3-2015

# Fairfax County Shoreline Management Plan

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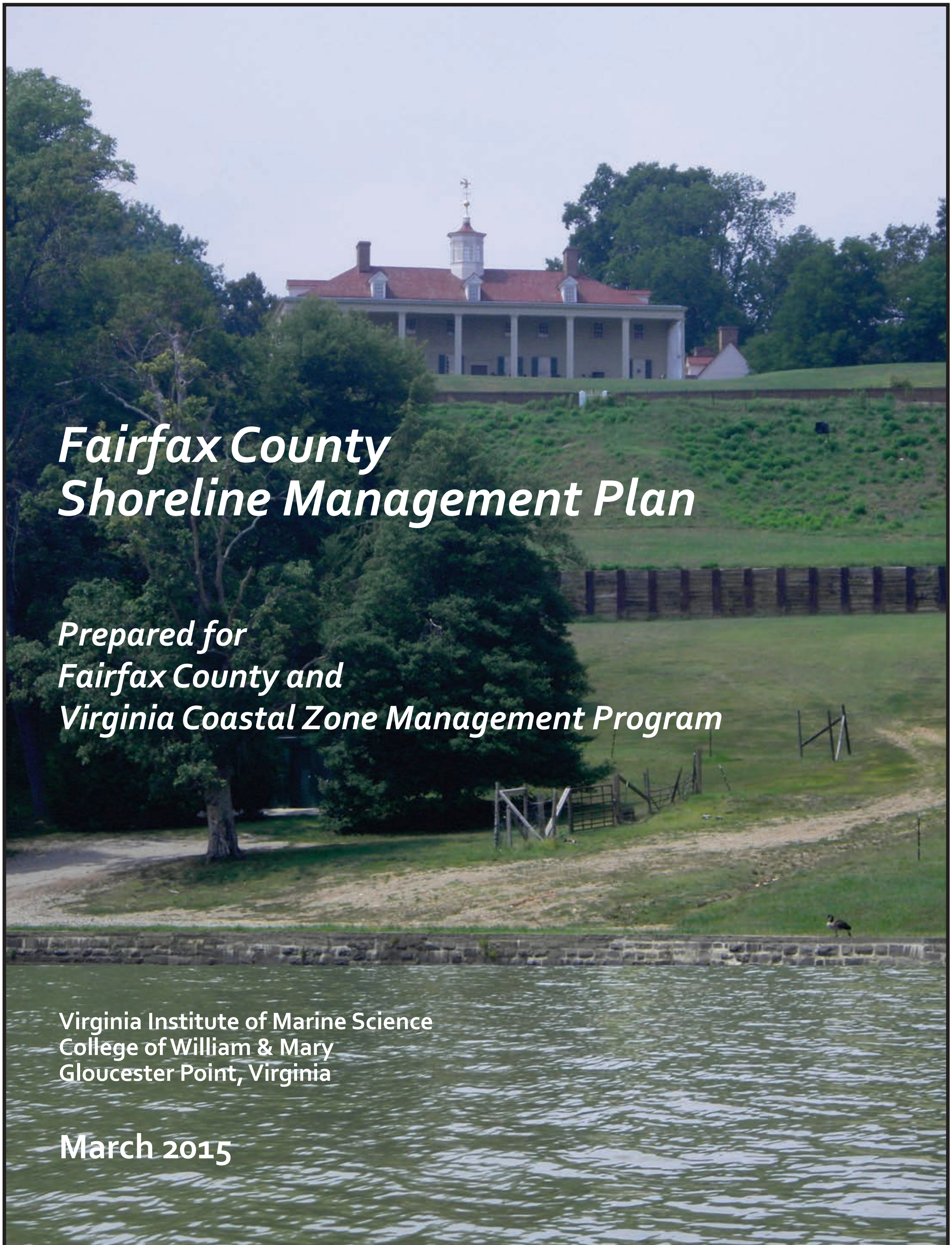

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*Prepared for*
*Fairfax County and*
*Virginia Coastal Zone Management Program*

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

March 2015

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This project was funded by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through Grant #NA13NOS4190135 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.


*March 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. Fairfax County understands that water resources are an integral part of the quality of life for its residents. With over 60% of its tidal shoreline in some form of public ownership, there has been a concerted effort to preserve the cultural, historic, and environmental resources within the County (Fairfax County Comprehensive Plan, 2013).

The tidal shores of Fairfax range from exposed open river to very sheltered creeks, and the nature of shoreline change varies accordingly (Figure 1-1). While the City's Comprehensive Plan provides general guidance for shore erosion control, a shoreline management plan

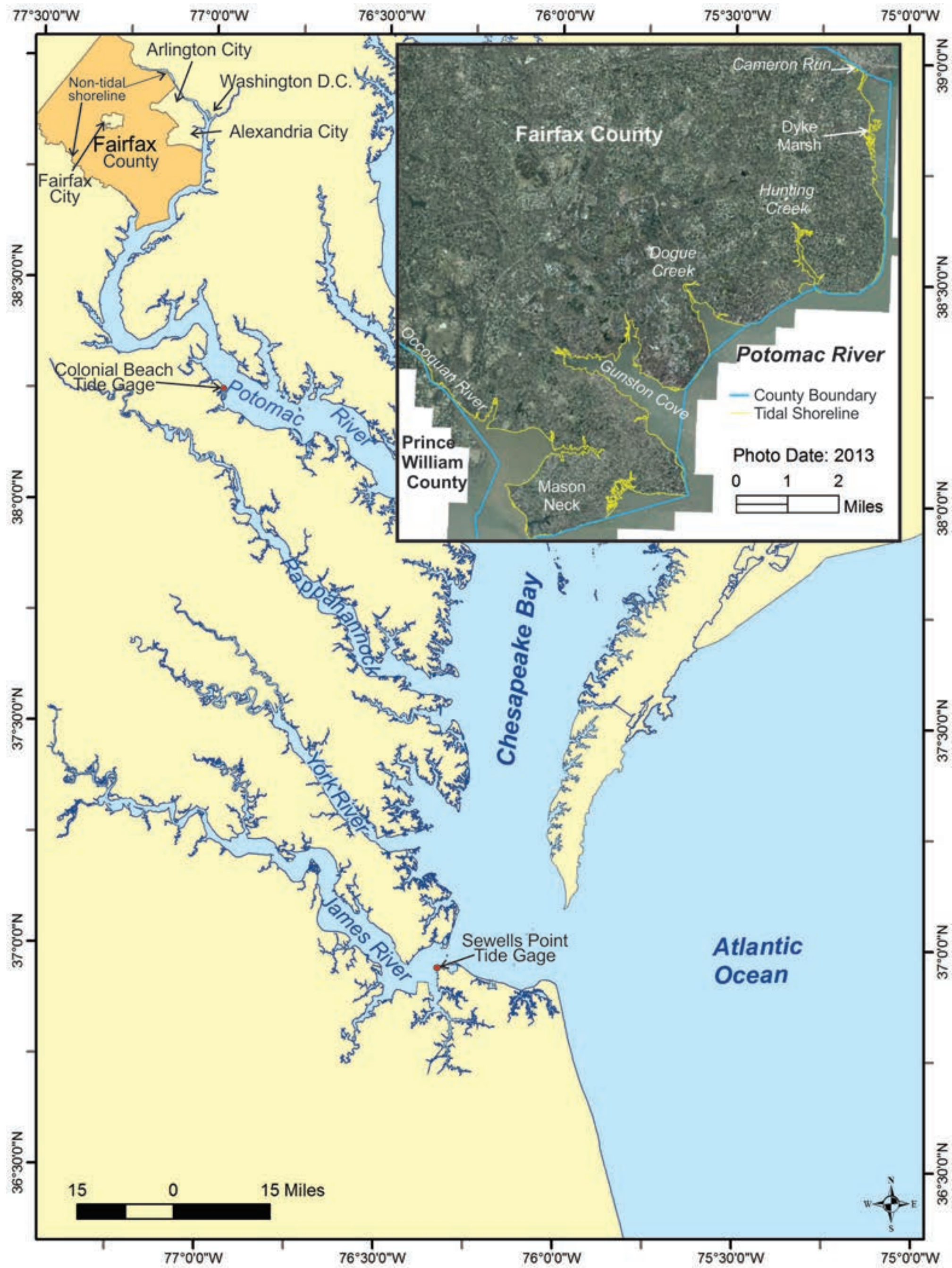


***Figure 1-1.*** *Location of Fairfax County within the Chesapeake Bay estuarine system. The location of the National Oceanic and Atmospheric Administration tide gage is shown.*

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

Much of the Fairfax County's tidal 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 Fairfax 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

Fairfax County straddles the "Fall Line" which is the boundary between the Piedmont and Coastal Plain with the Coastal Plain located east of the fall line. The fall line delineates the change between tidally and non-tidally influenced water. The extent of Fairfax's tidal shoreline is shown in Figure 1-1. The southernmost extent of tidal shoreline in Fairfax occurs along the Occoquan River just downstream of a dam on the River. The northernmost extent of Fairfax County's tidal shoreline is along Cameron Run at the Alexandria City boundary. The tidal shoreline encompasses all the rivers, creeks, and embayed shorelines in between including Gunston Cove, Dogue Creek, and Little Hunting Creek which enter the Potomac laterally from the northwest. Fairfax County has non-tidal shoreline along the Potomac River and Occoquan River that is not included in this Management Plan.

Figure 2-1 shows the geology of Fairfax County. Many areas of the tidal shoreline are exposed Quaternary sediments which tend to be sandy in nature. Mason Neck is exposed Quaternary Shirley Formation which varies between low interfluves and eroding sandy banks up to 40 feet high. While a few areas reach 40 feet high, most areas are 30 feet or less. The older Potomac Formation from the Cretaceous tends to be higher reaching heights of 50-100 feet. It outcrops in Gunston Cove, on the headland between Gunston Cove and Dogue Cove, and farther north between Sheridan Point and Dyke Marsh. The shoreline between Dyke Marsh and Cameron Run is composed of Alluvium deposited most recently during the Holocene and is composed mostly of clay or mud.

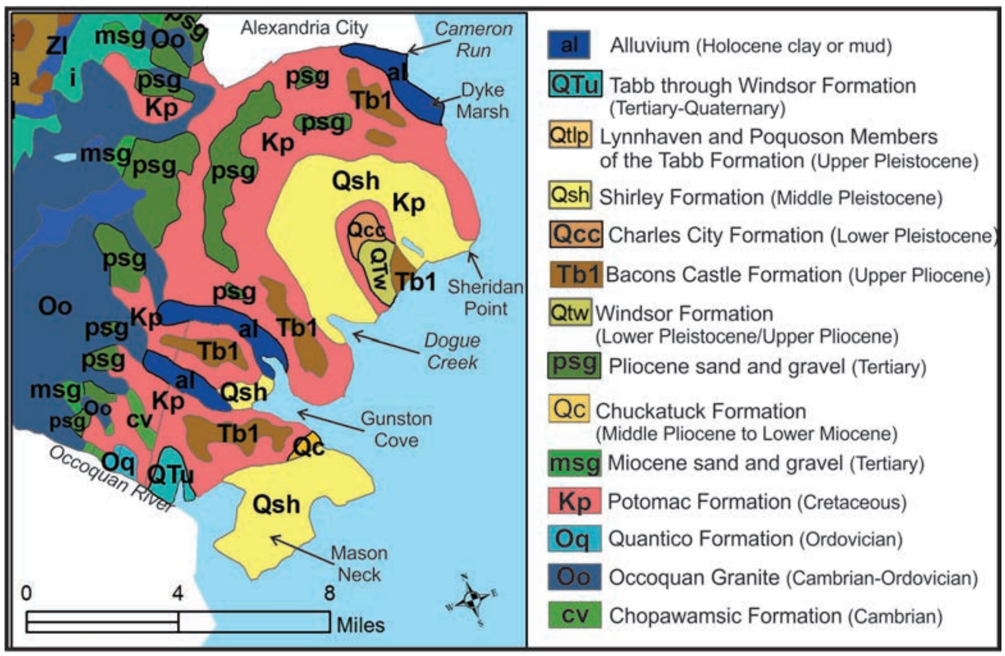


***Figure 2-1.*** *Geology of Fairfax County (Mixon* et al.*, 1989).*

The tidal portion of Fairfax County's Potomac River shoreline along with Alexandria's and Arlington's shoreline is the geomorphic transition from the lower, more open Potomac River (downriver from Mason Neck) to the more riverine meandering Potomac River above Alexandria. The river width at Mason Neck is about 2 miles while the river width at Washington D.C. is less than 1 mile.

### 2.1.2 Shoreline Morphology

The Fairfax County shoreline can be divided into three reaches for ease of discussion based on shoreline morphology, presence of tidal creeks and geology. Reach 1 extends from dam on Occoquan River down to Belmont and Occoquan Bays to High Point on Mason Neck, then north along the Potomac River to Hallowing Point (Figure 2-2). Reach 2 extends from Hallowing Point along Gunston Cove and Dogue Creek to Little Hunting Creek (Figure 2-3). Reach 3 extends from Little Hunting Creek along the Potomac to Cameron Run (Figure 2-4).

**Reach 1**

The Town of Occoquan on the Prince William County side of the Occoquan River is the approximate limit of tidal influence before reaching a small set of rapids and a dam. The Fairfax County side has a more rural wooded coastline and limited development. The Occoquan River is about 0.1 miles wide at the Rt 1. Bridge and Colchester.

Broad and fringing tidal fresh water marshes occur along the entrance of Belmont Bay (Figure 2-5). The coast has limited development with hardened

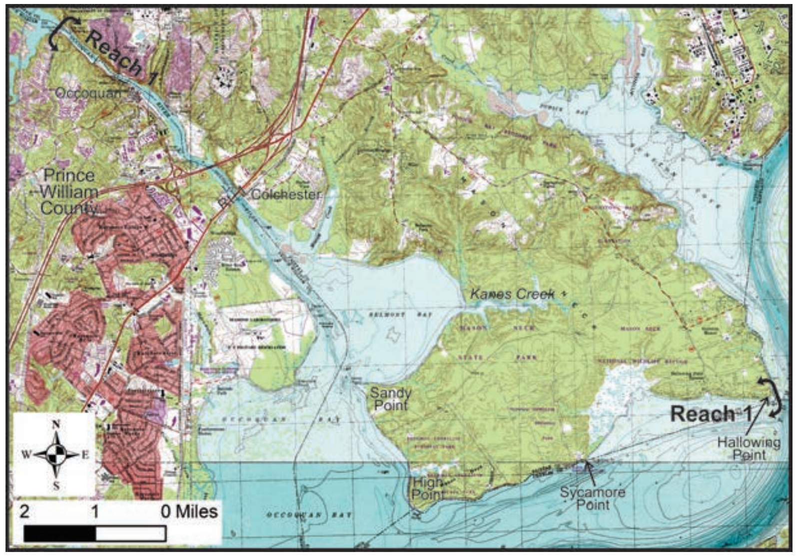


*Figure 2-2. Topographic sheet of Reach 1 in Fairfax County.*

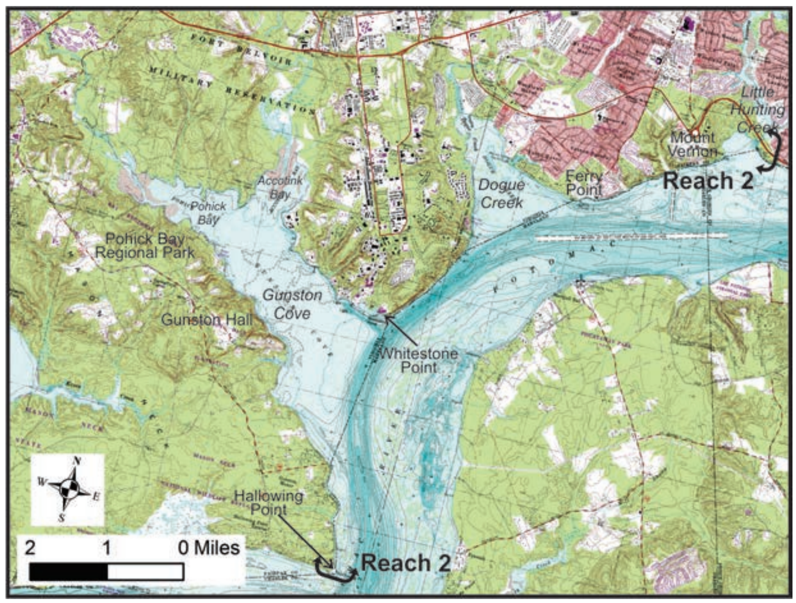


*Figure 2-3. Topographic sheet of Reach 2 in Fairfax County.*


*Figure 2-4. Topographic sheet of Reach 3 in Fairfax County.*

*Figure 2-5. Broad, fringing tidal fresh water marshes along Belmont Bay.*

shorelines (Figure 2-6) that transition to intermittently eroding upland banks along Belmont Bay to Kanes Creek (Figure 2-7). From Kanes Creek to Sandy Point the shoreline is alternating high eroding banks and low marsh coast with numerous trees along the bank and shore. This shore segment is part of Mason Neck State Park. There are three gabion structures just down river of the Park visitor's center (Figure 2-8) that are acting as breakwaters along the shoreline.

Sandy Point is a low marsh and partially wooded coast with a narrow beach on both the Belmont Bay and Occoquan Bay side of the Point. The Point has been eroding at -2.5 ft/ yr and little sand remains at the Point, itself. The shoreline between Sandy Point and High Point faces southwest (downriver) and is mostly eroding high upland bank. Intermittent low drainages occur along the reach with low wooded shorelines. Two revetments and two rock breakwater systems occur along the subreach, both with four breakwater units and little or no sand fill. Accordingly, these are classified as detached breakwaters. The first system is just downriver from the first revetment and has another revetment along the shore behind it. The second breakwater system (Figure 2-9) is just north of High Point along Occoquan Bay which continues to erode.

***Figure 2-6.*** *Shore protection along eroding banks of Belmont Bay.*

***Figure 2-7.*** *Eroding banks along Belmont Bay.*

***Figure 2-8.*** *Gabion structures that are acting as breakwaters along Mason Neck State Park. From Bing Maps.*

The shoreline along Mason Neck on the Potomac River continues as a high eroding southward facing upland bank for about 2.0 miles upriver of High Point where a broad tidal marsh complex occurs beginning at Sycamore Point. The first 0.5 miles of the marsh complex has a wooded berm along the marsh edge which transitions to eroding marsh peat coast (Figure 2-10). The Potomac River coast abruptly returns to high bank shoreline for the next 7,000 feet to Hallowing Point. This segment of coast is heavily developed as part of Hallowing Point Estates which has mostly been hardened with bulkheads of varying types from wood, vinyl and concrete. The banks have mostly been graded as well along with numerous piers.

**Reach 2**

Hallowing Point, where Reach 2 begins (Figure 2-3), is low and wooded shoreline with a narrow beach. The upriver side of Hallowing Point is a continuation of developed upland banks along the Potomac River. Farther north, Gunston Hall Plantation and Pohick Bay Regional Park reside along the south shore of Gunston Cove. This east and northeast facing coast occurs as a series of headland points and shallow bays. The developed coast is mostly hardened high uplands (20 to 30 Ft) with stable graded banks (Figure 2-11) with numerous piers.

The upland banks rise to 50 and 100 ft along the developed areas of Gunston Cove near Gunston Hall. The banks are generally natural and erosional but heavily vegetated (Figure 2-12). The upland banks drop down to about 5 ft at the boat ramp at Pohick Bay Regional Park where gabions have been installed for shore protection. The upper Pohick Bay and Accotink Bay shorelines occur as low tidal freshwater marsh in front of wooded uplands.

From the east side of the mouth of Accotink Bay, the shoreline becomes low upland bank with a local waterfront park part of Fort Belvoir Military Reservation. The coast to Whitestone Point is 10 ft upland banks that are hardened in front of military infrastructure. Whitestone Point is eroding.

Reach 2 continues from Whitestone Point along the Potomac River and Dogue Creek to Ferry Point. The shoreline is an eroding high bank toward the mouth of Dogue Creek where it drops down to a low beach and wooded back shore with stable wooded banks. The south coast of Dogue Creek begins with a wide sandy backshore, wooded with stable uplands and intermittent tidal freshwater marsh fringes that transitions to upland banks with minor erosion and little or no sand beach or backshore.

Dogue Creek transitions quickly to a very narrow tidal channel entrance. Just beyond is a marina sited on the north side of the Creek.

***Figure 2-9.*** *One attached and three detached breakwaters along Mason Neck north of High Point. As the sandy bank erodes, the breakwaters likely will become attached. From Bing Maps.*

***Figure 2-10.*** *Broad, shallow marsh along the Potomac River between High Point and Hallowing Point.*

***Figure 2-11.*** *The shorelines along this section of shoreline in Reach 2 along the Potomac River has been graded and protected at the base.*

***Figure 2-12.*** *Along the Gunston Cove shoreline, the high upland bank is mostly in a natural state and is erosional.*

Beyond the entrance and continuing along the north shore of Dogue Creek, there are developed upland banks with gentle graded banks and hardened shoreline (Figure 2-13). The north coast of Dogue Creek continues to Ferry Point at the confluence with the Potomac River as a highly developed shoreline. Ferry Point is protected with rock (Figure 2-14).

***Figure 2-13.*** *Development and shore protection along Dogue Creek.*

***Figure 2-14.*** *Ferry Point differs from other points in Fairfax in that it is developed and protected with a large revetment.*

The shoreline north of Ferry Point until the end of Reach 2 at Little Hunting Creek is developed high bank shoreline with two upland drainages intersecting the coast before you reach Mount Vernon. The shoreline occurs as heavily vegetated and natural in some areas while other sections have graded banks with a few defensive shoreline structures. The Mount Vernon shoreline extends for about 0.5 miles along the Potomac before turning into the embayed coast at the entrance to Little Hunting Creek. The Mount Vernon shoreline is mostly low banks then high graded bluff with stone block seawall (Figure 2-15). Beyond the manor house the shoreline occurs as intermittently eroding high bank, heavily vegetated before the Little Hunting Creek embayment. The Little Hunting Creek bay shoreline is low and heavily wooded before reaching the fixed entrance to Little Hunting Creek itself (Figure 2-16) where the George Washington Parkway crosses.

***Figure 2-15.*** *The high bank at Mount Vernon has been graded and the shoreline protected with a stone block seawall.*

**Reach 3**

Reach 3 extends up the Potomac River to the border with Alexandria City. The creek at the border is called both Hunting Creek and Cameron Run on topographic maps (Figure 2-4); however, this report uses Cameron Run. The George Washington Memorial Parkway (GWP) runs along the shoreline for several miles of the reach. The shoreline occurs as a low wooded bank except where the GWP gets close to the river. The GWP coast varies from low to high upland bank that is intermittently landscaped and hardened (Figure 2-17).

***Figure 2-16.*** *The fixed entrance to Little Hunting Creek.*

Where the GWP turns away from the shoreline, development of the bank begins again with mostly hardened shorelines and graded banks (Figure 2-18). At Hog Island the shoreline landscape becomes low and heavily wooded. From there northward along the Potomac River to Belle Haven Marina, the shoreline is a freshwater swamp and tidal freshwater marsh complex called Dyke Marsh. The shoreline is erosive with intermittent wooded islands along the reach (Figure 2-19). Dyke Marsh is currently being considered for extensive restoration. It was once a much larger feature and extensive mining of the gravelly nearshore from 1940 to 1972 reduced its acreage by over 50%. Chronic shoreline erosion has reduced it even more. The restoration plan has several option from complete restoration to protecting what's left.

The remainder of Reach 3 extends from Belle Haven Marina to the mouth of Cameron Run. This shoreline is mostly low banks heavily wooded except for open areas that provide vistas along the GWP which comes back close to and runs along the shoreline. Sections of the shoreline have areas of dumped rock and broken concrete with berms of drift wood. Wide tidal flats extend along the nearshore region as sediment has collected over the years in the broad embayment between Belle Haven Marina and Jones Point (in Alexandria City).

***Figure 2-17.*** *The George Washington Memorial Parkway runs along the shoreline in Reach 3.*

***Figure 2-18.*** *Development along Reach 3.*

***Figure 2-19.*** *Dyke Marsh with wooded upland and occasional treed islands.*

Cameron Run is narrow, tapering gradually to the first dam where there are numerous sandy shoals. Along the way, the creek flows under seven roads, off-ramps, a railroad bridge, Telegraph Road and I-95. Upriver, the shoreline landuse includes a golf course, office complexes, and a stretch of wooded shoreline. The shoreline has been mostly hardened with bulkheads along office complexes and intermittent areas of rock along the wooded coast.

## 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;

Basco and Shin (1993) described the wave climate near the Fairfax County's coast for use in planning and designing structures. Their analysis utilized moderate winds of 35 miles per hour to generate waves with characteristics that could be expected to impact the coast about once every two years. The storm surge for this event is about 2.5 feet above MHW. Wave heights and wave periods in Occoquan Bay (Figure 2-20) are about 3.0 ft with a 3.4 second period before nearshore shoaling. Farther north along the Potomac River in the vicinity of Hallowing Point, wave heights and wave periods are about 2.5 ft with a 3.1 second period. Continuing north along the Potomac River to Cameron Run, the wave height is 2.0 feet with a 2.7 second period.

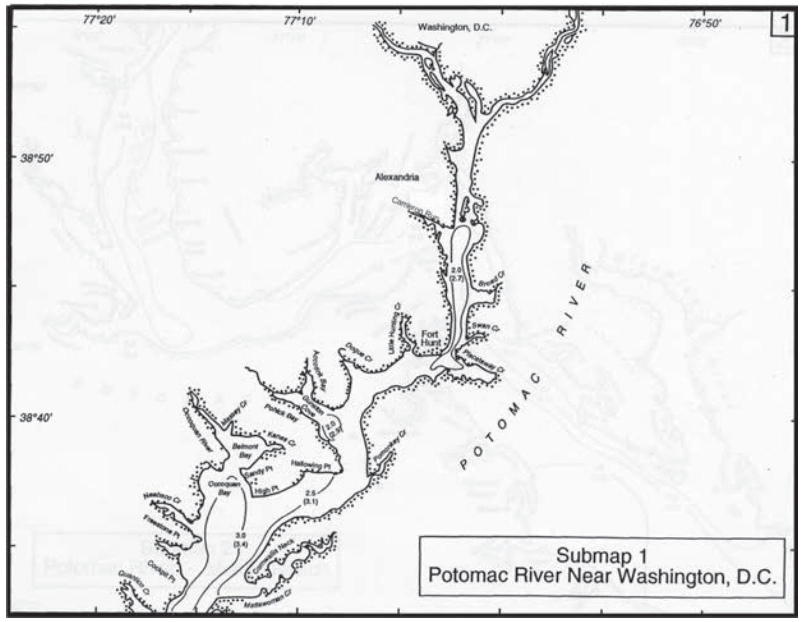


*Figure 2-20. Wave climate map for the Potomac River (from Basco and Shin, 1993).*

Tide ranges vary along the Fairfax County shoreline (Table 2-1). Mean tide range is lowest at High Point on Mason Neck on the Potomac River at 1.6 ft. As the Rivers become narrower, the tide range increases. At Washington D.C., the mean tide range is 2.8 ft.

| Tide Station | Mean Range (ft) | Spring Range (ft) |
|---|---|---|
| High Point | 1.6 | 1.8 |
| Gunston Cove | 2.0 | 2.3 |
| Washington D.C. | 2.8 | 3.2 |

***Table 2-1.*** *Tide Range in Fairfax County.*

### 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. The recent trend based on wave gauge data at Washington D.C. shows the annual rate to be 1.1 feet/100 years (3.22 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 determined between 1927 and 2013) will only result in 0.53 feet rise in water level by 2050. At Colonial Beach on the Potomac River, historic sea level rise (1972-2010) is rising at an even higher rate of 1.6 feet in 100 years (4.89 mm/yr). 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/fairfax/sealvlrise.html).

### 2.2.3 Shore Erosion

Shoreline erosion results from the combined impacts of waves, sea level rise, tidal currents and, in some cases, boat wakes and shoreline hardening. Table 2-2 shows the average historical shoreline rates of change for various areas throughout the County. Much of the shoreline has a very low rate of erosion. Cameron Run shows a large rate of accretion due to man-made placement of material along the shoreline. More detailed shoreline change information can be found in Milligan *et al.* (2014).

The shorelines with the largest historical shoreline rates of change have mostly been hardened. 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 |
|---|---|---|
| Occoquan River and Belmont Bay | -0.3 | Very Low Erosion |
| Occoquan Bay | 0.0 | Very Low Erosion |
| Occoquan Bay along Potomac River to Hallowing | -0.9 | Very Low Erosion |
| Hallowing Point to Gunston Cove | -0.7 | Very Low Erosion |
| Gunston Cove | 0.0 | Very Low Erosion |
| Whitestone Point to Dogue Creek | 0.4 | Very Low Accretion |
| Dogue Creek | 0.0 | Very Low Erosion |
| Dogue Creek to Little Hunting Creek | 0.0 | Very Low Erosion |
| Little Hunting Creek | -1.0 | Low Erosion |
| Little Hunting Creek to Fort Hunt Park | -0.4 | Very Low Erosion |
| Potomac River North to Cameron Run | -3.6 | Medium Erosion |
| Cameron Run | 7.39 | High Accretion |

***Table 2-2.*** *Average end point rate of change (1937-2009) for Fairfax 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 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 Fairfax, 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.

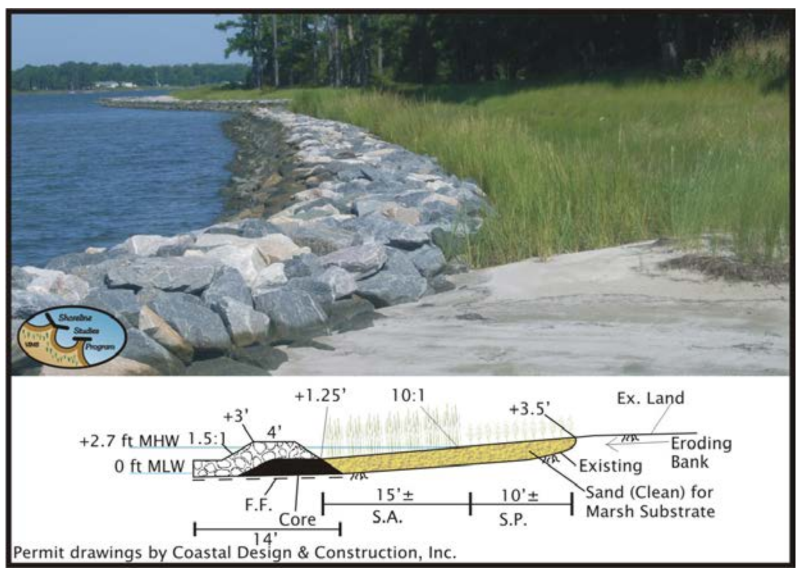


***Figure 3-5.*** *Sand fill with stone sills and marsh plantings at Poplar Grove, Mathews County, Virginia after six years and the cross-section used for construction (From Hardaway* et al., *2010).*

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).

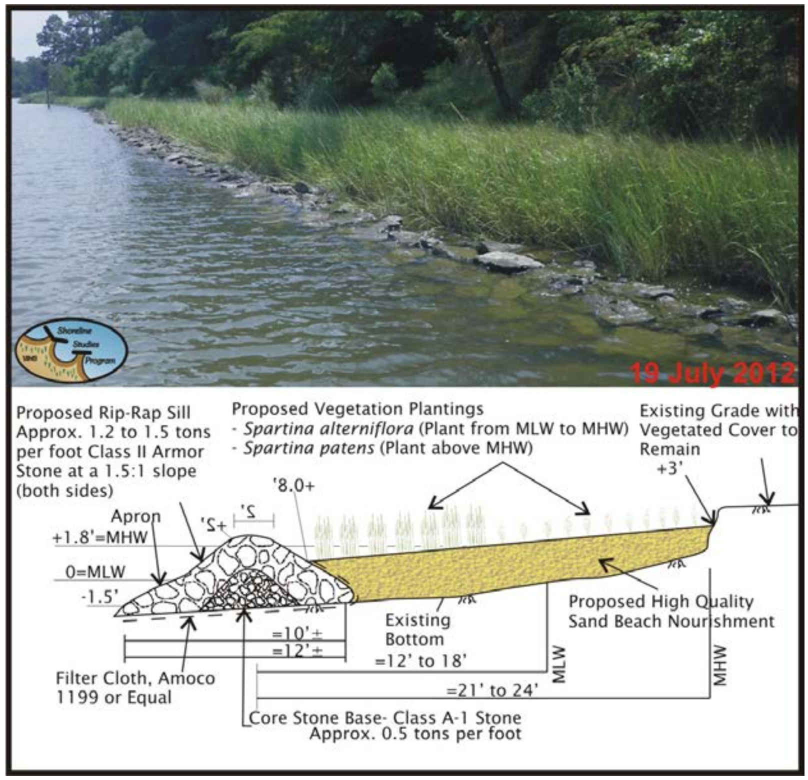


***Figure 3-6.*** *Longwood University's Hull Springs Farm four years after construction and the cross-section used for construction (from Hardaway* et al., *2010).*

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

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

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

### *3.4.2 Breakwaters*

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

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

Hardaway and Byrne (1999) suggest that breakwater systems in medium energy environments should utilize at least 200 feet of shoreline, preferably more, because individual breakwater units should have crest lengths of 60 to 150 feet with crest heights 2 to 3 feet above mean high water. Minimum mid-bay beach width should be 35-45 feet above mean high water. On high energy coasts, the mid-bay beach widths should be 45 to 65 feet especially along high bank shorelines (Figure 3-8). 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.


***Figure 3-8.*** *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.*

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

# 4 Methods

## 4.1 Shore Status Assessment

The shore status assessment was made from a small, shallow draft vessel, navigating at slow speeds parallel to the shoreline during field days in August 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

| 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.*

in Table 4-1, the majority of these data are collected and maintained for the Fairfax County Shoreline Inventory. (http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/virginia/fairfax_alex/fairfax_alex_disclaimer.html) developed by CCRM (Berman *et al.*, 2010). 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 Fairfax County

## 5.1 Shoreline Management Model (SMM) Results

In the Fairfax County, the SMM was run on 91 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 Fairfax County can be achieved without the use of traditional erosion control structures, and with few exceptions, very little structural control. Over 70% of the shoreline can be managed simply by enhancing the riparian buffer, beach, 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. Along the open Potomac River, the use of breakwaters with beach nourishment is recommended. Sills are recommended a many areas along the creeks and bays. Table 5-1 summarizes the model output for Fairfax based on strategy(s) and shoreline miles. The glossary in Appendix 2 gives meaning to the various Shoreline BMPs listed in Table 5-1.

| ShoreBMP | Length (miles) |
|---|---|
| Enhance Riparian/Marsh Buffer | 2.75 |
| Enhance Riparian/Marsh Buffer OR Beach Nourishment | 0.07 |
| Enhance/Maintain Beach | 0.09 |
| Enhance/Maintain Marsh | 26.71 |
| Enhance/Maintain Riparian Buffer | 27.27 |
| Groin Field with Beach Nourishment | 0.03 |
| Maintain Beach OR Offshore Breakwaters with Beach Nourishment | 20.31 |
| Plant Marsh with Sill | 6.05 |
| Revetment | 0.12 |
| Widen Marsh | 1.25 |
| Widen Marsh/Enhance Buffer | 0.09 |
| | |
| **UplandBMPS** | Length (miles) |
| Area of Special Concern | 4.95 |
| Enhance Riparian/Marsh Buffer | 67.84 |
| Forest Management | 5.48 |
| Grade Bank | 10.32 |
| Land Use Management | 1.99 |
| No Action Needed | 0.57 |

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

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/fairfax/).

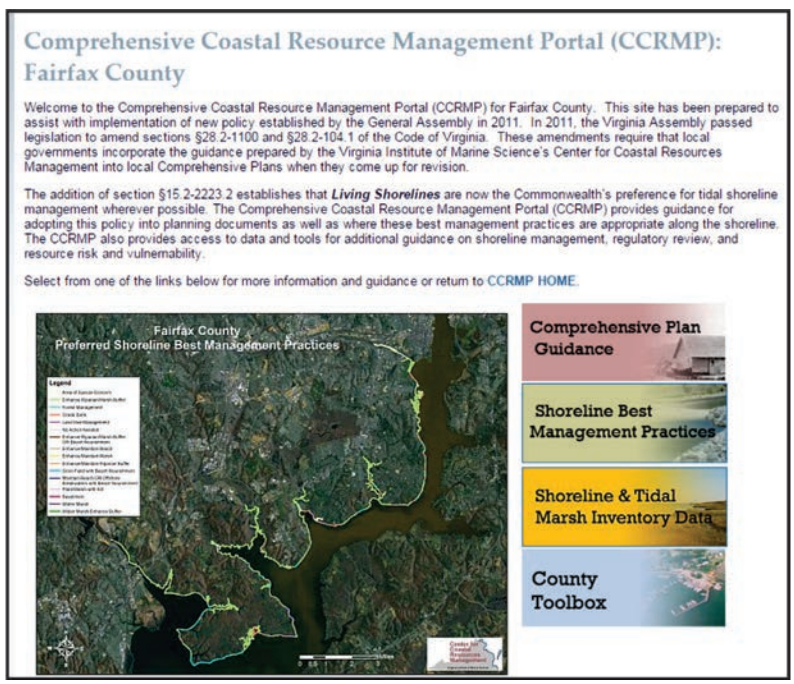


***Figure 5-1.*** *Portal for Comprehensive Coastal Resource Management in Fairfax County.*

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.

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

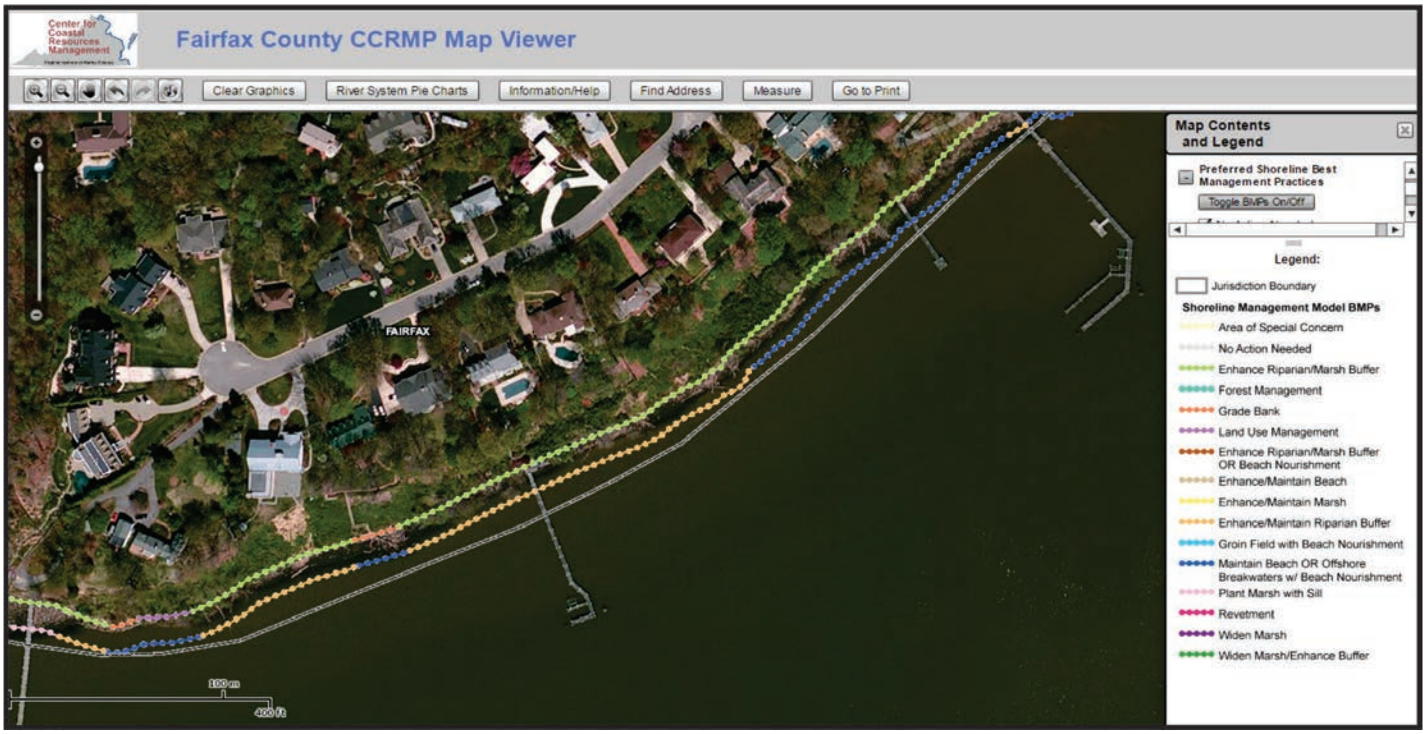


***Figure 5-2.*** *The Map Viewer displays the preferred Shoreline BMPs in the map window. The color-coded legend in the panel on the right identifies the treatment option recommended.*

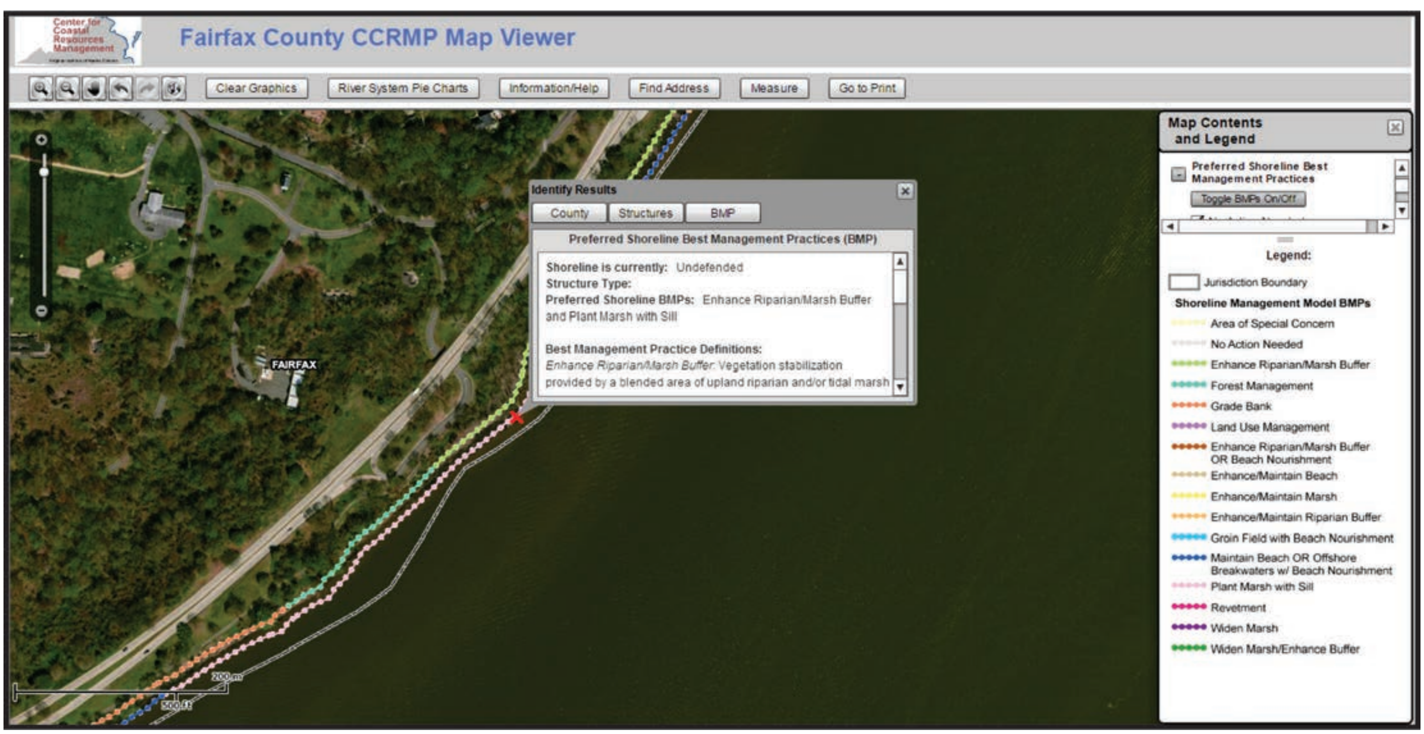


***Figure 5-3.*** *The pop-up window contains information about the recommended Shoreline BMP at the site selected. Additional information about the condition of the shoreline also is given.*

## 5.2 Shore Segments of Concern/Interest

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

The conceptual designs presented in this section utilize the typical cross-sections that are shown in Appendix 3. The guidance provided in Appendix 3 describes the environments where each type of structure may be necessary and provides an estimated cost per foot. The designs presented are conceptual only; structural site plans should be created in concert with a professional experienced in the design and construction of shore protection methods in Chesapeake Bay.

### 5.2.1 (Area of Interest#1) Mason Neck Headland Breakwater System

The shoreline along Mason Neck at High Point is a high eroding bank (Figure 5-4). The bank is eroding at -2 to -5 ft/yr. In order to maintain High Point, a series of attached breakwaters are recommended (Figure 5-5). Detached breakwaters were built along a section of the coast in order to capture sand as the banks continued to erode (Figure 2-9). While these structures will eventually fill up with sand to create stable embayments, it is recommended that the breakwaters along High Point be attached in order to maintain the point. A typical cross-section is shown in Appendix 3, Figure 3-3.


***Figure 5-4.*** *Existing conditions at High Point on Mason Neck.*

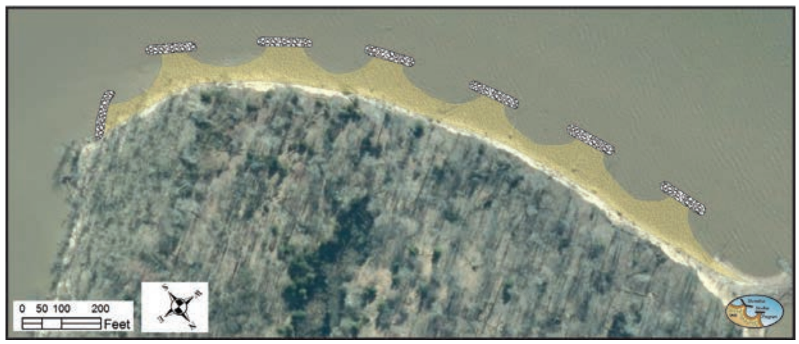


***Figure 5-5.*** *Proposed configuration of the breakwater shoreline BMP for High Point.*

### 5.2.2 (Area of Interest #2) Turnout on GWP Low Sill

The second area of interest is a turnout along the GWP (Figure 5-6). This section of coast has a very low erosion rate (Figure 5-7), less than -1 ft/yr, but the Mount Vernon Trail, a paved multi-use trail that stretches from George Washington's Mount Vernon estate to Theordore Roosevelt Island, is relatively close to the shoreline (Figure 5-8). In addition to providing a buffer along the shore, a sill will create habitat and enhance the view along the turnout. A typical cross-section for a sill at this site is shown in Appendix 3, Figure 3-1.


***Figure 5-6.*** *Location of Area of Interest #2 and #3 along the George Washington Memorial Parkway.*

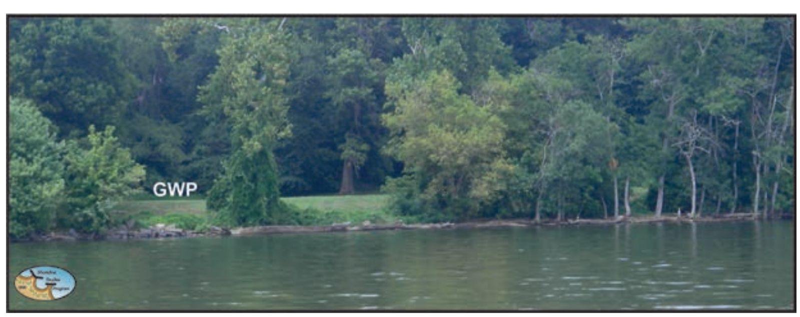


***Figure 5-7.*** *Existing conditions at the GWP turnout Area of Interest #2.*

### 5.2.3 (Area of Interest#3) Turn out on GWP Medium Sill

The third area of interest is also a turnout along the GWP (Figure 5-6). This section of coast has a higher erosion rate, -2 to -5 ft/yr, and the Mount Vernon Trail and turnout are very close to the eroding bank (Figure 5-9). A medium sill will protect the Trail and the shoreline from continued erosion (Figure 5-10). A typical cross-section for a sill at this site is shown in Appendix 3, Figure 3-2.


***Figure 5-8.*** *Proposed configuration of sill shoreline BMP for Area of Interest #2 along the GWP.*


***Figure 5-9.*** *Existing conditions at the GWP turnout Area of Interest #3. From Bing Maps.*


***Figure 5-10.*** *Proposed configuration of sill shoreline BMP for Area of Interest #3 along the GWP.*

# 6 Summary and Links to Additional Resources

The Shoreline Management Plan for Fairfax 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: Fairfax County Map Viewer**

http://cmap.vims.edu/CCRMP/FairfaxCCRMP/Fairfax_CCRMP.html

**VIMS: Living Shoreline Design Guidelines**

http://www.vims.edu/research/departments/physical/programs/ssp/shoreline_management/living_shorelines/index.php

**VIMS: Why a Living Shoreline?**

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

**VIMS: Shoreline Evolution for Fairfax County**

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

**NOAA: Living Shoreline Implementation Techniques**

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

**Chesapeake Bay Foundation: Living Shoreline for the Chesapeake Bay Watershed**

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

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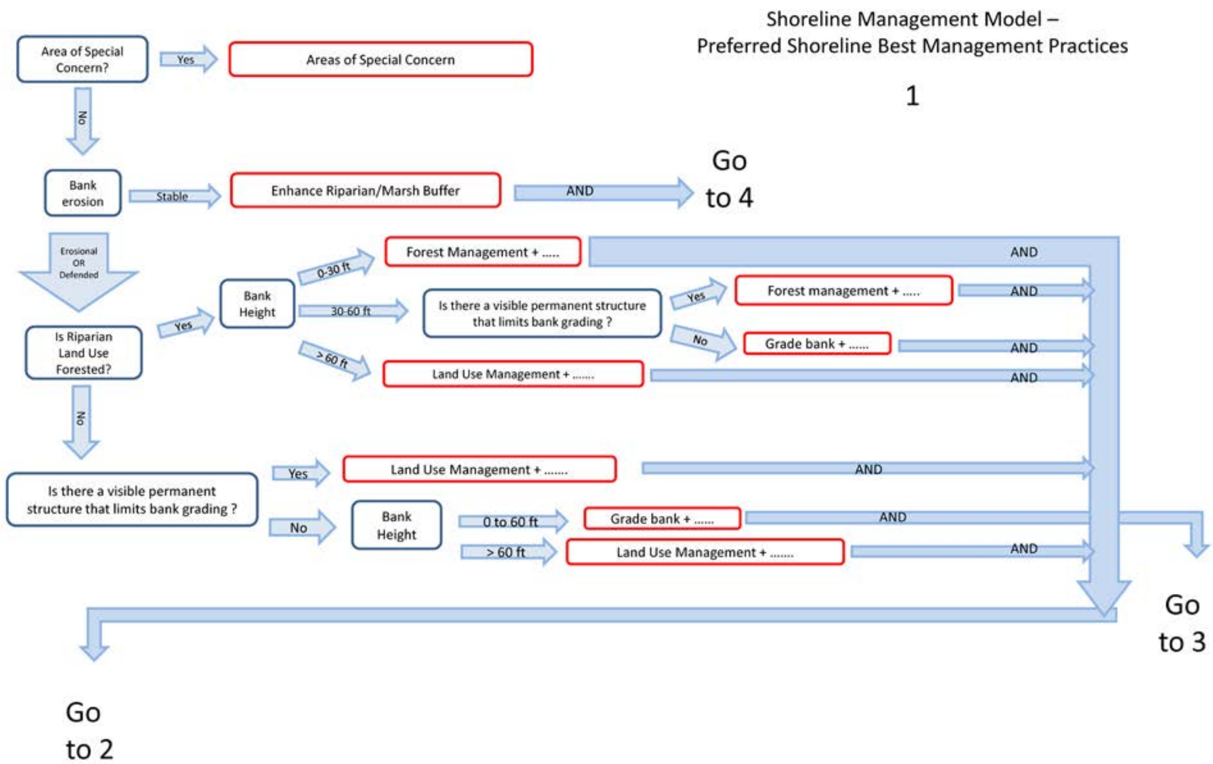
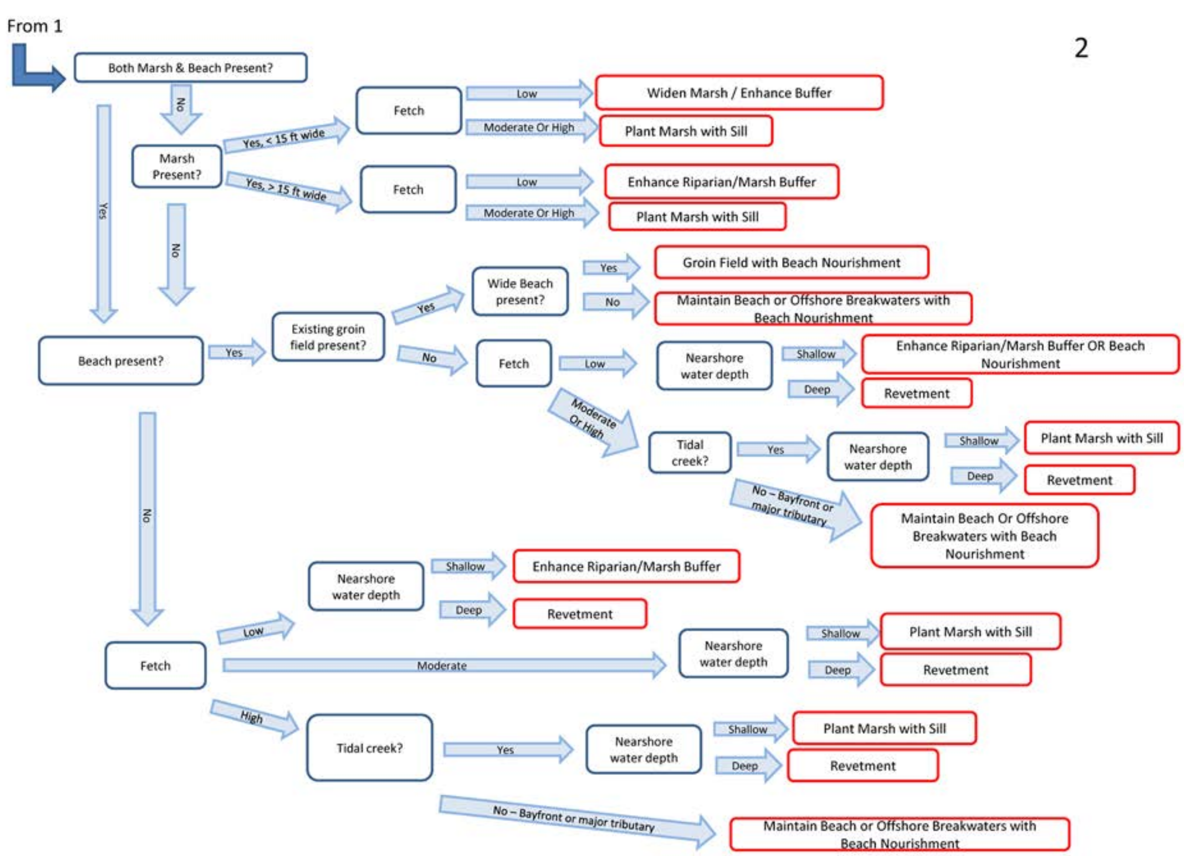
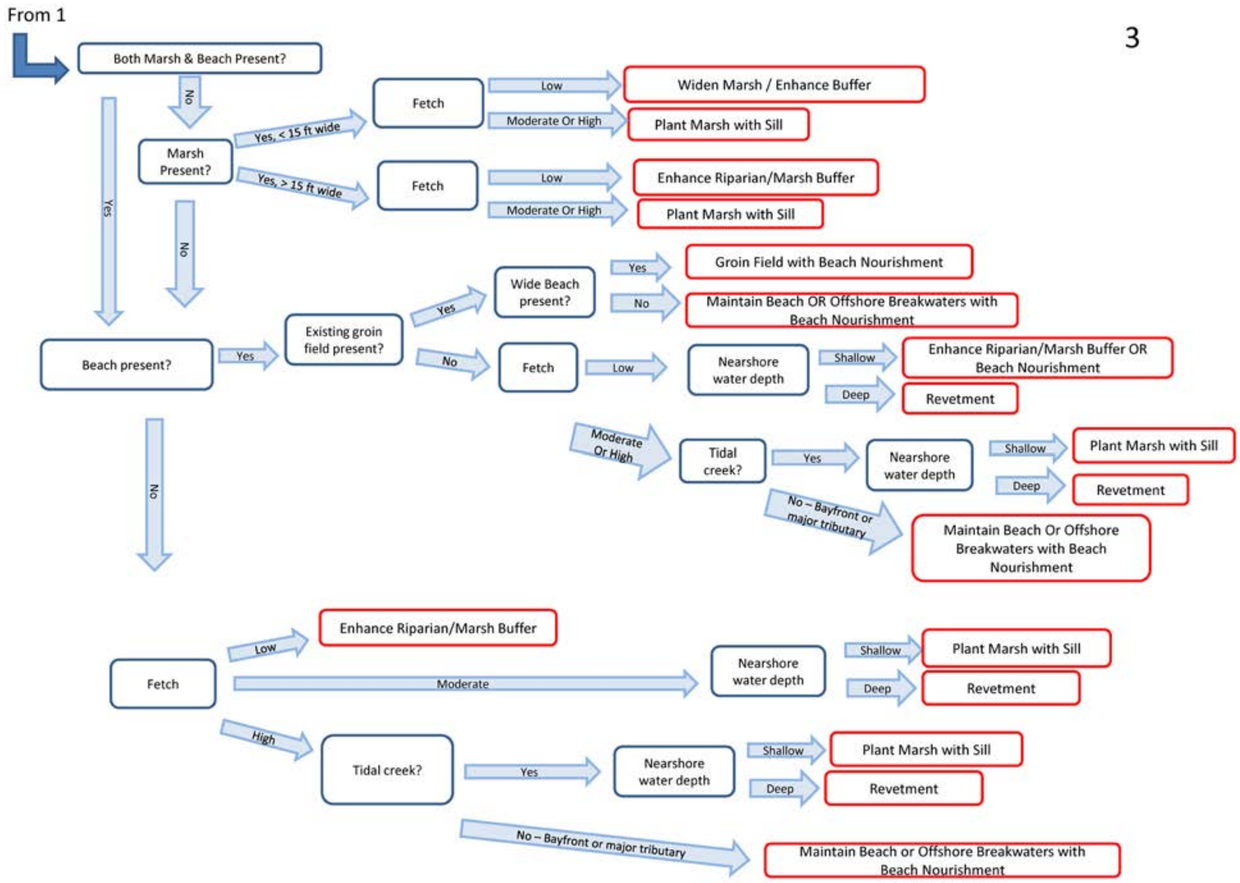
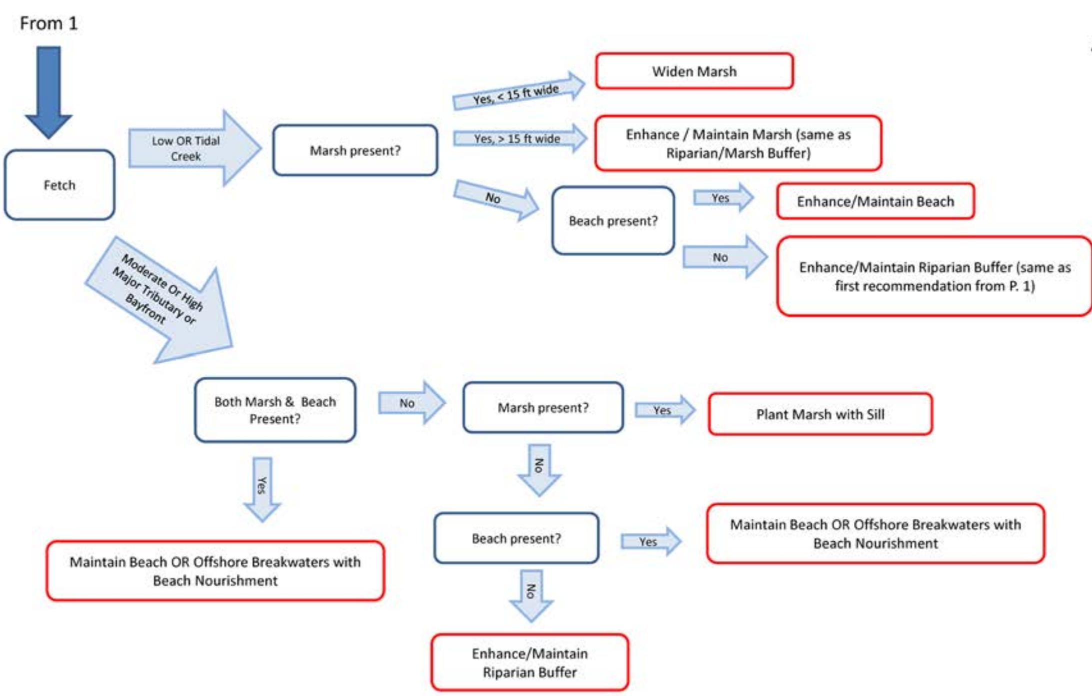
# APPENDIX 1

## Shoreline Management Model Flow Diagram




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


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

# APPENDIX 2

# Glossary of Shoreline Best Management Practices

### Preferred Shoreline Best Management Practices

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

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

### Upland & Bank Areas

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

For Fairfax County, three typical cross-sections for stone structures have been developed. The dimensions given for selected slope breaks have a range of values from medium to high energy exposures becoming greater with fetch and storm wave impact. 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.

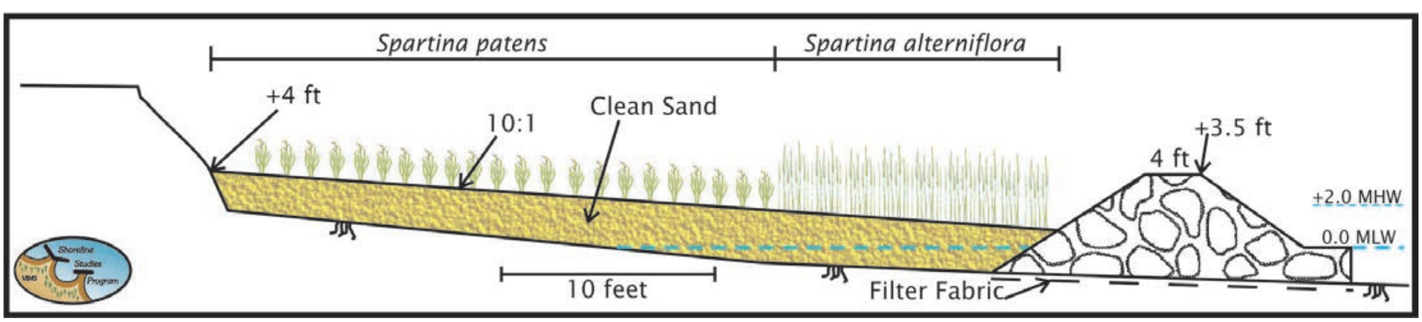
| Type of Structure | Estimated Cost per Linear Foot* |
|---|---|
| Low Sill | $150 -$250 |
| High Sill | $250 - $400 |
| Breakwater | $600 - $1,000 |

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

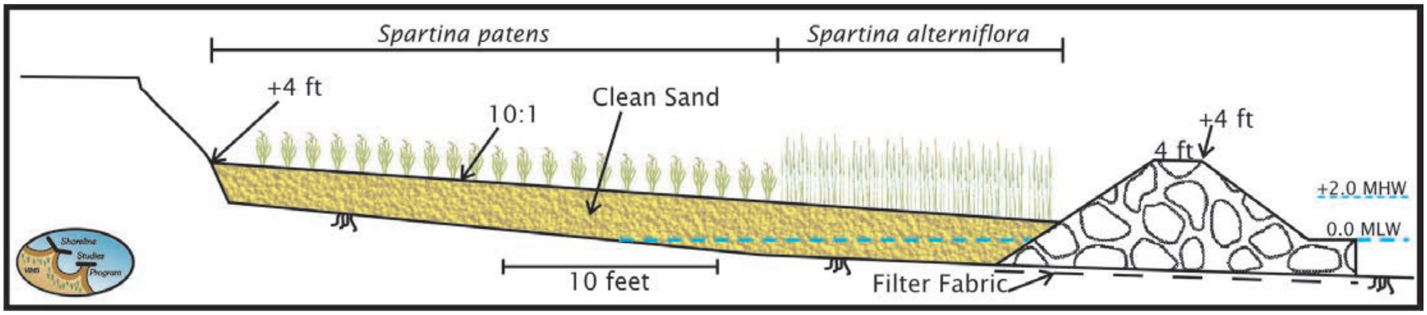
**Based on typical cross-section. Cost includes only rock, sand, plants. It does not include design, permitting, mobilization or demobilization.*

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 Fairfax, 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.

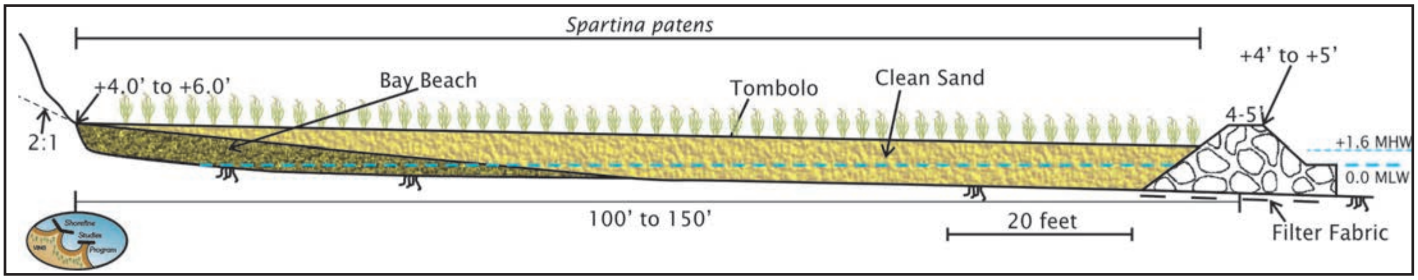
Breakwater systems are applicable management strategies along much of the Fairfax's Potomac River coast and other areas with a medium to high energy shores. The actual planform design is dependent on numerous factors and should be developed by a professional. However, a typical breakwater tombolo and embayment cross-section is provided to help determine approximate system cost (Appendix 3, Figure 3).




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




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




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