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Jackson Creek Federal Navigation Project: Stove Point Placement Area Analysis Final Draft

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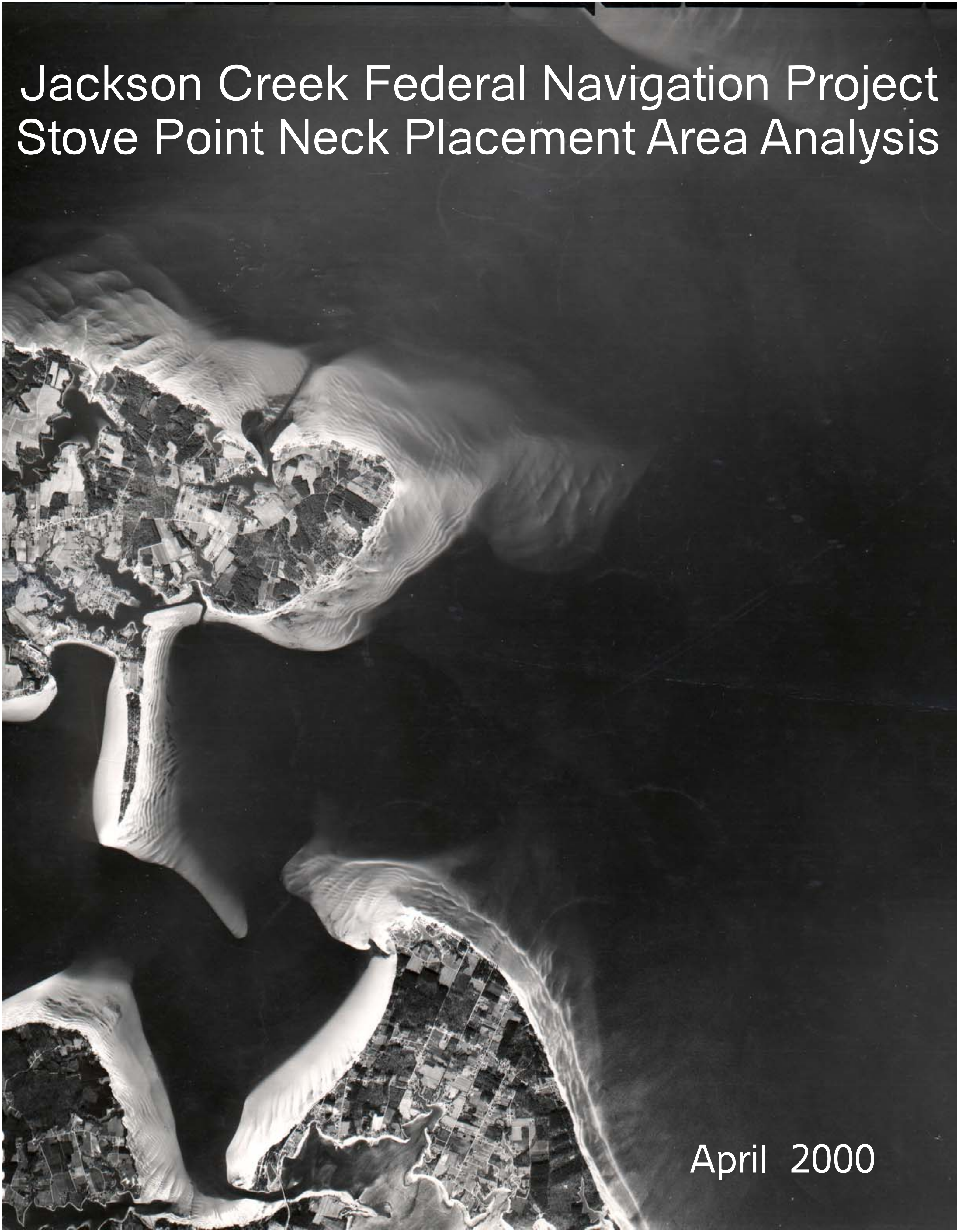

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Final Draft

Jackson Creek Federal Navigation Project: Stove Point Placement Area Analysis

by

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EXECUTIVE SUMMARY

Jackson Creek is located in Middlesex County and empties into the Piankatank River. Jackson Creek of which there are three branches, west, northwest and north. Stove Point Neck is a long peninsula that extends into the Piankatank River. Stingray Point is a headland on the Chesapeake Bay between the Piankatank and Rappahannock Rivers. It has four small creeks along its shore.

The primary goal of this project is to determine the best placement of sand dredged from Jackson Creek Navigation Channel in order to maximize beach nourishment benefits but also reduce the amount of sand transported back into the channel.

The following techniques were used to assess Stove Point's shoreline. In addition, Stingray Point was looked at in historical terms.

- Vertical aerial imagery and the U.S. Army Corps of Engineers bathymetric and shore survey were used to determine present shoreline position. These data were compared to historical shoreline positions, and rates of shoreline change were calculated between shoreline positions.
- Oblique, low-level, aerial video was obtained along Stingray Point and Stove Point shorelines and was compared to oblique aerial video made by VIMS in 1985, 1990 and 1999 and slides taken in 1975. This semi-quantitative assessment shows changes in shore structures through the period of record.
- In order to quantify the general wave climate acting upon the Stove Point's shoreline, the local wind climate was evaluated utilizing the long-term wind data set for Norfolk International Airport. The wind field evaluation and effective fetch as well as bathymetric contours and storm surge were input to the SMB computer modeling program which generates simulated wave height, period, and length for a suite of wind speeds.
- RCPWAVE, a linear wave model, takes an incident wave condition at the seaward boundary of the grid, propagates it shoreward across the nearshore bathymetry, and allows the wave to diffract, shoal, refract, and dissipate due to friction.
- Breaking wave height and angle, which are the output of RCPWAVE, were used to determine sediment transport along Stove Point.
- The calculated transport data were mean-weighed with the wind data in order to describe the relative amounts of transport occurring alongshore.

The proposed placement site was determined from analysis of the site utilizing the above tasks. According to the U.S. Army Corps of Engineers, approximately 5,000 cubic yards of sand will be dredged with a 6 ft channel every 12 years or 10,000 cubic yards of sand will be dredged for an 8 ft channel every seven years. The placement of this material along the Stove Point shoreline would be in shore Section C which has a net transport to the south. Sand potentially could be transported northward during extreme storm events with wind/waves from the southeast or east. Over the last decade, Section C has been void of a sand beach.

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1 INTRODUCTION

1.1 Study Site Location

Jackson Creek is located in Middlesex County and empties into the Piankatank River (Figure 1). Jackson Creek of which there are three branches, west, northwest and north. Stove Point Neck is a long peninsula that extends into the Piankatank River. Stingray Point is a headland on the Chesapeake Bay between the Piankatank and Rappahannock Rivers. It has four small creeks along its shore.

The Jackson Creek Navigation Channel was first dredged in 1937. It provides access to boat traffic in and out of Jackson Creek by both recreational and commercial boats.

1.2 Project Rationale

The purpose of this study is to perform a shore assessment around Jackson Creek in order to determine what processes are affecting sedimentation in the creek mouth. In addition, the placement of sandy dredge material from Jackson Creek onto Stove Point also was to be determined. The Jackson Creek-Stove Point-Stingray Point evaluation includes an assessment of shore conditions and historic shore changes as well as a wave climate and sediment transport analysis. The product of this study is a recommendation as to the location of placement of dredge spoil for beach nourishment along the Stove Point Shoreline.

Sand when available from dredging should be used, if possible, in a beneficial manner such as beach nourishment and/or habitat creation. In the case of Stove Point, shoreline hardening over the years has reduced significantly the source of sand from updrift beach erosion. Also, groins constructed along shore restrict the movement of sand in the littoral transport system. The intent is to nourish the Stove Point Neck shoreline in a manner that produces a wider protective beach where needed without the material coming back into the channel.

Jackson Creek was dredged in 1937 and 1970 (USACE, Unknown). Approximately 40,000 cubic yards (cy) of material initially was dredged from the Jackson Creek entrance channel and placed in three locations around Jackson Creek (Figure 2). In 1970, maintenance dredging produced approximately 15,000 cy of material that was placed in the nearshore area of Jackson Creek's mouth. In order to maintain the channel, the Corps plans to dredge the channel. If dredged to 6 ft, then 5,000 cy of sand will be available for beach nourishment every 12 years. If dredged to 8 ft, about 10,400 cy of sand will be placed on the beach every 7 years (D.H. Stamper, *pers. comm*.).

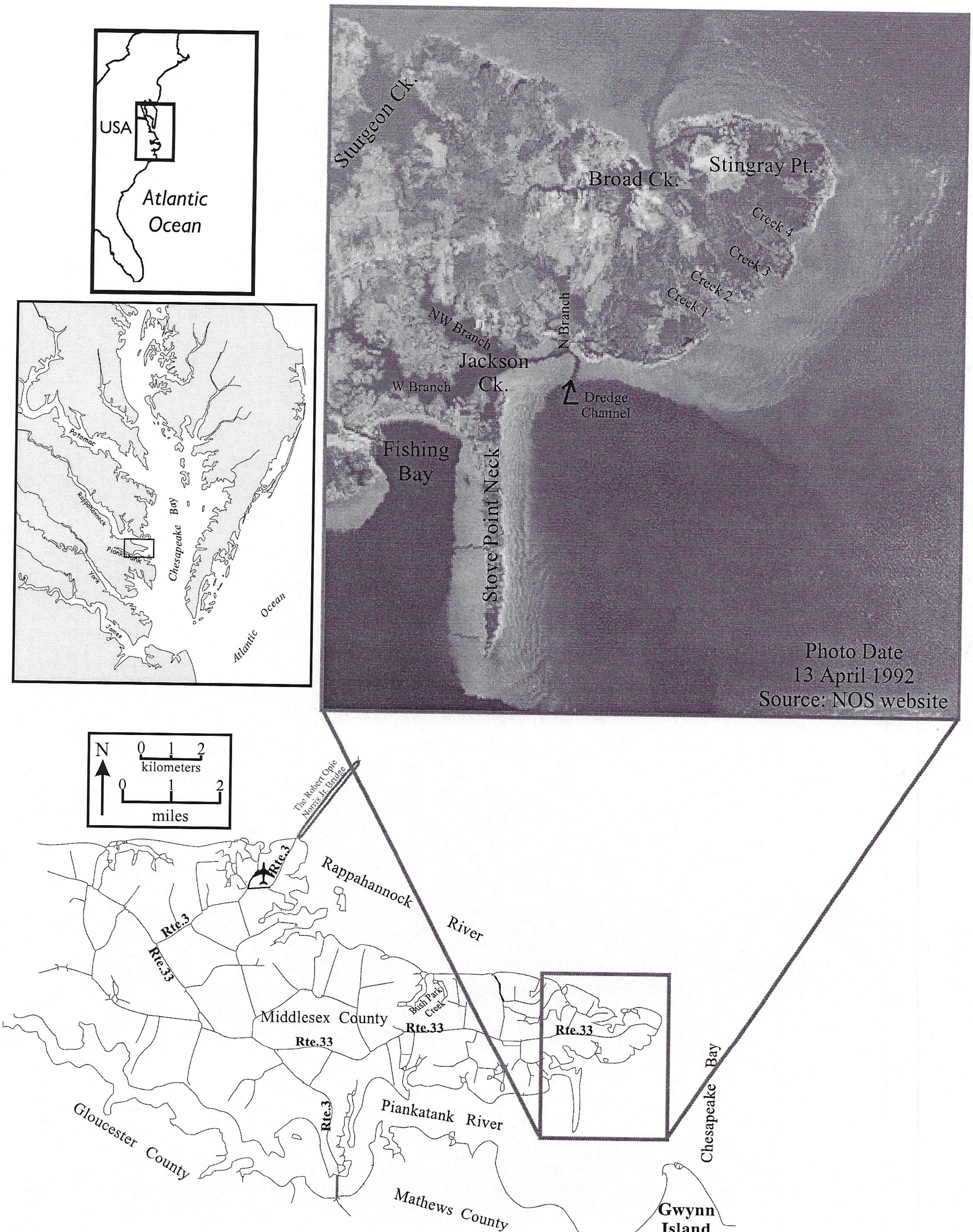


Figure 1. Stove Point Neck and Jackson Creek study site location.

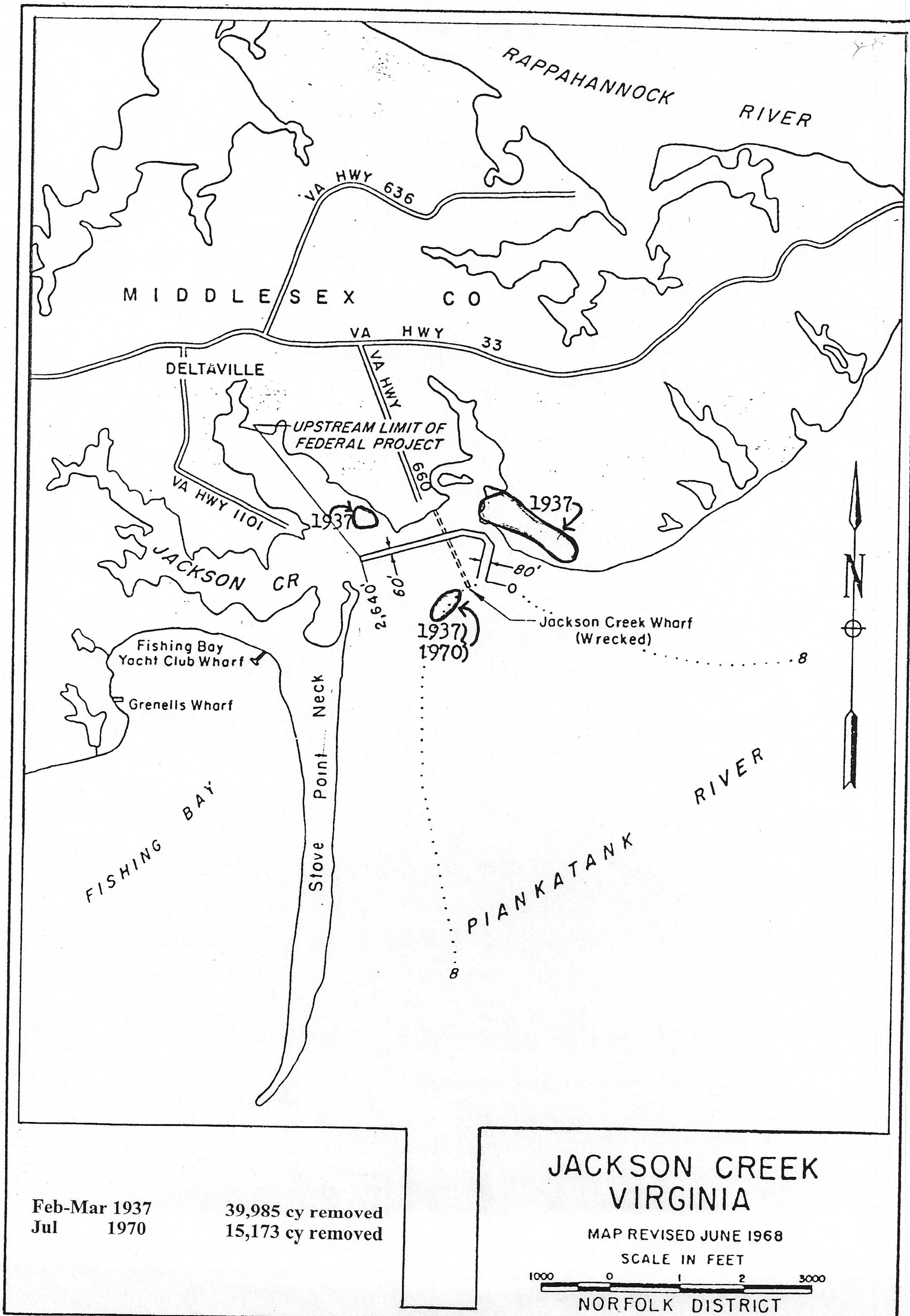


Figure 2. Placement and amount of material dredged from Jackson Creek Navigation Channel (U.S. Army Corps of Engineers, Unknown).

2 METHODS

2.1 Determine Long-Term Shoreline Change Patterns

Understanding long-term shoreline change is critical to assessing shoreline reaches in Chesapeake Bay. Vertical aerial imagery was taken on 29 October 1999, and historical shoreline positions were obtained from VIMS's archives and compared to the present shoreline position. Shorelines from different sources were overlain for comparison, and five reaches were established for the shore change analysis (Figure 3). Reach 1 includes all of Stove Point Neck. Reach 2 extends from the north branch of Jackson Creek approximately 3,500 ft alongshore. Reach 3 extends from Reach 2 to the northeastern most point of Stingray Point. Reach 4 encompasses the headland of Stingray Point and Reach 5 includes the northern side of Stingray Point almost to the mouth of Broad Creek. The historic and recent shorelines were digitized, and the change in shore position was determined in the alongshore direction for each reach at 61 m increments. Rates of shoreline change were calculated between shoreline positions, and the rates were averaged across each shore grid to give an overall average rate of change. The End Point Rate (EPR) method (Fenster *et al.*, 1993), which is the rate of change calculated from the first and last shoreline positions available, is useful to determine the overall rate of change along a shore reach where an average rate may be influenced by shorter-term changes due to anthropogenic actions or other factors.

2.2 Establish Existing and Previous Shoreline Conditions

Oblique, low-level aerial video imagery obtained in 1985, 1990, and 1999 and oblique aerial slides taken in 1975 were evaluated to show changes in structures in the shore zone. Shoreline categories were coded onto a mylar print of 7.5 minute topographic maps and then digitized. The digitized information was converted to Geographic Information System (GIS) format for ease of comparison and display. The longshore error may be +/- 100 ft over a mile of shoreline. Shoreline structure codes differentiate groinfields, riprap revetments, and bulkheads.

2.3 Wave Climatology

In order to quantify the general wave climate acting upon the Stove Point shoreline and to provide our wave refraction model with reasonable incident wave conditions, it was necessary to evaluate the local wind climate. The long-term wind data for Norfolk International Airport are applicable at Stove Point Neck. Hourly wind measurements taken between 1960 and 1990 are summarized in Table 1. These data are used to generate a corresponding wave field using procedures developed by <u>S</u>verdrup and <u>M</u>onk (1947) and <u>B</u>retschneider (1958) as modified by Kiley (1982). SMB is a shallow water estuarine wind-generated wave prediction model; it generates waves which cross Chesapeake Bay and are directed toward Stove Point. The procedure involves the following steps for each grid:

- Determine effective fetch for each grid using procedures outlined in the U.S. Army Corps of Engineers Shore Protection Manual (1984).
- Use the above data as input into the SMB program which provides wave height and period for a suite of wind speeds and water levels.

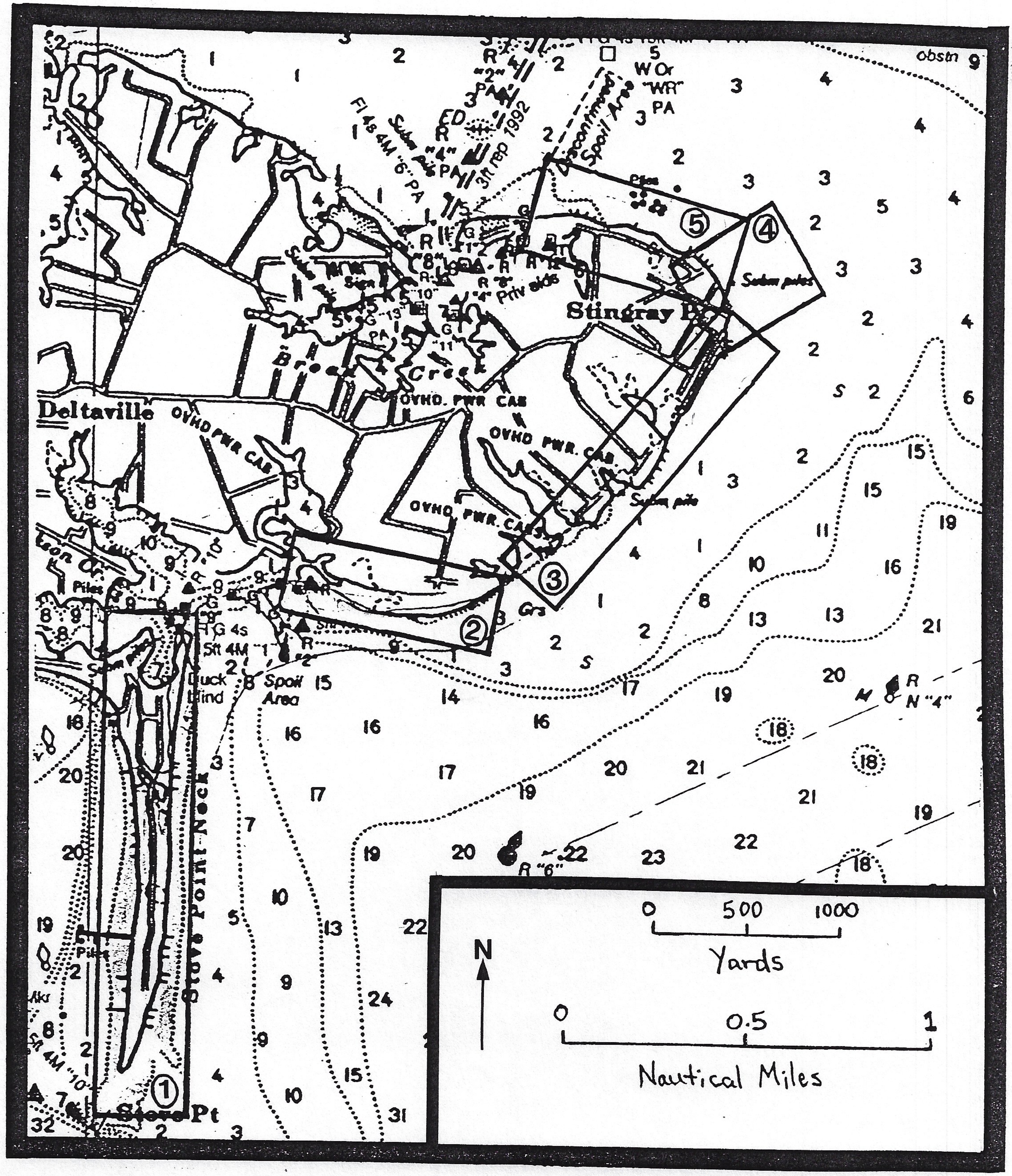


Figure 3. Location of Reaches used in the historical shoreline change analysis.

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

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

*Number of occurrences   +Percent

Effective fetch, a parameter in wind wave growth, was determined for the three directions, northeast (NE), east (E), and southeast (SE), which are assumed to significantly impact Stove Point Neck. The wind field evaluation and effective fetch as well as bathymetric contours and storm surge are input to the SMB program which provides wave height, period, and length for a suite of wind speeds. In this case, wind speeds of 8, 16, 26, 36, 46, and 60 mph were used. Specified water levels ranged from 2 to 5 feet. Offshore, the wind and wave direction were assumed the same. However, at about -15 ft MLW, the waves enter the nearshore shoaling region and must be evaluated using a hydrodynamic wave refraction model. The predicted wave heights and periods for the three subject directions (NE, E, and SE) are used as input to the hydrodynamic model, RCPWAVE. The process, which calculates the impinging wave climate at a site, was developed and used during previous projects (Hardaway *et al*., 1991; Hardaway *et al*., 1993; Milligan *et al.*, 1995; Milligan *et al.*, 1996; Hardaway *et al.*, 1999).

Storm surge may pose a threat to certain resources regardless of potential wave impacts. The wave climate assessment included a determination of the frequency of storm surges and flooding based on research by Boon *et al.* (1978) (Table 2). This assessment is critical when determining the potential impacts of the local wave climate and related storm surge on shoreline management strategies. The mean tide range at Stove Point Neck is 1.2 ft with a spring tide range of 1.4 ft (NOAA, 1989).

Table 2. Storm-surge elevations at Windmill Point from Boon *et al.* (1978) in feet above mean low water.

Storm Event Frequency	Storm Surge Height (ft MLW)
10 year	3.8
25 year	4.0
50 year	4.3

The conditions input into RCPWAVE are listed in Table 3. The direction is a wind blowing from the northeast/east/southeast generating a wave orthogonal traveling to the southwest/west/northwest or 235ºTN/270ºTN/315ºTN. The northeast condition used a wind-generated wave from slightly east of northeast (55ºTN) because Rosen (1976) showed that the Rappahannock Spit off the mouth of the Rappahannock River would alter waves generated from northeast winds. The wave condition number is an assigned designation for each case run through RCPWAVE. The water level is the estimated storm surge, in ft above MLLW, associated with each event. The modal, or annual average conditions, described by the 8, 16, and 26 mph winds were run at spring high water or slightly above. The storm surge elevations for the storm events were based on Boon *et al.* (1978). Wave height and period were determined by the SMB analysis.

RCPWAVE is a linear wave propagation model designed by the USACE (Ebersole *et al.*, 1986) for engineering purposes. It computes changes in wave characteristics that result naturally from refraction, shoaling, and diffraction over complex topography. To this fundamental, linear theory-based model, we have added routines to estimate wave energy dissipation due to bottom friction (Wright *et al.*, 1987). The use of RCPWAVE to model the hydrodynamics at Stove Point assumes that only the offshore bathymetry affects wave transformation; the application does not include the effects of tidal currents.

RCPWAVE takes a simulated incident wave condition at the seaward boundary of the grid and allows it to propagate shoreward across the nearshore bathymetry. Frictional dissipation due to bottom roughness is accounted for in this analysis and is relative in part to the mean grain size of the bottom sediment. Waves also tend to become smaller over shallower bathymetry and remain larger over deeper bathymetry. Upon entering shallow water, waves are subject to refraction, in which the direction of wave travel changes with decreasing depth in such a way that wave crests tend to become parallel to the depth contours. Irregular bottom topography can cause waves to be refracted in a complex way and produce variations in the wave height and energy along the coast. In general, waves break when the ratio of wave height to water depth equals 0.78 (Komar, 1976).

Table 3. Incident wave conditions input to RCPWAVE. Also indicated are conditions associated with a particular storm event.

Direction	Wind Speed (mph)	Wave Condition	Water Level (feet MLLW)	Wave Height (feet)	Wave Period (seconds)
Northeast	8	1-1	2.0	0.96	2.13
55ºTN	16	1-2	2.0	2.31	3.23
	26	1-3	3.0	3.76	4.14
10-yr	36	1-4	4.0	5.07	4.87
25-yr	46	1-5	4.0	5.81	5.18
50-yr	60	1-6	5.0	6.90	5.60
East	8	2-1	2.0	0.83	1.95
90ºTN	16	2-3	2.0	1.97	3.06
	26	2-5	3.0	1.99	3.05
10-yr	36	2-7	4.0	3.92	4.80
25-yr	46	2-9	4.0	4.46	5.12
50-yr	60	2-11	5.0	5.31	5.57
Southeast	8	2-2	2.0	0.88	2.02
135ºTN	16	2-4	2.0	2.10	3.21
	26	2-6	3.0	3.16	4.27
10-yr	36	2-8	4.0	3.93	4.80
25-yr	46	2-10	4.0	4.46	5.13
50-yr	60	2-12	5.0	5.32	5.58

Two grids (Figure 4) of the study region were digitized from a National Oceanic and Atmospheric Administration chart no. 12235, updated to 26 March 1994 by BBA Chart Kits. In order to represent the shoreline and very nearshore more accurately within the model, survey data obtained by USACE in September 1998 and January 1999 were integrated with the digitized bathymetric data. Bathymetric Grid 1 was used for the northeast wind while bathymetric Grid 2 accommodates the east and southeast winds. Both grids are orientated north-south, however Grid 1 is larger to include the shoal off Stingray Point which may potentially impact waves coming from the northeast.

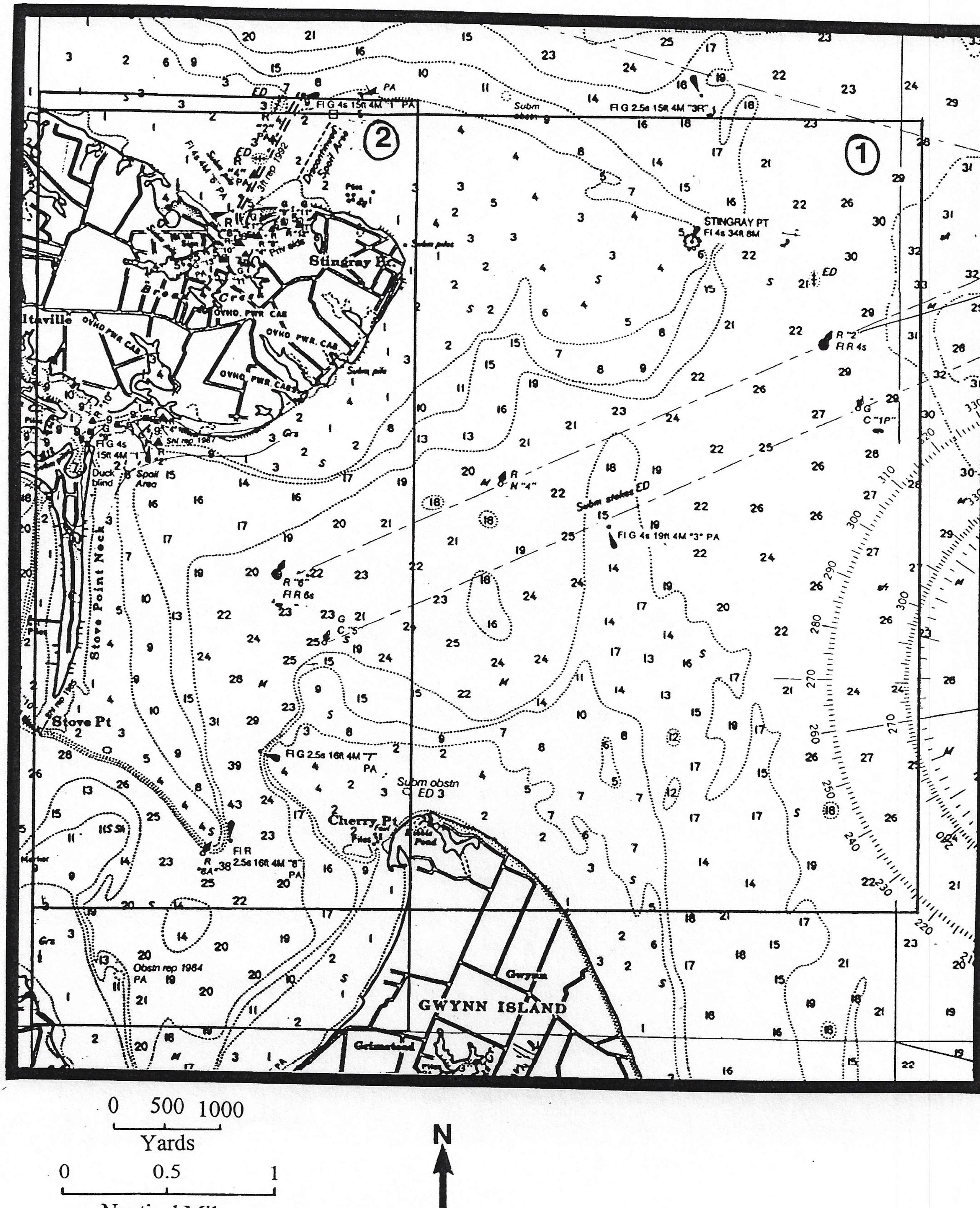


Figure 4. Location of bathymetric Grids 1 and 2 used by the RCPWAVE wave model. Grid 1 was used to model the northeast wind/wave condition while Grid 2 was used to model the east and southeast wind/wave conditions.

The results of the RCPWAVE analysis are wave vector and wave orthogonal plots showing wave attenuation and refraction across the nearshore and shoreline that allow us to determine the net movement of littoral materials. Wave vector plots show modeled wave orthogonals that have a magnitude and direction associated with them. Wave orthogonal plots can indicate areas of the shoreline that might be impacted by a convergence or divergence of wave energy. Areas of convergence indicate an increased amount of energy is impacting a section of shore whereas divergence indicates that the wave orthogonals are spreading out resulting in a lesser amount of energy impacting that shore. Breaking wave heights and angles along the Stove Point Neck modeled shore were output and used to calculate littoral transport in the system.

The wind analysis was used to determine the relative amounts of energy impacting the shore. The output wave data was mean-weighed with the wind data in order to describe the annual, modal condition along each section of the shoreline. These modal conditions determine the long-term angle of wave approach which significantly influences morphologic shape of the shore and will dictate the beach planform shape between headland breakwaters.

2.4 Sediment Transport

The movement of sand along a beach zone is dependent on breaking wave height and angle of wave approach. Applications of littoral drift formulae are subject to large errors; hence, the absolute magnitudes predicted must be considered suspect or, at best, accepted with caution (Wright *et al*., 1987). However, the relative magnitudes as they vary along the coast under different wave scenarios is probably more meaningful as are predicted directions of transport. Overall, the $\pm$50% accuracy of littoral drift methods probably provides a first order estimate of littoral drift along straight, low-gradient beaches.

The methods of littoral drift used here are known as the CERC formula (U.S. Army Corps of Engineers, 1984). The rate (Q) at which littoral drift is moved parallel to the shoreline is the longshore transport rate. Since this movement is parallel to the shoreline, there are two possible directions, right or left, relative to an observer standing on the shore looking out over the water. Movement from the observer's right to his left is motion toward the left or to the north along Stove Point Neck (Qleft (-)), while movement toward the observer's right is known as Qright (+) and is transport to the south along Stove Point Neck. Gross longshore transport is the sum of the amounts of littoral drift transported to the right and to the left past a point on the shoreline in a given time period. Net longshore transport is defined as the difference between the amounts of littoral drift transported to the right and to the left past a point on the shoreline in a given time period.

For each wave condition analyzed in RCPWAVE, the breaking wave height and angle were exported and used to calculate the Gross, Net, Qright, and Qleft transport rates. The count cells number indicates the number of alongshore cells that had breaking waves. The percent indicates the percentage of breaking waves to the total number of waves. Waves generally do not numerically break because they are too small to reach the breaking wave criteria. The smaller the percentage, the less reliable the transport figure. The net transport was mean-weighed against the number of occurrences in the Norfolk wind data for each condition.

Once the overall Stove Point Neck sediment transport was determined, the shoreline was divided into five sections in order to determine the sediment transport for each section. These sections, labeled A through E (Figure 5), were determined by the morphology of the shore as well as the inferred direction of sediment transport based on an inspection of present shore conditions. Data from each section were mean-weighed to determine the net direction of transport in each section.

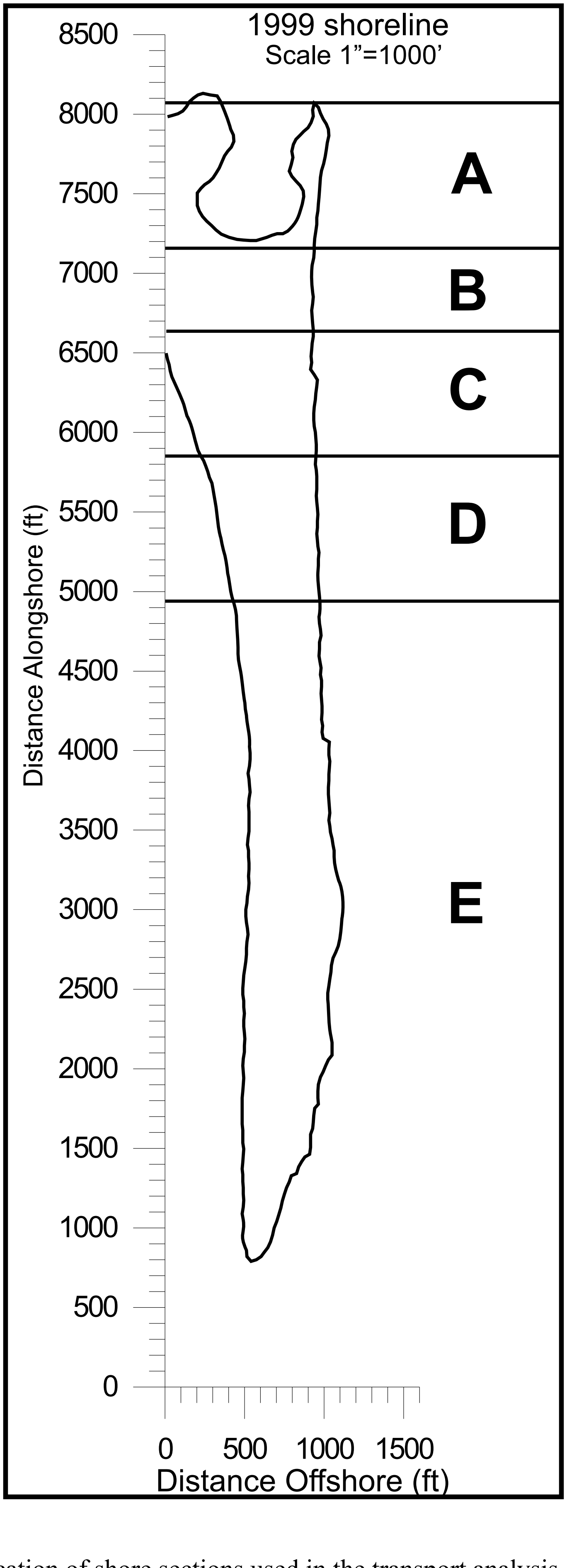


Figure 5. Location of shore sections used in the transport analysis.

3 RESULTS

3.1 Geomorphic Setting

Stove Point Neck is an ancient spit feature. Maximum upland elevations are about 10 ft. The shore faces approximately north-south. The nearshore zone is relatively shallow with an extensive bar system, indicating a great deal of sand is present in the littoral system. Long-term erosion of upland banks provides the bulk of sand material that makes up the shoals, spits, and beaches in the Chesapeake Bay.

In order to determine what is impacting the shoaling within the mouth of Jackson Creek, it was necessary to study the historical shoreline change of Stove Point Neck and Stingray Point. In recent history, the east side of Stove Point Neck has been characterized by recession or erosion (Figure 6). Between 1856 and 1942, the shore was eroding at a rate of about 2.7 ft/yr. The southern tip of Stove Point Neck elongated into a spit indicating a net southerly transport system. A 1937 aerial photo (Appendix 1) showed an undeveloped, wooded upland with no structures along the shoreline. The same aerial also showed the dredged navigation channel to Jackson Creek. By 1968, many structures, including bulkheads and groins, had been placed along the shoreline (Figure7). The rate of shoreline change had decreased to -1.1 ft/yr, and one section of shore even showed accretion (Figure 6). Extensive submerged aquatic vegetation (SAV) communities are shown in the 1968 aerial photos. Continued development and placement of structures along the shoreline (Table 4) decreased the overall movement of the shoreline to nearly zero between 1968 and 1999. However, both 1989 and 1999 photos indicate that the SAV communities no longer exist along this section of shore. The distal end of Stove Point Neck, which had eroded 900 ft in length between 1942 and 1968, was hardened with a revetment between 1989 and 1999. The overall rate of change between 1856 and 1999 was -1.8 ft/yr.

Figure 8 shows the historical shoreline positions and rates of change for Reach 2. Between 1856 and 1942, this section of shore was accreting at a rate of +3.6 ft/yr. Most likely, this accretion was due to accumulation of sand eroded from updrift to the east. The 1937 aerial photos show that some SAV existed along this stretch of shore. However, by 1968, the SAV community was extensive. Between 1942 and 1968, the accretionary trend had reversed itself such that the shore was eroding at a rate of about -0.8 ft/yr. Only the section of shore closest to the northern branch of Jackson Creek continued to accrete. This reversal in trend could be due, in part, to a reduction in the sand transport alongshore. Groins had been built along the eastern section of this shore reach as well as further updrift (Figure 7, Table 4). Between 1968 and 1999, the erosion rate had increased to -2.4 ft/yr. However the net overall change between 1856 and 1999 was +1.5 ft/yr.

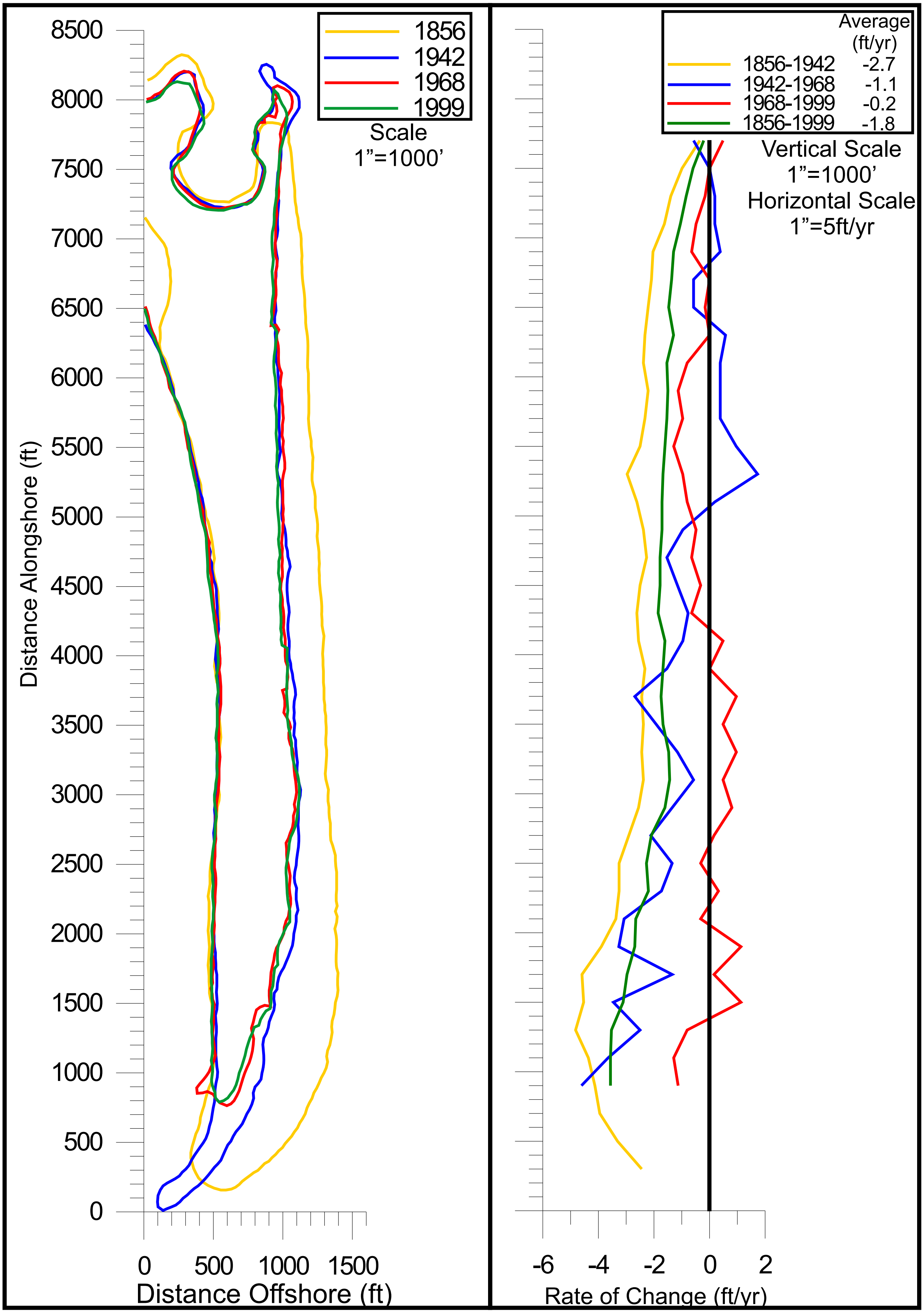


Figure 6. Stove Point (Reach 1) historical shoreline positions and shoreline rates of change.

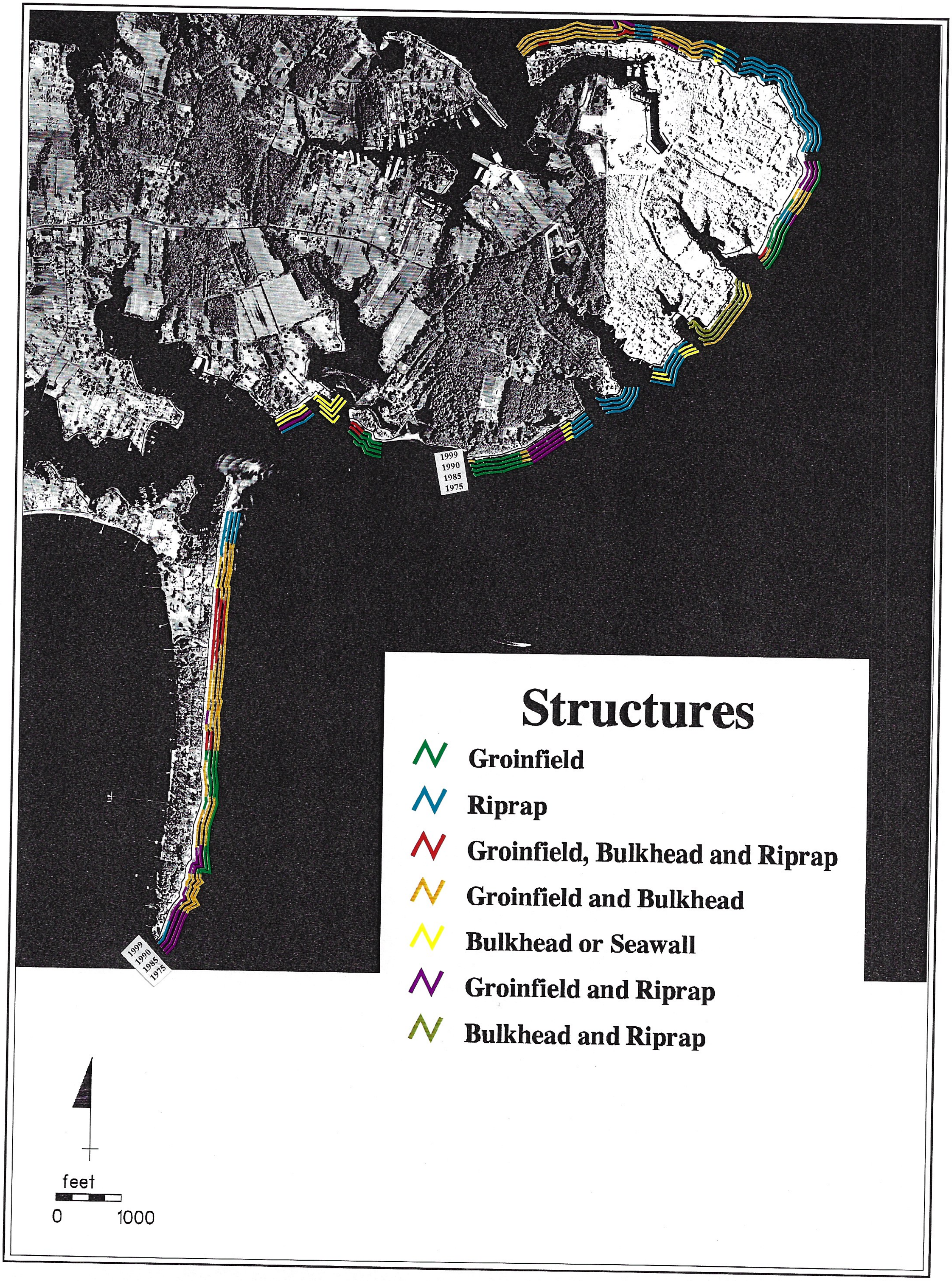


Figure 7. Stove Point and Stingray Point shoreline structure type and location.

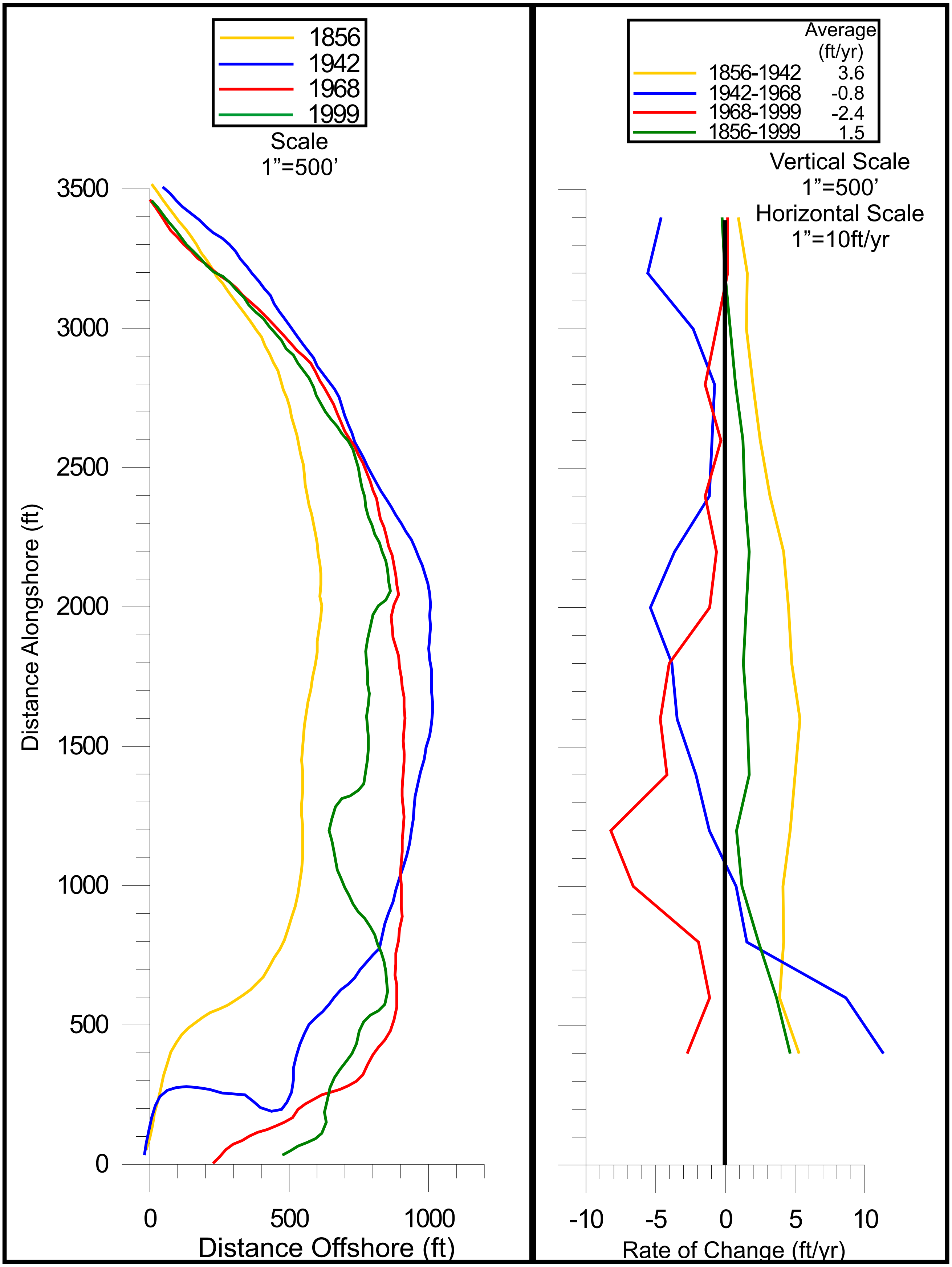


Figure 8. Stingray Point (Reach 2) historical shoreline positions and shoreline rates of change.

Table 4. Lengths of structures located along the Stove Point Neck and Stingray Point shorelines by year.

Structure	Shore Structure Length (feet)			
	1975	1985	1990	1999
groinfield	4,332.8	3,294.8	2,379.7	2,101.2
riprap	5,071.0	4,416.2	4,416.3	5,410.7
groinfield, bulkhead, and riprap	7,809.9	681.8	1,820.4	2,371.2
groinfield and bulkhead	1,263.9	7,111.5	6,401.5	4,818.5
bulkhead or seawall	1,720.2	1,515.9	1,661.1	1,555.9
groinfield and riprap		2,161.7	2,140.6	2,404.2
bulkhead and riprap		1,015.9	1,378.3	1,536.8

Reach 3 (Figure 9) contains four small creeks that were not open to the Bay in 1856. By 1942, one of the creeks had breached and the other three were close to breaching. Development of the northern part of the reach had begun by 1937 with three piers being constructed along the shore (Figure 7). Overall, the shore retreated at a rate of -3.5 ft/yr. However, as the shoreline eroded back into the marsh and the creeks breached, the erosion rate slowed to -1.4 ft/yr between 1942 and 1968. By 1968, this section of shore was highly developed with many groins and bulkheads (Table 4) placed along the shore to abate erosion slowing the rate to almost zero between 1968 and 1999. Shore hardening reduces the supply of beach sands. The extensive SAV beds that existed in 1968 no longer occurred in 1999. The bar system is very large along this reach. The photos show a bar system ranging in distance from the shoreline at the southern end of the reach from 1,700 ft to 2,800 ft from the shoreline at the northern end of the reach. Overall, the net change between 1856 and 1999 was -2.6 ft/yr.

Reach 4 is located on the easternmost section of Stingray Point. It underwent severe erosion between 1856 and 1942 at a rate of -14.6 ft/yr (Figure 10). Development began on this stretch of shore as early as 1937. Two groins were already constructed along the shore at this time (Table 4). Continued development between 1942 and 1968 slowed the erosion rate to -4.4 ft/yr. By 1968, the entire shore along this reach was protected by riprap resulting in a negligible erosion rate of -0.2 ft/yr between 1968 and 1999. The EPR rate of change between 1856 and 1999 was –9.6 ft/yr.

All of Reach 5 suffered severe erosion between 1856 and 1942 at a rate of -7.2 ft/yr (Figure 11). However, between 1942 and 1968 the erosion rate decreased to about -4.8 ft/yr. By 1968, this reach and the area west of the reach to Broad Creek had been highly developed. With development, structures were built along the shoreline in order to protect upland buildings. This altered the erosion rate such that there was slight accretion during the 1968 to 1999 time frame. Overall, the net change between 1856 and 1999 was -5.2 ft/yr.

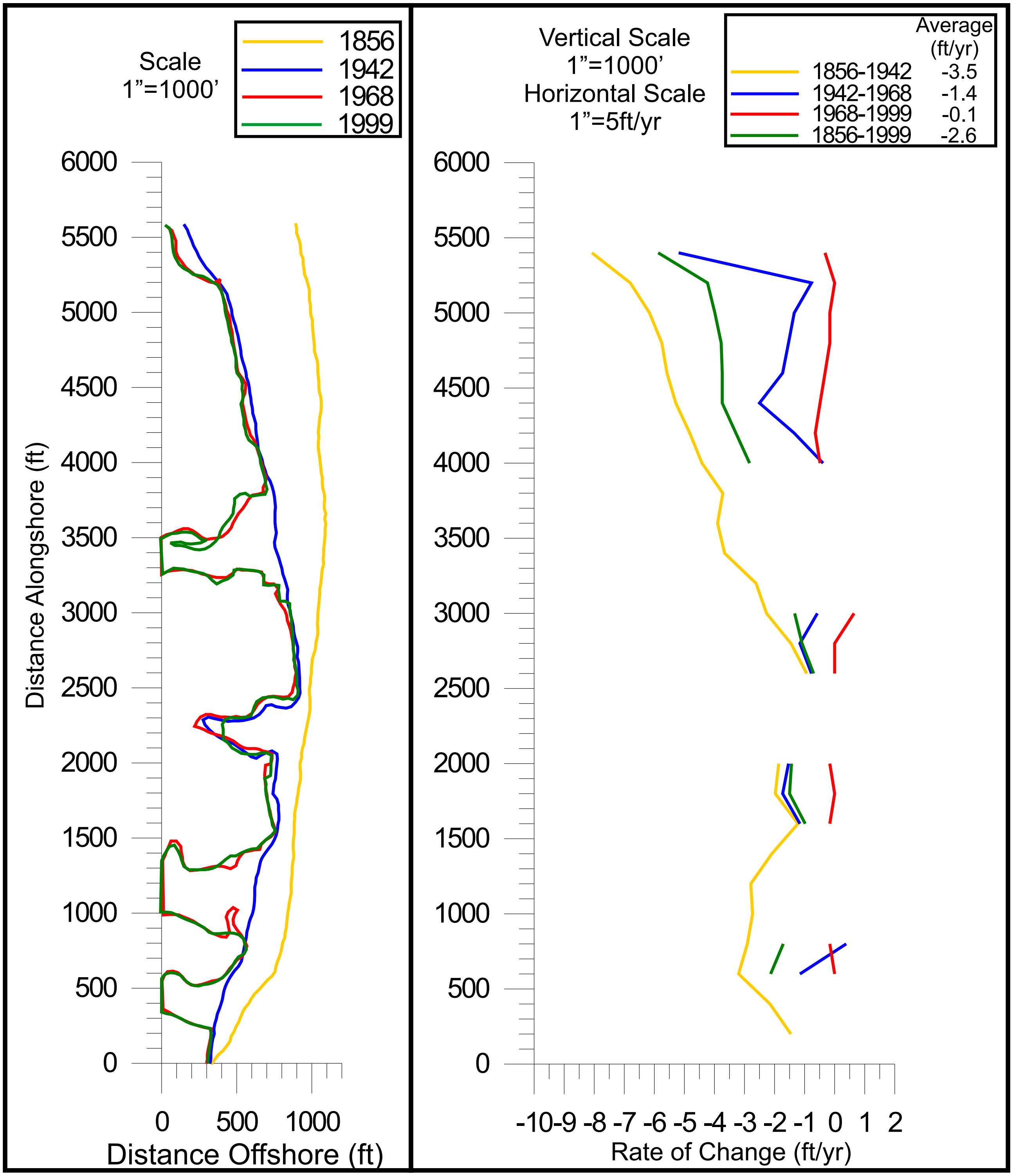


Figure 9. Stingray Point (Reach 3) historical shoreline positions and shoreline rates of change.

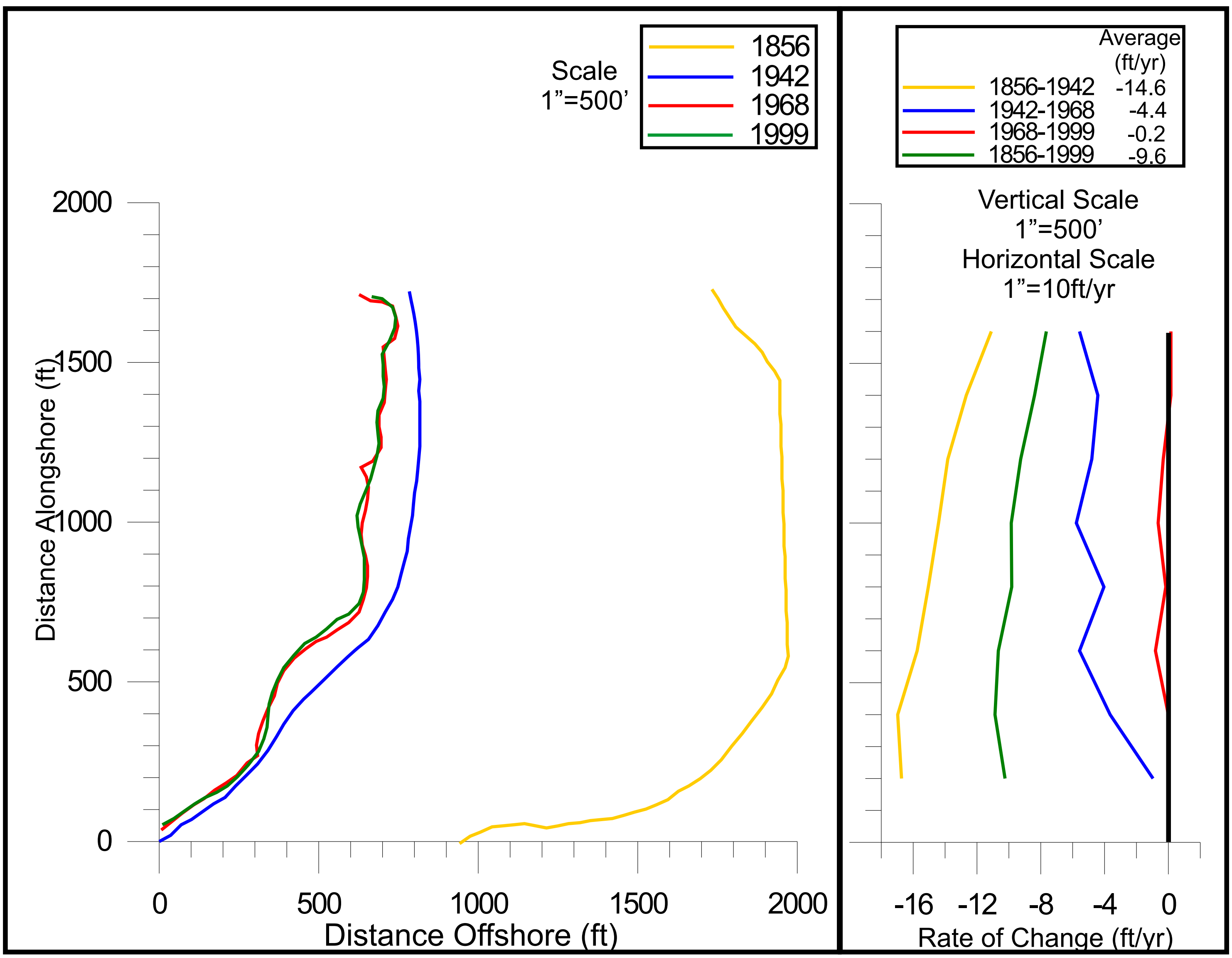


Figure 10. Stingray Point (Reach 4) historical shoreline positions and shoreline rates of change.

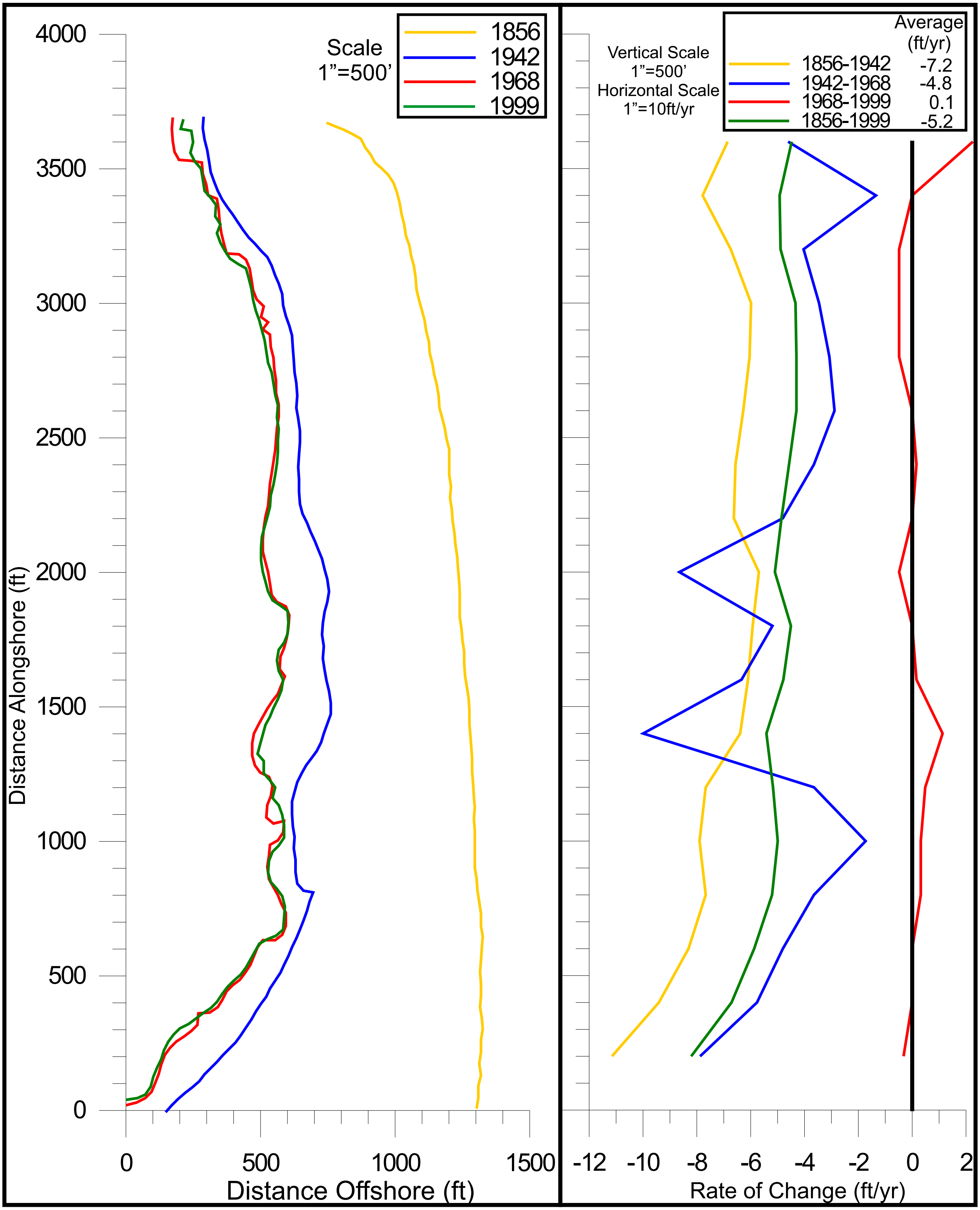


Figure 11. Stingray Point (Reach 5) historical shoreline positions and shoreline rates of change.

3.2 Hydrodynamic Setting

The assessment of hydrodynamic conditions along the Stove Point Neck shoreline results in the determination of the annual, average or modal conditions as well as the storm conditions impacting the site. The assessment is based on the wind field analysis as well as the hydrodynamic modeling. Stove Point Neck and Stingray Point have effective fetches to the NE, E, and SE of 32.7 nautical miles (nm), 16.6 nm and 21.1 nm, respectively. Effective fetch is a measure of the size of waves that can be generated at a shoreline. Winds less than 7 mph were not used in the analysis because they typically generate wind chop which is not sufficiently large or organized to move sediment. Winds from 10-36 mph generate local wind waves when propagated over a Bay fetch (Ludwick, 1987). Long-term wind frequencies of the directions that impact the study shoreline indicate the northeast wind is dominant in the 5-31 mph range followed by the east, then the southeast.

Two types of storms can impact the area. A storm that will impact Stove Point Neck from the southeast is a hurricane or other low-pressure system off the Atlantic coast of the Eastern Shore. A storm of this type could generate large waves over the southeast fetch as well as produce a large storm surge. However, this is a rare event, and the wind data indicate that storm conditions experienced at Stove Point are generally from the northeast. These second, more frequent types of storms are the extratropical storms or northeasters. While the upper part of Stove Point Neck is protected from northeast winds, wind-generated waves can refract around Stingray Point and impact its shoreline. The lower portion of Stove Point Neck is exposed to these waves. Northeasters have a smaller storm surge than a hurricane but can last several tidal cycles longer.

When waves approach at an angle to the shoreline, alongshore sediment transport is initiated. With the longest effective fetch to the northeast as well as the high frequency of wind from that direction, waves are generated that significantly impact the alongshore transport system tending to drive sediment to the south. However, wind-generated waves from the southeast are a significant modal condition. Even though they are lower energy waves, they are the second-most frequent wind direction in the 5-11 mph range and the 11-21 mph range, both of which are more frequent than the northeast condition. The lower portion of Stove Point Neck is protected partially from southeast waves by Gwynn Island. The upper portion of Stove Point is not. There is likely a slight component of the littoral transport system that moves sand north toward Jackson Creek. During southeast modal conditions, waves are reduced significantly in height as the they pass over the shallow nearshore bathymetry (Figure 12A). The nearly shore-parallel bathymetric contours reduce even storm waves in height and alter their direction (Figure 12B). The representative plots shown do not include data for the entire grid modeled in RCPWAVE. The portion of the grid that is shown is shown in Figure 13.

The wave orthogonals for these same two wave conditions are shown in Figure 12C and 12D. Under modal southeast conditions (Figure 12C), the energy is fairly evenly distributed along most of Stove Point Neck. The model showed convergence at the southernmost section of the Neck. However, southeast waves impacting that particular reach of shore would be fetch-

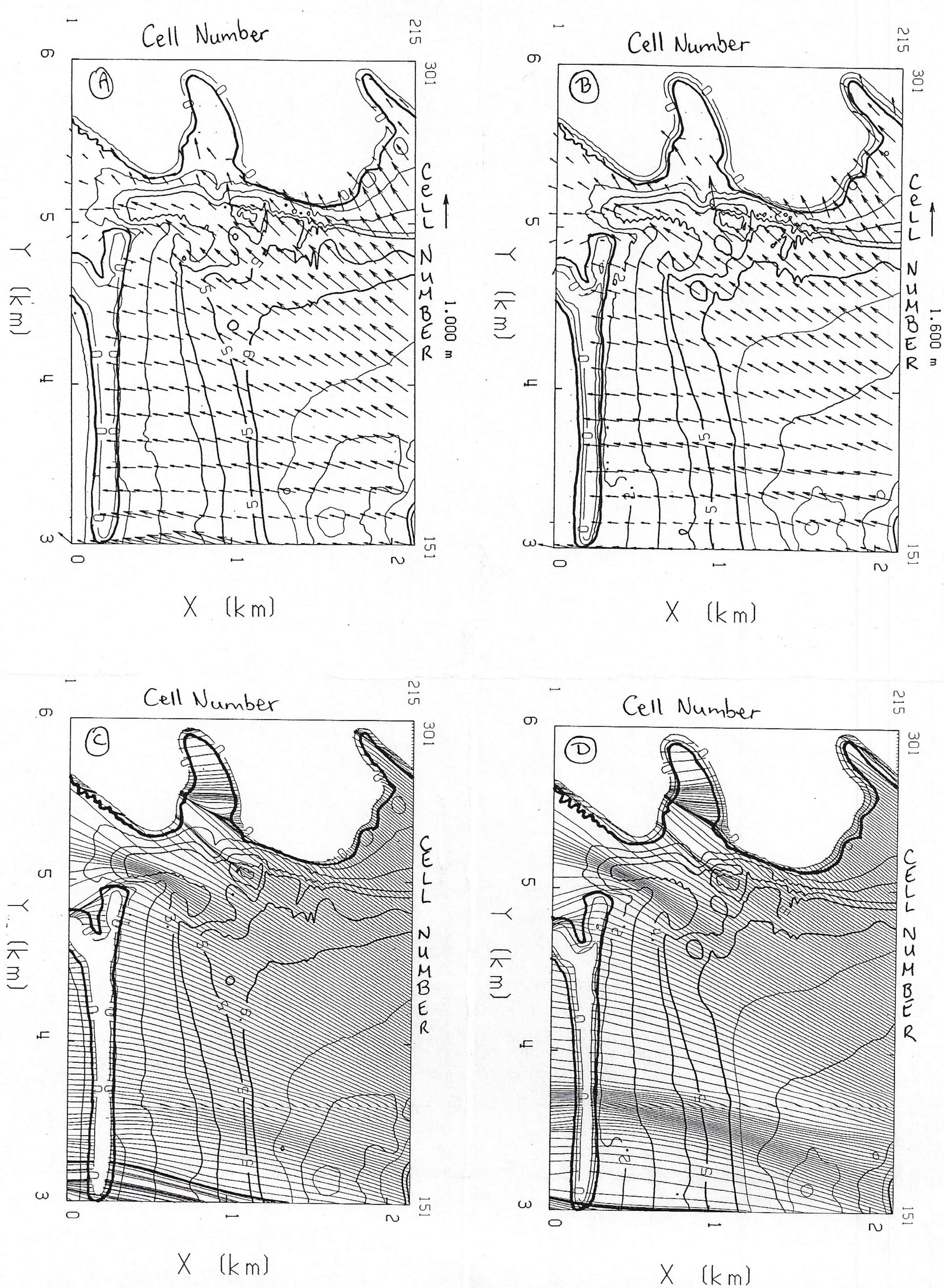


Figure 12. Wave vector plots from the southeast along Stove Point and the mouth of Jackson Creek for A.) modal condition (26 mph) and B.) storm condition (60 mph). Wave orthogonal plots from the southeast for C.) modal condition (26 mph) and D.) storm condition (60 mph).

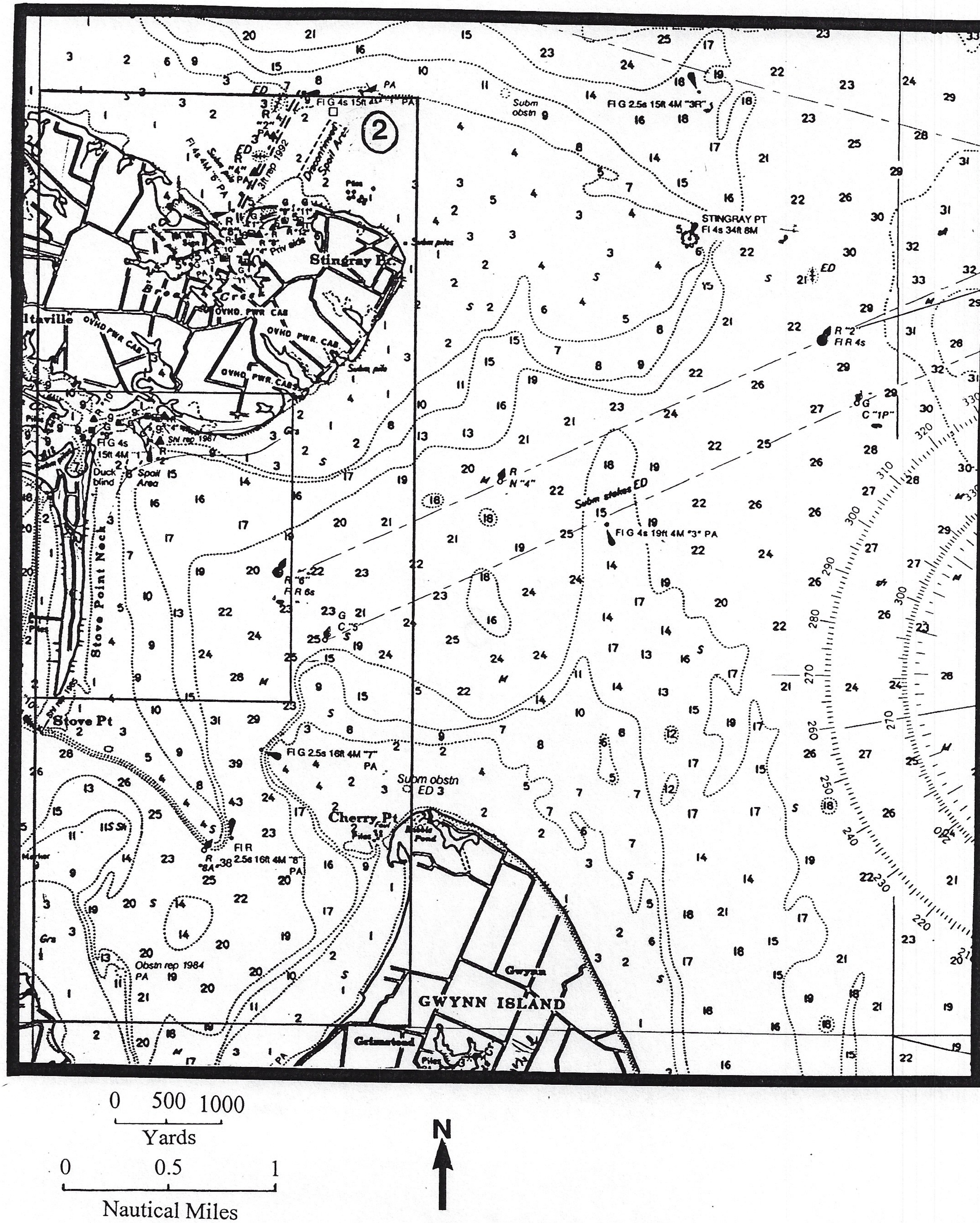


Figure 13. The subsection of Grid 2 plotted by RCPWAVE and shown in Figures 12 and 14.

limited since it is protected by Gwynn Island. Under southeast storm conditions (Figure 12D), there is a definite area of convergence on the southern section of the Neck.

RCPWAVE allows us to determine the wave climate along a shore reach. Individual cases indicate specific conditions. The RCPWAVE plot for the east condition under modal conditions (26 mph wind) shows that, in general, waves tend to refract away from Stove Point Neck (Figure 14A). The bathymetry allows the waves to impact the shoreline straight on in the middle of Stove Point. However, at the ends of the Neck, the waves tend to refract into Jackson Creek and toward the southern shore of the Piankatank River. This allows sediment to move north at the northern end of the Neck and south at the southern end of the Neck creating a nodal point in between. This same scenario occurs for the 50-yr storm event (Figure 14B). The wave orthogonals plotted in Figures 14C and 14D indicated an even energy distribution across the entire Stove Point Neck shore.

Under northeast modal conditions, the waves are reduced in height by the large shoal off of Stingray Point (Figure 15A). Little wave energy impacts the upper portion of Stove Point Neck, and the waves that do are refracted by the bathymetry such that they may tend to move sediment to the north. Along the lower portion of the Neck, the waves impact the shoreline at an angle that tends to drive sediment toward the south. These same conditions occur during northeast storms (Figure 15B). In fact, the energy distribution (Figures 15C and 15D) show a wide divergence at the northern section of the Neck and a fairly even distribution of energy along the rest of the Neck. Figure 16 shows the subsection of the northeast RCPWAVE grid that is shown in Figure 15.

The sediment transport along Stove Point Neck’s shoreline was calculated using output from the wind/wave analysis and the RCPWAVE model. For each wave condition run through RCPWAVE, a plot was generated showing the breaker angle and height, the calculated Q (in cy/yr) and the cell number of breaker cell. The y-axis, alongshore cell number, corresponds to the RCPWAVE cell number. Refer to Figure 5 for the alongshore location.

Figure 17 shows the transport data for the southeast wind/wave condition under modal (Figure 17A) and storm (Figure 17B) conditions. The alongshore transport is variable, but generally, the movement is to the north. Figure 18A shows the transport for the 26 mph modal wave condition from the east. Alongshore transport was somewhat variable; however, since many of the waves were breaking relatively shore normal, alongshore transport was minimal. Under storm conditions from the east (Figure 18B), a more definite trend developed. In section E, transport was generally to the south whereas north of there, transport was generally to the north. Few cells had breaking waves in the northern section of the Neck mainly due to the fact that waves are reduced in height by the offshore bathymetry before they reach the shore (Figure 19A). This reduces the reliability of the transport estimate. Under northeast storm conditions (Figure 19B), transport is definitely to the south.

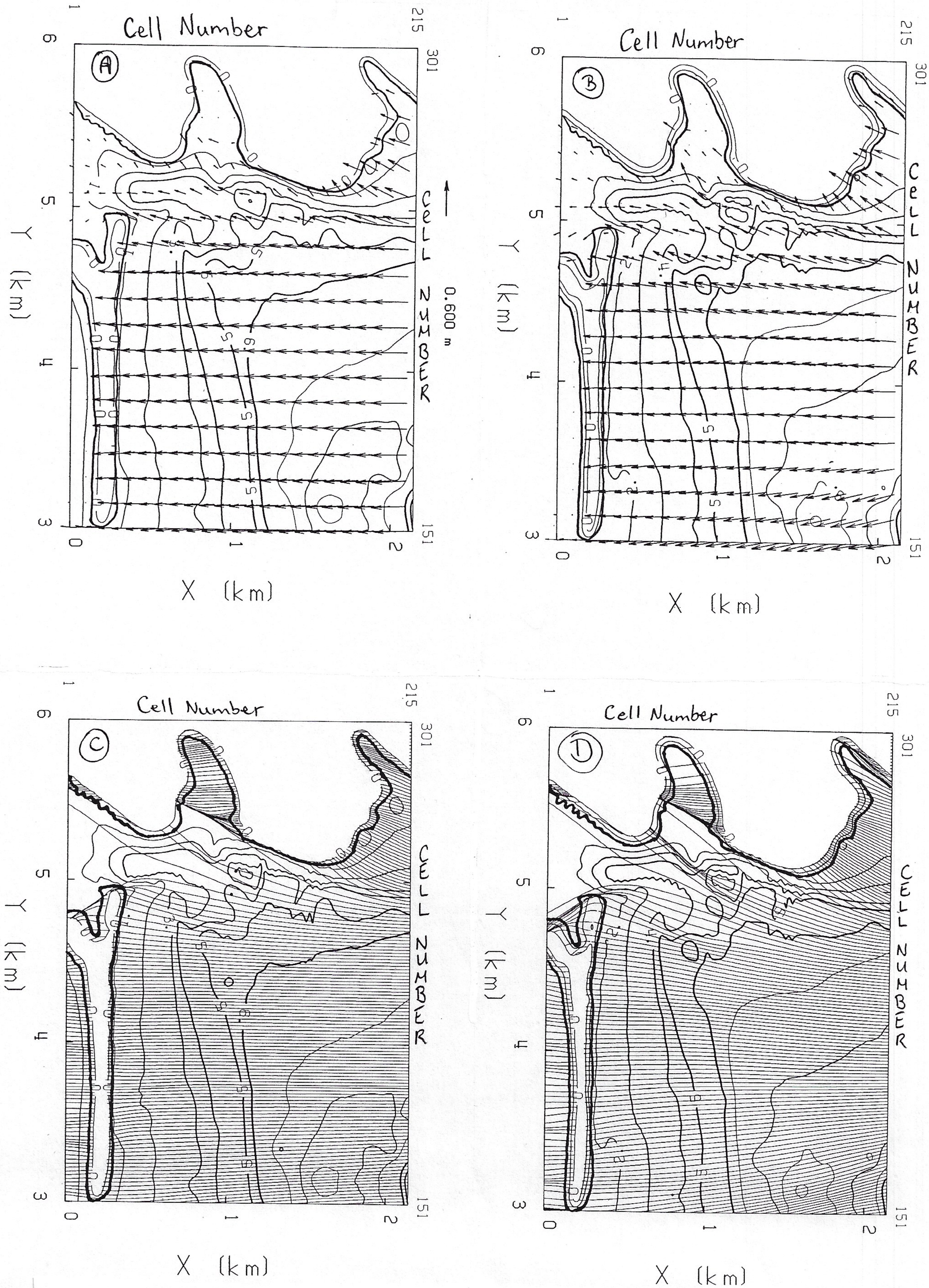


Figure 14. Wave vector plots from the east along Stove Point and the mouth of Jackson Creek for A.) modal condition (26 mph) and B.) storm condition (60 mph). Wave orthogonal plots from the east for C.) modal condition (26 mph) and D.) storm condition (60 mph).

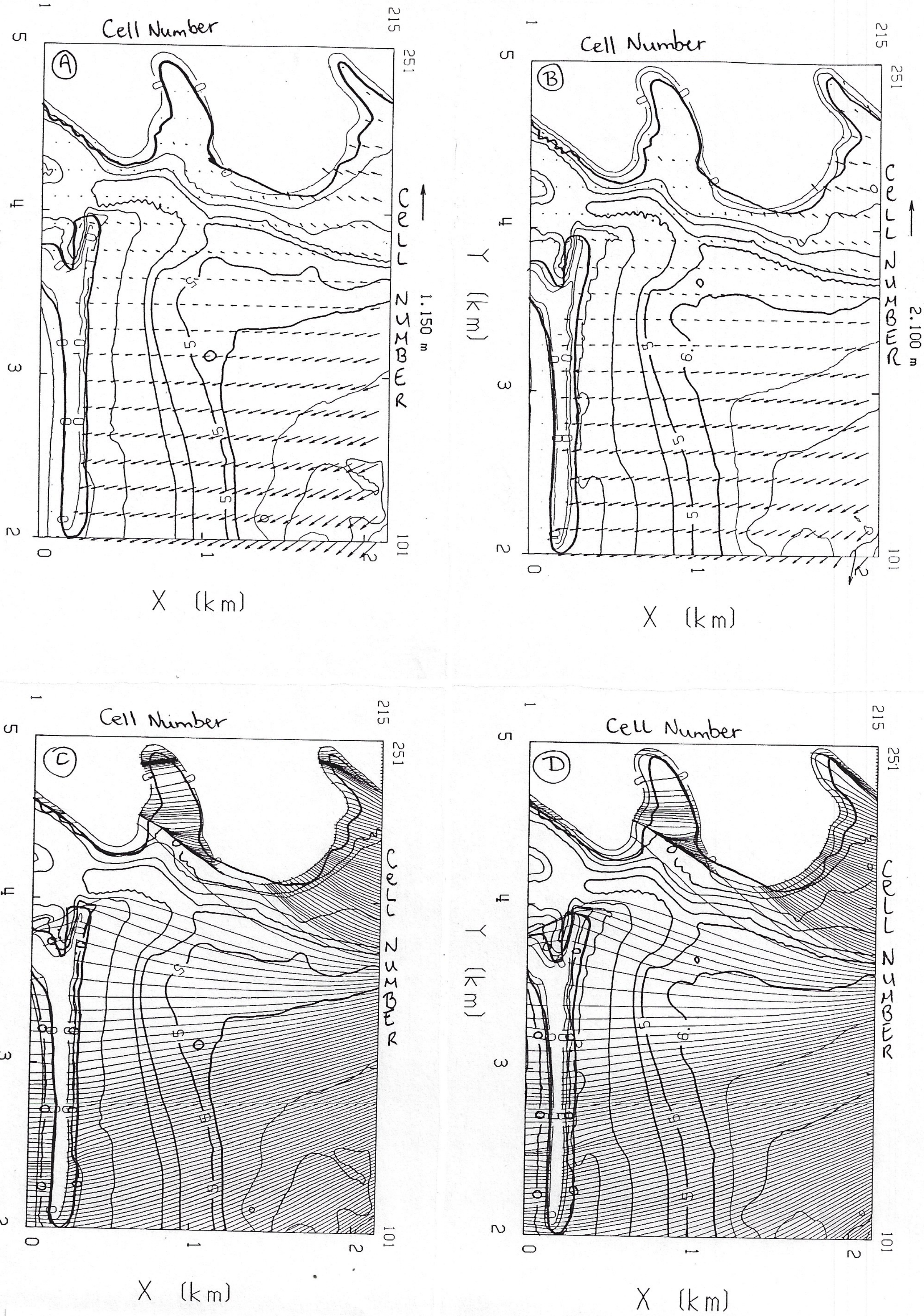


Figure 15. Wave vector plots from the northeast along Stove Point and the mouth of Jackson Creek for A.) modal condition (26 mph) and B.) storm condition (60 mph). Wave orthogonal plots from the northeast for C.) modal condition (26 mph) and D.) storm condition (60 mph).

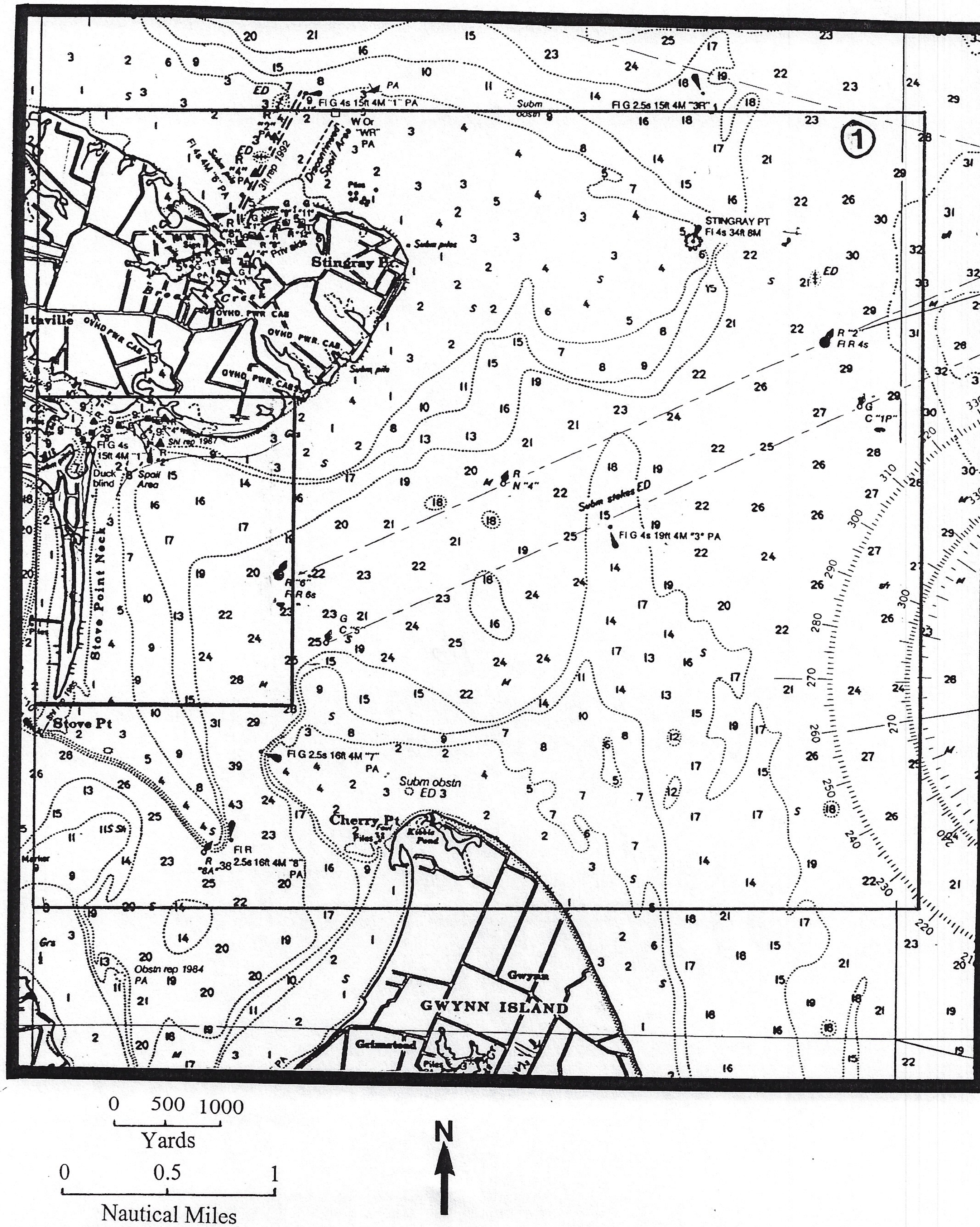


Figure 16. The subsection of Grid 1 plotted by RCPWAVE and shown in Figure 15.

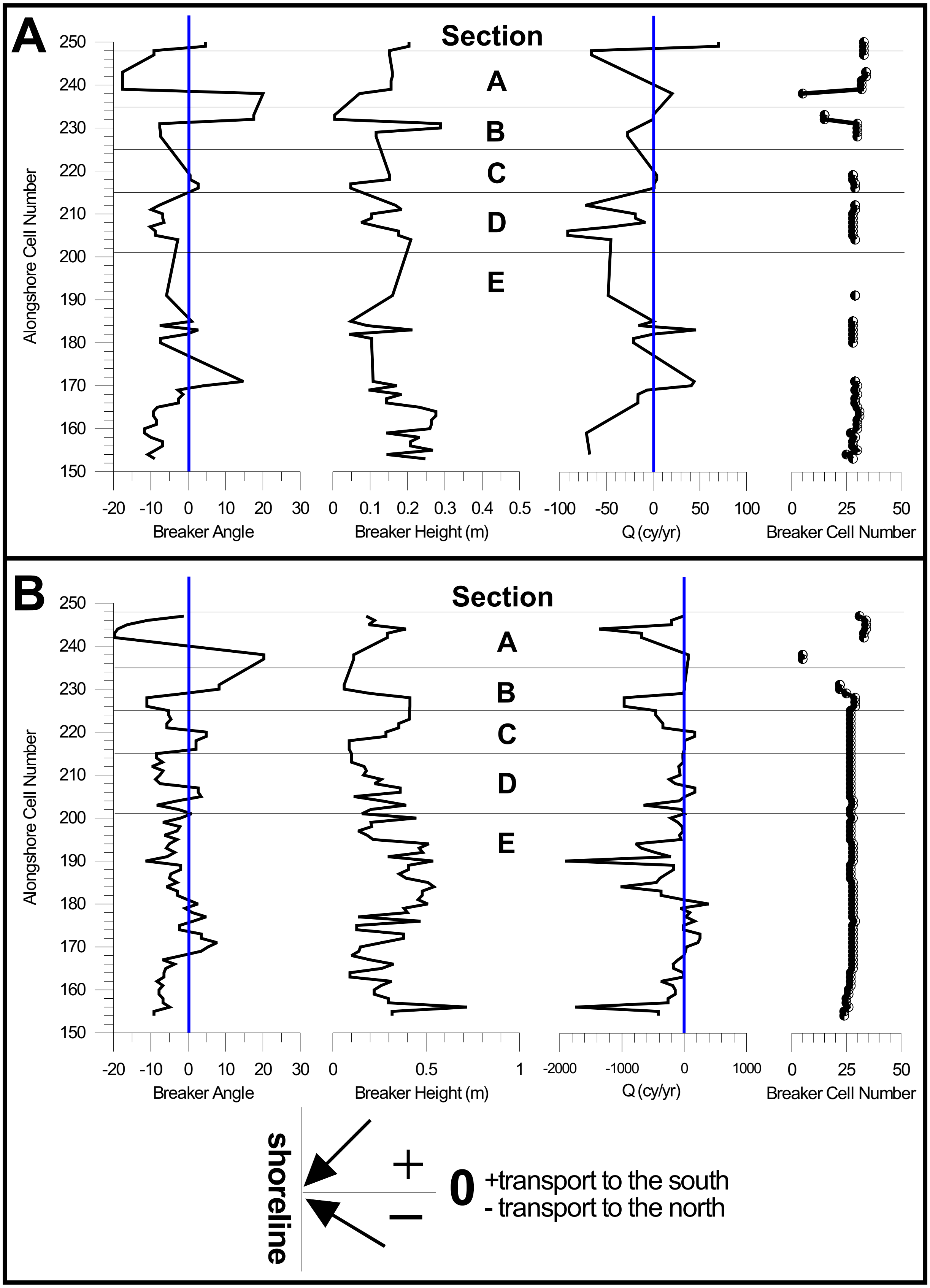


Figure 17. RCPWAVE output (Breaker Angle, Height, and Cell Number) and calculated longshore sediment transport (Q) for wind/waves from the southeast along Stove Point under A.) Modal conditions (26 mph), and B.) Storm conditions (60 mph).

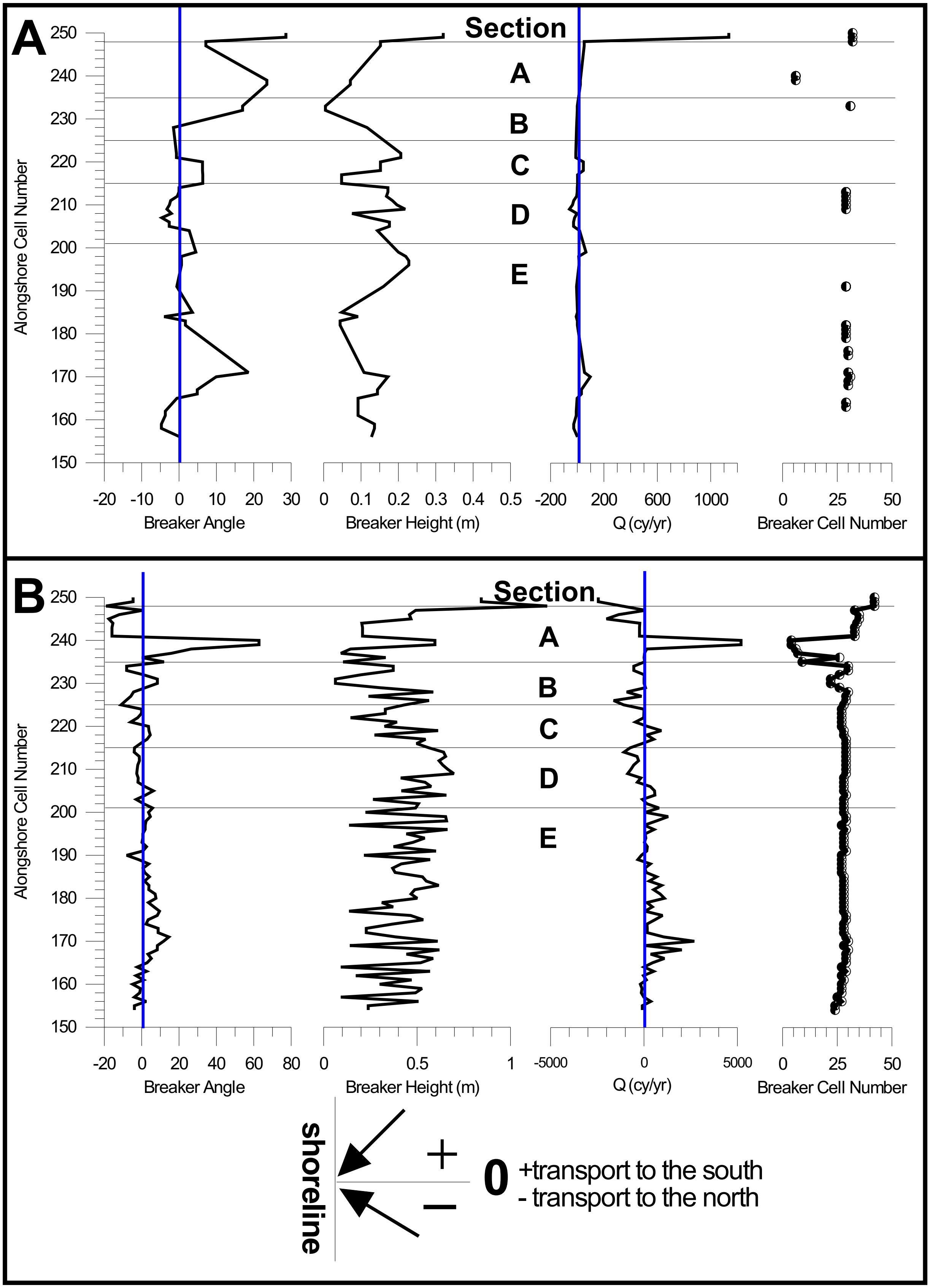


Figure 18. RCPWAVE output (Breaker Angle, Height, and Cell Number) and calculated longshore sediment transport (Q) for wind/waves from the east along Stove Point under A.) Modal conditions (26 mph), and B.) Storm conditions (60 mph).

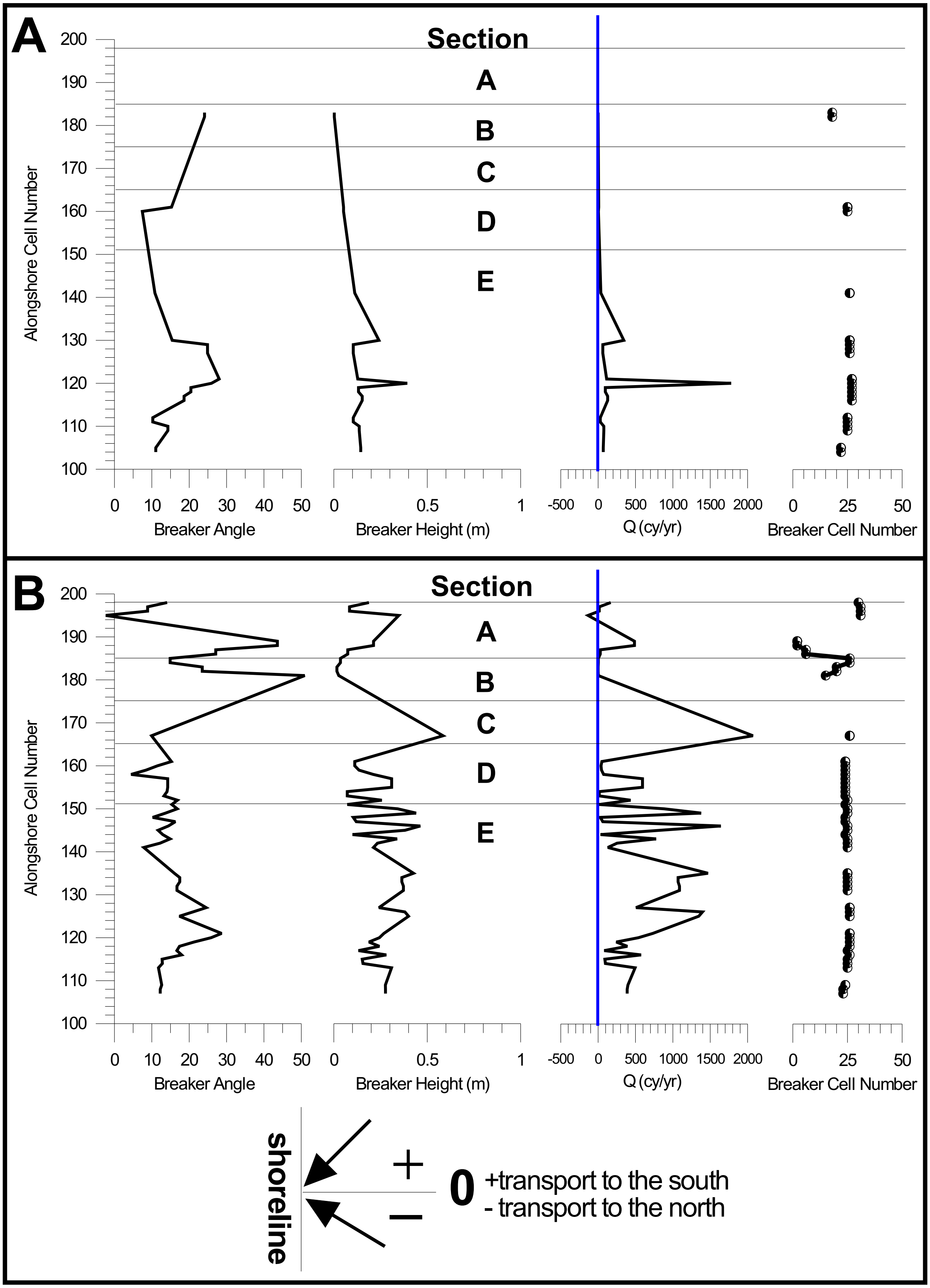


Figure 19. RCPWAVE output (Breaker Angle, Height, and Cell Number) and calculated longshore sediment transport (Q) for wind/waves from the northeast along Stove Point under A.) Modal conditions (26 mph), and B.) Storm conditions (60 mph).

Table 5 shows the calculated longshore gross and net transport for each wave condition used in RCPWAVE as well as the transport to the left (north) and to the right (south) for the entire Stove Point Neck shore. Under northeast conditions, transport is definitely to the south except for a slight component to the north under severe storm conditions. Under both the east and southeast conditions, sediment transport was more variable. During easterly modal conditions, more transport occurred to the south than to the north. However, that trend reverses itself under storm conditions when more transport occurs to the north. The southeast wind/wave conditions have transport directed mostly northerly, but there is a slight southerly component.

Table 5. Calculated longshore gross and net transport for each wave condition used in RCPWAVE as well as the transport to the left (north) and to the right (south). Also indicated are number of cells with breaking waves and the percent of breaking wave cells versus total number of cells.

Direction	Wind Speed (mph)	Wave Condition	Gross (cy/yr)	Net (cy/yr)	Qleft (cy/yr)	Qright (cy/yr)	Count Cells	Percent (%)
Northeast	8	1-1	239,600	239,600	0	239,600	8	7.9
	16	1-2	228,000	228,000	0	228,000	11	10.9
	26	1-3	653,200	653,200	0	653,200	21	20.8
10-yr	36	1-4	3,960,200	3,960,200	0	3,960,200	55	54.5
25-yr	46	1-5	4,390,800	4,390,800	0	4,390,800	64	63.4
50-yr	60	1-6	5,076,200	5,022,000	27,000	5,049,200	55	54.5
East	8	2-1	34,200	-2,600	18,400	15,800	18	17.18
	16	2-3	405,400	263,600	71,000	334,600	46	45.5
	26	2-5	643,600	517,800	63,000	580,800	47	46.5
10-yr	36	2-7	8,059,200	-5,816,600	6,938,000	1,121,400	83	82.2
25-yr	46	2-9	9,172,000	-3597200	6,384,600	2,787,400	97	96
50-yr	60	2-11	15,621,400	-1,812,400	8,717,000	6,904,600	97	96
Southeast	8	2-2	145,000	-144,800	145,000	0	11	10.9
	16	2-4	117,200	-48,000	82,600	34,600	24	23.8
	26	2-6	996,200	-875,200	935,800	60,400	55	54.5
10-yr	36	2-8	2,249,800	-1,514,200	1,882,000	367,800	68	67.3
25-yr	46	2-10	2,429,400	-1,941,600	2,185,400	244,000	72	71.3
50-yr	60	2-12	4,831,200	-3,905,200	4,368,200	463,000	86	85.1

The transport data were mean-weighed with the Norfolk wind data. Overall, the net transport for the entire Stove Point Neck shoreline was +6,640 cy/yr (Table 6). This indicates that over the long-term, transport is to the south. In order to determine the best placement of dredge material, the shoreline was divided into five sections based on shore morphology. The net transport for each section was mean-weighed with 30 years of Norfolk wind data (Table 6). Sections A and B have small amounts of transport to the north. Section C has transport to the south while, surprisingly, Section D has transport to the north. Section E has a large amount of transport to the south.

Table 6. Littoral transport along Stove Point Neck or a section of the Neck mean-weighed with Norfolk wind data.

Reach	Mean-Weighed Transport (cy/yr)
Entire shore	+6,640
Section A	-100
Section B	-200
Section C	+540
Section D	-340
Section E	+5,160

4 DISCUSSION

The geomorphic evolution of Stove Point's shoreline indicates a movement of littoral materials to both the north and the south. Development along the entire study area shore has altered the historic erosion rate. Most of the Stingray Point and Stove Point Neck shorelines were eroding at a high rate between 1856 and 1942. This was likely due to the highly erosive nature of sand systems plus the several large hurricanes that impacted the lower Chesapeake Bay during that time frame. Overall, the entire shore was eroding at about -5 ft/yr. Interestingly, Reach3 eroded at -3.5 ft/yr during this time frame while Reach 2, which is downdrift of Reach 3, accreted at a rate of +3.6 ft/yr, *i.e.* a cut and fill scenario. These rates and patterns of shore change were altered by the development of the shoreline. The 1937 photos indicate some structures were located along the shore.

Between 1942 and 1968, the overall erosion rate decreased to -2.5 ft/yr. Reach 2 which had been accreting began to erode as the sediment supply was cut off updrift. By 1968, very little of the shore within the entire study area was left unprotected. This had a profound impact on the rates of shoreline change. Reaches 1, 3, 4, and 5 had negligible erosion rates; all were between $\pm$0.2 ft/yr. Reach 2 had an increased erosion rate of -2.4 ft/yr. A large section of this shore is unprotected, and much of the sediment supplied by the littoral transport system has been restricted by updrift structures.

Stove Point Neck has also been impacted by structures, particularly groins, that interrupt the littoral transport system and have been placed along the shore. The distal end of the Neck had been decreasing in length until the groins and riprap was installed in the 1960s. The subaerial spit that once existed off the southernmost point of Stove Point no longer exists. There is a great deal of sand in this system as evidenced by the extensive bar systems present within the study area which allows the groins installed along the shore to function properly. While a definitive analysis has not been performed, the photos may indicate that the bar system bayward of Stove Point Neck is decreasing in width.

The wave climate analysis showed that the east wave conditions under both modal and storm conditions result in the development of a nodal point along the Stove Point Neck shoreline. Where that nodal point is on any given day is determined by the prevailing wind and wave conditions at the site. The northeast component is the most frequent wind condition impacting this system such that the nodal point location could be influenced by this wind particularly during storm conditions.

The mean-weighed data showed that in fact there are two nodal points or more likely a nodal zone. The nodal point between Sections D and E is most pronounced under the east condition. The net southerly transport of Section C generally is not discernable from the transport plots. However, the trend does show up on several transport plots for the east conditions and one from the southeast. This concept of a nodal zone is supported by the morphology along the shoreline. Aerial photos from 1999 show that there is a chaotic very nearshore bar system in Section C. A review of the shape of sand within groin cells along shore show that groins in Section D indicate a net northerly transport as do the structures and/or bars in Sections A and B.

5 SUMMARY AND CONCLUSIONS

The draft results of the mean-weighed net transport for each section are shown in Figure 20. Placement of the dredge material placement in Sections A and B would allow the sand to drift relatively slowly to the north and spill across the shoals along the mouth of Jackson Creek. Placement in Section C would allow the material to move primarily southward and placement in Section D would have it move north again. This seems to indicate a moving nodal "point" which in reality is a nodal zone. Onshore/offshore movement also is occurring, but RCPWAVE cannot measure it. While some sand may move north, Section C might be most appropriate for placement due to the need to create a beach there. However, to insure southward movement, Section E would be the choice.

The impacts from the 50-year storm (60 mph winds at +5 ft MLW) show that southeast wind/waves drive all the sand along Stove Point northward; a northeast storm condition drives all the sand southward; and the easterly wind/waves have the same basic pattern as shown in Figure 20. The northeast event would be like the Ash Wednesday Storm (1962), and the southeast event would be a hurricane. The east event would be rare, but it could be a component of a hurricane or an extratropical storm. The effects of the groins are not considered and would come into play once the beach berm has eroded to groin level and in areas beyond the beach fill. The groins will tend to slow the littoral movement and thus the fill dispersion.

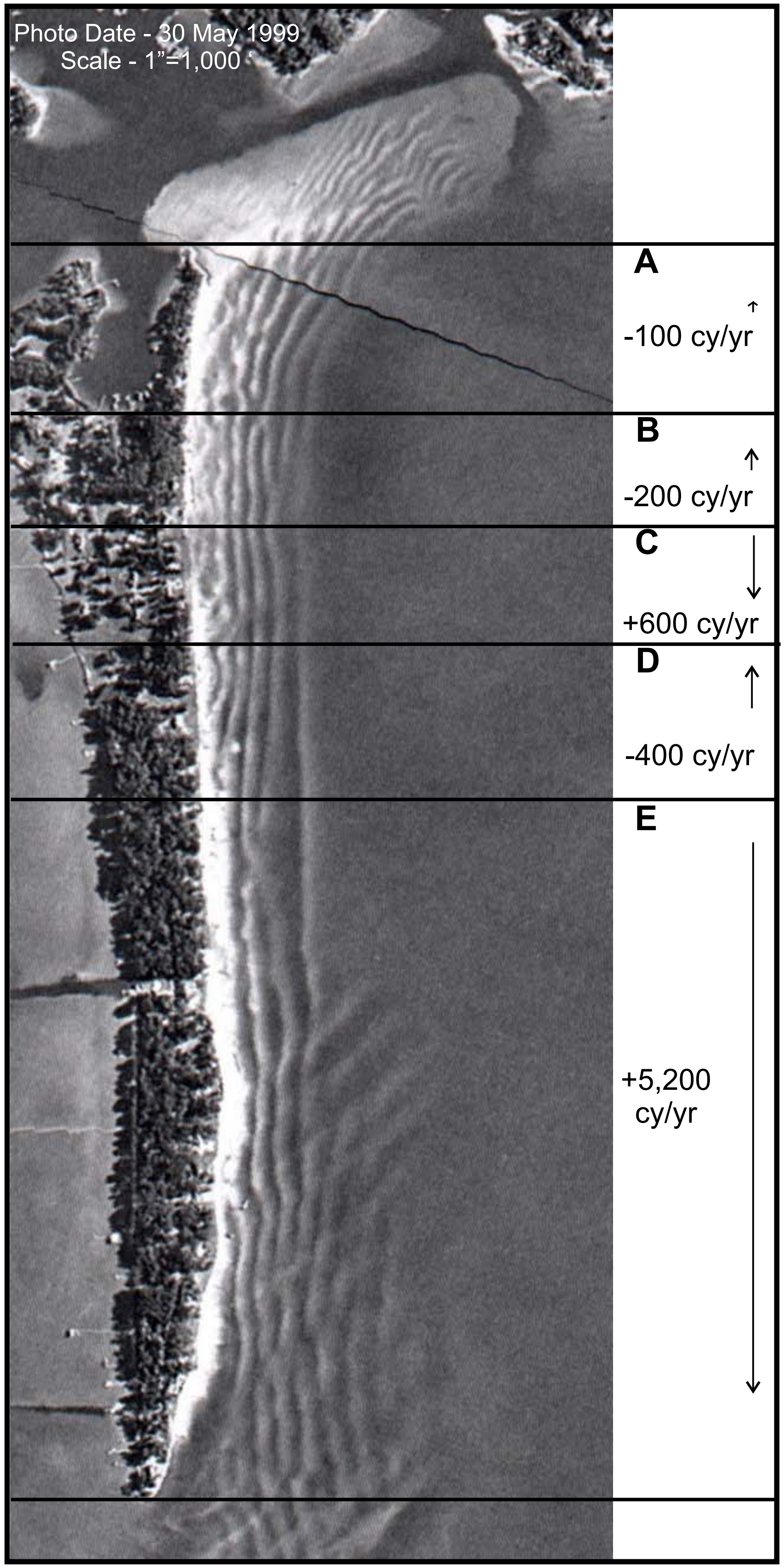


Figure 20. A 1999 aerial photo showing the mean-weighed net sediment transport along Stove Point shoreline.

6 REFERENCES

Boon, J.D., C.S. Welch, H.S. Chen, R.J. Lukens, C.S. Fang, and J.M. Zeigler, 1978. *A Storm Surge Model Study, Vol. I. Storm Surge Height-Frequency Analysis and Model Prediction for Chesapeake Bay.* SRAMSOE No. 189. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 149 pp + app.

Bretschneider, C.L., 1958. Revisions in wave forecasting: Deep and shallow water. *Proceedings Sixth Conf. on Coastal Engineering, ASCE, Council on Wave Research.*

Ebersole, B.A., M.A. Cialone, and M.D. Prater, 1986. *RCPWAVE - A Linear Wave Propagation Model for Engineering Use*. CERC-86-4, U.S. Army Corps of Engineers Report, 260 pp.

Fenster, M.S., R. Dolan, and J.F. Elder, 1993. A new method for predicting shoreline positions from historical data. *J. Coast Res,* **9**(1): 147-171.

Hardaway, C.S., Jr. and J.R. Gunn, 1991. *Headland breakwaters in Chesapeake Bay*. Proceedings: Coastal Zone '91, Long Beach, CA: 1267-1281.

Hardaway, C.S., Jr., L.M. Varnell, D.A. Milligan, W.I. Priest, G.R. Thomas, R.C.H. Brindley, and S. Dewing, 1999. Shoreline Management Plan with Habitat Enhancement for Town of Saxis, Virginia. Technical Report, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA, 55 pp + app.

Hardaway, C.S., Jr., D.A. Milligan, and G.R. Thomas, 1993. *Public Beach Assessment Report, Cape Charles Beach*, *Town of Cape Charles, Virginia*. Technical Report, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA, 42 pp + app.

Kiley, K., 1982. *Estimates of bottom water velocities associated with gale wind generated waves in the James River, Virginia*. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA.

Komar, P.D., 1976. *Beach Processes and Sedimentation*. Prentice-Hall, Inc., Englewood Cliffs, NJ, 429 pp.

Ludwick, J.C., 1987. Mechanisms of Sand Loss from an Estuarine Groin System Following an Artificial Sand Fill. Dept. of Oceanography, Technical Report 87-2, Old Dominion University, Norfolk, VA, 89 pp.

Milligan, D.A., C.S. Hardaway, Jr., and G.R. Thomas, 1996. *Public Beach Assessment Report: Yorktown Public Beach*, *Yorktown*, *Virginia*. Technical Report, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA, 47 pp. + app.

NOAA, 1989. East Coast of North and South America Including Greenland, Tide Tables 1989. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service

Rosen, P.S., 1976. *The Morphology and Processes of the Virginia Chesapeake Bay Shoreline*. Unpublished Dissertation. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA.

Stamper, D.H., 2000. *Personal Communication*. U.S. Army Corps of Engineers.

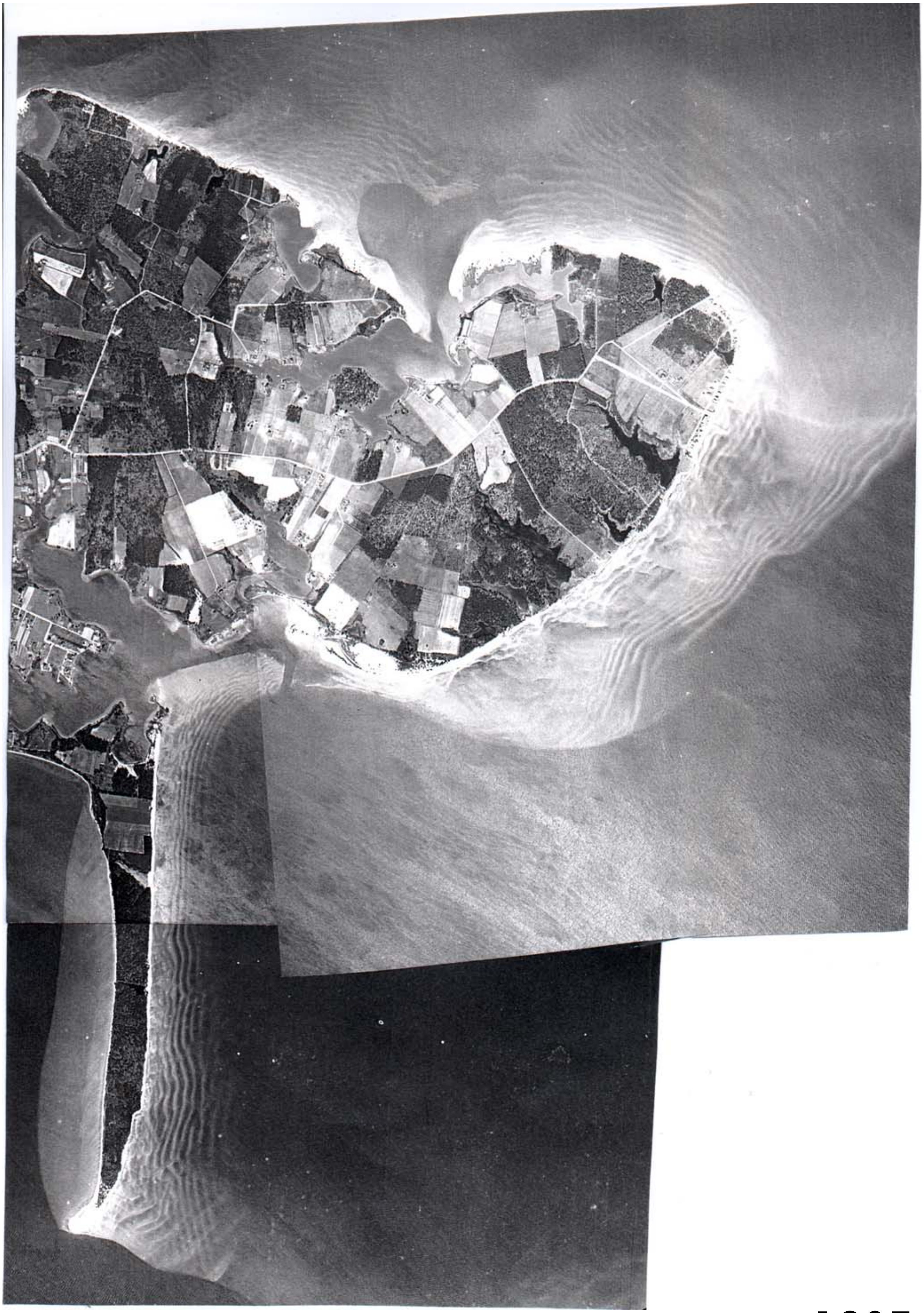
Sverdrup, H.U. and W.H. Munk, 1947. *Wind, sea, and swell: Theory of relations for forecasting*. U.S. Navy Hydrographic Office Publ. No. 601.

U.S. Army Corps of Engineers, Unknown. *Dredging Quantities and Disposal Areas*. Norfolk District, Norfolk, VA.

U.S. Army Corps of Engineers, 1984. *Shore Protections Manual*. U.S. Government Printing Office, Washington, D.C.

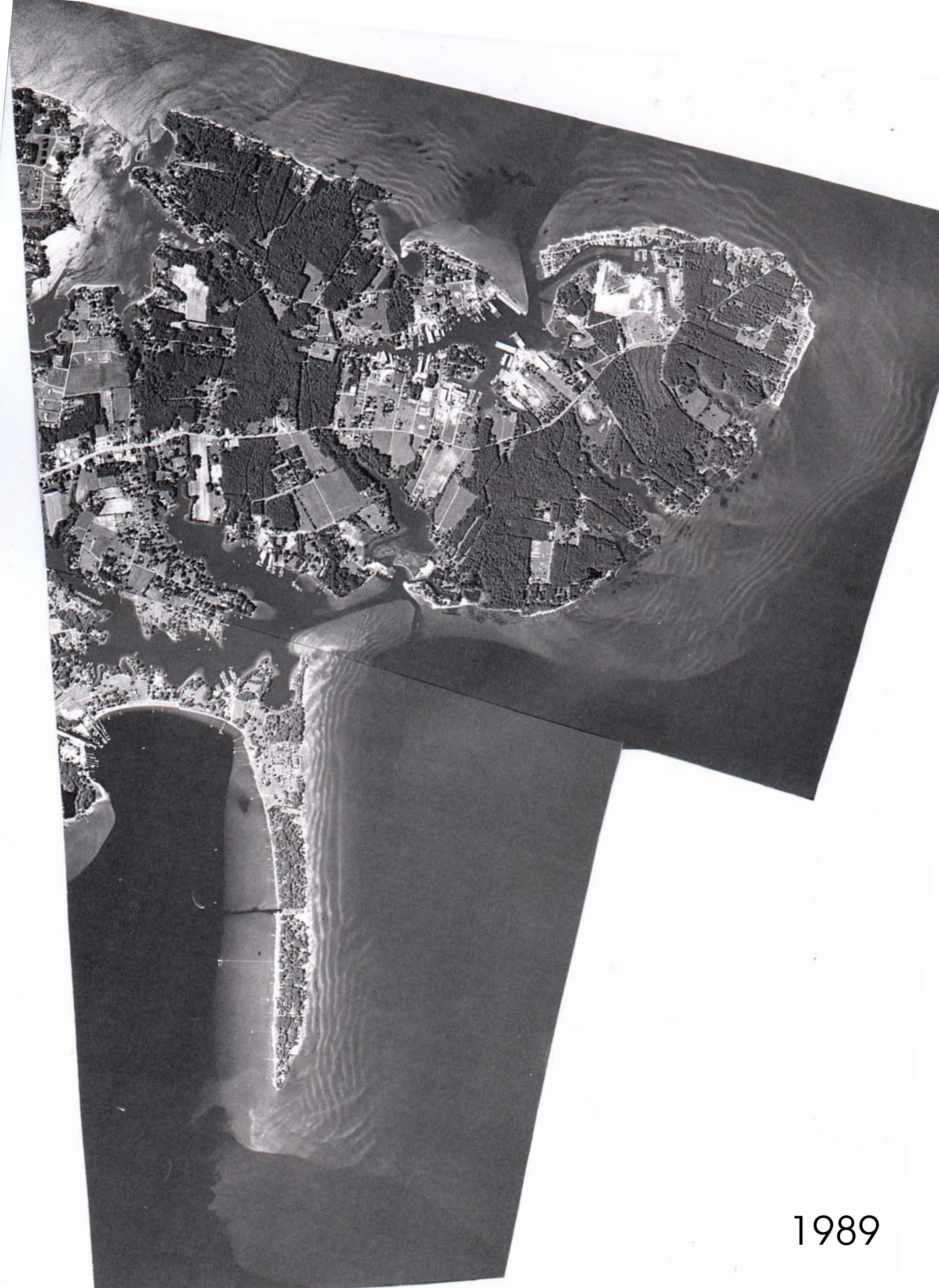
Wright, L.S., C.S. Kim, C.S. Hardaway, Jr., S.M. Kimball, and M.O. Green, 1987. *Shoreface and Beach Dynamics of the Coastal Region from Cape Henry to False Cape, Virginia*. Technical Report, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA., 116 pp.

Appendix 1
Historic and Recent Aerial Photos

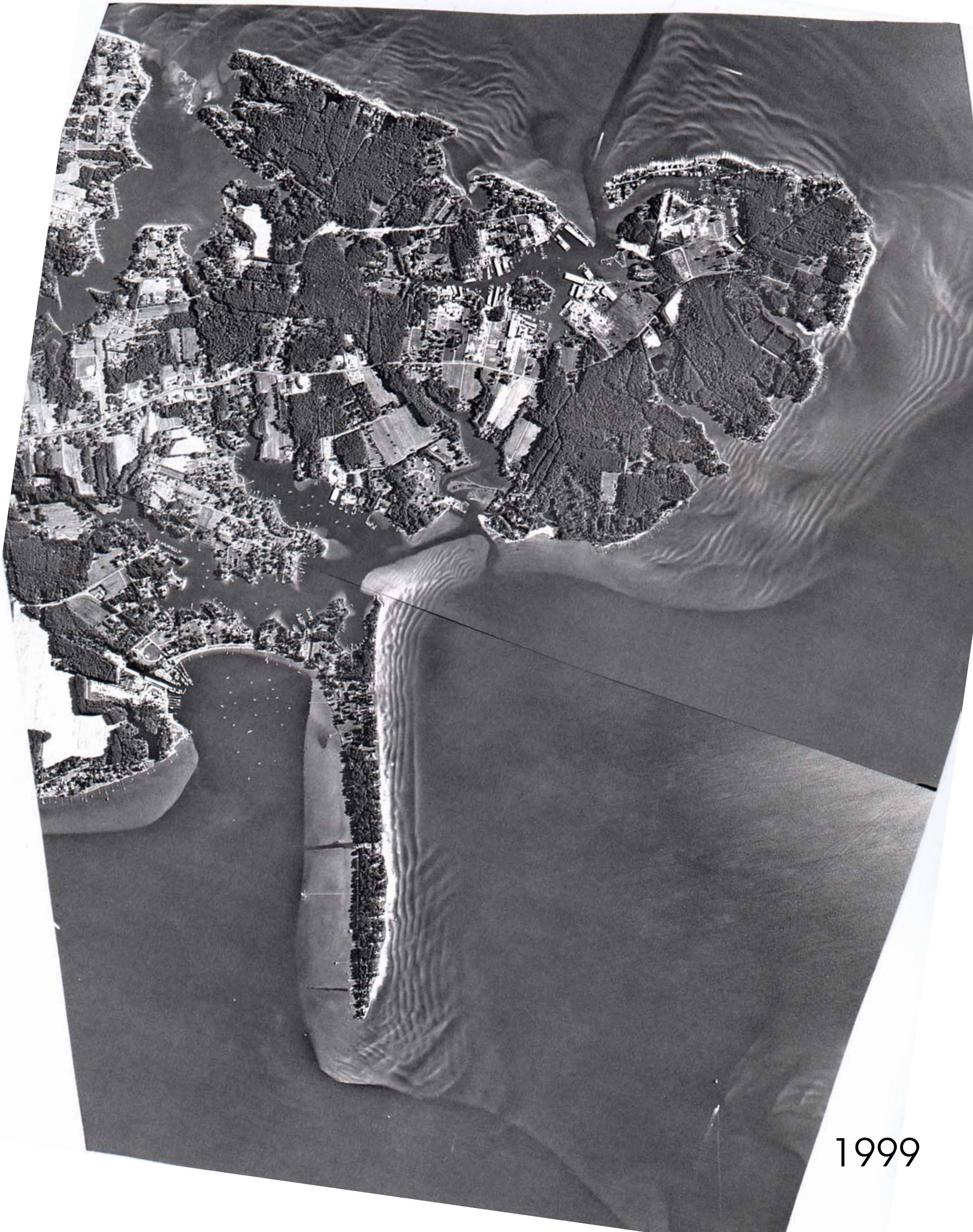


1937

1968



1989



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