Self-Taught Education Unit

Coastal Shoreline Defense Structures

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Objectives

The purpose of this self-taught education unit is to acquaint the reader with the various types of shoreline defense structures which are employed in the Chesapeake Bay region and the U.S. in general. There are more erosion control measures than those explained here but these are the most generally used and accepted within the marine community. Each structure will be defined and its use along the shoreline will be described. General design and location considerations will be discussed as well as the general definitions and terminology necessary for each type of structure.

Following completion of this study unit, the reader will be generally acquainted with:

1. Shoreline erosion and its causes;
2. The types of structures most often employed to address shoreline erosion;
3. General design considerations for each shoreline structure;
4. Specific definitions and terminology for each structure.

Introduction

At the present time the Chesapeake Bay and most areas of the east and gulf coasts are experiencing varying degrees of relative sea level rise. This is defined as the net change in water elevation due to the combined influence of local land movement (subsidence) and the absolute change in water level. The primary result of sea level rise is shoreline retreat (erosion) along with other secondary shoreline changes.

Chesapeake Bay sea level rise is approximately one foot per century at present. There is some evidence that sea level rise is accelerating due to global climate change. This factor has not been completely documented however, primarily due to the difficulty involved with modelling weather and climate features on a global scale and determining long term trends in the absence of adequate data.

Erosion or shoreline retreat may be caused on a local scale by differences in erodibility of soils, water currents, boat wakes etc. Any of these local features, sea level rise or a combination of any and all may be the reason a structure is employed along a particular reach of shoreline. It may also be present for purely landscape and/or aesthetic reasons.

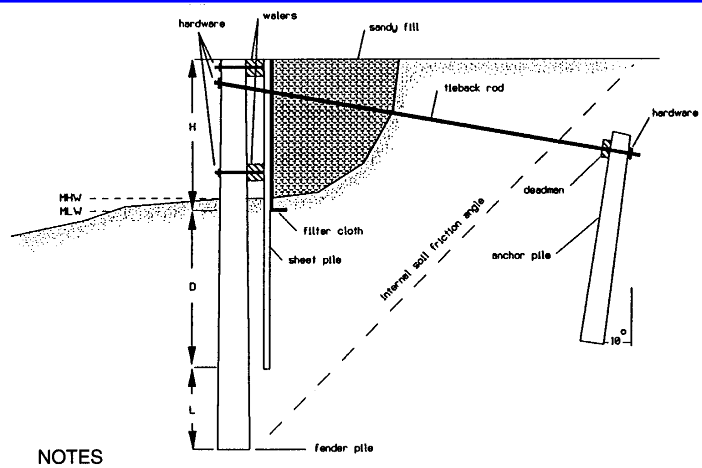
The remainder of this educational unit will characterize and describe the following shoreline erosion defense structure types:

1. bulkheads
2. riprap
3. marsh toe protection
4. breakwaters
5. groins and jetties
6. vegetative control

Bulkheads

A bulkhead (Figure 1) is a vertical wall generally aligned parallel to the shoreline and designed to retain granular backfill material (soil, sand) and to prevent wave-induced erosion. (Figures 2, 3, 4, 5) Bulkheads are usually constructed of chemically treated wood with galvanized fixtures. Bulkheads are also constructed of concrete, asbestos plates, steel, aluminum and most recently from recycled plastics. Asbestos is no longer used and the new recycled products are presently being tested in a variety of situations.

In general, a bulkhead is constructed of round pilings which are driven (by pile drivers) or jetted (by water pressure) into the bottom. (Figures 6, 7) Vertical tongue-and-



NOTES

- H - Height of sheet pile above MLW.
- D - Depth of sheet pile below MLW. (D should be equal to or greater than H.)
- L - Represents the difference in length between the sheet and fender piles (minimum of 2 to 4 feet.)
- MLW - mean low water
- MHW - mean high water

a. All hardware (bolts, nuts, washers, etc.) should be galvanized.
b. Large end of all piles should go into ground.
c. All wood should be pressure-treated to a minimum of 1.5 lbs/ft^3 of CCA or have a minimum creosote level of 12 lbs/ft^3.
d. In general, the length of the tieback rod should be equal to or greater than the length of the sheet pile.
e. Filter cloth should extend to at least MLW elevation.
f. Fill should be free of debris and a good-quality, sandy soil.

Figure 1. *Typical bulkhead cross section. (From Dept. of Conservation and Recreation, Shoreline Programs Office)*

Figure 2. *Bulkhead (typical).*

Figure 3. *Oceanfront bulkhead.*

Figure 4. *Aluminum bulkhead.*

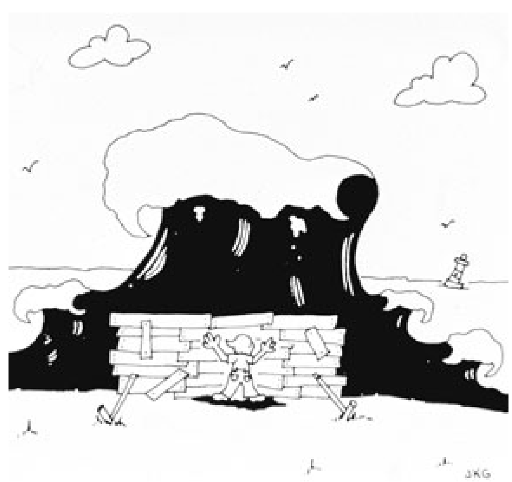


Figure 5. *Design criteria are important!*

Figure 6. *Installing sheet piles.*

Figure 7. *Tie back rods.*

Figure 8. *Loss of backfill and eventual bulkhead failure is the result of sheeting not driven to sufficient depth.*

Figure 9. *Galvanized rod tie-backs.*

groove sheeting forms the "wall" and goes into the bottom in the same manner. The structure should be driven or jetted to a depth at least equal to the height of the structure above the mud line. (Figure 8) Whalers run horizontally between the pilings and brace the sheeting. Tiebacks, usually galvanized steel rods, pass through the pilings and the wall adjacent to the bulkhead and are tied to anchor piles (wooden vertical posts, commonly called deadmen) which help to anchor the wall. (Figure 9) Screw anchors may be employed in specific situations where it is not feasible to use deadmen and tie-backs. Return walls are employed at the ends of the bulkhead in situations where it does not tie into an existing structure protecting adjacent property. (Figure 10) Return walls run back to the land, approximately perpendicular to the wall, and prevent the wall from being outflanked as erosion continues to occur on adjacent unprotected property. The landward side of the entire structure is generally faced with geotechnical material (filter cloth), a woven synthetic textile which when placed between the wall and the backfill material, prevents the washout of soil while allowing water to

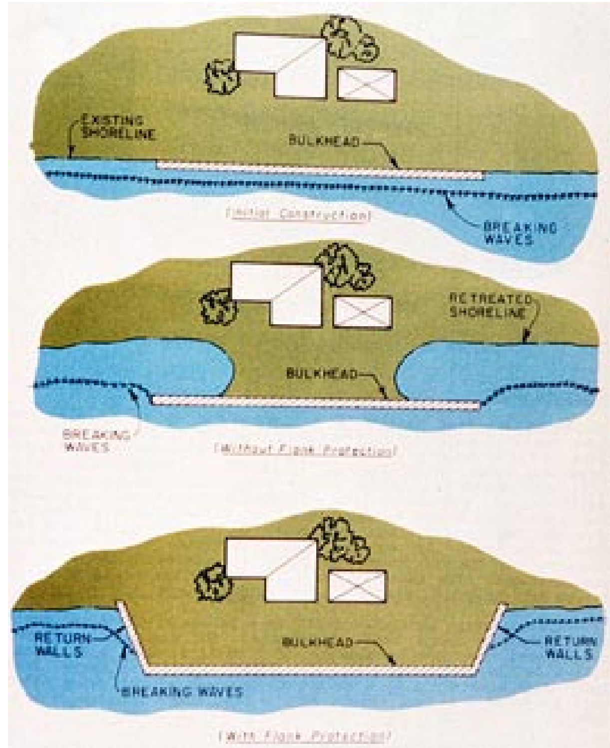
Figure 10. *Steel bulkhead (return wall).*

Figure 11. *Note the filter cloth lining the landward face of this bulkhead.*

pass. (Figure 11) This minimizes the build-up of a hydraulic head landward of the structure.

Bulkheads should be aligned landward of all wetlands and should be properly engineered for the marine environment. Riprap, placed along the seaward toe of the bulkhead, may be necessary to prevent scour in front of the structure due to wave energy. A major problem of bulkheads is that they reflect most waves striking them. In many cases this results in passing the erosion problem along to the next strip of unprotected shoreline. (Figure 12) Bulkheads provide minimal habitat for marine organisms and may adversely affect organisms living in adjacent bottom sediments.

Figure 12. *Typical bulkhead "end effects."*



Bulkheads can be employed along any type of shoreline and in any land use situation but are most often used in residential situations where the waterway is narrow and in industrial areas where ships need to be berthed immediately adjacent to the upland. The expected life span of a properly designed and installed treated wood bulkhead is twenty to twenty-five years. Untreated wood is subject to destruction relatively quickly in marine (salt) waters due to wood-boring organisms.

Riprap

A riprap revetment (Figure 13) is a sloping structure consisting of layers of stone or other material placed along an eroding bank. (Figure 14) The structure is generally composed of smaller "core stone" placed on filter cloth and this is covered with at least 2 layers of larger stone, including an "armor" layer of the largest stone needed for the particular wave conditions at the site. (Figures 13, 15) Riprap can be concrete rubble, granite stone or other material used to build the revetment.

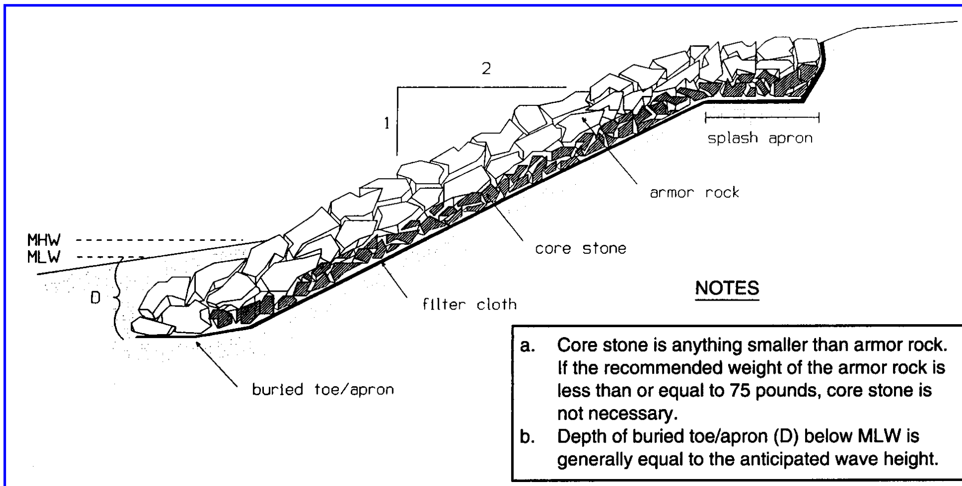


Figure 13. *Representative cross section - riprap revetment. (From Dept. of Conservation and Recreation, Shoreline Programs Office)*

Figure 14. *Properly designed riprap revetment.*

Riprap is used to prevent erosion in the same manner as a vertical bulkhead but has the added advantage of being able to dissipate most wave energy rather than merely reflect it as with vertical structures.

In designing a riprap revetment for a particular site, considerations include the slope of the revetment (usually 2 horizontal:1 vertical or 2H:1V) and the size of the armor stone. (Figures 16, 21, Table 1) Each factor affects the other with the goal to create a structure which is stable for the particular wave height expected at the site. Stability refers to movement of the stone or other material. If waves are able to move the revetment material around, it is not stable. (Figures 15, 17, 18)

Additionally, the seaward toe or bottom edge of the revetment should be buried below the sediment surface to minimize wave scour around the structure. (Figures 19, 22) Filter cloth should be placed under and up the landward face of the wall so that it is between the wall and the backfill. Note that a very wide sheet or several overlapping sheets of standard width cloth may be needed to run under and behind the revetment. The filter cloth serves the same purpose as with the bulkhead but with riprap it also serves as a structural base helping to distribute the weight of the structure more evenly. (Figures 20, 23)

Figure 15. *Armor stone set on base of core stone and filter fabric.*

Figure 16. *Riprap must be sized for expected wave height.*

Riprap is divided into the following class sizes in the Virginia Erosion and Sediment Control Handbook (1992)

Riprap Class/Type	Weight Range* (lbs.)	Requirements for Stone Mixture
Class AI	**25-75**	**Max. 10% 75 lbs.**
Class I	**50-150**	**60% 100lbs.**
Class II	**150-500**	**50% 300lbs.**
Class III	**500-1,500**	**50% 900lbs.**
Type I	**1,500-4,000**	**Avg. weight=2,000 lbs.**
Type II	**6,000-20,000**	**Avg. weight=8,000 lbs.**

*In all classes/types of riprap, a maximum of 10% of the stone in the mixture may weigh less than the lower end of the range.

Table 1.

Figure 17. *Underdesigned revetment before storm.*

Figure 18. *Revetment in Figure 17 failed after a storm.*

Figure 19. *Riprap buried toe construction.*

Figure 20. *Core stone being placed on filter cloth.*

Properly designed and constructed riprap revetments have many advantages, not the least of which is an unlimited life span in the environment. Adding some stone when differential settling occurs may be needed from time to time. Riprap also can be molded to the curves of the natural shoreline contours, many times helping to reduce total length and cost of the structure. Riprap, due to its overall weight, is limited to shorelines with sediment types which can support its overall structure. (Figure 24)

Figure 21. *Riprap classification.*

Figure 22. *Toe of riprap revetment/landward of fringe marsh.*

Figure 23. Revetment constructed with filtercloth.

Figure 24. Established revetment.

From an environmental perspective, riprap is favored over vertical structures made of wood or concrete. Riprap provides habitat where organisms can hide, feed, rest, attach and grow. (Figure 25) Its long life span minimizes future disruptions to the shoreline environment. Like any sediment impermeable structure however, it blocks the resupply of sediments to the shoreline from wave-fastland interactions. This can result in beach narrowing, steepening and/or drowning immediately seaward of the structure and on the adjacent shoreline.

Figure 25. *Revetment provides habitat and erosion protection.*

Marsh Toe Protection

Marsh toe protection (Figure 26) is a specialized form of riprap revetment designed to attenuate erosion taking place on the face of a wetland scarp. The riprap in this case is low profile, meaning the revetment is less than a foot higher than the marsh surface and there is no backfill involved. The low profile structure protects the marsh face from further erosion but allows tidal inundation (hydrology) to continue over and through the stone revetment. (Figures 25, 26) This maintains the viability of the wetland and allows most ecological functions to continue within the system. These functions include inter-community interactions

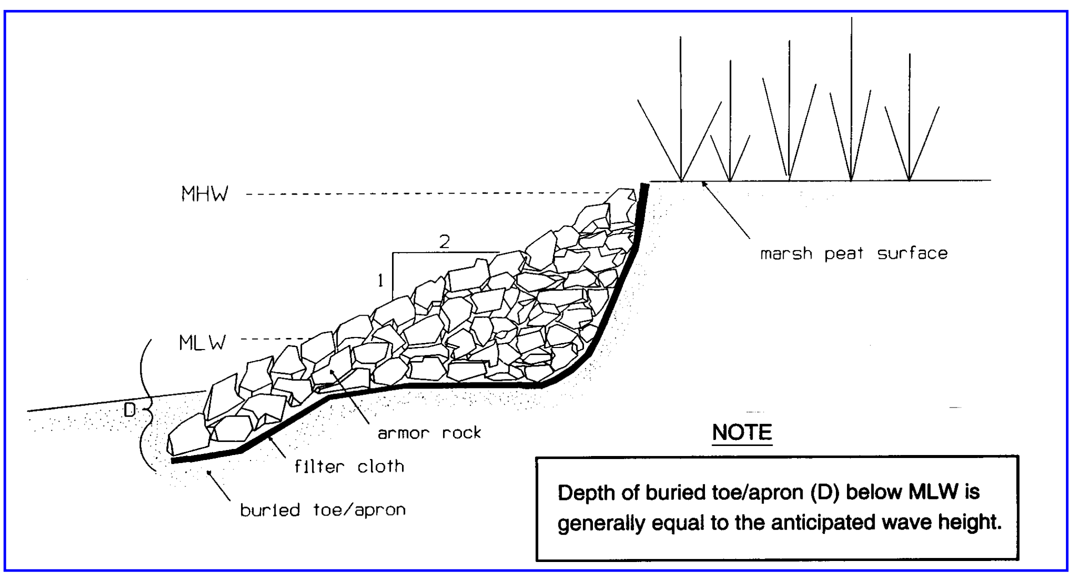


Figure 26. *Representative cross section - riprap wedge for eroding fringe marsh. (From Dept. of Conservation and Recreation, Shoreline Programs section)*

Figure 27. *Marsh toe protection.*

Figure 28. *Marsh sill.*

such as feeding by fish and birds at different tide stages, the recycling of nutrients on the marsh, and the trapping of sediments in the water column by the wetland. (Figures 27, 28)

For design considerations see the preceding section on riprap. (Table 2)

Comparison of Rip Rap Revetment and Rip Rap Marsh Toe Protection

	Rip Rap Revetment	Rip Rap Marsh Toe Protection
Location	**Landward of of marsh**	**Channelward of marsh**
Height	**Based on slope-depends upon location and fetch**	**Approx. equal to the height of the marsh substrate**
Purpose	**Protect upland. Isolate landward area.**	**Protect exposed eroding scarp. Permits interaction of marsh & tides**
Filter Cloth	**Always**	**Always, but not above MHW**

Table 2.

Breakwaters

A breakwater (Figure 29) is an offshore structure aligned parallel to the shoreline. The purpose of the structure is to intercept and dissipate wave energy before it reaches the shoreline and initiates erosion. Because the waves are "tripped" by the breakwater, the area between the breakwater and the shore becomes a relatively quiescent, low energy zone. (Figure 30) Sand and other sediments tend to settle out in this quiet area forming sediment deposits. These deposits may then be colonized by marsh grasses

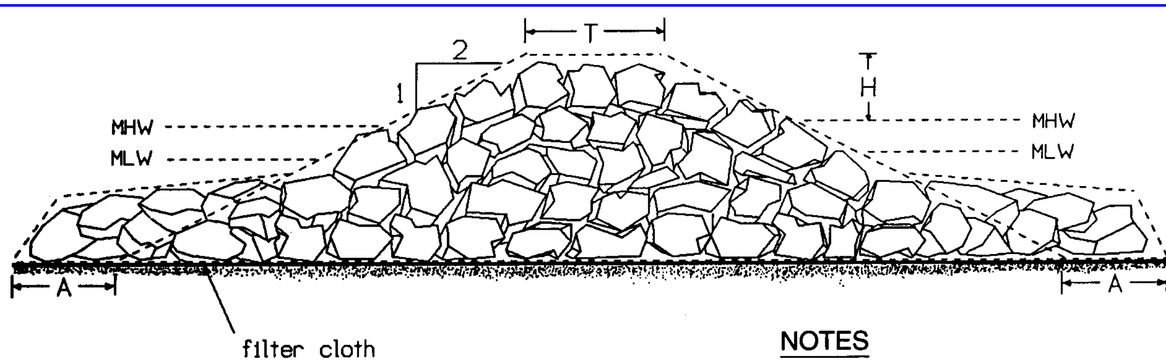


Figure 29. *Representative cross section - riprap breakwater. (From Dept. of Conservation and Recreation, Shoreline Programs section)*

NOTES

T = Minimum top width based on rock size
H = Minimum height above MHW
A = Minimum apron width

such as saltmarsh cordgrass, *Spartina alterniflora* and associated fauna such as worms, snails, crabs and shrimp to name a few.

Breakwaters are generally considered to be a “softer” approach to shoreline protection with “hardened” shorelines being those protected by vertical seawalls and riprap revetments. The soft approach generally refers to the use of vegetation (see below) or a structure, which though it modifies the behavior of the near shore zone, does not fix it permanently in place. The shoreline responds to natural physical changes such as storms, sea level rise, etc., but still retains a measure of protection from erosion due to the structure.

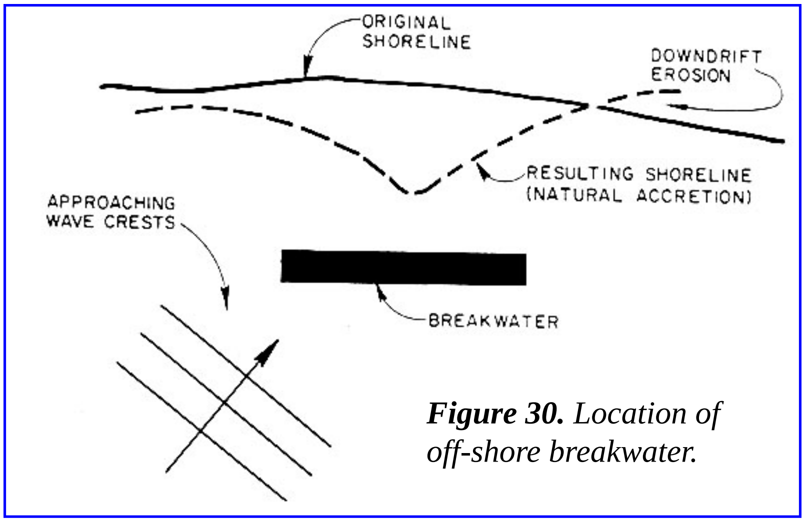


Figure 30. *Location of off-shore breakwater.*

Fixed breakwaters are generally constructed so that their top elevation is one to three feet above mean high water. Since most erosion is sporadic, occurring during storms, the breakwater must be high enough to allow for the storm surge. Storm surge is high water which is generally a product of low pressure systems such as “nor’easter’s” and hurricanes generated or passing over large bodies of water.

Fixed breakwaters are usually constructed of stone or concrete rubble. They may also utilize gabion baskets which are heavy gauge wire baskets filled with stone or sometimes other heavy materials. (Figures 31, 32, 33) Gabion baskets are wired together and filled. They can be stacked and strung end to end to form a continuous structure. The advantage of the baskets is that they allow smaller (cheaper) materials to be used but once placed in the baskets a total mass is achieved which resists movement during storms. (Figure 34)

Many fixed breakwaters are designed with open spaces between sections of the structure. These are termed gapped breakwaters. (Figures 35, 36) They have generally been found to form the most stable

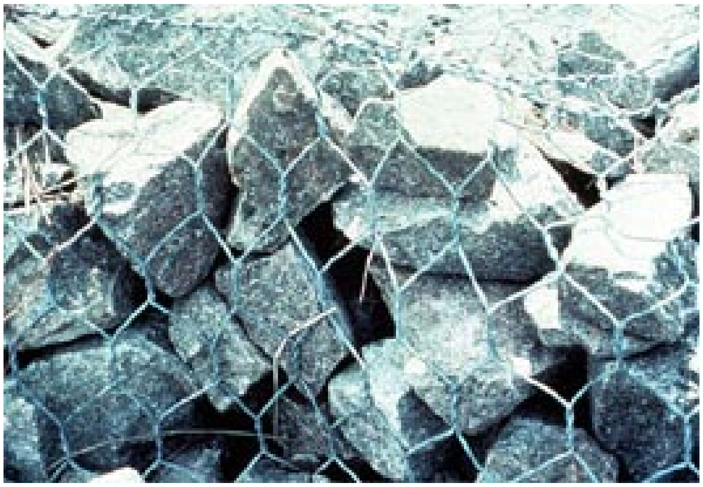


Figure 31. *Gabion basket with stone.*


Figure 32. *Gabion baskets forming a gapped breakwater.*


Figure 33. *Gabion basket breakwater.*

shorelines when properly designed and constructed. The ideal situation occurs when a tongue of sand, termed a tombolo, ties each segment of breakwater to the land and this area is further stabilized by vegetation. This, of course, requires an adequate supply of sand in the nearshore system to make up the tombolo. Sand may also be brought in from upland sources, spread and vegetated. (Figures 37, 38, 39)

Breakwaters can be floating; that is constructed of tires, logs, fabricated containers, baffles or other floating materials. Floating breakwaters depend on their width, not height, to dampen waves as they try to move through the structure. Problems with floating structures range from the attachment of fouling organisms causing the structure to sink, to the failure of anchors and tie materials during storms. (Figure 40)

As with revetments, breakwaters should be used with filter cloth and should have armor stone designed to resist movement when under wave attack during expected storm severity for the local area. The design wave that the structure is meant to attenuate is based on geomorphology of the basin, fetch, water depth, exposure and other factors.

Environmentally, gapped breakwaters are preferred for the same reasons as described under the preceding riprap discussion but have the further advantage of allowing the shoreline to flex with changing conditions. Bulkheads and revetments are impermeable, immovable barriers which do not change with changing parameters such as sea level. Because a wetland or beach, located seaward of one of these structures, cannot migrate landward as sea level rises, they will eventually be covered with water and disappear.

Figure 34. *Revetment made of gabion baskets.*

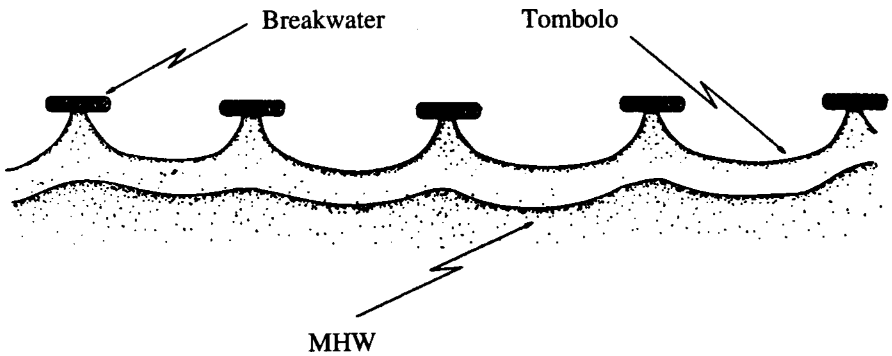


Figure 35. *Breakwater system (From Shoreline Development BMP's, VMRC 1993.)*

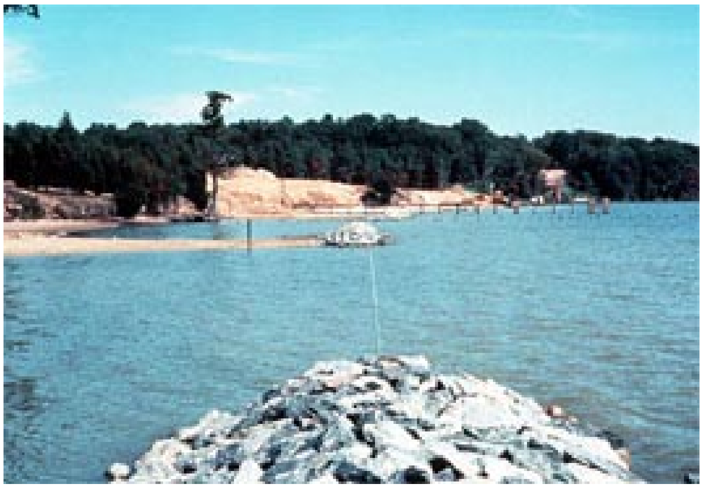


Figure 36. *Gapped breakwater.*

Figure 37. *Beach before installation of offshore breakwaters.*

Figure 38. *Typical tombolo formation landward of breakwater.*

Figure 39. *Breakwater field.*

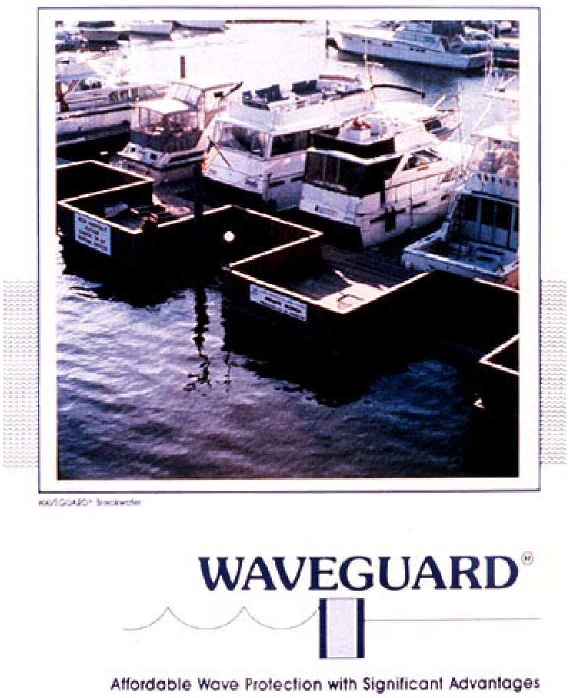


Figure 40.

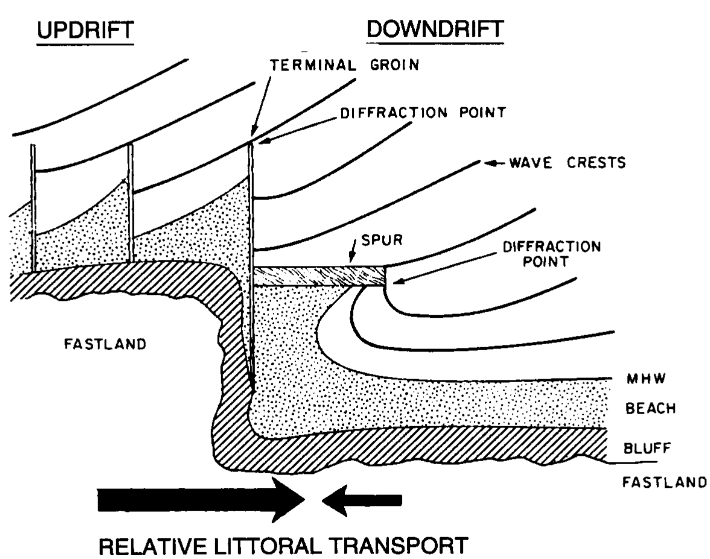


Figure 41. *Groin field with spur. (From Anderson, Hardaway, and Gunn, 1983.)*

Groins

Shoreline erosion is a problem that has been around ever since man began settling adjacent to the water and groins are one of the oldest types of structures used to deal with the problem. Groins are structures placed perpendicular to the shoreline which extend into the water a prescribed distance based on the geomorphology of the shoreline. (Figures 41, 42)

The purpose of the groin is to trap sand moving along the beach with the longshore currents. (Figure 43) When groins are working properly, sand accumulates on the updrift side of the structure acting to widen and raise the elevation of the beach. (Figure 44) Incoming waves then dissipate their energy on the accumulated sand and only attack the fastland during storm events which produce higher than normal water levels. Groins are generally ineffective in preventing shoreline erosion, but exhibit their most success if there is enough sand moving in the nearshore zone that they trap and raise the elevation of the backshore enough that vegetation can establish and further stabilize the shoreline.

As recognized above, groins are dependent on longshore drift and in general do not achieve their intended function where sand is not being transported along the beach. Depending on wind direction, sand may be trapped on either side of a groin at any given time. (Figures 45, 46) Sand may also move onshore and offshore. The net direction of movement determines the updrift side of the groin where the largest amount of sediment is deposited. In the vast majority of cases, groins deprive the immediate downdrift shoreline of sand causing a loss of beach or "notching," which is accelerated erosion. This reaction to the groin generally disappears a short distance downdrift of the structure. (Figures 47, 48)

Groins are primarily constructed of two materials although others have been tried with highly variable success. Timber tongue and groove sheeting with pilings for stability are used along the majority of shorelines. These are either driven or jetted into the bottom, with driven structures being the most durable. The second most popular material is riprap. (Figure 49) It is

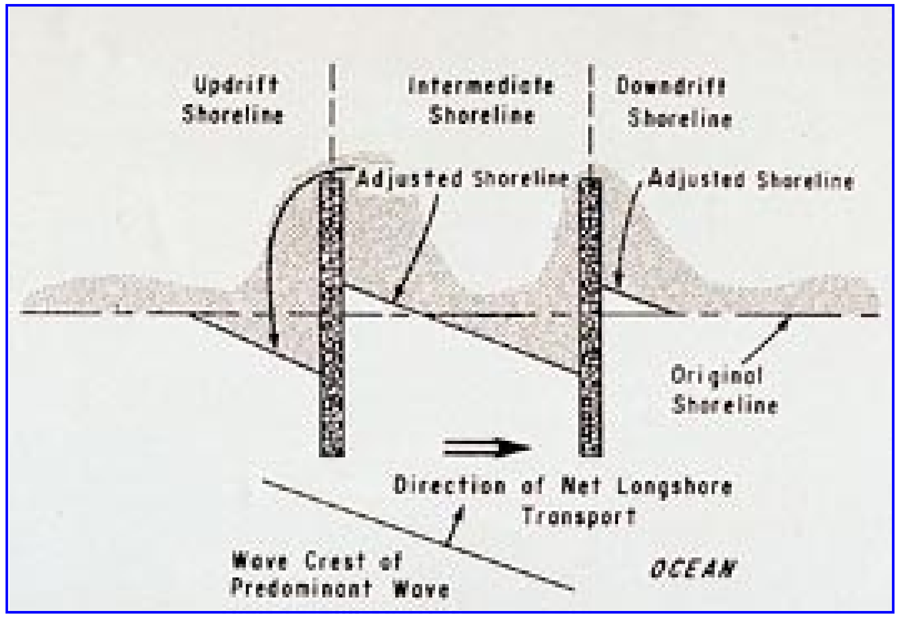


Figure 42. *Groins function to trap sand.*

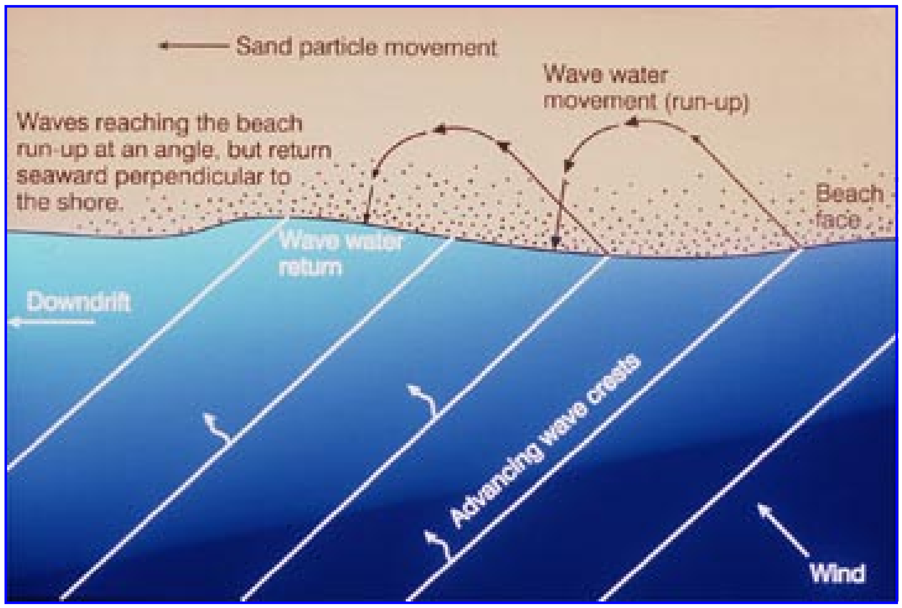


Figure 43. *Movement of sand along shoreline.*

Figure 44. *Groin trapping sand on updrift side.*

Figure 45. *Groin trapping sand.*

Figure 46. *Groin with spur.*

Figure 47. *Downdrift erosion at end of groin field.*

Figure 48. *Beach erosion due to groins.*

Figure 49. *Riprap groin trapping sand.*

generally placed on a bed of geotechnical material (filter cloth) and is constructed in a manner to be free standing and thus is trapezoidal in cross-section. (Figure 50)

In general, groins should be designed to mimic the beach and should be higher at their landward end in order to build the elevation of the backshore. Length is not critical in most cases, and commonly need only be extended ten to twenty feet beyond mean low water. Groins which are too long interfere with the normal movement of sand in the nearshore area and may deprive downdrift beaches of sand needed to maintain equilibrium with erosion forces. Low-profile is the recommended design for groins of either timber or stone. Low-profile requires the channelward end of the groin have an elevation no greater than that of mean low water (Figures 51, 52). This allows sand to begin bypassing the groin more quickly once the groin cell has filled, lessening the period of interrupted longshore sand movement and minimizing to a degree, the adverse effects of the groin to downdrift shorelines. If groins are considered desirable in a given situation, downdrift sand deprivation can be

Figure 50. *Riprap groin placed on filter cloth.*

minimized by filling the groin cell artificially from an upland sand source.

Another method which can be used in specific situations to minimize downdrift erosion due to groins is the attachment of a spur (Figures 41, 53, 54, 55, 56) The spur is generally a short (12-15 feet) structure of the same design as the groin which is attached to the downdrift side and extends out from the groin parallel to the shoreline. The spur may be placed anywhere along the groin between mean low water and the channelward end, depending on specific shoreline geomorphology. Spurs generally cause the accumulation of sand landward of their location, helping to minimize downdrift effects of the groin.

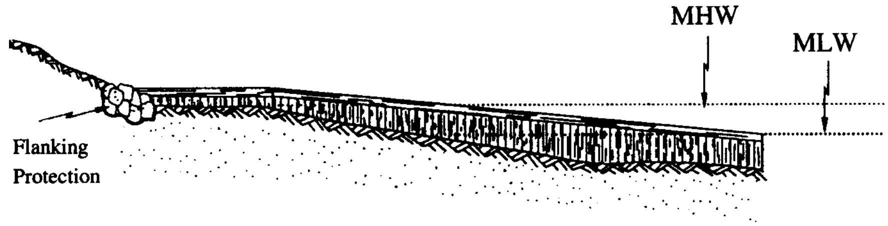


Figure 51. *Low profile groin. (From Shoreline Development BMP's, VMRC, 1993.)*

Provided that there is sufficient sand in the nearshore zone for groins to be effective, the most important additional structural and design considerations are two:

1. Groins must be securely fastened to the uplands so that sand cannot get around them at their shoreward ends. Many groins fail when erosion occurs so quickly that the landward end of the groin is exposed

Figure 52. *Low profile groin design.*

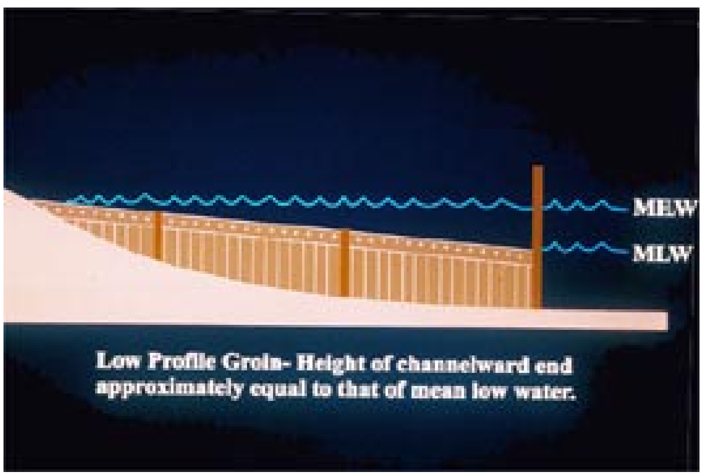


Figure 53. *Sand accumulated on updrift side of groin.*

Figure 54. *Spur prevents erosion on downdrift side of groin.*

Figure 55. *Groin with spurs.*

Figure 56. Groin with spur.

Figure 57. Groin field flanked by erosion.

before the structure has enough time to build up sand and stabilize the beach. If rapid erosion is a concern, riprap may be placed adjacent to the point where the groin meets the fastland. (Figure 57)

2. Groins must be solid structures which only allow passage of sand overtop of them or around their channelward ends. Groins constructed of used tires, well casings or other porous materials are ineffective because the sand passes through them. Old groins with loose or missing timbers fail for the same reason.

Jetties

Jetties are structures very similar to groins in design and construction. The difference between the two is that whereas groins are used on and attached to any suitable reach of shoreline, jetties generally define and protect inlets and/or harbor entrance channels from shoaling by preventing sand from accumulating in the channel or moving across the channel with longshore currents. (Figures 58, 59) Jetties may also function to dampen waves moving across an inlet or

Figure 58. *Riprap protecting a channel.*

Figure 59. *Riprap jetty and adjacent wetland.*

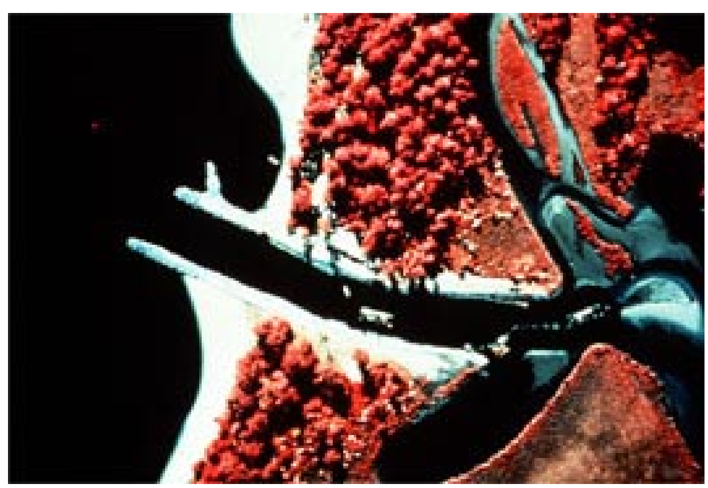


Figure 60. *Stone jetties protect channel.*

Figure 61. Single jetty protecting channel.*

entrance channel, making navigation easier and safer. (Figures 60, 61)

Vegetative Control

Although not a structural option, per se, using vegetation to control shoreline erosion can be very effective in the right circumstances and has the added benefit of providing highly beneficial habitat to marine and freshwater systems. (Figure 62) Vegetative control may be used by itself or in concert with conventional structures such as gapped breakwaters or offshore sills.

When vegetation, usually some type of wetland or submerged aquatic vegetation (SAV), establishes on a shoreline, its root and rhizome system serves to stabilize the existing substrate in place and the sub-aerial shoots baffle water movement causing sediment particles to be deposited along the shoreline. This action helps to build and maintain the intertidal and subtidal zone, minimizing the severity of erosion in many cases.

Figure 62. *Vegetated wetland protecting shoreline from erosion.*

Figure 63. *Planting on 18" center grid.*

Many types of fringe marshes can be very effective as shoreline stabilizers, with a width of eight feet or greater width on the shoreline generally being highly effective. Not all situations are suitable for vegetative control however. Research indicates that shorelines with less than a mile of fetch generally can be stabilized with wetland vegetation. Freshwater marshes do not generally have the thick root and rhizome systems that brackish and salt marshes have, so they must be significantly wider to have the same wave baffling effectiveness that their saltwater cousins have.

Marshes can be established on suitable shorelines using either transplants from established wetlands or nursery grown stock. (Figure 63) In either case some knowledge of wetland plants is necessary along with information on planting elevations (the primary factor in successful establishment), fertilization requirements and plant spacing. This information is available from the Virginia Institute of Marine Science, the Department of Conservation and Recreation and a number of publications available from libraries and bookstores. (Figures 64, 65)

Many waterfront property owners reject the idea of controlling erosion with marsh plantings as infeasible because the wetlands cannot be counted on to inhibit erosion on a long term basis. Many fringe marshes, once established however, may last at least as long as the design life of the average wood bulkhead (i.e. 20 years).

Figure 64. *Planted wetland.*

Figure 65. *Planted wetland shown in Figure 66 after one growing season.*

Figure 66. *Fringe marsh protecting shoreline.*

Figure 67. *Bulkhead reflecting wave energy.*

(Figure 66) When one considers the lower cost, reduced adverse impact and positive environmental contribution of this option, it should be considered a viable alternative to structural erosion control. It bears repeating however, that vegetative control should only be considered for shorelines with less than a mile of fetch. (Figure 67) A good indicator of potential success is whether wetlands exist in other sections of the same reach of shoreline.

Glossary

Anchor piles These are anchors, usually vertical piles driven into the ground, on the landward side of the bulkhead, to which the bulkhead is tied by tiebacks or tie-rods (commonly called deadmen).

Armor This refers to the larger stone used as the outer layers of a revetment which is directly exposed to waves.

Breakwater A breakwater is an offshore structure which is aligned parallel to the shoreline. A **fixed** breakwater refers to one generally constructed of stone or gabion baskets (wire baskets or mattresses which are filled with stone), placed on the bottom. **Floating** breakwaters should be firmly anchored and may be constructed of tires, logs, specially fabricated boxes and baffles, or other floating materials.

Buried toe This is the practice of trenching in the seaward toe of a riprap structure to help prevent scour and shifting of the structure.

Core The core is the smaller stone used as the base of the revetment which is not directly exposed to waves.

Fetch Fetch is the distance that wind blows over water prior to its reaching a shoreline. Generally it is used as an estimate of potential wave energy or stress the shoreline may expect.

Filter cloth Filter cloth is the synthetic textile placed between sheeting and backfill which prevents soil loss but is water-permeable.

Groin This is a structure that is perpendicular to the shoreline and extends into the water. They function in trapping sand moving in the along-shore currents.

Jetting Jetting is a method of sinking structures in substrate where high pressure water "washes" the structure down and the hole refills with sediment as the pressurized water is cut off.

Jetty As with groins, jetties are linear structures placed perpendicular to the shoreline and cross the intertidal zone to deeper water. They function to intercept sand moving along the shoreline and protect channels and inlets from shoaling and wave energy.

Low-profile This is a recommended design for either timber or stone groins, in which the elevation of the channelward end of the groin is no greater than that of mean low water. This allows the sand to bypass the groin more quickly once the groin cell is filled, lessening the interruption of sediment movement to downdrift shorelines.

Marsh toe protection This is a low-profile rock structure placed channelward of a marsh, usually being placed directly against an eroding scarp.

Return walls These are walls located at each end of the bulkhead and shoreline, approximately perpendicular to the bulkhead and shoreline, which tie the bulkhead into the upland and prevent the bulkhead from being flanked.

Revetment A revetment is a sloped structure consisting of multiple layers of stone or other material placed along a bank.

Riprap Riprap is the stone used to build a revetment. Frequently, the structure itself is called riprap.

Screw anchors Screw anchors refer to another anchoring method that consists of rods that screw into the upland.

Sill Sill is a continuous low-profile breakwater structure.

Spur Spurs are attached to the downdrift side of the groin and oriented perpendicular to the groin, and parallel to the shoreline. The spur may be aligned anywhere between MLW and the channelward end of the groin. The purpose is to prevent characteristic erosion of sand immediately downdrift of the groin.

Tiebacks These are rods used to connect the bulkhead to the land anchor pile or deadmen (usually the horizontal piles connected to the anchor pile).

Tombolo This is the name given to the build-up of sand landward of gapped breakwaters.

Up- & down drift Updrift and downdrift refer to longshore drift, or the movement of sediment along the shore. Sediment may move in both directions along a particular shoreline. The net direction of movement determines the net accumulation of sediment by a groin. Groins necessarily deprive downdrift shorelines of their sand supply, worsening any existing erosion problems.

Vegetative control Vegetative control is the use of wetlands vegetation to deter erosion, either alone or in concert with an offshore breakwater or sill. Vegetation may be planted or allowed to colonize naturally.

Whaler Whaler refers to a structural member of a wood bulkhead or groin which runs horizontally between pilings and braces the sheeting.

Literature Cited

Anderson, G.L., C.S. Hardaway, and J.R. Gunn. 1983. Beach response to spurs and groins. In Coastal Structures 1983. Ed. J.R. Weggel. Amer. Soc. of Civil Engineers. New York, New York. pp 727-739.

Virginia Marine Resources Commission. 1993. Shoreline Development BMP's. 54 pp.

Suggested Reading List

Hardaway, Scott and Gary Anderson. 1980. Shoreline erosion in Virginia. Educational Series No. 31. VIMS Sea Grant Advisory Service.

U.S. Army Corps of Engineers. 1981. Low cost shore protection...a property owner's guide. Norfolk, Virginia. 159 pp.

U.S. Army Corps of Engineers. 1990. Chesapeake Bay shoreline erosion study. Feasibility report. Baltimore and Norfolk Districts. 111 pp.