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Shoreline Evolution: Prince William County, Virginia Potomac River, Occoquan Bay, and Occoquan River Shorelines

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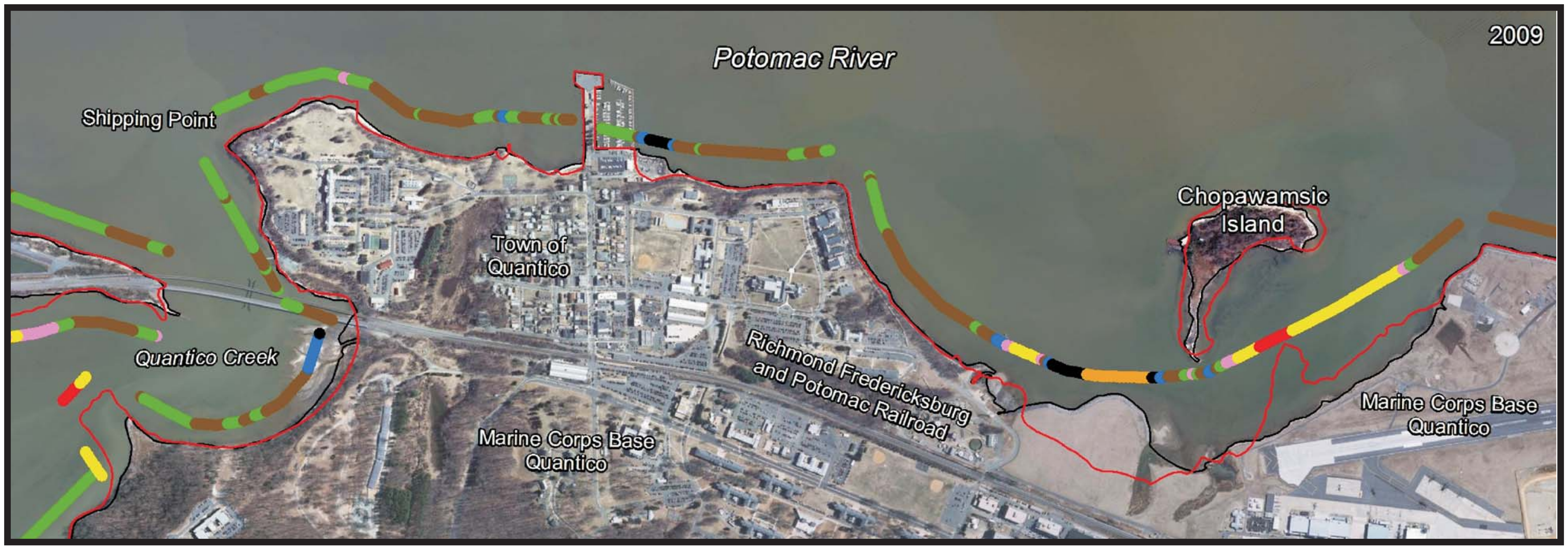

Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, Virginia

January 2012

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Prince William County, Virginia
Potomac River, Occoquan Bay, and Occoquan River Shorelines

Data Summary Report

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January 2012

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1 Introduction

Prince William County is situated along the Potomac River (Figure 1). Through time, the County's shoreline has evolved, and determining the rates and patterns of shore change provides the basis to know how a particular coast has changed through time and how it might proceed in the future. Along Chesapeake Bay's estuarine shores, winds, waves, tides and currents shape and modify coastlines by eroding, transporting and depositing sediments.

The purpose of this report is to document how the shore zone of Prince William County has evolved since 1937. Aerial imagery was taken for most of the Bay region beginning that year and can be used to assess the geomorphic nature of shore change. Aerial photos show 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. In addition to documenting historical shorelines, the change in shore positions along the rivers and larger creeks in Prince William County will be quantified in this report. The shorelines of very irregular coasts, small creeks around inlets, and other complicated areas will be shown but not quantified.

2 Methods

2.1 Photo Rectification and Shoreline Digitizing

An analysis of aerial photographs provides the historical data necessary to understand the suite of processes that work to alter a shoreline. Images of the Prince William County Shoreline from 1937, 1953, 1962, 1985, 1994, 2002, 2007 and 2009 were used in the analysis. The 1994, 2002, 2007 and 2009 images were available from other sources. The 1994 imagery was orthorectified by the U.S. Geological Survey (USGS) and the 2002, 2007 and 2009 imagery was orthorectified by the Virginia Base Mapping Program (VBMP). The 1937, 1953, 1962, and 1985 photos were a part of the VIMS Shoreline Studies Program archives. The historical aerial images acquired to cover the entire shoreline were not always flown on the same day. The dates for each year are:

1937 - April 19 and May 23;
1953 - December 18, 31 and February 10;
1962 - May 25;
1985 - February 18.

We could not ascertain the exact dates the 1994 images were flown. The 2002, 2007, and 2009 were all flown at various days in February, March, and April.

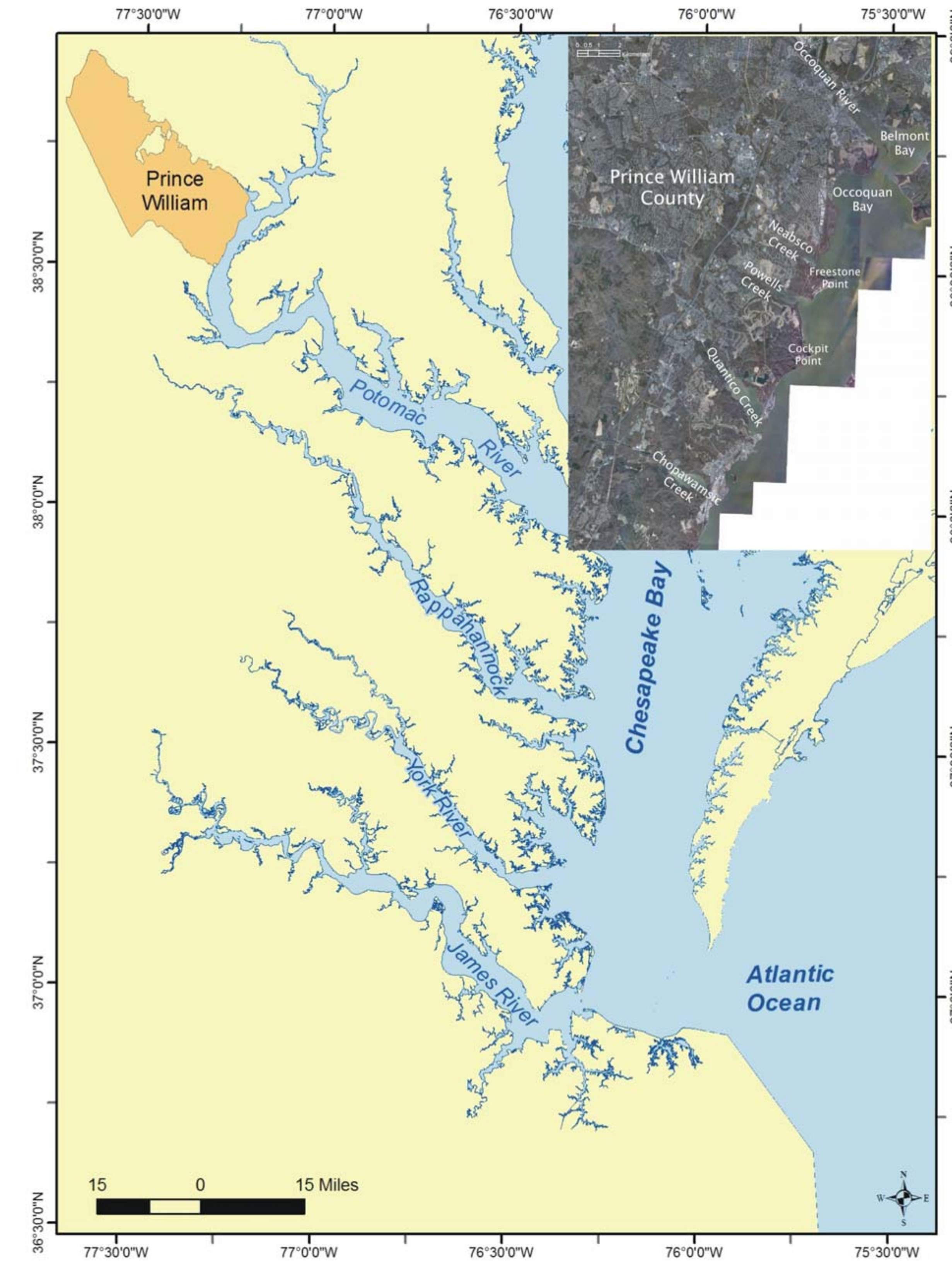

Figure 1. Location of Prince William County within the Chesapeake Bay estuarine system.

The 1937, 1953, 1962, and 1985 images were scanned as tiffs at 600 dpi and converted to ERDAS IMAGINE (.img) format. These aerial photographs were orthographically corrected to produce a seamless series of aerial mosaics following a set of standard operating procedures. The 1994 Digital Orthophoto Quarter Quadrangles (DOQQ) from USGS were used as the reference images. The 1994 photos are used rather than higher quality, more recent aerials because of the difficulty in finding control points that match the earliest 1937 images.

ERDAS Orthobase image processing software was used to orthographically correct the individual flight lines using a bundle block solution. Camera lens calibration data were 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. The exterior and interior models were combined with a digital elevation model (DEM) from the USGS National Elevation Dataset to produce an orthophoto for each aerial photograph. The orthophotographs 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 .img format. To maintain an accurate match with the reference images, it is necessary to distribute the control points evenly, when possible. This can be challenging in areas given the lack of ground features and poor photo quality on the earliest photos. Good examples of control points were manmade features such as road intersections and stable natural landmarks such as ponds and creeks that have not changed much over time. The base of tall features such as buildings, poles, or trees can be used, but the base can be obscured by other features or shadows making these locations difficult to use accurately. Most areas of the County were particularly difficult to rectify, either due to the lack of development when compared to the reference images or due to no development in the historical and the reference images.

Once the aerial photos were orthorectified and mosaicked, the shorelines were digitized in ArcMap with the mosaics in the background. The morphologic toe of the beach or edge of marsh was used to approximate low water. High water or the limit of runup can be difficult to determine on the shoreline due to narrow or non-existent beaches against upland banks or vegetated cover. In areas where the shoreline was not clearly identifiable on the aerial photography, the location was estimated based on the experience of the digitizer. The displayed shorelines are in shapefile format. One shapefile was produced for each year that was mosaicked.

Horizontal positional accuracy is based upon orthorectification of scanned aerial photography against the USGS digital orthophoto quadrangles. To get vertical control the USGS 30m DEM data was used. The 1994 USGS reference images were developed in accordance with National Map Accuracy Standards (NMAS) for Spatial Data Accuracy at the 1:12,000 scale. The 2002, 2007, and 2009 Virginia Base Mapping Program's orthophotography were developed in accordance with the National Standard for Spatial Data Accuracy (NSSDA). Horizontal root mean square error (RMSE) for historical mosaics was held to less than 20 ft.

2.2 Rate of Change Analysis

The Digital Shoreline Analysis System (DSAS) was used to determine the rate of change for the County's shoreline (Himmelstoss, 2009). All DSAS input data must be managed within a personal geodatabase, which includes all the baselines created for Prince William County and the digitized shorelines for 1937, 1953, 1962, 1985, 1994, 2002, 2007, and 2009. Baselines were digitized about 200 feet, more or less, depending on features and space, seaward of the 1937 shoreline and encompassed most of the County's main shorelines but generally did not include the smaller creeks. It also did not include areas that have unique shoreline morphology such as creek mouths and spits. DSAS generated transects perpendicular to the baseline about 33 ft apart, which were manually checked and cleaned up. For Prince William County, this method represented about 23 miles of shoreline along 3624 transects. The End Point Rate (EPR) is calculated by determining the distance between the oldest and most recent shoreline in the data and dividing it by the number of years between them. This method provides an accurate net rate of change over the long term and is relatively easy to apply to most shorelines since it only requires two dates. This method does not use the intervening shorelines so it may not account for changes in accretion or erosion rates that may occur through time. However, Milligan *et al.* (2010a, 2010b, 2010c, 2010d) found that in several localities within the bay, EPR is a reliable indicator of shore change even when intermediate dates exist. Average rates were calculated along selected areas of the shore; segments are labeled in Appendix A and shown in Table 1.

Using methodology reported in Morton *et al.* (2004) and National Spatial Data Infrastructure (1998), estimates of error in orthorectification, control source, DEM and digitizing were combined to provide an estimate of total maximum shoreline position error. The data sets that were orthorectified (1937, 1953, 1962, and 1985) have an estimated total maximum shoreline position error of 20 ft, while the total maximum shoreline error for the four existing datasets are estimated at 18.3 ft for USGS and 10.2 ft for VBMP. The maximum annualized error for the shoreline data is ±0.7 ft/yr. The smaller rivers and creeks are more prone to error due to their lack of good control points for photo rectification, narrower shore features, tree and ground cover and overall smaller rates of change. These areas are digitized but due to the higher potential for error, rates of change analysis are not calculated.

Prince William County shoreline was divided into 12 plates (Figure 2) in order to display that data in Appendices A and B. In Appendix A, all of the digitized shorelines

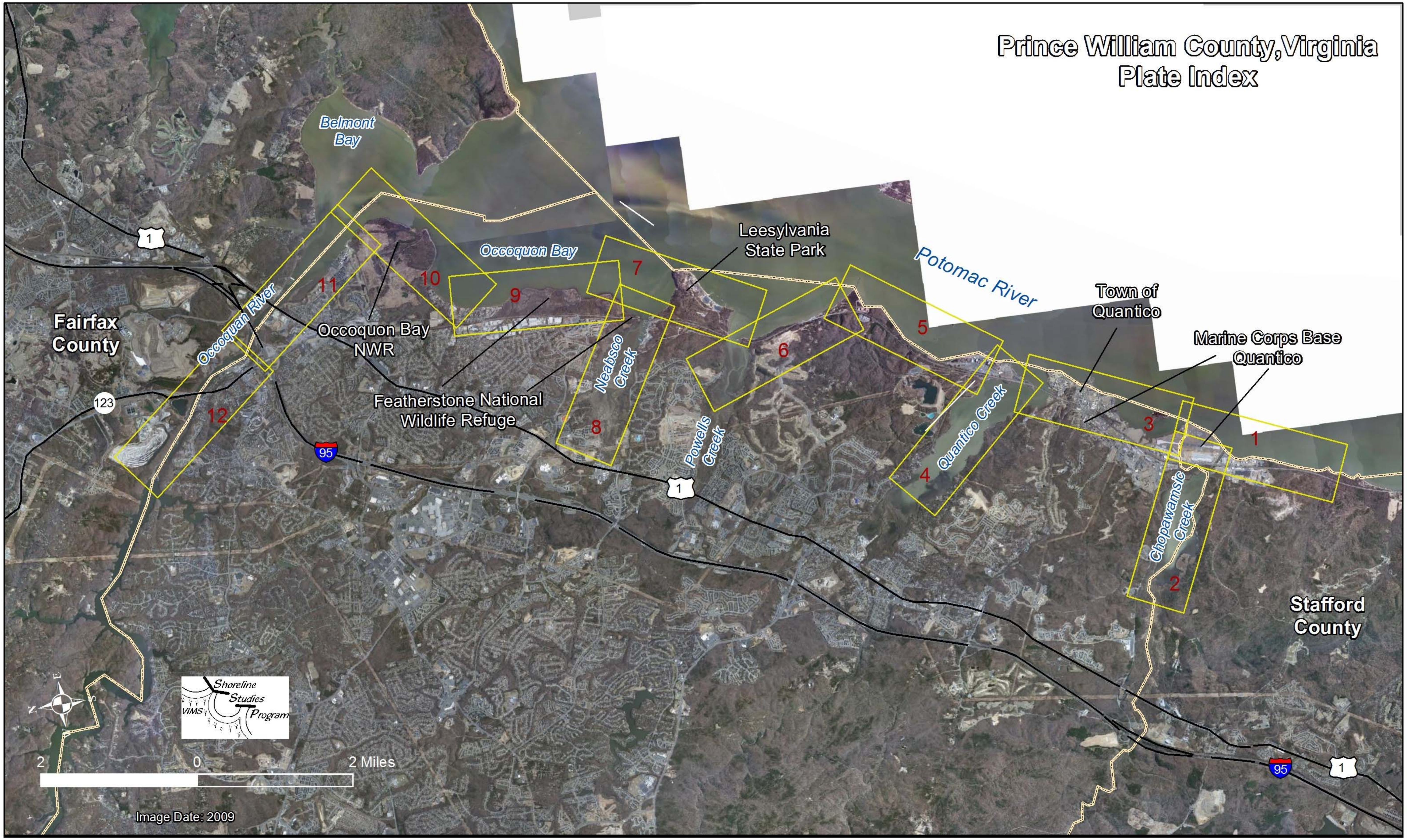

Figure 2. Index of shoreline plates

are shown, and the 2009 image is shown with only the 1937 and 2009 shorelines to show the long-term trends. In Appendix B, two photo dates and their associated shoreline are shown on each plate. These include the photos taken in 1937, 1953, 1962, 1985, 1994, 2002, 2007, and 2009.

3 Summary

The rates of change shown in Table 1 are averaged across large sections of shoreline and may not be indicative of rates at specific sites within the reach. In many areas of the County, the shoreline change rates are categorized as very low accretion. This may be the result of error within the method since most of the very low accretion and very low erosion categories falls within our calculated error rate. Along the Marine Corps Base, Quantico, the slight accretion may be real since much of the shoreline was stabilized with structures. One large section of shoreline on the Base had medium and high accretion rates due to placement of material along the shoreline. The Featherstone National Wildlife Refuge, in Segment H, along Occoquan Bay has had medium to high erosion occur along its shoreline.

Table 1. Average end point rate of change (ft/yr) between 1937 and 2009 for segments along Prince William County's shoreline. Segment locations are shown on maps in Appendix A

Segment Name	Location	Average Rate of Change (ft/yr)
A	Potomac River-County line to Shipping Point	0.1
B	Quantico Creek	-0.5
C	Potomac River, Possum Point to Cockpit Point	0.1
D	Potomac River, Cockpit Point to Powell's Creek	-0.5
E	Potomac River, Mouth of Powell's Creek	0.2
F	Potomac River, Freestone Point	0.2
G	Occoquan Bay, Freestone Point to Neabsco Creek	-0.4
H	Neabsco Creek to Taylors Point	-1.5
I	Belmont Bay	-0.4
J	Occoquan River	-0.2

4 References

Himmelstoss, E.A., 2009. "DSAS 4.0 Installation Instructions and User Guide" in: Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., and Ergul, Ayhan. 2009 Digital Shoreline Analysis System (DSAS) version 4.0 — An ArcGIS extension for calculating shoreline change: U.S. Geological Survey Open-File Report 2008-1278.

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Milligan, D. A., K.P. O'Brien, C. Wilcox, C. S. Hardaway, JR, 2010d. Shoreline Evolution: York County, Virginia York River, Chesapeake Bay and Poquoson River Shorelines. Virginia Institute of Marine Science. College of William & Mary, Gloucester Point, VA. http://web.vims.edu/physical/research/shoreline/docs/dune_evolution/York/1York_Shore_Evolve.pdf

Morton, R.A., T.L. Miller, and L.J. Moore, 2004. National Assessment of Shoreline Change: Part 1 Historical Shoreline Change and Associated Coastal Land Loss along the U.S. Gulf of Mexico. U.S. Department of the Interior, U.S. Geological Survey Open-File Report 2004-1043, 45 p.

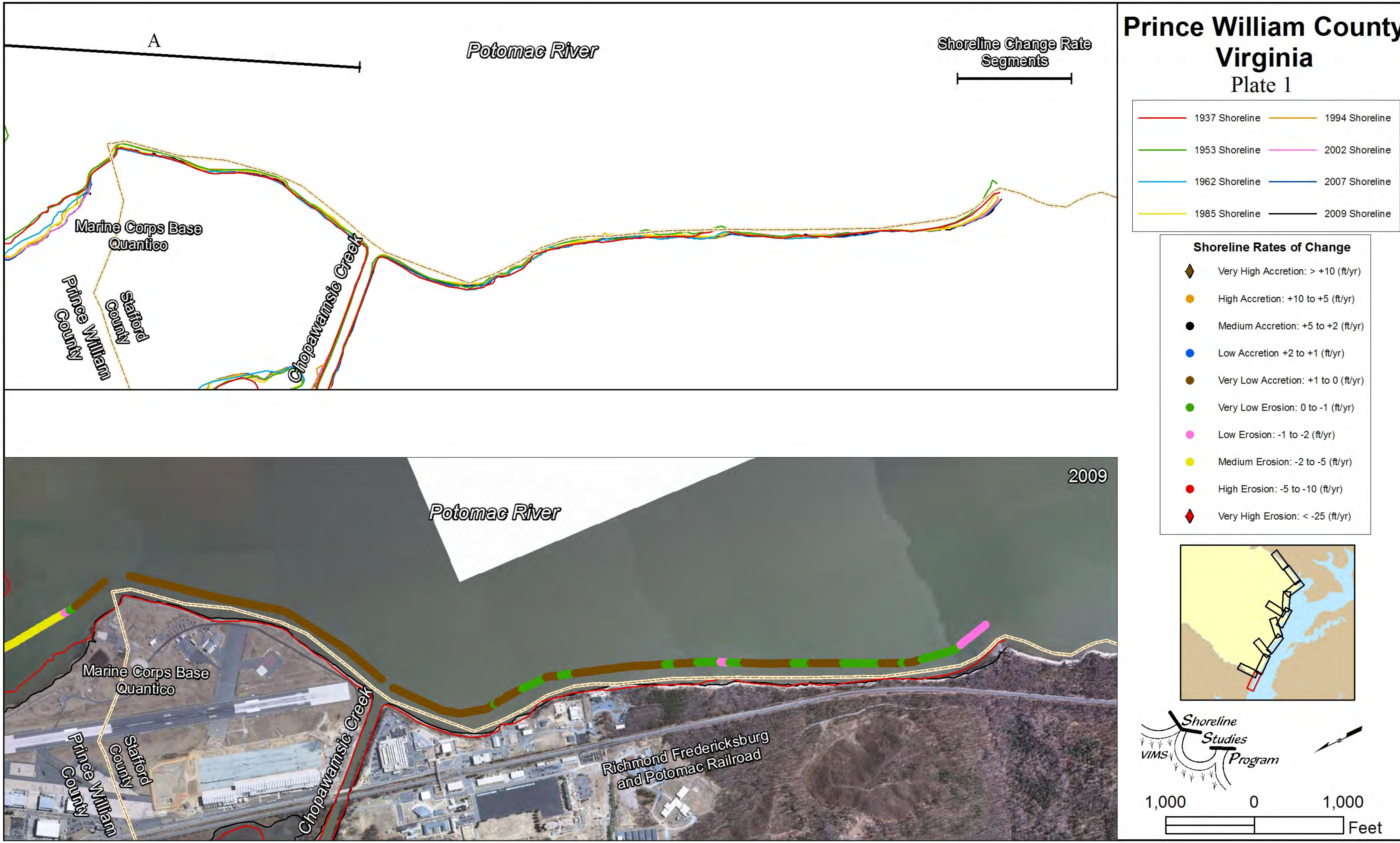
National Spatial Data Infrastructure, 1998. Geospatial Positional Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy. Subcommittee for Base Cartographic Data. Federal Geographic Data Committee. Reston, VA.

Appendix A

End Point Rate of Shoreline Change Maps

Shoreline change rate segments are shown on the top map. The calculated rates of change for each transect within the segment were averaged to determine an average rate of change as shown in Table 1 of the report.

Note: The location labels on the plates come from U.S. Geological Survey topographic maps, Google Earth, and other map sources and may not be accurate for the historical or even more recent images. They are for reference only.


Prince William County
Virginia
Plate 1
A
Potomac River
Shoreline Change Rate Segments
Marine Corps Base Quantico
Prince William County
Stafford County
Chopawamsic Creek
1937 Shoreline
1953 Shoreline
1962 Shoreline
1985 Shoreline
1994 Shoreline
2002 Shoreline
2007 Shoreline
2009 Shoreline
Shoreline Rates of Change
Very High Accretion: > +10 (ft/yr)
High Accretion: +10 to +5 (ft/yr)
Medium Accretion: +5 to +2 (ft/yr)
Low Accretion +2 to +1 (ft/yr)
Very Low Accretion: +1 to 0 (ft/yr)
Very Low Erosion: 0 to -1 (ft/yr)
Low Erosion: -1 to -2 (ft/yr)
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -25 (ft/yr)
2009
Potomac River
Marine Corps Base Quantico
Prince William County
Stafford County
Chopawamsic Creek
Richmond Fredericksburg and Potomac Railroad
Shoreline Studies Program
VIMS
1,000
0
1,000
Feet


Prince William County
Virginia
Plate 2
Shoreline Change Rate Segments
Chopawamsic Creek
Marine Corps Base Quantico
A
A
Potomac River
1937 Shoreline
1994 Shoreline
1953 Shoreline
2002 Shoreline
1962 Shoreline
2007 Shoreline
1985 Shoreline
2009 Shoreline
Shoreline Rates of Change
Very High Accretion: > +10 (ft/yr)
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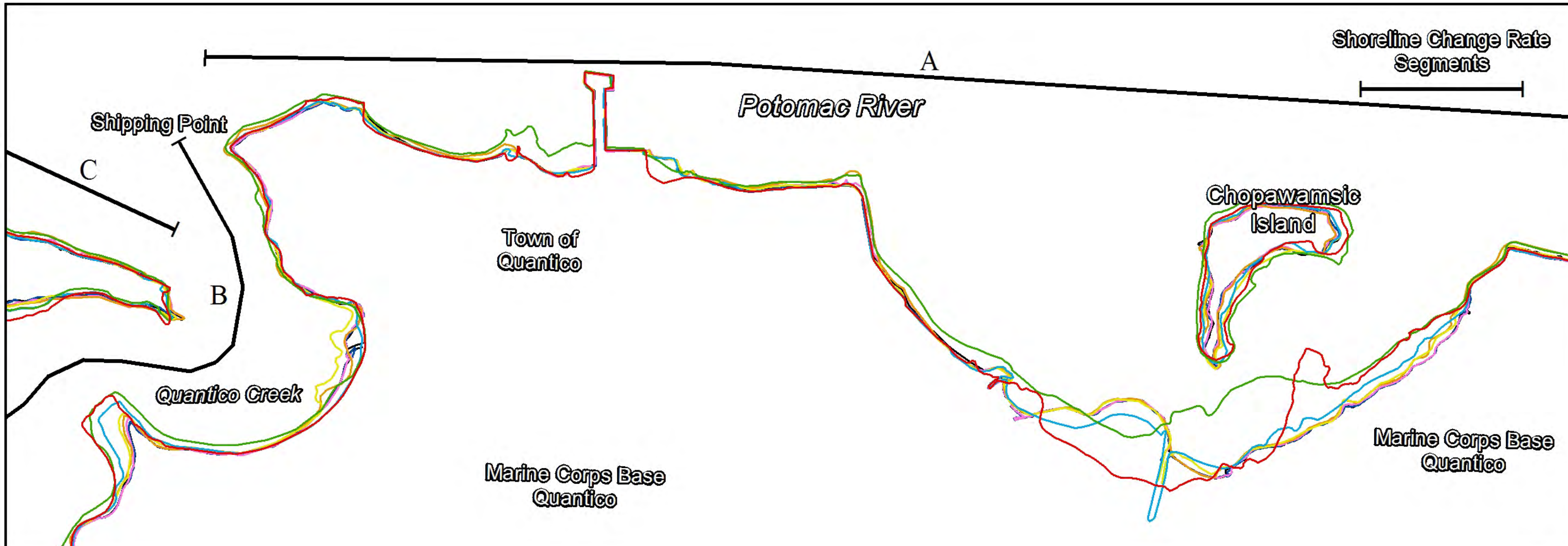
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -25 (ft/yr)
2009
Chopawamsic Creek
No Rates Calculated in Creek
Marine Corps Base Quantico
Richmond Fredericksburg and Potomac Railroad
Potomac River
Shoreline Studies Program
VIMS
1,000
0
1,000
Feet

Prince William County Virginia

Plate 3



1937 Shoreline	1994 Shoreline
1953 Shoreline	2002 Shoreline
1962 Shoreline	2007 Shoreline
1985 Shoreline	2009 Shoreline

Shoreline Rates of Change

- Very High Accretion: > +10 (ft/yr)
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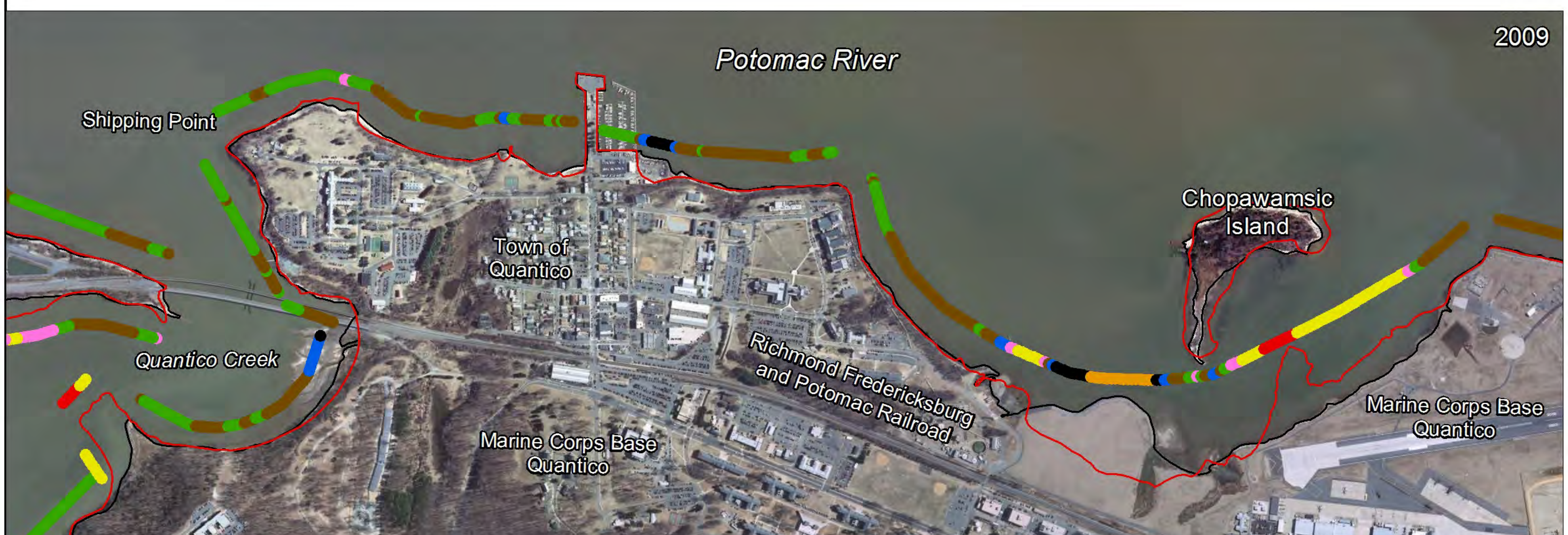
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -25 (ft/yr)



Shoreline Studies Program
VIMS

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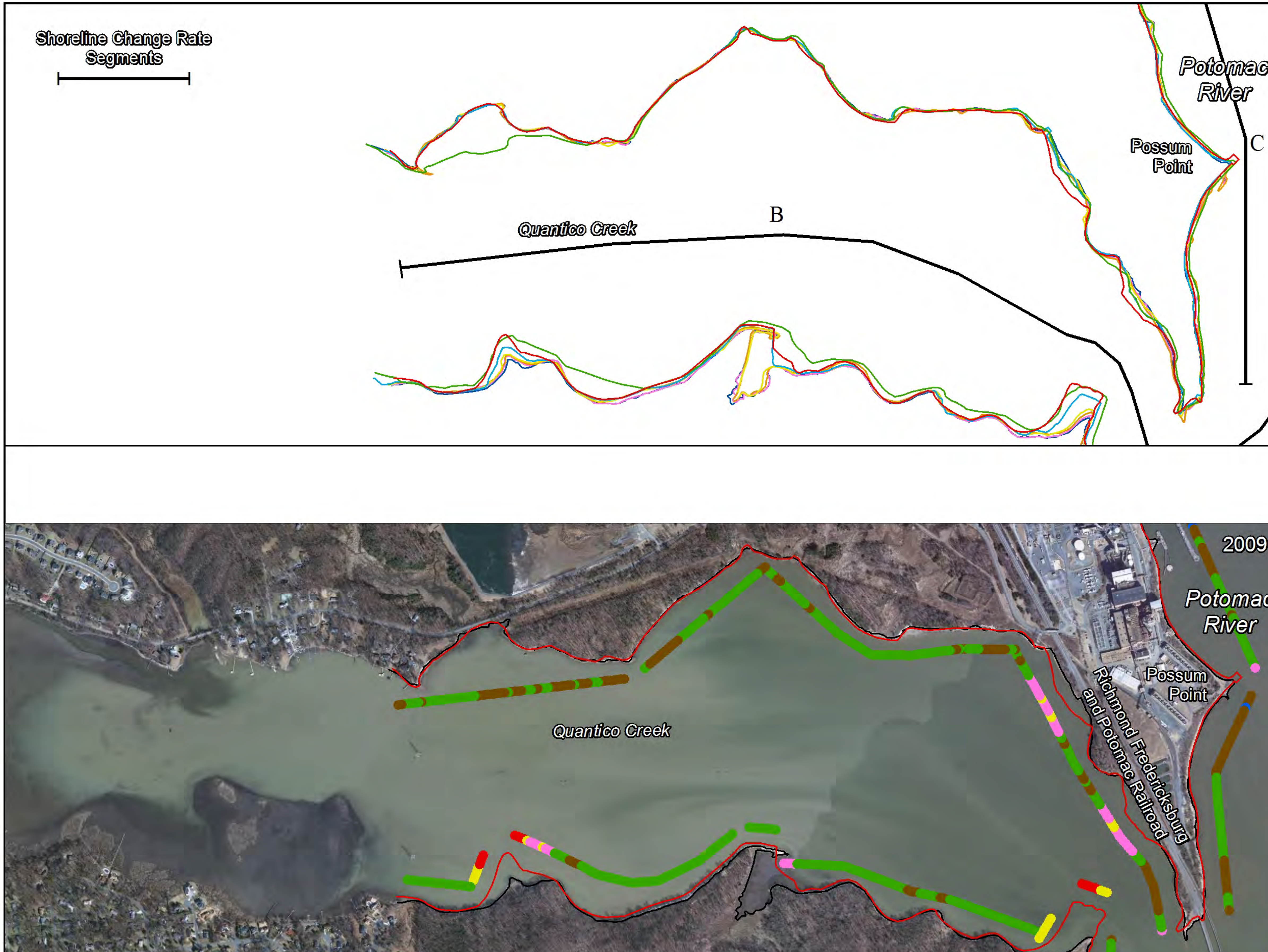
Feet

Prince William County Virginia

Plate 4



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1953 Shoreline	2002 Shoreline
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1985 Shoreline	2009 Shoreline

Shoreline Rates of Change

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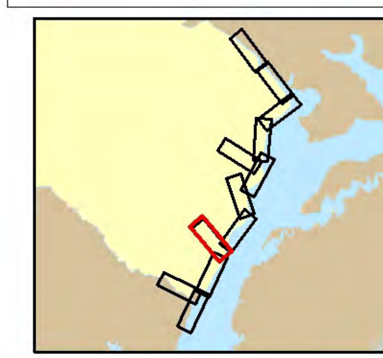
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -25 (ft/yr)



Shoreline Studies Program VIMS

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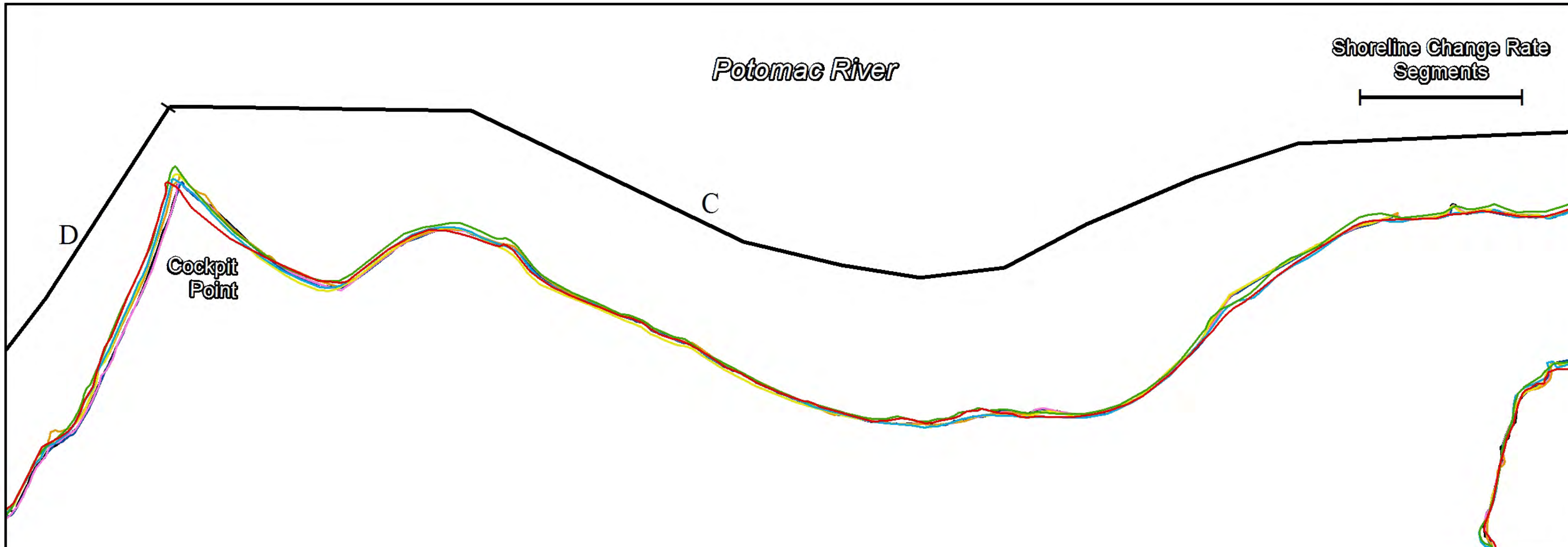
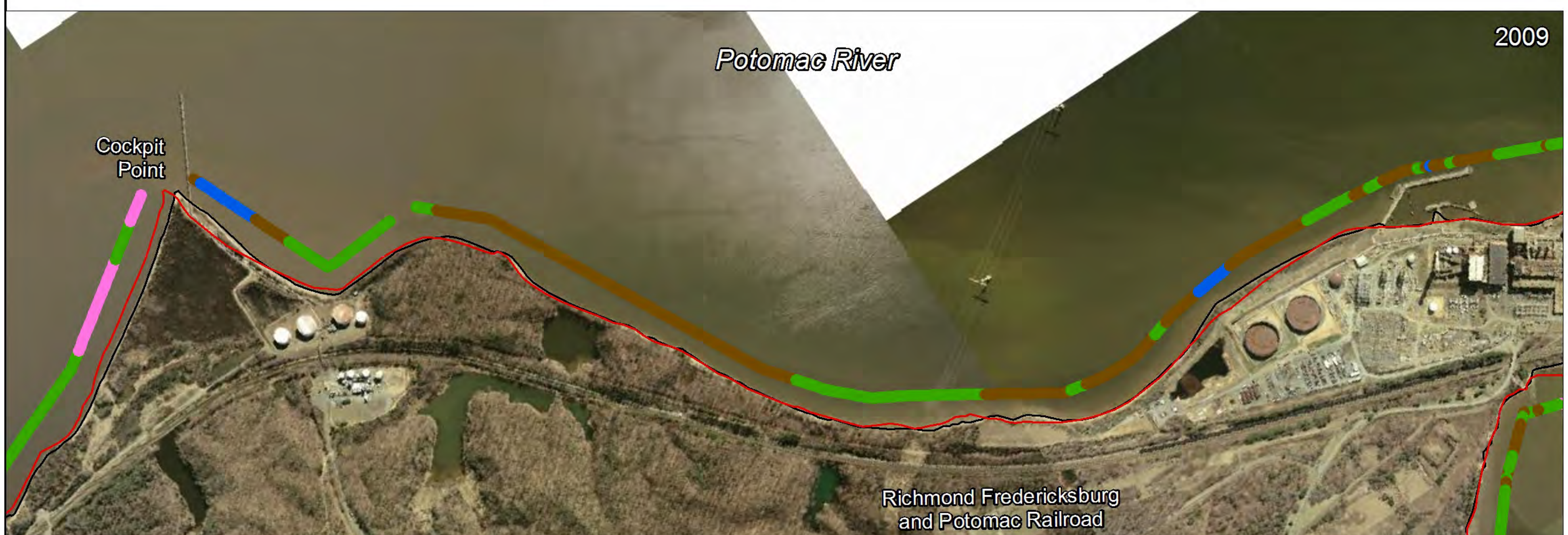
Prince William County Virginia

Plate 5





1937 Shoreline	1994 Shoreline
1953 Shoreline	2002 Shoreline
1962 Shoreline	2007 Shoreline
1985 Shoreline	2009 Shoreline

Shoreline Rates of Change

- Very High Accretion: > +10 (ft/yr)
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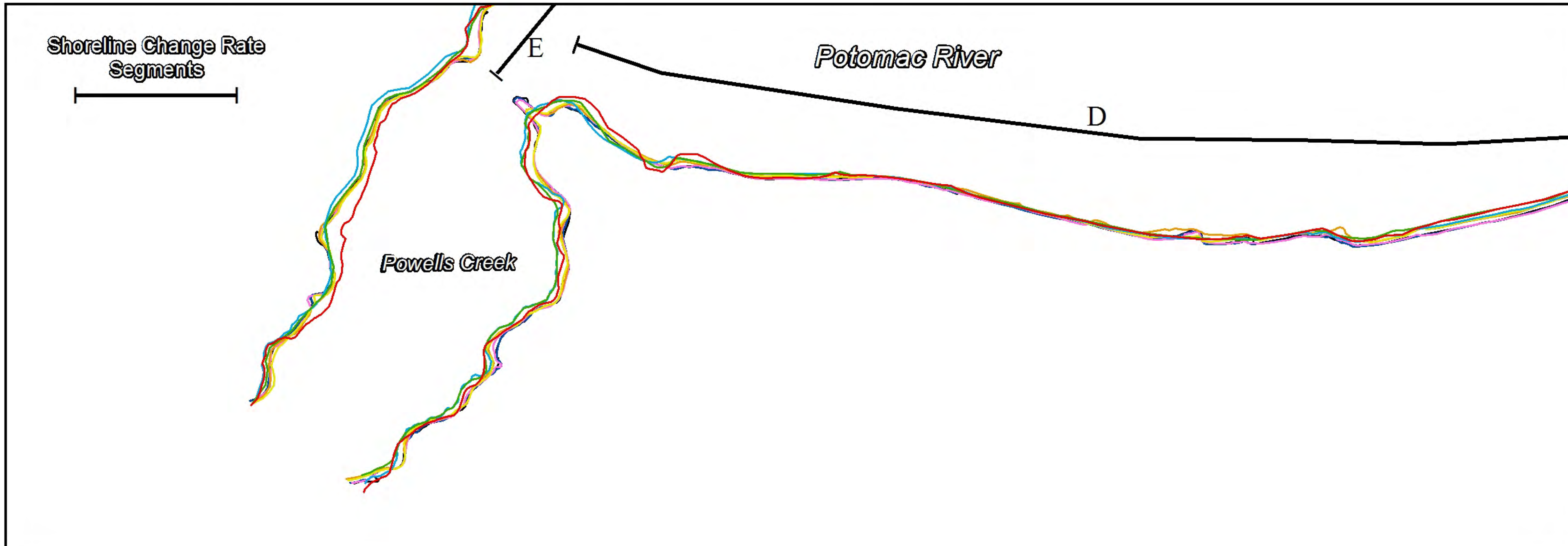
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -25 (ft/yr)

VIMS Shoreline Studies Program

1,000 0 1,000 Feet

Prince William County Virginia

Plate 6



1937 Shoreline	1994 Shoreline
1953 Shoreline	2002 Shoreline
1962 Shoreline	2007 Shoreline
1985 Shoreline	2009 Shoreline

Shoreline Rates of Change

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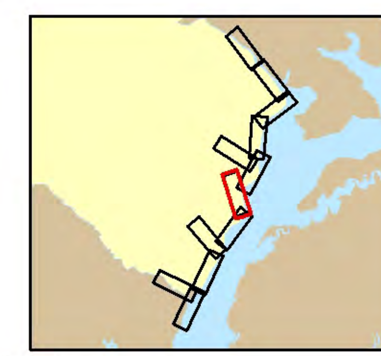
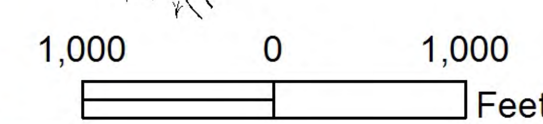
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -25 (ft/yr)



Shoreline Studies Program VIMS




Prince William County
Virginia
Plate 7
1937 Shoreline
1994 Shoreline
1953 Shoreline
2002 Shoreline
1962 Shoreline
2007 Shoreline
1985 Shoreline
2009 Shoreline
Shoreline Rates of Change
Very High Accretion: > +10 (ft/yr)
High Accretion: +10 to +5 (ft/yr)
Medium Accretion: +5 to +2 (ft/yr)
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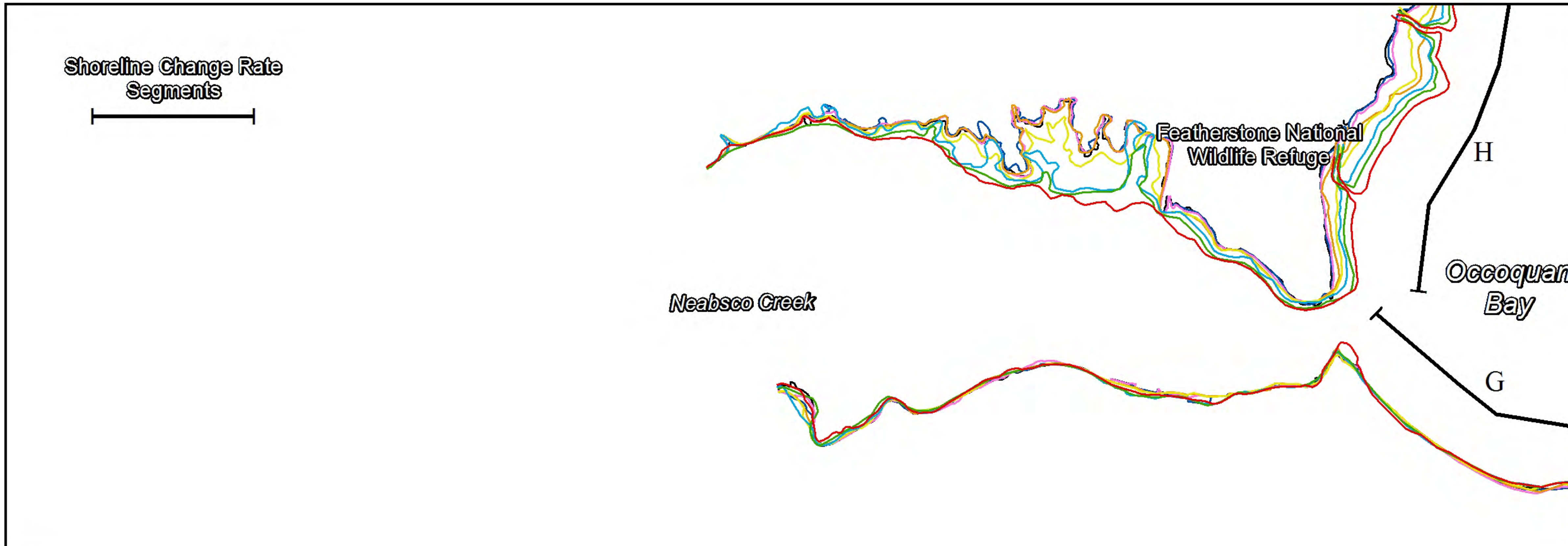
Medium Erosion: -2 to -5 (ft/yr)
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -25 (ft/yr)
Shoreline Change Rate Segments
Potomac River
Freestone Point
Occoquan Bay
Leesylvania State Park
Powells Creek
H
G
F
E
D
2009
Richmond Fredericksburg and Potomac Railroad
Shoreline Studies Program
VIMS
1,000
0
1,000
Feet

Prince William County Virginia

Plate 8



1937 Shoreline	1994 Shoreline
1953 Shoreline	2002 Shoreline
1962 Shoreline	2007 Shoreline
1985 Shoreline	2009 Shoreline

Shoreline Rates of Change

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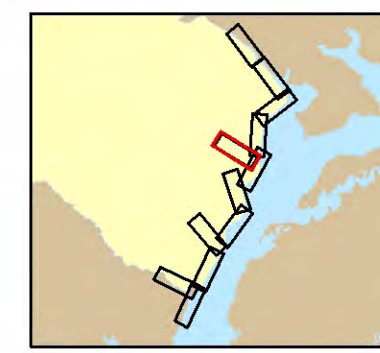
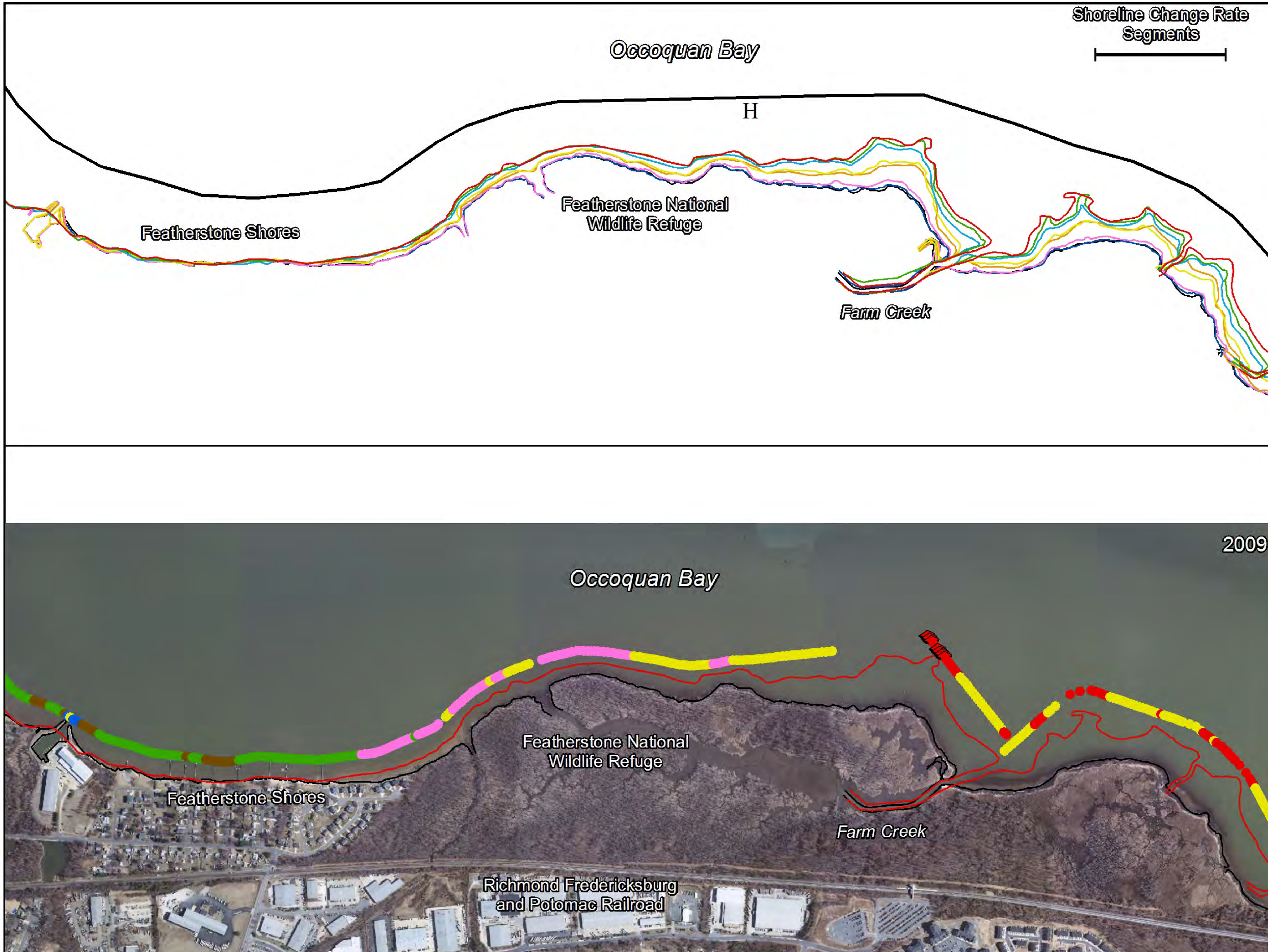


Shoreline Studies Program VIMS

1,000 0 1,000 Feet

Prince William County Virginia

Plate 9



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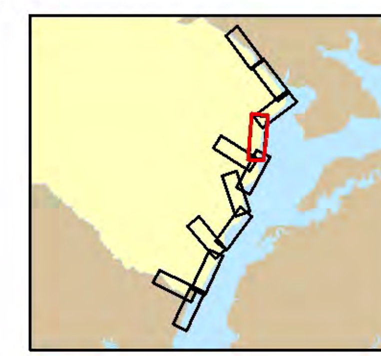

Shoreline Studies Program VIMS

1,000 0 1,000 Feet


Prince William County Virginia
Plate 10
Shoreline Change Rate Segments
H
I
Conrad Island
Deephole Point
Occoquan Bay
Occoquan Bay National Wildlife Refuge
Taylors Point
Belmont Bay
Bayside Park
Marumsco Creek
Featherstone Shores
2009
1937 Shoreline
1953 Shoreline
1962 Shoreline
1985 Shoreline
1994 Shoreline
2002 Shoreline
2007 Shoreline
2009 Shoreline
Shoreline Rates of Change
Very High Accretion: > +10 (ft/yr)
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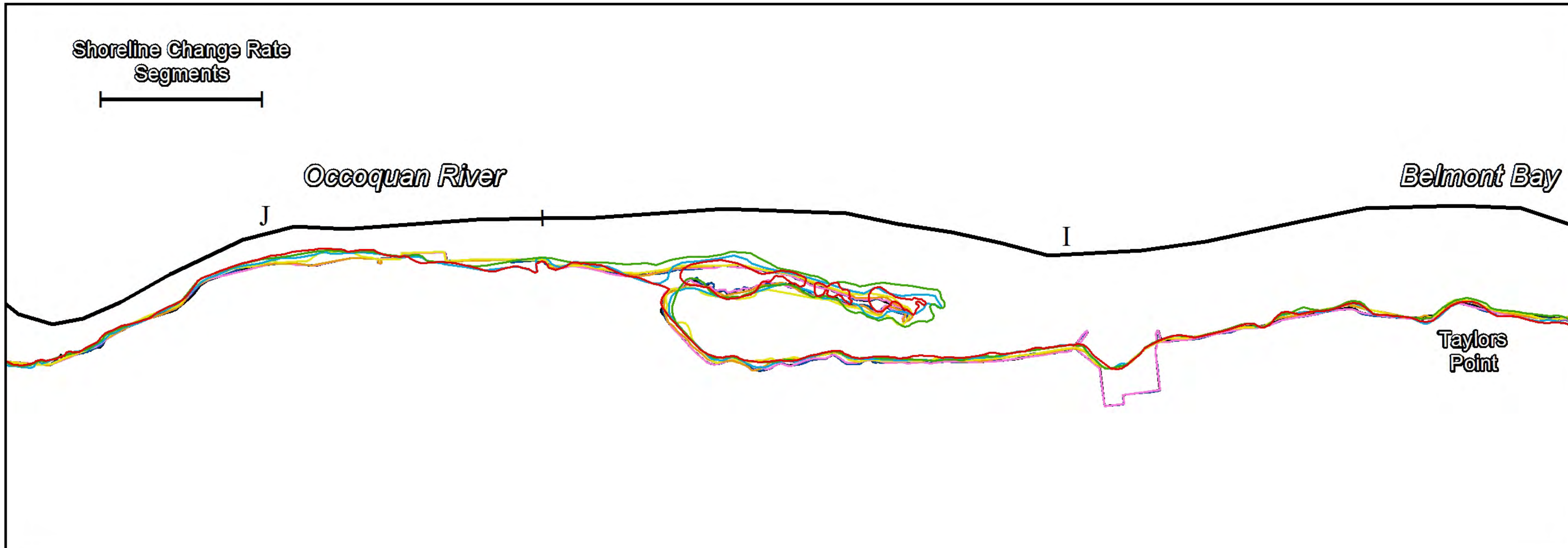
High Erosion: -5 to -10 (ft/yr)
Very High Erosion: < -25 (ft/yr)
Shoreline Studies Program
VIMS
1,000 0 1,000
Feet



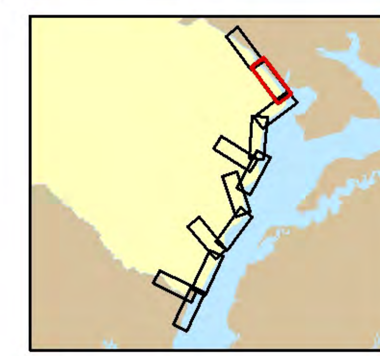
Prince William County Virginia

Plate 11

1937 Shoreline	1994 Shoreline
1953 Shoreline	2002 Shoreline
1962 Shoreline	2007 Shoreline
1985 Shoreline	2009 Shoreline

Shoreline Rates of Change

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -25 (ft/yr)

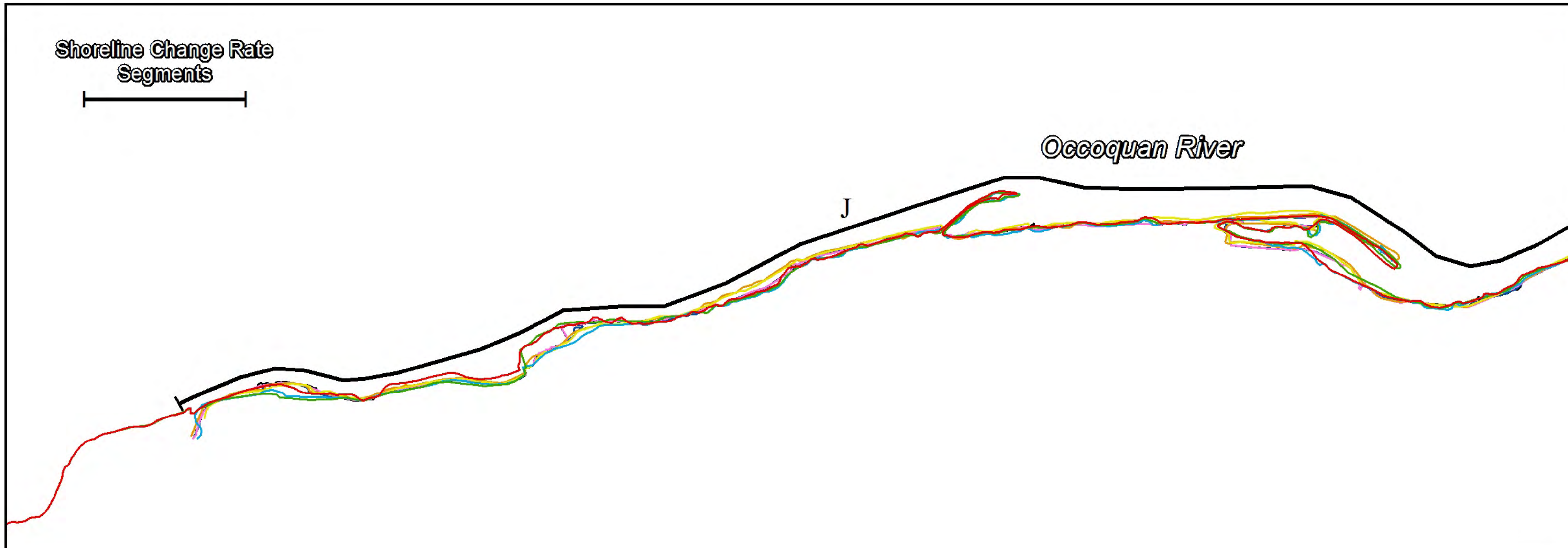


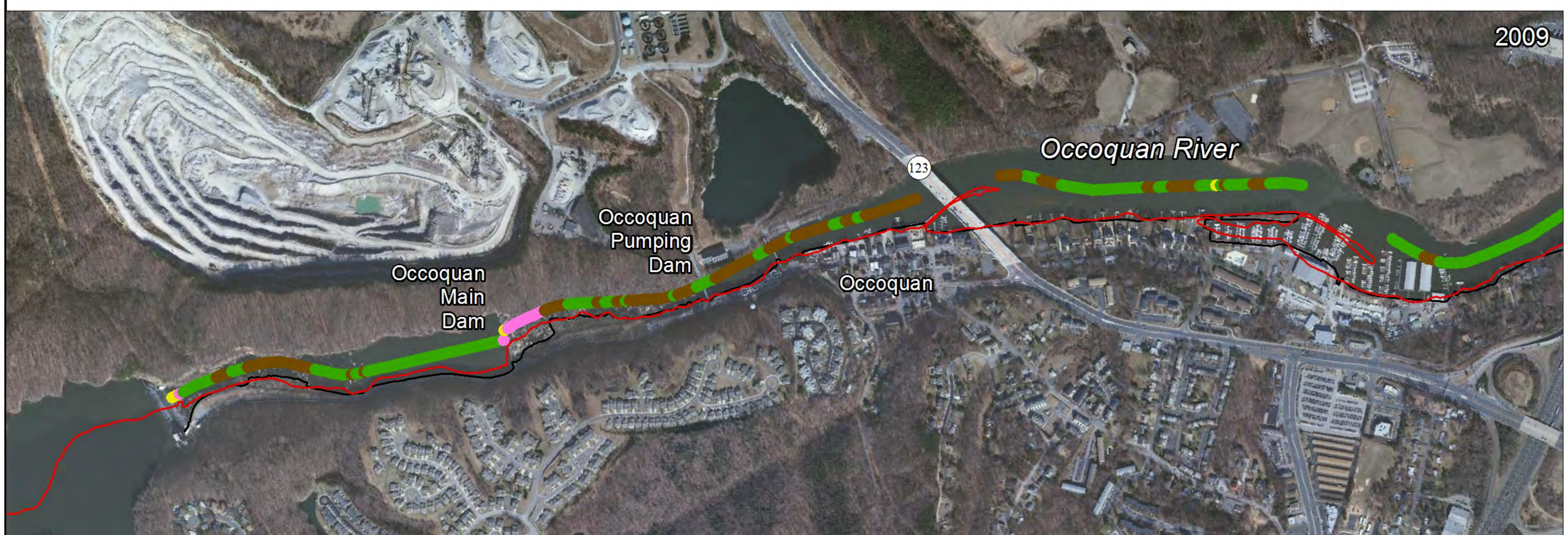
Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

Prince William County Virginia

Plate 12

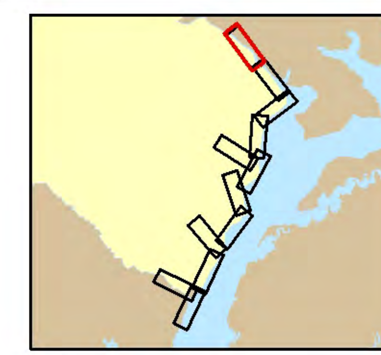




1937 Shoreline	1994 Shoreline
1953 Shoreline	2002 Shoreline
1962 Shoreline	2007 Shoreline
1985 Shoreline	2009 Shoreline

Shoreline Rates of Change

- Very High Accretion: > +10 (ft/yr)
- High Accretion: +10 to +5 (ft/yr)
- Medium Accretion: +5 to +2 (ft/yr)
- Low Accretion +2 to +1 (ft/yr)
- Very Low Accretion: +1 to 0 (ft/yr)
- Very Low Erosion: 0 to -1 (ft/yr)
- Low Erosion: -1 to -2 (ft/yr)
- Medium Erosion: -2 to -5 (ft/yr)
- High Erosion: -5 to -10 (ft/yr)
- Very High Erosion: < -25 (ft/yr)



VIMS Shoreline Studies Program

1,000 0 1,000 Feet

Appendix B

Historical Shoreline Photo Maps

Note: The location labels on the plates come from U.S. Geological Survey topographic maps, Google Earth, and other map sources and may not be accurate for the historical or even more recent images. They are for reference only.

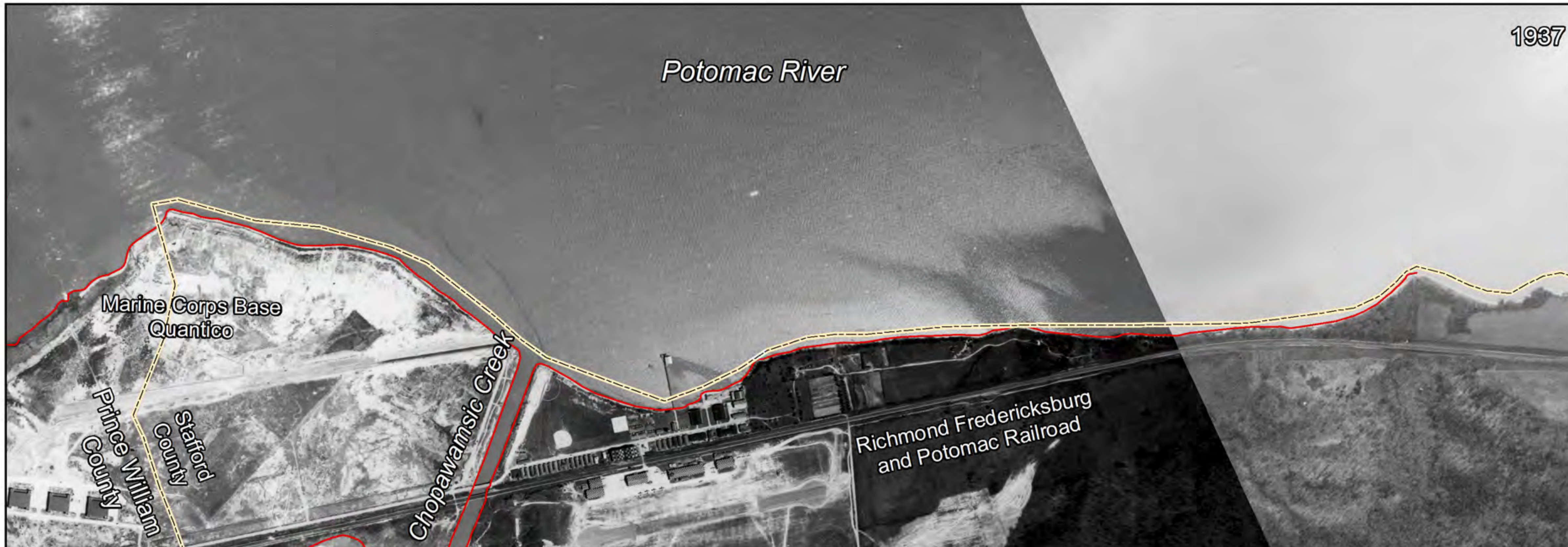
Prince William County Virginia

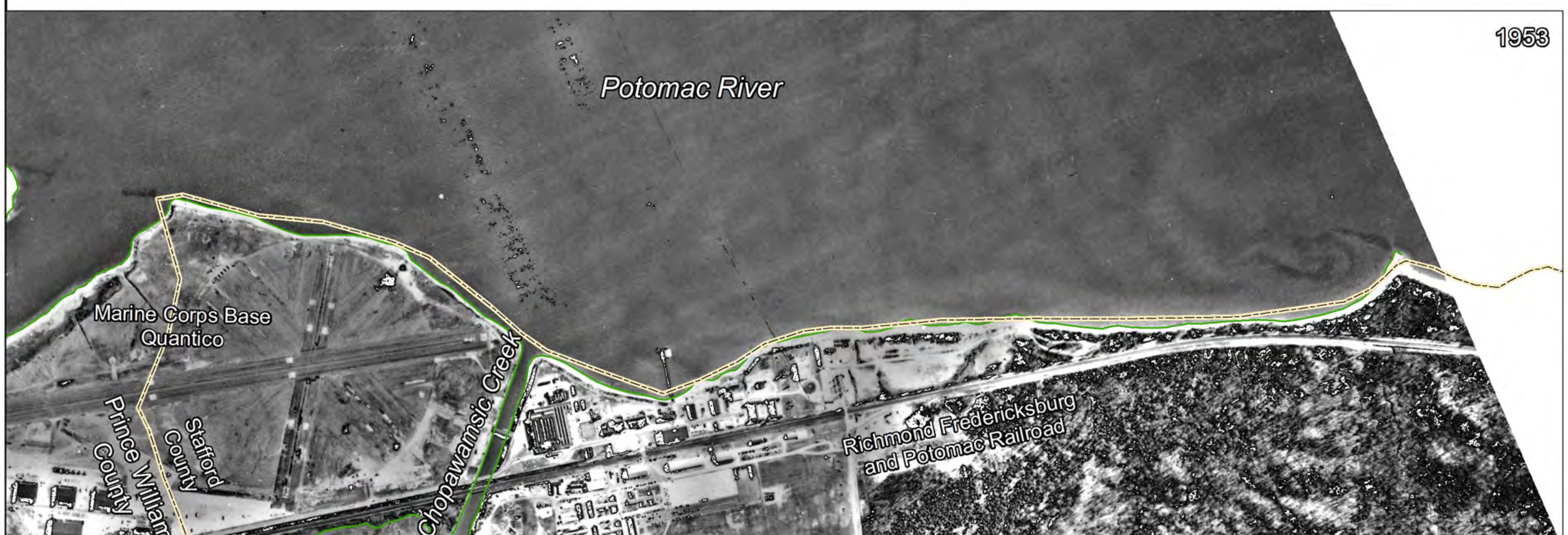
Plate 1

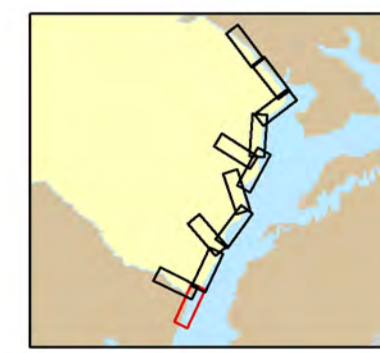
Legend

1937 Shoreline

1953 Shoreline





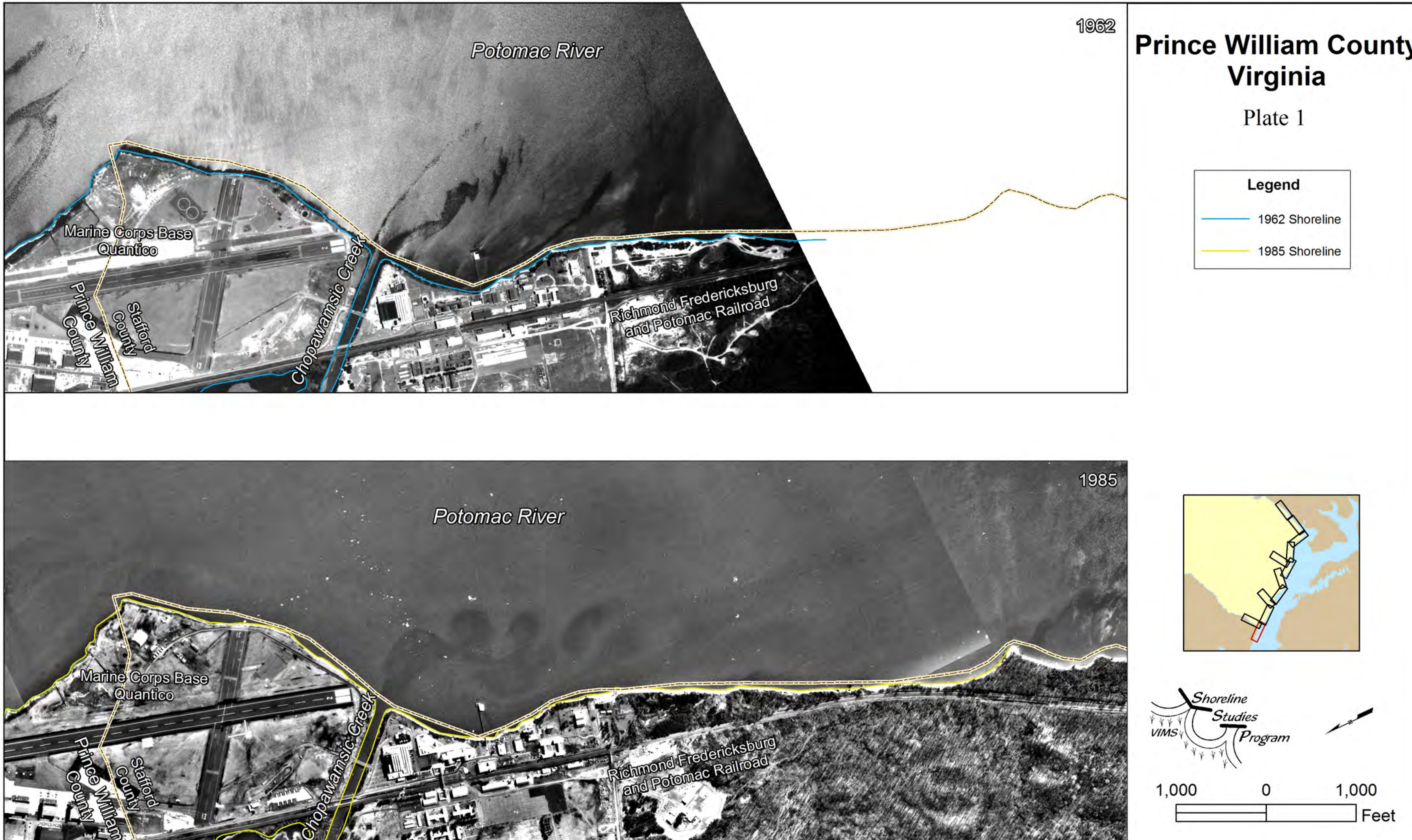


Shoreline Studies Program

VIMS

1,000 0 1,000

Feet

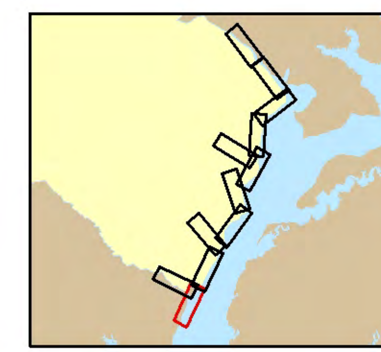

Prince William County
Virginia
Plate 1
1962
Potomac River
Marine Corps Base
Quantico
Prince William
County
Stafford
County
Chopawamsic Creek
Richmond Fredericksburg
and Potomac Railroad
Legend
1962 Shoreline
1985 Shoreline
1985
Potomac River
Marine Corps Base
Quantico
Prince William
County
Stafford
County
Chopawamsic Creek
Richmond Fredericksburg
and Potomac Railroad
Shoreline
Studies
Program
VIMS
1,000
0
1,000
Feet

Prince William County Virginia

Plate 1

Legend

- 1994 Shoreline
- 2002 Shoreline



VIMS Shoreline Studies Program

1,000 0 1,000 Feet

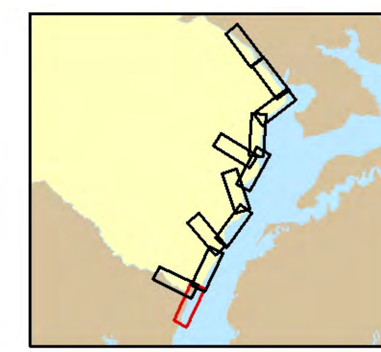
Prince William County Virginia

Plate 1

Legend

2007 Shoreline

2009 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

Prince William County Virginia

Plate 2

Legend

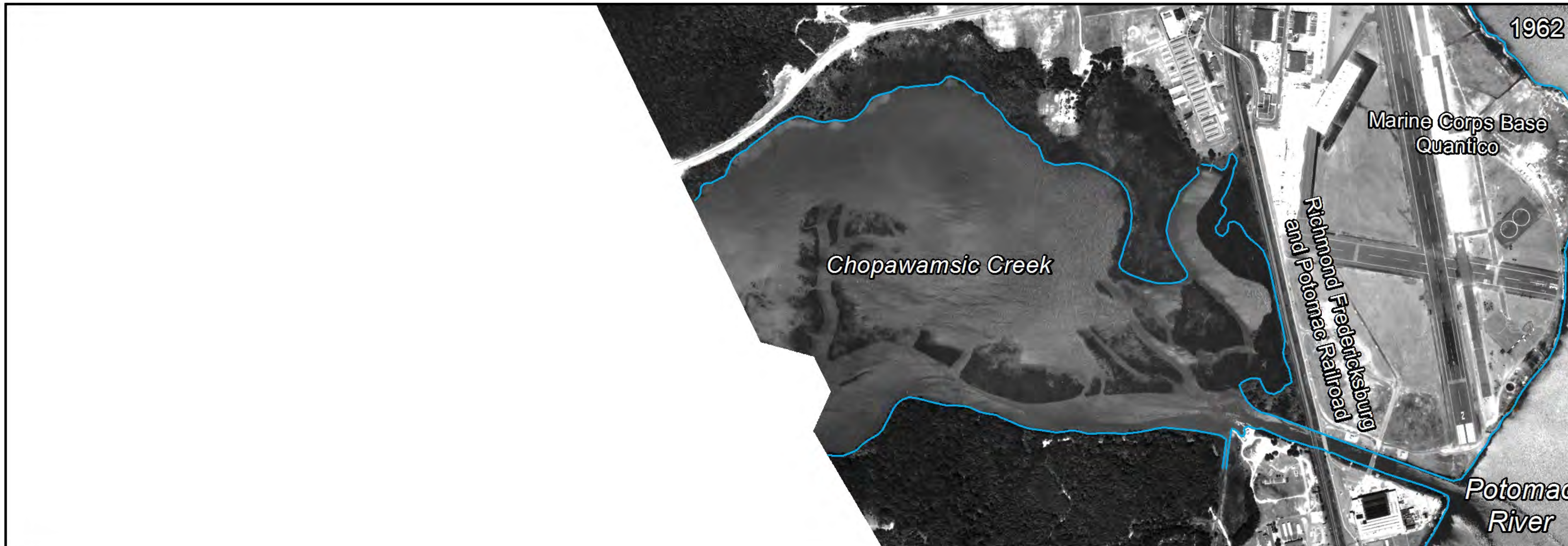
- 1937 Shoreline
- 1953 Shoreline

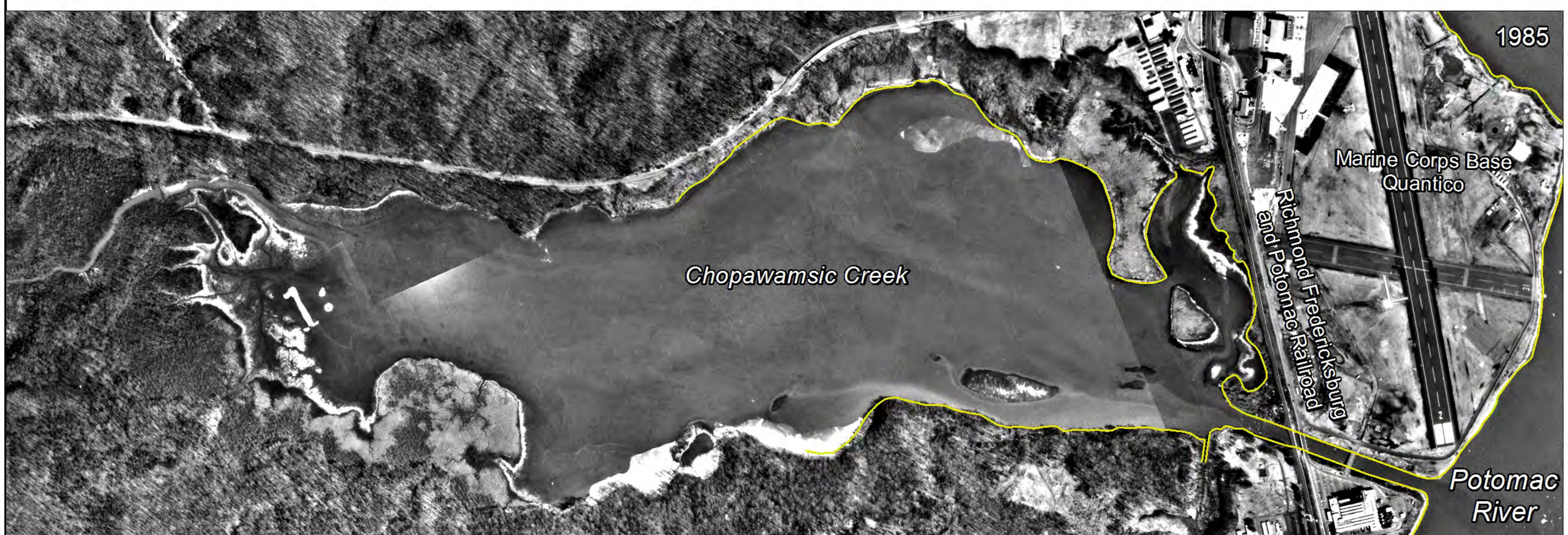
Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

Prince William County Virginia

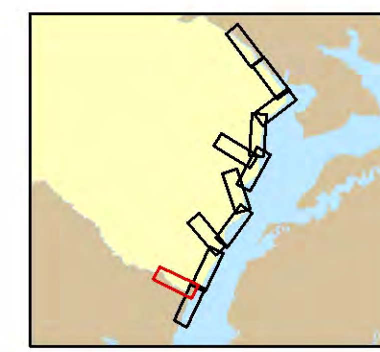
Plate 2





Legend

- 1962 Shoreline
- 1985 Shoreline

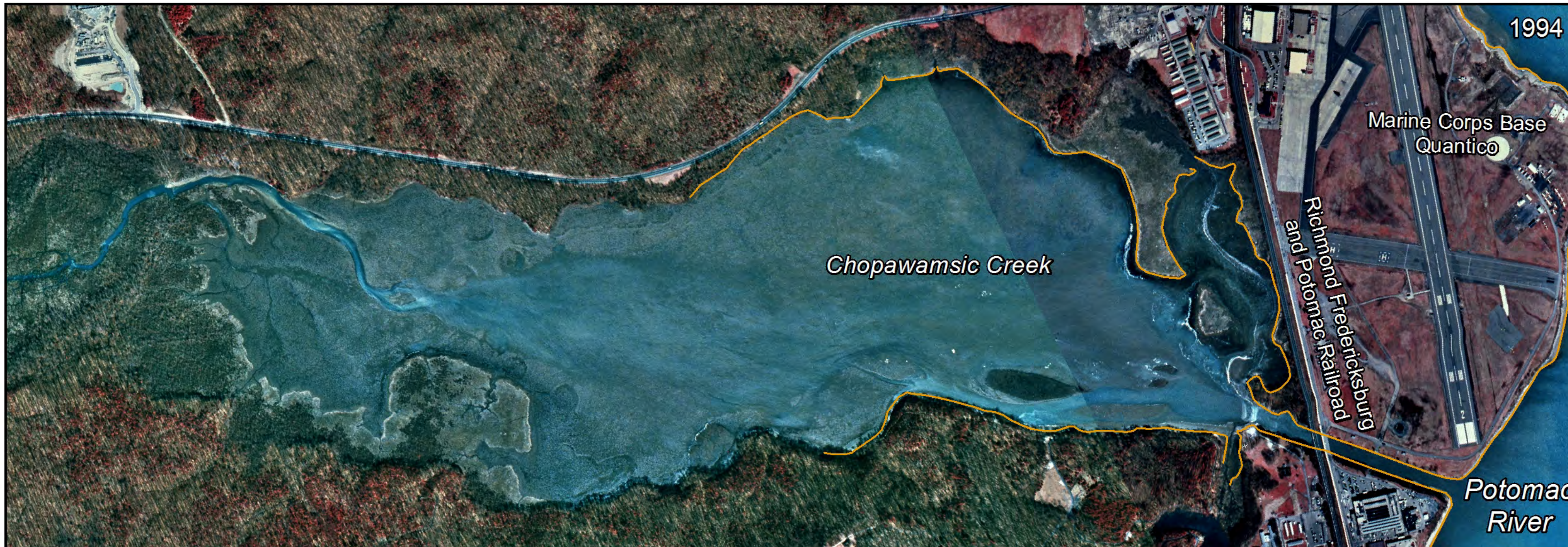


Shoreline Studies Program VIMS

1,000 0 1,000 Feet

Prince William County Virginia

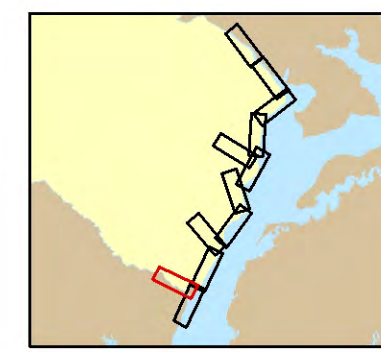
Plate 2



Legend

1994 Shoreline

2002 Shoreline



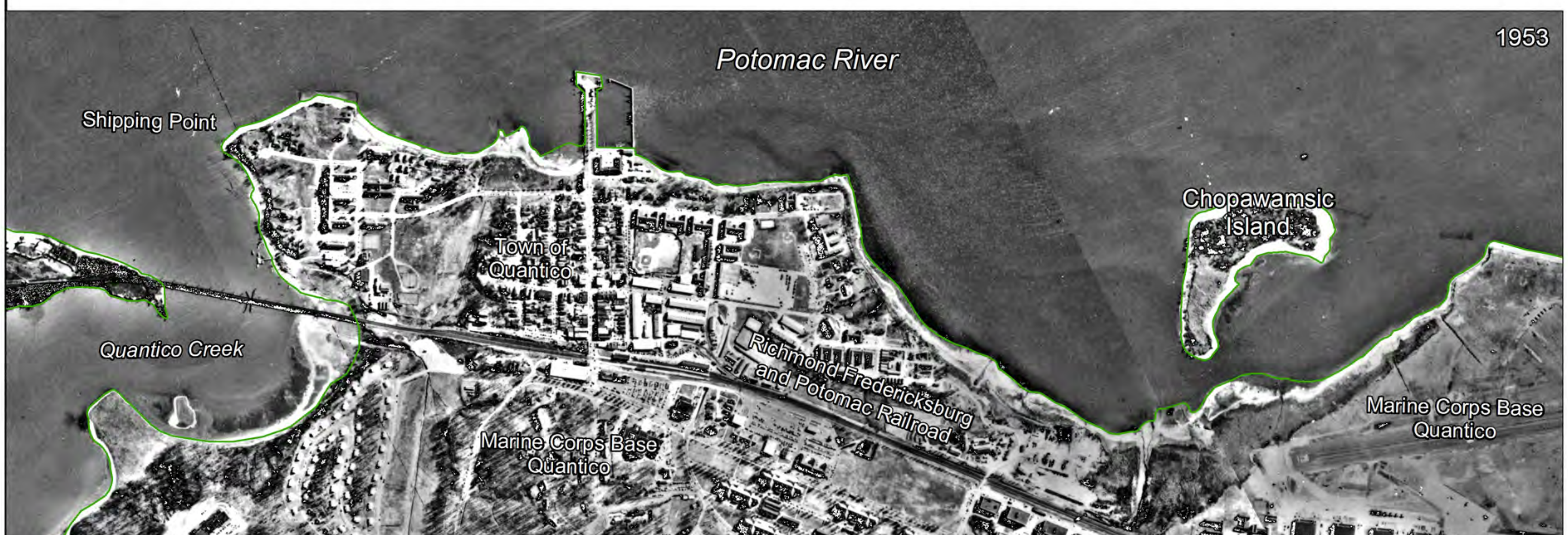
Shoreline Studies Program VIMS

1,000 0 1,000 Feet


Prince William County
Virginia
Plate 2
Legend
2007 Shoreline
2009 Shoreline
2007
Marine Corps Base
Quantico
Chopawamsic Creek
Richmond Fredericksburg
and Potomac Railroad
Potomac
River
2009
Shoreline
Studies
Program
VIMS
1,000
0
1,000
Feet

Prince William County Virginia

Plate 3

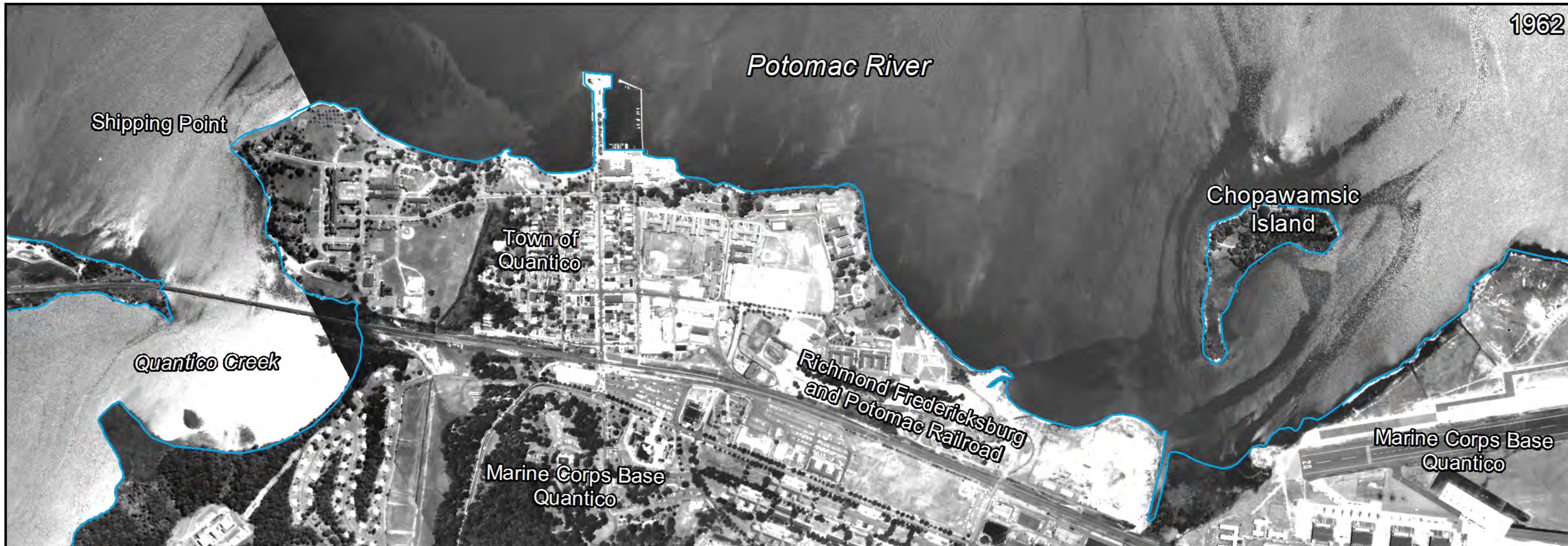


Legend

- 1937 Shoreline
- 1953 Shoreline

Shoreline Studies Program
VIMS

1,000 0 1,000
Feet



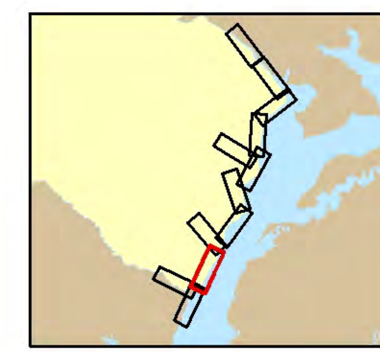
Prince William County Virginia

Plate 3

Legend

1962 Shoreline

1985 Shoreline



Shoreline Studies Program VIMS

1,000 0 1,000

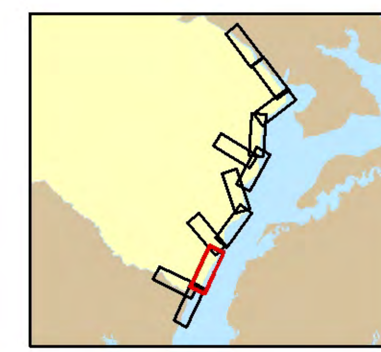
Feet

Prince William County Virginia

Plate 3

Legend

- 1994 Shoreline
- 2002 Shoreline

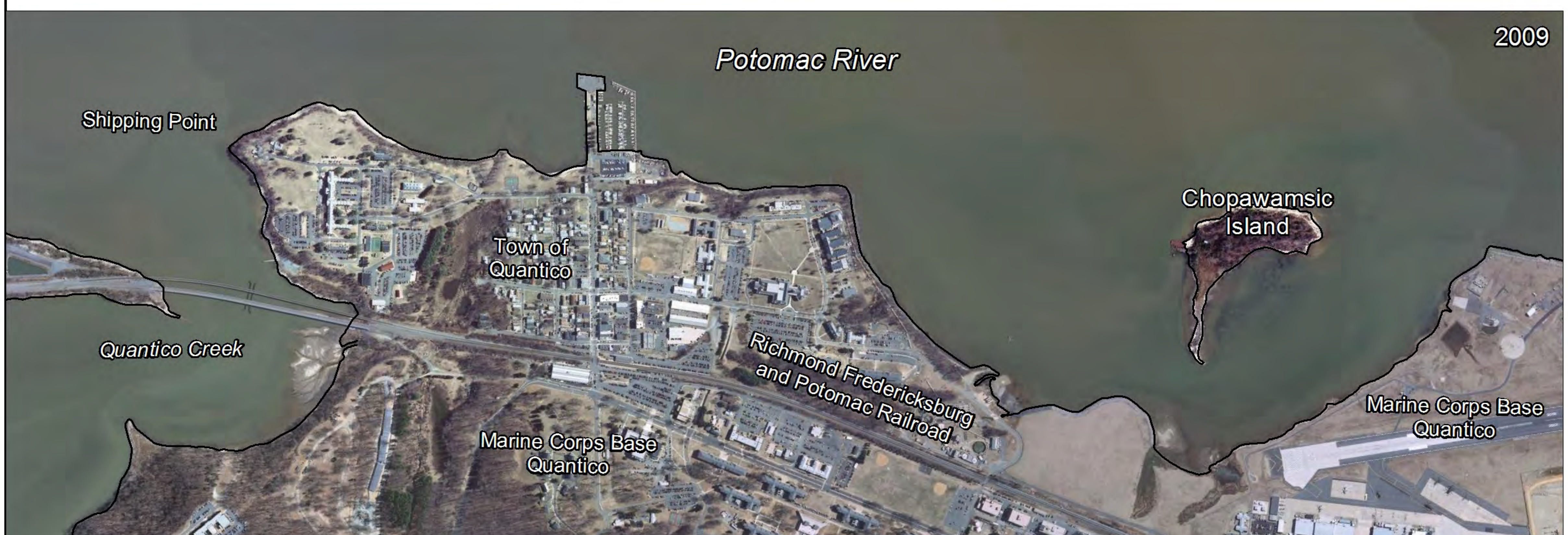


Shoreline Studies Program VIMS

1,000 0 1,000 Feet

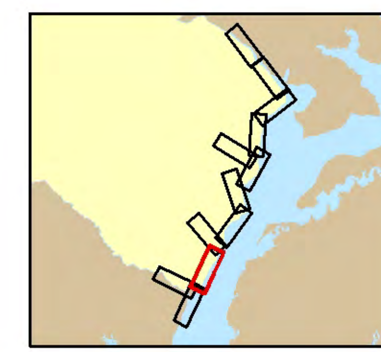
Prince William County Virginia

Plate 3



Legend

- 2007 Shoreline
- 2009 Shoreline



Shoreline Studies Program
VIMS

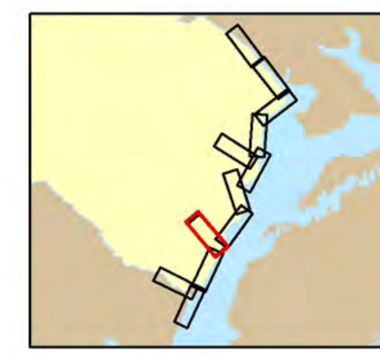
1,000 0 1,000
Feet

Prince William County Virginia

Plate 4

Legend

- 1937 Shoreline
- 1953 Shoreline

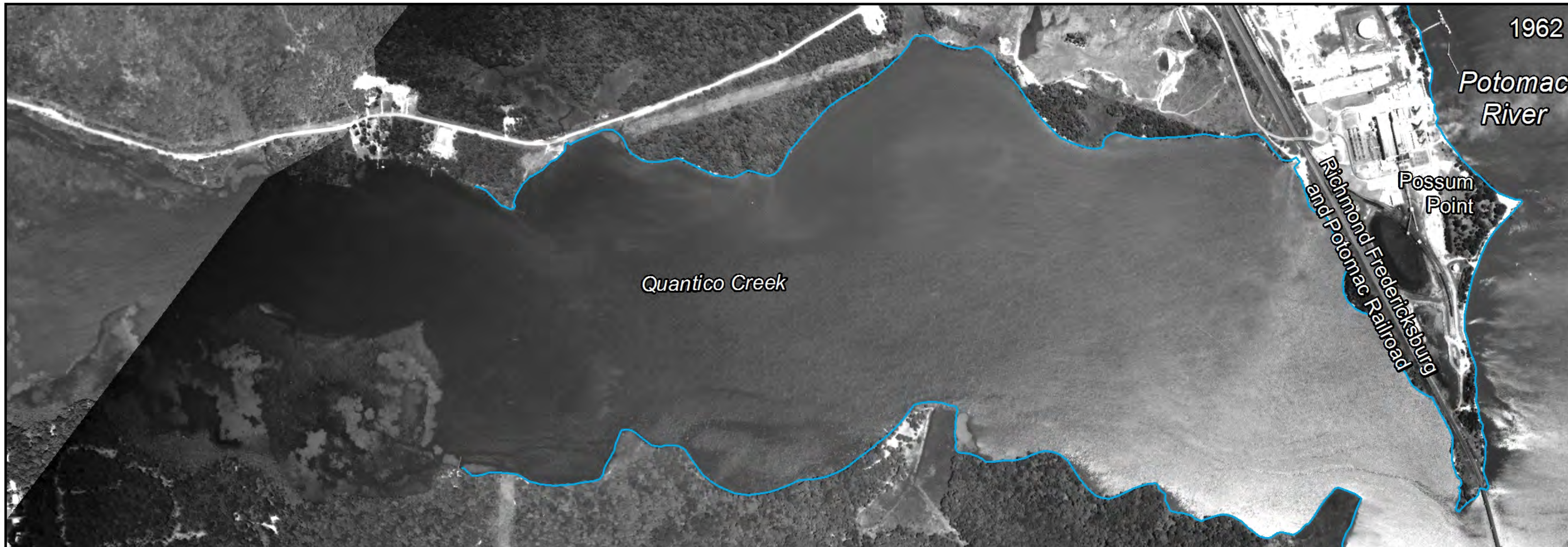


Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

Prince William County Virginia

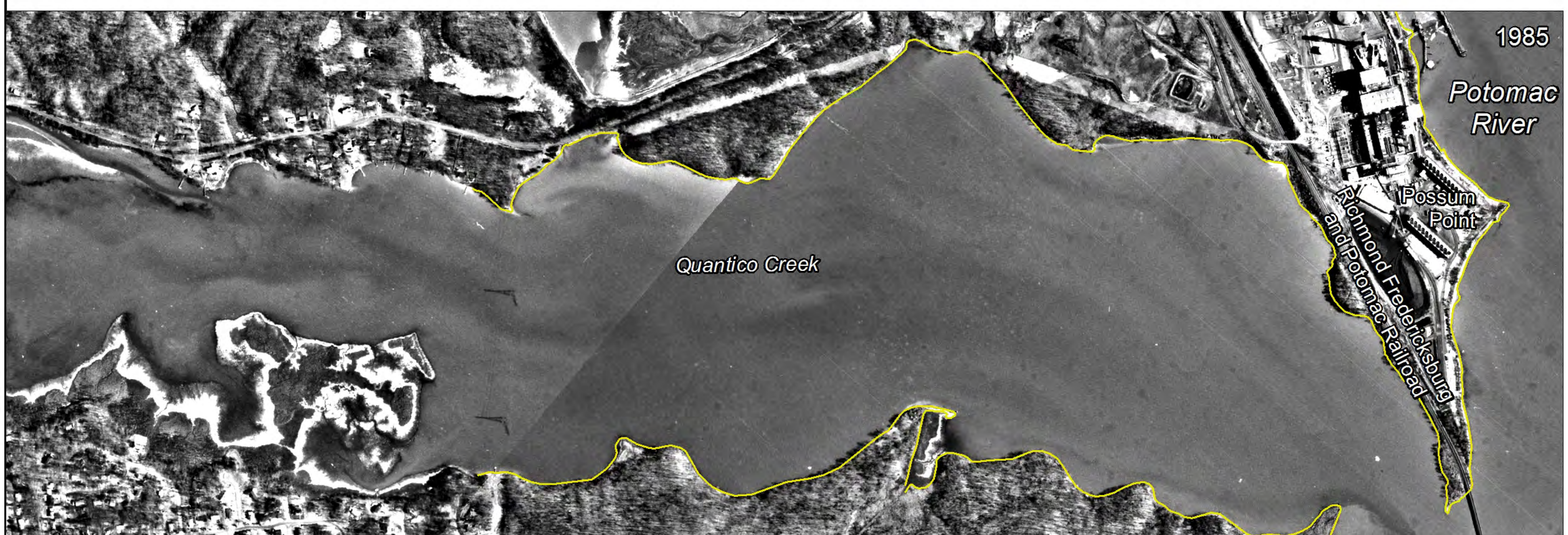
Plate 4

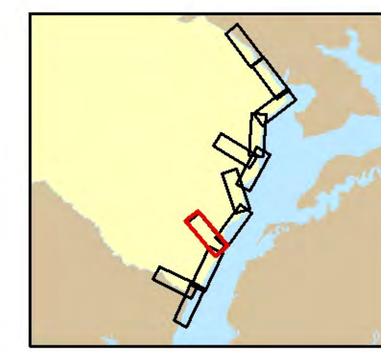


Legend

1962 Shoreline

1985 Shoreline





Shoreline Studies Program

VIMS

1,000 0 1,000 Feet

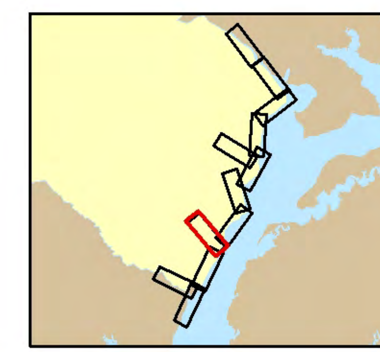
Prince William County Virginia

Plate 4

Legend

1994 Shoreline

2002 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

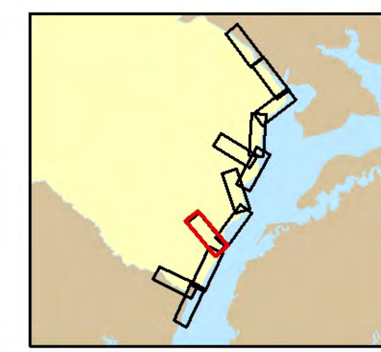
Prince William County Virginia

Plate 4

Legend

2007 Shoreline

2009 Shoreline



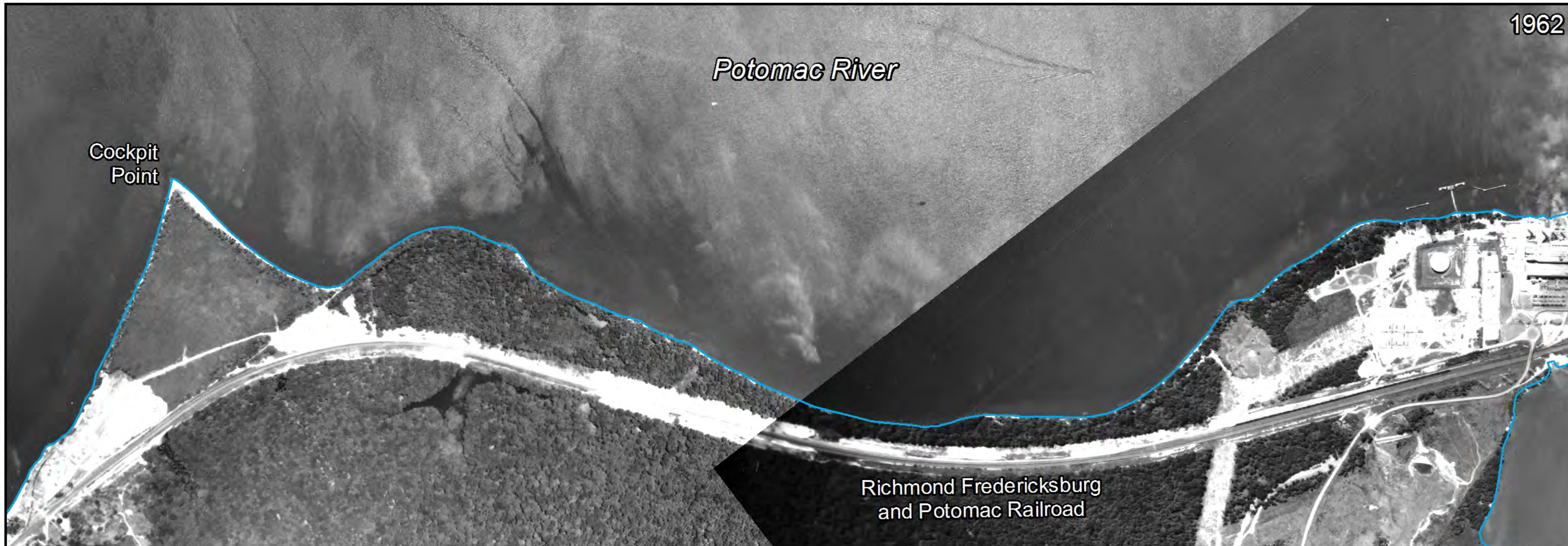
Shoreline Studies Program
VIMS

1,000 0 1,000
Feet


Prince William County
Virginia
Plate 5
Legend
1937 Shoreline
1953 Shoreline
1937
Potomac River
Cockpit
Point
Richmond Fredericksburg
and Potomac Railroad
1953
Potomac River
Cockpit
Point
Richmond Fredericksburg
and Potomac Railroad
Shoreline
Studies
Program
VIMS
1,000
0
1,000
Feet

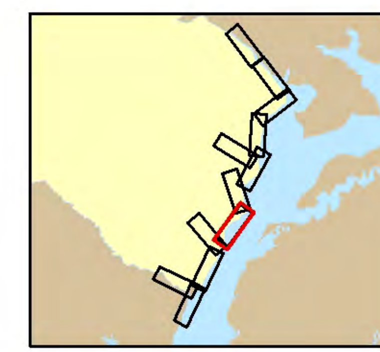
Prince William County Virginia

Plate 5



Legend

- 1962 Shoreline
- 1985 Shoreline

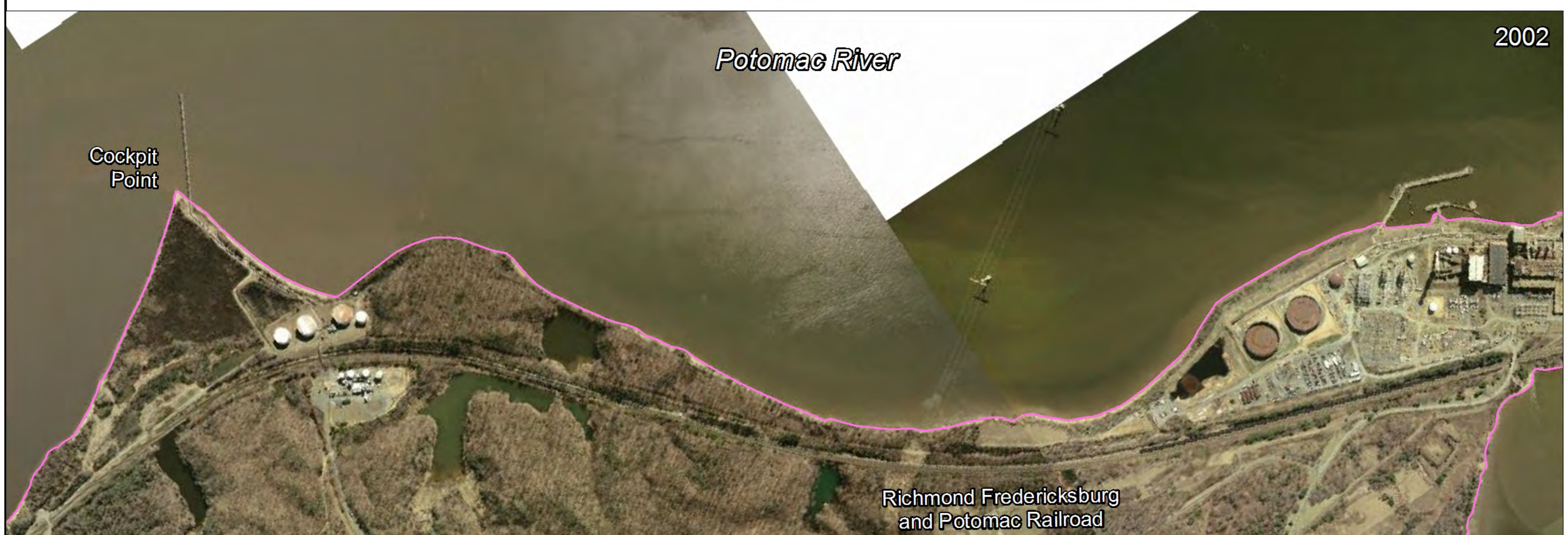


Shoreline Studies Program
VIMS

1,000 0 1,000 Feet

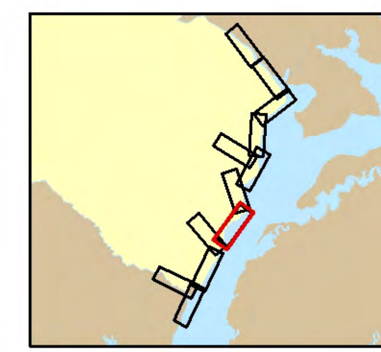
Prince William County Virginia

Plate 5



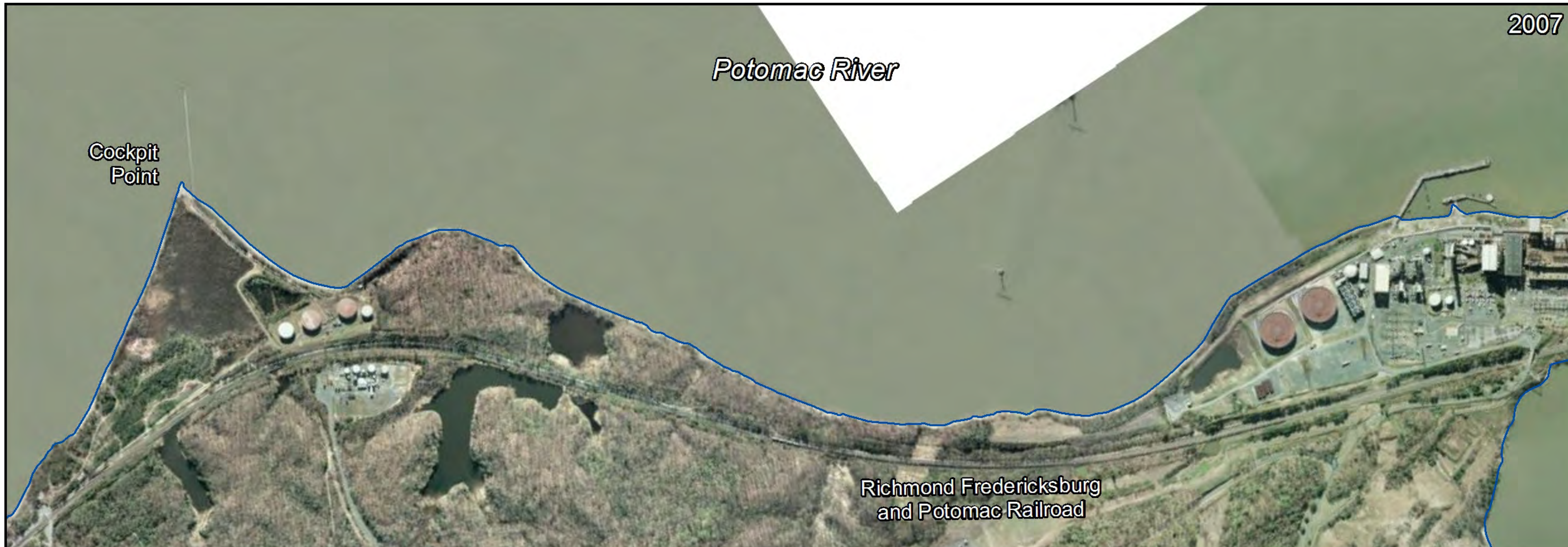
Legend

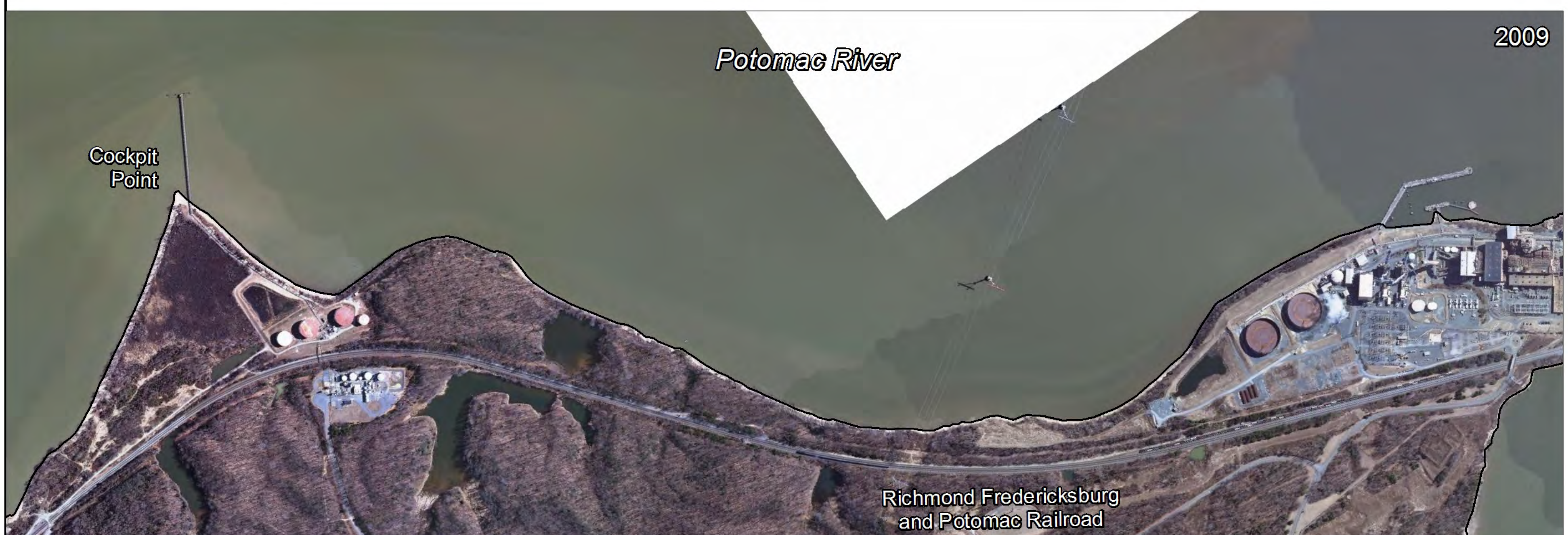
- 1994 Shoreline
- 2002 Shoreline



VIMS Shoreline Studies Program

1,000 0 1,000 Feet



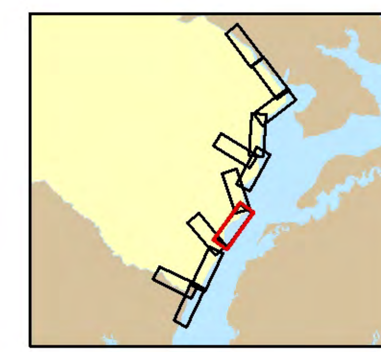


Prince William County Virginia

Plate 5

Legend

- 2007 Shoreline
- 2009 Shoreline



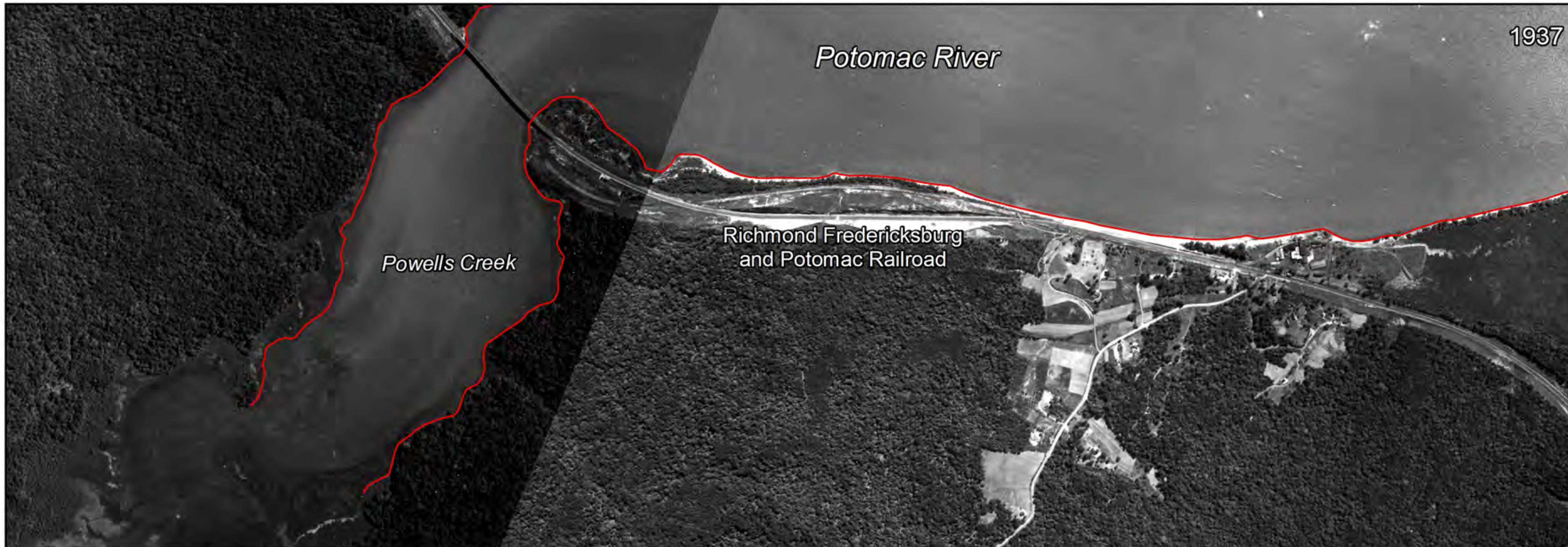
Shoreline Studies Program

VIMS

1,000 0 1,000 Feet

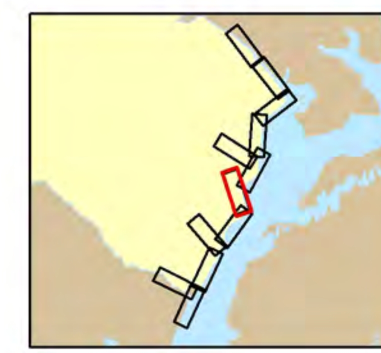
Prince William County Virginia

Plate 6



Legend

- 1937 Shoreline
- 1953 Shoreline

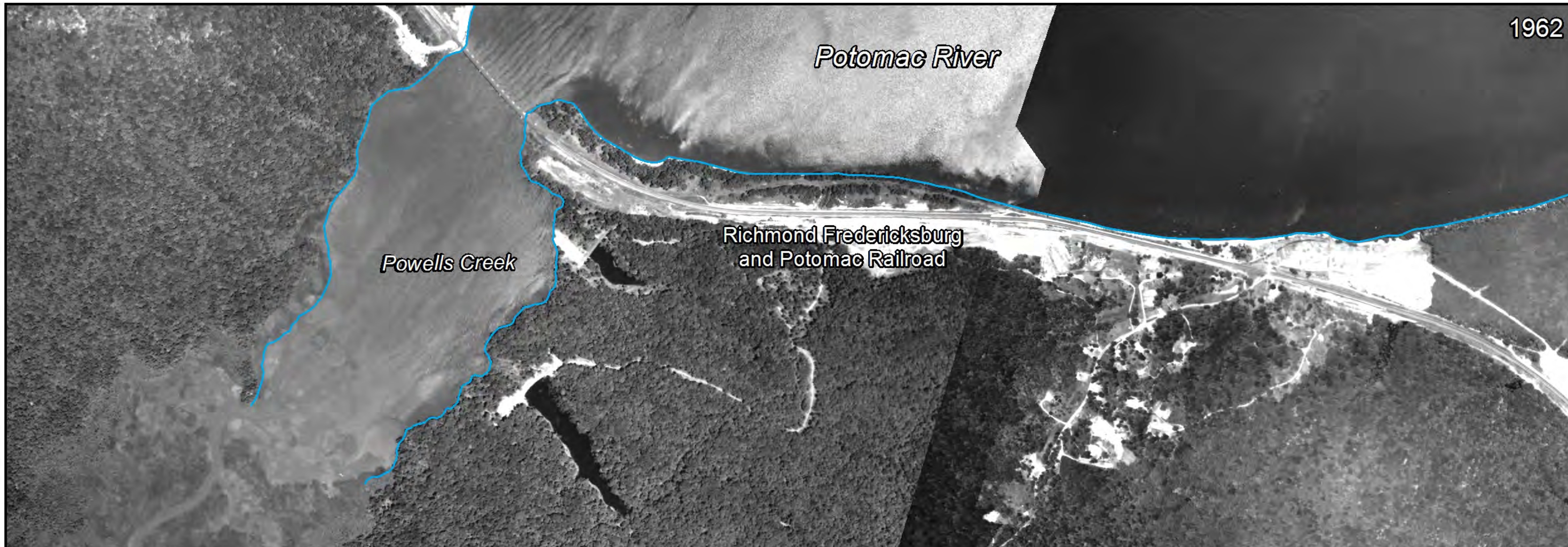


VIMS Shoreline Studies Program

1,000 0 1,000 Feet

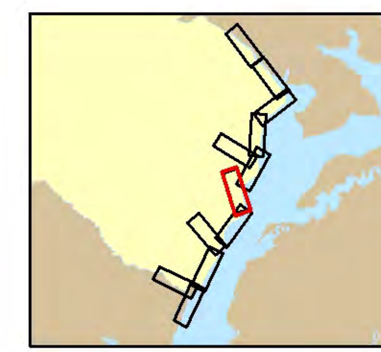
Prince William County Virginia

Plate 6



Legend

- 1962 Shoreline
- 1985 Shoreline

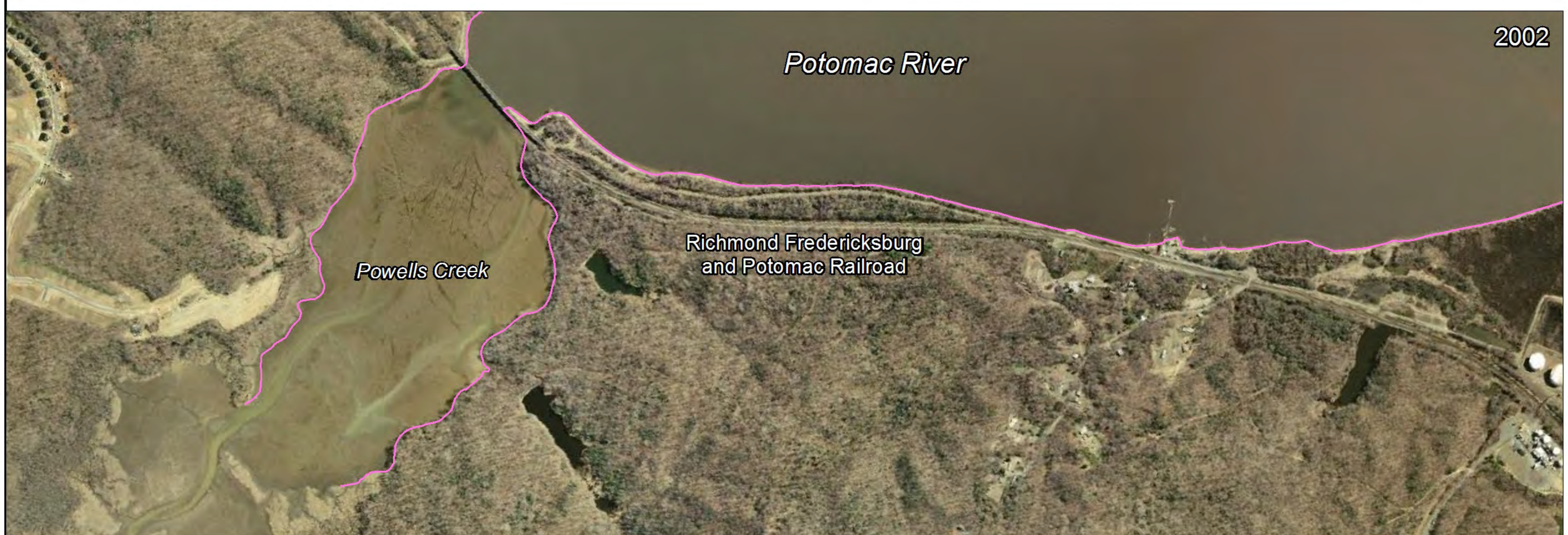


Shoreline Studies Program VIMS

1,000 0 1,000 Feet

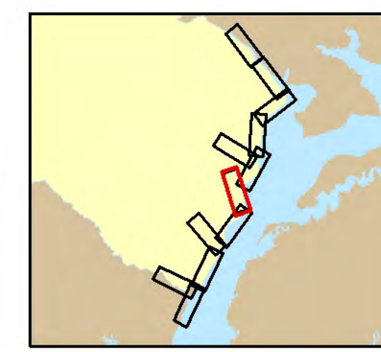
Prince William County Virginia

Plate 6



Legend

- 1994 Shoreline
- 2002 Shoreline



Shoreline Studies Program
VIMS

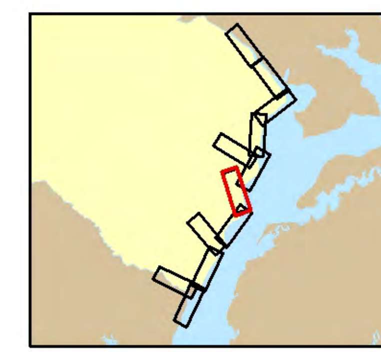
1,000 0 1,000
Feet

Prince William County Virginia

Plate 6

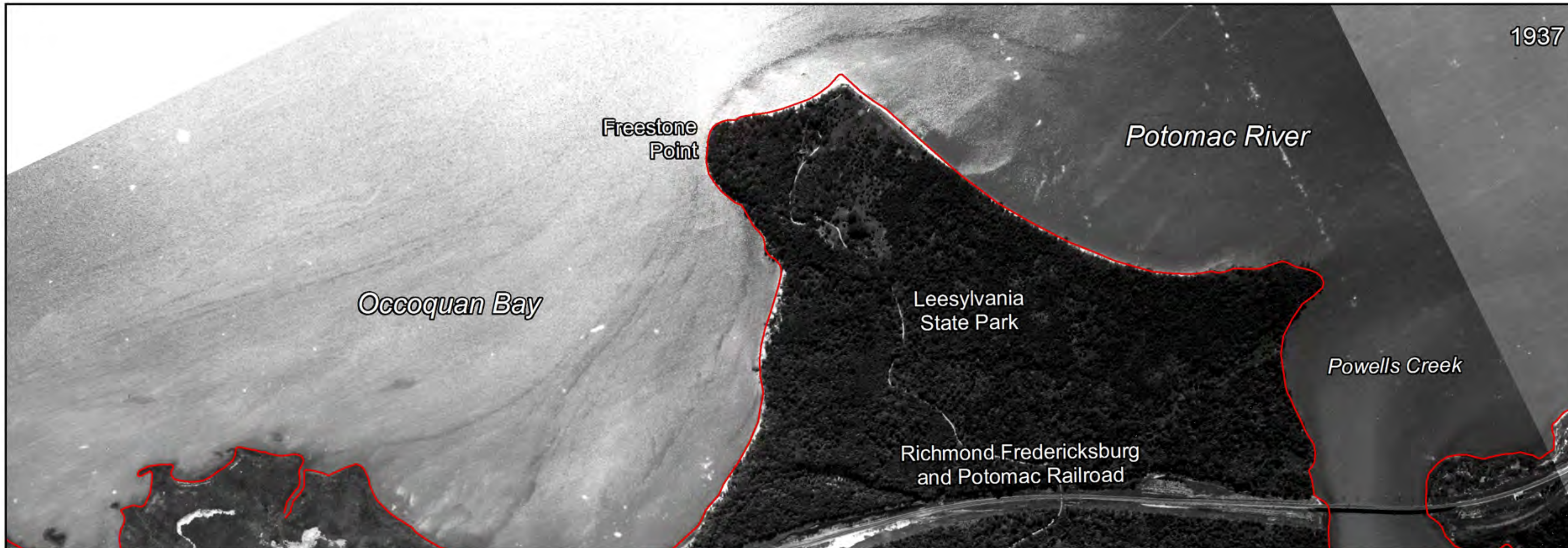
Legend

- 2007 Shoreline
- 2009 Shoreline



Shoreline Studies Program VIMS

1,000 0 1,000 Feet



Prince William County Virginia

Plate 7

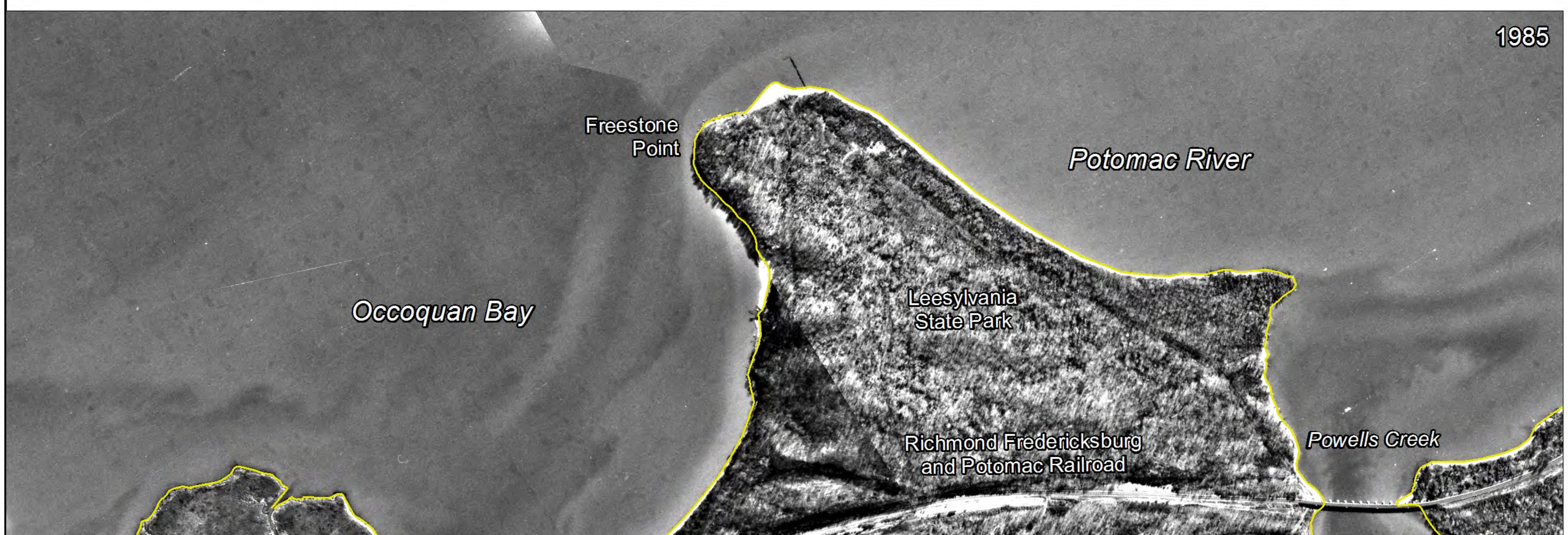
Legend

1937 Shoreline

1953 Shoreline

Shoreline Studies Program
VIMS

1,000 0 1,000
Feet



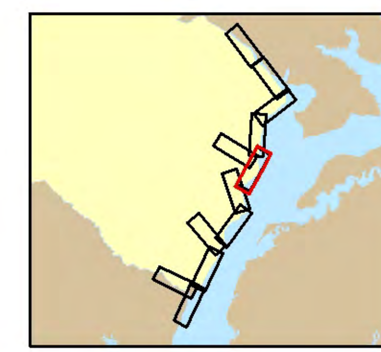
Prince William County Virginia

Plate 7

Legend

1962 Shoreline

1985 Shoreline



Shoreline Studies Program VIMS

1,000 0 1,000 Feet

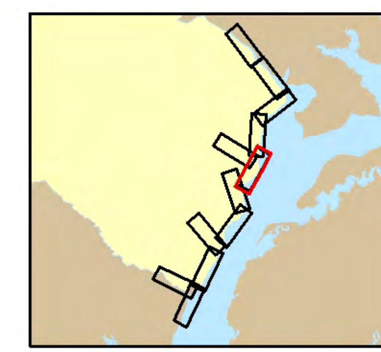
Prince William County Virginia

Plate 7

Legend

1994 Shoreline

2002 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

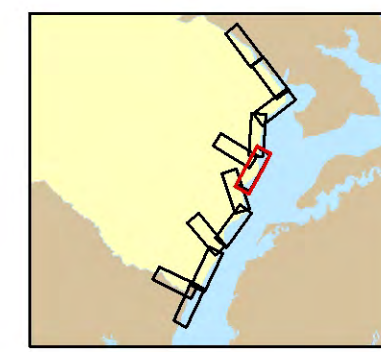
Prince William County Virginia

Plate 7

Legend

2007 Shoreline

2009 Shoreline



Shoreline Studies Program

VIMS

1,000 0 1,000

Feet

Prince William County Virginia

Plate 8

Legend

- 1937 Shoreline
- 1953 Shoreline

VIMS Shoreline Studies Program

1,000 0 1,000
Feet

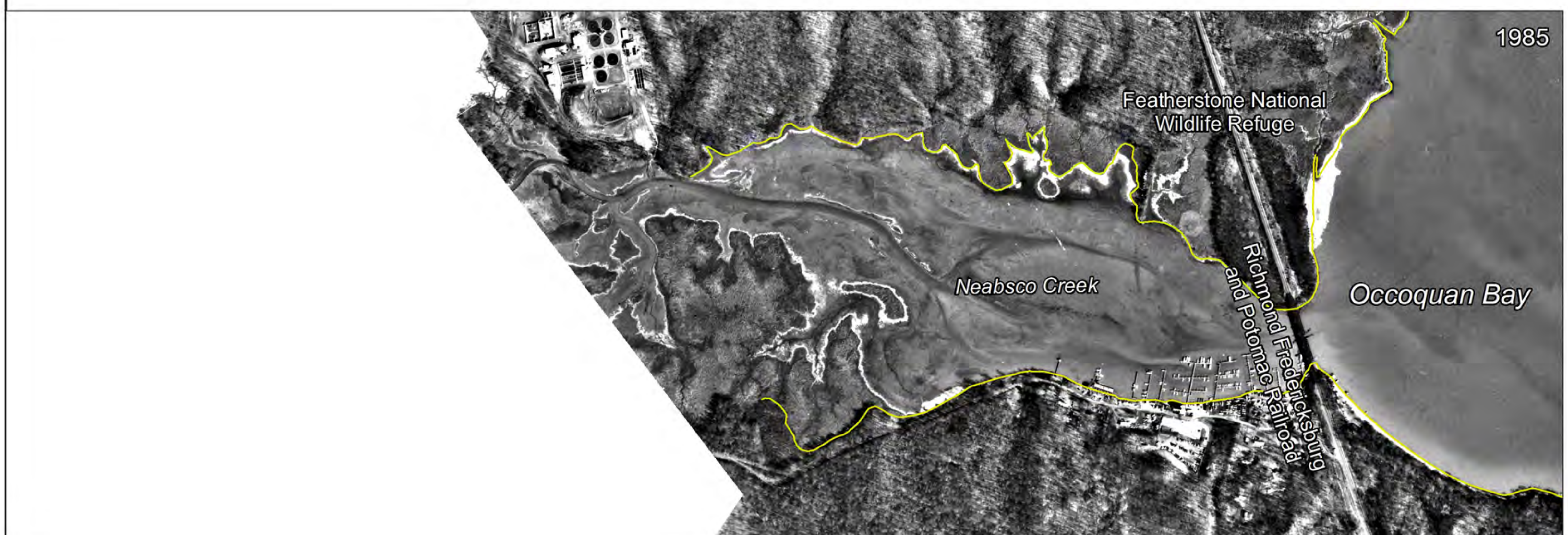
Prince William County Virginia

Plate 8

Legend

1962 Shoreline

1985 Shoreline



VIMS Shoreline Studies Program

1,000 0 1,000 Feet

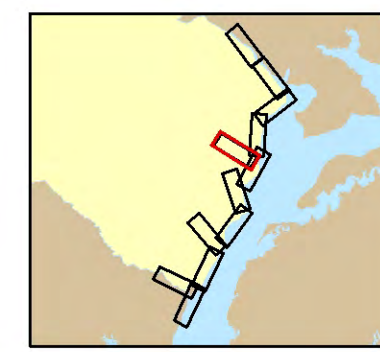
Prince William County Virginia

Plate 8

Legend

1994 Shoreline

2002 Shoreline



Shoreline Studies Program VIMS

1,000 0 1,000 Feet

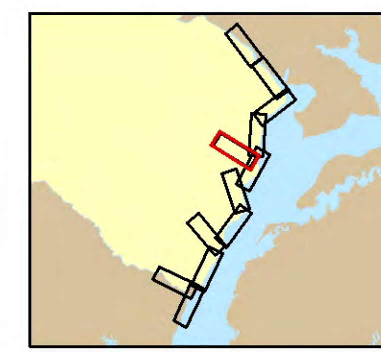
Prince William County Virginia

Plate 8

Legend

2007 Shoreline

2009 Shoreline

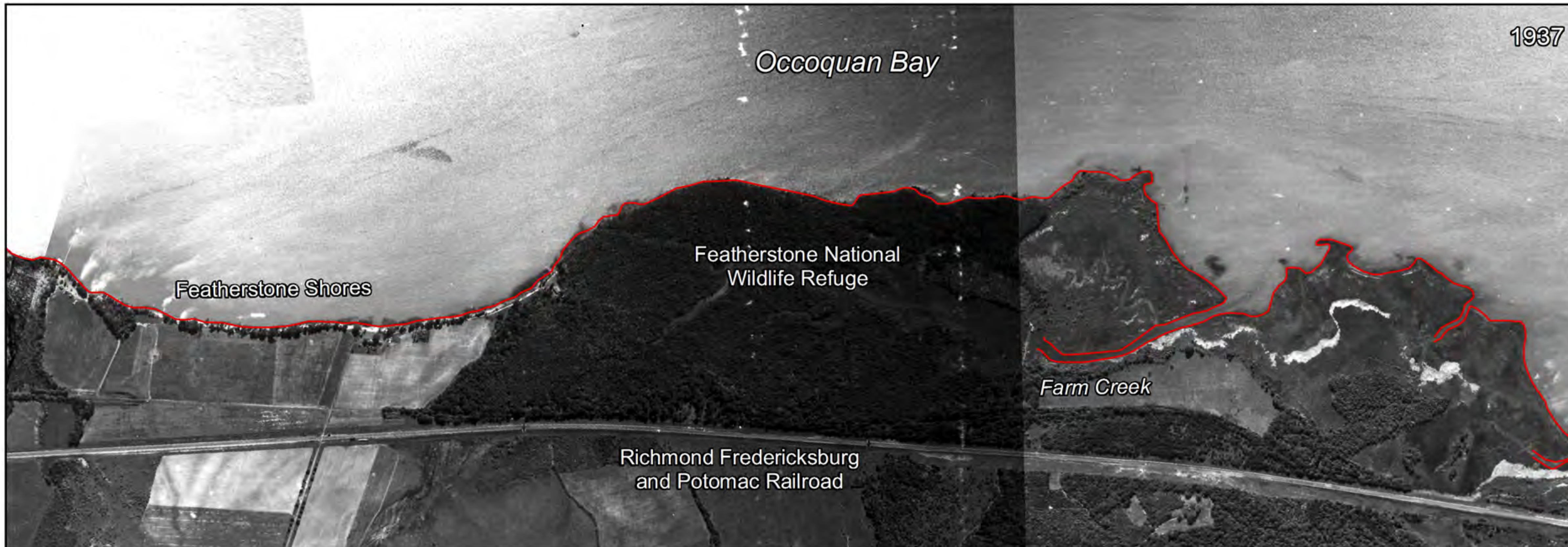


Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

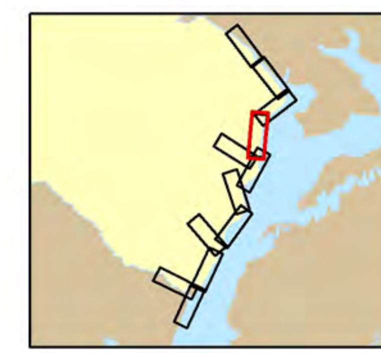
Prince William County Virginia

Plate 9



Legend

- 1937 Shoreline
- 1953 Shoreline

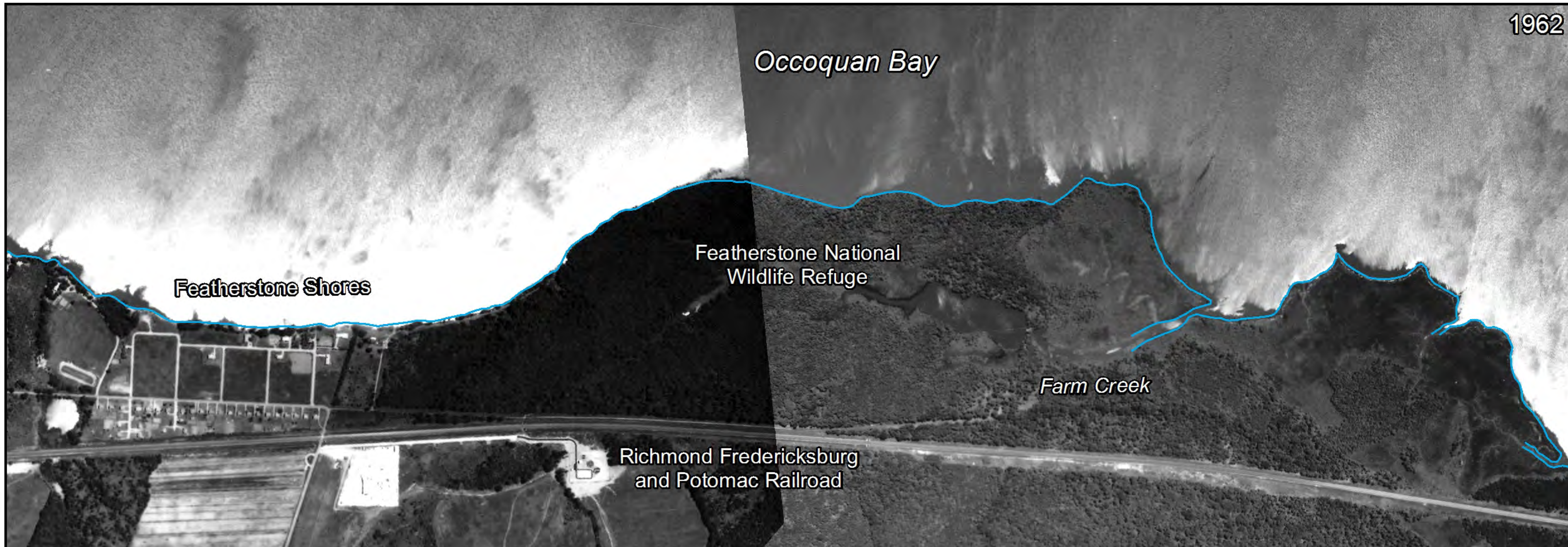


VIMS Shoreline Studies Program

1,000 0 1,000 Feet

Prince William County Virginia

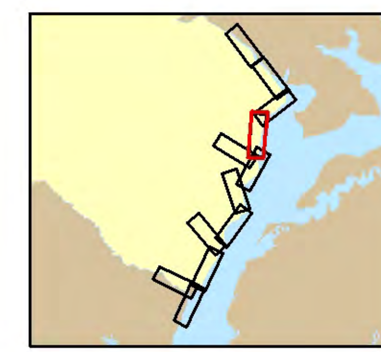
Plate 9



Legend

1962 Shoreline

1985 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

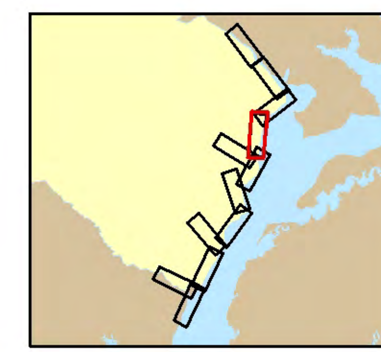
Prince William County Virginia

Plate 9

Legend

1994 Shoreline

2002 Shoreline



Shoreline Studies Program VIMS

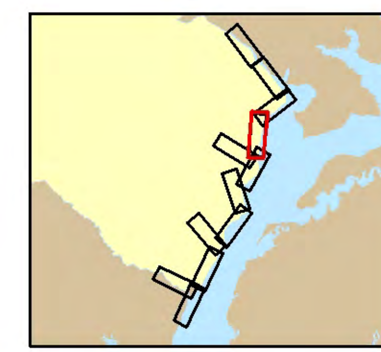
1,000 0 1,000 Feet

Prince William County Virginia

Plate 9

Legend

- 2007 Shoreline
- 2009 Shoreline

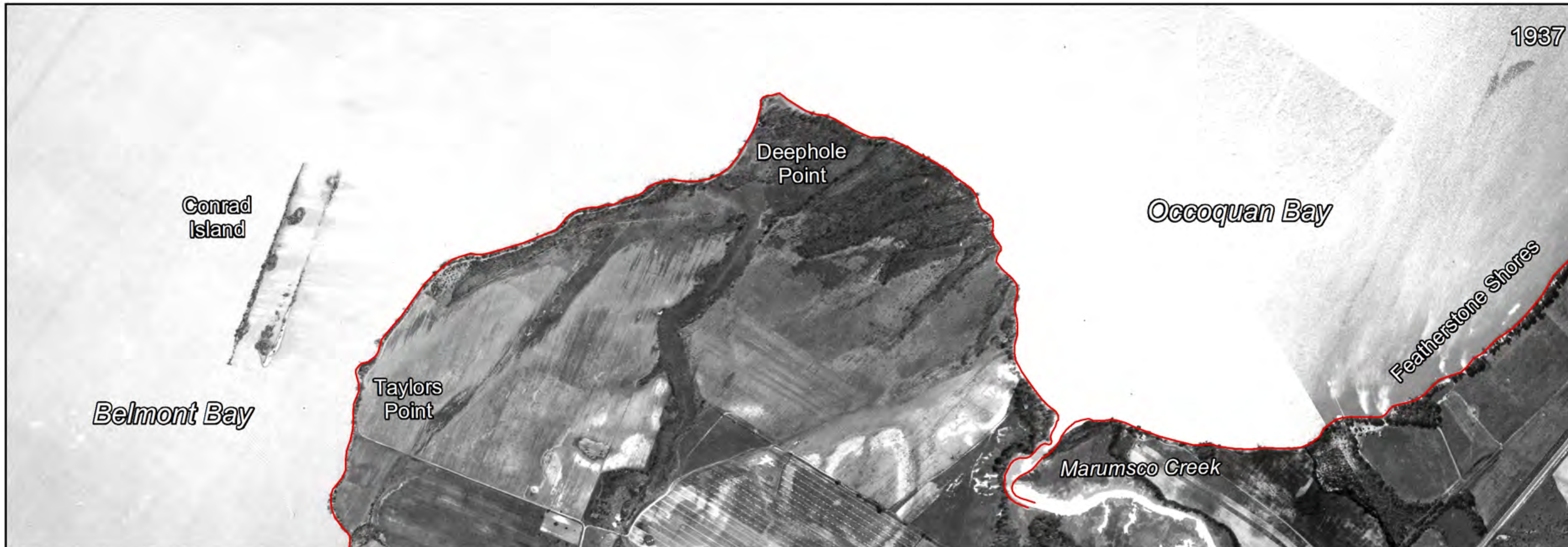


Shoreline Studies Program VIMS

1,000 0 1,000 Feet

Prince William County Virginia

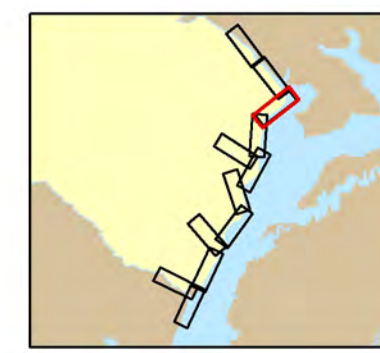
Plate 10



Legend

1937 Shoreline

1953 Shoreline

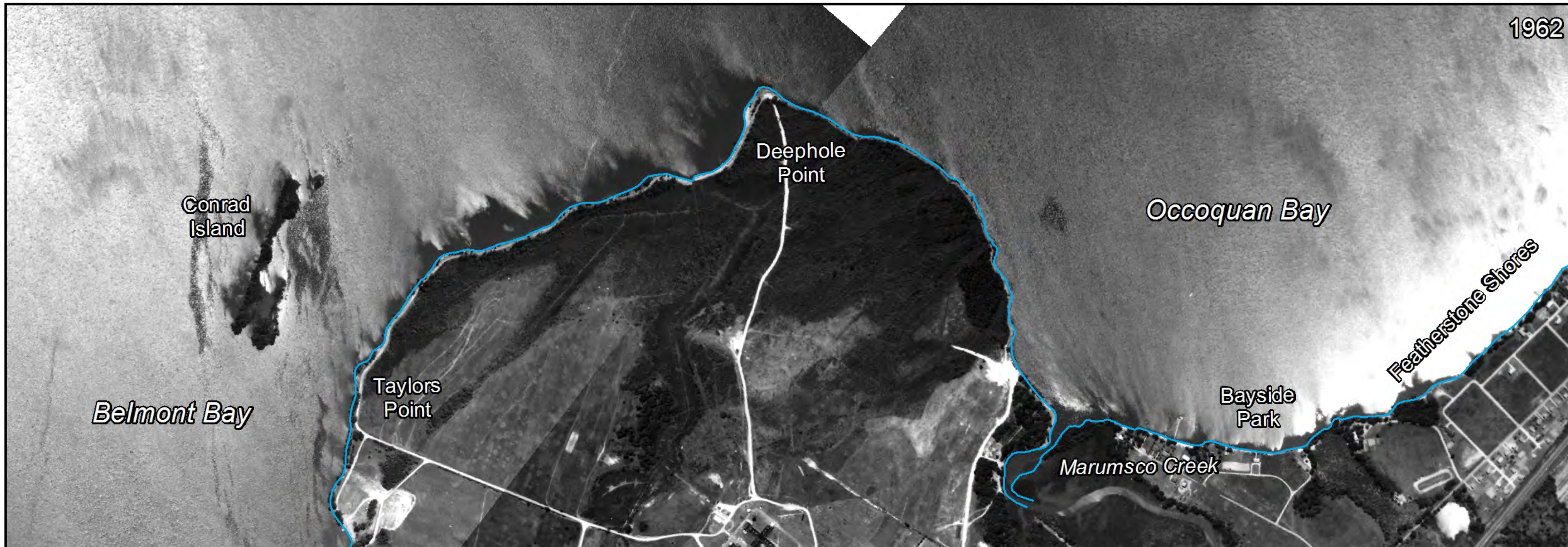


Shoreline Studies Program VIMS

1,000 0 1,000 Feet

Prince William County Virginia

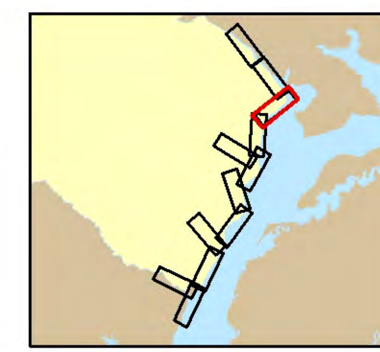
Plate 10



Legend

1962 Shoreline

1985 Shoreline

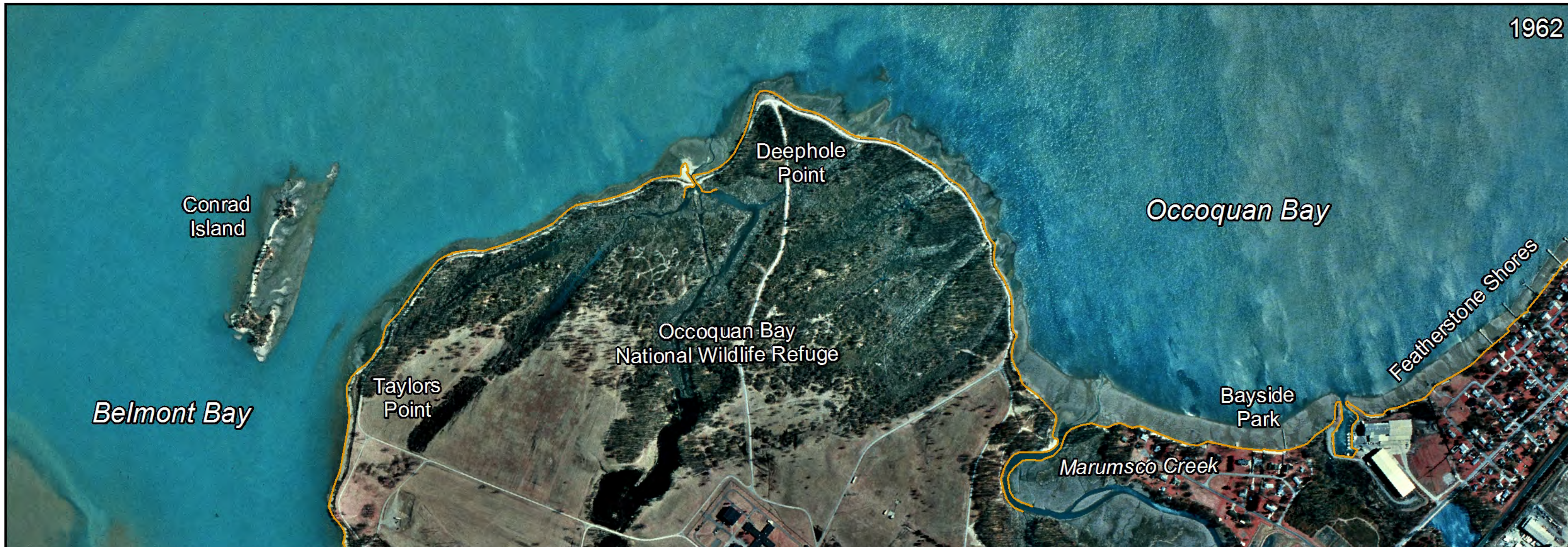


Shoreline Studies Program

VIMS

1,000 0 1,000

Feet



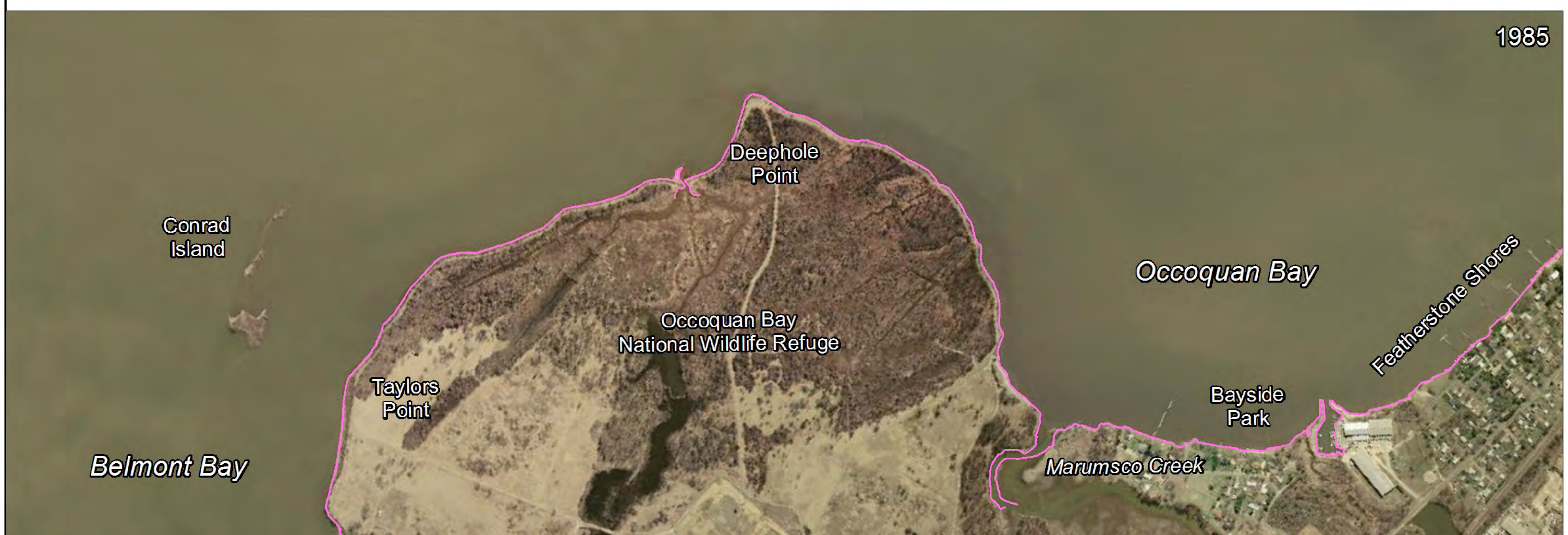
Prince William County Virginia

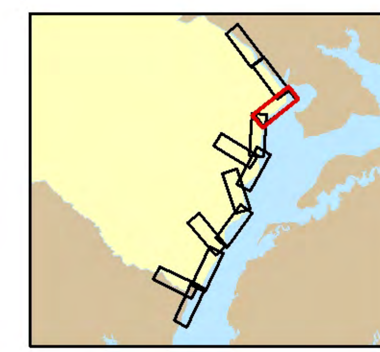
Plate 10

Legend

1994 Shoreline

2002 Shoreline





Shoreline Studies Program VIMS

1,000 0 1,000 Feet

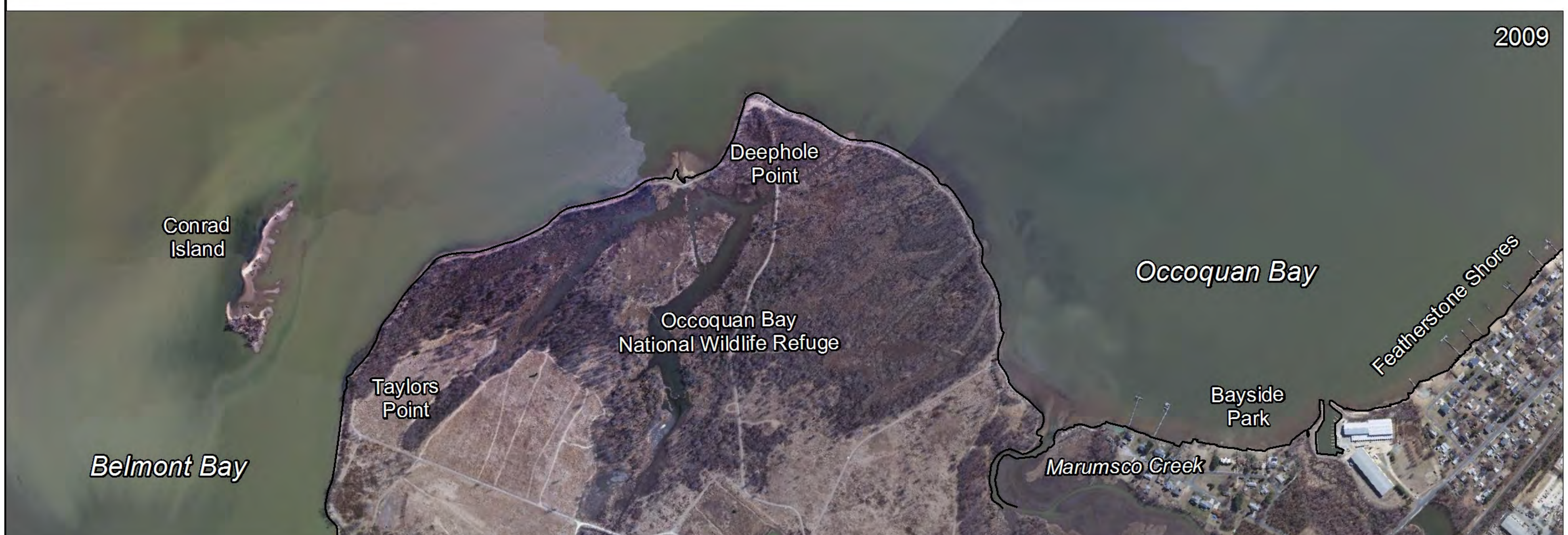
Prince William County Virginia

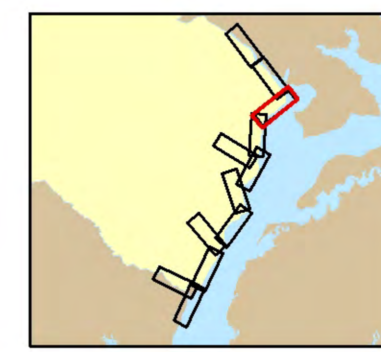
Plate 10

Legend

2007 Shoreline

2009 Shoreline





Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

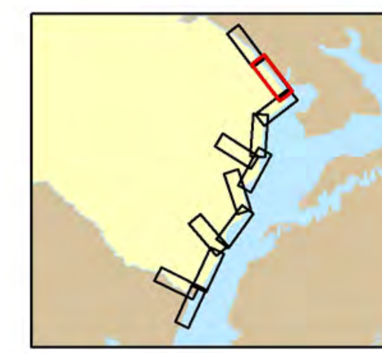
Prince William County Virginia

Plate 11

Legend

1937 Shoreline

1953 Shoreline



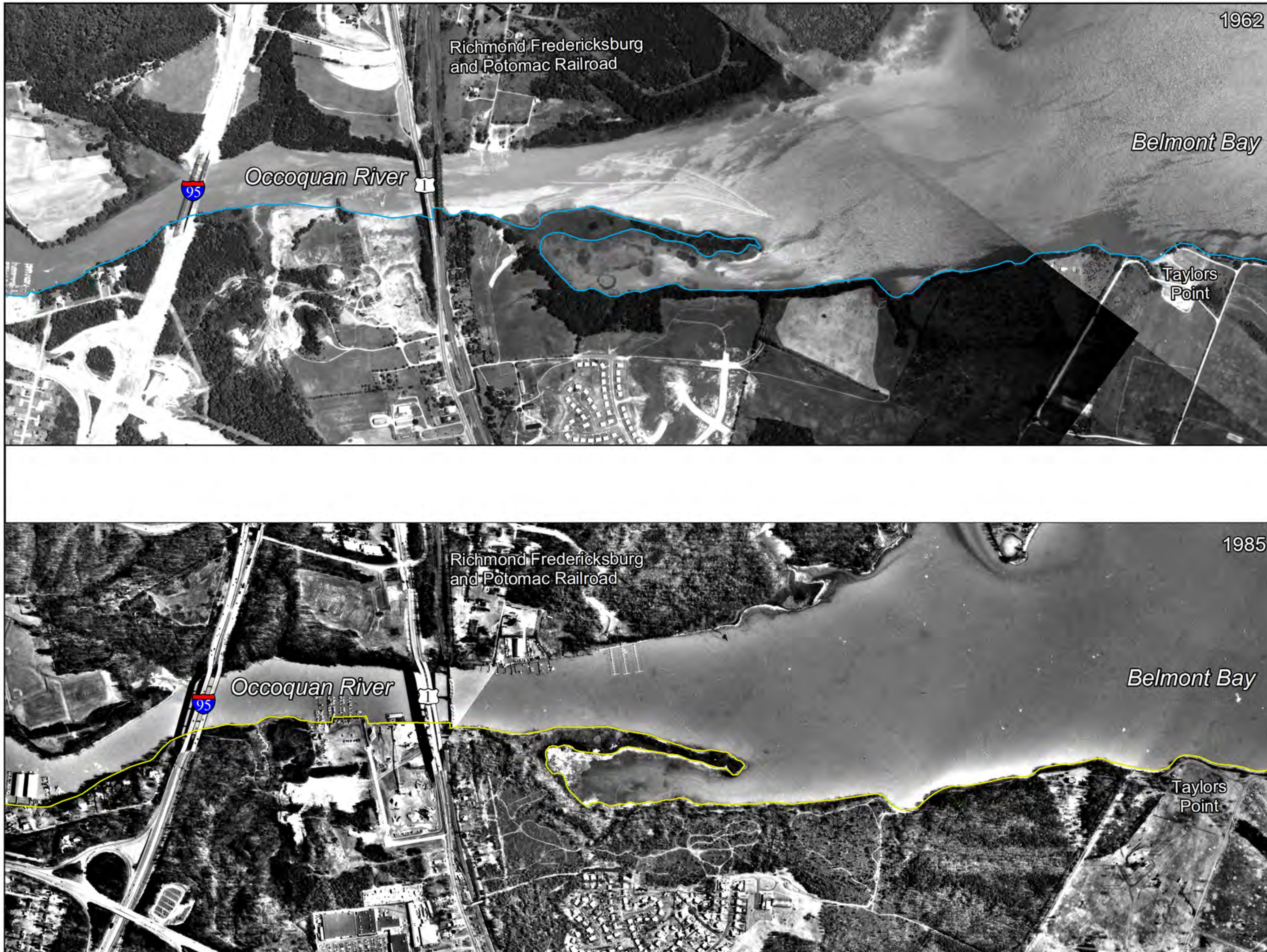
Shoreline Studies Program VIMS

1,000 0 1,000

Feet

Prince William County Virginia

Plate 11



Legend

1962 Shoreline

1985 Shoreline

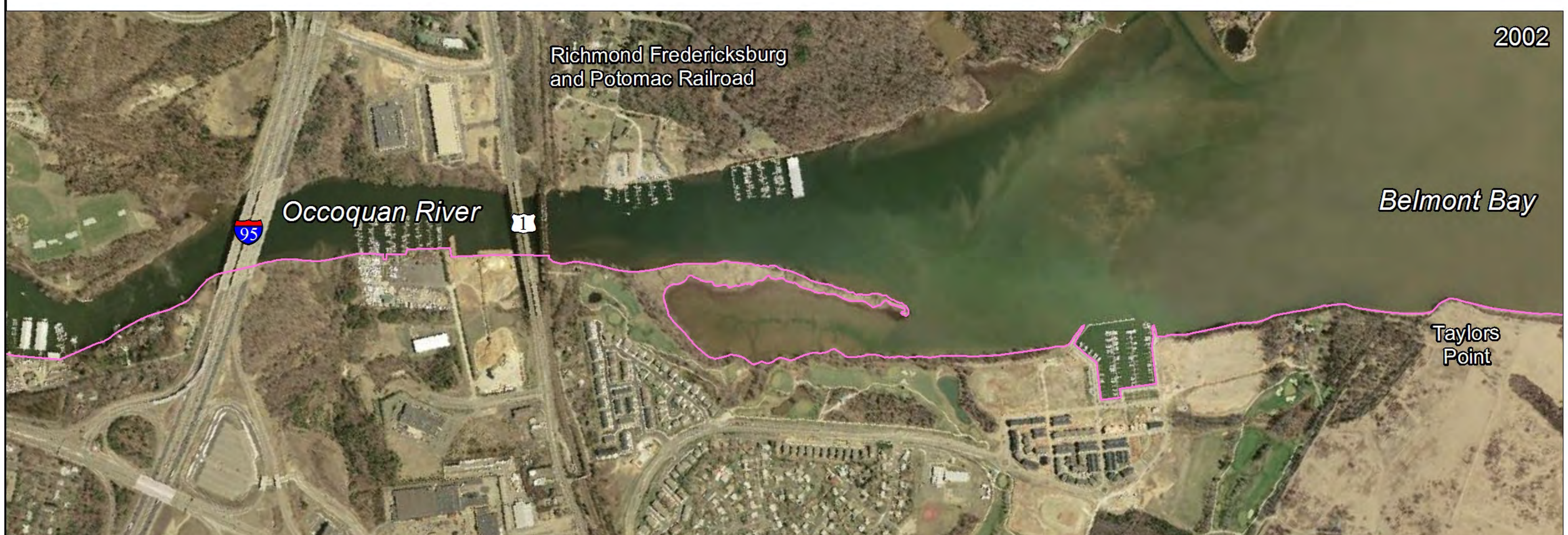
VIMS Shoreline Studies Program

1,000 0 1,000

Feet

Prince William County Virginia

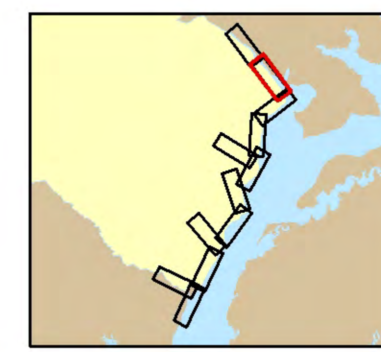
Plate 11



Legend

1994 Shoreline

2002 Shoreline

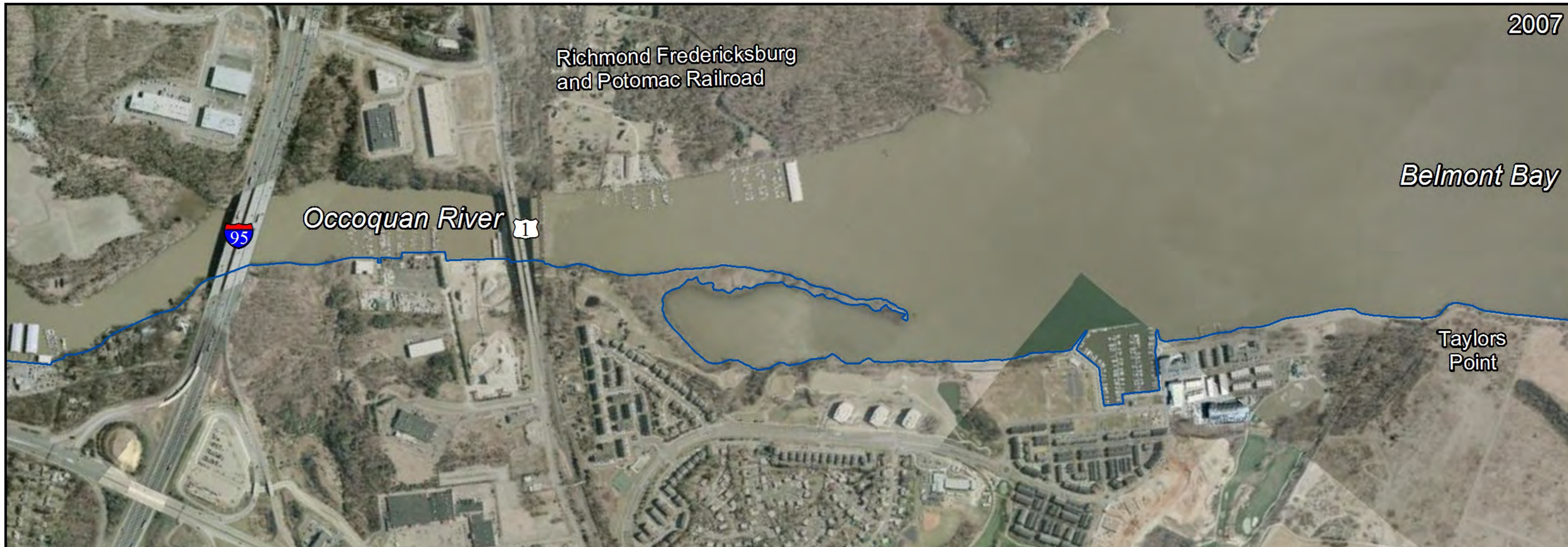


Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

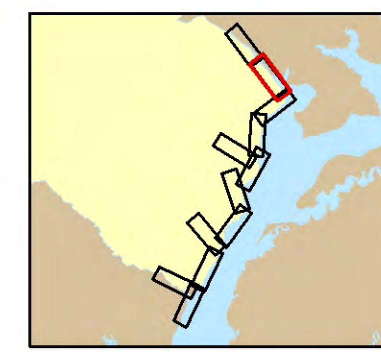
Prince William County Virginia

Plate 11



Legend

- 2007 Shoreline
- 2009 Shoreline

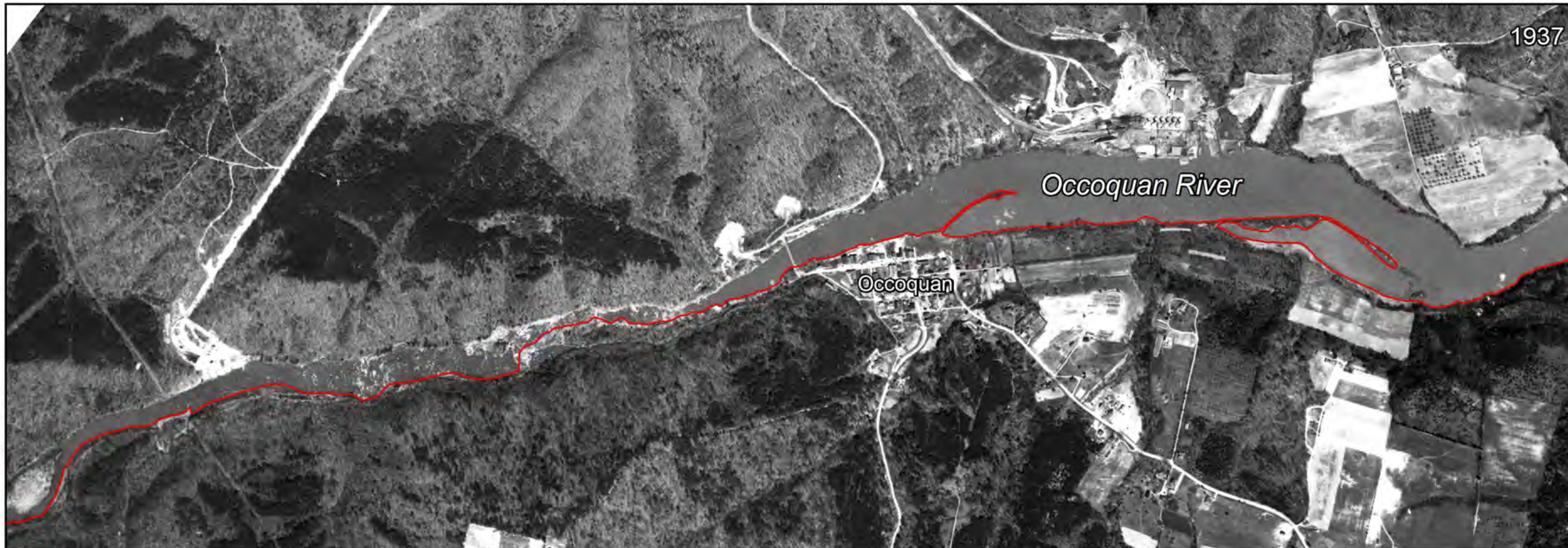


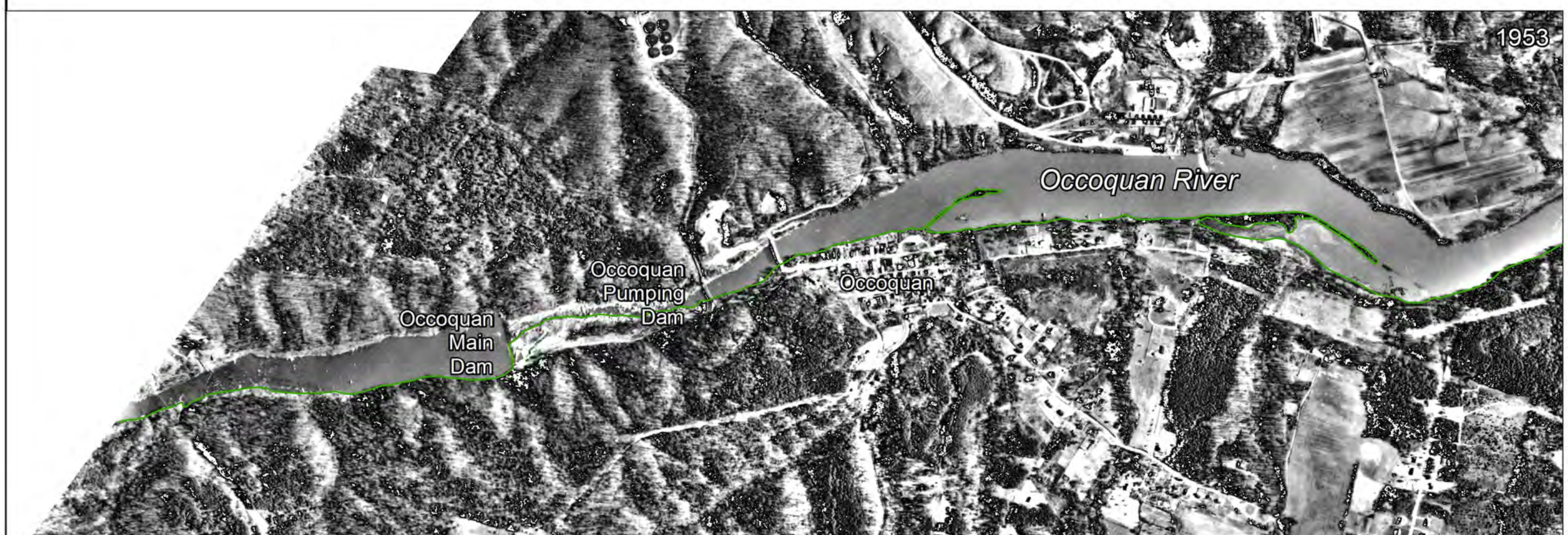
VIMS Shoreline Studies Program

1,000 0 1,000 Feet

Prince William County Virginia

Plate 12





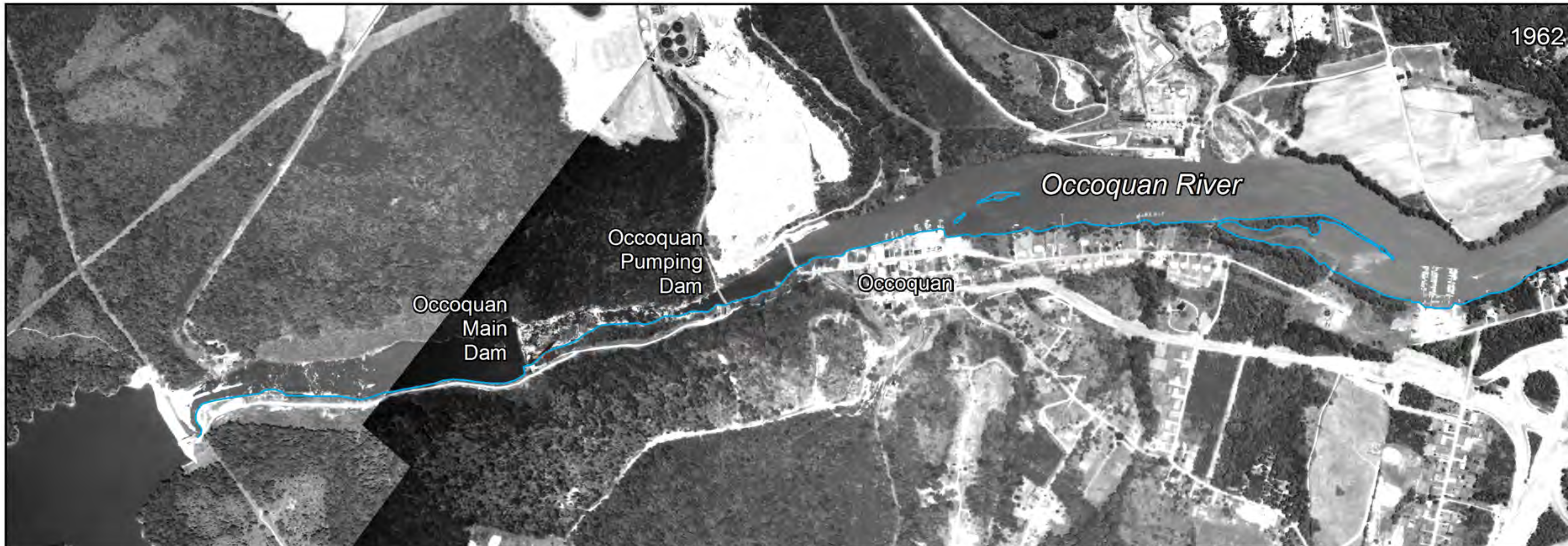
Legend

1937 Shoreline

1953 Shoreline

Shoreline Studies Program VIMS

1,000 0 1,000 Feet



Prince William County Virginia

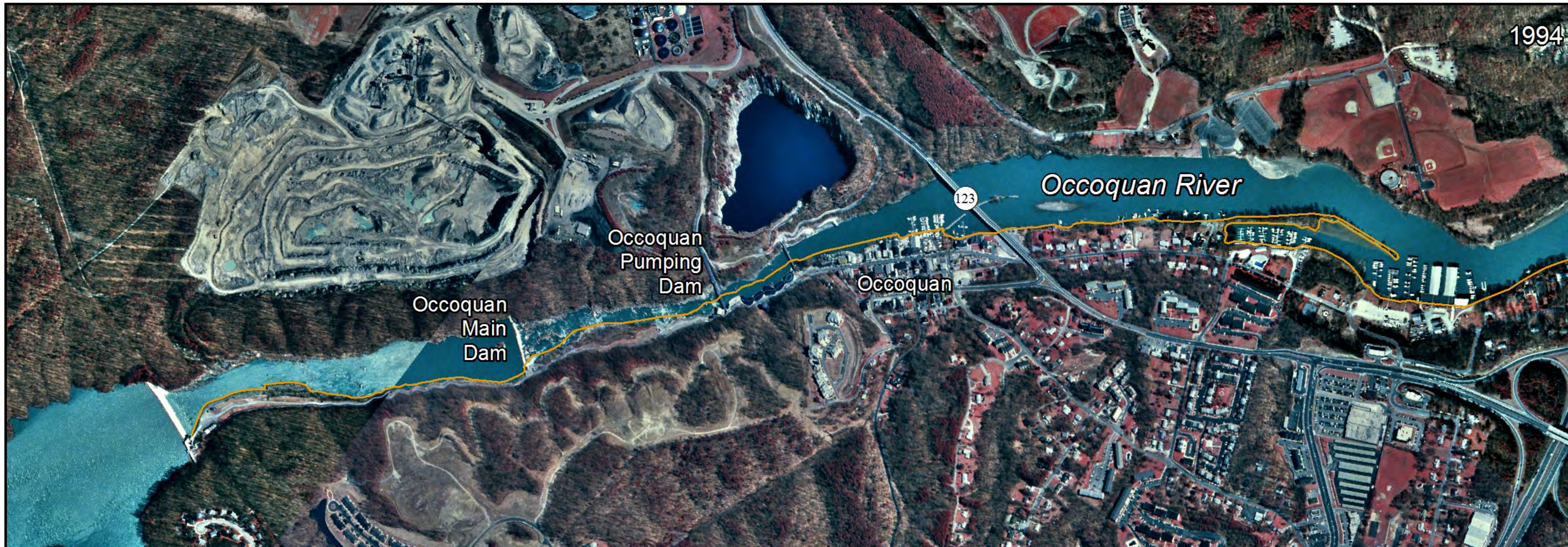
Plate 12

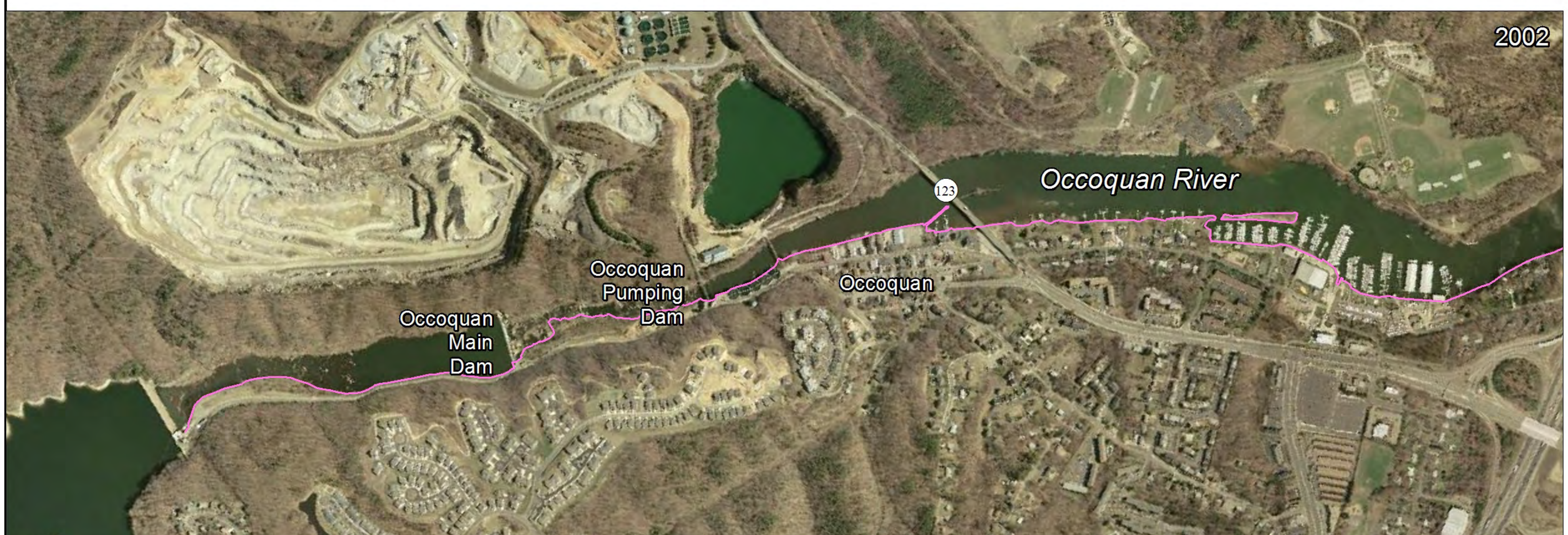
Legend

- 1962 Shoreline
- 1985 Shoreline

Shoreline Studies Program
VIMS

1,000 0 1,000
Feet





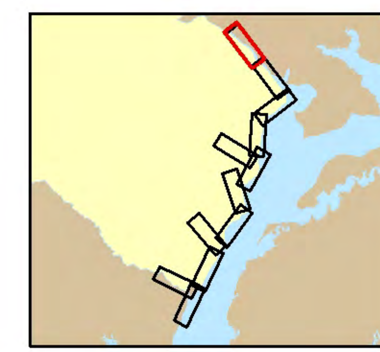
Prince William County Virginia

Plate 12

Legend

1994 Shoreline

2002 Shoreline



Shoreline Studies Program VIMS

1,000 0 1,000 Feet

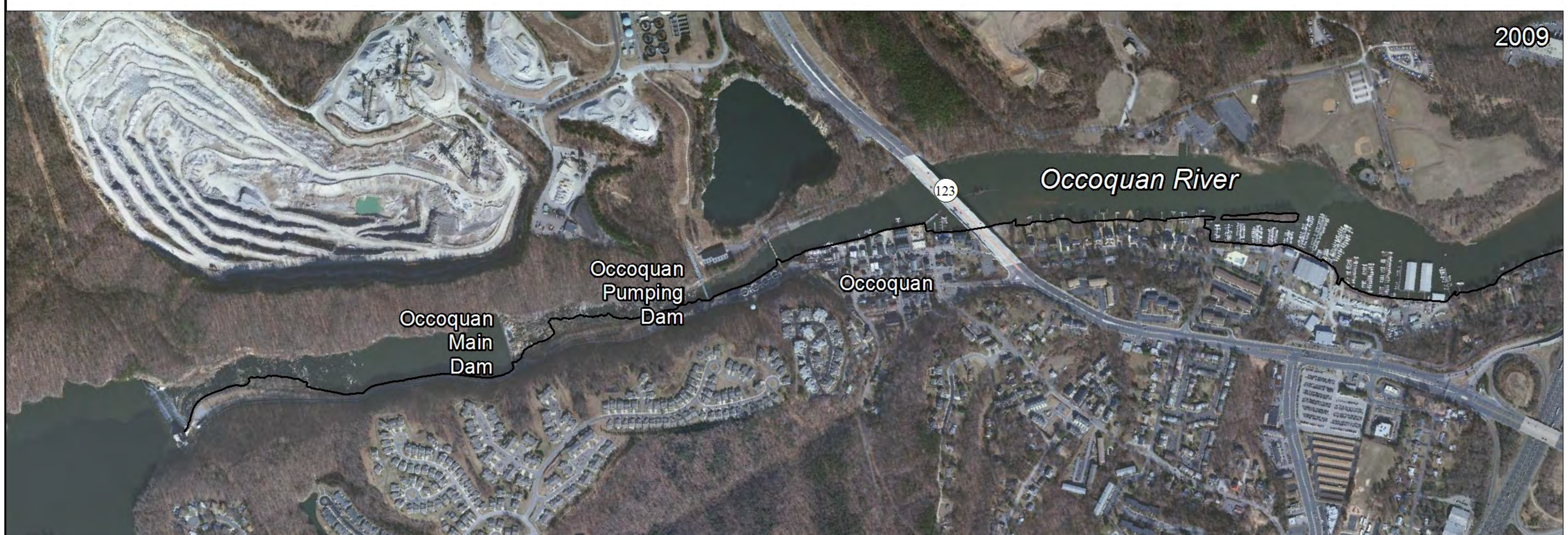
Prince William County Virginia

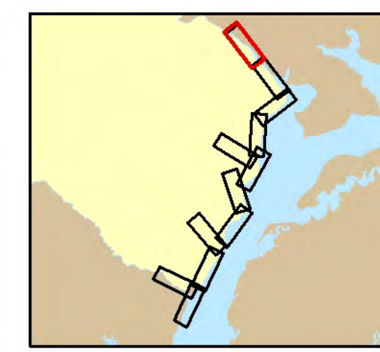
Plate 12

Legend

2007 Shoreline

2009 Shoreline





Shoreline Studies Program
VIMS

1,000 0 1,000
Feet