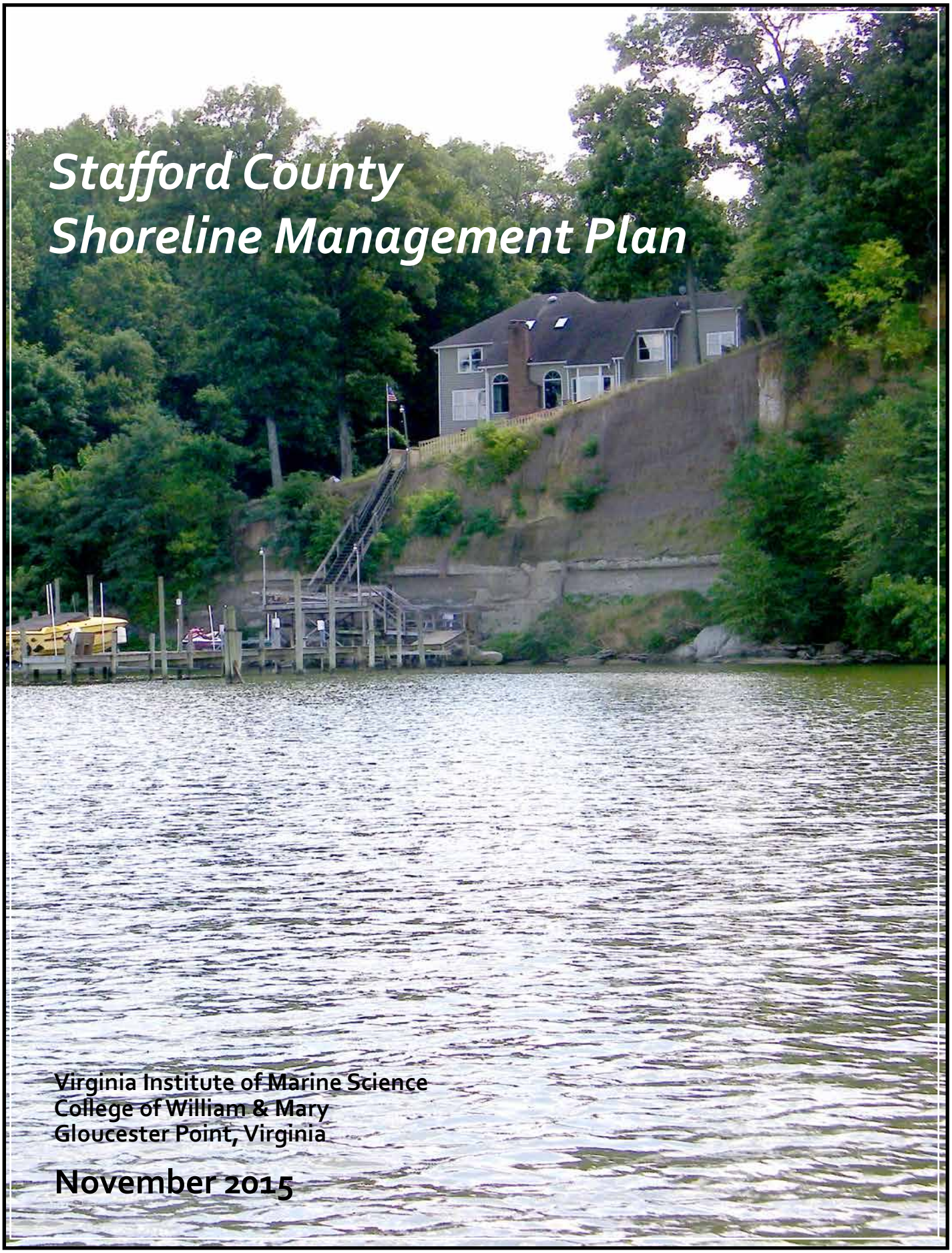

Stafford County Shoreline Management Plan

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

November 2015

Stafford County Shoreline Management Plan

Prepared for Stafford County and Virginia Coastal Zone Management Program

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This project was funded by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through Grant # NA14NOS419041 of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, under the Coastal Zone Management Act of 1972, as amended. The views expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Department of Commerce, NOAA, or any of its subagencies.

November 2015

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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. The County recognizes that development has led to increased runoff and non-point source pollution and identifies the need to guide efforts to maintain water quality, preserve wildlife habitats, and minimize the risk of natural hazards (Stafford County Planning Commission, 2010). The shores of Stafford 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 for evaluating and planning shoreline management strategies appropriate for all the creeks and rivers of Stafford. It ties the physical and hydrodynamic elements of tidal shorelines to the various shoreline protection strategies.

Much of Stafford 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

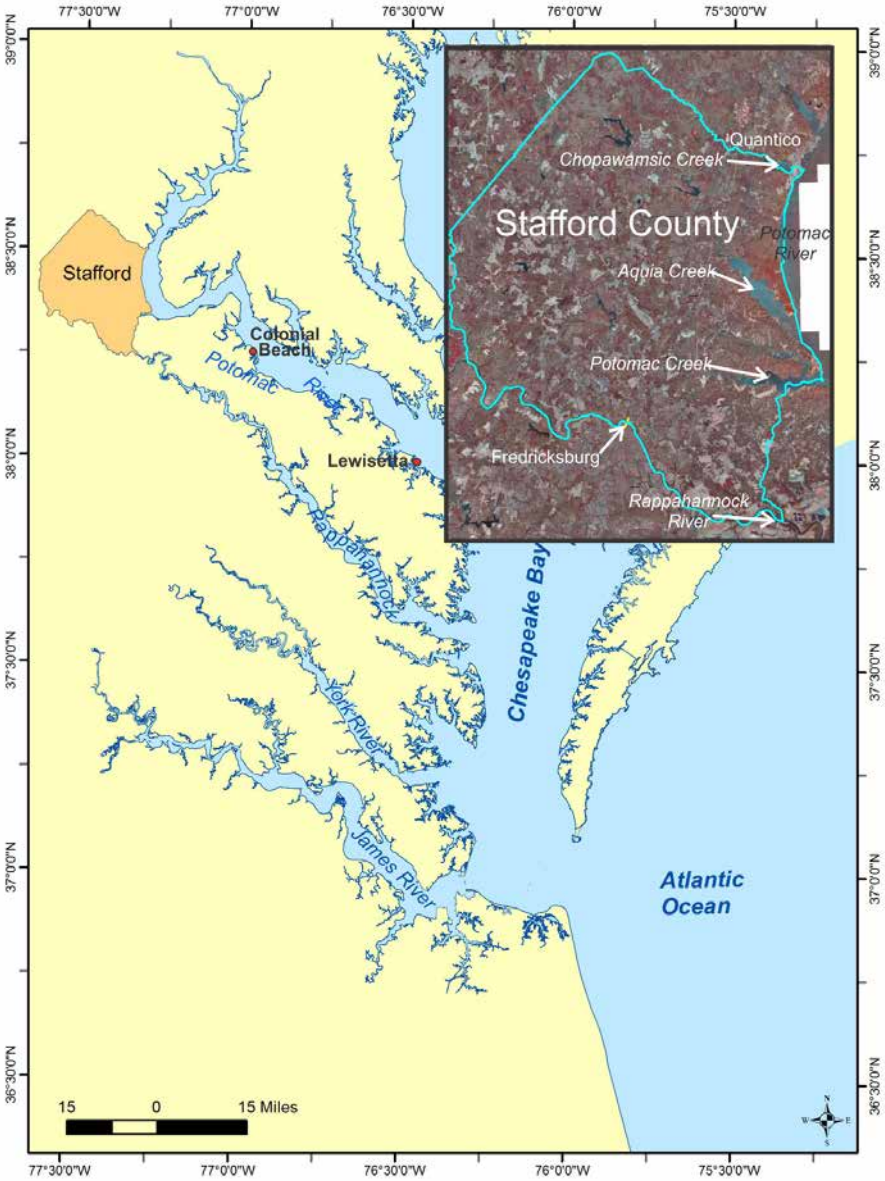

Figure 1-1. *Location of Stafford County within the Chesapeake Bay estuarine system. The locations of the National Oceanic and Atmospheric Administration tide gages are shown.*

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 Stafford 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

Stafford County lies in the coastal plain of Virginia. Like many coastal localities, the County boundaries are defined by creeks, rivers and watershed. The Rappahannock River bounds the south side of the County, and the Potomac River much of the east side (Figure 1-1). The Rappahannock River is tidal up to Fredericksburg and occurs as a meandering river set within the ancient watershed where the river banks are composed of sediments from the Lower to Middle Pleistocene in age (Figure 2-1). On the Potomac River and laterally connected tidal creeks, the shoreline banks are mostly Middle to Upper Pleistocene except for the south banks along Aquia Creek that have older strata of the Potomac Formation (Upper Cretaceous) and Lower Tertiary deposits (Oligocene) (Figure 2-2).

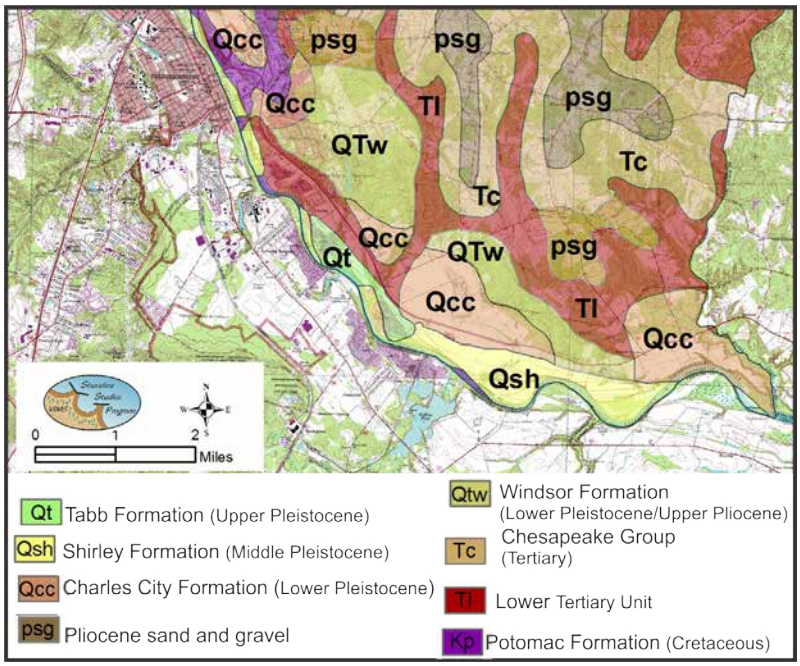

Figure 2-1. *Geology of Stafford County along the Rappahannock River (Mixon* et al.*, 1989).*

2.1.2 Shoreline Morphology

Present-day coastal morphology/ landscape is a function of the underlying geologic history. All of Stafford's Potomac River shoreline is tidal while two-thirds of the Rappahannock River is tidal. The County coast can be classified into reaches that are shown on Figure 2-3 and Figure 2-4: Rappahannock River (Reach 1), Potomac Creek (Reach 2), open Potomac River (Reach 3 and 5), and Aquia Creek (Reach 4).

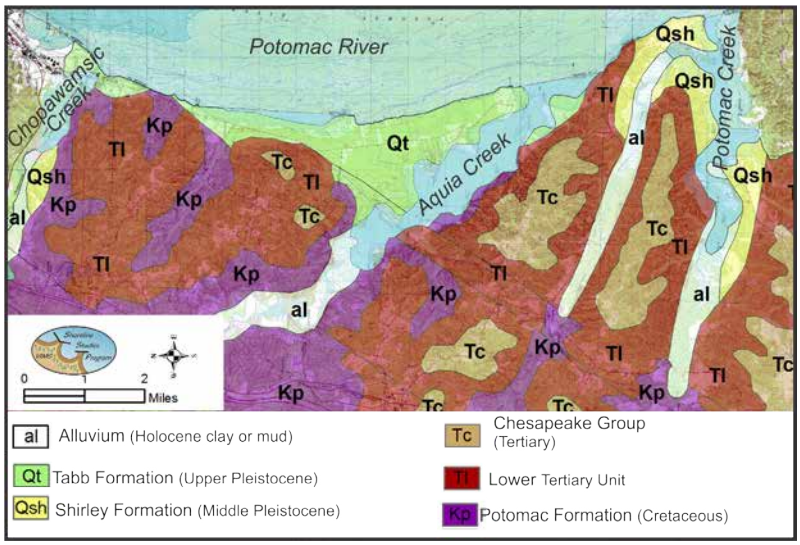

Figure 2-2. *Geology of Stafford County along the Potomac River (Mixon* et al.*, 1989).*

Reach 1 along the Rappahannock River has tidal shoreline that extends from Fredericksburg downriver to Muddy Creek (Figure 2-3). The river is navigable up to Fredericksburg with a narrow channel averaging about 10 feet deep. The shoreline is mostly tree-lined and occurs as low to high banks undercut by tidal action. Several gravel pits occur in the floodplain, and little development exists directly on the Stafford County side of the river. As such there

are no shore protection structures even though the high banks are slightly erosive (Figure 2-5). Historical erosion rates are very low.

Reach 2 starts on the south shoreline of Potomac Creek new Old Point Landing which is near the Stafford County/King George County boundary (Figure 2-4). The shoreline is residentially-developed and has a low bank which has mostly been hardened with bulkheads (Figure 2-6). The shore transitions to Big Marsh which is a marsh point. Farther into Potomac Creek, residential land use occurs and much of the shoreline is bulkheaded as well. Potomac Creek narrows quickly and proceeds westward as a very narrow meandering channel. The north side of Potomac Creek is undeveloped and slightly erosional with high wooded banks. On the north side, Accokeek Creek enters near the mouth of Potomac Creek. The upland is lower and transitions to a marsh shoreline on the west side of the mouth of Accokeek Creek. Indian Point, on the east side of the mouth of Accokeek Creek, has a low bank with residential development that is mostly protected by wood bulkheads.

Reach 3 starts at Marlboro Point and extends north to the mouth of Aquia Creek along the Potomac River. Marlboro Point marks the confluence of Potomac Creek and the Potomac River. It is protected by a gabion sill that was installed over 20 years ago and, except for some breaks in the baskets, it is still basically intact (Figure 2-7). From Marlboro Point heading upriver the shoreline has both low and high banks with residential land use for about 1 mile. North of there, the shoreline is less densely developed, and the bank rises in elevation. The bank stratigraphy also changes such that a hard limestone strata is exposed along the base of the banks (Figure 2-8). This layer is older Tertiary strata possibly of Eocene age. The banks rise to almost 100 feet with homes occupying the top of the bank (Figure 2-9). The vertically exposed base of the bank is erosion resistant, but the upper bank face continues to erode. No erosion control structures have been necessary since the base of bank is protected. Erosion rates are < 0.5 feet per year (Milligan *et al.*, 2015). The

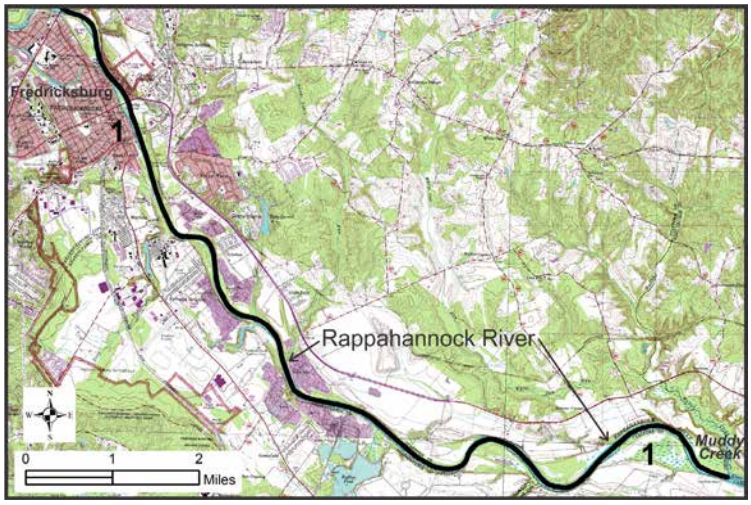

Figure 2-3. *Topographic sheet of the Rappahannock River in Stafford County. Also shown is the Reach 1 designation.*

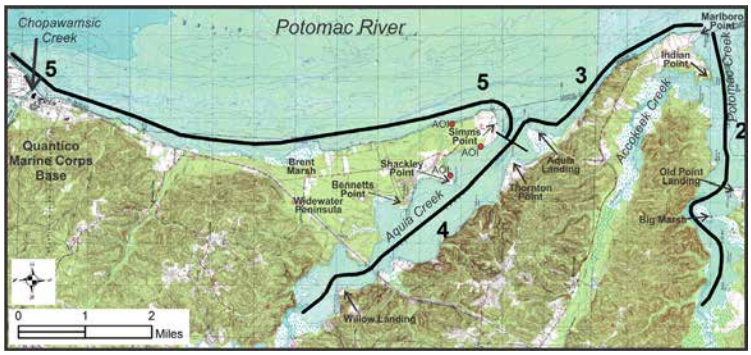

Figure 2-4. *Topographic sheet of the Potomac River section of Stafford County. Also shown are the reach designations and Areas of Interest (AOI).*

Figure 2-5. *Reach 1, Bing map of the eroding high banks along the Rappahannock River in Stafford County.*

Figure 2-6. *Reach 1, residential shoreline with low banks and bulkheads on Potomac Creek.*

base of bank limestone slowly falls off as slabs, and the upper bank slowly erodes in response. This segment of coast is unique to Bay shorelines. This strata extends 4,000 feet along shore, then the bank elevation drops to 20 to 30 feet and lower with slightly increased erosion rates and residential density. With a change in bank geology to softer strata, the shoreline has now been hardened with vertical concrete and wood bulkheads along the next 4,000 feet of coast.

Figure 2-7. *Reach 2, at the mouth of Potomac Creek, a gabion sill that has protected the shoreline for 20 years.*

The shoreline transitions and turns to the north along a wide low bank and marsh headland feature at the mouth of Aquia Creek. Aquia Landing, a county park and public beach (Linden *et al.*, 1991), lies along the Potomac River shoreline where an historic wharf area known as Youbedamn Landing occurs. This shoreline was significantly eroding until about 1987 when a series of headland breakwaters and beach fill were installed to protect the shore and provide a stable recreational beach for county residents (Figure 2-10). The distal end and the creek side were protected with stone revetment.

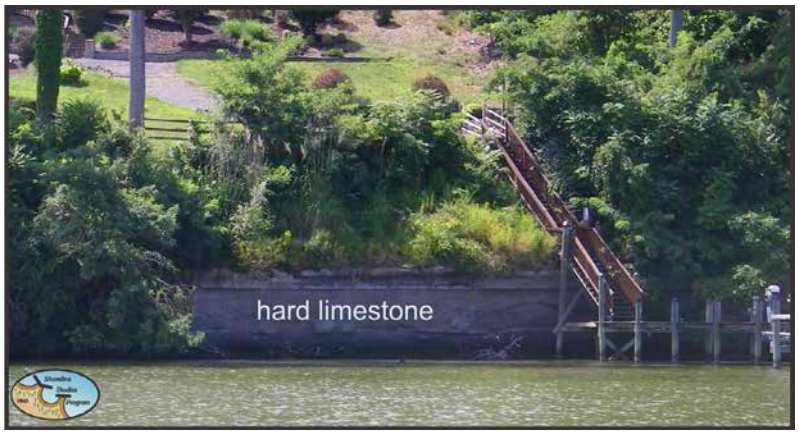

Figure 2-8. *Reach 3, Potomac River high bank shoreline with a hard, erosion resistant limestone base of bank.*

Moving upriver along the south side of Aquia Creek into **Reach 4,** the shoreline is embayed between Aquia Landing and Thornton Point. The high bluffs grade gently down to the shoreline where the bank height is only about 4 to 5 feet high adjacent to Thorny Point Road and protected with wood bulkheads and rock (Figure 2-11). The embayment is rich in submerged aquatic vegetation. Upriver of Thornton Point and along Thorny Point road, the shoreline is a very low bank that is residential and mostly hardened with bulkheads, rock, and broken concrete for about a half mile. The shore banks rise to over 100 feet for about 200 feet along the shore, then decline to low banks (10 feet) at the shoreline with the high bluffs farther inland. Intermittent shore protection includes bulkheads and rock. The shoreline above Willow Landing transitions to a broad marsh complex and the creek narrows to about 300 ft wide as it turns into a meandering tidal marsh system.

Figure 2-9. *Reach 3, high eroding bank on the Potomac River.*

On the north side of Aquia Creek, the shoreline is high, undeveloped, wooded banks from the upriver end down the creek until Bennetts Point. At Bennetts Point, the bank is about 15 feet high and residential

in landuse with extensive bulkheading and numerous piers along about 4,000 feet of shore to Shackely Point (Figure 2-12). The shoreline transitions to low banks and marsh at Shackley Point. Downriver of Shackley Point the shoreline is low (10ft) wooded and more erosive downriver to the mouth of Aquia Creek and Simms Point.

Simms Point is a low sandy spit, a product of eroding bank sediments accumulating at the mouth of Aquia Creek (Figure 2-13). The low sandy shoreline between Simms Point and Brent Marsh (**Reach 5**) represents the distal end of the Widewater Peninsula. The Potomac River side of the peninsula extends north almost three miles to Brent Marsh. The shoreline is eroding high bank (Figure 2-14) with sparse development; however, one landowner installed gabion baskets as a low breakwater units over 30 years ago (Figure 2-15). They are still in fairly good shape due, in part, to the relatively fresh water setting. Hardaway (1988) determined that gabions used in more saline estuarine waters had a limited life span due to corrosion of the gabion wire basket. The main residential development along this section of shoreline is mostly hardened with stone revetments and wood bulkheads. An old, wood hull is located offshore and is home for some hardy shrubs (Figure 2-16). At the upriver end of the residential reach the shoreline continues as an eroding upland bank for 1,000 feet before transitioning to the eroding marsh shore of Brent Marsh.

Brent Marsh extends about 1 mile along shore and although actively eroding, is still wide enough to provide a wave buffer to the adjacent upland banks (Figure 2-16). North of Brent Marsh several commercial fishing interests occur. In addition, along this reach, railroad tracks come close to the river, within 50 feet in several areas. The railroad is presently protecting one section of the shoreline with a stone revetment (Figure 2-17). Along the rest of Stafford's shoreline to the Quantico Marine Corps Base, only

Figure 2-10. *Reach 3, Bing map showing Aquia Landing Park and the breakwaters and beach fill that have been providing shore erosion control since 1987.*

Figure 2-11. *Reach 4, the shoreline is protected by a bulkhead in order to protect the road that runs along the shoreline between Aquia Landing and Thornton Point.*

Figure 2-12. *Reach 4, shorelines with a low bank and residential landuse. The shoreline has wood bulkheads for protection.*

Figure 2-13. *Reach 4, Simms Point at the confluence of Aquia Creek and the Potomac River.*

a few residential properties exist. Some sections of shore are low, but most of the shoreline is high eroding bank. This section has very hard material outcropping along the shoreline (Figure 2-2) which breaks off into rocks that stay along the shoreline until they erode and provide some shore protection (Figure 2-18). The Quantico Marine Corps Base was the subject of a site-specific shoreline management plan (Shoreline Studies Program, 2011) and will not be discussed here.

Figure 2-14. *Reach 5, eroding banks along the Widewater Peninsula on the Potomac River.*

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).

Figure 2-15. *Reach 5, gabions along the shoreline that are providing effective shore protection along the Potomac River.*

Figure 2-16. *Reach 5, Brent Marsh on the Potomac River.*

Figure 2-17. *Reach 5, construction of a new revetment along the Potomac River that will protect the eroding shoreline that is very close to railroad tracks which are still used daily to carry passengers and freight.*

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 are likely very site specific.

Basco and Shin (1993) described the wave climate in the Potomac River for use in planning and designing structures. Their analysis did not include Stafford's Rappahannock River shorelines. 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 along Stafford's Potomac River shoreline are 3.0 feet and 3.4 seconds, respectively (Figure 2-19).

Storm surge frequencies described by FEMA (2005) 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 Potomac River. For Stafford County these range from 4.5-4.8 ft MLLW, 6.4-6.7 ft MLLW, 7.4-7.7 ft MLLW and 10.3-10.6 ft MLLW, respectively.

Tide ranges vary along the Stafford County shoreline (Table 2-2). Tidal heights are higher in the Rappahannock River because its smaller width restricts flow. The tide range for Aquia Creek is inside the creek while the Clifton Beach tide station is across the Potomac River from Reach 5. 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.

Figure 2-18. *Reach 5, very hard rocks that have broken off from the bank along the Potomac River shoreline*

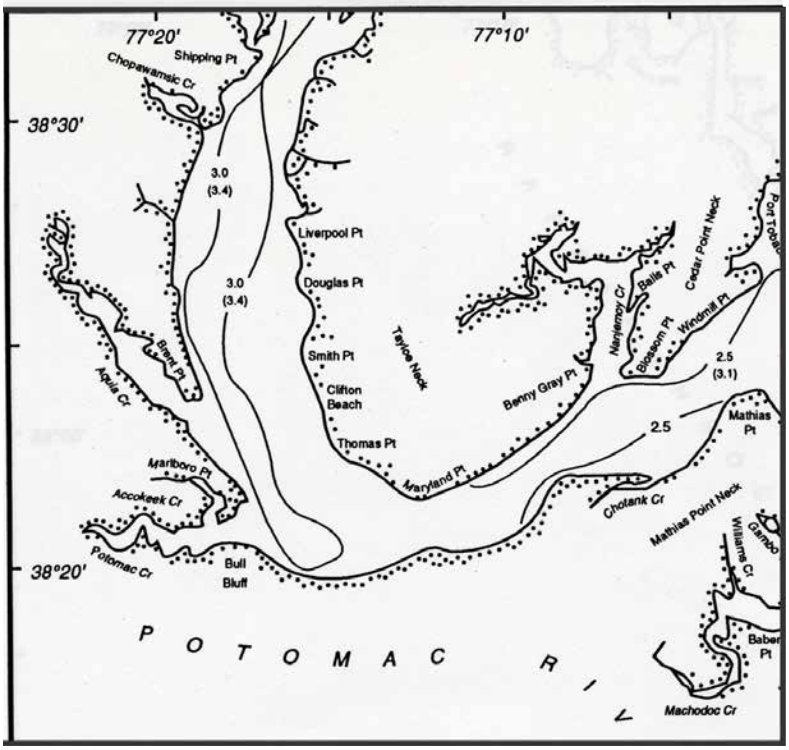

Figure 2-19. *Wave climate map for the upper reaches of the Potomac River (from Basco and Shin, 1993).*

Location	Annual Chance (feet MLLW)			
	10%	2%	1%	0.2%
At the confluence of Potomac Creek	4.5	6.4	7.4	10.3
At the confluence of Aquia Creek	4.6	6.5	7.5	10.4
At the confluence of Chopawamsic Creek	4.8	6.7	7.7	10.6

Table 2-1. *10 year, 50 year, 100 year, and 500 year storm predicted flood levels relative to MLLW (1983-2001). Source: Stafford County Flood Report, FEMA (2005). Converted from NAVD88 using NOAA's online program VDATUM.*

2.2.2 Sea-Level Rise

On monthly or annual time scales, waves dominate shore processes; during storm events, they leave the most obvious mark. However, on time scales approaching decades or more, sea level rise is the underlying and persistent force responsible for shoreline change. Recent trends based on wave gauge data at Colonial

Beach and Lewisetta show the annual rate to be 1.57 feet/100 years (4.78 mm/yr) and 1.63 feet/100 years (4.97 mm/yr). Boon (2012) predicted future sea-level rise by 2050 using tide gauge data from the East Coast of the U.S. Solomons Island, the nearest tide gauge to Stafford County analyzed, has a projected sea-level rise rate of 0.66 m (+/- 0.18m). This will result in water levels 2.2 feet higher by 2050. The historic rate at Solomons Island is only about 1.12 feet/100 years (3.41mm/yr). This potential increase in sea level rise rates warrant ongoing monitoring and consideration is shoreline management planning

Location	Tide Station	Mean Range (ft)	Spring Range (ft)
Potomac River	Clifton Beach, MD	1.1	1.3
Aquia Creek	Aquia Creek	1.3	1.5
Fredericksburg	Fredericksburg	2.8	3.2

Table 2-2. *Tide Range in Stafford County. The first two stations are in the Potomac River watershed. The third is on the Rappahannock River (from NOAA Tides and Currents Website, 2015).*

Reach Name	Average EPR (ft/yr)	Category
Potomac River from Prince William County Line to Aquia Creek	-1.3	Low Erosion
Aquia Creek	-0.3	Very Low Erosion
Potomac River from Aquia Creek to Potomac Creek	-0.7	Very Low Erosion
Accokeek Creek	-0.5	Very Low Erosion
Potomac Creek	-0.7	Very Low Erosion
Rappahannock River	0.1	Very Low Accretion

Table 2-3. *Average end point rate of change (1937-2009) for Stafford County's shoreline. The rates of change are given in feet per year. From Milligan* et al. *(2015).*

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, erosion is very low in most sections of Stafford 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*. (2015).

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.

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 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 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 Stafford, 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.

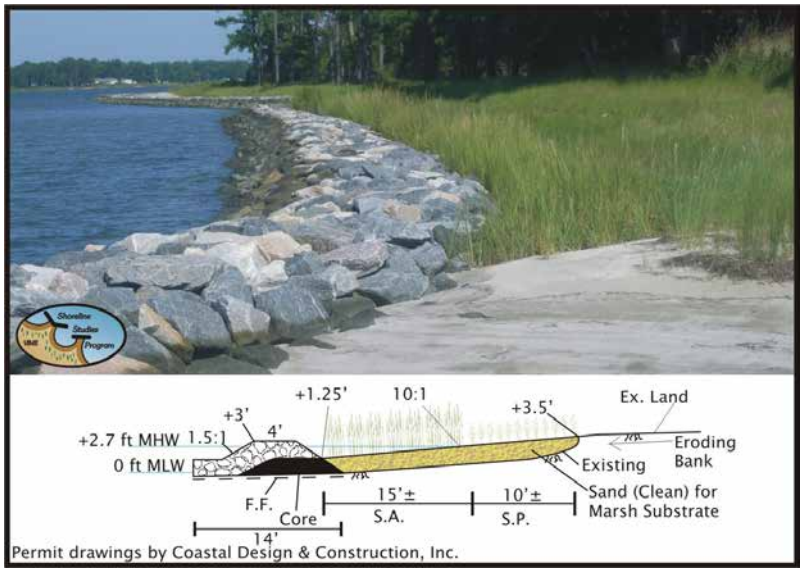

Figure 3-5. *Sand fill with stone sills and marsh plantings shown six years after installation and the cross-section used for construction (From Hardaway* et al.*, 2010).*

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. An 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.

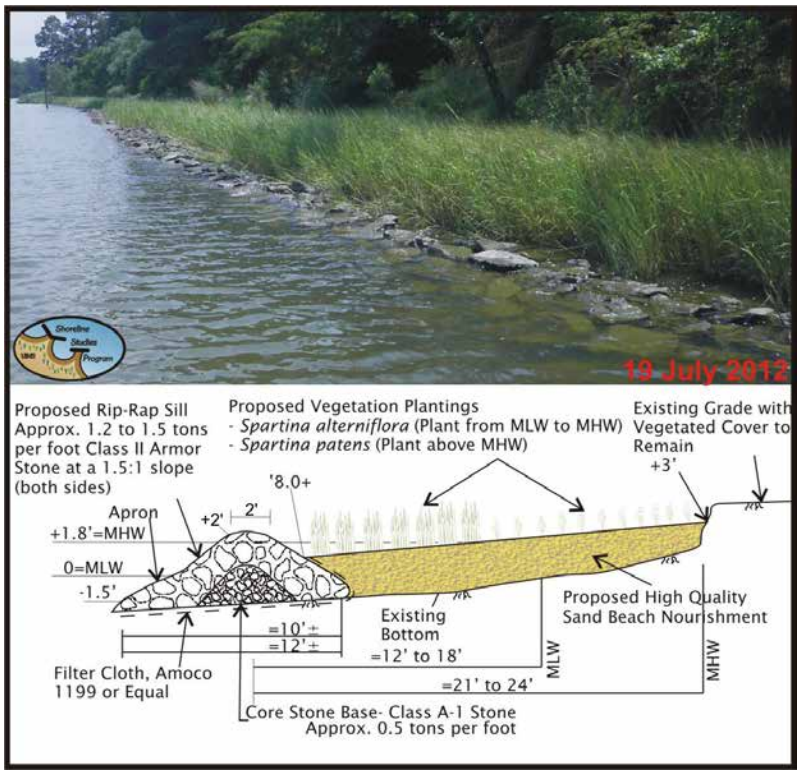

Figure 3-6. *Longwood University's Hull Springs Farm four years after construction and the cross-section used for construction (from Hardaway* et al.*, 2010).*

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. *Breakwaters at Colonial Beach designed to provide a recreational beach as well as storm erosion protection for the Town.*

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 on the Potomac River in Maryland. 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 August 2015. 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,

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.*

the majority of these data are collected and maintained for the Stafford County Shoreline Inventory. (http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/virginia/stafford/staffordva_disclaimer.htm) 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 Stafford County

5.1 Shoreline Management Model (SMM) Results

In the Stafford County, the SMM was run on 120 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 Stafford 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 Stafford based on strategy(s) and shoreline miles. The glossary in Appendix 2 gives meaning to the various Shoreline BMPs listed in Table 5-1.

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

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.

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

ShoreBMP	Length (miles)
Enhance Riparian/Marsh Buffer	0
Enhance Riparian/Marsh Buffer OR Beach Nourishment	0
Enhance/Maintain Beach	0
Maintain/Enhance/Create Marsh	69.5
Enhance/Maintain Riparian Buffer	0
Groin Field with Beach Nourishment	0.01
Maintain Beach OR Offshore Breakwaters with Beach Nourishment	12.1
Plant Marsh with Sill	27.9
Revetment	3.1
Widen Marsh	0
Widen Marsh/Enhance Buffer	0
UplandBMPS	**Length (miles)**
Area of Special Concern	5.5
Maintain/Enhance/Restore Riparian Buffer	106.6
Forest Management	0
Grade Bank	0
Land Use Management	5.9
No Action Needed	0.01

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

5.2 Shore Segments of Concern/ Interest

This section describes several areas of concern and/or interest in Stafford and demonstrates how the preferred alternative from the SMM could be adopted by the waterfront property owners. The location of the areas of interest (AOI) are shown on Figure 2-4. No areas of concern exist in Stafford 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.

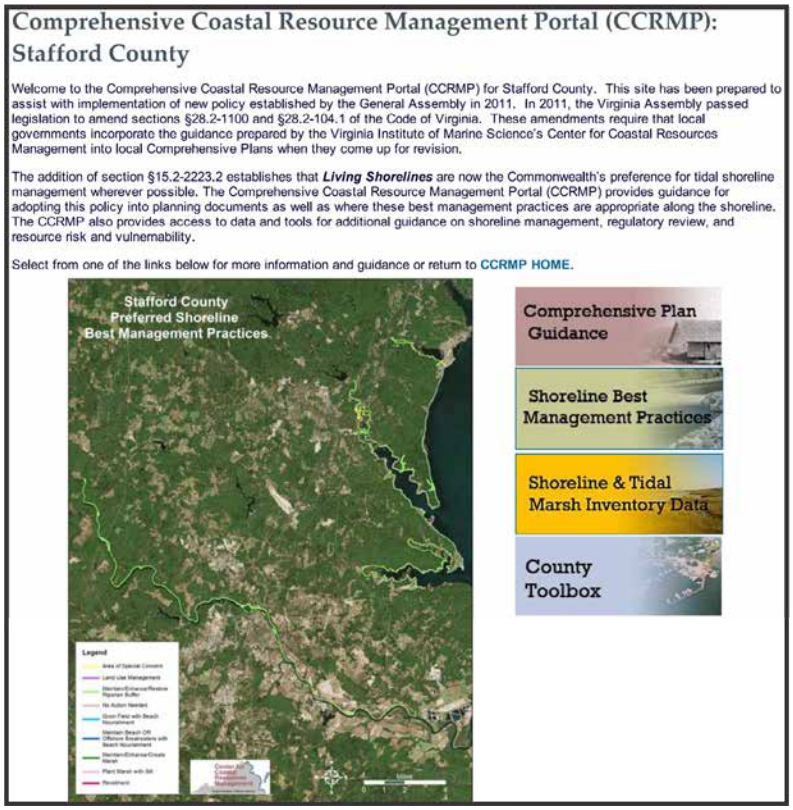

Figure 5-1. *Portal for Comprehensive Coastal Resource Management in Stafford County.*

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

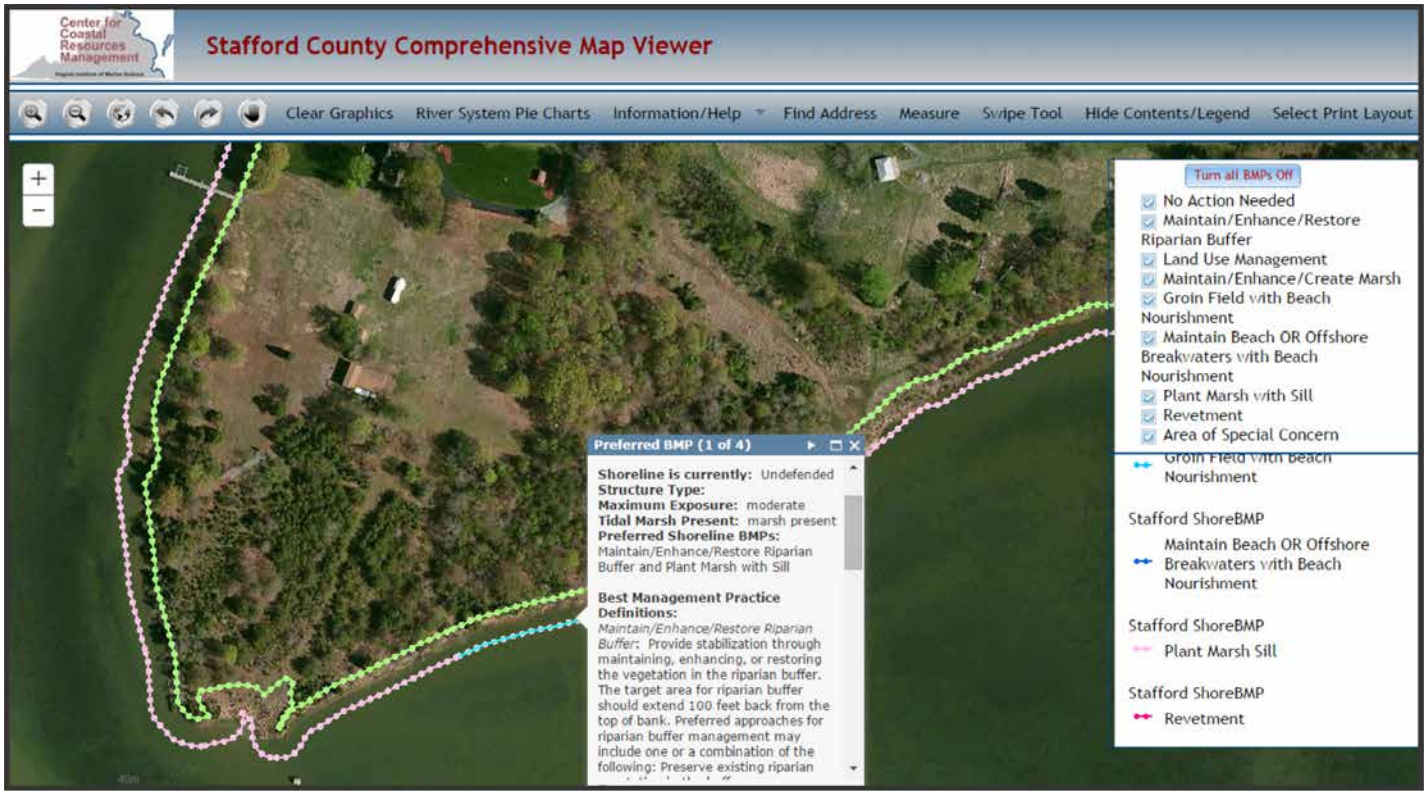

Figure 5-3. *The pop-up window contains information about the recommended Shoreline BMP at the site selected. Additional information about the condition of the shoreline also is given.*

5.2.1 Shackley Point Sill (Area of Interest)

The south side of Shackley Point in Aquia Creek has been eroding since 1967 (Milligan *et al.*, 2015). What was once wooded upland recently has been converted to residential (Figure 5-4). This low bank shoreline has a very small amount of existing marsh fringe (Figure 5-5). This stretch of shoreline generally is protected from large waves, but it is exposed to a southeasterly wave climate through the mouth of Aquia Creek. The maximum fetch distance is 6.5 miles. The SMM recommends a sill with marsh plantings along this stretch of shore. In order to hold the point of land and stop erosion of the property, about 500 feet of shoreline can be protected with a low sill (Figure 5-6). The cross-section for a typical sill for this site is shown in Appendix 3, Figure 1.

Figure 5-4. *Recent clearing of woodland and conversion to residential property at Shackley Point on Aquia Creek shown in Google Earth.*

5.2.2 Aquia Creek Side of Simms Point (Area of Interest)

This site is located on Aquia Creek north of Simms Point and has an exposed eroding bank (Figure 5-7). The site sits between two existing bulkheads and was chosen to illustrate the applicability of sills to this type of shoreline. The shoreline has a very low erosion rate (Milligan *et al.*, 2015), but because it is presently undeveloped and sits

between two bulkheads, it was chosen as an area of interest. The SMM recommends a sill with marsh plantings along this stretch of shore. Because of the higher bank, a medium sill is depicted in the design for the approximately 800 feet between the two existing structures (Figure 5-8). The cross-section for a typical sill for this site is shown in Appendix 3, Figure 2.

5.2.3 Potomac River Breakwaters (Area of Interest)

The shoreline along the Potomac River between Simms Point and Brent Marsh has a low to medium erosion rate (Milligan *et al.*, 2015). This stretch of shoreline has low density residential development, but the 1,400 feet of shoreline that is the area of interest is not developed. However, properties to the south and north have shore protection structures. To the south, a revetment exists along the shoreline and to the north gabions were placed along the shoreline as gapped sills/breakwaters (Figure 2-15). This is a relatively high energy area on the Potomac River with an eroding bank at heights up to 10 feet (Figure 5-9). The top of the bank is wooded, and a narrow beach exists. The SMM recommends breakwaters for this site so four offshore breakwaters are conceptualized to protect the base of bank and provide recreational access (Figure 5-10). The design also includes a spur that interfaces the system with the revetment to the south. The cross-section for a typical sill for this site is shown in Appendix 3, Figure 3.

Figure 5-5. *Existing conditions at the area of interest in Aquia Creek. The new residential property has a sparse fringe marsh that could be enhanced with a low sill.*

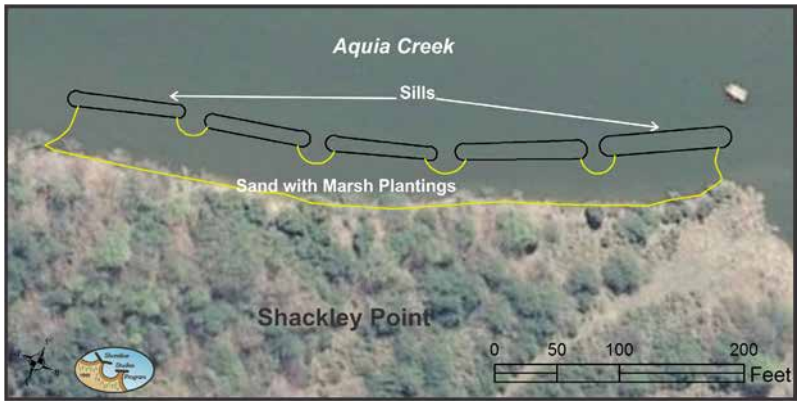

Figure 5-6. *Proposed conceptual design planform of the low sill at Shackley Point in Aquia Creek. The trees shown in this photo were recently cleared to build the house.*

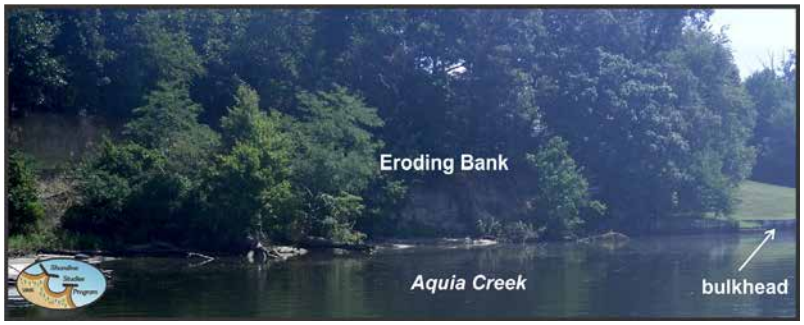

Figure 5-7. *Existing conditions at the area of interest near Simms Point along Aquia Creek. The property with the eroding bank is situated between two defensive shore protection structures.*

Figure 5-8. *Proposed conceptual design planform of the medium sill BMP.*

Figure 5-9. *Eroding bank along the Potomac River area of interest.*

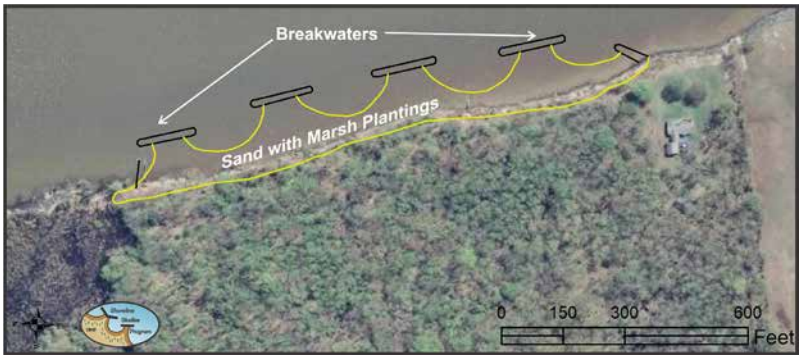

Figure 5-10. *Proposed conceptual design planform of the breakwater BMP along the Potomac River.*

6 Summary and Links to Additional Resources

The Shoreline Management Plan for Stafford 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: Stafford County Map Viewer

http://cmap2.vims.edu/CCRMP/Stafford2015/Stafford_CCRMP_Viewer.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 Stafford County

http://web.vims.edu/physical/research/shoreline/docs/Cascade/Shoreline_Evolution/STF_ShoreEvol2015-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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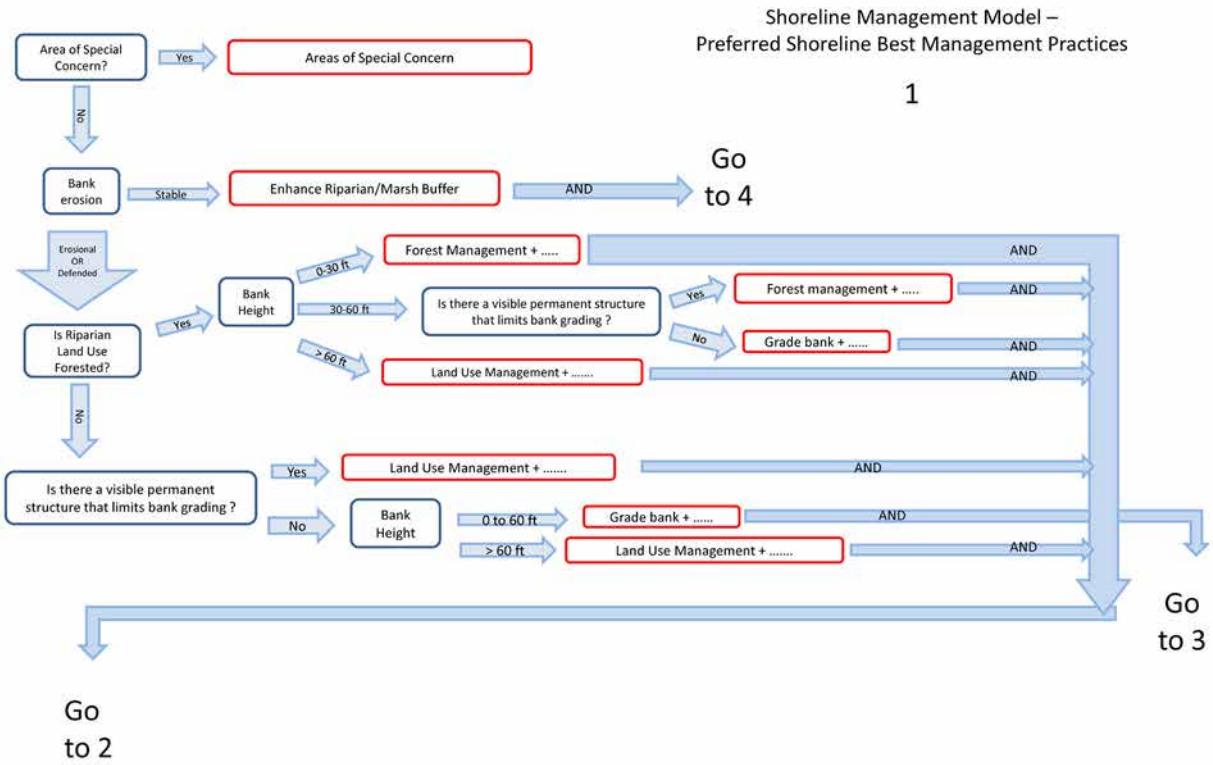
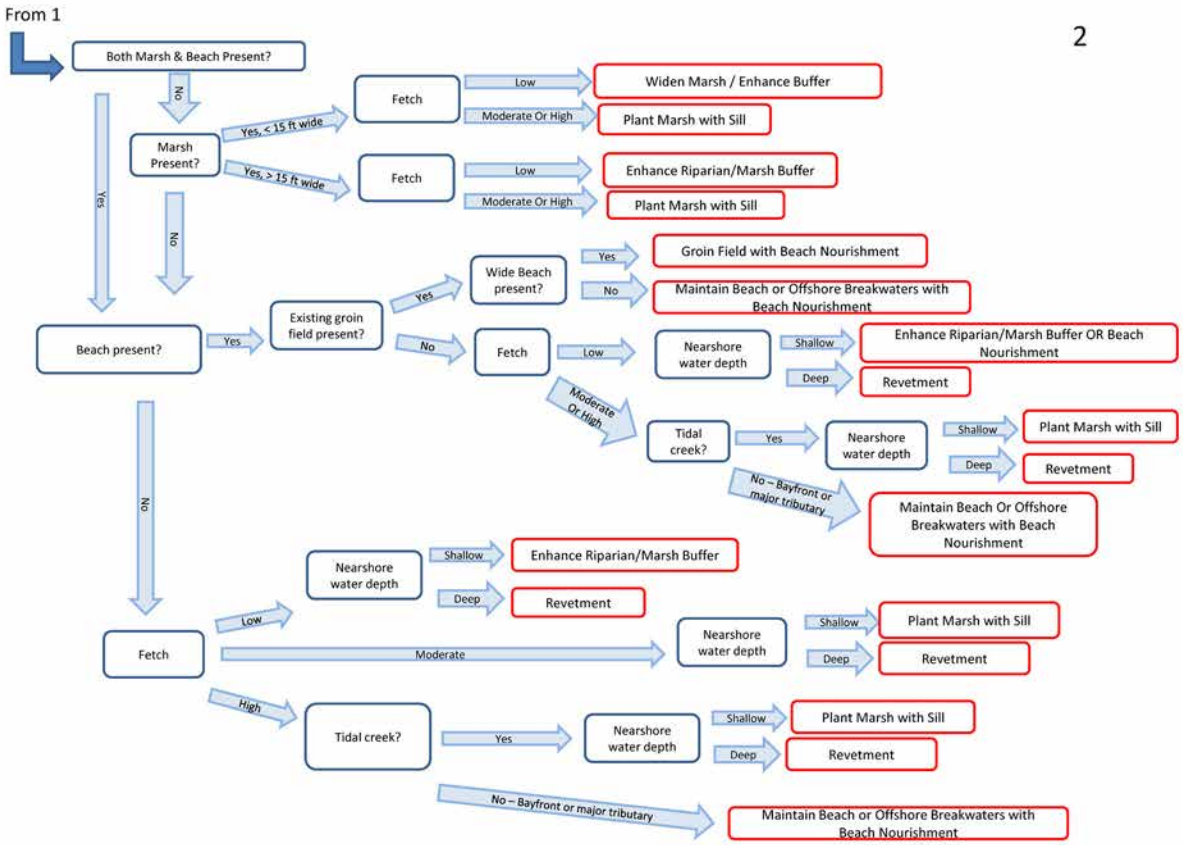
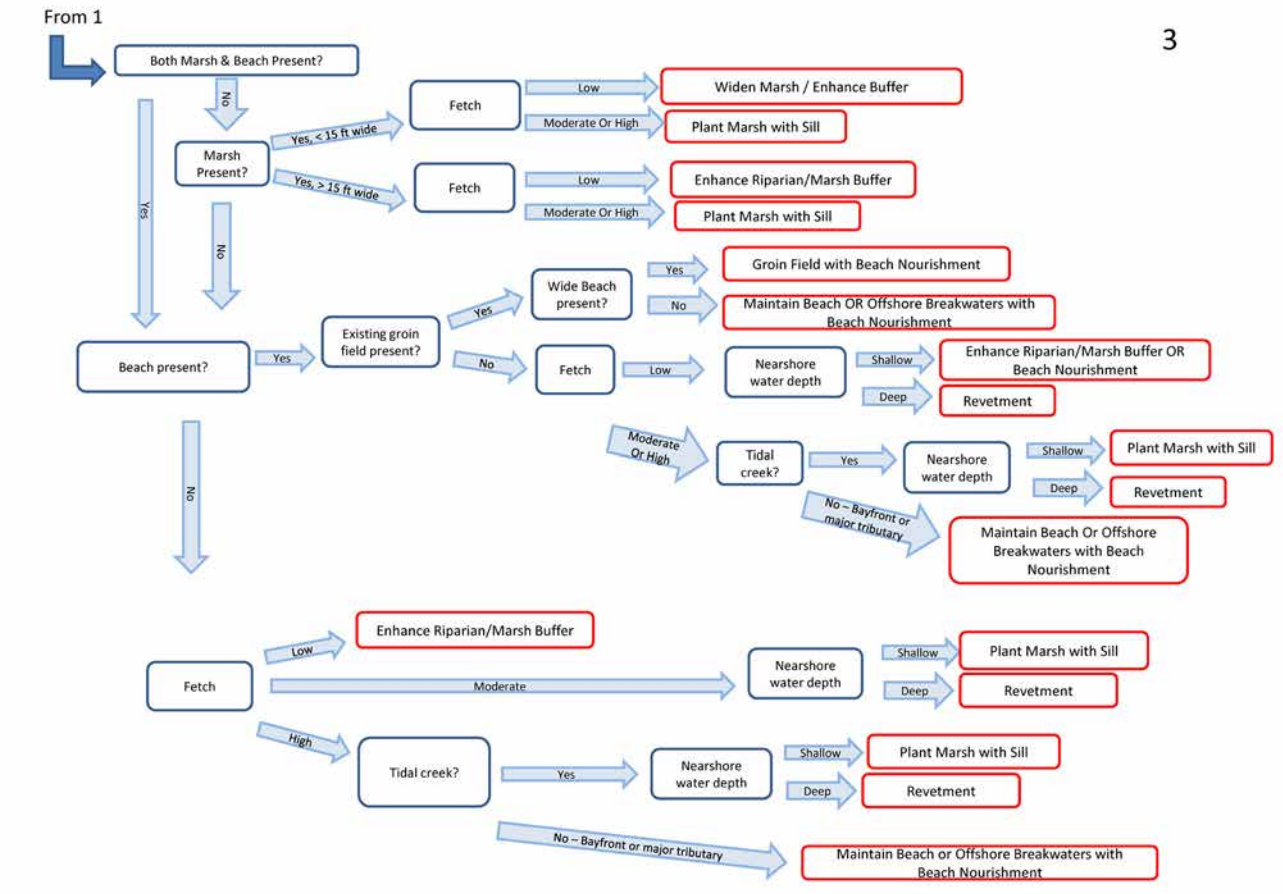
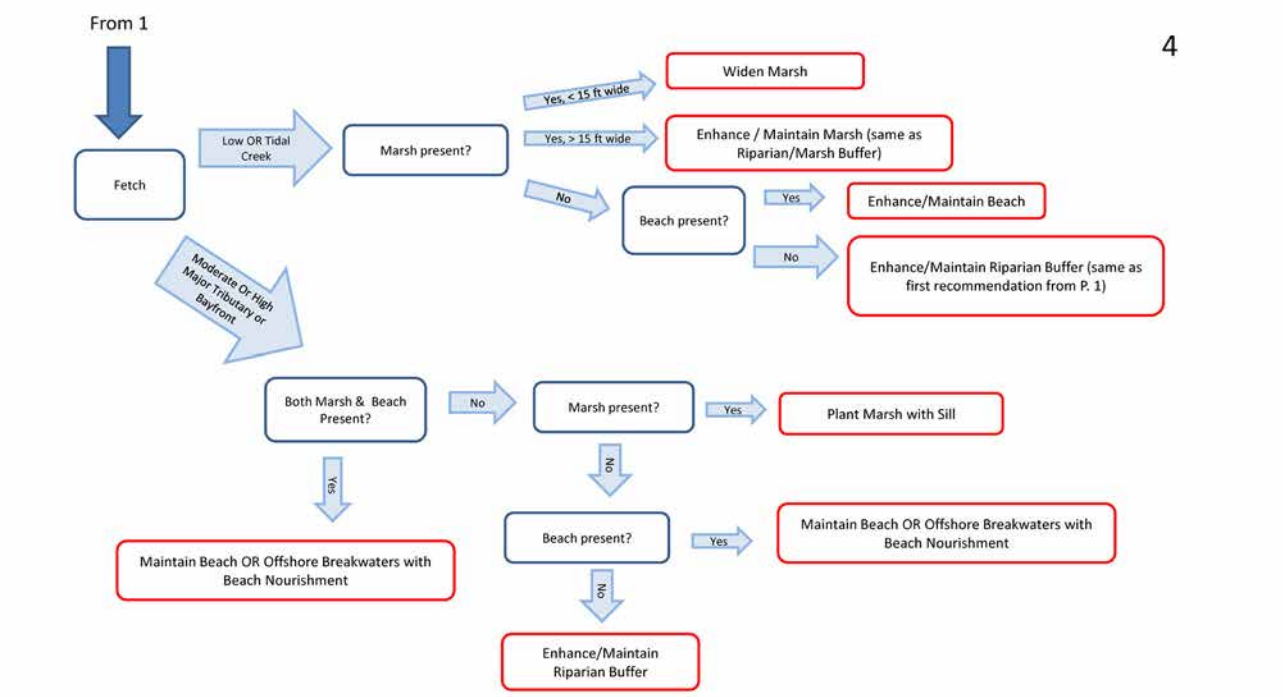
APPENDIX 1

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
Enhance Riparian/Marsh Buffer
Plant Marsh with Sill
Beach present?
Existing groin field present?
Wide Beach present?
Groin Field with Beach Nourishment
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
Nearshore water depth
Shallow
Deep
Enhance Riparian/Marsh Buffer OR Beach Nourishment
Revetment
Tidal creek?
Plant Marsh with Sill
Revetment
No – Bayfront or major tributary
Maintain Beach Or Offshore Breakwaters with Beach Nourishment
Enhance Riparian/Marsh Buffer
Moderate
High
Plant Marsh with Sill
Revetment
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
Yes
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
No
Beach present?
Yes
Maintain Beach OR Offshore Breakwaters with Beach Nourishment
No
Enhance/Maintain Riparian Buffer

APPENDIX 2
Glossary of Shoreline Best Management Practices

Preferred Shoreline Best Management Practices

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

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

Upland & Bank Areas

Land Use Management - Reduce risk by modifying upland uses, apply where bank and/or shoreline actions are extremely difficult or limited in effectiveness. May include relocating or elevating buildings, driveway relocation, utility relocation, hook up to public sewer/abandon or relocate sanitary 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 Stafford County

For Stafford 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 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 Stafford, a low sill might be appropriate (Appendix 3, Figure 1). Along medium energy shores or where there is nearby upland infrastructure, a high sill would be better (Appendix 3, Figure 2). Using sills on the open river should be carefully considered due to severity of storm wave attack.

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

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

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

Breakwater systems are applicable management strategies along Stafford's Potomac River 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 3). For long sections of agricultural land, a headland control system 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.

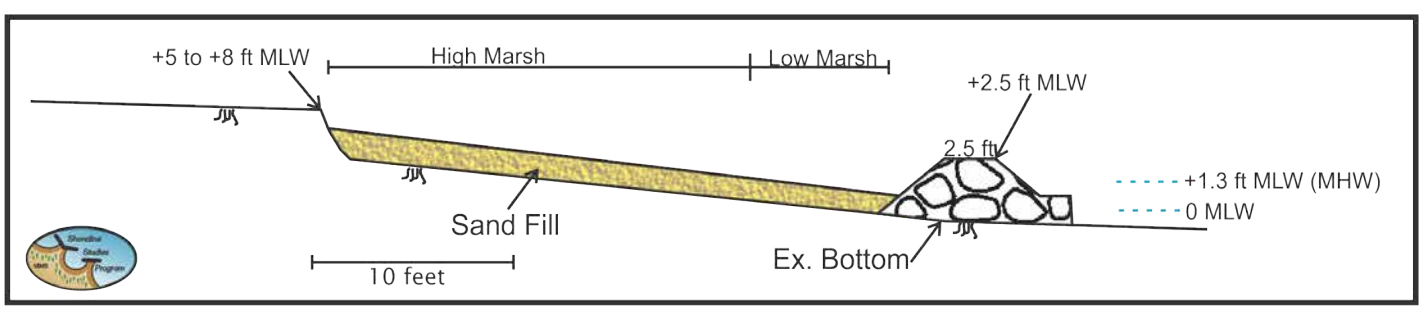


Figure 1. *Typical cross-section for a low sill that is appropriate for low to medium energy shorelines of Stafford County. The project utilizes clean sand on an 10:1 (H:V) slope, and the bank can be graded to a (minimum) 2:1 slope, if appropriate.*

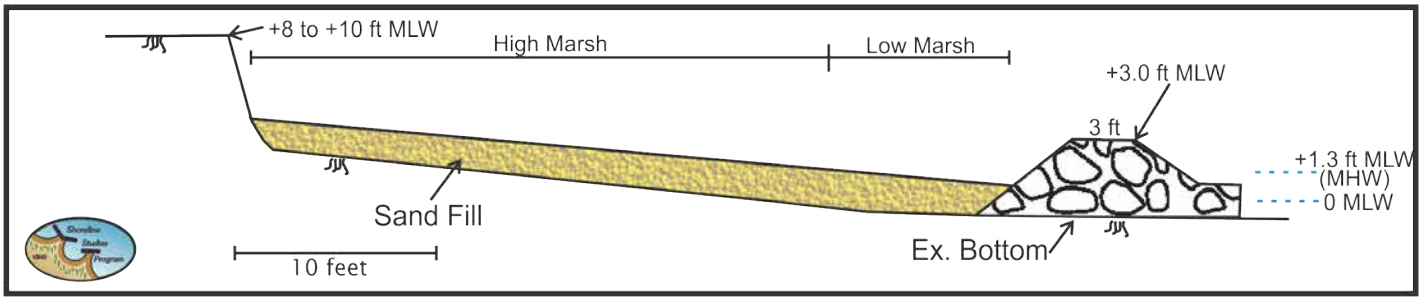


Figure 2. *Typical cross-section for a medium sill that is appropriate for the medium to high energy shorelines of Stafford County. The project utilizes clean sand, and the bank can be graded to a (minimum) 2:1 slope, if appropriate.*

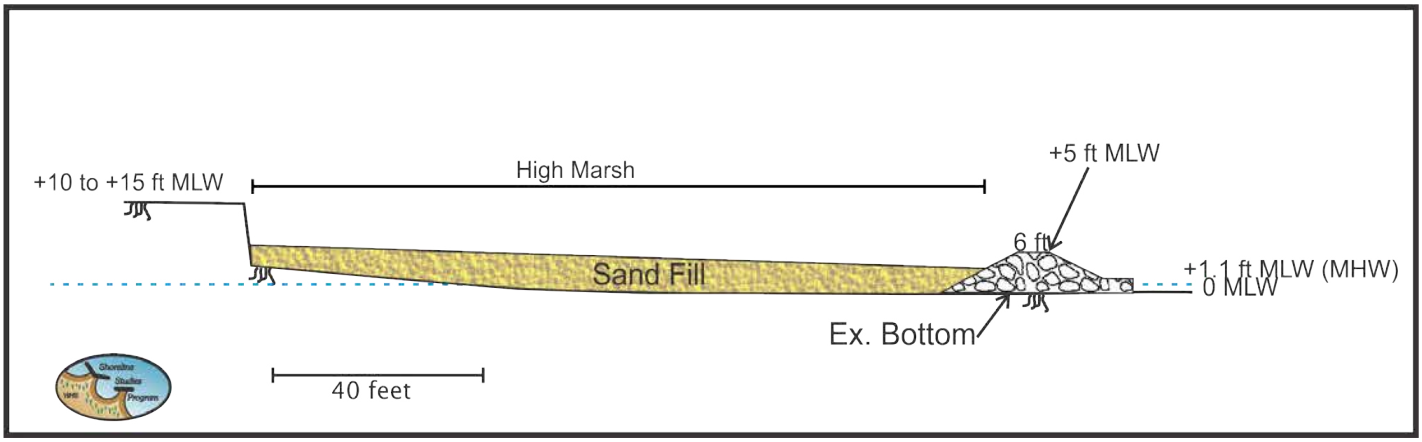


Figure 3. *Typical cross-section for a breakwater that is appropriate for shore protection along the medium to high energy shorelines of Stafford County. The project utilizes clean sand, and the bank can be graded to a (minimum) 2:1 slope, if appropriate.*