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Prince George County Shoreline Management Plan

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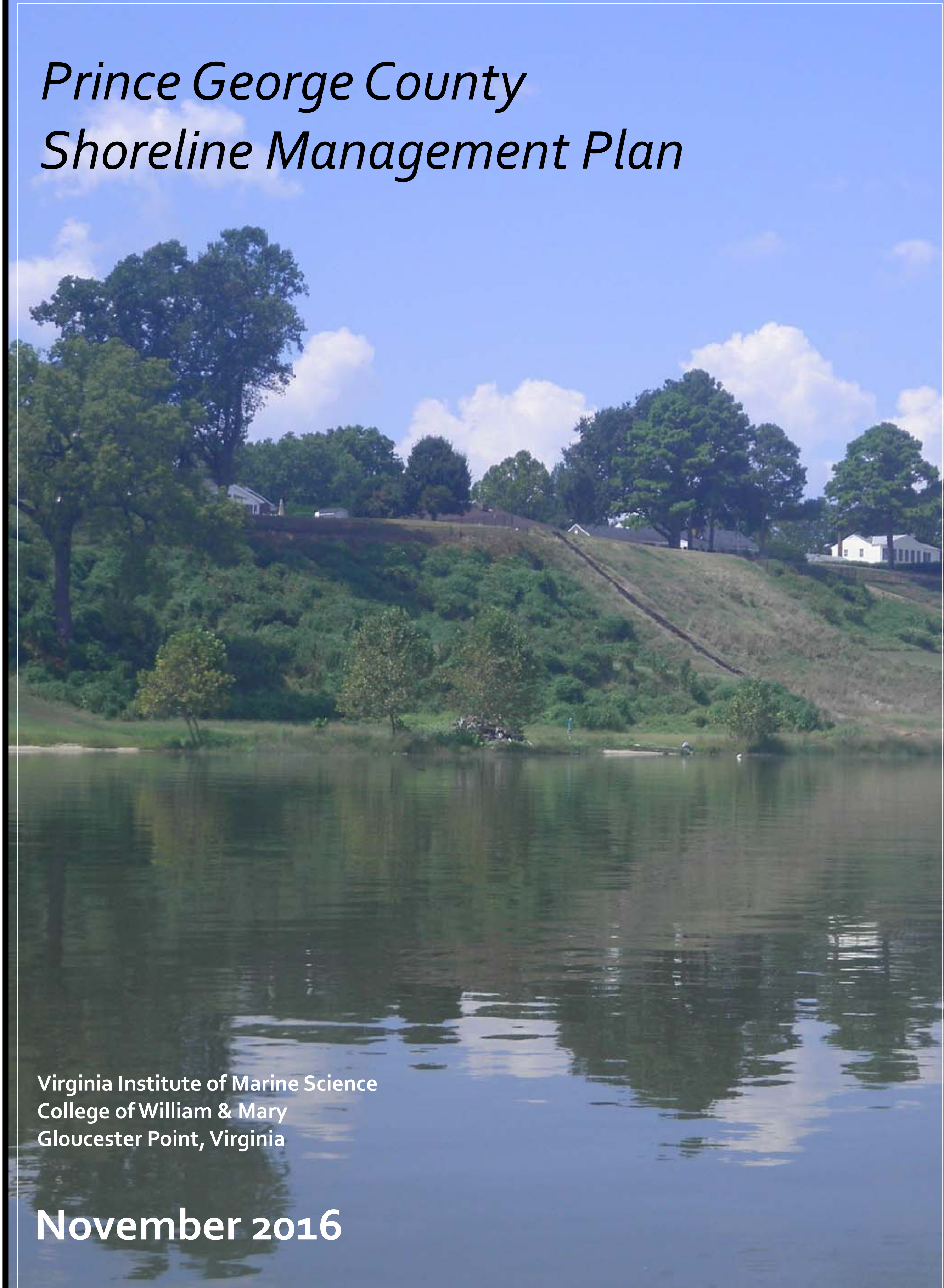

Prince George County Shoreline Management Plan

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

November 2016

Prince George County Shoreline Management Plan

Prepared for Prince George County and Virginia Coastal Zone Management Program

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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 maintains 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. Prince George County recognizes that the Chesapeake Bay and its tributaries are essential to the growth and vitality of Virginia (Prince George County, 2014). The shores of Prince George range from exposed open-river to very sheltered creeks (Figure 1-1); In fact, 80 percent of the County's shoreline is tidal marsh and swamp forest (Prince George County, 2014). However, along the banks of the James River, much of the shoreline is wooded or is used for agriculture and if development of these properties were to occur, this shoreline management plan will be useful for evaluating and planning management strategies

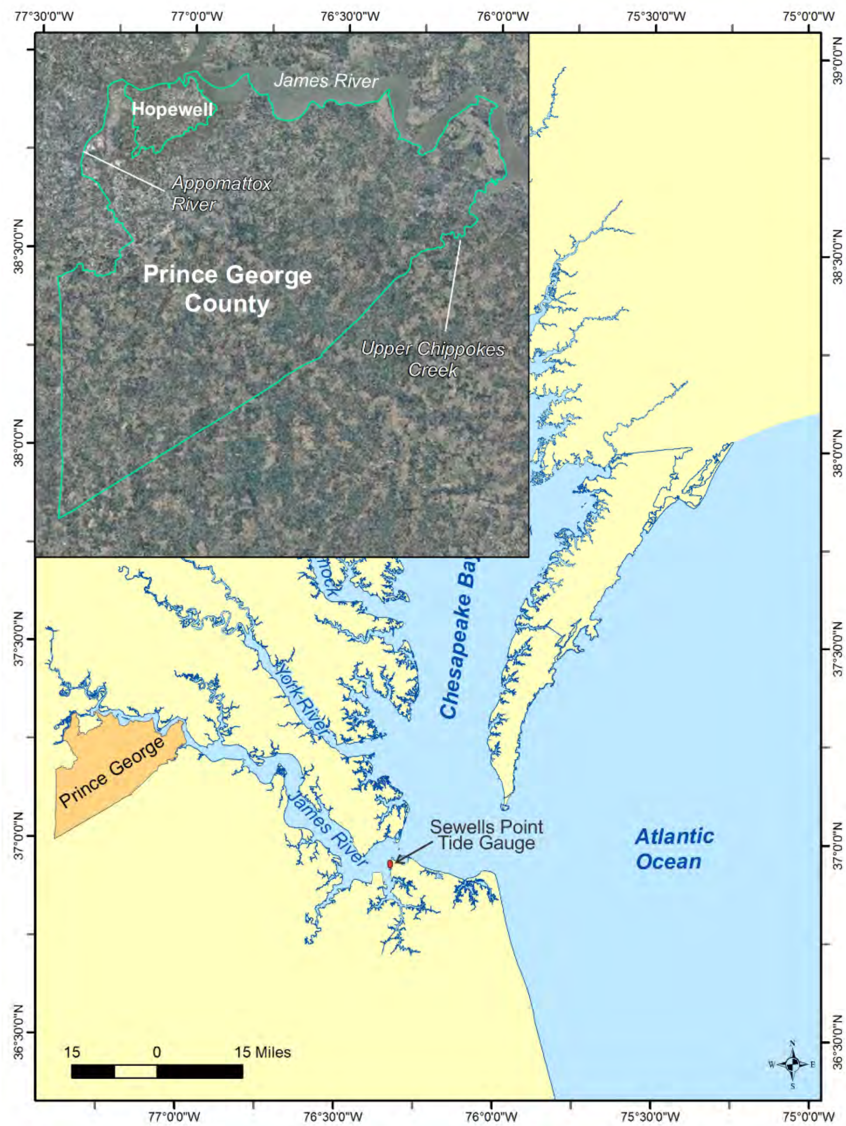

Figure 1-1. *Location of Prince George County within the Chesapeake Bay estuarine system. Tide prediction station location depicted in red.*

appropriate for all the creeks and rivers of Prince George. It ties the physical and hydrodynamic elements of tidal shorelines to the various shoreline protection strategies.

Much of Prince George County's shoreline is 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 final Prince George County Shoreline Management Plan is an educational and management reference for the County and its landholders.

2 Coastal Setting

2.1 Geology/Geomorphology

2.1.1 Geology

Prince George County lies in the coastal plain of Virginia. Like many coastal localities, the County boundaries are defined by creeks, rivers, and watershed. Prince George is bounded by the Appomattox River, James River, and Upper Chippokes Creek (Figure 1-1). These three bodies of water have nearly 130 miles of shoreline along these three rivers.

Sea level has risen and fallen across the Virginia Coastal Plain during the Pleistocene. In Prince George County these include depositional strata along the coast, from youngest to oldest: modern alluvium (Qal); upper Pleistocene Tabb Formation, Lynnhaven Member (Qtl), Sedgefield Member (Qts); Middle Pleistocene, Shirley Formation (Qsh), Chuckatuck Formation (Qc), Prince George Formation (Qcc) and the Yorktown Formation (Tc). The James River shoreline consists of eroding banks of the Tabb Formation (Qtl & Qts), Chuckatuck Formation (Qc), Shirley Formation (Qsh), Windsor Formation (Qtw) and upper Pliocene Bacon's Castle Formation (Tb2) (Figure 2-1).

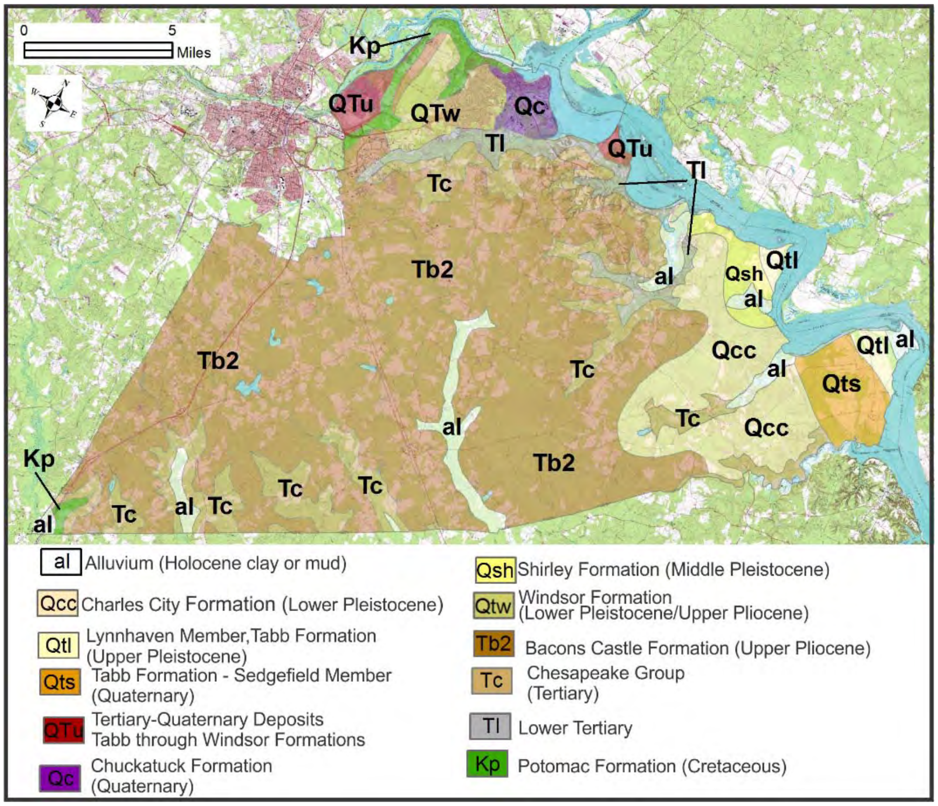

Figure 2-1. *Geology of Prince George County (Mixon et al., 1989).*

These riverine and estuarine sediments have been deposited in successive high stands which lie unconformably on each other and which overlie older Pliocene formations. The surficial geology of the shoreline banks include strata from Lower Pleistocene to Upper Pleistocene strata with Holocene marshes occupying secondary tidal creeks. Typically, the older strata are at higher elevations which decrease through time with each successive marine transgression. Therefore, the sediments differ in each strata graphic unit and provide different amounts of gravel, sand, silt, and clay to the littoral system through shoreline erosion.

The coastal morphology, topography, and hydrology of Prince George County are seen in Figures 2-2, 2-3, 2-4 and 2-5. The county shoreline can be assessed in six reaches, including the City of Hopewell. Reach 1 extends along the entire Appomattox River to City Point at the confluence of the Appomattox and James Rivers (Figure 2-2). The shoreline is mostly developed along Hopewell's high banks. Reach 2 extends from City Point down along the south shore of the James to Coggins Point and includes Jordan Point and Tar Bay (Figure 2-3). Here the James widens along the ancient meanders and narrows at the ancient point bars. The James River is about 0.8 miles wide at City Point and Jordan Point, but 1.8 miles wide between them in the adjacent embayment. The same pattern exists between Jordan and Coggins Points. The James is 2.0 miles wide at Tar Bay and 0.75 miles wide at Coggins Point. The Points tend to be low upland banks or marsh while the shoreline along the wide meander embayments are high upland banks and bluffs.

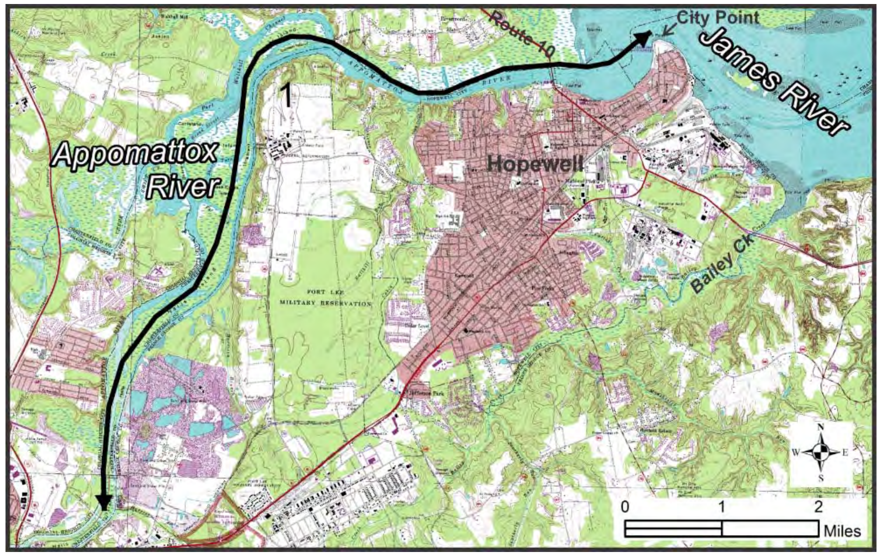

Figure 2-2. *Topographic sheet of Appomattox and James Rivers in Prince George County designated as Reach 1 in this report.*

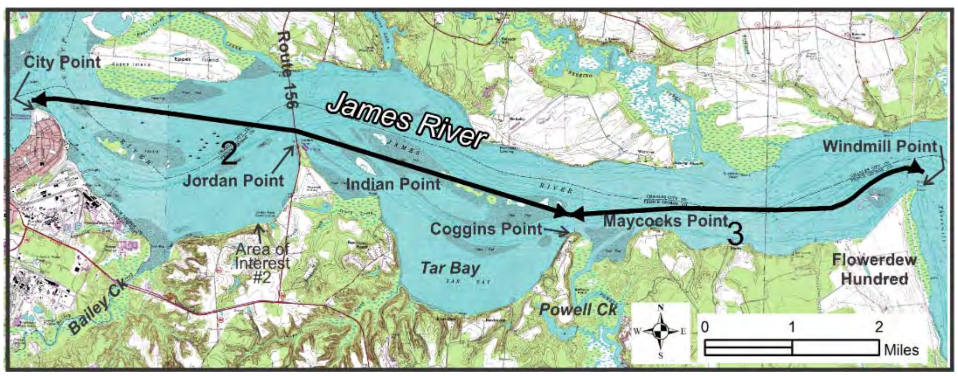

Figure 2-3. *Topographic sheet of the James River in of Prince George County designated as Reach 2 and 3 in this report.*

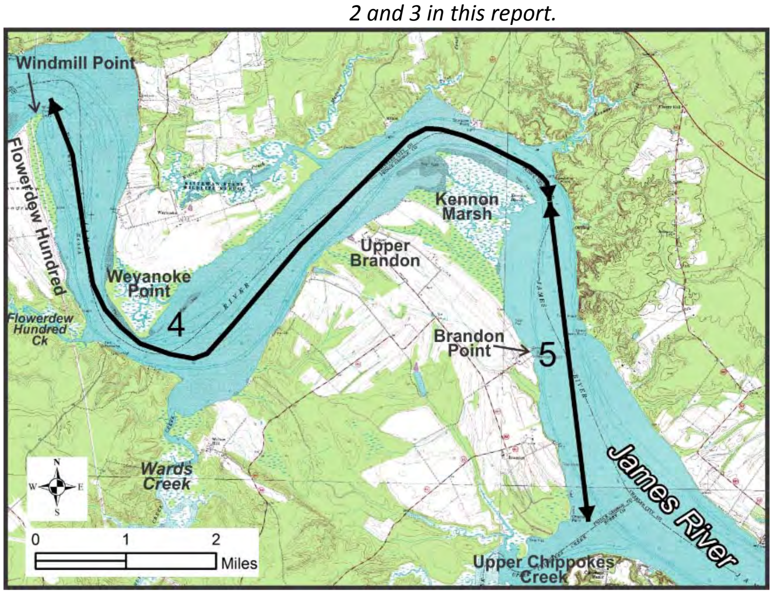

Figure 2-4. *Topographic sheet of the James River in Prince George County designated as Reach 4 and 5 in this report.*

Reach 3 extends from Coggins Point downriver past Powell Creek and Maycocks Point to Windmill Point (Figure 2-3). The banks are mostly upland. Reach 4 begins at Windmill Point and turns due south and narrows to about 1,500 feet at Weyanoke Point where the narrow channel goes to 90 feet deep (Figure 2-4). From there, the James widens and trends northeast and then east at Kennon Marsh point. Reach 5 begins at Kennon Marsh where the James turns southward and continues past Brandon Point to the mouth of the Upper Chippokes Creek. Reach 6 begins here and extend up the west coast of the Upper Chippokes Creek (Figure 2-5).

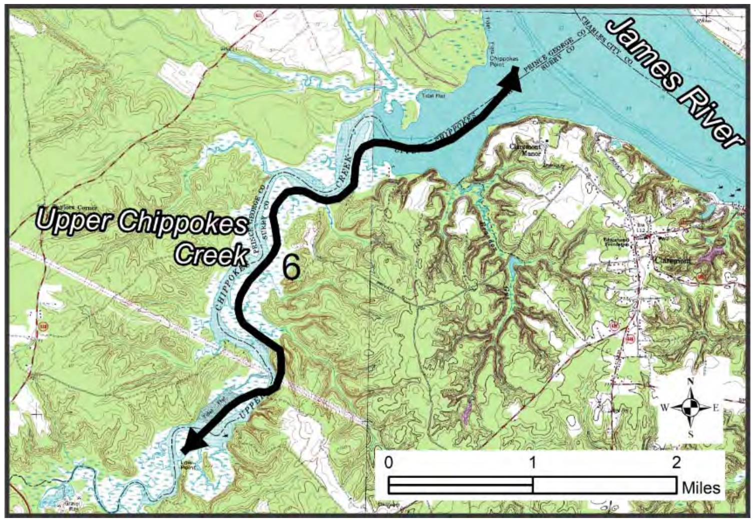

Figure 2-5. *Topographic sheet of Upper Chippokes Creek in Prince George County designated as Reach 6 in this report.*

2.1.2 Shoreline Morphology

Today's coastal morphology/landscape is a function of the underlying geologic history. All of Prince George's river shorelines are tidal.

Reach 1 contains upland banks upriver of the Route 10 Bridge that are 40 to 50 feet high with sparse residential development (Figure 2-6). Past the bridge the banks are generally vegetated slopes with slightly undercut base of banks. City Point at the mouth of the Appomattox River is heavily armored with rock (Figure 2-7) and marks the end of Reach 1.

Figure 2-6. *High upland bank along the Appomattox River.*

Figure 2-7. *Armored shoreline at City Point at the confluence of the Appomattox and James Rivers.*

Reach 2 begins at City Point. The channel is very close to the shoreline with the 18 foot bathymetric contour less than 100 feet offshore. The uplands drop down to about 5 feet along a public park coast (Figure 2-8) and extends along the industrial coast of Hopewell (Figure 2-9). Hopewell ends at Bailey Creek and the high upland banks downriver are intermittently exposed but relatively stable.

Figure 2-8. *Very low park shoreline along the James River in Reach 2 downriver of City Point.*

Figure 2-9. *Industrial development in Reach 2 along the low banks on the James River.*

Residential development increases downriver, and the upland coast drop down to about 10 feet with shoreline hardening. Jordan Point is where the Route 156 Bridge comes ashore in Prince George County with Jordan Point Marina on the downriver side.

The shoreline is mostly residential for about 3,000 feet past the Marina along a 10foot upland bank that is intermittently hardened (Figure 2-10). The shoreline then transitions to fresh water swamp

Figure 2-10. *Residential development along the James River. The shoreline is intermittently protected with structures.*

shoreline called Beachwood Manor that is mostly hardened with bulkheads. The shoreline continues to be alternating high and low bank coasts along Tar Bay reflecting the ancient upland watershed patterns. The upland banks are mostly stable with small fresh water fringe marsh and swamp forest

Figure 2-11. *High upland, residential banks at Coggins Point on the James River in Reach 2 as it transitions from +60 ft high to +30 ft high.*

shorelines. There is sparse development up to Coggins Point which is where a high upland scarp (+60 feet) intersects the James River and where the coastline landscape decreases in elevation to about +20 to +30 feet (Figure 2-11).

Reach 3: Powell Creek enters the James River just downriver of Coggins Point where the shallow embayed upland shoreline continues to Maycocks Point. Prince George's James River shoreline continues eastward and downriver for about three miles to Windmill Point. This subreach of coast is mostly stable, heavily vegetated high bank shoreline with intermittent marsh fringe which, when absent, is due to overhanging trees and shading. Minor base of bank scarping is evident and some more exposed banks occur farther downriver. There is little or no residential development until Flowerdew Hundred, one of the earliest English settlements in the New World. Here the bank height decreases and a few homes occur. Farther downriver, the upland landuse becomes agricultural with a narrow line of trees along the shoreline to Windmill Point (Figure 2-12).

Reach 4: The James River coast of Prince George County makes a sharp turn at Windmill Point and continues. For about 7,000 feet south of Windmill Point, the shore zone is swamp forest with numerous cypress trees. This type of coast makes it difficult to see where the actual shoreline is located (Figure 2-13). The landuse goes from

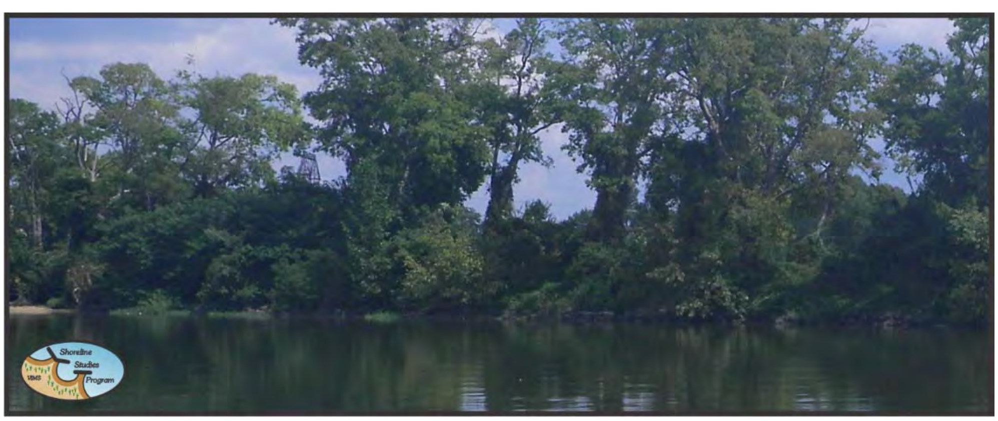

Figure 2-12. *Agricultural land with trees and shrubs along the shoreline at Flowerdew Hundred, James River.*

swamp forest to very low upland agricultural, part of Flowerdew Hundred, with narrow tree fringe. This shore type extends for about 0.5 miles and transitions to a higher relatively stable upland bank (20 ft) with a narrow swamp forest fringe down to Flowerdew Hundred Creek.

Figure 2-13. *Cypress trees along the shoreline tend to disguise the actual location of the upland bank.*

The neck of land from Flowerdew Hundred Creek and Ward Creek is about one mile in length and begins as an upland bank in transition as the treed fringe becomes sparse and less effective at wave attenuation and the shore becomes more exposed to a northeast fetch of over 4 miles. This is also the site of Fort Powhatan, a US Army secondary coastal fort established in 1808. It was used during the Civil War by both sides because of its strategic location, where the James River narrows to about 1,300 feet and the natural channel is only a few yards from the shoreline (Figure 2-14). The wooded upland shoreline continues down to the mouth of Wards Creek with the exception of a small residential development.

Figure 2-14. *Fort Powhatan in Reach 4 where the natural channel is only a few yards from the shoreline.*

Wards Creek has a wide swamp forest coast. The mouth of the downriver side has a cypress tree "spit" (Figure 2-15). The shoreline continues northeastward about 2,000 feet downriver as extensive swamp forest with many solitary cypress guarding the shore. The wide swamp forest transitions into an exposed upland bank with few shore trees where landuse becomes agriculture and the trees may have be felled for lumber. Some of the wooded upland banks have exposed bank faces (Figure 2-16). Sparse upland

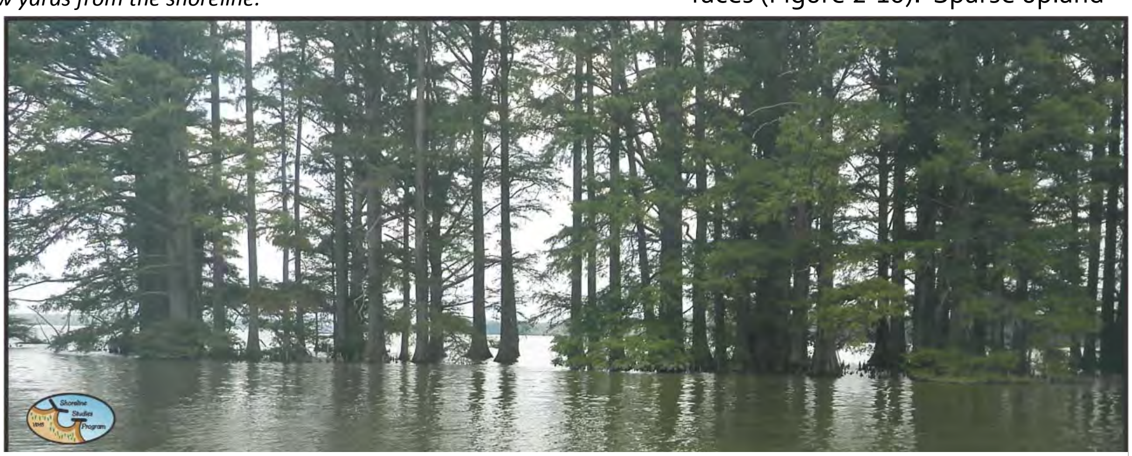

Figure 2-15. *Cypress tree "spit" at the mouth of Wards Creek in Reach 4 along the James River.*

Figure 2-16. *Exposed, eroding upland banks along the James River in Reach 4.*

development occurs toward Upper Brandon with landuse transitioning to agriculture. The banks are intermittently exposed with few trees and bank erosion is active at the main house. The agricultural land continues past the house with an increase in shore trees which quickly transitions into the very broad and extensive fresh water marsh and swamp forest complex called Kennon Marsh.

The Kennon Marsh is a major point bar on the James River. The shoreline begins at the upland/swamp forest transition heading northeastward and turns into a broad shallow embayment with low swamp forest with many sentinel cypress trees in the nearshore. The curvileanear distal end of Kennon Marsh extends about 6,500 feet trending generally northwest/southeast along the James before turning southwesterly and continuing another 6,500 feet and intersecting the agricultural uplands of Brandon. The entire coast of Kennon Marsh is intermixed fresh water marsh and swamp forest.

Reach 5: From the end of Kennon Marsh to Brandon Point is about 3,000 feet of agricultural landuse with a robust cypress tree fringe buffer. Brandon Point has an accretionary beach salient where the river drops to -45 feet only 200 feet offshore. From Brandon Point, the James River shoreline of Prince George County extends downriver about 10,000 feet to Upper Chippokes Point at the mouth of Upper Chippokes Creek. This coast is mostly low agricultural upland with intermittently exposed banks transitioning to swamp forest coast toward Upper Chippokes Point.

Reach 6: The fresh water marsh and swamp forest coast continues up Upper Chippokes Creek with no development.

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 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;

Ship wakes may also contribute to shoreline erosion along this shoreline. A major shipping channel occur in the James River with the natural channel coming close to the shore in several areas. However, their impact has not been quantified and are likely very site specific.

Basco and Shin (1993) described the wave climate along Prince George shoreline 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 MHW. Prince George County's shores are mostly in the narrow upper parts of the James where the waves are minimal and do not pose a threat to the Appomattox or the James River shorelines until Powell Creek. From Powell Creek to Windmill Point the wave height is 2.0 feet with a 2.7 second period. The only other area in Prince George County for which wave heights have been modeled is around the mouth of Upper Chippokes Creek. The area covered is from Chippokes Point to the mouth of Upper Chippokes. The wave height is 1.5 feet with a 2.3 second period (Figure 2-17).

Storm surge frequencies described by FEMA (2010) are shown in Table 2-1. The table shows the 10%, 2%, 1%, and 0.2% chances of water levels attaining these elevations for any given year along Prince George County's shoreline. The storm surge for the entire range of shorelines within the County are 7 MLLW, 8.3 MLLW, 9 MLLW, and 10.1 MLLW.

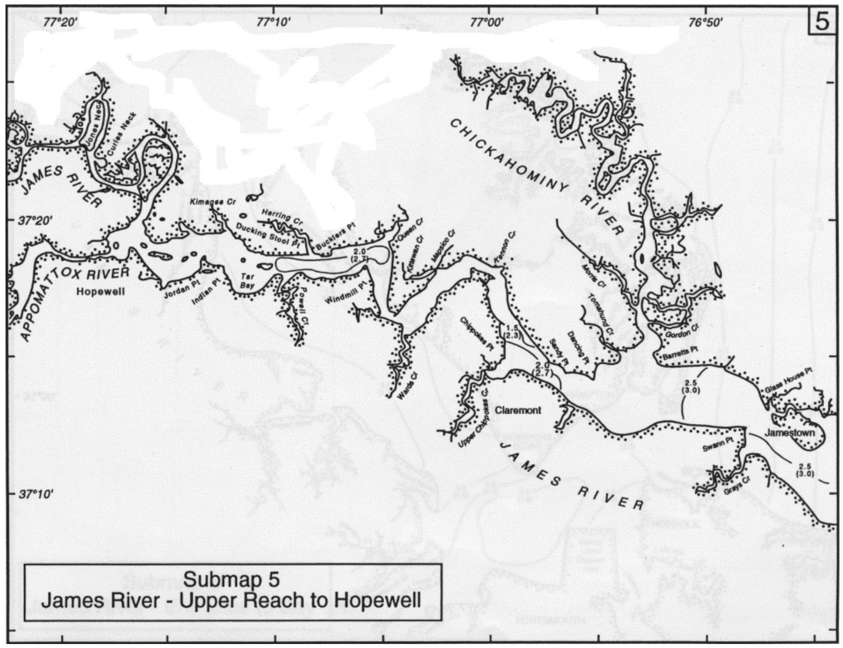

Figure 2-17. *Wave climate map for the upper James River (from Basco and Shin, 1993).*

Tide ranges vary along the Prince George County shoreline (Table 2-2). The mean tide range is lowest near Windmill Point at the Kennon Marsh on the James River at 2.3 feet and rises steadily moving towards City Point (Hopewell), where it's the highest at 2.6 feet.

Location	Annual Chance (feet MLLW)			
	10% 10 year	2% 50 year	1% 100 year	0.2% 500 year
James River – at confluence of Appomattox River	7	8.3	9	10.1

Table 2-1. *10 year, 50 year, 100 year, and 500 year storm predicted flood levels relative to MLLW (1983-2001). Source: Prince George County Flood Report, FEMA (2010). Converted from NAVD88 using NOAA's online program VDATUM.*

Location	Tide Station	Mean Range (ft)	Spring Range (ft)
James River	City Point (Hopewell)	2.6	3
James River	Jordan Point	2.5	2.9
James River	Windmill Point	2.3	2.7

Table 2-2. *Tide Ranges in Prince George County (from NOAA Tides and Currents Website, 2015).*

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. While trends have not been determined in Prince George County, the recent trend based on wave gauge data at Sewell Point in Norfolk, Virginia shows the annual rate to be 1.51 feet/100 years (4.59 mm/yr). Boon (2012) predicted future sea-level rise by 2050 using tide gauge data from the East Coast of the U.S. Sewell 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.

2.2.3 Shore Erosion

Shoreline erosion results from the combined impacts of waves, sea level rise, and tidal currents, in some cases, boat wakes, and shoreline hardening. Table 2-3 shows the average historical shoreline rates of change for the reaches described in this report throughout the County. Overall, the erosion is very low in most sections of Prince George County, even within the error limits for the shoreline change analysis. Along the James River toward Upper Chippokes Creek, the erosion rates increase slightly, while Upper Chippokes Creek has the highest erosion rate of the County because of several areas of marsh that are eroding rapidly. Individual areas, particularly headlands or points of land have slightly larger rates of change. More detailed shoreline change information can be found in Milligan *et al.,* 2016.

Typically, when shorelines exhibit erosion, property owners have tended to harden the shoreline. 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. While areas in Prince George County have installed some shore protection to address shore erosion control, it is important to address the unprotected, eroding shorelines.

Reach Name	Average EPR (ft/yr)	Category
Reach 1: Appomattox River – Harrison Creek to James River	-0.4	Very Low Erosion
Reach 2: James River – City Point to Coggins Point	0.0	Very Low Accretion
Reach 3: James River – Coggins Point to Windmill Point	-0.1	Very Low Erosion
Reach 4: James River – Windmill Point to Kennon Marsh	-0.4	Very Low Erosion
Reach 5: James River – Kennon Marsh to Upper Chippokes Creek	-0.4	Very Low Erosion
Reach 6: Upper Chippokes Creek	-0.8	Very Low Erosion

Table 2-3. *Average end point rate of change (1937-2009) for Prince George County's shoreline. The rates of change are given in feet per year. From Milligan et al., (2016).*

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 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.

Upland Shoreline BMPs	Shoreline BMPs
No Action Needed	Groin Field with Beach Nourishment
Area of Special Concern	Maintain/Enhance /Create Marsh
	Maintain Beach OR Offshore Breakwaters with Beach Nourishment
Land Use Management	Plant Marsh with Sill
	Revetment

Table 3-1. *Shoreline Best Management Practices*

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 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.

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.*

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

Figure 3-3. *Bank grading 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.

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.*

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).

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 onto nearshore bottom 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 drain fields, or hook-up to public sewer. All new construction should be located 100 feet or more from the top of the bank. Re-directing storm water 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 Prince George, these are marsh sills constructed of stone and offshore breakwaters.

As fetch exposure increases beyond about 1,000 feet, the intertidal marsh width is not sufficient to attenuate wave action, and the addition of sand can increase the intertidal substrate as well as the backshore region. However, as wave exposure increases, the inclusion of some sand retaining structure may be required to prevent sand from being transported away from the site. This is where a marsh sill is appropriate.

3.4.1 Sills

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 two 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.

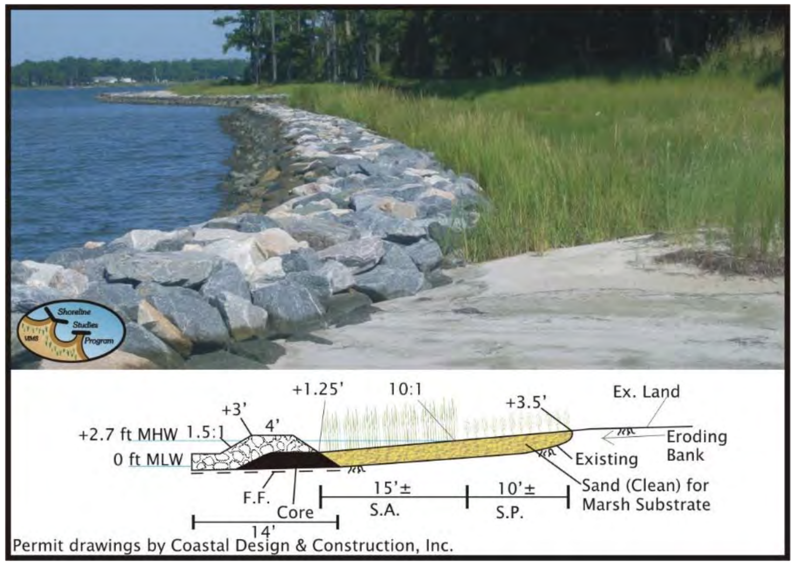

***Figure 3-5**. Sand fill with stone sills and marsh plantings shown six years after installation and the cross-section used for construction (From Hardaway et al., 2010).*

Hardaway and Byrne (1999) indicate that in lower 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 feet 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 patens* (Hardaway *et al*., 2010). The sill system was built in August 2008 and went through the Veteran's Day Northeaster (2009) with no impacts to the

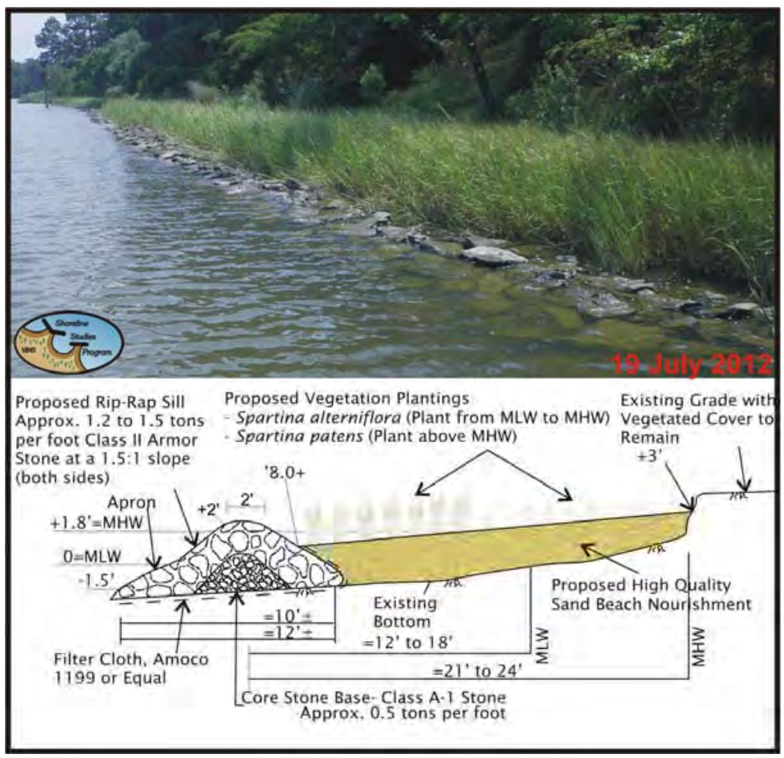

***Figure 3-6.** Longwood University's Hull Springs Farm four years after construction and the cross-section used for construction (from Hardaway et al., 2010).*

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.

Any addition of sand or rock seaward of mean high water (MHW) requires a permit. A permit also 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 (Figure 3-7). 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.

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.

Figure 3-7. *Breakwaters along the James River designed to provide a recreational beach as well as storm erosion protection.*

3.4.3 Headland Control

Headland Control is a unique shoreline management technique whereby existing geomorphic features (*i.e.* headlands) are enhanced by breakwaters or sills. Headland Control also can include placing stone breakwaters or sills are strategically place along eroding coasts to create headlands (Figure 3-8). These enhanced or created shore headlands are widely-spaced for economy. The adjacent coasts are allowed to continue to erode toward an equilibrium shore position or planform. The final equilibrium planform is a large pocket beach whose dimensions will depend on the amount of sand that will come to reside in the evolving embayment. Sand often is placed directly behind the created headland during construction and then vegetated. Headland control is applied to long reaches of agricultural or unmanaged woodland shores to begin the process of shore stabilization.

Figure 3-8. *Bing map showing headland breakwaters that were built along Jamestown Island's James River shore.*

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 field days in August 2016. Existing conditions and suggested strategies were entered 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 shorelines 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 collected and maintained for the Prince George County Shoreline Inventory which is in progress. 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 eliminate 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.

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 in-house (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 in-house (CCI) for project, unpublished	tidal creek	tidal creek, major tributary, bayfront

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

Shorelines were 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 50 meter 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 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.

5 Shoreline Management for Prince George County

5.1 Shoreline Management Model (SMM) Results

In Prince George County, the SMM was run on 470 miles of shoreline. The SMM provides recommendations for preferred shoreline best management practices along all shoreline. It will not be publically available until 2017. 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.

ShoreBMP	Length (miles)
Maintain/Enhance/Create Marsh	92.2
Groin Field with Beach Nourishment	0.02
Maintain Beach OR Offshore Breakwaters with Beach Nourishment	21.5
Plant Marsh with Sill	11.5
Revetment	1.5
UplandBMPS	Length (miles)
Area of Special Concern	1.4
Maintain/Enhance/ Riparian Buffer	123.9
Land Use Management	2.8
No Action Needed	0.01

Table 5-1. *Occurrence of descriptive Shoreline BMPs in Prince George County Watershed from the SMM.*

The majority of shoreline management in the Prince George 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 much of the shoreline resides within protected waters with medium to low energy conditions, Living Shoreline approaches are applicable. Table 5-1 summarizes the model output for Prince George 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 when it becomes publically-available, 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 and will be accessed at this website: http://ccrm.vims.edu/ccrmp/index.html.

The pdf file will be found under the tab for Shoreline Best Management Practices. The Map Viewer is 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 for printing.

Figure 5-1. *Portal for Comprehensive Coastal Resource Management.*

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.

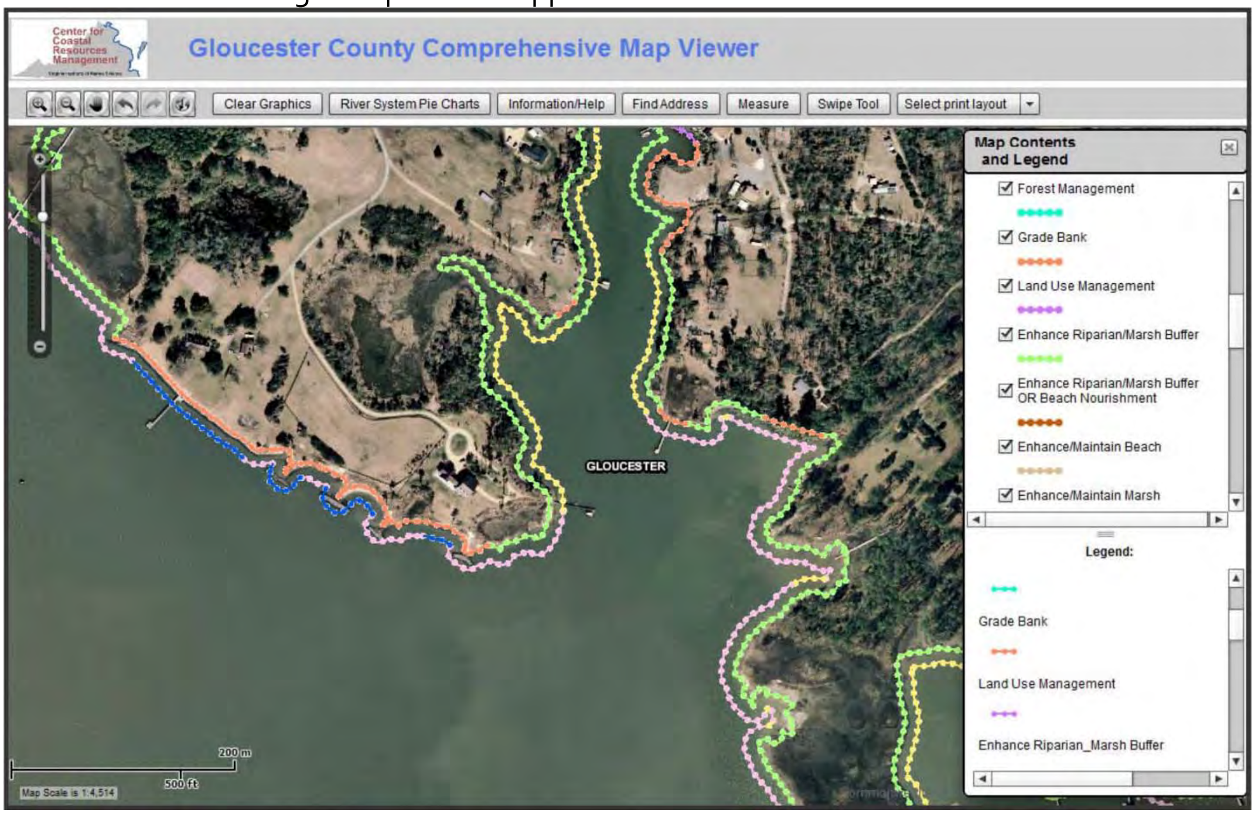

Figure 5-2. *The Map Viewer displays the preferred Shoreline BMPs in the map window. The color-coded legend in the panel on the right identifies the treatment option recommended.*

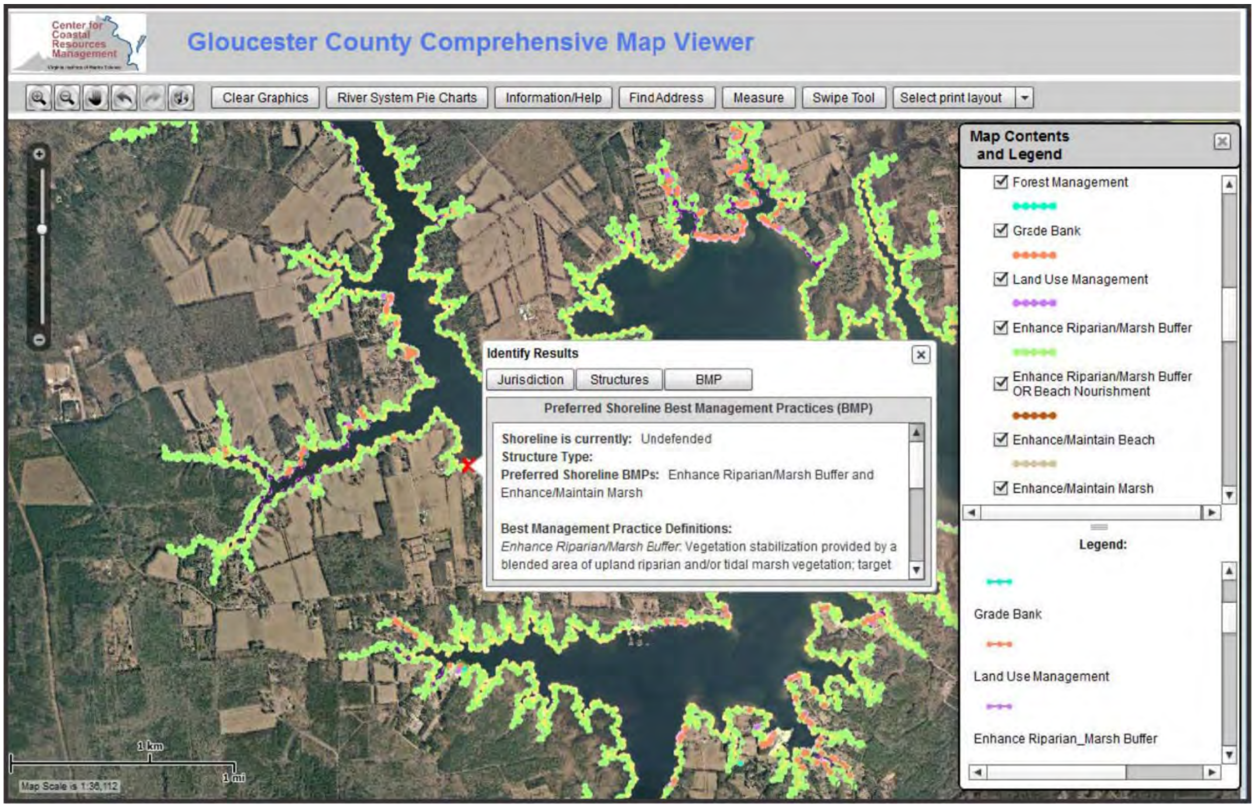

Figure 5-3. *The pop-up window contains information about the recommended Shoreline BMP at the site selected. Additional information about the condition of the shoreline also is given.*

5.2 Shore Segments of Interest

This section describes several areas of interest in Prince George and demonstrates how the preferred alternative from the SMM could be adopted by the waterfront property owners. Areas of 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 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 experienced in the design and construction of shore protection methods in Chesapeake Bay.

5.2.1 City Park (Area of Interest)

The City Park shoreline occurs just south of City Point on the James River in the City of Hopewell (Figure 2-2). The project shoreline is about 500 feet long and lies between two existing stone revetments (Figure 5-4). The shoreline occurs as a very low eroding upland bank with a narrow beach. The nearshore is extremely narrow. The James River channel is close to shore and the depths drop down to 18 feet less than 100 feet of the shoreline.

The SSM recommends a breakwater system but due to the very deep nearshore and very low bank, a sill with wide gaps is recommended. The wide gaps are to provide additional recreational access to the river (Figure 5-5). The cross-section for a typical sill for this site is shown in Appendix 3, Figure 1.

Figure 5-4. *Eroding shoreline at Area of Interest 1 on the James River at City Point.*

Figure 5-5. *Conceptual design of a shore protection system for the eroding shoreline along the park at City Point.*

5.2.2 Breakwater (Area of Interest)

Approximately one mile upriver from Jordan Point is the second Area of Interest (Figure 2-3). The project shoreline is about 1,000 feet long and occurs in front of 3 houses locate on a 130 foot bluff. The long bank slope has recently be cleared of vegetation and appears to be relatively stable, but the base of the bank is actively eroding (Figure 5-6). The SMM recommends a breakwater system. The conceptual plan is for six breakwater units and beach fill that transition on each end (Figure 5-7). A revetment occurs on the downriver end and the system can be tied into it. The beach fill will be planted in low marsh behind each unit and high marsh across the new backshore. The cross-section for a typical breakwaterl for this site is shown in Appendix 3, Figure 3.

Figure 5-6. *Eroding shoreline at Area of Interest 2 on the James River. The landowners clear cut the trees along the shoreline exposing a relatively stable, sloped bank with erosion along the base of bank.*

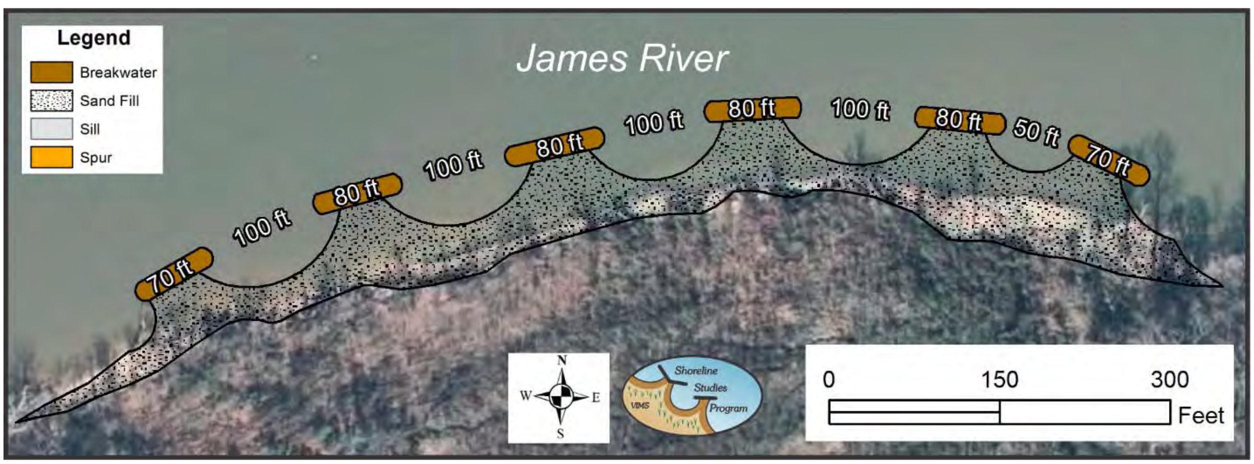

Figure 5-7*. Conceptual design of a shore protection system for the eroding bank at Area of Interest 2. The 2013 image shows the bank still covered in trees.*

5.2.3 Upper Brandon (Area of Interest)

Upper Brandon is a large farm/planation complex on the James River (Figure 2-4). The project site is about 1,000 feet long in front of the house. The eroding upland bank is about 10 feet high on the upriver end and decreasing to less than 5 feet high on the downriver end (Figure 5-8). The SSM recommends a sill. The conceptual plan is seen in Figure 5-9. An existing marsh headland separates the upriver and downriver sill systems. The cross-section for a typical sill for this site is shown in Appendix 3, Figure 2.

Figure 5-8. *Eroding bank and marsh fringe at Upper Brandon Area of Interest.*

Figure 5-9. *Conceptual design of a shore protection system for the eroding shoreline at Upper Brandon on the James River.*

6 Summary and Links to Additional Resources

The Shoreline Management Plan for Prince George County is presented as guidance to County planners, wetland board members, marine contractors, and private property owners. The plan has addressed all tidal shorelines 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: Living Shoreline Design Guidelines

http://www.vims.edu/research/departments/physical/programs/ssp/_docs/living_shorelines_guidelines.pdf

VIMS: Why a Living Shoreline?

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

VIMS: Shoreline Evolution for Prince George County

http://web.vims.edu/physical/research/shoreline/docs/Cascade/Shoreline_Evolution/PG_ShoreEvol-Final_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

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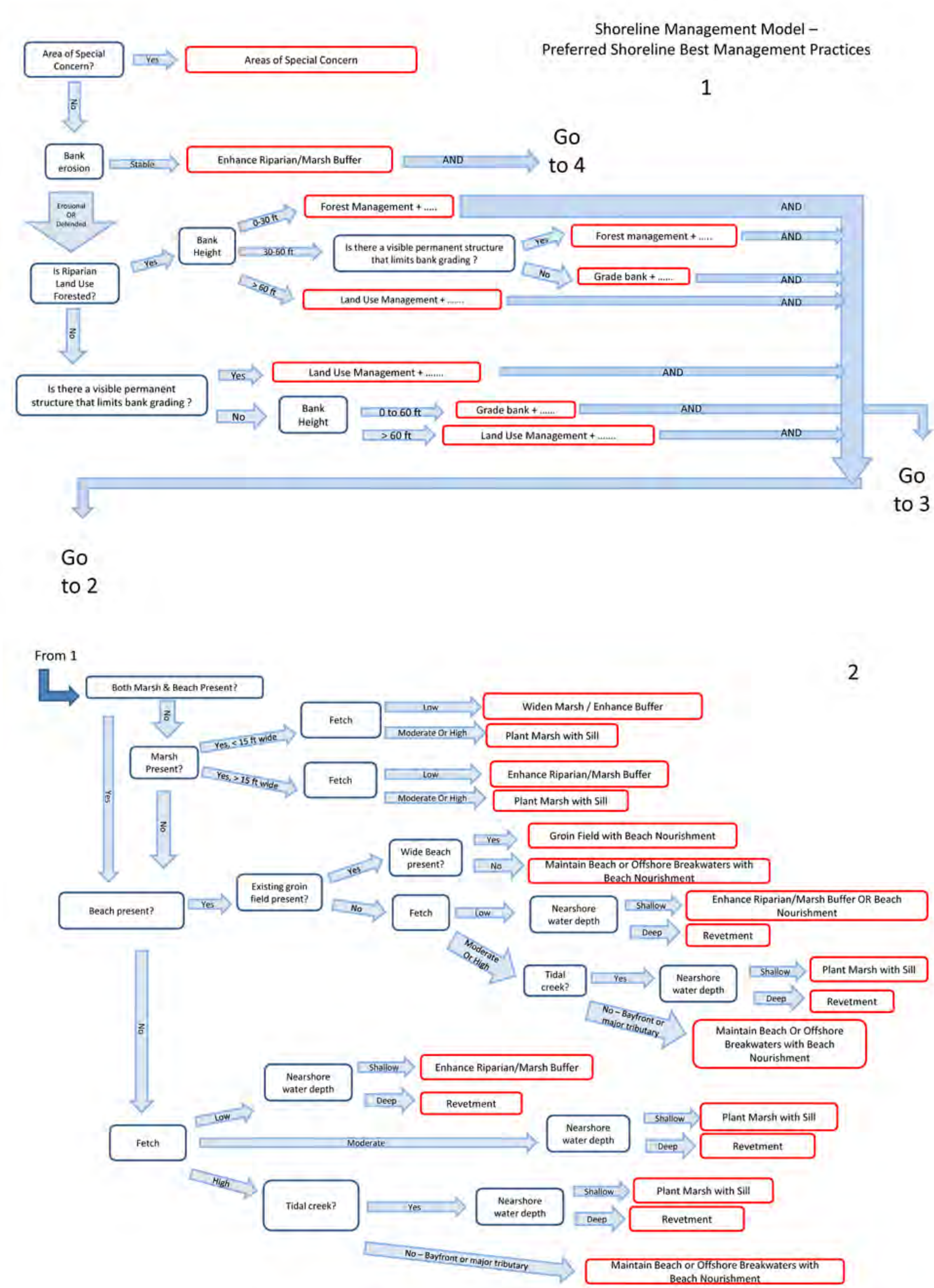
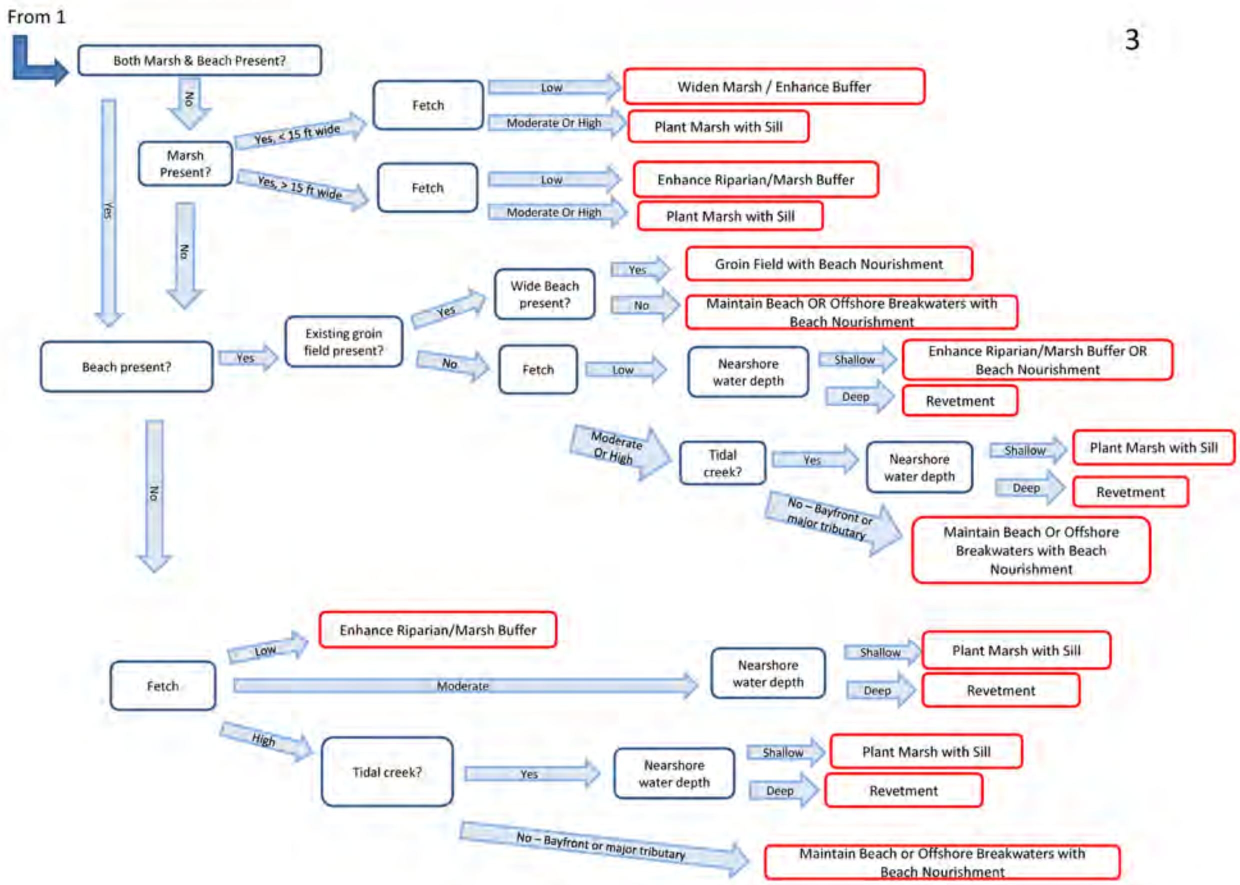
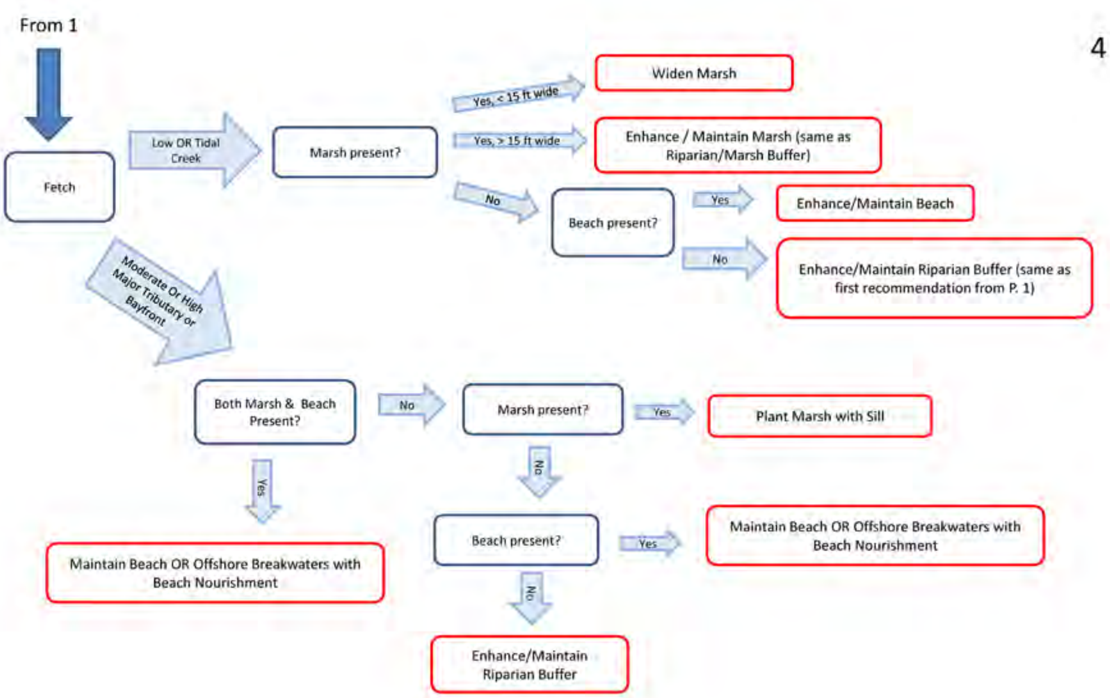
APPENDIX 1

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?
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
Yes
Maintain Beach OR Offshore Breakwaters with Beach Nourishment

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. May also 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 ft 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 ft wide, consider placing sill just offshore from marsh edge. If 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 Prince George County

For Prince George County, three typical cross-sections for stone structures have been developed. The dimensions given for selected slope breaks have a range of values from low to high energy exposures becoming greater with fetch and storm wave impact. A range of the typical cost/foot also is provided (Appendix 3, 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 very 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 low, medium, and high wave energy shores, the structure should become a more engineered coastal structure. In the lower fetch areas of Prince George, a low sill might be appropriate (Appendix 3, Figure 1). Along medium energy shorelines or where there is nearby upland infrastructure, a medium sill would be better (Appendix 3, Figure 2). Using sills on the open river requires careful consideration and design due to the severity of storm wave attack. In Prince George, the swamp forests and cypress trees are evidence of a fresh water system. For this environment, the typical vegetation that should be planted during the construction of these systems are *Scirpus americanus* in low marsh areas and *Panicum virgatum* in high marsh areas.

Breakwater systems are applicable management strategies along the James River shorelines that have high banks and a medium to high wave climate. 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 3).

Type of Structure	Estimated Cost per Linear Foot*
Low Sill	$150 -$250
Medium 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.***

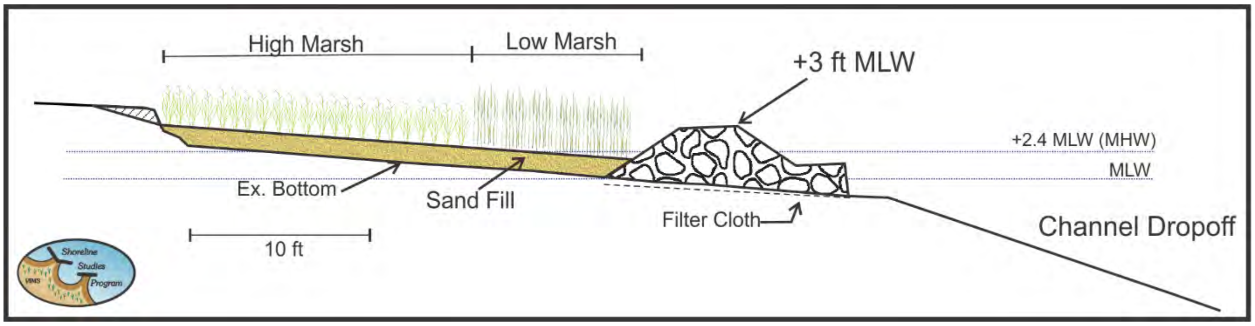


Figure 1. *Typical cross-section for a low sill that is appropriate for low to medium energy shorelines of Prince George County. The project utilizes clean sand on an 10:1 (H:V) slope, and the bank can be graded to a (minimum) 2:1slope, if appropriate.*

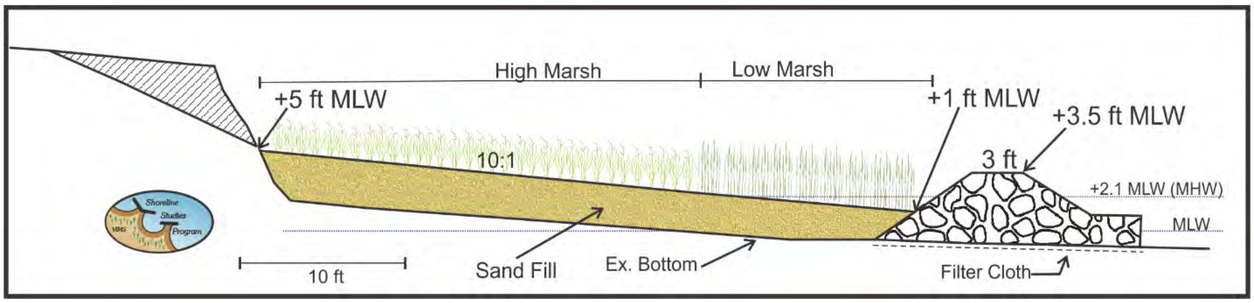


Figure 2. *Typical cross-section for a medium sill that is appropriate for the medium to high energy shorelines of Prince George County. The project utilizes clean sand, and the bank can be graded to a (minimum) 2:1slope, if appropriate.*

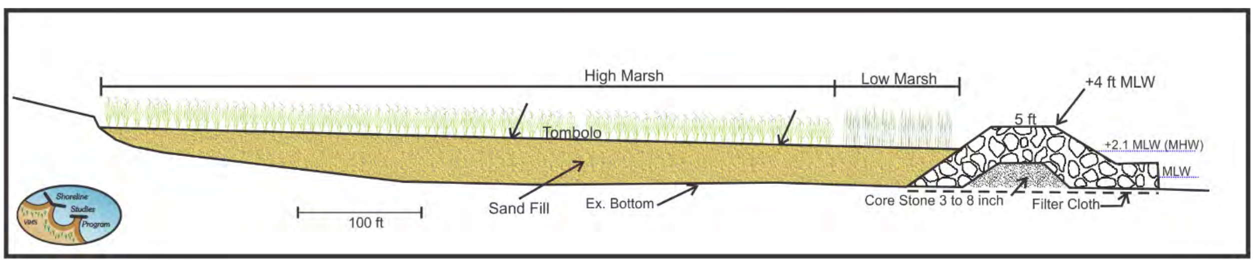


Figure 3. *Typical cross-section for a breakwater that is appropriate for shore protection along the medium to high energy shorelines of Prince George County. The project utilizes clean sand, and the bank can be graded to a (minimum) 2:1 slope if appropriate.*