1-2014

York County Shoreline Management Plan

C. Scott Hardaway Jr.
Virginia Institute of Marine Science

Donna A. Milligan
Virginia Institute of Marine Science

Christine A. Wilcox
Virginia Institute of Marine Science

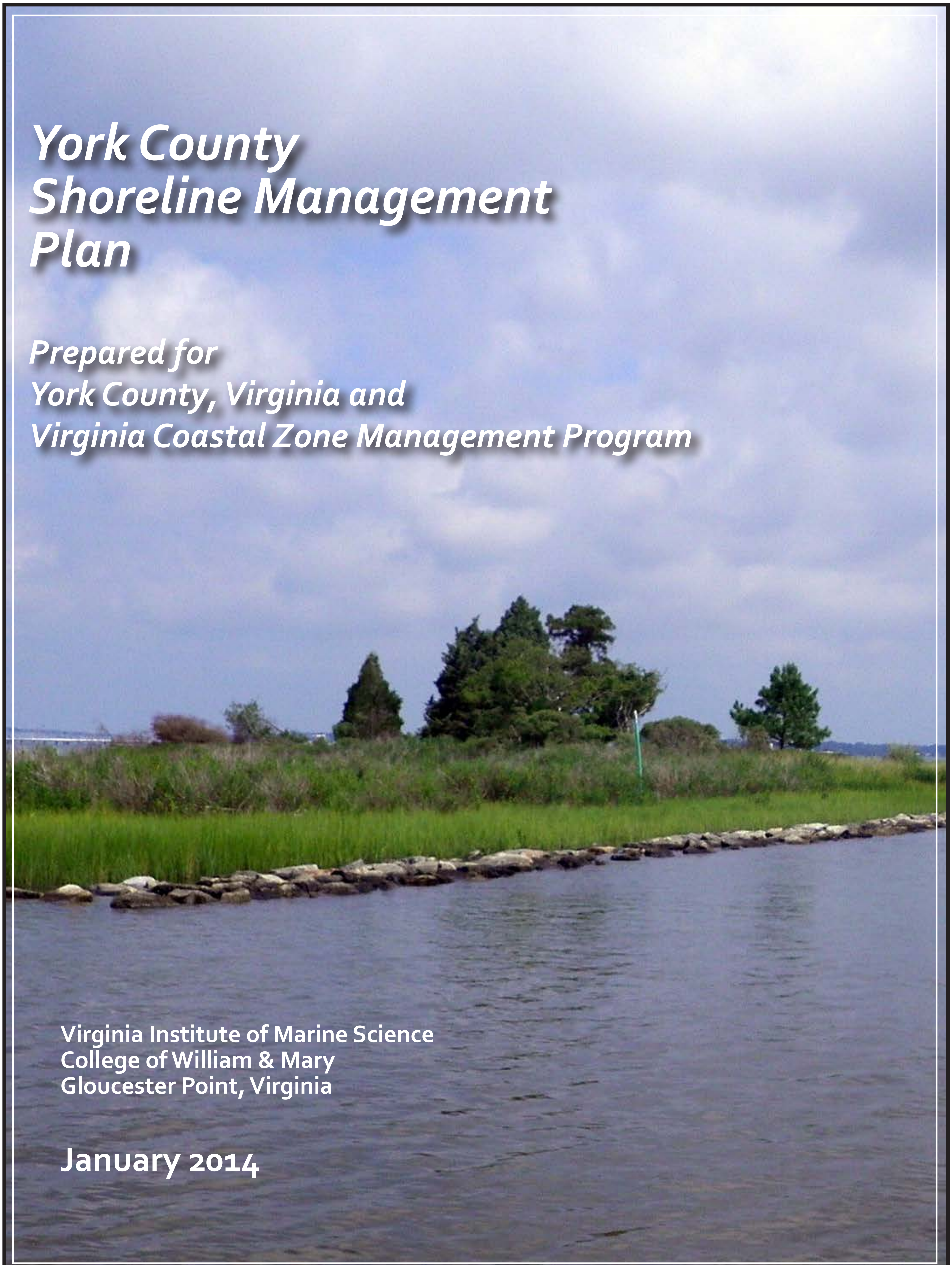
Marcia Berman
Virginia Institute of Marine Science

Tamia Rudnicky
Virginia Institute of Marine Science

See next page for additional authors

Recommended Citation

Hardaway, C., Milligan, D. A., Wilcox, C. A., Berman, M., Rudnicky, T., Nunez, K., & Killeen, S. (2014) York County Shoreline Management Plan. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.21220/V54C72



York County Shoreline Management Plan

Prepared for
York County, Virginia and
Virginia Coastal Zone Management Program

Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, Virginia

January 2014

York County
Shoreline Management Plan

Prepared for
York County, Virginia and
Virginia Coastal Zone Management Program

Shoreline Studies Program
C. Scott Hardaway, Jr.
Donna A. Milligan
Christine A. Wilcox

Center for Coastal Resources Management
Marcia Berman
Tamia Rudnicky
Karinna Nunez
Sharon Killeen

Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, Virginia

This project was funded by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through Grant #NA12NOS4190168 of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, under the Coastal Zone Management Act of 1972, as amended. The views expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Department of Commerce, NOAA, or any of its subagencies.

January 2014

Table of Contents

List of Figures

Appendix 3 Captions

List of Tables

1 Introduction

With approximately 85 percent of the Chesapeake Bay shoreline privately owned, a critical need exists to increase awareness of erosion potential and the choices available for shore stabilization that maintain ecosystem services at the land-water interface. The National Academy of Science published a report that spotlights the need to develop a shoreline management framework (NRC, 2007). It suggests that improving awareness of the choices available for erosion control, considering cumulative consequences of erosion mitigation approaches, and improving shoreline management planning are key elements to minimizing adverse environmental impacts associated with mitigating shore erosion.

Actions taken by waterfront property owners to stabilize the shoreline can affect the health of the Bay as well as adjacent properties for decades. With these long-term implications, managers at the local level should have a more proactive role in how shorelines are managed. The shores of York County vary from very open fetch exposures along Chesapeake Bay and up the York River to fairly sheltered coasts along its smaller creeks (Figure 1-1). Fourteen percent of the shoreline has existing traditional hardened shore protection. However, many areas these areas are suitable for a "Living Shoreline" approach to shoreline management. The Commonwealth of Virginia has adopted policy stating that Living Shorelines are the preferred alternative for erosion control along tidal waters in Virginia (http://leg1.state.va.us/cgi-bin/legp504.exe?111+ful+CHAP0885+pdf). The policy defines a Living Shoreline as …"a shoreline management practice that provides erosion control and water quality benefits; protects, restores or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural and organic materials." The key to effective implementation of this policy at the local level is understanding what constitutes a Living Shoreline practice and where those practices are appropriate. This management plan and its use in zoning, planning, and permitting will provide the guidance necessary for landowners and local planners to understand the alternatives for erosion control and to make informed shoreline management decisions.

The recommended shoreline strategies can provide effective shore protection but also have the added distinction of creating, preserving, and enhancing wetland, beach, and dune habitat. These habitats are essential to addressing the protection and restoration of water quality and natural resources within the Chesapeake Bay watershed. The York County Shoreline Management Plan is an educational and management reference for the county and its landholders.

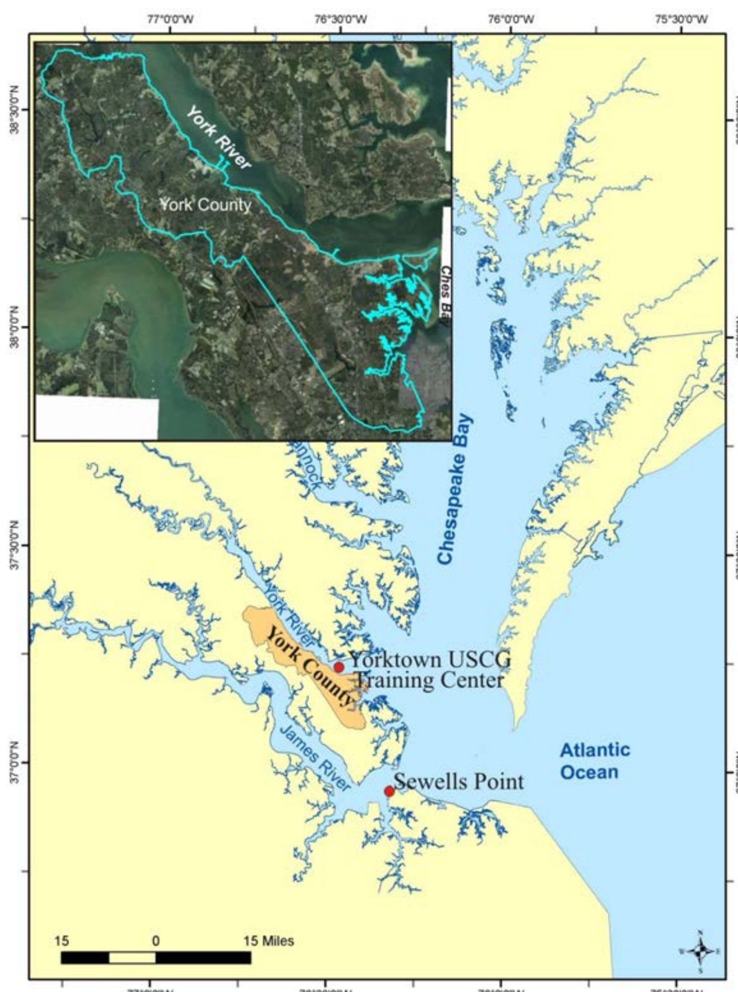


Figure 1-1. Location of York County within the Chesapeake Bay estuarine system. The location of National Oceanic and Atmospheric Administration tide gauges also are shown.

2 Coastal Setting

2.1 Geology/Geomorphology

2.1.1 Geology

York County lies within the coastal plain of Virginia with about 235 miles of tidal shoreline. The topography of York County varies from generally low, flat land with high water tables in the lower County to rolling terrain with well-drained soils in the northern regions at elevations up to 130 feet (York County, 2013). The topography is defined by the underlying geology which in turn controls the geomorphology of the County.

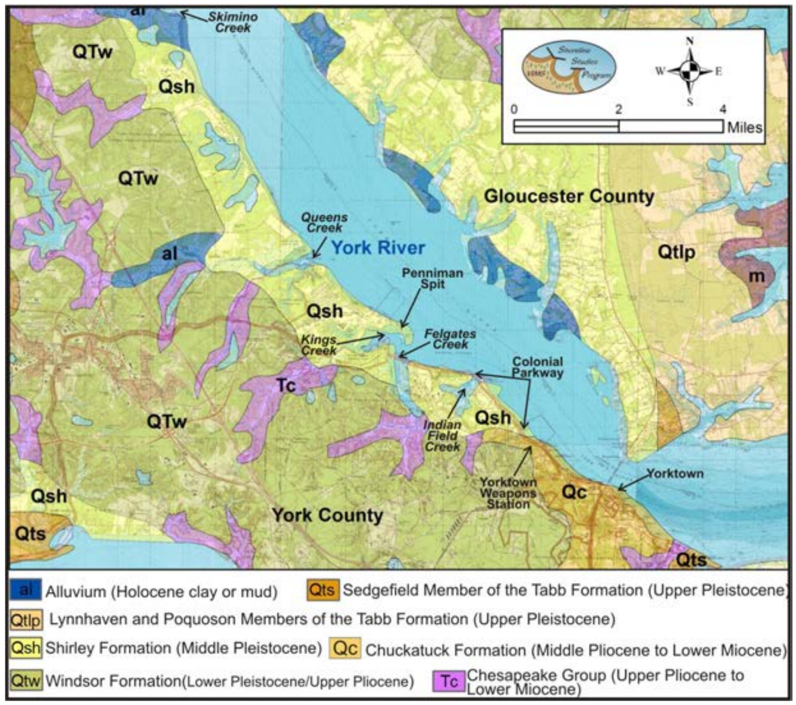


***Figure 2-1.** Geology of the upriver section of York County on the York River (Mixon* et al.*, 1989) overlain on a USGS topographic map.*

The geologic units along the county's tidal shorelines range from recent Holocene sediments of soft muds and marsh to Upper Pliocene and Lower Miocene strata exposed in the high banks along the York River. The base of the exposed banks consist of the Yorktown Formation (Tc) which is overlain by the Chuckatuck Formation (Qc) and the Shirley Formation (Qsh) (Figure 2-1). The Yorktown Formation of Lower Pliocene age is rich in shallow marine fossils including large shark's teeth, whale vertebrae and numerous mollusks, of which the large scallop, *Chesapecten jeffersonius*, is the state fossil. During the American Revolution, General Cornwallis made his headquarters in a cave along the river, dug into an indurated fossiliferous layer exposed at the base of the bluff. Today, the coastal morphology of York County is a reflection of these ancient processes, and the varying bank heights along the coast are a result. Erosion of these geologic units contributes to the sedimentary character of material supplied to the littoral system.

Extensive deposition of shallow marine sediments over three oceanic transgressions formed the Quaternary formations (Cronin *et al.*, 1984). As sea levels receded, the coastal plain drainages were deeply incised into the Yorktown strata. Subsequent oceanic transgressions extended landward progressively less across the Virginia coastal plain and resulted in deposition of sediments eroded from older strata with unconformities between each formation. In York County, these include the Windsor Formation (Qtw), the Chuckatuck Formation (Qc), the Shirley Formation (Qsh), the Tabb Formation (Lynnhaven (Qtl), Poquoson (Qtp) and Sedgefield (Qts) Members and the more recent Holocene marsh sediments (m) (Figure 2-2).

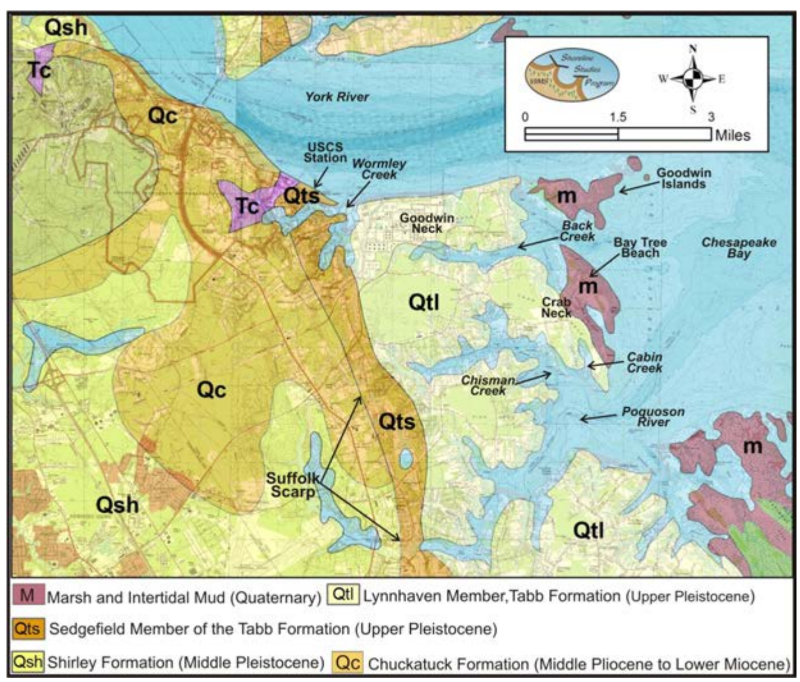


***Figure 2-2.** Geology of the downriver section of York County and it's Chesapeake Bay shoreline (Mixon* et al.*, 1989) overlain on a USGS topographic map.*

2.1.2 Shore Morphology

From Skimino Creek to Queens Creek, the federally-owned upland banks are 10 feet to 20 feet high and are a continuation of the Qsh strata (Figure 2-3). This long coast has a history of intermittent, eroding marshes. As the marshes narrow, the upland is impacted by the impinging wave climate. The banks become undercut, unstable, and erosive. Along this stretch of shoreline, various erosion control devices have been installed where infrastructure is threatened. Revetments, breakwaters, and groins have been installed with varying levels of success at slowing erosion. Many shore areas are off limits due to sensitive federal property ownership.

Figure 2-3. *Eroding banks, marsh fringe, and shore protection structures along the York River between Queens Creek and Skimino Creek. Several of the structures have been effective maintaining a marsh behind it thereby reducing direct wave impact to the upland bank and slowing erosion.*

Between Queens Creek and King Creek/Felgates Creek, the high banks (Qsh) are part of Cheatham Annex, U.S. Navy Supply Center. The Cheatham Annex headland has a history of shore erosion that has been altered by partial stabilization over the years. In 1937, a fairly continuous beach existed along this shoreline with some intermittent marsh fringe headlands (Milligan *et al*., 2010). Intermittent loss of the marsh fringes and consequent erosion lead to shoreline hardening by revetments, breakwaters and sills. Penniman Spit extends across the mouth of King Creek. It is the product of updrift erosion and transport downriver. Penniman Spit is discussed further in section 5.2.2 of this report.

The York River section of Colonial Parkway extends from King Creek/Felgates Creek to just upriver of Yorktown. With the exception of the Yorktown Naval Weapons Station, the shoreline is owned by the National Park Service. The once eroding high banks (Qts and Qc overlying Tc) have been mostly hardened by stone revetments including the segment from Yorktown Creek to the Yorktown Weapons Station and from Indian Field Creek almost to King Creek/Felgates Creek (Figure 2-4). The low sandy shoreline banks from the Yorktown Weapons Station to Indian Field Creek are mostly fill, placed when the Parkway was constructed. These have intermittent, low rock revetments along their extent. A concrete block breakwater system, installed in 1985 as a demonstration project, can be seen as you pass from high to low bank going northwest along the Parkway (Hardaway *et al*., 2006).

The Yorktown waterfront has had a long history including a significant colonial occupation as a commercial waterfront, staging area during the Civil War, and more recently,

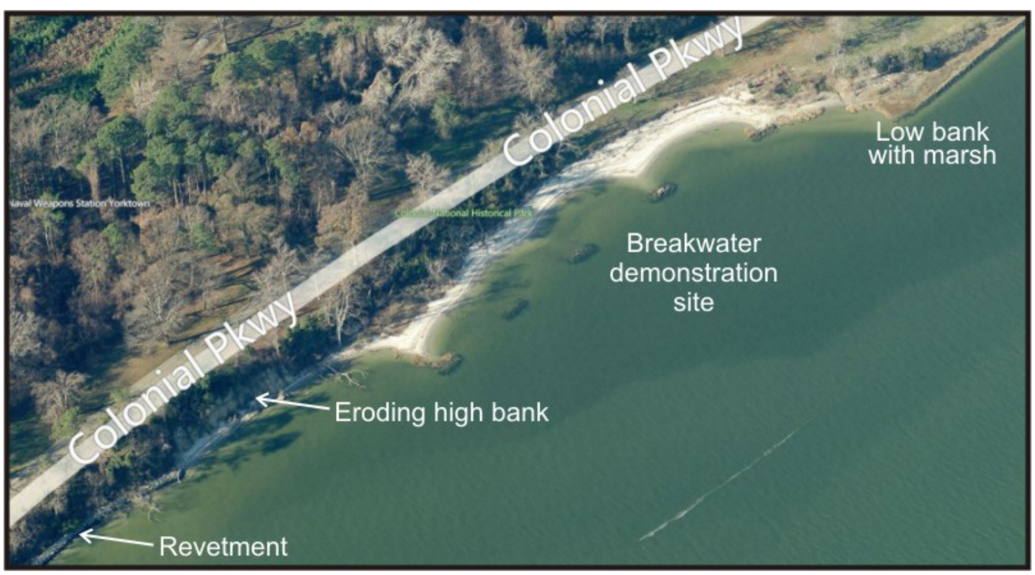


Figure 2-4. *Upland bank with revetment, an eroding high bank along the National Park Service's Colonial Parkway.*

a revised commercial landscape. The post WWII era saw the slow decline of the waterfront at Yorktown as the Ferry was replaced by the Coleman Bridge, and the beach eroded away. In the mid-1990s, waterfront revitalization began as breakwaters and beach nourishment were placed to restore the beach. This followed a master plan (Sasaki *et al.*, 1993) that resulted in over 4,000 feet of shoreline protected with breakwaters and beach fill that provided enhanced recreational access (Figure 2-5). Shops and restaurants along with a two-story parking garage were built along the shore. Other commercial interests, restaurants, and a hotel benefited from the Plan. More detailed information on Yorktown can be found in Hardaway *et al*., 2005; Milligan *et al*., 1996; and Milligan *et al.*, 2005).

From Yorktown to Wormley Creek the shoreline is high banks and mostly hardened by stone revetments (Figure 2-6). This shore reach also includes the U.S. Coast Guard Base which is protected by both a stone revetment and a high bulkhead. Farther alongshore toward Wormley Creek, the Suffolk Scarp, an ancient high stand of sea level that occupied a position along the Virginia and North Carolina coastal plains and intersects the York River just downriver of the Coast Guard Station. It separates the older Chuckatuck Formation (Qc) and Shirley Formation (Qsh) from the younger units of the Tabb Formation (Figure 2-2). This scarp is significant because the topography drops from 50 feet down to about 10 feet above sea level.

Wormley Creek occupies a unique position in the landscape at the foot of the Suffolk Scarp. Within the Wormley Creek watershed, the shoreline banks (30 to 50 feet) drain the higher uplands within and west of the Suffolk Scarp and along the York River. The shorelines along Wormley Creek are characterized by relatively steep vegetated high banks with narrow marsh fringes (Figure 2-7). Shore erosion is low, <0.5 feet/year. The neck between the branches of

Figure 2-5. *Yorktown breakwaters and beach nourishment project. Photo date 17 Oct 2010.*

Figure 2-6. *The shoreline between Yorktown and Wormley Creek generally has high banks that are hardened with stone revetments. Photo date 24 Jul 2013.*

Figure 2-7. *Steep, vegetated banks with narrow fringe marsh in Wormley Creek. Photo date 23 Jul 2013.*

Wormley Creek is mostly residential with many shorelines hardened even though erosion rates are very low (Figure 2-8).

Figure 2-8. *Low upland bank in a residential area that has a rock revetment for shore protection behind a fringe marsh*

Eastward from Wormley Creek along the York River, the shoreline banks are exposed strata of the Qts, which consists of fine silty sands and is only about 10 feet high. Most of the property along the north shore of Goodwin Neck is commercial. Historic erosion rates are low (0 to -2 feet/year) along shorelines that have been hardened over time and higher (up to -5 feet/year) along unprotected shorelines. The Thorofare separates Goodwin Neck from Goodwin Islands. Constant shoaling of the navigation channel requires maintenance dredging with the material being placed on Goodwin Islands.

Broad tidal marshes of Holocene age (Qm) occupy the open bay shoreline. Goodwin Islands, at the confluence of Chesapeake Bay and the York River, and Crab Neck have extensive salt-marsh surrounded by inter-tidal flats and extensive submerged aquatic vegetation (SAV), and shallow open estuarine waters. Salt marsh vegetation is dominated by salt marsh cordgrass *(Spartina alterniflora)* and salt meadow hay *(Spartina patens)*. Pleistocene outcrops form the highest elevations at Goodwin Island. These forested wetland ridges are dominated by estuarine scrub/shrub vegetation.

Back Creek, Chisman Creek, and the Poquoson River shorelines are highly developed, residential areas. Since it is eastward of the Suffolk Scarp, the elevations are relatively low (<5-10 feet) leaving properties susceptible to storm surge. Erosion rates also are low with the majority of shorelines having erosion rates of less than 1 foot per year in the areas with very little fetch. Toward the mouths of the creeks/rivers, increased fetch exposure increases the risk of shoreline erosion. Main Bay shorelines are eroding at a rate of up to -5 feet/year. Even though erosion rates are smaller in the creeks, erosion control structures are widely dispersed along shoreline properties (Figure 2-9).

Figure 2-9. *Low upland bank in a low-energy residential area that has a rock revetment for shore protection. Photo date 25 Jul 2013.*

2.2 Coastal Hydrodynamics

2.2.1 Wave Climate

Shoreline change (erosion and accretion) is a function of upland geology, shore orientation and the impinging wave climate (Hardaway and Byrne, 1999). Wave climate refers to averaged wave conditions as they change throughout the year. It is a function of seasonal winds as well as extreme storms. Seasonal wind patterns vary. From late fall to spring, the dominant winds are from the north and northwest. During the late spring through the fall, the dominant wind shifts to the southwest. Northeast storms occur from late fall to early spring (Hardaway and Byrne, 1999).

The wave climate of a particular site depends not only on the wind but also the fetch, shore orientation, shore type, and nearshore bathymetry. Fetch, the distance over which wind can blow to generate waves, can be used as a simple measure of relative wave energy acting on shorelines. Hardaway and Byrne (1999) suggested three general categories based on average fetch exposure:

Low-energy shorelines have average fetch exposures of less than 1 nautical mile and are mostly found along the tidal creeks and small rivers.

Medium-energy shorelines have average fetch exposure of 1 to 5 nautical miles and typically occur along the main tributary estuaries;

High-energy shorelines have average fetch exposures of over 5 nautical miles and occur along the main stem of the bay and mouth of tributary estuaries;

The York River and Chesapeake Bay shorelines are high-energy shorelines while their tributaries are relatively low energy. Inside the tributaries at their mouth, shoreline may be medium energy.

Basco and Shin (1993) described the wave climate along the York County coast for use in planning and designing structures. Their analysis utilized moderate winds of 35 miles per hour to generate waves with characteristics that could be expected to impact the coast about once every two years. The storm surge for this event is about 2.5 feet above mean high water or about 4.8 feet above mean low water. From their findings, wave heights and wave periods tend to decrease up the York River (Figure 2-10). Downriver of Yorktown, wave heights and periods could be 5 feet and 4.5 seconds. This decreases to a 3 foot wave that is 3.4 seconds. Along the Chesapeake Bay shoreline, waves are between 5.5 and 6 feet.

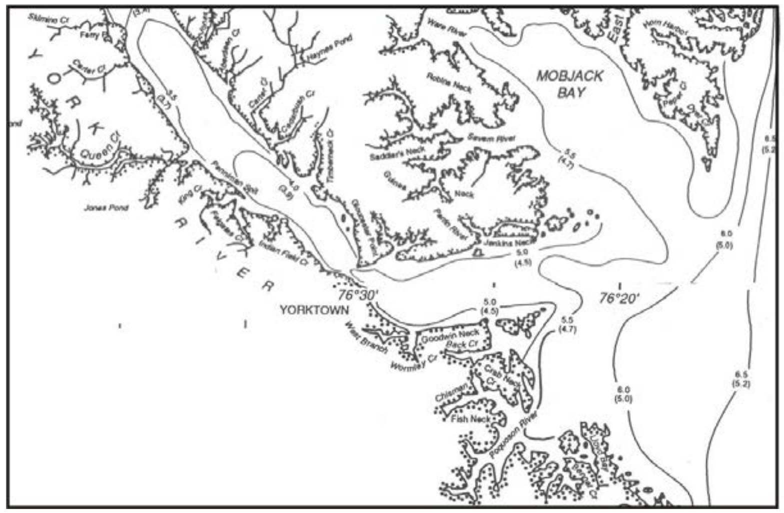


Figure 2-10. Predicted wave heights that would result from a 35 mph wind during a possible 2-yr event. (From Basco and Shin, 1993). Wave heights and period (in parentheses) are shown.

Storm surge frequencies described by FEMA (2009) are shown in Table 2-1. These show the 10%, 2% 1% and 0.2% chances of water levels attaining these elevations for any given year along York County's shorelines. These percentages correspond to a 10 year, 50 year, 100 year, and 500 year event. The mean tide range in York County at the USCG Training Station is 2.3 feet.   For a given storm, maximum wind speeds and direction also are important when developing shoreline management strategies, particularly in regard to determining the level of shore protection needed at the site.

Location	Annual Chance (feet MLLW)			
	10%	2%	1%	0.2%
Shoreline from York River to Poquoson River – includes Back Creek, Chisman Creek, Back Creek, Chisman Creek, and Poquoson River	5.9	7.5	8.1	9.7
Shoreline from Mouth to Amoco Tank Farm Docking Facilities	5.9	7.5	8.1	9.7
Shoreline from Amoco Tank Farm Docking Facilities to Coleman Memorial Bridge (U.S. Route 17)	5.8	7.3	8.0	9.8
Shoreline above Coleman Memorial Bridge (U.S. Route 17)	5.6	7.1	7.9	9.9

Table 2-1. *10 year, 50 year, 100 year, and 500 year storm predicted flood levels relative to MLLW (1983-2001). Source: York County Flood Report, FEMA (2009). Converted from NGVD using NOAA's online program VERTCON and published online datums.*

In York County, the 100 year and 500 year events, as described by FEMA and found in the York County Comprehensive Plan (York County, 2013), are depicted and show the coastal regions that would be impacted (Figure 2-11). Most of the areas impacted are found along the tidal creeks and along the Bay coast. Since the areas on the open York River have higher banks, they do not flood. They are, however, exposed to higher wave energies during storms.

2.2.2 Sea-Level Rise

On monthly or annual time scales, waves dominate shore processes and, during storm events, leave the most obvious mark. However, on time scales approaching decades or more, sea level rise is the underlying and persistent force responsible for shoreline change. Recent trends based on wave gauge data at Yorktown show the annual rate to be 1.25 feet/100 years (3.81 mm/year). The historic rate at Sewells Point (1.44 feet/100 years) will result in 0.53 feet rise in water level by 2050. Boon (2012) predicted future sea-level rise by 2050 using tide gauge data from the East Coast of the U.S. Sewells Point has a projected sea-level rise of 2.03 feet (0.62 m +/- 0.22m) by 2050. This increase in sea-level warrants ongoing monitoring of shoreline condition and attention in shoreline management planning.

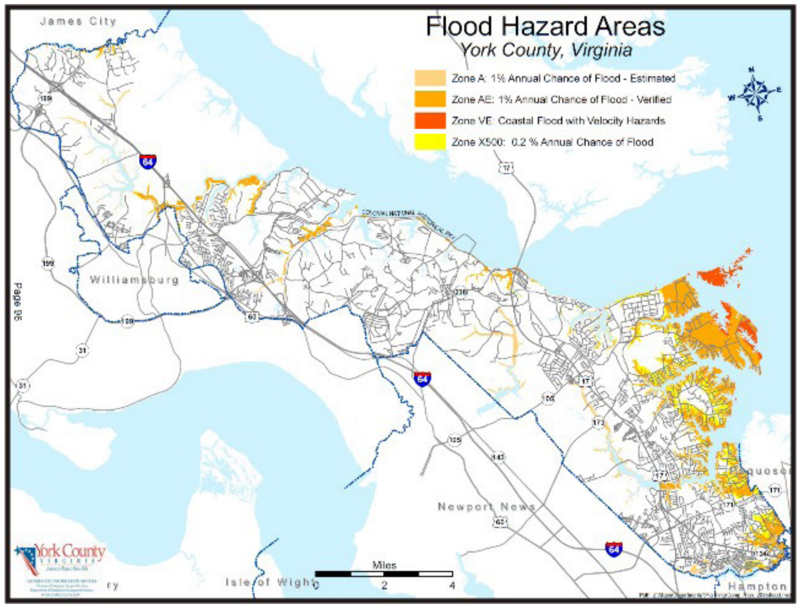


Figure 2-11. Map of the FEMA floodplains for the 100 year and 500 year events (York County, 2013).

2.2.3 Shore Erosion

Shoreline erosion results from the combined impacts of waves, sea level rise, tidal currents and, in some cases, boat wakes and shoreline hardening. Table 2-2 shows the average shoreline rates of change for various areas throughout the County. As expected, the greatest rates of shoreline change occur along the Chesapeake Bay shoreline which, in at least one area, had an erosion rate of almost -12 feet per year (Milligan *et al.*, 2010).

Location	Average	Maximum	Minimum
County-Wide	-0.8	4.0	-11.7
York River West of Yorktown	-0.7	2.4	-3.7
York River East of Yorktown	-1.0	4.0	-5.2
Chesapeake Bay	-0.8	1.8	-11.7

Table 2-2. *End Point rate of change (1937-2007) for York County's shoreline. The rates of change are given in feet per year. From Milligan* et al.*, (2010).*

The shorelines along the tidal creeks east of Yorktown, including Back Creek, Chisman Creek, and Poquoson River, generally have less than 1 mile of fetch and are highly developed. Shoreline change is mostly less than -1 feet/year in these areas. Over the last 50-60 years, shoreline hardening has been the most common management solution to shoreline erosion. After years of study and review, we now understand the short and long term consequences to those choices, and there is growing concern that the natural character of the shoreline cannot be preserved in perpetuity if shoreline management does not change.

3 Shoreline Best Management Practices

3.1 Implications of Traditional Erosion Control Treatments

Following decades of shoreline management within the constraints of Virginia's evolving regulatory program, we have been afforded the opportunity to observe, assess, monitor and ultimately revise our understanding of how the natural system responds to perturbations associated with traditional erosion control practices. Traditional practices include construction of bulkheads, concrete seawalls, stone revetments, and the use of miscellaneous materials purposefully placed to simulate the function that revetments or bulkheads perform. These structures have been effective at stabilizing eroding shoreline; however, in some places, the cost to the environment has been significant and results in permanent loss of ecosystem function and services.

For example, bulkheads constructed close to the water correlate with sediment loss and high temperatures in the intertidal zone, resulting in impacts to organisms using those areas (Spalding and Jackson, 2001; Rice *et al*. 2004; Rice, 2006). The reduction of natural habitat may result in habitat loss if the bulkhead cannot provide substitute habitat services. The deepening of the shallow water nearshore produced by reflective wave action could reduce habitat available for submerged grass growth.

Less is known about the long-term impacts of riprap revetments. Believed to be a more ecological treatment option than bulkheads, when compared with natural systems, riprap tends to support lower diversity and abundance of organisms (Bischoff, 2002; Burke, 2006; Carroll, 2003; Seitz *et al*., 2006). The removal of riparian vegetation as well as the intertidal footprint of riprap has led to concern over habitat loss to the coastal ecosystem (Angradi *et al*., 2004).

3.2 Shoreline Best Management Practices – The Living Shoreline Alternative

As Virginia begins a new era in shoreline management policy, Living Shorelines move to the forefront as the preferred option for erosion control. In the recent guidance developed by the Center for Coastal Resources Management at the Virginia Institute of Marine Science (CCRM,2013), Shoreline Best Management Practices (Shoreline BMPs) direct managers, planners, and property owners to select an erosion control option that minimizes impacts to ecological services while providing adequate protection to reduce erosion on a particular site. Shoreline BMPs can occur on the upland, the bank, or along the shoreline depending on the type of problem and the specific setting.

Table 3-1 defines the suite of recommended Shoreline BMPs. What defines a Living Shoreline in a practical sense is quite varied. With one exception, all of the BMPs constitute a Living Shoreline alternative. The revetment is the obvious exception. Not all erosion problems can be solved with a Living Shoreline design, and in some cases, a revetment is more practical. Most likely, a combination of these practices will be required at a given site.

3.3 Non-Structural Design Considerations

Elements to consider in planning shoreline protection include: underlying geology, historic erosion rate, wave climate, level of expected protection (which is based on storm surge and fetch), shoreline length, proximity of upland infrastructure (houses, roads, etc.), and the onsite geomorphology which gives an

Upland Shoreline BMPs	Shoreline BMPs
No Action Needed	No Action Needed
Land Use Management	Enhance/Maintain Marsh Buffer
Forest Management	Widen Marsh
Enhance/Maintain Riparian	Enhance/Maintain Beach
Grade Bank	Plant Marsh with Sill
	Beach Nourishment
	Groin Field with Beach Nourishment
	Offshore Breakwaters with Beach Nourishment
	Revetment

Table 3-1. *Shoreline Best Management Practices.*

individual piece of property its observable character (e.g. bank height, bank slope). These parameters along with estimated cost help determine the management solution that will provide the best shore protection.

In low energy environments, Shoreline BMPs rarely require the use of hard structures. Frequently the intent of the action is to stabilize the slope, reduce the grade and minimize under cutting of the bank. In cases where an existing forest buffer is present a number of forest management practices can stabilize the bank and prevent further erosion (Figure 3-1). Enhancing the existing forest condition and erosion stabilization services by selectively removing dead, dying and severely leaning trees, pruning branches with weight bearing load over the water, planting and/or allowing for re-generation of mid-story and ground cover vegetation are all considered Living Shoreline treatment options.

Enhancement of both riparian and existing marsh buffers together can be an effective practice to stabilize the coastal slope (Figure 3-2) from the intertidal area to the upland by allowing plants to occupy suitable elevations in dynamic fashion to respond to seasonal fluctuations, shifts in precipitation or gradual storm recovery. At the upland end of the slope, forest buffer restoration and the planting of ornamental grasses, native shrubs and small trees is recommended. Enhancement of the marsh could include marsh plantings, the use of sand fill necessary to plant marsh vegetation, and/or the need for fiber logs to stabilize the bank toe and newly established marsh vegetation.

In cases where the bank is unstable, medium or high in elevation, and very steep, bank grading may be necessary to reduce the steepness of bank slopes for wave run-up and to improve growing conditions for vegetation stabilization (Figure 3-3). The ability to grade a bank may be limited by upland structures, existing defense structures, adjacent property conditions, and/or dense vegetation providing desirable ecosystem services.

Figure 3-1. *One example of forest management. The edge of the bank is kept free of tree and shrub growth to reduce bank loss from tree fall.*

Figure 3-2. *Maintaining and enhancing the riparian and marsh buffers can maintain a stable coastal slope*

Figure 3-3. B*ank grading in Westmoreland County reduces steepness and will improve growing conditions for vegetation stabilization.*

Bank grading is quite site specific, dependent on many factors but usually takes place at a point above the level of protection provided by the shore protection method. This basal point may vary vertically and horizontally, but once determined, the bank grade should proceed at a minimum of 2:1 (2Horizontal:1Vertical). Steeper grades are possible but usually require geotechnical assistance of an expert. Newly graded slopes should be re-vegetated with different types of vegetation including trees, shrubs and grasses. In higher energy settings, toe stabilization using stone at the base of the bank also may be required.

Along the shoreline, protection becomes focused on stabilizing the toe of the bank and preventing future loss of existing beach sand or tidal marshes. Simple practices such as: avoiding the use of herbicides, discouraging mowing in the vicinity of the marsh, and removing tidal debris from the marsh surface can help maintain the marsh. Enhancing the existing marsh by adding vegetation may be enough (Figure 3-4).

***Figure 3-4**. This low-energy site had minor bank grading, sand added, and* Spartina alterniflora *planted. This photo shows the site after 24 years.*

In medium energy settings, additional shore protection can be achieved by increasing the marsh width which offers additional wave attenuation. This shoreline BMP usually requires sand fill to create suitable elevations for plant growth. Marshes are generally constructed on slopes between 8:1 and 14:1, but average about 10:1 (for every 10 ft in width, the elevation changes by 1 foot) (Hardaway *et al.*, 2010). Steeper systems have less encroachment into the nearshore but may not successfully stabilize the bank because the marsh may not attenuate the waves enough before they impact the bank. Shallower, wider systems have more encroachment but also have the advantage of creating more marsh and attenuating wave energy more effectively. Determining the system's level of protection, i.e. height and width, is the encroachment.

If the existing riparian buffer or marsh does not need enhancement or cannot be improved, consider beach nourishment if additional sand placed on the beach will increase the level of protection. Beach nourishment is the placement of good quality sand along a beach shoreline to increase the beach width and raise the elevation of the nearshore area. New sand should be similar in grain size or coarser than the native beach sand. Enhancing and maintaining existing beaches preserves the protection that beaches offer to the upland as sands move naturally under wave forces and wind energy. This encourages beach and dune formation which can further be enhanced and stabilized with beach and dune plants.

Where bank and/or shoreline actions are extremely difficult or limited in effectiveness Land Use Management may be required to reduce risk. Practices and strategies may include: relocate or elevate buildings, driveway relocation, abandon or relocate sanitary drainfields, or hook-up to public sewer. All new construction should be located 100 feet or more from the top of the bank. Re-directing stormwater runoff away from the top of the bank, or re-shaping the top of the bank may also assist in stabilizing the bank.

Creating a more gradual slope can involve encroaching into landward habitats (banks, riparian, upland) through grading and into nearshore habitats by converting existing sandy bottom to marsh or rock. These and other similar actions may require zoning variance requests for setbacks, and/or relief from other land use restrictions that increase erosion risk. Balancing the encroachment is necessary for overall shoreline management.

3.4 Structural Design Considerations

In medium to high energy settings, suitable "structural" Living Shoreline management strategies may be required. For York County these are marsh sills constructed of stone and offshore breakwaters.

3.4.1 Sills

As fetch exposure increases beyond about 1,000 ft and the intertidal marsh width is not sufficient to attenuate wave action, the inclusion of a retaining structure may be required to allow newly planted marsh grasses to become established or to prevent sand from being transported away from the site. This is where a low marsh sill is appropriate.

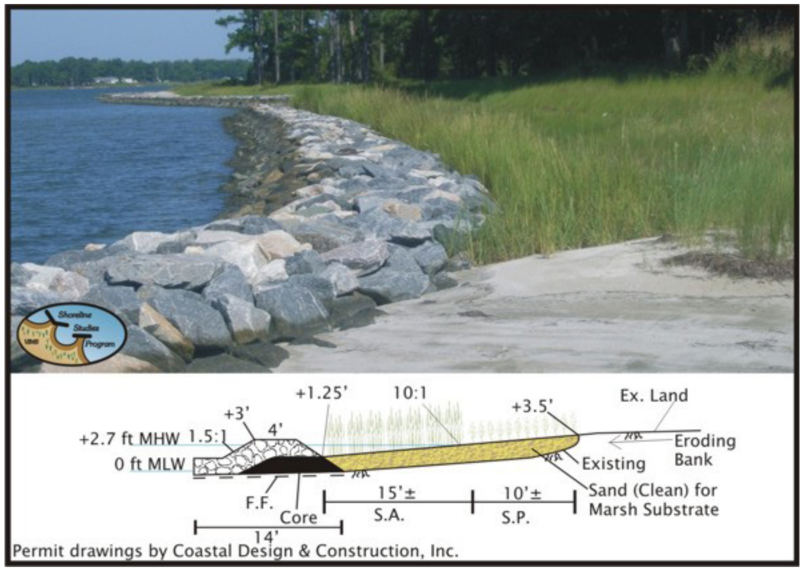


***Figure 3-5.** Sand fill with stone sills and marsh plantings at Poplar Grove, Mathews County, Virginia after six years and the cross-section used for construction (From Hardaway* et al.*, 2010).*

The stone sill has been used extensively in the Chesapeake Bay over the years (Figure 3-5). It is a rock structure placed parallel to the shore so that a marsh can be planted behind it. The cross-section in Figure 3-5 shows the sand for the wetlands substrate on a slope approximating 10:1 from the base of the bank to the back of the sill. The elevation of the intersection of the fill at the bank and tide range will determine, in part, the dimensions of the sill system. If the nearshore depth at the location of a sill is greater than 2 feet, it might be too expensive for a sill relative to a revetment at that location. Nevertheless, the preferred approach would still be the marsh sill.

Hardaway and Byrne (1999) indicate that in low wave energy environments, a sill should be placed at or near MLW with sand fill extending from about mean tide level on a 10:1 to the base of an eroding bank. The height of the rock sill should be at least equal to mean high water to provide adequate backshore protection. Armor stone should be VA Class I. A recent installation of a sill in a low energy environment in Westmoreland County was on Glebe Creek at Hull Springs Farm (Figure 3-6). The Hull Springs Farm sill was built in 2008 along about 300 feet of shoreline. The sand fill begins at +3 feet on the bank and old bulkhead and extends on a 10:1 slope to about mid-tide (+0.8 ft mean low water) at the back of the sill. This provides planting widths of about 10 feet for *Spartina alterniflora* and 12 feet for *Spartina*

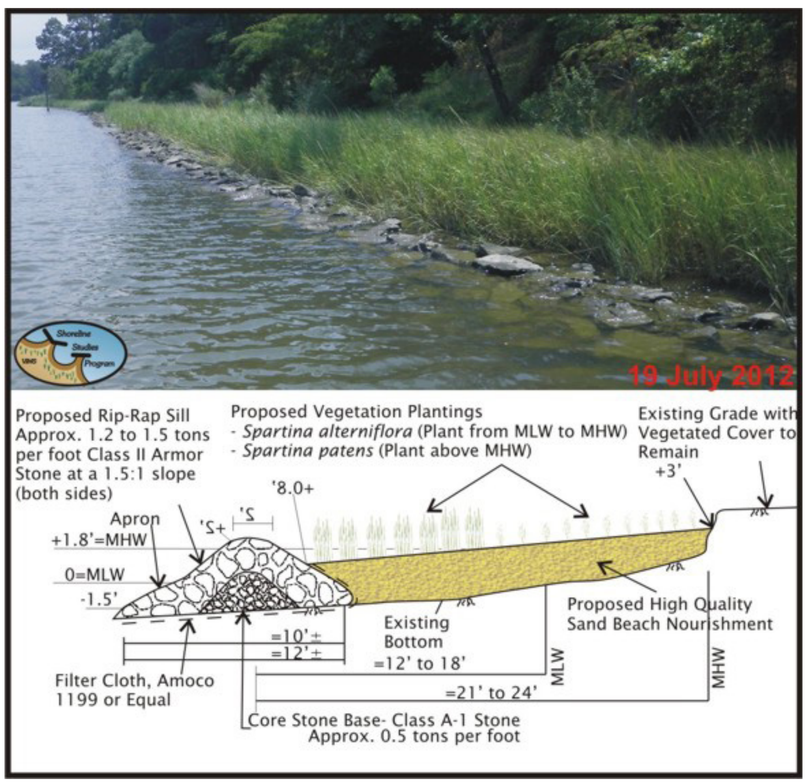


***Figure 3-6.** Longwood University's Hull Springs Farm four years after construction and the cross-section used for construction (from Hardaway* et al.*, 2010).*

patens (Hardaway *et al.*, 2010a). The sill system was built in August 2008 and went through the Veteran's Day Northeaster (2009) with no impacts to the unprotected base of bank. Marsh fringes were heavily covered with snow and ice during the winter of 2009 but reemerged intact.

For medium energy shorelines, sills should be placed far enough offshore to provide a 40 foot wide (low bank) to 70 foot wide (high bank) marsh fringe (Hardaway and Byrne, 1999). This distance includes the sill structure and is the width needed to attenuate wave action during seasonal storms. During extreme events when water levels exceed 3 feet above mean high water, some wave action (>2 feet) may penetrate the system. For this reason, a sill height of a least 1 foot above mean high water should be installed. Armor stone may be Class II (< 2 miles) to Class III (up to 5 miles).

Sills on high energy sites need to be very robust. Impinging wave heights can exceed 3 feet. Maintaining a vegetative fringe can be difficult. Therefore sill heights should be at least 2 feet above mean high water (MHW). The minimum size for armor stone should be Class III. A sill used along a high energy coast occurs at Westmoreland State Park (Figure 3-7). Placed along a very high eroding bluff this system will act to capture bank slump and may eventually lead to some bluff stability.

Figure 3-7. *High sills built along Westmoreland State Park's high energy, high bank shoreline. The material that slumps from the bank will be caught behind the sills and stabilize the base of the bank by protecting it from wave attack. A more recent photo shows that the slump material is starting to become vegetated.*

Any addition of sand or rock seaward of mean high water (MHW) requires a permit. A permit may be required landward of MHW if the shore is vegetated. As the energy environment increases, shoreline management strategies must adapt to counter existing erosion problems. While this discussion presents structural designs that typically increase in size as the energy environment increases, designs remain consistent with the Living Shoreline approach wherever possible. In all cases, the option to "do nothing" and let the landscape respond naturally remains a choice. In practice, under this scenario, the risk to private property frequently outweighs the benefit for the property owner. Along medium energy and high energy shorelines, a breakwater system can be a cost-effective alternative for shoreline protection.

3.4.2 Breakwaters

Breakwaters are a series of large rock structures placed strategically offshore to maintain stable pocket beaches between the structures. The wide beaches provide most of the protection, so beach nourishment should be included as part of the strategy and periodic beach re-nourishment may be needed.

Although single breakwaters can be used, two or more are recommended to address several hundred feet of coast. For breakwaters, the level of protection changes with the system dimensions such that larger dimensions generally correspond to bigger fetches and where a beach and dune shoreline is desired. Hardaway and Gunn (2010) and Hardaway and Gunn (2011) provide detailed research on the use of breakwaters in Chesapeake Bay.

Hardaway and Byrne (1999) suggest that breakwater systems in medium energy environments should utilize at least 200 feet of shoreline, preferably more, because individual breakwater units should have crest lengths of 60 to 150 feet with crest heights 2 to 3 feet above mean high water. Minimum mid-bay beach width should be 35-45 feet above mean high water. On high energy coasts, the mid-bay beach widths should be 45 to 65 feet especially along high bank shorelines. Crest lengths should be 90 to 200 feet. Armor stone of Class III (500 lbs.) is a minimum, but up to Type I (1500 to 4000 lbs.) may be required especially where a deep near shore exists.

Several breakwater examples occur in York County. Historically, the beach at Yorktwon was the result of erosion of nearby sandy upland banks which was transported alongshore. Over the years, the beaches along the waterfront began to narrow as the natural sediment supply was depleted by hardening of the updrift shorelines and the continued overwash during storms (Figure 3-8). Since 1978, various projects have taken place along Yorktown's shoreline in order to abate erosion, provide a recreational beach, and minimize damage to the upland during storms. Between 1994 and 2004, seven breakwaters with beach fill were installed along the shoreline (Figure 3-9). These structures have created a stable beach planform along the main recreational beach that was designed to withstand a 50-yr storm event. The shops and piers began construction in 2004, and required modification to the breakwaters along that section of shore. The additional breakwaters upriver of the Coleman Bridge were constructed in early 2005 as a structure downriver of the pier at the end of Comte de Grasse Street. An additional breakwater with pipes to stabilize the flow of Yorktown Creek was constructed in June 2006.

Figure 3-8. *Photo taken at Yorktown during a spring storm. The low coast was easily overwashed.*

Figure 3-9. *The breakwaters at Yorktown provide a wide recreational beach as well as storm erosion protection for the business district. These structures were phased in beginning in 1994. 2011 Virginia Base Mapping Program Image.*

Another headland breakwater system in York occurs at the confluence of Cabin Creek and the Poquoson River (Figure 3-10). This property is privately owned, and the system represents the use of breakwaters and sill to create a Living Shoreline that includes an enhanced beach/dune system on the open River/Bay exposure that transitions to a sill system along the more fetch-limited creek shoreline. A small inlet also was stabilized in order to protect a pocket tidal marsh on the property. The pre-project shoreline consisted of a broken concrete revetment around the peninsula shaped property. Much of that was incorporated as core material in the stone breakwaters and sill systems.

Figure 3-10. *Headland breakwaters at the confluence of Cabin Creek and the Poquoson River. These structures were built relatively closely-space to provide a recreational beach as well as to protect the upland. Left: A 2011 Virginia Base Mapping Program image shortly after installation. Right: Photo taken in July 2013. Planted beach grasses have thrived at the site.*

In most cases, breakwater construction includes the addition of sand between the stone breakwater and the shore. In lower energy settings, sand may be vegetated. The backshore region should be planted in appropriate dune vegetation. In higher energy settings, the nourished sand will be re-distributed, naturally under wave conditions. In some areas, additional nourishment may be required periodically in response to storms, or on some regular schedule.

4 Methods

4.1 Shore Status Assessment

The shore status assessment was made from a small, shallow draft vessel, navigating at slow speeds parallel to the shoreline during five field days between July and September 2013. Existing conditions and suggested strategies were noted on maps which were transcribed in the office to display in GIS. Once the data were compiled and evaluated, the preferred strategies were subjected to further analysis utilizing other collected data, including the condition of the bank face and toe, marsh width, landscape type, and GPS-referenced photos. The results of this analysis were compared to the results of the model described below.

4.2 Geospatial Shoreline Management Model

The Shoreline Management Model (SMM) is a geo-spatial tool that was developed to assess Shoreline Best Management Practices (Shoreline BMPs) comprehensively along tidal shoreline in Virginia. It is now necessary to provide recommended shoreline strategies that comply with an ecosystem based approach. The SMM has the capacity to assess large geographic regions quickly using available GIS data.

The model is constructed using multiple decision-tree pathways that lead the user to a final recommended strategy or strategies in some cases. There are four major pathways levels. The pathways are determined based on responses to questions that determine onsite conditions. Along the upland and the bank, the model queries a site for bank stability, bank height, presence of existing infrastructure, land use, and whether the bank is defended to arrive at an upland management strategy. At the shore the model queries a site for presence and condition of beaches, marshes, the fetch, nearshore water depth, presence of specific types of erosion control structures, and creek setting to drive the shore recommendations. Appendix 1 illustrates the logic model structure.

The responses are generated by searching site specific conditional geospatial data compiled from several sources representing the most current digital data available in shapefile and geodatabase formats (Table 4-1). As indicated in Table 4-1, the majority of these data are

Dataset	Origin	Contribution	Variables
Shoreline Inventory	Comprehensive Coastal Inventory (CCI), Center for Coastal Resources Management (CCRM), Virginia Institute of Marine Science (VIMS)	bank erosion	stable, erosional, defended
		riparian land use	forested
		bank height	0-30 feet, 30-60 feet, >60 feet
		beach	presence or absence
		erosion protection structures	defended; groin field present
Tidal Marsh Inventory	Center for Coastal Resources Management (CCRM), Virginia Institute of Marine Science (VIMS)	marsh width	absent, present; <15 feet wide, >15 feet wide
Roads	TIGER /Line, U.S. Census Bureau	permanent structure limiting bank grading	present or absent
Permanent Structures	created inhouse (CCI) for project, unpublished	permanent structure limiting bank grading	present or absent
Fetch	Comprehensive Coastal Inventory (CCI), Center for Coastal Resources Management (CCRM), Virginia Institute of Marine Science (VIMS)	fetch (distance to nearest shoreline calculated in 16 directions)	low = 0-0.5 mile; moderate = 0.5 - 2 miles; high = >2 miles.
Non-Jurisdictional Beach Assessment	Shoreline Studies Program, Virginia Institute of Marine Science	wide beach (width > 10 ft)	present or absent
Bathymetry	Special Projects Office of the National Ocean Service, NOAA	nearshore water depth	shallow = 1m bathymetric contour > 10m from shoreline; deep = 1m bathymetric contour <10m from shoreline
Tributary Designation	created inhouse (CCI) for project, unpublished	tidal creek	tidal creek, major tributary, bayfront

Table 4-1. *Shoreline Management Model (SMM) Data Sources and Applications.*

collected and maintained for the York County Shoreline Inventory (http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/virginia/york/york_disclaimer.html) developed by CCRM (Berman *et al.*, 2009). The model is programmed in ESRI's (Environmental Systems Research Institute) ArcGIS version 9.3.1 and version 10 software.

The shoreline inventory dataset contains several attributes required for the SMM that pertain to riparian land use, bank height, bank erosion, presence of beach, existing shoreline protection structures and marshes. Other data sources provide information on nearshore depth, exposure to wave energy, marsh condition, location of beaches, and proximity of roads and permanent structures to the shoreline.

The model is built using ArcGIS Model Builder and has 13 major processing steps. Through the step-wise process specific conditions, buffers, and offsets may be delineated to accurately assess the impact that a specific condition may have on the model output. For example, a permanent structure built close to the shoreline could prevent a recommendation of bank grading as a best management practice.

To determine if bank grading is appropriate a rough estimate formula that incorporates a 3:1 slope with some padding for variability within a horizontal distance of shoreline and bank top was developed. The shoreline was buffered based on the formula:

((3*mh) + 20) * 0.3048 where:

mh is the maximum height within the inventory height field (0-5 = 5ft; 5-10 = 10ft; 10-30 = 30ft; >30 = 40ft)

20 = is the padding for variability in the horizontal distance between the shoreline and the top of the bank in feet

0.3048 is the conversion from feet to meters.

Shoreline was coded for presence of permanent structures such as roads, houses, out buildings, swimming pools, etc. where observed in recent high resolution imagery to be within the computed buffer.

In the case of determining fetch or exposure to wave energy, the shoreline was divided into 50m segments, and represented by a single point on the line. Fetch distance was measured from the point to the nearest shoreline in 16 directions following the compass rose. The maximum distance over water was selected for each point to populate the model's fetch variable.

Field data from the Shoreline Inventory provided criteria to classify attributes assessed based on height (banks) or width (beaches and marshes) in many cases. Some observations were collected from other datasets and/or measured from high resolution aerial imagery. For example, the Non-Jurisdictional Beach Assessment dataset provided additional beach location data not available in the inventory. To classify beaches for the model as "wide" or "narrow", a visual inspection of imagery from the Virginia Base Map Program (VBMP), Bing, and Google Maps was used to determine where all beaches were wider than 10 feet above the high tide line.

Limitations to the model are primarily driven by available data to support the model's capacity to make automated decisions. If an existing structure is in place and the shoreline is stable, the model bases its decision on a stable shoreline. If an existing structure is in place and the shoreline is unstable, the model will return a recommendation based on the most ecological approach and will not consider the presence of the existing structure. In places where sufficient data are not available to support an automated decision, the shoreline is designated as an "Area of Special Concern". This includes shorelines that are characterized by man-made canals, marinas, or commercial or industrial land uses with bulkheads or wharfs. Marsh islands or areas designated as paved public boat ramps receive a "No Action Needed" recommendation.

The model output defines 14 unique treatment options (Table 4-2) but makes 16 different recommendations which combine options to reflect existing conditions on site and choices available based on those conditions. The unique treatment options can be loosely categorized as Upland BMPs or Shore BMPs based on where the modification or action is expected to occur. Upland BMPs pertain to actions which typically take place on the bank or the riparian upland Shore BMPs pertain to actions which take place on the bank and at the shoreline.

Upland BMPs	Shore BMPs
Enhance Riparian Buffer	Enhance or Maintain Marsh
Forest Management	Widen marsh
Grade Bank	Plant Marsh with Sill
Land Use Management	Enhance or Maintain Beach
	Beach Nourishment
Area of Special Concern	Groin Field with Beach Nourishment
No Action Needed	Offshore Breakwaters with Beach Nourishment
	Revetment
	Area of Special Concern
	No Action Necessary

Table 4-2. *Shoreline Management Model - Preferred Shoreline Best Management Practices.*

5 Shoreline Management for York County

5.1 Shoreline Management Model (SMM) Results

In York County, the SMM was run on 240 miles of shoreline. The SMM provides recommendations for preferred shoreline best management practices along all shoreline. At any one location, strategies for both the upland and the shore may be recommended. It is not untypical to find two options for a given site.

By and large, the majority of shoreline management in York County can be achieved without the use of traditional erosion control structures, and with few exceptions, very little structural control. Nearly 75% of the shoreline can be managed simply by enhancing the riparian buffer or the marsh if present. Since the much of the shoreline resides within protected waters with medium to low energy conditions, Living Shoreline approaches are applicable. Along the open York River shoreline the use of breakwaters with beach nourishment is commonly recommended. However, in some cases beach nourishment alone may be preferred. Table 5-1 summarizes the model output for York County based on strategy(s) and shoreline miles. The glossary in Appendix 2 gives meaning to the various Shoreline BMPs listed in Table 5-1.

To view the model output, the Center for Coastal Resources Management has developed a Comprehensive Coastal Resource Management portal (Figure 5-1) which includes a pdf file depicting the SMM output, an interactive map viewer that illustrates the SMM output as well as the baseline data for the model (http://ccrm.vims.edu/ccrmp/york/index.html).

The pdf file is found under the tab for Shoreline Best Management Practices. The Map Viewer is found in the County Toolbox and uses a Google-type interface developed to enhance the end-users' visualization (Figure 5-2). From the map viewer the user can zoom, pan, measure and customize maps

Shoreline BMPs	Shoreline Length (miles)
Enhance Riparian/Marsh Buffer	11.9
Enhance Riparian/Marsh Buffer OR Beach Nourishment	0.5
Enhance/Maintain Beach	0.1
Enhance/Maintain Marsh	127.0
Enhance/Maintain Riparian Buffer	25.6
Groin Field with Beach Nourishment	0.02
Maintain Beach OR Offshore Breakwaters with Beach Nourishment	16.1
Plant Marsh with Sill	17.6
Revetment	0.02
Widen Marsh	16.2
Widen Marsh/Enhance Buffer	4.3
Area of Special Concern	2.3
No Action Needed	15.8

Table 5-1. Occurrence of descriptive Shoreline BMPs in York County.

Table 5-1. *Occurrence of descriptive Shoreline BMPs in York County*

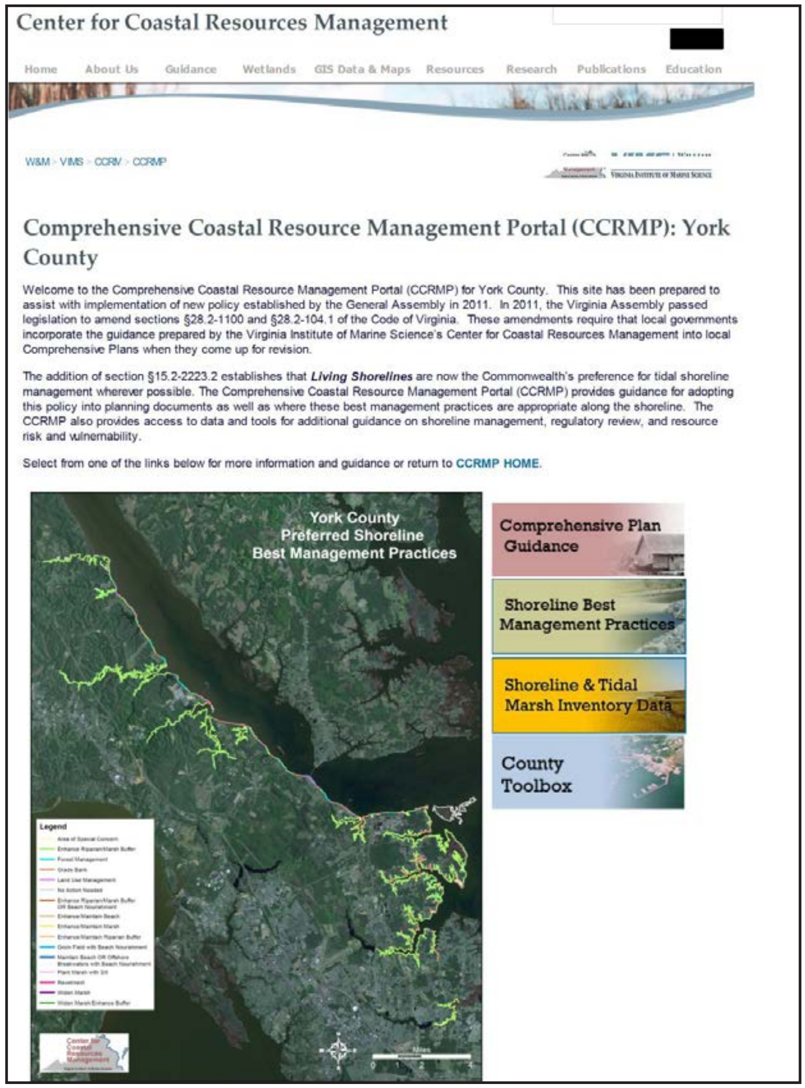


Figure 5-1. *Example of the online portal for Comprehensive Coastal Resource Management in York County.*

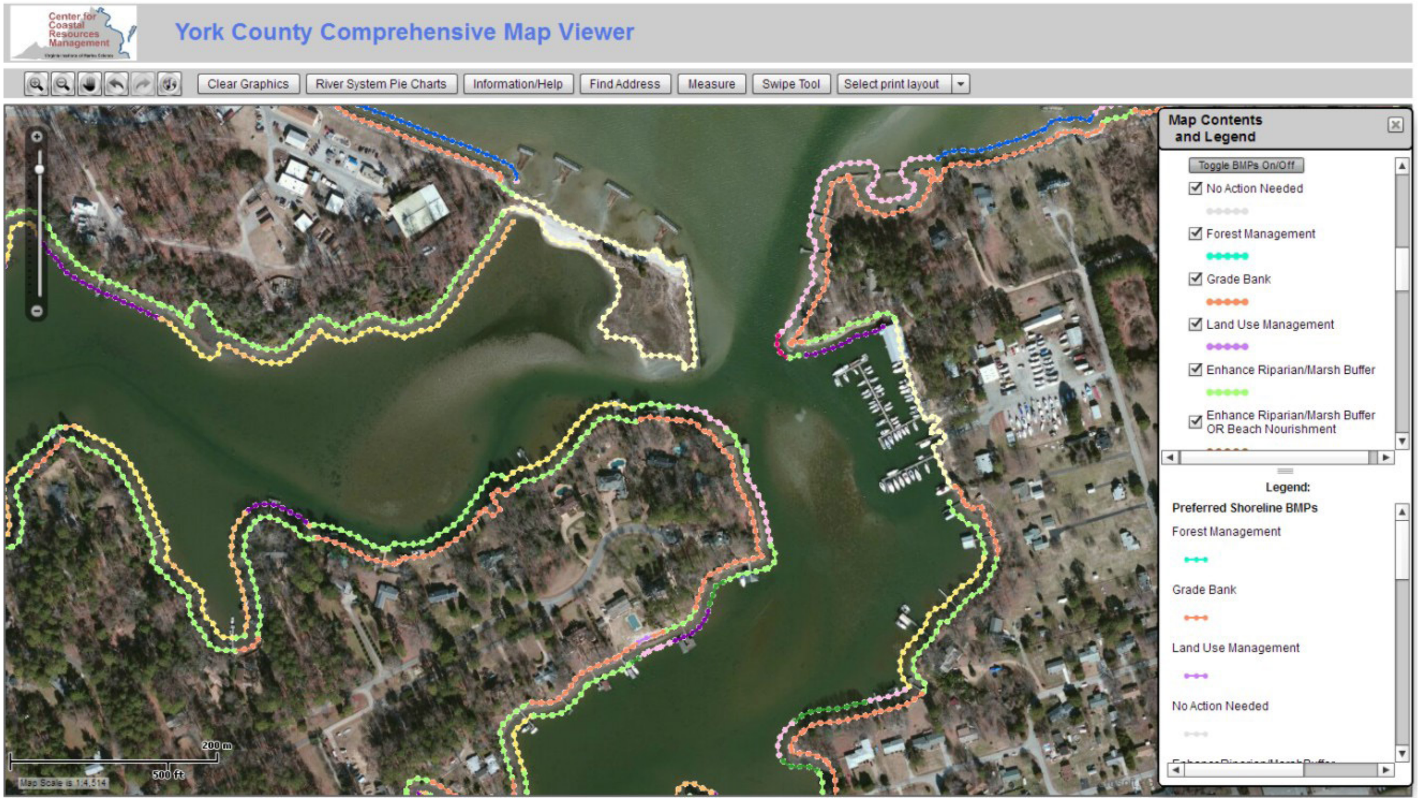


Figure 5-2. *The Map Viewer displays the preferred Shoreline BMPs in the map window. The color-coded legend in the panel on the right identifies the treatment option recommended.*

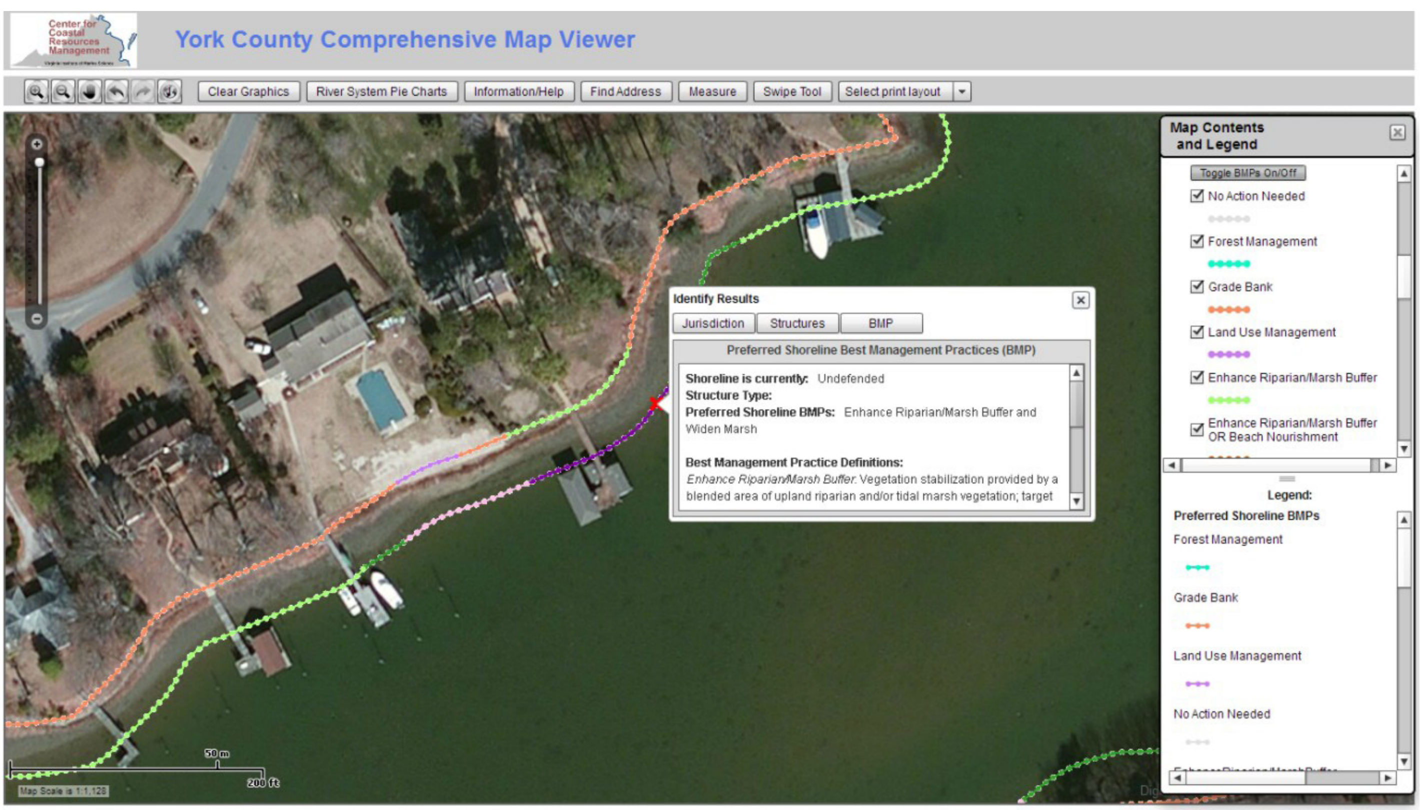


Figure 5-3. *The pop-up window contains information about the recommended Shoreline BMP at the site selected. Additional information about the condition of the shoreline also is given.*

for printing. When "Shoreline Management Model BMPs" is selected from the list in the right hand panel and toggled "on" the delineation of shoreline BMPs is illustrated in the map viewing window. The clickable interface conveniently allows the user to click anywhere in the map window to receive specific information that pertains to conditions onsite and the recommended shoreline strategy. Figure 5-3 demonstrates a pop-up window displayed onscreen when a shoreline segment is clicked in the map window.

Recommended Shoreline BMPs resulting from the SMM comply with the Commonwealth of Virginia's preferred approach for erosion control.

5.2 Shore Segments of Concern/Interest

This section describes several areas of concern and/or interest in York County and demonstrates how the preferred alternative from the SMM could be adopted by the waterfront property owners. The areas of concern and interest demonstrate how the previously discussed goals of Living Shoreline management could be applied to a particular shoreline.

The conceptual designs presented in this section are located in Figure 5-7 and 5-10 and utilize the typical cross-sections that are shown in Appendix 3. The guidance provided in Appendix 3 describes the environments where each type of structure may be necessary and provides an estimated cost per foot. The designs presented are conceptual only; structural site plans should be created in concert with a professional.

5.2.1 Bay Tree Beach Road: Chesapeake Bay (Area of Concern)

Bay Tree Beach Road development is located along the distal, easternmost end of Crab Neck (Figure 2-2). This shore reach extends from Bay Tree Point on the south to Green Point on the north, a length of about 8,000 ft. Bay Tree Road occurs along the southern half of the reach where there are about 11 residences along the northern half and one single resident at the end of the road. That resident currently has breakwaters for shore protection and is not part of the area of concern. The shoreline along the Bay Tree Road subreach presently has a fringing marsh that varies in width with occasional small pocket beaches between marsh headlands. The upland is very low and sandy overwash features occur along most of the shoreline. Most of the residential housing has been raised to avoid storm surge and wave action. The area of concern is in FEMA's VE zone.

In 1937, the area was uninhabited (Figure 5-4). At that time, the shoreline was 80 to 300 feet bayward

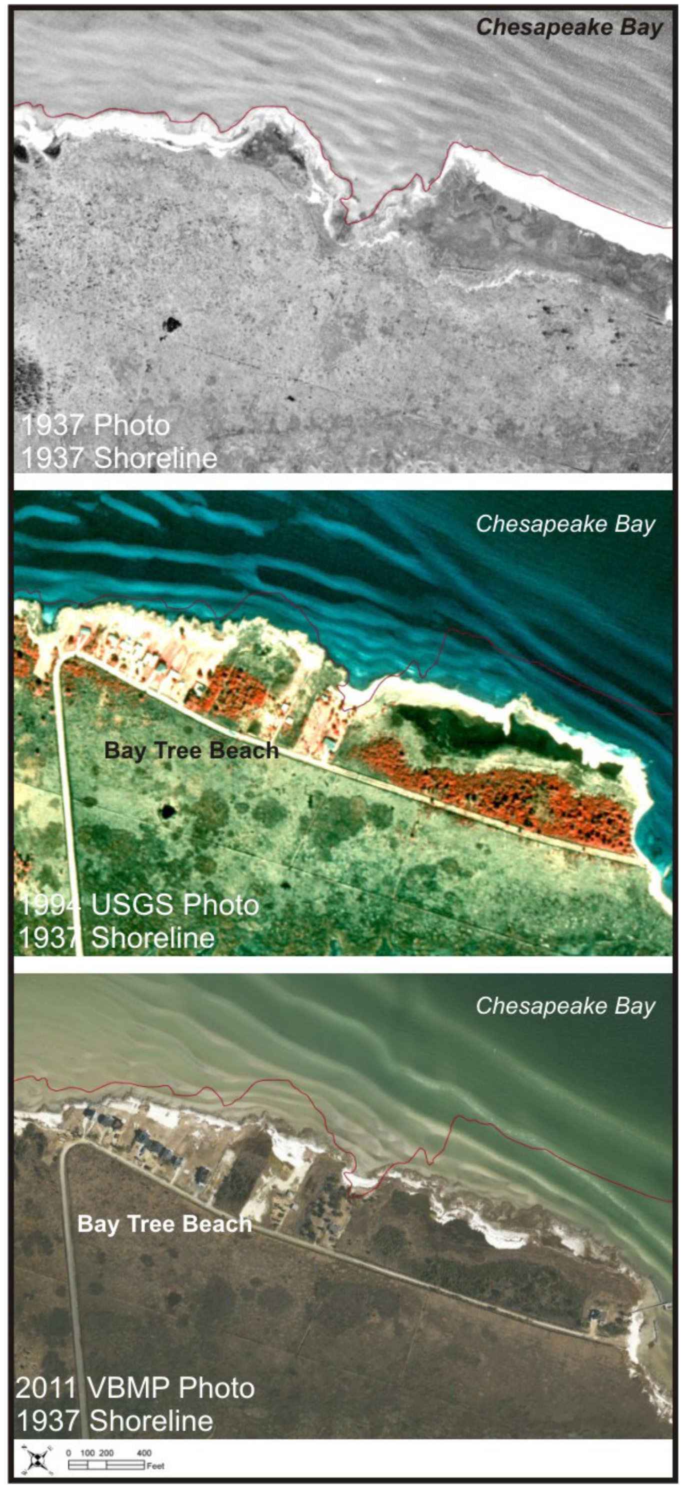


Figure 5-4. *Bay Tree Beach in 1937 (top), 1994 (middle), and 2011 (bottom). This marsh shoreline along Chesapeake Bay has eroded through time leading some residents to install a revetment for shore protection.*

Figure 5-5. *The Bay Tree Beach shoreline consists of eroding marsh headlands and sand washover. A revetment was constructed along the shoreline.*

of its present position. Historic shore erosion has proceeded at a rate of 1 to 4 ft/yr. In 1953, Bay Tree Road existed in its present configuration, crossing the marsh to the shoreline, then bending south. Several lots had been cleared and three houses were built on the north end of the development. More housing was slowly added over time. By 1994, the houses that exist today had been constructed (Figure 5-4). By 2010, a sewer substation was installed at the bend in the road.

Figure 5-6. *Erosion is threatening the sewer pump station for Bay Tree Beach.*

Today, the northern 3 properties have been hardened with stone revetments and the 6th house to the south has some rock in front (Figure 5-5). Ongoing hardening is anticipated. The problem with installing rock on such low land, less than 5 feet mean low water, is that the stone has to be higher than the land. While the revetment provides shore protection, it also limits homeowner access to the water, and ultimately may result in loss of the beach as erosion continues in front of the structure. Another issue is that the erosion on the northern end of the reach is threatening the sewer pump substation (Figure 5-6).

Figure 5-7. *Site-specific application of the Shoreline Management Model recommendation for Bay Tree Beach. The breakwater system will stabilize the shoreline, provide shore protection, and create a recreational beach. The sills will stabilize the marsh.*

The preferred recommendation is a breakwater system (Figure 5-7). Although, expensive, a properly designed and construction headland breakwater system can provide long-term shore protection and create a stable beach/dune system. Even so, on such an exposed and low coast, some maintenance can be expected. The cross-sections for a typical structure and bay beach for this site are shown in Appendix 3, Figure 2B.

5.2.2 Penniman Spit: York River (Area of Interest)

Penniman Spit is located on the York River at the mouth of King Creek and Felgates Creek (Figure 2-1). This spit was once more substantial than its present configuration and size. In 1937, the spit extended across the mouth of King Creek for over 3,000 feet and was over 450 feet at its widest part (Figure 5-8). Between

1937 and 1994, the spit stayed relatively the same length but narrowed by almost 100 feet in some areas. In 2011, the spit had narrowed in some areas by over 200 feet since 1937 and was close to breaching in the center. A 2012 aerial photo shows that the spit has indeed breached and is narrowing near its point of upland attachment (Figure 5-9).

Penniman Spit was formed and is maintained by erosion of upriver sediment banks. Material from the Quaternary formations erodes and is transported downriver in longshore drift. However, many of the shoreline updrift of the spit have been hardened in response to ongoing shore and bank erosion effectively reducing the amount of sand available to the long-shore transport system, and therefore the spit itself. Now that the spit has breached, spit decay will likely accelerate since what sand is available will not cross the breach to feed the end of the spit.

If the existing spit is not stabilized and it continues to erode, the dynamics at the mouths of both King Creek and Felgates Creek may change. Once the spit has been reduced, it will no longer provide protection to the shorelines behind it. Erosion could increase significantly behind it, particularly at the exposed Colonial Parkway shoreline near the bridge across Felgates Creek. This shoreline presently is protected from the north and northwest by Pennimans Spit. During extratropical northeast storms, the winds and therefore the waves rotate around to the north and northwest as the storm moves through the area. Presently, the spit protects the interior King Creek shoreline from waves from the northeast and the Parkway shoreline from waves from the north and northwest. Once the spit is gone, waves will be able to reach far into King Creek and impact shoreline that presently is only impacted during large storm events.

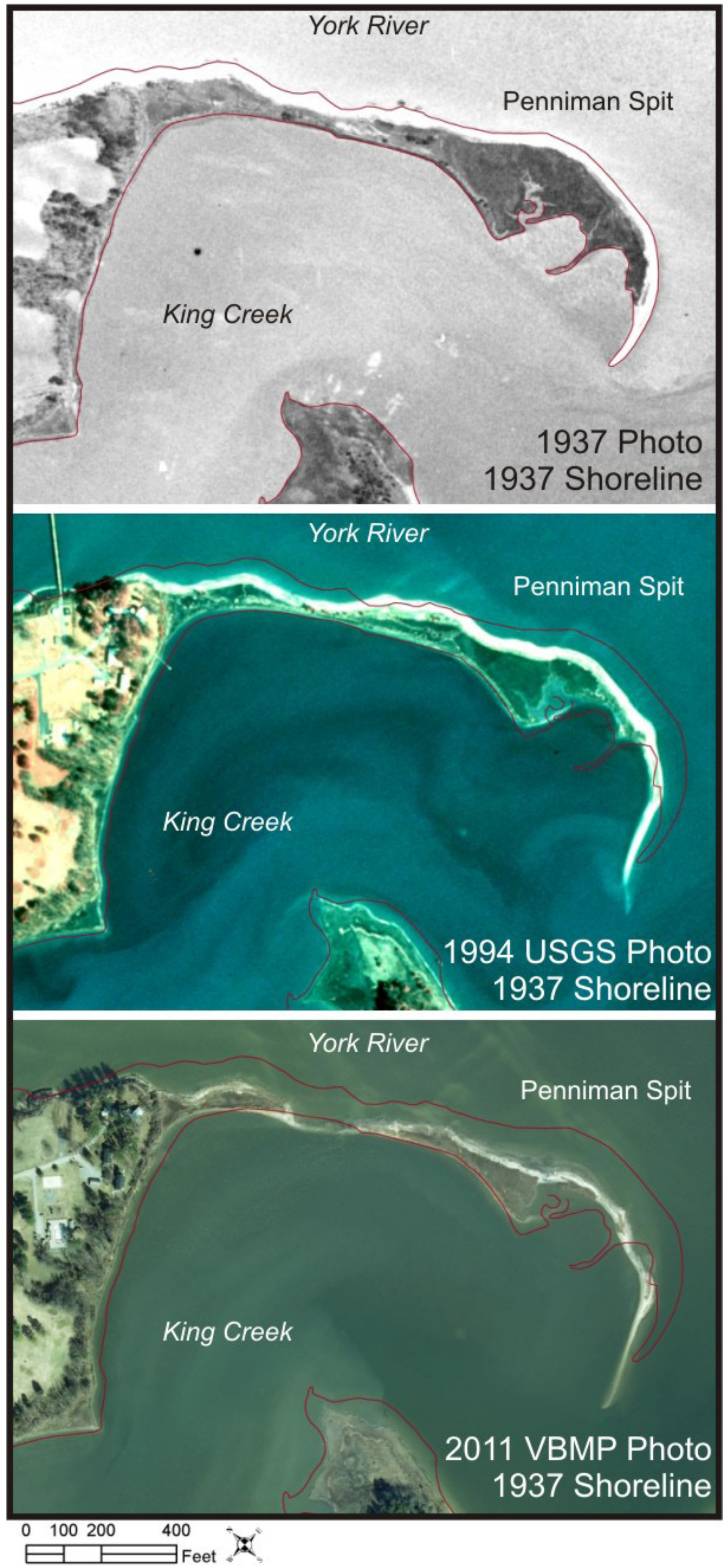


Figure 5-8. *Penniman Spit in 1937 (top), 1994 (middle), and 2011 (bottom). This marsh spit has eroded through time such that the center section has broken through.*

In order to continue protecting these shorelines as well as addressing the reduction in sediment transported onto the spit, a semi-continuous sill system is proposed (Figure 5-10). The sill system would rebuild sections of the marsh and protect the remaining sections from continued loss. The typical cross-section for the system is shown in Appendix 3, Figure 1B.

Figure 5-9. *Penniman Spit in 2012 (Bing Maps) showing the breach through its middle.*

Figure 5-10. *Site-specific application of the Shoreline Management Model recommendation for Penniman Spit. The sills will rebuild the spit thereby providing protection the shorelines landward of the spit.*

6 Summary and Links to Additional Resources

The Shoreline Management Plan for York County is presented as guidance to County planners, wetland board members, marine contractors, and private property owners. The plan has addressed all tidal shoreline in the locality and offered a strategy for management based on the output of a decision support tool known as the Shoreline Management Model. The plan also provides some site specific solutions to several areas of concern that were noted during the field review and data collection in the county. In all cases, the plan seeks to maximize the use of Living Shorelines as a method for shoreline stabilization where appropriate. This approach is intended to offer property owners with alternatives that can reduce erosion on site, minimize cost, in some cases ease the permitting process, and allow coastal systems to evolve naturally.

Additional Resources

VIMS: York County Map Viewer

http://cmap.vims.edu/CCRMP/YorkCCRMP/York_CCRMP.html

VIMS: Living Shoreline Design Guidelines

http://web.vims.edu/physical/research/shoreline/LivingShorelineDesign.html

VIMS: Why a Living Shoreline?

http://ccrm.vims.edu/livingshorelines/index.html

VIMS: Shoreline Evolution for York County

http://web.vims.edu/physical/research/shoreline/docs/Cascade/Shoreline_Evolution/York_ShoreEvolve-lr.pdf

NOAA: Living Shoreline Implementation Techniques

http://www.habitat.noaa.gov/restoration/techniques/livingshorelines.html

Chesapeake Bay Foundation: Living Shoreline for the Chesapeake Bay Watershed

http://www.cbf.org/document.doc?id=60

7 References

Angradi, T.R., E.W. Schweiger, D.W. Bolgrien, P. Ismert, and T. Selle, 2004. Bank stabilization, riparian land use and the distribution of large woody debris in a regulated reach of the upper Missouri river, North Dakota, USA. *River Res*. Appl. **20**(7): 829-846.

Basco, D.R. and C.S. Shin, 1993. Design Wave Information for Chesapeake Bay and Major Tributaries in Virginia. Coastal Engineering Program, Civil and Environmental Engineering Department, Old Dominion University, Norfolk, Virginia. Report No. 93-1.

Berman, M.R., H. Berquist, S. Killeen, C. Hershner, K. Nunez, K. Reay, T.H. Rudnicky, D. Schatt, and D. Weiss, 2009. York County Shoreline Inventory Report, Comprehensive Coastal Inventory Program, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Bischoff, A., and Humboldt-Universitaet zu Berlin, 2002. Juvenile fish recruitment in the large lowland river oder: Assessing the role of physical factors and habitat availability. Shaker Verlag GmbH, Aachen.

Boon, J.D., 2012, Evidence of Sea Level Acceleration at U.S. and Canadian Tide Stations, Atlantic Coast, North America. *J. Coast. Res* **28**: 1437-1445.

Burke, R., R. Lipcius, M. Luckenbach, P.G. Ross, J. Woodward, and D. Schulte, 2006. Eastern oyster settlement and early survival on alternative substrates along intertidal marsh, rip rap, and manmade oyster reef. *J. Shellfish Res.* **25**(2): 715.

Carroll, R., 2003. Nekton utilization of intertidal fringing salt marsh and revetment hardened shorelines. Masters thesis, Virginia Institute of Marine Science, College of William & Mary. Gloucester Point, Virginia.

Center for Coastal Resources Management (CCRM), 2013. Comprehensive Coastal Resource Management Guidance. Planning Information and Guidance for the Living Shoreline Preference. Virginia Institute of Marine Science, College of William & Mary. Gloucester Point, Virginia.

Cronin, T.M., L.M. Bybell, R.Z. Poore, B.W. blackwelder, J.C. Diddicoat, and J.E. Hazel, 1984. Age and correlation of emerged Pliocene and Pleistocene deposits, U.S. Atlantic coastal plain. *Palaeogeography, Palaeoclimatology, and Palaeoecology*, 47: 21-51.

Federal Emergency Management Agency, 2009. Flood Insurance Study: York County, Virginia and Incorporated Areas.

Hardaway, C.S., Jr. and R.J. Byrne, 1999. Shoreline Management in Chesapeake Bay. Special Report in Applied Marine Science and Ocean Engineering No. 356. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Hardaway, Jr., C.S., and Gunn, J.R., 2010. Design and Performance of Headland Bays in Chesapeake Bay, USA. *Coastal Engineering* 57: 203-212.

Hardaway, Jr., C.S., and Gunn, J.R., 2011. A Brief History of Headland Breakwaters for Shore Protection in Chesapeake Bay, USA. Shore & Beach 79(1): 26-34.

Hardaway, C.S., Jr., D.A. Milligan, C.A. Wilcox, L.M. Meneghini, G.R. Thomas, and T.R. Comer, 2005. The Chesapeake Bay Breakwater Database Project Hurricane Isabel Impacts to Four Breakwater Systems. Shoreline Studies Program, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia. http://www.vims.edu/research/departments/physical/programs/ssp/_docs/baa_isabel_report.pdf

Hardaway, C.S., Jr., D.A. Milligan, C.H. Hobbs, III, and C.A. Wilcox, 2006. Shoreline Management Plan: Phase II, York River Shoreline and Swanns Point, James River Shoreline. Shoreline Studies Program, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia. http://www.vims.edu/research/departments/physical/programs/ssp/_docs/colo_york_final.pdf

Hardaway, C.S., Jr., D.A. Milligan, K. Duhring, 2010. Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments. Version 1.2. Special Report in Applied Marine Science and Ocean Engineering No. 421. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Milligan, D.A., C.S. Hardaway, Jr., and G.R. Thomas, 1996. Public Beach Assessment Report, Yorktown Public Beach, Yorktown, Virginia. Technical Report. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Milligan, D.A., C.S. Hardaway, Jr., L.M. Meneghini, G.R. Thomas, and C.A. Wilcox, 2005. Yorktown Beach 2003-2005 with Hurricane Isabel Impacts. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Milligan, D.A., K.P. O'Brien, C.A. Wilcox, and C.S. Hardaway, Jr., 2010. Shoreline Evolution: York County, Virginia, York River, Chesapeake Bay and Poquoson River Shorelines. Data Summary Report. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Mixon, R. B., C. R. Berquist, Jr., W. L. Newell, G. H. Johnson, D. S. Powars, J. S. Schindler, E. K. Rader, 1989. Geological map and generalized cross sections of the coastal plain and adjacent parts of the Piedmont, Virginia. USGS IMAP: 2033. As modified in digital form by United States Geological Survey, 2005.

National Research Council, 2007. Mitigating Shore Erosion along Sheltered Coasts. The National Academies Press, Washington, D.C.

Rice, C.A. 2006. Effects of shoreline modification on a northern Puget sound beach: Microclimate and embryo mortality in surf smelt (hypomesus pretiosus). *Estuaries Coasts.* **29**(1): 63-71.

Rice, C., K. Sobocinski, and Puget Sound Action Team, Olympia, WA (USA), 2004. Effects of shoreline modification on spawning habitat of surf smelt *(hypomesus pretiosus)* in Puget sound, Washington. Puget Sound Action Team, Olympia, Washington.

Sasaki Associates, Inc., Carlton Abbott and Partners, Inc., and Anderson Associates, Inc., 1993. Yorktown Master Plan. Prepared for the York County Board of Supervisors and the Yorktown Revitalization Steering Committee.

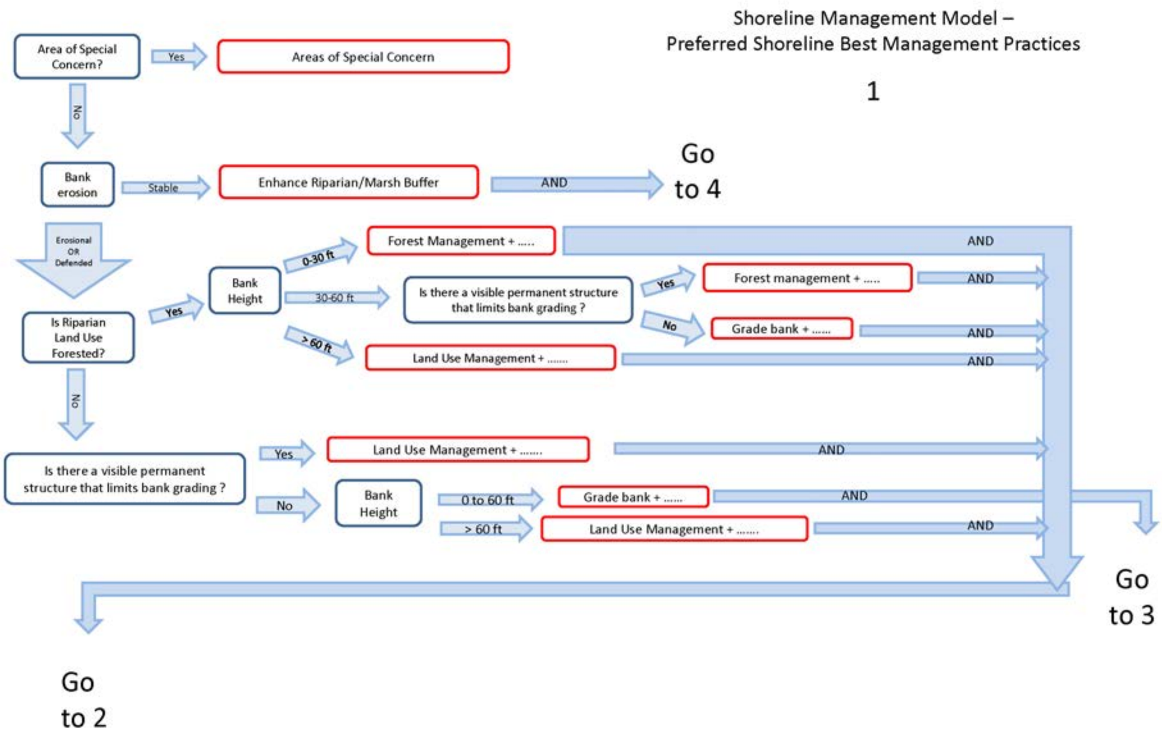
Seitz, R.D., R.N. Lipcius, N.H. Olmstead, M.S.Seebo, and D.M. Lambert, 2006. Influence of shallow-water habitats and shoreline development on abundance, biomass, and diversity of benthic prey and predators in Chesapeake Bay. *Mar. Ecol. Prog. Ser.* **326**: 11-27.

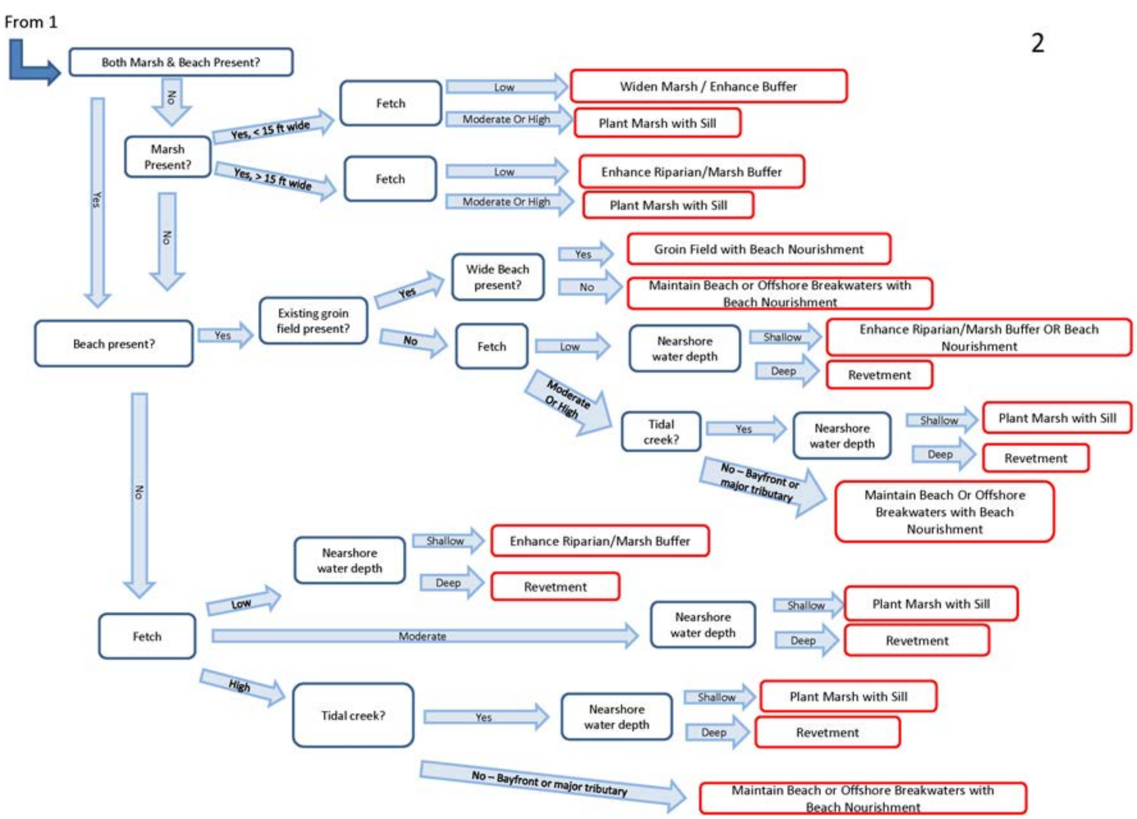
Spalding, V.L. and N.L. Jackson, 2001. Field investigation of the influence of bulkheads on meiofaunal abundance in the foreshore of an estuarine sand beach. **J. Coast. Res. 17**:363-370.

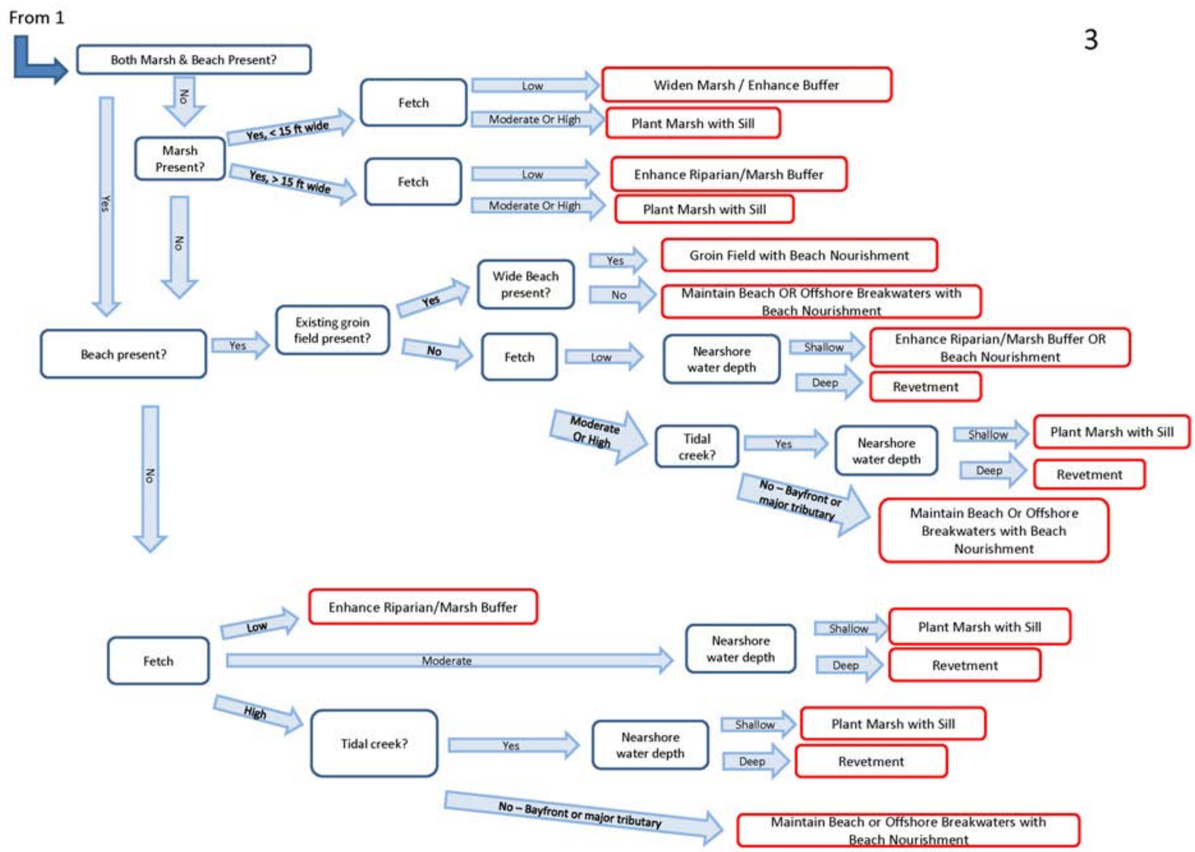
York County, 2013. The County of York Comprehensive Plan, Charting the Course to 2035. http://www.yorkcounty.gov/CountyGovernment/Administration,County/Planning/ComprehensivePlan/2012ComprehensivePlanReviewandUpdate.aspx

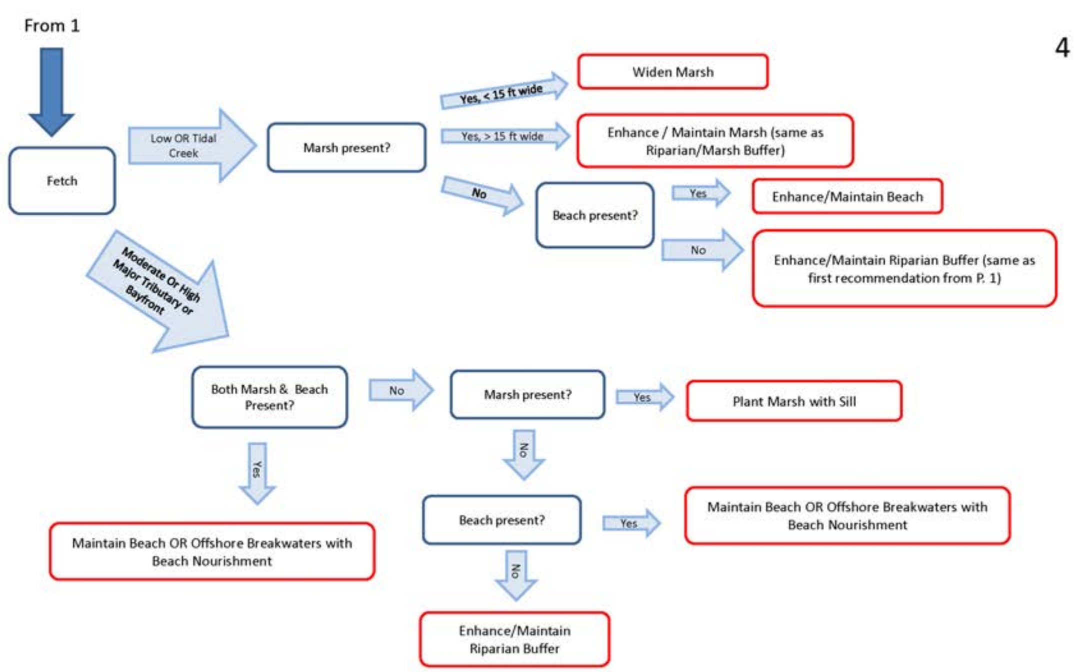
APPENDIX 1

Shoreline Management Model Flow Diagram






From 1
3
Both Marsh & Beach Present?
No
Yes
Marsh Present?
Yes, < 15 ft wide
Yes, > 15 ft wide
Fetch
Low
Moderate Or High
Widen Marsh / Enhance Buffer
Plant Marsh with Sill
Fetch
Low
Moderate Or High
Enhance Riparian/Marsh Buffer
Plant Marsh with Sill
No
Beach present?
Yes
Existing groin field present?
Yes
Wide Beach present?
Yes
Groin Field with Beach Nourishment
No
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
No
Fetch
Low
Nearshore water depth
Shallow
Enhance Riparian/Marsh Buffer OR Beach Nourishment
Deep
Revetment
Moderate Or High
Tidal creek?
Yes
Nearshore water depth
Shallow
Plant Marsh with Sill
Deep
Revetment
No – Bayfront or major tributary
Maintain Beach Or Offshore Breakwaters with Beach Nourishment
No
Fetch
Low
Enhance Riparian/Marsh Buffer
Moderate
Nearshore water depth
Shallow
Plant Marsh with Sill
Deep
Revetment
High
Tidal creek?
Yes
Nearshore water depth
Shallow
Plant Marsh with Sill
Deep
Revetment
No – Bayfront or major tributary
Maintain Beach or Offshore Breakwaters with Beach Nourishment


From 1
4
Fetch
Low OR Tidal Creek
Marsh present?
Yes, < 15 ft wide
Widen Marsh
Yes, > 15 ft wide
Enhance / Maintain Marsh (same as Riparian/Marsh Buffer)
No
Beach present?
Yes
Enhance/Maintain Beach
No
Enhance/Maintain Riparian Buffer (same as first recommendation from P. 1)
Moderate Or High Major Tributary or Bayfront
Both Marsh & Beach Present?
Yes
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
No
Marsh present?
Yes
Plant Marsh with Sill
No
Beach present?
Yes
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
No
Enhance/Maintain Riparian Buffer

APPENDIX 2

Glossary of Shoreline Best Management Practices

Preferred Shoreline Best Management Practices

Areas of Special Concern (Marinas - Canals - Industrial or Commercial with bulkhead or wharf – Other Unique Local Features, e.g. developed marsh & barrier islands) - The preferred shoreline best management practices within Areas of Special Concern will depend on the need for and limitations posed by navigation access or unique developed areas. Vegetation buffers should be included where possible. Revetments are preferred where erosion protection is necessary. Bulkheads should be limited to restricted navigation areas. Bulkhead replacement should be in same alignment or landward from original bulkhead.

No Action Needed – No specific actions are suitable for shoreline protection, e.g. boat ramps, undeveloped marsh & barrier islands.

Upland & Bank Areas

Land Use Management - Reduce risk by modifying upland uses, apply where bank and/or shoreline actions are extremely difficult or limited in effectiveness. May include relocating or elevating buildings, driveway relocation, utility relocation, hook up to public sewer/abandon or relocate sanitary drain fields. All new construction should be located 100 feet or more from the top of the bank. Re-direct storm water runoff away from top of the bank, re-shape or grade along top of the bank only. Land use management also may include zoning variance requests for setbacks, relief from other land use restrictions that increase erosion risk.

Forest Management - Enhance the existing forest condition and erosion stabilization services by selectively removing dead, dying and severely leaning trees, pruning branches with weight bearing load over the water, planting or allow for re-generation of mid-story and ground cover vegetation, control invasive upland species introduced by previous clearing.

Enhance/Maintain Riparian Buffer – Preserve existing vegetation located 100 feet or less from top of bank (minimum); selectively remove and prune dead, dying, and severely leaning trees; allow for natural re-generation of small native trees and shrubs.

Enhance Riparian/Marsh Buffer – Vegetation stabilization provided by a blended area of upland riparian and/or tidal marsh vegetation; target area extends from mid-tide to upland area where plants can occupy suitable elevations in dynamic fashion, e.g. seasonal fluctuations, gradual storm recovery; no action may be necessary in some situations; may include existing marsh management; may include planted marsh, sand fill, and/or fiber logs; restore riparian forest buffer where it does not exist; replace waterfront lawns with ornamental grasses, native shrubs and small trees; may include invasive species removal to promote native vegetation growth

Grade Bank - Reduce the steepness of bank slope for wave run-up and to improve growing conditions for vegetation stabilization. Restore riparian-wetland buffer with deep-rooted grasses, perennials, shrubs and small trees, may also include planted tidal marsh. NOTE - The feasibility to grade bank may be limited by upland structures, existing defense structures, adjacent property conditions, and/or dense vegetation providing desirable ecosystem services.

Tidal Wetland – Beach – Shoreline Areas

Enhance/Maintain Marsh – Preserve existing tidal marsh for wave attenuation. Avoid using herbicides near marsh. Encourage both low and high marsh areas; do not mow within 100 ft from top of bank. Remove tidal debris at least annually. Repair storm damaged marsh areas with new planting.

Widen Marsh – Increase width of existing tidal marsh for additional wave attenuation; landward design preferred for sea level rise adjustments; channelward design usually requires sand fill to create suitable elevations.

Widen Marsh/Enhance Buffer – Blended riparian and/or tidal marsh vegetation that includes planted marsh to expand width of existing marsh or create new marsh; may include bank grading, sand fill, and/or fiber logs; replace waterfront lawns with ornamental grasses, native shrubs and small trees.

Plant Marsh with Sill – Existing or planted tidal marsh supported by a low revetment placed offshore from the marsh. The site-specific suitability for stone sill must be determined, including bottom hardness, navigation conflicts, construction access limitations, orientation and available sunlight for marsh plants. If existing marsh is greater than 15 feet wide, consider placing sill just offshore from marsh edge. If the existing marsh is less than 15 ft wide or absent, consider bank grading and/or sand fill to increase marsh width and/or elevation.

Enhance/Maintain Beach - Preserve existing wide sand beach if present, allow for dynamic sand movement for protection; tolerate wind-blown sand deposits and dune formation; encourage and plant dune vegetation.

Beach Nourishment - Placement of good quality sand along a beach shoreline to increase the beach width and raise the elevation of the nearshore area; grain size of new sand should be similar to native beach sand

Enhance Riparian/Marsh Buffer OR Beach Nourishment – Increase vegetation stabilization with a blended area of upland riparian and/or tidal marsh vegetation; restore riparian forest buffer where it does not exist; replace waterfront lawns with ornamental grasses, native shrubs and small trees; may include planted marsh, sand fill, and/or fiber logs.

Consider beach nourishment if existing riparian/marsh buffer does not need enhancement or cannot be improved and if additional sand placed on the beach will increase level of protection. Beach nourishment is the placement of good quality sand along a beach shoreline to increase the beach width and raise the elevation of the nearshore area; grain size of new sand should be similar to native beach sand.

Maintain Beach OR Offshore Breakwaters with Beach Nourishment – Preserve existing wide sand beach if present, allow for dynamic sand movement for protection; nourish the beach by placing good quality sand along the beach shoreline that is similar to the native sand.

Use offshore breakwaters with beach nourishment only where additional protection is necessary. These are a series of large rock structures placed strategically offshore to maintain stable pocket beaches between the structures. The wide beaches provide most of the protection, so beach nourishment should be included; periodic beach re-nourishment may be needed. The site-specific suitability for offshore breakwaters with beach nourishment must be determined, seek expert advice.

Groin Field with Beach Nourishment - A series of several groins built parallel to each other along a beach shoreline; established groin fields with wide beaches can be maintained with periodic beach nourishment; repair and replace individual groins as needed.

Revetment - A sloped structure constructed with stone or other material (riprap) placed against the upland bank for erosion protection. The size of a revetment should be dictated by the wave height expected to strike the shoreline. The site-specific suitability for a revetment must be determined, including bank condition, tidal marsh presence, and construction access limitations.

APPENDIX 3

Guidance for Structural Design and Construction in York County

For York County, two typical cross-sections for stone structures have been developed. The dimensions given for selected slope breaks have a range of values from medium to high energy exposures becoming greater with fetch and storm wave impact. Storm surge frequencies are shown for guidance. A range of the typical cost/foot also is provided (Table 1). These are strictly for comparison of the cross-sections and do not consider design work, bank grading, access, permits, and other costs. Additional information on structural design considerations are presented in section 3.4 of this report.

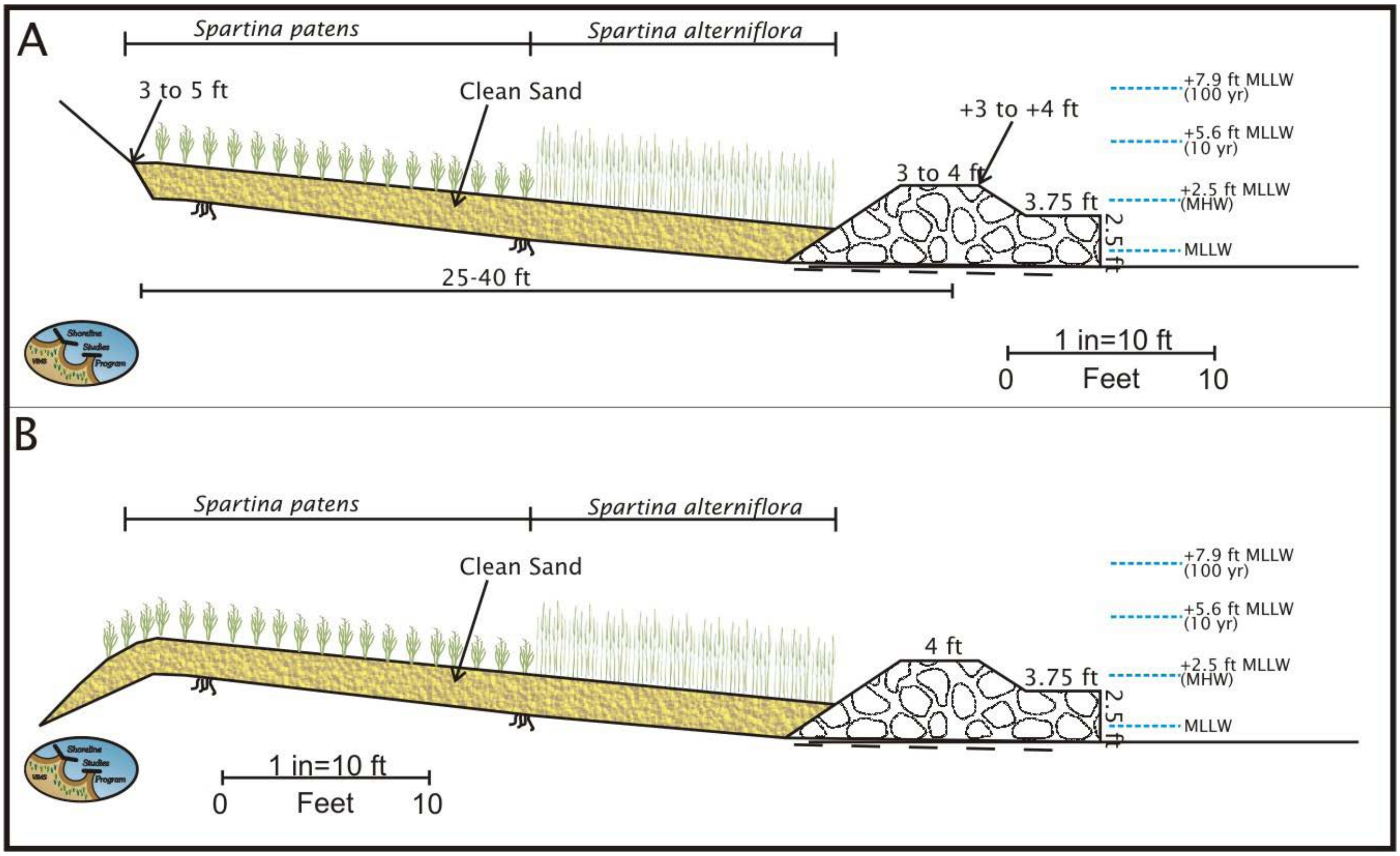
Stone sills are effective management strategies in all fetch exposures where there is shoreline erosion; however, in low energy environments the non-structural shoreline best management practices described in Chapter 3 of this report may provide adequate protection, be less costly, and more ecological beneficial to the environment. Stone revetments in low energy areas, such as creeks, are usually a single layer of armor. In medium to high wave energy shores, the structure should be an engineered coastal structure. Along medium/high energy shores or where there is nearby upland infrastructure, a high sill would be better (Appendix 3, Figure 1). Using sills on the open river should be carefully considered due to severity of storm wave attack.

Type of Structure	Estimated Cost per Linear Foot*
Low Sill	$150 -$250
High Sill	$250 - $400
Breakwater	$600 - $1,000

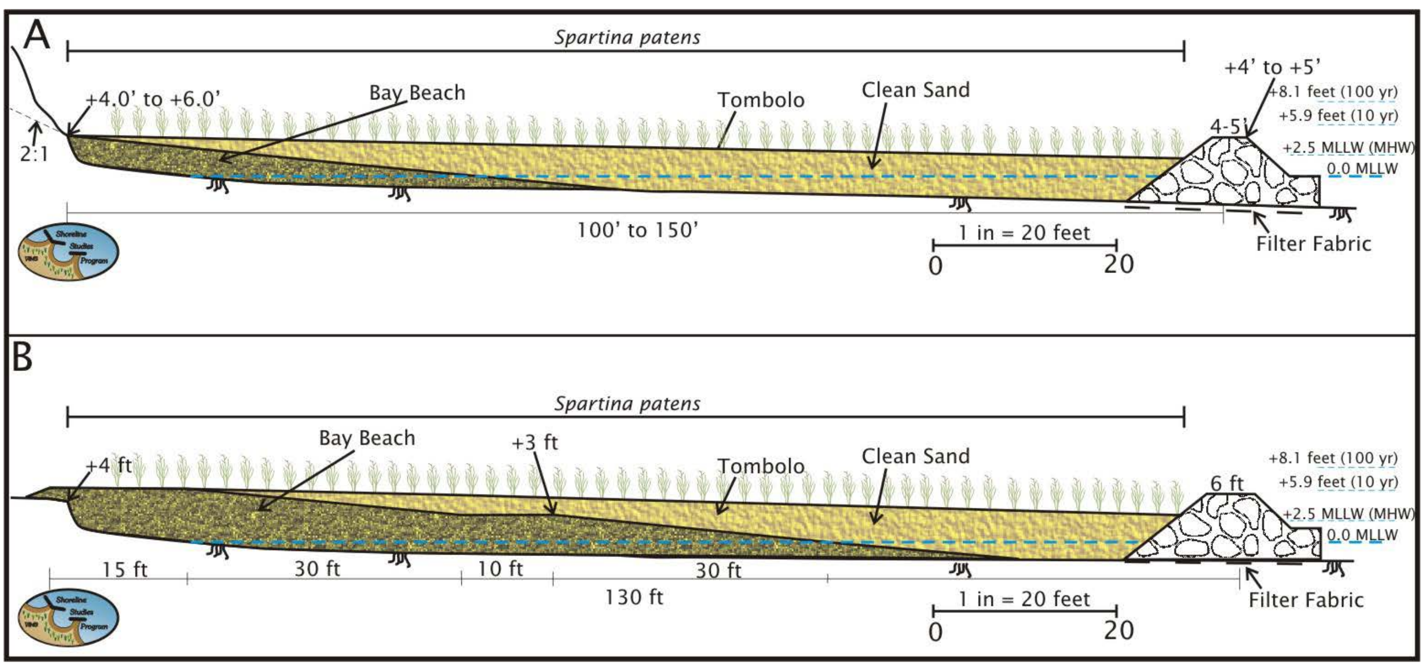
Table 1. *Approximate typical structure cost per linear foot.*

**Based on typical cross-section. Cost includes only rock, sand, plants. It does not include design, permitting, mobilization or demobilization.*

Breakwater systems are applicable management strategies along much of the York River and Bay coasts. The actual planform design is dependent on numerous factors and should be developed by a professional. However, a typical breakwater tombolo and embayment cross-section is provided to help determine approximate system cost (Appendix 3, Figure 2).



Appendix 3, Figure 1. *A) Typical cross-section for a high sill that is appropriate for the medium to high energy shorelines of York County. The project utilizes clean sand on an 10:1 (H:V) slope. B) Typical cross-section modified for the area of interest at Penniman Spit.*



Appendix 3, Figure 2. *A) Typical cross-section for a breakwater system that is appropriate for the medium to high energy shorelines of York County. Shown is the cross-section for the tombolo and rock structure. In addition, the typical cross-section for the bay beach between the structures is superimposed in a slightly different color. Note: the beach material is the same for the two cross-sections. B) Typical cross-section modified for the area of concern at Bay Tree Beach. Due to Bay Tree Beach's low backshore, a wide dune will have to be built.*