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Shoreline Evolution: Prince George County, Virginia Upper Chippokes Creek, James and Appomattox River Shorelines

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Shoreline Evolution: Prince George County, Virginia Upper Chippokes Creek, James and Appomattox River Shorelines



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

August 2016

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Data Summary Report

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August 2016

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1 Introduction

Prince George County is situated between on the James River between Upper Chippokes Creek and the Appomattox Rivers (Figure 1). Because the County's shoreline is continually changing, determining where the shoreline was in the past, how far and how fast it is moving, and what factors drive shoreline change will help define where the shoreline will be going in the future. These rates and patterns of shore change along Chesapeake Bay's estuarine shores will differ through time as 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 George 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 larger creeks in Prince George County will be quantified in this report. The shorelines of very irregular coasts, small creeks and around inlets, and other complicated areas will be shown but not quantified.

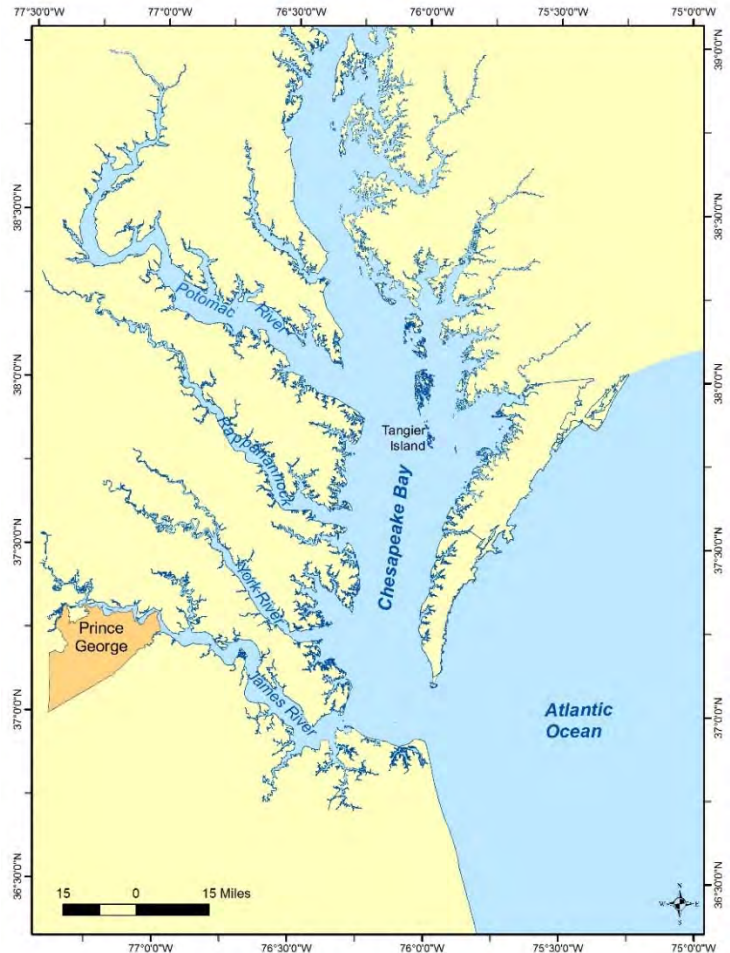


Figure 1. Location of Prince George County within the Chesapeake Bay estuarine system.

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 George County Shoreline from 1937, 1954, 1965, 1994, 2002, 2009, and 2013 were used in the analysis. The 1994, 2002, 2009, and 2013 images were available from other sources. The 1994 imagery was orthorectified by the U.S. Geological Survey (USGS) and the 2002, 2009, and 2013 imagery was orthorectified by the Virginia Base Mapping Program (VBMP). The 1937, 1954, and 1965 photos are part of the VIMS Shoreline Studies Program archives. The historical aerial images used to analyze the entire County shoreline were not always flown on the same day. The exact dates that the 1994 images were flown could not be ascertained; however, the dates for the other years are as follows:

1937 – April 1, 12 and 17;

1954 – March 22;

1965 – April 5;

2002 – February 22 and 24;

2009 – February 1, 5, 7 and 20

2013 – February 21, March 4, 10 and 14, April 3 and 10;

The 1937, 1954, and 1965 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 aeriels 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. Some areas of the County were difficult to rectify, either due to the lack of development when compared to the reference images or due to changing development between 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 feature digitized is noted in the shoreline attributes for the 2009 photos. For Prince George, the high water line was approximated. High water limit of run-up can be difficult to determine on some shorelines due to narrow or non-existent beaches against upland banks or vegetated cover. Tide levels at the time the photos were taken are noticeably variable between photosets requiring us to approximate the high water line (Figure 2A). Large amounts of slumping of base of bank can also contribute to inaccuracies by depositing bank material and therefore reducing erosion rates in high erosion areas (Figure 2B).

Nearly 107 miles of shoreline were digitized from the 2009 photos. However, not all tidal shoreline was digitized inside very small creeks and marshes. Poor quality photos in some areas made rectifying and digitizing images difficult. Environmental conditions along the shoreline made it difficult to delineate the shoreline even on the latest photos. In some areas trees can obscure the true shoreline locations due to overhanging branches, leaning trees or a slight angle on the aerials (Figure 2C). Shorelines in cypress marshes are very difficult to distinguish from aerial photography (Figure 2D) because the actual marsh shoreline is obscured in the trees that can survive in the river (Figure 2E). 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. For 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 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.



Figure 2A. Variable water levels between photo dates (left photo 1937 and right photo 2009).

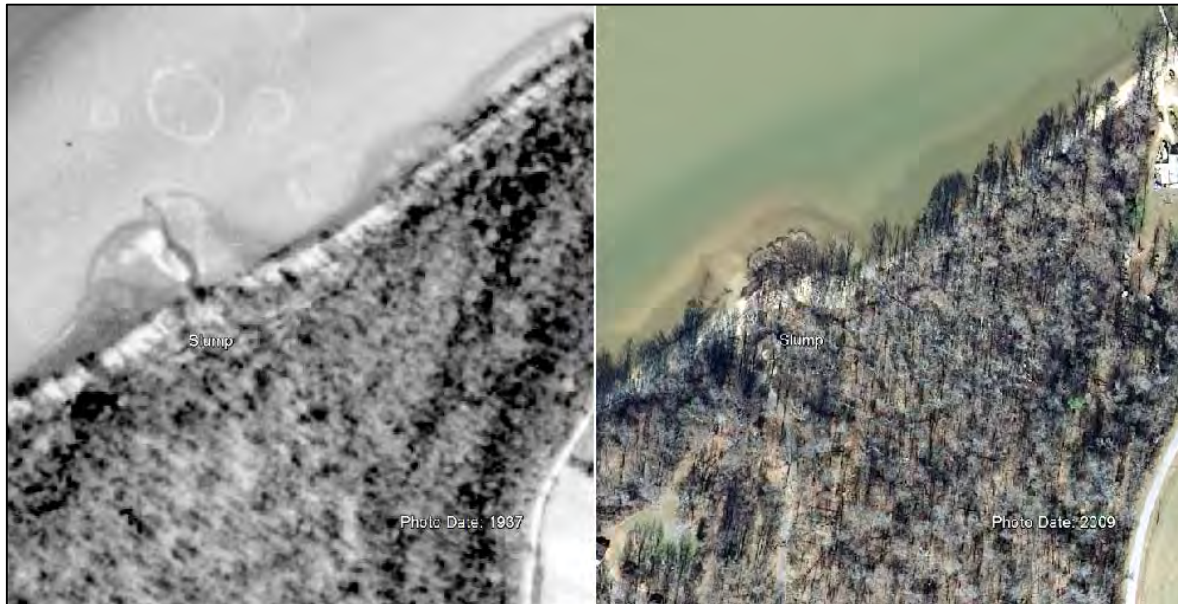


Figure 2B. Slump – area where base of bank is slumping, offsetting erosion (left photo 1937 and right photo 2009).

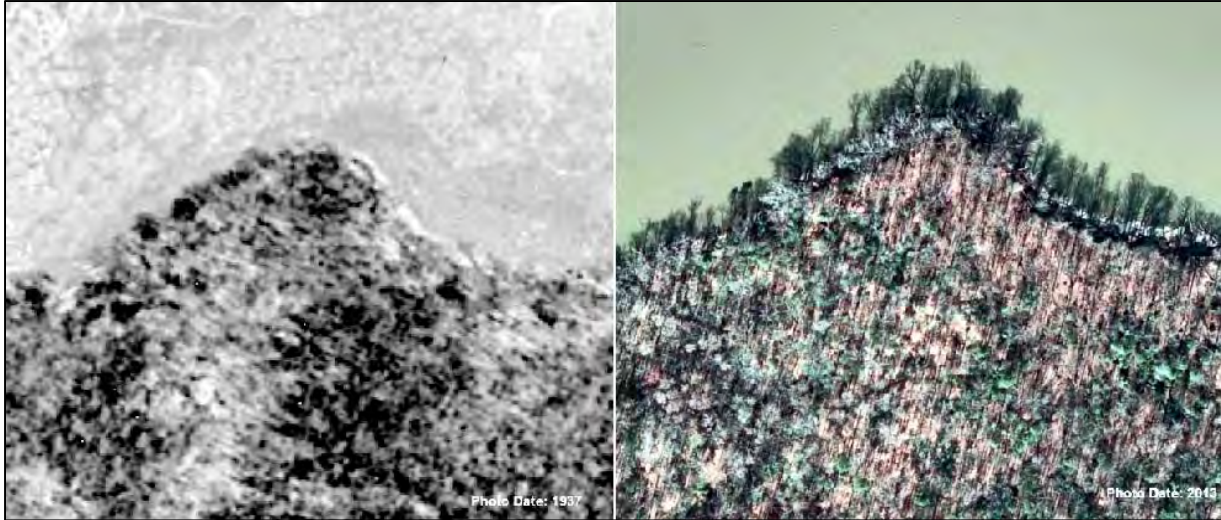


Figure 2C. Trees blocking the view of the shoreline (left photo 1937 and right photo 2009).

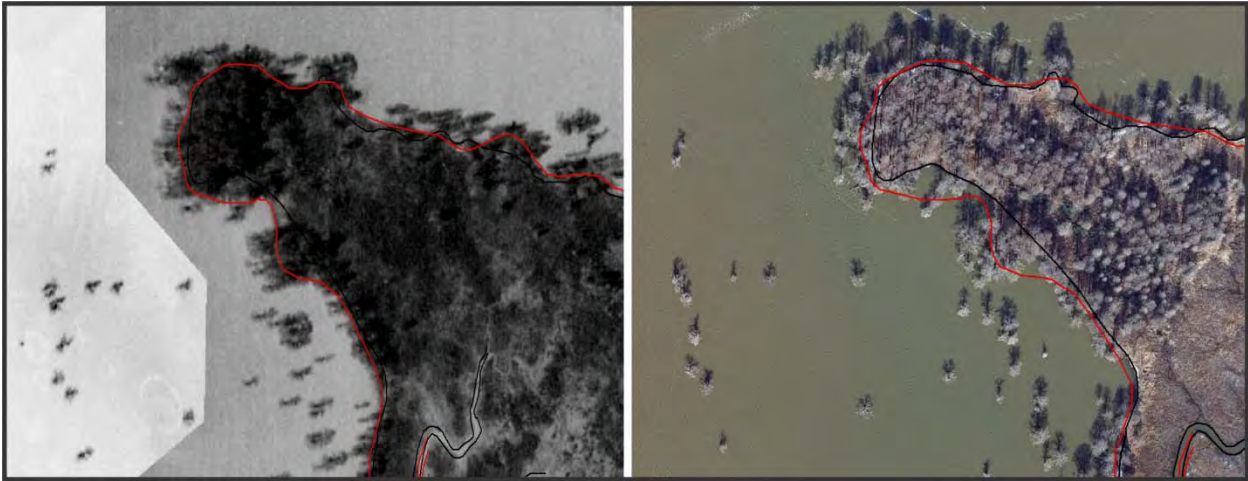


Figure 2D. Cypress marsh shorelines are difficult to determine from aerial photography (left photo 1937 and right photo 2009).



Figure 2E. The marsh shoreline is obscured by the cypress trees that can survive submerged in the river.

2.2 Rate of Change Analysis

The Digital Shoreline Analysis System (DSAS) was used to determine the rate of change for Prince George County shoreline (Himmelstoss, 2009). All DSAS input data must be managed within a personal geodatabase, which includes all the baselines created for Prince George County and the digitized shorelines for 1937, 1954, 1965, 1994, 2002 and 2009. Baselines were digitized about 200 feet, more or less, depending on features and space, seaward of the 1937 shoreline and encompassed the County's main shorelines as well as most of the smaller creeks. It did not include areas that have unique shoreline morphology such as creek mouths and spits. DSAS generated transects perpendicular to the baseline about 30 feet apart, which were manually checked and cleaned up before running the End Point Rate (EPR) calculations. Forty eight miles of baselines and 7795 transects were used.

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.

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, 1954, and 1963) have an estimated total maximum shoreline position error of 20.0 feet, while the total maximum shoreline error for the three existing datasets are estimated at 18.3 feet for USGS and 10.2 feet for VBMP. The maximum annualized error for the shoreline data is ± 0.6 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. Many areas of Prince George County have shore change rates that fall within the calculated error. Some of the areas that show very low accretion or very low erosion can be due to errors within the method as described above.

The Prince George County shoreline was divided into 15 plates (Figure 3) in order to display the shoreline data. In Appendix A, the 2009 image is shown with the 1937 and 2009 shorelines and the calculated EPR of change. In Appendix B, one photo date and the associated shoreline is shown on each map

for each year. These include the photos taken in 1937, 1954, 1965, 1994, 2002, 2009, and 2013.

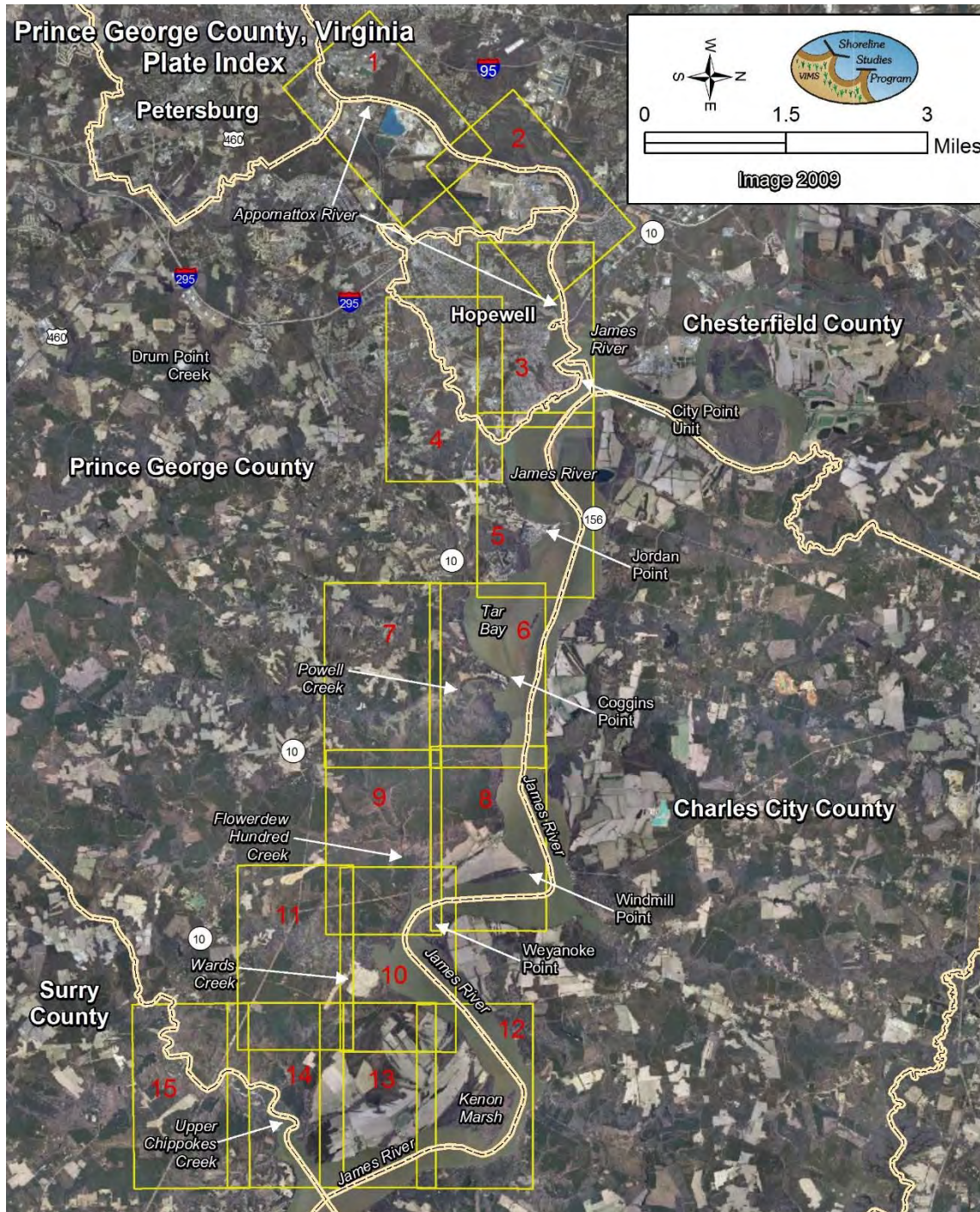


Figure 3. Plate index for Prince George County shorelines.

3 Results and Discussion

In this relatively low fetch environment, shoreline change is mostly minimal. Most of the river and creek shoreline in Prince George County is experiencing very low erosion (<1 ft/yr). Table 1 shows the average EPR of change for sections of the County based on the digitized shorelines. Even though wave action is limited due to small fetches, during storms, waves can directly impact the base of bank causing the entire bank to slump. This can deposit enough material to offset the erosion and transport material downdrift to adjacent shorelines leading to the very low accretion rates.

Two areas of the Prince George County show low to medium accretion due to placement of material (Appendix A-1 and Appendix A-3). A few, intermittent shoreline reaches show low to medium erosion often near the creek or river mouth. Kenon Marsh (Appendix A-12) is eroding on its eastern edge most likely due to the slightly longer fetch down the James River. The area with the highest erosion rate is in Upper Chippokes Creek. Two significant areas of marsh have been lost at a rate of -5 to -10 ft/year or more than -10 ft/year (Appendix A-14). The shoreline change data is available online for more detailed viewing at www.vims.edu/research/departments/physical/programs/ssp/gis_maps.

Table 1. Average end point rates of shoreline change (1937-2009) in feet per year along sections of Prince George County's coast.

Reach Name	Plate Number	Avg EPR (ft/yr)	Category
Appomattox River to James River (City Point Unit)	1, 2 and 3	-0.36	Very Low Erosion
James River from City Point Unit to Coggins Point	5 and 6	0.01	Very Low Accretion
James River from Coggins Point to Windmill Point	6 and 8	-0.14	Very Low Erosion
James River from Windmill Point to Kenon Marsh	8 to 12	-0.41	Very Low Erosion
James River from Kenon Marsh to Upper Chippokes Creek	12 and 13	-0.36	Very Low Erosion
Upper Chippokes Creek starting at James River	14 and 15	-0.78	Very Low Erosion

4 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. Some areas of the County, where the shoreline change rates are categorized as accretion, have structures along the shoreline which results in a positive long-term rate of change due to the structures themselves or due to slumps. Some of the areas with very low accretion, particularly in the smaller creeks and

rivers, may be the result of errors within photo rectification and digitizing wooded shorelines.

5 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.
- Milligan, D. A., K.P. O'Brien, C. Wilcox, C. S. Hardaway, JR, 2010a. Shoreline Evolution: City of Newport News, Virginia James River and Hampton Roads Shorelines. Virginia Institute of Marine Science. College of William & Mary, Gloucester Point, VA.
http://web.vims.edu/physical/research/shoreline/docs/Cascade/Shoreline_Evolution/Newport_News_ShoreEvolve-Ir.pdf
- Milligan, D. A., K.P. O'Brien, C. Wilcox, C. S. Hardaway, JR, 2010b. Shoreline Evolution: City of Poquoson, Virginia, Poquoson River, Chesapeake Bay, and Back River Shorelines. Virginia Institute of Marine Science. College of William & Mary, Gloucester Point, VA.
http://web.vims.edu/physical/research/shoreline/docs/Cascade/Shoreline_Evolution/Poquoson_ShoreEvolve-Ir.pdf
- Milligan, D. A., K.P. O'Brien, C. Wilcox, C. S. Hardaway, JR, 2010c. Gloucester County, Virginia York River, Mobjack Bay, and Piankatank River Shorelines. Virginia Institute of Marine Science. College of William & Mary, Gloucester Point, VA.
http://web.vims.edu/physical/research/shoreline/docs/Cascade/Shoreline_Evolution/Gloucester_ShoreEvolve-Ir.pdf
- 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/Cascade/Shoreline_Evolution/York_ShoreEvolve-Ir.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

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.

Plate 1 Plate 2 Plate 3

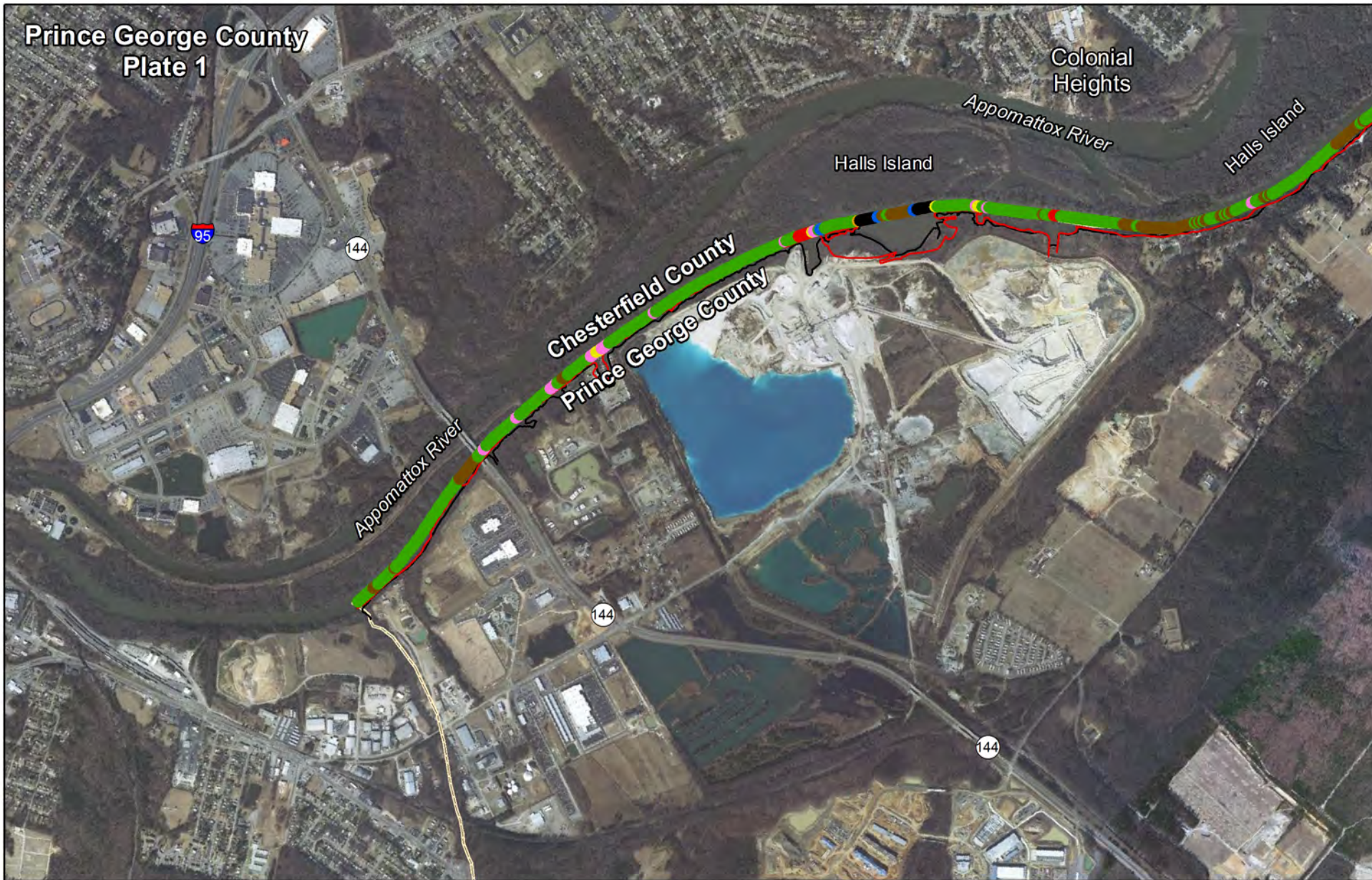
Plate 4 Plate 5 Plate 6

Plate 7 Plate 8 Plate 9

Plate 10 Plate 11 Plate 12

Plate 13 Plate 14 Plate 15

Prince George County
Plate 1



Shoreline Rates of Change

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

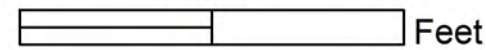
Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



0 2,000 4,000



Feet A-1

**Prince George County
Plate 2**



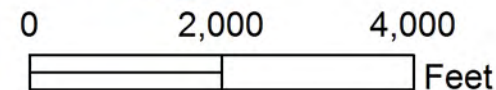
Shoreline Rates of Change

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

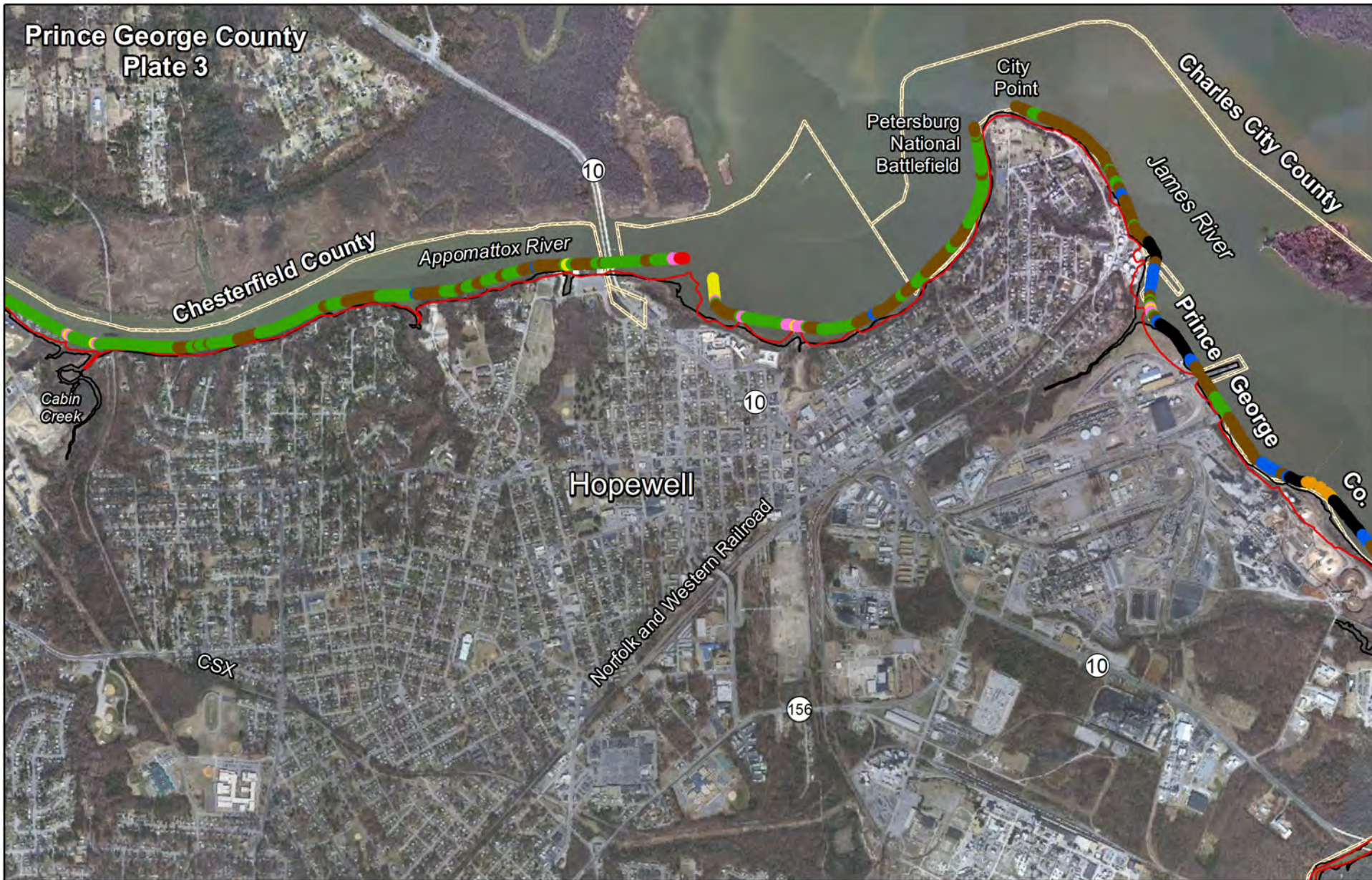
Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



**Prince George County
Plate 3**



Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

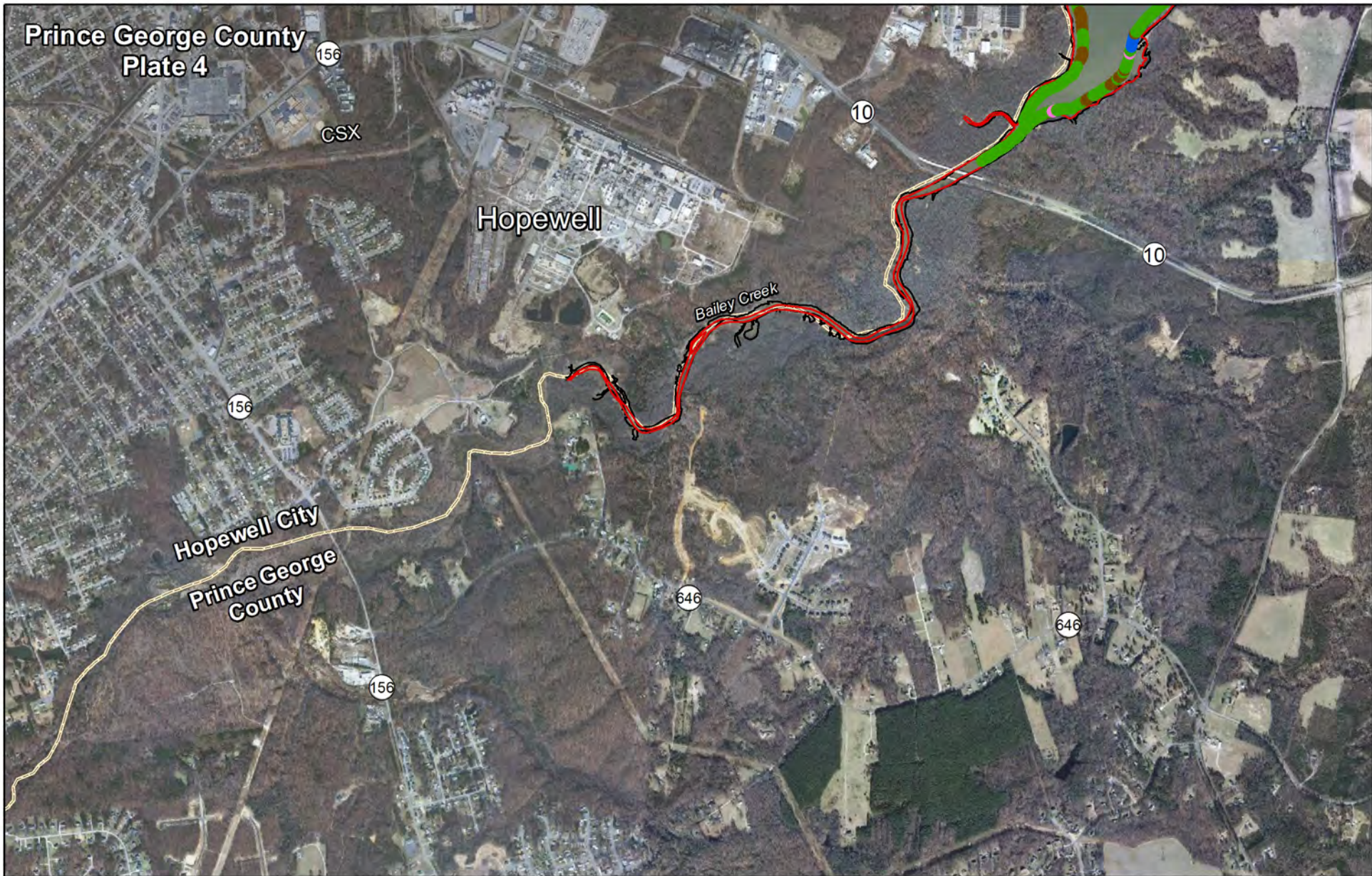
2009 VBMP Photo



0 2,000 4,000

Feet

A-3



Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo

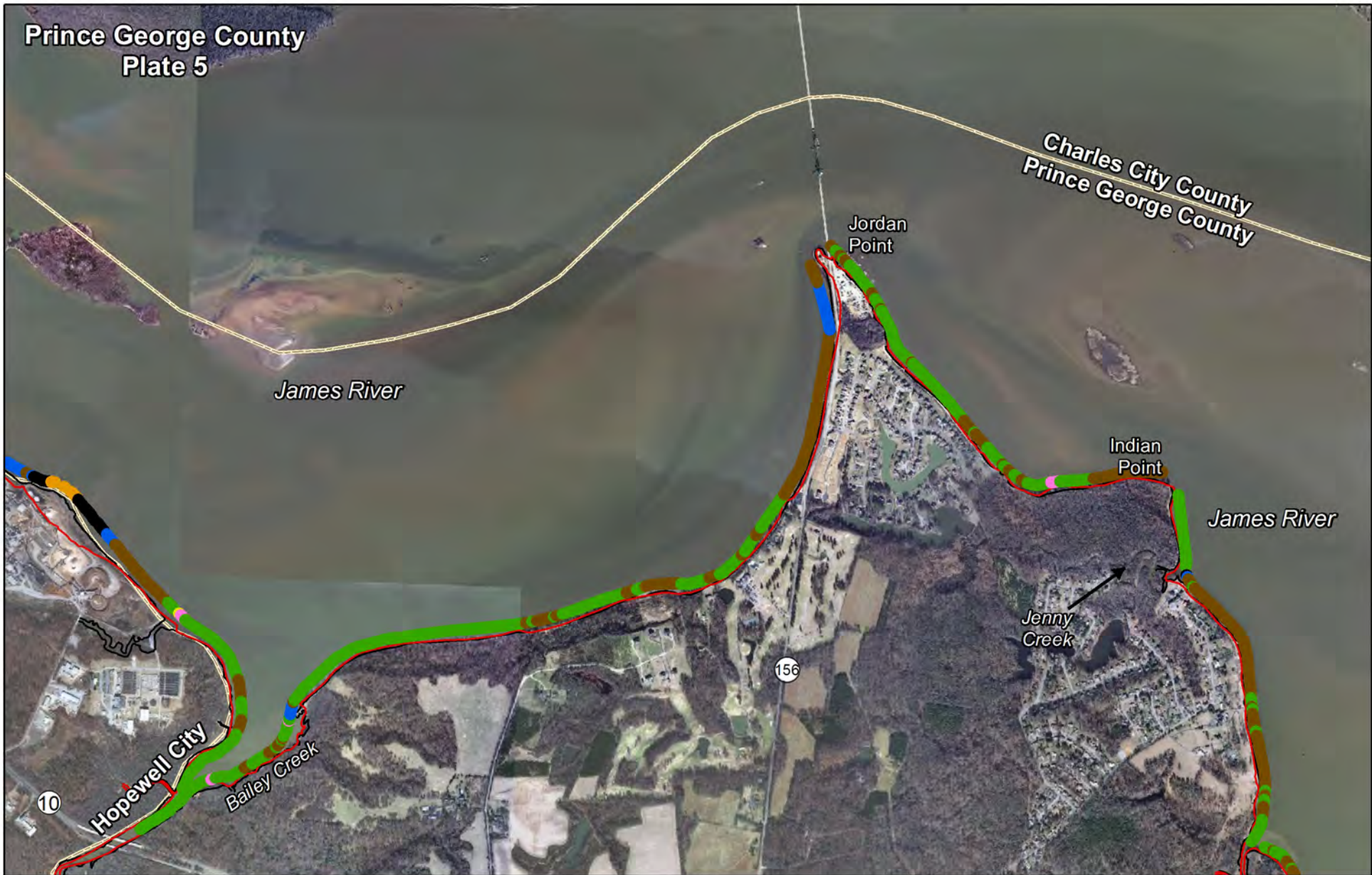


0 2,000 4,000

Feet

A-4

**Prince George County
Plate 5**



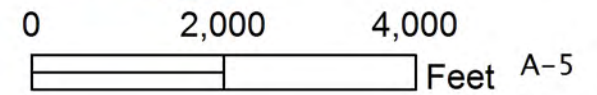
Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



**Prince George County
Plate 6**



Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo

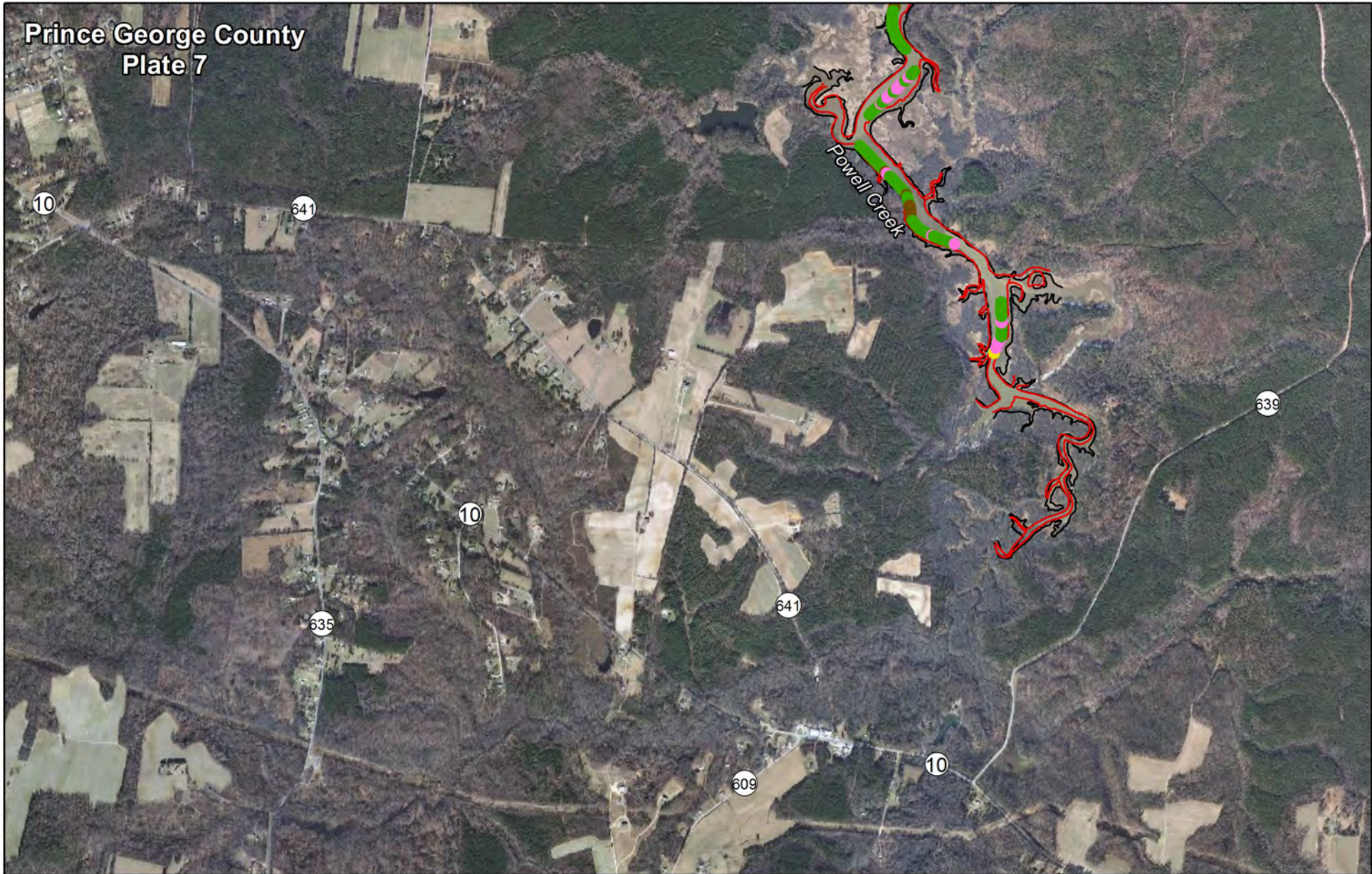


0 2,000 4,000

Feet

A-6

Prince George County
Plate 7



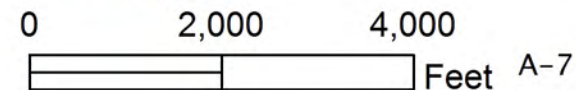
Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



Prince George County
Plate 8

Charles City County
Prince George County



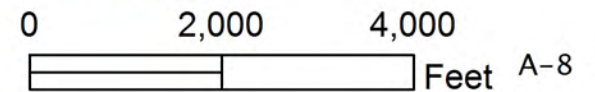
Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



**Prince George County
Plate 9**



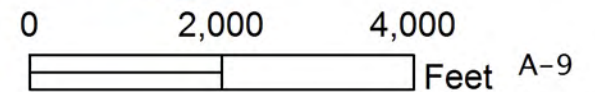
Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo





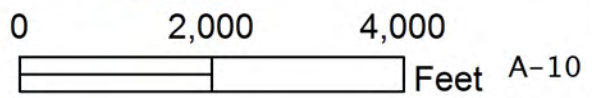
Shoreline Rates of Change

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

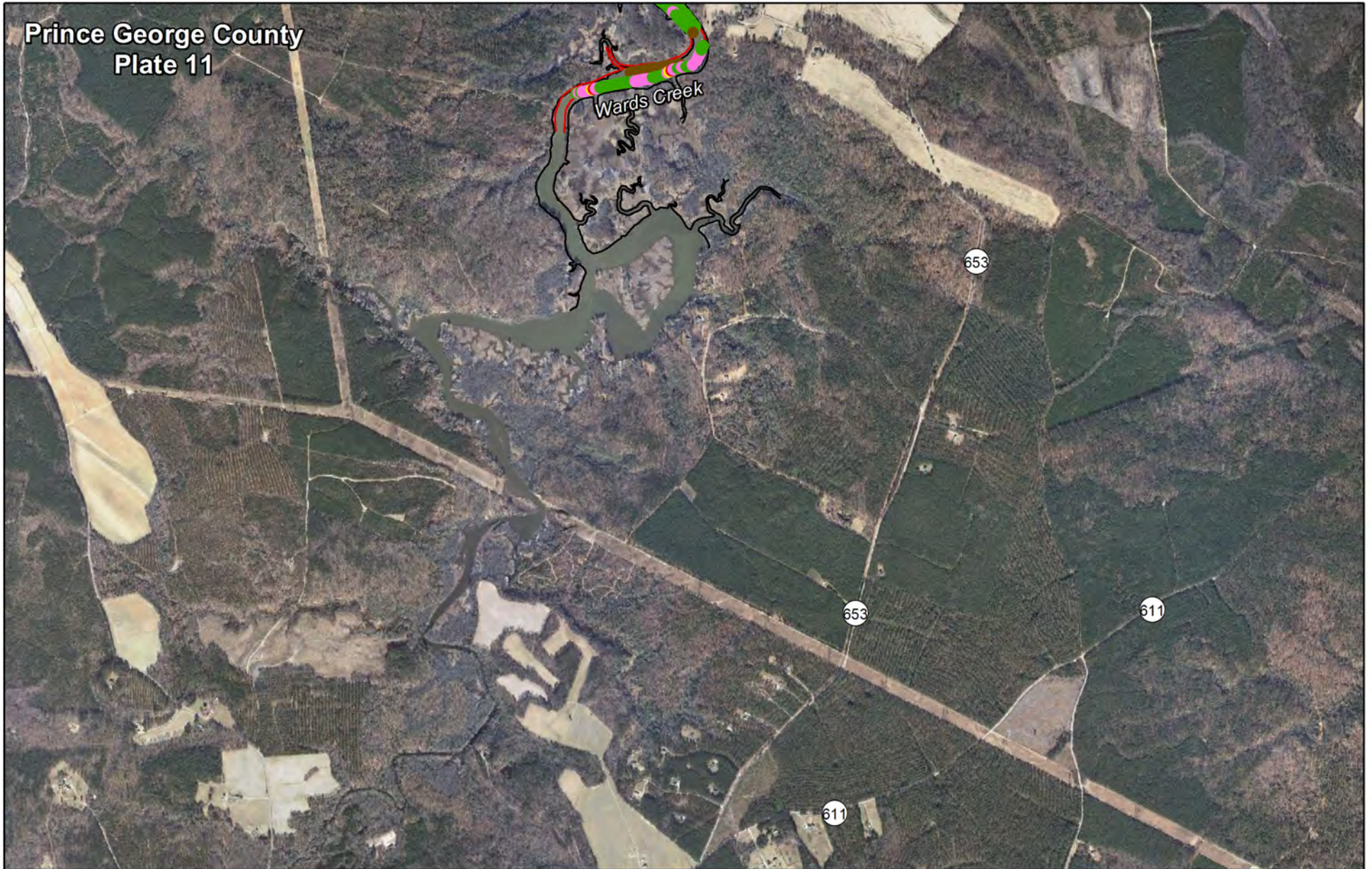
Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



**Prince George County
Plate 11**



Shoreline Rates of Change

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

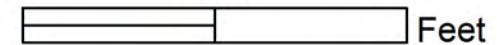
Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



0 2,000 4,000



Feet A-11

**Prince George County
Plate 12**

James River

Sturgeon Point

Kittewan Creek

Charles City County
Prince George County

Kenon Marsh

James River

Shoreline Rates of Change

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

Legend

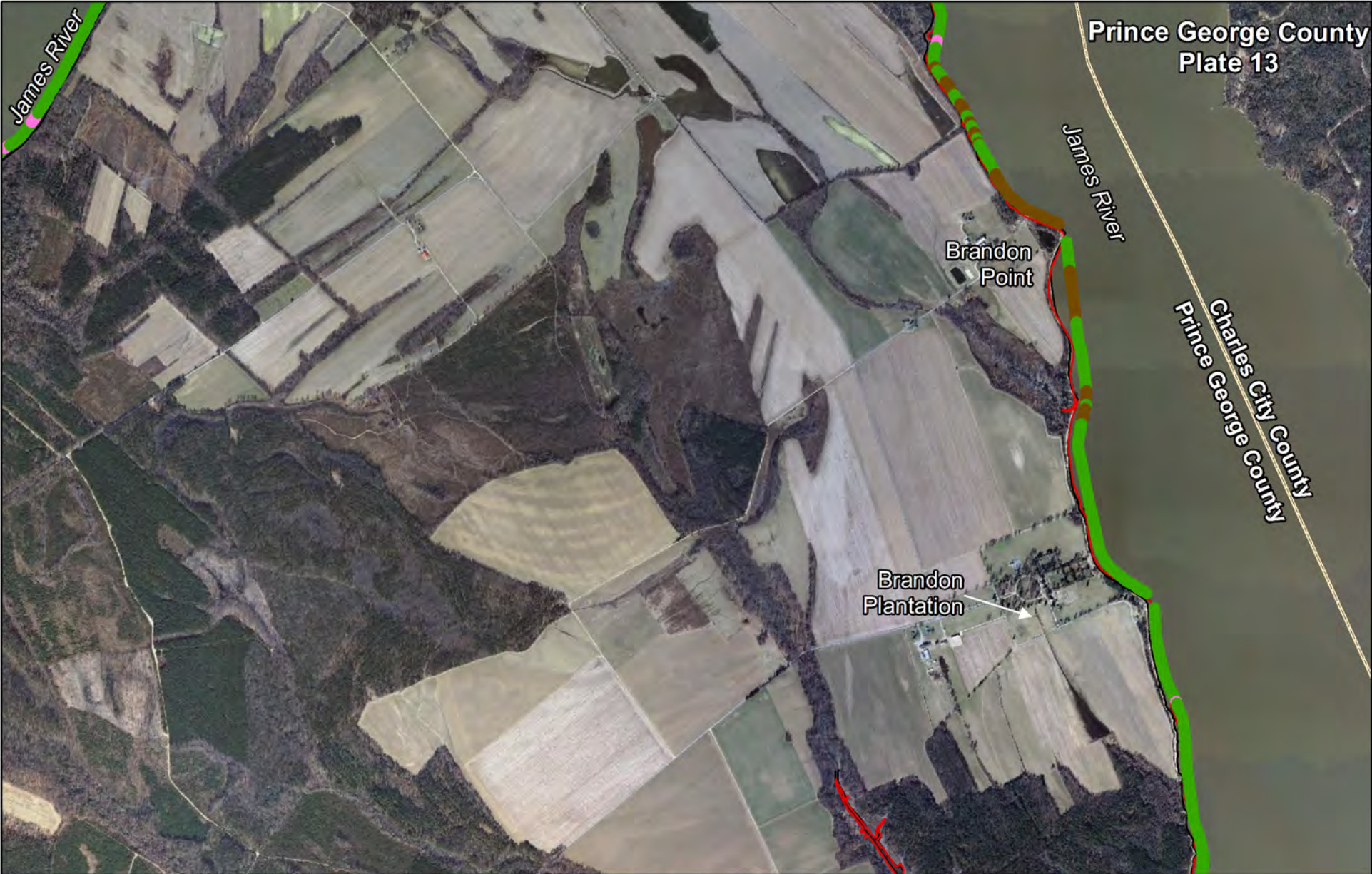
- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



0 2,000 4,000

Feet



Prince George County
Plate 13

James River

James River

Brandon Point

Charles City County
Prince George County

Brandon Plantation

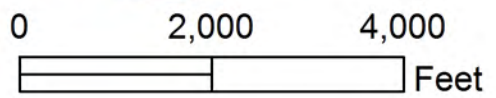
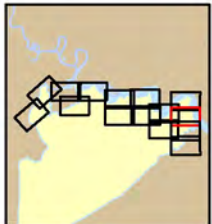
Shoreline Rates of Change

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

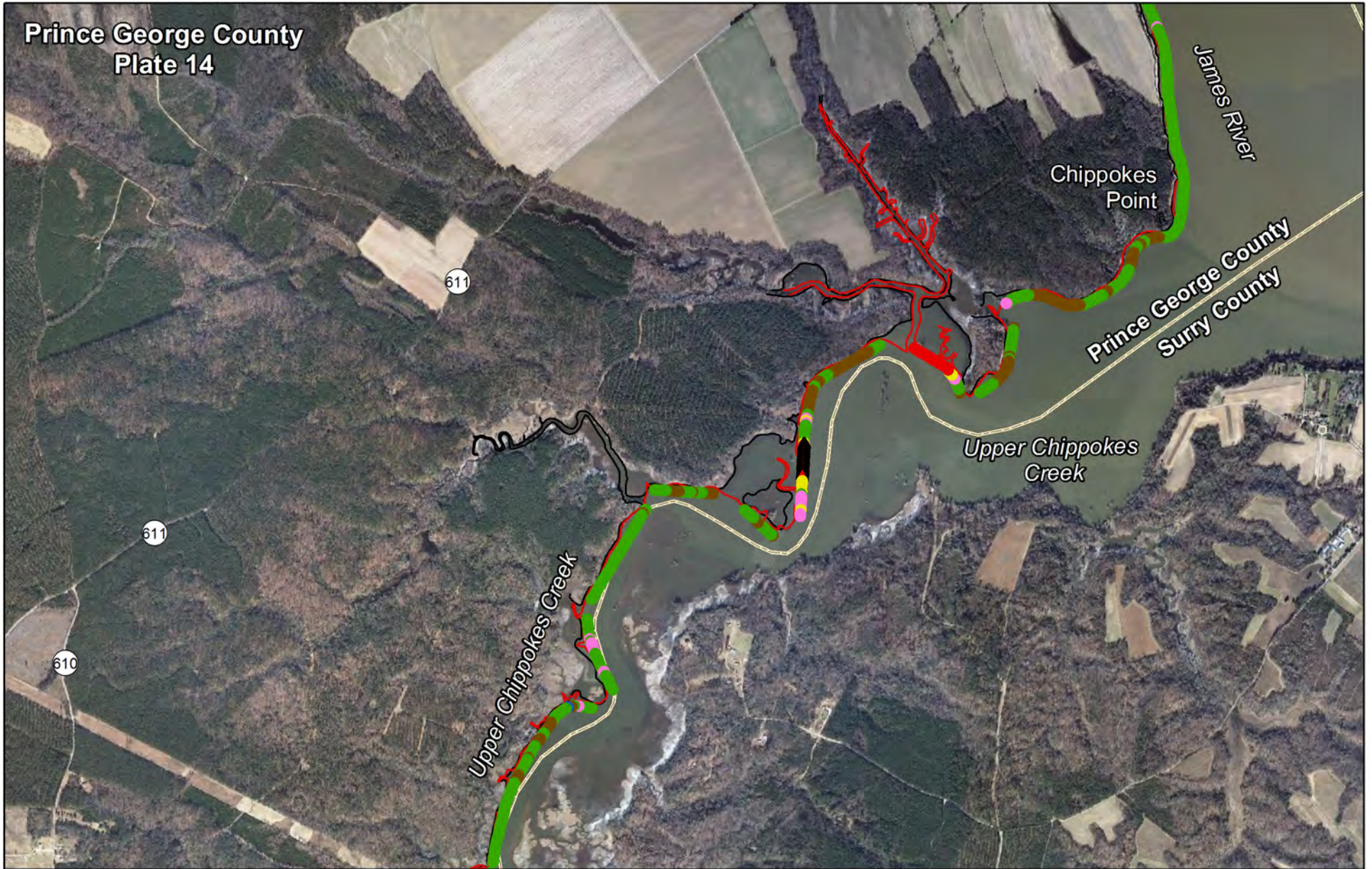
Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



Prince George County
Plate 14



Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

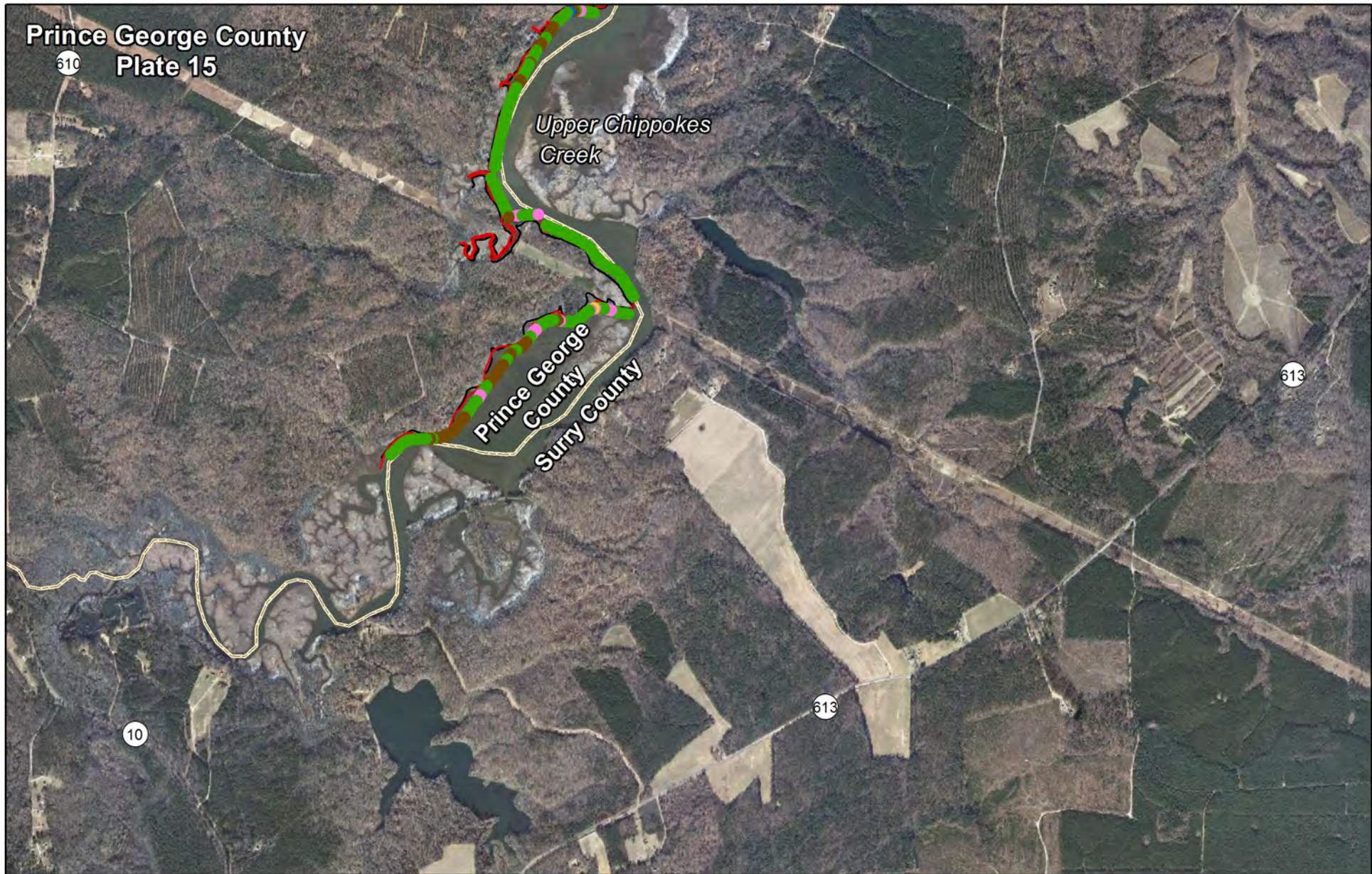
2009 VBMP Photo



0 2,000 4,000

Feet

Prince George County
Plate 15



Shoreline Rates of Change

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

Legend

- Shoreline 1937
- Shoreline 2009

2009 VBMP Photo



0 2,000 4,000

Feet

Appendix B

Historical Photo and Digitized Shoreline 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.

Plate 1 Plate 2 Plate 3

Plate 4 Plate 5 Plate 6

Plate 7 Plate 8 Plate 9

Plate 10 Plate 11 Plate 12

Plate 13 Plate 14 Plate 15



Legend
 — Shoreline 1937



**Prince George County, Virginia
 Plate 1**

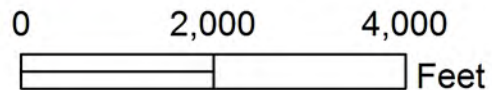
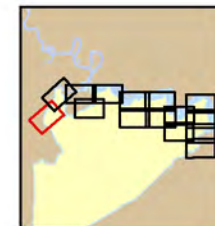
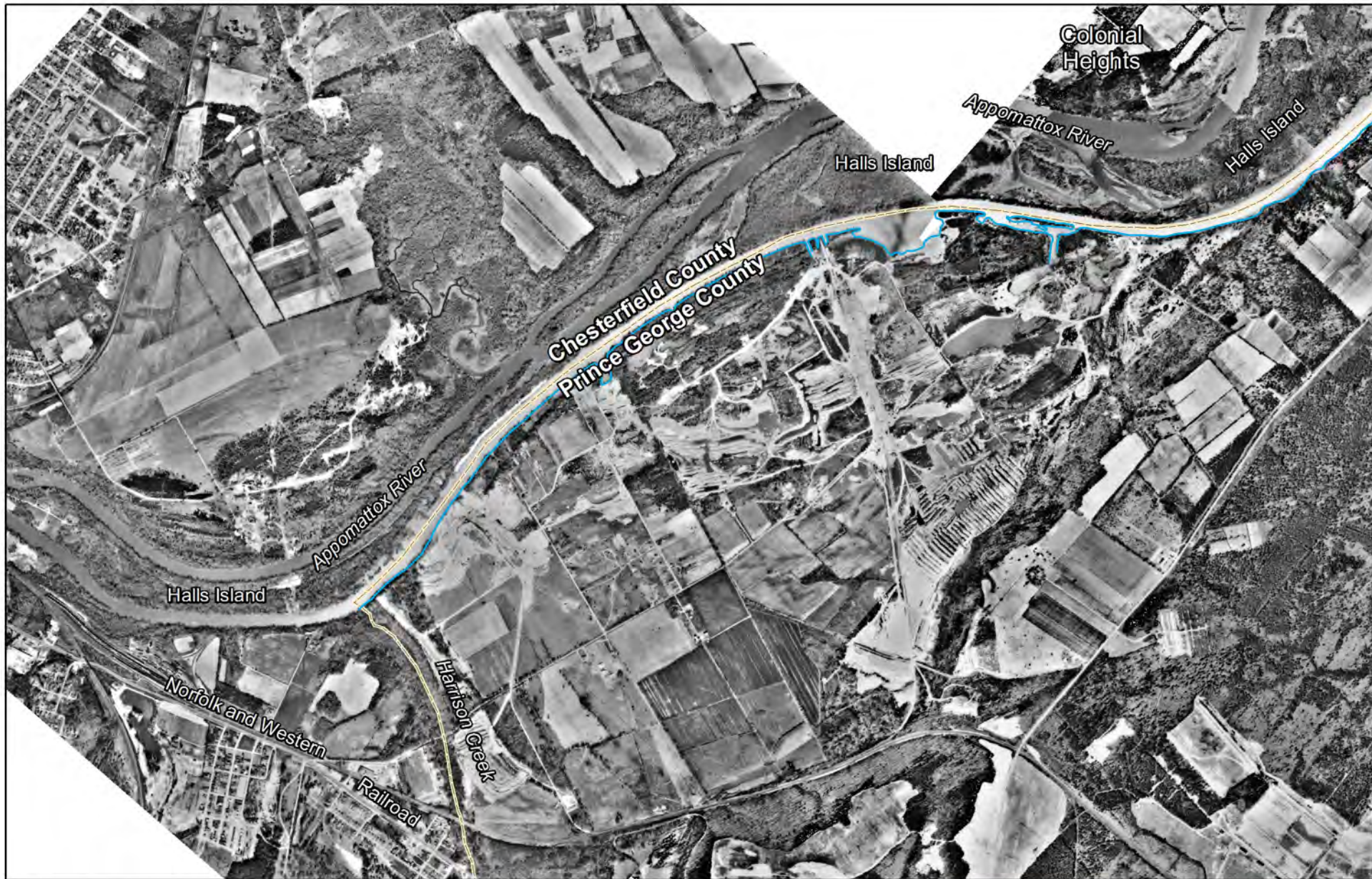


Photo Date: 1937



Legend

— Shoreline 1954



**Prince George County, Virginia
Plate 1**

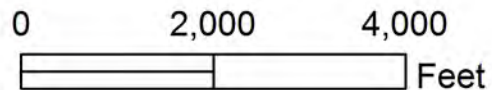


Photo Date: 1954



Legend
 — Shoreline 1965



**Prince George County, Virginia
 Plate 1**



0 2,000 4,000
 Feet

Photo Date: 1965



Legend

Shoreline 1994



Prince George County, Virginia
Plate 1

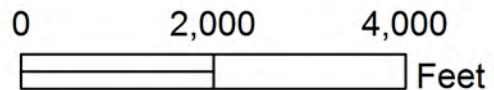


Photo Date: 1994



Legend
 — Shoreline 2002



**Prince George County, Virginia
 Plate 1**

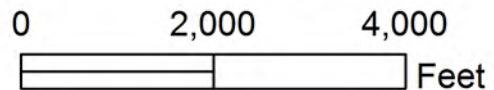
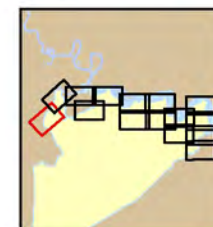


Photo Date: 2002



Legend
 — Shoreline 2009



**Prince George County, Virginia
 Plate 1**



0 2,000 4,000
 Feet

Photo Date: 2009



Legend

— Shoreline 2013



**Prince George County, Virginia
Plate 1**

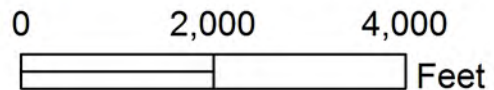
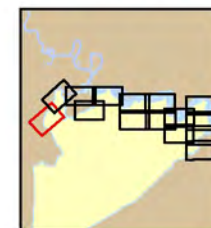


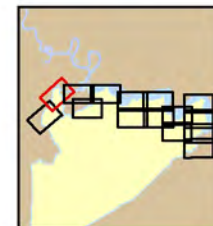
Photo Date: 2013



Legend
 — Shoreline 1937



**Prince George County, Virginia
 Plate 2**



0 2,000 4,000
 Feet

Photo Date: 1937



Legend
 — Shoreline 1954



**Prince George County, Virginia
 Plate 2**

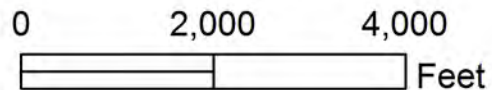
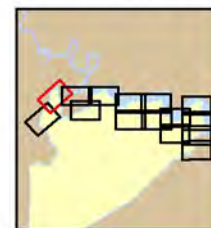


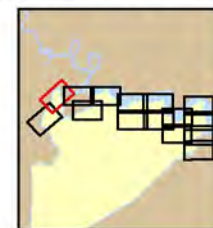
Photo Date: 1954



Legend
 — Shoreline 1965



**Prince George County, Virginia
 Plate 2**

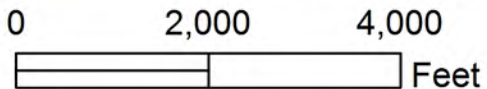


0 2,000 4,000
 Feet

Photo Date: 1965

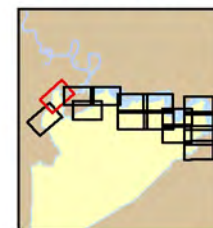


Legend
 — Shoreline 1994



**Prince George County, Virginia
 Plate 2**

Photo Date: 1994





Legend
 — Shoreline 2002



**Prince George County, Virginia
 Plate 2**

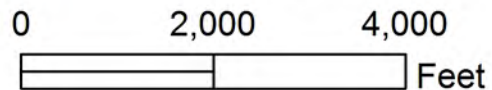
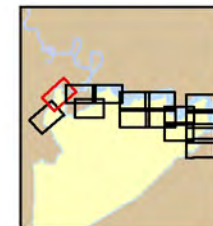


Photo Date: 2002



Legend
 — Shoreline 2009



**Prince George County, Virginia
 Plate 2**

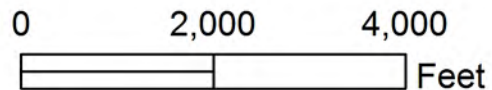
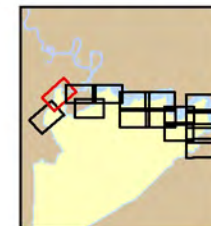
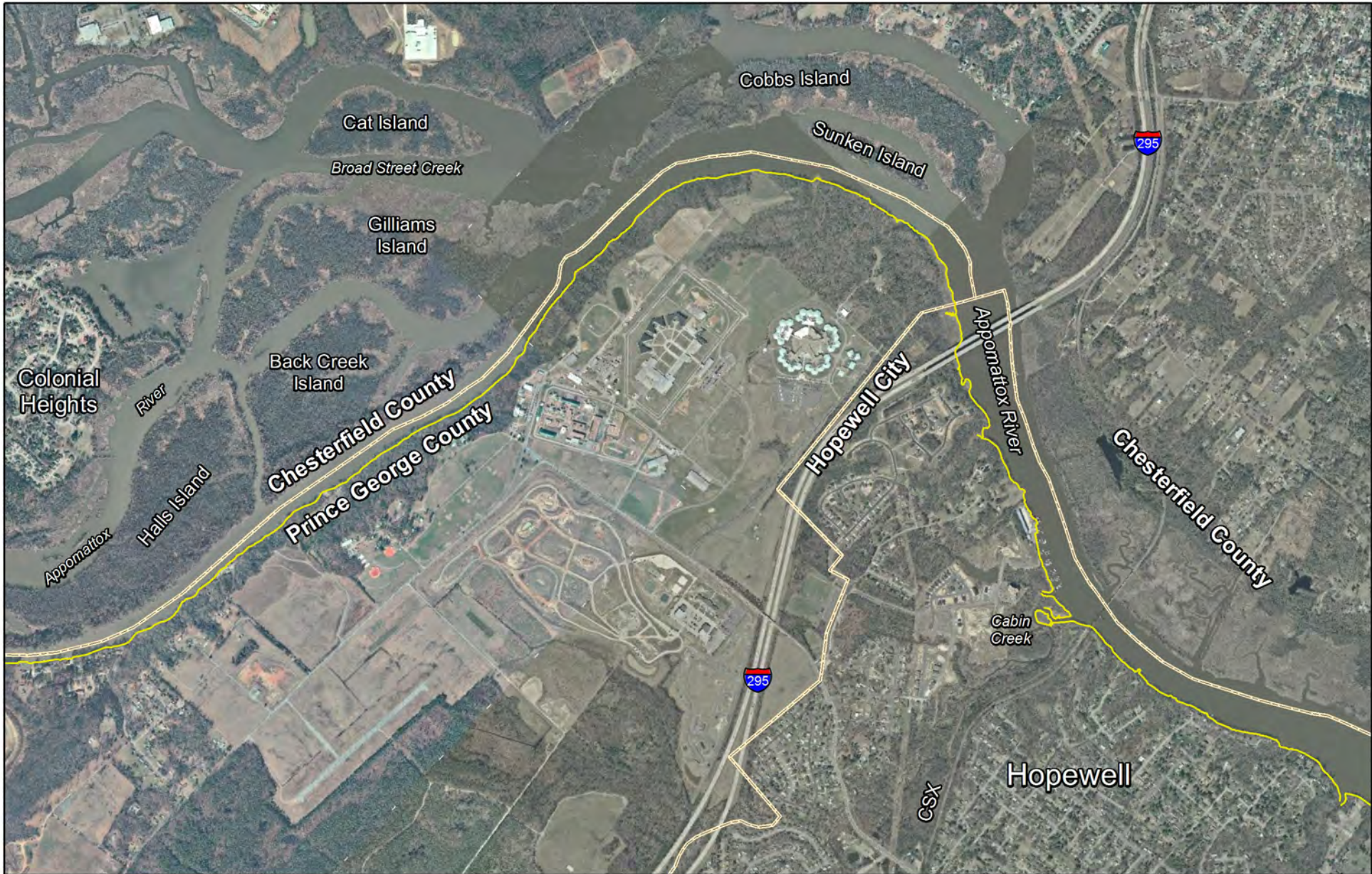


Photo Date: 2009



Legend
 — Shoreline 2013



**Prince George County, Virginia
 Plate 2**

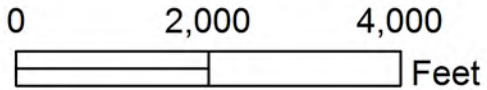


Photo Date: 2013



Legend
 — Shoreline 1937

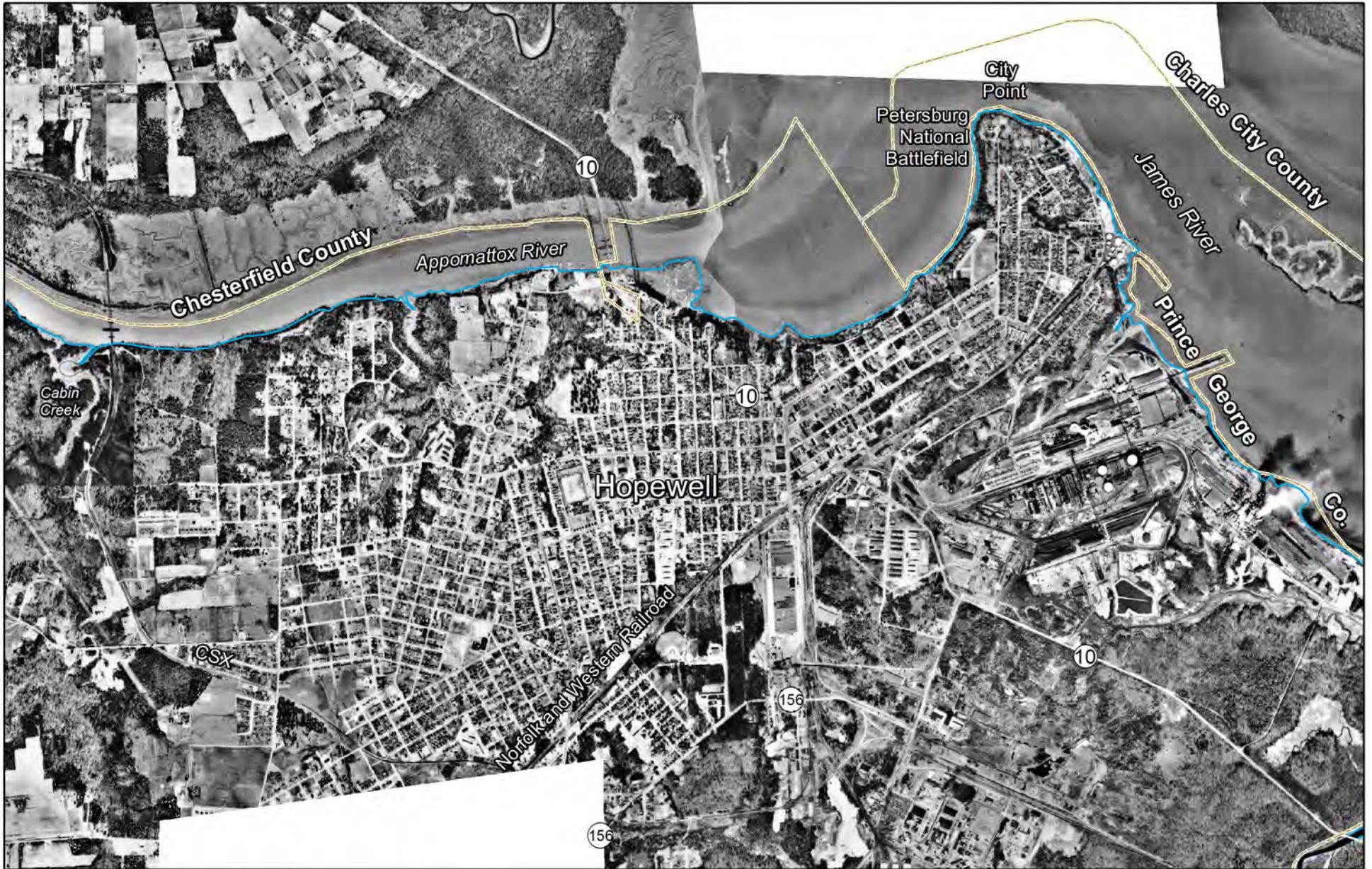


0 2,000 4,000
 Feet

Prince George County, Virginia Plate 3

Photo Date: 1937





Legend
 — Shoreline 1954



0 2,000 4,000
 Feet

Prince George County, Virginia Plate 3

Photo Date: 1954





Legend
 — Shoreline 1965



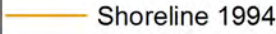
0 2,000 4,000
 Feet

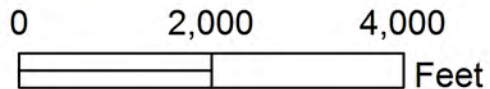
Prince George County, Virginia Plate 3

Photo Date: 1965



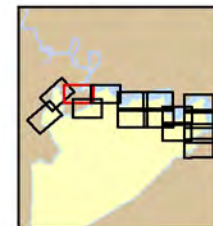


Legend
 Shoreline 1994



Prince George County, Virginia Plate 3

Photo Date: 1994





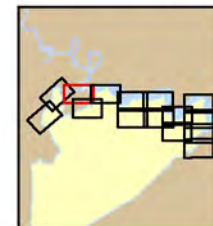
Legend
 — Shoreline 2002



0 2,000 4,000
 Feet

Prince George County, Virginia Plate 3

Photo Date: 2002





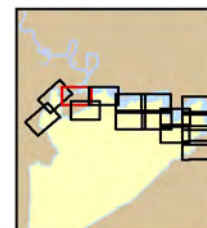
Legend
 — Shoreline 2009




0 2,000 4,000
 Feet

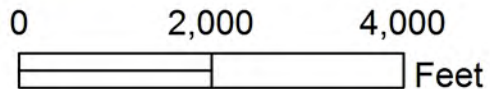
Prince George County, Virginia Plate 3

Photo Date: 2009



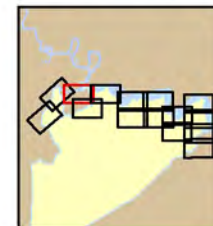


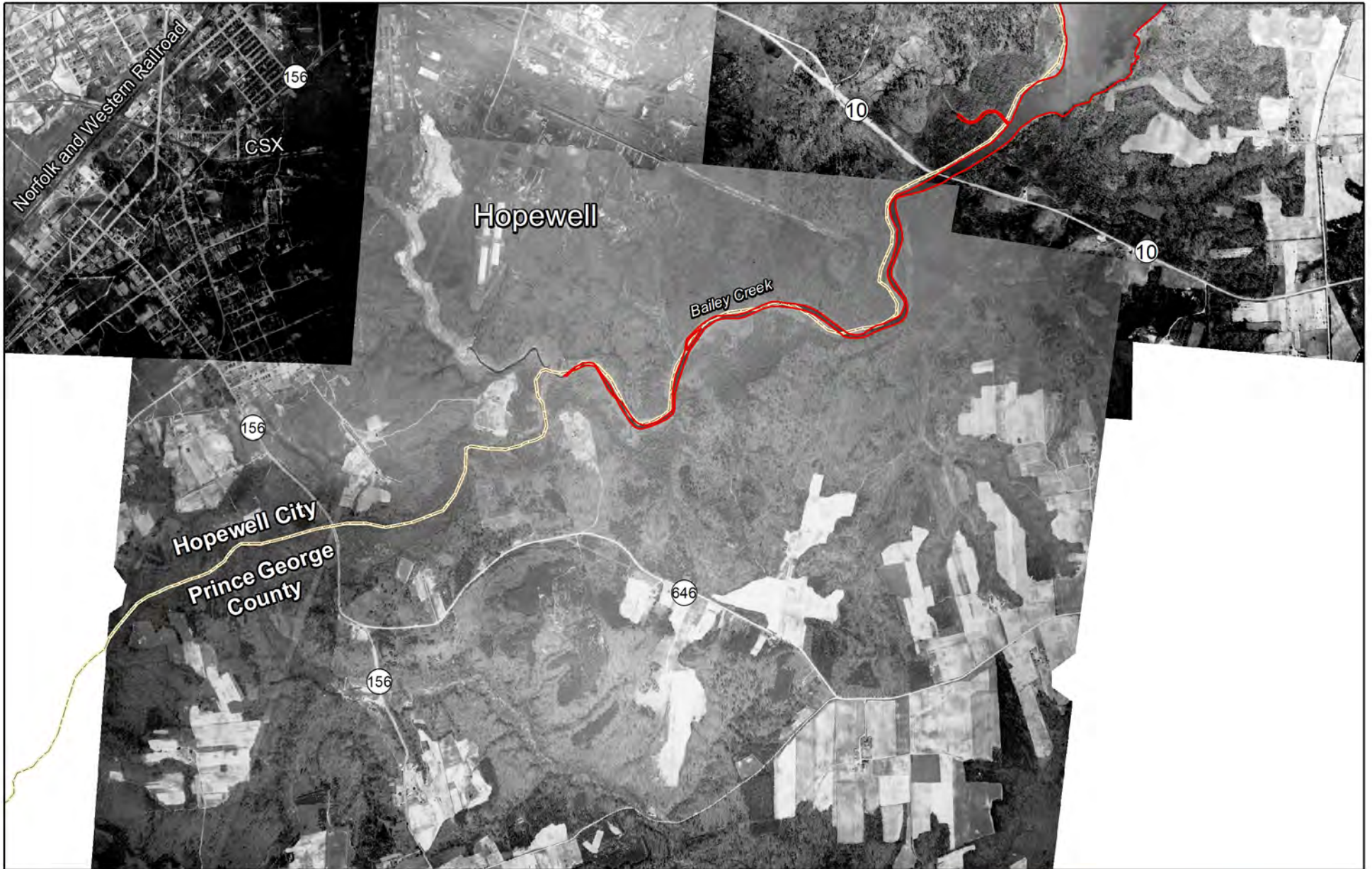
Legend
 Shoreline 2013



Prince George County, Virginia Plate 3

Photo Date: 2013





Legend
 — Shoreline 1937



**Prince George County, Virginia
 Plate 4**

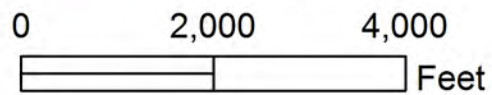
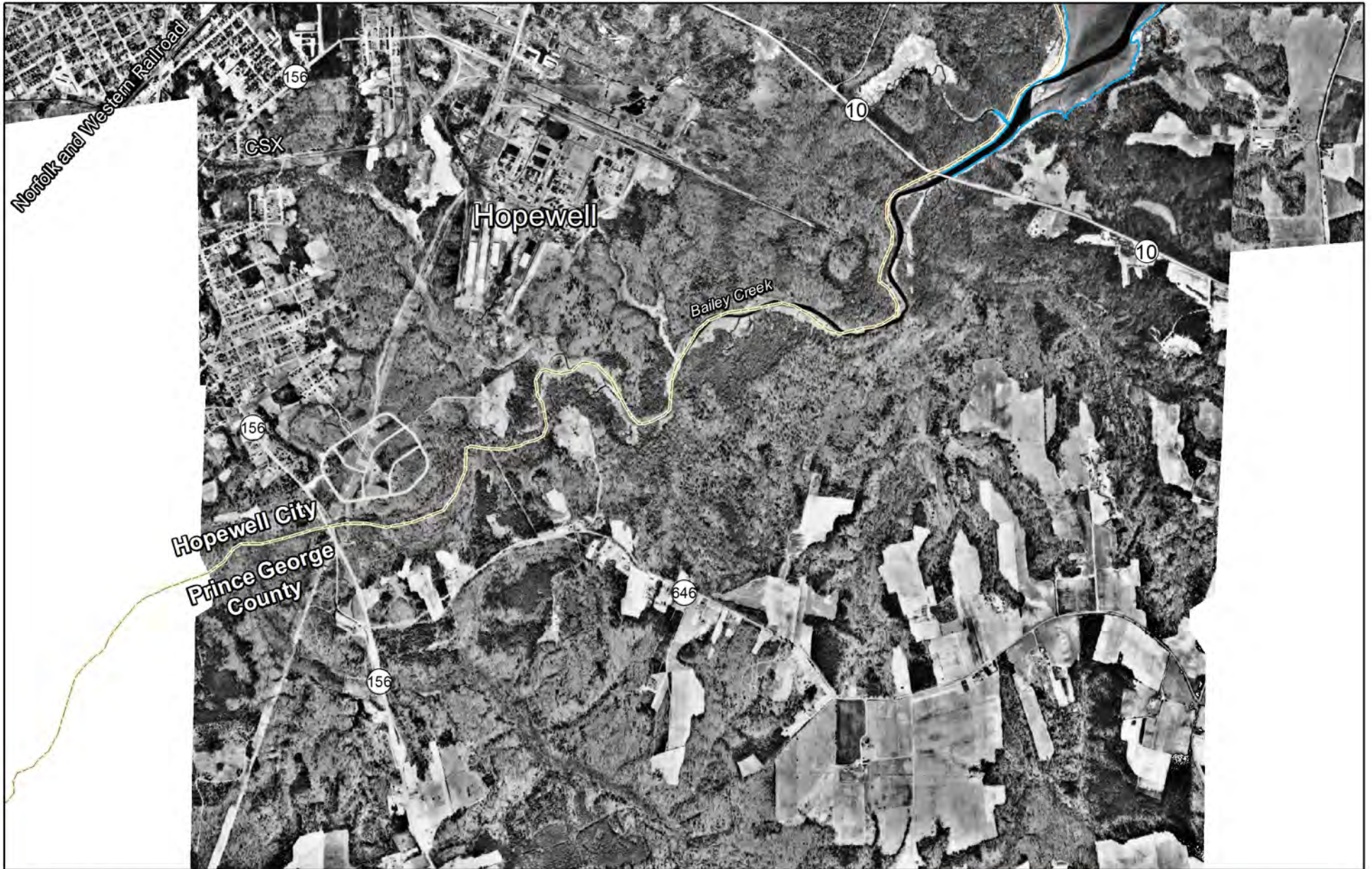


Photo Date: 1937



Legend
 — Shoreline 1954



0 2,000 4,000
 Feet

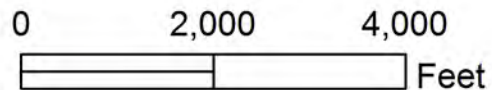
**Prince George County, Virginia
 Plate 4**

Photo Date: 1954





Legend
 — Shoreline 1965




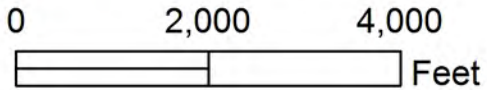
**Prince George County, Virginia
 Plate 4**

Photo Date: 1965





Legend
 Shoreline 1994



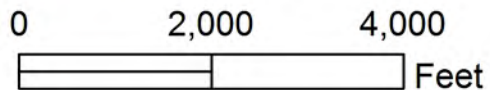
**Prince George County, Virginia
 Plate 4**

Photo Date: 1994



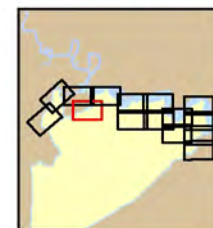


Legend
 — Shoreline 2002



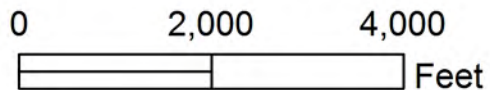
**Prince George County, Virginia
 Plate 4**

Photo Date: 2002



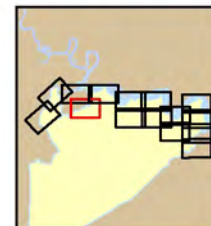


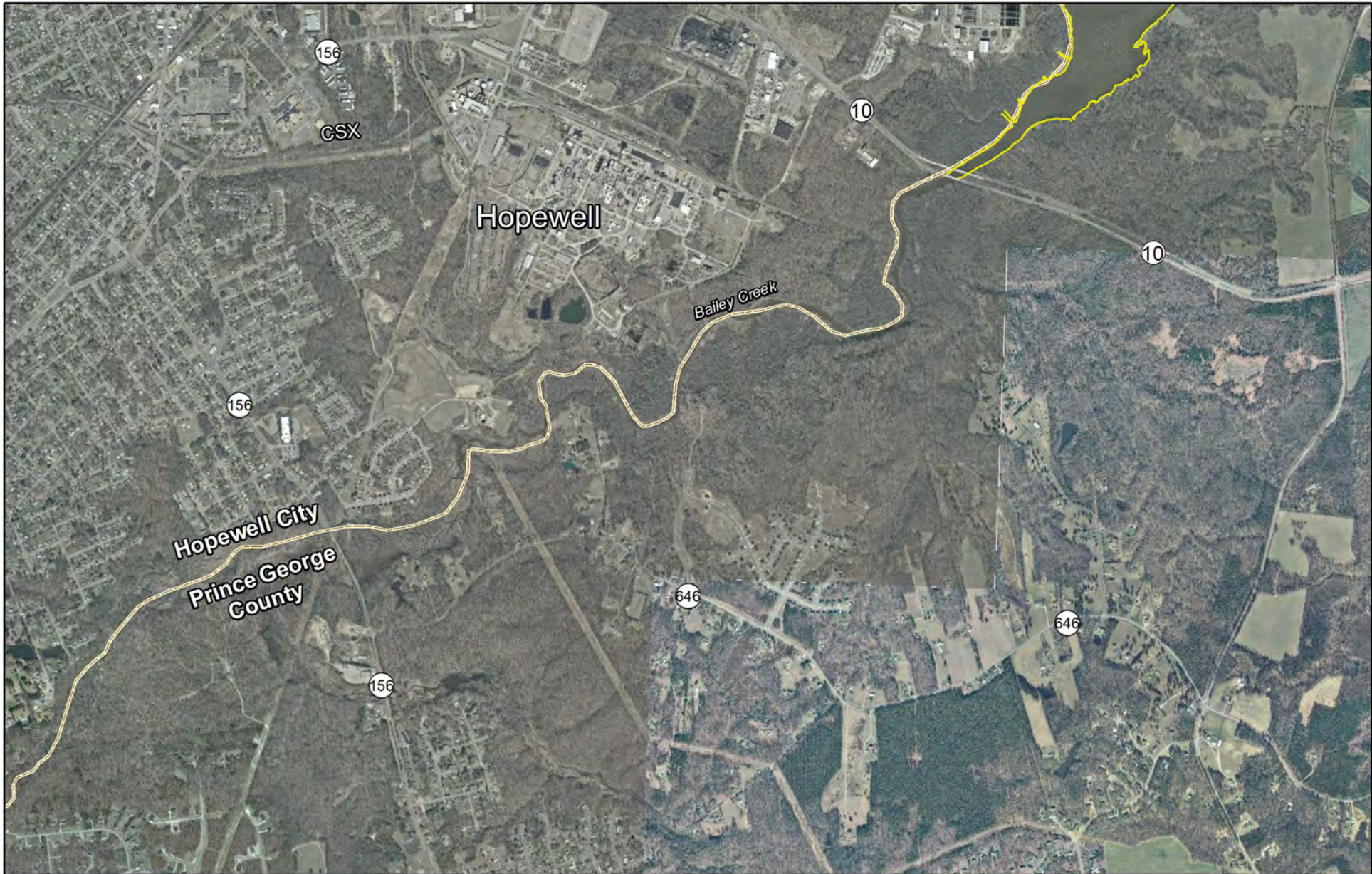
Legend
 — Shoreline 2009




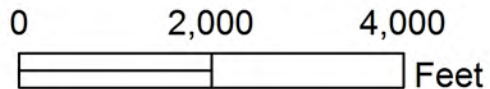
**Prince George County, Virginia
 Plate 4**

Photo Date: 2009



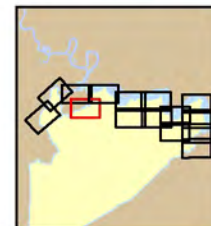


Legend
 Shoreline 2013



**Prince George County, Virginia
 Plate 4**

Photo Date: 2013





Legend
 — Shoreline 1937

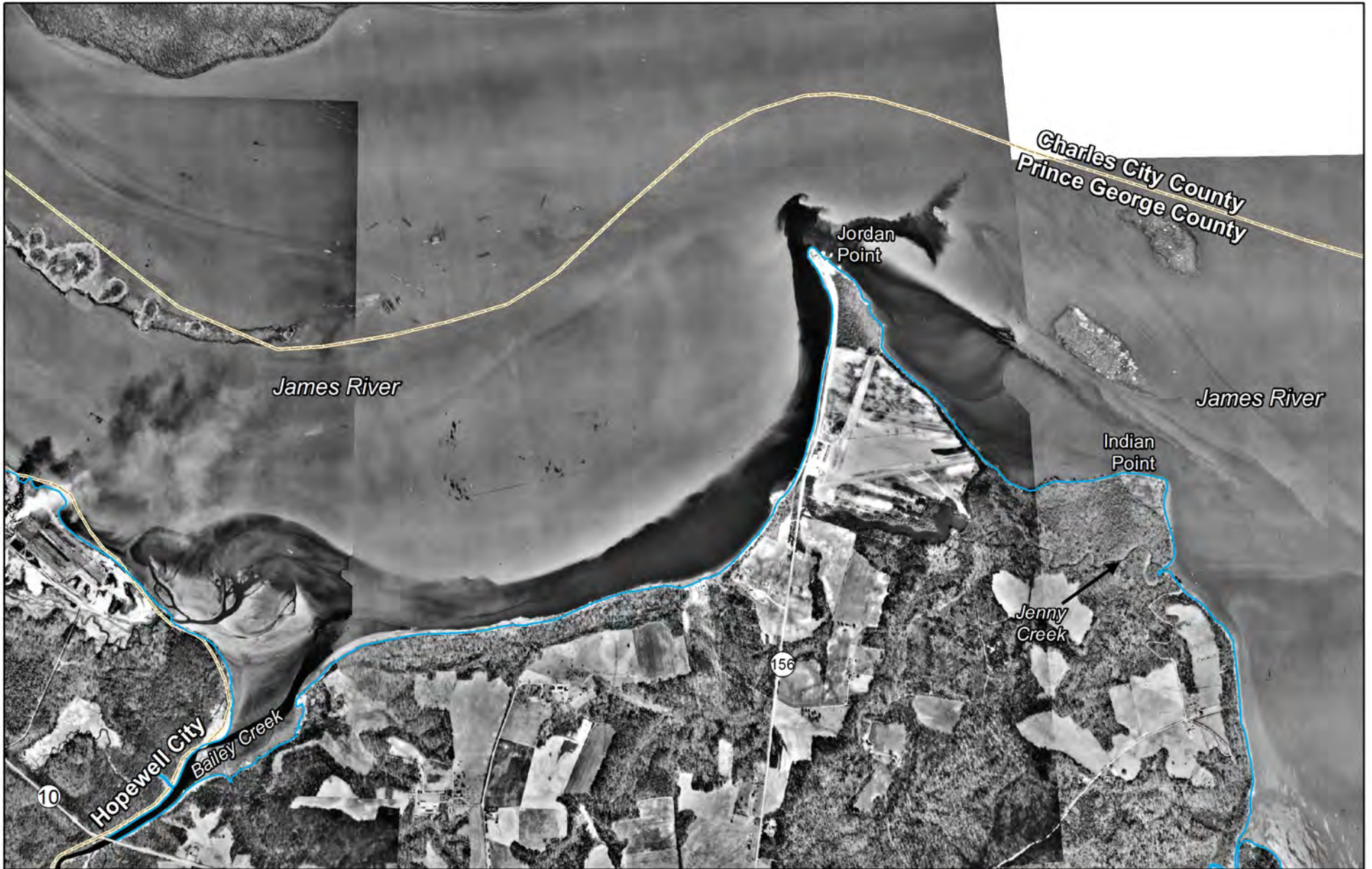


0 2,000 4,000
 Feet

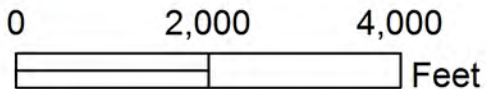
**Prince George County, Virginia
 Plate 5**

Photo Date: 1937





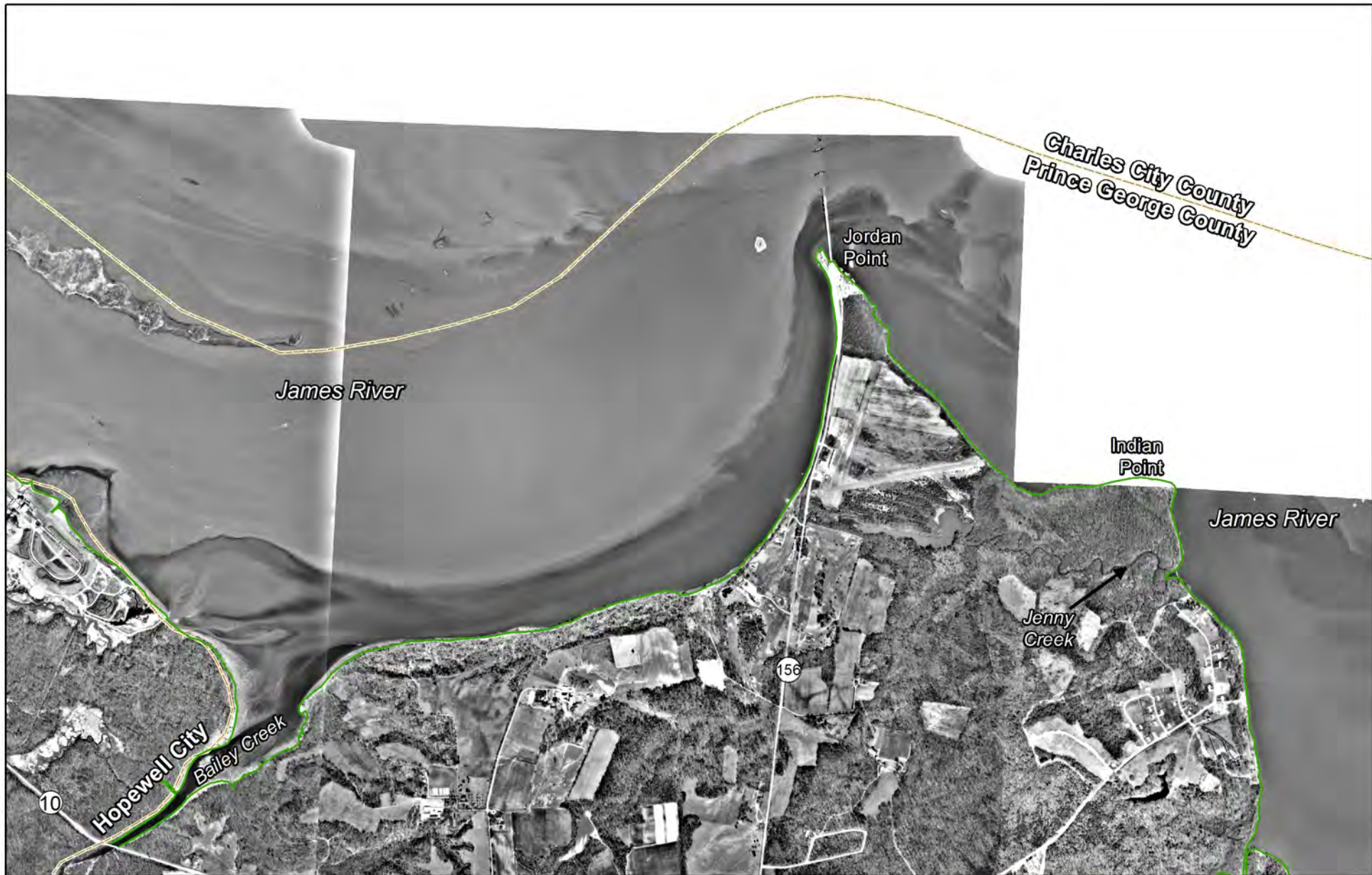
Legend
 — Shoreline 1954



**Prince George County, Virginia
 Plate 5**

Photo Date: 1954





Legend
 — Shoreline 1965



**Prince George County, Virginia
 Plate 5**

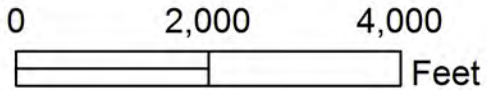


Photo Date: 1965



Legend
 — Shoreline 1994



**Prince George County, Virginia
 Plate 5**

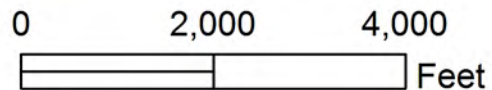
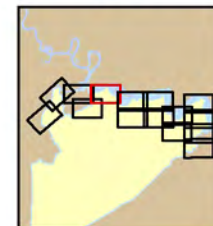


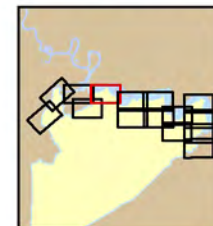
Photo Date: 1994



Legend
 — Shoreline 2002

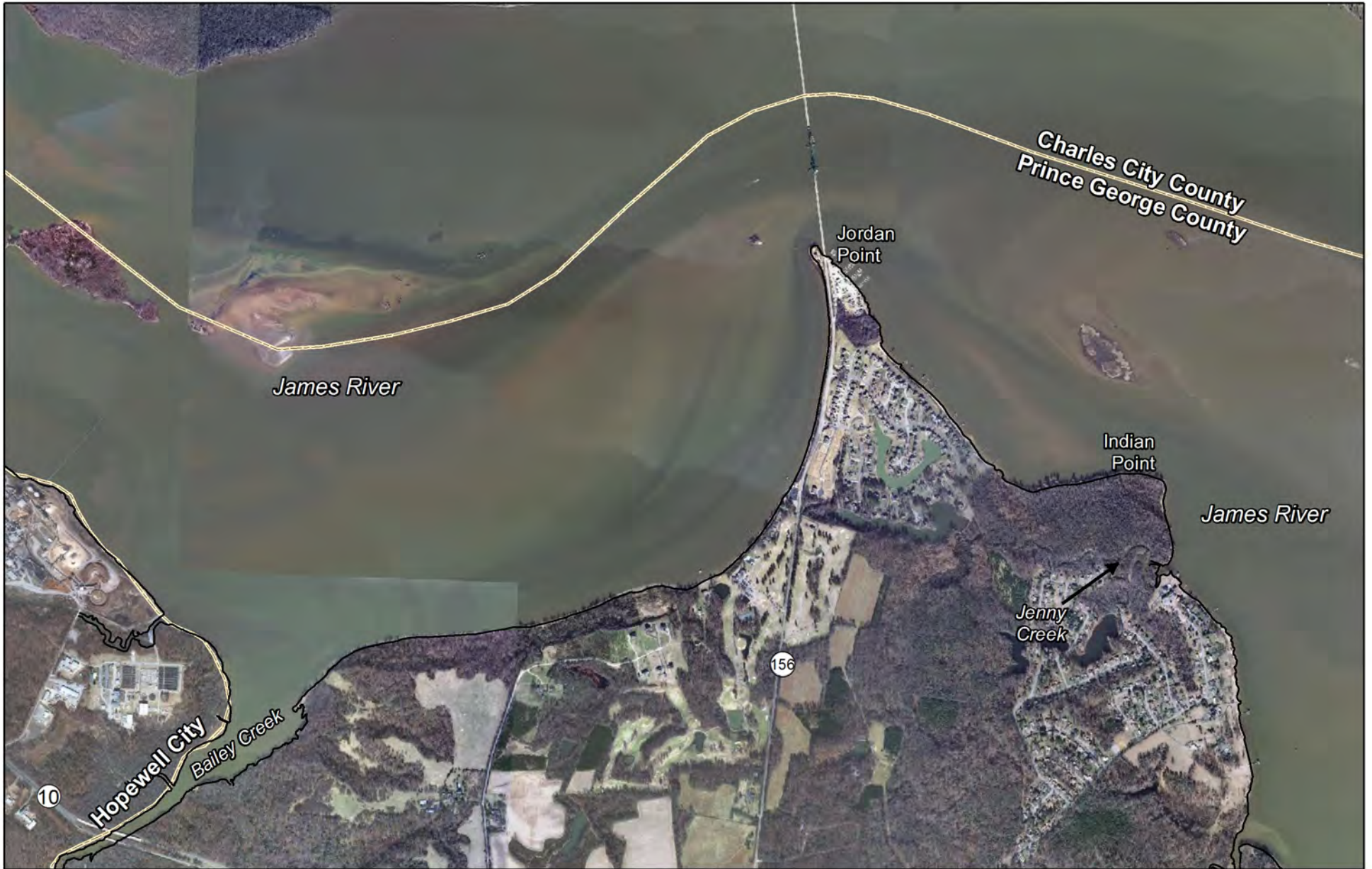


**Prince George County, Virginia
 Plate 5**



0 2,000 4,000
 Feet

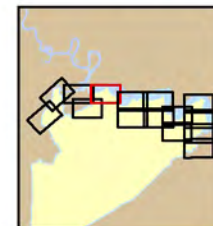
Photo Date: 2002



Legend
 — Shoreline 2009



**Prince George County, Virginia
 Plate 5**

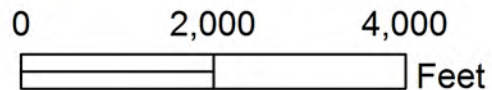


0 2,000 4,000
 Feet

Photo Date: 2009

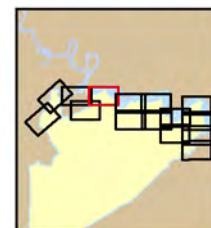


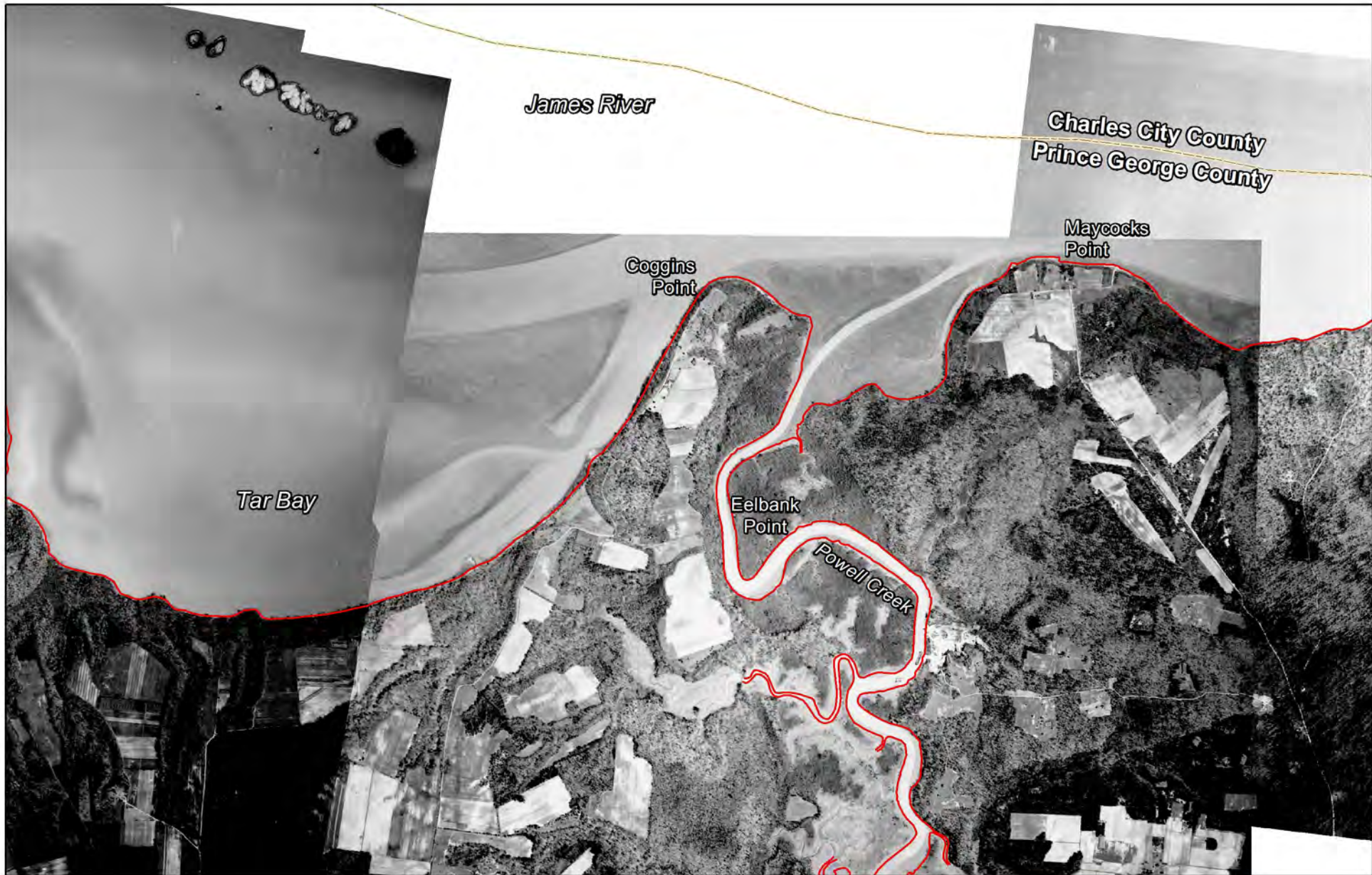
Legend
 Shoreline 2013



**Prince George County, Virginia
 Plate 5**

Photo Date: 2013





Legend
 — Shoreline 1937



**Prince George County, Virginia
 Plate 6**

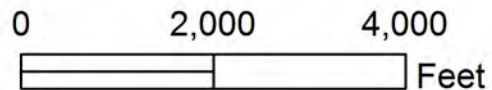


Photo Date: 1937



Legend
 — Shoreline 1954



**Prince George County, Virginia
 Plate 6**

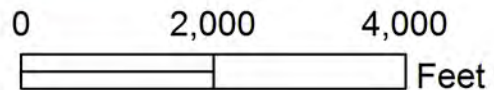


Photo Date: 1954



Legend
 — Shoreline 1965



**Prince George County, Virginia
 Plate 6**

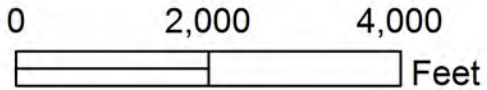



Photo Date: 1965



Legend
 Shoreline 1994



**Prince George County, Virginia
 Plate 6**

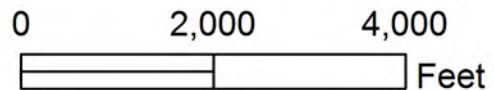
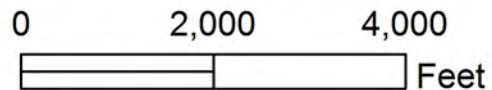


Photo Date: 1994

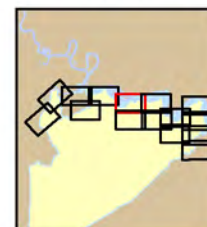


Legend
 — Shoreline 2002



**Prince George County, Virginia
 Plate 6**

Photo Date: 2002





Legend
 — Shoreline 2009



**Prince George County, Virginia
 Plate 6**

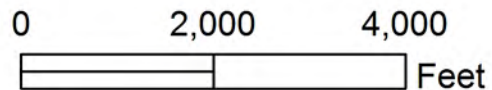


Photo Date: 2009



Legend
 — Shoreline 2013



**Prince George County, Virginia
 Plate 6**

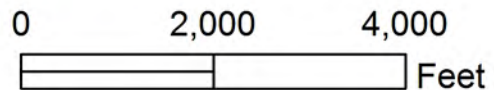


Photo Date: 2013



Legend
— Shoreline 1937



Prince George County, Virginia Plate 7

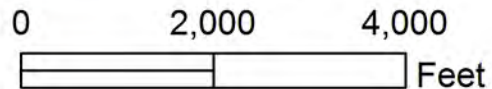
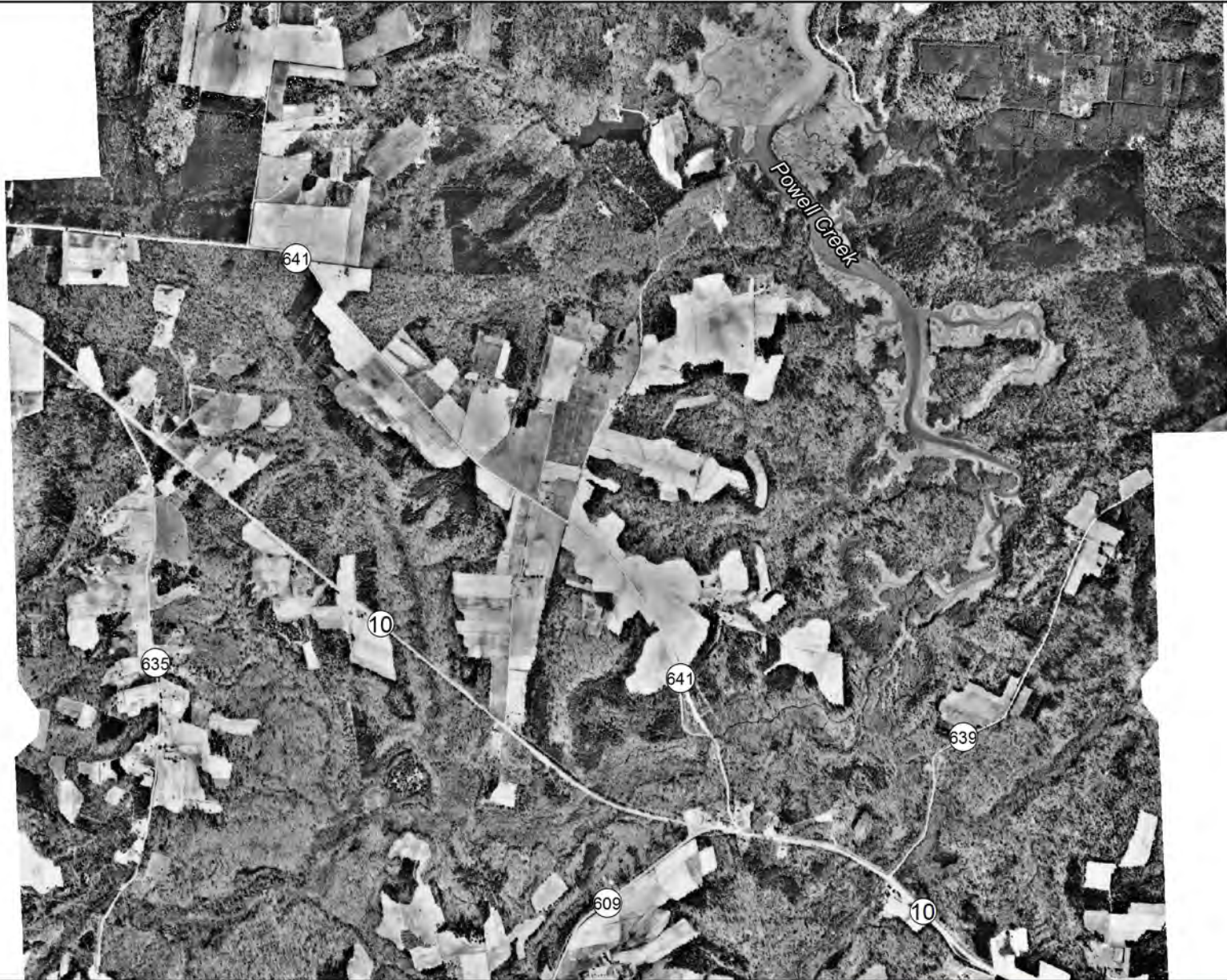


Photo Date: 1937



Legend
— Shoreline 1954

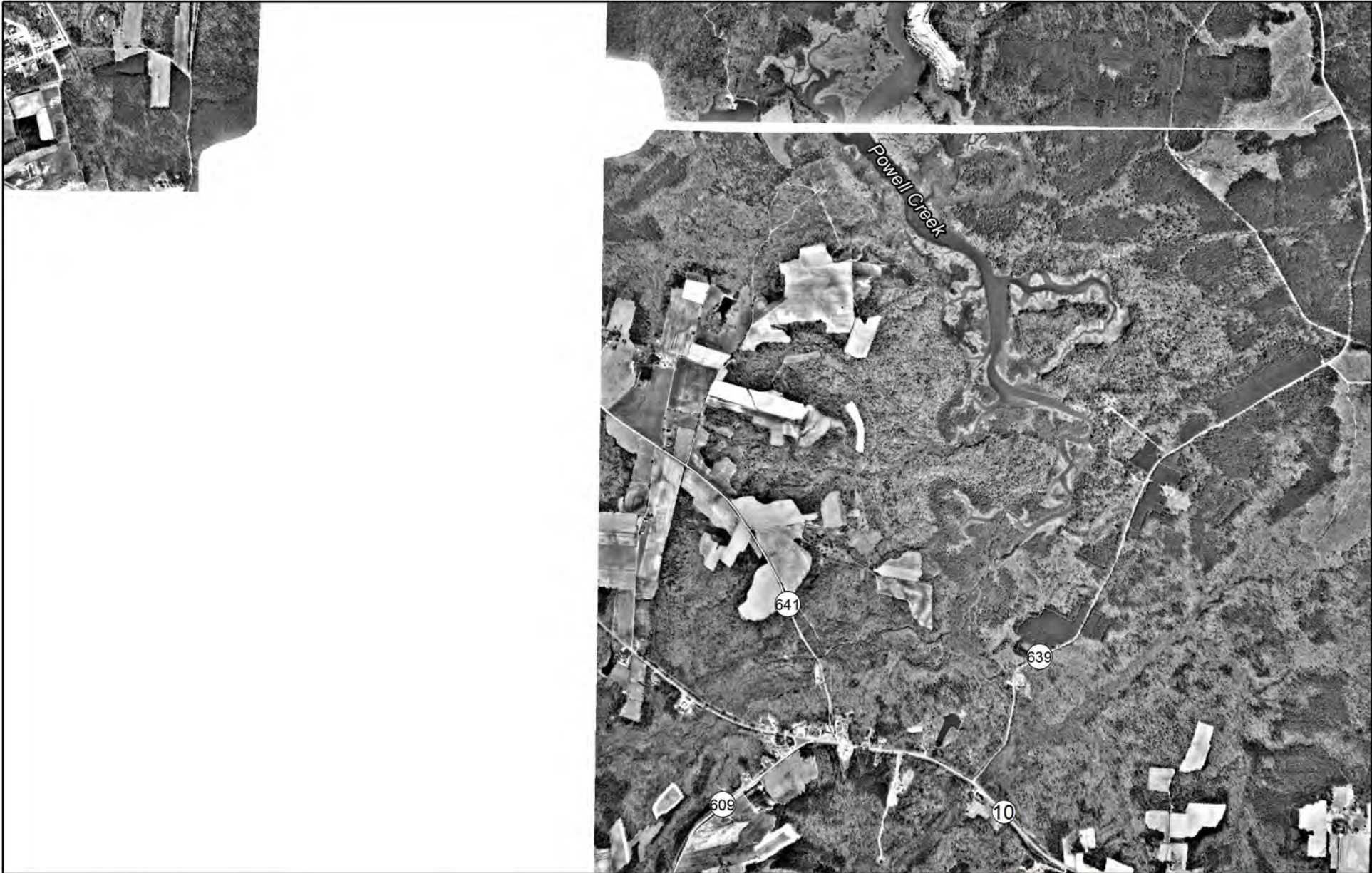


Prince George County, Virginia Plate 7

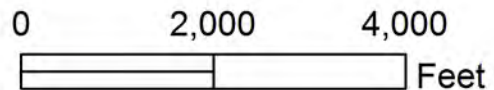


0 2,000 4,000
Feet

Photo Date: 1954

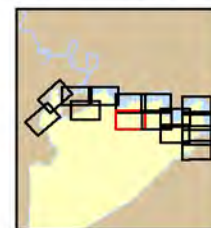


Legend
— Shoreline 1965



Prince George County, Virginia Plate 7

Photo Date: 1965





Legend
— Shoreline 1994



Prince George County, Virginia Plate 7

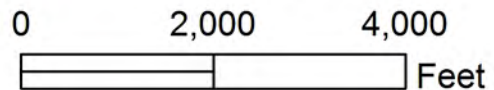


0 2,000 4,000
Feet

Photo Date: 1994

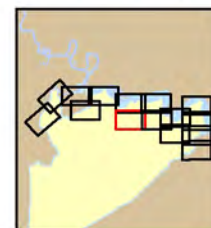


Legend
— Shoreline 2002



Prince George County, Virginia Plate 7

Photo Date: 2002





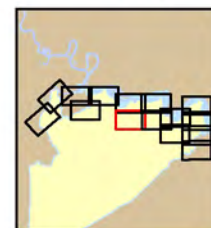
Legend
 — Shoreline 2009

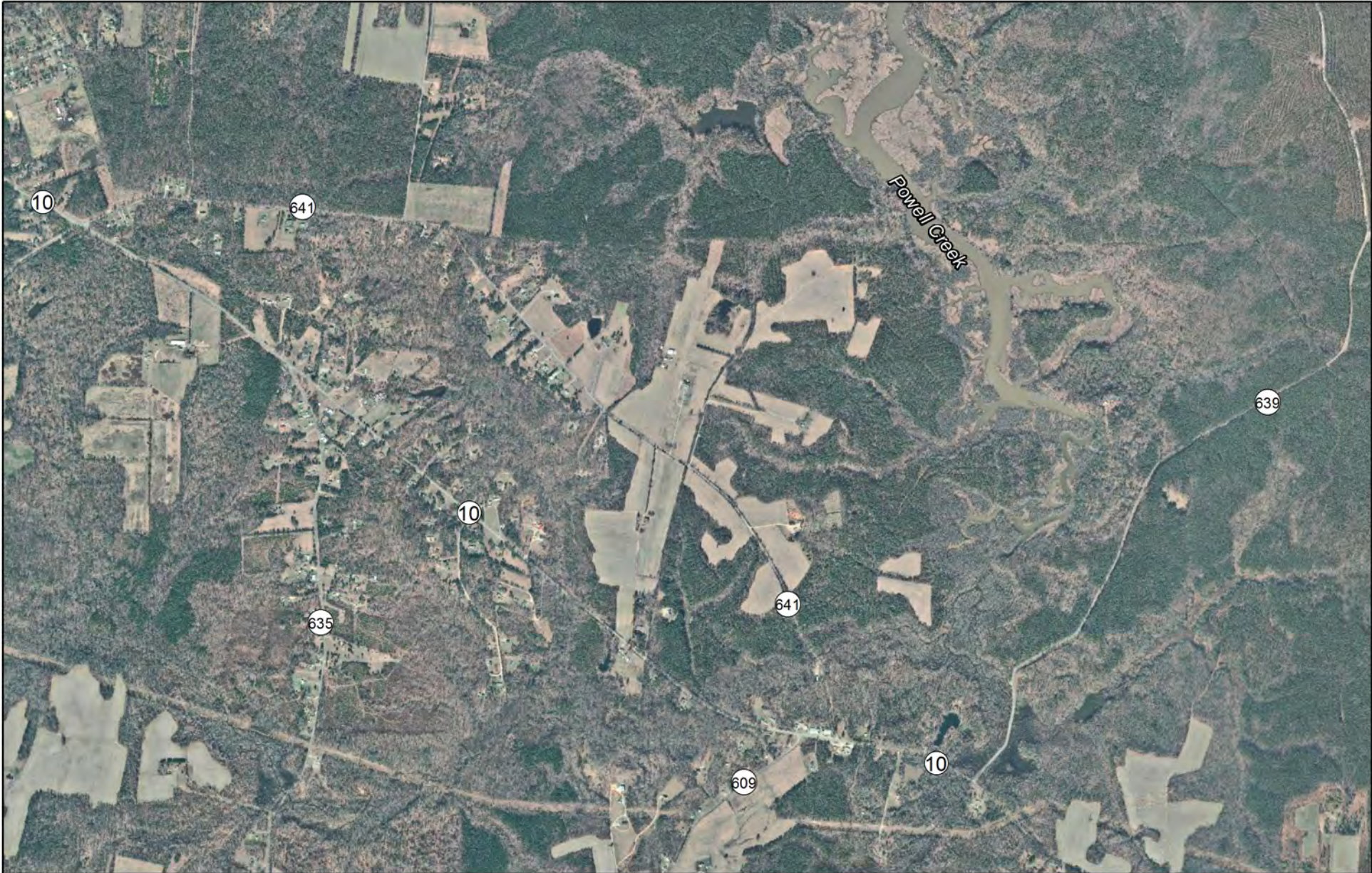


0 2,000 4,000
 Feet

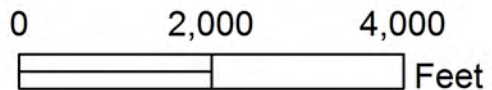
**Prince George County, Virginia
 Plate 7**

Photo Date: 2009



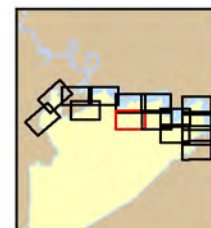


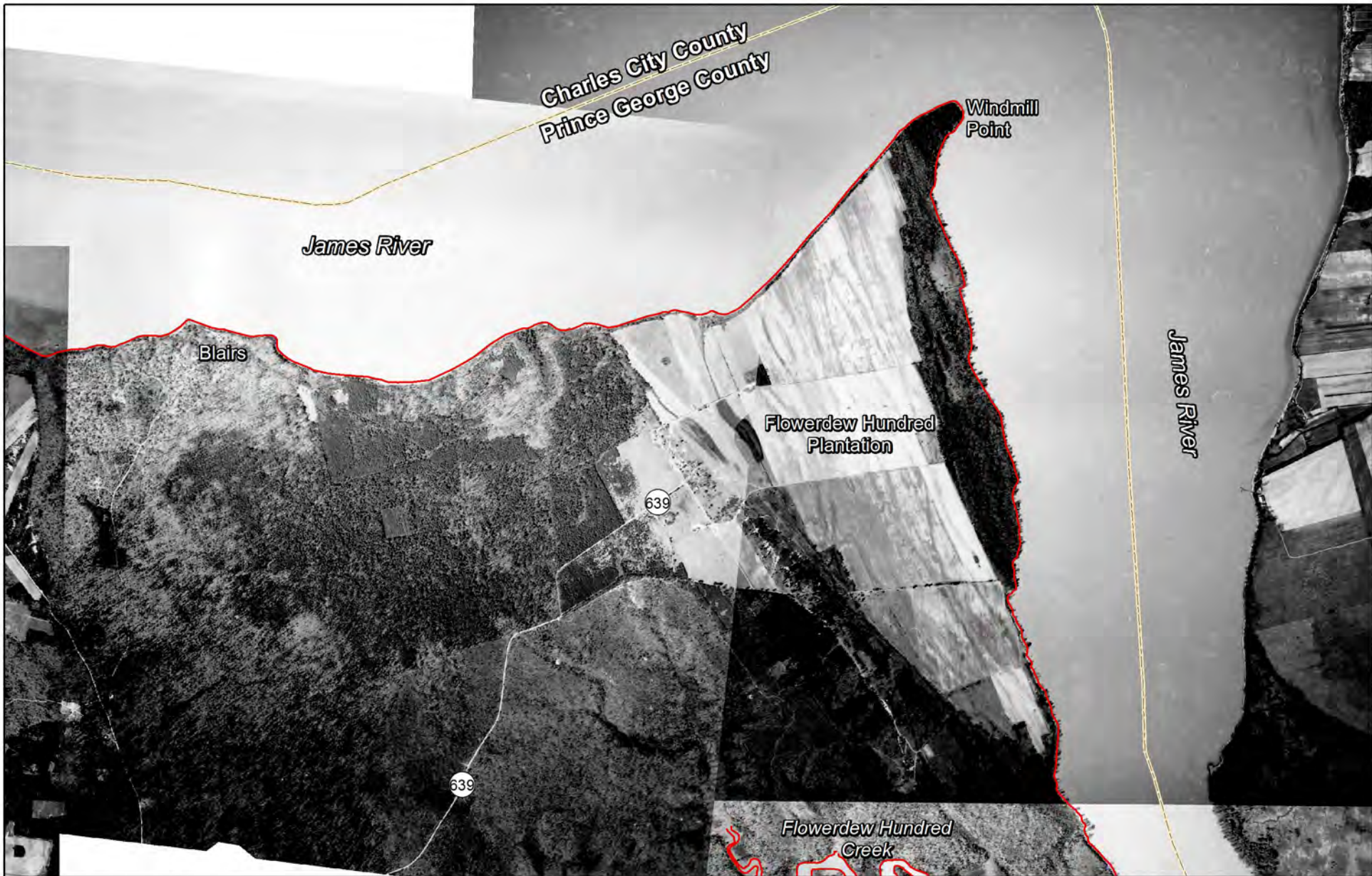
Legend
— Shoreline 2013



Prince George County, Virginia Plate 7

Photo Date: 2013





Legend
 — Shoreline 1937



0 2,000 4,000
 Feet

**Prince George County, Virginia
 Plate 8**

Photo Date: 1937





Legend
 — Shoreline 1954



0 2,000 4,000
 Feet

**Prince George County, Virginia
 Plate 8**

Photo Date: 1954





Legend
 — Shoreline 1965



**Prince George County, Virginia
 Plate 8**

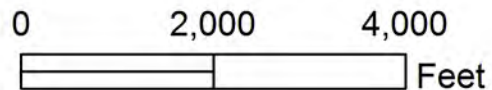


Photo Date: 1965



Legend
 — Shoreline 1994



**Prince George County, Virginia
 Plate 8**

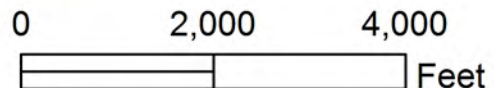
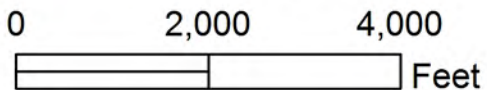


Photo Date: 1994



Legend
 — Shoreline 2002



**Prince George County, Virginia
 Plate 8**

Photo Date: 2002





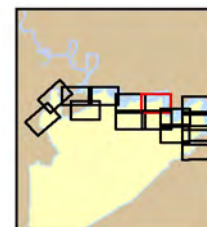
Legend
 — Shoreline 2009



0 2,000 4,000
 Feet

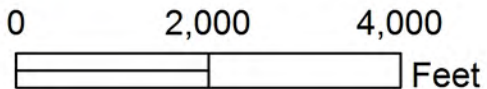
**Prince George County, Virginia
 Plate 8**

Photo Date: 2009





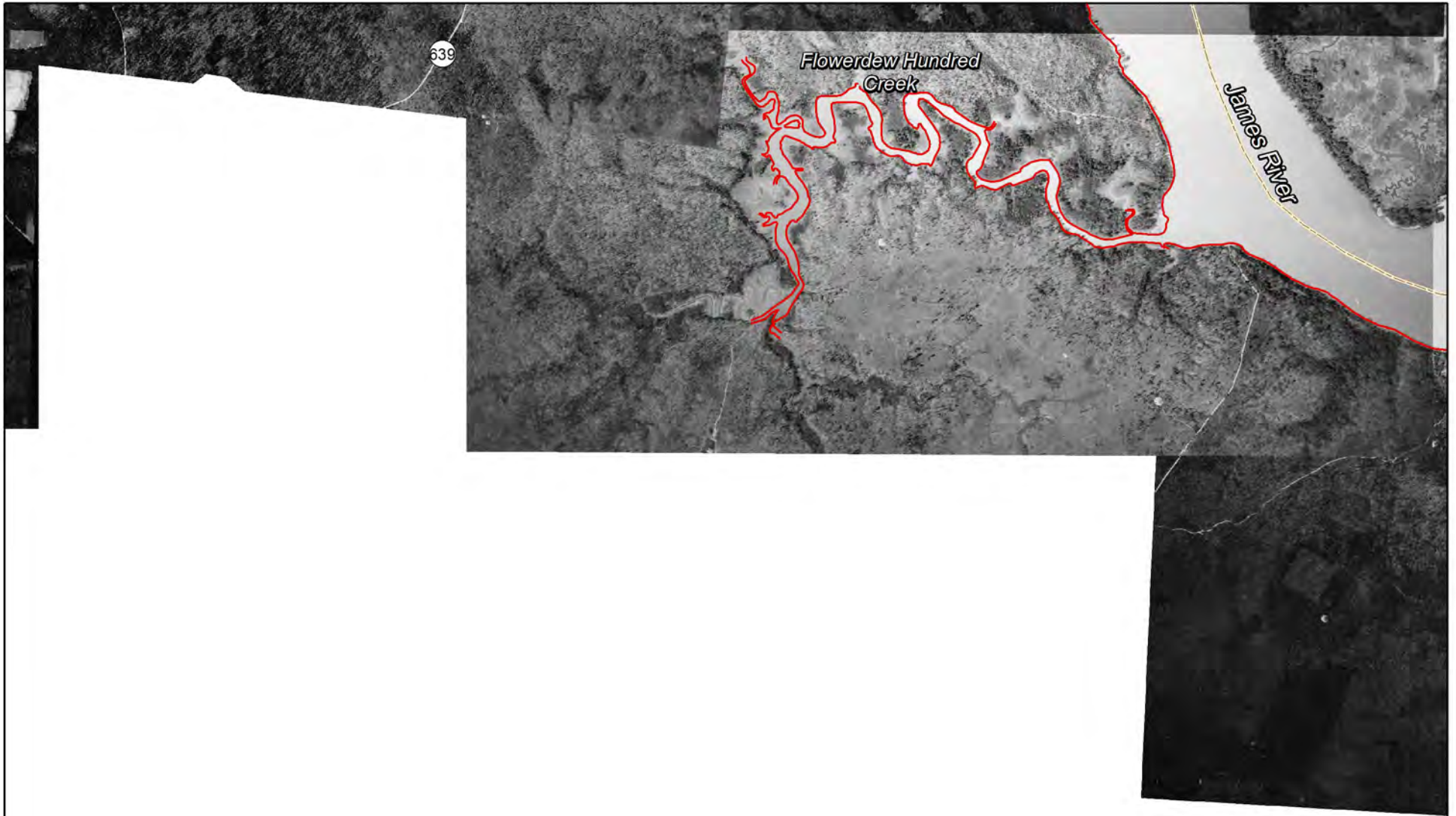
Legend
 — Shoreline 2013



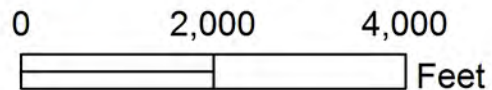
**Prince George County, Virginia
 Plate 8**

Photo Date: 2013





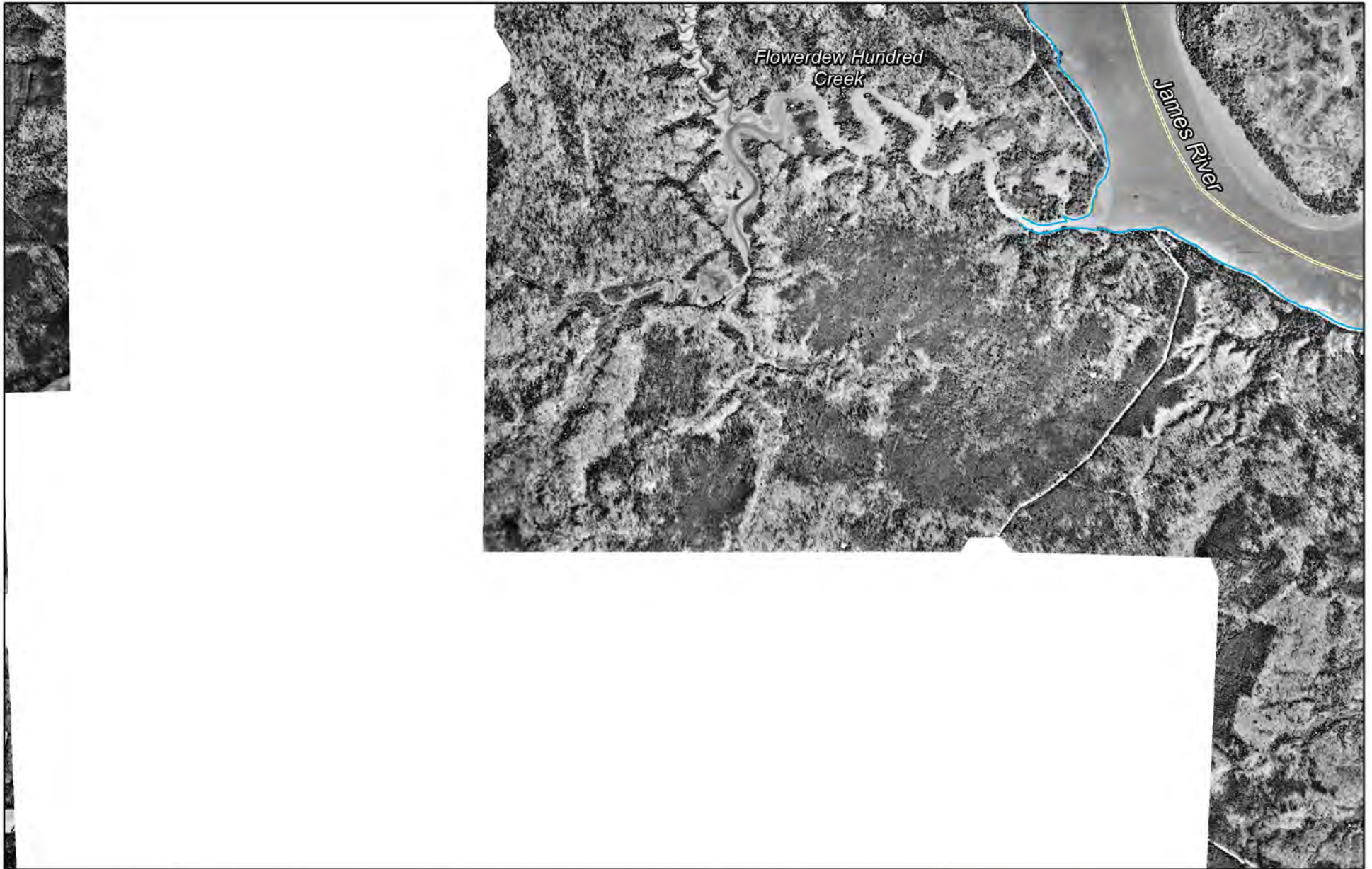
Legend
— Shoreline 1937



Prince George County, Virginia Plate 9

Photo Date: 1937

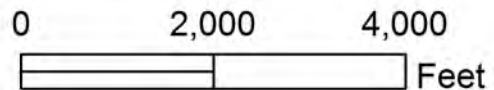




Flowerdew Hundred
Creek

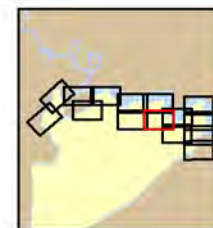
James River

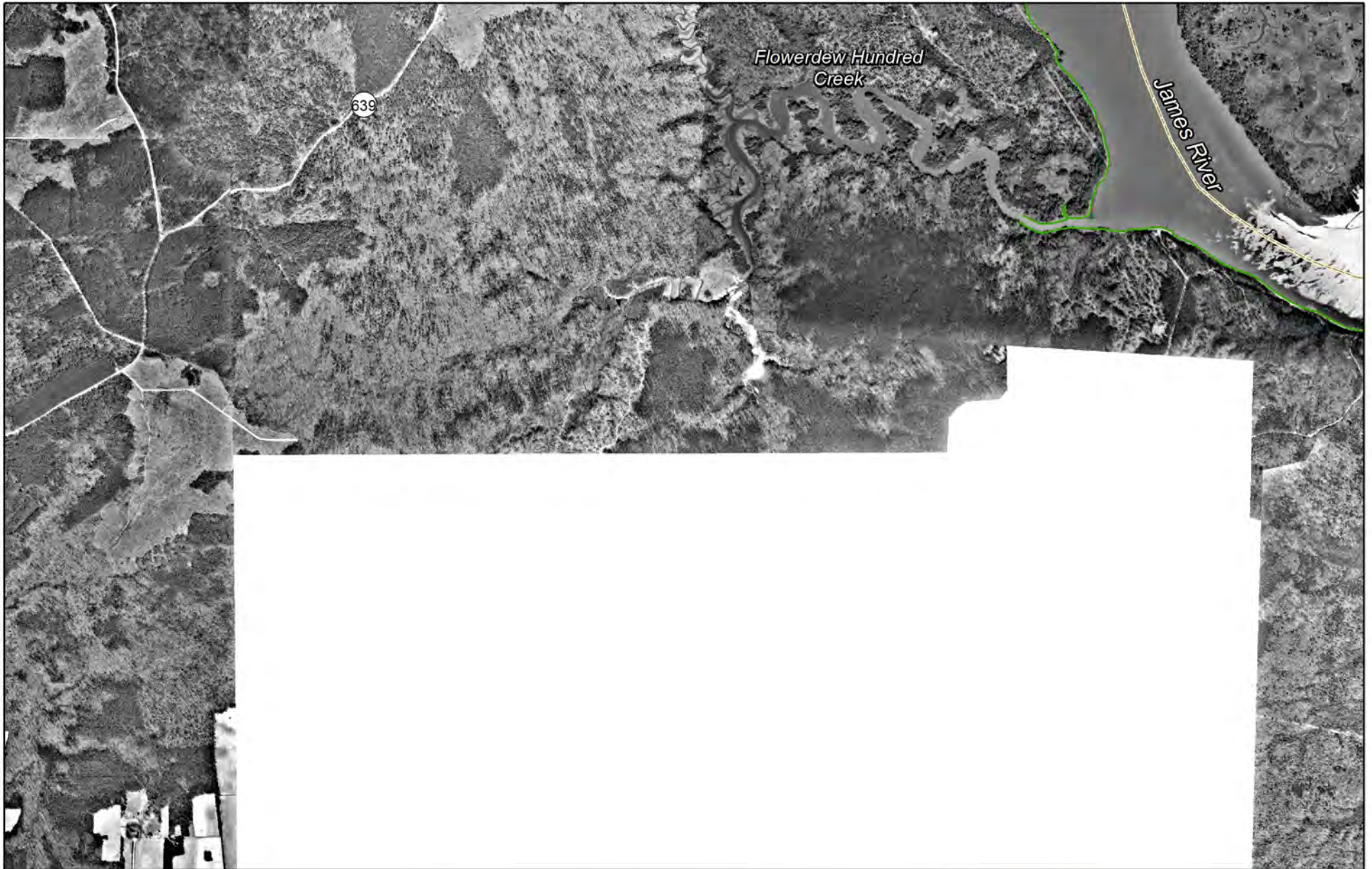
Legend
— Shoreline 1954



Prince George County, Virginia Plate 9

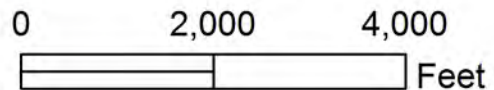
Photo Date: 1954





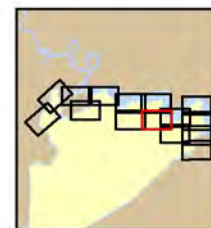
Legend

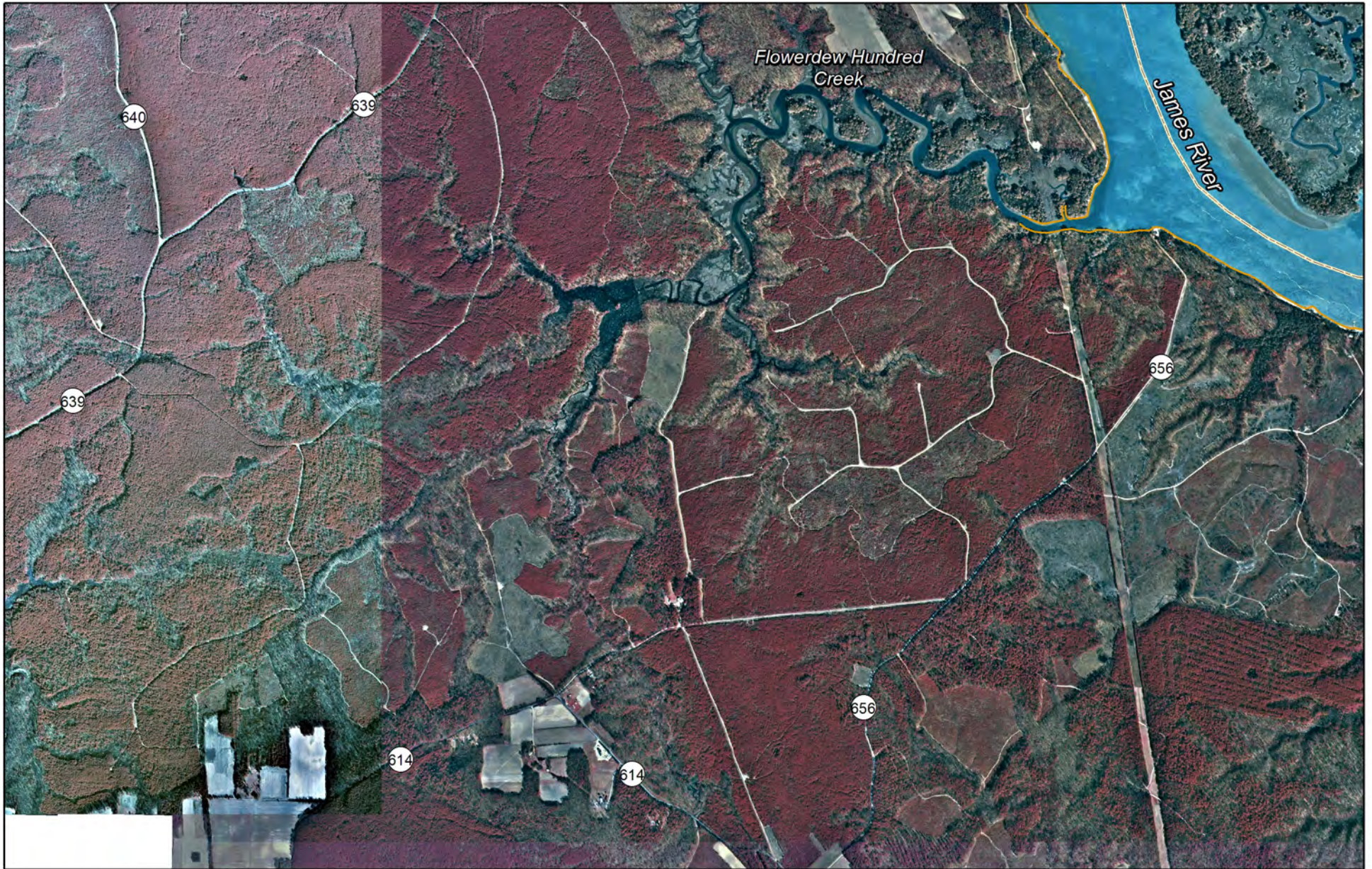
— Shoreline 1965



**Prince George County, Virginia
Plate 9**

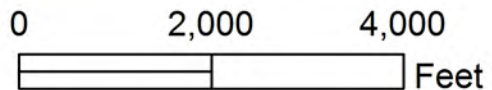
Photo Date: 1965





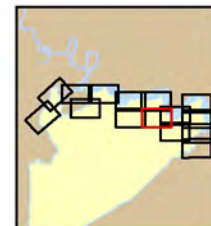
Legend

— Shoreline 1994



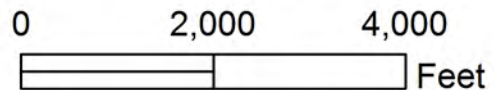
**Prince George County, Virginia
Plate 9**

Photo Date: 1994



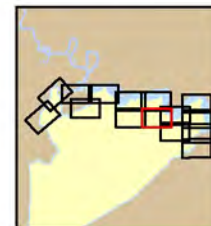


Legend
— Shoreline 2002



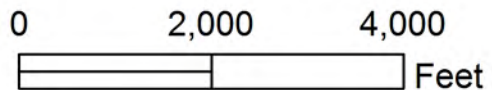
Prince George County, Virginia Plate 9

Photo Date: 2002



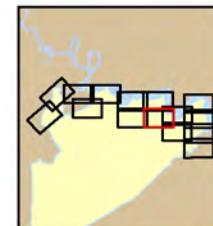


Legend
 — Shoreline 2009




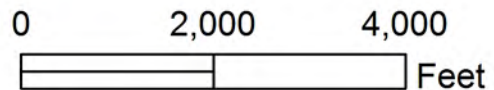
**Prince George County, Virginia
 Plate 9**

Photo Date: 2009



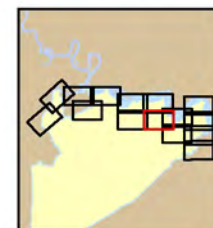


Legend
 Shoreline 2013



**Prince George County, Virginia
 Plate 9**

Photo Date: 2013





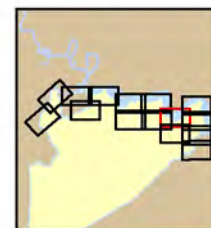
Legend
 — Shoreline 1937

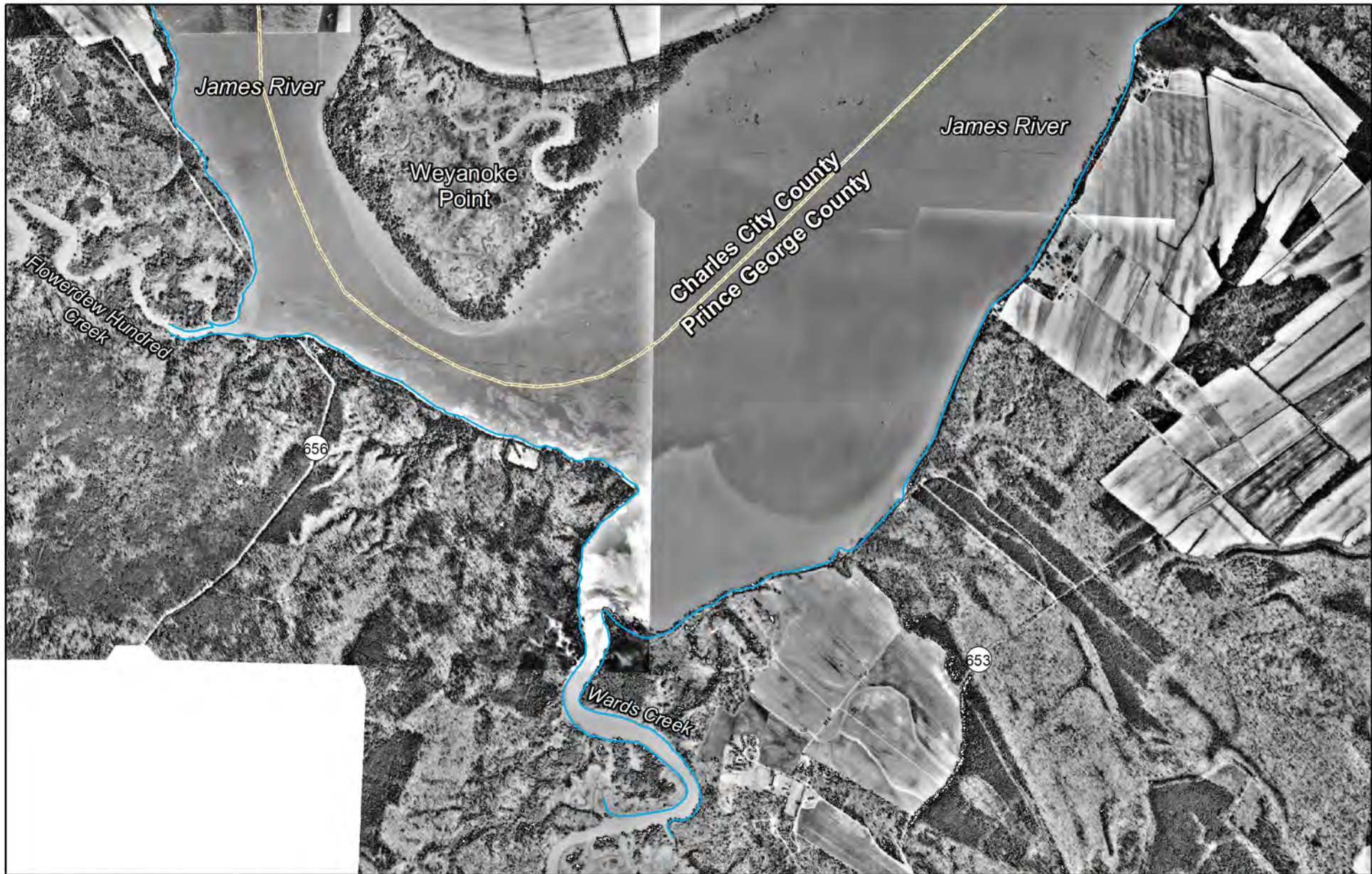


0 2,000 4,000
 Feet

**Prince George County, Virginia
 Plate 10**

Photo Date: 1937





Legend
— Shoreline 1954



0 2,000 4,000
Feet

Prince George County, Virginia Plate 10

Photo Date: 1954





Legend
 — Shoreline 1965



0 2,000 4,000
 Feet

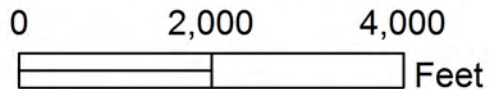
Prince George County, Virginia Plate 10

Photo Date: 1965



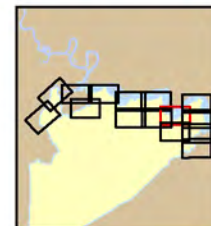


Legend
 — Shoreline 1994



**Prince George County, Virginia
 Plate 10**

Photo Date: 1994





Legend
 — Shoreline 2002



0 2,000 4,000
 Feet

**Prince George County, Virginia
 Plate10**

Photo Date: 2002





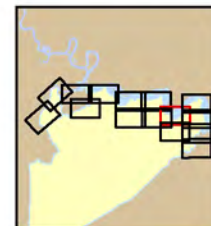
Legend
 — Shoreline 2009



0 2,000 4,000
 Feet

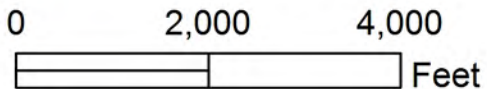
**Prince George County, Virginia
 Plate10**

Photo Date: 2009



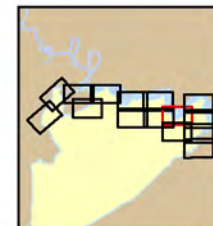


Legend
 — Shoreline 2013



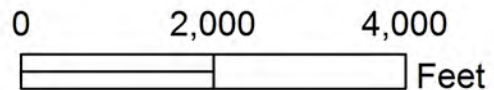
**Prince George County, Virginia
 Plate10**

Photo Date: 2013





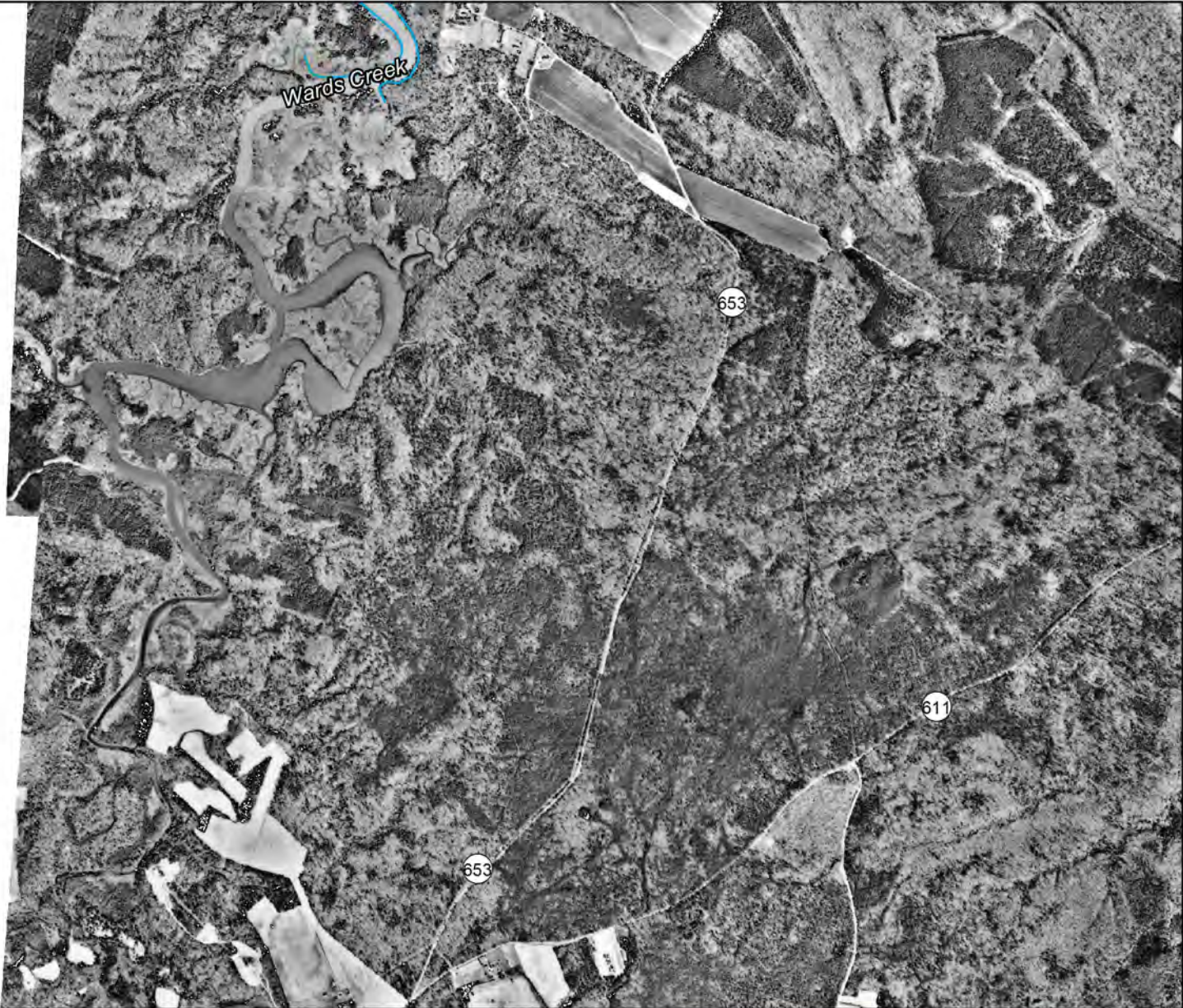
Legend
— Shoreline 1937



Prince George County, Virginia Plate 11

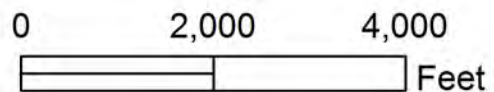
Photo Date: 1937





Legend

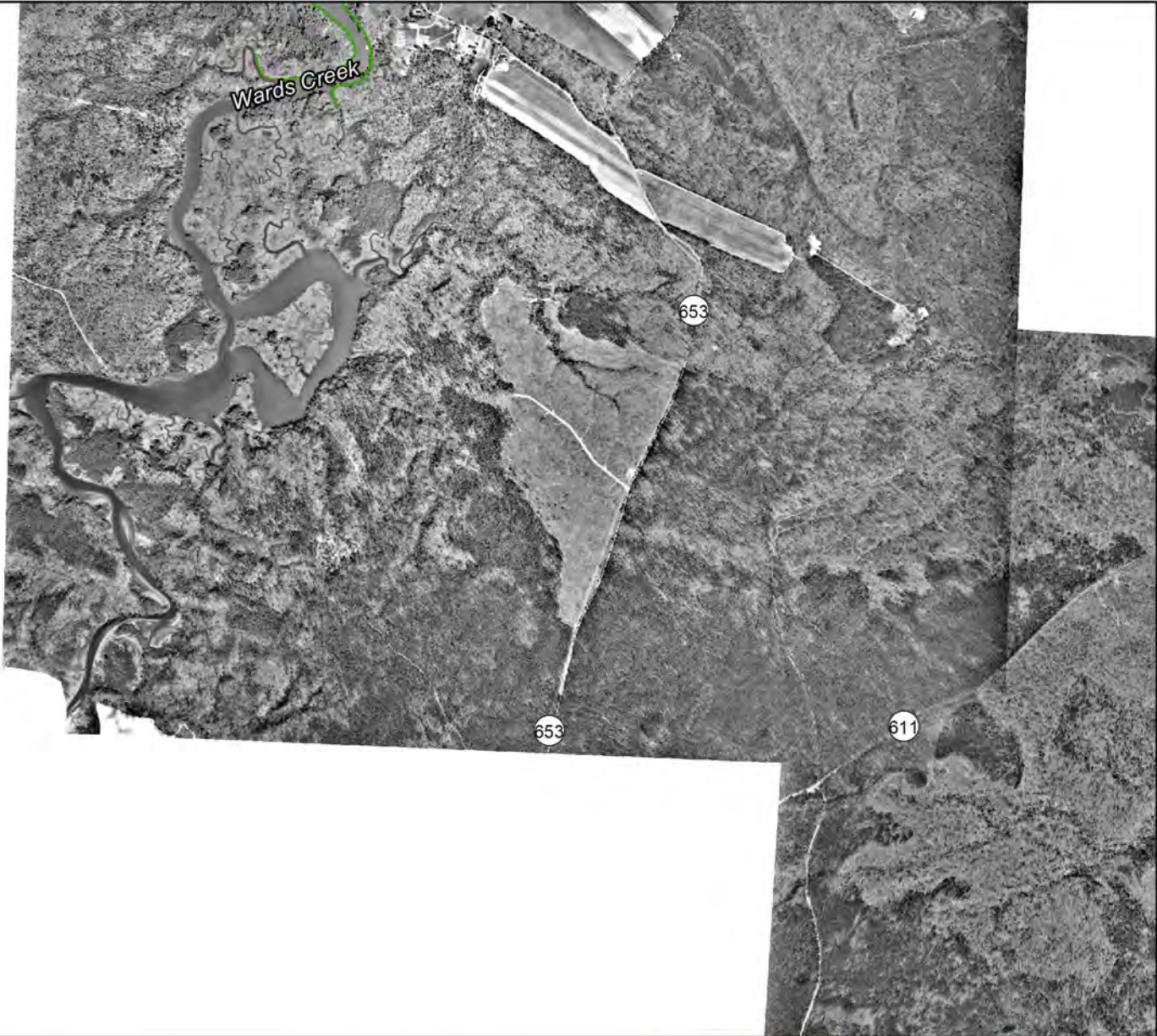
— Shoreline 1954



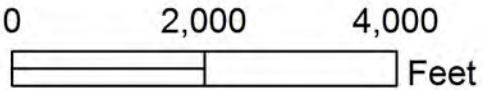
**Prince George County, Virginia
Plate 11**

Photo Date: 1954





Legend
— Shoreline 1965



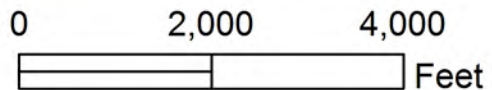
Prince George County, Virginia Plate 11

Photo Date: 1965





Legend
 — Shoreline 1994



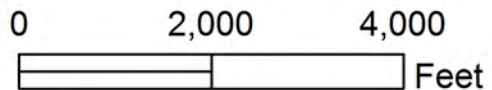
**Prince George County, Virginia
 Plate 11**

Photo Date: 1994





Legend
— Shoreline 2002



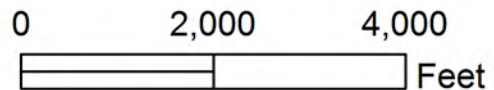
Prince George County, Virginia Plate 11

Photo Date: 2002





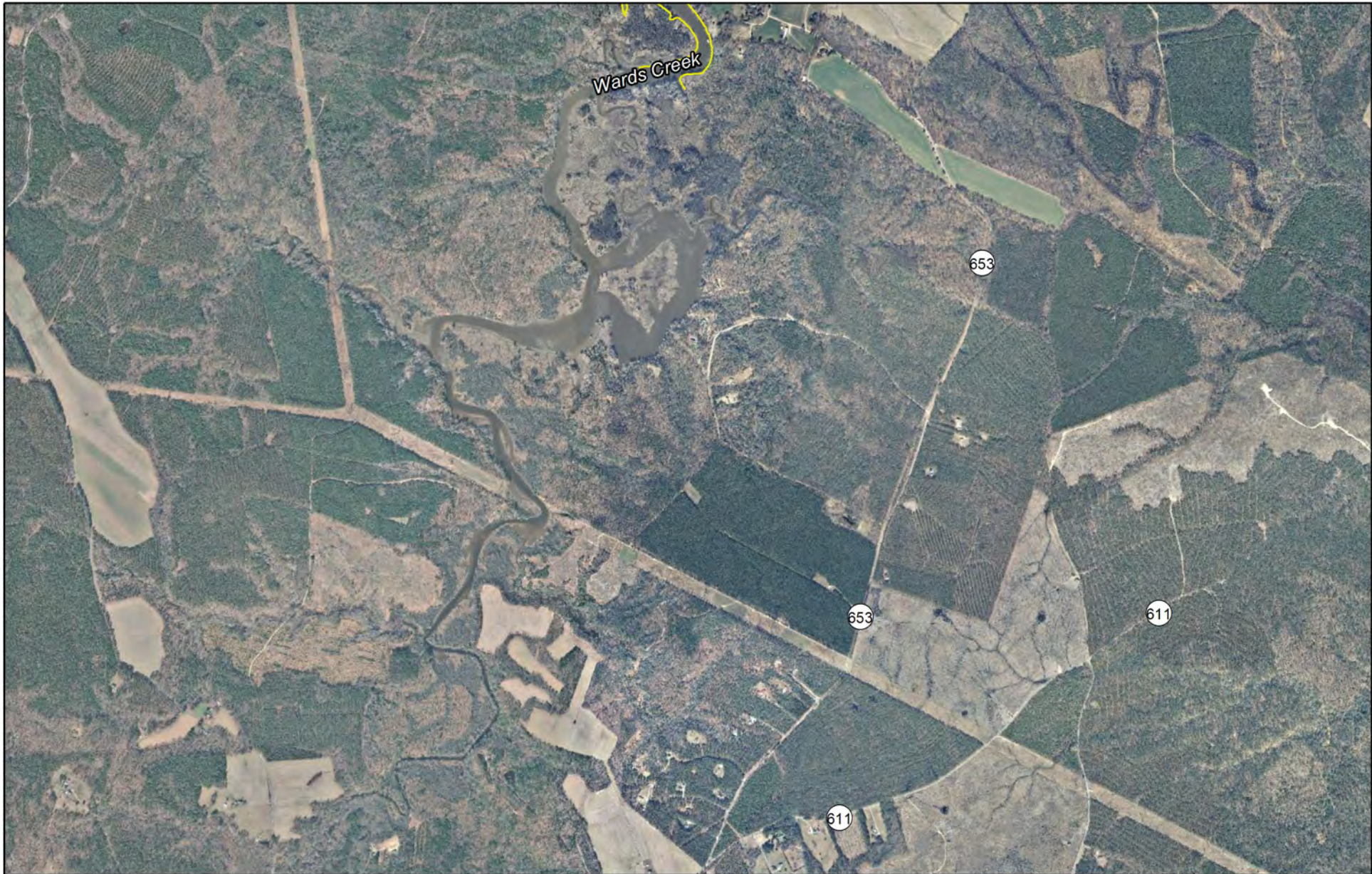
Legend
— Shoreline 2009



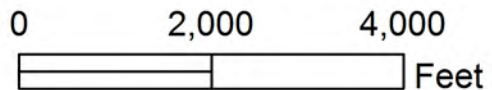
Prince George County, Virginia Plate 11

Photo Date: 2009





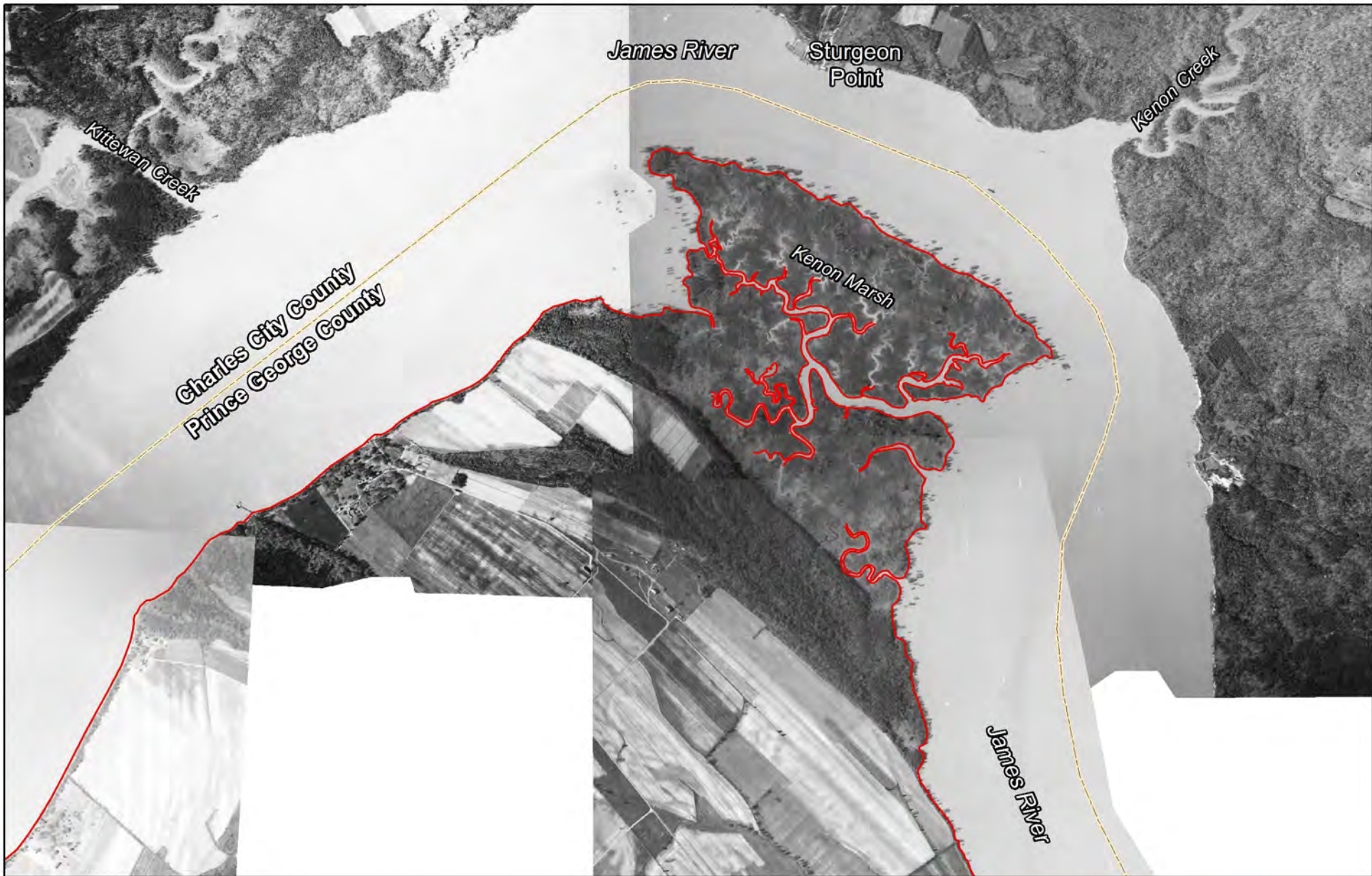
Legend
— Shoreline 2013



Prince George County, Virginia Plate 11

Photo Date: 2013





Legend
 — Shoreline 1937



**Prince George County, Virginia
 Plate 12**

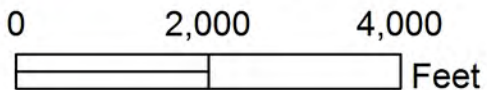
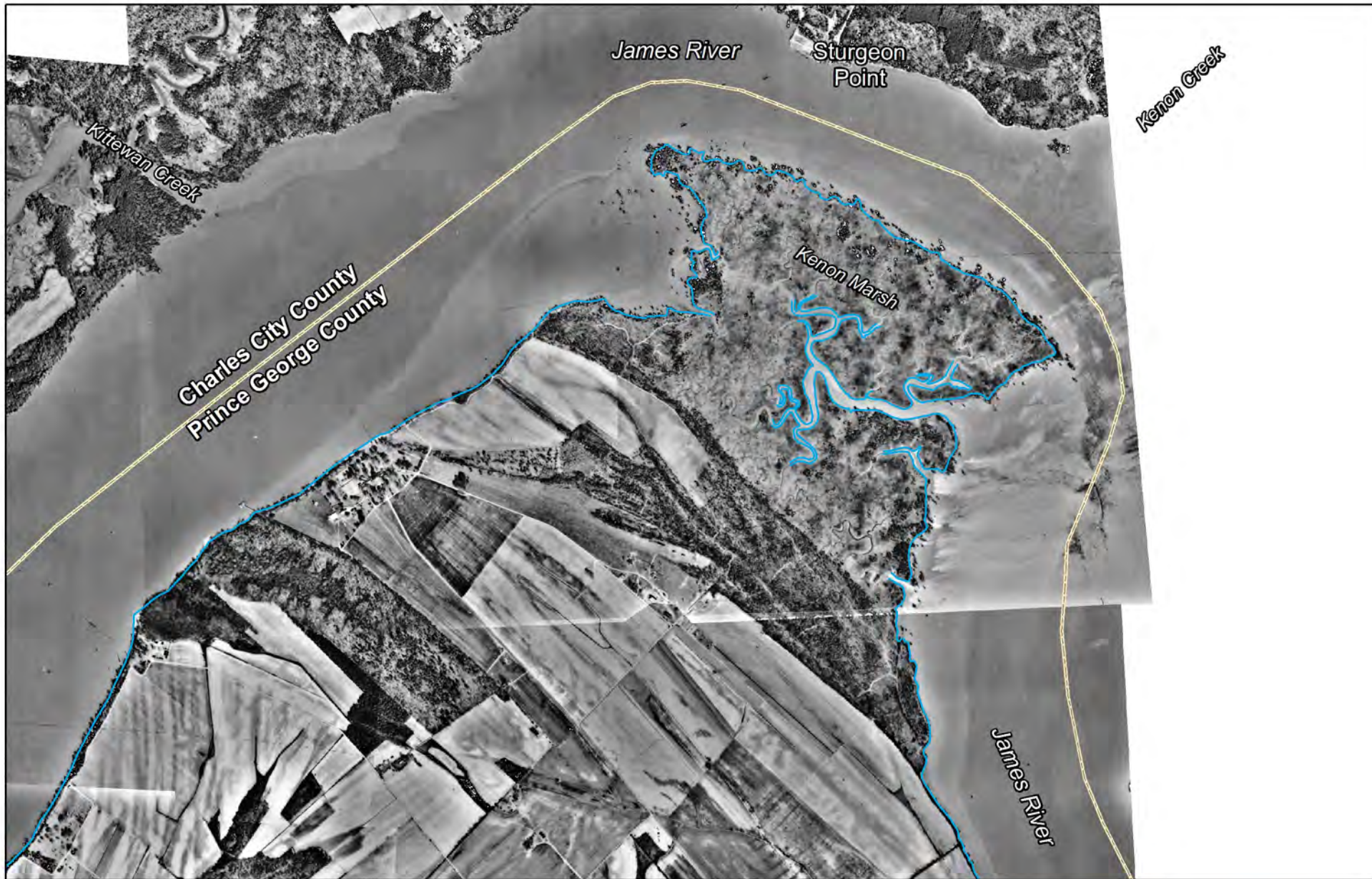


Photo Date: 1937





Legend
 — Shoreline 1954



**Prince George County, Virginia
 Plate 12**

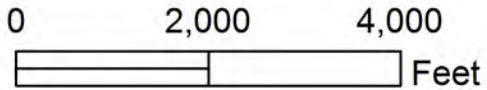
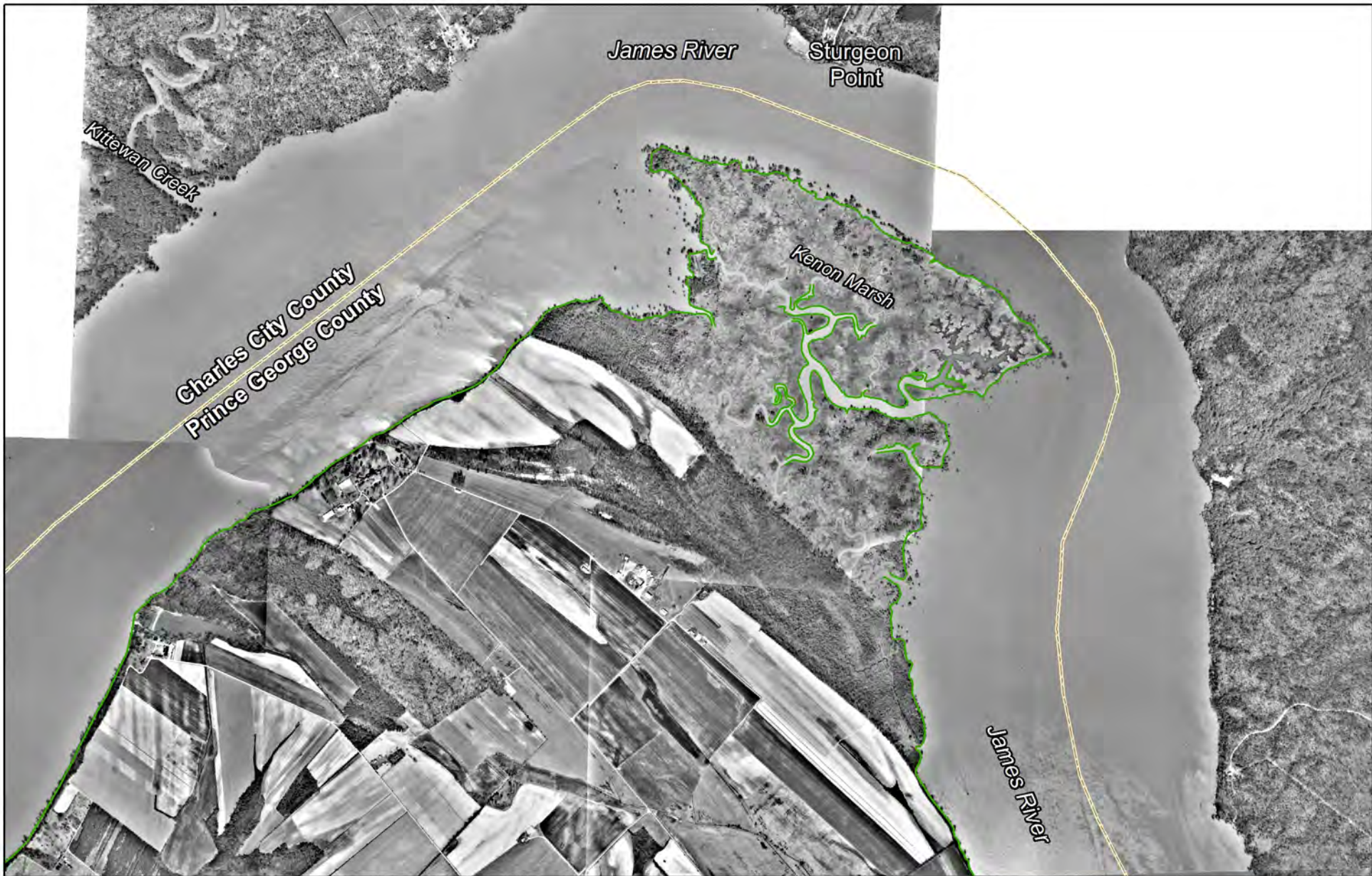


Photo Date: 1954



Legend
 Shoreline 1965



**Prince George County, Virginia
 Plate 12**

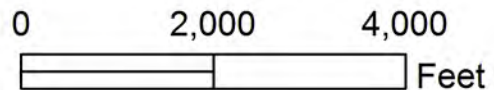
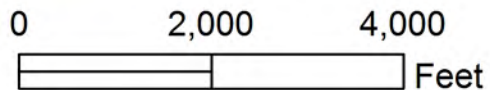


Photo Date: 1965

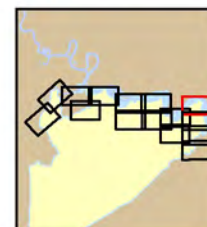


Legend
 — Shoreline 1994




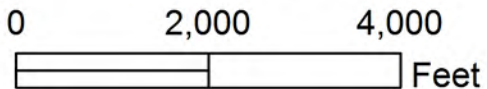
**Prince George County, Virginia
 Plate 12**

Photo Date: 1994



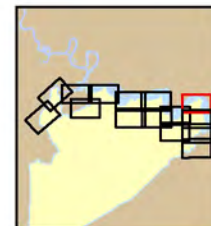


Legend
 Shoreline 2002



**Prince George County, Virginia
 Plate12**

Photo Date: 2002





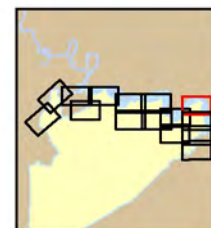
Legend
 — Shoreline 2009



0 2,000 4,000
 Feet

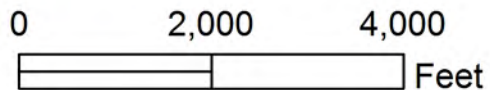
**Prince George County, Virginia
 Plate 12**

Photo Date: 2009





Legend
 — Shoreline 2013



**Prince George County, Virginia
 Plate12**

Photo Date: 2013





Legend
— Shoreline 1937



0 2,000 4,000
Feet

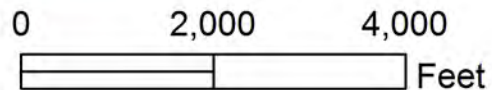
Prince George County, Virginia Plate 13

Photo Date: 1937





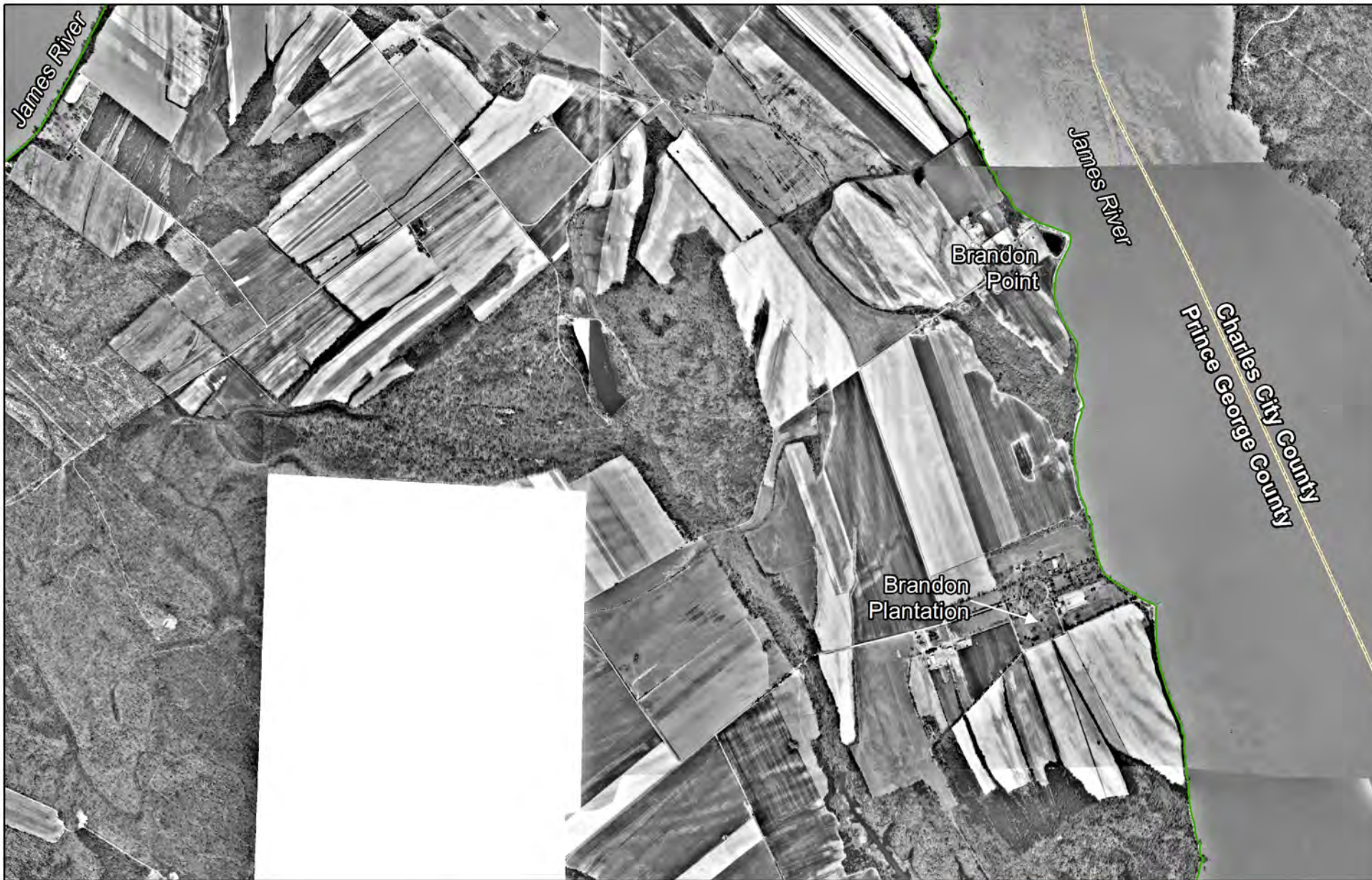
Legend
— Shoreline 1954



Prince George County, Virginia Plate 13

Photo Date: 1954





Legend
— Shoreline 1965

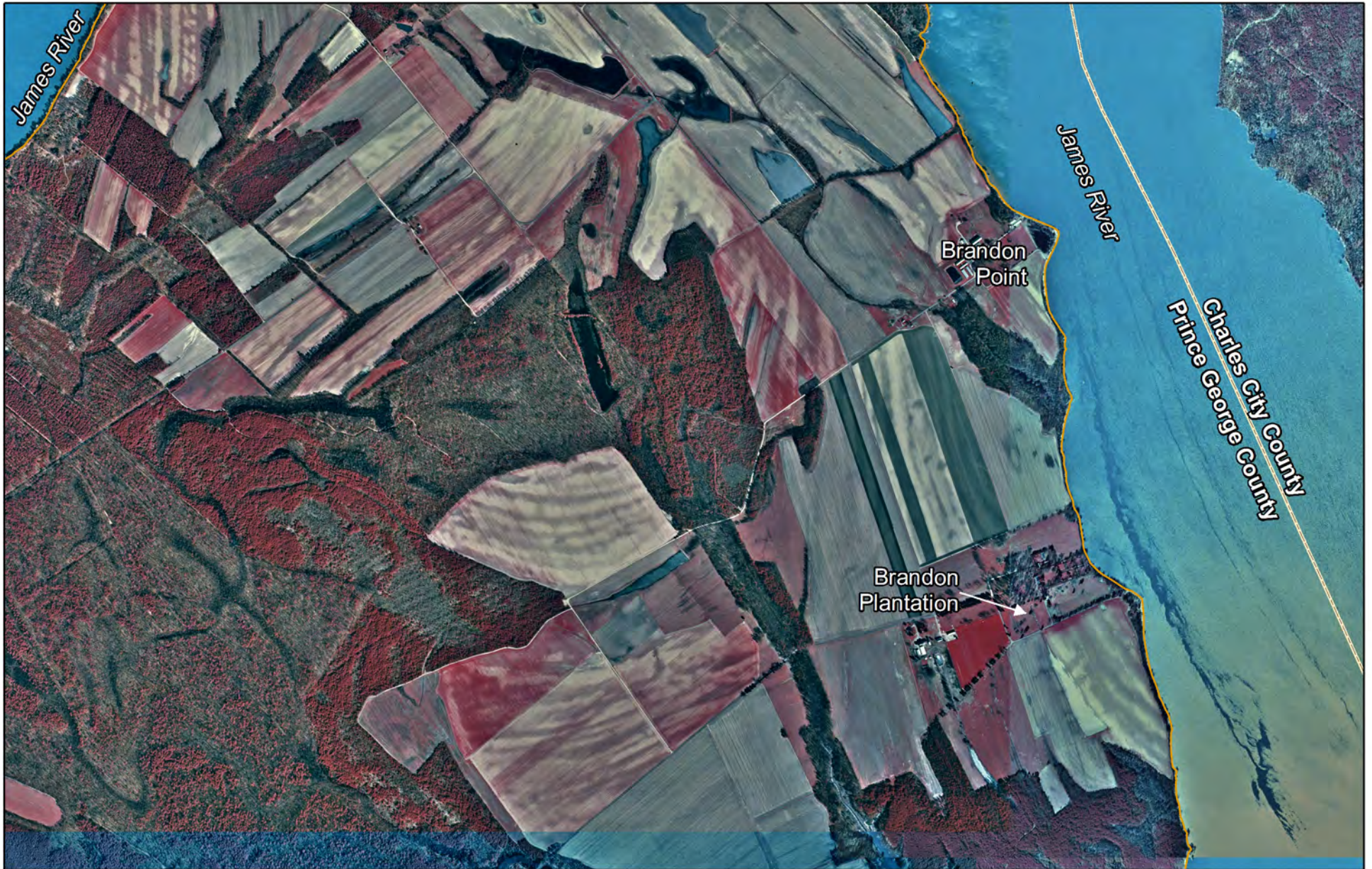


0 2,000 4,000
Feet

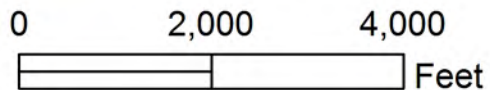
Prince George County, Virginia Plate 13

Photo Date: 1965





Legend
 — Shoreline 1994



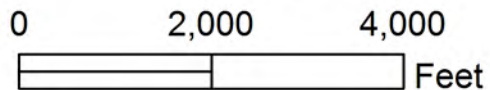
**Prince George County, Virginia
 Plate 13**

Photo Date: 1994





Legend
— Shoreline 2002



Prince George County, Virginia Plate 13

Photo Date: 2002





Legend
— Shoreline 2009




0 2,000 4,000
[Scale bar] Feet

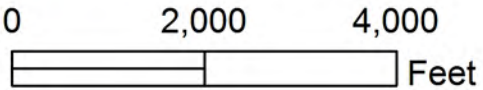
Prince George County, Virginia Plate 13

Photo Date: 2009





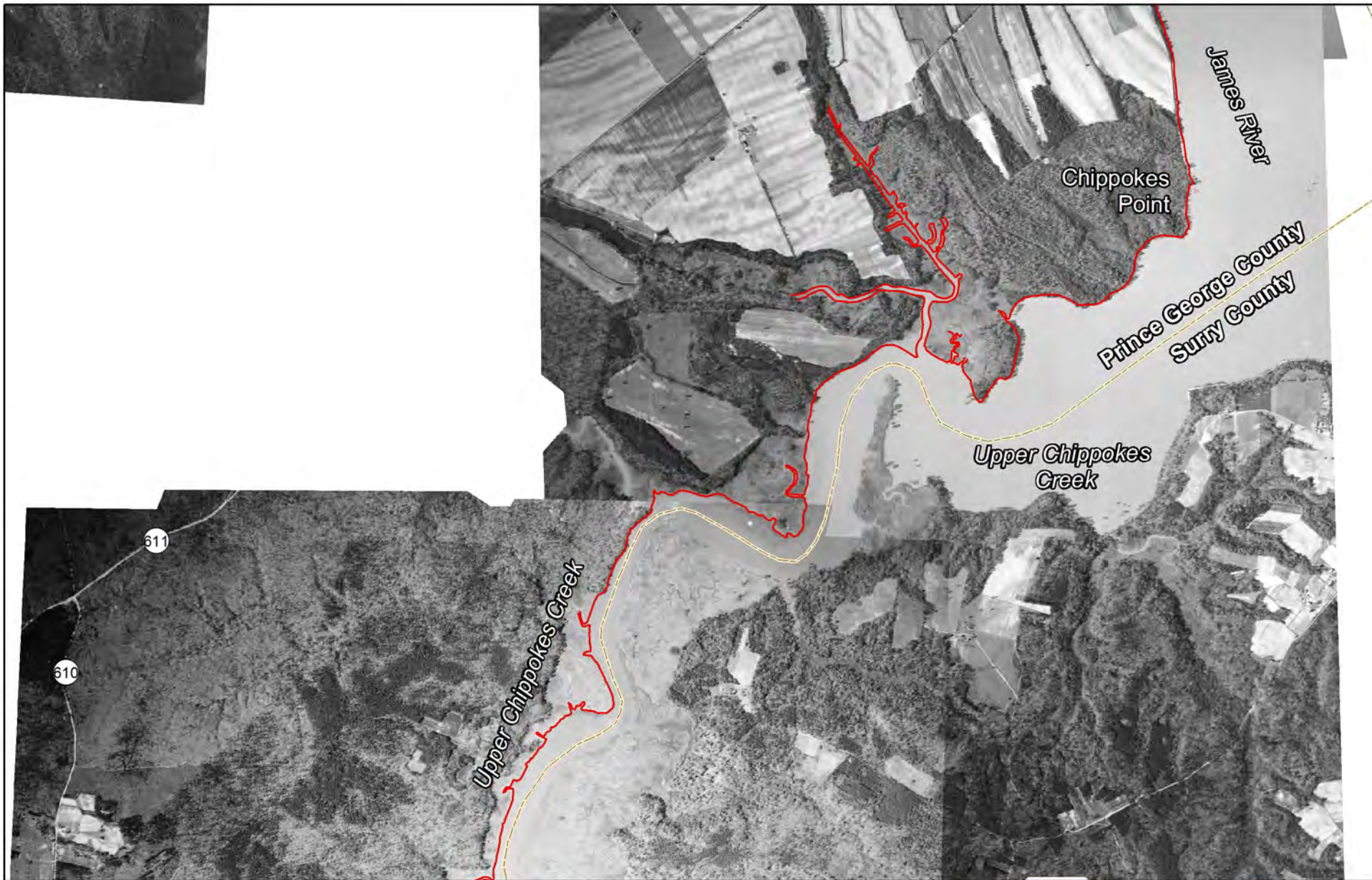
Legend
 Shoreline 2013



**Prince George County, Virginia
 Plate13**

Photo Date: 2013





Legend
 — Shoreline 1937

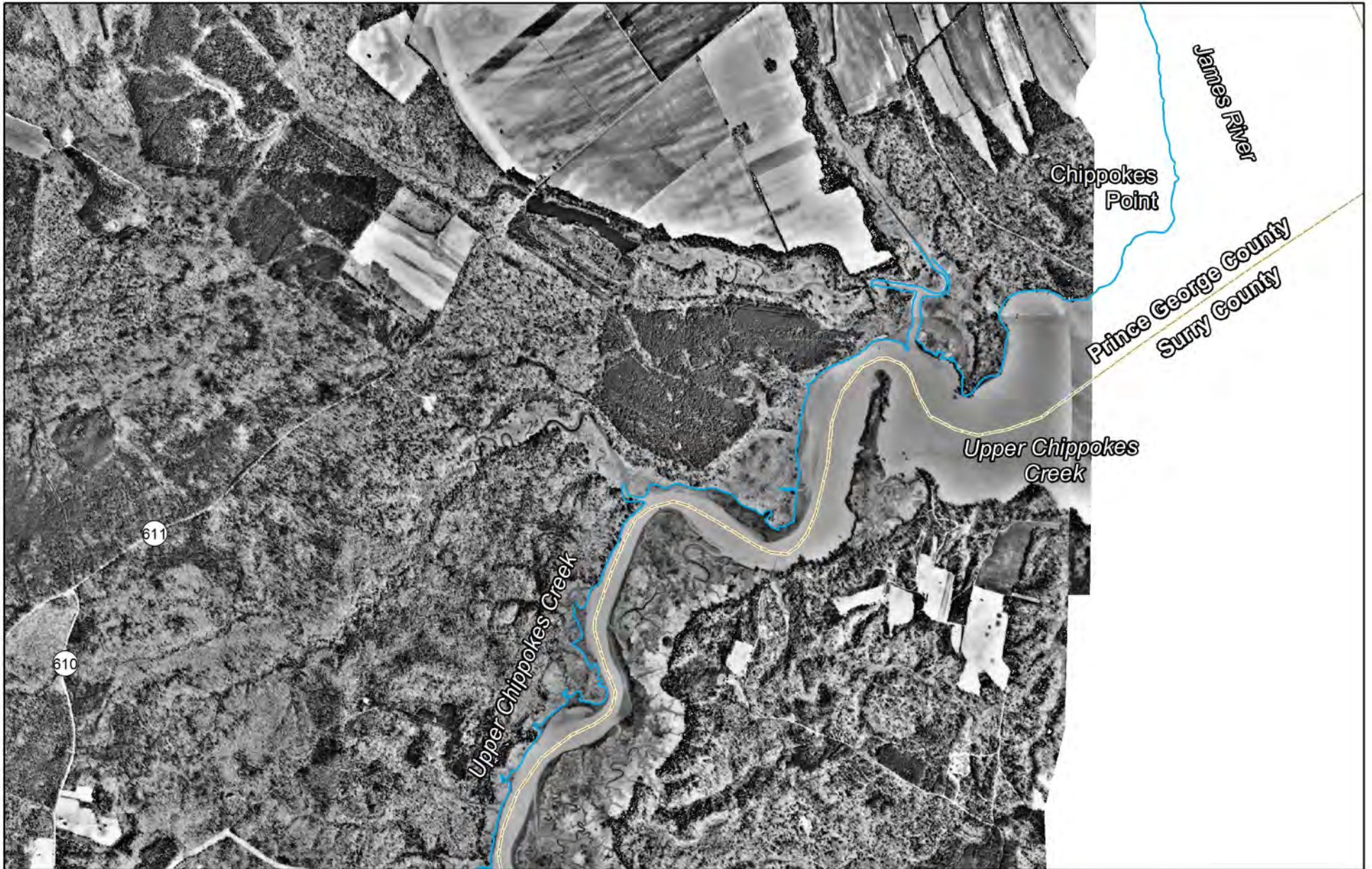


**Prince George County, Virginia
 Plate 14**



0 2,000 4,000
 Feet

Photo Date: 1937



Legend
 — Shoreline 1954



**Prince George County, Virginia
 Plate 14**

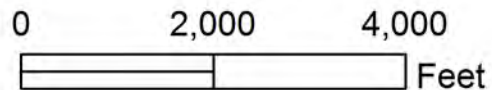
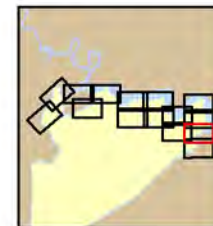


Photo Date: 1954



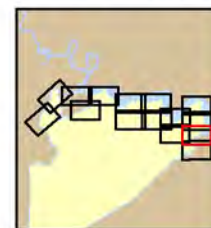
Legend
 — Shoreline 1965

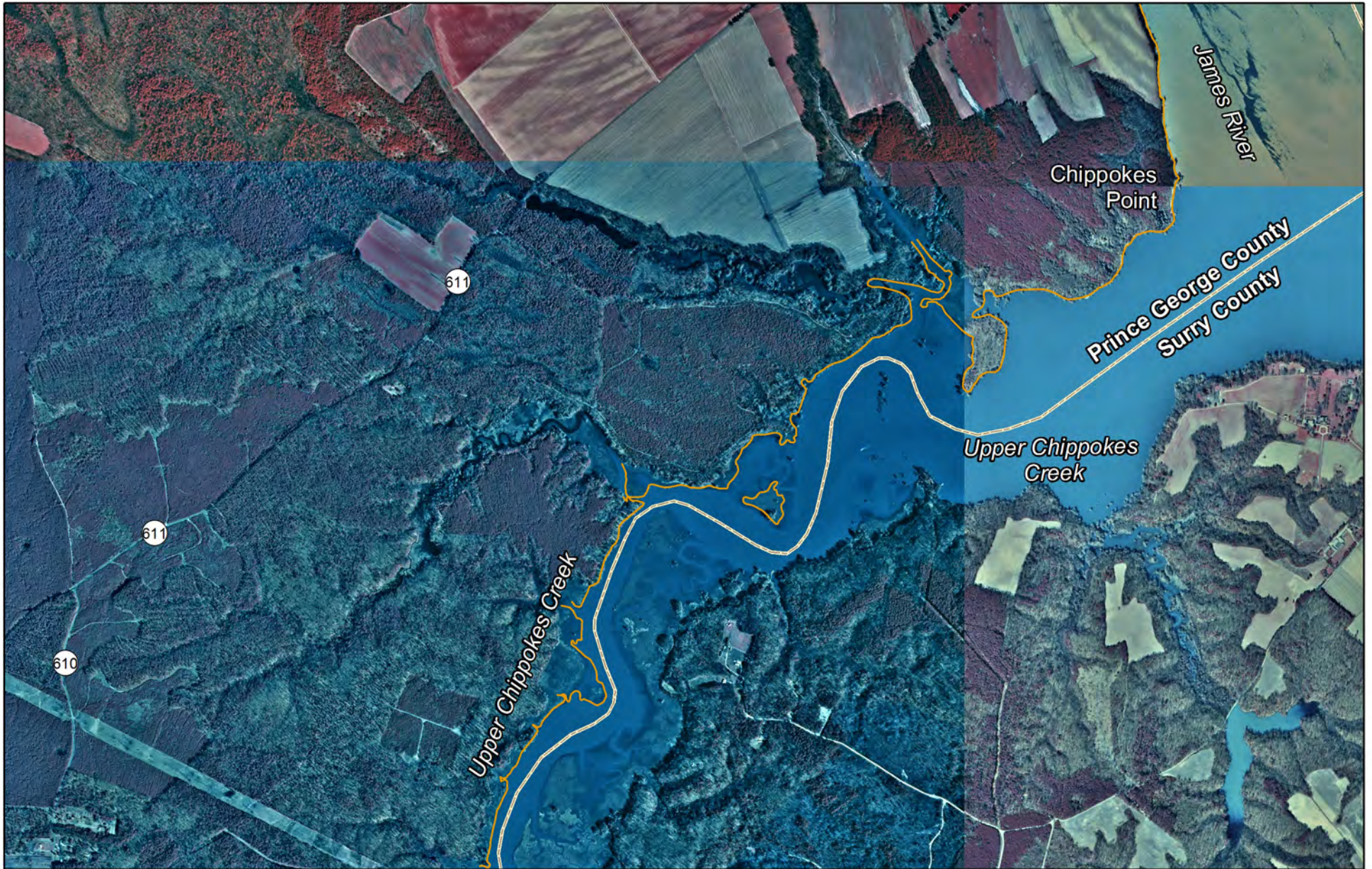


0 2,000 4,000
 Feet

Prince George County, Virginia Plate 14

Photo Date: 1965





Legend
 — Shoreline 1994



**Prince George County, Virginia
 Plate14**

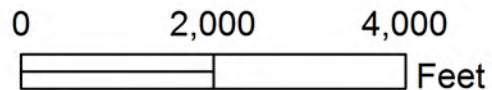


Photo Date: 1994



Legend
 — Shoreline 2002



**Prince George County, Virginia
 Plate 14**

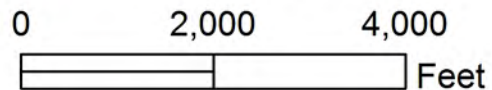
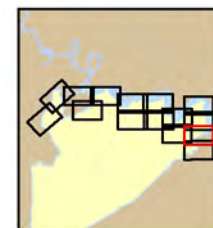


Photo Date: 2002



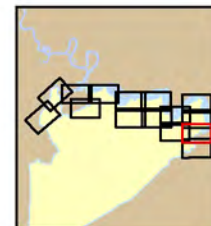
Legend
 — Shoreline 2009



0 2,000 4,000
 Feet

**Prince George County, Virginia
 Plate14**

Photo Date: 2009





Legend
 — Shoreline 2013



**Prince George County, Virginia
 Plate14**

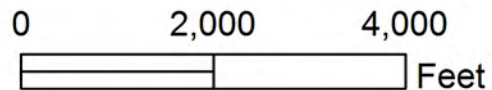
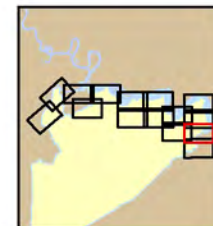
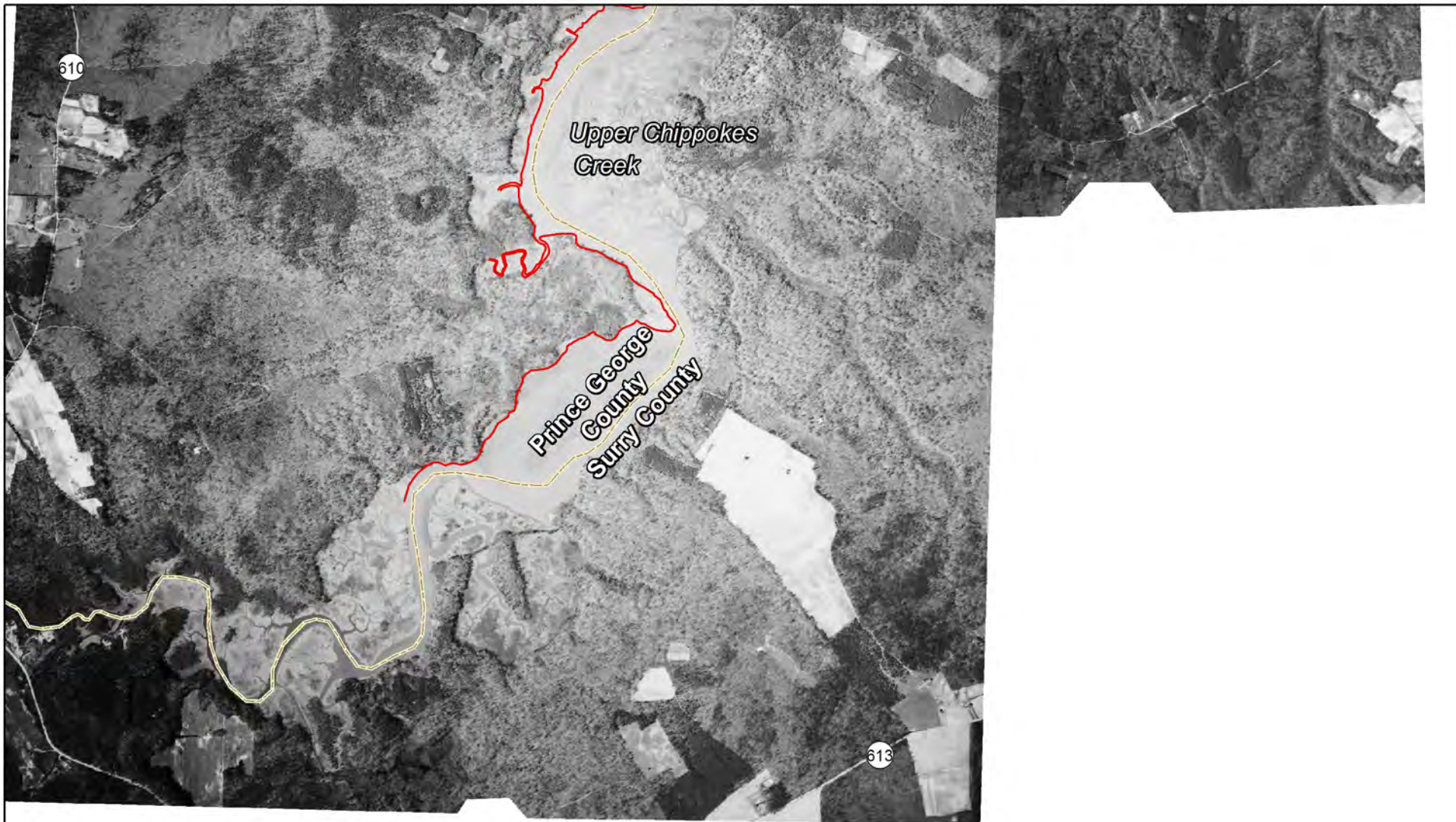
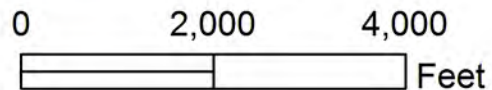


Photo Date: 2013



Legend

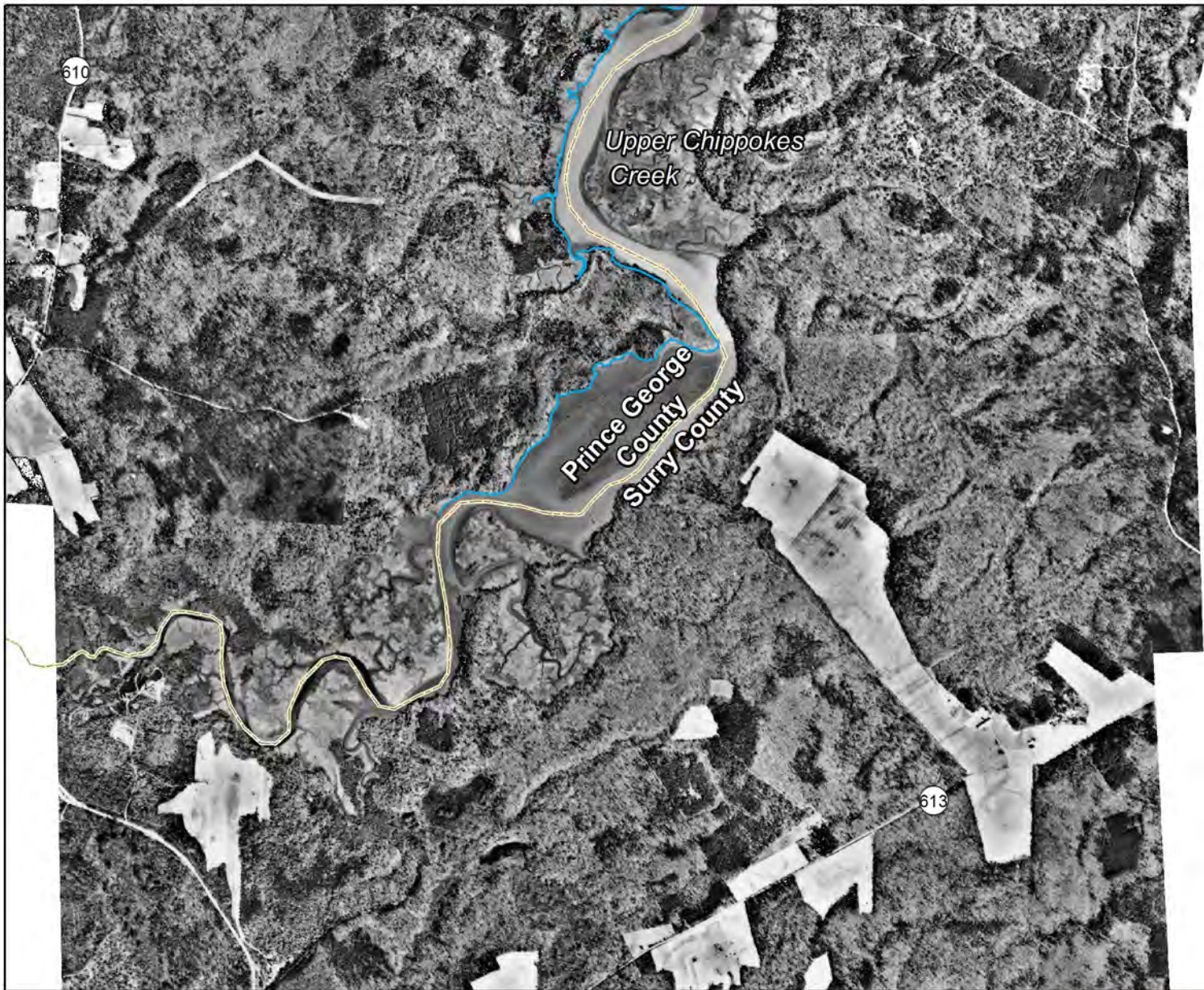
— Shoreline 1937



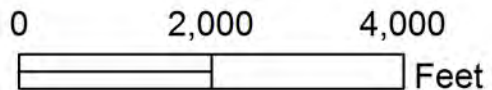
**Prince George County, Virginia
Plate 15**

Photo Date: 1937



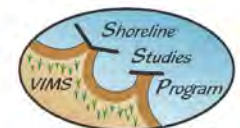


Legend
— Shoreline 1954



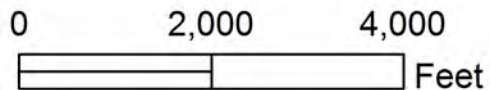
Prince George County, Virginia Plate 15

Photo Date: 1954



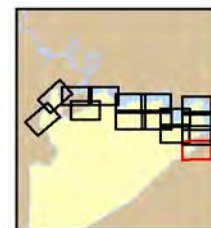


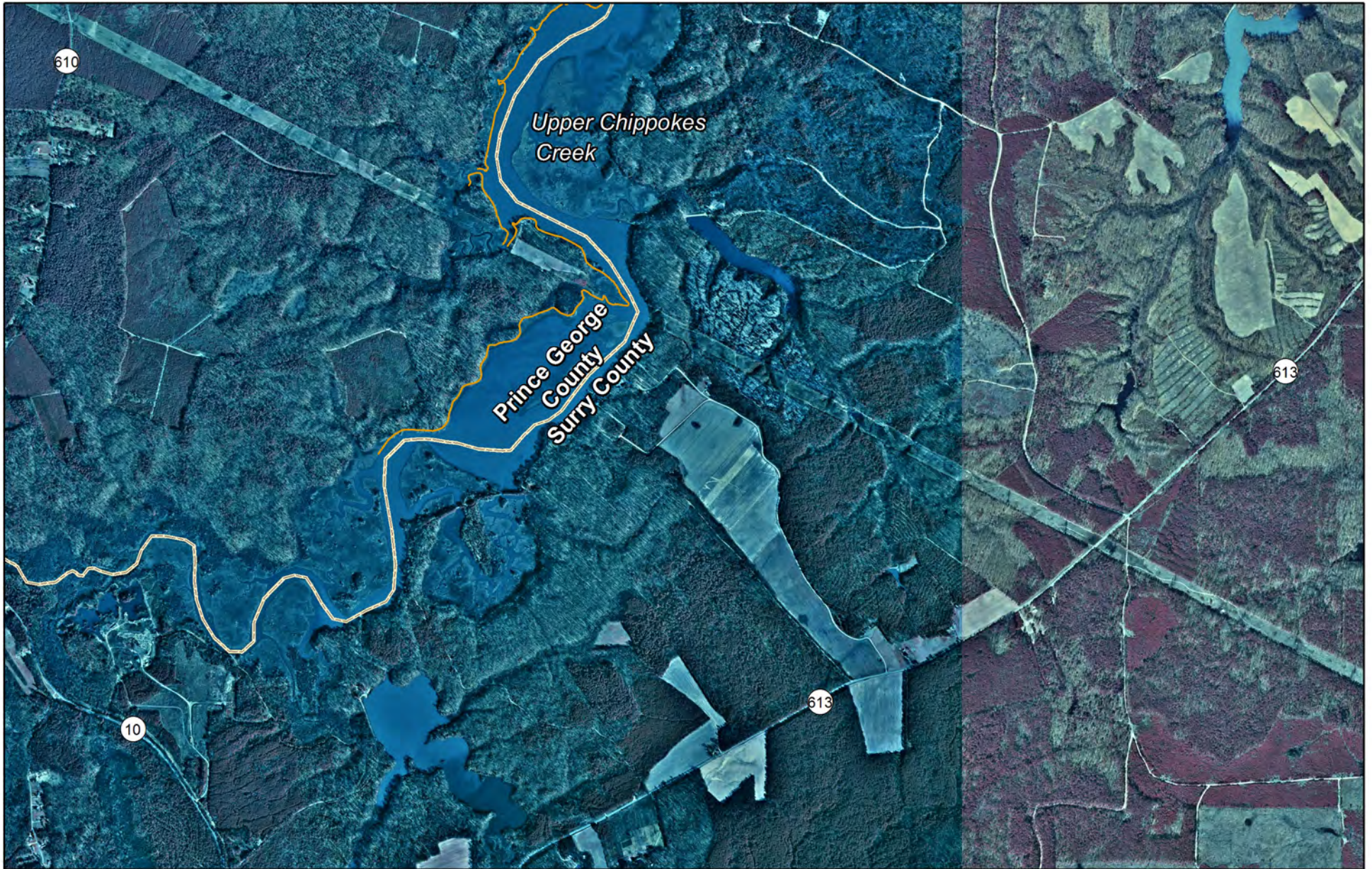
Legend
 — Shoreline 1965



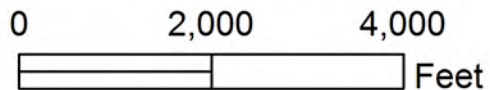
Prince George County, Virginia Plate 15

Photo Date: 1965



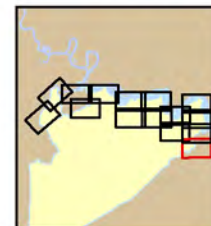


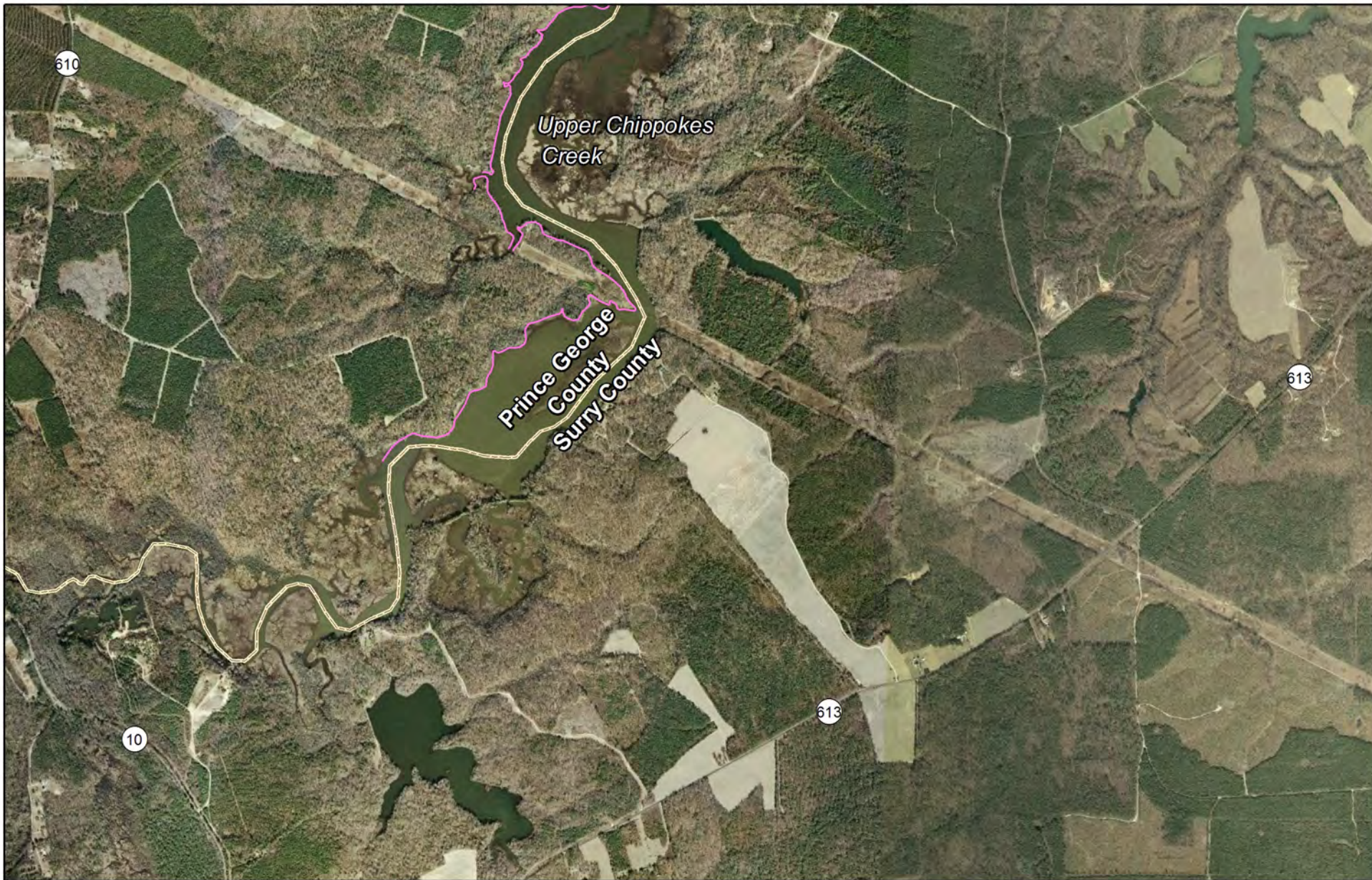
Legend
 — Shoreline 1994



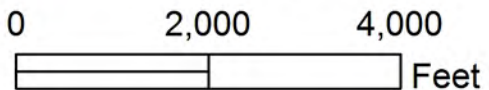
Prince George County, Virginia Plate 15

Photo Date: 1994



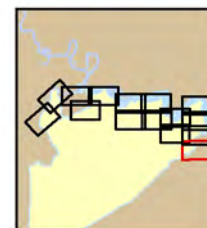


Legend
 — Shoreline 2002



**Prince George County, Virginia
 Plate15**

Photo Date: 2002





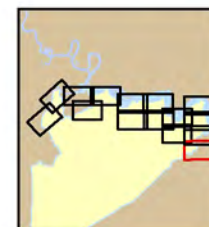
Legend
 — Shoreline 2009



0 2,000 4,000
 Feet

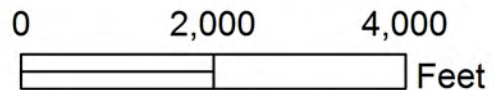
**Prince George County, Virginia
 Plate15**

Photo Date: 2009





Legend
 — Shoreline 2013



**Prince George County, Virginia
 Plate 15**

Photo Date: 2013

