Chesapeake Bay Shoreline Erosion In Maryland: A Management Guide

2010

Purpose of This Management Guide

- Identify areas around the Chesapeake Bay in Maryland where ecological, socioeconomic, or cultural resources may be vulnerable to effects from shoreline erosion over 50 years.
- Provide information on using stand-alone and online Geographic Information Systems (GIS) tools to screen and evaluate potential impacts from shoreline erosion.
- Present background data and studies that may be used to support shoreline erosion projects.

How to Use this Guide to Evaluate Shoreline Erosion

This DRAFT Management Guide provides the following information on shorelines of the Chesapeake Bay:

1) The problems that the Bay faces;
2) A way to identify areas likely to be impacted by shoreline erosion during the next 50 years, and;
3) An example with results of shoreline areas that may be in the Federal interest for project formulation.

An overview of how to utilize this Management Guide is presented below:

1 Determine your area of interest

Are you looking at a region, county, municipality, or other entity?

See Chapter 5 and Appendix C for location-specific information

2 Determine objectives and constraints

What is the shoreline erosion problem and what will it affect?

See Chapters 1-3

3 Gather information about the area of interest

You may wish to find spatial, demographic, ecological, or other types of information.

See Chapters 2, 4, Annex 1, and Appendix B for types of data and sources of data

Also see: **http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability/** for online data and data downloads

4 Set conditions on which you can narrow the focus of your area of interest

You may be more interested in wastewater facilities within 100 yards of a highly eroding shoreline but not interested in eroding wetlands.

See Chapter 4

5 Within your area of interest, screen for areas that meet your criteria

See Chapter 4

6 Devise a response for identified areas

This will involve evaluating the engineering constraints, environmental conditions, and other considerations that are specific to each area.

See Appendix C, Appendix E, and the Chesapeake Bay Technical Guide

7 Execute your project

Not covered in this guide

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Acknowledgements

This report was prepared by the U.S. Army Corps of Engineers, Baltimore District, as part of a study authorized by a resolution of the U.S. Senate Committee on Environment and Public Works dated 23 May 2001. The resulting feasibility study was undertaken with the participation and sponsorship of the Maryland Department of Natural Resources. The Maryland Department of Natural Resources participated in team meetings, provided data, provided study direction, and reviewed draft reports. The Maryland Department of the Environment provided review and comments on drafts of this report. The study team would like to thank all those who provided assistance, data, and comments for this report.

Acronyms

BMP: Best Management Practice

CAP: Chesapeake Action Plan

CBP: Chesapeake Bay Program

CGIS: Center for GIS, Towson University

DOQQ: Digital Orthophoto Quarter-Quadrangles

ERDC: Engineer Research and Development Center

ETM: Estuarine Turbidity Maxima Zone

EVA: Erosion Vulnerability Assessment

GIS: Geographic Information System

HPM: Hedonic Pricing Model

IHP: Inventory of Historic Places (Maryland)

MDDNR: Maryland Department of Natural Resources

MDE: Maryland Department of the Environment

MGS: Maryland Geological Survey

MHW: Mean High Water

NED: National Economic Development

NER: National Ecosystem Restoration

NOAA: National Oceanic and Atmospheric Administration

NRHP: National Register of Historic Places

NWF: National Wildlife Federation

RTE: Rare, Threatened, and Endangered Species

SAV: Submerged Aquatic Vegetation

SCM: Shoreline Conservation and Management Service (MDDNR)

SHA: State Highway Administration

SLR: Sea-Level Rise

SLAMM: Sea-Level Affecting Marshes Model

SLOSH: Sea, Lake and Overland Surges from Hurricanes model

SSPRA: Sensitive Species Project Review Area

USACE: United States Army Corps of Engineers

USEPA: United States Environmental Protection Agency

USFWS: United States Fish and Wildlife Service

USGS: United States Geological Survey

VIMS: Virginia Institute of Marine Science, College of William and Mary

VMRC: Virginia Marine Resources Commission

WSSC: Wetland of Special State Concern

Executive Summary

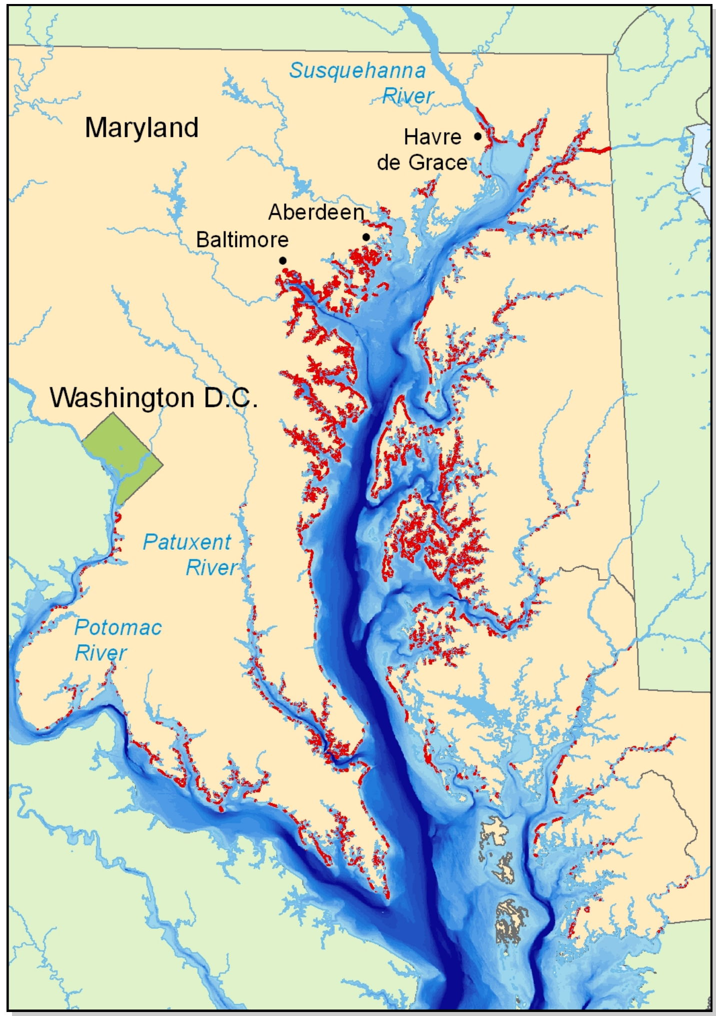


Figure ES-1. The shorelines represented in red are artificially stabilized shorelines in the study area which account for about 1,000 of Maryland's 7,000-mile Bay shoreline.

This study was authorized by a resolution of the U.S. Senate Committee on Environment and Public Works in 2001. The resolution directed the U.S. Army Corps of Engineers (USACE) to review and update the 1990 *Chesapeake Bay Shoreline Erosion Study*, previously completed as a joint effort by the Baltimore and Norfolk Districts. Baltimore District USACE began work with the Maryland Department of Natural Resources in 2004, conducting a review focused on Maryland's portion of the Chesapeake Bay Shoreline.

Since completion of the 1990 study, substantial change has occurred. We are more knowledgeable about the environment, and we are more aware of environmental problems. In the 20 years since the study, shoreline development has increased along the Chesapeake Bay in Maryland, and about 1,000 miles of Maryland's 7,000 mile Bay shoreline are now artificially stabilized (Figure ES-1). Shoreline stabilization is likely to continue into the future.

To minimize environmental impacts of future development, regulations have evolved that now promote more sustainable stabilization techniques. A prime example is the Maryland Living Shorelines Act of 2008, which requires the use of living shorelines for shoreline protection, with some exceptions.

In the past, shoreline erosion was considered environmentally harmful. Naturally eroding shorelines are now recognized to be important habitat for Bay fish and wildlife. Shoreline erosion is a natural environmental process that simultaneously creates, maintains, and destroys shoreline habitats. A basic challenge of shoreline management is how to balance maintaining natural shoreline habitats — fundamental to the character and health of the Chesapeake Bay — with the legal right of shoreline property owners to protect their properties from erosion. Conflict may arise because beach and tidal wetland landward migration is often limited by landuse practices and existing infrastructure, preventing formation of new beach and tidal wetlands.

This guide was developed to serve as a decision support tool for shoreline management in Maryland. This guide characterizes environmental and social effects of shoreline erosion and forecasts areas that may be vulnerable to future shoreline erosion over the next 50 years. Action to minimize the effects of shoreline erosion may be appropriate when natural shoreline erosion processes are altered by human activities, important habitat is threatened by shoreline erosion, or property valued by people may be impacted.

Ecological resources identified as being vulnerable to these interactions included 9,423 acres of wetlands; 420 miles of beach; and 743 acres where rare species occur. Historic properties and structures vulnerable to future erosion occur on 185 acres, and 2,948 acres of public infrastructure is vulnerable to future erosion.

The guide also identifies specific vulnerable shorelines where there may be Federal interest in undertaking ecosystem restoration, cultural/historic resource protection, or public infrastructure protection projects (Figure ES-2).

There may be a Federal interest in restoring ecosystems potentially threatened by the interacting effects of erosion and existing shoreline stabilization works. Additional screening criteria, including engineering practicability, economic costs and benefits, and environmental impacts and benefits would need to be applied to determine whether shoreline restoration or protection projects may be appropriate for these shorelines.

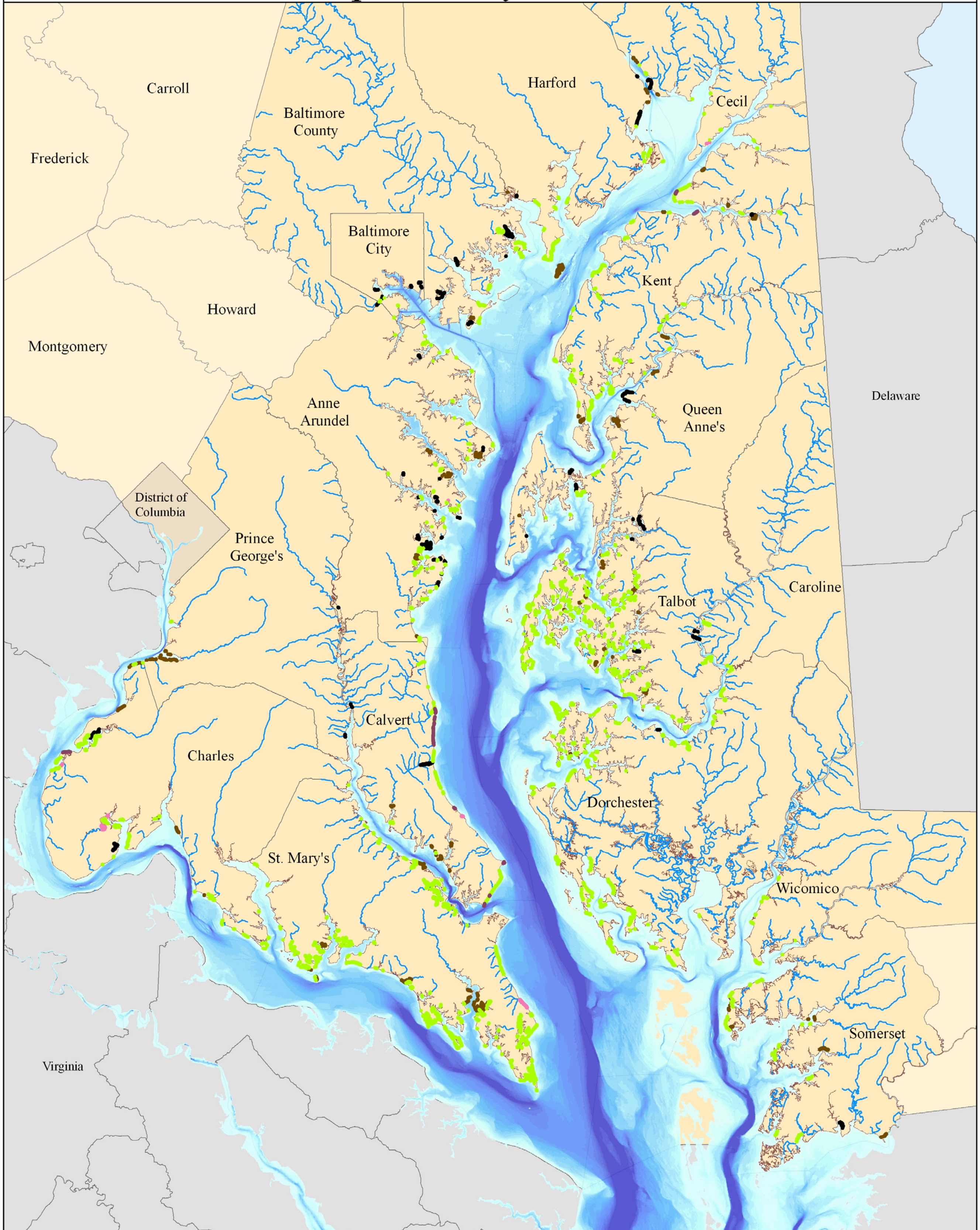
The management guide does not provide a generic set of recommended actions for shoreline regions or sites. Differences among Bay tidal waterways in shoreline habitat status and trends, varying tolerances of property owners/managers to erosion, and the range of potential solutions rendered this inappropriate.

This guide contributes to a growing knowledge base that Federal and State agencies and the private sector are using to support comprehensive shoreline management in Maryland. Information products completed during this study include the following: 1) A study of the impacts of erosion on property values 2) Regional wave energy modeling 3) Statistical study of erosion as a function of shoreline conditions and wave energy 4) Identification of shoreline-dependent species 5) Production of an online Geographic Information System (GIS) Erosion Vulnerability Assessment and Planning Tool (EVA).

Status of Bay Shorelines

- Water levels in the Bay have been rising continuously since the last Ice Age. Bay shorelines have been predominantly erosional over the entire geologic history of the Bay.
- Natural Bay beaches depend on a sand source derived from an erosional shoreline. Natural bay beaches are expected to retreat landward as the sea rises, but they will persist when replacement sand is available and when landward movement is not prohibited by development.
- Over the history of the Bay, as water levels rise, tidal wetlands are destroyed by shoreline erosion, while new tidal wetlands are created by landward migration. Over geologic time, the location and number of tidal wetlands has varied as a function of topography, rate of sea-level rise, and other factors that control erosion and migration.
- Sediment loading rates to the Bay from the watershed doubled following European settlement. Sedimentation rates greatly increased in headwater tributaries of the Western Shore and in deep waters of the Bay.
- Following European settlement, sedimentation rates and bottom grain-size along the flanks of the mainstem bay did not change because wave and water current patterns remained unchanged. In these areas, prevailing conditions prevented excess sedimentation.
- About 1,000 miles of the mapped 7,000-mile Bay shoreline in Maryland is now stabilized artificially.
- Current shoreline sediment inputs to the Bay are assumed to be less than pre-European settlement conditions because of the extent of shoreline armoring.
- Based on shoreline conditions in 2006 and historic erosion rates, this study projects a net loss of more than 12,000 acres of mainland shoreline to erosion within a 50 year period. Island loss rates were not evaluated.
- Nearly 975 acres of cultural resources are vulnerable to loss from erosion over 50 years.
- Bay beach and tidal wetland landward migration is limited by landuse practices and existing infrastructure, preventing formation of new beach and tidal wetlands that could otherwise compensate for erosional losses.
- Nearly 40% of all Bay beaches are projected to be vulnerable to exacerbated erosion induced by adjacent shoreline stabilization work. About 11 miles of beach (2.5%) are expected to experience moderate to high erosion (6 or 11 feet/year on average).
- Over the next 50 years, more than 3,000 acres of wetlands are projected to be lost to erosion, with about 10% of the loss directly attributed to anthropogenic influences (erosion control structures or land use). The effects of sea-level rise are not considered in this estimate; sea-level rise is expected to exacerbate factors that contribute to wetland loss.
- Sea-level rise scenarios, while not explicitly considered in this report, should be applied to this tool in a future effort to determine the spatial extent of sea-level rise effects on erosion and deposition along the Maryland shoreline.

ES-2: Chesapeake Bay Shoreline Erosion



Areas of Potential Federal Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams

N W E S

10 5 0 10 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
Refer to online Erosion Vulnerability Assessment (EVA) tool for additional analysis:
http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
Maryland shoreline informaiton may be found at:
http://shorelines.dnr.states.md.us/

US Army Corps of Engineers
Baltimore District

Maryland Department of Natural Resources

Not a regulatory document 2010

Summary of Study Products (Appendices)

Erosion Vulnerability Assessment (EVA) (Appendix A)

Completed in September 2008. EVA provides planners, managers, and the general public with information about resources, land use, features, and infrastructure susceptible to shoreline erosion in the next 50 years along Maryland's Chesapeake Bay shoreline. EVA projected historic shoreline change rates determined by the Maryland Geologic Survey into the future to roughly predict the position of the shoreline in 50 years, except where the shoreline is currently stabilized as identified in Maryland Department of Natural Resource's Comprehensive Shoreline Inventory. EVA forecast no change in future position for stabilized shorelines. The area from the existing shoreline to the approximate future shoreline constitutes a 50-year planning window. Criteria were developed to rank erosion vulnerability of ecological resources such as wetlands and beaches within the planning window. Socioeconomic features were depicted with respect to the 50-year planning window. Using these data sets, an interactive map interface was created using a Geographic Information System. The map interface allows the user to view the assessment output as well as all base layers used in the analysis and reviewed for the project. From the interface, the user can also query the associated attribute information, construct maps, and export map compositions to a local printer. The following website provides a link to the EVA tool as well as spatial data files, metadata, and the report: http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability/index.html.

Ancillary Economic Analysis Report: Economic Social Effects Modeling (Appendix B)

Completed in September 2008. This study examined the relationship between shoreline stability and adjacent property values along the Chesapeake Bay in Maryland using hedonic pricing models (HPM). The study revealed a statistically significant influence of erosion status on property value. A rigorous statistical analysis of data from shorelines of the 16 counties in Maryland bordering the Bay showed a 17% decrease in property value where shorelines had a high/medium erosion status. The analysis could not differentiate among the type of erosion control method employed with regard to property value. Nevertheless, the study suggests that environmentally sensitive shoreline stabilization measures would not be expected to have a negative impact on property values, provided erosion is effectively controlled.

Assessing the Relation of Shoreline Erosion Rates to Shoreline Features and Wave Action in Maryland Chesapeake Bay (Appendix C)

Completed in June 2008. This study established the statistical relationships among shoreline erosion rates, shoreline characteristics, and wave energy. On unprotected shorelines, high wave energy is the dominant predictor of where high erosion areas may occur. Geography also plays an important role. Wave action is initiated by wind energy and then constrained by geography, so it is difficult to sort the effects of wave action and geography. Although the study clearly demonstrates the effectiveness of shoreline protection measures in mitigating erosion effects, the predictive value of the analysis is limited. It was suggested statistically that while the model is useful for identifying and ranking the variables that affect erosion rates, it is not adequate as a predictive tool.

Preliminary Study on Shoreline Erosion in the Upper Chesapeake Bay (Appendix D)

Completed in 2006. In this preliminary study the USACE Engineer Research and Development Center (ERDC) analyzed and modeled meteorological forcing and responding waves and water levels. Resultant water levels and wave energies under a variety of meteorological condition were simulated and depicted graphically. The modeled wave energies may be useful in preliminary determinations of appropriate stabilization structures for shorelines along the Bay.

USFWS Planning Aid Report: Prominent Shoreline-Dependent Species (Appendix E)

Completed in January 2007. The report provides information on prominent species that depend on Maryland's Bay shorelines for breeding or foraging. Four species are considered to be strongly dependent on the Chesapeake Bay shoreline for breeding and other life history requirements. These include two species of tiger beetles that are on the federal list of threatened species, the diamondback terrapin, and the horseshoe crab. Several other species exhibit varying lesser degrees of dependence on Bay shorelines. These include bank nesting species (bank swallow, rough-winged swallow, and belted kingfisher); beach nesting species (American oystercatcher, common tern, Forster's tern, least tern, and black skimmer); shorebird foraging species (sandpipers and plovers); other avian shoreline foraging species (herring gull, great black-backed gull, fish crow, boat-tailed grackle, and green heron); and the sensitive joint vetch, which is on the federal list of threatened plants.

Chapter 1: Introduction

The Chesapeake Bay is one of the United States' premier natural resources, its largest estuary, home to a complex ecosystem, and a transportation and recreational corridor that helps drive the regional economy. The well-being of the Bay, its watershed, and its inhabitants is dependent on healthy ecosystem function, and successful response to changing conditions.

When Captain John Smith sailed north up the Bay in 1608, he experienced a Bay shoreline much different in appearance and function than what is present today. One natural agent of change is shoreline erosion and sediment transport, which constantly and naturally reshapes and sustains the Bay. Shoreline erosion causes the loss of land, leading to sediment entering the aquatic ecosystem of the Bay. This process supports the Chesapeake Bay's extensive marshes and wetlands and creates and maintains beaches. However, excessive shoreline erosion can also threaten the functioning of marshes and wetlands, particularly in areas of modified shorelines, and may endanger human property.

Humans have placed stationary structures and communities within a naturally migrating landscape, necessitating management strategies for shoreline erosion. To guard against loss of property and life, shoreline erosion protection measures have been implemented throughout the Chesapeake Bay. Within Maryland, landowners have the legal right to implement shoreline protection projects. These measures have ranged from hardened structural solutions such as bulkheads and revetments to "living shoreline" projects that stabilize shorelines in an environmentally-sensitive manner.

Nearly 1,000 miles of approximately 7,000 miles of Maryland Bay shoreline have man-made erosion control structures. While all these measures are intended to protect the shoreline from eroding, and most successfully achieve that goal, some measures have adverse side effects, including the following:

- Wetland loss bay-ward of the structure
- Loss of shallow water habitat bayward of structures
- Erosion and loss of shoreline habitat downdrift of structures
- Failure of structures due to scour leading to increased erosion

Recognizing the significant challenges that shoreline erosion poses in Maryland, the U. S. Army Corps of Engineers (USACE) Baltimore District with authority from Congress initiated the Chesapeake Bay Shoreline Erosion Reconnaissance study in 2001.

In 2002, the Chesapeake Bay Shoreline Erosion Reconnaissance Report – Part I was completed. This report focused on the Susquehanna River and sediment accumulating behind dams at the mouth of the river. The Chesapeake Bay Shoreline Erosion Reconnaissance Report – Part II was completed in 2003. This report concluded that further investigation of management opportunities using a regional approach and project development to reduce shoreline erosion, restore and protect critical coastal habitats, and improve water quality within the Chesapeake Bay watershed was necessary. In 2004 USACE and the Maryland Department of Natural Resources (MDDNR) signed a Feasibility Cost Sharing agreement to conduct a feasibility study. This feasibility study has identified a diverse array of strategies, developed tools and compiled data, and identified potential projects that address shoreline erosion and sediment management within the Chesapeake Bay watershed.

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About This Management Guide

The Chesapeake Bay Shoreline Erosion Reconnaissance Report recommended that (1) shoreline erosion in the Chesapeake Bay be examined regionally, and (2) strategies for addressing erosion also be undertaken on a regional scale. Recent legislation like the Living Shorelines Protection Act of 2008 and increasing scientific and technical understanding of the role of shoreline erosion to the Bay's ecosystem and human use and enjoyment have shaped the regional examination of shoreline erosion. As a result, this DRAFT Management guide is intended to identify areas on the Chesapeake Bay in Maryland where ecological, socioeconomic, and cultural resources may be vulnerable to shoreline erosion during the next 50 years. This document also provides information about using stand-alone and online Geographic Information Systems (GIS) tools to screen and evaluate potential impacts from shoreline erosion.

Finally, this document provides background data and studies that may be used to support shoreline erosion project formulation. These data include geospatial layers (available online) detailing shoreline condition and land areas that may be impacted by erosion in the next 50 years. Studies include technical research into wave effects on shoreline erosion, effects of shoreline erosion on land value, and information about shoreline-dependent species in the Chesapeake Bay in Maryland. An online tool that allows users to map, query, and examine forecasted shoreline erosion in Maryland is available at http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability/index.html.

Study Area

The Chesapeake Bay watershed drains 64,000 square miles of New York, Pennsylvania, West Virginia, Maryland, the District of Columbia, Delaware, and Virginia (Figure 1.1). The Bay watershed includes seven major basins: the Susquehanna River, the Patuxent River, the Eastern Shore, the Potomac River, the York River, the Rappahannock River, and the James River. Of these major drainage basins, the Susquehanna, Eastern Shore, and Potomac cross Maryland. The Patuxent River drainage lies entirely within Maryland.

The Bay proper is about 200 miles long, stretching from Havre de Grace, Maryland at the northern end, to Norfolk, Virginia at the southern end. Its width varies from just 3.4 miles at its northern end near Aberdeen, Maryland, to about 35 miles wide

Figure 1.1 The Chesapeake Bay Watershed is about 64,000 square miles in New York, Pennsylvania, West Virginia, Maryland, Washington D.C., Delaware, and Virginia.

at its midpoint near the mouth of the Potomac River along the Maryland-Virginia border, to about 15 miles wide at its southern end. Including its tidal tributaries, the Bay has about 11,684 miles of shoreline. Approximately 60% of the shoreline is within Maryland, and 40% is within Virginia.

The average depth of the Bay is only about 28 feet. About two-thirds of the Bay is 18 feet deep or less.

The primary focus of this study is the immediate land-water interface along the tidal shoreline of the Chesapeake Bay and its tributaries in Maryland. Secondary concern is placed on near-shore inland areas. Shoreline erosion may also occur landward of the shoreline when water levels are elevated during storm events. Inland effects from shoreline erosion are discussed briefly.

During the reconnaissance phase of this study process, the study area was defined to include the near-shore zone, extending bay-ward to a depth of 35 feet (mean high water), the historic extent of oyster (*Crassostrea virginica*) bars. However, because the aquatic near-shore zone is being investigated in several other studies being undertaken by USACE and MDDNR, the near-shore zone to 35 feet was excluded from the feasibility study area during this study phase. Bay-ward, the study area encompasses water to a depth generally necessary for the implementation of living shoreline projects (generally several feet in depth) and other near-shore erosion control systems (about 9 feet in depth).

Specifically excluded from the study area are many large Bay islands, including Smith, South Marsh, Poplar, and Bloodsworth Islands (Figure 1.2). Shorelines were evaluated at Barren and James Islands, but projects were not considered during the evaluation of shoreline erosion. USACE and the State of Maryland are conducting separate investigations and projects at Smith, Poplar, Barren, and James Islands. The proposed and existing projects for these islands will cumulatively restore more than 3,000 acres of island habitat, accounting for about one-third of the estimated 10,000 acres of habitat that have been lost to erosion and drowning in place over the past 200 years.

Erosion in the Chesapeake Bay

Shorelines lie at the boundary between the aquatic ecosystem of the Bay and uplands or emergent (above water) wetlands. Natural shorelines are dynamic, constantly changing features that are influenced by what occurs both on the land and in the water.

The Bay shoreline has eroded continuously since the Bay formed about 10,000 years ago. Sea-level has risen since the Bay formed and sea-level rise is one of the primary long-term causes of shoreline erosion. Over shorter periods of time, waves and storm events are the primary cause of changes in shoreline conditions.

Human actions in the watersheds and along the coast have altered shoreline and sediment processes. These activities have caused significant changes in the landscape and have impacted water quality, shoreline stability, habitat, and the environmental character and resources of the Chesapeake Bay.

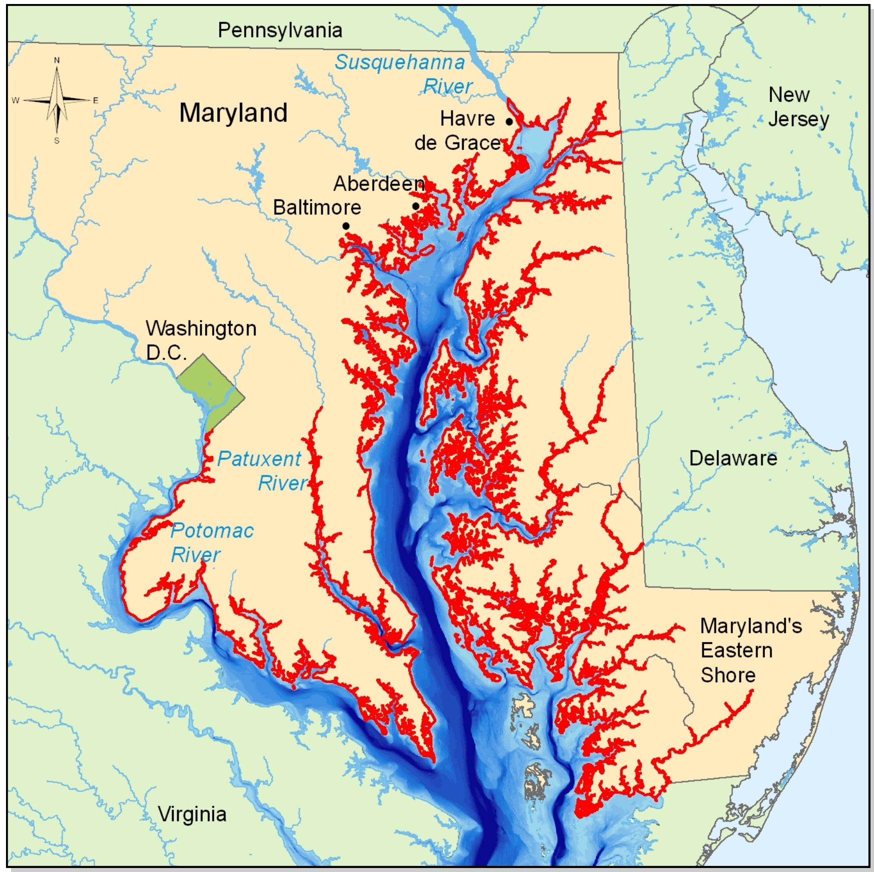


Figure 1.2 Shorelines included in this study and evaluated in this Management Guide are shown as thick red lines. Smith, South Marsh, Poplar, and Bloodsworth Islands are excluded from evaluation.

Sediments generated from shoreline erosion create and maintain Bay beaches and shallow water habitat. Sediments from shoreline sources also help maintain tidal wetlands. Beaches are dynamic depositional features built from sand derived from shoreline erosion and subtidal sources. When shorelines that are sources of sediment for a beach are stabilized, the beach may vanish. Over historic and geologic times most Bay beaches that front mainland will retreat landward as sea-level rises and the mainland erodes.

Erosion also produces banks along the shoreline, with the resulting bank height dependent on the height of the land into which the Bay is eroding. Depositional features (such as spits) occur locally where substantial material from eroding shorelines accumulates in the nearshore zone.

Shoreline Related Programs, Regulations, and Projects

Environmental regulations serve to maintain and restore water quality in the Bay and to protect highly valued aquatic habitats. This section provides an overview of the programs, policies and projects undertaken by various public and private entities to protect shorelines, control nutrient and sediment runoff into the Bay, and restore shoreline and underwater habitats.

1. Chesapeake Bay Program

The Chesapeake Bay Program (CBP), a partnership between Maryland, Virginia, Pennsylvania, the District of Columbia, and the Federal Government was created in 1983 with the goal of protecting and restoring the Chesapeake Bay's ecosystem. The CBP member organizations have signed several agreements setting goals for the program:

- In the 1987 Bay Agreement, the CBP partners set a 40% nutrient reduction goal to be accomplished by 2000. As of 2009, 51% of the goal for nitrogen, and 67% of the goal for phosphorus has been achieved.

- The partners of the CBP signed an agreement in 2000 that reaffirmed the call for a significant reduction in nutrient pollutant input to the Bay and added sediment as a pollutant. One of the goals of the 2000 agreement is to improve water quality of the Bay and its tributaries such that future regulatory restrictions, which may otherwise be implemented by the U.S. Environmental Protection Agency, will not be required.

- In 2003, CBP partners agreed to cap sediment loads entering the Bay, a reduction of 29% from the 1985 sediment loads. As of 2009, 69% of the sediment reduction goal had been achieved.

As of 2007, 21% of water quality goals had been met. There are many Federal, State, and local projects underway that are contributing to a reduction of sediment in Maryland and Chesapeake Bay waterways.

In 2008 the CBP developed the Chesapeake Action Plan (CAP) outlining a renewed vision for Chesapeake Bay restoration. USACE assumed shared responsibilities with other Federal agencies for collaboration in planning and implementing projects and programs that support Chesapeake Bay restoration, consistent with the CAP. USACE involvement includes senior management level participation in the Management Board and Principals' Staff Committee, as well as staff level participation in various CAP Goal Implementation Teams.

2. Regulatory Policies

Shoreline erosion control projects are regulated by the Tidal Wetlands Act of 1970, which is further refined by the Maryland Living Shorelines Protection Act of 2008. The 2008 act extends the right of waterfront property owners to protect their property against shoreline erosion, but it requires the use of nonstructural shoreline stabilization methods in tidal wetlands. Limited exceptions may be made where the Maryland Department of the Environment (MDE) has determined that structural shoreline stabilization methods are appropriate and in other areas where property owners can demonstrate that living shorelines are not feasible. Many other State and local

Andrew Roach

The Nanticoke River at the entrance to Cedar Hill Marina in Wicomico County, Maryland. A stone jetty protects the entrance to the marina while segmented breakwaters provide shoreline protection and encourage wetlands.

regulations also govern activities along the Chesapeake Bay shoreline in Maryland.

Federal and State laws and policies that regulate dredging and coastal developments provide an additional measure of protection to shoreline and near-shore aquatic habitats. These regulations cover both point and non-point pollution sources. Point sources of pollution are sources that can be attributed to a specific physical location, often an identifiable, end-of-pipe “point.” The largest point sources of nutrient pollution are wastewater treatment plants. Non-point sources are pollution sources that are not attributable to any specific location; rather they are the aggregate result of many separate factors and practices. Non-point sources include agricultural areas, suburban development, storm sewers, and impervious surfaces. Point sources are strictly controlled through Federal and State laws that govern releases of nutrient and sediment pollutants into the waters of the Bay and its tributaries. Non-point sources are managed and monitored through numerous Federal and State programs.

Federal and State law strictly protect coastal wetlands. Development within the critical area boundary, defined by the Critical Area Act in 1984 as all lands within 1,000 feet of tidal waters or adjacent tidal wetlands in Maryland, is regulated through local land use ordinances to protect the Bay.

U.S. DoD, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Volunteers plant wetland grasses as part of a habitat restoration and shoreline protection project along the Patuxent River at Webster Field, part of the Naval Air Station Patuxent River in St. Mary’s County, Maryland.

Other regulations apply to fishers and related resources. For example, oysters are harvested commercially in Maryland, but regulations limit the harvests and are designed to maintain oyster populations.

All of these regulatory policies are intended to protect Chesapeake Bay habitat and generate sustainable environmental solutions to the impacts of people living and working within the Chesapeake Bay basin while providing for human health, welfare, and needs.

3. Shoreline Protection Projects

Numerous private and public projects have been constructed to protect eroding shorelines where property or infrastructure were threatened. Projects are concentrated in urban and suburban areas but also occur in agricultural areas. Shoreline protection projects range from living shoreline type projects (including groins and breakwaters), which are preferred, to rudimentary shoreline debris and rubble piles to engineered bulkheads, revetments, and seawalls. Many of the latter types of projects have been constructed historically. However, in many areas, their use today may no longer be appropriate as a result of increased knowledge about sediment transport, shoreline evolution, and impacts to aquatic habitats. Furthermore, changing regulations may preclude their use in many areas.

MDDNR has undertaken numerous shoreline protection projects. For example, MDDNR was involved with projects at the Chesapeake Bay Education Center in Queen Anne’s County, the London Town Publik House and Garden in Anne Arundel County, and the Arlington Echo Outdoor Education Center in Anne Arundel County, as

Jane Thomas, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Grassed waterways are an agricultural best management practice (BMP) that helps slow the flow of runoff and absorb nutrients.

well as many others, often in the roles of facilitation, training, and financial support. The MDDNR Shoreline Conservation and Management (SCM) Service, within the Ecosystem Restoration Services program, is one MDDNR branch that has been involved in many shoreline protection projects in Maryland. The SCM Service provides assistance to Maryland property owners in resolving shoreline and streambank erosion problems, and it provides technical and financial assistance.

MDE also provides technical assistance and administers several loan programs that may be used for shoreline protection projects (Annex 4). The MDE Wetlands and Waterways Program has published several documents that provide guidelines on implementing shore erosion control projects in Maryland. These are available from MDE and online at www.mde.state.md.us.

4. Habitat Restoration

A wide array of public and private efforts are underway to restore Bay oyster reefs, submerged aquatic vegetation (SAV) beds, shorelines, tidal and non-tidal wetlands, and stream habitats. These projects benefit a wide array of fish and wildlife species, as well as providing numerous benefits to people. Habitat restoration projects may provide shoreline protection through the construction of marsh and wetland habitat, while providing a beneficial use for material dredged from the Bay's many navigation channels. Even while not focused specifically on shoreline erosion or shorelines, many of these projects directly or indirectly benefit shorelines, shoreline habitat, and human communities.

The Chesapeake Bay Oyster Recovery Project is a comprehensive, multi-agency effort to improve the native oyster population in both the Maryland and Virginia portions of the Bay and is currently underway, with the participation of MDDNR, the Virginia Marine Resources Commission (VMRC), and USACE. Project activities include restoring oyster bars; using oyster spat from hatcheries to seed oyster bars; and monitoring for disease, survival, and growth. The project has resulted in the construction of several seed bars and new oyster bars in the Bay and has provided for the monitoring of these bars. The project is organized into two phases. Phase I lasted from 1997 to 2003 with monitoring until 2004. Phase II is ongoing and includes a long-term master plan for oyster recovery.

5. Nutrient and Sediment Reduction

Land use practices along the Bay's shoreline have the potential to impair habitat quality and availability. Substantial efforts to control the delivery of nutrients and sediment from land and anthropogenic sources to the Bay have been undertaken. These efforts range from government regulations and incentives for agriculture, construction, and human waste management to voluntary efforts undertaken by individuals and communities.

- Agricultural Best Management Practices (BMPs): These include a range of activities that reduce or eliminate soil loss, prevent runoff, and provide for proper application of fertilizers to cropland. Examples of BMPs include cover crops, no-till farming, and stream buffers.

- Animal Waste Management: This includes manure storage structures, runoff controls for barnyards, guttering, and nutrient management. These systems address the handling, storage, and transport of animal waste, as well as its utilization as fertilizer on cropland.
- Urban Best Management Practices: These BMPs are undertaken on industrial, commercial, and residential lands. These practices include erosion and sediment control, stormwater management, and septic system maintenance.
- Point Source Controls: Although releases of nutrient and sediment pollutants from these sources are already regulated, efforts are underway to further reduce the quantities of pollutants released. These efforts include upgrading existing wastewater treatment equipment, and providing biological nutrient removal to existing wastewater treatment plants.

5. Chesapeake Bay Executive Order

On May 12, 2009, the President of the United States signed an Executive Order (EO 13508) recognizing the Chesapeake Bay as a national treasure and calling on the federal government to lead a renewed effort to restore and protect the Bay and its watershed. A Federal Leadership Committee was formed to oversee the development and coordination of reporting, data management, and other activities done by agencies involved in Bay restoration. On May 12, 2010, a Strategy for Protecting and Restoring the Chesapeake Bay Watershed was released. This strategy outlines numerous actions to which Federal agencies have committed in the restoration of the Bay. These actions are focused on achieving the most essential priorities for a healthy Bay ecosystem: restoring clean water, recovering habitat, sustaining fish and wildlife, and conserving land and increasing public access. The Chesapeake Bay Shoreline Erosion study is identified as one action being taken to meet these priorities.

An annual Chesapeake Bay Action Plan will be developed annually, describing how federal funding will be allocated toward Bay restoration in the upcoming year. The Federal Leadership Committee will also publish an Annual Progress Report reviewing indicators of environmental conditions and an assessment of strategy implementation.

Other Studies

Several other unrelated studies that examine aspects of Chesapeake Bay shoreline erosion are ongoing or have recently been completed. The *National Shoreline Management Study*, a USACE study undertaken by the Institute for Water Resources and begun in 2002, is examining the status of the Nation's shoreline for the first time in 30 years. The national study is (1) summarizing information about shoreline change using existing data sources; (2) examining causes of shoreline erosion and accretion along with economic and environmental effects; (3) identifying and describing federal, state, and local government shore restoration and nourishment programs and resources; and (4) exploring a systems approach to sand management.

The Maryland Commission on Climate Change, assembled by the governor of Maryland, released a final Climate Action plan in August 2008. The plan includes recommended actions to protect property and life from rising sea levels and changing weather patterns. The report concludes that rising sea-level will negatively affect wetland and wetland-dependent living resources.

In 2008, the National Wildlife Federation (NWF) released a study examining changes to wetland composition and shoreline position in the Chesapeake Bay resulting from long-term sea-level rise. Based on the Sea Level Affecting Marshes Model (SLAMM), this study projects large scale wetland loss on the eastern shore of Maryland.

In 2006, the efficacy of wetlands constructed for shoreline erosion control in the Maryland Chesapeake Bay was evaluated for the Maryland Department of the Environment by researchers at the University of Maryland. Project results included refined field assessment methodologies, field assessments of 80 shoreline wetland sites, and compiled data. Factors influencing the success of constructed wetlands included: sufficient light, proper fill technique and material, protection of shoreline, and others.

In 2009, a report was published based on extensive mapping conducted by the U.S. Environmental Protection Agency (USEPA) in conjunction with local county governments. The study details the likelihood that shorelines would be protected from erosion if current erosional and sea level trends continue. For Maryland, the study concludes that the western shore of the Chesapeake Bay is largely developed with shore protection almost certain to be installed except where prohibited. The Eastern shore and most Bay tributaries are more lightly developed and less likely to see shore protection. This is important when considering the ability of wetlands to migrate upland as sea-level rises. Maps and data are available at risingseas.net.

A comprehensive list of previous and ongoing studies and projects relevant to shoreline erosion and coastal risk in the Chesapeake Bay region is included in Annex 2.

Chapter 2: The Chesapeake Bay Shoreline

This section provides an overview of the Chesapeake Bay, its shorelines and characteristic habitats, unique resources, and ongoing challenges related to shorelines and shoreline erosion.

This document is focused on the conditions of the Chesapeake Bay shoreline in Maryland, generally delimited by Mean High Water (MHW) and tidal wetlands (Figure 2.1). However, since the full range of tides often extend many miles inland, such as in Dorchester County, this document also considers these lands and waters, where appropriate.

The Chesapeake Bay's water quality, SAV beds, and shoreline are among the best documented of any estuary in the world. According to the Maryland Geological Survey (MGS, 2007), the Chesapeake Bay shoreline in Maryland is about 7,000 miles long. At the time of the study, manmade structures were incorporated into nearly 1,000 miles of shoreline. The extent of artificial shoreline stabilization and associated loss of natural shoreline habitats is a growing environmental concern in the Chesapeake Bay and in other estuaries.

Shorelines and Tides

The Chesapeake Bay shoreline, when viewed on a map or seen in an aerial photograph, can be considered a linear feature that separates open water from dry land. However, defining precisely where the shoreline is — what constitutes the boundary between land and water — is often difficult. For the purposes of this document the shoreline is assumed to be the MHW line. For marsh shorelines, the marsh edge is considered to be the shoreline unless otherwise indicated. For artificially stabilized shorelines, the toe of the shoreline structure is considered the shoreline.

From a habitat or human-use perspective, the shoreline can be thought of as that area occurring between regularly occurring low and high tides (Figure 2.1). On beach shorelines, little or no vegetation occurs within this zone. In tidal wetlands the upper boundary extends landward to about the elevation of regular flooding during spring high tide. In Dorchester and Somerset Counties, the mean spring high water shoreline is often located more than 10 miles inland of the marsh edge or beach shoreline.

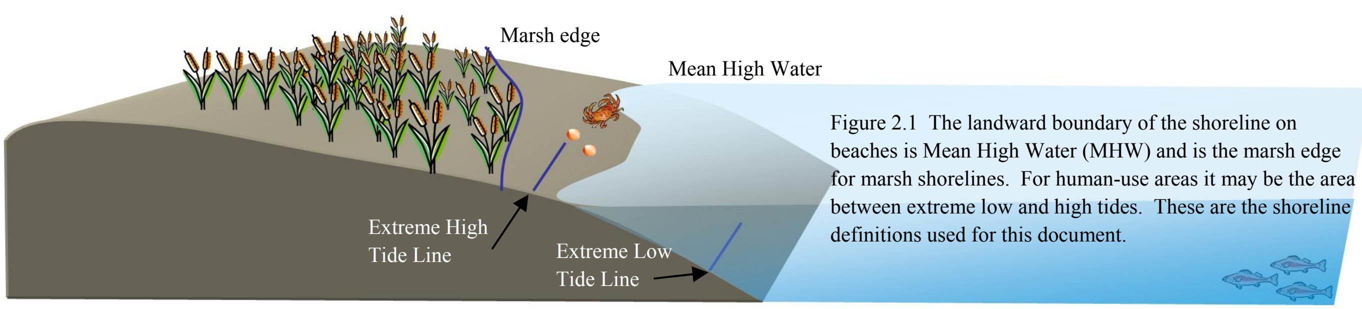


Figure 2.1 The landward boundary of the shoreline on beaches is Mean High Water (MHW) and is the marsh edge for marsh shorelines. For human-use areas it may be the area between extreme low and high tides. These are the shoreline definitions used for this document.

Shoreline Types

Natural shorelines include nonvegetated and vegetated shorelines. Nonvegetated shorelines include intertidal flats of mud or sand, beaches, and banks. Banks are the eroded edge of mainland and include bluffs and cliffs. Banks along the Bay reach their greatest height in Calvert County, where cliffs are more than 100 feet high.

Vegetated shorelines include those bounded by wetland or upland vegetation. Wetlands include tidal marshes and some tidal swamps. Marshes are wetlands dominated by grasses and grass-like plants, while swamps are wetlands dominated by woody vegetation.

Tidal swamps generally occur in low salinity tidal waters. Upland vegetation bordering the Bay was historically primarily forest. Today, however, landscaped and managed areas often front the Bay shoreline.

Fabricated shorelines include bulkheads, revetments, sea walls, and other installed erosion control structures. When marshes and beaches are incorporated into modern shoreline protection measures, they are often called "living shorelines."

Specific information on shoreline stabilization techniques for the Chesapeake Bay are provided in the forthcoming technical guide entitled *Shore Protection: A Guide for Engineers and Contractors.* Guidelines specific to Maryland are also contained in *Shore Erosion Control Guidelines*, from MDE (www.mde.maryland.gov). Detailed engineering specifications and other technical information is available in the USACE Coastal Engineering Manual (http://chl.erdc.usace.army.mil/cem). Definitions of shoreline types can be found in the Acronyms and Definitions section of this document.

Ben Longstaff, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Developed shoreline with many docks and two groins along the Eastern Shore of Maryland. Stone revetment is also installed along much of this stretch of shoreline.

Shoreline Erosion Control Measures Used in Maryland

USACE

Living shoreline marsh creation with a stone revetment. Living Shorelines are the preferred type of erosion control measure in Maryland and provide habitat while offering shoreline protection.

USACE

Stone revetment at Tylerton, Smith Island, Somerset County, Maryland. Revetment in the absence of other measures may be appropriate in high wave energy environments.

USACE

Wooden bulkhead on Barren Island in Chesapeake Bay, Maryland. Bulkheads may be appropriate where boats must access the shore.

USACE

Stone sill on Barren Island in the Chesapeake Bay, Maryland. Stone sills are also often used in living shoreline applications to hold material in place until marsh can be established.

USACE

Segmented breakwaters at Eastern Neck, Maryland. Segmented breakwaters are often used to encourage beach and wetland creation and may be used in living shoreline applications.

USACE

Beach replenishment on Barren Island in the Chesapeake Bay, Maryland. Generally, beach replenishment projects are undertaken on recreational beaches in the Chesapeake Bay in Maryland. A stone sill is also used in this project to contain the beach material.

Shoreline Stabilization in Maryland

Many types of erosion control measures have been implemented along the shoreline of the Bay. Nearly 1,000 miles of mapped Bay shoreline (as defined for this report) have some sort of structure present (Table 2.1, Figure 2.2). This constitutes nearly 14% of the total mapped Bay shoreline (7,092 miles).

Erosion control measures utilized along the Bay include living shorelines, which are the preferred method for managing erosion, as well as stone revetments, riprap, and bulkheads in various states of repair. Other methods that have been attempted include geotextile tubes filled with sand. In the past, debris and trash were sometimes used as revetment. Historic practices such as these should not be used to manage shoreline property. The Living Shorelines Act of 2008 requires that living shorelines be considered for erosion control unless MDE grants a waiver (see Chapter 5 for a short discussion).

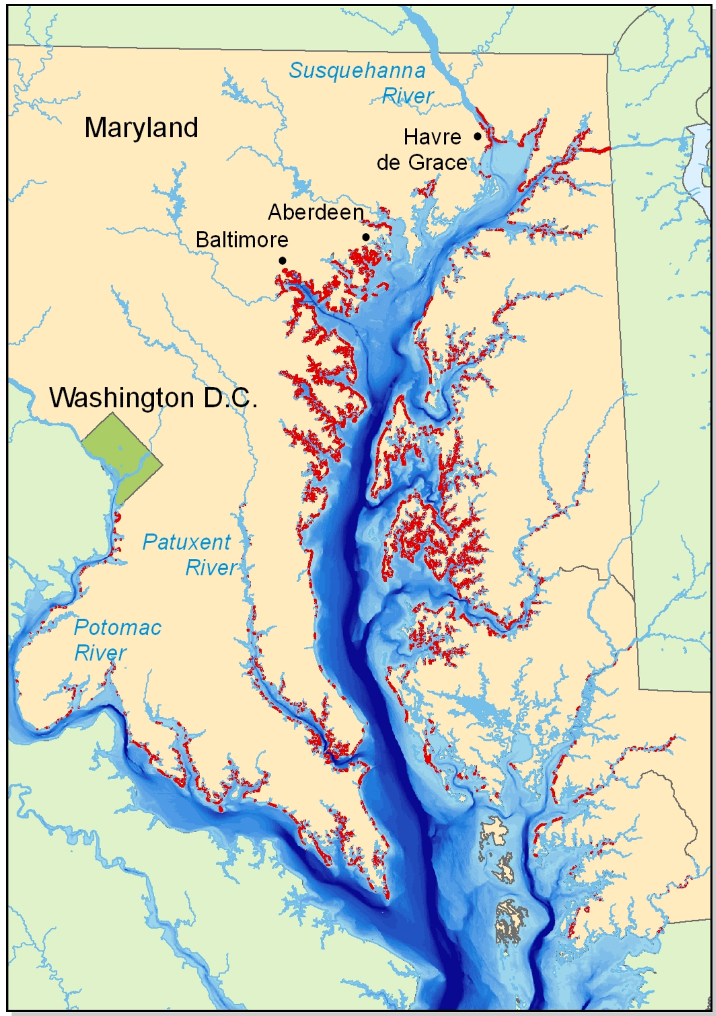


Figure 2.2 Stabilized shorelines on the Chesapeake Bay in Maryland. The red areas represent stabilized shorelines listed in Table 2.1. Only surveyed shorelines as outlined in Chapter 1 are included.

Structure Type	Miles of Shoreline*
None	6,123
Riprap	521
Breakwater	9
Bulkhead	375
Debris	10
Unconventional	16
Miscellaneous	38
Total	**7,092**

Table 2.1 Length of shoreline erosion control structures along the Bay shoreline in Maryland. The shoreline surveyed includes those areas outlined in Chapter 1. Unconventional structures include living shorelines and other innovative measures.

* Miles of shoreline are rounded to nearest mile.

In the past, shoreline erosion was often viewed as environmentally harmful. Naturally eroding shorelines are now recognized to be important habitat for Bay fish and wildlife. Shoreline erosion is a natural environmental process that simultaneously creates, maintains, and destroys shoreline habitats. Nevertheless, action to minimize the effects of shoreline erosion may be appropriate when natural shoreline erosion processes are altered by human activities, important habitat is threatened by shoreline erosion, or property valued by people may be impacted.

Habitats and The Organisms that Occupy Them

Habitats are the places where plants and animals live, feed, take shelter, and reproduce. The character of habitat is determined by the physical environment (such as rocks, soil, wind, and sunlight) as well as the structure of immobile living creatures occurring there (for example, trees or oysters). Several of the Bay's habitats require a specific type or range of landscape position on the shoreline and essentially only occur in these unique settings. Example habitats include intertidal flats, beaches, bluffs, and cliffs. Other habitats (such as tidal wetlands and shallow water) may not be shoreline dependent, but they are often associated with and heavily influenced by their shoreline position. Finally, other habitats (such as forests) may occur on the shoreline but are more commonly found elsewhere in the landscape.

Natural processes simultaneously create, maintain, and destroy habitats. Some of these processes vary from year to year (for example, precipitation), while others show consistent long-term trends (for example, shoreline erosion). Humans have also exerted substantial influence on the shoreline, and natural processes and human impacts continue to interact to affect shoreline character.

Beaches and Tidal Flats

The surf zone and beach constitute highly dynamic habitat created and maintained by strong wave energies and currents coupled with constantly shifting sand substrate Beach formation in the Bay depends on shoreline erosion. Shoreline erosion has the potential to maintain beaches and tidal flats or cause net losses or net gains in habitat. The natural habitat features along these types of shorelines include beaches, bars, muddy shores, outcrops of peat and clay, fallen trees and other woody debris, marsh edges (especially those altered by accumulation of sand and wrack), and upland banks/bluffs.

Intertidal flats occur in a strip along the Bay shoreline and consist of sand or mud that is regularly exposed and flooded by tides. Tidal flats occur where vegetation cannot survive because of instability of the substrate materials, high wave energy, and changing water levels. As a consequence of the small tidal regime of the Bay, tidal flats are fairly narrow. However, they occupy a large area due to the great length of Bay shoreline. Tidal flat and beach habitat has been lost in the Bay concomitant with construction of shoreline structures.

A number of wildlife species are either dependent on beach and tidal flat habitat or are highly associated with such habitat. Beach and tidal flat species include both common and rare species. The U.S. Fish and Wildlife Service (USFWS) conducted a literature review on this topic for the study (Appendix E). The following paragraphs discuss species of special concern and regular dwellers in the beach and tidal flat zones.

USFWS

The Puritan tiger beetle (*Cicindela puritana*), is a Federally listed threatened species found at eroding Bay bluffs.

Two Federally-listed threatened tiger beetle species, Puritan (*Cicindela puritana*) and Northeastern Beach (*Cicindela dorsalis* dorsalis) depend on Bay beach and bluff habitat. Puritan tiger beetles inhabit high eroding bluffs and adjacent beaches. Northeastern beach tiger beetles inhabit natural beaches with little human use; its range has diminished significantly as a result of the destruction and disturbance of natural beach habitat by shoreline development, beach stabilization structures, and intensive human recreational use.

In the 1940s and 1950s, least tern (*Sternula antillarum*) colonies were located on both shores of the Chesapeake Bay north to Baltimore and Kent Counties, generally on natural beaches. Today, the least tern is listed as a State-threatened species in Maryland. Least terns frequently move their colonies due to predation or threats from flooding (summarized in Robbins and Blom, 1996). Another beach-dependent bird, the American oystercatcher (*Haematopus palliates*), often nests on beaches along the shorelines of salt marsh islands (summarized in Robbins and Blom, 1996). The American oystercatcher is on the Maryland State watch list. Oystercatchers and least terns are threatened by the same loss of habitat that affects tiger beetles.

Bird species that have some dependence on Bay beach and tidal flat shoreline habitat include bank nesting swallows [bank swallow (*Riparia riparia*), rough-winged swallow (*Stelgidopteryx serripennis*), and belted kingfisher (*Ceryle alcyon*)], beach nesting birds [common tern (*Sterna hirundo*), Forster's tern (*Sterna forsteri*), least tern (*Sterna antillarum*), and black skimmer (*Rynchops niger*)], and foraging bird species [sandpipers and plovers (*Charadriiformes*), herring gull (*Larus argentatus*), great black-backed gull (*Larus marinus*), fish crow (*Corvus ossifragus*), boat-tailed grackle (*Quiscalus major*), and green heron (*Butorides virescens*)].

Formerly common species, though now less so, horseshoe crab (*Limulus polyphemus*) and diamondback terrapin (*Melaclemys terrapin*) are also strongly dependent on natural beach and tidal flat habitats.

Kevin T. Edwards IAN Image Library (www.ian.umces.edu/imagelibrary/)

A male Least Tern offering a fish to a female.

Beach Nourishment

While a substantial number of artificially nourished pocket beaches exist along the Chesapeake Bay shoreline (Dean et al., 2008), at this time their total extent along the Maryland bay shoreline is believed to be limited. Beach nourishment is of local importance as a factor controlling the presence of beaches and beach stability. Table 2.2 lists beaches that have been nourished at least once historically by MDDNR (McKnight, 2007). This list does not represent all beaches in Maryland that have been nourished, either by MDDNR or by others.

Beach	County
Bay Ridge	Anne Arundel
Highland Beach	Anne Arundel
Sandy Point State Park—East Beach	Anne Arundel
Hart and Miller Islands	Baltimore Co.
Jefferson Patterson Park and Museum	Calvert
North Beach	Calvert
Charlestown Veterans Park	Cecil
Rock Hall Town Park	Kent
Terrapin Beach	Queen Anne's
Elms Power Plant	St. Mary's
Jefferson Island Club	St. Mary's
Point Lookout State Park—Hammerman Area	St. Mary's
Tanners Creek	St. Mary's
Choptank River Fish Pier	Talbot
Claiborne Landing	Talbot

Table 2.2. Beaches on the Chesapeake Bay in Maryland that have had beach nourishment undertaken by MDDNR.

Wetlands

For thousands of years before European settlement, new tidal wetlands continuously formed at the leading edge of tidal influences (about mean high water spring). They maintained their surface elevation by accumulating sediments as the water rose, and eventually they eroded on their bayside margin, converting to open water (Figure 2.3) (Brinson, 1991).

Natural tidal marsh on the Bay shoreline occurs where the rising water has intercepted and flooded low-lying Coastal Plain terraces. Natural tidal marshes also occur on recent deposits in tidal rivers and waterways. Terrace wetlands predominate on the Lower Eastern Shore. On the

Jane Thomas, IAN Image Library (www.ian.umces.edu/imagelibrary/)

Healthy (green) and stressed (brown) marshes in and around Blackwater National Wildlife Refuge and Fishing Bay Wildlife Management Area, Dorchester County, Maryland.

Western Shore, large areas of tidal marsh occur along tidal rivers where substantial sediments have accumulated since European settlement (Gottschalk, 1945; Khan and Brush, 1994).

Historic trends in Bay tidal wetlands have not been quantified accurately (Tiner and Burke, 1995). It is probable that a net loss has occurred naturally as erosion and inundation exceeded tidal wetland formation rates. Human impacts contributed to this natural trend (Stevenson et al., 2000). Approximately 0.5% of the Bay's tidal wetlands were lost between 1982 and 1989, with the majority of these losses occurring via conversion to open water (Tiner et al., 1994). Ongoing climate change and forecasted acceleration in the rate of sea-level rise is anticipated to increase the rate of conversion of Bay tidal wetlands to open water and will likely lead to a substantial net loss over the next century (Titus and Strange, 2008).

One Federally threatened vegetative species dependent on tidal wetlands in Maryland is the sensitive joint vetch (*Aeschynomene virginica*). It occurs in fresh to slightly brackish tidal river systems, within the intertidal zone. In Maryland, sensitive joint vetch typically occurs in marsh interiors where local nutrient deficiencies maintain a sparsely vegetated condition. It also occurs at the outer fringe of marshes or shores within deposition zones of tidal rivers.

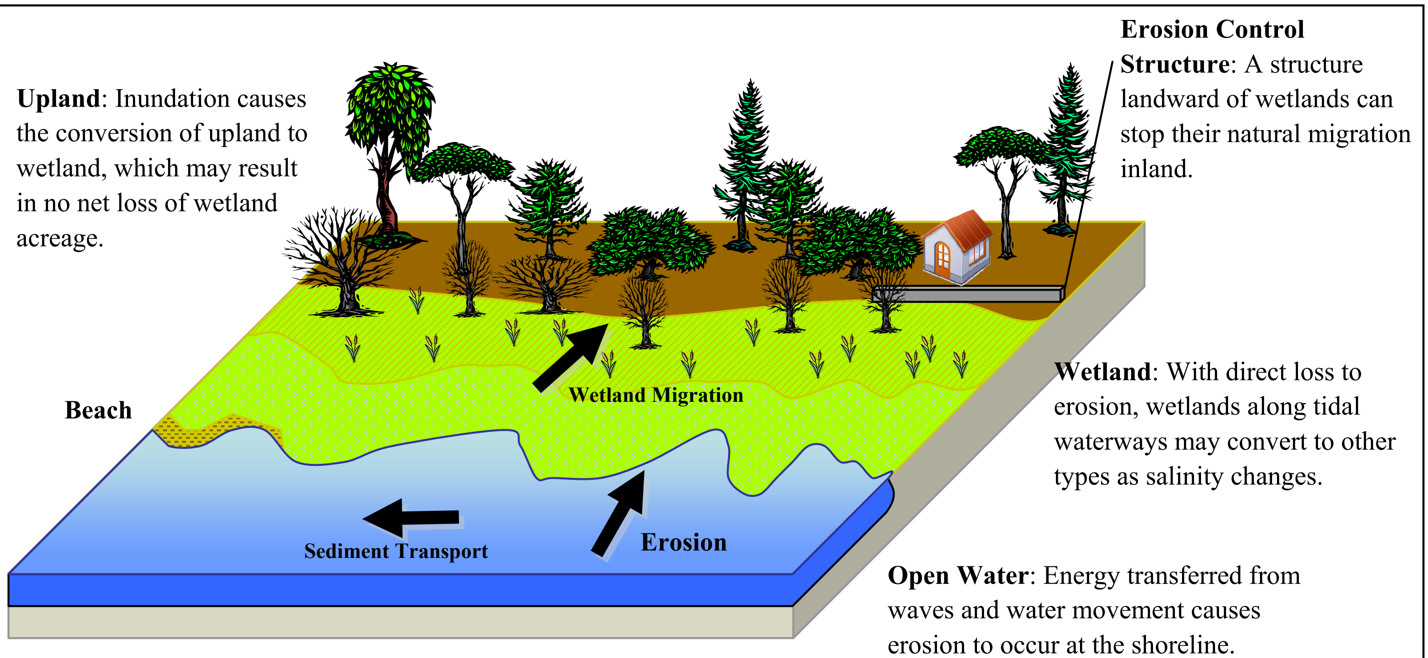


Figure 2.3. Tidal wetlands naturally migrate inland, driven by rising sea level and increasing inundation of land. Tidal wetlands build their surfaces from accumulated plant remains and sediment conveyed in tidal waters. In tidal waterways, as the shoreline erodes more land is potentially exposed to inundation, and wetlands may convert from one type to another due to increases in salinity. Beaches also migrate and may occupy former upland or wetland areas. Erosion is a driving force in beach evolution, but the continued existence of beaches depends on a sediment source transported to the beach through currents and waves. Sediment that forms beaches may be transported downstream in rivers or eroded from shorelines. The natural process of wetland and beach migration may be interrupted by erosion control structures, which can limit the land available for conversion.

Shallow Water Habitats

Shallow water habitat is typically considered to occur from the shoreline to about a depth of 6 feet. Human impacts have caused both gains and losses in the total shallow water habitat in the Bay. As a consequence of increased sedimentation following European settlement, shallow water habitats in tidal tributaries of the Western Shore likely increased substantially (Gottschalk, 1945), and deep water channels near the shore were lost (Miller, 1986). While tidal tributary shallow water habitat may have gained area, it is unlikely that the area of shallow water habitat in the Bay mainstem was affected; rates of post-European settlement sedimentation do not show a clear pattern of increase in Bay mainstem shallows (Colman et al., 2002; Saenger et al., 2008).

Shallow water habitats are maintained by sediment from shoreline and watershed sources. In many of the Bay's tidal tributaries, watershed sources of sediment are of equal or greater importance than shoreline erosion for maintenance of shallow water. In large tidal tributaries where wave energy becomes sufficient to erode shorelines and create beaches and bluffs, shoreline sources become a principal source of sediment for creation and maintenance of habitat (Marcus and Kearney, 1991).

Shallow waters serve as important nursery and juvenile habitat for numerous fish species. Species such as menhaden are often found in the shallow water habitats of the Bay before they mature and move to deeper waters. In the shallows, young fish avoid predation by larger fish that have difficulty in shallow water.

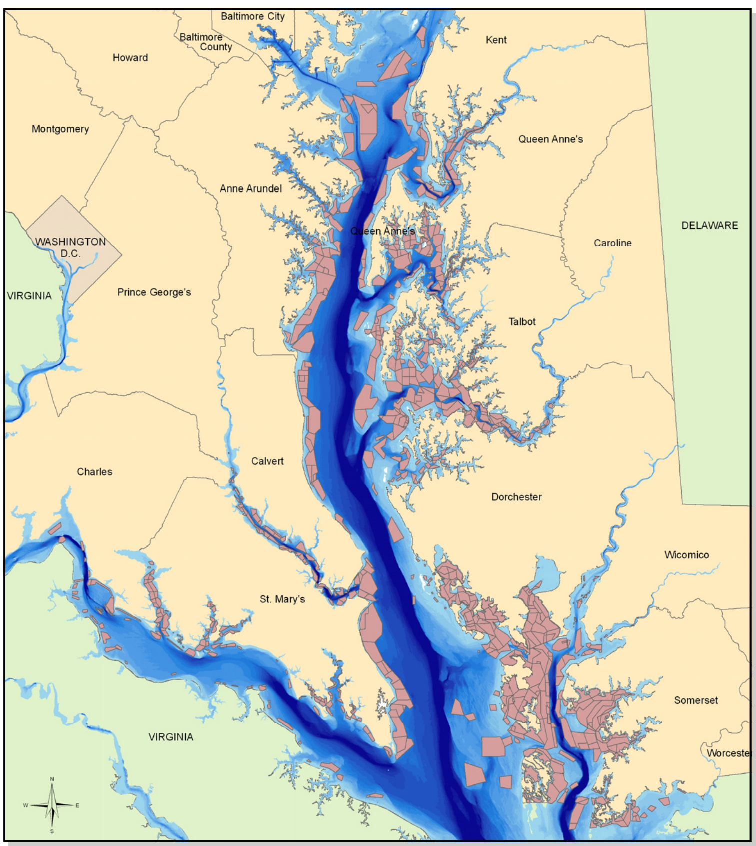


Figure 2.4 Historic extent (1906-1977) of natural oyster bars as charted in the Chesapeake Bay of Maryland.

Oysters

Concentrations of oysters form a distinct habitat type in the Bay. North of the Potomac River, oysters historically occurred in vast "beds" on the bottom of the Bay (Figure 2.4). These beds had relatively low relief off the Bay bottom, most plentiful in water from 5 to 30 feet deep—essentially below the active wave depth—such that they probably did not have a significant effect on shoreline processes (Smith et al. 2003, Stevenson 1894). From the Potomac River south, oysters formed reefs with substantial vertical relief off the bottom. These reefs likely posed a risk to navigators in southern Bay waters, and reefs likely provided shore protection from waves, at least locally. Today, the mean depth of existing oyster habitat in Maryland is about 14 feet, with a range of 5 to 32 feet (USACE et al., 2009). Seasonal hypoxia/anoxia caused by anthropogenic nutrient loading have reduced quality of deeper waters as oyster habitat. In an effort to prevent exposure to anoxic waters, the Chesapeake Bay Oyster Management Plan suggests that reefs be

Eastern oysters (*Crassostrea virginica*)

constructed at depths les than 20 feet (CBP 2004). Oysters also occur intertidally as fouling organisms on natural and manmade surfaces. Throughout the 20th century, intense overfishing, exotic diseases and parasites, and sedimentation caused a dramatic decline in eastern oysters. Although the total loss in bed area is uncertain, Bay oyster populations are currently though to be about 1% of historic levels.

Oyster beds have been demonstrated to reduce shoreline erosion in coastal areas (Meyer et al, 1997). While it is commonly speculated that the loss of oyster beds has contributed to accelerated shoreline erosion, in Maryland, north of the Potomac River, the wave protection function of oyster beds was limited due to their depth. Thus, the loss of oysters in Maryland has likely had little impact on shoreline erosion rates.

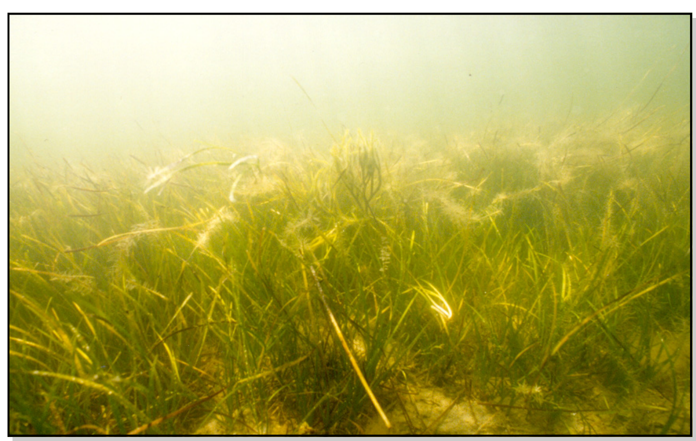
In the Potomac River and in Virginia waters, oysters formed reefs with substantial vertical relief. Oyster loss in these areas may have exacerbated shoreline erosion.

Oyster larvae require hard surfaces on which to settle and grow. On healthy oyster "reefs," oysters can produce new shell substrate at a rate that matches Bay sedimentation rates. In stressed oyster communities, suspended sediment can cover oyster reefs and other hard-bottom substrates, limiting oyster recruitment. Since oysters now fail to produce substantial shell material, natural sedimentation has dramatically reduced the amount of hard-bottom habitat available to oyster in the Bay (Smith et al., 2005). Loss of hard-bottom substrate from reduced shell availability may limit future increases in oyster abundance. It may be expected that increases in Bay sedimentation would result in a loss of oyster abundance.

Submerged Aquatic Vegetation

Similarly to oysters, submerged aquatic vegetation (SAV) forms a distinct habitat type. SAV helps improve water clarity by absorbing nutrients, settling sediment suspended in the water, and stabilizing the Bay bottom. SAV also absorbs some of the wave energy that can cause shoreline erosion.

SAV research and monitoring in the Chesapeake Bay is among the best in the world and annual inventories of SAV communities have been conducted in most years since 1984; some data records go back to the 1930s. In addition, paleoecological research has provided data on SAV trends in the Bay for thousands of years before the present time.



Submerged aquatic vegetation (SAV) - eelgrass (*Zostera marina*).

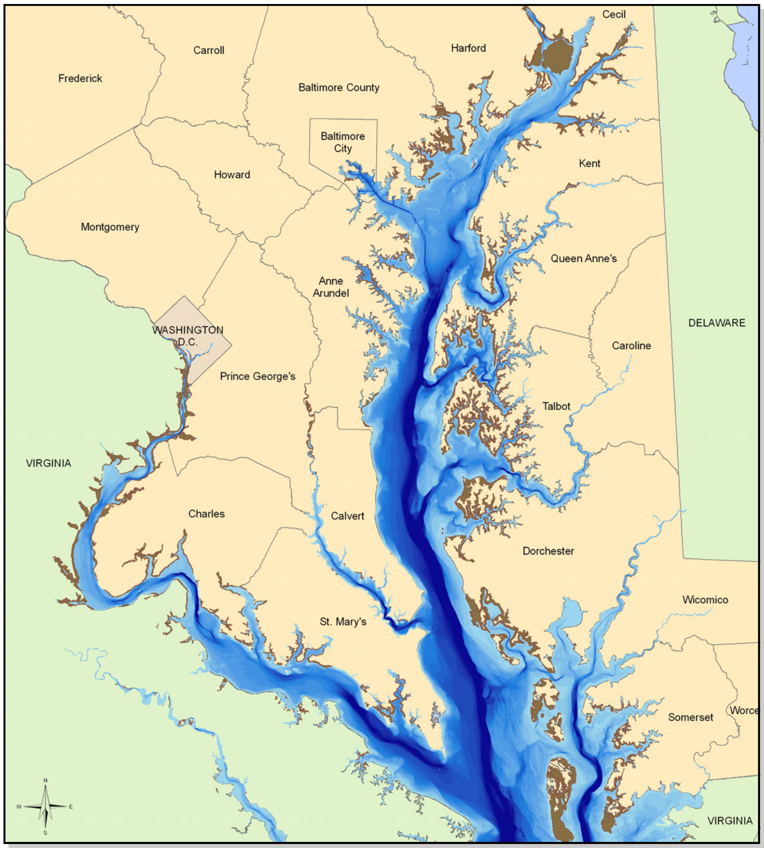


Figure 2.5 Composite coverage of submerged aquatic vegetation (SAV) within the Chesapeake Bay of Maryland from 1990 to 2007.

Before European settlement, SAV occupied Bay shallow water habitat; populations were not constant over time, waxing and waning substantially (Brush and Hilgartner, 2000). SAV coverage initially increased following European settlement, presumably as a consequence of increased sediment and nutrient availability as settlers altered landforms in the watershed (Brush and Hilgartner, 2000). SAV coverage declined drastically through the 1960s as a result of water quality declines, disturbance of SAV beds, and alteration of shallow water habitat. Other natural factors, particularly Hurricane Agnes in 1972, may have compounded the impact of excess sedimentation and associated nutrients.

SAV has recovered somewhat since the 1970s. SAV exhibits pronounced year to year variation in coverage and density. Between 1995 and 2003, SAV in the Bay occupied from 30 to 50% of its greatest known historic coverage (1930s to 1950s) (Figure 2.5).

Reduced water clarity can limit the growth and extent of SAV because sunlight is required for photosynthesis and growth. Shoreline erosion and wave action that resuspends bottom sediments are natural causes of poor water clarity. Because SAV helps to reduce wave energy, when SAV is lost in an area, that area may be more vulnerable to accelerated shoreline erosion.

Historic and Cultural Resources

The Chesapeake Bay watershed has had human occupants for at least the past 12,000 years. Native Americans utilized the rich natural resources of the Bay, particularly beginning between 5000 – 3000 years ago. Archeological evidence suggests that inland waterways were used as navigation corridors by hunting parties. The 1608 Captain John Smith map of the Chesapeake Bay and major tributaries illustrates that Native American settlements were well established at that time up to the Fall Line.

This settlement pattern likely prevailed throughout the region at the time of contact with European explorers and settlers. Archaeological resources associated with the shorelines include oyster middens (remnants of oyster shells discarded by ancient people), settlement sites with numerous artifacts, projectile points, and ceramics, among others. Shoreline erosion has presumably destroyed many Native American archaeological resources along much of the Chesapeake Bay shoreline.

Beginning in the early to mid-17th century, European settlement of the Chesapeake Bay region concentrated along inland waterways. The Chesapeake Bay and its tributaries were important transportation corridors for tobacco and other

Based on a 3-month exploratory survey by boat in the summer of 1608 under the direction of Captain John Smith, this is the earliest published map of the entire Chesapeake region. It not only shows the location of Jamestown, the first English settlement in the region, but also the location of Indian villages along the Bay and its numerous tributaries. The map is oriented with west at the top.

trade goods. The tobacco trade was centered on largely autonomous plantations, serviced by small towns for their civil law needs. Early settlement patterns were largely dispersed with small concentrations of people. Shipbuilding also became an important industry along the Chesapeake Bay shoreline due to the relative navigational ease of the Bay and access to nearby timber resources.

Shoreline stabilization practices were not widespread prior to the mid-20th century, other than in harbors and at highly valued economic and military sites. Historic cultural resources on the shoreline include several historic districts listed on the National Register of Historic Places (NRHP), numerous early farms and settlements, lighthouses, and boats.

Throughout the 20th century urbanization and industrialization in the Chesapeake Bay region increased. The contemporary shoreline is a mosaic of undeveloped land, agricultural land, residential development, harbor facilities, and heavy industrial sites.

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The Sparrow's Point steel mill in Baltimore County. First developed in 1889, by the mid-20th century the Bethlehem Steel-owned mill was the largest in the world. Its position on the shoreline of the Chesapeake Bay enabled the transport of raw materials and finished goods.

Chesapeake Bay Challenges

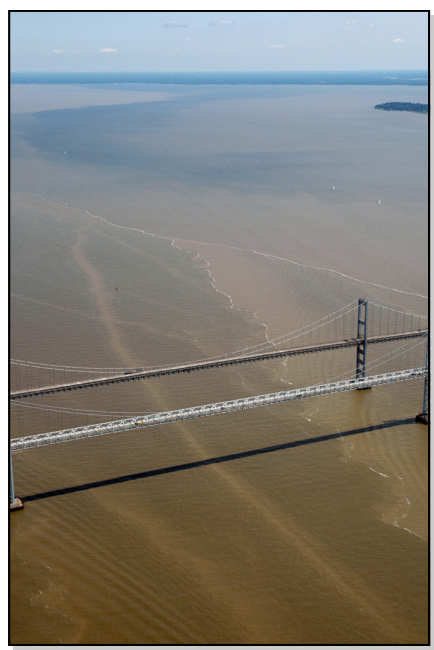
The ecological and cultural integrity of the Chesapeake Bay, as well as the safety, health, and welfare of the human inhabitants along its shores, are being stressed and challenged. Shoreline erosion contributes to property loss and leads to reductions in wetlands and other important habitats. The Chesapeake Bay is also experiencing rising sea-levels, which may lead to reduced ecological functioning and may threaten human infrastructure. In addition, inundation from storm events threatens lives and livelihoods.

Erosion

As previously stated, shoreline erosion is a natural process that is fundamental to the character of the Bay ecosystem. Sea-level rise drives shoreline erosion over the long-term, gradually flooding upland and wetland areas, converting them to open water. Sea-level has risen in the Chesapeake Bay since the Bay's formation over 10,000 years ago.

Over the short-term, shoreline erosion is driven by episodic storm events. Storm events can include tropical storms and hurricanes or the more common and often more destructive Nor'easter. Tropical storms generally pass through the Chesapeake Bay area quickly and are not a regular occurrence. Nor'easters often linger in the area for a substantial amount of time, are more frequent, and while they may have less energy, their cumulative impact may be greater. The effects of storms on sediment entering the Bay, either through shoreline erosion or sediment transported by tributaries, may result in massive sediment plumes in the Bay.

Shoreline erosion rates appear to have accelerated beginning in 1850, as the climate warmed following the end of the Little Ice Age; rates since that time appear to be higher than rates prior to 1850 (Kearny, 1996). Between 1845 and 1942, prior to substantial human shoreline stabilization, shoreline erosion in Maryland along 1,460 miles of analyzed shoreline averaged 1.3 feet per year (USACE, 1990). It is likely that shoreline erosion



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Several sediment plumes in the Chesapeake Bay underneath the Chesapeake Bay Bridge.

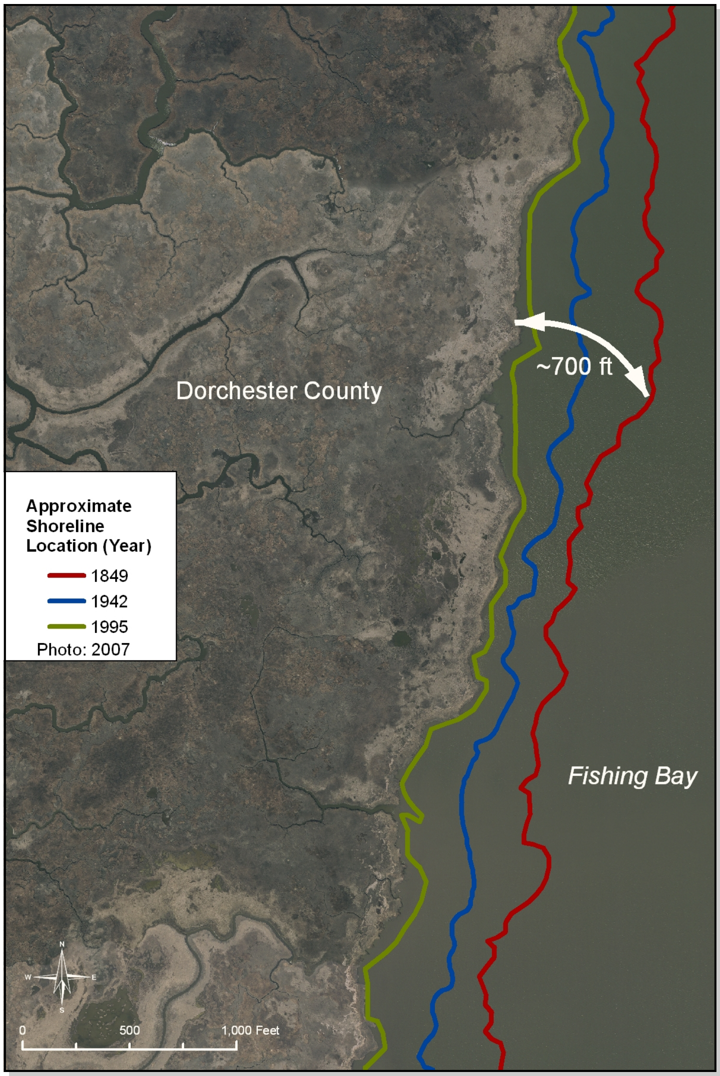

Figure 2.6. Approximate shoreline position between 1849 and 2007 along Fishing Bay in Dorchester County, Maryland. This area of Dorchester County, including Blackwater National Wildlife Refuge to the north, is experiencing substantial wetland loss.

has decreased regionally as a consequence of shoreline hardening. During the 1990s, armoring was occurring at a rate of 10 to 25 miles per year on the Maryland Bay shorelines (Titus, 1998).

Sediments generated from shoreline erosion create and maintain Bay beaches and shallow water habitat. Sediments from shoreline sources also contribute to tidal wetland maintenance. Beaches are depositional features built from sand derived from shoreline erosion and sub-tidal sources.

When shorelines that are sources of sediment for a beach are stabilized, the beach may vanish. Although beaches are depositional features, they are dynamic. Over historic and geologic time, most Bay beaches that front mainland will retreat landward as the mainland erodes. Thus, shoreline erosion is a process that creates, maintains, and destroys the natural habitat of Bay shorelines (Figure 2.6).

Erosion also produces banks along the shoreline, with their height dependent on the height of the land into which the Bay is eroding. Depositional features such as spits occur locally where substantial material from eroding shorelines accumulates in the nearshore environment.

Much of the eroded shoreline material in the Bay is transported offshore and effectively "lost." Along Calvert County's open Bay shorelines, only 3% of eroded material stayed along the shoreline over a 124-year period from 1847 to 1971 (Downs 1993).

Water Quality

Initial human-induced nutrification of the Chesapeake Bay began about 200 years ago. Signs of increased phytoplankton and decreased water clarity first appeared about 100 years ago (Kemp et al., 2005). Human-induced nutrient loading rates increased markedly following World War II, coincident with a pronounced increase in the use of artificial fertilizers (Boesch, 2002). Severe, recurring deep-water hypoxia first became evident in the 1950s (Kemp et al., 2005). Nitrogen and phosphorus nutrient loading to the Chesapeake Bay are currently at about 6 to 8 and 13 to 24 times pre-European settlement rates, respectively (Boynton et al., 1995).

Studies conducted for the Chesapeake Bay Water Quality Model have quantified total nitrogen and phosphorus nutrient loading. The rates of nitrogen and phosphorus loading from shoreline sources are within the natural bounds of nutrient loading rates. Therefore, shoreline erosion is not a probable cause of or significant contributor to impaired Bay water quality from nutrients. In addition, the extent of shoreline hardening in the Bay suggests that the rate of nitrogen and phosphorus inputs from shoreline sources is less than the historic rates from when the Bay ecosystem was healthy.

Water quality is impaired by excess algal growth and suspended sediment. Reduced water clarity limits the growth and extent of SAV, which is severely reduced in the Chesapeake Bay. Shoreline erosion and wave action that resuspends bottom sediments are natural causes of poor water clarity.

Rivers also deliver suspended sediment to the Bay. River loading of sediments from the Bay watershed is twice the pre-European settlement rates as a consequence of human activities (Cronin et al., 2008). The majority of fine-grained, river-borne sediment delivered to the Bay is trapped in estuarine turbidity maxima (ETM) zones and only escapes the upper reaches of the northern Bay and upper parts of tributaries during extreme precipitation events (USGS, 2003). In the Mid-Bay, shoreline sources (upland and nearshore) have been determined to deliver the majority (~53%) of the suspended sediment load (silt/clay) (Biggs, 1970), and suspended sediments from the nearshore are major causes of increased light attenuation in this region (CBP Water Quality Model, Cerco, 2002).

Water quality in the entire Chesapeake Bay is impaired through excessive nutrient and sediment inputs, but, overall, the primary source of nutrients and sediments into the Bay is not from shoreline erosion. Future challenges for Bay water quality include changing the mindset that all sediment is bad sediment. Practices, policies, and regulations should reflect current understanding about the sources of nutrients and sediments. Solutions for reducing suspended sediment in the Bay need to be implemented, but these will most likely need to attack this problem indirectly by focusing on reducing nutrient inputs.

Sea-Level Rise

The sea has been rising for the last 17,000 years, since the end of the last Ice Age. Sea-level initially rose at rates much greater than today, slowing to nearly its present rate about 5,000 years ago (Fairbanks, 1989). The Bay began to form about 10,000 years ago via inundation and erosion of the mainland, driven by rising sea level, and it has continued to grow in areal extent ever since (Colman et al., 2002).

According to the National Oceanic and Atmospheric Administration, in Maryland sea level is currently rising at a rate in excess of 3 mm (0.12 inches) per year (0.3 m [1 foot] per 100 years) (Zervas, 2001). This rate exceeds the global average due to regional geologic factors. In 2007, the International Panel on Climate Change forecast that the sea would rise globally between 0.4 and 0.6 m (1.3 to 2.0 ft) by the year 2090. In the Chesapeake Bay, because of regional geologic factors, sea-level rise is forecast to be 0.8 m to 1.0 m (2.7 to 3.4 ft) by 2100 (Maryland Commission on Climate Change, 2008).

Inundation from Storms

Shoreline erosion occurs chronically from medium and high wave energy, with more rapid losses occurring during severe storms. Shoreline erosion along low energy shorelines is episodic, with minimal loss occurring for lengthy periods of time between storms. Severity of storm winds, and consequent wave energy and heights, largely determine whether storms cause severe shoreline erosion.

Storm surge water surface elevations control the land elevations at which this erosion occurs. At high water surface elevations bluffs and cliffs may be subject to direct wave attack well above the normal Bay water level, while very low-lying features—such as the surface of tidal wetlands—may be drowned below the level of high wave energy and somewhat protected from wave erosion.

Shore erosion during a single storm event can vary from none to substantial. The Maryland Geological Survey estimated that Hurricane Isabel, in 2003, converted 20 acres of land to open water; this represents 15% of average annual loss of land over the Maryland Bay shorelines (Hennessee and Halka, 2003). In contrast, Hurricane Agnes—the flood of record for much of the Chesapeake Bay watershed—apparently caused only minimal shoreline erosion, and largely from excess soil saturation rather than waves (Ruzecki et al., 1976).

Computer models have been developed to forecast storm surge in the Bay associated with severe storms. Substantial improvements were made in the models following Hurricane Isabel in 2003. Although computer models have been developed to predict beach erosion from individual storm events on the Atlantic Ocean coast, no comparable models have been developed for the Chesapeake Bay shoreline. The complex interaction between factors governing shoreline erosion at any one location has made modeling problematic.

Storm surge forecast mapping has been conducted through the use of the Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model for Maryland (Figure 2.7). SLOSH allows the evaluation of storm surge threats, and emergency managers use these forecasts to determine evacuation areas. SLOSH output is also used by the National Hurricane Program (Federal Emergency Management Agency) when conducting Hurricane Evacuation Studies. For these studies, SLOSH is used as a hazard analysis tool to assist with the creation of state and local hurricane evacuation plans or zones. SLOSH model results are combined with roadway network and traffic flow information, rainfall amounts, river flow, or wind-driven waves to determine a final analysis of at-risk areas.

A detail of a SLOSH model output map is shown in Figure 2.7. Model results and Hurricane Evacuation Study reports for the western Maryland shore may be found at www.nab.usace.army.mil/HES/hes.htm. Eastern Maryland shore results may be found at www.nap.usace.army.mil/HES/Delmarva/index.html.

As sea levels rise in the Bay, storm surge will be exacerbated during storm events. As a result, more land area may be inundated, or different land areas may be inundated. Magnitude and frequency of storms in the Mid-Atlantic region is predicted to increase over the next 100 years due to anticipated climate change, with rising sea level and storm surge posing increasing challenges for coastal management.

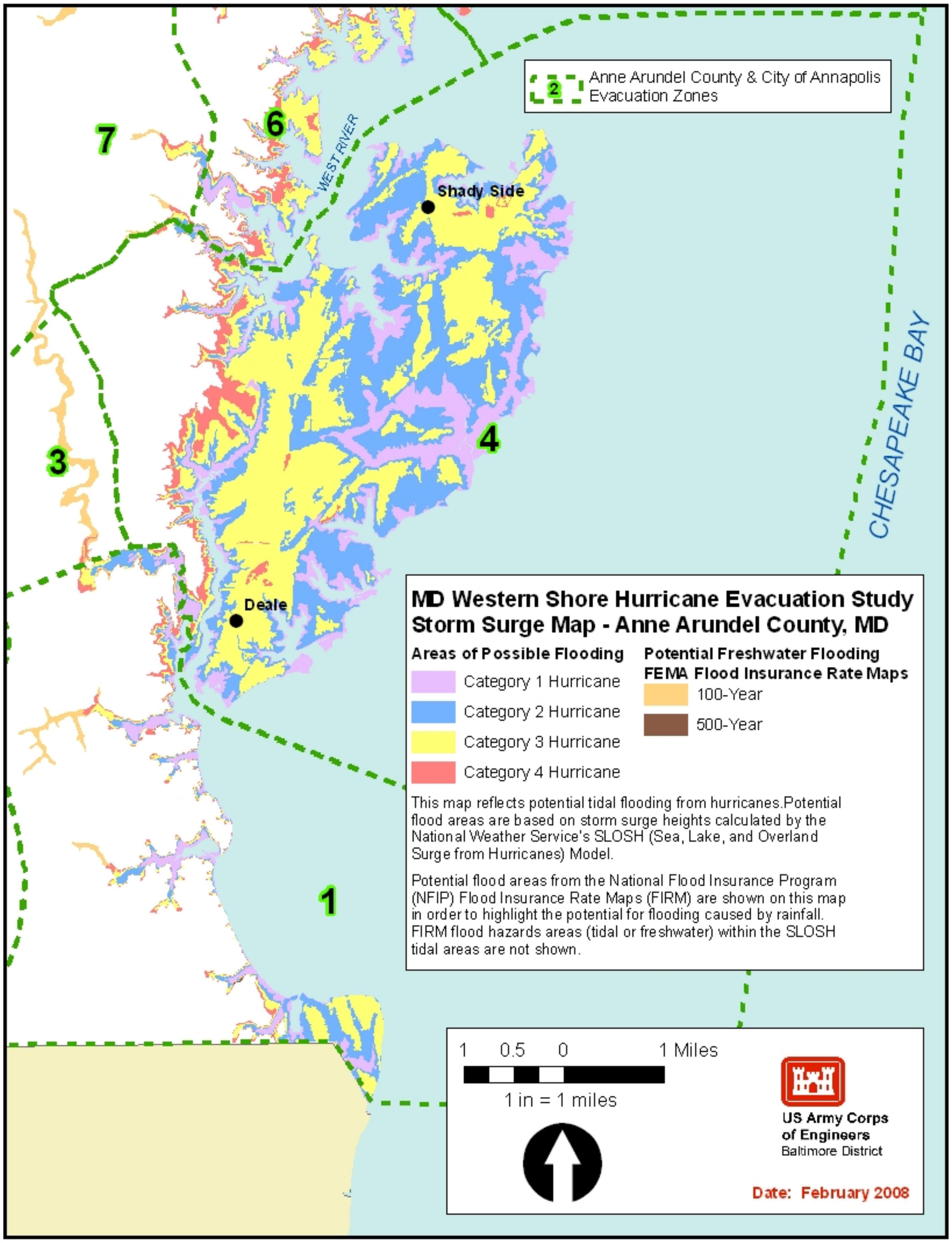

Figure 2.7. Storm surge inundation mapping for the Shady Side peninsula in Anne Arundel County, Maryland using SLOSH modeling data. Information for Western Shore Counties may found at www.nab.usace.army.mil/HES/hes.htm. Information for Eastern Shore counties may be found at www.nap.usace.army.mil/HES/Delmarva/index.html .

Chapter 3: Problems, Needs, and Opportunities

Shoreline erosion represents a threat to human properties and structures, but it is also a natural process fundamental to the ecosystem of the Bay and its long history of changing sea levels. The majority of the Chesapeake Bay shoreline is eroding naturally and has been for thousands of years, since the Bay formed. While erosion destroys shoreline habitats, it also simultaneously creates and maintains them.

The following sections briefly discuss problems caused by past shoreline stabilization methods, effects of shoreline erosion on the ecology of near-shore habitats, and the effects of shoreline erosion on socioeconomic and cultural resources. Shoreline management implications are also introduced.

Shoreline Stabilization

About 15% of the Chesapeake Bay shoreline has been stabilized with manmade structures (Chapter 2). Interest in protecting the remaining natural shoreline is anticipated to increase, particularly as erosion is anticipated to increase due to sea-level rises, and intensifying storms due to climate change. Shoreline stabilization with traditional coastal engineering measures typically reduces the natural shoreline sediment supply, halting the processes that create and maintain intertidal and shallow water habitat. While shoreline stabilization effectively halts upland erosion, bayward of the engineered structure erosion continues to active wave depth (as much as 6 feet along the mainstem Bay). As the erosion continues into the Bay, it gradually eliminates habitat for plants, fish, and wildlife species that depend on natural shorelines and shallow water habitat. While stabilization structures effectively protect property and infrastructure, they unintentionally cause the loss of public intertidal property and associated recreational opportunities — eliminating beaches and limiting access from land and water (Titus et al., 1998). The cumulative impacts of shoreline stabilization are an environmental issue of increasing concern (Titus et al., 1998; CBP, 2007a; CBP, 2007c).

Ecological Resource Effects

Chapter 2 briefly discussed the habitats found within the Chesapeake Bay. These habitats experience various effects from shoreline erosion, ranging from direct habitat loss to degraded habitat as a result of sediment deposition. The subsections below provide an overview of the effects of shoreline erosion on important species, habitats, and resources.

Water Quality, Oysters, And SAV

Chesapeake Bay water clarity is impaired from historic conditions, and this has substantially reduced acreage of SAV habitat to the detriment of the Bay ecosystem (CBP, 2007b). Recently adopted tidal water clarity standard regulations for protection of SAV focus on the effect of sediment loads on Bay water clarity (USEPA 2003a, 2003b). Shoreline erosion contributes suspended sediment to Bay water, and emphasis has been placed on the potential need to control this sediment to improve water clarity for SAV (USACE, 1990; CBP, 2005; CBP, 2006). Recently, perspectives are shifting about the cause of excess suspended sediments in the water column and whether shoreline erosion should be viewed as a problem for the Bay (CBP, 2007). SAV thrived historically in spite of shoreline erosion, and human shoreline stabilization has probably reduced the rate of sediment delivery to the Bay from shoreline sources. Excess suspended sediments in the water column and consequent detrimental impacts to water clarity are viewed as a failure of oysters to filter sediment (Newell, 1988), as well as heightened algal flocculent (caused by nutrient loading) impeding sediment settling rates (Gallegos et al., 2005; CBP, 2007). Thus, stabilizing shorelines to reduce erosion may prevent some suspended sediment, but the root causes of water clarity problems will not be addressed. Shoreline stabilization may, in some cases, produce detrimental environmental tradeoffs (CBP, 2007).

Efforts to restore Bay oysters for erosion control would be most appropriate for consideration along the Potomac River shoreline of Maryland because they were and are largely restricted to greater water depths elsewhere in the Bay. Opportunities to restore oysters along the St. Mary's County shoreline were recently investigated by USACE and St. Mary's County. Other oyster restoration efforts are planned.

Beaches, Intertidal Flats, Bluffs

Bay intertidal flats and beaches are dependent on erosion of landward or updrift shorelines as the source of sediment that sustains these habitats. Unvegetated bluffs are dependent on erosion at the top of the slope and deposition of bluff material at the bottom of the slope in order to maintain an unvegetated condition. Where shorelines have been stabilized, beaches and intertidal flat habitats immediately fronting and downdrift of the stabilization structures are often gradually converted to open water and thus lost. Over time, the stabilization structure becomes the shoreline, and natural unvegetated bluff habitat landward of the structure often becomes vegetated.

Sediment that forms beaches and intertidal habitats is generally from local sources. Material that forms these habitats includes sand that has been transported short distances from erosional sources, as well as relict geologic materials that haven't yet been eroded. Only in "delta" areas is sediment derived from riverine upland watershed sources important in forming intertidal and beach habitat (USGS, 2003).

Much of the 1,000 miles of the Bay shoreline that has been stabilized was historically fronted by combinations of these intertidal flat, beach, and bluff habitats. Much of the stabilized shoreline has continuous stabilization structures that limit aquatic organisms access to habitats landward of the structures, and eliminate habitat for organisms dependent upon intertidal flats, beaches, or bluffs when these habitats are lost. Beach nourishment often becomes necessary to maintain recreational beaches in these settings.

Tidal Wetlands

Bay tidal wetlands that occur on recent geologic deposits, such as in the lee of spits and at river mouths, are dependent upon continued delivery of sediment for substrate maintenance. Interruption of sediment supplies from shoreline or watershed sources to these tidal wetlands can lead to their loss through drowning-in-place or erosion.

The majority of the Bay's tidal wetlands occur on drowned uplands. While tidal waters bring sediment that maintains the wetland surface (in combination with plant growth), tidal wetlands are generally not directly dependent upon adjacent shoreline erosion as a primary sediment source. However, tidal wetlands on the shore fringe are vulnerable to increased bayside erosion where updrift stabilization structures cut off sediment supplies that maintain shallow water bayward of the tidal wetland. Shallow waters serve to reduce wave energy striking the shoreline. Loss of incoming sediment that creates and maintains shallow water can cause water deepening immediately off the shoreline, allowing greater wave energy to strike the shore.

Natural creation of new fringe wetlands is dependent, in part, upon flat ground landward of the existing tidal wetland to provide migration space as the sea rises. Shoreline stabilization structures constructed landward of tidal wetlands often effectively prevent natural creation of new tidal wetlands.

Tidal wetlands that have been impacted by man such that the shoreline erosion rate is increased or natural creation process (i.e., landward migration) interrupted merit investigation for restoration or protection measures. Construction of stabilization structures to protect existing tidal wetlands from erosion in these settings (particularly urban waterways) may be appropriate because the natural processes which otherwise create and maintain these habitats are impaired. In rural settings, ensuring future landward migration space is important to ensure natural future tidal wetlands creation which can compensate for natural loss.

The State of Maryland has designated some wetlands as Wetlands of Special State Concern (WSSC). These wetlands may be critical habitat for rare, threatened, or endangered species, or possess other attributes that have been deemed important for conservation. Loss of WSSC to shoreline erosion could potentially have cascading ecological effects throughout the Chesapeake Bay.

Socioeconomic Resource Effects

Shoreline erosion has the potential to affect socioeconomic interests of humans, including roads, buildings, property, open space, agricultural land, and other infrastructure. Shoreline erosion causes the land upon which an activity is based to be lost, causes land providing protection from storm inundation or sea-level rise to be lost, or it may affect other values (economic, aesthetic) that are placed on a parcel of land.

The effects on socioeconomic interests are varied. If not managed for, shoreline erosion can threaten Bay water quality by enabling the failure or undermining of wastewater treatment facilities and outfalls during storm events. Inundation during storms, exacerbated by shoreline erosion, may flood roads designated as evacuation routes. The identification of areas vulnerable to erosion can help identify socioeconomic interests at risk.

USACE

Shoreline erosion can cause a loss of property and threaten structures.

The impacts of shoreline erosion may be dealt with in a variety of ways, including retreat from eroding shores, shoreline stabilization efforts, and planning human use to account for projected future erosion. An economic evaluation of the impact of shoreline erosion on real estate valuation conducted for this study found that shoreline erosion affects property values. A 17% decrease in property value was attributable to high/medium (4 ft/year or more) erosion rates on unstabilized properties' shorelines (Appendix B).

Cultural Resource Effects

The cultural heritage of the Bay is highly valued and is often associated with close proximity to the shoreline. As a result, cultural resources may be at risk through loss or damage from shoreline erosion. Archeological sites associated with shoreline use may be lost as land erodes, and historic structures may potentially be lost as the land upon which their foundations rest erodes.

In addition to potential losses of cultural resources, the living cultural heritage of the Chesapeake Bay may also be disrupted by shoreline erosion. For example, the unique culture of the watermen of Smith Island may be impacted by ongoing shoreline erosion in synergy with sea-level rise, contributing to increased inundation of the homes and businesses of these watermen and loss of environmental quality on which their livelihoods depend.

Shoreline Management Needs

In light of the problems described above, there is a great need to promote shoreline management approaches that minimize loss of natural shoreline, shallow water habitats, and public shoreline access while also protecting property from erosion. Balancing these conflicting needs could be improved if shoreline management decisions were made routinely from a regional or reach perspective rather than on a site-specific basis. To help achieve this goal, data must be developed and made available to allow planners and

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The Custom House in Chestertown, Kent County, Maryland is an historic structure within the Chestertown historic district, listed on the National Register of Historic Places. This historic district is within the 50-year planning window and may be vulnerable to erosion. The Custom House is protected by a stone revetment — other structures in the Chestertown historic district and elsewhere on the Bay may also require shoreline stabilization measures to protect their integrity.

regulators—locally and regionally—to assess the state of their shorelines, project conditions into the future, and plan comprehensively at regional scales.

Along waterways where shorelines have been extensively stabilized, management measures should be considered that would restore natural shoreline habitats. Stabilization structures often increase erosion along downdrift shorelines. Increased wave energy from boats can increase erosion rates along heavily traveled waterways. Where either of these threaten shoreline habitats, shoreline erosion could be appropriately considered as an environmental problem requiring correction.

Development landward of existing shoreline habitats prevents gradual landward habitat migration as the sea rises. Where natural shoreline erosion processes continue unabated, this leads to gradual elimination of shoreline habitats. Appropriate shoreline strategies and engineering should be tailored to a specific site and situation but planned regionally. These strategies may range from land easements allowing the natural migration of shoreline features, to living shorelines, to bulkheads in built-up and high energy areas. For example, in urban waterways, a comprehensive view may be that the healthy ecosystem has been broken, and site-specific shoreline armoring may be appropriate to protect remaining habitat, as well as existing residential, commercial, and industrial development.

Landowners, shoreline managers, and planners also need information to enable them to implement appropriate site-specific solutions to shoreline erosion problems that fit into regional planning efforts. Such information includes guidance on the selection of methods and materials to plan for, ameliorate, and mitigate the effects of shoreline erosion.

Finally, the implications of sea-level rise and storm inundation must be understood and managed along with shoreline erosion. Sea-level rise, storm inundation, and shoreline erosion are synergistic actors within the Bay. As the sea rises, storm inundation will be worsened, and the effects of shoreline erosion may be magnified. Shoreline management must be comprehensive and address all three coastal processes.

Shoreline Management Considerations

- Fill critical data gaps: Addressed with this study—spatial data and online mapping available at:http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
- Apply shoreline management strategies specific to problem situations on a regional or reach-specific scale.
- Develop and utilize technical guidance on implementing shoreline management solutions: see *Shore Protection: A Guide for Engineers and Contractors* — developed as part of this study.
- Consider shoreline erosion, storm inundation, and sea-level rise as synergistic coastal processes and comprehensively plan and manage for all processes.

Chapter 4: Evaluation of Priority Areas

The ecological, socioeconomic, and cultural resources of the Chesapeake Bay are all components of the shoreline system. These components must be evaluated for their vulnerability to shoreline erosion and other coastal processes in order to determine priorities and develop management strategies. This management guide evaluates these components based on several underlying assumptions about shoreline erosion and other natural processes (Fundamental Points).

Fundamental Points

- Shoreline erosion is a natural process that has shaped the Chesapeake Bay since its formation from drowned river valleys. Shoreline erosion is a naturally occurring process and it is within the context of a particular landscape and value-system that shoreline erosion must be managed.
- The right of property owners to protect land from the effects of shoreline erosion is recognized, is incorporated in this management guide, and must be incorporated into shoreline protection projects.
- Shoreline erosion, while a significant concern for many reaches of Bay shoreline, is only one of several issues that must be considered when evaluating a particular region or reach for coastal risk. Other areas of concern include inundation from storms and sea-level rise.
- Natural beaches depend on eroding shorelines as sand sources in the Chesapeake Bay.
- For the majority of the Bay, tidal wetlands have probably been undergoing a natural trend of net loss since the 1850s. Despite today's environmental laws and regulations that protect tidal wetlands from direct human destruction, human actions indirectly cause tidal wetlands losses by limiting landward migration, accelerating erosion, and accelerating drowning-in-place.
- The Bay grows in area by hundreds to thousands of acres per year. Upland mainland undergoes a net loss in area as the Bay shoreline erodes because no natural processes are creating new upland mainland.

Data Inventory

The Virginia Institute of Marine Science (VIMS), at the College of William and Mary, was contracted by USACE and MDDNR to gather and analyze spatial data important to understanding shoreline erosion and its impact on the ecological functioning, socioeconomic well-being, and cultural integrity of the Bay. Data was compiled and analyzed from existing sources, and several new datasets were created through field surveys and analyses of existing data. These new datasets included the base data listed in Table 4.1. The report from this exercise is included as Appendix A and the newly created datasets are available at the Erosion Vulnerability Assessment (EVA) website listed below.

Erosion Vulnerability Assessment

The EVA tool (http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability/) is an interactive method of viewing, querying, and analyzing data pertinent to assessing shoreline erosion risks and opportunities. Data that was created for this management guide is also available for download and use in geographic information systems (GIS) such as ESRI's ArcGIS. Many topics can be explored using EVA, such as whether a particular shoreline reach may be vulnerable to shoreline erosion during a 50-year period, and what types of land use may be affected by shoreline erosion. The use of this tool is recommended to anyone interested in shoreline erosion, particularly those people who do not have access to a stand-alone GIS.

Generally, spatial data used in analyzing coastal risk can be divided into 2 categories: physical process data and resource-based data. Physical process data includes the location of shorelines, erosion rates, and vulnerability to inundation from sea-level rise. The resource based data includes wetlands, beaches, shoreline structures, socioeconomic features such as hospitals, and cultural resources such as historic districts. The interplay between processes and resources can be used by planners, manager, regulators, and decision makers to determine an area's vulnerability to coastal erosion.

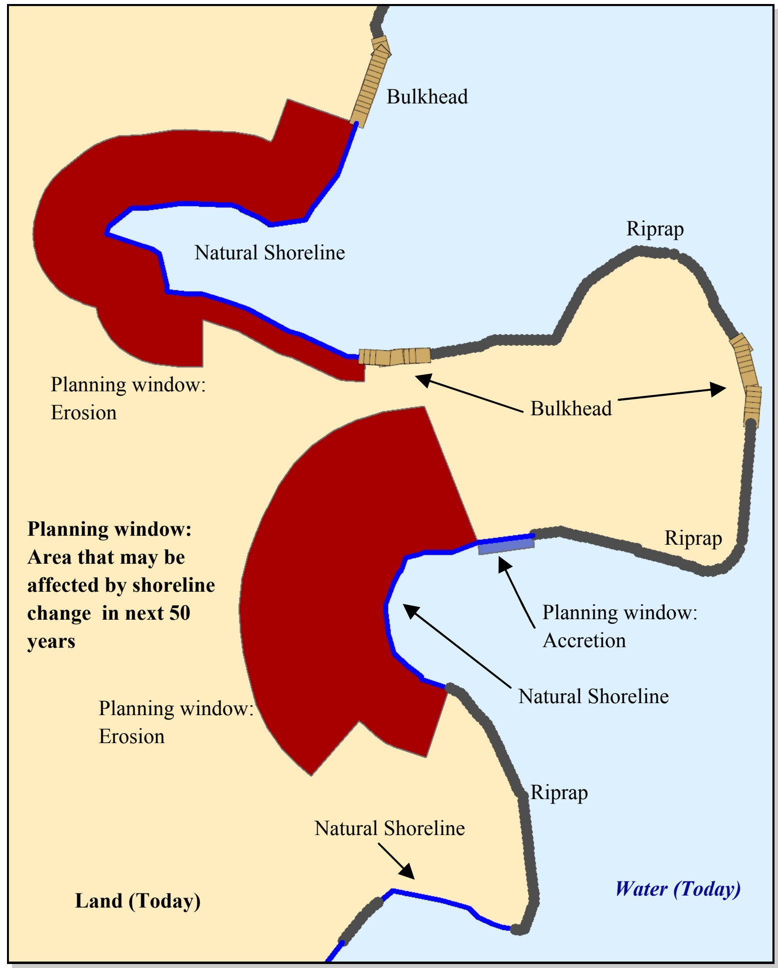


Figure 4.1 The planning window represents areas with natural shorelines that have the potential to be affected by shoreline change during a 50-year period. This diagram shows two planning window areas that may experience erosion (at different rates) and one small area that may accrete. There are several natural shoreline areas, several of which have changing shorelines and consequently flank the planning window. One natural shoreline area is not associated with a changing shoreline. Much of the shoreline in this diagram is protected by bulkheads and riprap. In these areas no shoreline change is projected even if the shorelines changed prior to stabilization.

Planning Window

Shoreline change is typically depicted as the difference in position of a stretch of shoreline over time measured from a common baseline. Past shoreline change projected into the future was used to forecast approximate areas of future impact in 2045, in comparison to the shoreline in 1995. Where shoreline protection measures exist (as identified during surveys in 2002-2007), no shoreline change was projected. As a result, for areas with bulkheads, revetments, or other structures, the shoreline position in 2045 is projected to be the same as in 1995.

The future projected area of potential impact and the shoreline position in 1995 were then used to create a polygon feature called the "planning window" (Figure 4.1). Based on historic trends, the planning window may be affected by changing shoreline position during this 50-year period. Change may result in erosion or accretion of land. Without stabilization efforts in areas where shoreline is eroding, land areas and associated features (buildings, roads, wetlands, etc.) that fall within the planning window have the potential for loss during the 50-year period.

In the EVA tool and in the analysis used in this management guide, the planning window is the base dataset used to evaluate what features may be impacted by shoreline erosion. Other datasets used in this analysis are listed in Table 4.1.

The planning window is the spatial representation of a temporal "50-year planning window." A 50-year planning window refers to the timeframe in which to base planning decisions. Uncertainty about shoreline erosion and its consequences rises as it is projected further into the future. Therefore, 50-years is an appropriate threshold for making planning decisions. Depending upon context, the term planning window may either refer to the time period for making planning decisions as related to shoreline erosion, or a spatial representation of land and other features that may be impacted by shoreline erosion during the 50-year threshold for making planning decisions.

The planning window provides a tool for shoreline management. This tool is the first of its kind in the Chesapeake Bay to forecast shoreline erosion while accounting for current shoreline erosion control structures. It provides an easily accessible graphical presentation of areas that may be affected directly by shoreline erosion during the 50-year period.

Base Data	Ecological Data	Socioeconomic & Cultural Data	Other Coastal Risk Data Not Included In This Analysis
Planning Window	State Mapped Tidal Wetlands (1988-1995, DNR)	Transportation	Sea Level Rise Inundation
Base Shoreline	Wetlands of Special State Concern (WSSC)	Community Services/ Structures	Sea, Lake, and Overland Surges from Hurricanes (SLOSH)
Erosion Control Structures	Wetland Vulnerability Modifiers	Socioeconomic	
	Beaches		
	Ecological Resources		

Table 4.1. GIS datasets used in the analysis of shoreline erosion and coastal risk. Other supporting datasets have been used for cartographic purposes. More information about these datasets, including sources and descriptions, may be found in Annex A.

This tool does not provide information to determine vulnerability to flooding or inundation from sea-level rise. The 50-year projection of potentially impacted areas also does not consider other changes to the shoreline or surrounding landscape that may occur in that time. Future increases in the rate of sea-level rise is not factored into the planning window. Although it can be surmised that past sea-level rise has affected the erosion rates upon which the planning window is based, an increase in the rate of sea-level rise would be expected to increase this rate of erosion. The planning window also does not consider sediment source or littoral sediment transport systems and their influence on shoreline position. Given these limitations, the planning window should only be used as a planning tool, and its results should not be interpreted as an exact representation of future shoreline conditions.

County	Erosion (Acres)	Accretion (Acres)	Net Loss (Acres)
Anne Arundel	606.2	74.2	532.0
Baltimore	741.6	47.4	694.2
Baltimore City	49.4	13.2	36.2
Calvert	533.0	37.6	495.4
Caroline	152.3	4.4	147.9
Cecil	324.2	51.0	273.2
Charles	781.9	64.9	717.0
Dorchester	3,151.9	66.8	3,085.1
Harford	629.2	77.8	551.4
Kent	723.8	83.9	639.9
Prince George's	32.0	36.7	-4.7
Queen Anne's	500.4	38.9	461.5
Somerset	1,222.7	54.6	1,168.1
St. Mary's	1,613.8	135.6	1,478.2
Talbot	1,507.5	101.7	1,405.8
Wicomico	74.9	10.1	64.8
Unknown*	564.6	23.3	541.3
Grand Total	**13,209.4**	**923.0**	**12,286.4**

Table 4.2. Summary of erosion and accretion in the 50-year planning window for Maryland Chesapeake Bay counties.

*Erosion window segments for which a county was not identified; that is, county boundary and shoreline segments were not coincident.

Forecast Conditions

Erosion rates were calculated for 6,600 miles of Maryland Chesapeake Bay shoreline. This rate, which does not include large islands such as Smith and South Marsh Island, was used to produce the planning window that is the basis for evaluation.

The analysis projected 13,210 acres of land lost to erosion in Maryland over the 50-year period, with 923 acres of land projected to be gained through accretion (Table 4.2). Dorchester County is projected to experience the largest loss of land due to shoreline erosion, with a net loss of 3,085 acres of land during 50 years, more than twice the amount of land loss projected for St. Mary's County (1,478 acres), the next most affected county. Prince George's County is projected to lose only 32 acres of land to shoreline erosion, but the county is projected to experience a net gain in land through accretion (5 acres). These trends are also reflected in a statistical analysis of shoreline erosion in Maryland (Appendix C). Areas on the lower Eastern Shore that are adjacent to the main channel of the Bay experience the greatest rates of erosion.

	Human Influenced Wetland (acres)	"Natural" Wetlands (acres)	Total (acres)
WSSC Within Planning Window	<1	276	276
State Mapped Tidal Wetlands Within Planning Window	279	2,450	2,729
Subtotal	**279**	**2,726**	**3,005**
WSSC Adjacent to Planning Window	122	5,080	5,202
State Mapped Tidal Wetlands Adjacent to Planning Window	9,022	27,330	36,352
Subtotal	**9,144**	**32,410**	**41,554**
Grand Total	**9,423**	**35,136**	**44,559**

Table 4.3. Wetland type and location relative to planning and the proportion of each wetland determined to have greater vulnerability to erosion due to human influences. Less than 0.1% of WSSC wetland areas, within or near to the planning window, are considered to have greater vulnerability to loss due to their proximity to certain land uses or erosion control systems. However, nearly 24% of all other wetlands may have greater vulnerability to erosion due to their proximity to engineered stabilization structures.

Ecological

Available ecological data was evaluated for its proximity to the planning window. Features lying wholly within the planning window were classified as being "within" the planning window, while contiguous features that shared a boundary with the planning window were classified as "adjacent." Features were clipped to the boundaries of the planning window; as a result, a geographically continuous feature such as a wetland may have a portion classified as being within the planning window and a portion classified as being adjacent to the planning window.

Wetlands within Planning Window

In Maryland, more than 44,500 acres of identified wetlands were either within the planning window or were immediately adjacent to the planning window — potentially a direct loss of nearly 3,000 acres of wetlands over 50 years, with another 41,500 acres of wetlands potentially affected by an altered shoreline. More than 275 acres of wetlands identified as being superlative (Wetlands of Special State Concern, WSSC) are found within the planning window.

These results do not consider the natural landward migration of wetlands in response to rising sea-level or losses of wetlands to drowning in place. Flat topography landward of existing tidal marsh is conducive to landward migration as the sea rises. When this natural progression is impeded through land use or erosion control systems, loss of the wetland area and associated functions may occur.

Wetlands were further evaluated to determine if they had greater vulnerability to net land loss through erosion due to their proximity to certain land uses or erosion control systems. As was discussed above, if a bulkhead is constructed landward of a wetland, there is a greater risk of wetland loss due to greater wave reflection, toe scour at the base of the bulkhead, and decreased opportunity for wetland migration and replenishment. Along the Maryland shoreline, less than 0.1 acre of WSSC wetlands were identified within the planning window adjacent to land use or erosion control structures that have the potential to increase erosion vulnerability (Table 4.3).

Vulnerable Beaches

Along the Maryland Bay shoreline, the EVA tool projects that more than 176 miles of beaches are vulnerable to human-exacerbated erosion, representing about 42% of the total beach length Eleven miles of vulnerable beach occur in areas with the highest erosion rates, 6 to 11 ft/year (Table 4.4). Like wetlands, beaches also will migrate landward as their bayward extent is lost and natural migration landward may be impeded through land use and erosion control systems (Figure 2.3). Unlike wetlands, natural beaches are fundamentally dependent upon eroding shorelines as sand sources.

Average Erosion Rate	Length (miles)	Percent of Total Length
None	244	58%
Slight – 1ft/year	138	33%
Low – 3 ft/year	27	6.5%
Moderate or High – 6 or 11 ft/year	11	2.5%
Total	**420**	—

Table 4.4. Length of Chesapeake Bay beaches vulnerable to erosion and the percentage of the total length of beach vulnerable to erosion.

Rare, Threatened, and Endangered Species

The presence of habitat for federally-listed threatened and endangered species was considered when determining areas where important resources may be vulnerable to shoreline erosion. About 743 acres of habitat for listed animal and plant species were identified within the planning window in Maryland; these areas occur in only seven coastal counties (Table 4.5).

County	Animal Habitat (Acres)	Plant Habitat (Acres)	Total (Acres)
Calvert	375	1	376
Cecil	30	—	30
Charles	12	58	70
Kent	40	—	40
Prince George's	—	3	3
Somerset	222	—	222
St. Mary's	2	—	2
Total	**681**	**62**	**743**

Table 4.5. Acreage of rare, threatened, and endangered species habitat within the 50-year planning window. Only those counties that had RTE habitat in the planning window are listed in this table.

Socioeconomic

Throughout Maryland, nearly all the Bay shoreline can be classified into one of three broad socioeconomic land use categories: agriculture, infrastructure, and open space/natural areas. The areas within these categories are defined by their land use and zoning code. By summarizing the amount of land within the planning window in each category, we see an overview of the relative distribution of erosion effects across Maryland (Figure 4.2, Table 4.6). The amount of open space/natural area vulnerable to erosion is greatest in Dorchester County, agricultural vulnerability is greatest in Talbot County, and infrastructure vulnerability is greatest in St. Mary's County.

The data used to analyze the impact of erosion on socioeconomic land use areas is independent of the ecological and cultural data used in the overall analysis. The same area had the potential to be tallied multiple times under the ecological, socioeconomic, or cultural categories. However,

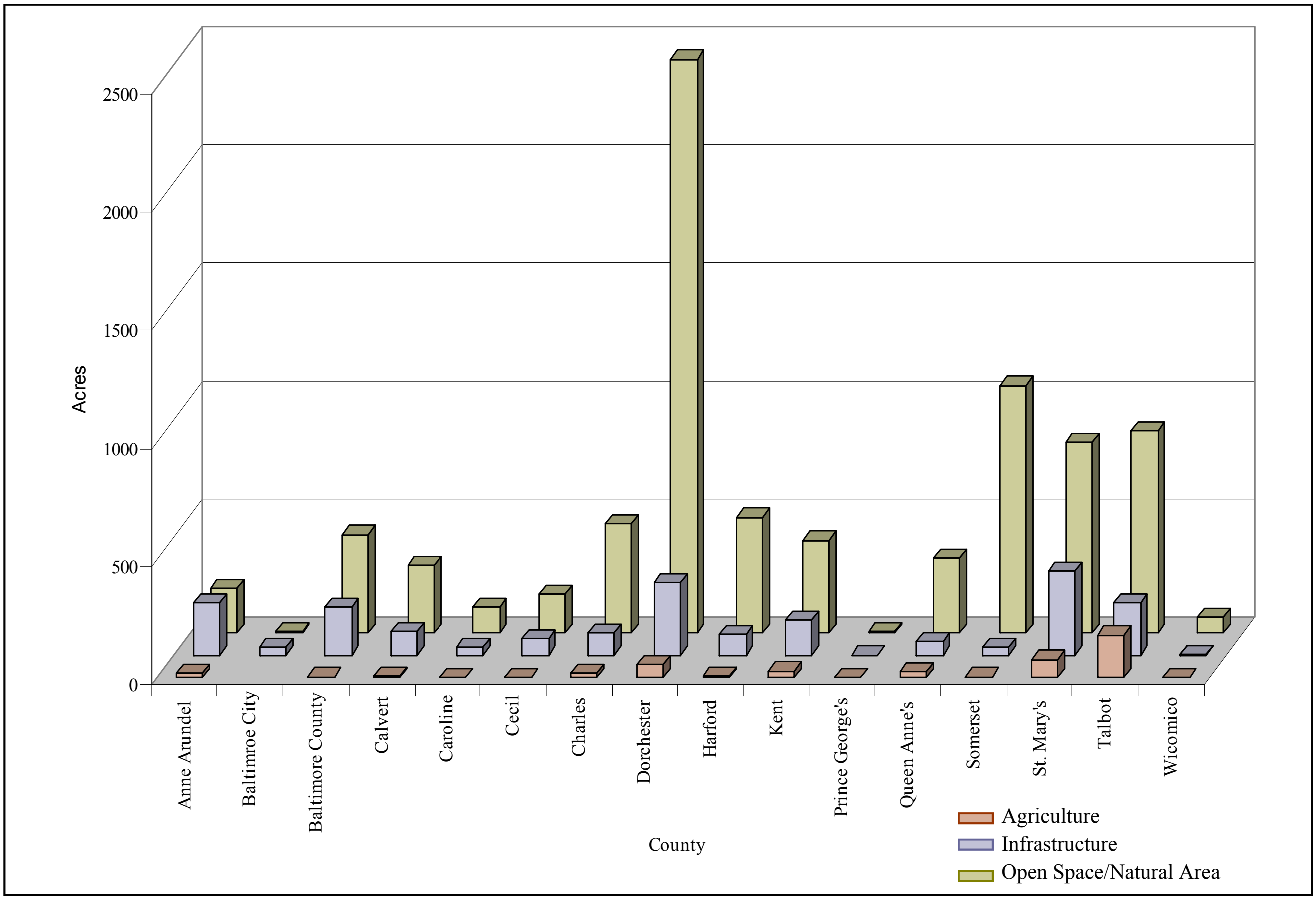


Figure 4.2. Land within the planning window categorized by socioeconomic category. Land use listed as water is not included in this graph.

Agriculture (438 Acres)		**Infrastructure (1,993 Acres)**		**Open Space/Natural Areas (8,065 Acres)**	
Type	**Acres**	**Type**	**Acres**	**Type**	**Acres**
Ag Facilities	< 1	Commercial	96	Beaches	13
Cropland	418	Extractive (mining)	1	Brush	121
Feeding Operations	< 1	High-Density Residential	28	Deciduous Forest	1,072
Orchards/Vineyards	1	Medium-Density Residential	215	Evergreen Forest	409
Pasture	17	Low-Density Residential	809	Mixed Forest	637
Row and Garden Crops	< 1	Industrial	74	Extractive (mining)	5
		Institutional	146	Wetlands	4,218
		Open Urban Land	58	Other	1,590
		Other	566		

Table 4.6. Land within the planning window was categorized within three broad socioeconomic categories comprised of various land uses listed here. Land use listed as water is not included in this table.

no areas of overlapping categories were encountered in our analysis of erosional areas. Using different selection criteria, it is possible that an area would be found under multiple categories, as shown in Figure 4.10.

Within these broad socioeconomic land use categories there are individual features that are vulnerable to erosion. These include one fire station identified within the planning window, 11 wastewater treatment plants, and about 397 distinct areas where roads are vulnerable. Vulnerable roadways include more than 14 linear miles of minor and major roads, state highways, and interstate highways.

Cultural

The initial analysis of shoreline erosion focuses on three categories of cultural resources: sites listed on the National Register of Historic Places (NRHP), sites listed on the Maryland State Inventory of Historic Properties (IHP), and properties that have an historic trust easement. The boundaries defining these areas are often ill-defined; therefore, the total acreage within the planning window is only approximate. Furthermore, the definition of these areas is broad, with at least 9 floating historic boats and 13 historic districts represented in the NRHP. Eighty-five NRHP-listed locations are within the planning window, covering about 185 acres (Table 4.7).

County	National Register of Historic Places (acres)	Maryland Inventory of Historic Properties (acres)	Maryland Historic Trust Easements (acres)	Total (acres)
Anne Arundel	23	34	10	67
Baltimore	2	14	—	16
Calvert	8	15	1	24
Caroline	—	<1	—	<1
Cecil	9	38	2	49
Charles	17	152	—	169
Dorchester	2	179	—	181
Harford	3	9	<1	12
Kent	6	16	—	22
Prince George's	20	19	—	39
Queen Anne's	20	11	2	33
Somerset	13	35	4	52
St. Mary's	53	149	24	226
Talbot	11	—	70	81
Wicomico	—	3	—	3
Total	**187**	**674**	**113**	**974**

Table 4.7. Acreage of cultural resources within the planning window along the Chesapeake Bay in Maryland.

Shoreline Erosion Vulnerability: Potential Federal Interest for USACE Projects

The Federal government may have an interest in controlling shoreline erosion if undertaking such work would further national ecosystem restoration (NER) or national economic development (NED).

Under its NER mission, USACE restores physical habitat where this work would produce cost-effective benefits to aquatic organisms in accordance with national restoration priorities. NER projects are formulated and selected based on comparison of quantifiable aquatic ecosystem restoration benefits to costs. NER shoreline projects include work such as salt marsh restoration.

NED shoreline erosion protection projects typically occur on public shorelines where public infrastructure is threatened by erosion and coastal storm damage. USACE undertakes shoreline erosion control projects under its NED mission when the project would increase the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and for the rest of the nation.

The planning window was used to find features from the resource categories forecast to be vulnerable to impact from the loss of land over 50 years. For example, a wastewater treatment facility located within the planning window may be considered vulnerable to erosion, while a facility near the shore of the Bay but outside the planning window would not be considered vulnerable. Similarly, a beach within the planning window may be considered vulnerable to erosion, while a beach outside the planning window would not. This analysis constitutes the basic level of analysis for shoreline erosion vulnerability and is the starting point for further evaluations.

The steps in the analysis of shoreline vulnerability are outlined in Figures 4.3-4.10. Each pathway, ecological, socioeconomic, and cultural leads to the identification of areas of potential Federal priority interest. These areas, which are derived separately, may then be evaluated collectively for areas of intersection; where multiple vulnerabilities may exist within a particular region or reach (Figure 4.10).

The process of identifying areas vulnerable to erosion and that are of potential Federal management interest may vary depending upon the priorities that are placed upon different attributes. The process outlined in this management guide was conducted in ArcGIS (ESRI); if the EVA tool is used, the identification process will differ due to fewer abilities to query and select features. However, the thought process leading to priority area identification will be similar. Figure 4.7 to 4.9 list three separate paths for identification of areas of interest. These paths correspond with a priority ranking used in this management guide. Other choices may be made by others, and different results will be obtained.

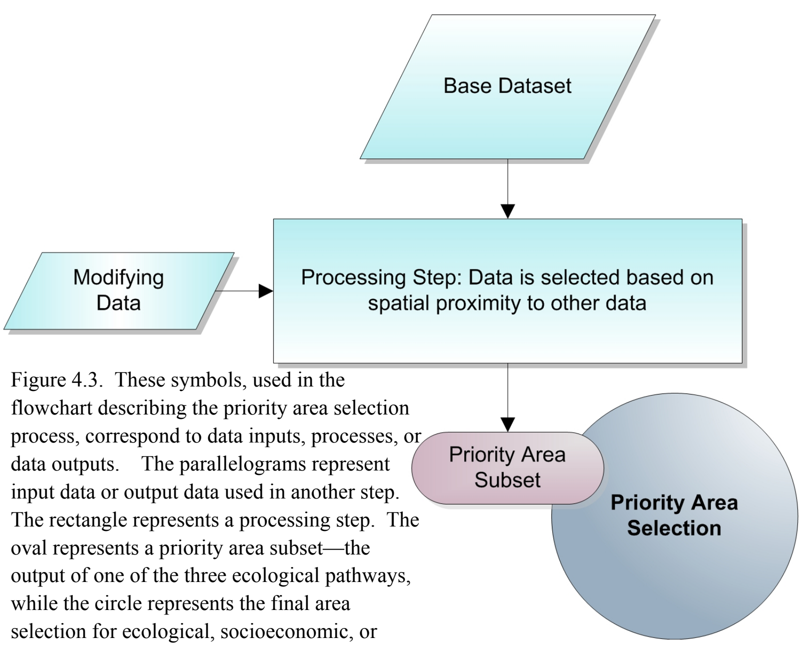


Figure 4.3. These symbols, used in the flowchart describing the priority area selection process, correspond to data inputs, processes, or data outputs. The parallelograms represent input data or output data used in another step. The rectangle represents a processing step. The oval represents a priority area subset—the output of one of the three ecological pathways, while the circle represents the final area selection for ecological, socioeconomic, or cultural resources.

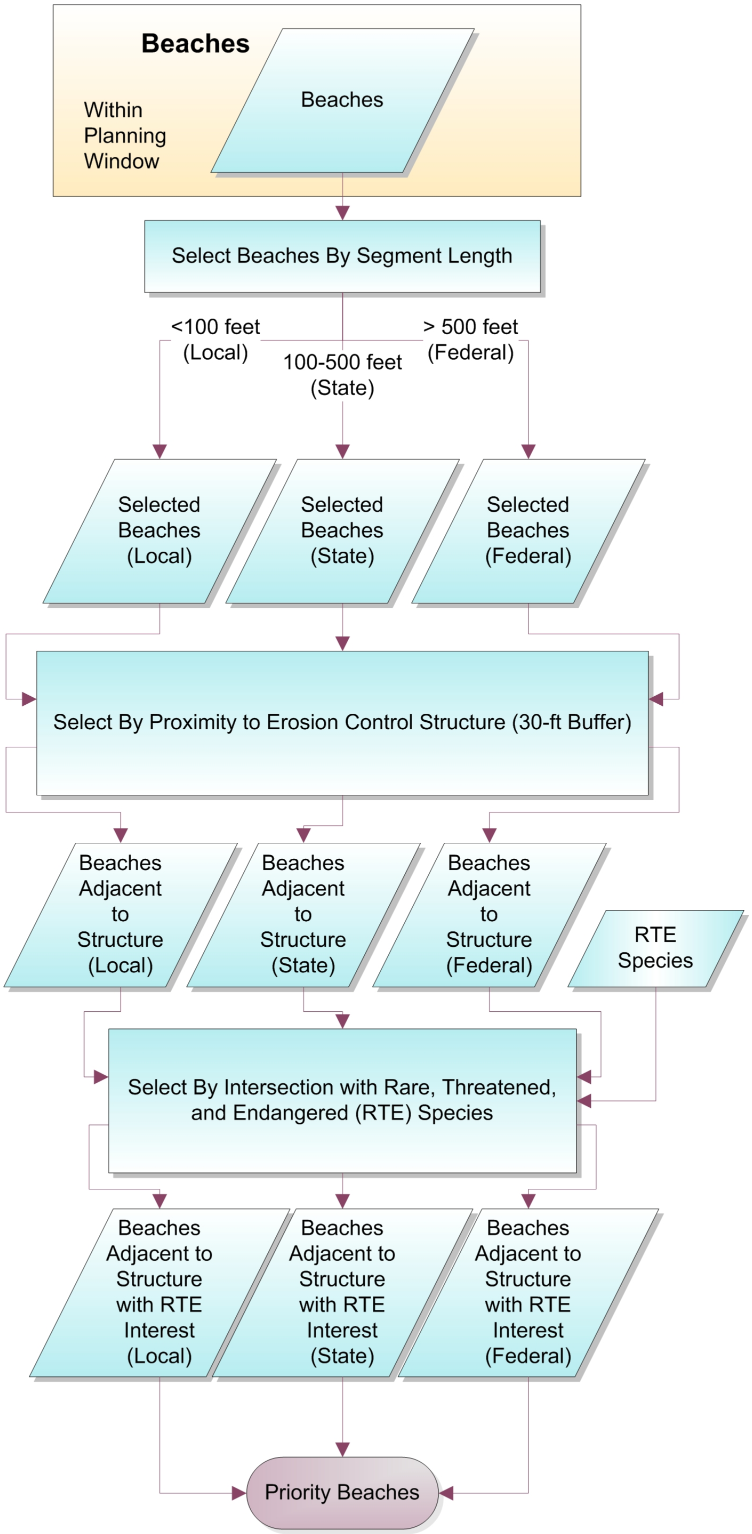


Figure 4.4. GIS screening steps to identify beaches of potential Federal interest. The beaches identified in the maps in this report (Chapter 5, Annex 1) followed the "Federal" path shown on the far right of the diagram. The "State" and "Local" paths are suggested, but other criteria may used to determine those areas in State or Local interest.

Ecological

Beaches

Beaches were first selected based on contiguous length within the planning window (Figure 4.4). Federal interest was deemed most likely for long reaches of beach. USACE and MDDNR excluded beaches less than 500 feet in length, narrowing the evaluation and ensuring that potential future projects would be of sufficient size and significance to warrant Federal participation. However, beaches of less than 500 feet in length are also vulnerable to erosion and may also provide opportunities for shoreline management projects by others.

The selected beaches were then further refined by eliminating beaches that were more than 30 feet from an identified shore protection structure. At least one area along a reach of beach had to be within 30 feet of a structure. The intent of this step was to include only those beaches that may be experiencing erosion due to human influences. We did not wish to include beaches that are undergoing natural processes absent other influencing factors because erosion is a naturally occurring process that influences natural beach habitat.

Finally, those beaches that did not contain habitat for Federally listed rare, threatened, and endangered species were eliminated from consideration. Those beaches that were left in the selection process thus were at least 500 feet in contiguous length, within 30 feet of a shore protection structure, and contained habitat for a Federally listed rare, threatened, or endangered species. Thirteen beaches of interest were identified. Other potential ecologically important beaches could include beaches with high concentration of horseshoe crab or nesting diamondback terrapin. These beaches were not evaluated in this study.

Wetlands

Both WSSC and state mapped tidal wetlands were used to identify wetlands of potential Federal interest (Figure 4.5). For each type of wetland, areas were selected that contain habitat for federally listed rare, threatened, and endangered species, contain critical habitat, are natural heritage areas, are identified as being part of Maryland's green infrastructure, or are identified as Sensitive Species Project Review Areas (SSPRA). This evaluation was intended to screen for wetlands that had superlative ecological characteristics.

Selected wetlands were further refined by evaluating negative impacts from an erosion control structure or certain adjacent land uses such

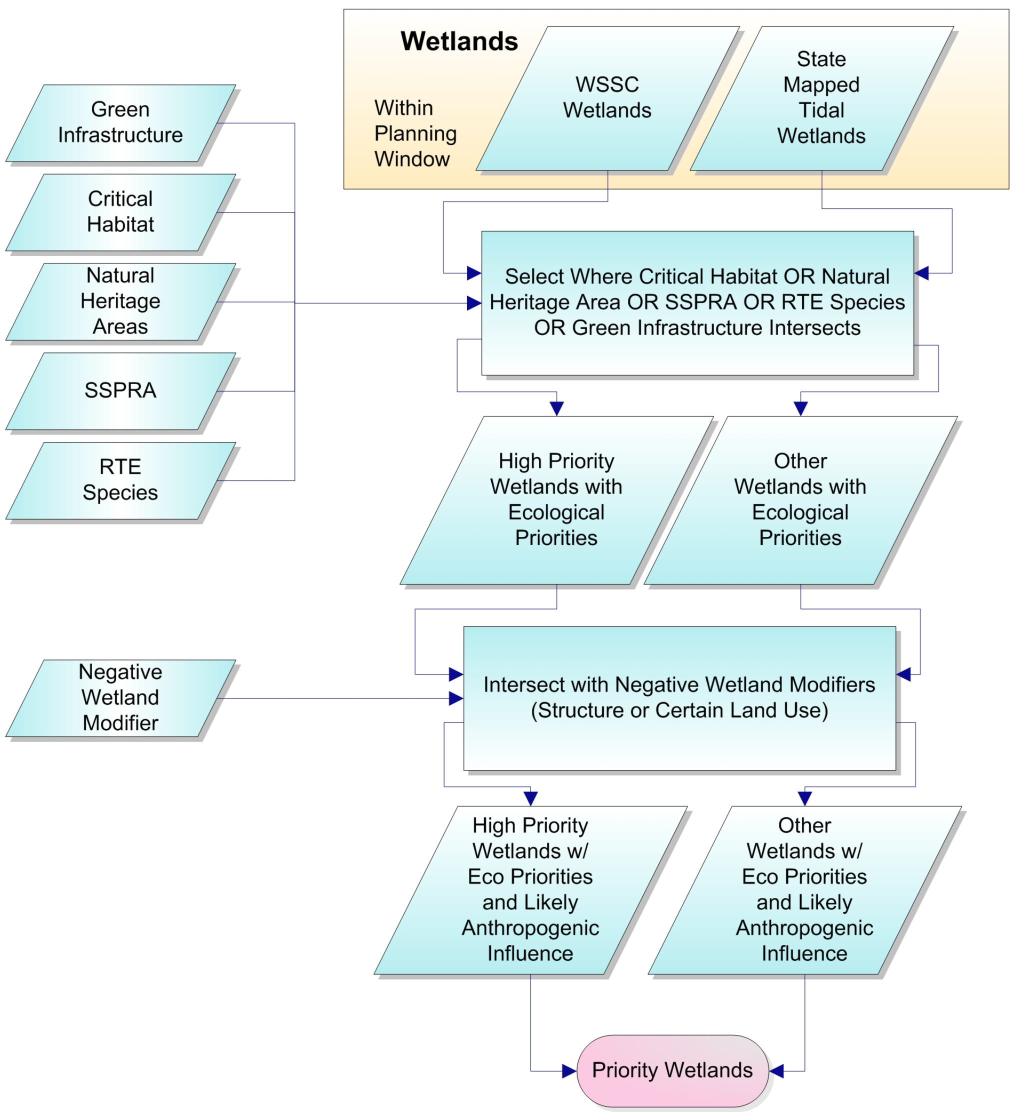


Figure 4.5. GIS screening steps used to determine priority wetlands. The polygons on the left of the figure represent separate datasets used in different steps to select wetland areas that intersect with that feature of interest. Two types of wetlands constitute priority wetlands: WSSC wetlands that meet these criteria and state mapped wetlands that meet these criteria.

as commercial, residential, industrial, institutional, and transportation. The presence of erosion control structures and selected land use comprised the Negative Wetland Modifiers layer. Thus, wetlands of potential Federal interest are identified as those wetlands within the planning window that are identified as having certain ecological resources and that may be under negative influence from human sources such as erosion control structures.

Structures built to counter bank erosion problems perhaps have the greatest potential to exacerbate wetland loss from erosion. These structures create barriers to the natural horizontal migration of wetlands landward. Structures may also generate wave reflection at the structure's base, which can deepen the adjacent shallow water platform, making it impossible for a wetland to maintain itself vertically. The result is that the wetland erodes and eventually drowns in place. The following structures placed landward of the wetland to prevent erosion of the upland bank face increase the risk of wetland loss: bulkheads, riprap, or stabilizing walls.

In contrast, structures built bayward of the wetland can protect against the erosive force of wave energy. Structures such as breakwaters, marsh toe revetments, and even groin fields may offer direct or indirect protection to the wetland and therefore reduce the threat of wetland loss. These types of structures were excluded from analysis in assessing wetland areas of interest. More information about the Negative Wetland Modifiers layer may be found in Annex 2 or in the layer's metadata.

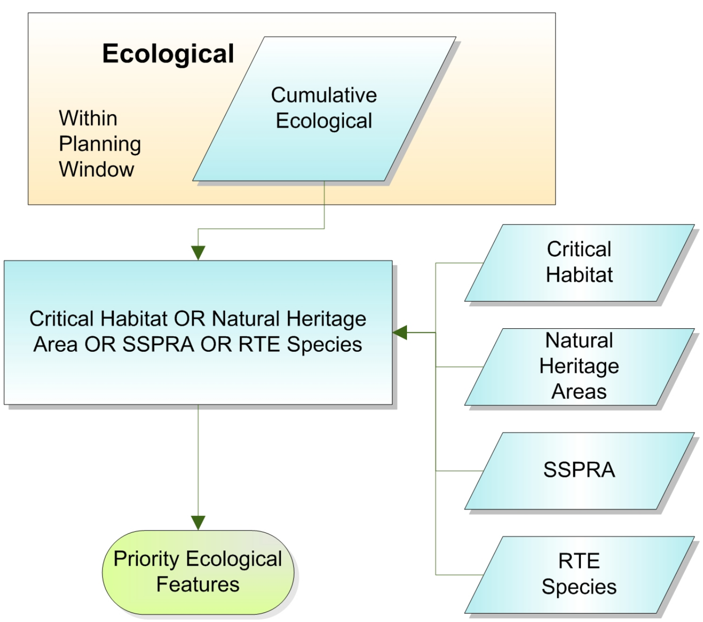


Figure 4.6. GIS screening steps used to determine ecological features potentially in the Federal interest. Ecological features were screened separately, even though used in the screening of beaches and wetlands to ensure that important ecological features that were not coincident with wetlands or beaches were captured.

Federally Listed Rare, Threatened, and Endangered Species

Habitat for Federally listed rare, threatened, and endangered species habitat was evaluated separately from their inclusion in the selection process for beaches and wetlands (Figure 4.6). The protection and preservation of rare, threatened, and endangered species is a fundamental concern for Federal, state, and local agencies, and so the identification of habitat vulnerable to erosion is very important.

Priority beaches, priority wetlands, and priority ecological features combine and represent "ecological priority areas" (Figure 4.7).

Socioeconomic

Community Services

All community services found within the planning window were evaluated, including fire stations, public schools, hospitals, police stations, and both industrial and municipal wastewater treatment facilities (Figure 4.8). The relocation or protection of these facilities is a concern for Federal, state, and local agencies, both for the services they provide to their communities and to protect the water quality of the Bay. Inundation of wastewater treatment plants exacerbated by shoreline erosion has the potential for severe water quality degradation. Similarly, inundation of hospitals or other public facilities during high water events (exacerbated by shoreline erosion) would have severe implications for community health and emergency service.

Only one public building was identified within the planning window: a fire station in Port Deposit, Cecil County. Site-specific information was reviewed to further evaluate vulnerability. The fire station lies at the furthest extent landward of the planning window, across a road from a marina with a jetty. It is unlikely that this fire station will be vulnerable to shoreline erosion within 50-years if the marina and road are maintained.

Transportation

Maryland roads were placed in three categories: interstates and highways, major roads, and minor roads, as defined during the production of the VIMS EVA tool (Figure 4.8). Categorizing roads vulnerable to erosion in this manner helps identify the appropriate agency to remedy potential problems. Areas where minor roads are vulnerable to shoreline erosion were identified and mapped. For many areas of Maryland, the identification of minor roads vulnerable to shoreline erosion is important because these roads may serve as the only access routes for communities. Shoreline erosion along interstates and major roads is likely to be addressed by the agencies responsible for the maintenance of these roads. Interstates and highways, major roads, and minor roads vulnerable to erosion were identified where they were within the planning window. These roads were considered vulnerable to shoreline erosion. While all road types were identified, only minor roads were considered for Federal interest evaluation.

Railroads, airports, and port facilities were not evaluated in this exercise due to lack of data but may be included in other analyses.

Other Socioeconomic Vulnerable Areas

County parks and private conservation properties that are within the planning window were also identified (Figure 4.8). County parks may be areas of concern for the well-being of communities, providing opportunities for outdoor education and recreation. Private conservation properties are generally owned by non-profit organizations for whom property loss in unacceptable.

Socioeconomic priority areas include those areas within the planning window with identified wastewater treatment facilities, minor roads, county parks, or conserved properties.

Cultural

Properties listed on the National Register of Historic Places have been determined to be significant to the nation, the state, or the community. Their listing recognizes the accomplishments of peoples who have contributed to the history and heritage of the United States, and these properties have been determined to be important historic or archeological properties worthy of preservation. NRHP properties within the planning window were identified and constitute the cultural priority areas for Federal participation (Figure 4.9).

Nexus

After areas of potential Federal interest have been identified by the previous steps, a subset of areas that have ecological, socioeconomic, or cultural interest were identified. In theory, an area with socioeconomic interest may also be spatially coincident or may neighbor an area with cultural interest. All three types of priority areas could exist in the same or nearly the same area. These areas would be considered "Nexus" areas and would likely represent an area with higher priority for investigation than an area with one type of priority area (Figure 4.10).

The analysis of potential Federal interest found no Nexus areas where more than one type of priority area was coincident. However, in some places, different priority areas lie along a reach of shoreline. While no Nexus areas exist based on area classification, there are a number of areas that are located along shorelines experiencing high erosion rates. A description of these areas is provided in Chapter 5.

Areas Vulnerable to Shoreline Erosion: Potential State and Local Interest

The previous pages describe the approach used to evaluate areas of shoreline erosion for potential interest to the Federal Government for further study and possible action. A similar screening process may be done by local and state agencies using the same data or other data as deemed appropriate.

Local and state agencies may make different decisions about the importance of various features. On a local level, small beaches may play an important economic and ecological role, and their protection may best be undertaken by local agencies. Furthermore, local communities may have data that would enable more detailed analyses.

Several things that should be kept in mind when using other data sources: scale of the data, temporal extent of the data, and quality of the data. In this management guide, and in the online EVA tool, we have attempted to use data at the largest scale possible, enabling the finest grained analysis. This approach allows discrete features to be evaluated — for example, a contiguous area of wetland, rather than a region classified as wetland. These distinctions become important when dealing with the highly fragmented landscape of the Chesapeake Bay watershed.

The temporal extent of the data is important because old data may not depict conditions occurring today, and relying on old data may lead to poor decision making. The planning window is based on the most recent comprehensive shoreline position data available. As new data is collected in the future, new shoreline erosion rates can be determined and future erosion extent projected. Similarly, when evaluating the potential for lateral wetland and beach migration, the most current land use data available should be used.

Finally, the spatial and tabular accuracy of the data is paramount. To enable useful analyses of shoreline erosion and its potential affects on an area, the features of interest need to be mapped accurately. For example, wetland should not be represented where a beach actually exists. Similarly, it is important to classify data correctly. There are differences among shoreline stabilization methods, for example, and different methods will impact potential shoreline erosion in different ways.

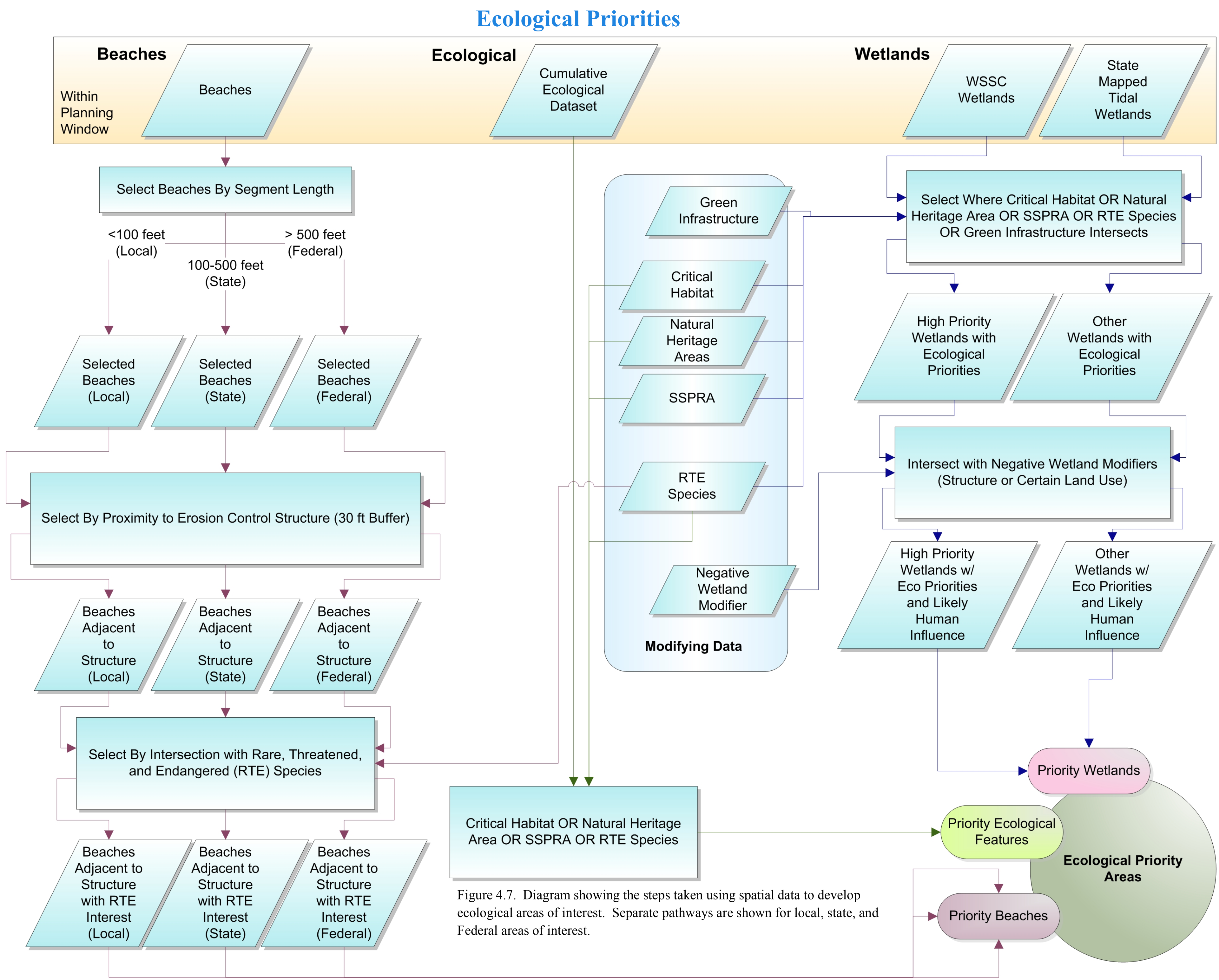


Figure 4.7. Diagram showing the steps taken using spatial data to develop ecological areas of interest. Separate pathways are shown for local, state, and Federal areas of interest.

Socioeconomic Priorities

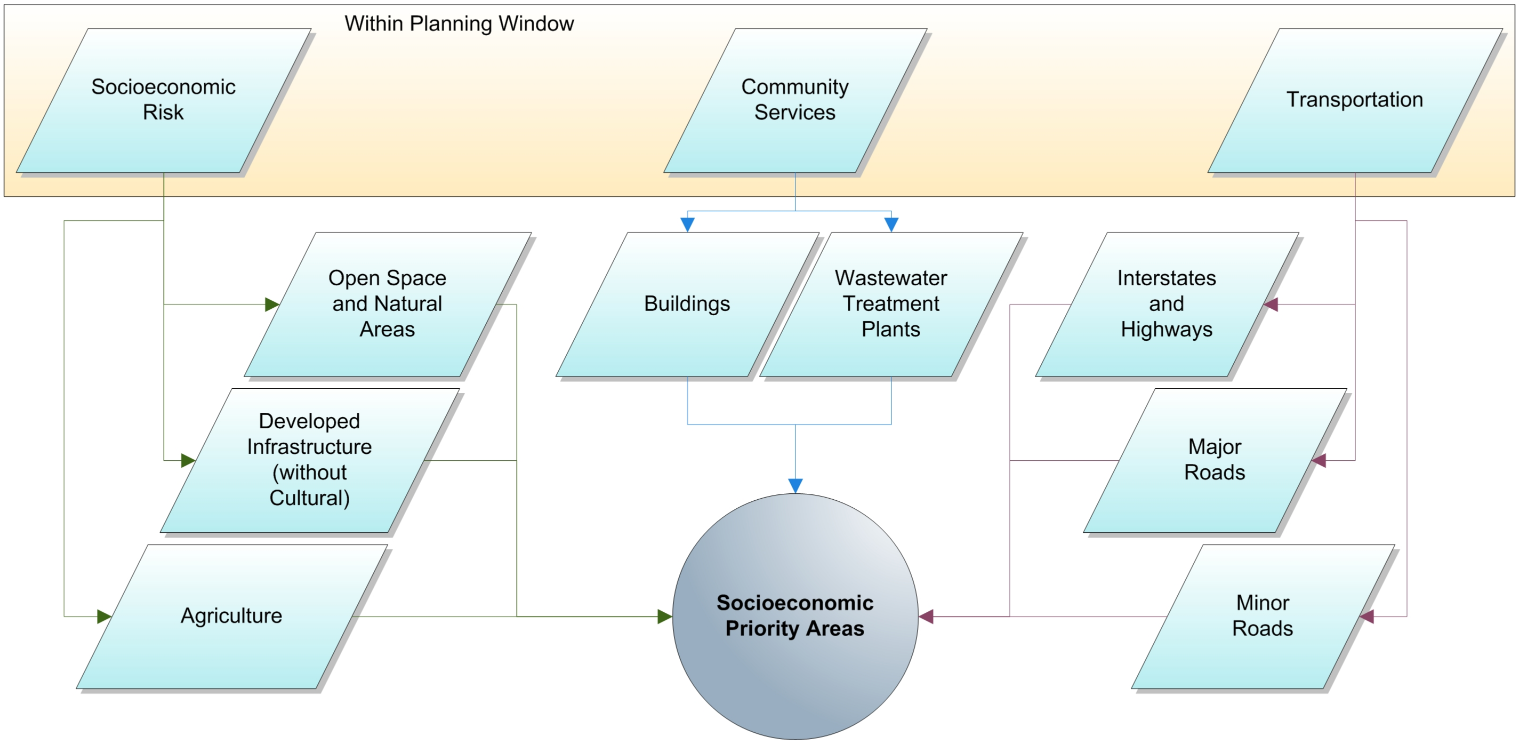


Figure 4.8. Data analysis pathways for determining areas of socioeconomic interest that may be impacted by shoreline erosion within 50 years. The maps in Section 5 include minor roads as socioeconomic priority areas but exclude major roads or interstate highways.

Cultural Priorities

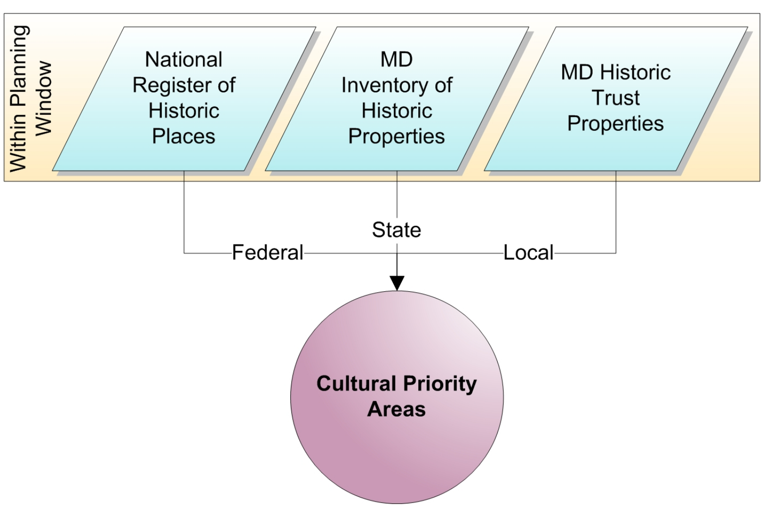


Figure 4.9. Data analysis pathways for determining areas of cultural interest that may be impacted by shoreline erosion within 50 years. The maps in Chapter 5 show only the results of the Federal pathway—properties that are listed in the National Register of Historic Places.

Nexus Projects

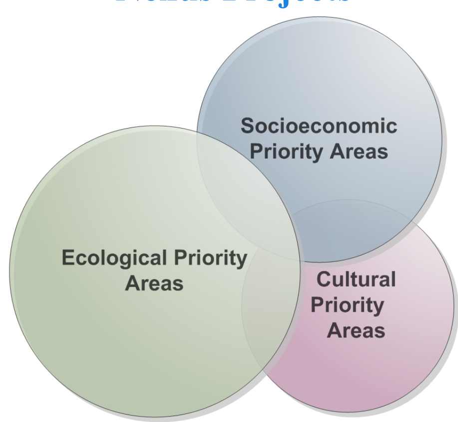


Figure 4.10. When the ecological, socioeconomic, and cultural areas of interest are examined together, Nexus areas may be found within certain geographic areas. In the context of the study, ecological areas take precedence over socioeconomic areas, which take precedence over cultural areas. If areas of interest are found together along a reach, that reach would be a priority area for erosion management solutions.

Other Factors Influencing Project Selection

The factors influencing shoreline erosion and residential land value were not used explicitly in conducting screening for areas of interest in this study. However, they are important factors to consider in justifying project implementation based on economic factors, and shoreline protection implementation on a regional or local level.

Factors Influencing Shoreline Erosion Rates

Developing regional strategies for shoreline management requires identifying the most important factors controlling shoreline erosion by region. A statistical study was conducted in conjunction with preparation of this Management Guide to establish associations between shoreline erosion rates, shoreline characteristics, and wave action on the Maryland Chesapeake Bay (Appendix C). The information generated may help guide regional shoreline management.

As expected, wave action was found to be strongly correlated with shoreline erosion rates on unprotected shorelines, with areas having greatest wave action generally having greatest erosion rates. Both mean and extreme levels of wave action can be important for the prediction of erosion rates. Of several variables analyzed that contributed to wave action, fetch was generally found to be the most important single predictor, varying by region. Existing shoreline protection structures were associated with lower erosion rates.

Geographic location was found to be an important variable in predicting the rate of shoreline erosion, so three areas were selected and investigated in more detail: Hoopers Island in Dorchester County, Patuxent River mouth in St. Mary's and Calvert Counties, and Upper Tangier Sound in Dorchester County. Erosion rates in the Hoopers Island area appear not to be affected by fetch. Erosion rates in this area were strongly associated with wave action at high water elevations. Erosion in the Patuxent River mouth area was also associated with high water elevations. In contrast, in Upper Tangier Sound rapid erosion was associated with wave action at low water levels. This difference in erosion as a function of water levels may be due to geographical differences in shoreline character. Upper Tangier Sound possesses marshes with scarped shorelines, and wave action at lower levels might promote undermining of the shoreline. Wave action at higher water levels could pass over the marsh surface. Shorelines with a gentler slope would potentially attenuate wave energy at lower water levels, while waves at higher water elevations would strike upland on vegetation and promote erosion.

Residential Land Value

One measure undertaken in project evaluation and selection is the economic benefits that may be derived from implementation. A study was undertaken in conjunction with this Management Guide to examine the benefits of shoreline stability as measured by adjacent property values along the Chesapeake Bay in Maryland (Appendix B).

In Maryland counties with Bay shoreline, residential properties average $167,000 more in value per acre than non-shorefront properties. This is similar to differences in value seen between waterfront and non-waterfront property in other areas of the United States such as Florida.

The analysis also revealed that those properties near markedly eroded shorelines have less value than those with minimal or no visible erosion. High or medium erosion results in an average 17% decrease in property value as compared to property with no erosion.

Coastal Risk: Long-Term Erosion, Storm Inundation, Sea-Level Rise

This management guide discusses vulnerability to shoreline erosion; however, a property owner or resource manager must consider several other issues when evaluating coastal risk. Along with the long-term effects of shoreline erosion, the episodic effects of storms and the long-term changes brought about by sea-level rise must be evaluated.

Property along the Bay may be affected by either tropical storms or nor'easters, both of which may cause serious inundation from waves, storm surge, and heavy rainfall. Projected inundation from tropical storms has been modeled with the SLOSH model by USACE to support storm evacuation and emergency planning. These modeled inundation levels show maximum projections for different hurricane categories. Similar inundation levels may be expected from nor'easters of similar intensity.

Sea-level rise must be considered for long-term project planning. Maryland has published inundation projections for three categories of sea-level rise (http://dnrweb.dnr.state.md.us/gis/data/). Decision-makers and planners should use these projections along with the sea-level rise scenario they wish to evaluate.

Example "Hotspot"

Southern Anne Arundel County, particularly the Shady Side Peninsula, is vulnerable to erosion, inundation from storms, and inundation from sea-level rise. It is a good example of how to examine these three coastal risks. In the examples to the left, position A is vulnerable to shoreline erosion (within the 50-year planning window) and is vulnerable to category 1 hurricane inundation, but it is not vulnerable to inundation from a 2-foot rise in sea-level. Position B is vulnerable to shoreline erosion, category 1 hurricane inundation, and inundation from a 2-foot rise in sea-level. As shown in this example, when undertaking planning and prioritization efforts, all facets of coastal risk should be considered.

Chapter 5: Priority Areas: County Maps

This section presents, county-by-county, the results of the screening process outlined in Chapter 4 that identified areas of potential Federal interest. The descriptions for each county focus on the areas of interest (environmental, socioeconomic, and cultural) that are along shorelines experiencing a high rate of erosion (6-11+ feet/year on average). Not all areas that may be affected by erosion during the 50 year study period are depicted on the following maps. The maps show only those areas identified by the screening process in Chapter 4 (areas of potential Federal interest). Other areas may be experiencing shoreline erosion.

This guide provides no recommendation on appropriate shoreline management strategies for specific counties or particular shoreline regions of the Bay. Specific recommendations were not appropriate given the differences among Bay tidal waterways in status and trends of shoreline habitats, tolerances of property owners/managers to erosion, as well as the range of potential solutions.

County Shoreline Erosion Maps

For each county description a map is presented that shows the results of the screening process outlined in Chapter 4. Areas of interest that are within the 50-year planning window are shown, and areas of historically high erosion that are coincident with the priority areas are called out in separate boxes. The areas shown met the screening criteria set forth by the USACE and MDDNR team that developed this guide and generally indicate areas where there may be a Federal interest in pursing a project that addresses shoreline erosion. However, property owners will presumably elect to stabilize shorelines in many other areas where properties and structures are sufficiently valued. The analyses were conducted at a regional scale. Therefore, individual parcels require scrutiny with site-specific information.

The maps in this chapter are intended to help guide Federal, state, and county planners in evaluating areas for further study. Each reach of shoreline has unique characteristics, and any potential solution must evaluate and consider the characteristics for each reach or region. Furthermore, the areas of interest represented on these maps are based on a projection of shoreline erosion in a 50 years period. Many factors have the potential to impact these projections, such as storm frequency and intensity, adjacent shoreline erosion protection projects, land use change, and rate of sea-level rise.

The maps that follow are designed to guide planning activities. They are not regulatory documents.

The data on which these maps are based is available at:

http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability

Datasets produced for this study are available for download, and this data may also be used in an interactive map viewer. Details and instructions are included in Appendix A.

All aerial photos on the following pages are from 2007 or 2008 unless otherwise noted.

Erosion Management in Maryland

The selection of any shoreline stabilization method requires careful planning, design, and construction considerations to withstand the erosive forces that may be encountered. The Living Shorelines Act of 2008 requires landowners to consider erosion control measures by a set priority order: (1) No Action and Relocation, (2) Non-Structural/Living Shoreline, (3) Revetment, (4) Offshore breakwaters, (5) Groins, and (6) Bulkheads. A structural practice cannot be undertaken unless MDE determines that erosion is severe enough that an erosion control measure must be installed. Once it is determined that a "no action" or relocation alternative is not sufficient, a non-structural/living shoreline method must be used unless granted a waiver by MDE. Waivers may be granted for certain areas that have been pre-designated to be unsuitable or impracticable for living shoreline stabilization. These areas are designated by MDE and are available online from MDE. The following criteria were considered when predesignating areas:

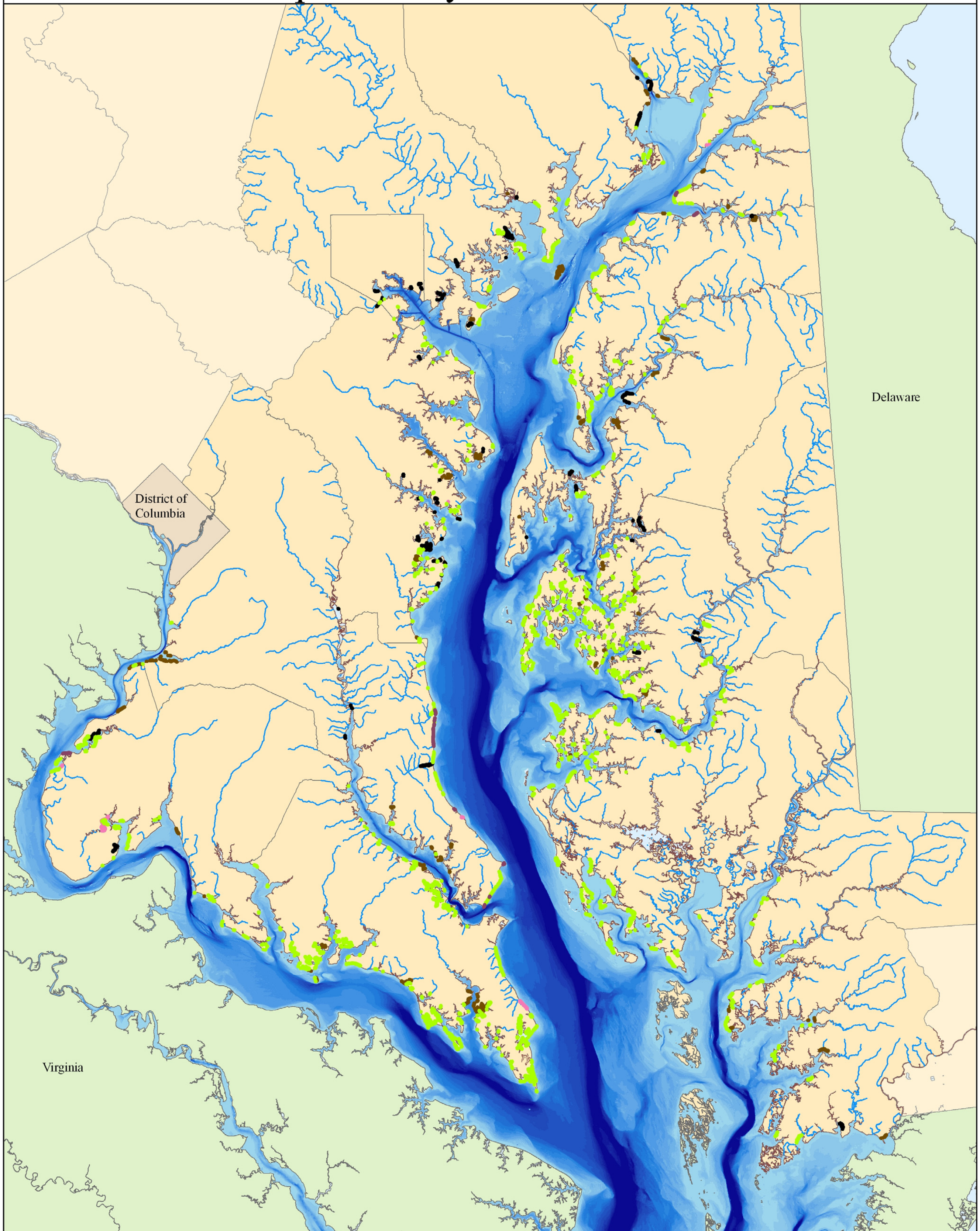
- Areas that lack an adjacent natural shoreline
- Proximity to navigation channels, where a nonstructural practice may impede passage of vessels
- High energy shoreline—severely eroding shorelines where nonstructural methods are impractical
- Inaccessible shoreline — landform characteristics such as very steep, high banks, and nearshore shallow water that prohibits both land and barge access necessary for the transportation of construction materials to the site
- Commercial vessel berthing — commercial water-dependent facilities when loading and unloading operations require a bulkheaded shoreline.

Contact MDE at www.mde.state.md.us/Programs/WaterPrograms/Wetlands_Waterways for the most current information on shoreline stabilization methods and maps depicting areas where structural stabilization practices may be permitted.

If an area is not predesignated, applicants must demonstrate to MDE that nonstructural stabilization is not feasible because other constraints to these methods cannot be overcome at a particular site, including the following:

- Channel width inadequate to support a nonstructural shoreline stabilization measure
- Adverse impacts on tidal flushing of waterway from establishment of a nonstructural shoreline stabilization measure
- Adverse impacts on navigation
- Lack of suitable bottom elevation and slope at mean low water for sustaining a nonstructural shoreline stabilization measure, as measured in the field
- Severe tides and high energy wave action
- Bank elevation and orientation that would prevent grading and successful establishment of vegetation
- Other physical constraints to successful establishment of a nonstructural shoreline stabilization measure
- Other environmental factors or benefits that would be adversely affected by the proposed nonstructural shoreline stabilization practice.

Chesapeake Bay Shoreline Erosion



Areas of Potential Federal Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- Study Shoreline

N
W E
S

10 5 0 10 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
Refer to online Erosion Vulnerability Assessment (EVA) tool for additional analysis:
http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
Maryland shoreline informaiton may be found at:
http://shorelines.dnr.states.md.us/

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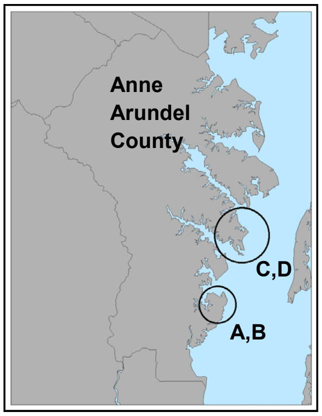


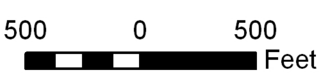
Anne Arundel County

Four areas are identified in Anne Arundel County as areas of interest. These areas were determined by the screening process outlined in Chapter 4 and they also have shorelines that can be classified as having high erosion rates (6 to 11 feet of erosion per year on average). Anne Arundel County is a western shore county, with some shoreline areas exposed to the southeast with high fetch (Shady Side peninsula). However, many shoreline areas are along tidal rivers with very little fetch. Anne Arundel County has the second highest number of Bay shoreline parcels in Maryland.

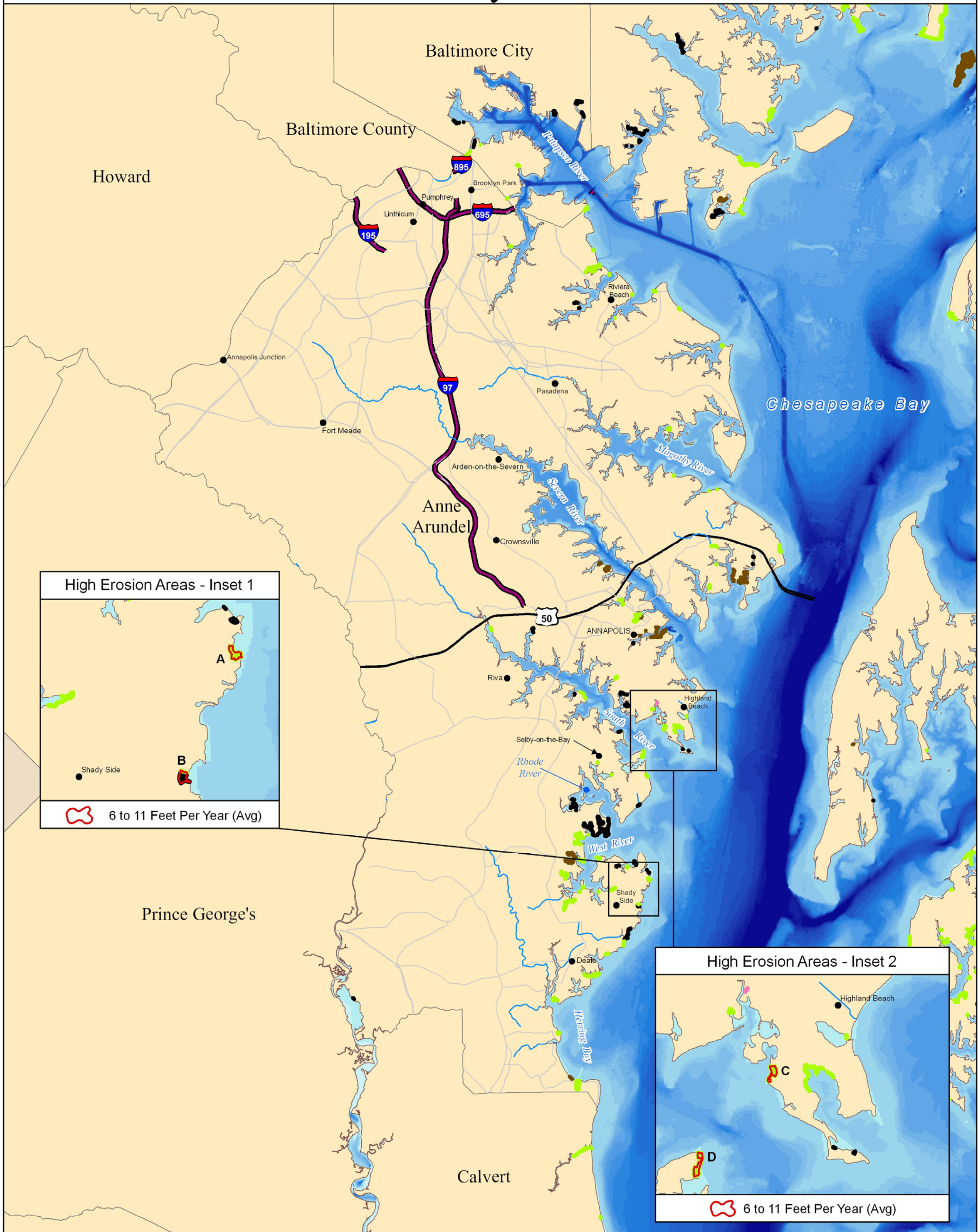
Inset 1: Area A is a wetland area on the Shady Side peninsula, near Cedarhurst. This parcel is connected to a larger wetland area and provides important ecosystem services and benefits. This wetland has limited potential to migrate.

Area B is an area of socioeconomic resources on the Shady Side peninsula at Columbia Beach.

Inset 2: Areas C and D are wetland parcels on opposites sides of the mouth of the South River.



Anne Arundel County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- River/Streams
- US Highways
- State Highways

N
W E
S

5 2.5 0 5 Miles

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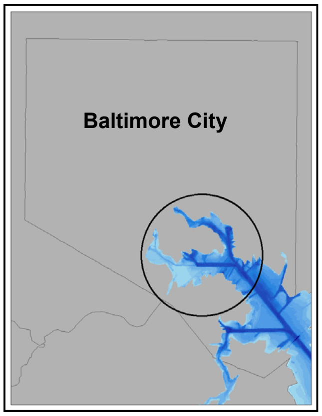
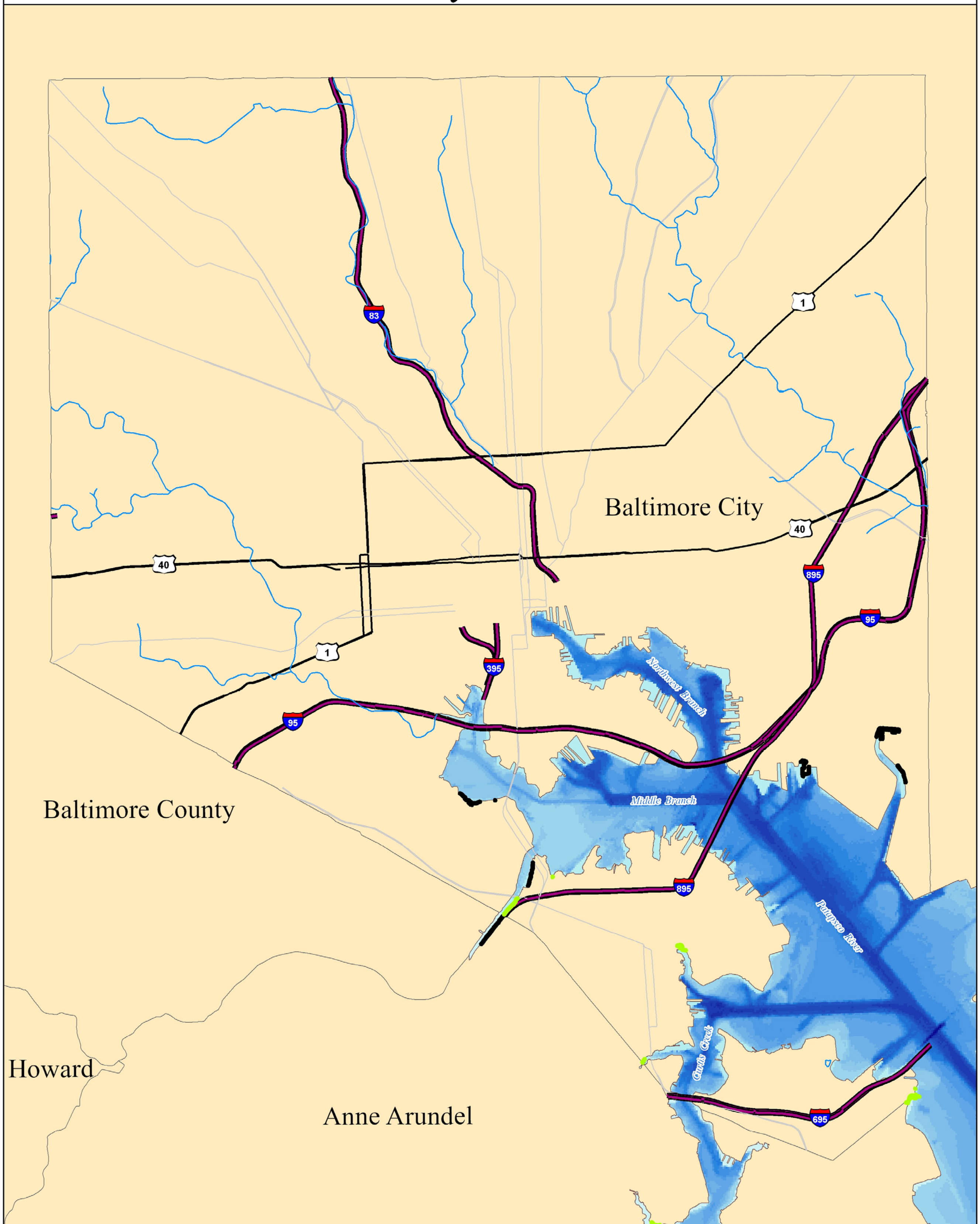


Baltimore City

No areas of interest with high erosion rates were identified in Baltimore City. Within the city, the shoreline is highly developed, with very little natural shoreline. The City has the highest number of shoreline parcels along the Chesapeake Bay in Maryland.

Areas of interest in Baltimore City are generally socioeconomic, though there are several areas of wetlands at erosional risk. Of particular note, an area of potential erosion flanks I-895, and another area of erosion was identified as potentially impacting an industrial water treatment facility.

Baltimore City Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- River/Streams
- US Highways
- State Highways

N
W E
S

1 0.5 0 1 Miles

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US Army Corps of Engineers
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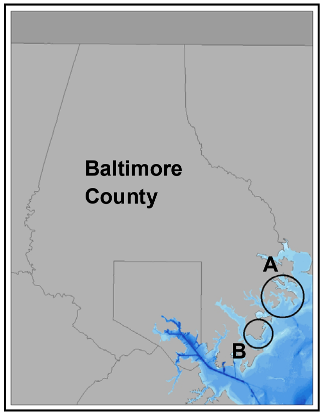
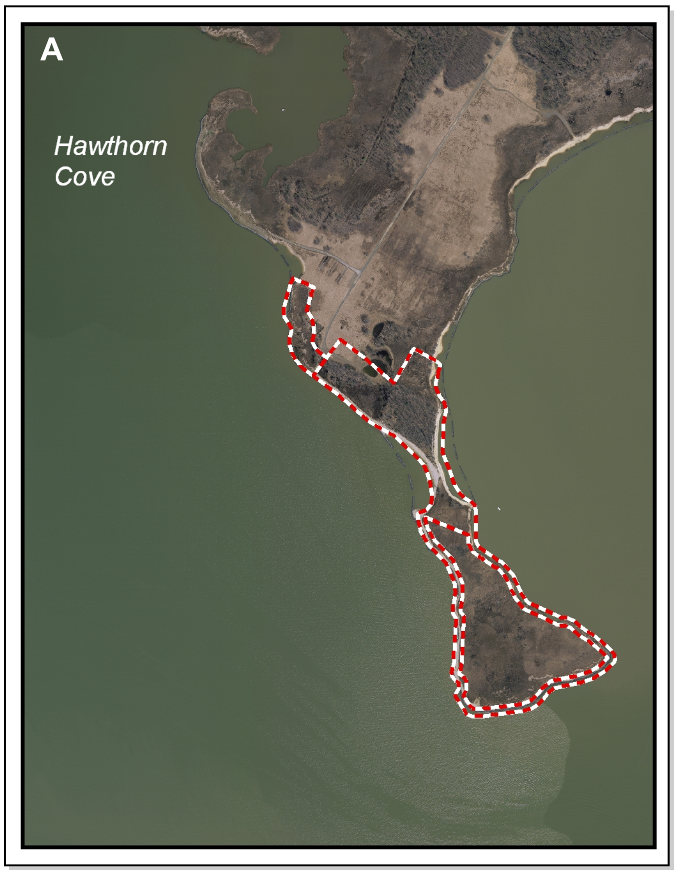


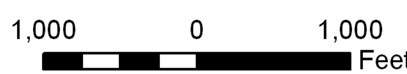
Baltimore County

Two areas of interest in Baltimore County are associated with high erosion shorelines. Baltimore County has several areas with large fetch to the southeast, while there are many areas with low fetch along tidal rivers. Baltimore County has the third highest number of shoreline parcels in Maryland.

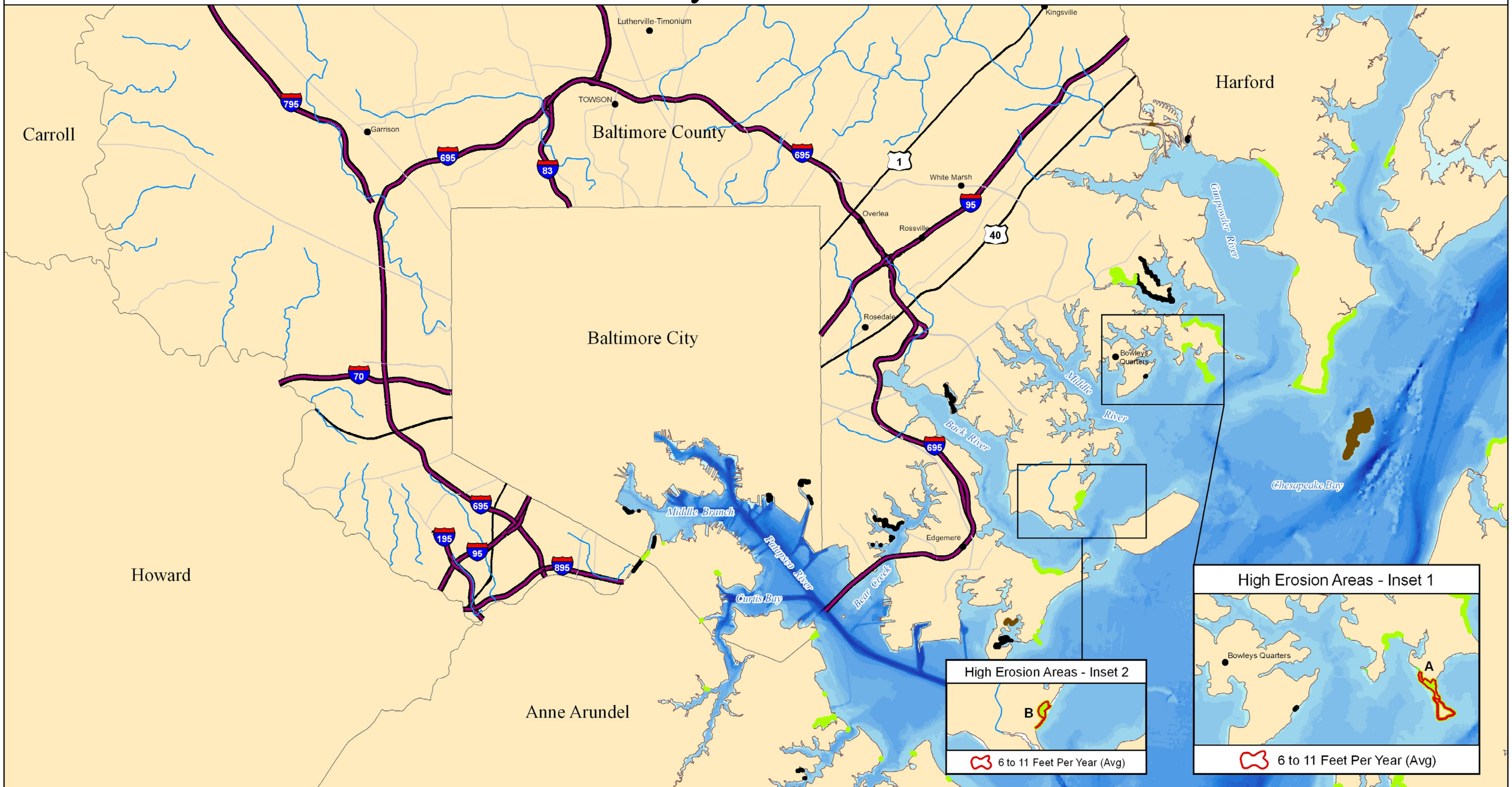


Inset 2: Area B is a wetland area north of Rocky Point. This stretch of shoreline has relatively short fetch because it is fronted by Hart-Miller Island about 1.5 miles to the east.

Inset 1: Area A is an area of wetlands on a spit jutting into the Chesapeake Bay on Carol Island. It lays at the mouth of the Gunpowder River and is exposed to waves on the Gunpowder, as well as the Bay.



Baltimore County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- Interstates
- US Highways
- State Highways

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
Refer to online Erosion Vulnerability Assessment (EVA) tool for additional analysis:
http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
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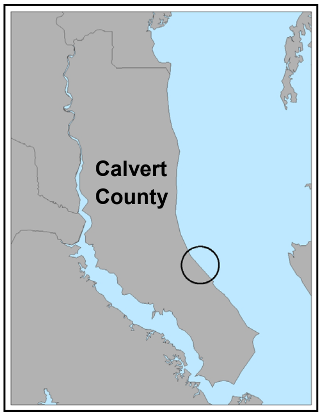
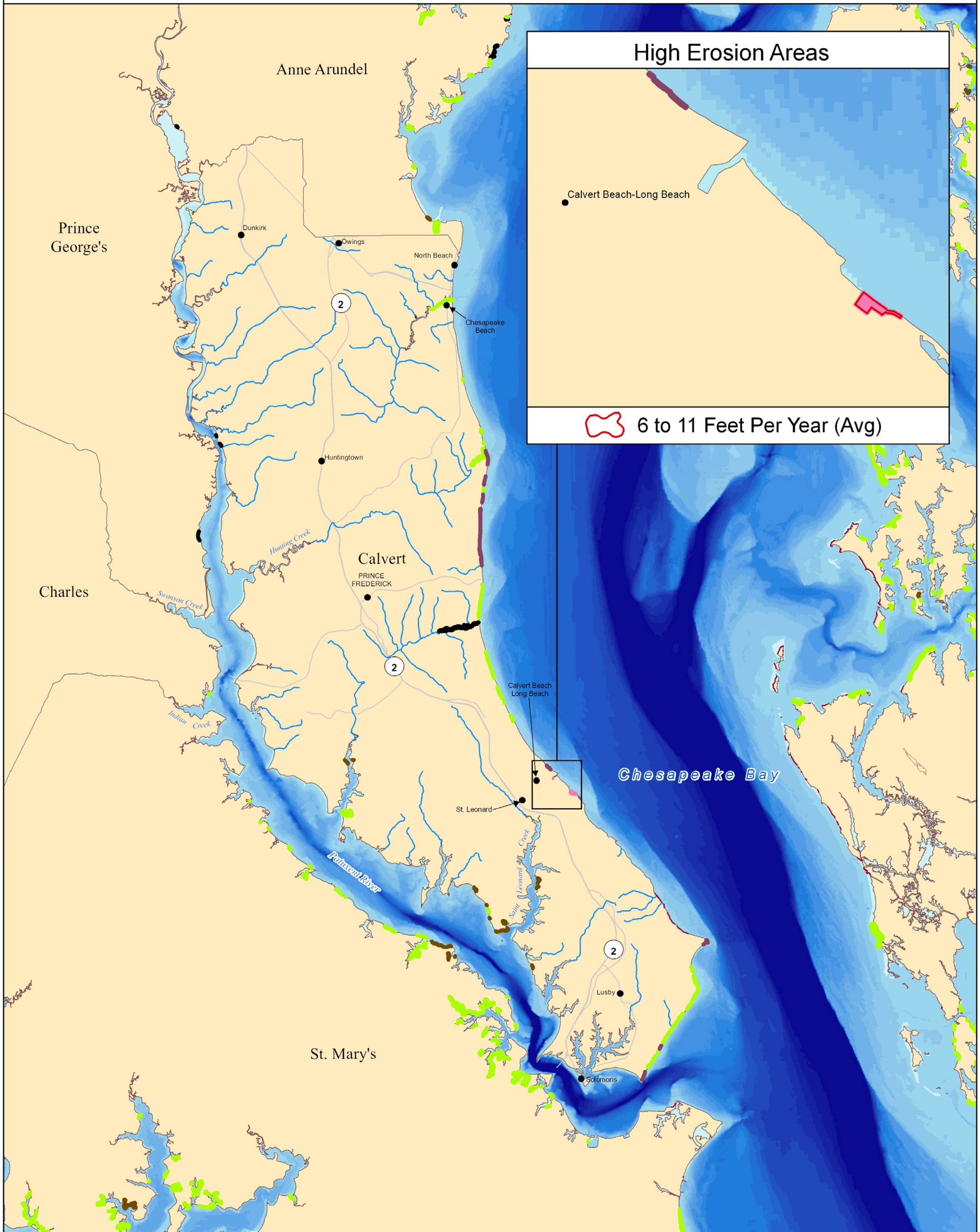


Calvert County

One area of interest in Calvert County is associated with high erosion shorelines: an area of wetlands of special state concern with Flag Ponds Nature Park, a Calvert County owned park. While not within an area of high erosion, Calvert Count has extensive beaches that are vulnerable to erosion and are habitat for a rare, threatened, or endangered species.

Flag Ponds Nature Park directly fronts the mainstem of the Bay. The park protects a variety of natural environments—from sandy beach, to freshwater ponds, to the forested Calvert Cliffs. The wetland area at risk of erosion is designated a wetland of special state concern, thus it is afforded special status and protection relative to other Maryland wetlands.

Calvert County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- State Highways

N
W E
S

4 2 0 4 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
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US Army Corps of Engineers
Baltimore District

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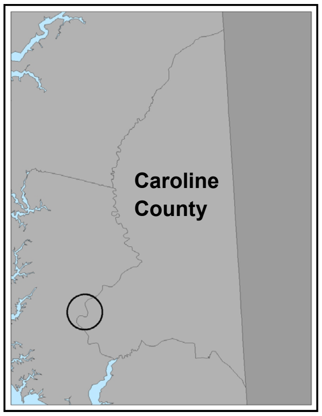
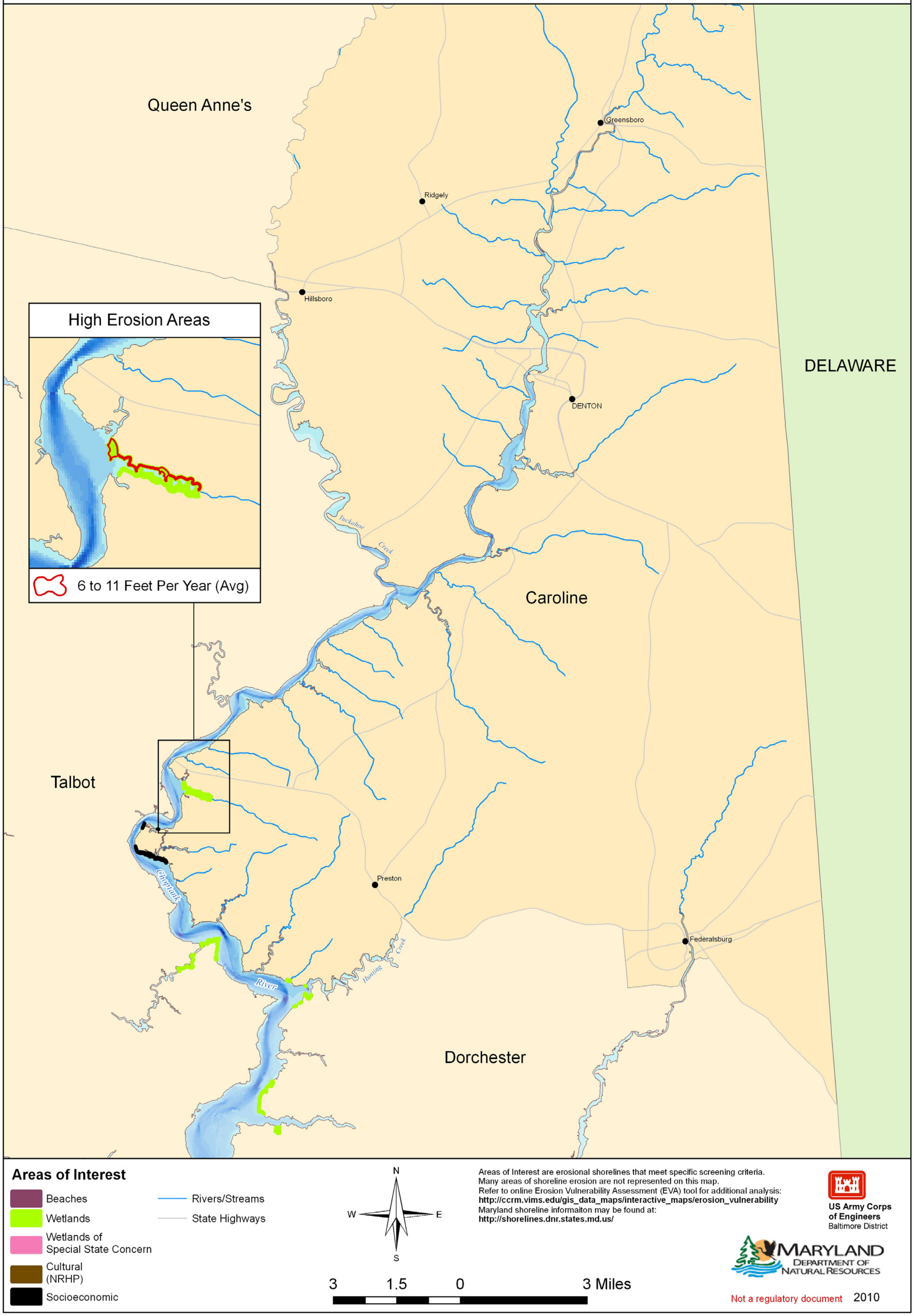


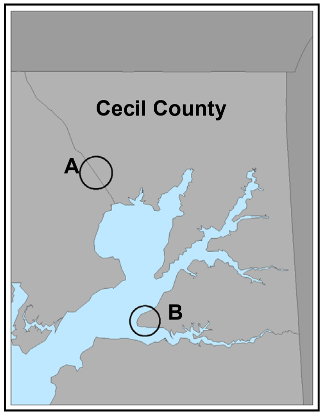
Caroline County

Caroline County has no shoreline on the Bay mainstem. Nearly all of Caroline County's shoreline is along the Choptank River, where a wetland area of interest has undergone high erosion. While tidally influenced, this area has no direct frontage to the Bay and the shoreline is characterized by a low wave energy environment. Caroline County has the least number of affected parcels and these parcels are concentrated in a relatively small area where the Choptank river is nearest the Bay.

The wetland area is located along the north bank of Little Creek at its mouth with the Choptank River. From the Choptank River to Frazier Neck Road, the creek is meandering and marshy, with forest and agricultural areas along the wetland. At Frazier Neck Road, the creek becomes more defined and quickly narrows.

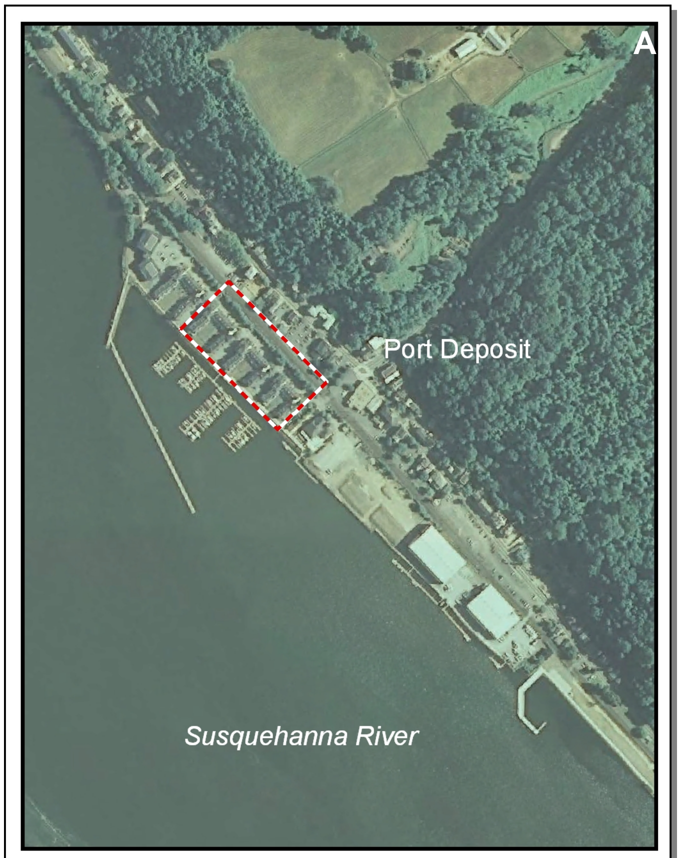
Caroline County Shoreline Erosion





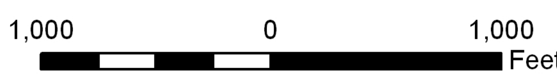
Cecil County

Cecil County has two identified areas of interest that are also areas of high erosion. Cecil County is at the head of the Bay. Many shoreline reaches have large fetch to the southwest, though there are areas that also have large fetch to the northwest.



Inset 1: Area A is a cultural area of interest in Port Deposit near the mouth of the Susquehanna River. The Port Deposit Historic District is listed on the National Register of Historic Places. The high erosion area is a small portion of the entire district. Existing shoreline protection structures may exist in this area based on evaluations of aerial photography; however, an examination of the vulnerability of loss and any historic structures in the district may be warranted.

Inset 2: Area B is a beach fronting the Bay mainstem near the dredged approach channel for the C&D canal on Grove Neck. This beach area is flanked north and south by wetland areas that are not in high erosion areas but are areas of interest.



Cecil County Shoreline Erosion

Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- Interstates
- US Highways
- State Highways

N W E S

6 3 0 6 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
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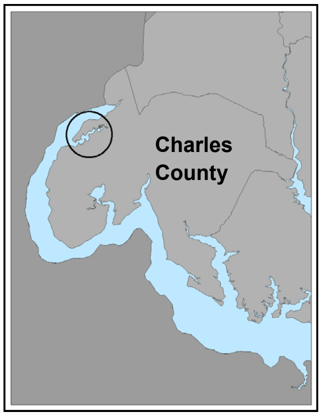

Charles County

Charles County has three identified areas of interest with high erosion. Along the confluence of Mattawoman Creek with the Potomac River near the town of Indian Head, three separate areas are located along the north bank of the creek. One area is a long wetland area while the other two are identified with socioeconomic resources, specifically, waste-water treatment facilities. Data indicates that there may be several discharge points within the zone of high erosion.

Charles County also has several other significant wetland and socioeconomic areas of interest, including wetlands of special state concern on the Nanjemoy Creek. These areas are not within areas of high erosion, but the environmental services of this area of wetlands is expected to be high.

Charles County Shoreline Erosion

Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- US Highways
- State Highways

N W E S

6 3 0 6 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
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US Army Corps of Engineers
Baltimore District

MARYLAND DEPARTMENT OF NATURAL RESOURCES

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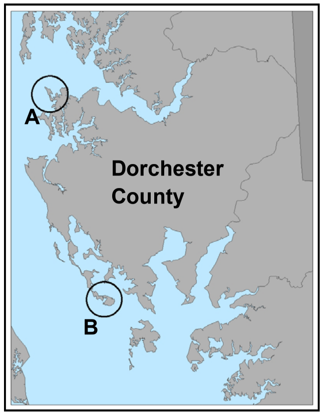
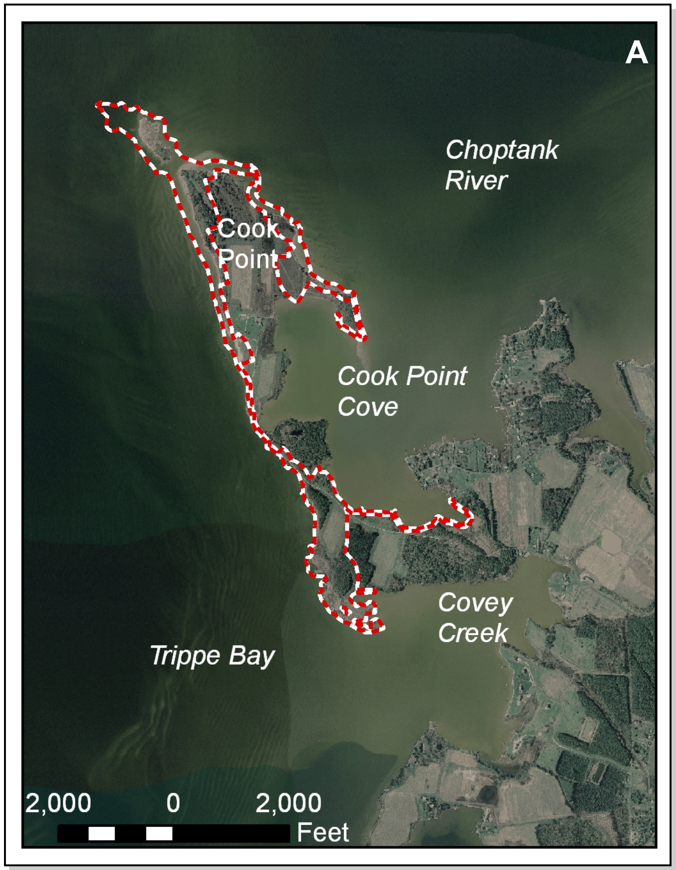
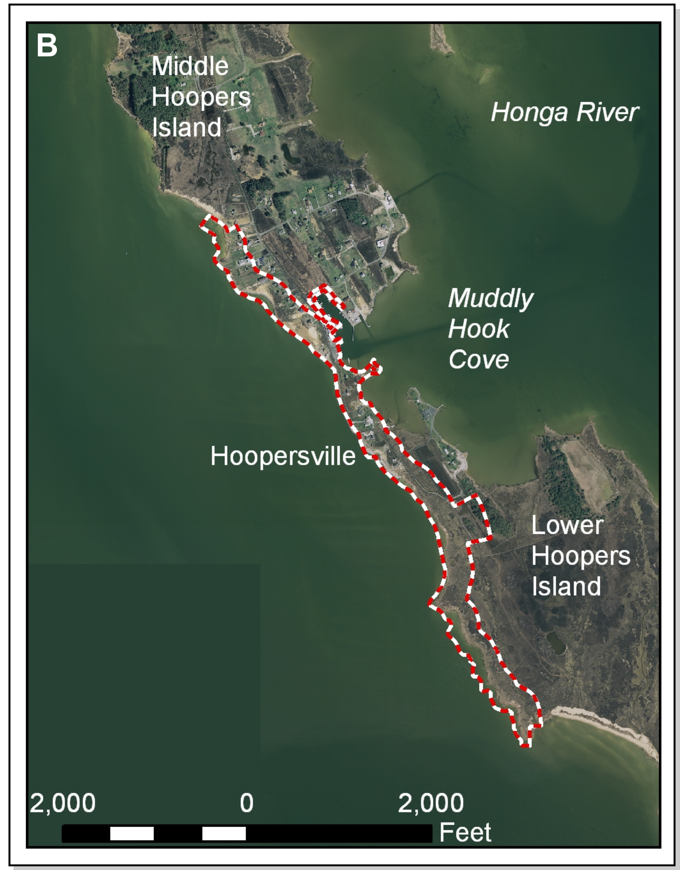


Dorchester County

Nearly all areas of interest identified in the county are wetland areas. Two of these areas are also associated with high erosion rates. At Hoopers Island, high erosion rates were associated with high water elevation, while in Upper Tangier Sound, high erosion rates were associated with low water elevation.



Inset 1: Area A is a wetland encompassing much of Cook Point where it extends into the bay at the mouth of the Choptank River.



Inset 2: The wetland at Area B lies along Middle and Lower Hoopers Islands, nearly encompassing the small town of Hoopersville. This area has seen large losses of land during the past 50 years, and several erosion control projects have been constructed here.

Dorchester County Shoreline Erosion

Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- US Highways
- State Highways

N W E S

10 5 0 10 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
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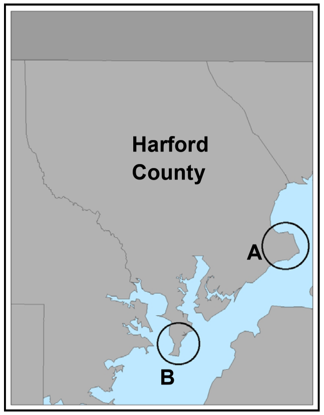
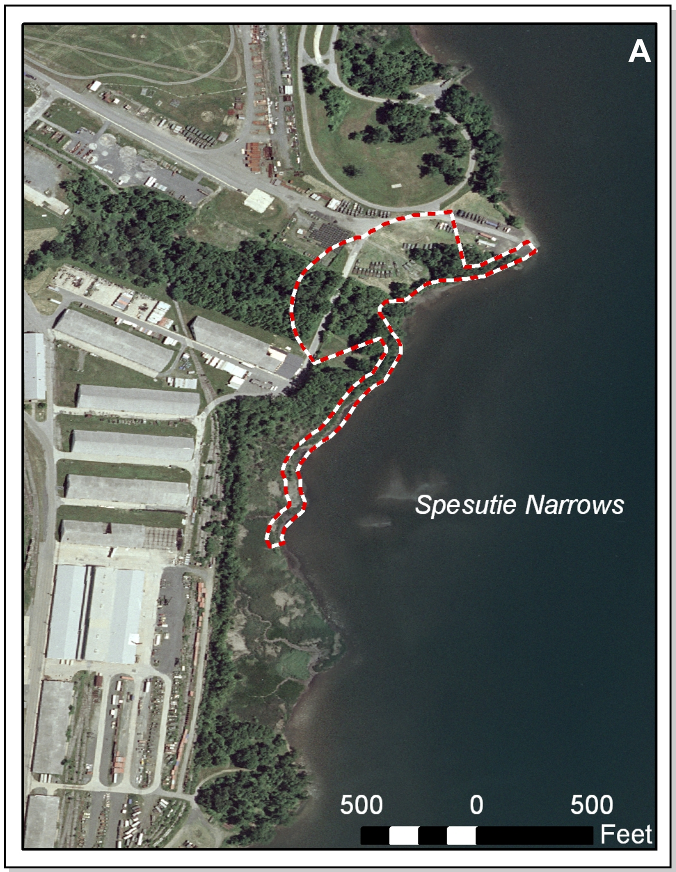


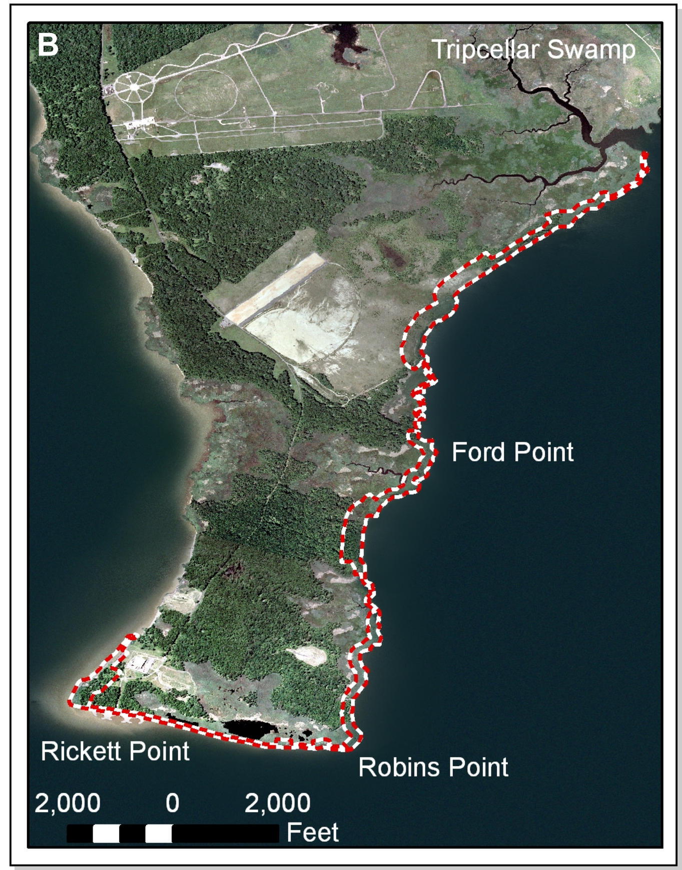
Harford County

Harford County has two wetland areas of interest that experience high erosion. In addition, a significant cultural resource, not located in a high erosion area, is nevertheless completely within the 50– year planning window.



Inset 1: Wetland Area A lies along Spesutie Narrows within Aberdeen Proving Ground, a U.S. Army facility. Fetch and wave energy are low.

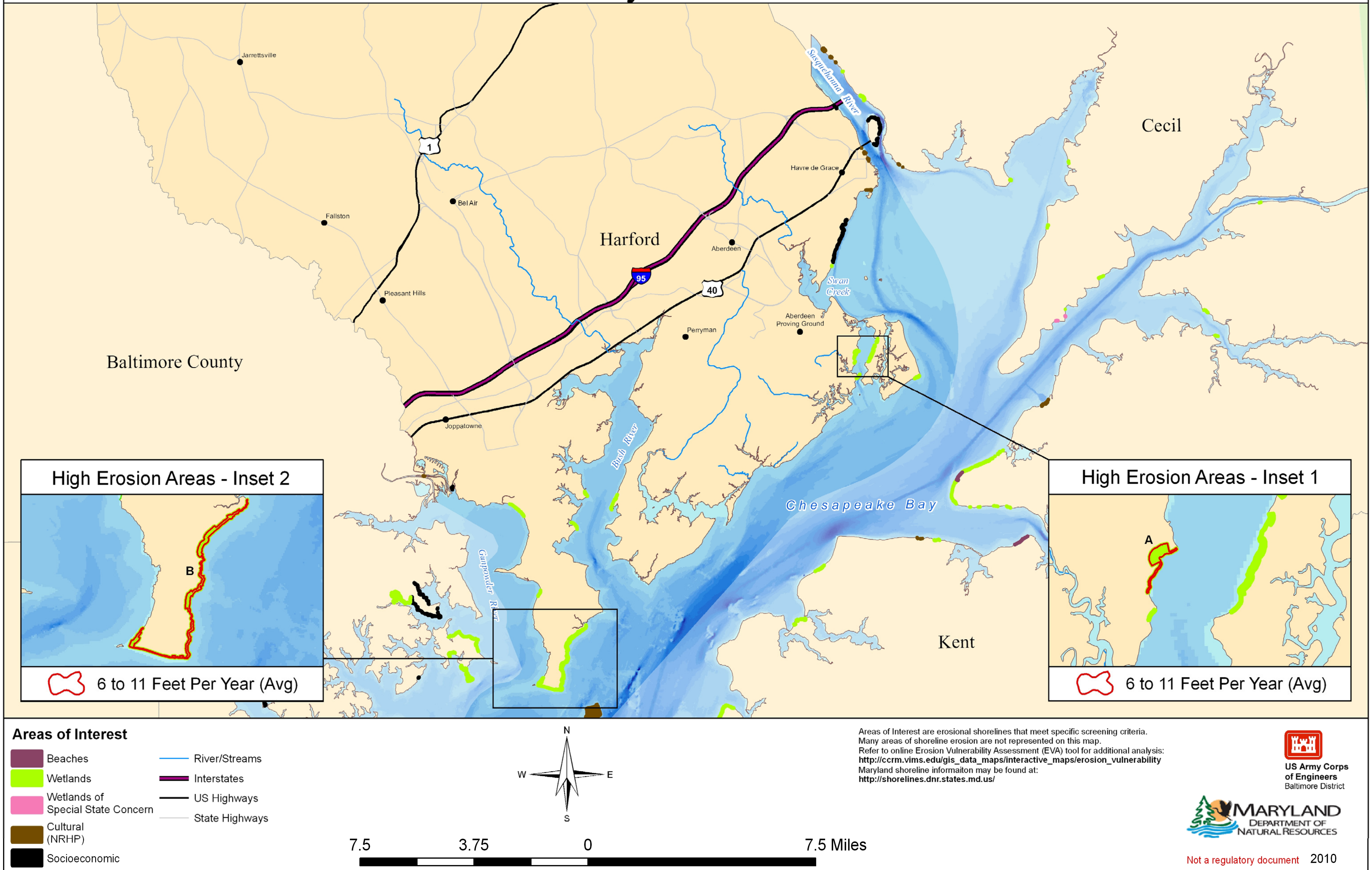
Inset 2: Area B is a wetland on Gunpowder Neck, extending roughly from Rickett Point to Tripcellar Swamp in Aberdeen Proving Ground. This area is exposed to the Bay mainstrem with high fetch and high wave energy.



Pooles Island (not shown), owned by the U.S. Army and housing the National Register listed Pooles Island Lighthouse, is completely within the 50-year planning window. Temporary erosion protection measures installed previously appear to have failed. The island is in the middle of the Bay at the mouth of the Bush and Gunpowder Rivers — a dynamic, high energy environment. The island has unique ecological value because it is undeveloped and generally unused by humans.

Aerial images acquired in 2006.

Harford County Shoreline Erosion



Areas of Interest are erosional shorelines that meet specific screening criteria.
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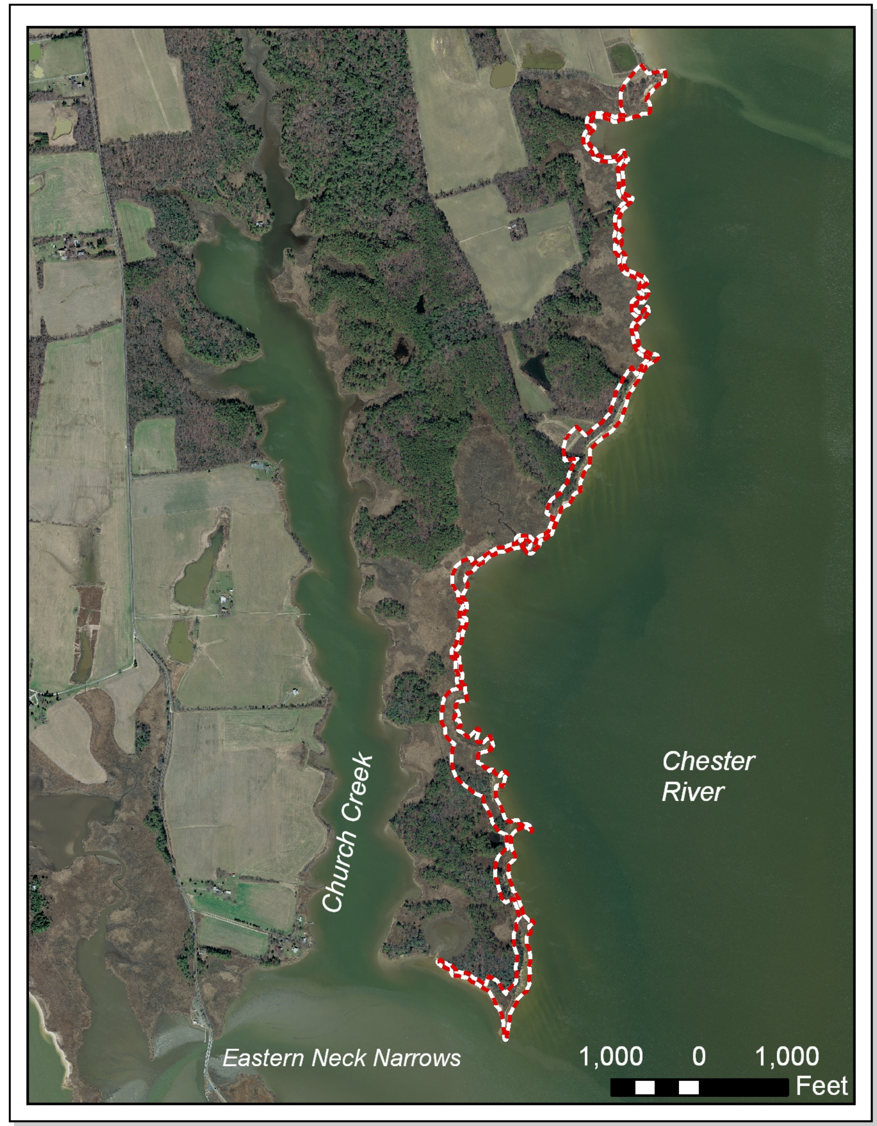
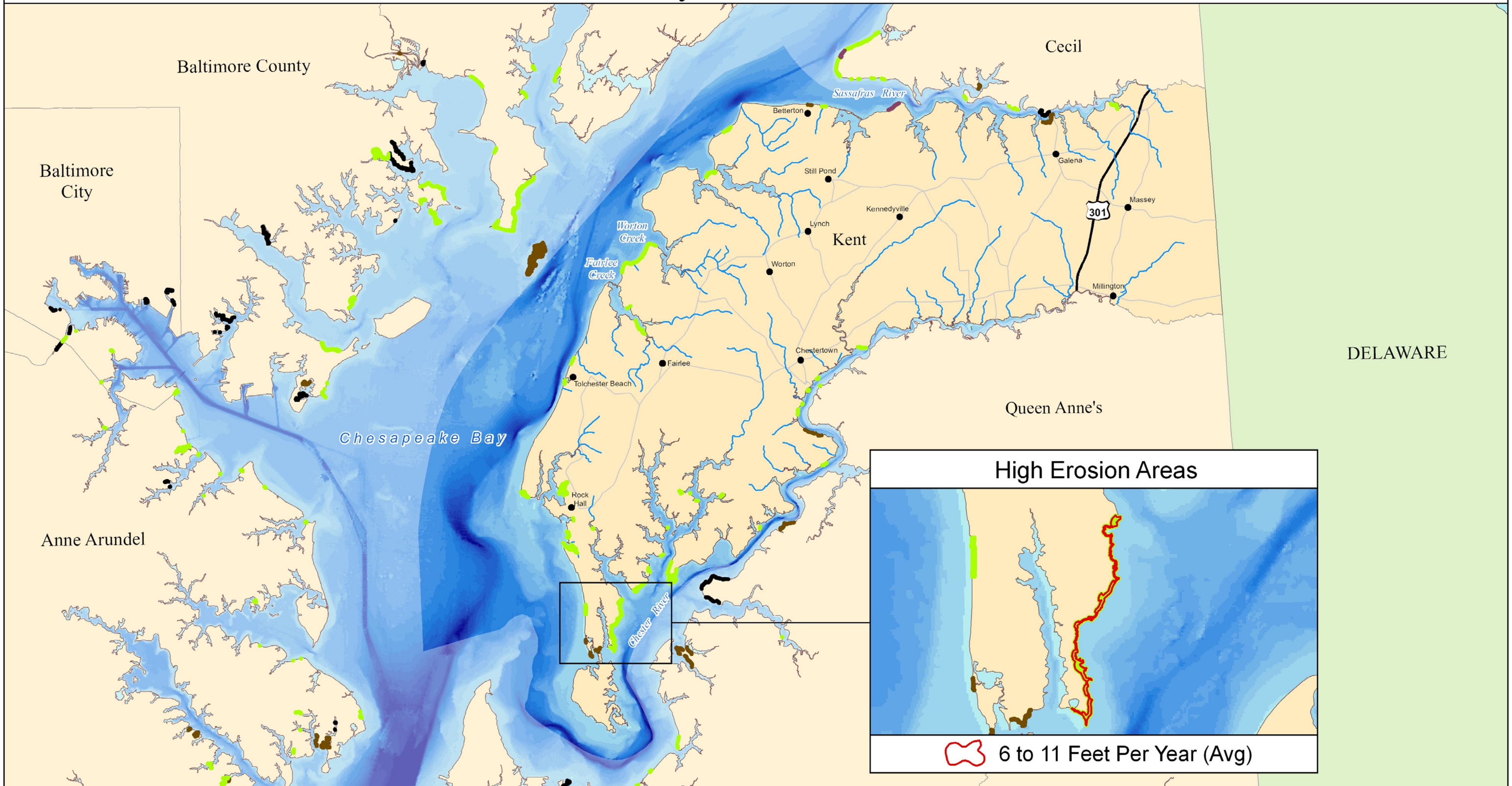
Kent County

Kent County has one high erosion area of interest: a long wetland area on the western side of the Chester River, upstream of a large bend before it enters the Bay. The wetland is close to several other eroding wetland areas on the Chester River, and erosion protection measures may be employed on a regional scale here.

Kent County also has numerous wetland areas that are within the 50-year planning window that are areas of interest but are not high erosion areas.



Kent County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- US Highways
- State Highways

N W E S

10 5 0 10 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
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US Army Corps of Engineers Baltimore District

MARYLAND DEPARTMENT OF NATURAL RESOURCES

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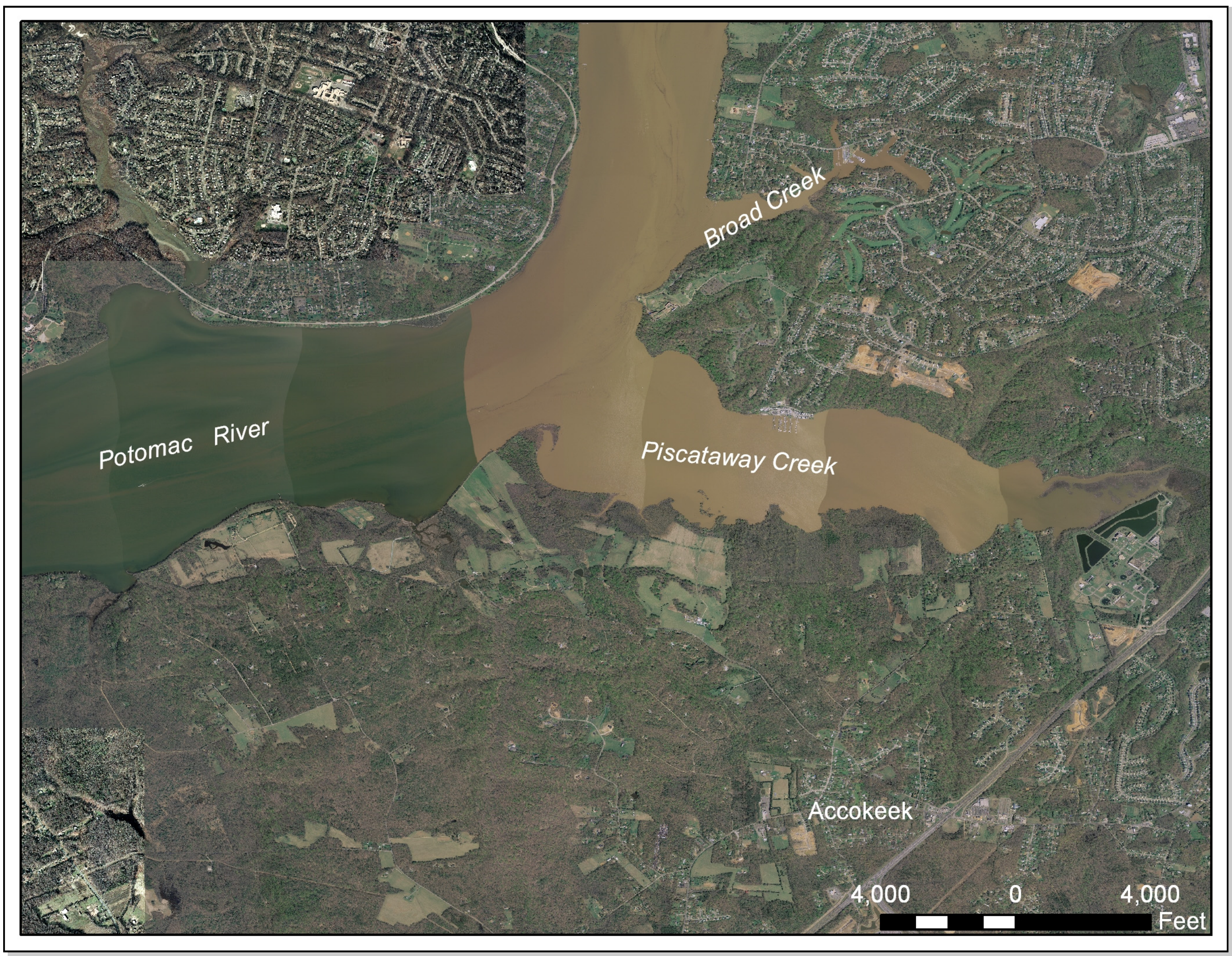
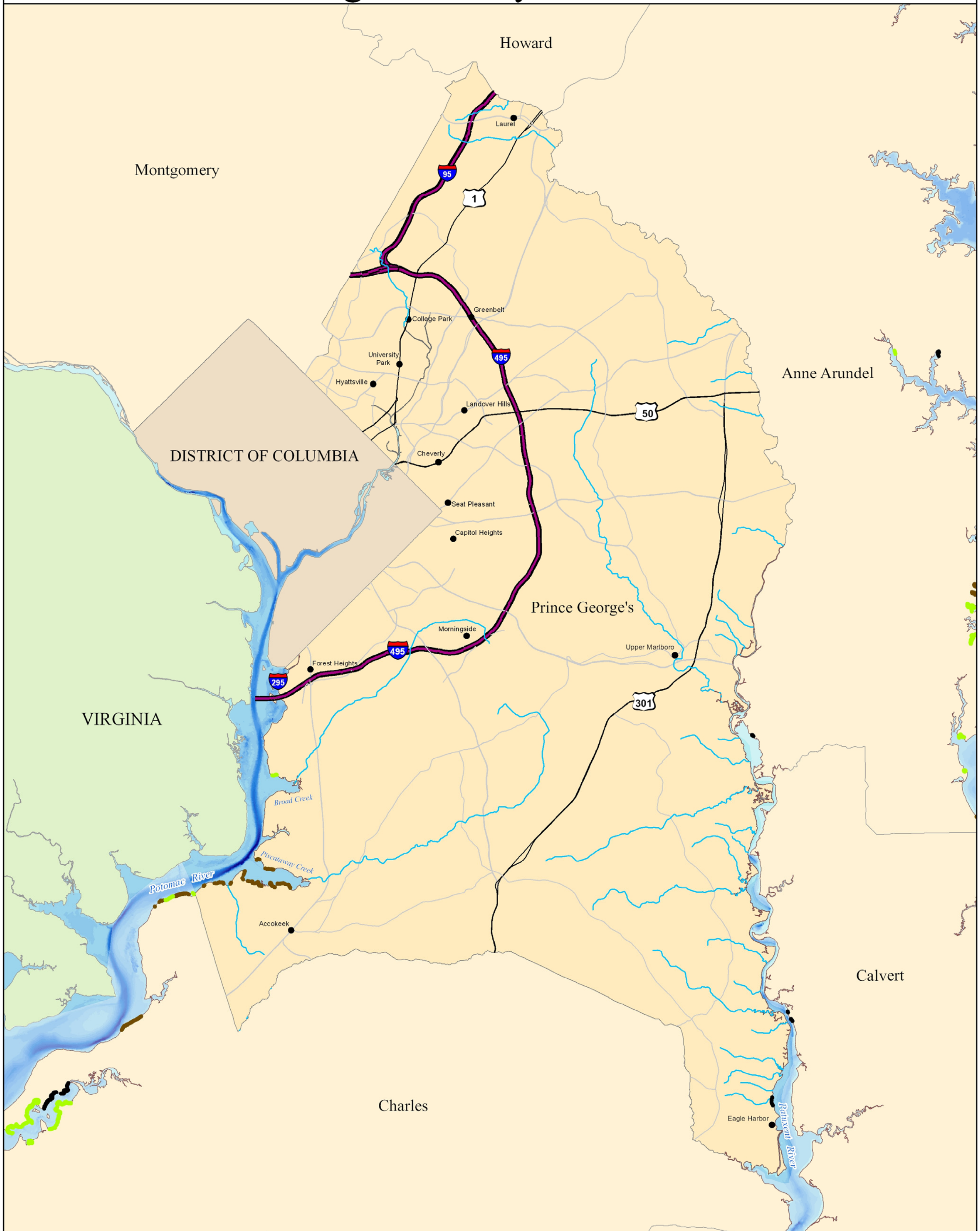
Prince George's County

There are no areas of high erosion that coincide with areas of interest in Prince George's County. The county is bordered by the Patuxent River to the east and the Potomac River to the West. Along the Potomac River, near the town of Accokeek, National Register-listed property is located on a long reach of shoreline that is vulnerable to erosion.



Prince George's County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- Interstates
- US Highways
- State Highways

N W E S

4 2 0 4 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
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US Army Corps of Engineers
Baltimore District

MARYLAND DEPARTMENT OF NATURAL RESOURCES

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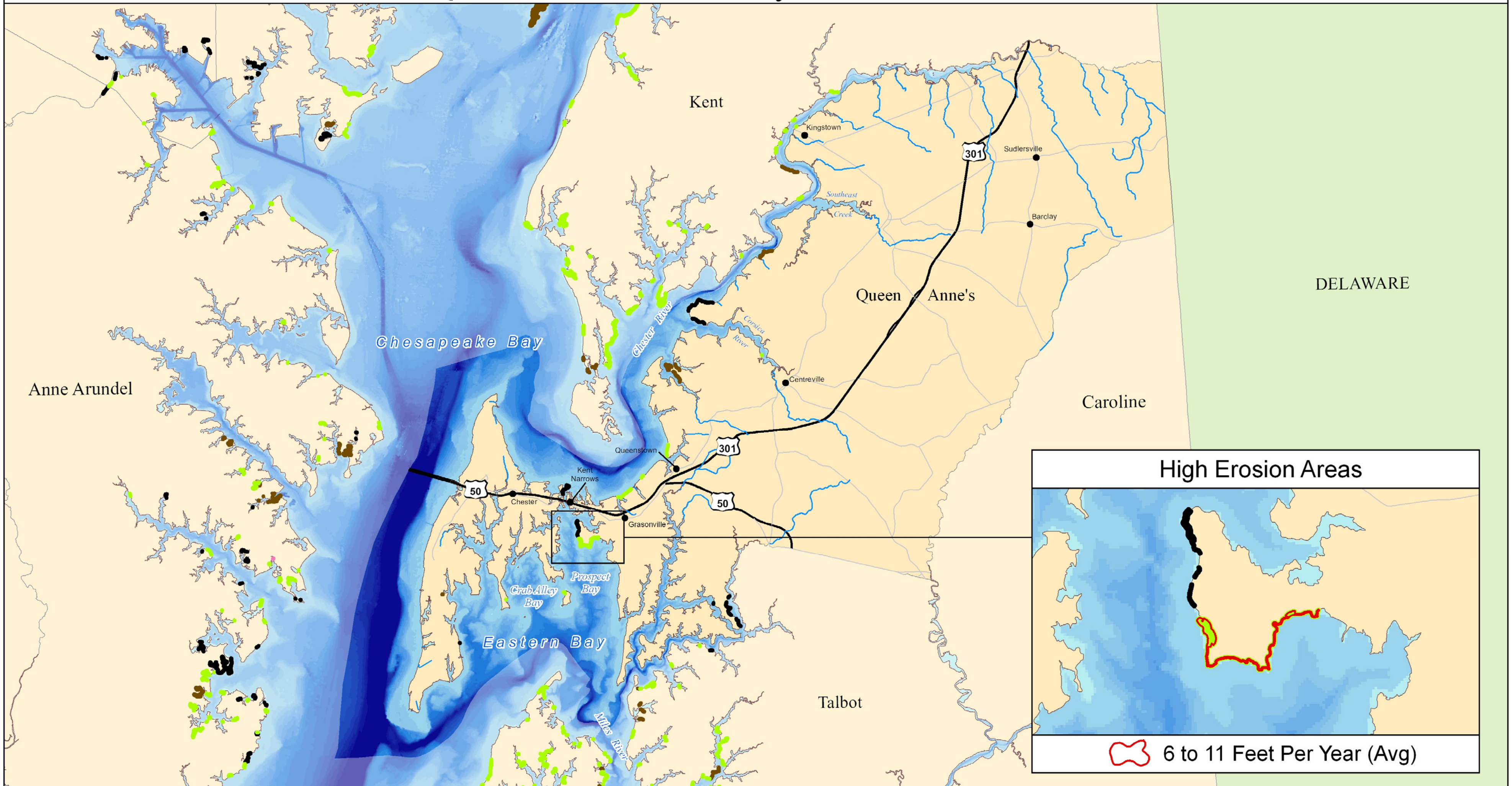
Queen Anne's County

One wetland area of interest in Queen Anne's County is within an area of high erosion. This wetland is situated near Hood Point fronting Prospect Bay. To the north of the wetland is an area of identified socioeconomic resources that are within the planning window. A shoreline erosion protection strategy at this location should consider the entire peninsula.

While relatively few areas of interest were identified in Queen Anne's County, many wetland areas are within the planning window. These wetland areas did not meet any other criteria for selection.

Queen Anne's County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic

- Rivers/Streams
- US Highways
- State Highways

N W E S

10 5 0 10 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
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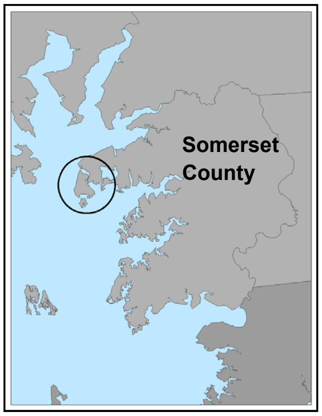


Somerset County

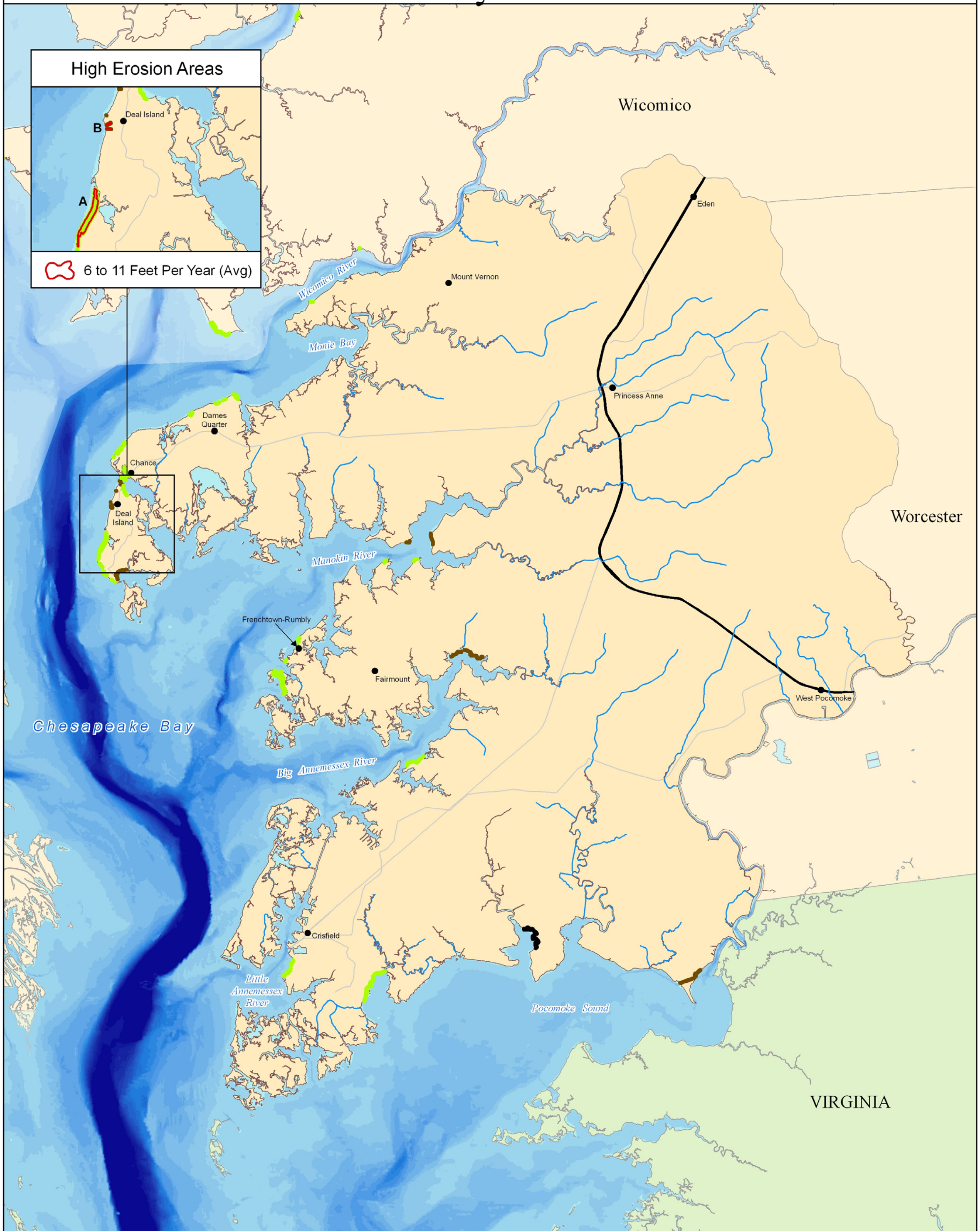
Somerset County has two areas of high erosion with areas of interest. Both areas are on Deal Island, directly fronting the Bay mainstem. This area has significant fetch to the west.

Area A is a wetland area fronting a tidal pond and creek system.

Area B, immediately north of Area A with the same geographic characteristics, consists of two cultural areas of interest. Both of these areas are part of the Deal Island Historic District.

1,000 0 1,000
Feet

Somerset County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- River/Streams
- US Highways
- State Highways

N
W E
S

4 2 0 4 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
Refer to online Erosion Vulnerability Assessment (EVA) tool for additional analysis:
http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
Maryland shoreline informaiton may be found at:
http://shorelines.dnr.states.md.us/

US Army Corps of Engineers
Baltimore District

Maryland Department of Natural Resources

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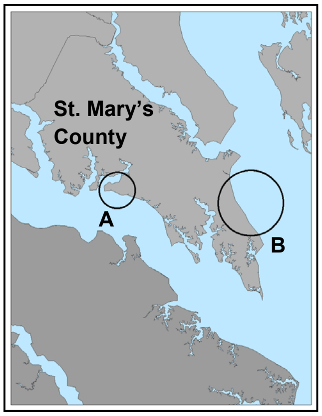
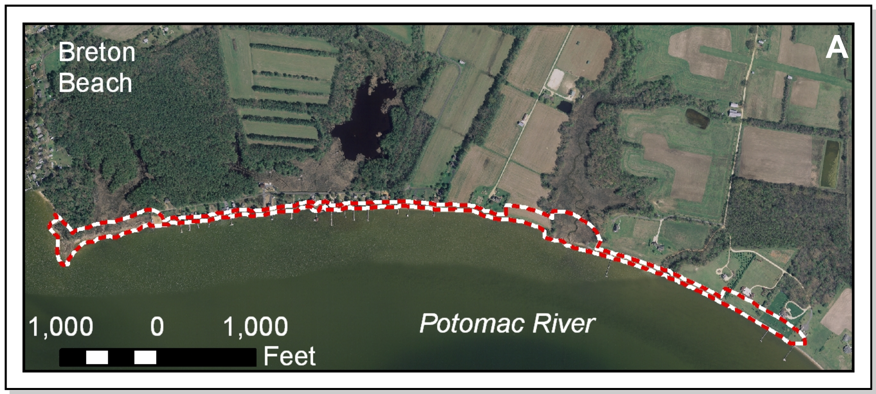


St. Mary's County

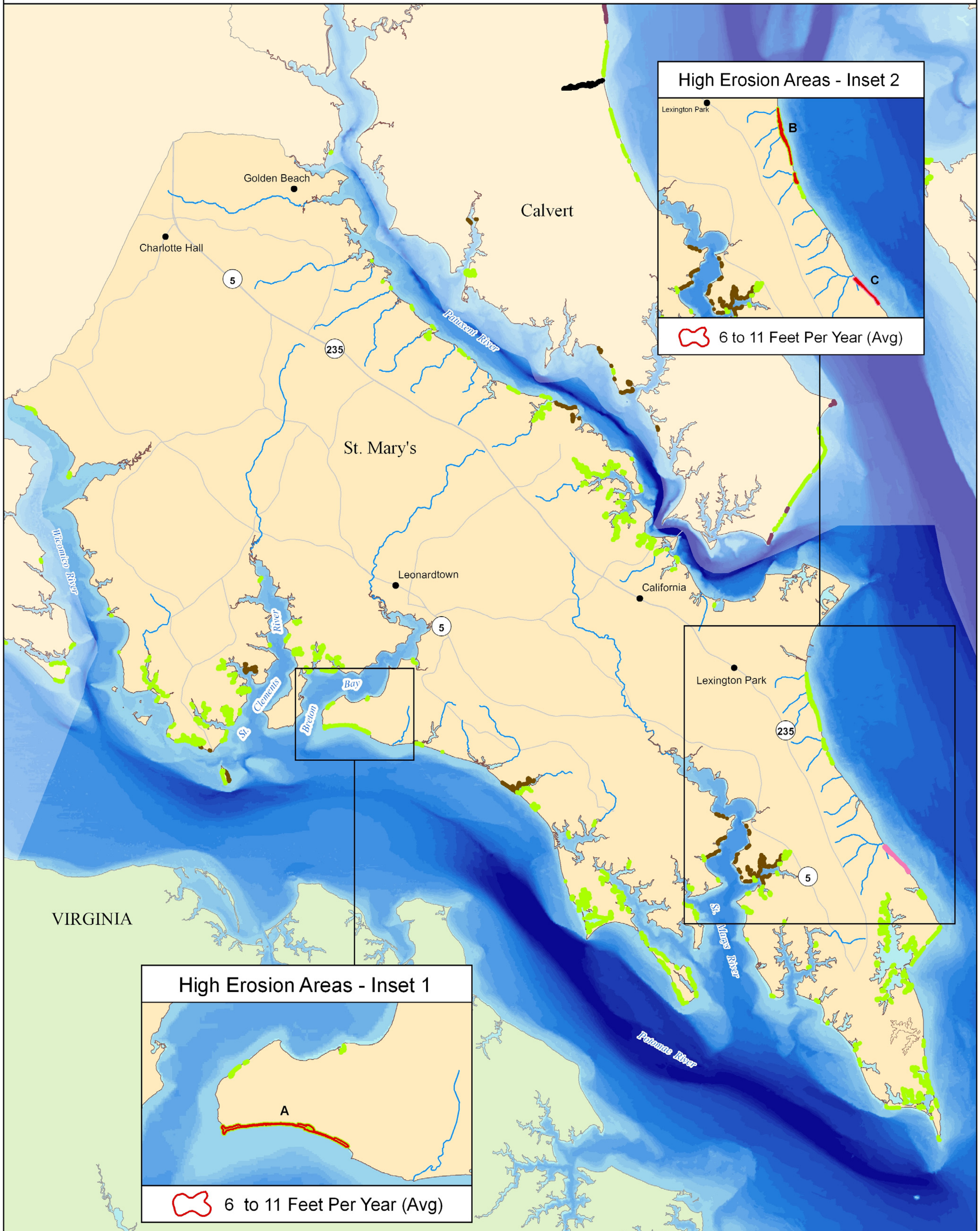
Two high erosion areas with identified areas of interest are within St. Mary's County on the western shore of the Bay. St. Mary's county has significant wetland areas identified as areas of interest, as well as cultural areas on the St. Mary's River.



Inset 1: Area A is a wetland area along the northern side of the Potomac River at the mouth of Breton Bay.

Inset 2: Areas B and C are wetland areas near the town of Lexington Park, fronting the mainstem of the Bay. There is significant fetch to the east, and this is a high wave energy environment. The long linear segment in Area C is a WSSC wetland.

St. Mary's County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/Streams
- State Highways

N / W / E / S

4 2 0 4 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
Refer to online Erosion Vulnerability Assessment (EVA) tool for additional analysis:
http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
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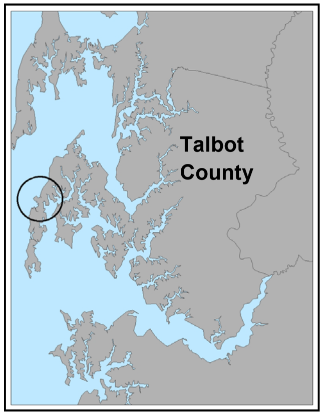
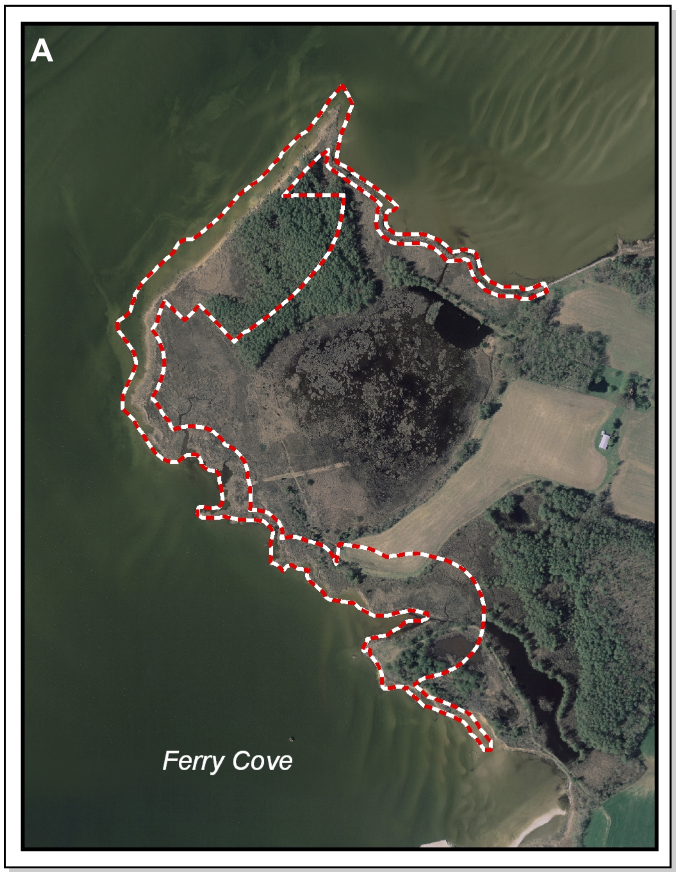
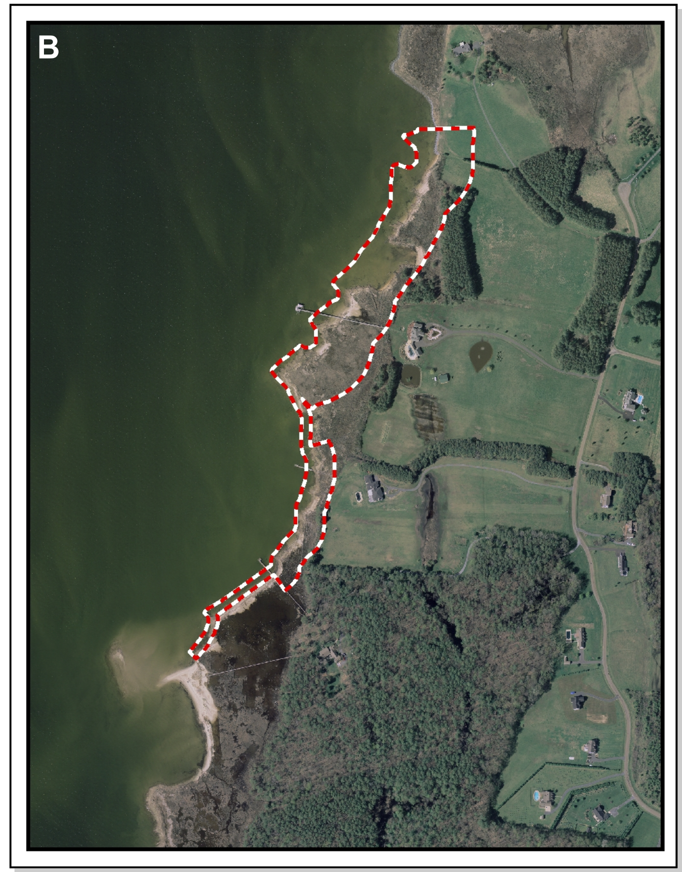


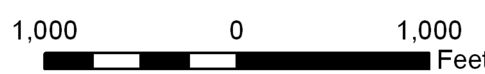
Talbot County

Two wetlands in Talbot county are located within a high erosion area. Area A partially borders Ferry Cove, and Area B is located off of Punch Point Road, on the peninsula of land between Harris Creek and the Bay. The two areas are separated by about 4,000 feet at their nearest point, although the shoreline distance is significantly longer.

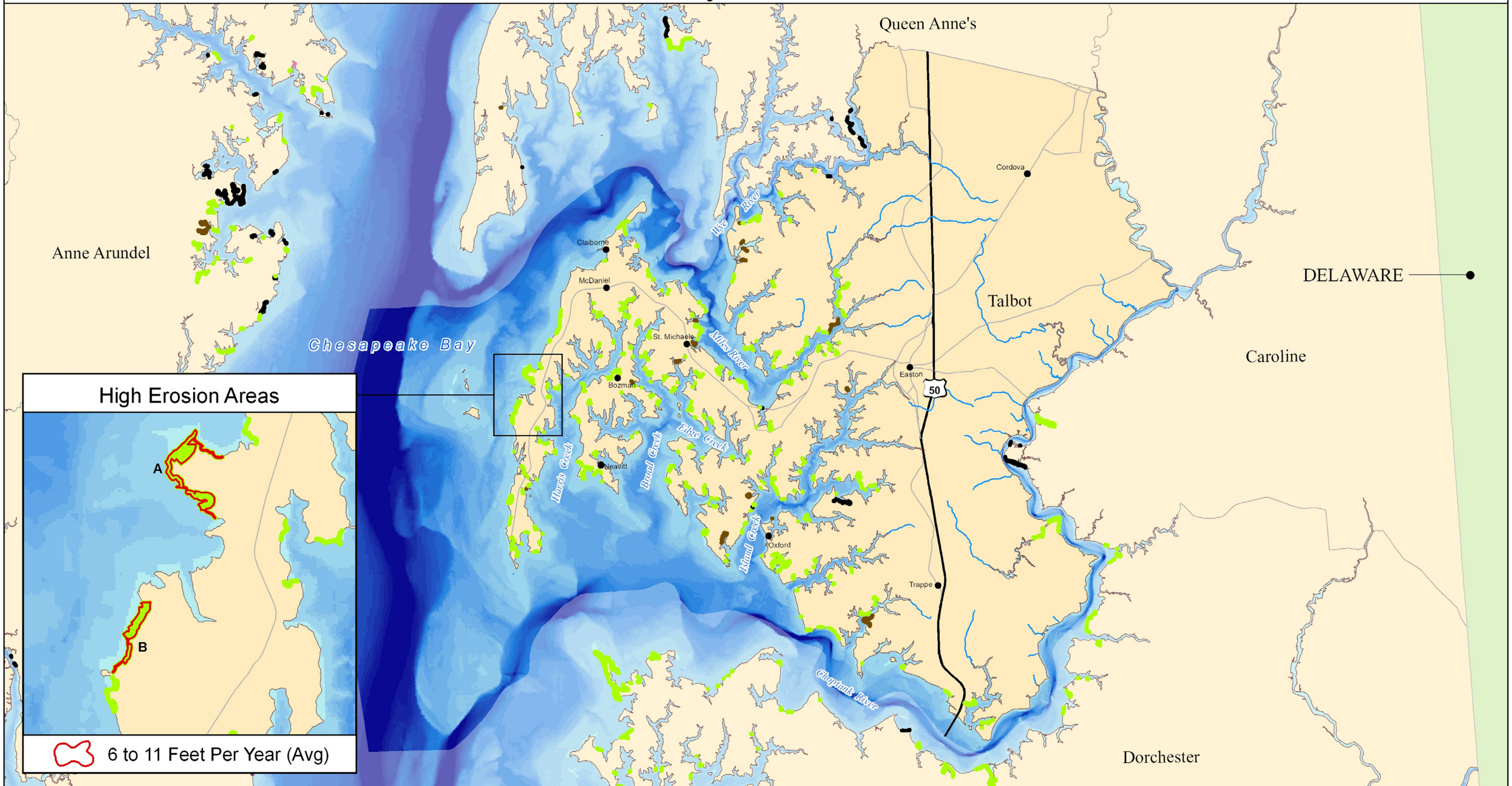




These wetlands front the Bay, but in recent years the fetch to the west has been decreased with the construction of the Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island. Poplar Island provides these wetlands some protection from high wave energy across the bay.



Talbot County Shoreline Erosion



Areas of Interest

- Beaches
- Wetlands
- Wetlands of Special State Concern
- Cultural (NRHP)
- Socioeconomic
- Rivers/ Streams
- US Highways
- State Highways

N W E S

9 4.5 0 9 Miles

Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
Refer to online Erosion Vulnerability Assessment (EVA) tool for additional analysis:
http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
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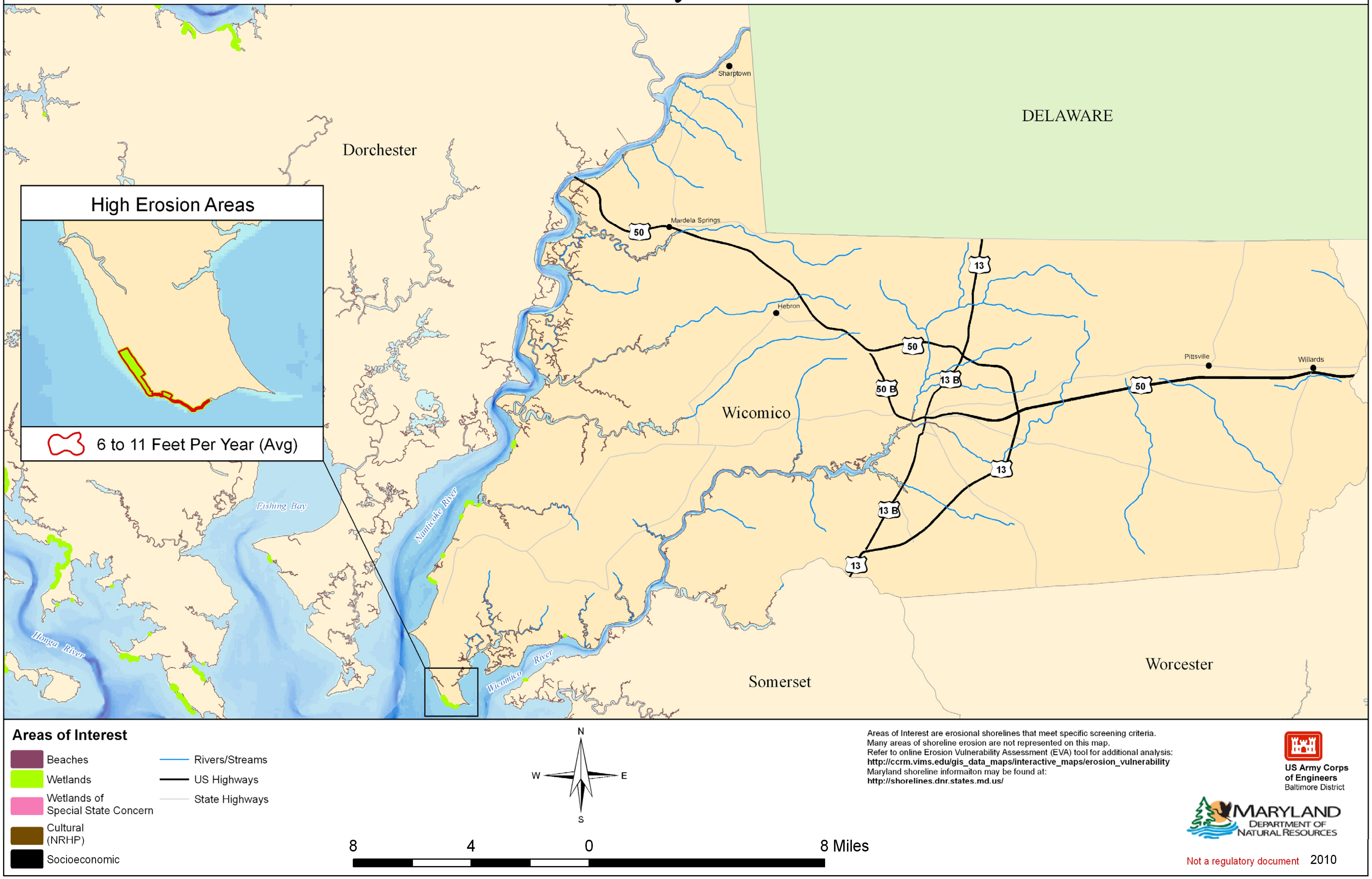
Wicomico County

Wicomico County has several wetland areas along the Nanticoke River that are within the 50-year planning window and meet the area of interest criteria. However, only one wetland area is experiencing high erosion. This wetland is located at the mouth of the Nanticoke River and the Wicomico River.

This wetland area is situated at the southern end of a marshy peninsula and has large fetch to the southwest.

Wicomico County Shoreline Erosion



Areas of Interest are erosional shorelines that meet specific screening criteria.
Many areas of shoreline erosion are not represented on this map.
Refer to online Erosion Vulnerability Assessment (EVA) tool for additional analysis:
http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability
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Chapter 6: Conclusions

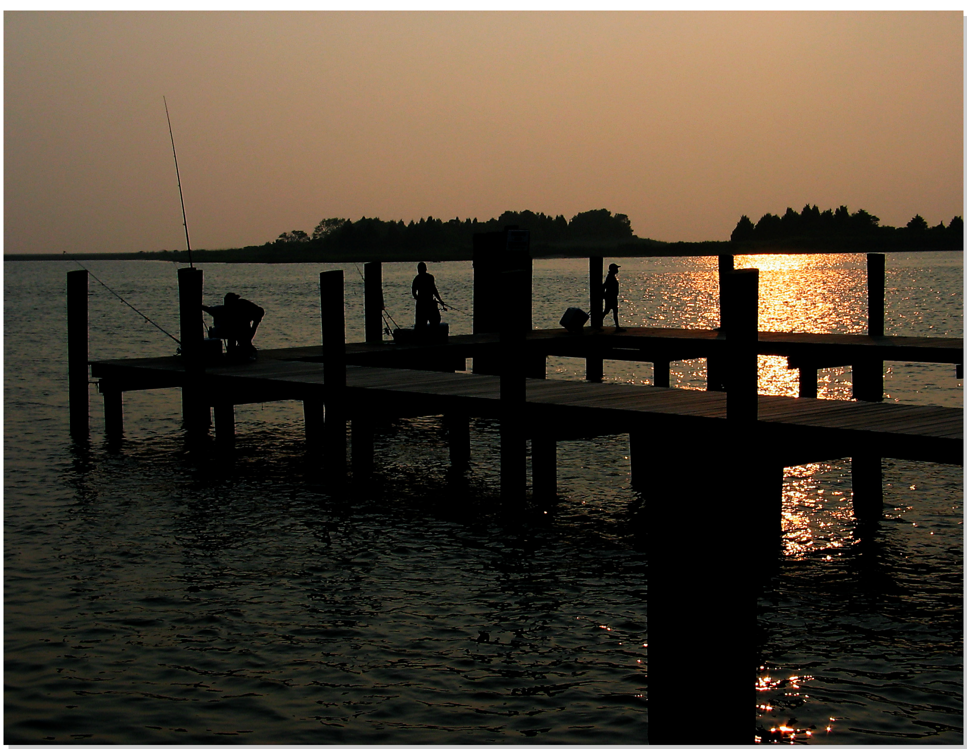
Shoreline erosion in the Chesapeake Bay is a natural process that has been ongoing since the formation of the Bay over 10,000 years ago. Maryland's 7,000 miles of Bay shoreline provide important fish and wildlife habitat, as well as human access to the Bay for navigation, fishing, and recreation and serving as a natural property amenity.

Shoreline erosion and rising sea-level simultaneously create, maintain, and destroy habitat. About 1,000 miles of the Maryland Bay shoreline is currently artificially stabilized to stop erosion. Based on these existing shoreline conditions, this study projects a net loss of over 12,000 acres of Bay shoreline in Maryland in the next 50 years.

Effects from sea-level rise and changing climatic conditions will likely increase shoreline erosion rates. Where shoreline erosion has the potential to impact human structures or highly valued property, property owners will likely implement shoreline protection measures to prevent erosion.

When highly valued wildlife habitat is being destroyed by shoreline erosion, it is appropriate to undertake stabilization measures if human alteration of natural shoreline and coastal processes substantially contributes to the erosion or if human land use precludes natural landward migration of these habitats. To maintain ecosystem services provided by natural shorelines, shoreline protection should be undertaken in an environmentally-sensitive manner. This principle is embodied in Maryland Law.

This Management Guide gives users the tools and data to evaluate shoreline areas of interest and make informed decisions about whether action is appropriate. No engineering or technical site-specific information for project design is given. An accompanying technical guide to shoreline erosion protection structures for contractors, engineers, and planners is being produced as part of this study.



Andrew Roach

Sunset over the public pier in Crisfield, Somerset County, Maryland.

Shoreline Erosion & Ecological Response

Tidal wetlands, beaches, intertidal flats, and bluffs all, depend on shoreline erosion for maintenance or creation. However, many of these habitats have been directly altered through human actions, land use changes have changed long-term viability, or overall changes to the landscape of the Bay watershed have caused certain habitats to gain in ecological importance. About 3,750 acres of ecological areas and 176 miles of beach are within the 50-year planning window and therefore may be vulnerable to loss through erosion (Figure 6.1). For these ecological areas, investigation of shoreline erosion stabilization measures is appropriate.

Wetlands, for example, may be lost to shoreline erosion because they cannot naturally migrate inland due to human influences as discussed in Chapter 2. Living shorelines and created wetlands could provide both shore protection and ecological function—an opportunity to protect this national treasure.

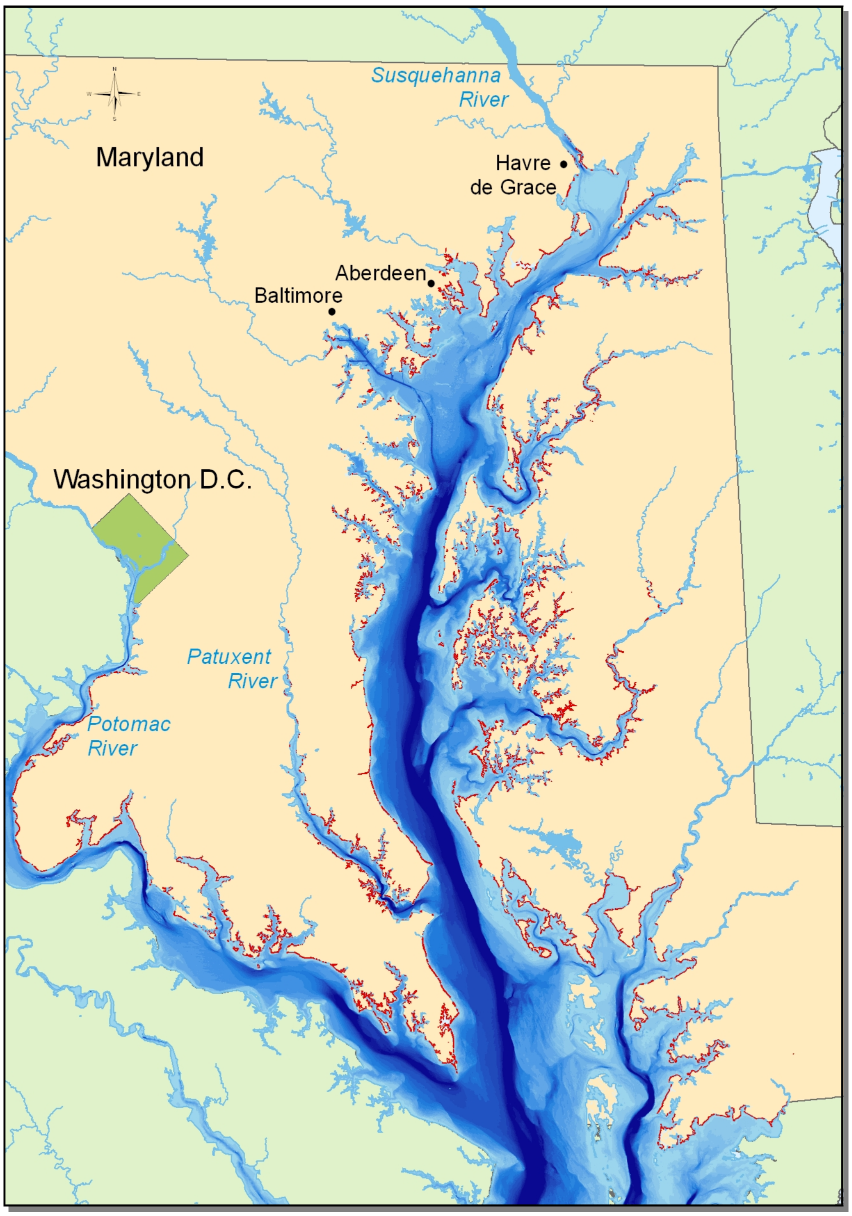


Figure 6.1 Ecological areas that have the potential to be influenced by erosion in the future are shown in red. Ecological areas include beaches, wetlands, critical habitat, natural heritage areas, or habitat for rare, threatened, and endangered species. Those areas shown in maps in Chapter 5 are a subset of the areas shown on this map.

Shoreline Erosion & Socioeconomic and Cultural Response

The shoreline of the Bay has been used by humans since our arrival. Cultural artifacts of that use are found throughout the Bay region and include archeological sites, Native American and early European homesteads, historic districts, as well as many others. Preservation of these artifacts and sites is important and when threatened with shoreline erosion, stabilization measures are often appropriate.

Today, human use of the Bay shoreline includes extensive public and private infrastructure. Shoreline erosion has the potential to affect roads; utilities; public buildings (schools, emergency buildings, and public works); and other publicly owned facilities. Private homes, businesses, and agricultural lands are also effected. Long-term planning or immediate stabilization measures are different ways to deal with the effects of shoreline erosion, and either may be appropriate. While there are many miles of roads vulnerable to shoreline erosion in the next 50 years, there are few public buildings and water treatment facilities at risk.

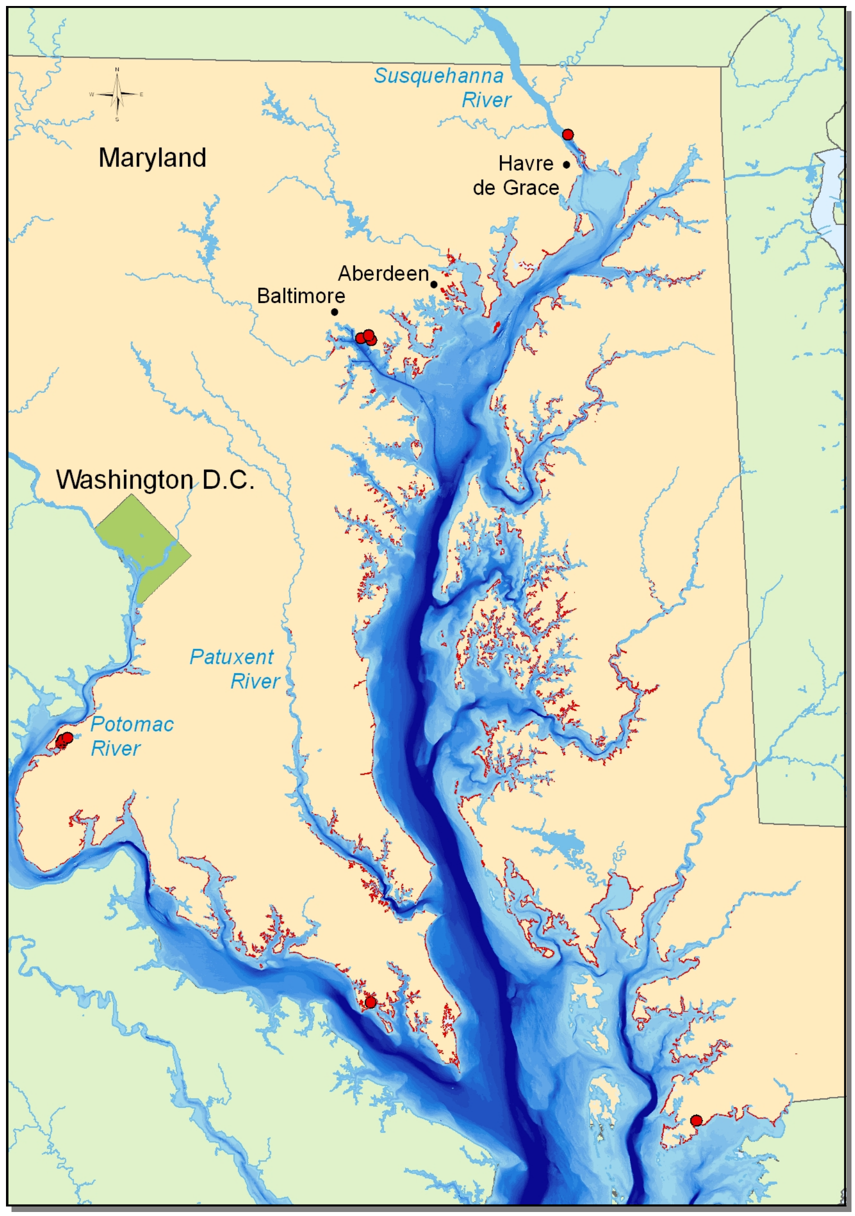


Figure 6.2 Socioeconomic and cultural areas that have the potential to be influenced by erosion in the future are shown in red. Socioeconomic and cultural areas include roads, public buildings, wastewater treatment facilities, county parks, historic properties, and properties listed on the National Register of Historic Places, as well as other features. Those areas shown in maps in Chapter 5 are a subset of the areas shown on this map.

Available Data and Tools

As part of this study, shoreline erosion was projected 50 years into the future. The area of possible shoreline erosion, termed the "planning window," demarcates an area where resources of interest may be at risk for loss from shoreline erosion. Areas within the planning window were examined for ecological, socioeconomic, and cultural importance (Figures 6.1 and 6.2). Shoreline stabilization condition and other spatial datasets were also compiled (Please see Annex 1 for a listing of datasets used). These data are available for download and use at: http://ccrm.vims.edu/gis_data_maps/interactive_maps/erosion_vulnerability/. An interactive tool —the EVA— was also developed to allow planners and other interested people to interact with the spatial data without the need for a stand-alone desktop GIS. The EVA tool is also available at the website listed above.

Screening Outcome

A template for screening the Bay shoreline for areas of interest in erosion protection is provided in this guide. The screening template may serve as the basis for exploring available data for other interested parties. About 26 distinct areas with historically high erosion may be in the Federal Interest for further study into shoreline protection measures. Areas that may be in the Federal Interest to protect include historic districts listed on the National Register of Historic Places as well as many wetland areas that are experiencing high rates of erosion. Other areas may also be in the Federal Interest.

The eastern shore counties of Dorchester, Somerset, and Talbot, along with St. Mary's County on the western shore are projected to account for over half the net loss of land due to erosion during the period of study. Many acres of ecologically important wetlands area being lost in these counties with reduced ability for wetland migration inland. Action may be needed soon to preserve and protect these resources. Opportunities for non-Federal sponsors to partner with USACE in cost-shared projects are available under a variety of different authorities (Annex 4). These authorities allow opportunities such as ecosystem restoration and storm damage protection to be addressed on non-private lands. A specific authority for shoreline projects on the Bay would be helpful in protecting the valuable resources of the Bay.

Other shoreline reaches may meet criteria for local and State interest in shoreline stabilization projects. Funding for these projects may be available from a variety of Federal, state, and non-profit sources. Annex 4 lists several funding opportunities and resources for more information.

Recommendations For Further Work

While not explicitly covered in this management guide, it is clear that sea-level rise must be considered in project formulation for shoreline erosion. In the last thousand years, sea-level has risen in the Bay and the rate of rise is forecast to increase. Integration of projected sea-level rise with historic erosion rates would enable increased regional planning opportunities along with better project design. Those areas of interest identified in this guide may lose their importance over time, and other areas gain in importance as the rate of sea-level rise changes.

Finally, a critical component of analyzing site-specific shoreline erosion and methods of stabilization is the effect of littoral drift on sediment supply. Littoral drift maps (1982, http://shorelines.dnr.state.md.us/conditionsMaps.asp) for the Bay should be updated because bay conditions and technologies have changed since the mapping was completed in 1982.

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Glossary

Accretion

May be either natural or artificial. Natural accretion is the buildup of land, solely by the action of the forces of nature, on a beach by deposition of water– or airborne material. Artificial accretion is a similar buildup of land by reason of an act of people, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means.

Alongshore

Parallel to and near the shoreline; longshore.

Anoxic

Refers to an environment that contains little or no dissolved oxygen and hence little or no macrobenthic marine life. These conditions arise in some basins where physical circulation of seawater is limited.

Armor Unit or Stone

A relatively large quarrystone or concrete shape that is selected to fit specified geometric characteristics and density. It is usually of nearly uniform size and usually large enough to require individual placement. In normal cases it is used as primary wave protection and is placed in thicknesses of at least two units.

Artificial Nourishment

The process of replenishing a beach with material (usually sand) obtained from another location.

Attenuation, Light

The decrease in light intensity with depth in the water column due to absorption and scattering.

Attenuation, Wave

(1) A lessening of the amplitude of a wave with distance from the origin. (2) The decrease of water-particle motion with increasing depth. Particle motion resulting from surface oscillatory waves attenuates rapidly with depth, and practically disappears at a depth equal to a surface wavelength.

Basin, Boat

A naturally or artificially enclosed or nearly enclosed harbor area for small craft.

Bathymetry

The measurement of water depths in oceans, seas, and lakes; also information derived from such measurements.

Bay

A recess in the shore or an inlet or arm of a sea between two capes or headlands, not as large as a gulf but larger than a cove.

(Definitions based on: USACE, Costal Engineering Manual, 2003)

Beach

The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach—unless otherwise specified—is the mean low water line. A beach includes foreshore and backshore.

Beach Berm

A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

Beach Erosion

The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

Beach Fill

Material placed on a beach to renourish eroding shores, usually pumped by dredge but sometimes delivered by trucks.

Beneficial Use of Dredged Material

Placement or use of dredged material for some productive purpose.

Benthic

Pertaining to the sub-aquatic bottom.

Benthos

Animals who live on the sediments of the sea floor - both mobile and non-mobile forms.

Bluff

A high, steep bank or cliff.

Breakwater

A man-made structure protecting a shore area, harbor, anchorage, or basin from waves.

Buffer Area

A parcel or strip of land that is designed and designated to permanently remain vegetated in an undisturbed and natural condition to protect an adjacent aquatic or wetland site from upland impacts, to provide habitat for wildlife and to afford limited public access.

Bulkhead

A structure or partition to retain or prevent sliding of the land and protect the upland against damage from wave action.

Clay

A fine grained, plastic, sediment with a typical grain size less than 0.004 mm. Possesses electromagnetic properties which bind the grains together to give a bulk strength or cohesion. With silt, comprises mud.

Cliff

A high, steep face of earth; a precipice.

Climate

The characteristic weather of a region, particularly regarding temperature and precipitation, averaged over some significant interval of time (years).

Coast

(1) A strip of land of indefinite width (may be several kilometers) that extends from the shoreline inland to the first major change in terrain features. (2) The part of a country regarded as near the coast.

Coastal Plain

The plain composed of horizontal or gently sloping strata of sediments, generally representing a strip of sea bottom that has emerged from the sea in recent geologic time. May extend inland many kilometers.

Coastal Processes

Collective term covering the action of natural forces on the shoreline, and near shore seabed.

Coastal Zone Management (CZM)

The integrated and general development of the coastal zone. Costal Zone Management is not restricted to coastal defense works, but includes also development in economical, ecological, and social terms.

Coastline

(1) Technically, the line that forms the boundary between the coast and the shore. (2) Commonly, the line that forms the boundary between the land and the water, esp. the water of a sea or ocean. The shoreline.

Cove

A small, sheltered recess in a coast, often inside a larger embayment.

Current, Littoral

Any current in the littoral zone caused primarily by wave action.

Deep Water

Water so deep that surface waves are little affected by the Bay bottom. Generally, water deeper than one-half the surface wavelength is considered deep water.

Depth

The vertical distance from a specified datum to the sea floor.

Design Wave

In the design of harbors, harbor works, etc., the type or types of waves selected as having the characteristics against which protection is desired.

Detached Breakwater

A breakwater without any exposed connection to the shore.

Differential Erosion / Weathering

These features develop in rocks which have varying resistance to the agencies of erosion and/or weathering so that parts of the rock are removed at greater rates than others. A typical example is the removal of soft beds from between harder beds in a series of sedimentary rocks. The term may be applied to any size of feature, from small-scale ‘etching’ to the regional development of hills and valleys controlled by hard and soft rocks.

Diffraction (of water waves)

Phenomenon by which energy is transmitted laterally along a wave crest. When a part of a train of waves is interrupted by a barrier, such as a breakwater, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.

Dolphin

A cluster of piles.

Downdrift

The direction of predominant movement of littoral materials.

Elevation

The vertical distance from mean sea level or other established datum plane to a point on the earth’s surface; height above sea level. Although sea floor elevation below mean sea level should be marked as a negative value, many charts show positive numerals for water depth.

Embayment

An indentation in the shore forming an open bay.

Endemic

Native or confined to a specific geographic area.

Erosion

The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by wind.

Escarpment

A more or less continuous line of cliffs or steep slopes facing in one general direction which are caused by erosion or faulting.

Estuary

(1) The part of a river that is affected by tides. (2) The region near a river mouth in which the fresh water of the river mixes with the salt water of the sea and which received both fluvial and littoral sediment influx.

Eustatic Sea Level Change

Change in the relative volume of the world’s ocean basins and the total amount of ocean water.

Eutrophic

Abundant in nutrients and having high rates of productivity, frequently resulting in oxygen depletion below the surface layer.

Fetch

The area in which seas are generated by a wind having a fairly constant direction and speed.

Foreshore

The part of the shore, lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low-water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

Gabion

(1) Steel wire-mesh basket to hold stones or crushed rock to protect a bank or bottom from erosion. (2) Structures composed of masses of rocks, rubble or masonry held tightly together usually by wire mesh so as to form blocks or walls.

Geographical Information System (GIS)

Database of information which is geographically referenced, usually with an associated visualization system.

Geomorphology

(1) That branch of physical geography which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc. (2) The investigation of the history of geologic changes through the interpretation of topographic forms.

Geotextile

A synthetic fabric which may be woven or non-woven used as a filter.

Global Positioning System (GPS)

A navigational and positioning system by which the location of a position on or above the Earth can be determined by a special receiver at that point interpreting signals received simultaneously from several of a constellation of special satellites.

Groin

Narrow, roughly shore-perpendicular structure built to reduce longshore currents, and/or to trap and retain littoral material. Most groins are of timber or rock and extend from a seawall, or the backshore, well onto the foreshore and rarely even further offshore.

Groin System

A series of groins acting together to protect a section of beach. Commonly called a groin field.

Headland (Head)

(1) A comparatively high bluff with either a cliff or steep face extending out into a body of water, such as a sea or lake. An unnamed head is usually called a *headland*. (2) Seaward end of breakwater or dam.

High Tide, High Water (HW)

The maximum elevation reached by each rising tide.

High Water (HW)

Maximum height reached by a rising tide. The height may be solely due to the periodic tidal forces or it may have superimposed upon it the effects of prevailing meteorological conditions.

High Water Line

In strictness, the intersection of the plane of mean high water with the shore. The shoreline delineated on the nautical charts of the National Ocean Service is an approximation of the high water line. For specific occurrences, the highest elevation on the shore reached during a storm or rising tide, including meteorological effects.

Higher High Water (HHW)

The higher of the two high waters of any tidal day. The single high water occurring daily during periods when the tide is diurnal is considered to be a higher high water.

Higher Low Water (HLW)

The higher of two low waters of any tidal day.

Impermeable Groin

A groin constructed such that sand cannot pass through the structure (but sand may still move over or around it).

Inlet

A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water. (2) An arm of the sea (or other body of water) that is long compared to its width and may extend a considerable distance inland.

Jetty

On open seacoasts, a structure extending into a body of water, which is designed to prevent shoaling of a channel by littoral materials and to direct and confine the stream or tidal flow. Jetties are built at the mouths of rivers or tidal inlets to help deepen and stabilize a channel.

Levee

(1) A ridge or embankment of sand and silt, built up by a stream on its flood plain along both banks of its channel. (2) A large dike or artificial embankment, often having an access road along the top, which is designed as part of a system to protect land from floods.

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.

Littoral Cell

A reach of the coast that is isolated sedimentologically from adjacent coastal reaches and that features its own sources and sinks. Isolation is typically caused by protruding headlands, inlets, and river mouths.

Littoral Zone

In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

Longshore

Parallel to and near the shoreline

Low Tide (Low Water, LW)
The minimum elevation reached by each falling tide.

Low Water (LW)
The minimum height reached by each falling tide.

Lower High Water (LHW)
The lower of the two high waters of any tidal day.

Lower Low Water (LLW)
The lower of the two low waters of any tidal day. The single low water occurring daily during periods when the tide is diurnal is considered to be a lower low water.

Managed Retreat
The deliberate setting back (moving landward) of the existing line of sea defense in order to obtain engineering or environmental advantages - also referred to as managed landward realignment. Sometimes refers to moving roads and utilities landward in the face of shore retreat.

Marsh
(1) A tract of soft, wet land, usually vegetated by reeds, grasses and occasionally small shrubs.
(2) Soft, wet area periodically or continuously flooded to a shallow depth, usually characterized by a particular subclass of grasses, cattails and other low plants.

Mean High Water Springs (MHWS)
The average height of the high water occurring at the time of spring tides.

Mean High Water (MHW)
The average height of the high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is either semidiurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.

Mean Higher High Water (MHHW)
The average height of the higher high waters over a 19-year period. For shorter periods of observation, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19-year value.

Mean Low Water (MLW)
The average height of the low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All low water heights are included in the average where the type of tide is either semidiurnal or mixed. Only lower low water heights are included in the average where the type of tide is diurnal. So determined, mean low water in the latter case is the same as mean lower low water.

Mean Lower Low Water (MLLW)
The average height of the lower low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. Frequently abbreviated to lower low water.

Mean Sea Level (MSL)
The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings. Not necessarily equal to mean tide level. It is also the average water level that would exist in the absence of tides.

Nearshore
In beach terminology an indefinite zone extending seaward from the shoreline well beyond the wave breaker zone.

Nourishment
The process of replenishing a beach. It may occur naturally by longshore transport, or be brought about artificially by the deposition of dredged materials or of materials trucked in from upland sites.

Offshore
In beach terminology, the comparatively flat zone of variable width, extending from the shoreface to the edge of the continental shelf. It is continually submerged. (2) The direction seaward from the shore. (3) The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the sea bed on wave action is small in comparison with the effect of wind. (4) The breaker zone directly seaward of the low tide line.

Ordinary High Water Mark (OHWM)
That mark that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation as that condition exists on June 1, 1971, as it may naturally change thereafter, or as it may change thereafter in accordance with permits issued by a local government. Also defined as mean high water line.

Overtopping
Passing of water over the top of a structure as a result of wave runup or surge action.

Overwash
(1) The part of the uprush that runs over the crest of a berm or structure and does not flow directly back to the Bay. (2) The effect of waves overtopping a coastal defense, often carrying sediment landwards which is then lost to the beach system.

Perched Beach
A beach or fillet of sand retained above the otherwise normal profile level by a submerged dike.

Permeable Groin
A groin with openings or voids large enough to permit passage of appreciable quantities of littoral drift through the structure.

Pier

A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, recreational facility, etc., rather than to afford coastal protection or affect the movement of water.

Pile

A long, heavy timber or section of concrete or metal that is driven or jetted into the earth or seabed to serve as a support or protection.

Profile, Beach

The intersection of the ground surface with a vertical plane; typically perpendicular to the local shoreline, and may extend from the behind the dune line or the top of a bluff to well seaward of the breaker zone.

Recession

(1) A continuing landward movement of the shoreline. (2) A net landward movement of the shoreline over a specified time.

Reef Breakwater

Rubble mound of single-sized stones with a crest at or below sea level which is allowed to be (re)shaped by the waves.

Reflection

The process by which the energy of the wave is returned seaward.

Revetment

(1) A facing of stone, concrete, etc., to protect an embankment, or shore structure, against erosion by wave action or currents. (2) A retaining wall. (3) Facing of stone, concrete, etc., built to protect a scarp, embankment or shore structure against erosion by waves of currents.

Riparian

(1) Pertaining to the banks of a body of water. (2) Of, on or pertaining to the banks of a river or bay.

Riprap

A protective layer or facing of quarrystone, usually well graded within wide size limit, randomly placed to prevent erosion, scour, or sloughing of an embankment or bluff; also the stone so used. The quarrystone is placed in a layer at least twice the thickness of the 50 percent size, or 1.25 times the thickness of the largest size stone in the gradation.

Rubble-Mound Structure

A mound of random-shaped and random-placed stones protected with a cover layer of selected stones or specially shaped concrete armor units. (Armor units in a primary cover layer may be placed in an orderly manner or dumped at random.)

Salient

A bulge in the coastline projecting towards an offshore island or breakwater, but not connected to it as in the case of a tombolo. Developed by wave refraction and diffraction and longshore drift.

Salt Marsh

A marsh periodically flooded by salt water.

Salt-Wedge Estuary

In this circulation type, the density-driven component dominates and two well-mixed layers are separated by a sharp halocline. The seawater entering the channel appears as a tongue or wedge. The Chesapeake Bay is a partially stratified estuary.

Scarp, Beach

An almost vertical slope along the beach caused by erosion by wave action. It may vary in height from a few cm to a meter or so, depending on wave action and the nature and composition of the beach.

Seashore

(1) (Law) All ground between the ordinary high-water and low-water mark. (2) The shore of the sea or ocean, often used in a general sense (e.g., to visit the seashore).

Seawall

(1) A structure, often concrete or stone, built along a portion of a coast to prevent erosion and other damage by wave action. Often it retains earth against its shoreward face. (2) A structure separating land and water areas to alleviate the risk of flooding by the sea. Generally shore-parallel, although some reclamation seawalls may include lengths that are normal or oblique to the (original) shoreline. A seawall is typically more massive and capable of resisting greater wave forces than a bulkhead.

Sediment

(1) Loose, fragments of rocks, minerals or organic material which are transported from their source for varying distances and deposited by air, wind, ice and water. Other sediments are precipitated from the overlying water or form biologically or chemically, in place. Sediment includes all the unconsolidated materials on the sea floor. (2) The fine grained material deposited by water or wind.

Sediment Transport

The main agencies by which sedimentary materials are moved are: gravity (gravity transport); running water (rivers and streams); ice (glaciers); wind; the sea (currents and longshore drift). Running water and wind are the most widespread transporting agents.

Self-Sustaining Beach

A beach that has either natural or engineered sand retention and that can be stable through the continued supply of natural sediment sources, without any mechanical nourishment over a long period. Subsets include:

Natural or Geomorphically Self-sustaining Beaches: self-sustaining naturally without the construction of retaining structures and with no continued mechanical sand nourishment.

Anthropogenically Self-sustaining Beaches: self-sustaining by the construction of retaining structure(s) with or without initial beach fill but with no continued mechanical sand nourishment.

Setback

A required open space, specified in shoreline master programs, measured horizontally upland from an perpendicular to the ordinary high water mark.

Shore

The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach. Also used in a general sense to mean the coastal area (e.g., to live at the shore). Also sometimes known as the littoral.

Shoreline

The intersection of a specified plane of water with the shore or beach (e.g., the high water shoreline would be the intersection of the plane of mean high water with the shore or beach). The line delineating the shoreline on National Ocean Service nautical charts and surveys approximates the mean high water line.

Sill

A low or submerged structure.

Soft Defenses

Usually refers to beaches (natural or designed) but may also relate to energy-absorbing beach-control structures, including those constructed of rock, where these are used to control or redirect coastal processes rather than opposing or preventing them.

Storm Surge

A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress.

Surf

(1) Collective term for breaking waves. (2) The wave activity in the area between the shoreline and the outermost limit of breakers. (3) In literature, the term *surf* usually refers to the breaking waves on shore and on reefs when accompanied by a roaring noise caused by the larger waves breaking.

Surf Zone

The zone of wave action extending from the water line (which varies with tide, surge, set-up, etc.) out to the most seaward point of the zone (breaker zone) at which waves approaching the coastline commence breaking.

Sustainable Beach

A beach area that is now and will continue to receive sufficient sediment input over a long period (years or decades) to remain stable. Such sediment input can be through either natural supplies of sediment or various forms of mechanical beach nourishment (placement by hydraulic dredge, land haul of material, nearshore deposition, etc.)

T-Groin

A groin built in the shape of a letter “T” with the trunk section connected to land.

Terminal Groin

A groin, often at the end of a littoral cell or at the updrift side of an inlet, intended to prevent sediment passage into the channel beyond.

Tidal Flats

(1) Muddy areas covered and uncovered by the rise and fall of the tide. (2) Marshy or muddy areas of the seabed which are covered and uncovered by the rise and fall of tidal water.

Tide

The periodic rising and falling of the water that results from gravitational attraction of the Moon and Sun and other astronomical bodies acting upon the rotating Earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as tidal current, reserving the name tide for the vertical movement.

Turbidity

(1) A condition of a liquid due to fine visible material in suspension, which may not be of sufficient size to be seen as individual particles by the naked eye but which prevents the passage of light through the liquid. (2) A measure of fine suspended matter in liquids.

Tombolo

A bar or spit that connects an island to the mainland or to another island. Also applied to sand accumulation between land and a detached breakwater.

Updrift

The direction opposite that of the predominant movement of littoral materials.

Upland

Dry land area above and landward of the ordinary high water mark (OHWM). Often used as a general term to mean high land far from the coast and in the interior of the country.

Waterline

A juncture of land and sea. This line migrates, changing with the tide or other fluctuation in the water level. Where waves are present on the beach, this line is also known as the limit of backrush (approximately, the intersection of the land with the still-water level.)

Wave Height

The vertical distance between a crest and the preceding trough.

Wave Period

The time for a wave crest to traverse a distance equal to one wavelength. The time for two successive wave crests to pass a fixed point.

Wavelength

The horizontal distance between similar points on two successive waves measured perpendicular to the crest.

Wetlands

Lands whose saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities that live in the soil and on its surface (e.g. salt marsh).

Annex 1: Data Used In Shoreline Analyses

	Name	Source	Description
Base Data	50-Year Planning Window	VIMS	The 50-year planning window denotes an estimated shoreline position in 50 years. The "window" was developed using multiple datasets to achieve the most robust prediction of shoreline position within the framework of a two-dimensional simplistic spatial model. The planning window was created from the shoreline and average erosion rates of the base shoreline layer. To fill certain data gaps, the base shoreline was modified using updated conditions of shoreline protection and stability based on field surveys conducted within the past 5 years from the Maryland Shoreline Inventories. The planning window layer should be viewed in conjunction with the base shoreline layer.
	Base Shoreline	VIMS/MGS	A series of recent shorelines (1988-1995) was used by MGS to produce a shoreline coded with erosion rates. VIMS updated this dataset to reflect updated conditions of shoreline protection and stability based on field surveys conducted within the past 5 years from the Maryland Shoreline Inventories.
	Erosion Control Structures	VIMS	This dataset presents the presence and type of erosion control structures along Maryland's shoreline. Data collected describes conditions in the immediate riparian zone, the bank, and along the shore. Data collection occurred from 2002-2006.
Ecological	State Mapped Tidal Wetlands (DNR)	MDDNR	Wetlands mapped by Maryland DNR from DOQQs from 1988 to 1995
	Wetlands of Special State Concern (WSSC)	MDDNR	Wetlands of Special State Concern. Identified and regulated by MDE and based on NWI wetlands with field inspections. These are generally wetlands with rare, threatened, or endangered species or unique habitat.
	Wetland Vulnerability Modifiers	VIMS	Shoreline reaches where conditions are conducive to increases wetland vulnerability to erosion. Conditions include the presence of structures landward of wetlands within the planning window, and certain land use neighboring wetlands.
	Beaches	VIMS	The presence of beaches was identified in the Comprehensive Shoreline Inventory for Maryland, completed by VIMS. In this study, attributes were added to the spatial data to indicate the rate of erosion.
	Ecological Resources	VIMS	This layer is a compilation of a variety of ecologically related data. The layer presents how many different layers intersect at a particular location. The data included within this layer is: wetlands of special state concern (WSSC), state mapped tidal wetlands (titled DNR wetlands in EVA tool), green infrastructure hubs and corridors, critical habitat resource conservation areas, sensitive species project review areas, Federal threatened and endangered species, and natural heritage areas.

	Name	Source	Description
Socioeconomic & Cultural	Transportation	SHA	This dataset includes interstates, highways, major roads, and minor roads.
	Community Services/ Structures	VIMS	Compiled from multiple sources, including SHA, this dataset includes the location of public buildings (fire stations, hospitals, police stations, schools), and wastewater treatment plans (municipal and industrial).
	Socioeconomic	VIMS	This compiled dataset includes many data layers from multiple sources (SHPO, MDP, MDDNR): land use, county parks, private conservation properties, forest legacy easements, MD environmental trust easements, general zoning, National Register of Historic Places, MD Historic Trust Easements, inventory of historic properties.
Other Coastal Risk	Sea Level Rise Inundation*	CGIS/ MDDNR	The Sea Level Rise Inundation dataset is a derivative of high-resolution topographic data (LiDAR) that the State of Maryland, in cooperation with local and federal agencies, has acquired to identify areas vulnerable to inundation and flooding. The dataset represents inundation areas of Maryland coastal counties in the event of sea level rise. Data is not available for Harford Co., Prince George's Co., and Baltimore City. Data is available for 2-foot, 2- to 5-foot, and 5- to 10-foot sea level rise scenarios.
	Sea, Lake, and Overland Surges from Hurricanes*	USACE	This data was generated as part of the Hazards Analysis within the Hurricane Evacuation Study for the Maryland Western Shore. Storm surge zones have been developed for category 1-4 hurricanes represented by the Saffir-Simpson Scale. The storm surge zones data used in this application were generated using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model. SLOSH is a computerized model run by the National Weather Service to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes. The model creates its estimates by assessing the pressure, size, forward speed, track, and wind data from a storm. Graphical output from the model displays color-coded storm surge heights for a particular area. The calculations are applied to a specific locale's shoreline, incorporating the unique bay and river configurations, water depths, bridges, roads, and other physical features. The SLOSH MOM data is utilized. MOM is the "Maximum of Maximum." MOM output represents the highest water level or the "worst case scenario" for the entire Slosh basin.

Table A1.1. GIS datasets used in the analysis of shoreline erosion and coastal risk. Other supporting datasets have been used for cartographic purposes. Datasets NOT included in the online EVA tool are noted with an asterisk (*).

Expanded Data Descriptions

Base Data

50-Year Planning Window

The Erosion Vulnerability Assessment (EVA) developed a 50-year planning window denoting an estimated shoreline position in 50 years. The "window" was developed using multiple datasets to achieve the most accurate prediction of shoreline position within the framework of a two-dimensional simplistic spatial model. The planning window (a polygon layer) was created from the shoreline and average erosion rates of a data layer referenced as "Recent (1988-1995) Maryland Shorelines with Erosion Rate Attributes" produced by the Maryland Geological Survey, and hereafter referred to as the base shoreline. To fill certain data gaps, the base shoreline was modified using updated conditions of shoreline protection and stability based on field surveys conducted within the past 5 years from the Maryland Shoreline Inventories (aka Maryland Shoreline Situation Portfolios) produced by the Center for Coastal Resources Management, Virginia Institute of Marine Science (2002-2006). The planning window layer should be viewed in conjunction with the base shoreline layer. EVA provides a visual evaluation of risk within the planning window with a focus on ecological resources and socioeconomic resources. The 50-year planning window was incorporated into an online interactive interface. The tool contains base data layers, ecological vulnerability layers, socioeconomic vulnerability layers, and a cumulative ecological resources layer.

Base Shoreline

Using a series of recent shorelines (1988-1995), the Maryland Geological Survey (MGS) produced a recent shoreline coded with erosion rates. This shoreline was updated by the Center for Coastal Resources Management (CCRM), Virginia Institute of Marine Science to reflect the current status (2002-2006) of shoreline protection (“protected” category) and improve on the shoreline segments previously classified as “unknown” or “no data.” The Maryland Shoreline Inventories use a different shoreline as a base, so the attribute information was transferred to the MGS shoreline using ArcGIS 9.2. For a detailed description of the original MGS shoreline and contact information, see http://www.mgs.md.gov and SLMetadata.doc. For a detailed description of the Maryland Shoreline Inventories see http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/index.html and the metadata files: Maryland_Inventory_Shoreline_Condition.htm and Maryland_Inventory_Structures.htm.

Three categories from the original dataset were improved: protected (levelid = 6), unknown (levelid = 7), and no data (levelid = 8). For the protected category, regardless of the original MGS coding, the levelid was changed to 6 where the Shoreline Inventory identified six structure types: breakwater, bulkhead, riprap, debris, miscellaneous, and unconventional. In areas where the MGS shoreline was coded as protected, but there were no structures according to the Shoreline Inventory, the shoreline coding was changed to match the closest arc. For areas classified by MGS as unknown or no data, qualitative attributes associated with erosion at the bank (e.g. low erosion, high erosion, and undercut) were incorporated from the Shoreline Inventories. Low erosion segments were classified as "no change." Since most of the segments occurred in low fetch environments, high erosion and undercut segments were classified as "slight", indicative of erosion rates between 0-2 ft/year. Where there were no inventory conditions for erosion, the shoreline was recoded as "no data" (the new category 9). This shapefile is called shl_master.shp.

The shoreline condition information (locations of beaches) and erosion control structures in the Maryland Shoreline Inventory were transferred to the MGS shoreline using ArcGIS 9.2 and then manually corrected for discrepancies. These data are stored in two separate shapefiles called structure_master.shp and beach_master.shp.

Erosion Category	Average Erosion Rate (m/yr))	Average Erosion Rate (ft/yr)	Original DNR coding ('levelid')	New DNR/CCRM coding ('levelid_fn')
No change	0	0	0	0
Accretion	+0.15	+0.5	1	1
Slight	-0.3	-1	2	2
Low	-0.9	-3	3	3
Moderate	-1.8	-6	4	4
High	-3.4	-11	5	5
Protected	0	0	6	6
Unknown	0 or -0.3	0 or -1	7	Not applicable
No Data	0	0	8	9

Ecological

Wetlands (State Mapped DNR and WSSC)

The Erosion Vulnerability Assessment (EVA) assigns a qualitative index to all tidal wetlands mapped by the state of Maryland. The 50-year planning window, depicting the location of the shoreline in 50 years based on historic erosion rates, provides the basis for evaluating vulnerability of a shoreline segment to recession. This rate of recession is assumed to continue providing the shoreline is not stabilized. Given that, wetlands (i.e. polygons and lines) with boundaries that lie completely outside the planning window are not considered to be vulnerable to erosion in the next 50 years. These wetlands are not ranked and therefore not displayed in the output of the vulnerability analysis for wetlands. However, in situations where a portion of a wetland is within the planning window and a portion is outside the planning window, low risk is assigned to that portion residing outside the window and moderate vulnerability is assigned to the portion within the window. If the wetland is designated by the state of Maryland as a Wetland of

Special State Concern (WSSC), the vulnerability factor for that wetland portion partially or entirely within the planning window is elevated to "high."

Wetlands ranked moderate or high are located along a stretch of shoreline that is currently undergoing erosion. If processes continue, the wetland could be impacted in the future. The actual risk of erosion and habitat loss depends on additional factors we refer to as "modifiers." Factors such as topography, shoreline armoring, and land use decisions are all important for increasing or decreasing the potential for wetland loss due to erosion. Modifiers are discussed in further detail.

Note on mapping: wetlands may appear to extend seaward of the shoreline. This discrepancy is due to differences between shoreline data layers used as reference lines in the origination of the wetland layer versus the base shoreline used in the erosion analysis.

Wetland Vulnerability Modifiers

The Erosion Vulnerability Tool (EVA) has identified wetlands at risk based on the wetland's geographic relationship to the 50-year planning window. It is understood that surrounding features (attributes) and conditions on the landscape can modify a wetland's risk to shoreline erosion based on numerous factors. Various external datasets are used to extract conditions and attributes with the ability to increase or decrease wetland risk. The EVA model searches for places where "at risk" wetlands (wetlands within the 50-year planning window) are coincident with these attributes or conditions. These areas are highlighted in the interactive map tool for planning and management purposes. The attributes noted to affect a wetland's sustainability under erosive conditions, have themselves not been assessed for risk.

Structures built to counter bank erosion problems perhaps have the greatest potential for enhancing risk. Erosion control at the bank, landward of the wetland, is detrimental for wetland survival. These structures create barriers to the natural horizontal migration of wetlands landward, and this process has been well documented. Structures also can generate wave reflection at the structure's base, which can deepen the adjacent shallow water platform making it impossible for a wetland to maintain itself vertically or move horizontally. The result is that the wetland erodes and eventually drowns in place. Structures placed landward of the wetland to defend erosion of the upland bank face, which increase the risk to a wetland include: bulkheads, riprap, or stabilizing walls constructed of miscellaneous or unconventional material, including debris, plastics, and concrete.

In contrast, structures built seaward of the wetland can provide protection to the erosive force of wave energy. Structures such breakwaters, marsh toe revetments, and even groin fields may offer direct or indirect protection to the wetland and therefore reduce risk.

Land use in the riparian zone often dictates the anticipated management of a reach. While all management scenarios cannot be assumed, there is a tendency for managed lands to create impediments or barriers to the inland migration of natural systems like wetlands. These barriers may be erosion control structures, road networks, dwellings, or building complexes. With the high economic investment in such infrastructure, we can assume that property owners will ultimately protect the existing infrastructure and risk the wetland survival. The EVA model, therefore considers riparian land uses such as commercial, high-density residential, industrial, institutional, low-density residential, medium-density residential, and transportation to elevate the risk of a wetland found within the planning window. Current management practices now encourage protection of the wetland through living shoreline treatments in the hope to reverse this trend by offering protection to both the marsh and the riparian use.

In contrast to the above, unmanaged lands or those designated here as bare ground, beaches, brush, cropland, deciduous forest, evergreen forest, extractive, mixed forest, orchards/vineyards/horticulture, pasture, row and garden crops, water, or wetlands will reduce the risk to a wetland since the opportunity for natural maintenance of the wetland remains possible.

Beaches, regardless of land use will always serve to offer additional natural protection to the marsh and the adjacent upland. However, land use will most likely have a greater affect on determining the long-term sustainability of the wetland under erosive conditions. For this reason, beaches associated with developed lands and wetlands may slow erosion but not necessarily reduce the long-term risk to the wetland over the planning period. The model therefore does not consider the presence of beaches with respect to wetlands to be a positive modifier that reduces the risk of wetland loss.

Beaches

The Erosion Vulnerability Assessment (EVA) assigns a vulnerability factor to all beaches identified in the Comprehensive Shoreline Inventory for Maryland. The classification of vulnerability is based directly on the erosion rates calculated in the revised Maryland Geological Survey's (MGS) Shoreline Changes study that used historic and current shoreline survey positions to compute change in position. This study was revised for EVA to extend into smaller tributaries and to reflect the current state of shoreline hardening in the bay. The vulnerability index is below:

Erosion level	Average erosion rate	Beach Vulnerability
Slight	1 ft/yr	Low
Low	3 ft/yr	Moderate
Moderate or High	6 ft/yr or 11 ft/yr	High
Accretion, No Change or Protected (structure)	0 ft/yr	No Risk

Ecological Resources

The Erosion Vulnerability Assessment reviewed eight different ecologically based data layers. Without weighting or assigning independent degrees of importance to individual layers, there is nevertheless value in knowing where cumulative ecological losses of resources may be greatest. With possible numbers ranging from 1-8, this cumulative index reveals the number of ecological resources co-occurring in the 50 year planning window. The eight data layers included are:

1. MD Department of Natural Resource (MDDNR) wetlands inventory
2. MD's Wetlands of Special State Concern (WSSC)
3. Critical Habitat
4. Natural Heritage Areas
5. Sensitive Species Project Review Areas
6. Federal Threatened and Endangered Species
7. Green Infrastructure hubs and corridors
8. Beaches*

* Thickness of beach polygons is not an indication of beach width, merely of beach presence.

Socioeconomic and Cultural

Transportation

The Erosion Vulnerability Tool (EVA) has identified the transportations networks located in areas shown to be vulnerable to shoreline erosion over the next 50 years. Interstates, highways, major roads, as well as minor roads are included in this analysis. The identification of these socioeconomic indicators attempts to better understand the trade-offs in diverse management options.

Community Services/Structures

The Erosion Vulnerability Tool (EVA) has identified community services/structures vulnerable to shoreline erosion over the next 50 years based on their spatial relationship to the 50-year planning window. The socioeconomic features (attributes) that are considered in this assessment are: Buildings (fire stations, hospitals, police stations, and schools) and Wastewater Treatment Plants (municipal and industrial). In addition, structures (buildings or wastewater treatment plants) that are 10m landward of the planning window were identified as "potentially vulnerable."

Socioeconomic

The Erosion Vulnerability Tool (EVA) has identified socioeconomic features vulnerable to shoreline erosion based solely on their geographic relationship to the 50-year planning window. Various external datasets are combined into three major socioeconomic categories for the assessment: Open Space/Natural Areas, Developed Infrastructure, and Agriculture. The Open space/Natural Areas category encompasses the following data layers: county parks, private conservation properties, forest legacy easements, MD environmental trust easements, and land use corresponding to open space and natural areas, such as forest and bare ground, among others. The Developed Infrastructure category includes historic resources (MD Inventory of Historic Properties, MD Historic Trust Easements, National Register of Historic Places), general zoning, as well as land use defined as commercial, industrial, institutional, low-density residential, medium-density residential, high-density residential, and transportation. The identification of these vulnerable areas can help to prioritize coastal restoration projects, identify possible areas for conservation, and provide planning and zoning guidance to expanding waterfront communities.

Annex 2: Other Federal, State, and Local Studies and Reports

Numerous studies and reports have been prepared by the Corps, other Federal, State, and local government agencies, and academic scientists that investigated shoreline and water resources issues within the Chesapeake Bay watershed. Below is a list and description of those with particular relevance to this study. In addition, there are several ongoing Baltimore District USACE studies that cover topics pertinent to this study. Additional sources of information, which include published and non-published reports as well as Internet sources, are listed in Section XX of this report.

Corps of Engineers Studies and Reports

(1) Chesapeake Bay Shoreline Erosion Study, U.S. Army Corps of Engineers, October 1990.

The 1990 Chesapeake Bay Shoreline Erosion Study identified two major issues: (1) more than 200 miles of publicly-owned shoreline are severely eroding, threatening publicly-owned property and infrastructure; (2) and more than 4,700,000 cubic yards of sediment enter the Bay annually from shoreline erosion, contributing to exacerbated shoaling of navigation channels. Of the severely eroded areas investigated, the report identified Federal interest in protecting 23.6 miles of shoreline. The study also recommended the development of a comprehensive erosion plan for Federal, State, and local interests. It was estimated that implementation of this plan could potentially prevent 15 to 20% of the sediment derived from shoreline erosion from entering the Bay.

(2) Smith Island, Maryland, Final Integrated Feasibility Report and Environmental Assessment, U.S. Army Corps of Engineers, May 2001.

In 2001, the U.S. Army Corps of Engineers released the *Final Integrated Feasibility Report and Environmental Assessment* for Smith Island, Maryland. The report discussed the problems associated with severe shoreline loss experienced on Smith Island. The USACE proposes to construct a series of breakwaters more than 2 miles in length along the western shoreline of Martin Wildlife Refuge, and along Fog Point and Back Cove. The action would restore a measure of geologic integrity to the island, restore 1,900 acres of submerged aquatic vegetation (SAV), and protect 216 acres of emergent marsh. An additional 23 acres of marsh would be created/restored. The protected acreage of emergent marsh and restored SAV would be unprecedented in the Bay. This study is relevant because it highlights a restoration project formulated to protect the near-shore environment at a relatively large scale, emphasizing beach habitat, SAV, and marsh restoration as linked resources.

(3) Chesapeake Bay Shoreline Erosion Interim Reconnaissance Report: Part I – Sediment Behind the Dams On the Lower Susquehanna River, U.S. Army Corps of Engineers, November 2002.

Conference report language for the Chesapeake Bay Shoreline Erosion study authority directed the USACE to investigate sediment accumulation behind four hydroelectric dams on the Lower Susquehanna River, the Chesapeake Bay's largest freshwater source. The Part I reconnaissance report was certified by Headquarters USACE in December 2002. The report was prepared in conjunction with the reconnaissance study leading to the present study. The Part I reconnaissance report highlighted the potential threat of increased sediment and nutrient loads to the Upper Bay and their potential negative impact on the ecosystem and economic vitality of the region. Part I also focused on and recommended future feasibility studies of sediment accumulation behind four hydroelectric dams on the Lower Susquehanna River sediment transport, and the overall sediment management in the Chesapeake Bay.

(4) *Final Mid-Chesapeake Bay Island Ecosystem Restoration Integrated Feasibility Report & Environmental Impact Statement (EIS)*, U.S. Army Corps of Engineers, September 2008.

In 2008 a final report was produced by the Baltimore District, in partnership with the State of Maryland, Department of Transportation, Maryland Port Administration (MPA), that recommends the placement of dredged material from the Port of Baltimore navigation channel system at the eroding Barren and James Islands. This project will restore approximately 2,144 acres of remote island habitat, and provide direct protection to SAV beds.

(5) *Baltimore Harbor and Channels (MD and VA) Dredged Material Management Plan and Final Tiered Environmental Impact Statement*, U.S. Army Corps of Engineers, December 2005.

In 2005 the Baltimore District prepared a Dredged Material Management Plan (DMMP) that addressed all channels authorized under the Baltimore Harbor & Channels 50-Foot and 42-Foot projects, the Baltimore Harbor & Anchorages project, as well as non-Federal dredging requirements associated with the projects. A recommendation of the plan is a continued search for beneficial uses of dredged material, including the restoration of island and wetland habitat.

(6) National Shoreline Management Study, U.S. Army Corps of Engineers, ongoing.

The USACE began the National Shoreline Management Study in 2002, with the goal of examining the status of the Nation's shoreline for the first time in 30 years. This is being done to provide a basis for Federal actions regarding shoreline management and the study will provide a technical basis and analytical information useful in developing recommendations regarding shoreline management. The study is summarizing information about shoreline change using existing data sources, examining causes of shoreline erosion and accretion along with economic and environmental effects, identifying and describing Federal, state, and local government shore restoration and nourishment programs and resources, and exploring a systems approach to sand management.

State of Maryland Studies and Reports

(1) Maryland Geological Survey. *Shoreline change maps*. 1994-2005.

Maryland Geological Survey initiated a project to update the erosion rates calculated throughout the 20th century. The multi-phase study was undertaken to support research and management of sources of non-point source pollutants, buffer areas of critical concern, and to reduce vulnerability to coastal hazards and was funded by Maryland Coastal Programs. In 2003 the project was largely completed with updated digital shoreline positions and calculations of linear rates of shoreline erosion across the State. In 2005 the updated Shoreline Change Study and historical shorelines were provided through an interactive mapping application for coastal managers, planners, and homeowners.

(2) *State of Maryland Shore Erosion Final Report*, Shore Erosion Task Force, January 2000.

In 2000, the State of Maryland *Shore Erosion Task Force* released its *Final Report* that recognized the significance of Maryland's rapidly eroding Chesapeake Bay shoreline. The intention of the task force was to make recommendations for developing shoreline erosion control criteria and strategies, identify funding needs and sources, asses the shoreline erosion situation, increase public outreach, and develop strategies to review erosion control projects. Many of the recommendations from this task force have been incorporated into this report. The report identified many of the natural and anthropogenic causes of shoreline erosion such as increased stormwater runoff and the unintended consequences of shoreline hardening. The report suggested a 10-year timeline in which Maryland would coordinate with State and Federal agencies, involve the public, develop review criteria for future projects and construct erosion control projects.

(3) *A Sea Level Rise Response Strategy for the State of Maryland*, Maryland Department of Natural Resources-Coastal Zone Management Division, October 2000.

In 2000, the Maryland Department of Natural Resources released the *Sea Level Rise Response Strategy for the State of Maryland*. The DNR report recognized the significance of global sea level rise on the local environment. The report also recognized that the relative sea level rise rate in Maryland was higher than many other coastal locations, averaging around 2 to 4 mm per year. Relative sea level rise is defined as a combination of sea level rise and land subsidence, creating a measurable change in the landscape. This would have greatest significance for low-lying areas. The report recommended that coastal management incorporate consideration of sea level rise. The report made four recommendations that would enable comprehensive planning for the State over a 5-year timeline. The DNR report also described the importance of accurate data collection to characterize the specific challenges that come with rising sea level. Recommendations from the Sea Level Rise Strategy for agency planning included strategically aligning Federal and State agencies that are involved in watershed management, shoreline erosion, and permitting and implementation in the coastal environment. Statewide policy initiatives, data collection, and dedicated funding were identified as crucial to the success of long range planning and protection of the coastal zone in Maryland.

(4) *Climate Action Plan*, Maryland Commission on Climate Change, August 2008.

After nearly 2 years of study, the Maryland Commission on Climate Change released a Climate Action plan, detailing the effects of global warming on the State of Maryland, recommended actions to protect property and life from rising sea levels and changing weather patterns, and outlines actions to help reduce pollution from Maryland. The Commission concludes that significant economic and environmental benefits would accrue to Maryland if early, immediate actions are taken to reduce pollution. Furthermore, the report concludes that rising sea level will negatively effect wetland and wetland-dependent living resources.

(5) *Constructed Wetland for Shoreline Erosion Control: Field Assessment and Data Management*, Maryland Department of the Environment, April 2006.

The Maryland Department of the Environment (MDE) worked with the University of Maryland to evaluate wetlands built for shoreline erosion control. Project results included refined field assessment methodologies, field assessments of 80 shoreline wetland sites, and compiled data. Factors influencing the success of constructed wetlands included: sufficient light, proper fill technique and material, equal split between high and low marsh, protection of shoreline, staggered or dog-legged vents in sill, independently stabilized cliff, proper grading and sill placement, and proper maintenance.

Other Relevant Studies and Reports

(1) *State and Local Governments Plan for Development of Most Land Vulnerable to Rising Sea Level along the U.S. Atlantic Coast*, Titus, J.Gl, D.E. Hudgens, D.L. Trescott, M. Craghan, W.H. Nuckols, C.H. Hershner, J.M. Kassakian, C.J. Linn, P.G. Merritt, T.M. McCue, J.F. O'Connell, J. Tanski, and J. Wang. *Environmental Research Letters* 3:4, 2009.

USEPA working with local county governments produced a series of regionwide maps that use existing data, filtered through the local governments who plan and govern how land is used. The maps represent the likelihood that shorelines would be protected from erosion if current trends continue. The maps divide coastal low lands into four categories: developed (shore protection almost certain), intermediate (shore protection likely), undeveloped (shore protection unlikely), and conservation (no shore protection). For Maryland, USEPA obtained statewide land use, planning, and conservation data, and comprehensive plans for 9 of Maryland's coastal counties. USEPA consulted with all 16 coastal counties and the City of Baltimore about how to best interpret the data given existing statutes, regulations, and policies. The western shore of Chesapeake Bay is largely developed with shore protection almost certain, except for several military installations and parts of Calvert County, where cliff regulations prohibit shore protection to preserve habitat for endangered species. The Eastern shore and most tributaries to the bay are more lightly developed. Because of the state's Critical Areas Act, 90% of the undeveloped areas will have no more than 1 home per 20 acres, making shore protection unlikely. The maps from this study can be downloaded from risingseas.net.

(2) *Sea-Level Rise and Coastal Habitats of the Chesapeake Bay*, National Wildlife Federation, 2008.

In 2008, the National Wildlife Federation (NWF) utilized the Sea Level Affecting Marshes Model (SLAMM) to examine changes to wetland composition and shoreline position resulting from long-term sea level rise.

(3) *The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure: Phase 1 – Final Report: the District of Columbia, Maryland, North Carolina, and Virginia*, U.S. DOT Center for Climate Change and Environmental Forecasting, August 2008.

The US Department of Transportation, Center for Climate Change and Environmental Forecasting produced a study providing rough estimates of how future sea level rise and storm surge could affect the transportation infrastructure on the East Coast of the United States. In this study, transportation infrastructure includes roads, railways, and port facilities.

(4) *National Assessment of Coastal Vulnerability to Future Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast.* U.S. Geological Survey, Open-File Report 99-593. Thieler, E.R., and Hammar-Klose, E.S., 1999. http:\\woodshole.er.usgs.gov/project-pages/cvi

The USGS Coastal and Marine Geology Program produced a National Assessment that determined the relative risks due to future sea-level rise for the continental U.S. ocean coasts. Through the use of a coastal vulnerability index (CVI), the relative risk that physical changes will occur as sea-level rises is quantified based on the following criteria: tidal range, wave height, coastal slope, shoreline change, geomorphology, and historical rate of sea-level rise.

Other Federal, State, and Local Projects, Policies, and Regulations

Environmental regulations serve to maintain and restore water quality in the Bay, and to protect coastal wetlands and other highly valued aquatic habitats. Numerous projects have been constructed by various public an private entities along the Chesapeake Bay coastline and in the interior watershed to protect shorelines, control nutrient and sediment runoff into the Bay, and restore shoreline and underwater habitats.

A partnership between Maryland, Virginia, Pennsylvania, and District of Columbia, and the Federal Government was created in 1983 with the goal of protecting and restoring the Chesapeake Bay's ecosystem. This partnership is title the Chesapeake Bay Program. Maryland DNR has been a partner in the Chesapeake Bay Program since its inception while the USACE became a partner in 1984. The Bay Program members have signed several agreements setting goals for the program. In the 1987 Bay Agreement, the Chesapeake Bay Program partners set a 40% nutrient reduction goal to be accomplished by 2000, which was not met. The partners of the Bay program signed an agreement in 2000 that reaffirmed the call for a significant reduction in nutrient pollutant input to the Bay. One of the goals of this agreement is to improve water quality of the Bay and its tributaries such that future regulatory restrictions, which may otherwise be implemented by the U.S. Environmental Protection Agency, will not be required. As of 2007, 21% of water quality goals had been met. In 2003, Bay Program partners agreed to cap sediment loads entering the Bay, a reduction of 29% from the 1985 sediment loads. As of 2006, 62% of the sediment reduction goal had been achieved. There are many Federal, State, and local projects underway that are contributing in the attempt to meet these water quality goals.

1. Regulatory Policies

Federal and State laws and policies that regulate dredging and coastal developments provide a measure of protection to aquatic habitats. These regulations cover both point and non-point pollution sources. Point sources of pollution are sources that can be attributed to a specific physical location, often an identifiable, end of pipe “point”. The largest point sources of nutrient pollution are wastewater treatment plants. Non-point sources are pollution sources that are not attributable to any specific location; rather they are the aggregate result of many separate factors and practices. Non-point sources include agricultural areas, suburban development, storm sewers, and impervious surfaces. Point sources are strictly controlled through Federal and State laws that govern releases of nutrient and sediment pollutants into the waters of the Bay and its tributaries. Non-point sources are also governed through numerous Federal and State programs, although they are more difficult to develop and implement. In addition, fisheries are strictly regulated. Oysters are harvested commercially in Maryland, but regulations limit the harvests, and are designed to maintain oyster populations. Federal and State law strictly protect coastal wetlands. Development in the Critical Area along Chesapeake Bay within Maryland is controlled to protect the Bay.

Additionally, shoreline erosion control projects are regulated by Tidal Wetlands Act of 1970, and the Maryland Living Shorelines Protection Act of 2008, which extends the right of waterfront property owners to protect their property against shoreline erosion, but requires the use on nonstructural shoreline stabilization methods in tidal wetlands. Exceptions may be made where the Maryland Department of the Environment has determined that structural shoreline stabilization methods are appropriate, and in areas where property owners can demonstrate that living shorelines are not feasible. Many other state and local regulations also govern activities along the Chesapeake Bay shoreline in Maryland.

2. Shoreline Protection Projects

Numerous private and public projects have been constructed to protect erosional shorelines where property and/or infrastructure were threatened. Projects are concentrated in urban and suburban areas, but also occur in agricultural areas. Shoreline protection projects range from living shoreline type projects, which are preferred, to rudimentary shoreline debris and rubble piles to groins, bulkheads, revetments, seawalls, and breakwaters. Many of the latter type projects have been constructed historically, but may not be appropriate as knowledge increases and regulations change.

The Corps 1990 Shoreline Erosion Report identified 15 potential project sites covering 9.3 miles of Bay shoreline. Of these 15 sites, 10 did not receive the necessary non-Federal financial support for further investigation and design work, and only 5 were evaluated for potential projects. Two of these sites were rejected because public access requirements mandated for receipt of Federal funding could not be met. The study also involved construction of several innovative erosion control measures and monitoring of several such measures that had been built previously. As an outcome of the 1990 report, three demonstration projects were constructed under the USACE’s Continuing Authorities Program (CAP).

The three projects were authorized under Section 14 of the Flood Control Act of 1946, as amended. These projects tested innovative techniques for controlling shoreline erosion. Demonstration projects were constructed at Middle Hooper Island, Solomon's Island, and McCready's Point Road in Maryland.

The Maryland DNR Living Shorelines program has been involved in many shoreline protection projects across the Bay in Maryland. For example, MD DNR was involved with projects at the Chesapeake Bay Education Center in Queen Anne's County, the London Town Publik House and Garden in Anne Arundel County, and the Arlington Echo Outdoor Education Center in Anne Arundel County. MD DNR has had involvement in numerous other projects and its role in facilitation, training, funding support, and demonstration projects continues.

The Maryland Department of the Environment has several programs that support shoreline stabilization projects and marsh creation. The Wetlands and Waterways Program provided funding and re-constructed the shoreline of Bear Creek at Fleming Park in Baltimore City. MDE also was a partner with multiple other agencies for creation, shoreline stabilization, and floodplain re-connection along Marshyhope Creek in Caroline County and the Town of Federalsburg. MDE also provides funds as part of a parnerhsip with the Chesapeake Bay Trust to fund marsh creation projects.

3. Nutrient and Sediment Reduction

Substantial efforts to control the delivery of nutrients and sediment from anthropogenic sources to the Bay have been and are being undertaken. Regulations governing releases of nutrients and sediment were described in sub-section (1) above. Additional efforts vary by nutrient source and land use, and are summarized below. The information in this subsection is largely taken from information prepared by the Chesapeake Bay Program.

Agricultural Best Management Practices (BMPs): these include a range of activities that reduce or eliminate soil loss, prevent runoff, and provide for proper application of fertilizers to cropland. BMPs include cover crops, no-till farming, and stream buffers.

Animal Water Management: this includes manure storage structures, runoff controls for barnyards, guttering and nutrient management. These systems address the handling, storage, and transport of animal waste, as well as its utilization as fertilizer on cropland.

Urban Best Management Practices: these BMPs are undertaken on industrial, commercial, and residential lands. These practices include erosion and sediment control, stormwater management, and septic system maintenance.

Point Source Controls: although current releases of nutrient and sediment pollutants from these sources are already regulated, efforts to further reduce the quantities of pollutants released are underway. These efforts include upgrading existing wastewater treatment plants, and providing biological nutrient removal to existing wastewater treatment plants.

4. Habitat Restoration

A wide array of public and private efforts to restore bay oyster reef, SAV bed, shoreline, tidal and non-tidal wetland, and stream habitats are underway in the Bay watershed. These projects will benefit a wide array of fish and wildlife species. Habitat restoration projects in the Bay watershed often have the additional purpose/benefit of reducing nutrient/sediment loads to the Bay. Habitat restoration projects also often have the dual purpose by providing a beneficial use for dredged material.

Of particular relevance to this study, the Maryland DNR now has a living shorelines program, which promotes environmentally sensitive methods to protect human property and infrastructure while also maintaining shoreline habitats. This program assists property owners with project design and implementation, and has evaluated successes and failures for projects across the bay region.

The USACE has been involved in a comprehensive, multi-agency effort to improve the native oyster population in both the Maryland and Virginia portions of the Bay. The Chesapeake Bay Oyster Recovery Project is a multi-year plan of integrated activities. These activities include restoring oyster bars, using oyster spat from hatcheries to seed oyster bars, and monitoring for disease, survival, and growth. The project has resulted in the construction of several seed bars and new oyster bars in the Bay and provided for their monitoring. The project is organized into two phases. Phase I lasted from 1997 to 2003 with monitoring until 2004. Phase II is ongoing and includes a long-term master plan for oyster recovery and monitoring.

Annex 3: Agency Coordination

This section contains a summary of interagency coordination efforts external to USACE & DNR study team and contractors during the execution of the CBSE study from 2005 to 2009. In some cases, study team meetings are listed when representatives of other agencies attended for purposes of interagency coordination.

Date	Organization/Agency	Summary Pertinent to CBSE Study
Feb 11, 2004	CBP Sediment Workgroup.	J. Kapusnick (USACE) and Audra Luscher (Md DNR) attended meeting in Annapolis. Discussed need for coordination with Sediment Workgroup on ongoing USACE/MdDNR efforts related to shoreline erosion: working to develop a Maryland Inventory of Shorelines and Problems.
November 30, 2004	Md Dept. of Natural Resources, Md. Dept. of the Environment, Md Board of Public Works	USACE representatives met with Maryland agency representatives to introduce and discuss structure of CBSE Study and how to compliment ongoing state efforts. Discussed preparation of homeowners' guidebook as study product.
January 11, 2005	MDE	Discussed homeowners' guidebook.
April 26, 2005	Keely Clifford / USEPA	Email from C. Spaur. Provided comments on draft Tidal Sediment Guidelines prepared by CBP Sediment Workgroup.
May 20, 2005	Nancy Simon / USGS	Email to C. Spaur. Provided information on factors controlling distribution of phosphorus in watershed sediments and waters. Phosphorus is readily taken up by living things, and typically cycled multiple times from source in watershed to sink in Bay. Phosphorus adsorption to particles controlled by iron.
May 23, 2005	Nancy Simon / US Geological Survey	Email to C. Spaur. Provided information on phosphorus distribution in sediments of Popes Creek and Pocomoke River watersheds. Phosphorus content largely a function of poorly crystalline iron content.
June 9, 2005	US Fish and Wildlife Service, MD DNR, MDE	USACE Planning Division and Regulatory Branch representatives met resource agency representatives to discuss shore erosion control project impacts on Puritan tiger beetle. Discussed design, feasibility, and funding for alternatives to revetments for controlling shore erosion in Puritan tiger beetle habitat. Discussed permitting potential proposed private shoreline stabilization projects at Grove Point.
July/August 2005	Representatives of USEPA, Md. DNR, USFWS, VIMS, NOAA, MDE	Draft electronic copies of homeowners' guidebook emailed to resource agency representatives for review.
July 28, 2005	MDE, DNR	Meeting to discuss draft homeowners' guidebook.
Aug. 19, 2005	Denise Clearwater / MDE	Email to S. Kopecky and C. Spaur. Provided comments on draft homeowners' guidebook. Expressed serious concerns about contents.

Oct. 2005	Representatives of USEPA, Md. DNR, USFWS, VIMS, NOAA, MDE	Draft copies of homeowners' guidebook distributed electronically to resource agency representatives for comment.
October 27, 2005	CBP Sediment Workgroup	Meeting in Annapolis. C. Spaur and J. Kapusnick gave presentation covering summary of Md. shoreline conditions from VIMS inventory and on proposed/ongoing efforts of CBSE Study
October 31, 2005	Conor Shea / USFWS	Email to S. Kopecky. Provided comments on draft homeowners' guidebook.
Nov. 1, 2005	Denise Clearwater / MDE	Email to S. Kopecky. Provided comments on draft homeowners' guidebook. Expressed serious concerns. Recommend a meeting between the USACE, MDE, and DNR to resolve some of the issues raised.
Nov. 4, 2005	Rick Ayella / MDE; Tom Brower / DNR; Audra Luscher / DNR; Woody Francis / USACE; C. Spaur / USACE; S. Kopecky / USCE; K. Nook / USACE	Meeting at Michael Baker, Jr., Inc. office. Discussed draft homeowners' guidebook. Group expressed general dissatisfaction with draft product in current state. Attendees discussed means to improve review process.
February 9 & 10, 2006	CBP STAC	J. Kapusnick and C. Spaur attended CBP STAC Workshop on Assessing Cumulative Impacts of Shoreline Modification. Provided brief overview of CBSE Study.
Feb. 23, 2006	CBP Sediment Workgroup	J. Kapusnick participated in meeting via conference call.
Mar. 21, 2006	Bryan Watts / College of William and Mary, Virginia	Email to C. Spaur. Provided summary information on 1995&6 data set on birds nesting in bluffs and banks of Chesapeake Bay shoreline.
Mar. 27, 2006	Jim Titus / USEPA	Email to C. Spaur seeking USACE review of USEPA documents on topic of loss of tidal marsh to sea level rise.
March to April 2006	USFWS	USACE and USFWS representatives developed Scope of Work for USFWS to provide support to CBSE Study. USFWS to prepare Planning Aid Report on Bay shoreline-dependent species.
Apr. 27, 2006	CBP Sediment Workgroup	J. Kapusnick participated in meeting in Annapolis.
June 14, 2006	Lynn Davidson / DNR; George Ruddy, USFWS; Leslie Gerlich USFWS	Meeting with USACE representatives in Annapolis. Reviewed CBSE study components and ongoing efforts (master plan, homeowners' guidebook, VIMS support, wave energy analysis). Discussed Md DNR Heritage Program GIS support for USFWS PAR preparation.
June 27, 2006	George Ruddy / USFWS; Lynn Davidson / DNR Heritage	Email with USACE and MdDNR study team members discussing preparation of GIS and inventory data so that USFWS could prepare PAR focused on shoreline dependent spp.

July 26, 2006	Dr. Doug Lipton, resource economist / Univ of MD	Phone conversation with C. Tennity. Discussed economic effects of eroding shorelines and stabilization structures on properties and structures. Also discussed possible social effects. Discussed what studies would be necessary to evaluate this relationship, and that this could be useful ancillary study for CBSE Study.
Aug. 21, 2006	George Ruddy / USFWS	George Ruddy attended CBSE study team meeting. Discussed northeastern beach tiger beetle and potential beach nourishment project.
August 22, 2006	Robert Zepp / USFWS	Letter to Colonel Mueller. Provided Draft Planning Aid Report "Prominent Shoreline-Dependent Species" to Baltimore District.
Sept. 21, 2006	CBP Sediment Workgroup	J. Kapusnick and C. Tennity attended meeting in Annapolis. C. Spaur attended by conference call. Discussed sediment provenance information needs and interagency draft text prepared for Sediment Workgroup Sedimentsheds Report.
Oct. 26, 2006	CBP Sediment Workgroup	K. Brennan, T. Myrah, J. Kapusnick, C. Spaur (USACE) and A. Luscher, Catherine McCall (DNR) attended meeting in Annapolis. J. Kapusnick and A. Luscher gave presentation on CBSE Study components, structure, and status of efforts. Group discussed how CBSE Study fit in with ongoing Sediment Workgroup sediments efforts. Sediment Workgroup members agreed to write proposal to USACE/ DNR regarding specific sediment/water clarity relationships work is needed on.
November 28. 2006	George Ruddy / USFWS	C. Spaur E-mail to G. Ruddy. Provided USACE and Md DNR comments on draft PAR.
Dec. 12, 2006	CBP Sediment Workgroup	C. Spaur and K. Nook attended meeting in Annapolis. Provided update on CBSE Study efforts, including EVA work by VIMS. Discussed potential sediment provenance study to be undertaken by NOAA.
January 2007	USFWS	Final Planning Aid Report "Prominent Shoreline-Dependent Species" provided to Baltimore District.
Jan. 30 & 31, 2007	CBP STAC	C. Spaur participated in Sedimentsheds Workshop in Annapolis. Discussed links between impaired water clarity and sediment in Chesapeake Bay. Fine-grained sediment in water column that impairs water clarity likely not settling because of "organic soup." Need to better understand what changed in Bay to cause sediment not to settle compared to historic times when equal or greater loads were entering Bay but sediment apparently had minimal detrimental impact on Bay. Sand from eroding shorelines of critical importance for SAV bed establishment and maintenance.
March 1, 2007	CBP Sediment Workgroup	C. Spaur attended meeting in Annapolis. Discussed minutes from January STAC meeting, finalizing Sedimentsheds report, and research needs to better understand relationship between impaired water clarity and sediments.
Apr. 26, 2007	CBP Sediment Workgroup	C. Spaur attended meeting in Annapolis. Reviewed draft final Sedimentsheds report. Discussed watershed sources of sediments. Discussed future workgroup workplan.

May 1, 2007	Federal Register	Notice of Intent that USACE would prepare a *Draft Environmental Impact Statement* for the CBSE Study published.
May 24, 2007	CBP Sediment Workgroup	C. Spaur and J. Trulick participated in conference call. Discussed workgroup workplan. Discussed sources of information on historic sediment loading rates.
June 2007	U.S. E.P.A.	C. Spaur reviewed and provided comments on draft publication "Maps of Lands Close to Sea Level along the Middle Atlantic Coast of the United States: An Elevation Data Set to Use While Waiting for LIDAR."
July 10 & 11, 2007	CBP Sediment Workgroup	C. Spaur attended meeting in Annapolis. Reviewed progress of Chesapeake Bay Model and suspended sediment.
July 12, 2007	Bruce Michael, DNR	E-mail to C. Spaur stating concurred with emerging consensus that SAV decline primarily related to nutrient loading and oyster loss. Bay management strategies should focus on N and P loading reductions.
Oct. 9, 2007	CBP Sediment Workgroup	C. Spaur and J. Trulick participated via conference call. Discussed watershed sediment sources and research needs. Announced that USACE had decided not to fund sediment provenance study since methods and results in early experimental stages. Practical application to solving sediment problems highly unlikely.
November 2007	U.S. Climate Change Science Program	C. Spaur reviewed and provided comments on "Expert Draft Synthesis and Assessment Product 4.1 document: Coastal Sensitivity to Sea-Level Rise. A Focus on the Mid-Atlantic Region."
Nov. 21, 2008	CBP Sediment Workgroup	C. Spaur attended meeting in Annapolis. Discussed sediment scoping scenarios being run in Chesapeake Bay Model and how to incorporate shoreline erosion.
Jan. 13, 2009	CBP Sediment Workgroup	C. Spaur attended meeting in Annapolis. Discussed Chesapeake Bay Model sediment scoping scenarios and data on protected shorelines.
May 28 & 29, 2009	CBP STAC	C. Spaur participated in Tidal Sediments Workshop in Annapolis. Workshop reviewed relationship between impaired water clarity and suspended sediments. Focus was on impacts of eutrophication driving reduced sediment settling rate. Watershed loading and shoreline erosion of less importance.
Aug. 21, 2009	Representatives of MDE & DNR	Meeting in Baltimore. Reviewed and discussed ongoing shoreline management efforts of each agency. MDE will review draft shoreline management guide.

Note: Minutes of CBP Sediment Workgroup and STAC meetings available online at CBP Calendar of Events by date of event at http://archive.chesapeakebay.net/calendar.cfm

Nov. 17, 2009	Representatives of MDE & DNR	Meeting in Baltimore. Carl Cerco of ERDC gave summary presentation reviewing findings of previously-completed wave energy modeling effort and interrelated findings of statistical study. Although there are enormous scaling issues to surmount when translating regional information to specific sites, general guidelines derived from this scale are likely the most practical basis for shoreline permitting decisions since the state can't call in a team of physical scientists to measure and compute wave energy for every shoreline segment.
Nov. 24, 2009	MDE	E-mail to A. Roach. MDE provided comments on version 3 of draft shoreline management guide.
Aug. 6, 2010	MDE	E-mail to A. Roach. MDE provided comments on version 4 of draft shoreline management guide.

Annex 4: Funding Opportunities

Numerous sources of funding may be available to state and local governments, non-profit groups, and private entities to help plan, design, and build shoreline protection projects. The following table lists some of the funding that may be available: some as cost-share project funding, others in the form of grants and low-interest loans. Many programs have restrictions on the type of project, funding limits, and organizations that may be funded.

For projects that have been identified as potentially in the Federal Interest, in this study many may have possibilities as being funded under the USACE Continuing Authorities Program (CAP) Section 206 Aquatic Ecosystem Restoration. Living shoreline programs that restore and create wetland habitat are prime candidates. CAP Section 14 emergency streambank protection may be appropriate for shoreline areas where erosion may threaten infrastructure or buildings. Implementation of projects as regional sets may require specific authority under the General Investigations program.

Assistance with locating sources of funding for shoreline projects may also be obtained from the Maryland Eastern Shore Resource Conservation and Development Council (www.md-esrcd.org).

Financial Assistance Programs For Shoreline Protection and Restoration				
Program	Type	Purpose	Notes	Contact Information
United States Army Corps of Engineers				
Continuing Authorities Program (CAP): Section 14: Emergency Streambank Protection	65/35% Cost share - $1,500,000 Federal Limit	Protection of public and non-profit facilities	Government and non-profits	www.nab.usace.army.mil/whatwedo/civwks/cap.htm
CAP Section 111: Mitigation of Shore Damage	Variable cost-share - $5,000,000 Federal limit	Damage attributable to a Federal navigation project	Government and non-profits	www.nab.usace.army.mil/whatwedo/civwks/cap.htm
CAP Section 204: Beneficial Uses of Dredged Material for Ecosystem Restoration	75/25% cost share	Restoration and creation of aquatic habitat associated with dredged material from an authorized Federal navigation project	Government and non-profits	www.nab.usace.army.mil/whatwedo/civwks/cap.htm
CAP Section 206: Aquatic Ecosystem Restoration	65/35% cost share - $5,000,000 Federal limit	Restore degraded aquatic ecosystem	Government and non-profits	www.nab.usace.army.mil/whatwedo/civwks/cap.htm
Section 510: Chesapeake Bay Environmental Restoration, MD, PA, & VA	75/25% cost share	Provide environmental assistance to design and construct projects in the Bay watershed	Government and non-profits	www.nab.usace.army.mil

Maryland Department of Natural Resources				
Non-structural Erosion Control	Zero Interest Loans	All land owners eligible; 100% for local governments; $25,000 maximum for private owners		Shore Erosion Control Program Phone: 410-260-8523 www.dnr.state.md.us/grantsandloans/sec.html
Maryland Department of the Environment				
Linked Deposit Program	Low Interest Loans	All property owners and all types of projects	Water quality capital improvements	Water Quality Financing Administration www.mde.state.md.us/programs/waterprograms/water_quality_finance/link_deposit/index.asp
Water Quality Revolving Loan Fund (WQRLF)	Low Interest Loan	Public and Private Entities	Low-interest loans to improve water quality from non-point sources (in part)	Water Quality Financing Administration http://www.mde.state.md.us/Programs/WaterPrograms/Water_Quality_Finance/Water_Quality_Fund/index.asp
Chesapeake Bay Trust				
Living Shoreline Initiative, General Program	50/50 Preferred Match	Community projects, Local governments, Non-profits	Grant program has specific application deadlines	Phone: 410-974-2941 Email: postermater@cbtrust.org www.chesapeakebaytrust.org
Fish America				
CBT/FAF Partnership	Cost-Share, Variable Rate	Community Projects, Local Government, Non-Profit	Grant program has specific application deadlines	www.fishamerica.org
National Oceanic and Atmospheric Administration				
Restoration Center	Cost-Share, Variable Rate	Community Projects, Local government, Non-profits		www.nmfs.noaa.gov/habitat/restoration
National Fish & Wildlife Foundation				
Small Watershed Grants	Cost-Share, Variable rate	Community Projects, Local governments, Non-profits	Grant program has specific application deadlines	www.nfwf.org/