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Shoreline Evolution: City of Newport News, Virginia James River and Hampton Roads Shorelines

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Data Report



Shoreline Studies Program
Department of Physical Sciences

Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, Virginia
March 2010

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March 2010

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1 Introduction

Shoreline evolution is the change in the shore zone through time. Along the shores of Chesapeake Bay, it is a process and response system. The processes at work include winds, waves, tides and currents which shape and modify coastlines by eroding, transporting and depositing sediments. The shore line is commonly plotted and measured to provide a rate of change, but it is as important to understand the geomorphic patterns of change. Shore analysis provides the basis to know how a particular coast has changed through time and how it might proceed in the future.

The purpose of this data report is to document how the shore zone of Newport News (Figure 1) 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 imagery shows how the coast has changed, how beaches, dunes, bars, and spits have grown or decayed, how barriers have breached, how inlets have changed course, and how one shore type has displaced another or has not changed at all. Shore change is a natural process but, quite often, the impacts of man through shore hardening or inlet stabilization come to dominate a given shore reach. The change in shore positions along the rivers and larger creeks in the City of Newport News 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 Shore Settings

2.1 Physical Setting

The City of the Newport News is located on Virginia's Peninsula and has about 90 miles of tidal shoreline along Hampton Roads and the James River. When all creeks and rivers that drain into these bodies of water are included, these areas have about 5 miles and 84 miles, respectively. Historic shore change rate on the James River averaged -0.2 ft/yr; there are no historic shore change rates for Hampton Roads (Byrne and Anderson, 1978).

The coastal geomorphology of the City is a function of the underlying geology and the hydrodynamic forces operating across the land/water interface, the shoreline (Figure 2). The Atlantic Ocean has come and gone numerous times over the Virginia coastal plain over the past million years or so. The effect has been to rework older deposits into beach and lagoonal deposits at the time of the transgressions. The topography of Newport News is a result of these changes in sea level. The Hampton Roads portion of the City is made up of sediment from the Lynnhaven Member of the Tabb Formation which was deposited about 105,000 years before present. The James River shorelines are older being made of the Shirley Formation which was deposited about 184,000 years ago. The exception is Mulberry Island which is the Poquoson Member of the Tabb Formation that was deposited about 80,000 years ago.

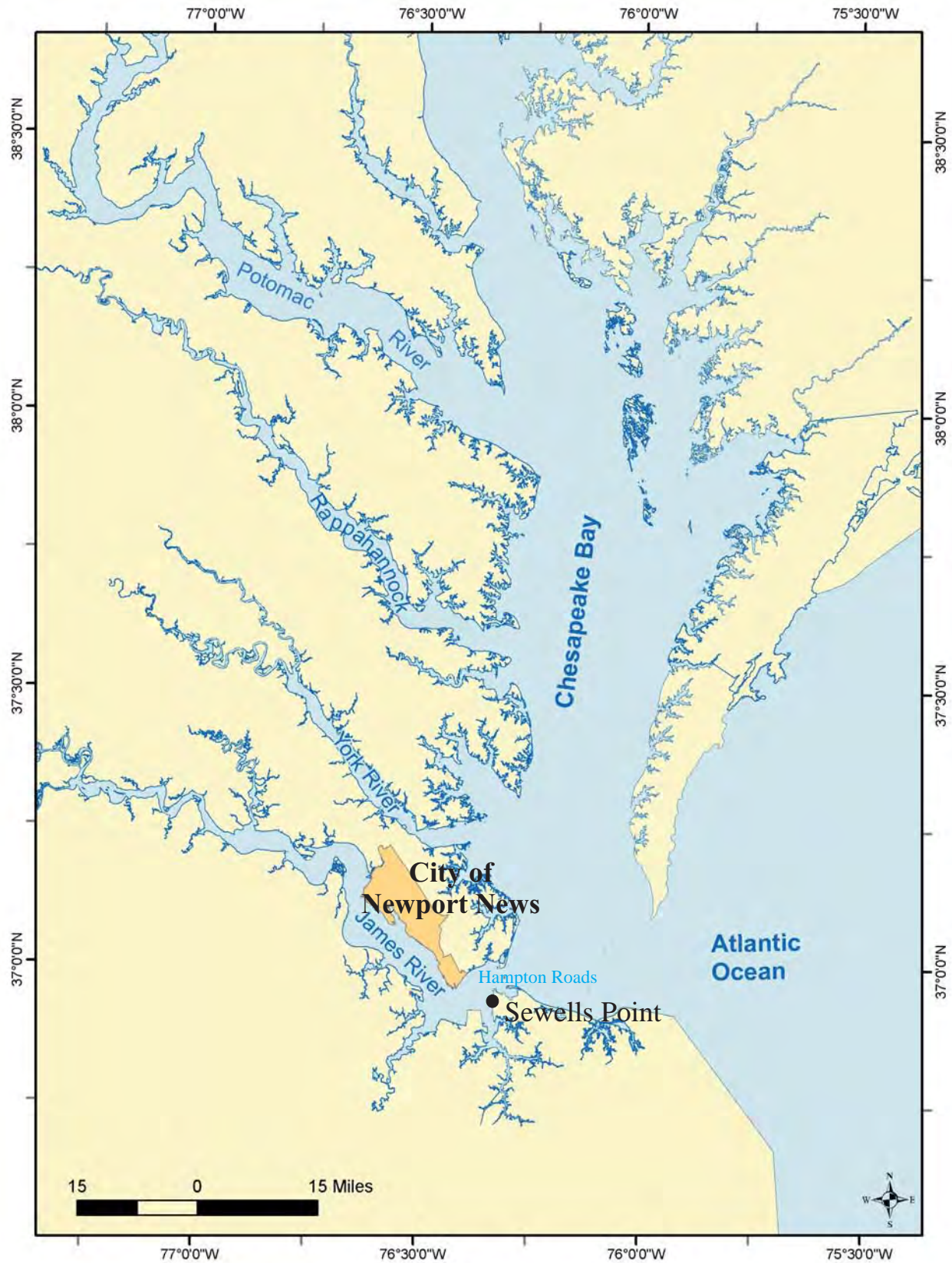
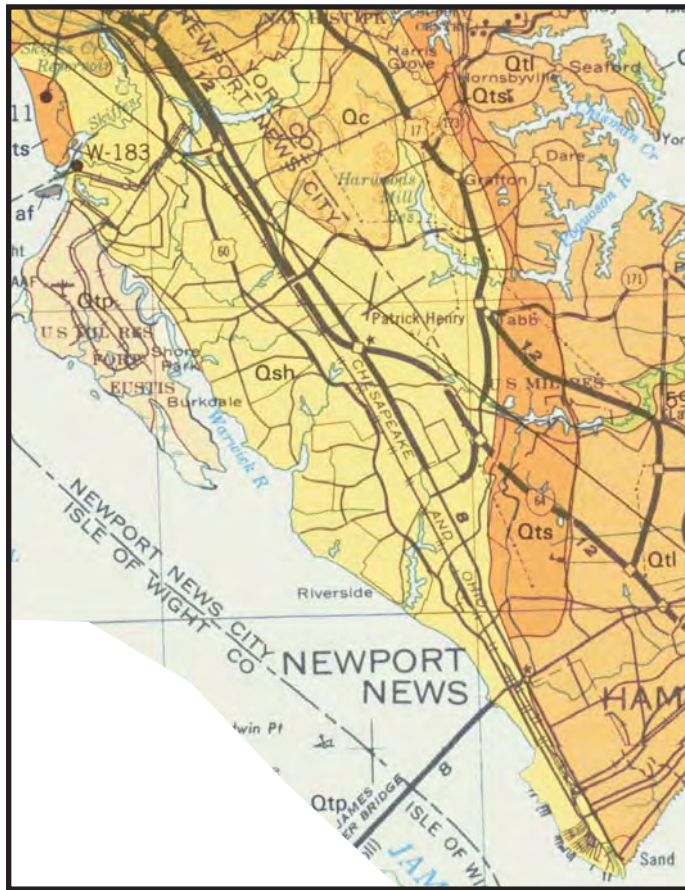


Figure 1. Location of City of Newport News within the Chesapeake Bay Estuarine System



1 Mile

1 km

Regional stratigraphic column of formations and members.

System	Series	Mixon and others (1989)		
Quaternary 1.8 mya-today	Holocene Last 10,000 years	Coastal barriers, lagoons, alluvial, swamp, eolian		
	Pleistocene 1.8 mya-10,000 ybp	U Tabb Fm.	Poquoson Mem. Lynnhaven Mem. Sedgefield Mem.	
		M	Shirley Fm.	
		L	Chuckatuck Fm.	
			Charles City Fm.	
		Windsor Fm.		
Tertiary 65-1.8 mya	Pliocene 5.3 mya-1.8 mya	U	Moorings Unit Bacons Castle Fm.	
		L	Yorktown Fm.	
	Miocene 23.8 mya-5.3 mya	Chesapeake Group	U	Eastover Fm.
			L	

Mya=millions of years ago

ybp=years before present

U=Upper

M=Middle

L=Lower

Fm.=Formation

Mem.=Member

Qal

Alluvium - Fine to coarse gravelly sand and sandy gravel, silt, and clay, light- to medium- gray and yellowish-gray. Mostly Holocene but, locally, includes low-lying Pleistocene(?) Terrace deposits. As much as 80 ft thick along major streams.

Qtp

Poquoson Member of Tabb Formation- Medium to coarse pebbly sand grading upward into clayey fine sand and silt, light- to medium-gray; underlies ridge and swale topography (altitude ranges from sea level to 11ft) along the margin of Chesapeake Bay and in the lower and middle parts of Coastal Plain rivers. Unit is 0-15 ft thick.

Qtl

Lynnhaven Member of Tabb Formation - Pebbly and cobbly, fine to coarse gray sand grading upward into clayey and silty fine sand and sandy silt; locally, at base of unit, medium to coarse crossbedded sand and clayey silt containing abundant plant material fill channels cut into underlying stratigraphic units. Thickness is 0-20 ft.

Qts

Sedgefield Member of Tabb Formation - Pebbly to bouldery, clayey sand and fine to medium, shelly sand grading upward to sandy and clayey silt. Unit constitutes surficial deposit of river- and coast-parallel plains (alt. 20-30 ft) bounded on landward side by Suffolk and Harpersville scarps. Thickness is 0-50 ft.

Qsh

Shirley Formation (middle Pleistocene) - Light-to dark-gray and brown sand, gravel, silt, clay, and peat. Thickness is 0-80 ft.

Qc

Chuckatuck formation (middle (?) Pleistocene) - Light- to medium-gray, yellowish-orange, and reddish-brown sand, silt and clay and minor amounts of dark-brown and brownish-black peat. Unit is 0 - 26 ft thick.

Qtw

Windsor Formation (lower Pleistocene or upper Pliocene) - Gray and yellow to reddish-brown sand, gravel, silt, and clay. Constitutes surficial deposits of extensive plain (alt. 85-95 ft) seaward of Surry scarp and coeval, fluvial-estuarine terrace west of scarp. Unit is 0-40 ft thick.

Figure 2. Geologic map of the City of Newport News (from *Mixon et al.*, 1989).

The last low stand found the ocean coast about 60 miles to the east when sea level about 400 feet lower than today and the coastal plain was broad and low (Toscano, 1992). This low-stand occurred about 18,000 years ago during the last glacial maximum. The present estuarine system was a meandering series of rivers working their way to the coast. As sea level began to rise and the coastal plain watersheds began to flood, shorelines began to recede. The slow rise in sea level is one of two primary long-term processes which cause the shoreline to recede; the other is wave action, particularly during storms. As shorelines recede or erode the bank material provides the sands for the offshore bars, beaches and dunes.

Sea level rise has been well documented in the Tidewater Region. Tide data collected at Sewells Point in Norfolk show that sea level has risen 0.17 inches/yr or 1.45 ft/century (<http://www.co-ops.nos.noaa.gov/>). This directly effects the reach of storms and their impact on shorelines. Anecdotal evidence of storm surge during Hurricane Isabel, which impacted North Carolina and Virginia on September 18, 2003, put it on par with the storm surge from the “storm of the century” which impacted the lower Chesapeake Bay in August 1933. Boon (2003) showed that even though the tides during the storms were very similar, the difference being only 1.5 inches, the amount of surge was different. The 1933 storm produced a storm surge that was greater than Isabel’s by slightly more than a foot. However, analysis of the mean water levels for the months of both August 1933 and September 2003 showed that sea level has risen by 1.35 ft at Hampton Roads in the seventy years between these two storms (Boon, 2003). This is the approximate time span between our earliest aerial imagery (1937) and our most recent (2009) which means the impact of sea level rise to shore change is significant.

Three shore reaches exist along the coast of City of Newport News (Figure 3). Reach 1 extends from the Skiffes Creek to mouth of the Warwick River at Fort Eustis. Reach 2 extends from mouth of the Warwick River to Newport News Point. Reach 3 extends from Newport News Point to the Newport News/Hampton jurisdictional border.

2.2 Hydrodynamic Setting

Tide range varies along its variable coast from 2.4 to 2.6 ft in Newport News. The three reaches have different tidal and hydrodynamic conditions. On the James River, the mean is tidal range 2.4 ft (2.9 ft spring range) at the Mulberry Point tide station (Figure 3) and 2.6 ft (3.2 ft spring range) at Huntington Park. The main river shorelines are relatively protected from northeast winds. However, during northeast storms, winds frequently shift from the northeast to the northwest. This reach is vulnerable to wind waves from the northwest. The mean tide range of Reach 2 decreases slightly from 2.6 ft (3.2 ft spring range) at Huntington Park to 2.5 ft (3.0 ft spring range) at Newport News Tide Station (Figure 3). Reach 3 is along Hampton Roads and has a mean tide range of 2.5 ft (3.0 ft spring range) at Newport News Tide Station (Figure 3). This Reach has the largest wind-wave climate as waves from the Chesapeake Bay can impact this region.

City of Newport News, Virginia Plate Index

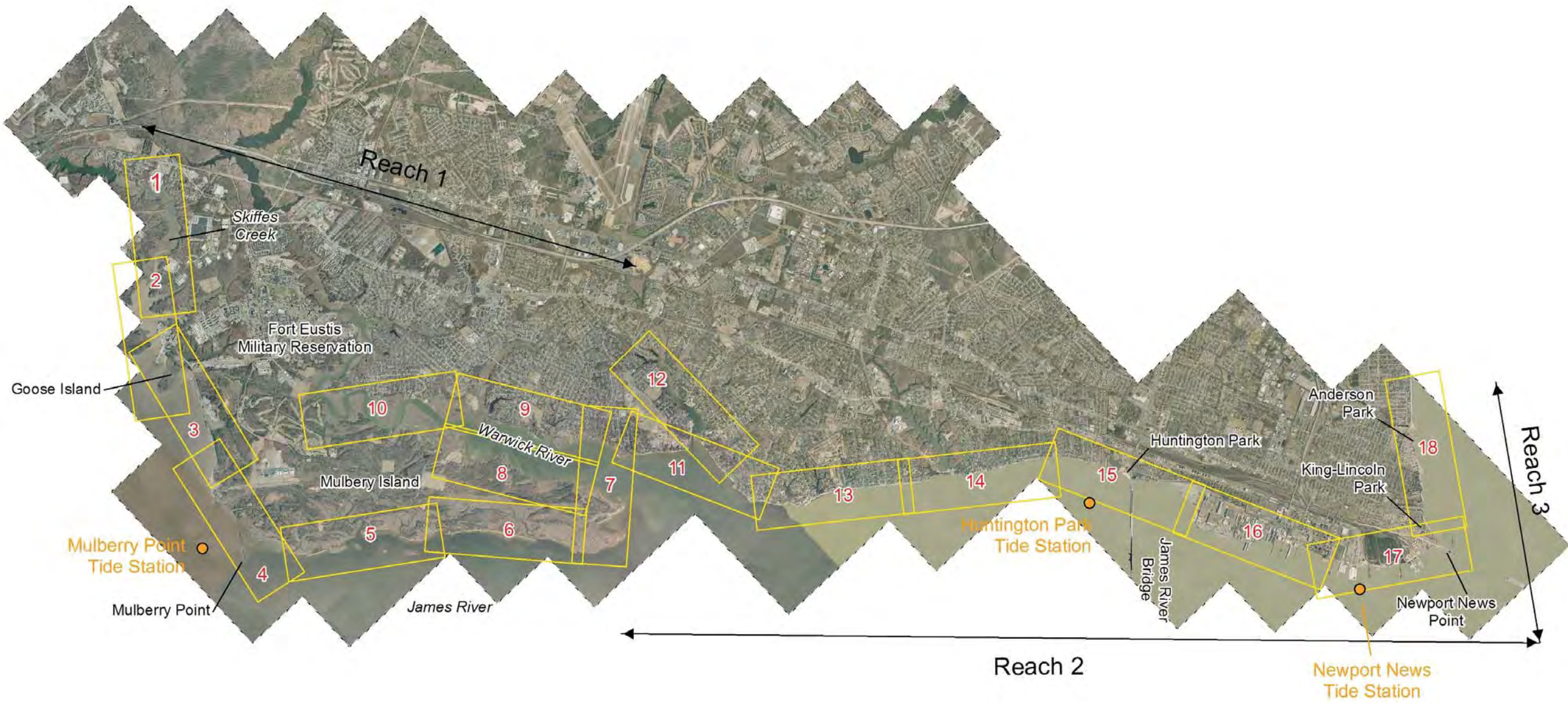


Figure 3. Index of shoreline plates.

Wind data from Norfolk International Airport reflect the frequency and speeds of wind occurrences from 1960 to 1990 (Table 1). These data provide a summary of winds possibly available to generate waves. Winds from the north and south have the largest frequency of occurrence, but the north and northeast have the highest occurrence of large waves. Reach 1 and 2 being generally south-facing shorelines are not impacted by those waves. However, winds from the southwest also have a high occurrence of large waves and can generate waves that impact these shores.

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

Wind Speed (mph)	Mid Range (mph)	WIND DIRECTION								Total
		South	South west	West	North west	North	North east	East	South east	
< 5	3	5497*	3316	2156	1221	35748	2050	3611	2995	56594
		2.12 ⁺	1.28	0.83	0.47	13.78	0.79	1.39	1.15	21.81
5-11	8	21083	15229	9260	6432	11019	13139	9957	9195	95314
		8.13	5.87	3.57	2.48	4.25	5.06	3.84	3.54	36.74
11-21	16	14790	17834	10966	8404	21816	16736	5720	4306	100572
		5.70	6.87	4.23	3.24	8.41	6.45	2.20	1.66	38.77
21-31	26	594	994	896	751	1941	1103	148	60	6487
		0.23	0.38	0.35	0.29	0.75	0.43	0.06	0.02	2.5
31-41	36	25	73	46	25	162	101	10	8	450
		0.01	0.03	0.02	0.01	0.06	0.04	0.00	0.00	0.17
41-51	46	0	0	0	1	4	4	1	0	10
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		41989	37446	23324	16834	70690	33133	19447	16564	259427
		16.19	14.43	8.99	6.49	27.25	12.77	7.50	6.38	100.00

*Number of occurrences ⁺Percent

Hurricanes, depending on their proximity and path also can have an impact to the City of Newport News' coast. On September 18, 2003, Hurricane Isabel passed through the Virginia coastal plain. The main damaging winds began from the north and shifted to the east then south. Sewells Point tide station recorded wind gusts at 58 mph, a peak gust at 73 mph with a storm surge 7.9 ft (Beven and Cobb, 2004) and having water levels 7.9 ft above mean lower low water (MLLW). (NOAA, 2009). Hurricane Isabel was not the only recent tropical event to pass through the city; Tropical Storm Ernesto (September 1, 2006) brought wind speeds of 46 mph and a peak gust of 60 mph at the Dominion Terminal Associates station (NOAA, 2009) and water levels 5.5 ft above MLLW at the Sewells Point tide station (NOAA, 2009). The City of Newport News

also was hit by The Veteran's Day Storm on November 11, 2009 which had water levels of 5.2 ft above MLLW with wind speeds at 29 mph with gusts at 53 mph (NOAA, 2009)

3 Methods

3.1 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 Newport News Shoreline from 1937, 1953, 1963, 1994, 2002, and 2007 were used in the analysis. The 1994, 2002, and 2007 images were available from other sources. The 1994 imagery was orthorectified by the U.S. Geological Survey (USGS) and the 2002 and 2007 imagery was orthorectified by the Virginia Base Mapping Program (VBMP).

The 1937, 1953, and 1963 images were scanned as tiffs at 600 dpi and converted to ERDAS IMAGINE (.img) format. They were orthorectified to a reference mosaic, the 1994 Digital Orthophoto Quarter Quadrangles (DOQQ) from USGS. The original DOQQs were in MrSid format but were converted into .img format. ERDAS Orthobase image processing software was used to orthographically correct the individual flightlines 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. A minimum of four ground control points was used per image, allowing two points per overlap area. 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 that cover each USGS 7.5 minute quadrangle area were adjusted to approximately uniform brightness and contrast and were mosaicked together using the ERDAS Imagine mosaic tool to produce a one-meter resolution mosaic also in .img format. To maintain an accurate match with the reference images, it was necessary to distribute the control points evenly. This can be challenging in areas with little development. Good examples of control points were manmade features such as corners of buildings or road intersections and stable natural landmarks such as easily recognized isolated trees. Some areas of the county were particularly difficult to rectify due to the lack of development that provide good control points.

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 mean low water (MLW). Mean high water (MHW)/ limit of runup is difficult to determine on much of 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 using USGS DOQQs. Vertical control is the USGS 100 ft (30 m) DEM. 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 2007 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.

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, and 1963) have an estimated total maximum shoreline position error of 20.0 ft, while the total shoreline error for the three 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 general lack of good control points for photo rectification, narrower shore features, tree and ground cover and overall smaller rates of change. For these reasons, some areas were only digitized in 1937 and 2007. It was decided that digitizing the intervening years would introduce more errors rather than provide additional information.

3.2 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 for Gloucester and the digitized shorelines for 1937, 1953, 1963, 1994, 2002 and 2007. Baselines were created about 200 feet 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. For Newport News, this method represented about 28 miles of shoreline along 4,412 transects.

Two types of shoreline change rates are determined by the program. 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 (Figure 4A). 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. However, 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.

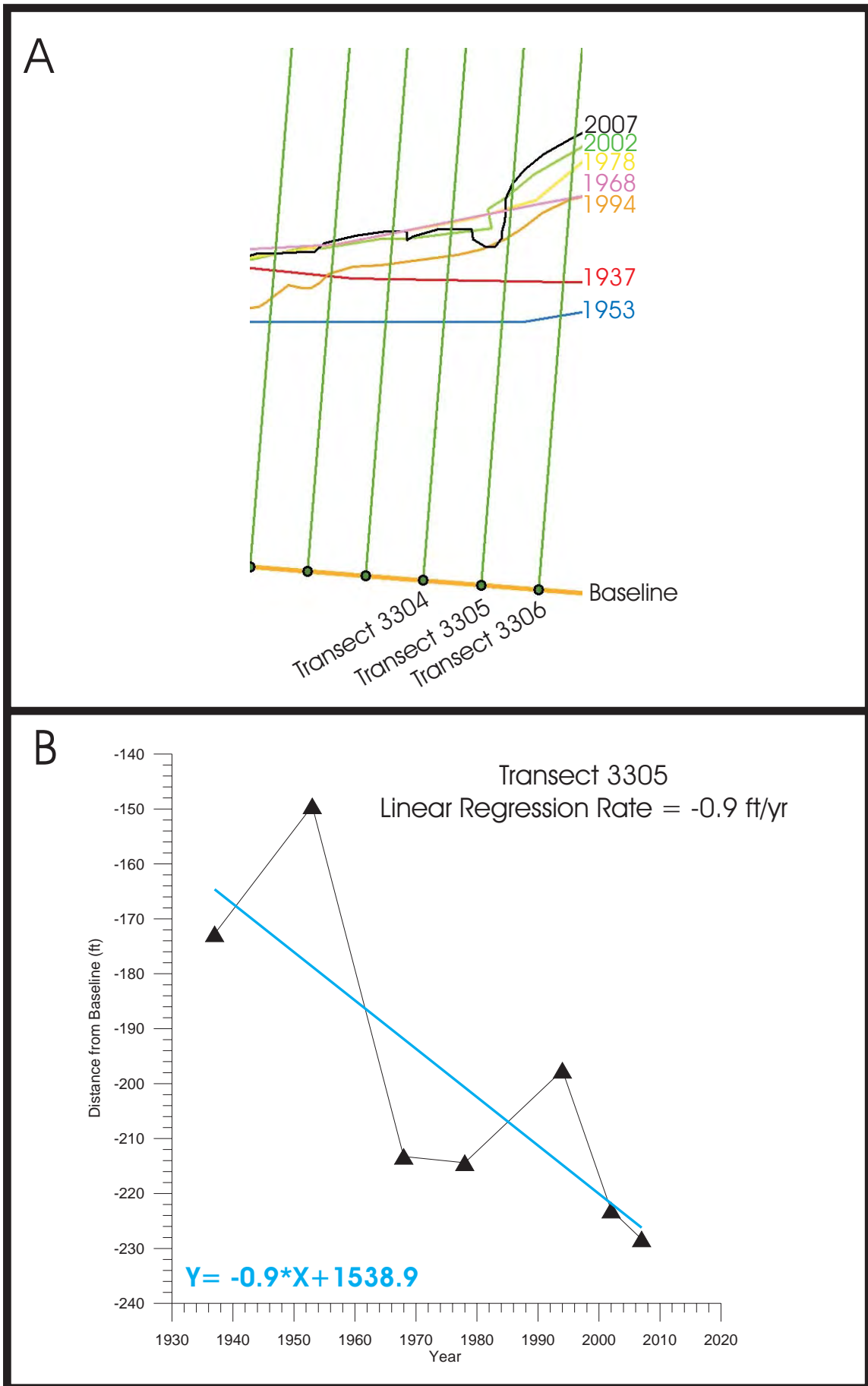


Figure 4. Graphics depicting A) sample DSAS baseline, transects and measured shoreline, and B) how the measured shoreline data is analyzed in a linear regression.

The Linear Regression Rate (LRR) is determined in DSAS by fitting a least-squares regression line to all shoreline points for given transect. The LRR is the slope of the calculated line (Figure 4B). This method uses all data and is based on accepted statistical concepts. In all areas, a rate can be determined by regression analysis because there is change in the shoreline position. However, mathematically it may not be significant because the line is so flat. In an estuarine environment, variable rates of change led to concerns that the slope of the calculated regression line may not be significantly different from zero. In order to determine if the shoreline data was amenable to explanation by regression analysis, a two-tailed t-test at 95% significance was run on the data to determine if the rate is statistically significant.

In ArcMap, the rates of change were categorized and plotted at the intersection of individual transects and the baseline. This provided a relatively efficient way to express rates of change along 28 miles of shoreline. For the Linear Regression Rate maps, only those transects that passed the significance test were plotted. The rates calculated along the other transects were not considered statistically significant. In addition, for Newport News, LRR that used less than six shorelines available for analysis were not plotted

4 Results and Discussion

The City of Newport News' shoreline through time is depicted in 18 map plates in Appendix A & B. These plates show the individual photos and shorelines for each date analyzed. In addition, the Linear Regression Rates and End Point Rates were plotted where available/significant. City-wide and in subreaches, the average End Point and Linear Regression rates of change are nearly identical (Table 2). The maximum and minimum rates did vary slightly, but generally, they were similar. This analysis includes all the regression rates, not just those that are statistically significant. Using only those transects that passed the t-test removes about 34% of the transects from the data. This study showed that the use of the LRR method to report erosion rate does not provide additional information when compared to the EPR particularly in situations where the rate is minimized such that the slope of the regression line is shown not to be significantly different from zero.

Table 2. Comparison of the End Point Rate and the Linear Regression Rate results for Newport News' shorelines. The Linear Regression Rate uses all data, not just those that were determined to be statistically significant. The industrial land creation along the James River was not included in the rate analysis. Rates are in feet per year.

Location	End Point Rate			Linear Regression Rate		
	Avg	Max	Min	Avg	Max	Min
City-Wide	-0.3	39.7	-8.3	-0.4	20.7	-9.1
James River North of Fort Eustis	-0.6	39.7	-3.7	-0.9	20.7	-9.1
James River South of Fort Eustis	-0.2	5.7	-3.4	-0.2	7.6	-3.7
Hampton Roads	-0.1	8.4	-8.3	0.0	8.4	-3.6

4.1 Reach 1

Reach 1 extends from Skiffes Creek to mouth of the Warwick River at Fort Eustis along the James River, the Reach contains Plates 1-10. Reach 1 has an average long-term erosion rate of -0.6 ft/yr (Table 2) with greater rates at Marshy Point on Plate 5 and north of Jail Point on Plate 7 with rates varying from -1 to -10 ft/yr. Mand-made accretion occurred at Goose Island on Plate 2 with a long-term rate of over +10 ft/yr. Goose Island was created in the late 1940s and early 1950s with material that was dredged from Skiffes Creek (Hardaway *et al.*, 1997). It was originally deposited offshore and with time has eroded and the material moved onshore such that the Island became attached to the mainland during the 1970s (Hardaway *et al.*, 1997). Accretion also occurred on Plate 4 around a breakwater system that was installed between 1994 and 1995.

4.2 Reach 2

Reach 2 extends from the mouth of the Warwick River to Newport News Point and contains Plates 11-17. Reach 2 has an average long-term erosion rate of -0.2 ft/yr (Table 2); however that does not include the manmade accretion on Plates 16 and 17. Over time, the industrial use of the shoreline expanded in these areas resulting in the filling of the shorezone and the stabilizing of the shoreline with bulkheads. The rates were not included because they are not a true representation of Newport News' shoreline evolution.

4.3 Reach 3

Reach 3 extends from Newport News Park to the Newport News/Hampton border and contains Plate 18. Reach 3 has an average long-term erosion rate of -0.1 ft/yr (Table 2) but the shoreline had accreted due to a beach fill near King-Lincoln Park. Newport News creek has been stabilized with bulkheads as it was turn into a boat harbor. The shoreline at Anderson Park has been stabilized with a breakwater and beach fill system.

5 Summary

Shoreline change rates vary around the City of Newport News. Generally, the subreaches with smaller fetches such as along the Warwick and tributaries to the larger rivers and bays had smaller rates of change. Along some individual transects, the LRR may provide better information than the EPR; however, City-wide and in individual subreaches, this was not the case. In addition, the LRR along many transects could not reliably be used in all shoreline situations as could the EPR. So, in the City of Newport News, the EPR is a reliable indicator of shoreline change rates even when intervening dates are available.

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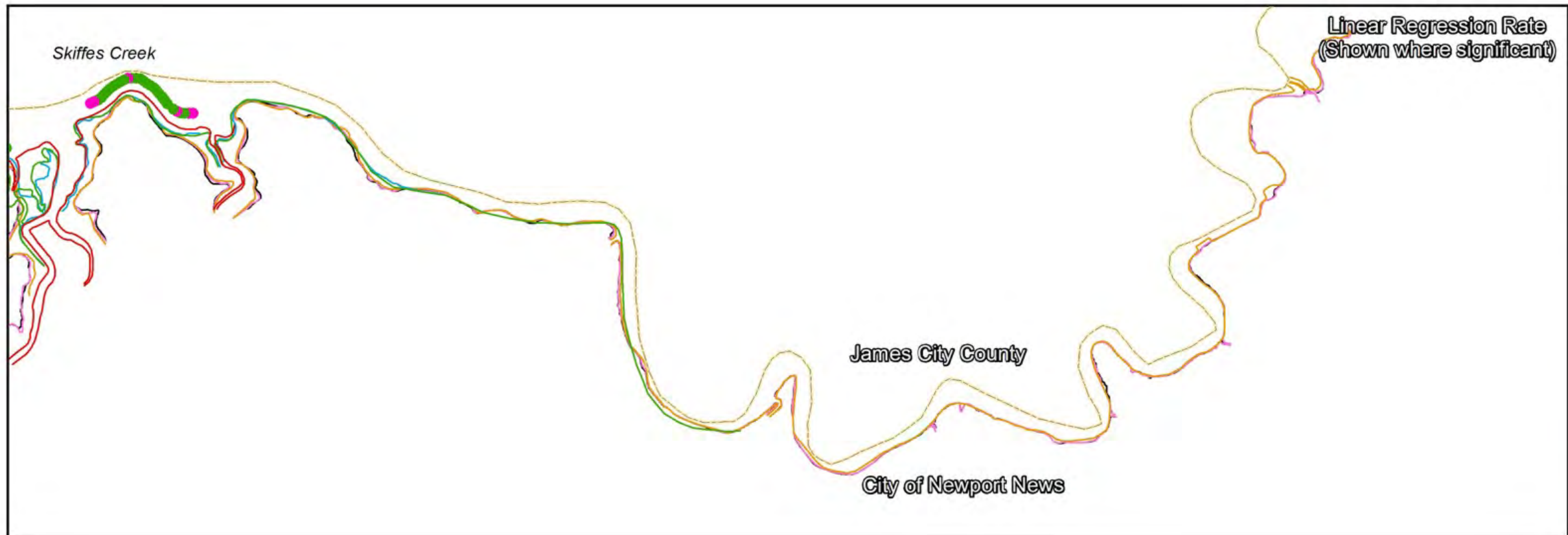
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Appendix A

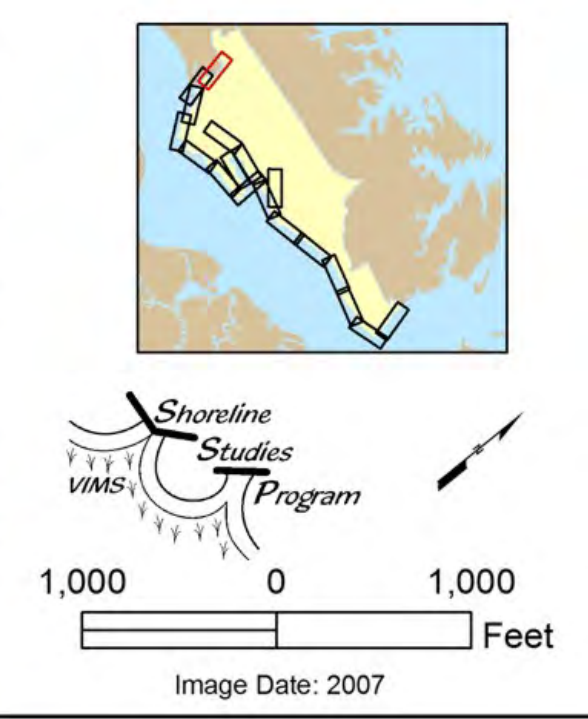
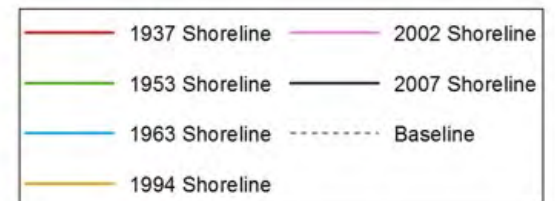
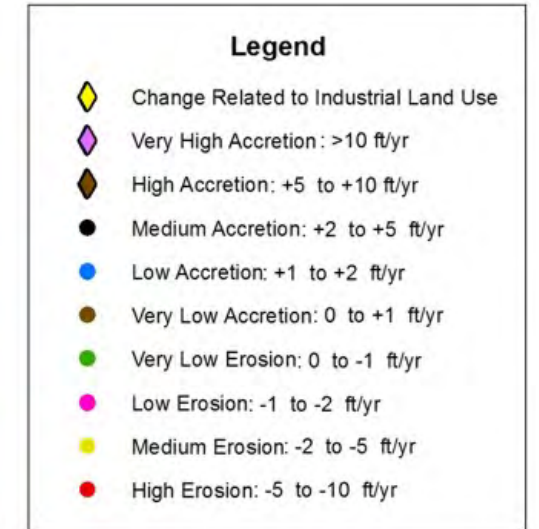
Shoreline Change Rates

Plate 1	Plate 7	Plate 13
Plate 2	Plate 8	Plate 14
Plate 3	Plate 9	Plate 15
Plate 4	Plate 10	Plate 16
Plate 5	Plate 11	Plate 17
Plate 6	Plate 12	Plate 18



City of Newport News Virginia

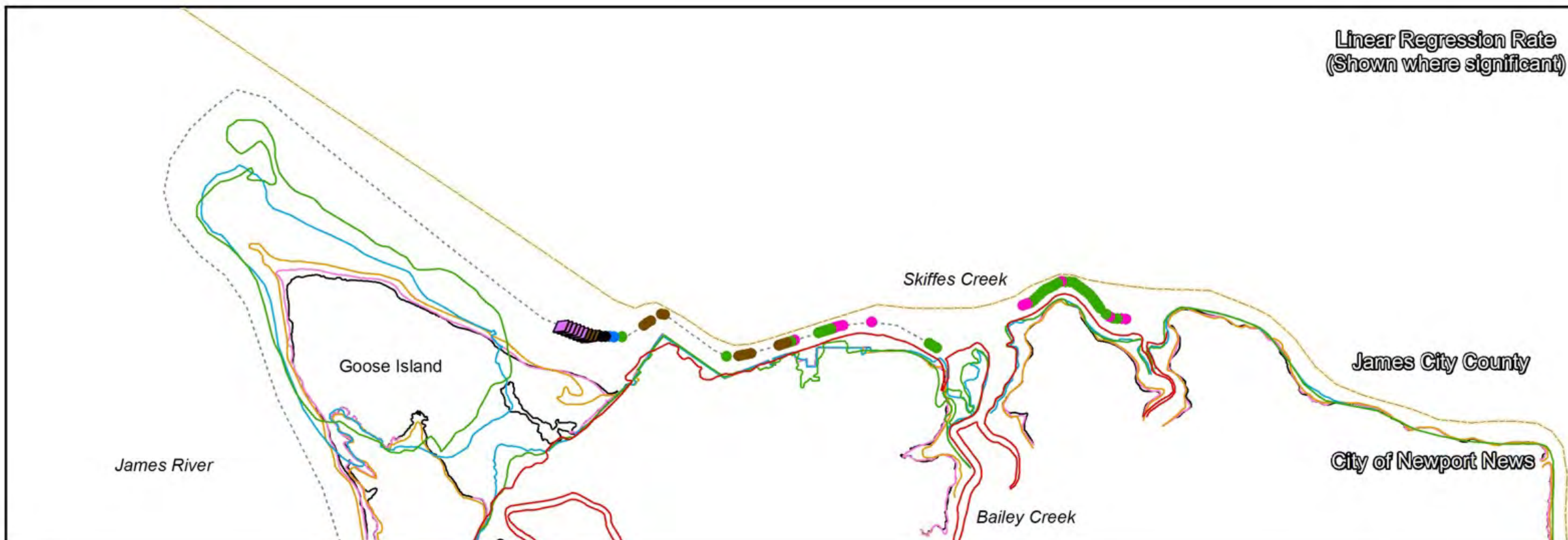
Plate 1



City of Newport News Virginia

Plate 2

Linear Regression Rate
(Shown where significant)



Legend

- ◆ Change Related to Industrial Land Use
- ◆ Very High Accretion: >10 ft/yr
- ◆ High Accretion: +5 to +10 ft/yr
- Medium Accretion: +2 to +5 ft/yr
- Low Accretion: +1 to +2 ft/yr
- Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- Baseline

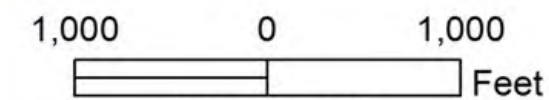
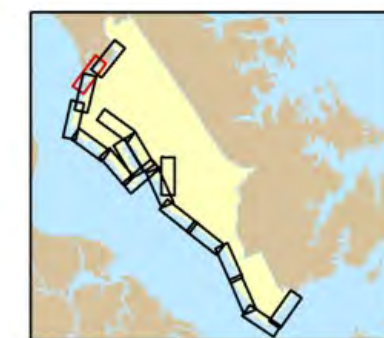
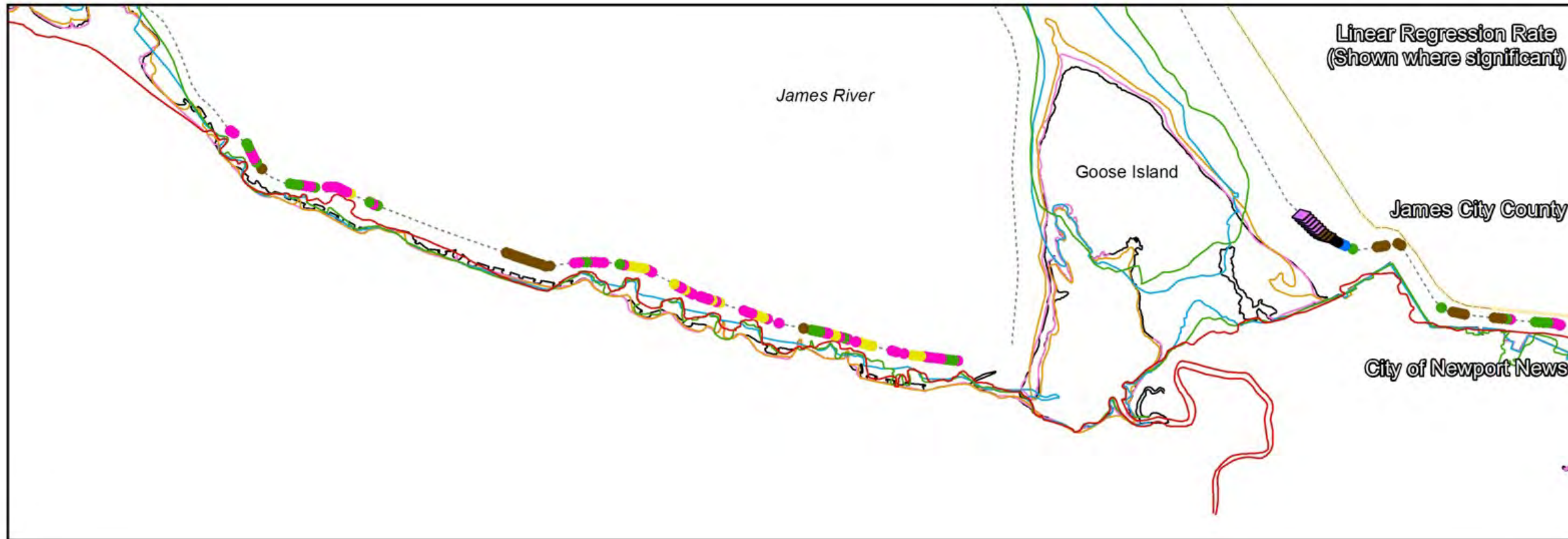


Image Date: 2007



City of Newport News Virginia

Plate 3

Legend

- ◆ Change Related to Industrial Land Use
- ◆ Very High Accretion: >10 ft/yr
- ◆ High Accretion: +5 to +10 ft/yr
- Medium Accretion: +2 to +5 ft/yr
- Low Accretion: +1 to +2 ft/yr
- Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- - - - - Baseline

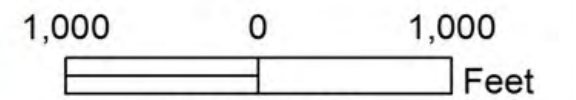
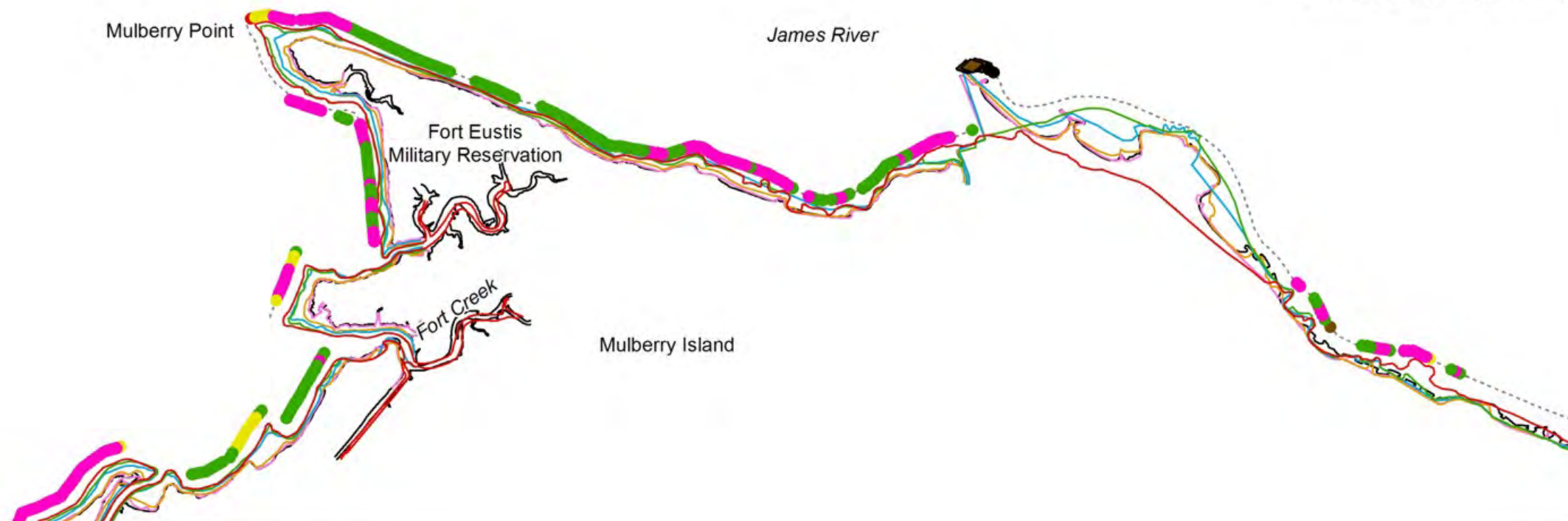


Image Date: 2007

City of Newport News Virginia

Plate 4

Linear Regression Rate
(Shown where significant)



Legend

- ◆ Change Related to Industrial Land Use
- ◆ Very High Accretion: >10 ft/yr
- ◆ High Accretion: +5 to +10 ft/yr
- Medium Accretion: +2 to +5 ft/yr
- Low Accretion: +1 to +2 ft/yr
- Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- - - - - Baseline

End Point Rate

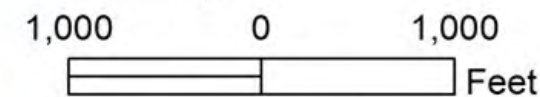


Image Date: 2007

City of Newport News Virginia

Plate 5

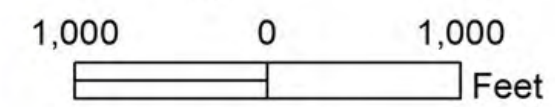
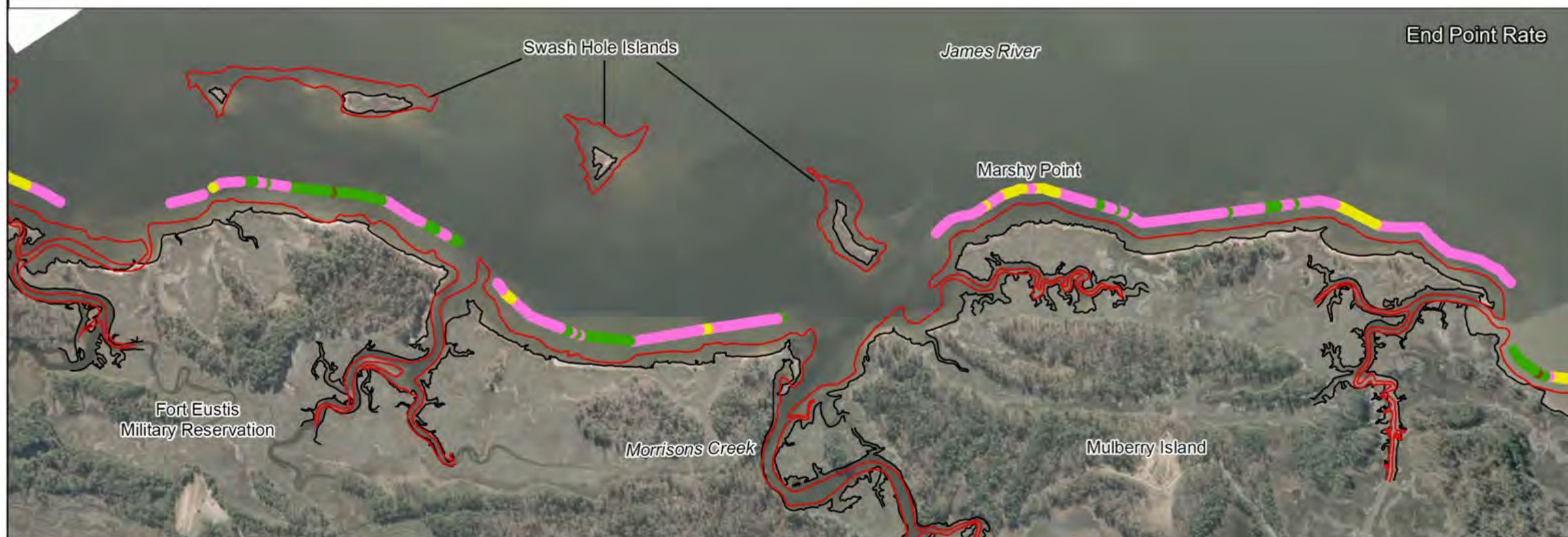
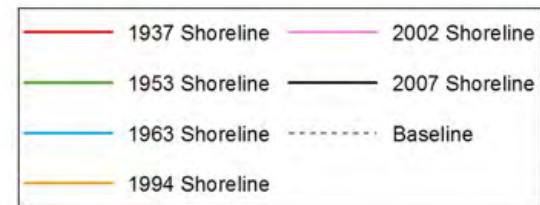
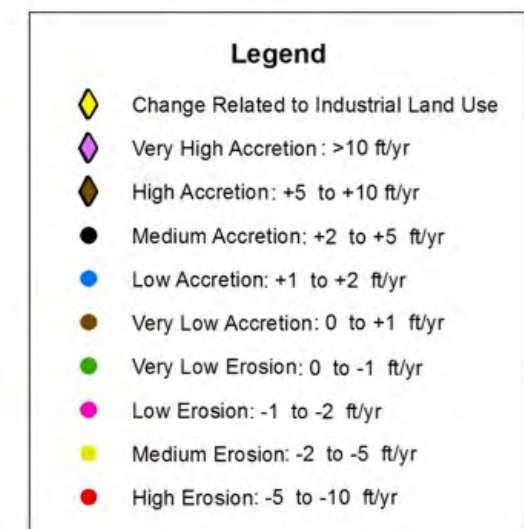
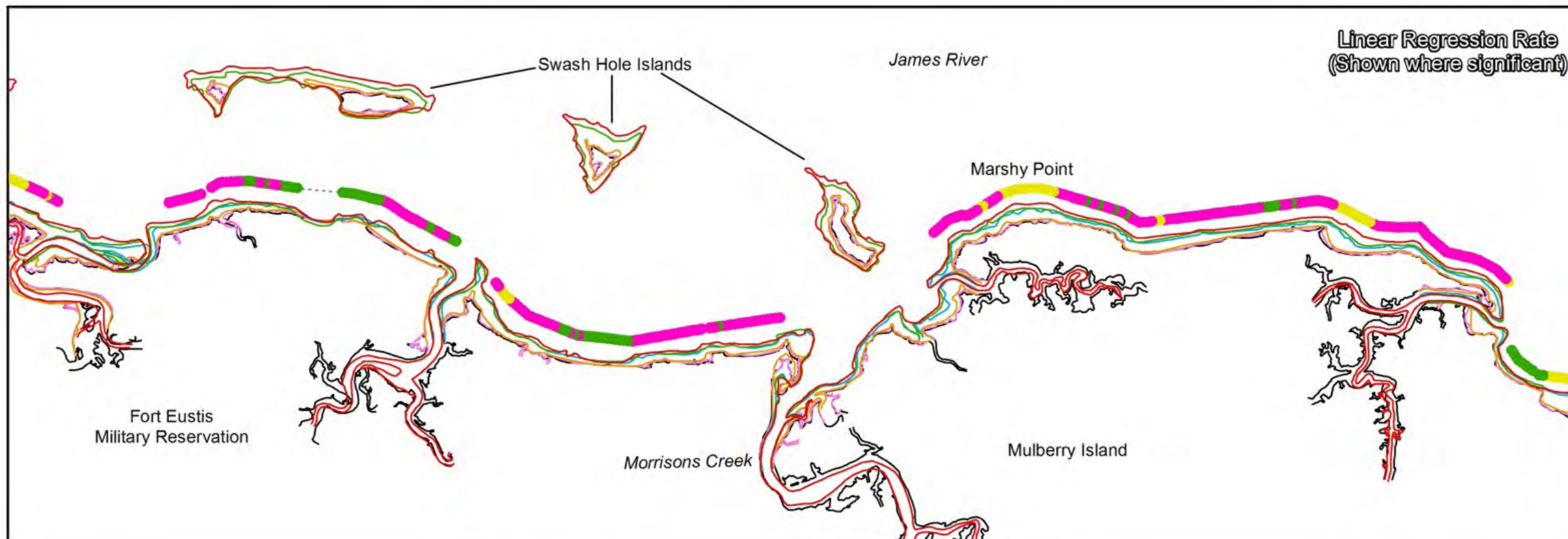


Image Date: 2007

City of Newport News Virginia

Plate 6

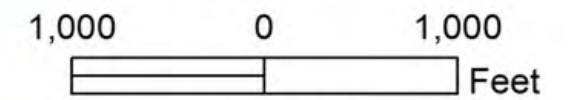
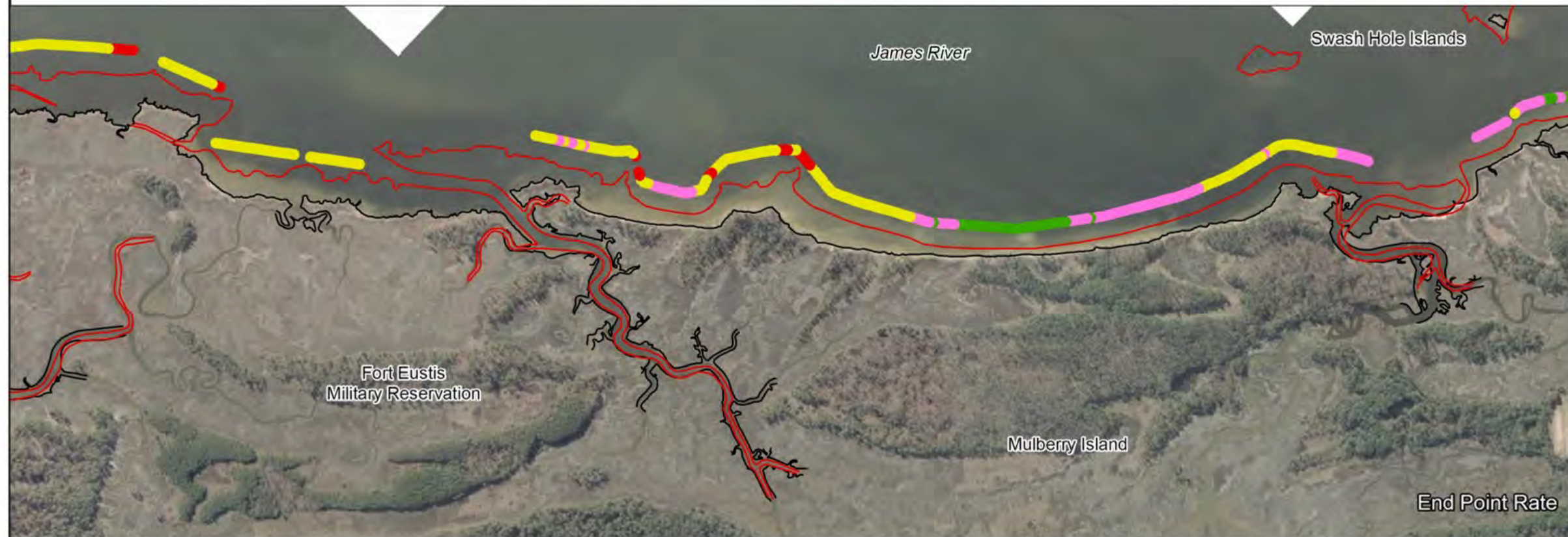
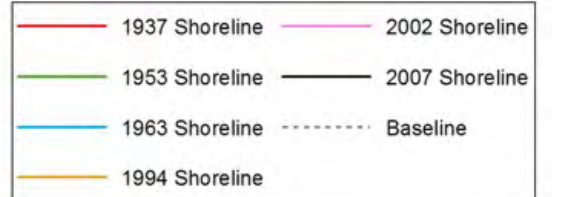
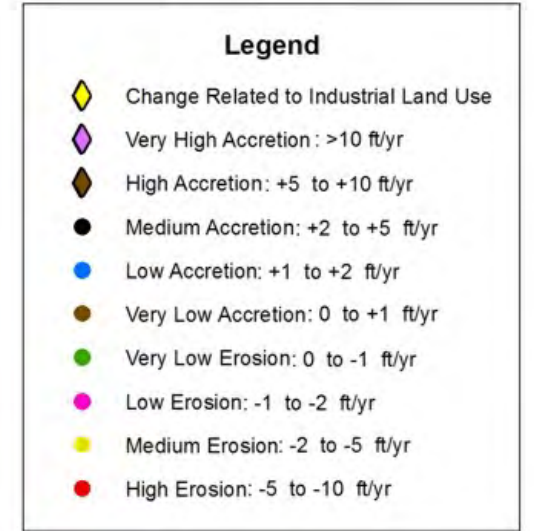
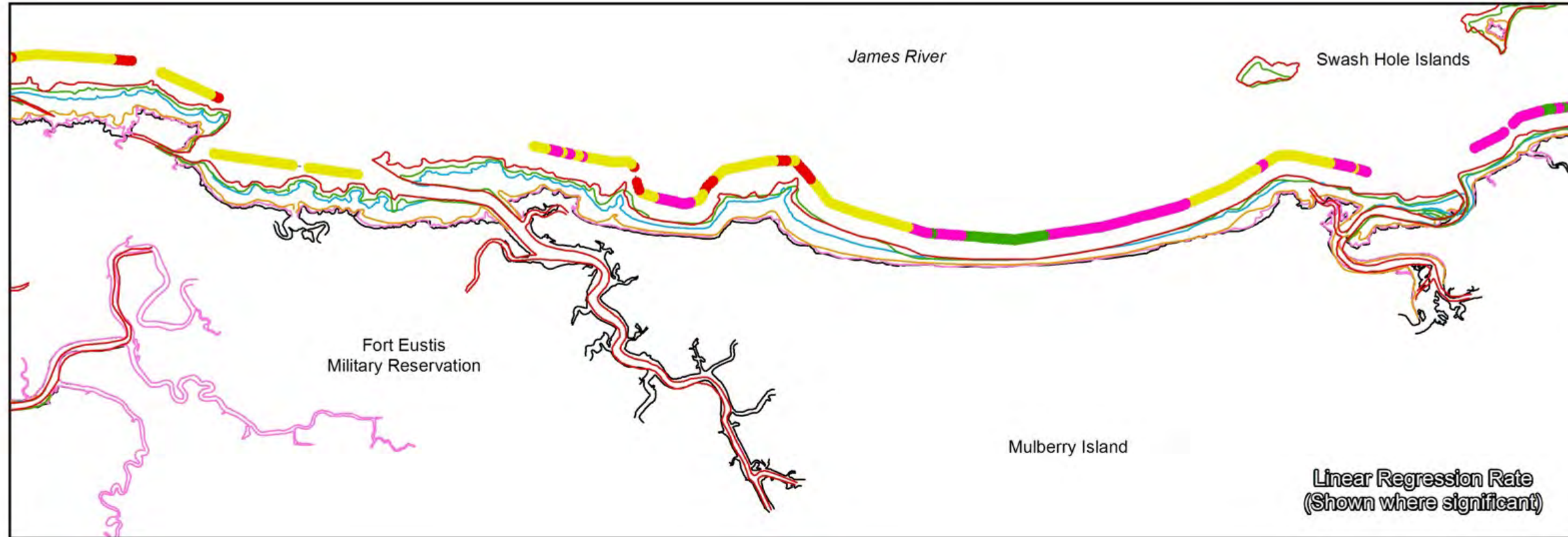
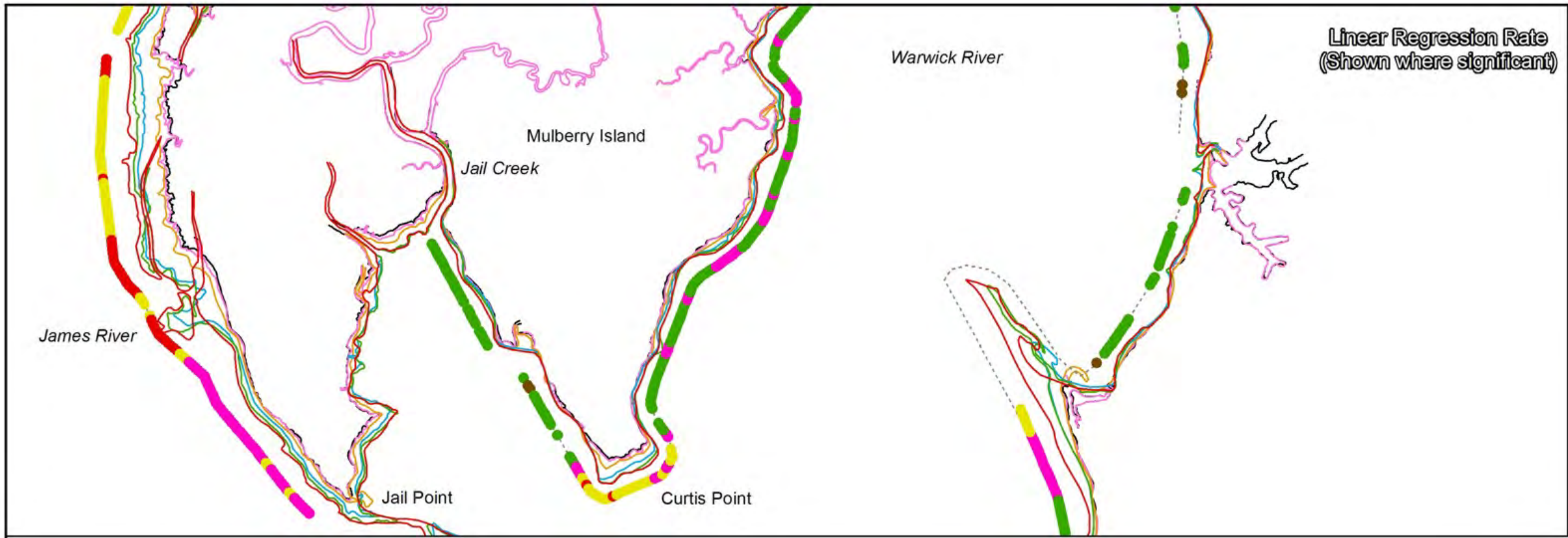


Image Date: 2007



City of Newport News Virginia

Plate 7

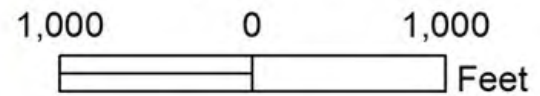
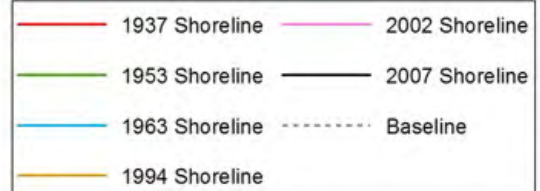
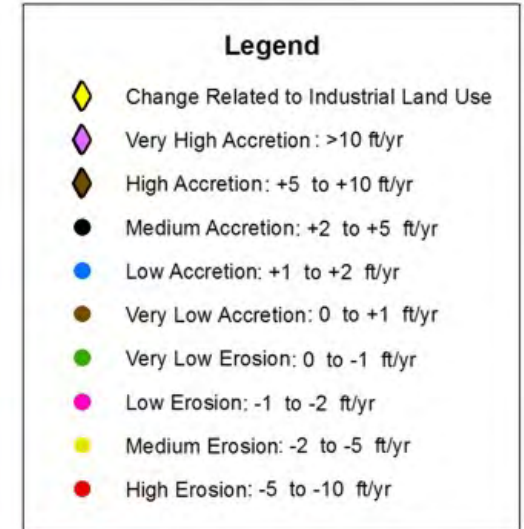


Image Date: 2007

City of Newport News Virginia

Plate 8

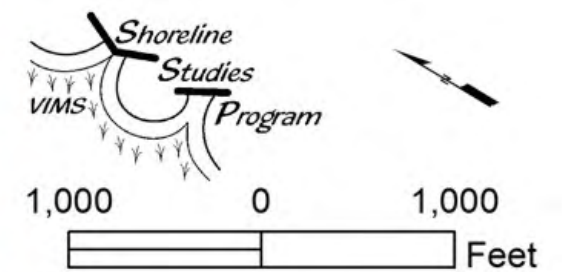
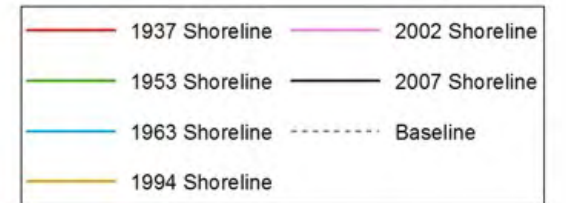
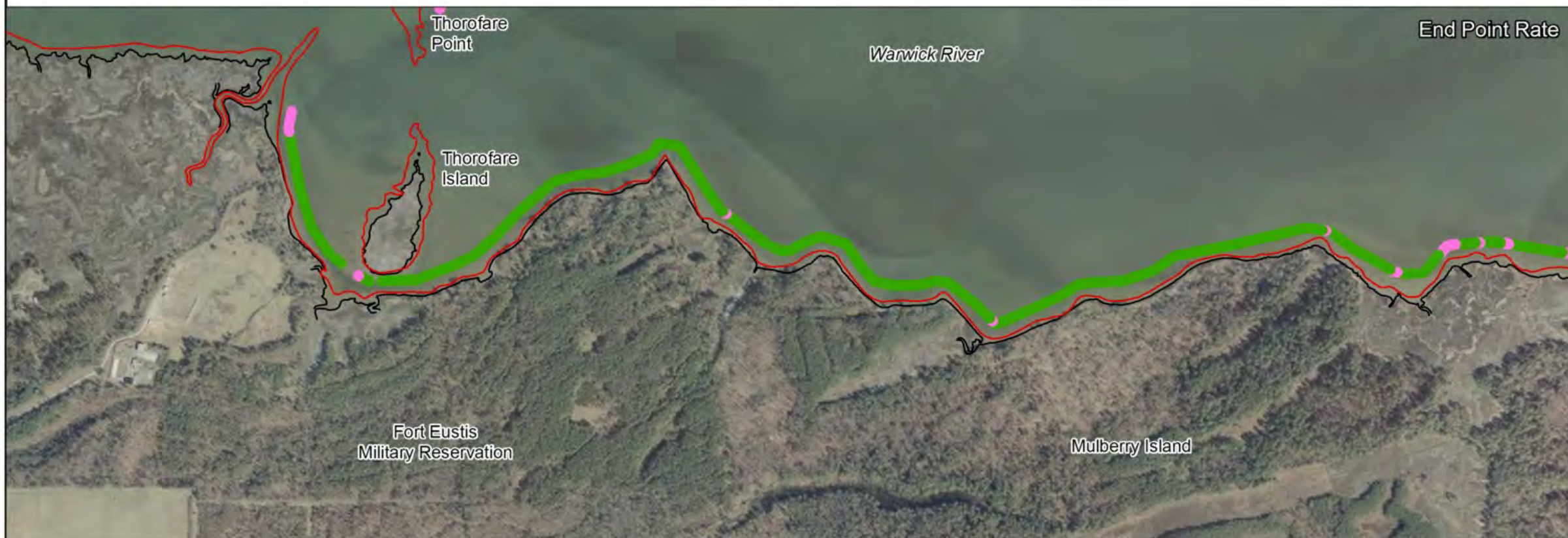
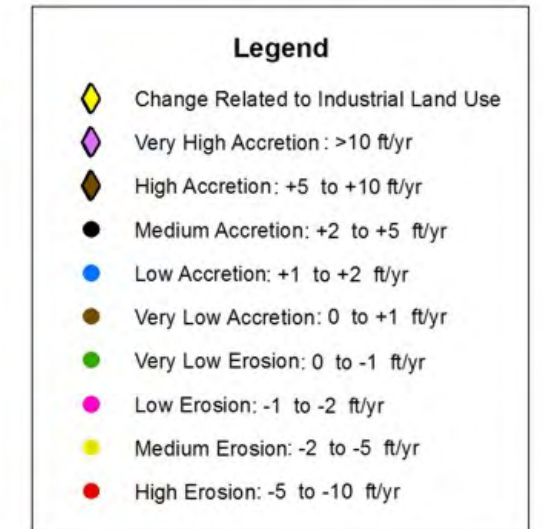
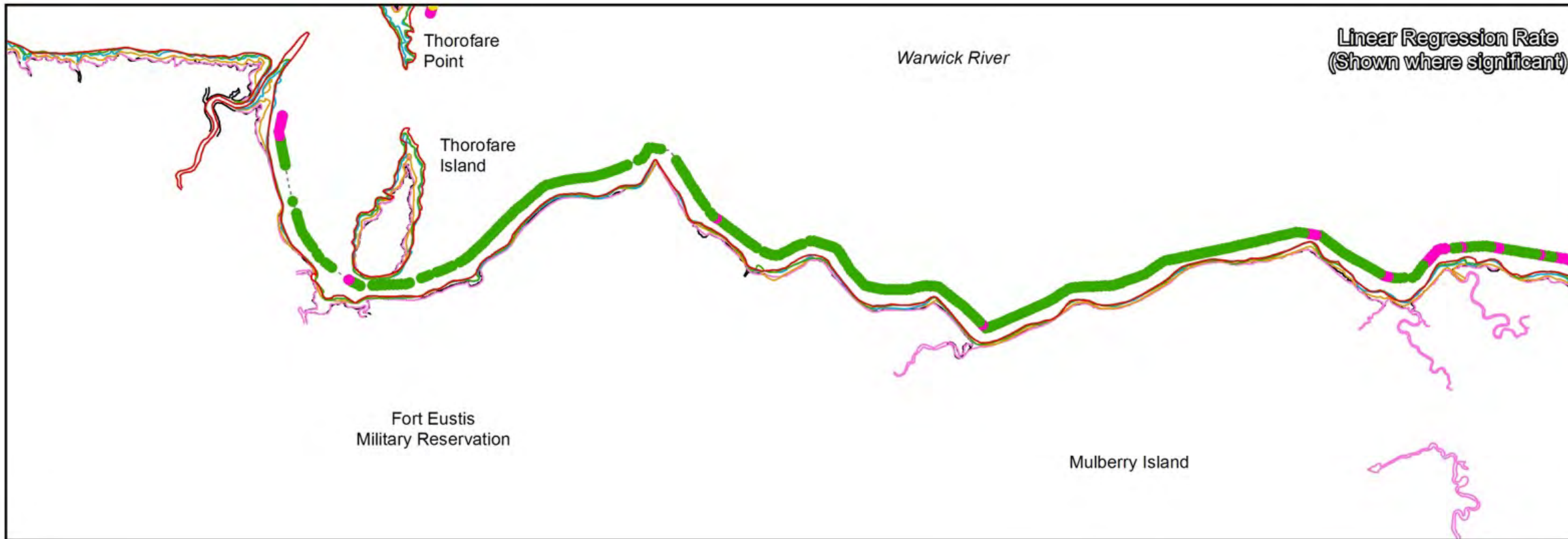


Image Date: 2007

City of Newport News Virginia

Plate 9

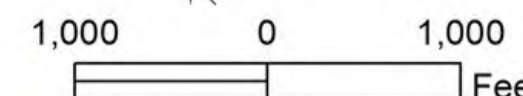
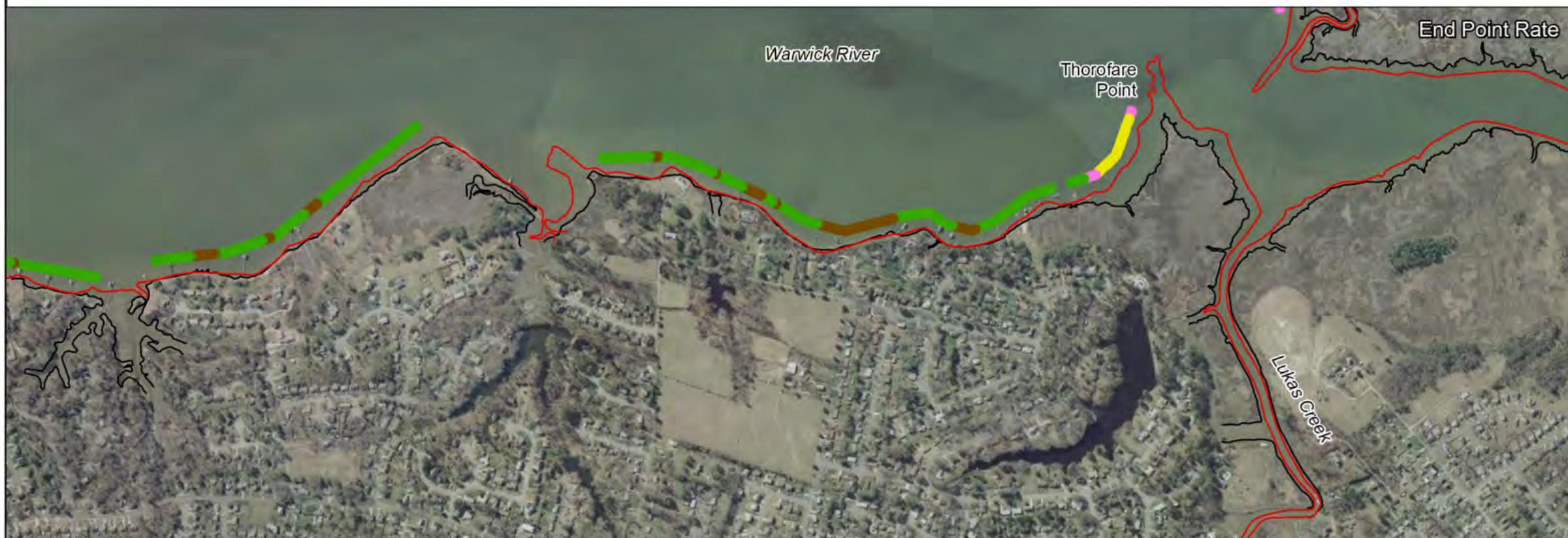
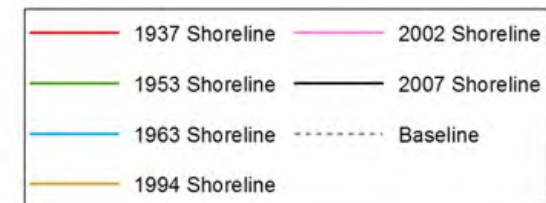
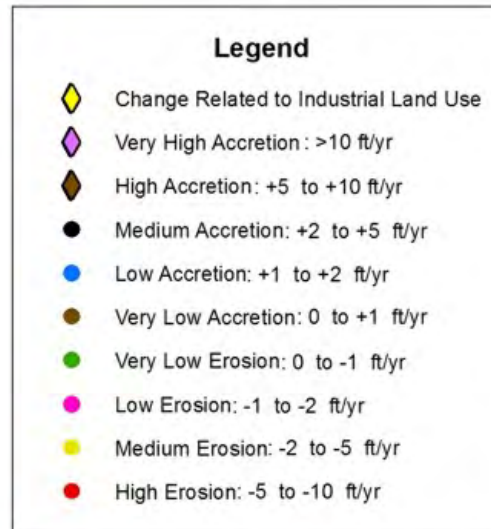
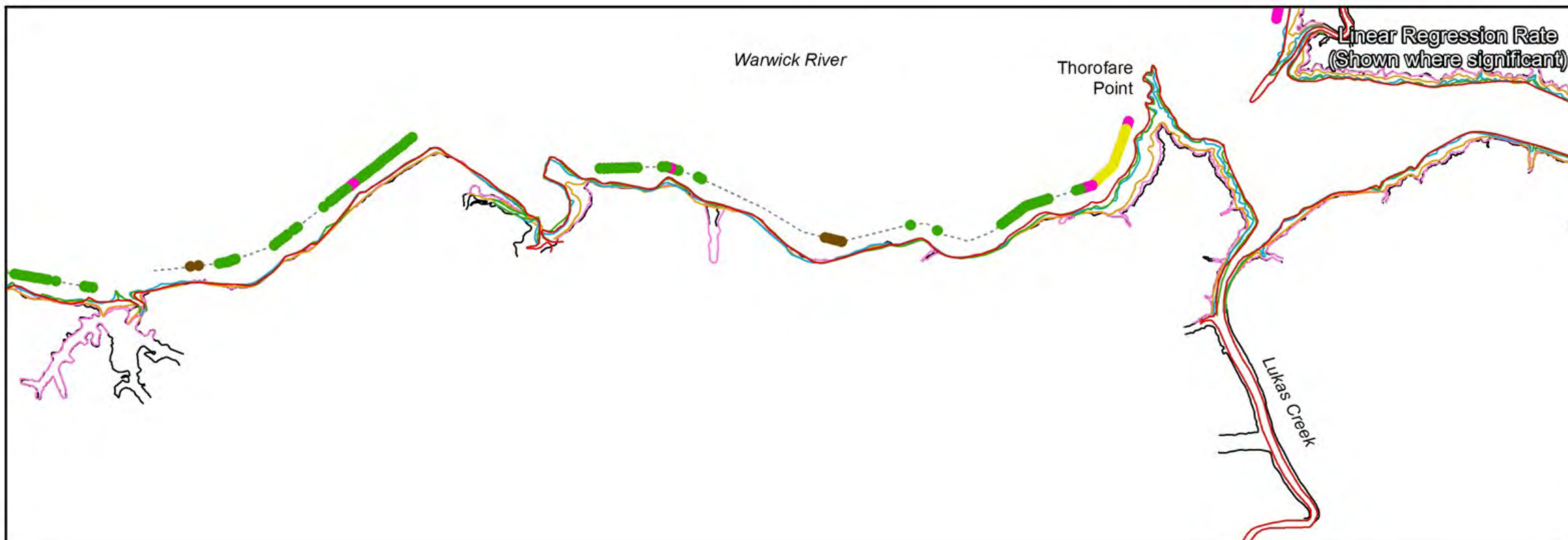
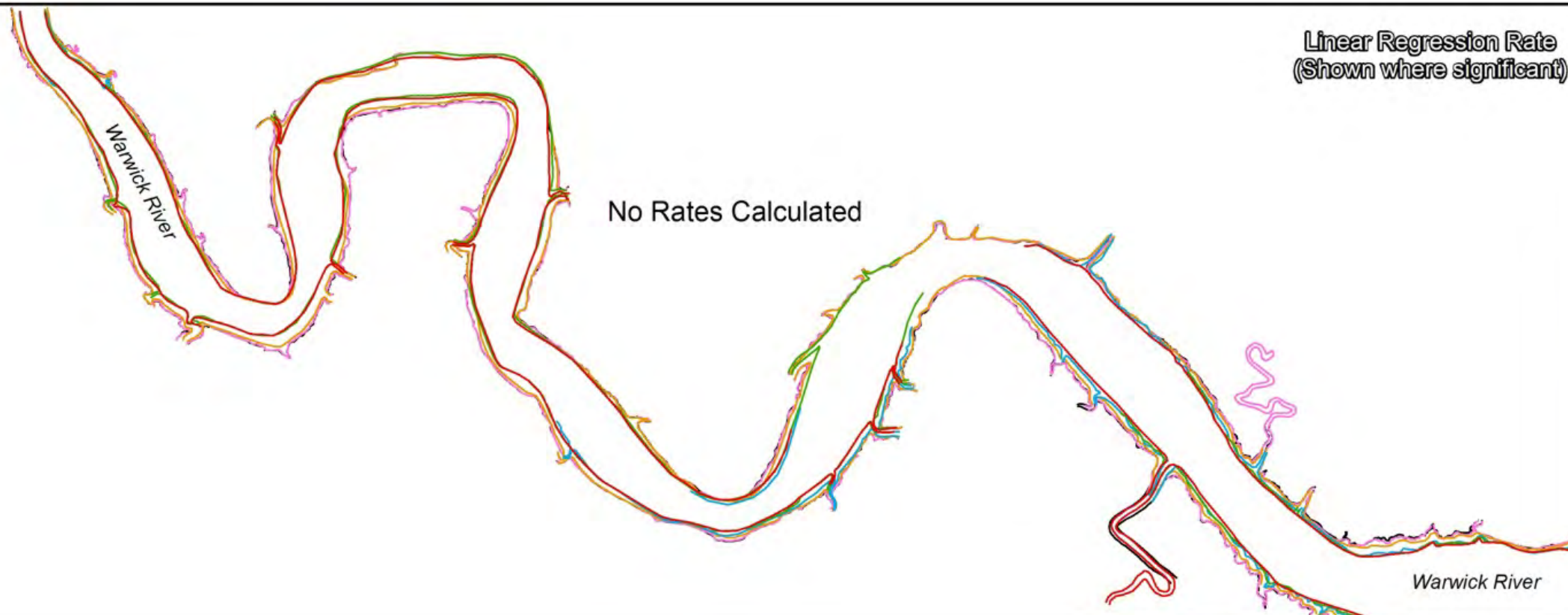


Image Date: 2007

City of Newport News Virginia

Plate 10

Linear Regression Rate
(Shown where significant)



Legend

- ◆ Change Related to Industrial Land Use
- ◆ Very High Accretion: >10 ft/yr
- ◆ High Accretion: +5 to +10 ft/yr
- Medium Accretion: +2 to +5 ft/yr
- Low Accretion: +1 to +2 ft/yr
- Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- - - - Baseline

End Point Rate

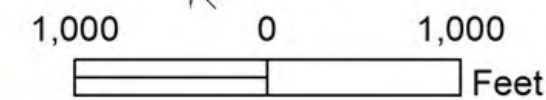


Image Date: 2007

City of Newport News Virginia

Plate 11

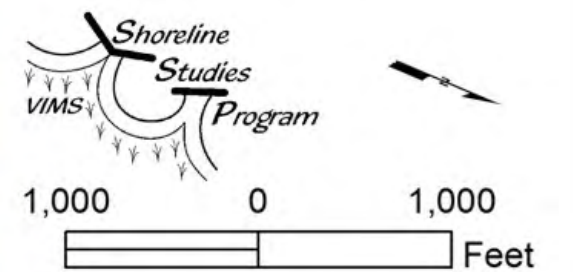
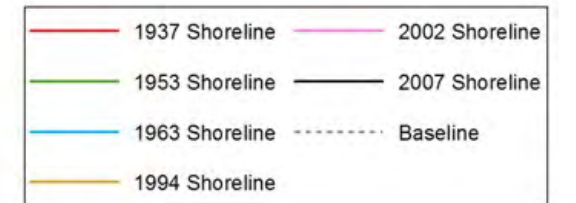
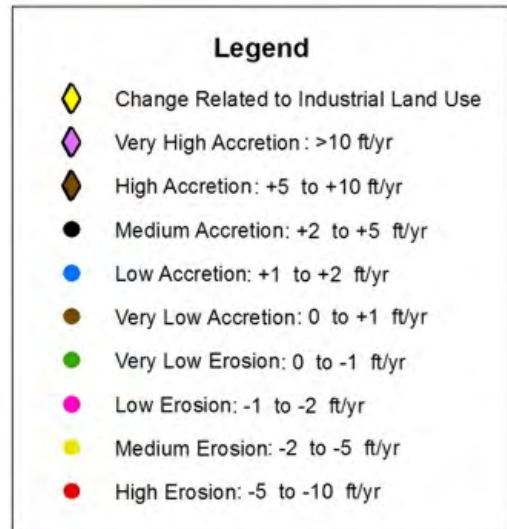
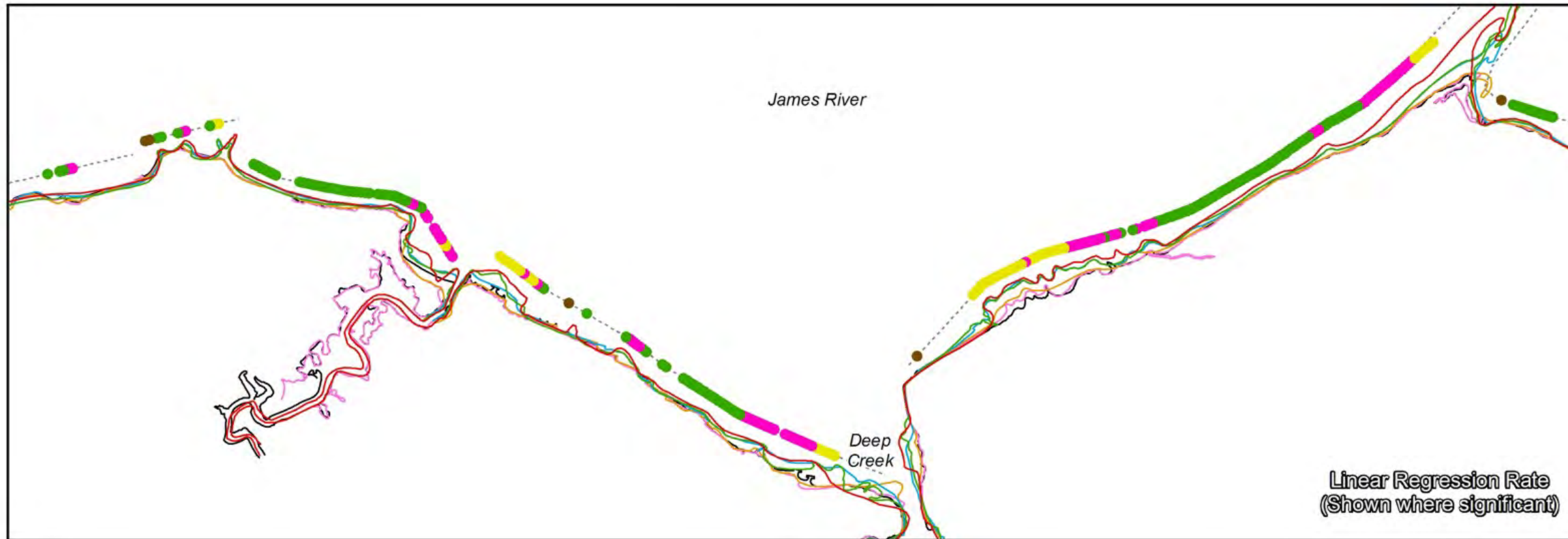
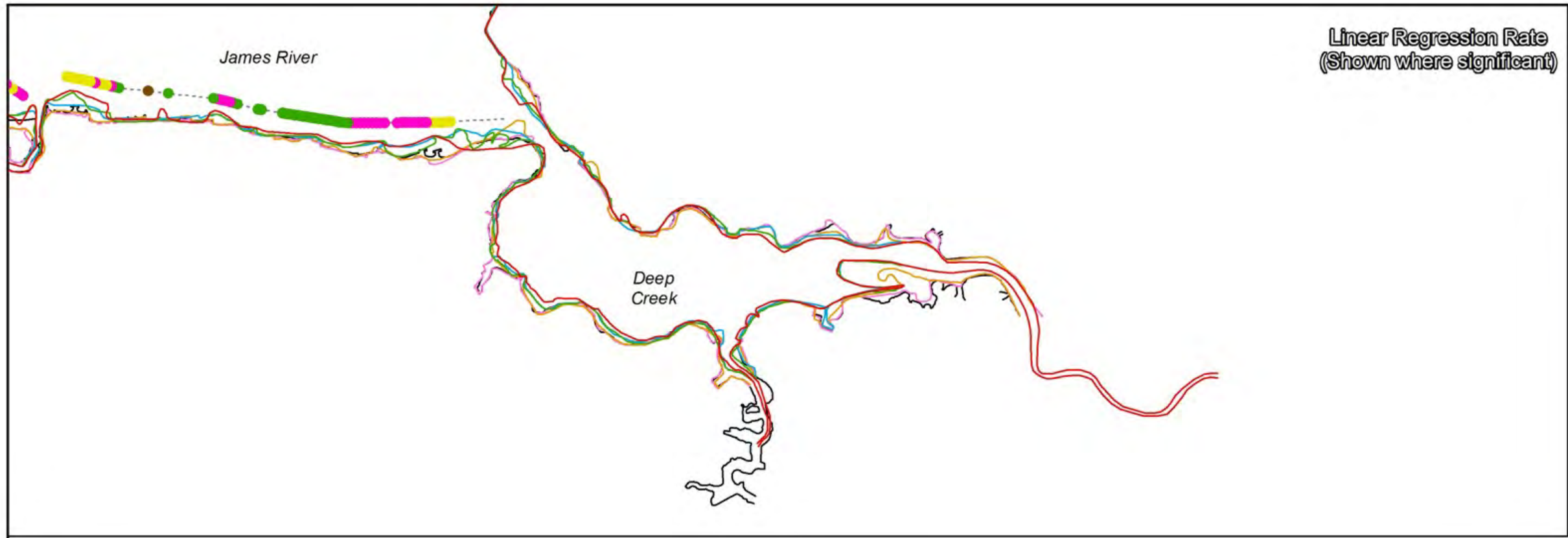


Image Date: 2007



City of Newport News Virginia

Plate 12

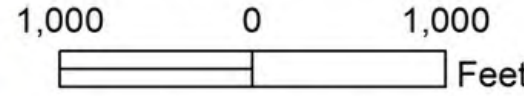
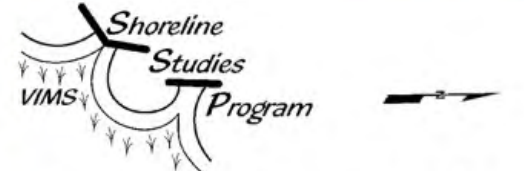
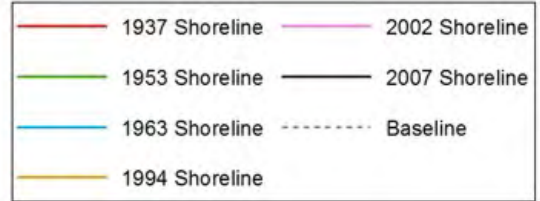
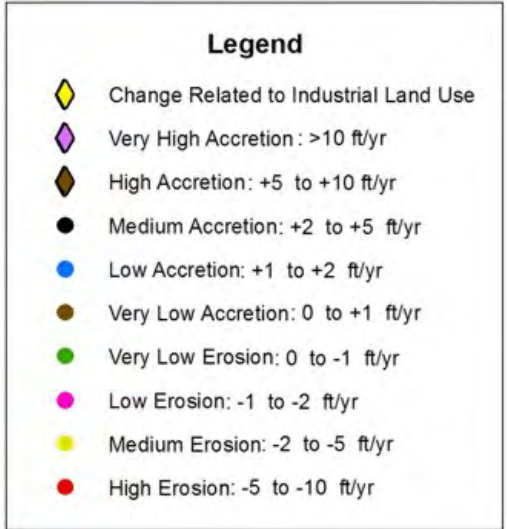


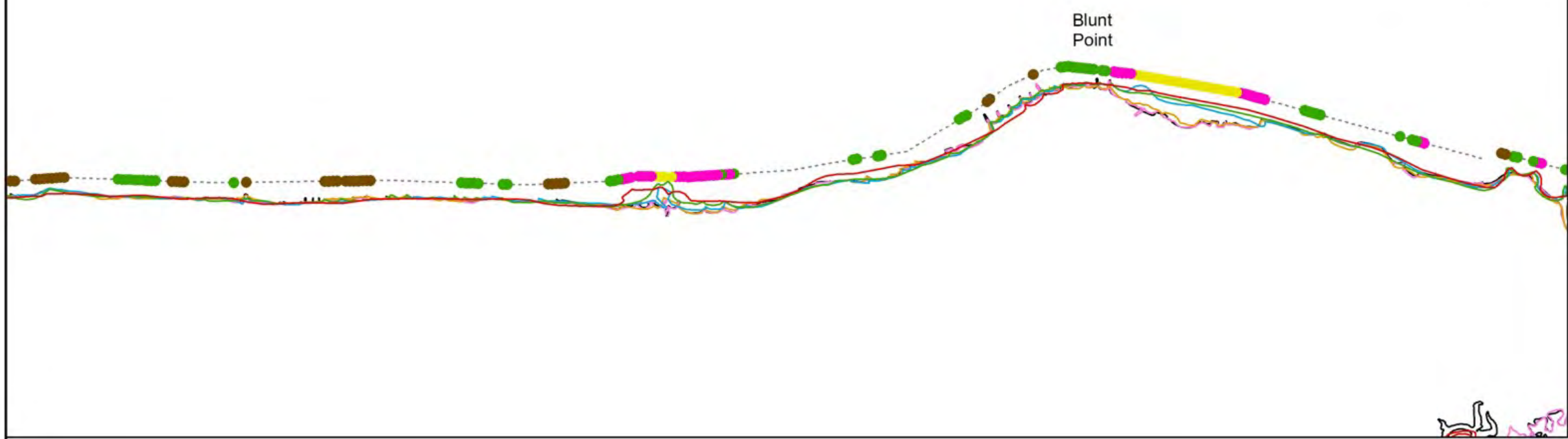
Image Date: 2007

James River

Linear Regression Rate
(Shown where significant)

City of Newport News Virginia

Plate 13



- Legend**
- ◆ Change Related to Industrial Land Use
 - ◆ Very High Accretion: >10 ft/yr
 - ◆ High Accretion: +5 to +10 ft/yr
 - Medium Accretion: +2 to +5 ft/yr
 - Low Accretion: +1 to +2 ft/yr
 - Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- - - Baseline

James River

End Point Rate

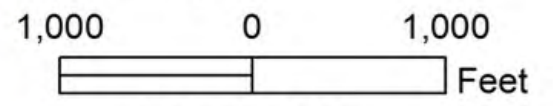
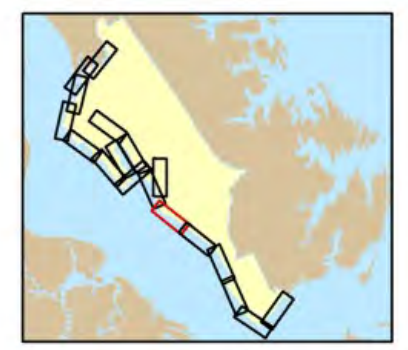


Image Date: 2007

James River

Linear Regression Rate
(Shown where significant)

City of Newport News Virginia

Plate 14



Legend

- ◆ Change Related to Industrial Land Use
- ◆ Very High Accretion: >10 ft/yr
- ◆ High Accretion: +5 to +10 ft/yr
- Medium Accretion: +2 to +5 ft/yr
- Low Accretion: +1 to +2 ft/yr
- Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- Baseline

James River

End Point Rate

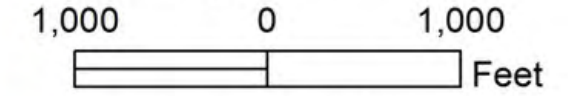
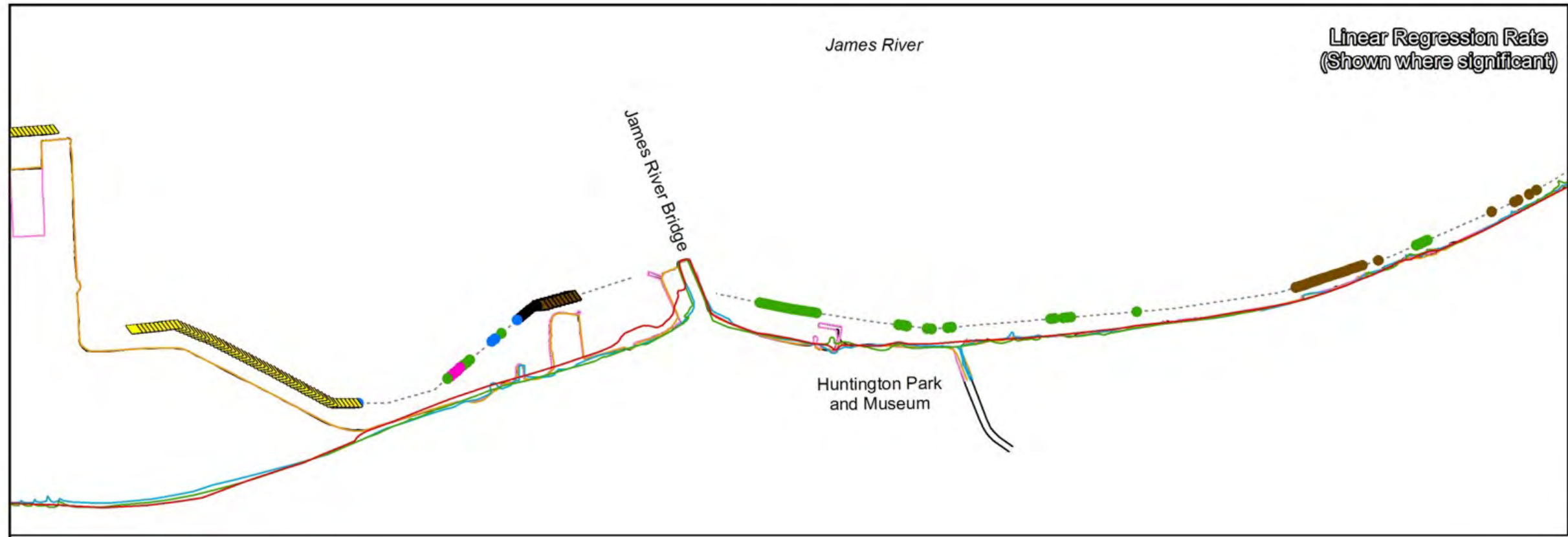


Image Date: 2007



City of Newport News Virginia

Plate 15

- Legend**
- ◆ Change Related to Industrial Land Use
 - ◆ Very High Accretion: >10 ft/yr
 - ◆ High Accretion: +5 to +10 ft/yr
 - Medium Accretion: +2 to +5 ft/yr
 - Low Accretion: +1 to +2 ft/yr
 - Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 2002 Shoreline
- 1953 Shoreline
- 2007 Shoreline
- 1963 Shoreline
- - - - - Baseline
- 1994 Shoreline

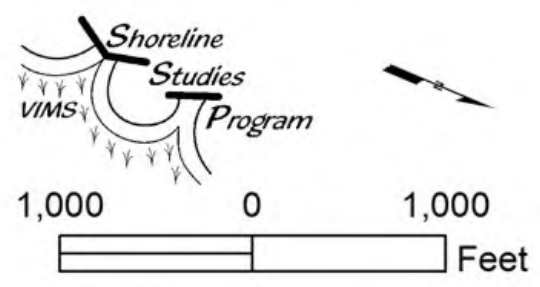


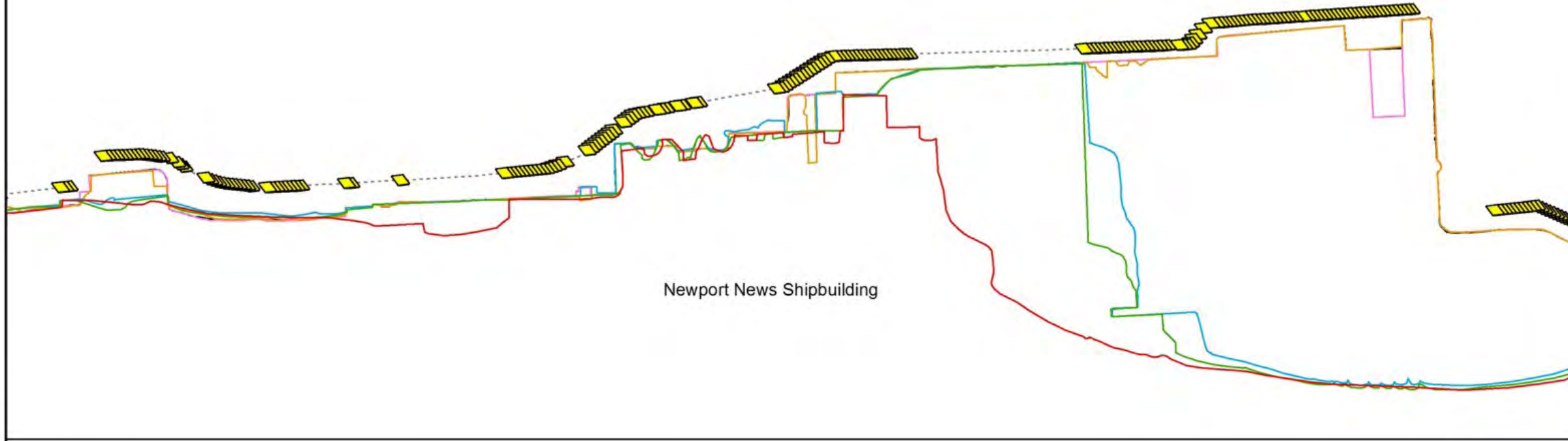
Image Date: 2007

James River

Linear Regression Rate
(Shown where significant)

City of Newport News Virginia

Plate 16



Newport News Shipbuilding

Legend

- ◆ Change Related to Industrial Land Use
- ◆ Very High Accretion: >10 ft/yr
- ◆ High Accretion: +5 to +10 ft/yr
- Medium Accretion: +2 to +5 ft/yr
- Low Accretion: +1 to +2 ft/yr
- Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- - - - - Baseline

James River

End Point Rate



Victory
Landing
Park

Newport News Shipbuilding

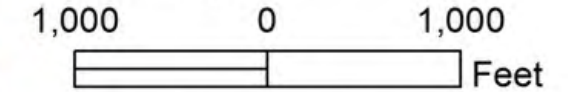


Image Date: 2007

James River

Linear Regression Rate
(Shown where significant)

City of Newport News Virginia

Plate 17



Legend

- ◆ Change Related to Industrial Land Use
- ◆ Very High Accretion: >10 ft/yr
- ◆ High Accretion: +5 to +10 ft/yr
- Medium Accretion: +2 to +5 ft/yr
- Low Accretion: +1 to +2 ft/yr
- Very Low Accretion: 0 to +1 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

- 1937 Shoreline
- 1953 Shoreline
- 1963 Shoreline
- 1994 Shoreline
- 2002 Shoreline
- 2007 Shoreline
- - - - - Baseline

James River

End Point Rate

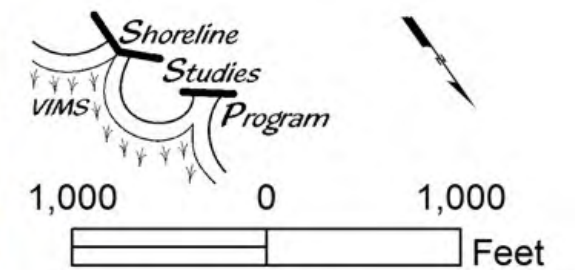
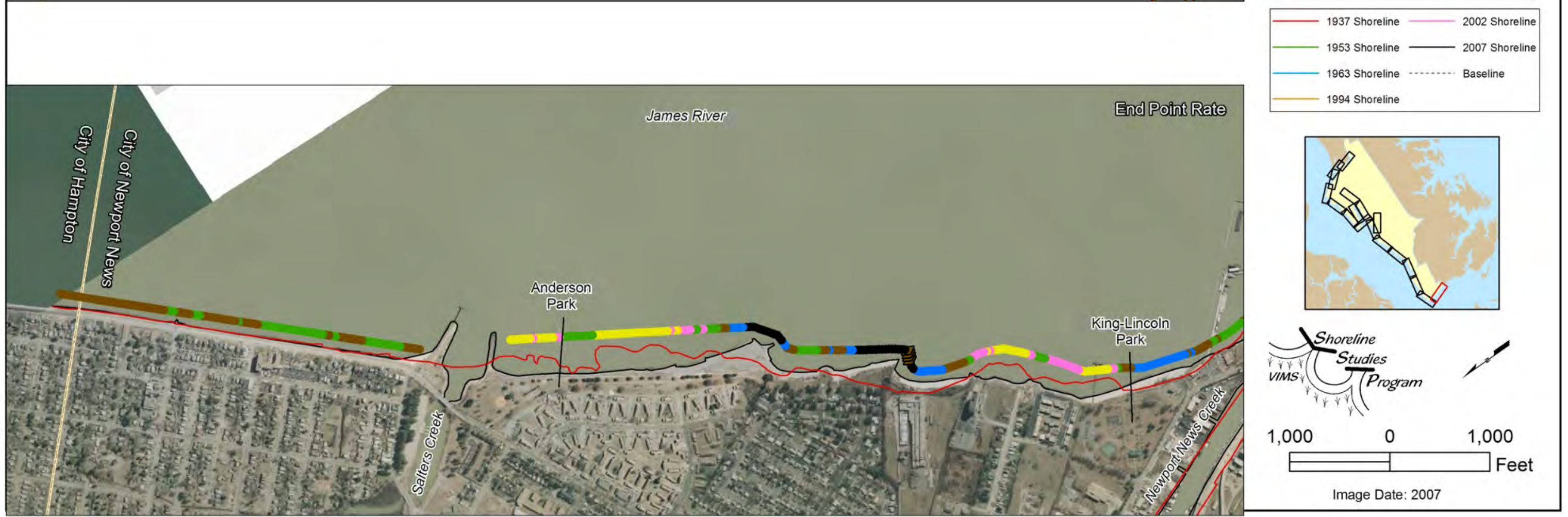


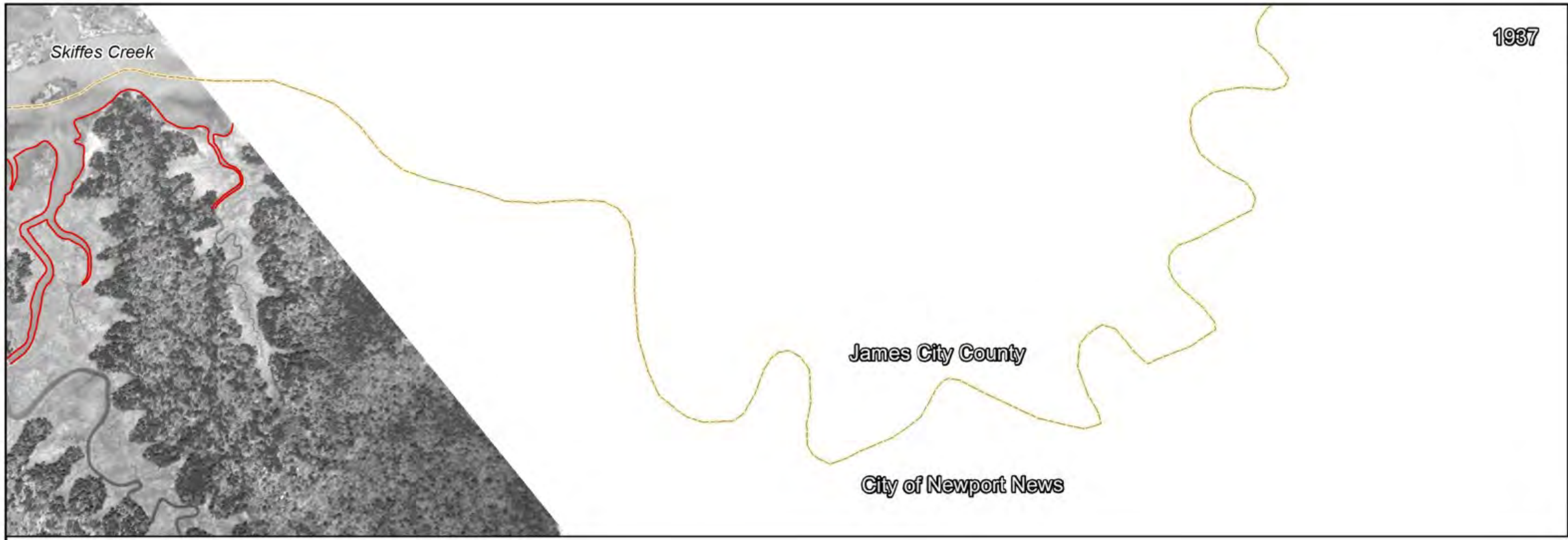
Image Date: 2007



Appendix B

Historical Shoreline Photos

Plate 1	Plate 7	Plate 13
Plate 2	Plate 8	Plate 14
Plate 3	Plate 9	Plate 15
Plate 4	Plate 10	Plate 16
Plate 5	Plate 11	Plate 17
Plate 6	Plate 12	Plate 18



1937

City of Newport News Virginia

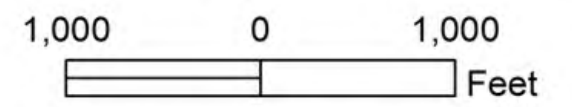
Plate 1

Legend

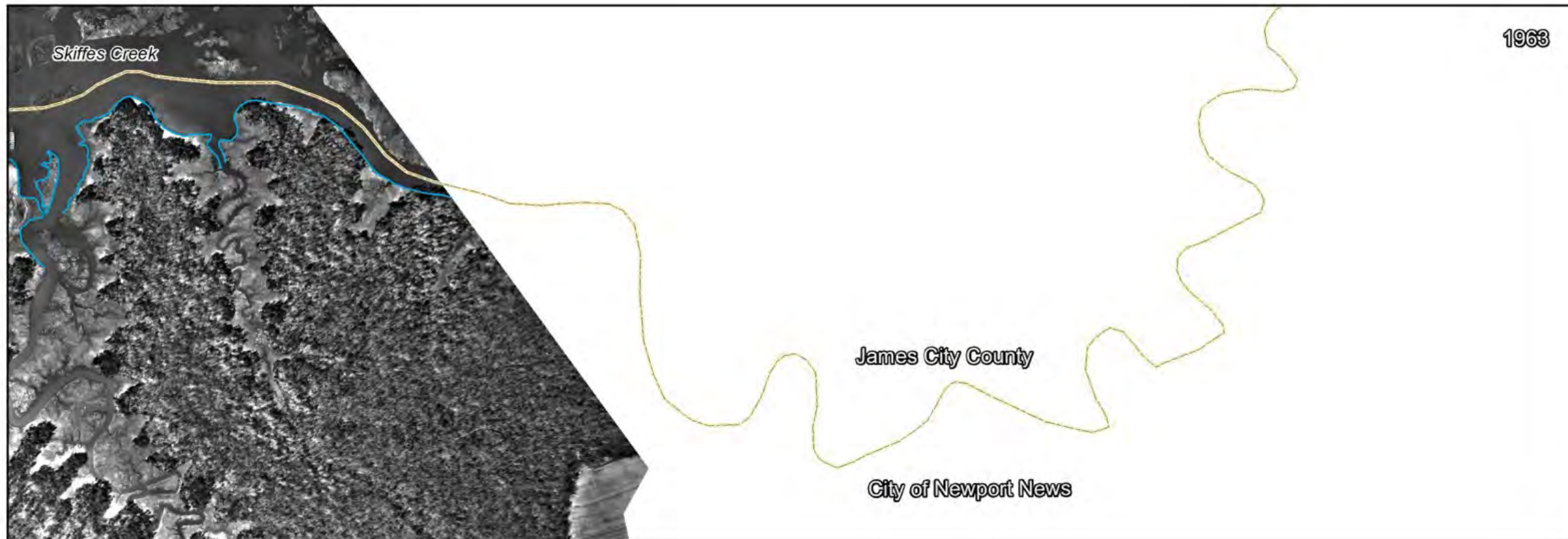
- 1937 Shoreline
- 1953 Shoreline



1953



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.



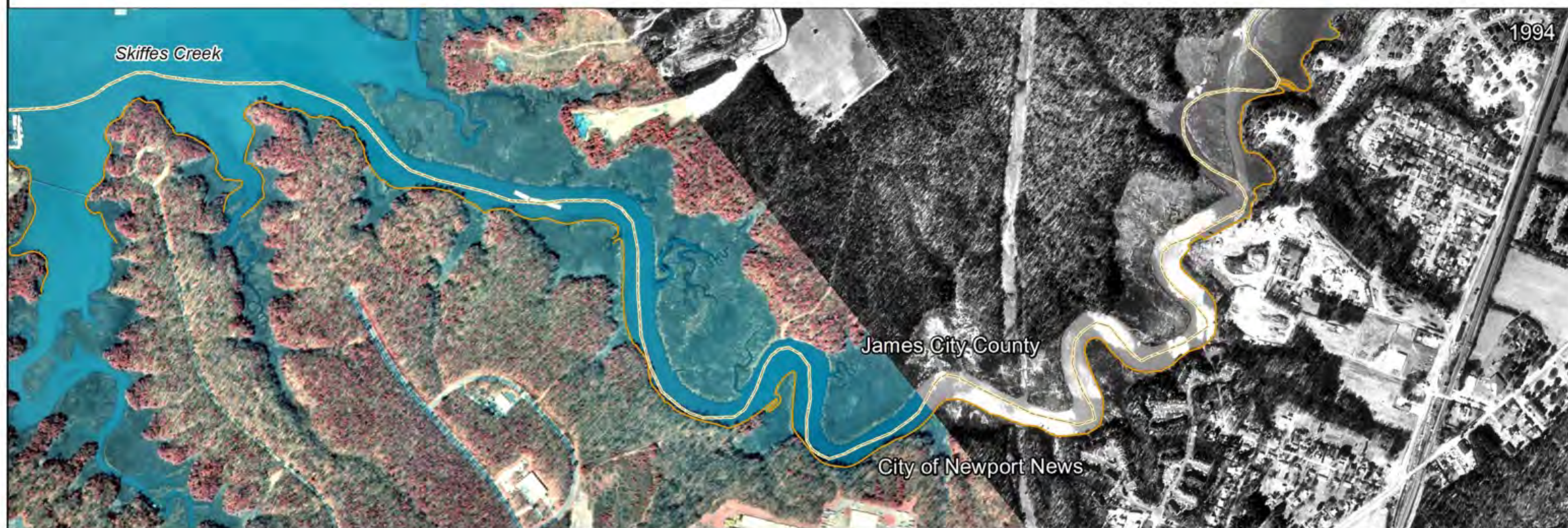
1963

City of Newport News Virginia

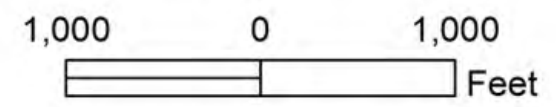
Plate 1

Legend

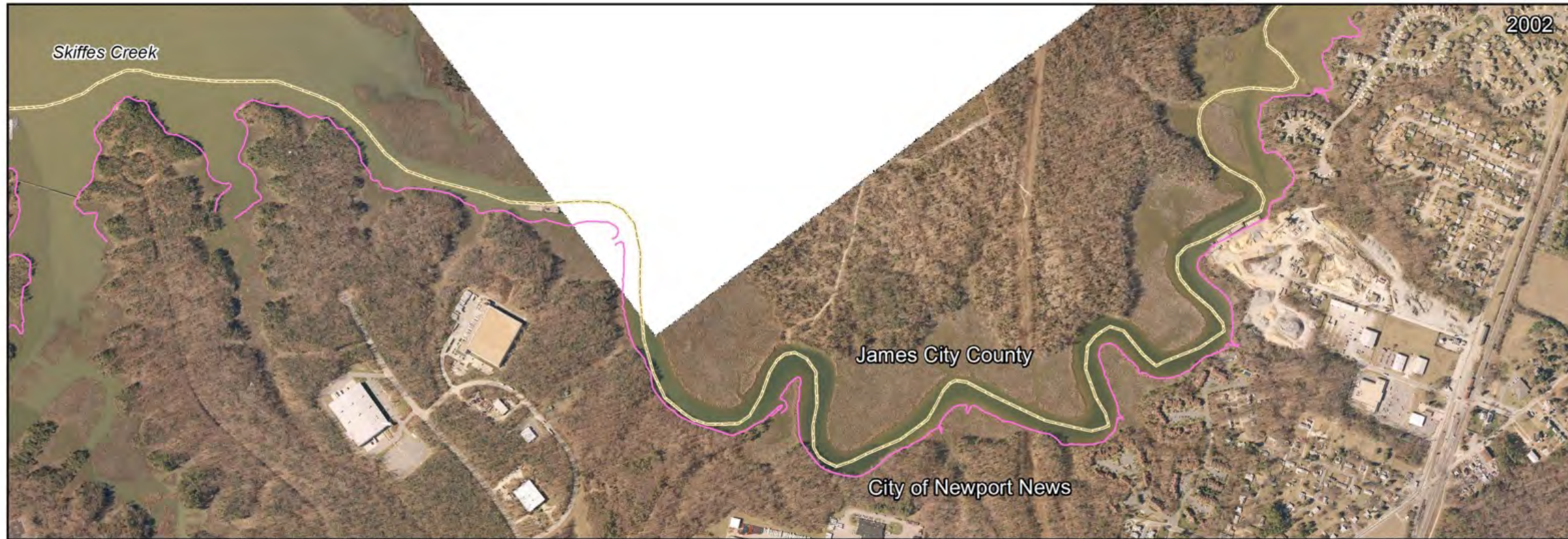
- 1963 Shoreline
- 1994 Shoreline



1994



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

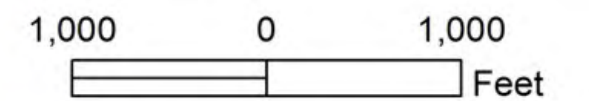


City of Newport News Virginia

Plate 1

Legend

- 2002 Shoreline
- 2007 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

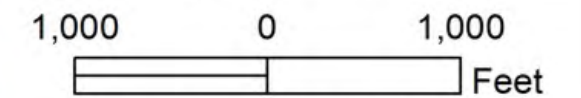


City of Newport News Virginia

Plate 2

Legend

- 1937 Shoreline
- 1953 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

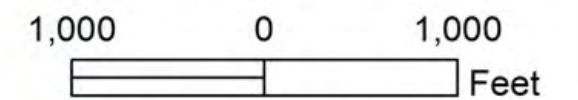


City of Newport News Virginia

Plate 2

Legend

- 1963 Shoreline
- 1994 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.



**City of Newport News
Virginia**

Plate 2

Legend

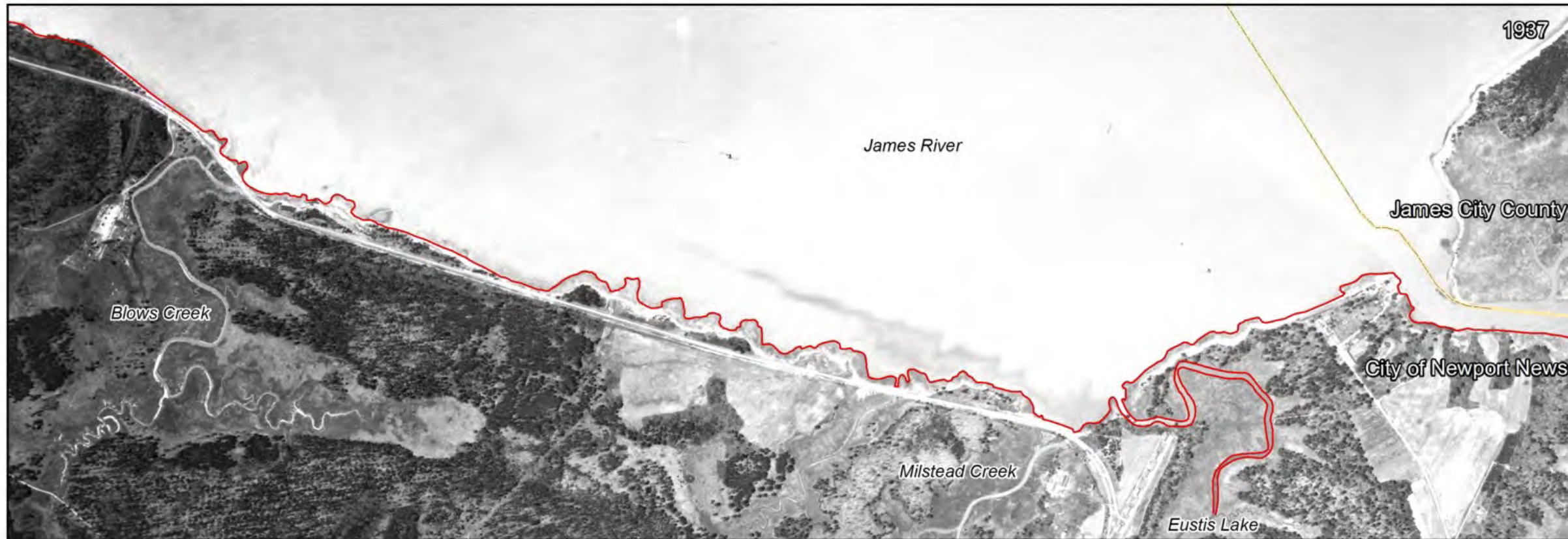
- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

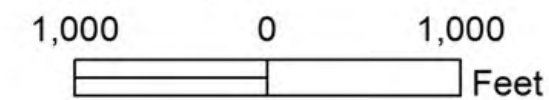


City of Newport News Virginia

Plate 3

Legend

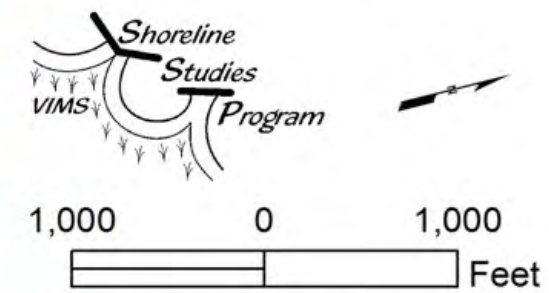
- 1937 Shoreline
- 1953 Shoreline





City of Newport News Virginia

Plate 3



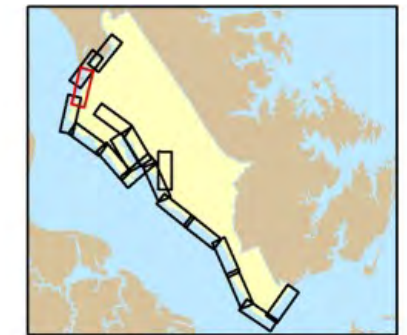


City of Newport News Virginia

Plate 3

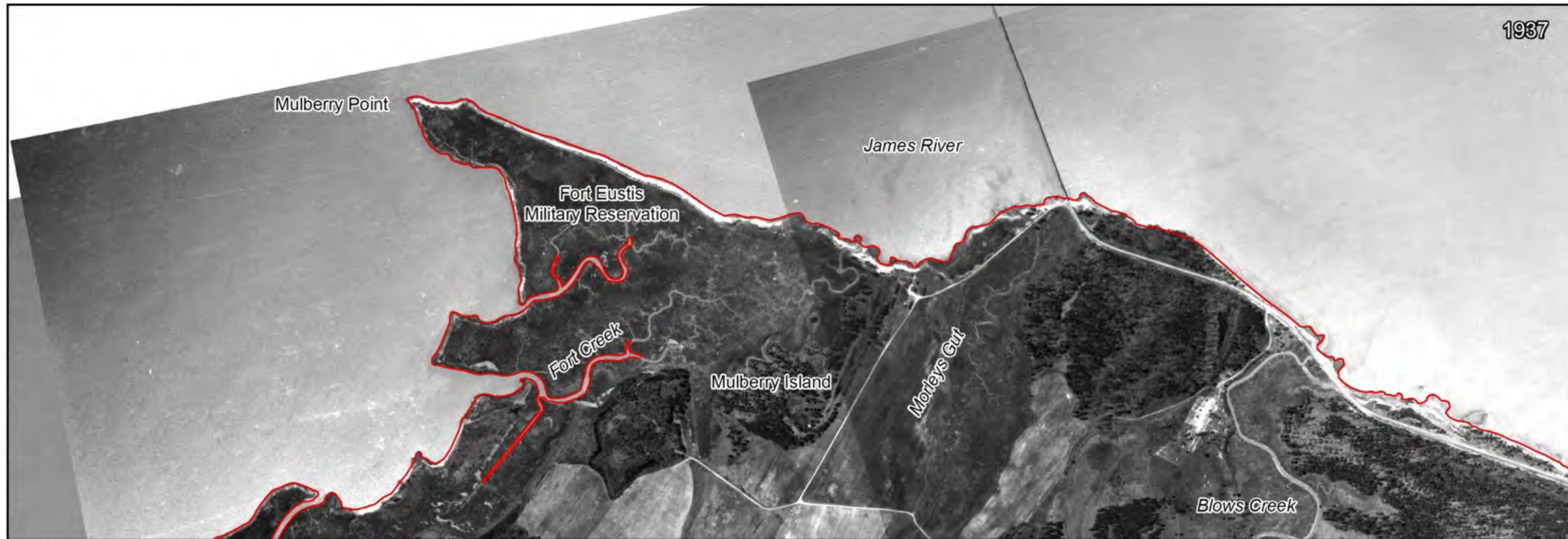
Legend

- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000 Feet

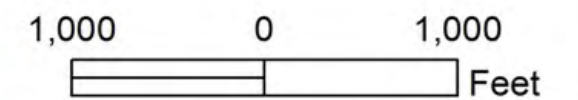
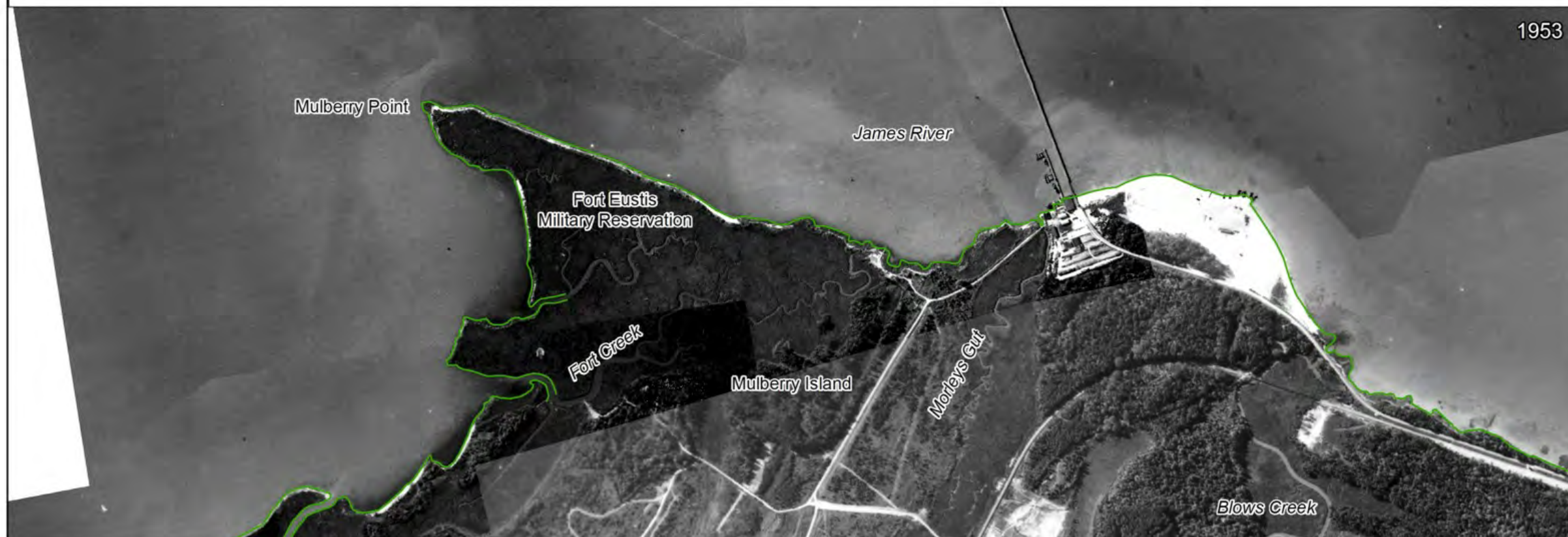


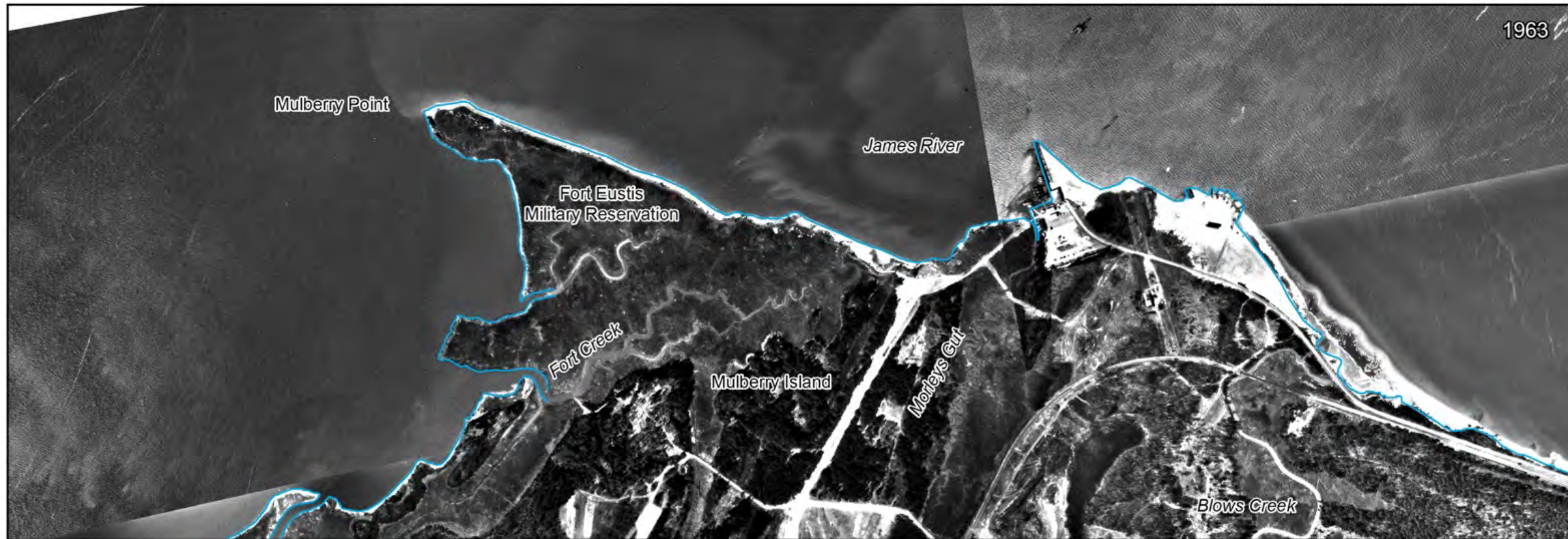
City of Newport News Virginia

Plate 4

Legend

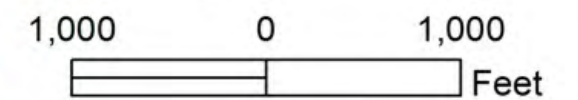
- 1937 Shoreline
- 1953 Shoreline





City of Newport News Virginia

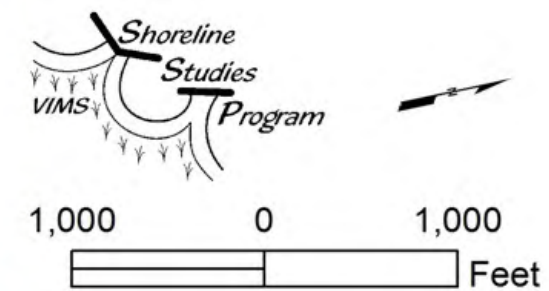
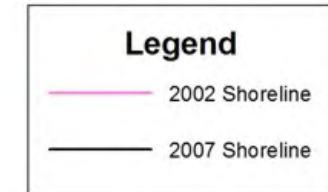
Plate 4

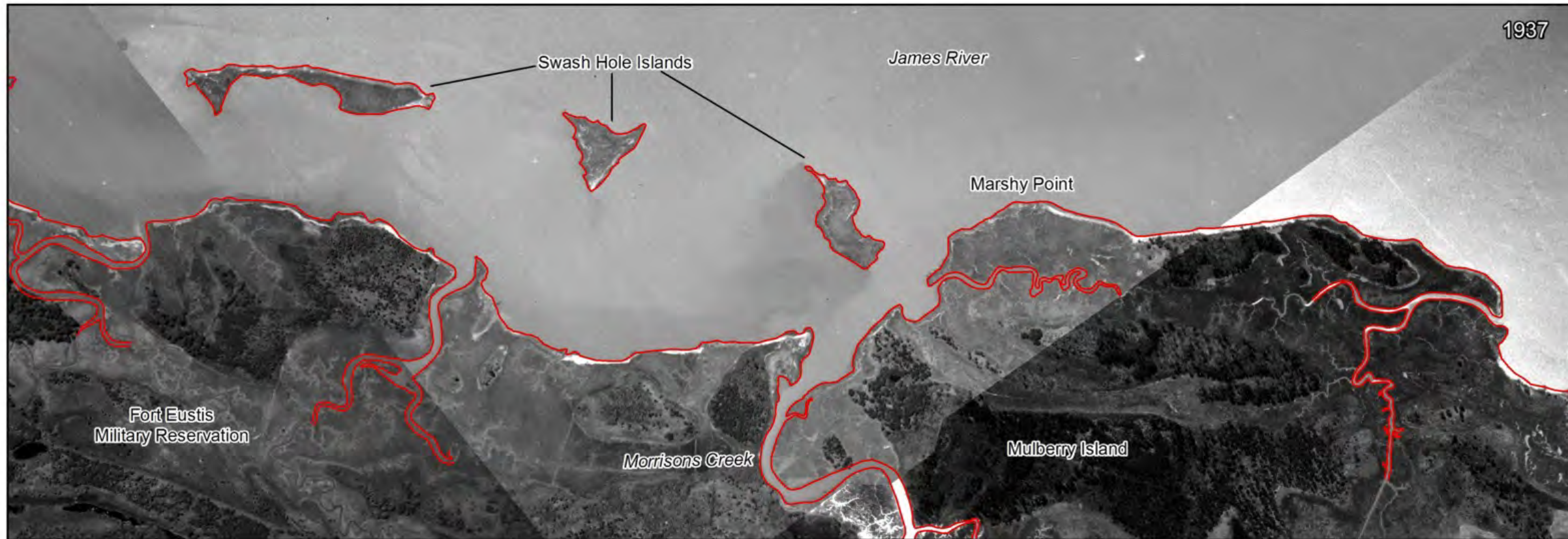




City of Newport News Virginia

Plate 4



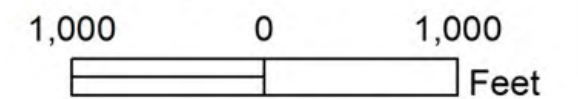
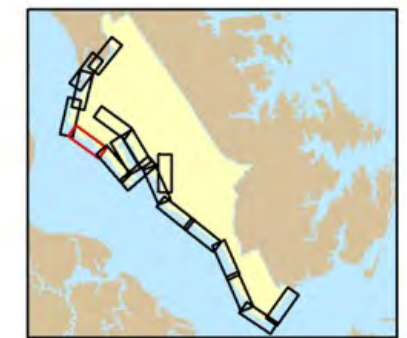
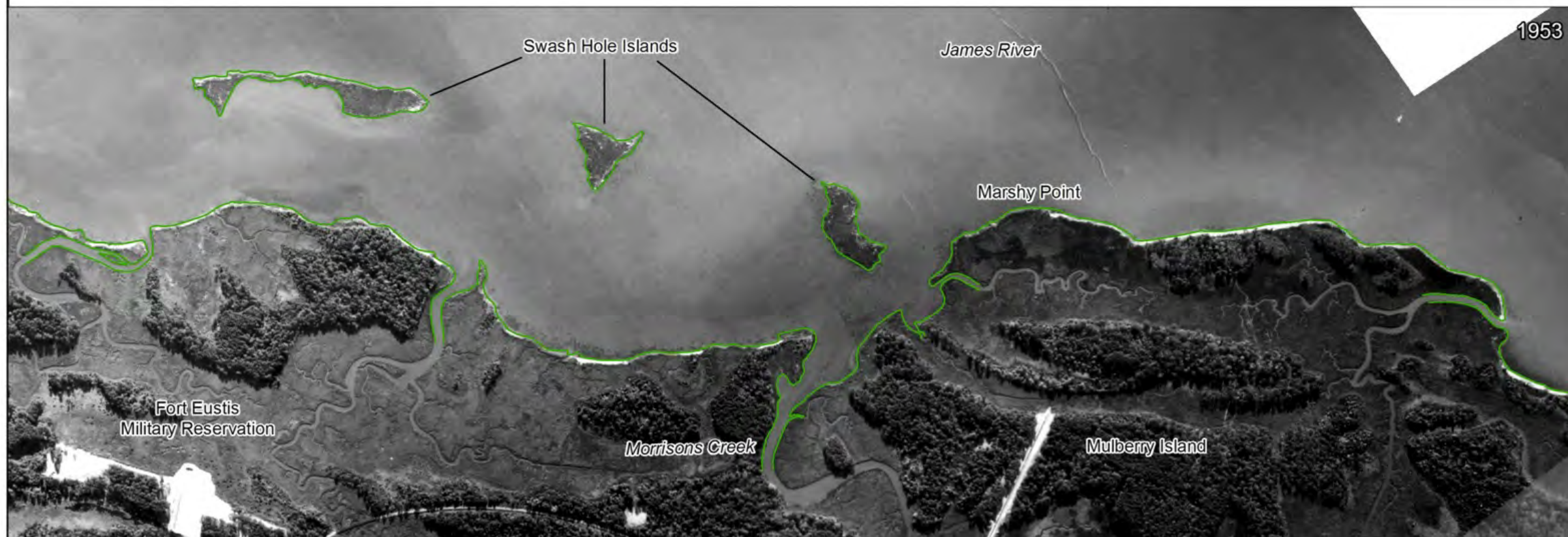


City of Newport News Virginia

Plate 5

Legend

- 1937 Shoreline
- 1953 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

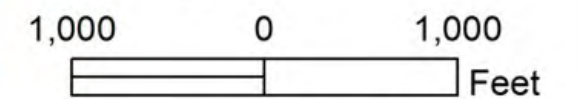


City of Newport News Virginia

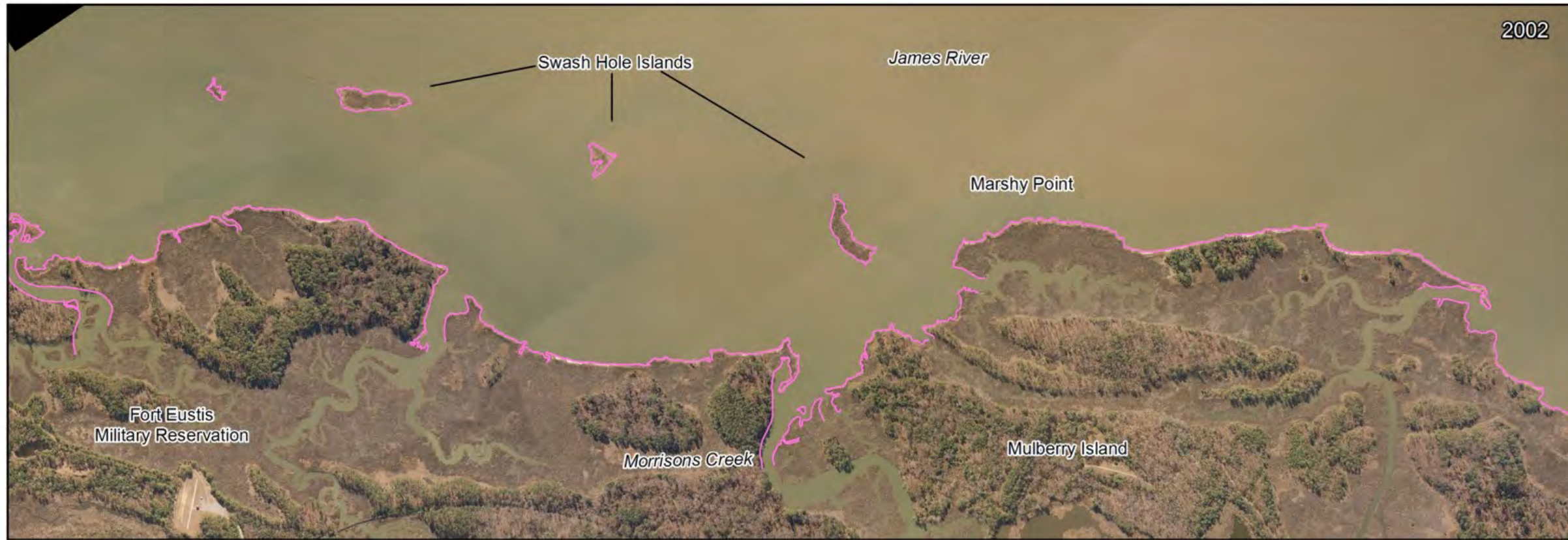
Plate 5

Legend

- 1963 Shoreline
- 1994 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

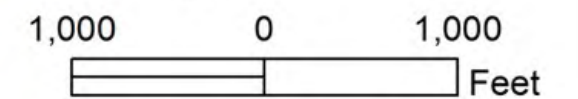
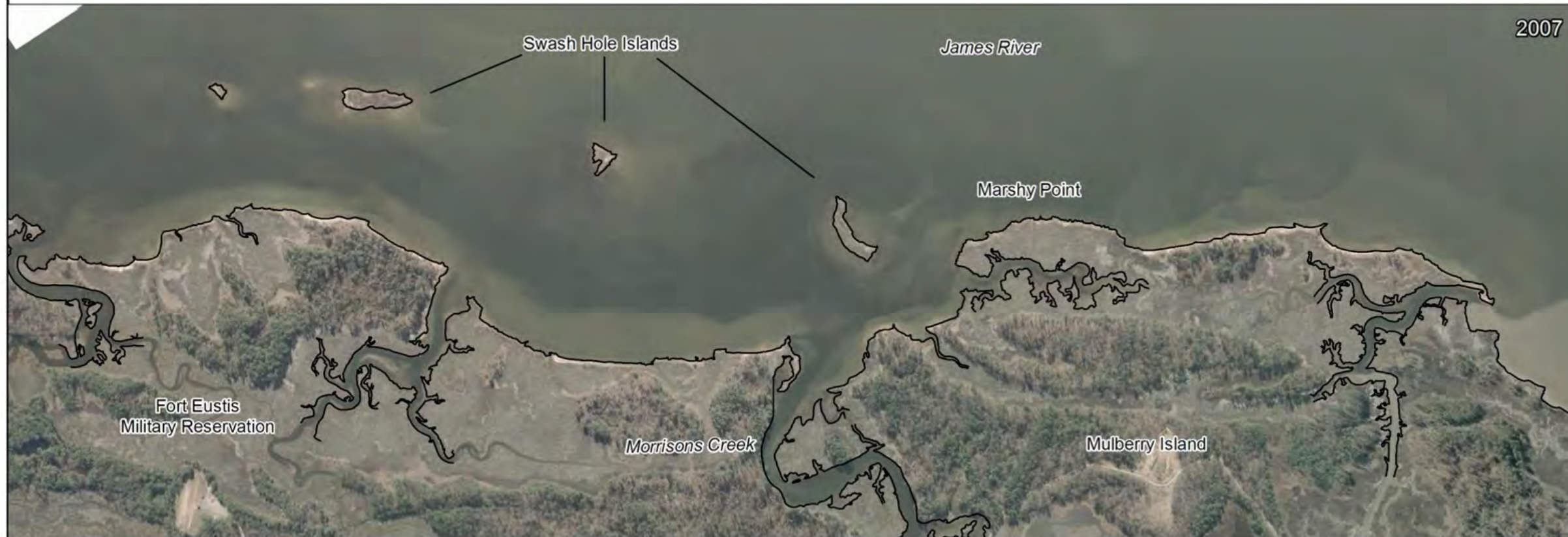


City of Newport News Virginia

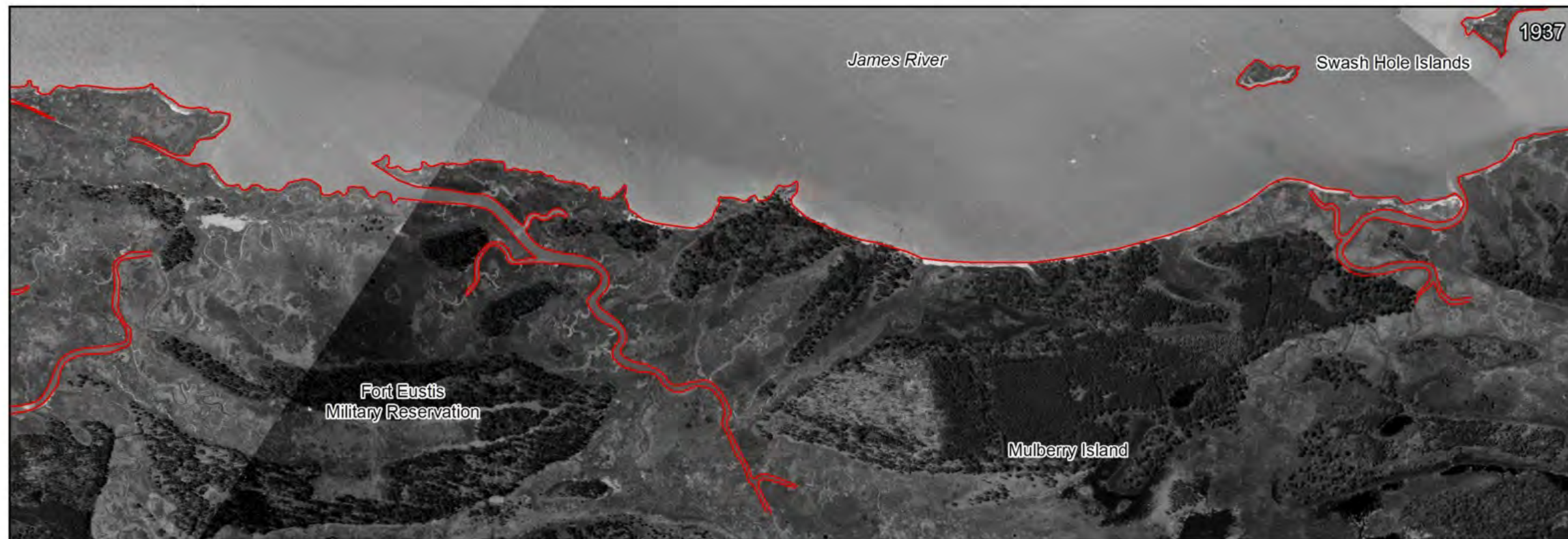
Plate 5

Legend

- 2002 Shoreline
- 2007 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

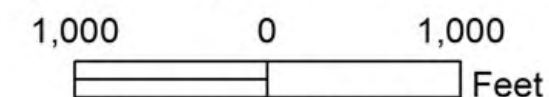


City of Newport News Virginia

Plate 6

Legend

- 1937 Shoreline
- 1953 Shoreline

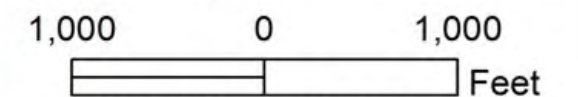


Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.



City of Newport News Virginia

Plate 6



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

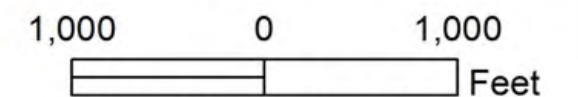


City of Newport News Virginia

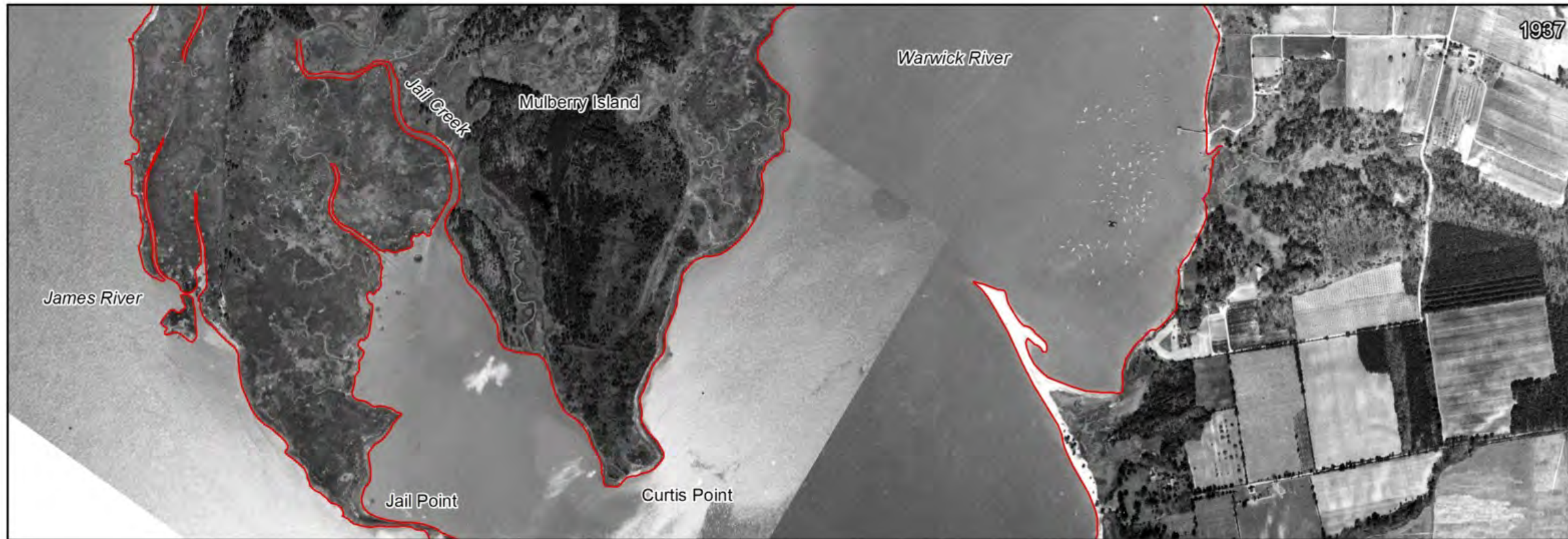
Plate 6

Legend

- 2002 Shoreline
- 2007 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

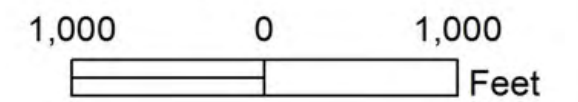
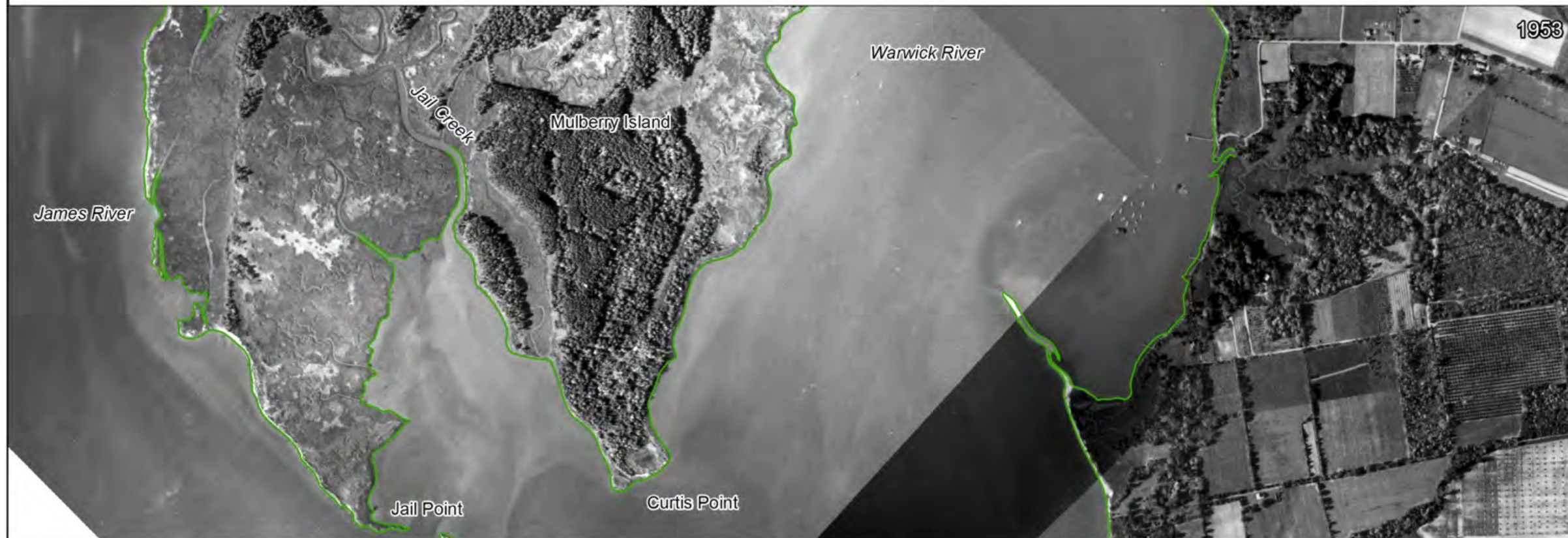


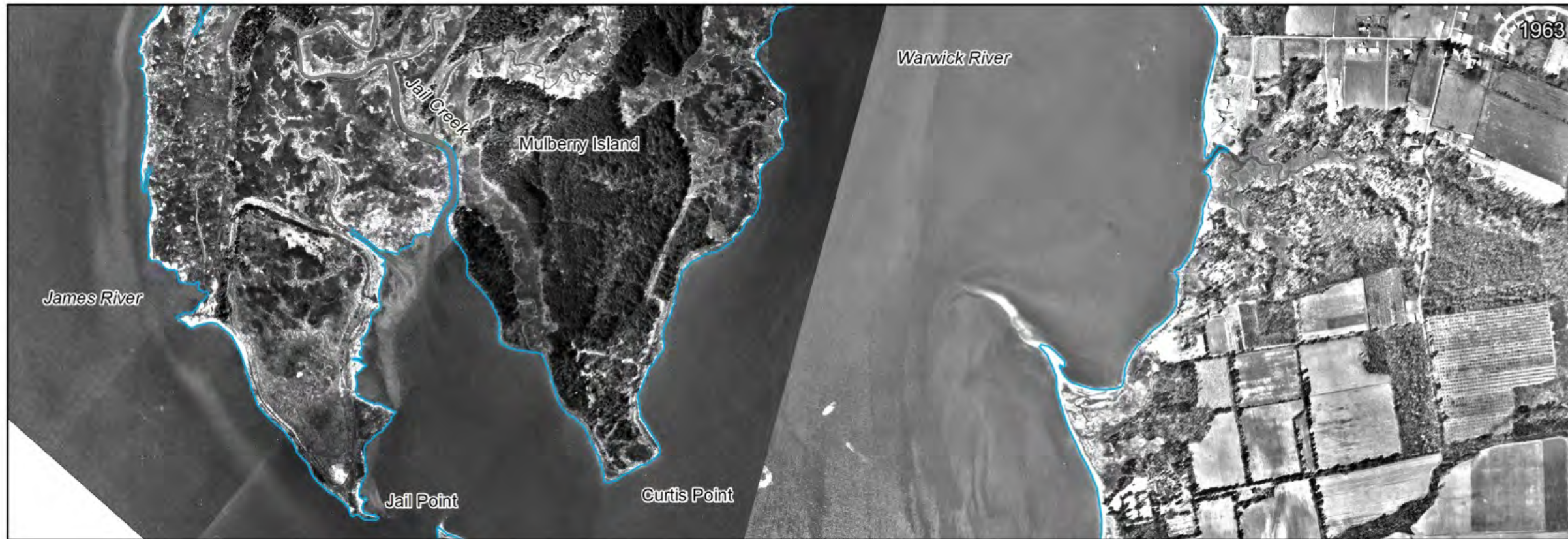
**City of Newport News
Virginia**

Plate 7

Legend

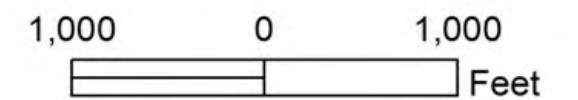
- 1937 Shoreline
- 1953 Shoreline





City of Newport News Virginia

Plate 7



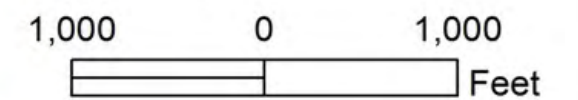


City of Newport News Virginia

Plate 7

Legend

- 2002 Shoreline
- 2007 Shoreline



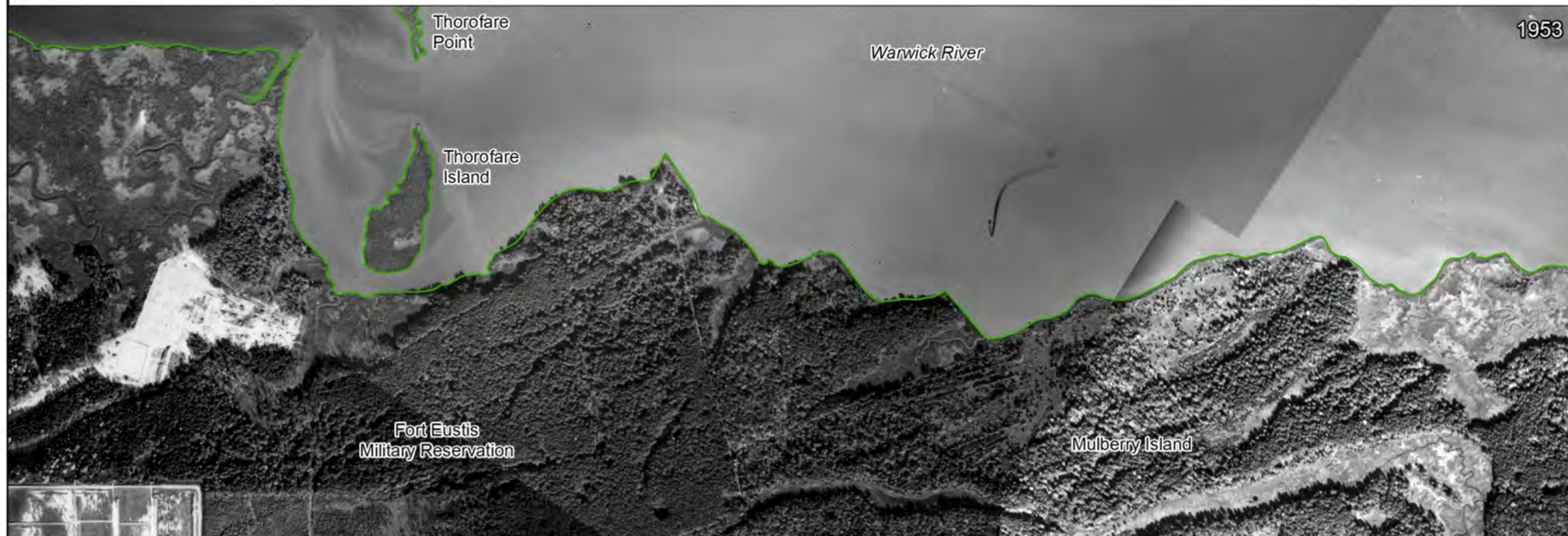


City of Newport News Virginia

Plate 8

Legend

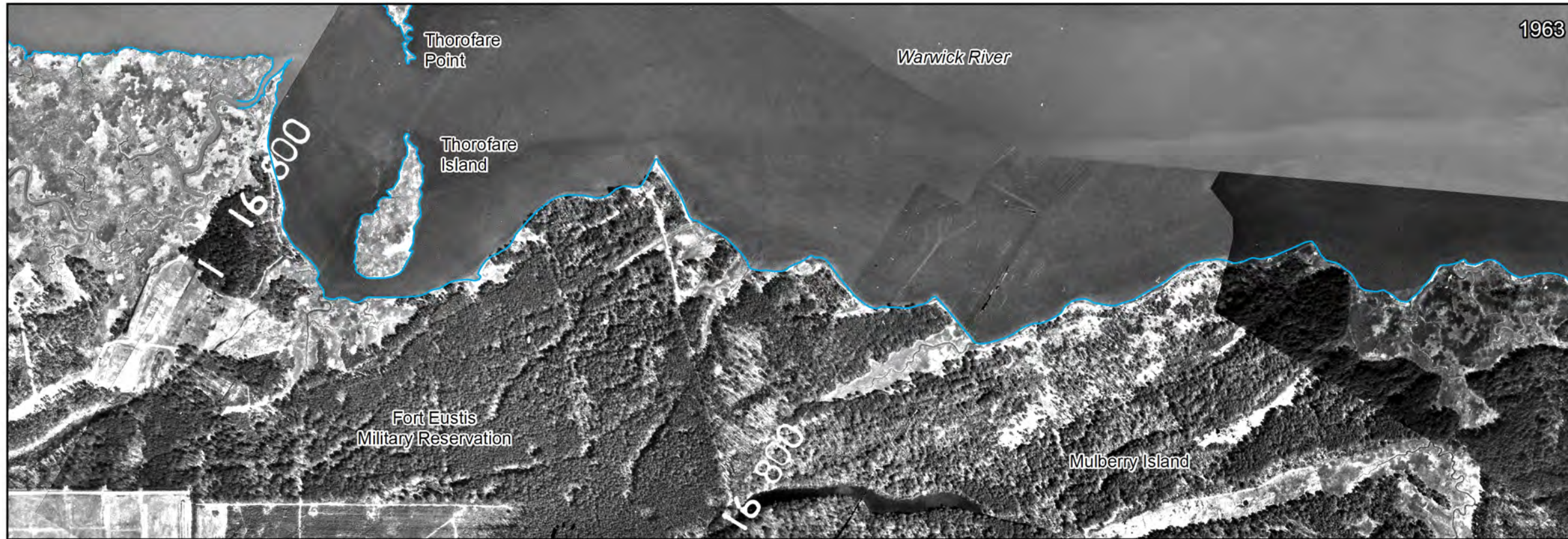
- 1937 Shoreline
- 1953 Shoreline



Shoreline Studies Program

VIMS

1,000 0 1,000 Feet



1963

City of Newport News Virginia

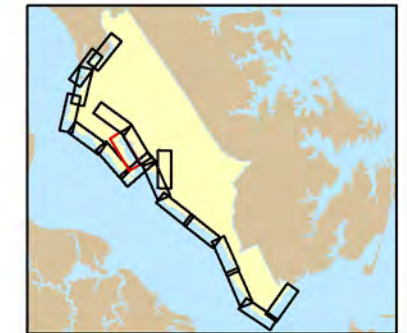
Plate 8

Legend

- 1963 Shoreline
- 1994 Shoreline



1994



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet



City of Newport News Virginia

Plate 8

Legend

- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000 Feet

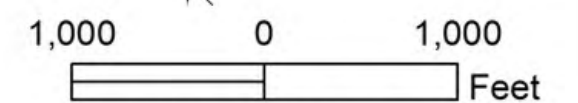


City of Newport News Virginia

Plate 9

Legend

- 1937 Shoreline
- 1953 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

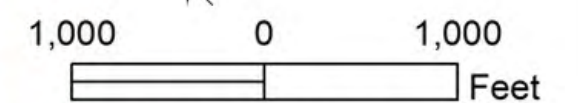


City of Newport News Virginia

Plate 9

Legend

- 1963 Shoreline
- 1994 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.

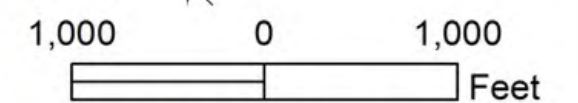


City of Newport News Virginia

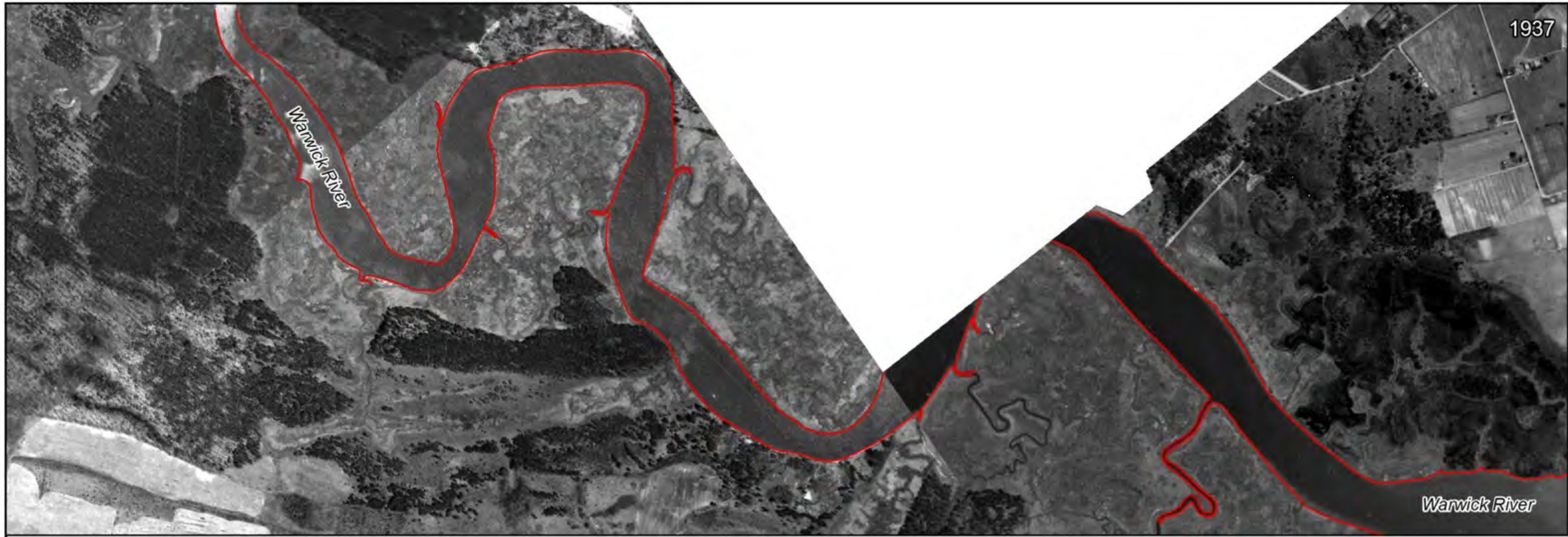
Plate 9

Legend

- 2002 Shoreline
- 2007 Shoreline



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.



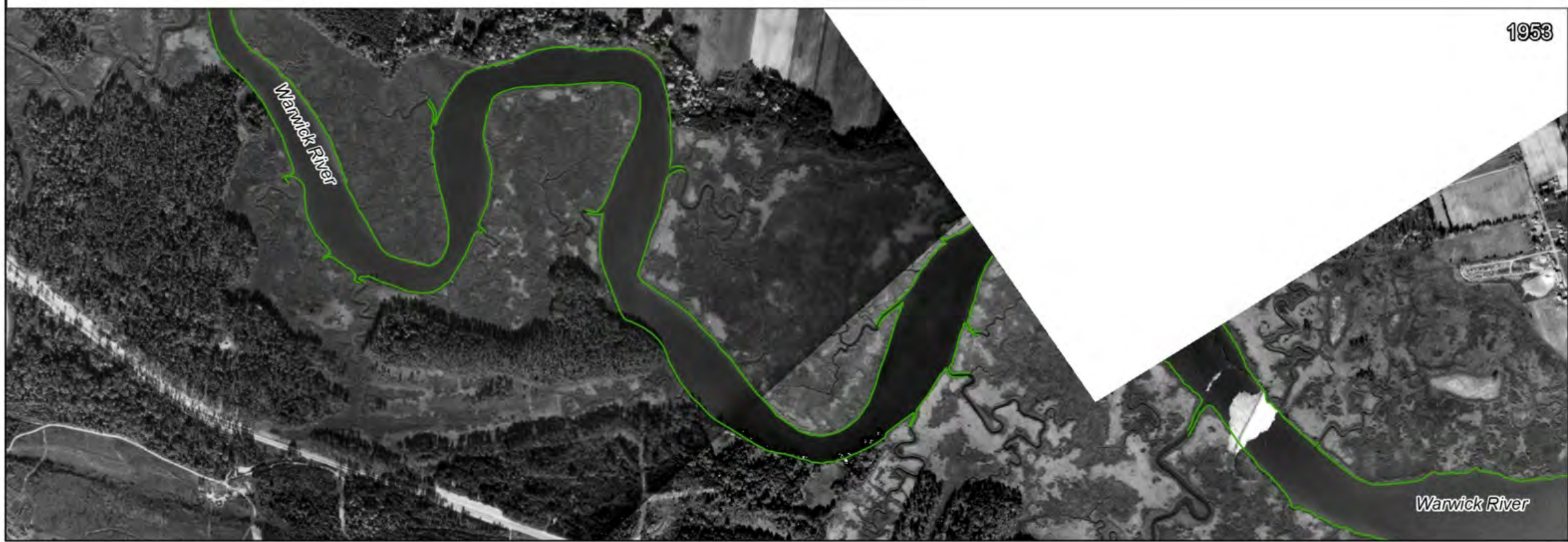
1937

City of Newport News Virginia

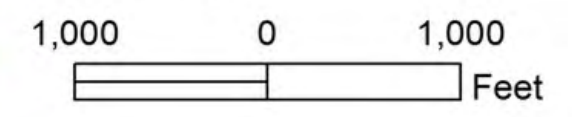
Plate 10

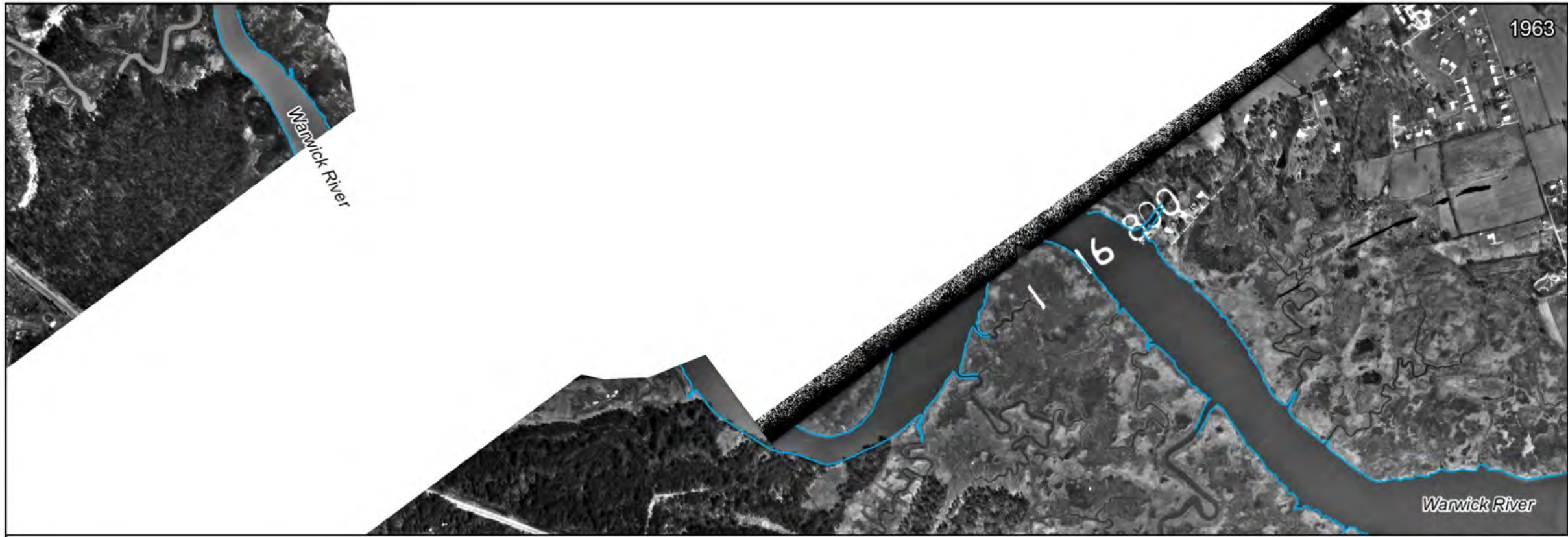
Legend

- 1937 Shoreline
- 1953 Shoreline



1953





City of Newport News Virginia

Plate 10

Legend

- 1963 Shoreline
- 1994 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

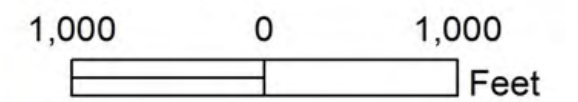


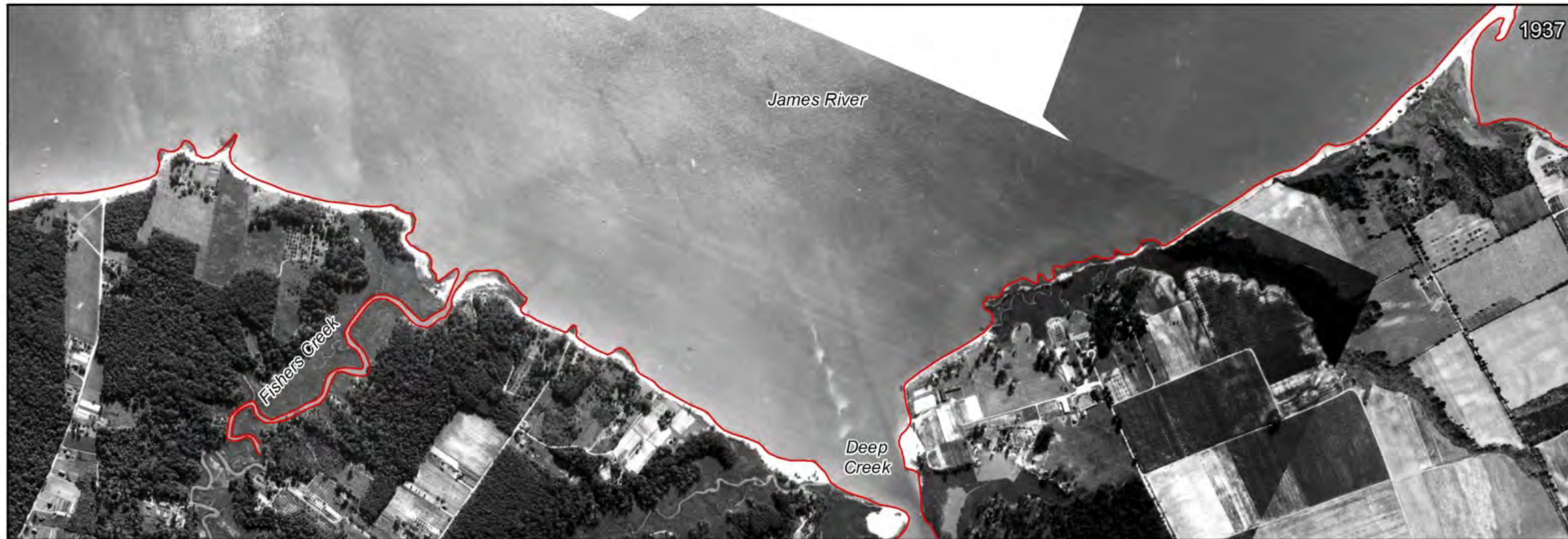
City of Newport News Virginia

Plate 10

Legend

- 2002 Shoreline
- 2007 Shoreline



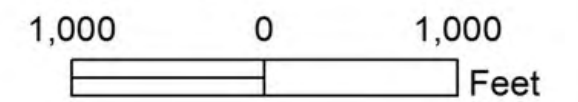


City of Newport News Virginia

Plate 11

Legend

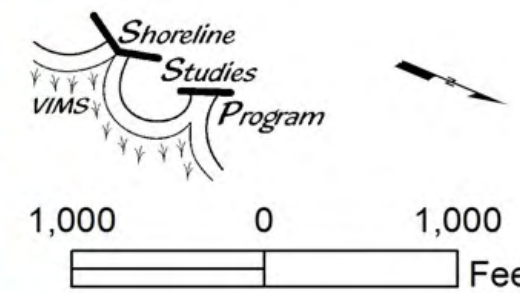
- 1937 Shoreline
- 1953 Shoreline





City of Newport News Virginia

Plate 11





City of Newport News Virginia

Plate 11

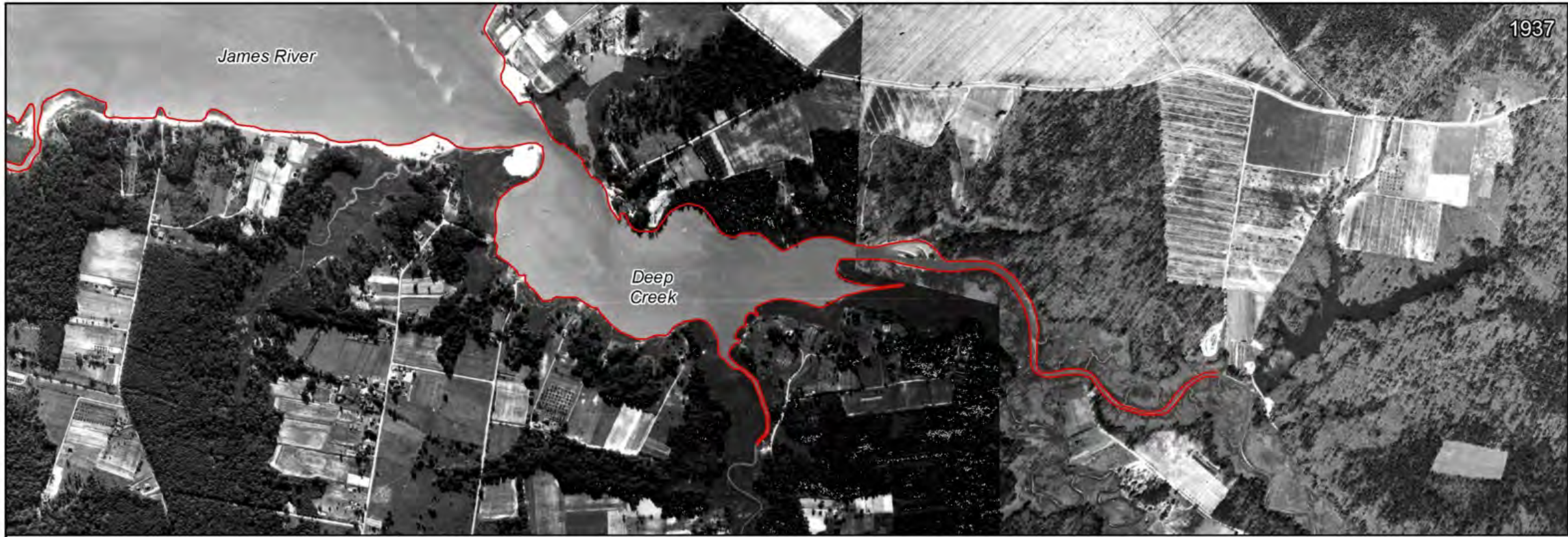
Legend

- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet



City of Newport News Virginia

Plate 12

Legend

- 1937 Shoreline
- 1953 Shoreline



Shoreline Studies Program
VIMS

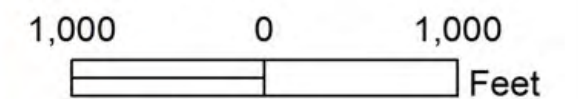
1,000 0 1,000
Feet

Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.



City of Newport News Virginia

Plate 12



Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.



City of Newport News Virginia

Plate 12

Legend

- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

Note: The digitized shorelines are not available for the upper reaches of some creeks between the years 1937 and 2007.



1937

**City of Newport News
Virginia**

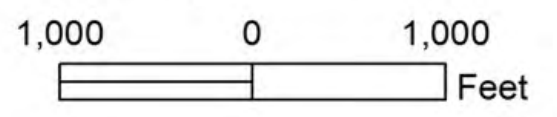
Plate 13

Legend

- 1937 Shoreline
- 1953 Shoreline



1953





1963

City of Newport News Virginia

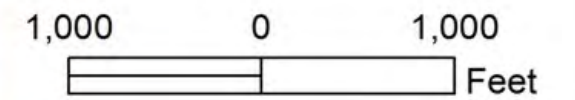
Plate 13

Legend

- 1963 Shoreline
- 1994 Shoreline



1994



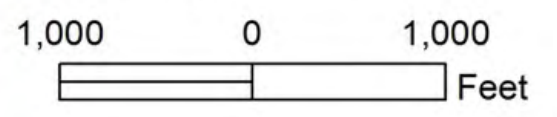


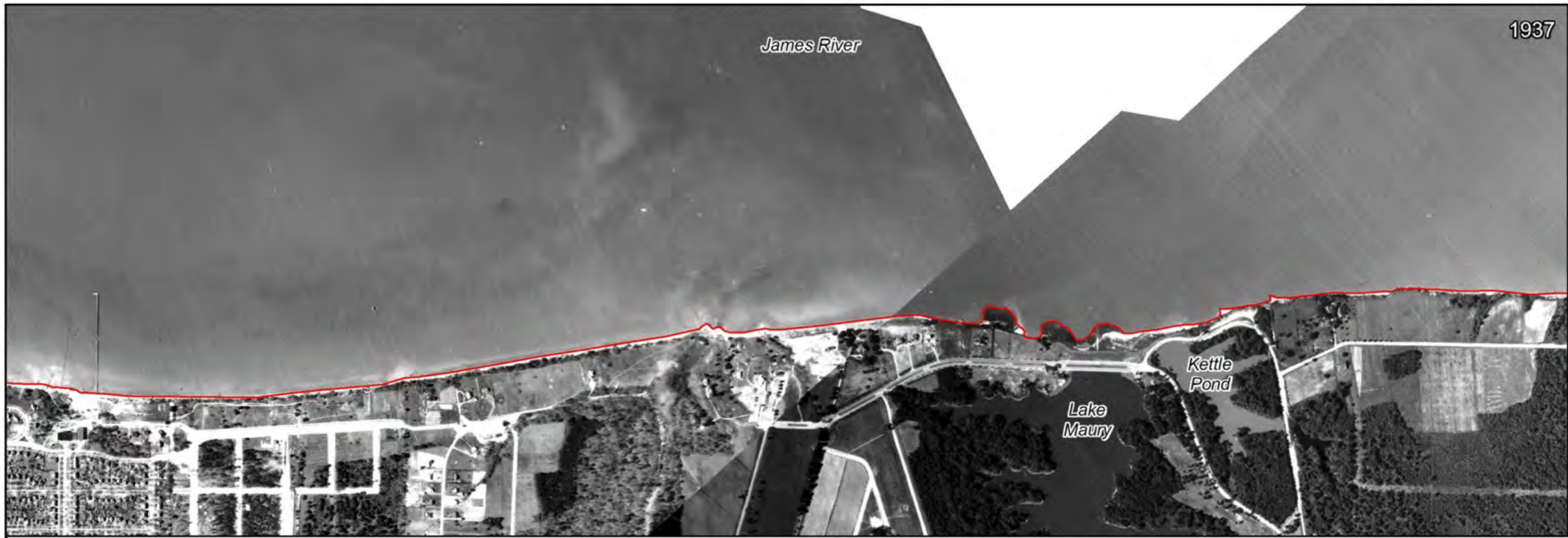
**City of Newport News
Virginia**

Plate 13

Legend

- 2002 Shoreline
- 2007 Shoreline



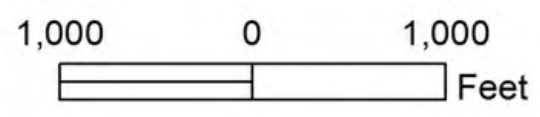


**City of Newport News
Virginia**

Plate 14

Legend

- 1937 Shoreline
- 1953 Shoreline



James River

1963

City of Newport News Virginia

Plate 14

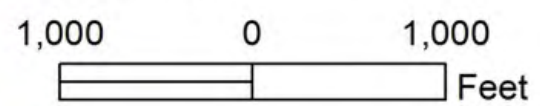
Legend

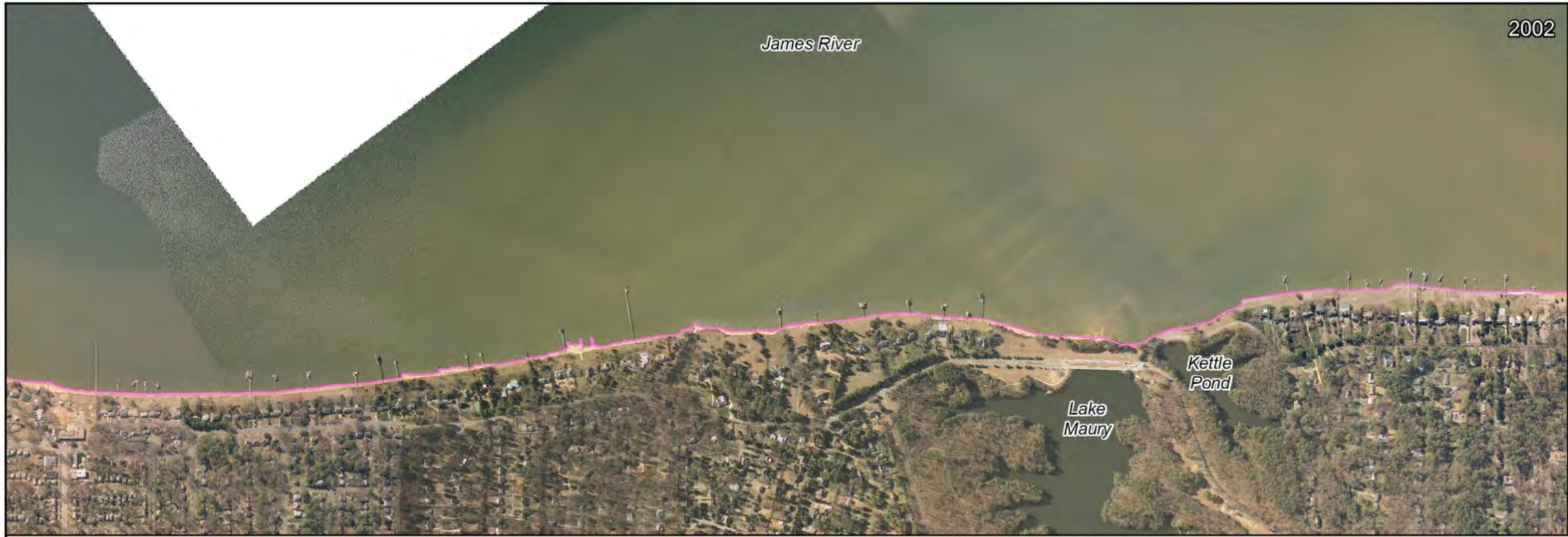
- 1963 Shoreline
- 1994 Shoreline



James River

1994



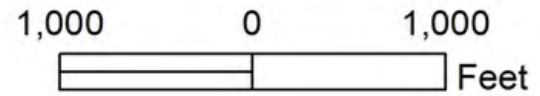
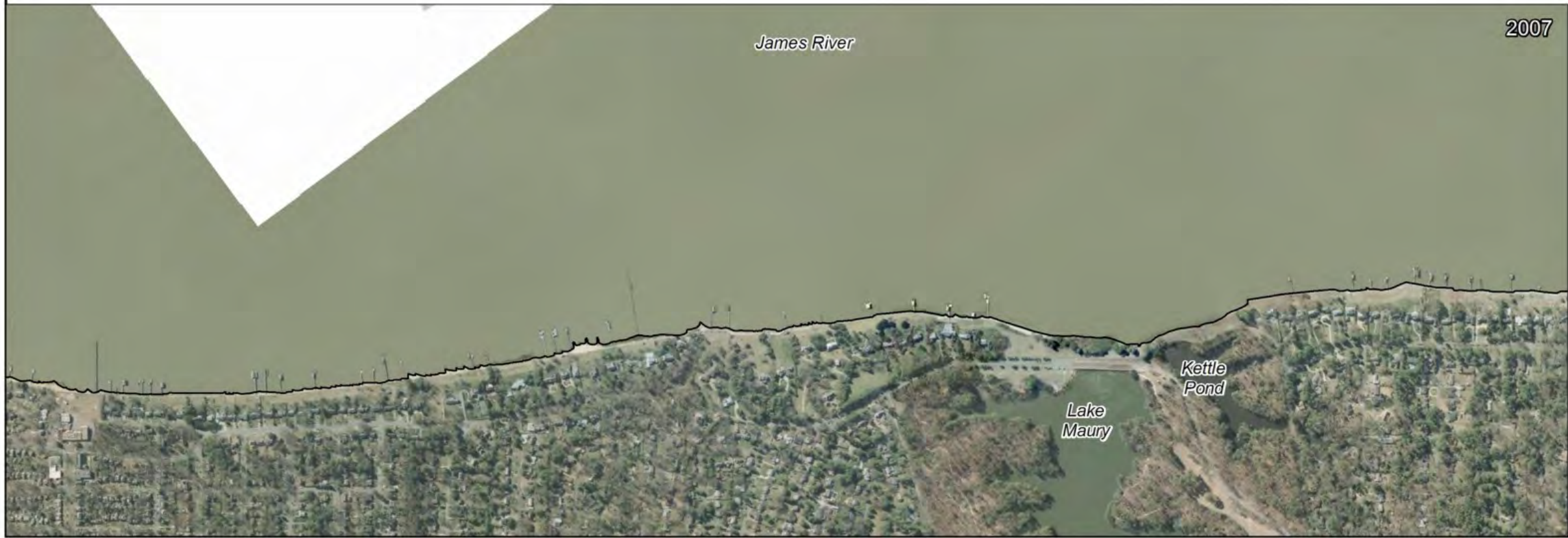


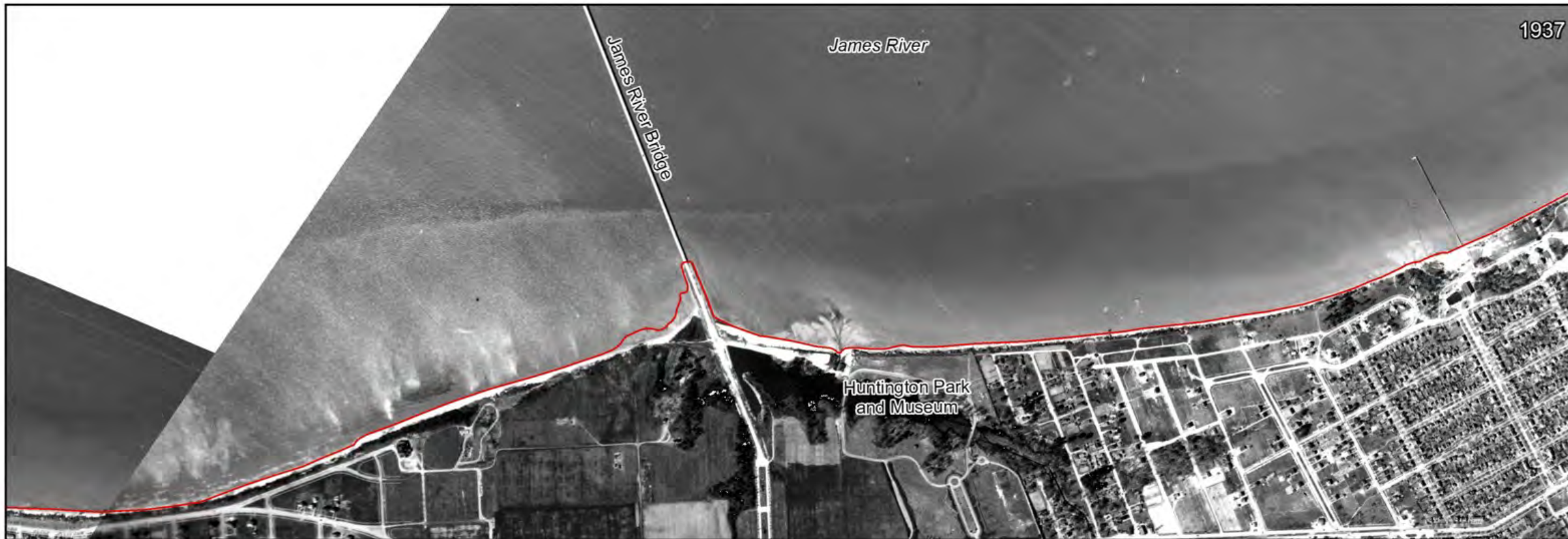
**City of Newport News
Virginia**

Plate 14

Legend

- 2002 Shoreline
- 2007 Shoreline



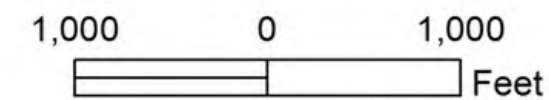


City of Newport News Virginia

Plate 15

Legend

- 1937 Shoreline
- 1953 Shoreline





1963

City of Newport News Virginia

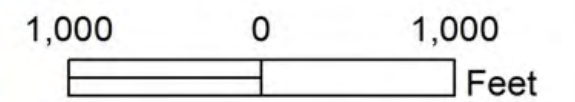
Plate 15

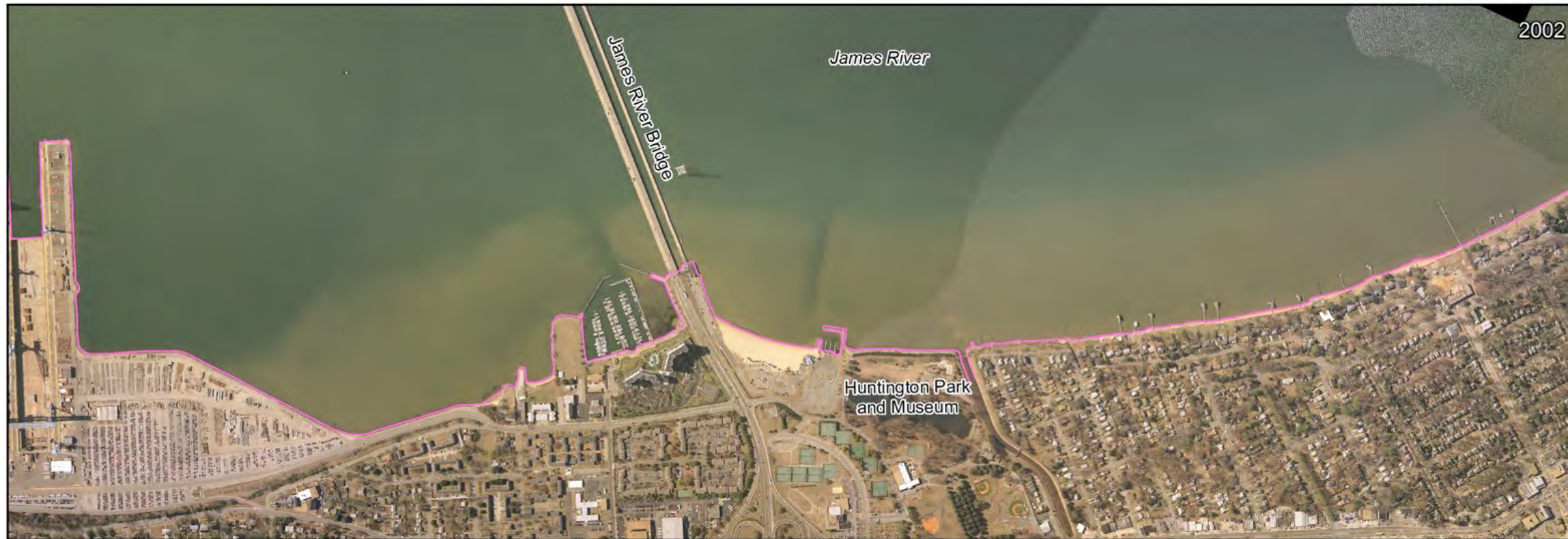
Legend

- 1963 Shoreline
- 1994 Shoreline



1994



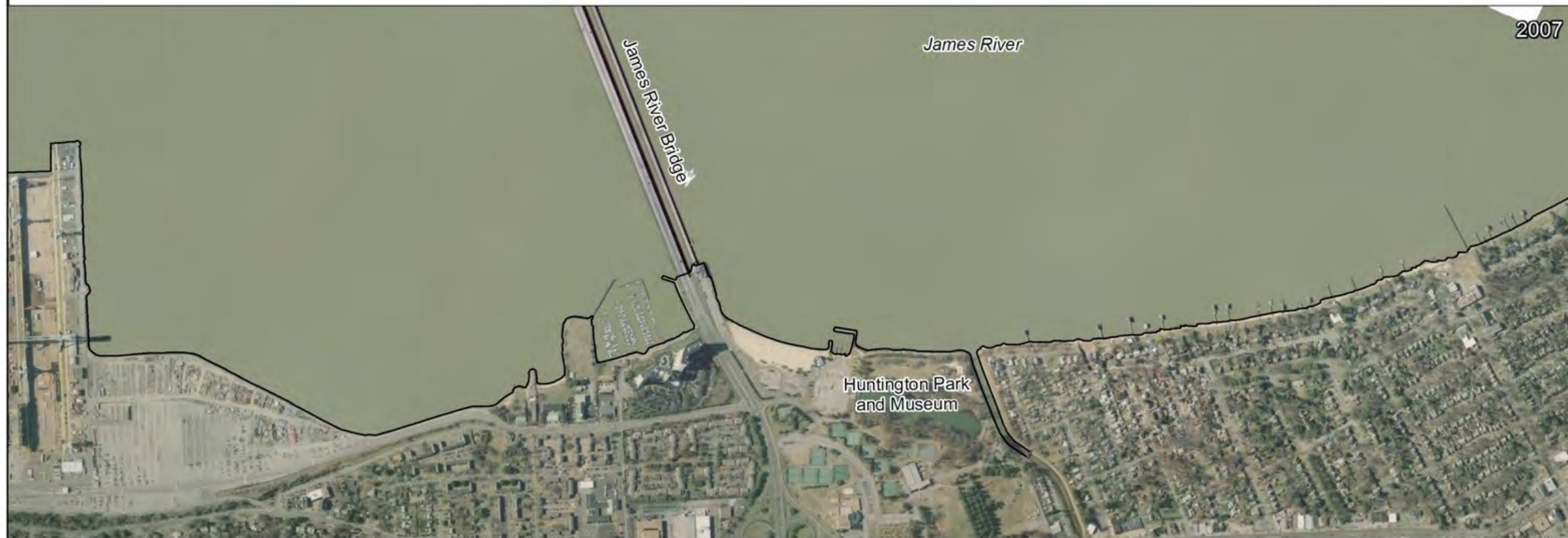


City of Newport News Virginia

Plate 15

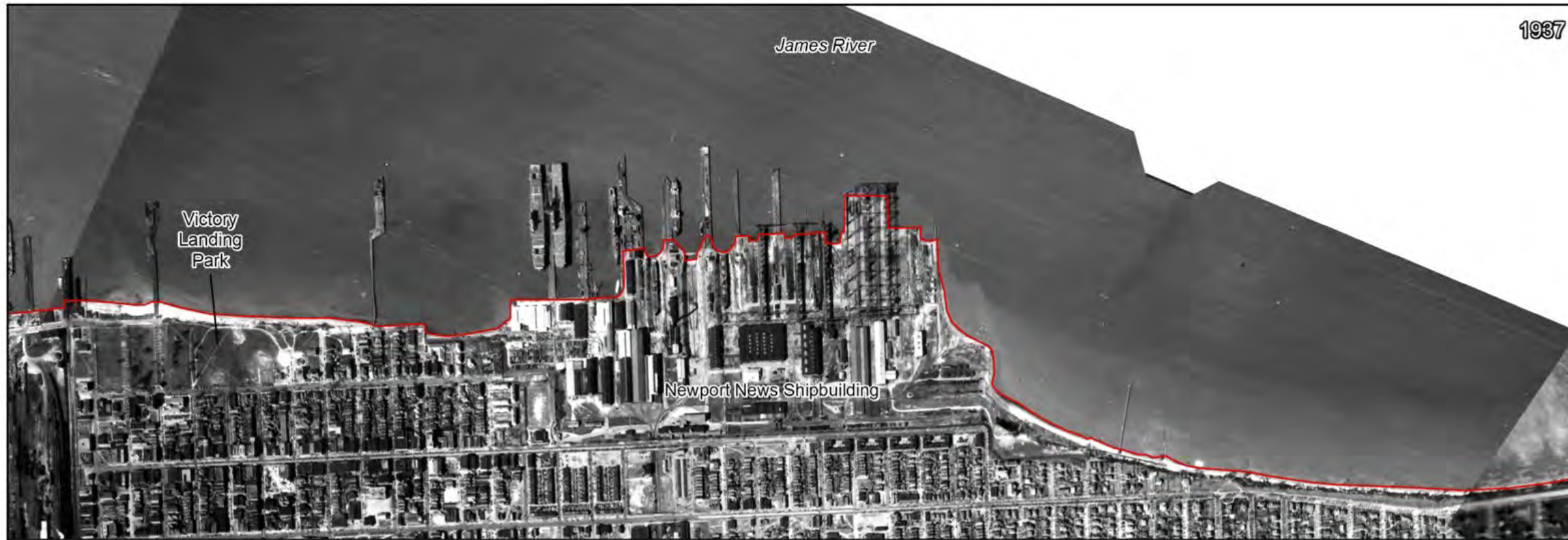
Legend

- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet



1937

City of Newport News Virginia

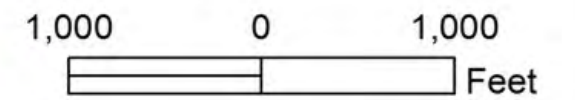
Plate 16

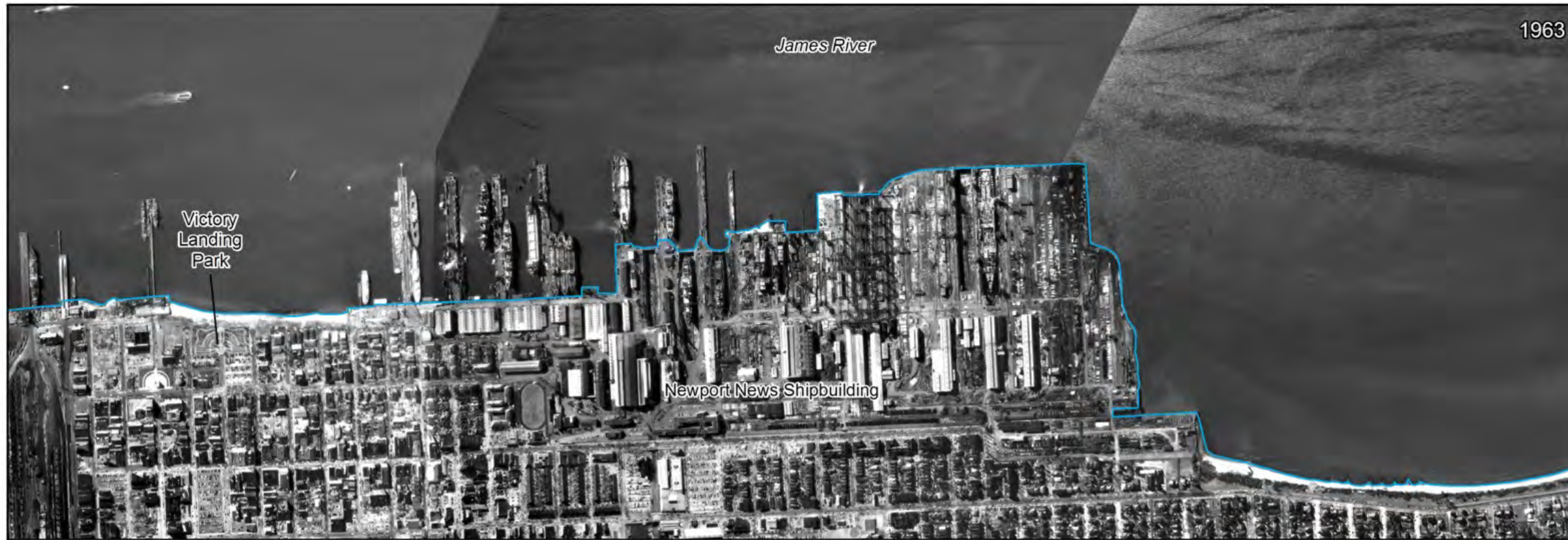
Legend

- 1937 Shoreline
- 1953 Shoreline



1953





1963

City of Newport News Virginia

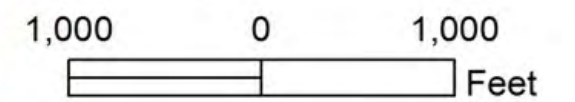
Plate 16

Legend

- 1963 Shoreline
- 1994 Shoreline



1994



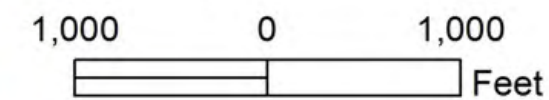
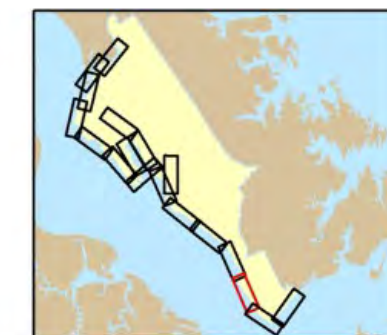
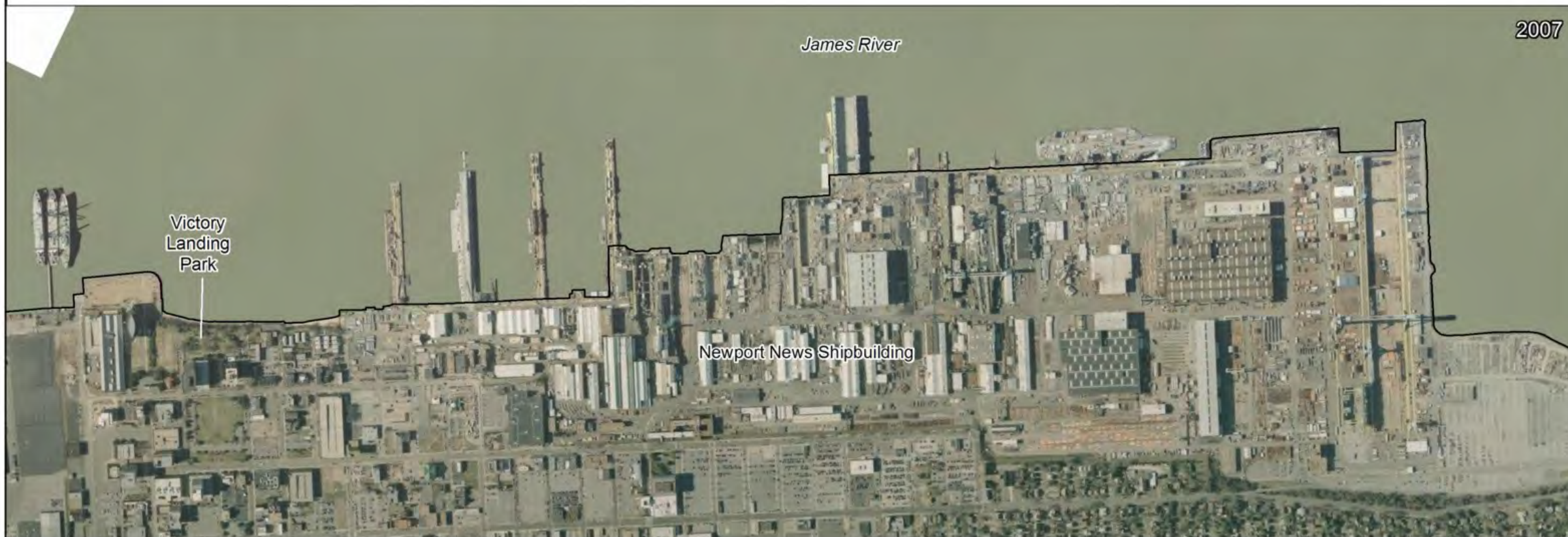


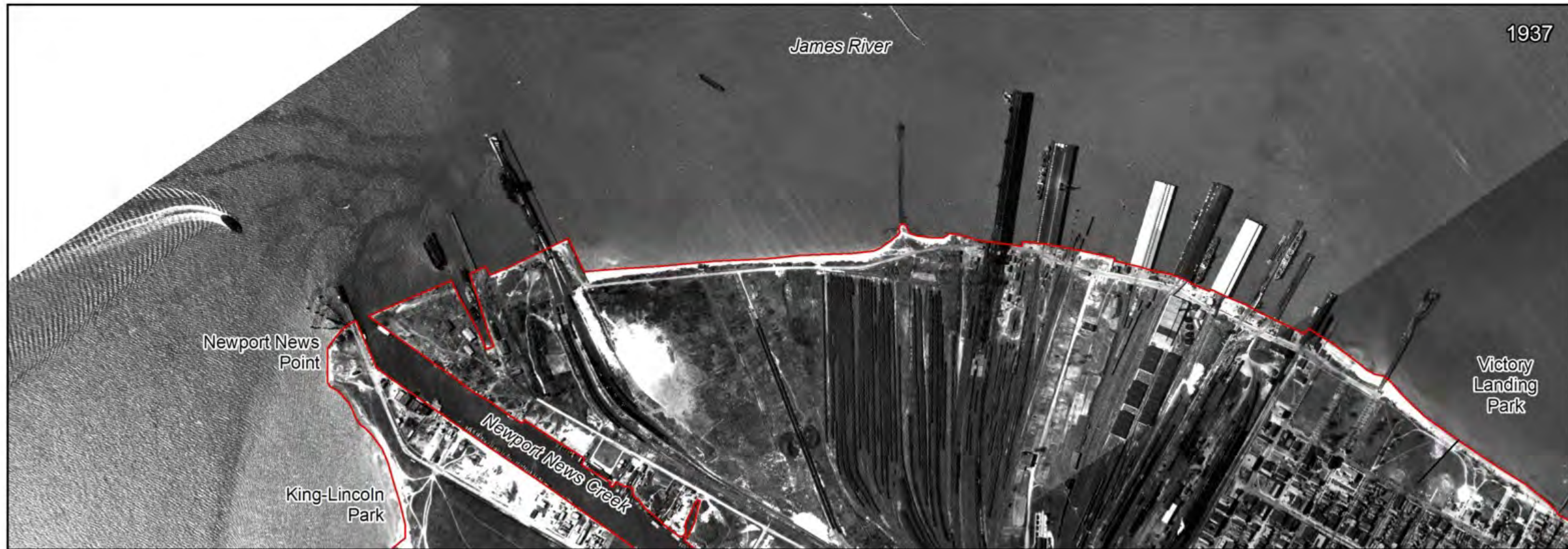
City of Newport News Virginia

Plate 16

Legend

- 2002 Shoreline
- 2007 Shoreline



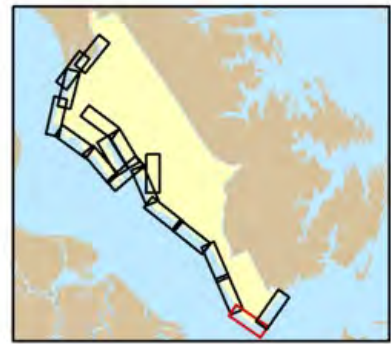


City of Newport News Virginia

Plate 17

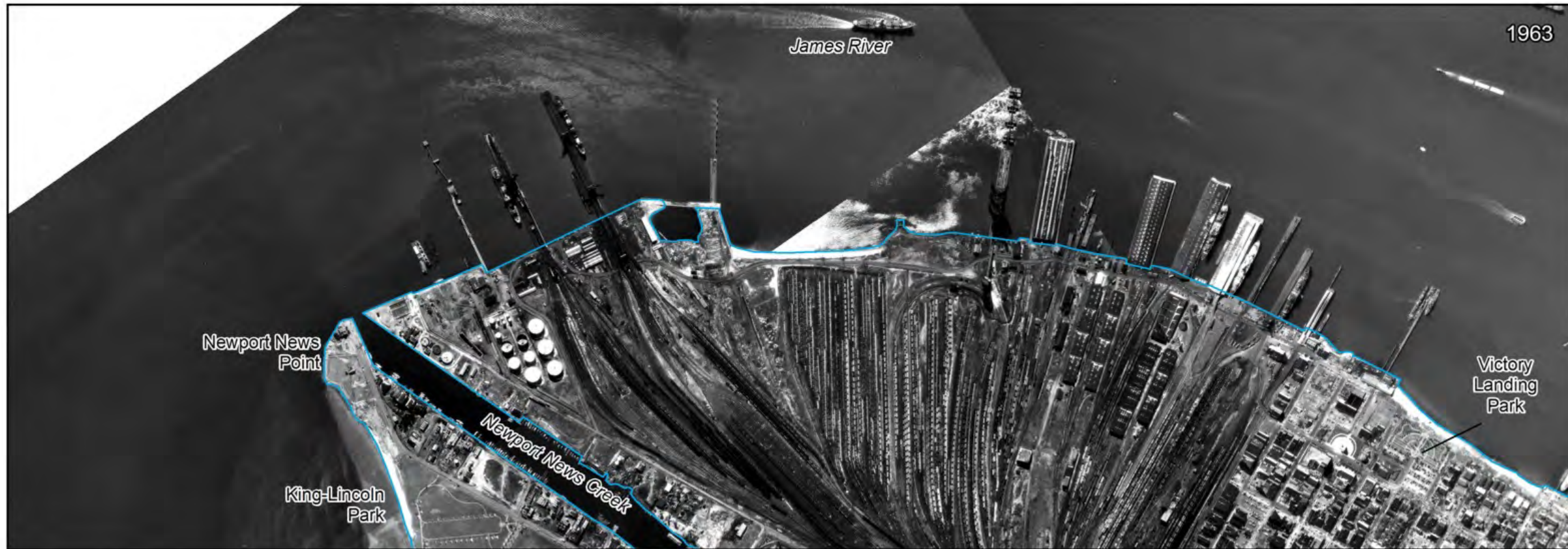
Legend

- 1937 Shoreline
- 1953 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet

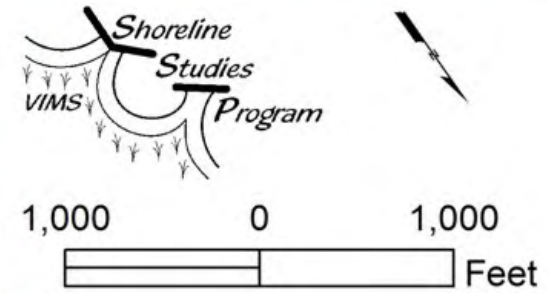
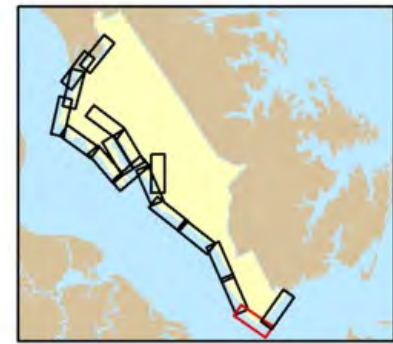


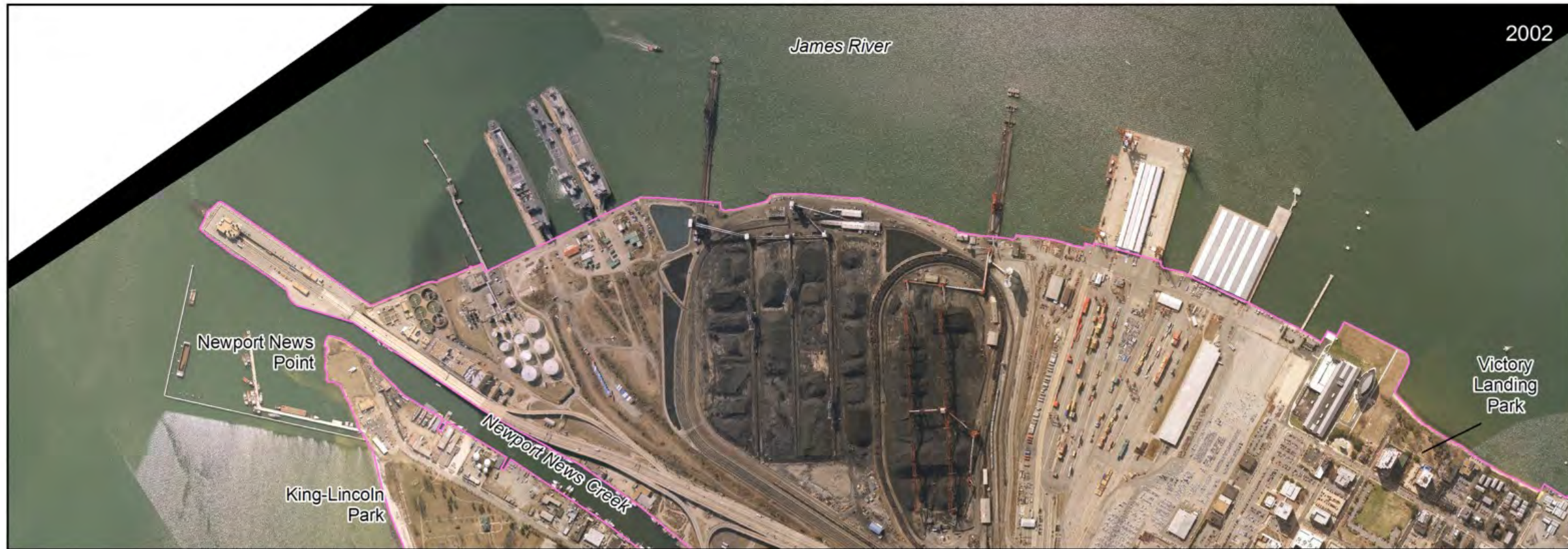
City of Newport News Virginia

Plate 17

Legend

- 1963 Shoreline
- 1994 Shoreline



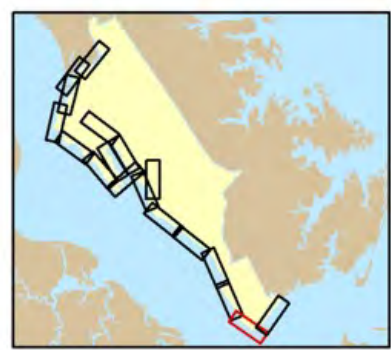
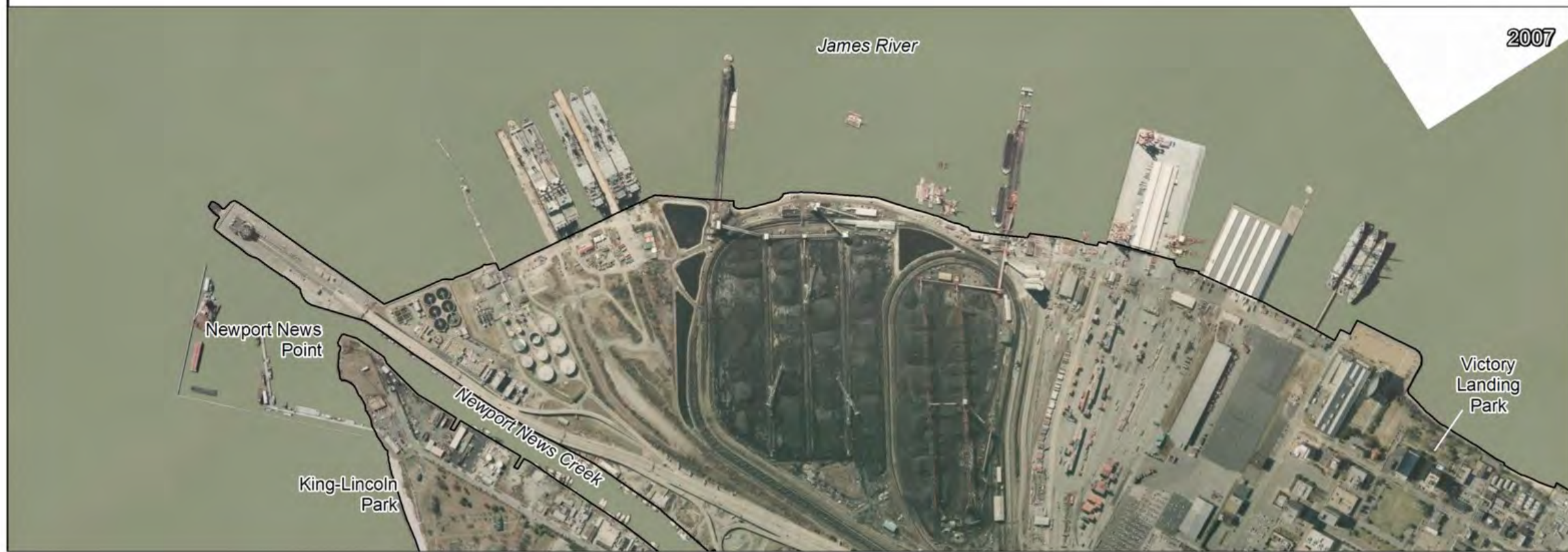


City of Newport News Virginia

Plate 17

Legend

- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program
VIMS

1,000 0 1,000
Feet



City of Newport News Virginia

Plate 18

Legend

- 1937 Shoreline
- 1953 Shoreline



Shoreline Studies Program

VIMS

1,000 0 1,000 Feet



City of Newport News Virginia

Plate 18

Legend

- 1963 Shoreline
- 1994 Shoreline



Shoreline Studies Program

VIMS

1,000 0 1,000 Feet



City of Newport News Virginia

Plate 18

Legend

- 2002 Shoreline
- 2007 Shoreline



Shoreline Studies Program

VIMS

1,000 0 1,000 Feet