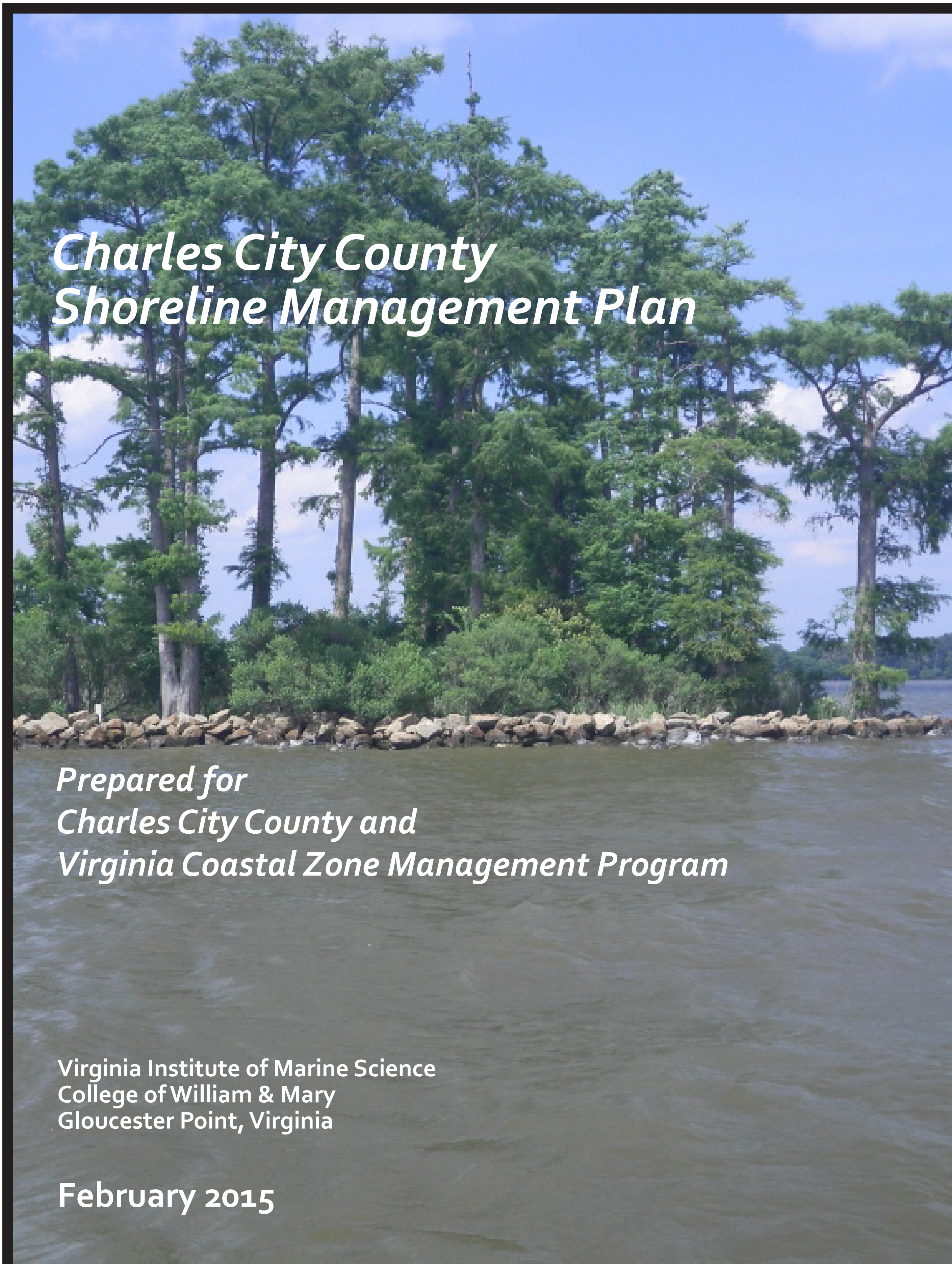

Charles City County Shoreline Management Plan

Prepared for
Charles City County and
Virginia Coastal Zone Management Program

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

February 2015

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February 2015

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 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. Water quality is an important issue for Charles City County. The protection of groundwater and surface water is important in the short and long-term both as a source of drinking water and for recreation and for fish and wildlife habitat (Charles City County, 2014). The shores of Charles City range from exposed open river to very sheltered creeks, and the nature of shoreline change varies accordingly (Figure 1-1). This shoreline management plan is useful

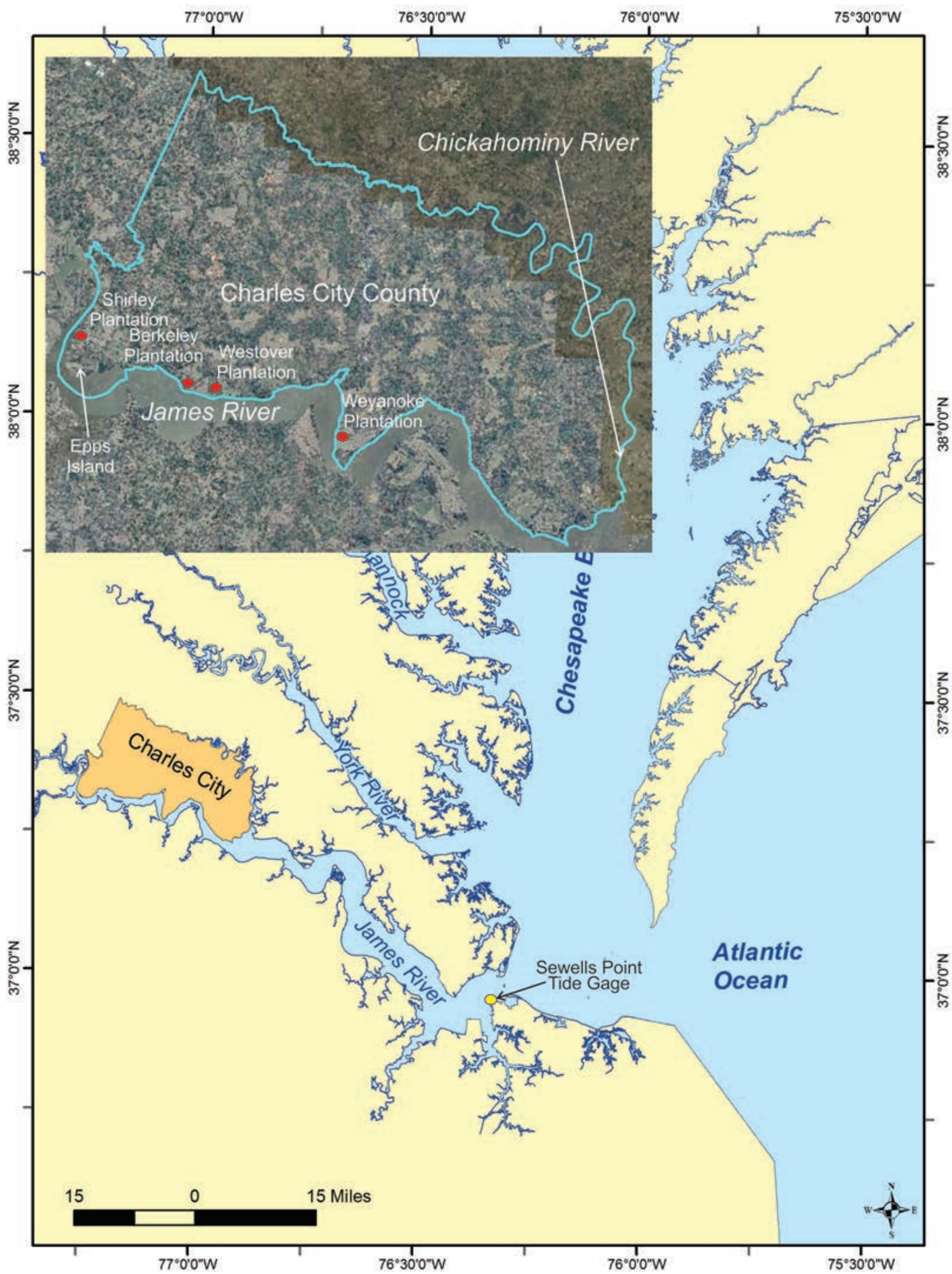

Figure 1-1. *Location of Charles City County within the Chesapeake Bay estuarine system. The location of the National Oceanic and Atmospheric Administration tide gage is shown.*

for evaluating and planning shoreline management strategies appropriate for all the creeks and rivers of Charles City. It ties the physical and hydrodynamic elements of tidal shorelines to the various shoreline protection strategies.

Much of the Charles City 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 Charles City County Shoreline Management Plan is an educational and management reference for the City and its landholders.

2 Coastal Setting

2.1 Geology/Geomorphology

2.1.1 Geology

Charles City County lies in the coastal plain of Virginia. Like many coastal localities, the county boundaries are defined by creeks, rivers and watershed. It is bounded to the north and east by the Chickahominy River and on the south and west by the James River. Only seven miles of shoreline along the western boundary is not bounded by water (Charles City, 2014).

Charles City County is defined by the tidal water sheds of the Chickahominy River and the James River which have broad flood plains that have been occupied by the Chickahominy and James for 100,000s years as sea level has risen and fallen across the Virginia Coastal Plain during the Pleistocene. These include 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), Charles City Formation (Qcc) (Figure 2-1).

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 meandering nature of the coast and multiple depositional features are shown in Figure 2-1. The rich soils of the Charles City County James River floodplain also are where some of the largest plantations in Virginia were established. Some of those plantations, Shirley, Berkley, Westover and Weyanoke, still exist along the shoreline.

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.

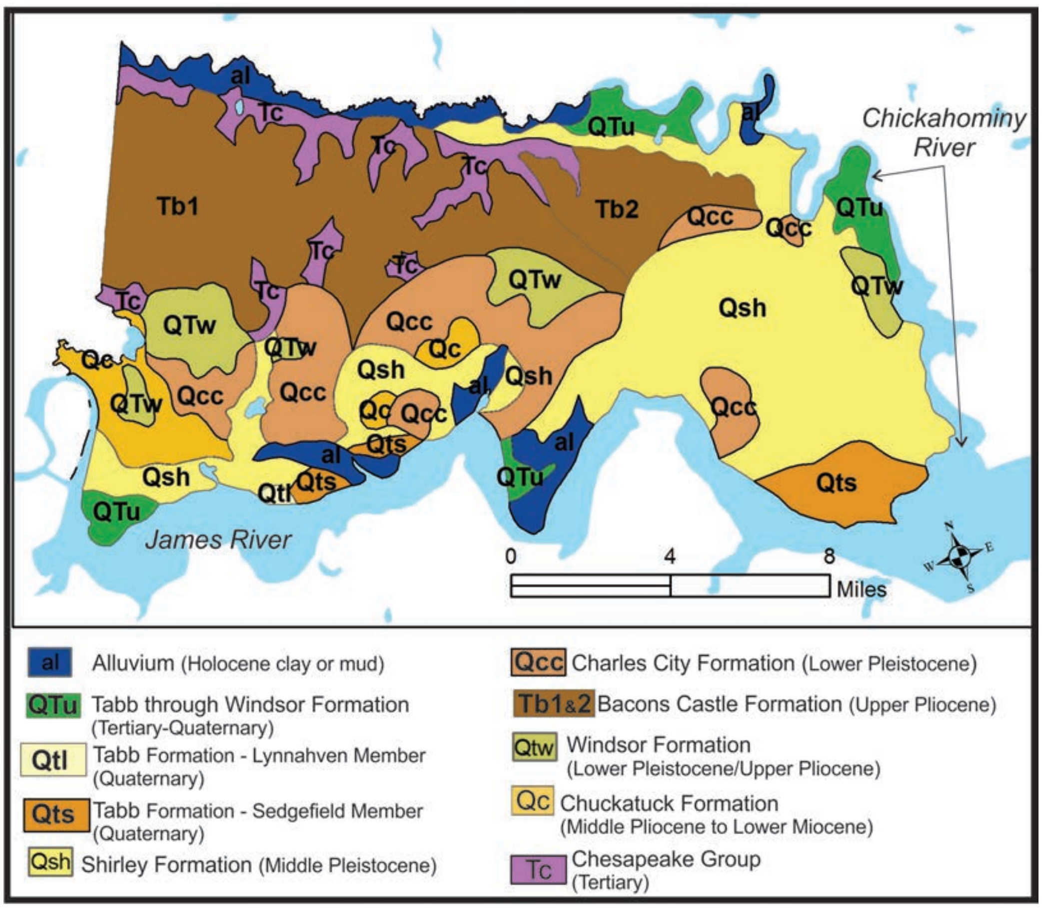

Figure 2-1. *Geology of Charles City County (Mixon* et al., *1989).*

The coastal morphology, topography and hydrology of Charles City County are seen in Figures 2-2 and 2-3. The James River from the Chickahominy River to Eppes Island is a transition zone between the sharp meandering tidal channels of the upriver section and the wider estuarine section of the watershed. The erosion processes go from tide dominated in the upriver section to wind/wave driven in the downriver section.

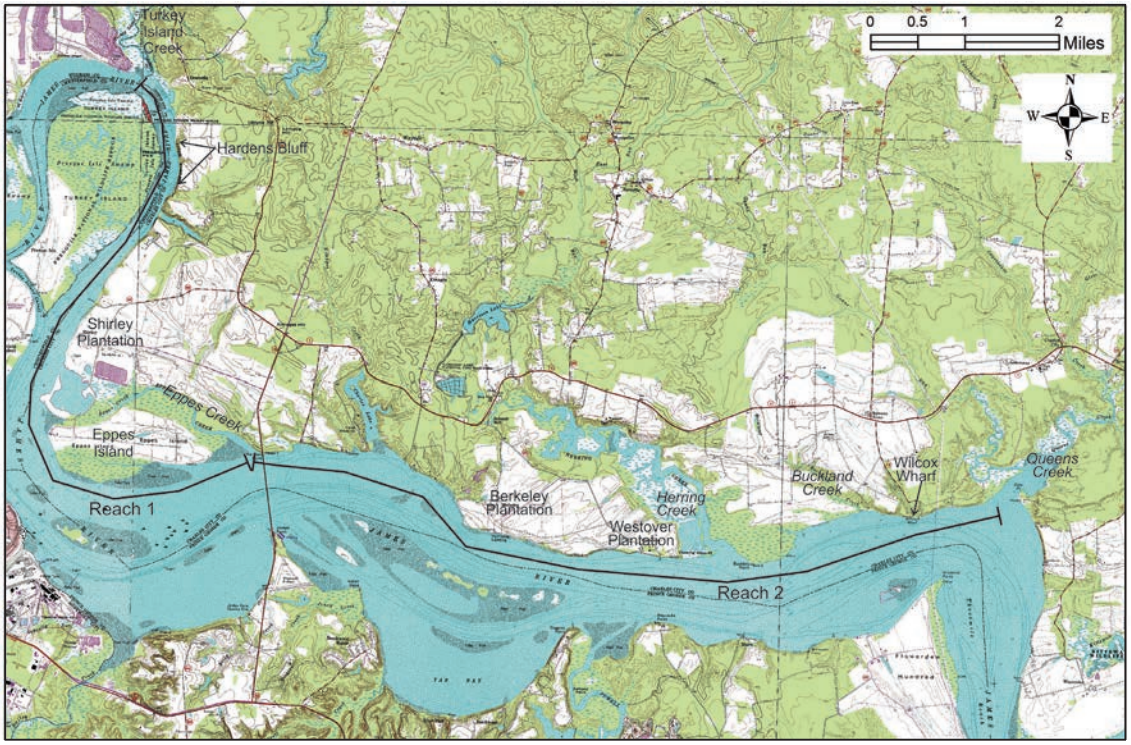

Figure 2-2. *Topographic sheet of the upriver section of Charles City County. Also shown are the reach designations.*

The James River channel thalweg coincides with the shipping channel, and ship wakes add to the hydrodynamic processes. Maintenance dredging has been required for a long time and often the dredged material was placed onto adjacent shoals thereby altering tidal flow and wind driven wave generation across certain fetch exposures. Naturally deep channels in Charles City County that are self-maintaining include the narrow 30 foot deep channel along Hardens Bluff (Figure 2-2), the 90 ft deep channel off Weyanoke Marsh and the 80 foot deep channel along Kennon Marsh (Prince George County) (Figure 2-3).

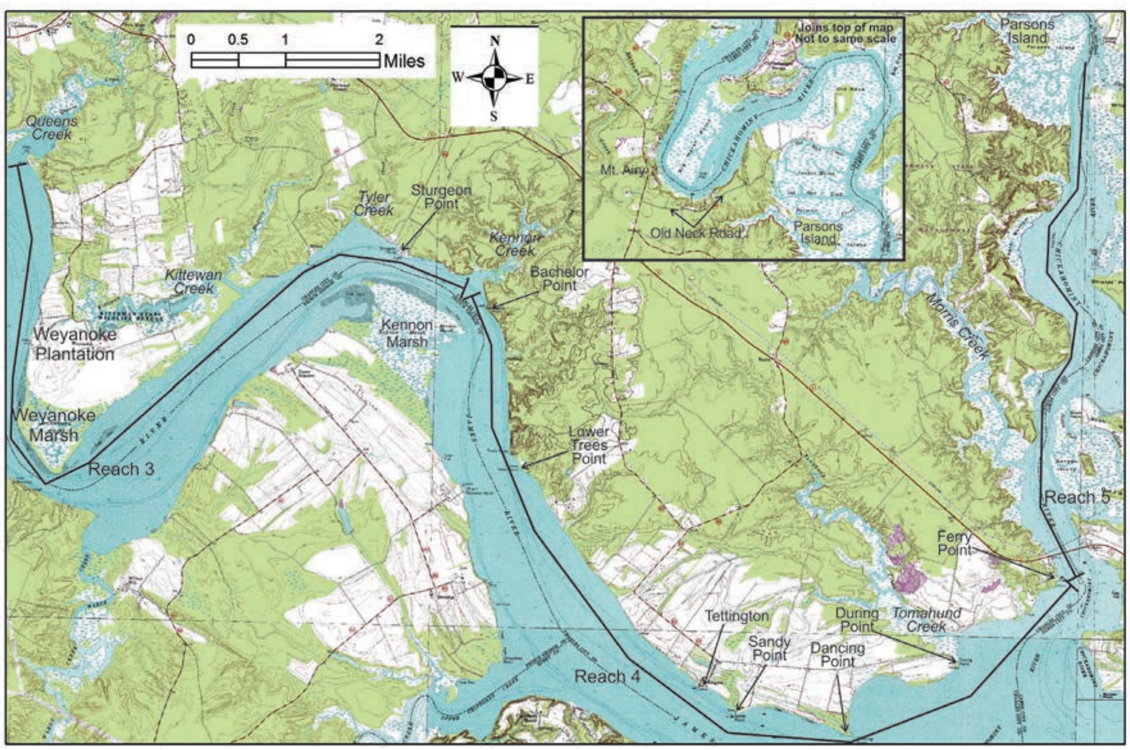

Figure 2-3. Topographic sheet of the downriver section of Charles City County. Also shown are the reach designations.

These channels are relicts of the deep downcutting in the older coastal plain strata that occurred during the Yorktown time when sea level was much lower. Numerous oceanic transgressions and regression have occurred since, modifying the flood plain sedimentation each time. The last low stand was about 15,000 before present when the ocean coast was about 60 miles east and sea level was about 300 feet lower.

2.1.2 Shoreline Morphology

Today coastal morphology /landscape is a function of the underlying geologic history. All of Charles City's James River shoreline is tidal while two-thirds of the Chickahominy is tidal. The County coast can be divided into 5 reaches for ease of discussion (Figures 2-2 and 2-3). These reaches are defined based on shore morphology and drainage patterns. There are four reaches along the James River (1-4) coast while Reach 5 includes the Charles City County coast all the way up the Chickahominy River.

<u>Reach 1:</u> Turkey Island Creek to Eppes Creek. Includes Shirley Plantation

<u>Reach 2:</u> Eppes Creek to Queens Creek. Includes Herring Creek, Buckland Creek, Berkley Plantation, Westover Plantation, and Wilcox Wharf

<u>Reach 3:</u> Queens Creek to Kennon Creek. Includes Weyanoke Plantation, Weyanoke Marsh, Kittewan Creek, Tyler Creek and Sturgeon Point.

<u>Reach 4:</u> Kennon Creek to Mouth of Chickahominy River

<u>Reach 5:</u> Chickahominy River to New Kent County line.

Reach 1

Reach 1 begins upriver at the Henrico/ Charles City County line and Turkey Island Creek and extends down to a point bar feature called Eppes Island and ending at Eppes Creek (Figure 2-2). The Reach 1 shoreline begins as low fringing tidal freshwater marsh (Figure 2-4) just downriver of Turkey Island Creek. The coast becomes a forested upland bluff that quickly rises to about 50 feet in elevation along Hardens Bluff (Figure 2-5). Bank erosion is minor due, in part, to very short fetch exposure. The base of bank and bank face are relatively stable, but some bare banks are noted. The small amount of sediment input from the eroding bank sediments contribute to raising the shoreline elevation enough to provide a place for intertidal fresh water marshes to become established (Figure 2-6). These features often are ephemeral until the next flooding event.

The wooded bluffs continue downriver for about 5,000 feet, then gradually descend down to about 10 feet in elevation over the next 8,000 feet which includes Shirley Plantation and the associated agricultural

Figure 2-4. *Reach 1 fringing freshwater marsh near Turkey Island Creek.*

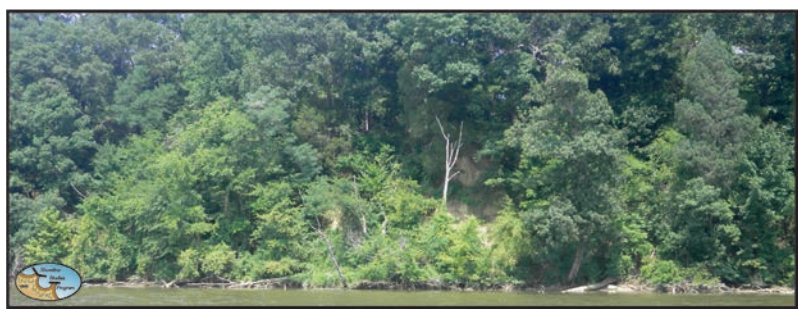

Figure 2-5. *Reach 1 forested high upland bank along Hardens Bluff.*

Figure 2-6. *Reach 1 intertidal fresh water marsh.*

landuse (Figure 2-7). Downriver of Shirley, a barge port supports the sand mining operation nearby. A large circular embayment (the barge port) has been formed over the years as the sand and gravel is mined from the floodplain and surrounding borrow pits and barged downriver (Figure 2-2).

Figure 2-7. Reach 1 lower bank elevations at Shirley Plantation.

The rest of the reach is low upland bank and then freshwater tidal forested wetlands (Swamp Forest) across the end of Eppes Island. Intermittent intertidal freshwater wetlands occur. Downriver, the Eppes Island shoreline transitions to upland bank toward Eppes Creek where a Swamp Forest/tidal marsh complex resides. Landward of the upland is a large pond, once an active borrow pit, built into the surrounding agricultural landscape.

The fetch along Reach 1 is restricted, only about 0.2miles wide along the northern section at Harden Bluff and gradually widening to almost 2 miles across at the end of Eppes Isand. Shoreline erosion rates increase accordingly where there is almost zero to about 1.5 ft/yr, respectively

The northernmost section of the reach has a steep nearshore gradient; the -6 ft contour is only a few feet off the shoreline. However, it becomes shallower as the river widens. This corresponds to the shipping channel which is only 500 feet off of Harden Bluff and 6,000 feet offshore of Eppes Island. Wind driven waves are limited along the upper reach but can become a factor as the river widens causing increased bank loss.

Minimal residential development occurs along the Reach 1 shoreline. Shoreline management strategies to date are hardened structures especially around the barge port. In the future, if shore hardening structures are proposed, a Living Shoreline should be considered. Along sections of shoreline where there is obvious but minor bank instability with an erosive base of bank, a low sill could be recommended from one of the preferred shore protection strategies. However, this would be difficult along the deep nearshore off and along Hardens Bluff but is more reasonable along the rest of the reach as the nearshore becomes shallower.

Reach 2

Reach 2 begins at mouth of Eppes Creek and extends down river to Queens Creek. The coast is oriented generally east west, faces south and undulates across alternating headlands and embayments reflecting the old meandering James River channel.

At the upper Reach 2 boundary, the 20 ft upland (old coastal terrace) intersects the shoreline. Relatively new residential properties occur for about 2,000 feet to the Harrison Bridge and continuing downriver for another 1,200 feet across this headland feature to a spit and unnamed creek (Figure 2-8). Intermittent residential development occurs for another 2 miles down to Berkeley Plantation. The upland banks often are wooded and slightly undercut with sparse, narrow tidal marsh fringes. Many of the banks have been modified or graded and trees thinned or planted with varying types of stabilizing vegetation including low growth and trees.

Figure 2-8. Reach 2 relatively new residential development.

Shoreline erosion rates are less the 0.5 ft/yr due in part to limited fetch exposures of less than 2 miles in any direction. Numerous small islands and tidal flats act as wave attenuation features as well. Shoreline management along this section of Reach 2 consists of defensive structures, usually rock revetments.

Reach 2 continues from Berkley about 15,000 feet of shoreline to Herring Creek. The upland banks drops down to about 5-10 feet high with a narrow band of woods fronting a wide agricultural landscape (Figure 2-9) with areas of minor bank erosion. Historic bank erosion varies from Harrison Landing at Berkley plantation from about 2 ft/yr down to less than 1 ft/yr along the Westover coast. Eroded bank materials occasionally provide elevated nearshore for tidal freshwater marsh grasses but most of the reach is wooded.

Figure 2-9. *Reach 2 low agricultural land.*

Westover plantation was fitted with a concrete seawall and short groins in years past that still functions today (Figure 2-10). Reach 2 continues from Herring Creek to Queens Creek, about 17,000 feet. It starts as a low swamp forest headland at Bucklers Point (Figure 2-11) and transitions to a very low upland backed by agricultural land, toward Buckland Creek. Buckland Creek extends northwest along the base of an old upland river terrace that intersects the James River just downriver from Buckland Creek where the banks quickly rise to 50 feet in elevation (Figure 2-12). The high upland bank continues for about 6,500 feet to the swamp forest coast at the mouth of Queens Creek.

Figure 2-10. *Reach 2 bulkhead and short groins at Westover Plantation.*

Historic shoreline erosion along this section of Reach 2 averages about 0.5 ft/yr. Limited residential development occurs downriver of Wilcox Wharf with an occasional bulkhead and bank grading. Downriver the upland bank is heavily wooded, slightly under cut and slightly eroding. There is little or no development up Queens Creek.

Figure 2-11. *Reach 2 very low swamp forest headland at Buckners Point.*

Reach 3

Reach 3 begins at the mouth of Queens Creek and extends downriver to Kennon Creek. This includes the large peninsula of Weyanoke Plantation and Weyanoke Point, a major headland feature formed along the meandering course of the James River. From Queens Creek to the distal end of Weaynoke Point, the shoreline is oriented north south. Most of the shoreline is sheltered by the south shore of the James; however along the

Figure 2-12. *Reach 2 high upland bank with erosive face.*

north section of the reach, there is one long fetch of almost 8 miles upriver. Generally, the fetch is about 1 mile but decreases to about 0.5 miles off Weyanoke Point. The Reach 3 shoreline begins as a low bank and tidal marsh for about 1,500 feet but quickly rises to over40 feet for the next 3,000 feet of coast. The shoreline is heavily wooded, often undercut with numerous logs along the shore (Figure 2-13). The upland banks descend to about 5 ft over the next 8,000 feet, the west coast of Weyanoke Plantation. Then the coast transitions to the swamp forest comprising Weyanoke Point. Shoreline erosion is minor along the section of Reach 3.

Figure 2-13. *Reach 3 high eroding bank about halfway between Queens Creek and Weyanoke Point.*

Figure 2-14. *Reach 3 shoreline structures at Weyanoke Plantation.*

Weyanoke Plantation's west coast is hardened in a few areas (Figure 2-14) where infrastructure resides. Weyanoke point is all swamp forest (Figure 2-15) and the James River only about 1,200 feet wide, but the channel is 90 feet deep. The river widens down river and the shipping channel resides more along the south side of the James River.

Figure 2-15. *Reach 3 swamp forest at Weyanoke Point.*

Reach 3 continues along the southeast side of the Weyanoke peninsula beginning at Weyanoke Marsh for about 22,000 feet to Tyler Creek. The east side of Weyanoke Point remains swamp forest but with a higher rate of erosion, about 1 ft /yr as fetch exposure increases to about 4,000 feet southeast across the James . Consequently, there are numerous single cypress trees dotting the nearshore region (Figure 2-16). Downriver of the Weyanoke Point Swamp Forest, the low east coast of the Weyanoke peninsula resides along the coast with a swamp forest fringe down to Kittewan Creek.

Figure 2-16. *Reach 3 along the southeast side of Weyanoke Marsh showing lone cypress trees scattered along the shoreline (2013 Virginia Base Mapping Program Image).*

From Kittewan Creek to Tyler Creek, the shoreline is mostly an alternating high bank and lower bank shoreline with several small upland drainages entering the James. Reach 3 continues as the shoreline turns 90 degrees to face southwest and extends from Tyler Creek to Kennon Creek, 7,000 feet. Shore erosion is minor. The James River narrows to about 2,000 feet here, and the shoreline remains mostly a high bank coast where cypress trees dot the nearshore (Figure 2-17) and are even become part of the landscaping (note the pier in foreground built around a cypress tree). Beyond Sturgeon Point, the upland banks are lower at about 10 feet and heavily wooded with a few cypress along the shore. A cypress tree cluster guards the mouth of Kennon Creek on an old shoal.

Reach 4

Reach 4 begins at Kennon Creek and extends downriver to the mouth of the Chickahominy River. It is a broad curvilinear headland at the downstream limit of Charles City County. The James River channel runs along the upriver section of Reach 4 at a depth of 40 feet. The river width (fetch) increases gradually off Kennon Marsh from 2,000 feet to 3,000 feet. The river and channel widen to where the 18 foot contour resides just off of Sandy Point.

Figure 2-17. *Reach 3 between Tyler Creek and Kennon Creek showing an eroding bank and cypress trees incorporated into the landscape.*

The shoreline along Reach 4 from Kennon Creek downriver to Lower Trees Point, about 10,000 feet, runs about north south and is mostly high bank with several small intermittent drainages. The banks are heavily wooded with numerous cypress trees alongshore. The navigation channel comes in close to the shoreline just south of Kennon Creek at Bachelor Point (Figure 2-18). Shoreline erosion is low between 0.5 and 1.0 ft/yr. This section of the reach is mostly undeveloped and. The nearshore may be too deep for offshore structures until past Lower Tree Point where the bank drops down to less the 5 feet high and is sandy.

Figure 2-18. *Reach 4 at Bachelor Point where the navigation channel comes close to the shoreline.*

Figure 2-19. *Reach 4 low graded bank with shore protection structures.*

Figure 2-20. *Reach 4 erosional bank with no shore protection structures.*

Reach 4 continues downriver from Lower Tree Point around to Sandy Point where the shoreline turns east then sharply north at Dancing Point. The shoreline is upland bank, about 20 feet high grading down to about 10 ft high where agricultural lands begin. The bank is mostly stable with an intermittent fringe of cypress. There is sparse residential development, and some hardened coast (Figure 2-19) and some not (Figure 2-20). This condition continues to Tettington where land use becomes more residential fronting agricultural land, and shore hardening includes a concrete seawall. It's mostly continued residential for the next 2,500 feet to Sandy Point.

Sandy Point is a point of land where deep water provided for a wharf as well as a loading facility for mined upland sand pits. A conveyor would bring the product to waiting barges. The shoreline from Sandy Point to Dancing Point has a low erosion rate and is mostly upland/agricultural land with a wooded bank, intermittent marsh grass and cypress trees. Dancing Point has been hardened with stone and marks a 90 degree turn to the north.

Reach 4 continues from Dancing Point north and eastward toward During Point, about 8,000 feet. The shoreline along the segment is 5 to 10 feet high slowly eroding agricultural land with dense wooded bank and bank face with a few scattered cypress and sparse development. The nearshore shoals become very wide with the 6 feet contour lying over 1 mile offshore, but there is a long fetch down the James River of over 7 miles.

The entrance to Tomahund Creek and associated Swamp Forest shoreline has erosion rate of 3 ft/yr which leaves numerous single cypress in the nearshore. The Tomahund Creek watershed runs southeast/northwest along the base of an ancient fluvial terrace. The terrace intersects the shoreline with 30 feet high upland banks some of which have been developed. The high bank coast has low erosion and is mostly wooded and continues to Ferry Point which is the end of Reach 4. The landuse is agricultural, mining, and residential adjacent to Ferry Point where most of the shoreline is hardened with a few scattered breakwater units.

Reach 5

Reach 5 consists of the Charles City County side of the Chickahominy River. It begins at Ferry Point and extends to the Henrico county line. The shoreline is mostly marsh and swamp forest with some eroding upland banks. The landscape is mostly wooded along the Charles City County side of the river. There is limited development concentrated along Old Neck Road and the Mt. Airy area. The Old Neck Road segment is mostly swamp forest shore where the home owners have long piers to get to the Chickahominy River (Figure 2-21). The Mt. Airy residents have mostly hardened their shoreline with small stone revetments and wood bulkheads. There is a small marina off just north of Mt. Airy.

Figure 2-21. *Reach 5 swamp forest along the Chickahominy River. From Bing Maps.*

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 runs very close to shore along some sections of the County. However, their impact has not been quantified and is likely very site specific.

Basco and Shin (1993) described the wave climate in the James River 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. Wave heights and wave periods in the upper reaches of the James River (Figure 2-22) near the Chickahominy River are about 2.5 ft with a 3.0 second period before nearshore shoaling. Farther north along the James River where the River narrows, wave heights and wave periods are about 1.5 ft with a 2.3 second period. In the River near Queens Creek, the wave heights increase to 2.0 ft with a 2.7 second period.

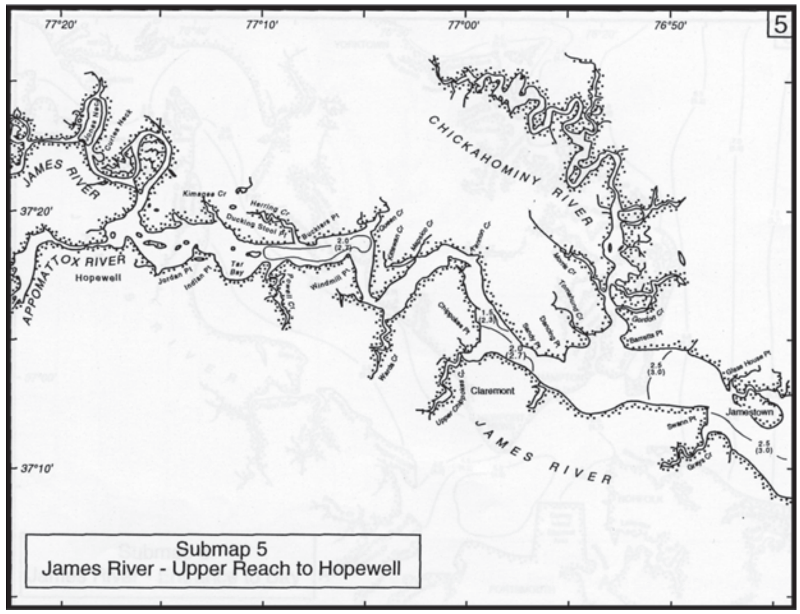

Figure 2-22. *Wave climate map for the James River (from Basco and Shin, 1993).*

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 the James River and Chickahominy River coasts. For Charles City County these are 6.5 ft MLLW, 7.9 ft MLLW, 8.6 ft MLLW and 9.9 ft MLLW, respectively. This part of James River is prone to flooding from down the James River as the narrow tidal channel opens up at Eppes Island.

Location	Annual Chance (feet MLLW)			
	10%	2%	1%	0.2%
James River and Estuaries within Charles City	6.5	7.9	8.6	9.9
Chickahominy River and Estuaries	6.5	7.9	8.6	9.9

Table 2-1. *10 year, 50 year, 100 year, and 500 year storm predicted flood levels relative to MLLW (1983-2001). Source: Charles City County Flood Report, FEMA (2009). Converted from NAVD88 using NOAA's online program VDATUM.*

Tide ranges vary along the Charles City County shoreline (Table 2-2). Tide range is lowest near the mouth of the Chickahominy River. As the Rivers become narrower, the tide range increases. 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. During hurricanes, the coastal regions that would be impacted as shown in Figure 2-23. Most of the areas impacted are found along the James River, Chickahominy River, and associated tidal creek shorelines. Areas with higher banks, do not flood as readily. They are, however, exposed to higher wave energies during storms.

Location	Tide Station	Mean Range (ft)	Spring Range (ft)
Shirley Plantation	Bermuda Hundred	2.6	3.0
Wilcox Wharf	Wilcox Wharf	2.2	2.4
Kennon Marsh	Sturgeon Point	2.1	2.5
Ferry Point	Ferry Point	1.9	2.3
Mt. Airy	Mt. Airy	2.2	2.6

Table 2-2. *Tide Range in Charles City County. The first three stations are on the James River. The last two stations are on the Chickahominy River.*

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 Charles City County, the recent trend based on wave gauge data at Sewells Point on the James River shows the annual rate to be 1.5 feet/100 years (4.44 mm/yr). 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. The historic rate at Sewells Point (1.44 feet/100 years) will result in 0.53 feet rise in water level by 2050. This increase in sea-level warrants ongoing monitoring of shoreline condition and attention in shoreline management planning. The Center for Coastal Resources Management's Comprehensive Coastal Resource Management Portal (CCRMP) provides a tool for Charles City County that uses NOAA's National Climate Assessment sea level rise predictions (http://ccrm.vims.edu/ccrmp/charlescity/sealvlrise.html)

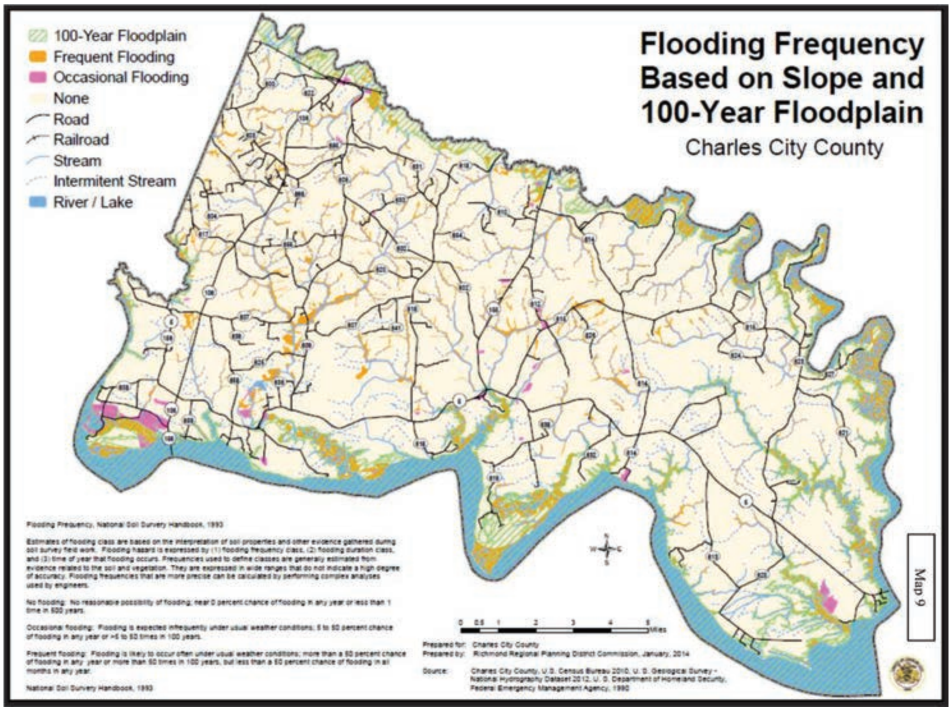

Figure 2-23. *Flooding frequency based on slope and 100 year floodplain (from Charles City County, 2014).*

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 2-3 shows the average historical shoreline rates of change for various areas throughout the County. Overall, the erosion is very low in most sections of Charles City County. 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.*, 2014.

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.

Reach Name	Avg EPR (ft/yr)	Category
James River Turkey Island Creek to Epps Island*	-0.1	Very Low Erosion
James River Epps Island to Herring Creek	-0.3	Very Low Erosion
Herring Creek	-0.4	Very Low Erosion
James River Herring Creek to Queens Creek	-0.5	Very Low Erosion
Queens Creek	-0.3	Very Low Erosion
James River Queens Creek to Kennon Creek	-0.4	Very Low Erosion
James River Kennon Creek to Tomahund Creek	-0.1	Very Low Erosion
Chickahominy River	-0.6	Very Low Erosion

**excludes dredge area*

Table 2-3. *Average end point rate of change (1937-2009) for Charles City County's shoreline. The rates of change are given in feet per year. From Milligan* et al., *(2014).*

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.

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 Buffer	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.*

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.

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.

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.*

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.

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

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.

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

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 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 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 Charles City, these are marsh sills constructed of stone and offshore breakwaters.

As fetch exposure increases beyond about 1,000 ft, 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 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.

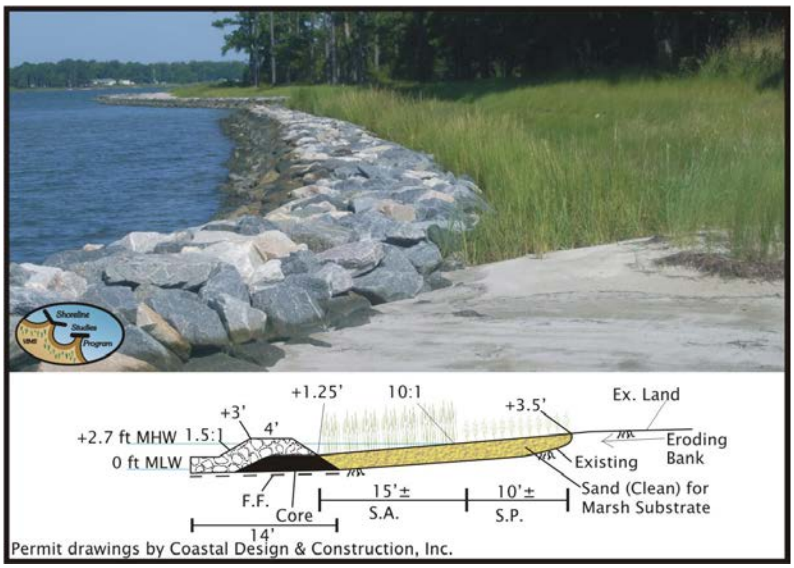

Figure 3-5. *. Sand fill with stone sills and marsh plantings at Poplar Grove, Mathews County, Virginia after six years and the cross-section used for construction (From Hardaway* et al., *2010).*

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 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 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 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.

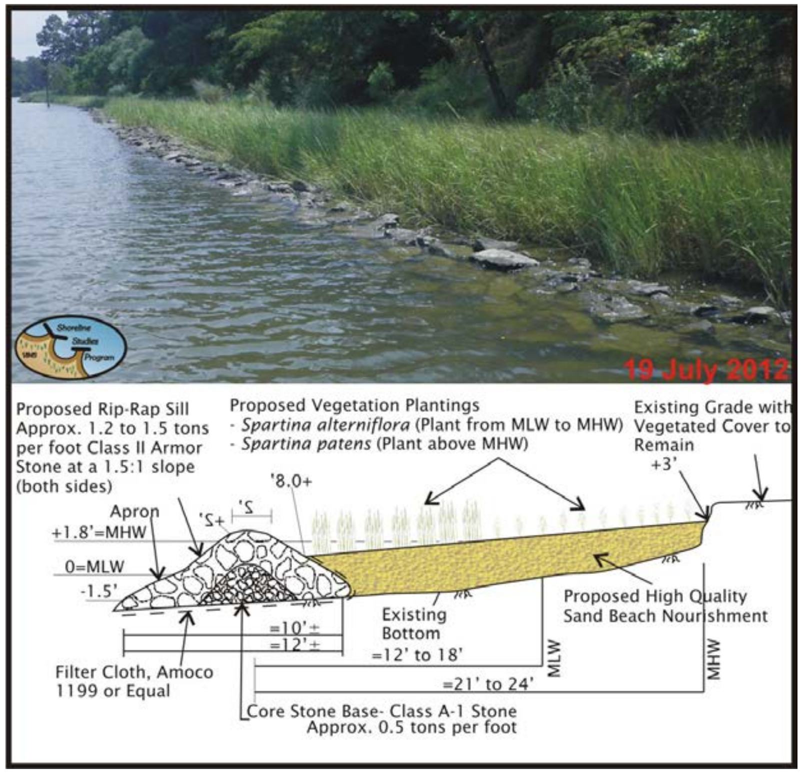

Figure 3-6. *Longwood University's Hull Springs Farm four years after construction and the cross-section used for construction (from Hardaway* et al.*, 2010).*

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 (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. *The breakwaters at Colonial Beach provide a wide recreational beach as well as storm erosion protection for the residential upland. These structures were installed in 1982.*

3.4.3 Headland Control

Headland Control is a unique shoreline management technique whereby existing geomorphic features (i.e. headlands) are enhanced 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.

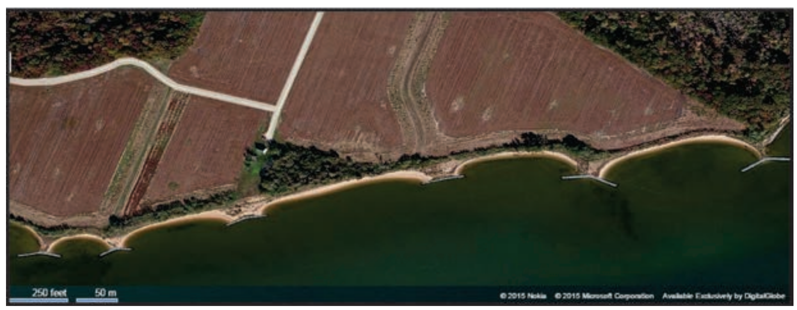

Figure 3-8. *Headland control along the Potomac River. Widely-spaced, shore-attached breakwaters are placed along eroding farm land to provide shore protection. The coast between the structures will erode into a stable embayment over time. (from Bing Maps).*

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 July 2014. 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 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 Charles City County Shoreline Inventory. (http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/virginia/charlescity/charlescity_disclaimer.html) developed by CCRM (Angstadt *et al.*, 2013). 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 Charles City County

5.1 Shoreline Management Model (SMM) Results

In the Charles City County, the SMM was run on 330 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.

The majority of shoreline management in the Charles City County can be achieved without the use of traditional erosion control structures, and with few exceptions, very little structural control. Nearly 85% of the shoreline can be managed simply by enhancing the riparian buffer or the marsh if present. Since the majority 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 Charles City based on strategy(s) and shoreline miles. The glossary in Appendix 2 gives meaning to the various Shoreline BMPs listed in Table 5-1.

Shoreline BMPs	Shoreline Length (miles)
Enhance Riparian/Marsh Buffer	284.0
Enhance/Maintain Riparian Buffer	86.7
Forest Management	2.9
Grade Bank	5.5
Land Use Management	0.4
Enhance/Maintain Marsh	178.4
Widen Marsh	2.9
Widen Marsh/Enhance Buffer	0.03
Plant Marsh with Sill	3.7
Enhance Riparian/Marsh Buffer OR Beach Nourishment	0.0
Enhance/Maintain Beach	2.6
Groin Field with Beach Nourishment	0
Maintain Beach OR Offshore Breakwaters with Beach Nourishment	17.0
Revetment	0.4
Area of Special Concern	0.1
No Action Needed	35.21

Table 5-1. *Occurrence of descriptive Shoreline BMPs in the Charles City County Watershed.*

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/charlescity/).

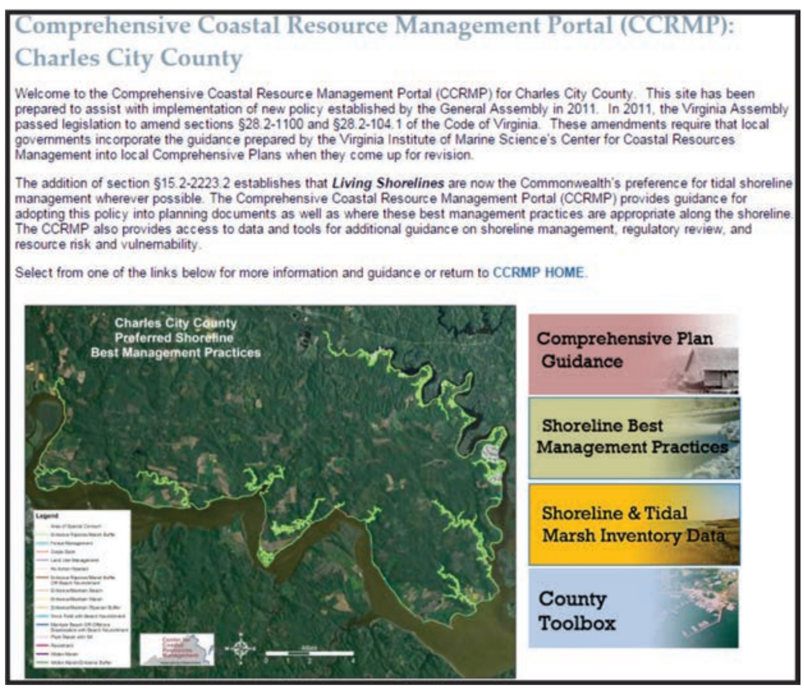

Figure 5-1. *Portal for Comprehensive Coastal Resource Management in Charles City County.*

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 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.

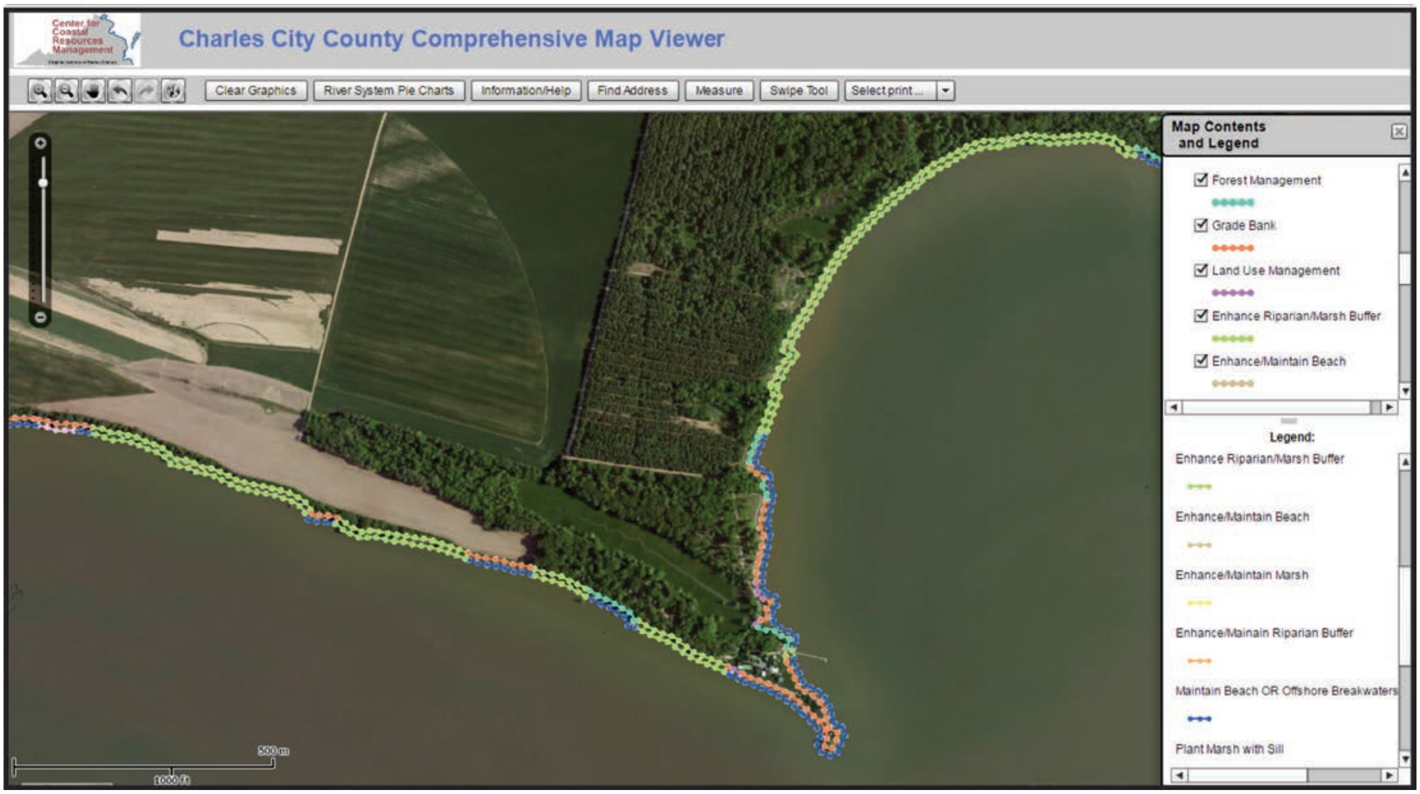

__Figure 5-2__. The Map Viewer displays the preferred Shoreline BMPs in the map window. The color-coded legend in the panel on the right identifies the treatment option recommended.

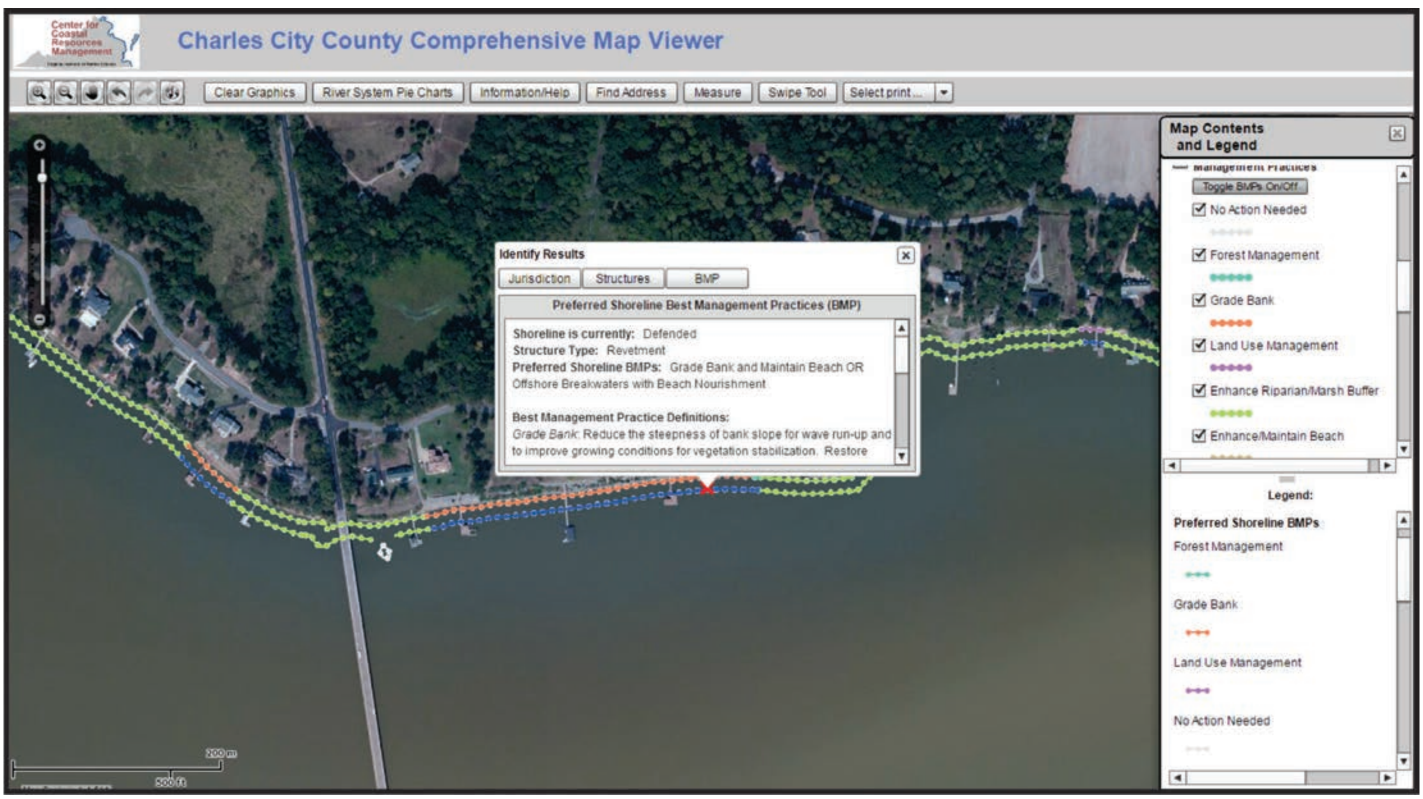

__Figure 5-3__. The pop-up window contains information about the recommended Shoreline BMP at the site selected. Additional information about the condition of the shoreline also is given.

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 Charles City and demonstrates how the preferred alternative from the SMM could be adopted by the waterfront property owners. No areas of concern exist in Charles City County. 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 Berkeley Plantation Sill (Area of Interest)

The point of land at Berkeley Plantation where the shoreline direction of face changes from westerly to south, just upriver of Harrisons Landing, has an historic erosion rate of 1 to 2 ft/yr with fetch exposures to the west, southwest, and south of 5.0 miles, 1.4 miles, and 2.1 miles, respectively. The southerly fetches are relatively shallow. The SMM recommends a sill along this stretch of shore. In order to hold the point of land and stop erosion of the low, eroding agricultural land, about 400 feet of shoreline that has an existing intermittent tidal freshwater marsh fringe can be protected (Figure 5-4). The proposed sill will maintain and enhance the existing wetland fringe (Figure 5-5). The site has easy access by and existing road. The cross-section for a typical sill for this site is shown in Appendix 3, Figure 1.

Figure 5-4. *Existing conditions at the Berkeley Plantation area of interest.*

Figure 5-5. *Proposed configuration of the sill shoreline BMP for Berkeley Plantation.*

5.2.2 Sturgeon Point Breakwaters (Area of Interest)

This site is located in Reach 3 just upriver of Sturgeon Point. The erosion rate is less the 0.5 ft/yr, but the site has a long fetch to the southwest of over 4 miles. This is a segment of residential coast where the SMM strongly recommends offshore breakwaters and beach fill along about 1,700 feet. About 800 feet of the shoreline does not have existing protective structures (Figure 5-6). For this 800 feet, four offshore breakwaters and sand fill are recommended to start upriver of the existing pier and continue upriver to the heavily wooded upland. This can be classed as a medium energy coast, and Hardaway and Byrne (1999) suggest breakwater lengths should 60 feet to 150 feet long. At this site, breakwaters with lengths of 80 feet spaced about 120 feet apart (Figure 5-7) are suggested. Beach fill will be placed along shore into pocket beach configuration. The existing cypress trees should be avoided or included as part of the plan. The cross-section for a typical sill for this site is shown in Appendix 3, Figure 2.

Figure 5-6. *Existing conditions at the site of the Sturgeon Point area of interest.*

Figure 5-7. *Proposed configuration of Shoreline BMP for Sturgeon Point.*

5.2.3 Shoreline between Sandy Point and Dancing Point (Headland Control)

The shoreline from Sandy Point to Dancing Point in Reach 4 occurs as a long curvilinear embayment and is mostly low eroding farmland with bank heights from 5 to 10 feet. Fetch exposures are to the southwest, south, and southeast at 1.2 miles, 1.4 miles and 3.5 miles respectively, placing the site in the medium energy category. Long-term erosion is low between 0.3 and 0.5 ft/yr. Sandy Point and Dancing Point are major headland features. The top of the bank is wooded with a narrow beach at low tide and scattered cypress trees along the coast (Figure 5-8). These cypress trees act as small headland features.

Figure 5-8. *Existing conditions at the site of the Sandy Point to Dancing Point area of interest. Note the cypress tree in the nearshore that acts as a headland that would be enhanced with a breakwater.*

This section of coast could be protected with Headland Control since the SMM recommends breakwaters and beach fill. However, because it is such a long stretch of shoreline, closely-spaced shore attached breakwaters may be cost prohibitive. By strategically placing breakwaters in front of existing headland features (cypress trees), the shoreline will begin the process of long-term shoreline stabilization (Figure 5-9). The adjacent shoreline will continue to recede toward static equilibrium. Seven headland breakwaters are proposed for this site ranging from 60 ft to 80 ft. Construction access will be along the adjacent farm field and then laterally through the existing woods to the each structure. Sand fill will be required to build the road and associated tombolos. The cross-section for a typical sill for this site is shown in Appendix 3, Figure 3.

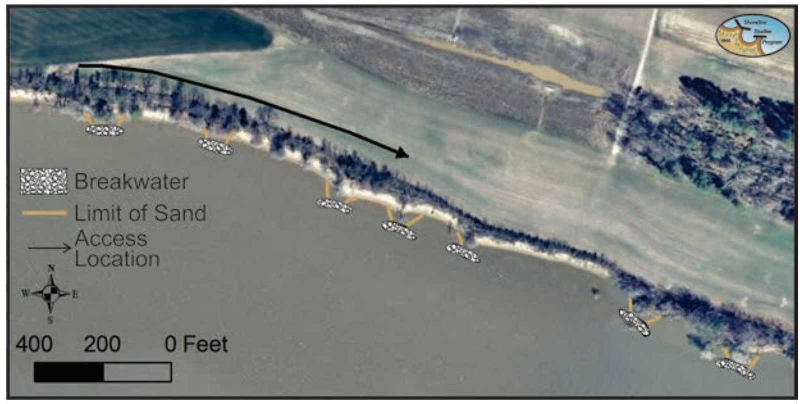

Figure 5-9. *Proposed configuration of Shoreline BMP for Sandy Point to Dancing Point. Erosion will continue between the widely-spaced breakwaters until the shore reaches dynamic equilibrium.*

6 Summary and Links to Additional Resources

The Shoreline Management Plan for Charles City 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: Charles City County Map Viewer

http://cmap.vims.edu/CCRMP/CharlesCityCCRMP/CharlesCity_CCRMP.html

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 Charles City County

http://web.vims.edu/physical/research/shoreline/docs/Cascade/Shoreline_Evolution/CharlesCity_ShoreEvol_2014.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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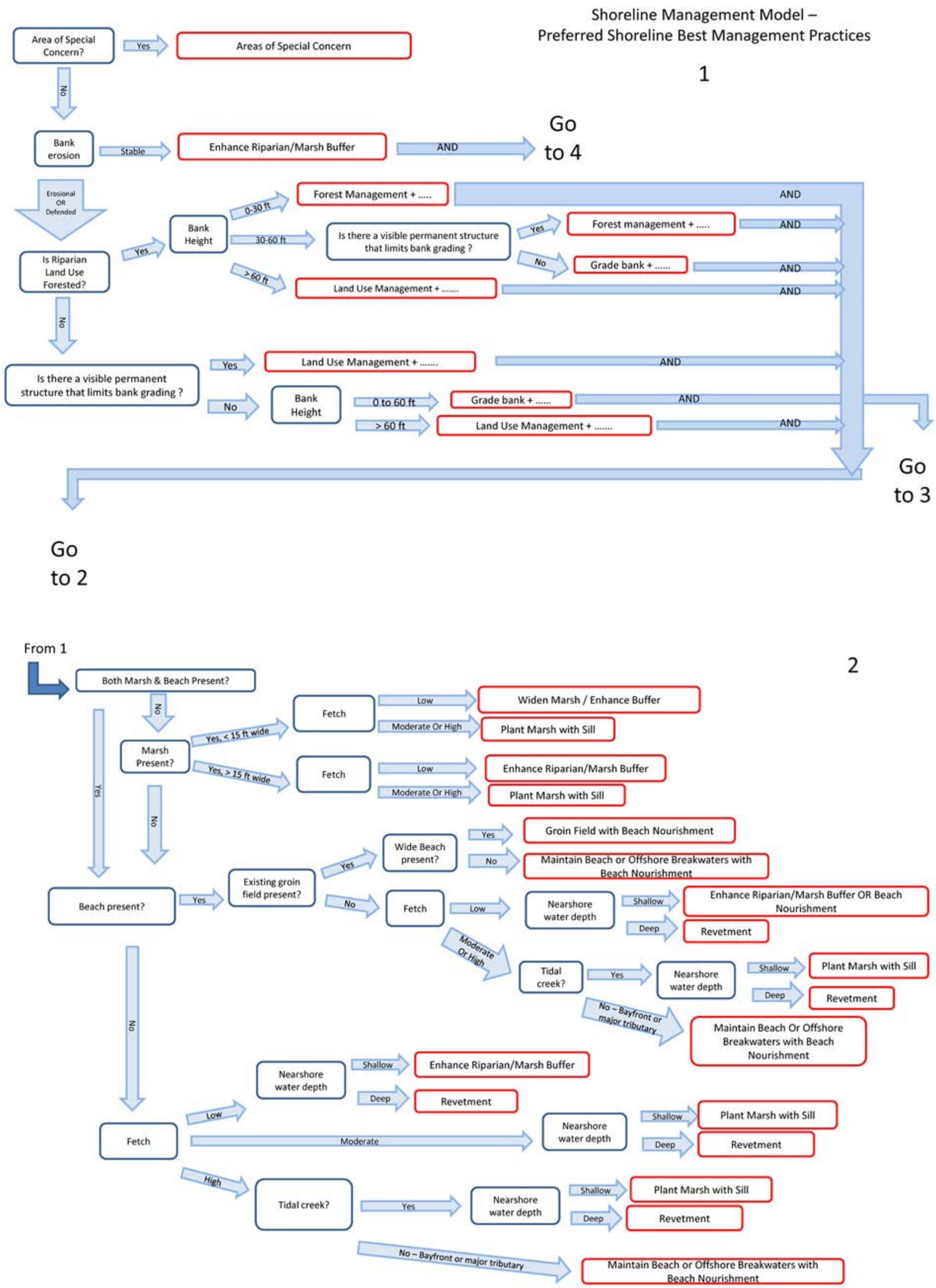
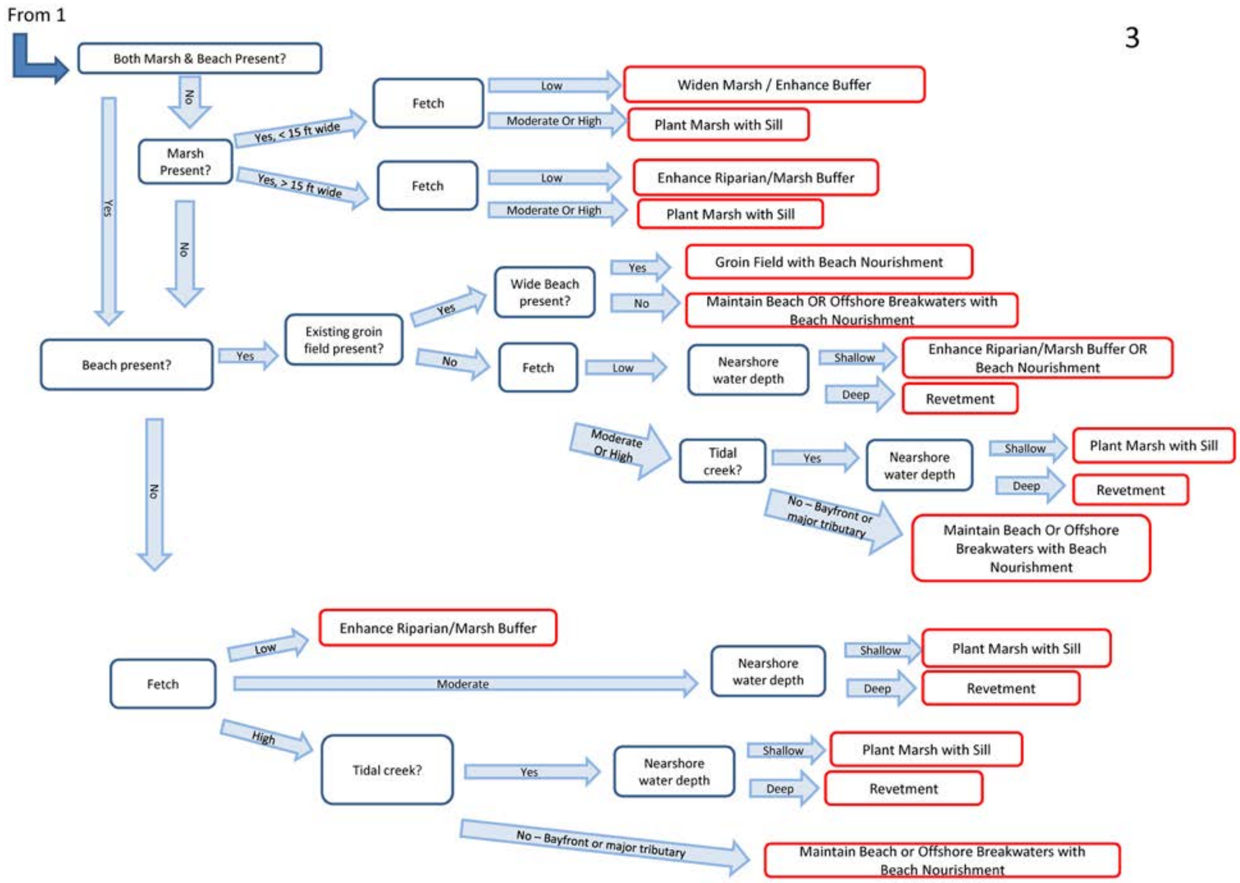
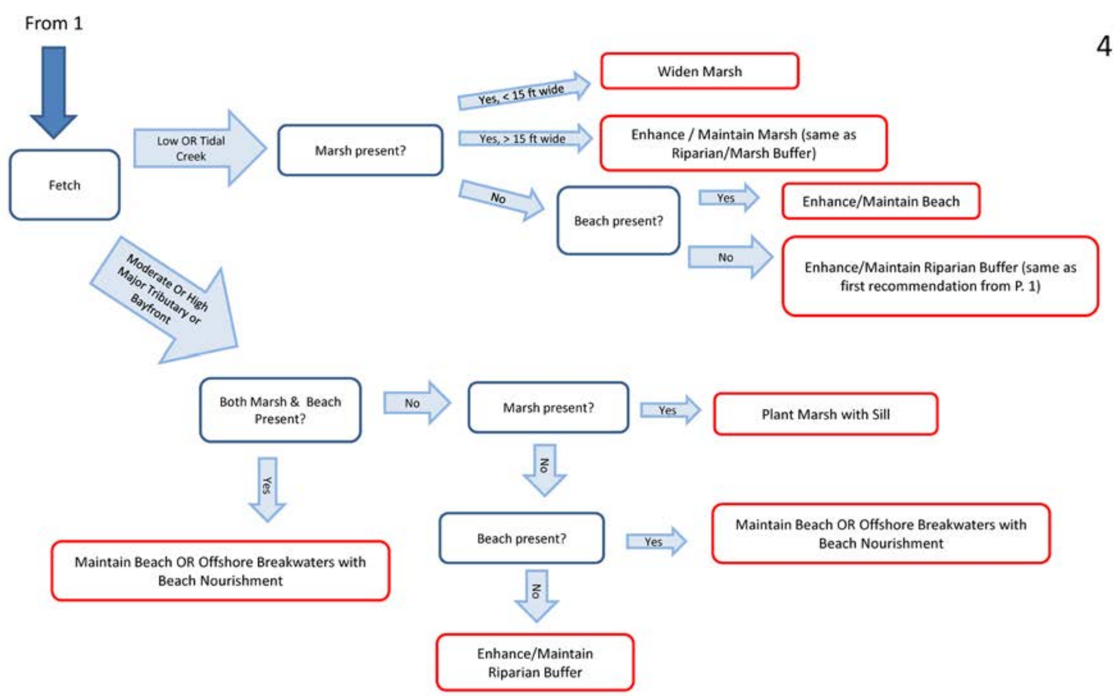
APPENDIX 1

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
Enhance Riparian/Marsh Buffer
Plant Marsh with Sill
Groin Field with Beach Nourishment
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
Wide Beach present?
Existing groin field present?
Beach present?
Fetch
Nearshore water depth
Shallow
Deep
Enhance Riparian/Marsh Buffer OR Beach Nourishment
Revetment
Moderate Or High
Tidal creek?
Plant Marsh with Sill
Revetment
No – Bayfront or major tributary
Maintain Beach Or Offshore Breakwaters with Beach Nourishment
Enhance Riparian/Marsh Buffer
Fetch
Moderate
High
Nearshore water depth
Plant Marsh with Sill
Revetment
Tidal creek?
Plant Marsh with Sill
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
Yes, > 15 ft wide
Widen Marsh
Enhance / Maintain Marsh (same as Riparian/Marsh Buffer)
No
Beach present?
Enhance/Maintain Beach
Enhance/Maintain Riparian Buffer (same as first recommendation from P. 1)
Moderate Or High Major Tributary or Bayfront
Both Marsh & Beach Present?
Marsh present?
Plant Marsh with Sill
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
Beach present?
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
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 <u>or unique developed areas</u>. 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, <u>undeveloped marsh & barrier islands</u>.

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 drainfields. All new construction should be located 100 feet or more from the top of the bank. Re-direct stormwater 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 Charles City County

For Charles City 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. Storm surge frequencies are shown for guidance. 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.

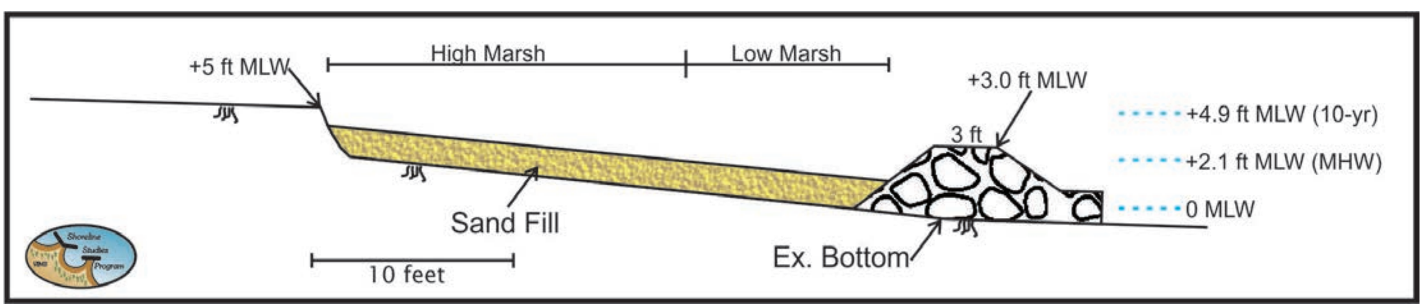
Type of Structure	Estimated Cost per Linear Foot*
Low Sill	$150 -$250
High Sill	$250 - $400
Breakwater	$600 - $1,000

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

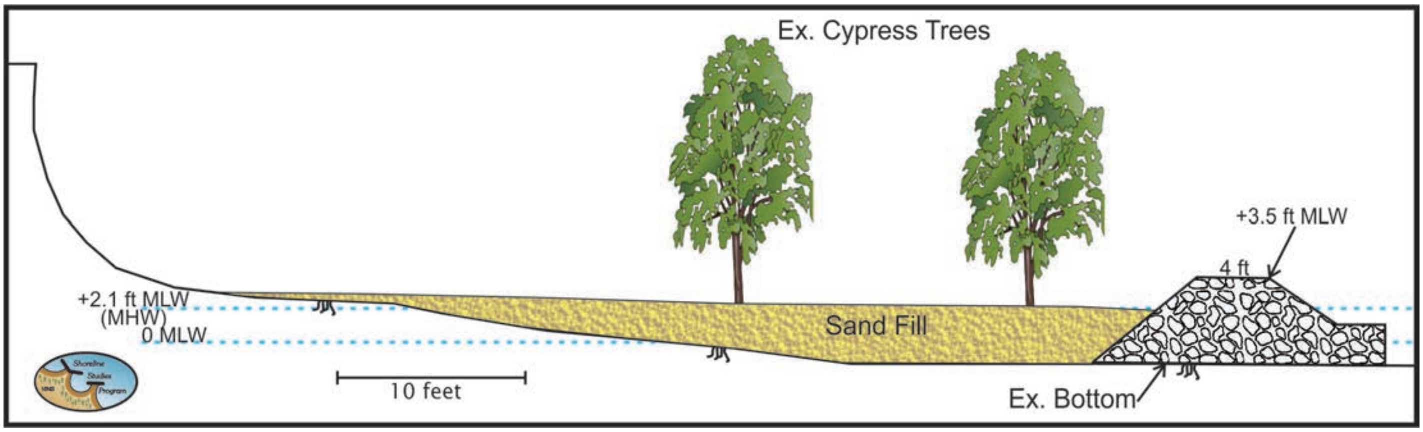
**Based on typical cross-section. Cost includes only rock, sand, plants. It does not include design, permitting, mobilization or demobilization.*

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 become a more engineered coastal structure. In the lower fetch areas of Charles City, a low sill might be appropriate (Appendix 3, Figure 1). Using sills on the open river should be carefully considered due to severity of storm wave attack.

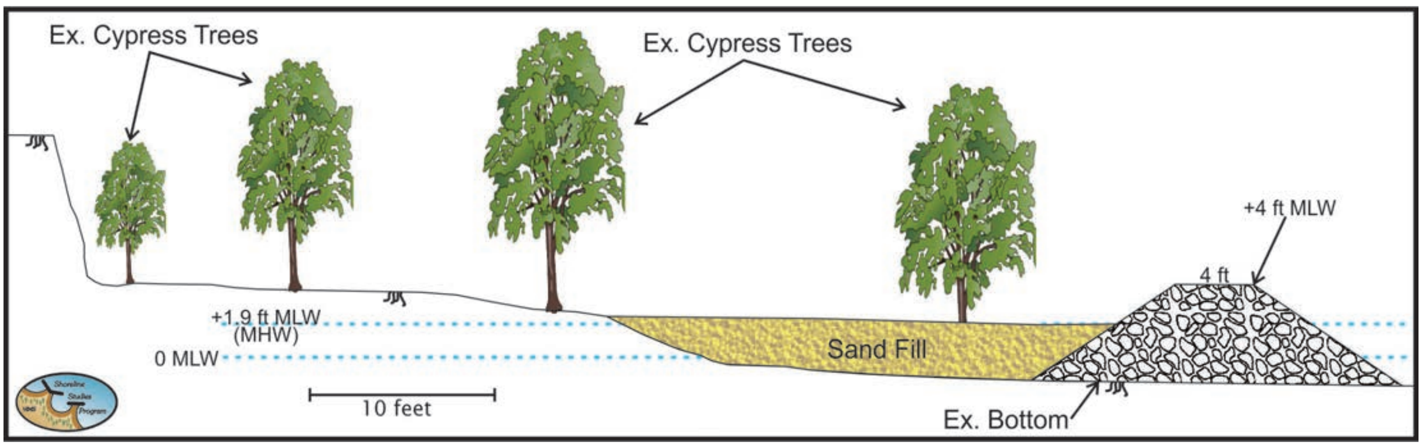
Breakwater systems are applicable management strategies along the Charles City's James River with a medium to high energy shores. The actual planform design is dependent on numerous factors and should be developed by a professional. However, a typical breakwater tombolo and embayment cross-section is provided to help determine approximate system cost (Appendix 3, Figure 2). For long sections of agricultural land, a headland control system (Appendix 3, Figure 3) can be used to protect shoreline more cost effectively. Costs vary for this type of system and cannot be estimated since the size of the structure and how far apart they are placed are factors.



Appendix 3, Figure 1. *Typical cross-section for a low sill that is appropriate for low to medium energy shorelines of Charles City 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.*



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



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