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## Shoreline evolution, City of Hampton, Virginia, Hampton Roads, Chesapeake Bay, and Back River Shorelines

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# **Shoreline Evolution City of Hampton, Virginia**

**Hampton Roads, Chesapeake Bay,  
and Back River Shorelines**

# Shoreline Evolution

## City of Hampton, Virginia

### Hampton Roads, Chesapeake Bay, and Back River Shorelines

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2005

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The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies or DEQ.



## TABLE OF CONTENTS

<b>TABLE OF CONTENTS</b> .....	i
<b>LIST OF FIGURES</b> .....	i
<b>LIST OF TABLES</b> .....	i
<b>I. INTRODUCTION</b> .....	1
A. General Information .....	1
B. Chesapeake Bay Dunes .....	1
<b>II. SHORE SETTING</b> .....	1
A. Physical Setting .....	1
B. Hydrodynamic Setting .....	5
<b>III. METHODS</b> .....	6
A. Photo Rectification and Shoreline Digitizing .....	6
B. Rate of Change Analysis .....	6
<b>IV. RESULTS</b> .....	8
A. Reach I .....	8
B. Reach II .....	8
C. Reach III .....	8
D. Reach IV .....	8
<b>V. DISCUSSION: NEAR FUTURE TRENDS OF DUNE SITES</b> .....	9
A. Reach I .....	9
B. Reach II .....	9
C. Reach III .....	9
D. Reach IV .....	9
<b>VI. SUMMARY</b> .....	11
<b>VII. REFERENCES</b> .....	12
Acknowledgments .....	12
<b>APPENDIX A</b> .....	Plates 1-9 of Hampton’s shoreline with historical aerial photography, digitized shorelines, and rates of shoreline change.
<b>APPENDIX B</b> .....	Tables of specific dune site information.

## LIST OF FIGURES

<b>Figure 1.</b> Location of City of Hampton within the Chesapeake Bay estuarine system..	2
<b>Figure 2.</b> Location of localities in the Dune Act with jurisdictional and non-jurisdictional localities noted.	2
<b>Figure 3.</b> Geological map of City of Hampton (from <i>Mixon et al.</i> , 1989).	3
<b>Figure 4.</b> Index of shoreline plates	4
<b>Figure 5.</b> Variability of dune and beach profiles within City of Hampton.	7
<b>Figure 6.</b> Typical profile of a Chesapeake Bay dune system.	7
<b>Figure 7.</b> Photos of Hampton’s shoreline showing dune site HP2	10
<b>Figure 8.</b> Photos of Hampton’s shoreline showing dune sites HP4, HP6, HP7, HP8, and HP12.	11

## LIST OF TABLES

<b>Table 1.</b> Summary wind conditions at Norfolk International Airport from 1960-1990	5
<b>Table 2.</b> Summary shoreline rates of change and their standard deviation	12

**Cover Photo:** Photograph of dune at Fort Monroe’s Dog Beach. Photo taken by Shoreline Studies Program on 23 April 2002.

## 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 the Hampton Roads, Chesapeake Bay, and Back River shores of Hampton (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 Bay coast of Hampton 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)<sup>1</sup>. 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 City of Hampton Dune Inventory. That report detailed the location and nature of the jurisdictional primary dunes along the Bay shore of Hampton 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 2000. This information is not intended to be used for jurisdictional determinations regarding dunes.

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<sup>1</sup>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 Hampton Roads and Bay shoreline of the City of Hampton extends from the city line with Newport News to Old Point Comfort and northward to Northend Point. This includes about 7.5 miles of tidal shoreline along Hampton Roads and 8 miles along Chesapeake Bay. In addition, about five miles occurs along Back River. The shorelines along Hampton Roads are mostly bulkheaded while the Bay shorelines are exposed to the open Bay as well as the Atlantic Ocean. Historic shore change rates vary from 0 ft/yr to over 4.5 ft/yr for both shore recession and shore advance along the Bay coast (Byrne and Anderson, 1978).

The coastal geomorphology of the City is a function of the underlying geology and the hydrodynamic forces operating across the land/water interface, the shoreline. The Chesapeake Bay coast of Hampton is almost exclusively Holocene beach sands which overlie earlier Holocene sands, mud and clays (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. Hampton's littoral system is sand rich from erosion over time of the sandy upland banks and nearshore substrate as evidenced by mostly sand beaches along the coast and a very extensive and complex system of offshore sand bars. These sand bars greatly influenced and are themselves influenced by the impinging wave climate.

Sea level is continuing to rise in the Tidewater Region. 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/>). This directly effects 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 or about an inch and a half, 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 Hampton (Figure 4). Reach I extends along the Hampton Roads coast from the city line to Mill Creek. Reach II goes from Old Point Comfort and Fort Monroe northward along the Chesapeake Bay to Salt Ponds Inlet. Reach III picks up at Salt Ponds Inlet and goes to Northend Point, and Reach IV occurs along the Back River shore to Tabbs Creek.



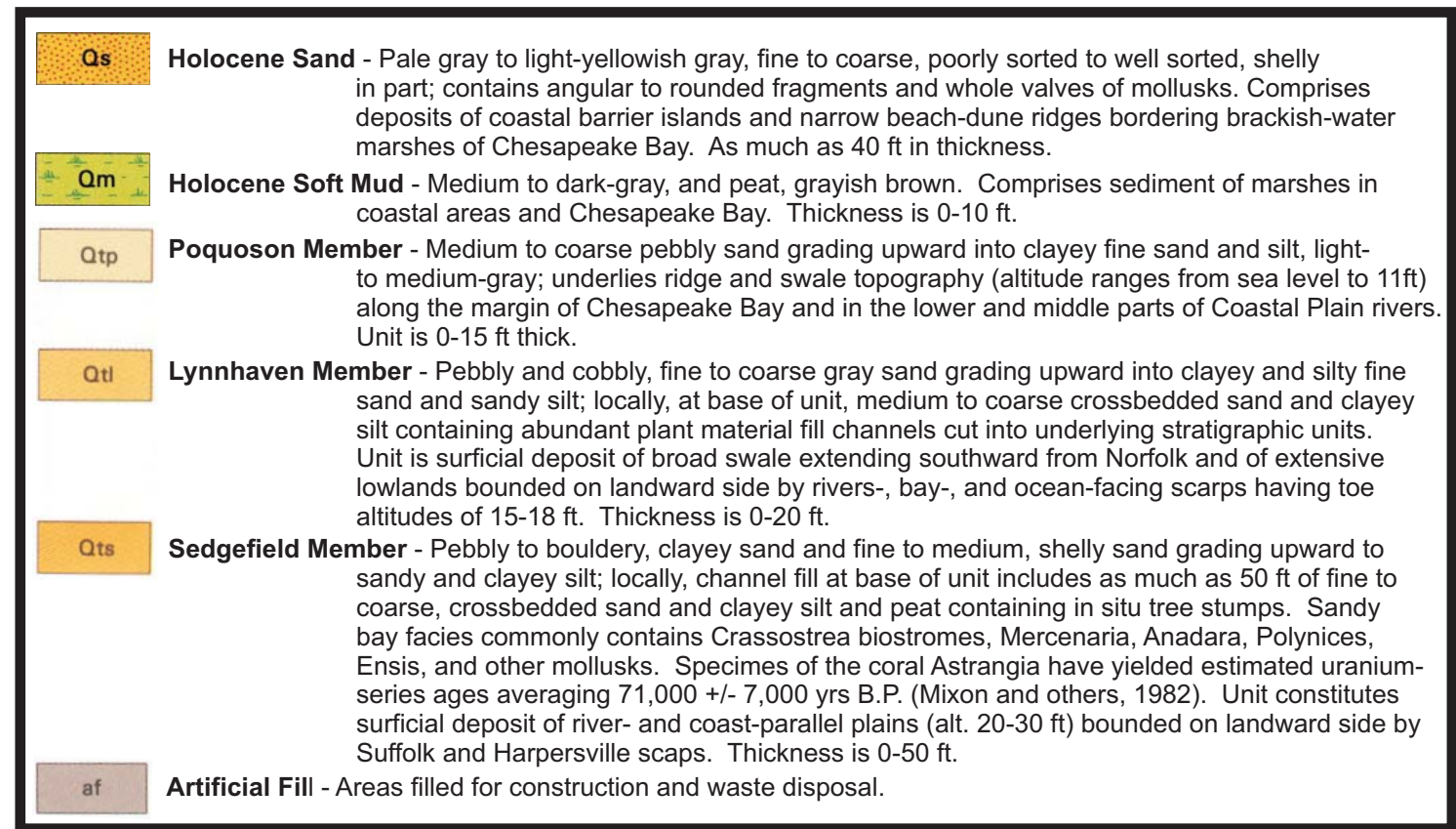
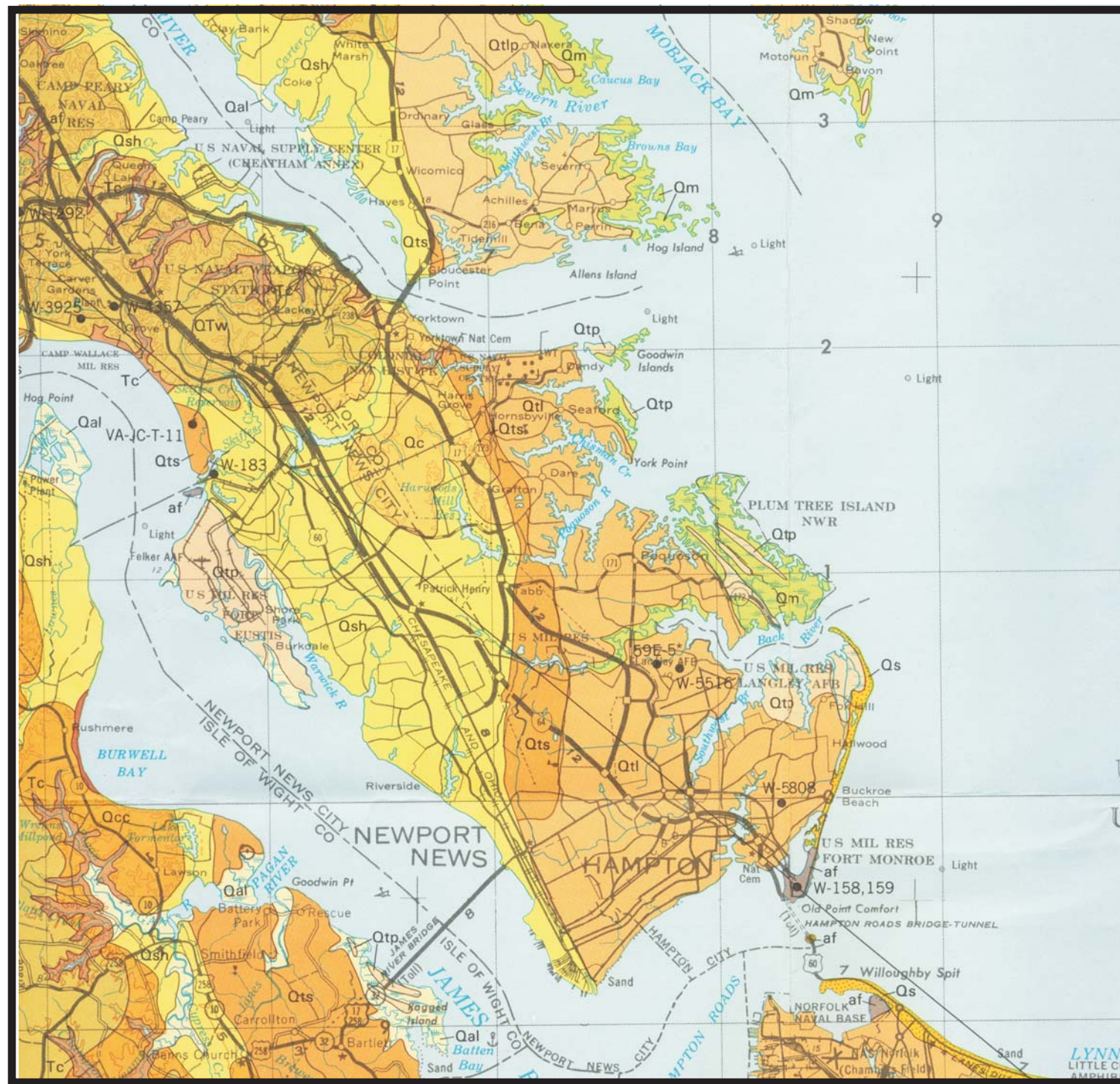
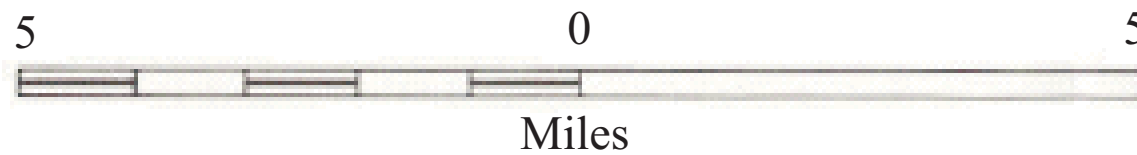


Figure 3. Geologic map of the City of Hampton (from Mixon *et al.*, 1989).



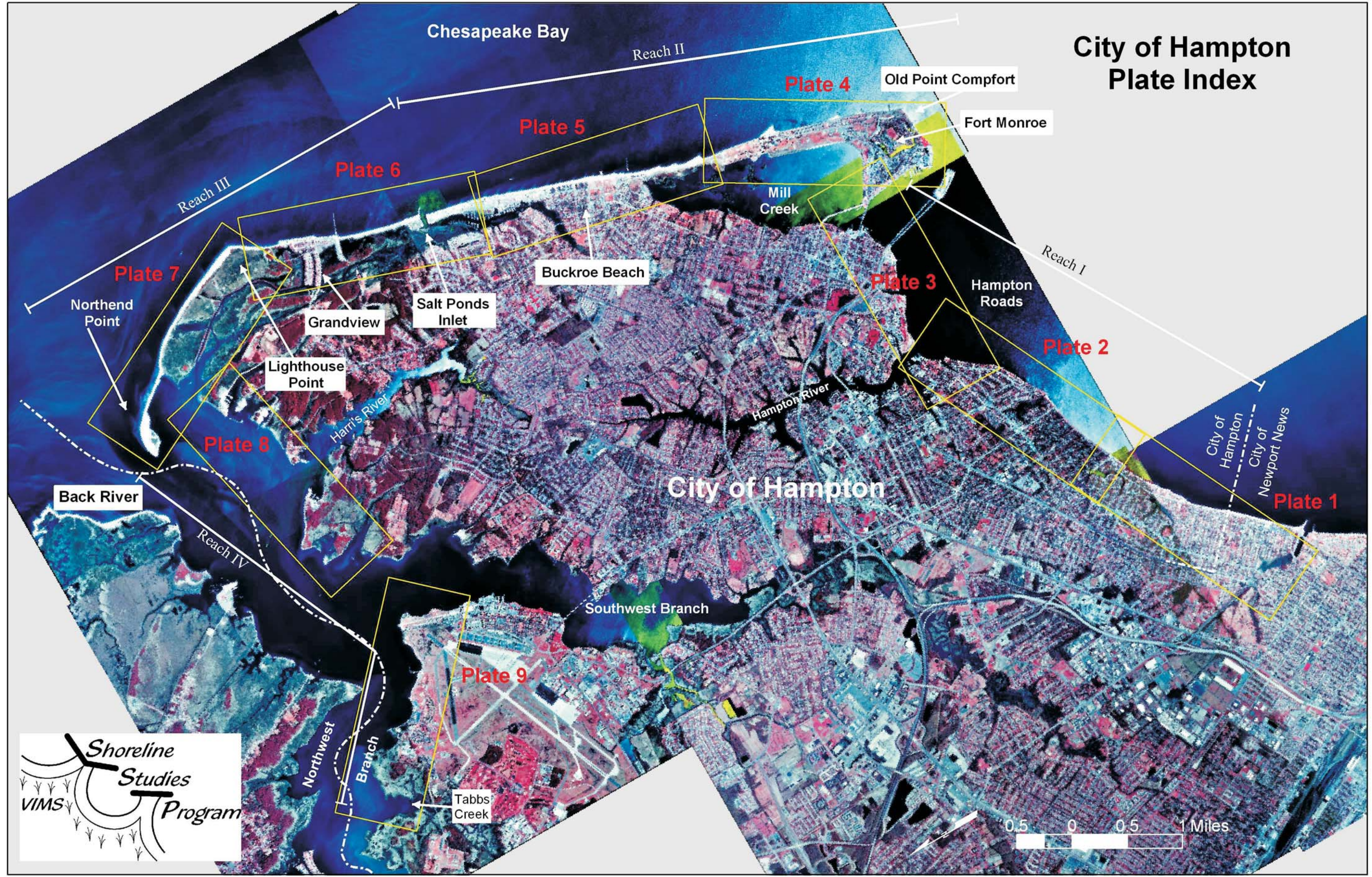


Figure 4. Index of shoreline plates.



B. Hydrodynamic Setting

Mean tide range along the Bay coast of Hampton is about 2.5 ft . The wind/wave climate impacting the Hampton Bay coast is defined by large fetch exposures to the northeast and east across Chesapeake Bay. Wind data from Norfolk International Airport reflect the frequency and speeds of wind occurrences from 1960 to 1990 (Table 1) which characterize the locally-generated Bay waves. However, the shorelines of Reach II and Reach III also are partially impacted by incoming ocean swell. In characterizing the lower Chesapeake Bay wave climate, Boon *et al.* (1990) noted a bimodal distribution of the wave directions. Except for late spring and summer months, all of the wave directions tend to fall into two groups centered on the (1) south and (2) west to northwest compass headings. In 1993, Boon *et al.* saw clear evidence of an interplay between bay and ocean-generated waves that vary from year to year, but is itself a characteristic feature of the region.

Northeasters are particularly significant in terms of the impacts of storm surge and waves on beach and dune erosion. The Ash Wednesday Storm of 1962 caused considerable property damage along the Buckroe and Grandview coasts. 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. The hardened coast of Reach I (shown on Plates 1 and 2) was severely damaged. Storm surge along the Hampton coast was comparable to the Hurricane of 1933, the storm of the century in Tidewater Virginia.

Table 1. Summary wind conditions at Norfolk International Airport from 1960-1990.

Wind Speed (mph)	Mid Range (mph)	WIND DIRECTION								Total
		South	South west	West	North west	North	North east	East	South east	
< 5	3	5497*	3316	2156	1221	35748	2050	3611	2995	56594
		2.12 <sup>†</sup>	1.28	0.83	0.47	13.78	0.79	1.39	1.15	21.81
5-11	8	21083	15229	9260	6432	11019	13139	9957	9195	95314
		8.13	5.87	3.57	2.48	4.25	5.06	3.84	3.54	36.74
11-21	16	14790	17834	10966	8404	21816	16736	5720	4306	100572
		5.70	6.87	4.23	3.24	8.41	6.45	2.20	1.66	38.77
21-31	26	594	994	896	751	1941	1103	148	60	6487
		0.23	0.38	0.35	0.29	0.75	0.43	0.06	0.02	2.5
31-41	36	25	73	46	25	162	101	10	8	450
		0.01	0.03	0.02	0.01	0.06	0.04	0.00	0.00	0.17
41-51	46	0	0	0	1	4	4	1	0	10
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>		41989	37446	23324	16834	70690	33133	19447	16564	259427
		16.19	14.43	8.99	6.49	27.25	12.77	7.50	6.38	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 Hampton. 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, 1963, 1980, 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 Hampton's coast, an approximation to mean high water (MHW) 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 Hampton 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.

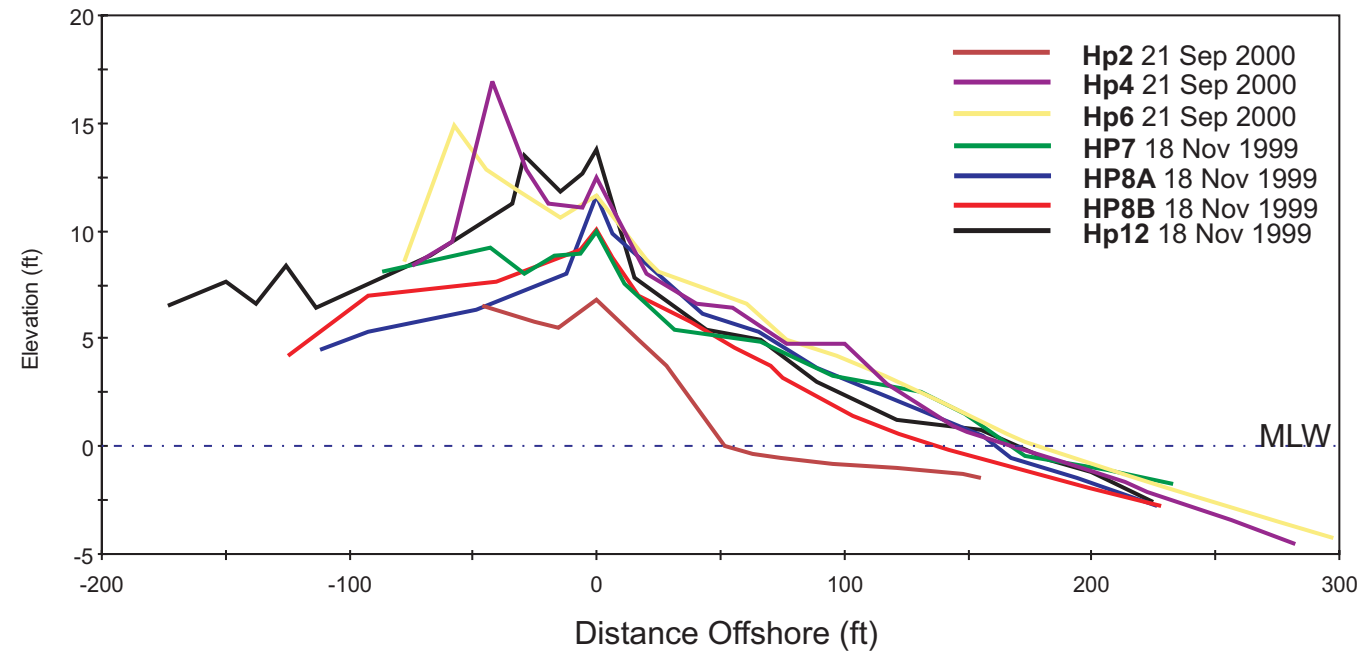


Figure 5. Variability of dune and beach profiles in the City of Hampton.

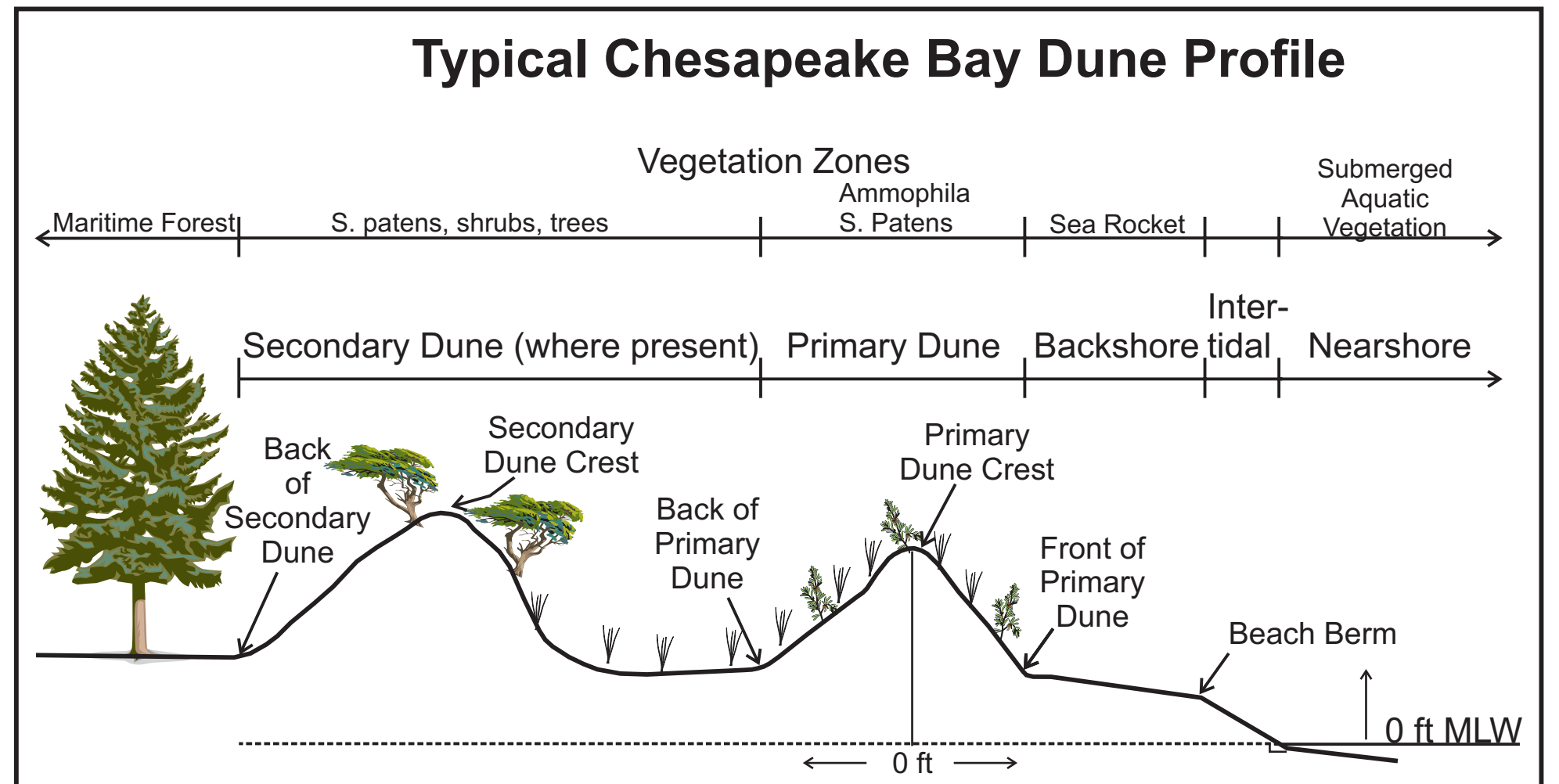


Figure 6. Typical profile of a Chesapeake Bay dune system (from Hardaway *et al.*, 2001).

## 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 Hampton 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 includes Plates 1, 2 and 3 extends from the City line to Mill Creek; dune site HP2, a small pocket beach recently stabilized by breakwaters, is shown on Plate 2. Dune site HP2 is an erosional remnant that has remained in about the same position since 1937. Most of Reach I has been hardened over the years by bulkheads and/or stone revetments and groins. These have combined to cut the natural source of sand off (*i.e.* sediments from bank erosion). The largest shoreline change occurs at the small creeks that occur along the shore. A large positive shore change occurs on Plate 3 in regards to the construction of the Hampton Roads Bridge Tunnel (HRBT). Likely fill was added to the shore while the bridge was being built.

### B. Reach II

Reach II includes Plates 4, 5 and 6 and extends from Old Point Comfort at Fort Monroe to Salt Ponds Inlet. Generally, the shoreline on Plate 4 was erosional between 1937 and 1953. A beach existed in front of the seawall at Fort Monroe in 1937; however by 1953, much of the beach had disappeared except where the shore was stabilized with large rubble groins. Between 1994 and 2002, the shore was highly accretionary on Plate 4 likely due to the influx of sand from beach nourishment at Buckroe Beach. Buckroe Beach has been nourished periodically since the mid-1970s with several large fills occurring in the 1990s. Fort Monroe's Bay shores have benefitted from beach nourishment projects at Buckroe Beach since the net littoral movement of sands is southward in this area. However, on Plate 5, the highly accretionary period was between 1980 and 1994. On Plate 5, the breakwater built at Buckroe is visible on the 2002 photo.

Dune sites HP4, HP6 and HP7 all occur on Plate 5. HP4 and HP6 have evolved in the large rubble groin cells. As the beaches widened along Dog Beach on Fort Monroe, so did the backshore and eventually primary dunes developed and grew. By 2002, a secondary dune had developed at HP4 along the Bayside. Site HP7 occurs along a residential coast just north of Buckroe Beach. It is controlled in part by groins and has benefitted from the northward moving fraction of beach fill at Buckroe Beach. It also has widened enough to have developed a secondary dune.

### C. Reach III

Reach III extends from Salt Ponds Inlet north and west to Northend Point and is shown on Plates 6 and 7. On Plate 6, the marshes were subject to erosion and overwash. However, when the north side of Salt Ponds Inlet was stabilized in 1980 with a large jetty, sand accreted on the north side of the jetty since sand transport is

to the south. Severe erosion did not occur downdrift due to the slight northward sand transport of beach nourishment from Buckroe Beach. In addition, geotubes were placed on the beach in front of the Salt Ponds residential development as a dune core, and beach fill was used to cover them in 1998.

Dune sites HP 8A, HP 8B and HP 12 are found in Reach III. Site HP8A and HP8B are basically one long dune field that extends from Salt Ponds Inlet to Grandview. They are primary dune features with low vegetated backslopes that extend to a back barrier tidal marsh system and are separated by a short non-dunal area. They have evolved as part of a landward advancing low barrier beach system and now reside in a slightly curvilinear embayment between the Salt Ponds jetty and a rock headland formed by the offset at the Grandview Fishing pier. The system was relatively stable by 2002 as evidenced by reduced erosion rates from 1994 to 2002.

Site HP 12 is a dune field that occurs just northwest of the Lighthouse Point. It is a remnant of a longer dune site and has evolved in the more stable part of the spit. The spit once extended to Northend Point, but it was breached in approximately 1996. It has developed a secondary dune and reportedly was extensively planted with dune grasses in the early 1980s.

### D. Reach IV

Reach IV extends from Northend Point, up Back River to Tabb's Creek. No dune sites are reported in this reach, but shoreline evolution is illustrated in Plates 8 and 9. Shoreline change data were not calculated due to the irregularity of the shoreline. With the exception of the development/decay of spits and the erosion of several marsh islands, little shore change is occurring along Plates 8 and 9.

## 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 HP 2 has been a relatively stable dune through time and is probably more secure within the confines of the breakwater system installed in 2000. However, Hurricane Isabel overwashed the dune at site HP2 (Figure 7A). In fact, damage occurred to many shore protection structures along Hampton’s Hampton Roads shoreline (Figure 7B).

### B. Reach II

Hurricane Isabel eroded the primary dune along the entirety of Dog Beach. Surge levels overwashed the seawall at Fort Monroe. Several breaches occurred in the HP4 groin cell (Figure 8A); a large one occurred about the middle of the groin cell where sand was carried beyond the dune system and onto the adjacent road bed. This was also the area where the dune was low and interrupted by a pedestrian access. No overwashes occurred in the HP6 groin cell perhaps due to the broken concrete dune core. Ongoing beach fill at Buckroe Beach will help support HP4 and HP6 along Dog Beach over the long term. Recent rebuilding of the groins may allow each site to expand Bayward.

Hurricane Isabel impacts to HP7 were also severe (Figure 8B). Numerous breaches occurred along the primary dune and large volumes of sand were carried into adjacent yards and under cottages. Evidence of sand movement back to the beach can be seen in imagery taken right after the storms (Figure 8B). The primary dune is on a slow a road to recovery; ongoing beach fill at Buckroe Beach should aid in this process.

### C. Reach III

Although set in a relatively stable embayment, further recession onto the adjacent marsh can be expected during serve storms(Figure 8C). Hurricane Isabel altered the morphology when surge washed over dune site HP8 in its entirety; however, the primary dune vegetation line remained mostly intact. Recovery has been slow, and no sand has been placed updrift to help the process. The site’s geomorphic setting, a linear embayment, appears to aid the process of healing along the site.

Dune Site HP12, the long dune field north and west of Lighthouse Point was also a direct recipient of storm surge and waves from Hurricane Isabel. It was not overtopped or breached during the event but the

primary dune was significantly eroded receding more than 25 feet in some areas (Figure 8D). This left the secondary dune as the primary dune. By enhancing the dune with plantings and increasing its height to almost 14 ft MLW, the wave energy was expended on the dune face instead of washing over like at HP 8 and HP 7.

### D. Reach IV

No dune sites occur along Reach IV.



Figure 7. Hampton Roads shoreline after Hurricane Isabel A) at dune site Hp2 and B) along a typical shoreline. Photo date: 22 Sep 2003.

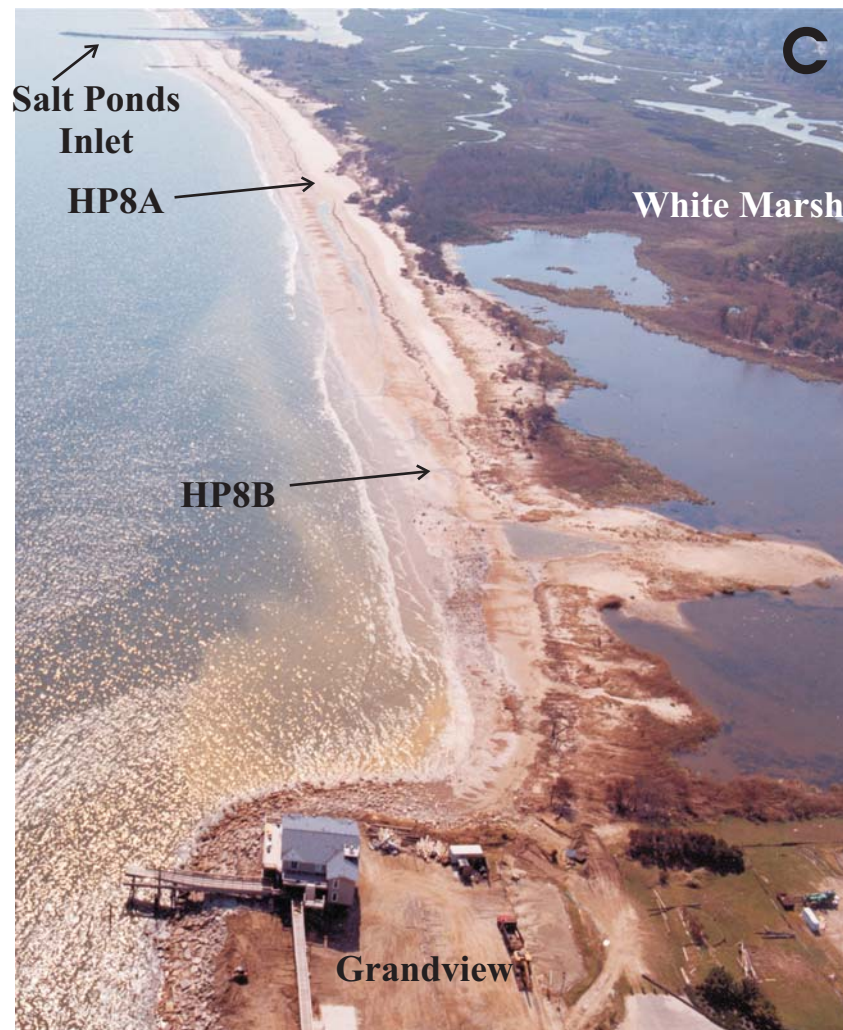
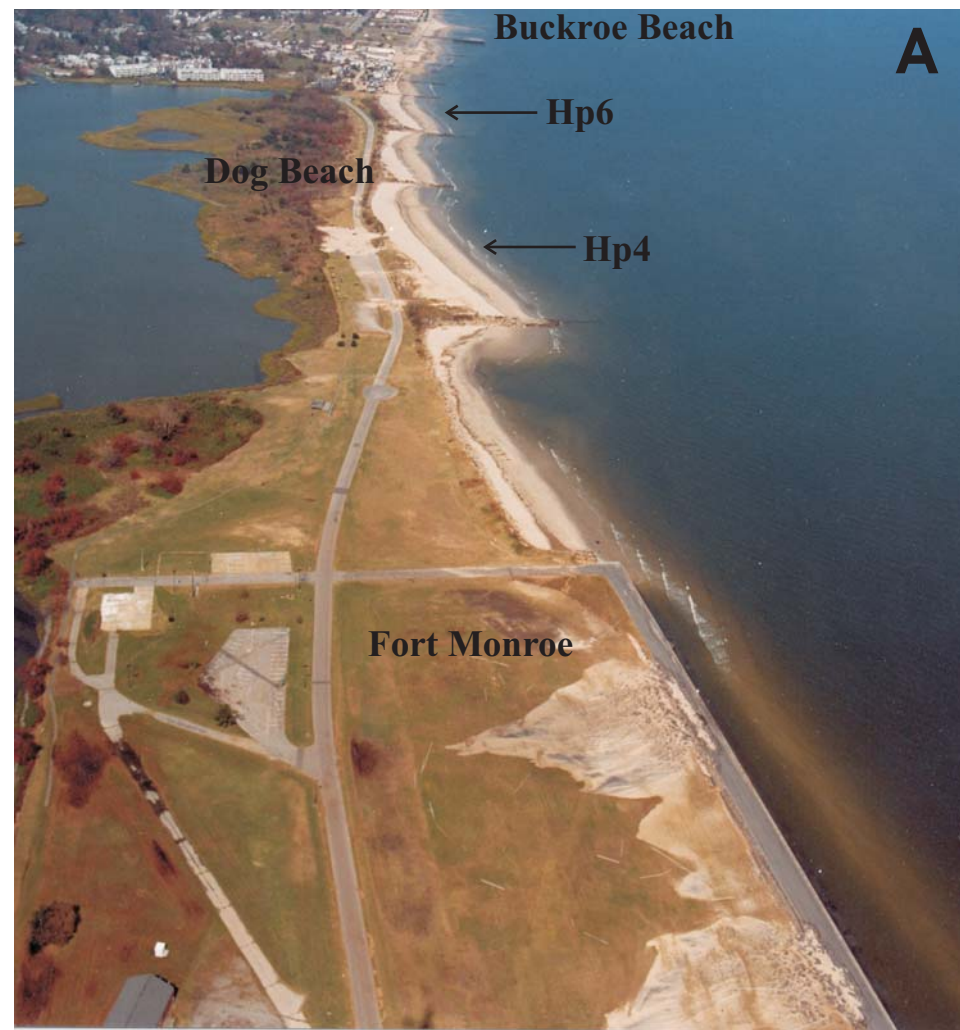


Figure 8. Aerial photos taken of the Hampton shoreline on 24 Jan 2004 after Hurricane Isabel. A) Looking north from Fort Monroe toward Dog Beach and Buckroe Beach, B) Non-rectified aerial photo mosaic shore segment between Buckroe Beach and Salt Ponds Inlet, C) Looking south toward Salt Ponds Inlet from Grandview, and D) looking north along Grandview Nature Preserve.

## 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 City of Hampton. 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 six 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 6. For instance, between 1994 and 2002, the standard deviation is 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 of the dates for this section of shore had mean shore change rates with large standard deviations. For several periods, 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.

Plate No.	Mean Shore Change 1937-1953		Mean Shore Change 1953-1963		Mean Shore Change 1963-1980		Mean Shore Change 1980-1994		Mean Shore Change 1994-2002		Mean Shore Change 1937-2002	
	(ft/yr)	Std Dev (ft/yr)	(ft/yr)	Std Dev (ft/yr)	(ft/yr)	Std Dev (ft/yr)	(ft/yr)	Std Dev (ft/yr)	(ft/yr)	Std Dev (ft/yr)	(ft/yr)	Std Dev (ft/yr)
<b>Plate 1</b>	-1.2	2.7	-1.4	1.3	-0.5	2.9	0.9	3.4	-2.0	6.1	-0.8	1.4
<b>Plate 2</b>	-0.8	2.8	-0.3	2.0	-1.1	3.3	0.9	3.3	1.1	0.9	-0.2	0.7
<b>Plate 3</b>	0.9	1.0	2.2	9.1	0.2	1.5	-0.3	1.3	1.6	1.7	0.6	1.4
<b>Plate 4</b>	-2.2	3.1	0.5	3.1	0.7	1.1	0.1	1.0	2.6	2.3	0.1	0.8
<b>Plate 5</b>	-0.6	1.8	0.6	4.5	0.0	2.1	3.7	2.1	-0.4	2.0	0.7	0.7
<b>Plate 6</b>	-5.3	2.5	-11.0	5.2	-2.2	1.4	-2.3	4.2	-0.6	4.0	-4.1	2.4
<b>Plate 7</b>					0.6	2.6	-2.7	5.5	-3.5	6.2	-3.9	3.9
<b>Average<sup>^</sup></b>	-1.5	2.3	-1.6	4.2	-0.5	2.1	0.5	2.5	0.4	2.8	-0.6	1.2

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

<sup>^</sup>Calculated using all available data

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## Acknowledgments

The authors would like to thank the personnel in VIMS' Publications Center, particularly Susan Stein, Ruth Hershner, and Sylvia Motley, for their work in printing and compiling the final report.



## APPENDIX A

For each Plate shown on Figure 4, Appendix A contains orthorectified aerial photography flown in 1937, 1953, 1963, 1980, 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.**

[Plate 1](#)   [Plate 4](#)   [Plate 7](#)  
[Plate 2](#)   [Plate 5](#)   [Plate 8](#)  
[Plate 3](#)   [Plate 6](#)   [Plate 9](#)



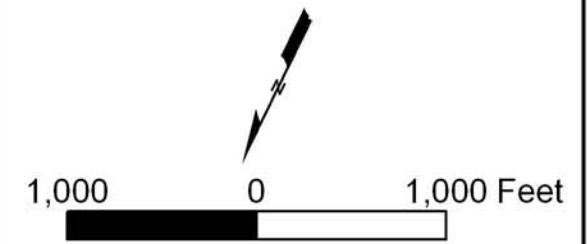
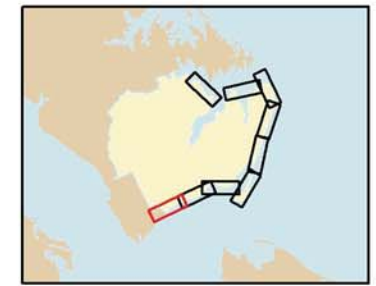
# City of Hampton

## Plate 1

Morphological Reach I  
Hampton City Line to Mill Creek

**Legend**

- Transect Point
- Baseline
- 1937 Shoreline
- 1953 Shoreline



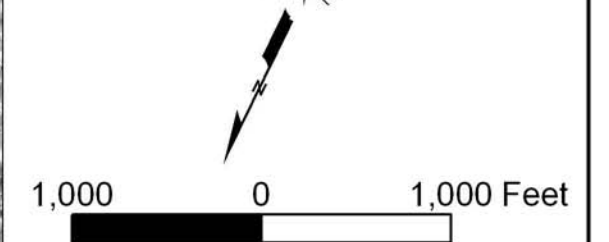
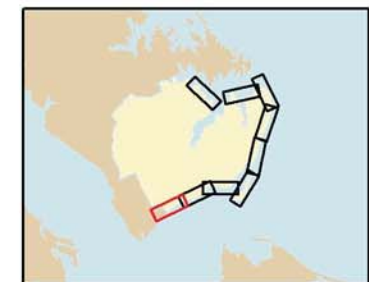


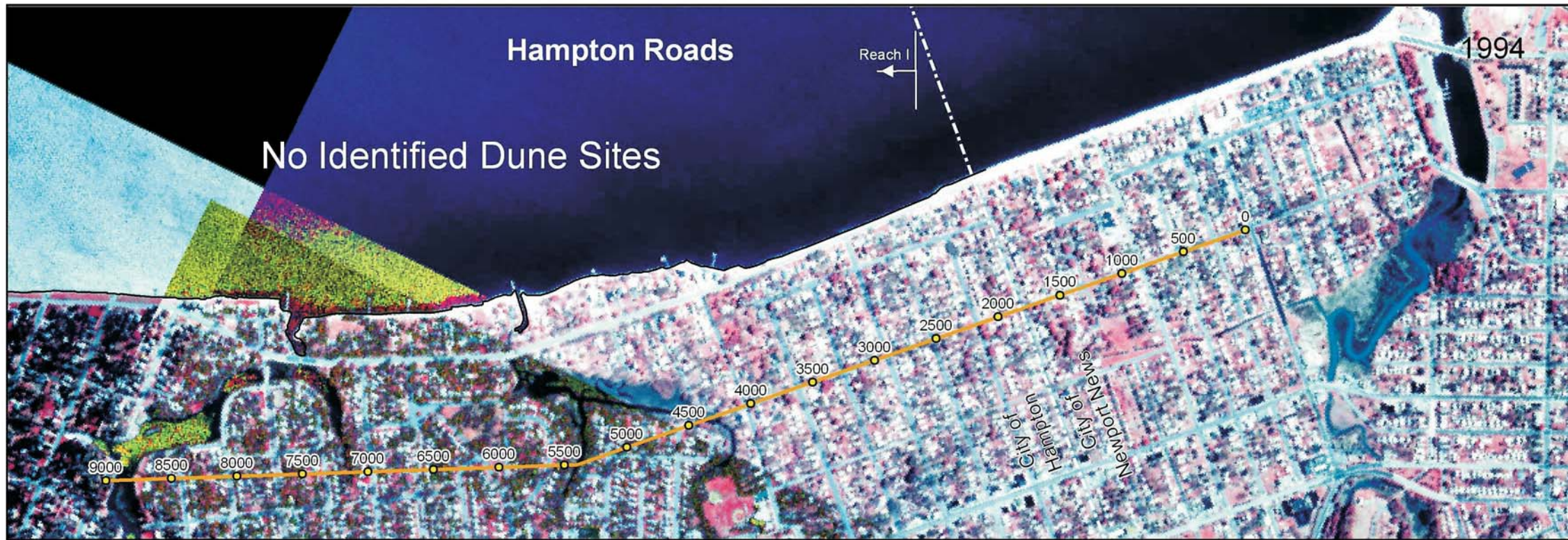
# City of Hampton Plate 1

Morphological Reach I  
Hampton City Line to Mill Creek

**Legend**

- Transect Point
- Baseline
- 1963 Shoreline
- 1980 Shoreline





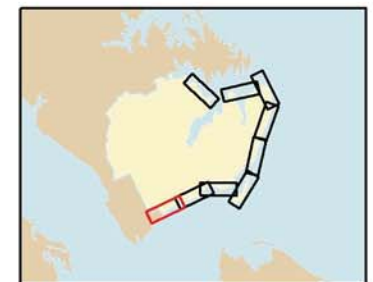
# City of Hampton

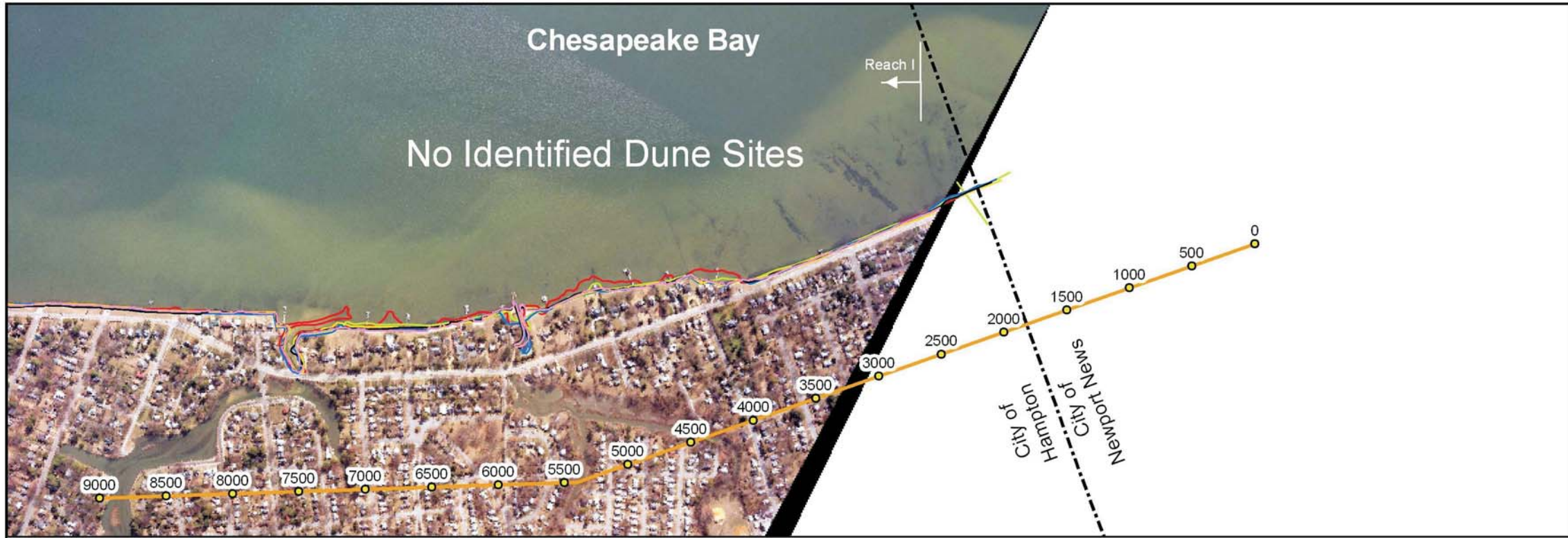
## Plate 1

Morphological Reach I  
Hampton City Line to Mill Creek

### Legend

- Transect Point
- Baseline
- 1994 Shoreline
- 2002 Shoreline



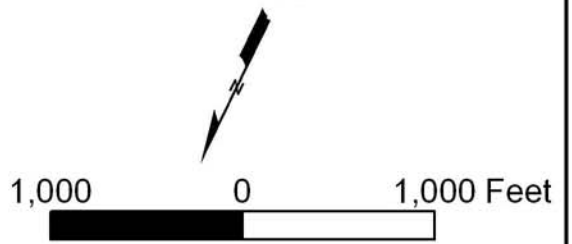
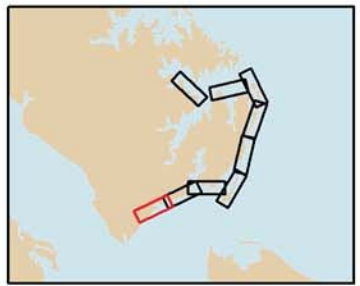


# City of Hampton

## Plate 1

**Legend**

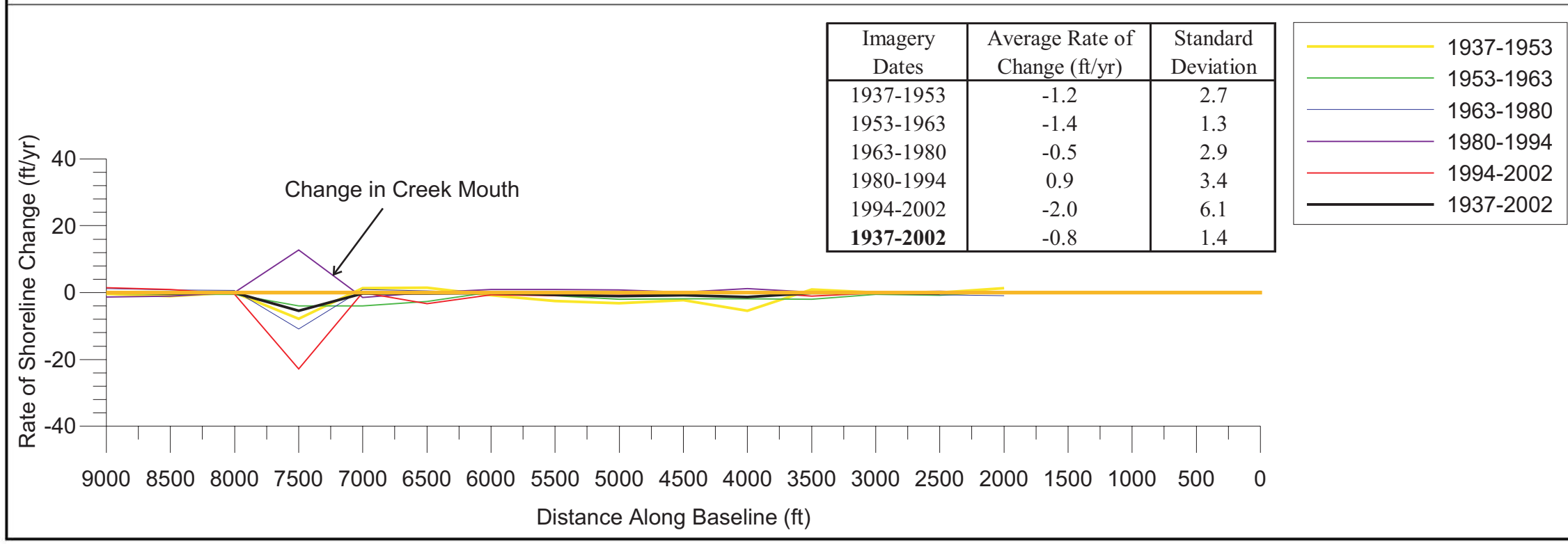
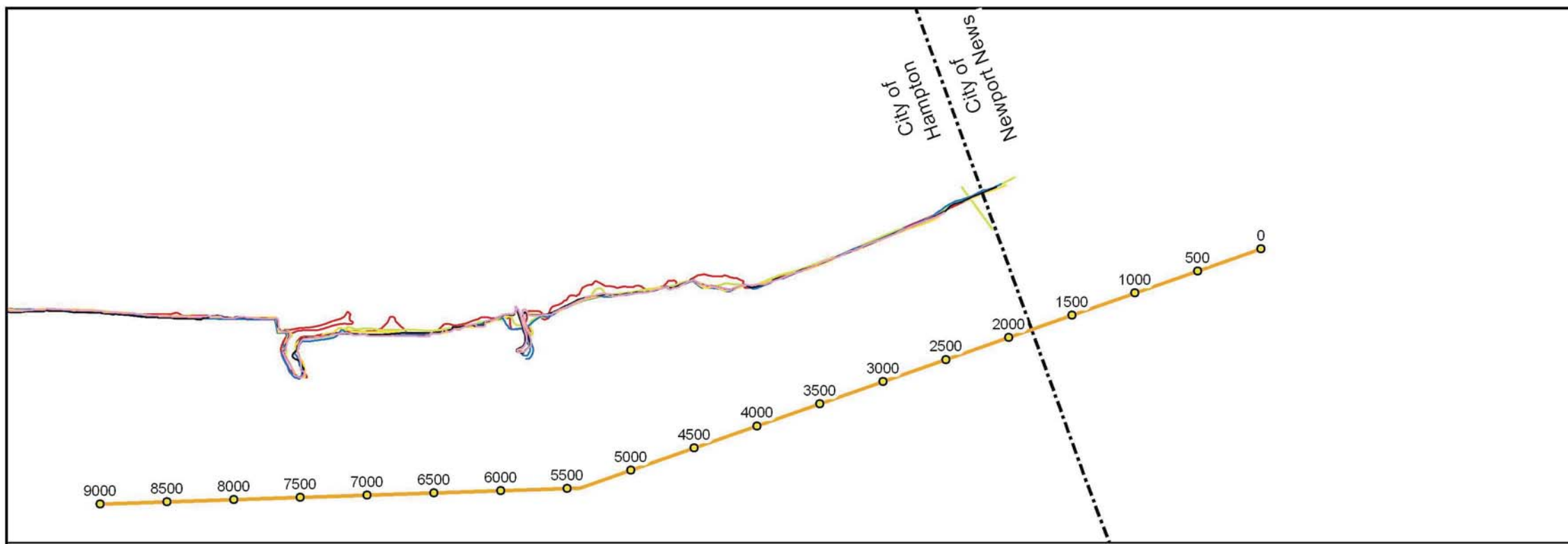
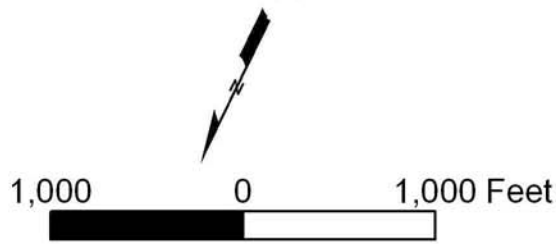
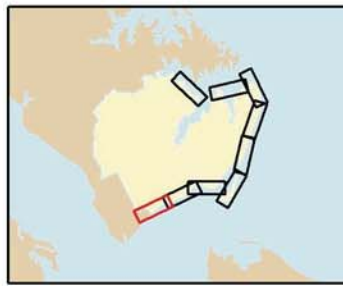
- Transect Point
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline

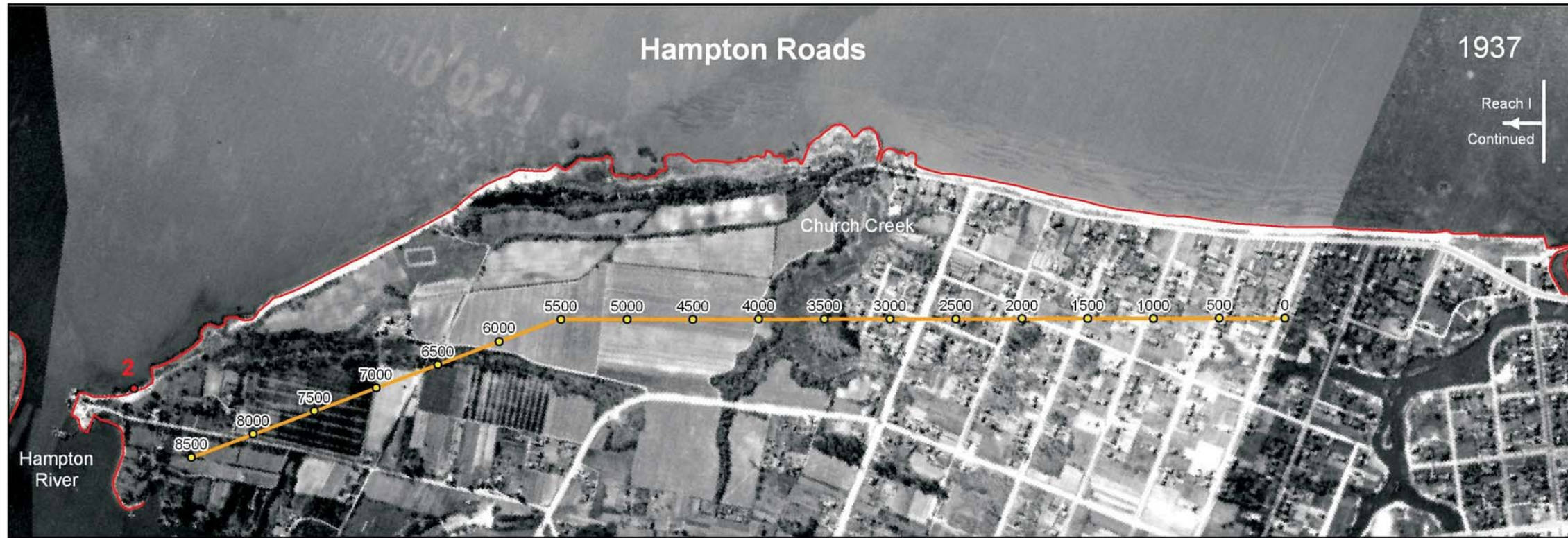


# City of Hampton Plate 1

## Legend

- Transect Point
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline





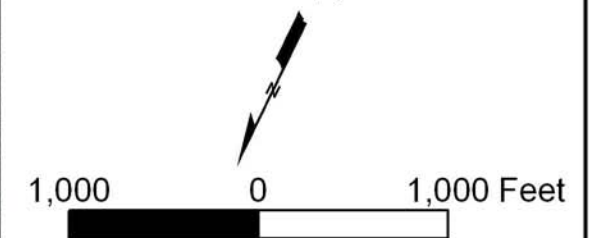
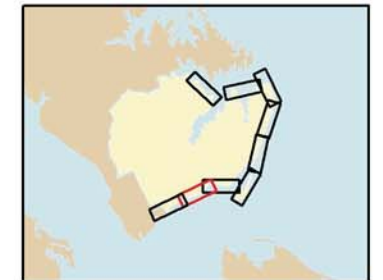
# City of Hampton

## Plate 2

Morphological Reach I  
Hampton City Line to Mill Creek

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline



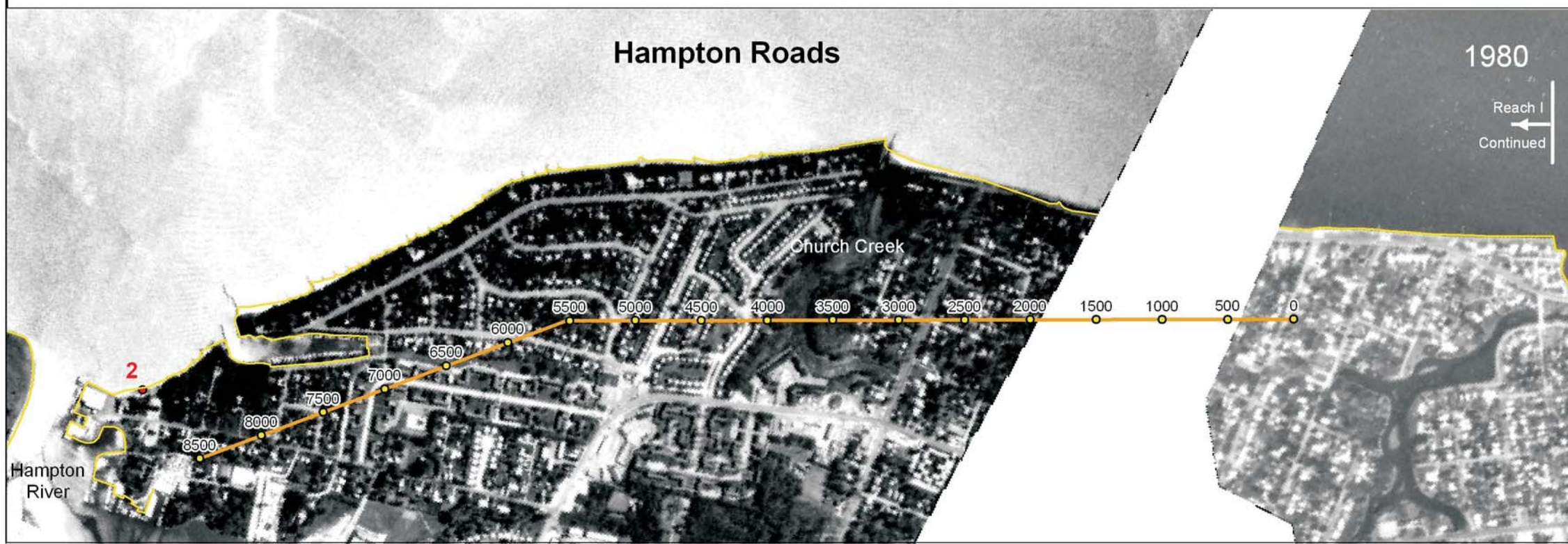


## City of Hampton Plate 2

Morphological Reach I  
Hampton City Line to Mill Creek

### Legend

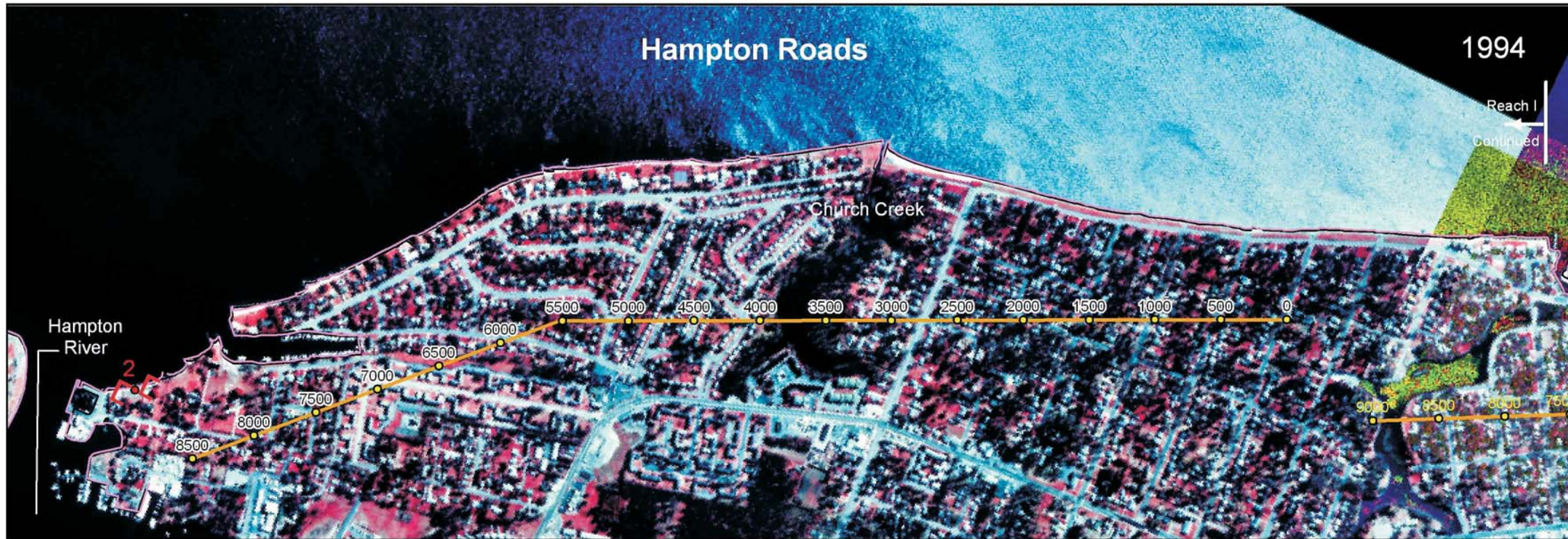
- Transect Point
- Identified Dune Sites
- Baseline
- 1963 Shoreline
- 1980 Shoreline



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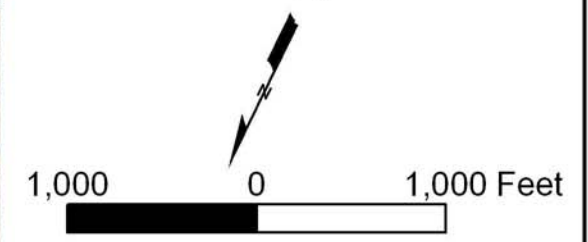
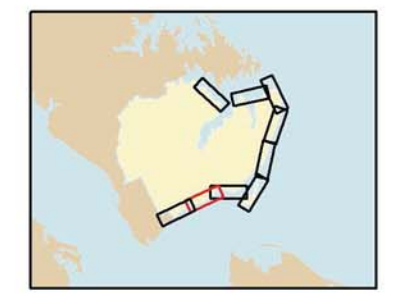


# City of Hampton Plate 2

Morphological Reach I  
Hampton City Line to Mill Creek

**Legend**

- Transect Point
- Identified Dune Sites
- Dune Site Limits
- Baseline
- 1994 Shoreline
- 2002 Shoreline

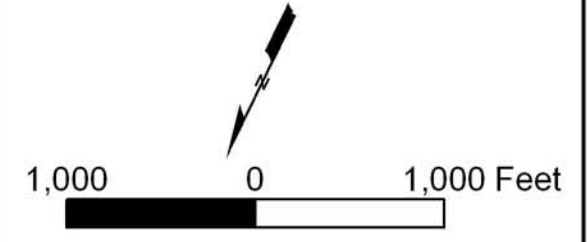
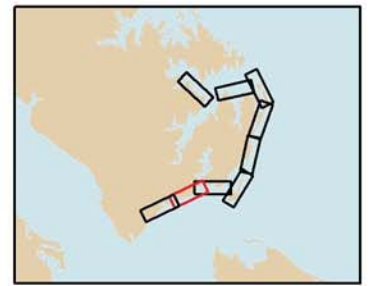




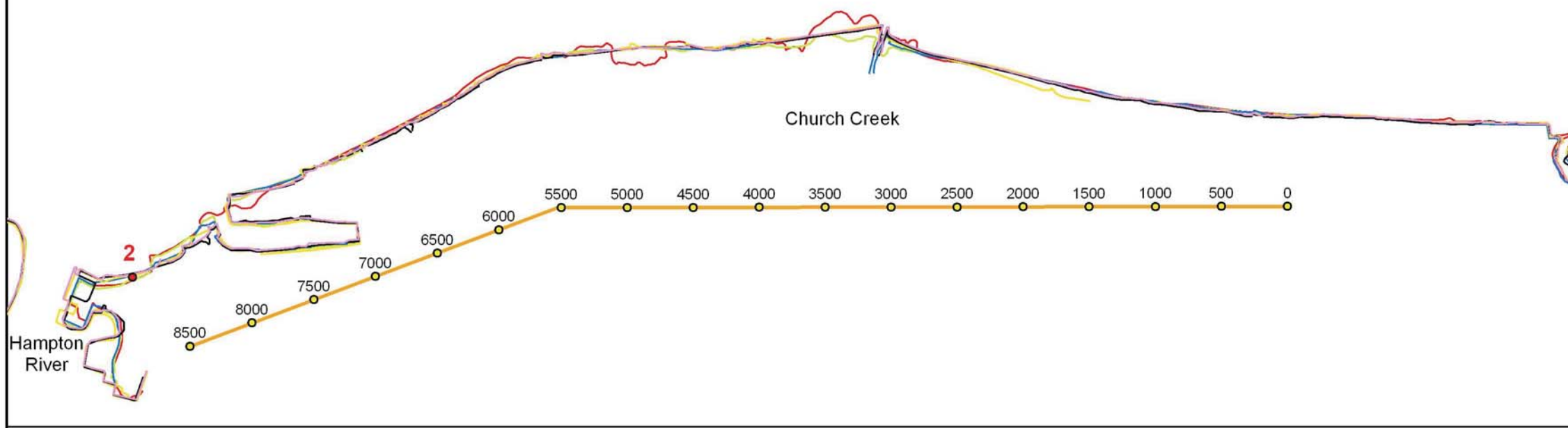
# City of Hampton Plate 2

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline



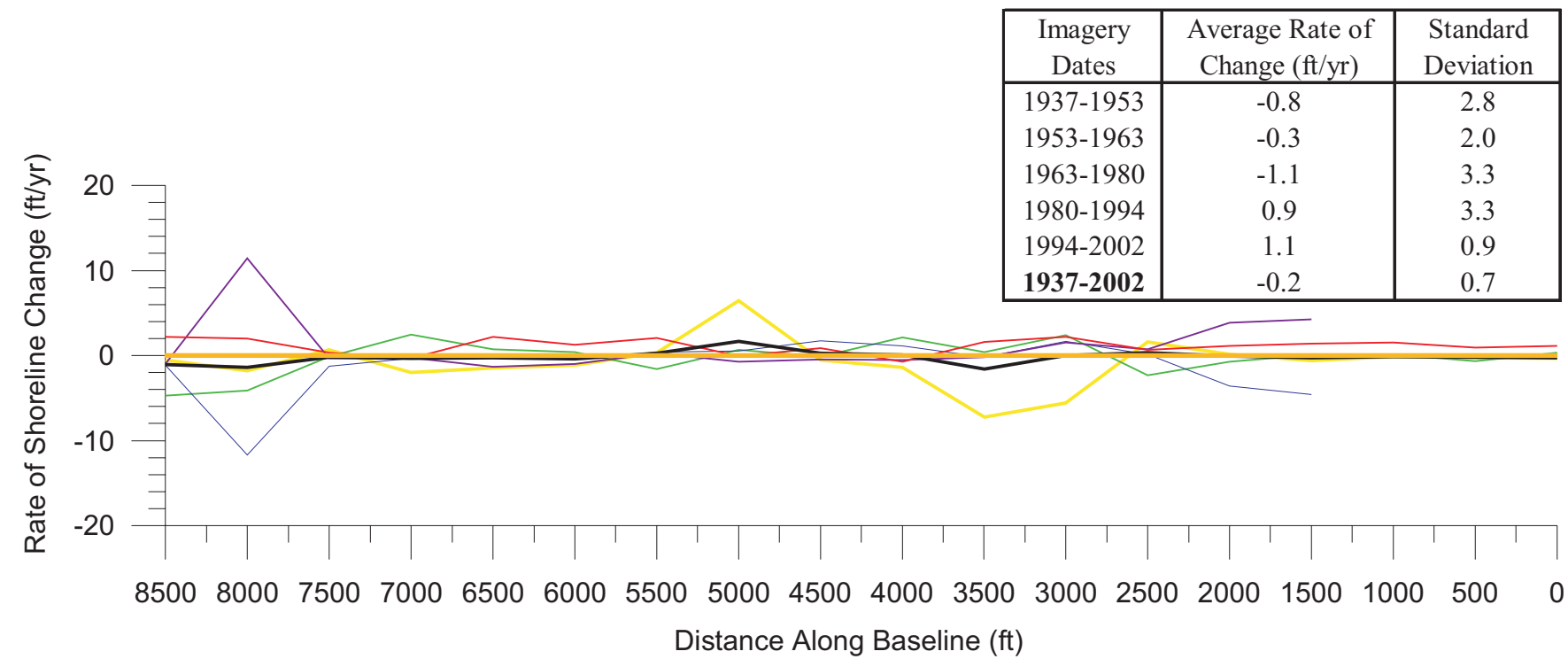
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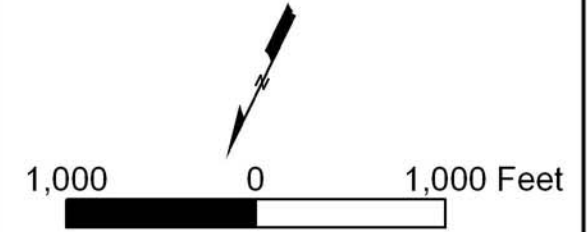
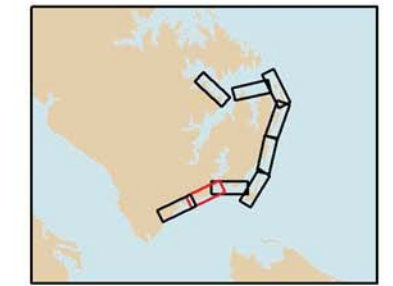
## City of Hampton Plate 2

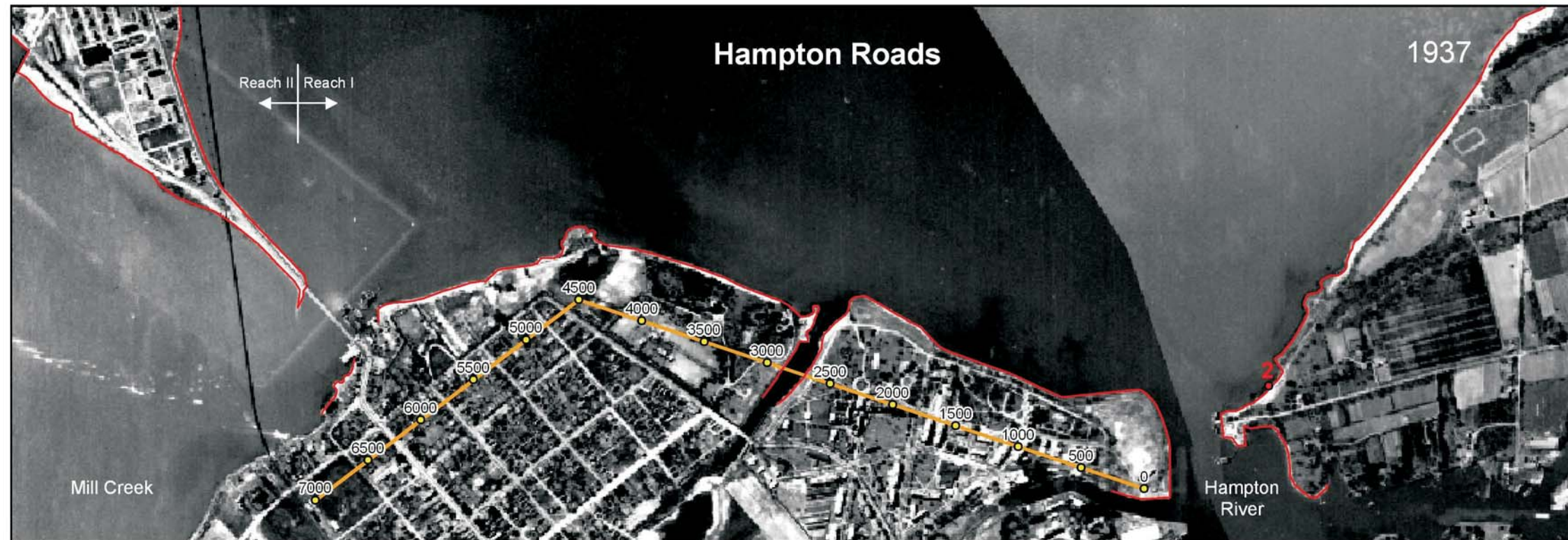
**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline



- 1937-1953
- 1953-1963
- 1963-1980
- 1980-1994
- 1994-2002
- 1937-2002

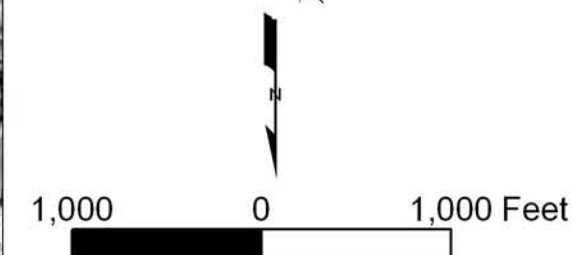




**City of Hampton**  
**Plate 3**  
 Morphological Reach I  
 Hampton City Line to Mill Creek

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline



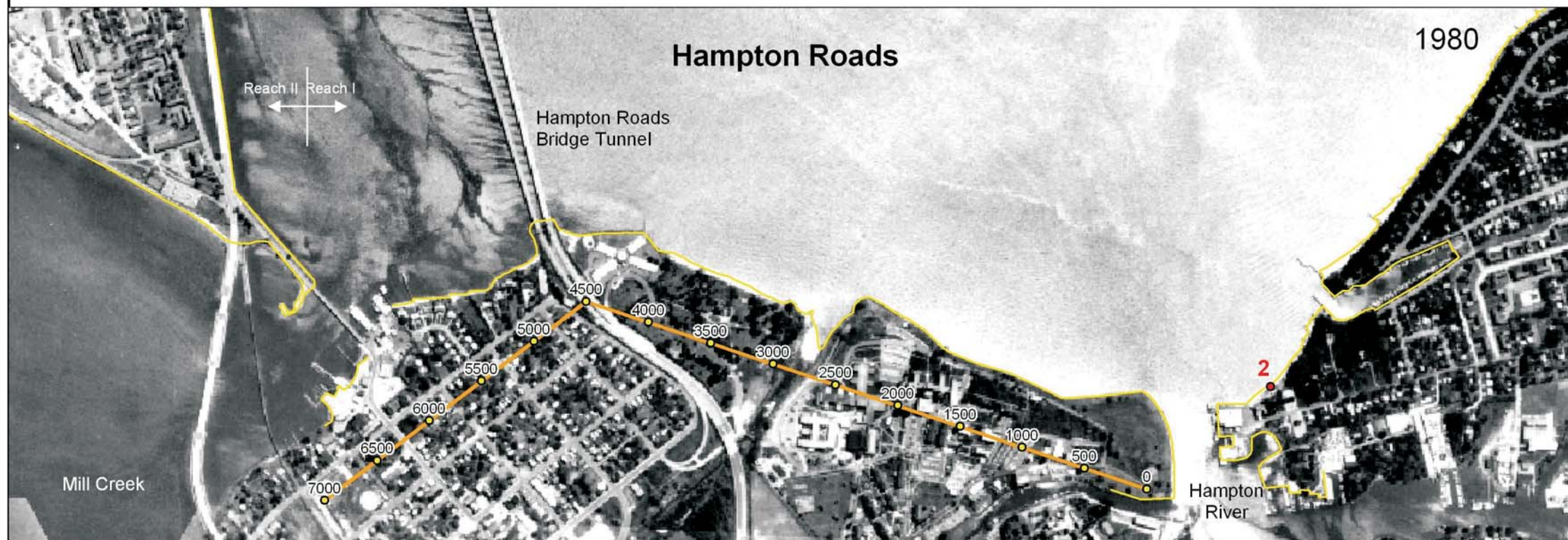


# City of Hampton Plate 3

Morphological Reach I  
Hampton City Line to Mill Creek

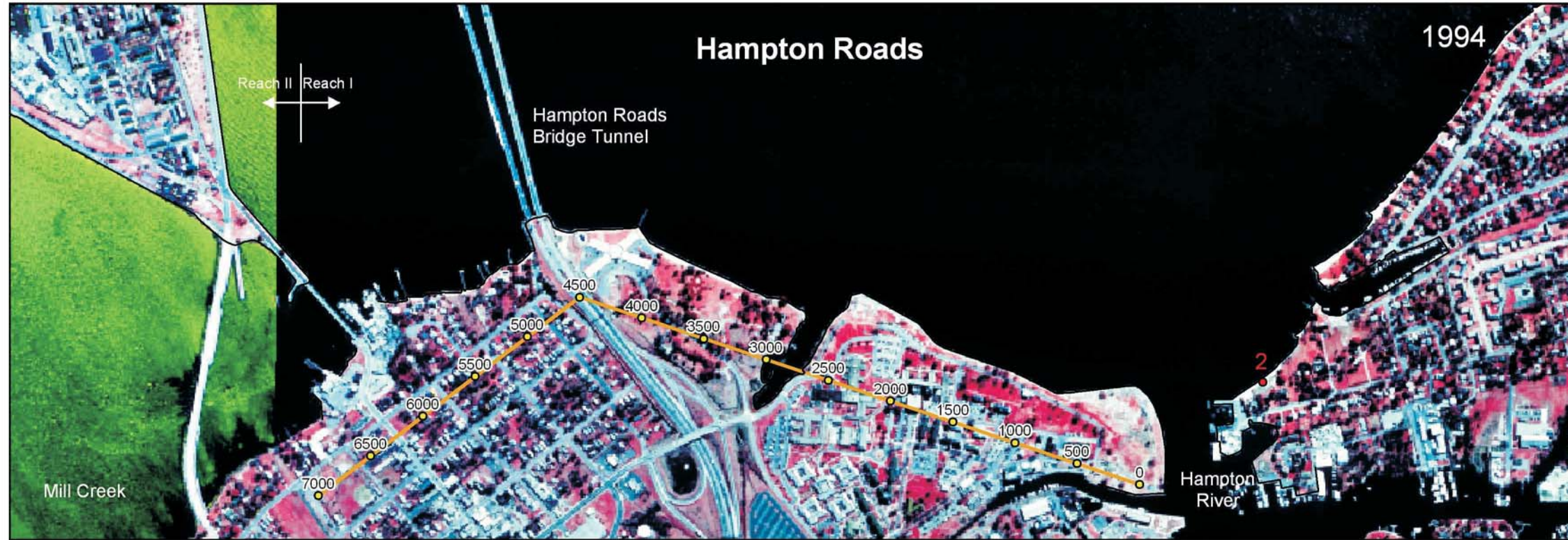
**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1963 Shoreline
- 1980 Shoreline



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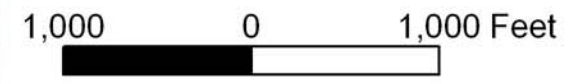
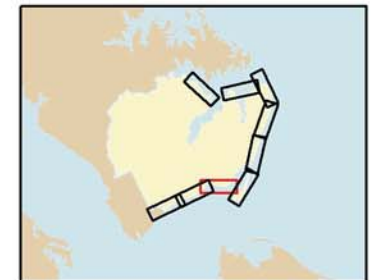
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**City of Hampton**  
**Plate 3**  
 Morphological Reach I  
 Hampton City Line to Mill Creek

**Legend**

- Transect Point
- Identified Dune Sites
- Dune Site Limits
- Baseline
- 1994 Shoreline
- 2002 Shoreline

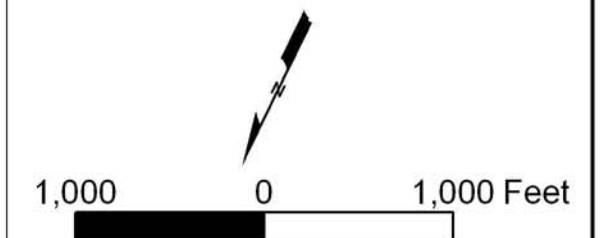


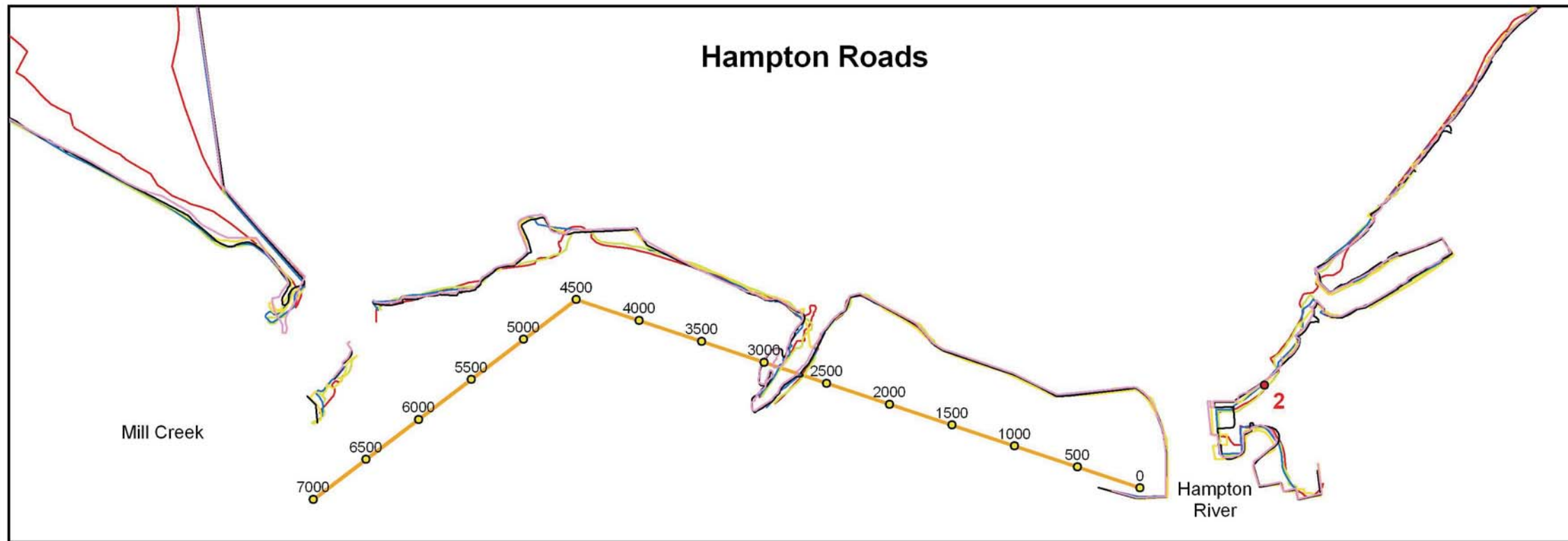


# City of Hampton Plate 3

## Legend

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline

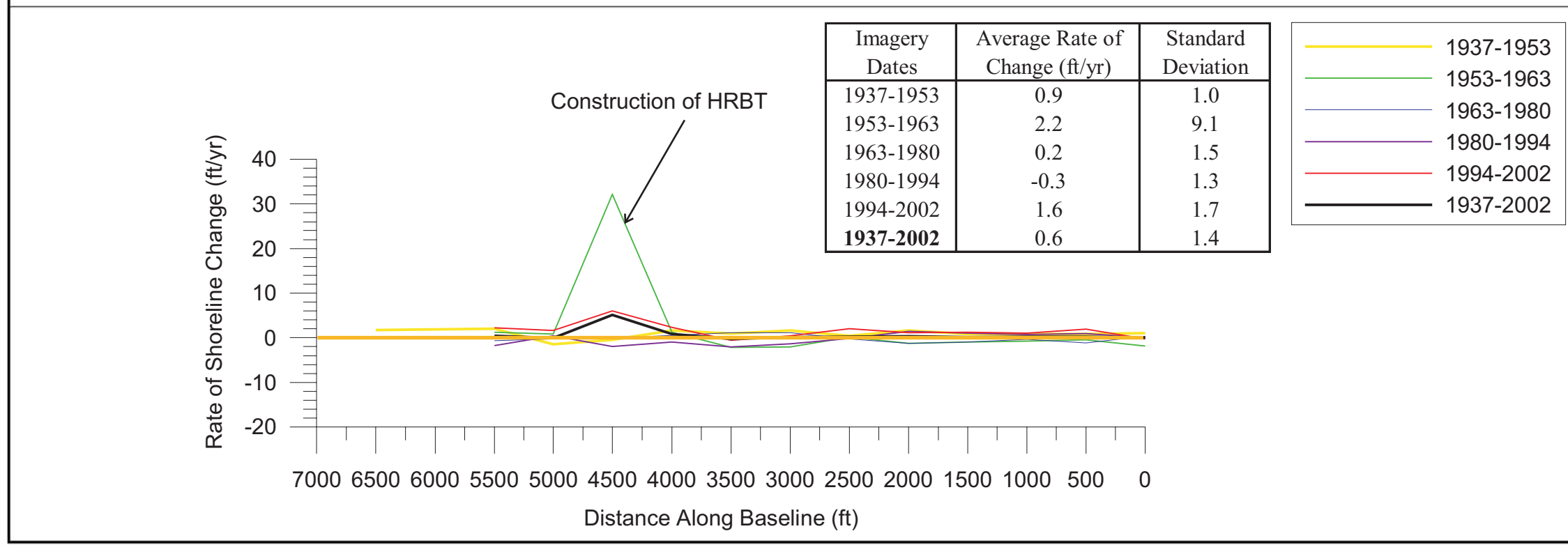




## City of Hampton Plate 3

### Legend

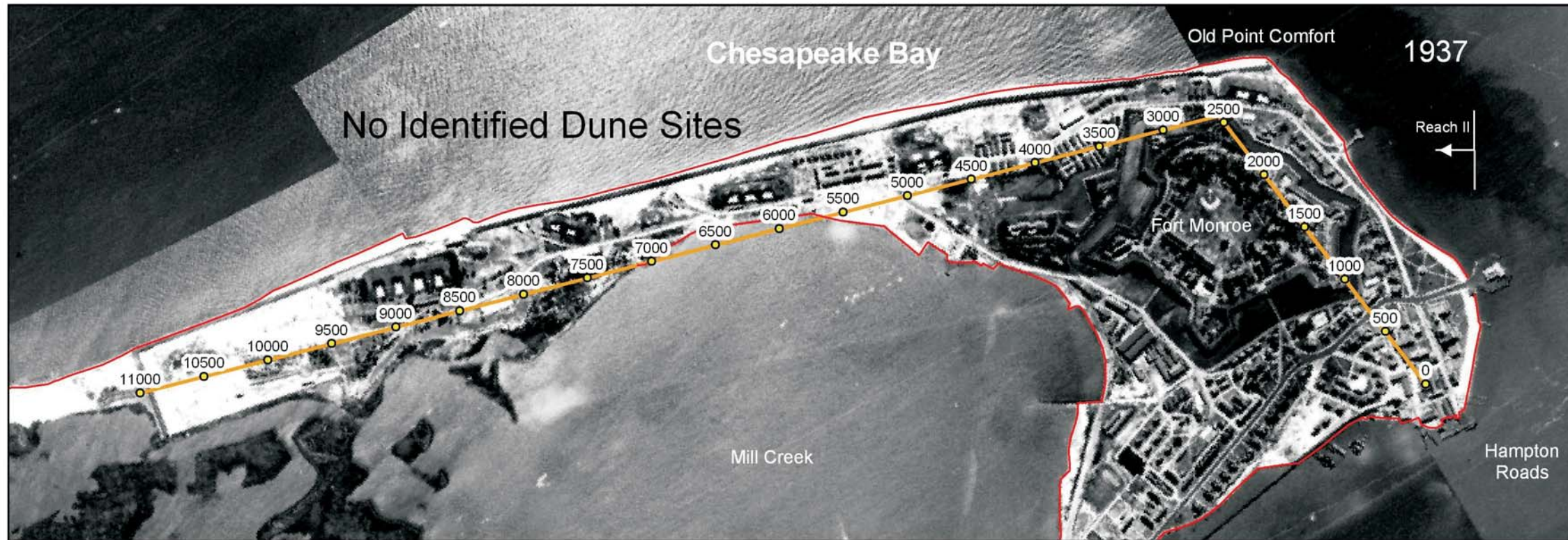
- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline



VIMS  
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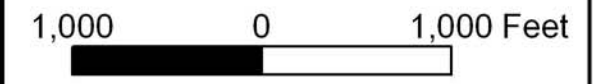
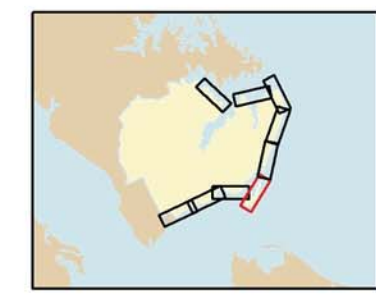
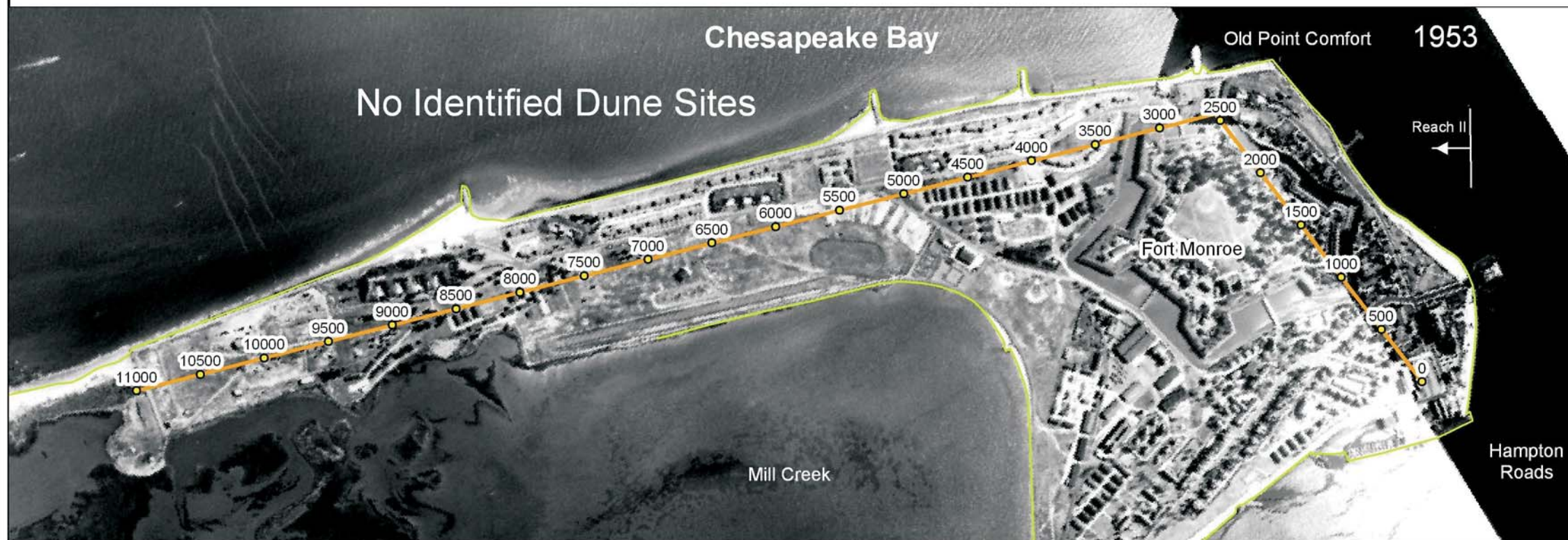


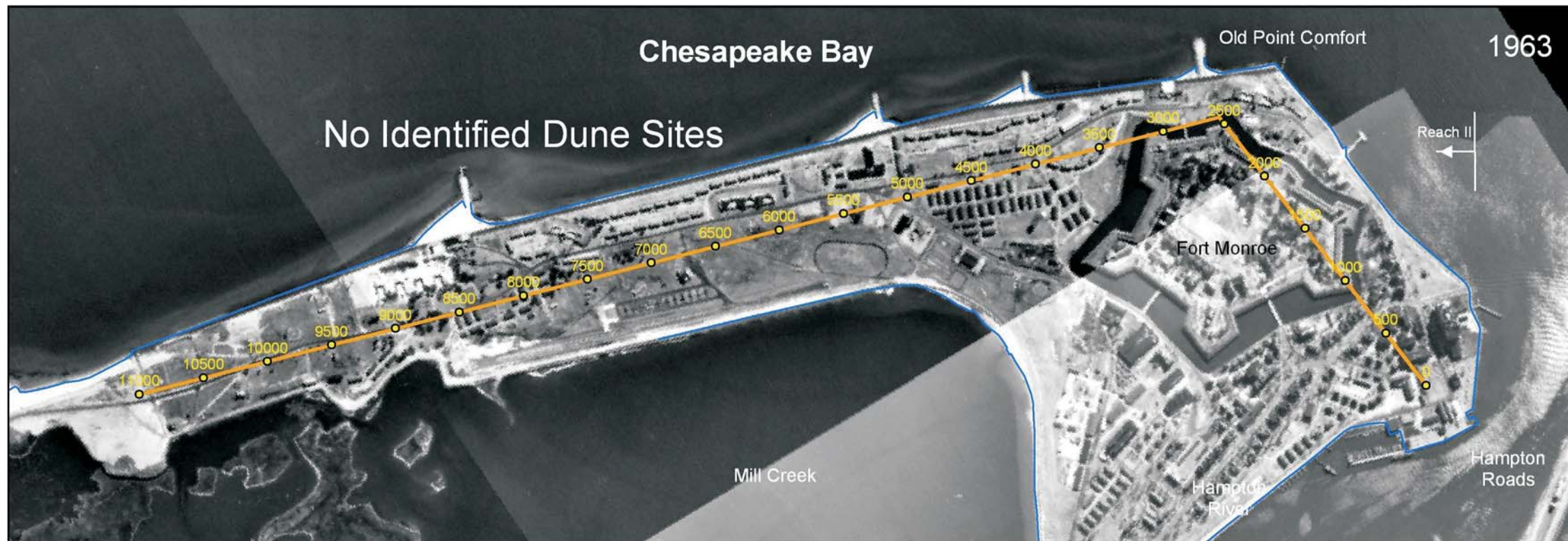
# City of Hampton Plate 4

Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet

**Legend**

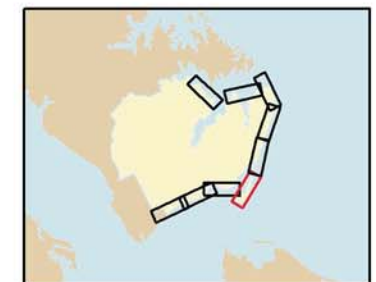
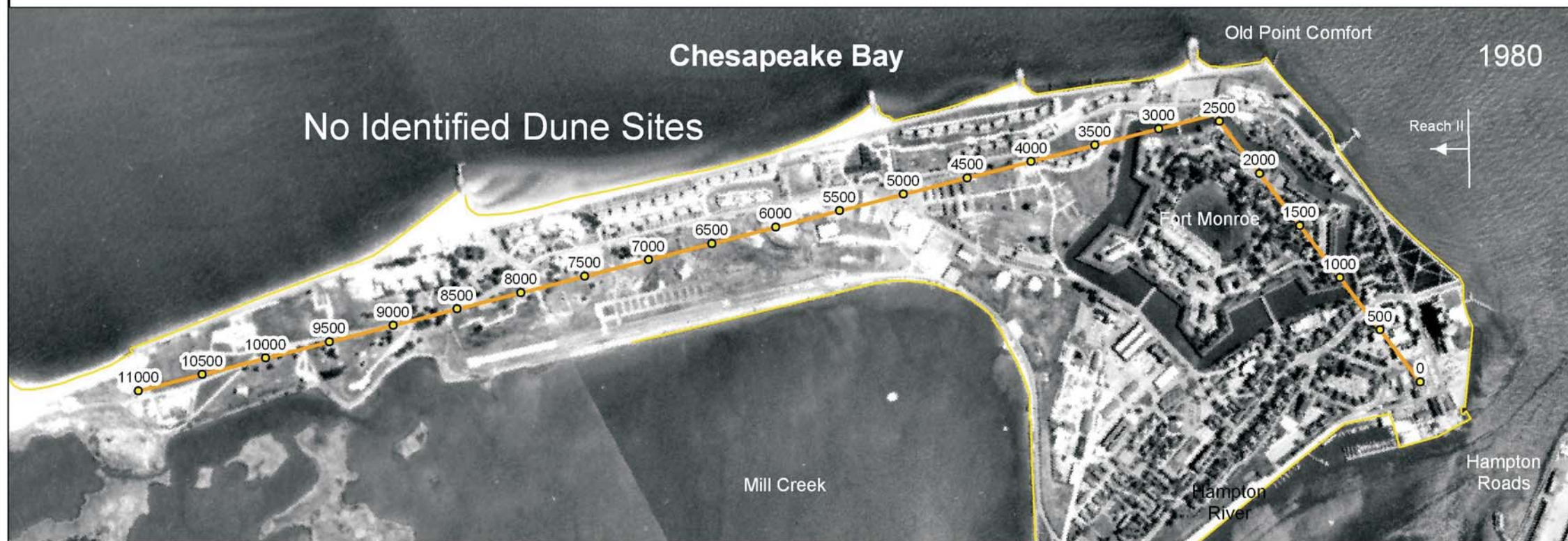
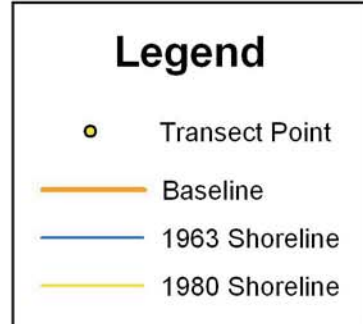
- Transect Point
- Baseline
- 1937 Shoreline
- 1953 Shoreline

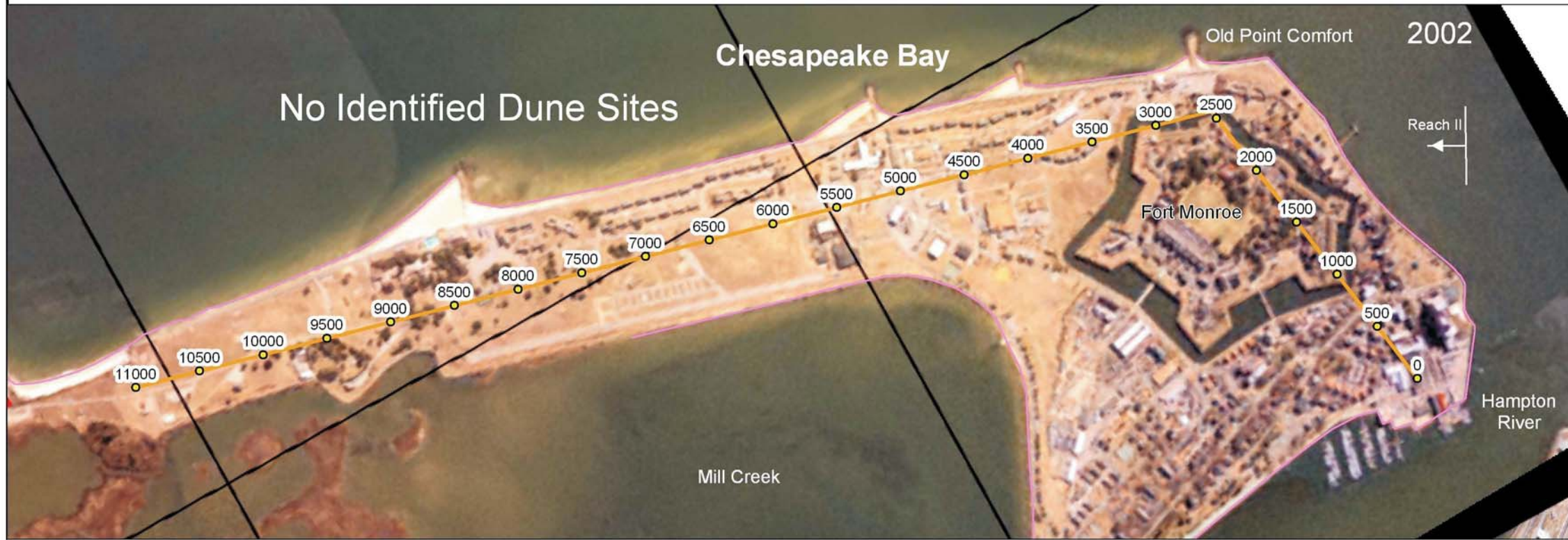
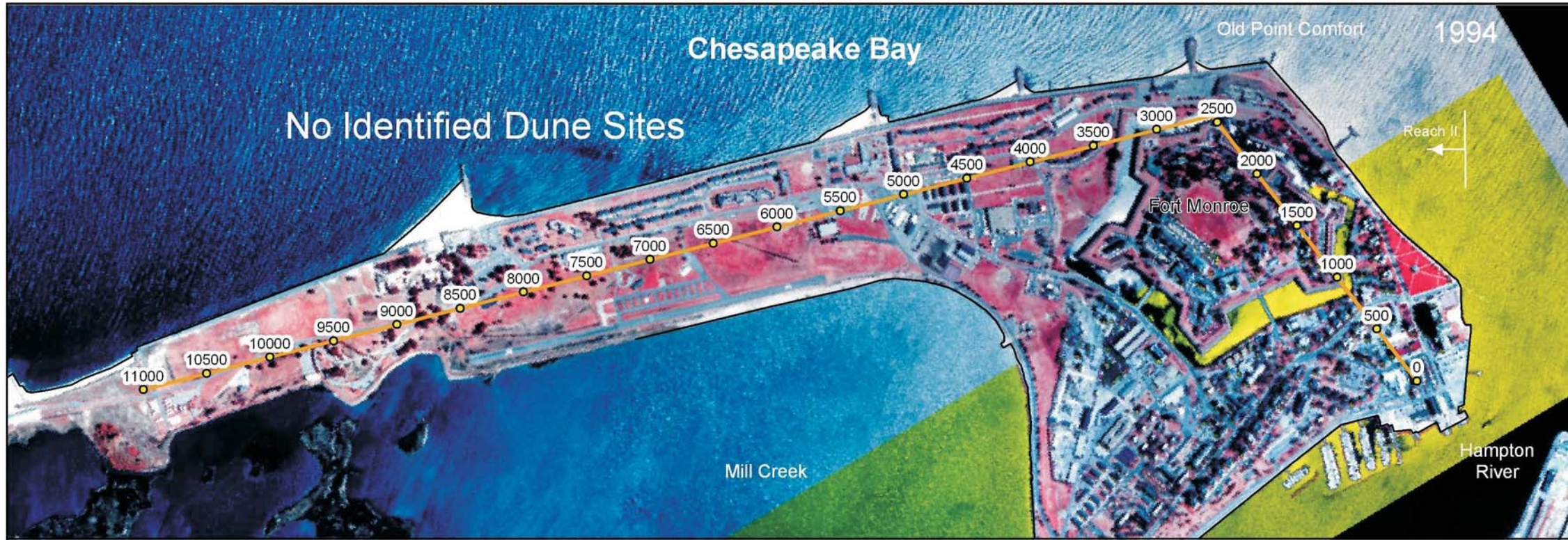




# City of Hampton Plate 4

Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet





## City of Hampton Plate 4

Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet

### Legend

- Transect Point
- Baseline
- 1994 Shoreline
- 2002 Shoreline

*Shoreline Studies Program*  
VIMS

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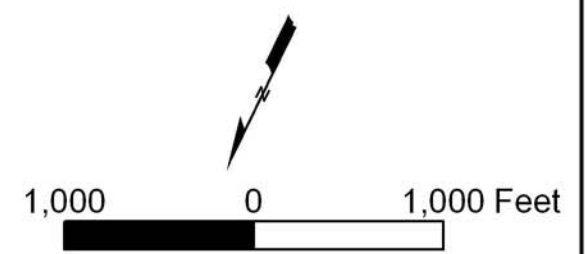
# City of Hampton

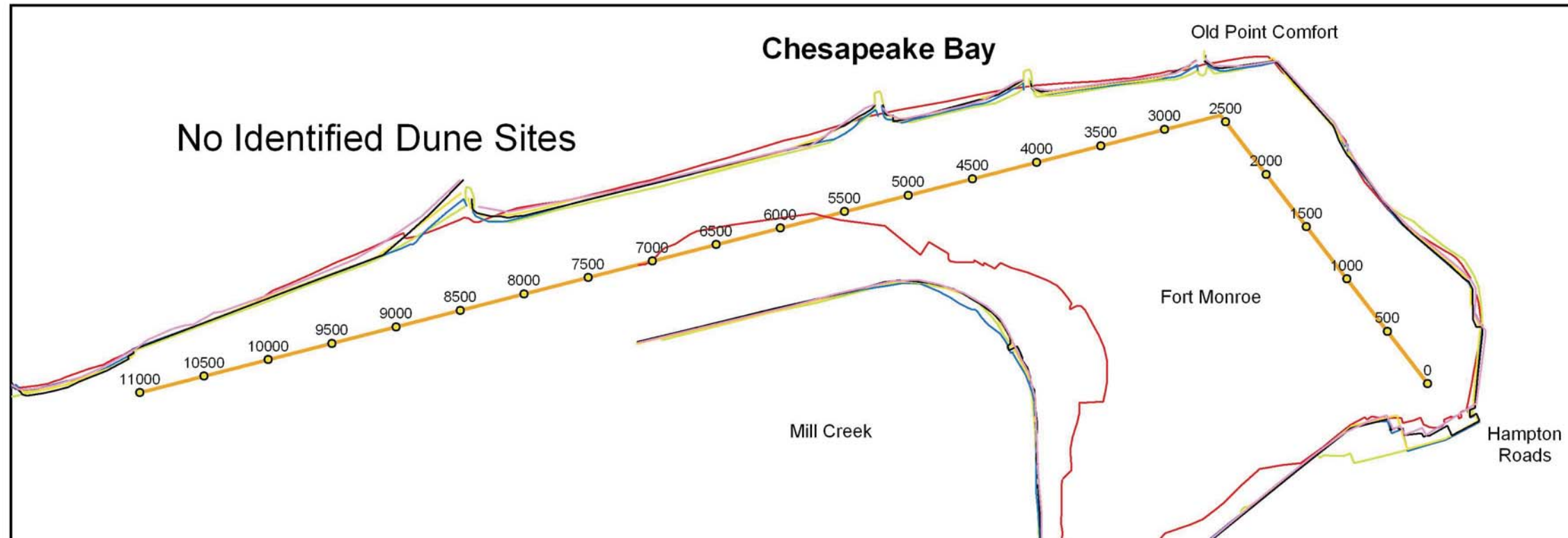
## Plate 4

Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet

**Legend**

- Transect Point
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline

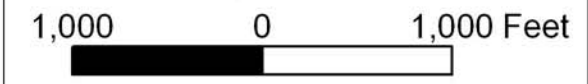
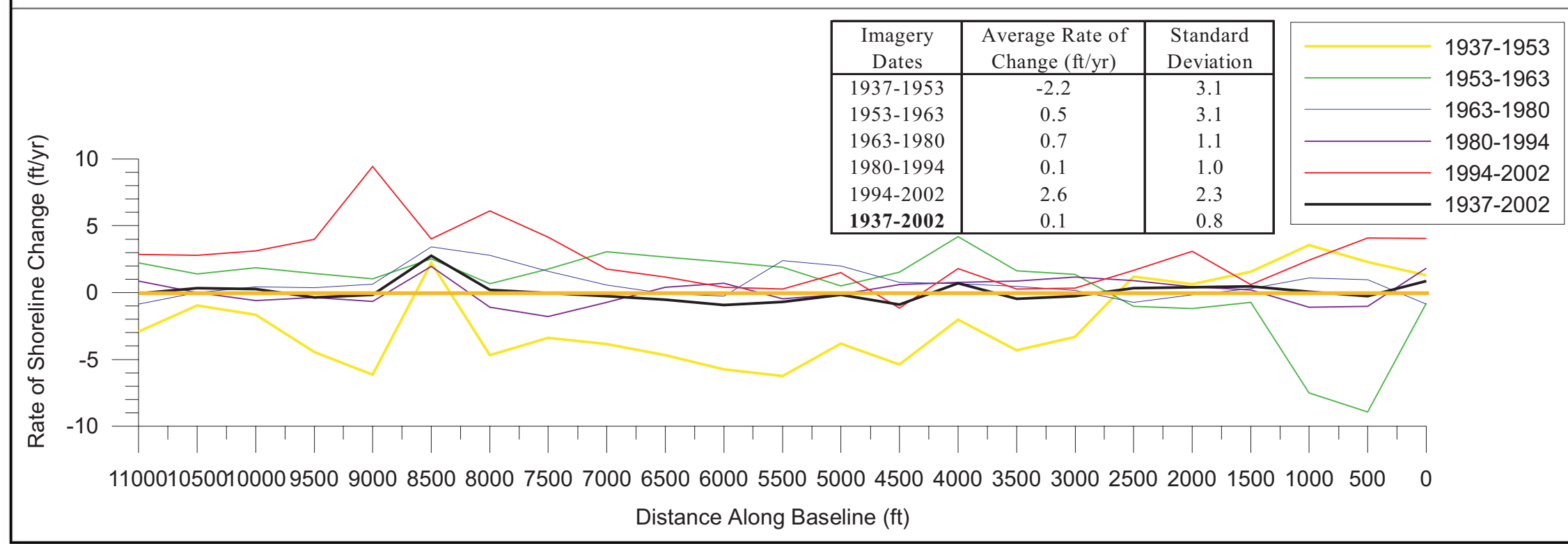
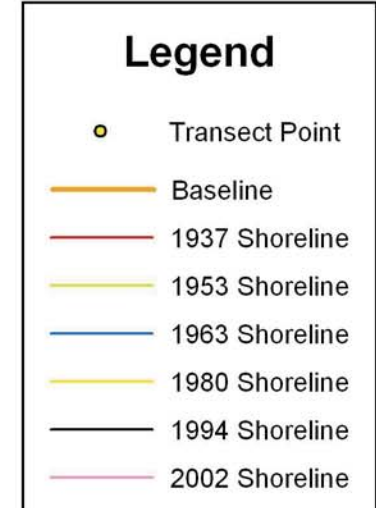


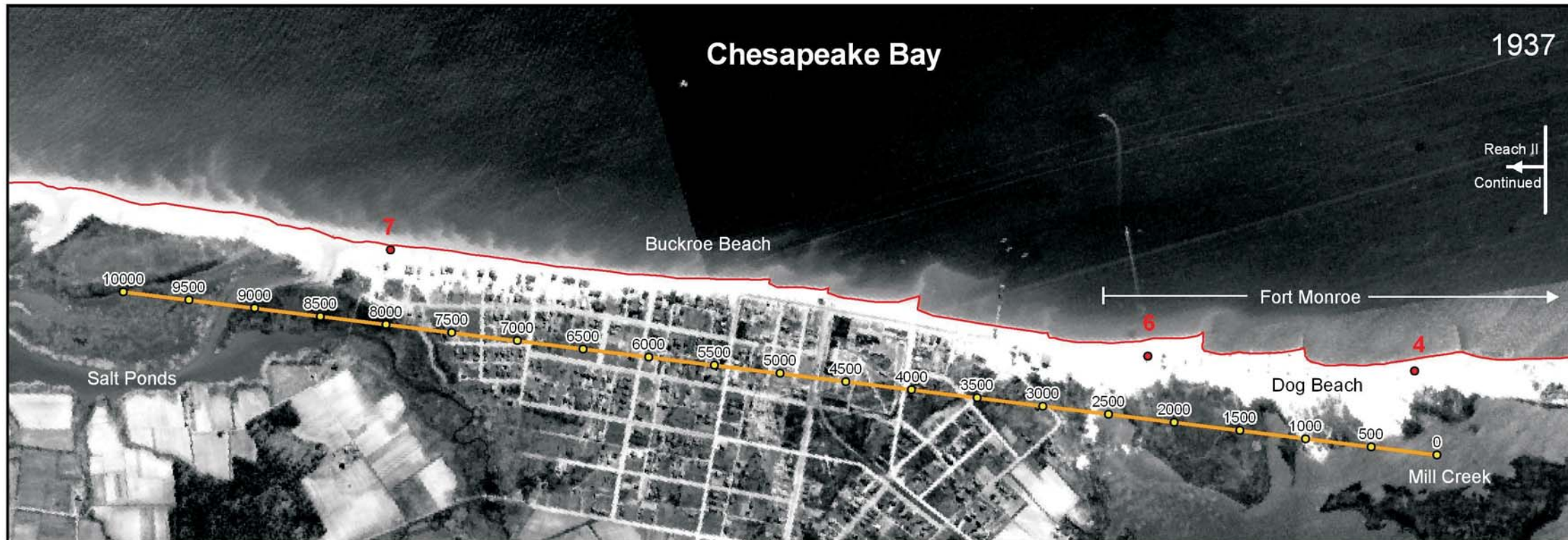


## City of Hampton

### Plate 4

Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet



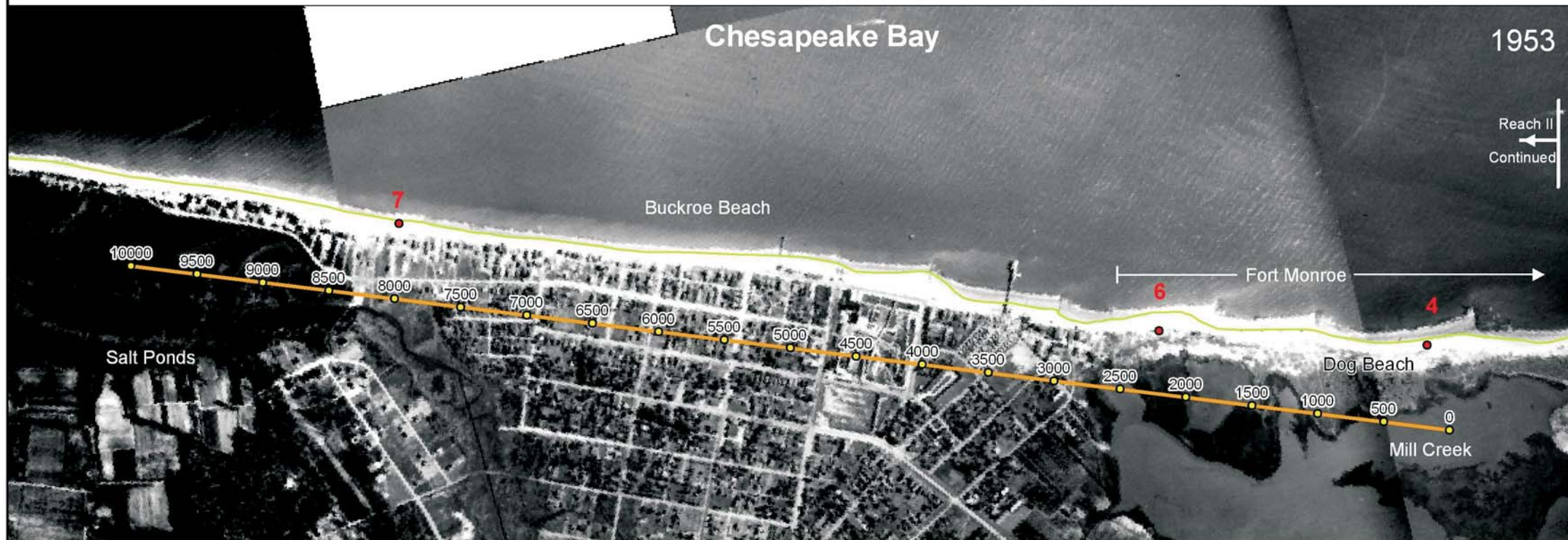


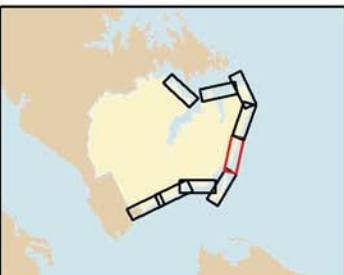
## City of Hampton Plate 5

Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet


### Legend


- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline



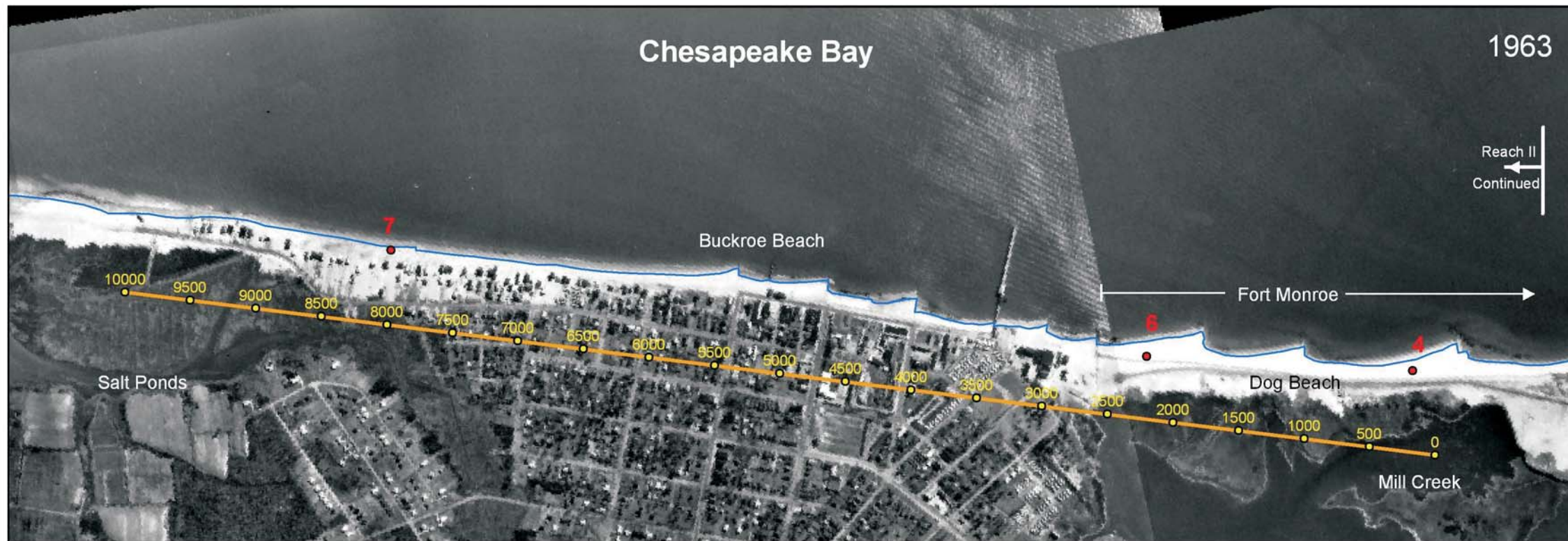


Shoreline Studies Program  
VIMS





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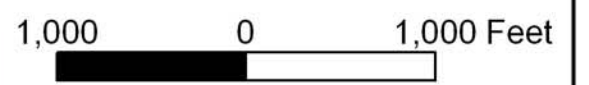
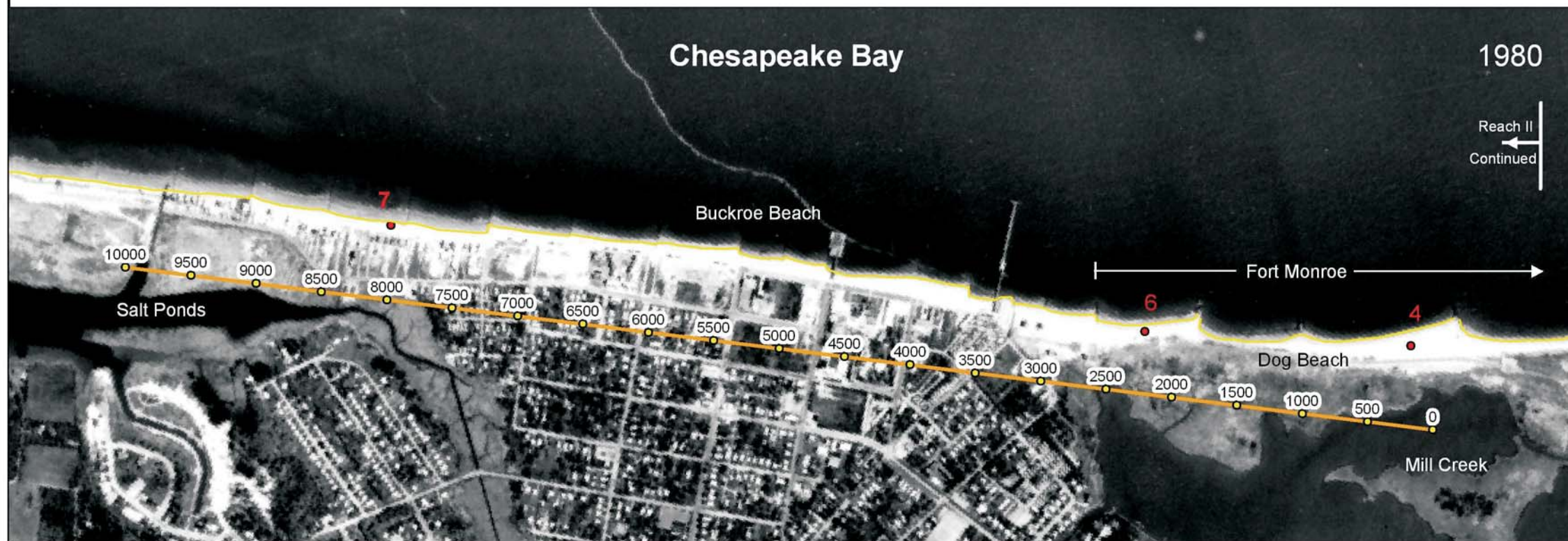


# City of Hampton Plate 5

Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1963 Shoreline
- 1980 Shoreline

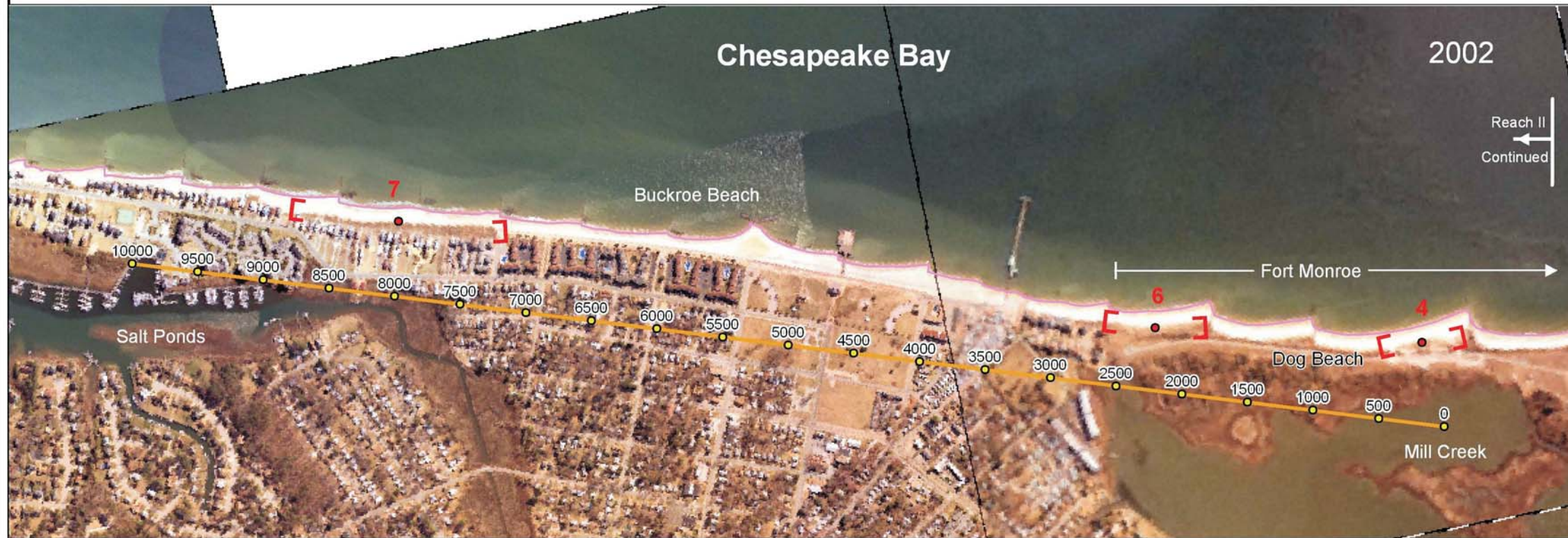
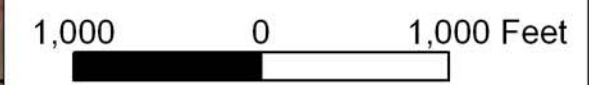




**City of Hampton**  
**Plate 5**  
 Morphological Reach II  
 Old Point Comfort to Salt Ponds Inlet

**Legend**

- Transect Point
- Identified Dune Sites
- Dune Site Limits
- Baseline
- 1994 Shoreline
- 2002 Shoreline







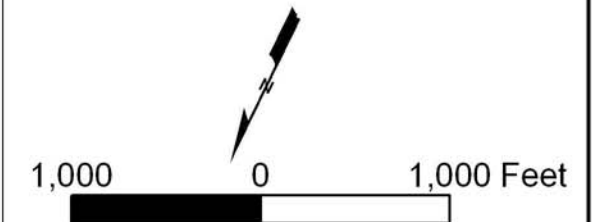
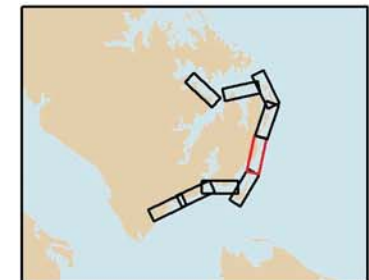
# City of Hampton

## Plate 5

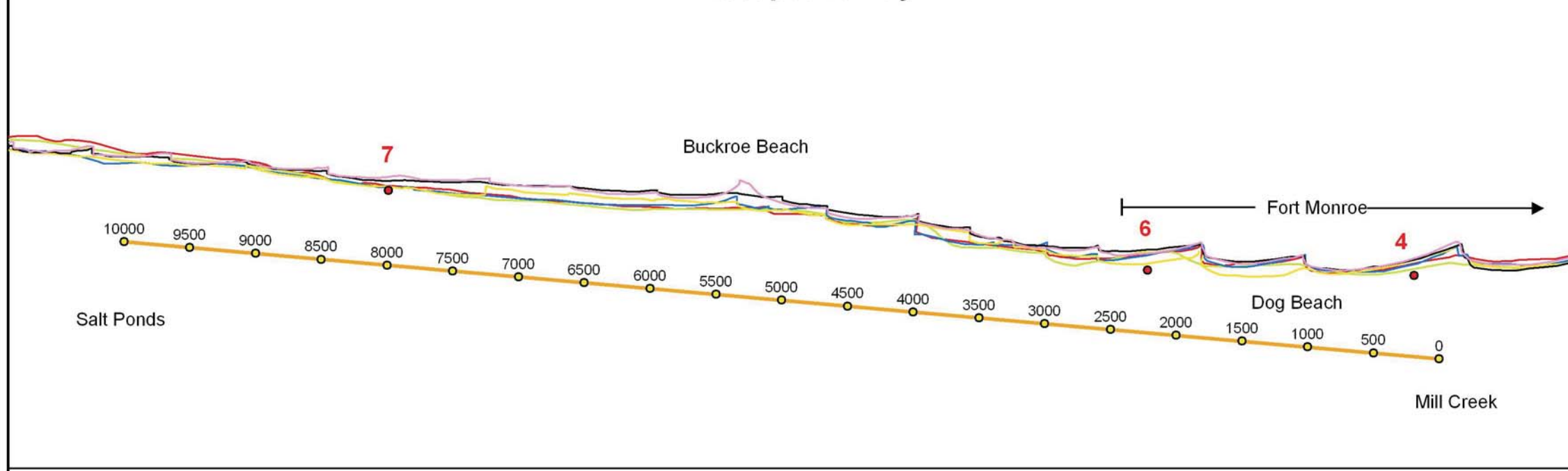
Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline



# Chesapeake Bay

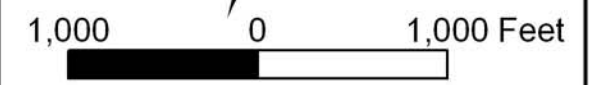
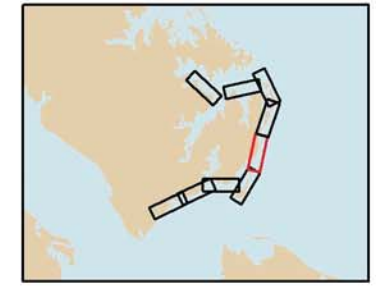


## City of Hampton Plate 5

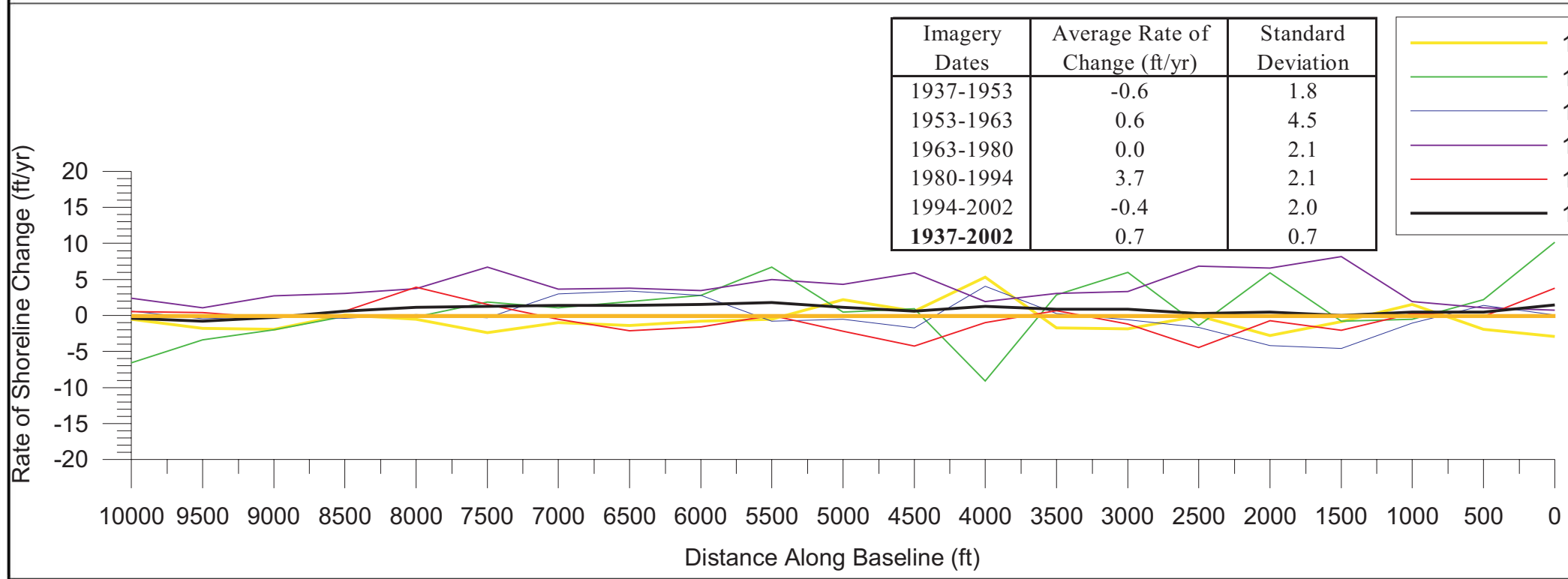
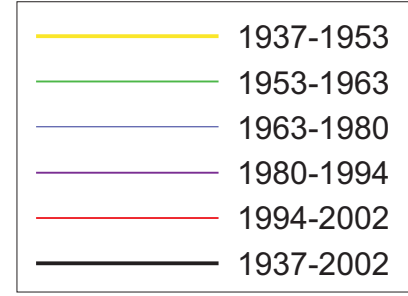
Morphological Reach II  
Old Point Comfort to Salt Ponds Inlet

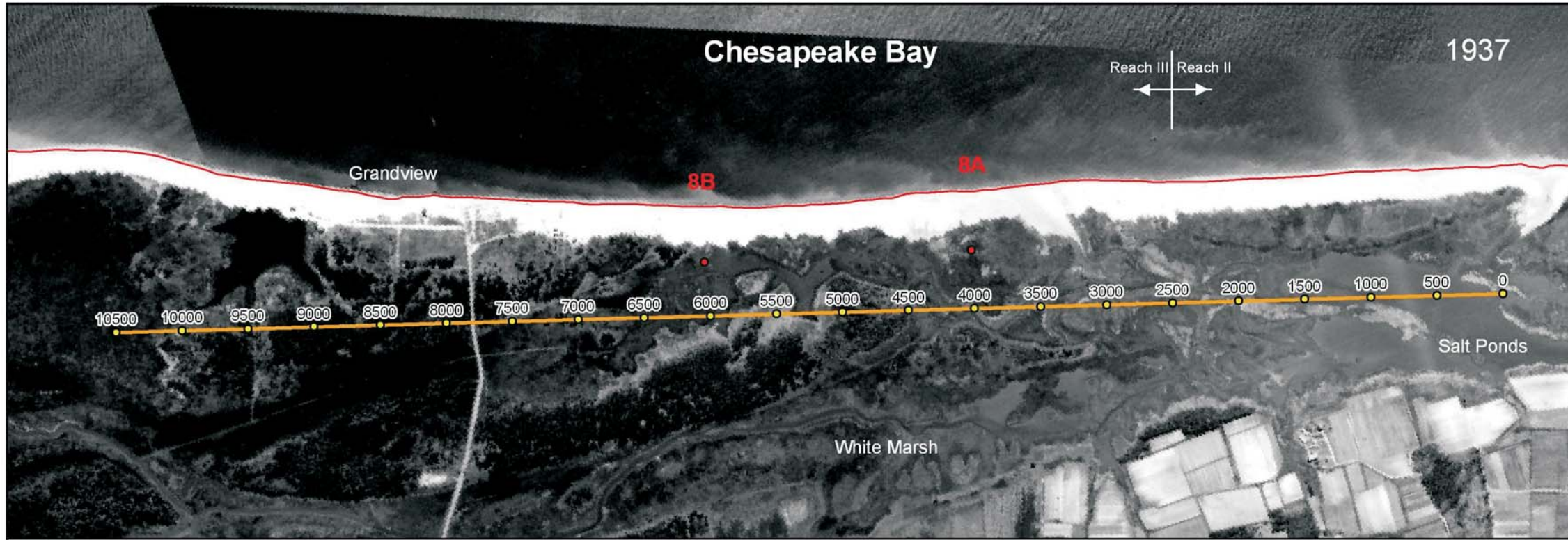
**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline



Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-1953	-0.6	1.8
1953-1963	0.6	4.5
1963-1980	0.0	2.1
1980-1994	3.7	2.1
1994-2002	-0.4	2.0
<b>1937-2002</b>	<b>0.7</b>	<b>0.7</b>



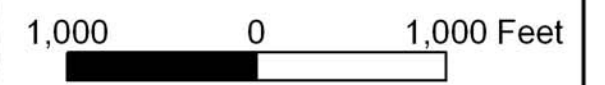
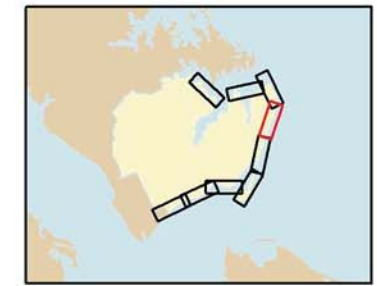
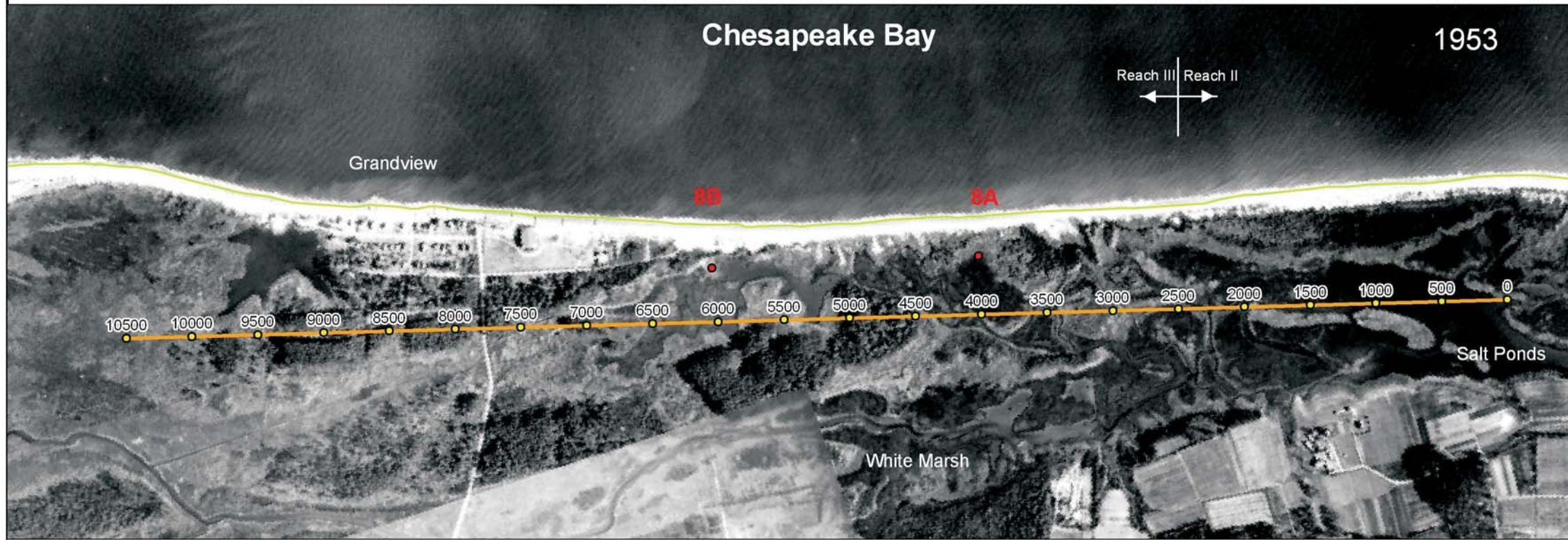


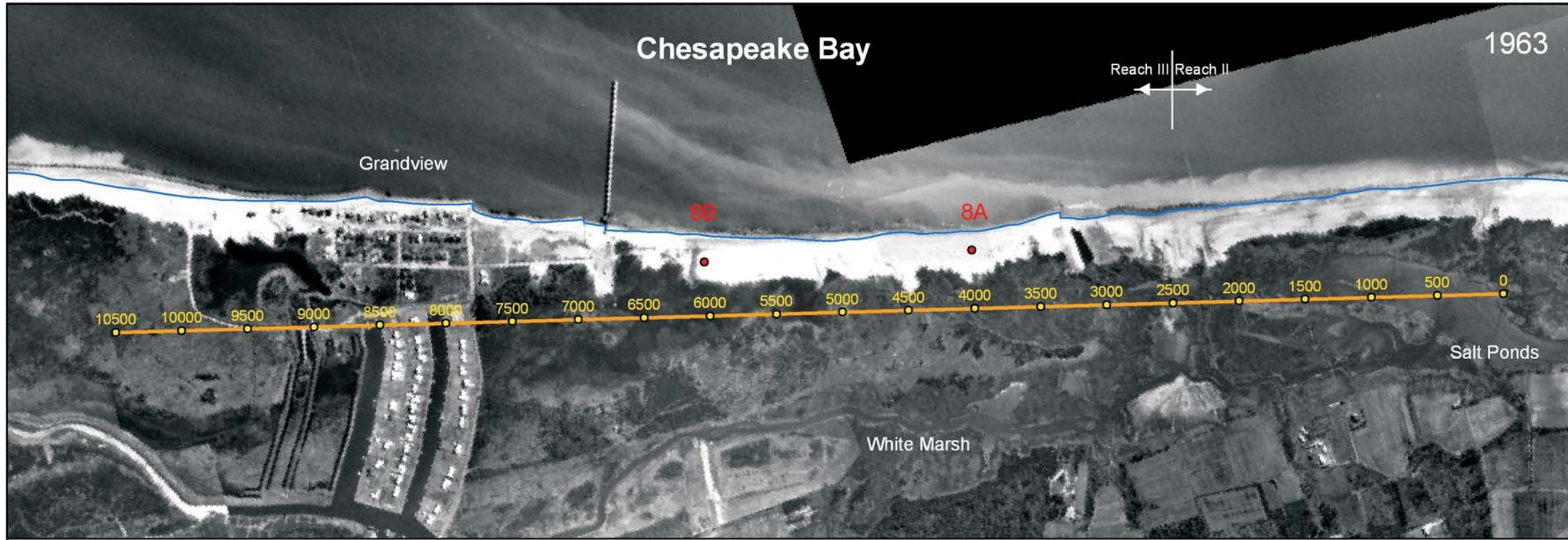
# City of Hampton Plate 6

Morphological Reach II and Reach III  
Old Point Comfort to Salt Ponds Inlet  
Salt Ponds Inlet to Northend Pt

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline





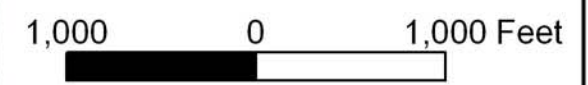
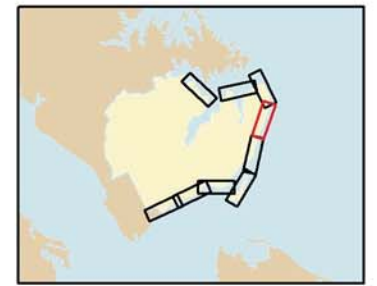
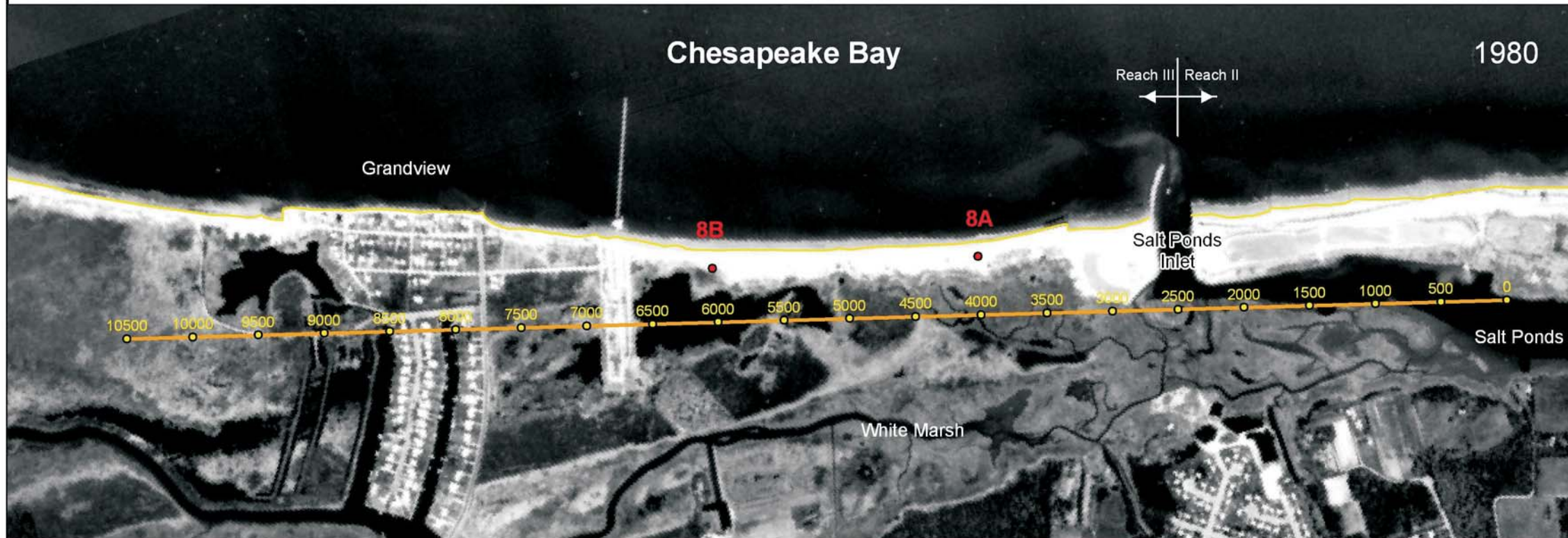
# City of Hampton

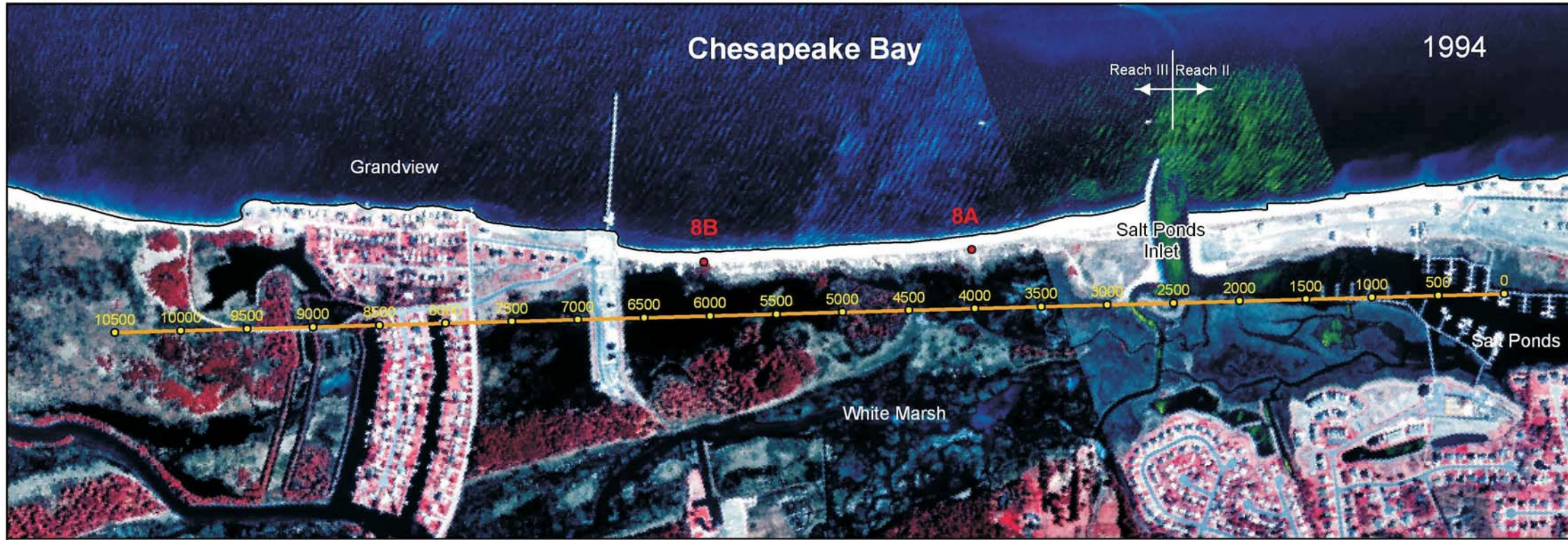
## Plate 6

Morphological Reach II and Reach III  
Old Point Comfort to Salt Ponds Inlet  
Salt Ponds Inlet to Northend Pt

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1963 Shoreline
- 1980 Shoreline



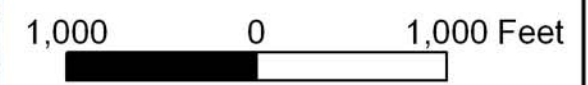
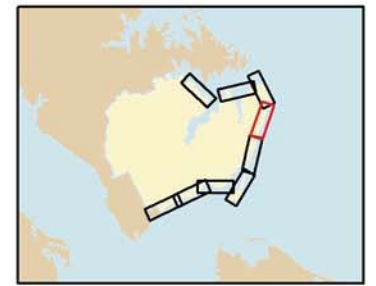


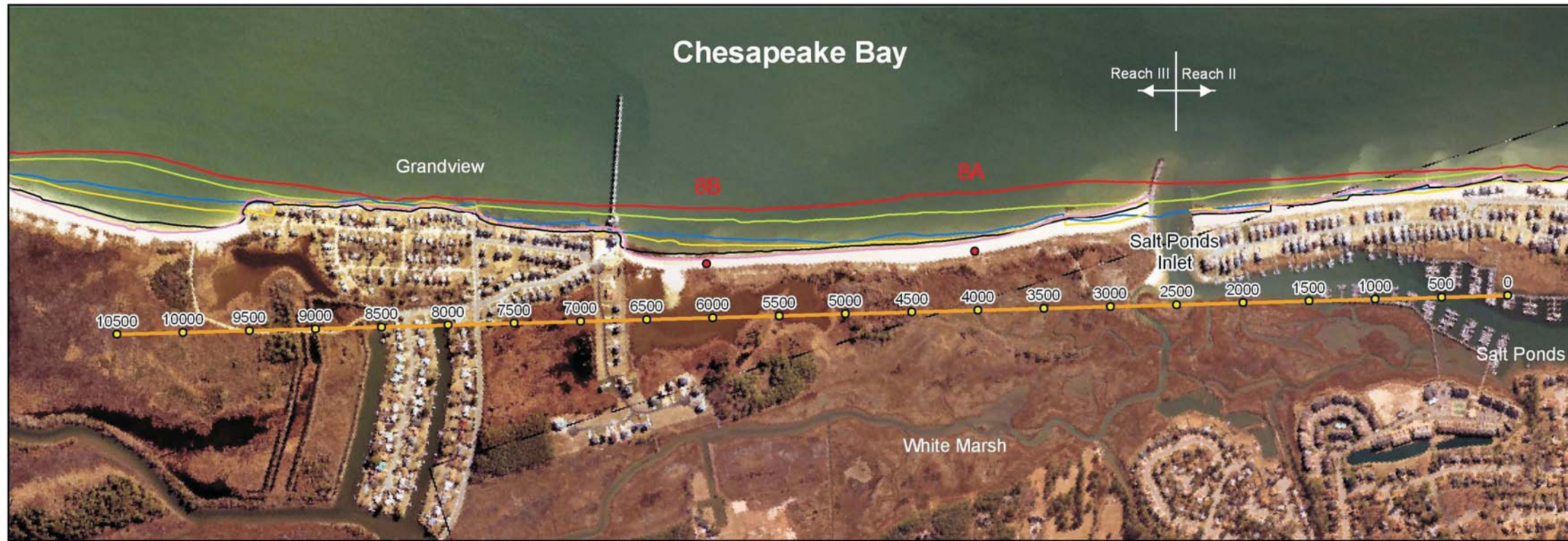
# City of Hampton Plate 6

Morphological Reach II and Reach III  
Old Point Comfort to Salt Ponds Inlet  
Salt Ponds Inlet to Northend Pt

**Legend**

- Transect Point
- Identified Dune Sites
- Dune Site Limits
- Baseline
- 1994 Shoreline
- 2002 Shoreline



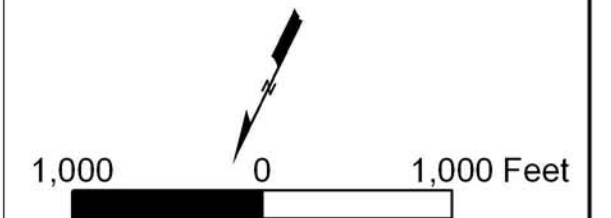
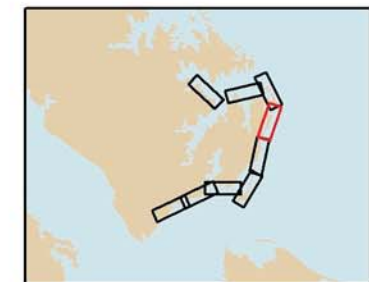


# City of Hampton Plate 6

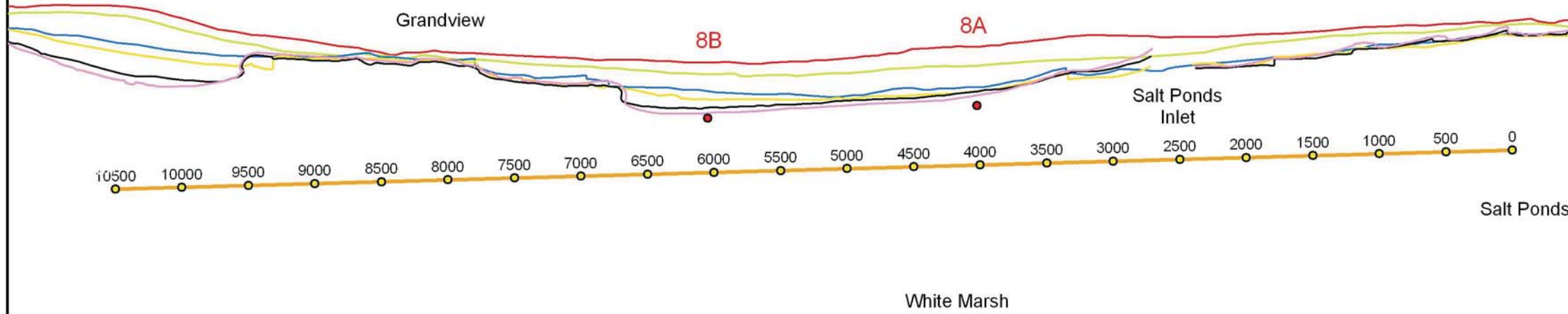
Morphological Reach II and Reach III  
Old Point Comfort to Salt Ponds Inlet  
Salt Ponds Inlet to Northend Pt

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline

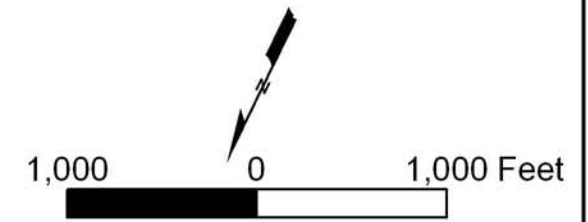
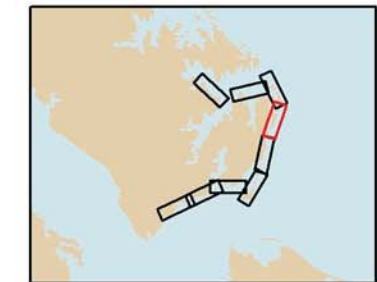
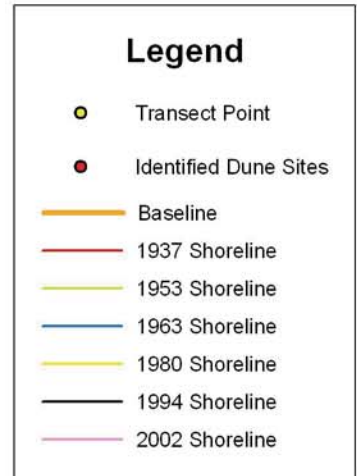


# Chesapeake Bay

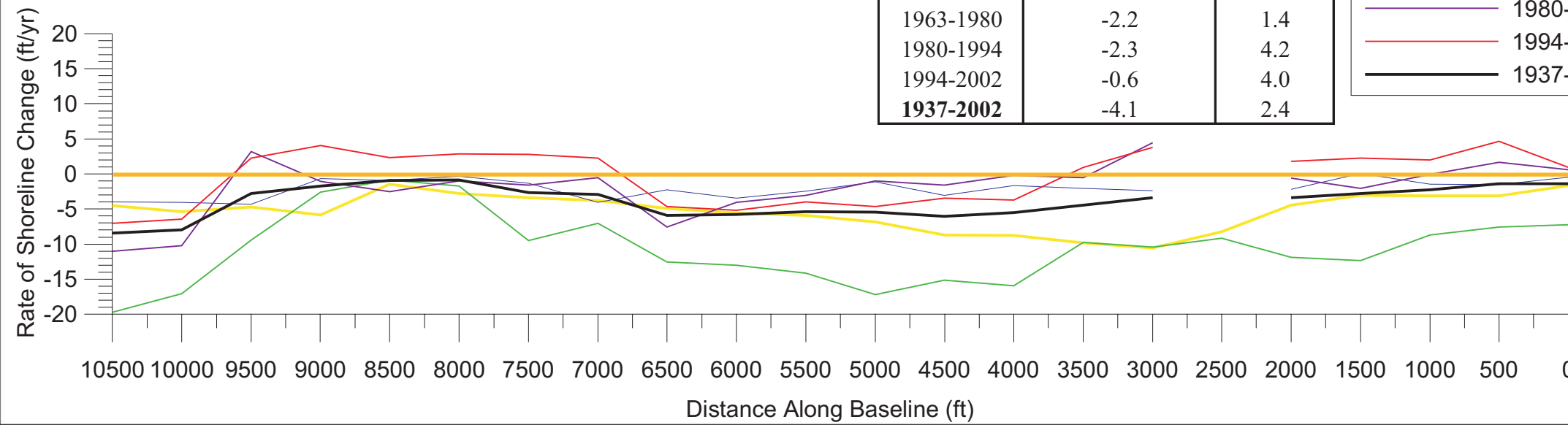
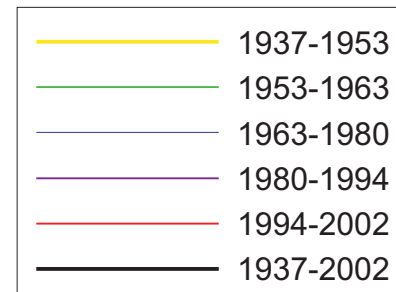


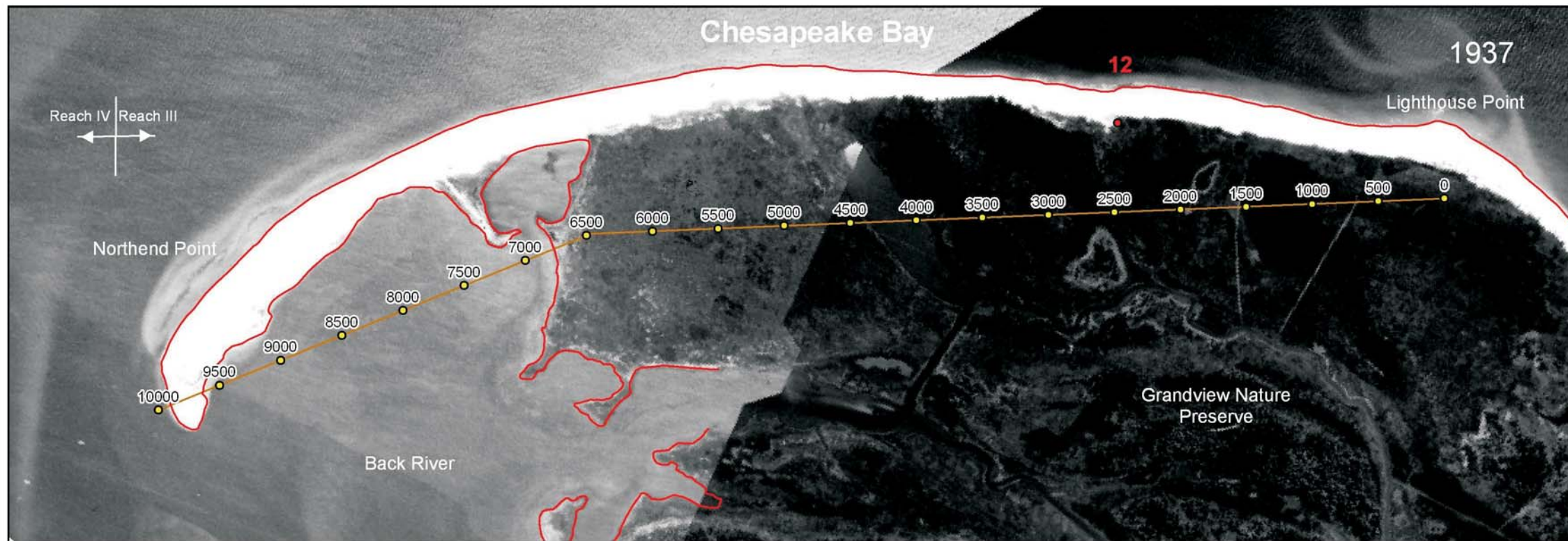
## City of Hampton Plate 6

Morphological Reach II and Reach III  
Old Point Comfort to Salt Ponds Inlet  
Salt Ponds Inlet to Northend Pt



Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1937-1953	-5.3	2.5
1953-1963	-11.0	5.2
1963-1980	-2.2	1.4
1980-1994	-2.3	4.2
1994-2002	-0.6	4.0
<b>1937-2002</b>	<b>-4.1</b>	<b>2.4</b>

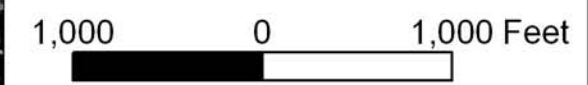
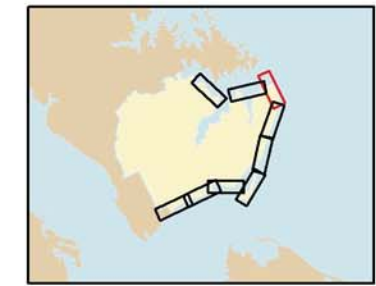
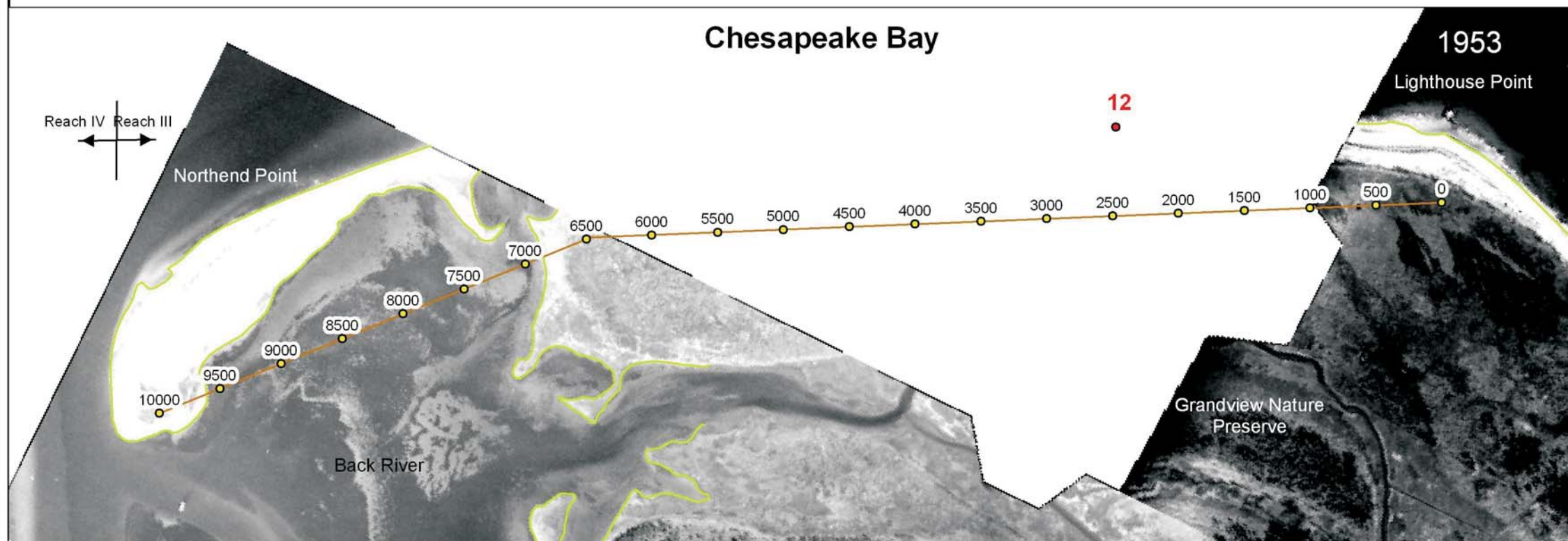




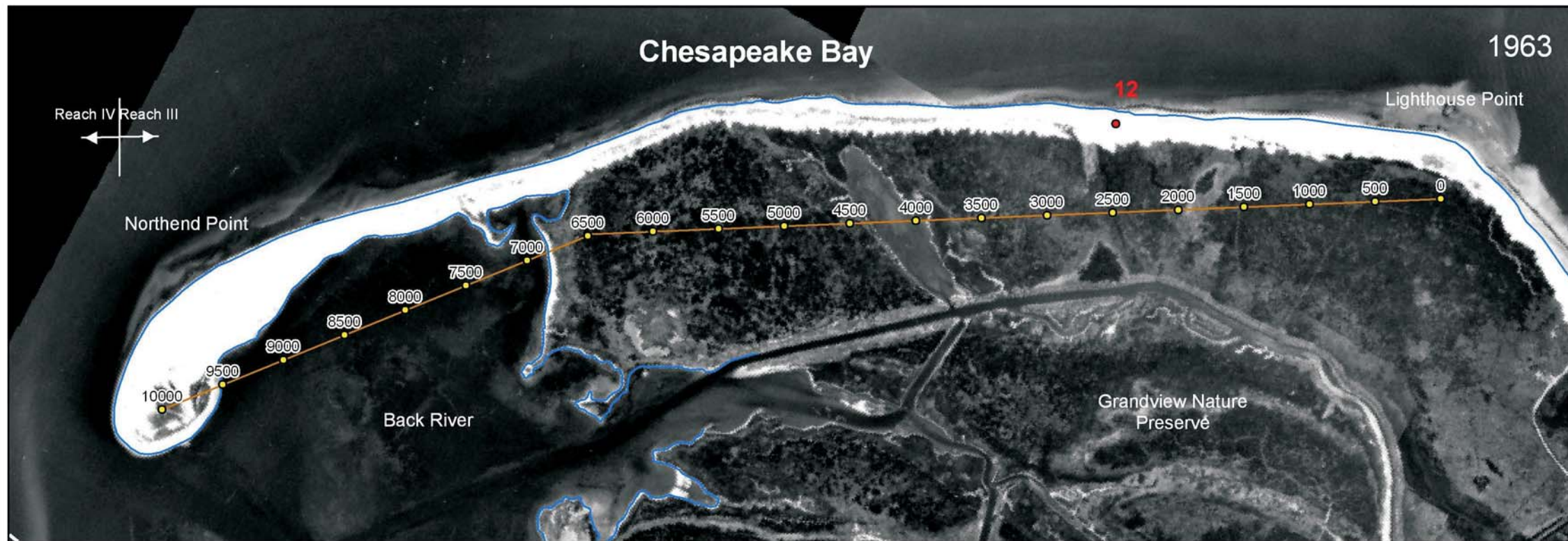
**City of Hampton**  
**Plate 7**  
 Morphological Reach III  
 Salt Ponds Inlet to Northend Pt.

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline





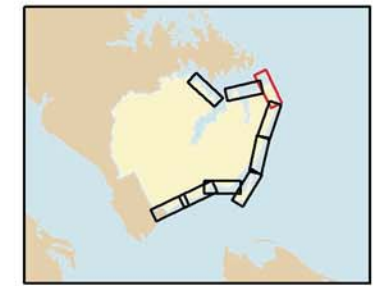
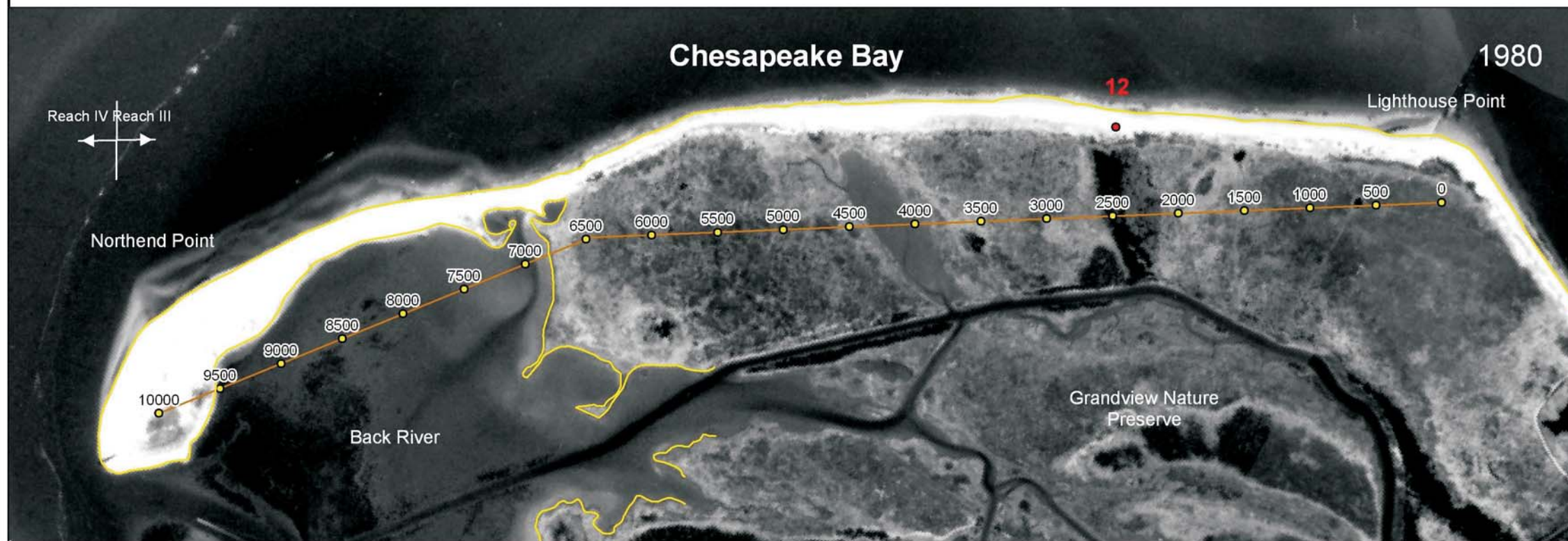


# City of Hampton Plate 7

Morphological Reach III  
Salt Ponds Inlet to Northend Pt.

**Legend**

- Transect Point
- Identified Dune Sites
- Baseline
- 1963 Shoreline
- 1980 Shoreline

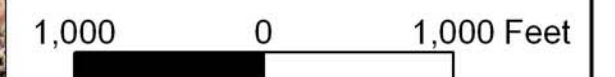
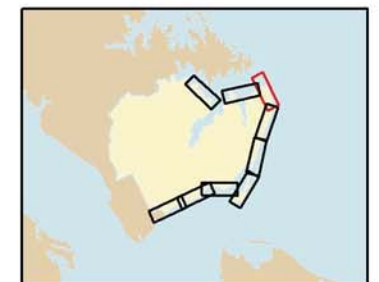


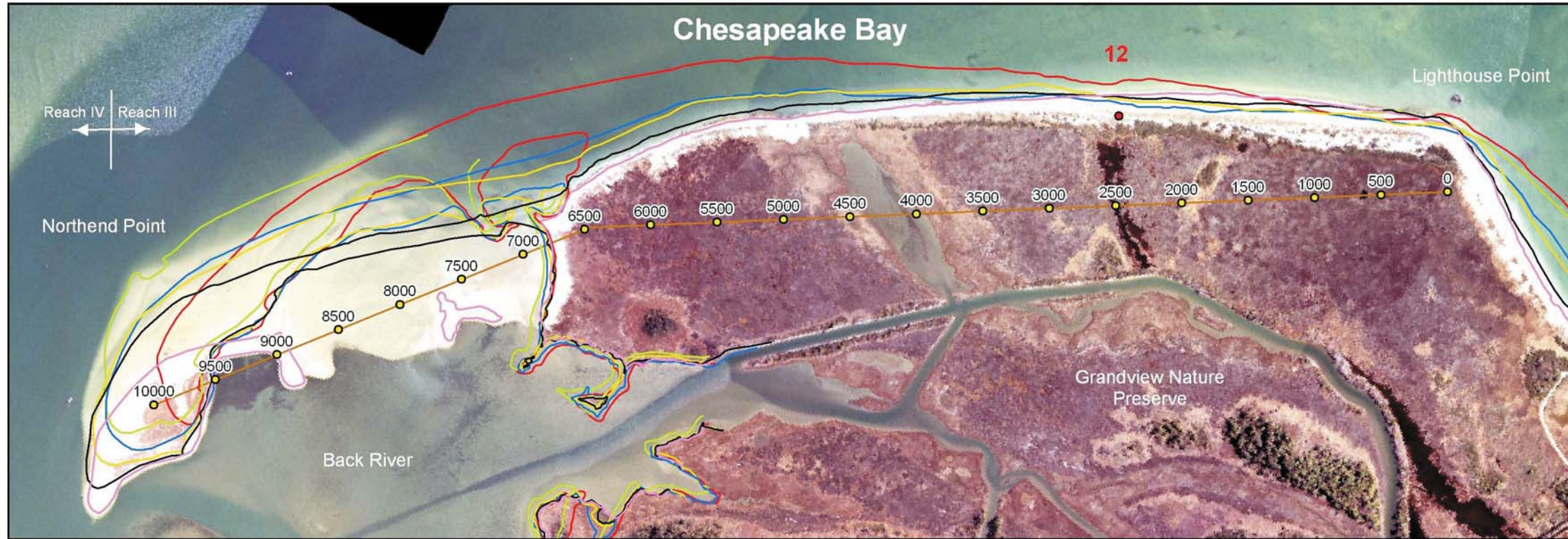


**City of Hampton**  
**Plate 7**  
 Morphological Reach III  
 Salt Ponds Inlet to Northend Pt.

**Legend**

- Transect Point
- Identified Dune Sites
- Dune Site Limits
- Baseline
- 1994 Shoreline
- 2002 Shoreline





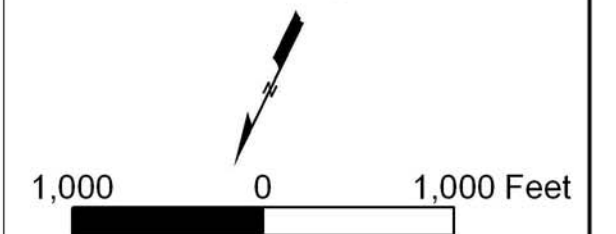
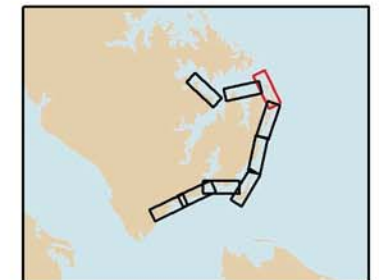
# City of Hampton

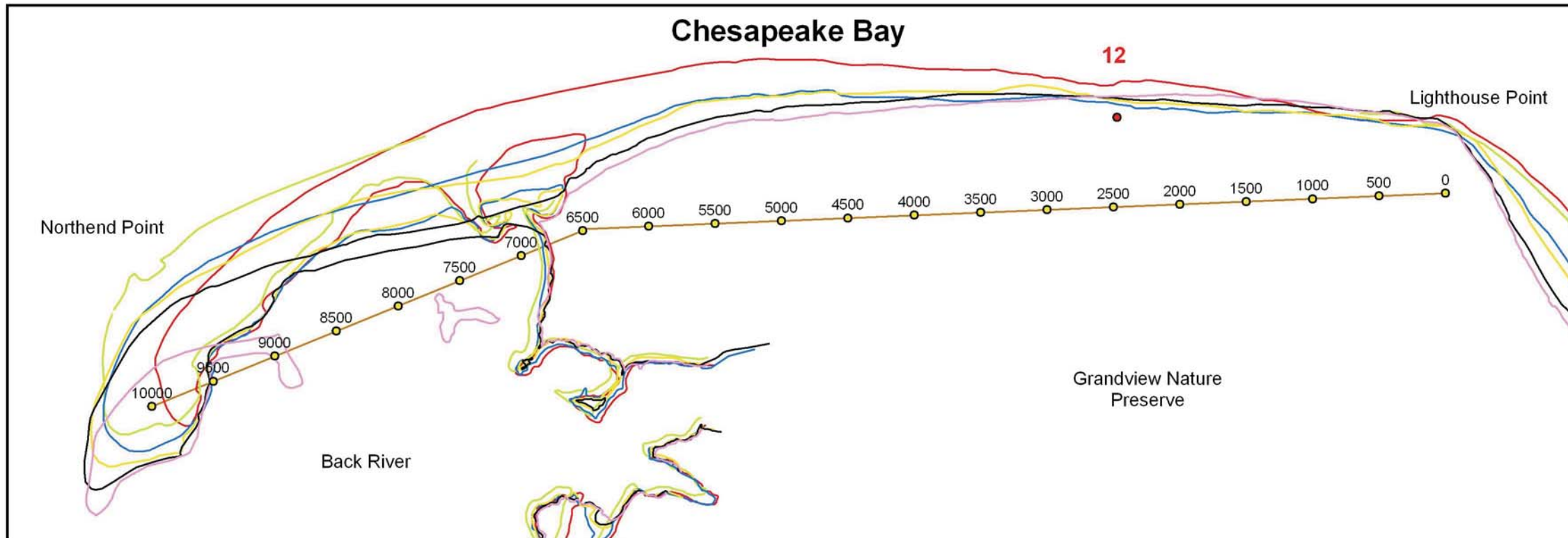
## Plate 7

Morphological Reach III  
Salt Ponds Inlet to Northend Pt.

### Legend

- Transect Point
- Identified Dune Sites
- Baseline
- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline

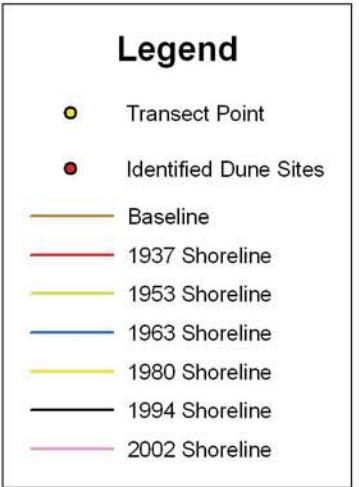




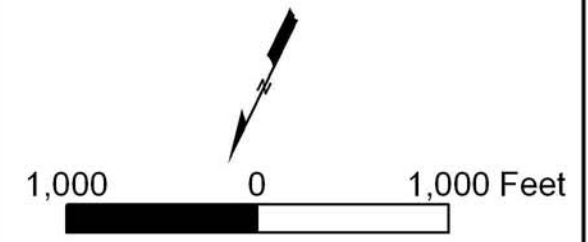
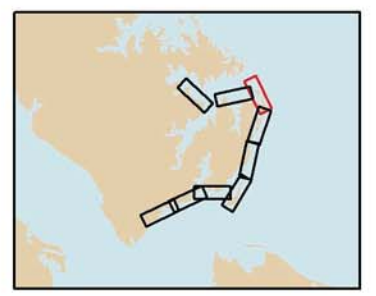
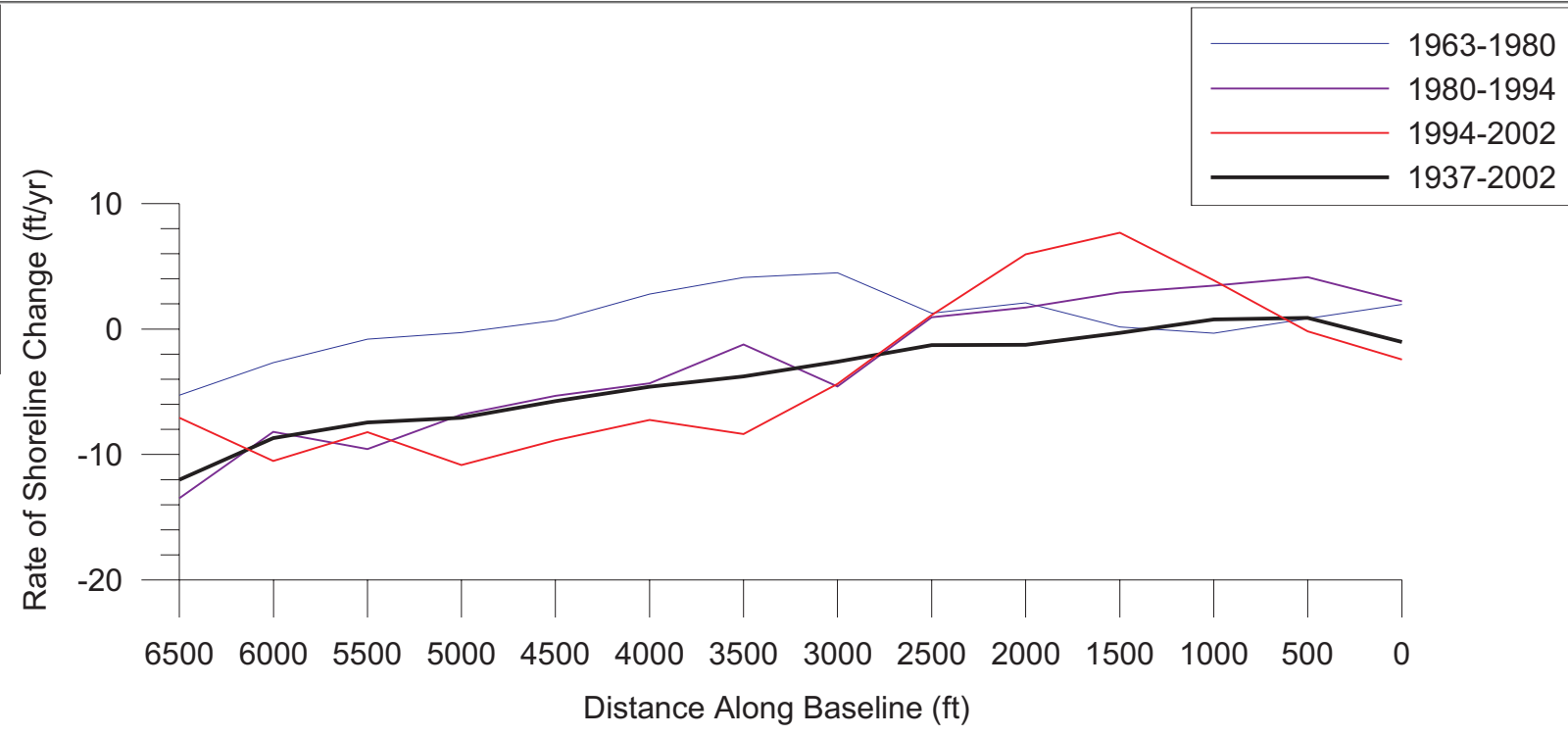
## City of Hampton

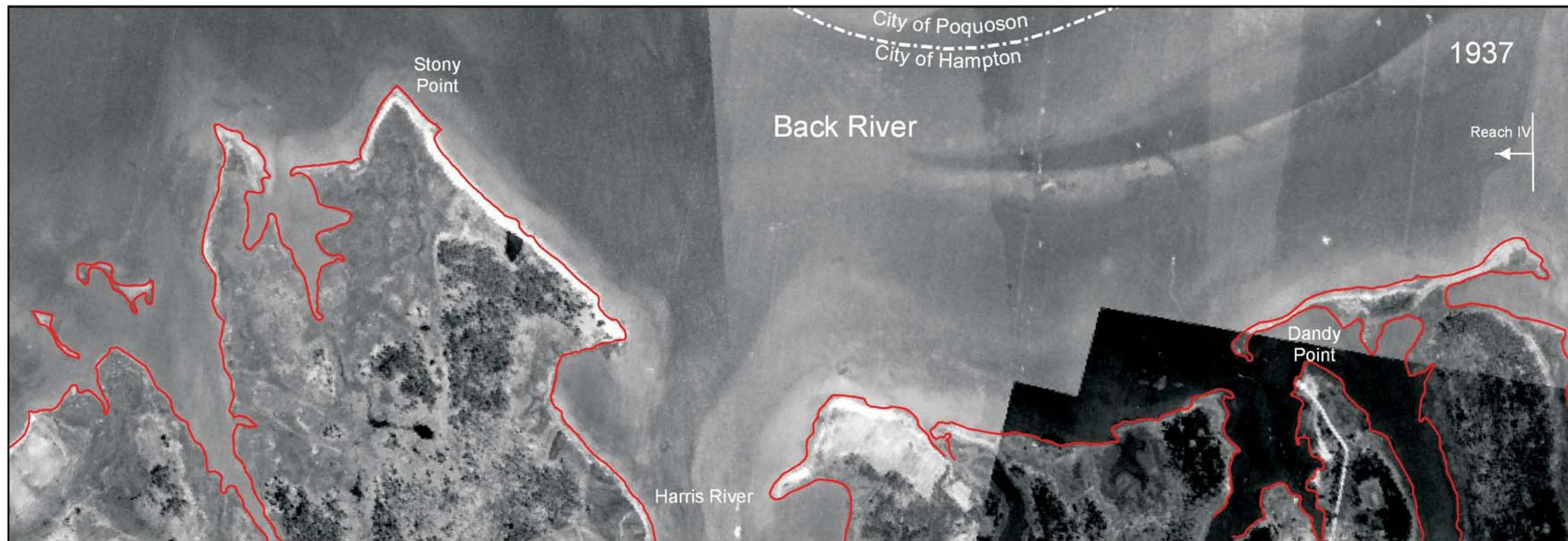
### Plate 7

Morphological Reach III  
Salt Ponds Inlet to Northend Pt.



Imagery Dates	Average Rate of Change (ft/yr)	Standard Deviation
1963-1980	0.6	2.6
1980-1994	-2.7	5.5
1994-2002	-3.5	6.2
<b>1937-2002</b>	<b>-3.9</b>	<b>3.9</b>



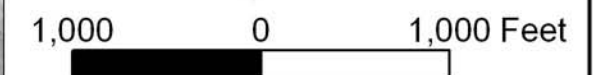
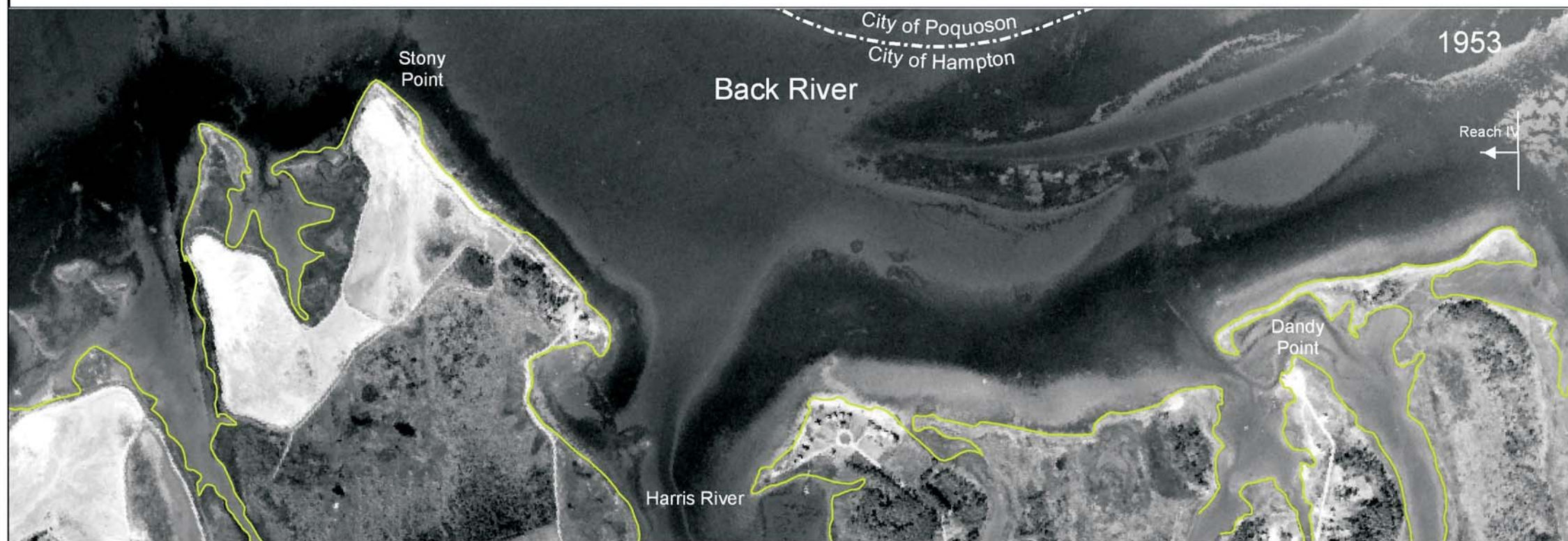


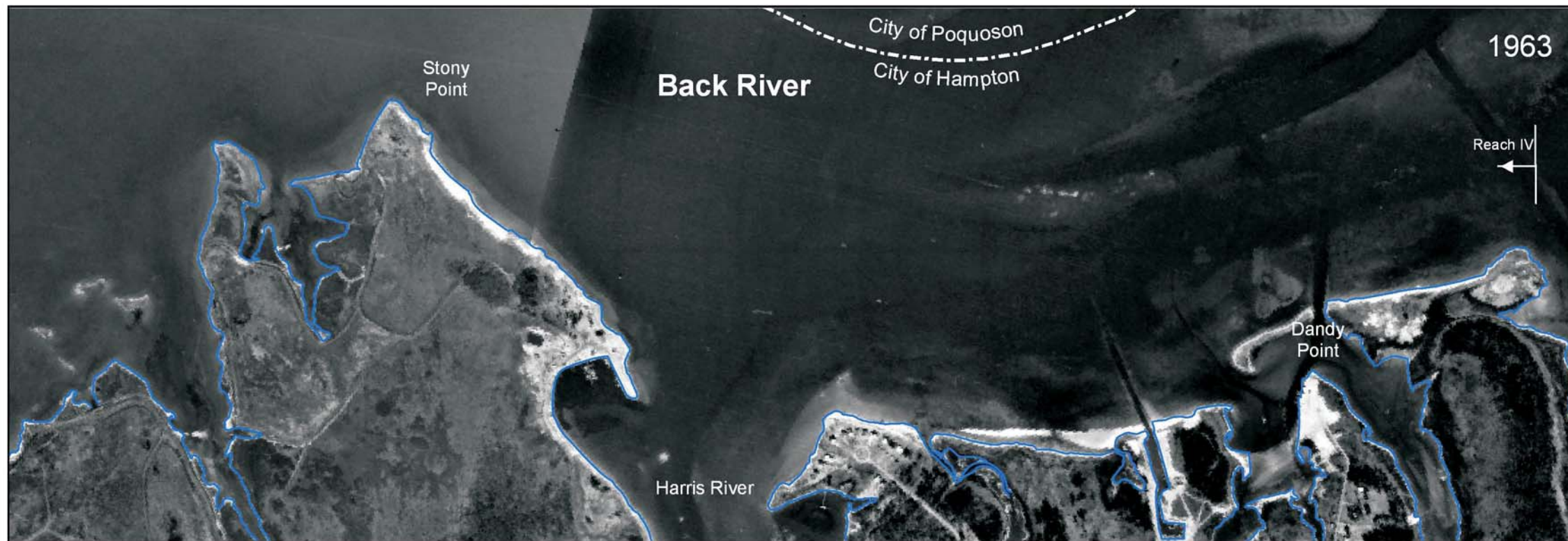
# City of Hampton Plate 8

Morphological Reach IV  
Northend Point to Tabbs Creek

### Legend

- 1937 Shoreline
- 1953 Shoreline



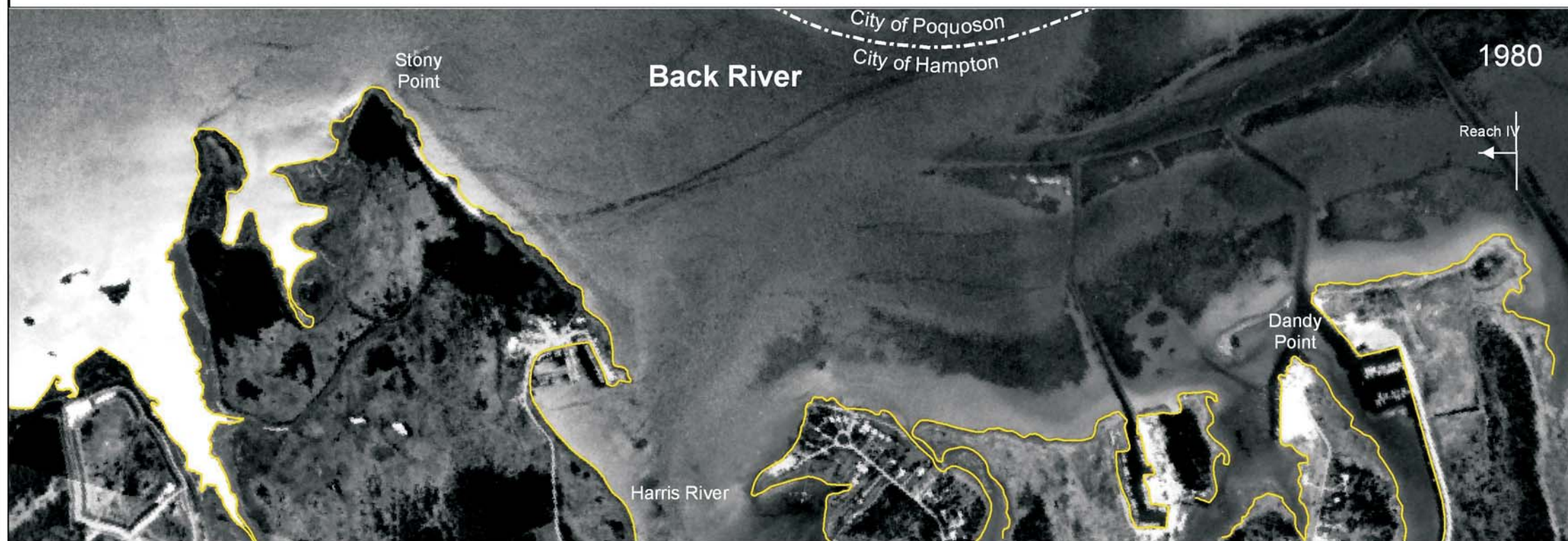


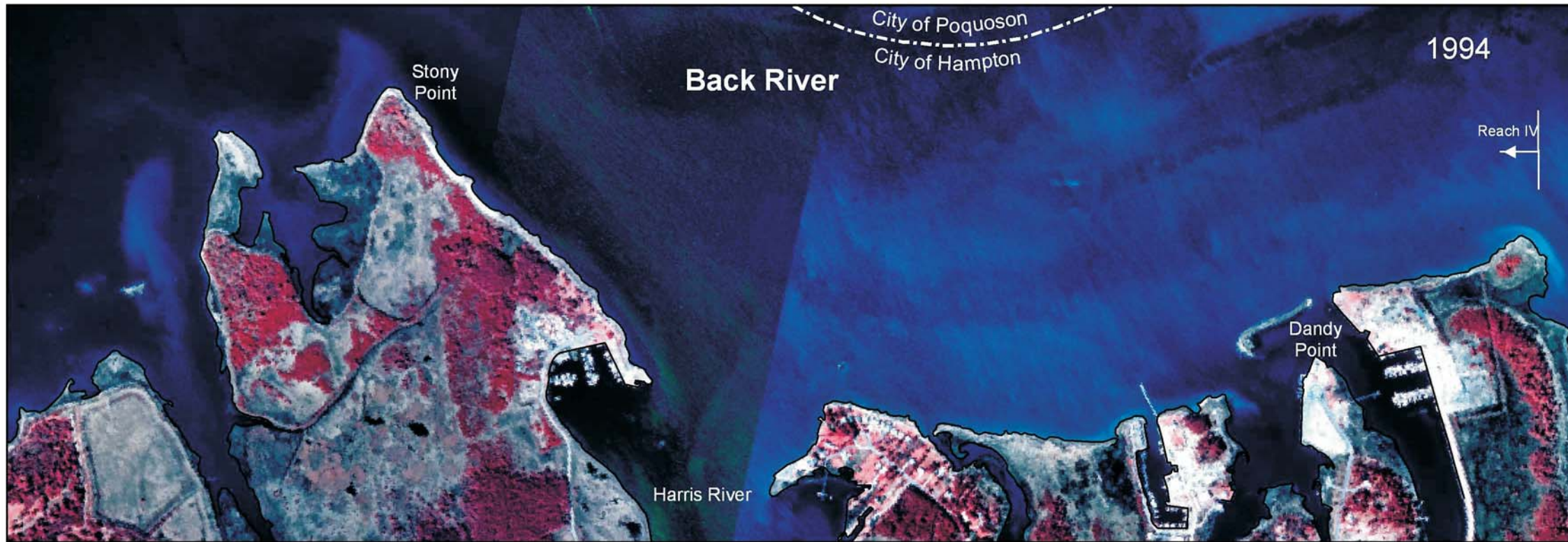
# City of Hampton Plate 8

Morphological Reach IV  
Northend Point to Tabbs Creek

## Legend

- 1963 Shoreline
- 1980 Shoreline



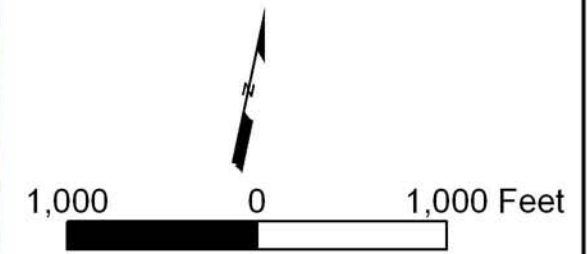
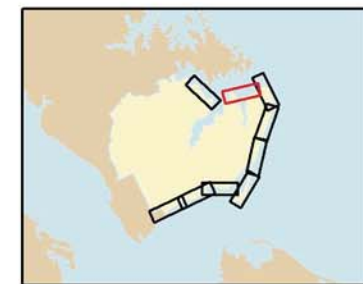


# City of Hampton Plate 8

Morphological Reach IV  
Northend Point to Tabbs Creek

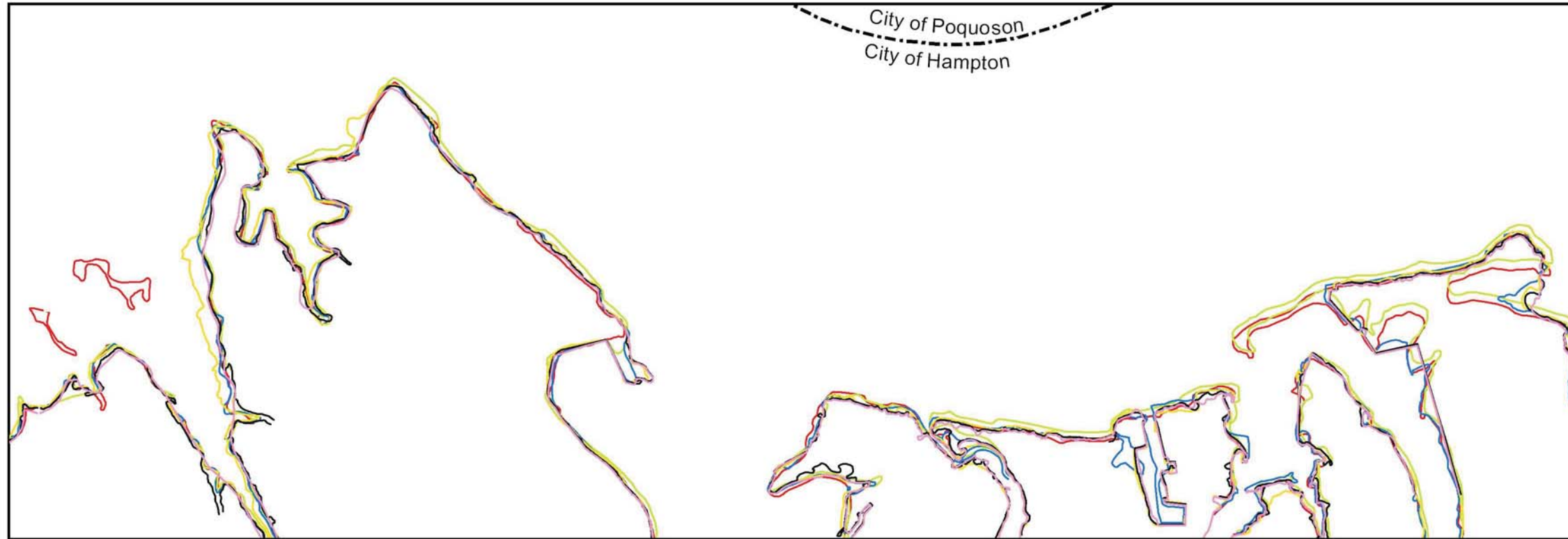
**Legend**

- 1994 Shoreline
- 2002 Shoreline





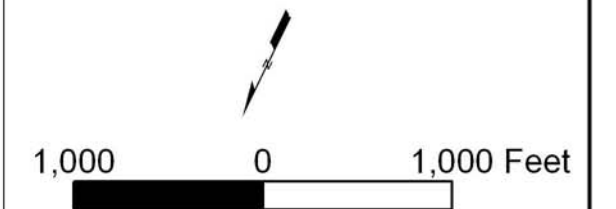
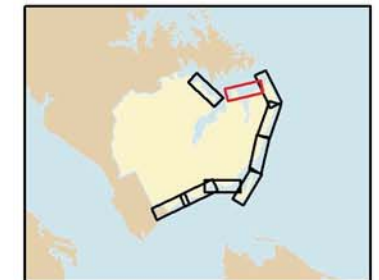
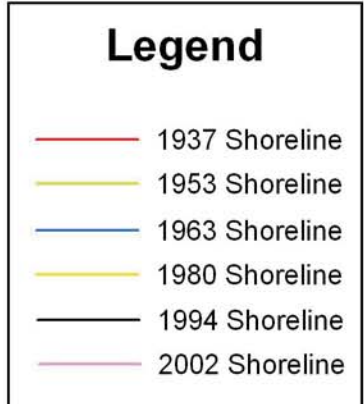




**No Shoreline Change Data Available**

## City of Hampton Plate 8

Morphological Reach IV  
Northend Point to Tabbs Creek



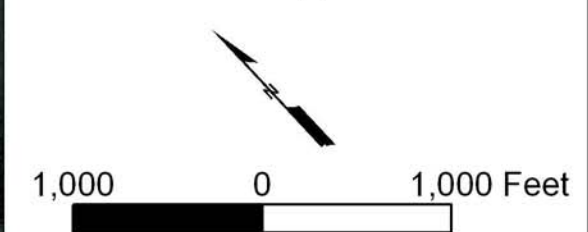
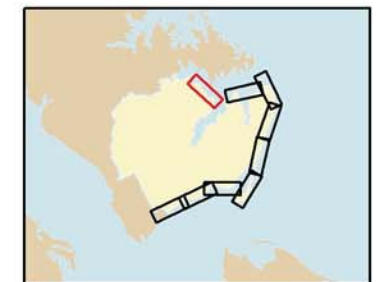


# City of Hampton Plate 9

Morphological Reach IV  
Northend Point to Tabbs Creek

**Legend**

- 1937 Shoreline
- 1953 Shoreline



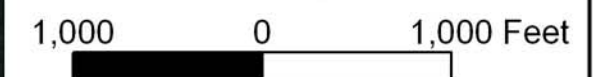
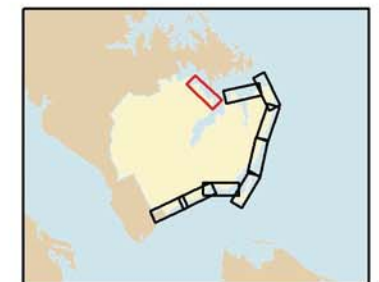
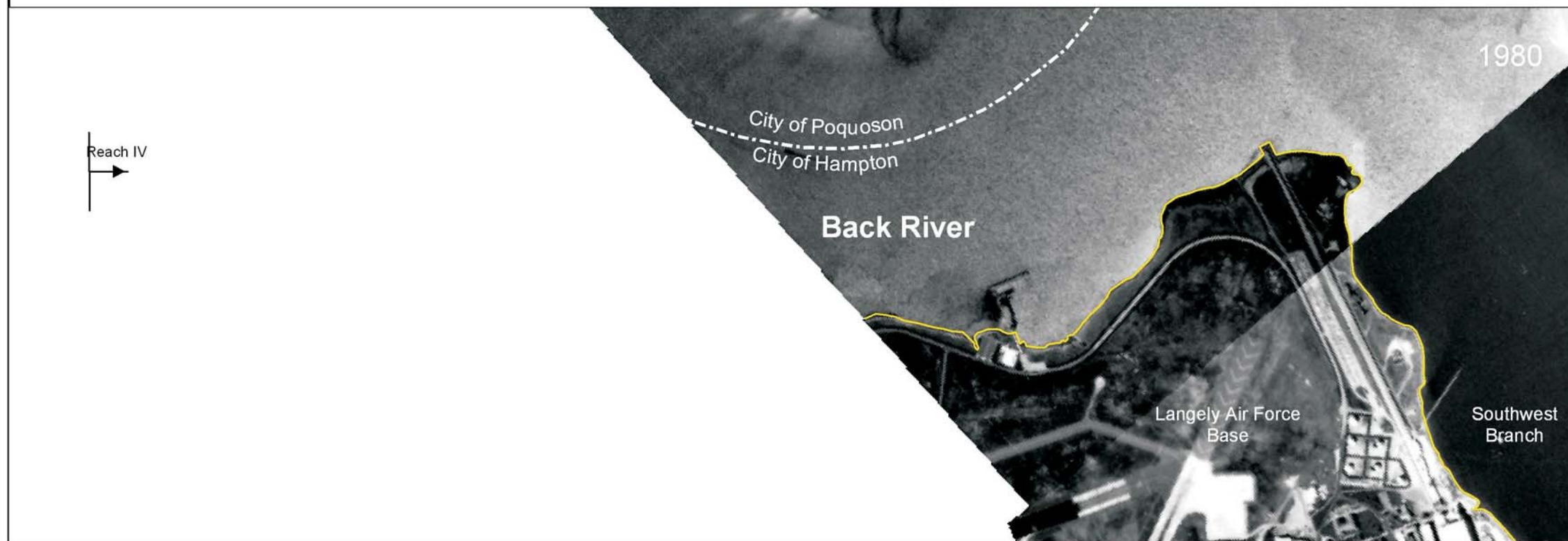


# City of Hampton Plate 9

Morphological Reach IV  
Northend Point to Tabbs Creek

## Legend

- 1963 Shoreline
- 1980 Shoreline







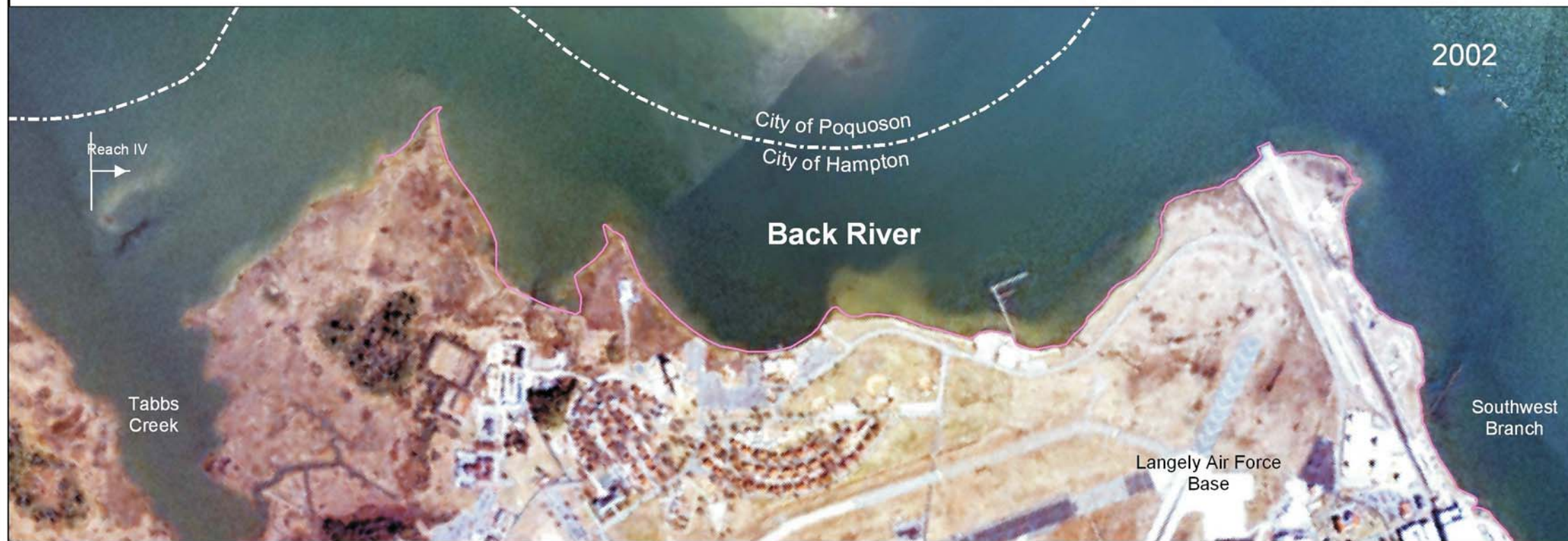
1994

# City of Hampton Plate 9

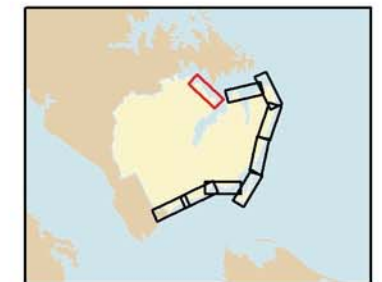
Morphological Reach IV  
Northend Point to Tabbs Creek

## Legend

-  1994 Shoreline
-  2002 Shoreline



2002



1,000 0 1,000 Feet





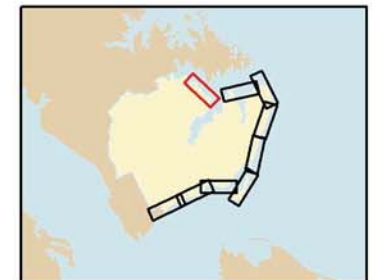
# City of Hampton

## Plate 9

Morphological Reach IV  
Northend Point to Tabbs Creek

### Legend

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1980 Shoreline
- 1994 Shoreline
- 2002 Shoreline



1,000 0 1,000 Feet

No Shoreline Change Data Available

## 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 City of Hampton as of 2000

Dune Site No.	Location <sup>^</sup>			Dune Shore Length (Feet)	Primary Dune Site?	Secondary Dune Site?	*Public Ownership?
	Easting (Feet)	Northing (Feet)	Date Visited				
2	2,629,850	255,100	9/21/00	220	Yes		
4	2,643,450	260,450	9/21/00	550	Yes	Yes	Yes
6	2,643,950	262,500	9/21/00	680	Yes		Yes
7	2,645,750	268,050	11/18/99	1,540	Yes	Yes	
8A <sup>^</sup>	2,647,250	274,750	11/18/99	2,250	Yes		
8B <sup>^</sup>	2,647,850	276,700	11/18/99	1,100	Yes		
12	2,649,650	282,900	11/18/99	4,200	Yes	Yes	Yes
<b>Total</b>				10,540			

\*Public ownership includes governmental entities including local, state, and federal; otherwise ownership is by the private individual.

<sup>^</sup>Location is in Virginia State Plane South, NAD 1927

<sup>^</sup>One site with variable alongshore dune conditions

Dune site measurements in City of Hampton as of 2000.

Site No.	Dune Shore Length (Feet)	Dune Site Measurements							
		Primary Dune			Jurisdiction	Crest Elev (ft MLW)	Secondary Dune		
		Crest Elev (ft MLW)	Distance from Crest landward to back base (Feet)	To MLW (Feet)			Primary Crest landward to profile end (Feet)	2nd Crest landward (Feet)	2nd Crest seaward to 1st back base (Feet)
HP 2	220	6.8	15	51					
HP 4	55	12.5	6	167	Yes	17.0	58	16	36
HP 6	680	11.6	37	179					
HP 7	1,540	10.0	7	166	Yes	9.2	87	44	36
HP 8A	2,250	11.6	12	161					
HP 8B	1,100	10.0	125	135					
HP 12	4,200	13.8	68	169	Yes	8.4	174	48	58

Dune site parameters in City of Hampton as of 2000.

Site No.	Type	Dune Site Parameters								
		Fetch Exposure	Shoreline Direction of Face	Nearshore Gradient	Morphologic Setting	Relative Stability	Underlying Substrate	Structure or Fill		
		A	B	C	D	E	F	G		
HP 2	Man Inf	Riverine	Southeast	Steep	No Bars	Isolated, pocket	Stable	Upland	Groin, BW	
HP 4	Man Inf	Open Bay	East	Steep	No Bars	Dune Field, pocket	Stable	Marsh/CB	Groin	
HP 6	Man Inf	Open Bay	East	Steep	No Bars	Dune Field, linear	Erosional	Marsh/CB	Groin	
HP 7	Man Inf	Open Bay	East	Steep	No Bars	Dune Field, linear	Stable	Upland	Groin	
HP 8A	Man Inf	Open Bay	East	Steep	No Bars	Dune Field, linear	Stable	Marsh/CB	Groin, Jetty	
HP 8B	Man Inf	Open Bay	East	Steep	No Bars	Dune Field, linear	Erosional	Marsh/CB	Revet	
HP 12	Natural	Open Bay	Northeast	Medium	No Bars	Dune Field, linear	Stable	Marsh/CB		

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

Site No.	Long-Term Stability 1937-2002	Recent Stability 1994-2002	Near Future Prediction
HP 2	Accretionary	Stable	Stable
HP 4	Accretionary	Accretionary	Stable
HP 6	Accretionary	Erosional	Stable
HP 7	Accretionary	Accretionary	Stable
HP 8A	Erosional	Erosional	Erosional
HP 8B	Erosional	Erosional	Erosional
HP 12	Erosional	Erosional	Erosional