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# SEDIMENT IN THE CHESAPEAKE BAY AND MANAGEMENT ISSUES: TIDAL EROSION PROCESSES

**Prepared by the Tidal Sediment Task Force of the Sediment Workgroup under the Chesapeake Bay Program, Nutrient Subcommittee**

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## EXECUTIVE SUMMARY


In 2003, the Chesapeake Bay Program partners agreed to reduce upland sediment pollution to help achieve the water clarity in tidal shallow water habitats necessary for restoring 185,000 acres of submerged aquatic vegetation (SAV). These goals, adopted as loading caps allocated by major tributary basins by jurisdiction, were based on sediment load reductions estimated from management actions directed toward reducing phosphorous runoff. Sediment is the third biggest pollutant to the Bay and its tributaries. Excess sediment in the water column is a key contributor to degraded water quality and damages critical habitats (e.g. SAV beds and oysters bars) and living resources (shellfish, finfish and waterfowl). Suspended sediment reduces the amount of light available to support healthy and abundant SAV communities.

There are many sources of sediment in the Chesapeake Bay. These include, but are not limited to, upland surfaces, stream corridors, shorelines, ocean input and internal biogenic production. It is estimated that 57 percent of the total sediment load into the Chesapeake Bay is from **tidal erosion.** Tidal erosion is the combination of both **fastland** erosion (land above tidal water, often called shoreline) and **nearshore** erosion (the shallow water close to shoreline). The remaining 43 percent of the estimated sediment load into the Bay is from upland or watershed sources and oceanic input.

A primary goal of reducing sediment pollution in the Chesapeake Bay is to improve water clarity to restore SAV. While there is a clear relationship between tidal erosion of fine-grained sediments and water clarity in areas immediately adjacent to eroding shorelines, no relationship has been established between a rapidly eroding shoreline and the survivability of SAV in adjacent waters. The current understanding of sediment loads from these sources and adjacent tidal water quality effects is incomplete. Given the uncertainties surrounding tidal erosion, the partners did not include tidal sediment in the sediment cap load allocations they agreed to in 2003.

The Chesapeake Bay Program has created maps of the tidal portions of each tributary basin that highlight the locations of significant resources. These include SAV restoration zones based on the historical distribution of SAV, historic oyster beds and wetlands. These maps may be viewed as large PDF files (up to 4.6 mb each for 13 different tributary basins) on the Internet at: ftp://ftp.chesapeakebay.net/tsgm/ which may help identify and prioritize potential tidal sediment reduction areas and create suitable SAV habitat to help meet the 185,000 acre SAV restoration goal.

The tributary teams should explore a comprehensive suite of management actions to achieve local water clarity and SAV restoration goals. Upland sediment controls alone are insufficient to achieve these goals in some areas, thus the tributary teams should assess varied and innovative methods to achieve both water clarity and SAV regrowth in such areas.

To help restore the Chesapeake Bay we must treat our shorelines differently. We need to protect or restore our shorelines' natural riparian buffers and do a better job of managing shoreline development so that it does not exacerbate tidal erosion. We need to consider implementing environmentally sensitive or living shorelines to protect shorelines experiencing erosion of two feet or less per year. Where severe erosion is occurring and living shorelines are not possible, hard structures may be considered. Finally, there are eroding shorelines where no action should be taken if the eroded shorelines are replenishing beaches or providing a unique habitat for endangered species. Please read the following full report for detailed information and resources to help understand shoreline management options for your tributary.

## INTRODUCTION

This document addresses six important questions and provides regional contacts and resources for further study and information. It provides useful background information on sediment processes and data that can help tributary teams determine the effects of tidal sediment in their watershed and help assess whether reductions in tidal sediment input may be effective in meeting the sediment allocation cap loads. This document also can serve as a general targeting and prioritization tool for shoreline management and sediment controls that can improve water quality and help restore and protect valuable living resources.

## BACKGROUND

Tidal Erosion is the combination of both fastland erosion (land above tidal water, often called shoreline erosion) and nearshore erosion (the shallow water close to an eroding shoreline). Tidal erosion can present both environmental and economic problems. Sea level rise, land subsidence and increasing rates of shoreline development intensify tidal erosion, causing property loss and water quality degradation.

It is imperative that decision makers and landowners understand the nuances and long-term benefits and effects of shoreline management. This document also is intended to provide a brief overview of factors that should be considered in evaluating a proposed tidal erosion control practice and to prioritize the expenditures of resources to maximize the return in terms of meeting tributary strategy goals.

Private landowners control approximately 85 percent of Chesapeake Bay's shoreline (Claggett 2005). Although tidal erosion is a natural process, anthropogenic activities make tidal erosion worse. At the same time, man-made shoreline development inhibits the Bay shoreline's natural progression. If there were no shoreline development, then as the fastland continued to erode, the beaches and tidal wetlands would continue to move inland as the shoreline retreats and sea level rises, as they have done for thousands of years. Today, however, beaches are no longer present and wetlands can no longer form in the many shoreline areas that have been hardened and developed. Installing bulkheads usually increases nearshore erosion. To help restore the Chesapeake Bay we must treat our shorelines differently by implementing environmentally sensitive or living shorelines, which will protect the land, reduce detrimental erosion and create or improve habitats conducive to SAV and other living resources of the Bay.

The Maryland Shore Erosion Task Force estimated that more than 260 acres of tidal shoreline are lost each year in Maryland (State of Maryland Shore Erosion Task Force 2000). This translates into an estimated 4.7 million cubic yards of sediment delivered to the Bay. As development along the shore continues, each year more of the shoreline is protected or hardened. It is estimated that each year, in the 10 years preceding 2000, 18 miles of shoreline were hardened in Virginia (Virginia Wetlands Report 2000). In Maryland, more than 300 miles of tidal shoreline were armored between 1978 and 1997 (Titus 1998). A hardened shoreline does protect property, and sometimes it is the best solution in high-energy areas, however it does not provide a viable or natural habitat for the Bay's living resources. Often shorelines are unnecessarily hardened in areas that have low erosion rates. In areas experiencing erosion of two feet per year or less, nonstructural or bioengineering shore erosion controls which create protective vegetative buffers should be considered as a more environmentally sensitive way to protect shorelines, reduce erosion and help provide good habitat. The Army Corps of Engineers estimated that for every dollar spent to control tidal erosion, as much as $1.75 is returned to the economy in the form of improvements to resources, including SAV, fish, benthic organisms, shellfish, waterfowl and wetland habitat (Army Corps of Engineers 1990).

**Question 1: What are the tidal sediment processes in the Chesapeake Bay?**

Managing the Chesapeake Bay's shorelines should start with an understanding of how today's shorelines reached their present condition. The current Chesapeake Bay estuarine system, with more than 9,000 miles of tidal shoreline is considered geologically young. Approximately 15,000 years ago the ocean coast was about 60 miles east of its present location, and sea level was about 300 feet lower. The coastal plain was broad and low. The estuarine system took the form of a meandering series of rivers working their way to the coast. As sea level gradually rose over the centuries, the rivers were inundated with ocean water flooding the now Chesapeake Bay causing the shorelines to recede inland. In geologic terms, these ancient river channels and their tributaries are referred to as drowned river valleys (Hardaway and Byrne 1999). Relative sea level continues to rise in the Chesapeake Bay due to a variety of factors, including land subsidence and global sea level rise. Over the past century sea level has risen over one foot, and it may rise by as much as two to three feet in the next 100 years (Leatherman et al. 1995).

The slow rise in sea level is one of two primary long-term processes that cause the shoreline to recede; the other process is wave action. Waves mold the shape and position of the shore as they erode and transport sediments from one part of the shore to another. Such reshaping is particularly noticeable after a severe northeast storm or the occasional hurricane. Such storms can induce a short-term, super-elevation of water level known as storm surge, and powerful waves. During these storms, the high water level and aggressive waves often reach high, upland banks out of the range of normal tides and waves. Thus, fastland erosion, often called shore erosion, is caused by forces that are both passive (long-term rise in sea level and subsequent drowning of river valleys) and active (storm-induced high sea level and large waves) (Hardaway and Byrne 1999). A natural consequence of these two processes has been the continued relocation (usually recession) of the shoreline, as illustrated in Figure 1.

**Figure 1.** Example of changing shorelines at Tilghman Island, Maryland overlaid on a 1989 color infrared photograph of the island. The white line indicates the shoreline position in 1842, the blue in 1945 and the yellow in 1989. (Source: Maryland Geological Survey)

Tidal erosion is a significant source of suspended sediment in many portions of the Chesapeake Bay and its tidal tributaries (Figure 2). While tidal erosion is primarily a direct consequence of wind and wave action (exacerbated when shorelines are denuded of their historic forest cover and other natural buffer vegetation), the continued rise in sea level permits these agents to affect the shoreline at progressively higher levels over time, causing continued erosion. Tidal erosion should be viewed as an integral part of the natural ecosystem processes in the Bay and a necessary component of a properly functioning ecosystem. However, excess sediment delivered from many sources, including tidal erosion, is directly linked to degraded water quality and has adverse effects on critical habitats such as SAV beds and living resources such as shellfish and finfish in the Chesapeake Bay and its watershed (Langland and Cronin 2003).

An often-neglected source of eroding sediments in the shallow tidal waters of the Bay and its tributaries is the erosion of the bottom sediments in shallow waters immediately in front of eroding shores as shown in Figure 2. This is called nearshore erosion. Hardened shorelines, particularly bulkheaded shorelines, usually increase nearshore erosion, while slowing or preventing fastland erosion during normal weather. The nearshore sediments are eroded to a water depth corresponding to the base of wave action. While this depth and its distance offshore are highly variable in the Bay, the average maximum water depth in which nearshore erosion can occur has been estimated to be 8 feet (Army Corps of Engineers 1990). The Army Corps of Engineers Shore Erosion Study in 1986 estimated that of the total sediment delivered to the Bay by tidal erosion, nearshore erosion contributed 57 percent and fastland erosion 43 percent (Figure 2). In the middle portions of the Bay, distant from major watershed sediment sources and the ocean sources near the Bay mouth, the relative contribution of sediment from tidal erosion is highest. SAV helps stabilize these bottom sediments, provides a protective nursery for many aquatic organisms and is a valuable food source for waterfowl.

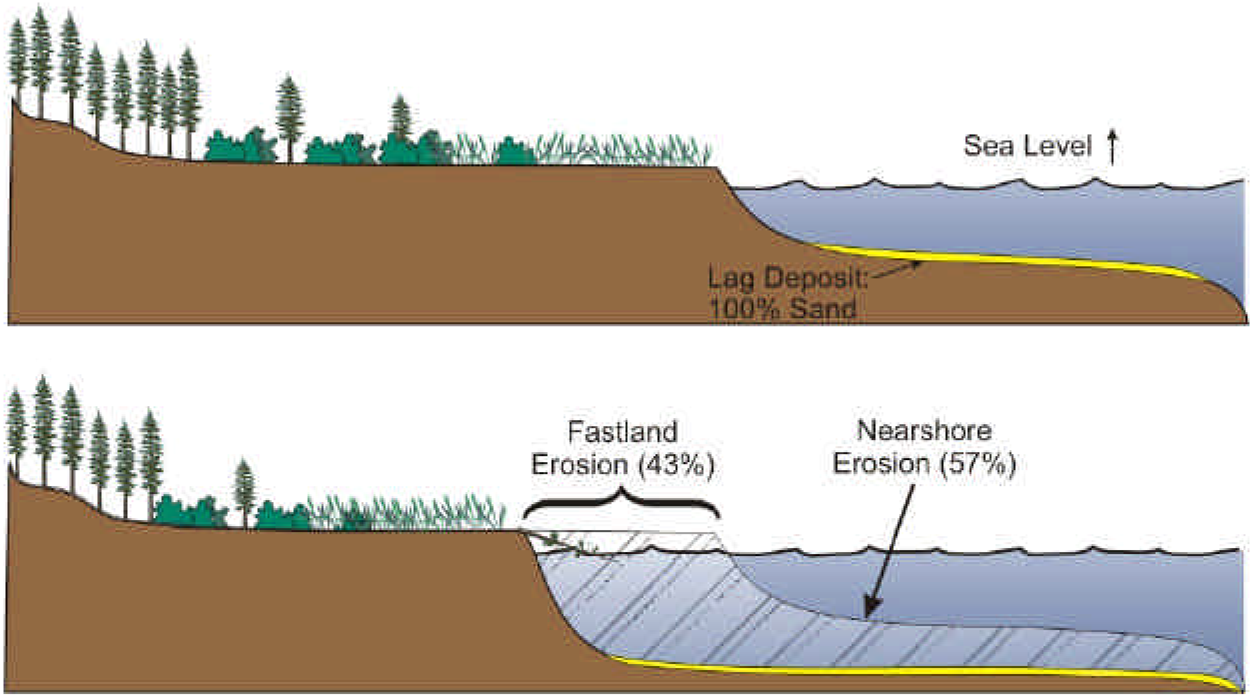


**Figure 2.** Cross-sectional view of tidal erosion, indicating the relative contributions of fastland erosion and nearshore erosion to the sediment load to the estuary. (Source: Maryland Geological Survey modified from U.S. Army Corps of Engineers 1990).

Not all portions of the shorelines in the Chesapeake Bay are eroding at equal rates, and in the short term in some regions, shorelines are accreting (e.g., gaining new sediment deposits). Over long time scales all the Bay shorelines will continue to erode as long as sea level continues to rise, but localized exceptions occur. Areas where the shorelines are accreting are generally quite small, but may seem large from a local perspective. These accreting shorelines are generally located in places where there is a large source of sediment from an adjacent eroding shoreline. If the eroding shoreline has a significant proportion of sand- sized materials and its orientation relative to the wind and waves result in the movement of that sand along the shoreline, then the sand can be transported along the shore until reaching an area of accumulation. Examples in Maryland include the Cove Point and Flag Pond spits along Calvert Cliffs and Point Patience on the Patuxent River. One example in Virginia is Kiptopeke State Park on the lower eastern shore of Virginia.

Tidal erosion contributes various sediment sizes to the estuary, ranging from relatively coarse gravel and sand-sized particles to finer particles, such as silts and clays. These sediment particles serve a variety of functions in the estuarine system, which can have both negative and positive consequences.

Gravel-sized particles are very rare in the estuary, because the rivers do not have sufficient energy to move gravel into and through their tidal portions, and sediment originating from eroding shorelines rarely contains gravel-sized particles. Areas where gravels are found form a unique habitat type in the Bay and can be attractive to a variety of fish species that use that habitat.

Sand is more widely distributed than gravel on the current Bay bottom but is still limited to certain areas. In the southern portions of the Bay near the mouth, sand is relatively common in the eroding shorelines and banks and is present in sufficient amounts to form beaches and occasionally dunes where those shorelines are eroding. Further north in the central and upper reaches of the Bay, sand becomes less common and the occurrence of beaches is more restricted. This is particularly true in the central Eastern Shore, including the Choptank River and upper Tangier Sound. Here the sand beaches form a rare habitat sought by many species for feeding and nesting, most notably terrapins and horseshoe crabs.

As they do in the case of gravels, the Bay's tributary rivers lack the energy to deliver sandy particles into the lower tributaries and mainstream. The presence of sandy beaches also serves to buffer the shorelines from continued wave-induced erosion because the sloping beaches are effective at absorbing wave energy. Sand also can be transported along stretches of shoreline, forming beaches in down-drift areas adjacent to eroding areas. Preventing tidal erosion – a significant source of sand in these areas - can eliminate the adjacent beaches, resulting in an increase in the erosion rate of the adjacent area.

The finest silt and clay-sized particles may be transported long distances in the Chesapeake Bay because they settle very slowly through the water column. These fine particles can have positive environmental effects because they can be transported to and retained within tidal marshes, thus enhancing the marshes' ability to keep pace with continued sea-level rise. However, fine-grained sediments can most negatively impact the ecosystem when their concentrations are high. These negative impacts occur because sediment clouds the water, which interferes with filter feeding organisms and SAV growth, and because these sediments often retain and transport anthropogenic contaminants such as toxic substances, nitrogen and phosphorus.

Both Maryland and Virginia scientists are moving toward gaining a better understanding of the relative proportions of sediment derived from tidal erosion and river-borne sediment delivered from the watershed on a tributary-by-tributary basis. The Chesapeake Bay Program's Sediment Workgroup, a panel of regional experts in sediment processes, recently compiled a summary document that was published by the US Geological Survey in 2003 (Langland and Cronin 2003). Due to the long transit time for sediment derived from upland sources to travel to the Bay, (or so-called legacy sediments), the USGS publication recommended that the Bay community consider "…land-based practices nearer the tidal portions of the Bay and its tributaries and additional management strategies both along and in the Bay coastal zones to help meet water-clarity goals by 2010" (Langland and Cronin 2003). This does not suggest that reductions elsewhere are not important; however, the results of sediment reductions in close proximity to the tidal areas may have greater short-term impacts. Research is underway to gain an improved understanding of the transport, deposition and impacts of the sediments throughout the Chesapeake. As these data and interpretations become more developed and available prior to the Chesapeake Bay Program's 2007 re-evaluation of the existing sediment cap load allocations, the effects of tidal erosion-derived sediments on the Chesapeake Bay ecosystem will be better understood.

**Question 2: What factors contribute to tidal erosion?**

Tidal erosion is caused by many factors that individually and collectively produce varying rates and types of erosion throughout the Chesapeake. These factors include anthropogenic actions, shoreline type, shoreline sediment composition, wave energy, shoreline slope and orientation and upland runoff. Tidal erosion tends to be worse where sediments are unconsolidated and barren of vegetation, **fetch** (the distance along open water over which wind blows) is greater than one mile and upland areas are developed or generate significant runoff. Anthropogenic factors such as shoreline development, which removes the natural protective riparian buffer, shoreline reinforcement activities and surface water and ground water usage are also important factors that contribute to tidal erosion. Protecting shorelines' natural riparian buffers can help reduce tidal erosion.

Sea level rise also contributes to tidal erosion. Sea level in the Chesapeake Bay has risen approximately 1.3 feet over the past 100 years, and is expected to continue to rise in the next century. Recent estimates suggest that this rate may increase to as much as 2-3 feet in the next 100 years (Leatherman et al. 1995). As sea level rises, erosion increases because storm surges and waves batter retreating shorelines further into the coastal zone. Because of regional land subsidence and ocean warming, rates of sea level rise in the Chesapeake Bay and along the mid-Atlantic coast are nearly double the global average (Langland and Cronin 2003). The potentially large effect of sea level rise on erosion rates thus merits careful consideration in any comprehensive tidal erosion control plan.

Each type of shoreline has a different response to the factors that contribute to tidal erosion and, therefore, the specific site conditions must be carefully evaluated when considering installing a shoreline erosion structure.

Several shoreline classifications have been suggested for the Chesapeake Bay. The Army Corps of Engineers (1986) defined four basic types – high bluff, low bluff, beach and marsh – which could coexist in particular shoreline reaches. The most common shoreline types present in the Chesapeake Bay are:

1) High bluff greater than 20 feet in height fronted by a beach;
2) Low bluff less than 20 feet in height fronted by a beach;
3) High bluff greater than 20 feet in height fronted by a marsh;
4) Low bluff less than 20 feet in height fronted by a marsh;
5) Marsh, with no significant bluff; and
6) Beach, with no significant bluff.

The wave energy that affects a shoreline is determined by the fetch, orientation of the shoreline relative to the prevailing winds and storm wind directions. Offshore water depths and the presence of plants and animals such as SAV and oyster reefs can reduce wave energy levels. The ability of a given wave to erode a shoreline is influenced by the shore type and sediment composition, and the presence of vegetation on the shore. In addition, there are factors not directly related to wave energy that influence shoreline stability, such as saturation of the sediment with water, upland runoff, and the action of freeze-thaw cycles.

Fetch has been used as a simple measure of relative wave energy to categorize susceptibility to erosion forces. Low-energy shorelines have average fetch exposures of less than one mile and generally have low erosion rates. Medium-energy shorelines have fetch distances between one and five miles and commonly have higher erosion rates. High-energy shorelines, where fetch exceeds five miles generally have the highest erosion rates (Hardaway and Byrne 1999).

The shoreline orientation relative to the fetch will modify the rate of erosion. Eastward-facing shorelines tend to have lower overall erosion rates than westward-facing shorelines because of the prevailing westerly winds in the mid-Atlantic region. However, storm events with associated east winds can result in dramatic erosion rates over the short term.

Similarly, offshore characteristics can modify and reduce wave energy. Shallow nearshore regions reduce the incoming wave energy more effectively than deeper water, and the presence of SAV can weaken wave action providing some shoreline protection. Additionally, tidal erosion is also influenced by the **bathymetry** (the topography, or contours, of the Bay bottom) and the **geomorphology** (form and general configuration of the land) of the area.

The composition and slope of a shoreline also affect erosion rate. For example, a gently sloping beach can withstand waves better than a vertical bank with no beach. The composition of the shore or bank also affects the rate of erosion. Compacted clays, naturally cemented sands and slopes that are heavily vegetated with root-mat forming plants resist erosion better than loosely consolidated sands or shorelines barren of vegetation. All of these factors combine to determine the erosion potential of any shoreline. Understanding these factors will provide a better understanding of a shoreline's vulnerability to erosion.

**Question 3: What are the Chesapeake Bay tributary basins' tidal erosion rates relative to other sources of sediment?**

Many people think that the watershed is the major source of sediment that flows into the Bay. This is an important sediment source; however, sediment entering the Bay from the watershed travels downriver and much is trapped and retained in the zone where fresh river water meets and mixes with salt water from the Bay.

Below this mixing area, called **Estuarine Turbidity Maximum** or **ETM**, near-shore sources of sediment are considered to be the most important source of sediment supplied to the estuary. The map below shows the approximate location of the ETM zones in the major tributaries. It is downstream from these zones that the tributary teams should consider shoreline management activities to help achieve the sediment reduction goals, because such efforts have the greatest chance to improve local water clarity conditions. In the ETM zones the high turbidity levels are most influenced by sediment sources in the tributary watersheds.

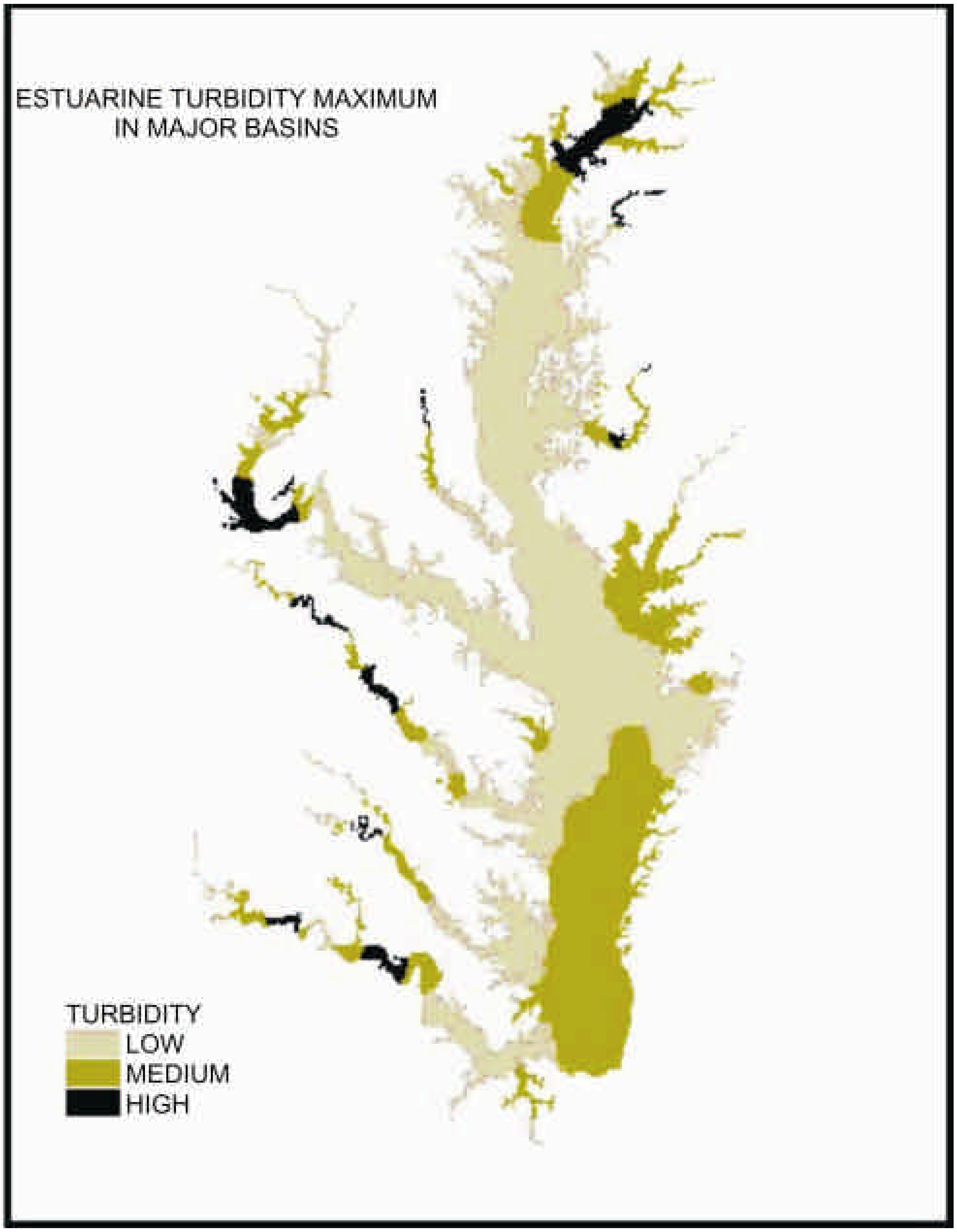


**Figure 3.** General location of Estuarine Turbidity Maxima (dark areas) for the major tributaries and the Bay. The ETM is generally found at the interface of fresh and salt water and is based on annual long-term average total suspended solids concentrations. Source: US EPA 2003.

An overall sediment source budget for the Chesapeake has not yet been developed. The Chesapeake Bay Program Sediment Workgroup compendium report stated, “There are enormous scientific and technical challenges to constructing a realistic, quantitative sediment budget for the Bay” (Langland and Cronin 2003). However, some idea of the contribution of tidally eroded sediments to the overall sediment supply in various portions of the Bay can be obtained from a comparison of the modeled contributions from the tributary watersheds above the fall line, the tidal portions of watersheds below the fall line and tidal erosion.

Figure 4, based on the model data summarized in Langland and Cronin (2003) shows the anticipated contributions from each of these three major sources. It is apparent that for the major tributaries with the largest drainage basins, the tributary basins themselves are the largest contributors of sediment to the estuarine waters. These tributaries are the Susquehanna, Potomac and James rivers. In the Coastal Plain portions of the Chesapeake, where the rivers have low discharge and the basin has low slopes, tidal erosion dominates the sediment sources.

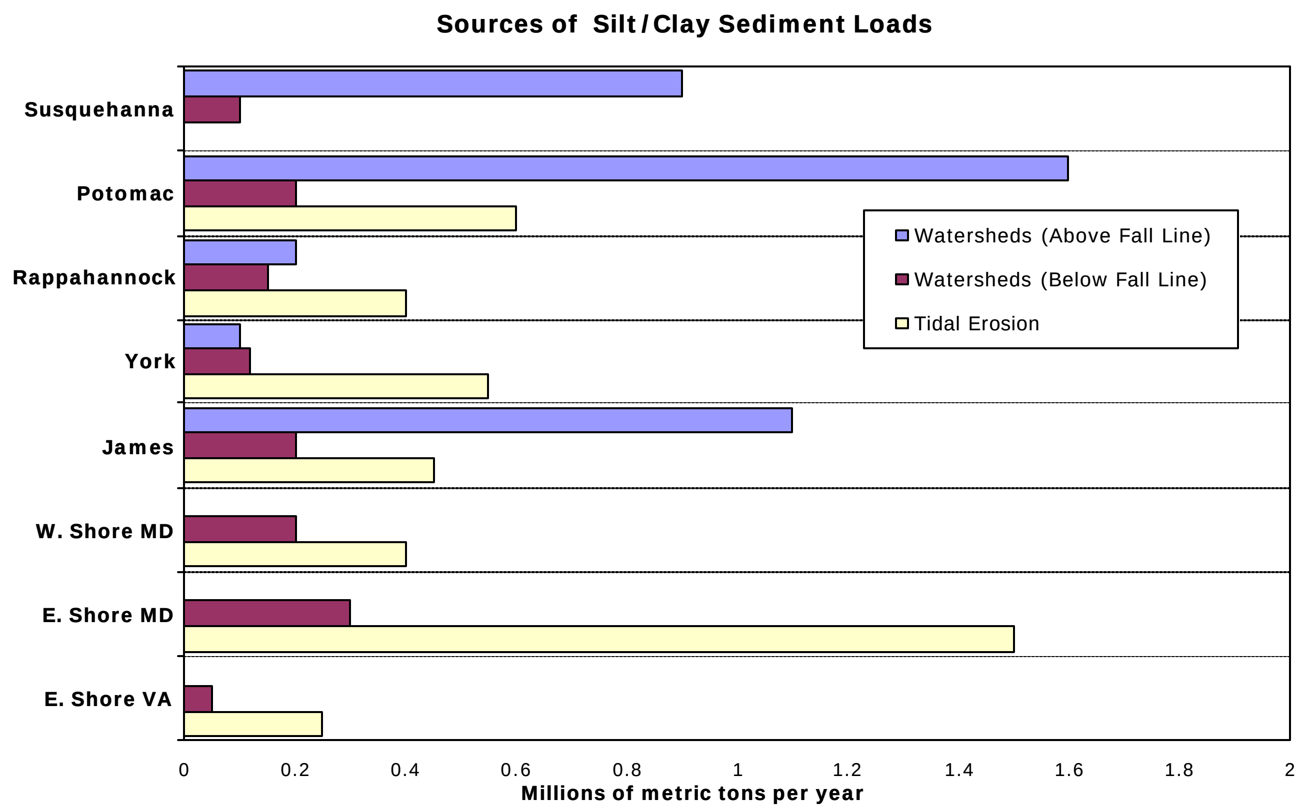


**Figure 4.** Sources of Silt/Clay Sediment Loads**:** (Source: Modified from Langland and Cronin 2003)

The following section summarizes the approximate tidal erosion rates in the various tributary basins. Direct calculations of sediment contributed by tidal erosion have not been calculated in either Maryland or Virginia. Rates of fastland or shoreline erosion have been calculated in both states using historically mapped shoreline locations. However, this information has not yet been converted to sediment amounts due to the lack of suitable data on elevation and bank composition. The time period utilized differ in the two states, as outlined below.

Tables 1 and 2 summarize the approximate tidal erosion rates in the various tributary basins in Maryland and Virginia, respectively. This information may be useful in identifying the basins where the input of sediment from tidal erosion is likely to be a major contributor relative to other sources, either because of the high relative erosion rates, or because of a high shoreline length, or both.

## MARYLAND

The Maryland Geological Survey recently produced updated maps that plot historical shorelines for the tidewater areas of the state. The earliest shorelines date from the mid-1800s and the most recent from the period between 1988 and 1995, depending on the specific location in the Bay. From these mapped shorelines, average erosion rates have been calculated throughout Maryland, using the most recent shorelines available within each area. Typically the time period covered spans approximately a 50-year period from the early 1950s to the 1990s.

Historical shorelines are available at http://www.mgs.md.gov/coastal/maps/changewect.html. A web site is under development that will show the actual erosion rates for all Maryland shorelines. When completed, this site will help identify reaches that may be supplying high sediment loads to the Chesapeake within each basin.

**Table 1.** Average fastland or shoreline erosion rates in nine Maryland tributary basins, calculated over the approximate period 1940 – 1990.

| Tributary Basin | **Average Erosion Rate** | **Approximate Shoreline Length** |
|---|---|---|
| | **(ft/yr)** | **(miles)** |
| Middle Potomac[a] | - | 36 |
| Patuxent | -0.46 | 470 |
| Patapsco/Back[b] | - | 237 |
| Upper Western Shore | -0.69 | 410 |
| Lower Western Shore | -0.47 | 433 |
| Lower Potomac | -0.71 | 609 |
| Upper Eastern Shore | -0.39 | 1103 |
| Choptank | -0.62 | 927 |
| Lower Eastern Shore | -0.75 | 2218 |

Source: Maryland Geological Survey

Notes: a – Shoreline erosion rates below limit of resolution, thus erosion rate not calculated.
b – Much of shoreline is accretionary due to harbor construction or is protected by structures.

## VIRGINIA

Erosion rates in Virginia have also been determined from historical shoreline positions; however, the maps used were both older and covered a longer time period than for Maryland. Depending on the specific location the older set of maps were produced between 1849 and 1904, while the newer set range from 1941 to 1968.

**Table 2.** Average fastland or shoreline erosion rates in five major Virginia tributary basins, by different shores.

| Tributary Basin | **Average Erosion Rate** | **Approximate Shoreline Length** |
|---|---|---|
| **York River** | **(ft/yr)** | **(miles)** |
| North Shore | -0.5 | 137 |
| South Shore | -1.0 | 67 |
| **James River** | | |
| North Shore | -0.0 | 208 |
| South Shore | -0.4 | 226 |
| **Rappahannock River** | | |
| North Shore | -0.5 | 256 |
| South Shore | -1.2 | 204 |
| **Chesapeake Bay** | | |
| Western Shore | -1.0 | 652 |
| Eastern Shore | -1.2 | 447 |
| Southern Shore | -1.4 | 260 |
| **Potomac River** | | |
| South Shore | -1.5 | 211 |

Source: Bryne and Anderson 1976

**Question 4: Which living resource habitats benefit from tidal erosion?**

Tidal erosion helps create beaches. In Virginia, where sand is more common in the eroding banks, adjacent beaches are more frequent. Large stretches of the Maryland shoreline have few or no sandy beaches. Beaches provide valuable habitat for a variety of species in the Chesapeake, most notably the diamondback terrapin, horseshoe crab and shorebirds that use these beaches for nesting purposes. Beach and exposed banks and bluffs also provide critical habitat for some endangered species, such as the tiger beetle. Identification and preservation of prime nesting beaches and habitats that support threatened and endangered species should be a high priority of ecosystem management. Tidal erosion, which helps create offshore sand bars, can promote SAV growth; this occurs mainly on Virginia's eastern shore. Marsh erosion on Maryland's eastern shore often exposes hard sediments that do not support SAV growth, unless sand eroded from nearby dunes is deposited on top of it (Stevenson 2002). Thus, the relationships between tidal erosion and sediment suitability for SAV growth nearby are complex.

Tidal erosion also can be beneficial to tidal wetlands. Wetlands accrete vertically by trapping sediment. The vegetation in a wetland slows the water velocity, causing sediment to be deposited on the marsh surface. This accumulation of sediment enables wetlands to keep pace with sea level rise and maintains healthy wetland ecosystems. Tidal erosion, particularly in the middle portions of the Bay, may be the primary source of sediment allowing the marshes to accrete vertically and keep pace with sea level rise.

**Question 5: Which living resources are harmed by tidal erosion?**

A primary reason for reducing sediment loads is to provide suitable habitat for SAV. Suspended sediment is a major cause of light attenuation, which impairs SAV growth. The potential for sediment reductions as a result of shoreline management is likely to be most applicable along shorelines adjacent to existing SAV beds or along shorelines where SAV has historically been observed but that lack beds now. These maps may be viewed as large PDF files (up to 4.6 mb each for 13 different tributary basins on the Internet at: ftp://ftp.chesapeakebay.net/tsgm/).

The most intensely negative effects of tidal erosion may occur in areas where SAV is growing, or can potentially grow, adjacent to shorelines that are actively eroding and that produce a large quantity of finely grained suspended sediments. Unfortunately, the extent of SAV beds has been severely diminished in the Chesapeake in recent decades, with some recovery in the last decade or so. The decline of SAV was followed closely by reductions in the numbers of fish and wildlife species that require healthy SAV habitats for sustenance. For example, severe decreases in wintering populations of SAV-feeding waterfowl coincided with the decline in SAV. SAV provides a protective nursery for many aquatic organisms that are valuables food source for waterfowl.

The Virginia Institute of Marine Science (VIMS) has annually mapped the location and extent of tidal Chesapeake Bay SAV beds since 1984, with less frequent baywide surveys starting in 1978. These maps from 1994 onward are available on the Internet at http://www.vims.edu/bio/sav/. To view the maps, go to the section on this web site called SAV Monitoring Project Reports and click on the link for the desired year. The maps can be examined relative to eroding adjacent shorelines to determine those areas with the greatest potential for a negative impact to adjacent SAV habitat. VIMS maps are available baywide.

Suspended sediments also are a major factor affecting water clarity in the open water habitats of the Chesapeake Bay. Lower concentrations of suspended sediments will improve water clarity in open water habitats and reduce the frequency of algal blooms. Poor water clarity stresses **phytoplankton** (microscopic floating aquatic plants) and stimulates an increase in the chlorophyll concentrations of the phytoplankton cells. If nutrients are plentiful, stressed phytoplankton cells with elevated chlorophyll concentrations will rapidly form algal blooms when currents or weather events hold them into surface waters. Unstressed cells, with their lower chlorophyll concentrations, do not form algal blooms, even when nutrient concentrations are moderately high (Buchanan et al 2005).

An oyster bed can be affected by an eroding shoreline. Most of the oyster shell substrate in the Chesapeake Bay and its tidal tributaries is now covered by sediment. Fine-grained sediments interfere with oyster filter feeding, leading to physiological stress and slower growth rates. In many parts of Chesapeake Bay excessive sediments bury oyster shell at rates too fast for weakened oyster populations to keep pace via shell growth. Shell burial decreases the availability of suitable habitat for oyster larval settlement. New acoustic techniques for surveying the bottom suggest that less than 1 percent of Maryland's historic oyster grounds can be classified as clean or lightly sedimented shell. The vast majority of these suitable substrates are within areas where the state has recently planted shell. However, shell plantings that are subject to harvest, high rates of oyster mortality from disease, low rates of recruitment and high rates of sedimentation, have effective lifetimes that average only three to five years. Although the link between tidal erosion and sediment effects on oyster beds has not been definitively established, most of the historic oyster beds in the Chesapeake Bay occur in shallow, nearshore waters where the contribution of sediments from tidal erosion can logically be expected to have significant effects. Maps illustrating oyster restoration sites, which could help target and prioritize shoreline protection efforts, may be viewed as large PDF files (up to 4.6 mb each for 13 different tributary basins on the Internet at: ftp://ftp.chesapeakebay.net/tsgm/

Wetlands may be adversely affected by tidal erosion in two ways. First, tidal erosion may occur at the leading edge of the marsh (between the marsh and main water body), where waves impinge, removing sediment from the root mass and causing the marsh edge to retreat. Second, during unusually high-water events, waves may flood the marsh surface. If the marsh-upland interface is a bluff, the waves may erode and undercut its base, causing sediment to slump onto the marsh surface. A small amount of sediment may be beneficial to the marsh, but large quantities may smother the vegetation. Both tidal and nontidal wetland maps by the National Wetlands Inventory (NWI) are available online at http://wetlands.fws.gov/. The codes used to label each polygon indicate whether it is a tidal or nontidal wetland.

Each ecosystem component may be affected by tidal erosion control activities, particularly in immediately adjacent shorelines. Other aspects of the ecosystem should also be considered in assessing the potential effects of any shore protection structure, such as the location of rare and endangered species, special and unique habitats and eroding areas that supply sands that maintain adjacent beaches.

**Question 6: What shoreline management strategies improve water clarity?**

The Chesapeake Bay Program has created maps of the tidal portions of each tributary basin that highlight the locations of SAV Restoration Zones based on the historical distribution of SAV, historic oyster beds and wetlands. These maps may be viewed as large PDF files (up to 4.6 mb each for 13 different tributary basins) on the Internet at: ftp://ftp.chesapeakebay.net/tsgm/ and may help identify and prioritize potential tidal sediment reduction areas to help create SAV habitat to meet the 185,000-acre SAV goal.

To help restore the Chesapeake Bay we must treat our shorelines differently than we have in the past. We need to protect or restore our shorelines' natural riparian buffers and do a better job of managing shoreline development so that it does not exacerbate tidal erosion. We need to consider implementing environmentally sensitive or living shorelines first to protect shorelines experiencing erosion of two feet per year or less. Where severe erosion is occurring and living shorelines are not possible, hard structures may be considered. Finally, there are eroding shorelines where no action should be taken if the eroded shorelines are replenishing beaches or provide a unique habitat for endangered species.

Tidal erosion control mechanisms that are envisioned at any specific location should be assessed within the context of a broader reach and not as isolated actions. A **reach** is a segment of shoreline in which influences, such as wind direction, wave energy and sand transport, among other variables, mutually interact. Shorelines within a reach generally have similar orientations, offshore bathymetry and exposure to fetch and are separated from adjacent reaches by inlets or projecting headlands and peninsulas. The shoreline segments within any reach should be carefully assessed to determine the sediment characteristics, the processes contributing to erosion and the rates of erosion. Some shoreline areas may be supplying sand that maintains beaches that help buffer the shore itself or provide essential habitat. Other shorelines within the reach may consist of eroding silts and clays, which are generally more detrimental to living resources and may be good candidates for tidal shoreline management actions.

It should be noted that tidal erosion is a natural process that may not always require corrective measures. In general, eroding shorelines that threaten private and public property should be protected with nonstructural options that use bioengineering to create protective vegetative buffers wherever the fetch and wave energy allows. Nonstructural or living shorelines projects along protected tidal shorelines are usually accomplished by placing clean sand fill in the intertidal zone and stabilizing it with tidal marsh grasses. Placement of some stone may also be necessary to protect the newly created marsh. This type of shoreline protection helps to create habitat for crabs, fish, terrapins, tiger beetles and other living resources in the Bay, in addition to stabilizing the shore and protecting the waterfront property.

Hard shoreline protection structures, such as bulkheads and revetments, while potentially reducing fastland erosion, may actually increase bottom scour and erosion in the nearshore zone in front of the structures because they tend to reflect the oncoming wave energy (Army Corps of Engineers 2002). They also eliminate the natural shorelines of the Bay and the associated natural habitats, including SAV. Steep, high cliffs are difficult to stabilize because the erosion of these cliffs often occur as mass slumping events that result from freeze-thaw cycles and the saturation of the soil and sediments in the cliffs.

In all coastal counties of Virginia and many coastal counties of Maryland, Shoreline Situation Reports are available to help determine the site specific characteristics of the shoreline. For this information, please see http://ccrm.vims.edu/gisdatabases.html. Then choose Shoreline Situation Reports and select Riparian Land Use, Bank and Buffer conditions or Shoreline Features. Seven of Maryland's 16 coastal counties have Shoreline Situation Reports completed. The other nine counties will be completed by March 2006.

## RECOMMENDATIONS

To help restore the Chesapeake Bay we must treat our shorelines differently than we have in the past. We need to protect or restore our shorelines' natural riparian buffers, and do a better job of managing shoreline development so that it does not exacerbate tidal erosion. We need to consider implementing environmentally sensitive or living shorelines to protect those experiencing erosion of two feet or less per year. Where severe erosion is occurring and living shorelines are not possible, hard structures may be considered. Finally, in some eroding shorelines, no action should be taken if they are replenishing beaches or providing a unique habitat for endangered species.

The tributary teams should explore a comprehensive suite of management actions to achieve the local SAV restoration and sediment reduction goals. It is apparent that upland sediment controls alone are insufficient to achieve the local SAV restoration goals in some areas, thus the tributary teams should assess varied and innovative methods to achieve SAV regrowth in such areas.

## REGIONAL CONTACTS

Throughout the Chesapeake Bay watershed, the NOAA Restoration Center provides financial and technical assistance for estuarine and riparian habitat restoration projects that restore and stabilize eroding shorelines. In 2004, NOAA, the Chesapeake Bay Foundation, the Keith Campbell Foundation for the Environment and the National Fish and Wildlife Foundation created a partnership to fund living shoreline restoration projects in Maryland and Virginia. For more information on NOAA funding opportunities contact Alison Ward Maksym at (410) 267-5644, alison.ward-maksym@noaa.gov or Rich Takacs at (410) 267-5672, rich.takacs@noaa.gov at the NOAA Restoration Center. Additional information on funding availability can be found at http://www.nmfs.noaa.gov/habitat/restoration/funding_opportunities/funding.html

In Virginia, the Department of Conservation and Recreation provides waterfront property owners with free assistance about how to protect eroding shorelines. For property on the north side of the York River and north, please call (804) 443-3803. For property on the south side of the York River and south, please call (757) 925-2468.

In Maryland, the Department of Natural Resources (MD DNR) provides waterfront property owners with free technical and financial assistance. Two agencies within DNR provide this assistance:

- The Coastal Zone Management Program (CZM) offers technical assistance, data and information. Call (410) 260-8743.
- The Shore Erosion Control Program (SEC) offers technical and financial assistance. Call (410) 260-8523.

CZM, in cooperation with Towson University, is developing a shoreline management information portal entitled *Shorelines Online*. *Shorelines Online* will be an Internet-based resource providing data distribution capabilities, Internet mapping tools, and information about coastal hazard activities in the State of Maryland. The site will focus mainly on shoreline management as it relates to shoreline erosion and sea level rise, and will promote innovative methods for shoreline protection and restoration. The portal will provide a framework for improving shoreline and hazard planning by promoting a wider array of stakeholder involvement in decision-making and data use. The first stage of the website will be available in March 2005 with the mapping and assessment tools to be completed by March 2006. For more information on *Shorelines Online* contact Audra Luscher at MD DNR CZM (410) 260-8743 or aluscher@dnr.state.md.us.

Additional Maryland regional contacts include:
Dave Wilson and Gerry Walls of the Maryland Eastern Shore Resource Conservation & Development Area, (410) 822-9300
Bruce Young, Manager of the St. Mary's County Soil Conservation District (301) 475-8402

**Useful Sources of Information**

Hardaway, C. S., Jr. and R. J. Byrne. 1999. Shoreline Management in Chesapeake Bay. Virginia Institute of Marine Science, VSG-99-11. Call (804) 684-7170 to order.

Langland M. and T. Cronin, eds., 2003. A Summary Report of Sediment Processes in Chesapeake Bay and Watershed. USGS Water Resources Investigations Report 03-4123 http://pa.water.usgs.gov/reports/wrir03-4123.pdf

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U.S. Environmental Protection Agency, 2004. New Tools Measure Chesapeake Bay Health. EPA/600/F-04/203. Office of Research and Development, National Center for Environmental Research, Washington, D.C.