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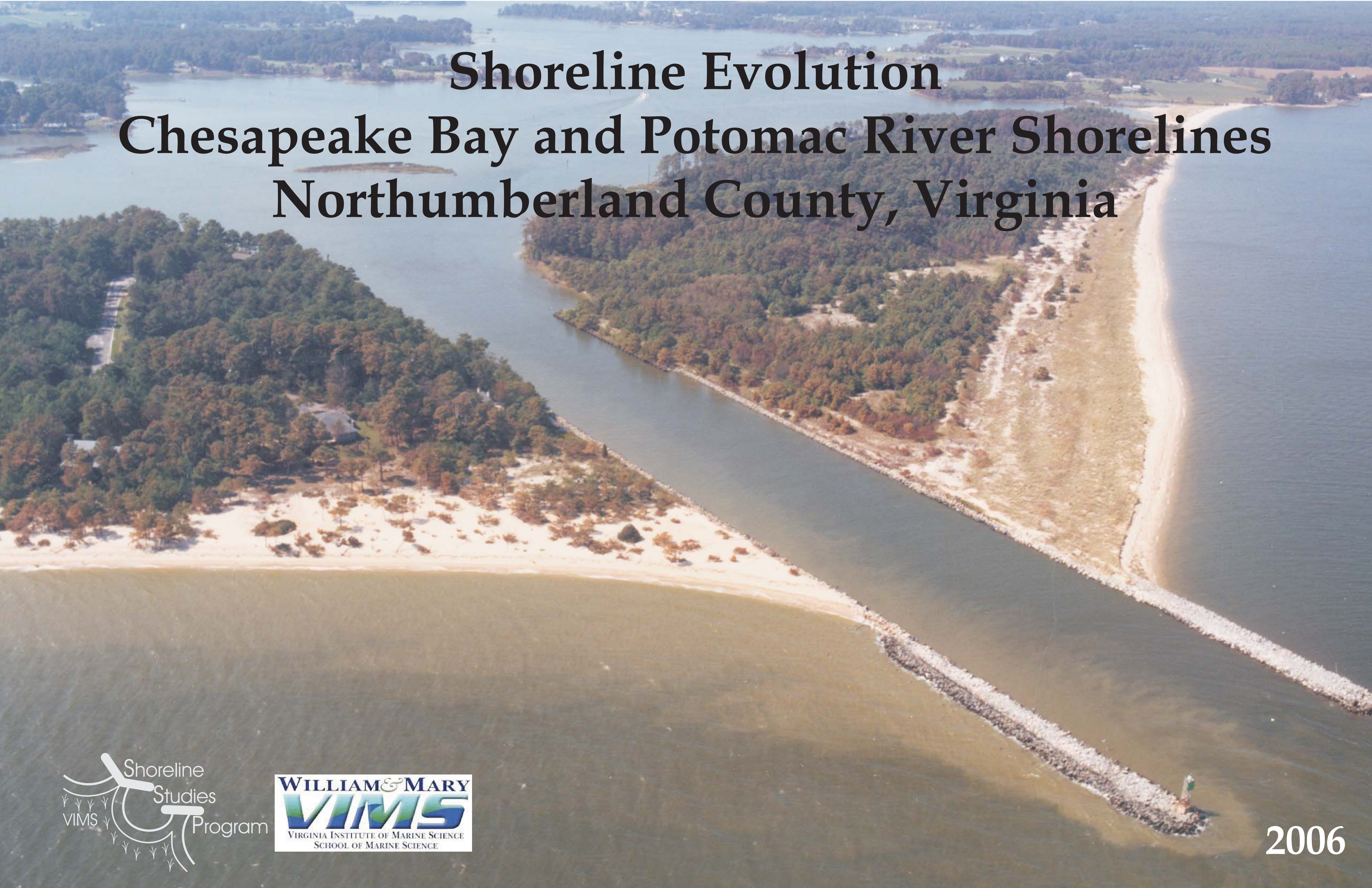

Shoreline Studies Program
VIMS

WILLIAM & MARY
VIMS
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

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Shoreline Evolution
Chesapeake Bay and Potomac River Shorelines
Northumberland County, Virginia

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Cover Photo: Photograph of Smith Point jetties and the Little Wicomico River. Photo taken by Shoreline Studies Program on 25 September 2003 .

I. INTRODUCTION

A. General Information

Shoreline evolution is the change in shore position through time. In fact, it is the material resistance of the coastal geologic underpinnings against the impinging hydrodynamic (and aerodynamic) forces. Along the shores of Chesapeake Bay, it is a process-response system. The processes at work include winds, waves, tides and currents, which shape and modify coastlines by eroding, transporting and depositing sediments. The shore line is commonly plotted and measured to provide a rate of change but it is as important to understand the geomorphic patterns of change. Shore analysis provides the basis to know how a particular coast has changed through time and how it might proceed in the future.

The purpose of this report is to document how dunes on the Potomac River and Chesapeake Bay shores of Northumberland (Figure 1) has evolved since 1937. Aerial imagery was taken for most of the Bay region beginning that year, and it is this imagery that allows one to assess the geomorphic nature of shore change. Aerial imagery shows how the coast has changed, how beaches, dunes, bars, and spits have grown or decayed, how barriers have breached, how inlets have changed course, and how one shore type has displaced another or has not changed at all. Shore change is a natural process but, quite often, the impacts of man through shore hardening or inlet stabilization come to dominate a given shore reach. Most of the change in shore positions will be quantified in this report. Others, particularly very irregular coasts, around inlets, and other complicated areas will be subject to interpretation.

B. Chesapeake Bay Dunes

The primary reason for developing this Shoreline Evolution report is to be able to determine how dunes and beaches along the River and Bay coasts of Northumberland have and will evolve through time. The premise is that, in order to determine future trends of these important shore features, one must understand how they got to their present state. Beaches and dunes are protected by the Coastal Primary Sand Dune Protection Act of 1980 (Act)[1]. Research by Hardaway *et al.* (2001) located, classified and enumerated jurisdictional dunes and dune fields within the eight localities listed in the Act. These include the counties of Accomack, Lancaster, Mathews, Northampton and Northumberland and the cities of Hampton, Norfolk and Virginia Beach (Figure 2). Only Chesapeake Bay and river sites were considered in that study.

In 2003, Hardaway *et al*. created the Northumberland County Dune Inventory. That report detailed the location and nature of the jurisdictional primary dunes along the Bay shore of Northumberland and those results appear in Appendix B. For this study, the positions of the dune sites are presented using the latest imagery in order to see how the sites sit in the context of past shoreline positions. The dune location information has not been field verified since the original visits in 1999. This information is not intended to be used for jurisdictional determinations regarding dunes.

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[1]The General Assembly of Virginia enacted the Coastal Primary Sand Dune Protection Act (the Dune Act) in 1980. The Dune Act was originally codified in § 62.1-13.21 to -13.28. The Dune Act is now recodified as Coastal Primary Sand Dunes and Beaches in § 28.2-1400 to -1420.

II. SHORE SETTING

A. Physical Setting

The Potomac River and Chesapeake Bay shoreline of Northumberland County extends from the county line with Westmoreland at the Yeocomico River down river to Smith Point and southward to the Lancaster County line at Indian Creek. This includes about 17 miles of tidal shoreline along the Potomac River and 18 miles along Chesapeake Bay. Additional shoreline is included in the tributaries. Historic shore erosion rates vary from 0 ft/yr to over 7 ft/yr along the Bay coast with several areas of localized accretion. The Potomac River shoreline change rates varied between +1 ft/yr to -10 ft/yr (Byrne and Anderson, 1978).

The coastal geomorphology of the County is a function of the underlying geology and the hydrodynamic forces operating across the land/water interface, the shoreline. The Chesapeake Bay and Potomac River coasts of Northumberland are almost exclusively Upper Pliestocene undifferentiated members of the Tabb Formation. Several areas of Holocene beach sands and muds occur along the Chesapeake Bay shore (Figure 3). The Atlantic Ocean has come and gone numerous times over the Virginia coastal plain over the past million years or so. The effect has been to rework older deposits into beach and lagoonal deposits at time of the transgressions. The last low stand found the ocean coast about 60 miles to the east when sea level about 300 feet lower than today and the coastal plain was broad and low. The current estuarine system was a meandering series of rivers working their way to the coast. About 15,000 years ago, sea level began to rise and the coastal plain watersheds began to flood. Shorelines began to recede. The slow rise in sea level is one of two primary long-term processes which cause the shoreline to recede; the other is wave action, particularly during storms. As shorelines recede or erode, the bank material provides the sands for the offshore bars, beaches and dunes. Parts of Northumberland's littoral system is sand rich from erosion over time of the sandy, sometimes high, upland banks and the nearshore substrate. Many sand beaches occur along the coast and an extensive system of offshore sand bars exist along both the Potomac and Chesapeake shores. These sand bars greatly influenced and are themselves influenced by the impinging wave climate.

Sea level is continuing to rise in Chesapeake Bay. Tide data collected at Sewells Point in Norfolk show that sea level has risen 4.42 mm/yr (0.17 inches/yr) or 1.45 ft/century (http://www.co-ops.nos.noaa.gov/). Lewisetta on the Potomac River in Northumberland County rose 4.85 mm/yr or 1.59 ft/century. Increased water levels directly effect the reach of storms and their impact on shorelines. Anecdotal evidence of storm surge during Hurricane Isabel, which impacted North Carolina and Virginia on September 18, 2003, put it on par with the storm surge from the "storm of the century" which impacted the lower Chesapeake Bay in August 1933. Boon (2003) showed that even though the tides during the storms were very similar, the difference being only 4 cm (~0.5 in), the amount of surge was different. The 1933 storm produced a storm surge that was greater than Isabel's by slightly more than a foot. However, analysis of the mean water levels for the months of both August 1933 and September 2003 showed that sea level has risen by 41 cm (1.35 ft) at Hampton Roads in the seventy years between these two storms (Boon, 2003). This is the approximate time span between our earliest aerial imagery (1937) and our most recent (2002), which means the impact of sea level rise to shore change is significant. The beaches, dunes, and nearshore sand bars try to keep pace with the rising sea levels.

Four shore reaches are considered in this report along the shoreline of Northumberland (Figure 4). Reach I extends along the Yeocomico River and Potomac River from the boundary with Westmoreland County to Lewisetta. Reach II goes from the Coan River to the jetties at Smith Point. Reach III picks up at the jetties and heads south to the Wicomico River. Reach IV occurs on Chesapeake Bay from the Wicomico River to the boundary with Lancaster County at Indian Creek.

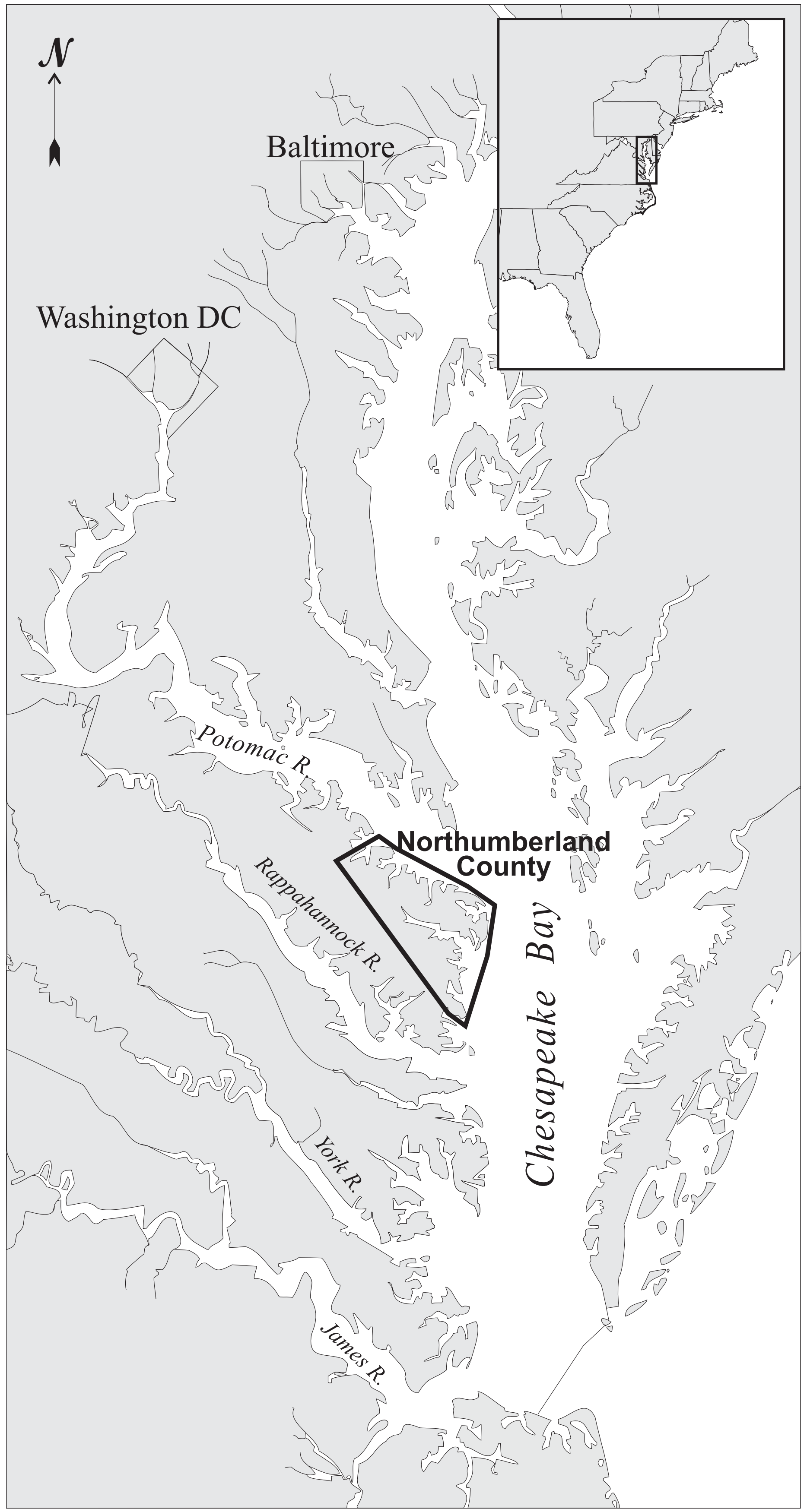

Figure 1. Location of Northumberland County within the Chesapeake Bay estuarine system.

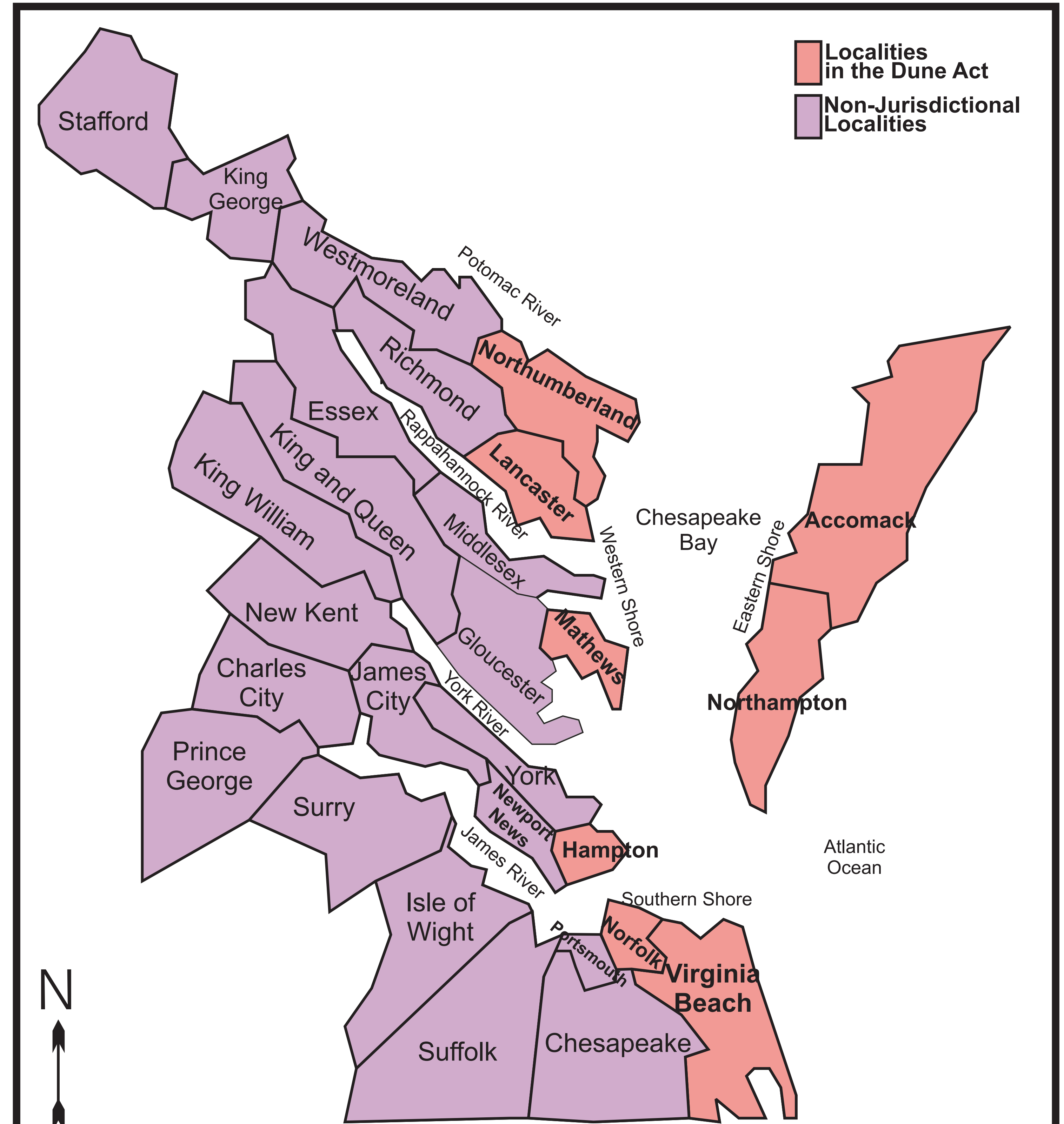

Figure 2. Location of localities in the Dune Act with jurisdictional and non-jurisdictional localities noted.

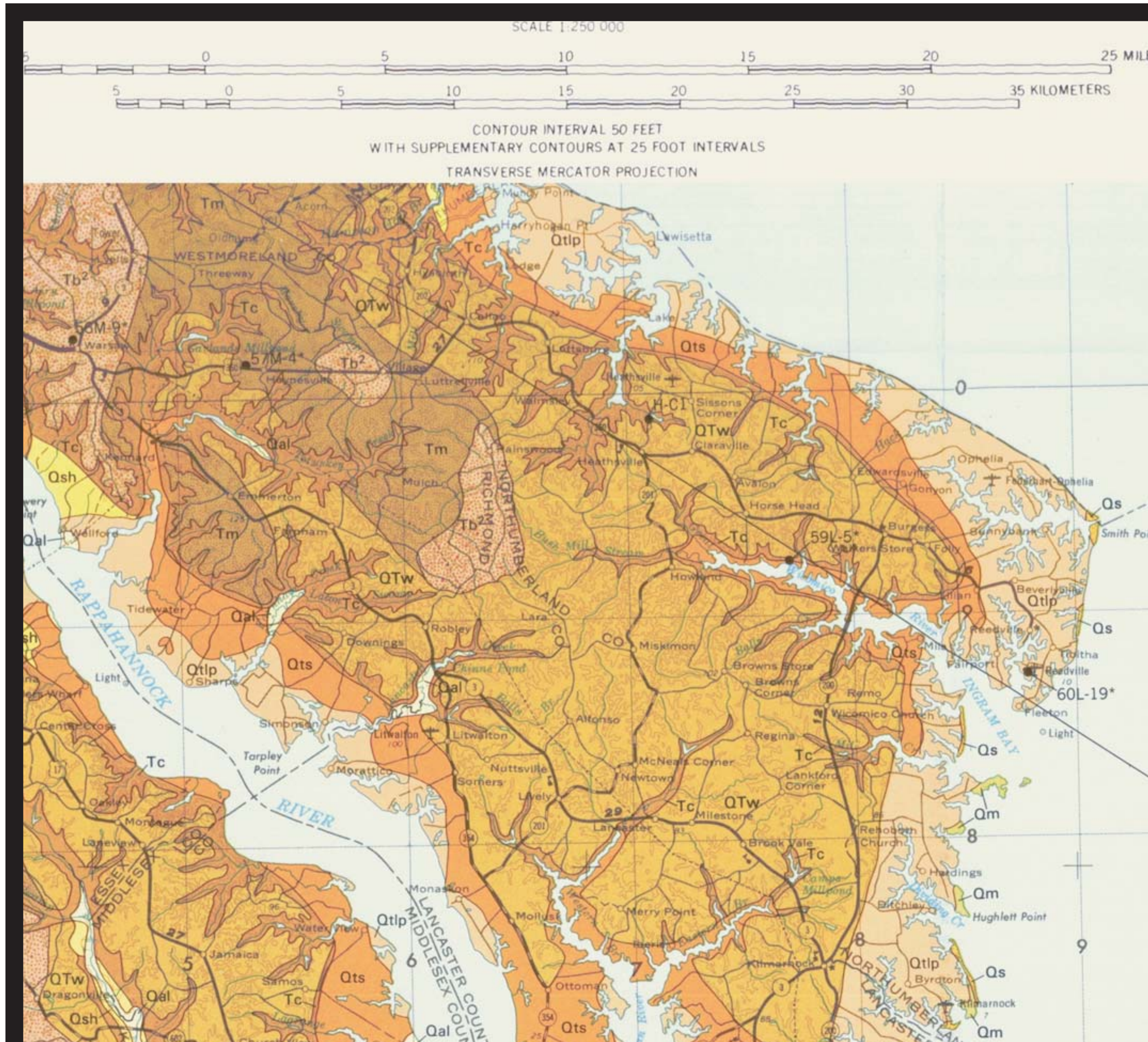

Figure 3. Geologic map of Northumberland County (from Mixon *et al*., 1989).

Qm **Holocene Soft Mud** - Medium to dark-gray, and peat, grayish brown. Comprises sediment of marshes in coastal areas and Chesapeake Bay. Thickness is 0-10 ft.

Qs **Holocene Sand** - Pale gray to light-yellowish gray, fine to coarse, poorly sorted to well sorted, shelly in part; contains angular to rounded fragments and whole valves of mollusks. Comprises deposits of coastal barrier islands and narrow beach-dune ridges bordering brackish-water marshes of Chesapeake Bay. As much as 40 ft in thickness.

Qtlp **Lynnhaven and Poquoson Members, undifferentiated (Upper Pleistocene)**.

Qts **Sedgefield Member (Upper Pleistocene)** - Pebbly to bouldery, clayey sand and fine to medium, shelly sand grading upward to sandy and clayey silt; locally, channel fill at base of unit includes as much as 50 ft of fine to coarse, crossbedded sand and clayey silt and peat containing in situ tree stumps. Sandy bay facies commonly contains Crassostrea biostromes, Mercenaria, Anadara, Polynices, Ensis, and other mollusks. Specimes of the coral Astrangia have yielded estimated uranium-series ages averaging 71,000 +/- 7,000 yrs B.P. (Mixon and others, 1982). Unit constitutes surficial deposit of river- and coast-parallel plains (alt. 20-30 ft) bounded on landward side by Suffolk and Harpersville scarps. Thickness is 0-50 ft.

Qsh **Shirley Formation (middle Pleistocene)** - Light-to dark-gray and brown sand, gravel, silt, clay, and peat. Constitutes surficial deposits of riverine terraces and relict baymouth barriers and bay-floor plains (alt. 35-45 ft) inset below depositional surfaces of the Chuckatuck Formation (Johnson and Peebles, 1984). Upper part of unit is truncated on the east by the Suffolk and Harpersville scarps; locally, lower part extends east of scarps. Fluvial-estuarine facies comprises (1) a lower pebble to boulder sand overlain by (2) fine to coarse sand interbedded with peat and clayey silt rich in organic material, including in situ tree stumps and leaves and seeds of cypress, oak, and hickory, which grades upward to (3) medium- to thick-bedded, clayey and sandy silt and silty clay. Marginal-marine facies in lower James River and lowermost Rappahannock River areas is silty fine sand and sandy silt containing *Crassostrea virginica*, *Mulinia*, *Noetia*, *Mercenaria*, and other mollusks. *Astrangia* from lower Rappahannock River area has yielded a uranium-series age of 184,000 +/- 20,000 years B.P. (Mixon and other, 1982). Thickness is 0-80 ft.

QTw **Windsor Formation (lower Pleistocene or upper Pliocene) -** Gray and yellow to reddish-brown sand, gravel, silt, and clay. Constitutes surficial deposits if extensive plain (alt. 85-95 ft) seaward of Surry scarp and coeval, fluvial-estuarine terrace west of scarp. Fining-upward sequence beneath plain consists of basal pebbly sand grading upward into crossbedded, quartzose Sand and massive, clayey silt and silty clay; lower and upper parts of sequence were deposited, repectively, in shallow-marine or open-bay and restricted-bay or lagoonal environments. In terraces west of Surry scarp, fluvial-estuarine deposit comprise muddy, coarse, trough-crossbedded sand and gravel grading upward to sandy silt and clay. Unit is 0-40 ft thick.

Tc **Chesapeake Group (upper Pliocene to lower Miocene) -** Fine to coarse, quartzose sand, silt, and clay; variably shelly and diatomaceous, deposited mainly in shallow, inner- and middle-shelf waters. Ages of units based in studies of foraminiferal, nannofossil, diatom, and molluscan assemblages in Virginia and adjacent states (Andrews, 1988; Gibson, 1983; Gibson and others, 1980; Poag, 1989; Ward and Blackwelder, 1980; Ward and Krafft, 1984), Includes the following formations (see also sheet 2, figure 1), from youngest to oldest; Chowan River Formation (upper Pliocene), Yorktown Formation (lower upper and lower Pliocene), Eastover Formation (upper Miocene), St. Mary's Formation (upper and middle Miocene), Choptank Formation (middle Miocene), and Calvert Formation (middle and lower Miocene).

Tm **Moorings unit of Oaks and Coch (1973) (upper Pliocene) -** White, light-gray, and grayish-yellow quartzose sand and gray to grayish-brown clayed silt and silty clay. Constitutes discontinuous linear body along and just west of Surry scrap; depositional surfaces range in altitude from 130 ft along slightly higher, ridge-like topography at scarp to about 110 ft west of scarp. Eastern facies of unit is unfossiliferous, massive to cross-laminated, moderately well-sorted, fine sand believed to have been deposited in beach and near shore environments. Upper part of fine sand facies interfingers westward with massive, bioturbated clay and slit deposited in a lagoon or shallow bay. Unit is as much as 30 ft thick.

Tb¹ Tb² **Bacons Castle Formation (upper Pliocene) -** Gray, yellowish-orange, and reddish-brown sand, gravel, silt, and clay; Constitutes surficial deposits of high plain extending from Richmond, VA., Eastward to Surry Scrap. Unit is subdivided into two members: Tb^1 and Tb^2. Tb^2 predominantly thin-bedded and laminated clayey silt and silty fine sand. TB^2 is characterized by flaser, wayy, and lenticular bedding and rare to common clay-lined burrows including *Ophiomorpha nodosa.* Unit is 0-70 ft thick.

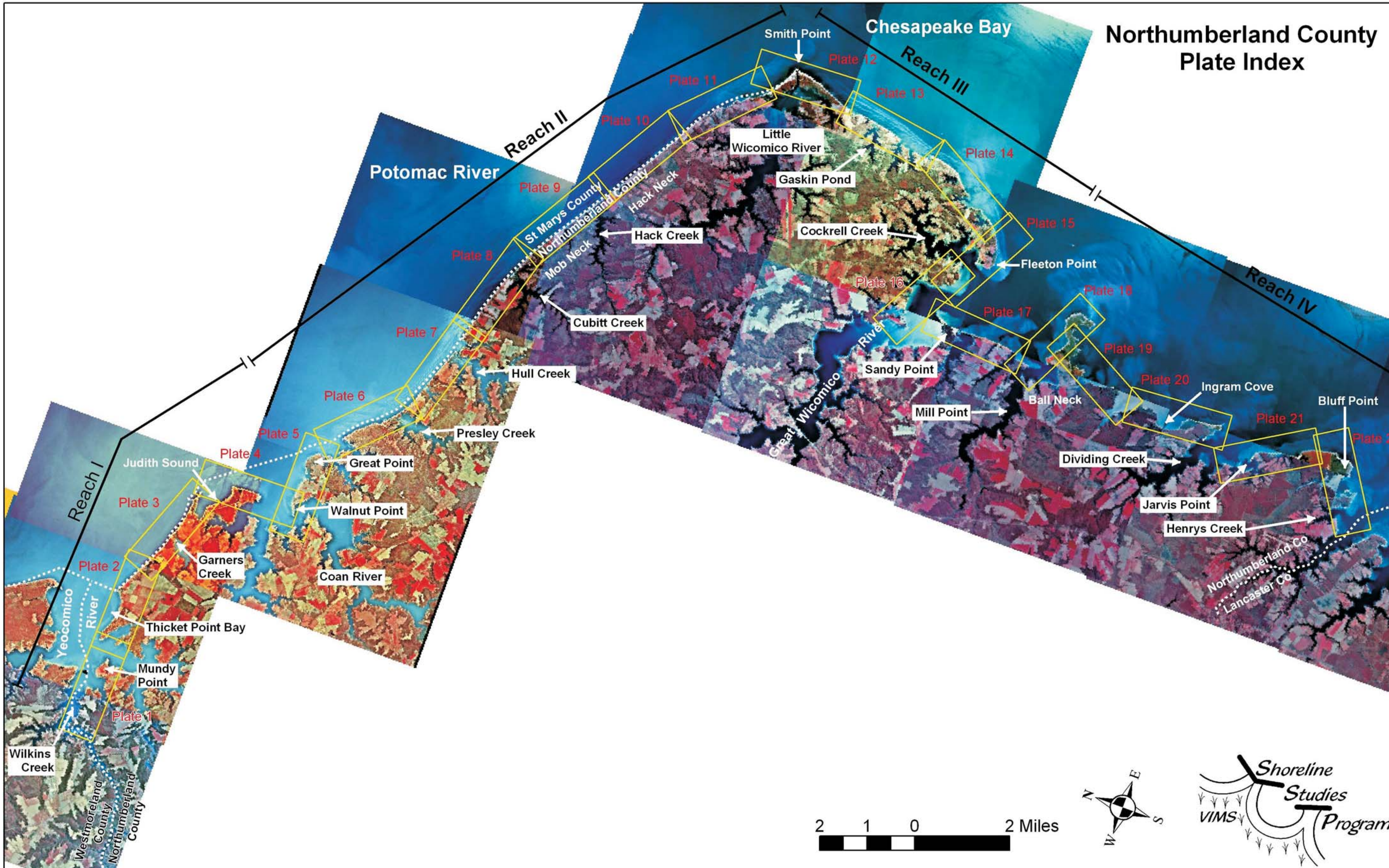

Figure 4. Index of shoreline plates.

B. Hydrodynamic Setting

Mean tide range along the upper Potomac River coast of Northumberland is about 1.2 ft (1983-2001 Tidal Epoch at Lewisetta). Spring tide range is 1.5 ft. The Chesapeake Bay shoreline in Northumberland has similar tide ranges. The wind/wave climate impacting the Northumberland Bay coast is defined by large fetch exposures to the northeast, east, and spoutheast across Chesapeake Bay and fetch exposures to the northwest, north, and northeast along Potomac River. Wind data from Quantico Marine Corps Base upriver reflect the frequency and speeds of wind occurrences from 1973 to 2001 (Table 1) which characterize the locally-generated Bay waves.

Northeasters are particularly significant in terms of the impacts of storm surge and waves on beach and dune erosion. Hurricanes, depending on their proximity and path can also have an impact to the Virginia Beach coast. On September 18, 2003, Hurricane Isabel passed through the Virginia coastal plain. The main damaging winds began from the north and shifted to the east then south. Beach erosion and dune scarping were significant but areas with wide beaches offered more protection to the adjacent dunes.

Table 1. Summary wind conditions at Quantico Marine Corps Base from 1973-2001.

		WIND DIRECTION								
Wind Speed (mph)	**Mid Range (mph)**	**North**	**North east**	**East**	**South east**	**South**	**South west**	**West**	**North west**	**Total**
< 5	3	5703* 3.21+	3330 1.87	3868 2.18	4792 2.70	12257 6.90	4291 2.42	7070 3.98	15437 8.69	56748 31.95
5-11	8	17454 9.82	10087 5.68	6504 3.66	8117 4.57	22593 12.72	8515 4.79	13391 7.54	18453 10.39	105114 59.17
11-21	16	3698 2.08	1460 0.82	386 0.22	517 0.29	2030 1.14	1156 0.65	1129 0.64	4601 2.59	14977 8.43
21-31	26	165 0.09	64 0.04	34 0.02	21 0.01	60 0.03	64 0.04	102 0.06	274 0.15	784 0.44
31-41	36	7 0	1 0	2 0	0 0	1 0	1 0	7 0	7 0	26 0.01
41-50	46	0 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0	1 0
>50		1 0	3 0	3 0	3 0	4 0	0 0	7 0	5 0	26 0.01
Total		27028 15.20	14945 8.41	10797 6.08	13450 7.57	36946 20.79	14027 7.9	21706 12.22	38777 21.82	177676 100.00

*Number of occurrences +Percent

III. METHODS

A. Photo Rectification and Shoreline Digitizing

Recent and historic aerial photography was used to estimate, observe, and analyze past shoreline positions and trends involving shore evolution for Northumberland. Some of the photographs were available in fully geographically referenced (georeferenced) digital form, but most were scanned and orthorectified for this project.

Aerial photos from VIMS Shoreline Studies and Submerged Aquatic Vegetation (SAV) Programs, as well as from United States Geological Survey (USGS) archives were acquired. The years used for the shoreline change analysis included 1937, 1953, 1969, 1994, and 2002. Color aerials were obtained for 1994 and 2002. The 1994 imagery was processed and mosaicked by USGS, while the imagery from 2002 was mosaicked by the Virginia Base Mapping Program (VBMP). The aerial photography for the remaining years were mosaicked by the VIMS Shoreline Study Program.

The images were scanned as tiffs at 600 dpi and converted to ERDAS IMAGINE (.img) format. They were orthorectified to a reference mosaic, the 1994 Digital Orthophoto Quarterquadrangles (DOQQ) from USGS. The original DOQQs were in MrSid format but were converted into .img format as well. ERDAS Orthobase image processing software was used to orthographically correct the individual flightlines using a bundle block solution. Camera lens calibration data was matched to the image location of fiducial points to define the interior camera model. Control points from 1994 USGS DOQQ images provide the exterior control, which is enhanced by a large number of image-matching tie points produced automatically by the software. A minimum of four ground control points were used per image, allowing two points per overlap area. The exterior and interior models were combined with a 30-meter resolution digital elevation model (DEM) from the USGS National Elevation Dataset (NED) to produce an orthophoto for each aerial photograph. The orthophotographs that cover each USGS 7.5 minute quadrangle area were adjusted to approximately uniform brightness and contrast and were mosaicked together using the ERDAS Imagine mosaic tool to produce a one-meter resolution mosaic also in an .img format.

To maintain an accurate match with the reference images, it was necessary to distribute the control points evenly. This can be challenging in areas with little development. Good examples of control points are permanent features such as manmade features and stable natural landmarks. The maximum root mean square (RMS) error allowed is 3 for each block.

Once the aerial photos were orthorectified and mosaicked, the shorelines were digitized in ArcMap with the mosaics in the background to help delineate and locate the shoreline. For Northumberland's coast, an approximation to mean low water (MLW) was digitized. This often was defined as the "wetted perimeter" on the beach sand as the last high water location. In areas where the shoreline was not clearly delineated on the aerial photography, the location was estimated based on the experience of the digitizer. Digitizing the shoreline brings in, perhaps, the greatest amount of potential error because of the problems of image clarity and definition of shore features. A series of Northumberland dune site profiles are displayed in Figure 5 which shows beach/dune variability. Figure 6 shows the relationship of MHW, MLW and beach/dune system components.

B. Rate of Change Analysis

A custom Arcview extension called "shoreline" was used to analyze shoreline rate of change. A straight, approximately shore parallel baseline is drawn landward of the shoreline. The extension creates equally-spaced transects along the baseline and calculates distance from the baseline at that location to each year's shoreline. The output from the extension are perpendicular transects of a length and interval specified by the user. The extension provides the transect number, the distance from beginning baseline to each transect, and the distance from the baseline to each digitized shoreline in an attribute table. The attribute table is exported to a spreadsheet, and the distances of the digitized shoreline from the baseline are used to determine the rates of change. The rates of change are summarized as mean or average rates and standard deviations for each Plate.

It is very important to note that this extension is only useful on relatively straight shorelines. In areas that have unique shoreline morphology, such as creek mouths and spits, the data collected by this extension may not provide an accurate representation of true shoreline change. The shore change data was manually checked for accuracy. However, where the shoreline and baseline are not parallel, the rates may not give a true indication of the rate of shoreline change.

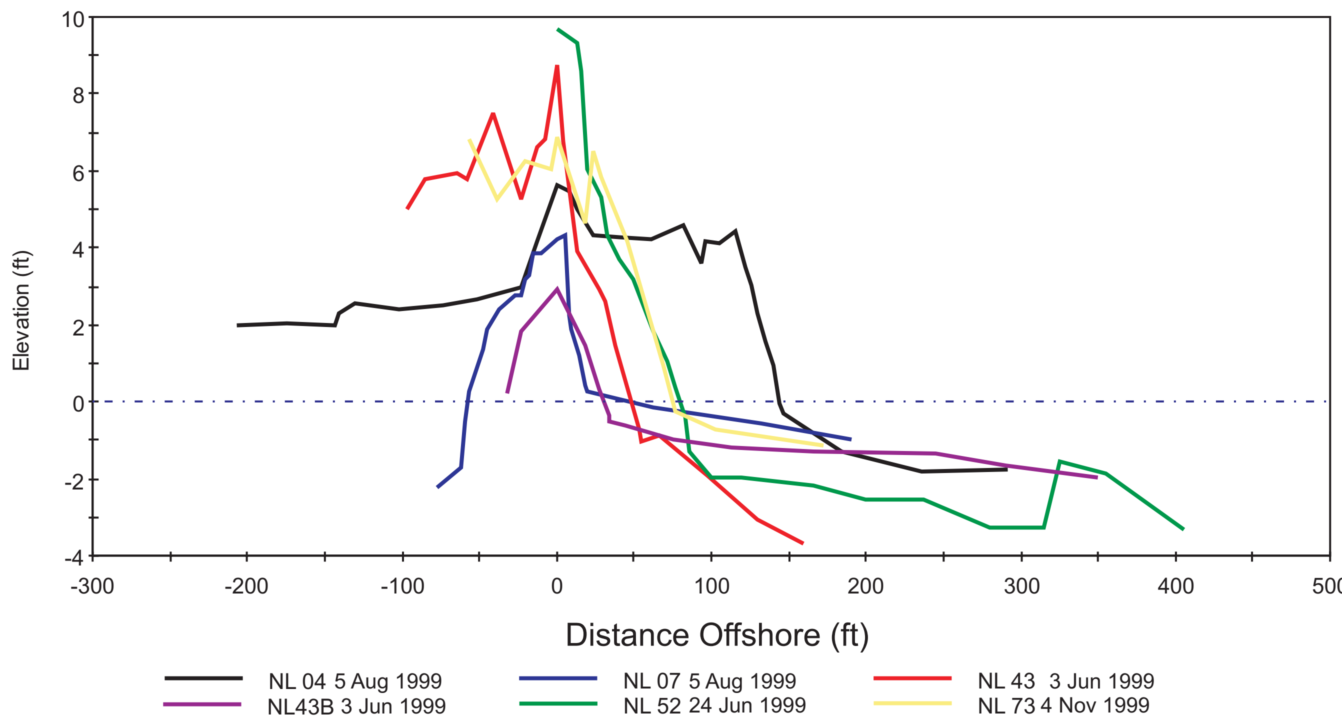

Figure 5. Variability of dune and beach profiles in Northumberland County.

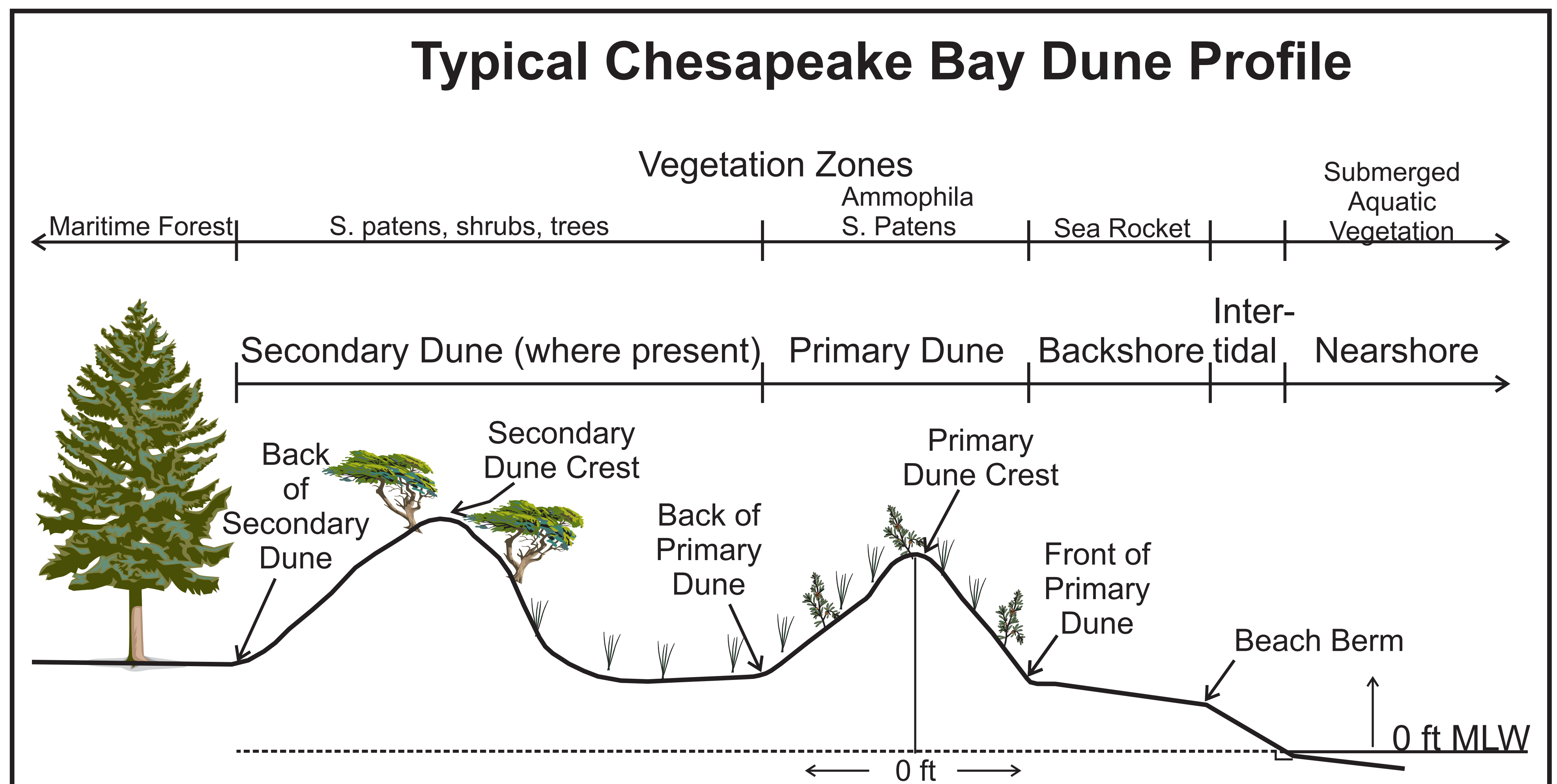

Figure 6. Typical profile of a Chesapeake Bay dune system (from Hardaway *et al.*, 2001).

IV. RESULTS

The Plates referenced in the following sections are in Appendix A. Dune locations are shown on all photo dates for reference only. Dune sites and lengths are positioned accurately on the 2002 photo. Because of changes in coastal morphology, the actual dune site might not have existed earlier. Site information tables are in Appendix B. More detailed information about Chesapeake Bay dunes and individual dune sites in Northumberland can be found in Hardaway *et al.* (2001) and Hardaway *et al.* (2003). Since much of the dune data were collected several years ago and the beach and dune systems may have changed, this report is intended as a resource for coastal zone managers and homeowners; it is not intended for use in determining legal jurisdictional limits.

A. Reach I

Reach I begins on the upriver side of the Potomac River coast at the Yeocomico River and extends downriver to Lewisetta. It includes Plates 1 through 5. Only Plate 4 has a dune site, NL78. Plate 1 shows the convoluted coast of Yeocomico River where shore change is minimal, and no erosion rate baselines were created. Plate 2 has two baselines, 2A and 2B which indicate a net long term (1937-2002) shore change rate of -1.3 and -1.1 ft/yr respectively. Long-term erosion rates of over -8 ft/yr occur at and adjacent to Thicket Point. Plate 3 has a long-term erosional trend of -2.6 ft/yr with significant recession of -5 ft/yr along the Potomac River side of the peninsula to Judith Sound.

Plate 4 highlights the Travis Point/Lewisetta Neck and dune site NL78 which can be seen evolving between two groins in the 1969 imagery. The embayment has become relatively stable. This evolution is reflected in shore change at station 500. The long-term trend for the subreach is -0.5 ft/yr. Plate 5 has no dune sites and has a significant long-term erosional trend of -7.3 ft/yr. Great Point has had some of the severest erosion along the Potomac River due to its low bank with rates greater than -25 ft/yr for the time period 1953-1969.

B. Reach II

Reach II is extends from the Coan River to Smith Point, approximately 14 miles. Most of the coast is relatively straight and is included in Plates 6 through 12. Plate 6 has dune site NL73 which can be seen forming at the mouth of Presley Creek in 1969 and has remained in place even though the inlet channel has moved upriver over the years. The overall long-term erosion rate along the Plate 6 shorelines is -2.6 ft/yr. Plate 7 also has one dune site, NL70, that has evolved over time as an erosional remnant of a once more extensive dunal spit across the mouth of Hull Creek. Average long-term erosion rates along the Plate 7 coast is -3.5 ft/yr.

Plate 8 has three dune sites, NL62, NL63, and NL67. All three sites are isolated erosional remnants of a once more extensive dune fields. Dune site NL67 resides in front of a pond that was once an intermittent drainage and is controlled by a groin field. Dune sites NL63 and NL62 are creek mouth dunes lying on either side of Cubitt Creek. The average long-term erosion rate along the Plate 8 coast is -1.4 ft/yr.

Plate 9 includes dune sites NL61, NL59, and NL58. All sites are remnants of a more extensive beach/dune system which existed in 1937. Site NL61 resides in front of Condit Pond while NL59 is controlled by a groin field that was installed in the 1970s. Site NL58 lies on a broad spit feature that crosses the mouth of Hack Creek and has a secondary dune. A few groins and a wood jetty help stabilize this site. The Plate 9 coast has a long-term erosion rate of only -0.3 ft/yr due, in part, to shore stabilization efforts.

Five dune sites exist along Plate 10 including NL55, NL54, NL52, NL51, and NL50. They are all isolated remnants of a once continuous beach/dune system. Site NL55 developed on the old (1937) flood shoal of Flag Pond. The other four have been maintained and controlled by a long groin field. Long-term average erosion rate for Plate 10 is 0.9 ft/yr, but with a high degree of variability between interim years.

Plate 11 has eight dune sites, all are located well landward from the 1937 shoreline. Shoreline evolution and intermittent shoreline hardening by bulkheads and groins created an irregular set of headlands and embayments where sand accumulated, and beaches and dunes developed. Isolated dune sites NL50, NL49, and NL48 developed within an extensive groin field that created enough backshore to allow dunes to grow. Site NL47 developed in a large shoreline offset and embayment between adjacent man-made headlands (groins) by 1969. Sites NL46 and NL45 came into being as the uplands evolved between headlands. By 1994, enough backshore had accumulated to allow dune development. Dune sites 43B and 43A developed on beach fill placed there over the years from maintenance dredging of the Little Wicomico River. Constant erosion and deposition keeps these sites very mobile. Long-term shore change is erosional at -4.1 ft/yr. Shorelines on both sides of Smith Point have been influenced by the channel jetties at the mouth of the Little Wicomico River. The dunes sites on the Potomac River shore of Plate 12, NL43A and NL43 are segments of a semi-continuos beach/dune system separated by a short wooded area. Over time, major accretion against the northwest jetty has allow these systems to evolve and are maintained, in part, by the jetty and ongoing dredging and subsequent fill at dune site NL43B (Plate 11). Net shore change has been positive along this subreach.

C. Reach III

Reach III extends from Smith Point to the Great Wicomico River and includes Plates 12, 13, 14, 15, and 16. This is a fairly continuous coast interrupted by a several small tidal creeks. It has long fetch exposures up, across, and down Chesapeake Bay to the north, east and southeast.

Reach III on Plate 12 encompasses the shoreline on the Chesapeake Bay side of Smith Point and includes dune site NL42. Shorelines on both sides of Smith Point have been influenced by the channel jetties at the mouth of the Little Wicomico River. Site NL42, on the Chesapeake Bay side of Smith Point is a long low beach/dune system that is beginning to be impacted by the northward encroaching construction of groins. The shoreline along this subreach has experienced long-term accretion near the jetties and general recession toward the south end of the plate boundary. Long-term shore change is -1.5 ft/yr.

The shoreline along the Plate 13 coast was once a continuous beach/dune system that has significantly eroded with time, breached Owens Pond and left a string of isolated dunes sites. Site NL40 has evolved on an over wash into an adjacent unnamed pond between to groin fields. Dune site NL38 has developed at the mouth of Gaskin Pond that is controlled by wood jetties. Sites NL37and NL36 developed in small, low overwashes into adjacent small ponds. Dune sites NL35, NL34, and NL33 are small isolated pockets that developed after the breach into Owens Pond and the subsequent transport of sand onto the mainland coast. The erosion rates are quite variable as a result of the breach, but the net change rate was -5.9 ft/yr.

Plate 14 includes the shorelines in and adjacent to Taskmakers Creek. Dune sites NL32, NL31, and NL30 presently occur along a long low beach/dune coast that receded into its present day location. They are separated by short areas without dune features. In 1937, a long spit protected the present dune sites from direct bay wave attack. By 1953, the spit was gone, sand entered the newly created embayment, and the foundation for the dune sites was created. The long-term shoreline change patterns are therefore complex but yield a net average of -4.2 ft for the Plate 14 shorelines.

Three isolated dune sites occur on the Plate 15 including NL28, NL27, and NL26. Site NL28 is an erosional remnant of a spit feature that had developed in 1953 but only occurs as salient feature by 2002. Site NL27 evolved in a small embayment, and NL26 developed in a small protected washover. Shore change was variable along the Potomac River shoreline with mostly erosion along most of Bull Neck except for accretion at Fleeton Point. The overall net change for that subreach was -2.1 ft/yr.

Plate 16 depicts shorelines at the entrance to the Great Wicomico River. Sites NL27 and NL26 were discussed previously in Plate 15. Dune sites NL23A and NL23B on Hayne Point have been around since 1953 on a spit that has moved back and forth over the years.

D. Reach IV

Reach IV extends form The Great Wicomico River to Indian Creek and the county line with Lancaster County. It is a very convoluted and complex coast dissected by many modest sized tidal creeks and rivers. Much of the Bay fronting coast is low and marshy.

Ingram Bay shorelines are shown in Plate 17 and include dune sites NL22A, NL22, NL21, NL20 and NL19. Site NL22A was once part of a large sandy spit feature (1937) but is now a small isolated remnant. Dune site NL22 evolved on a washover into an unnamed pond on the south side of Sandy Point. Towles Creek had a narrow inlet and associated sandy dune shorelines on either side until it was dredged and stabilized with jetties sometime before 1969. Site NL20 now resides on the south side of the inlet. Dune site NL19 has resided in about the same place since 1937, in a small curvilinear embayment. Long-term average erosion for Plate 17 is -2.3 ft/yr.

Plate 18 includes two sites along the Dameron Marsh peninsula. Site NL17 did not come into existence until just before 1994 and occurs as a spit dune feature that continues to evolve. Dune site NL15 also became more prominent by 1994 in a long shallow embayment. It appears to have reached a state of dynamic equilibrium and will migrate as the adjacent headland coasts erode.

Four dune sites are shown on Plate 19. Dune site NL14 came into existence sometime before 1994 in a shallow cove. Site NL12 evolved across a small pond and can be seen as early as 1937. Sites NL11A and NL11 reside in two adjacent bays created by three marshy headlands. Erosion patterns are complex but headland and bay features tend to persist over time.

Plate 20 has three dune sites. Site NL10 was part of small spit feature in 1953 and 1969. The small tidal creek was all but closed off by 1994, more sand came into the embayment, and the site expanded alongshore. Site NL9 has been part of long curvilinear embayment on the north side of Hughlett Point since 1937, and today represents a significant dune field. A spit evolved up Dividing Creek as seen in 1994 imagery and became home for NL8. Site NL7 is also located on Dividing Creek. However, it is not shown on the plates. It is a delta-shaped spit that is exposed to a bimodel wind/wave climate along the north shore of Dividing Creek. Long-term shore change along the Chesapeake Bay coast of Plate 20 was -2.9 ft/yr.

Dune site NL6 on Plate 21 is an erosional remnant of a longer beach/dune feature seen in 1937 imagery. The shoreline from Jarvis Point to Bluff Point (plate 22) has had siginificant erosion with a long term rate of -8.8 ft/yr. Site NL4A is a small remainder of what was once a long barrier dune beach system about 1mile in length up until 1969. Then the barrier broke through leaving NL4 as a large washover into a large tidal pond.

Three isolated dune sites occur on Plate 22. Site NL3 evolved on a washover in 1969 and 1994 and is now a cove feature. Site NL2 was part of long spit but now resides as an erosional remnant. As Barnes Creek was opened up, NL1 evolved by 1994 on the south flank of the creek shore. Long-term erosion along the Bay coast of Plate 22 is -6.9 ft/yr.

V. DISCUSSION: NEAR FUTURE TRENDS OF DUNE SITES

The following discussion is a delineation of shoreline trends based on past performance. Ongoing shore development, shore stabilization and/or beach fill, and storms will have local impacts on the near term. "Near Future" is quite subjective and only implies a reasonable expectation for a given shore reach to continue on its historic course for the next 10 to 20 years. In addition, the basis for the predictions are the shorelines digitized on geo-rectified aerial photography which have an error associated with them (see Methods, Section III). Each site's long-term and recent stability as well as a near future prediction are shown in a table in Appendix B. **This data is intended as a resource for coastal zone managers and homeowners; it is not intended for use in determining legal jurisdictional limits.**

A. Reach I

Site NL78, the only dune site in Reach I, should remain stable as long as the supporting groinfield remains intact (Figure 7).

B. Reach II

Although located at the mouth of Presley Creek, an historically mobile inlet, the site NL73 may shift in response but should keep its general dimensions and integrity(Figure 8). Site NL70 at the mouth of Hull Creek has been in a state of decay for years and will most likely continue that trend. Site NL67 should remain stable as long as the groinfield is intact (Figure 8). Like other creek mouth dune sites, NL63 will remain a dune entity but may move in response to inlet dynamics (Figure 8). Site NL62 has been modified with beach fill and offshore breakwaters so the nature of the site has changed, but the beach and associated future dune should be relatively stable.

Even after Hurricane Isabel, sites NL61, NL59 and NL58 should be relatively stable in the near term (Figure 8). A slight erosional tendency occurs on the downriver end of NL58. Site NL55 should continue to evolve toward stability between the revetment boundaries (Figure 8). Sites NL54, NL52, and NL51 all lie within the confines of extensive groinfields and should be stable for the near term (Figure 8). Site NL 50 is eroding as the groinfield fails and the beach face retreats.

Dune sites NL49 and NL48 occur within old deteriorating wood groin field. The primary dune faces are often steep and slumping but the overall dune appears relatively stable for the near term. Further loss of groin structures may cause a recessional trend. Site NL47 is on the tangential section of spiral embayment bounded by groins and appears relatively stable. The large embayment where NL46 sits is also a stable beach shore planform (Figure 8). Site NL45 is a sparsely vegetated low dune that is receding into an adjacent pond. Sites 43B and 43A are, by nature, erosional as they are dredge disposal for material from the Little Wicomico River. Site 43, on the other hand, is the recipient of that material and will erode and accrete as a function of beach fill periodicity but will always retain a minimum shore position (Figure 8).

C. Reach III

Site NL42 has been historically accretionary and mobile, but the south boundary continues to be impacted by groin construction toward the jetties which may be causing localized erosion. Site NL40 has evolved into a relatively stable embayment. North of Gaskin Pond lies NL38 bounded by the channel jetty and a revetment (Figure 9). It should be stable for the near term as long as the north wood jetty remains intact. A small groin field has helped create and stabilize NL37 but NL36 is decaying as the low bank headland to the north erodes (Figure 9). Dune sites NL35, NL34 and NL33 are stable isolated pocket dunes on the mainland coast of Owens Pond (Figure 9).

Sites NL32, NL31 and NL30 share the same stable subreach north of Taskmakers Creek (Figure 9). Site NL28 is an erosional salient while NL27 and NL26 are small stable isolated features (Figure 9). Sites NL23A and 23B share and accreting sand spit that should continue grow and provide dune growth elements as long as sand is available within the littoral system (Figure 9).

D. Reach IV

Dune site NL22A is a small, relatively stable dune on the Great Wicomico River side of Sandy Point while NL22 resides in a groin field on the Ingram Bay side (Figure 10). Site NL21 is a small stable dune at the mouth of Cranes Creek. The south channel jetty into Towles Creek creates a stable north boundary for site NL20, and a revetment creates the south boundary. The dune at NL19 is a mostly erosional feature open to the Bay. Site NL17 is on a mobile spit that cannot be called stable while NL15 occupies a long, stable bay on the north side of Dameron Marsh.

Dune sties NL14 and NL12 are linear isolated dune features that are relatively stable but will migrate as the controlling marsh headland erode. Currently those marsh headlands appear relatively stable unlike the controlling marsh headlands bounding NL11A and NL11 (Figure 10). These marsh headlands are more erosive as they and sites NL11A and NL11 are on the exposed distal end of Ball Neck (Figure 10).

Site NL10 had evolved in a deep stable bay called Ingram Cove and NL9 although currently relatively stable as the bounding headland erode it will leave the site more exposed and erosive (Figure 10). Site NL8 resides on a mobile but stabilizing spit feature. Site NL7 is a small erosional isolated dune and NL6 has resides on stable coast bounded by revetments. Sites NL4A and NL4 are long low stable slightly embayed dune sites but subject to storm overwash (Figure 10). Sites NL3 and NL2 are isolated dunes that will migrate as the bounding peat substrate erodes and NL1 is on an accreting spit that goes into Barnes Creek.

Figure 7. Dune site NL78 in Reach I on Potomac River on 4 Nov 1999.

Figure 8. Photos of Northumberland's shoreline showing dune sites in Reach II.

Figure 9. Photos of Northumberland's shoreline showing dune sites in Reach III.

Figure 10. Photos of Northumberland's shoreline showing dune sites in Reach IV.

VI. SUMMARY

Shoreline change rates are based on aerial imagery taken at a particular point in time. We have attempted to portray the same shoreline feature for each date along the coast of Northumberland County. Every 500 feet along each baseline on each plate, the rate of change was calculated. The mean or average rate for each plate is shown in Table 2 for five time periods with the long-term rate determined between 1937 and 2002. The total average and standard deviation (Std Dev) for the entire data set of individual rates is also given. The standard deviation shows the relative spread of values about the mean or average. Larger standard deviation values relative to the mean indicates a wider scatter of erosion rates about the mean while lower standard deviation values indicates erosion rates are concentrated near the mean (*i.e.* all the rates calculated for the entire plate were similar).

The largest variability in mean shore change rates and standard deviations were recorded for the shoreline on Plate 21 with the rates of change and standard deviation reaching over 20 ft/yr. Plate 12A had standard deviations that were much larger than the average rate of change indicating that the overall rate is probably not indicative of the change which occurred on this section of shore. However, not all dates for this section of shore had mean shore change rates with large standard deviations. For 1959-1982, the standard deviation was half the mean shore change rate indicating that the shore change rates were relatively consistent for that time period.

When short time frames are used to determine rates of shoreline change, shore alterations may seem amplified. The rates based on short-time frames can modify the overall net rates of change. Hopefully, the shore change patterns shown in this report along with the aerial imagery will indicate how the coast will evolve based on past trends and can be used to provide the basis for appropriate shoreline management plans and strategies. Dunes and beaches are a valuable resource that should be either maintained, enhanced or created in order to abate shoreline erosion and provide sandy habitat.

Table 2. Summary shoreline rates of change and their standard deviation.

	Plate 2A		Plate 2B		Plate 3		Plate 4		Plate 5		Plate 6	
Imagery Dates	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**
1937-1953	-0.3	0.6	-0.2	0.6	-3.6	3.4	-0.6	1.9	-7.2	8.4	-5.2	2.7
1953-1969	-2.1	3.9	-4.7	3.5	-5.4	6.7	-1.4	2.1	-5.5	8.1	-4.8	3.8
1969-1994	-1.6	3.0	-0.3	0.8	-0.5	1.8	-0.3	0.7	-8.3	3.4	-0.5	3.0
1994-2002	-1.0	4.9	1.6	1.0	-1.1	4.1	1.1	1.0	-8.7	3.7	0.2	3.0
1937-2002	**-1.3**	**2.7**	**-1.1**	**1.0**	**-2.6**	**2.7**	**-0.5**	**0.7**	**-7.4**	**5.0**	**-2.6**	**1.9**

	Plate 7		Plate 8		Plate 9		Plate 10		Plate 11		Plate 12A		Plate 12B	
Imagery Dates	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**
1937-1953	-4.1	1.5	-1.0	2.3	0.2	1.5	-2.4	2.8	-4.1	8.0	2.2	13.6	0.4	3.9
1953-1969	-5.6	1.7	-2.7	1.4	-1.5	1.4	-1.1	1.7	-4.6	8.1	4.1	1.3	-4.2	4.2
1969-1994	-2.0	1.9	-0.6	1.4	0.4	1.1	0.0	1.2	-3.5	5.6	4.6	3.0	-1.2	3.4
1994-2002	-3.2	3.7	-1.9	2.1	-1.1	2.0	-0.7	1.8	-5.0	7.6	0.2	4.8	-1.0	5.8
1937-2002	**-3.6**	**1.2**	**-1.4**	**0.9**	**-0.3**	**0.4**	**-0.9**	**0.6**	**-4.1**	**2.8**	**3.4**	**4.8**	**-1.5**	**2.2**

	Plate 13		Plate 14		Plate 15		Plate 17		Plate 20		Plate 21		Plate 22	
Imagery Dates	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**	**Rate of Change (ft/yr)**	**Std. Dev.**
1937-1953	-2.5	1.9	-9.4	17.0	-0.3	10.7	-1.6	5.4	-2.4	3.9	-7.7	2.1	-11.0	3.2
1953-1969	-5.9	1.8	-4.4	5.8	-3.6	3.8	-2.4	3.6	-3.2	2.0	12.2	5.7	-7.6	4.4
1969-1994	-9.4	11.0	-1.4	4.2	-3.7	3.6	-2.5	6.6	-2.6	3.7	-18.5	7.7	-3.0	1.8
1994-2002	-1.6	3.9	-2.1	7.3	2.7	6.9	-3.5	2.8	-4.5	3.4	-22.3	23.2	-9.7	6.0
1937-2002	**-5.9**	**4.6**	**-4.2**	**3.7**	**-2.1**	**2.7**	**-2.3**	**2.9**	**-2.9**	**2.2**	**-8.8**	**3.0**	**-6.9**	**2.2**

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APPENDIX A

For each Plate shown on Figure 4, Appendix A contains orthorectified aerial photography flown in 1937, 1953, 1969, 1994, and 2002.
Also shown are the digitized shorelines, identified dune sites, and an arbitrarily created baseline.
A plot shows only the relative locations of the shorelines while another one depicts the rate of shore change between dates.
A summary of the average Plate rate of change in ft/yr as well as the standard deviation for each rate is also shown.

This data is intended as a resource for coastal zone managers and homeowners;
it is not intended for use in determining legal jurisdictional limits.

APPENDIX B

The data shown in the following tables were primarily collected as part of the Chesapeake Bay Dune: Evolution and Status report and presented in Hardaway *et al.* (2001) and Hardaway *et al.* (2003). Individual site characteristics may now be different due to natural or man-induced shoreline change.

An additional table presents the results of this analysis and describes each dune site's relative long-term, recent, and near-future predicted stability. This data results from the position of the digitized shorelines which have an error associated with them (see Methods, Section III).

Since much of the dune data were collected several years ago and the beach and dune systems may have changed, this report is intended as a resource for coastal zone managers and homeowners; it is not intended for use in determining legal jurisdictional limits.

These data were collected as part of the Chesapeake Bay Dune: Evolution and Status Report (Hardaway *et al.*, 2001). Site characteristics may now be different due to natural or man-influenced shoreline change.

. Identified dune sites in Northumberland County as of 1999.

Dune Site No.	Location^ Easting (Feet)	Location^ Northing (Feet)	Date Visited	Dune Shore Length (Feet)	Primary Dune Site?	Secondary Dune Site?	*Public Ownership?
1	2,630,850	499,900	8/5/99	140	Yes		
2	2,634,800	501,100	8/5/99	210	Yes		
3	2,635,950	503,000	8/5/99	250	Yes		
4	2,634,300	507,000	8/5/99	710	Yes	Yes	
4A	2,633,300	509,700	8/5/99	580	Yes		
6	2,630,400	511,700	8/5/99	180	Yes		
7	2,629,500	518,750	8/5/99	320	Yes		
8	2,632,050	517,350	8/5/99	270	Yes		
9	2,633,700	518,350	8/5/99	2,200	Yes		
10	2,631,350	522,300	8/5/99	1,360	Yes		
11	2,633,300	528,200	9/14/99	200	Yes		
11A	2,633,500	528,550	9/14/99	400	Yes		
14	2,634,150	533,150	9/14/99	510	Yes		
15	2,635,750	535,500	9/14/99	1,360	Yes		Yes
17	2,633,200	536,200	9/14/99	250	Yes		Yes
19	2,632,200	538,900	9/14/99	1,050	Yes		
20	2,633,400	542,150	9/14/99	290	Yes		
21	2,632,250	547,380	4/29/99	170	Yes		
22	2,633,150	548,600	4/29/99	390	Yes		
22A	2,632,950	548,900	4/29/99	160	Yes		
23A	2,631,050	552,600	5/13/99	300	Yes		
23B	2,631,050	552,600	5/13/99	140	Yes		
26	2,637,150	550,000	5/13/99	120	Yes		
27	2,637,950	549,300	5/13/99	180	Yes		
28	2,641,050	546,150	5/13/99	480	Yes		
30	2,647,600	552,200	5/13/99	250	Yes		
31	2,648,100	552,850	4/29/99	620	Yes		
32	2,648,700	553,400	5/13/99	360	Yes		
33	2,649,300	558,000	5/13/99	180	Yes		
34	2,649,500	558,500	5/13/99	180	Yes		
35	2,649,600	560,100	5/13/99	280	Yes		
36	2,650,450	561,600	5/13/99	120	Yes		
37	2,650,550	562,300	5/13/99	240	Yes		
38	2,650,800	564,350	5/13/99	230	Yes		

Dune Site No.	Location^ Easting (Feet)	Location^ Northing (Feet)	Date Visited	Dune Shore Length (Feet)	Primary Dune Site?	Secondary Dune Site?	*Public Ownership?
40	2,650,900	566,800	4/29/99	600	Yes		
42	2,652,500	572,400	4/29/99	3,690	Yes	Yes	
43	2,651,150	575,100	6/3/99	2,750	Yes	Yes	
43A	2,650,000	575,950	6/3/99	870	Yes	Yes	
43B	2,649,100	576,650	6/3/99	400	Yes		
45	2,648,100	577,750	6/3/99	220	Yes		
46	2,647,500	578,750	6/3/99	650	Yes		
47	2,646,800	579,500	6/3/99	320	Yes		
48	2,643,500	582,450	6/3/99	200	Yes		
49	2,642,500	583,000	6/3/99	470	Yes		
50	2,641,700	583,450	6/3/99	160	Yes		
51	2,640,850	583,800	6/24/99	190	Yes		
52	2,640,150	584,150	6/24/99	300	Yes		
54	2,637,750	585,400	6/24/99	240	Yes		
55	2,633,700	587,700	6/24/99	250	Yes		
58	2,630,450	589,550	6/24/99	900	Yes	Yes	
59	2,629,200	590,300	6/24/99	1,680	Yes	Yes	
61	2,626,900	591,750	6/24/99	400	Yes		
62	2,620,600	594,850	11/4/99	970	Yes		
63	2,619,800	595,250	11/4/99	250	Yes		
67	2,615,150	596,750	11/4/99	90	Yes		
70	2,608,500	598,300	11/4/99	670	Yes		
73	2,599,600	601,950	11/4/99	750	Yes		
78	2,586,800	614,250	11/4/99	540	Yes		

*Public ownership includes governmental entities including local, state, and federal; otherwise ownership is by the private individual.
^Location is in Virginia State Plane South, NAD 1927
‘One site with variable alongshore dune conditions

These data were collected as part of the Chesapeake Bay Dune: Evolution and Status Report (Hardaway *et al*., 2001). Site characteristics may now be different due to natural or man-influenced shoreline change.

Dune site measurements in Northumberland County as of 1999.

Dune Site Measurements

Site	No.	Dune Shore Length (Feet)	Primary Dune Crest Elev (ft MLW)	Primary Dune Distance from Crest landward to back base (Feet)	Primary Dune Distance from Crest To MLW (Feet)	Secondary Dune 2nd Dune Site	Secondary Dune Crest Elev (ft MLW)	Distance From Primary Crest to 2nd Crest (Feet)	Distance From 2nd Crest landward (Feet)	Distance From 2nd Crest seaward to 1st back base (Feet)
NL	1	140	3.9	25	86					
NL	2	210	5.1	45	36					
NL	3	250	4.5	44	71					
NL	4	710	5.6	23	144	Yes	2.6	130	77	107
NL	4A	580	4.4	69	36					
NL	6	180	5.5	6	71					
NL	7	320	4.2	23	45					
NL	8	270	4.8	19	18					
NL	9	2,200	6.3	31	40					
NL	10	1,360	5.7	40	52					
NL	11	200	3.3	47	39					
NL	11A	400	4.3	22	66					
NL	12	450	6.8	17	56					
NL	14	510	5.5	37	41					
NL	15	1,360	6.1	44	38					
NL	17	250	3.5	81	20					
NL	19	1,050	5.4	33	39					
NL	20	290	5.8	50	38					
NL	21*	170								
NL	22	390	4.0	35	27					
NL	22A	160	3.5	10	35					
NL	23A	300	4.3	13	52					
NL	23B	140	4.1	16	51					
NL	26	120	5.0	16	45					
NL	27	180	4.6	14	34					
NL	28	480	4.5	15	30					
NL	30	250	5.6	45	85					
NL	31	620	4.5	39	48					
NL	32*	360								
NL	33	180	4.9	31	63					
NL	34	180	5.4	77	61					
NL	35	280	5.3	38	75					
NL	36	120	5.0	14	43					
NL	37	240	6.3	5	66					
NL	38	230	3.5	45	40					
NL	40	600	4.5	25	50					
NL	42	3,690	5.6	69	40	Yes	9.8	125	21	56
NL	43	2,750	8.8	23	48	Yes	7.5	41	56	18
NL	43a	870	8.2	29	34	Yes	6.0	54	26	25
NL	43b	400	2.9	32	28					
NL	45	220	3.2	36	35					

*Not profiled

Dune Site Measurements

Site	No.	Dune Shore Length (Feet)	Primary Dune Crest Elev (ft MLW)	Primary Dune Distance from Crest landward to back base (Feet)	Primary Dune Distance from Crest To MLW (Feet)	Secondary Dune 2nd Dune Site	Secondary Dune Crest Elev (ft MLW)	Distance From Primary crest to 2nd Crest (Feet)	Distance From 2nd Crest landward (Feet)	Distance From 2nd Crest seaward to 1st back base (Feet)
NL	46	650	5.5	10	52					
NL	47	320	6.2	60	35					
NL	48	200	9.9	14	58					
NL	49	470	9.6	3	51					
NL	50	160	12.7	4	56					
NL	51	190	6.7	4	44					
NL	52	300	9.7	15	77					
NL	54	240	6.1	10	40					
NL	55	250	4.9	7	50					
NL	58	900	6.6	8	49	Yes	9.0	19	92	11
NL	59	1,680	8.2	7	52	Yes	11.3	40	6	33
NL	61	400	7.5	18	52					
NL	62	970	6.5	52	49					
NL	63	250	5.7	19	77					
NL	67	90	7.7	13	62					
NL	70	670	5.9	5	78					
NL	73	750	6.9	4	75					
NL	78	540	6.5	10	62					

These data were collected as part of the Chesapeake Bay Dune: Evolution and Status Report (Hardaway *et al*., 2001). Site characteristics may now be different due to natural or man-influenced shoreline change.

Dune site parameters in Northumberland County as of 1999.

Dune Site Parameters

	Site No.	Type	Fetch Exposure A	Shoreline Direction of Face B	Nearshore Gradient C	Morphologic Setting D	Relative Stability E	Underlying Substrate F
NL	1	Natural	Open Bay	East	Shallow	Isolated, linear	Accretion	Marsh/CB
NL	2	Natural	Open Bay	South	Shallow Bars	Isolated, pocket	Stable	Marsh/CB
NL	3	Natural	Open Bay	Southeast	Shallow	Ck Mouth	Stable	Marsh/CB
NL	4	Natural	Open Bay	Northeast	Medium	Ck Mouth	Stable	Marsh/CB
NL	4A	Natural	Open Bay	Northeast	Medium	Spit	Stable	Marsh/CB
NL	6	Man Inf	Open Bay	Northeast	Steep	Isolated, bay	Stable	Upland
NL	7	Natural	Riverine	Southeast	Steep	Spit	Stable	Marsh/CB
NL	8	Natural	Riv-Bay	South	Steep	Spit	Accretion	Upland
NL	9	Natural	Open Bay	East	Medium	Dune Field, linear	Stable	Marsh/CB
NL	10	Natural	Open Bay	Northeast	Medium Bars	Dune Field, bay	Erosional	Marsh/CB
NL	11	Natural	Open Bay	East	Medium	Isolated, pocket	Erosional	Marsh/CB
NL	11A	Natural	Open Bay	East	Medium	Isolated, pocket	Erosional	Marsh/CB
NL	12	Natural	Open Bay	East	Medium	Ck Mouth	Stable	Marsh/CB
NL	14	Natural	Open Bay	East	Shallow	Isolated, pocket	Stable	Marsh/CB
NL	15	Natural	Open Bay	Northeast	Medium	Dune Field, bay	Stable	Marsh/CB
NL	17	Natural	Riv-Bay	Northwest	Steep	Spit	Erosional	Upland
NL	19	Natural	Open Bay	East	Steep	Dune Field, linear	Erosional	Upland
NL	20	Man Inf	Open Bay	East	Medium	Isolated, linear	Accretion	Upland
NL	21	Natural	Riv-Bay	East	Steep	Isolated, linear	Stable	Upland
NL	22	Man Inf	Riv-Bay	East	Medium	Ck Mouth	Stable	Marsh/CB
NL	22A	Natural	Riverine	Northwest	Steep	Spit	Stable	Upland
NL	23A	Natural	Riv-Bay	West	Steep	Spit	Accretion	Upland
NL	23B	Natural	Riverine	Southeast	Steep	Spit	Accretion	Upland
NL	26	Man Inf	Riverine	Southwest	Medium	Ck Mouth	Stable	Marsh/CB
NL	27	Natural	Riv-Bay	South	Shallow	Isolated, pocket	Stable	Upland
NL	28	Man Inf	Open Bay	South	Medium	Isolated, salient	Accretion	Upland
NL	30	Man Inf	Open Bay	Southeast	Shallow	Isolated, pocket	Stable	Upland
NL	31	Natural	Open Bay	Southeast	Shallow	Ck Mouth	Stable	Upland
NL	32	Man Inf	Open Bay	Southeast	Shallow	Ck Mouth	Stable	Upland
NL	33	Man Inf	Open Bay	East	Shallow Bars	Isolated, pocket	Stable	Upland
NL	34	Natural	Open Bay	East	Medium Bars	Isolated, pocket	Stable	Upland
NL	35	Man Inf	Open Bay	East	Medium Bars	Isolated, pocket	Stable	Upland
NL	36	Man Inf	Open Bay	East	Medium Bars	Isolated, pocket	Erosional	Marsh/CB
NL	37	Man Inf	Open Bay	East	Medium Bars	Isolated, pocket	Accretion	Upland
NL	38	Man Inf	Open Bay	East	Medium Bars	Ck Mouth	Stable	Marsh/CB
NL	40	Natural	Open Bay	East	Medium Bars	Ck Mouth	Stable	Marsh/CB
NL	42	Man Inf	Open Bay	East	Medium	Dune Field, linear	Stable	Upland
NL	43	Man Inf	Open Bay	Northeast	Medium No Bars	Dune Field, linear	Stable	Marsh/CB
NL	43A	Man Inf	Open Bay	Northeast	Medium	Dune Field, linear	Erosional	Marsh/CB
NL	43B	Man Inf	Open Bay	Northeast	Medium	Ck Mouth	Erosional	Marsh/CB
NL	45	Man Inf	Open Bay	Northeast	Medium Bars	Ck Mouth	Erosional	Marsh/CB
NL	46	Man Inf	Open Bay	Northeast	Medium Bars	Dune Field, bay	Erosional	Upland
NL	47	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Stable	Marsh/CB
NL	48	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Stable	Upland
NL	49	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Stable	Upland
NL	50	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Erosional	Upland
NL	51	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Stable	Upland
NL	52	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Stable	Upland
NL	54	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Stable	Upland
NL	55	Man Inf	Open Bay	Northeast	Medium Bars	Ck Mouth	Stable	Marsh/CB
NL	58	Man Inf	Open Bay	Northeast	Medium Bars	Dune Field, linear	Stable	Upland
NL	59	Man Inf	Open Bay	Northeast	Medium Bars	Dune Field, linear	Stable	Upland
NL	61	Man Inf	Open Bay	Northeast	Medium Bars	Isolated, linear	Stable	Upland
NL	62	Man Inf	Open Bay	Northeast	Shallow Bars	Ck Mouth	Erosional	Upland
NL	63	Man Inf	Open Bay	Northeast	Shallow Bars	Ck Mouth	Erosional	Marsh/CB
NL	67	Man Inf	Open Bay	North	Medium Bars	Ck Mouth	Erosional	Marsh/CB
NL	70	Man Inf	Riv-Bay	North	Medium Bars	Ck Mouth	Erosional	Marsh/CB
NL	73	Man Inf	Riv-Bay	Northeast	Medium Bars	Spit	Stable	Marsh/CB
NL	78	Man Inf	Riv-Bay	East	Medium No Bars	Isolated, linear	Erosional	Marsh/CB

These data were collected as part of the Chesapeake Bay Dune: Evolution and Status Report (Hardaway *et al*., 2001). Site characteristics may now be different due to natural or man-influenced shoreline change.

Long-term, recent stability and future predictions of shore erosion and accretion rates for dune sites in Northumberland County.

Site No.		Long-Term Stability 1937-2002	Recent Stability 1994-2002	Near Future Prediction
NL	1	Erosional	Stable	Accretionary
NL	2	Erosional	Stable	Erosional
NL	3	Erosional	Erosional	Erosional
NL	4	Erosional	Accretionary	Stable
NL	4A	Erosional	Erosional	Stable
NL	6	Stable	Stable	Stable
NL	7	Accretionary	Erosional	Erosional
NL	8	Accretionary	Erosional	Stable/Accrete
NL	9	Stable	Stable	Erosional
NL	10	Accretionary	Stable	Stable
NL	11	Erosional	Erosional	Erosional
NL	11A	Erosional	Erosional	Erosional
NL	12	Stable	Stable	Stable
NL	14	Erosional	Erosional	Stable
NL	15	Erosional	Stable	Stable
NL	17	Accretionary	Erosional	Erosional
NL	19	Stable	Stable	Erosional
NL	20	Erosional	Stable	Stable
NL	21	Stable	Stable	Stable
NL	22	Erosional	Stable	Stable
NL	22A	Accretionary	Stable	Stable
NL	23A	No Data	Stable	Accretionary
NL	23B	No Data	Stable	Accretionary
NL	26	Erosional	Stable	Stable
NL	27	Erosional	Stable	Stable
NL	28	Accretionary	Accretionary	Erosional
NL	30	Erosional	Stable	Stable
NL	31	Accretionary	Accretionary	Stable
NL	32	Accretionary	Stable	Stable
NL	33	Erosional	Stable	Stable
NL	34	Erosional	Stable	Stable
NL	35	Erosional	Stable	Stable
NL	36	Erosional	Stable	Erosional
NL	37	Erosional	Stable	Stable
NL	38	Erosional	Stable	Stable
NL	40	Erosional	Stable	Stable
NL	42	Eros/Accete	Stable	Eros/Accete
NL	43	Accretionary	Stable	Eros/Accete
NL	43A	Erosional	Erosional	Erosional
NL	43B	Erosional	Erosional	Erosional
NL	45	Erosional	Erosional	Erosional
NL	46	Erosional	Accretionary	Stable
NL	47	Erosional	Erosional	Stable
NL	48	Erosional	Stable	Stable
NL	49	Erosional	Stable	Stable
NL	50	Erosional	Stable	Erosional
NL	51	Erosional	Erosional	Stable
NL	52	Erosional	Stable	Stable
NL	54	Erosional	Stable	Stable
NL	55	Erosional	Stable	Stable
NL	58	Erosional	Stable	Stable
NL	59	Stable	Stable	Stable
NL	61	Stable	Stable	Stable
NL	62	Erosional	Erosional	Stable
NL	63	Erosional	Erosional	Stable
NL	67	Erosional	Stable	Stable
NL	70	Erosional	Erosional	Erosional
NL	73	Erosional	Accretionary	Stable
NL	78	Erosional	Accretionary	Stable