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Historical shoreline changes and wave refraction analysis, Smith Island, Chesapeake Bay : final report

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FINAL REPORT

HISTORICAL SHORELINE CHANGES AND WAVE REFRACTION ANALYSIS
SMITH ISLAND, CHESAPEAKE BAY

Contract No. DACW31-78-M-1362 for the
Baltimore District Army Corps of Engineers

by

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I INTRODUCTION - Scope of Work

The objective of this study was to develop wave and sediment transport estimates (based on wave refraction analysis and historical shoreline change analysis) for the western shoreline of the Chesapeake Bay Smith Island area (W.E. Trieshman, Jr., letter of 24 July 1978; V. Goldsmith, letter of 3 August 1978). The requested analysis has been performed and reported in two previous interim reports (Goldsmith, et al., 23 February 1979; Goldsmith, et al., 13 March 1979). A summary of the study, comparison between wave refraction and shoreline change, and overall conclusions of the study are contained within this final report.

A. Wave Refraction and Sediment Transport Analysis

The following wind wave conditions were examined and reported in Goldsmith, et al. (13 March 1979).

Fetch	Wind Velocity (KTS)
NW	10
NW	25
NW	40
W	10
W	25
W	40
SW	10
SW	25
SW	40

The output data consisted of:

1. Wave refraction diagrams for each fetch and speed combination.
2. Computer printouts of wave parameters at each computational time step in the wave refraction analysis.

3. Shoreline histograms of wave height and wave period along the western shoreline of Smith Island.

4. Shoreline histograms of wave ray orthogonal density for NW and SW conditions (Figures 1-6 of this report).

B. Historical Shoreline Change Data

Historical shoreline changes were estimated from six maps of the area made between 1849 and 1978 (Goldsmith, et al., 23 February 1979). The output consisted of:

1. Computer drawn digitized shorelines of the western shoreline of Smith Island.

2. Summaries of shoreline segment changes.

3. Erosion and accretion plots along the shoreline.

C. Comparison Between Wave Refraction Data and Shoreline Change Data

This comparison is included in the conclusions section of this report.

II HISTORICAL SHORELINE CHANGES

Methods

Smith Island is located in the Chesapeake Bay north of Tangier Island at 38^{o}N latitude and 76^{o}W longitude. The study area involves the northernmost part of Smith Island south to approximately $37^{o}56'$N latitude, a total of about 6 nautical miles of shoreline.

The base map was drawn from hydrographic sounding sheet No. H-8069 at a scale of 1:20,000 from a survey done in 1951. Table 1 shows the other shorelines that were either directly transferred if scale allowed or drawn using a Zoom Transfer Scope as in the case of the aerial photographs.

The x-y coordinate system from the Chesapeake Bay Wave Climate Model was carefully read from the grid using latitude-longitude as the mode of transfer. After the coordinate system was drawn, a check was made to insure that all lines were equidistant and perpendicular. This x-y grid system is comprised of boxes which measure one quarter nautical mile or 1520 feet on each side. Each of these grid units were then divided five more times into 25 boxes which allowed us to measure down to an interval of one tenth grid unit, or every 152 feet along the shoreline.

After the shorelines were digitized and keypunched, the cards were submitted as data in a program. This program plots the points making a computer drawn diagram of the shorelines previously digitized. These plots allow us to proof the cards more easily since any mistakes in digitizing or keypunching is seen as a peak or trough on the plotted shorelines.

The correct digitized shorelines are then used as data in the program which calculates shoreline change (Goldsmith, et al., 1978). In the case of Smith Island, two points should be noted. The calculations of shoreline change cannot continue should one shoreline terminate; therefore, shorelines must start and stop at approximately the same point. This sometimes reduces the length of shoreline since calculations begin at the southernmost starting shoreline and end at the last point of the shortest shoreline. The problem of erroneous calculations is also avoided by starting and stopping at the same x value.

Inlets along the western shore of Smith Island that were narrower than 0.2 grid units were ignored and treated as land. Here again the inlet migration would reduce the length of shoreline; so when circumstances allow, inlets are digitized along with the whole beach front.

Table 1

MAPS USED IN SHORELINE COMPARISON

T-271 (H-211)	1849	1:20,000	Direct Transfer
T-2556	1901	1:40,000	Lat-Long Transfer
H-3361	1911	1:40,000	Lat-Long Transfer
H-8069	1951	1:20,000	Base Map
EWELL TOPO	1967	1:24,000	Zoom Transfer Scope
EARTHSAT AERIAL	1978	1:24,000	Zoom Transfer Scope

Results (Refer to diagrams sent in interim report, dated 23 February 1979.)

The northern six nautical miles of Smith Island have been erosional since at least 1850. From Big Thoroughfare to Fog Point, the rate of erosion was between 2.3 and 2.6 m/yr from 1849 to 1978. Immediately south of Goose Harbor Cove, the rate of erosion is 1.43 m/yr and the rate increases as you move south to 4.80 m/yr from 1849 to 1978 for the Hog Neck area.

The area from one-half nautical mile south of Fog Point to just north of Hog Neck shows the highest erosion rate from 1967 to 1978. From 1901 to 1911, the shoreline is accretional (0.15 to 0.45 m/yr) from Fog Point to Channel Point. Channel Point to just north of Hog Neck is erosional (-0.25 to -0.58 m/yr) with accretion south of this area ranging from 0.21 to 2.55 m/yr as you move toward Cheesman Point.

III WAVE REFRACTION ANALYSIS

Results (Refer to diagrams sent in interim report, dated 13 March 1979, and to Figures 1-6, appended here.)

A review of the wave refraction diagrams indicates that wave refraction and convergence is more pronounced for the northwest wind conditions than for the southwest wind conditions. This is significant since the degree of convergence of wave orthogonals along the shoreline (orthogonal density) shows the highest degree of correlation with shoreline change, when other wave parameters are similarly compared (Fisher, 1977). A comparison of the wave refraction diagrams with charts of the area (Goldsmith, et al., 1977; U.S. Dept. of Commerce, NOAA, NOS, 1979) reveals a possible cause for the more intense northwest wave convergence. For the 25 and 40 kt wind conditions, the waves appear to experience the most refraction in regions with depths between 12 and 24 ft. Northwest waves undergo the most refraction in the vicinity of Holland Bar, 5 nautical miles to the northwest, and a somewhat circular area used for bombing, 5 nautical miles to the west northwest. The circular shape of the bathymetry in these areas results in high degree of wave convergence (Frisch, 1979). Southwest waves do not experience nearly as much refraction or convergence as the northwest waves. This possibly results from the fact that the 12-24 ft depth contours to the southwest of Smith Island are fairly straight and parallel, oriented to the south southeast.

Histograms of the number of wave orthogonals (at depths of approximately 4 ft) per quarter nautical mile grid interval along the shoreline have been constructed for northwest and southwest wind conditions (Figures 1-6). In general, these show distinctly higher orthogonal densities for the northwest wind conditions. Areas with the highest orthogonal densities for northwest conditions include the shoreline from Channel Point extending two-thirds of the way north to Fog Point, and the shoreline directly west of Rhodes Point extending south to Cheesman Point. A significant difference between the histograms of the southwest conditions and those of the northwest conditions is an increase in the wave orthogonal density in the area that includes the shoreline directly west of Rhodes Point extending one-half the way north to Goose Harbor Cove. This includes about two-thirds of the shoreline of particular concern.

Longshore Transport

Plots of potential longshore transport values along the shoreline (enclosure 3 of 13 March 1979 interim report) indicate the areas of Smith Island delineated above as having high wave orthogonal densities in general also have high values of longshore transport. For the 10 kt wind conditions, the distribution of longshore transport values along the shoreline is fairly uniform, suggestive of relatively little shoreline change. The distribution is irregular for the 25 and 40 kt conditions, with the highest values occurring along the shoreline extending from Big

Thoroughfore one-half the way north to Fog Point and along the shoreline extending from Cheesman Point one-half the way north to directly west of Rhodes Point. The smaller longshore transport values along the shoreline west of Rhodes Point and directly south may be the result of relatively small shoreline — crest angles associated with these waves. In general, the values of longshore transport are consistent with the historically high erosion rates for the areas discussed above. Due to the higher values of longshore transport for northwest conditions and the greater annual percentage of northwest winds in the 11-40 kt range (enclosure 6 of 13 March 1979 interim report), the potential net longshore transport due to waves is to the south and is estimated to be on the order of 2-3 X $10^4 m^3$/yr using the CERC (U.S. Army, Corps of Engineers, 1975) and Inman and Bagnold (Komar, 1976) Formulas. To arrive at the total net longshore transport in this area, net currents and sediment flux should be included in the analysis.

IV CONCLUSIONS

Historically, Smith Island has experienced significant shoreline erosion, especially along its northwest and southwest boundaries. Northwest waves predominate throughout the year due to the distribution of annual winds (Rosen, 1976). Significant wave refraction and convergence occurs for waves generated by winds of 25 kts or greater. This is especially true for northwest winds, as the waves they generate refract along circular shoal regions to the northwest and subsequently converge along the northwest and southwest shorelines of Smith Island. These areas of wave ray convergence are likely to be associated with shoreline erosion, and indeed coincide with the areas of historically greater erosion (Figure 7). Due to the predominance of northwest winds, net annual longshore transport is to the south.

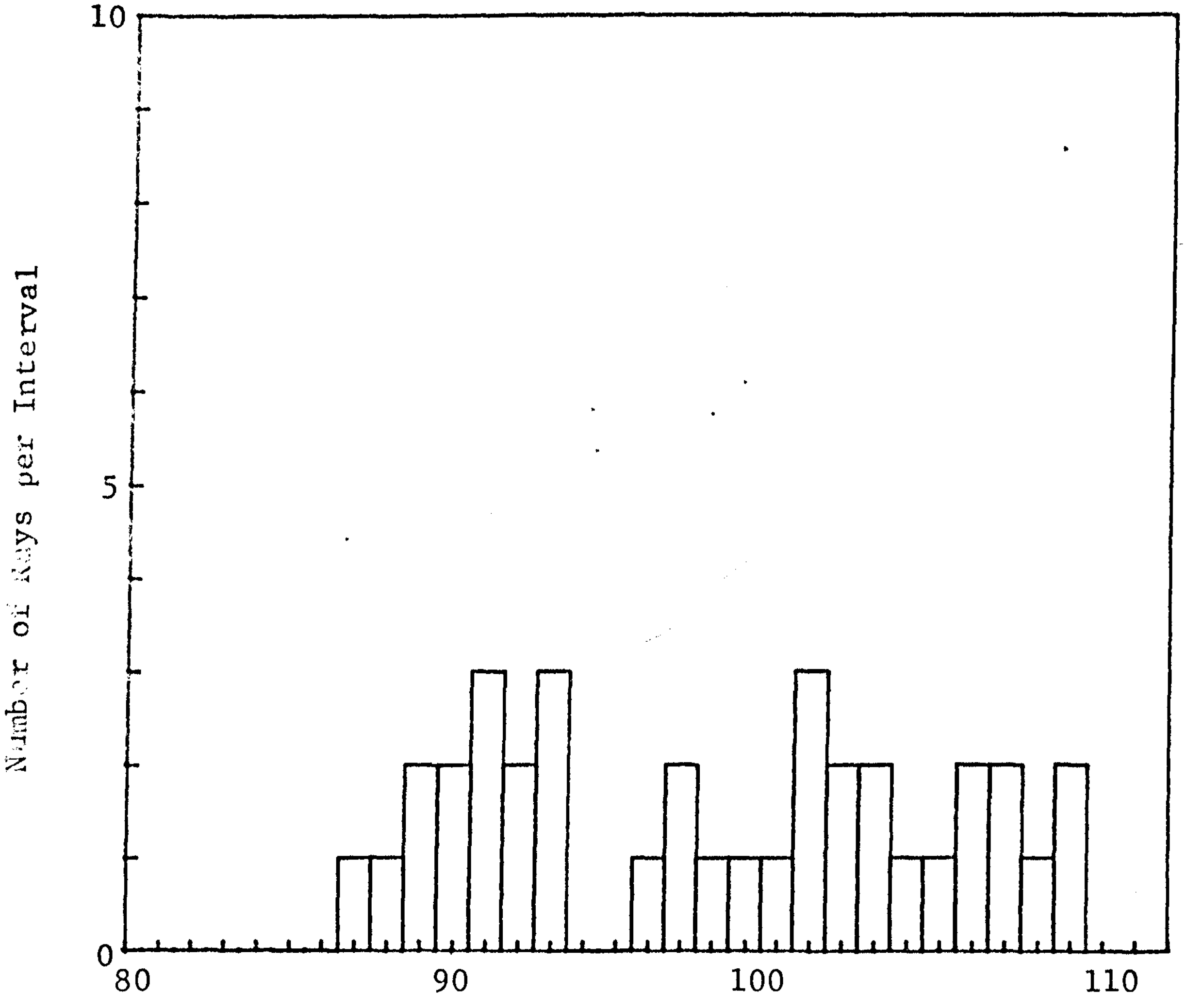
The southern third of the shoreline of particular concern is an area of northwest wave convergence, while the northern third is located in an area of southwest wave convergence. In general, the shoreline of particular concern is estimated to have low to average rates of longshore transport, suggestive of relatively low to average erosional rates compared to other sections of the island.

Figure 1

WAVE RAY HISTOGRAM

Western Shoreline of Smith Island

Wind Speed 10 Kts., Wind Direction NW



Grid Interval

Figure 2

WAVE RAY HISTOGRAM

Western Shoreline of Smith Island

Wind Speed 10 Kts., Wind Direction SW

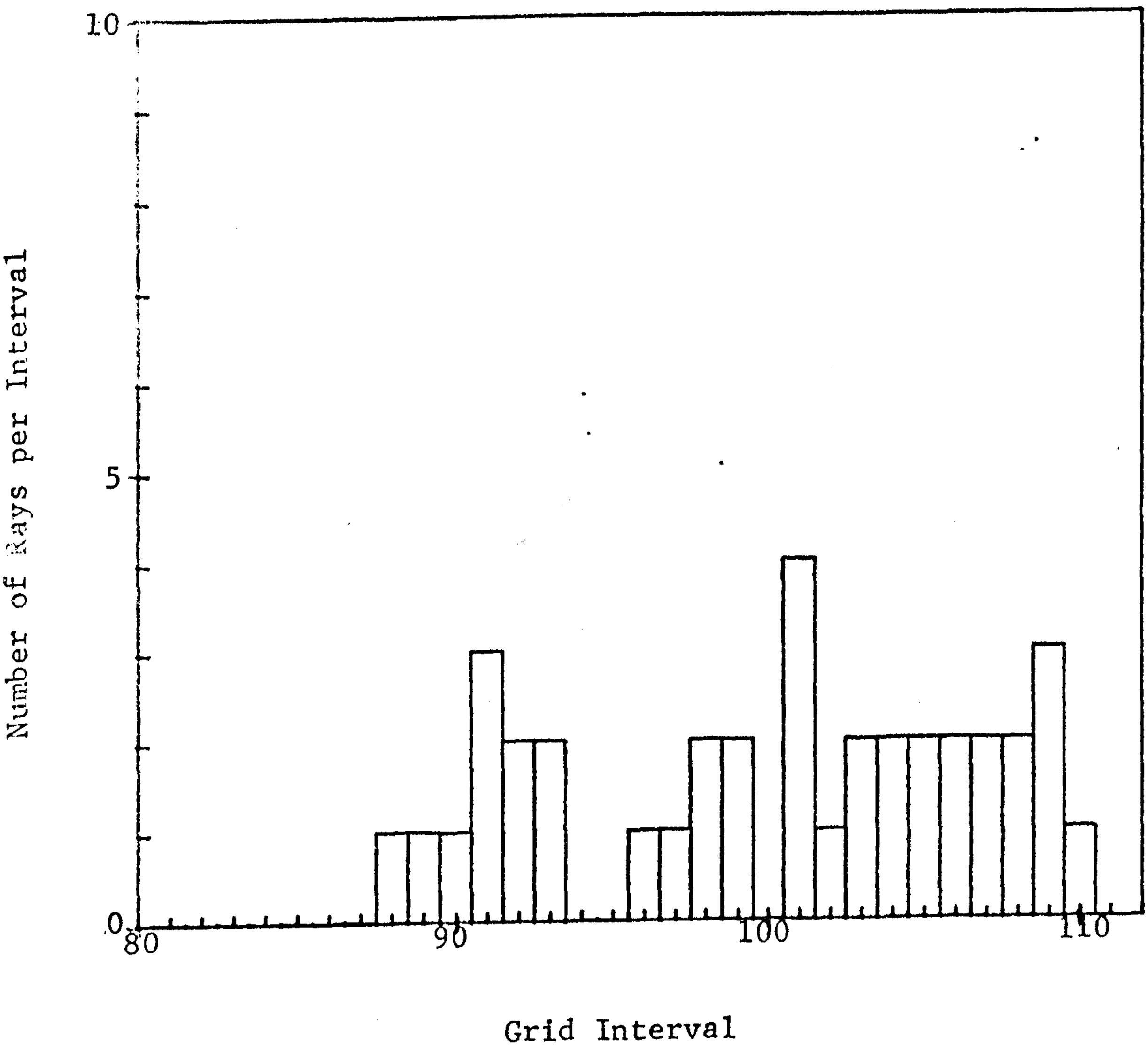


Figure 3

WAVE RAY HISTOGRAM

Western Shoreline of Smith Island

Wind Speed 25 Kts., Wind Direction NW

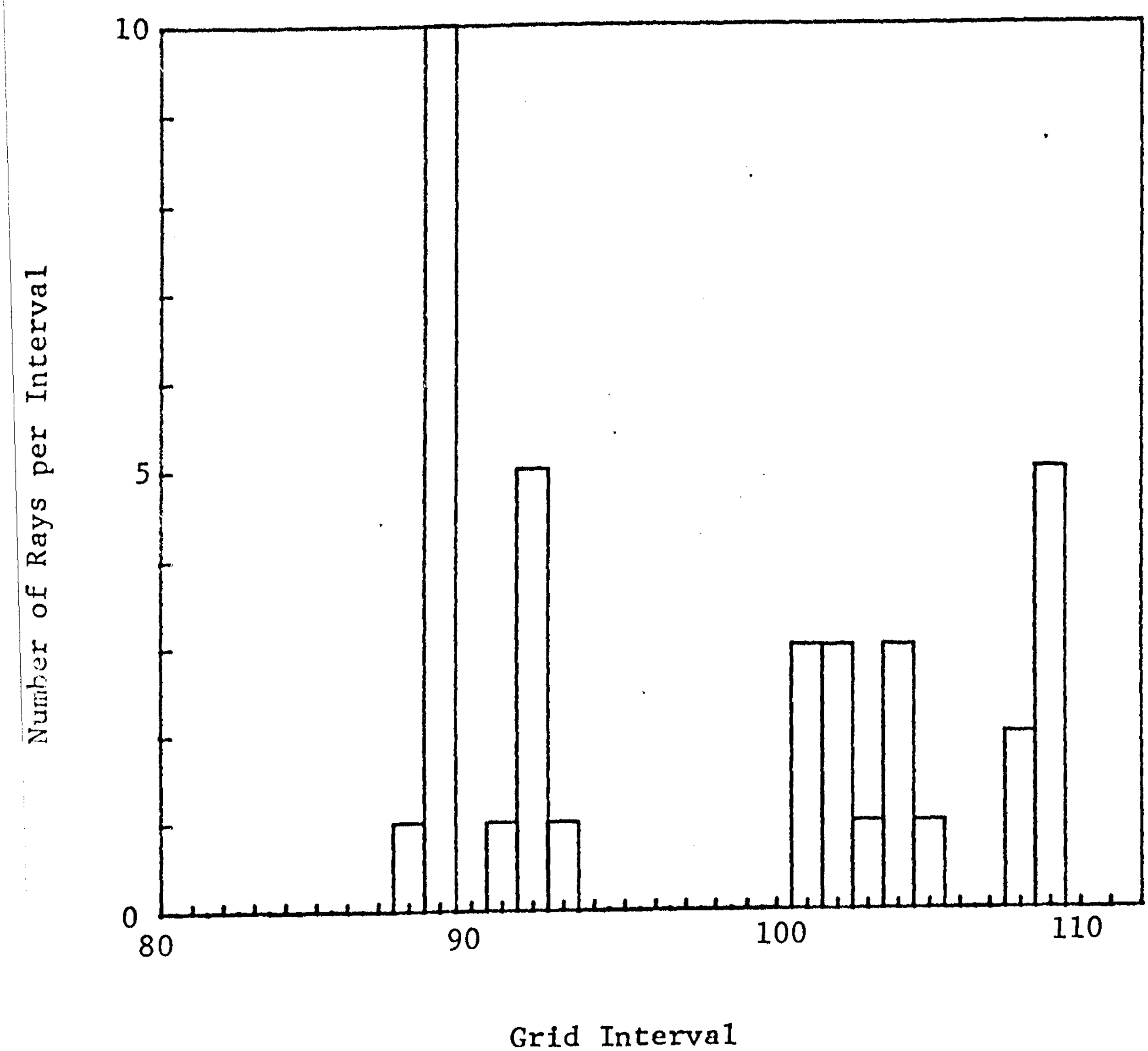


Figure 4

WAVE RAY HISTOGRAM

Western Shoreline of Smith Island

Wind Speed 25 Kts., Wind Direction SW

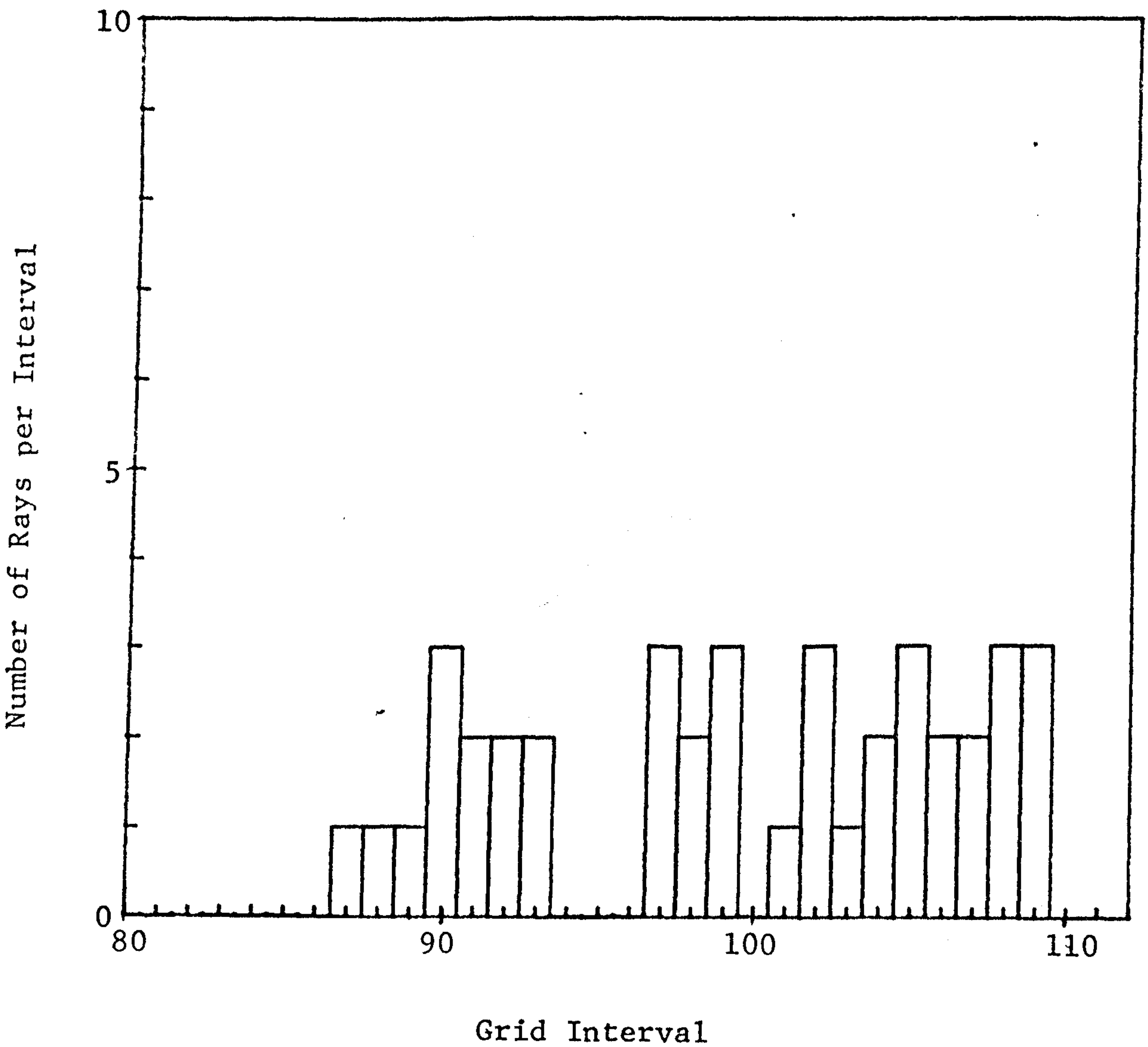


Figure 5

WAVE RAY HISTOGRAM

Western Shoreline of Smith Island

Wind Speed 40 Kts., Wind Direction NW

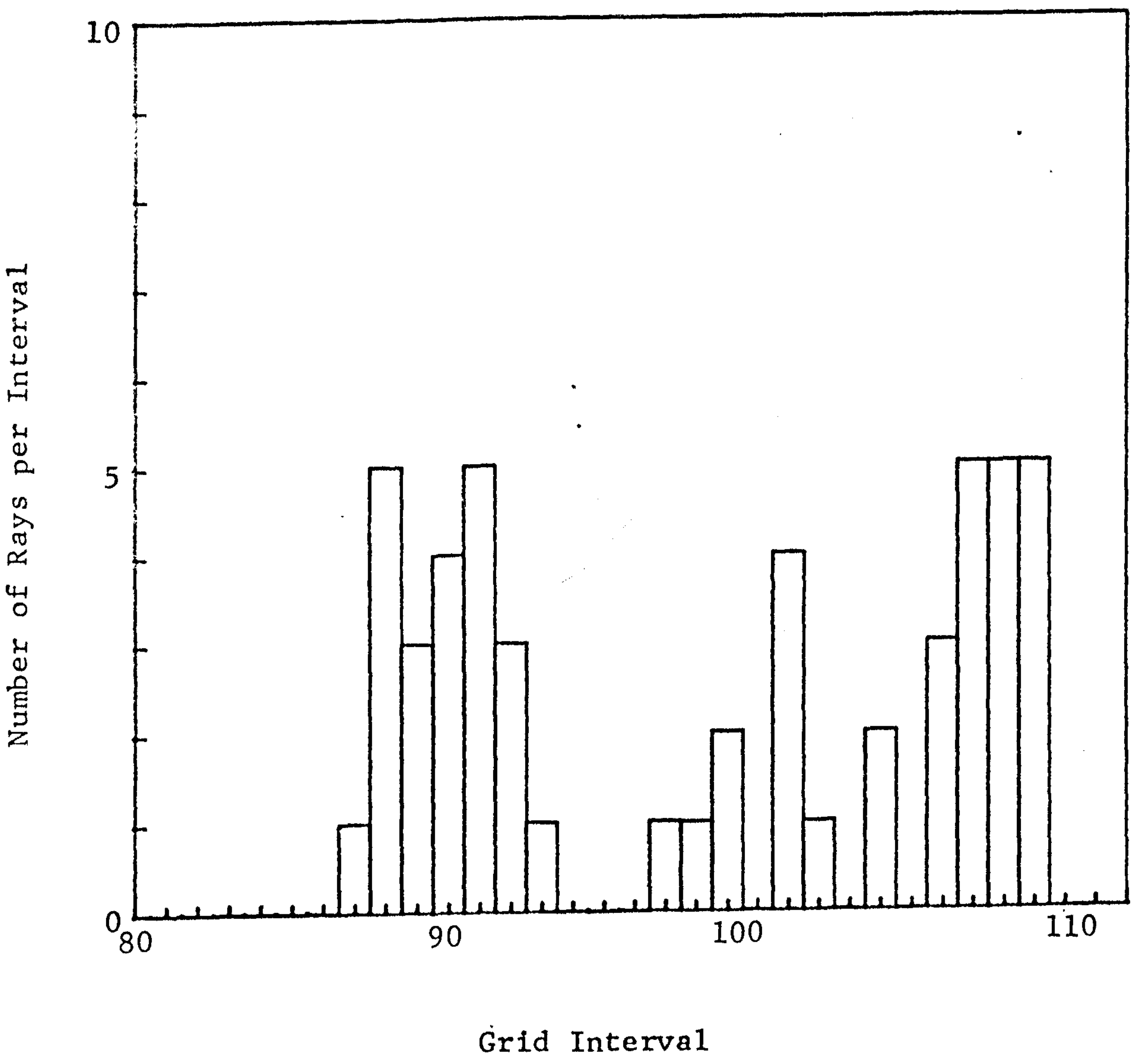
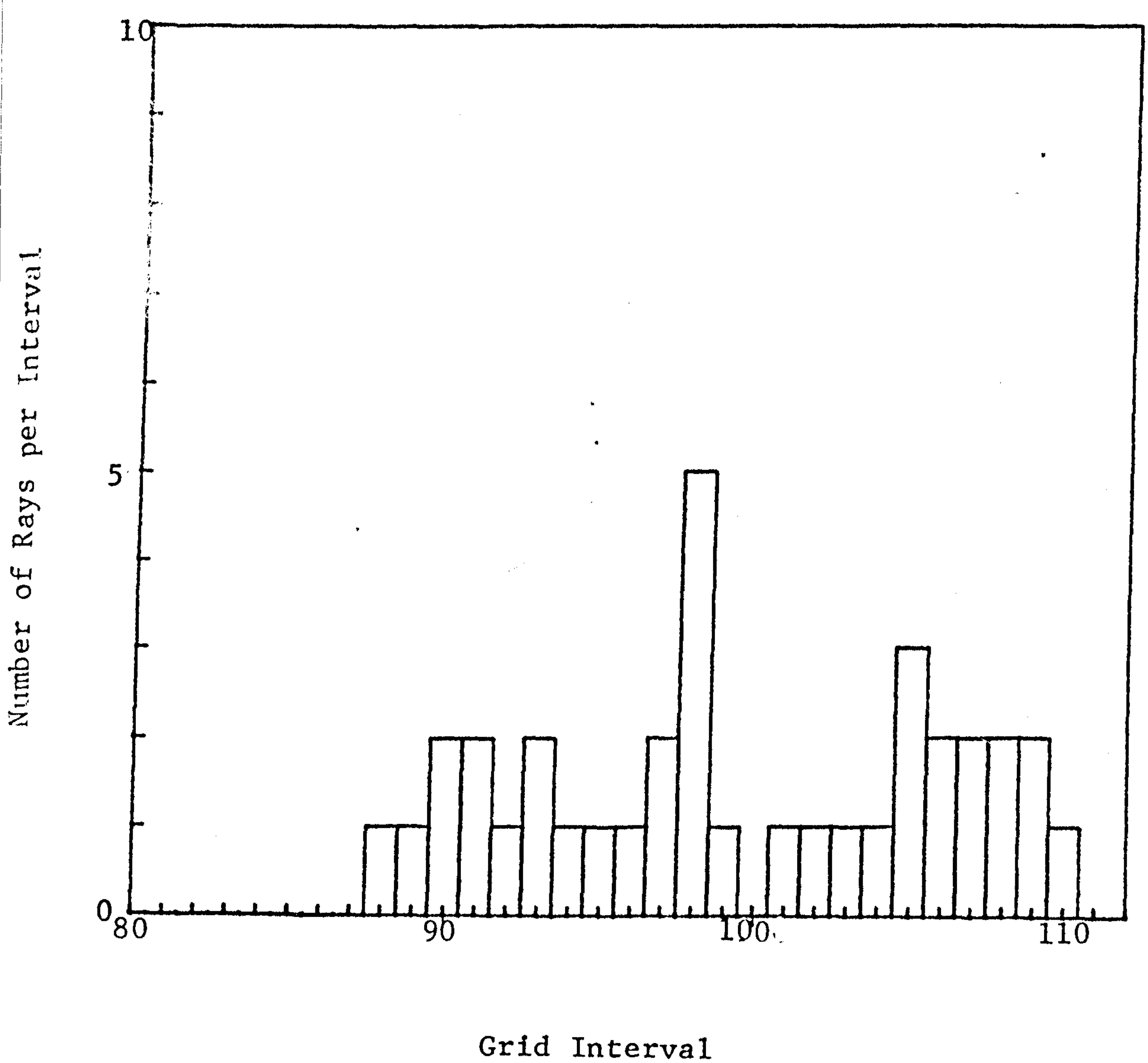


Figure 6

WAVE RAY HISTOGRAM

Western Shoreline of Smith Island

Wind Speed 40 Kts., Wind Direction SW



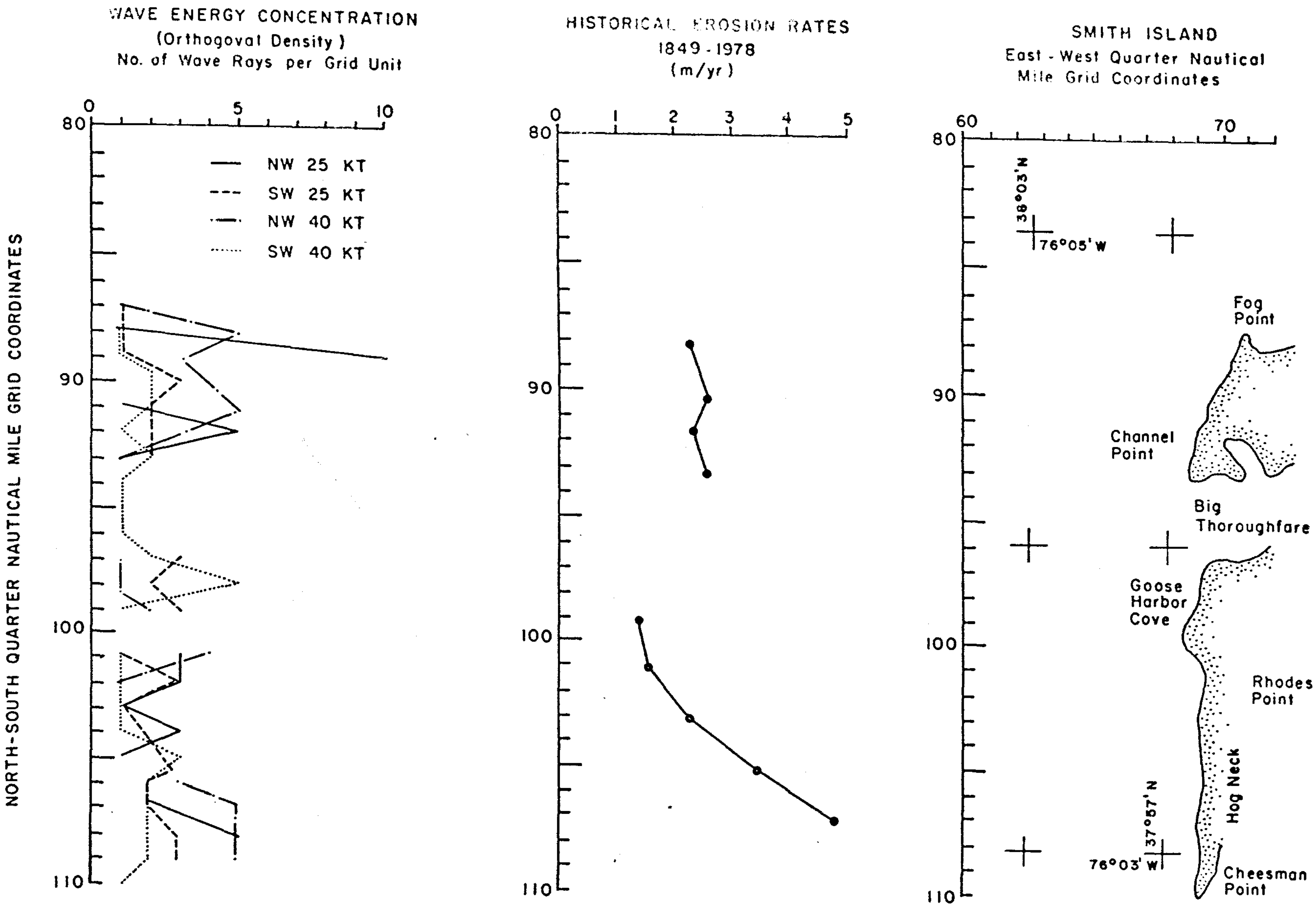


Figure 7. Summary of historical shoreline changes vs. wave energy concentration for 25 and 40 knot wind conditions.

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