King and Queen County Shoreline Situation Report

Prepared By:
Comprehensive Coastal Inventory Program
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

Supported By:
Virginia Institute of Marine Science, and King and Queen County
through Grant No 99-1-039 with the Chesapeake Bay Local Assistance Department.

Special Report in Applied Marine Science and Ocean Engineering
SRAMSOE No.363

June, 2000

Comprehensive Coastal Inventory
Center for Coastal Resources Management
Virginia Institute of Marine Science

King and Queen
Shoreline Situation Report

Supported by the Virginia Institute of Marine Science Comprehensive Coastal Inventory Program, and King and Queen County through Grant No 99-1-039 with the Chesapeake Bay Local Assistance Department.

Prepared By:

Marcia Berman
Harry Berquist
Tamia Rudnicky
Julie Glover
Sharon Dewing
Daniel Schatt
Kevin Skunda

Project Supervisors:
Marcia Berman - Director, Comprehensive Coastal Inventory Program
Carl Hershner - Director, Center for Coastal Resources Management

Special Report in Applied Marine Science and Ocean Engineering No. 363 of the Virginia Institute of Marine Science

Cover Design by Harold Burrell/photo by Dwight Dyke

June, 2000

CHAPTER I - Introduction

1.1 Background

In the 1970s, the Virginia Institute of Marine Science (VIMS) received a grant through the National Science Foundation's Research Applied to National Needs Program to develop a series of reports which would describe the condition of tidal shorelines in the Commonwealth of Virginia. These reports became known as the Shoreline Situation Reports. They were published on a county by county basis with additional resources provided by the National Oceanic and Atmospheric Administration's Office of Coastal Zone Management (Hobbs et.al., 1979).

The Shoreline Situation Reports quickly became a common desktop reference for nearly all shoreline managers, regulators, and planners within the Tidewater region. They provided useful information to address the common management questions and dilemmas of the time. Despite their age, these reports remain a desk top reference for many today.

The CCI Program is committed to developing a revised series of Shoreline Situation Reports which are aimed at addressing the management questions of today. The series reports shoreline conditions on a county by county basis. Reports are distributed in hardcopy, but are also available after publication as pdf files on the CCI web site at www.vims.edu/ccrm/publications.html.
The digital GIS coverages developed for the report are also available on the web at www.vims.edu/ccrm/gis/gisdata.html .

1.2 Description of the Locality

King and Queen County includes approximately 318 square miles of land area, and another 9 square miles of water on the Middle Peninsula of Virginia (Figure 1). Primary waterways within the county are the Mattaponi, York, and the Poropotank Rivers. Small headwater streams within the county drain into the Rappahannock River watershed along the east boundary. These non-navigable waterways are not included in this situation report. The county borders Caroline County to the northwest, Essex and Middlesex Counties to the east - northeast, and Gloucester County to the southeast. The York River separates King and Queen from New Kent county, and the Mattaponi River divides the land mass between King and Queen and King William county.

King and Queen County is rural in character. The 1994 Comprehensive Plan for the county reports that three fourths of the land area is forested, with one-third of that land holding owned by forest industries. Population densities estimated in that report for 1990 were 20 persons per square mile (King and Queen County Planning Commission, 1994). A few housing developments are located along the Mattaponi River.

Tidal shoreline protection is afforded through regulations established by the Clean Water Act, and the Chesapeake Bay Preservation Act. King and Queen county established Resource Protection Areas (RPAs) in accordance with the Chesapeake Bay Preservation Act (100 foot buffers landward of all streams, adjoining wetlands, and related sensitive areas). Resource Management areas (RMAs) extend an additional 250 feet landward of the inland limit of the RPA buffer (King and Queen County Planning Commission, 1994).

1.3 Purpose and Goals

This shoreline inventory has been developed as a tool for assessing conditions along the tidal shoreline of the rivers and tributaries in King and Queen County. Recent conditions are reported for three zones within the immediate riparian river area: riparian land use, bank and buffers, and the shoreline. A series of maps and tabular data are published to illustrate and quantify results of an extensive shoreline survey. The survey extends from the mouth of the Poropotank River to just below the Rt 628 crossing over the Mattaponi (Figure 1). The shorelines of the Poropotank, Mattaponi, and York rivers were surveyed, along with some of their smaller contiguous creeks.

1.4 Report Organization

This report is divided into several sections. Chapter 2 describes methods used to develop this inventory, along with conditions and attributes considered in the survey. Chapter 3 identifies potential applications for the data, with a focus on current management issues. From existing literature and the current survey, Chapter 4 reports the general state of the county's shoreline, and integrates a series of maps which illustrate current conditions.

1.5 Acknowledgments

This report has been primarily funded by the Comprehensive Coastal Inventory Program with monies appropriated by the General Assembly. A component of the field work was collected with monies provided by King and Queen County through Grant No 99-1-039 with the Chesapeake Bay Local Assistance Department.

This work was completed entirely with staff support and management from the Virginia Institute of Marine Science's Comprehensive Coastal Inventory Program (CCI). A host of individuals are acknowledged. In addition to those listed as preparers, the project directors would like to thank Dave Weiss of CCI, graduate students Donna Bilkovic and Julie Herman, the VIMS Vessel Center, and the VIMS Publication Center for their support.

Headwaters of the Mattaponi, photo courtesy of MPRA

CHAPTER 2 - The Shoreline Assessment: Approach and Considerations

2.1 Introduction

The Comprehensive Coastal Inventory Program (CCI) has developed a set of protocols for describing shoreline conditions along Virginia's tidal shoreline. The assessment approach uses state of the art Global Positioning Systems (GPS), and Geographic Information Systems (GIS) to collect, analyze, and display shoreline conditions. These protocols and techniques have been developed over several years, incorporating suggestions and data needs conveyed by state agency and local government professionals.

Three separate activities embody the development of a Shoreline Situation Report: data collection, data processing and analysis, and map generation. Data collection follows a three tiered shoreline assessment approach described below.

2.2 Three Tiered Shoreline Assessment

The data inventory developed for the Shoreline Situation Reports is based on a three-tiered shoreline assessment approach. This assessment characterizes conditions in the shorezone, which extends from a narrow portion of the riparian zone seaward to the shoreline.   This assessment approach was developed to use observations which could be made from a moving boat. To that end, the survey is a collection of descriptive measurements which characterize conditions. GPS units log location of observed conditions observed from a boat. No other field measurements are performed.

The three tiered shoreline assessment approach divides the shorezone into three regions: 1) the immediate riparian zone, evaluated for land use; 2) the bank, evaluated for height, stability and natural protection; and 3) the shoreline, describing the presence of shoreline structures for shore protection and recreational purposes. Each tier is described in detail below.

2.2a. Riparian Land Use: Land use adjacent to the bank is classified into one of eight categories (Table 1). The categories provide a simple assessment of land use, and give rise to land management practices which could be anticipated. GPS is used to measure the linear extent along shore where the practice is observed. The width of this zone is not measured. Riparian forest buffers are considered the primary land use if the buffer width equals or exceeds 30 feet. This width is calculated from digital imagery as part of the quality control in data processing.

2.2b. Bank Condition: The bank extends off the fastland, and serves as an interface between the upland and the shore. It is a source of sediment and nutrient fluxes from the fastland, and bears many of the upland soil characteristics which determine water quality in receiving waters. Bank stability is important for several reasons. The bank protects the upland from wave energy during storm activity. The faster the bank erodes, the sooner the upland will be at risk. Bank erosion can contribute high sediment loads to the receiving waters. Stability of the bank depends on several factors: height, slope, sediment composition, vegetative cover, and the presence of buffers to absorb energy impact to the bank itself.

The bank assessments in this inventory address three major bank characteristics: bank height, bank stability, and the presence of stable or unstable natural buffers at the toe of the bank (Table 2). Conditions are recorded continuously using GPS as the boat moves along the shoreline. The GPS log reflects any changes in conditions observed.

Bank height is described as a range, measured from the toe of the bank to the top. Bank stability characterizes the condition of the bank face. Banks which are undercut, have exposed root systems, or exhibit slumping of vegetation or other material qualify as a "high erosion". At the toe of the bank, natural marsh vegetation and/or beach material may be present. These features offer protection to the bank and enhance water quality. Their presence is noted in the field, and a general assessment (stable/unstable) describes whether they are experiencing any erosion. Sediment composition and bank slope cannot be surveyed from a boat, and are not included.   Bank cover was added as a feature to be surveyed subsequent to data collection for this inventory. Other Shoreline Situation Reports will include bank cover as a descriptive attribute.

Trimble's Geo Explorer GPS unit is used to collect data in the field

Table 1. Tier One - Riparian Land Use Classes

Forest	stands greater than 18 feet / width greater than 30 feet
Scrub-shrub	stands less than 18 feet
Grass	includes grass fields, pasture land, and crop land
Residential	includes single or multi family dwellings
Commercial	includes industrial, small business, recreational facilities
Bare	lot cleared to bare soil
Timbered	clear-cuts
Unknown	land use undetectable from the vessel

Table 2. Tier 2 - Bank Conditions

Bank Attribute	Range	Description
bank height	0-5 ft	from the toe to the edge of the fastland
	5-10 ft	from the toe to the edge of the fastland
	> 10 ft	from the toe to the edge of the fastland
bank stability	low erosion	minimal erosion on bank face or toe
	high erosion	includes slumping, scarps, exposed roots
marsh buffer	no	no marsh vegetation along the bank toe
	yes	fringe or pocket marsh present at bank toe
marsh stability (if present)	stable	no obvious signs of erosion
	unstable	marsh edge is eroding or vegetation loss
beach buffer	no	no sand beach present
	yes	sand beach present
beach stability (if present)	stable	accreting beach
	unstable	eroding beach or non emergent at low tide

2.2c. Shoreline Features: Features added to the shoreline by property owners are recorded as a combination of points or lines. These features include defense structures, which are constructed to protect shorelines from erosion; offense structures, designed to accumulate sand in longshore transport; and recreational structures, built to enhance recreational use of the water. The locations of these features along the shore are surveyed with a GPS unit. Linear features are surveyed without stopping the boat. Structures such as docks, and boat ramps are point features, and a static ten-second GPS observation is collected at the site. Table 3 summarizes shoreline features surveyed. Linear features are denoted with an "L" and point features are denoted by a "P." The glossary describes these features, and their functional utility along a shore.

Table 3. Tier 3 - Shoreline Features

Feature	Feature Type	Comments
Control Structures		
riprap	L	
bulkhead	L	
breakwaters	L	first and last of a series is surveyed
groinfield	L	first and last of a series is surveyed
miscellaneous	L	can include tires, rubble, tubes, etc.
Recreational Structures		
pier/wharf	P	includes private and public
boat ramp	P	includes private and public
boat house	P	all covered structures, assumes a pier
marina	L	includes piers, bulkheads, wharfs

2.3 Data Collection/Survey Techniques

Data collection is performed in the field, from a small, shoal draft vessel, navigating at slow speeds parallel to the shoreline. To the extent possible, surveys take place on a rising tide, allowing the boat to be as close to shore as possible. The field crew consists of a boat operator, and two data surveyors. The boat operator navigates the boat to follow the shoreline geometry. One surveyor collects information pertinent to land use and bank condition. The second surveyor logs information relevant to shoreline structures.

Data is logged using the handheld Trimble GeoExplorer GPS unit. GeoExplorers are accurate to within 4 inches of true position with extended observations, and differential correction. Both static and kinematic data collection is performed. Kinematic data collection is a collection technique where data is collected continuously along a pathway (in this case along the shoreline). The GPS units are programmed to collect information at a rate sufficient to compute a position anywhere along the course. The shoreline survey collects kinematic data at a rate of one observation every five seconds. The land use, bank condition, and linear shoreline structures are collected using this technique.

Static surveys are used to pin-point fixed locations which occur at very short intervals. The boat actually stops to collect these data, and the boat operator must hold the boat against the tidal current, and surface wind waves. Static surveys collect 10 observations recorded at a rate of one observation per second at the fixed station. The GPS unit computes one position, in part, using an averaging technique of the 10 static observations. Static surveys are used to position point features like piers, boat ramps, and boat houses.

The GPS units are preprogramed with the complete suite of shoreline features described in section 2.2. These features are stored in a "data dictionary" prepared specifically for this project. As features are observed in the field, the GPS unit tags each geographic coordinate pair with the attribute's code. The survey, therefore, is a complete set of geographically referenced shoreline features.

Collecting data with Trimble's Geo Explorer GPS unit

2.4 Data Processing

Data processing occurs in two parts. Part one processes the raw GPS field data, and converts the data to GIS coverages. Part two corrects the GIS coverages to reflect true shoreline geometry.

2.4a. GPS Processing: Differential correction improves the accuracy of GPS data by correcting for erroneous errors introduced by "selective availability", a process in which the government scrambles satellite signals to degrade positional data. Differential correction is the first step to processing GPS data. Trimble's Pathfinder Office GPS software is used. The software reviews simultaneously the GPS data logged in the field and data from a selected base station. Data from GPS base stations established by the United States Coast Guard can be used. Data from the VIMS base station can be used for differential correction if the site is within 124 miles of the base station. Differential correction improves the position of the GPS field data based on the known location of the base station, the satellites, and the satellite geometry.

Although the Trimble Geo-Explorers are capable of decimeter accuracy (~ 4 inches), the short occupation of sites in the field reduces the accuracy to 5 meters (~16 feet). In many cases the accuracy achieved is better, but the overall limits established by the CCI program are set at 5 meters. This means that features are mapped to within 5 meters (~16 feet) (or better) of their true position on the earth's surface.

An editing function is used to clean the GPS data. Cleaning corrects for breaks in the data which occur when satellite lock is lost during data collection. Editing also eliminates erroneous data collected when the boat circles off track, and the GPS unit is not switched to "pause" mode.

The final step in GPS processing converts the files to three separate ArcInfo GIS coverages. The three coverages are: a land use and bank condition coverage, a shoreline structure coverage (lines only), and a shoreline structure coverage (points only).

2.4b. GIS Processing: GIS processing uses ESRI's ArcInfo® GIS software, and ERDAS' Imagine ® software. Several data sets are integrated to develop the final inventory products: the shoreline conditions surveyed and processed using GPS, a digital baseline shoreline coverage defining the high water shoreline, and digital imagery for collateral information.

The base shoreline is derived from a digitized record of the high water shoreline illustrated on 7.5 minute USGS topographic maps for the study area. Since it is available for the entire Tidewater area, this shoreline has been selected as the baseline shoreline for development of all Shoreline Situation Reports. The digital coverage was developed by the CCI program in the early 1990s using the most recent topographic maps available. These maps range from the late 1960s to the early 1980s. As USGS updates these maps, revisions to the digital basemap series can be made.

Color infra-red Digital Ortho Quarter Quadrangles (DOQQs) are digital image products circulated by the USGS. DOQQs are fully rectified digital imagery representing one quarter of a USGS quadrangle. They were released in

1997, and use imagery flown in1994. The imagery are used as background during data processing and map production. They are an important quality control tool for verifying the location of certain landscape attributes, and provide users with additional information about the coastal landscape.

GIS processing includes two separate activities. Part one checks the relative accuracy of the shoreline coverage. Since this coverage was developed from topographic maps dating back to the 1960s, significant changes in the shoreline orientation may have occurred. While this process does not attempt to re-compute a shoreline position relative to a vertical tidal datum, it adjusts the horizontal geographic position to reflect the present shoreline geometry. Using ERDAS' Imagine software, the 1994 imagery is displayed onscreen behind the digitized shoreline coverage. The operator looks for areas where the digitized shoreline departs greatly from the land water interface illustrated in the background image. The digitized shoreline coverage is then corrected using Imagine's onscreen digitizing techniques to align more closely with the land water interface displayed. This revised shoreline coverage is used in all subsequent inventory steps and products.

Step two corrects the coverages generated from the field data to the shoreline record. These coverages, having been processed through GPS software, are geographically coincident with the path of the boat, from where observations are made. They are, therefore, located somewhere in the waterway. Step two transfers these data back to the corrected shoreline record so the data more precisely reflects the location being described along the shore.

The majority of data processing takes place in step two, which uses all three data sets simultaneously. The corrected shoreline record, and the processed GPS field data are displayed onscreen in ArcInfo together. The imagery is used in the background for reference. The corrected shoreline is the base coverage. The remaining processing re-codes the base shoreline coverage for the shoreline attributes mapped along the boat track. Each time the boat track data indicates a change in attribute type or condition, the digital shoreline arc is split, and coded for the attribute using ArcInfo techniques.

This step endures a rigorous sequence of checks to insure the positional translation is as accurate as possible. The major features and attributes; land use, bank condition, and shoreline condition, are processed separately. The final products are three new coded shoreline coverages. Each coverage has been checked twice onscreen by different GIS personnel. A final review is done on hardcopy printouts.

2.4c. Maps and Tables: Large format, color maps are generated to illustrate the attributes surveyed along the shore. A three-part map series illustrates the three tiers individually. Plate A describes the riparian land use as color coded bars along the shore. A legend keys the color to the type of land use.

Plate B depicts conditions of the bank and natural buffers following criteria in Table 2. A combination of color and pattern symbology gives rise to a vast amount of bank and buffer information. Erosional conditions are illustrated in red for both bank and buffer. Stable, or low erosion conditions are illustrated in green. Bank height varies with the thickness of the line; where the thickest lines designate the highest banks (> 10 feet). Open circles just seaward of the line indicate a natural fringe marsh along the base of the bank. Solid circles indicate a sand beach buffer at the base of the bank. It is possible to have both. Red circles indicate the buffer is eroding. Green circles indicate the buffer is stable. Along portions of King and Queen County, no erosional data was collected for the buffer. This is illustrated by tan circles. The length of the symbology along the shore reflects the length alongshore that the features persist. The symbology changes as conditions change.

Plate C combines recreational and shoreline protection structures in a composition called Shoreline Features (Table 3). Linear features, described previously, are mapped using color coded bar symbols which follow the orientation of the shoreline. Point features use a combination of colors and symbols to plot the positions on the map.

DOQQ imagery is used as a backdrop, upon which the shoreline data is superimposed. The original color infra-red image is used as a backdrop to Plate A. A gray scale version of this same image is used for Plates B and C.

For publication purposes the county is divided into a series of plates set at a scale of 1:12,000. The number of plates was determined by the geographic size and shape of the locality. An index is provided which illustrates the orientation of plates to each other. The three map compositions (A,B, and C) described above are presented for each plate. The county is divided into nineteen plates (plate 1a, 1b, 1c, etc.), for a total of 57 map compositions.

Tables 4 quantifies features mapped along the rivers using frequency analysis techniques in ArcInfo. The values quantify features on a plate by plate basis. For linear features, values are reported in actual miles surveyed. The number of point features surveyed are also listed on a plate by plate basis. The total miles of shoreline surveyed for each plate is reported. The total river miles surveyed, 76.64 miles, can not be reached by adding the shoreline miles for each plate since there is some plate overlap. The last row of Table 4 gives the total value for each feature computed along the entire surveyed shoreline.

Walkerton, photo by Dwight Dyke

Chapter 3. Applications for Management

3.1 Introduction

There are a number of different management applications for which the Shoreline Situation Reports (SSRs) support. This section discusses four of them which are currently high profile issues within the Commonwealth or Chesapeake Bay watershed. The SSRs are data reports, and do not necessarily provide interpretation beyond the characteristics of the nearshore landscape. However, the ability to interpret and integrate these data into other programs is key to gleaming the full benefits of the product. This chapter offers some examples for how the data within the SSRs can be integrated and synthesized to support current state management programs.

3.2 Shoreline Management

The first uses for SSRs were to prepare decision makers to bring about well informed decisions regarding shoreline management. This need continues today, and perhaps with more urgency. In many areas, undisturbed shoreline miles are almost nonexistent. Development continues to encroach on remaining pristine reaches, and threatens the natural ecosystems which have prevailed. At the same time, the value of waterfront property has escalated, and the exigency to protect shorelines through stabilization has increased. Generally speaking, this has been an accepted management practice. However, protection of tidal shorelines does not occur without incidence.

Management decisions must consider the current state of the shoreline, and understand what actions and processes have occurred to bring the shoreline to its current state. This includes evaluating existing management practices, assessing shore stability in an area, and determining future uses of the shore. The SSRs provide data to perform these evaluations.

Plate A defines the land use adjacent to the shoreline. To the extent that land use directs the type of management practices found, these maps can predict shoreline strategies which may be expected in the future. Residential areas are prone to shoreline alterations. Commercial areas my require structures along the shore for their daily operations. Others frequently seek structural alternatives to address shoreline stability problems. Forested riparian zones, and large tracts of grass or agricultural areas are frequently unmanaged even if chronic erosion problems persist.

Stability at the shore is described in Plate B. The bank is characterized by its height, its state of erosion, and the presence or absence of natural buffers at the bank toe. Upland adjacent to high, stable banks with a stable natural buffer at the base are less prone to flooding or erosion problems resulting from storm activity. Upland adjacent to banks of lesser height (< 5feet) are at greater risk of flooding, but if the banks are stable with marshes or beaches present, erosion may not be a significant concern. Survey data reveals a strong correlation between banks of high erosion, and the absence of natural buffers. Conversely, the association between stable banks and the presence of marsh or beach is also well established. This suggests that natural buffers such as beaches and fringe marshes play an important role in bank protection. This is illustrated on the maps. Banks without natural buffers, yet classified as low erosion, are often structurally controlled with rip rap or bulkheads.

Plate C delineates structures installed along the shoreline. These include erosion control structures, and structures to enhance recreational use of the waterway. This map is particularly useful for evaluating requests from property owners seeking structural methods for controlling shoreline erosion problems. Shoreline managers can evaluate the current situation of the surrounding shore including: impacts of earlier structural decisions, proximity to structures on neighboring parcels, and the vicinity to undisturbed lots. Alternative methods such as vegetative control may be evaluated by assessing the energy or fetch environment from the images. Use this plate in combination with Plate B to evaluate the condition of a bank proposed for protection.

A close examination of shore conditions may suggest whether certain structural choices have been effective. Success of groin field and breakwater systems is confirmed when sediment accretion is observed. Low erosion conditions surveyed along segments with bulkheads and riprap indicate structures have controlled the erosion problem. The width of the shorezone, estimated from the background image, also speaks to the success of structures as a method of controlling erosion. A very narrow shorezone implies that as bulkheads or riprap have secured the erosion problem at the bank, they have also deflated the supply of sediment available to nourish a healthy beach. This conflict remains unresolved in most management cases.

Shoreline managers are encouraged to use all three plates together when developing management strategies or making regulatory decisions. Each plate provides important information independent of the others, but collectively the plates become a more valuable management tool.

3.3 Non-Point Source Targeting

The identification of potential problem areas for non-point source pollution is a focal point of water quality improvement efforts throughout the Commonwealth. The three tiered approach provides a collection of data which, when combined, can allow for an assessment of potential non-point source pollution problems in a waterway.

Grass land, which includes cultivated and pasture lands, has the highest potential for nutrient runoff. These areas are also prone to high sediment loads since the adjacent banks are seldom restored when erosion problems persists. Residential, bare, and commercial land uses rank second because of the types of practices which prevail, and the large impervious surface areas.

The highest potential for non-point source pollution combines these land uses with "high" bank erosion conditions and no marsh buffer protection. The potential for non-point source pollution moderates as the condition of the bank changes from "high" bank erosion to "low" bank erosion, or with the presence or absence of stable marsh vegetation to function as a nutrient sink for runoff. Where defense structures occur in conjunction with "low" bank erosion, the structures are effectively controlling erosion at this time, and the potential for non-point source pollution is reduced. If the following characteristics are delineated: low bank erosion, stable marsh buffer, riprap or bulkhead; the potential for non-point source pollution from any land use class can be lowered.

At the other end of the spectrum, forested and scrub-shrub sites do not contribute significant amounts of non-point source pollution to the receiving waterway. Forest buffers, in particular, are noted for their ability to uptake nutrients running off the upland. Forested areas with stable or defended banks, a stable fringe marsh, and a beach would have the lowest potential as a source of non-point pollution. Scrub-shrub with similar bank and buffer characteristics would also be very low.

A quick search for potential non-point source sites would begin on Plate A. Identify the "grass" areas. Locate these areas on Plate B, and find those which have eroding banks (in red) without any marsh protection. The hot spots are these sites where the banks are highest (thick red line), so the potential sediment volume introduced to the water is greatest. Finally check plate C to determine if any artificial stabilization to protect the bank has occurred. If these areas are without stabilizing structures, they indicate the hottest spots for the introduction of non-point source pollution.

Bank cover is also an important attribute for assessing stability, and the potential for sediment load input. This attribute is now being considered in upcoming SSRs. Re-vegetation of eroding banks with little cover is often a preferred alternative to shoreline hardening.

3.4 Designating Areas of Concern (AOC) for Best Management Practice (BMP) Sites

Sediment load and nutrient management programs at the shore are largely based on installation of Best Management Practices (BMPs). Among other things, these practices include fencing to remove livestock from the water, installing erosion control structures, and bank re-vegetation programs. Installation of BMPs is costly. Cost share programs provide relief for property owners, but funds are scarce in comparison to the capacious number of waterway miles needing attention. Targeting Areas of Concern (AOC) can prioritize spending programs, and direct funds where most needed.

Data collected for the SSR can assist with targeting efforts for designating AOCs. AOCs can be areas where riparian buffers are fragmented, and could be restored. Use Plate A to identify forested upland. Breaks in the continuity of the riparian forest can be easily observed in the line segments, and background image. Land use between the breaks relates to potential opportunity for restoring the buffer where fragmentation has occurred. Agricultural tracts which breach forest buffers are more logical targets for restoration than developed residential or commercial stretches. Agricultural areas, therefore, offer the highest opportunity for conversion. Priority sites for riparian forest restoration should target forested tracts breached by "grass" land (green-yellow-green line pattern).

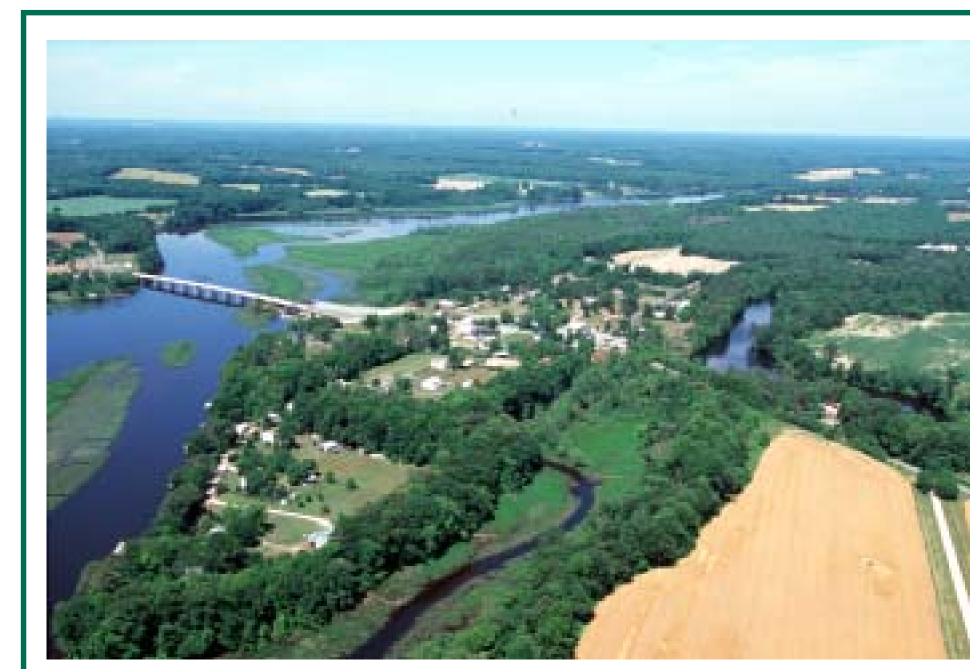
Plate B can be used to identify sites for BMPs. Look for where "red" (i.e. eroding) bank conditions persist. The thickness of the line indicates bank height and erosional quality. The fetch, or the distance of exposure across the water, can offer some insight into the type of BMP which might be most appropriate. Re-vegetation may be difficult to establish at the toe of a bank with high exposure to wave conditions. Plate C should be checked for existing shoreline erosion structures in place.

3.5 Targeting for Total Maximum Daily Load (TMDL) Modeling

As the TMDL program in Virginia evolves, the importance of shoreline erosion in the lower tidal tributaries will become evident. Total maximum daily loads are defined as a threshold value for a pollutant, which when exceeded, impedes the quality of water for specific uses (e.g. swimming, fishing). Among the pollutants to be considered are: fecal coliform, pathogens, nitrogen, phosphorous, and sediment load.

State agencies will develop models to address each of these parameters. In upper watersheds, nutrient and fecal coliform parameters will be critical where high agricultural land use practices prevail. Sediment loads will eventually be considered throughout the watershed. In the lower watersheds, loads from shoreline erosion must be addressed for a complete sediment source budget. Erosion from shorelines has been associated with high sediment loads in receiving waters (Hardaway et.al., 1992), and the potential for increased nutrient loads (Ibison et.al., 1990). Virginia's TMDL program is still developing. Impaired stream segments are being used to initially identify where model development should focus. For Virginia, this streamlining has done little to reduce the scope of this daunting task, since much of the lower major tributaries are considered impaired. Additional targeting will be necessary to prioritize model development.

Targeting to prioritize TMDL can be assisted by maps which delineate areas of high erosion, and potential high sediment loads. Plate B in this inventory delineates banks of high erosion. Waterways with extensive footage of eroding shorelines should be targeted. The volume of sediment entering a system is also a function of bank height. Actual volumes of sediment eroded can be estimated by using bank height, and the linear extent that the condition persists along the shore. Bank height is an attribute defined in Plate B by the width of the line. Eroding banks (in red) with heights in excess of 10 feet (thickest line) would be target areas for high sediment loads. Plate A can be used in combination with Plate B to determine the dominant land use practice, and assess whether nutrient enrichment through sediment erosion is also a concern. This would be the case along agriculturally dominated waterbodies. Table 4 quantifies the linear extent of high, eroding banks on a plate by plate basis.



Walkerton, photo by Dwight Dyke

Chapter 4. The Shoreline Situation

The shoreline situation is described for conditions in King and Queen County extending along the Poropotank River, the York River, and the Mattaponi River, from its mouth to just below the Rt 628 crossing. Only the portion of these rivers within King and Queen County jurisdiction are described.

Brief descriptions are provided on the basis of river segments, designated on a geographic basis. These summarize data from Table 4, and discuss notable features present. Four segments are defined. Segment 1 includes plates 1-2. Segment 2 includes plates 3-5. Segment 3 combines plates 6-11, and Segment 4 describes plates 12-19. Important documentation pertaining to each plate map precedes the compositions.

Guthrie Creek, photo by Kirk Havens

Segment 1 (plates 1 and 2)

Description: Segment 1 consists mainly of the wide embayed marshes along the meandering headwaters of the Poropotank River. This narrow river stretch soon gives way to the much wider Morris Bay (Plate 2) before flowing into the York River. Numerous tidal creeks extend from the Poropotank, including Poplar Spring Branch, and Guthrie Creek. Approximately 11.7 miles of this segment were surveyed in August, 1998 out of a total 23.27 shoreline miles. The majority of unsurveyed shoreline is at the extreme headwaters, and along shallow tidal creeks.

Land Use: The riparian upland of this segment is dominated by forested land use. Forest cover averages more than 87% of land use on each plate. Just over 0.5 mile of shoreline is residential in this segment. Residential areas along the main stem of the Poropotank were not detected, but were surveyed at isolated locations in Guthrie Creek. Overall, this segment can be characterized as woody and rural.

Bank Condition: Banks along the shoreline of this segment range from under five feet to over ten feet. Approximately 83% of shoreline miles surveyed have bank heights under five feet, while 15% of the banks are over ten feet. Field observations record the condition of the bank as mostly stable. Only 3.7% of the banks surveyed were classified as high erosion. These areas tend to be concentrated along Guthrie Creek where there is undercutting of the bank, and a few isolated blow-out areas. This segment does not contain any beaches and is characterized as having a low, noncritical flood potential (Byrne and Anderson., 1978).

Shore Condition: The presence of wide, embayed marshes and fringe marshes, which protect the upland, contribute to the low erosion potential of the shoreline along this segment. Fetches are mostly low and thus wind waves are not a constant threat to the shoreline. Tidal currents, however, have been a major force in eroding approximately 43% of the marshes along the meandering stretches of the headwaters. Historical erosion rates are low in this area and should continue as such due to the presence of these marshes (Byrne and Anderson, 1978). Also, the absence of any significant residential development has helped to keep the erosion potential low. There are few piers and boat ramps in this segment; which would be expected with the low residential shore use. In addition, no boathouses, groins, and almost no riprap and bulkhead exist along this segment.

Gutherie Creek and Morris Bay, photo by Kirk Havens

Segment 2 (Plates 3 - 5)

Description: Segment 2 overlaps with Segment 1 around Morris Bay and Guthrie Creek, but continues along the shoreline of the York River, beyond Roane, and just below West Point, in the vicinity of the Municipal Airport. Approximately 16.53 miles of 41.86 miles of shoreline were survey in this segment during August, 1998. The unsurveyed shoreline occurs along major shallow tidal creeks, such as Hockley Creek. From aerial imagery it is known that these creeks are dominated by well established embayed marshes. The land use is a combination of forest cover with intermittent agricultural/grass uses. Overall, the surveyed portion of this segment is a mix of rural areas and residential development with forested and scrub-shrub.

Land Use: Forested land use dominates this segment. Approximately 61.8% of the shoreline can be characterized as forested, while 16.1% of the shoreline is scrub-shrub. Residential development contributes another 17% of land use along this segment. Scrub-shrub dominates around Roane, and residential development along the York River at Belleview. From Hockley Creek to the mouth of the Mattaponi River, forest cover dominates with sections of scrub-shrub. A significant residential community is located just south of the bridge. Residential development along the York River has increased since the 1970s. This increase has occurred in a few specific areas, but has been especially prominent near Belleview (Hobbs et.al., 1975).

Bank Condition: Most of the banks (92.3%) along this segment of King and Queen County shoreline are under five feet in height. Higher bank conditions are located mostly along Guthrie Creek.. Field observations record the stability of the banks as stable along more than 95% of surveyed shoreline. The one predominant area of instability is near Belleview, on a developed tract with little to no fringing marsh evident. The flood potential is low and noncritical in this segment for most of the shoreline. It does, however, become moderate and critical at Roane and for several of the residential areas near Belleview (Hobbs et.al., 1975).

Shore Condition: Higher fetches along the shoreline in this segment result in more marsh erosion, especially near Roane and in Morris Bay. Shoreline stability is good, and marsh erosion is low in Guthrie Creek. Along the mainstem of the York River, fringe marshes are common, and a few beaches exist. The extent of marsh erosion can not be determined since data was not collected on marsh condition for much of this shoreline. Historic erosion rates are slight with no shoreline change in Morris Bay, and for parts of the York River mainstem (Byrne and Anderson, 1978). Moderate, noncritical erosion rates characterize the shoreline from Belleview to Goff Point, delineated in Plate 5. This area has a historical erosion rate of 1.1 to 1.6 feet per year. Shoreline erosion structures are more frequent in this segment as 8.6% of the surveyed shoreline is bulkheaded or has riprap. Piers and boathouses are abundant near Belleview, and north of Goff Point.

York River, West Point, photo by Dwight Dyke.

Segment 3 (Plates 6 - 11)

Description: Segment 3 covers the lower portion of the Mattaponi River near West Point and continues upriver to Log Landing. This segment trends from northwest to southeast and is fetch-limited. The King and Queen county shore of the lowest portion of the Mattaponi is absent the industrial character present along King William county shoreline. In the vicinity of the Route 33 bridge, the shore is predominantly residential land use. Beyond West Point, the river meanders, and wide embayed marshes dominate. Approximately 19.25 miles of shoreline was surveyed in July and August,1998 out of a total 36.48 miles of shoreline. The bulk of the shoreline that was not surveyed is within two shallow tidal creeks (Burnt Mill Creek and Corbin Creek), near West Point.

Mattaponi River, photo by James P. Blair

Land Use: Similar to Segment 2, more than three quarters of the surveyed shoreline in Segment 3 is forested. Only 18% of the shoreline can be characterized as residential. The largest concentration of such development can be found near Courthouse Landing. Grass and scrub-shrub land uses are not very common, nor is commercial land use. Development of these shorelines has not occurred to a large extent since the 1970s, leaving the forested shorelines backed by agricultural land mostly untouched.

Bank Condition: Approximately 78% of the banks along this segment are under five feet in height, while approximately19% are 5-10 feet high. Only a few banks in this relatively low-lying area have heights over 10 feet. Field observations characterize more than 94% of these banks as stable with low erosion. Banks with high erosion can be found along some of the river meanders where the river width narrows and switches course. The flood hazard for Segment 3 is low and noncritical.

Shore Condition: Wide, embayed marshes are common along this segment, which help to keep upland erosion down and offer bank protection. As noted in plate B, no data exists on marsh stability. Beaches, which also protect upland from wave induced erosion, are not found along this segment. Only 0.41 mile of bulkhead and 0.26 mile of riprap are found in Segment 3, owing much to the low residential density along these shorelines. Piers are relatively scarce for most, but increase in density near Courthouse Landing residential area. No groinfields were found. Due to the low fetches and embayed marshes, erosion potential due to wind waves is minor along these stretches. Erosion due to tidal currents or sea level rise is possible.

Rainbow Acres Campground, photo by Donna Bilkovic

Segment 4 (Plates 12 - 19)

Description: The last segment of King and Queen County covers the upper portion of the Mattaponi River. This stretch of shoreline is defined by the presence of intertidal marsh islands that have formed at the meanders of the river. Segment 4 begins past Log Landing and continues toward the headwaters, ending just below the Route 628 road crossing. Approximately 35.71 miles of shoreline in Segment 4 were surveyed in July and August, 1998 from a total of 54.74 miles of shoreline. Shallow tidal creeks such as Garnetts Creek were not surveyed at this time, and are included in the unsurveyed shoreline miles. This section of the Mattaponi is very fetch limited, and shoreline conditions are generally influenced by tidal currents or sea level rise, as opposed to wind generated waves.

Land Use: Similar to other shorelines of the county, approximately 86.5% of the shoreline along this segment is forested. Another 12.5% of the shoreline is residential, and land uses of grass, scrub-shrub and commercial are not very common. The residential areas within this segment are mostly concentrated at the towns of Mantapike, Rickahock, Walkerton, and Whitehall. Erosion of these shorelines is mainly low except at selected river meanders.

Bank Condition: Bank heights along this segment vary from 0-5 feet to over 10 feet in height. Almost half (46.3%) of the banks are under 5 feet, while 40% of the banks are from 5-10 feet in height. Approximately 13.8% of the banks are over 10 feet. Most of these banks are characterized as low erosion. Only 1.21 miles of banks are considered to be highly eroding.

Garnetts Creek, photo by Dwight Dyke

Shore Condition: This segment is marked by an absence of beaches. It is also marked by a mix of embayed and fringing marshes. Almost half (6.37 miles) of the marshes surveyed are classified as stable, while another 6.86 miles of marsh are surveyed without any indication of stability. Pier density is relatively high in the residential areas. Almost half of the piers are concentrated around Mantapike. Boathouses are commonly found along the shoreline of this segment. No groins, marinas, or breakwaters exist. This segment has virtually no shoreline armoring; only 0.35 mile of bulkhead. A lack of armored shoreline along this segment is due to the low wave energy environment. Tidal current energy, however, is moderately high due to the narrowing of the river and meandering stretches.

Aylett, photo by Dwight Dyke

Map Compositions

Plate 1

Location:	Headwaters of river to near Partridge Landing
Major River:	Poropotank
Total Shoreline Miles:	4.83
Shoreline Miles Surveyed:	4.03
Survey Date(s):	8/17/98
Plate Rotation:	43 degrees E

Plate 2

Location:	Partridge Landing to Roane
Major River:	Poropotank
Total Shoreline Miles:	18.87
Shoreline Miles Surveyed:	8.10
Survey Date(s):	8/17/98
Plate Rotation:	14 degrees E

Plate 3

Location:	Morris Bay to 0.5 miles east of Belleview
Major River:	Poropotank, York
Total Shoreline Miles:	16.24
Shoreline Miles Surveyed:	10.87
Survey Date(s):	8/17/98
Plate Rotation:	66 degrees W

Plate 4

Location:	0.5 miles east of Belleview to 0.6 miles west of Bakers Creek
Major River:	York
Total Shoreline Miles:	13.60
Shoreline Miles Surveyed:	2.86
Survey Date(s):	8/5/98
Plate Rotation:	66 degrees W

Plate 5

Location:	0.2 miles east of Robinson's Creek to 0.4 miles south of Lord Delaware Bridge
Major River:	York
Total Shoreline Miles:	17.76
Shoreline Miles Surveyed:	2.93
Survey Date(s):	8/5/98
Plate Rotation:	66 degrees W

Plate 6

Location:	0.4 miles south of Lord Delaware Bridge to 0.3 miles northwest of Corbin's Creek
Major River:	Mattaponi
Total Shoreline Miles:	11.81
Shoreline Miles Surveyed:	2.46
Survey Date(s):	8/5/98
Plate Rotation:	23 degrees E

Plate 7

Location:	0.3 miles northwest of Corbin's Creek to the Rt. 657 approach to the river
Major River:	Mattaponi
Total Shoreline Miles:	9.7
Shoreline Miles Surveyed:	1.27
Survey Date(s):	8/5/98
Plate Rotation:	0 degrees

Plate 8

Location:	Muddy Point to Clifton
Major River:	Mattaponi
Total Shoreline Miles:	3.9
Shoreline Miles Surveyed:	3.9
Survey Date(s):	8/5/98
Plate Rotation:	90 degrees W

Plate 9

Location:	0.75 miles southeast of Chelsea Landing to Boardley
Major River:	Mattaponi
Total Shoreline Miles:	3.91
Shoreline Miles Surveyed:	3.91
Survey Date(s):	8/5/98
Plate Rotation:	90 degrees W

Plate 10

Location:	**Boardley and around Gleason Marsh**
Major River:	**Mattaponi**
Total Shoreline Miles:	**4.73**
Shoreline Miles Surveyed:	**4.73**
Survey Date(s):	**7/9/98 and 8/5/98**
Plate Rotation:	**90 degrees W**

Plate 11

Location:	0.75 miles southeast of Mitchell Hill Creek to Log Landing
Major River:	Mattaponi
Total Shoreline Miles:	8.39
Shoreline Miles Surveyed:	4.14
Survey Date(s):	7/9/98
Plate Rotation:	0 degrees

Plate 12

Location:	Log Landing to De Farges Bar
Major River:	Mattaponi
Total Shoreline Miles:	9.86
Shoreline Miles Surveyed:	3.59
Survey Date(s):	7/9/98
Plate Rotation:	16 degrees W

Plate 13

Location:	De Farges Bar to Rickahock
Major River:	Mattaponi
Total Shoreline Miles:	8.61
Shoreline Miles Surveyed:	3.5
Survey Date(s):	7/9/98
Plate Rotation:	46 degrees W

Plate 14

Location:	Rickahock to west of Walkerton
Major River:	Mattaponi
Total Shoreline Miles:	8.33
Shoreline Miles Surveyed:	3.51
Survey Date(s):	7/9/98
Plate Rotation:	46 degrees W

Plate 15

Location:	0.6 miles west of Walkerton to Line Tree Bar
Major River:	Mattaponi
Total Shoreline Miles:	4.84
Shoreline Miles Surveyed:	2.91
Survey Date(s):	7/8/98
Plate Rotation:	46 degrees W

Plate 16

Location:	Line Tree Bar to Cape Charlie
Major River:	Mattaponi
Total Shoreline Miles:	6.92
Shoreline Miles Surveyed:	5.84
Survey Date(s):	7/8/98
Plate Rotation:	90 degrees W

Plate 17

Location:	Cape Charlie into headwaters of river
Major River:	Mattaponi
Total Shoreline Miles:	6.91
Shoreline Miles Surveyed:	6.8
Survey Date(s):	7/8/98 and 8/6/98
Plate Rotation:	90 degrees W

Plate 18

Location:	Headwaters of river
Major River:	Mattaponi
Total Shoreline Miles:	3.95
Shoreline Miles Surveyed:	3.95
Survey Date(s):	8/6/98
Plate Rotation:	90 degrees W

Plate 19

Location:	Headwaters of river
Major River:	Mattaponi
Total Shoreline Miles:	6.55
Shoreline Miles Surveyed:	6.35
Survey Date(s):	8/6/98
Plate Rotation:	61 degrees W

Mattaponi River, photo by James P. Blair

Glossary of Shoreline Features Defined

Bare - Land use defined as bare includes areas void of any vegetation or obvious land use. Bare areas include those which have been cleared for construction.

Beaches - Beaches are sandy shores which are subaerial during mean high water. These features can be thick and persistent, or very thin lenses of sand.

Boat house - A boathouse is considered any covered structure alongside a dock or pier built to cover a boat. They include true "houses" for boats with roof and siding, as well as awnings which offer only overhead protection. Since nearly all boat houses have adjoining piers, piers are not surveyed separately, but are assumed. Boat houses may be difficult to see in aerial photography. On the maps they are denoted with a blue triangle.
Boat Ramp - Boat ramps provide vessels access to the waterway. They are usually constructed of concrete, but wood and gravel ramps are also found. Point identification of boat ramps does not discriminate based on type, size, material, or quality of the launch. Access at these sites is not guaranteed, as many may be located on private property. The location of these ramps was determined from static ten second GPS observations. Ramps are illustrated as purple squares on the maps.

Breakwaters - Breakwaters are structures which sit parallel to the shore, and generally occur in a series along the shore. Their purpose is to attenuate and deflect incoming wave energy, protecting the fastland behind the structure. In doing so, a beach may naturally accrete behind the structures if sediment is available. A beach nourishment program is frequently part of the construction plan.

The position of the breakwater offshore, the number of breakwaters in a series, and their length depends on the size of the beach which must be maintained for shoreline protection. Most breakwater systems sit with the top at or near MHW and are partially exposed during low water. Breakwaters can be composed of a variety of materials. Large rock breakwaters, or breakwaters constructed of gabion baskets filled with smaller stone are popular today. Breakwaters are not easily observed from aerial imagery. However, the symmetrical cuspate sand bodies which may accumulate behind the structures can be. In this survey, individual breakwaters are not mapped. The first and last breakwater in the series are surveyed as a ten-second static GPS observation. The system is delineated on the maps as a line paralleling the linear extent of the breakwater series along the shore.

Bulkhead - Bulkheads are traditionally treated wood or steel "walls" constructed to offer protection from wave attack. More recently, plastics are being used in the construction. Bulkheads are vertical structures built slightly seaward of the problem area and backfilled with suitable fill material. They function like a retaining wall, as they are designed to retain upland soil, and prevent erosion of the bank from impinging waves. The recent proliferation of vertical concrete cylinders, stacked side by side along an eroding stretch of shore offer similar level of protection as bulkheads, and include some of the same considerations for placement and success. These structures are also included in the bulkhead inventory.

Bulkheads are found in all types of environments, but they perform best in low to moderate energy conditions. Under high energy situations, the erosive power of reflective waves off bulkheads can scour material from the base, and cause eventual failure of the structure.

Bulkheads are common along residential and commercially developed shores. From aerial photography, long stretches of bulkheaded shoreline may be observed as an unnaturally straight or angular coast. In this inventory, they are mapped using kinematic GPS techniques. The data are displayed as linear features on the maps.

Commercial - Commercial zones include small commercial operations and larger industrial facilities. These operations are not necessarily water dependent businesses.

Dock/Pier - In this survey, a dock or pier is a structure, generally constructed of wood, which is built perpendicular or parallel to the shore. These are typical on private property, particularly residential areas. They provide access to the water, usually for recreational purposes. Docks and piers are mapped as point features on the shore. Pier length is not surveyed. In the map compositions, docks are denoted by a small green dot. Depending on resolution, docks can be observed in aerial imagery, and may be seen in the maps if the structure was built prior to 1994, when the photography was taken.

Mattaponi River, photo by James P. Blair

Forest Land Use - Forest cover includes deciduous, evergreen, and mixed forest stands greater than 18 feet high. The riparian zone is classified as forested if the tree stand extends at least 33 feet inland of the seaward limit of the riparian zone.

Grass - Grass lands include large unmanaged fields, managed grasslands adjacent to large estates, agriculture tracts reserved for pasture, and cultivated fields.

Groinfield - Groins are low profile structures that sit perpendicular to the shore. They are generally positioned at, or slightly above, the mean low water line. They can be constructed of rock, timber, or concrete. They are frequently set in a series known as a groinfield, which may extend along a stretch of shoreline for some distance.

The purpose of a groin is to trap sediment moving along shore in the littoral current. Sediment is deposited on the updrift side of the structure and can, when sufficient sediment is available in the system, accrete a small beach area. Some fields are nourished immediately after construction with suitable beach fill material. This approach does not deplete the longshore sediment supply, and offers immediate protection to the fastland behind the system.

For groins to be effective there needs to be a regular supply of sediment in the littoral system. In sediment starved areas, groin fields will not be particularly effective. In addition they can accelerate erosion on the downdrift side of the groin. The design of "low profile" groins was intended to allow some sediment to pass over the structure during intermediate and high tide stages, reducing the risk of down drift erosion.

From aerial imagery, most groins cannot be observed. However, effective groin fields appear as asymmetrical cusps where sediment has accumulated on the updrift side of the groin. The direction of net sediment drift is also evident.

This inventory does not delineate individual groins. In the field, the first and last groin of a series is surveyed. Others between them are assumed to be evenly spaced. On the map composition, the groin field is designated as a linear feature extending along the shore.

Marina - Marinas are denoted as line features in this survey. They are a collection of docks and wharfs which can extend along an appreciable length of shore. Frequently they are associated with extensive bulkheading. Structures associated with a marina are not identified individually. This means any docks, wharfs, and bulkheads would not be delineated separately. Marinas are generally commercial operations. Community docks offering slips and launches for community residents are becoming more popular. They are usually smaller in scale than a commercial operation. To distinguish these facilities from commercial marinas, the riparian land use map (Plate A) will denote the use of the land at the site as residential for a community facility, rather than commercial.

Marshes - Marshes can be extensive embayed marshes, or narrow, fragmented fringe marshes. The vegetation must be relatively well established, although not necessarily healthy.

Miscellaneous - Miscellaneous point features represent short isolated segments along the shore where material has been dumped to protect a section of shore undergoing chronic erosion. Longer sections of shore are illustrated as line features. They can include tires, bricks, broken concrete rubble, and railroad ties as examples.

Residential - Residential zones include rural and suburban size plots, as well as multi-family dwellings.

Riprap - Generally composed of large rock to withstand wave energy, riprap revetments are constructed along shores to protect eroding fastland. Revetments today are preferred to bulkhead construction. They reduce wave reflection which causes scouring at the base of the structure, and are known to provide some habitat for aquatic and terrestrial species. Most revetments are constructed with a fine mesh filter cloth placed between the ground and the rock. The filter cloth permits water to permeate through, but prevents sediment behind the cloth from being removed, and causing the rock to settle. Revetments can be massive structures, extending along extensive stretches of shore, and up graded banks. When a bulkhead fails, riprap is often placed at the base for protection, rather than a bulkhead replacement. Riprap is also used to protect the edge of an eroding marsh. This use is known as toe protection. This inventory does not distinguish among the various types of revetments.

Riprap revetments are popular along residential waterfront as a mechanism for stabilizing banks. Along commercial or industrial waterfront development such as marinas, bulkheads are still more common since they provide a facility along which a vessel can dock securely.

Riprap is mapped as a linear feature using kinematic GPS data collection techniques. The maps illustrate riprap as a linear feature along the shore.

Scrub-shrub - Scrub-shrub zones include trees less than 18 feet high, and is usually dominated by shrubs and bushy plants.

Walkerton, photo by Dwight Dyke

References

Anderson, G.L., Williams, G.B., Peoples, M.H., and L. Weishar, 1976. Shoreline Situation Report - Gloucester County, Virginia. Special Report in Applied Marine Science and Ocean Engineering No. 83, Virginia Institute of Marine Science, Gloucester Point, VA, 71 pp.

Byrne, R.J. and G.L. Anderson, 1978. Shoreline Erosion in Tidewater Virginia. Special Report in Applied Marine Science and Ocean Engineering No. 111, Virginia Institute of Marine Science, Gloucester Point, VA, 102 pp.

Hardaway, C.S., Thomas, G.R., Glover, J.B., Smithson, J.B., Berman, M.R., and A.K. Kenne, 1992. Bank Erosion Study. Special Report in Applied Marine Science and Ocean Engineering No. 319, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA, 73 pp.

Hobbs, C.H., III, Owen, D.W., and L.C. Morgan, 1979. Summary of Shoreline Situation Reports for Virginia's Tidewater Localities. Special Report in Applied Marine Science and Ocean Engineering No. 209, Virginia Institute of Marine Science, Gloucester Point, VA, 32 pp.

Hobbs, C.H., III, Peoples, M.A., Anderson, G.L., and Peter Rosen, 1975. Shoreline Situation Report - New Kent, King William, and King and Queen Counties, Virginia. Special Report in Applied Marine Science and Ocean Engineering No. 44, Virginia Institute of Marine Science, Gloucester Point, VA, 89 pp.

Ibison, N.A., Baumer, J.C., Hill, C.L., Burger, N.H., and J.E. Frye, 1992. Eroding bank nutrient verification study for the lower Chesapeake Bay. Department of Conservation and Recreation, Division of Soil and Water Conservation, Shoreline Programs Bureau, Gloucester Point, VA.

King and Queen County Planning Commission, 1994. King and Queen County Virginia - Comprehensive Plan.

Whitcomb, N.J., Patton, M.A., Peoples, M.H., Anderson, G.L., and C.H. Hobbs III, 1975. Shoreline Situation Report - Middlesex County, Virginia. Special Report in Applied Marine Science and Ocean Engineering No. 100, Virginia Institute of Marine Science, Gloucester Point, VA, 65 pp.

Walkerton, photo by Dwight Dyke