A Best Management Plan for the Shoreline and Slopes Along the Scientists' Cliffs Shoreline of the Chesapeake Bay, Maryland

Scientists' Cliffs Association

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Table of Contents

Section 1 Background and Executive Summary 1

1.0 Introduction 1

1.1 Geographic Scope and Executive Summary 2

1.1.1 Geographic Scope 2

1.1.2 Executive Summary 2

1.2 Background Information and Data 6

1.2.1 Slope Segments and Dominant Processes 7

1.2.2 Calvert Cliffs' Stratigraphy 11

1.3 Site Description: Scientists' Cliffs 15

1.3.1 Stratigraphy 15

1.3.2 Shoreline Orientation and Toe Conditions 17

1.3.3 Physiography 19

1.3.4 Mean Water Levels Relative to the 1929 National Geodetic Vertical Datum. 21

1.4 Modeling the Wave Climate 23

1.4.1 Model Input 24

1.4.2 Nearshore Calculated Wave Heights and the Breaking Wave Criterion 28

1.4.3 Wave Stress Calculations 29

1.4.4 Frequency of Occurrence of Wave Stress at the Shoreline 31

1.5 Summary of Groundwater Conditions 34

1.6 Slope Stability Analyses 38

1.6.1 Infinite Slope Stability Analysis 38

1.6.2 Block Failures 41

1.7 Endangered and Threatened Species 46

1.7.1 U.S. Fish and Wildlife Service Recovery Strategy for the Northeastern Beach and Puritan Tiger Beetles 48

1.7.2 Summary of Key Elements Related to the Presence of Tiger Beetle Habitat along the Scientists' Cliffs' Shoreline. 50

1.8 Section 1 References 52

Section 2 Environmental Mechanisms – Slope and Shoreline Processes 57

2.0 Introduction 57

2.1 The Dominant Mechanisms of Slope Erosion Along Scientists' Cliffs 59

2.1.1 Summary of Slope Erosion Mechanisms and Rates 59

2.1.2. The role of vegetation on the erosion of slopes at Scientists' Cliffs. 62

2.1.3 Sea Level Rise 64

2.1.4 Coastal Slopes Concept to Carry Forward Into Best Management Practices 64

2.2 The Dominant Mechanisms of Shoreline Erosion and Stabilization Along the Scientists' Cliffs' Shoreline. 65

2.2.1 Longshore and Cross-shore Sediment Transport Processes 67

2.2.2 Concepts to Carry Forward Into Best Management Practices 84

2.3 Section 2 References: 86

Section 3: Past and current beach and slope stabilization practices 87

3.1 Community Historical Practices and Observations 87

3.2 Beach Erosion and Stabilization 87

3.3 Slope Erosion and Stabilization 88

3.4 History of Regulatory Consultation 90

Section 4: The Regulatory Environment and Applicable Requirements 94

4.1 Federal, State, and County Laws and Regulations 94

4.1.1 Federal Laws and Regulations 96

4.1.2 State Laws, Programs, and Regulations 102

4.1.3 Calvert County Zoning Ordinance (May 2006) 106

4.2 Permits – Integrating Across Federal, State, and Local Requirements 127

4.2.1 Federal Permitting Considerations 127

4.2.2 State Permitting and Fee Considerations 128

4.2.3 The Joint Federal and State Permit Application Process 128

4.2.4 County Permitting and Fee Considerations 134

4.3 Section 4 References... 140

Section 5 Best Practices 141

5.1 Introduction.. 141

5.2 Shoreline Considerations 142

5.2.1 Shoreline Recommendations 144

5.2.2 Measurements to be Made to Evaluate the Effectiveness of Changes to the Groin System 152

5.3 Slope Considerations 158

5.3.1 Slope Recommendations... 159

5.3.2 Measurements to be Made to Evaluate the Effectiveness of Slope Management Practices 165

5.4 Permitting Requirements Associated with Best Management Recommendations. 167

5.5 Section 5: References... 175

Section 6 Best Management Practices and the Conservation of Tiger Beetle Habitat Along the Scientists' Cliffs' Shoreline (Tiger Beetle Habitat Protection Plan) 176

6.1 Background.. 176

6.1.1 Current Conceptual Model Associated with Conserving Tiger Beetle Habitat 176

6.1.2 USFWS Recovery Strategies 178

6.2 Shoreline and Slope Best Management Practices and Conservation of Tiger Beetle Habitat - Approach... 181

6.3 Section 6: References:.. 188

Primary Authors... 189

Tables

Table 1.1 Site Physical Characteristics 19

Table 1.2 Principal Fetch Lengths at Scientists' Cliffs Used for Wave Modeling 24

Table 1.3 Wind Speed and Direction Data Used to Develop Wave Model Input 25

Table 1.4 Storm Surge Water Surface Elevations Associated with Wind Conditions and Fetch Directions 26

Table 1.5 SC-SCN, Wave Height/Length Combinations and the Associated Wave Stress at the SWL for Prevailing Wind and Bathymetric Conditions 32

Table 1.6 SC-SCS, Wave Height/Length Combinations and the Associated Wave Stress at the SWL for Prevailing Wind and Bathymetric Conditions 33

Table 1.7 Midslope Angles [Modeled (FS=1) Versus Observed] 43

Table 1.8 U.S. Fish and Wildlife Service Recovery Strategy for the Northeastern Beach and Puritan Tiger Beetles 49

Table 2.1 Nearshore Wave Energy Dissipation Mechanisms 73

Table 2.2 Constructive and Destructive Cross-shore "Forces" in Terms of Induced Bottom Shear Stresses 78

Table 2.3 Linking the Causes of Constructive and Destructive Forces to Shoreline Best Management Practices 81

Table 2.4 Functional Properties Attributed to Groins and their Critical Evaluation. 83

Table 2.5 Main Parameters Governing Beach Response and Bypassing at Groins 84

Table 4.1 of Calvert County Environmental Requirements and Their Applicability to Shoreline and Slope Stabilization Measures That May Be Undertaken at Scientists' Cliffs. 112

Table 4.2 Brief Summary of the Joint (Federal/State) Application Process 132

Table 4.3 Summary of Calvert County Critical Area Permitting Requirements 134

Table 5.1 Measurement of Environmental Parameters Important to Beach Development 154

Table 5.2 Measurement to be Made to Evaluate Effectiveness of Slope Management Practices 166

Table 5.3 Best Practices Recommendations Summary Table 168

Table 6.1 Recovery tasks - Chesapeake Bay tiger beetle populations (USFWS 1993, 94) 180

Table 6.2 Tiger Beetle Limiting Factors (USFWS 1993, 94).. 181

Figures

Figure 1.1 Best Management Plan Scope Area 2

Figure 1.2 Calvert Cliffs' Dominant Slope Erosion Processes 9

Figure 1.3 Calvert Cliffs' Stratigraphic Column 14

Figure 1.4 Scientists' Cliffs' Geotechnical Profile 15

Figure 1.5 Chesapeake Bay 20

Figure 1.6 Relationship of Mean Water Levels to the 1929 NGVD 22

Figure 1.7 Rayleigh Wave Height Distribution 27

Figure 1.8 Primary Hydrostratigraphic Units and Well Screen Intervals 35

Figure 1.9 Scientists' Cliffs' Saturation Zone Schematic 37

Figure 1.10 Stability Analysis of an Infinite Slope Subject to Shallow Slides 39

Figure 1.11 Undercut Block Stability Analysis Geometry 41

Figure 1.12 The Effect of Saturation Depth on the Critical Slope Angle 44

Figure 2.1 One Freeze-Thaw Season of Erosion Pin Record – Chestnut Cabin 61

Figure 2.2 Longshore (*qx*) and Cross-shore (*qy*) Sediment Transport Components 67

Figure 2.3 Distribution Over Depth of the Flux of the Onshore Component of Momentum 76

Figure 2.4 Bottom Stresses Caused by Surface Winds 77

Figure 3.1 Correspondence Between Scientists' Cliffs and Maryland's Department of Geology, Mines, and Water Resources (1962) 92

Figure 3.2 Correspondence Between Scientists' Cliffs and the U.S Army Corps of Engineers (1969) 93

Figure 5.1: Transects and monuments 158

Section 1 Background and Executive Summary

(For Executive Summary see Section 1.1.2)

1.0 Introduction

By implementation of this Best Management Practices Plan (BMP), the Scientists' Cliffs Association (SCA), an association of property owners at Scientists' Cliffs, Calvert County, Maryland, seeks to continue a long and historic practice of environmental conservation on property within the SCA boundaries, along the shoreline and slopes abutting the Chesapeake Bay.

The goals of developing and implementing the best practices in this plan are to:

- Encourage the presence of a stable beach,
- Minimize the rate of slope erosion and property loss along the Scientists' Cliffs coastal slopes,
- Encourage the safety of activities conducted along the slopes and shoreline,
- Be considerate of other species that use the beach and slopes as habitat,
- Undertake conservation practices in compliance with existing laws and regulations,
- Provide a basis for the SCA and the regulatory community for documenting and better understanding information important to implementing best slope and shoreline practices and provide a framework for systematically improving upon that understanding, and
- Consider cumulative impacts resulting from individual practices and seek to minimize the negative impacts and promote positive effects.

The philosophy of this plan is to implement best practices that are designed based on an understanding of the local driving environmental mechanisms and in a way that allows the effectiveness of the practices to be measured, is affordable to the community, aesthetically acceptable, sensitive to concerns about the environment, and compliant with existing regulations.

1.1 Geographic Scope and Executive Summary

1.1.1 Geographic Scope

The geographic scope of this plan is limited to the nearshore waters, shoreline, and coastal slope faces, to the bluff top, within the SCA boundaries. See Figure 1.1 for a map of the geographic scope area.

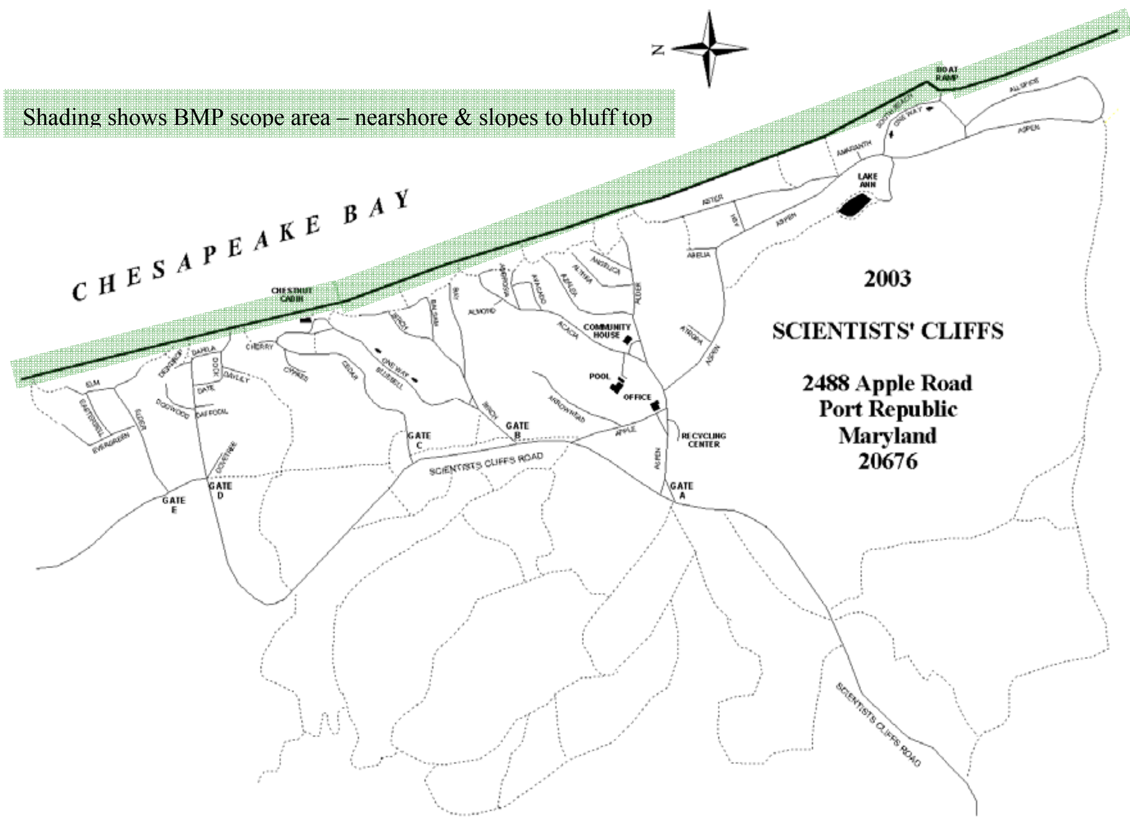


Figure 1.1 Best Management Plan Scope Area

1.1.2 Executive Summary

Many of the beach and slope stabilization practices conducted by SCA require permits issued by Federal, State, and County agencies. Pertinent regulations are discussed in Section 4 of this plan. The purpose of this Section, Best Management Practices, is to discuss and recommend practices that should be conducted to manage the beach and slopes in a way that best meets SCA's interests and comply with the existing laws and regulations.

Long before many major environmental laws embraced conservation, the Scientists' Cliffs' community was actively undertaking conservation practices in a thoughtful and forward looking way, seeking outside expertise as appropriate. Section 3 of this plan documents the priority the community has placed on conservation as the community developed. Conservation continues to be emphasized as a community priority and is an explicit priority in this plan.

The recommendations carried forward in this plan attempt to strike a balance between encouraging stable beaches along the Scientists' Cliffs' shoreline, minimizing the rate of retreat of the coastal slopes, enhancing safety by minimizing the threat of large, dangerous landslides, complying with existing laws and regulations including conservation of tiger beetle habitat, and maximizing the aesthetic qualities of the SCA shoreline. The recommended practices are developed based on understanding, managing, and adapting to the important environmental mechanisms that act along the beach and slopes of SCA.

The overall approach is concisely summarized below. The rationale behind the approach and specific practices will be systematically presented following this summary. Following the rationale, a discussion of the permitting requirements relative to implementing the recommended practices will be presented.

Because SCA has a considerable investment in the existing gabion groin system, the approach to promoting the stability and extent of the beaches is to continually improve the understanding of the performance of the existing groin system within the context of the environmental mechanisms (wave activity, storms, sediment transport mechanisms, etc.) acting on the SCA shoreline. This approach includes modifying the groin system design to adapt to the dominant environmental mechanisms acting over time and implementing a program to measure and document that performance so that future decisions about modifications to the system can be made with a higher degree of understanding and confidence as to the expected outcome. Increased predictability in the effects of modifications help to reduce costs to the community by optimizing the effectiveness of modifications to the groin system and promotes understanding and confidence within the regulatory community as they assess the potential impacts of the proposed activities. Where possible, a distinction is made between actions intended to maintain the existing groin system and activities considered to be expansion or major modification to achieve a significant improvement in the performance of the system.

Peripheral activities supporting modifications to the groin system, such as stockpiling and transporting rock for the gabions, will be explicitly discussed in an attempt to anticipate and mitigate potential impacts from those activities and to anticipate and comply with associated permit requirements.

A high priority is placed on understanding and conserving populations of tiger beetles, as well as considering and promoting the environmental well-being of the entire shoreline and slope ecosystem. Because this plan takes a holistic, integrated approach to beach, slope, and wildlife conservation, a Habitat Protection Plan (HPP) for the Puritan and northeastern beach tiger beetles in included as Section 6. The HPP is intended to accompany permit requests put forward by SCA and is explicitly developed in conjunction with the best practices described in Section 5 so that individual actions can be examined with respect to how they fit into the overall conservation approach being implemented by SCA and cumulative impacts can be evaluated.

Wide, stable, and laterally continuous beaches are thought to be favorable to the sustenance of the northeastern beach tiger beetle. Adult Puritan tiger beetles are also known to occupy the beach when foraging for food. However, it has been postulated that wide stable beaches may deleteriously affect the habitat of the Puritan tiger beetle larvae because they reduce the direct erosion of coastal slopes by waves.

Based on detailed observations of the erosion of the coastal slopes along Scientists' Cliffs, the assumption that erosion of the SCA slopes is primarily driven by direct wave action is not supported by the evidence. In fact, the overall rate of erosion of the coastal slopes along SCA is driven by freezing and thawing of the lower slopes with waves acting to remove the debris produced by that action. This is a very important distinction and is fundamentally important to understanding the recommendations for best practices to manage the erosion of the coastal slopes while encouraging the habitat for Puritan tiger beetles along SCA.

As discussed in Sections 1 and 2, the lower slopes along the SCA shoreline are composed of relatively fine-grained materials possessing cohesive properties. The material strength is high enough to resist direct erosion by waves in all but the most extreme wave conditions (i.e., those generated by the most rare and powerful hurricanes). Repeated freezing and thawing of the lower slopes occurs annually. As a result, the lower slopes retreat and undercut the coarser-grained mid and upper slopes. Eventually, the undercutting creates a condition where the support from below has been sufficiently removed so that a landslide ensues originating in the midslope. Usually, sliding happens as the slope surface becomes saturated either from prolonged rainfall or snowmelt or a combination of the two. The water acts in two principal ways to trigger the sliding: 1) the added weight of the water aggravates the instability and 2) as the water pressure between the grains of the geologic materials increases (i.e., as saturation proceeds into the slope), the strength of the material is decreased in direct proportion to the increase of the water pressure causing the materials to become weaker and prone to failure.

Vegetation plays an important role in slope stability and proper management of the vegetation on slopes plays a key role in the best management practices recommended here, particularly with respect to both minimizing the occurrence of large, dangerous landslides and maintaining habitat for the Puritan tiger beetle.

The depth to which various plants root and the density of rooting is a factor in slope stability. Roots can be thought of as a contributor to the strength of a geologic material much like reinforcing rods in concrete contribute to its overall strength. This concept in its simplest form is that deeply rooted plants tend to reinforce the slope to greater depths than do shallowly rooted plants. The consequence is that slopes with deeply rooted plants tend to slide less frequently, but with significantly more mass involved, than slopes with shallow rooted plants. In other words, encouraging shallow rooted over deep rooted vegetation on mid and upper slopes will encourage more frequent, but shallower and less dangerous slides for a given overall slope retreat rate.

It is only when the erosion rate of the toe achieves zero that this process stops and is replaced by processes causing the bluff top to recede “away” from the slope toe resulting in eventual overall stability of the slope.

Therefore, the overall approach of this plan is to

- Encourage continuous, stable beaches and enhance both Puritan and northeastern beach tiger beetle habitat, by systematically improving the performance of the groin system,
- Attempt to minimize the rate of retreat of the coastal slopes along SCA, but not implement practices that would drive the rate of retreat to zero, and
- Encourage shallow-rooted plants on the slope surfaces rather than deep-rooted plants to discourage large, less frequent landslides in favor of relatively more frequent shallow landslides, thereby promoting safety and encouraging Puritan tiger beetle larvae habitat.

1.2 Background Information and Data (based on Miller 1995)

The beaches and slopes are an inter-related environmental system. The mechanisms of coastal slope erosion can be grouped into two categories: those related to wave activity and those related to the material and hydrologic characteristics of the slope. Ultimately, wave activity drives the retreat of eroding coastal slopes. But, this is an oversimplification. The rate at which the slopes erode may depend directly on the ability of the waves to actively erode intact slope material. But, along the Calvert County shoreline, slope erosion more often depends on how quickly the waves can remove debris relative to the rate it is delivered to the slope toe by other erosion processes acting along the entire length of the slope.

If the rate at which debris is delivered from upslope exceeds the capacity of the waves to remove it, the debris accumulates at the base of the slope. Were this accumulation to continue unabated, the slope would become graded to a gentle, stable angle. On slopes where the waves are just capable of removing the material delivered to the base, the slope morphology and dominant erosion process is entirely determined by a combination of the hydrology and materials comprising the slope. If all of the toe zone debris has been removed by waves, the intact slope becomes vulnerable to direct wave attack. The portion of the lower slope exposed to wave activity will be eroded at a rate determined by the erodability of the basal material and the force with which the waves strike the slope. Or, where the lower slope is relatively durable, the lower slope will erode at the rate at which weathering processes are capable of degrading the intact slope material. The interaction of wave undercutting at the slope base with erosion mechanisms operating on the midslope may result in a compound slope profile that is steep in the wave cut zone and less steep in the slope above, but this form is not diagnostic of the dominant processes acting on the slope segments. Similar slope profiles can be created when freezing and thawing drive the erosion of the lower slope. At high rates of wave undercutting, the slope may be steepened sufficiently to cause mass failures of the undercut material from the slope toe to the bluff top. This latter condition does not occur along the Scientists' Cliffs' shoreline.

The occurrence, distribution, and movement of water is important to material transport and the progression of physical and chemical weathering. On portions of slopes where the surface material is immediately available for transport (i.e., easily detached) and the hydraulic conditions are favorable, hydrologic mechanisms are effective in removing material from its original position and transporting it downslope. Hydrologic transport and erosion mechanisms include groundwater seepage erosion, surficial erosion and transport by flow from excess rainfall, and raindrop impact.

Many slope materials must be chemically or physically disintegrated (i.e., weathered) before transport can occur. Weathering processes are subdivided into physical and chemical processes. Chemical weathering results in the degradation of the intergranular bonds between the material grains. Physical weathering may be caused by changing thermal conditions; plant, animal, or insect activity; or by wetting and drying cycles. Consider a spectrum of material types ranging from solid rock to loose sand. Considerable weathering would have to occur before hydrologic processes could physically transport the material from a rock slope. However, sand on slopes with no intergranular cement or cohesion is readily transported. At Scientists' Cliffs, there are a number of stratigraphic formations that are comprised of either cohesive or partially-cemented materials. The rate at which weathering of these materials proceeds frequently limits the overall retreat rate of the slope, particularly when cohesive materials are located in the lower portion of the slopes.

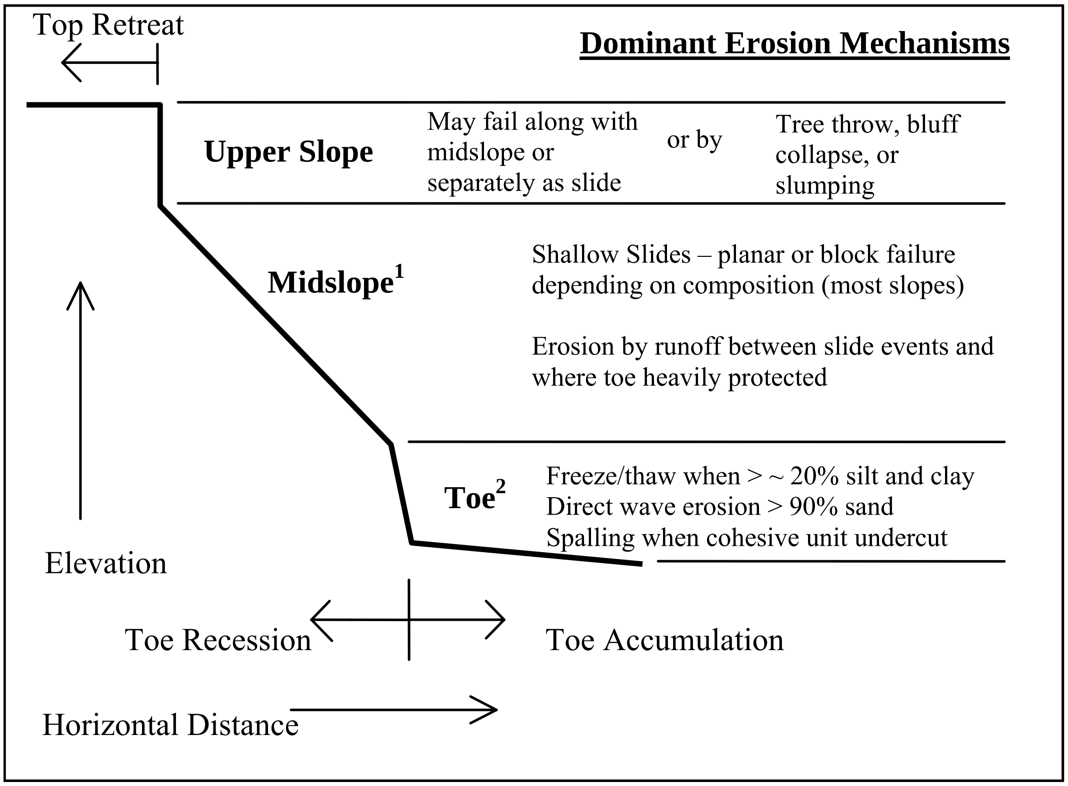
The rate at which groundwater moves through the subsurface and the distribution of its mass determines the pore pressure distribution and the magnitude and direction of seepage forces. Increases in pore pressure reduce the resistance of slope materials to shear stresses and increase the likelihood of subsurface failures. Groundwater seepage zones are often more densely vegetated than other portions of the slope. Groundwater may dissolve or create chemical bonds in sediments. A constant supply of groundwater also feeds the freezing and thawing process in saturated slopes where the face is exposed directly to the air.

1.2.1 Slope Segments and Dominant Processes

Although many erosion mechanisms may act simultaneously on a slope, a slope profile may often be divided into segments upon which one erosion process dominates. The slope morphology and the domain of a dominant erosion process may change with time. The following general discussion of rapidly retreating coastal slopes identifies the types of dominant erosion processes and the portions of the slope on which they operate. This plan will emphasize those processes that dominate the erosion of the coastal slopes of Calvert Cliffs, particularly Scientists' Cliffs.

Distinct morphologic zones can often be identified on coastal slopes. The Calvert Cliffs' slopes may be divided into three zones within which different types of erosion processes dominate. A consistent distinction between these zones can be made based on material properties and the degree of saturation. The lower portions of the Calvert Cliffs' slopes are typically saturated. The lower slope extends from the slope toe to a stratigraphic permeability contrast higher in the slope that separates a relatively coarse-grained and dry zone, overlying the wetter lower slope composed of finer-grained materials. A midslope zone, often with a different set of dominant erosion processes, extends from the permeability contrast to near the base of the root zone near the top of the slope. The upper slope typically is nearly vertical and encompasses the soil developed on the bluff top and the entire root zone. Where present, fine-grained materials subjected to the tensional effects of negative pore pressures may extend the vertical face created by the root zone.

The morphologic zones and associated erosion processes that are typical of an eroding coastal bluff are shown in Figure 1.2 (adapted for Calvert Cliffs' slopes from Edil and Vallejo, 1980). In the following discussion, the dominant erosion processes acting on each zone along the Calvert Cliffs will be identified along with the physical controls of each dominant erosion process. Emphasis will be placed on the manner in which dominant processes affect the form from zone to zone.



[1] Shallow slide depth strongly dependent on depth of saturation from surface of slope inward during prolonged wet periods and rooting depth of vegetation (where present).

[2] Sand, silt, clay percentages are to be used as a rule of thumb. Actual threshold between wave undercutting and freeze/thaw as dominant mechanism depends on the duration and magnitude of wave forces and the lower slope cohesive strength which is a strong function of clay content.

Important note: The overall long-term rate of slope retreat is established by the rate of lower slope retreat unless the slope toe is completely protected from erosion.

Figure 1.2 Calvert Cliffs' Dominant Slope Erosion Processes

1.2.1.1 Zone 1- Toe zone (**Lower Slope**)

Wave erosion occurs on slopes where wave action is able to reach the slope base at least part of the time. Wave erosion may consist of intermittent removal of colluvial debris or it may include undercutting of intact slope material. The relative rates of erosion and accumulation at the toe play a major role in determining the overall stability and configuration of coastal slopes. Wave undercutting of the intact material in the toe zone causes shallow slides and steep profiles in that zone. The rate of sliding may be great enough to steepen the lower portion of the midslope and initiate sliding there.

Toe zone form is controlled by both wave activity and the material characteristics. Transport by overland flow and detachment by physical and chemical weathering occur in this zone, especially freezing and thawing. For many of the slopes along the Scientists' Cliffs' shoreline, freezing and thawing is the primary mechanism for detaching intact material from the slope. Elsewhere along the Calvert Cliffs, the effects of physical and chemical weathering on slope form may be overshadowed by erosion driven directly by wave action.

Spalling, a slab-like form of sheet failure along steep, slope-parallel surfaces, is common along the lower slopes of Calvert County. Spalling is rare along Scientists' Cliffs. However, it is common along the shoreline extending from the northern boundary of Scientists' Cliffs to Parker Creek. The toe zones of Calvert County slopes are further characterized by the presence of saturated materials that may extend far upslope, above the portion of slope directly in contact with waves. For the purposes of this study, the distinct, lower saturated segment of slope will be known as the lower slope, regardless of how far upslope it extends. The saturated portion of the slope displays consistent suites of erosion characteristics from the wave zone to the saturated/unsaturated boundary above.

1.2.1.2 Zone 2 - Intermediate zone (**Midslope**)

If the rate of lower slope retreat is insufficient to generate midslope sliding, then the material properties, the groundwater conditions, surface water transport capacity, and vegetative cover will determine the forms of erosion and transport that dominate on the midslope. These processes include: solifluction, overland flow, rain drop impact, shallow mass movements, groundwater seepage, and physical and chemical weathering.

Along the Calvert Cliffs, the lower boundary of the midslope is distinguished by the presence of a permeability contrast in the slope materials. The boundary is characterized by a relatively permeable, coarse-grained material overlying a relatively impermeable, fine-grained material. Saturated zones in the midslope are frequently perched above the permeability contrasts. These groundwater bodies tend to be confined within laterally continuous hilltop recharge areas. However, recharge may occur from wide areas inland of the slope if streams are not incised to an elevation whereby they act as drains on the groundwater body. The midslope frequently stands at shallower angles than the lower slope, creating compound profiles that are steep in the lower slope and more gentle in the midslope.

<u>1.2.1.3 Zone 3 - Bluff top (**Upper slope**)</u>

Edil and Vallejo (1980) characterize this zone as the upper portion of the slope capable of maintaining a nearly vertical face and subject to shallow slides and slumps. The rate of bluff top retreat is determined by the rate of erosion of the slope below. Plant roots can bind the soil in the upper part of this zone and soil horizons may be present in the vicinity of the root zone. Observations in Calvert County indicate that this zone is normally unsaturated. Fine-grained materials may be subject to columnar desiccation jointing. The columns topple when undercut.

<u>1.2.2 Calvert Cliffs' Stratigraphy</u>

The erosion of the Calvert Cliffs is strongly influenced by the arrangement and geotechnical properties of the slope materials, which are closely linked to the marine environments in which the sediments were deposited. The Calvert Cliffs are composed primarily of non-lithified, interbedded fossiliferous sands, gravelly sands, silts, and clays deposited during the Miocene Epoch. Laterally discontinuous patches of indurated, gravelly sands, commonly known as ironstone, are the strongest material present in the slopes. The regional dip is less than one degree to the southeast and the sequence of materials varies gradually and predictably along the shoreline, both within each site and between sites.

Many workers have described the Miocene stratigraphy along the Calvert County Shoreline (Shattuck, 1904; Dryden, 1930, Dryden, 1936; Schoonover, 1941; Gibson, 1962; Gernant, 1970; Gernant, Gibson, and Whitmore, 1971; Blackwelder and Ward, 1976; Andrews, 1978; Newell and Rader, 1982; Kidwell, 1982, 1984; 1997, and Vogt and Eshelman, 1987). Shattuck's 1904 subdivision of the Calvert, Choptank, and St. Marys' formations into 24 distinct stratigraphic units continues to provide a common basis for the description of the Calvert Cliffs' stratigraphy. Shattuck's terminology will be referenced in this document. However, the Kidwell (1982) description of the stratigraphic relations of the Calvert (Plum Point Member) and Choptank formations will be used to describe the geologic setting of Scientists' Cliffs. Kidwell's interpretation is used because the physical characteristics of the strata important to the erosion mechanisms are described relative to the depositional setting and the transgressive-regressive depositional cycles.

The stratigraphic descriptions of Kidwell and Shattuck provide perspective and predictability to the interpretation of the important geotechnical characteristics of the Calvert Cliffs. The following text synopsizes the Miocene stratigraphy of the Calvert County coastal slopes.

Kidwell (1982) measured and described 54 stratigraphic sections along the Calvert County shoreline of the Chesapeake Bay. The stratigraphic descriptions were supplemented with numerous grain-size analyses. The stratigraphic relations as described by Shattuck were noted by Kidwell to be groups of depositional sequences displaying strong cyclic trends in sedimentation patterns and lithology and bounded by disconformities. Kidwell's nomenclature for the stratigraphic units comprising the Calvert and Choptank formations is used in this document. A combination of Shattuck's nomenclature and an informal classification based on distinct geotechnical characteristics is used to discuss the remainder of the strata exposed along the Calvert County shoreline. Kidwell (1984) describes the stratigraphic patterns in the following manner:

> *"The Calvert (Plum Point Member) and Choptank formations are subdivided by a series of erosion surfaces into six depositional sequences traceable over a 9,000 sq-km (3,475 sq-mi) study area in Maryland and Virginia. The disconformities take the form of burrowed firmgrounds in outcrop, but exhibit up to 14 m (46 ft) of topographic relief locally and represent transgressive and regressive ravinement surfaces. ··· Internal facies relations within the depositional sequences are complex but basically cyclic, consisting usually of a basal condensed shell or bone deposit formed under prolonged conditions of reduced net sedimentation and grading upward into less fossiliferous and siltier facies in regressive sequence. Each sequence consists of two or more of the original lithologic zones of Shattuck (1904)."*

Figure 1.3 correlates the descriptions of Kidwell, Shattuck, and the few informally-named strata of this study. Shattuck's zones were numbered from one through twenty-four. Kidwell used geographic names to distinguish four, richly fossiliferous key beds and one key bone-rich horizon [the Camp Roosevelt Shell Bed (CRSB), Kenwood Beach Shell Bed (KBSB), the Drumcliff Shell Bed (DCSB), the Boston Cliff Shell Bed (BCSB), and the Parker Creek Bone Bed (PCBB), respectively]. Each of these strata are easily distinguished by high concentrations of fossiliferous material and have a discontinuity at their base. The key beds represent relatively coarse-grained units overlain by relatively shell-poor strata. The shell poor strata are finer grained and are named for distinctive and abundant macro-invertebrate genera contained within. [*Note: The Plum Point Member (Shattuck, 1904) consists of Kidwell's <u>Ostrea-Corbula</u> interval, the CRSB, the Barren interval, the PCBB the <u>Glossus-Chione</u> interval, the KBSB, and the lower <u>Turritella-Pandora</u> interval*].

The vertical cyclicity of the sediments is perhaps the single most important factor influencing the erosion of the Calvert Cliffs. The boundary between the lower slope and midslope is normally coincident with a stratigraphic disconformity. Groundwater seepage is common at this boundary and the sandy strata are prone to shallow sliding and transmit water the most readily. Fine-grained strata act as aquitards, are prone to freeze-thaw erosion, and are capable of standing in steep faces. Changes in dominant erosion processes typically occur at stratigraphic boundaries.

Miocene formation	Kidwell		Shattuck	This study
St. Marys	Not studied		Post Miocene upland deposit	CRE-Sand
	Not studied		23	CRE clay
	Not studied		23	23 Upper 23 Lower
	Not studied		22	22
	Not studied		21	21
Choptank	Unnamed N. of Rocky Point		20	Unnamed N. of Rocky Point
	Boston Cliffs Shell Bed (BCSB)		19	Boston Cliffs Shell Bed (BCSB)
	Mytilus		18	Mytilus
	Drumcliff Shell Bed (DCSB)		17	Drumcliff Shell Bed (DCSB)
	Gov. Run Sand		17	Gov. Run Sand
Calvert	Turritella-Pandora		15 & 16	Turritella-Pandora
	Kenwood Beach Shell Bed (KBSB)		14	Kenwood Beach Shell Bed (KBSB)
	Chione-Glossus		13	Chione-Glossus
	Parker Ck. Bone Bed (PCBB)		12	Parker Ck. Bone Bed (PCBB)
	Barren		11	Barren
	Camp Roosevelt Shell Bed (CRSB)		10	Camp Roosevelt Shell Bed (CRSB)
	Corbula-Ostrea		4 to 9	Corbula-Ostrea
	Fairhaven		3	Fairhaven

Bold lines indicate basal disconformities.

Figure 1.3 Calvert Cliffs' Stratigraphic Column (Miller 1995)

1.3 Site Description: Scientists' Cliffs

1.3.1 Stratigraphy

The lower slopes of Scientists' Cliffs are formed in the Calvert formation (Figure 1.4). The units include the PCBB, the Glossus-Chione interval, the KBSB, and the Turritella-Pandora interval. The lower slope/midslope boundary coincides with the contact between the Calvert and Choptank formations. The midslopes are formed in the Governor Run Sand, the Mytilus interval, the DCSB, the Anadara Sand (a local non-fossiliferous sand associated with the BCSB). The upper slopes are formed in the BCSB, and where the slopes exceed 30 meters in height, the Unnamed interval. The regional stratigraphy dips at less than one degree to the southeast. Individual stratigraphic thicknesses and bedding orientations at Scientists' Cliffs are less uniform than elsewhere along the Calvert Cliffs.

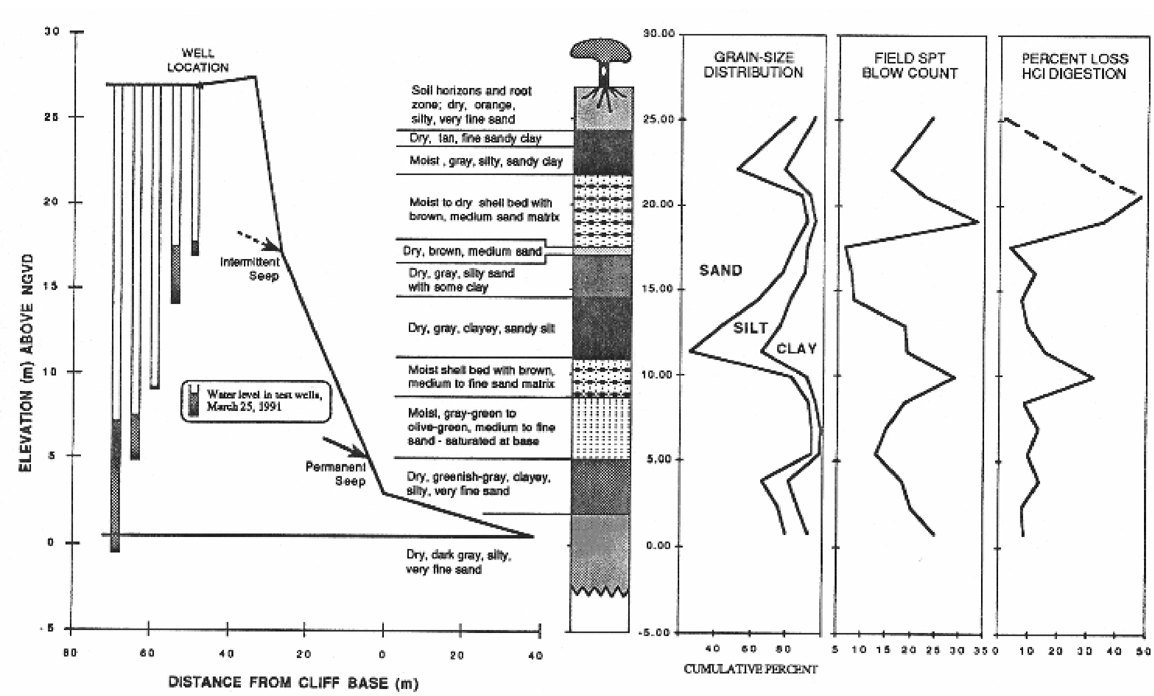


Figure 1.4 Scientists' Cliffs' Geotechnical Profile

Key Strata in the sequence

Kidwell, (1982) made the observation that a laterally extensive Miocene erosion channel, filled by the Governor Run Sand, is present along the Calvert Cliffs from near Governor Run to just north of the community of Scientists' Cliffs. The following quotation is from Kidwell, 1982.

> *"· · · the [Governor Run] sand fills an erosion channel developed in the* Turritella-Pandora *strata. The lower boundary of the channel is marked by a thin (about 6 inches) basal lag deposit of clean sand with calcitic shell hash, locally indurated. · · · The southern flank of this channel is well exposed in the cliffs stretching north from Governor Run to the southern end of Scientist Cliffs. The thickly and distinctly interbedded sand and clay lithology of the channel fill can be readily distinguished from the more thinly and subtly interbedded lithology of the* Turritella-Pandora *interval cut by the channel, although it has been the gross similarity of these two lithologies that has caused them to be confused in the past. ...*
>
> *The northern flank of the channel stretches from the northern end of the Scientist Cliffs community to Parker Creek and forms the unconformity recognized by Shattuck from offshore. The contact between the Governor Run sand and the* Turritella-Pandora *interval there is quite noticeable. Although it exhibits only slight scour undulations, the contact is overlain by a 6-inch to 1-foot thick lag of sand with calcitic shell hash and progressively rises in the section from a position at the top of the Kenwood Beach shell bed at Scientist Cliffs to a position well within the* Turritella-Pandora *interval at Parker Creek.*
>
> *Along Scientist Cliffs themselves, the channel cuts irregularly across the Kenwood Beach shell bed--in some places above it by a few feet, in others well within it. The lower few feet of the Governor Run sand in the central axis of the channel consist of clayey sediments, so that the basal contact of the Governor Run sand is locally a clay-on clay contact. "*

The Governor Run Sand is the single most important stratigraphic unit along SC. Except near its base and along the channel flanks, the Governor Run Sand is composed of predominantly fine to medium uniform sand. Recognizing the presence of this sand-filled channel is critical to understanding the erosion of both the topographic surface and the slope face along the entire Scientists' Cliffs' site. With the exception of the four major shell beds, the Governor Run Sand is the only major, uniformly-graded sand deposit along the Calvert Cliffs. It is important because it has very low cohesive strength and high permeability. The position of the Governor Run Sand is also important because it overlies the relatively fine-grained Calvert formation and strong seepage occurs at the base of the sand along the length of Scientists' Cliffs. The Governor Run Sand is also a likely source of sand for the extensive sand bar system along that community's shoreline.

The topographic surface across the Scientists' Cliffs' community is dissected with deep ravines where small streams have cut through the easily eroded Governor Run Sand. The downcutting abruptly terminates on the <u>Turritella-Pandora</u> interval and the gradient of the streams flatten as they make their way across the top of the <u>Turritella-Pandora</u> interval toward the bay. Small waterfalls are common along the beach where the streams exiting the slopes to the bay do not downcut through the <u>Turritella-Pandora</u> interval as rapidly as the slope retreats through it. This is evidence that the process that erodes the lower slope face acts faster than stream downcutting on the <u>Turritella-Pandora</u> interval, even when the stream has a strong gradient.

Along the segment of shoreline from northern Scientists' Cliffs to Parker Creek the PCBB is exposed to wave action near MHHW. The lower <u>Mytilus</u> and the <u>Turritella-Pandora</u> intervals act as aquitards, the Anadara Sand/BCSB and Governor Run Sand as aquifers.

<u>1.3.2 Shoreline Orientation and Toe Conditions</u>

The cliffs face east along the Scientists' Cliffs' shoreline. Beach stabilization exists in the form of gabion groins spaced at roughly 35 to 40 meter intervals. The beach along the groins is up to one meter higher than that found at the subsites along the shoreline to the north and south where groins are not present. The beach offers a significant degree of slope toe protection. Unprotected slope toes to the north and south have either low, seasonal beaches or no beaches at all. Active toe erosion by waves is common at these subsites.

As erosion proceeds into the slope, material that was once confined on all sides experiences a gradual reduction in confining pressure on the side toward the eroding slope face. Exfoliation joints occur in response to this unloading and are evident in the fine-grained strata. Typically, exfoliation joints are nearly parallel to the cliff face and act as planes of weakness for spalling failures.

The geotechnical properties of the lower slope stratigraphic units exposed to wave action are of particular importance to this study. Materials of low cohesive strength are far more susceptible to wave erosion than the cohesive fine-grained units. The units exposed in the wave zones along Scientists' Cliffs are given in Table 1.1.

It is interesting to note that very few tall slopes exist along the Calvert County shoreline where the lower slope is composed of a very low cohesion material and is exposed to wave action. At locations where the dip of the non-cohesive strata would carry the unit into the tidal zone, bluffs are typically not present. It is thought that the non-cohesive strata have been rapidly eroded, both by the downcutting of streams preferentially selecting the weaker sediments for their course, and by wave attack.

Subsite	Wave Climate		Hydrologic Drainage Area (m^2/m slope face)		Materials	Slope Height
	Shoreline Orientation	Toe Protection	Surface water	Ground-water	Wave Zone	(m)
Parker Creek south to Governor Run						
North Boundary of SCA to Parker Creek	ENE	None	350	350	Barren to Glossus-Chione, sandy clays	30
From Chestnut Cabin north to SCA	ENE	Groins	380	400	PCBB & Glossus-Chione, sandy clays	29
From Boat Launch north to Chestnut Cabin	ENE	Great Jetty, groins, & parking lot	20	350	Glossus-Chione, sandy clay	26
From Boat Launch south to Last southern groin	ENE	Groins	20	350	Chione & KBSB, sandy clay to sand	35
From last southern groin to Governor Run pier	ENE	None	20	350	Chione & KBSB, sandy clay to sand	33

Table 1.1 Site Physical Characteristics

1.3.3 Physiography

The topography of the Calvert County shoreline region is gently rolling with elevations ranging between sea level and 200 feet. Non-coastal slopes are generally stable against mass movements and are well-vegetated. A well-developed, dendritic drainage pattern has created a scattered sequence of knolls and hillocks. Because the southeast dip of the stratigraphic units directs groundwater toward the bay, the elevation to which the strata are dissected by the stream valleys is important. Coarse grained materials that extend large distances westward without being dissected are important conduits for directing surface recharge to the slope face. Therefore, seepage is strong on slopes with coarse grained strata at low elevations and with large undissected contributing areas. Conversely, coastal slopes that exist as hills with coarse grained strata high in the profile and streams cut deeply into the topographic surface immediately to the west generally have weak or ephemeral seepage zones.

The Chesapeake Bay has a gentle, arc shape along the Calvert County shoreline (Figure 1.5). The arc is oriented nearly north-south along northern Calvert County. The longest fetches occur for winds blowing from the north-northeast and from the south-southeast, ranging between 70 to 105 km and 150 to 175 km, respectively.

Figure 1.5 Chesapeake Bay
(Adapted from Liam Gumley, Space Science and Engineering Center, University of Wisconsin-Madison)

1.3.4 Mean Water Levels Relative to the 1929 National Geodetic Vertical Datum

Elevation measurements must be referenced to a datum. Typically, a vertical datum is referenced to a statistically defined mean ocean surface or to an imaginary three-dimensional geoid surface. In regions affected by tidal waters, mean tidal water surfaces serve as useful datums for local elevation measurements. The water surfaces referred to in this plan were established for the tidal gauging station at Ft. McHenry in Baltimore, Maryland. These data have been referenced to the 1929 National Geodetic Vertical Datum (NGVD) (Balazs, 1991). Figure 1.6 shows the relationship of mean lower low water (MLLW), mean tide level, mean sea level (MSL) for the 1960-1978 epoch, and mean higher high water (MHHW) relative to the 1929 NGVD. All elevations mentioned in this study are referenced to the 1929 NGVD. The tidal water surfaces are defined in the following manner (NOAA, 1990):

Mean sea-level (MSL) - "A tidal datum. The arithmetic mean of hourly water elevations observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch)."

Mean Lower Low Water (MLLW) - "A tidal datum. The arithmetic mean of the lower low water heights of a mixed tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). Only the lower low water of each pair of low waters, or the only low water of the tidal day is included in the mean."

Mean Higher High Water (MHHW) - "A tidal datum. The arithmetic mean of the higher high water heights of a mixed tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). Only the higher high water of each pair of high waters, or the only high water of the tidal day is included in the mean."

Mean Tide Level - "Also called half-tide level. A tidal datum midway between mean high water and mean low water."

Water level data for Chesapeake Bay recorded at Solomons Island, MD since 1937 shows sea level in that portion of the Bay rising at a rate of 3 mm/yr (approximately 1 foot per century) and the rate of rise is accelerating (USGS 1998).

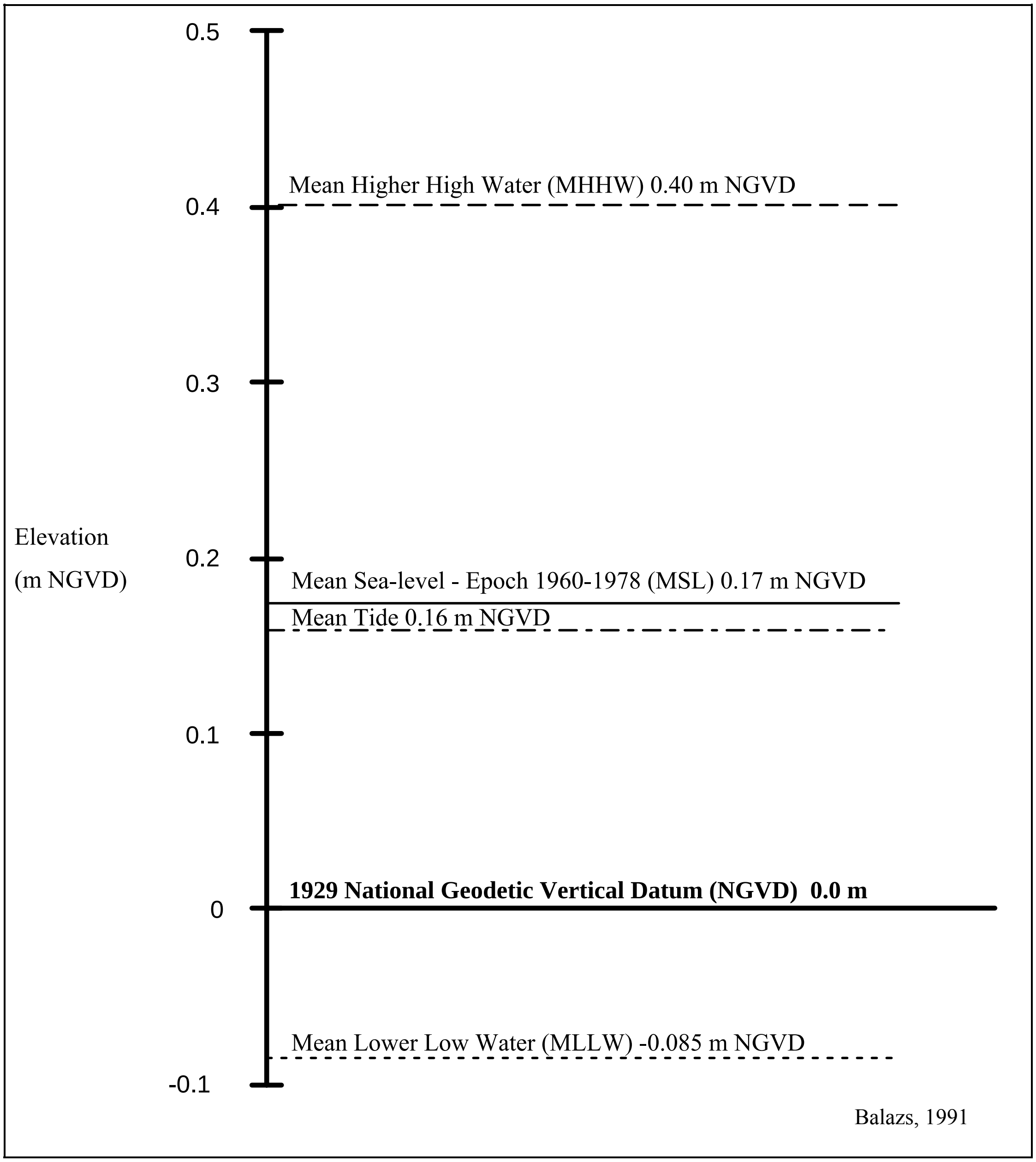


Figure 1.6 Relationship of Mean Water Levels to the 1929 NGVD
at Fort McHenry (Baltimore, Maryland)

1.4 Modeling the Wave Climate

Wave activity drives the erosion of coastal slopes. Waves can either remove debris transported to the slope toe by other erosion mechanisms or they can cut into and remove the intact slope. The rate of wave erosion of a coastal slope depends on the strength of the materials in the wave zone, the storm surge elevation and the height, period, and frequency of the nearshore waves. Computations were made to determine these parameters for all wind conditions that could produce erosion of the Calvert Cliffs (Shea, 1994).

The height and frequency of nearshore waves are determined by the frequency, magnitude, and orientation of the incoming deep water waves, and their modification as they traverse the nearshore. The deepwater wave conditions were established for each study site (Shea, 1994) and used as input to RCPWAVE, a shallow water wave model produced by the U.S. Army Corps of Engineers (Cialone, 1991a). RCPWAVE is a numerical model used to predict linear wave propagation over an open coast region of arbitrary bathymetry. Refractive and bottom-induced diffractive effects are included in the model. It uses offshore wave height, direction, and period as input. The nearshore bathymetry is established on a grid and the wave parameters recalculated based on conservation of energy at each grid point. This model was used to provide measures of the nearshore wave period and wave height.

This section will discuss the methods used to model the wave climate. The modeled wave height and period will then be used to show the frequency and wave stress with which potentially erosive waves strike the Calvert County shoreline. Later in this plan, the material properties that affect the potential for erosion will be discussed. The concepts developed in each of these sections will be synthesized to examine the climatic and slope conditions for which intact slope toe erosion occurs. The wave climate analysis is summarized here and described in detail by Shea (1994).

1.4.1 Model Input

The capacity for waves to cause erosion depends on the frequency of their occurrence, as well as the stress they exert on the material. The frequency of different wind speeds was determined for all wind directions that can produce waves capable of eroding the Calvert County shoreline. Each fetch/wind velocity combination was used as input to RCPWAVE along with a corresponding storm surge elevation.

The conditions used as input to the model for each wind class consisted of the storm surge elevation, the offshore wave heights, the corresponding wave periods, and the direction of propagation. The storm surge, offshore wave heights, and wave periods were predicted using historical wind conditions and the bay bathymetry.

1.4.1.1 Wind Speed, Direction, and Fetch

The Calvert Cliffs face toward the east, northeast, and southeast (Figure 1.5). The middle Chesapeake Bay has a gentle arc shape which creates major fetch directions from the northeast and southeast along the main channel of the bay (Figure 1.5). The fetch directions from the eastern 180 degrees of the compass were divided into three equal portions, north-northeast, east, and south-southeast. Fetch lengths are provided in Table 1.2. Using 37 years of record (1945-1982) from the Patuxent Naval Air Station, 5 wind speed intervals were constructed which spanned the entire range of wind speeds greater than 2.7 m/s along each fetch (see Table 1.3) giving 15 wind speed/direction classes. The 15 wind classes were used to establish the offshore wave climate at each site. Wave modeling was done for the 5, 9, 13.5, and 23 meters per second wind speed intervals. Nearshore wave conditions for the 7 m/s interval were interpolated from the values calculated for the other four wind speed intervals.

NNE fetch length (km)	E fetch length (km)	SSE fetch length (km)
90	20	135

Table 1.2 Principal Fetch Lengths at Scientists' Cliffs Used for Wave Modeling

*Wind speed interval (m/s)	Design Wind Conditions Values used to represent wind speed interval in model input	Number. of days per year this condition occurred from 1945-1982		
		NNE	**E**	**SSE**
0 to 2.7	None - not effective in cliff erosion	**(24.6)	**(17.9)	**(31.5)
2.8 to 6.7	5	19.8	10.4	25.7
6.8 to 8.9	*** 7	10.5	3.8	13.0
9.0 to 11.6	9	2.6	0.7	2.6
11.7 to 17.4	13.5	0.8	0.2	0.2
17.5 to >24.6	23	0.07	0.03	0.12
	Total	33.77	15.13	41.62
Total Number of Days per Year Represented in Model Input Data = 90.52				

* Wind speed interval boundaries established by PNAS data report format.

** Not included in totals.

*** Nearshore wave climate interpolated for this interval.

Table 1.3 Wind Speed and Direction Data Used to Develop Wave Model Input

1.4.1.2 Storm Surge

The cumulative stress of strong, steady winds over a fetch causes the downwind water surface to be higher than the elevation predicted from astronomical tidal influences. The difference in elevation is the storm surge. Both meteorological and bathymetric conditions influence the magnitude and timing of the surge (Pore, 1960; Moses and Blair, 1988). Chesapeake Bay storm surge predictive curves for frequent extra-tropical storms were developed by Boon et al. (1978) from empirical observations of meteorological and tidal records for the bay. Chen (1978) developed a predictive storm surge model for less frequent tropical storms and hurricanes based on the wind conditions, storm speed and radius, and barometric pressure.

Observations were made of the water surface elevations at Scientists' Cliffs and at the Randle Cliffs' pier during three storms with sustained winds from the northeast. In each case, the observed values agreed well with those predicted by the empirical curves of Boon et al. (Shea, 1994). No events occurred during the study period to which Chen's model could be compared. Storm surge elevations as predicted by Boon et al. and Chen were used as input to RCPWAVE for the appropriate wind conditions. Table 1.4 shows the storm surge elevations used in the model for each wind class.

Wind speed intervals	Water surface elevation due to storm surge (m NGVD)		
(m/s)	NNE	E	SSE
5	0.40	0.40	0.40
7	0.50	0.45	0.50
9	0.60	0.50	0.60
13.5	1.04	0.94	1.04
23	No winds occurred in this wind speed interval for these directions.		1.30

Table 1.4 Storm Surge Water Surface Elevations Associated with Wind Conditions and Fetch Directions

1.4.1.3 Offshore Wave Heights (Rayleigh Distribution)

The wave field associated with a wind condition contains a range of wave heights. Because the transformation of a wave as it traverses the nearshore bathymetry depends on its height, a distribution of wave heights was assigned to each wave class. A Rayleigh distribution was used because it is found to represent the distribution of wave heights well (Longuet-Higgins, 1952) and may be calculated from the significant wave height. Significant wave heights were calculated for the wind speed intervals of 5, 7, 9, 13.5, and 23 m/s using the 15 meter shallow water wave tables in the Shore Protection Manual (U.S. Army, 1984). The Rayleigh probability density function is given by:

$$f[(\hat{H} - \Delta H) \leq H \leq (\hat{H} + \Delta H)] = \frac{2H}{H_{rms}^2} e^{-(\frac{\hat{H}}{H_{rms}})^2} \qquad \text{Equation 1.1}$$

where:

H = trough to crest wave height which exceeds a wave of height $\hat{H}$

and

$$H_{rms} = \frac{H_s}{1.416} \qquad \text{Equation 1.2}$$

Equation 1.2 expresses the theoretical relationship between the significant wave height, H_s, and H_{rms}, the root mean square of the Rayleigh wave height distribution (U.S. Army, 1984).

A Rayleigh wave height distribution for a significant wave height of 2.0 meters is shown in Figure 1.7 (Shea, 1994).

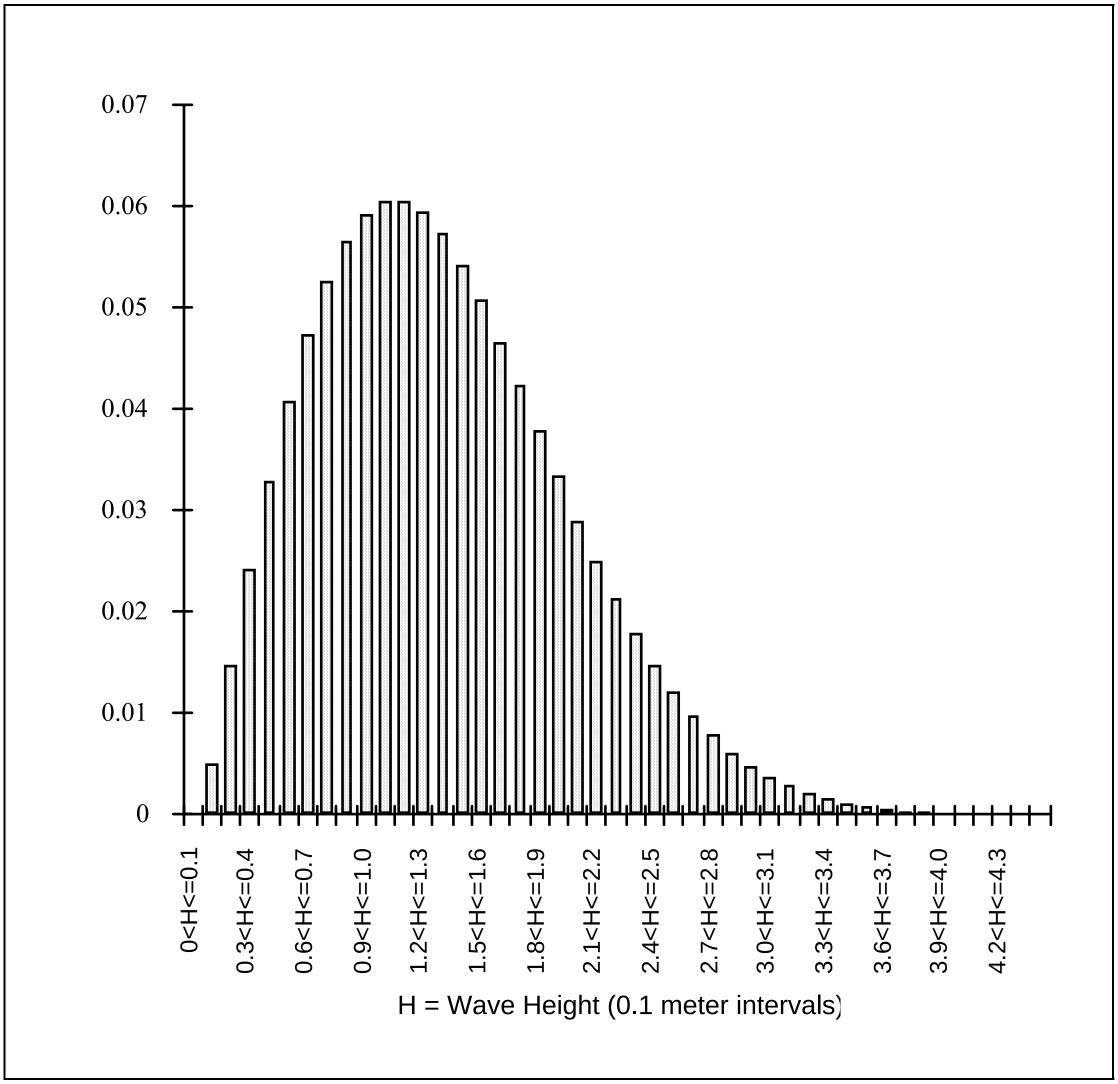


Figure 1.7 Rayleigh Wave Height Distribution
for significant wave height of 2.0 meters (Shea, 1994)

1.4.2 Nearshore Calculated Wave Heights and the Breaking Wave Criterion

Waves breaking in the nearshore can be of three types: standing, broken, and breaking (Sunamura, 1983). Of these three types, breaking waves exert the greatest forces on shoreline features (Muller and Whittaker, 1993). The nearshore bathymetry and the storm surge water level determine where the waves begin to break relative to the shoreline. Waves that break before they strike the slope are unlikely to have sufficient energy to directly erode the intact slope material. Therefore, to evaluate the potential for wave erosion of the intact material, it is necessary to estimate the location of the wave breaking relative to the slope toe.

The location of a breaking wave and the force of the wave impact (discussed below) depend on the height of the wave. The slope of the nearshore bottom and the wave period also affect the point at which a wave will break. For two waves of similar height, but different bottom slopes, the wave on the steeper slope will break in deeper water than the wave on the shallow slope. Similarly, a longer period wave will break in deeper water than a shorter period wave of the same height. The breaking wave criterion is typically expressed as a ratio of wave height to water depth. The value of the ratio may vary between 0.5 and 1.1 depending on the bottom slope and the wave period. For the relatively shallow nearshore slopes along the study sites and for the calculated wave periods, a value of 0.78 was taken as the wave breaking criterion (U.S. Army, 1984).

The wave height at the shoreline depends on the offshore wave height and period, the water level, and the shallow water bathymetry. Elevated water levels reduce the energy losses of breaking waves and expose portions of the shoreline to wave attack that are protected under normal conditions (Shea, 1994). Frictional drag causes a reduction in the wave height. Frictional losses increase with decreasing water depths, increasing travel distances, and increasing deepwater wavelengths.

RCPWAVE calculates the height of the waves generated at grid positions near the shoreline. The model does not carry the calculations into water depths less than 0.3 meter. The water depth varies with the storm surge and the nearshore bottom slopes gently along the Calvert County shoreline. Therefore, the grid position of the shoreline varied with the storm surge, moving landward with large surges, and bayward for small storm surges. The shoreward grid point for which wave heights were calculated varied between 5 and 10 meters from the slope toe. Also, at some locations, the water at the slope toe was deeper than the water at the last shoreward grid point. These two conditions made it necessary to apply the breaking wave criterion at a position shoreward of the last grid point at.

Waves breaking at the last grid point calculated by RCPWAVE are likely to expend their energy prior to contacting the slope and are considered broken waves in this analysis. Waves reaching the critical water depth for breaking at the slope toe may not be sufficiently formed so as to exert the potential maximum stress. Therefore, the depth of water at a position halfway between the two points was used to calculate whether the wave was a breaking wave.

1.4.3 Wave Stress Calculations

Wave erosion of the lower slope is accomplished by hydraulic and mechanical forces (Sunamura, 1983). Compression, tension, and shearing forces are produced by waves breaking on the slope and mechanical abrasion occurs when sand and other debris carried by the water impact the slope material. The proportional contributions of these forces to the erosion are difficult to separate and have not been distinguished either in the field or the laboratory. However, Sunamura (1983) recognized that the erosion due to both hydraulic and mechanical forces could be characterized as a force/resistance problem. In essence, for erosion to occur, the force that the waves exert on the intact material, either by direct action or through particle impacts, must exceed the capacity of the material to resist it.

Minikin (1963) developed theoretical expressions for shock pressure exerted by breaking waves on shoreline structures. He cited a series of wave tank experiments in which Bagnold (1939) showed that extreme pressures occurred as a plunging wave entraps air against the object it is striking. The method is organized to use "known dimensions of waves, such as length, height, period, and velocity, and the effect of the orbital path of the water particles when entering shallow water" and assumes that the kinetic energy of the breaking wave is used to compress the air between the wave and the structure.

The highest pressures resulting from breaking waves occur for only fractions of a second and are highest near the still water level (SWL) (Kirkgoz, 1991). The pocket of air is compressed and moves downward as the wave collapses. Shearing and compression forces are exerted on and within the material. Air is compressed in fractures within the material, and as the wave passes the compression is explosively released (Sunamura, 1983).

The expression Minikin developed to determine the pressure of breaking waves exerted on a structure at the SWL includes a dynamic term and a hydrostatic term.

The pressure below the water surface is:

$$p_h = (d_1 + \frac{H}{4})\frac{\gamma_w}{2}H \qquad \text{Equation 1.3}$$

(Quinn, 1972)

The dynamic pressure exerted by the wave is defined in terms of its kinetic energy:

$$P_d = 101\gamma_w \frac{H}{\lambda}\frac{d_1}{d}(d + d_1) \qquad \text{Equation 1.4}$$

(U.S. Army, 1984)

The total pressure exerted on a unit length of shoreline by a breaking wave at the SWL is:

$$p = p_h + p_d \qquad \text{Equation 1.5}$$

where:
d_1 = depth of water at slope toe,
d = depth of water for stable wave height,
H = trough to crest wave height,
λ = wavelength,
γ_w = unit weight of water,
p_h = hydrostatic pressure at SWL,
p_d = dynamic pressure at SWL, and
p = total breaking wave pressure at SWL.

This study focuses on the stresses that breaking waves exert on coastal slopes because breaking waves produce short duration, high magnitude shock pressures that standing and broken waves do not. As Sunamura (1983) noted, it is difficult to measure wave stress and the subsequent erosion in the field. The complexity of the wave dynamics and the severity of the environmental conditions at the shoreline during erosive events prevent direct measurement of the wave stress. Therefore, the pressure exerted on the slope toe by a breaking wave was calculated using Minikin's expression, Equation 1.5.

The Shore Protection Manual (U.S. Army, 1984) states that the Minikin method can calculate wave forces that are 15 to 18 times higher than those calculated for breaking waves and suggests that caution be exercised in its use. However, laboratory experiments of breaking waves on vertical and sloping walls showed that the measured breaking wave pressure (P_{max}) exceeded the pressure calculated by the Minikin formulation for ninety percent of the wave impacts (Kirkgoz, 1991). In the same study the median value of P_{max} was approximately three times the Minikin estimate.

Considerable uncertainty is associated with estimates of the stress exerted on slope toes by waves. Due to the complexity and variability of wave breaking, the wave parameters (e.g., wave height, wave length, etc.) were calculated. Therefore, little emphasis is placed on the actual values of the calculated stresses. Rather, the discussion of slope undercutting by waves concentrates on a comparison of the estimated wave energy and slope undercutting among different slopes and, therefore, on relative values of calculated stress.

1.4.4 Frequency of Occurrence of Wave Stress at the Shoreline

It is necessary to know not only the stress applied to the slope by waves, but also the frequency with which the waves occur. The values used as input to RCPWAVE were chosen to represent the full range of conditions for which erosion by waves might occur. Such conditions occur approximately 90 days per year and are produced by winds that blow from the eastern 180 degrees of the compass (e.g., north to south from the east). A Rayleigh distribution of the offshore waves was used as input to RCPWAVE for each wind/fetch condition. Wave stress calculations were performed using Equation 1.5 for the resulting wave height/periods at the shoreline.

Subsite: SC-SCN

Wind Speed and Direction (m/s)	Storm surge water surface for this wind condition (m NGVD)	Hours per year this wind condition occurs	Modal (most frequent) wave height-wave length combination H (m), λ (m)		Modal(most frequent) wave stress (kN/m^2)	Wave height-wave length combination to produce maximum breaking wave stress H (m), λ (m)		Minikin maximum breaking wave stress at the SWL (kN/m^2)
NNE (5)	0.4	475	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
E (5)	0.4	250	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (5)	0.4	615	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
NNE (7)	0.5	250	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
E (7)	0.45	90	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (7)	0.5	310	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
NNE (9)	0.6	63	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
E (9)	0.5	16	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (9)	0.6	63	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
NNE (13.5)	1.04	16	0.75	11.4	5.4	0.94	14.2	6.8
E (13.5)	0.94	3.4	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (13.5)	1.04	3.4	0.88	11.8	6.7	0.88	11.5	6.8
SSE (23)	1.30	0.8	0.94	15.7	29.7	1.05	13.7	* 37

*Breaking waves produced because wave height to water depth ratio exceeds 0.78.
B>SS = Beach elevation exceeds storm surge water surface elevation - no waves reach toe.

Table 1.5 SC-SCN, Wave Height/Length Combinations and the Associated Wave Stress at the SWL for Prevailing Wind and Bathymetric Conditions

Subsite: SC-SCS

Wind Speed and Direction (m/s)	Storm surge water surface for this wind condition (m NGVD)	Hours per year this wind condition occurs	Modal (most frequent) wave height-wave length combination H (m), λ (m)		Modal(most frequent) wave stress (kN/m^2)	Wave height-wave length combination to produce maximum breaking wave stress H (m), λ (m)		Minikin maximum breaking wave stress at the SWL (kN/m^2)
NNE (5)	0.4	475	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
E (5)	0.4	250	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (5)	0.4	615	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
NNE (7)	0.5	250	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
E (7)	0.45	90	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (7)	0.5	310	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
NNE (9)	0.6	63	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
E (9)	0.5	16	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (9)	0.6	63	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
NNE (13.5)	1.04	16	0.99	12.3	7.9	0.99	12.3	7.9
E (13.5)	0.94	3.4	B>SS	B>SS	B>SS	B>SS	B>SS	B>SS
SSE (13.5)	1.04	3.4	0.98	12.7	7.6	0.98	12.7	7.6
SSE (23)	1.30	0.8	1.06	16.7	* 32	1.27	16.3	* 40

*Breaking waves produced because wave height to water depth ratio exceeds 0.78.
B>SS = Beach elevation exceeds storm surge water surface elevation - no waves reach toe.

Table 1.6 SC-SCS, Wave Height/Length Combinations and the Associated Wave Stress at the SWL for Prevailing Wind and Bathymetric Conditions

1.5 Summary of Groundwater Conditions

Piezometers were installed at five elevations (Figure 1.8) on the hilltop west of the beach parking lot. Groundwater seepage is evident along exposed cliff faces and tends to occur near the base of the two coarse-grained stratigraphic intervals: the Anadara and Governor Run Sands. An upper, permanent water table exists in the Anadara Sand above 10.0 m (stratigraphic elevations correspond to those measured at the piezometer site at Scientists' Cliffs). Highly localized hilltop surface drainage contributes a large fraction of water to this horizon. Residential septic systems are an additional source of water to this seepage zone and may act as sources of pollution to Chesapeake Bay as slope erosion proceeds into drainage fields. Water in piezometer SC4 was noted to have a septic smell. Seepage from this zone is responsible for undercutting the upper slopes on an infrequent basis along SC. The Scientists' Cliffs' topography consists of numerous hilltops separated by stream drainages. Therefore, this upper groundwater body is not continuous across SC, but exists as numerous isolated groundwater bodies. A permanent water table at this elevation occurs only on the larger hilltops.

The relatively impermeable lower Mytilus interval effectively isolates the upper groundwater bodies occurring in the near surface materials from the deeper, permanent, regional groundwater regime. The groundwater regime below the Mytilus interval receives recharge from surface waters up to a kilometer away from the slope face. Piezometers SC1, SC2, and SC3 are located within the regional groundwater system (see Figure 1.8).

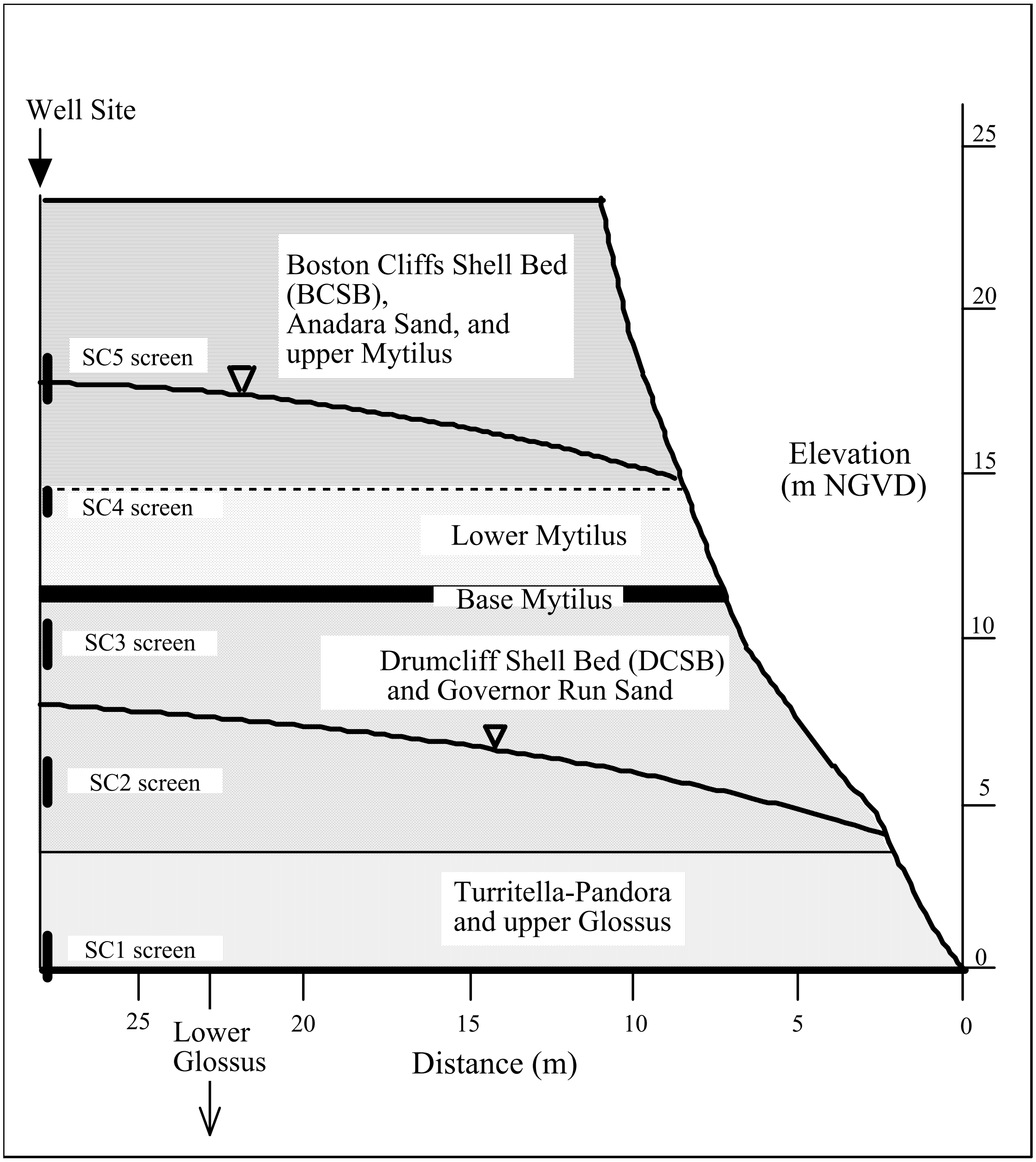


Figure 1.8 Primary Hydrostratigraphic Units and Well Screen Intervals

A large permeability contrast with associated seepage occurs at the contact between the Governor Run Sand and the Turritella-Pandora interval. A distinct darkening of the slope face occurs below the base of the Governor Run Sand. The darkening results from constant saturation of the materials below the regional groundwater surface and seepage from the slope face at the stratigraphic permeability contrast.

Due to the vertical heterogeneity of the stratigraphy along the Calvert County shoreline, more than one saturated horizon may exist along a slope section, separated by an unsaturated wedge of sediments (Figure 1.9). The wedge is thickest at the slope face, and tapers into the slope. The size of the wedge depends on the amount of recharge available to the upper groundwater body and the magnitude of the permeability contrast near the base of the upper saturated zone (Rulon, Rodway, and Freeze, 1985).

The lowermost groundwater regime normally draws recharge from a region exceeding 10 square kilometers. Perched, upper groundwater lenses are usually limited to hilltops and draw recharge from much smaller areas, on the order of one square kilometer.

The groundwater systems of the Calvert Cliffs usually produce distinct moisture patterns on the slope face. Lower slope faces are constantly moist due to a combination of constant seepage from within the lowermost portions of the lower slopes and the movement of seepage along the slope face from seepage outflow at the midslope/lower slope boundary. The lowermost midslopes often produce visible seepage flow and the saturated slope face may extend one to two meters vertically along the surface of the midslope.

Perched seepage zones higher in the midslope are usually indicated by lines of vegetation, and may be evident as a darkened band of sediments due to constant saturation.

Recharge travels slowly through all of the formations, usually taking a month to several months to reach the water table from the surface. The seepage rates in the saturated portions of the lower slope range between 7×10^{-10} and 5×10^{-7} m^3/s per square meter of slope (e.g., m/s). Seepage rates at the base of the midslopes vary between 1.2×10^{-7} and 4×10^{-6} m/s. Where the flow rate was high enough to make it possible to directly measure the seepage, the measured value was 1.4 to 3.7 times the modeled value. It is likely that the use of field determined permeabilities in the flow model account for this difference. The field tests are not capable of determining the anisotropy of the hydrologic units.

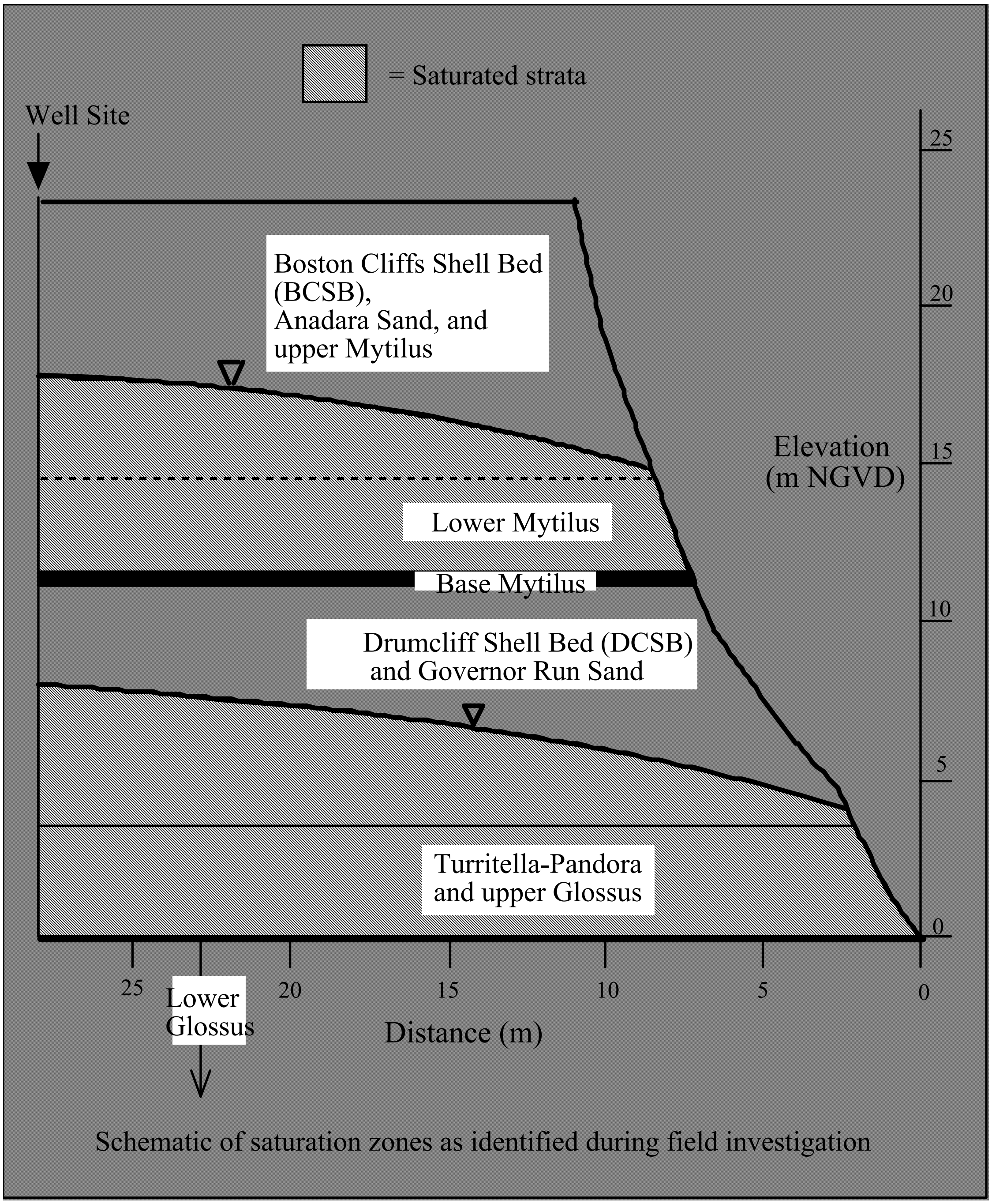
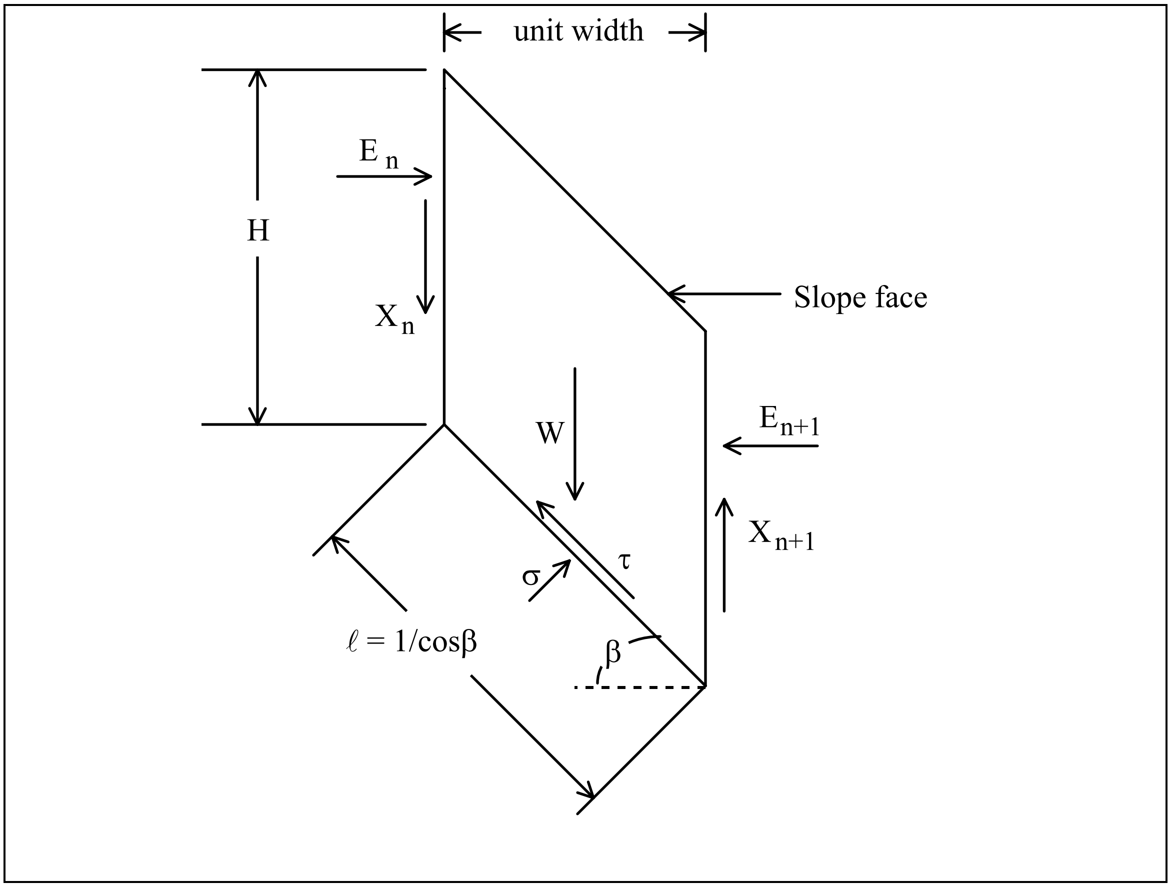


Figure 1.9 Scientists' Cliffs' Saturation Zone Schematic

1.6 Slope Stability Analyses

1.6.1 Infinite Slope Stability Analysis

Shallow slides (i.e., slides that are much wider than they are deep) in cohesionless materials and residual or colluvial soils over bedrock are most appropriately modeled by the infinite slope analysis (Hunt, 1984). This analysis requires that the depth to the failure plane be small compared to the slope length because the end and side effects are ignored. An infinite, slope-parallel failure plane is assumed to occur at some depth, H, below the slope surface and a single column of soil of unit lateral dimension is taken to represent the slope (Carson and Kirkby, 1972). For the purposes of modeling shallow sliding along the midslopes of the Calvert Cliffs, H was determined from measurements made of observed shallow slides. Saturation of the full height of the column is assumed with infiltration occurring vertically downward. Under these conditions, the pore pressure along the failure surface is closely approximated by hydrostatic conditions. Critical slope angles were determined for the conditions just above the midslope/lower slope boundary at each site. This position was chosen because it is continually saturated due to groundwater seepage. During storms, it is the first portion of the slope to experience an increase in the destabilizing pore pressures. Figure 1.10 shows the geometry used for the stability analysis.



Notes:
(after Carson and Kirkby, 1972)
$E_n = E_{n+1}$; $X_n = X_{n+1}$;
Slope is saturated from the surface to the slide surface (depth = H)

Figure 1.10 Stability Analysis of an Infinite Slope Subject to Shallow Slides.

In the infinite slope model the driving forces are balanced against the resisting forces only along the base of the slide. The driving force at the base of the slide is due to the downslope component of the slab weight:

$$\tau = \frac{W \sin\beta}{\ell} = \gamma_s H \sin\beta \cos\beta \qquad \text{Equation 1.6}$$

where:

$$W = H\gamma_s \qquad \text{Equation 1.7}$$

$$l = 1/\cos\beta \qquad \text{Equation 1.8}$$

The resisting force per unit area is provided by:

$$S = c' + (\sigma - u)\tan(\phi') \qquad \text{Equation 1.9}$$

where:

$$\sigma = \gamma_s H \cos^2\beta \qquad \text{Equation 1.10}$$

$$u \approx \gamma_w H \qquad \text{for vertical infiltration} \qquad \text{Equation 1.11}$$

resulting in a factor of safety:

$$FS = \frac{H\gamma_s \sin\beta \cos\beta}{c' + (H\gamma_s \cos^2\beta - (\gamma_w H))\tan\phi'} \qquad \text{Equation 1.12}$$

and

W	=	weight of the unit width of block,
H	=	height of the block above the failure surface,
β	=	the angle the slope face makes with a horizontal plane,
l	=	the length of the failure surface,
c	=	cohesive shear strength of the material,
σ	=	normal stress,
ϕ	=	angle of internal friction of material,
u	=	pore pressure,
γ_w	=	the unit weight of water, and
γ_s	=	wet unit weight of the material.

The observed slope angles versus those predicted by the infinite slope model for each a number of subsites along the Calvert County shoreline, including the Scientists' Cliffs' area, and are shown in Table 1.7

1.6.2 Block Failures

Lower slopes have relatively high cohesive strengths compared to midslopes and tend to stand at steeper angles over greater heights. Sliding failures occur when these cohesive materials are undercut by waves, freeze-thaw, or seepage erosion. Spalling is the method of failure and spalling can be modeled as an undercut block failure.

Whenever undercutting occurs, regardless of the mechanism, the undercut block projects from the slope in the manner of a cantilever. Failure occurs along a nearly vertical, slope-parallel plane. Along the Calvert Cliffs, the failure planes tend to coincide with near-surface exfoliation planes that develop as a result of slope face unloading. Groundwater seepage and subsurface stormflow preferentially travel along the exfoliation surfaces. Iron-staining is common on exfoliation surfaces. Exfoliation surfaces are typically discontinuous, and failure surfaces typically cross non-exfoliated portions of material. Inspection of failure surfaces immediately after spalling events suggest that between one-third and one-quarter of the shear surface passes through intact material. The upper surface of the block is normally a contact between different materials and is assumed to have no strength in tension. Undercut block failures were evaluated in the following manner (see Figure 1.11):

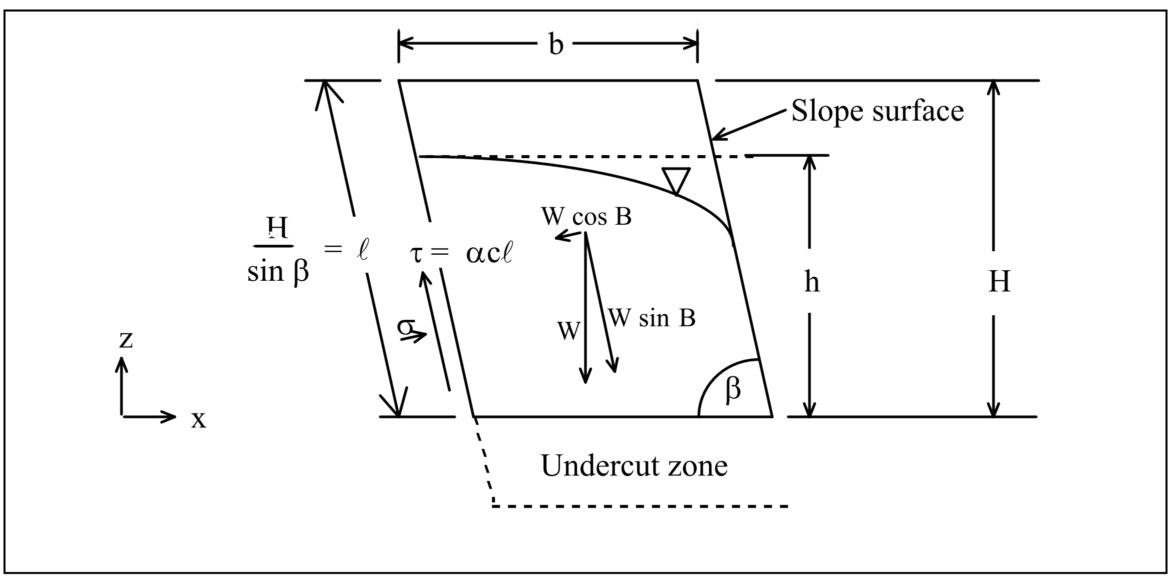


Figure 1.11 Undercut Block Stability Analysis Geometry
for a Coulomb failure of a unit thickness

The driving force is the downslope component of the weight of the block:

$$W \sin\beta$$

The resisting forces are due to the strength of the material:

$$\alpha c' l + (\sigma \cos\beta - u)\tan\phi'$$

where:

$$W = Hb\gamma_s \qquad \text{Equation 1.13}$$

$$l = H/\sin\beta \qquad \text{Equation 1.14}$$

$$u = \gamma_w \int_0^h (h - z)dz = \frac{h^2}{2}\gamma_w \qquad \text{Equation 1.15}$$

The factor of safety is the ratio of disturbing to resisting forces.

$$FS = \frac{Hb\gamma_s \sin\beta}{\alpha c' \ell + (\sigma \cos\beta - (\gamma_w h^2 / 2))\tan\phi'} \qquad \text{Equation 1.16}$$

FS = 1 at failure.

and

W = weight of the unit width of block,
H = height of block above datum defined by top of undercut zone,
β = the angle the slope face makes with a horizontal plane,
b = the horizontal distance of undercutting,
l = the length of the block along the slope face,
c = cohesive shear strength of the material,
α = portion of failure plane not jointed by exfoliation (0.2 to 0.6),
σ = normal stress across a unit width of block,
ϕ = angle of internal friction of material,
h = height of phreatic surface above datum,
u = pore pressure,
γ_w = the unit weight of water,
γ_s = wet unit weight of the material, and
z = elevation above datum defined by top of undercut zone.

With FS = 1, the block fall analysis estimates the amount of lateral undercutting required for block failure. Each site noted to be subject to spalling was analyzed in order to estimate the lateral undercutting required to cause spalling there. The results are presented in Table 1.7.

Site and Subsite*	Formation	Analysis Type	C kN/m^2	ϕ degree	U kN/m^3	β critical degree	β field degree	Lateral undercutting req'd. for block failure (m)
NRL-HB&RC	Camp Roosevelt Shell Bed	Block	5	28	1.0	70	70	0.4
NRL-HB	Camp Roosevelt Shell Bed	Infinite Slope	1	34	1.0	48	48	
SC-PCS	Gov. Run Sand	Infinite Slope	2	32	3.0	45	48	
SC-SCN/SCS	Gov. Run Sand	Infinite Slope	2	32	3.0	45	49	
SC-GR	Gov. Run Sand	Infinite Slope	2	32	2.4	47	49	
CCSP-RP	Zone 23	Infinite Slope	6	28	5.4	49	41	
CCSP-GYCN	Zone 23	Block	6	28	1.0	68	68	0.4
CCSP-GYCS-n	Zone 23	Infinite Slope	6	28	7.4	50	53	
CCSP-GYCS-s	Zone 23	Infinite Slope	6	28	7.4	50	49	
CRE-LCP	CRE upper	Infinite Slope	2	32	2.0	52	53	
CRE-LL	CRE upper	Infinite Slope	2	32	2.35	47	47	
CRE-SBN	CRE upper	Infinite Slope	2	32	1.5	58	57	

* Acronyms are abbreviations used for study sections distributed along the length of Calvert County shoreline during the study conducted by Miller (1995).

Table 1.7 Midslope Angles [Modeled (FS=1) Versus Observed]

All midslopes except RP are near the critical angle for failure.

The depth of saturation is critical to midslope sliding because the pore pressure increases with increasing saturation. The ability of a material to resist failure is reduced as the pore pressure increases. Figure 1.12 shows how the critical angle for sliding in the Governor Run Sand is reduced as the saturation proceeds vertically into the slope. This analysis assumes that the failure plane occurs along a plane equal in depth to the saturated portion of slope and the slope is unvegetated.

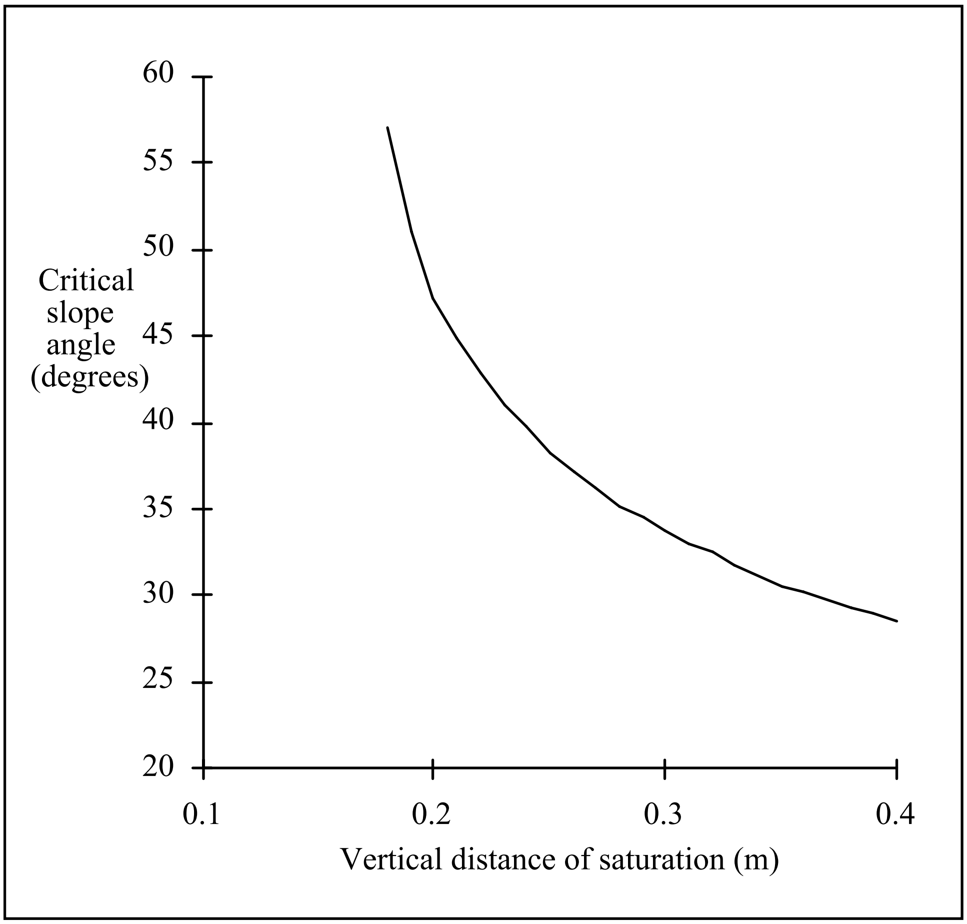


Figure 1.12 The Effect of Saturation Depth on the Critical Slope Angle for the Non-Vegetated Governor Run Sand as Determined by the Infinite Slope Analysis

Failures on vegetated slopes typically occur along planes 0.3 to 0.4 meter deep and occur less frequently than on non-vegetated slopes in similar materials. The primary reason is that the roots provide strength near the surface, but the root strength diminishes rapidly with depth. The slides in the vegetated slopes of Scientists' Cliffs are characteristic of this type of slide. At this site, rainfall or snowmelt must saturate the slope to greater than 0.3 meter in order to cause slides in the material at the base of the vegetative mat. The failures occur at depths where only a few scattered root tendrils remain to provide cohesive strength. Along the reach of shoreline north of Scientists' Cliffs toward Parker Creek, very little vegetation exists on the Governor Run Sand, and smaller, shallower slides occur on a more frequent basis.

1.7 Endangered and Threatened Species

The shoreline and slopes along SCA are identified as Critical Area Site CT L-5 because they have been documented to provide habitat to two species of tiger beetle that are rare, threatened, and/or endangered.

Both the northeastern beach tiger beetle (cicindela dorsalis dorsalis) and the Puritan tiger beetle (cicindela Puritanus) are listed as Endangered by the State of Maryland and as Threatened in Maryland by the U.S. Fish and Wildlife Service (http://www.fws.gov/endangered/ accessed 02 January 2006).

The family Cicindelidae is diverse with nearly 100 species in the United States and over 2000 identified worldwide and is considered an excellent indicator of regional biodiversity (USFWS 1994, Boyd and Rust 1982, Pearson and Cassola 1992). Over 100 subspecies and colorforms have been identified in the United States (USFWS 1994, Boyd and Rust 1982).

The northeastern beach tiger-beetle (Cicindela dorsalis dorsalis) (Figure 1.13) whose range extends along the Atlantic Coast from Cape Cod through southern New Jersey and along both shores of the Chesapeake Bay in Maryland and Virginia, is one of four subspecies of the species cicindela dorsalis (USFWS 1994). "The northeastern beach tiger beetle, described as Cicindela dorsalis by Say (1817), has white to light tan elytra, often with fine dark lines, and a bronze—green head and thorax. It measures 13 to 15.5 mm (1/2 to 3/5 inch) in total length."

Figure 1.13 Cincindela dorsalis dorsalis (www.uvm.edu)

The Puritan tiger beetle 's (cicindela Puritanus) current range includes two sites in New England and sixteen in Maryland. It's range was reported to have been considerably larger during the 19th century when it's range included larger parts of New England.

Figure 1.14 Cicindela Puritana Horn 1871

http://collections2.eeb.uconn.edu/collections/insects/CTBnew/Puritana.html

The Puritan tiger beetle is "a medium—sized (males average 11.5 mm and females average 12.4 mm in Calvert County) terrestrial beetle of the family Cicindelidae (Figure 1.14). This family is closely related to the family Carabidae and is included as a subfamily of Carabidae by some authors. The background coloration of C. Puritana is dark bronze—brown to bronze—green with cream—colored markings on the elytral surfaces." (USFWS 1993).

Scientists' Cliffs is one of three locations in Calvert County and five statewide that have been identified as a priority area for conservation of the Puritan tiger beetle (USFWS 1993). Nine "geographic recovery areas" (GRA) have been identified for the northeastern beach tiger beetle from Virginia through Massachusetts. Calvert County is one of four identified in the Chesapeake Bay region (USFWS 1994).

1.7.1 U.S. Fish and Wildlife Service Recovery Strategy for the Northeastern Beach and Puritan Tiger Beetles

Recovery Criteria:

Table 1.8 lists the recovery criteria documented in the recovery plans for the northeastern beach and Puritan tiger beetles, respectively.

The species can be removed from threatened status when [underline added for emphasis]:

Northeastern Beach Tiger Beetle (USFWS 1994)	Puritan Tiger Beetle (USFWS 1993)
At least three viable populations have been established and permanently protected in each of four designated Geographic Recovery Areas covering the subspecies' historical range in the Northeast, with each GRA having one or more sites with large populations (peak count > 500 adults) and sufficient protected habitat for expansion and genetic interchange.	*A minimum of six large (500-1000+ adults) populations and their habitat are protected in perpetuity at current sites along both shores of the Chesapeake Bay.*
At least 26 viable populations distributed throughout all five Chesapeake Bay GRAs are permanently protected.	*Sufficient habitat between these populations is protected to support smaller populations, providing an avenue for genetic interchange among large populations and ensuring a stable metapopulation structure.*
Life history parameters (including population genetics and taxonomy), human impacts, and factors causing decline are understood well enough to provide needed protection and management.	*A minimum of three metapopulations, at least two of which are large (500-1000+ adults), are maintained (at extant sites) or established within the species' historical range along the Connecticut River, and the habitat they occupy is permanently protected.*
An established, long-term management program exists in all states where the species occurs or is reintroduced.	*There exists an effective and long-term program for site-specific management that is based on an adequate understanding of life history parameters, human impacts, factors causing decline, population genetics, and taxonomy.*
Actions Needed:	
1. Monitor known populations and any additional populations that are discovered.	*Monitor known populations, including any additional populations that are found.*
2. Determine population and habitat viability.	*Determine population and habitat viability.*
3. Protect viable populations and their habitat.	*Identify and protect viable populations and their habitat.*
4. Study life history parameters.	*Implement appropriate management at natural population sites.*
5. Evaluate human impacts.	*Study anthropogenic influences.*
6. Implement management measures at natural population sites.	*Study life history parameters and taxonomic relationships*
7. Develop captive rearing techniques and conduct reintroductions.	*Develop techniques for and conduct reintroductions at appropriate sites.*
8. Implement educational activities.	*Conduct a public education program.*

Table 1.8 U.S. Fish and Wildlife Service Recovery Strategy for the Northeastern Beach and Puritan Tiger Beetles

1.7.2 Summary of Key Elements Related to the Presence of Tiger Beetle Habitat along the Scientists' Cliffs' Shoreline.

The recovery plans for these beetles have a heavy emphasis on establishing permanent protection and maintaining suitable habitats. However, the concepts of what "permanent protection" and "suitable habitat" are not well-defined because of key gaps in the understanding of the conditions required for maintaining viable habitat for these two species and how a dynamic environment influences those habitats. It is important to note that neither the recovery criteria nor the recommended actions recognize the need for better understanding how erosion processes and conservation practices may affect the preservation of these two species, despite the fact that such understanding will need to be an essential part of their recovery. The plans call for county governments to provide permanent protection. Counties may have difficulty developing recovery plans because details are not provided as to what types of protection are required and what kind of mechanisms are available to cause that protection to be permanent. Further, there is a complicated mix of Federal, state, and county legislation that must be considered as part of the habitat protection process.

Because there is so much uncertainty as to how erosion and deposition processes affect tiger beetle habitat either positively or negatively, it seems premature to make statements such as: "…shoreline development and shoreline stabilization are the most serious and least controllable threats to Puritan tiger beetles in Maryland" (USFWS 1993). According to the recovery plans for the northeastern beach and Puritan tiger beetles, historically, the Chesapeake Bay area was thought to have few populations of this beetle (USFWS 1993 and 1994). But in the 1980s and 1990s, at least 16 significant occurrences now have been documented as a result of intensive surveys. This could be viewed as an apparent growth in the total population and distribution of these beetles. However, it more likely to be a result of different methods and intensities of the historic and recent surveys. Based on the data presented in the recovery plans, there is no way to conclude whether the populations are growing, diminishing, or stable in the Bay region, particularly since it is known that adult numbers fluctuate widely from one year to the next at a given location (USFWS 1993). It is important to note that the Scientists' Cliffs' community has had a consistent and continuous practice of beach and slope land use and conservation for over half a century. Yet, it was only as of 1988 that populations of the northeastern beach tiger beetle were discovered along the Scientists' Cliffs' shoreline (USFWS 1994) indicating that some important factor(s) are fostered as part of the long-term conservation practices of the community. It should also be noted that survey methods have likely differed over time so that comparisons between surveys should be considered when assessing characteristics like the presence, continuity, and population stability over time.

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Section 2 Environmental Mechanisms – Slope and Shoreline Processes

2.0 Introduction

The nearshore, shoreline, and coastal slopes of the community are an integrated system. It is important to recognize that the system is dynamic, and composed of physical and ecological components. People are drawn to this interface of earth, air, and water because it is complex and beautiful. While the slopes and shoreline of Scientists' Cliffs may be taken as a constant in the daily experience of a resident, one can not help but realize that every hour of every day brings a change in the water, light, plants, animals, insects, and atmosphere. These observations may appear to be a digression from the development of a best management plan. But, it is experiencing these ever-changing conditions that provides the most direct and tangible introduction to understanding the important environmental parameters and the ranges over which vary.

A direct understanding of beach and slope erosion is possible when the environmental mechanisms that dominate the erosion can be identified and measured. The dominant mechanism can vary over place and time. The recognition of dominant processes is necessary for developing best management practices because dominant processes can be described and examined in terms of their controlling physical parameters. Tests and measurements can be made that directly measure the state or magnitude of controlling physical parameters as they occur at Scientists' Cliffs over the course of time. Designs can be developed that attempt to maintain the values of the controlling parameters within ranges that best achieve the shoreline and slope management objectives of the community.

The key environmental mechanisms must be identified within the context of the objectives of this plan. The goal of this plan is to develop best practices for encouraging stable beaches and to minimize the rate of retreat of the coastal slopes. History suggests that the beach and offshore bar system along Scientists' Cliffs is a persistent natural feature, and that the historical coastal slope erosion rate is relatively low compared to other segments of Calvert County shoreline. It would be disingenuous to not recognize that circumstance has created a combination of environmental factors that contribute to the presence of significant beaches and relatively low rates of coastal slope retreat along Scientists' Cliffs. However, it would be short-sighted to overlook the fact that a historic perspective is necessarily long-term and backward looking. In addition to notable and severe perturbations to an apparently long-term, relatively stable condition, it can be expected that a rapidly increasing rate of sea-level rise and potential changes to the local climate may increase the frequency and duration over which unfavorable values of the controlling environmental parameters occur.

For any shoreline segment, two main questions must be considered for the development of this plan.

1) What measures can be taken to encourage the long-term and relatively uninterrupted presence of a beach?
2) What measures can be taken to minimize the rate at which the coastal slopes retreat?

The first question can be viewed from the perspective that a stable beach is the prevailing condition. In this case the question may be phrased, "What conditions cause erosion of the beach and how can they be discouraged?" Another perspective may be, how can the conditions causing a natural beach be encouraged?

Answering Question 2 requires recognizing the dominant mechanism(s) causing slope erosion along any specific reach of coastal slopes.

A great deal of research has been done on both of these questions. In some cases, studies have been conducted and observations have been made directly along the Scientists' Cliffs' shoreline. Specifically, the second question has been addressed in detail along the Scientists' Cliffs' shoreline. So it is useful to tackle this one first in order to establish a systematic approach to the first question.

<u>What measures can be taken to minimize the rate at which the coastal slopes retreat?</u>

This question ultimately will be answered in Section 5 (Best Management Practices) after the mechanisms of slope erosion are identified and quantified and after important constraints on actions that can be taken have been discussed. Such constraints include the community's fiscal resources, the regulatory and permitting process, ecological and other environmental constraints, and availability of suitable materials. The first issue that must be addressed is what are the dominant mechanisms causing slope erosion along the Scientists' Cliffs' coastal slopes.

2.1 The Dominant Mechanisms of Slope Erosion Along Scientists' Cliffs

A field investigation on the controls of the dominant slope erosion processes along the Calvert County shoreline was conducted from 1990 to 1994 (Miller, 1995). The slopes and shoreline along Scientists' Cliffs was one of four study areas. Objectives of the study important to the task at hand included:

1) Determine the dominant erosion processes and the slope segments on which they act.
2) Determine the physical controls of the dominant processes and the range of values for each control as they occur along the Calvert Cliffs.
3) Using an experimental framework, determine the variations in each control.
4) Identify the conditions under which extreme erosion rates occur.
5) Attempt to link historical erosion rates to the suite of dominant erosion processes active over time along the Calvert County shoreline.

The information presented in this BMP will draw heavily on this study. Only the information necessary to develop the plan's logic and best management practices will be included in the BMP. The remainder will be supported by reference.

The key, measurable elements of the dominant mechanisms acting on coastal slopes are organized by the categories of:

- stratigraphy
- groundwater
- wave climate
- geometry of the shoreline and slopes

2.1.1 Summary of Slope Erosion Mechanisms and Rates

The long-term, historic gross rate of shoreline erosion as determined by the Maryland Geological Survey for the reach from Governor Run to the northern end of Scientists' Cliffs is approximately 0.1 meter (approximately 4 inches) per year (Kerhin, Hennessee, Isoldi, and Gast, 1993). Erosion pin measurements conducted over the past 15 years along Scientists' Cliffs document lower slope erosion rates ranging from less than one inch per year to nearly 8 inches per year at the northern boundary of Scientists' Cliffs. Note that installation of the groin system to stabilize the beach along Scientists' Cliffs began in the 1940s.

The overall rate of slope and bluff top retreat is set by the rate at which the lower slope retreats. The time scale over which this is true is at least over a decade. That is, the midslope, upper slope, and bluff top tend to recede episodically. The bluff top may recede three to five feet in one episode of slope failure. But, the longer term rate will match the rate at which the lower slope is receding. At Scientists' Cliffs, the processes by which slope material is lost is varies between slope segments. While other slopes along the Calvert County shoreline may be directly undercut by waves, this is a rare occurrence at Scientists' Cliffs. Erosion pin fields established in the early 1990s and still currently maintained clearly demonstrate that freezing and thawing of the lower slope material is the dominant mechanism for directly eroding intact slope material along the Scientists' Cliffs' shoreline. This is true because the strength of lower slope material and the duration of wave events sufficiently strong to erode the intact lower slope material combine to create unfavorable circumstances for direct wave erosion (Wilcock, Miller, Shea, and Kerhin, 1998).

Figure 2.1 shows a detailed portion of the erosion pin record for the pin field installed just north of the steps to Chestnut Cabin from the beach. Important items to note include:

- Expansion of the slope face due to the expansion of water as it freezes and
- Virtually all of the loss of slope face for this year was due to freeze thaw and is typical of the fifteen year record.

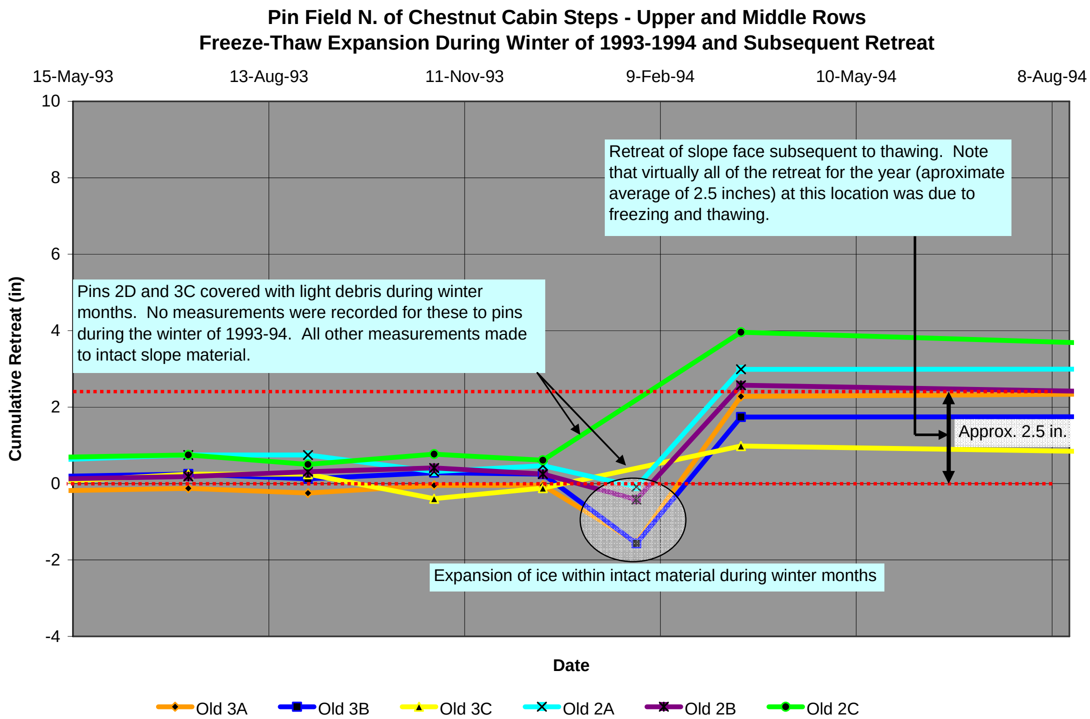

Figure 2.1 One Freeze-Thaw Season of Erosion Pin Record – Chestnut Cabin

Because of the sandy composition of at least two major stratigraphic intervals within the midslope along most of the Scientists' Cliffs' shoreline, the midslope tends to recede in shallow landslides. These landslides often occur after prolonged rain storms and may extend all the way to the bluff top. Sometimes, the midslope materials slide out from beneath the upper slope material bound by tree roots and leave the bluff top temporarily undercut and unstable.

The key to successfully addressing slope erosion in the BMP is to recognize that the overall rate of slope retreat is set by the rate at which the lower slope retreats due to freezing and thawing. If the mix of vegetation remains unchanged, an increase in the rate of intact material lost to freezing and thawing will primarily increase the frequency of shallow landslides in the midslopes and upper slopes. Typically, the immediate trigger of midslope slides is due to the weight of water added by prolonged storms and from the weakening that occurs along the slide plane due to infiltrating water and the resulting increase in water pressure between the grains of the material. The rate at which storms occur to generate these conditions, assuming the midslope is sufficiently near the critical angle for sliding, is far greater than the upper limit of the rate of lower slope erosion whereby freezing and thawing could remove material sufficiently quickly to undercut the midslope so that it would slide regardless of the moisture conditions. This introduces another important point. In order for freezing and thawing to be effective, the material accumulating on the beach at the slope toe must be periodically removed by waves. Otherwise, it forms a very effective insulating blanket preventing additional cycles of freezing and thawing. Ultimately, the rate of freezing and thawing in the lower slope is determined by the frequency at which waves remove the debris at the base of the slope and expose fresh, intact lower slope material.

Conversely, a decrease in the rate of lower slope retreat would reduce the frequency of midslope and upper slope landslides, but probably not their magnitude (in the absence of changes to the mix of vegetation present on the slopes. It is of interest to note that even if the lower slope erosion rate was reduced to zero, midslope and upper slope landslides would occur for a considerable period of time, up to thirty years, becoming less and less frequent, until the overall slope attained a stable angle.

Theoretically, it is possible that by lowering the rate of lower slope erosion sufficiently, the dominant erosion mechanism of the midslope would become erosion and transport of midslope material by rainfall and snowmelt. However, this is unlikely for two reasons. The sandy materials comprising the midslope are quite permeable and water soaks in quickly reducing the likelihood of downslope transport of sediments by overland flow. Second, the slopes of this area support vegetative cover that reduces the effects of raindrop impact and binds the soil particles together, thereby making individual soil particles less available for transport. Therefore, it is most likely that even under very low rates of lower slope erosion, the midslope would continue to fail by sliding, just less frequently.

2.1.2. The role of vegetation on the erosion of slopes at Scientists' Cliffs.

Vegetation occurs naturally on most of the coastal slopes along Scientists' Cliffs. Notable exceptions occur on constantly wave-washed surfaces, very steep clayey intervals, on recent landslide surfaces, and on a few very sandy, very well-drained midslope surfaces.

Undercut bluff-top trees and larger trees on the midslope can be nuisances and hazards. The bluff top trees are prone to toppling in the wind and taking the soil captured in their roots along when they fall. Falling and sliding trees are clearly hazards to persons and animals on the beach. Once resident on the beach, fallen trees and their root balls capture soil and other debris moving down the slope to the beach and provide some measure of protection to the lower slope during small to moderate storm events. However, root balls and tree branches can act as very effective tools that dig and gouge the slope toe during powerful storm surges and wave events.

Roots affect the behavior of shallow slides in several ways. They provide a component of cohesive strength against shallow sliding acting as a stabilizing fabric. However, the depth to which plants root varies by species and the strengthening effect ends near or above the average rooting depth. In addition, plants may destabilize slopes by leaching cementing materials from the soil, breaking chemical bonds in clays, causing fissures and preferential pathways for the downward movement of water, and weakening the soil by rocking in the wind. This latter action becomes much worse with increasing height.

On the positive side, vegetative cover reduces the erosive impact of rain drops. Raindrop impact onto sandy, steep surfaces can cause a surprising amount of downslope movement of slope material. Actively growing vegetation also transpires water from a slope; water that may otherwise act to destabilize the slope.

During the study of the Scientists' Cliffs' slopes, it was noted that a number of shallow slides sheared along planes characterized by a common root diameter. That is, the remnants of the roots on the shear surfaces had similar diameters, indicating that the shearing forces acted along a plane that was a function of the root depth and strength of the vegetation on the slope. The implication is that the strength of the roots, the density of the root spacing, and the depth of rooting affects the depth of the slide plane. As noted above, roots also act as preferential pathways for water to infiltrate and the build up of water pressure within the slope acts to weaken the slope.

Also during the study of the slopes, an important aspect related to vegetation was noted. A substantial blanket of English Ivy growing at the interface between the lower slope and midslope where moisture is readily available draped over the nearly vertical face of the lower slope causing a blanketing effect. One of the three sets of erosion pins installed along the Scientists' Cliffs' lower slopes was installed beneath this blanket of ivy to test the degree to which the number of freeze-thaw cycles affects the lower slope erosion rate. Because the ivy prevented the sun from warming the frozen lower slope on a diurnal cycle, the face of the lower slope remained frozen, and the rate of freeze-thaw related slope loss was minimized compared to the other two erosion pin fields where no such protection was present.

2.1.3 Sea Level Rise

For the sake of thoroughness, it should be noted that rising sea level has the potential to change the dominant erosion mechanism of the lower slope along Scientists' Cliffs from one that is driven by freezing and thawing to that of direct undercutting by wave action. The likely result of such a change would be more rapid retreat of the Scientists' Cliffs' slopes. While sea level would have to rise roughly two to three meters so that waves were capable of directly eroding the relatively weak Governor Run Sand (i.e., a reduction in the strength of the material comprising the lower slope), the wave climate may change under conditions of rising sea level so that the frequency and duration of waves capable of directly eroding the intact lower slope material increase (due to increasing nearshore water depths and increased frequency of erosive storms). However, it is beyond the scope of this BMP to project the likelihood of such wave climate conditions occurring.

2.1.4 Coastal Slopes Concept to Carry Forward Into Best Management Practices

1) The long-term, overall rate of slope erosion and bluff top recession at Scientists' Cliffs is determined by the rate at which the lower slopes erode driven by freezing and thawing. Reducing the long-term rate of slope erosion and bluff top retreat requires reducing the rate of lower slope erosion (i.e., minimizing the occurrence and frequency of freeze-thaw cycles).
2) In the absence of a change in slope management practices, reducing the rate of lower slope erosion will reduce the frequency of midslope and upper slope landslides, not the magnitude.
3) Vegetative cover that insulates the lower slope during the winter months reduces the rate of lower slope erosion due to freezing and thawing.
4) For a constant lower slope erosion rate, deeply rooted vegetation on the midslopes and upper slopes may reduce the frequency of landslides, but will increase their magnitude. Shallower rooted material may increase the frequency of midslope and upper slope landslides, but their magnitude would be reduced.
5) The combination of reducing the rate of lower slope erosion and introducing more deeply rooted vegetation would significantly reduce the frequency of midslope and upper slope landslides, however their magnitudes would be larger. The long-term rate of slope and bluff retreat would still equal the retreat rate of the lower slope.

2.2 The Dominant Mechanisms of Shoreline Erosion and Stabilization Along the Scientists' Cliffs' Shoreline.

<u>What measures can be taken to encourage the long-term and relatively uninterrupted presence of a beach?</u>

Like the parallel question related to slope erosion discussed above, this question ultimately will be answered in Section 5 (Best Management Practices) after the mechanisms of beach erosion are identified and quantified and after important constraints on actions that can be taken have been discussed. First, the mechanisms of beach erosion and stabilization most relevant to the existing conditions at Scientists' Cliffs will be discussed.

Waves and currents deposit and erode the sand that forms the beach. Waves of relatively high energy are caused by storms and elevated water levels associated with storms allow the waves to extend farther inland than the waves under non-storm conditions. Wave energy increases exponentially with wave height.

The size or volume of a beach is a direct measure of its ability to buffer the erosive energy produced by storm-driven waves. Therefore, maximizing the width and elevation of the beach is an important objective of shoreline stabilization projects.

Generally, beaches are eroded during storms and build during periods when the wave climate is mild. Another important general observation is the slope of the beach is relatively shallow during erosive storms and steeper during periods of sand accumulation. An equilibrium beach profile (measured perpendicular to the shoreline) is typically concave upward (USACE 2003). During storms, as the elevation of the water surface increases and the water pushes further inland, sand from the higher parts of the beach are moved seaward, filling in the concavity of the profile.

It is important to describe the elements and mechanisms of coastal deposition and erosion in terminology used by practitioners of coastal engineering because coastal systems are extremely complex and the consistent use of well-defined and accepted terms helps to reduce unnecessary confusion that may accompany the discussion and analysis of these complex issues. The basic concepts and terminology used to describe coastal energy and sediment transport processes are mainly quoted directly from the CEM (USACE 2003) and provided below.

Key Terminology

bed load – *sediment transport mode in which individual particles either roll or slide along the bed as a shallow, mobile layer a few particle diameters deep, the part on the load that is not continuously in suspension.*

cross-shore – *perpendicular to the shoreline.*

downdrift – *the direction of predominant movement of littoral materials.*

fetch – *a reach of uninterrupted water over which waves are generated by wind having a fairly constant speed and direction.*

littoral – *of or pertaining to a shore, especially of the sea. Often used as a general term for the coastal zone influenced by wave action or, more specifically, the shore zone between the high and low water marks.*

longshore – *parallel to and near the shoreline.*

overwash - *the process of landward transport due to overtopping of the normal land mass due to high tides and waves.*

nearshore – *(1) in beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker zone. (2) The zone which extends from the swash zone to the position marking the start of the offshore zone, typically at water depths of the order of 20 m.*

suspended load – *(1) the material moving in suspension in a fluid, kept up by the upward components of turbulent currents or by colloidal suspension.*

swash zone – *the zone of wave action on the beach, which moves as water levels vary, extending from the limit of run-down to the limit of run-up. Run-up and run-down are the upper and lower levels reached by a wave on a beach or coastal structure, relative to still-water level..*

updrift – *the direction opposite that of the predominant movement of littoral materials.*

2.2.1 Longshore and Cross-shore Sediment Transport Processes

The following synopsis of longshore and cross-shore sediment transport processes taken from the CEM (USACE 2003) describes the basic level of uncertainty that any shoreline stabilization project must recognize and accept. Basically, shoreline processes are complex and, despite many years of study, major factors about erosion and deposition of materials along a shoreline remain poorly understood.

"Sediment transport at a point in the nearshore zone is a vector with both longshore and cross-shore components [Figure 2.2] [Figure III-3-1 of the CEM]. *It appears that under a number of coastal engineering scenarios of interest, transport is dominated by either the longshore or cross-shore component. The subject of total longshore sediment transport has been studied for approximately five decades. There is still considerable uncertainty regarding certain aspects of this transport component including the effects of grain size, barred topography, and the cross-shore distribution of longshore transport.*

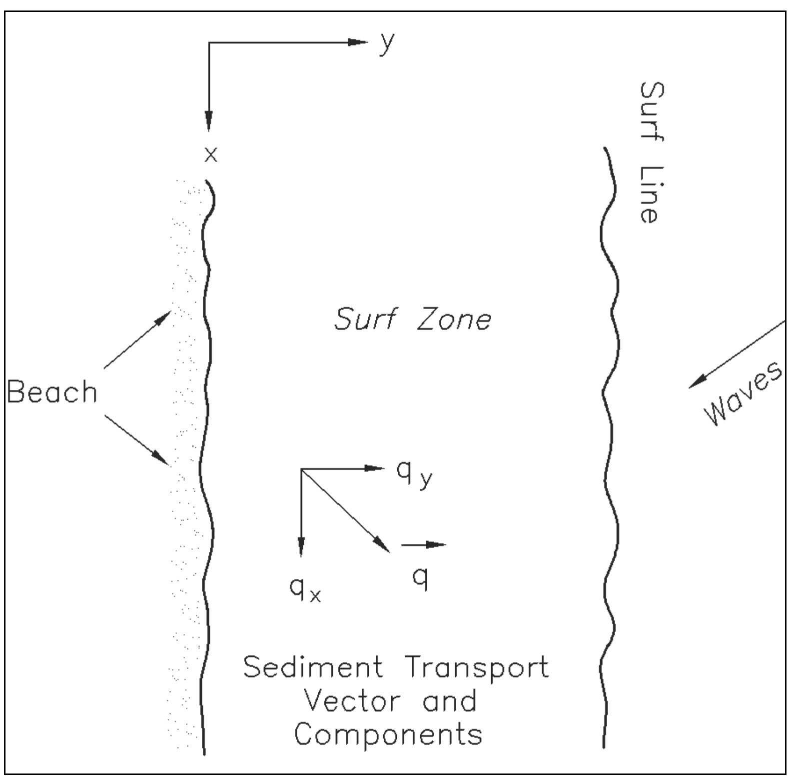

Figure 2.2 Longshore (*qx*) and Cross-shore (*qy*) Sediment Transport Components (USACE 2003)

Cross-shore sediment transport encompasses both offshore transport, such as occurs during storms, and onshore transport, which dominates during mild wave activity. Transport in these two directions appears to occur in significantly distinct modes and with markedly disparate time scales; as a result, the difficulties in predictive capabilities differ substantially. Offshore transport is the simpler of the two and tends to occur with greater rapidity and as a more regular process with transport more or less in phase over the entire active profile. This is fortunate since there is considerably greater engineering relevance and interest in offshore transport due to the potential for damage to structures and loss of land. Onshore sediment transport within the region delineated by the offshore bar often occurs in "wave-like" motions referred to as "ridge-and-runnel" systems in which individual packets of sand move toward, merge onto, and widen the dry beach. A complete understanding of cross-shore sediment transport is complicated by the contributions of both bed and suspended load transport. Partitioning between the two components depends in an unknown way on grain size, local wave energy, and other variables. Cross-shore sediment transport is relevant to a number of coastal engineering problems, including: a) beach and dune response to storms, b) the equilibration of a beach nourishment project that is placed at slopes steeper than equilibrium, (c) so-called "profile nourishment" in which the sand is placed in the nearshore with the expectation that it will move landward nourishing the beach (this involves the more difficult problem of onshore transport), (d) shoreline response to sea level rise, (e) seasonal changes of shoreline positions, which can amount to 30 to 40 m, (f) overwash, the process of landward transport due to overtopping of the normal land mass due to high tides and waves, (g) scour immediately seaward of shore parallel structures, and (h) the three-dimensional flow of sand around coastal structures in which the steeper and milder slopes on the updrift and downdrift sides of the structure induce seaward and landward components, respectively."

Because of the considerable uncertainty about the primary erosional and depositional mechanisms, a best management plan must seek to identify the local dominant environmental mechanisms and the timing of their actions. In essence, hypotheses must be established about their actions locally, and practices should be designed to accommodate these mechanisms. Further, systematic measurements must be made to document the results of changes made to the system, to update the working hypotheses, and to modify the best practices accordingly.

2.2.1.1 Forces acting in the nearshore.

As part of this BMP, it will be important to understand the environmental mechanisms that cause sand to be deposited and eroded from the beaches along Scientists' Cliffs. Understanding the origin, magnitude, and timing of the constructive and destructive components of these mechanisms is essential to developing practices in direct response to their actions. As noted in the CEM, despite decades of study, there is still considerable uncertainty about the fundamental processes that build and erode beaches (i.e., longshore and cross-shore sediment transport).

Because of this complexity, it is essential that the approach to developing best management practices be based on the Scientific Method. The Scientific Method has been used for centuries by scientists and engineers to define, address, and resolve uncertainty in the natural world. The method can be stated rather simply.

The Scientific Method

- Form an hypothesis.
- Develop a test of they hypothesis.
- Test the hypothesis.
- Modify the hypothesis based on the test results.
- Re-test the hypothesis if necessary.

Engineers have adopted this approach on projects for which considerable uncertainty exists. Existing theories are used to postulate how conditions must be modified to achieve the desired end condition as described by the project's objectives. Tests and/or design elements are implemented and design-specific measurements are made to test the original design assumptions (i.e., hypothesis). The tests and/or designs are modified accordingly and the changes are implemented. Iterations of this process are conducted until the design is optimized.

Over the past seven decades, the gabion groin system at Scientists' Cliffs has been continuously modified. However, reports on the performance of the system have been largely anecdotal and not tied in a meaningful way to the environmental mechanisms that cause beach growth or erosion. Therefore, it is difficult to determine how to immediately optimize the performance of the system.

A main objective of this BMP is to determine the performance of the gabion groin system in terms of its ability to maintain a stable beach that acts to minimize the damage due to wave erosion.

In order to achieve this objective, it is necessary to describe the constructive and destructive "forces" acting on the beaches at Scientists' Cliffs. The term "forces" is used in its common form, (i.e., its efficacy to influence, affect, or control) and "*[E]stablished terminology is that onshore- and offshore-directed forces are referred to as "constructive" and "destructive," respectively* (USACE 2003)."

But, prior to more carefully describing the forces that act to build or erode beaches, it is useful to describe conceptually the beach building and erosion process. Some sand on the beach is virtually always in motion. Even during relatively calm conditions, small waves in the swash zone cause sand to move back and forth. As the intensity of wind, waves, and currents increases, more sand moves in more locations. Sand washes up and down the beach with the waves. It may move in rivulets somewhat parallel to the shoreline as wave wash recedes. Wind may pick up and transport dry sand. Beneath the water surface, waves and currents are also capable of moving sand.

At its most basic, a beach is built when water carries sand above the low water line and deposits it there. Conversely, a beach is eroded when sand is moved from a point above the low water line to a point below it. Simple observations show that water, usually in the form of a breaking or broken wave, carries sand upward onto the beach. During constructive conditions, some of the water percolates into the beach leaving less water (and hence less energy) to carry sand back down to the water line. This typically happens under relatively mild wave conditions. Under these conditions, sand accumulates on the beach.

Sand is eroded from a beach when the outgoing water has sufficient energy remaining to transport not only the sand that came in with the wave (or current), but additional sand that had been previously resident on the beach. This typically happens during storm conditions. A main cause is due to elevated water levels associated with storms that keep the beach constantly saturated, thereby preventing water from percolating into the beach sand and allowing it to remain available to transport sand off the beach. Saturation of the beach sediments is often aggravated during storms due to direct rainfall, storm runoff, and increased groundwater flow.

The problem becomes complex when an attempt is made to distinguish and estimate the environmental parameters that contribute to the flow of the water that is carrying the sediment that erodes or builds the beach. The driving factors include wind speed and direction, water depth, the slope of the nearshore and beach (these factors combine to determine wave height), and, when attempting to determine sediment transport, the size, shape, and density of the particles in transport.

2.2.1.2 Longshore Transport

Sources of sediment into a control volume include longshore transport, cross-shore transport in the onshore direction, contributions from rivers and streams, seaward transport by wind, and erosion of coastal dunes and cliffs. Sources of sediment out of a control volume include longshore transport, cross-shore transport in the offshore direction, shoreward transport by wind, and the washing of sediment over a beach berm.

Longshore currents are produced by waves breaking obliquely to the beach and it is these currents that transport sediment along the shore. Sediment moving in currents is generally considered to be transported as either bed load or suspended load.

In areas where the availability of sand in the nearshore is high, longshore transport is a major mechanism of transport. Most of the sediment moved in the longshore direction occurs in the surf zone and it is this sediment that is mainly responsible for buildup of beaches. Waves breaking at oblique angles to the beach drive the longshore sediment transport process. The direction of the fetches, and the duration and magnitude of the winds along the fetches are the primary factors determining the magnitude and direction of longshore sediment transport (assuming there sediment is readily available for transport).

In the case of Scientists' Cliffs, there are two principal fetch directions (north-northeast and south-southeast) and a minor fetch from the east. Thirty-seven years of hourly wind data measured at Patuxent Naval Air Station between 1945 and 1982 showed winds of all measured speeds blow along the north-northeast fetch (0 to 60 degrees, 40 to 65 mile fetch length) roughly 58 days per year and from the south-southeast (120 to 180 degrees, 40 to 85 mile fetch length) roughly 73 days per year. Winds blow from the east (60 to 120 degrees, 6 to 12 mile fetch length) approximately 33 days per year. Winds blow from non-fetch directions (i.e., 180 to 360 degrees) approximately 200 days per year (Shea 1994).

The most dependable indicator of the long-term predominant (i.e., net) longshore drift direction along the Scientists' Cliffs' portion of Calvert County is sand that is trapped by relatively large, shore-perpendicular structures such as the Great Jetty near the boat ramp at Gate A in Scientists' Cliffs and the jetty at Flag Harbor. Sand has consistently accumulated on the north sides of these structures and the period of record spans decades. Observation of the smaller groins along the Scientists' Cliffs' shoreline shows that the drift direction reverses at times as evidenced by periodic accumulation of sand on the south side of those structures. In 2003, Hurricane Isabel, which had strong winds sustained over the southeast fetch caused the remnants of a wrecked vessel to be transported approximately a mile north of where it had long resided in the swash zone near Gate D at Scientists' Cliffs. The movement of this object indicates that a strong current existed during that storm and its net transport direction was north.

The following excerpt from Coastal Engineering Manual (USACE 2003) describes the variability of longshore sediment transport along a general profile perpendicular to the shoreline.

"In general, the field (and laboratory) studies of longshore transport indicate that (1) significant levels of transport may occur at and above the shoreline, (2) about 10 to 30 percent of the total transport occurs seaward of the breaker line, (3) maximum local transport has been noted within the shoreward half of the surf zone as often as within the seaward half, and (4) greater transport is often associated with shallower depths and breaking waves (i.e., breakpoint bars and the shoreline). Overall, field measurements demonstrate great variability in the shape of the longshore transport distribution profile across shore."

While longshore currents move sediment along the shore in the surf zone, it is cross-shore processes that are primarily responsible for moving sand onto the beach. Forces exerted by waves are discussed below in the cross-shore transport section of this BMP. Generally, the stresses induced by cross-shore forces decrease from the breaker zone to the shoreline, but in a highly variable manner due to the irregularity of the nearshore bottom configuration.

2.2.1.3 Cross-shore Transport

Wave energy is proportional to the square of the wave height. As wave energy is lost, wave height diminishes. Energy imparted to the water is responsible for moving sand. Essentially, constructive forces result in the energy being dissipated in such a way that the net movement of sand is in a direction that causes buildup of the beach.

Conversely, destructive forces dissipate energy in a manner that moves sand away from the beach. Stutz, et. al., (1998), discussed the differing mechanisms of wave dissipation in the nearshore, from the wave shoaling zone, through the surf zone, and into the swash zone.

They found the following:

Zone	Energy Dissipation Mechanisms	Notes
Shoaling zone	• Bottom friction • Percolation into bottom substrate • Bed fluctuations	Dominant mechanism is often a function of lithology
Surf zone	• Turbulence	Turbulence dominates here due to the breaking of waves. It is only significant in the surf zone and the differences in energy dissipation between various types of breaking waves is not well understood.
Swash zone	• Turbulence • Bottom Friction • Percolation to the beach	Bottom friction is strongly non-linear and increases sharply in shallow water. Although a very small percentage of the wave's initial energy, it is wave runup that causes considerable erosion, overtopping, and property damage.

Table 2.1 Nearshore Wave Energy Dissipation Mechanisms
(adapted from Stutz, et. al. 1998)

Note that Table 2.1 describes the mechanisms responsible for dissipating energy in the nearshore zones. However, it does not express whether the dissipation of energy is translated into forces that are constructive or destructive. Relative to shoreline stabilization, the goal is to determine how best to encourage the constructive forces and mitigate the destructive forces. An important issue discussed in Stutz et al. (1998) is the concept of an equilibrium beach profile, which theoretically results due to an equilibrium between wave energy and sediment characteristics. However, "the [beach] profile shape is dominated by wave energy." Because energy dissipation is extremely non-uniform varying widely over both space and time, the notion that an equilibrium profile endures over long periods of time should not be encouraged. For the purposes of this BMP, the concept of an equilibrium profile will only be used when it is introduced in cited research. Because the rate and spatial distribution of energy dissipation is the driving mechanism behind the forces moving sand in the nearshore, to be effective, this BMP must attempt to address the important spatial and temporal characteristics of energy dissipation in the near shore of Scientists' Cliffs.

The following excerpts are from the Coastal Engineering Manual (USACE 2003). All material in italics is extended quotation. Extended quotations are used where USACE establishes the accepted terminology and paraphrasing would detract from the meaning. In those cases where paraphrasing is used (i.e., no italics), concepts have been summarized.

"There are several identifiable forces that occur within the nearshore active zone that affect sediment motion and beach profile response. The magnitudes of these forces can be markedly different inside and outside the surf zone. Under equilibrium conditions, these forces are in balance and although there is motion of the individual sand grains under even low wave activity, the profile remains more or less static. Cross-shore sediment transport occurs when hydrodynamic conditions within the nearshore zone change, thereby modifying one or more of the forces resulting in an imbalance and thus causing transport gradients and profile change. Established terminology is that onshore- and offshore-directed forces are referred to as 'constructive' and 'destructive,' respectively. These two types of forces are briefly reviewed below; however, as will be noted, the term 'forces' is used in the generic sense. Moreover it will be evident that some forces could behave as constructive under certain conditions and destructive under others."

Constructive "Forces"

- Time varying <u>average bottom shear stress due to non-linear waves</u> has a positive value in the shoreward direction.
- *"A second constructive force originates within the bottom boundary layer, causing a net mean velocity in the direction of propagating water waves. This streaming motion was first observed in the laboratory by Bagnold (1940) and has been quantified by Longuet-Higgins (1953) as due to <u>the local transfer of momentum associated with energy losses by friction</u>. For the case of shallow water and a wave height proportional to the breaking depth, this force is shown to be 1.5 times the average of the return flow due to the mass transport."* [Mass transport is the average movement of water mass offshore during onshore winds

and onshore during offshore winds. It is considered constructive for offshore winds and destructive for onshore winds].

- *"Within the surf zone, cross-shore transport may be predominantly due to sediment in suspension. If the suspension is intermittent, occurring each wave period, the average water particle velocity during the period that the particle is suspended determines the direction of cross-shore transport. Turbulence, although also not a true force, can be effective in mobilizing sediment and dependent on whether the net forces are shoreward or seaward at the time of mobilization, can be constructive or destructive, respectively. Dean (1973) noted that suspended sediment can move either onshore (constructive) or offshore (destructive), depending on how high a sand grain is suspended off the bottom. Under the wave crest, if the sediment particle is suspended a distance above the bottom proportional to the wave height H, and if the particle has a fall velocity w, then the time required for the grain to fall back to the bottom would be proportional to H/w. If this fall time is less than one-half of the wave period, then the particle should experience net onshore motion, whereas the particle should move offshore if the fall time is greater than one-half the wave period. While such an approach is overly simplistic, and does not include the effects of mean cross-shore currents, it has been shown that net onshore or offshore sediment transport can be correlated to the so-called fall time parameter H/wT."*

Destructive Forces

- *"Gravity is the most obvious destructive force, acting downslope and in a generally seaward direction for a monotonic profile. However, for the case of a barred profile, gravity can act in the shoreward direction over portions of the profile. Gravity tends to "smooth" any irregularities that occur in the profile. If gravity were the only force acting, the only possible equilibrium profile would be horizontal and sandy beaches as we know them would not exist. It should be recognized, however, that gravity may also serve as a stabilizing force, since sediment particles cannot be mobilized from the bed unless: (a) upward-directed forces associated with fluid turbulence can exceed the submerged weight of the sediment, and/or (b) slope-parallel fluid shear forces can exceed the frictional resistance of sediment. Also, as noted, gravity causes suspended sediment to settle out of the water column, with fall velocity w, which may cause suspended sediment to move shoreward if not suspended too high in the water column."*

- *"Other destructive forces are generally related to the vertical structure of the cross-shore currents. The undertow, the seaward return flow of wave mass transport, induces a seaward stress on the bottom sediment particles."*

- *"It is well-known that associated with wave propagation toward shore is a shoreward flux of linear momentum (Longuet-Higgins and Stewart 1964). When waves break, the momentum is transferred to the water column, resulting in a* *shoreward-directed thrust and thus a wave-induced setup within the surf zone, the gradient of which is proportional to the local bottom slope. This momentum is distributed over depth, as shown in Figure III-3-6* [Figure 2.3]. *In shallow water, linear water wave theory predicts that one-third of the momentum flux originates between the trough and crest levels and has its centroid at the mean water level. The remaining two-thirds originates between the bottom and the mean water level, is uniformly distributed over this dimension, and thus has its centroid at the mid-depth of the water column. Because of the contribution at the free surface, breaking waves induce an equivalent shear force on the water surface which will be quantified later. <u>This causes a seaward bottom shear stress within the breaking zone</u>. The bottom shear stress is dependent on the rate of energy dissipation. This effective shear force due to momentum transfer must be balanced by the bottom shear stress and the pressure forces due to the slope of the water surface."*

- *"Often during major storm events, strong onshore winds will be present in the vicinity of the shoreline. These winds cause a shoreward-directed surface flow and a seaward-directed bottom flow, as shown in Figure III-3-7* [Figure 2.4]. *Of course, seaward-directed winds would cause shoreward-directed bottom velocities and thus constructive forces. Thus, landward- and seaward-directed winds result in destructive and constructive forces, respectively. "*

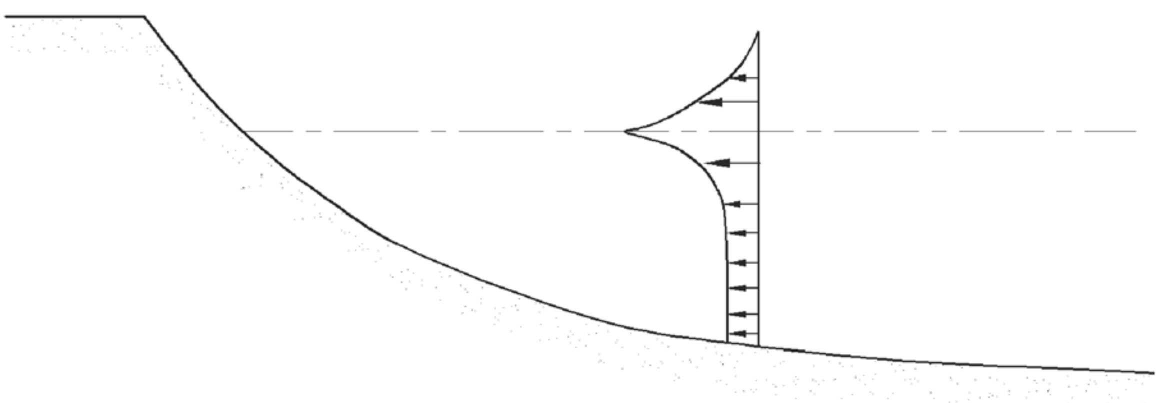

Figure 2.3 Distribution Over Depth of the Flux of the Onshore Component of Momentum

[Above figure is Figure III-3-6 from USACE 2003]

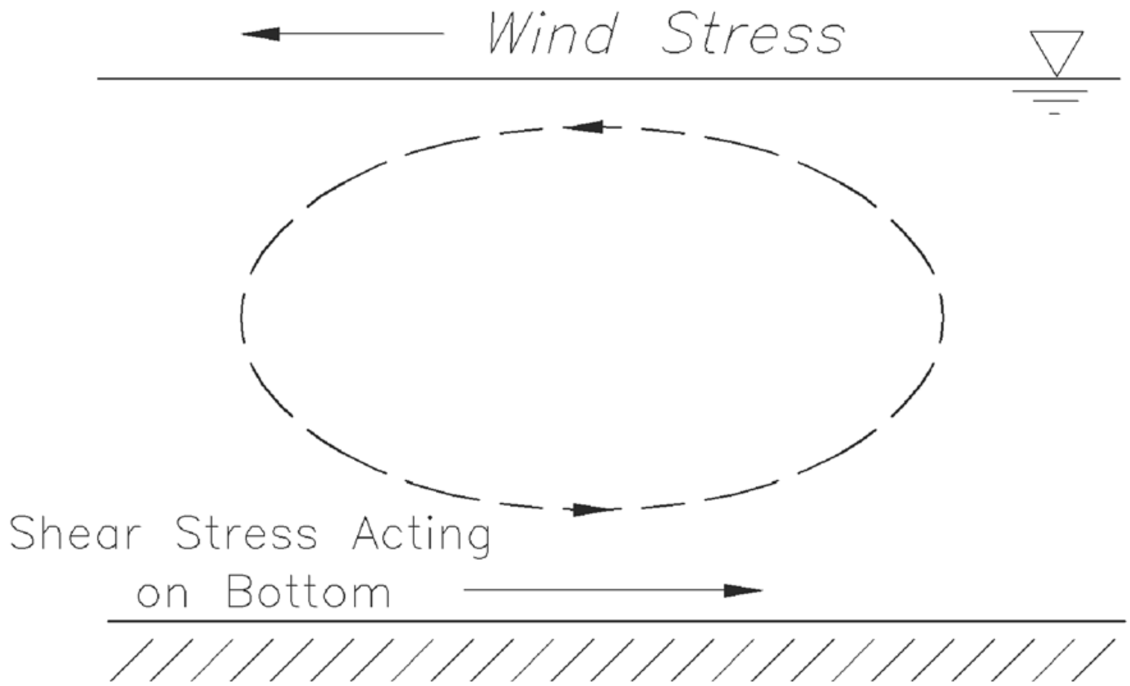

Figure 2.4 Bottom Stresses Caused by Surface Winds

[Above figure is Figure III-3-7 from USACE 2003]

"Table III-3-1 [Table 2.2] *summarizes the mechanisms identified as contributing to constructive and/or destructive forces and, where possible, provides an estimate of their magnitudes. For purposes of these calculations, the following conditions have been considered: an equilibrium beach profile with a grain size of D = 0.2 mm, h = 1 m, H = 0.78 m, T = 8 s, ε = 0.04 m2/s, wind speed = 20 m/s.* [The assumed conditions are those associated with storms]. *It is seen that of the bottom stresses that can be quantified, those associated with undertow due to mass transport and momentum flux transfer are dominant."*

Table III-3-1 Constructive and Destructive Cross-shore "Forces" in Terms of Induced Bottom Shear Stresses			
Constructive or Destructive	Description of Force	Magnitude of Force (N/m^2)	
		Breaking Waves	Nonbreaking Waves
Constructive	Average Bottom Shear Stress Due to Nonlinear Waves[1]	0.84	0.84
	Streaming Velocities[2]	28.9	28.9
	Overtopping	28.6	28.6
Destructive	Gravity[3]	0.046	0.046
	Undertow Due to Mass Transport	28.6	28.6
	Undertow Due to Momentum Flux Transfer	7.9	0
Constructive or Destructive	Intermittent Suspension	?	?
	Turbulence	Relatively Large	Relatively Small
	Wind Effects[4]	0.95	0.95

Notes:
For the calculations resulting in the values in this table: H = 0.78 m, h = 1.0 m, T = 8 s.
[1] f = 0.08
[2] $\varepsilon = 0.04\ m^2/s$
[3] Equilibrium profile with D = 0.2 mm
[4] Wind speed = 20 m/s.

Table 2.2 Constructive and Destructive Cross-shore "Forces" in Terms of Induced Bottom Shear Stresses

[Table 2.2 above isTable III-3-1 from USACE 2003.]

Table 2.3 begins to link actions or practices to their effects on mitigating destructive forces and encouraging constructive forces. For instance, recall from Table 2.2 that streaming velocities and overtopping are significant constructive forces for both breaking and non-breaking waves. Groins and beach profiles that cause onshore flows carrying sediment to lose energy will cause sand to accumulate on the beach. Groins that are poorly designed or constructed may aggravate destructive forces like return flow undertow. The last column in Table 2.3 suggests practices that directly address the constructive and destructive forces active along a shoreline.

Table 2.3 follows:

Mechanism	Constructive or Destructive	Strong Function of:	Relative Contribution to Transport		Comment	How to Encourage or Mitigate
			During Storms	Milder Periods		
Shoreward directed bottom shear stress due to non-linear waves	Constructive	Wave height (water depth), wind speed, direction, and duration	Small	Moderate	Sand moving alongshore is intercepted and carried onto beach	Implement techniques to encourage sand moving onto beach to remain. For instance: 1) Regularly adjust groin elevations in swash zone to surrounding beach elevation to discourage localized currents adjacent to groins. 2) minimize contribution of storm runoff directly to beach so that incoming water percolates into beach allowing incoming sand to remain.
Transfer of momentum associated with energy losses by friction	Constructive	Wave Height	Large	Small	Can be 50 percent greater than return flow due to mass transport (below) Momentum loss occurs when water encounters rough, irregular surfaces and objects	Encourage smooth flow of water in longshore transport zone between groins. Regularly adjust groin elevations in swash zone to surrounding beach elevation. Encourage momentum loss to occur on the beach above the swash zone to the beach crest and beyond or to slope toe by encouraging vegetation on the beach. Shore parallel gabion baskets abuting the slope toe will also cause loss of momentum high on the beach during storms which will cause sand to fall out of suspension there.

Mechanism	Constructive or Destructive	Strong Function of:	Relative Contribution to Transport		Comment	How to Encourage or Mitigate
			During Storms	Milder Periods		
Undertow - Seaward return flow of wave mass transport	Destructive unless waves "overtop" beach – then constructive	Wave Speed	Large	Small	A goal is to diminish the magnitude and velocity of the flow returning to the Bay after washing over the beach.	Encourage percolation of water into beach. Encourage beach vegetation, particulary where beach crests are present. Attempt to redirect water that has runup the beach to directions other than directly back down the beach. Groins notched in the swash zone may partially disrupt return flow and diminish undertow.
Undertow due to shoreward flux of linear momentum transferred to water column by breaking waves. Results in seaward directed shear stress in the breaking zone	Destructive	Breaking Wave Energy Wave height (water depth), wind speed, direction, and duration	Moderate	Small	The net linear momentum directed Bayward from waves breaking in the nearshore to the swash zone moves sand Bayward from that zone (i.e., zone of maximum longshore transport) often causing that sand to be lost to the beach system.	Maximize the capacity of groins to break storm waves and disrupt Bayward momentum of water. Consider using T-shaped groin-ends (discussed in Section 5 of this BMP) to break waves outside of nearshore during strong northeastern or southeastern storms.

Mechanism	Constructive or Destructive	Strong Function of:	Relative Contribution to Transport		Comment	How to Encourage or Mitigate
			During Storms	Milder Periods		
Turbulence	Destructive during storms (i.e., shorter wave periods) and constructive during milder conditions (longer wave periods)	Vertical fall velocity of sediment grains entrained by turbulence (grain size, density). Water depth Wave frequency and height Wind speed, direction, and duration	Uncertain	Uncertain	As waves pass by, turbulence occurs in the water column. Turbulence reaches a maximum as the wave crest passes and a minimum in the troughs. If a sediment grain can fall to the bottom prior to the next wave passing, it is likely to become unavailable for transport by currents.	During mild periods, turbulence will suspend sediment grains in water as it approaches the swash zone. Incoming waves will move this suspended sediment shoreward. Encourage deposition of this sediment by enhancing percolation into the beach and minimizing over-sand return flow Notched groins may partially suppress effects of turbulence.
Bottom flow moving in direction opposite to wind direction	Constructive during offshore winds (generally not storms). Destructive during onshore winds (NE & SE storms in Bay generally have onshore wind component.	Wind speed and direction	Small	Small		Implement techniques to encourage sand moving onto beach to remain. For instance: 1) Regularly adjust groin elevations in swash zone to surrounding beach elevation to discourage localized currents adjacent to groins. 2) minimize contribution of storm runoff directly to beach so that incoming water percolates into beach allowing incoming sand to remain.

Table 2.3 Linking the Causes of Constructive and Destructive Forces to Shoreline Best Management Practices

As noted throughout this section, because of the complex mix of mechanisms that cause any specific beach to build or erode, and because the proportional contribution of any particular mechanism differs depending on weather conditions and the existing configuration of the shoreline (i.e., temporal variation), accurate prediction of the response of a beach to the construction or modification of a shoreline structure is burdened with considerable uncertainty.

However, groins and jetty systems have been used for many years to manage beaches. Table 2.4 takes advantage of years of observations to evaluate commonly held notions concerning elements or aspects of groins and jetties and whether experience confirms or rebuts these notions.

Some aspects of groins important to Scientists' Cliffs' beach management include:

- Groins should be permeable
- When practicable, newly constructed groin fields should be filled to minimize downdrift erosion
- It is unlikely that groins cause erosion of the offshore profile

Property	Comment
Wave angle and wave height are leading parameters (longshore transport)	Accepted. For fixed groin length, these parameters determine bypassing and the net and gross longshore transport rates.
Groin length is a leading parameter for single groins. (Length controls depth at tip of groin.)	Accepted, with groin length defined relative to surf zone width.
Groin length to spacing ratio is a leading parameter for groin fields.	Accepted. See previous item.
Groins should be permeable.	Accepted. Permeable groins allow water and sand to move alongshore and reduce rip current formation and cell circulation.
Groins function best on beaches with predominant longshore transport direction.	Accepted. Groins act as rectifiers of transport. As the ratio of gross to net transport increases, the retention functioning decreases.
The updrift shoreline at a groin seldom reaches the seaward end of the groin.	Accepted. Because of sand bypassing, groin permeability, and reversals in transport, the updrift shoreline cannot reach the end of a groin by longshore transport processes alone. Onshore transport is required for the shoreline to reach a groin tip, for a groin to be buried, or for a groin compartment to fill naturally.
Groin fields should be filled (and/or feeder beaches emplaced on the downdrift side).	Accepted. Filling promotes bypassing and mitigates downdrift erosion.
Groin fields should be tapered if located adjacent to an unprotected beach.	Accepted. Tapering decreases the impoundment and acts as a transition from regions of erosion to regions of stability.
Groin fields should be built from the downdrift to updrift direction.	Accepted, but with the caution that the construction schedule should be coordinated with expected changes in seasonal drift direction.
Groins cause impoundment to the farthest point of the updrift beach and erosion to the farthest point of the downdrift beach.	Accepted Filling a groin field does not guarantee 100% sand bypassing. Sand will be impounded along the entire updrift reach, causing erosion downdrift of the groin(s).
Groins erode the offshore profile.	Questionable and doubtful. No clear physical mechanism has been proposed.
Groins erode the beach by rip-current jetting of sand far offshore.	Questionable. Short groins cannot jet material far offshore, and permeable groins reduce the rip-current effect. However, long impermeable jetties might produce large rips and jet material beyond the average surf zone width.
For beaches with a large predominant wave direction, groins should be oriented perpendicular to the breaking wave crests.	Tentatively accepted. Oblique orientation may reduce rip current generation and provide more sheltering.

Table 2.4 Functional Properties Attributed to Groins and their Critical Evaluation.

(From Basco and Pope 2004).

Groin(s)	Beach and Sediment	Waves, Wind, and Tide
Length Elevation Porosity Configuraton (straight, T, L, etc.) Orientation to the shoreline Spacing between groins Tapering	Depth at tip of groin Depth of closure Sediment availability Median grain size and variability	Wave height, period, and angle and their variability Tidal range and variability Wind speed, direction, and duration and their variability

Table 2.5 Main Parameters Governing Beach Response and Bypassing at Groins (Adapted from Basco and Pope 2004).

2.2.2 Concepts to Carry Forward Into Best Management Practices

The objective of Section 2.2 has been to establish an understanding of the environmental mechanisms that cause beaches to build and erode, to link key aspects of the environmental mechanisms to practices specific to Scientists' Cliffs, and to provide a basis for undertaking specific best practices that are based on the driving mechanisms in a way whereby the performance of those changes can be measured and directly tied to the underlying mechanisms.

As a result, there are several key concepts that will be carried out of this section and into Section 5 where the best management practices are discussed and integrated into an overall plan that also considers slope erosion management, sensitive species, fiscal and aesthetic concerns of the community, and which can be conducted sensibly within the existing regulatory environment.

Those key concepts include:

- The length to spacing ratio of the groins in the groin system is important. SCA has recognized this for years and has acted to optimize this ratio. If changes are made as part of future practice to this ratio, the effects on the beach should be directly measured.
- Porous groins are an important feature of groin fields. Scientists' Cliffs has some remnant structures that are relatively non-porous. The groin system maintenance program should systematically remove the non-porous structures and optimize the porosity of existing groins. In addition to the gabion-style construction, notching of groins in the swash zone should be considered.

- Future practices should focus specifically on those aspects of the groins and jetties that encourage the constructive forces described above and discourage the destructive forces. Any modifications to groins or the overall system should be evaluated in with specific consideration as to how they may affect the balance of constructive vs. destructive forces. For instance, it appears that the current groin configuration suffers from destructive forces from strong storms with winds from the south. Measurements of the effects of these practices should be made in conjunction with the changes.
- Beach filling an accepted part of good beach stabilization and restoration practice when major new groin or jetty construction is undertaken.
- Changes to the groin system should be conducted moving from downdrift to updrift.
- Beach vegetation helps to secure stable beaches and diminish wave energy resulting in constructive conditions.

2.3 Section 2 References:

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16 May 2002 - Parts I-IV and Appendix A have been officially released as U.S. Army Corps of Engineers guidance.

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Section 3: Past and current beach and slope stabilization practices

3.1 Community Historical Practices and Observations

Scientists' Cliffs was founded in 1935 by a group of scientists studying chestnut blight. The group expanded to include other scientists and professional persons with like interests. They built rustic cabins and generally preserved a rustic setting, which became the culture of the community. Through the years since the 30's, efforts to preserve the beach, cliffs and ravines have been constant, first as individuals, then as a community. Two resident scientists, Dr. Leonard Schultz and Wallace Ashby, made observations and studies over many years of the nature of beach and cliff erosion and the effectiveness of existing groins. In 1967 they produced a paper titled, "An Analysis of an Attempt to Control Beach Erosion in Chesapeake Bay, at Scientists' Cliffs, Calvert County, Maryland". Wallace Ashby was chairman of the Beach Committee during this time. Members followed their lead in taking action to preserve the beach and cliffs through construction of groins along the bay, and through plantings on the cliff face. John O'Neill became an educated observer of the wave action on the beach and led an initiative in furthering the concept of groins in beach stabilization. He was chairman of the Beach Committee in the 1970's and early 1980's. The Army Corps of Engineers and other experts were consulted on the methods used to construct these groins.

3.2 Beach Erosion and Stabilization

Early groins were made of stake and whaler (posts with vertical boards in between connected by horizontal timbers), originating at the cliff face and continuing into the water at various lengths. Later, well rings were placed in a line from the cliff face to the water. These were easier to install, but not as effective in building and maintaining a beach. Between 1947 and 1960, 15 groins were constructed along the shoreline. In 1952 a Great Jetty was installed at south beach. A boat ramp was built next to the Great Jetty in the lee to the south. In 1954, Hurricane Hazel removed large quantities of sand from the beach, which was not easily replenished. This permitted the waves to expose the base of the cliff to erosion in certain areas. For example, at the far southern end of the property the blue marl clay receded more than 12 feet between 1954 and 1962. In 1962, the Scientists' Cliffs Association authorized a long-term program of groin construction, which included 54 groins to be spaced 150 to 200 feet apart and to extend into the bay from 60 to 75 feet. By the end of 1966, 45 groins were in various stages of completion. Nine groins which had been in use 7 years or longer had collected enough sand to allow debris to accumulate along the slope toe thereby protecting slope toes of the cliffs. Twenty-seven groins had stabilized the beach at a useable level, but not high enough to afford sufficient protection of the slope toe. Nine groins in use less than 4 years had not built up a beach. (Schultz 1967) The Great Jetty was enlarged and extended to 239 feet in 1964. This stone jetty was built to stabilize a road to the beach and a parking area. However, it began to build a wide beach tapering to the north.

With the success of early efforts to preserve the beach through groins, a Beach and Cliffs Committee was formed to oversee the groin system along the SCA shoreline. The maintenance of existing groins and the addition of new ones became part of the annual operating budget of SCA. The budget was used for materials and community volunteers under the direction of the paid community staff did work. The introduction of gabions (wire cages filled with rock) became the preferred material for constructing groins. The cages came in several lengths and could be stacked on top of each other to raise the height of the groin as the beach rose or the basket sunk in the sand. This is the material used at present.

Maintaining groins along the beach is an ongoing project. First, the old well rings are breaking up and exposing wire that presents a hazard to beachcombers and swimmers. Second, gabion cages must be replaced periodically due to rusting or storm wave action that breaks them open. Other maintenance is performed to raise or lower the profile of the groin to afford better sand retention. The community still uses volunteers with the support of the community manager and staff to do this work. Members of the Beach and Cliffs Committee survey the beach continually and prepare an annual repair and maintenance schedule that is factored into the committee's annual budget request.

3.3 Slope Erosion and Stabilization

The community was conceived initially for summer time recreational use. Dwellings were rustic log cabins without insulation or heat. They had individual septic systems, but a central water supply. Several cabins on the cliff front were constructed with the septic drain fields in the back yard next to the bay. After at least one plumbing mishap that caused the cliff face to slide, this septic drain field location was abandoned.

Most slides were caused by erosion of the cliff at the toe. This led to the effort to develop the groin system to build up the beach and lessen the direct wave action against the cliff. Of course, major storms and hurricanes, starting with Hazel in 1954, and ending with Isabel in 2003 have done serious damage to the beach. Compared with other sections of the Calvert Cliffs, such as the sections south of Parker's Creek and north of Governors Run, Scientists' Cliffs has sustained less erosion. The most consistent observation following a major storm is that the cliff face will vegetate within a year to eighteen months and the beach will replenish the sand. The talus that sloughs off during the freeze-thaw cycle during the winter months will remain to insulate the toe of the cliff until the next big storm. The result is less of a vertical angle to the cliff face where the groins exist as a system.

Over the years, the community has created special committees to address erosion on the cliffs. Following a banner year for landslides in 1979 due to freak snow storms, freezes and rains, the President and Board at Scientists' Cliffs created an Erosion Committee to re-examine the erosion problem and recommend remedies. Dr. Peter Vogt, an earth scientist and community resident was appointed chairman. He set out to collect data on cliff erosion from cliff-front property owners. In 1980 he distributed a questionnaire. The questionnaire asked for measurements or estimates of erosion and efforts used to slow it. The responses were provided to the Board. The average cliff retreat rate corresponded to the rate the Maryland Geological Survey reported and later measurements made in subsequent studies reported in this BMP.

In 1994 an ad hoc Cliffs Preservation Committee was created. Membership was comprised of a representative from each of the gates and a few at-large persons. Two sub-committees were formed; Erosion and Vegetation. The Erosion sub-committee reported to the community after six months study in July 1995. In brief, their conclusions were that there is no sand in the bay that contributes to the beaches. The beach is from the community's own cliffs plus some sand coming from the north to Parker's Creek. The consensus was that the groins have helped hold the local sand in place longer than usual, but require constant maintenance and may not be the best designed by today's technology. The group concluded that "whatever we do in the future should be in the form of a long-range plan with target dates for implementation, and submittal for approval." The Vegetation sub-committee considered the following questions: Would seeding the face of the cliffs have any effect on cliff erosion? If seeding would be effective, what species should be used, and what initial steps might be taken? The sub-committee identified several vegetative species and suggested doing some experiments in an area six feet square. Some of the species suggested were switchgrass (panicum virgatum), eastern gammagrass (tripsacum dactyoides), tall fescue (festuca arundinacea), ventiver grass (vetiteria zizanioides), reed grass (phragmites australis), and sericea lespedeza. However, the group stated that the primary problem is not the vegetative cover but the freezing and thawing taking place at the base of the cliff.

There are 75 cliff front homes at Scientists' Cliffs. Individual owners have tried various means to slow the erosion of their yards. Many have channeled storm water run-off into drains.

Dr. Leonard Shultz planted wild roses on the cliff face as far down as he could reach. Others have thrown grass seed and planted other vegetation to hold the edge. Many owners have removed trees that were on the edge and in danger of falling into the bay. One owner thirty years ago brought in kudzu and planted it on the cliff. The community is still trying to eradicate it. All cliff front owners are looking for the best way to protect the cliff from excessive erosion. Many in the community have been lived here long enough to see the effect of decades of erosion. Several of the early cabins are now literally a few feet from the edge. Some cliff-front owners have constructed revetments at the cliff base in front of their property using wire cages filled with rock in a stair step construction.

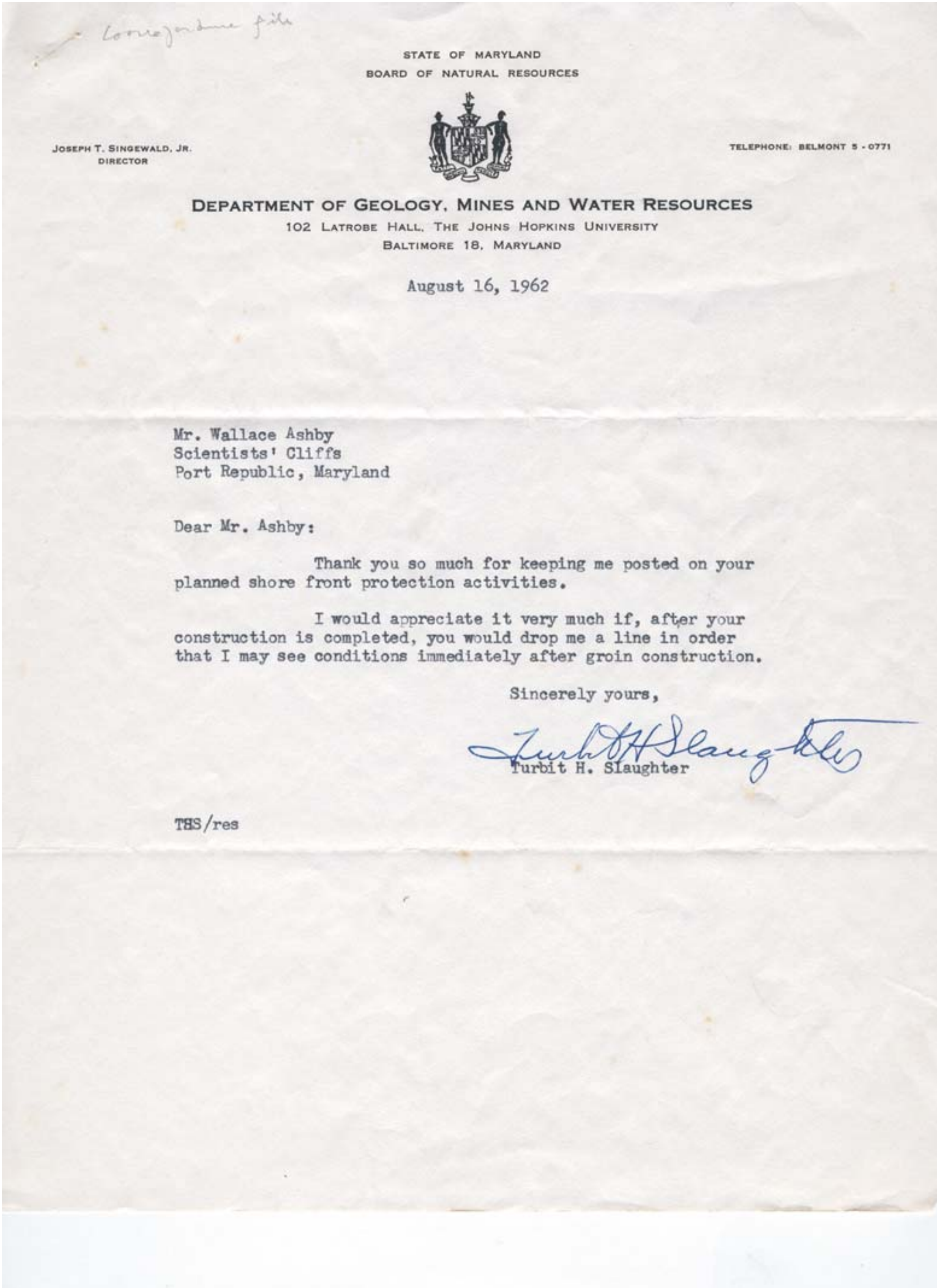
3.4 History of Regulatory Consultation

Beach Committee leadership has sought information and expertise from many sources over the years, especially from regulatory agencies. Wallace Ashby contacted the Johns Hopkins University, Department of Geology, Mines and Water Resources for consultation and assistance on shore erosion. The Department sent a team on a site visit to inspect Scientists' Cliffs' shoreline and wrote a plan of consideration, including construction criteria. (See attached correspondence)

On several occasions, representatives from the Army Corps of Engineers have met with SCA leaders to discuss and evaluate efforts to control erosion on the cliffs and beach. For example, in November 1969 a corps member met with the Beach Committee. Mr. O'Hagan outlined the Army Engineer's position regarding the general problem of Chesapeake Bay erosion control. He pointed out that the beach and cliff erosion has been a continuing process for many hundreds of years that cannot be stopped with less than very expensive erosion control measures. Having said that, Mr. O'Hagan was much impressed with the results Scientists' Cliffs had been able to achieve with the groins. In most of the areas, they were, in his opinion, helping to maintain some beach sand as well as prevent erosion of the cliffs. He also suggested the community might want to truck in additional sand to augment the natural supply in this critical area (see attached correspondence Figures 3.1 and 3.2).

Since the introduction of critical areas controls in 1989, and the designation of local beetle species as endangered, new procedural requirements have complicated access to technical assistance and interaction with experts. Advice and guidance on planting proper vegetation, erosion control measures, storm water management and even maintenance of established structures is contingent on securing permits. While authorities are helpful, identifying the appropriate agency and the correct process to follow, and interpreting regulations has proven difficult. Scientists' Cliffs members have found themselves uncertain about continuing work they have been doing for decades, or unable to continue with the work in a timely manner. Review and approval of permit requests can take months.

The community agreed in 2003 that a comprehensive plan to treat the shoreline as one system was needed. This plan would be scientifically developed and become the basis for all future actions taken to preserve the cliffs and beach at Scientists' Cliffs.


Correspondence file

STATE OF MARYLAND
BOARD OF NATURAL RESOURCES

JOSEPH T. SINGEWALD, JR.
DIRECTOR

TELEPHONE: BELMONT 5 - 0771

DEPARTMENT OF GEOLOGY, MINES AND WATER RESOURCES
102 LATROBE HALL, THE JOHNS HOPKINS UNIVERSITY
BALTIMORE 18, MARYLAND

August 16, 1962

Mr. Wallace Ashby
Scientists' Cliffs
Port Republic, Maryland

Dear Mr. Ashby:

Thank you so much for keeping me posted on your planned shore front protection activities.

I would appreciate it very much if, after your construction is completed, you would drop me a line in order that I may see conditions immediately after groin construction.

Sincerely yours,

Turbit H. Slaughter

THS/res

Figure 3.1 Correspondence Between Scientists' Cliffs and Maryland's Department of Geology, Mines, and Water Resources (1962) correspondence file

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1715
BALTIMORE, MARYLAND 21203

NABEN-B

4 December 1969

Mr. J. B. Feagin
207 Poplar Drive
Falls Church, Virginia 22046

Dear Mr. Feagin:

In response to your request of 29 October 1969, Mr. John P. O'Hagan of this office met with you and other members of the Scientists' Cliffs Association on 19 November 1969 to inspect the erosion area described in your letter.

Inspection of the shoreline showed that the groins that have been constructed on the northerly and southerly ends of the shorefront property have built up a reasonably wide beach that is protecting Scientists' Cliffs. Because the groins located in a 1,000-foot reach near the midpoint of the property, however, are in need of repairs, no beach has accreted in this area and consequently erosion of the cliffs is occurring. On the day of the inspection waves were striking well above the base of the cliff. It is for this reach that you requested our advice and guidance.

Based on information furnished by members of the Association, it appears that the sand offshore is too fine to be effectively used as beach material; and because of the inaccessibility of the problem area, truck haul of sand would be extremely costly. Since the Association actually desires a beach as well as protection of the cliffs, rehabilitation of the existing groins or construction of new groins would be a prudent solution to the problem based on the success and costs of the groins constructed to date by the Association.

Inclosed for your information are some general suggestions on bank protection and beach preservation. If you should have any further questions, please do not hesitate to call on me.

Sincerely yours,

W. J. Love

W. J. LOVE
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Figure 3.2 Correspondence Between Scientists' Cliffs and the U.S Army Corps of Engineers (1969)

Section 4: The Regulatory Environment and Applicable Requirements

4.1 Federal, State, and County Laws and Regulations

There are a number of Federal, state, and county laws and regulations that affect the scope and timing of activities the SCA undertakes to stabilize the shoreline and minimize coastal slope erosion. Compliance is one of the main reasons a plan is necessary for documenting the needs, bases, and analyses that are used to formulate the nature of the actions to be implemented along the shoreline. Because there are a number of agencies involved with a range of goals intended to be accomplished through regulation, maintaining compliance can be a complex task.

Generally, the various governmental goals range from ensuring continued navigability to protection of endangered species and shared high-quality natural resources. Many of the stated regulatory goals are also general goals of the community and, as such, there is considerable compatibility between the two.

The intent of this section is to describe the legal and regulatory constructs with which actions undertaken by the community must comply and to establish the basis for the compliance protocol developed for the permitting of specific actions executed as a result of this BMP. An overall goal of this BMP is to streamline and expedite the compliance process for actions undertaken by Scientists' Cliffs to stabilize the beaches and minimize the coastal slope erosion.

The flow of intent, authority, and funding for instituting regulatory oversight of development and construction activities along the coastal zones of the United States is from the Federal level through the states to the local levels. The following discussion is structured to follow that flow and will discuss the following laws, programs, and ordinances:

- Federal
    - Section 10 of the River and Harbors Act
    - Section 404 of the Federal Water Pollution Control Act, commonly known as the Clean Water Act
    - The Coastal Zone Management Act of 1972 as amended through P.L. 104-150, The Coastal Zone Protection Act of 1996
    - The Endangered Species Act
- State
    - Maryland's Coastal Zone Management Program
    - The Critical Areas Act of 1984
    - Natural Resources Article, Sections 8-1001 through 8-1008 as amended through 1998
- County

- Calvert County Zoning Ordinance

While the Federal and State governments retain authority to regulate many of the actions undertaken along Calvert County's shoreline, the vast majority of the regulations affecting actions taken along the shoreline are established by the Coastal Zone Management Act and are implemented through the Calvert County Zoning Ordinance.

4.1.1 Federal Laws and Regulations

4.1.1.1 Section 10 of the River and Harbors Act

The Rivers and Harbors Act, Section 10 (33 U.S.C. 403), requires authorization from the U.S. Army Corps of Engineers (USACE) for the construction of any structure in or over any navigable waters of the United States, the excavation/dredging or deposition of material in these waters, or any obstruction of or alteration in a "navigable water" (see below). Work outside the limits defined for the navigable waters of the U.S. require a “Section 10 permit” if the structure or work affects the course, location, condition, or capacity of the water body.

“Navigable waters of the United States” are those subject to the ebb and flow of the tide which are presently used, or have been used in the past, or are susceptible for use to transport interstate or foreign commerce. The term includes coastal and inland waters, lakes, rivers and streams that are navigable, and the territorial seas. 33 CFR Part 329. Structures or work are in navigable waters of the United States if they fall within the definitions provided below. Chesapeake Bay is considered navigable waters for the purposes of Section 10 permitting.

“Waters of the United States” are defined in 33 CFR Part 328: they include more than navigable waters of the United States and are the waters where permits are required for the discharge of dredge or fill material pursuant to Section 404 of the Clean Water Act.

“Structures” within the meaning of this Act include but are not limited to piers, boat docks, boat ramps, wharfs, breakwaters, bulkheads, revetments, ripraps, jetties, permanent mooring structures, power transmission lines, permanently moored floating vessels, pilings, aids to navigation, or any other obstacle or obstruction to the waterway. 33 CFR Part 329.

“Work” means, without limitation, any dredging or disposal of dredged material, excavation, filling, or other modification of a navigable water of the United States. 33 CFR Part 329.

“Individual permit” means an authorization by the USACE that is issued following a case-by-case evaluation of a specific structure or work in accordance with established procedures, 33 CFR Part 320, and a determination that the proposed work or structure is in the public interest.

A Section 10 permit issued by the USACE is required for structures and/or work in or affecting navigable waters of the United States except as provided at CFR Part 322.4 (below). If an activity is not exempted by Part 322.4 or otherwise, an individual Section 10 permit is required for the proposed activity.

Activities **not** requiring a Section 10 permit (i.e. **exempt** under 33 CFR Part 322.4):

- Bridges or causeways - includes highways, railroad, and foot bridges as well as aqueducts, aerial tramways, conveyers, and overhead pipelines. It does not include power transmission lines, communication cables, submerged pipelines or tunnels. Bridges do, however, require authorization for discharges or fill material under Clean Water Act (CWA) Section 404.
- Wharves and piers – to avoid requiring a Section 10 permit, must be located on water wholly within a single state and determined navigable, and not have an unacceptable impact on navigation.
- Hydropower facilities licensed by the Department of Energy, but discharges of dredged or fill material associated with these facilities do require a CWA Section 404 permit.
- Floating recreational facilities at USACE owned reservoirs.
- USACE civil works projects.
- CERCLA (Superfund) cleanup actions.

Generally, a Section 10 permit will be required for activities such as maintaining the groin system, installing engineered structures to minimize slope erosion if the structures extend into the tidal zone, installing or repairing the boat ramp, etc. Section 10 and the Clean Water Act (CWA) Section 404 overlap in some activities, mostly involving wetlands. Permits for activities regulated under both are processed simultaneously by the USACE. There is a Joint Federal/State Permit Application for proposed activities in jurisdictional wetlands and waterways which requires the applicant's certification that the proposed activity for which Federal permits are being sought also will be conducted in a manner consistent with Maryland's CZMP (see Section 4.1.1.3).

4.1.1.2 Section 404 of the Clean Water Act (i.e., Federal Water Pollution Control Act)

Section 404 of the Clean Water Act (33 U.S.C. 1344) establishes a program to regulate the discharge of dredged and and fill material into waters of the United States, including wetlands. Activities in waters of the United States that are regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry.

Under CWA Section 404, no discharge of dredged or fill material can he permitted if a practicable alternative exists that is less damaging to the aquatic environment or if the nation's waters would be significantly degraded. In other words, when you apply for a permit, you must show that you have:

- taken steps to avoid wetland impacts where practicable
- minimized potential impacts to wetlands
- provided compensation for any remaining, unavoidable impacts through activities to restore or create wetlands.

According to the USEPA,

"*For regulatory purposes under the Clean Water Act, the term wetlands means "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.*" (http://www.epa.gov/owow/wetlands/what/definitions.html accessed 08 January 2006).

According to USACE (2006), a Federal permit is not required for projects that are above high tide.

Regulated activities are controlled by a permit review process. An **individual permit** is usually required for potentially significant impacts. However, for most discharges that will have only minimal adverse effects, the USACE often grants up-front **general permits**. These may be issued on a nationwide, regional, or state basis for particular categories of activities (for example, minor road crossings, utility line backfill, and bedding) as a means to expedite the permitting process.

Section 404(f) exempts some activities from regulation, such as many ongoing farming, ranching, and silviculture practices.

Agency authority under CWA Section 404:

The USACE administers the day-to-day program, including making individual permit decisions and jurisdictional determinations, develops policy and guidance, and enforces Section

404 provisions. The U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and state resource agencies have important advisory roles.

EPA develops and interprets environmental criteria used in evaluating permit applications, determines scope of geographic jurisdiction, approves and oversees state assumptions, identifies activities that are exempt, reviews/comments on individual permit applications, has authority to veto the USACE's permit decisions (Section 404[c]), can elevate specific cases (Section 404[q]), and enforces Section 404 provisions.

CWA's Section 404 Individual Permit Process:

While it is likely that the activities conducted under this BMP will be permitted using the Joint Application process, the individual permit process for a CWA Section 404 permit is described here for the sake of thoroughness and because there may be times when an individual permit application review is required under the Joint Application process protocol.

Public notice is issued by the USACE within 15 days of receiving all permit information. The public notice describes the permit application, including the proposed activity, its location, and potential environmental impacts. The public notice invites comments within a specified time.

The **comment period** is 15 - 30 days, depending on the proposed activity.

The application and comments are reviewed by the USACE and other interested Federal and state agencies, organizations, and individuals. The USACE determines whether an Environmental Impact Statement is necessary.

A **public hearing** may be held at the request of any interested citizen, but they are not normally held and not required by law. The USACE evaluates the permit application based on the comments received, as well as its own evaluation.

A **Statement of Finding,** which explains how the permit decision was made, is available to the public. A USACE district engineer's decision on a permit denial or a declined individual permit is subject to administrative appeal by the affected party in accordance with the procedures contained in 33 CFR Parts 320, 326, and 331.5. See also "*33 CFR Parts 320, 326, and 331, Administrative Appeal Process*, *Establishment for the Regulatory Program of the Corps of Engineers; Final Rule,"* Federal Register, March 9, 1999.

4.1.1.3 Coastal Zone Management Act of 1972 (CZMA), as amended through P.L. 104-150, The Coastal Zone Protection Act of 1996:

Recognizing the increasing pressures of over-development upon the nation's coastal resources, Congress enacted the Coastal Zone Management Act (CZMA) in 1972. The CZMA encourages states to preserve, protect, develop, and, where possible, restore or enhance valuable natural coastal resources such as wetlands, floodplains, estuaries, beaches, dunes, barrier islands, and coral reefs, as well as the fish and wildlife using those habitats. A unique feature of the CZMA is that participation by states is voluntary. To encourage states to participate, the act makes Federal financial assistance available to any coastal state willing to develop and implement a comprehensive coastal management program. The Federal law with the widest application to activities at Scientists' Cliffs is the Coastal Zone Management Act.

Administration of the CZMA has been delegated to the National Oceanic and Atmospheric Administration (NOAA)'s Office of Ocean and Coastal Resource Management (OCRM), which administers individual state programs. In addition to resource protection, the CZMA specifies that coastal states may manage coastal development. A state with an OCRM-approved program can deny or restrict any development that is inconsistent with its coastal zone management program.

"The CZMA requires that Federal actions which are reasonably likely to affect any land or water use, or natural resource of a state's coastal zone, be conducted in a manner that is consistent with a state's Federally approved Coastal Zone Management Plan (CZMP)" (MDNR, 2004). The procedures used by the State of Maryland to implement the Federal consistency requirement are summarized in Section 4.2.3 of this BMP and more fully described in '*A Guide to Maryland's Coastal Zone Management Program Federal Consistency Process*,'(MDNR, 2004).

The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) amended the CZMA to clarify that **Federal consistency requirements apply** when any Federal activity, regardless of location, affects any land or water use or natural resource of the coastal zone. CZARA also clarified that coastal effects include cumulative and secondary effects: *". . .therefore, the term "affecting" is to be construed broadly, including direct effects which are caused by the activity and occur at the same time and place, and indirect effects which may be caused by the activity and are later in time or farther removed in distance but are still reasonably foreseeable."* (H.R. Conference Report No. 964, 101st Congress, 2d Session, 970-72.)

Much of the CZMA and its amendments, found at 16 U.S.C. Section 1456, are implemented through the County's zoning ordinances. Therefore, activities affected by the CZMA are coordinated and permitted through the Calvert County, and through the joint application process, coordinated between the State of Maryland and the USACE. Table 4.1 shows the sections of the County's zoning ordinance that potentially apply to beach and slope management activities along Calvert County's shoreline.

4.1.1.4 Endangered Species Act

The Endangered Species Act, codified at 7 U.S.C Section 136 and 16 U.S.C. Section 1531 et seq., was enacted in 1973 to provide a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The U. S. Department of the Interior's Fish and Wildlife Service (FWS) maintains the list of over 600 "endangered" species (326 are plants) and 190 "threatened" species (78 are plants). See http://www.epa.gov/epahome/exitepa.htm.

Species include birds, insects, fish, reptiles, mammals, crustaceans, flowers, grasses, and trees. Anyone can petition FWS to include a species on this list. The law prohibits any action, administrative or real, that results in a "taking" of a listed species, or adversely affects habitat. The import, export, interstate, and foreign commerce of listed species are all prohibited.

Existing Habitat Protection Districts are identified on official Critical Area maps approved by the Critical Area Commission and maintained by the County (as described later in Section 4 of this BMP). Future districts are to be delineated by County Commissioners if the Department of Natural Resources (DNR) designates additional species by regulation.

No designation of habitat and protective measures may be accomplished without a public hearing.

Scientists' Cliffs supports two globally rare species of tiger beetles: the Northeastern Beach tiger beetle (Cicindela dorsalis) and the Puritan tiger beetle (Cicindela Puritana). Both are listed by the State as endangered, and both are candidates for Federally endangered designation.

4.1.2 State Laws, Programs, and Regulations

4.1.2.1 The Coastal Zone Management Program

Maryland's Coastal Zone Management Program was established by executive order and approved in 1978 in response to the enactment of the National Coastal Zone Management Act in 1972. The key feature of this Federal legislation is the creation of a partnership among Federal, state, and local governments that assures consultation and cooperation as they seek solutions to problems caused by competing coastal pressures. The Act provides two incentives for states to exercise their full authority over their own lands and waters: funding with which state and local governments can manage coastal resources, and a promise to carry out Federal activities, or actions authorized by a Federal permit, in a manner consistent with a state's plan.

Maryland's coastal zone includes the Chesapeake Bay, coastal bays, and the Atlantic Ocean, as well as the towns, cities, and counties that contain and help govern the coastline. The state's Coastal Zone Management Program strives to achieve a balance between development and protection in the coastal zone. Through partnerships and funding to local governments, state agencies, non-profit organizations, and universities, the Coastal program addresses a variety of coastal issues including provision of public access, nonpoint source pollution reduction, coastal hazards mitigation, habitat and living resources protection, and growth management. The Maryland Department of Natural Resources is the lead agency for the Coastal Zone Management Program.

4.1.2.1.1 Critical Area Program

Maryland's Critical Area Act of 1984 was significant, marking the first time that state and local governments jointly addressed the impacts of land development on habitat and aquatic resources. It defines "critical areas" as all land within a thousand feet of the mean high water line of tidal waters (or the landward edge of tidal wetlands) and all waters of, and lands under, the Chesapeake Bay and its tributaries. The Act also created the Critical Area Commission.

4.1.2.1.2 Critical Area Commission: www.dnr.state.md.us/criticalarea

Created by the Critical Area Act in 1984, the Commission was initially charged with adopting regulations and criteria necessary to effectively implement the Act. This effort was completed in 1985; whereupon the Commission was required to review and approve all local government plans, programs, ordinances, and regulations that were proposed as part of a jurisdiction's Critical Area Program. This review and approval process took several years, but all local Critical Area Programs were operational in 1990.

The Critical Area Commission oversees the development and implementation of local land use programs in or near critical areas. The Commission's stated goals are:

- to minimize adverse impacts on water quality that result
- from pollutants discharged from structures or conveyances
- of that have runoff from surrounding lands;
- to conserve fish, wildlife, and plant habitat in critical areas; and
- to establish land use policies for development in critical areas
- which accommodate growth and which also address the fact that
- even if pollution is controlled, the number, movement, and
- activities of persons in critical areas can create adverse impacts.

The Commission has developed criteria that had been used by local jurisdictions to

develop individual Critical Area Programs and to amend local comprehensive plans, zoning ordinances, and subdivision regulations. The programs that have subsequently been adopted by local governments are specific and comprehensive, designed to address the unique characteristics and needs of each county and municipality.

Today the Commission's primary responsibilities are the following:

- Review and approve state projects on state-owned land in the Critical Area;
- Review and approve state or local agency actions resulting in major development on private lands or lands owned by local jurisdictions; and
- Review and approve all changes to a jurisdiction's Critical Area Program, including changes to ordinances, regulations, and maps.

4.1.2.2 Tidal Wetlands Program

Taken from: http://www.dnr.state.md.us/bay/czm/nps/plans/Section_4.html 31 December 2005

> *"MDE administers the Tidal Wetlands Program. Tidal wetlands in Maryland are classified as state or private wetlands. State* [tidal] *wetlands include all of the land and open water situated below the mean high water line (average high tide).*[1]

[1] The definition of "tidal wetland" is slightly different from, but generally consistent with the definition in the Code of Maryland Regulations (COMAR). COMAR 26.24.01.02.
"`Tidal wetlands' means all State and private tidal wetlands, marshes, submerged aquatic vegetation, lands, and open water affected by the daily and periodic rise and fall of the tide within the Chesapeake Bay and its tributaries,

The State of Maryland owns these wetlands and they are held in trust for all citizens of the State. Private wetlands are the lands above the mean high water line that are subject to the periodic rise and fall of the tide and support aquatic plants. Most tidal wetlands are state wetlands.

The rationale for regulating activities in Marylands tidal wetlands is summarized below (excerpt from http://www.mde.state.md.us/Permits/WaterManagementPermits/water2.asp#3.16)

> *"Tidal wetlands, which fringe many of the shorelines of the Chesapeake Bay and its tidal tributaries, as well as the Coastal Bays, include marshes, shrub swamps, forested wetlands and submerged aquatic vegetation. Each type of wetland plays a vital role in the health of the Chesapeake and Coastal Bay estuaries. Tidal wetland functions and values include fish and wildlife habitat, water quality enhancement, natural shoreline protection, flood protection, recreational opportunities, and aesthetics.*
>
> *The goal of the tidal wetlands program is to manage tidal wetlands to provide reasonable use while furnishing essential resource protection. To accomplish this goal, the following activities are regulated by the Department:*
>
> - *Filling of open water and vegetated wetlands*
> - *Construction of piers, bulkheads, revetments*
> - *Dredging*
> - *Marsh establishment*
>
> *AUTHORITY*
>
> *STATE: Environment Article Title 16; COMAR 26.24*
>
> *REQUIREMENTS*
>
> *Applicants are required to demonstrate that proposed impacts to tidal wetlands are necessary and unavoidable. The application review process first eliminates then reduces impacts through avoidance and minimization. An alternatives analysis may be required as part of this process. Mitigation may be required for authorized impacts. Wetland mitigation monitoring may be required and may extend beyond construction of an approved mitigation project."*

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the coastal bays adjacent to Maryland's coastal barrier islands, and the Atlantic Ocean to a distance of 3 miles offshore of the low water mark." Excerpted from: http://www.dsd.state.md.us/comar/26/26.24.01.02.htm accessed 01 January 2006.

4.1.2.3 Shore Erosion Control Program

Taken from: http://www.dnr.state.md.us/bay/czm/nps/plans/Section_4.html 31 December 2005

"The DNR Shore Erosion Control Program was established in 1968 by act of the Maryland General Assembly for the purpose of addressing shoreline and streambank erosion problems along the Chesapeake Bay and it's tributaries.

There are approximately 4,360 miles of tidal shoreline within the Maryland portion of the Chesapeake Bay watershed. One thousand three hundred miles of tidal shoreline have been identified as eroding at various yearly rates. In addition, approximately 14,063 miles of fresh water streams, an integral part of the Chesapeake Bay watershed system, are experiencing intermittent erosion problems. Shoreline and streambank erosion not only result in the loss of land and the reduction of riparian buffer areas and wildlife habitat, but are identified as major contributors of sediment to the waters of Maryland. Approximately 5.1 million cubic yards of sediment are delivered annually to the Chesapeake Bay from these sources. Sedimentation increases nutrient pollution and degrades water quality.

The Shore Erosion Control Program provides assistance to Maryland property owners in resolving shoreline and streambank erosion problems. Since 1968, the program has assisted numerous property owners and established more than 800 structural projects and 325 non-structural projects. Property owners in Maryland can request technical assistance and financial assistance from the Shore Erosion Control Program. Shore erosion control projects require authorization from the MDE's Tidal Wetlands Division. [Underline added for emphasis].

Projects are designed to protect eroding shorelines, to retain established vegetative buffer areas, to act as filter systems and to prevent nutrient laden sediments from the entering waters of the Chesapeake Bay and its tributaries."

Lead Agency: Maryland Department of Natural Resources.

4.1.2.4 Natural Resources Title 10 Wildlife Subtitle 2A – Nongame and Endangered Species Conservation Act

"The primary State law that allows and governs the listing of endangered species is the Nongame and Endangered Species Conservation Act (Annotated Code of Maryland 10-2A-01). This Act is supported by regulations (Code of Maryland Regulations 08.03.08) which contain the official State Threatened and Endangered Species list." (MDNR 2006 - http://www.dnr.state.md.us/wildlife/espaa.asp accessed July 2006.

Species designated under the Federal Endangered Species Act whose habitat is found in Maryland are deemed endangered. Species not on the Federal ESA may also be designated by the state secretary based on habitat and population factors

This act states that a person may not:

(1) Export the species from the State;

(2) Take the species within the State;

(3) Possess, process, sell or offer for sale, deliver, carry, transport, or ship the species by any means; or

(4) Violate any regulation pertaining to the conservation of the species or to any threatened species of wildlife listed pursuant to this subsection and adopted by the Secretary pursuant to authority provided by this section.

"Take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

Persons found in violation of provisions of the act shall be fined not more than $1,000 or be imprisoned not more than 1 year, or both and equipment used in the taking of designated species may be seized.

4.1.3 Calvert County Zoning Ordinance (May 2006)

In Calvert County, the implementation of the State's Critical Area Act is accomplished primarily through Article 8 – Environmental Regulations and Article 9-8 – Shore Erosion Protection Works of the Calvert County Zoning Ordinance (Calvert County, 2006). In Article 8, the Critical Area District and Critical Area Buffer are defined and regulations are set forth that govern activities conducted within the Buffer. The issues addressed in Articles 8 and 9-8 are the most relevant portions of the Calvert County Zoning Ordinance to the development of this BMP and include:

- Shore Erosion Protection Measures
- Cutting or Clearing of Trees
- Water Polluting Activities
- Habitat Districts for Threatened and Endangered Species
- Plant and Wildlife Habitat
- Soil Erosion and Sediment Control
- Control of Stormwater Runoff
- Protection Areas (Conservation Districts) for Shoreline and Cliff Areas

The zoning ordinance addresses a wide range of environmental issues and requires these issues to be addressed as part of the permitting process.

The Calvert County Zoning Ordinance contains a number of definitions that are important to the analysis and actions described in this BMP. Key definitions include:

Zoning Ordinance Definitions (Calvert County, May 2006)

Best Management Practices - Conservation practices or systems of practices and management measures that control soil loss and reduce water quality degradation caused by nutrients, animal waste, toxics, and sediment. Agricultural BMPs include, but are not limited to, strip cropping, terracing, contour stripping, grass waterways, animal waste structures, ponds, minimal tillage, grass and naturally vegetated filter strips, and proper nutrient application measures

Cliff - A high steep face of l0 feet or higher from the toe of the slope with a slope in excess of 50 percent either vegetated or non-vegetated adjacent to the Chesapeake Bay, Patuxent River, and their tidal tributaries within Calvert County.

Critical Area - All lands and waters defined in Section 8-1807 of the Natural Resources Article, Annotated Case of Maryland. They include: all waters of and lands under the Chesapeake Bay and its tributaries to the head of tide as indicated on the state wetlands maps, and all state and private wetlands designated under Title 9 of the Natural Resources Article, Annotated Code of Maryland; all land and water areas within 1,000 feet beyond the landward boundaries of state or private wetlands and the heads of tides designated under Title 9 of the Natural Resources Article, Annotated code of Maryland; and modification to these areas through inclusions or exclusions proposed by local jurisdictions and approved by the Critical Area Commission as specified in Section 8-1807 of the Natural Resources Article, Annotated Code of Maryland.

Critical Habitat Area - A critical habitat for an endangered species and its surrounding protection area. A critical habitat area shall: (a) Be likely to contribute to the long-term survival of the species; (b) Be likely to be occupied by the species for the foreseeable future; and (c) Constitute habitat of the species which is considered critical under Natural Resources Article, Sections 4-2A-04 and 10-2A-06, Annotated Code of Maryland.

Critical Habitat for Endangered Species - A habitat occupied by an endangered species as determined or listed under Natural Resources Article, Sections 4-2A-04 and 10-2A-04, Annotated Code of Maryland.

Development - Any activity, other than normal agricultural and/or forestry activity, which materially affects the existing condition or use of any land or structure.

Endangered Species - Any species of fish, wildlife, or plants which have been designated as such by regulation by the Secretary of the Department of Natural Resources. Designation occurs when the continued existence of these species as viable components of the State's resources are determined to be in jeopardy. This includes any species determined to be an "endangered" species pursuant to the Federal Endangered Species Act.

Forest - A biological community dominated by trees and other woody plants covering a land area of 1,000 square feet or more. This also includes forests that have been cut, but not cleared. Areas commercially harvested of forest cover in the Critical Area will be considered forested for development purposes. Outside of the Critical area and relative to the Forest Conservation Program, forests shall be defined as 10,000 square feet or greater and shall include: 1) areas that have at least 100 trees per acre with at least 50 percent of those trees having a two inch or greater diameter, and 2) forest areas that have been cut but not cleared. Forest does not include orchards.

Habitat Protection Area - An area where plant communities and physiographic features provide food, water cover, nesting, foraging or feeding conditions necessary to maintain populations of rare, threatened or endangered species; or colonial water bird nesting sites, historic waterfowl staging and concentration areas, riparian forest or other areas identified to be of local, state or Federal significance for existing plant and wildlife habitat areas

Non-tidal Wetlands - Nontidal wetlands are areas that are: (1) Inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal conditions do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation; (2) Considered a nontidal wetland in accordance with the publication known as the "Federal Manual for Identifying and Delineating Jurisdictional Wetlands," published in 1989 and as may be amended and interpreted by the U.S. Environmental Protection Agency and (3) do not include tidal wetlands regulated under Natural Resources Article, Title 9, Annotated Code of Maryland.

Shore Erosion Protection Works - Those structures or measures constructed or installed to prevent or minimize erosion of the shoreline in the Critical Area.

Steep Slopes - Within the Critical Area: Slopes greater than 15 percent incline. Outside the Critical Area: 25 percent or greater slopes. Slopes greater than 50 percent are defined as Cliffs See: Cliff

Structure - A combination of materials to form a construction for use, occupancy, or ornamentation whether installed on, above, or below the surface of land or water.

Threatened Species - Any species of fish, wildlife, or plants designated as such by regulation by the Secretary of the Department of Natural Resources which appear likely, with the foreseeable future, to become endangered, including any species of wildlife or plant determined to be a "threatened" species pursuant to the Federal Endangered Species Act, 16 U.S.C. 153 et seq., as amended.

Tidal Wetlands – Undefined in current version Calvert County Zoning Ordinance (May 2006)

Wetlands - Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. (Man-made stormwater management devices and sediment control devices are not included under this definition.)

The term “development” is used frequently throughout the Calvert County Zoning Ordinance and is usually used, as is common in the parlance of land use planning, to refer to the development of property for residential, commercial, or industrial use. However, the definition in the ordinance encompasses a wider range of activities and, when used in its broadest sense, (i.e., “Any activity, other than normal agricultural and/or forestry activity, which materially affects the existing condition or use of any land or structure.”), influences the execution of actions undertaken as part of this BMP. For instance, construction or removal of revetments and groins are activities which may materially affect the existing condition of the beaches and slopes at Scientists’ Cliffs.

Table 4.1 evaluates the individual sections of Articles 8 for applicability to activities that may be undertaken as part of this BMP as part of an effort to develop clear guidance to be used by SCA when seeking permits as part of the implementation of their shoreline stabilization and slope erosion control measures. While there are a number of requirements in Article 8 that apply to development of structures (i.e., primarily residences) in the Critical Area Buffer, they are excluded from consideration here because the geographic scope of this document does not extend into areas of the community where such development is exists or is feasible. That is, the scope of this BMP is limited to the shoreline and coastal slopes of the SCA where it is not feasible to locate permanent residential structures. On the other hand, sections of the ordinance that regulate development in the broader sense, as applied to activities along the shoreline and slopes, are retained.

The evaluation of the Calvert County Zoning Ordinance provided in Table 4.1 will be used in Section 5 of this document to develop best management practices and to propose a streamlined and efficient process for seeking permits to implement these practices.

Table 4.1 of Calvert County Environmental Requirements and Their Applicability to Shoreline and Slope Stabilization Measures That May Be Undertaken at Scientists' Cliffs.

Based on the Calvert County Zoning Ordinance, Final, May 2006

Article 8—Environmental Regulations

Section	Title	Environmental Requirement	Applicable?
8-1	Critical Area District (CAD)		No
8-1.01	Introduction		No
8-1.02	General Regulations	Specific only to agriculture, heavy industry, transportation, utilities, waste, & landfills.	No
8-1.03	Intensely Developed Area	There are no Intensely Developed Areas within the geographic scope of this BMP plan.	No
8-1.04	Limited Development Area (LDA and LDA-3 on Critical Area Map)	Most of this section is <u>not within the scope</u> of this BMP plan. That is, development density specifications apply to density of dwellings and the scope of this BMP does not extend past the bluff top. Applicable items in this section may include: However, there are requirements in Section 1.04G.1 that do, and may, apply. Specifically, for maintenance activities and stream crossings, development of roads, and utilities, etc. that may occur in Habitat Protection Areas. Criteria for Habitat Protection as described in Section 8-1.08 apply.	Not generally, but there are a few requirements that do apply
8-1.05	Resource Conservation Area	Resource Conservation Areas (RCAs) are those areas within the Critical Area District characterized by nature-dominated environments (that is, wetlands,	Portions are applicable if

Section	Title	Environmental Requirement	Applicable?
	(marked RCA on Critical Area map)	forests, abandoned fields) and resource-utilization activities (agriculture, forestry, fisheries activities, or aquaculture). RCAs have at least one of the following features: density less than one dwelling unit per five acres; or, dominant land use is in agriculture, wetland, forest, barren land, surface water, or open space. **8-1.05G: Development activity within an RCA must be in accordance with the criteria for the LDA (see sections G.1.a and b); at Section 8-1.04, land use mgmt practices must be consistent with the policies and criteria for HPAs.)**	any of the area within the scope of the BMP plan is within a Resource Conservation Area. **Yes, if forest and/or woodland are present in an RCA and w/in geographic cope of the BMP plan.**
8-1.06	Location & Extent of Future Intensely Developed (IDA) and Limited Development (LDA) Areas		Unlikely

Section	Title	Environmental Requirement	Applicable?
8-1.07	**Grandfathering**	**8-1.07.A: After Critical Area Program (CAP) approval (13 Dec 1988), the continuation of any use in existence on that date is permitted. If the use has been abandoned for more than one year, then it is no longer grandfathered. Existing uses not conforming with the provisions of the County CAP may only be intensified or expanded only in accordance with the procedures outlined in this Ordinance. (See also Sections 2-6.01 and 11-1.02.)** **8-1.07.C: For purposes of implementing this regulation, the County has determined which land areas fall within the three types of development areas described in Sections 8-1.03, 8-1.04, and 8-1.05.** **8-1.07.D: Nothing in this regulation may be interpreted as altering any requirements of this Ordinance for development activities for Water Dependent Facilities and Habitat Protection Areas.**	**Yes--** **Sections A, C, & D** Section B is not within the scope of this BMP plan because it applies only to development of single family residences
8-1.08	**Habitat Protection Areas (HPAs)**	**8-1.08.A: The state has designated certain areas and plant and animal species as meriting special protection. They are: Critical Area Buffer, wetlands, threatened and endangered species and species in need of conservation, plant and wildlife habitat, and andromous fish propagation waters.** **8-1.08.B: Boundaries for each type of habitat protection area are described in the applicable Section.**	**Yes** **Yes**

Section	Title	Environmental Requirement	Applicable?
8-108.C	**Habitat Protection Plans (HPPs)**	**8-1.08.C. Criteria for Development. HPPs are required for all development activities, redevelopment, or maintenance in HPAs** **8-1.08.C.1. If proposed development activities, including clearing or cutting of trees, impact any known habitats of the types listed in this Section, then a HPP must be developed by the owner or owner's agent and approved by the Dept of Planning and Zoning using the expertise of appropriate State and Federal agencies (Section 8-1.08.C.1).** **8-1.08.C.1.c: HPPs should provide protection measures, including buffer areas where appropriate for the plant and wildlife habitat.** Section 8-1.08.C.1.d: HPPs should assure that development activities, including the clearing or cutting of trees, are conducted so as to conserve riparian and forest interior wildlife species, and their habitats. Other requirements as listed in this Section. Section 8-1.08.C.1.e: When development activities, or the cutting/clearing of trees, occurs in forested areas, corridors of existing forest or woodland vegetation will be maintained to provide effective connections between habitat areas.	**Yes** **Yes** **Yes** Only if SCA slopes are considered to be "forested areas"

Section	Title	Environmental Requirement	Applicable?
		Section 8-1.08.C.1.f: HPPs should protect by appropriate means those plant and wildlife habitats considered to be of significance to the County even if they are not necessarily of statewide significance.	**Yes**
		Section 8-1.08.C.1.g: Natural Heritage Areas should be protected from alteration due to development activities or cutting/clearing so that the structure and species composition of the areas are maintained.	**Yes**
		Section 8-1.08.C.3: Criteria for Habitat Protection Plans. **a. For Habitat Protection Areas, except the Critical Area Buffer areas that do not have another Habitat Protection Area overlay, proposed plans for development activities, clearing, or cutting of vegetation in these areas shall be submitted to the Department of Planning and Zoning for review and approval. The Department of Planning and Zoning will forward copies of the proposed plans to the Critical Area Commission and Natural Heritage Divisions of Maryland Department of Natural Resources for review and comment. Criteria set by the State and Federal agencies and County review staff shall be included in the Habitat Protection Plan. The criteria shall be consistent with Section 8-1.08.C.1. The applicant may appeal approval criteria to the Planning Commission. The Habitat Protection Plan shall be recorded in the Land Records of Calvert County and/or on a record plat.**	**Yes**

Section	Title	Environmental Requirement	Applicable?
		b. Critical Area Buffer areas (including expanded Buffer areas) that do not have another Habitat Protection Area overlay, require a Buffer Management Plan for development activities, clearing, or cutting of vegetation in these areas. The Buffer Management Plan shall be submitted to the Department of Planning and Zoning for review and approval and shall address the following: **i. Minimization of the removal of vegetation; and** **ii. Plant and wildlife habitat protection; and** **iii. Reduction of the runoff of pollutants; and** **iv. Required reforestation and/or afforestation including a planting plan and other mitigation measures; and** **v. Protection of the area during development activities.** **Appeals of decisions made by the Department of Planning and Zoning with regard to Buffer Management Plans for subdivisions and site plans may be appealed to the Planning Commission. Appeals of decisions regarding Buffer Management Plans for other activities proposed in the Critical Area Buffer may be appealed to the Board of Appeals.**	

Section	Title	Environmental Requirement	Applicable?
8-1.08.D	Critical Area Buffer	**Section 8-1.08.D.1: The Critical Area Buffer regulates the removal or reduction of sediments, nutrients, and potentially harmful or toxic substances in runoff entering the Bay and its tributaries; minimizes the adverse effects of human activities on stream banks, wetlands, tidal waters, shorelines, and aquatic resources; maintains an area of transitional habitat between aquatic and upland communities; maintains the natural environment of streams; and protects riparian wildlife habitats.**	Yes
		Section 8-1.08.D.2a: The Buffer shall consist at a minimum of the area one hundred feet landward from the mean high water line of tidal waters, tributary streams, and tidal wetlands and shall be expanded as set out in paragraph 8-1.08.D.2.b which says the buffer shall be expanded 100 feet landward from MHHW for a variety of reasons, steep slopes, and possibly streams, being the reasons applicable to SCA.	Yes
8-1.08.D	Critical Area Buffer (cont.)	**Section 8-1.08.D.3.a: The Buffer shall be maintained in native vegetation and shall be managed to achieve or enhance the functions stated in Section 8-1.08.C. Cutting, clearing, and topping of trees and removal of existing natural vegetation, including understory trees, shrubs, and groundcover within the Buffer is prohibited.**	Yes

Section	Title	Environmental Requirement	Applicable?
8-1.08.D	Critical Area Buffer (cont.)	Section 8-1.08.D.3.b: Notwithstanding the prohibitions of paragraph 'a' above, the following activities may be allowed with and approved HPP and either a grading permit, grading exemption, or Buffer cutting permit. No permits are required for pruning limited to the lower one-third of the tree. i. Cutting of trees or removal of vegetation may be permitted where necessary of the following purposes, provided that the vegetation is replaced on a one-to-one (1:1) basis: a. One access to the water front for a private pier or b. A boat ramp, or c. To install or construct a shore erosion protection device or measure, or a water-dependent facility, providing the device measure, or facility has received all necessary State and Federal permits. No more than one access through the Buffer is permitted per waterfront lot. A four-foot wide access is allowed if the access is for steps or a pathway; or a 12-foot wide access is allowed for vehicular access. ii. Individual trees may be removed which are in danger of falling and causing damage to dwellings or other structures, or which are in danger of falling and therefore causing the blockage of streams, or resulting in accelerated shore erosion.	Yes

Section	Title	Environmental Requirement	Applicable?
		iii. **Appropriate horticultural practices may be used to maintain the health of individual trees, including removal of noxious, invasive, and exotic species which impair the function and growth of a forested Buffer. Inappropriate horticultural practices such as topping, girdling, over pruning or severely damaging trees are prohibited.** **iv.** **Other cutting techniques may be undertaken within the Buffer and/or under the advice and guidance of the Department of Agriculture and/or Natural Resources, if necessary to preserve the forest from extensive pest or disease infestation or threat from fire.** **v.** **Selective thinning and cutting may be approved by the Department of Planning and Zoning if the Department determines that the function of the Buffer will not be impaired.** **vi.** **Removal of vegetation for permitted development and redevelopment activities may be permitted**	
8-1.08.D	**Critical Area Buffer (cont.)**	**Section 8-1.08.D.3.c. New development including structures, roads, septic systems, and parking areas shall not be permitted in the Buffer, except for those necessarily associated with water-dependent facilities or for shore erosion control. If no vegetative Buffer exists, one shall be established with native vegetation for any planting required for the activity.**	**Yes**

Section	Title	Environmental Requirement	Applicable?
8-1.08.D	**Critical Area Buffer (cont.)**	**Section 8-1.08.D.3.f Grading or disturbance in the Buffer, without tree removal, is only allowed for erosion control or to enhance the Buffer function, and requires a grading permit and mitigation as per Section 8-1.04.G.3.**	**Yes**
8-1.08.E	**Wetlands**	The provisions of Section 8-2.05 apply to tidal and nontidal wetlands within the Critical Area. [Note: There are no non-tidal wetlands as defined in the zoning ordinance within the scope of this BMP. However, tidal wetlands are not defined in the zoning ordinance. Therefore, depending on how Calvert County chooses to define tidal wetlands, Section 8-2.05 may apply.]	**Possibly**
8-1.08.F	**Rare, Threatened, and Endangered Species and Species in Need of Conservation**	**Existing HPAs are identified on the official Critical Area maps. Future areas are to be delineated by the County Commissioners if the Secretary of the Dept of Natural Resources designates additional species by regulation. And, if future designation and habitat protective measures are to be designated, public notice and an opportunity to be heard are required by Section 8-1.08.F.2.b. Administration of HPAs rests with the County (see Section 8-1.08.EF.3.a), which shall use the expertise of the Maryland Department of Natural Resources and other appropriate organizations and agencies when an activity is proposed which requires the development of protection areas (Section 1.08.F.3.b). Natural Heritage Areas and the CAB, likewise, require HPPs (Section 8-1.08.E.3.e-h).**	**Yes**

Section	Title	Environmental Requirement	Applicable?
		Section 8-1.08.F.3.c Protection of verified bald eagle nesting sites	none currently
8-1.08.G	**Plant and Wildlife Habitats (P/W)**	**Boundaries of Habitat Protection Areas are as determined by the State of Maryland. Applicable HPAs which require Habitat Protection Plans include: G.3.(f) Other plant and wildlife habitats determined to be of significance to Calvert County, G.3.(h) State-listed species sites (i.e. tiger beetles).** **8-1.08.G.4. These protection plans shall be developed prior to any development plans being approved.**	**Yes** **Yes**
8-1.09	**Fines and Penalties**	**The following shall apply to violations of Section 8-1:** **1. Any person in violation of Section 8-1.04.G (Criteria for Development, Redevelopment, and Maintenance in the LDA, LDA-3, and RCA) shall pay a fine not to exceed $1,000 for each violation and shall be required to replant trees to replace those that have been removed as prescribed in paragraph 'B' of this Section.** **2. A surety bond shall be posted for any replanting that is done in order to correct a violation. See Section 8-1.04.G.4, which describes the bonding process.**	**Yes** **Yes**

Section	Title	Environmental Requirement	Applicable?
		B. Replanting to correct a violation shall be calculated at the rate of four square feet to one square foot (4:1) of the area cleared, graded, or cut in violation of the provisions of this Article. A mitigation plan shall be approved by the Department of Planning and Zoning and shall include canopy trees at a rate equal to one tree per 400 square feet and understory trees and/or shrubs at a rate equal to one per 200 square feet as described in the document entitled, "Calvert County Critical Area Native Trees", adopted by the Board of County Commissioners and available from the Department of Planning and Zoning.	**Yes**
8-2	**Natural Resources Protection (NRP) Areas (formerly Natural Resources Conservation Districts)**	**Applies to properties inside and outside the Critical Area (see Section 8-1 for Critical Area Regulations); NRP Areas have been created to protect environmental features which may be adversely affected by normal development of permitted and special exception uses in the underlying Area.**	**Yes**
8-2.01	**General Requirements**	**Boundaries are approved by the Dept of Planning & Zoning and the Planning Comm'n during the subdivision, site plan, & building permit processes.**	**Yes**

Section	Title	Environmental Requirement	Applicable?
8-2.02	**Shoreline and Cliff Areas on the Chesapeake Bay & Patuxtent River and Their Tributaries**	**… The geology of the shorelines of Calvert County and the naturally occurring erosion processes combine to present the landowners with three complex problems: the possibility of moderate to severe shoreline erosion, greater exposure to storms, and cliff failure (Section 8-2.02.A.2).** **Regulations governing development along the shoreline are designed to allow development in a manner that will protect the property and the lives of residents, reduce various forms of pollution (sediment/pesticides/herbicides/ septic leachate) and protect the scenic, paleontological, and natural resource values of the shoreline (Section 8-2.02.A.3).**	**Yes.**
	Shoreline and Cliff Areas on the Chesapeake Bay & Patuxtent River and Their Tributaries, cont.	**There are many factors to be considered when dealing with shore erosion control measures. By allowing shore erosion control within the cliff and shoreline areas, the risk of altering many of the existing features increases. For example, shore erosion control stops the natural erosion process that supplies sand to Calvert County beaches. The Puritan Tiger Beetle, an endangered species, depends on the natural erosion process for its survival. Shore erosion control allows the cliffs to reach a natural angle of repose which will become vegetated and destroy the paleontology, natural beauty and scenic vistas of the cliffs. [Note: This BMP notes that, along Scientists' Cliffs' shoreline, only when shore erosion control reduces the erosion of a shoreline or lower slope to zero does the angle of the cliff begin to decline to a stable angle.]**	**Yes**

Section	Title	Environmental Requirement	Applicable?
		Section 8-2.02.B: Boundaries include all cliff and shoreline areas on the Chesapeake Bay, Patuxent River, and their tributaries. The cliff areas have been separated into three categories based on their priority for preservation: Category 1, given the greatest priority, is designated for undeveloped cliff sections with significant preservation needs requiring the highest priority for total preservation. Category 2 is designated for developed cliff sections with significant preservation needs and includes Scientists' Cliffs (Section 8-2.02.B.2). Category 3 includes cliffs not placed in the other two categories.	**Yes**
8-2.03	Flood Plain Area		No
8-2.04	Slopes 25 percent or Greater and Erodible Soils Adjoining Streams		No--outside scope
8-2.05	Wetlands	Purpose appears to be to protect wetlands from the negative effects of siltation and nutrification caused by development. It is the goal of the County to achieve no significant loss of wetlands. [Note: There are no non-tidal wetlands as defined in the zoning ordinance within the scope of this BMP. However, tidal wetlands are not defined in the zoning ordinance. Therefore, depending on how Calvert County chooses to define tidal wetlands, Section 8-2.05 may apply.]	Possibly,[1]

[1] If tidal wetlands are determined to exist within the scope area, some subsections could be construed as applicable as follows: Section 8-2.05.C.1 (delineation), .2 (waivers), .3 (platting), .4 (width of buffer), and .5 (approvals by other agencies) and Section 8-2.05.C.6 (filling of wetlands not permitted).

Section	Title	Environmental Requirement	Applicable?
8-2.06	Development Adjacent to…Streams	Purpose is to reduce pollutant loadings transported from land to water via sediments and stormwater run-off into perennial and intermittent streams.	No. Outside scope area of BMP
8-2.07	Fines and Penalties	8-2.07.A.2 Applies if 8-2.05 applies (see above). Any person in violation of Section 8-2.05 (Wetlands) shall pay a fine not to exceed $1,000 for each violation and shall be required to mitigate at the rate of one square foot to one square foot for the area cleared, graded, or cut in violation of the provisions of Section 8-2.05.	Possibly
8-3	Forest Conservation Requirements	This section of the Zoning Ordinance implements the provisions of the Maryland Forest Conservation Act (codified at the Natural Resources Article, Title 5, Subtitle 16, and the Code of Maryland Regulations, Title 8, Subtitle 19, both as amended from time to time).	No

4.2 Permits – Integrating Across Federal, State, and Local Requirements

4.2.1 Federal Permitting Considerations

The USACE has authorized its district engineers to issue formal determinations concerning the applicability of both the Clean Water and the Rivers and Harbors Acts to activities or tracts of land. The USACE district engineers are likewise authorized to issue general permits of statutory exemptions to proposed activities. A determination pursuant to these authorizations constitutes a (USACE) final agency action, but a district engineer's decision on a permit denial or a declined individual permit is subject to administrative appeal by the affected party in accordance with the procedures contained in 33 CFR Part 331.5.

Permits are required for structures and/or work in or affecting navigable waters of the United States except those specifically exempted in 33 CFR Section 322.4 (see above) or otherwise. If an activity is not exempt, an individual Section 10 permit is required for the proposed activity.

The decision whether to issue a permit is based on an evaluation of the probable impacts, including cumulative effects, of the proposed activity and its intended use on the public interest (33 CFR Part 320). The decision whether to authorize a proposal/grant a permit, and if so, the conditions under which it will be allowed to occur, are determined through a balancing process that weighs the benefits which may reasonably be expected to accrue against reasonably foreseeable detriments. All factors which may be relevant to the proposal must be considered, including the cumulative effects thereof, including: conservation principles, aesthetics, wetlands, historic properties, fish and wildlife values, water supply and conservation, flood hazards, floodplain values, land use, navigation, energy needs, safety, food and fiber production, mineral needs, property values, general environmental concerns and general needs and welfare of the affected communities.

The specific weight of each factor is determined by its importance and relevance to the particular proposal; how important a factor is and how much consideration it deserves necessarily varies with each proposal. Full consideration and appropriate weight is given to all comments, including those of the Federal, state, and local agencies, and other experts commenting on matters within their expertise.

Applicants for Federal licenses or permits (the vast majority of which are for USACE Section 10 and Clean Water Act Section 404 activities), must certify that the proposed activity is consistent with Maryland's Coastal Zone Management Plan; there is a joint Federal/state permit application (see Section 4.2.3) which contains the required certification.

The terms “permit denial” and “declined permit” are defined at 33 CFR Part 331.2. Affected parties must exhaust any administrative appeals available pursuant to 33 CFR Part 331 and receive a final USACE decision on the appealed action prior to initiating a lawsuit in the Federal courts. 33 CFR Part 331.12

See www.usace.army.mil/inet/functions/cw/cecwo/reg/33cfr320.htm and

www.usace.army.mil/inet/functions/cs/cecwo/reg/33cfr325.htm

4.2.2 State Permitting and Fee Considerations

Taken from: http://www.dnr.state.md.us/bay/czm/nps/plans/Section_4.html 31 December 2005

If a project involves filling, dredging, or discharging stormwater in tidal wetlands, Maryland Tidal Wetland Law requires a license or permit from the State of Maryland. Examples of projects that need permits or licenses include: bulkheads, stone revetments, large piers, dredging, and boat ramps. Licenses are issued by MDE or the Board of Public Works for work in state wetlands and permits are issued by MDE for work in private wetlands. Permits and licenses are obtained by submitting a completed joint application to the MDE Permit Service Center [see Section 4.2.3 of this BMP for permit process]. *Maryland's tidal wetland law requires protection of tidal wetlands but also allows for reasonable access to waterways and protection of property from erosion.*

Lead Agency: Maryland Department of the Environment”

4.2.3 The Joint Federal and State Permit Application Process

The CZMA Federal consistency requirement applies to Federally-issued licenses or permits. A majority of the practices described in this BMP will require permits issued by the USACE authorized pursuant to Section 10 of the River and Harbor Act and Section 404 of the Clean Water Act. The issuance of these types of permits make up at least 95 percent of the Federal permit actions reviewed for consistency as part of Maryland’s CZMP. For activities covered by these two Federal laws, tidal or non-tidal wetlands and waterways authorization is also required from the State.

The Maryland Department of Natural Resources (MDNR) is the lead agency for the State's CZMP. However, MDE carries out the Federal consistency requirements through the Coastal Zone Consistency Division in the Wetlands and Waterways Program of the Water Management Administration (WMA) in MDE. "Although the WMA is responsible for the official Federal consistency determination, the decision is often based partially or entirely upon the findings of a variety of agencies within the CZMP network" (MDNR 2004).

The joint application is used to authorize all types of work in all waters of the State, including wetlands. The permit review conducted and coordinated by the State, generally addresses Federal issues for the activities for which a permit is being sought. Therefore, the State's decision also constitutes the Federal consistency decision for many of the activities that require a USACE permit.

4.2.3.1 Maryland State Programmatic General Permit (MDSPGP)

As noted in the excerpt below, the MDE receives joint applications and coordinates the permitting process with other state and Federal agencies.

> *"On May 1, 1996, [the] Baltimore [District of the U.S. Army Corps of Engineers] issued, for a five year period, the Maryland State Programmatic General Permit (MDSPGP-1) for activities in wetlands and waters within the State of Maryland. It is administered by the Corps and Maryland Department of the Environment (MDE). The MDSPGP-1 was extended to September 30, 2001."*
>
> *"The current permit, MDSPGP-2 [available as a PDF document at the web address above], was implemented and in full effect within the State of Maryland on October 1, 2001 and will expire on September 31, 2006.*
>
> *Upon receipt of a COMPLETE application, MDE assigns the application a State and Corps tracking number, acknowledges receipt of the application, and reviews the proposed work to determine if the work is authorized under a category of activities in the MDSPGP-2. For minor, non-controversial work that meets the impact limits and activity-specific conditions for any of the Category I activities, MDE includes a copy of the Corps' MDSPGP-2 authorization with the State authorization. For activities or work that do not qualify for Category I authorization, MDE forwards the application to the Corps for concurrent review.*

The Corps initially reviews the project to determine if it can still be authorized under the MDSPGP-2 under another category. If so, the Corps completes their review of the project and notifies MDE that Corps authorization can be granted under the MDSPGP-2 with any necessary special conditions.

If during its initial review, the Corps concludes that the project will have more than minimal environmental impacts, it does not qualify for MDSPGP-2 authorization and must undergo the Corps' Individual Permit (IP) review."

Above excerpt taken from: http://www.nab.usace.army.mil/Regulatory/permits.htm 10 July 2005

Additional detail relevant to this BMP as to the decision logic used by MDE and USACE as to which category applies to a particular permit application is provided below:

Category I Status under the MDSPGP-2

An application is considered for Category 1 status if the affected area is less than one acre and if Federally-listed threatened or endangered (T&E) species are not affected.

Category II Status under the MDSPGP-2

Category II activities are activities reviewed by the Corps to determine general permit eligibility. These include activities that are exempt or grandfathered from State Permit requirements; conducted within 150 feet of a Federal navigation channel; are adjacent to or within a Federal project or are a Section 10 and/or 404 violation..

Category III Status under the MDSPGP-2

If the screening of the application by MDE indicates it is not eligible for either Category I or Category II status, then it is considered for Category III status.

If the initial screening indicates that a Federally-listed T&E species may be present, the following process occurs.

"The MDSPGP-2 does not authorize any activity that may affect a Federally-listed threatened or endangered species or a species proposed for such designation, as identified under the Endangered Species Act (ESA); or which may destroy or adversely modify the critical habitat of such species unless and until appropriate coordination with the applicable resource agency(s) is complete and all such issues are resolved in accordance with the applicable regulations and the procedures outlined in the MDSPGP-2 [underline added]. Joint permit applications are screened by MDE's Regulatory Services Coordination Office on their GIS for the potential presence of threatened or endangered (T&E) species or critical habitat within the vicinity of the proposed project site. Copies of those applications that receive a "hit" for the possible presence of Federally- and/or state-listed T&E species are then forwarded to DNR's Natural Heritage Program for further investigation." (USACE and MDE 2005).

Also, "If the screening concludes that there may be a T&E issue, the MDE is to advise the Corps, who shall determine if consultation with FWS or NMFS is required under Section 7 of the ESA. It is the Corps who must ensure that the ESA requirements have been satisfied and that the activity is eligible for MDSPGP-2 verification." (USACE and MDE 2005).

Table 4.2 is a brief summary of the process for applying for a permit using the joint application process. No fees are required to apply.

APPLICATION PROCESS
1) Complete a "Joint Federal/State Application for the Alteration of any Floodplain, Waterway, Tidal or Nontidal Wetland in Maryland" application. 2) Mail the original plus four copies of the application, plans, vicinity maps and any supporting documentation to: Regulatory Services Coordination Office (RSC) MDE, Water Management Administration 1800 Washington Boulevard, Suite 430 Baltimore, Maryland 21230-1708 3) Upon receipt of the application package, the RSC will determine what type of permit is necessary and will forward the application to the appropriate governmental agencies. The RSC receives applications for the Nontidal Wetlands and Waterways Division, Tidal Wetlands Division, and Dam Safety Division of the Maryland Department of the Environment, as well as the U.S. Army Corps of Engineers. The Department conducts the review in cooperation with local, state, and Federal agencies. 4) Depending on the nature of the project, it may be advertised for comment and an opportunity for public informational hearing. The applicant may be required to notify adjacent property owners. 5) The Department may perform a site evaluation. 6) At the conclusion of the review process, the Department will make a decision on the application. Upon receipt of final construction plans, a permit or license is issued by the Department. In some instances, a license may be issued by the Maryland Board of Public Works (BPW) based on a recommendation from the Department.

Table 4.2 Brief Summary of the Joint (Federal/State) Application Process

from http://www.mde.state.md.us/Permits/WaterManagementPermits/water2.asp#3.16

4.2.3.2 Review Times for the Joint Application Process

"*The review time for Federal licenses and permits, particularly Corps of Engineers' permits, is dependent on the nature of the project and the magnitude of impacts. Minor activities are usually completed with 30-90 days. Major projects may take 120-180 days*" (MDNR 2004).

4.2.3.3 Compliance, Enforcement and Penalties Associated with the Joint Application Process

> *"DA [Department of the Army] authorization is required for any discharge of dredged and/or fill material into Waters of the United States including jurisdictional wetlands. The Corps has the lead on enforcement cases for Section 301 of the Clean Water Act (CWA) violation in Maryland. The lead was established through the 1989 National Memorandum of Agreement but EPA still remains the primary authority for enforcement under the CWA.*
>
> *Work that is performed involving a discharge of fill material and is in noncompliance with a DA permit is considered a violation of Section 404 of the CWA. In this situation, the Corps is the lead Federal agency responsible for investigation and resolution of any violation of the permit authorization, which can include issuance of administrative penalties (33(CFR 326.6)).*
>
> *The Corps is the only enforcement agency responsible for Section 10 of the Rivers and Harbor Act of 1899 violations and permit noncompliance. This includes all work performed in, over and under navigable waters of the United States.*
>
> *The enforcement and compliance section of the MDSPGP-2 SOP identifies that all enforcement cases, including after-the-fact (ATF) authorizations, which could qualify for verification under MDSPGP-2, must first be coordinated with the Corps enforcement officers. All efforts are made between MDE and the Corps to bring the violation into compliance with the MDSPGP-2 and resolved voluntarily."* (USACE and MDE, 2005).

Civil or criminal penalties for violations of the State's tidal and nontidal wetlands laws in the forms of fines can only be imposed only through the courts. Legislation was proposed in the late 1990s to allow for the imposition of administrative penalties, but the measure did not succeed (MDNR 2003). Federal penalties may be severe including fines and requirements to remove the violation and restore the site. Criminal prosecution is usually reserved for extreme violations.

4.2.4 County Permitting and Fee Considerations

4.2.4.1 Calvert County Permit Considerations Pertaining to the 100-Foot Buffer

Taken from: http://www.co.cal.md.us/residents/building/planning/howtoguide/criticalareas/ accessed July 2006.

Activities Prohibited (Violations) in the 100-foot Buffer[1]

- Removal of trees without a permit.
- Removal of existing vegetation, including understory shrubs and ground cover, without a permit.
- Inappropriate horticultural practices such as topping, girdling, over pruning or severely damaging trees.
- Grading, or disturbance, without tree or vegetation removal.
- Installation of shore erosion control devices, piers, or structures without a permit.
- Construction of structures or installation of impervious surfaces without a permit. Any non-water dependent structures or impervious surfaces, unless permitted for access or shore erosion control, require a variance from the Board of Appeals.

Activities Requiring Permits in the 100-foot Buffer

- Trees and vegetation may be removed if a permit is obtained. Vegetation must be replaced on an equal basis elsewhere within the buffer. A surety bond must be posted to assure the survivability of the replacement trees and vegetation. Acceptable reasons include 1) Access to water (minimized access), 2) Shore erosion control installation or maintenance, or 3) Removal of a hazardous tree which is in danger of falling and damaging structures or increasing erosion.
- Dead trees may be removed if a permit is obtained. Dead trees, if they are not hazardous, should remain as snags and habitat for osprey, eagles and other wildlife.
- Grading, adding fill material, or shore erosion control methods require permits.
- Construction of fences over 4 feet in height requires a permit and Board of Appeals approval.

Activities Not Requiring Permits in the 100-foot Buffer (Planning and Zoning approval required)

- Mature trees may be pruned without a permit if the pruning is restricted to the lower one-third of the tree. (Only branches less than a third of the way up the tree may be removed.) No more than one quarter of the tree's branches may be removed in a single year.
- Planting to enhance the buffer is allowed at any time. Native species are encouraged.

[1]Prohibited activities are violations. Required replacement is 4:1 and fines may also be assessed.

Table 4.3 Summary of Calvert County Critical Area Permitting Requirements

BUFFER CUTTING PERMIT PROCESS

Step 1: Complete a Buffer Cutting Plan (available from the Department of Planning & Zoning), which is an application for cutting and removing vegetation within the 100-foot buffer and expanded buffer adjacent to tidal waters, wetlands and tributaries of the Bay. **A sketch is required as part of the application**. The sketch does not have to be drawn to scale, but must show the location of tree and vegetation cover to be removed.

Step 2: Mail, fax or bring the completed application to the Department of Planning & Zoning, County Services Plaza (3rd Floor), 150 Main St., Prince Frederick, MD 20678.

Step 3: Planning & Zoning will review your application and contact you regarding your permit requirements. A site visit may be required prior to issuing a permit. Vegetation removal in the 100-foot buffer usually requires replacement on an equal basis, i.e., plant 1 large tree (400 sq. ft. coverage), or 2 small trees, for each tree removed. A refundable bond ($200.00 per large tree) and a planting plan for replacement will be required and the bond held for 1 year from planting to assure adequate survival of the required planting.

Step 4: Planning & Zoning will contact you when your Buffer Cutting Plan has been approved and the permit is ready. Bonds can be posted (sign bond form and pay) when you pick up the permit at the Planning & Zoning Office (see above address).

Step 5: Replacement plantings must be made within 1 year of receiving the permit. As soon as the trees and shrubs are planted, as specified by the planting plan, notify Planning & Zoning to schedule an initial inspection. The planting can only be considered successful, and the bond returned, if an initial inspection is conducted following the planting.

Step 6: Notify Planning & Zoning one year after the initial inspection to schedule a final planting inspection. The planting will be considered successful and the bond returned if the plants have satisfactorily survived for one year .

Areas Outside of the 100-Foot Buffer, But Within the Critical Area

Activities Requiring a Permit

- Cutting or clearing of vegetation in forests requires a grading exemption, grading permit, or Timber Harvest Permit**.** Clearing must be in conformance with approved clearing limits for subdivision, per recorded plat.
- Construction or installation of new structures or impervious surfaces requires a permit. Total area of impervious surfaces must be in conformance with approved limits for subdivision, per recorded plat.
- Grading or adding considerable amount of fill requires a grading permit or grading exemption.

Activities Not Requiring a Permit

- Removal of dead trees does not require a permit.
- Removal of impervious surfaces does not require a permit.

GRADING PERMIT EXEMPTION PROCESS

To remove trees outside the 100-foot buffer, but within the Critical Area limits (within 1,000 feet of mean high water line of tidal waters), complete a Grading Permit Exemption application. Grading Permit Exemption applications are available at:

Soil Conservation District Office
Kaine Building
65 Duke Street
Prince Frederick, MD 20678
Phone: (410) 535-1521
Fax: (410) 535-0591

Inspections & Permits
County Services Plaza
150 Main Street
Prince Frederick, MD 20678
Phone: (410) 535-1600 ext. 2552
Fax: (410) 535-2181

Planning & Zoning
County Services Plaza
150 Main Street
Prince Frederick, MD 20678
Phone: (410) 535-1600 ext. 2356
Fax: (410) 414-3092

A sketch is required as part of the application. The sketch does not have to be drawn to scale, but must indicate the distance between the location of the activity and buildings, roads, steep slopes (>15%), open water, wetlands and direction of overland water flow. The sketch must also show the tree and vegetation cover and indicate the amount of cover to be removed.

Other information may be necessary on some projects. A Grading Permit Exemption does not exempt you from other Federal, state or local permits that may be required for the proposed activity. Proposed activities within a wetland or shoreline (or their buffers) may require review/approval by the Department of Natural Resources, Army Corps of Engineers, Maryland Department of the Environment, and Critical Area Commission.

The exemption application requires several reviews and signatures in the following sequence before a permit exemption can be issued:

1. Applicant's signature.
2. Submittal to the Division of Inspection & Permits
3. Department of Planning and Zoning review and signature of approval.
4. Calvert Soil Conservation District (SCD) review and signature of approval.
5. Issuance of the Grading Permit Exemption by the Division of Inspections & Permits.

STEPS FOR APPLYING FOR GRADING PERMIT EXEMPTION ONLY

(no building permit) [2]

Step 1: For tree cutting in the Critical Area, it is recommended that you speak to the Critical Area Reforestation Planner in the Department of Planning & Zoning prior to submitting the Grading Permit Exemption application. For all other activities, it is recommended that you speak to your Soil Conservation District representative prior to submitting the Grading Permit Exemption application.

Step 2: Complete the application and submit to the Division of Inspections & Permits. They will forward the application to the Department of Planning & Zoning, where it is reviewed for compliance with the above criteria and the Zoning Ordinance. If Planning & Zoning is unable to approve the application, a staff member will contact you. If approved, the application will be forwarded to Calvert SD.

[2]Note: if you are applying for a building permit, submit your Grading Permit Exemption application at the same time.

Step 3: Calvert SCD will review and verify that the project qualifies for a Grading Exemption. If it does not, you will be contacted. If it meets all Calvert SCD requirements, they will sign the Exemption application and return it to the Division of Inspections & Permits for issuance.

Step 4: Contact the Division of Inspections and Permits to obtain the Exemption. The only fees required are the fees-in-lieu of replanting for cutting trees in the Critical Area (see fee schedule on the following page).

NOTE: The Grading Permit exemption is void if the project exceeds the limits stated on the application or the applicant has not accurately disclosed the nature or location of the activity.

You will be contacted if the reviewing departments have any questions or if additional information is necessary. The permit should be approved in 14-21 working days if there are no problems.

CRITICAL AREA FEES-IN-LIEU OF PLANTING & BONDS

If the property is located in the Critical Area, it is subject to Critical Area Fees-in-Lieu and/or Critical Area Bonds. (Amounts may vary under certain circumstances. Fees will be determined by Planning and Zoning).

Fees-in-Lieu of Planting for Approved Clearing of Trees

$.30/ s.f., if < 6000 s.f. or <20% of property, whichever is greater
$.45/ s.f., if >6000 s.f. and between 20% and 30%
$1.20/ s.f., if >6000 s.f. and > 30% (requires Board of Appeals approval)
$.80/ s.f. in the 100-ft. buffer (may require Board of Appeals approval)
$.40/ s.f. in the 100-ft. buffer for water dependent structures

Bonding:

$200.00 per tree for replanting (large tree) bond

Violations:

$1.20/s.f., if >1000 s.f. outside the 100-ft. buffer without permits or approvals
$1.60/s.f., in the 100-ft. buffer without permits or approvals
$1.60/s.f., if > 6000 s.f. and >30% without permits and approvals

If you have any questions concerning these regulations or any activities not specifically mentioned, please do not hesitate to call the Department of Planning and Zoning at 410-535-1600, ext. 2356

Click here to print this Guide and all relevant forms in Adobe Acrobat format.

4.3 Section 4 References

Calvert County Zoning Ordinance. (2006). May.

Maryland Department of the Environment (MDNR) (2003). *Maryland State Wetland Conservation Plan*. Water Management Administration, Wetlands and Waterways Program, Wetland Conservation Plan Work Group, April.

Maryland Department of Natural Resources (MDNR), 2004. "*A Guide to Maryland's Coastal Zone Management Program Federal Consistency Process*." Annapolis, MD. February.

U.S. Army Corps of Engineers and The Maryland Department of the Environment (USACE and MDE), 2005. *Maryland State Programmatic General Permit-2 (MDSPGP-2), 2 ½-Year Monitoring Report*. June.

Section 5 Best Practices

5.1 Introduction

The goal of developing and implementing best practices is to encourage the presence of a stable beach and minimize the rate of slope erosion along the Scientists' Cliffs' shoreline. The philosophy of the plan is to implement best practices that are designed based on a growing understanding of the local driving environmental mechanisms and in a way that allows the effectiveness of the practices to be measured, is affordable to the community, aesthetically acceptable, sensitive to concerns about the environment, and compliant with existing regulations.

The beach and slopes are an inter-related environmental system. A stable beach with an elevation substantially above MHHW promotes accumulation of debris at the toe of the slopes. The rate of erosion for most of the eroding slopes at Scientists' Cliffs is driven by freezing and thawing of the lower slope. A significant debris cover minimizes the exposure of the lower slopes to freeze-thaw action by acting as an insulating blanket. Evergreen vegetative cover can also serve a similar purpose on the lower slope. Conversely, for slopes where wave action can reach the toe under most circumstances, debris is washed away regularly and, during the times of the year when the slopes freeze, freezing and thawing are able to disintegrate the cohesive materials driving the rate of erosion of the entire slope.

Beaches and eroding slopes also are habitat for two types of tiger beetles that are endangered species according to the Federal government and the State of Maryland (MDNR 2004). The northeastern beach tiger-beetle (Cicindela dorsalis dorsalis) depends on the presence of a beach. The Puritan tiger beetle (Cincindela Puritana) depends on exposed the presence of a beach and sandy slope surfaces in which the larvae exist in burrows through two winter hibernations. The sandy surfaces must be relatively free of vegetation. The midslopes of the Scientists' Cliffs' slope developed in the Governor Run Sand offer this habitat. Slope toe accumulation rarely reaches upward to the base of the Governor Run Sand because it usually take over a decade for such a buildup to occur, except where recent landslides are present. It is important to note that none of the slope stabilization methods described in this plan call for reducing the long-term slope erosion rate to zero. That is, transforming the lower slope so that debris accumulates permanently on the mid and upper slopes is not recommended in this plan for a number of reasons.

Because of this, reducing the rate at which the slopes retreat by establishing a more stable beach may actually increase the availability of Northeastern Beach tiger beetle habitat, while not affecting the habitat of the Puritan Tiger Beetle. In addition to changes to tiger beetle habitats due to actions taken to stabilize the beach or minimize slope erosion, the best management practices in this plan will consider the life cycles of tiger beetles and take care to halt optional activities that may cause harm to tiger beetles during stages of their life cycles when they are particularly vulnerable.

This BMP assumes that, at least for the near future, the existing system of groins will continue to be used as the primary means for stabilizing the beach along the community. This is important because recommendations for the construction of alternative structures are not made in this plan. However, as part of this plan, metrics will be established to determine the effectiveness of the groins and it is possible that these observations could potentially lead to the conclusion that something other than a groin system is most appropriate for shoreline stabilization along Scientists' Cliffs.

Table 5.1 summarizes the recommendation for best practices made as part of this plan. While presented as individual recommendations, there are interdependencies between them and the details of how the recommendations work together are explained in the sections below.

5.2 Shoreline Considerations

As noted in Section 2 (Erosion and Stabilization Mechanisms), there is considerable uncertainty about the local behavior of the shoreline in response to the driving mechanisms of shoreline morphology. For instance, while it is known that the predominant direction of longshore transport is to the south along Scientists' Cliffs, the rate of transport and the thresholds between climatic conditions under which the beaches are actually built or eroded are not well understood. It is also well known that the longshore drift direction changes to northward for significant periods of time causing considerable movement of sand northward during those times.

Other key sources of uncertainty include:

- The source(s) of the sand in transport and available for building the beach
- Whether and how sand moves from the offshore bars onto the beach

- Whether significant quantities of sand are moved northward during extreme storms like Hurricane Isabel, partially replenishing the sand supply to the north of Scientists' Cliffs

It is not currently possible to even semi-quantitatively link changes in the shoreline to changes in the groin system. Because of this, predicting the performance of different structures is problematic.

However, since the groin system has been maintained for more than half a century, certain practical observations have been made that must continue to be incorporated into the shoreline stabilization practices along with best practice techniques for groin structures drawn from the literature. Key local observations include:

1. Where coastal slopes are present, groins must abut the cliff base to prevent waves and currents from undermining the groin from the backside.
2. Optimal length is 72 feet from lower slope or beach crest.
3. The upper surface elevation of the shoreward portion of the groin must be approximately the same elevation as the beach around it or as the elevation to which the beach is expected to build. Achieving the optimal top surface elevation may be iterative whereby gabion layers are either added or removed in response to the accumulation or erosion of sand adjacent to the groin. If the top surface is too high, it causes differential erosion during storms on the downwind side of the groin and if it is too low, insufficient sand accumulates.
4. The top surface of the groin slopes so that it is below water at mean low tide.
5. The spacing of groins at the most stable beaches along the Scientists' Cliffs' shoreline have a spacing ranging between 90 and 165 feet.
6. The porosity of the gabion construction allows water and sand to pass through the groins helping to equilibrate deposition on either side of the groin.
7. Groins that are "notched" in the swash zone allow some of the sand to bypass and tend to create a shoreline that is continuous across groin.

Items 1 through 7 portray "optimized" conditions according to the most current understanding of the SCA groin system and are consistent with practices recommended in Section 2.

8. Historic observations have noted a seasonal fluctuation in the building and degrading of beaches with beach building occurring during the summer and fall and beach degradation during the winter. This is consistent with general observations made on other beaches in the region and is attributed to the concept that beaches are built under mild wind and wave climates and degraded during high energy wind and wave climates.

9. Strong storms from the north-northeast or south-southeast (i.e., the major fetch directions) cause erosion of the beaches, particularly where groin dimensions are not optimized. Particularly strong storms erode beaches even where the groin spacing is optimized. For instance, the storm surge and wave action produced by Hurricane Isabel in September 2003 caused significant erosion of the beach south of the Great Jetty. This beach had been stable for approximately a decade and the groin system associated with that beach was considered in an "optimum" condition.
10. The beach north of the Great Jetty has been stable under all wind and wave climate conditions since its completion in 1964.

5.2.1 Shoreline Recommendations

Because there is considerable uncertainty in the magnitude and timing of the local driving mechanisms of beach erosion and deposition and optimization of the groin system has taken place using primarily qualitative observations, it is recommended that a two pronged approach be undertaken for improving the performance of the groin system.

First, modifications are recommended based on initial postulations about the values of the environmental mechanisms that have been observed to cause either local beach buildup or erosion. As modifications are proposed and implemented, attempts should be made to predict the expected performance of the changes. Predicting changes in beach systems is a difficult undertaking even for those who make it their profession. Undertaking intensive modeling is not recommended at this time because there are many large uncertainties concerning the source and movement of sand along the shoreline that can only be addressed by direct observation and because community resources are insufficient to perform such modeling at the required levels of effort and geographic scale of the problem. Rather, expectations of performance should be based on past observations and consideration of the known driving mechanisms such as wind speed, frequency of occurrence, and fetch and focused on anticipating how, where, and when beach changes will take place as a result of the modifications.

Second, a system to assess the effects of the modifications should be put in place and developed based on performance expectations. Rather than try to monitor all modifications that are made to the groin system, it will be more efficient and effective to focus on portions of the groin system where it may be possible to isolate the effects of a particular mechanism. For instance, the beach south of the Great Jetty is protected from the north-northeast fetch, but exposed to the south-southeast fetch. As noted earlier, Hurricane Isabel caused significant erosion of this beach that had been stable for many years. This observation suggests that the groin system in that area was optimized with respect to waves generated from the north-northeast fetch, but not the south-southeast fetch.

The goal of developing a means to systematically assess the performance of the groin system is to quantitatively determine the effects of changes made to the shoreline so that future activities can be conducted cost effectively and with a higher degree of confidence in their outcome. Further, activities will be undertaken to establish the links between the environmental mechanisms and the practices that have been identified to be effective over time.

Initial, drastic changes in the existing practices are not recommended. Rather, the immediate recommendations are to assure that existing stabilization activities are conducted in a manner that conforms with existing regulations, are economically sensible and aesthetically acceptable, and incorporate ecological and paleontological considerations.

Actions taken to encourage the presence and spatial continuity of beaches along Scientists' Cliffs are not anticipated to have substantial deleterious affects on the habitat of tiger beetles. While substantial and durable beaches ultimately reduce the overall rate of slope erosion, at Scientists' Cliffs, waves very rarely directly erode the lower slope. As discussed in Section 1.7, the moist, fine-grained sand deposits thought to be favored habitat by Puritan tiger beetle larvae occur primarily within the midslope. The dimensions and spatial distribution of beaches along this reach of shoreline do not change the dominant slope erosion mechanism of the mid and upper slopes which is landsliding. Rather, it is possible that stable beach conditions enhance the scavenging opportunities for the adult beetles in their search for food and provide increased stability of the beach which is favorable because northeastern beach tiger beetle larvae inhabit beach burrows for up to two years in a row.

<u>5.2.1.1 Groin System – Maintenance Recommendations</u>

<u>*Shoreline Recommendation 1: Uniformly Optimize Groin System*</u>

As noted in Section 5.2, decades of practical experience have contributed to a substantial understanding of what constitutes a well-functioning groin system for the conditions in the Scientists' Cliffs' area. However, not all of the groins in the system have been optimized to the existing specifications. In addition, remnants of older structures such as wooden "whaler" walls and concrete rings remain along the beach and intertidal zone and need to be removed or integrated into the existing system. The first step is to optimize the existing system per the current understanding of what constitutes a well-functioning groin system and measure the effects of these improvements.

Key elements of these recommended improvements include:

- The shoreward end of the groin should abut lower slope where appropriate or extend to the existing beach crest where slopes are not present.
- Length: The optimum groin length is currently thought to be 72 feet from lower slope or beach crest.
- Spacing: Optimum groin spacing has been observed to be 90 to 165 feet center to center, 125 feet is target spacing.
- The top of the groin should be no higher than mean higher high water at mean tide line. The groin should slope so that top surface of groin of the last 12 feet bayward is below mean low water.
- Continue to use rock-filled gabion baskets to construct groins.

There are several basic postulations about how the groins function in the Scientists' Cliffs' environment. Generally, the direction of sand movement in the system (longshore drift) is southward along the shoreline. The bulk of the sand that is trapped by the groins is thought to move between the intertidal zone and the first offshore sandbar. The distance from the base of the slope to the crest of the first sand bar varies significantly along the Scientists' Cliffs' shoreline. In six relatively evenly spaced transects measured in 1990, the distance between the base of the slope toe and the crest of the first offshore sand bar varied between 65 and 165 feet with an average of 110 feet. A groin length of 72 feet captures encompasses roughly 65 percent of the average distance.

The ability of some of the sand to move over the groin in the intertidal zone during storms and slowly through the porous rock structure helps to minimize large differences in the beach elevation between the updrift and downdrift sides of the groin. When the elevation of sand is evenly balanced across a groin there is far less tendency for the down drift side to be scoured. The idea is to make sure that the waves are not undersaturated with respect to the sediment load they are carrying ensuring that they do not have excess energy with which to erode sand from the beach.

Keying the shoreward end of the groin to the lower slope where applicable is important so that the water is forced to move over the groin rather than around the back end where it may be channeled through a gap between the groin end and the slope and cause scouring.

Since it is recognized that there are large uncertainties about the magnitude and timing of sand transport through this groin system, it is important to point out that is likely that improvements in the performance of the groin system can be made. However, improvements will have to be identified based on a systematized understanding of the wind and wave climate combined with metrics that allow the changes that result from changes to the system to be quantified.

One significant change to the groin system is suggested immediately below and a series of metrics are established in Section 5.4 that will help the community measure the effects of changes made to the groin system so that future improvements can be based on quantified observations about the system's performance.

A goal of this recommendation is to increase the spatial and temporal continuity of the beaches along Scientists' Cliffs. Since the entire life cycle of the northeastern beach tiger beetle occurs in beach habitat, impact to that beetle should be favorable. The beach is also habitat for the adult Puritan tiger beetle (and in some cases, the larval stage). For the adult Puritan tiger beetle, this modification should be favorable. Because the slopes along Scientists' Cliffs are very rarely eroded by direct wave action, and waves are frequently able to remove debris from the slope toe when beaches are present, very little change to the frequency and type of mid and upper slope sliding is expected to result from this activity. Therefore, the conditions for the larval stage of the Puritan tiger beetle will remain essentially unchanged.

5.2.1.2 Groin System – Substantive Improvements

Shoreline Recommendation 2: Elevate and Form T Shapes on Bayward End of Groins

During the early 1990s, measurements were taken of the beach elevations and cross-shore bathymetric profiles. At that time, the beach elevation was sufficient to protect the slope toe from wave action for wind speeds up to approximately 10 m/s (22 mph) (see Tables 1.5 and 1.6). Since the 1990s, storms have occurred where strong winds traveled along the north-northeast and south-southeast fetches causing significant beach erosion along the northern portions of the Scientists' Cliffs' shoreline and south of the Great Jetty respectively. During the storm events, the storm surge and wave regime exceeded the ability of the groin system to protect the stability of the beach in the most vulnerable places resulting in significant beach erosion at those locations.

Because the beach that occurs between groins is a major factor in diminishing the energy of storms and much of that capacity is lost with the loss of a beach, erosion from a relatively extreme storm can cause the remnant beach to be vulnerable to less powerful events. In essence, an unraveling of the beach occurs whereby smaller storms are capable of causing additional damage subsequent to large storms. This in turn requires that the groin system be modified (i.e., the base elevation of the groins in the intertidal zone be reduced) in order to begin capturing new sand and minimize scour related to large elevation differences between the groin top and the surface of the sand.

In short, large storms destabilize the mechanics of deposition and erosion of the beach and the configuration of the groin system must be iteratively manipulated in order to regain a stable configuration.

Therefore, a recommendation is put forth to modify the groins so that they are better able to diminish the energy from strong, rather infrequent storms. The modification is based on the design storm conditions of an average wind speed of 13.5 m/s (30 mph) from both the north-northeast and south-southeast directions. (See tables 1.5 and 1.6). For these wind speeds and fetch directions, a storm surge of approximately 1 meter (3.2 ft) is predicted and the wave height that causes the greatest breaking stress on the shoreline is approximately 0.9 m (3 ft) from both the south-southeast (0.88 m) and north-northeast (0.94 m) directions.

As a result of this observation, it is recommended that the bayward half of each groin be formed into a “T” shape within two experimental areas and configured so that the top surface of the modified portions is at approximately 1 foot above MSL. The shoreward half of each groin should stay in the “optimized” condition as it is currently understood. One experimental area should be established north of the Great Jetty where its effects appear to diminish and one experimental area should be established immediately south of the Great Jetty. It is recommended that a minimum of eight groins be involved in each experimental section.

The rationale for establishing the elevation of the “T” and the bayward half of the groin at one foot above MSL is that the groin should cause the design extreme storm wave to break. This requires that the top of the groin be at an elevation where the most frequent wave will break considering the storm surge associated with the storm. For this design, the storm surge is estimated at approximately 3.2 feet above MSL and the most frequent wave height is roughly 3 feet. This means that the water depth above the top of the groin during the storm must be shallower than 0.78 x the wave height or shallower than roughly 2.5 feet. Therefore, the top of the groin must be no more than 2.5 feet below the storm surge surface. The storm surge water surface for this design is 3.2 feet above MSL. Therefore, the top of the groin elevation for the last half of the groin and the "T" portion should be a minimum of 0.7 feet above MSL. Given that construction of the groin is only accurate to roughly 0.5 feet NGVD, the elevation for this portion of the groin should be maintained at roughly 1 foot above MSL. The shoreward half of the groin should conform to the current "optimized" configuration.

As part of the program to establish performance metrics and monitor the effects of the changes, both experimental areas should be included in the measurement program described in Sections 5.4. In addition to the modifications, the best practices to maintain the "optimum" groin configuration, such as iterative adjustment of the groin to the beach elevation in the intertidal zone should be continued.

It is important to note that implementation of this recommendation is not expected to result in a condition whereby wave action never erodes the beach or debris accumulated at the base of the slope. Rather, it is a measure recommended to increase the time between erosive events allowing longer periods of time over which slope debris is allowed to accumulate on the face of the lower slope reducing the rate of lower slope retreat due to freezing and thawing and encouraging a wider, more stable beach. Further, this recommendation should be considered as part of the overall strategy to minimize the long-term rate of slope erosion and increase the linear continuity and overall stability of the beaches.

5.2.1.3 Major Shoreline Structures

Shoreline Recommendation 3: Consider Additional Jetties

Consider installing additional jetties similar to the Great Jetty working to the north from the Great Jetty.

It is clear that the Great Jetty has protected the beach north of it from wave action generated by winds out of the southeast. A stable beach extends for approximately 1,000 ft northward. Similarly, the Great Jetty has protected the beach to its south from wave action generated by winds from the northeast. As noted previously, the beach south of the Great Jetty was significantly eroded by Hurricane Isabel due to a wave attack generated by winds from the south-southeast fetch. However, the beach to the north remains in good condition despite several strong wave attacks from the north-northeast fetch. The fact that the northern beach has remained stable while the southern beach was eroded is instructive.

Beaches with substantial width and elevation allow waves to move across them and if the sand is not saturated all the way upward to the surface of the beach, water from the waves is able to infiltrate into the sand and is removed from the flow of water returning to the Bay after the wave crest has passed. This causes sand being carried by the waves to remain on the beach because, by losing water to infiltration, the water is no longer available to transport the sand to the Bay.

The Great Jetty is positioned such that there is a fairly wide expanse between the shoreline and slope toe to its north, but a relatively narrow distance from the shoreline to the slope toe to the south. During the early 1960s, grading was conducted to form the beach parking lot creating the relatively flat extended surface extending from the slope toe to the shoreline north of the Great Jetty. The result of the creation of this surface in combination with the construction of the Great Jetty was to provide a protected area across which waves moving from the northeast direction during strong storms could expend their energy and deposit sand.

But, even at its recent maximum, the beach south of the Great Jetty had a relatively narrow portion of the beach that was high enough above most storm surges to allow percolation of the wave water into the beach. Therefore, the combined storm surge and wave energy associated with Isabel exceeded the threshold of the beach to infiltrate the water and dissipate the wave energy.

The concept for recommending the consideration of additional jetties similar to the Great Jetty is based on two key features of the jetties (as compared to groins): 1) they provide good protection from extreme storms from both major fetch directions (i.e., north-northeast and south-southeast) and 2) the jetties would help to build a wider, higher beach that is better able to infiltrate water during extreme events and dissipate the erosive wave energy.

The key elements of this recommendation are:

- Use the existing Great Jetty as a design example.
- This action will require filling the updrift area with sand to encourage immediate bypass of sand around jetty and to prevent erosion of the beach downdrift. Use sand

with a grain size distribution similar to that of the sand currently trapped by the Great Jetty. The logistics and cost associated with this activity may make the entire recommendation difficult to implement. It has become unacceptable practice not to use sand to fill the updrift beach and intertidal zone of major structures to their expected configuration upon construction because of the high likelihood of causing severe erosion in the down drift direction.

- Undertake one jetty at a time for both fiscal considerations and to allow good understanding of single jetty impacts on beach stabilization.
- Locate the first new jetty north of the Great Jetty at the point where the tangent of the curve of the beach trapped by the Great Jetty becomes nearly parallel with the direction of the shoreline to the north.
- Encourage native beach vegetation as beaches become established.

There is at least one important uncertainty associated with this recommendation. Is there sufficient sand available and in transport in the nearshore littoral system to maintain a higher, wider beach updrift of each new jetty? This question is not easily answered and the scope of the question extends far past the boundaries and means of Scientists' Cliffs. Significant issues related to the rate and distribution of sediment transport throughout the Chesapeake Bay remain unresolved.

An important element of this question that is unresolved locally is: What are the sources of sand that contribute to the beaches along Scientists' Cliffs?

Sand from the Upland Deposits distributed across much of the surface of Calvert County is a likely potential source of the sand present on the beaches and in the nearshore along the middle and northern Calvert Cliffs. Local observations of the ravine bottoms along Scientists' Cliffs show sand and some coarse sand and gravel, is funneled to the beaches via the steep ravines, where even modest storm flows can carry coarse materials (Vogt, 2006). However, no measurements of the rate of sediment transport or the grain-size distribution of the sediments moving through the ravines have been made.

Clearly, there is a significant mass of sediment resident in the sand bar system offshore of Scientists' Cliffs. Section 1 describes the Governor Run Sand formation, an ancient Miocene-aged channel filled primarily with sand, the width of which extends from approximately the northern boundary of the Scientists' Cliffs' property to Governor Run, essentially coincident with the north-south extent of the sand bar system.

Grain size data collected from the Governor Run Sand (Miller 1995) and grain size data collected from the offshore sand bar system at Scientists' Cliffs (Downs 1993) suggest that the grain sizes between the two sand bodies are similar. However, the proportional contribution and timing of sand contributed by the sand bar system to the sand on the Scientists' Cliffs' beaches is unknown. A study of this subject would be helpful to understanding the types of shoreline structures that may perform well along this reach of the Bay. However, a study that would provide conclusive results is far beyond the means of the Scientists' Community and would necessarily extend outside the immediate area around Scientists' Cliffs. The only approach currently available to the community to assess whether additional jetties would enhance the presence and stability of the beach is an empirical approach using careful measurements of the conditions prior and subsequent to the construction of each jetty. Because an empirical approach is the only feasible option available, if this recommendation is considered, part of the recommendation is to "go slow." That is, install one jetty at a time and measure the effects making sure to provide beach nourishment using sand of a grain size similar to that composing the current beach north of the Great Jetty.

5.2.1.4 Use Vegetation and Natural Debris to Resist Beach Erosion

Shoreline Recommendation 4: Encourage Accumulation of Natural Debris and Vegetation on back beaches

Beach vegetation helps to stabilize beaches. Natural debris serves as foci for the accumulation of sand and absorbs wave energy reducing the potential for waves to erode the beaches. Key elements of this recommendation include:

- Allow natural woody debris to accumulate on back beaches adjacent to slopes.
- Plant and/or encourage the growth of native grasses and vegetation in these areas to help stabilize the beaches.
- Remove unsightly or unsafe debris

A balance must be struck between the potential for large tree trunks and limbs to cause damage to beach structures and the lower slope during high energy wave events.

5.2.2 Measurements to be Made to Evaluate the Effectiveness of Changes to the Groin System

To acquire information sufficient to make decisions about future shoreline stabilization practices, this plan recommends developing a set of measurements that are derived from the fundamental parameters governing the mechanisms of erosion and deposition.

Objective

The objective is to determine how well the changes to the groin system serve to stabilize/build the beach.

A series of measurement objectives are developed that, when combined, conclusively satisfy this main objective.

Approach

Ideally, the parameters that are measured not only clearly provide conclusive quantification relative to the main objective. But, they should also be compatible with (i.e., derived from) the independent variables that are characteristic of the environmental processes that build or erode the beach (i.e., wind speed and direction, wave height and frequency, geometry of the shoreline and nearshore, geometry of the beach structures, grain-size and density of the sand, etc.)

The important environmental parameters contributing to beach development and erosion are provided in Table 5.1.

Parameter	**Comment**
Slope of the shore	Measured perpendicular to the waterline
The width of the shore from one of the tidal positions (i.e., mean high water, mean tide, mean low water, etc.) to the slope face. Include the beach crest, if present.	This is a parameter fundamental to the main goal.
**The velocity of the water*	It is preferable to calculate the velocity under a variety of conditions from wave height estimates and measurements of beach geometry. Measuring water velocities at key times and locations, particularly during storms is problematic, expensive, and beyond the capabilities of the community.
The timing and direction of sand movement	It is important to get a sense of the paths and transit times of the sand in the system in order to optimize the techniques that are used to encourage beach development. The most practical and effective measure of sand movement is to periodically survey the beach geometry prior to changing the groin system configuration and at strategic times, like before and after storms, after changes are made.
The prevailing wind directions	It will be necessary to obtain the wind record during the period of time over which observations are made and to link key observations to the wind activity. For instance, it may be the case that there is substantial beach development when the winds blow from the northeast for several days at a moderate wind speed, but beach erosion occurs when the wind speed is higher from the same direction. Attempt to obtain meteorological records from Calvert Cliffs Nuclear Plant on a regular basis.
The grain size distribution of the sand	It is possible that different distributions of sand grain size occur seasonally. The grain size distribution will also change along shore-parallel transects between groins and along shore perpendicular transects. So, really understanding the grain size distribution and how it varies temporally and spatially will require considerable effort. Grain size information is available for the major stratigraphic intervals (Miller 1995) and for the sand bars (Downs 1993).
The density of the sand	Will be determined along with grain size distribution.
The presence, type, and density of vegetation	Pictures will be helpful. Close ups and broad scale shots will be necessary. As part of the longer term BMP, Systematic documentation will be necessary.
The elevation, dimensions, and spacing of groins and other significant structures along the shoreline	
The degree to which stabilizing features break the waves and dissipate wave energy.	This is mainly related to the way the groins are constructed (i.e., composed of rocks in baskets) and their configuration.

Table 5.1 Measurement of Environmental Parameters Important to Beach Development

**Italics indicates that direct measurements of these parameters is not recommended as part of this plan. The comments column will briefly provide the rationale.*

<u>The Measurements to be Made (see Figure 5.1)</u>

This section is meant to describe what should be measured and how and when the measurements should be made. Of the parameters listed above, it will be most fruitful to measure the physical dimensions of the beach and structures. An automatic laser level will be a very useful tool.

The basic idea is to measure the beach and the bottom offshore as far as can safely be measured. Ideally this should be done prior to beginning modification over a selected area of the beach and periodically afterwards.

It will be important to know how the volume of sand being managed by the structures varies over time and how that relates to the wind and wave climate and modifications made to the structures. It will be particularly important to know how quickly the beach and nearshore change after the completion of the work.

It will also be important to keep the process of measuring as simple and quick as possible so that people (i.e., volunteers) are likely to perform them at the appropriate frequencies. Therefore, the following process is suggested.

Currently the SCA has five vertical benchmarks (i.e., monuments) that are likely to remain stable over a decade or longer. Accurately knowing the elevation of the beach, nearshore bottom, and structures is essential to judging how well the structures perform and optimizing their performance. Install additional benchmarks as necessary and survey them with an accuracy of a half-inch in elevation. Groins can't serve as monuments since it is known they shift position. The best type of monument is one that is concrete, established as far away from the water as is practical, installed well below frost depth and to height that will allow it to not be buried by sand, and ideally it should be installed into the native strata beneath the beach sand. It is useful to have at least three monuments within the reach of a measuring tape along any particular study section. This is recommended for a couple of reasons. First, when using a tape measure to locate a point, you must make at measurements to at least two known points. Second, it lets vertical data be cross-checked between them. Finally, if a monument is damaged or destroyed, temporal continuity is maintained by the others. When installing monuments, make sure to measure their positions relative to each other (i.e., take measurement from each one to all of the others). Engage a surveyor to survey the horizontal and vertical positions of the monuments and map them.

Each time measurements are made:

1) Set up at least three straight lines parallel to each other and the water line from at least 200 feet (the more the better) south of the project to 200 feet north of the project.
    a) One line should run near the slope base (measure the distance of the line from the slope toe at several measured distances along the line,
    b) One line near the water line, and
    c) One line near or just past the end of the longest groin (if the water is not too deep). If the water is too deep there, move the line to where it can be safely measured.
    d) Measure the distance from the beginning, end, and several key distances in between of the transects to the monuments. It is necessary when making this type of measurement (i.e., locating the end of a transect) to know its position relative to two other known points, preferably monuments). You'll need a long tape measure. There are other options if this isn't possible.
    e) If possible, take compass bearings on each transect (this will be true for the perpendicular transects described below also).

Try to keep the lines as close to parallel as possible, mark off every ten feet and make elevation measurements at those marks.

Make sure to periodically recheck the elevation of the monument to make sure the level hasn't shifted. This is useful, because if it does shift, you only have to return to the place along the line where you made the last correct measurement of the monument rather than repeat the whole line. It's OK if there is a small shift, but if it gets outside of an inch (preferably a half inch), the portion in question should be remeasured.

2) Do transects perpendicular to the water line beginning at the slope base and extending at least to the most Bayward of the shore-parallel lines. Make sure to note the slope base, the position of each shore-parallel line, and the position and time of the water line. Do this on either side of each groin and midway in between each.

Whenever elevation of the water line is measured, note the time and the bay and wind conditions.

3) Measure the groins:
    a) Height (total height is preferable – be sure to note where it is only made relative to the bottom or beach), width, length. At the locations where the height is measured, measure the distance to at least two known points (i.e., positions on your transects or to the monuments.
    b) Do an elevation profile along the length of the groin spacing the measurements every five feet or so. Start the groin profiles at a known

point relative to the beach transects (make measurements to several known points for redundancy).

4) Install vertical, graduated measuring staffs at several locations along the groins including in the water to provide a quick way of estimating whether it would be fruitful to acquire another full set of transect measurements.

Other things to do:

- Make careful notes.
- Sketch everything you measure.
- Take lots of pictures.
- Take note of the beach and nearshore bottom positions on the vertical staff gauges installed by the groins.
- Estimate the time of occurrence of low and high tides.

Supplies that will be needed:

- A long cloth or plastic measuring tape.
- A surveyors rod marked off in units of inches and feet.
- The laser level
- A “write in the rain” field note book
- A camera (it would be ideal to use the same camera for all pictures over the life of the project). Take at least some of the pictures from the same locations over time and use the same lens setting and focal length.
- Small stakes and flagging.
- A hammer or mallet for driving the stakes.
- Staff gauges composed of a suitable material and capable of being marked with indelible ink.

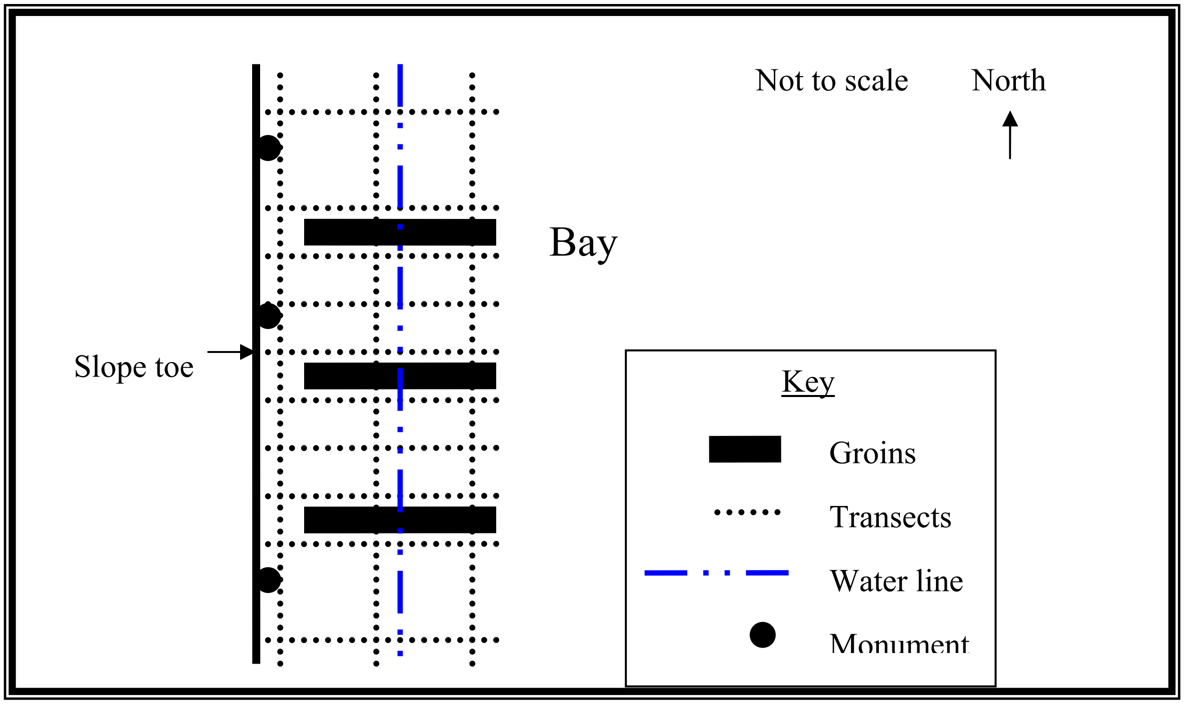

Figure 5.1: Transects and monuments

5.3 Slope Considerations

There is considerably more certainty about the timing and magnitude of the mechanisms driving slope erosion along the Scientists' Cliffs' shoreline. As discussed in Section 2 (Erosion and Stabilization Mechanisms), two lines of evidence show that freezing and thawing of the lower slope materials drive the rate of erosion of the coastal slopes along Scientists' Cliffs. The first is direct measurement of erosion pins installed in the lower slopes that have been monitored for approximately 13 years. Those measurements show that the rate of erosion of the lower slope due to freezing and thawing is consistent with the long-term rate of slope retreat there. Secondly, because of the cohesive strength of the lower slope materials relative to the forces with which the waves strike the slopes, waves forces are only able to directly erode the intact material of the lower slopes for less than an hour per year on average. This assumes that no slope debris exists which must be removed before the waves can directly erode the lower slope, a very conservative assumption.

The midslope and upper slope erode at the same long-term rate as the lower slope. As long as the lower slope retreats, even at a very slow rate, the midslope will eventually be undercut and failure of the midslope will occur. For a given undercutting rate, the depth and frequency of sliding depends largely on the depth to which water saturates the slopes during long duration, heavy rainfall and/or snow melt and the rooting depth of plants growing on the slope. In the event where the rate of lower slope erosion becomes and remains zero, landslides in the mid and upper slopes will continue for many years. But eventually, because of the redistribution of slope material from the upper slopes to the toe, the angle of the slope diminishes and bluff top retreat will stop.

A very important goal of this plan is to balance the needs of the community to minimize the occurrence of large, dangerous landslides and the rate of property loss against the habitat requirements of the Puritan tiger beetle larvae (i.e., bare sandy, moist slopes). This plan uses the observations and conclusions from a detailed study of the dominant erosion mechanisms conducted at Scientists' Cliffs in the early 1990s (Miller 1995) develop the approaches recommended in this plan.. The recommendations of this plan for both the slopes and the beaches are integrated and are aimed at collectively achieving that balance.

5.3.1 Slope Recommendations

5.3.1.1 Protective Structures and Practices – Slope Parallel Gabion Baskets

Slope Recommendation 1: Install Slope Parallel Gabion Baskets at Base of Lower Slope Where Freeze-Thaw Degradation is Active

Because the rate of lower slope erosion drives the rate of overall slope retreat and the dominant erosion mechanism of the lower slope is freezing and thawing along the SCA shoreline, and because one of the goals of this plan is to reduce the overall retreat rate, methods that reduce the rate of erosion of the lower slope are desirable.

This recommendation suggests the use of rock-filled gabion baskets like those used to construct the groin system to be installed in a stepped fashion along the face of the lower slope.

Key Features:

- The base of lower gabion basket should be installed above MHHW
- The lowermost row of gabions should be keyed into intact geologic material
- A stepped and interlocking construction is recommended
- The elevation of upper gabion should be no higher than 6 feet above MHHW

These structures serve two valuable purposes. One is to catch debris moving from the mid and upper slopes to the toe and protect it from wave action. As the debris accumulates on the gabion structures, it covers and insulates the lower slope reducing the overall rate of lower slope erosion. Secondly, during significant storms these structures and the debris they collect intercept waves before they strike the slope and dissipate the wave energy. By dissipating wave energy, they help to reduce the degree of beach erosion that occurs during a storm and, in some cases, allow sand carried by the waves to be deposited on the beach.

A very important aspect of these structures is that they do not permanently prevent lower slope erosion; they are meant to reduce the rate of lower slope erosion. This aspect is a key element of the attempt to achieve and overall balance between minimizing the rate of slope erosion and sustaining habitat for Puritan tiger beetle larvae.

Some very strong storms will be able to remove the lower slope debris trapped by these structures and temporarily expose the lower slope to degradation. By permitting some lower slope erosion, undercutting of the mid and upper slopes will continue to occur albeit at a reduced rate. This means that the mid and upper slope dominant erosion mechanism will continue to be landsliding. When combined with the recommended practice to discourage deep-rooted plants from colonizing the slope faces, and hence forcing more frequent shallow sliding to be favored over deep, less frequent slides, the rate of slope retreat can be reduced while maintaining exposed slope faces for beetle larvae to occupy at spatial distributions similar to current conditions.

Because of the need to achieve such a balance, structures that permanently eliminate erosion of the lower slope are not recommended. In addition, such structures tend to create unfavorable conditions for the buildup of beaches, are often aesthetically objectionable, and are expensive to build and maintain.

5.3.1.2 Protective Structures and Practices – Insulating Vegetation and/or Man-made Materials

Slope Recommendation 2: Encourage the Presence of Insulating Vegetation and/or Use Man-made Materials to Insulate the Lower Slope Face

One of the original experiments begun in the early 1990s and continued through today at Scientists' Cliffs is a comparison between the rates of lower slope erosion between slope faces, as measured by erosion pins, where all of the major variables to erosion are held constant (i.e., material type, wave climate, groundwater flux to slope face, and slope geometry and orientation) and only the exposure to sunlight varies. Both slopes face east and the exposure to sunlight was controlled by the presence or absence of vegetative cover. The pin field just north of the Chestnut Cabin steps was, and continues to be, substantially covered with English ivy. The pin field south of Groin 30 is directly exposed to sunlight from the east. In addition to demonstrating that the overall rate of erosion at both pin fields is driven by freezing and thawing, the lack of large diurnal temperature differences for the pin field near the Chestnut Cabin steps allowed that face to remain frozen for the duration of sub-freezing air temperatures. The result was that diurnal freezing and thawing caused the lower slope face near Groin 30 to recede more quickly because, as each thawing event took place, the material would fall from the face toward the beach, making fresh material available for the next freeze.

Therefore, it is recommended that where conditions are amenable, appropriate vegetative cover be used to insulate the slope face from the warming of the sun during periods when the air temperature is below freezing. It is important that an evergreen variety of plant be used or a deciduous variety that leaves a thick mat during the winter. Native species are preferred when possible.

In addition to natural vegetation, consider using man-made materials as slope insulating blankets that can be applied during periods when the air temperature is sustained below freezing. This recommendation is considered experimental because there are a number of difficulties associated with this option. Among the potential difficulties are:

- Finding a suitable method for securing and removing the insulating material from the slope face
- Potential damage and scattering of the material as a result of storms
- Aesthetic concerns
- Costs
- Potential habitat for undesirable insects, mold, etc.

5.3.1.3 Mid and Upper Slope Vegetation Practices

Slope Recommendation 3: Encourage Shallow-rooted Vegetation over Deep-rooted Vegetation on Coastal Slopes

This activity is an essential part of the overall slope and beach management recommendations made in this plan. Two major and related objectives are to be accomplished via this practice: 1) reduction of the occurrence and frequency of large, dangerous landslides and 2) encouragement of bare slope habitat necessary for Puritan tiger beetle larvae.

Currently, there is no effort to systematically manage vegetation on the coastal slopes along Scientists' Cliffs. The result is a that a mix of trees, shrubs, vines, and grasses occupy the slopes. Because there is typically a significant period of time (on the order of decades) between landslides at any particular location along the shoreline, deep-rooted plants are able to gain a purchase on the slopes until they are stripped away by a subsequent landslide. Because significant periods of time pass between slides, the largest, deepest slides frequently involve trees of significant size.

For a given slope retreat rate, fewer large, deep landslides are required to remove an equal mass of slope material as more numerous, shallower landslides would remove. It is a goal of this plan to reduce the overall rate of slope erosion along the Scientists' Cliffs' shoreline. With no changes in the management of vegetation on the slopes, which implies the magnitude and dimensions of landslides would occur similar to how they occur now, the result would be to reduce the frequency of landslides. In turn, this would reduce the amount of bare slope face present at any given time causing less favorable habitat conditions for Puritan tiger beetle larvae.

In order to maintain an equivalent area of bare slope exposed at any given time under a reduced slope erosion rate, and assuming an average slide affects an area similar to the current average slide, the average depth of each landslide must be reduced.

In conceptual terms, this means that if the rate of slope retreat is diminished by half due to implementation of the best practices recommended here, assuming planar landslides (a fairly accurate assumption), in order to maintain the same area that is devegetated by current landslides, the depth of sliding would have to be reduced by 50 percent and a frequency of sliding similar to that of the last few decades would have to be maintained.

Rooting depth is a key factor in the stability of the Scientists' Cliffs' slopes (see Section 1.6). Recall that as water from significant storms and/or snowmelt saturates the surface of the slope and infiltrates into the slope, there is a depth of saturation for any given combination of slope angle and material strength at which a shallow, planar landslide will occur. Since the sandy midslope material reported to be favored by Puritan tiger beetle larvae has very little cohesive strength, roots are essentially the only source of cohesive strength on the sandy slopes. Generally, the thicker and deeper the roots, the more resistant the slope is to shallow sliding.

This means that a shift must be made to encourage the average rooting depth of plants occupying the slope to be reduced. The intended result is to make the landslides smaller, less dangerous, and maintain equivalent habitat.

Some of the species previously suggested by committees at SCA were switchgrass (panicum virgatum), eastern gammagrass (tripsacum dactyoides), tall fescue (festuca arundinacea), ventiver grass (vetiteria zizanioides), reed grass (phragmites australis), and sericea lespedeza (see Section 3.3)..

5.3.1.4 Water Management Practices

Slope Recommendation 4: Minimize the input of water to the slope face or directed over the slope face to the beach.

Key practices include:

- Route stormwater away from coastal slopes
- Where possible, orient septic drainage fields to drain away from coastal slopes
- Discontinue routing stormwater via piping over slope face directly to beach.

Water percolating into the slopes that is not used by vegetation eventually moves downward to the geologic contact between relatively coarse-grained materials above and fine-grained materials below. Typically, the water then moves laterally toward the Bay and exits at the contact between the lower slope and midslope. The contact between the lower and midslope is often the location at which relatively large landslides initiate. Therefore, minimizing the input of water to the slope is desirable. Localized sources of water such as septic input or stormwater runoff have the most effect at locations where the drainage area contributing water to the local water table are small because they represent larger proportional contributions.

Routing stormwater over the slope to the beach via pipes significantly contributes to localized beach erosion where the water flows onto the beach. The reason this practice is undesirable is because, by definition, stormwater occurs during storms when the beach is likely to be experience elevated water surface levels and some degree of destructive wave attack. A beaches capacity to resist erosion by waves and storm currents is strongly influenced by its ability to infiltrate water into the sand which reduces the amount washing back over the beach on its return to the Bay. Stormwater directed to the beach and focused by piping at specific locations along the beach cause the sand to become saturated more rapidly than it normally would. The saturation prevents infiltration of the waves and storm surge enhancing the ability of the return flow to pick up sand from the beach and transport it Bayward.

There are two other broader best practices reasons to manage water on, within, and around coastal slopes.

- Minimizing runoff traveling along the slope face reduces undesirable sediment migration into the Bay and
- Routing septic drainage away from the slope faces helps to reduce the nutrient input to the Bay.

Reducing water input to the slope face may slightly reduce the rate at which vegetation recolonizes landslide scars and an overall reduction of water to the slope may reduce the likelihood of large landslides occurring. Reducing the likelihood of large landslides forces the dominant erosion mechanism to be shallow landslides that occurs more frequently. The combined effect should be that greater areas of bare slope face are exposed at any given time.

5.3.1.5 Best Practices for Bluff top Trees

Slope Recommendation 5: Minimize the presence and profile of tall trees along the bluff top edge in order to prevent trees toppling due to wind-throw.

Key practices include:

- Thin branches from trees along bluff top
- Remove dead or dying trees located near the bluff top
- Discourage the presence of tall trees near the bluff top

Tall trees tend to have high wind profiles and large root balls. When these trees topple, they take large sections of the bluff top along with them. For large trees currently growing along the bluff top, taking steps to reduce the likelihood of their toppling is desirable. Discouraging their presence altogether reduces the likelihood of large root balls removing large sections of bluff top as failure occurs. An important concept to remember is the overall rate of bluff top retreat is set by the overall rate of lower slope retreat unless the lower slope erosion rate is reduced to zero. It is fallacious to think that large root systems somehow reduce the rate of bluff top loss. Root masses simply prevent smaller, more frequent bluff top failures in favor of large failures involving the bulk of the root ball. Therefore, minimizing the presence of large root balls at the bluff top serves to ensure that only relatively small segments of the bluff top are lost in any single failure. This practice is not expected to impact tiger beetle habitat.

5.3.2 Measurements to be Made to Evaluate the Effectiveness of Slope Management Practices

To acquire information sufficient to make decisions about future coastal slope management practices, this plan recommends developing a set of measurements quantitatively document the rates of erosion related to the dominant erosion mechanisms along the Scientists' Cliffs coastal slopes.

Objective

The objective is to determine the effectiveness of techniques used to slow lower slope erosion and minimize the frequency of large landslides in favor of more frequent shallow slides.

Approach

The important measurements to be made to evaluate the effectiveness of slope management techniques are provided in Table 5.2.

Measurement to be made	Details
Lower slope retreat	Measure the length of exposure of erosion pins in the two existing pin fields quarterly. Be sure that a measurement is taken before freezing begins in the fall, during freezing weather, and after threat of freezing is over. If significant storms occur where waves directly contact the slope base, acquire measurement after the event.
Document rate of lower slope and bluff top retreat	Approximately once every five years have the horizontal and vertical position of the lower slopes and bluff tops along the entire shoreline of Scientists' Cliffs professionally surveyed. Each time this survey is conducted, be sure to measure the monuments present along the shoreline.
Frequency and depth of midslope landslides	Typically, each year brings periods when the slope face is saturated sufficiently to generate midslope landslides. Such circumstances typically occur just prior to vegetation reemerging from dormancy combined with heavy rain or snowmelt and for a few days after significant rainfall events with durations of at least several days. Two or three surveys of the shoreline should be conducted each year in conjunction with such events and the location, number, and approximate length, width, and depth of each landslide should be documented. If broken root tendrils are evident on the slide surface, safely attempt to determine their diameter and approximate spatial density. Select representative landslides and take photographs of the debris and the slide surface. Revisit the slide several times during the year, particularly during the growing season and take additional photographs. Attempt to frame the photographs similar to those taken during preceding visits.
Rate and nature of revegetation of landslide surfaces.	Use the photographic evidence described above to document the rate at which slide surfaces revegetate. Seek the assistance of a botanist familiar with the local species to document the types of plants that recolonize the slide surface.
Measure the coverage and duration of talus covering the lower slope.	In the various circumstances where talus covers all or portions of the lower slope, document the presence via photographs in representative cases (i.e., where stabilization measures are present, where a significant beach is present, where little beach is present, etc.). Periodically revisit the same sites and document the time period over which the talus builds and those time at which it is removed. When talus is removed, attempt to document the associated preceding wind and wave conditions and note the date(s) that they occurred.
Meteorological measurements	Acquire a continuous record of wind speed and direction, temperature, and precipitation from the Calvert Cliffs Nuclear Plant.

Table 5.2 Measurement to be Made to Evaluate Effectiveness of Slope Management Practices

5.4 Permitting Requirements Associated with Best Management Recommendations.

Permit requirements associated with the various best practice recommendations are provided in Table 5.3. A full discussion of they types of permits and processes for obtaining the permits is provided in Section 4.

In addition to describing the construction or modification of structures, it is important to include details about where and how materials will be stockpiled and transported. For Federally-related permits, it will be necessary to discuss how the proposed actions may affect the Puritan and northeastern beach tiger beetle habitats. This information is also provided in Table 5.3.

Table 5.3 Best Practices Recommendations Summary Table

Category/Recommendation	Key Elements	Permit Requirements	Comments	Tiger Beetle Habitat Considerations
Groin System Maintenance				
Uniformly Optimize Groin System	• Abut lower slope where appropriate • Length: 72 feet from lower slope or beach crest • Spacing: 90 to 165 feet center to center, 125 feet is target spacing • Top of groin no higher than mean higher high water at mean tide line. Sloped so that top surface of groin of the last 12 feet bayward is below mean low water • Continue to use rock-filled gabion baskets to construct groins.	• Joint USACE/MDNR • County Grading Permit Permit requests should cover multiple years of maintenance activities	Porosity of rock baskets is important to maintaining longshore transport of sand. Sand must be able to move over groin in the intertidal zone during. Increasing the elevation of the groins to optimum elevation should be done over time so that the large elevation differences do not exist between the top of the groin and the elevation of the beach in the intertidal zone.	A goal of this recommendation is to increase the spatial and temporal continuity of the beaches along SC. Since the entire life cycle of the northeastern beach tiger beetle occurs in beach habitat, impact to that beetle should be favorable. The beach is also habitat for the adult Puritan tiger beetle (and in some cases, the larval stage). For the adult Puritan tiger beetle, this modification should be favorable. Because the slopes along SC are very rarely eroded by direct wave action, and waves are frequently able to remove debris from the slope toe when beaches are present, very little change to the frequency and type of mid and upper slope sliding is expected to result from this activity. Therefore, the conditions for the larval stage of the Puritan tiger beetle will remain essentially unchanged. When transporting material to the position where the structure will be installed, care should be taken to avoid the upper intertidal and high drift zones of the beach to avoid harming northeastern beach tiger beetle larvae. Further, construction activities should be limited to months when adult tiger beetles are not active.

Category/Recommendation	Key Elements	Permit Requirements	Comments	Tiger Beetle Habitat Considerations
Elevate and Form T Shapes on bayward end of groins. Initiate experimental modification of groins to diminish wave energy from less frequent strong storms	• Select two "optimized" sets of groins at least 8 groins wide. One on the north side of the Great Jetty and one on the south side. • For both the north-northeasterly and south-southeasterly fetch directions, the elevation of bayward half of the groin and the "T" portion should be approximately 1 foot above mean sea level. • In addition to the experimental modifications, the existing "optimization" protocol should be followed.	• Joint USACE/MDNR • County Grading Permit Combine this activity with optimization activity above under a single multi-year permit application.	The rationale for establishing the elevation of the "T" and the bayward half of the groin at one foot above MSL is that the groin should cause the most frequent extreme storm wave height to break. This requires that the top of the groin be at an elevation where the most frequent wave will break considering the storm surge associated with the storm. For this design, the storm surge is estimated at approximately 3.2 feet above MSL and the most frequent wave height is roughly 3 feet. This means that the water depth above the top of the groin during the storm must be shallower than 0.78 x the wave height or shallower than 2.5 feet. So, the top of the groin must be no more than 2.5 feet below the storm surge surface. The storm surge water surface for this design is 3.2 feet above MSL. Therefore, the top of the groin elevation for the last half of the groin and the "T" portion should be a minimum of 0.7 feet above MSL. Given that construction of the groin is only accurate to roughly 0.5 feet NGVD, the elevation for this portion of the groin should be maintained at roughly 1 foot above MSL. The shoreward half of the groin should conform to the current "optimized" configuration.	Similar to above.

Category/Recommendation	Key Elements	Permit Requirements	Comments	Tiger Beetle Habitat Considerations
Major Groin System Activities				
Consider installing additional jetties similar to the Great Jetty working to the north from the Great Jetty.	• Use the existing Great Jetty as a design example. • This action will require filling the updrift area with sand to encourage immediate bypass of sand around jetty and to prevent erosion of the beach downdrift. Use sand with a grain size distribution similar to that of the sand currently trapped by the Great Jetty. The logistics and cost associated with this activity may make the entire recommendation difficult to implement. It has become unacceptable practice not to fill major structures to their expected configuration upon construction because of the high likelihood of causing severe erosion in the down drift direction. • Undertake one jetty at a time for both fiscal considerations and to allow good understanding of single jetty impacts on beach stabilization. • Locate the first new jetty north of the Great Jetty at the point where the tangent of the curve of the beach trapped by the Great Jetty becomes nearly parallel with the direction of the shoreline to the north. • Encourage native beach vegetation as beaches become established.	• Joint USACE/MDNR • County Grading Permit	The cost of this recommendation is considered at the upper limit of the community's fiscal resources. If this action is considered, compare costs and potential effectiveness to offshore arcuate protection structures.	Similar to above if lengths of jetties are limited so that wave action from very large storms are able to reach slope toes.
Lower Slope and Beach				

Category/Recommendation	Key Elements	Permit Requirements	Comments	Tiger Beetle Habitat Considerations
Management				
Slope parallel gabion baskets at base of lower slope where freeze-thaw degradation is active. Other materials such as fibrous artificial log-like structures may also be considered provided they perform similar functions.	• Base of lower gabion basket installed above MHHW • Lower gabion keyed into intact geologic material • Stepped construction recommended • Elevation of upper gabion should be no higher than 6 feet above MHHW	• County Grading Permit	There are two main goals to be achieved by these structures. 1) They allow soil and debris moving from the mid and upper slopes to accumulate along the lower slope. They both trap debris and protect it from being washed away by waves, thereby insulating the lower slope from freezing and thawing. 2) Slope parallel gabion structures help to break the incoming wave energy and slow the velocity of the water returning to the bay minimizing erosion of the beach and, in some cases, encouraging sand to be deposited on the beach. These rock-filled gabion structures are preferred over hard surface revetments that prevent all wave contact at the slope toe. First, because they encourage the buildup of a beach bayward of where they are installed because of their ability to diminish wave energy. Second, while durable, these structures do not permanently protect the slope toe from erosion. Therefore, they do not cause the lower slope erosion rate to go to zero. Strong storms with elevated surges are still capable of periodically removing debris from behind these structures. The mid and upper slope dominant erosion mechanism still remains shallow sliding when combined with encouragement of shallow-rooted vegetation on the mid and upper slopes. The concept is to reduce the rate of slope retreat while accommodating the presence of bare faces that result from shallow landslides to encourage habitat for the larval stage of the Puritan tiger beetle.	It is important to recognize that this activity attempts to strike a balance between property owner needs to minimize the rate of erosion, Calvert County's preference for enhancing the 100 foot critical area buffer with native vegetation, and the maintenance of habitat for the larval stage of the Puritan tiger beetle. The gabion style baskets are recommended to reduce the overall rate of slope retreat over structures that completely eliminate the effect of wave activity on the slopes. Eliminating the effects of all wave activity stops slope retreat altogether and changes the dominant slope face erosion process from sliding to a depositional condition. Large storms are able to periodically remove the accumulated debris from behind the gabion structures. The goal is to reduce the frequency with which debris removal occurs compared to the current situation so that freezing and thawing is not the driving mechanism causing degradation of the lower slope face. By eliminating freezing and thawing as the primary degradation mechanism, slower chemical processes dominate the degradation process, slowing the overall destruction and retreat of the lower slope. It is important to note that in order to maintain habitat for the larval stage of the Puritan tiger beetle, shallow landslides should be favored over deep landslides because they occur more frequently for a given rate of overall slope face retreat, thereby providing more frequent exposures of bare slopes for the tiger beetle larvae to inhabit. So, this practice must be conducted in conjunction with discouraging the presence of deep-rooted vegetation on the slope faces. When transporting material to the position where the structure will be installed, care should be taken to avoid the upper intertidal and high drift zones of the beach to avoid harming northeastern beach tiger beetle larvae. Further, construction activities should be limited to months when adult tiger beetles are not active.

Category/Recommendation	Key Elements	Permit Requirements	Comments	Tiger Beetle Habitat Considerations
Encourage accumulation of natural debris and vegetation on back beaches	• Allow natural woody debris to accumulate on back beaches adjacent to slopes. • Plant and/or encourage the growth of native grasses and vegetation in these areas to help stabilize the beaches. • Remove unsightly or unsafe debris	None	Beach vegetation helps to stabilize beaches. Natural debris serves as foci for the accumulation of sand and absorbs wave energy reducing the potential for waves to erode the beaches. A balance must be struck between the potential for large tree trunks and limbs to cause damage to beach structures and the lower slope during high energy wave events.	Unknown. It is possible that such conditions enhance the scavenging opportunities for the adult beetles in their search for food.
Slope Management Practices				
Use natural and man-made covers to insulate slope during winter months	• Use vegetation to provide insulation from diurnal freeze-thaw cycles during periods when air temperature is below freezing • Use evergreen material or deciduous plants that are densely matted • Use native species when possible • Consider man-made materials to perform similar functions, but treat as experimental until several significant uncertainties are addressed	Establishment of vegetation, particularly native vegetation, is encouraged within the 100 foot buffer zone by Calvert County. Trees and vegetation may be removed, if necessary, if a permit is obtained from Calvert County.		Because the lower slope materials are comprised primarily of dense silts and clays, they are not likely to be habitat for the Puritan tiger beetle larvae. However, precautions should be taken and observations made to confirm that such practices do not have substantial deleterious effects on the ability of the tiger beetles to establish their burrows.
Encourage shallow-rooted vegetation over deep rooted vegetation on coastal slopes	• Discourage the trees and other deep-rooted plants on the face of the slopes. • Allow landslide scars to vegetate naturally, but only allow shallow rooted plants to colonize the scars • Encourage native species in currently vegetated areas	Trees and vegetation may be removed if a permit is obtained from Calvert County.	This activity is an essential part of the overall slope and beach management recommendations made in this plan. Two major and related objectives are to be accomplished via this practice: 1) reduction of the occurrence and frequency of large, dangerous landslides and 2) encouragement of bare slope habitat necessary for Puritan tiger beetle larvae.	In order to maintain habitat for the larval stage of the Puritan tiger beetle, shallow landslides should be favored over deep landslides because they occur more frequently for a given rate of overall slope face retreat, thereby providing more frequent exposures of bare slopes for the tiger beetle larvae to inhabit. So, this practice must be conducted in conjunction with discouraging the presence of deep-rooted vegetation on the slope faces.

Category/Recommendation	Key Elements	Permit Requirements	Comments	Tiger Beetle Habitat Considerations
Minimize the input of water to the slope face or directed over the slope face to the beach.	• Route stormwater away from coastal slopes • Where possible, orient septic drainage fields to drain away from coastal slopes • Discontinue routing stormwater via piping over slope face directly to beach.	Any grading requires a Calvert County grading permit.	Water percolating into the slopes that is not used by vegetation eventually moves downward to the geologic contact between relatively coarse-grained materials above and fine-grained materials below. Typically, the water then moves laterally toward the beach and exits at the contact between the lower slope and midslope. The contact between the lower and midslope is often the location at which relatively large landslides initiate. Therefore, minimizing the input of water to the slope is desirable. Localized sources of water such as septic input or stormwater runoff have the most effect at locations where the drainage area contributing water to the local water table are small because they represent larger proportional contributions. Routing stormwater over the slope to the beach via pipes significantly contributes to localized beach erosion where the water flows onto the beach. Minimizing runoff traveling along the slope face reduces undesirable sediment migration into the Bay. Routing septic drainage away from the slope faces helps to reduce the nutrient input to the Bay.	Reducing water input to the slope face may slightly reduce the rate at which vegetation recolonizes landslide scars and an overall reduction of water to the slope may reduce the likelihood of large landslides occurring. Reducing the likelihood of large landslides forces the dominant erosion mechanism to be shallow landslide that occurs more frequently and thereby offers greater areas of bare slope face at any given point in time.

Category/Recommendation	Key Elements	Permit Requirements	Comments	Tiger Beetle Habitat Considerations
Minimize the presence and profile of tall trees along the bluff top edge in order to prevent trees toppling due to wind-throw.	• Thin branches from trees along bluff top • Remove dead or dying trees located near the bluff top • Discourage the presence of tall trees near the bluff top	Calvert County permit required	Tall trees tend to have high wind profiles and large root balls. When these trees topple, they take large sections of the bluff top along with them. For large trees currently growing along the bluff top, taking steps to reduce the likelihood of their toppling is desirable. Discouraging their presence altogether reduces the likelihood of large root balls removing large sections of bluff top as failure occurs. An important concept to remember is the overall rate of bluff top retreat is set by the overall rate of lower slope retreat unless the lower slope erosion rate is reduced to zero. Therefore, minimizing the presence of large root balls at the bluff top serves to ensure that only relatively small segments of the bluff top are lost in any single failure.	None

5.5 Section 5: References

Downs, Linda L. (1993). Historical Shoreline Analysis and Determination of Littoral Cells: Rockhold Creek to Solomons Island, Chesapeake Bay. Thesis for Master of Arts. University of Maryland, College Park, MD.

Vogt, P. (2006) Personal communication.

Section 6 Best Management Practices and the Conservation of Tiger Beetle Habitat Along the Scientists' Cliffs' Shoreline (Tiger Beetle Habitat Protection Plan)

6.1 Background

The shoreline and slopes along SCA are identified as Critical Area Site CT L-5 because they have been documented to provide habitat to two species of tiger beetle that are rare, threatened, and/or endangered.

Both the northeastern beach tiger beetle (Cicindela dorsalis dorsalis) and the Puritan tiger beetle (Cicindela Puritanus) are listed as Endangered by the State of Maryland and as Threatened in Maryland by the U.S. Fish and Wildlife Service (http://www.fws.gov/endangered/ accessed 02 January 2006).

Section 1.7.1.2 of this BMP discusses the biology of the northeastern beach tiger beetle and is primarily drawn from the U.S. Fish and Wildlife Service's recovery plan for the northeastern beach tiger beetle (USFWS 1994). Section 1.7.2.2 of this BMP discusses the biology of the Puritan tiger beetle and is primarily drawn from the U.S. Fish and Wildlife Service's recovery plan for the Puritan tiger beetle (USFWS 1993). Key elements of the beetles' biology and habitat are discussed in this section with the goal of establishing a basis for SCA to develop a best management approach to conserving tiger beetle habitat.

Section 6 of this BMP is intended to meet the requirements of Calvert County described in Table 4.1 (Summary of Pertinent Calvert County Zoning Ordinances) where a Habitat Protection Plan is required for all development activities, redevelopment, or maintenance in the Habitat Protection Areas.

6.1.1 Current Conceptual Model Associated with Conserving Tiger Beetle Habitat

Adult northeastern beach and Puritan tiger beetles rely on the presence of beaches where their primary food supplies are found. Northeastern beach tiger beetles emerge in mid-June, reach peak abundance in mid-July, and decline in abundance through August concentrating along wider sections of beach. Puritan tiger beetles peak in late June to early July and decline in abundance through mid-August. Adults are active on warm, sunny days and less active on cool, cloudy days.

The habitat for Puritan tiger beetle larvae is distinctly different from that for northeastern beach tiger beetle larvae in that northeastern beach tiger beetle larvae burrow primarily in the upper intertidal to high drift zone of the beach whereas (USFWS 1994), Puritan tiger beetle larvae primarily inhabit sandy slope faces relatively free of vegetation.

According to the Puritan tiger beetle recovery plan (USFWS 1993),

"*In Maryland, c. Puritana larvae live in deep burrows, which they dig in sandy deposits on non-vegetated portions of the bluff face. They may also burrow at the base of the bluffs in sediment deposits that have eroded from the bluff face. Knisley (1987a) and Hill and Knisley (1991) have found Chesapeake Bay populations to be most abundant where bluffs are long and high, with little or no vegetation, and composed at least in part of yellow or red sandy soil. Wave—producing storms and concomitant erosion of bluffs are necessary to maintain the bare bluff faces required for larval habitat. Larvae will not utilize densely vegetated bluffs; for instance, Hill and Knisley (1991) found that no tiger beetle larvae or adults occupied bluffs stabilized by kudzu at Calvert Beach, Maryland, although both C. Puritana and C. repanda were numerous on adjacent natural bluffs.*"

Because the larval stage lasts for two years for both the northeastern beach and Puritan tiger beetles and because the larvae are relatively immobile, they are particularly vulnerable to disturbance while in their burrows as larvae. Northeastern beach tiger beetle larval mortality rates from natural causes such as storms, predators, erosion, lack of food, and excessive erosion or deposition of beach sand are thought to be in the range of 95 percent (Knisely 1987b). Human-induced disturbances in the intertidal zone may include vehicle and heavy pedestrian traffic and construction activities that disturb and/or compact intact sand and possibly disrupt local thermal and moisture conditions. The relative importance of the various natural and human disturbances to the survivability of the northeastern beach tiger beetle is not well understood (USFWS 1994). The recovery plan for the northeastern beach tiger beetle (USFWS 1994) suggest that specific threats exist at Scientists' Cliffs from "…oil spills, erosion, and recreational beach use." Since there is no significant use of petroleum products at Scientists' Cliffs, it is surmised that oil spills refer to discharges from marine vessels.

"Beach erosion, resulting from natural or anthropogenic beach modifications, may also have serious effects on C. d. dorsalis larval habitat. The northeastern beach tiger beetle typically is not found at sites that have only narrow, eroded beaches. At sites with large populations, few or no larvae are found in areas of narrow beach (1—3 m

wide). Larvae seem to be limited to areas where beaches are at least 5 m wide, with some sand above the high tide zone. Adults are also less abundant in these narrow sections, although larvae are more sensitive to erosion and beach impacts than are adults" (USFWS 1994).

The Puritan tiger beetle experiences similar threats to its survival as the northeastern beach tiger beetle. A notable difference is that, because of the differences in larval habitat, Puritan tiger beetle larvae are susceptible to changes in their sandy slope-face habitat.

"It is suspected that many larvae die when winter storms shear off large sections of bluff (Hill and Knisley 1991). Larval mortality associated with winter storms may contribute to the dramatic local fluctuations observed in some C. Puritana populations" (USFWS 1993)."

The recovery plan for the Puritan tiger beetle (USFWS 1993) states that the most serious threats to the beetle are shoreline development and stabilization.

"*Shoreline stabilization structures, including revetments, offshore breakwaters, and groins, are designed to minimize wave-induced erosion at the base of the bluff such that, over time, the slope of the bluff will decrease, eventually reaching a stable angle of repose. Slopes thus stabilized eventually become vegetated, making them unsuitable for C. Puritana larval habitat (Hill and Knisley 1991 and pers. obs.)* (USFWS 1993).

6.1.2 USFWS Recovery Strategies

"*The primary strategy for recovery within the Chesapeake Bay portion of the species' range will be to classify and protect as much extant C. Puritana habitat as feasible. Habitat protection will be accomplished through public education, acquisitions, easements, and working with landowners and local planning authorities to initiate and implement regulations for habitat conservation*" (USFWS 1993).

"*Recovery for the northeastern beach tiger beetle will depend to a large extent on reestablishing the species across its former range along the Atlantic Coast and protecting it within the Chesapeake Bay region. The best approach for achieving this is through landscape scale conservation. This recovery plan thus defines several Geographic Recovery Areas (GRAs) for conserving C. d. dorsalis and its ecosystem, providing a framework within which protection and population establishment efforts can be ranked and implemented. Recovery will hinge on maintaining the ecological integrity of essential* *tiger beetle habitat within each CPA, in order to achieve the population levels and structure needed for this species*" (USFWS 1994).

Note that Calvert County is listed as GRA 5 in the northeastern beach tiger beetle recovery plan and is documented as having the four largest known populations.

Specific elements of the recovery strategies for each of the tiger beetle species are provided in Table 6.1. Gray shading indicates elements of the recovery strategies where opportunities exist to incorporate elements of the recovery strategies into aspects of the practices described in this BMP and may enhance the understanding of the tiger beetles and their habitats, conserve their habitat, and potentially improve the viability of the populations inhabiting the beaches and slopes of Scientists' Cliffs. This BMP is also intended to provide a bridge between the need for the conservation of tiger beetle habitat while balancing the needs and aesthetic concerns of the SCA property owners.

The USFWS recovery strategies acknowledge the fact that considerable uncertainty exists about many of the parameters thought to be important to promoting tiger beetle habitat and survivability. This BMP specifically calls for establishing performance metrics associated with implementation of the recommended practices. Clarifying and resolving uncertainties related to parameters governing the suitability of tiger beetle habitat will be an element of the performance metrics established herein.

Table 6.2 lists factors currently viewed as limiting the success of the tiger beetles in building larger, more numerous, sustainable populations. To avoid the potential for activities proposed as part of this BMP to deleteriously affect tiger beetle habitat, the practices here have been developed into an integrated system for both managing the erosion of the beaches and shorelines along Scientists' Cliffs and for enhancing the conservation of tiger beetle habitat there. The limiting factors will be examined and addressed below.

Task - Gray shading indicates potential recovery activities compatible with this BMP. X indicates an activity called for in USFWS recovery plans.	Puritan	NE Beach
1) Maintain a recovery group and ad hoc task force		X
2) Monitor existing adult and larval populations	X	X
3) Search for additional populations	X	X
4) Analyze population viability	X	X
5) Model effects of habitat changes	X	X
6) Identify and protect viable populations and their habitat		
• Long-term protection of priority sites	X	X
• Initiate landowner contacts for all known populations	X	X
• Use existing laws/regs to protect beetles and their habitats	X	X
• Identify additional protection needs	X	
7) Implement management measures at natural population sites	X	X
8) Study anthropogenic influences		
• Study the effects of recreational use on beetle habitat and survival	X	
• Examine possibilities for shoreline erosion control in Maryland/Study effects of shoreline alteration	X	X
• Complete human impact studies		X
9) Study life history parameters and taxonomic relationships		
• Determine natural limiting factors	X	X
• Determine the importance of dispersal	X	X
• Conduct morphometric and breeding behavior studies	X	
• Analyze genetic variability	X	
• Complete taxonomic studies		X
10) As appropriate, reintroduce populations to sites in C.d. dorsalis' historical range		X
11) Conduct a public education process	X	X
12) Coordinate implementation of recovery program	X	

Table 6.1 Recovery tasks - Chesapeake Bay tiger beetle populations (USFWS 1993, 94)

Limiting Factors – gray shading indicates limiting factors that may be explored via performance metrics established as part of this BMP	Tiger Beetle	
Sensitive to natural and human induced changes to beaches (including shore erosion control)	Puritan (adult)	Northeastern Beach (adult and larvae)
Sensitive to natural and human induced changes to bluffs	Puritan (larvae)	
Sensitive to human traffic	Puritan (adult)	Northeastern Beach (adult and larvae)
Sensitive to water borne pollution	Puritan (adult)	Northeastern Beach (adult and larvae)
Habitat factors that affect larval distribution	Puritan	
Importance of sources of mortality	Puritan	
Importance of sympatric congeners	Puritan	
Reproductive output per female	Puritan	

Table 6.2 Tiger Beetle Limiting Factors (USFWS 1993, 94)

6.2 Shoreline and Slope Best Management Practices and Conservation of Tiger Beetle Habitat - Approach

Wide, dynamic, and laterally continuous beaches that are not subject to heavy human traffic are thought to be favorable to the sustenance of the northeastern beach tiger beetle (USFWS 1994). Adult Puritan tiger beetles also occupy the beach when foraging for food. It may be the case that adult Puritan tiger beetles also prefer wide beaches. However, it is has been postulated that wide beaches may deleteriously affect the habitat of the Puritan tiger beetle larvae because substantial and stable beaches reduce the direct erosion of coastal slopes by waves.

Because both Puritan and northeastern beach tiger beetles have been noted to have significant populations at Scientists' Cliffs since active study of the beetles began in approximately 1976 (Glaser, 1976), an apparent contradiction exists concerning the interplay between the presence of substantive beaches necessary for the northeastern beach and adult Puritan tiger beetles relative to the need for bare, eroding slopes necessary for Puritan tiger beetle larvae. The continued presence of both species suggests that some degree of balance in the geomorphic mechanisms acting along this segment of shoreline has been struck creating beaches suitable for sustaining northeastern beach tiger beetle adults and larvae and Puritan tiger beetle adults, and the availability of unvegetated sandy slopes for Puritan tiger beetle larvae. This is an important observation because it offers clues to how beach and slope management practices can be optimized simultaneously with conserving tiger beetle habitat.

The overall rate of bluff retreat is low at Scientists' Cliffs compared to other Calvert County coastal slopes ranging between one and eight inches per year with a long-term, overall average of approximately four inches per year (see Section 2.1.1) The beach and slope conditions have changed little for at least fifty years. Relatively stable beaches have been maintained by the groin system. The slopes are primarily vegetated with freezing and thawing as the dominant cause of slope toe retreat, setting the overall bluff retreat rate, and shallow, infrequent landsliding driving the retreat of the mid and upper slopes. When compared to the ideal conditions for the tiger beetles, i.e., wide, dynamic beaches for the northeastern beach tiger beetle and wave-driven, actively eroding slopes free of vegetation for the Puritan tiger beetle larvae, the long-term conditions along the Scientists' Cliffs' shoreline would not seem immediately favorable to either species.

The environmental mechanisms that drive the erosion and deposition of the beaches and slopes at Scientists' Cliffs have been studied in detail over the past decade. That research forms the basis of the principles used to develop the best practices of this plan and may offer resolution to this apparent contradiction. The research also serves as a basis for advancing the understanding of how tiger beetles interact with the geomorphic environment that occurs along the shoreline of Calvert County with the goal of conserving their habitat.

There are some basic assumptions present in the recovery plans for the Puritan and northeastern beach tiger beetles concerning the environmental mechanisms that drive erosion and deposition in this environment that bear further examination and testing.

Assumptions:

1. "Shoreline stabilization structures, including revetments, offshore breakwaters, and groins, are designed to minimize wave-induced erosion at the base of the bluff such that, over time, the slope of the bluff will decrease, eventually reaching a stable angle of repose. Slopes thus stabilized eventually become vegetated, making them unsuitable for C. Puritana larval habitat" (USFWS 1993).
2. Larvae are sensitive to destruction by beach stabilization structures (USFWS 1994).
3. "The beach ecosystem conducive to C. dorsalis survival is undisturbed by heavy human use, highly dynamic, and subject to natural erosion and accretion processes (USFWS 1994).
4. "Wave-producing storms and concomitant erosion of bluffs are necessary to maintain the bare bluff faces required for larval habitat" (USFWS 1993).
5. Winter storms shear off large sections of bluff (USFWS 1993).

These are very important assumptions because they are the focus of the tension created between efforts to conserve tiger beetle habitat and landowners efforts to preserve their property. An underlying theme to these assumptions is that most, if not all, anthropogenic modifications to the beach and slope environment is harmful to tiger beetle habitat.

Other uncertainties exist (USFWS 1993, 1994)

1. The width of the beach preferred by adult Puritan tiger beetles. "Nothnagle (1991) reports that adult beetles preferred wide, sandy beaches in 1988 and 1989, but were found in greatest concentrations on narrow beaches below sandy clay banks in 1990. This year-to-year variability in microsite preference bears further study" (USFWS 1993).
2. Little is known about dispersal.
3. The degree of Puritan tiger beetle larval mortality associated with slope erosion and failures.
4. The effects of beach nourishment on northeastern beach tiger beetle larvae.

Based on detailed observations of the erosion of the coastal slopes along Scientists' Cliffs, the assumption that erosion of the SCA slopes is primarily driven by direct wave action is not supported by the evidence. In fact, the overall rate of erosion of the coastal slopes along SCA is driven by freezing and thawing of the lower slopes with waves acting to remove the debris produced by that action. Wave action due to winter storms virtually never "shear[s] off large sections of bluff" along the Scientists' Cliffs' shoreline. This is a very important distinction and is fundamentally important to understanding the recommendations for best practices to manage the erosion of the coastal slopes while encouraging the habitat for Puritan tiger beetles along SCA.

As discussed in Sections 1 and 2, the lower slopes along the SCA shoreline are composed of relatively fine-grained materials possessing cohesive properties. The material strength is high enough to resist direct erosion by waves in all but the most extreme wave conditions (i.e., those generated by the most rare and powerful hurricanes). Repeated freezing and thawing of the lower slopes occurs annually. As a result, the lower slope retreats and undercuts the coarser-grained mid and upper slopes. Eventually, the undercutting creates a condition where the support from below has been sufficiently removed so that a landslide ensues originating in the midslope. Landsliding dominates the midslope along Scientists' Cliffs because of the presence of the Governor Run Sand formation in the midslope. Sand has little cohesive strength and is prone to shallow planar failures. It has been noted above that sand is considered the preferred habitat of Puritan tiger beetle larvae.

Usually, sliding happens as the slope surface becomes saturated either from prolonged rainfall or snowmelt or a combination of the two. Midslope and upper slope landsliding may occur during any month of the year. The water acts in two principal ways to trigger the sliding: 1) the added weight of the water aggravates the instability and 2) as the water pressure between the grains of the geologic materials increases (i.e., as saturation proceeds into the slope), the strength of the material is decreased in direct proportion to the increase of the water pressure causing the materials to become weaker and prone to failure.

Vegetation plays an important role in slope stability and proper management of the vegetation on slopes plays a key role in the best management practices recommended here, particularly with respect to both minimizing the occurrence of large, dangerous landslides and maintaining habitat for the Puritan tiger beetle.

The depth to which various plants root and the density of rooting is a factor in slope stability. Roots can be thought of as a contributor to the strength of a geologic material much like reinforcing rods in concrete contribute to its overall strength. This concept in its simplest form is that deeply rooted plants tend to reinforce the slope to greater depths than do shallowly rooted plants. The consequence is that slopes with deeply rooted plants tend to slide less frequently, but with significantly more mass involved, than slopes with shallow rooted plants. In other words, encouraging shallow rooted over deep rooted vegetation on mid and upper slopes will encourage more frequent, but shallower and less dangerous slides for a given overall slope retreat rate.

It is only when the erosion rate of the toe achieves zero that this process stops and is replaced by processes causing the bluff top to recede "away" from the slope toe resulting in eventual overall stability of the slope.

The surface remaining after a shallow midslope landslide will soon begin to naturally revegetate. However, slide faces typically remain relatively exposed for two to three years offering the opportunity for habitation by Puritan tiger beetle larvae.

The relatively stable beaches along Scientists' Cliffs have been encouraged by the system of groins that are perennially modified to adapt to significant changes in the sand deposition patterns. When scouring from large storms creates large elevation differences between the top of the groin and the beach or bay bottom below, gabion baskets are removed to diminish the effect of scouring. As beaches build during relatively quiescent conditions, gabion sections are added. In this way, large, rapid changes to the elevation of the beach surface are avoided. This is likely a factor that favors the survival of northeastern beach tiger beetle larvae.

Groin construction and maintenance and recreation activities along the SCA shoreline have occurred for many decades and have not changed significantly over that time. Because the existing practices of slope and beach management at Scientists' Cliffs have encouraged the presence of both Puritan and northeastern beach tiger beetles, the overall approach of this plan is to optimize and improve upon existing practices and to better understand the cause and effect of actions taken by the community by:

- Encouraging continuous, stable beaches by systematically improving the performance of the groin system,
- Attempting to minimize the rate of retreat of the coastal slopes along SCA, but not implement practices that would drive the rate of retreat to zero,
- Encouraging shallow-rooted plants on the slope surfaces rather than deep-rooted plants to discourage large, less frequent landslides in favor of relatively more frequent shallow landslides, thereby promoting safety and encouraging Puritan tiger beetle larvae habitat

- Developing protocol for measuring the performance of existing and proposed practices and the effect of these practices on tiger beetles and their habitat.

It is important to note that the concept of diminishing the rate of bluff retreat without causing the slope to decline to a stable angle was recognized in the recovery plan for the Puritan tiger beetle

> *"It may be possible to engineer a structure or other method of erosion control that would decrease but not wholly eliminate erosion of the cliff face. Such a design would be worth investigating, and even testing, on a short section of C. Puritana habitat. Until such an experimented is conducted, however, all existing shore erosion control structures must be viewed as incompatible with long-term Puritan tiger beetle survival" (USFWS 1993).*

Scientists' Cliffs is designated as a priority recovery site in the USFWS's recovery plan for the northeastern beach tiger beetle (USFWS 1994). The current groin system at Scientists' Cliffs is such a system and this plan proposes to optimize that system and measure the performance.

Table 5.3 provides a synopsis of the best management practices described in Section 5 and discusses them with respect to conserving tiger beetle habitat and promoting healthy tiger beetle populations along the Scientists' Cliffs' shoreline. Key elements of this integrated strategy include:

1. Stable beaches are encouraged by using an adaptive groin maintenance program designed to promote beaches that do not rapidly aggrade or degrade so that northeastern beach tiger beetle larvae are not destroyed by erosion of their beach habitat, nor buried under sand that accumulates to rapidly.

2. Slope toe structures constructed to accumulate insulating talus along the lower slope are encouraged to minimize, but not drive to zero, the rate of erosion of the slope toe.

3. Shallow-rooted, native vegetation on the midslope is to be encouraged to minimize the depth to which landsliding occurs. This is to be done for two primary reasons: (a) to maintain the same magnitude and frequency of sandy, midslope faces that are unvegetated (as a result of sliding) as the rate of slope toe retreat diminishes in order to preserve the existing proportion of slope face available to Puritan tiger beetle larvae for burrowing and (b) to encourage smaller rather than larger slides for safety reasons.

4. Activities that require transport of materials across the beach should limit transport to periods of time when adult tiger beetles are not present (i.e., avoid the months from May through September). The use of vehicles on the beach should be minimized. Vehicle and foot traffic should avoid the upper intertidal to high drift zone whenever possible to avoid damaging northeastern beach tiger beetle larvae.
5. Foot traffic on the beach should continue to be limited to residents and their guests in order to minimize damage to tiger beetles and their larvae on the beach.
6. Develop cooperative projects with biologists, geomorphologists, and engineers to make measurements and improve the understanding of tiger beetles and their habitat and how changes, both anthropogenic and natural affect the beetles. In conjunction with this outreach, develop practice-specific performance metrics to evaluate the effect of the recommended best practices and natural changes on tiger beetles and their habitat. Be sure to test basic assumptions about the tiger beetles, their habitat, and geomorphic processes important to their survival.
7. A program of community awareness of the life cycles and habitats of tiger beetles should be developed. This program should consider (a) inviting guests to speak about tiger beetles and their habitats, (b) posting information about tiger beetles in SCAN, and (c) encourage community members to assist with the tasks designed to measure the effects of the best management practices on the tiger beetles and their habitat.

6.3 Section 6: References:

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Dr. Miller has 20 years of experience in civil, geological, and environmental engineering. He is currently section manager of the Geosciences and Information Technology Section in the Environmental Sciences Division (EVS) at Argonne National Laboratory. At Argonne, he is an environmental engineer providing environmental engineering, decision support, and policy expertise to a wide range of sponsors including the USEPA, USACE, USDOE, USAF, the National Guard Bureau, the Bureau of Reclamation, the Bureau of Land Management, and the Western Pennsylvania Conservancy. Dr. Miller's experience includes environmental assessments of watersheds, applying real-time decision-making to the detection and mobility of contaminants in groundwater, and slope and shoreline erosion management. Previous experience includes private civil and environmental engineering consulting and glacier research for the U.S. Geological Survey.

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