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Shoreline Management In Chesapeake Bay

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Shoreline Management In Chesapeake Bay

C. S. Hardaway, Jr. and R. J. Byrne



Virginia Institute of Marine Science
College of William and Mary

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By

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1999

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Preface

When most people consider buying a piece of bayfront property along the Chesapeake Bay, they imagine sunsets spent boating on the water. But there are also unsettling mornings after a severe storm when one awakes to find a beach suddenly narrower. Or, perhaps the bulkhead that once permitted picnics on the grass at the water's edge has failed and now lies in pieces.

The Chesapeake Bay and its extensive shoreline is a dynamic place. Change is constant, but not always consistent. Years can go by with little impact to a shoreline, but a major storm or change in land-use management can suddenly make a huge difference. Property owners, land-use planners, city, county, and state officials, resource managers, watermen, marina owners, and many others are all concerned with and involved in shoreline management along the Chesapeake Bay.

This book addresses shoreline management from a comprehensive standpoint. It not only takes into account shoreline erosion, but also explains the basic physical parameters behind shoreline change. Furthermore, this book presents solutions to management problems with an eye to cost-effectiveness, sound construction, coastal hazards, property loss, habitat preservation, and water quality.

This document describes and illustrates specific, practical responses to shoreline management issues. We will begin with a look at the evolution of the Chesapeake Bay and its ongoing, long-term processes. We will proceed to a discussion of the daily, physical mechanisms that affect shoreline change and the topics professionals address in evaluating sites. We will then discuss strategies for managing shorelines, such as bulkheads, seawalls, revetments, groins, breakwaters, beach nourishment, and marsh fringes, as well as taking no action. Finally, we will give you a framework to apply these ideas in terms of the physical environment at the site and the applicable shoreline strategies.

In the past, shoreline erosion has often been addressed in a haphazard fashion without a basic understanding of how the physical environment, man-made constructions, and land-use patterns impact each other. Yet the impact of these changes can be substantial. Land-use patterns have changed substantially since colonial times.

Over the years, lands along the rivers, creeks, and bays once predominantly woodland, have been converted to agricultural areas, with pockets of residential development ever increasing (Hardaway et al., 1992). As a consequence, the influx of nutrients, herbicides, and pesticides has increased and has also become a more direct influence on waterways. At the same time, marsh fringes that once lined many shorelines have eroded, leaving uplands often unprotected from wave action. While these physical changes have taken place, waterfront property values have steadily increased, and controlling shoreline erosion has become expensive. The need for shoreline management becomes critical when human occupation and investments are threatened.

Shoreline Evolution

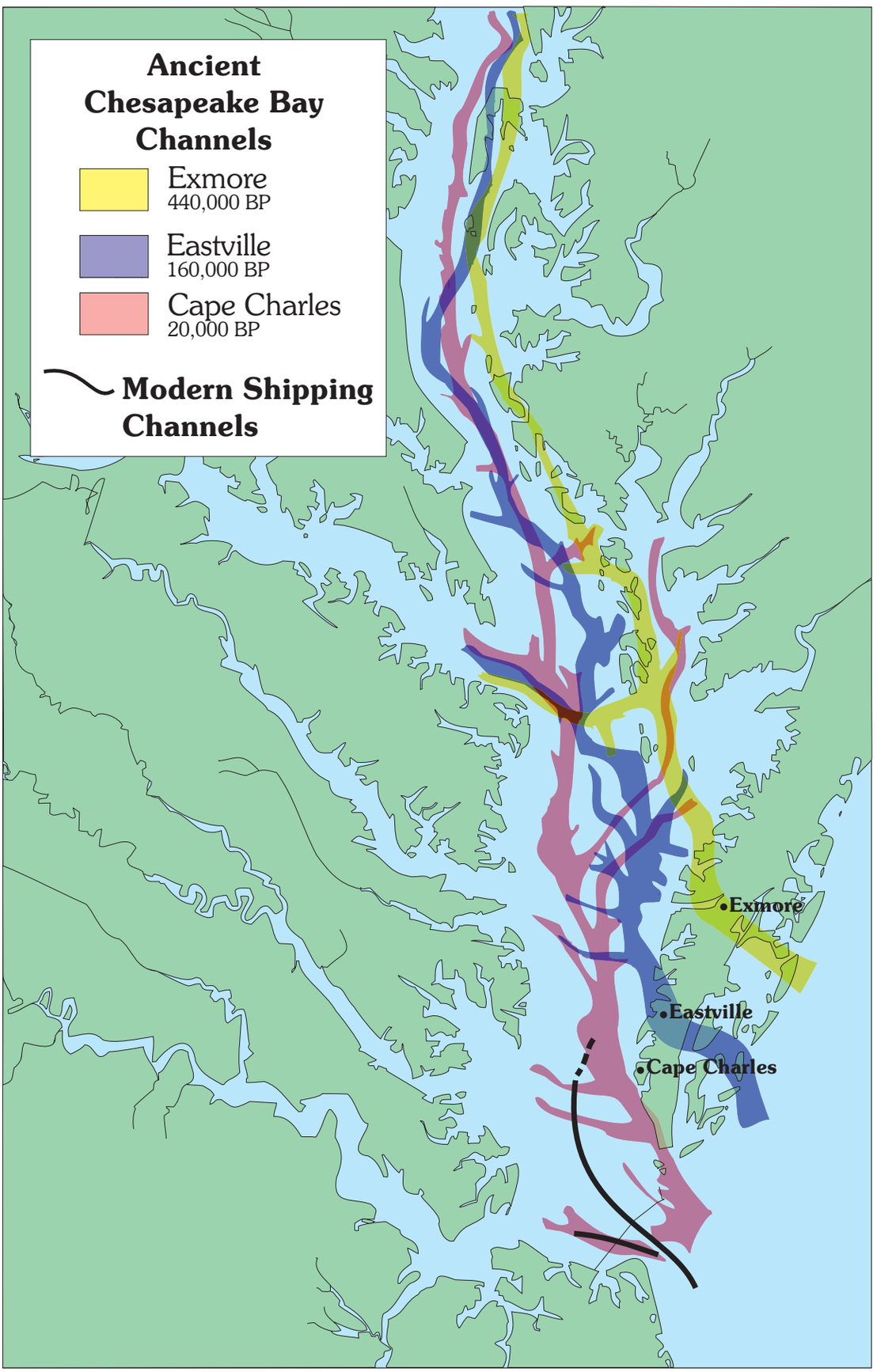


Figure 1
Map of the Chesapeake Bay today showing shifts in the Susquehanna River drainage. The Cape Charles channel formed about 20,000 years BP (before present); the Eastville channel formed about 160,000 BP; and the Exmore channel formed about 440,000 BP.



Figure 2
Broad marshes in foreground give way to fringing marshes downstream where there is greater fetch exposure. At the transition point (T), shoreline processes go from tidally dominated to wave dominated (Ware River, Va).

Geologic History & Long-term Processes

Managing the Chesapeake Bay's shorelines starts with an understanding of how today's shorelines reached their present state.

Approximately 15,000 years ago the ocean coast was about 60 miles east of its present location, and sea level was about 300 feet lower. The coastal plain was broad and low. The estuarine system was a meandering series of rivers working their way to the coast. As sea level gradually rose over millennia, the rivers were inundated with water causing the shoreline to recede. In geologic terms, these ancient river channels, and their tributaries, are referred to as drowned river valleys *(Figure 1)*. Relative sea level continues to rise in the Chesapeake Bay, currently at about 1 foot per century. The current Chesapeake Bay estuarine system, with more than 9,000 miles of tidal shoreline is considered geologically young.

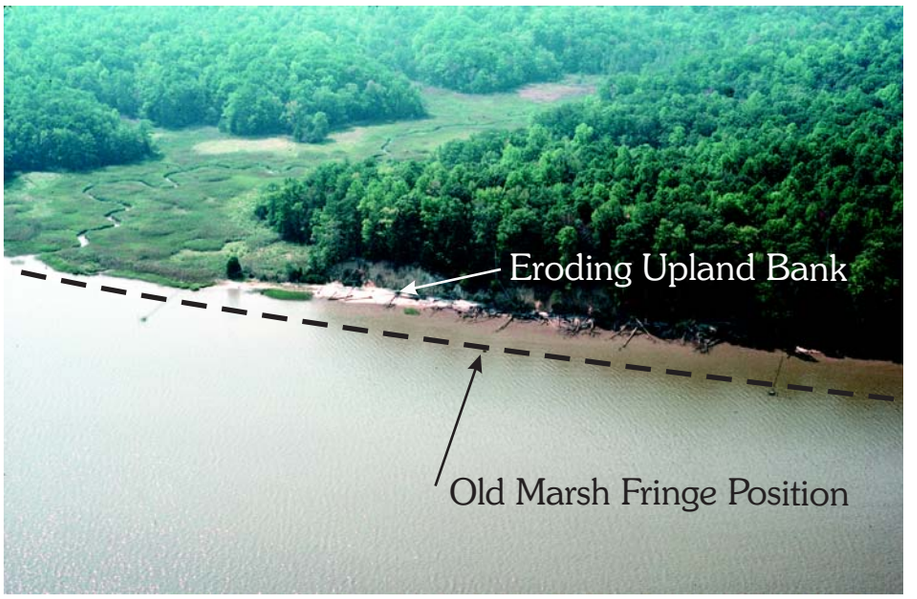
The slow rise in sea level is one of two primary long-term processes which causes the shoreline to recede; the other is wave action.

Waves mold the shape and position of the shore as they erode and transport sediments from one part of the shore to another. Such reshaping is particularly noticeable after a severe northeast storm or the occasional hurricane. Such storms induce a short-term, super elevation of water level, known as storm surge, and strong, powerful waves. During these storms, the high water level and aggressive waves often reach high, upland banks which would be out of the range of normal tides and waves. Thus, shore recession, often called shore erosion, is caused by both passive (long-term rise in sea level and subsequent drowning of river valleys) and active (storm-induced high sea level and large waves) forces.



Figure 3
This marsh fringe along the York River (James City County, Va.) is eroding on the water side, but it is wide enough to protect the upland region from wave attack.

Figure 4
York River shoreline with fringe marsh absent due to erosion. The upland banks are directly exposed to the force of the waves. The result: eroding upland banks.



Shore Types & Coastal Features

The major shore types associated with the oceanic transgression include marsh and upland banks with fronting sand dunes, beaches, and spits. Marshes occupy the fringes of watersheds and low regions in front of uplands *(Figure 2)*. Marshes and their associated peat substrates are important features. Marshes grow vertically and laterally landward in response to sea level rise. Although the face of the marsh may erode in response to wave action, the remaining marsh fringe protects the upland areas from erosive forces *(Figure 3)*.

If the marsh fringe erodes faster than it grows, then it becomes too thin to protect the upland region *(Figure 4)*. Uplands which are exposed to direct wave action erode more quickly. Without the protective marsh fringe, the geology of the eroding banks becomes the primary factor controlling the height and composition of these banks *(Figure 5)*.

Bank erosion is the process which provides additional sediments to the estuarine system, thus, helping to create natural landforms such as

beaches, dunes, shoals, and sand spits *(Figure 6)*.

Bank sediments typically consist of fine-grained silt and clay as well as coarser sands and gravel. As a bank erodes, these materials slump to the base or beach. Wave action then winnows out the finer sediments suspending them in the water, and reshapes the coarser, heavier sand on the shore. The resultant beach deposit, a sand product derived from bank erosion, absorbs the energy from incoming waves until the deposit is eroded during subsequent storm events.

Beaches are dynamic features, constantly reshaped as wave conditions vary. In addition to sand movement in the onshore-offshore direction, sand is transported alongshore, which is known as littoral transport. Thus, bank erosion at one site provides sand to adjacent beaches and creates nearshore features such as tidal flats, offshore sand bars, and shoals. If the beach feature is wide enough, it can protect uplands banks from storm waves.

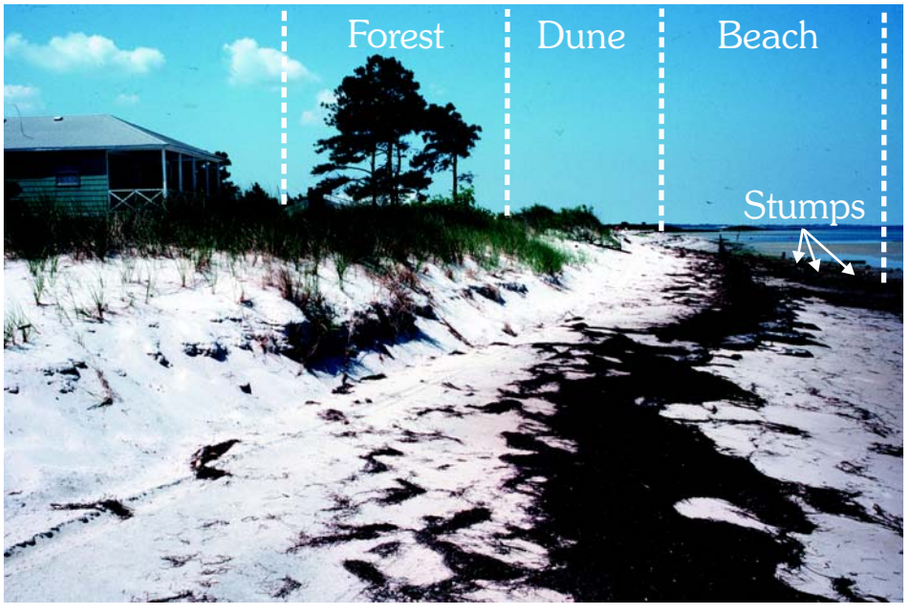


Figure 5

Exposed and eroding upland banks along the Rappahannock River, Va. Note: Basal clay acts as a groundwater perch causing the upper layer of sand to slump.

Figure 6

Dune and beach system along the Chesapeake Bay, Mathews County, Va. Old stumps in the nearshore area are evidence of landward migration of dune and beach systems.



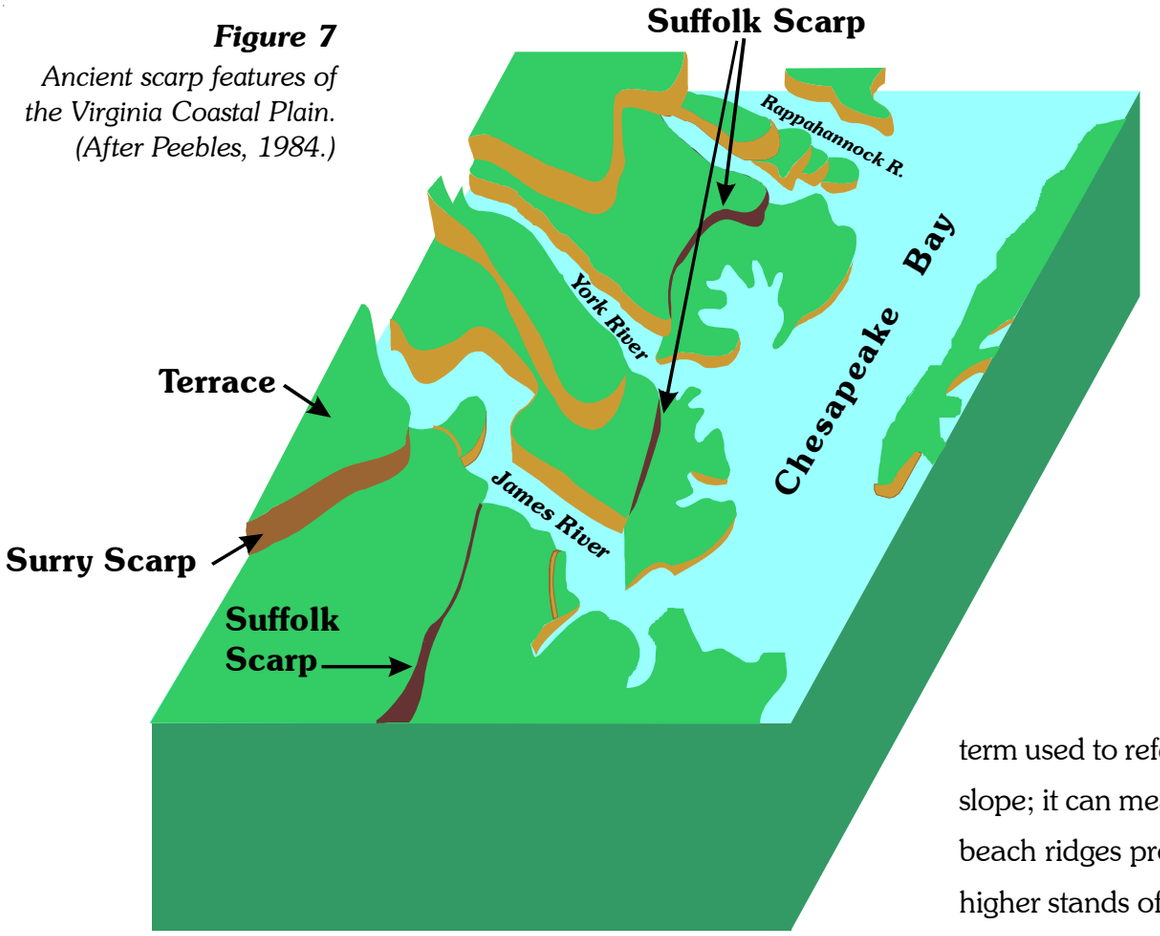


Figure 7
Ancient scarp features of the Virginia Coastal Plain. (After Peebles, 1984.)

Nearshore features also evolve with time, and their position is a function of shoreline erosion patterns, intensity of wave action, sediment supply, and tidal currents. Nearshore depth is a critical parameter in attenuating wave energy, and thus the erosive force of waves in a given area. Wave energy is a function of wave height, and wave height is significantly reduced when waves travel over shallow flats and sand bars.

Further from the shoreline, and on a larger scale, some of the most significant coastal features are scarps. Scarp is the term used to refer to a steep slope; it can mean a series of beach ridges produced by higher stands of sea level, or simply a low, steep beach slope caused by wave erosion. In Virginia, the Suffolk Scarp, which runs the length of the Virginia Coastal Plain along the



Figure 8
Major slump feature along Nomini Cliffs in Westmoreland County.

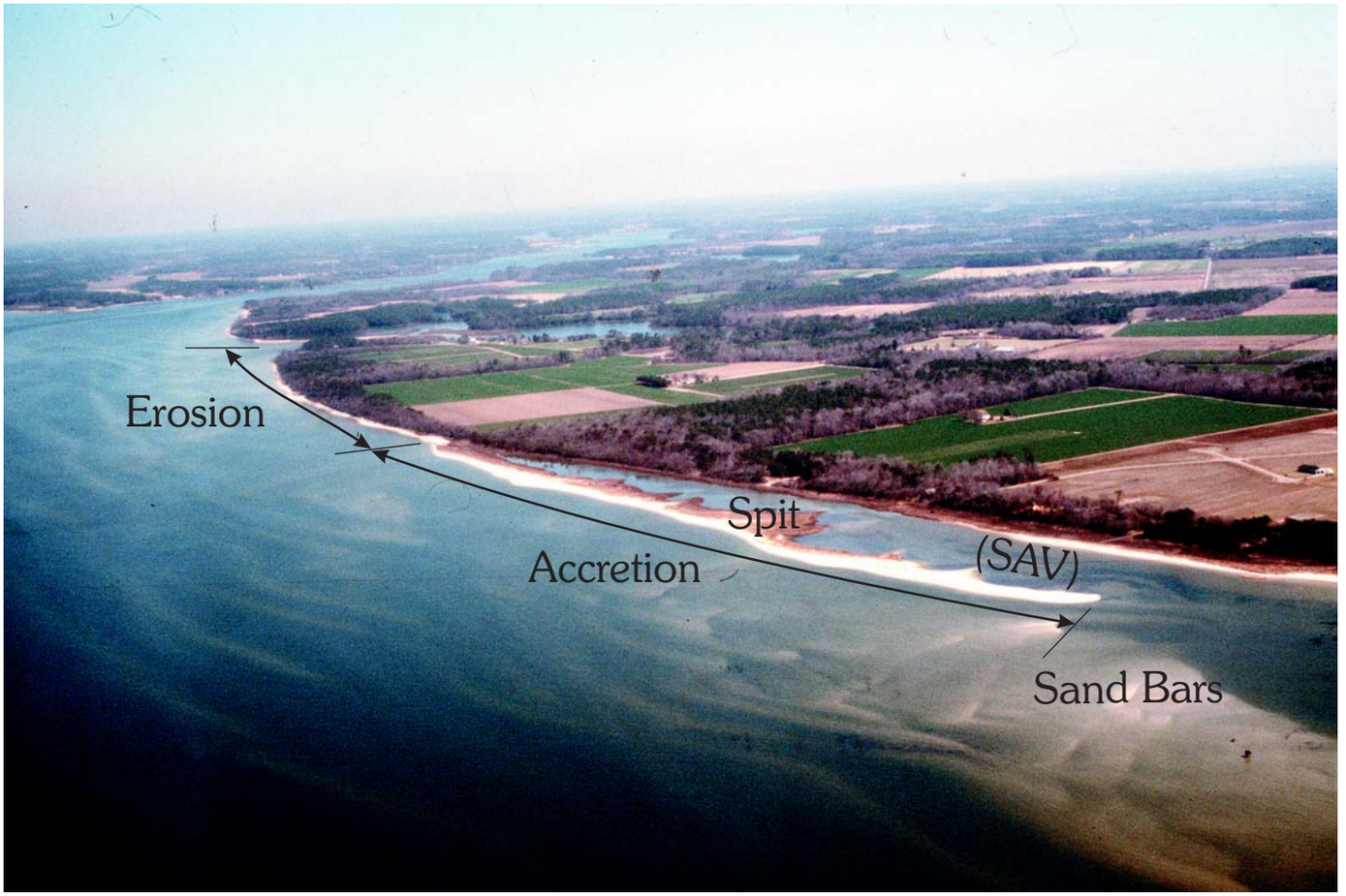


Figure 9

Erosion of sandy upland banks along the Eastern Shore provides significant sediment to create spits and offshore sand bars that protect the "mainland" from wave attack in addition to providing a haven for submerged aquatic vegetation.

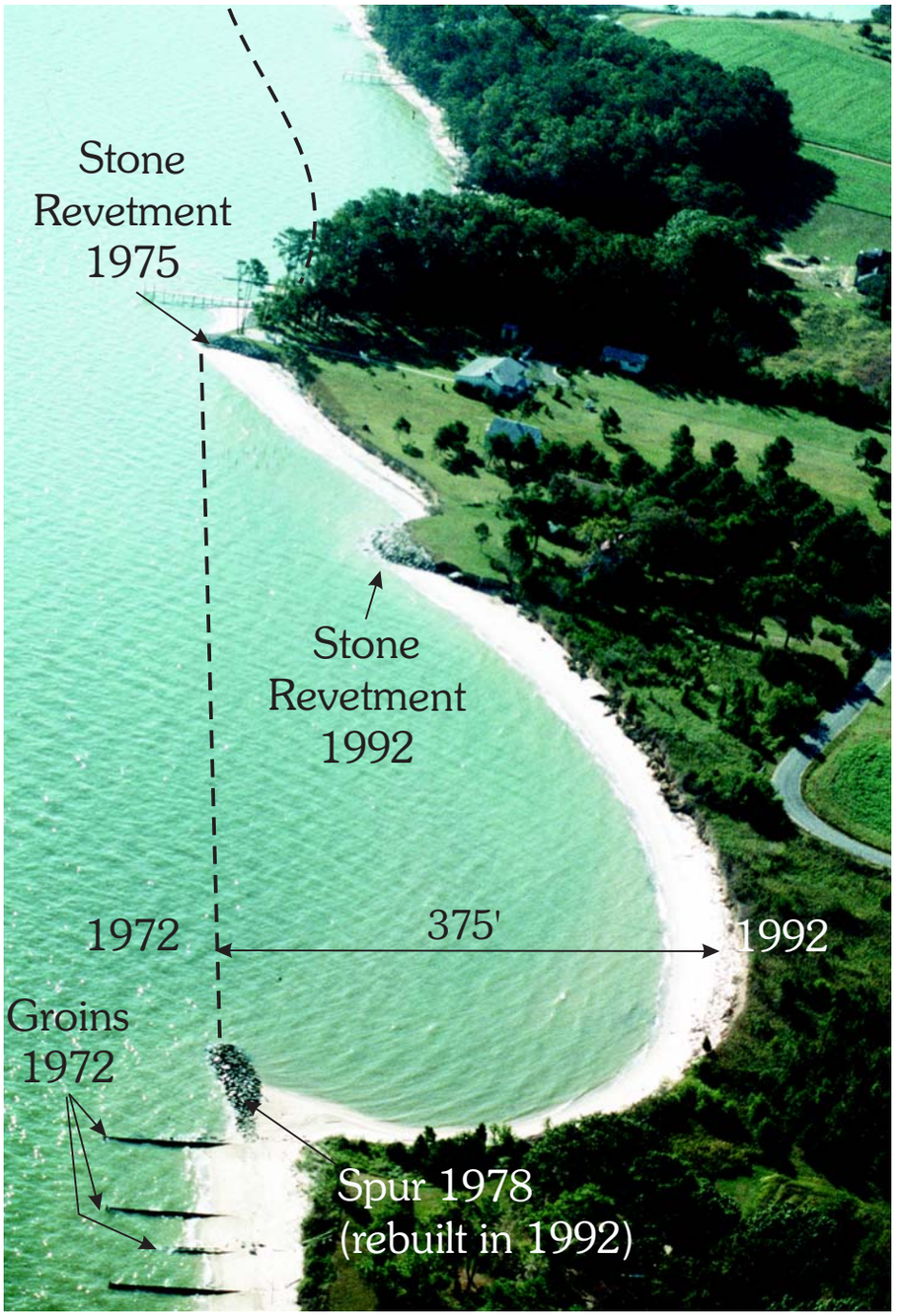
west side of Chesapeake Bay *(Figure 7)*, was formed about 2 million years ago during the Pleistocene epoch. An ancient beach feature formed during a high stand in sea level, the Suffolk Scarp is a distinguishing feature of Virginia's present coastline.

West of the Suffolk Scarp, the shoreline banks rise to heights of 25 to 50 feet. Other ancient shoreline scarps to the west, like the Surry Scarp, cause the land and shoreline banks to rise even higher (70 to 100 feet) as is the case with Nomini Cliffs in Westmoreland County *(Figure 8)*. East of the Suffolk Scarp, land elevations may be less than 5 feet above sea level. Here, extensive marshes occupy the lowland drainages and define the areas prone to tidal flooding. These areas include much of the bayfront shoreline in the cities of Norfolk, Hampton, and Poquoson, as well as York, Gloucester, Mathews, and Middlesex counties in Virginia.

Much of Maryland's lowland areas include bayfront shoreline in Somerset, Wicomico, Dorchester, Talbot, and Queen Anne's counties along the Eastern Shore. Calvert Cliffs are high bank features along the Chesapeake Bay in Calvert County, Maryland.

The Eastern Shore was created over thousands of years as sediments were successively deposited at the tip of the Delmarva Peninsula gradually extending it south many miles.

The bay side of the Eastern Shore has evolved in a manner similar to the western side of the bay. Large expanses of embayed tidal marsh occur in and around Pocomoke Sound (Va./Md.) and Eastern Bay (Md.). Further south along the bayside shoreline in Virginia, the land rises around Onancock Creek to expose eroding sandy upland banks. Eroding upland necks of the southern Eastern Shore provide large amounts of sediments to adjacent downdrift shorelines and supply sand for extensive offshore bar systems *(Figure 9)*. These bars and spits provide habitat for a wide expanse of submerged aquatic vegetation (SAV) beds.



Up to this point we have talked about shorelines primarily along the main stem of the Chesapeake Bay, but the system also includes many subestuaries known as tidal rivers and creeks. These are an integral part of the bay's flooded, dendritic watershed. Of varying size, these tidal rivers and creeks impact littoral processes and shoreline evolution in that they form shoal deposits due to flood and ebb currents. These shoals often restrict navigation, and thus dredging and/or jetties are needed to keep the channels open. Shorelines flanking creek

Figure 10
Shoreline evolution in Northumberland County, Va. Note: Groin field in foreground was upland in early 1970s. Spiral shaped embayment formed between the groin field built in 1972 and a revetment installed in 1975 such that the maximum offset was 375 feet by 1992.

entrances are directly affected by these measures—either by sand accretion or sand deprivation, which in turn affects shoreline erosion in that area.

Impacts of Development on Shoreline Erosion

The evolution of the Chesapeake Bay shoreline has also been influenced by residential and commercial development along the tidal shoreline. Commercial shoreline development in urban areas dates to post-colonial times, but up until World War II, most of these areas were used for agriculture or were simply managed as rural areas.

After World War II, with the advent of "leisure time," residential development along the shorelines of Chesapeake Bay began to increase. Cottage communities were established along upland areas with beachfronts. The increased development added pressure to upland banks that were already prone to erosion. Unfortunately this erosion generally went unnoticed until homes and improvements became threatened. If measures were used to protect shorelines, they usually consisted of inexpensive and unsightly means, such as dumping broken concrete, old cars, or tree stumps. With time, more substantial coastal structures were installed, and these projects began to alter the geomorphic patterns of the shoreline.

The impact of shoreline protection installations on the recent shoreline evolution process is two-fold. First of all, the eroding sediment banks that once provided sands for beaches, spits, and offshore bars no longer supply their "natural" input of sand. Secondly, protected segments of shoreline can remain essentially as hard points or headland features while adjacent unprotected properties continue to erode, sometimes at an accelerated rate *(Figure 10)*. In order to understand the processes of shoreline change, we must also understand the hydrodynamic processes—in other words, the way water and waves work on any given shore.

Shoreline Processes

Wave Climate

Wave climate refers to averaged wave conditions as they change throughout the year. As waves are generated by winds, wave climate reflects both seasonal winds as well as those caused by extreme storms. Wave climate is a good measure of potential shoreline change because on a daily basis shorelines erode minimally. As previously mentioned, pronounced erosion often occurs during high-energy storms, such as northeasters and hurricanes, when high winds blow across the bay and greatly increase wave conditions.

Seasonal wind patterns vary in the Chesapeake Bay region. From late fall to spring, the dominant wind directions are north and northwest. During the late spring, the dominant wind shifts to the southwest and continues so until the following fall. Northeast storms, which occur from late fall to early spring, are associated with eastward moving, low pressure areas. Often, there is a period of intense north to northwest wind after a storm front passes. Hurricanes, with sustained winds of at least 74 mph, occur from mid-summer to mid-fall. Although hurricanes generate higher winds and storm surge than northeast storms, their duration generally is shorter.

During storms, the rate of erosion at any location depends upon the following conditions (Riggs *et al.,* 1978):

1. Storm frequency
2. Storm type and direction
3. Storm intensity and duration
4. Storm surge, currents, and waves.

The wave climate of a particular shoreline along the Chesapeake Bay system depends upon several factors other than wind, including: fetch, shore orientation, shore type, and nearshore bathymetry.

Fetch is the distance of open water over which wind can blow and generate waves in an area. The greater the fetch, the greater the potential wave energy. Wave energy is measured by wave height and wave period (refer to Glossary). (Wave period is the time it takes successive waves to pass a fixed point).

Fetch can be used as a simple measure of relative wave energy. Hardaway *et al*. (1984) categorized wave energy acting on shorelines into three general categories based on average fetch exposure:

1. Low-energy shorelines have average fetch exposures of less than 1 nautical mile and often are found along tidal creeks and small tributary rivers.
2. Medium-energy shorelines typically occur along the main tributary estuaries; average fetch exposures of 1 to 5 nautical miles.
3. High-energy shorelines occur along the main stem of the bay and at the mouths of tributary estuaries; average fetch exposures of over 5 nautical miles.

Note, as fetch exposures of more than 20 nautical miles are common along the bay stem, it is also true that Chesapeake Bay

TABLE 1

AVERAGE SHORELINE EROSION RATES
TIDEWATER VIRGINIA

YORK RIVER

NORTH SIDE	EROSION RATES	AVERAGE
Gloucester Co.	- 0.5 ft/yr	- 0.4 ft/yr
King and Queen Co.	- 0.3 ft/yr	- 0.4 ft/yr
SOUTH SIDE	**EROSION RATES**	**AVERAGE**
York Co.	- 0.9 ft/yr	
James City Co.	- 1.8 ft/yr	- 1.2 ft/yr
New Kent Co.	- 0.9 ft/yr	

JAMES RIVER

NORTH SI DE	EROSION RATES	AVERAGE
Newport News	- 0.8 ft/yr	
James City	- 0.1 ft/yr	- 0.45 ft/yr
SOUTH SIDE	**EROSION RATES**	**AVERAGE**
Isle of Wight Co.	- 1.8 ft/yr	
Surry Co.	- 1.2 ft/yr	- 1 .5 ft/yr

RAPPAHANNOCK RIVER

NORTH SIDE	EROSION RATES	AVERAGE
Lancaster Co.	- 0.6 ft/yr	
Richmond Co.	- 0.6 ft/yr	- 0.6 ft/yr
SOUTH SIDE	**EROSION RATES**	**AVERAGE**
Middlesex Co.	- 1.0 ft/yr	
Essex Co.	- 1.2 ft/yr	- 1.1 ft/yr

CHESAPEAKE BAY

WESTERN SHORE	EROSION RATES	AVERAGE
Gloucester Co.	- 0.6 ft/yr	
Hampton	- 1.0 ft/yr	
Lancaster Co.	- 1.4 ft/yr	
Mathews Co.	- 0.8 ft/yr	
Northumberland Co.	- 1.0 ft/yr	
York Co.	- 1.5 ft/yr	- 0.9 ft/yr
EASTERN SHORE	**EROSION RATES**	**AVERAGE**
Accomack Co.	- 1.5 ft/yr	
Northampton Co.	- 0.7 ft/yr	
Fisherman's Is.	+ 11 ft/yr	- 1.0 ft/yr*
SOUTHERN SHORE	**EROSION RATES**	**AVERAGE**
Virginia Beach	- 1.7 ft/yr	
Norfolk	- 1.2 ft/yr	
Nansemond	- 1.2 ft/yr	- 1.4 ft/yr

*Does not factor in Fisherman's Island.

After Hardaway and Anderson, 1980.

is susceptible to a high degree of shoreline erosion. Figure 11 illustrates how to estimate average fetch exposure.

Generally the wind/wave window is 90°, measured 45° on either side of the shore strike (a line drawn perpendicular to the orientation of the shore). There is often a long fetch component up- or down-river that will significantly influence the wave climate at a particular shore.

Hardaway and Anderson (1980) noted that the southern sides of Virginia's major tributary estuaries (James, York, and Rappahannock rivers) are eroding at a rate more than twice that of the northern sides of these rivers *(Table 1)*. The reason is that southern shores are exposed to the northwest, north, and northeast directions from which the most severe seasonal winds originate.

Shore type and substrate composition also affect the rate of shoreline erosion. Upland banks, composed of light clay or well-cemented sand or marl, resist erosion better than soft clays or unconsolidated sands. Hardaway (1980) found that low, upland banks erode almost twice as fast as marsh shorelines with similar fetch exposures and nearshore depths.

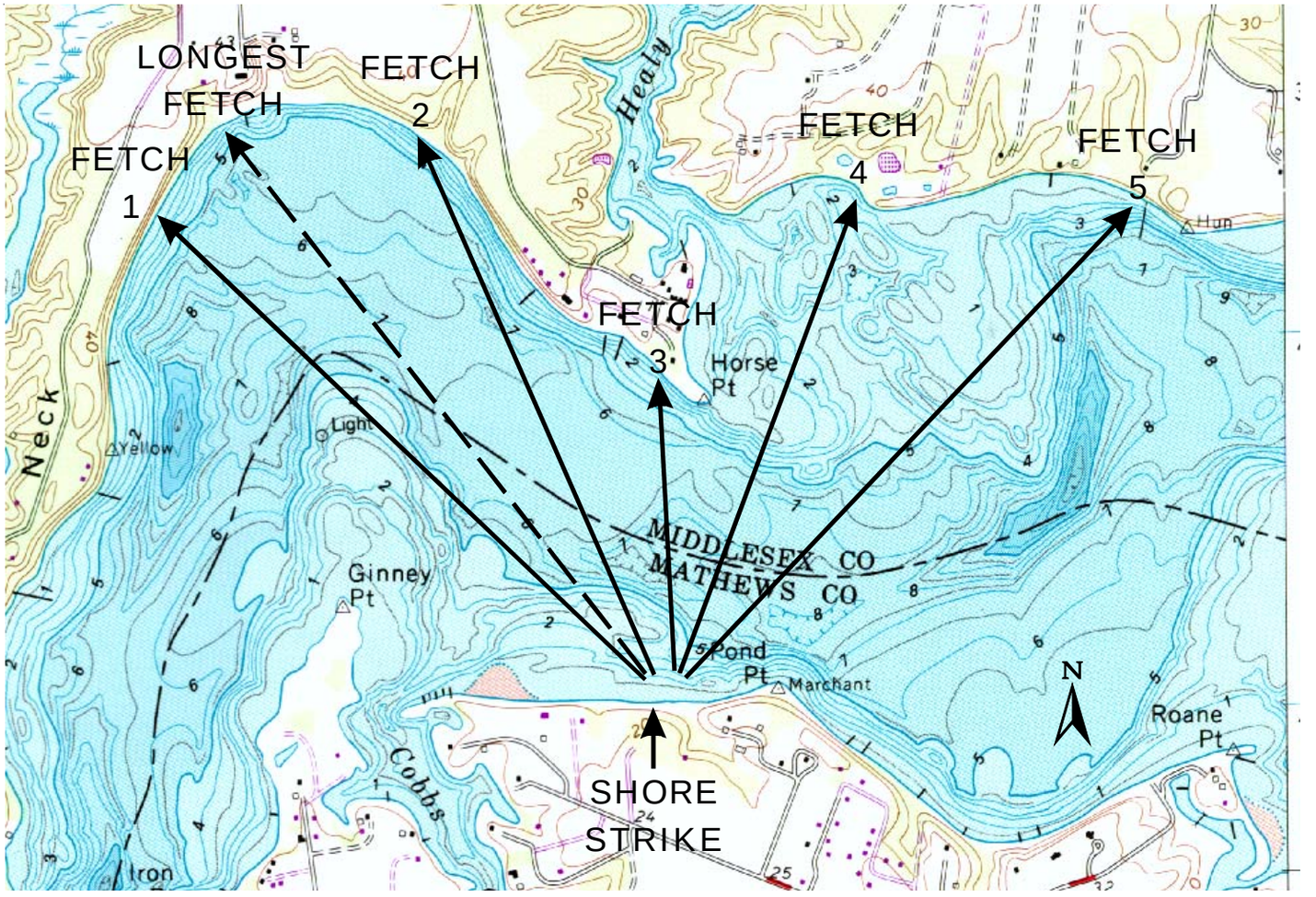


Figure 11

Measured parameters include average fetch (AF=F1+F2+F3+F4+F5/5), and longest fetch. Also shown is shore strike from which the wind/wave window for fetch and shore orientation are established (After Hardaway et al. 1992). Shore orientation in this case is about due north.

Shallow nearshore regions, such as tidal flats and sand bars, reduce incoming wave energy better than deeper waters which allow a greater portion of wave energy to reach the shore. Wide beds of submerged aquatic vegetation (SAV) reduce wave height—thus wave energy—as they approach a shoreline.

Storm surge, as has been mentioned, is a critical element in assessing the impact of local wave climate on shoreline erosion. In the lower Chesapeake Bay, storm surges for 10-year, 25-year, 50-year, and 100-year recurrence intervals are estimated at 4.5 feet, 4.8 feet, 5.5 feet, and 6.1 feet above mean sea level (Boon *et al.,* 1978). Storm surge estimates for other Bay regions are shown in Table 2. Table 3 lists significant storm events in the last 100 years and their associated storm surge maximums.

According to Basco and Shin (1993), during moderate northeast storms (which occur about every two years) sustained winds of 30 to 40 mph can generate waves with heights of 5 to 7 feet in the Bay (high energy waves), 2 to 5 feet in the main tributary estuaries (medium energy), and about 1 foot in small tidal creeks (low energy).

TABLE 2.
Height Frequency Levels of Total Tide at Selected Chesapeake Bay Stations

Western Shore Stations				
Station	Annual Frequency			
	10 Yr.	50 Yr.	100 Yr.	500 Yr.
Havre De Grace, Md.	5.3	9.6	11.5	14.6
Baltimore, Md.	4.1	6.8	8.1	10.7
Annapolis, Md.	4.0	6.2	7.2	9.4
Chesapeake Beach, Md.	3.5	5.2	6.1	7.9
Cove Point, Md.	3.4	4.5	5.2	6.6
Solomon's Island, Md.	3.4	4.8	5.5	7.0
Cornfield Harbor, Md.	3.2	4.2	4.6	5.8
Windmill Point, Va.	3.2	3.7	3.9	4.4
Gloucester Point, Va.	3.2	3.7	3.9	4.4

*Heights in feet above NGVD.**

**National Geodetic Vertical Datum*

Eastern Shore Stations				
Station	Annual Frequency			
	10 Yr.	50 Yr.	100 Yr.	500 Yr.
Betterton, Md.	5.1	8.7	10.5	13.4
Tolchester, Md.	4.3	7.2	8.7	11.5
Love Point, Md.	4.3	6.4	7.4	9.7
Matapeake, Md.	4.2	6.2	7.2	9.2
Cambridge, Md.	3.9	5.1	5.9	7.5
Hoopers Island, Md.	3.5	4.7	5.3	6.6
Chance, Md.	4.2	5.4	5.8	6.8
Crisfield, Md.	3.9	4.8	5.1	6.1
Guard Shores, Va.	4.2	5.6	6.3	7.8
Gaskins Point, Va.	3.5	4.0	4.2	4.6
Eastville, Va.	3.6	4.1	4.4	4.9
Kiptopeke Beach, Va.	4.1	4.8	5.2	6.2

TABLE 3
Significant Storm Surges in Chesapeake Bay During the 20th Century.

Date	Event	Location	Storm Surge (ft)
04 Aug 1915	Hurricane	Baltimore	4.5
24 Oct 1923	Hurricane	Baltimore	3.0
29 Sep 1924	Hurricane	Baltimore	2.4
19 Sep 1928	Hurricane	Baltimore	4.2
		Hampton Roads	4.8
23 Aug 1933	Hurricane	Baltimore	7.3
		Hampton Roads	7.5
16 Sep 1933	Hurricane	Hampton Roads	5.6
18 Sep 1936	Hurricane	Hampton Roads	6.2
05 Oct 1948	Extratropical	Hampton Roads	4.9
16 Oct 1954	Tropical Storm Hazel	Baltimore	4.8
13 Aug 1955	Hurricane Connie	Baltimore	6.0
18 Aug 1955	Hurricane Diane	Baltimore	3.1
13 Apr 1956	Extratropical	Hampton Roads	4.1
27 Sep 1956	Tropical Depression Flossy	Hampton Roads	5.4
06 Oct 1957	Extratropical	Hampton Roads	5.1
30 Jul 1960	Tropical Storm Brenda	Solomon's Island	2.2
12 Sep 1960	Hurricane Donna	Hampton Roads	5.5
08 Mar 1962	Ash Wednesday Storm	Annapolis	3.6
		Hampton Roads	6.7
23 Jun 1972	Tropical Storm Agnes	Baltimore	2.1
31 Oct 1991	Halloween Extratropical	Hampton Roads	2.9
10 Dec 1992	Extratropical	Baltimore	2.6

From U.S. Army Corps of Engineers, Norfolk District, Baltimore District, and NOAA.

Shoreline Erosion

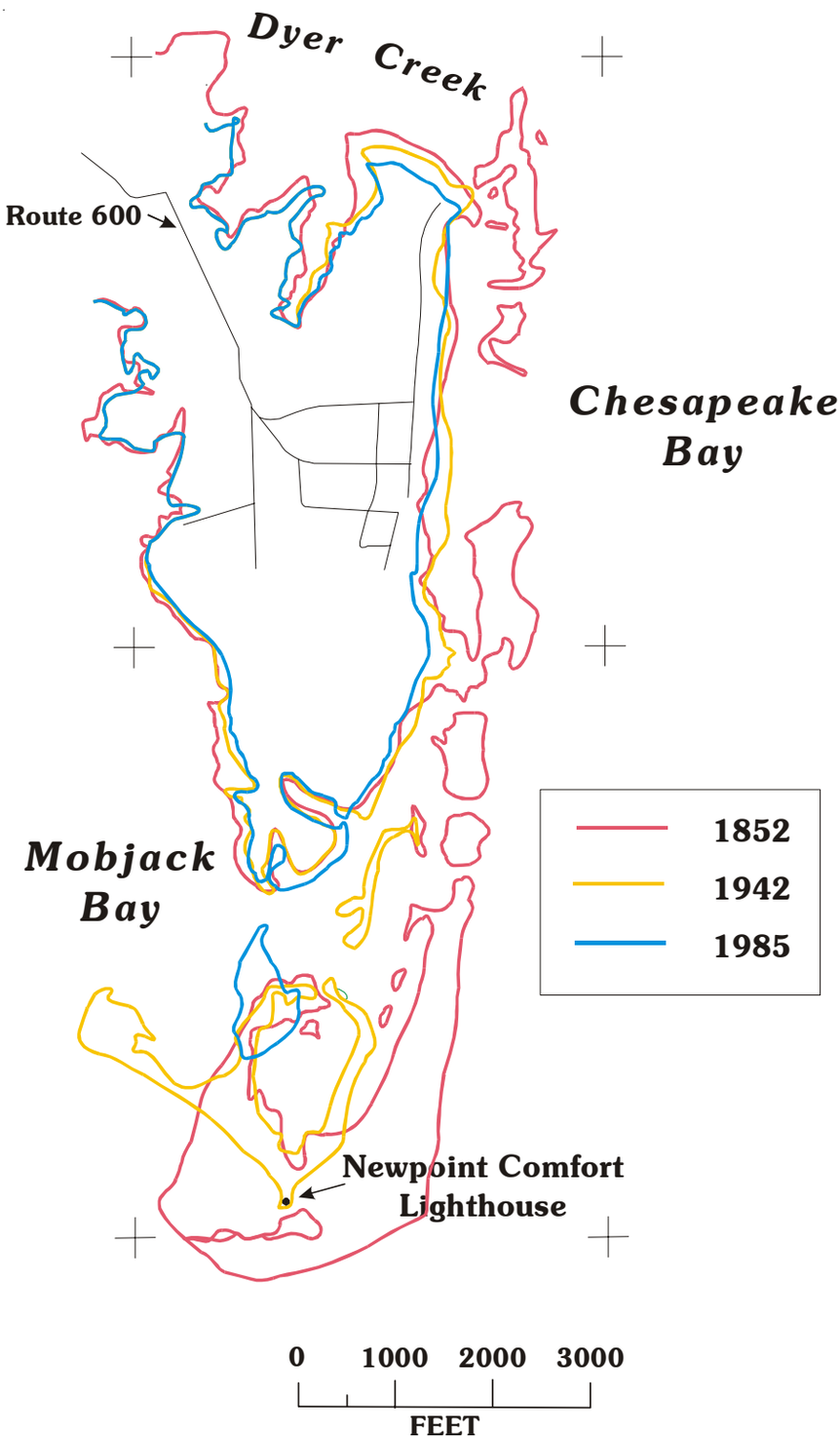


Figure 12
Historic shoreline change in southeast Mathews County, Va. (VIMS Shoreline Studies, G. Thomas-Cartographer)

The tidal shoreline of the Chesapeake Bay extends for about 9,000 miles, and is roughly evenly divided between Maryland and Virginia. During the period 1850-1950 assessments indicated a loss of about 47,000 acres of land along this shoreline due to erosion (22,000 acres in Virginia; 25,000 acres in Maryland) (Byrne and Anderson, 1978; Singewald and Slaughter, 1949; U.S. Army Corps of Engineers, 1973). Most of this erosion occurred along less than 1,000 miles of the shoreline, along the main stem of the Chesapeake Bay. Figure 12 shows how a bay shoreline in southeast Mathews County, Va., has evolved. The 1852 shoreline includes the marsh islands in the Chesapeake Bay; notice the extent of New Point Comfort at that time.

Taking into account the role that fetch, storm surge, and other factors play in long-term trends of shoreline erosion, there are also some shore types that are more susceptible to erosion than others.

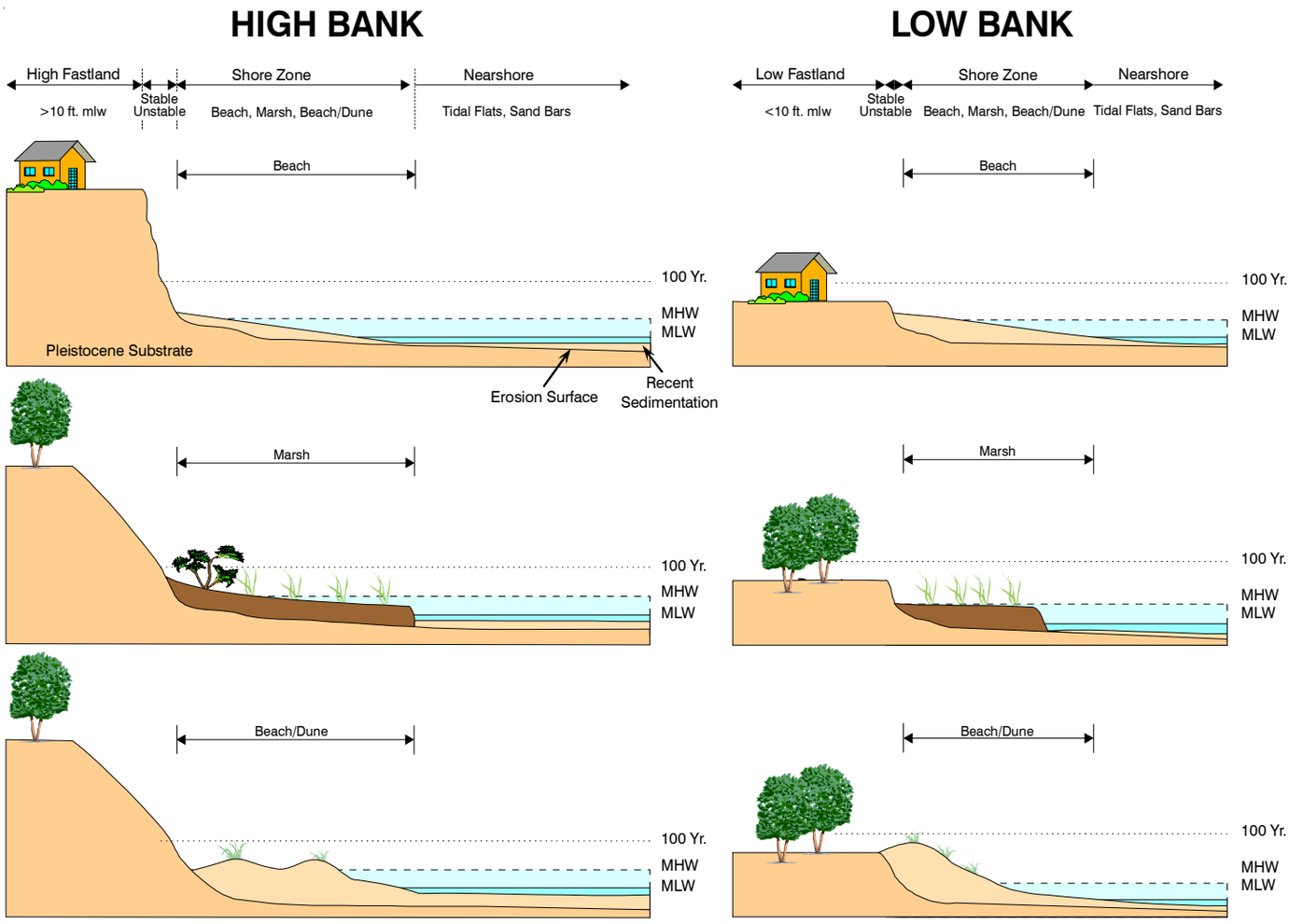


Figure 13

Six typical shoreline profiles around Chesapeake Bay. The stability of the bank face is dependent upon the width and type of shore zone features. Wide beaches/dunes and marsh zones can offer significant wave protection even during storms. (Mean high water (MHW), mean low water (MLW), and 100-year storm surge elevation.)

The tidal shorelines of the Chesapeake Bay can be classified into six basic types *(Figure 13)* depending on the height of the upland banks.

A high bank, for our purposes, is defined as any upland elevation greater than 10 feet above mean low water and a low bank is 10 feet or less above mean low water. The rationale for this is that low upland regions will be susceptible to potential frequent flooding, whereas high banks will not. On low banks, waves may attack landward, flooding the top of the bank and directly threatening property improvements, such as houses and roads. Property improvements on high banks will not be impacted directly by storm surge or wave action. However, if the improvements are near the edge of a high bank, bank erosion and slumping from wave undercutting could threaten structures.

The six basic shore settings also take into account different shore zone features which vary in type and width. These differences, in turn, determine the bank face stability and the potential need to protect the bank from erosion.

Wide fringing marshes, beaches and dunes reduce the effects of wave action during storms such that adjacent upland banks may only be impacted by the most severe events or not at all (i.e., 100-year storm). Narrow shore zone features allow waves to more frequently impact upland banks, thus causing chronic instability and continual erosion.

Various combinations of these six situations may occur adjacent to each other. Moreover, actions taken on adjacent shore segments may impact sand supply to neighboring shore segments.

Along low bank shorelines, where storm surges frequently flood the uplands, building shoreline protection structures to completely stop upland wave attack on property improvements generally is not feasible. However, placing a shore protection system that will withstand the waves and storm surge as well as remain intact after a severe storm is quite feasible. These factors must be considered in the design phase of any shoreline management strategy. In choosing a strategy, consider also the long- and short-term impacts of a "no-action" management approach.



Yorktown waterfront adjacent to Cornwallis's Cave during a Northeaster, October 22, 1985.

Reach Assessment

Before any shoreline strategy is planned, the site should be evaluated within the context of the "reach." A "reach" is defined as a segment of shoreline where the erosion processes and responses mutually interact. For example, very little sand is transported by wave action beyond a major headland, creek mouth, tidal inlet, or major change in shoreline orientation. Keep in mind, several properties may be contained along a reach.

It may not be possible for all property owners to have their sites assessed, but knowing the basic elements that go into an evaluation should be helpful. Reach assessments involve six principal points:

1. Determine the reach limits in which the site is located.
2. Determine the historical rates and patterns of erosion and accretion for the reach. Identify shore types (upland banks, marsh, etc.) and impacts to shoreline processes and evolution.
3. Determine within the reach which sites supply sand and the volume of that supply for incremental erosion distances. Often, within a reach, there are subreaches that interact with each other. These subreaches either supply sediment to other subreaches (erosion), transport sediment from one subreach to the next, or are subreaches where sediments accumulate (accretion). A reach may feature all three types of subreaches.
4. Determine wave climate and the direction of net littoral sand drift.
5. Identify the factors causing erosion (other than waves). These may include groundwater, surface runoff, or other processes.
6. Estimate potential and active sources of nutrient loading (i.e., farmland, commercial, or residential land), and the means by which this occurs, such as surface runoff, eroding sediments, and/or groundwater discharge. Nutrients don't impact erosion, but they do impact water quality. Adding breakwaters, revetments, or other shoreline erosion treatments, inevitably change water discharge patterns and thus the overall coastal water quality. In order to minimize water quality problems, shoreline erosion strategies can and should be designed so that nutrients don't adversely impact water quality or are actually treated by the strategy.

Understanding the size of the reach and those factors which influence it gives property owners a sense of the spatial parameters within which to address shoreline erosion—it puts the problem into context.

Management Strategies

Bulkheads and Seawalls

Bulkheads, revetments, and groins are the most common protection strategies currently employed. In 1985, of the approximately 400 miles of eroding upland shorelines along the Virginia side of the bay's main stem and major tributaries, about 58 miles of shoreline were defended by bulkheads or revetments and about 18 miles had groins and groin fields. By 1990, defended (bulkheads and revetments) shorelines had increased 13 miles (22%) to cover 71 miles of eroding upland shorelines. Groins increased to a total of 26 miles by 1990 for that 400 miles of upland estuarine shore in Virginia (Hardaway *et al.*, 1992)

Vertical wooden bulkheads and concrete "seawalls" were installed to protect shorelines in the 1950s, 1960s, and 1970s following the post-World War II increase in bayshore second homes. As more people developed summer retreats, they also had to invest in structures to protect their cabins and beaches. They chose shoreline protection strategies that were primarily "defensive" structures, built as a last line of defense against impinging waves *(Figures 14A & 14C)*. Some of these structures still remain and are, to some degree, intact. However, most that were built along the bay



Figure 14A *Bulkhead and graded bank.*

Figure 14B

Results of "short sheeting" and flanking resulting in loss of backfill in bulkhead construction. This particular structure was less than 2 months old.



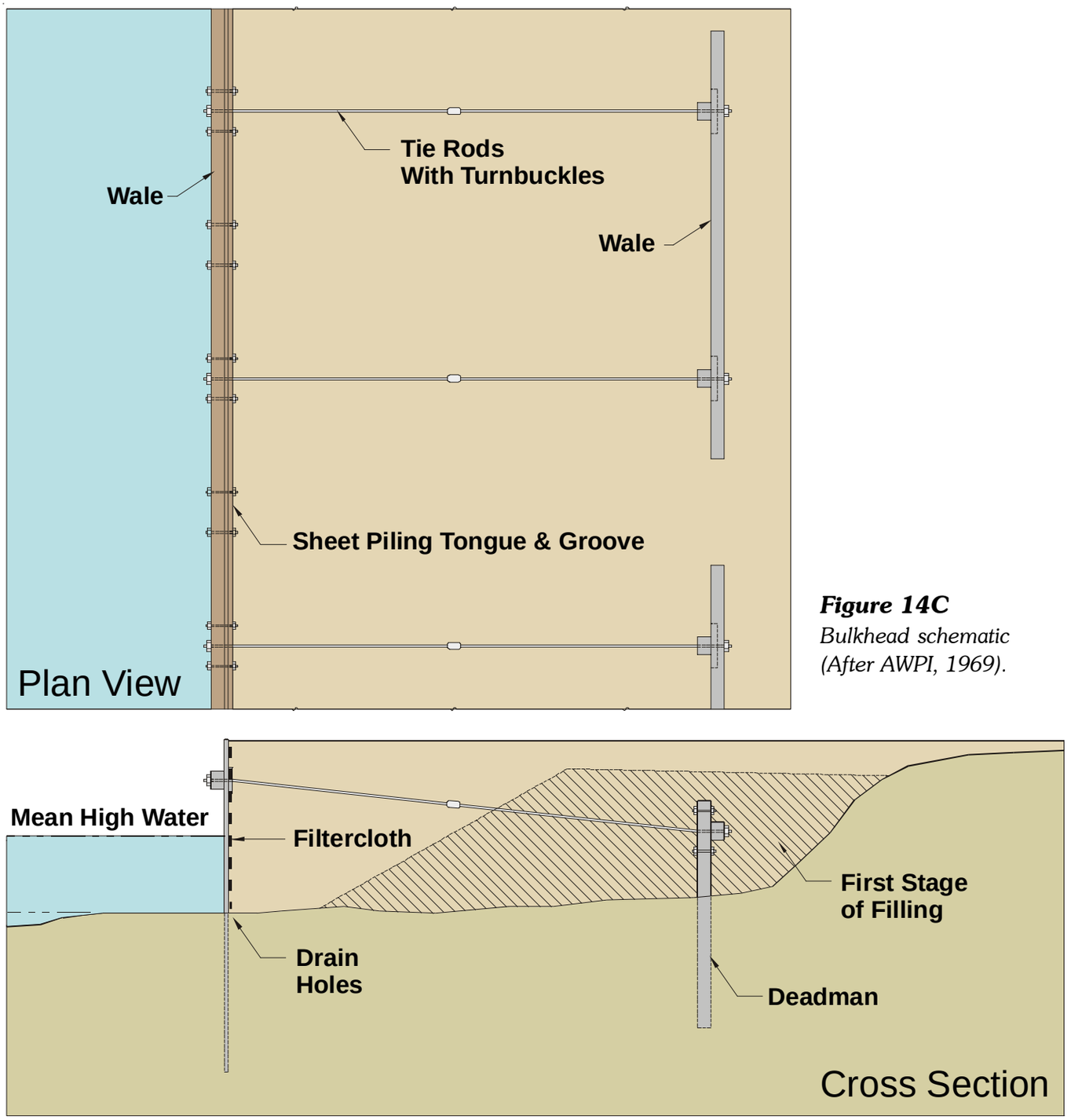


Figure 14C
Bulkhead schematic (After AWPI, 1969).

stem and major tributary estuaries have deteriorated, have been rebuilt, or have been replaced by rock structures. However, wooden bulkheads are still employed extensively today; the craftsmanship and wood preservation methods have improved since the late 1970s. Assuming that quality materials and high concentrations of wood preservatives are used, property owners can expect such a structure to last twenty years.

Bulkhead and seawall are two terms often used to denote the same type of shoreline protection structure. However, there is a significant difference: bulkheads are generally smaller and less expensive than seawalls. Bulkheads are usually made of wood. They are designed to retain upland soils and often provide minimal

protection from severe wave action. Seawalls are generally made of poured concrete and are designed to withstand the full force of waves (U.S. Army Corps of Engineers, 1984).

When using vertical structures, such as bulkheads and seawalls, be cognizant of impinging wave action. Structures with sloping faces dissipate wave energy. By contrast, vertical faces reflect wave energy and cause currents to scour out the substrate at the toe of the structure. The depth of potential scour should be included in the structure design; otherwise, the structure could be undermined by wave action and collapse.

Problems occur when the sheeting is not long enough or not driven into the ground deep enough to withstand bottom scour and flooding by waves. Figure 14B depicts the results of "short sheeting" on the Potomac River where sheet piles were too short for site conditions. Providing weep or drain holes in the face of the structure allows hydrostatic pressures (water force from the land side from groundwater or water trapped due to storm surge) to be released. Figure 15B shows a similar seawall situation with massive failure due to hydrostatic loading of water trapped behind the structure.

The vertical face of concrete seawalls and bulkheads causes a high degree of wave reflection which may prevent sand from residing on the water side. Figure 15A shows a concrete seawall with groins in place for 20 years. In this case, the high reflectivity of the seawall prevented the groins from trapping sufficient sand to maintain a beach at high tide.



Figure 15A (top)
Concrete seawall on James River in Newport News, Va.

Figure 15B (bottom)
Concrete seawall failure due to hydrostatic loading.



Revetments

Rock (sometimes known as riprap) revetments became more widely used in the late 1970s, 1980s, and 1990s. Today, a properly designed and constructed rock revetment can last fifty years or more. The stone, itself, could last indefinitely. Stone revetments feature sloped and roughed faces that decrease wave reflection and associated bottom scour. Bottom scour that causes increased depths can threaten the long-term integrity of any shoreline protection system—structures should be properly designed and installed.

Figures 16A & 16B show an example and a typical design cross-section of a stone revetment placed along a high bank. Revetments need to be high enough to withstand waves that may break over the top of the structure in extreme conditions. Banks usually need to be graded in order to obtain a stable slope. Armor stone must be good quality and proper size in order to support the size structure needed for a given shoreline. Armor made of



Figure 16A

Stone revetment shortly after construction on the Potomac River, Va.

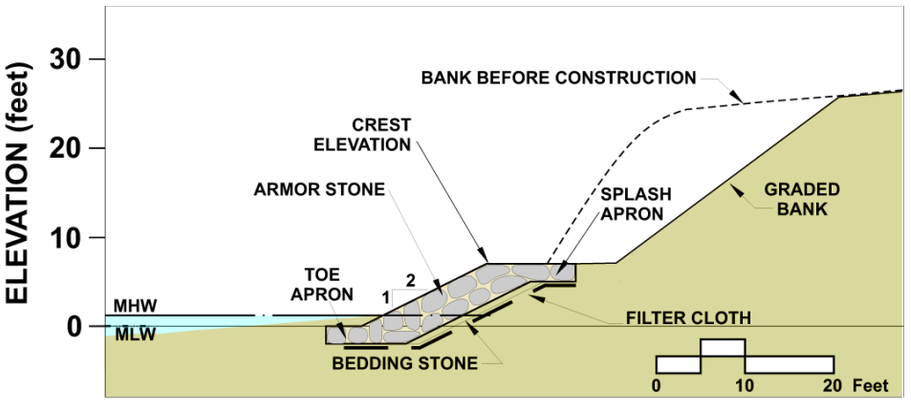


Figure 16B.

Cross-section of elements necessary for proper stone revetment design. There are usually two layers of armor stone over a bedding stone layer with filter cloth between the earth subgrade and bedding layer. Armor size is dependent on the design wave height which is determined from an analysis of wave climate for each project site.

precast concrete may be used, but these are specialized devices with limited applications, and their consideration is beyond the scope of this report.

Problems can occur when the armor stone is undersized, placed in only one layer, or on too steep a slope. Figures 17A and 17B illustrate how such design flaws can result in total structural failure of a revetment.

Along eroding marsh peat shorelines, low revetments can be installed. These are known as marsh toe revetments; they require special attention to potentially soft peat foundation conditions where settling might occur. Laying filter cloth under such structures is a highly recommended way of preventing differential settling.

Figure 17A (top)
Stone revetment built with only one layer of undersized armor stone on too steep a slope.

Figure 17B (bottom)
Failure of above structure after a modest storm event.





Groins

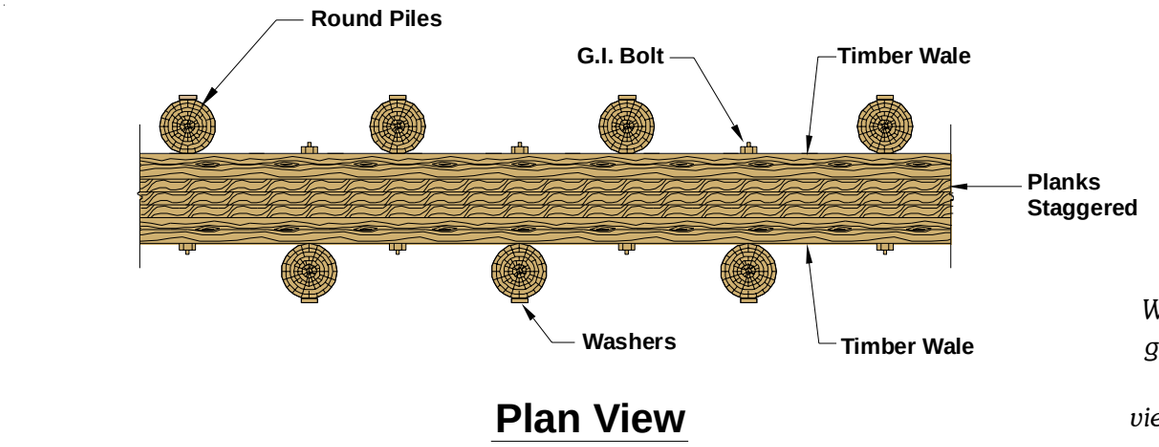


Figure 18
Wood bulkhead and groin: typical cross-sections and plan views (after USACE, 1984).

Between the 1950s and 1980s, groins were a popular way to trap sand and build a modest beach area. Traditionally these structures are constructed of wood *(Figure 18)*. When used with or without a bulkhead or "seawall," groin and groin fields (the space between groins) can cause significant impacts to adjacent unprotected shorelines.

On the positive side, a relatively wide sand beach tends to accrete on the updrift side of groins. If enough sand were available, the shoreline banks would gain some degree of protection *(Figure 19A)*. On the negative side, the sand build-up might prevent sand from reaching downdrift shores,

thereby decreasing beach widths and increasing the potential for shoreline erosion in these areas *(Figure 19B)*. Counting on a long-term, "endless" supply of sand is unwise; if a property owner installs an erosion mitigation structure updrift of your site, you may see your supply of sand—and thus your beach—greatly reduced. Groins may not be appropriate in areas with little or no sand supply, and if utilized, accompanying beach nourishment is recommended.

Even at sites with appreciable littoral sand supply, there is often an impact at the downdrift terminal groin. Wave diffraction at the groin tip "wraps" wave fronts around the the structure causing waves to break nearly parallel to the beach *(Figure 20A)*. When this happens, the bank may recede and adjacent downdrift shorelines may erode. If the problem is allowed to continue, the terminal groin may separate from the bank, causing sand to leak and the groin field to fail.

One way to combat this problem is with spurs. Spurs placed on the downdrift side of a groin parallel to the shore to help prevent flanking *(Figure 20B)*. They redirect incoming waves to allow a sheltered area in the lee and promote the accumulation of sand.

Groins are a popular strategy, and they function best if they are used in combination with sand beach fill. But remember, it is the beach that protects the adjacent upland banks, not the groins.





Figure 19A (top)
Groin field on Rappahannock River, Va., with adequate sand supply to provide a protective beach zone to upland property.

Figure 19B (bottom)
Inadequate sand supply along shore reach. The topmost groin acts as a littoral barrier.

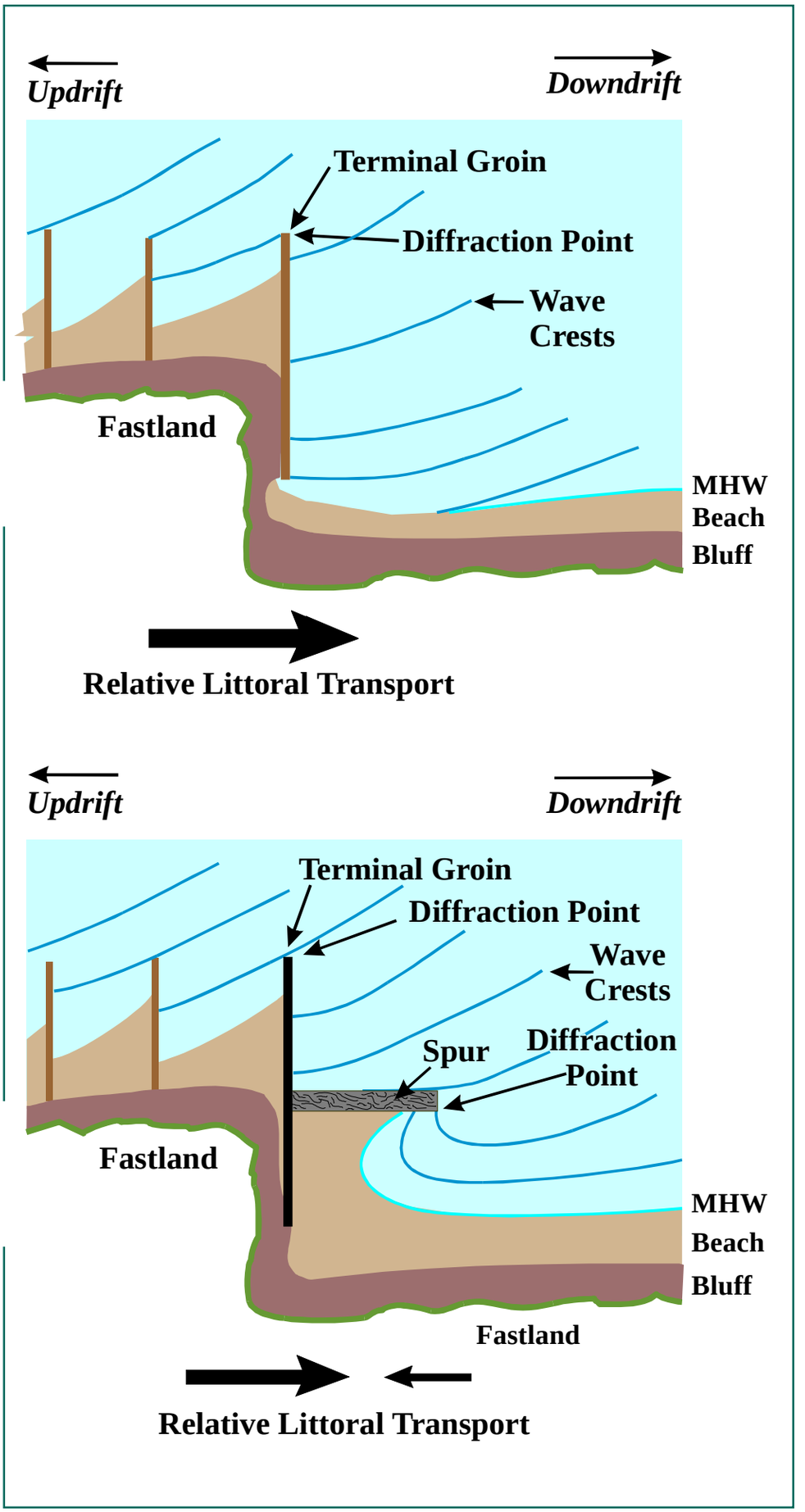


Figure 20A (top)
Groin field depicting downdrift offset and direction of wave approach (After Anderson et al., 1983).

Figure 20B (bottom)
Groin field with spur addition on downdrift side of terminal groin (After Anderson et al., 1983).

Breakwaters and Sills

Breakwaters

Offshore breakwaters are used to control shoreline erosion by maintaining a wide, protective beach. Their popularity has increased significantly over the past decade. Research on the subject supports the use of this stretegy (Hardaway *et al*, 1991; Hardaway and Gunn, 1998).

Breakwaters are considered offensive structures (as opposed to defensive structures such as revetments and bulkheads) because they address the impinging wave climate before it reaches upland properties. The breakwater, as the name implies, "breaks" the force of the waves and dissipates the energy so the waves do not erode the beach or upland banks. Unlike groins and groin fields, in which the structure is merely a vessel for sand which actually does the work of protecting against erosion, breakwaters themselves reduce erosion to the beach or uplands.

Breakwater systems—which usually include beach nourishment—are designed to create stable beaches and allow various species of marsh grasses to be established at the site (*Figures 21A & 21B*). Marsh grasses are additional insurance against erosion. Also, while a breakwater will initially cover a section of the nearshore bottom, the protection the breakwater affords will ultimately create and perserve extensive intertidal and marsh habitat.

As with groins and other shoreline structures, breakwaters must be designed with the potential impacts to the adjacent shoreline in mind. Breakwater systems can be misused by being built smaller than is needed for the shoreline's wave

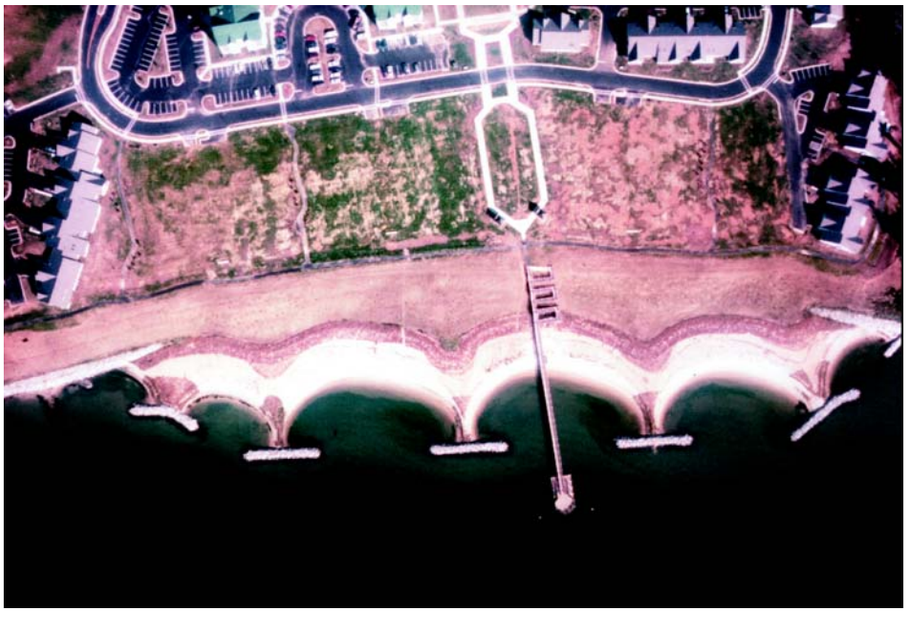


Figure 21A (top)
Breakwater system on Patuxent River in Calvert County, Md.

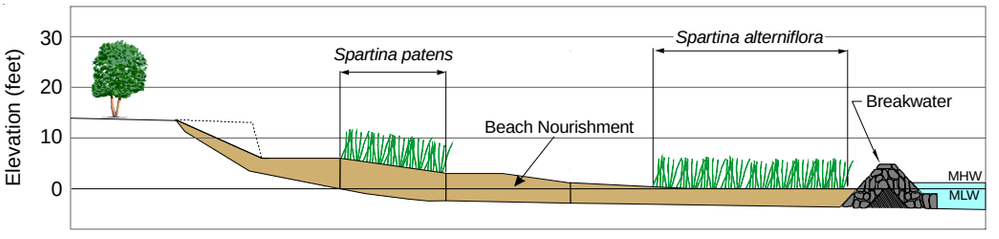


Figure 21B (bottom)
Typical breakwater cross-section.

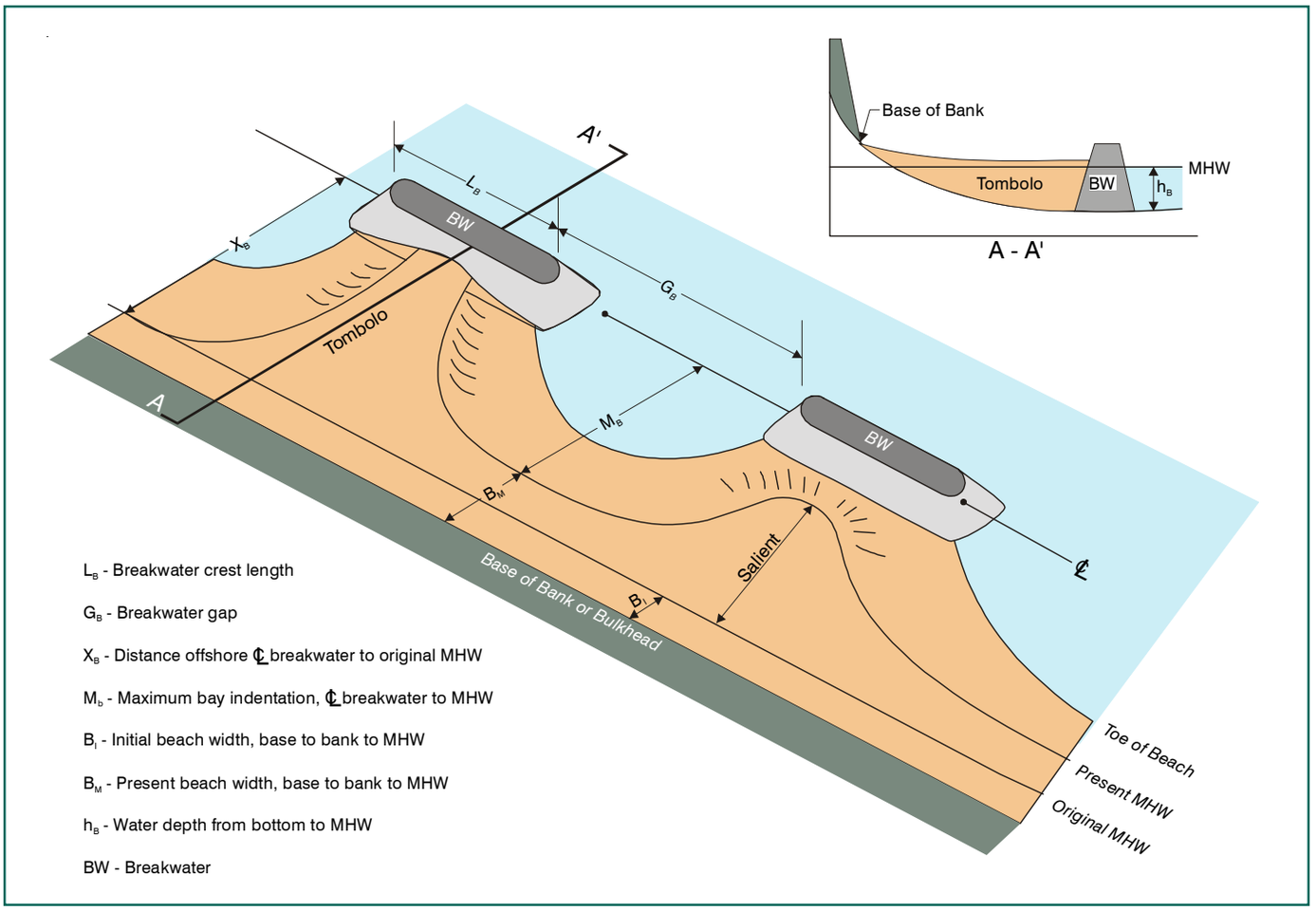


Figure 22 *Breakwater design parameters (After Suh, 1987).*

climate. Breakwater systems must be designed by a competent shoreline professional or contractor with considerable experience in this shore management application.

Figure 22 shows design elements for a typical breakwater system. Primary parameters are breakwater length (L_B), distance offshore (X_B), the gap between breakwater units (G_B) and the maximum embayment indentation distance (M_b). These parameters revolve around the minimum beach width (B_m) required for shoreline protection. In general, a B_m width of 40 to 60 feet is necessary for minimum bay shoreline protection. Hardaway *et al.* (1991) found the ratio for a stable embayed shore planform is a M_b:G_B ratio of 1:1.65.

Sills

Sills combine elements of rock revetments and offshore breakwaters. Rock sills generally have a "free standing" trapezoidal cross-section similar to breakwaters. However, they are usually smaller than breakwaters; they are built relatively close to shore, and are usually continuous *(Figure 23A)*. Typically, beach fill is needed to supplement the backshore so a marsh fringe can be established in the lee of the sill. Sills can be used in higher wave energy regimens to establish intertidal marsh grasses. Once again, potential impacts to adjacent shorelines must be considered. Figures 23B & 23C show a curvilinear sill, connected to breakwaters with marsh grass planted behind, soon after construction and five years later.



Figure 23A
Stone sill with marsh planting on Chester River, Kent County, Md.

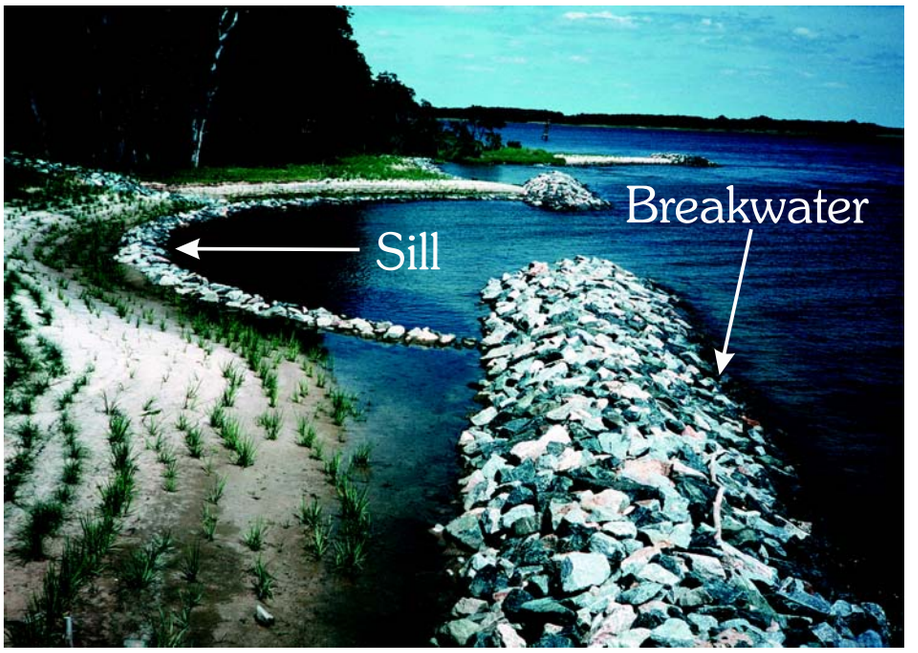


Figure 23B
Stone sill connecting breakwaters with sand fill and marsh implantation on Choptank River, Talbot County, Md.



Figure 23C
Breakwater and sill project after 5 years.

Beach Nourishment

Throughout this discussion of shore protection methods, there are many references to accompanying beach nourishment as a component of the overall strategy. In some cases, beach nourishment provides a jump start for anticipated reduction in sand supply from adjacent shore segments. In other cases, constructing an artificial beach is intrinsic to the plan, such as in cases where shoreline protection structures are intended to maintain a beach regardless of sand supply from nearby sources.

Beach nourishment, as a sole method of shoreline erosion control, is generally employed in situations where the desire for a public beach coincides with a need to protect fastland. In cases where there is a nearby source of sand, beach nourishment may be the most cost-effective protection strategy. Beach nourished shorelines typically need to be replenished with additional sand in order to maintain an adequate beach width. This topic is exhaustively treated in a report by the National Research Council (1995).

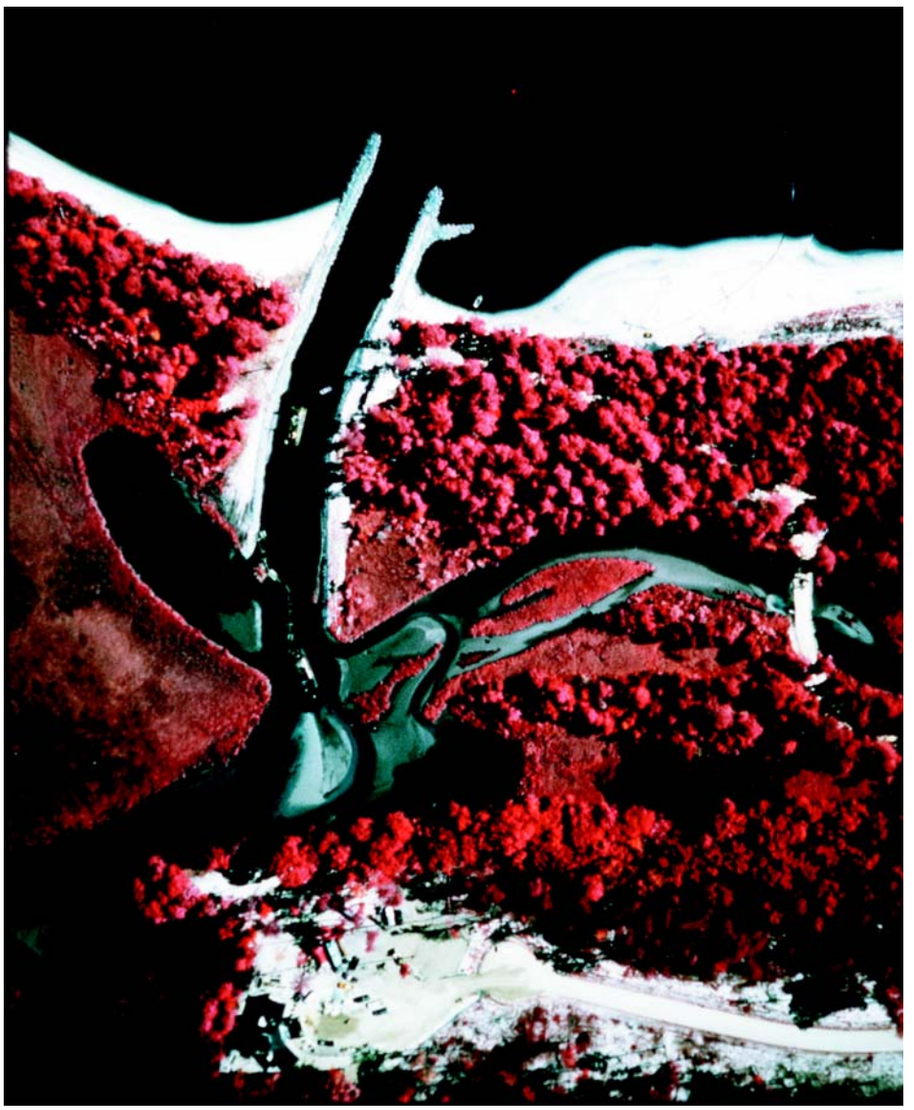


Figure 24
Cabin Point Creek, Westmoreland County, Va. New inlet established in 1981, with jetties to stabilize inlet channel. Spur and dredged channel sands placed downdrift (right side of inlet) permit sediment bypass and erosion control.

Current policy in Virginia and Maryland assigns beach nourishment as a priority mode of disposal for sand dredged from navigation channels, maintenance, or construction (*Figure 24*). Cost factors can limit this application to beaches in close proximity to the dredging project except in instances where groin fields or breakwaters systems are constructed. Beach nourishment is typically a part of breakwater applications.

Marsh Fringe

Planted marshes are used to create a protective fringe usually along low-energy shorelines, such as tidal creeks with fetch exposures of less than 0.5 nautical miles. In some cases, the marsh can be reestablished on the existing substrate *(Figures 25A, B, and C)*; in others, a wider marsh substrate can be made using sand fill *(Figure 25D)*.

Marshes planted behind breakwaters and sills allow a marsh fringe to be established along higher wave energy shorelines. Keep in mind, however, that in slightly higher wave energy situations the marsh fringe must be periodically replanted and maintained.







Figure 25A (top)
Marsh planting along Occahannock Creek, Northampton County, Va.

Figure 25B (middle)
Occohannock Creek marsh planting after 1 year of growth.

Figure 25C (lower)
Occohannock Creek marsh planting after 10 years of growth.

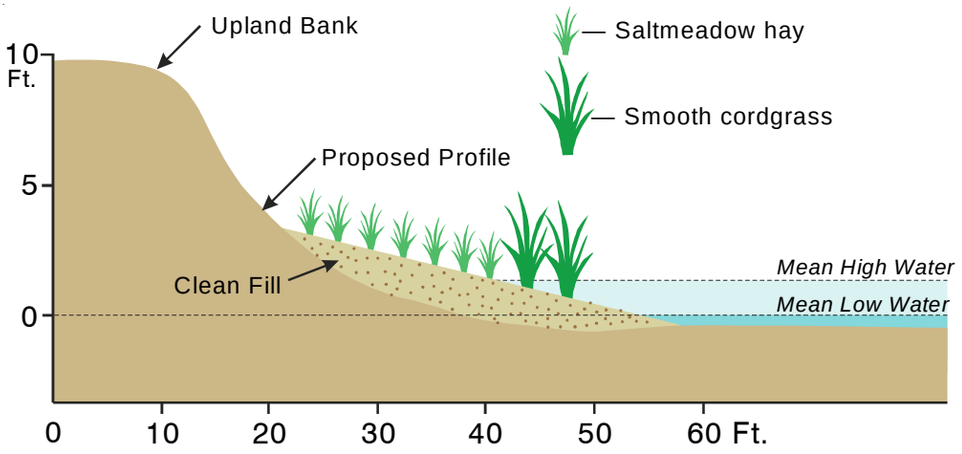


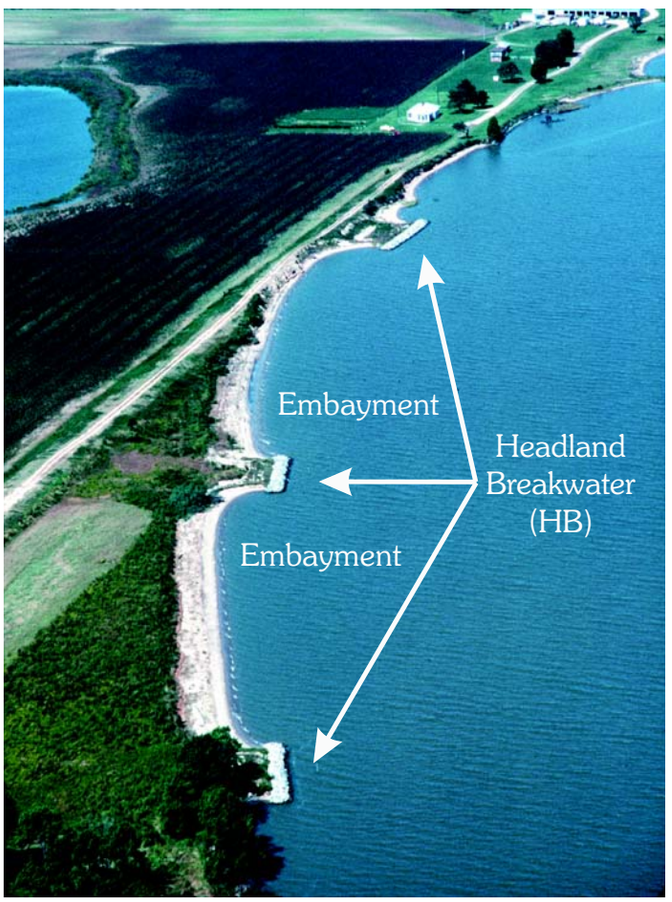
Figure 25D
This cross section shows a proposal plan to stabilize a typical eroding shoreline using clean sand to create the appropriate planting area.

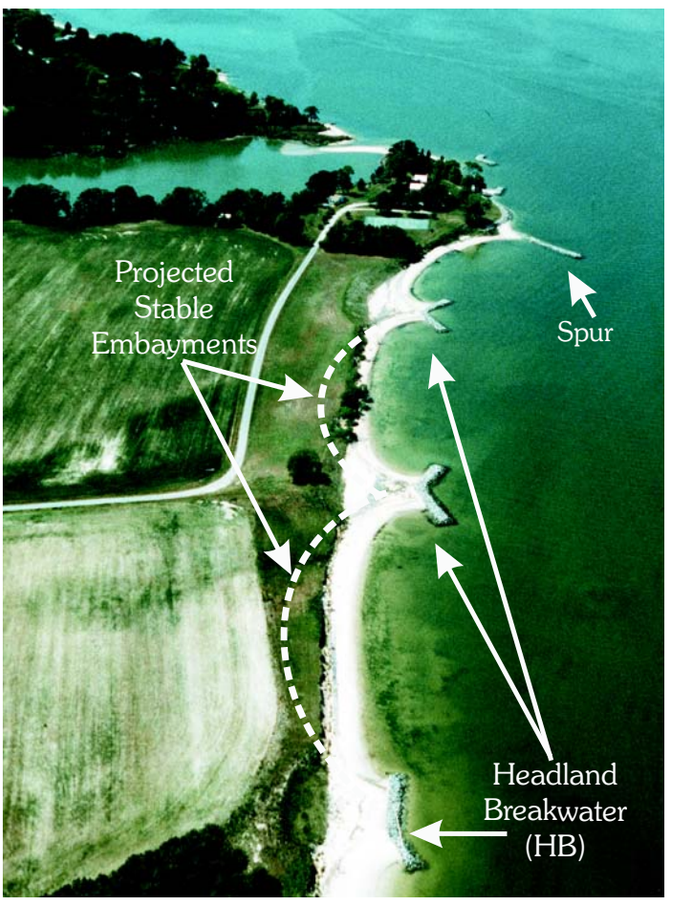
Headland Control

Since shoreline erosion and management is most cost-effectively handled on a reach basis, headland control can be a very good option. This method allows long stretches of shoreline to be addressed with a few strategically placed structures. Headland control reduces the linear feet of structure needed, and thus keeps the overall cost down. Headland control is accomplished by accentuating existing features or creating permanent headlands that allow adjacent, relatively wide, embayments to achieve stable configurations *(Figure 26)*. Although headland control is a relatively new application in the Chesapeake Bay, it is a well-established method in other parts of the world. In shoreline reaches with multiple waterfront ownership, coordinating funding and the objectives of individual owners is essential. Remember, all sites within the reach may be affected by a headland control strategy.

Figure 26A
Placing widely spaced breakwaters and allowing adjacent embankments to erode and evolve into equilibrium embayments can be a cost-effective method of reach management, as seen at Hog Island, James River, Va.

Figure 26B
Headland control system in Westmoreland Co., Va. in Potomac River, installed 1998.





Other Elements to Consider

Existing structures must be accounted for in designing and installing a new shoreline protection system. Structures on adjacent properties also must be incorporated in a common sense fashion, especially if they differ significantly from the structures in the proposed strategy.

The preference for stone over wood has increased in the last 20 years. Quality stone has long-term durability if the structure is properly designed and installed. However, many sites are more practically treated with traditional wooden bulkheads.

Broken concrete, a very common restoration by-product, can be used instead of rock for shoreline protection systems, as long as the material is free of reinforcement bar and is similar in size and shape to comparable rock. The key is to properly interlock the concrete pieces. Long, flat slabs are cumbersome and should be broken into more equidimensional sections Broken concrete, due to its lower specific weight, is best used as a base or core upon which rock armor can be placed to form revetments, breakwaters and sills.

There are other erosion control methods in limited use around the shorelines of the Chesapeake Bay which utilize other construction materials such as concrete forms, gabions, and plastic bags. These methods are used by landowners who desire a treatment method which is initially less expensive. However, design elements must still be followed and long-term maintenance should be expected.

This report presents common, sound methods used for shoreline protection that have a discernible track record.

Environmental

Usually permits are required for shoreline modification in the tidal waters of Virginia and Maryland at the local, state, and federal levels depending on the nature of the project. Agencies are concerned with potential impacts to the coastal environment. Refer to the following agencies for detailed information on shoreline permits:

Virginia
Virginia Marine ResourcesCommission
Habitat Management Division
2600 Washington Ave., P.O. Box 756
Newport News, VA 23607

Maryland
Regulatory Services Coordination Office
Maryland Department of the Environment
2500 Broening Highway
Baltimore, MD 21224

Virginia and Maryland are jurisdictionally different; they use different tidal datums to delineate state ownership of subaqueous bottom. Virginia uses mean low water (MLW) and Maryland uses mean high water (MHW).

Shoreline Management Goals & Applied Strategies

The first step in developing a framework for shoreline management is to prioritize your goals—to define what is most important to you as a property owner. Below are a few goals that should be taken into account.

1. Prevent loss of taxable land. Protect shoreland improvements; and provide for personal safety.
2. Enhance water quality by managing upland runoff and groundwater flow by maintaining wetland habitat.
3. Protect, maintain, enhance and/or create wetlands and other intertidal habitat.
4. Provide access and/or create recreational opportunities such as a beach.
5. For a proposed shore strategy, address potential impacts within the reach.
6. Align costs with goals.

You may have additional goals you wish to achieve, but you should at least assess your goals within the context of the shoreline reach. Otherwise, you may not address all of the mechanisms which could affect erosion along your property. Be prepared to work with your neighbors; within a reach property owners may have different and possibly conflicting goals. While the goals of each property owner should be taken into account, they won't all carry the same weight. In fact, trying to satisfy everyone's goals for a given reach may not be possible as some goals may be mutually exclusive (Byrne *et al.*,1979).

One way to focus your efforts is to look at the reach in terms of the main objective for the area. There are three general objectives and a fourth which can make use of all three.

1. Defend an eroding bank with a structure, such as bulkhead, seawall, or revetment.

TABLE 4

GENERAL ASSESSMENT OF SHORE PROTECTION STRATEGIES

Goals	Revetments/ Bulkheads	Groins	Marsh	Break-waters	Headland Control
A-Stop erosion	1	2	1	1	1 to 2
B-Water quality	3	2	1	1	1
C-Wetland habitat	3	3	1	1	2
D-Access	3	2	2	1	1
E-Reach Impacts	1 to 2	3	1	2	1
F-Costs	3	2	1	2 to 3	2 to 3
Total*	**14 to 15**	**14**	**7**	**8 to 9**	**8 to 9**

For goals A, B, C, and D in the matrix, the ranking of 1, 2, and 3 refer to good, fair and poor, respectively. The rankings for goals E and F are 1, 2, and 3, and refer to low, medium and high potentials, respectively.

**The higher the total value, the less the strategy addresses the six management goals. (After Reynolds and Hardaway, 1995)*

2. Maintain and/or enhance an existing shore zone feature such as a marsh fringe or beach that is presently offering a limited amount of protection. This can be accomplished by a marsh toe revetment, sill, breakwater system, or by beach nourishment.
3. Create a shore zone system of beaches, dunes, and marsh fringe. This is best done with a breakwater system or a sill. Beach nourishment usually is needed to provide the proper setting for a beach and marsh substrate.
4. Headland control. This may combine all three of the above mentioned objectives along a reach in order to achieve integrated, long-term shoreline management.

Table 4 provides a general assessment of the shore protection strategies with respect to the goals noted above. Keep in mind that some of these strategies have added factors to consider. For example, to stop erosion, groins must have an adequate supply of sand. Also marshes, as a single erosion control strategy, will be most effective in low-fetch conditions (i.e., less than 0.5 nautical miles). As you can see by the table, generally it is not possible to achieve the optimum outcome of highest effectiveness and lowest cost. Planting marshes comes close, but, as noted, this strategy is limited to low wave-energy conditions, such as narrow waterways.

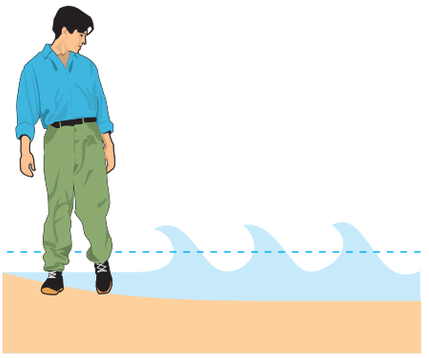
As you consider an approach, pay close attention to cost. Compare costs for stone revetments, nearshore segmented breakwaters, and headland control. In particular, distinguish between the cost per foot of structure and cost per foot of shoreline protection. Stone revetments are continuous structures so the cost per foot and per foot of protection are the same. For segmented breakwaters, the cost per foot of structure may be greater than for a revetment due to the expense of establishing the structure offshore although breakwaters may contain more rock per linear foot of structure. However, the cost per foot of shore protection using breakwaters may be less than a revetment even with the beach fill component. Headland control, on the other hand, involves placing revetment/breakwater segments, thus the cost per foot of structure is similar, but the cost per foot of protection is more favorable after equilibrium is attained.

A "no action" approach should also be considered. It may be more advantageous to move houses, roads, etc., on the uplands than to spend money to protect a severely eroding shore.

Shoreline erosion control simply provides a man-made shore feature to protect the upland. Absolute protection from the most rare and damaging storms usually is too expensive to achieve. Thus, shore protection systems are designed to be effective for intermediate storm conditions (i.e., for a 25- to 50-year storm surge and wave height), but to retain their overall integrity for a longer period.

For this reason, waterfront property owners should get good advice early in the process. Seek out individuals and companies to help you design and implement shoreline management strategies, but make sure you review their work history and references. Select those with a history of completing successful, environmentally sound projects. These experts can tell you if what you are considering will work for your site.

Low Wave-Energy



In low wave-energy environments (small tidal creeks), shore types are usually slowly eroding, upland sediment banks or marshes. Shorelines with a sufficiently wide marsh fringe generally have little or no problem with upland bank erosion because established marsh fringes will absorb most of the wave energy before it can impact the upland banks.

Shorelines that have exposed and eroding upland banks most likely had a marsh fringe in the past. However, the marsh slowly eroded away leaving the base of the upland vulnerable to wave attack. Oftentimes, on low energy shorelines, the base of the bank is eroding, and the upper bank face is relatively stable as evidenced by abundant, woody vegetation. In these cases, the bank does not require grading, and only the base needs to be protected.

In many instances, overhanging tree limbs shade out the marsh fringe leaving the base of the upland banks vulnerable to even the slightest wave action. In the low-energy regimens, boat wakes may even increase shoreline erosion.

Recommended erosion control measures in the low-energy wave regimen include marsh planting and bank grading, marsh toe revetments, small stone breakwaters or sills (to maintain beach fill), and small, stone revetments or bulkheads. Sometimes the solution can be as simple as pruning overhanging tree limbs so the marsh fringe grasses can get more sunlight. If grading upland banks is part of your erosion control solution, keep in mind that such activities must comply with state erosion and sediment control procedures.

Using and enhancing vegetation on both the upland and the shoreline is highly recommended. Vegetation filters nutrient-laden storm runoff and traps sediments, which helps create an erosion-resistant turf (Barnard and Hardaway, 1994). Established marsh fringes also denitrify nutrient-laden water from groundwater seeps and springs. Along shorelines with fetch exposures of less than 0.5 nautical miles, establishing a marsh fringe is a very viable option. If there is an existing narrow marsh, it can be enhanced by adding plantings or installing a low sill. In low wave-energy environments with an existing, but threatened marsh fringe, or areas with a greater fetch exposure, more protective measures may be needed. For marsh fringes which have started to erode but are still protecting upland banks, consider installing a marsh toe revetment. A rock toe wedge placed over filter cloth against the peat scarp may be sufficient in lower wave-energy areas.

For fetch exposures approaching 1 nautical mile, consider installing a splash apron (3 to 5 feet wide) as a landward extension across the top of the marsh scarp *(Figure 16B)*. The splash apron will help prevent waves from scouring out the marsh peat from behind the marsh toe revetment. Without a splash apron, the armor rock might migrate landward, thus

reducing the height of the structure and adversely impacting its effectiveness.

A sill is often effective in situations where the existing marsh is inadequate or no marsh or little beach exists, and the base of the bank is eroding. Generally, a sill is placed at or near mean low water over filter cloth with sand fill in the lee to provide a substrate for establishing a marsh. The height of the sill should be at least equal to mean high water to provide adequate backshore support. Armor rock of 300 to 900 pound range should be used for the structure (see note).

A revetment is a good solution along low wave-energy shorelines where the upland banks are eroding. In the low-energy regimens, the height of the revetment is determined by the design water level and whether the bank needs grading. Since wave heights of less than 2 feet can be expected, the armor stone can be relatively small (300 to 900 pounds). As such circumstances involve relatively low wave energy, the elevation of the structure generally only needs to be high enough to accommodate storm surge. For instance, if the objective for the structure is to protect against damage from 50-year storm surge in the lower bay (which is 6.5 feet above mean low water) (Boon *et al*., 1978), the height of the revetment should be at least 6.5 feet above mean low water with a splash apron of 3 to 5 feet. Storm waves will break over the splash apron. Filter cloth should be laid under the revetment, and dense vegetation established at the rock/upland interface.

Wooden bulkheads have been used along tidal creeks because they allow lawns to extend to the waters' edge. The rule of thumb for bulkheads is to have at least the same length of structure along the bottom as above water. For 8 feet of sheeting the structure should have at least 4 feet penetration below mean low water. For this scenario, the top of the structure would be 1.5 feet above mean high water and would be flooded about once a year in the lower bay region. Adequate bank grading and vegetative stabilization is necessary.

Groins can also be used along low-energy shores. They have been used successfully in conjunction with beach fill and marsh plantings. They can be stone or wood and generally have a low profile.

As you consider different strategies, one key that should be part of your plan is the type of material which comprises the bottom of your shoreline. Soft clays and peats need to be properly accounted for with added filter layers or excavation to prevent settlement of the structure—especially with gravity structures like rock revetments, breakwaters and sills. In some areas, a hard marl substrate may prevent proper sheetpile penetration for wooden bulkheads and a gravity rock structure may be more suitable.

Note:

Reference Armor Stone: The State of Maryland, had for many years, a Shore Erosion Control Program in the Department of Natural Resources and directed by Mr. Lin Casanova. They developed reasonable set of armor stone guidelines for varying wave regimes in Chesapeake Bay that are used in this document. We reference Mr. Jordan Loran, engineer, Maryland Department of Natural Resources through oral communication on these armor stone ranges. Armor stone is not a broad range of rock sizes but a set limit that have been shown to interlock properly for that particular application. For example, an armor stone range from 600 to 1600 lbs. means just that, not having some percentage below 600 lbs. although a few larger stone are acceptable. In the Chesapeake Bay region good armor rock can by granite, quartzite and metamorphosed limestone. Armor stone should not be weathered or easily broken and should be installed as a tightly packed matrix. Virginia and Maryland Departments of Transportation have "Class" rock sizes (i. e., Class I, II, III) that may be the only source of armor rock available. The size limits should roughly coincide with armor stone limits references here. Some smaller stones will be included and these should be used in underlayers of revetments and on the lee side of the breakwater and sills.

Figure 27A (top)

Marsh grass plantings with sand fill and short, stone groins 3 months after installation on Wye Island, Kent County, Md.

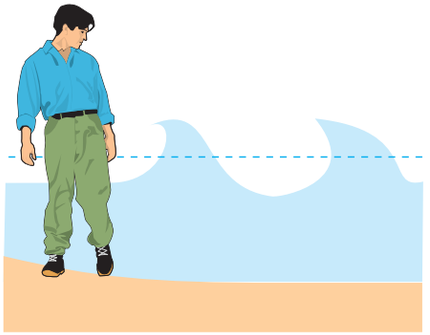
Figure 27B (bottom)

Wye Island project 4 years after construction.





Medium Wave-Energy



Medium wave-energy environments generally are located along main tributaries of the Chesapeake Bay. Shoreline types include moderately to highly eroding upland banks and marsh shorelines. Shore zone features need to be wider in this regimen than in low-energy environments to compensate for higher wave energy.

Recommended abatement measures in the medium wave-energy regimen include bank grading combined with bulkheads and stone revetments, and headland breakwaters with beach fill and marsh plantings. Along eroding marsh shorelines, marsh toe revetments and sills are recommended.

Marsh fringes cannot be adequately established along shorelines with fetch exposures of more than about 0.5 nautical miles. However, marsh grasses can be established in conjunction with breakwaters and sills and should be used to create an erosion-resistant turf in the landward side of these systems.

Marsh toe revetments should have a splash apron when used along medium-energy shorelines. It is also important to make sure the structure ends either by a return into the marsh or by designing the last 25 feet or so as a free-standing sill. Without these features, a marsh toe revetment will likely fail at the ends of the structure. For such environments, use minimum armor rock between 400 and 1,200 pounds, and lay filter cloth under the structure.

A rock sill over filter cloth can enhance an eroding marsh if it is placed far enough offshore to widen the marsh to a protective width. In the case of medium-energy shorelines, a marsh fringe of 40 to 70 feet may be



Figure 28

Kingsmill on the James, James City County, Va. Shore protection system utilizing headland, breakwaters, beach fill with wetland vegetation, bank grading with upland vegetation, a revetment, and an interfacing low-crested breakwater.

needed to attenuate wave action during seasonal storm events. During extreme events, when water levels exceed 3 feet above mean high water (about every 10 years in the lower bay), some wave action may penetrate this system. Therefore, the sill height should be at least 1 foot above mean high water.

A breakwater system can be cost-effective along medium-energy shorelines. If there is a weak link it is the mid-bay beach width *(Figure 22)*. The beach width in that area should be at least 35-45 feet wide from mean high water to base of bank. Armor rock for breakwaters in the medium energy regimen should be a minimum of 800 to 2,000 pounds. Larger rock is necessary in breakwater structures than in revetments because they are located offshore and receive higher waves than shore-based structures like bulkheads and revetments. Once again, lay filter cloth under the structure.

While breakwaters can be very useful for controlling erosion, they can also impact adjacent shorelines. One way to address potential problems is to place low, broad breakwaters close to the shore. These will reduce downdrift effects when used as an interface between the main breakwater system and the adjacent unprotected shore (Hardaway *et al.*, 1993).

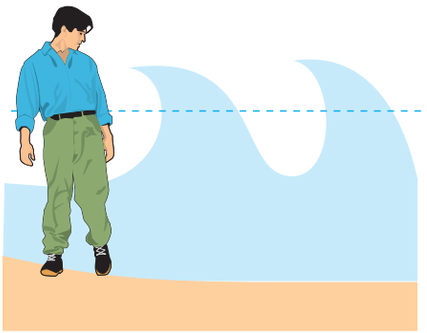
Breakwaters are not suitable for every landowner and site-specific design is required. These systems are best utilized on shorelines of 200 feet or longer. Individual breakwaters should have crest lengths of 60 to 150 feet and crest heights ranging from 2 to 3 feet above mean high water.

Revetments installed along medium-energy shorelines should have two layers of armor rock, with each rock ranging between 600 and 1,600 pounds at a minimum. Shoreline projects that occur on the higher range of fetch exposures (5 to 10 nautical miles) particularly on the lower portions of the main tributary estuaries, should consider armor rock of a minimum of 800 to 2,000 pounds. Revetment height and scour depth are important considerations as well. Depending on bottom conditions, scour depths of up to 3 feet should be considered possible for the toe of the structure. The top of a revetment should be at least as high as the design storm surge with a splash apron of at least 6 to 10 feet. The entire structure should be underlain with filter cloth.

When evaluating the benefits of bulkheads versus stone revetments on medium-energy shorelines, be careful to look at both cost and performance. Realize also the potential for scour and increased bottom depth over time is greatest with a vertical structure such as a bulkhead. The rule of thumb in designing a bulkhead is to plan for at least ½ length penetration and ½ exposed; but for a medium wave-energy environment the bulkhead may need to penetrate deeper still. Depth below existing, mean low water should be the line of penetration—not the existing beach or backshore. For a revetment, scour potential can be addressed by using a wider toe apron.

Along medium-energy shorelines, low-profile groins are generally ineffective for long-term shoreline protection. Longer, higher groins are considered unacceptable because of the potential to block sand bypassing and cause major downdrift impacts. If used, groins, and groin fields should include beach fill and, at least, a spur on the downdrift structure.

High Wave-Energy



High wave-energy environments are generally located on the Chesapeake Bay proper. Shoreline types include highly eroding upland banks, sand beaches, and marsh shorelines. The increased fetch in these areas results in larger waves hitting the shoreline in storm conditions. Increased wave size also translates to high costs for a properly designed structure. Protective measures such as bank grading, marsh plantings, and beach fill may be used in these areas, but are best applied in combination with headland breakwaters, sills, and groins.

In high-energy environments, more than in medium-energy regimens, stone revetments, seawalls, and bulkheads must be designed to withstand powerful waves that may run up, or even break over the top of the structure.

Marsh toe revetments can be used, but the high wave-energy environment will require increased rock size; a sill might be a better option—both should be considered. Armor rock should be 600 to 1,600 pounds each for sills along high-energy shorelines. Large armor rock will create a thick structure; plan on using two layers of armor stone. Again, use filter cloth.

Breakwater systems along high-energy shorelines work best when there is at least 300 feet of shoreline—or better yet, the entire reach—to be considered *(Figure 29)* so impacts to adjacent beaches can be taken into account. When possible, such strategies should end at a convenient reach break such as an existing shoreline structure, inlet jetty, or a natural headland to minimize any effects on neighboring beaches. The mid-bay beach width should be 45 to 65 feet from mean high water to the base of the bank with an elevation of 3 to 4 feet above mean high water where the backshore meets the bank. Beach nourishment is usually necessary to acheive these beach widths. Armor stone should be a minimum of 1000 to 2,500 pounds, but a better range is 2,000 to 5,000 pounds each to provide long-term stability. Armor stone should even larger on extreme exposures, such as along Ocean View and Willoughby Spit on the southern shore of the bay in Norfolk, Va. Individual breakwater units should have crest lengths of 90 to 200 feet and crest elevations of 3 to 5 feet above mean high water depending on project goals. Lower crest elevation (1 to 2 feet above mean high water) should be used if the landowner wants to allow a limited amount of sand to pass by the structure.

The backshore and tombolo area of a breakwater system must be planted in order to create an erosion-resistant turf. A low dune can also be built to store sand for repairing beaches after an extreme storm event.

Revetments built along high-energy shores need to be properly sized to withstand expected storm surge and wave conditions. Armor stone should be at least 1000 to 2,500 pounds each, but larger ranges are also recommended for some shore settings. Depending on site conditions, anticipate scour depths of up to 4 feet, and

address this problem by excavating the toe and filling it with stone, or building a wide, toe apron of at least 6 feet. Splash aprons should also be at least 10 feet wide. The larger size of armor rock should be placed at the toe of the structure to provide support.

Return sections for revetments should be built well into adjacent banks. Such sections can become free-standing structures (trapezoidal in cross-section like a breakwater) because shoreline erosion may proceed on adjacent, unprotected shorelines. Severe flanking will cause a structural failure of a revetment wall but not a freestanding design. Once again, treating longer reaches of shoreline is a more cost-effective means of controlling erosion.

Bulkheads built along open, high-energy shorelines should be fairly massive. Potential scour problems can be treated by adding short groins (20 to 40 feet) to the bulkhead. Some sand may be trapped by the groins which will help reduce storm-induced scour. Adequate return walls must be included so backfill is not lost, otherwise the structure will fail.

Groin fields can be effective along high-energy shorelines because high erosion rates yield plenty of sand, but these scenarios are becoming more rare as shorelines are treated. Downdrift impacts can be minimized by using spurs. It should be again emphasized that during storm conditions, it is the beach that dissipates the wave energy, not the groins. Expect to provide long-term beach nourishment in high wave-energy shorelines. If erosion control structures are added to adjacent shorelines, the net effect may be to reduce sand sources throughout the reach.

Headland control is most appropriate along medium- and high-energy shorelines where cost is a major factor. Eroding agricultural and unmanaged wooded shorelines are appropriate situations to use headland control. Establishing or enhancing headlands at strategic locations and allowing adjacent shorelines to erode to an ultimately stable planform is a viable, cost-effective erosion management option. The addition of beach sand to a shore reach will enhance the headland control method and help create a stable shore.

As mentioned, beach nourishment as a sole method for erosion abatement is not discussed in detail here because it is very site-specific. However, for sites that are near navigation channels, transportation costs are lower, thus making dredged sand a viable way to create a protective beach and dune system. If dredging is done frequently, then dredged material may be all that is needed.



Figure 29
Breakwater system on Chesapeake Bay, Elm's Beach, St. Mary's County, Md.

Summary

These management strategies are intended to address the goals of both private and public shoreline property owners in Chesapeake Bay and to significantly reduce shoreline erosion with cost-effective and environmentally acceptable methods. Keep in mind that these are general guidelines and that an assessment, by a professional, should be conducted before any shoreline management strategy is implemented.

Environmental regulators and local officials should evaluate the long-term and cumulative impacts of shore protection on a reach basis and monitor the effectiveness of previous installations within a reach.



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Other Sources of Information

Agencies

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Virginia Marine Resources Commission
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Regulatory Services Coordination Office
Maryland Department of the Environment
2500 Broening Highway
Baltimore, MD
21224
(410) 631-8075

Maryland Department of Natural Resources
Tawes State Office Building
Annapolis, MD
21401
(410) 260-8100

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Shoreline Development BMP's: ***Best Management Practices for Shoreline Development Activities which Encroach In, On, or Over Virginia's Tidal Wetlands, Coastal Primary Sand Dunes and Beaches and Submerged Lands.***
Virginia Marine Resources Commission, 2600 Washington Ave., Newport News, VA

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Contact: The District Engineer, U.S. Army Corps of Engineers, P.O. Box 1715, Baltimore, MD 21203.

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Glossary

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

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

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

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

Dendritic watershed *An area or region bounded by waterways which drain the area branching out into a complex array of many large, medium, and small channels. The Chesapeake Bay watershed is a good example of a dendritic watershed.*

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

Drowned river valley *A river valley which has become submerged due to a rise in sea level.*

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

Gabion *A basket or cage filled earth or rocks used in building a support or abutment.*

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

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

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

Incident waves *A term refering to waves as they approach a shore, barrier, or other point.*

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

Marl *A mixture of clay and calcium carbonate which has been deposited through sedimentary processes, i.e., the clay and calcium carbonate have been transported by, allowed to settle, and eventually compacted into rock.*

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

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

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

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

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

Scarp *The term used to refer to a steep slope; it can mean a series of beach ridges produced by higher stands of sea level, or simply a low, steep beach slope caused by wave erosion.*

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

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

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

Shore orientation *The compass direction the shoreline faces.*

Shore strike *An abstract line that runs perpendicular to the shore. Shore strike is used as a point of reference for determining fetch and shore orientation. See Figure 11 Page 19.*

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

Splash apron *A structural component, often of rock, used to prevent forceful waves from scouring out material from the top of a revetment. See Figure 16B on page 28 for more information.*

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

Tombolo *The accumulation of beach material directly behind a breakwater.*

Uplands *Land that is relatively elevated compared to sea level.*

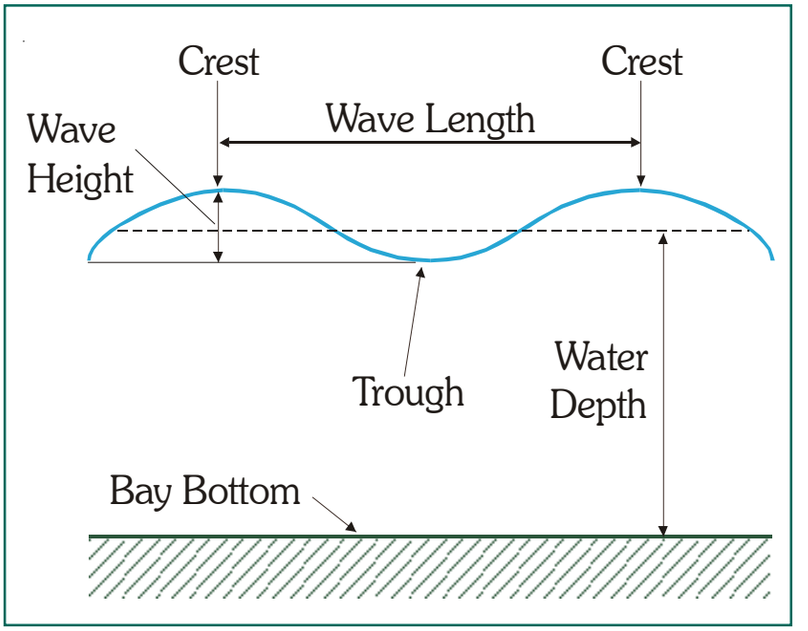
Wave climate *The averaged wave conditions as they impact a shoreline including waves, fetch, dominant seasonal winds, and bathymetry.*

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

Wave height *The vertical measurement of a single wave from its base or trough to its top or crest.*

Wave length *The distance between successive crests or troughs.*

Wave period *The time it takes successive waves to pass a fixed point.*



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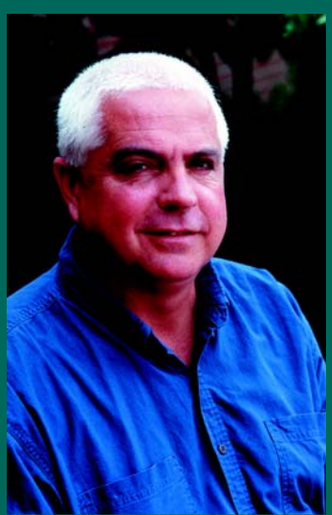
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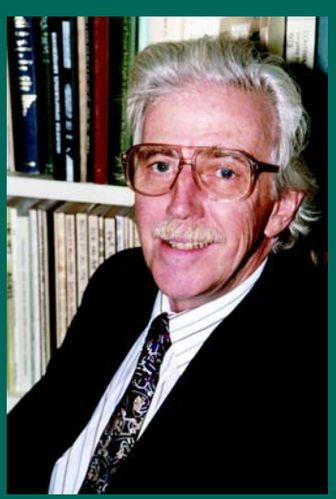
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