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ABSTRACT

The term "living shoreline" was recently associated with particular types of shoreline stabilization methods that emphasize the use of natural habitat features such as deeply rooted riparian vegetation, vegetated wetlands, and sand beaches. This overview of living shoreline design options for tidal tributaries describes six nonstructural and four "hybrid" or structural methods for erosion protection. Structures are included with living shoreline design options to make habitat restoration or creation possible without substantial impacts to tidal exchange or habitat functions. The use and effectiveness of other methods not included in this summary are still under investigation, such as oyster shell reefs and pre-cast concrete structures.

INTRODUCTION

Erosion Protection Methods

There are a variety of erosion control methods for tidal shorelines of the Chesapeake Bay depending on the expected wave climate of a particular shoreline location. The term "shoreline armoring" refers to the practice of installing protective structures such as bulkheads and rock revetments. Erosion protection is the primary purpose for these structures and the permanent loss of natural shoreline habitats tends to be unavoidable where they are installed (1).

Nonstructural methods will stabilize bank erosion and restore wetland habitat in protected, low energy settings. Natural erosion buffers are integral, such as riparian buffers with deeply rooted vegetation, wide tidal marshes, and sand beaches. Successfully using planted tidal marshes and other nonstructural techniques depends on the shoreline location and wave climate (2,3). The fetch or distance across open water should be short, the erosion trend moderate, and the water depth near the shoreline should be shallow (4). Plenty of sunlight and existing marshes in the general vicinity also indicate suitable growing conditions for vegetative treatments.

"Hybrid" designs combine advantages of both nonstructural and structural methods. The strategic placement of structures makes restoration or creation of natural erosion buffers possible. In addition to erosion protection, this provides water quality and habitat benefits usually displaced by extensive shoreline armoring (1,5).

What is a "Living Shoreline" Method?

The term "living shoreline" is associated with options in the nonstructural and hybrid categories of stabilization methods. This approach advocates the restoration and enhancement of natural habitat features that are increasingly needed in developed watersheds (1,6). If functioning riparian buffer and tidal wetland habitats can be sustained instead of replaced by stabilization projects, they will reduce non-point source pollution by filtering ground and surface water runoff and trapping sediment.

Various agencies and organizations have their own working definitions of living shoreline methods to advocate their use (6-8). This concept was previously referred to as the "natural," "soft," or "nonstructural" approach. Common themes in these definitions include strategies for managing shoreline erosion while also preserving and improving valuable ecosystem services, such as providing habitat for terrestrial and aquatic species and maintaining water quality.

Another shared concept is integrating three distinct yet ecologically connected shoreline habitats - the riparian buffer, tidal wetland, and subtidal area. There is also a consistent reference to gradual slopes to provide optimal growing conditions for vegetation. The strategic placement of structures and other materials such as sand fill and wetland plants should only minimally disrupt normal coastal processes, such as tidal exchange and sediment transport.

Guidelines are available for non-tidal stream bank stabilization using similar methods, but these design options are not readily transferred to estuarine settings (9). The same principles for enhancing natural erosion buffers still apply, but different applications and design specifications are needed to include estuarine habitats. Living shoreline treatments for tidal tributaries must also be able to withstand tidal currents, wind, and wave climates not present in non-tidal settings.

METHODS

The following description of living shoreline design options for tidal shorelines includes six nonstructural and four "hybrid" methods commonly used in the Chesapeake Bay region (Table 1). Each description includes the primary design features and the most suitable site characteristics where it can be applied effectively. This information was compiled from existing descriptions and findings from recent studies.

Nonstructural	Hybrid
Riparian vegetation management	Marsh toe revetment
Beach nourishment & dune restoration	Marsh sill
Tidal marsh enhancement	Marsh with groins
Tidal marsh creation	Offshore breakwater system
Bank grading	
Fiber logs	

Table 1. *Living shoreline design options are divided into nonstructural and "hybrid" methods that include structures to support habitat restoration or creation.*

RESULTS

Nonstructural Design Options

Riparian Vegetation Management

Activities to enhance the density or species diversity of stabilizing bank vegetation are referred to collectively as riparian vegetation management. These actions include trimming tree branches overhanging a marsh to increase sunlight, selectively choosing desirable plants for natural regeneration, or planting additional landscape material to increase cover or diversity. Using vegetation buffers to intercept stormwater runoff from developed areas and controlling invasive species that degrade habitat quality and stabilization effectiveness are also included. Most tidal shorelines are suitable for some type of riparian vegetation management and enhancement activities.

Beach Nourishment and Dune Restoration

Beach nourishment is the addition of sand to a beach to raise its elevation and increase its width to enhance its ability to buffer the upland from wave action. Dune restoration is the process of reshaping and stabilizing a dune with appropriate plants usually after a beach nourishment event. Common plant species for Chesapeake Bay beaches and dunes include *Ammophila breviligulata*, *Panicum amarum,* and *Spartina patens*.

These actions are best suited for gently sloping, sandy beach shorelines with low erosion. Beach and bank erosion may still occur during storms. Periodic replenishment is usually needed to maintain the desired beach profile. This method may not provide sufficient protection where no beach currently exists or where tidal currents and wave action remove sand rapidly.

Tidal Marsh Enhancement

Tidal marsh enhancement includes adding new marsh plants to barren or sparsely vegetated marsh areas. Sand fill can be added to a marsh surface to maintain its position in the tide range or to increase its width for more protection. Replacing marsh plants washed out during storms also fits into this category. Less mowing of wetland vegetation can also enhance the stabilizing and habitat features of a tidal marsh.

Shorelines with existing marshes or where marshes are known to have occurred in the recent past may be suitable for this treatment. Water depth and the amount of sunlight available are key factors to consider. A wide, gently sloping intertidal area with minimal wave action also indicates suitability.

Tidal Marsh Creation

Tidal marsh creation can be applied where a natural marsh does not exist. Non-vegetated intertidal areas can be converted to a tidal marsh by planting on the existing substrate. Because a wide marsh is needed for effective stabilization, this method normally requires either grading the riparian area landward or filling channelward into the subtidal area for a wider intertidal zone. The plant species will depend on the local salinity range plus the depth and duration of tidal flooding. Two common tidal marsh grasses used for this purpose are *Spartina alterniflora* and *S. patens*.

The most suitable shorelines for tidal marsh creation have wide, gradual slopes from the upland bank to the subtidal waters, a sandy substrate without anaerobic conditions, and plenty of sunlight. Extensive tree removal in the riparian buffer just to create suitable growing conditions for a tidal marsh should be avoided, especially if the forested bank is relatively stable. Salt marsh plants have a limited tolerance for wave action (10). The wave climate and the frequency and size of boat wakes must also be considered (2,10).

Bank Grading

Bank grading is a land disturbance activity that physically alters the slope of a shoreline segment, particularly shorelines with near vertical slopes. A dense cover of deeply rooted vegetation on the graded bank acts as a buffer for upland runoff and groundwater seepage. Stabilization in the wave strike zone can be provided with dense vegetation on the lower portion of the graded bank. Bank grading can also be combined with planted tidal marshes and beach nourishment.

Low eroding banks with only partial or no vegetative cover are particularly suited for bank grading. Confining layers in the bank material and the transition to adjacent shorelines may dictate the extent of possible grading. Surface and groundwater management measures may be needed.

Fiber Logs

Fiber logs are also known as coir logs or biologs. These biodegradable logs come in a variety of sizes and grades for different applications. They must be aggressively staked into place to prevent them from being lifted and moved by tidal currents and wave action. Fiber logs are particularly useful to temporarily contain sand fill and reduce wave action at planted marsh sites (Fig. 1).

Fiber logs decay in five years or less. They may need to be replaced if the planted marsh does not stabilize before the logs break down. They have also been placed along undercut banks where excessive shading prevents the growth of marsh vegetation. The effectiveness of using fiber logs to reduce the undercutting effect of tidal currents and boat wakes is still under investigation, but it is assumed that they must be inspected regularly and replaced periodically.

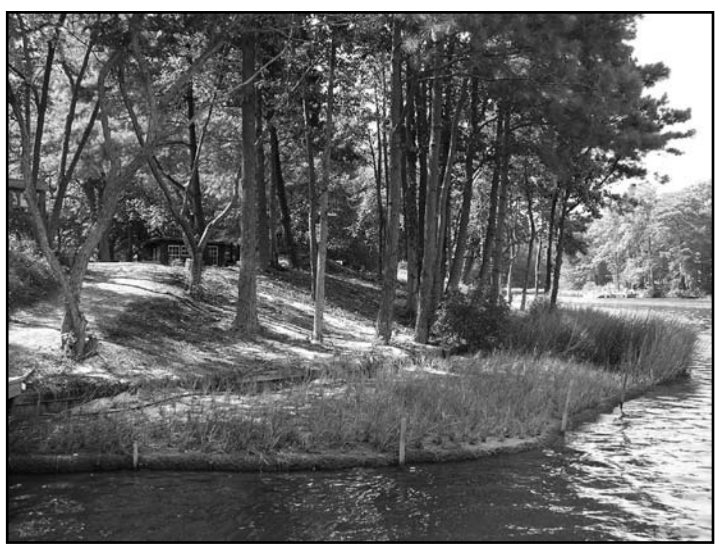

Figure 1. *Fiber logs provide temporary soil containment and protection for planted marshes until the root system becomes established.*

Hybrid Design Options

Marsh Toe Revetment

Marsh toe revetments are low profile structures placed at the eroding edge of an existing tidal marsh. This approach is also known as marsh edge stabilization. They are typically constructed with quarry stone. If the structure height will exceed the mean high water elevation due to the expected wave height or the target shoreline requires a long continuous structure, then gaps may be needed to facilitate tidal exchange. The most suitable sites for this treatment have existing tidal marshes wide enough to provide upland erosion protection but with an eroding edge and a trend for landward retreat.

Marsh Sill

Marsh sills are a similar type of low stone structure, but they are used where no existing marsh is present. Sills are usually located near the low tide line, then backfilled with clean sand to create a suitable elevation and slope for planted tidal marsh vegetation (Fig. 2). Like marsh toe revetments, the height of the sill should be near the mean high water elevation to minimize interruption of tidal exchange.

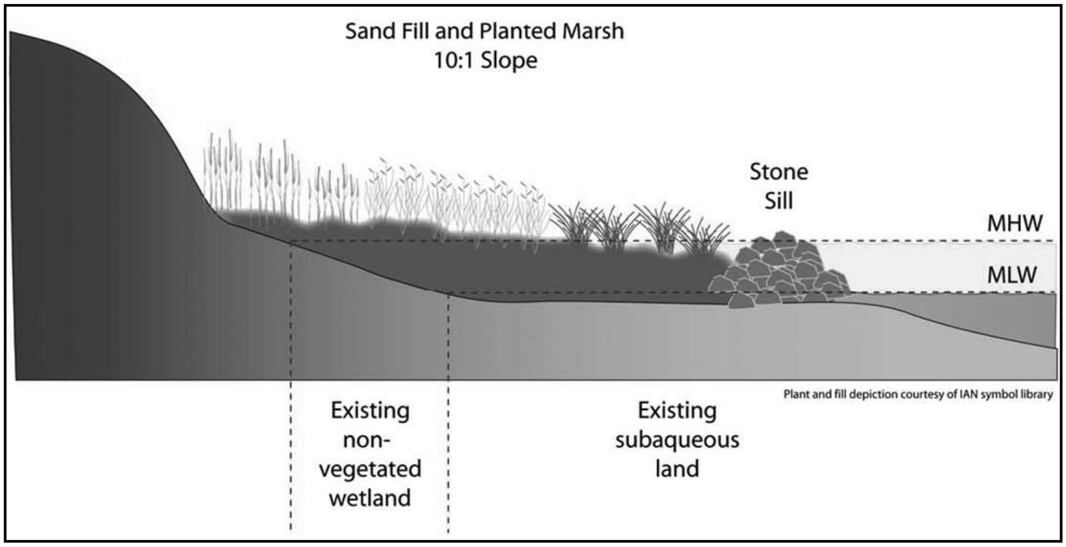

Figure 2. *A typical cross-section for a marsh sill with sand fill and planted tidal marsh vegetation. Marsh toe revetments are similar structures adjacent to natural tidal marshes.*

Eroding banks without a tidal marsh present are candidate sites for marsh sills, particularly if marshes exist in the general vicinity. However, the physical alterations needed to create suitable planting elevations and growing conditions should not require major disturbance to desirable shoreline habitats, such as mature forested riparian buffers or valuable shallow water habitats (e.g., shellfish beds, submerged aquatic vegetation). If bank grading is appropriate to create target slopes, then the bank material can possibly be used to backfill a marsh sill if it is mostly coarse-grained sand. Sand fill can also be imported from an upland source.

Marsh with Groins

Using short stone groins to support a planted marsh is a similar approach to a marsh sill, except these structures are placed perpendicular rather than parallel to the shoreline. The groins can be used to contain sand fill within the project site. This method is suitable for lower energy shorelines where erosion of the unprotected marsh edge is expected to be minimal, while sills can be used where direct wave action and boat wakes need to be reduced. However, the potential effects on sediment transport and downdrift shorelines need to be considered.

Offshore Breakwater System

An offshore breakwater system is a series of freestanding trapezoidal structures strategically positioned offshore to create a stable beach profile with embayments. Even though they tend to be large and costly projects, offshore breakwater systems are commonly included as a living shoreline approach because they include a dynamic, natural beach feature in the design. Non-vegetated beach areas within breakwater systems also provide habitat for terrestrial and aquatic wildlife, including shorebirds, turtles, terrapins, and the northeastern beach tiger beetle. Oysters, mussels, algae, and other reef-dwelling organisms may colonize the shallow water structures.

Suitable sites for offshore breakwater systems are medium and high-energy sand beaches, banks, and bluffs without adequate sand for erosion protection and an historic trend for landward retreat. Like groins, offshore breakwater systems can interrupt longshore sediment transport and adversely affect downdrift shorelines. Beach nourishment and stabilizing beach and tidal marsh vegetation are usually included rather than allowing for natural accretion of sand.

DISCUSSION

This brief summary includes methods for erosion protection and habitat restoration collectively referred to as the "living shoreline" approach for tidal shorelines. If shoreline erosion must be stabilized, then choosing the least intrusive yet effective method is the main objective. Nonstructural methods that emphasize the use of dense riparian and wetland vegetation can be applied to many low energy shorelines with minimal wave action or boat wakes. They can also be combined with hybrid methods, such as a marsh sill combined with bank grading and a planted marsh.

The hybrid types of living shoreline design options have several characteristics in common. The structures should be necessary to support habitat enhancement, restoration, or creation. Important coastal processes are also minimally disrupted by properly designed hybrid projects, particularly tidal exchange and sediment transport. Effective hybrid projects provide enough protection without the need for erosion control structures at the riparian-wetland habitat interface if possible. This allows for the landward retreat of tidal marshes and sand beaches in response to rising sea levels. Connections between riparian and wetland habitats can enhance bank stability in the wave strike zone while also providing wildlife habitat value with food, cover, and vegetated corridors.

Some methods were not included in this summary of living shoreline design options because they are not widely practiced and their effectiveness is still under investigation. Oyster shell reefs can be designed to mimic marsh toe revetments or marsh sills, but it is not clear if uncontained oyster shell is sufficiently resistant to wave action and tidal currents. The placement of oyster shell adjacent to existing or planted marshes to support native oyster restoration efforts is most likely suitable even with limited erosion protection benefits.

Pre-cast concrete structures in various shapes have also been deployed in intertidal and subtidal areas to provide wave dissipation as well as habitat for shellfish and other reef dwellers. "Living walls" for steep bank stabilization is another method commonly applied to upland slopes, but only recently installed on tidal shorelines in Virginia. This engineered system of support structures with planted vegetation is intended to provide stabilization without extensive land disturbance and bank grading.

Selecting the most appropriate erosion protection method depends on the level of protection that is desired. Nonstructural and hybrid methods may not provide enough protection in some circumstances. Rock revetments and other defensive structures may be more suitable than a living shoreline approach where upland improvements are at significant risk (e.g., buildings, roads, utilities, septic drain fields, etc.), or where it is necessary to protect public health and safety. Limited construction access for installation and maintenance may also limit possible alternatives.

Depending on the level of protection that is needed, nonstructural and hybrid methods may not always be easier, less costly, or require less maintenance than rock revetments and bulkheads. While this may be the case with tidal marsh enhancement and creation projects, professional design and engineering assistance is usually required. Local knowledge or predictions of tide range, predominant wind direction, and wave height are required for effective designs. The amount of sand fill needed for sills, groins, and breakwater systems has to be accurately calculated to prevent adverse downdrift effects. Predicting how banks should be graded to achieve stable slopes and determining if the bank material is suitable for backfill also requires professional expertise.

Wider acceptance of the living shoreline approach with its inherent limitations could shift the current trend for shoreline armoring, particularly in very low energy settings. The guiding principles presented here can assist with the selection of possible alternatives, but site-specific design considerations are also required. Contacting local, state, and federal regulatory agencies for permit requirements is also advisable before any shoreline work is performed.

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