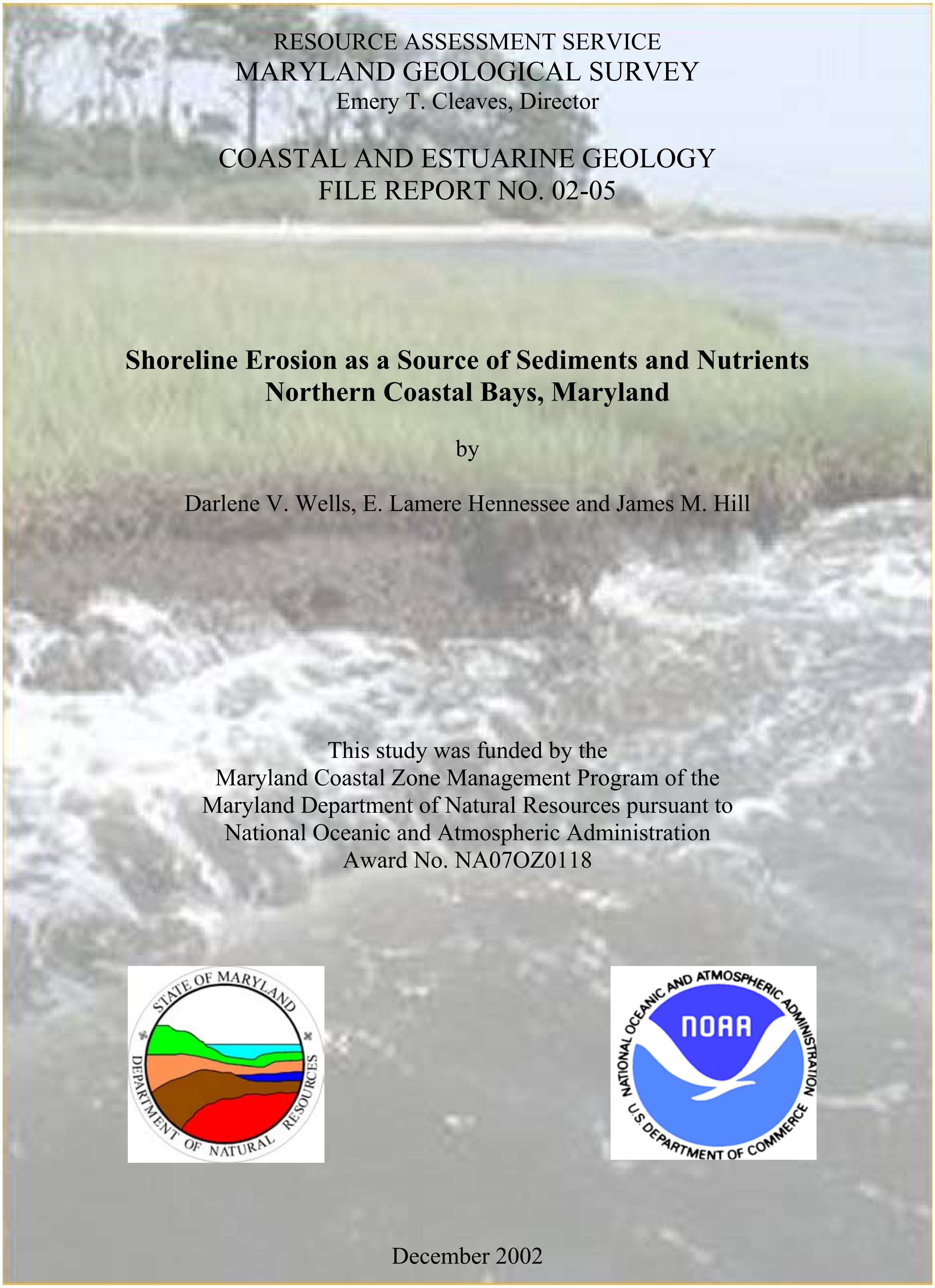

RESOURCE ASSESSMENT SERVICE
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

COASTAL AND ESTUARINE GEOLOGY
FILE REPORT NO. 02-05

Shoreline Erosion as a Source of Sediments and Nutrients Northern Coastal Bays, Maryland

by

Darlene V. Wells, E. Lamere Hennessee and James M. Hill

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For information or additional copies, please contact:

Maryland Department of Natural Resources
Maryland Geological Survey
2300 St. Paul Street
Baltimore, MD 21218
(410) 554-5500
Website: www.mgs.md.gov

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EXECUTIVE SUMMARY

The Maryland Geological Survey (MGS) began a multi-year study to determine the flux of sediments and nutrients eroding from unprotected shorelines bordering Maryland's coastal bays. The first year of study focused on the northern-most bays: Assawoman and Isle of Wight Bays and the St. Martin River.

Sampling locations were selected on the basis of linear rates of shoreline change, as well as geology and geomorphology (marsh, bluff, or beach). At each of the 16 sites, bank heights were measured. Sediment samples were collected from marshes and beaches and from distinct geologic horizons within banks. Samples were analyzed for grain size composition, bulk density, total organics, total carbon (TC), nitrogen (TN), phosphorus (TP), and a suite of trace metals. The analytical results were then used in conjunction with coastal land loss estimates to determine sediment and nutrient loadings to the bays. Annual land lost was based on a digital comparison of two historical shorelines dating from 1942 and 1989.

Based on geomorphologic variability and differing rates of shoreline erosion, the study area shoreline was divided into 23 reaches, ranging in length from about 600 m to 45,000 m; most were less than 9,000 m long. A template of irregular polygons was constructed to demarcate the reaches, and total land loss (m^2) during the 47-year period was determined for each polygon. These "land loss" polygons provided a structure for organizing the results of the physical and chemical analyses. Each sampling site was associated with one or more of the land loss polygon. Mean bank heights and concentrations of the measured constituents (i.e., TN, TP, TSS, etc. in kg/m^3), averaged for each of the sampling sites, were used to calculate annual loadings (kg/yr) for each polygon.

During the 47-year period, shoreline erosion contributed an estimated 11.6×10^6 kg/yr of total sediments into the three-bay system (Table ES-1). Of the total sediment load, approximately 42%, or 4.9×10^6 kg/yr, were total suspendable solids (TSS). That amounts to about one-third of the TSS load from upland (surface) run-off. Annual total sediment loadings were greatest in the St. Martin River (6.9×10^6 kg/yr), due in part to high bank elevations and relatively dense bluff material. Bulk densities of sediments collected from bluffs averaged 1.4 g/cm^3. Total sediment loading from shore erosion in Assawoman Bay was about half that of the St. Martin River (3.2×10^6 kg/yr). Sediment loadings from Isle of Wight Bay shorelines were even lower (1.5×10^6 kg/yr). Much of the shoreline bordering Assawoman and Isle of Wight Bays is low-lying marsh, composed of sediments with average bulk densities of 0.4 g/cm^3.

Sand-sized sediments account for approximately 57% of the total sediments contributed from shoreline erosion. The sand contributed from erosion about half of the sand coming into the bays. More than one-third of the sand is eroded from the St. Martin River shoreline.

Shoreline erosion is a significant source of nutrients, contributing up to 8.5% of the total nitrogen and total phosphorus delivered to the system. Nutrient contributions from shoreline erosion slightly exceed input from point sources. In addition to nutrients, erosion also contributes significant amounts of Pb and Zn, accounting for 4% and 9.5%, respectively, of the total loadings of those metals to the bays.

Table ES-1. Annual loadings (kg/yr) of nutrients and sediments, northern coastal bays. The 1989 shoreline length applies to the shoreline included in the land loss polygons.

Component	Assawoman Bay	Isle of Wight Bay	St. Martin River	Total
1989 shoreline length (m)	81,164	25,296	59,378	165,839
Total Solids	3,206,065	1,471,477	6,888,572	11,566,114
Suspendable Solids	2,151,542	955,737	1,771,102	4,878,381
Carbon	214,743	87,424	122,398	424,565
Nitrogen	11,649	4,477	7,247	23,373
Phosphorus	1,070	497	777	2,344
Pb	80	29	99	208
Zn	182	77	260	519

1. INTRODUCTION

The Maryland Coastal Bays Program has developed a four-pronged action plan to restore and protect the natural resources of the State's coastal bays (MCBP, 1999). The plan addresses (1) water quality, (2) fish and wildlife, (3) recreation and navigation, and (4) community and economic development. Meeting the goals associated with the first three of these depends in part on understanding the sediment and nutrient input contributed by shoreline erosion to the coastal bays. Shoreline erosion releases sediments to the water column. Finer-grained sediments tend to remain suspended in the water, reducing water clarity and affecting underwater habitat (e.g., reducing light penetration for submerged aquatic vegetation). The eventual deposition of eroded sediments contributes to the in-filling of navigational channels. Shoreline erosion also acts as a non-point source of nutrients (nitrogen and phosphorus), which affect the water quality of the coastal bays.

Although shoreline erosion has been identified as a source of sediments and nutrients to nearby waters, there has been little effort to quantify that input and to compare it to other sources. To provide this information, the Maryland Geological Survey (MGS) began a multi-year study to determine the flux of sediments and nutrients eroding from unprotected shorelines bordering the coastal bays. The first year of study focused on the northernmost coastal bays: Assawoman Bay, Isle of Wight Bay, and the St. Martin River. The results of that study are presented in this report.

OBJECTIVES

To estimate the nutrient and sediment loads contributed by shoreline erosion to the northern coastal bays of Maryland, MGS set the following objectives:

1. Identify unprotected reaches of shoreline at greatest risk of erosion, based on historical linear rates of change;
2. Measure certain physical, chemical, and biological properties of eroding sediments; and
3. Determine the volume of eroding sediments and the flux of sediments and nutrients into the northern coastal bays. Examine the flux of material from shoreline erosion in the context of existing nutrient budgets for the study area.

ACKNOWLEDGMENTS

This study was funded by the Coastal Zone Management Program of the Maryland Department of Natural Resources pursuant to National Oceanic and Atmospheric Administration Award #NA07OZ0118. The authors extend their gratitude to the many landowners who allowed access to their property, so that MGS might collect samples and measure bank heights. They also wish to thank Neil Dunnemyer, Richard Ortt, Dan Sailsbury, and Geoff Wikel, who assisted with sample collection and laboratory analyses. Special thanks are due to Al Wesche and Jim Casey for their assistance in collecting cores and the use of Fisheries' boat.

2. PREVIOUS STUDIES

SHORELINE CHANGE AND COASTAL LAND LOSS STUDIES

The earliest, comprehensive shoreline change information available for the coastal bays, excluding the upstream portions of some of the tributaries, comes from a 1949 study of tidewater Maryland by Singewald and Slaughter. The authors calculated rates of erosion by comparing two sets of shorelines, dating from *ca*. 1850 and *ca*. 1940. Conkwright (1975) updated their work, producing a series of maps that depict the 1850 and 1940 shorelines on 7.5-minute U.S. Geological Survey (USGS) topographic quadrangles. The most recent shorelines shown on the topographic base maps range between 1942 and 1972.

Using the shoreline change data reported by Singwald and Slaughter, Bartberger (1973, 1976) estimated the volume of sediment contributed to Chincoteague Bay from shore erosion, as part of his study of the origin, distribution and rates of accumulation of sediments in the bay. Based on Bartberger's estimates, shore erosion contributes approximately 40 x 10^3 m^3/yr of sediment to Chincoteague Bay, approximately eight times the amount delivered by streams. Almost all of the eroded sediment comes from the mainland shore and bay islands, which consist largely of marsh. Bartberger assumed that shore-derived sediments consisted primarily of mud (silt plus clay fraction). Because the sand:mud ratio of sediments deposited on the bay floor was 1:1, he reasoned that an equal amount of sand was introduced into the bay from other sources, mainly from Assateague Island through overwash processes and wind deposits. Transport of sand through the active inlets, Ocean City Inlet and Chincoteague Inlet, is important only as a local source.

Later studies of coastal erosion in the region, including those by the National Oceanic and Atmospheric Administration (NOAA, 1988) and Leatherman (1983), were more limited in area, for example, to the vicinity of the Ocean City Inlet or the Atlantic shoreline of Maryland. Volonté and Leatherman (1992) predicted future wetlands and upland losses for the mainland (western) shores of Assawoman and Isle of Wight Bays and their main tributaries, including the St. Martin River. As part of that study, they measured linear rates of shoreline change along 41 miles of shoreline (at 215 sites located approximately 1000 ft apart) for the period 1850-1989. Their findings for several reaches of shoreline are relevant to this study (Table 2-1). Average rates of recession in the study area, by water body, range from -0.2 to -1.1 ft/yr (-0.6 to -0.34 cm/yr). Based on that study, Volonté and Leatherman concluded that marshy shorelines undergo the highest rates of erosion.

Recently, MGS remapped and assessed shoreline change in Maryland's coastal bays (Hennessee and Stott, 1999; Hennessee and others, 2002; Stott and others, 1999, 2000). The project involved digitizing historical and recent shoreline positions for the 450 mi (724 km) of shoreline defining the coastal bays. Using a geographic information system (GIS), MGS digitally updated nine 7.5-minute quadrangles covering the coastal bays and produced a corresponding series of *Shoreline Changes* maps. MGS also determined the area of land lost within the coastal bays since the mid-1800s. Between 1850 and 1989, Assawoman Bay lost a net of 948 acres (3.84 km^2) to shoreline erosion, at an annual rate per mile of shoreline of 0.09

acres/mi/yr (226.3 m^2/km/yr). Comparable figures for Isle of Wight Bay and the St. Martin River, respectively, are 159 acres (0.64 km^2) at a rate of 0.03 acres/mi/yr (75.4 m^2/km/yr) and 254 acres (1.03 km^2) at a rate of 0.10 acres/mi/yr (251.5 m^2/km/yr).

Table 2-1: Average rates of recession (ft/yr) for reaches of shoreline in the study area, from Volonté and Leatherman (1992).

Zone	Area	Linear rate of recession (ft/yr)
1	Isle of Wight Bay	-1.0
5	St. Martin River	-1.1
6	Shingle Landing Prong	-0.2
7	Bishopville Prong	-0.3
8	Isle of Wight	-1.1
9	Assawoman Bay	-0.5

NUTRIENT BUDGET AND POLLUTANT LOADING STUDIES

In 1993, the Maryland Department of the Environment (MDE) conducted an assessment of Maryland's coastal bay aquatic ecosystem (UM and CESI, 1993). The authors reviewed existing data for trends in the overall quality of the bays' ecosystem. One objective was to assess terrestrial pollutant loadings. The study identified contributing sources and estimated pollutant loadings from point source discharges, surface runoff, and direct discharge of groundwater into the bays. Loadings from shoreline erosion were not considered. The pollutants included nitrogen, phosphorus, total suspended solids (TSS), metals (zinc and lead) and biochemical oxygen demand (BOD). Estimates of pollutant loadings from surface runoff were based on land use and land cover. The study identified the upper bays (Assawoman and Isle of Wight Bays) and, in particular, the St. Martin River as areas exhibiting serious water quality problems due, in part, to poor flushing, waterfront development, and high nutrient loadings. Estimated loading rates for all of the pollutants included in the assessment were very high for Turville and Herring Creeks and the St. Martin River, compared to those observed for the other coastal bays and selected portions of the Chesapeake Bay.

Impaired by nutrients (nitrogen and phosphorus), the St. Martin River was placed on Maryland's list of water-quality-limited segments in 1994. Two years later, Assawoman and Isle of Wight Bays were added to the list. As a result, the State was required, under Section 303(d) of the Federal Clean Water Act, to develop a total maximum daily load (TMDL) for these two bays. A TMDL reflects the total pollutant loading of an impairing substance that a water body can receive and still meet water quality standards. In the process of developing the TMDLs, MDE revised the nutrient loadings reported in the UM and CESI report (MDE, 2001). MDE recalculated nutrient loadings based on 1997 land use information and updated groundwater inputs based on data from a recent groundwater study (Dillow and others, 2002). Again, in developing a nutrient budget for the northern coastal bays, MDE omitted contributions from shoreline erosion.

In general, few published nutrient budgets have included input from shoreline erosion. One exception was a study conducted by Ibison and others (1990), who measured sediment and nutrient contributions from eroding banks along tidal shorelines of the Virginia portion of the Chesapeake Bay and several of its major tributaries. The researchers selected 14 non-marsh sites that were undergoing high rates and volumes of erosion and that were located near living marine resources. For fastland bank samples, nitrogen concentrations ranged from 0.01 to 3.34 mg/g (0.001 to 0.334%); phosphorus concentrations ranged from 0.01 to 1.28 mg/g (0.001 to 0.128%). The authors compared their results with nutrient loadings from controllable non-point sources. Shoreline erosion contributed 5.2% of the nitrogen load and 23.6% of the phosphorus load. Differences in nutrient loadings among the sites were due to differences in bank heights and erosion rates; differences in nitrogen and phosphorus concentrations were not a significant factor.

Two years later, Ibison and others (1992) expanded their initial research to include an additional 44 eroding banks. They examined the relationship between nutrient concentrations and land use for four land use categories: active farms, fallow farms, wooded, and rural residential. And, they resolved a question that arose following the publication of their earlier report. Was the mineral apatite in fossiliferous soil horizons a possible source of error in their phosphorus measurements?

The researchers confirmed that nutrient concentrations and loading rates varied greatly from site to site. Nutrient loading rates from shoreline erosion exceeded those from agricultural runoff because of the large volumes of soil lost to shoreline erosion. Nutrient loading concentrations and land use were related. The highest mean total nitrogen and total phosphorus loading concentrations were associated with the cultivated croplands of active farms. Surprisingly, though, average total nitrogen loading concentrations were equally high for wooded land. For fossiliferous horizons, mean total phosphorus loading concentrations were about twice the mean for unfossiliferous banks. However, mean inorganic phosphorous loading concentrations were the same for both.

3. STUDY AREA

GEOMORPHOLOGY

The study area is located on the Atlantic coast of the Delmarva Peninsula (Fig. 3-1). Isle of Wight and Assawoman Bays are the two northernmost coastal bays in Maryland. Fenwick Island, part of the barrier island/southern spit unit of the Delmarva coastal compartment (Fisher, 1967), separates the two coastal bays from the Atlantic Ocean. The Town of Ocean City is located on Fenwick Island.

Assawoman Bay and Isle of Wight Bay, microtidal (<2 m tidal range) coastal lagoons, are contiguous with each other. For this discussion, the boundary between Assawoman Bay and Isle of Wight Bay is the Rt. 90 Bridge, which spans Fenwick Island (Ocean City at 60th Street) and Isle of Wight (Fig. 3-2). St. Martin River, which drains into Isle of Wight Bay, is the major tributary, accounting for 62 % of the total drainage area for the two bays (Bartberger and Biggs, 1970; UM and CESI, 1993). In addition to the St. Martin River, several smaller streams drain into the two bays. Roy Creek and Greys Creek drain into Assawoman Bay. Manklin Creek, Turville Creek, and Herring Creek drain into Isle of Wight Bay. Table 3-1 lists basic morphometric data for both bays and the St. Martin River.

Table 3-1. Morphometric data for Isle of Wight and Assawoman Bays and the St. Martin River; area data compiled from UM and CESI (1993) and this study. Total shoreline includes islands and reaches of major tributaries: Grey, Herring, Manklin and Turville Creeks, as shown in Figure 3-2.

	Assawoman Bay	Isle of Wight Bay	St. Martin River	Northern Bay System
Surface area	20.9 km^2	19 km^2	7 km^2	46.9 km^2
Maximum length	7.9 km	6.7 km	5.9 km	14.5 km
Drainage area	24.7 km^2	146.4 km^2 *	106 km^2	171.1 km^2
Total shoreline (1989)	152.5 km	125.2 km	84.8 km	401.7 km **

* Drainage area for Isle of Wight Bay includes that of the St. Martin River
** Northern Bay system shoreline includes Delaware portion of Assawoman Bay (39.2 km).

The two bays are connected to the Atlantic Ocean through a single outlet, Ocean City Inlet, located at the southern end of Isle of Wight Bay. Ocean City Inlet formed during a hurricane in 1933 and was immediately stabilized by jetties to keep it open. A canal, known as "The Ditch," connects Assawoman Bay to Little Assawoman Bay, in Delaware.

Historically, several other inlets have been documented along Fenwick Island (Truitt, 1968). These inlets, like Ocean City Inlet, also formed during storms. Eventually, they filled in as a result of natural processes. During the Ash Wednesday storm in March 1962, Fenwick Island was breached in the vicinity of 71st Street, and a 50-ft-wide channel was cut through to the bay

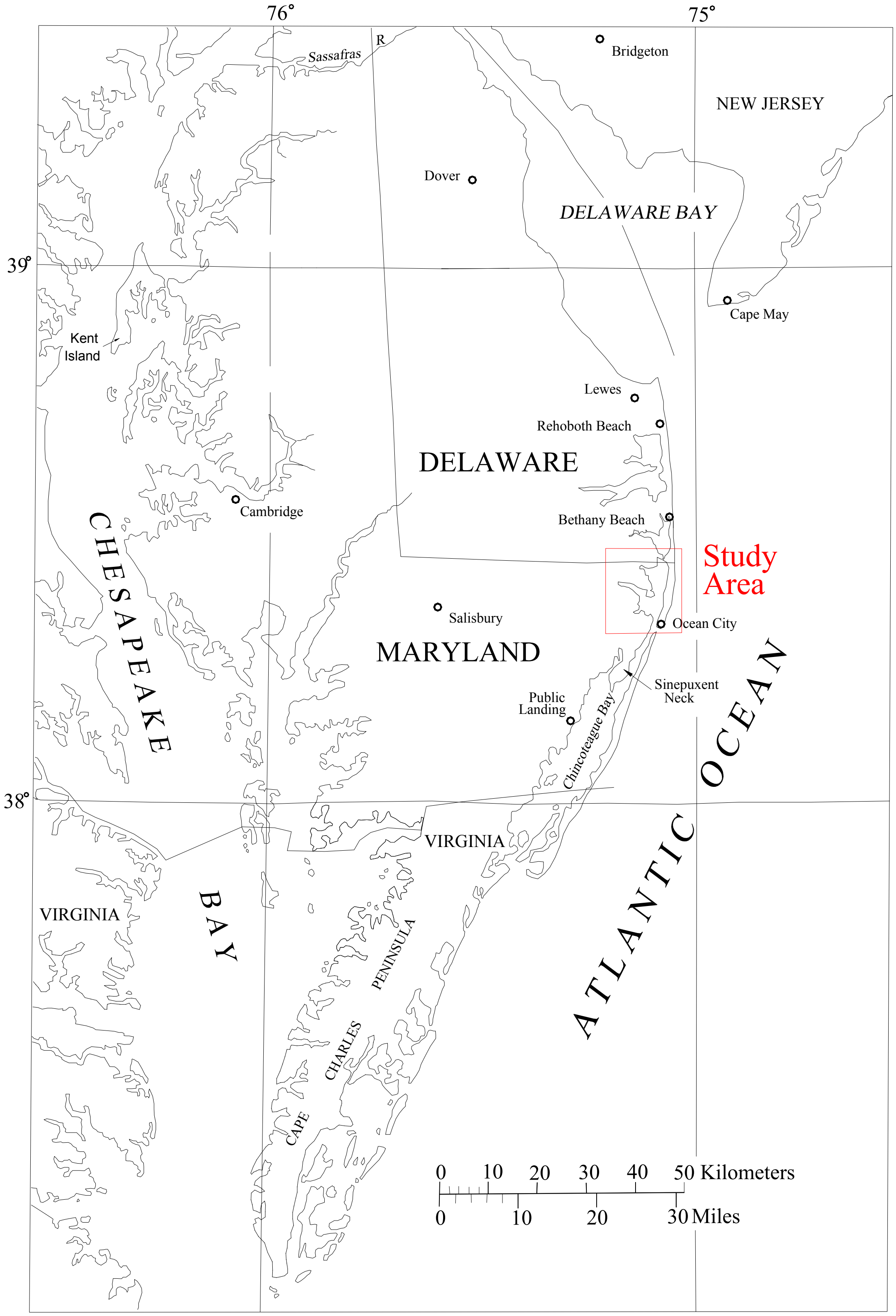


Figure 3-1. The Delmarva Peninsula, showing the location of the study area.

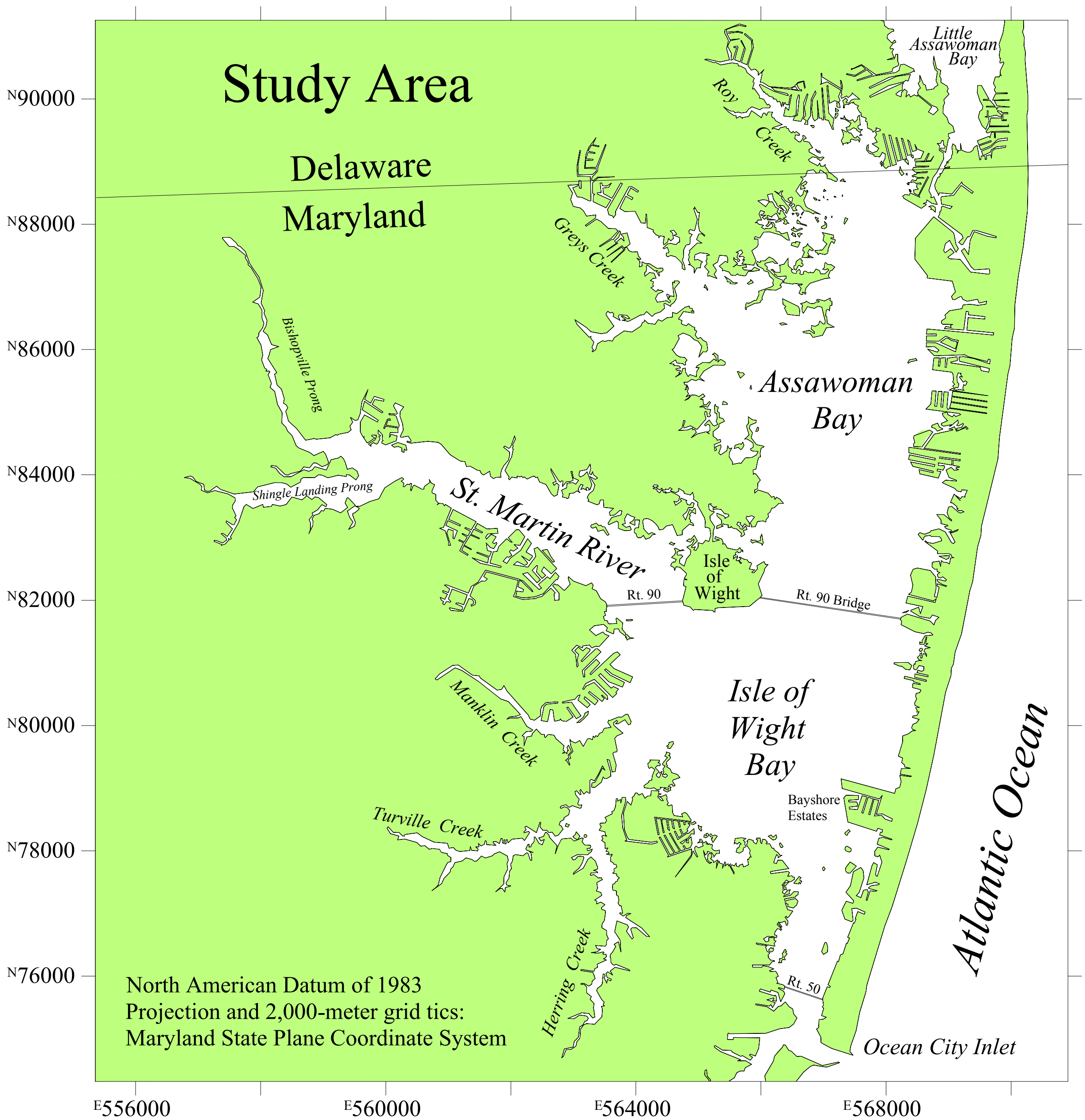


Figure 3-2. Study area.

(U.S. Army Corps of Engineers, 1962). The Army Corps of Engineers immediately filled in the inlet with sand dredged from Assawoman Bay.

Circulation patterns and tidal ranges in the two bays depend on proximity to the Ocean City Inlet and wind conditions. Near the inlet, currents are affected primarily by tidal cycles. Current velocities near the inlet and within the federal navigation channel commonly exceed 200 cm/sec. The maximum tide range is approximately 0.6 meters (2 ft.) at the inlet and diminishes with distance from the inlet. Most of the tide attenuation occurs around 27th Street (Bayshore Estates), at which point Isle of Wight Bay widens dramatically. North of the Rt. 90 bridges (St. Martin River and Assawoman Bay), the mean tide range is relatively constant at 0.3 meters (1 ft) (Wells and Ortt, 2001). In St. Martin River and along the western and northern margins of Assawoman Bay, wind conditions can have a greater effect than tides on water levels and current velocities.

The shoreline bordering the bays is dominantly wetlands and marshes. Much of the bay side of Fenwick Island (Town of Ocean City, proper) has been developed at the expense of wetlands (Dolan and others, 1980). Large areas have been in-filled and built up, and more than 75% of the natural shoreline has been armored by bulkheads or rip-rap.

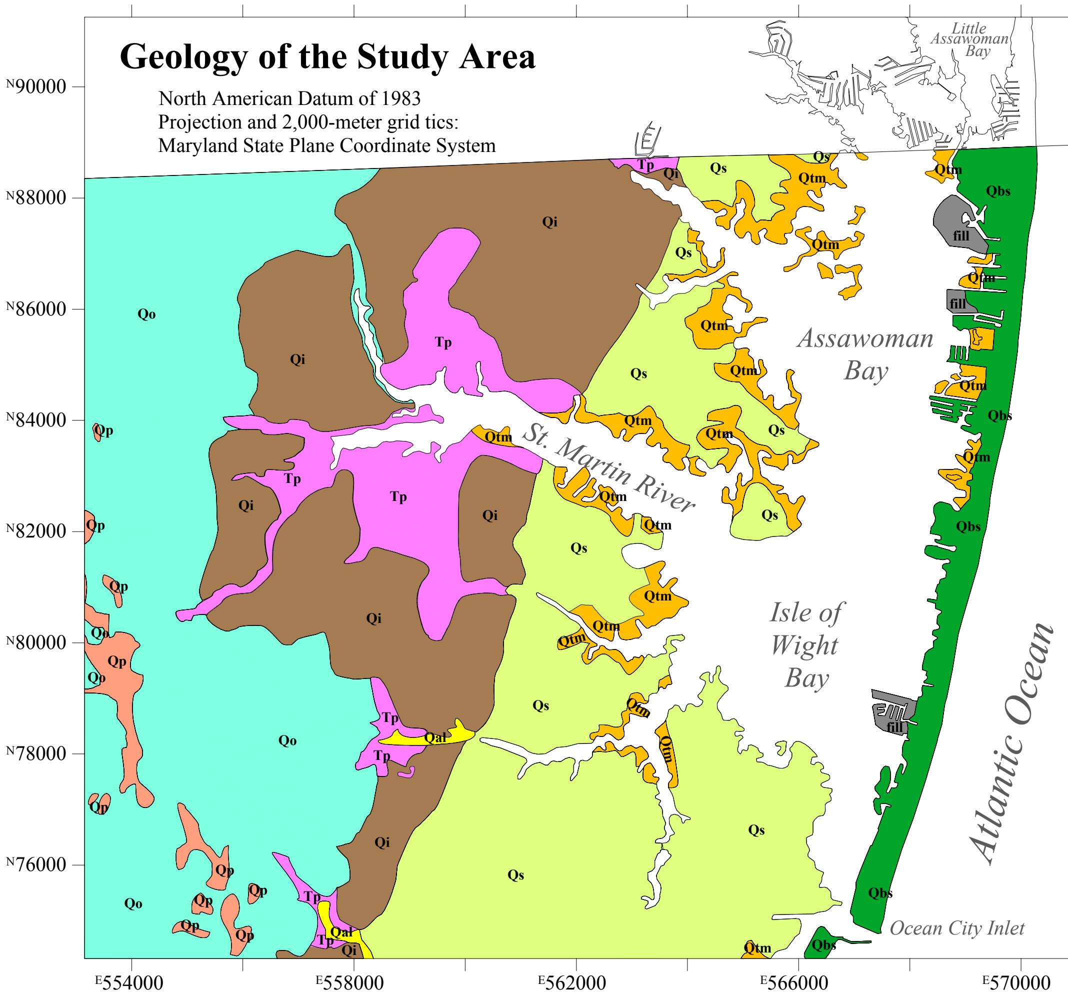
GEOLOGY

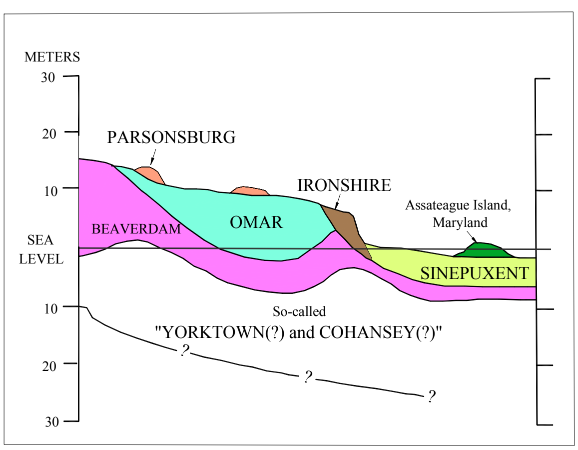
Unconsolidated Coastal Plain sediments, the upper 60 m of which are Cenozoic in age, underlie the study area. Sediments of the Sinepuxent Formation (Qs) are exposed along much of Maryland's coastal area from Bethany Beach, Delaware, southward to the Maryland-Virginia border (Fig. 3-3). The formation directly underlies Assawoman and Isle of Wight Bays and is exposed in several non-marsh areas along the mainland shore of both bays. However, Owens and Denny (1978) classified most of the shoreline marshes as Holocene (modern) deposits (Qtm). It is unclear why the marshes bordering southern Isle of Wight Bay were not distinguished from the underlying Sinepuxent Formation.

The Sinepuxent Formation is composed of dark colored, poorly sorted, silty fine-to-medium sand with thin beds of peaty sand and black clay. Heavy minerals are abundant and consist of both amphibole and pyroxene minerals. All of the major clay mineral groups – kaolinite, montmorillonite, illite, and chlorite – are represented. The sand consists of quartz, feldspar and an abundance of mica – muscovite, biotite, and chlorite. The preponderance of mica makes the Sinepuxent Formation lithologically distinct from underlying older units (Owens and Denny, 1979).

The Sinepuxent Formation, interpreted to be a marginal marine deposit, has been correlated with offshore Q2 deposits dating from 80,000 to 120,000 years before the present (Toscano, 1992; Toscano and others, 1989; Toscano and York, 1992).

The western edge of the Sinepuxent Formation abuts the Ironshire Formation (Qi). Consisting of pale yellow to white sand and gravelly sand, the Ironshire Formation is thought to be a barrier-back barrier sequence (Owens and Denny, 1978). Although the Ironshire Formation





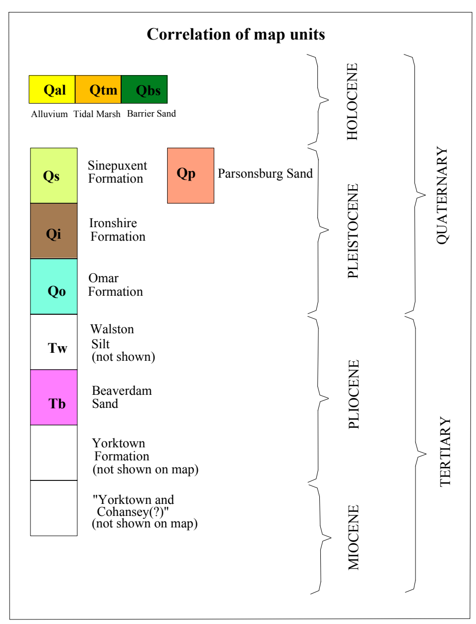


Figure 3-3. Geology of the study area. The cross-section illustrates the general relationship of geologic formations (modified from Owens and Denny, 1978 1979).

sits unconformably above the Beaverdam Sand, at no point does it underlie the Sinepuxent Formation (Owens and Denny, 1979). Within the study area, the Ironshire Formation is exposed along the upstream area of Greys Creek.

The Sinepuxent is underlain by the Beaverdam Sand (Tb), which is Pliocene in age. The exposed portion of the Beaverdam Formation is characterized by extensively cross-stratified sand, interbedded with clay-silt laminae. Unweathered Beaverdam Sand sediments may be pale blue-green or white; weathered sediments are orange or reddish brown. Due to the abundance of silt, the Beaverdam Sand is more cohesive than the Ironshire Formation. Locally, the Beaverdam Sand is exposed along the upstream area of the St. Martin River (Fig. 3-3).

The Omar Formation (Qo), thought to be early Pleistocene in age, is exposed west of the Ironshire Formation and lies directly above the Beaverdam. Within the study area, the Omar Formation consists of interstratified light colored sand and dark colored sand-silt-clay or silty clay. It is exposed along the banks of the Bishopville Prong, one of the two main branches of the St. Martin River.

Bay Bottom Sediments

The average grain size distribution of bottom sediments in Assawoman and Isle of Wight Bays is 54% sand, 28% silt, and 18% clay (Wells and others, 1996; Wells and Conkwright, 1999). The sand to mud ratio is nearly 1:1, similar to Bartberger's (1976) findings for Chincoteague Bay. Bottom sediments include seven of Shepard's (1954) ten categories (see Fig. 4-2), although most of the samples are classified as Sand, Clayey-Silt, or Silty-Sand.

Bottom sediments tend to become coarser, that is, increase in grain size, from west to east (Fig. 3-4). Sandy sediments (i.e., sand > 75%) are found primarily along the eastern side of the bays. Clayey-Silts are found in the tributaries and in isolated pockets associated with marshy shorelines. Silty-Clays are restricted to upstream areas of tributaries. Silty-Sands, Sandy-Silts, and Sand-Silt-Clays are found in isolated pockets along marshy shorelines and along the boundaries between Sand and Clayey-Silts. The boundary areas represent zones of mixing between the coarser- and finer-grained end members of the sediment distribution. However, the transition between mud-dominated and sand-dominated areas is quite abrupt for most of the bays.

Sediment distributions reflect the energy of the environments, as well as proximity to sediment source. Sand found along the western side of the bays represents material carried across the barrier island, Fenwick Island, as washover or eolian deposits, or carried through the inlet. These areas are shallower and exposed to a relatively large fetch. The bottom in these areas is subject to higher energies from wind-generated waves. Fine-grained sediments are either not deposited or are actively winnowed from these higher energy areas. At the southern end of Isle of Wight Bay, large sand shoals have been deposited as part of the flood tidal delta associated with Ocean City Inlet. Based on vibracores collected from these shoals, Wells and Kerhin (1982) determined that the central flood tidal delta is about 4.2 m (14 ft) thick and contains medium-to-fine sand.

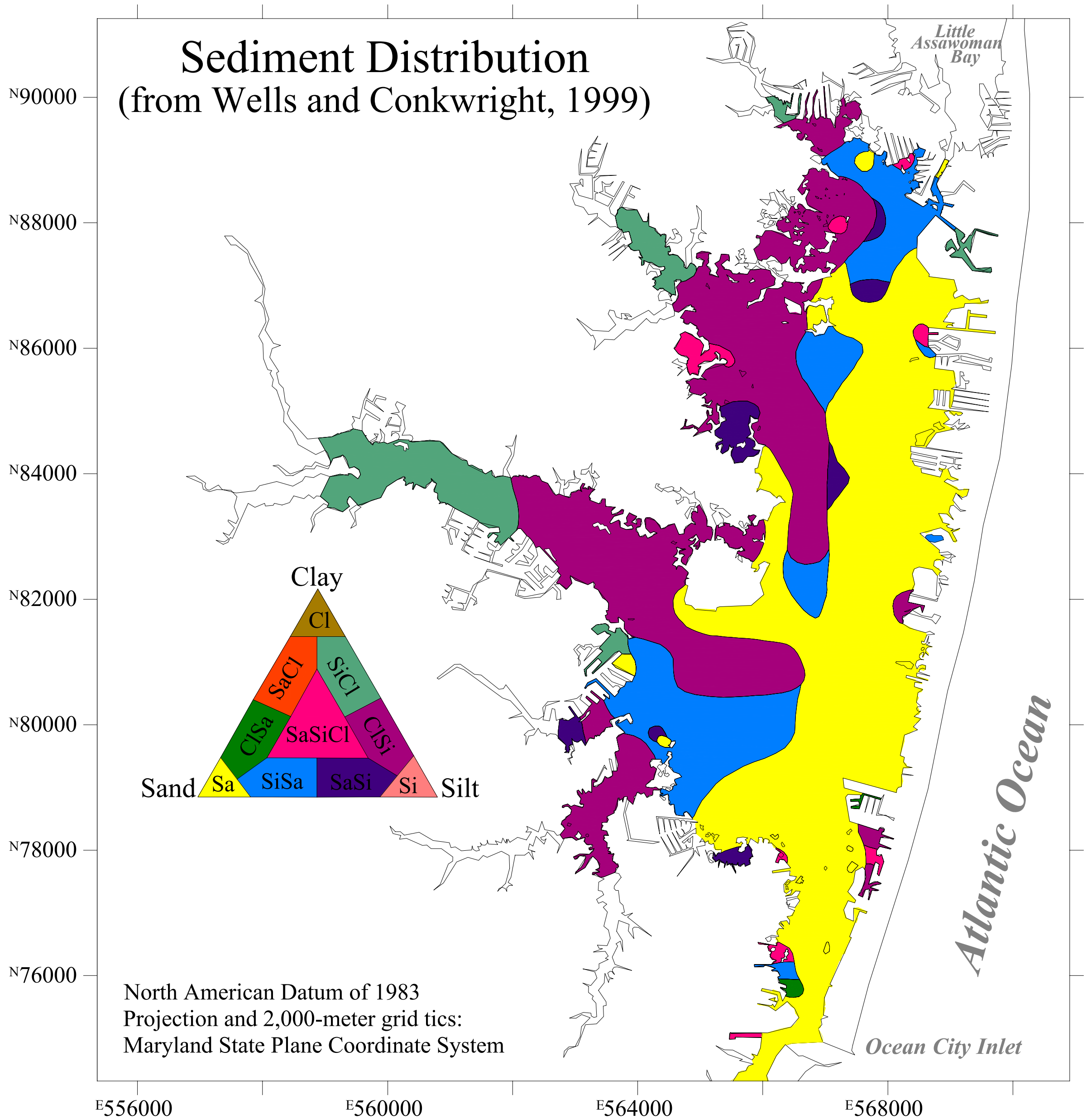


Figure 3-4. Distribution of bottom sediments, based on Shepard's (1954) classification.

The sand-dominated area around Isle of Wight is interpreted to be reworked sand from the exposed pre-transgression surface, which seismic data show outcropping in this area. This exposed surface is interpreted to represent the former footprint of a larger Isle of Wight.

Silty-Clays and Clayey-Silts are confined primarily to marsh areas and tributaries. Clayey-Silts are found in the lower reaches of tributaries and in lobes extending from the tributaries into the main bays (Fig. 3-4). Silty-Clays are found in the upper reaches of tributaries. The source of the fine-grained deposits is sediments transported by surface runoff or eroded directly from the shoreline. The finer-grained material eroded from shorelines is selectively removed, suspended, and deposited in areas where wave action is minimal – areas of limited fetch (e.g., protected marshy areas) and areas below wave base (e.g., deeper mid-channel areas).

4. METHODS

SELECTION OF SAMPLING SITES

Sampling locations were selected primarily on the basis of historical shoreline retreat, geology, geomorphology, and marsh type. First, possible candidates were chosen by identifying unprotected reaches of shoreline that had experienced relatively high rates of erosion, as shown on *Shoreline Changes* maps of the area. Within those reaches, researchers selected 22 sites that represented:

1 the main water bodies in the study area,
2 the diverse geomorphology, namely marsh, bluff, and beach,
3 the various geological formations exposed along area shorelines, and
4 the different types of vegetation in marshes bordering the rivers and bays.

Target UTM coordinates of the 22 original sites were acquired from rectified digital aerial photography (Table 4-1). MGS then contacted property owners, identified from State Property Tax maps, to obtain permission to access the sites. Three of the original sites were eliminated because MGS was unable to obtain the owner's permission. Three more sites were eliminated because the shoreline had been altered (e.g., filled and/or armored). In the end, MGS sampled 16 sites as representative of eroding shoreline material – 13 marsh sites and 3 bluff/beach sites (Fig. 4-1). To assess the biotic component of nutrient input, the University of Maryland Center for Environmental Science (UMCES) collected samples at Sites 1, 14, and 19, located in the St. Martin River, Isle of Wight Bay, and Assawoman Bay, respectively. Results of the UMCES analyses are detailed in a separate report.

Table 4-1. Sampling sites. The sites that were eliminated are indicated by shading.

Site	Name	Location	UTM coordinates (NAD 83, meters)		Comments
			Northing	Easting	
1	Hasty Point (or The Pocket)	St. Martin R. – south shore about 1 mi. downstream from confluence of Shingle Landing and Bishopville Prongs	4251063	486039	Marsh; Joint site, sampled by both MGS and UMCEES
2	Holiday Harbor	St. Martin R. – north shore at mouth of Bishopville Prong; upstream of Hasty Point	4251726	485220	Marsh; Eliminated, unable to obtain permission from landowner
3	Windmill Creek	Shingle Landing Prong – south shore: mouth of Windmill Creek	4250799	484364	Bluff/beach
4	Bishopville Prong	Bishopville Prong mid-way up stream	4252930	483615	Bluff/beach
5		St. Martin R. – north shore opposite Station 1 (Hasty Point)	4251580	486313	Bluff/beach
6	Peach Point	St. Martin R. – north shore mouth of Harry Creek	4251114	487056	Marsh

Table 4-1. Sampling sites. The sites that were eliminated are indicated by shading.

Site	Name	Location	UTM coordinates (NAD 83, meters)		Comments	
			Northing	Easting		
7	Salt Grass Point	St. Martin R. – north shore vicinity of Buck Island Pond and Buck Island Creek	4250713	488658	Marsh	
8	Smokehouse Cove	St. Martin R. – north shore NW of Isle of Wight	4249726	489906	Marsh	
9	Drum Point	Assawoman Bay – west shore easternmost extent of St. Martin Neck	4250598	491619	Marsh	
10	Tulls Island	Assawoman Bay – west shore unnamed point between Drum Point and Hills Island, immediately west of former Tulls Island	4251941	491252	Marsh	
11	Goose Pond	Assawoman Bay – west shore	4252708	491080	Marsh	
12	Peeks Creek	Assawoman Bay – west shore or Greys Creek – south shore shoreline between Peeks Creek and Back Creek; SE of confluence of Greys Creek and Back Creek	4253294	490442	Marsh	
13*	South Hammocks	Assawoman Bay – west shore SE side of South Hammocks; ~ due north of Drum Point ~1.75 mi.	4253246	492193	Core 13	Marsh
			4253251	492200	Core 13B (second core taken)	
14*	Lone Cedar Point	Assawoman Bay – west shore northern extent of study area in MD	4255752	492582	Core 14	Marsh; Joint site, sampled by both MGS and UMCES
			4255727	492780	Core 14B (second core taken)	
15	Caine Keys	Assawoman Bay – east shore ~ opposite South Hammocks	4253790	494430	Marsh; Eliminated, not natural shoreline	
16	Swan Point	Assawoman Bay – east shore ~1 mi. N of Rt. 90 Bridge; ~ opposite Drum Point	4250065	493830	Marsh; Eliminated, unable to obtain permission from landowner	
17	Bay Shore Acres	Isle of Wight Bay – west shore immediately nw of Horn Island; ~0.5 mi. N of Rt. 50 bridge	4244389	491773	Marsh; Eliminated, unable to obtain permission from landowner	

Table 4-1. Sampling sites. The sites that were eliminated are indicated by shading.					
Site	**Name**	**Location**	**UTM coordinates (NAD 83, meters)**		**Comments**
			Northing	**Easting**	
18	Wire Pond	Isle of Wight Bay – southwest shore – 1st cove west of The Thorofare	4245252	490931	Marsh
19*	Keyser Point	Isle of Wight Bay – west shore confluence of Turville Creek (south shore) and Isle of Wight Bay	4246364	489794	Marsh; Joint site, sampled by both MGS and UMCES
20	Jenkins Point	Isle of Wight Bay – west shore confluence of St. Martin River (south shore) and Isle of Wight Bay			Eliminated – shoreline altered
21	Margot's Island	St. Martin River – south shore between Jenkins Point and Shell Gut Point; ~ opposite Saltgrass Point			Eliminated – shoreline altered
22	Isle of Wight	Assawoman Bay – west shore NE shore of Isle of Wight	4249932	490966	Marsh

FIELD METHODS

Sediment Sampling

Field teams accessed all sampling sites by boat. Once on site, they recorded actual UTM coordinates using a hand held differential GPS unit, briefly described the site, and took photographs. Depending on the nature of the site (i.e., marsh, beach, or bluff), different methods were used to collect sediments for *in situ* bulk density determinations and for chemical and textural analyses.

At bluff sites, several samples were collected from the bluff face, the beach, and offshore along a profile line perpendicular to the shore. Before collecting bluff samples, field personnel cut a shallow, vertical trench into the bluff face to expose an unweathered surface. Sediment samples were collected from each visually distinctive sediment layer by inserting a short length (15 to 25 cm) of clear, cellulose acetate butyrate (CAB) plastic tube (6.7 cm diameter) horizontally into the bluff face. The tube was dug out of the bluff face, and its ends were trimmed in such a way that the inside of the tube was completely filled with sediment (no gaps). Sample tubes were capped and labeled. Grab samples collected on the beach and offshore were placed in Whirl-pak bags. Bluff height and the elevations of sediment horizons and sample locations along the bluff/beach profile were determined using a level and a stadia rod.

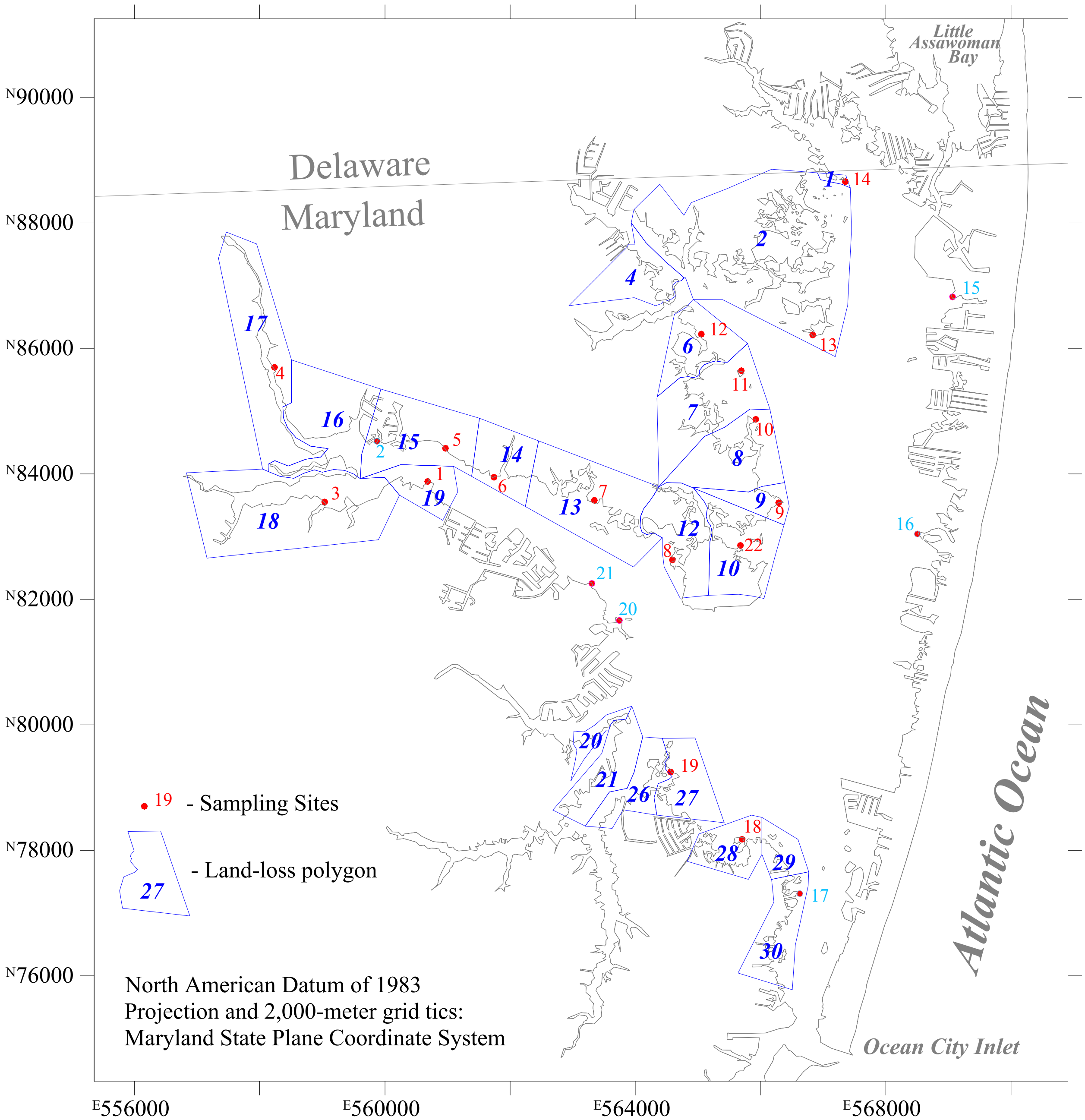


Figure 4-1. Locations of sampling sites (in red) and land loss polygons (in blue). The sampling sites with light blue numbers were eliminated from the study because the shoreline at the site was altered or researchers could not obtain the owner's permission to access the site.

At marsh sites, a continuous sediment core was collected on a prominent neck or point of the marsh, approximately 1 m from the water's edge. The length of core needed at each site was determined by averaging several bank height measurements. Bank height was defined as the distance between the top of the marsh and the base of the erosional scarp at the marsh edge. The base of the scarp was usually underwater. Marsh cores were collected by vibrating or pounding 7.62 cm-diameter aluminum tubing into the marsh surface down to the desired depth. Sediment compaction was measured and recorded before the core was extracted. Following extraction, the liner was trimmed to the top of the sediment and sealed at both ends for transportation back to the lab. There, it was kept refrigerated until it was processed. A grab sample was collected approximately 0.3 m offshore adjacent to the core location.

LABORATORY METHODS

Quantifying Land Loss

The amount of land lost annually in the study area is based on a digital comparison of two historical shorelines, one dating from 1942 and the other from 1989. The 1942 shoreline was previously digitized from 1:20,000-scale National Oceanic and Atmospheric Administration (NOAA) coastal survey maps, also known as topographic (T-) sheets. The 1989 shoreline was previously interpreted from 1:12,000-scale orthophotography. At the time it was delineated, the 1989 shoreline was also classified by shoreline type (i.e., beach, structure, vegetated, or water's edge) (Hennessee, 2001). MGS used a geographic information system (GIS), MicroImages' TNTmips, to compare shoreline positions and quantify losses due to erosion.

Different stretches of shoreline erode at different rates. To account for this variability, MGS divided the study area shoreline into 23 segments. Shoreline reaches ranged in length from about 600 m to 45,000 m; most were less than 9,000 m long. To demarcate the reaches, MGS constructed a template of irregular, mostly contiguous, "land loss" polygons. The polygons were drawn in such a way that:

- They contained all unprotected shoreline in the study area, except for the following, unsampled tributaries: the head of Greys Creek; Back Creek; the upstream reaches of Manklin Creek; and Turville and Herring Creeks above their confluence.
- They excluded protected shoreline: the western side of Fenwick Island (eastern Assawoman and Isle of Wight Bays); the southern end of Isle of Wight; the south shore of the St. Martin River bordering the community of Ocean Pines; the north shore of Manklin Creek; and a short stretch of shoreline in the vicinity of Octopus Pond.
- With the exceptions listed above, as well as a short reach of shoreline in the vicinity of Saltgrass Pt., they initially included the 1942 and 1989 shorelines in their entirety. (Only one shoreline was available for Saltgrass Pt.)
- Based on researchers' field experience and an inspection of 1989 digital orthophotography, each contained, as far as practicable, similar types of shoreline (i.e., marsh or upland).

- In areas of changing geology, their boundaries coincided with the contacts between geologic formations. For instance, the cross-shore boundaries of polygon P16 at the mouth of Bishopville Prong coincided with an outcrop of the Beaverdam Sand.
- In the vicinity of a bay or tributary mouth, polygon boundaries coincided with the mouth (e.g., polygons P8 and P12), to allow researchers to report their results by water body.
- In the absence of any of the above criteria, polygon boundaries were drawn equidistant between sample locations (e.g., polygons P6 through P10). No polygon included more than one sampling site.

Each land loss polygon in the template was assigned a number, P#. The polygons are shown in Figure 4-1, and a description of their locations is presented in Table 4-2.

Table 4-2. Land loss polygons and associated sampling sites

Land loss polygon	Location	Geology*	Associated sampling site
P1	<u>Assawoman Bay</u> Lone Cedar Pt.	(P & S) – **Holocene Tidal Marsh Deposits (Qtm)**	14B
P2	<u>Assawoman Bay</u> Marsh south of Lone Cedar Pt., along western shore of Assawoman Bay and northern shore of Greys Cr., including Corn Hammocks, South Hammocks, and Swan Gut	(P) – Mostly Qtm, except **Middle-Wisconsin Sinepuxent Fm. (Qs)** upstream of Swan Gut; polygon boundary drawn at contact between Qs and **Upper Sangamon Ironshire Fm. (Qi)** (S) – Qtm	13B
P4	<u>Greys Creek</u> Southern shore of Grays Cr. upstream of Back Cr.	(P) – Mostly Qtm, except some Qs; polygon boundary drawn at contact between Qs and Qi (S) – No sample in polygon	12
P6	<u>Assawoman Bay</u> Western shore of Assawoman Bay (or southern shore of Greys Cr.) from Back Cr. to Peeks Cr.	(P & S) – Qtm	12
P7	<u>Assawoman Bay</u> Northern Goose Pond	(P) – Mostly Qtm, except some Qs (S) – Qtm	11
P8	<u>Assawoman Bay</u> Southern Goose Pond; Tulls Island to Drum Pt.	(P & S) – Qtm	10
P9	<u>Assawoman Bay</u> Drum Pt.	(P) – Equally Qs and Qtm (S) – Qtm	9

Table 4-2. Land loss polygons and associated sampling sites			
Land loss polygon	**Location**	**Geology***	**Associated sampling site**
P10	Assawoman Bay Drum Pt. to Wight Pt.	(P & S) – Qtm	22
P12	St. Martin River West side of Isle of Wight, north of Rt. 90 bridge, and Smokehouse Cove	(P) – Qtm, except for some Qs on southwest side of Isle of Wight (S) – Qtm	8
P13	St. Martin River Northern shore of St. Martin R. from Smokehouse Cove west past Saltgrass Pt. to vicinity of mouth of Buck Island Cr.; includes Buck Island Pond and Buck Island Cr.	(P & S) – Qtm	7
P14	St. Martin River Northern shore of St. Martin R. in vicinity of Peach Pt. and mouth of Harry Cr.	(P & S) – Qtm	6
P15	St. Martin River Northern shore of St. Martin R. in vicinity of Woods Pt. at mouth of Zippy Cr.	(P & S) – **Pliocene Beaverdam Fm. (Tb)**	5
P16	Bishopville Prong Both shores of Bishopville Prong from mouth of prong north to contact between Beaverdam Sand and Ironshire Fm.	(P) – Tb (S) – No sample in polygon	5
P17	Bishopville Prong Both shores of Bishopville Prong bordered by Ironshire Fm.	(P & S) – **Lower Sangamon Omar Fm. (Qo)**	4
P18	Shingle Landing Prong Both shores of Shingle Landing Prong, from mouth upstream past confluence of Birch Br., Middle Br., and Church Br.	(P & S) – Tb	3

Table 4-2. Land loss polygons and associated sampling sites			
Land loss polygon	**Location**	**Geology***	**Associated sampling site**
P19	St. Martin River Southern shore of St. Martin R. from mouth of Shingle Landing Prong east past Hasty Pt. to first canal	(P) – Mostly Qtm, except some Tb (S) – Qtm	1
P20	Manklin Creek Southern shore of Manklin Cr. immediately upstream of mouth	(P) – Mostly Qs, except some Qtm (S) – No sample in polygon	8
P21	Turville Creek Northern shore of Turville Cr. from mouth of Herring Cr. to Mocassin Pond	(P) – Equally Qs and Qtm (S) – No sample in polygon	8
P26	Turville Creek Southern shore of Turville Cr. from mouth of Herring Cr. to Keyser Pt.	(P) – Mostly Qs, except some Qtm (S) – No sample in polygon	19
P27	Isle of Wight Bay Keyser Pt. to Octopus Pond	(P & S) – Qs	19
P28	Isle of Wight Bay Wire Pond and undeveloped (eastern) section of Octopus Pond	(P & S) – Qs	18
P29	Isle of Wight Bay The Thorofare, from Drum Island to the start of the marsh bordering Wire Pond	(P) – Qs (S) – No sample in polygon	18
P30	Isle of Wight Bay Rt. 50 bridge to Drum Island	(P) – Qs (S) – No sample in polygon	18
* within polygon (P) and at sampling site (S)			

Once it was constructed, the polygon template was merged first with the 1942 shoreline and then with the 1989 shoreline. Both shoreline/template files were edited:

- Long stretches of developed shorelines were erased.
- Small gaps in the remaining shoreline were closed, usually by drawing short, straight lines between the dangling shoreline segments.
- Man-made features, usually canals, present in one year but not the other, were deleted. (In some cases, the headward reach of a small tributary extended further upstream in one

year than in another. Likewise, some ponds and coves, particularly in or along marshes, were evident in only one coverage. These features were left unaltered.)

- Within each of the land loss polygons, interior polygons were assigned one of the following attributes: "fastland," "island," or "water."

For each land loss polygon, the areas (m^2) covered by fastland, island and water were recorded, by year, in an Excel spreadsheet. Likewise, the total length (m) of the 1989 shoreline, as well as the length of each type of shoreline (beach, structure, vegetated, water's edge) was recorded. For each polygon, land loss over the 47-year period was determined by subtracting water area in 1989 from water area in 1942. The difference in water area is equivalent to the area of land lost by erosion. A summary of area and shoreline changes for each polygon is presented in Table D-1 (Appendix D).

The land loss polygons provided a structure for organizing the results of the sediment, pore water, and plant tissue analyses. Each sample location was associated with one or more of the land loss polygons (Table 4-2). In the simplest case, where polygons and samples were co-located, the association is direct. For instance, the results for Site 13, located within polygon P12, are associated with polygon P12. For unsampled polygons, the association was based either on similarity in geology or shoreline type (marsh or upland), or on proximity.

<u>Bank Height</u>

At each sampling location, including one at which no sample was collected (Site 17 in polygon P29), bank height measurements (m) were taken at several places and averaged for the site. The mean heights were assigned to the associated land loss polygon(s), except as follows. The banks measured at Sites 3 and 5 were not representative of bank heights along the length of shoreline included in the associated land loss polygons. Much of the shoreline in those polygons borders low-lying marsh. So, for polygons P15, P16, and P18, researchers classified the 1989 digital shoreline as marsh, bank, or protected, based on their field experience and a visual inspection of the associated digital orthophotography. For each of the three land loss polygons, a weighted average bank height was calculated by multiplying the length of marsh shoreline by 0.5 m and the length of bank shoreline by the bank height at the associated sampling site, then dividing the sum of those two numbers by the length of unprotected shoreline (Table 4-3).

Table 4-3. Mean bank heights (m) calculated for land loss polygons P15, P16, and P18.

Polygon	Marsh length (m)	Bank length (m)	Protected length (m)	Unprotected length (m)	Marsh height (m)	Bank height (m)	Mean bank height (m)
P15	1,948.66	2,263.92	1,412.05	4,212.58	0.50	2.12	1.4
P16	3,286.39	3,723.21	561.99	7,009.60	0.50	2.12	1.4
P18	4,588.49	7,807.85	0.00	12,396.34	0.50	2.79	1.9

Sediments

Core Processing

Before opening the cores, MGS x-rayed them in their liners using a TORR-MED medical X-ray unit. The exposure settings were 84 to 90 kilovolts for 6 to 8 seconds at 5 milliAmps. Radiographic images were developed using a Xerox 125 xeroradiograph processor.

After x-raying was completed, each core was cut in half lengthwise. First, the aluminum liner was cut using a circular saw. The sediment core within the liner was then cut in half with a very sharp, stainless steel knife. The knife produced a clean cut through the plant roots and peat material, minimizing deformation of the core structure or shape. Lab personnel photographed and described the split core, noting changes in sediment and structure with depth. Xeroradiographs (x-rays), photographs and core logs are presented in Appendix A. The core was divided into sections 10 to 25 cm long. The exact length depended on lithological changes observed in the split core and in the radiographs. Each section was split lengthwise into three or four subsamples, which were designated for specific analyses (i.e., bulk density, grain size, or chemical analyses). The sub-samples were placed in Whirl-Pak bags. Bulk density splits were processed first, before other splits were made (see next section).

Bulk Density and Water Content

For both bluff samples and cored marsh sediments, MGS used similar methods to determine bulk density and water content. Grab samples collected from the beach and nearshore were processed for water content only.

Bluff Samples

The entire sediment sample was removed from the plastic core tube and weighed. The length of the tube was recorded. The sample was then mixed to homogenize it. Exactly ¼ of the sample, by weight, was placed in a drying vessel, dried at 60°C, and then reweighed. The dried sample was saved for chemical analyses. The remaining ¾ of the sample was saved for grain size analysis.

Water content was calculated as the percentage of water weight to the total weight of wet sediment, as follows:

$$\%\ H_2O = \left(\frac{W_w}{W_t}\right) * 100 \qquad \textbf{Eq. 4-1}$$

where: W_w is the weight (g) of water, and
W_t is the weight (g) of wet sediment.

Wet and dry bulk densities (referred to in this study as "measured" bulk density, in g/cm^3 or Kg/m^3) were calculated as the wet weight or dried weight (g), respectively, of the subsample divided by ¼ of the volume of the entire bluff sample. Volume was calculated using the volume formula for a cylinder:

$$V = \pi r^2 l \qquad \textbf{Eq. 4-2}$$

where:
- V is the volume (cm^3) of the subsample,
- π is 3.14159,
- r is the radius of the circumference of the CAB tube liner, or ½ the diameter (6.7 cm), and
- l is the length (cm) of the core tube.

A second method was used to calculate bulk density (wet) using the water content of the sediment (Bennett and Lambert, 1971). This method assumes that average sediment grain density is 2.72 g/cm^3 and that the sample is fully saturated with water.

$$\rho_{(B\ \&\ L)} = \frac{W_t}{\frac{W_d}{2.72} + W_w} \qquad \textbf{Eq. 4-3}$$

where:
- $\rho_{(B\ \&\ L)}$ is the calculated bulk density, based on Bennett and Lambert,
- W_t is the weight (g) of wet sediment,
- W_d is the weight (g) of dry sediment, and
- W_w is the weight (g) of water.

Cored Marsh Samples

Each section of core was weighed to determine the total weight of the section. Exactly ½ of the section, by weight, was place in a drying vessel, dried at 60°C, and then reweighed. The dried sample was archived.

Water content and calculated wet bulk density, based on Bennett and Lambert, were calculated using Equations 4-1 and 4-3, respectively. Measured bulk densities were calculated as the wet and dried weights (g) of the subsample divided by ½ of the volume of the core section. The volume of the core section was calculated using Equation 4-2, where r = ½ the diameter of the aluminum tubing (7.62 cm diameter) and l = section length.

Dry bulk density of the core section was adjusted to account for any core compaction. For most of the cores, there was some compaction (compression) of the sediments during the insertion of the core liner. The amount of compaction was measured as the difference between the top of the marsh and the top of the sediment in the core liner once the liner was emplaced. The degree of compaction along the length of the core varied depending on sediment texture. However, for this study, MGS assumed that compaction was evenly distributed over the length of the core. Bulk densities were multiplied by a compaction correction calculated as:

$$c_{(c)} = 1 - \left(\frac{l_{(s)} - l_{(t)}}{l_{(s)}} \right) \qquad \textbf{Eq. 4-4}$$

where, $c_{(c)}$ is the compaction correction,
$l_{(s)}$ is the length or depth (cm) of the sediment column cored or sampled, and
$l_{(t)}$ is the length (cm) of the sediment core collected.

Grain Size Analysis

In preparation for grain size analysis, sediment samples underwent a cleaning process to remove soluble salts, carbonates, and organic matter. These constituents may interfere with the dispersal of individual sediment particles and, thereby, affect the subsequent separation of the sand and mud fractions. All sediment samples were treated first with a 10% solution of hydrochloric acid (HCl) to remove carbonate material, such as shells, and then with a 6% or 15% solution of hydrogen peroxide (H_2O_2) to remove organic material. A 0.26% solution of the dispersant sodium hexametaphosphate ($(NaPO_3)_6$) was then added to ensure that individual grains did not clump, or flocculate, during pipette analysis.

Marsh samples, which contained significant amounts of plant material, were wet-sieved through a 14-mesh (~1.4 mm) nylon screen to remove large plant roots and debris. The plant material was dried and weighed. Usually, plant matter was separated from sediments after the HCl treatment. However, for cores collected at sites sampled jointly by MGS and UMCES, samples were sieved prior to HCl treatment, and the plant fractions (> 1.4 mm) were saved for chemical analysis.

For each sample, the sand fraction was separated from the mud fraction by wet-sieving through a 4-phi mesh sieve (0.0625 mm, U.S. Standard Sieve #230). The sand fraction (i.e., particles > 0.0625 mm) was dried and weighed. The mud fraction (i.e., sediment passing through the #230 sieve) was analyzed using a pipette technique to determine the proportions of silt and clay (Krumbein and Pettijohn, 1938). The mud fraction was suspended in a 1000-ml cylinder in a solution of 0.26% sodium hexametaphosphate. The suspension was agitated and, at specified times thereafter, 20 ml pipette withdrawals were made. The rationale behind this process is that larger particles settle faster than smaller ones. By calculating the settling velocities of different sized particles, withdrawal times can be determined. At the time of withdrawal, all particles larger than a specified size have settled past the point of withdrawal. Sampling times were calculated to permit the determination of the total amount of silt and clay (4 phi) and clay-sized (8 phi) particles in the suspension. Withdrawn samples were dried at 60°C and weighed. From these dry weights, the percentages of sand, silt, and clay were calculated for each sample and classified according to Shepard's (1954) nomenclature (Fig. 4-2).

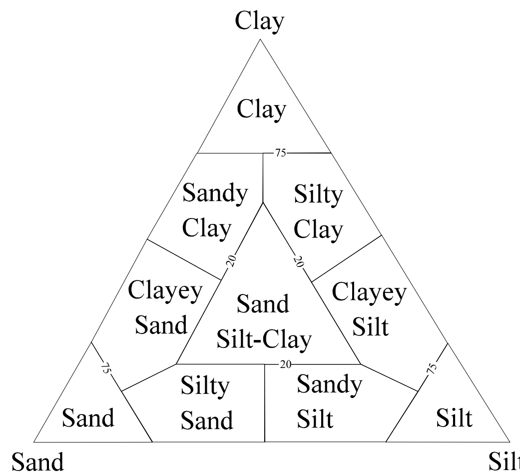


Figure 4-2. Shepard's (1954) classification of sediment types.

<u>Chemical Analysis</u>

Sample Preparation

Before marsh samples were dried and ground, they were processed using a commercially available food blender and plastic (styrene copolymer) processor containers. Between 50 to 100 g of wet core sample, roots and all, were mixed with 50 to 100 ml of ultra-pure water. The slurry was processed at hi/liquefy for 1 minute or until no visible pieces of plant material remained. The processed slurry was then transferred to an evaporating dish and dried at 60°C.

The dried marsh samples and the bluff samples dried for bulk density/water content determinations were ground in tungsten-carbide vials using a ball mill, placed in Whirl-Pak bags, and stored in a desiccator.

Total Carbon and Nitrogen Analysis

Untreated, ground sediments were analyzed for total nitrogen, carbon, and sulfur (NCS) using a Carlo Erba NA1500 analyzer. Approximately 10 to 15 mg of dried sediment were weighed into a tin capsule. The exact weight of the sample, to the nearest µg, was recorded. To ensure complete combustion during analysis, 15 to 20 mg of vanadium pentoxide (V_2O_5) were added to the tin capsule and mixed with the sediment. The capsule was then crimped to seal and stored until analysis.

The encapsulated sediment sample was dropped into a combustion chamber, where the sample was oxidized in pure oxygen. The resulting combustion gases (N, C, H, and S), along with pure helium, the carrier gas, were passed through a reduction furnace to remove free oxygen and then through a sorption trap to remove water. Separation of the gas components was achieved by passing the gas mixture through a chromatographic column. A thermal conductivity detector was used to measure the relative concentrations of the gases.

The NA1500 Analyzer was configured for NCS analysis using the manufacturer's recommended settings. As a primary standard, 5-chloro- 4-hydroxy- 3-methoxy-benzylisothiourea phosphate was used. Blanks (tin capsules containing only vanadium pentoxide) were run every 12 samples. Replicates of every fifth sample were run. As secondary standards, at least one standard reference material (SRM) (NIST SRM #1646 – Estuarine Sediment; NIST SRM #2704 – Buffalo River Sediment, or the National Research Council of Canada PACS-1 – Marine Sediment) was run every six or seven samples. Comparisons of the results of the SRMs to the certified values are presented in the discussion of quality assurance and quality control (Appendix C).

Total Phosphorus and Metals

Activation Laboratories, Ltd. (Actlabs) of Tucson, Ariz., analyzed bluff and marsh sediments for 22 elements including total phosphorus. The lab used a four-acid, "near total" digestion process, followed by analysis of the digestate by inductively coupled plasma emission spectroscopy (ICP-OES). The four-acid digestion employed perchloric ($HClO_4$), hydrochloric (HCl), nitric (HNO_3), and hydrofluoric (HF) acids. Quality assurance was checked using the method of bracketing standards (Van Loon, 1980). The SRMs, similar to the sediments being analyzed, included the same standards used in the total nitrogen, carbon, and sulfur analyses. Actlabs' results of the analyses of the SRMs are listed in Appendix B. Analytical results for the bluff and marsh core samples are listed in Appendix C.

DATA REDUCTION

Average concentrations of nutrients (total carbon, nitrogen, and phosphorus), specific metals (Pb and Zn), and textural components (total solids, sand, silt, clay) were calculated for each core or bank/bluff site by averaging the concentrations of the individual core samples or bluff samples, normalized to bank height. Mean site concentrations were then assigned to specific land loss polygons (see Table 4-2) to calculate the component loadings for the polygons. Equations for the data reductions, along with detailed explanations and calculation tables, are presented in Appendix D.

5. RESULTS AND DISCUSSION

FIELD AND LAB OBSERVATIONS

Within the study area, sediment samples were collected from three basic types of shorelines: marsh, bluff and beach. Sites 3, 4, and 5, in the upstream area of the St. Martin River, are located along shorelines dominated by low bluffs, 2 to 3 m high, fronted by a narrow (6 to 9 m wide), sandy beach (Fig. 5-1). Both the Omar Formation (Site 5) and the Beaverdam Formation (Sites 3 and 5) are exposed along this portion of the river (Fig. 3.3). The bluff sediments consist of predominately grayish yellow to brownish gray sands with some mud. The lower half of the bluff at Site 3 consists of greenish blue sandy mud, which is more resistant to erosion. As a result, the bluff at Site 3 has a 40% slope. The bluffs at Sites 4 and 5 are steeper, with slopes greater than 60%.

Figure 5-1. Bluff at Site 5.

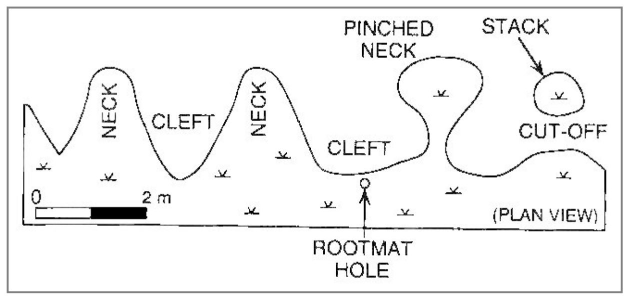


Figure 5-2. The main features developed along a marsh shoreline due to wave erosion (from Schwimmer, 2001).

The remaining sites are located on prominent points along marshy shorelines composed of either Holocene tidal marsh deposits or Sinepuxent deposits (Fig. 3-3). Most marsh shorelines are highly convoluted and edged by a 0.3 to 0.7 m erosional scarp, which is often undercut beneath the root mat layer. Features observed along the marsh shoreline include neck and cleft, pinched necks, stacks and isolated islands (Fig. 5-2), all of which are indicative of wave attack, a significant erosional process operating in the coastal bays (Schwimmer, 2001).

Pocket beaches (Fig. 5-3), the lengths of which range from 10 m to more than 50 m, are common along the marsh shoreline, particularly on the mainland side of Assawoman Bay. Pocket beaches may reflect a localized sand source (e.g., sandy facies in the underlying Sinepuxent Formation), nearshore sediment transport processes, or a combination of both. Most marsh sites characterized by sandy sediments are located near eroding headlands, a potential source of sand. In Rehoboth Bay, Delaware, Schwimmer (2001) observed that sandy beaches occur where eroding shoreline intersects upland areas. Subtle variations in lithologies at marsh sites may be related to antecedent topography, as well as to local sediment transport processes.

The dominant marsh vegetation is *Spartina alterniflora*. At many sites, the marsh surface and scarp are armored with live mussels (*Modiolus sp*) (Fig. 5-4).

Based on an examination of the marsh cores, sediment characteristics vary not only from site to site, but both vertically and laterally across a given site. Marsh sediments are predominately fine-grained muds with abundant plant material and organic matter (peat). Bulk organic content ranges from less than 5% (dry weight) to 71%. Sand content decreases with depth at most sites. Active (live) root zones range from depths of 20 cm (Site 13) to 50 cm (Site 10) below the marsh surface. In many cores, a redox boundary is evident just below the active root zone. Also, a 10 to 20 cm thick layer containing very high peat or plant material content with little sediment occurs at or below the active root zone. This "spongy" layer accounts for most of the compaction that occurs during the collection of cores and the "quaking" of the marsh surface felt when large waves hit the shoreline or when walking.

Figure 5-3. Pocket beach. This sandy beach is one of several found at Site 14 (Lone Cedar Point). A short core collected from this beach revealed a layer of sand overlying marsh mud.

Figure 5-4. Mussels armoring scarp face at Site 1.

LAND LOSS (AREA AND VOLUME)

For the 47-year period between 1942 and 1989, Table 5-1 shows land lost and rates of erosion for the northern coastal bays. Overall, the 166 km of shoreline lost about -1.2 x 10^6 m^2 of land to erosion. On average, the shoreline retreated a total of -7.3 m, at an annual rate of -16 cm/yr. Rates of loss varied widely (Fig. 5-5). The protected shorelines of Bishopville Prong (P17) and Shingle Landing Prong (P18), tributaries of the St. Martin River, experienced minimal erosion, -4 cm/yr. Rates reached a maximum of -39 cm/yr along the exposed western shore of Isle of Wight Bay (P27). These annual erosion rates are similar to those measured along marsh shorelines in Rehoboth Bay, Delaware, where, over a three year period, rates averaged between -14 to -43 cm/yr (Schwimmer, 2001).

Considering the three main bodies of water, overall erosion rates were highest along the shores of Isle of Wight Bay (-24 cm/yr) and lowest along the St. Martin River (-13 cm/yr), with Assawoman Bay in between (-15 cm/yr).

In addition to the loss of land area, shoreline erosion typically involves a vertical component, that is, the retreat of a bank of bluff. The volume of sediment lost depends on the height of the eroding bank. Table 5-1 also shows volumetric losses, the result of multiplying the change in a polygon's land area (See Appendix D, Table D-1) by the associated bank height. The calculation assumes uniform bank height throughout the polygon and vertical, as opposed to sloping, banks. Except for Bishopville and Shingle Landing Prongs, bank heights in the study area are less than 1 m in elevation.

Table 5-1. Volume (m^3) and rate of land lost during the 47-year period between 1942 and 1989 and linear rates (m/yr) of shoreline erosion, by basin. Negative numbers indicate erosion.

Basin	1989 shoreline length (m)	Rate of shoreline change (m/yr)	Change in land area (m^2)	Mean bank height (m)	Volume loss for period (m^3)	Rate of volume loss (m^3/yr)
Assawoman Bay	81,164	-0.15	-573,150	0.52	316,356	-6,731
St. Martin River	59,378	-0.13	-361,877	1.29	362,426	-7,711
Isle of Wight Bay	25,296	-0.24	-280,630	0.54	143,007	-3,043
Total	**165,838**		**-1,215,657**		**821,789**	**-17,485**
Average		**-0.16**		**0.79**		

Over the course of the 47 years, the total volume of sediment lost to shoreline erosion amounted to -822 x 10^3 m^3. Annually, that translates to -17.5 x 10^3 m^3/yr. Volumetric losses are greatest in the St. Martin River (-7.7 x 10^3 m^3/yr), due in part to relatively high bank elevations along Bishopville and Shingle Landing Prongs. Annual volumetric losses in Assawoman Bay are nearly as high (-6.7 x 10^3 m^3/yr), whereas, those in Isle of Wight Bay are considerably lower (-3.0 x 10^3 m^3/yr). Factoring in bank height changes the rank ordering of the three water bodies in terms of losses. Based on linear rates of change, Isle of Wight Bay is the biggest loser. Based on volumetric loss, the St. Martin River is (Fig. 5-5). Depending on one's perspective, one measure may be more useful than the other. Waterfront property owners, for example, may be most concerned about how rapidly the shoreline is approaching their homes. Coastal zone managers, attempting to control turbidity, may be more interested in volumetric losses.

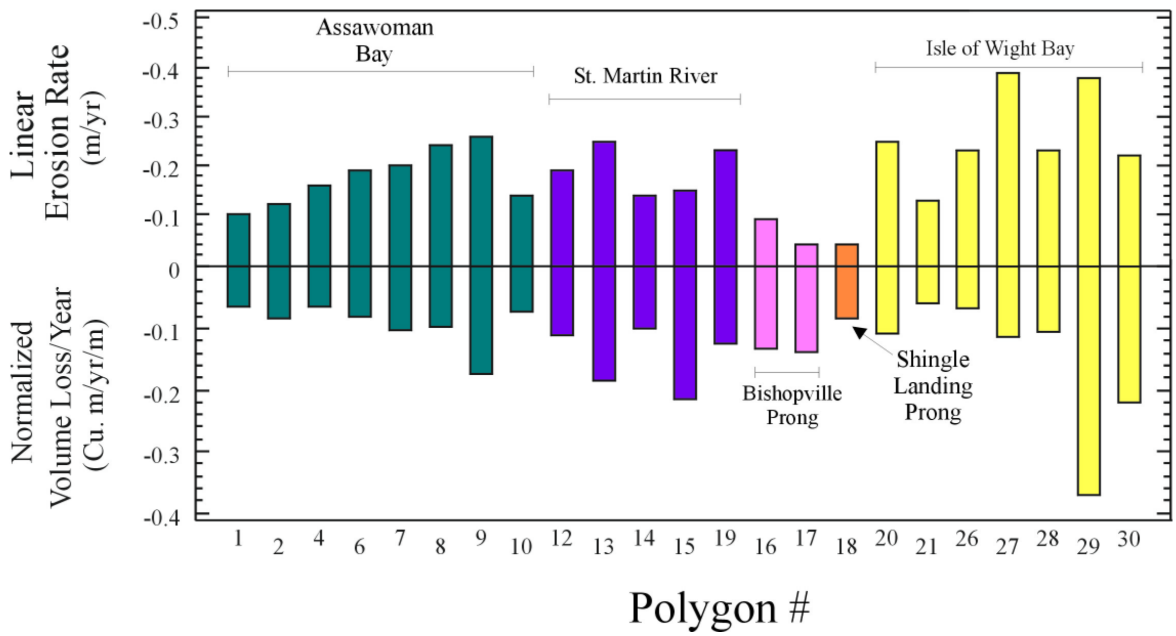


Figure 5-5. Comparison of linear erosion rate and volumetric loss for each land loss polygon. To normalize differences in polygon area, volume loss for each polygon is divided by shoreline length within the polygon; losses are given as volume (m^3) per year per linear meter of shoreline.

SEDIMENTS

Bulk Density

One of the most important parameters measured in this study is bulk density, a determination of the total solids in a volume of sediment. Bulk density is used to convert the volume of land lost to mass loadings. Bulk density is calculated by two different methods. First, it is measured directly. A known volume of sediment is weighed and assumed to reflect the *in situ* density of shoreline sediments, accounting for all air pockets, clastics, plant material, etc. Second, bulk density is calculated as a function of water content (Bennett and Lambert, 1971). Results of both methods, reported in Appendix C, are discussed below. The emphasis is on measured dry bulk density, the number used in the mass loading calculations.

The measured dry bulk density of sediments ranges from 0.12 to 1.54 g/cm^3. Higher bulk densities (i.e., >1.25 g/cm^3) are associated with sediments sampled from bluff sites (Sites 3, 4, and 5). These sediments consist almost entirely of sand and contain little plant material or organic matter. The average dry bulk density of bluff sediments is 1.39 ± 0.13 g/cm^3, which is slightly lower than the average bulk density of 1.5 g/cm^3 used by Ibison and others (1990, 1992).

The measured dry bulk density of marsh sediments ranges from 0.12 to 1.03 g/cm^3, averaging 0.43 ± 0.28 g/cm^3. This range is within the range of values observed in marsh sediments in the Chesapeake Bay (Anderson and others, 1997; Stevenson and others, 1985). Higher bulk densities correspond to the sandy sediments found at the tops of cores. At most core sites, densities decrease with depth below the marsh surface. The lowest bulk densities correspond to a "spongy" layer, which consists of abundant plant material and organic matter, and very little sand or mud.

Water Content

Water content of marsh samples ranges from 28 to 86%, averaging 65 ±17%. Bluff sediments contain very little water, less than 10% for all samples except the clay unit at the base of Site 3. For sediments that are saturated with water, particularly marsh samples, water content is inversely related to bulk density (Figs. 5-6 and 5-7). Water content, which reflects the volume of pore space between solid particles, is a function of grain size, grain shape, and the packing of grains. Measured wet bulk density is typically 5% less than the calculated Bennett and Lambert values (B&L bulk density). The difference is attributable to incomplete saturation with water, as with the bluff samples, and to the deviation of the average specific gravity (i.e., density) of the solids in the sediment from the constant, 2.72 g/cm^3, used by Bennett and Lambert (Eq. 4-3).

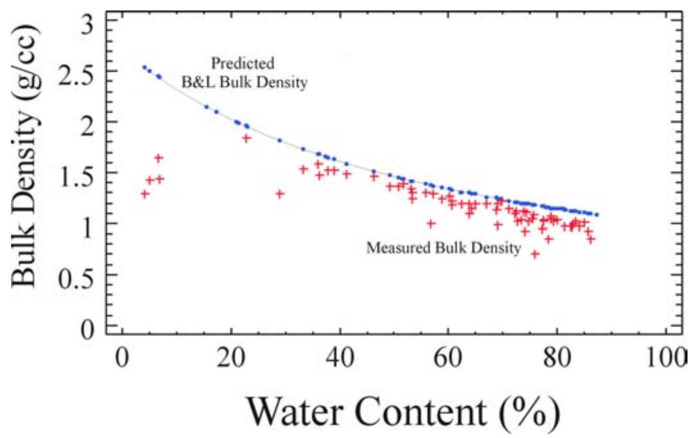


Figure 5-6. Measured wet bulk density as a function of water content. Superimposed on the plot is a (blue) curve representing bulk density calculated using Bennett and Lambert's equation. Measured wet bulk density values agree very well with Bennett and Lambert values ($R^2 = 0.95$). The outlying cluster of four data points (water content < 20%) corresponds to bluff samples.

Marsh sediments contain varying amounts of plant material, which reduces the overall (average) density. Figure 5-7 is a graph of the difference (% variation) between measured bulk density and B&L bulk density, plotted against plant content (i.e., plant > 14 mesh). Plant content accounts for much of the variation from the calculated bulk density.

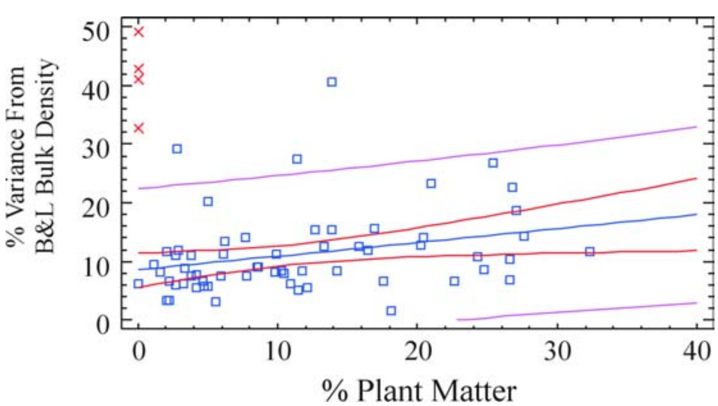


Figure 5-7. Difference (%) between measured wet bulk density and B&L bulk density, plotted against the plant content of the sediment. Superimposed on the plot are the 99% (red) and 95% (purple) confidence level limits and trend line (blue; $R^2 = 0.158$). The red Xs represent bluff samples and are treated as outliers.

Texture (Grain size composition)

The average textural composition of the clastics (i.e., mineralic or abiotic component) eroded from the study area shoreline is 67% sand, 18% silt, and 15% clay; the sand to mud ration is 2:1. Sand is the most abundant component; silt and clay are present in nearly equal proportions.

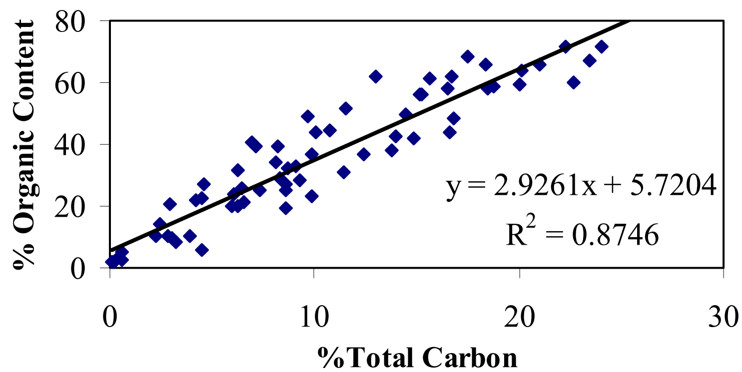
Bluff sediments consist almost entirely of clastics (% dry weight). The bulk of the clastics consists of sand-sized particles, except for the clayey unit at Site 3, which is a Sand-Silt-Clay. The beach at each of the bluff sites and the area immediately offshore of Site 3 consist almost entirely of sand (>95%). Gravel is a minor component, contributing approximately 1% of the total clastic component. Samples collected at Sites 4 and 5 are the only sediments that contain gravel.

Marsh sediments contain between 28 to 90% clastics, the textural composition of which varies with depth below the marsh surface. Plant root mass (i.e., plant material and roots retained on a 14-mesh or 1.4 mm sieve) range from <1 to 32% (dry weight). At most sites fine sand is a major clastic component in the upper 20 cm and decreases with depth below the marsh surface. At depth, sediments consist predominately of Silty-Clay and Clayey-Silt (mud). The decrease in sand explains the down-hole decrease in bulk density observed in the cores. There is a significant relationship between % sand and measured dry bulk density ($R^2 = 0.84$). The concentration of sand at the tops of cores may be an artifact of local transport processes. Cores were collected within 1 to 1.5 m of the marsh edge, within the observed wrack line. The sand may have been deposited by over-topping waves during storm events.

Nutrients

Table 5-2 lists summary statistics (mean and standard deviation) for each of the measured nutrients, grouped by type of sample (e.g., bluff, marsh). Total carbon content measured in all bluff and core sediments ranges from 0.04 to 23.4%. Bluff sediments contain the least amount of total carbon, averaging 0.41 ± 0.2%. Carbon content of marsh sediments ranges from 2.29 to 23.4%, averaging 11 ± 6.2%. The average carbon content of the plant material (i.e., >14 mesh) is 32.6 ± 4.7%. Total carbon in the sediments is directly proportional to the total biotic component, accounting of one-third of the total organic content (Fig. 5-8).

Figure 5-8. Total carbon content vs. organic content of the sediments. Superimposed on the plot are the regression line and the equation defining the relationship.



Total nitrogen content measured in bluff and marsh sediments ranges from 0.004 to 1.28%. As with carbon, bluff samples contain the least amount of total nitrogen, averaging less than 0.05%. Marsh sediments yield nitrogen values between 0.13 to 1.28%, averaging 0.58 ± 0.31%. Total nitrogen content of the plant fraction averages 1.02 ± 0.18%.

Table 5-2. Summary statistics for each of the elements measured in the samples. BDL indicates below detection limit for the analytical method.

	Marsh sediments		**Bluff sediments**		**Plant fraction (>14 mesh)**	
	Ave.	**Std.**	**Ave.**	**Std.**	**Ave.**	**Std.**
Nutrients (%)						
Carbon (C)	11	6.2	0.41	0.2	32.6	4.7
Nitrogen (N)	0.58	0.31	0.036	0.014	1.02	0.18
Phosphorus (P)	0.042	0.017	0.007	0.005	0.052	0.02
Sulfur (S)	1.61	0.77	0.008	0.015	2.57	2.05
Metals (ppm)						
Silver (Ag)	0.47	0.11	BDL		0.67	0.15
Aluminum (Al, %)	3.65	0.82	2.54	1.47	1.95	0.33
Beryllium (Be)	1.11	0.31	BDL		BDL	
Bismuth (Bi)	2.42	0.79	BDL		BDL	
Cobalt (Co)	8.48	2.04	8	4.2	14.4	7.7
Copper (Cu)	16.4	8.9	17	4.2	23.4	12
Iron (Fe, %)	1.84	0.57	1.51	0.99	2.18	2.14
Manganese (Mn)	161	68	89	32	88	37
Molybdenum (Mo)	5.73	2.44	BDL		9.78	
Nickel (Ni)	25.4	7.5	5.8	4.2	15.7	10.6
Lead (Pb)	24.9	10.6	10.8	3.6	45.9	55.7
Strontium (Sr)	146	39	82	22	88	38
Titanium (Ti, %)	0.278	0.063	0.19	0.13	0.13	0.03
Vanadium (V)	63.9	18.4	37	33.6	57.5	14.3
Yttrium (Y)	11.8	3.3	4.8	1.3	14	3
Zinc (Zn)	61	20	37	12	63	23

Generally, for all of the sediments measured, nitrogen content correlates well with carbon content (R^2 = 0.78). Depending on the nature of the organic source, nitrogen is expected to maintain a fairly constant proportionality with carbon content, as shown in Table 5-3, which lists the C:N ratios for the different samples. The mean C:N ratio for marsh samples is higher than both the mean ratio of 7.04, obtained from bottom samples collected in the northern coastal bays (Wells and others, 1994), and the Redfield's ratio of 5.7 for planktonic organisms (Redfield and others, 1963). The intermediate C:N ratio found in the marsh sediment reflects a combination of organic material types.

Total phosphorus content measured in bluff and marsh sediment ranges from 0.004 to 0.124%. As with carbon and nitrogen, the bluff samples contain the least amount of total phosphorus, averaging less than 0.01%. Marsh sediments contain an average of 0.04 ± 0.012%. Total phosphorus content of the plant fraction is higher, averaging 0.05 ± 0.02%. Compared to nitrogen, phosphorus is not as strongly correlated with carbon (R^2 = 0.25). In most cores, phosphorus content decreases with depth below the marsh surface, suggesting an upward cycling of phosphorus within the sediment column.

Table 5-3. Comparison of mass ratios of C, N, and P observed in different samples (sources).

	C:N	**C:P**	**N:P**
Plant (>14 mesh)	32.3	711.2	21.7
Marsh sediments	18.1	243.6	13.0
Bay bottom sediments (Wells and others, 1994)	7.0	65.1	9.3
Plankton (Redfield and others, 1963)	5.7	41.0	7.2

Although not considered a nutrient, sulfur is closely related to nutrient cycling. In sediments, sulfur occurs primarily as inorganic metal sulfides and elemental sulfur. These sulfur species form as a result of a bacterially-mediated reaction involving the oxidation of organic carbon. Under anaerobic conditions, dissolved sulfate (SO_4^{-2}) from seawater acts as the oxidant (Berner, 1967, 1970; Goldhaber and Kaplan, 1974). During the process, sulfate is reduced to sulfide. The sulfide reacts with ferrous iron (Fe^{+2}), forming an iron monosulfide precipitate, which further reacts with elemental sulfur to form FeS_2 (pyrite and its polymorph, marcasite) (Berner, 1970). The process results in the enrichment and preservation of sulfur in the sediments and the simultaneous depletion of sulfur.

Sulfur content measured in bluff and marsh sediments ranges from below the detection limit (BDL) to 3.10%. Bluff samples contain the least amount of sulfur, averaging less than 0.05%. Average sulfur content in marsh sediments is 1.61 ± 0.77%. Sulfur content in the plant fraction is significantly higher, averaging 3.23 ± 2.73%. At most marsh sites, sulfur content increases with depth below the marsh surface.

Metals

In addition to the three nutrients (N, C, and P) and sulfur, sediment samples were analyzed for 21 other elements, including 17 metals. Summary statistics for the metals are listed in Table 5-2. A cursory assessment of the results suggests that certain metals, particularly Co, Cu, Fe, Mo, and Pb, are concentrated in the plant material.

Because the sediments analyzed in this study vary significantly in texture and plant content, several techniques were used to evaluate the behavior of the nutrients and metals. One technique, the use of enrichment factors (EF), allows for the comparison of sediments from different environments and for the comparison of sediments whose trace metal contents were obtained by different analytical techniques (Sinex and Helz, 1981; Wells and others, 1994). An enrichment factor is defined as:

$$EF_{(x)} = \frac{(X / Fe)_{sample}}{(X / Fe)_{reference}} \qquad \textbf{Eq. 5-1}$$

where: $EF_{(x)}$ is the enrichment factor for the metal X,

$X/Fe_{\ sample}$ is the ratio of the concentrations of the metal X to Fe in the samples, and

$X/Fe_{\ reference}$ is the ratio of the concentrations of the metal X to Fe in the reference material, such as an average crustal rock.

Fe is used for normalizing because anthropogenic sources of Fe are small compared to natural sources (Sinex and Helz, 1981). Taylor's (1964) average continental crust is used as the reference material.

Table 5-4 presents mean EF values, referenced to Taylor's average crustal material, for six metals: Co, Cu, Mn, Ni, Pb, and Zn, for which there are comparable data from other estuaries and coastal bays (Sinex and Helz, 1981). Mean EF values for marsh and bluff sediments lie within the range of values obtained for other coastal bays not affected by industry. When the mean EF values of the various sediment sources within the bay system (i.e., marsh vs. bottom sediments) are compared, several trends become apparent. For example, Zn enrichment is about the same for marsh, bluff and bottom sediments. Marsh sediments are enriched in Cu, Ni and Pb. Curiously, EF values for Co and Cu are highest for bluff sediments.

Table 5-4. Comparison of average enrichment factors of certain metals measured in the different groups of sediments from the northern coastal bays. Enrichment factors are referenced to the average earth's crust (Taylor, 1964) and calculated using Equation 5-1.

	Co	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**
Marsh sediments (this study)	1.18 ±0.63	0.98 ±0.68	0.56 ±0.21	1.22 ±0.51	6.41 ±2.91	2.79 ±0.90
Bluff sediments (this study)	2.23 ±1.89	1.90 ±0.89	0.61 ±0.35	0.49 ±0.25	5.53 ±2.53	2.93 ±0.98
Bay bottom sediments (Wells and others, 1994)	–	0.52 ±0.29	0.98 ±0.85	0.61 ±0.37	2.98 ±1.40	2.54 ±0.63

Regression Analysis

Another approach used to evaluate the geochemical behavior of nutrients and metals, regression analysis is a technique that MGS has employed routinely for evaluating sediments in the Chesapeake Bay and the coastal bays (Hill and others, 1990; Wells and others, 1994, 1996, 1999). Hill and others (1990) initially devised the method for monitoring bottom sediments in the vicinity of the Hart-Miller Island Dredged Material Containment Facility in northern Chesapeake Bay. This technique is a sensitive indicator that can be used to measure (1) anthropogenic loading, (2) differences in source material, or (3) changes in geochemical environment. The analysis is based on the association of an element, in this case, a nutrient or metal, with different physical components of the soils or sediments. In this study, the behavior of an element is determined by correlating its concentration with the associated grain size (adjusted by the clastic content) and plant content of the sediment, as shown in Equation 5-2.

$$X = a(\text{Sand}) + b(\text{Silt}) + c(\text{Clay}) + d(\text{Plant}) \qquad \textbf{Eq. 5-2}$$

where: X	is the element (nutrient or metal) of interest,
a, b, c, and *d*	is the determined coefficients (see Table 5.5),
Sand, Silt, and Clay	is the grain size fractions of the sample multiplied by the clastic fraction, and
Plant	is the plant (>14 mesh) fraction

A least-squares fit of the data is obtained using a multiple stepwise regression analysis. The results of this analysis are presented in Table 5-5. Equation 5-2 states that the elemental composition of a sediment is a linear combination of end member components (i.e., Sand, Silt, Clay, and Plant). For any given component, the associated coefficient is the concentration of the element in the pure end member.

The results of this analysis indicate the following:

- The association of the elements with the different grain size fractions is relatively uniform throughout the study area. If there were a significant variation among the samples, the correlation of the regression fit would be poor. Samples that did not follow the general trend would be outliers to the regression fit. However, this is not the case. This provides a higher confidence level in extrapolating the data across the region calculating input values. It also provides a potential tool to do a more detailed study using more samples and fewer chemical analyses. Such a study would rely more heavily on grain size analyses and the elemental associations reported here.

- Plant matter is frequently the component with the highest concentration of a given element and is a significant factor in all of the elements analyzed. This is shown in the Rank column in Table 5-5. The rank, ranging from 1 to 4, is the order of the plant material coefficient, 1 being the most concentrated and 4, the least. In nine of the 15 elements included in the regression analysis, plant matter is the most concentrated component. Analytical results of the isolated plant material (Table 5-2) are directly comparable to the determined plant coefficient. Consequently, the plant component must be taken into account when determining nutrient input due to shoreline erosion, especially in soils or sediments with high organic matter content, such as those found in marshes.

- The agreement between the measured metals and nutrients in the plant matter and the determined contribution from the plant end member (regression coefficient) is excellent. Eight of the fifteen elements are within one standard deviation. Where there are differences between the measured plant material and the regression coefficients, the measured values are lower. This is expected, due to the loss of finer plant material in the separation process. This serves as an internal consistency test to validate the interpretative technique used.

Table 5-5. Coefficients of multiple-stepwise regression of nutrient and metal data. The determined value is the elemental concentration and the factors are the clastic (Sand, Silt, and Clay) and plant fractions of the samples, values of are which substituted into Equation 5-2.

Element (X)	Rank	Estimates of coefficient				R^2
		a **(Sand)**	***b*** **(Silt)**	***c*** **(Clay)**	***d*** **(Plant)**	
Nutrients (%)						
C	1	---	---	20.5	56.1	88
N	1	---	---	1.18	2.79	89
P	1	0.008	---	0.1	0.155	91
Metals (ppm)						
Co	1	7.9	7.1	15.4	18.6	94
Cu	1	12.1	---	36.5	62.5	85
Mo	1	---	---	15.8	18.5	88
Pb	1	12.1	7.1	53.4	87	91
Zn	1	25	59	104	176	94
Y	1	3.6	11.2	21.3	31.2	96
Ni	2	17.1	62.6	9.2	37.1	91
V	2	9.6	69.5	170	84	98
Ag	3	0.389	0.964	0.52	0.419	96
Al (%)	3	2.35	4.77	7.02	4.12	98
Fe (%)	3	0.66	2.11	4.82	1.81	95
Ti (%)	3	0.153	0.522	0.442	0.264	97

SEDIMENTS AND NUTRIENT LOADINGS

The annual loads (kg/yr) of nutrients and sediments for each of the basins of the northern coastal bays are summarized in Table 5-6. Shoreline included in the land loss polygons accounts for approximately 45% of the total shoreline in the northern coastal bays. Most of remaining shoreline was modified in some way (e.g., hard stabilization, in-filled, etc.) and, therefore, excluded from this study. During the 47-year period, shoreline erosion contributed an estimated 11.6×10^6 kg/yr of total sediments into the three-bay system. Of the total sediments, approximately 42%, or 4.9×10^6 kg/yr, are total suspendable solids (TSS). Supendable solids include the fine-grained clastics (silt and clay) and organic fraction. Annual total sediment loadings are greatest in the St. Martin River (6.9×10^6 kg/yr), due in part to high bank elevations and relatively dense bluff material, particularly in the Bishopville Prong. Bulk densities of sediments collected from bluffs averaged 1.4 g/cm^3. Total sediment loadings from shore erosion in Assawoman Bay are about half those of St. Martin River (3.2×10^6 kg/yr), and those in Isle of Wight Bay are even lower (1.5×10^6 kg/yr). Much of the shoreline bordering Assawoman and Isle of Wight is low-lying marsh composed of sediments with average bulk densities of 0.4 g/cm^3.

Sand-sized sediments account for approximately 57% of the total sediments contributed from shoreline erosion. More than one-third of the sand is eroded from the St. Martin River shoreline (Fig. 5-9). Sand is probably deposited locally, as indicated by the sand that has collected immediately offshore of the bluff sites. Eroded sand tends to remain in the vicinity of its source. Except under extremely high flow conditions, sand is generally not considered suspendable. Given the volume of sand eroding into the St. Martin River, one would expect to find a mixture of sandy sediments on the river bottom. Wells and others (1994) mapped fine sediments in the St. Martin River (refer to Fig. 3-4), based on sampling sites located some distance from shore. They probably missed areas covered with sand-sized sediments.

Table 5-6. Summary of annual loadings of sediments and nutrients contributed by shoreline erosion in the northern coastal bays. The length of the 1989 shoreline applies only to the shoreline included in the land loss polygons (Fig. 4-1).

Component	Basin					
	Assawoman Bay	**Bishopville Prong**	**Shingle Landing Prong**	**St. Martin River**	**Isle of Wight Bay**	**Total**
1989 shoreline length (m)	81,164	16,269	12,403	30,706	25,296	165,839
Annual volume of erosion (m^3/yr)	6,731	2,178	1,002	4,531	3,043	17,485
Total sediments (kg/yr)	3,206,065	3,037,005	1,271,018	2,580,549	1,471,477	11,566,114
Total organics (kg/yr)	804,329	63,831	39,031	435,512	345,508	1,688,212
Carbon (kg/yr)	214,743	4,979	7,329	110,090	87,424	424,565
Nitrogen (kg/yr)	11,649	603	603	6,041	4,477	23,373
Phosphorus (kg/yr)	1,070	161	96	520	497	2,344
Pb (kg/yr)	80	33	13	53	29	208
Zn (kg/yr)	182	91	43	126	77	519
Total clastics (kg/yr)	2,401,736	2,973,173	1,231,987	2,145,036	1,125,969	9,877,902
Sand (kg/yr)	1,054,523	2,462,059	1,027,552	1,513,751	515,740	6,573,625
Silt (kg/yr)	768,639	188,739	120,419	290,110	381,012	1,748,918
Clay (kg/yr)	578,574	230,862	84,016	318,582	229,217	1,441,251
Gravel (kg/yr)		114,108				114,108

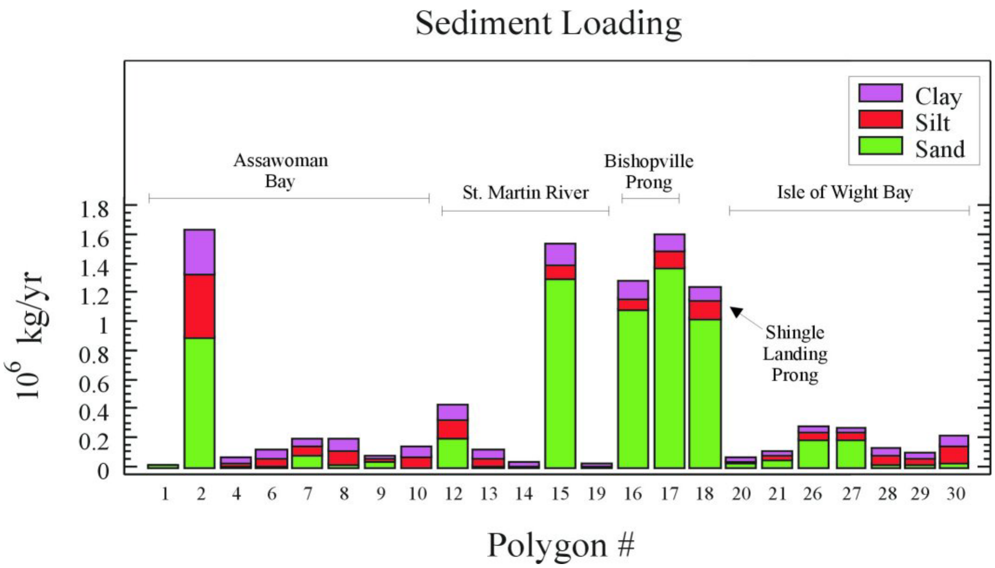


Figure 5-9. Loadings of sand, silt, and clay for each land loss polygon. Gravel, which accounts for less than 1% of the total sediment load, is not shown. Only samples collected in Polygons 16, 17, and 18 contained gravel.

Comparison with existing models and previous studies

Tables 5-7 and 5-8 summarize total nitrogen (TN) and total phosphorus (TP) loads from various sources for the northern coastal bays. Loading figures are taken from two reports: UM and CESI (1993) and MDE (2001). For comparison, the loading estimates for TN and TP from this study are included in the tables. The estimates from the UM and CESI and the MDE reports are presented in this discussion as the range of values for nitrogen and phosphorus loadings into the northern coastal bays. The UM and CESI estimates are about twice those reported by MDE. UM and CESI attributed a large proportion of the runoff loading to feedlot operations, the discharge from which was assumed to enter streams directly. MDE considered the UM and CESI feedlot calculations to be too high (Sajan Pokharel, pers. comm.). Instead, MDE treated feedlot operations as confined and used urban land use loading rates to calculate their loadings. Although MDE used the UM and CESI loading coefficients to calculate runoff based on land use, they updated the land use acreage, using 1997 data. The loading estimates reported by MDE are more conservative, representing an annual baseline loading for the study area. MDE loading estimates were used in developing TMDLs for the northern bays. Neither report considered contributions from shore erosion.

Shoreline erosion represents a significant source of TN and TP loadings to the bays. Depending on the nutrient budget used for comparison (Fig. 5-10), shore erosion contributes between 4.1% to 8.5% of the total nitrogen and 4.7% to 8.5% of the total phosphorus delivered to Maryland's northern coastal bays. Nutrient contributions from shoreline erosion slightly exceed input from known point sources.

Table 5-7. Annual total nitrogen (TN) and total phosphorus (TP) loadings (kg/yr) to the northern coastal bays, based on the UM and CESI (1993) report. Total loadings contributed from shoreline erosion are included for comparison.

Basin [1]	Point sources[1]	Non-point sources [2]	Atmospheric sources [3]	Shore erosion (this study)	Total loading
Nitrogen loading (kg/yr)					
Assawoman Bay	0	52,091	39,800	11,649	103,540
Isle of Wight Bay	0	91,218	32,902	4,477	128,597
St. Martin River	18,290	302,867	12,382	7,247	340,786
Total	**18,290**	**446,179**	**85,084**	**23,373**	**572,923**
Phosphorus loading (kg/yr)					
Assawoman Bay	0	4,776	1,602	1,070	7,448
Isle of Wight Bay	0	8,944	1,324	497	10,765
St. Martin River	1,569	28,897	498	777	31,741
Total	**1,569**	**42,617**	**3,424**	**2,344**	**49,954**

[1] Point source data for nitrogen and phosphorus were developed by Coastal Environmental Services, Inc., based on information from the Maryland Dept. of the Environment. Data are for 1990-91.
[2] Non point sources include surface water inputs (runoff), groundwater inputs and inputs from chicken rendering operations. Loading from direct groundwater discharge into the northern coastal bays (from Snug Harbor to Maryland/Delaware line) were estimated using Ritter (1986) coefficients: TN= 123,804 kg/yr and TP=9,420 kg/yr.
[3] Atmospheric inputs represent total nitrogen and phosphorus deposition in wet-fall directly to the surface of bay waters, based on an average annual rainfall of 43.8 inches/yr reported for 1990. Concentrations of TN and TP are from Smullen and others (1982).

The N:P (mass ratio) loading ratio for material eroded from the shoreline is about 10:1. This ratio is consistent with loading ratios based on both UM and CESI data (N:P = 12:1) and MDE data (N:P = 10:1), both of which are higher than the Redfield ratio (N:P = 7.2:1). The differences are related to the types of nutrient sources (Table 5-3).

In Table 5-9, annual TSS, Pb, and Zn loadings from the UM and CESI report are compared with estimates from this study (MGS). (MDE did not report loading components other than TN and TP.) The annual TSS loadings reported by UM and CESI represent suspended solids delivered by overland runoff. That amount is about three times the TSS contributed by shoreline erosion for the entire study area. However, in Assawoman Bay, the annual contribution of TSS from shoreline erosion is slightly more than input from runoff. Conversely, in the St. Martin River, the annual TSS load from overland runoff is five times that contributed from shoreline erosion.

The sand:mud ratio of sediments contributed from shoreline erosion is 2:1. In the St. Martin River, the ratio is much larger, 4:1. However, the sand:mud ratio of 1:1 reported for the bottom sediments (Wells and others, 1994) in the northern coastal bays does not reflect this large influx of sand. The difference in sand proportions may be accounted for by the contribution of fine-grained material from upland runoff, which has the effect of "diluting" the sand being eroded from the shoreline, explaining the preponderance of fine-grained sediments mapped in the river.

Assuming that the 15.1 x 10^6 kg/yr of TSS from runoff reported by UM and CESI has approximately the same percentage of organics as the sediment contributed from shoreline erosion (i.e. 34.6% organics), then the mud portion of the TSS contributed from upland runoff is 9.81 x 10^6 kg/yr. The total mud contribution from shoreline erosion and upland runoff would be 13.00 x 10^6 kg/yr. When compared to the sand contribution of 6.57 x 10^6 kg/yr from shoreline erosion (assuming that no sand is being contributed from upland runoff), the sand:mud ratio of sediment entering the northern bays is 1:2. To bring the ratio to 1:1, other sources of sand may be assumed, contributions on the order of 6.43 x 10^6 kg/yr of sand from wind deposits and overwash across Fenwick Island and loads transported through the Inlet.

Shoreline erosion contributes significant amounts of Pb and Zn, accounting for 4% and 9.5%, respectively, of the total loadings of these metals from runoff into the bays. However, these percentages may be high. UM and CESI calculated annual loading values for Pb and Zn based on runoff from urban land only, coefficient factors for the two metals being equal. Runoff coefficients for other non-urban land were unavailable at the time.

Table 5-8. Annual total nitrogen (TN) and total phosphorus (TP) loadings (kg/yr) to the northern coastal bays, based on TMDL study for the same study area (MDE, 2001). Total loadings contributed from shoreline erosion are included for comparison.

Basin	Point sources	Overland runoff	Ground-water discharge[1]	Atmospheric deposition	Shore erosion (this study)	Total loadings
Nitrogen loading (kg/yr)						
Assawoman Bay	0	35,086	4,386	23,182	11,649	74,302
Isle of Wight Bay*	0	33,472	4,385	24,377	4,477	66,710
St. Martin River	16,621	117,001	1,258	7,599	7,247	149,726
TOTAL	**16,621**	**185,559**	**10,028**	**55,157**	**23,373**	**290,738**
Phosphorus loading (kg/yr)						
Assawoman Bay	0	4,293	N/R	1,431	1,070	6,795
Isle of Wight Bay*	0	3,732	N/R	1,533	497	5,762
St. Martin River	1,051	13,941	N/R	431	777	16,200
TOTAL	**1,051**	**21,967**		**3,395**	**2,344**	**28,757**

[1] The direct groundwater loads for TN were estimated based on methods described in Dillow and Greene (1999). Direct discharge to the northern coastal bays was separated out from the total reported by John Dillow. MDE did not report groundwater loads for TP.

Table 5-9. Comparison of the UM and CESI (1993) loadings and MGS estimates from shoreline erosion for total suspended solids (TSS), Pb and Zn. All loads in kg/yr.						
	UM and CESI (1993)			**MGS (This study)**		
Basin	**TSS**	**Pb**	**Zn**	**TSS**	**Pb**	**Zn**
Assawoman Bay	1,918,741	832	832	2,151,542	80	182
Isle of Wight	4,184,314	2,642	2,642	955,737	29	77
St. Martin River	8,992,063	1,493	1,493	1,771,102	99	260
Total	**15,095,118**	**4,967**	**4,967**	**4,878,381**	**208**	**519**

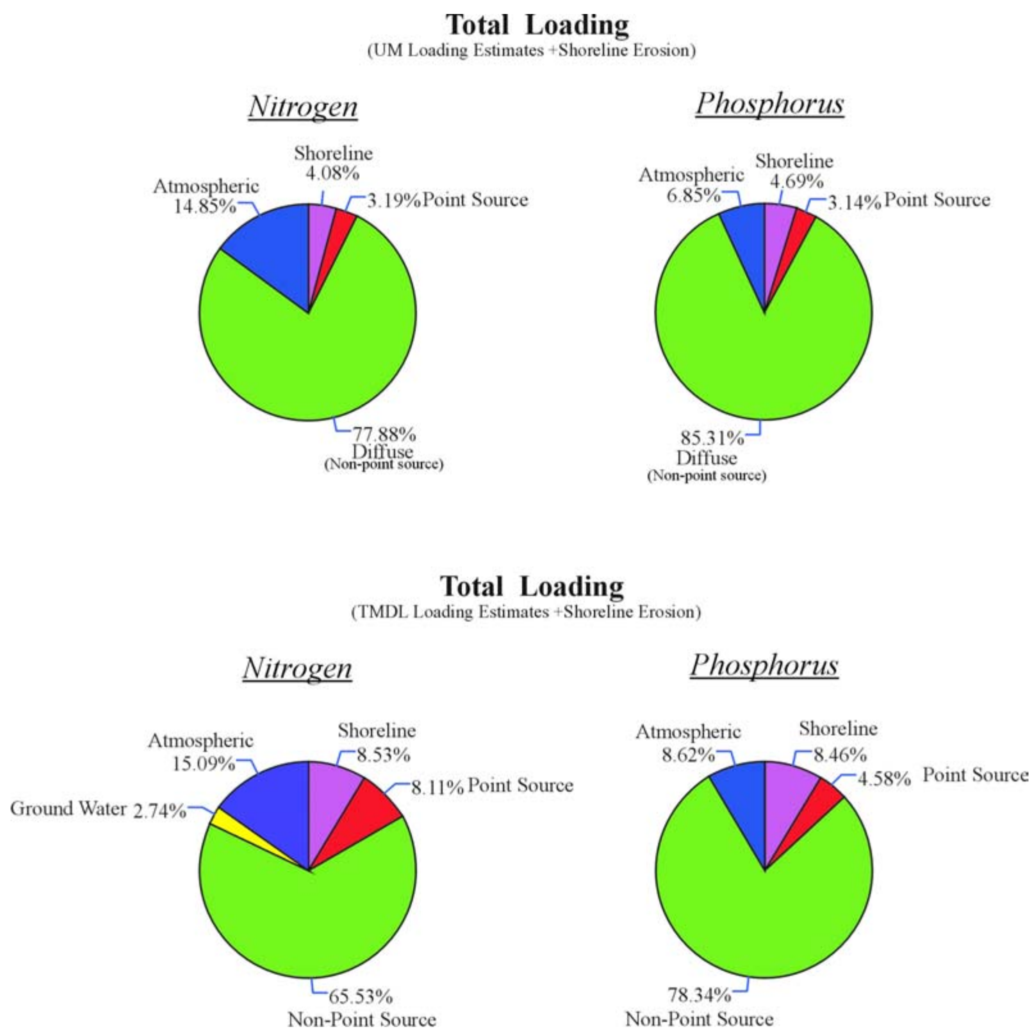


Figure 5-10. Annual total nitrogen and total phosphorus loads entering the northern coastal bays, revised to include contributions from shoreline erosion. Top pie charts depict annual loads based on loading report by UM and CESI (1993). The bottom pie charts depict annual loads based on loadings reported by MDE (2001).

6. CONCLUSIONS

Anthropogenic loading of nutrients, metals, and sediment and shoreline armoring alter the natural cycles that operate in the evolution of the coastal bays. These alterations affect the ecosystem of the coastal bays, changing biological communities and the physical structure of the system. Stewardship of these resources requires balancing human impacts to minimize the effects on these natural cycles, while allowing the watersheds to be used for a variety of commercial and residential purposes. Understanding the relative contribution and effects of each of the inputs to the system allows for effective management of the ecosystem. The contribution of shoreline erosion as a component of the natural cycles in the coastal bays was unknown prior to this study. This study has found:

- Rather than relying on general sediment density estimates, this study directly measured sediments for bulk density, improving the accuracy of nutrient load estimates.

- While shoreline erosion contributes a considerable load of suspendable solids, the contribution is about 1/3 that from overland runoff. In Assawoman Bay, TSS loads from shoreline erosion exceed those contributed from upland runoff. On the other hand, runoff is the dominant source of TSS in Isle of Wight Bay and the St. Martin River, where the bulk of the TSS is delivered from the major tributaries (Bishopville and Shingle Landing Prongs, Turville and Manklin Creeks).

- Shoreline erosion is a dominant source of sand into the northern bay system, contributing approximately 6.57×10^6 kg/yr or about half of the sand coming into the bays. Other sources include sand transported through the Inlet and carried across Fenwick Island by wind and overwash. Presumably, upland runoff contributes an insignificant amount of sand. Sand is important in maintaining a healthy balance of bottom habitats in the bays.

- Shoreline erosion is a significant source of nutrients, contributing between 4.1% to 8.5% of the total nitrogen and 4.7% to 8.5% of the total phosphorus delivered to Maryland's northern coastal bays. Nutrient contributions from shoreline erosion slightly exceed input from point sources, and are comparable to, but lower than, atmospheric sources. However, the total nitrogen and total phosphorus measurements do not distinguish among the different forms of the nutrients (i.e., nitrates, ammonia, orthophosphate, etc.) and do not reflect how much of the total may be available for biological uptake.

- In addition to nutrients, shoreline erosion contributes 208 kg/yr of Pb and 519 kg/yr of Zn, accounting for 4% and 9.5 % of the total loadings of those metals, respectively, to the bays.

RECOMMENDATIONS

- This report provides initial estimates of the sediment and nutrient loads contributed by shoreline erosion. The load calculations are based on two assumptions: 1) the component concentrations, averaged for each site, reflect the average lithology along the shoreline within a given polygon and 2) bank heights are uniform throughout any given land loss polygon, and the banks themselves are vertical, rather than sloping. To refine these estimates, additional field work and analyses are required.

- Loadings reflect the average annual input over a 47-year period (between 1942 and 1989). The assumption is that contribution rates also apply for the period between 1989 and the present and will continue for some time in the future. Additional study should look at contributions from erosion in the future based on projected rates of sea level rise and resulting changes in shoreline configuration (refer to Volonté and Leatherman, 1992).

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APPENDIX A

Site descriptions (field notes, photos, cross sections, profiles)

Core logs (core descriptions, lithology, radiographs, photos)

Note: In the radiographs, sediment layers with more plant material, which is nearly transparent to x-rays, appear as darker areas in the image. Layers with higher percentages of clastics (i.e., sand-, silt-, and clay-sized minerals) are denser or more opaque to x-rays and appear as lighter areas. White layers represent denser lenses of sediment, not necessarily composed of sand, but containing a higher percentage of clastics (non-plant material).

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE FIELD DESCRIPTION: Site 1- Hasty Pt.

Site ID: 1 (Joint site w/ UMCES
Site name: Hasty Point (or White Horse Pt.)
Location: St. Martin River- south shore near northern terminus of Beauchamp Rd.; approx. 1 mi. downstream from confluence of Shingle Landing and Bishopville Prongs

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 251 063	486 039

Date: Multiple dates, first visited 11/28/00; samples collected on 7/17/01
Time:
Described by: DVW; JMH
Shoreline type (e.g., marsh, bluff, beach): extensive marsh
Extent (length) of reach (ft):

Land use/cover along reach: residential; mixed wooded and cultivated fields
Comments: Set out pore water equilibrators (peepers) w/ Court Stevenson, on 5/2/01; took hydrolab readings offshore of site (see next page).
Site description: Site located on eastern most point of marsh, extending into St. Martin River; uniformly flat, very thick grass (predominately *S. alterniflora*); root mat extends 12 " or more in depth; could not core through root mat, removed top 12"with a spade, then cored below that. Other vegetation included *S. patens* (~10 meters from edge; small bushes (*Iva*) and *Distichlis* in between
Reach description: Extensive Spartina marsh, extending ~500 meters landward; backed by pine/oak forest and houses (trailer park).
Plants:

Species	Percent
Spartina alterniflora	90%
Distichlis (Spike grass)	2.5%
Iva (Marsh Elder)	2.5%
S. patens	5%

Samples: Samples taken 7/17/01

ID	Type*	Location/Descpt.
1-plug	All	1.02 meters from edge of marsh (point); top 33 cm
1-core	All	Bottom 38 cm;
1-off	GS	0.3 m offshore

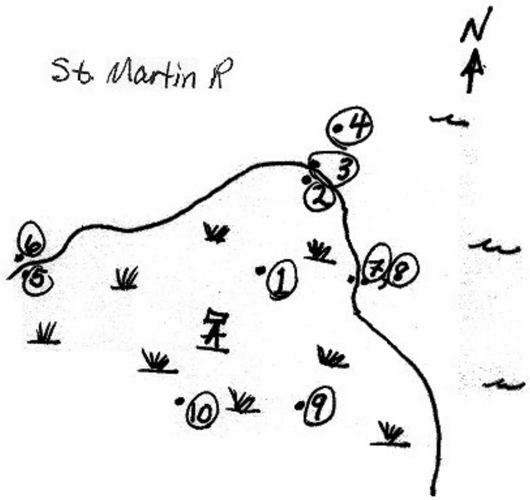
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Card	Frame	Date/Time	Subject
	6-11	11/28/00 12:36p-1:17p	
	5	5/1/01 11:27a	
	6	5/1/01 11:27a	
	7	5/1/01 11:29a	
	5	7/17/01 8:57a	

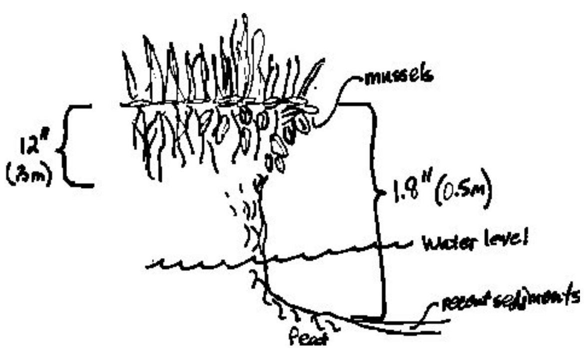
Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE FIELD DESCRIPTION: Site 1- Hasty Pt.

Plan view (sample locs; site features, reach & beach extents)



Stadia readings (see fig to right for locations)						
Pt.	Top	Mid	Bot	Dist (from level) (ft)	Bank Hgt (ft)	Comments
Level Λ		4.62		0		
1	4.84	4.77	4.70	14		
2	5.19	5.04	4.89	30	1.83	By Court's post
3	7.025	6.87	6.715	31		Base of marsh
4	7.71	7.51	7.31	40		Off shore
5	4.905	4.80	4.69	43	1.615	Top of marsh
6	6.52	6.415	6.30	22		Base of marsh
7	4.78	4.64	4.50	28	1.8	Top of marsh
8	6.59	6.44	6.29	30		Base of marsh
9	4.78	4.525	4.25	53		
10	4.79	4.515	4.24	55		

Stratigraphic section



Hydrolab readings taken 5/2/01 1:35 pm EDT		
Temp. (degrees C)	21.7	
Salinity (ppt)	24.25	
DO (mg/l)	8.89	113% Saturation
pH	5.88	
Turb. (ntu)	9.8	
Depth (m)	1.5	

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 3- Windmill Creek

Site ID: 3
Site name: Windmill Creek
Location: Shingle Landing Prong- south shore, north side of the mouth of Windmill Creek

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 250 799	484 364

Date: 5/01/01
Time: 12:33 pm EDT
Described by: Jim Hill
Shoreline type (e.g., marsh, bluff, beach): bluff fronted by narrow beach

Bank elevation (ft):
Above water: see stadia data
Below water
Land use/cover along reach: forest behind bluffs
Site description: Fine sand beach with ~12 ft bluff backing beach; top of bluffs moderately to highly vegetated; mix pine/oak with shrubs, low trees under-story (pred. Maples, bayberry and holly). Off shore bottom sediments very red, clayey.

Reach description: Bluffs along eroding headland, extending ~300 meters, southeast end truncated by a spit at mouth of Windmill Ck., north end truncated by shallow cove.

Plants:

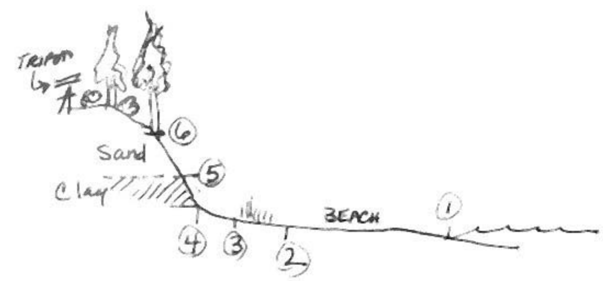
Species	Percent
Pine	35
Oak	35
Maple	10
Bayberry	10
holly	10

Samples:

ID	Type*	Location**
3-T	All	Top layer of bluff
3-B	All	Bottom of bluff; clay layer
3-beach	GS	Grab from beach
3-Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)
****Location** = show on stratigraphic section

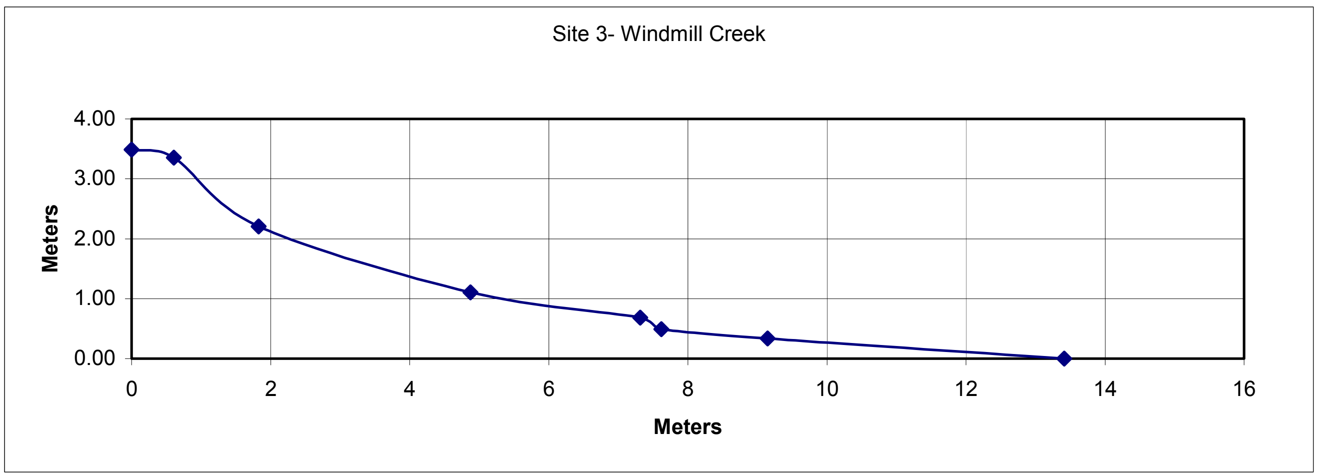
Stratigraphic section: Top 7.8 ft sandy loam, weathering to reddish color; sharp contact, below it greenish clayey sand, very hard, dry; part of bluff face is vegetated



Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 3- Windmill Creek

Site 3- Windmill Creek

Stadia Readings	Stadia rod intercept (Feet)			Feet		Meters		
Pt.	top	middle	bottom	Dist	Elev	Dist	Elev	
1	15.69	15.48	15.25	44	0	13.41	0.00	WL
2	14.52	14.37	14.22	30	1.11	9.14	0.34	Beach, Beach grab sample
3	13.99	13.87	13.74	25	1.61	7.62	0.49	Base of bluff
4	13.35	13.23	13.11	24	2.25	7.32	0.69	Clay, bluff sample
5	11.94	11.86	11.78	16	3.62	4.88	1.10	Sand/clay interface
6	8.26	8.24	8.2	6	7.24	1.83	2.21	Sand, Bluff sample
Tripod		4.04		0	11.44	0.00	3.49	Top of bluff



Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)

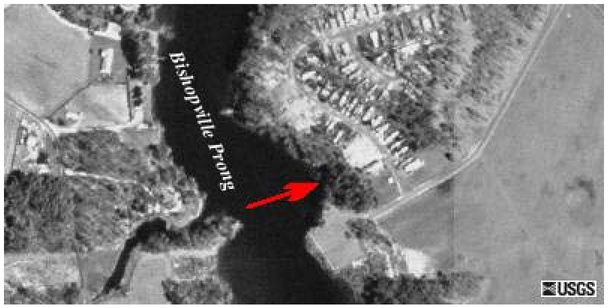
SITE/SAMPLE DESCRIPTION: Site 4 - Bishopville Prong

Site ID: 4

Site name: Bishopville Prong

Location: East bank of Bishopville Prong, just north of public boat ramp (Shell Mill Landing)

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 252 930	483 615



Date: 4/30/01

Time: 12:28 EDT

Described by: DVW/JMH

Shoreline type (e.g., marsh, bluff, beach): bluff

Extent (length) of reach (ft):

Bank elevation (ft): 2.7 m

Land use/cover along reach: forested; south end of bluff backed by parking lot

Site description: Fine sand muddy beach with ~8 ft bluff backing beach; top of bluffs moderately vegetated; mix pine/oak with shrubs. Some grass along beach.

Reach description: Low bluffs along east bank of Bishopville Prong, just upstream of boat ramp, extending north ~250 ft (~80 m), to small stream, salt marsh. Bluffs continue upstream. Both sides of river characterized by vegetated bluffs, heights varying from 6 to 10 ft.

North end: N 4 252 977 E 483 630 UTM

South end: N 4 252 900 E 483 608

Plants:

Species	Percent
Pine	40
Oak	25
maple	20
other	15

Samples:

ID	Type*	Location**
4-T	All	Top of bluff
4-B	All	Bottom of bluff
4-beach	GS	Grab on beach

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

****Location** = show on stratigraphic section

Photos:

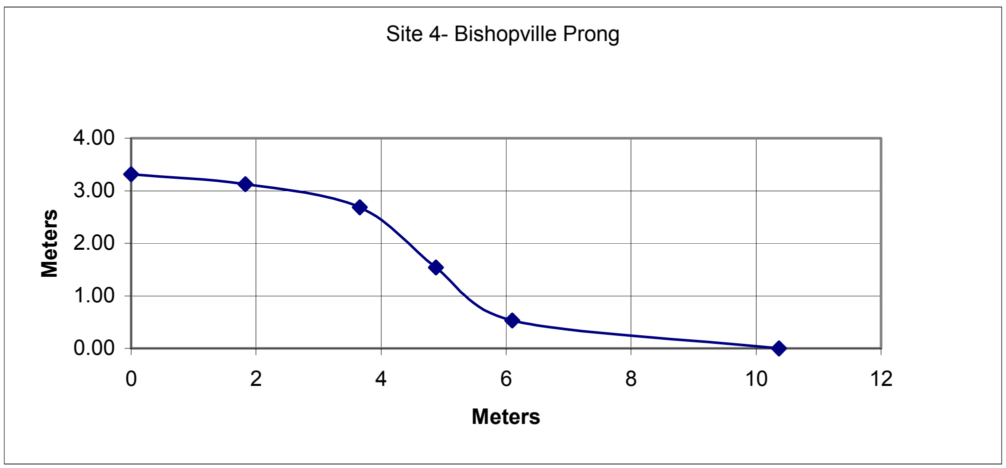
Card	Frame	Time	Subject
2	1	1:18	Dan sampling
2	2	1:19	Dan sampling
2	3	1:19	Bluff from water
2	4	1:20	Bluff close-up

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 4 - Bishopville Prong

Stratigraphic section Bluff appeared to be homogenous in material, yellowish gray sand with some clay, clay content slightly higher toward the top of the bluff; sampled top and bottom.

Site 4- Bishopville Prong

Stadia Readings		Feet		Feet		Meters			
Pt.	top	middle	bottom	Dist	Elev	Dist	Elev		
5	15.43	15.26	15.09	34	0	10.36	0.00	Water	
4	13.62	13.52	13.42	20	1.74	6.10	0.53	Sample	Base of bluff
3	10.29	10.21	10.13	16	5.05	4.88	1.54		
2	6.52	6.46	6.4	12	8.8	3.66	2.68	Sample	
1	5.03	5	4.97	6	10.26	1.83	3.13		
Tripod		4.38		0	10.88	0.00	3.32		Top of bluff



Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 5 – Photographed bluff

Site ID: 5
Site name: Photographed bluff
Location: St. Martin River- north shore; opposite Station 1 (Hasty Pt.)

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 251 580	486 313

Date: 5/1/01
Time: 1:54 pm EDT
Described by: DVW/JMH
Shoreline type (e.g., marsh, bluff, beach): bluff
Extent (length) of reach (ft): ~200 meters
Bank elevation (ft): 2 m
Land use/cover along reach: agriculture/field

Site description: Narrow beach backed by acute bluff stabilized by tree roots; vegetated buffer backed by large field. Bluff composed of laminated deposits w/ pebble lenses.

Reach description: Bluffs along eroding headland, extending ~200 meters, truncated on the north end by small stream/marsh and on south end by small cove/marsh.
North end: N 4 251 607 E 486 262 UTM
South end: N 4 251 476 E 486 398

Plants:

Species	Percent
Pine	45
Oak	45
Maple	10

Samples:

ID	Type*	Location**
5	All	Mid bluff
5-beach	GS	Grab on beach
5-off	GS	Grab offshore

*__Type__ = bulk density (BD); grain size (GS); trace metal (TM)
**__Location__ = show on stratigraphic section

Photos:

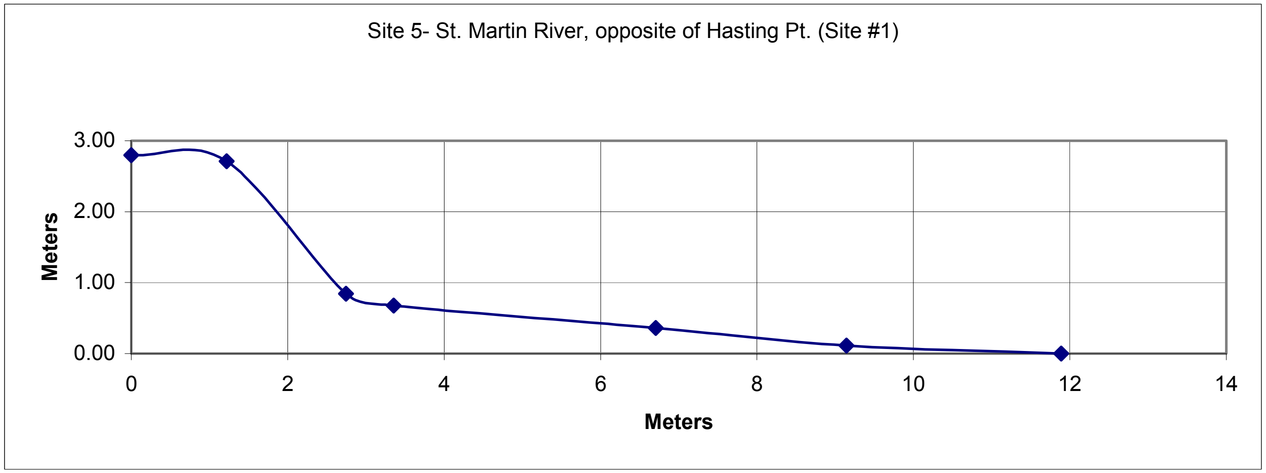
Card	Frame	Time	Subject
	1	2:09p	Field behind bluff
	2	2:09p	Beach from top
	3	2:09p	Level
	4	2:23p	Close up of bluff face
	5	2:24p	
	6	2:27p	Bluff face w/Dan

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 5 – Photographed bluff

Stratigraphic section Lamination evenly distributed along height of bluff, yellowish gray sand with gravel lenses and trace of clay. Photo to the right: Bluff face with Dan Sailsbury holding stadia rod. Bluff is approximately 2 meters high. Profile of bluff is shown below.

Site 5- St. Martin River, opposite of Hasting Pt. (Site #1)

Stadia Readings		Feet		Feet		Meters		
Pt.	top	middle	bottom	Dist	Elev	Dist	Elev	
1	13.685	13.49	13.295	39	0	11.89	0.00	
2	13.27	13.12	12.97	30	0.37	9.14	0.11	Water line
3	12.42	12.31	12.2	22	1.18	6.71	0.36	
4	11.32	11.265	11.21	11	2.225	3.35	0.68	
5	10.77	10.725	10.68	9	2.765	2.74	0.84	Base of bluff
Tripod		4.31		0	9.18	0.00	2.80	Top of bluff



Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 6 – Peach Pt.

Site ID: 6

Site name: Peach Point

Location: St. Martin River, north shore at mouth of Harry Creek

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 251 114	487 056

Date: 5/1/01

Time: 13:13 EDT

Described by: JMH

Shoreline type (e.g., marsh, bluff, beach): marsh

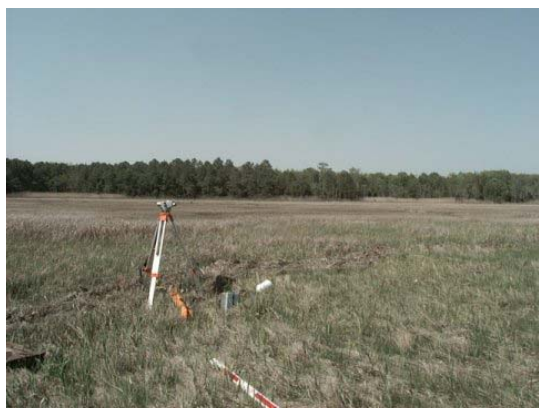
Extent (length) of reach (ft): 500 m

Bank elevation (ft): 0.7 m (2.2 ft)

Land use/cover along reach: Marsh

Site description: Sampling site is on small point (Peach Pt.) of marsh on north side of Harry Creek, small tributary flowing into St. Martin River

Reach description: Extensive marsh on north side of Harry Creek. Marsh is flat, uniform, *Spartina sp*. dominating, shoreline irregular. Small stream to the north and Harry Creek to the south truncate reach. Marsh is backed by forest.



Plants:

Species	Percent
S. alterniflora	90
Iva	5
Limonium	2

Samples:

ID	Type*	Location
Core 1	All	43 " from edge of water
Plug 1	All	Top 9.5 " of sediment column
1- off	GS	Offshore grab

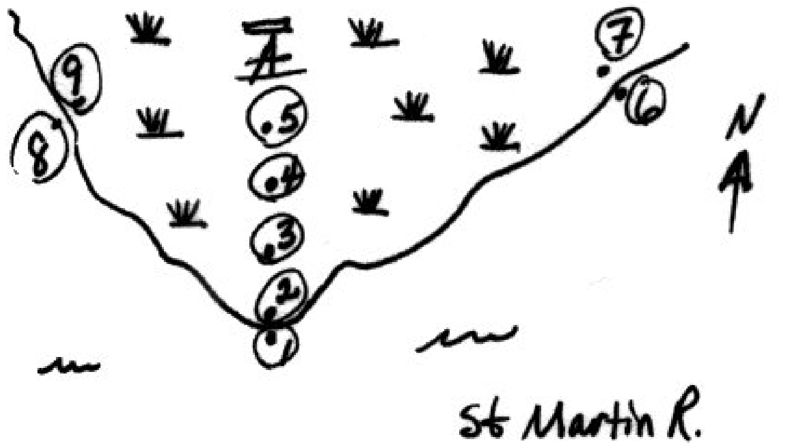
***Type** = bulk density (BD); grain size (GS); trace metal (TM)

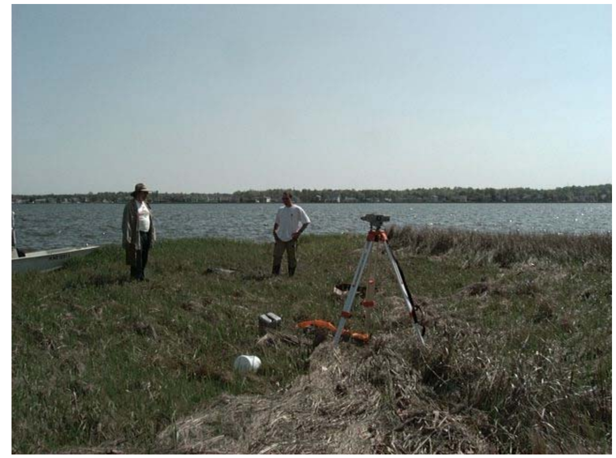
Photos:

Date	Time	Subject
5/1/01	15:29	Marsh toward tree line
5/1/01	15:29	On site w/ JimH and DanS
7/17/01	10:23	DanS and NeilD

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 6 – Peach Pt.

Plan view





Site 6 - Peach Point   Stadia data

Stadia Readings		Ft.		Feet		Meters		
Pt.	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height
tripod		4.3			0			
1	7.35	7.08	6.81	54	-2.78	16.5	-0.85	2.69
2	4.67	4.39	4.13	54	-0.09	16.5	-0.03	
3	4.72	4.48	4.24	48	-0.18	14.6	-0.05	
4	4.66	4.48	4.3	36	-0.18	11.0	-0.05	
5	4.58	4.49	4.4	18	-0.19	5.5	-0.06	
6	6.86	6.71	6.56	30	-2.41	9.1	-0.73	2.245
7	4.61	4.465	4.32	29	-0.165	8.8	-0.05	
8	6.35	6.095	5.84	51	-1.795	15.5	-0.55	1.725
9	4.62	4.37	4.12	50	-0.07	15.2	-0.02	

*assumed elevation for tripod (level) pt.

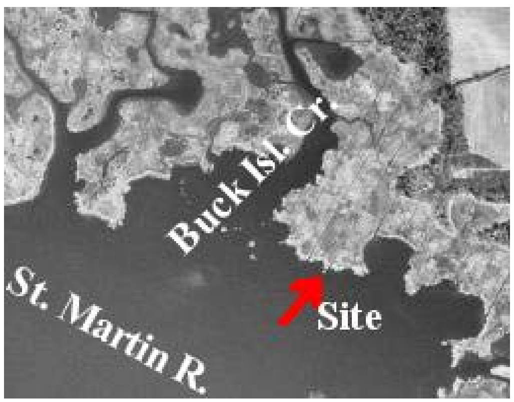
Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 7 – Saltgrass Pt.

Site ID: 7

Site name: Saltgrass Point

Location: On north shore of St. Martin River, in vicinity of Buck Island Pond and Buck Island Creek

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 250 713	488 658



Date: 5/1/01; 7/16/01

Time: 15:45; 16:30 EDT

Described by: JMH

Shoreline type (e.g., marsh, bluff, beach): marsh

Land use/cover along reach: natural

Extent (length) of reach (ft):

Bank elevation (ft): 0.7 m (2.4 ft)

Site description: Site is on a 'pinched point" that is almost an island. Mosquito ditching is east of point. Shoreline convoluted. Marsh is flat, uniform, *Spartina alternaflora* dominating. Abundant mussels covering on top marsh and in sediment. Entire site is very 'spongy,' quaking when walking.

Reach description: Extensive marsh characterized by very convoluted shoreline, and network of ditching. Several creeks meander through marsh area. Marsh is backed by forest buffer, then agriculture fields.

Plants:

Species	Percent
Spartina alterniflora	95

Samples:

ID	Type*	Location
Core 7	All	110 " from edge
Plug 7	All	Top 8" of sediment
7-Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

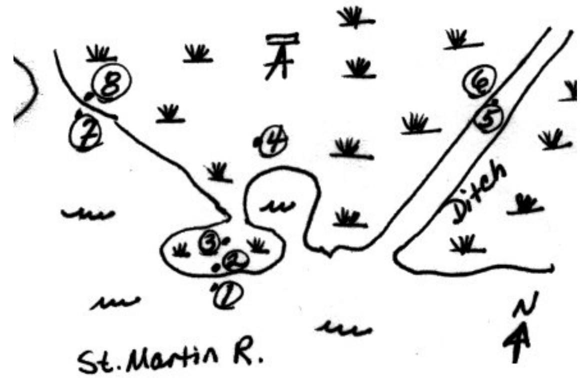
Date	Time EDT	Subject
5/1/01	15:56	Level & tripod
5/1/01	16:03	Ditching
7/16/01	16:40	Core site

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 7 – Saltgrass Pt.

Photo: Dan Sailsbury on site with stadia rod. Red flag marks location of core.

Photo: Mosquito ditching east of sampling site.

Plan view



Site 7 - Salt Grass Point

Stadia Readings		Feet		Feet		Meters		
Pt.	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height
1	8.2	7.88	7.57	63	-3.54	19.2	-1.08	3.23
2	4.96	4.65	4.34	62	-0.31	18.9	-0.09	
3	4.66	4.39	4.12	54	-0.05	16.5	-0.02	
4	4.55	4.42	4.29	26	-0.08	7.9	-0.02	
tripod		4.34			0		0.00	
5	6.95	6.78	6.6	35	-2.44	10.7	-0.74	2.20
6	4.75	4.58	4.41	34	-0.24	10.4	-0.07	
7	7	6.69	6.38	62	-2.35	18.9	-0.72	1.66
8	5.34	5.03	4.72	62	-0.69	18.9	-0.21	

*assumed elevation for tripod (level) pt.

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 8 – Smokehouse Cove

Site ID: 8
Site name: Smokehouse Cove
Location: St. Martin River, north shore, on west side of Isle of Wight

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 249 726	489 906

Date: 5/3/01, 7/16/01
Time: 1618; 1620 EDT
Described by: JHM, DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft):
Bank elevation (ft): 0.6 m (1.9 ft)

Site description: Site on point of extensive, irregularly shaped shoreline, marsh with pocket beaches each side. Marsh predominately *Spartina sp* with some marsh Elder (*Iva*), some barren spots.

Reach description: Extensive marsh characterized by convoluted shoreline of mixed marsh and sandy beaches, and large open water areas. Marsh interrupted with higher areas of pine/oak cover; area backed by forest toward Isle of Wight.

Plants:

Species	Percent
Spartina alterniflora	80
Iva	15

Samples:

ID	Type*	Location
Core 8	All	63”: from edge
8-Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Date	Time	Subject
5/3/01	1650	site
5/3/01	1652	
7/16/01	1620	Core site w/Dan
7/16/01	1622	Stand of oaks/pines
7/16/01	1623	Picket beach

Photo: Shoreline to the south of site, with small pocket beach

Plan view

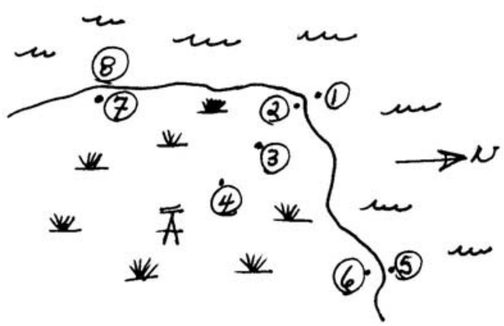


Photo: Site showing pocket beach to the north.

Site 8 - Smokehouse Cove

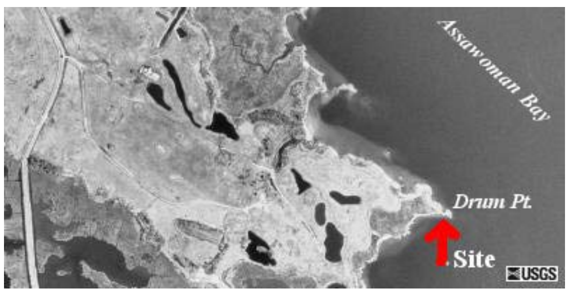
Stadia Readings		Feet		Feet		Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height
1	6.8	6.48	6.16	64	-2.00	19.5	-0.61	2.15
2	4.75	4.33	4.11	64	0.15	19.5	0.05	
3	4.48	4.15	3.9	58	0.33	17.7	0.10	core site
4	4.41	4.28	4.15	26	0.20	7.9	0.06	
tripod		4.48		0	0.00		0.00	
5	6.92	6.65	6.38	54	-2.17	16.5	-0.66	1.72
6	5.18	4.93	4.66	52	-0.45	15.8	-0.14	
7	6.48	6.06	5.64	84	-1.58	25.6	-0.48	1.74
8	4.73	4.325	3.91	82	0.16	25.0	0.05	

*assumed elevation for tripod (level) pt.

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 9 – Drum Point

Site ID: 9
Site name: Drum Point
Location: Assawoman Bay, west shore, first point north of Isle of Wight

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 250 598	491 619



Date: 5/1/01; 7/17/01
Time: 1730 EDT
Described by: JMH; DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft):
Bank elevation (ft): 0.6 m (2.0 ft)
Land use/cover along reach: Golf course

Site description:. Site on end of small 'pinched' point, tipped with small island. Fairly flat marsh, backed (~100 yds) by Lighthouse SoundGolf Course. Very little natural vegetation as buffer between Golf Course and marsh areas.

Reach description: Reach highly irregular shoreline, with islands, and pocket beaches. In some areas, shoreline protection has been emplaced, particularly where golf greens are near the shoreline (see photo to right with Darlene and Dan surveying: in background two golfer are putting on green located on point north of site.

Plants:

Species	Percent
Spartina sp.	100

Samples:

ID	Type*	Location
Core 9	All	31" from edge
Plug 9	All	Top 7.25" of sediment
9-OFf	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

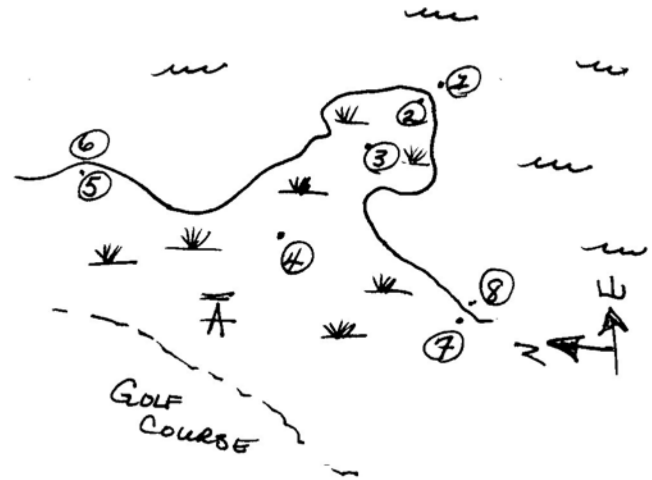
Photos:

Date	Time EDT	Subject
5/1/01	1725	Drum Pt.
5/1/01	1730	Golf course

Photo: Level site, looking northwest; golf green in background

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 9 – Drum Point

Photo: Level, looking east toward core site.



Site map: stadia data next page

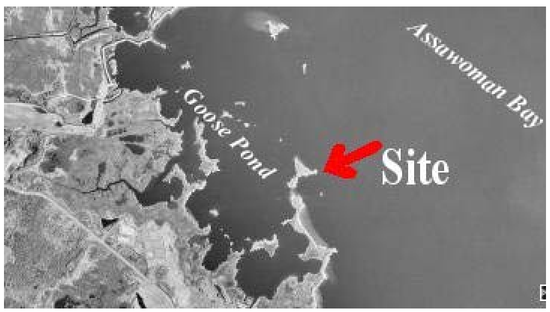
Site 9 - Drum Point

Stadia Readings		Feet			Feet	Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height (ft.)
1	7.62	7.305	6.99	63	-3.02	19.2	-0.92	2.69
2	4.93	4.62	4.31	62	-0.33	18.9	-0.10	
3	4.86	4.58	4.3	56	-0.29	17.1	-0.09	core site
4	4.62	4.47	4.32	30	-0.18	9.1	-0.05	
tripod		4.29		0	0.00	0.0	0.00	
5	6.76	6.63	6.49	27	-2.34	8.2	-0.71	2.06
6	4.7	4.57	4.44	26	-0.28	7.9	-0.09	
7	5.99	5.83	5.67	32	-1.54	9.8	-0.47	1.33
8	4.66	4.5	4.34	32	-0.21	9.8	-0.06	
					*assumed elevation for tripod (level) pt.			Ave.-2.03

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 10 – Tulls Island

Site ID: 10
Site name: Tulls Island
Location: Assawoman Bay, west shore, unnamed point between Drum Point and Hills Island, immediately west of former Tulls Island.

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 251 937	491 272



Date: 5/1/01; 7/17/01
Time: 1740 EDT
Described by: JMH; DVW
Shoreline type (e.g., marsh, bluff, beach): marsh

Extent (length) of reach (ft):
Bank elevation (ft): 0.4 m (1.3 ft)
Land use/cover along reach: Golf course; Lighthouse Sound Development (residential)
Site description:. Site on end of large island. Fairly flat marsh, irregularly shaped; abundant mussels, some bald (no vegetation) spots.
Photo: Behind level, look east toward core site.

Reach description: Reach highly irregular shoreline, with islands, and some pocket beaches. Site on island which recently (within last 25 years) separated from end of extensive peninsula.

Samples:

ID	Type*	Location
Core 10	All	31" from edge
Plug 10	All	Top 8.5" of sediment
10-Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Plants:

Species	Percent
Spartina sp.	90
Broad leaf shrub (*Iva*?)	<10

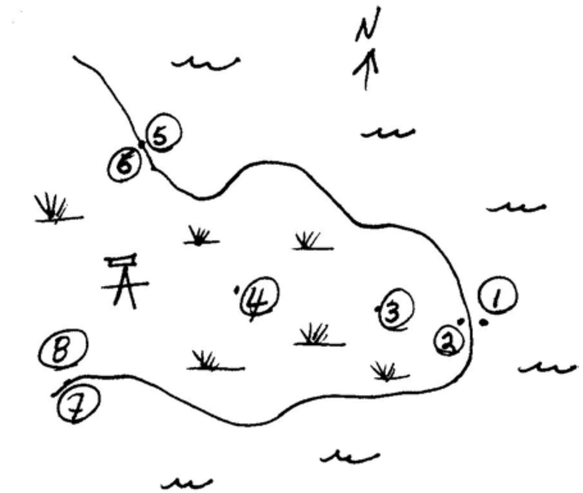
Photos:

Date	Time EDT	Subject
5/1/01	1755	Site with boat, looking due east
5/1/01	1730	Site looking northwest

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 10 – Tulls Island

Photo: Level, looking southeast toward core site (behind boat).

Plan view



Site 10 - Tulls Island

Stadia Readings		Feet			Feet	Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height
1	5.82	5.49	5.16	66	-1.32	20.1	-0.40	1.35
2	4.46	4.14	3.82	64	0.03	19.5	0.01	
3	4.49	4.22	3.95	54	-0.05	16.5	-0.02	
4	4.27	4.17	4.07	20	0.00	6.1	0.00	
tripod		4.17		0	0.00	0.0	0.00	
5	5.97	5.89	5.83	14	-1.72	4.3	-0.52	1.46
6	4.49	4.43	4.37	12	-0.26	3.7	-0.08	
7	5.42	5.33	5.24	18	-1.16	5.5	-0.35	1.08
8	4.34	4.25	4.16	18	-0.08	5.5	-0.02	

*assumed elevation for tripod (level) pt. Average-1.30

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 11 – Hills Island

Site ID: 11
Site name: Hills Island
Location: Assawoman Bay, west shore, on island north of Tulls Point in Goose Pond area

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 252 708	491 080

Date: 7/17/01
Time: 1623 EDT
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft): `1000 m
Bank elevation (ft): 0.5 m (1.6 ft)

Land use/cover along reach: Duck blind on island; Golf course; Lighthouse Sound Development (residential) on mainland
Site description: Site on north side of small island marsh east of Goose Pond area. Island ~ 75 x 100 meters. Marsh predominately *Spartina*, some beach lavender; edge of marsh armored with live mussels (photo to the right).
Reach description: Reach highly irregular shoreline, with islands, and some pocket beaches.

Plants:

Species	Percent
Spartina alterniflora	90
Limonium	>5

Photos:

Date	Time EDT	Subject
7/17/01	1655	Site showing mussel shells
7/17/01	1655	Core site
7/17/01	1655	Island looking west

Photo: Core site with areas of exposed mud, and live mussels

Photo: Looking east toward duck blind on point.

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 11 – Hills Island

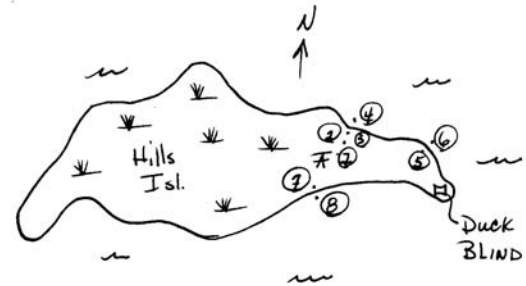
Samples:

ID	Type*	Location
Plug 11	All	Top 7.5” of sediment column
Core 11	All	48” from edge
11-Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photo: At level, looking west.

Plan view stadia data below



Site 11 - Hills Island

Stadia Readings		Feet		Feet		Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height
1	4.51	4.425	4.34	17	-0.13	5.2	-0.04	
2	4.96	4.81	4.66	30	-0.51	9.1	-0.16	core site
3	4.57	4.41	4.23	34	-0.11	10.4	-0.03	-1.74
4	6.32	6.15	5.98	34	-1.85	10.4	-0.56	
tripod		4.3		0	0.00	0.0	0.00	
5	4.97	4.75	4.53	44	-0.45	13.4	-0.14	-0.91
6	5.89	5.66	5.43	46	-1.36	14.0	-0.41	
7	4.54	4.32	4.1	44	-0.02	13.4	-0.01	-2.27
8	6.81	6.585	6.36	45	-2.29	13.7	-0.70	
					*assumed elevation for tripod (level) pt.			Average -1.64

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 12 – Peeks Creek

Site ID: 12
Site name: Peeks Creek
Location: Assawoman Bay, west shore, shoreline between Peeks Creek and Back Creek, SE of confluence of Greys Creek and Back Creek

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 253 294	490 442

Date: 5/3/01; 7/17/01
Time: 1255 EDT; 1500 EDT
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft): ~700 m (length of peninsula)
Bank elevation (ft): 0.4 m (1.4 ft)
Land use/cover along reach: Undeveloped, mixed marsh, woods

Site description: .Site on marsh point protruding NW into Greys Creek. Sandy beach to the north of site. Marsh is predominately *S. alterniflora*, with some *Limonium* (sea lavender) and *D. spicata* (spike grass). Some mussels on surface, near edge. Marsh backed by stands of shrubs (*Iva*), cedars, and various hardwoods, some of which were dead or dying.

Reach description: Reach is northeast shore of small peninsula or neck separating Peeks Creek from Greys Creek. Shoreline is irregular and consists of alternating marsh points and pocket beaches. Neck is ~150 m wide, with large expanse of water and channeling behind it.

Photos:

Date	Time EDT	Subject
5/3/01	1255	Reach to south
5/3/01	1256	Reach to north
5/3/01	1257	Core site
7/17/01	1508	Close up of marsh eroding

Samples:

ID	Type*	Location
Plug 12	All	Top 8” of sediment
Core 12	All	35” from edge
12-Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Plants:

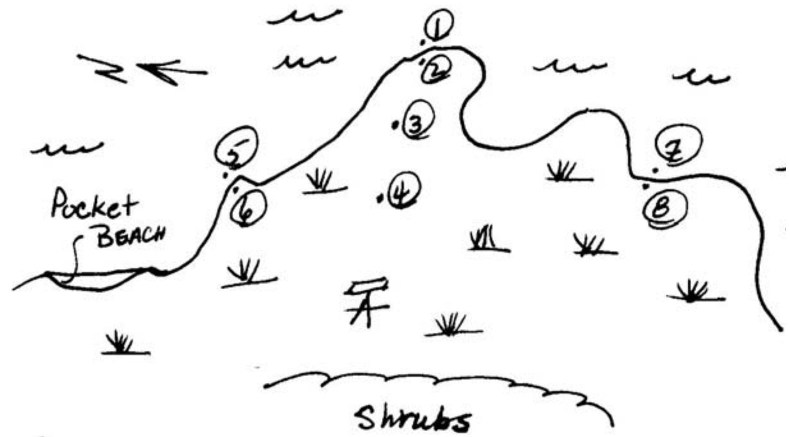
Species	Percent
Spartina alterniflora	85
Limonium	<5
Distlichlis spicata	<5

Photo : Reach looking north; note small cove and pocket beach in background

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 12 – Peeks Creek

Photos: Above: Reach looking southeast; Below: looking northwest toward back pond

Plan view



Site 12 - Peeks Creek

Stadia Readings		Feet			Feet	Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height
1	7.41	6.83	6.25	116	-2.58	35.4	-0.79	1.44
2	5.97	5.39	4.81	116	-1.14	35.4	-0.35	
3	5.68	5.26	4.84	84	-1.01	25.6	-0.31	
4	5.12	4.89	4.66	46	-0.64	14.0	-0.20	
tripod		4.25			0.00	0.0	0.00	
5	6.88	6.69	6.5	38	-2.44	11.6	-0.74	1.75
6	5.13	4.945	4.76	37	-0.70	11.3	-0.21	
7	6.61	5.965	5.31	130	-1.72	39.6	-0.52	0.89
8	5.71	5.08	4.43	128	-0.83	39.0	-0.25	
					*assumed elevation for tripod (level) pt.			Average -1.36

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)

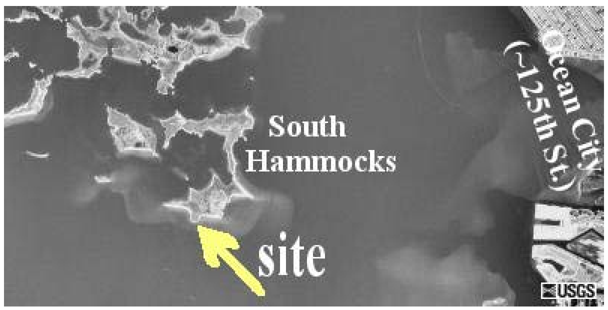
SITE/SAMPLE DESCRIPTION: Site 13 - South Hammocks

Site ID: 13

Site name: South Hammocks

Location: Assawoman Bay – west shore, SE south tip of southern-most island

UTM Zone 18 NAD83, m	Northing	Easting
Site 13	4 253 246	492 193
Site 13B	4 253 251	492 200



Date: 5/3/01; 7/17/01; 12/11/01

Time: 1320 EDT; 1400 EDT; 1528 EST

Described by: DVW

Shoreline type (e.g., marsh, bluff, beach): marsh

Extent (length) of reach (ft): ~500 m (length of island)

Bank elevation (ft): 0.7 m (2.2 ft)

Land use/cover along reach: Undeveloped, marsh with some forest cover

Site description: Site on southern most point of South Hammocks Island, eroding marsh between two pocket beaches; vegetation predominately *S. alterniflora*, with some scrubs backing marsh; pines and hardwoods in interior of island.

Reach description: Southern shoreline of South Hammocks Island; irregular shoreline of alternating marsh and sandy beaches. The southern half of island now separated from northern half.

Plants:

Species	Percent
Spartina alterniflora	>95
Limonium	<5

Samples: Note two cores collected at this site.

ID	Type*	Location
Plug 13	All	Top 7” of
Core 13	All	166” from edge
13 Off	GS	Grab offshore
Core 13B	All	36” from edge; no top plug taken

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

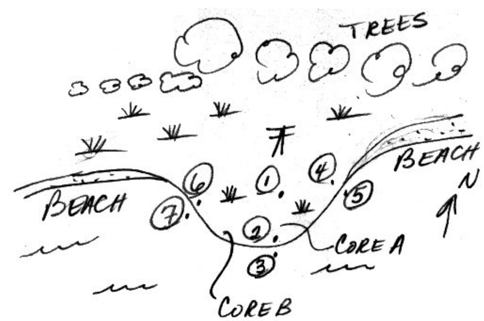
Date	Time EDT	Subject
5/3/01	1323	Close-up of bank showing slumping
5/3/01	1324	Site look W, from offshore
7/17/01	1413	Site looking WNW, from offshore
7/17/01	1413	Site looking N, from offshore
7/17/01	1414	Close-up of bank showing shelf and slumping
12/11/01	1422	Coring site
12/11/01	1422	Close-up of bank
12/11/01	1423	Site looking NE, from offshore

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)

SITE/SAMPLE DESCRIPTION: Site 13 - South Hammocks

Photo: Reach to the east of core site; note pocket beach

Site map:



Site 13 - South Hammocks Island 7/17/2001 1420 EDT

Stadia Readings	Feet			Feet		Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height (ft.)
1	4.1	3.98	3.86	24	0.17	7.3	0.05	
2	4.31	4.12	3.94	37	0.03	11.3	0.01	-1.80
3	6.11	5.92	5.73	38	-1.77	11.6	-0.54	
tripod		4.15		0	0.00	0.0	0.00	
4	4.09	3.85	3.61	48	0.30	14.6	0.09	-2.05
5	6.15	5.9	5.65	50	-1.75	15.2	-0.53	
6	4.96	4.75	4.54	42	-0.60	12.8	-0.18	-2.86
7	7.83	7.61	7.39	44	-3.46	13.4	-1.05	

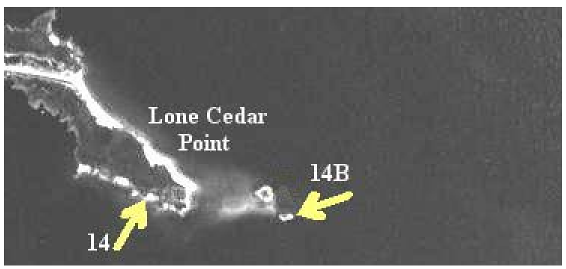
*assumed elevation for tripod (level) pt. -2.24

Photo: Offshore looking at site toward west.

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 14 – Lone Cedar Point

Site ID: 14 (joint site with UMCES)
Site name: Lone Cedar Point
Location: Assawoman Bay – west shore; extreme northern extent of study area (on Md/Del State Line), site of eroding cemetery

UTM Zone 18 NAD83, m	Northing	Easting
Site 14	4 255 752	492 582
Site 14B	4 255 727	492 780



Date: 11/28/00; 5/2/01; 7/17/01; 12/11/01
Time: 1400 EST**;** 1400 EDT; 1200 EDT; 1300 EST
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh

Extent (length) of reach (ft): 250 m (750 ft) approx. length of peninsula
Bank elevation (ft): 0.6 m (2.0 ft)

Land use/cover along reach: eroded roadbed runs along north side of peninsula; abandon cemetery on point; otherwise, mixed forest/marsh; undeveloped

Site description: Site 14: original site located on south side of Lone Cedar Point, an eroding peninsula. Site on marshy point with sandy beach on both sides.
Site 14B:Due to high pedestrian traffic (popular sunbathing area), UMCES moved site to marsh island off top of Lone Cedar Pt. Island dominated by *S. alterniflora*. Also "quaking" (i.e., shakes when walking, with tide/waves).

Reach description: Eroding peninsula with mixed marsh, beach shoreline; deciduous trees and shrubs in center; sandy beach along north side; pocket beached along south side, some topography.

Photo: Site 14B looking toward Lone Cedar Pt.

Plants:

Species (Site 14)	Percent
Spartina alterniflora	80
Limonium	<5
Spartina patens	<5
Iva	1
Phragmites	1

Photo: Site 14-original site looking east.

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 14 – Lone Cedar Point

Samples:

ID	Type *	Location
Plug-14	All	Top 7" of sediment column
Core-14	All	43" from edge
Core 14 beach	GS	Back side of beach to the east
14- Off	GS	Grab offshore
Core 14B	All	Island, 3.3 ft from waters edge

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Date	Time EDT	Subject
11/28/00	1404	CourtS, setting out peerpers, collecting plant tissue
11/28/00	1405	"
11/28/00	1414	Beach east
12/11/01	1337	Site 14B-Dan&Rich collecting core
12/11/01	1338	Site 14B-Dan&Rich
12/11/01	1350	Site 14B looking to Lone Cedar Pt.

Hydrolab readings 5/2/2001 12:52 EDT		
Temp	21.32	degrees C
Salinity	23.6	ppt
DO	7.37	
Sat	91	%
pH	5.54	
Turb	8.1	NTU
Depth	0.93	ft

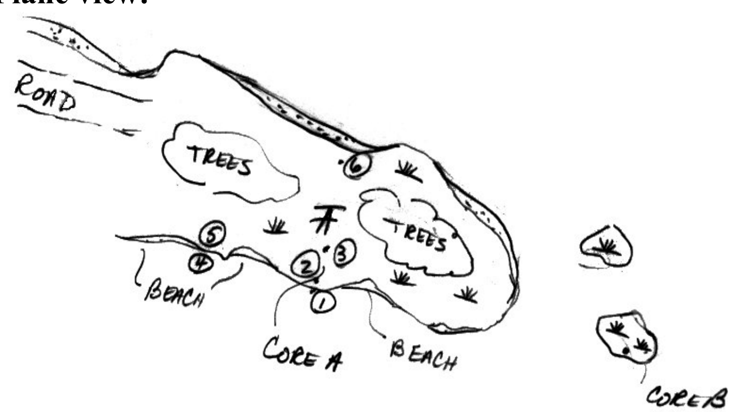
Note: We had trouble collecting a core at site 14 due to significant compression when inserting liner and suction when extracting core. Collected second core on adjacent beach to see if sand overlies muddy marsh sediment.

Site 14 - Lone Cedar Point

	Stadia Readings	Feet		Feet		Meters		
Pt. #	**top**	**middle**	**bottom**	**Dist**	**Elev***	**Dist**	**Elev**	**Bank Hht (ft.)**
1	7.2	6.93	6.65	55	-2.31	16.8	-0.70	2.21
2	5	4.72	4.44	56	-0.10	17.1	-0.03	
3	4.73	4.595	4.46	27	0.03	8.2	0.01	
4	6.88	6.62	6.36	52	-2.00	15.8	-0.61	1.83
5	5.05	4.79	4.53	52	-0.17	15.8	-0.05	
tripod		4.62		0	0.00	0.0	0.00	
6	4.61	4.08	3.55	106	0.54	32.3	0.16	
								Average 2.02

*assumed elevation for tripod (level) pt.

Plane view:



Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 18 – Wire Pond

Site ID: 18
Site name: Wire Pond
Location: Isle of Wight Bay – southwest shore; first cove west of the Thorofare

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 245 252	490 931

Date: 11/28/00; 5/2/01
Time: 1500 EST**;** 0853 EDT
Described by: JMH
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft):
Bank elevation (ft): m (ft)
Land use/cover along reach:

Site description:.On first marsh point east of mouth to Wire Pond; extensive flat marsh; shallow shelf surrounding point.

Photo: Site looking SW toward Wire Pond

Reach description: Site is on island marsh at mouth of Wire Pond, south Isle of Wight Bay; deep channel (The Thorofare)cuts along north side of island

Plants:

Species	Percent
Spartina alterniflora	70
Distichlis *(Spike grass)*	<10
Limonium (Sea Lavander)	<10

Samples:

ID	Type*	Location
Plug 18	All	Top 9.5" of sed column
Core 18	All	39" from edge
18 Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

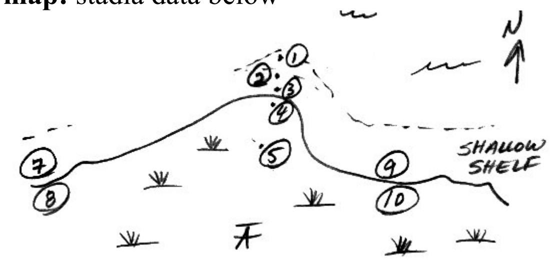
Photos:

Date	Time EDT	Subject
11/28/00	1512	Site from distance
11/28/00	1513	Site looking SW
11/28/00	1514	Site looking SE
5/2/01	0905	Site
5/2/01	0905	Site

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 18 – Wire Pond

Photo: Looking to SW at sampling site on point

Site map: stadia data below



Site 18 - Wire Pond

Stadia Readings		Feet			Feet	Meters		
Pt. #	**top**	**middle**	**bottom**	**Dist**	**Elev***	**Dist**	**Elev**	**Bank Height (ft.)**
1	13.14	12.52	11.9	124	-7.89	37.8	-2.40	
2	8.36	7.74	7.12	124	-3.11	37.8	-0.95	
3	6.35	5.84	5.32	103	-1.21	31.4	-0.37	1.02
4	5.33	4.82	4.31	102	-0.19	31.1	-0.06	
5	5.31	4.805	4.3	101	-0.18	30.8	-0.05	
6	4.8	4.61	4.43	37	0.02	11.3	0.01	
tripod		4.63		0	0.00	0.0	0.00	
7	6.03	5.585	5.14	89	-0.96	27.1	-0.29	0.85
8	5.18	4.74	4.3	88	-0.11	26.8	-0.03	
9	7.35	6.81	6.27	108	-2.18	32.9	-0.66	1.77
10	5.58	5.04	4.5	108	-0.41	32.9	-0.12	

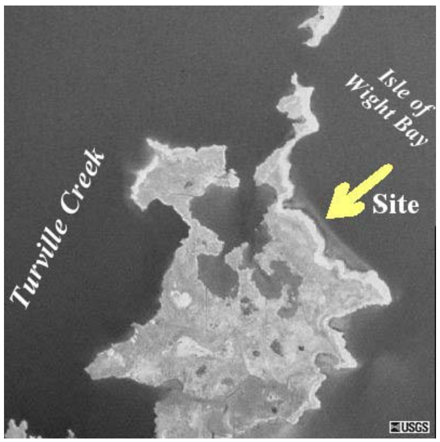
*assumed elevation for tripod (level) pt.

Average 1.21

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 19 – Keyser Point

Site ID: 19 (joint with UMCES)
Site name: Keyser Point
Location: Isle of Wight, west shore; south side of mouth into Isle of Wight Bay

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 246 364	489 794



Date: 11/28/00; 5/2/01; 5/3/01
Time: 12:00 EDT;
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft): ~450 m (length of island

Bank elevation (ft): 0.28 m (0.925 ft)

Land use/cover along reach:
undeveloped marsh; forest and large homes on mainland next to island.
NOTE: visited the site several times; the first and second times with Dr. Stevenson to set out pore water equilibrators (peepers) and to take hydrolab data offshore (see next page)

Site description:. Site on eastern shore of island marsh; site almost entirely vegetated with *S. alterniflora* and some small shrubs (*Iva*).

Reach description: Site located on rregularly shaped extensive island marsh, approx. 450 m by 300 m; marsh punctuated with internal ponds/channels;

Plants:

Species	Percent
Spartina alterniflora	70
Distichlis (Spike grass)	20
Limonium (Sea Lavander)	>5

Samples:

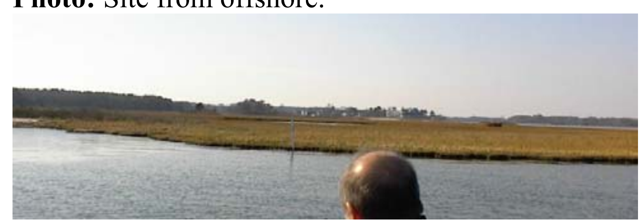
ID	Type*	Location
Plug 19	All	Top 7" of sediment
Core 19	All	61" from edge
10 Off	GS	Grab offshore

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Date	Time EDT	Subject
11/28/00	1158	Setting out grid for grass tissue sampling
11/28/00	1159	Clipping grasses (for biomas)
11/28/00	1207	Site from offshore

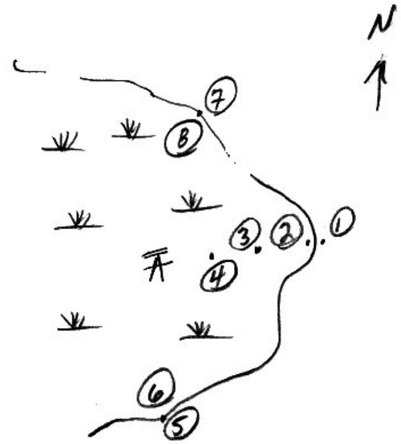
Photo: Site from offshore.



Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 19 – Keyser Point

Photo: Court Stevenson and Al Wesche setting out grids to collect plant tissue samples. Isle of Wight is in background

Plan view



Hydrolab readings		**5/2/2001**		
Offshore at site 19		12:00 EDT	At OC Inlet	14:15 EDT
Temp	18.5	degrees C	11.75	degrees C
Salinity	28.9	ppt	32.25	ppt
DO	7.49	mg/l	8.72	mg/l
Sat	93	%	95	%
pH	5.64		5.6	
Turb	3.8	NTU	3.7	NTU
Depth	1.5	m	1.25	m

Site 19 - Keyser Point

Stadia Readings		Feet			Feet	Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height (ft.)
1	6.33	5.97	5.61	72	-1.41	21.9	-0.43	0.94
2	5.39	5.025	4.66	73	-0.47	22.3	-0.14	
3	5.09	4.76	4.43	66	-0.20	20.1	-0.06	
4	4.69	4.52	4.36	33	0.04	10.1	0.01	
tripod		4.56		0	0.00	0.0	0.00	
5	5.82	5.59	5.36	46	-1.03	14.0	-0.31	0.67
6	5.15	4.92	4.69	46	-0.36	14.0	-0.11	
7	6.39	5.93	5.47	92	-1.37	28.0	-0.42	1.16
8	5.23	4.77	4.31	92	-0.21	28.0	-0.06	

*assumed elevation for tripod (level) pt. Average 0.93

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 22 – Isle of Wight

Site ID: 22
Site name: Isle of Wight
Location: Assawoman Bay – west shore; NE shore of Isle of Wight, directly across from site 8 on NW shore of Isle.

UTM Zone 18 NAD83, m	Northing	Easting
Actual	4 249 932	490 966

Date: 7/17/01
Time: 1845 EDT
Described by: DVW
Shoreline type (e.g., marsh, bluff, beach): marsh
Extent (length) of reach (ft): ~1000 m

Bank elevation (ft): 0.49 m (1.6 ft)
Land use/cover along reach:
Undeveloped marsh; backed by forest
Site description:. Site on small island on point of extensive marsh; thickly vegetated with almost all Spartina alterniflora, some beach lavender.

Reach description: Site on small island off very extensive marsh area characterized by convoluted shoreline with islands and ditching

Photo: Dan and Neal collecting core at site; looking SE

Plants:

Species	Percent
Spartina alterniflora	>90
Limonium	5

Samples:

ID	Type*	Location
Plug 22	All	Top 9" of sediment
Core 22	All	45" from edge
22 Off	GS	Offshore grab

***Type** = bulk density (BD); grain size (GS); trace metal (TM)

Photos:

Date	Time EDT	Subject
7/17/01	1845	Dan and Neal w/core
7/17/01	1845	Site
7/17/01	1848	Neal w/core
7/17/01	1907	Site from distance
7/17/01	1908	OC sunset

Shore Erosion as a Source of Sediments & Nutrients, Northern Coastal Bays, Maryland (CZM Grant M01-057 CZM 040)
SITE/SAMPLE DESCRIPTION: Site 22 – Isle of Wight

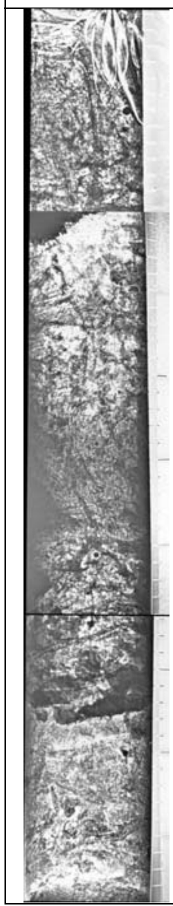
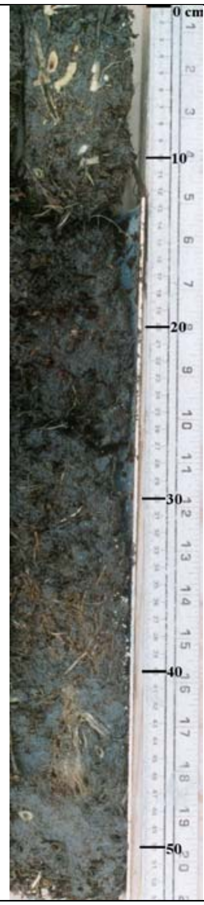
Photo: Main marsh, looking SW from site.

Plan view

Site 22 - Isle of Wight

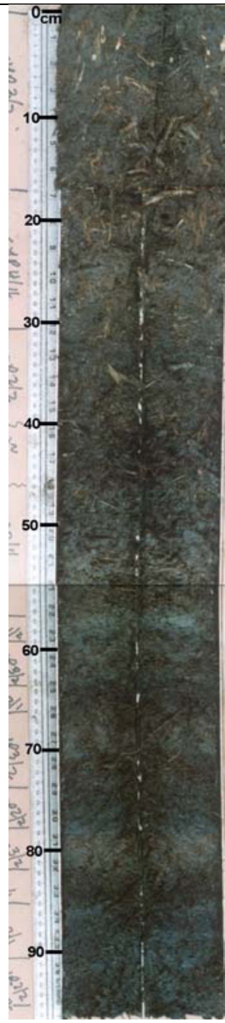
Stadia Readings		Feet		Feet		Meters		
Pt. #	top	middle	bottom	Dist	Elev*	Dist	Elev	Bank Height (ft.)
1	4.12	4.03	3.94	18	0.00	5.5	0.00	
2	4.35	4.13	3.92	43	-0.10	13.1	-0.03	1.61
3	5.97	5.74	5.51	46	-1.71	14.0	-0.52	
tripod		4.03		0	0.00	0.0	0.00	
4	4.2	4.12	4.04	16	-0.09	4.9	-0.03	1.26
5	5.48	5.375	5.27	21	-1.35	6.4	-0.41	
6	4.22	3.99	3.76	46	0.04	14.0	0.01	1.93
7	6.16	5.92	5.68	48	-1.89	14.6	-0.58	

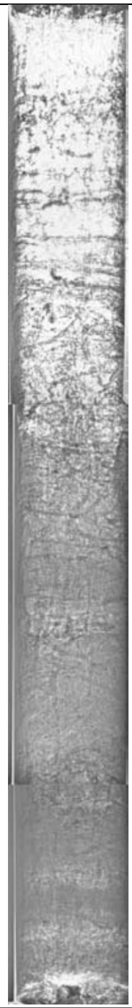
*assumed elevation for tripod (level) pt. Average = 1.60

Site #1- White Horse Point, St. Martin River Total length - 53.3 cm Date collected - 7/17/01 Date processes - 7/31/01				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-13	5YR 2/2 to 10 YR 3/2	Active root zone; dark gray brown silty mud; lots of large (2-4 cm diameter) rhizomes; some mussels shells in life position at top
		13-19	10 YR 3/2	Active root zone; gray brown mud with rhizomes, root material
		19-27	10 R 3/2	Gray brown, more compact mud w/ large fibrous root remnants
		27-32	5 YR 3/2	Gray brown spongy peat w/ voids; very little sediment (clastics)
		32-38	5 YR 2/2	Dark gray brown mud w/ root remnants
		38-42	5 YR 2/1	Dark gray black mud, watery, w/ peat and root remnants
		42-46.5	5 YR 2/2 mottled w/ 10 R 3 /4	Dark gray brown silty mud mottled with peat and root remnants
		46.5-47.5	10 R 3 /4	Reddish brown peat
		47.5-53.3	5 YR 2/2	Dark gray brown silty mud with abundant peat and root remnants

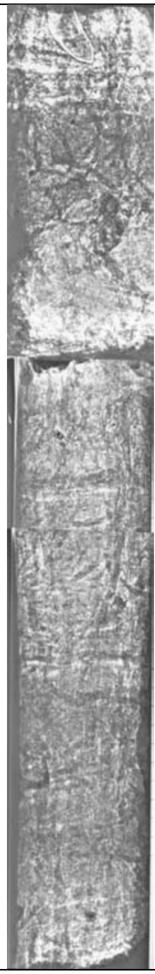
Site #6 Peach Point, St. Martin River, Core 6 Total length- 61 cm Date collected- Date processed-				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-11	5 YR 2/2, mottled with N2	Active root zone, live mussels in very top, live small crab; dark brown to black silty mud, lots of active roots
		11-24	10 YR 2/2	Active root zone; section lighter in color, dark brown to ducky yellowish brown silty mud
		24-38	10 YR 3/2	Active root zone; long fibrous roots, moderate dusky grown mud
		38-45	5 YR 2/2	Very dark dusky brown mud, root material, short peat-like
		45-48.5	5 YR 2/1	Very dark gray brown mud, less plant material
		48.5-61	10 YR 2/2	Dark brown dusky yellow mud with pockets of reddish brown peat, lots of root material, spongy layer

Site #7 – Salt Grass Point, St. Martin River Total length-95 cm Date collected- Date processed-
Note: Overall appearance is banding alternating dark and light layers; clastics generally brown to olive gray, and plant material more yellow to reddish in color.

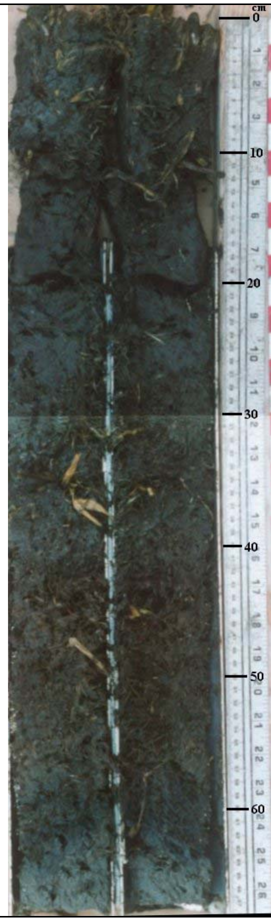
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-11	5 YR 3/2	Active root zone; layered brownish gray to moderate brown, very compact silty mud; some sand with lots of large roots
		11-14	5 YR 2/2	
		14-17	5 YR 3/2	
		17-30.5	5 YR 4/4	Active root zone; moderate brown mud, spongy, less dense, root material smaller in size and oriented more horizontal than vertical
		30.5-40	10 R 2/2	Very dusky red, less dense mud with peat like root material, some larger plant pieces, layered horizontally
		40-46	5 YR 2/2	Dusky brown, less dense spongy peat layer
		46-56.5	10 R 2/4	Moderate yellow brown mud, abundant plant material, lots of voids
		56.5-59	5 YR 4/2	Alternating brown to brownish gray mud and yellow brown to reddish brown peat layers
		59-63.5	5 YR 3/2	
		63.5-66	5 YR 2/1	
		66-73.5	5 YR 3/2	
		73.5-77.5	5 YR 2/2	
		77.5-82	10 YR 3/2	
		82-85	5 Y 2/1	
		85-90.5	5 YR 2/1	
		90.5-95.5	10 YR 2/2	

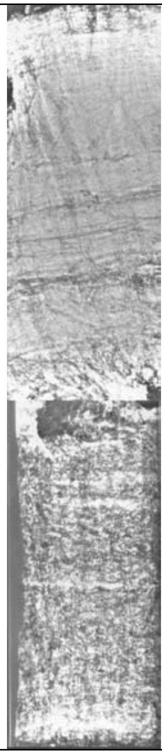
<table>
<tr><td colspan="5">Site #8 Smokehouse Cove, St. Martin River Total length- 63.5 cm Date collected- 7/16/01 Date processed- 8/9/01</td></tr>
<tr><th>Radiograph</th><th>Photograph</th><th>Interval (cm)</th><th>Color (Munsell Color Standard, GSA, 1991)</th><th>Description</th></tr>
<tr><td rowspan="7"></td><td rowspan="7"></td><td>0-14.5</td><td>Banded 10 YR 2/2 to 5 Y 5/2</td><td>Active root zone; banded olive gray to dusky yellow brown mud and sand layers, layers ranging 1 to 3 cm thick, abundant roots</td></tr>
<tr><td>14.5-26.5</td><td>5 YR 2/2</td><td>Active root zone; uniform dark brown silty mud, sand decreasing with depth, roots</td></tr>
<tr><td>26.5-29</td><td>10 YR 2/2</td><td>Active root zone; darker dusky brown mud, root material, peat like clumps</td></tr>
<tr><td>29-51</td><td>5 YR 2/2</td><td>Uniform dusky brown mud with peat and roots</td></tr>
<tr><td>51-57</td><td>10 Y 2.5/1</td><td>Dark brown peaty mud</td></tr>
<tr><td>57-59</td><td>5 Y 4/4</td><td>Olive brown silty mud with some roots and peat</td></tr>
<tr><td>59-63.5</td><td>N2</td><td>Very dark almost black, mud with abundant peat material</td></tr>
</table>

Site # 9 Drum Point, Assawoman Bay	Total length- 78 cm	Date collected-7/17/01	Date processed- 8/20/01	
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-2.5	Banded 5 YR 5/2 & 10 YR 6/2	Active root zone; banded (lamina) pale brown to pale yellow brown, sandy mud, mussels at top, roots
		2.5-18	Banded 5 YR 2/1; 5 YR 3/2; 10 R ¾ (oxidized roots)	Active root zone; Less obvious banding, and decreasing with depth, abundant roots, moderate brown to dark brown black sandy mud, some root tracks highly oxidized
		18-26.5	Mottled N4 & 5 Y 3/1	Active root zone; mottled dark gray to dark olive gray more compact mud, abundant roots
		26.5-33.5	5 YR 2/2	Dark dusky brown peaty mud, root material becoming more horizontal in orientation
		33.5-40	5 YR 2/1 to 5 YR 2/2	Sharp contact? Redox interface; dark brown, less dense very peaty layer, with very top and bottom slightly darker
		40-50	5 YR 2/2	Dusky brown very peaty mud
		50-55.5	5 YR 3/2	Dusky gray brown, very fibrous mud, reddish brown peat clumps
		55.5-58	5 R 2/1	Very dark brownish black peaty mud, very fibrous, spongy
		58-67	10 YR 2/2	Light dusky yellow brown spongy peaty mud
		67-78	10 YR 3/2	Note: bottom 2 cm lost when core was opened; yellowish brown, more compact mud containing less plant material

Site # 10 Tulls Island, Assawoman Bay Total length- 50.5 cm Date collected- 7/17/01 Date processed- 8/22/01				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-2.5	5 YR 3/2	Brownish black to olive black mud, abundant plant roots; root orientation becoming more random with depth; although lamina (`1-2 cm thick) visible in radiograph, not discernable visually; no abrupt or obvious boundaries, very subtle, gradual lightening down core, based on radiograph, an increase in plant material downcore
		2.5-21.5	5 YR 2/2	
		21.5-50.5	5 YR 2/1 to 5 Y 2/1	

Site # 11 Goose Pone, Assawoman Bay	Total length- 60 cm	Date collected- 7/17/01	Date processed- 8/23/01		
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description	
		0-6	5 Y 4/1	Active root zone: olive gray sandy silty mud with very large roots; thick layer of mussels on surface; subtle color banding, gradual darkening down core.	
		6-8.5	5 G 3/1		
		8.5-19	5 GY 3/1	Active root zone: dark greenish gray mud with large, thick stems; root abundance decrease with depth	
		19-34	5 Y 3/1	Active root zone: dark olive gray mud with root material, several very large woody (non root) stems; shift from predominately vertical orientation of plant material to horizontal orientation	
		34-41	5 Y 2/1	Very dark olive gray mud; abundant peat material	
		41-47	N 1 to 5 GY 1/1	Redox boundary at 41 cm; dark greenish black to black peaty mud	
		47-60	5 G 2/1	Slightly lighter greenish black, watery muddy peat, very "loose" packing (with voids), some discernable root stems	

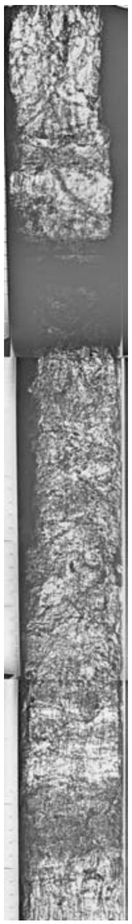
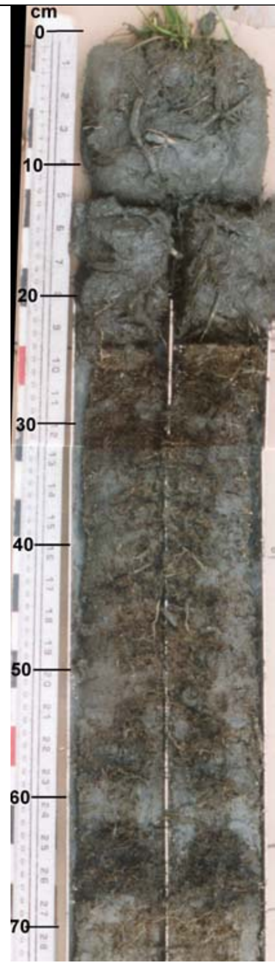
Site # 12 Peeks Creek, Assawoman Bay	Total length- 67.5 cm	Date collected- 7/17/01	Date processed- 8/24/01	
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-20.5	5 y 2/1	Active root zone: dark olive black sandy silty mud with mussels on top; large roots; radiograph incite thin lamina (sandier?) but not visible to the eye
		20.5-32.5	5 GY 2/1	Active root zone: dark greenish black slightly less dense silty mud with abundant roots
		32.5-38	5 YR 2/1	Brownish black muddy peat; some larger root stems, appears to be more oxidized than surrounding layers
		38-43	5 Y 2/1	Dark olive black peaty mud
		43-58.5	10 YR 2/2 to 10 YR 3/2	Dusky yellow brown, highly peaty, gradually lightens to yellowish brown; plant material decrease with depth
		58.5-64	5 G 2/1 to N 1	Redox boundary at 58.5 cm; greenish black to black peaty mud
		64-67.5	5 GY 4/1	Dark greenish gray mud, lighter in color than rest of core; also less plant material

<table>
<tr><td colspan="5">Site # 13 – South Hammocks, Assawoman Bay Total length- 35.5 cm Date collected- 7/17/01 Date processed- 8/27/01</td></tr>
<tr><td>Radiograph</td><td>Photograph</td><td>Interval (cm)</td><td>Color (Munsell Color Standard, GSA, 1991)</td><td>Description</td></tr>
<tr><td rowspan="6"></td><td rowspan="6"></td><td>0-1</td><td>5 Y 8/1</td><td>Active root zone; yellowish gray sand</td></tr>
<tr><td>1-3</td><td>5 Y 2/1</td><td>Active root zone; dark olive black to brown muddy sand</td></tr>
<tr><td>3-7</td><td>5 Y 8/1</td><td>Active root zone; yellowish gray very fine sand</td></tr>
<tr><td>7-19</td><td>Banded; 5 Y 8/1
10 YR 4/2
N 3</td><td>Active root zone; alternating lamina of yellowish gray sand, dark yellow brown sandy mud, and dark gray very compact sandy mud; sand increased down core, bottom of section is dark brown gray sand ; plant material present but not abundant except in very bottom of section</td></tr>
<tr><td>19-29.5</td><td>Mottled;
5 YR 4/1
N 2</td><td>Active root zone; mottled brownish gray to gray black silty mud; plant material throughout section; redox boundary at 27 cm</td></tr>
<tr><td>29.5-35.5</td><td>5 GY 2/1</td><td>Greenish black mud with abundant plant material (roots and peat)</td></tr>
</table>

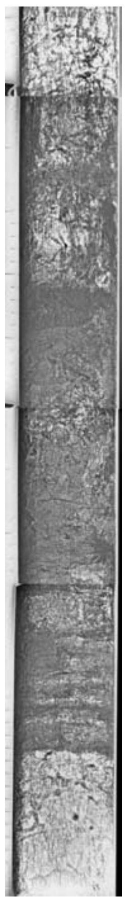
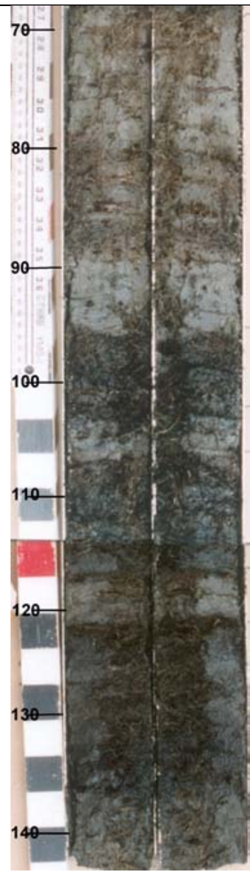
Site # 13B South Hammocks, Assawoman Bay Total length- 70.5 cm Date collected- 12/11/01 Date processed- 12/18/01				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-8	10 YR 3/2	Active root zone; dark yellow brown muddy very fine sand, mottled with black muddy sand; abundant live roots
		8-14	5 Y 2/1	Active root zone; sharp boundary at 8 cm, black muddy sand, gradually lightening down core
		14-22	10 YR 3/2	Active root zone (to 20 cm); olive brown to black mud, less sand
		22-26	5 Y 2/1	Olive black mud with peat and roots
		26-47	Mottled and banded 5 G 3/1 to 5 YR 3/1	Mottled and subtly banded dark greenish gray mud to dark brownish gray sandy mud, peat increasing downcore
		47-70.5	Mottled; 5 YR 3/2 5 YR 2/2	Mottled grayish brown to dusky brown sandy mud with abundant plant (peat and roots) material, very peaty at bottom of core

Site # 14 Lone Cedar Point, Assawoman Bay Total length- 45 cm Date collected- 7/17/01 Date processed- 8/27/01				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-2	5 Y 4/1	Active root zone; olive gray, very compact muddy sand w/ lenses of sand, roots
		2-3	5 Y 7/1	Active root zone; yellow gray sand, roots
		3-17.5	5 YR 2/1	Active root zone; olive black to brownish black, silty mud, very compact, roots
		17.5-26	5 GY 2/1	Active root zone; greenish black silty mud, less compact; abundant plant material, roots, peat; gap where core broke when extracting from site; plant roots orientation shifting from vertical to horizontal
		26-34.5	5 GY 4/1 to 5 G 5/1	Active root zone; firm, dark greenish gray silty mud; gradually darkening to dark greenish gray; plant material
		34.5-38	5 GY 3/1	Redox interface at 34.5 cm; greenish black firm sandy mud; plant material
		38-45	5 Y 2/1	Olive black sandy mud; plant material

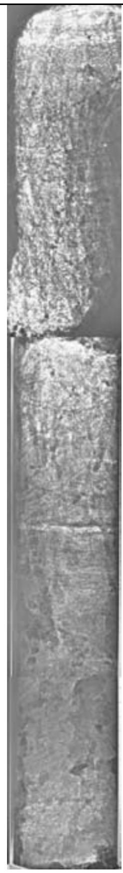
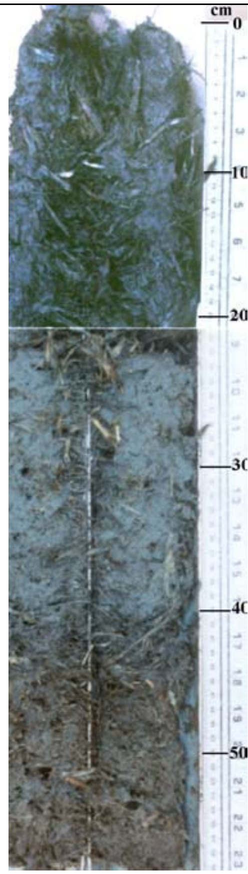
Site #14B Lone Cedar Key, Assawoman Bay, Total Length- 86.5 cm Date collected- 12/11/01 Date processes- 12/18/1				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
 Note: bottom 10 cm not in radiograph		0-13	5 YR 4/1 to 5 YR 2/1	Active root zone; mottled medium to dark gray brown mud, with abundant rhizomes; very muddy at top, sand gradually increasing w/depth
		13-15	5 Y 5/1	Active root zone; dark gray brown sandy mud with rhizomes
		15-23.5	5 YR 2/1 to N2	Active root zone to 19 cm; dark gray brown mud with roots
		23.5-32.5	5 YR 2/1	Gray brown peat, slight banding
		32.5-46.5	5 YR 3/1	
		46.5-64.5	5YR 2/1, 5 YR 4/1, 5 Y 4/1	Banded peaty mud with sand lenses
		64.5-75.5	N6 to 5 B 7/1	Sharp contact; steel gray, very clayey compact, dry mud
		75.5-80	5 YR 2/1	Very dark olive black peaty mud, less compact
		80-85	N6 to 5 B 7/1	Sand lenses at 81-82 cm, interbedded w/ peaty mud layers
		85-86.5	N2	Very dark gray, peaty mud

Site # 18, Top section; Wire Pond, Isle of Wight Bay Total length- 143 cm Date collected- 5/2/01 Date processed- 5/14/01 Comments: H_2S odor; distinct banding				
Radiograph 0-70 cm	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-24.5	(color not true; turned anoxic in bag	Active root zone; grayish brown silty mud with abundant roots
		24.5-63	5 YR 3 /4 5 Y 4/1	Active root zone; mottled moderate brown to olive gray silty mud with abundant roots
		63-68	5 YR 2/1	Brownish black muddy peat

Site # 18, Bottom section; Wire Pond, Isle of Wight Bay Total length- 143 cm Date collected- 5/2/01 Date processed- 5/14/01
Comments: H_2S odor; distinct banding

Radiograph 70-143 cm	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		68-96	5 Y 3/2 5 G 4/1	Subtlety banded olive gray to greenish gray clayey mud, roots and peat; very clayey at bottom of section
		96-103	5 YR 2/2	Alternate layers of dusky brown peaty mud, dusky yellow brown mud with some plant material, and olive gray mud with little plant/peat
		103-107	10 YR 2/2	
		107-118	5 YR 2/2	
		118-122	5 Y 3/2	
		122-137	5 YR 2/1	Brownish black muddy peat
		137-143	5 Y 3/2	Olive gray mud with some peat pockets

Site #19 Keyser Pt., Isle of Wight Bay,		Total Length- 59 cm	Date collected- 5/3/01	Date processes- 9/10/01
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-15	5 Y 4/1; 5 YR 4/1; 10 R 3 /4	Active root zone; mottled olive gray mud, very sandy with inclusion's of large (>5 cm) sand pockets, light brown, gritty, lots of mica, highly oxidized around some root paths (dark reddish brown); abundant roots, plant material
		15-19.5	5 GY 41	Active root zone; very compact, greenish gray mud, micacous, faint laminations, abundant roots and root material
		19.5-21.5	5 Y 3/1	?Active root zone; olive gray mud, laminated, roots
		21.5-23.5	5 Y 6/1	
		23.5-46.5	5 G 4/1; 5 YR 4/1; 5 B 4/1	Alternating dark olive gray to light olive gray mud; highly laminated, compact, silty mud, micaceous layers range from 1 cm to 3 cm, sand lenses, root material
		46.5-51.5	5 Y 2/1	Very sharp change to olive black peaty mud
		51.5-59	5 YR 2/1	Sharp change to very dark brownish black peat, with some clastics

Site # 22 Isle of Wight, Assawoman Bay Total length- 58.5 cm Date collected- 7/17/01 Date processed- 9/13/01				
Radiograph	Photograph	Interval (cm)	Color (Munsell Color Standard, GSA, 1991)	Description
		0-2	5 G 2/1; 5 Y 3/1	Active root zone; top 2 cm mottled greenish black and dark olive gray mud with abundant plant and root material
		2-22	5 Y 4/1	Active root zone; dark olive gray mud with abundant plant and root material
		22-42	5 GY 3/1	Active root zone; dark greenish gray silty mud with abundant plant material; radiograph indicates slightly denser layer at 36 cm which is not visible w/eye
		42-48.5	5 YR 3/1	Brownish gray peat with mud, spongy
		48.5-58.5	5 Y 3/1	Olive gray peaty mud, not as peaty as overlying section

APPENDIX B
Quality Assurance/Quality Control

Textural Analyses

The techniques used to determine grain size composition are based on traditional analytical methods developed for the sedimentology lab. Still, some analytical error is inherent in the methodology. For example, results can be affected by the technician's level of skill and/or changes in laboratory conditions, such as sudden temperature changes. Furthermore, no standard reference material includes the broad range of particle sizes and shapes contained in natural sediment. To maximize the consistency of textural analyses, several checks are used to monitor results. Calculated gravel, sand, silt, and clay percentages are checked against (1) field descriptions of the samples, (2) calculated water content, and (3) calculated weight loss of the sample during processing. These comparisons are made to determine if the grain size composition matches the visual description of the sample and/or falls within an expected Shepard's (1954) class with respect to water content and weight loss. Any discrepancy is flagged, and the results are reviewed to determine if reanalysis is warranted.

Specifically, the criteria for each of the internal checks are as follows:

(1) Calculated gravel, sand, silt, and clay percentages and Shepard's classification are compared with the field description of the sediment. If the results seem to indicate a very different sample from the one described, then the sample is reanalyzed.

(2) Gravel, sand, silt, and clay percentages are compared to calculated water content. For each of the sediment types, Table B-1 lists the typical mean and range of values for water content, based on bottom sediments collected in Isle of Wight and Assawoman Bays. The mean and range of values for marsh sediments collected as part of this study fall within expected values for water content (Table B-2).

(3) Sample loss (% dry weight) during cleaning is calculated for each sample. The calculated water content, which is usually measured shortly after the sample is collected, is used to determine weight loss. If the sediment dries out, even slightly, before it is sub-sampled for textural analysis, then weight loss is underestimated and, in some instances, negative. The weight lost during the cleaning process is related to sediment type, that is, grain size composition, as well as to the organic and/or carbonate content of the sediment. Organic-rich, fine-grained bay bottom sediments (i.e., silty clay and clayey silt) may lose up to 30% dry weight during cleaning (Table B-1). Sand, which is fairly clean, usually losses the least weight and often shows a negative weight loss, due to errors inherent in water content determinations. In this study, many of the core sediments lost over 50% dry weight during the cleaning process due to the very high amount of plant material (Table B-2).

Table B-1. Mean and range of water content and calculated weight loss after cleaning for each sediment type (Shepard's (1954) classification), based on sediments collected in Isle of Wight and Assawoman Bays (Wells and others, 1994). Means are rounded to the nearest whole percentage.

Sediment type	Water content (% wet weight)		Weight loss (% dry weight)	
	Mean	Range	Mean	Range
Sand	22	17 - 27	1	-4 - 6
Silty-Sand	39	31 - 47	7	2 - 12
Clayey-Sand	47	41 - 53	3	0 -6
Sandy-Silt	48	42 - 54	13	5 - 21
Clayey-Silt	60	53 - 67	20	13 - 27
Silty-Clay	70	67 - 73	28	23 - 33
Sand-Silt-Clay	56	49 - 63	13	2 - 24

Table B-2. Mean and range of water content and calculated weight loss after cleaning for each sediment type (Shepard's (1954) classification), based on sediments collected for this study. Means and ranges are rounded to the nearest whole percentage. Blank range values indicate that only a single sample represented the sediment class.

Sediment type	Water content (% wet weight)		Weight loss (% dry weight)	
	Mean	Range	Mean	Range
Sand	21	4 - 37	4	-3 - 10
Silty-Sand	42	38 - 51	17	6 - 27
Clayey-Sand	51		26	
Sandy-Silt	46		11	
Clayey-Silt	70	52 - 86	39	19 - 66
Silty-Clay	78	69 - 86	55	23 - 72
Sand-Silt-Clay	62	23 - 87	36	5 - 69

For this study, less than 5% of the sediment samples were flagged for repeated textural analyses. Table B-3 lists the results of the replicated analyses. Results of all duplicate analyses yielded sand, silt, and clay percentages that fell within 5% of their first analyses.

Table B-3. Comparison of results of replicate textural analyses of selected core samples									
Sample ID	**% Water**	**% Sand**	**% Silt**	**% Clay**	**Shepard's classification**	**Δ Sand**	**Δ Silt**	**Δ Clay**	**Comments**
13-20	53.14	19.64	51.05	29.31	Clayey-Silt	0.32	0.77	1.18	Change in classification as a result of slight change in % sand
13-2 R	53.14	20.06	51.82	28.13	Sand-Silt-Clay				
13-3	49.31	34.35	40.77	24.88	Sand-Silt-Clay	0.59	0.36	0.95	No change in classification
13-3 R	49.31	34.94	41.13	23.93	Sand-Silt-Clay				
13-4	62.45	17.21	45.13	37.67	Clayey-Silt	0.45	0.56	0.02	No change in classification
13-4 R	62.45	17.66	45.69	36.65	Clayey-Silt				

Nitrogen, Carbon and Sulfur Analyses

As part of MGS's QA/QC protocol, several standard reference materials (SRMs) are used as secondary standards and run every 6 to 7 samples (unknowns). Table B-4 compares MGS results with certified SRM values for total carbon, nitrogen, and sulfur. The detection limit for this method is 0.001% for all three elements. There is excellent agreement between SRM values and MGS's results.

In addition to SRMs, replicate analyses were done on every seventh sediment sample. The relative standard deviation for the replicate analyses may be used to determine analytical variability of the method with respect to concentration. The relative standard deviation plots for total nitrogen and carbon show that variability decreases with increasing concentrations (Figs. B-1 and B-2).

Table B-4. Results of nitrogen, carbon, and sulfur analyses of NIST SRM 1646 (Estuarine Sediment) and National Research Council of Canada SRM PACS-1 (Marine Sediment) compared to the certified or known values. MGS values were obtained by averaging the results of all SRM analyses run during this study. All samples were analyzed over a two-week period.

Component	**NIST SRM 1646 – Estuarine Mud**			**PACS-1 – Marine Sediment**		
	Certified values*	**MGS results**		**Certified values**	**MGS results**	
	Value ±Std Dev	**Mean value ±Std Dev**	**% Recovery**	**Value ±Std Dev**	**Mean value ±Std Dev**	**% Recovery**
Nitrogen	0.180	0.17± 0.00	96.96	0.260	0.276 ± 0.011	106.14
Carbon	1.720	1.64± 0.05	95.21	3.690	3.578 ± 0.097	96.96
Sulfur	0.960	1.02 ± 0.08	106.25	1.320	1.252 ± 0.046	94.85

* The value for carbon is certified by NIST. The sulfur value is the non-certified value reported by NIST. The NIST did not report nitrogen for the SRM. The value for nitrogen was obtained from repeated analyses in-house and by other laboratories (Haake Buchler Labs and the U.S. Dept. of Agriculture).

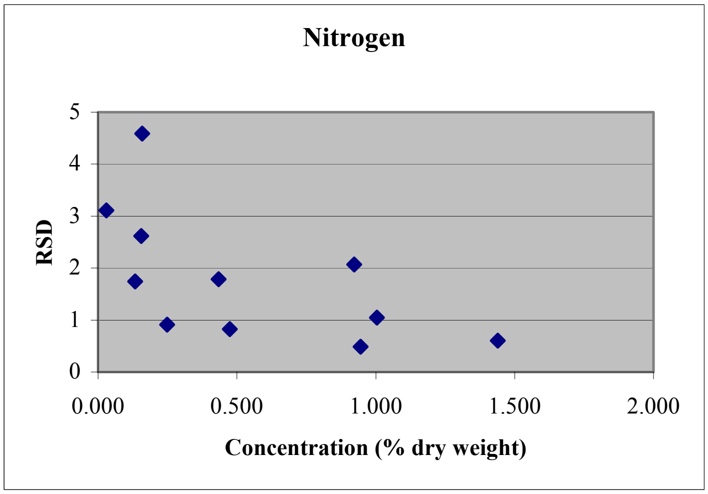
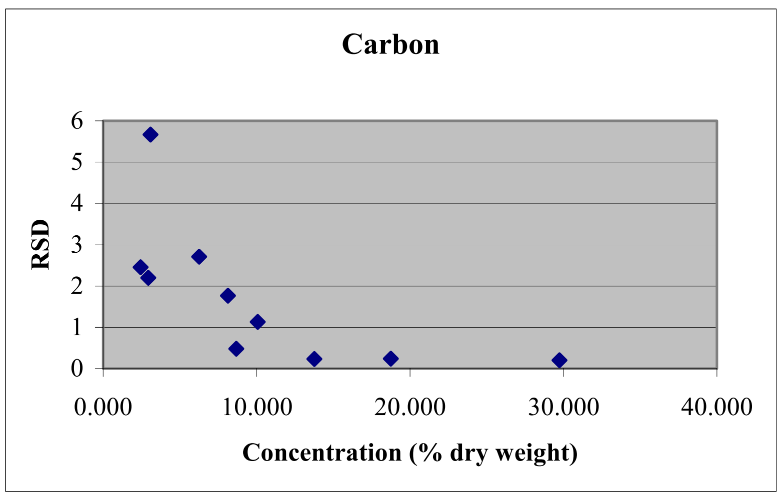


Figure B-1. Relative standard deviation (%) vs. concentration of total nitrogen for the suite of replicate and triplicate analyses.

Figure B-2. Relative standard deviation (%) vs. concentration of total carbon for the suite of replicate and triplicate analyses.



Metal Analyses

For elemental analyses completed by Activation Laboratories, Ltd. (Actlabs), quality assurance was confirmed in the following manner. The set of sediment samples sent to Actlabs contained a series of SRMs and replicate samples, the identities of which were not revealed to Actlabs. MGS also requested that Actlabs run a reagent blank every 20 samples. The three SRMs used were (1) NIST-SRM #1646a – Estuarine Sediment, (2) NIST-SRM #2704 – Buffalo River Sediment, and (3) National Research Council of Canada PACS-2 – Marine Sediment. These SRMs closely resembled the types of sediments being analyzed (i.e., fine-grained marine sediment). Results of the analyses of the three standard reference materials are compared to the certified values in Table B-5.

As part of their internal QA/QC protocol, Actlabs analyzed a suite of standards used by the U.S. Geological Survey. Those results are presented in Table B-6. Actlabs also ran a replicate of every tenth sample; independent of the blind replicates that MGS included. As a result, some samples were analyzed three times. The relative standard deviation for the replicate and triplicate analyses were calculated and used to determine analytical variability with respect to concentration. A plot of the relative standard deviation (RSD) vs. the concentration of total phosphorus shows that variability decreases with increasing concentration (Fig. B-3).

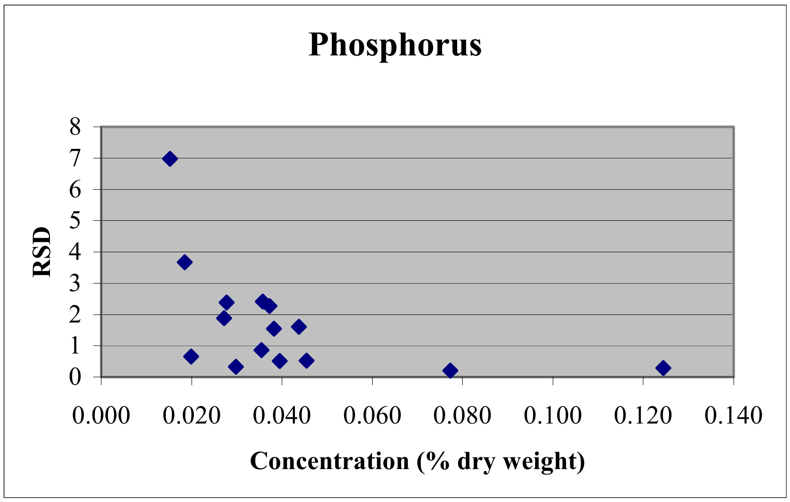


Figure B-3. Relative standard deviation (%) vs. concentration of total phosphorus for the suite of replicate and triplicate analyses.

Table B-5. Comparison of certified values to the analytical results from Actlabs for the SRMs. Values in parentheses are non-certified values. "NA" indicates that no value was reported for the element.

Element	NIST 1646a – Estuarine Mud			NIST 2704 – Buffalo River Mud			PACS-2 – Marine Mud		
	Certified values	Actlabs Results		Certified values	Actlabs Results		Certified values	Actlabs Results	
	Value ±Std dev	Value ±Std dev	*% Recovery*	Value ±Std dev	Value ±Std dev	*% Recovery*	Value ±Std dev		*% Recovery*
Ag (ppm)	**(<0.3)**	0.4 ± 0.1	*119.9*	**NA**	1.00 ± 0.08	---	**1.22 ± 0.14**	1.27 ± 0.11	*103.7*
Al (%)	**2.297 ± 0.018**	2.162 ± 0.063	*94.1*	**6.11 ± 0.16**	5.34 ± 0.29	*87.4*	**6.62 ± 0.32**	10.02 ± 1.72	*151.4*
Be (ppm)	**(<1)**	-1	---	**NA**	1.87 ± 0.06	---	**1 ± 0.2**	1.19 ± 0.03	*118.9*
Bi (ppm)	**NA**	-2	---	**NA**	-2.00	---	**NA**	-2 ± 0	---
Ca (%)	**0.519 ± 0.020**	0.541 ± 0.01	*104.2*	**2.6 ± 0.03**	2.72 ± 0.10	*104.6*	**1.965 ± 0.18**	2.15 ± 0.05	*109.3*
Cd (ppm)	**0.148 ± 0.007**	-0.30	---	**3.45 ± 0.22**	1.98 ± 0.75	*57.5*	**2.11 ± 0.15**	1.11 ± 0.16	*52.6*
Co (ppm)	**(5)**	4.67 ± 0.48	*93.4*	**14 ± 0.6**	13 ± 0.44	*93.6*	**11.5 ± 0.3**	10.96 ± 0.52	*95.3*
Cu (ppm)	**10.01 ± 0.34**	15.94 ± 6.66	*159.3*	**98.6 ± 5**	97.79 ± 5	*99.2*	**310 ± 12**	305 ± 12	*98.5*
Fe (%)	**2.008 ± 0.039**	1.955 ± 0.055	*97.4*	**4.11 ± 0.1**	4.09 ± 0.16	*99.5*	**4.09 ± 0.06**	4.14 ± 0.13	*101.2*
K (%)	**0.864 ± 0.016**	0.809 ± 0.022	*93.6*	**2 ± 0.04**	1.88 ± 0.09	*94.2*	**1.23 ± 0.05**	1.53 ± 0.14	*124.3*
Mg (%)	**0.388 ± 0.009**	0.441 ± 0.012	*113.7*	**1.2 ± 0.02**	1.30 ± 0.05	*108.3*	**1.472 ± 0.133**	1.98 ± 0.19	*134.6*
Mn (ppm)	**234 ± 2.8**	233 ± 3.49	*99.5*	**555 ± 19**	580 ± 25	*104.5*	**440 ± 19**	430 ± 15	*97.6*
Mo (ppm)	**(1.8)**	2.28 ± 0.53	*126.7*	**NA**	5.01 ± 1	---	**5.43 ± 0.28**	6.35 ± 0.92	*116.9*
Na (%)	**0.741 ± 0.017**	0.766 ± 0.027	*103.4*	**0.547 ± 0.014**	0.626 ± 0.039	*114.5*	**3.71 ± 0.185**	3.62 ± 0.19	*97.7*
Ni (ppm)	**(23)**	23 ± 1.06	*99.3*	**44.1 ± 3**	43.89 ± 2	*99.5*	**39.5 ± 2.3**	40.8 ± 1.5	*103.2*
P (ppm)	**270 ± 10**	250 ± 7.7	*92.5*	**998 ± 28**	884 ± 31	*88.5*	**960 ± 44**	945 ± 40	*98.5*
Pb (ppm)	**11.7 ± 1.2**	12.54 ± 1.04	*107.2*	**161 ± 17**	168.59 ± 7	*104.7*	**183 ± 8**	185 ± 5	*100.9*
S (%)	**(0.352)**	0.39 ± 0.01	*109.9*	**0.397 ± 0.004**	0.419 ± 0.018	*105.6*	**1.29 ± 0.13**	1.41 ± 0.03	*109.6*
Sr (ppm)	**(68)**	69 ± 1.78	*100.8*	**(130)**	133 ± 6	*102.4*	**276 ± 30**	289 ± 10	*104.6*
Ti (%)	**0.456 ± 0.021**	0.395 ± 0.015	*86.6*	**0.457 ± 0.018**	0.398 ± 0.028	*87.1*	**0.443 ± 0.032**	0.42 ± 0.01	*95.9*
V (ppm)	**44.84 ± 0.76**	40.40 ± 3.08	*90.1*	**95 ± 4**	99 ± 3	*104.7*	**133 ± 5**	139 ± 5	*104.3*
Y (ppm)	**NA**	9.91 ± 0.33	---	**(2.8)**	23.49 ± 1.18	*838.8*	**NA**	25.23 ± 4.52	---
Zn (ppm)	**48.9 ± 4.6**	59.61 ± 14.20	*121.9*	**438 ± 12**	405 ± 9	*92.4*	**364 ± 23**	349 ± 12	*95.9*

Table B-6. Comparison of certified values to Actlab's analytical results for U.S. Geological Survey standards. Certificate data underlined are recommended values; other values are proposed except those preceded by a "(", which are information values.

Element	G-2 (granite)		SDC-1 (mica schist)		DNC-1 (dolerite)		SCO-1 (cody shale)		GXR-6 (soil)		GXR-2 (soil)		GXR-1 (jasperoid)		GXR-4 (copper mill head)	
	Certified values	Actlab results	Certified value	Actlab results	Certified value	Actlab results	Certified value	Actlab results	Certified value	Actlab results	Certified value	Actlab results	Certified value	Actlab results	Certified value	Actlab results
Ag (ppm)	**0.04**	-0.3	**0.041**	-0.3	**(.027**	-0.3	**0.134**	0.5	**1.3**	0.7	**17**	16.3	**31**	30.6	**4**	3.6
Al (%)	**8.147**	5.82	**8.338**	6.02	**9.687**	9.72	**7.24**	5.69	**17.68**	9.03	**16.46**	6.90	**3.52**	1.80	**7.20**	6.09
Be (ppm)	**2.5**	2	**3.0**	3	**1**	-1	**1.84**	2	**1.4**	1	**1.7**	2	**1.22**	1	**1.9**	2
Bi (ppm)	**0.037**	-2	**0.26**	-2	**(.02**	-2	**0.37**	-2	**(.29**	-2	**(.69**	-2	**1380**	1518	**19**	35
Ca (%)	**1.401**	1.17	**1.001**	0.94	**8.055**	8.08	**1.87**	1.80	**0.179**	0.15	**0.929**	0.70	**0.958**	0.94	**1.01**	1.05
Cd (ppm)	**0.016**	-0.3	**(.08**	-0.3	**(.182**	-0.3	**0.14**	-0.3	**(1**	-0.3	**4.1**	2.0	**3.3**	1.8	**(.86**	-0.3
Co (ppm)	**4.6**	3	**17.9**	18	**54.7**	58	**10.5**	11	**13.8**	12	**8.6**	8	**8.2**	7	**14.6**	15
Cu (ppm)	**11**	11	**30**	29	**96**	124	**28.7**	39	**66**	66	**76**	76	**1110**	1210	**6520**	6464
Fe (%)	**1.86**	1.75	**4.825**	4.82	**6.94**	7.23	**3.59**	3.48	**5.58**	5.09	**1.86**	1.82	**23.64**	25.74	**3.09**	3.15
K (%)	**3.718**	3.45	**2.722**	2.53	**0.19**	0.25	**2.30**	2.11	**1.87**	1.43	**1.37**	1.13	**0.05**	0.05	**4.01**	3.97
Mg (%)	**0.452**	0.42	**1.019**	1.03	**6.06**	6.99	**1.64**	1.70	**0.61**	0.47	**0.85**	0.74	**0.22**	0.22	**1.66**	1.88
Mn (ppm)	**232**	246	**883**	866	**1154**	1122	**410**	385	**1008**	920	**1008**	791	**853**	979	**155**	147
Mo (ppm)	**(1.1**	1	**(.25**	3	**(.7**	1	**1.37**	1	**2.4**	3	**(2.1**	3	**18**	21	**310**	308
Ni (ppm)	**(5**	3	**38**	34	**247**	251	**27**	26	**27**	24	**21**	19	**41**	42	**42**	39
Na (%)	**3.027**	2.98	**1.521**	1.57	**1.39**	1.61	**0.67**	0.69	**0.1**	0.10	**0.56**	0.54	**0.05**	0.05	**0.56**	0.55
P (%)	**0.061**	0.050	**0.069**	0.056	**0.037**	0.025	**0.090**	0.077	**0.035**	0.057	**0.105**	0.057	**0.065**	0.060	**0.120**	0.124
Pb (ppm)	**30**	31	**25**	22	**6.3**	10	**31**	32	**101**	97	**690**	699	**730**	802	**52**	53
S (%)	**(0.01**	0.016	**0.065**	0.065	**(0.039**	0.067	**0.063**	0.067	**0.016**	0.011	**0.031**	0.027	**0.257**	0.281	**1.770**	1.995
Sr (ppm)	**478**	430	**183**	173	**145**	147	**174**	161	**35**	35	**160**	136	**275**	324	**221**	232
Ti (%)	**0.288**	0.29	**0.606**	0.58	**0.287**	0.29	**0.38**	0.34	**0.498**	0.48	**0.3**	0.29	**0.036**	0.02	**0.29**	0.26
V (ppm)	**36**	38	**102**	103	**148**	159	**131**	141	**186**	198	**52**	55	**80**	91	**87**	96
Y (ppm)	**11**	6	**40**	24	**18**	19	**26**	17	**14**	5	**17**	9	**32**	35	**14**	13
Zn (ppm)	**86**	86	**103**	103	**66**	66	**103**	99	**118**	125	**530**	509	**760**	739	**73**	79

APPENDIX C
Data Tables

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates was calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm) Bluff sample - height above shoreline (m)		Bulk density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval	Lower interval	Wet (g/cm^3)	Dry (g/cm^3)	Plant (% >14 mesh)	Clastic (%)	Reactive organics/ carbonates (%)	Total organics		
1-1	0.0	12.7	0.92	0.24	20.96	50.15	28.89	49.85	1	239.90
1-2	12.7	27.0	0.95	0.22	27.01	31.49	41.50	68.51	0.89	192.18
1-3	27.0	38.0	0.85	0.12	26.74	28.52	44.73	71.48	0.89	105.09
1-4	38.0	53.3	0.85	0.18	25.43	40.03	34.53	59.97	0.89	162.44
6-1	0.0	27.5	1.03	0.27	20.37	37.82	41.81	62.18	1	273.07
6-2	27.5	44.0	1.03	0.21	26.56	40.90	32.54	59.10	0.85	175.84
6-3	44.0	61.0	1.07	0.22	26.56	34.08	39.35	65.92	0.85	190.95
8-1	0.0	14.5	1.52	0.95	10.50	79.51	9.99	20.49	0.94	890.25
8-2	14.5	29.0	1.29	0.55	5.02	74.86	20.12	25.14	0.94	520.90
8-3	29.0	45.0	1.10	0.31	8.63	55.17	36.19	44.83	0.94	286.97
8-4	45.0	63.5	1.09	0.27	3.78	57.71	38.51	42.29	0.94	250.18
7-1	0.0	20.0	1.02	0.26	27.62	44.19	28.19	55.81	1	257.92
7-2	20.0	40.0	0.98	0.16	32.33	28.15	39.52	71.85	0.88	137.04
7-3	40.0	60.0	0.97	0.18	7.67	41.86	50.47	58.14	0.88	158.93
7-4	60.0	78.0	1.02	0.17	3.38	41.26	55.36	58.74	0.88	148.02
7-5	78.0	95.0	1.01	0.15	8.53	33.03	58.43	66.97	0.88	134.46
9-1 #1	0.0	19.0	1.49	0.88	3.26	93.88	2.86	6.12	1	878.89
9-2	19.0	39.0	1.22	0.48	9.81	70.87	19.33	29.13	0.94	452.03
9-3	39.0	59.0	1.02	0.23	20.25	38.91	40.84	61.09	0.94	217.02

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates was calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm) Bluff sample - height above shoreline (m)		Bulk density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval	Lower interval	Wet (g/cm^3)	Dry (g/cm^3)	Plant (% >14 mesh)	Clastic (%)	Reactive organics/ carbonates (%)	Total organics		
9-4	59.0	76.0	1.13	0.35	1.17	72.66	26.17	27.34	0.94	330.57
10-1	0.0	23.5	1.27	0.51	11.51	65.88	22.62	34.12	1	505.40
10-2	23.5	35.5	1.19	0.39	4.15	74.77	21.08	25.23	0.96	376.82
10-3	35.5	48.5	1.14	0.33	4.66	68.86	26.49	31.14	0.96	316.14
11-1	0.0	19.0	1.36	0.67	10.94	72.99	16.07	27.01	1	668.60
11-2	19.0	36.0	1.10	0.40	12.70	60.94	26.36	39.06	0.86	341.12
11-3	36.0	47.0	1.00	0.17	24.28	34.08	41.64	65.92	0.86	146.00
11-4	47.0	60.0	0.97	0.17	6.26	55.83	37.90	44.17	0.86	146.08
12-1 #1	0.0	21.0	1.18	0.46	9.94	67.95	22.12	32.05	1	464.93
12-2	21.0	38.0	1.05	0.22	24.77	38.22	37.02	61.78	1	221.98
12-3	38.0	52.0	0.93	0.13	13.88	36.30	49.82	63.70	1	131.68
12-4	52.0	67.5	1.02	0.21	6.14	62.96	30.90	37.04	1	210.75
13-1	0.0	21.0	1.29	0.92	2.84	89.94	7.22	10.06	1	920.29
13-2	21.0	35.5	1.34	0.63	12.11	59.63	28.27	40.37	0.87	544.64
13B-1	0.0	8.0	1.54	1.03	3.84	90.54	5.63	9.46	0.95	981.41
13B-2	8.0	20.0	1.48	0.95	2.88	91.54	5.58	8.46	0.95	899.48
13B-3	20.0	35.0	1.36	0.69	5.95	77.21	16.84	22.79	0.95	654.88
13B-4	35.0	46.5	1.20	0.45	10.26	78.77	10.97	21.23	0.95	429.13
13B-5	46.5	70.5	1.03	0.23	16.46	44.13	39.41	55.87	0.95	220.30
14-1	0.0	17.5	1.24	0.58	13.30	60.55	26.14	39.45	1	577.33
14-2	17.5	26.0	1.02	0.28	16.91	50.91	32.18	49.09	1	278.28

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates was calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm) Bluff sample - height above shoreline (m)		Bulk density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval	Lower interval	Wet (g/cm^3)	Dry (g/cm^3)	Plant (% >14 mesh)	Clastic (%)	Reactive organics/ carbonates (%)	Total organics		
14-3	26.0	45.5	1.19	0.43	14.20	56.43	29.37	43.57	1	430.21
14B-1	0.0	16.0	1.30	0.61	11.75	76.02	12.23	23.98	0.85	516.60
14B-2	16.0	28.5	1.31	0.58	4.76	80.26	14.99	19.74	0.85	491.31
14B-3	28.5	46.5	1.12	0.29	17.55	61.98	20.46	38.02	0.85	249.66
14B-4	46.5	64.5	1.20	0.37	5.57	77.04	17.39	22.96	0.85	314.85
14B-5	64.5	75.5	1.39	0.67	2.11	78.24	19.65	21.76	0.85	570.05
14B-6	75.5	86.5	1.19	0.42	4.19	80.88	14.93	19.12	0.85	354.33
18-0	0.0	24.5	1.00	0.43	11.34	68.07	20.59	31.93	1	434.80
18-1	24.5	37.0	0.70	0.17	13.88	57.92	28.19	42.08	0.97	163.79
18-2	37.0	62.0	0.99	0.31	4.98	67.39	27.62	32.61	0.97	299.15
18-3	62.0	87.0	1.14	0.41	2.09	79.93	17.98	20.07	0.97	395.29
18-4	87.0	112.0	1.05	0.26	2.68	48.18	49.14	51.82	0.97	247.93
18-5	112.0	143.0	1.24	0.51	1.65	73.90	24.45	26.10	0.97	494.57
19-1	0.0	17.0	1.58	1.01	2.73	89.91	7.37	10.09	1	1010.00
19-2	17.0	30.0	1.52	0.93	2.27	85.93	11.80	14.07	1	927.95
19-3	30.0	46.5	1.46	0.79	2.22	89.39	8.39	10.61	1	785.65
19-4	46.5	57.5	1.11	0.28	22.63	51.60	25.77	48.40	1	284.80
22-1	0.0	23.0	1.22	0.37	18.14	63.03	18.83	36.97	1	369.33
22-2	23.0	42.0	1.12	0.31	7.82	71.55	20.63	28.45	0.85	260.96
22-3	42.0	58.0	0.98	0.17	15.83	41.89	42.27	58.11	0.85	142.39
Site 3-T	2.8	0.4	1.29	1.24	0.00	97.34	2.66	2.66	1	1238.92

Table C-1. Sample data: physical properties. **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Core compaction factor used to correct bulk density for sediment compaction. Adjusted dry bulk density is assumed to represent total solids in the sediment. Percent reactive organics and carbonates was calculated from sample weight loss due to cleaning. $Kg/m^3 = g/cm^3 * 1000$.

Sample ID	Sediment interval: Core samples - depth below marsh surface (cm) Bluff sample - height above shoreline (m)		Bulk density (measured)		Bulk composition				Core compaction factor	Total solids (Kg/m^3)
	Upper interval	Lower interval	Wet (g/cm^3)	Dry (g/cm^3)	Plant (% >14 mesh)	Clastic (%)	Reactive organics/ carbonates (%)	Total organics		
Site 3-B	0.4	0.0	1.84	1.43	0.00	94.91	5.09	5.09	1	1434.43
Site 4-T	2.6	1.3	1.43	1.35	0.00	97.58	2.42	2.42	1	1346.65
Site 4-B	1.3	0.0	1.65	1.54	0.00	97.92	2.08	2.08	1	1538.04
Site 5	2.1	0.0	1.44	1.34	0.00	98.07	1.93	1.93	1	1336.30
1-Off					0.00	56.10	43.90	43.90		
3-Beach					0.00	98.99	1.01	1.01		
3-Off					0.00	96.03	3.97	3.97		
4-Beach					0.00	96.52	3.48	3.48		
5-Beach					0.00	97.04	2.96	2.96		
6-Off					0.00	39.98	60.02	60.02		
7-Off					0.00	32.60	67.40	67.40		
8-Off					0.00	73.60	26.40	26.40		
9-Off					0.00	61.83	38.17	38.17		
10-Off					0.00	51.98	48.02	48.02		
11-Off					0.00	64.86	35.14	35.14		
12-Off					0.00	30.99	69.01	69.01		
13-Off					0.00	100.00	0.00	0.00		
14A-Off					0.00	96.21	3.79	3.79		
22-Off					0.00	50.14	49.86	49.86		

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	Upper interval (cm)	Lower interval (cm)	H_20 (% wet weight)	Bulk density (Bennett & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
1-1	0.00	12.70	73.99	1.20	0.00	24.44	26.17	49.39	Sand-Silt-Clay
1-2	12.70	27.00	77.24	1.17	0.00	9.24	39.45	51.30	Silty-Clay
1-3	27.00	38.00	86.15	1.10	0.00	0.98	29.10	69.92	Silty-Clay
1-4	38.00	53.30	78.48	1.16	0.00	2.31	44.98	52.71	Silty-Clay
6-1	0.00	27.50	73.48	1.20	0.00	8.70	37.36	53.94	Silty-Clay
6-2	27.50	44.00	79.90	1.15	0.00	10.39	46.93	42.68	Clayey-Silt
6-3	44.00	61.00	78.93	1.15	0.00	2.27	49.16	48.57	Clayey-Silt
8-1	0.00	14.50	37.85	1.65	0.00	74.56	16.52	8.92	Silty-Sand
8-2	14.50	29.00	57.08	1.37	0.00	29.10	40.27	30.62	Sand-Silt-Clay
8-3	29.00	45.00	72.29	1.21	0.00	1.03	52.82	46.15	Clayey-Silt
8-4	45.00	63.50	75.60	1.18	0.00	8.12	40.95	50.93	Silty-Clay
7-1	0.00	20.00	74.70	1.19	0.00	7.24	42.95	49.81	Silty-Clay
7-2	20.00	40.00	84.07	1.11	0.00	1.97	44.90	53.13	Silty-Clay
7-3	40.00	60.00	81.36	1.13	0.00	4.02	50.21	45.77	Clayey-Silt
7-4	60.00	78.00	83.49	1.12	0.00	4.10	54.74	41.17	Clayey-Silt
7-5	78.00	95.00	84.93	1.11	0.00	0.15	44.01	55.84	Silty-Clay
9-1 #1	0.00	19.00	41.18	1.59	0.00	73.06	15.95	11.00	Silty-Sand
9-2	19.00	39.00	60.54	1.33	0.00	10.31	51.25	38.44	Clayey-Silt
9-3	39.00	59.00	77.38	1.17	0.00	5.55	48.53	45.92	Clayey-Silt
9-4	59.00	76.00	68.83	1.25	0.00	10.18	44.19	45.62	Silty-Clay
10-1	0.00	23.50	60.10	1.34	0.00	16.45	49.25	34.31	Clayey-Silt
10-2	23.50	35.50	67.02	1.26	0.00	0.78	54.02	45.20	Clayey-Silt
10-3	35.50	48.50	71.13	1.22	0.00	0.28	50.53	49.19	Clayey-Silt
11-1	0.00	19.00	50.88	1.45	0.00	61.93	22.02	16.06	Silty-Sand
11-2	19.00	36.00	63.87	1.30	0.00	3.91	54.69	41.40	Clayey-Silt

Sample ID	Upper interval (cm)	Lower interval (cm)	H_20 (% wet weight)	Bulk density (Bennett & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
11-3	36.00	47.00	83.00	1.12	0.00	0.58	45.53	53.89	Silty-Clay
11-4	47.00	60.00	82.53	1.12	0.00	4.23	47.14	48.63	Silty-Clay
12-1 #1	0.00	21.00	60.70	1.33	0.00	12.52	44.97	42.51	Clayey-Silt
12-2	21.00	38.00	78.95	1.15	0.00	0.82	42.93	56.25	Silty-Clay
12-3	38.00	52.00	85.79	1.10	0.00	4.37	50.91	44.73	Clayey-Silt
12-4	52.00	67.50	79.33	1.15	0.00	6.55	50.72	42.72	Clayey-Silt
13-1	0.00	21.00	28.85	1.82	0.00	75.06	17.24	7.71	Sand
13-2	21.00	35.50	53.14	1.42	0.00	19.64	51.05	29.31	Clayey-Silt
13B-1	0.00	8.00	33.13	1.73	0.00	80.39	13.54	6.07	Sand
13B-2	8.00	20.00	36.13	1.68	0.00	76.82	14.96	8.22	Sand
13B-3	20.00	35.00	49.31	1.47	0.00	34.35	40.77	24.88	Sand-Silt-Clay
13B-4	35.00	46.50	62.45	1.31	0.00	17.21	45.13	37.67	Clayey-Silt
13B-5	46.50	70.50	77.48	1.17	0.00	4.91	46.35	48.74	Silty-Clay
14-1	0.00	17.50	53.42	1.42	0.00	43.75	29.33	26.92	Sand-Silt-Clay
14-2	17.50	26.00	72.80	1.21	0.00	8.15	44.72	47.13	Silty-Clay
14-3	26.00	45.50	63.80	1.30	0.00	47.68	27.00	25.32	Sand-Silt-Clay
14B-1	0.00	16.00	53.23	1.42	0.00	48.69	28.14	23.17	Sand-Silt-Clay
14B-2	16.00	28.50	55.90	1.39	0.00	30.42	34.43	35.15	Sand-Silt-Clay
14B-3	28.50	46.50	73.75	1.20	0.00	8.39	40.64	50.97	Silty-Clay
14B-4	46.50	64.50	69.14	1.24	0.00	11.96	42.21	45.82	Silty-Clay
14B-5	64.50	75.50	51.81	1.44	0.00	2.01	55.67	42.32	Clayey-Silt
14B-6	75.50	86.50	64.88	1.29	0.00	2.97	61.72	35.31	Clayey-Silt
18-0	0.00	24.50	56.69	1.38	0.00	16.48	52.25	31.26	Clayey-Silt
18-1	24.50	37.00	75.79	1.18	0.00	15.63	50.44	33.93	Clayey-Silt
18-2	37.00	62.00	68.98	1.24	0.00	13.08	50.75	36.17	Clayey-Silt
18-3	62.00	87.00	64.36	1.29	0.00	1.25	61.39	37.35	Clayey-Silt

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	Upper interval (cm)	Lower interval (cm)	H_20 (% wet weight)	Bulk density (Bennett & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
18-4	87.00	112.00	75.55	1.18	0.00	1.07	50.62	48.31	Clayey-Silt
18-5	112.00	143.00	58.75	1.35	0.00	44.90	25.65	29.45	Sand-Silt-Clay
19-1	0.00	17.00	35.91	1.68	0.00	75.25	17.40	7.35	Sand
19-2	17.00	30.00	38.89	1.63	0.00	60.43	27.19	12.38	Silty-Sand
19-3	30.00	46.50	46.25	1.51	0.00	39.61	45.37	15.03	Sandy-Silt
19-4	46.50	57.50	74.36	1.19	0.00	24.59	55.02	20.40	Sand-Silt-Clay
22-1	0.00	23.00	69.74	1.24	0.00	0.99	54.90	44.11	Clayey-Silt
22-2	23.00	42.00	72.50	1.21	0.00	0.61	51.26	48.13	Clayey-Silt
22-3	42.00	58.00	82.84	1.12	0.00	2.33	46.56	51.12	Silty-Clay
Site 3-T	2.79	0.42	4.06	2.54	0.00	90.60	7.22	2.18	Sand
Site 3-B	0.42	0.00	22.71	1.96	0.00	47.46	22.53	30.02	Sand-Silt-Clay
Site 4-T	2.60	1.30	5.03	2.50	3.62	77.78	11.31	7.29	Sand
Site 4-B	1.30	0.00	6.44	2.45	4.98	86.35	2.54	6.13	Sand
Site 5	2.12	0.00	6.75	2.44	1.45	83.39	5.99	9.18	Sand
1-Off			77.87	1.16	0.00	41.83	35.92	22.25	Sand-Silt-Clay
3-Beach			17.24	2.10	0.00	98.82	1.18	0.00	Sand
3-Off			21.48	1.99	0.00	96.45	2.15	1.40	Sand
4-Beach			20.88	2.00	0.71	95.69	2.77	0.84	Sand
5-Beach			15.33	2.15	0.90	98.30	0.80	0.00	Sand
6-Off			81.55	1.13	0.00	10.53	40.21	49.26	Silty-Clay
7-Off			81.07	1.14	0.00	13.20	39.33	47.47	Silty-Clay
8-Off			51.42	1.44	0.13	64.89	14.62	20.36	Clayey-Sand
9-Off			71.21	1.22	0.00	15.84	48.36	35.81	Clayey-Silt
10-Off			80.77	1.14	0.00	31.46	41.04	27.50	Sand-Silt-Clay
11-Off			62.18	1.31	0.00	30.95	42.89	26.16	Sand-Silt-Clay
12-Off			87.35	1.09	0.00	21.00	37.53	41.48	Sand-Silt-Clay

Table C-1. Sample data: physical properties (cont.). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). Bulk density calculated using Bennett and Lambert (1971) method.

Sample ID	Upper interval (cm)	Lower interval (cm)	H_2O (% wet weight)	Bulk density (Bennett & Lambert) (g/cm^3)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Shepard's (1954) classification
13-Off			37.38	1.66	0.00	93.60	3.51	2.89	Sand
14A-Off			23.02	1.95	0.04	95.04	3.32	1.60	Sand
22-Off			83.26	1.12	0.00	4.14	46.56	49.29	Silty-Clay

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."											
Sample ID	**Upper interval (cm)**	**Lower interval (cm)**	**Nutrients**			**Elements**					
			N (%)	**C (%)**	**P (%)**	**S (%)**	**Ag (ppm)**	**Al (%)**	**Be (ppm)**	**Bi (ppm)**	
1-1	0.00	12.70	0.935	13.750	0.125	0.829	0.4	3.70	1.560	BDL	
1-1 R	0.00	12.70	0.908	13.795	0.124	0.783	BDL	3.17	1.528	BDL	
1-2	12.70	27.00	0.955	16.775	0.069	1.334	BDL	3.12	1.341	BDL	
1-3	27.00	38.00	1.255	23.083	0.066	1.673	BDL	2.35	1.072	2.388	
1-4	38.00	53.30	1.122	21.737	0.048	2.444	BDL	2.45	BDL	3.264	
1-1 P	0.00	12.70	1.433	27.842	0.102	0.725	BDL	2.11	BDL	BDL	
1-1 P R			1.445	29.943		1.110					
1-2 P	12.70	27.00	1.159	31.493	0.064	1.081	BDL	2.04	BDL	BDL	
1-3 P	27.00	38.00	1.222	38.817	0.048	1.145	BDL	1.50	BDL	BDL	
1-4 P	38.00	53.30	0.927	34.554	0.039	1.375	BDL	1.73	BDL	BDL	
6-1	0.00	27.50	0.786	13.007	0.077	1.121	0.4	4.03	1.330	BDL	
6-1 R	0.00	27.50			0.077		0.3	4.49	1.309	BDL	
6-2	27.50	44.00	0.882	20.012	0.062	2.603	0.4	3.42	1.187	BDL	
6-3	44.00	61.00	0.975	21.003	0.045	2.669	0.3	3.11	1.153	BDL	
7-1	0.00	20.00	0.880	15.176	0.066	1.224	0.5	3.91	1.257	2.006	
7-2	20.00	40.00	1.044	22.280	0.055	2.858	BDL	2.58	BDL	2.036	
7-3	40.00	60.00	0.981	18.500	0.044	2.193	0.3	2.98	1.128	BDL	
7-4	60.00	78.00	1.011	18.780	0.043	2.281	BDL	3.16	1.128	BDL	
7-4 R	60.00	78.00	0.996	18.715	0.044	2.314	BDL	3.48	1.146	BDL	
7-5	78.00	95.00	1.281	23.432	0.065	2.923	0.5	8.34	2.437	2.324	
8-1	0.00	14.50	0.158	2.895	0.019	0.438	0.4	3.07	BDL	BDL	
8-1 R	0.00	14.50	0.153	2.986	0.019	0.445	0.5	3.00	BDL	BDL	
8-1 T	0.00	14.50			0.018		0.5	2.83	BDL	BDL	
8-2	14.50	29.00	0.380	7.293	0.036	1.131	0.5	2.80	1.230	BDL	
8-3	29.00	45.00	0.606	10.715	0.043	1.671	0.5	3.63	1.377	BDL	

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
8-4	45.00	63.50	0.713	13.958	0.051	1.554	0.3	3.78	1.455	BDL
9-1 #1	0.00	19.00	0.250	4.506	0.039	0.592	0.5	3.29	BDL	BDL
9-1 #1 R	0.00	19.00			0.038		0.4	2.96	BDL	BDL
9-1 #2	0.00	19.00	0.247	3.745	0.038	0.504	0.5	2.90	BDL	BDL
9-2	19.00	39.00	0.456	8.331	0.038	0.973	0.6	3.98	1.333	BDL
9-3	39.00	59.00	0.808	15.651	0.047	2.974	0.4	3.46	1.187	BDL
9-4	59.00	76.00	0.489	8.635	0.026	2.129	0.5	3.99	1.350	BDL
10-1	0.00	23.50	0.439	8.239	0.046	1.243	0.6	4.50	1.448	BDL
10-1 R	0.00	23.50	0.428	8.036	0.045	1.242	0.6	4.35	1.459	BDL
10-2	23.50	35.50	0.478	8.596	0.039	2.187	0.7	4.19	1.613	BDL
10-3	35.50	48.50	0.535	11.444	0.038	3.095	0.5	3.93	1.487	BDL
10-3 R	35.50	48.50			0.037		0.5	3.66	1.441	BDL
11-1	0.00	19.00	0.267	4.547	0.030	0.605	0.6	3.83	1.025	BDL
11-1 R	0.00	19.00			0.030		0.5	3.54	1.033	BDL
11-2	19.00	36.00	0.394	7.093	0.040	1.453	0.6	4.49	1.620	BDL
11-3	36.00	47.00	0.944	18.397	0.053	2.889	BDL	3.48	1.073	BDL
11-4	47.00	60.00	0.770	16.660	0.047	2.263	0.4	3.24	BDL	BDL
12-1 #1	0.00	21.00	0.472	8.620	0.040	1.294	0.4	4.31	1.497	BDL
12-1 #1 R	0.00	21.00	0.479	8.687		1.277				
12-1 #2	0.00	21.00	0.472	8.695	0.039	1.292	0.4	4.22	1.477	BDL
12-2	21.00	38.00	0.885	16.746	0.042	2.951	0.3	3.34	1.286	BDL
12-3	38.00	52.00	0.928	20.151	0.037	2.396	0.3	2.86	BDL	2.258
12-4	52.00	67.50	0.632	12.405	0.040	1.454	BDL	3.70	1.222	BDL
13-1	0.00	21.00	0.149	2.294	0.026	0.200	0.3	3.00	BDL	BDL
13-2	21.00	35.50	0.396	6.898	0.043	1.242	0.6	4.02	1.322	BDL
13B-1	0.00	8.00	0.157	3.051	0.022	0.273	0.5	2.74	BDL	BDL

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
13B-2	8.00	20.00	0.154	2.957	0.020	0.275	0.5	2.60	BDL	BDL
13B-2 R	8.00	20.00	0.165	3.204	0.020	0.476	0.4	2.44	BDL	BDL
13B-3	20.00	35.00	0.279	4.543	0.036	0.997	BDL	3.94	1.139	BDL
13B-4	35.00	46.50	0.400	6.592	0.040	1.536	0.4	3.84	1.426	BDL
13B-5	46.50	70.50	0.792	15.252	0.044	2.548	0.3	3.38	1.092	BDL
14-1	0.00	17.50	0.493	8.204	0.042	0.772	0.4	3.06	BDL	BDL
14-2	17.50	26.00	0.493	9.572	0.038	1.151	0.5	3.92	1.203	BDL
14-3	26.00	45.50	0.554	9.993	0.037	1.232	BDL	2.83	BDL	BDL
14-3 R	26.00	45.50	0.555	10.154		1.263				
14B-1	0.00	16.00	0.299	6.017	0.030	0.863	0.4	3.25	BDL	BDL
14B-2	16.00	28.50	0.351	6.224	0.035	1.446	0.6	4.11	1.346	BDL
14B-2 R	16.00	28.50			0.036		0.5	4.44	1.393	BDL
14B-3	28.50	46.50	0.801	13.833	0.051	2.397	0.5	3.55	1.272	BDL
14B-4	46.50	64.50	0.564	9.876	0.041	1.429	0.5	4.04	1.367	BDL
14B-5	64.50	75.50	0.244	4.208	0.033	1.859	0.6	5.01	1.660	BDL
14B-6	75.50	86.50	0.403	8.606	0.028	1.881	0.5	4.23	1.383	BDL
14B-6 R	75.50	86.50			0.027		0.6	4.03	1.348	BDL
14B-1 P	0.00	16.00	0.898	25.112	0.036	1.909	0.8	1.86	BDL	BDL
14B-2 P	16.00	28.50	1.081	31.556	0.044	5.005	0.4	1.94	1.005	BDL
14B-3 P	28.50	46.50	1.044	29.903	0.049	2.911	BDL	2.41	BDL	BDL
14B-4 P	46.50	64.50	0.989	32.706	0.044	2.411	BDL	2.47	1.006	BDL
14B-5 P	64.50	75.50	0.790	30.799	0.029	7.875	BDL	2.19	BDL	BDL
14B-6 P	75.50	86.50	0.970	37.499	0.032	5.004	BDL	1.67	BDL	BDL
18-0	0.00	24.50	0.302	6.138	0.038	1.110	0.7	4.06	1.429	BDL
18-0 R			0.304	6.378		1.113				
18-1	24.50	37.00	0.717	14.877	0.038	1.898	0.5	3.56	1.027	BDL

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
18-2	37.00	62.00	0.500	9.107	0.037	1.466	0.5	3.83	1.351	BDL
18-3	62.00	87.00	0.348	5.927	0.034	1.007	0.6	3.84	1.474	BDL
18-4	87.00	112.00	0.571	11.574	0.028	2.705	0.5	4.21	1.390	BDL
18-5	112.00	143.00	0.327	6.430	0.027	1.400	0.5	3.71	1.109	3.706
18-5 R	112.00	143.00			0.027		0.3	3.44	1.196	BDL
18-5 R	112.00	143.00			0.027		0.3	3.20	1.143	BDL
18-5 T	112.00	143.00			0.028		BDL	3.83	1.146	BDL
19-1	0.00	17.00	0.167	3.858	0.035	1.066	0.3	3.78	1.014	BDL
19-1 R	0.00	17.00			0.036		0.4	3.67	1.024	BDL
19-1 T	0.00	17.00			0.036		0.3	3.56	1.002	BDL
19-2	17.00	30.00	0.132	2.392	0.023	0.572	0.5	4.01	1.048	BDL
19-2 R	17.00	30.00	0.136	2.477		0.527				
19-3	30.00	46.50	0.159	2.745	0.031	0.809	0.8	4.17	1.302	BDL
19-4	46.50	57.50	0.673	16.597	0.041	2.173	0.3	2.85	BDL	BDL
19-1 P	0.00	17.00	0.748	25.756	0.081	0.756	0.7	2.16	BDL	BDL
19-2 P	17.00	30.00	0.949	29.787	0.057	1.285	0.8	2.01	BDL	2.202
19-2 P R	17.00	30.00	0.942	29.702		1.200				
19-3 P	30.00	46.50	0.910	32.688	0.048	1.856	0.5	1.99	BDL	BDL
19-4 P	46.50	57.50	0.977	40.018	0.049	2.522	BDL	1.25	BDL	BDL
22-1	0.00	23.00	0.466	9.895	0.041	1.154	0.6	3.62	1.360	BDL
22-2	23.00	42.00	0.476	9.268	0.036	1.368	0.4	3.67	1.477	BDL
22-3	42.00	58.00	0.966	16.478	0.040	2.129	0.4	3.45	1.121	BDL
Site 3-T	Bluff	top	0.019	0.405	0.006	BDL	BDL	1.56	BDL	BDL
Site 3-B	Bluff	bottom	0.031	0.537	0.014	0.044	0.6	4.73	1.280	BDL
Site 3-B R	Bluff	bottom	0.030	0.534	0.016	0.023	0.6	4.52	1.229	BDL
Site 4-T	Bluff	top	0.013	0.259	0.005	BDL	BDL	2.08	BDL	BDL

Table C-2. Sample data: chemical analyses. Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: T and B denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Nutrients			Elements				
			N (%)	C (%)	P (%)	S (%)	Ag (ppm)	Al (%)	Be (ppm)	Bi (ppm)
Site 4-B	Bluff	bottom	0.010	0.167	0.004	BDL	BDL	1.80	BDL	BDL
Site 5	Bluff		0.004	0.041	0.006	0.007	BDL	3.60	BDL	BDL
1-Off			0.801	16.977		1.649				
3-Beach										
3-Off			0.032	0.273		0.053				
4-Beach										
5-Beach										
6-Off			0.932	18.151		2.216				
7-Off			0.823	14.673		1.928				
8-Off			0.181	3.468		0.369				
9-Off			0.533	10.245		1.185				
10-Off			0.594	14.041		1.713				
11-Off			0.317	5.753		0.785				
12-Off			0.833	19.449		2.781				
13-Off			0.127	2.468		0.443				
14A-Off			0.029	0.446		0.058				
14B-Off			0.026	0.377		0.045				
22-Off			0.781	16.023		2.603				

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: **T** and **B** denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
1-1	0.00	12.70	1.74	BDL	10	49	1.83	1.25	0.94	176
1-1 R	0.00	12.70	1.72	BDL	10	38	1.69	1.17	0.89	170
1-2	12.70	27.00	0.49	BDL	9	32	1.29	0.93	0.71	161
1-3	27.00	38.00	0.52	BDL	12	39	0.88	0.71	0.93	54
1-4	38.00	53.30	0.48	BDL	10	20	1.66	0.74	0.70	67
1-1 P	0.00	12.70	1.18	BDL	14	32	0.86	0.63	0.56	95
1-1 P R	0.00	12.70								
1-2 P	12.70	27.00	0.30	BDL	10	23	0.93	0.51	0.47	46
1-3 P	27.00	38.00	0.32	BDL	8	26	0.42	0.20	0.42	65
1-4 P	38.00	53.30	0.26	BDL	10	13	1.44	0.41	0.33	40
6-1	0.00	27.50	4.54	BDL	8	30	1.98	1.36	0.93	170
6-1 R	0.00	27.50	4.54	BDL	8	30	1.94	1.34	0.93	168
6-2	27.50	44.00	0.62	BDL	11	25	2.00	1.02	0.79	103
6-3	44.00	61.00	0.63	BDL	8	21	2.00	0.94	0.88	105
7-1	0.00	20.00	0.60	BDL	7	32	1.43	1.28	0.96	158
7-2	20.00	40.00	0.51	BDL	9	27	1.48	0.78	0.90	76
7-3	40.00	60.00	0.62	BDL	6	19	1.26	1.05	0.94	90
7-4	60.00	78.00	0.73	BDL	7	15	1.04	1.13	1.07	88
7-4 R	60.00	78.00	0.74	BDL	7	12	1.05	1.16	1.09	78
7-5	78.00	95.00	1.30	BDL	5	21	1.78	4.26	1.32	540
8-1	0.00	14.50	0.39	BDL	13	15	0.91	1.36	0.34	113
8-1 R	0.00	14.50	0.39	BDL	13	17	0.86	1.31	0.33	105
8-1 T	0.00	14.50	0.38	BDL	12	13	0.86	1.29	0.34	110
8-2	14.50	29.00	0.49	BDL	6	17	1.68	1.38	0.70	145

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: **T** and **B** denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
8-3	29.00	45.00	0.56	BDL	7	17	1.99	1.33	0.95	148
8-4	45.00	63.50	0.65	BDL	7	15	1.60	1.32	1.14	127
9-1 #1	0.00	19.00	0.48	BDL	6	12	1.46	1.37	0.51	164
9-1 #1 R	0.00	19.00	0.46	BDL	7	12	1.40	1.33	0.48	158
9-1 #2	0.00	19.00	0.45	BDL	6	12	1.41	1.28	0.48	157
9-2	19.00	39.00	0.67	BDL	8	15	1.83	1.64	0.84	194
9-3	39.00	59.00	0.60	BDL	11	9	2.53	1.20	0.99	114
9-4	59.00	76.00	0.69	BDL	8	10	2.51	1.60	0.96	166
10-1	0.00	23.50	0.68	BDL	8	16	2.21	1.63	0.86	215
10-1 R	0.00	23.50	0.68	BDL	9	20	2.24	1.62	0.85	218
10-2	23.50	35.50	0.69	BDL	12	21	3.04	1.58	0.99	215
10-3	35.50	48.50	0.61	BDL	12	16	3.37	1.38	1.07	198
10-3 R	35.50	48.50	0.59	BDL	11	16	3.23	1.28	0.99	191
11-1	0.00	19.00	0.84	BDL	6	12	1.33	1.46	0.59	170
11-1 R	0.00	19.00	0.83	BDL	6	12	1.37	1.43	0.59	173
11-2	19.00	36.00	0.67	BDL	10	15	2.53	1.65	0.90	215
11-3	36.00	47.00	0.60	BDL	9	9	2.27	1.10	1.02	90
11-4	47.00	60.00	0.71	BDL	9	9	1.40	1.15	1.07	99
12-1 #1	0.00	21.00	0.63	BDL	9	15	2.31	1.60	0.91	206
12-1 #1 R	0.00	21.00								
12-1 #2	0.00	21.00	0.61	BDL	8	15	2.22	1.58	0.89	201
12-2	21.00	38.00	0.54	BDL	9	15	2.50	1.13	1.02	127
12-3	38.00	52.00	0.68	BDL	5	8	1.09	1.02	0.98	75
12-4	52.00	67.50	0.74	BDL	8	7	1.48	1.44	0.98	150
13-1	0.00	21.00	0.44	BDL	5	7	1.20	1.39	0.43	173

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: **T** and **B** denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
13-2	21.00	35.50	0.65	BDL	9	16	2.32	1.52	0.94	212
13B-1	0.00	8.00	0.48	BDL	15	11	0.81	1.30	0.31	135
13B-2	8.00	20.00	0.41	BDL	7	8	1.07	1.31	0.35	157
13B-2 R	8.00	20.00	0.40	BDL	7	11	1.06	1.30	0.34	154
13B-3	20.00	35.00	0.62	BDL	7	12	2.06	1.52	0.68	243
13B-4	35.00	46.50	0.63	BDL	9	15	2.55	1.54	0.87	265
13B-5	46.50	70.50	0.59	BDL	8	10	2.38	1.17	1.11	181
14-1	0.00	17.50	0.47	BDL	6	13	1.71	1.16	0.74	165
14-2	17.50	26.00	0.53	BDL	9	29	2.07	1.42	0.81	178
14-3	26.00	45.50	0.50	BDL	7	12	1.45	1.07	0.69	129
14-3 R	26.00	45.50								
14B-1	0.00	16.00	0.45	BDL	10	14	1.35	1.19	0.53	149
14B-2	16.00	28.50	0.60	BDL	10	22	2.23	1.50	0.78	204
14B-2 R	16.00	28.50	0.63	BDL	10	14	2.31	1.56	0.83	209
14B-3	28.50	46.50	0.65	BDL	9	15	2.12	1.20	0.93	135
14B-4	46.50	64.50	0.75	BDL	8	10	1.88	1.54	0.94	188
14B-5	64.50	75.50	0.78	BDL	10	12	3.33	1.86	0.94	242
14B-6	75.50	86.50	0.80	BDL	7	11	2.20	1.58	0.87	176
14B-6 R	75.50	86.50	0.77	BDL	7	11	2.12	1.53	0.85	167
14B-1 P	0.00	16.00	0.56	BDL	11	52	1.14	0.65	0.45	95
14B-2 P	16.00	28.50	0.43	0.4	15	33	5.01	0.52	0.57	164
14B-3 P	28.50	46.50	0.52	BDL	10	9	1.67	0.66	0.72	89
14B-4 P	46.50	64.50	0.60	BDL	8	13	1.58	0.67	0.81	98
14B-5 P	64.50	75.50	0.44	BDL	36	31	8.60	0.50	0.60	153
14B-6 P	75.50	86.50	0.58	BDL	16	21	2.72	0.43	0.76	73

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: **T** and **B** denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
18-0	0.00	24.50	0.79	BDL	9	15	2.31	1.60	0.81	231
18-0 R	0.00	24.50								
18-1	24.50	37.00	0.63	BDL	7	17	1.62	1.20	0.90	134
18-2	37.00	62.00	0.73	BDL	9	8	1.89	1.46	0.82	164
18-3	62.00	87.00	0.75	BDL	8	8	2.10	1.65	0.83	209
18-4	87.00	112.00	0.65	BDL	12	7	2.67	1.47	0.94	116
18-5	112.00	143.00	0.65	BDL	7	32	1.58	1.37	0.63	137
18-5 R	112.00	143.00	0.64	BDL	8	5	1.60	1.37	0.65	144
18-5 R	112.00	143.00	0.61	BDL	7	4	1.55	1.34	0.62	137
18-5 T	112.00	143.00	0.67	BDL	8	4	1.63	1.40	0.66	147
19-1	0.00	17.00	0.77	BDL	6	7	1.34	1.42	0.51	163
19-1 R	0.00	17.00	0.76	BDL	6	8	1.36	1.48	0.52	162
19-1 T	0.00	17.00	0.75	BDL	6	6	1.34	1.46	0.50	161
19-2	17.00	30.00	0.84	BDL	8	8	1.20	1.50	0.52	167
19-2 R	17.00	30.00								
19-3	30.00	46.50	0.86	BDL	9	9	1.75	1.63	0.65	215
19-4	46.50	57.50	0.66	BDL	8	8	1.44	1.03	0.87	119
19-1 P	0.00	17.00	0.46	0.3	24	19	1.59	0.71	0.47	113
19-2 P	17.00	30.00	0.28	BDL	19	28	1.56	0.59	0.37	79
19-2 P R	17.00	30.00								
19-3 P	30.00	46.50	0.30	0.4	18	23	2.28	0.58	0.38	73
19-4 P	46.50	57.50	0.25	BDL	7	5	1.15	0.32	0.35	44
22-1	0.00	23.00	0.54	BDL	9	37	1.97	1.47	0.97	183
22-2	23.00	42.00	0.56	BDL	10	13	2.03	1.41	0.95	174
22-3	42.00	58.00	0.49	BDL	6	9	1.73	1.22	0.91	89

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites: **T** and **B** denoting top and bottom of bluff. All other sites are coring sites (marsh). BDL denotes "below detection limit."

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)							
			Ca (%)	Cd (ppm)	Co (ppm)	Cu (ppm)	Fe (%)	K (%)	Mg (%)	Mn (ppm)
Site 3-T	Bluff	top	0.11	BDL	14	12	0.56	0.79	0.05	91
Site 3-B	Bluff	bottom	0.30	BDL	5	22	2.38	1.67	0.34	133
Site 3-B R	Bluff	bottom	0.29	BDL	5	21	2.34	1.64	0.33	129
Site 4-T	Bluff	top	0.03	BDL	8	16	0.74	0.92	0.08	67
Site 4-B	Bluff	bottom	0.02	BDL	8	18	0.99	0.80	0.06	64
Site 5	Bluff		0.10	BDL	7	20	0.64	1.71	0.04	121
1-Off										
3-Beach										
3-Off										
4-Beach										
5-Beach										
6-Off										
7-Off										
8-Off										
9-Off										
10-Off										
11-Off										
12-Off										
13-Off										
14A-Off										
14B-Off										
22-Off										

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites. All other sites are coring sites (marsh). BDL denotes "below detection limit".

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
1-1	0.00	12.70	4	3.37	24	45	159	0.26	78	21	110
1-1 R	0.00	12.70	3	3.33	23	41	141	0.25	75	18	103
1-2	12.70	27.00	7	3.35	20	39	97	0.25	66	14	82
1-3	27.00	38.00	5	4.57	13	39	98	0.16	52	13	61
1-4	38.00	53.30	12	3.02	15	21	91	0.18	52	11	71
1-1 P	0.00	12.70	5	1.18	13	29	116	0.15	48	15	100
1-1 P R											
1-2 P	12.70	27.00	9	1.13	12	44	67	0.13	50	13	62
1-3 P	27.00	38.00	8	1.02	7	35	57	0.06	40	10	45
1-4 P	38.00	53.30	14	0.80	10	14	55	0.10	44	10	55
6-1	0.00	27.50	4	3.28	23	38	324	0.27	79	19	97
6-1 R	0.00	27.50	5	3.27	24	34	323	0.27	76	19	96
6-2	27.50	44.00	12	3.57	23	43	119	0.22	61	16	112
6-3	44.00	61.00	8	3.52	19	20	114	0.21	55	14	61
7-1	0.00	20.00	6	4.03	22	31	126	0.28	82	16	81
7-2	20.00	40.00	12	5.24	19	41	103	0.16	67	12	92
7-3	40.00	60.00	6	4.73	17	14	122	0.23	55	11	49
7-4	60.00	78.00	6	5.28	18	10	140	0.21	54	14	43
7-4 R	60.00	78.00	5	5.28	18	7	148	0.22	57	16	42
7-5	78.00	95.00	11	9.05	18	21	214	0.19	55	24	61
8-1	0.00	14.50	3	1.68	19	16	137	0.25	30	8	41
8-1 R	0.00	14.50	3	1.62	18	19	133	0.25	30	8	41
8-1 T	0.00	14.50	2	1.67	17	15	129	0.25	29	7	42
8-2	14.50	29.00	5	2.65	23	30	110	0.35	66	10	77

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites. All other sites are coring sites (marsh). BDL denotes "below detection limit".

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
8-3	29.00	45.00	5	3.71	20	25	116	0.32	74	11	65
8-4	45.00	63.50	6	4.59	20	14	135	0.28	75	14	46
9-1 #1	0.00	19.00	3	1.90	40	24	135	0.27	46	10	52
9-1 #1 R	0.00	19.00	4	1.84	39	21	131	0.27	45	9	48
9-1 #2	0.00	19.00	3	1.82	39	25	127	0.25	44	9	48
9-2	19.00	39.00	5	3.12	25	28	156	0.35	78	12	60
9-3	39.00	59.00	7	4.78	24	20	126	0.26	66	14	79
9-4	59.00	76.00	6	3.92	25	13	157	0.33	80	11	53
10-1	0.00	23.50	3	2.82	26	32	159	0.35	77	15	69
10-1 R	0.00	23.50	5	2.84	26	32	160	0.35	78	15	72
10-2	23.50	35.50	5	3.10	27	38	146	0.37	94	14	93
10-3	35.50	48.50	5	3.67	27	33	119	0.30	79	12	110
10-3 R	35.50	48.50	5	3.49	25	33	114	0.29	77	13	109
11-1	0.00	19.00	4	1.82	33	25	148	0.30	59	11	50
11-1 R	0.00	19.00	5	1.81	35	21	146	0.30	60	10	48
11-2	19.00	36.00	6	2.67	27	39	150	0.38	92	14	88
11-3	36.00	47.00	7	4.82	17	19	126	0.23	57	14	50
11-4	47.00	60.00	6	5.45	16	14	139	0.25	58	11	34
12-1 #1	0.00	21.00	5	2.74	26	35	145	0.35	91	14	68
12-1 #1 R	0.00	21.00									
12-1 #2	0.00	21.00	6	2.64	25	36	144	0.29	87	13	69
12-2	21.00	38.00	9	3.98	23	32	115	0.23	69	12	77
12-3	38.00	52.00	8	5.38	15	11	134	0.21	46	8	28
12-4	52.00	67.50	5	4.03	21	11	162	0.25	68	10	41
13-1	0.00	21.00	2	1.99	25	16	143	0.25	29	7	33

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites. All other sites are coring sites (marsh). BDL denotes "below detection limit".

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
13-2	21.00	35.50	4	3.42	44	33	152	0.32	73	12	79
13B-1	0.00	8.00	3	1.35	33	15	134	0.25	27	6	31
13B-2	8.00	20.00	2	1.46	22	16	131	0.29	30	7	40
13B-2 R	8.00	20.00	2	1.44	23	17	132	0.28	30	6	42
13B-3	20.00	35.00	4	2.14	32	27	156	0.26	60	11	66
13B-4	35.00	46.50	4	2.68	27	32	149	0.32	79	12	73
13B-5	46.50	70.50	7	4.50	21	23	121	0.25	65	11	55
14-1	0.00	17.50	4	2.51	33	27	108	0.33	62	9	52
14-2	17.50	26.00	7	3.06	23	38	117	0.33	82	9	70
14-3	26.00	45.50	3	2.50	30	20	110	0.28	47	9	44
14-3 R	26.00	45.50									
14B-1	0.00	16.00	3	1.59	31	25	115	0.28	51	11	54
14B-2	16.00	28.50	5	2.12	38	34	149	0.36	71	13	74
14B-2 R	16.00	28.50	4	2.19	36	36	149	0.35	73	14	76
14B-3	28.50	46.50	6	3.29	26	61	127	0.29	70	14	54
14B-4	46.50	64.50	5	3.14	26	17	158	0.35	79	11	43
14B-5	64.50	75.50	6	2.34	35	17	175	0.40	96	14	64
14B-6	75.50	86.50	7	3.05	22	12	173	0.33	75	13	43
14B-6 R	75.50	86.50	8	2.98	23	11	167	0.31	73	13	42
14B-1 P	0.00	16.00	6	1.16	10	33	84	0.14	43	9	62
14B-2 P	16.00	28.50	14	0.64	22	81	85	0.15	77	16	103
14B-3 P	28.50	46.50	5	0.97	18	230	99	0.18	53	15	53
14B-4 P	46.50	64.50	5	0.73	14	13	109	0.19	60	17	38
14B-5 P	64.50	75.50	26	0.53	50	28	83	0.14	82	17	68
14B-6 P	75.50	86.50	19	0.66	18	12	101	0.13	69	20	37

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites. All other sites are coring sites (marsh). BDL denotes "below detection limit".

Sample ID	Upper interval (cm)	Lower interval (cm)	Elements (Cont.)								
			Mo (ppm)	Na (%)	Ni (ppm)	Pb (ppm)	Sr (ppm)	Ti (%)	V (ppm)	Y (ppm)	Zn (ppm)
18-0	0.00	24.50	6	2.78	39	31	177	0.33	74	12	87
18-0 R											
18-1	24.50	37.00	7	4.23	21	28	127	0.28	68	11	51
18-2	37.00	62.00	6	3.21	27	15	163	0.31	69	11	51
18-3	62.00	87.00	6	2.90	27	15	164	0.36	84	10	52
18-4	87.00	112.00	12	3.85	27	11	137	0.29	78	12	54
18-5	112.00	143.00	5	2.71	48	12	175	0.26	47	9	34
18-5 R	112.00	143.00	6	2.81	49	12	154	0.27	48	9	30
18-5 R	112.00	143.00	5	2.75	46	10	142	0.26	47	7	28
18-5 T	112.00	143.00	6	2.77	49	11	181	0.24	48	9	29
19-1	0.00	17.00	3	2.15	33	20	196	0.21	37	9	45
19-1 R	0.00	17.00	3	2.18	33	19	196	0.20	38	9	47
19-1 T	0.00	17.00	3	2.14	32	17	193	0.19	37	8	44
19-2	17.00	30.00	3	2.29	30	18	212	0.22	39	8	46
19-2 R	17.00	30.00									
19-3	30.00	46.50	3	2.41	35	23	204	0.33	54	11	68
19-4	46.50	57.50	4	4.54	23	21	137	0.21	40	13	55
19-1 P	0.00	17.00	6	1.46	11	36	107	0.17	42	15	72
19-2 P	17.00	30.00	6	0.79	12	27	65	0.15	54	14	46
19-2 P R	17.00	30.00									
19-3 P	30.00	46.50	8	0.75	14	40	65	0.17	66	18	95
19-4 P	46.50	57.50	6	1.03	9	21	53	0.09	26	12	41
22-1	0.00	23.00	6	3.19	32	29	110	0.36	90	11	65
22-2	23.00	42.00	6	3.20	27	31	114	0.34	84	13	67
22-3	42.00	58.00	9	3.87	20	17	106	0.28	69	12	44

Table C-2. Sample data: chemical analyses (cont.). Sample ID: **P** = Plant tissue samples; **R** = Replicate sample (QA/QC); **T** = triplicate sample (QA/QC). **Off** denotes offshore grab sample. Sites 3, 4, and 5 are bluff sites. All other sites are coring sites (marsh). BDL denotes "below detection limit".

Sample ID	**Upper interval (cm)**	**Lower interval (cm)**	**Elements (Cont.)**								
			Mo (ppm)	**Na (%)**	**Ni (ppm)**	**Pb (ppm)**	**Sr (ppm)**	**Ti (%)**	**V (ppm)**	**Y (ppm)**	**Zn (ppm)**
Site 3-T	Bluff	top	BDL	0.28	3	9	66	0.11	6	3	29
Site 3-B	Bluff	bottom	2	0.90	12	16	131	0.29	64	5	54
Site 3-B R	Bluff	bottom	2	0.89	14	20	126	0.32	68	5	56
Site 4-T	Bluff	top	BDL	0.14	5	10	52	0.05	10	6	32
Site 4-B	Bluff	bottom	BDL	0.11	3	8	47	0.07	10	2	31
Site 5	Bluff		BDL	0.31	8	14	109	0.21	16	3	28
1-Off											
3-Beach											
3-Off											
4-Beach											
5-Beach											
6-Off											
7-Off											
8-Off											
9-Off											
10-Off											
11-Off											
12-Off											
13-Off											
14A-Off											
14B-Off											
22-Off											

APPENDIX D
Land loss and loading calculations

Calculating Land Loss (Area and Volume)

For each land loss polygon, the area (m^2) covered by water is recorded for the years 1942 and 1989. Likewise, the total length (m) of the 1989 shoreline is recorded. Land loss over the 47-year period is determined by subtracting water area in 1989 from water area in 1942. The difference in water area is equivalent to the area of land lost by erosion. Table D-1 is a tabulation of water area, land loss, and shoreline length for each polygon and basin. Land loss is indicated by a negative (-) sign, which is dropped in subsequent calculations.

For any given land loss polygon, the associated rate of shoreline retreat is calculated by dividing area lost by the length of the reach:

$$R = \frac{A_{(1989\ -\ 1942)} / SL_{(1989)}}{47\,yr} \qquad \textbf{Eq. D-1}$$

where:

R	is the annual rate of shoreline retreat (m/yr),
$A_{(1989\text{-}1942)}$	is the area of land (m^2) lost to erosion within the land loss polygon between 1942 and 1989 (47-year period), and
$SL_{(1989)}$	is the length (m) of the shoreline within the polygon.

Table D-1. Area (m^2) and volume (m^3) of land lost during the 47-year period between 1942 and 1989 and linear rates (m/yr) of shoreline erosion, by shoreline reach (land loss polygon).

Polygon	1942 water area (m^2)	1989 water area (m^2)	*SL* 1989 shoreline length (m)	$A_{(1989-1942)}$ Change in land area (m^2)	Change per meter of shoreline	*R* Annual shoreline change (m/yr)	$\overline{H}$ Bank height (m)	Volume (m^3)	Annual volume (m^3/yr)
P1	47,950.94	50,805.64	583.18	-2,854.70	-4.90	-0.10	0.6	-1,712.82	-36.44
P2	3,526,880.74	3,778,632.75	44,410.90	-251,752.01	-5.67	-0.12	0.68	-171,191.37	-3,642.37
P4	298,803.57	331,356.66	4,444.16	-32,553.09	-7.32	-0.16	0.4	-13,021.24	-277.05
P6	628,573.16	697,538.96	7,531.84	-68,965.80	-9.16	-0.19	0.4	-27,586.32	-586.94
P7	888,199.10	953,787.44	6,962.69	-65,588.34	-9.42	-0.20	0.5	-32,794.17	-697.75
P8	670,821.01	741,784.40	6,301.49	-70,963.39	-11.26	-0.24	0.4	-28,385.36	-603.94
P9	154,799.59	168,758.89	1,135.80	-13,959.30	-12.29	-0.26	0.65	-9,073.55	-193.05
P10	566,711.81	633,225.41	9,793.89	-66,513.60	-6.79	-0.14	0.49	-32,591.66	-693.44
P12	472,959.59	572,462.32	11,258.65	-99,502.73	-8.84	-0.19	0.57	-56,716.56	-1,206.74
P13	1,116,239.83	1,219,653.87	8,740.04	-103,414.04	-11.83	-0.25	0.72	-74,458.11	-1,584.22
P14	264,016.06	283,567.41	2,892.47	-19,551.35	-6.76	-0.14	0.68	-13,294.92	-282.87
P15	643,466.91	683,503.74	5,637.03	-40,036.83	-7.10	-0.15	1.4	-56,051.56	-1,192.59
P16	430,363.14	463,622.89	7,582.11	-33,259.75	-4.39	-0.09	1.4	-46,563.65	-990.72
P17	246,228.81	264,120.82	8,687.06	-17,892.01	-2.06	-0.04	3.12	-55,823.07	-1,187.72
P18	916,842.02	941,630.89	12,403.39	-24,788.87	-2.00	-0.04	1.9	-47,098.85	-1,002.10
P19	430,330.55	453,762.39	2,177.43	-23,431.84	-10.76	-0.23	0.53	-12,418.88	-264.23
P20	114,667.58	132,586.22	1,533.47	-17,918.64	-11.69	-0.25	0.42	-7,525.83	-160.12
P21	578,696.59	610,993.02	5,135.51	-32,296.43	-6.29	-0.13	0.42	-13,564.50	-288.61
P26	446,165.72	498,731.88	4,816.07	-52,566.16	-10.91	-0.23	0.28	-14,718.52	-313.16
P27	762,215.56	814,221.01	2,821.89	-52,005.45	-18.43	-0.39	0.28	-14,561.53	-309.82
P28	418,131.38	476,037.20	5,325.49	-57,905.82	-10.87	-0.23	0.45	-26,057.62	-554.42
P29	301,883.44	322,794.91	1,181.26	-20,911.47	-17.70	-0.38	0.98	-20,493.24	-436.03
P30	454,263.04	501,288.98	4,482.79	-47,025.94	-10.49	-0.22	0.98	-46,085.42	-980.54
Totals	**14,379,210.14**	**15,594,867.70**	**165,838.61**	**1,215,657.56**	**Mean = -7.33**	**Mean = -0.16**	**---**	**821,788.75**	**17,484.87**

Calculating mean component concentrations for each site

The mean bulk concentration of each nutrient (total carbon, nitrogen, and phosphorus) was calculated for each core or bank/bluff site by averaging the concentrations of the individual core samples using equation D-2.

$$\overline{C}_{N(site)} = \frac{\sum_i \left(\rho_{adj(i)} * 1000 * \frac{[N]_{(i)}}{100} * l_{(i)}\right)}{l_{(t)}} \qquad \textbf{Eq. D-2}$$

where: $\overline{C}_{N(site)}$ is the mean bulk concentration (Kg/m^3)of the component of interest (N) (e.g., carbon, nitrogen, phosphorus, etc.) for core/site,

$\rho_{adj(i)}$ is the adjusted dry bulk density (g/cm^3) of the sample section *(i),* corrected to account for any core compaction,

1000 factor to convert g/cm^3 to Kg/m^3

$[N]_{(i)}$ is the nutrient concentration (% dry weight) measured for sample section (*i*),

$l_{(i)}$ is the length, in meters, of the sample section *(i)*, and

$l_{(t)}$ is the total core length, in meters, truncated to measured bank height or, in the case of a bluff sample, bluff height.

Mean bulk concentrations of sand, silt, and clay components for each site were calculated using a slightly different equation (Eq. D-3). The sand, silt, and clay percentages obtained from the textural analysis applied the abiotic or mineral portion of the sediment sample only, not the whole sample. Therefore, textural component percentages were multiplied by the fraction representing the mineral portion of whole sediment:

$$\overline{C}_{S(site)} = \frac{\sum_i \left(\rho_{adj(i)} * 1000 * \frac{[S]_{(i)}}{100} * \frac{[M]_{(i)}}{100} * l_{(i)}\right)}{l_{(t)}} \qquad \textbf{Eq. D-3}$$

where: $\overline{C}_{S(site)}$ is the mean bulk concentration (Kg/m^3)of the textural component of interest (S) (*e.g.*, sand, silt, clay-size particles, etc.) for core/site;

$\rho_{adj(i)}$ is the adjusted bulk density (g/cm^3) of the sample section *(i),* corrected to account for any core compaction;

1000 factor to convert g/cm^3 to Kg/m^3

$[S]_{(i)}$	is the textural component (% dry weight sand, silt, or clay) measured for sample section (i);
$[M]_{(i)}$	is the abiotic or mineral portion (%dry weight) of the sample section;
$l_{(i)}$	is the length, in meters, of the sample section *(i);*
$l_{(t)}$	is the total core length, in meters, truncated to measured bank height; or, in the case of a bluff sample, height of the bluff.

Table D-2. Mean textural and nutrient concentrations calculated for each site using equations D-2 and D-3. **All values listed are Kg/m^3.** These site values are assigned to specific land loss polygons (see Table **4-2**) to calculate the sediment and nutrient contribution rates for the polygon using equation D-4.

Site	Total solids	Total organics (biotic component)	Nutrients			Textural component		
			Nitrogen	Carbon	Phosphorus	Sand	Silt	Clay
1	177.04	107.28	1.84	33.07	0.143	9.00	24.10	36.65
3	1268.35	38.95	0.60	7.31	0.096	1025.39	120.17	83.84
4	1442.34	32.27	0.35	3.45	0.064	1161.32	93.46	94.05
5	1336.30	25.74	0.20	0.89	0.086	1092.87	78.47	120.27
6	223.88	139.73	1.91	36.71	0.149	6.48	35.44	42.23
7	178.53	107.49	1.71	32.15	0.098	3.66	33.26	34.11
8	492.20	138.09	1.72	32.30	0.151	166.06	105.61	82.43
9	493.28	99.51	1.97	36.25	0.191	190.06	111.38	92.33
10	445.54	140.92	2.02	37.95	0.193	32.89	154.37	117.36
11	410.93	138.98	1.51	27.15	0.143	117.87	86.77	67.31
12	339.81	139.33	2.04	37.96	0.137	20.70	89.65	90.13
13	766.86	144.58	1.69	27.83	0.236	393.56	152.12	76.60
13B	560.88	111.60	1.69	30.53	0.169	245.32	121.40	82.56
14	458.42	193.45	2.43	41.90	0.181	110.60	79.36	75.01
14B	384.69	97.57	1.85	32.05	0.145	85.45	99.71	101.96
18	325.46	108.08	1.36	26.65	0.123	32.90	112.02	72.46
19	977.77	113.18	1.64	32.75	0.300	604.17	181.11	79.31
22	294.89	104.70	1.49	29.90	0.115	1.72	101.06	87.40

Calculating component loadings (Kg/yr)

The mean site concentration values were then assigned to specific polygons to calculate the nutrient loading for the polygon using the following equation:

$$L_{(N),(S)} = \overline{C}_{N,S(site)} * \left(\frac{A_{(1989-1942)} * \overline{H}}{47yr} \right) \qquad \textbf{Eq. D-4}$$

where: $L_{(N),(S)}$	is the annual loading (Kg/yr) of the component of interest (*N*: e.g., carbon, nitrogen or phosphorus; or *S*: e.g., sand, silt, clay) for the land loss polygon;
$\overline{C}_{N,S(site)}$	is the mean loading concentration (Kg/m^3)of the component of interest (N) (*e.g.*, carbon, nitrogen, phosphorus, etc.) for core/site assigned to the land loss polygon;
$A_{(1989\text{-}1942)}$	is the area of land (m^2) lost to erosion within the land loss polygon between 1942 and 1989 (47 year period);
$\overline{H}$	is the mean bank height assigned to the land loss polygon.

Table D-3. Annual component loadings (Kg/yr) for each land loss polygon. Loadings (except total volume eroded) were calculated using Equation D-4. Area eroded ($A_{(1989\text{-}1942)}$) and mean bank height ($\overline{H}$) are listed in Table D-1.

Polygon	Volume eroded (m^3/yr)	Carbon (Kg/yr)	Nitrogen (Kg/yr)	Phosphorus (Kg/yr)	Total solids (Kg/yr)	Total organics (Kg/yr)	Total sediments (Kg/yr)	Sand (Kg/yr)	Silt (Kg/yr)	Clay (Kg/yr)	Pb (Kg/yr)	Zn (Kg/yr)
P1	36.44	1,168	68	5.29	14,019	3,556	10,464	3,114	3,634	3,716	0.456	0.801
P2	3,642.37	111,184	6,140	613.99	2,042,932	406,496	1,636,436	893,532	442,187	300,717	44.190	103.692
P4	277.05	10,517	564	37.91	94,143	38,602	55,541	5,734	24,837	24,970	3.150	6.516
P6	586.94	22,281	1,195	80.31	199,448	81,781	117,667	12,147	52,620	52,901	6.673	13.804
P7	697.75	18,942	1,052	99.72	286,726	96,972	189,755	82,244	60,545	46,965	8.136	17.230
P8	603.94	22,919	1,219	116.60	269,078	85,106	183,973	19,866	93,230	70,876	9.065	21.011
P9	193.05	6,998	380	36.83	95,230	19,211	76,020	36,691	21,503	17,825	2.265	5.525
P10	693.44	20,733	1,031	79.80	204,488	72,606	131,881	1,195	70,082	60,604	5.884	13.081
P12	1,206.74	38,983	2,075	182.33	593,953	166,643	427,310	200,390	127,447	99,473	4.940	13.207
P13	1,584.22	50,927	2,707	155.62	282,829	170,291	112,537	5,804	52,691	54,043	22.204	58.311
P14	282.87	10,383	539	42.09	63,330	39,527	23,804	1,834	10,025	11,945	2.192	5.821
P15	1,192.59	1,057	233	102.02	1,593,657	30,703	1,562,954	1,303,347	93,578	143,436	21.926	45.116
P16	990.72	878	193	84.75	1,323,897	25,506	1,298,391	1,082,728	77,738	119,156	18.214	37.479
P17	1,187.72	4,100	410	75.88	1,713,108	38,325	1,674,782	1,379,331	111,001	111,706	15.215	53.893
P18	1,002.10	7,329	603	96.10	1,271,018	39,031	1,231,987	1,027,552	120,419	84,016	12.630	42.736
P19	264.23	8,739	487	37.87	46,779	28,348	18,431	2,377	6,369	9,685	1.705	3.994
P20	160.12	5,173	275	24.19	78,813	22,112	56,701	26,590	16,911	13,199	0.656	1.752
P21	288.61	9,323	496	43.61	142,052	39,855	102,197	47,926	30,481	23,790	1.182	3.159
P26	313.16	10,255	515	93.85	306,198	35,443	270,754	189,200	56,716	24,838	5.942	13.817
P27	309.82	10,146	510	92.84	302,932	35,065	267,866	187,182	56,111	24,573	5.879	13.670
P28	554.42	14,775	754	68.18	180,442	59,924	120,519	18,239	62,107	40,173	4.423	12.624
P29	436.03	11,620	593	53.62	141,910	47,127	94,783	14,344	48,845	31,594	3.479	9.928
P30	980.54	26,132	1,334	120.59	319,130	105,981	213,149	32,258	109,842	71,049	7.823	22.327