Atlantic States Marine Fisheries Commission

Living Shorelines: Impacts of Erosion Control Strategies on Coastal Habitats

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Working towards healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

ASMFC Habitat Management Series #10

Living Shorelines: Impacts of Erosion Control Strategies on Coastal Habitats

Smooth cord grass fringe stabilizing a sandy point on an Indian River Lagoon spoil island (Photo credit: Florida FWC)

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Chapter 1. Introduction

Wave action, **shoreline erosion**, and the mixing of saline and fresh waters are a few of the physical processes in estuaries and coastal zones that help create and maintain diverse **habitat** for resident and transient marine species. Human activities can alter these processes, and ultimately deteriorate the quality and quantity of habitat available for use by associated organisms. Estuaries and shallow ocean waters provide critical habitat for either entire life cycles or specific life history stages of an extensive and diverse set of species, including important commercial and recreational fish species. Therefore, fisheries and wildlife managers must understand the impacts on habitat when human activity alters the natural processes that create and maintain coastal and estuarine shorelines.

One change to critical fish habitat common along the Atlantic coast is the alteration of shoreline erosion patterns. Shoreline erosion is the natural, ongoing process in coastal areas in which sediment moves away from one part of the **shore** and is transported elsewhere. As this natural course progresses, some beaches or shorelines migrate landward, with the eroded sediment either accreting elsewhere or being lost (deposited) to deeper waters. Human activities such as boat traffic and alterations to sediment drift patterns can exacerbate natural erosion rates.   Because humans now use large portions of our shorelines for housing, fishing, or other recreational and commercial activities, this natural loss of shoreline is seen as a detriment.

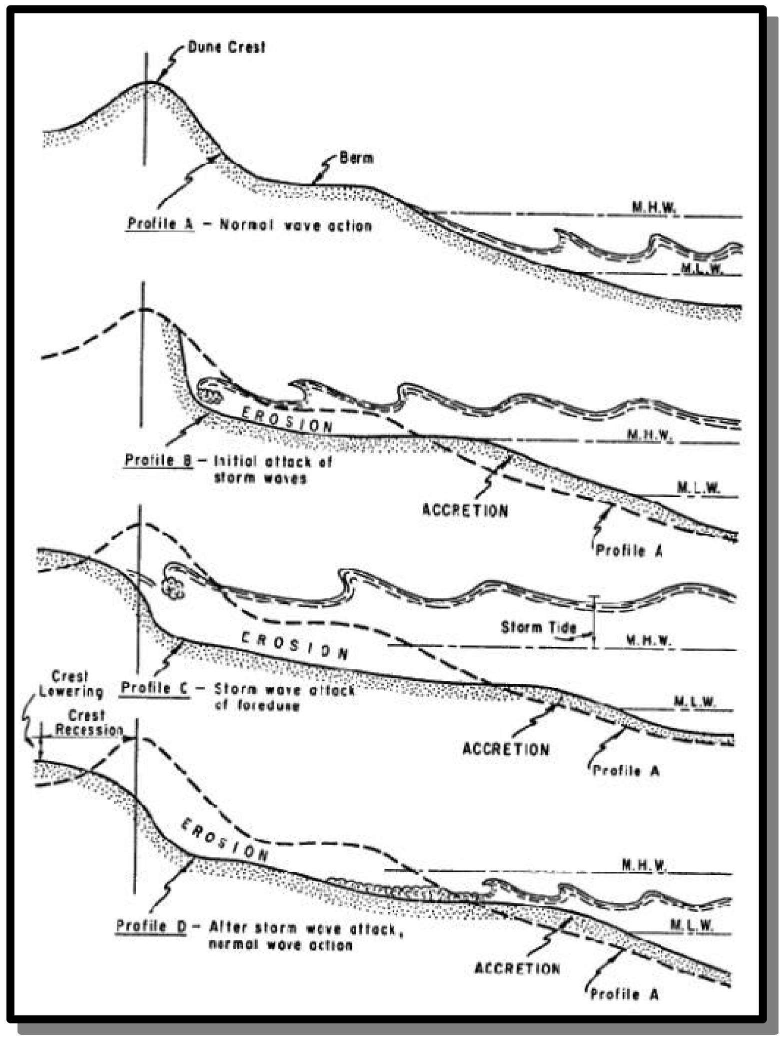


Figure 1: Impacts of storms on beach erosion
(Image credit: U.S. Army Corps of Engineers)

Long-term, or passive, erosion is caused by wave action moving **sediment** within the coastal system. Waves generally approach the shoreline at an angle, transporting sediment in the direction of breaking waves. Fine grained materials are often deposited in deeper adjacent waters. Erosion results when there is an insufficient supply of new sediment to replenish the material removed by wave action. **Sea** level rise and wave action are the predominant long-term, passive processes that drive shoreline erosion. When sea levels become elevated, river systems are inundated with water, taking sediment from the shoreline as the water recedes. The rate of erosion is gradual, although it can be alarming to owners of structures sited close to the water.

Short-term, or active, erosion is driven by high-energy storms and large waves (Figure 1). Hurricanes and strong northeast storms can quickly erode and reshape **coastlines**. These storms produce a short-term elevation of the water level, or **storm surge**, and strong powerful waves. During such storms, powerful waves break aggressively on the shoreline, eroding and moving more sediment than a typical wave.

Resource managers must work to meet the sometimes divergent goals of maintaining quality habitat and preserving private property and public infrastructure. In smaller **beach** areas, or areas with housing or development, landowners and land managers often want to mitigate the erosion so that there is no net loss in land or beach area. Private property owners are particularly interested in maintaining beaches to protect their land and housing.

Landowners deal with erosion using regulatory and structural tools. Landowners actually change shoreline erosion patterns by adding structures to the shoreline that reduce the amount of material lost. Structural techniques, also known as shoreline hardening, use a variety of man-made hard structures to alter the patterns of erosion and deposition of sediment. These structures, aimed at reducing erosion in one location, can actually contribute to erosion problems down-drift, or immediately in front of the structure. However, private landowners generally prefer structural techniques to non-structural alternatives because they are immediately effective at reducing erosion. Aesthetically, landowners sometimes prefer the neat, symmetric look of structures such as bulkheads.

Figure 2: Living shoreline stabilized using sand fill and dredge material, coir fiber logs, wetland plants, submerged aquatic vegetation, an oyster reef breakwater, and fish habitat structures at Horsehead Wetlands, Chesapeake Bay, Maryland. (Photo credit: NOAA)

Living shorelines, or soft shorelines, are an approach to shoreline stabilization that preserves natural sand edge or vegetated shoreline (Figure 2). In general, the living shoreline approach is most suitable for low to moderate wave energy climates. Many living shorelines projects attempt to retain natural characteristics of valuable coastal habitat while reducing shoreline erosion. Sometimes living shorelines are used in conjunction with hard structures that lessen the rate of erosion while also restoring or preserving aspects of the system's natural state. The term *living shoreline* was coined to describe the preferred condition of the shoreline, wherein the shoreline provides living space for coastal and estuarine organisms, such as beach, **marsh**, submerged aquatic vegetation (SAV), or oyster reef.

Living shorelines are becoming an increasingly popular management strategy along the Atlantic coast. In addition to controlling erosion, living shorelines create environmentally desirable features including habitat and vegetated **buffers** that improve water quality and reduce the effects of **upland** runoff. Unlike traditional bulkhead or revetment approaches to shoreline protection, living shorelines also tend to dissipate rather than reflect wave energy.

Property owners and local governments face difficult choices as they select cost-effective and environmentally sound strategies for dealing with shoreline erosion. Historically, shoreline erosion has been approached in a haphazard manner without a basic understanding of how the physical environment, man-made constructions, and land-use patterns influence one another. In response to growing evidence of problems associated with traditional shoreline erosion control measures, many coastal states have started to encourage property owners to incorporate more natural forms of erosion control into their management strategies. If habitat is considered in the planning process, a shoreline management plan can provide both effective erosion control and habitat protection.

For this document, we give a brief overview of traditional erosion control methods, living shorelines, and the types of habitats that may be considered when creating these areas. We also discuss the impacts of some shoreline erosion control measures on the environment, and examples of how various regulatory authorities are involved. To illustrate the value of living shorelines in a "real world" setting, we have provided a case study of their use in Maryland. Furthermore, we include a bibliography of living shorelines-related literature (Chapter 4), and a glossary of related terms (Appendix A). Words within the text of the document in **bolded and enlarged font** can be found in the glossary. This document should not be considered a complete review of existing living shorelines literature. That information can be found in other documents included in the bibliography. Appendix B suggests potential erosion control projects. The purpose of this document is to provide resource managers and the general public with a concise comparative discussion of the benefits of living shorelines, and a case study of successful projects to use for reference within their own programs.

Chapter 2. Traditional Erosion Control

Traditional erosion control measures vary from shoreline hardening (e.g., vertical structures prevent wave action from moving sediment down the shoreline) and soft techniques (e.g., **beach nourishment**), to regulatory and policy tools. There are also other options for shoreline erosion control that combine hard and soft approaches. Generally, these are bioengineered structures, which utilize native vegetation and boulders or other quasi hard structures to prevent erosion.

Land Management

Property owners often feel the value of their shoreline property is reduced as land disappears into the water. The true value of waterfront property, however, is derived from its location and view rather than the total land area. As long as the property maintains these qualities, the value of the property generally does not suffer from losing small amounts of shore to natural processes. Land managers have developed a variety of regulatory and permitting programs designed to alleviate erosion problems and prevent further property damage by erosion.

Permits

In some local, state, and federal jurisdictions, permits are required to alter **wetlands** or shoreline areas. Some states create incentives for more natural erosion buffers by requiring a lengthy and difficult permitting process for hardened structures compared to natural erosion control methods.

For more information on shoreline modification permitting and regulations in your state, please contact your local natural resources agency. Each state has different processes and allowances regarding shoreline alteration.

Setbacks & Construction Control Lines

Some property owners plan for and live with erosion, rather than attempting to combat it. These property owners account for historical erosion rates when siting a new structure. Building as far landward as possible typically increases the length of time a building is unaffected by erosion. Living with erosion is often the lowest-cost option for a property owner because no action is needed and has the added benefit of having the lowest impact on the surrounding environment. Many land managers have implemented mandatory development **setbacks** that restrict building within a certain distance from shore in order to accommodate some natural erosion. Land managers may also require buffer zones of shoreline vegetation (Luscher 2002).

Construction control lines are similar to setbacks, but are used to mark out an area parallel to the shoreline, prohibiting construction waterward of that line without a permit (Luscher 2002).

Buffers & Easements

Buffer zones are established along the **banks** of a waterway to limit activities in the area. These zones preserve the natural landscape and function of the shoreline (Luscher 2002).

Similarly, easements give the natural migration of the shoreline right of way over property ownership. In other words, property owners that own **riparian** land are not permitted to hold back the waterline. A public easement gives the state the right to allow use of private property for a specified purpose, such as public access or riparian buffer. The easement is separated from the right to own the land (Luscher 2002).

Soft Stabilization

Beach Nourishment (or Fill)

Beach nourishment, or fill, is the placement of sand on a sediment-deficient beach (Figure 3 and 4). Beach nourishment is a continual process because sand must be periodically added to the beach. Adding sand does not cure **beach erosion**, but rather it is a short-term treatment for the problem. Beach nourishment in one area can slow erosion rates on neighboring properties when sand fill acts as a source of depositional material as it is transported down the beach. This activity also provides wider recreational beaches, and may create suitable habitat for sea turtles and shorebirds (LeBuff and Haverfield 1990; Melvin et al. 1991; Spadoni and Cummings 1991; NRC 1995; Rogers and Skrabal 2001).

However, even successful nourishment projects have trade-offs. Nourished beaches erode at higher rates than natural beaches, leading to an increase in demand for sand over the lifetime of the nourishment project (Trembanis et al. 1998). Another problem with beach nourishment is that replacement sediment must be similar in grain size to the original beach sediment so that it is compatible with local **depth** and wave conditions. Sediment that is not similar may be more susceptible to erosion and could alter the surrounding community.

Figure 3: Sand-starved beach renourishment project (Photo credit: Florida FWC)

Furthermore, placement of fill material on the beach has adverse impacts on the fauna living in both the **intertidal** and supratidal where the fill is placed. Beach fill can also have adverse impacts on bottom organisms that live in the subtidal areas adjacent to the beach. When beach fill is placed in breaking waves, the sand, and to a much lesser extent, silts and clays, are often redistributed into the shallow waters of the surf zone and can smother bottom communities there, especially if they are sessile reef biota (NRC 1995; Greene 2002).

In addition, organisms and vegetation in the **borrow area** are removed by the dredging process, and the area can only recover after sufficient time has allowed recruitment to occur at these sites. Borrow areas may suffer from long-term changes in habitat characteristics, which can affect this recruitment process (Greene 2002).

Because of the potential negative environmental impacts of beach nourishment on sensitive estuarine shorelines, most states do not allow beach fill for erosion control along estuarine shorelines where beaches do not exist. All states do, however, allow for beach nourishment on existing estuarine and marine beaches.

Figure 4: Renourishment with heavy equipment (Photo credit: Florida FWC)

For more information on the affects of beach nourishment on habitat, see Greene (2002).

Shoreline Hardening

Bulkheads and Seawalls

Bulkheads and seawalls are terms often used interchangeably to describe similar shoreline protection structures. Both bulkheads and seawalls are vertical structures placed parallel to the shoreline that retain **soil** behind the structure (Figure 5 and 6). Bulkheads are generally smaller and less expensive than seawalls. Bulkheads are typically made of wood, and often provide minimal protection from severe wave action. In contrast, seawalls are generally made of poured concrete and are designed to withstand the full force of waves.

Figure 5: Concrete seawall with oyster settlement structures placed at the base (Photo credit: Florida FWC)

Although designed to reduce erosion, shoreline protection structures can contribute to erosion on beaches other than the beach they were built to protect. Birkemeier (1980) showed that erosion rates **downdrift** from a Lake Michigan seawall were equivalent to the amount of sediment retained by the wall. Furthermore, Walton & Sensabaugh (1979) suggest that bulkheaded shorelines experience greater than average erosion rates and property damage under hurricane conditions.

Scour, another term for erosion, is a problem with vertical bulkheads and seawalls. As waves break against the structures, the wave energy is reflected both upward and downward, increasing **current** velocity around the structure and leading to scour at the base (or **toe**). The extent of the scour depends on the substrate, the orientation of the shore and the structure, the **fetch**, the frequency of storms, and numerous other factors. Generally, the scoured area becomes as deep as the original depth of the water, and can create a channel deep enough that standing water remains in front of the structure when the tide is out, potentially permanently flooding areas in front of the structure (Watts 1987). Existing wetlands and submerged aquatic vegetation beds in front of the structure can also be scoured away. Deep water zones created by the bulkheads or seawalls have been shown to have lower concentrations of **detritus**, lower phytoplankton production, and fewer **benthic** organisms than areas without bulkheads (Odum 1970).

Installation of shoreline protection structures often eliminate submerged aquatic vegetation, macrophytic algae, snags, or overhanging branches of upland vegetation, and can reduce the amount of woody debris on the sea floor— factors which all contribute to the complexity of the habitat. Habitat complexity offers species protection from predators and provides foraging habitat. In fact, Mock (1966) showed that reduced densities of shrimp at bulkhead sites were related to reduced organic detritus on the sea bottom. Lower species densities at bulkhead sites have also been linked to sediment disturbance by waves and changes in currents around the structure (Dean 1981; Fegley 1987; Denny 1988). Changes in habitat complexity and availability may ultimately lead to reduced diversity and ability for species to maintain sustainable populations in these areas.

Figure 6: Seawall developed seaward of an eroded shoreline (Photo credit: Florida FWC)

Shorter-term effects on habitat generally occur during construction of shoreline protection structures, which requires pile driving and possibly **dredging**. These activities can disturb bottom sediments that become temporarily suspended in the water column. The suspended sediments reduce light penetration, which can lead to decreased primary productivity and cascading effects to higher order organisms. Suspended sediments can also interfere with the respiration and feeding of fish, zooplankton, and benthic organisms. Certain life stages of organisms, juvenile fish for example, may be more vulnerable to increased turbidity than other organisms. Construction may also cause re-suspension of bottom sediments that may contain higher concentrations of toxic substances than already in the water column (Watts 1987).

Construction of shoreline protection structures also has long-term effects on habitat. Backfilling and heavy equipment used in construction often destroys established vegetation in the edge zone. These edge zones often are not re-established with native species adapted to the forces of erosion (Figure 7). Increased turbidity and scour may prevent marsh grasses from successfully establishing in areas where they were previously found (Watts 1987).

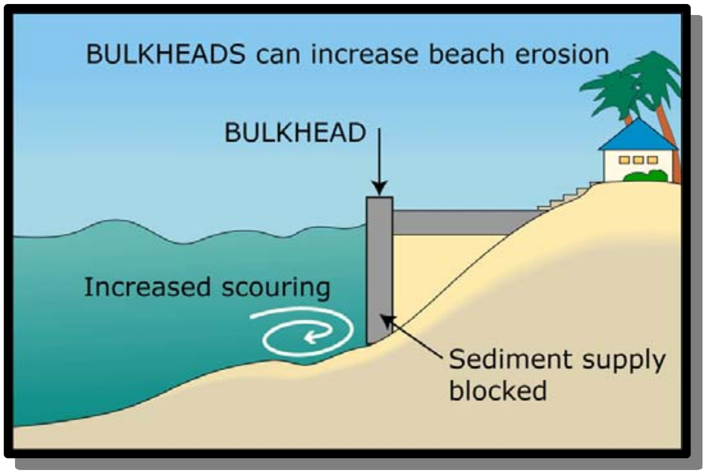
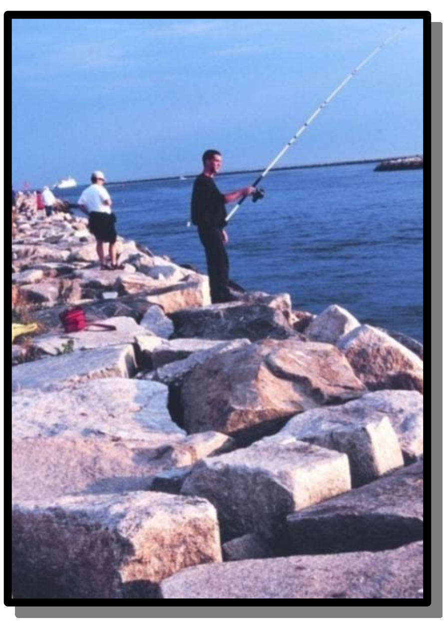


Figure 7: Diagram of a bulkhead
(Image credit: USGS)

In addition, bulkheads and seawalls can adversely affect water quality by causing a net loss in water-filtering wetland vegetation. Vegetative buffers are important components of natural water-filtering systems, and reduce terrestrial runoff that is often high in nutrients and pollutants. Consequently, in some cases, a mixture of shallow-rooted grasses and deep-rooted grasses are planted landward of the bulkhead to attempt to mitigate for the loss of vegetative buffers (Rogers and Skrabal 2001).

Another issue, specifically with wooden bulkheads, is that they may contain chromated copper arsenate (CCA), a preservative used for long-term protection of wood from fungi, insects, and marine borers. Lumber intended for use in marine settings is treated with several times more CCA than terrestrial lumber. The problem is that some of the copper (Cu), chromium (Cr), and arsenic (As) leach out of the wood directly into the marine environment. Arsenic is a known carcinogen and is acutely toxic, although the risk of toxic effects is dependent on toxicity and exposure. Once in the marine **ecosystem**, these chemicals can pose serious health threats to marine and terrestrial ecosystems. In 2002, the EPA announced a voluntary decision by the lumber industry to move consumer use of treated lumber products away from CCA treated wood in favor of new preservatives. However, the move did little to reduce the use of CCA treated wood in the marine environment; CCA treated wood is still considered acceptable for use in docks, bridges, and bulkheads (EPA 2002).

Jetties and Groins



Jetties (usually comprised of stone and logs) and **groins** (usually rock or stone walls) are shoreline protection structures that run perpendicular to the beach, and extend outward into the waterbody (Figure 8). These structures trap sand on the **updrift** side, causing a sediment deficit on neighboring properties downdrift of the structure.

Jetties and groins are used on shorelines where sand moves predominantly in one direction over the course of a year. These structures change the shoreline alignment by trapping sediment on the updrift side of the groin, and preventing it from being distributed to downdrift beaches. Although jetties and groins may control

Figure 8: Fishing off a jetty at Point Judith, RI
(Photo credit: W. B. Folsom, NOAA)

erosion where they are installed, they actually increase erosion problems elsewhere on the shoreline.

In many cases, groins are constructed on adjacent properties, creating a groin field. Each successive groin traps sediment, exacerbating erosion problems downdrift of the last groin, and ultimately leading to a change in the overall shoreline alignment. Groins offer the most protection from erosion under moderate wave conditions, and only offer limited protection during storms with large waves. In some cases during storm events, groins force the **alongshore** current in the **offshore** direction, increasing erosion in the area.

Jetties and groins eliminate bottom habitat and exacerbate erosion problems downdrift of the structure (Figure 9). These shoreline protection structures often affect a larger geographical area than other hardened structures; a loss of sediment from an upstream neighbor's groin leads property owners to install their own groin, ultimately leading to groin fields and erosion problems along the entire shoreline.

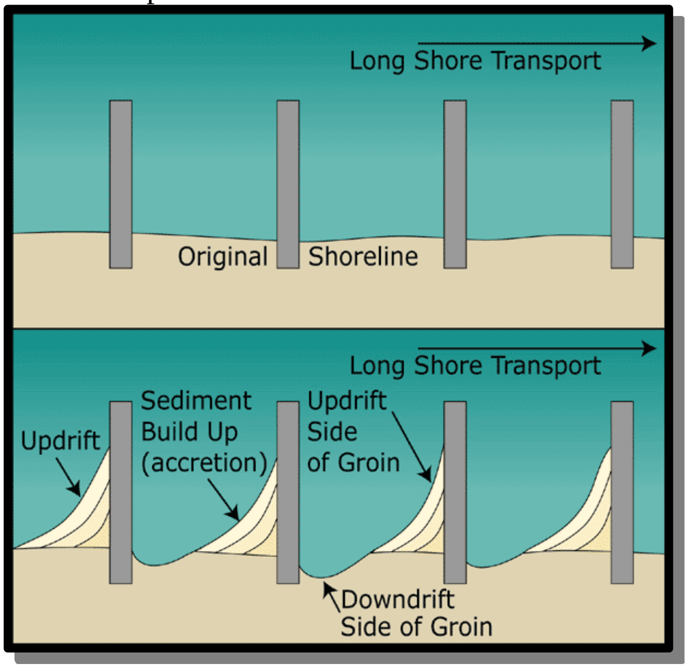


Figure 9: Diagram of sediment transport along groins (Image credit: NOAA)

Revetments

Rock, or **riprap**, **revetments** are similar to bulkheads and seawalls, but are designed with a sloping surface to break waves more gradually than vertical walls (Figure 10). Revetments are constructed by grading the shoreline to an appropriate slope and installing layers of suitably sized rock or rock-like materials to maintain property landward of the structure.

Figure 10: Sloped beach revetment made of native limerock (Photo credit: Florida FWC)

Revetments must be high enough to withstand waves in extreme conditions and must incorporate enough large stones that will maintain their position over time. Revetments are better wave barriers than vertical structures, and generally cause less toe scour than vertical walls. However, the need for a sloping surface generally causes a wider footprint that extends further inland (Rogers and Skrabal 2001). Revetments often fail due to improper design.

In order to prevent failure, the revetment must have large enough stones, a shallow enough slope, and a toe deep enough to prevent collapse (FHA 1989). Normal wave height and wave heights associated with boat wakes and storms should be factored into the design of a revetment. Effects of revetments on habitat are much the same as bulkheads (Broderick and Ahrens 1982).

Breakwaters

Breakwaters are structures built parallel to the shoreline in open water. Breakwaters cause waves to break prematurely, thus reducing the erosive potential of the waves. Some breakwaters are constructed of vertical walls of poured concrete, while others are made of large riprap. Breakwaters are designed to withstand the impact of large waves because of their placement in moderately deep water. Generally, breakwaters are positioned in water deep enough to prevent scour under them even during intense storms (Davis 1994).

Figure 11: Concrete bag breakwater offshore of a sand beach
(Photo credit: Florida FWC)

Breakwaters control erosion by dissipating wave energy and building up sediment behind the structure (Figure 11). The height of the breakwater and the size of the stones affect how effective the breakwater is at dissipating waves. Typical wave heights in an area should be analyzed to determine the proper size and shape of a breakwater for a particular system. Generally, the larger the wave, the more effective the breakwater is at dissipating wave energy. However, under intense storm conditions, high waves can impede the ability of the breakwater to trip the wave (Ahrens and Fulford 1988).

Diminished wave action behind breakwaters interrupts natural alongshore **sediment transport**, allowing sediment to accumulate between the breakwater and land. To prevent sediment from completely filling in the area between the breakwater and the shore, and to allow some movement of sediment downdrift of the structure, a breakwater can be placed to allow waves to periodically overtop the structure (Ahrens 1981).

A segmented breakwater (Figure 12) is a series of breakwaters separated by unprotected gaps. The adjacent structures stabilize enough sand in the gaps to maintain a wide beach for upland protection along a longer stretch of shoreline. Sediment accumulates behind each breakwater, forming a scalloped shoreline (e.g., tombolo formation). The length of the breakwater segments, the size of the gaps, the distance offshore, the wave climate, and the available sediment supply determine the final shape of the shoreline. Breakwaters can maintain a sandy beach indefinitely without beach fill. However, breakwaters typically do not provide as much upland protection during storms as well designed bulkheads or revetments because the wave action still reaches the shore. Breakwaters are more expensive to install than other options because large volumes of stone are required, and there is increased cost associated with installing a structure in open water.

Figure 12: Segmented breakwater and scalloped (tombolo) shoreline on Raccoon Island, Louisiana (Photo credit: USDA)

Breakwaters increase hard substrate for settlement of sessile organisms, such as barnacles and oysters, and increase foraging areas for fish. In addition, marsh systems may develop on the sediment that accumulates behind the breakwater system, providing **intertidal** and marsh habitat. However, breakwaters eliminate open water bottom habitat, and often benthic organisms at the construction site are killed, or at least displaced, during the construction process. Bottom habitat is lost behind the structure as sediment fills in the area forming a dry beach (Figure 13). While breakwaters trap sediment in the local area, they may cause erosion downdrift of the structure due to the interruption in the **littoral** transport system. Ultimately, this perpetuates the erosion problem by simply displacing it downdrift to another location that will likely need to take action in the future (Davis 1994).

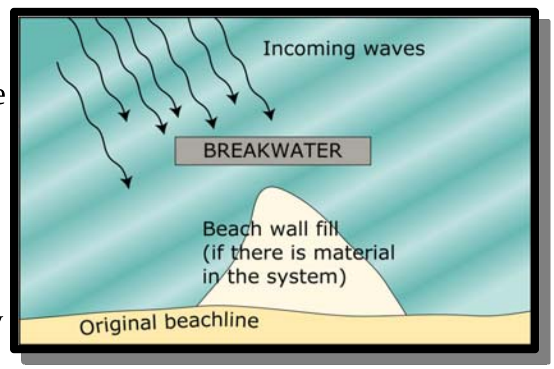


Figure 13: Diagram of a breakwater (Image credit: NOAA)

Sills

Sills combine elements of rock revetments and offshore breakwaters, and are used in conjunction with natural or planted marshes (Figure 14). Sills are designed to maintain a wide marsh fringe, which acts as the primary erosion control device in the system. They are similar to breakwaters, but are smaller and constructed closer to shore. Rock sills are generally in open water, free standing, and have a trapezoidal cross-section. The structures are positioned to protect existing marshes that are actively eroding, or to provide protection to a planted marsh. Sills are low profile structures, generally no more than 6 to 12 inches above the normal high water level. Storm induced waves pass over sills, allowing some natural movement of sediment to take place behind the structure. The lower profile and smaller size of sills also reduces construction costs.

Figure 14: Oyster reef sill in the Mosquito Lagoon, Florida (Photo credit: Florida FWC)

Sills can be constructed out of rock or other natural materials, such as oyster reefs. Oyster reefs placed at the toe of the marsh act as the sill or breakwater for the system. Oyster reef sills provide both protection from erosion and oyster habitat. In addition, oyster reefs filter water and improve water quality and clarity. However, the specific placement of oyster reef sills is important to their success (O'Biern et al. 2000).

The effect of sills on habitat is similar to the effect of breakwaters. In both cases, dry beach habitat is lost and replaced with a marsh system, and aquatic bottom is traded for wetlands. Sills create marsh systems that trap sediment that would normally have been eroded from the shoreline and transported to adjacent areas. Consequently, creating sills can lead to erosion in adjacent areas. However, given the multiple advantages of planted marshes, the tradeoffs of creating sills are usually considered to be acceptable (Rogers and Skrabal 2001).

Generally speaking, the selection of an erosion control strategy is entirely site-dependant. In some cases, in order to create a stable living shoreline, some type of armoring might be needed, especially in higher energy wave environments. For example, if erosion protection is going to be allowed, and maintaining sediment transport is the most important objective, you might prefer a sill or breakwater. Any structure which maintains faunal access and use while minimizing littoral and sediment drift changes to the greatest extent is preferable to those that do not (J. Gill, U.S. Fish and Wildlife Service, personal communication).

Impact of Shoreline Hardening on Populations

The importance of natural sandy beaches as foraging, nesting, and nursery areas is well known. However, the ecological impacts of shoreline hardening on populations of associated species are not well understood. As a result, these impacts are often overlooked in permitting and policy decision-making processes (Dugan et al. 2008). Intertidal zones are disproportionately affected by shoreline hardening, which results in a series of ecological impacts. Consequently, Dugan and Hubbard (2006) concluded that, "the alteration of sandy beaches by coastal armoring causes significant ecological responses of intertidal beach communities, including overall loss of habitat, the loss and reduction of intertidal zones, altered wrack deposition and retention, and reduced diversity and abundance of macroinvertebrates, shorebirds, gulls, and other birds." Similarly, Kahler et al. (2000) concluded in a literature review of many types of hardening structures that, "a negative response to human disturbance and habitat alteration is consistent among diverse aquatic/marine communities."

Fish, Bivalves, and Crustaceans

Williams and Thom (2001) found that the migration of many species, including larval forms, was inhibited by tall vertical structures, such as bulkheads. In contrast, natural material provided protective cover, refuge from predation, and shallow water shelter. Additional impacts may occur in nursery habitat when hardened structures block or alter access through inlets to important estuarine nursery areas. Spawning forage fish may also be impacted by shoreline armoring via alteration of cover or hydrology. Resident fish may experience effects due to a fragmented nearshore landscape, which can cause altered habitat use and movement (Williams and Thom 2001). Hardened shorelines may also attract predators to the area, especially if they have caused an aggregation of prey resources by blocking dispersal, eliminating shallow water refuges, and removing complex woody debris, vegetation, and substrate used for protection (Kahler et al. 2000; Williams and Thom 2001).

The survival of intertidal species, such as crabs and clams, is likely to be negatively impacted by hardened shorelines as their upward migration with tides and waves is restricted. This is problematic for fish and birds that prey upon benthic species, and depend on them for survival (Williams and Thom 2001; Dugan and Hubbard 2006). Furthermore, altered substrate conditions, water properties, and hydrologic conditions can affect benthic prey resources. In addition, the soft-bottom benthic communities in areas adjacent to armoring structures may be affected by altered patterns of sediment and organic matter transport (Williams and Thom 2001). Dugan and Hubbard (2006) predicted that beach armoring, through the loss or reduction of intertidal zones, would depress the diversity and abundance of macroinvertebrates. In a test of that prediction, Dugan et al. (2008) found a significant decrease in abundance, biomass, and size of upper intertidal macroinvertebrates in armored beach areas.

Jennings et al. (1999) found that fish did not actually respond to shoreline structures, but rather to the suite of habitat characteristics that result from the presence of the structure. The habitat characteristics influenced by armoring structures include things like changes to the area that result from the placement of the structure (such as the removal of vegetation or woody debris). Generally, these researchers found that vertical, smooth bulkheads located in deep water, and lacking overhanging vegetation, would provide the most stressful passage and forage conditions for juvenile salmon and small fish in general (Jennings et al. 1999).

In a study on Lake Michigan, Brazner (1997) found that areas adjacent to human disturbance had lower species richness and abundance. Additionally, the species found in those areas were often more disturbance-tolerant species, which indicates that armoring structures may have some bearing on the species assemblage in certain areas (particularly if they are influenced by cumulative impacts of human disturbance) (Brazner 1997). Similarly, Lange (1999) concluded that highly disturbed areas with low vegetation abundance tended to have the lowest species richness and total abundance. This researcher thought that shoreline development was, "a likely agent in causing system-wide disruption of fish…" (Lange 1999).

In another example, Byrne (1995) observed that while species assemblage was identical in bulkheaded and non-bulkheaded shallows of a lagoon, the catch was consistently lower in the bulkheaded shorelines, especially for sheepshead minnow and mummichog. The researcher hypothesized that the abundance was lower at bulkheaded sites due to the lack of structural complexity of the habitat. It was noted that, "submerged aquatic vegetation, attached macrophytic algae, snags, overhanging and submerged branches of upland vegetation, and wood debris were scare or absent in the bulkheaded shallows, but characteristic, to some degree, of the non-bulkheaded shorelines" (Byrne 1995).

Another potential issue of concern related to pier, dock, and bulkhead construction is the leaching of chromium, copper, and arsenic from pressure-treated wood. These contaminants can leach into sediments and tissues of associated organisms. The effects of bioaccumulation of these chemicals in marine organisms is not well studied (Kahler et al. 2000).

Birds

Beach armoring has an impact on beach-associated birds, as a result of the decrease in biocomplexity and availability of habitat for foraging and nesting. In a modeling study, Dugan and Hubbard (2006) predicted that beach armoring would cause 2.3 times lower species richness and more than three times lower abundance of shorebirds. Researchers observed that the thirteen species of shorebirds included in their study were more abundant on unarmored beaches. They predicted that ecological response is influenced by the interaction between an armoring structure and the waves and tides. Because the response of the shorebirds to armoring was greater than predicted by the loss of habitat alone, the researchers concluded that other factors (such as prey abundance and diversity, and refuge availability at high tide) influenced populations in these areas. The impacts of beach armoring are therefore a major concern for declining shorebird populations (Dugan and Hubbard 2006).

In testing these predictions, Dugan et al. (2008) found that shorebirds had two times lower species richness, and more than three times lower abundance, on armored beach segments. Furthermore, armored segments with beach roosting birds (gulls, seabirds, etc.) in some cases led to a more than seven times reduction in abundance. The researchers note that investigating the ecological responses to beach armoring will become increasingly important as climate change begins to have an increased impact on coastal ecosystems (Dugan et al. 2008).

Chapter 3. Living Shorelines

Riparian Habitat

The term 'riparian area' refers to the parts of water bodies that form the transition between aquatic and terrestrial environments (e.g., stream banks or shore areas), and are important because they supply irrigation water, drinking water, fish habitat, and recreational opportunities. Riparian habitat along rivers provides physical structure, maintains water quality, and regulates water flow. Riparian vegetation also plays an important role in filtering runoff from urban and agricultural areas, and preventing excessive sediment from entering waterways (Koski 1992).

In small streams with stable *beds* and minor erosion problems, living shorelines may stabilize stream banks. Shrubs and trees can be planted alone or in conjunction with an erosion control fabric, or other stabilization material, depending on the level of the erosion problem. Erosion control fabrics help stabilize sediments while plantings are forming roots. In some areas, it may be appropriate to install riprap in addition to native vegetation, but this practice should only be used for very steep or severely eroded areas (Georgia Soil and Water Conservation Commission 2000).

Riparian vegetation forms the primary ecological link between aquatic and terrestrial systems, thus the use of native vegetation to stabilize stream banks and shorelines is generally encouraged by land managers. In addition to providing erosion control, riparian systems act as buffer zones for non-point source pollutants, and provide wildlife habitat. Leaf litter from stream bank vegetation forms the energy base of riparian food webs in streams and rivers, and provides habitat and food for a variety of organisms. Furthermore, riparian buffers improve water clarity, water quality, and channel stability, but macroinvertebrates that decrease water temperatures and increase dissolved oxygen levels do not show improvement until a full vegetation canopy develops (Parkyn et al. 2003).

Salt Marsh

Figure 15: Smooth cordgrass marsh system
(Photo credit: Florida FWC)

Salt marshes dominate temperate, coastal regions of the United States. Salt marsh vegetation is adapted to withstand inundation by salt water during high tide (Figure 15). Salt marshes are divided into two areas based on flooding cycles. The low marsh is flooded frequently by tidal cycles and is composed of species able to withstand the tidal flooding and changes in **salinity**, temperature, and water levels. Low marshes on the Atlantic coast are dominated by smooth cordgrass (*Spartina alterniflora*). The high marsh is flooded less frequently and is composed of species less tolerant to hypersaline conditions. Dominant species in high marshes include saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*), black-grass (*Juncus gerardi*), and black needlerush (*Juncus romerianus*) (Knutson and Woodhouse 1983).

Salt marsh vegetation controls erosion via three mechanisms. First, marsh vegetation traps sediment in the root matrix and provides stability by holding sediment in place. Second, marsh vegetation dissipates wave energy. Third, vegetation slows the velocity of the waves to allow for sediment deposition. Gleason et al. (1979) showed that higher stem densities dissipate more wave energy. Similarly, Bricker-Urso et al. (1989) demonstrated that densely vegetated marshes dissipate wave energy and slow currents enough to allow sediment **accretion** in a marsh, which allows the marsh to maintain and keep up with sea level rise. Researchers also showed that higher stem densities correlate to higher accretion rates in marshes (Bricker-Urso et al. 1989).

Salt marshes are a valuable component of the ecosystem because they provide food and valuable habitat for juvenile fish, invertebrates, and nesting shorebirds. Additionally, salt marshes sequester pollutants and remove nutrients that contribute to eutrophication via emergent vegetation that traps sediment from upland runoff. They also control erosion by efficiently trapping and retaining sediment, in some cases leading to shoreline accretion.

Marsh grass can be used to establish living shorelines in areas naturally devoid of vegetation, or they can be planted to restore a marsh in a declining state. However, it is important to understand the reasons for decline of the plant species or why they do not exist at the location. There may be an environmental reason for the decline or absence. If so, additional plantings may not produce the desired results. Other considerations when planting marsh grass should include an account for slope, exposure to wave action, soil characteristics, and salinity. The tidal regime of the area should also be taken into account.

The stability of marsh plantings can be enhanced in marginally acceptable areas by incorporating sills composed of natural or manmade materials into the design plans. Adding these structures to the toe reduces breaking wave energy on the planted marsh, and allows the plantings a favorable environment for proper establishment. North Carolina, Virginia, Maryland, and Delaware have achieved shoreline stabilization using the marsh-sill method.

Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV, or **seagrass**) grows in sheltered sand or muddy-sand subtidal habitat in estuaries and **bays** along the **coast** (Figure 16). SAV provides many of the same structural elements as other living shorelines. The roots and rhizomes anchor the plants to the substrate and take up nutrients from the sediment. Seagrasses slow current and wave speeds, thus enhancing sediment stability and increasing the accumulation of organic material (Kirkman 1992). These plants also bind sediment in their roots, reducing erosion. Additional benefits of SAV establishment include: sediment stabilization, water filtration, food chain base support, and nursery, forage, and refuge habitat functions. SAV also enhances water quality and is critical to many bio-chemical processes.

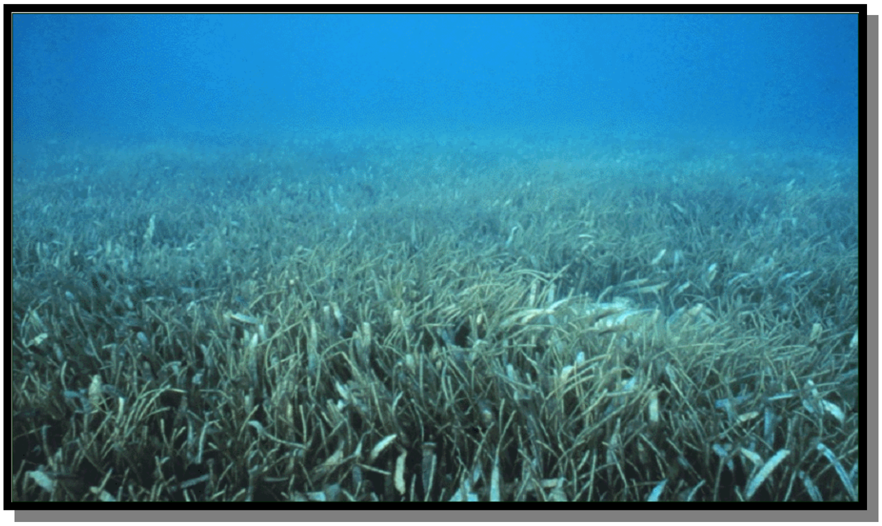


Figure 16: Turtle and manatee seagrass meadow
(Photo credit: Florida FWC)

According to Duarte (2002), seagrasses are important ecosystem components because they store about 15% of the total carbon sequestered by the ocean, and export around 24.3% of their net production to adjacent ecosystems. SAV also helps improve water quality, and has been used to stabilize dredge spoil sediments. Furthermore, seagrass leaves provide both food and shelter for many marine organisms. Surveys indicate that there may be as much as 6.2 million acres of seagrass habitat in the area between New Jersey and Texas (Duarte 2002).

Seagrass beds often grow in proximity to salt marshes or oyster reefs, both of which help maintain water quality at levels that seagrasses can tolerate. De Falco et al. (2000) estimated that without the sediment binding abilities of seagrasses, the amount of sediment that would be resuspended in the water column would be approximately 30 to 90 x 10^3 tons of mud per km^2, enough to influence water quality and ecosystem stability. *Posidonia oceania*, a common seagrass, has been shown to reduce sediment re-suspension. This is important because reduced sediments in the water column contribute to reduced erosion in the coastal zone (De Falco et al. 2000).

Typically, seagrasses are used in conjunction with other features to create a living shoreline. Seagrasses can be planted near the base of a marsh to act as a natural wave buffer. Seagrasses dampen wave energy offshore, but often not enough to provide maximum erosion control. The most successful sites are those established in an area of historical seagrass growth. It is not beneficial to fill in patchy areas of established seagrass, as those areas generally do not retain the plantings (Fonseca 1992). It is important to note that SAV restoration can be unpredictable, and success may vary. In some cases, SAV plantings must be coupled with other shoreline stabilization methods in order to achieve some level of permanence. Generally, these types of restorations are completed by larger agencies with adequate resources to address the approach (J. Gill, U.S. Fish and Wildlife Service, personal communication).

Oyster Reefs

Oyster reefs are sometimes used as natural breakwaters, or sills, at the toe of a planted marsh (Figure 17). However, there is sparse literature discussing the use of oyster reefs in this capacity. Ideally, reefs provide the same wave damping function as rock structures, but also enhance the natural productivity of the system. Oyster reefs protect the marsh from erosion, enhance water quality, and provide substrate for the recruitment of new larval oysters. Oyster reefs are also "self maintaining". If alive, they will continue to build new reef.

Oyster reefs provide habitat and foraging areas for many species of finfish and shellfish. Oysters remove algae and sediment, which helps to improve water quality and clarity. Salt marshes, oyster reefs, and SAV create a positive feedback loop for oyster growth. While marsh systems filter runoff and improve water quality, filter feeding oysters also improve water quality. Consequently, filtration by oyster reefs improves light penetration leading to good conditions for SAV growth. In turn, SAV stabilizes the bottom, which also improves water quality. Without the filtering of the marshes and oyster reefs, increased sediments inhibit filter feeding by oysters and can ultimately lead to eutrophication. Eutrophication limits light penetration through the water column and slows SAV growth.

Figure 17: Intertidal Mid-Atlantic American eastern oyster reef
(Photo credit: Florida FWC)

Mangroves

Mangroves are woody plants adapted for survival in the saline, waterlogged soils of tropical and subtropical estuarine environments. Temperature sensitivity limits mangrove distribution in the United States to central and southern Florida. Consequently, marsh grasses replace mangroves as the dominant shoreline vegetation in more temperate climates. In Florida, there are three dominant types of mangroves: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), and white mangrove (*Laguncularia racemosa*). Black mangroves are the most cold-tolerant species and have the most northernmost distribution of the three mangrove species (Stevely and Rabinowitz 1982).

Mangroves (Figure 18) play an important role in south Florida ecosystems by providing nursery habitat for economically valuable species, protection from tidal erosion and storm surges, and acting as sediment traps for land accretion (Pernetta 1993). Mangroves contribute organic detritus to the ecosystem, and distribute essential nutrients, such as carbon, nitrogen, and phosphorous, to coastal food webs (Beck et al. 2003). Decomposing mangrove leaves form the primary energy source for these coastal food webs, and provide a valuable food source for a variety of marine species including red drum, oyster, and shrimp. Mangroves also provide nursery areas for fish, crustaceans, and shellfish. Furthermore, many waterbirds rely on the mangrove system for nesting sites. Mangroves also enhance water quality and reduce pollution by filtering suspended and dissolved materials (Stevely and Rabinowitz 1982).

Figure 18: Mangrove swamp
(Photo credit: NOAA)

In addition, mangroves serve a critical function in stabilizing the shoreline. Mangroves retain sediment, prevent excessive shifting and eroding of shorelines, and buffer the effect of wind and waves during storms. This capacity is maintained by a substantial root system that binds soil at an early age to stabilize sediment. All of Florida's dominant mangroves develop sub-surface and above ground accessory root systems that retain sediment. Black mangroves develop an extensive sub-surface root system earlier than both white and red mangroves. White mangrove root systems develop the slowest of the dominant species. Restoration projects using red and black mangroves have shown that black mangroves may be better at stabilizing sediment because of their root structure. Black mangroves are also better adapted to withstand cold temperatures, which make them better suited for living shorelines projects in colder, higher latitude areas (Savage 1972).

Mangroves also have high value on shorelines that experience frequent tropical disturbances (Tomlinson 1986). The loss of mangroves leaves shorelines exposed to increased erosion, which may be further amplified under scenarios of global climate change and sea level rise (Pernetta 1993).

Benefits of Living Shorelines

The term living shorelines encompasses a wide variety of environmentally friendly erosion control devices. When properly installed, living shorelines reduce and control eroding sediments. Living shorelines act as natural buffers, filtering pollutants and upland runoff, and improving water quality and clarity in the surrounding aquatic waters. Improved water quality translates into better habitat for many commercially and recreationally important species of fish and invertebrates. For example, living shorelines are designed to function as living space for wildlife. They provide additional foraging and nesting areas for native species, and often replace areas that were previously lost to erosion. Living shorelines also provide aesthetic value, enhancing views and creating wildlife viewing opportunities for landowners and the general public.

Relative to costs, living shorelines can be competitive or cheaper in low wave energy environments than traditional armored approaches to shoreline protection. As wave energy increases, living shoreline costs go up as a function of larger stone breakwater requirements and more placed fill material for planting a marsh. Obviously costs vary based on the area of the country and site specific conditions. In general, a living shoreline in a low wave energy environment will cost 10 to 15% less than a traditional wooden bulkhead (using anchoring dead-men and 18 inch channelward encroachment). Higher wave climates, which require larger offshore, segmented breakwaters tend to be approximately 20% more expensive (Slear, Environmental Concern, personal communication). Landowners must weigh the costs of various approaches with the overall outcome. All the approaches discussed can be designed for predictable erosion control benefits. If the desire is also to provide a sense of place and privacy and a natural landscape to enjoy, a living shoreline might be the preferred alternative.

Chapter 4. Case Study: Living Shoreline Programs in Maryland

Tidal and non-tidal shorelines comprise important habitats for multiple life history stages of many fishes. Available fish habitat is reduced when shorelines are fortified with hard structures; they tend to lose stability and erosion rates increase. To enhance the ecological function of shorelines, legislation has been enacted at both state and federal levels in Maryland to promote living shorelines. The following information is a case study on the implementation of living shorelines in Maryland.

Figure 19: Example of a living shoreline in Maryland
(Photo credit: Maryland Department of Natural Resources)

Maryland Regulatory Authorities

Federal

Several pieces of legislation (both federal and state) provide regulatory authority for shoreline management, including living shorelines. The *Rivers and Harbors Appropriation Act* (1899) and the *Clean Water Act* (1972; Section 401) establish federal authority for permitting oversight with the U.S. Army Corps of Engineers (USACE). Development and coordination of shoreline use among federal and state agencies is handled by the Office of Ocean and Coastal Resource Management (OCRM), within the National Oceanic and Atmospheric Administration's

(NOAA) National Ocean Service (NOS), which was established by the *Coastal Zone Management Act* (CZMA) in 1972.

State

Maryland's regulatory authority over shoreline alteration was established in 1970 by *Environment Article* Title 16, *Wetlands and Riparian Rights Act*, and the associated rules in the *Code of Maryland Regulations* (COMAR) 26.24 Tidal Wetlands (revised 1994). A NOAA-approved Executive Order in 1978 established Maryland's Coastal Program, which consists of several state agencies under the lead of the Department of Natural Resources (DNR). Maryland regulatory agencies have the authority to approve, condition, or deny federally approved permits. Permit decisions are made after consideration of compliance with applicable state regulations.

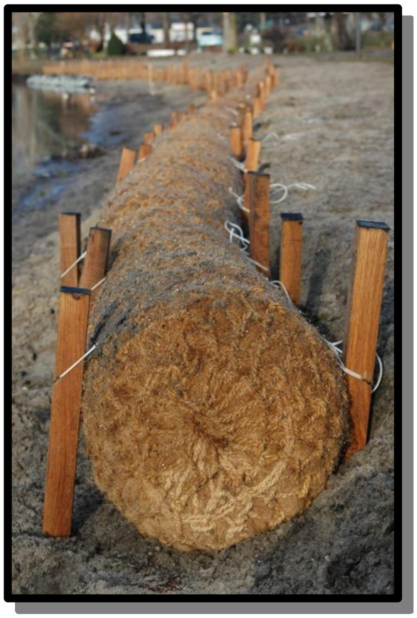


Figure 20: Example of a living shoreline stabilizer called biodegradable organic natural fiber logs (bio-logs) (Photo credit: Maryland Department of Natural Resources)

Local

Local jurisdictions in Maryland have authority to manage shoreline erosion and protection via the *Erosion and Sediment Control Law* (1957), and the *Chesapeake Critical Area Program* (Chesapeake and Atlantic Coastal Bays Critical Area Protection Program 1984). Local managers are responsible for encouraging protection of rapidly eroding shorelines by public and private landowners within the Critical Area. The Critical Area in Maryland consists of all land within 1,000 feet of mean high water, or the landward edge of wetlands, for all tidal waters of the Chesapeake Bay and its tributaries. Local managers are required to encourage landowners to use non-structural shoreline protection measures (i.e., living shorelines) to prevent shoreline erosion.

Maryland Statute

In 1999, the Maryland General Assembly passed *Resolution 19*, which established a Shoreline Erosion Task Force. Among the Task Force recommendations was the development of a *Comprehensive Shore Erosion Control Plan* that would prioritize and target areas of shoreline erosion, and develop a project review process and engineering standards. The *Shore Erosion Control Plan* is currently under development.

In 2008, the *Living Shoreline Protection Act* was passed (Chesapeake and Atlantic Coastal Bays Critical Area Protection Program). This legislation requires construction projects in tidal wetlands to use non-structural shoreline stabilization methods. Maryland Department of the Environment (MDE) may grant exemptions from this requirement in areas where it has been demonstrated that such an approach is not feasible. Prior to this legislation, use of living shorelines was encouraged in appropriate locations, but was voluntary.

The *Shoreline Erosion Control Law* (1998) requires the Maryland DNR to develop education and outreach materials, develop shore erosion control districts, provide technical assistance to any interested party, administer a fund to support implementation costs, implement shore erosion control projects on state lands, and develop regulations to implement the law.

Maryland Project Permit Process

Joint federal and state permitting was established in 1996 when the MDE and the USACE combined permit applications to streamline the permit review process. The joint permit (*Maryland State Programmatic General Permit*) is overseen by the MDE Water Management Administration. A joint permit is required for all projects proposed in navigable waters. In addition to the joint permit, a *Maryland State Tidal Wetlands License* issued by the Maryland Board of Public Works is required when a project is larger than 500 linear feet and extends more than 35 feet into navigable waters.

An individual permit from USACE is required when a project's impact will exceed one acre. Furthermore, USACE can require an individual permit if a proposed project will potentially have significant individual or cumulative impacts to natural, historical, cultural, or other public resources.

Living shoreline projects are required to obtain a local grading or building permit in addition to the joint federal/state permit. Regulatory authority by local governments is implemented differently among local jurisdictions in Maryland. Some counties align their permit decisions on the outcome of the joint state and federal permit process. Other counties have been proactive by implementing their own living shoreline policies. These local permit policies vary among jurisdictions, but they can be more stringent than policies established at the state and federal levels.

Project Implementation in Maryland

Owners of property adjacent to any water body in Maryland may apply for shoreline erosion control design, construction, and funding assistance from the State of Maryland (Appendices C through F). The Shoreline Conservation and Management Service (SCMS) of the Maryland DNR, established in 1964 by the Maryland General Assembly, facilitates property owners in resolving shoreline and stream bank erosion problems along the Chesapeake Bay and its tributaries. Property owners in Maryland can request technical and financial assistance from the SCMS. Technical assistance is provided through site evaluations, problem assessments, and recommended solutions. Project planning and implementation by a property owner requires an understanding of alternative methods of protection, costs, maintenance needs, regulatory requirements, contracting, and project management. Properties located outside of specific physiographic regions, a shore

Figure 21: Seagrass planting
(Photo credit: Maryland Department of Natural Resources)

erosion control district, or in areas deemed unfeasible or unnecessary may not be approved for shoreline erosion control assistance from the state.

In addition, if a shoreline erosion control project is implemented on multiple properties, approval of the project requires all property owners within the physiographic unit to contribute to all stages of the project unless the exclusion of a property owner does not affect the project.

A *Shore Erosion Control Construction Loan Fund* was established to provide financial assistance for shoreline erosion control project costs, including: construction, contractor fees, maintenance of completed projects, loans to political subdivisions, and funds for state-owned properties. *Fund* loans cover construction costs based upon the total project construction cost. They are recorded on county land records and subject to state inspection (Appendix G).

The operations budget of Maryland DNR may appropriate monies from the *Fund* for technical and administrative costs of shoreline erosion control projects, including review and evaluation, construction supervision, and inspection. Property owners may incur part, or all, of the project costs, some of which may be reimbursed by the Maryland DNR. Maryland DNR service costs are not included as part of the construction costs, and are reimbursed by the property owner. Cash contributions to the project cost by the property owner are placed in escrow.

Figure 22: Example of pre (left) and post-installation (right) of a living shoreline in Maryland (Photo credit: Maryland Department of Natural Resources)

Technical Assistance

A living shoreline professional training course entitled *Contractor's Training on Living Shoreline Installation: Introduction to Principles and Practices* was developed through Maryland DNR's Chesapeake and Coastal Program partners (MD DNR[b]). The living shoreline professionals training covers site selection criteria, project and design elements, online information and mapping, and permitting considerations. In addition, demonstration project construction has also been utilized to provide contractor training, and to show how these shoreline projects can be applied in a variety of environments.

Technical assistance from the Maryland DNR includes structural, material, and vegetative design based on: 1) site characteristics; 2) navigating regulatory requirements; 3) installation and maintenance cost estimation; and 4) general contracting and project management. Within the Maryland DNR, the Shoreline Conservation and Management Service, Riparian and Wetland Restoration Services, and Critical Area Commission can provide technical assistance for the implementation of living shorelines.

Several entities are available for assisting in living shoreline development. The Resource Conservation and Development Council (RC&D; the grassroots arm of the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS)) provides site visits, technical assistance, plan review, and other services on shore erosion issues. Soil Conservation Districts (SCD) develop locally driven solutions to help implement farm conservation practices to keep soil in the fields and out of waterways. SCD's also restore wetlands and enhance forest and buffer resources.

Technical assistance and information is also available from the U.S. Fish and Wildlife Service, Chesapeake Bay Trust, Chesapeake Bay Foundation, BayScapes Program - Partners for Fish and Wildlife, Maryland Native Plant Society, and the multi-stakeholder Living Shorelines Stewardship Initiative (MD DNR[d]).

Figure 23: Example of a hybrid hard-soft shoreline stabilization (Photo credit: Maryland Department of Natural Resources)

Financial Assistance

Owners of property adjacent to any body of water in Maryland may apply for assistance with project design, construction, and financing to control stream bank erosion or shoreline erosion. Financial assistance through the *Shore Erosion Control Law* is only available for non-structural projects. Financial assistance for non-structural projects is awarded to the individual property owners in accordance with the loan formula of the *Shore Erosion Control Law*. Interest-free 5, 15, or 20 year loans are available depending on project design. Loans are available to any owner of property bordering waterways, pending project priority and availability of funds (Appendix F). These interest-free loans are not available for structural projects.

Several other funding opportunities for living shoreline projects exist in Maryland. MDE established the *Maryland Link Deposit* to provide low interest loans to property owners. These loans are available to both non-structural and structural shoreline projects.

MDE has also established the *Small Creeks and Estuaries Grant Program* through the Water Management Administration. Local governments can apply for a 3:1 cost-share grant to fund both non-structural and structural shoreline projects.

In addition, several non-profit organizations offer funding opportunities for living shoreline projects. The Chesapeake Bay Trust (CBT) is a non-profit collaboration of governmental and non-governmental organizations including the National Oceanic and Atmospheric Administration's Restoration Center, MDE, and the Keith Campbell Foundation. CBT operates the *Living Shoreline Initiative*, which provides a 1:1 match for living shoreline projects that meet certain criteria.

Furthermore, Fish America and the National Fish and Wildlife Foundation offer cost-share opportunities for community, non-profit, and local government projects.

A final report is required for all living shoreline projects once completed in Maryland. The report must summarize the living shoreline construction, detail the monitoring plan and results, provide an accounting of expenditures, and discuss opportunities to use the project for outreach.

Public Education and Outreach

The Maryland DNR, in coordination with federal agencies, continues to develop outreach, educational, and technical literature about living shorelines. Documents available for reference include: *Management, Policy, and Science: Living Shoreline Summit* (Erdle et al. 2006); *Shoreline Erosion in Depth* (MD DNR[c]); *Vegetation for Tidal Shoreline Stabilization in the Mid-Atlantic States* (Sharp, Belcher, and Oyler); *Shore Erosion Control: The Natural Approach* (Lusher and Hollingsworth 2005); and *Stream Restoration: Using Bioengineering Techniques "A Demonstration Project" Rock Creek Park* (Maryland Eastern Shore RC&D Council).

Furthermore, Maryland state agency websites contain pages specific to the topic of living shorelines. In addition, the Maryland DNR Chesapeake & Coastal Program publishes living shorelines brochures and offers a two-hour computer training course related to online mapping and technical tools.

Figure 24: A living shoreline in Maryland (Photo credit: Maryland Department of Natural Resources)

Several living shoreline demonstration sites can be found in Maryland (Chesapeake Bay Trust 2006). The Chesapeake Bay Education Center in Queen Anne's County established a system of oyster bars along the shoreline to dissipate wave energy, and installed a living shoreline project behind them (Figure 19). In Anne Arundel County, the Arlington Echo Outdoor Education Center constructed a marsh fringe along a retaining wall. The marsh was constructed of coir fiber logs, sand, and mash plants overlaid on a rock base (Figure 20). Similarly, the nearby London Town Public House and Garden constructed a marsh fringe. A living shoreline project was also installed in Annapolis on the campus of St. John's College on a site that previously had a bulkhead. These four sites illustrate the effectiveness of living shorelines in low energy (Arlington Echo Outdoor Education Center and St. John's College), moderate energy (London Town Public House and Garden), and high energy (Chesapeake Bay Education Center) systems.

Local Government Case Study: Kent County, Maryland

Current Kent County policy for shoreline erosion control requires property owners to consider a living shoreline option first. Proposed installation of hardened shoreline armor requires the property owner to justify that a living shoreline is inappropriate for the site. This shoreline erosion control policy has been codified into the *Land Use Ordinance Kent County, Maryland* (2002). The *Ordinance* states the following:

> The purpose of this section is to encourage the protection of rapidly eroding portions of the shoreline in the County by public and private landowners. When such measures can effectively and practically reduce or prevent shoreline erosion, the use of nonstructural shore protection measures shall be encouraged to conserve and protect plant, fish, and wildlife habitat. The following criteria shall be followed when selecting shore erosion protection practices:
>
> 1) Nonstructural practices shall be used whenever possible;
> 2) Structural measures shall be used only in areas where nonstructural practices are impractical or ineffective;
> 3) Where structural measures are required, the measure that best provides for the conservation of fish and plant habitat and which is practical and effective shall be used;
> 4) If significant alteration of the characteristics of a shoreline occurs, the measure that best fits the change may be used for sites in that area.

This shoreline erosion control policy action is significant due to the fact that Kent County is a *Code Home Rule* county (Maryland State Archives 2008). This gives the county the option to enact regulations that are more restrictive than the state. Furthermore, Kent County lacks a Critical Area overlay allowing the county's shoreline erosion control policy to apply in both Critical Areas (the area 1000 ft landward of the shoreline) and non-critical areas (Dixon 2007). Therefore, Kent County has lead authority in determining land use activities within the county.

Kent County's Department of Planning and Zoning has established several outreach mechanisms that compliment this *Ordinance*. Several educational sessions have been conducted to raise awareness of living shoreline concepts among local contractors, commissioners, local realtors, watershed associations, and other community groups. Continued public outreach to promote living shoreline practices has been supported through a grant from the Maryland Coastal Program (administered by the Eastern Shore Resource, Conservation, and Development Council).

Summary of Maryland's Involvement with Living Shorelines

Increased awareness of shoreline function has lead to the enactment of legislation in Maryland that promotes the use of living shorelines in place of hardened shorelines. Maryland has actively pursued the protection and restoration of shorelines through legislation, regulation, technical assistance, financial assistance, and public outreach and education. Maryland's efforts were enhanced by legislation in 2008, making living shorelines required for projects that impact a shoreline. Previously, living shorelines were preferred by the state but voluntary.

Several non-governmental organizations have established demonstration sites to promote living shorelines. Additionally, Maryland counties promote living shorelines to varying extents. Kent County has been unique by using their legal authority to establish more stringent rules than the state, which has allowed them to influence impacts to shorelines within their jurisdiction. Maryland's comprehensive living shoreline program is critical to the conservation and preservation of important fish habitat in state waters.

Figure 25: A hybrid reinforced living shoreline in Maryland
(Photo credit: Maryland Department of Natural Resources)

Chapter 5. Conclusions and Recommendations

Conclusions

There are tradeoffs associated with the installation of any form of shoreline stabilization, natural or manmade. Hardened structures eliminate the ecotone between land and water. In some cases, hardened structures provide habitat for sessile organisms, such as barnacles or oysters. In turn, this can improve water quality and provide foraging grounds for other organisms. For example, bulkheads eliminate natural sandy beach and vegetated habitat, but add muddy bottom habitat valuable to many burrowing organisms and algae. Other hardened structures eliminate bottom area for burrowing organisms, but provide space for settlement of sessile organisms. Even marsh grasses eliminate bottom habitat, but increase intertidal habitat.

Property owners should evaluate tradeoffs when choosing a living shoreline system, as their choice may affect the ecosystem as a whole. Encouraging property owners to work with neighboring properties to develop regional plans could reduce negative effects on the entire ecosystem.

Recommendations

- Encourage studies on using oyster reefs as breakwaters or sills, and evaluate the habitat exchange impact (i.e., reef for hard bottom sediment or soft bottom sediment)
- Identify areas for regional control plans
- Improve coordination among and between agencies and individuals to encourage regional control plans
- Conduct scientific and technical evaluations of living and 'non-living' erosion control features to assess specific effects on habitat
- Assess local species habitat needs, taking into account potential changes from global warming
- Develop financial incentives for the use of living shorelines
- Develop standardized monitoring protocols so restoration sites can be compared
- Develop public information materials that include information on natural or living shorelines, including the impacts of climate change on those areas
- Develop criteria for use of different types of structures within each state
- Take sea level rise into account when conducting any type of shoreline alteration project

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Appendix A. Glossary

Note: *Italicized* words in the glossary are defined elsewhere in the glossary.

Accretion: The accumulation of *sediment*, deposited by natural flow processes on beaches or *marshes*.

Alongshore: Parallel to and near the *shoreline*; same as *longshore*.

Attenuation: The loss or dissipation of wave energy, resulting in a reduction of wave height.

Backshore: (1) The upper part of the active beach above the normal reach of the tides (high water), but affected by large waves occurring during a high tide event.

(2) The *accretion* or *erosion* zone, located landward of ordinary high tide, which is normally wetted only by storm tides.

Bank: The rising ground bordering a lake, river, or *sea*.

Bar: An *offshore* ridge or mound of sand, gravel, or other *unconsolidated* material which is submerged (at least at high tide), especially at the mouth of a river or *estuary*, or lying parallel to, and a short distance from the beach.

Barrier beach: A *bar* essentially parallel to the *shore*, which has been built up so that its crest rises above the normal high water level. Also called *barrier island* and *offshore barrier*.

Barrier island: A detached portion of a *barrier beach* between two inlets.

Bay: A recess or inlet in the *shore* of a *sea* or lake between two capes or headlands.

Beach: (1) A deposit of non-cohesive material (e.g., *sand* or gravel) situated on the interface between dry land and the *sea* (or other large expanse of water) and actively "worked" by present-day hydrodynamics processes (i.e., waves, tides, and *currents*) and sometimes by winds.

(2) The zone of *unconsolidated* material that extends landward from the low *water line* to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation. The seaward limit of a beach – unless otherwise specified – is the mean low *water line*. A beach includes *foreshore* and backshore.

(3) The zone of *unconsolidated* material that is moved by waves, wind, and tidal currents, extending landward to the *coastline*.

Beach crest: The point representing the limit of high tide storm wave run-up.

Beach erosion: The carrying away of *beach* materials by wave action, tidal currents, *littoral* currents, or wind.

Beach face: The section of the *beach* normally exposed to the action of wave uprush; the *foreshore* of the beach.

Beach head: The cliff, dune, or seawall looming the landward limit of the active *beach*.

Beach nourishment: The process of replenishing a *beach* by artificial means (e.g., by the deposition of dredged materials); also called *beach replenishment* or *beach feeding*.

Beach width: The horizontal dimension of the *beach* measured normal to the *shoreline*.

Bed: The bottom of a watercourse, or any body of water; also called *seabed*.

Benthos: Those animals that live on the *sediments* of the *sea* floor, including both mobile and non-mobile forms.

Benthic: Pertaining to the sub-aquatic bottom.

Berm: (1) On a *beach*: a nearly horizontal plateau on the *beach face* or backshore, formed by the deposition of beach material by wave action or by means of a mechanical plant as part of a beach recharge scheme.

(2) On a structure: a nearly horizontal area, often built to support, or key-in, an armor layer.

(3) A linear mound or series of mounds of *sand* and/or gravel generally paralleling the water at, or landward of, the line of ordinary high tide.

Berm breakwater: Rubble mound with horizontal *berm* of armour stones at about seaside water level, which is allowed to be (re)shaped by the waves.

Berm crest: The seaward limit of the *berm*, or the minimum *depth* of a submerged *berm*; also called *berm edge*.

Borrow area: The area *offshore* where replacement *sand* has been taken from for *beach nourishment*.

Breakwater: (1) A structure protecting a harbor, anchorage, or basin from waves.

(2) *Offshore* structure aligned parallel to the *shore*, sometimes shore-connected, that provides protection from waves.

(3) A *detached breakwater* is a *breakwater* without any constructed connection to the *shore*.

Buffer area: A parcel or strip of land that is designed and designated to permanently remain vegetated in an undisturbed and natural condition to protect an adjacent aquatic or wetland site from *upland* impacts, to provide *habitat* for wildlife, and to afford limited public access.

Bulkhead: (1) A structure separating land and water areas, primarily designed to resist earth pressures.

(2) A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the *upland* against damage from wave action.

Clay: A fine-grained *sediment* with a typical grain size less than 0.004 mm. Possesses electromagnetic properties which bind the grains together to give a bulk strength or cohesion.

Coast: A strip of land of indefinite length and width (may be tens of kilometers) that extends from the *seashore* inland to the first major change in terrain features.

Coastal currents: (1) Those *currents* which flow roughly parallel to the *shore* and constitute a relatively uniform drift in the deeper water adjacent to the *surf zone*. These *currents* may be tidal currents, transient, wind-driven currents, or currents associated with the distribution of mass in local waters.

(2) For navigational purposes, the term is used to designate a *current* in coastwise shipping lanes where the tidal current is frequently rotary.

Coastal defense: General term used to encompass both *coast* protection against *erosion*, and *sea* defense against flooding.

Coastal management: The development of a strategic, long-term, and sustainable land use policy, sometimes also called *shoreline management*.

Coastal plain: The plain composed of horizontal or gently sloping strata of *sediment* fronting the *coast* and generally representing a strip of recently emerged *sea* bottom that has emerged from the *sea* in recent geologic times.

Coastal processes: Collective term covering the action of natural forces on the *shoreline*, and the *nearshore* seabed.

Coastal zone: The land-sea-air interface zone around continents and islands extending from the landward edge of a *barrier beach*, or *shoreline* of coastal bay, to the outer extent of the *continental shelf*.

Coastline: (1) Technically, the line that forms the boundary between the *coast* and the *shore*.

(2) Commonly, the line that forms the boundary between the land and the water.

(3) The line where terrestrial processes give way to marine processes, tidal currents, wind waves, etc.

Continental shelf: (1) The zone bordering a continent extending from the line of permanent immersion to the *depth*, usually about 100 m to 200 m, where there is a marked or rather steep descent toward the great depths.

(2) The area under active *littoral* processes during the Holocene period.

(3) The region of the oceanic bottom that extends outward from the *shoreline* with an average slope of less than 1:100, to a line where the gradient begins to exceed 1:40 (the *continental slope*).

Continental slope: The declivity from the *offshore* border of the *continental shelf* to oceanic depths. It is characterized by a marked increase in slope.

Cross-shore: Perpendicular to the *shoreline*.

Current: (1) The flowing of water, or other liquid or gas.

(2) The portion of a stream of water that is moving with a velocity much greater than the average, or in which the progress of the water is principally concentrated.

(3) Ocean *currents* can be classified in a number of different ways. Some important types include the following:

Periodic: Due to the effect of the tides; such *currents* may be rotating rather than having a simple back and forth motion. The *currents* accompanying tides are known as *tidal currents*.

Temporary: Due to seasonal winds

Permanent (or ocean): Constitute a part of the general ocean circulation. The term *drift current* is often applied to a slow broad movement of the oceanic water.

Nearshore: Caused principally by waves breaking along a *shore*

Delta: (1) An alluvial deposit, usually triangular, at the mouth of a river of other stream. It is normally built up only where there is no tidal or *current* action capable of removing the *sediment* as fast as it is deposited, and hence the delta builds forward from the *coastline*.

(2) A tidal delta is a similar deposit at the mouth of a tidal inlet, put there by tidal currents.

(3) A wave delta is a deposit made by large waves that run over the top of a spit or bar beach and down the landward side.

Depth: Vertical distance from still-water level to the bottom.

Detritus: Non-living particulate organic material.

Downdrift: The direction of predominant movement of *littoral* materials.

Dredging: Excavation or displacement of the bottom or *shoreline* of a water body. *Dredging* can be accomplished with mechanical or hydraulic machines. Most is done to maintain channel depths or berths for navigational purposes; other *dredging* is for shellfish harvesting or for cleanup of polluted *sediments*.

Dunes: (1) Accumulations of windblown *sand* on the backshore, usually in the form of small hills or ridges, stabilized by vegetation or control structures.

(2) A type of *bed* form indicating significant *sediment transport* over a sandy seabed.

Ebb: Period when tide level is falling.

Ecosystem: The living organisms and the nonliving environment interacting in a given area.

Eelgrass: A submerged marine plant with very long narrow leaves; scientific name is *Zostera marina*.

Erosion: Wearing away of the land by natural forces. On a *beach*, the carrying away of beach material by wave action and tidal currents.

Estuary: (1) A semi-enclosed coastal body of water, which has a free connection with the open *sea*. The seawater is usually measurably diluted with freshwater.

(2) The part of the river that is affected by tides.

(3) The zone or area of water in which freshwater and saltwater mingle and water is usually brackish due to daily mixing and layering of fresh and salt water.

Fetch: The length of unobstructed open *sea* surface across which the wind can generate waves.

Fetch length: (1) The horizontal distance (in the direction of the wind) over which a wind generates seas or creates wind setup.

(2) The horizontal distance waves travel in open water from their point of origin to the point of breaking.

Foreshore: (1) The part of the *shore*, lying between the *berm crest* and the ordinary low water mark, which is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

(2) The same as the *beach face* where *unconsolidated* material is present.

(3) In general terms, the *beach* between mean higher high water and mean lower low water.

Gabion: (1) Steel wire-mesh basket to hold stones or crushed rock to protect a bank or bottom from *erosion*.

(2) Structures composed of masses of rocks, rubble, or masonry held tightly together (usually by wire mesh), so as to form blocks or walls. Sometimes used on heavy *erosion* areas to retard wave action or as a foundation for *breakwaters* or *jetties*.

Groin: (1) A shore-protection structure (built usually to trap *littoral* drift or retard *erosion* of the *shore*). It is narrow in width (measured parallel to the *shore*) and its length may vary from tens to hundreds of meters (extending from a point landward of the *shoreline* out into the water). *Groins* may be classified as *permeable* (with openings through them) or *impermeable* (a solid or nearly solid structure).

(2) A barrier-type structure extending from the backshore or stream bank into a water body for the purpose of the protection of a *shoreline* and adjacent *upland* by influencing the movement of water and/or deposition of materials.

Habitat: The place where an organism lives.

Hard defenses: A general term applied to impermeable coastal defense structures of concrete, timber, steel, masonry, etc., which reflect a high proportion of incident wave energy.

Impermeable groin: A *groin* through which *sand* cannot pass.

Inshore: (1) The region where waves are transformed by interaction with the seabed.

(2) In *beach* terminology, the zone of variable width extending from the low *water line* through the breaker zone.

Inshore current: Any *current* inside the *surf zone*.

Intertidal: The zone between the high and low water marks.

Jetty: (1) On open seacoasts, a structure extending into a body of water to direct and confine the stream or tidal flow to a selected channel, or to prevent shoaling. Jetties are built at the mouth of a river or entrance to a *bay* to help deepen and stabilize a channel and facilitate navigation.

(2) A structure usually projecting out into the *sea* at the mouth of a river for the purpose of protecting a navigational channel, a harbor, or to influence water *currents*.

Littoral: (1) Of, or pertaining to, a *shore* (especially a *seashore*).

(2) Living on, or occurring on, the *shore*.

Littoral currents: A *current* running parallel to the *beach*, and generally caused by waves striking the *shore* at an angle.

Littoral drift: (1) The sedimentary *material* moved in the *littoral* zone under the influence of waves and *currents*.

(2) The mud, sand, or gravel material moved parallel to the *shoreline* in the *nearshore* zone by waves and *currents*.

Littoral transport: The movement of *littoral drift* in the *littoral* zone by waves and *currents*; includes movement parallel (*longshore drift*) and sometimes also perpendicular (*cross-shore* transport) to the *shore*.

Littoral zone: An indefinite zone extending seaward from the *shoreline* to just beyond the breaker zone.

Longshore: Parallel and close to the *coastline*.

Longshore current: A *current* located in the *surf zone,* moving generally parallel to the *shoreline,* generated by waves breaking at an angle with the *shoreline,* also called the *alongshore* current.

Longshore drift: Movement of *sediments* approximately parallel to the *coastline*.

Marsh: (1) A tract of soft, wetland, usually vegetated by reeds, grasses, and occasionally small shrubs.

(2) Soft, wet area periodically or continuously flooded to a shallow *depth*, usually characterized by a particular subclass of grasses, cattails, and other low plants.

(3) *Salt marsh* is a *marsh* periodically flooded by salt water.

(4) *Diked marsh* is a former *salt marsh* that has been protected by a dike.

Nearshore: (1) In *beach* terminology, an indefinite zone extending seaward from the *shoreline* well beyond the breaker zone.

(2) The zone which extends from the swash zone to the position marking the start of the *offshore* zone, typically at water *depths* on the order of 20 m.

Nearshore current: The *current* system caused by wave action in and near the breaker zone, and which consists of four parts: the shoreward mass transport of water; *longshore currents*; rip currents; and the *longshore* movement of the expanding heads of rip currents.

Nourishment: The process of replenishing a *beach*. It may be brought about naturally, by *longshore* transport, or artificially by the deposition of dredged materials.

Offshore: (1) In *beach* terminology, the comparatively flat zone of variable width, extending from the *shoreface* to the edge of the *continental shelf*. It is always submerged.

(2) The direction seaward from the *shore*.

(3) The zone beyond the *nearshore* zone where *sediment* motion induced by waves alone effectively ceases and where the influence of the seabed on wave action is small in comparison with the effect of wind.

(4) The breaker zone directly seaward of the low tide line.

Offshore breakwater: A *breakwater* built towards the seaward limit of the *littoral* zone, parallel (or nearly parallel) to the *shore*.

Offshore currents: (1) *Currents* outside the *surf zone*.

(2) Any *current* flowing away from the *shore*.

Onshore: A direction landward from the *sea*.

Onshore current: Any *current* flowing towards the *shore*.

Ordinary high water mark (OHWM): Refers to the highest level reached by a body of water that has been maintained for a sufficient period of time to leave evidence on the landscape; it may be indicated by destruction of terrestrial vegetation, the presence of marks on trees, or *debris* deposits.

Particle size: In dealing with *sediments* and sedimentary rocks, it is necessary that precise dimensions should be applied to such terms as *clay*, sand, pebble, etc. Numerous scales have been suggested, but in this work, the Wentworth-Udden scale is used. This scale is widely accepted as an international standard. In the table that follows, *particle size* limits are shown, but within most groups further subdivision is possible. For example, *sand* may be described as very fine, medium, coarse, or very coarse. *Particle size* is normally determined by hand measurement of pebbles, cobbles, and boulders, sieving of gravel, sand, and *silt*, and elutriation of *silt* and *clay*.

Particle	***Size Range***
Boulder	>256 mm
Cobble	64 – 256 mm
Pebble	4 – 64 mm
'Granule', gravel	2 – 4 mm
Sand	1/16 – 2 mm
Silt	1/256 – 1/16 mm
Clay	<1/256 mm

Peak period: The wave period determined by the inverse of the frequency at which the wave energy spectrum reaches its maximum.

Permeability: The property of bulk material (sand, crushed rock, or soft rock *in situ*), which permits movement of water through its pores.

Permeable groin: A *groin* with openings large enough to permit passage of appreciable quantities of *littoral* drift.

Reef breakwater: Rubble mound of single-sized stones with a crest at, or below, *sea* level, which is allowed to be (re)shaped by the waves.

Reflected wave: That part of an incident wave that is returned (reflected) seaward when a wave impinges on a *beach*, seawall, or other reflecting surface.

Revetment: (1) A facing of stone, concrete, etc., to protect an embankment, or *shore* structure, against *erosion* by wave action or *currents*.

(2) A retaining wall.

(3) Facing of stone, concrete, etc., built to protect a scarp, embankment, or *shore* structures against *erosion* by waves of *currents*.

Riparian: (1) Pertaining to the banks of a body of water.

(2) Of, on, or pertaining to, the banks of a river.

Riprap: (1) Broken stones used for *revetment*, *toe* protection for bluffs, or structures exposed to wave action, foundations, etc.

(2) Foundation of wall or stones placed together irregularly.

(3) A layer, facing, or protective mound of stones placed to prevent *erosion*, scour, or sloughing of a structure or embankment; also the stone so used.

Salinity: Number of grams of salt per thousand grams of seawater, usually expressed in parts per thousand.

Salinity gradient: Change in *salinity* with *depth*, expressed in parts per thousand per foot.

Sand: A geologically *unconsolidated* mixture of inorganic *soil* (that may include disintegrated shells and coral) consisting of small, but easily distinguishable, grains ranging in size from about 0.062 mm to 2.0 mm.

Sandbar: (1) See *bar*.

(2) In a river, a ridge of *sand* built to, or near, the surface by river *currents*.

Sand dune: A dune formed of *sand*.

Sand spit: A narrow *sand* embankment, created by an excess of deposition at its seaward terminus, with its distal end (the end away from the point of origin) terminating in open water.

Scour protection: Protection against *erosion* of the seabed in front of the *toe*.

Sea: (1) See ocean.

(2) A large body of saltwater, second in rank to an ocean, more or less landlocked, and generally part of, or connected with, an ocean or a larger *sea.*

(3) Waves caused by wind at the place and time of observation.

(4) State of the ocean or lake surface, in regard to waves.

Seagrass: Members of marine seed plants that grow chiefly on *sand* or sand-mud bottom. They are most abundant in water less than 9 m deep. The common types are: eelgrass (*Zostera* sp.), turtle grass (*Thallasia* sp.), and manatee grass (*Syringodium* sp.).

Seashore: (1) (Law) All ground between the ordinary high-water and low-water marks.

(2) The *shore* of the *sea* or ocean.

Seawall: (1) A structure built along a portion of a *coast* primarily to prevent *erosion* and other damage by wave action. It retains earth against its shoreward face.

(2) A structure separating land and water areas primarily to prevent *erosion* and other damage by wave action. Generally more massive and capable of resisting greater wave forces than a *bulkhead*.

Sediment: (1) Loose, fragments of rocks, minerals, or organic material that are transported from their source for varying distances, and deposited by air, wind, ice, and water. Other *sediments* are precipitated from the overlying water, or form chemically in place. *Sediment* includes all the *unconsolidated* materials on the seafloor.

(2) The fine grained material deposited by water or wind.

Sediment transport: The main agencies by which sedimentary materials are moved are: gravity (gravity transport); running water (rivers and streams); ice (glaciers); wind; and the *sea* (*currents* and *longshore drift*). Running water and wind are the most widespread transporting agents. In both cases, three mechanisms operate, although the *particle size* of the transported material involved is very different, owing to the differences in density and viscosity of air and water. The three processes are: rolling or traction, in which the particle moves along the *bed*, but is too heavy to be lifted from it; siltation; and suspension, in which particles remain permanently above the *bed*, sustained there by the turbulent flow of the air or water.

Setback: A required open space, specified in *shoreline* master programs; measured horizontally *upland* perpendicular to the *ordinary high water mark*.

Shore: That strip of ground bordering any body of water which is alternately exposed, or covered by tides and/or waves. A *shore* of *unconsolidated* material is usually called a *beach*.

Shoreface: The narrow zone seaward from the low tide *shoreline* permanently covered by water, over which the *beach* sands and gravels actively oscillate with changing wave conditions.

Shoreline: (1) The intersection of a specified plane of water with the *shore*.

(2) All of the water areas of the state, including reservoirs and their associated *upland*s, together with the lands underlying them, except those areas excluded under RCW 90.58.030(2)(d).

Shoreline management: The development of strategic, long-term and sustainable coastal defense and land-use policy within a sediment cell.

Silt: *Sediment* particles with a grain size between 0.004 mm and 0.062 mm (i.e., coarser than *clay* particles, but finer than *sand*).

Soil: A layer of weathered, *unconsolidated* material on top of bedrock; often defined as containing organic matter, and being capable of supporting plant growth.

Storm surge: A rise, or piling-up, of water against *shore*, produced by strong winds blowing *onshore*. A *storm surge* is most severe when it occurs in conjunction with a high tide.

Surf: (1) Collective term for breakers.

(2) The wave activity in the area between the *shoreline* and the outermost limit of breakers.

(3) The term *surf* in literature usually refers to the breaking waves on *shore*, and on reefs when accompanied by a roaring noise caused by the larger waves breaking.

Surf zone: The zone of wave action extending from the *water line* (which varies with tide, *surge*, set-up, etc.) out to the most seaward point of the zone (breaker zone) at which waves approaching the *coastline* commence breaking, typically in water *depths* of between 5 m and 10 m.

Surge: (1) Long-interval variations in velocity and pressure in fluid flow, not necessarily periodic, perhaps even transient in nature.

(2) The name applied to wave motion with an intermediate period between that of an ordinary wind wave and that of the tide.

(3) Changes in water level as a result of meteorological forcing (e.g., wind, high or low barometric pressure) causing a difference between the recorded water level and that predicted using harmonic analysis (may be positive or negative).

Suspended load: The finest of the *beach sediments*, light enough in weight to remain lifted indefinitely above the bottom by water turbulence.

Tidal flats: (1) Marshy or muddy areas covered and uncovered by the rise and fall of the tide. A *tidal marsh*.

(2) Marshy or muddy areas of the seabed which are covered and uncovered by the rise and fall of tidal water.

Tidal marsh: Same as *tidal flats*.

Tidal pool: A pool of water remaining on a *beach* or reef after recession of the tide.

Toe: (1) Lowest part of the sea and portside *breakwater* slope, generally forming the transition to the seabed.

(2) The point of break in slope between a *sand dune* and a *beach face*.

Turbidity: (1) A condition of a liquid where fine visible material is in suspension that may not be of sufficient size to be seen as individual particles by the naked eye, but which prevents the passage of light through the liquid.

(2) A measure of fine suspended matter in liquids.

Turbidity current: A flowing mass of *sediment*-laden water that is heavier than clear water, and therefore flows downslope along the bottom of the *sea* or a lake.

Unconsolidated: In referring to *sediment* grains, loose, separate, or unattached to one another.

Updrift: The direction to which the predominant *longshore current* carries beach *sediment* towards.

Upland: Generally described as the dry land area above and landward of the *ordinary high water mark*.

Water line: (1) The juncture of land and *sea*. This line migrates, changing with the tide or other variation of the water level. Where waves are present on the *beach*, this line is also known as the limit of backrush.

(2) The common boundary between the water surface and any immersed structure.

Wetlands: Lands where saturation with water is the dominant factor determining the nature of *soil* development and the types of plant and animal communities that live in the *soil* and on its surface (e.g., mangrove forests).

Appendix B. Suggestions for Erosion Control Projects

Identifying Erosion Problems on a Property

- Consider factors that contribute to and exacerbate natural erosion.
- Identify sources of erosion, such as boat wakes or wave energy.
- Determine if erosion is due to natural, long-term erosion, or a single event, such as a strong storm.
- Evaluate whether the shoreline is a low, moderate, or high-energy beach.
- Identify problems facing neighboring properties.

Site Evaluation

- Consider historic changes and rates of erosion. Historic changes are usually the best tool for predicting future erosion.
- Look at old surveys or photographs of the area to determine how the shoreline has changed through time.
- Consider the orientation of the property and surrounding land uses. Property exposed to storm waves erodes faster than property sheltered in a cove.
- Identify areas where buffers have been removed, or impervious surfaces can increase runoff and erosion by removing sediment from the shoreline as storm water washes over.
- Document land type (e.g., sandy beaches, upland vegetation). Sandy beaches often experience too much wave energy for plants to establish naturally. Sandy beaches can also be a sign of active erosion on the site or a nearby area, and it is important to determine where beach sediment comes from. Upland vegetation (e.g., woody trees and shrubs) indicates a relatively stable area. Upland vegetation cannot tolerate saltwater intrusion, and will not grow in areas that are frequently inundated from tides or storms. If wetland vegetation dominates the landscape, it is an indicator that the area receives enough salt water influence to prevent upland species from growing. Wetlands are low elevation areas; they are subject to daily tidal and wave influences. Generally, wetland areas experience small to moderate erosion rates resulting from daily wave conditions. A slight loss of marsh vegetation therefore, is not a cause for alarm.
- Evaluate the overall context of the site. Be aware of all potential sources of the erosion. When considering management alternatives, be fully aware how each strategy will affect neighboring properties and runoff patterns. Controlling erosion on one site should not lead to devastating impacts on another.

Costs and Availability of Materials

- Consider site accessibility for construction needs, costs of labor and equipment, and long-term durability/expected lifetime of each alternative. Sometimes the least expensive alternative is not the most cost-effective in terms of benefits achieved, long-term stability, and protection/enhancement of natural ecosystems.

- Compare the costs per linear foot of the structure to the costs per foot for overall protection. In some cases, it may be more effective to take no action over any structural measure. Under certain conditions, it may be more cost-effective to relocate structures further away from the eroding area than to implement costly and unsuccessful measures. Environmentally sensitive property owners may also wish to consider costs to the environment compared to the benefits each measure would produce.

Permit Requirements

- Consider local, state and federal permits that may be required to complete the project.
- Contact appropriate state agencies to gather advice on permit procedures and rules governing approvals for each of the alternatives under consideration (see *Appendix 3*).

Finalizing an Approach

- Develop a realistic goal for your project. The advantages and risks of each option should be evaluated before making a final decision. Keep in mind that it is unrealistic to design any erosion control option to withstand catastrophic conditions, such as severe hurricanes.

Implementing Living Shorelines

- If you are experiencing an erosion problem, first contact an appropriate state agency to inquire about natural alternatives to hardened structures. Land managers will gladly direct you to local how-to manuals for your area. Additional references are provided in Chapter 4.

Appendix C. Maryland Application for State Assistance (Part 1)

State of Maryland
Department of Natural Resources
Engineering & Construction
Shore Erosion Control
580 Taylor Avenue, D-3
Annapolis, MD 21401
Phone: 410-260-8523 Fax: 410-260-8894
Toll-Free 1-877-620-8367, Extension 8523

Application for State Assistance

Please Print or Use Typewriter

	(For Department Use Only)
1. Where was this application obtained? Field Inspector? ____ By Mail?____ From County?____ Tawes Bldg.? _________ Other? ___________________ 2. Have you ever applied for State Assistance? Yes___ No___ 3. Has your property ever been inspected by this Department? Yes___ No___ If yes, date(s) ___________________ 4. How long have you owned this property? ____Yrs. ____Mos. 5. Name of previous owner(s)? ________________________	Date Received: **AN** ____________

OWNER(S) OF PROPERTY: ____
(First) (Middle) (Last)
____
(First) (Middle) (Last)

MAILING ADDRESS: ____
(Street or Route and Box Number)
____
(City) (State) (Zip)

TELEPHONE NUMBERS: Home: ________________ Office: ____________________

Cell: _________________ Fax: ____________________

LOCATION OF PROPERTY: Street: _________________________ Community:__________

County ____________________ Body of Water:____________

ZONING: Residential, Year-Round___ Residential, Summer___ Agricultural___ Public Use___

Commercial_____ Other_____ Describe:________________________________

NAME AND ADDRESS OF ADJOINING PROPERTY OWNERS: (Facing Water)

At Right: ____
(Name)
____
(Address)

At Left: ____
(Name)
____
(Address)

(CONTINUED)

Appendix D. Maryland Application for State Assistance (Part 2)

APPLICATION FOR STATE ASSISTANCE

I/We request that assistance from the Department of Natural Resources be made available for the above-described property under the Shore Erosion Control Program. I/We understand the provision of the Shore Erosion Control Program, pursuant to the Annotated Code of Maryland, Natural Resources Article, Sections 8-1001 through 8-1008, and agree to furnish the Department surveys information as may be required. I/We further understand that this application will be considered for eligibility as prescribed by Law. I/We will be responsible for the maintenance of the project after it is completed. I/We grant permission for the Department's personnel to enter the property for the purpose of inspecting the shoreline.

I/We understand that two of the major factors in determining the acceptability of an application is the severity of the erosion problem at the property and the availability of funds. I/We further understand that this Application for State Assistance will not be processed unless it is accompanied by all of the following:

1. A photocopy of the recorded deed(s) to the property.
2. A photocopy of the recorded plat(s) of the property and house location survey, if available.
3. A map of the area so that the Department's personnel may inspect the property, unless a site inspection was previously conducted.

Date:__________ ______________________________ ______________
(Signature of Applicant) (SSN or FID)

Date:__________ ______________________________ ______________
(Signature of Applicant) (SSN or FID)

Signature of authorized representative of the local government is necessary when a County or Municipality sponsors the Applicant.

______________________________ ______________
(County or Municipality) (FID)

Date:__________ By:______________________________ ______________
(Authorized Representative) (Title)

Appendix E. Maryland Project Selection Criteria

Project Selection Criteria DNR-SCMS

	Creek, Cove >	Minor River >	Major Tributary >	Bay
Water Depth	-1.0 ft	-1.0 to -2.0	-2.0 to –4.0	-4.0 to –15.0
Fetch	0.5 mile	1.0 to 1.5 mile	2.0 or more	2.0 or more
Erosion	2 ft/yr or less	2 to 4 ft/yr	4 to 8 ft/yr	8 to 20 ft/yr

Low wave energy > Medium wave energy > High wave energy

Non-Structural > Hybrid > Structural

Type I	Type II	Type IV
Beach replenishment	Marsh fringe w/stone groins	Bulkheads
Fringe marsh creation	Marsh fringe with stone sills	Revetments
Marshy islands	Marsh fringe with stone breakwaters	Stone reinforcing
Coir logs edging and groins		Pre-cast concrete units

Type III

Stone breakwaters with beach replenishment and appropriate vegetation

Least expensive >	Medium priced >	High priced >	Expensive
\$100 - \$200/L.F.	\$250 - \$400/L.F.	\$450 - \$600/L.F.	\$500 - \$1,500/L.F.

Appendix F. Maryland Erosion Control Financial Assistance Matrix

MARYLAND DEPARTMENT OF NATURAL RESOURCES
ECOSYSTEM RESTORATION SERVICES
SHORELINE CONSERVATION AND MANAGEMENT SERVICE

FINANCIAL ASSISTANCE FOR SHORE EROSION CONTROL PROJECTS*

TYPE OF PROJECT	TYPE I	TYPE II	TYPE III
TYPE OF FUNDS USED	STATE	STATE	STATE
TYPE OF ASSISTANCE**	LOAN	LOAN	LOAN
LOAN INTEREST	0%	0%	0%
LOAN TERM	5 YEARS	15 YEARS	20 YEARS

Type I Projects: Marsh creation/protection using natural/living materials
Type II Projects: Marsh creation/protection with stone edging, stone sills and/or stone groins, with sand fill and marsh plantings
Type III Projects: Marsh creation/protection with stone breakwaters, with sand fill & marsh plantings

APPLICANT	EXTENT OF ASSISTANCE****		
PRIVATE PROPERTY OWNERS/BUSINESSES	75% NTE $20,000	LOAN FORMULA ***	LOAN FORMULA ***
COMMUNITY ASSOCIATIONS/NON-PROFIT ORGANIZATIONS/SERVICE ORGANIZATIONS	75% NTE $20,000	100%	100%
MUNICIPALITY - PUBLIC LANDS	75% NTE $20,000	100%	100%
MUNICIPALITY - SPONSORING PRIVATE OWNERS/BUSINESSES	75% NTE $20,000	LOAN FORMULA ***	LOAN FORMULA ***
COUNTY - PUBLIC LANDS	75% NTE $20,000	100%	100%
COUNTY - SPONSORING PRIVATE OWNERS/BUSINESSES	75% NTE $20,000	LOAN FORMULA ***	LOAN FORMULA ***
COUNTY - SPONSORING COMMUNITIES/NON-PROFIT ORGANIZATIONS/SERVICE ORGANIZATIONS	75% NTE $20,000	100%	100%

* Financial Assistance provided based on project priority and availability of funds
** Matching grants are not available
*** Loan Formula as established in Natural Resources Article, Section 8-1005 of the Annotated Code of Maryland
**** A one-time Administrative Fee applies to all project types based on an Administrative Fee Formula

Loan Formula:

Project cost	$0 to $60,000	100% loan	$60,000 loan	$0 Property owner's cash
Next	$20,000	50/50%	$10,000	$10,000
Next	$20,000	25/75%	$ 5,000	$15,000
Above	$100,000	10/90%		

No financial assistance provided for structural/barrier type projects

DNR/ERS/SCM 04/15/08

M:SEC/Forms/FinancialAssistance Matrix

Appendix G. Maryland Request for Field Inspection Form

STATE OF MARYLAND
DEPARTMENT OF NATURAL RESOURCES
SHORE EROSION CONTROL

REQUEST FOR FIELD INSPECTION

OWNER OF PROPERTY:

NAME

MAILING ADDRESS

TELEPHONE NUMBERS

HOME   OFFICE   FAX

LOCATION OF PROPERTY:

STREET   COMMUNITY or POINT OF LAND

COUNTY   BODY OF WATER

PROPERTY INFORMATION:

LENGTH OF SHORELINE   TIME OWNED

PREVIOUS OWNER   PREVIOUS SEC INSPECTION

OWNER AT RIGHT (facing water)

OWNER AT LEFT (facing water)

ADDITIONAL COMMENTS:

DATE OF REQUEST: **REQUEST TAKEN BY:** ________________________

Atlantic States Marine Fisheries Commission

1444 Eye Street, N.W., Sixth Floor
Washington, D.C. 20005
(202)289-6400 (phone) (202)289-6051 (fax)
info@asmfc.org (email) www.asmfc.org