



**SOUTH RIVER
SHORE EROSION MANAGEMENT
AND LIVING SHORELINE
GUIDELINES**

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Disclaimer

The opinions and guidance offered in this document are those of the authors unless otherwise noted. The South River Shore Erosion Management and Living Shoreline Guidelines have not been evaluated or endorsed by Maryland State or Local government agencies and may contain material that is in conflict with existing requirements for shoreline development. Waterfront landowners are advised to consult with shoreline regulators and qualified professionals prior to initiating any shore erosion control management actions and related alterations in the Critical Area buffer.

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Introduction

To a greater or lesser degree, all waterfront communities throughout the Chesapeake Bay and its tidal tributaries are affected by shoreline erosion. Erosion is a natural process that occurs over both long and short time periods. Long term erosion is caused primarily by a combination of sea level rise and continuous wave energy that erodes, transports and deposits sediment along the shoreline. Short term erosion is driven by high energy storm events that temporarily raise water levels and form powerful wind generated waves that can substantially erode and reconfigure the shoreline. The forces from long and short term erosion erode the banks and deposit sediment disproportionately along the shoreline forming familiar coastal features such as spits, beaches, barrier islands and sand bars. Where sediment is removed faster than it is replaced – continued erosion occurs. In shoreline reaches where sediment loads are deposited at a rate higher than they are removed “accretion” occurs. In other reaches, these forces can strike a relative balance that results in greater shoreline stability.

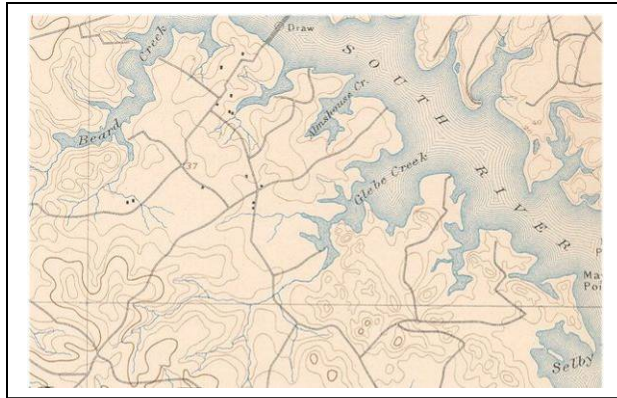


Figure 1. Middle segment of South River, Maryland

Beyond the Bay being a complex estuarine system that is strongly influenced by these shoreline processes, it is well known as a place of natural beauty, abundant fish and wildlife and water-based recreation. The expansive and inspiring scenes of native fringe marsh are a significant element of the Bay’s rich character and play a vital role in maintaining a healthy estuary and shoreline environments. Strategically located at the land-water interface, wetlands provide a host of natural services that collectively represent an irreplaceable resource. Some vital services provided by both restored and natural wetlands include:

- Anchoring and stabilization of shoreline sediments and reducing land losses due to the erosive effects of wind driven waves and boat wakes;
- Filtering and removing nutrients and pollutants and reducing sediment loads from upland sources and in the water column;
- Providing a food source to wildlife like:
 - waterfowl and small mammals that eat seeds of marsh plants;
 - fiddler crabs, snails, amphipods and other invertebrates that feed upon organic matter accumulated in wetland soils; and
 - fish that are, in part, supported by an aquatic food web based on “detritus” (fragments of dead plant/animal material)

Marsh plants help reduce erosion in several ways. First, marsh vegetation forms a dense, flexible mass of stems that help dissipate wave energy as water moves through the marsh.

Second, as the wave energy decreases, sediment transported from shallow waters is deposited in the marsh – causing shoreline accretion. Finally, as root matter from the plants form dense root-rhizome mats, the marsh elevation builds vertically and the sediment becomes two to three times stronger than unvegetated soils. This is especially important during the wintertime when plant stems provide much less resistance to waves.

Unfortunately, scientists are warning us about the coming widespread loss of wetlands and other important low lying natural coastal features from the steady onslaught of sea level rise. According to a recent report by the Chesapeake Bay Program (Scientific and Technical Advisory Committee [STAC] 2003), a combination of land subsidence and sea level rise or “relative sea level rise” will result in rising shoreline water levels in the Bay from 1.5 to 3.5 feet over the next century. These higher water elevations will have a pronounced effect on shoreline erosion.

Additionally, along the South River and other Bay tributaries, erosion caused by natural wave action, boat wakes, damage from invasive and nuisance species, and the relentless hardening of our shorelines has displaced many former native fringe marshes.



Figure 2. Smooth cordgrass (*Spartina alterniflora*) native fringe marsh

In years past, fewer “soft” shoreline stabilization alternatives were available and landowner awareness of the need for improved shoreline management practices was lacking. As a result, landowners relied upon traditional erosion control techniques such as bulkheading and riprap revetments. Further, intensive structural treatments were often used in protected coves and embayments where erosion threats were minor or non-existent. Fortunately, a growing number of landowners are looking into living shoreline protection alternatives and retro-fitting previous hardened shorelines by creating a marsh fringe in front of their structure. There are many opportunities for “naturalizing” existing hardened shorelines.

An analysis of recent South River shoreline structures data, collected by Virginia Institute of Marine Science, indicates that of the 84 miles surveyed by VIMS between September 2002 and May 2005 – approximately 45% or 38 miles of the shoreline had structures (Berman et al, 2006) . Nearly 31 miles or 37% of the shoreline surveyed was either bulkhead or riprap. Less than 1/3 or approximately 9.5 miles of the shorelines with bulkheads or riprap also had some fringe marsh associated with the structure. This is

likely due to a combination of natural colonization, existing fringe marsh before construction and recent marsh planting/living shorelines initiatives.

The Living Shoreline Concept

To counter-balance the negative effects of shoreline hardening, government and non-profit organizations, are paying increasing attention to the importance of maintaining, creating, and restoring “living” or natural shorelines. The descriptive term “living shoreline” readily conveys the image of a shoreline characterized by wetlands, sand beaches, submerged aquatic vegetation, mud flats, and/or oyster reefs that provide living spaces for a broad array of aquatic and terrestrial organisms.

The information and guidelines presented in this document are designed to complement a voluntary, river-wide estuarine and shoreline restoration framework developed by the Chesapeake Bay Foundation and its partners, which waterfront landowners and others can reference to help restore the South River and other Bay tributaries.

The fundamental objective of the living shoreline approach is to protect eroding shorelines while enhancing water quality and habitat for living resources in the Bay.

“Soft” or natural shoreline edges facilitate the landward migration of marshes as erosion and sea level rise progress over time.

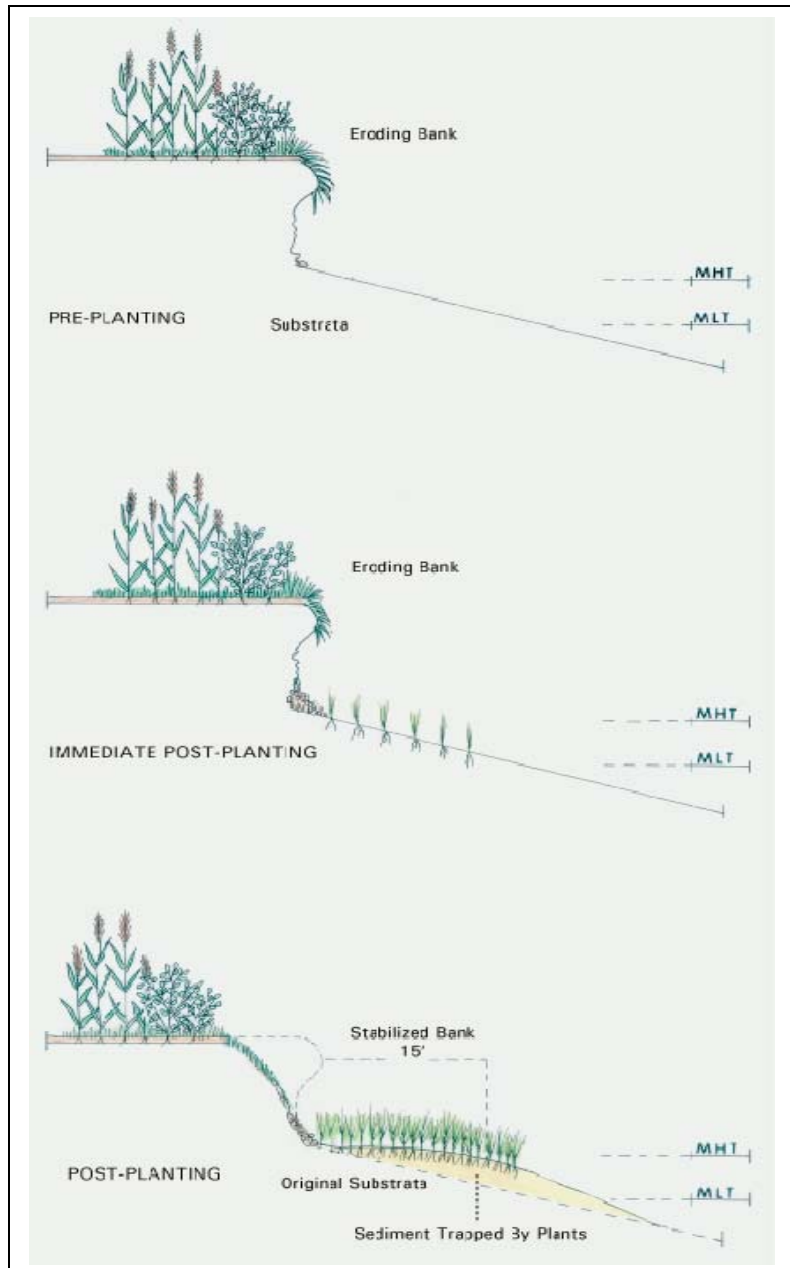


Figure 3. Sequence of changes before and after planting *Spartina alterniflora* along an unvegetated shoreline. Source: Rufus Toomey

With approximately 85% of the Chesapeake Bay shoreline being privately owned, there is a critical need to inform landowners of their shoreline management options.

This guidebook refers to the concept of using a “*living shoreline treatment*” as a means of achieving a combination of social and ecological objectives and as such is defined as:

“a shoreline management practice that provides erosion control benefits; protects, restores or enhances natural shoreline habitat; and helps maintain coastal processes through the strategic placement of plants, stone, sand fill and other structural and organic materials.”

Summary of Shoreline Stabilization Methods

The guidelines discussed in this document primarily focus on alternative shoreline stabilization methods that have the potential to control erosion and create habitat. Therefore, they represent only a partial solution to the problem of eroding shorelines. Other guidebooks that address coastal shoreline management are available from a variety of sources and should be consulted to evaluate a broader array of techniques – particularly involving structural solutions and bank stabilization. Consult the references used to compile these guidelines for further information.

Primary Erosion Control Treatment Options

Shoreline stabilization methods can be broadly sorted into three categories:

- Non-structural - which involve nourishing existing beaches with additional sand or establishing marsh grass without installing permanent structures to support plants after they are established. These methods are typically, but not always, used where erosion potential is limited – often referred to as low wave energy environments.
- Hybrid – are actually a combination of techniques which incorporate sand, wetland and other components that are permanently supported by stone structures that help keep the restored features in place where greater vulnerability to erosion is present.
- Structural – which utilize substantial shoreline armoring elements such as stone revetments, and breakwaters where considerable vulnerability to wave action exists.

These primary erosion control measures can be used in a variety of wave climates discussed in greater detail later in this document.

A series of indexed shoreline maps has been developed to show where opportunities for creating living shorelines exist along the South River and they are available, on the Chesapeake Bay Foundation website. These maps have been coded to reflect the type of shoreline stabilization method that was indicated for possible application along a specific shoreline reach.

The stabilization methods and their *associated map codes* (in parenthesis) are listed below. Generally speaking, these 3 broad classes of techniques increase in complexity and cost as they progress from non-structural to structural. Erosion control techniques designated below by an asterisk(*) are essentially the same technique (i.e. breakwaters) however; they are used for different purposes. Refer to the discussion of each technique later in this document for a more detailed explanation.

Table 1. Stabilization Methods and Map Codes

<u><i>Non-structural</i></u>
• Beach\sand replenishment (N-1)
• Fringe marsh creation or restoration (N-2)
• Fringe marsh creation or restoration with coir log edging (N-3)
<u><i>Hybrid Projects</i></u>
• Marsh fringe with groins (H-1)
• Marsh fringe with sills (H-2)
• Marsh fringe with breakwaters (H-3)*
• Beach replenishment with breakwaters (H-4) *
• Marsh toe revetment (H-5)
<u><i>Structural Projects</i></u>
• Revetment (S-1)
• Breakwater system (S-2) *
• Spurs (S-3)

The table below helps illustrate the general relationship between shoreline stabilization methods, habitat and erosion control goals.

Table 2. Shoreline Stabilization Methods & Habitat/Erosion Control Goals*

Nonstructural	Hybrid	Structural
<p><u>Habitat Goal:</u></p> <p>Marsh restoration/ creation achieved <i>without</i> structures. habitat features may include: marsh, sand edge</p>	<p><u>Habitat Goal:</u></p> <p>Marsh restoration/creation and protection of existing marsh achieved in combination <i>with</i> structures. Habitat features may include: marsh, sand edge, beach strand</p>	<p><u>Habitat Goal:</u></p> <p>Habitat restoration/ creation possible only <i>with</i> structures in certain situations. Habitat features may include: marsh, SAV, oyster reefs, beach strand, pocket beaches</p>
<p><u>Erosion Control Goal:</u></p> <p>Erosion control achieved by wave dampening, effects of marsh vegetation, designed beach width & elevated backshore profile conditions. Limited potential to protect banks.</p>	<p><u>Erosion Control Goal:</u></p> <p>Erosion control achieved by combination of wave dampening effects of marsh, elevated backshore & structures. Limited to moderate potential to protect banks</p>	<p><u>Erosion Control Goal:</u></p> <p>Erosion control achieved by engineered structures & elevated backshore primarily in <i>high</i> wave energy conditions. Moderate to excellent potential to protect banks.</p>
<p><u>Typical Methods:</u></p> <ul style="list-style-type: none"> -Beach/sand replenishment -Marsh plantings on existing substrate or sand fill -Marsh plantings using bio-log edging 	<p><u>Typical Methods:</u></p> <ul style="list-style-type: none"> -Marsh plantings in conjunction with stone containment groins -Segmented, low profile sills -Marsh toe revetments 	<p><u>Typical Methods:</u></p> <ul style="list-style-type: none"> -Attached, detached or submerged stone breakwaters with beach fill & possibly artificial oyster reefs &/or SAV planted in shallow water landward of structure -Groin fields with sand beaches -Stone revetments & bulkheads positioned landward of wetlands & tidal waters

* These are general statements about each method. Site specific situations and shore morphology will dictate details of the design and construction. The desired level of protection will determine the dimensionality of a given project.

Traditional Structural Erosion Control and Living Shorelines

Traditional erosion control methods of bulkheading and riprap have a number of associated structural and environmental problems. Bulkheading is often subject to a scouring effect at the base of the structure which can remove material and undermine the integrity of the bulkhead. Loss of backfill material behind the bulkhead can result from water overtopping, or by wave action at the ends of the structure – a process called flanking. Although there are construction practices designed to address these common concerns, in the long run the repair or replacement of a bulkhead will be due to one or more of these factors.

Aquatic life can also be harmed from arsenic, chromium, copper and other contaminants coming from pressure treated timber bulkheads. Also, the scouring effect at the base of bulkheads in open waters creates an inhospitable high-energy environment for juvenile fish. Further, the vertical design of bulkheading placed in open waters, permanently reduces the availability of refuge habitat for small fish and attachment surfaces for algae and micro-organisms that serve as important food sources for invertebrates and some fish. On a large scale, hardening of shorelines through bulkheading and riprap can reduce sediment sources along the shoreline, which may cause the loss of beaches, bars, and smaller accretions of sand that help protect the shoreline from further erosion. Although rock or stone riprap, if installed properly, can limit erosion and is less harmful than bulkheading, the wildlife and water quality benefits are inferior to vegetated shorelines.

A Virginia Institute of Marine Science researcher (Carroll 2002) found that both the total numbers and diversity of fish species are much greater in shallow waters where even very narrow (2-4 meters wide) wetlands are present versus riprap shorelines.

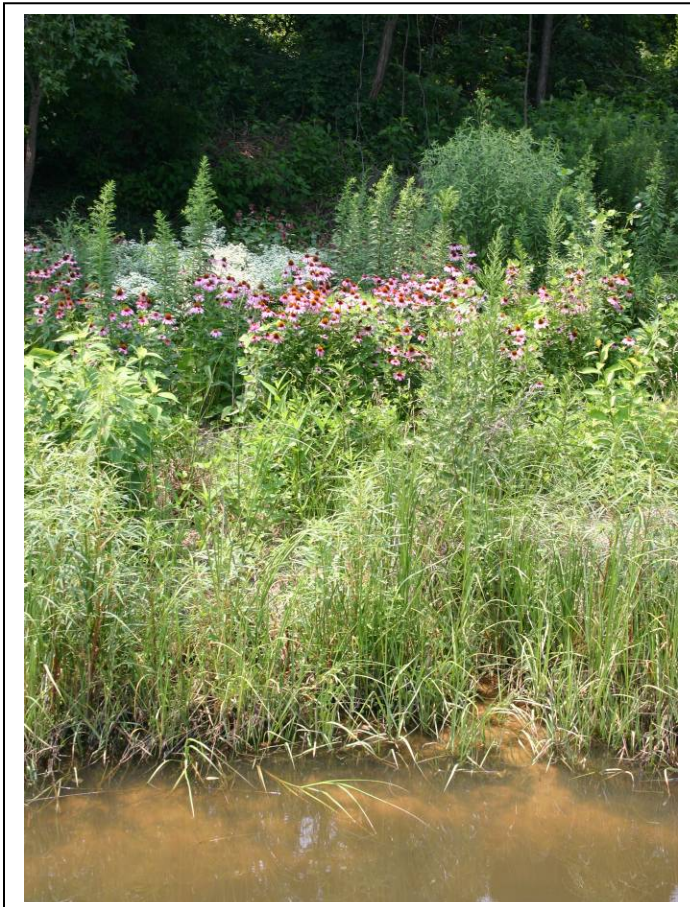


Figure 4. Artificially created smooth cordgrass fringe marsh enhanced with perennial wildflowers

Table 3. Comparison of Traditional and Living Shoreline Erosion Control Treatments

Traditional Structural Methods (Bulkhead/Riprap)	Living Shoreline Treatments
<i>Advantages</i>	
<p>Longevity more predictable</p> <p>Excellent wave energy dissipation, (Rip-rap)</p> <p>Low maintenance requirement (Rip-rap)</p> <p>Contractors familiar with installation methods</p> <p>Good pier & landside access (Bulkhead)</p> <p>Retains soil and prevents sliding of the land behind (bulkhead)</p>	<p>Excellent habitat for aquatic & terrestrial wildlife</p> <p>Improves water quality</p> <p>Can be least expensive option</p> <p>Individual landowners can install some types</p> <p>Continued access to natural sand/vegetated shoreline</p> <p>Permits usually easier to obtain</p> <p>Less impacts to adjoining landowners in low energy shores</p>
<i>Disadvantages</i>	
<p>On eroding reaches, isolated armoring accelerates downdrift erosion</p> <p>Toe scour, flanking, and overtopping can often cause structural failure (Bulkhead)</p> <p>Professional installation usually required</p> <p>Limited habitat for aquatic & terrestrial wildlife</p> <p>Can leach toxic pollutants into water (Bulkhead)</p> <p>Permits may be harder to obtain</p> <p>Greater impacts to adjoining landowners</p>	<p>Relies mainly on dissipation of wave energy to protect eroding banks</p> <p>Fewer contractors familiar with installation methods</p> <p>May host undesirable plant/wildlife</p> <p>Need goose fencing first two growing seasons</p> <p>Vegetation requires some maintenance</p> <p>Longevity can vary substantially</p>

While limited studies have been conducted to determine how much wave dissipation marshes provide, Knutson and others (1982) found that the energy in a ½ foot wave was reduced 72 percent in a 15-foot traverse across the marsh. Tidal fringe wetlands can also help anchor and stabilize shorelines by forming dense root mats and building vertically on average from 0.14-0.3 inches per year (Griffin and Rabenhorst 1989) in the Chesapeake. Hardaway (1980) found that low upland banks erode at nearly twice the rate as marsh shorelines with similar fetch exposures and nearshore depths. Generally, the wider the planting area, the greater the erosion control benefits.

It is interesting to note that the oldest reported example of shoreline stabilization with salt marsh vegetation occurred on Maryland's Eastern Shore (Knutson, Ford and Inskeep 1981). In 1928, a property owner planted smooth cordgrass (*Spartina alterniflora*) to reduce erosion. His site remained stable for more than 50 years.

With that said, after intense storms, it is expected that some damage to the shoreline and vegetation will occur.

Therefore, longevity of a marsh creation project is dependant upon the rate at which the shoreline and vegetation can sufficiently recover to avoid further exacerbating shoreline instability during the next storm event.

A recent study (Burke, Koch and Stevenson 2005) of the performance of several different types of living shoreline treatments reaffirmed their durability and habitat benefits when properly constructed and maintained.

While in many instances it is impractical or inappropriate to use marsh grass alone to maintain or restore a given shoreline, landowners can use plants in addition to other structures to protect property and help the Bay at the same time. Over time, soft shoreline approaches may also enhance property values as more waterfront home-buyers are educated about the associated benefits and amenity features.

Considerations in Selecting and Monitoring a Living Shoreline Treatment

The Chesapeake Bay and its major tributary systems, like the South River, experience major storms and hurricanes on a periodic basis. The combined storm surge and wave conditions generated from these events causes varying degrees of damage to shorefront property, erosion control structures and natural features along the shoreline. In association with coastal hazards planning and engineering, these storm events are often categorized by their intensity and recurrence interval, or probability of occurring once in a 1, 2, 5, 10, 25, 50 or 100 year period. Measures of storm intensity allow further distinctions to be made between two separate storm events that share the same recurrence probability interval. To state more precisely what hypothetical storm event a shore protection structure is designed to withstand, coastal engineers select a "design storm" condition, beyond which there will be an acknowledged risk of damage or failure. A design storm consists of a design wave condition, a design water level and duration.

Unfortunately, biologists still lack comparable levels of precision and empirical standards for living shoreline treatments and their associated risks of failure. For example, what

level of wave action a given wetland can handle is unknown. However, research recently done in Mississippi by the U.S. Army Engineer Research and Development Center by Shafer and others (2003) provides some insights, although it is not directly applicable to Chesapeake wetlands for various reasons.

The Center found where wave heights greater than 1 foot occurred more than 20% of the time, (called the 20th percentile exceedence level) extensive natural marsh vegetation could not be restored. They concluded that both natural and created coastal wetlands can be maintained and are apparently able to tolerate wave heights of up to 0.46 ft. at the 20th percentile exceedence level. The researchers also suggested that where wave energy would overwhelm wetlands, that structural protection was warranted. However, they noted, coastal engineers should consider designing lower structures where the top elevations are nearer the wetland sediment surface.

Readers should also note, unlike the coastal engineers “design storm” standard which incorporates the concept of damage or failure beyond a certain point, living shoreline treatments have natural resilience qualities that can repair at least some of the damage. For example, during intense storms, wetlands and shoreline profiles can undergo significant changes and visible damage. This includes bank eroded sediments that can bury wetland plants and cause temporary or long term damage to portions of the marsh. Yet, at the same time, a marsh system can recolonize the damaged area, stabilize newly eroded sediments and build up the beach profile - all helping to reduce future erosion of the bank. A combination of natural and engineered structures (i.e. “hybrid” style living shoreline approach) allows more predictability for erosion protection and more longevity for natural features that may not otherwise develop at higher energy sites.

To put the “risks” in perspective, it is clear that both shore protection costs and cumulative environmental impacts escalate proportionately as natural shorelines are replaced with hard structures which permanently alter living resources and coastal processes. Learning to live with and accept some degree of erosion is a viable solution, particularly where upland structures are not threatened.

Coastal erosion is a normal process that allows eroded sediments to remain in shallow coastal waters - nourishing beaches and allowing a natural evolution of the shoreline. Unfortunately, there are serious negative impacts that include increased sedimentation and nutrient inputs which are a key part of restoring the Chesapeake Bay and its tidal tributaries.

To stimulate thoughtful individual and collective actions, shoreline treatments for the South River have been suggested by the Chesapeake Bay Foundation study team and can be referenced through a system of color coded maps depicting candidate locations for living shoreline treatments. Other shore protection alternatives are clearly possible for any given reach of shoreline and it is up to landowners to decide what course of action is best for their situation.

Property Owner/Consultant Steps

Landowners are reminded that the causes of and solutions to eroding shorelines are linked to dynamic and complex coastal processes. Consultation with a professional contractor is recommended after reviewing the living shoreline treatment solutions identified in these guidelines and the general steps outlined below.

1) Conduct a Simple Site Assessment

a) Determine the magnitude of the current erosion problem e.g. active bank erosion with visible losses of vegetation/soil; sediment in the water column at the site; minor bank undercutting etc. If available, consult historic maps or photographs to assess long term erosion patterns. Some of this information and links to other resources are available from Maryland Department of Natural Resources website Shorelines Online http://shorelines.dnr.state.md.us/sc_online.asp

b) Identify the causes of erosion e.g. boat wakes, wave energy; large storm event; upland runoff from unbuffered areas or impervious surfaces; subsurface drainage moving through and destabilizing the bankface etc.

c) Examine the site orientation:

- i) Protected water bodies; irregular shorelines; shallow offshore depths; evidence of nearby marsh grass; a toe of slope or bank which is high relative to average storm high water - signal a vegetative approach may be possible.
- ii) Open, exposed water bodies; no beach present at high tide; deeper offshore profiles (3-5ft.); eroding banks/marshes indicate structural support is needed to protect /establish marsh fringe or other shoreline features at risk.

d) Observe if adjacent properties have similar problems that may be resolved at the same time as part of a larger, more effective solution.

e) Consult your neighbors about the possibilities for cooperative action.

2) Review Criteria for Living Shoreline and Other Treatment Alternatives

a) Consider first, the feasibility of relocating upland structures away from severely eroding areas.

b) Review the guidelines to identify how living shoreline treatments are applied in specific circumstances.

c) Note the least intrusive methods possible to solve the problem and avoid “overprotecting” areas with unnecessary structures. Proceed with the assumption that

non-structural, hybrid and then structural options are the preferential order of erosion control solutions.

- d) Evaluate what level of protection and risks are associated with each approach.
- e) Consider site accessibility needs (if applicable) for construction equipment, materials, stockpiling etc. and temporary impacts or permanent site alterations.
- f) Compare average costs per linear foot for labor and installation and consider non-monetary benefits of aesthetics, protection and enhancement of natural ecosystems.
- g) Understand maintenance requirements associated with each alternative.

3) Examine Permit Requirements

- a) Consider local, state and federal permits that may be required.
- b) Contact appropriate state, local or federal agencies for a site visit and advice on permit procedures and rules governing approvals for each solution considered.

4) Select a Treatment Option

- a) Work with a “team” of permitting authorities, a specialized marine contractor, and a professional engineer (in situations where exposed sites erode at a high rate e.g. 2’/yr. or greater) to select an appropriate alternative that will produce the best results.
- b) Obtain multiple bids and professional oversight for complex projects to ensure applicable design, installation and regulatory standards are met.

5) Monitoring and Maintenance

- a) Observe permit or grant conditions that may call for project monitoring to ensure specified conditions are met, such as marsh plant coverage/survival rates (e.g. for tidal marsh creation projects under Maryland State Programmatic General Permit – 2, aerial coverage of non-nuisance wetland plant species must be 85% for three consecutive years).
- b) Understand what to look for to determine if your project is performing according to expectations and conduct inspections after major storms and at least annually.
- c) Undertake necessary corrections and maintenance throughout the expected life of the project.

The Role of Professional Erosion Control Experts

It is not unusual to observe previous unsuccessful attempts of shore erosion control initiated by inexperienced contractors or property owners trying to solve problems on their own. Professional shore protection experts can reduce the odds of failure and help property owners wade through an often confusing array of permits, bidding procedures, construction activities and unexpected surprises that require timely decisions and follow-up actions. Shore protection projects can be complex and involve different components that require specialized skill sets and expertise. In areas with banks over 20 feet high, slope stability may be an issue that requires special expertise and management of surface drainage and groundwater flow. Outflow of groundwater along a slope may lead to slope failure and erosion. Where shore protection structures are a critical element of a medium or high wave energy environment project, an engineer with shore protection experience can design a structure with the features and specifications needed to withstand anticipated wave, current and water level conditions. An engineer can also assist property owners in evaluating and overseeing contractor bidding and selection procedures and monitoring critical elements of the construction process. In summary, professionals can help with the following phases of an erosion control project:

1. Inventory and Assessment

- a) A field inventory of existing conditions including necessary land and bathymetric surveys (e.g. offshore bottom depths/characteristics), upslope drainage patterns, soil conditions, vegetation and habitat types.
- b) A shoreline reach assessment that determines adjacent sediment supply/transport processes; wave climate; historic erosion/accretion patterns; and erosion, if any, relating to surface or groundwater movement.
- c) Identification of alternative erosion control measures related to site features, conditions and exposures.

2. Design and Permitting

- a) Preparation of a design that: can withstand typical storm events and minimizes damage done by major storms; minimizes adverse impacts to adjacent properties and the water body; and incorporates habitat protection or enhancement elements.
- b) Preparing and submitting required permit applications to regulatory agencies.
- c) Incorporating modifications requested by reviewing agencies and securing final approvals.

3. Contract/Construction Oversight

- a) Prepare plans, specifications, bid documents and soliciting bids and evaluating contractor qualifications.
- b) Administer the construction contract and inspecting the contractor's work and materials during major installation stages (i.e. grading, stone emplacement, planting etc.). Adhering to specifications for sand and stone sizes; condition and spacing of plants; and other details ensure greater success of the project.

Erosion Control Alternatives

The discussion below examines specific erosion control treatment types and associated mapping codes used by the study team to set forth a river-wide framework for habitat creation and erosion control benefits. General categories and specific treatment types are organized around the 3 primary erosion control approaches reviewed above. The first group includes nonstructural treatments identified by map codes N-1, N-2 and N-3. Permanent structures, mostly stone emplacements, are not usually included in these treatments. The second group - "hybrid" erosion control alternatives, deploy a combination of structural and natural components, and are designated by map codes H-1 through H-5. The third group are categorized as "structural" - using permanent stone emplacements to stabilize the shoreline and include map codes S-1, S-2 and S-3.

A single site may have several different wave climates and protection needs that call for a combination of approaches. The design solution should be tailored to meet landowner goals and the particular wave climate, natural and man-made features of the site. "Fetch," or the distance of open water over which wind can blow and generate waves, is a good indicator of relative wave energy. Hardaway et al. (1984) divided wave energy acting on shorelines into three general categories based on average fetch exposure: 1) low-energy shorelines having average fetch exposures of less than 1 nautical mile and occurring along tidal creeks and small tributary rivers; 2) medium-energy shorelines having average fetch exposures of 1 to 5 nautical miles and occurring along main tributary estuaries; and 3) high-energy shorelines having average fetch exposures over 5 nautical miles and occurring along the main stem Chesapeake Bay and at the low end of tidal tributaries. This document incorporates and makes frequent reference to these categories when referring to shoreline "energy" conditions and various erosion control techniques. Readers should also refer to the glossary included at the end of this publication.

Non-structural Options

Non-structural erosion control strategies can be used in a variety of wave climates with low or high energy conditions. Marsh fringe establishment techniques (N-2 and N-3) are appropriate for low energy shoreline environments, like small tributary rivers, sheltered embayments and tidal creeks that are protected from larger waves that can noticeably erode the shoreline, especially during storms. Normally, shorelines with average fetch exposures of less than 1 nautical mile are low energy environments. In addition to naturally occurring waves, boat wakes can have a substantial effect on shoreline stability

- potentially elevating the energy curve up a notch where hybrid solutions may be more appropriate. Beach/sand replenishment (N-1) is normally associated with high energy shorelines on the main stem of Chesapeake Bay and tidal tributaries. In low energy environments a sand replenishment project will not remain a beach for long as emergent wetland plants will soon invade and the area will revert to marsh. Beach replenishment is often accomplished in conjunction with breakwater systems – see discussion under types H-4 (beach replenishment with breakwaters) and S-2 (breakwater systems).

Category: Non-structural includes types N-1, N-2 and N-3.

I. Treatment Type & Mapping Code: Beach/sand replenishment (N-1).

Description: **Introducing appropriately sized sand material to an existing beach or sand edge which is experiencing erosion.** As noted above, small scale sand replenishment or sand fill projects in sheltered areas (shown in photo) may soon be colonized by emergent wetland plants.

Self-sustaining beaches are formed as a result of a dynamic equilibrium between the amount of sand supplied to the beach and losses caused by wave erosion. Sand replenishment may be needed when shoreline alterations reduce or cut off available sediment sources that normally supply the beach; or when major storm events permanently move sediments to deeper waters. Sand replenishment can temporarily stop erosion and periodic maintenance is usually required. In appropriate areas, where a broader beach is established, dune grasses can be added to the backshore for enhanced stability.



Figure 5. Beach/sand replenishment (N-1)

Shoreline Exposure/Geography: The presence of a beach is indicated by a zone of unconsolidated material marked by an accumulation of wave-washed sand grains that extend between mean low water and landward to: a point where there is a distinct change

in material or physiographic form; or a line of permanent vegetation. Small scale beach nourishment may be appropriate on a naturally eroding beach with relatively low erosion rates and where gently sloping shoreline gradients exist. Beach replenishment may not be appropriate when the site is in close proximity to a tidal channel or in front of bulkheads or revetments with minimal dry beach area (under normal conditions) channelward of the structure. Similarly, beach nourishment is not appropriate where high erosion rates are present; cross-shore sediment transport processes are dominant; or where persistent variations in wave conditions are present due to irregular offshore bathymetry. Beach profiles typically change with the seasons, getting thinner and steeper in the winter storm months when waves move sand offshore and wider and more gently sloped during the summer months when waves move sand onto the beach.

Design/Installation Considerations: The erosion control goal of beach replenishment is to protect from upland erosion by restoring a beach that is wide enough to dissipate wave activity before it reaches the bank or upland. A beach nourishment plan should allow for a minimum dry beach width that protects the bank or upland from damage under normal or average storm conditions expected once a year or every two years. How often a beach must be replenished is dependent upon the erosion rate on-site and the supply of sediment available along and in front of the shoreline. Replenishment may be needed every 3 to 5 years and/or after potentially intense storm events.

Fill material is typically selected on the basis of having minimal very fine silts, clays or sands (less than 10%) with grain size characteristics very similar to or somewhat coarser than that of the existing beach. Coarser material improves erosion resistance but may steepen the beach gradient. Beach fill volumes are calculated based on overfill ratios which use a greater amount of borrow material to create stable beach material. Sand sources may be available from nearby dredging operations; offshore sources or from commercial suppliers from upland borrow pits. If structural support is needed to retain small scale beach replenishment material, see the description of low-profile groins under hybrid option H-1, marsh fringe with groins.

Risks: Small scale beach/sand replenishment, when carefully designed, is a relatively low risk practice that should not significantly affect adjacent properties. If the proposed sand source is from an offshore borrow area, additional analysis will be required to avoid adverse environmental effects. To avoid sediment loss from the beach, borrow areas should be sited beyond the limit of littoral transport. Over time, as sediment migrates from the replenishment site, adjacent land may benefit from longshore transport of sand that can help replace material lost from hardened shorelines or erosion.

It is unlikely that small scale beach replenishment will materially affect navigation channels or mooring access. Replenishing sand beyond the former width of the beach will result in some burial of aquatic species that are dependant upon shallow water bottom habitat. These benthic organisms can adjust to gradual changes in near shore sediment characteristics.

II. Treatment Type & Mapping Code: Fringe marsh creation or restoration (N-2).

Description: Establishing or restoring tidal wetland fringe marsh in the intertidal zone by planting in existing substrate without the aid of supporting structures.

Fringe marsh creation improves water quality, enhances wildlife habitat and dissipates wave energy roughly proportionate to the width of the created marsh.

Shoreline Exposure/Geography:

This treatment type is best suited to areas experiencing minimal erosion – less than 1 foot per year - with less than ½ mile of fetch (distance of open water where wind driven waves are created) and where the effects of boat wakes are limited.

Favorable conditions for fringe marsh creation include: shorelines with shallow offshore waters; sites with irregular coastlines (small coves, embayments etc.); shorelines that are protected from seasonal storm exposures (south/southeast and north/northeast); visible signs of existing tidal marsh vegetation within a few hundred feet of the site; a toe of slope or bank which is high relative to mean storm high water; and offshore beds of submerged aquatic vegetation.

If the water level remains at the base of a bank at low tide, marsh grass establishment is not possible without creating an intertidal planting zone by cutting and sloping back the bank area – thus avoiding fill placed in state waters. If bank grading is infeasible or undesirable, then new fill material, placed in state waters, is needed to achieve the necessary elevations for plant survival. In this case, refer to other treatment options discussed below (N-3, H-1 etc.).



Design/Installation Considerations: The most commonly accepted practice is the planting of *Spartina* species within the regularly and irregularly flooded tidal water zones. Smooth cordgrass, also called salt marsh cordgrass (*Spartina alterniflora*) can be planted from mid-tide (or somewhat below in sandy soils) to about mean high water and further landward up to spring tide elevation in sandy soils (Figure – Marsh). Saltmeadow hay, also called saltmeadow cordgrass (*Spartina patens*) is planted from near mean high water and above to the base of the bank. Nearby biological benchmarks for established wetland plants of the same type can be used to correctly locate *Spartina spp.* and other wetland plants within their tidal hydrology and salinity ranges. Both *Spartina* species are found in brackish to salt water from 10 to 35 parts per thousand (ppt). If planting in

salinities greater than 10ppt during the growing season, plants will survive better if acclimated prior to transplanting. Mean average surface salinities during the growing season in the South River are 5-10 ppt, well within the acceptable range.

The width of the planting terrace is a key determinant of erosion control effectiveness. Knutson and others (1981) cite a practical minimum planting width for successful erosion control of 20 feet. However, much reduced planting widths are commonly deployed in low wave energy areas with apparent benefits for both erosion control and wildlife. If the target width for a planting terrace is not provided by the existing substrate, then clean sand fill can be used to increase the planting terrace width and elevation.

Figure 7. Marsh – Planting Zones for *Spartina* Species

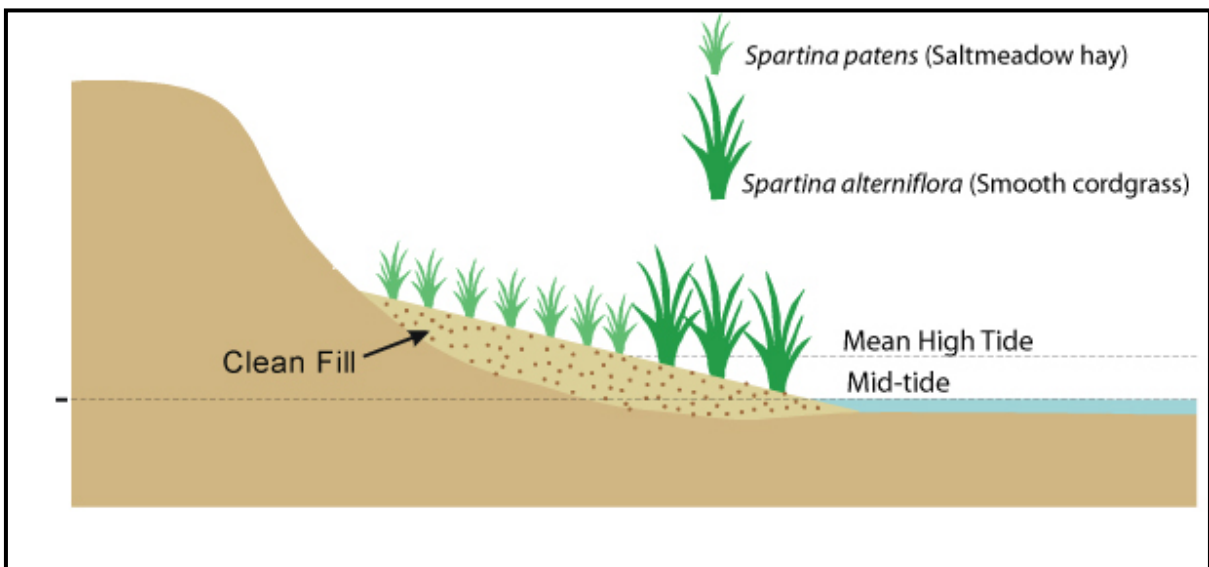


Diagram shows hydrologic zones and plant species recommended for fringe marsh creation in South River - Maryland. Fringe marsh creation or restoration is an important element of the following treatment types: N-2, N-3, H-1, H-2, H-3

Spartina species can tolerate a variety of substrate conditions from coarse sands to silty-clay, however, medium to coarse grained sandy soils are best. Planting in areas with high clay content will restrict plant growth to the planting hole, severely limiting plant growth or causing mortality. Generally, most fine roots that absorb nutrients occur in the top 30 cm (i.e. about 12 inches) of the soil. If an occluding layer such as rock, clay, or mineral deposits is more than 30 cm deep, rooting depth is adequate for both *Spartina* spp..

The slope of the planting area should be gradual – preferably rising no more than 1 foot vertically over 10 feet horizontally (1:10 ratio), although a 1:8 ratio is acceptable and steeper ratios will still work for a period of time. Gentle gradients of 1:15 or less provide a wider terrace, relative to the tide range, for plants to establish themselves

within their tidal zone. The planted area should be completely exposed at low tide. The substrate should be graded and stable prior to planting to avoid plants being uncovered by tidal current or wave action and to avoid pockets of standing water during receding tides.

Local native plant species should be used and established from mid-spring to early summer (by July) to allow plants to mature before the dormant season. Planting can be done at other times of the year; however several complications may arise that can lessen the odds of success.

For uniform cover in one season, *Spartina alterniflora* plants with well developed root systems (e.g. at least 6 inches high with at least 3 stems) planted 18 inches to 2 feet apart, in staggered rows is a typical treatment. *Spartina patens* plants should be planted about 12 inches apart. Seedlings should be planted at the same depth (for well settled sites) or up to a half inch deeper than the original soil line of the seedling. To prevent air pockets and drying of the soil, holes should be immediately filled and tamped around the seedling roots.

To avoid improper plant and fertilizer installation, planting should be conducted at low tide or “in the dry”. Nutrient supplies in regularly flooded brackish and salt marshes are usually adequate for growth of *S. alterniflora*. Some eroded shorelines may have higher clay content substrates that require nutrients to help establish the plants. Unless the substrate or local water quality conditions are known to have high nutrient concentrations a minimum 3-4 month slow release, balanced fertilizer such as Osmocote (e.g. 14-14-14; 0.5-1.0 oz. per plant) should be used for all plantings.

Slow release fertilizer should be placed in each hole under the plant. When applied in this manner, slow release fertilizers are directly accessible to the roots, with minimal atmospheric and water column nutrient losses. A longer release (e.g. 6-9 month release 18-6-12; 0.5 – 1.0 oz. per plant) may also be used for nutrient poor substrates or when placing plants in new sand fill, but are not needed thereafter.

Plants need a minimum of 6 hours of full sunlight during the growing season from April through October. Limbing of overhanging branches may be needed to ensure adequate sunlight. Tree clearing should be avoided and in compliance with local regulations. Trees that are unstable (e.g. with undercut banks or excessive angle of slope) may require removal. Sites with northern exposures with steep banks and tall trees may make fringe marsh establishment infeasible or undesirable due to unacceptable levels of tree limbing or clearing in the buffer zone.

To limit plant damage or mortality from wildlife grazing, especially from geese, mute swan or other waterfowl, a strategically placed “goose exclusion fence” consisting of commercially available polypropylene fencing (42” height) or a series of wooden stakes joined with 4-5 lines of cotton twine (bio-degradable) can discourage geese. Plants can be protected by installing fencing just beyond the planting area low water line; at the rear and sides of the planting; and, for large areas, twine may be strung across the fencing at regular intervals to deter geese from flying directly into the plantings.

Other plants can be used in open, sunny conditions, to anchor shorelines and sloping banks. Black needlerush (*Juncus roemerianus*) can be planted above mean high water to spring tide from fresh to salt water, up to 25 ppt. Switchgrass (*Panicum virgatum*) can be used to anchor shorelines from just above mean high water landward to uplands and tolerates up to 10ppt. salinity. Sweetfern (*Comptonia peregrine L.*), a low growing shrub, is especially suited as a groundcover for stabilizing steep, sandy banks. Little blue stem (*Schizachyrium scoparium*) does well on dry sites and poor soil conditions beyond the range of extreme storm tides; up the bank or on uplands. Similarly, Broomsedge (*Andropogon virginicus*) can be planted in dry to irregularly moist uplands on open sites. American beachgrass (*Ammophila breviligulata*) or coastal panicgrass (*Panicum amarum*) can be planted along coastal shores in dry sandy soils above the line of storm influence when a small dune is desired.

Risks: There is some risk of failure in attempting a marsh establishment treatment within the context of these guidelines. There are a number of reasons why a marsh may not be present in an area that otherwise meets all of the requirements mentioned above. Careful observations of why plants are currently absent may reveal the nature of the problem and the uncertainties of a successful planting. However, the low cost relative to the prospective benefits of this approach is likely worth the effort even if the treatment is unsuccessful. A small portion of a site can be vegetated as a “trial” effort to assess results.

Marsh plants alone have been used to stabilize shorelines with much larger fetch conditions up to a mile and beyond. A well constructed marsh can last for many years without eroding. In several years, depending upon the rate of accretion of the marsh substrate (from sediment trapping and below ground root development), a vertical edge or peat bank can form that may erode when subject to boat wakes or exposed wave conditions. A marsh toe revetment can be used (discussed below) to remedy this situation.

Monotypic stands of *Spartina alterniflora* can be subject to rust fungus disease during the spring and fall and may be wiped out, especially if the fungus appears in the spring. Damage from geese and muskrat can be a nuisance, but also can be controlled through special designs or periodic maintenance.

Plant losses due to shading, erosion, excessive debris or wrack accumulation (particularly just after planting operations) can also be monitored and controlled. Errors in establishing plants in their correct hydrologic zones are typical, but can be minimized by careful planning.

III. Treatment Type & Mapping Code: Fringe marsh creation or restoration with coir fiber log edging (N-3).

Description: Establishing or restoring tidal wetland fringe marsh by planting in existing substrate or sand fill with the aid of a bio-degradable, log shaped structure typically used to retain sand fill and/or provide temporary protection from wave energy while plants become established.

Wetland plants are established in the same manner discussed under treatment type N-2.

Coir logs are cylindrical shaped fabrications made from braided strands of coconut fiber and come in various diameters and lengths (e.g. 12" x 20', 16" x 20' or 20" x 10') that are used to stabilize eroding shorelines and banks. To meet various stabilization needs

discussed below, coir logs have been used at both the base of banks and in shallow water channelward of the planting terrace to help establish shoreline plantings and retain sediment.



Figure 8. Fringe marsh creation/restoration with coir logs (N-3)

Shoreline Exposure/Geography: This treatment type is best suited to areas experiencing minimal erosion – less than 1 foot per year - with less than 1 mile of fetch and where the effects of boat wakes are limited. Other Shoreline Exposure/Geography criteria mentioned under fringe marsh creation (N-2) above also apply to N-3 coir log treatments.

Design/Installation Considerations: When establishing a fringe marsh where additional fill is needed to meet the appropriate elevations required for wetland plants (see N-2); coir logs are generally placed at mid-tide elevation to help hold the sand fill and protect plants while they become established. Similarly, a coir log can simply be placed at mid-tide elevation to provide additional protection from waves or boat wakes, where no sand fill is involved. Coir logs have been successfully deployed at the base of slightly eroding banks to help temporarily reduce erosion, sedimentation, and reflected wave energy while plants become established. Also, coir logs are used at the toe of the bank to prevent sediment from migrating into the water column when the bank has been graded or disturbed during clearing, planting or trimming operations.

Government approved specifications for the uses of this product have not been developed and therefore, the quality of coir logs can vary substantially from loosely knit to dense, tight fabrications. High density coir logs are heavier (9lbs./cu. ft.) and more durable and are the appropriate choice for use in estuarine environments, subject to short term, moderate wave action. Coir logs are not light weight - a standard density 20 foot coir log with a 16 inch diameter weighs just over 200 lbs. and a 24 inch diameter log of the same length weighs approximately 450 lbs. Avoid the use of coir logs with synthetic polymer outer netting that is not biodegradable and may cause problems for aquatic and terrestrial wildlife. Coir logs have a functional life of approximately 3-4 years if they are not otherwise damaged by storm wave action.

To avoid lifting from water and ice, coir logs must be cinched down (top and bottom) and secured to the shoreline through the use of wooden stakes (2"x2"x 48-60") placed, in front and back of the log, along the entire length. Some distributors issue guidelines on staking, which advise using more stakes along the length of the log as wave energy conditions increase. The Chesapeake Bay Foundation (2006) uses the following protocol (herein modified by the authors) for coir log staking:

- Excavate a small trench (6-inch wide x 3-inch deep) where the logs are to be placed – place material landward of the log.
- Place the logs into the trench making sure to have continuous contact between the logs and the bottom of the trench (woody debris may need to be removed).
- Tie the logs together, end-to-end, using 1/8 inch woven nylon rope.
- Place 4-foot wooden stakes along the front and back edge of the log, every 2 feet along the coir log. Stakes should be notched about 3/4" deep, 6 inches down from the top.
- Drive stakes into substrate until 10 to 12 inches remain above the logs.
- Tie each stake individually from stake to stake, across the coir log, in an alternating pattern.
- Where logs do not butt into another log – bend the loose end into the bank and bury at least 1 1/2 – 2' to keep water from getting behind the log. Anchor these ends as well.
- After tying is complete, drive stakes down until the rope is flush with the logs.
- Backfill with sand behind the logs to achieve final grade.
- Optional - for narrow planting terraces (less than 10 feet wide) - plant herbaceous wetland plants (plugs are easier to plant) every foot along the log, and water them.
- Plant herbaceous wetland plants and shrubs behind the log.
- Coir log may be stacked in a double row and angled along the slope if more protection is required.

Although coir logs may be used as a planting medium, this practice is not requisite to successful marsh establishment. If this option is chosen, plants must have access to a continuous source of water from regular flooding or moisture from the wicking action of the coir log. When the area available for planting behind the coir log is limited, planting in the log is advisable.

Risks: This treatment type carries the same risk elements described under treatment type N-2 above. An additional consideration is the failure of the coir log protection device to perform as anticipated. Typical problems in this regard include: deterioration of the coir log from storm damage; improper anchoring – resulting in lifting, displacement or removal by ice or water action; and selection of a coir log with too small a diameter to stabilize added fill material or protect from waves. If the coir log was an integral component of the planting design (e.g. to achieve wave dampening or retain fill), then the desired grade and planting elevations may be adversely affected resulting in poor plant development or mortality.

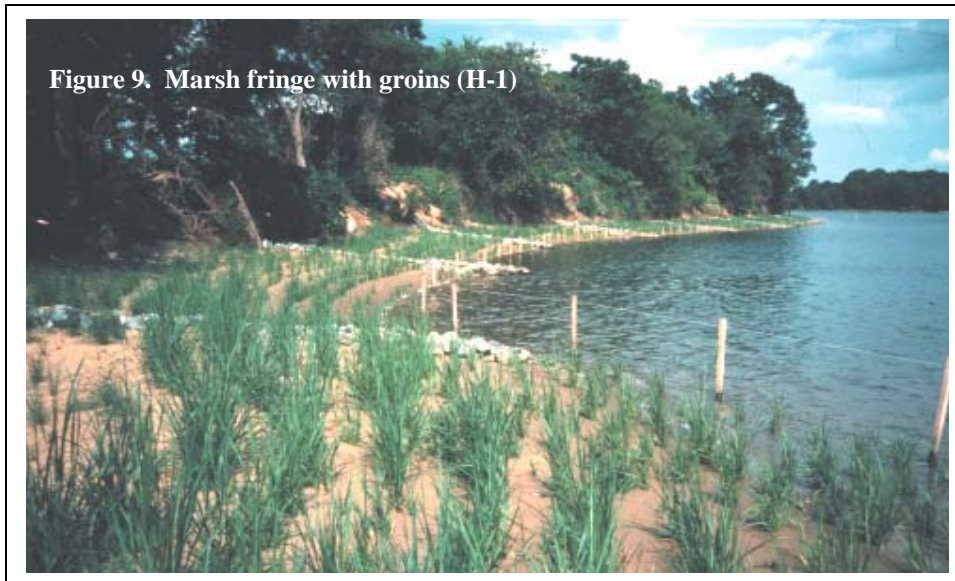
Hybrid Options

Hybrid erosion control options are often appropriate in wave climates associated with large tributary rivers with average fetch exposures of 1 to 5 nautical miles or in areas with moderate boat traffic. As a rule of thumb, small power boats of 20 feet or less don't produce large waves especially when they are on plane. Larger power boats can generate significant wakes when traveling at speeds of around 10-12 knots. Wave heights vary with hull design, where blunt, bathtub shaped hulls produce the largest wakes (Bottin, McCormick and Chasten, 1993).

Category: Hybrid options includes types H-1, H-2, H-3, H-4 and H-5

I. **Treatment Type & Mapping Code:** Marsh fringe with groins (H-1):

Description: Establishing or restoring tidal wetland fringe marsh by planting in sand fill material that is retained in place by stone groins generally installed *perpendicular to the shoreline*.



Shoreline Exposure/Geography: This treatment type is best suited to areas experiencing minimal erosion – less than 1 foot per year - with less than 1 mile of fetch and where the effects of boat wakes are limited to moderate. Other Shoreline Exposure/Geography criteria mentioned under fringe marsh creation (N-2) above also apply to H-1 fringe marsh/groin treatments. Also, note that shorelines which have northern exposures with high banks and heavily forested buffers may benefit from using an H-1 treatment to achieve a wider planting terrace and greater exposure to sunlight.

Groins are best installed along gently sloping areas, with shallow offshore depths 2-4ft. where unprotected shorelines downdrift of the groin will not be adversely affected by placement of the groins (e.g. significantly disrupting longshore transport that may protect adjacent properties). Marsh fringe with groins should not be installed on headlands or points along the shoreline that protrude channelward more so than adjacent lands. An H-1 treatment may also be a good choice in low wave energy areas that are overprotected such as in front of a deteriorating bulkhead where marsh is present on either side.

Design/Installation Considerations: Low profile, stone “surface” groins are typically installed as a series of structures or “groin field” spaced at regular intervals (about 50 to 60 feet apart or sometimes 2-3 groin lengths) forming “cells” that hold the sand fill. The landward end of the groin should be above the high water line and connect into the bank or other stable backshore feature to prevent flanking during design storm conditions. The channelward end of the groin should be at mean low water elevation or lower and should extend slightly beyond the channelward end of the fill material. The channelward position of the groin is located so as to retain some proportion of the longshore sediment transport during more severe wave conditions.

Groins are typically no more than 30 feet long and 1-2 feet higher than the ground surface; tapering along its length, being higher toward the bank, to hold more fill and protect upland, and lower channelward, to minimize erosion downdrift of the groins. Full sized containment groins should be placed at each end of the planting area where greater stability is required. These larger structures may be partially embedded into the existing substrate and the bank to protect the created wetland terrace and limit erosion from wave action where greater exposures occur. Smaller sized groins may be placed in between where erosive forces are of less concern.

All groins are placed on top of filter cloth and bedding stone. Stone sizes used in groin construction are variable according to anticipated wave conditions and other factors. Some installers/designers and non-profit grant making entities that support habitat restoration projects with erosion control benefits prefer projects with minimally sized rock structures that lessen impacts to sensitive shoreline environments. The use of 50-300 lb durable quarried stone for groins has proved successful on the Wye River of the Eastern Shore. Heavier armor stones (150-300 lbs) were placed at the base of these groins with chinking stones (50-150 lbs) at the surface/top of the structure. Alternatively, on the shoreline of a small protected tributary stream to the Wye River - stone weights in one successful H-1 project were between 10-25 lbs – allowing hand emplacement. Thus, a wide variation of stone weights are possible given different

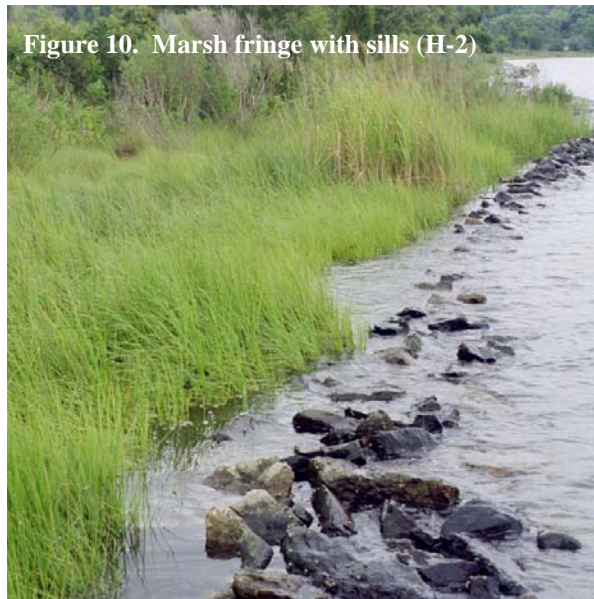
circumstances. A transition area or reach is needed when constructing a groin field next to an adjacent natural beach. There are several means of achieving the transition. One common method is by progressively decreasing the lengths and distances between each groin, from the last full-length groin, at an approximate angle of 6 degrees to the original shoreline (Bruun 1952). Another approach is to use a spur groin, a short stub groin placed at a right angle to the end groin, to redirect currents and sediment transport (Hardaway and Byrne 1999). Once the groins and fill material are in place and the sand has settled from normal tidal and wave action, plants are installed as described above in section (N-2).

Risks: This treatment type carries the same risk elements described under treatment type N-2 above. An additional consideration is the risk that a new fill and groin field may cause erosion to adjacent unprotected properties. Risks to adjacent property are less than those associated with the placement of groins that are not “pre-filled” with sand and must rely upon trapping and storing available nearshore sediments. Nearshore sediment transport patterns will adapt and adjust to the new structure in a relatively short period of time.

In reaches where adjacent lands are unprotected, more rapid erosion may occur on one or both sides of the structure that may threaten its stability. Sand may also be lost in between groin cells, if they are not properly spaced. A good design will incorporate protection for the sides and back of the structure consistent with the nature and rate of erosive forces acting upon it and the projected lifespan of the project.

II. Treatment Type & Mapping Code: Marsh fringe with sills (H-2).

Description: **Establishing or restoring tidal wetland fringe marsh by planting in sand fill material that is retained in place by a shore-parallel stone structure installed on the channelward side of the marsh.** Sills are typically low elevation stone structures usually placed at mean low water with varying amounts of fill material located shoreward of the sill. They are designed to allow some level of free exchange of tidal waters, nutrients and aquatic life to and from the planted marsh.



Shoreline Exposure/Geography: Sills may be necessary and are often deployed in medium wave-energy environments typically along main tributary estuaries of the Bay where the toe of the bank is eroding; where existing marsh is eroding; or where little or no beach is present. They can be used in areas with higher erosion rates,

above 2 feet per year, and in more intensive boat traffic or fetch conditions ranging from a few hundred feet to roughly 3 miles. Sills are appropriately used in low or medium energy environments with deeper water depths, from 3-5 ft., where steeper sloping nearshore conditions prohibit marsh establishment without a containment barrier for fill to create suitable gradients for marsh establishment. With regard to water quality considerations, sill structures appear to have the potential to retain more sediment than groin structures from sources both landward and channelward of the sill. Because sill structures reduce tidal flushing considerably, they may be more nutrient retentive and could be favorably situated with respect to upland non-point pollution sources (Burke, Koch and Stevenson, 2005).

Design/Installation Considerations: Sills are normally placed close to the shoreline, not more than 30 feet from the existing mean high water mark, over filter cloth with sand fill in the lee to provide a substrate for establishing a marsh. Sills are typically placed at or near mean low water and are designed with a top elevation between 6-12 inches above mean high water. However, a sill can be designed with a higher top elevation (1-2ft. above mean high water in medium to medium high energy environments) to provide greater shore protection or with a lower top elevation to “overtop” with the daily high tide (at mean high water elevation) - allowing more natural tidal nutrient exchange, and wildlife access.

The top elevations of sills can vary with the wave climate (e.g. low, medium or medium-high wave energy settings); and shoreline features they protect – higher in elevation in front of small headlands or protruding features; or lower in elevation in front of minor indentations and embayments. A sill should contain gaps or open segments that interrupt an otherwise continuous structure. This helps maintain normal water temperatures behind the sill; and allows access to quiescent pools of water, wetlands and edge habitats by a variety of larger life forms like fish, terrapins and river otters. To protect shoreline features behind the gaps, a sill can be curved and overlap at adjoining sections.

Marsh widths of 20ft. or wider will achieve more natural wave attenuation and erosion protection. Thus, a sill can be used to create a wider wetland planting terrace, typically 20-30 feet channelward of the former mean high water line, which would otherwise be prohibited due to deeper offshore bottom depths.

Duhring, Barnard and Hardaway (2006) recommend additional guidelines for sills that will help maintain marsh functions. A partial list includes:

1. A structure base width of 4-6 ft. in low energy settings; 8-14 ft. in medium and high-energy settings.
2. A crest height of less than +1 ft. MHW where fetch is less than 0.5 mile or marsh width is greater than 20 ft; +1 MHW at medium and high energy locations or if marsh width is less than 20 ft. in low energy settings.

3. Tidal openings strategically placed depending on shore morphology such as at tidal ponds and creeks, at pocket marshes, at structure ends – taking into account wave diffraction and shoaling at the opening.
4. Target height at the bank face should be at least +3 ft. MHW or higher for a specific design storm event.

Stone sizes used successfully on the Eastern Shore and elsewhere have ranged from 300-800 lbs of durable quarried stone. Armor stones (300-800 lbs) were placed around chinking stones (50-150 lbs) within the center of the structure. Bedding stone was 3-8 inches in size. As noted in the discussion regarding H-1 groin projects, stones can be much smaller in size depending upon the wave climate and primary objective i.e. habitat restoration versus shore protection. Smaller stones may be displaced more often by wave action or ice movement and may require more maintenance.

Risks: Low profile sills by themselves are not effective as upland erosion control structures. They must be used in conjunction with marsh plantings. Less than 20 feet in width of marsh planting may not provide adequate erosion control. Generally, uplands with vertical bank alignments are most susceptible to erosion during storm events. Maintaining a higher elevation of fill at the base of the bank (+3 ft. MHW or higher) can add greater protection.

A marsh terrace less than 20ft. wide will still be a helpful wave attenuation device. In models developed by the U.S. Army Corps of Engineers, the energy of 0.5 foot waves was dissipated 64% within the first 8.2 feet of smooth cordgrass marsh and 72 percent within the first 15 feet. (Knutson et al. 1982).

III. Treatment Type & Mapping Code: Marsh fringe with breakwaters (H-3)*.

*Note: Treatment types H-3 (marsh fringe with breakwaters); H-4 (beach replenishment with breakwaters); and S-2 (breakwater systems) all use breakwaters to achieve different purposes for the protected area behind the breakwater. They have been listed separately to simplify the discussion and to recognize technical and policy related distinctions between these applications that are made by the regulatory community during the permit review process.

Description: **Establishing a marsh fringe in conjunction with an appropriately sized structure, usually stone or concrete, erected offshore to protect a shoreline from the direct impact of incoming waves before they reach the shoreline.** Using a breakwater to establish a fringe marsh is more appropriate in a medium or medium high wave energy environment where a sill is not practical or feasible. In high wave energy environments establishing a marsh behind breakwaters is possible only within a relatively small portion of the area directly behind the breakwater that has a planting terrace specifically designed

to accommodate wetland plants. In high energy environments, the force of wave action found on the exposed shoreline between breakwaters forms a beach-like environment that will not support wetlands. However, in medium energy environments wetlands can be established along a greater portion of the shoreline, beyond the immediate “shadow” of the breakwater.



Figure 11. Marsh fringe with breakwaters (H-3)

All breakwaters are built in near-shore waters, usually parallel to the shoreline, to reduce wave energy on the land side of the structure. Depending upon their function, they can be deployed as freestanding structures, detached from the shoreline or they can be connected to the shoreline. They protect wetlands, beaches or uplands behind the structure by dissipating, reflecting, and refracting (bending waves in alignment with underwater contours) incoming waves. Where detached breakwaters are used, the reduced wave energy allows sediment, mostly from littoral currents, to build-up landward of the structure, oftentimes forming a natural connection (tombolo) behind the structure and fastland. A segmented breakwater is formed by placing additional structures next to each other separated by a gap in between.

Shoreline Exposure/Geography: Breakwaters provide protection in medium to high wave energy environments along exposed shorelines of major tributaries and the main stem of Chesapeake Bay. Breakwaters can be used in areas experiencing medium (2-4ft. per year) and high (4-8ft. per year) erosion rates where deeper near shore water depths prevail.

Design/Installation Considerations: Breakwater design is complex, involving a thorough understanding of the local wave climate and shoreline geomorphology. Breakwaters must be custom designed by a knowledgeable professional or contractor for the particular conditions of a given site. Key design considerations are breakwater length; distance offshore; gap width between breakwaters; and the maximum embayment indentation between breakwaters. Stone size, the top elevation of a breakwater (usually 1-3ft. above MHW) and other components are calibrated in relation to the design wave and storm conditions the structure is meant to attenuate.

A variety of heavy equipment including bulldozers and bucket loaders are used to install breakwaters. A proper foundation beneath the structure is critical. Breakwaters should not be placed in soft bottom conditions. Filter cloth is put beneath the structure, then smaller stones are added, forming a “core” and, finally, heavy armor stones are placed on top in a mounded or trapezoidal like configuration. Stones are deliberately placed to avoid damaging the filter cloth base.

The large surface area of breakwaters will displace and eliminate benthic organisms. At the same time, the rock structure and quiescent waters behind can create foraging opportunities for fish and provide habitat for aquatic species that attach to hard surfaces like oysters and barnacles. Once the breakwaters and fill material are in place and the sand has settled from normal tidal and wave action, herbaceous wetland plants are installed as described above in section (N-2) in areas designated in the breakwater design plan.

Risks: During major storm events, even a well designed breakwater may not provide as great a level of protection to uplands as a revetment or seawall placed against the shoreline. Poorly designed or damaged filter layers or poor foundation conditions can undermine the integrity of the structure and undersized stone may be displaced by storm wave action.

Minor damage of rubble mound breakwaters can occur without compromising functionality. Displaced stones can be repaired and replaced. Fringe marsh behind the breakwater may be subjected to high wave energies from periodic storm events that may cause some damage. This may require replanting in the damaged areas, although natural recolonization is also possible in many instances.

IV. Treatment Type & Mapping Code: Beach replenishment with breakwaters (H-4)*
*Reference the “note” under treatment type H-3 and the more complete discussion of beach/sand replenishment found under treatment type N-1.

Description: **Providing additional sand fill to an existing beach behind an appropriately sized breakwater erected offshore to protect and maintain the beach.** Breakwaters reduce the erosive action of waves and currents, particularly during intense storms, that can permanently remove sediments to deeper water and narrow the beach

width to an unacceptable level. A low dune and beachgrass can be incorporated on the backshore of the beach to protect the bank and provide a sand source to repair beaches after major storm events.

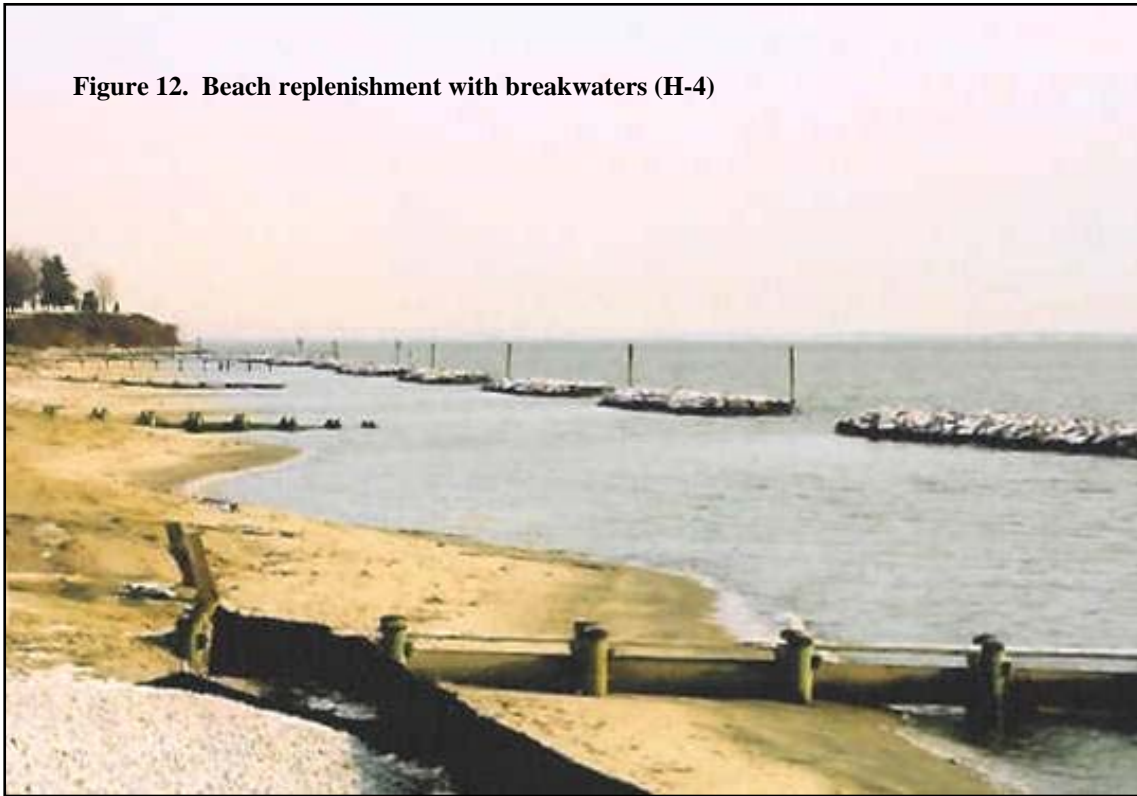


Figure 12. Beach replenishment with breakwaters (H-4)

Shoreline Exposure/Geography: Beach replenishment in conjunction with breakwaters provides protection in medium to high wave energy environments along exposed shorelines of major tributaries and the main stem of Chesapeake Bay.

Design/Installation Considerations: Sand grain size, source and fill ratios are important design considerations. See discussion under this section of treatment type (N-1).

Risks: See risk discussion under treatment type (N-1)

V. *Treatment Type & Mapping Code:* Marsh toe revetment (H-5).

Description: **Protecting an existing eroding marsh through the use of stone riprap placed, with no backfill, on the channelward edge of the marsh at a low elevation – usually equal to or less than a foot above the marsh surface.**



Figure 13. Marsh toe revetment (H-5)
Photo: Karen Duhring

Shoreline Exposure/Geography: Over time an existing or created marsh can undergo changes that disrupt the integrity of the marsh. An exposed eroding scarp can result on the leading edge of a marsh which can lead to further erosion if steps aren't taken to protect the exposed edge. Determining whether a marsh toe revetment is an appropriate treatment requires consideration of a number of factors.

In general, the rate of sediment retention in the marsh contributes to the soil development process which in turn influences below ground development of roots and rhizomes. Normally, this process contributes to the vertical growth of the marsh. When elevated sediment and nutrient delivery; stable hydrological conditions; and limited wave energy are present at a given site - conditions may be optimal for rapid vertical growth of the marsh which can elevate the system as a whole and set the stage for future erosion. Changes in the fetch exposure of a marsh, such as the reconfiguration or disappearance of a nearby spit, bar or offshore island, can increase wave energy, alter currents and sediment sources and accelerate erosion. Similarly, higher wave energies can arise from new boating patterns, particularly where there are an increased number of vessels with greater hull displacement, a major determinant of wave heights reaching the shoreline.

Marsh loss via a combination of excessive saturation and erosion at a given site can be attributed to "relative" sea level rise which takes into account changes in water level and land movement. These factors are complex, involving a number of considerations including the amount of sediment delivered to a marsh via upland erosion and transport.

In short, where the marsh is disappearing by a combination of sediment starvation, advancing water levels and wave energy, a marsh toe revetment treatment will help for a period of time, but may not address the underlying causes of marsh loss.

Design/Installation Considerations: Marsh toe revetments are placed at the face of the eroding marsh at a 1:2 slope (rise to run) at a height approximately equal to the height of the marsh substrate or not more than a foot above the marsh surface (Barnard [n.d.]) Filter cloth is placed underneath the structure and no backfill is used. To minimize wave scour around the structure, the toe or apron of the revetment is buried at a depth below mean low water that is generally equal to the anticipated wave height. Rock weights are sized according to the specific wave forces expected at the site and should be stable under normal and storm wave conditions.

Much like a sill treatment, a marsh toe revetment is placed at a low elevation to permit aquatic organisms to move to and from the marsh and to allow normal tidal water and nutrient exchange. Structures placed above mean high water elevation can significantly reduce this movement; affecting marsh health and the numbers and types of aquatic organisms that use the marsh.

Hardaway and Byrne (1999) make the observation that a rock toe wedge placed over filter cloth against the peat scarp may be adequate in low wave energy environments. They also note:

“For fetch exposures approaching 1 nautical mile, consider installing a splash apron (3 to 5 feet wide) as a landward extension across the top of the marsh scarp. The splash apron will help prevent waves from scouring out the marsh peat from behind the marsh toe revetment. Without a splash apron, the armor rock might migrate landward, thus reducing the height of the structure and adversely impacting its effectiveness.”

Risks: The stone revetment structure can be compromised in several ways. To prevent failure, armor stones must be placed in a stable substrate; sized appropriately, with gently sloped fronts; and placed deep enough to protect the toe from wave and current erosion which can undermine the structure. Stones must be placed in an irregular configuration to avoid channeling water flows in a concentrated manner which can cause differential erosion of the marsh and resultant destabilization of the structure. After the marsh system is protected, less erosion will occur, which diminishes the contribution of sediment and other littoral materials from the treated shoreline. This deficiency of material moving along the shoreline may cause erosion in other unprotected areas to accelerate.

Structural Options

Structural options are recommended along certain shoreline segments in the South River where other less intensive treatments were not feasible or practical. These options are typically used on high energy shorelines occurring at the mouths of tributary estuaries

and along the main stem of the Chesapeake Bay with average fetch exposures of over 5 nautical miles.

These environments require suitably engineered structures and are only briefly described in this document as they are not primarily associated with habitat or living shoreline features.

Category: Structural includes types S-1, S-2 and S-3.

I. Treatment Type & Mapping Code: Revetment (S-1):

Description: **A sloping structure placed along an eroding bank, made of layered stone or concrete rubble (or other materials) designed to dissipate wave energy and remain stable under design storm conditions.**

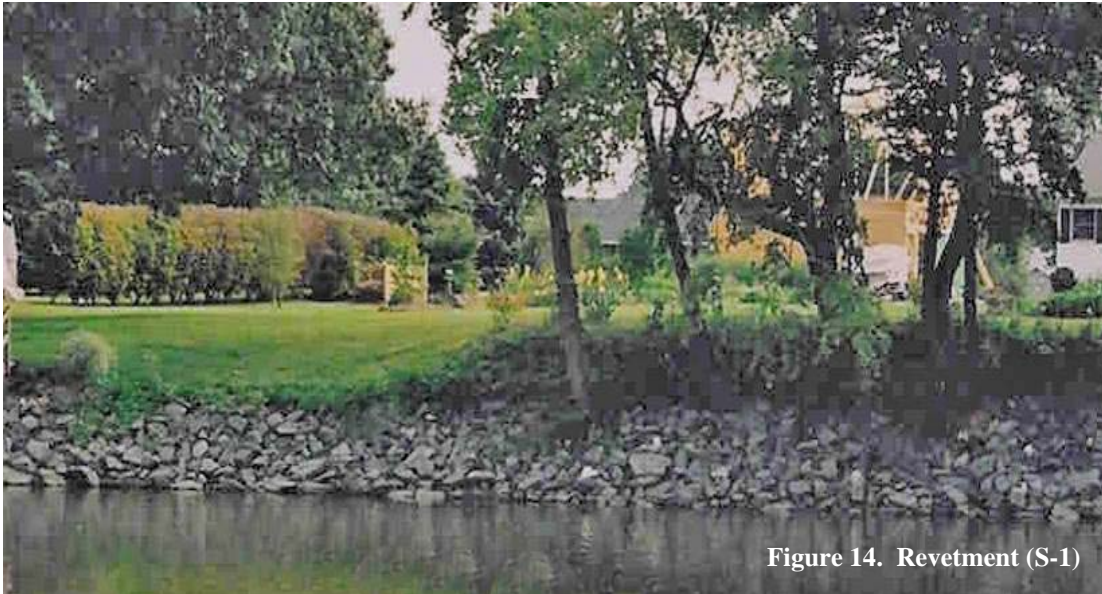


Figure 14. Revetment (S-1)

Shoreline Exposure/Geography: Revetments can be used in medium or high energy situations along exposed shorelines of tidal tributaries and the main stem Chesapeake Bay.

Installation Considerations: Revetment height and scour depth at the toe of the structure are important design considerations. Stone weights used in revetment design are sized to withstand expected storm surge and wave conditions. Hardaway and Byrne (1999) provide a good description of the parameters affecting revetment design and installation.

Risks: A well designed and constructed revetment can last fifty years or more. The use of undersized stone or a design height below the typical storm wave height may result in early failure.

II. Treatment Type & Mapping Code: Breakwater system (S-2).

Description: A series of offshore breakwaters designed to achieve site specific shoreline erosion control goals. The S-2 code is used in the South River to denote that a breakwater system along a designated reach is principally intended for erosion control, but a variety of marsh species and beach grasses can be incorporated into the design. The S-2 code may also include more complex design features such as supplementary sill and spur structures that work in conjunction with the breakwaters and a variety of other possible habitat protection or restoration features.



Shoreline Exposure/Geography: Breakwater systems provide protection in medium high to high wave energy environments along exposed shorelines of major tributaries and the main stem of Chesapeake Bay. Breakwater systems can be used as an alternative to revetments and are appropriate for protecting areas experiencing medium (2-4ft. per year) and high (4-8ft. per year) erosion rates where deeper near shore water depths prevail.

Design/Installation Considerations: Breakwater systems usually include beach nourishment and are used to control shoreline erosion by maintaining a wide protective beach. Breakwater systems work best when applied to at least a 300' area or an entire shoreline reach – terminating at a convenient reach break like an existing structure, inlet jetty, or a natural headland to minimize effects on adjacent shorelines. The beach area between breakwater systems can be allowed to erode to a stable concave or parabolic form. A general width of 40 to 60 feet of beach is needed in stable embayment for shore protection (Hardaway and Byrne 1999). Alternatively, a sill can be placed between one or more of the segmented breakwaters to form a protected marsh.

Risks: Breakwater systems are costly and can greatly affect neighboring shorelines. They must be designed by a competent shoreline professional or contractor with extensive experience with these structures.

III. *Treatment Type & Mapping Code:* Spurs (S-3).

Description: **An extension of a shore parallel sill or a free standing structure extending from the shoreline, channelward at an angle designed to provide additional shore protection and a transition for a variety of features leeward of the structure such as a beach, channel or sill opening etc.** Spurs are also used in conjunction with protecting the area drowndrift from a terminal groin.



Shoreline Exposure/Geography: Spurs are placed in a variety of fetch exposures and longshore sediment transport situations to control littoral drift, current and protect areas from erosion.

Risks: The use and placement of spurs are integral to the principal shore protection structure design. Improper design or installation would most likely result in localized, accelerated erosion and not the overall failure of the principal structure.

Glossary *

Armor Rock Large, heavy rocks used to build sills, breakwaters, or revetments.

Bathymetry A term that refers to the topography or contours of the bay bottom. Water depth can be correlated with bathymetry.

Breakwater A structure, usually built of rock or concrete, positioned a short distance from the shore. The purpose is to deflect the force of incoming waves, and thus, protect a shoreline.

Bulkhead An upright structure which acts as a retaining wall along a waterfront or shore.

Downdrift A term used to denote the resulting direction material is carried as waves strike a shore and move 'down' along a shoreline.

Fetch The distance along open water over which wind blows. For any given shore, there may be several fetch distances depending on predominant wind directions, but there is generally one fetch which is longest for any given shoreline exposure.

Groin A rigid structure built perpendicular to a shore to trap transporting sand or other material down a shoreline. Groins are often built in a series of several structures running parallel to each other.

Groin field Usually two or more groins in a series alongshore.

Headland A point of unusually high land jutting out into a body of water.

Littoral transport The movement, by wave action, of sand and other materials along the shoreline in the littoral zone, which may be the area of the beach between high and low watermarks during non-storm periods.

Marsh fringe A growth of marsh plants which runs closely to a shoreline.

Marsh toe revetment A low revetment built to protect a marsh along a shoreline that would be eroded otherwise.

Nearshore A general term referring to the area close to the shore but still partly submerged. This area is where sand bars and shoals often form.

Reach A segment of a shoreline where influences and impacts, such as wind direction, wave energy, littoral transport, etc., mutually interact.

Revetment A graded slope of large, heavy stone, often in two layers, used to anchor the foot of an often steep bank or shoreline, or one which receives a high level of forceful waves.

Sea level The level of the surface of the water; especially at the position midway between mean high and low water.

Seawall A vertical wall or embankment, usually taller and larger than a bulkhead, used to protect the shore from eroding.

Shoal A shallow area in a waterway, often created by nearby sandbars or sandbanks.

Sill An erosion protection measure that combines elements of both revetments and offshore breakwaters. Sills are usually built of stone; they are relatively low, are erected close to shore.

Storm surge The resulting temporary rise in sea level due to large waves and low atmospheric pressure created during storms.

Tombolo The accumulation of beach material directly behind a breakwater.

Uplands Land that is relatively elevated compared to sea level.

Wave climate The averaged wave conditions as they impact a shoreline including waves, fetch, dominant seasonal winds, and bathymetry.

Wave energy Wave energy is related to wave height and describes the force a wave is likely to have on a shoreline. Different environments will have lower or higher wave energy depending on environmental factors like shore orientation, wind, channel width, and bathymetry.

* **Selected glossary terms excerpted from Hardaway and Byrne (1999)**

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