by other existing frameworks. Following this protocol will allow the practitioner to determine basic characteristics of the structural effectiveness, functional success, and overall stability of the project. It also can provide an assessment of deficiencies that require remedial attention such as excessive sand loss or plant mortality.

Monitoring Plan Development

Establish Goals and Objectives for Project Phases

The first step in developing a monitoring plan for a project is to establish the goals and objectives for the plan that provides the answers needed by the owners. The goals need to be simple and easily achieved with a limited amount effort. A typical goal for the overall monitoring plan would be: Is the Living Shoreline performing as expected to provide shore protection?

The answer to this question is different based on when it is asked. Generally, a living shoreline project monitoring program has three phases: pre-construction and design, as-built and planting plan after construction, and long-term monitoring to document changes to the project as constructed and evaluate the success or failure of the Living Shoreline at achieving the goal of shoreline stabilization.

Monitoring for the pre-construction phase typically includes the topographic survey done for the design which documents the existing conditions at the site. It should also include photographs of the site taken at strategic permanent locations that provide a clear depiction of the site to compare with future photographs. The final component of this phase is the design drawings which indicate the location and dimensions of structures, fill elevations, the types and locations of proposed plantings and critical elevations like mean low water and mean high water.

The second phase of the monitoring plan includes the as-built survey showing the actual final location and dimensions of structures, substrate elevations, and the location and types of vegetation plantings. This phase serves as the baseline from which changes are measured and evaluated regarding the success and effectiveness of the project. This phase should also include photographic documentation of the site from the same strategic permanent stations used in the pre-construction phase as well as additional ones that document the structures.

The final phase is the actual long-term monitoring. This can be further divided into two separate phases: first year monitoring and subsequent years. The first year is different because it focuses on any rapid changes in substrate elevation and inordinate plant mortality that might indicate design flaws or deleterious conditions that need to be addressed with remedial measures to prevent future problems. The subsequent years of monitoring will determine the long-term viability and effectiveness of the Living Shoreline.

To develop the long-term monitoring plan decisions must be made on what parameters need to be sampled and the criteria for success. They should be easy to accurately quantify, require a minimum of time and effort, pertinent to achievement of stated objectives. For the purposes of this protocol, the wetland vegetation planted, tidal inundation and changes in substrate elevation are used to evaluate the success and effectiveness of the Living Shoreline.

Metrics

During the first year of monitoring it is critical to identify areas of rapid sand loss and large areas of plant mortality if these should occur. These factors can indicate flaws in the design or implementation. The causes of these problems need to be identified so remedial actions can be implemented to ensure the long-term success of the project. For example, if there is an area of rapid sand loss, you need to ask: Are the sill gaps too wide? Is the sill too low? Is the sand the right grain size? In the case of excessive vegetation mortality, you need to ask: Have the plants been planted at the wrong elevation? Are the plants not suited for the salinity regime? Were the plants washed out by a storm event? Is there a herbivory problem from geese or muskrats? Remedial for actions for sand loss can include: adjustment to the sill design to increase sand retention or the addition of coarser sand. For vegetation loss remedial actions might include: planting different species of plants better suited to the existing elevations or salinity regime or providing goose exclusion fencing to eliminate herbivory problems.

For long-term monitoring the vegetation will be sampled each year by using permanent meter square plots systematically placed along randomly selected transects (Neckles *et al*., 2002). Using a baseline established along the upland-wetland boundary, transects are randomly selected behind each sill using a random numbers table (Figure 7). Systematically locate the plots along these transects beginning at the upper limits of the wetland and ending at the back of the sill. These plots should be located at regularly spaced intervals of a few meters so as to ensure coverage of all of the vegetation communities present. Two to four transects with three to four plots behind each sill should be sufficient.

Figure 7. Vegetation sampling schematic. The baseline occurs along the upland/marsh boundary. Transects are selected by random numbers table along the baseline. The plots are selected randomly from the baseline.

These plots should be sampled in the late summer or early fall for percent cover, tallest stem length, and the number of flowering shoots. Percent cover (Figure 8) is usually defined as the vertical projection of the shoot area to the ground surface expressed as a percentage of the plot area (Mueller-Dombois & Ellenberg, 1974). Another way of expressing this is to assume a light bulb is hanging directly over the plot with the shade from the light on the ground being the percent cover. This should be determined for each species. The percent bare area, the area not shaded by vegetation, should be recorded as the percent no cover. Stem height and flowering shoots are measures of plant vigor that indicate the development of a viable plant population.

As an alternative to actual percent cover, cover classes can be used to simplify the process (Daubenmire, 1959). In this process, a range of percent cover is used to quantify the cover in each plot (Table 1 and Figure 8). This can facilitate the determination of cover and reduce the time and effort involved. The midpoint of each cover class can be used to calculate the average percent cover for the site. Vegetation is an important component of the overall shore protection system and must be thriving for the project to be a success. If plants are not thriving, shading should be considered as a cause. Growth of trees and shrubs over time can impact the amount of sunlight hitting the shore thereby reducing plant growth.

Tidal inundation can be qualitatively monitored be observing daily wrack lines, the accumulation of debris left at the upper limit of tidal inundation, along the shoreline or quantitatively measured with a tide staff calibrated to the local mean low water. These

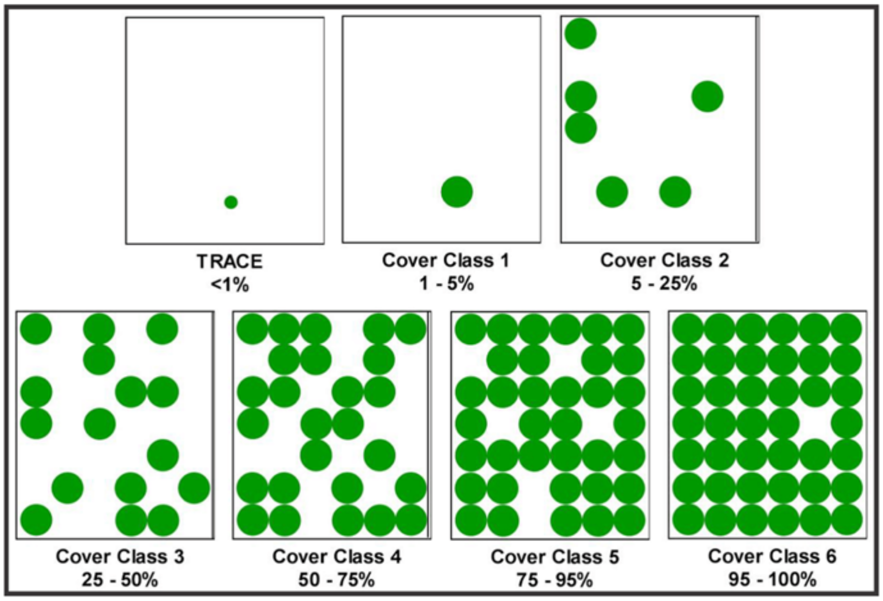

Figure 8. Percent cover depiction for vegetation monitoring. From Connecticut Sea Grant (n.d.).

observations are important to ensure that the wetland vegetation is being regularly inundated. In addition, any observed accumulations of wrack, vegetation debris and flotsam and jetsam, should be periodically removed to prevent smothering the planted vegetation.

The best way to measure changes in elevation is to periodically conduct a topographic survey of the site. As this can be costly, an alternative, an easy way to measure changes in elevation is to use strategically placed stakes driven into the substrate with a measurement from the top of the stake to the substrate surface. Periodically recording the changes in the exposed height of the stake can provide a semi-quantitative record of areas where sediment is being lost and where it accreting. This information can be used to identify areas where additional sand may be needed. These stakes should be placed within the permanent vegetation plots and along the centerline and immediately adjacent to the bays between the sills.

Table 1. Cover classes (Daubenmire, 1959)

Cover Class	Range of Coverage	Midpoint of Range
Trace	<1%	0.50%
1	1 - 5%	3.00%
2	5 - 25%	15%
3	25 - 50%	37.50%
4	50 -75%	62.50%
5	75 - 95%	85%
6	95 - 100%	97.50%

In addition to these measurements, photographs from the permanent stations should be taken every year in the late summer or early fall.

Measures of Success

Vegetation monitoring should indicate increasing cover, stem height and flowering shoots for the first three to four years until the cover stabilizes around 70% - 80%. There should also be a concomitant decrease in percent no cover.

Tidal inundation monitoring should indicate almost daily inundation of the wetlands vegetation at the lower elevations. The high marsh areas should also be periodically inundated during spring tides and storm events.

Sediment monitoring during the first year might reveal substantial changes in sediment elevation with some relocation as the system adjusts to wave action and tidal inundation. This is normal in most Living Shorelines as long as there is no radical loss of sand. After the first year, variation in sediment elevations and distribution should be relatively minimal.

Summary

In summary, this proposed monitoring plan is designed to make observations about a Living Shoreline constructed for shoreline stabilization and provide an accurate depiction of its effectiveness and stability with a minimum of time and effort. The goal is to ask and answer the simple questions, is the project improving? staying the same? Or deteriorating? These questions should be asked in the post installation monitoring period as well as in the longer-term monitoring period. Because the monitoring protocol does not require sophisticated equipment or extensive funding, it is appropriate for natural resource managers and homeowners that require quick and easy, yet accurate monitoring. Though many different, and more complex frameworks exist for monitoring of Living Shoreline projects, this methodology is provided so that monitoring does not become an onerous task but rather one that is simply useful.

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