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Beach-Nearshore Sediment Dispersal Matunuck Point, Rhode Island

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BEACH-NEARSHORE SEDIMENT DISPERSAL

MATUNUCK POINT, RHODE ISLAND

BY

RICHARD A. BEALE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

GEOLOGY

UNIVERSITY OF RHODE ISLAND

1975

ABSTRACT

The shore and shoreline processes were investigated in the vicinity of Matunuck Point, Rhode Island during 1973 - 1974. Studies of the beach foreshore and nearshore included topography and topographic changes; wave conditions and wave refraction; surface and bottom nearshore currents; sediment grain size and composition; and nearshore bedforms.

In the swash zone, beach drift resulted from refracted waves breaking on the shore and wind driven currents. Moreover McMaster's (1960) beach nodal zone originated in response to refraction of dominant southeast swell. On the beach foreshore variation in wave climate caused periods of accretion and erosion which did not necessarily follow the summer-winter seasons.

A nearshore nodal zone, characterized by a gravelly sand, was discovered about 3/4 miles west of Matunuck Point immediately seaward of the beach nodal zone in water depths down to at least -12 feet. The nodal zone is believed to result from a topographic controlled nearshore circulation pattern. An eastward turning gyre, produced by the direction of wave induced currents during the northwest flooding tide, was observed just west of Matunuck Point. Further west the flow was

found to be westward when relatively unrefracted predominant southeast swell was superimposed on the westward flooding tide. Orientation of nearshore bedforms and the hydraulic equivalence trend confirmed the westward movement of bottom sediment beyond the nodal zone.

Based upon mineralogy and beach-nearshore hydraulic equivalence trends, the immediate source of sediment for the beach and nearshore is believed to lie to the east, possibly Matunuck Point and the shoal area seaward of Matunuck Point, and Nebraska Shoals to the west.

ACKNOWLEDGEMENTS

I wish to thank Drs. Monty A. Hampton and John J. Fisher of the Geology Department for their helpful comments and guidance during many phases of the project. Sincere appreciation and heartfelt thanks goes to Dr. Robert L. McMaster, for his patience and time spent in preparation of the manuscript.

Last but far from least, I thank Mr. Edmund Fitch, without who's help much of the field work could not have been accomplished.

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INTRODUCTION

The southwest shore of Rhode Island consists of 24 miles of continuous beaches fronting Block Island Sound. Most of these beaches are barrier-connected headlands behind which are salt and brackish ponds (Fig. 1).

McMaster (1960) studied the heavy mineral distribution on these beaches and inferred the net directions of sediment movement along the beach foreshore (Fig. 1). He believed that a nodal zone, an area or region where sediment moves in divergent directions, exists between Matunuck Point and Card Ponds Inlet (Fig. 2). However no mechanism was offered to account for the westward beach drift west of this nodal zone or the eastern movement east of the zone.

Therefore, this investigation was undertaken to (1) determine the net sediment patterns on the beach foreshore and immediate nearshore between Matunuck Point and Card Ponds Inlet, with emphasis on the means by which sediment is supplied and dispersed to the beaches in the area, and (2) test the significance of the nodal zone located just west of Matunuck Point.

The investigation involved six phases of study. Sediment grain-size distributions were determined to infer net sediment dispersal patterns in the area; current velocities and directions were measured to see

Fig. 1. Location map, drift direction (McMaster, 1960)

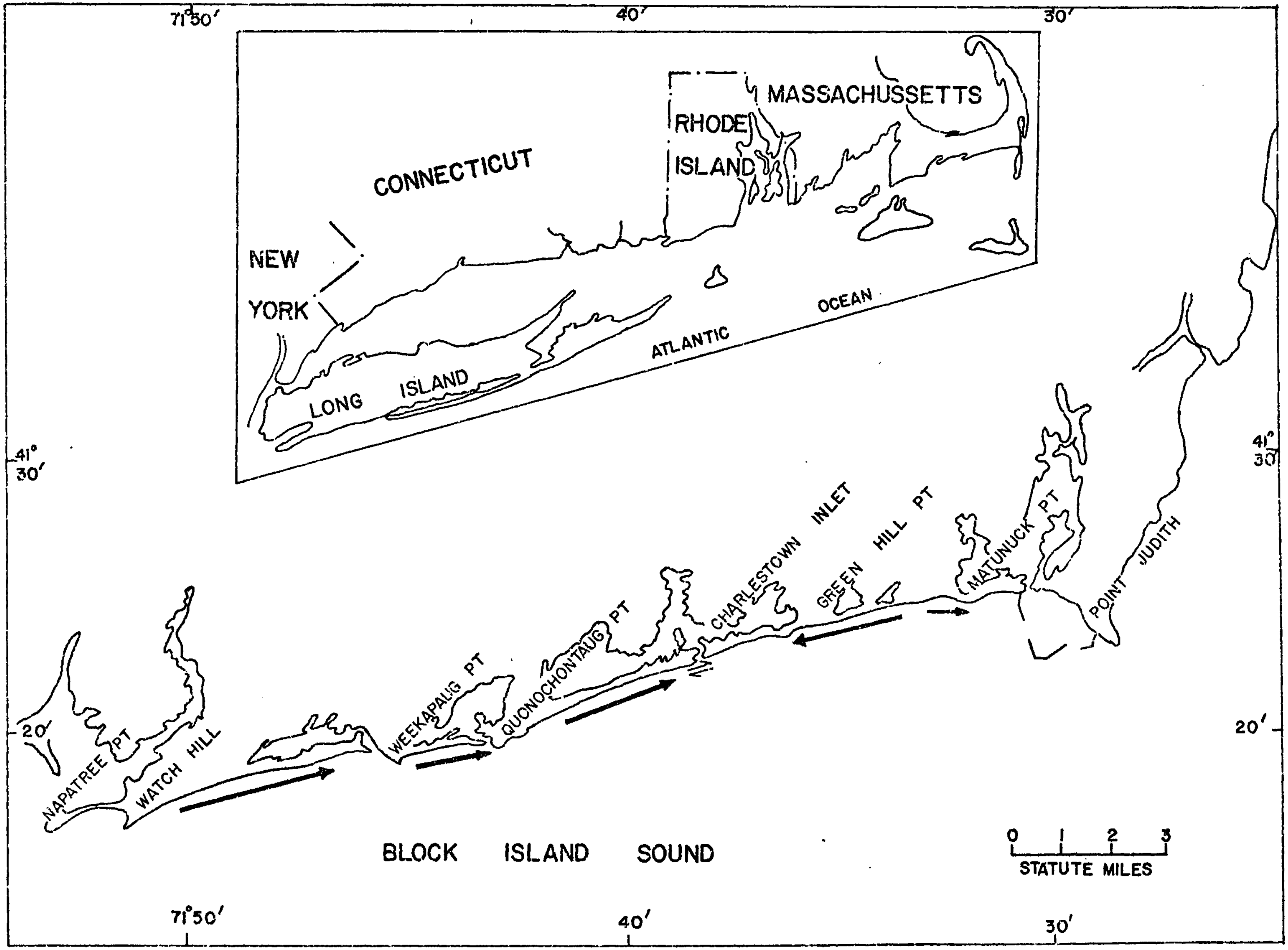
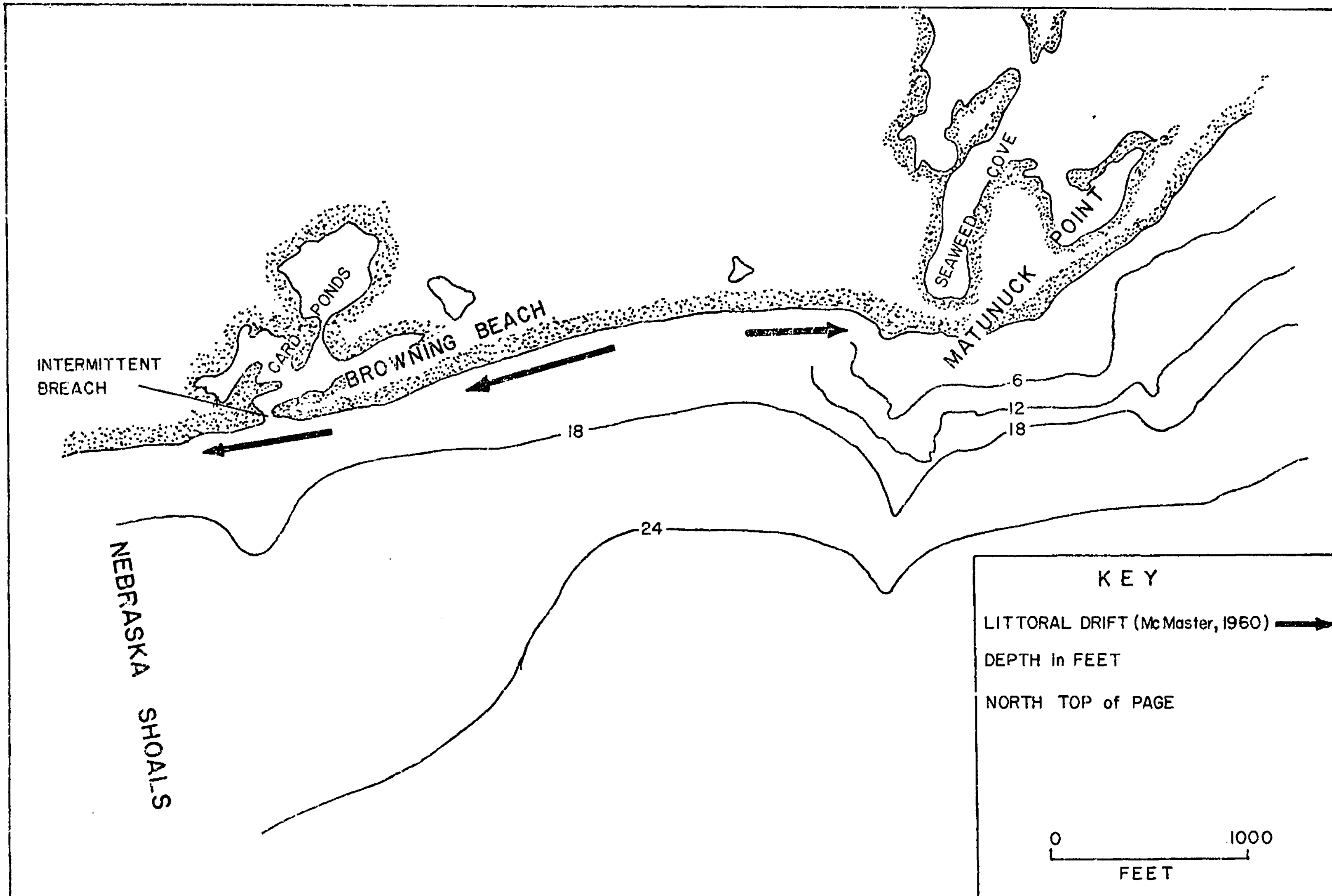

71°50′
40′
30′
CONNECTICUT
RHODE
ISLAND
MASSACHUSSETTS
NEW
YORK
LONG
ISLAND
ATLANTIC
OCEAN
41°
30′
20′
NAPATREE PT
WATCH HILL
WEEKAPAUG PT
QUONOCHONTAUG PT
CHARLESTOWN INLET
GREEN HILL PT
MATUNUCK PT
POINT JUDITH
BLOCK ISLAND SOUND
0
1
2
3
STATUTE MILES

Fig. 2. Enlargement of study area
with nodal point (after McMaster, 1960)


INTERMITTENT BREACH
CARD PONDS
BROWNING BEACH
SEAWEED COVE
MATUNUCK POINT
NEBRASKA SHOALS
6
12
18
18
24
KEY
LITTORAL DRIFT (McMaster, 1960)
DEPTH in FEET
NORTH TOP of PAGE
0
1000
FEET

if velocities near the bottom are great enough to move the sediment present and also to infer the direction in which movement occurs. The beach and nearshore topography was mapped to determine if a net gain or loss of sediment occurs above or below the mean low water line, and nearshore bed forms were mapped to determine their relationship to the direction of sediment movement. Wave refraction analysis through hindcasting of weather data and personal observation was performed to determine the energy expended on the beach by the larger storm waves relative to the average conditions found at other times during the year, and the resulting directions and relative magnitudes of nearshore currents along the shore. Hydraulic equivalence of the heavy to light minerals also was studied to infer net beach and nearshore sediment movement and relative distance the sediments have been transported from their source. Whereas one of these methods will not by itself completely define the processes at work, viewing all methods in conjunction should provide an understanding of such a dynamic zone as the beach-nearshore system.

Geology

Bedrock: Three basic rock types are found in Rhode Island. Pennsylvanian and Pre-Pennsylvanian igneous and metamorphic rocks underlie the western portion of the state, whereas Narragansett Basin Pennsylvanian metasedimentary rocks occur beneath the western shore of Narragansett Bay. The bedrock underlying the area of study is the Narragansett Pier Granite, a Post-Pennsylvanian igneous rock.

Surficial: Pleistocene glacial till and outwash overlies much of the bedrock of Rhode Island. Two basic tills have been recognized: a light till derived from the New England Upland crystaline rocks and present at Watch Hill, and a dark till originating from the Narragansett Basin rocks that crops out at Matunuck Point. A line running approximately north from Matunuck Point separates these tills (Kaye, 1960). The mineralogic differences between these two tills allowed McMaster (1960) to infer the drift directions along the shore. The light till contains a high proportion of amphiboles whereas the dark till has abundant garnet and black opaques.

The beaches in the vicinity of Matunuck Point consist of a thin veneer of sand, ranging from two inches to over two feet in thickness, overlying a coarse gravelly substrate of outwash deposit (Kaye, 1960). This coarse layer is sometimes exposed during winter storms and at times during the summer after coastal storms, particularly during the hurricane season of August and September.

Beach slopes range from 5 to 11 degrees and beach widths range from 100 to 180 feet measured from mean low water to the dunes. The beaches east of the nodal zone have seawalls and rock revetments at their furthest landward limits, and those west of the zone are bounded by dunes at their shoreward extremity.

The nearshore of the study area lies between the drowned headlands of Matunuck Point and Green Hill. The shoal seaward of Matunuck Point is a bouldery pavement that extends 1/2 mile offshore to 30 feet of water, while Nebraska Shoals adjoining Green Hill extends 1 1/4 miles seaward before a depth of 30 feet is attained. Between these headland extensions the bottom consists of boulders, cobble and sand.

Shoreline Changes and Processes: No evidence exists of a higher Quaternary sea level stand than at present. Either sea level has never been higher eustatically than now, or crustal subsidence has equaled or exceeded the limit of a higher sea level stand (Kaye, 1960). Lower stands of sea level during the Pleistocene have produced shorelines near the outer limits of the continental shelf (Flint, 1971). With the last deglaciation, subsequent sea level rise reworked the glacial sediments until the shoreline configuration of today appeared (Kaye, 1960).

Shoreline recession seems to be the dominant process along the southern Rhode Island coast (Kaye, 1960; U.S. Beach Erosion Board, 1950). Beaches have encroached upon the over-ridden salt marsh, lagoonal, and outwash deposits to the north (Dillon, 1970). The bouldery pavement off Matunuck Point represents former low hills of the ablation moraine complex having been leveled to just below sea level by wave attack (Kaye, 1960).

Prior to construction of the breakwaters of the Harbor of Refuge from 1891 - 1914 littoral drift moved sediment westward from Point Judith to Matunuck Point and accretion occured along that stretch of shoreline (U.S. Beach Erosion Board, 1950). During and after construction severe erosion had taken place at Matunuck Point (U.S. Beach Erosion Board, 1950). Sand is now being transported eastward with accumulation on the western side of the Jerusalem breakwater. Offshore contours show a slight regression westward of Matunuck Point and severe regression eastward of Matunuck Point (U.S. Army Corps of Engineers, 1957).

Waves and Currents

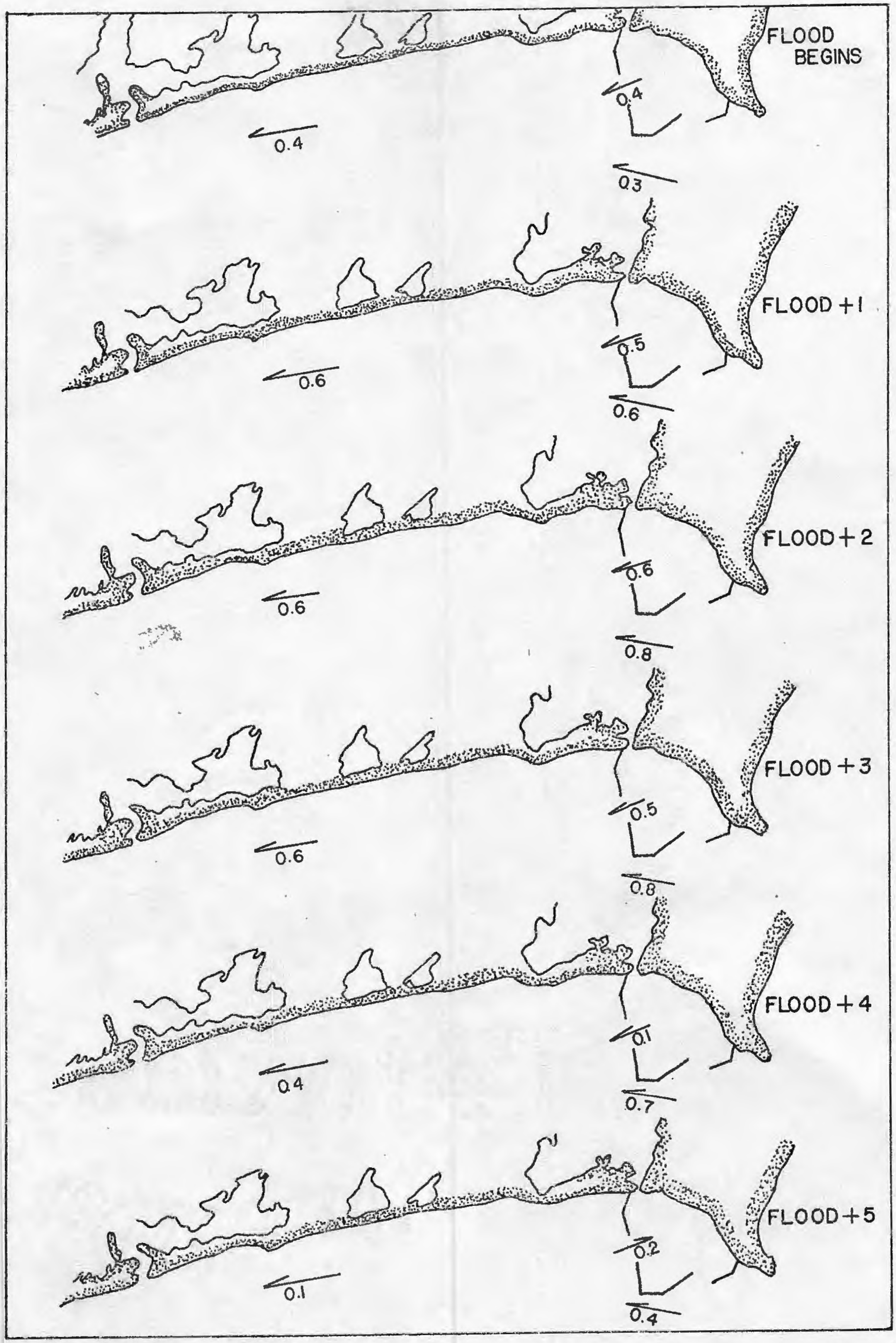
Waves: Unrestricted fetch occurs toward the east-southeast -- south-southeast. A fetch of only 25 miles lies toward the southwest. Block Island is located 5 miles to the south and shelters the study area from direct southerly Atlantic swell (Raytheon, 1975). Significant wave height is less than 1.5 feet 77.6% of the time from April to September 1974 and lower than 3 feet 96.2% of the time (Raytheon, 1975). Average wave periods are 6 to 10 seconds but no data are available as to direction. A previous compilation of wave characteristics for the Rhode Island coast indicates that predominant swell is from the east and southeast, as are the more severe storms (U.S. Beach Erosion Board, 1950). Wave energy of the southeast and east-southeast waves is 70 percent greater than energy of the south and southwest waves (U.S. Army, 1957).

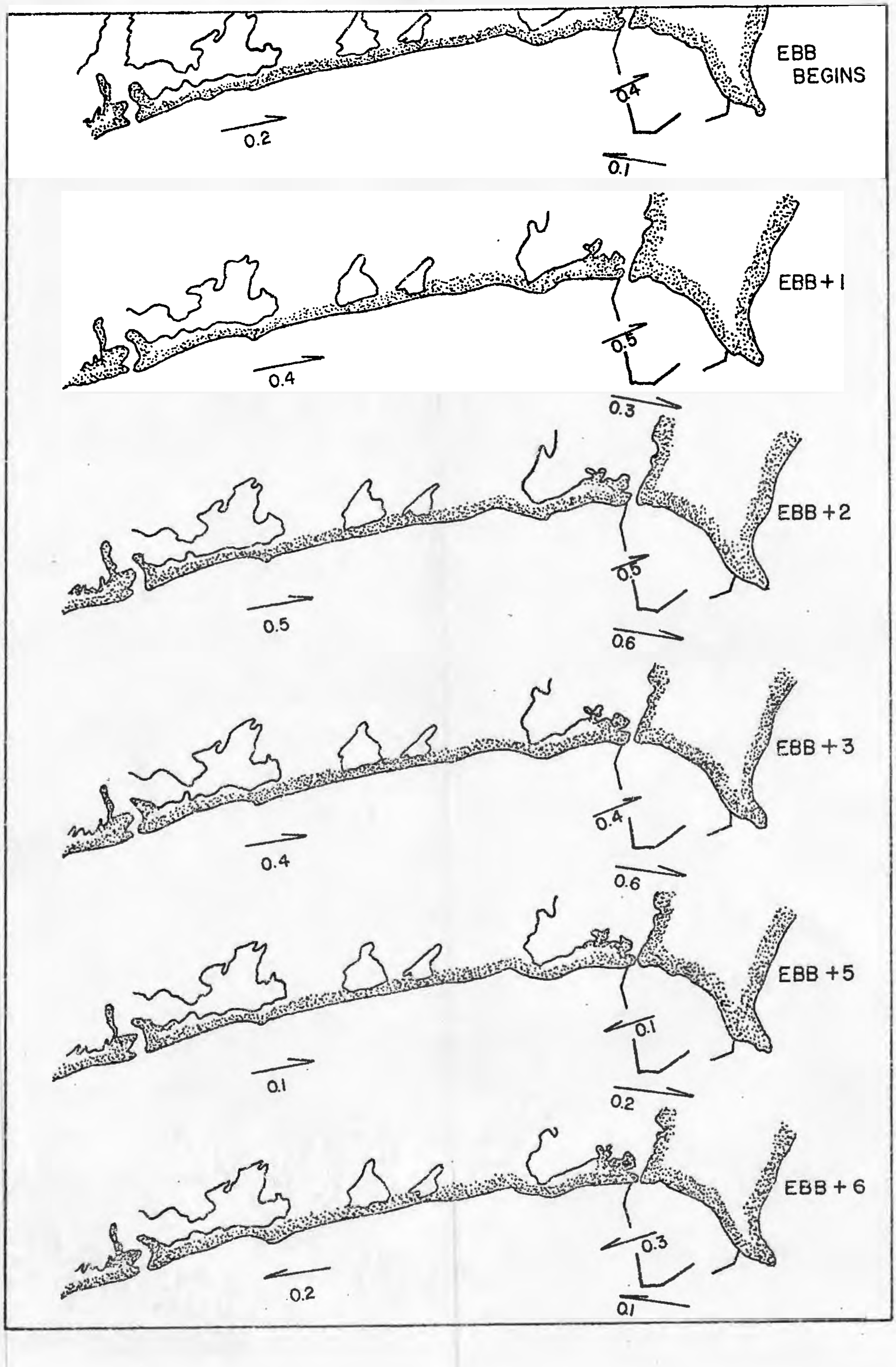
<u>Tidal Currents</u>: Surface tidal currents flood into Block Island Sound toward the west-northwest (310° T) and ebb to the east or east-southeast (90°-100° T) with speeds as high as 52 cm/sec but averaging 26 cm/sec. Bottom tidal currents flood toward the west (270° T) and ebb toward the southeast (130° T) with speeds as high as 31 cm/sec and averaging 21 cm/sec (First, 1972).

Tidal currents are oscillatory east - west at depths less than 18 feet but become rotary offshore. The westward flood currents have higher speeds and longer durations than the eastward ebb tides during the lunar cycle's neap tides. However at spring tides, current flow toward the west and east is balanced (Raytheon, 1975). Yet tidal charts of Block Island Sound (U.S. Dept. Commerce, NOAA, 1971) (Fig. 3A and B) for flow conditions at spring tides, based upon unspecified positions where measurements were made, indicate a longer westward flood pulse relative to the eastward ebb. These data are in apparent contradiction to the Raytheon findings. The contradiction is not as great as it seems, with the realization that only at the peak of spring tide is the flow balanced. Unbalanced flow occurs for the remainder of the lunar cycle reaching greatest inequality at the neap tide. Therefore an unbalanced flow exists during a major portion of the lunar cycle, causing the balanced spring flow to become insignificant.

Non-Tidal Currents: Residual surface and bottom water flow moves westward into Block Island Sound between Point Judith and Block Island, and joins a southeasterly flow out of Long Island Sound between Montauk Point and Block Island (Riley, 1952; Bumpus, 1965). Hollman and Sandberg (1972) in drifter studies indicate a generally southward surface transport at the western end of the Sound. Cook (1966) determined the surface and bottom drift between Point Judith and Block Island to be northwest to southwest during summer.

Fig. 3. Tidal current direction and speed in knots measured at spring tide (U.S. Dept. Commerce, 1971).


FLOOD BEGINS
0.4
0.4
0.3
FLOOD + 1
0.5
0.6
0.6
FLOOD + 2
0.6
0.6
0.8
FLOOD + 3
0.5
0.6
0.8
FLOOD + 4
0.1
0.4
0.7
FLOOD + 5
0.2
0.1
0.4


EBB BEGINS
0.2
0.4
0.1
EBB + 1
0.4
0.5
0.3
EBB + 2
0.5
0.5
0.6
EBB + 3
0.4
0.4
0.6
EBB + 5
0.1
0.1
0.2
EBB + 6
0.2
0.3
0.1

Cook also noted that short-term changes in surface water circulation could occur with changes in wind direction.

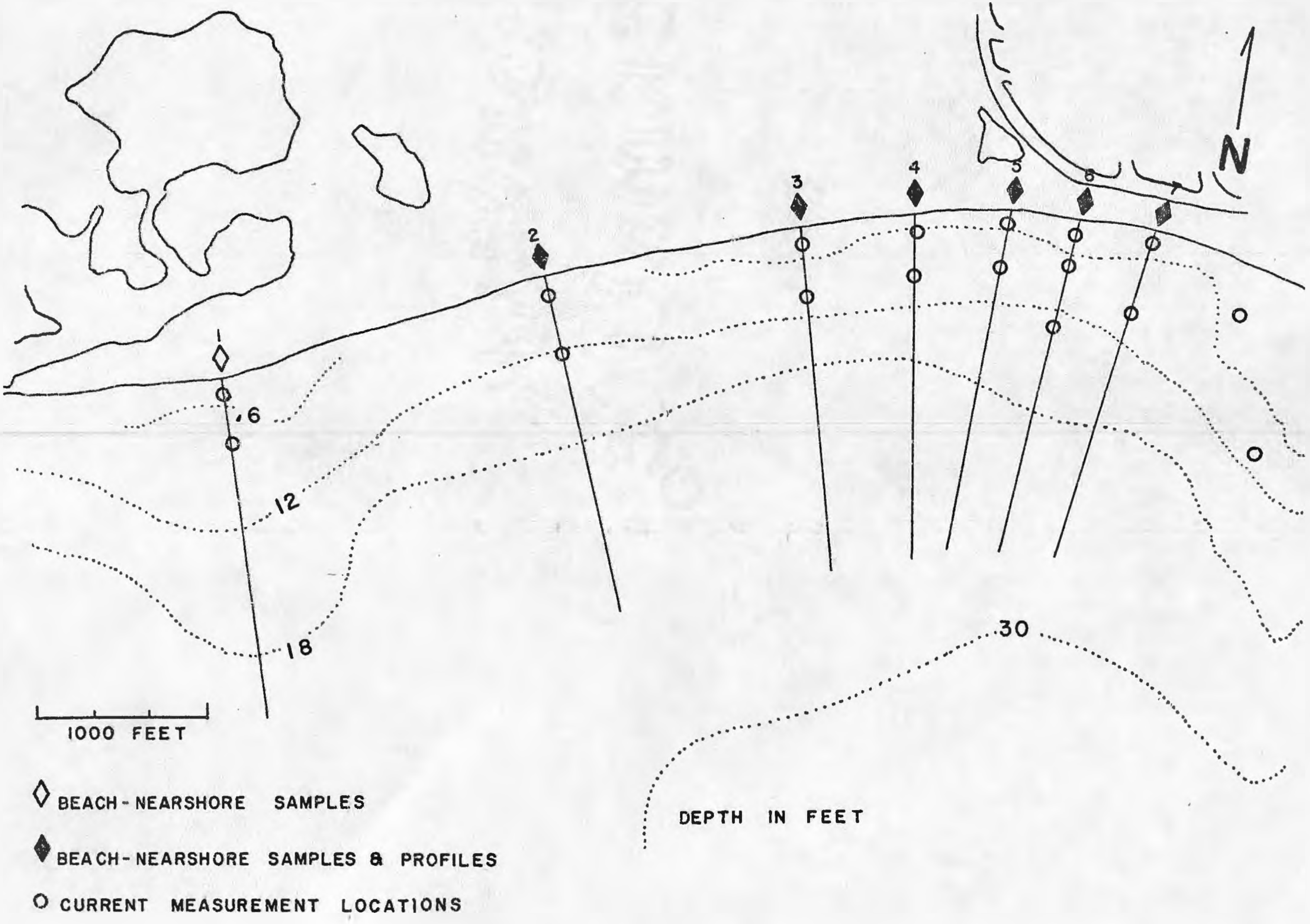
METHODS AND MATERIALS

Field Methods

Four topographic profiles for each of six stations were measured from the backshore to a depth of about 25 feet (sample locations are given in Figure 4). Beachface profiles were measured using a level line and stadia rod with horizontal distance measured with tape. Profiles were carried into water approximately four feet in depth. Nearshore segments of the profiles up to 200 feet from the beach were measured with a calibrated depth gauge and line on which positions of depth measurement were marked and later measured. SCUBA was used in nearshore work.

A total of 100 sediment samples was taken between October, 1973 and June, 1974 along seven beach-nearshore profiles. Groups were taken to represent pre-storm and post storm conditions. Samples also were taken at a two-week interval in April to determine sand movement during beach building. There were 31 pre-storm samples taken along transections 1, 2, 4, and 6; 11 post storm samples taken along transections 1, 2, and 6; and 49 samples were taken in April along transections 1 through

Fig. 4. Sample locations


N
1
2
3
4
5
6
7
6
12
18
30
1000 FEET
BEACH - NEARSHORE SAMPLES
BEACH - NEARSHORE SAMPLES & PROFILES
CURRENT MEASUREMENT LOCATIONS
DEPTH IN FEET

7 to document beach building. This averages to 7 samples per transection except during post storm conditions where weather made sample retrieval difficult. Nine samples were taken to determine reproducability and replicability. Their positions are indicated in Appendix B.

Sand samples were taken of the upper-most sedimentation unit along the profiles. Four small samples were collected at each sample site and combined into a composite to represent that site (Krumbein and Pettijohn, 1938). Periodically, duplicate samples were taken three feet from the initial sample to determine the variability within the sampling area. Explanation of variability is given in Appendix B.

Wave conditions were monitored prior to and during sampling using a technique proposed by Pierson et al (1955). Periods were determined by recording the time it took for two wave crests to pass a floating object. Wave heights and lengths were estimated using a floating object for scale. At least fifty observations were made for each reading to minimize observer error.

Currents were measured using Nalgene sample bottles filled with sand and water until they achieved the lowest possible profile in the water, yet were still visible. The bottles were thrown into the surf and the time required for them to travel a certain distance along the beach was recorded and converted into a velocity measurement.

Modified sea-bed drifters were used to determine subsurface current speeds and directions. The drifters consisted of a float and three to four feet of weighted line, tethered to a rod and spool of line onshore. As the drifter was pulled by currents the amount of line played out per unit time measured speed, and position of the float, along the beach, gave direction.

Bedforms were observed and measured along the near-shore sections of the profiles. Direct measurement of ripple height, ripple length and ripple wave length were made with a stadia rod and short rule. Orientation was determined using compass and surface observations.

Laboratory Methods

Sediment samples were prepared for analysis by first treating them with 10% HCL to remove any carbonate fraction, then dried and weighed to determine the percent carbonate. Organic matter then was removed by treatment with 30% H_2O_2 and percent organic matter was calculated. Less than one half percent of carbonate or organic was found in any of the samples. The treated sample was wet sieved through a 4Ø screen to remove the silt and clay fractions. The remaining sample was dried and approximately 100 grams was sieved to 1/4 Ø intervals on the Tyler Ro-Tap shaker. Each nest of sieves was run for twenty minutes on the machine, and the weight of sediment in each pan weighed and weight percents were calculated.

Samples with measureable silt and clay-size material were analyzed by pipette method. The pan fraction, after wet wieving, was dried and weighed, then resuspended in liter cyclinders with water and Calgon as the dispersing agent. Concentration of Calgon was 15 grams per liter. From this point on standard pipette procedure, as described in Krumbein and Pettijohn (1938) was performed.

These data were then reduced using a textural parameter computer program that calcualtes Folk-Ward's (1968), Inman's (1956) and Trask's (1930) graphic measures for the grain-size frequency distribution. Folk-Ward's (1968) statistics were used because they include 90 percent of the frequency curve in calculations. See Appendix A for further explanation of textural parameters of Folk.

Heavy minerals were separated from selected samples using bromoform. Further separation of garnet from the rest of the heavy minerals, using a Franz separator, was required to analyze the degree of hydraulic equivalence between light and heavy minerals of the selected samples.

The method of Hand (1967) and Lowright (1973) was used to determine hydraulic equivalence. Splits of the light and heavy fractions of each sample were introduced into a 150 cm settling tube. The time required for the entire sample to settle was recorded and the median velocity was determined. Subtracting the log of the median velocity of the lights from the log of the median velocity of the heavies resulted in a delta ($\triangle$) value (Hand, 1967; Lowright, 1973).

For the wave refraction analysis, weather data were compiled from records of the Providence, Rhode Island Weather Bureau (U.S. Dept. of Commerce, Weather Bureau, 1950 - 1966). Data compiled were prevailing monthly wind direction and intensity, as well as direction of highest wind speed, as recorded at Green State Airport in Warwick, Rhode Island. These data were then used, with the maximums observed in the study area, to hindcast "average" yearly wave conditions in the area using the methods of the Coastal Engineering Research Center (U.S. Army Coastal Engineering Research Center, 1966). The limitations of such a study are that the wind data are taken from records of an inland station, and are not always similar to records of a coastal station. However these records were the only readily available weather data for the area, and I believe the use of such data can be justified when used in conjunction with direct observation in the study area.

Bedform data were diagramatically represented to give an overall view of storm and non-storm bed conditions (Figs. 15 and 16). Orbital velocities at the bottom were computed from observed wave conditions (Inman and Nasu, 1956) and compared to bedform and size data to ascertain if the forms were produced by those conditions present, or conditions previous to observation. Also, observations of migration of bedforms and the sediment composing the forms were used to determine pathways of bedload movement.

RESULTS

Sediments

Sediment distribution appears to be relatively simple with the majority of the samples being clean, well sorted sands. (All sediment size data can be found in Appendix A.) Mean size ranges from 3.53 Ø (very fine sand) to -4.00 Ø (pebble). Standard deviation (sorting) ranges from 0.43 Ø (well sorted) to 1.71 Ø (poorly sorted). Variation of the means for replicate samples ranges from 0.07 phi to 0.46 phi, and variation in standard deviation for these same samples ranges from

0.22 phi to 0.27 phi. (An explanation of verbal limits is found in Appendix A, and of replicability in Appendix B.)

Gravel (granules, pebbles and cobbles) exists along the step or plunge point, near Matunuck Point, and gravel and boulder on Matunuck Point itself. Westward of Matunuck Point and offshore the mean sediment size decreases from 1.41 Ø to 3.25 Ø and sorting improves. The best sorted samples have means between 2.50 Ø and 3.50 Ø (Figs. 5 through 11).

Gravel Content: The gravel content found on the beach and nearshore bottom during the four sampling times is presented in Figures 5 through 8. A high percentage of gravel was found about 1/2 mile west of Matunuck Point under all conditions except those on April 14, 1974, when the content was lower. However the amount of gravel was still higher than that of other parts of the area at the time (Fig. 7).

The step contained the highest percentage of gravel after the February 15, 1974 storm period (Fig. 6) when it was 100%. Gravel content of Matunuck Point, based on visual observation, remained at 100% throughout the time of the study.

Width of the gravel band also changed with changing sea conditions. Post-storm conditions produced the widest band (Fig. 6).

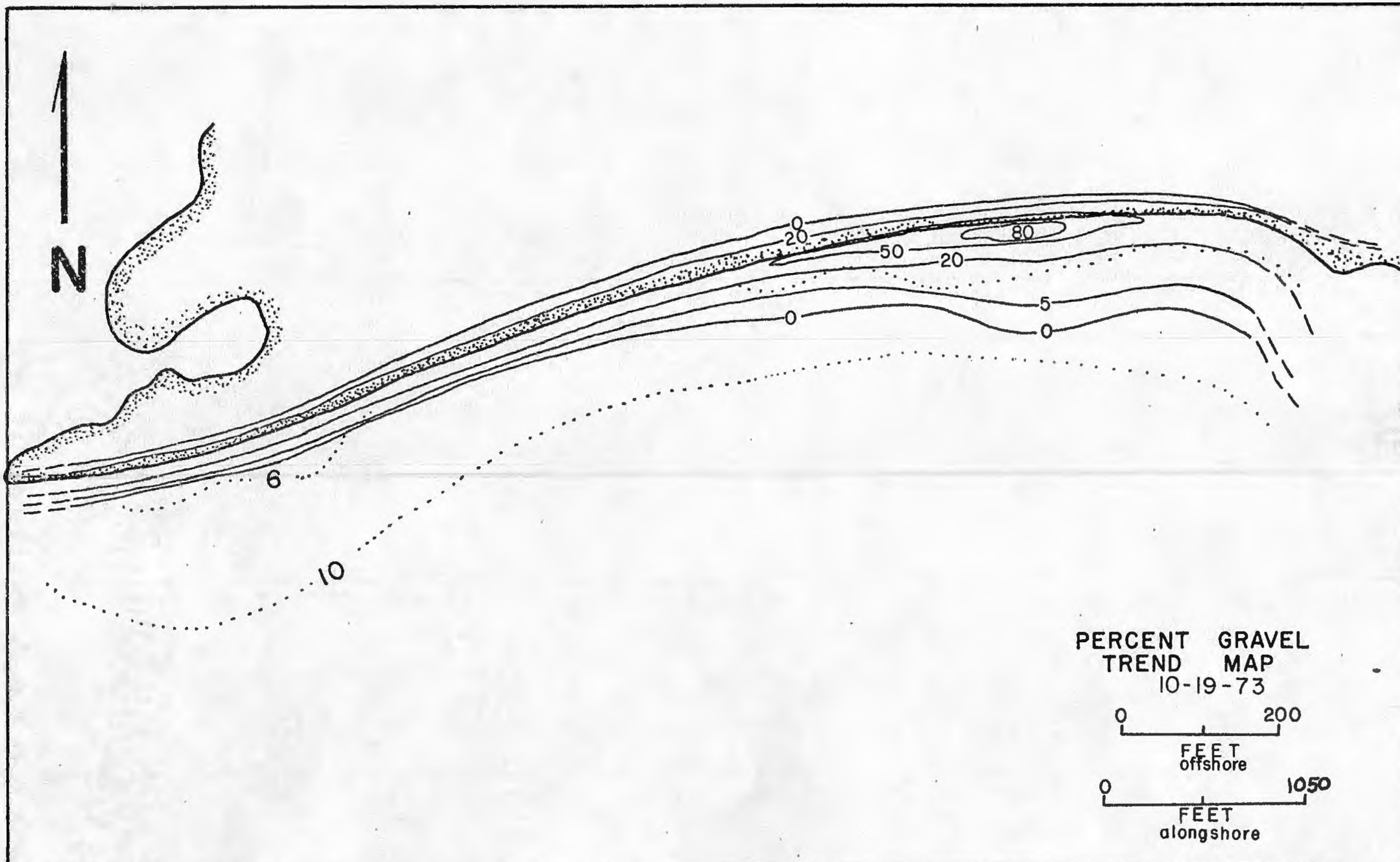

N
0
20
80
50
20
5
0
0
6
10
PERCENT GRAVEL
TREND MAP
10-19-73
0 200
FEET
offshore
0 1050
FEET
alongshore

Fig. 5.

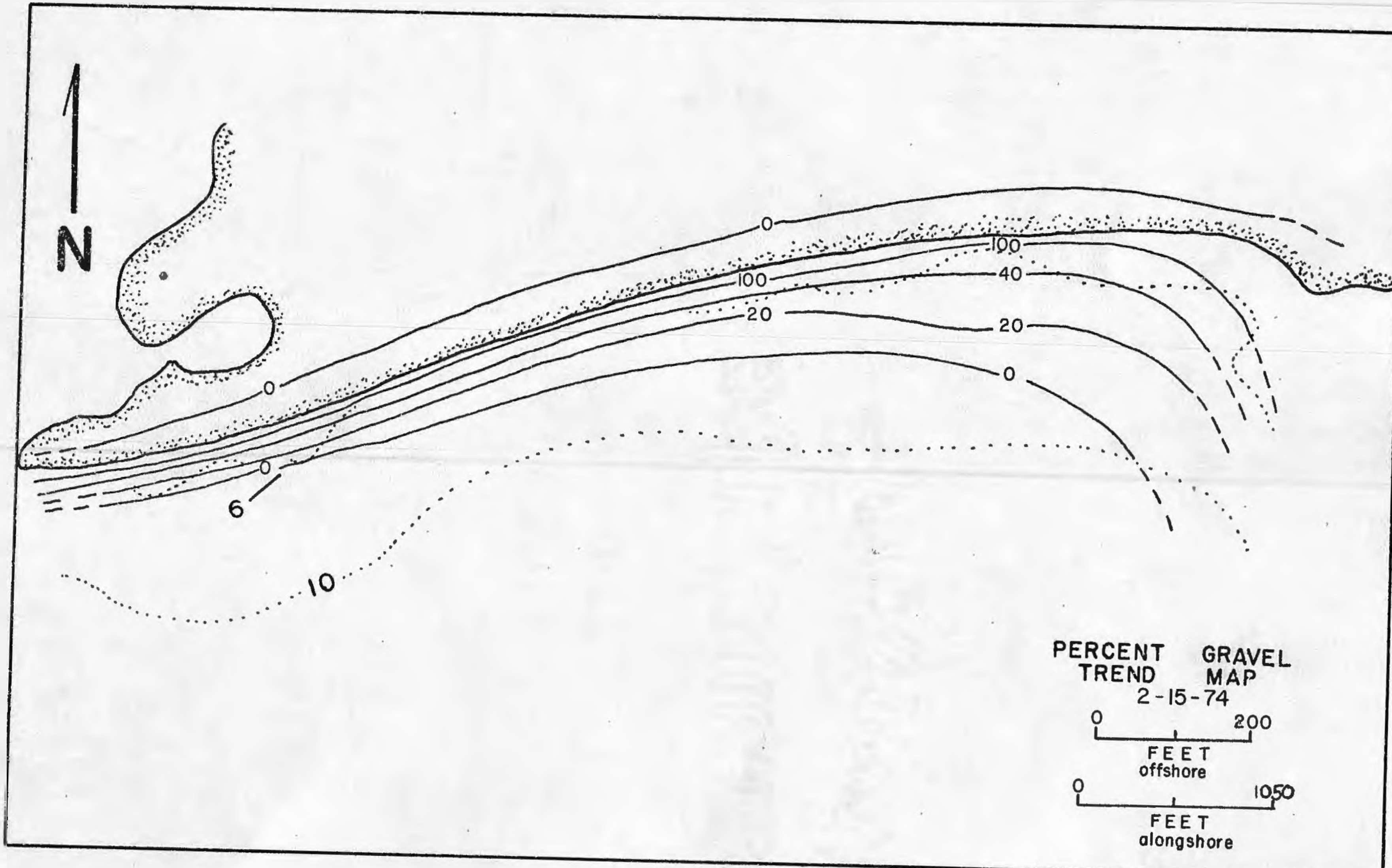

N
0
100
40
100
20
20
0
0
0
6
10
PERCENT GRAVEL
TREND MAP
2-15-74
0
200
FEET
offshore
0
1050
FEET
alongshore

Fig. 6.

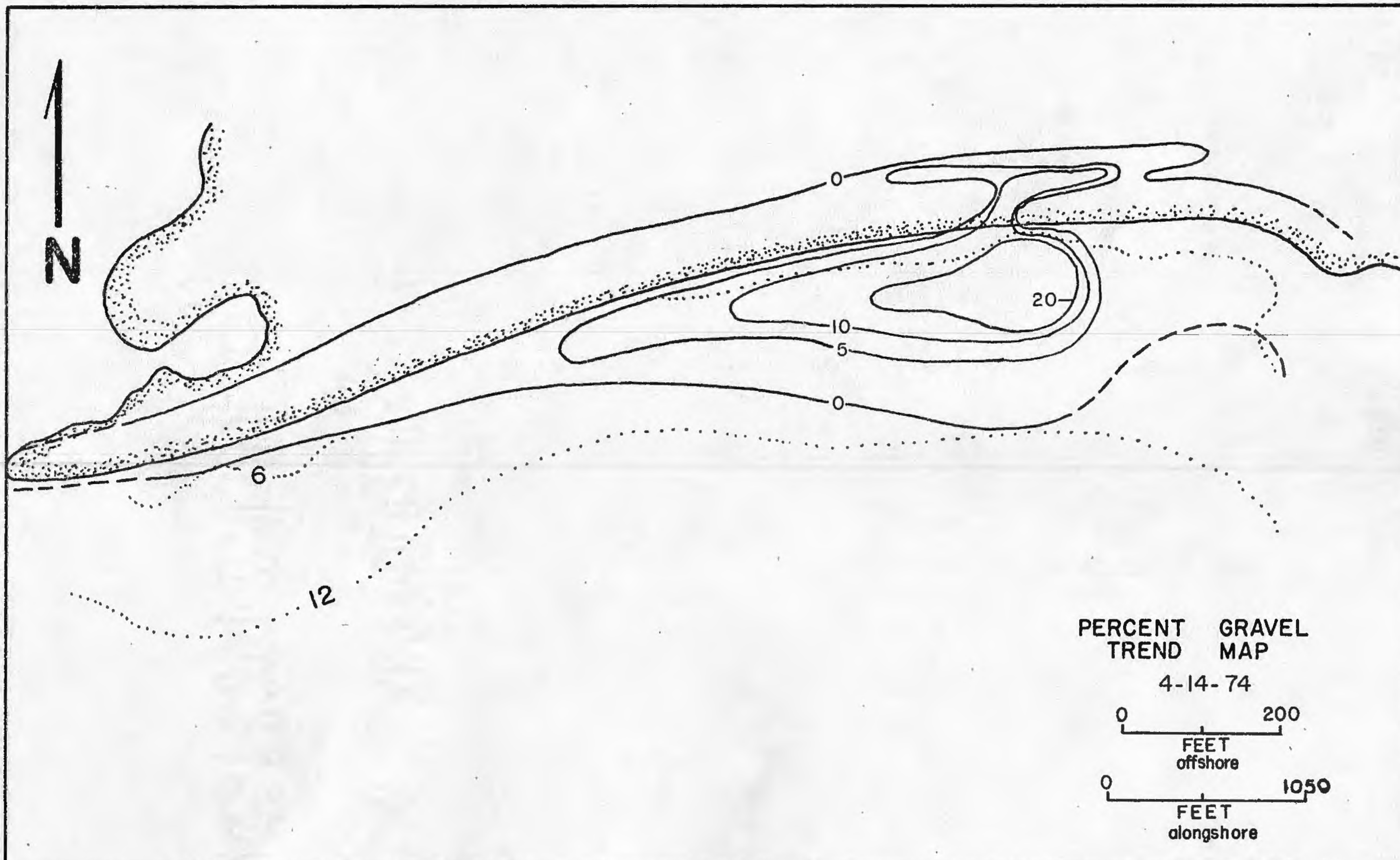

N
0
20
10
5
0
6
12
PERCENT GRAVEL
TREND MAP
4-14-74
0 200
FEET
offshore
0 1050
FEET
alongshore

Fig. 7.

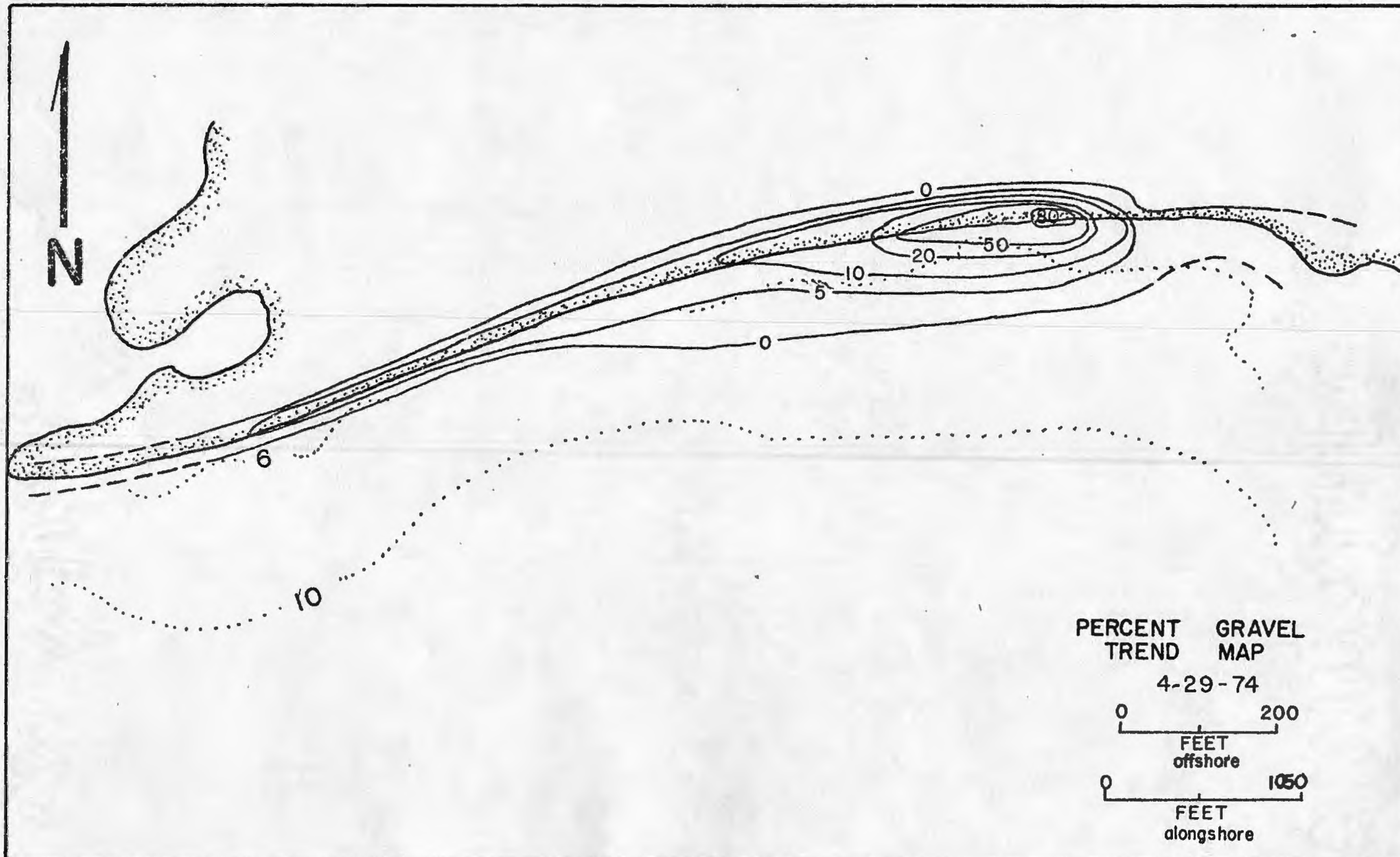

N
0
80
50
20
10
5
0
6
10
PERCENT GRAVEL
TREND MAP
4-29-74
0
200
FEET
offshore
0
1050
FEET
alongshore

Fig. 8.

Sand Content: The distribution of sand is shown in Figure 9. Coarse sand (0.50 Ø to 2.00 Ø) was found close to shore near Matunuck Point, fining toward the west and in an offshore direction, under all conditions.

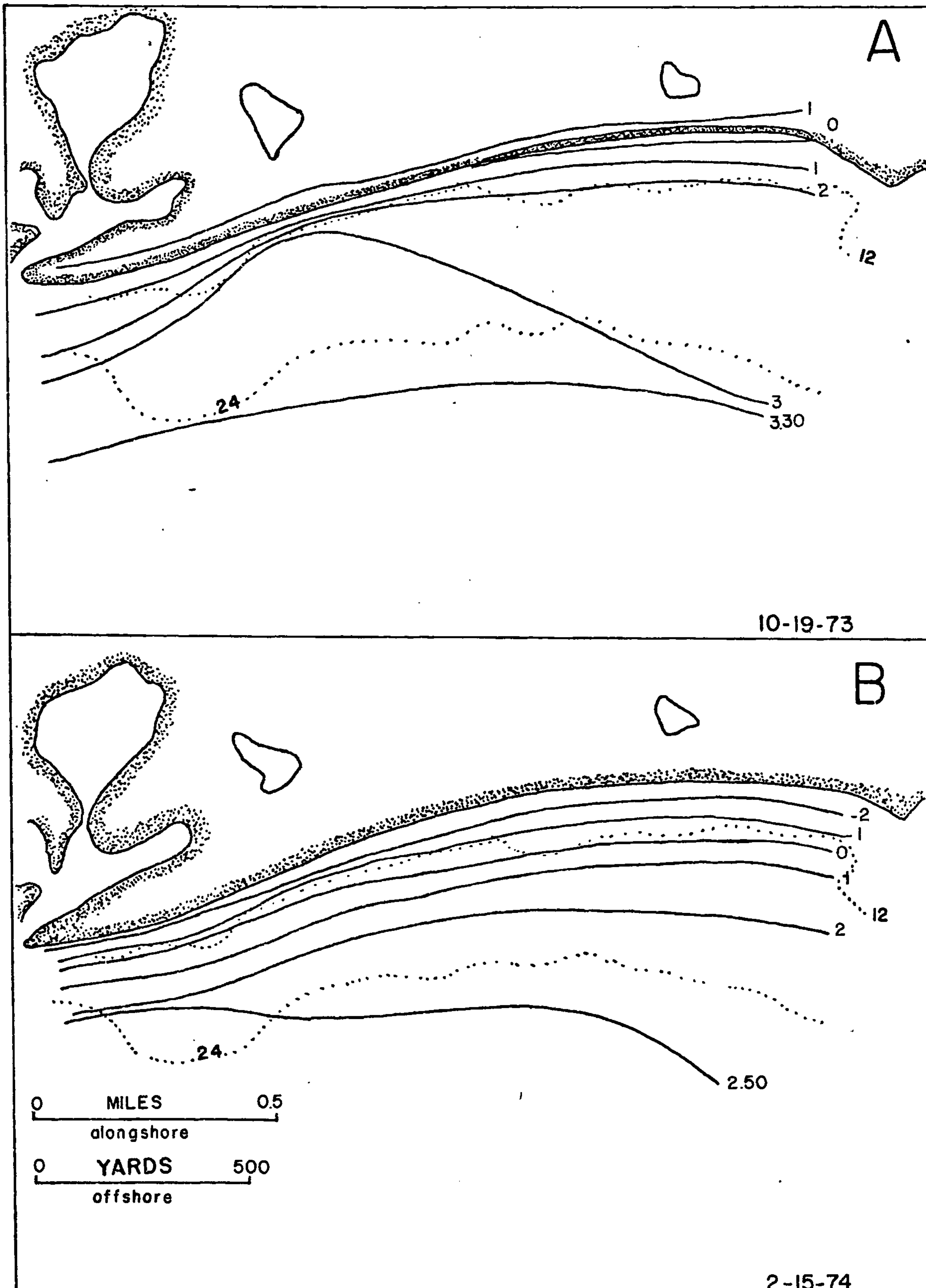
When the beach was building (Figs. 9C and 9D) fining occurred both east and west, offshore, of a position located about 1/2 mile west of Matunuck Point. Beach sand also fined east and west of that position.

Silt and Clay Content: No clay was present in the region of study during the sampling time. Silt was found only in the samples taken farthest west and offshore during pre-storm sampling (Fig. 10A). Other sampling times showed little silt content. Those sample locations containing silt are indicated on Figures 10B, 11 A and 11B. Contours could not be drawn due to a lack of sufficient data points. An apparent trend does exist, however, with silt content increasing toward the west.

Hydraulic Equivalence

The hydraulic equivalence of the heavy minerals to the light minerals of selected nearshore samples were measured to determine the relative distance of the samples from their source, and thereby transport direction. The samples chosen were from the subaqueous segments of the profiles of October 19, 1973 and April 14, 1974 (within 100 to 200 feet of the shoreline).

Fig. 9. Trend maps, sand content
numerical values are phi values


A
1
0
1
2
12
24
3
3.30
10-19-73
B
-2
1
0
1
12
2
24
2.50
0 MILES 0.5
alongshore
0 YARDS 500
offshore
2-15-74

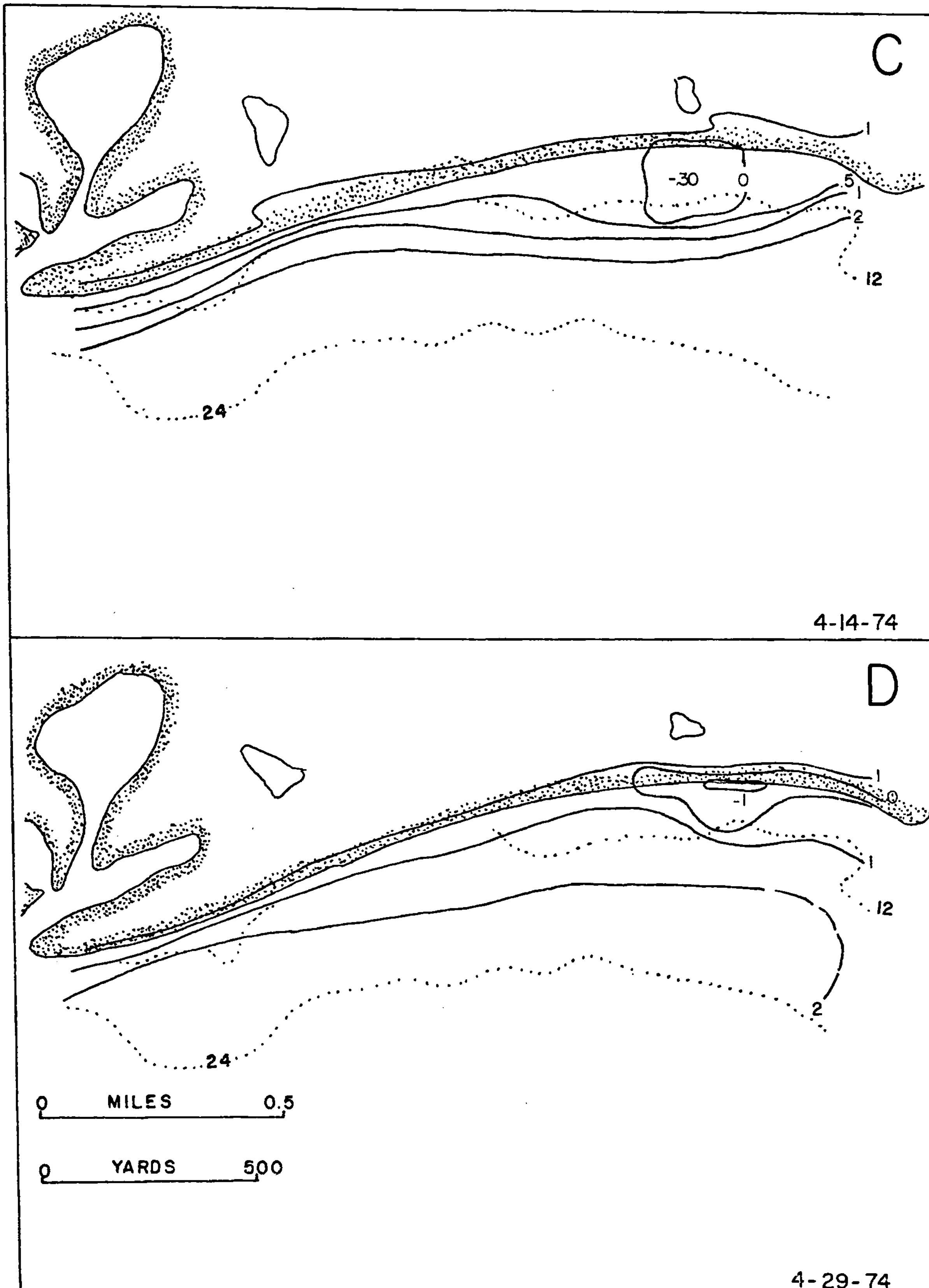
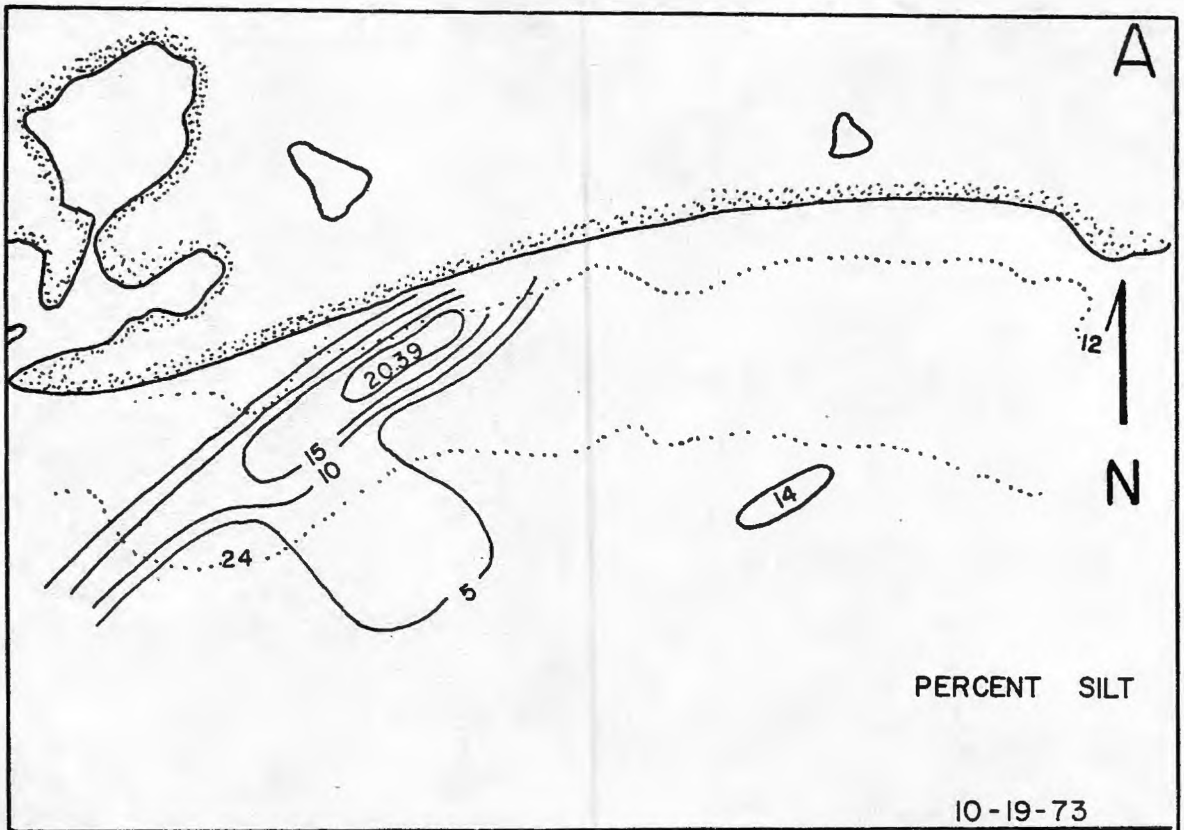

C
1
-30
0
.5
1
2
12
24
4-14-74
D
1
0
-1
1
12
2
24
0 MILES 0.5
0 YARDS 500
4-29-74

Fig. 10. Percent silt content


A
12
N
20.39
15
10
14
24
5
PERCENT SILT
10-19-73

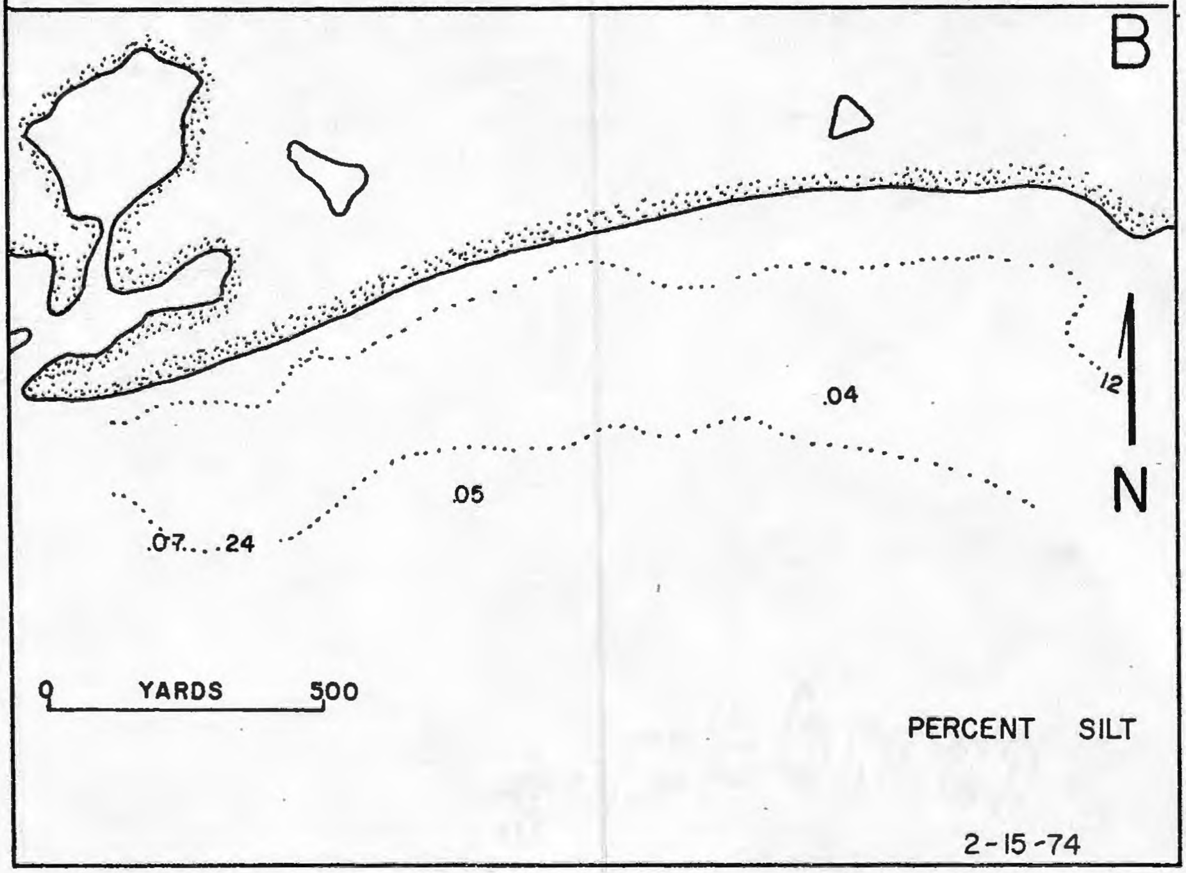
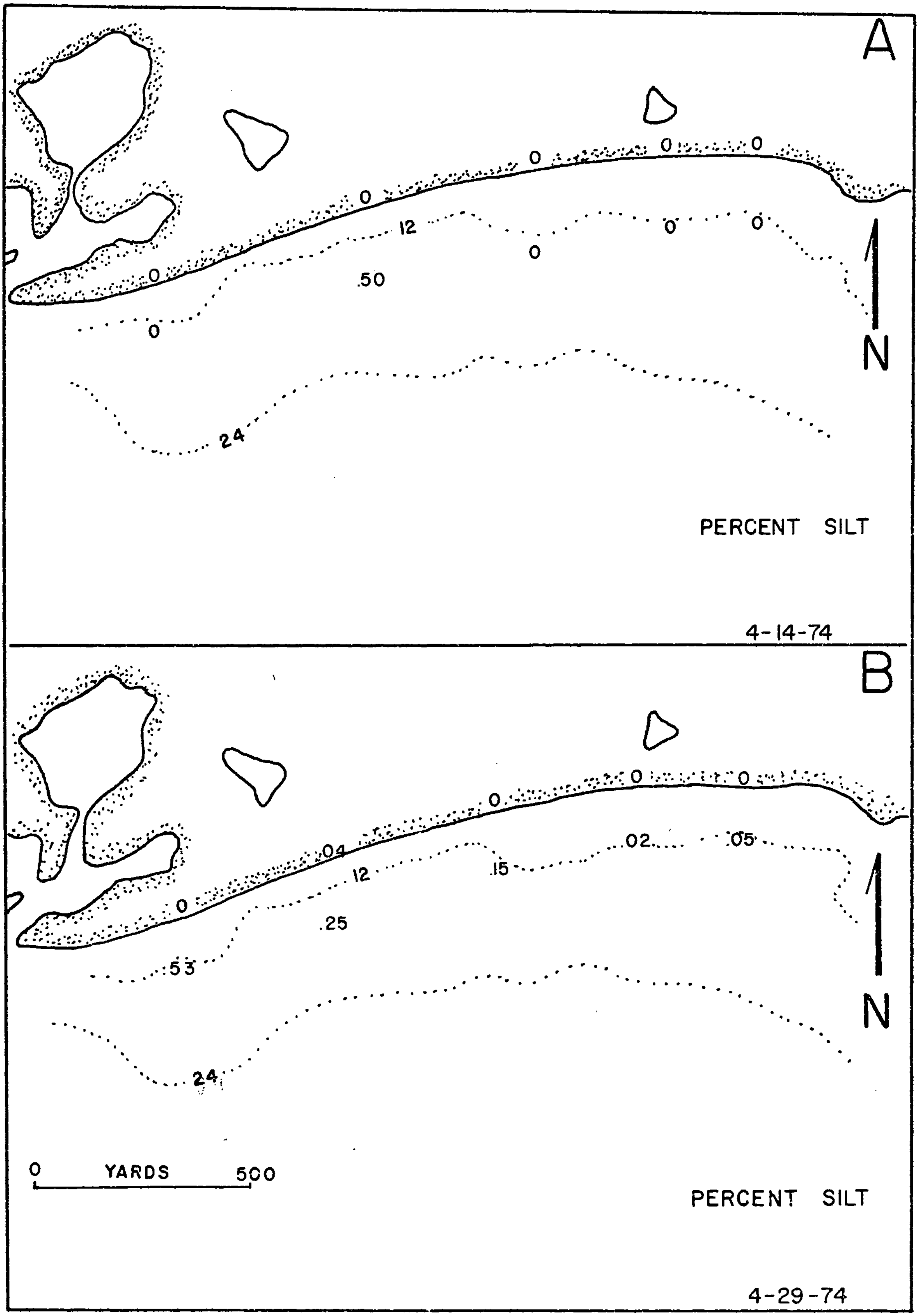

B
12
N
.04
.05
.07
24
0 YARDS 500
PERCENT SILT
2-15-74

Fig. 11. Percent silt content


A
0
0
0
0
0
0
12
0
0
0
.50
0
24
N
PERCENT SILT
4-14-74
B
0
0
0
.04
0
.02
.05
12
.15
.25
.53
24
N
0 YARDS 500
PERCENT SILT
4-29-74

the delta value, a measure of distance of transport from the source area (Lowright, 1973), decreases slightly in a westward direction from Matunuck Point (Figs. 12 and 13).

The decrease was not very marked probably due to the relatively short distance over which samples were taken. There was, however, one high delta value from the April 14, 1974 samples. The sample was located approximately 100 feet offshore and one mile west of Matunuck Point. Raw data from the hydraulic equivalence are in Appendix. C.

Nearshore Circulation

Maximum and minimum nearshore current velocities in the study area are given in Table I and Figure 14. It can be seen from these data that with the wind opposing the tide, a two-layer flow is developed, with the surface currents traveling in the direction of the wind and the near-bottom currents moving in the direction of the tide. When wind and tide coincide, a one-layer flow develops.

As depicted in Figure 14B and C, when the wind opposes the tide, a flood tide with southwest winds has greater near-bottom velocity than a flood tide with southeast winds (Table I). Also, an ebb tide with southeast winds is stronger than an ebb tide with southwest

TABLE I

Maximum and Minimum Nearshore Current Velocities
Recorded in Area Between Mid-Tide
Line and 12 Foot Depth Contour

(to correspond with Figure 14)

A

Eastward Ebbing Tide, West to Southwest Wind

	Surface	Near-Bottom
Browning Beach	61.0 cm/sec	12 cm/sec
	15.24 cm/sec	7 cm/sec
Carpenters Beach	45.7 cm/sec	11 cm/sec
	15.24 cm/sec	4.5 cm/sec
Matunuck Beach	31 cm/sec	15 cm/sec
	12.7 cm/sec	4.5 cm/sec

B

Westward Flooding Tide, West to Southwest Wind

	Surface	Near-Bottom
Browning Beach	59 cm/sec	28 cm/sec
	20.32 cm/sec	20 cm/sec
Carpenters Beach	31.5 cm/sec	22 cm/sec
	17.8 cm/sec	21 cm/sec
Matunuck Beach	48.26 cm/sec	35 cm/sec
	22.86 cm/sec	11 cm/sec

TABLE I

continued

C

Eastward Ebbing Tide, Southeast and Southerly Winds

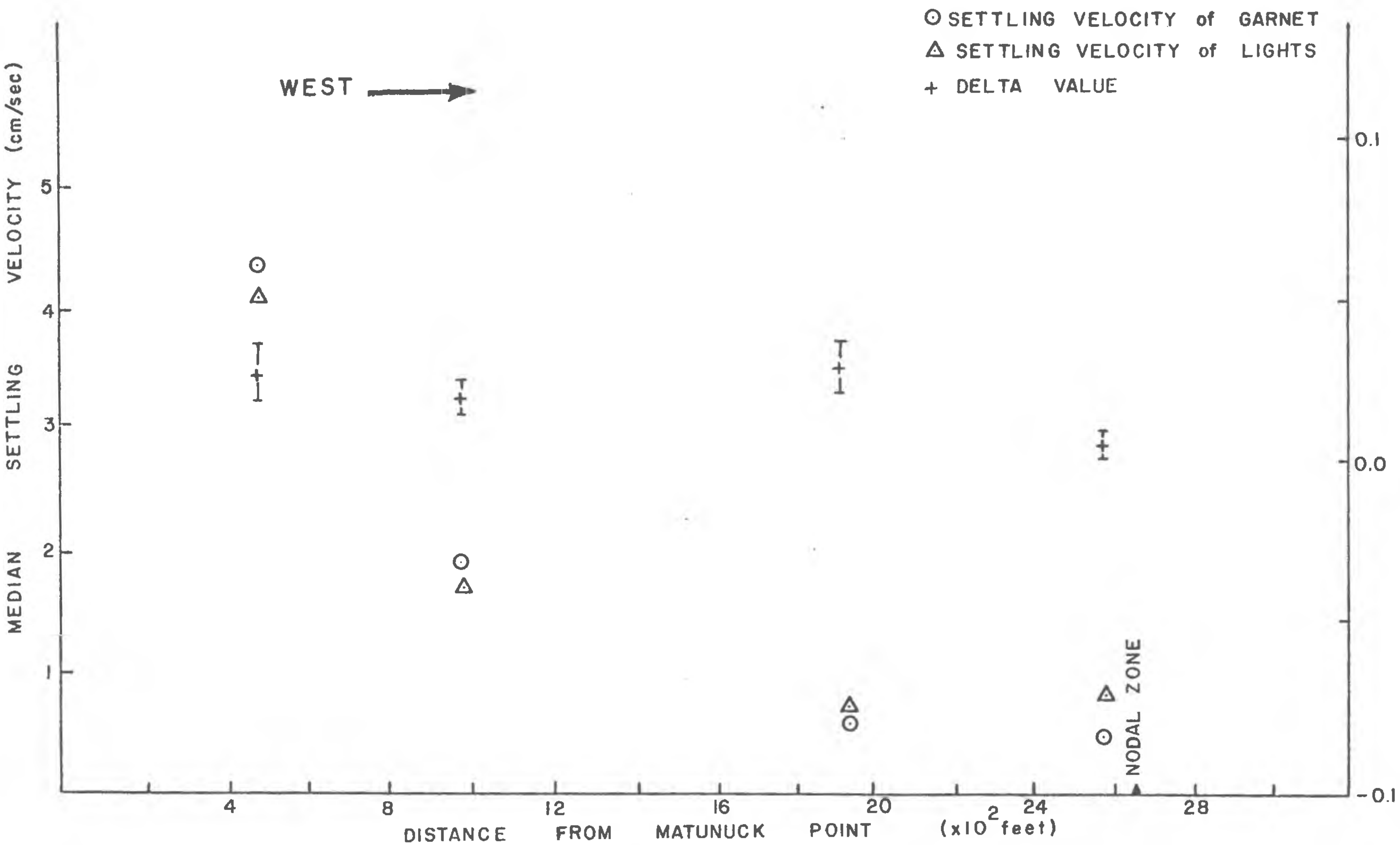
	Surface	Near-Bottom
Browning Beach	60.9 cm/sec	15 cm/sec
	24.13 cm/sec	7 cm/sec
Carpenters Beach	61 cm/sec	9 cm/sec
	30.48 cm/sec	7 cm/sec
Matunuck Beach	15.24 cm/sec	10 cm/sec
	14.90 cm/sec	6 cm/sec

D

Westward Flooding Tide, Southeast and Southerly Winds

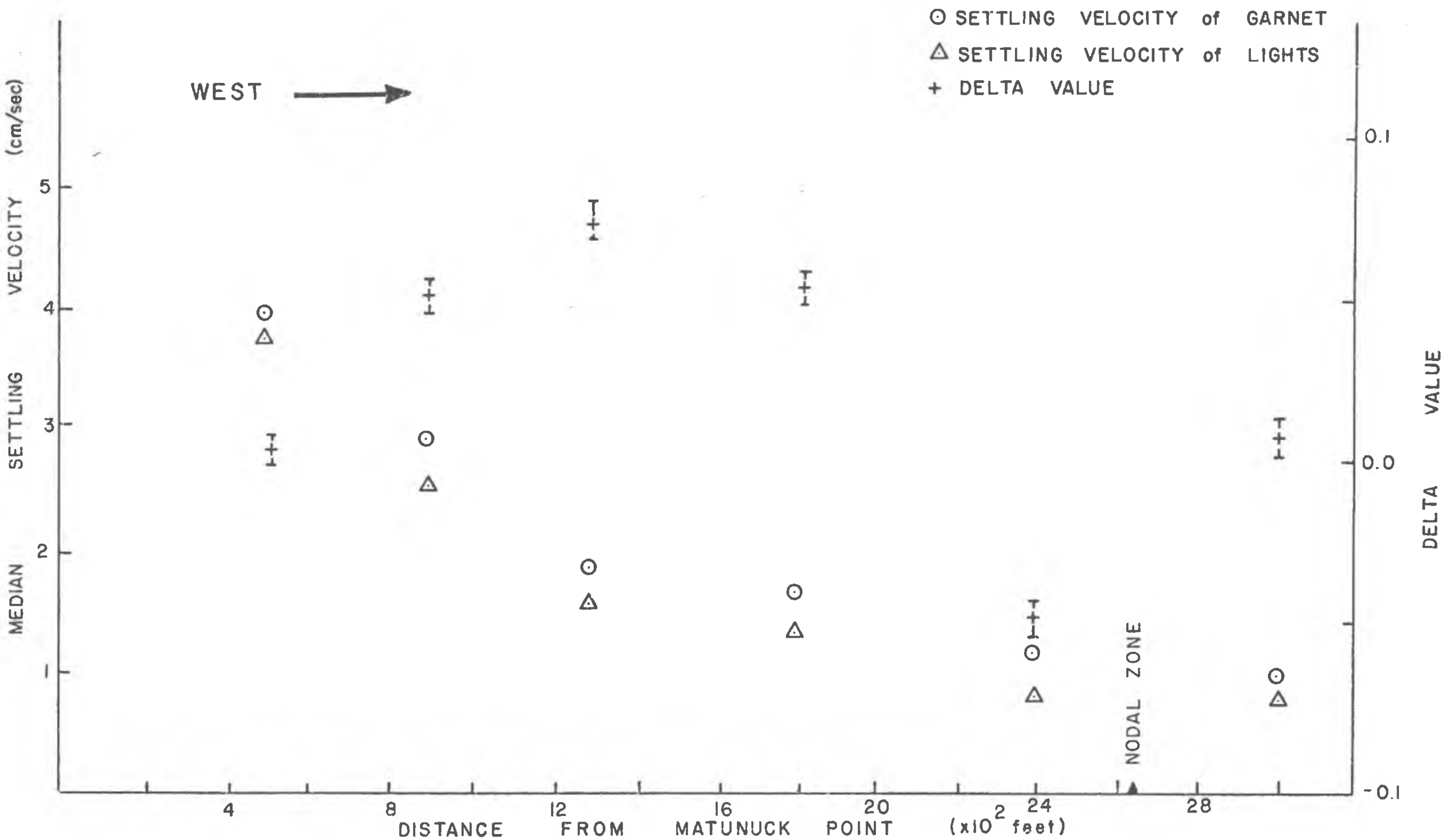
	Surface	Near-Bottom
Browning Beach	64.3 cm/sec	12 cm/sec
	30.48 cm/sec	8 cm/sec
Carpenters Beach	39.6 cm/sec	17 cm/sec
	27.43 cm/sec	113. cm/sec
Matunuck Beach	24.13 cm/sec	19 cm/sec
	15.24 cm/sec	15 cm/sec

Fig. 12. Hydraulic equivalence of selected pre-storm samples, 10-19-73



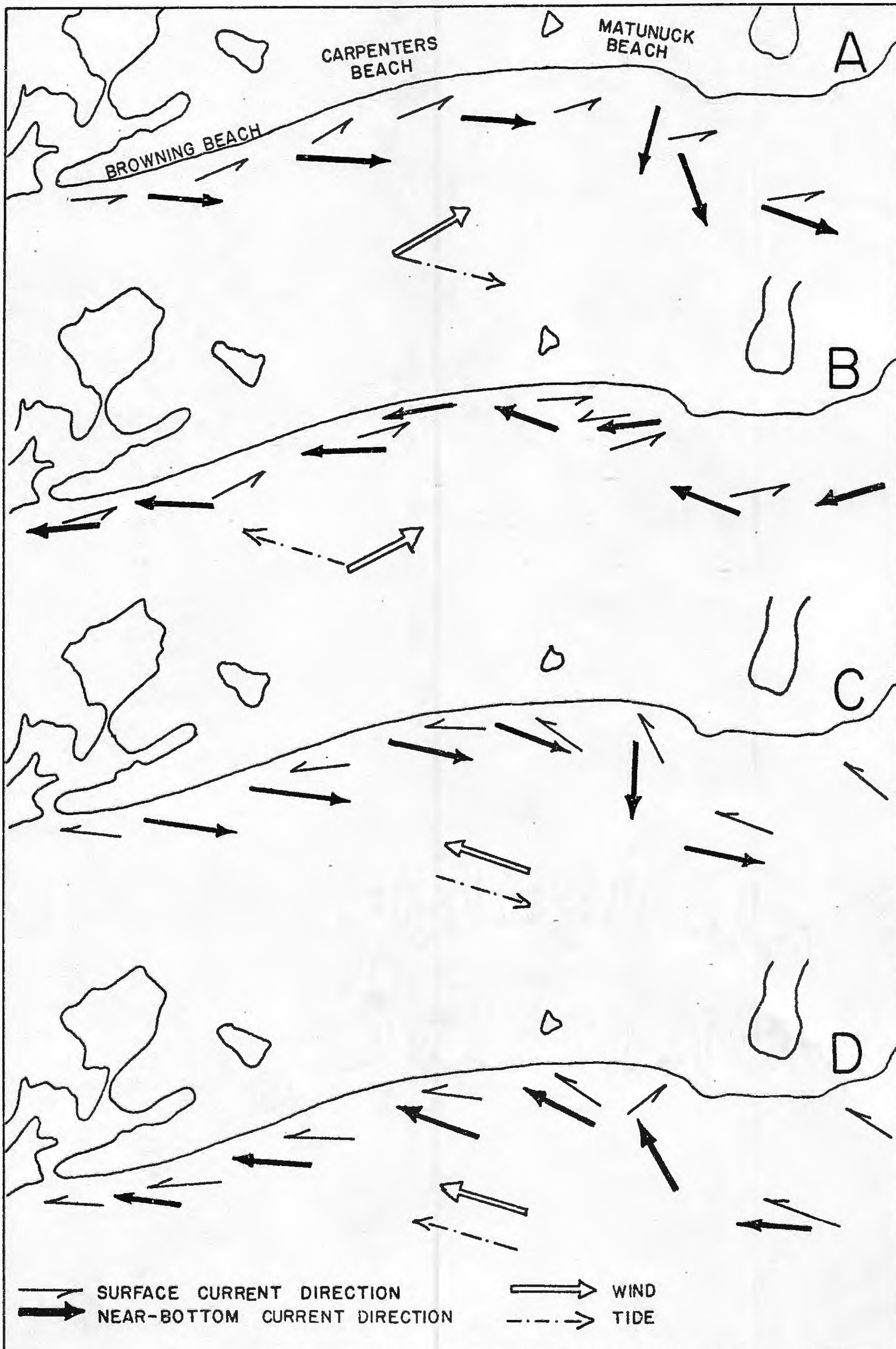
SETTLING VELOCITY of GARNET
SETTLING VELOCITY of LIGHTS
+ DELTA VALUE
WEST
MEDIAN SETTLING VELOCITY (cm/sec)
DELTA VALUE
NODAL ZONE
DISTANCE FROM MATUNUCK POINT (x10^2 feet)

Fig. 13. Hydraulic equivalence of selected samples, 4-14-74



SETTLING VELOCITY of GARNET
SETTLING VELOCITY of LIGHTS
DELTA VALUE
WEST
MEDIAN SETTLING VELOCITY (cm/sec)
5
4
3
2
1
0.1
0.0
-0.1
DELTA VALUE
NODAL ZONE
4
8
12
16
20
24
28
DISTANCE FROM MATUNUCK POINT ($x10^2$ feet)

Fig. 14. Current directions:
A) SW winds, ebb tide: B) SW winds, flood tide; C) SE winds, ebb tide: D) SE winds, flood tide. Measured in 10 - 12 feet of water.



CARPENTERS BEACH
MATUNUCK BEACH
BROWNING BEACH
A
B
C
D
SURFACE CURRENT DIRECTION
NEAR-BOTTOM CURRENT DIRECTION
WIND
TIDE

winds. Apparently, an opposing surface current tends to increase the near-bottom current velocities (Fig. 14 B and C; Table I B and C).

When the direction of the wind and tide coincide, velocities are greatest at the surface and decrease near the bottom (Fig. 14 A and D; Table I A and D). Also to be noted here, bottom currents are greater with a flood tide than with an ebb tide, following the relative magnitudes of the tidal velocities as depicted in Figure 3.

West of Matunuck Point observed current directions become more complex. With ebb flow, bottom currents are directed offshore (Fig. 14 A and C) following local bathymetry, while surface currents flow onshore west of Matunuck Point (Fig. 14C). Under flood conditions and southwest winds surface currents form a gyre west of Matunuck Point (Fig. 14B), and a similar gyre is developed under flood flow and southeast winds (Fig. 14D).

Bedforms

Bedforms were monitored to determine changes with season or sea conditions. The results are shown in Figure 15 and 16. Nomenclature is defined in Table II.

Orientation of the structures was controlled by the dominant forces at work. During periods of quiescence (low-energy waves), orientation of ripple crests approached

Fig. 15. Compilation of bedforms present under non-storm conditions: Zone 1 planar bed or ripples; Zone 2 asymmetric ripples with 3 to 4 inch wavelengths and 1/2 to 1 inch heights; Zone 3 asymmetric ripples with 4 to 5 inch wavelengths and 1 to 2 inch heights.

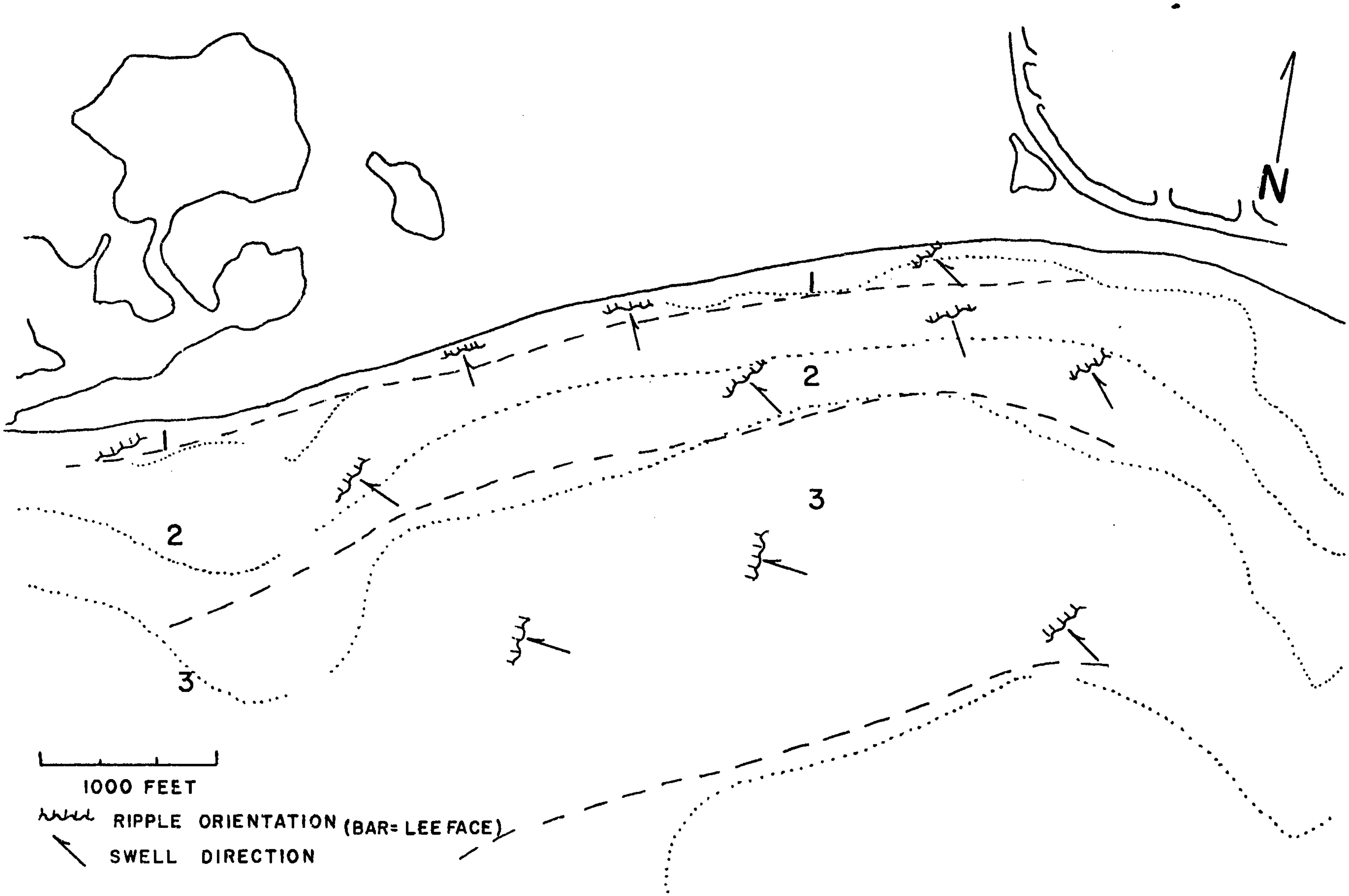

N
1
2
3
1000 FEET
RIPPLE ORIENTATION (BAR= LEE FACE)
SWELL DIRECTION

Fig. 16. Compilation of bedforms present under storm conditions: Zone 1 planar bed; Zone 2 ripples with 3 inch wavelengths and 1/2 inch heights merging shoreward to ripples with 3 inch wavelengths and 1/4 inch heights.

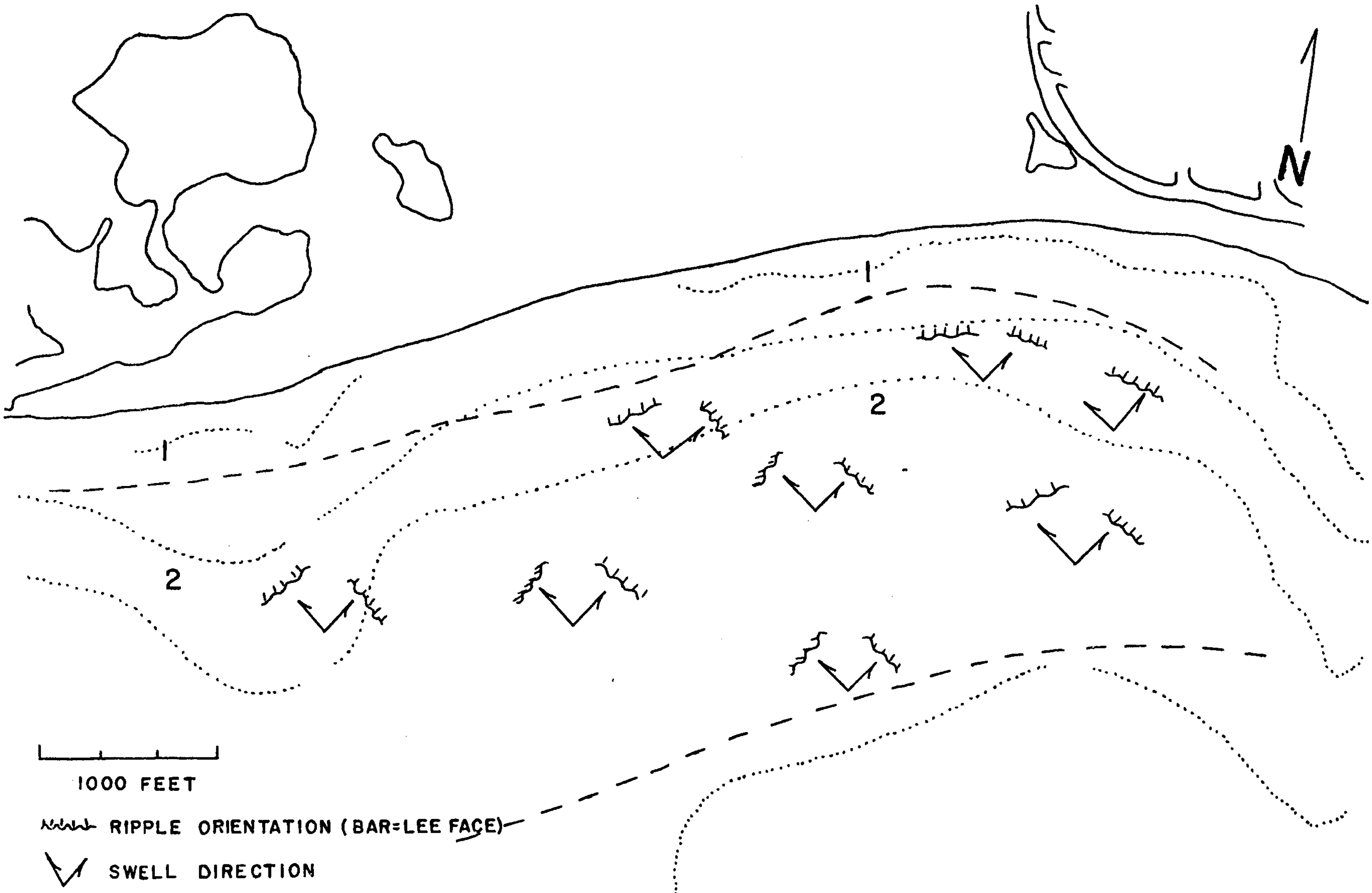

N
1
1
2
2
1000 FEET
RIPPLE ORIENTATION (BAR=LEE FACE)
SWELL DIRECTION

TABLE II

Definitions of Sedimentary Structures

(From the University of Massachusetts Coastal Research Group, 1969)

Ripples: Asymmetric bed forms formed by unidirectional flow, wavelength less than two feet.

Large Scale Ripples: Between one and two foot wavelengths.*

Megaripples: Larger than two foot wavelengths.*

Planar Beds: Flat surface upon which parallel laminations are deposited.

*author's subdivision

nearly perpendicular to the direction of tidal currents in the outer nearshore, and perpendicular to wave approach inshore. Storm conditions, however, seemed to cancel out any tidal induced orientation, and alignment was parallel to the approaching storm swells.

In the area of sample locations 3, 4, and 5 (Fig. 4) westerly facing caternary ripples (triangularly shaped) were found under non-storm conditions. Their presence was observed during periods of low waves (<1.5 feet) and flood tide. Formation of ripples have been ascribed to areas of shallow water or increasing currents (Allen, 1958), or to littoral currents (Shepard, 1973).

Also in this zone, large ripples were seen to be welding themselves to the beach step. These were traveling in a westerly direction while winds were from the southwest and beach drift was to the east.

<u>Non-Storm Conditions</u>: Non-storm or conditions of wave quiescence (Fig. 15) developed three distinct bedform zones in the nearshore. The zone farthest seaward of the breakers consisted of asymmetric ripples oriented obliquely to the beach, with heights of 1 to 2 inches (in fine sand), wavelengths (crest to crest measurement) of 4 to 5 inches, and ripple lengths (measured along ripple crest) of 12 to 15 feet. The

next zone shoreward contained asymmetric ripples of similar wavelength, but ripple length along crests was shortened and height reduced. Crest orientation approached normality to wave direction. The zone immediately seaward of the breaker zone had a planar bed on which small ripples formed between surges when fine sand was present. Where coarse sand was found, large-scale ripples developed.

The exception to this sequence occurred in the coarse sand and gravel near Matunuck Point. Because this coarse material extended further seaward here than elsewhere, the outermost nearshore bedform zone merged shoreward to become large-scale ripples and mega-ripples on which small ripples migrated up the stoss side. These forms then transformed into mega-ripples near the beach step.

Storm Conditions: Under storm conditions only two bedform zones were found in the nearshore. The zone further seaward contained ripples with wavelengths of 3 inches and heights of 1/2 inch merging to ripples with the same wavelength and heights of 1/4 inch. Ripple lengths could not be determined due to visibility difficulties under the turbulent sea conditions. Ripple orientation was parallel to approaching wave crests.

The next zone shoreward was a planar bed that remained planar between surges. This occurred in fine and coarse sand.

Beach and Nearshore Profiles

Beach Profiles: Six stations were monitored between October 19, 1973 and June 4, 1974. These stations were at sample locations 2, 3, 4, 5, 6, and 7 (Fig. 4). Profiles are shown in Figures 17 through 20.

A general sequence of seasonal changes among 5 of the 6 beach profiles is expressed as a gentle slope in October, a cutting back and steepening of the beach during the winter, and a return to a more gentle slope again in summer. An exception to these responses is found in profile 7 (Fig. 20) located just west of Matunuck Point. Here the beach was found to build out during the winter and retreat over the summer.

In spring and summer the beach grows seaward by removal of sediment from higher on the beach and from the nearshore and deposition of this material on the lower foreshore. It should be noted that the beach step of profile 5 moved seaward very little over the February - October period yet the beach lost the most material of all the beaches profiled. This indicates the material from the upper foreshore does not remain

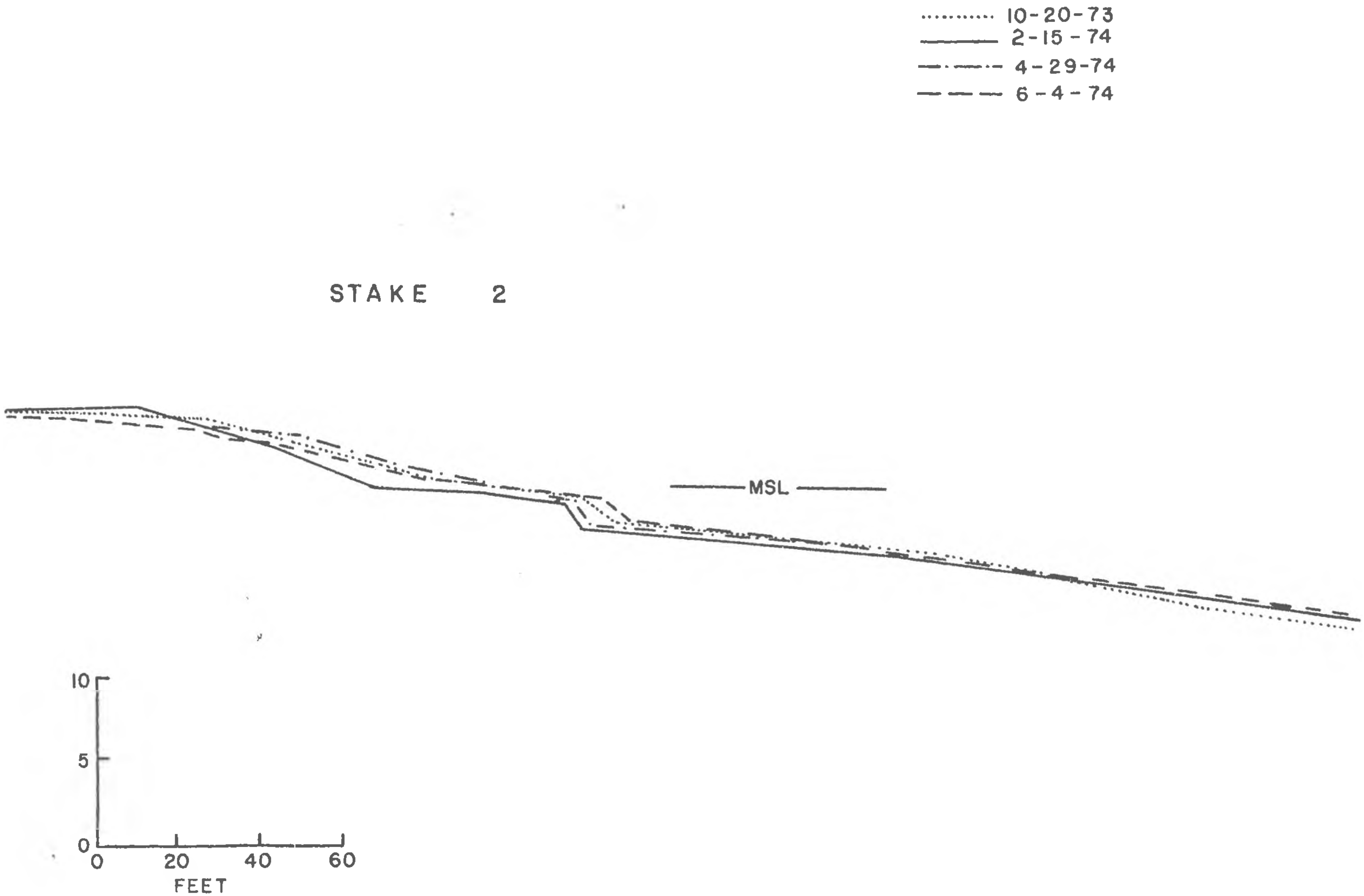


Fig. 17. Beach profile (see Fig. 3. for location)

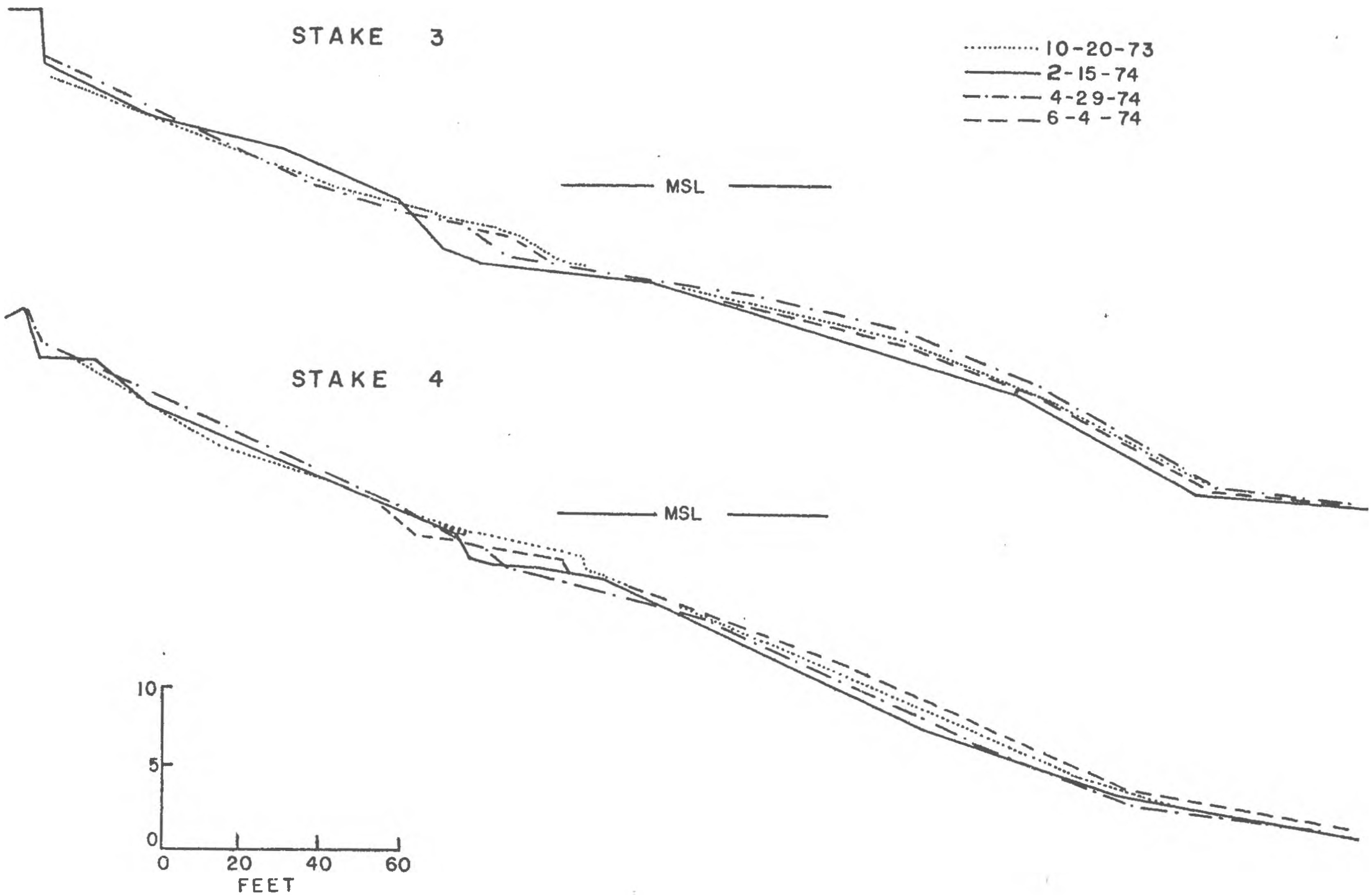


Fig. 18. Beach profiles (see Fig. 3. for location)

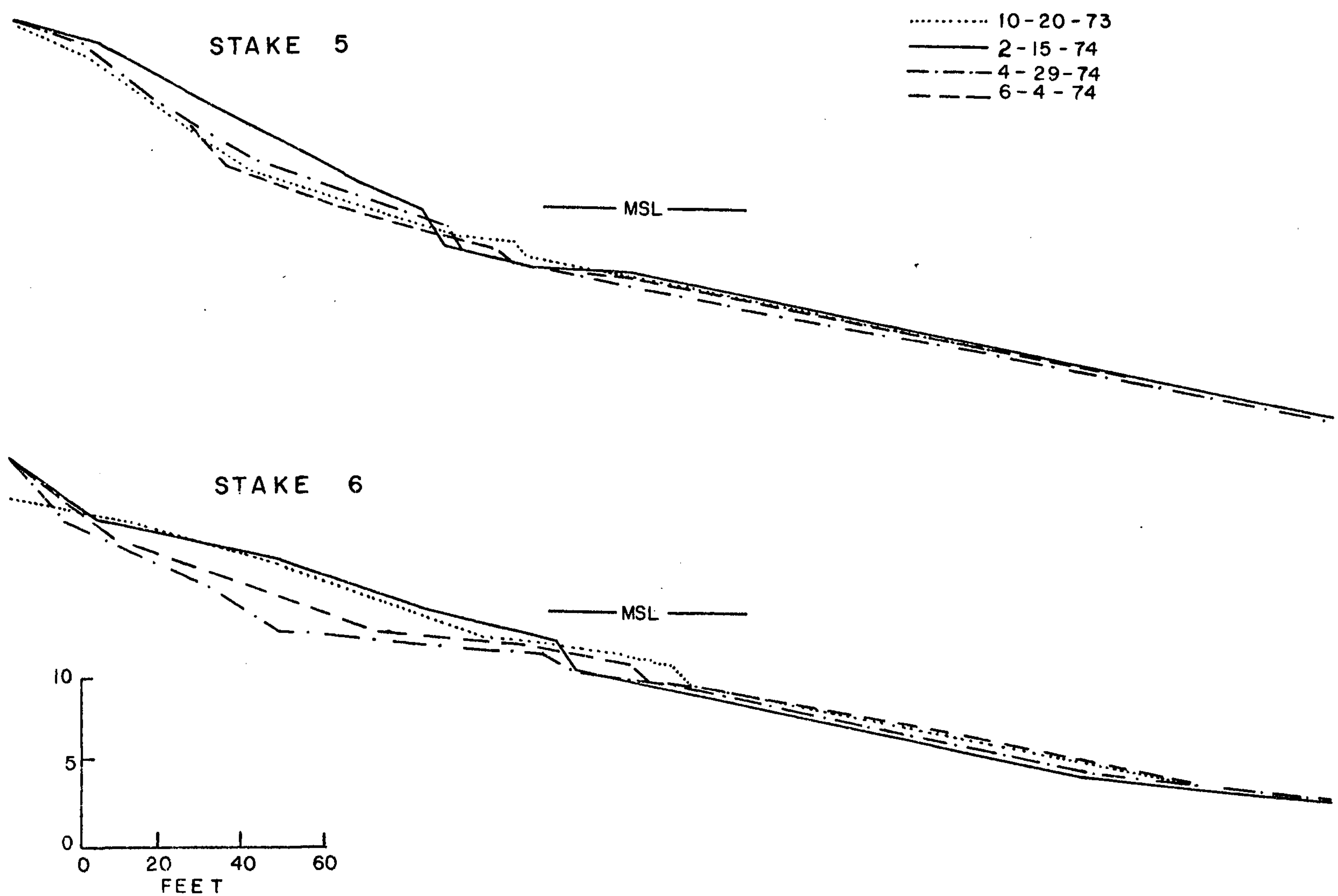


Fig. 19. Beach profiles (see Fig. 3. for location)

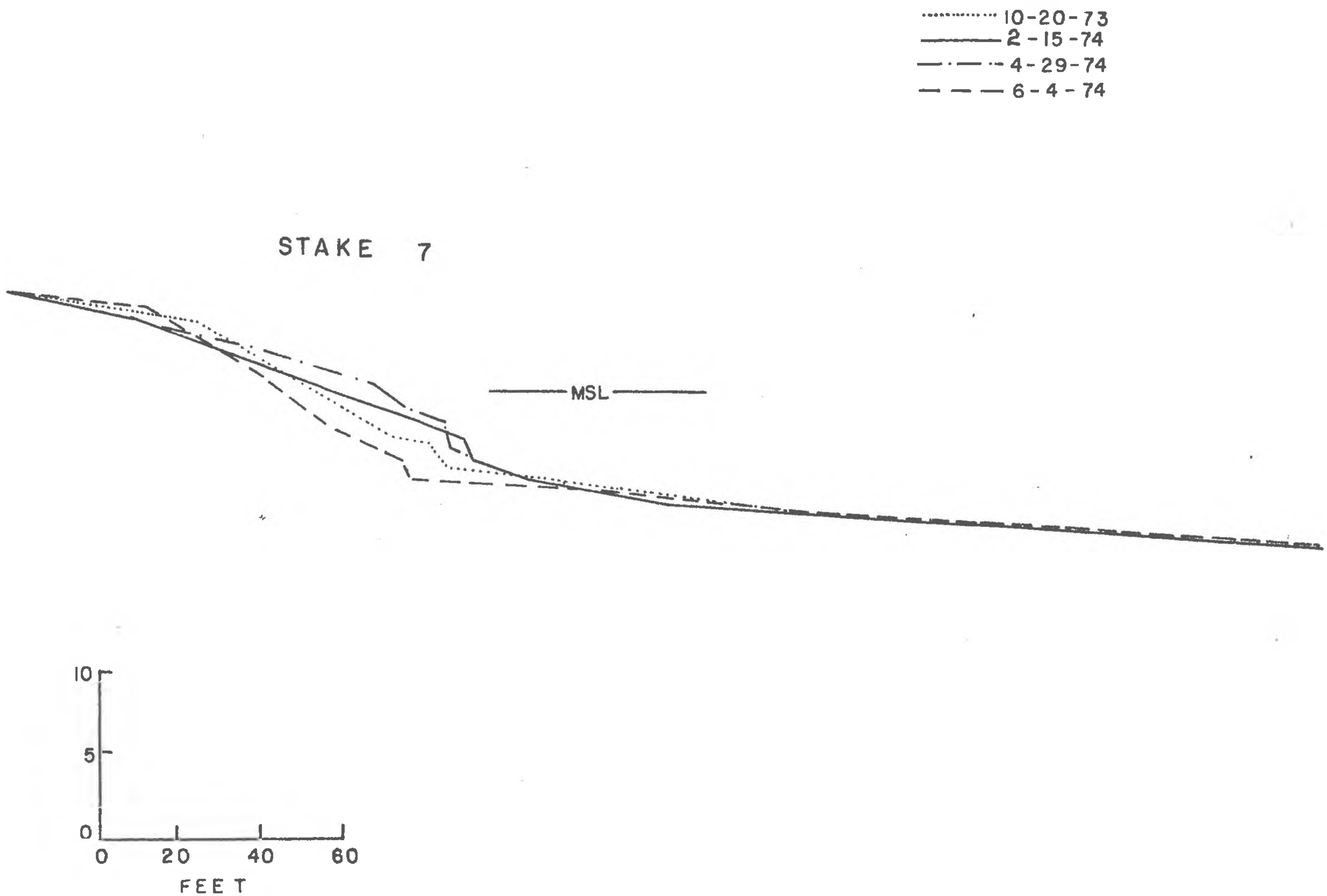


Fig. 20. Beach profile (see Fig. 3. for location)

in the vicinity of the step for very long, being transported further offshore or to the beaches east and west of the profile area.

Nearshore Profiles: Nearshore segments of the profiles revealed very little change in most of the transections. The general trend was toward accretion of the nearshore zone in a westerly direction (Profiles 2 and 3), with no detectable change in profile 7. More accretion occurred in profiles 2 and 3 than 5 and 6.

Accuracy and precision of depth measurement on the nearshore segments of these profiles are judged to be half a foot at best. This would seem to indicate even less change than the profiles show. Because of this, the nearshore sections were not used to support any conclusions of the study.

Wave Refraction Data

Compiled weather data can be found in Appendix E. The prevailing winds are from the southwest, occurring 37% of the time. Average speed is between 8 and 12 mph.

Refraction diagrams were constructed for waves from the southwest with a period of 6 seconds and from the southeast with a period of 10 seconds. These period waves were determined from hindcasting nomograms of the U.S. Army Coastal Engineering Research Center (1966).

While 10-second waves may appear to be unusual for the area, such period waves have been recorded regularly by researchers working 1.7 nautical miles east of the study area (First, 1972), and 6.25 miles west of the area (Raytheon, 1975).

It should also be noted here that the weather data were compiled from an inland station located approximately 30 miles north of the study area. The wind speeds recorded typically are less than those observed on the south shore due to friction over land (Miller, 1971), so any wave data compiled from these records can be considered as a conservative estimate for those actually occurring in the area.

With waves approaching from the southwest with 6-second periods, there is a zone of concentrated energy at Matunuck Beach (vicinity of stake 5), and more refraction west than east of that location (Fig. 21). The increased refraction results in less of a component of littoral drift west of Matunuck Beach than east of it. The greater refraction is caused by Nebraska Shoals.

Southeast waves with 10-second periods result in a larger component of littoral drift west of Matunuck Beach than east of Matunuck Beach (Fig. 22). These diagrams indicate that the Nebraska Shoals west of Matunuck Beach controls the resulting beach drift on the foreshore.

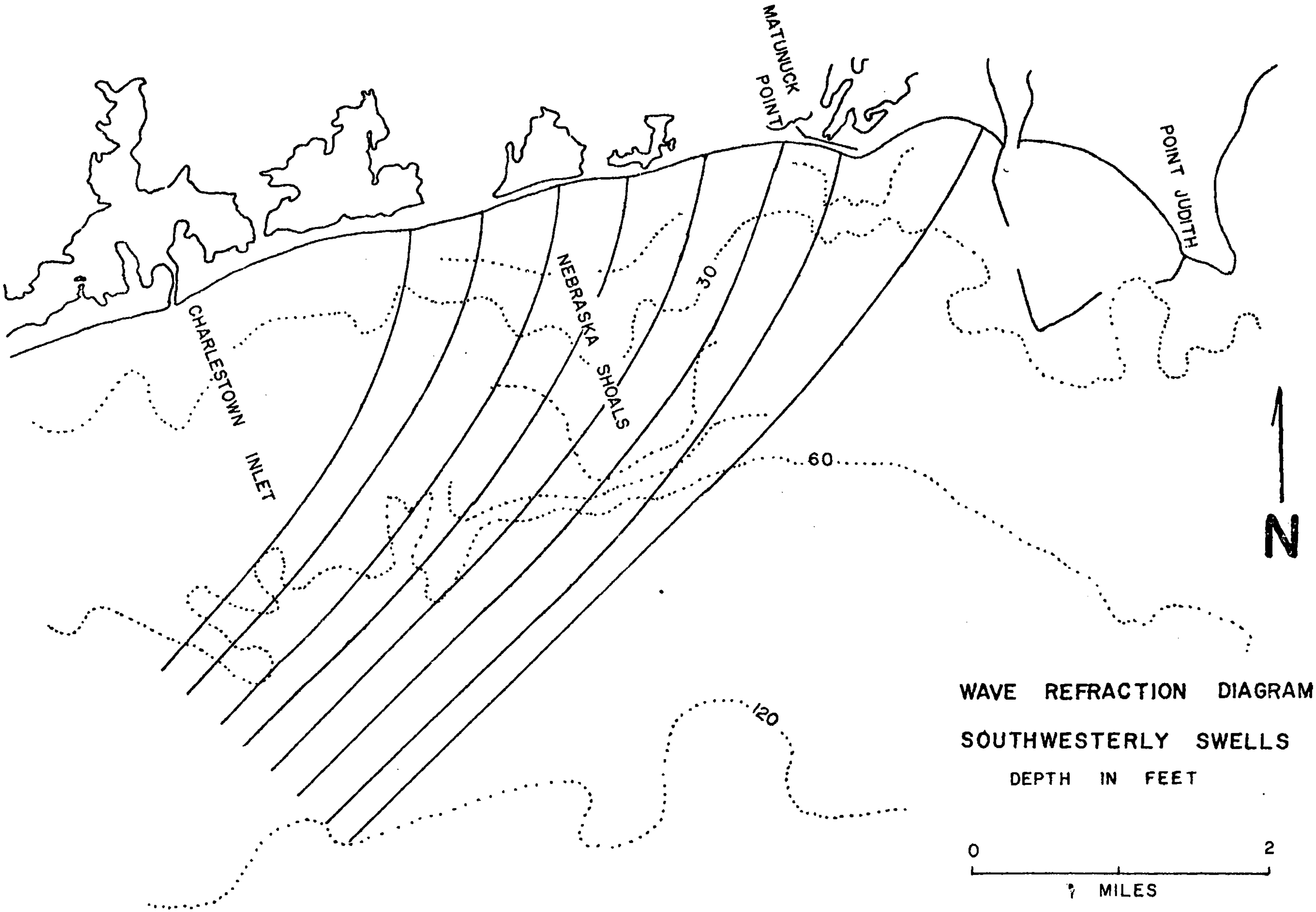

MATUNUCK POINT
POINT JUDITH
CHARLESTOWN INLET
NEBRASKA SHOALS
30
60
120
N
WAVE REFRACTION DIAGRAM
SOUTHWESTERLY SWELLS
DEPTH IN FEET
0
2
MILES

Fig. 21.

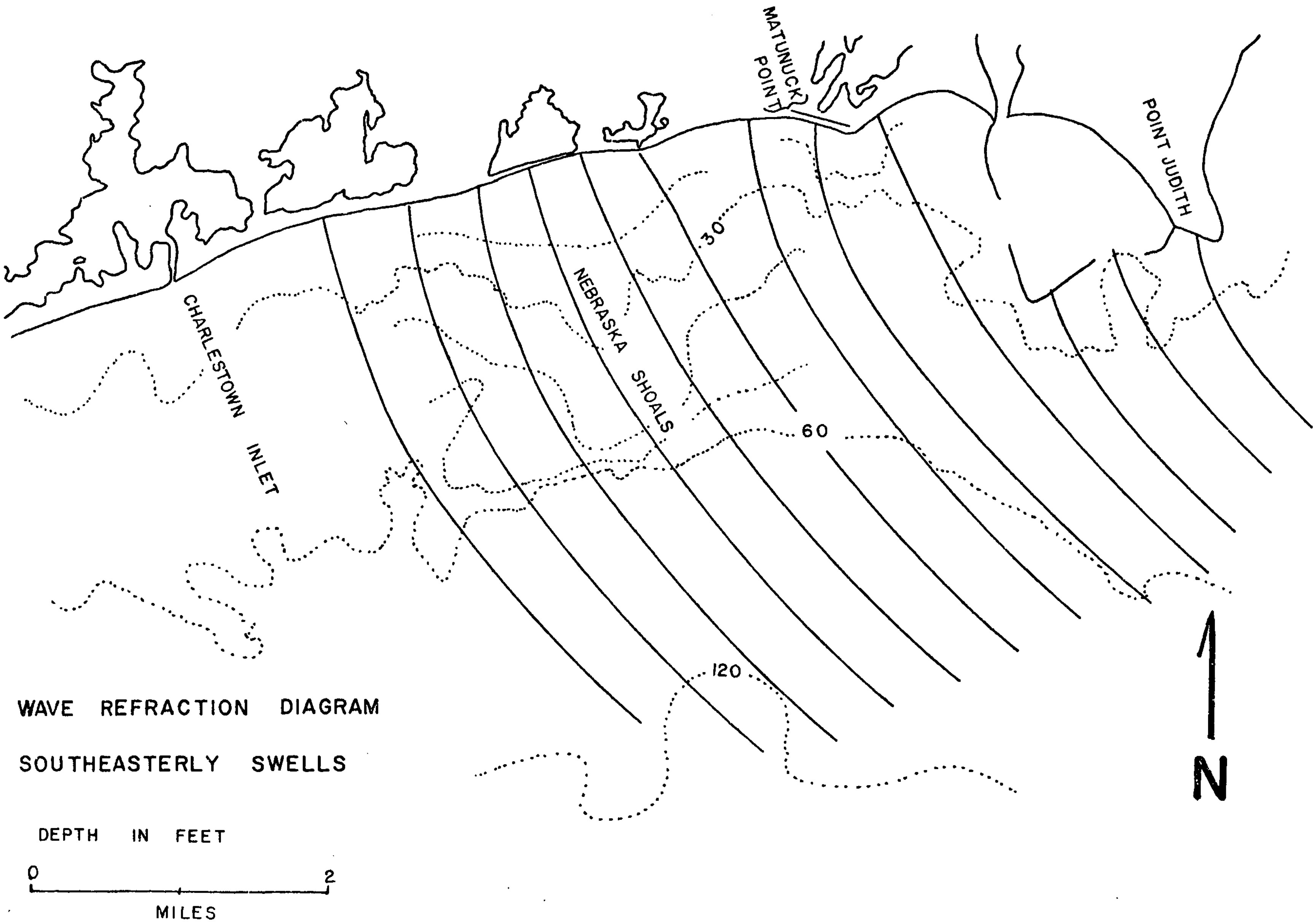

POINT JUDITH
MATUNUCK POINT
30
60
120
NEBRASKA SHOALS
CHARLESTOWN INLET
N
WAVE REFRACTION DIAGRAM
SOUTHEASTERLY SWELLS
DEPTH IN FEET
0
2
MILES

Fig. 22.

DISCUSSION

Beach And Nearshore Sedimentary Processes

The probable sediment transportation agents in the beach-nearshore zone in this area are waves, tidal currents, wind driven currents and perhaps the supplementary effect of residual drift in Block Island Sound. Numerous workers (Carr, Gleason, and King, 1970; Ingle, 1966; Ippen and Eagleson, 1955; Scott, 1954; Zenkovich, 1967) have determined that wave action is the dominant transporting agent along most shorelines. However, Bruun (1968) has stressed the importance of longshore tidal currents, superimposed on wave generated currents, for sediment transport in a low energy nearshore environment.

Beach Transport: Transport along the beach, shoreward of the plunge point is controlled by longshore drift. The dominant waves that approach the Rhode Island shore come from the east-southeast and southeast (U.S. Beach Erosion Board, 1950). Southeasterly swells breaking on the shore cause beach transport to be predominantly westward. Local reversals of longshore drift direction occur 3/4 miles west of Matunuck Point due to the refraction of southeast waves by the offshore topography and refraction around Matunuck Point (Fig. 22).

Some 2500 feet west of Matunuck Point, refraction is great enough most of the time to cause little or no westward transport and even some eastward transport under southwesterly winds (personal observation). This results from the approximate parallel approach of the wave crests to the shore and the prevailing southwest wind driven water movement after the waves break on the foreshore. This condition was observed numerous times during the study. About one mile west of Matunuck Point a zone of divergence of wave rays can been seen (Fig. 22) indicating the presence of less wave energy at that position than on either side.

Southwesterly swells are local in origin with maximum fetch distance being only 25 miles (Montauk Point to Point Judith). Refraction of these waves is greatest on the beaches shoreward of Nebraska Shoals (Fig. 21). This produces a more easterly beach drift 3/4 miles west of Matunuck Point (including McMaster's nodal zone) than farther west where the wave crests approach more parallel to shore.

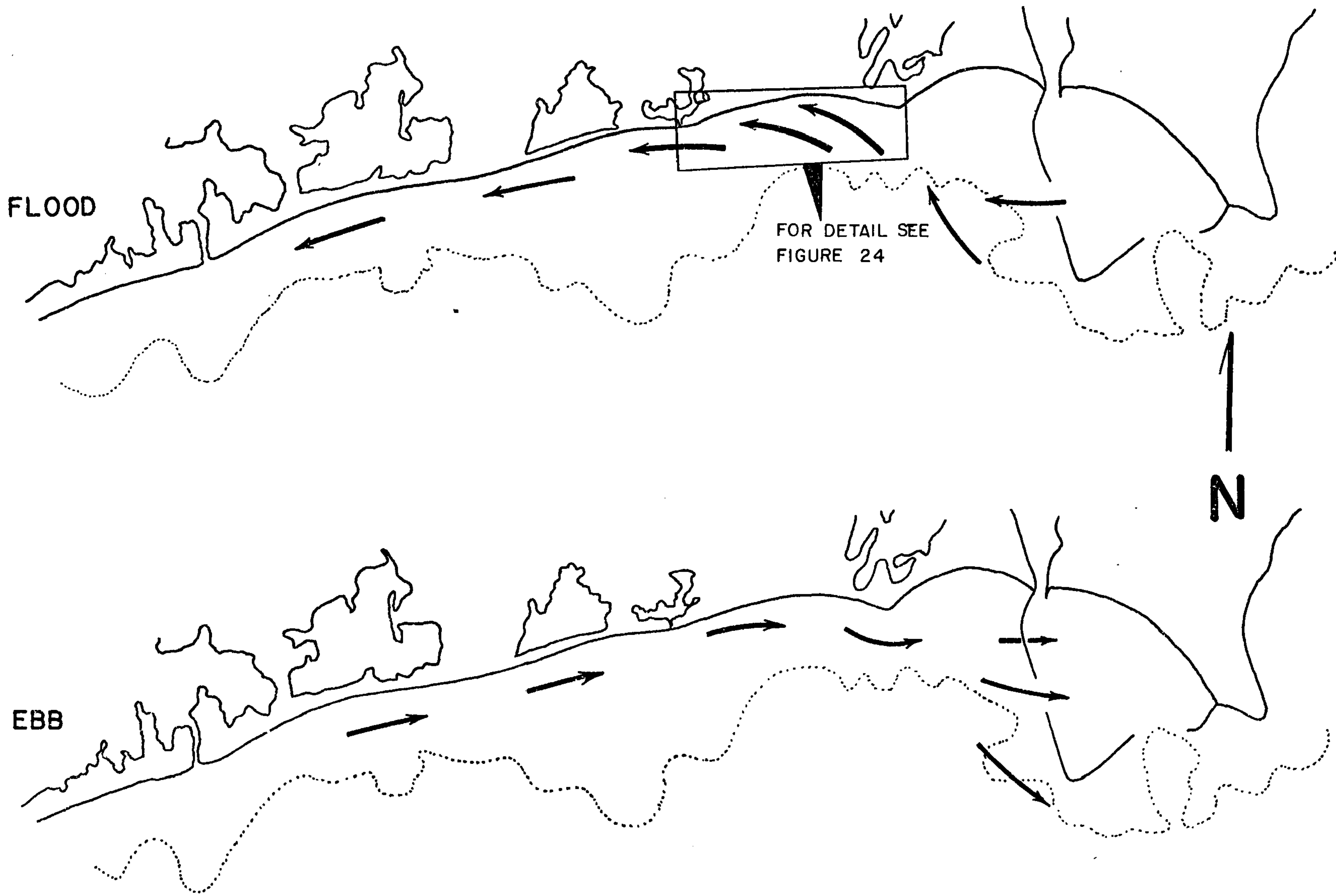
Nearshore Transport: Wave heights immediately seaward of the study area average one to three feet with periods from 6 to as great as 13 seconds (First, 1972), with predominant swell from the east-woutheast to southeast (U.S. Beach Erosion Board, 1950).

Tidal currents in the area average 26 cm/sec flood and 21 cm/sec ebb (First, 1972), but in water less than 18 feet these velocities decrease (Raytheon, 1975). A higher speed and longer duration of the westward flood tide over the eastward ebb occurs at all times except on spring tides. The existence of such an asymmetry (Eulerian Asymmetry) has been shown to cause a net transport of sediment in the direction of peak velocity (Krank, 1972).

The predominant swell, the inequality of tidal pulse and the residual bottom drift results in an observed net westward sediment transport for most of the study area.

About 3/4 of a mile west of Matunuck Point, immediately seaward of the beach nodal zone, a clockwise nearshore gyre is shown to develop during flood (U.S. Coast and Geodetic Survey, 1941; Fig. 14B and D; Fig. 23 and 24). This gyre is believed to be strengthened by the superimposed refraction of southeast swells around Matunuck Point which results in an eastward or negligible westward flowing nearshore current. The gyre appears to be a bifurcation of the flood tidal currents. Westerly moving currents west of the gyre are a continuation of those developed by flood tide and predominant southeast swell.

Fig. 23. Sediment movement in thesis area under flood and ebb tides. Combined with data of McMaster, 1960.


FLOOD
FOR DETAIL SEE
FIGURE 24
N
EBB

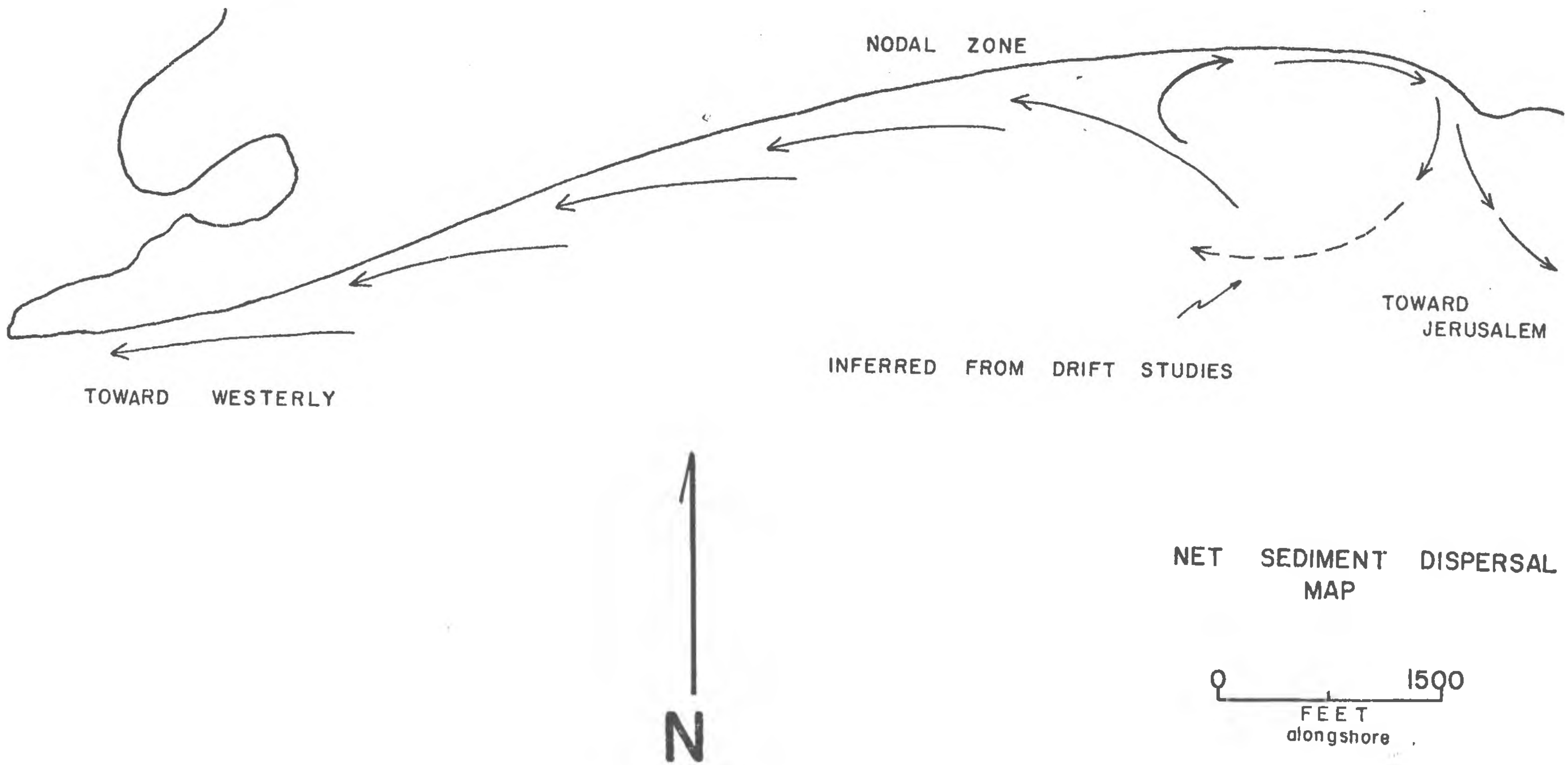


Fig. 24. Detailed net (long term) sediment movement around nodal point

This circulation pattern is presumed to transport nearshore bed sediment eastward east of a newly defined nearshore nodal zone. Also southwest swell is refracted more over Nebraska Shoals (located west of this nodal zone) than east of the shoals causing little eastward sediment movement west of the nodal zone but considerable eastward sediment transport east of the nodal zone (Fig. 14). This condition, along with ebb flow, further reinforces the transport initiated under southeast swell and a flooding tide east of the nodal zone. Currents available to produce this sediment transport are shown in Figure 14B and D.

Orientation and shape of the bedforms confirm the transport pattern in part (Fig. 15). Small scale bedforms are aligned parallel to the crests of the predominant southeast swell and perpendicular to flood currents, and indicate a westward and onshore oblique sediment movement. Landward migration results from refraction of swells around Matunuck Point and is best shown under storm conditions (Fig. 16) when southeast swell dominates.

In the nearshore, large ripples moving westward under a flood tide have been seen to weld themselves to the step 3/4 miles west of Matunuck Point. Winds at the time were from the southwest as were the waves.

Hence bedload movement beyond the beach step can be contrary to the surface currents and waves (Fig. 14B). Moreover it is possible that net transport of nearshore material can be opposite to the direction of beach drift. Migrating ripples were not seen to weld themselves to the step east of the nodal zone indicating either conditions do not encourage formation of such ripples or transport is not westward east of the zone because of the circulation.

Figure 10A showed an elongated band of positively skewed sediments located 1 1/4 miles west of Matunuck Point. According to the criteria suggested by Mothersill (1969) these fine skewed sediments may define a bar or sand wave trending obliquely to the shore, and probably indicating diagonal movement to the west. Rips, usually associated with bar movement (Sonu, 1968), were seen to occur in the area at other times during the year implying the periodic appearance of these bedforms.

Figures 5, 7, and 8 show a gravelly-sand about 1/2 miles west of Matunuck Point, with coarse to fine sand on either side. During the year sand sized sediment is supplied to the nearshore nodal zone from the nearshore. This gravelly-sand may indicate active winnowing of the sand sized sediment from the area and subsequent transport west and/or east. The extent of the gravel zone fluctuates with differing amounts of sediment supply (Fig. 7 and 8) to the nearshore zone. Greater movement is revealed westward than eastward as seen in comparing the gradients in Figures 7 and 8. This coarse sediment is maintained only under calm sea conditions (<3 feet), as during storm (Fig. 6) the entire step is gravel.

To determine if sufficient energy was available to transport the sediment size present, short term velocities were measured over half-hour periods and wave induced currents computed (Table I, III, and Appendix D). These data were then used in conjunction with the work of Sternberg (1971) to determine if the velocities measured could cause transport of the sediment sizes present.

Good correlation was obtained by Sternberg in comparing his field data with the experimental data of Allen (1965) and Inman (1963). Sternberg's velocities between 30 and 52 cm/sec for initiation of movement are within the error bands of Allens 35 - 50 cm/sec and Inman's 32 - 50 cm/sec values (measured one meter above bed) for general sediment motion (Sternberg, 1971).

Although these velocities were not recorded near the bottom, computed wave-induced current data indicate the attainment of these velocities in the study area.

TABLE III

Computed Wave-Induced Currents

(Corresponds to Appendix D)

Mild Waves (<1.5 feet in height)

Distance from Shore in Feet	10	45	120	185	220
Shoreward Component of Velocity (cm/sec)	48.16	34.75	27.13	22.86	21.03

Intermediate Waves (1.5 - 3 feet in height)

Distance from shore in Feet	10	45	120	185	220
Shoreward Component of Velocity (cm/sec)	140.82	81.38	66.45	64.31	60.35

(Local Storm Waves (>3 feet in height)

Distance from Shore in Feet	10	45	120	185	220
Shoreward Component of Velocity (cm/sec)	281.64	95.10	93.88	82.60	84.43

Komar and Miller (1973) have shown that under accelerating currents, such as those produced under oscillatory motion, the end of stroke acceleration before reversal is greatest and increases with decreasing wave period. This surge in velocity allows the movement of grains above the bed even at low average velocity. Once placed in motion above or along the bed less velocity is required to maintain the grain or grains in motion than was required to initiate movement (Allen, 1965). In this manner, wave-induced instantaneous surges initiate sediment movement and tidal and longshore currents continue movement.

Hydraulic equivalence studies of selected nearshore samples indicates a very slight decrease in the difference between settling velocity of heavy and light minerals (delta value) toward the west. This decrease is small due to the short distance over which the samples were taken. Lowright (1973) in his study of Lake Erie sediments, sampled an 18 mile stretch of shoreline to show a significant decrease in the delta value with transport distance. My sampling distance was about one mile, and revealed only a slight decrease in delta value. Lowright's gradient of 6.6×10^{-6} Δ/ft is less than my 1×10^{-5} Δ/ft indicating a greater gradient for my delta values and hence valid correlation to the work of

Lowright (1973). The decrease in the delta value to the west does then indicate a net transport to the west.

Net Dispersal Pattern: A model for net sediment dispersal in the total beach-nearshore system is shown in Figure 23. The determining factors of this net pattern are: the close proximity of the plunge point and step to the beach, the predominant swell direction, the intensity and duration of the tidal currents, and wind driven currents.

The location of the step and plunge point close to shore allows material entrained in the backwash to be introduced into the nearshore circulation pattern operating just seaward of the step (personal observation). Therefore, even if beach drift at a given time is eastward (Fig. 25), net nearshore sediment transport can be westward, via nearshore currents in response to refracted waves and tidal direction. This process has been seen operating when rips formed and their seaward head traveled westward while beach drift was eastward. Figure 26 depicts movements with directions of beach drift and tidal currents coinciding. Due to the lesser intensity and duration of the ebb flow, less material is transported then, than under flood conditions.

With westerly beach drift, due to predominant swell and westward flowing flood tide, all sediment

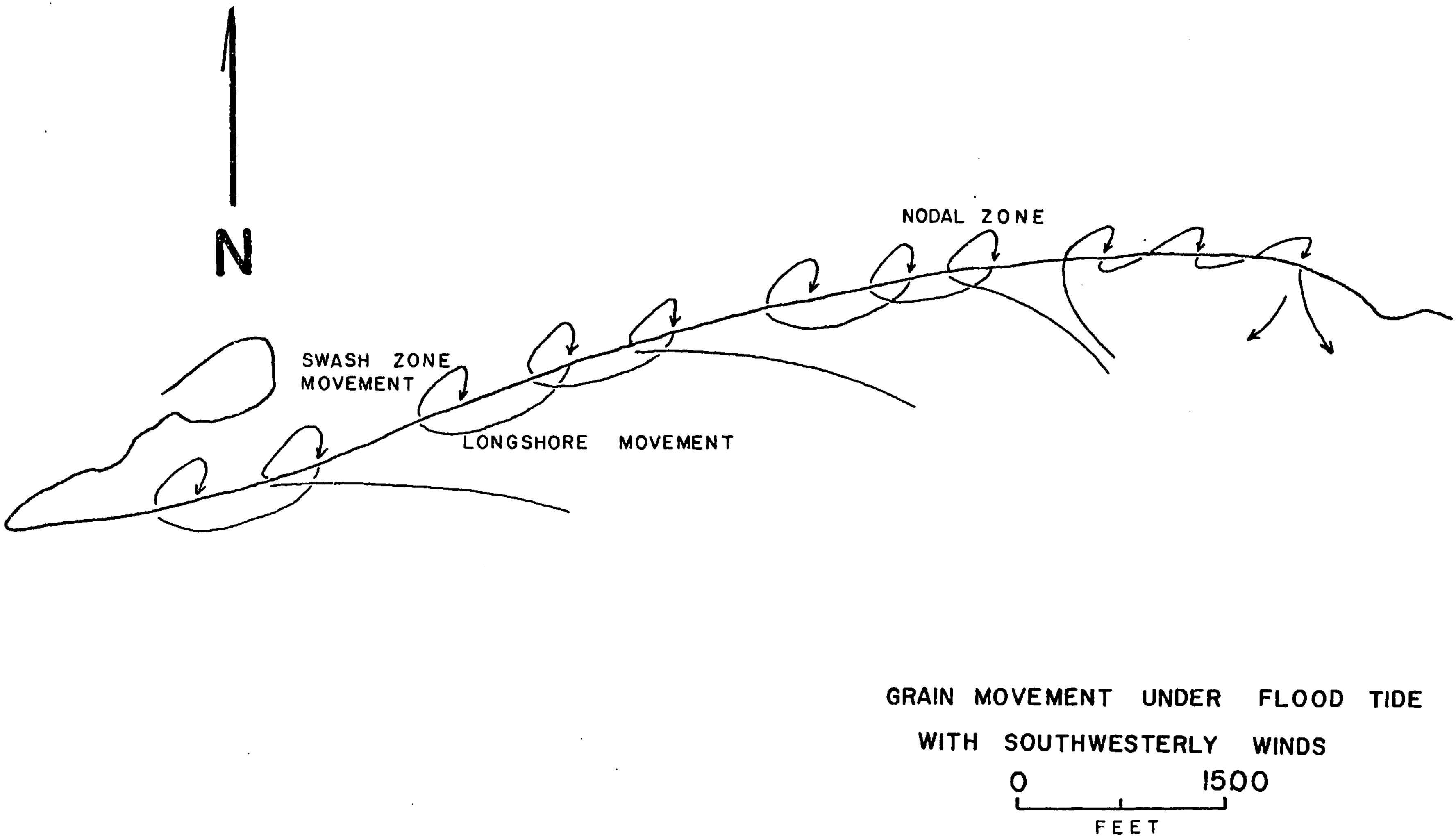


Fig. 25. Depicts hypothetical movement of one grain with beach and nearshore transport in opposing directions.

west of the beach nodal zone moves westward. East of the nodal zone material in the nearshore is moved eastward by a gyre set up in the lee of the point (U.S. Coast and Geodetic Survey, 1941; personal observation of drifters; and conversation with local fishermen). This process is also enhanced by the lesser amount of energy expended on the beach by southeasterly waves (Fig. 22), allowing more influence by the tidal currents and gyre at that point.

This pattern of sediment movement results in a net beach sediment distribution as suggested by McMaster (1960). The nodal zone, located 3/4 miles west of Matunuck Point (Fig. 24) is a feature not only of the beach but also of the immediate nearshore zone (less than 12 feet of water) and is produced in response to long-term sediment movement.

Thus sediment moved off the beach foreshore by erosion east of the beach-nearshore nodal zone during flood tide is transported westward by nearshore currents (Fig. 24 and 25). During ebb tide, these sediments probably move eastward around Matunuck Point and are deposited against the permeable Jerusalem Breakwater (Fig. 23 and 26; McMaster, 1960). Trask (1955) has shown through tracer studies that active sediment by-passing does occur around headlands provided water depth

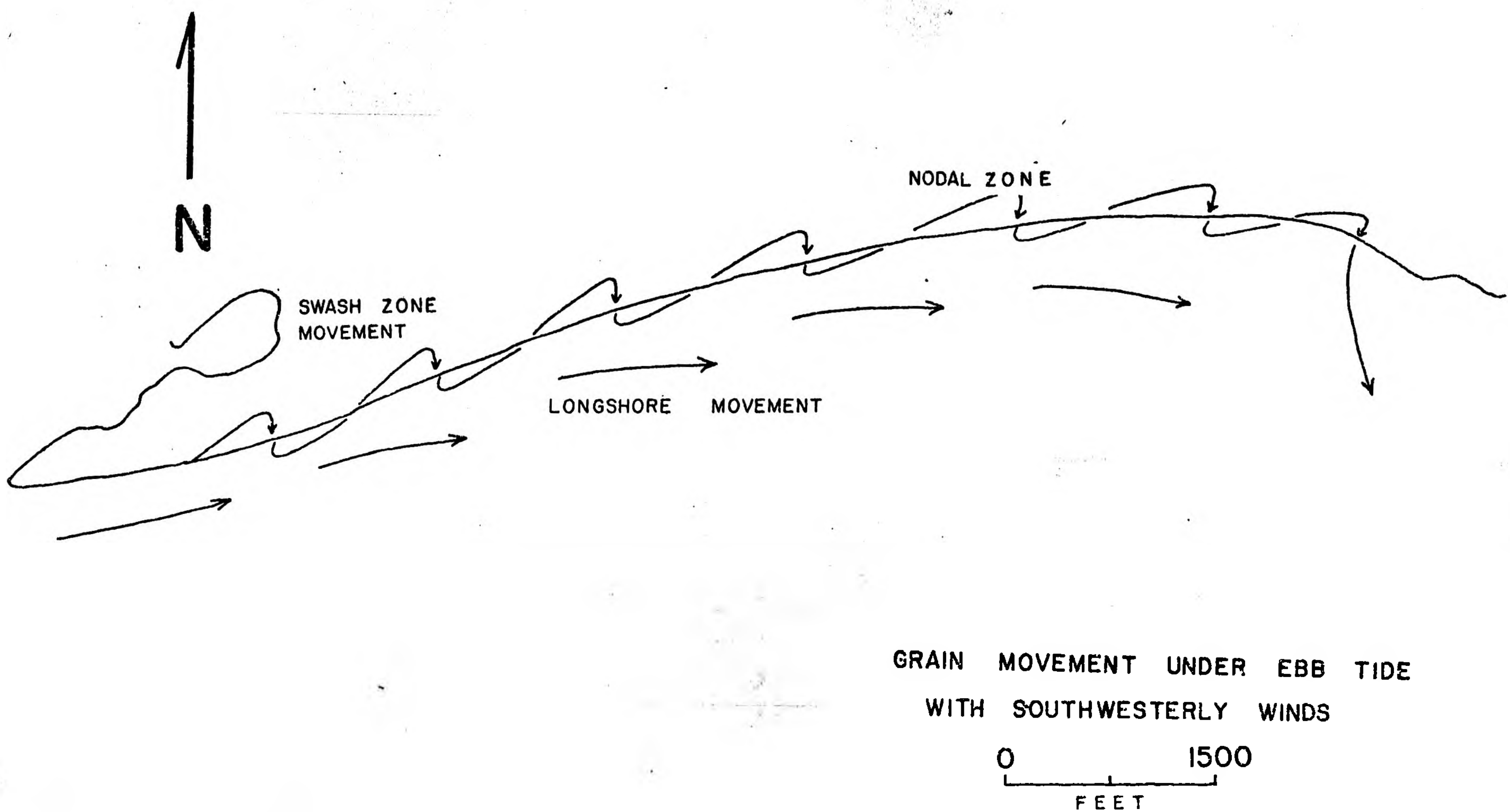


Fig. 26. Depicts hypothetical movement of one grain with beach and nearshore transport in same direction.

does not exceed 30 feet. This situation exists off Matunuck Point, and the process can account for the sand presently being deposited at the breakwater.

Seasonal Changes In Beach Profiles

A cycle of accretion and erosion is evident on the beaches within the study area. A gross seasonal summer-winter cycle as reported by Bascom (1964) and a shorter duration storm cycle that occurs during the summer cycle and is in response to local coastal storms in the area exist. During the storm cycle the beaches take on a profile similar to the winter profile of the same beaches.

Winter-Summer Cycle: The most marked change in the profile data between winter and summer is the retreat of the step shoreward and a subsequent steepening of the beach face during winter storms. Steepening is due to the addition of material high on the beach face by storm waves, and removal of material from the lower beach face.

During fair weather some of the upper, storm-built portion of the beach face is removed and deposited at the step. This is accomplished by the cutting of a scarp, calving of the material, and its redistribution down the beach face by swash and backwash to be later transported along the shore by nearshore currents.

In general, fair weather conditions during spring and summer months, barring storms, apparently produces the standard summer profile of Bascom (1964) with a gentle beach-face slope.

Storm Cycle: The storm cycle is best exemplified by the April profile in Figures 17 through 20. This profile is not as steep as the February profile, yet it is steeper than the June profiles and represents an intermediate profile between the winter and summer profiles. Duration of coastal storms during the spring and summer is two or three days at most. Hurricanes occurring during August and September have a longer duration, but they are not local storms.

Build-Up Near Matunuck Point: Profile 7 (Fig. 20) is interesting in that this beach acts in the reverse of the other beaches in the study region. The cycle here is a building out during the winter and a retreating during summer. This can be explained by suggesting that the large volume of material carried eastward by short-duration, high-intensity southwesterly storms is deposited on the weather side of the point in quantities greater than can be removed by seaward currents in the area (Fig. 14). During fair weather, when less material is transported eastward along the beach because of smaller waves and the resulting decrease in energy material impounded on the western side of Matunuck Point is taken offshore by the local nearshore currents.

Source

The source area for the beaches in the region of study probably contains till from the Narragansett Basin ice. This premise is based on the high percentage of garnet and black opaques found in the heavy mineral splits of the samples selected for the hydraulic equivalence study.

Because the net nearshore transport is westward, the source must be east of the study region. This limits the area for the source to Matunuck Point, the offshore of Point Judith, or off the mouth of Narragansett Bay where possibly low hills of the Harbor Hill (Charlestown) Moraine or the Ronkonkoma Moraine exist.

CONCLUSIONS

1. In the vicinity of Matunuck Point, shoreline processes at work on the beach foreshore and in the nearshore zone are generally similar to those processes operating along the shore in other areas.
2. Beach sediment transport results from refracted waves breaking on the shore and wind driven currents in the swash zone.
3. McMaster's (1960) beach nodal zone is formed and maintained by refraction of dominant swell.
4. The beaches undergo a cycle of accretion and erosion in response to wave conditions. Beach building occurs during fair weather with erosion taking place in storms. The cycle does not necessarily follow the summer-winter seasons.
5. In the nearshore, tidal currents superimposed on wave induced currents are the primary agents by which sediment is transported along this moderate energy shoreline.
6. A nearshore nodal zone exists about 3/4 miles west of Matunuck Point, immediately seaward of the beach nodal zone in water depths down to at least -12 feet. This zone is developed and sustained by a topographic controlled nearshore circulation pattern.

Just west of Matunuck Point an eastward turning gyre (clockwise) is produced by the direction of wave induced currents during the northwestward flooding tide. Further west, the flow is westward due to the relatively unrefracted predominant southeast waves linked with the westward flooding tide.

7. Within the nodal zone, grain size distribution indicates that winnowing may take place with sediment transport east and west as a result of the circulation pattern.
8. Westward movement of nearshore sediment beyond the nodal zone is confirmed by the orientation of nearshore bedforms and hydraulic equivalence trend.
9. Source materials for this stretch of shoreline are probably derived from the headlands of Matunuck Point and Point Judith during storms, and possibly from Nebraska Shoals located off Green Hill. This is based on the abundance of garnets and black opaques present in the heavy mineral splits of the samples and the presence of similar assemblages in the sediment deposited by the Narragansett Basin ice. Hydraulic equivalence also indicates source to be to the east as the delta value becomes more negative to the west indicating a westward transport of sediment.

APPENDIX A

Explanation of Graphic Measures
Size Data, Bottom Sediment Samples
Size Data, Beach Sediment Samples

Table IV

A Review of Grain Size Parameters
After R.L. Folk, 1968

The graphic parameters obtained from the sieve and pipette analysis data are: The Graphic Mean (M_Z). According to Folk, this is the best graphic measure for determining overall size as it approaches closely the mean when computed by moment methods. The computation is:

$M_Z = (\phi_{16} + \phi_{50} = \phi_{84})/3.$

The Inclusive Graphic Standard Deviation. (σ_I) was used to compute the degree of sorting of the samples. This formula,

$$\frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_{5}}{6.6}$$

was used because it takes in 90% of the distribution, giving a better "overall measure of sorting." The verbal scale used is also that of Folk.

$_I$ under .35ϕ very well sorted

.35 - .50ϕ well sorted

.50 - .71ϕ moderately well sorted

.71 - 1.0ϕ moderately sorted

1.0 - 2.0ϕ poorly sorted

2.0 - 4.0ϕ very poorly sorted

over 4.0ϕ extremely poorly sorted

Skewness, or the measure of asymmetry was computed using Folk's Inclusive Graphic Skewness (SK_I). Again, this measure was used because it covers 90% of the curve, and, according to Folk, most skewness occurs in the "tails" of the curves. This justifies its use over that of Inmann's where only 68% of the curve is used. Symmetrical curves have a skewness of 0.00. An excess of fine material would give a positive skewness, an excess of course material would give negative skewness. Folk's verbal scale for skewness is given below.

SK_I +1.00 to +.30 strongly fine-skewed

+.30 to +.10 fine-skewed

+.10 to -.10 near-symmetrical

-.10 to -.30 coarse-skewed

-.30 to -1.00 strongly coarse-skewed

The peakedness or Kurtosis "measures the ratio between the sorting in the 'tails' of the curve and the sorting in the central portion." Normal curves have a Kurtosis of $K_G = 1.00$. Excessively peaked curves (leptokurtic) have a K_G of less than 1.00. The verbal limits are given below.

K_G under 0.67 very platykurtic

0.67 to 0.90 platykurtic

0.90 to 1.11 mesokurtic

1.11 to 1.50 leptokurtic

1.50 to 3.00 very leptokurtic

over 3.00 extremely leptokurtic

Mathematical limits are from 0.41 to infinity.

Bottom Sediment Sample Size Data

Abbreviations

OS	Offshore (100 feet)
ST	Step
SW	Swash
FS	Foreshore
BS	Backshore

Sample Numbering Code

```
          ┌—indicates distance from MLW up beach
     1 - 300
 stake     distance from mean
number     low water offshore
```

Pre-Storm

SIZE ∅	1 -10 (%)	1 15 (%)	1 100 (%)	1 300 (%)
-2.00	0.00	0.34	0.00	0.00
-1.75	0.00	0.71	0.00	0.00
-1.50	0.00	0.99	0.56	0.00
-1.25	0.50	1.31	0.58	0.00
-1.00	1.03	2.07	1.33	0.00
-0.75	1.49	2.55	1.78	0.00
-0.50	2.23	3.06	2.57	0.00
-0.25	3.35	2.76	2.82	0.00
0.00	4.34	4.52	3.43	0.00
0.25	5.10	5.54	4.43	0.00
0.50	5.84	8.25	5.14	0.00
0.75	7.13	8.82	5.41	0.00
1.00	7.74	10.46	6.00	0.00
1.25	8.86	11.23	7.81	0.01
1.50	9.50	13.80	7.34	0.40
1.75	12.87	9.08	6.57	0.69
2.00	10.65	7.74	7.11	1.31
2.25	5.99	4.74	8.34	3.79
2.50	5.65	1.52	10.52	8.05
2.75	3.16	0.35	10.99	9.22
3.00	2.77	0.09	4.51	9.71
3.25	1.36	0.04	0.93	14.34
3.50	0.31	0.02	0.13	18.03
3.75	0.13	0.01	0.06	10.93
4.00	0.01	0.00	0.01	9.51
4.25	0.00	0.00	1.01	8.09
4.50	0.00	0.00	0.64	5.81
4.75	0.00	0.00	0.00	0.01
M_Z(∅)	1.20	0.85	1.41	3.26
σ_I(∅)	0.99	0.94	1.14	0.67
% Gravel	1.53	5.42	2.47	0.00
% Silt	0.00	0.00	1.65	13.91

SIZE Ø	SAMPLE NUMBER 1 400 (%)	2 -15 (%)	2 -10 (%)	2 50 (%)
-2.00	0.00	0.00	6.89	0.00
-1.75	0.00	0.00	9.34	0.00
-1.50	0.00	0.00	10.47	0.00
-1.25	0.00	0.00	8.00	0.00
-1.00	0.00	0.00	4.89	0.00
-0.75	0.00	0.08	2.55	0.00
-0.50	0.00	0.40	3.11	0.00
-0.25	0.00	1.66	4.39	0.00
0.00	0.00	3.09	4.49	0.00
0.25	0.00	5.52	6.13	0.00
0.50	0.00	8.05	7.69	0.00
0.75	0.00	10.80	8.67	0.00
1.00	0.08	13.10	9.17	0.00
1.25	0.11	15.89	6.02	0.15
1.50	0.88	12.62	4.02	0.11
1.75	1.07	11.75	1.46	0.13
2.00	2.69	8.08	1.12	0.33
2.25	5.03	4.15	0.75	0.54
2.50	8.28	2.59	0.44	1.40
2.75	10.21	1.39	0.28	4.06
3.00	18.26	0.48	0.12	8.64
3.25	22.36	0.14	0.01	11.15
3.50	15.64	0.13	0.00	27.17
3.75	6.80	0.07	0.00	14.68
4.00	4.30	0.00	0.00	11.25
4.25	3.20	0.00	0.00	10.20
4.50	1.09	0.00	0.00	10.13
4.75	0.00	0.00	0.00	0.06
M_Z(Ø)	2.99	1.10	-0.35	3.53
σ_I(Ø)	0.56	0.68	1.21	0.54
% Gravel	0.00	0.00	39.59	0.00
% Silt	4.29	0.00	0.00	20.39

Pre-Storm

SIZE Ø	2 100 (%)	2 300 (%)	2 410 (%)	2 525 (%)
-1.25	0.00	0.01	0.00	0.00
-1.00	0.00	0.08	0.00	0.00
-0.75	0.00	0.10	0.00	0.00
θ0.50	0.00	0.21	0.00	0.00
-0.25	0.00	0.28	0.02	0.15
0.00	0.00	0.11	0.01	0.05
0.25	0.00	0.10	0.05	0.05
0.50	0.05	0.12	0.06	0.11
0.75	0.05	0.12	0.08	0.16
1.00	0.08	0.19	0.15	0.26
1.25	0.12	0.28	0.20	0.52
1.50	0.14	0.32	0.24	0.52
1.75	0.21	0.44	0.33	0.64
2.00	0.46	0.95	0.65	0.95
2.25	0.70	1.26	1.05	1.26
2.50	2.09	3.02	2.89	2.71
2.75	4.99	6.45	5.76	6.00
3.00	10.15	12.91	12.19	10.95
3.25	14.82	13.93	15.50	16.15
3/50	32.95	29.38	31.75	30.38
3.75	15.96	13.82	14.25	13.69
4.00	9.55	9.55	8.71	9.05
4.25	7.68	6.37	6.12	6.40
M_Z (Ø)	3.11	3.29	3.30	3.29
σ_I (Ø)	0.45	0.51	0.47	0.50
% Gravel	0.00	0.09	0.00	0.00
% Silt	0.05	6.37	6.11	6.40

Pre-Storm

SIZE Ø	SAMPLE NUMBER 2 600 (%)	4 -10 (%)	4 15 (%)	4 30 (%)
-3.50	0.00	0.00	6.34	0.00
-3.00	0.00	0.00	12.48	0.00
-2.75	0.00	0.00	5.19	0.00
-2.50	0.00	0.00	5.85	0.00
-2.25	0.00	0.00	5.99	0.00
-2.00	0.00	0.00	9.38	0.00
-1.75	0.00	0.00	5.69	0.97
-1.50	0.00	0.00	7.42	0.73
-1.25	0.00	0.00	6.00	1.87
-1.00	0.00	0.00	5.78	4.37
-0.75	0.00	0.00	6.75	9.10
-0.50	0.00	0.00	5.96	14.87
-0.25	0.08	0.05	5.12	15.58
0.00	0.04	0.02	4.82	17.71
0.25	0.07	0.05	3.60	13.55
0.50	0.09	0.11	1.75	7.92
0.75	0.11	0.27	0.86	4.03
1.00	0.19	0.79	0.46	2.15
1.25	0.20	2.32	0.20	1.53
1.50	0.21	3.01	0.10	0.78
1.75	0.28	5.76	0.06	0.83
2.00	0.45	8.42	0.05	0.84
2.25	0.58	9.68	0.05	0.78
2.50	0.70	16.36	0.03	0.95
2.75	4.79	18.94	0.03	0.77
3.00	12.96	18.97	0.02	0.44

Pre-Storm

SIZE Ø	2 600 (%)	4 -10 (%)	4 15 (%)	4 30 (%)
3.25	17.71	9.90	0.01	0.09
3.50	33.29	4.68	0.01	0.07
3.75	13.57	0.24	0.00	0.01
4.00	7.92	0.42	0.00	0.02
4.25	5.76	0.01	0.00	0.04
M_Z(Ø)	3.31	2.41	-2.01	-0.19
σ_I(Ø)	0.43	0.57	1.18	0.70
% Gravel	0.00	0.00	76.87	7.94
% Silt	5.76	0.00	0.00	0.04

Pre-Storm

SIZE Ø	SAMPLE NUMBER 4 90 (%)	4 200 (%)	4 325 (%)	4 400 (%)
-0.25	0.49	0.00	0.02	0.12
0.00	0.98	0.00	0.07	0.16
0.25	1.77	0.09	0.34	0.37
0.50	2.38	0.18	0.50	0.53
0.75	3.86	0.21	0.86	0.90
1.00	6.21	0.38	1.79	1.83
1.25	7.64	0.64	4.15	4.54
1.50	7.14	1.01	6.26	6.77
1.75	8.78	1.98	10.45	11.33
2.00	11.14	4.59	14.92	14.31
2.25	9.88	7.03	11.53	12.08
2.50	13.52	14.65	14.92	12.92
2.75	11.91	15.93	10.73	9.83
3.00	10.08	24.94	13.07	12.18
3.25	3.30	18.07	6.70	6.68
3.50	0.80	9.09	3.19	3.99
3.75	0.03	0.71	0.24	0.62
4.00	0.07	0.47	0.22	0.48
4.25	0.01	0.03	0.05	0.36
M_Z(Ø)	1.90	2.73	2.45	2.21
σ_I(Ø)	0.81	0.48	0.66	0.69
% Gravel	0.00	0.00	0.00	0.00
% Silt	0.01	0.03	0.01	0.36

Pre-Storm

SIZE Ø	SAMPLE NUMBER 4 550 (%)	6 -10 (%)	6 10 (%)	6 15 (%)
-3.50	0.00	0.00	0.00	3.11
-3.00	0.00	2.36	0.00	2.30
-2.75	0.00	1.24	0.77	0.66
-2.50	0.00	2.92	1.40	2.00
-2.25	0.00	1.47	2.63	1.51
-2.00	0.00	1.65	1.54	2.06
-1.75	0.00	1.56	0.48	1.41
-1.50	0.00	2.47	1.12	2.31
-1.25	0.00	2.23	0.89	2.10
-1.00	0.00	2.55	1.36	3.14
-0.75	0.00	2.99	2.11	4.71
-0.50	0.00	3.25	3.03	6.94
-0.25	0.00	2.87	4.22	9.68
0.00	0.08	3.19	8.75	14.78
0.25	0.08	2.81	14.01	15.68
0.50	0.09	2.06	16.26	11.63
0.75	0.09	1.70	15.19	6.99
1.00	0.29	3.50	10.99	4.12
1.25	0.32	8.86	11.15	2.34
1.50	0.59	10.14	2.06	0.52
1.75	1.12	9.24	0.64	0.21
2.00	2.02	6.57	0.25	0.18
2.25	2.19	5.19	0.16	0.14
2.50	5.44	5.21	0.21	0.30
2.75	7.80	8.26	0.38	0.38
3.00	15.93	4.56	0.26	0.32
3.25	15.67	0.90	0.06	0.13
3.50	18.39	0.20	0.04	0.05
3.75	8.77	0.02	0.03	0.00
4.00	7.14	0.01	0.01	0.00
4.25	7.00	0.00	0.00	0.00

Pre-Storm

SIZE	SAMPLE NUMBER			
Ø	4 550 (%)	6 -10 (%)	6 10 (%)	6 15 (%)
4.50	5.41	0.00	0.00	0.00
4.75	1.58	0.00	0.00	0.00
M_Z(Ø)	3.25	0.83	0.30	-0.60
σ_I(Ø)	0.68	1.73	0.88	1.09
% Gravel	0.00	17.98	10.19	25.31
% Silt	13.99	0.00	0.00	0.00

Pre-Storm

SIZE ø	SAMPLE NUMBER 6 35 (%)	6 50 (%)	6 100 (%)	6 200 (%)
-3.50	1.96	0.00	0.00	0.00
-3.00	1.45	5.11	0.00	0.00
-2.75	0.67	2.64	0.00	0.00
-2.50	0.73	3.78	0.00	0.00
-2.25	0.84	2.22	0.00	0.00
-2.00	1.60	3.17	0.76	0.00
-1.75	1.07	2.22	1.11	0.00
-1.50	1.32	3.74	1.18	0.00
-1.25	1.36	2.59	0.73	0.00
-1.00	1.71	2.66	1.20	0.00
-0.75	1.54	3.49	1.96	0.00
-0.50	3.14	3.63	2.40	0.00
-0.25	5.36	3.60	2.79	0.02
0.00	9.32	4.12	3.36	0.04
0.25	13.83	4.05	3.27	0.09
0.50	14.84	4.01	2.95	0.29
0.75	11.83	4.25	2.89	0.88
1.00	8.68	4.86	2.79	2.38
1.25	6.73	7.14	3.83	6.71
1.50	2.66	5.45	3.46	7.78
1.75	2.05	6.06	5.30	11.92
2.00	1.19	5.17	6.81	13.64
2.25	0.55	4.27	7.66	11.74
2.50	0.69	3.68	10.78	12.78
2.75	1.00	3.35	14.89	14.73
3.00	1.69	2.20	11.18	10.75
3.25	1.03	0.86	4.93	4.51
3.50	0.77	0.68	2.22	1.41

Pre-Storm

SIZE	SAMPLE NUMBER			
Ø	6 35 (%)	6 50 (%)	6 100 (%)	6 200 (%)
4.00	0.19	0.21	0.61	0.16
4.25	0.12	0.56	0.71	0.08
M_Z (Ø)	0.02	0.89	1.66	2.11
σ_I (Ø)	1.17	1.08	1.33	0.64
% Gravel	14.25	28.13	4.98	0.00
% Silt	0.00	0.00	0.71	0.08

Pre-Storm

SIZE	SAMPLE	NUMBER	
ø	6 300 (%)	6 550 (%)	6 650 (%)
-2.50	0.00	0.00	1.87
-2.25	0.00	0.00	0.59
-2.00	0.00	0.00	0.16
-1.75	0.00	0.00	0.60
-1.50	0.00	0.00	0.26
-1.25	0.00	0.00	0.22
-1.00	0.00	0.00	0.24
-0.75	0.00	0.00	0.19
-0.50	0.00	0.00	0.36
-0.25	0.00	0.00	0.20
0.00	0.06	0.00	0.39
0.25	0.04	0.00	0.40
0.50	0.12	0.00	0.66
0.75	0.37	0.09	1.79
1.00	1.14	0.61	5.09
1.25	3.70	0.81	12.82
1.50	5.17	1.76	16.69
1.75	10.40	3.80	18.61
2.00	14.90	6.64	12.43
2.25	14.60	8.50	7.23
2.50	10.50	16.32	7.32
2.75	25.60	22.18	7.02
3.00	9.86	21.64	3.55
3.25	2.57	10.21	0.79
3.50	0.63	4.95	0.30
3.75	0.08	0.41	0.08
4.00	0.14	1.36	0.06
4.25	0.09	0.72	0.08

Pre-Storm

	SAMPLE NUMBER		
	6 300 (%)	6 550 (%)	6 650 (%)
M_Z (Ø)	2.20	2.58	1.67
σ_I (Ø)	0.54	0.51	0.75
% Gravel	0.00	0.00	3.94
% Silt	0.00	0.72	0.08

Post-Storm

SIZE ø	1 20 (%)	1 100 (%)	1 200 (%)	2 10 (%)
	SAMPLE NUMBER			
-6.00	0.00	0.00	0.00	23.60
-5.00	0.00	0.00	0.00	24.24
-4.50	0.00	0.00	0.00	24.57
-4.00	0.00	0.00	0.00	20.95
-3.50	0.00	0.00	0.00	3.89
-3.00	0.00	0.00	0.00	2.16
-2.75	0.00	0.00	0.00	0.42
-2.50	0.00	0.00	0.00	0.12
-2.25	40.15	0.00	0.00	0.04
-2.00	18.08	0.00	0.00	0.02
-1.75	9.17	0.00	0.00	0.01
-1.50	7.18	0.00	0.00	0.00
-1.25	8.65	0.12	0.00	0.00
-1.00	8.18	0.83	0.00	0.00
-0.75	3.37	2.03	0.00	0.00
-0.50	2.97	5.06	0.00	0.00
-0.25	0.93	6.47	0.00	0.00
0.00	0.75	8.59	0.00	0.00
0.25	0.56	11.50	0.35	0.00
0.50	0.01	13.85	0.86	0.00
0.75	0.00	12.77	0.93	0.00
1.00	0.00	11.09	1.15	0.00
1.25	0.00	8.60	1.78	0.00
1.50	0.00	5.42	3.06	0.00
1.75	0.00	5.09	5.29	0.00
2.00	0.00	3.56	6.61	0.00
2.25	0.00	2.03	7.74	0.00
2.50	0.00	1.18	8.99	0.00
2.75	0.00	0.80	11.73	0.00
3.00	0.00	0.53	15.61	0.00

Post-Storm

SIZE Ø	SAMPLE NUMBER 1 20 (%)	1 100 (%)	1 200 (%)	2 10 (%)
3.25	0.00	0.29	17.81	0.00
3.50	0.00	0.12	8.44	0.00
3.75	0.00	0.05	5.95	0.00
4.00	0.00	0.01	3.64	0.00
4.25	0.00	0.00	0.07	0.00
M_Z (Ø)	-1.91	0.57	2.64	-2.75
σ_I (Ø)	0.56	0.80	0.74	-
% Gravel	91.41	0.95	0.00	100.00
% Silt	0.00	0.00	0.07	0.00

Post-Storm

SIZE	SAMPLE	NUMBER		
Ø	2 50 (%)	2 200 (%)	2 300 (%)	6 10 (%)
-2.75	0.00	0.00	0.00	35.99
-2.50	0.00	0.00	0.00	21.41
-2.25	0.00	0.00	0.00	18.54
-2.00	0.00	0.00	0.00	10.22
-1.75	0.00	0.00	0.00	5.44
-1.50	0.00	0.00	0.00	4.07
-1.25	0.00	0.00	0.00	3.69
-1.00	0.02	0.00	0.00	0.65
-0.75	0.13	0.00	0.00	0.00
-0.50	0.44	0.00	0.00	0.00
-0.25	0.33	0.05	0.00	0.00
0.00	2.01	0.05	0.00	0.00
0.25	5.99	0.11	0.01	0.00
0.50	9.26	0.26	0.05	0.00
0.75	20.66	0.74	0.42	0.00
1.00	22.30	2.22	1.23	0.00
1.25	15.29	2.83	2.35	0.00
1.50	10.21	7.68	2.75	0.00
1.75	6.43	9.05	5.80	0.00
2.00	3.56	15.20	6.97	0.00
2.25	2.14	17.85	10.47	0.00
2.50	0.88	17.97	14.92	0.00
2.75	0.20	11.12	20.41	0.00
3.00	0.09	9.32	16.13	0.00
3.25	0.04	4.40	10.52	0.00
3.50	0.00	1.10	5.10	0.00
3.75	0.00	0.05	1.70	0.00
4.00	0.00	0.00	1.12	0.00
4.25	0.00	0.00	0.05	0.00

Post-Storm

	SAMPLE NUMBER			
	2 50 (%)	2 200 (%)	2 300 (%)	6 10 (%)
M_Z (Ø)	0.92	2.15	2.50	-2.51
σ_I (Ø)	0.52	0.58	0.61	0.43
% Gravel	0.02	0.00	0.00	100.00
% Silt	0.00	0.00	0.05	0.00

Post-Storm

SIZE Ø	SAMPLE NUMBER 6 100 (%)	6 200 (%)	6 300 (%)
-2.75	4.22	0.00	0.00
-2.50	7.41	0.00	0.00
-2.25	14.98	2.18	0.00
-2.00	22.01	3.25	0.00
-1.75	14.17	3.43	0.00
-1.50	12.61	2.65	0.00
-1.25	9.02	4.31	0.00
-1.00	6.59	4.19	0.00
-0.75	3.71	5.12	0.06
-0.50	2.35	5.43	0.50
-0.25	1.54	5.96	0.71
0.00	0.76	6.44	2.72
0.25	0.38	6.78	3.19
0.50	0.23	8.65	3.68
0.75	0.03	10.62	3.82
1.00	0.00	8.62	4.58
1.25	0.00	7.02	5.63
1.50	0.00	5.45	7.96
1.75	0.00	3.43	8.98
2.00	0.00	2.98	10.71
2.25	0.00	1.60	11.28
2.50	0.00	0.76	10.36
2.75	0.00	0.61	8.68
3.00	0.00	0.35	6.27
3.25	0.00	0.11	5.21
3.50	0.00	0.05	4.33
3.75	0.00	0.01	1.26
4.00	0.00	0.00	0.06
4.25	0.00	0.00	0.01
4.50	0.00	0.00	0.03

Post-Storm

	SAMPLE NUMBER		
	6 100 (%)	6 200 (%)	6 300 (%)
$M_Z(\phi)$	-1.89	0.08	1.85
$\sigma_I(\phi)$	0.60	1.21	0.98
% Gravel	91.01	20.01	0.00
% Silt	0.00	0.00	0.04

Beach Samples 4-14-74

SIZE	SAMPLE NUMBER			
Ø	1 SW (%)	2 SW (%)	3 SW (%)	4 SW (%)
-1.75	0.15	0.05	0.00	0.33
-1.50	0.10	0.00	0.07	0.19
-1.25	0.21	0.00	0.03	0.11
-1.00	0.34	0.05	0.13	0.28
-0.75	0.33	0.13	0.39	0.57
-0.50	0.83	0.32	3.38	1.86
-0.25	2.63	0.64	13.61	6.15
0.00	6.73	1.54	29.63	15.55
0.25	9.59	3.25	23.13	22.62
0.50	11.42	5.68	12.04	19.55
0.75	11.69	8.75	7.08	12.67
1.00	11.96	11.82	5.19	8.94
1.25	13.47	16.15	3.34	5.92
1.50	8.86	12.18	1.10	2.29
1.75	9.29	15.08	0.60	1.56
2.00	4.56	9.94	0.22	0.68
2.25	3.74	6.45	0.07	0.36
2.50	2.17	4.49	0.02	0.13
2.75	1.53	2.34	0.01	0.07
3.00	0.19	0.59	0.01	0.03
3.25	0.10	0.24	0.00	0.01
3.50	0.02	0.11	0.00	0.00
3.75	0.00	0.08	0.00	0.00
4.00	0.00	0.01	0.00	0.00
M_Z (Ø)	0.88	1.29	0.10	0.33
σ_I (Ø)	0.75	0.67	0.44	0.51
% Gravel	0.80	0.12	0.24	0.93
% Silt	0.00	0.00	0.00	0.00

Beach Samples 4-14-74

SIZE ϕ	5 SW (%)	6 SW (%)	7 SW (%)	1 FS (%)
	SAMPLE NUMBER			
-2.00	0.31	0.00	0.00	0.00
-1.75	0.19	0.00	0.00	0.00
-1.50	0.25	0.02	0.00	0.06
-1.25	0.83	0.17	0.01	0.00
-1.00	1.86	0.28	0.07	0.12
-0.75	3.46	0.31	0.48	0.12
-0.50	5.79	3.73	1.53	0.30
-0.25	8.90	5.75	4.01	0.46
0.00	11.92	6.73	10.09	1.20
0.25	11.83	7.78	21.63	3.08
0.50	10.99	9.58	28.86	5.36
0.75	10.15	10.16	18.54	7.16
1.00	9.65	11.99	8.53	10.16
1.25	9.44	14.79	3.74	16.47
1.50	4.73	10.21	1.15	14.51
1.75	4.31	10.16	0.72	18.38
2.00	1.95	5.43	0.32	10.32
2.25	1.74	1.54	0.14	5.51
2.50	0.83	0.90	0.06	3.28
2.75	0.47	0.30	0.04	1.83
3.00	0.17	0.09	0.00	0.91
3.25	0.08	0.00	0.00	0.39
3.50	0.02	0.00	0.00	0.25
3.75	0.01	0.00	0.00	0.11
4.00	0.00	0.00	0.00	0.02
$M_Z(\phi)$	0.38	0.80	0.36	1.31
$\sigma_I(\phi)$	0.81	0.76	0.40	0.63
% Gravel	3.45	0.48	0.09	0.18
% Silt	0.00	0.00	0.00	0.00

Beach Samples 4-14-74

SIZE Ø	SAMPLE NUMBER 2 FS (%)	3 FS (%)	4 FS (%)	5 FS (%)
-2.00	0.60	0.00	0.00	0.00
-1.75	1.35	0.00	0.34	0.62
-1.50	2.99	0.00	0.27	2.21
-1.25	6.28	0.00	0.13	3.86
-1.00	12.59	0.18	0.35	7.27
-0.75	11.76	0.13	0.34	11.10
-0.50	7.82	0.35	0.48	13.40
-0.25	4.68	0.71	0.83	14.24
0.00	4.46	1.50	1.53	13.55
0.25	3.05	2.29	4.23	10.21
0.50	3.07	3.19	8.91	6.39
0.75	2.85	5.71	12.46	4.20
1.00	3.15	9.39	13.26	3.15
1.25	3.36	15.48	16.07	2.22
1.50	3.93	12.35	10.18	1.34
1.75	5.18	16.45	11.58	1.66
2.00	4.80	12.98	7.43	1.33
2.25	4.96	7.14	5.12	1.12
2.50	5.22	6.29	3.76	1.05
2.75	4.03	4.67	1.78	0.74
3.00	2.81	1.11	0.73	0.29
3.25	0.71	0.08	0.23	0.06
3.50	0.29	0.00	0.00	0.00
3.75	0.06	0.00	0.00	0.00
4.00	0.01	0.00	0.00	0.00
M_Z(Ø)	0.27	1.46	1.14	-0.23
σ_I(Ø)	1.45	0.68	0.70	0.84
% Gravel	23.81	0.18	1.09	13.96
% Silt	0.00	0.00	0.00	0.00

Beach Samples 4-14-74

SIZE	SAMPLE NUMBER			
Ø	6 FS (%)	7 FS (%)	1 BS (%)	2 BS (%)
-1.75	0.00	0.00	0.00	0.24
-1.50	0.00	0.00	0.00	0.11
-1.25	0.00	0.00	0.00	0.39
-1.00	0.00	0.00	0.00	0.79
-0.75	0.11	0.09	0.00	1.59
-0.50	0.16	0.20	0.00	2.93
-0.25	0.53	0.76	0.08	5.36
0.00	1.04	2.06	0.88	9.37
0.25	2.50	5.05	3.70	12.66
0.50	5.47	12.37	7.55	14.02
0.75	11.07	20.50	10.45	12.50
1.00	14.49	22.35	14.78	11.69
1.25	20.01	17.85	20.00	9.53
1.50	12.61	8.01	15.10	5.45
1.75	14.16	6.26	15.42	5.16
2.00	8.62	2.53	6.41	2.76
2.25	5.23	1.17	3.05	2.01
2.50	2.62	0.62	1.50	1.65
2.75	0.95	0.10	0.90	1.21
3.00	0.34	0.07	0.19	0.39
3.25	0.11	0.00	0.00	0.19
M_Z(Ø)	1.21	0.86	1.14	0.60
σ_I(Ø)	0.58	0.48	0.55	0.78
% Gravel	0.00	0.00	0.00	1.53
% Silt	0.00	0.00	0.00	0.00

Beach Samples 4-14-74

SIZE ϕ	3 BS (%)	4 BS (%)	5 BS (%)	6 BS (%)
	SAMPLE NUMBER			
-2.00	0.00	0.23	0.00	0.00
-1.75	0.00	0.79	0.00	0.29
-1.50	0.00	0.88	0.51	0.85
-1.25	0.00	1.84	0.64	0.85
-1.00	0.00	3.21	1.26	2.01
-0.75	0.00	6.18	2.74	3.96
-0.50	0.60	8.22	5.05	5.75
-0.25	1.50	10.91	6.94	7.50
0.00	3.11	12.45	11.48	11.77
0.25	5.95	11.45	15.57	13.31
0.50	8.96	9.23	15.43	13.56
0.75	11.31	7.18	12.61	12.09
1.00	12.69	6.46	10.06	11.31
1.25	16.03	6.49	8.92	8.42
1.50	11.56	4.14	3.99	3.99
1.75	12.98	3.97	2.81	2.48
2.00	7.75	2.26	1.12	0.99
2.25	3.52	1.77	0.49	0.42
2.50	2.62	1.17	0.21	0.24
2.75	1.21	0.85	0.11	0.18
3.00	0.12	0.27	0.08	0.04
3.25	0.07	0.06	0.00	0.00
3.50	0.01	0.00	0.00	0.00
$M_Z(\phi)$	1.07	0.22	0.37	0.31
$\sigma_I(\phi)$	0.67	0.93	0.68	0.73
% Gravel	0.00	6.95	2.41	4.00
% Silt	0.00	0.00	0.00	0.00

Beach Samples 4-14-74

SIZE	SAMPLE NUMBER			
Ø	7 BS (%)	2 ST (%)	4 ST (%)	5 ST (%)
-2.75	0.00	0.00	0.77	0.00
-2.50	0.00	1.89	1.41	0.00
-2.25	0.00	0.60	2.65	0.00
-2.00	0.00	0.16	1.55	0.00
-1.75	0.00	0.61	0.48	0.95
-1.50	0.00	0.26	1.13	1.95
-1.25	0.00	0.22	0.90	5.67
-1.00	0.00	0.24	1.37	13.74
-0.75	0.28	0.19	2.12	19.69
-0.50	0.41	0.37	3.05	15.06
-0.25	0.58	0.21	3.54	9.41
0.00	2.72	0.39	8.82	7.07
0.25	6.06	0.40	14.12	4.22
0.50	10.84	0.67	16.39	2.90
0.75	15.81	1.81	15.30	2.34
1.00	18.16	5.14	11.07	3.01
1.25	22.17	12.94	11.23	3.63
1.50	11.36	16.85	2.08	2.57
1.75	8.19	18.77	0.66	2.86
2.00	2.29	12.54	0.26	1.93
2.25	0.81	7.29	0.16	1.26
2.50	0.24	7.38	0.21	0.90
2.75	0.07	7.08	0.38	0.59
3.00	0.00	2.56	0.26	0.20
3.25	0.00	0.79	0.06	0.02
3.50	0.00	0.30	0.03	0.01
3.75	0.00	0.08	0.02	0.00
4.00	0.00	0.06	0.01	0.00
4.25	0.00	0.03	0.00	0.00
4.50	0.00	0.02	0.00	0.00

Beach Samples 4-14-74

SIZE	SAMPLE NUMBER			
Ø	7 BS (%)	2 ST (%)	4 ST (%)	5 ST (%)
M_Z(Ø)	0.91	1.66	0.30	-0.30
σ_I(Ø)	0.51	0.74	0.88	0.96
% Gravel	0.00	3.98	10.26	22.31
% Silt	0.00	0.05	0.00	0.00

Beach Samples 4-14-74

SIZE	SAMPLE NUMBER			
Ø	6 ST (%)	2 OS (%)	3 OS (%)	4 OS (%)
-2.75	0.00	0.00	0.00	0.89
-2.50	0.00	0.00	0.00	1.54
-2.25	0.00	0.00	0.00	3.03
-2.00	0.00	0.00	0.00	1.84
-1.75	0.27	0.00	0.16	0.82
-1.50	0.28	0.00	0.10	1.19
-1.25	0.18	0.00	0.20	0.97
-1.00	0.23	0.00	0.37	0.85
-0.75	0.39	0.00	0.34	2.38
-0.50	1.27	0.00	0.94	3.51
-0.25	3.89	0.00	2.75	4.86
0.00	10.76	0.00	6.95	10.02
0.25	35.82	0.00	9.95	16.19
0.50	39.21	0.00	11.74	18.58
0.75	6.51	0.09	12.28	11.88
1.00	0.96	0.62	12.52	11.57
1.25	0.14	0.78	13.89	5.75
1.50	0.04	1.73	8.17	2.20
1.75	0.02	3.85	8.56	0.72
2.00	0.01	6.71	3.55	0.28
2.25	0.02	8.58	3.23	0.24
2.50	0.00	16.06	2.12	0.25
2.75	0.00	22.45	1.61	0.18
3.00	0.00	21.77	0.31	0.11
3.25	0.00	10.26	0.12	0.07
3.50	0.00	4.97	0.07	0.03
3.75	0.00	0.41	0.04	0.02
4.00	0.00	1.22	0.01	0.02
4.25	0.00	0.33	0.00	0.00
4.50	0.00	0.10	0.00	0.00
4.75	0.00	0.07	0.00	0.00

Beach Samples 4-14-74

SIZE $\underline{\phi}$	SAMPLE NUMBER 6 ST (%)	2 OS (%)	3 OS (%)	4 OS (%)
$M_Z(\phi)$	0.22	2.57	0.85	0.19
$\sigma_I(\phi)$	0.26	0.51	0.75	0.89
% Gravel	0.96	0.00	0.83	11.13
% Silt	0.00	0.50	0.00	0.00

Beach Samples 4-14-74

SIZE	SAMPLE NUMBER		
ø	5 OS (%)	6 OS (%)	7 OS (%)
-1.75	0.99	0.26	0.00
-1.50	1.95	0.27	0.00
-1.25	5.07	0.19	0.00
-1.00	13.83	0.22	0.17
-0.75	19.35	0.46	0.12
-0.50	15.66	1.29	0.27
-0.25	8.93	3.66	0.65
-0.00	8.10	10.61	1.23
0.25	4.22	33.82	2.85
0.50	2.90	36.75	3.48
0.75	2.53	7.71	6.34
1.00	3.02	3.45	10.21
1.25	3.64	1.01	15.66
1.50	2.58	0.14	12.51
1.75	2.46	0.09	13.50
2.00	1.97	0.04	12.33
2.25	0.98	0.02	7.35
2.50	0.86	0.01	6.84
2.75	0.62	0.00	4.27
3.00	0.32	0.00	2.00
3.25	0.04	0.00	0.12
3.50	0.01	0.00	0.08
3.75	0.00	0.00	0.01
M_Z(ø)	-0.31	0.23	1.45
σ_I(ø)	0.95	0.29	0.71
% Gravel	21.84	0.94	0.17
% Silt	0.00	0.00	0.00

Beach Samples 4-29-74

SIZE Ø	SAMPLE NUMBER 1 SW (%)	2 SW (%)	2aSW (%)	3 SW (%)
-2.00	0.27	0.00	0.78	1.55
-1.75	0.92	0.00	1.57	2.10
-1.50	0.96	0.00	2.21	2.32
-1.25	0.75	0.00	0.73	2.05
-1.00	1.66	0.00	0.99	2.31
-0.75	2.24	0.00	1.83	1.58
-0.50	2.74	0.00	4.49	1.47
-0.25	2.82	3.35	7.68	2.39
0.00	3.43	3.49	8.77	3.54
0.25	2.81	4.99	7.19	4.71
0.50	2.11	8.02	6.26	5.69
0.75	1.64	12.50	5.91	6.87
1.00	2.13	15.90	6.66	7.03
1.25	3.74	17.92	7.82	9.61
1.50	5.71	9.85	5.65	7.75
1.75	11.88	8.31	7.06	11.16
2.00	14.12	5.42	5.81	9.19
2.25	14.52	3.31	5.64	6.87
2.50	11.70	2.45	5.64	5.48
2.75	7.96	2.30	4.23	3.90
3.00	4.26	1.49	2.39	1.90
3.25	1.20	0.53	0.45	0.48
3.50	0.36	0.15	0.14	0.07
3.75	0.03	0.02	0.03	0.01
4.00	0.00	0.00	0.02	0.00
4.25	0.00	0.00	0.04	0.00
M_Z(Ø)	1.43	1.05	0.84	1.01
σ_I(Ø)	1.18	0.73	1.23	1.22
% Gravel	4.59	0.00	6.27	10.32
% Silt	0.00	0.00	0.04	0.00

Beach Samples 4-29-74

SIZE	SAMPLE NUMBER			
Ø	4 SW (%)	5 SW (%)	6 SW (%)	7 SW (%)
-2.00	0.00	5.11	0.00	0.00
-1.75	0.94	7.67	0.00	0.27
-1.50	1.95	22.12	0.00	0.28
-1.25	5.66	24.01	0.00	0.18
-1.00	13.71	20.88	0.00	0.23
-0.75	19.65	13.48	0.00	0.39
-0.50	15.03	4.51	0.07	1.27
-0.25	9.40	1.08	1.36	3.89
0.00	7.06	0.32	2.42	10.76
0.25	4.22	0.15	4.58	35.82
0.50	2.89	0.05	4.96	39.21
0.75	2.52	0.05	5.55	6.51
1.00	3.01	0.04	7.16	0.96
1.25	3.63	0.03	10.60	0.14
1.50	2.57	0.03	10.41	0.04
1.75	2.85	0.03	15.49	0.02
2.00	1.93	0.02	13.89	0.01
2.25	1.26	0.01	10.76	0.02
2.50	0.89	0.00	8.15	0.00
2.75	0.59	0.00	2.86	0.00
3.00	0.20	0.00	1.34	0.00
3.25	0.02	0.00	0.21	0.00
3.50	0.01	0.00	0.13	0.00
3.75	0.00	0.00	0.03	0.00
4.00	0.00	0.00	0.01	0.00
M_Z(Ø)	-0.30	-1.33	1.45	0.22
σ_I(Ø)	0.96	0.40	0.76	0.26
% Gravel	22.27	79.78	0.00	0.96
% Silt	0.00	0.00	0.00	0.00

Beach Samples 4-29-74

SIZE	SAMPLE NUMBER			
Ø/	3 FS (%)	4 FS (%)	5 FS (%)	6 FS (%)
-1.00	0.54	0.00	0.00	0.00
-0.75	0.83	0.00	0.00	0.00
-0.50	1.36	0.00	0.00	0.00
-0.25	2.88	0.55	0.77	0.08
0.00	3.08	0.87	2.48	0.11
0.25	3.39	1.27	6.70	0.20
0.50	5.54	1.84	10.09	0.45
0.75	7.54	2.76	11.05	0.88
1.00	11.92	5.17	10.48	2.41
1.25	15.16	10.73	12.09	7.48
1.50	12.95	11.77	9.43	10.62
1.75	14.89	17.77	12.61	21.48
2.00	8.66	15.96	9.25	20.91
2.25	5.54	12.19	6.81	15.96
2.50	3.21	9.86	4.27	10.51
2.75	1.81	5.22	2.71	6.44
3.00	0.67	3.16	0.79	2.30
3.25	0.04	0.65	0.43	0.23
3.50	0.00	0.20	0.05	0.00
M_Z(Ø)	1.17	1.71	1.18	1.84
σ_I(Ø)	0.75	0.64	0.75	0.49
% Gravel	0.54	0.00	0.00	0.00
% Silt	0.00	0.00	0.00	0.00

Beach Samples 4-29-74

SIZE ϕ	1 OS (%)	2 OS (%)	3 OS (%)	4 OS (%)
-1.00	0.00	0.09	0.00	0.02
-0.75	0.00	10.46	0.00	0.09
-0.50	0.00	16.48	0.00	0.11
-0.25	0.07	18.70	0.08	0.20
0.00	0.17	16.39	0.04	0.15
0.25	0.25	10.33	0.19	0.38
0.50	0.51	5.02	0.83	1.13
0.75	1.10	2.85	2.71	3.67
1.00	2.20	1.98	6.68	9.44
1.25	4.27	1.93	12.64	20.55
1.50	4.89	1.31	12.58	17.83
1.75	7.80	1.66	15.37	20.29
2.00	7.83	1.80	10.20	10.45
2.25	8.25	1.21	9.78	5.08
2.50	11.91	2.26	10.46	4.65
2.75	16.47	2.47	8.17	2.30
3.00	17.03	2.00	7.73	2.49
3.25	10.09	1.50	1.91	1.79
3.50	4.65	1.20	0.45	0.34
3.75	1.59	0.83	0.08	0.01
4.00	0.40	0.50	0.06	0.01
4.25	0.32	0.12	0.05	0.02
4.50	0.21	0.07	0.00	0.00
4.75	0.00	0.05	0.00	0.00
5.00	0.00	0.01	0.00	0.00
$M_Z(\phi)$	2.37	0.12	1.80	1.48
$\sigma_I(\phi)$	0.72	1.02	0.69	0.54
% Gravel	0.00	0.09	0.00	0.02
% Silt	0.53	0.25	0.05	0.02

Beach Samples 4-29-74

SIZE Ø	SAMPLE NUMBER 5 OS (%)
-1.75	11.25
-1.50	19.54
-1.25	12.09
-1.00	7.90
-0.75	10.61
-0.50	8.36
-0.25	5.33
0.00	3.63
0.25	2.08
0.50	1.41
0.75	1.28
1.00	1.44
1.25	1.73
1.50	1.21
1.75	1.74
2.00	1.87
2.25	1.44
2.50	1.71
2.75	1.59
3.00	1.37
3.25	0.99
3.50	0.72
3.75	0.33
4.00	0.11
4.25	0.09
4.50	0.05
4.75	0.01
M_z (Ø)	-0.81
σ_I (Ø)	0.73
% Gravel	50.79
% Silt	0.15

Table V

Skewness Value For Samples

Sample	Skewness		Sample	Skewness	
1 -10	-0.15	10-19-73	6 200	-0.06	
1 15	-0.24		6 300	-0.15	
1 100	-0.19		6 550	-0.16	
1 300	-0.05		6 650	-0.01	
1 400	-0.10		1 20	0.55	2-15-74
2 -15	-0.02		1 100	0.09	
2 -10	-0.09		1 200	-0.26	
2 50	0.11		2 10	0.31	
2 100	-0.05		2 50	0.13	
2 300	-0.15		2 200	-0.06	
2 410	-0.11		2 300	-0.18	
2 525	-0.15		6 10	0.37	
2 600	-0.06		6 100	0.24	
4 -10	-0.22		6 200	-0.19	
4 15	0.08		6 300	-0.15	
4 30	0.16		1 SW	0.05	4-14-74
4 90	-0.19		2 SW	0.01	
4 200	-0.20		3 SW	0.29	
4 325	-0.05		4 SW	0.16	
4 400	0.01		5 SW	0.06	
4 550	0.03		6 SW	-0.13	
6 -10	-0.40		7 SW	0.03	
6 10	-0.32		1 FS	-0.06	
6 15	-0.41		2 FS	0.37	
6 35	-0.11		3 FS	-0.05	
6 50	-0.26		4 FS	0.07	
6 100	-0.48		5 FS	0.22	

Table V

continued

Sample	Skewness	
6 FS	0.06	
7 FS	0.06	
1 BS	-0.02	
2 BS	0.12	
3 BS	-0.03	
4 BS	0.17	
5 BS	0.03	
6 BS	-0.04	
7 BS	-0.07	
2 ST	-0.02	
4 ST	-0.33	
5 ST	0.49	
6 ST	-0.15	
2 OS	-0.17	
3 OS	0.07	
4 OS	-0.32	
5 OS	0.49	
6 OS	-0.08	
7 OS	0.02	
1 SW	-0.48	4-29-74
2 SW	0.08	
3 SW	-0.26	
4 SW	0.49	
5 SW	0.04	
6 SW	-0.21	
7 SW	-0.15	
3 FS	-0.13	

Sample	Skewness
4 FS	-0.05
5 FS	0.04
6 FS	0.03
1 OS	-0.27
2 OS	0.55
3 OS	0.13
4 OS	0.16
5 OS	0.56

APPENDIX B

Repeat Sample Data Table VI

Replicate Sample Data Table VII

The purpose of these data are to determine the reproduceability of the sampling under similar situations of weather and wave conditions. The samples were taken under non-storm conditions at select transect points to duplicate the first non-storm samples.

The results show that variability is well within one standard deviation, indicating that under similar conditions, sand of a similar mean size will be found in any one particular area at any time. This is dependent not only on wave conditions of that day, but the conditions present during the week prior to sampling.

Also determined was the replicability of samples within a sampling site. Table VII gives the result of these data, indicating that variability within any one sampling site is within one standard deviation.

The data presented here indicates that single composite samples are valid representatives of any site, no matter when taken, as long as wave and weather conditions are similar prior to and during sampling.

Table VI

Repeat Samples, Taken Under

Pre-Storm Or Non-Storm Conditions

Sample	Standard Deviation	Mean Phi
1-100 A	1.14	1.41
B	1.14	1.56
4-200 A	0.48	2.73
B	0.50	2.89
4-325 A	0.66	2.45
B	0.63	2.47
6-200 A	0.64	2.11
B	0.69	2.43

Raw data for repeat samples follows

SIZE	SAMPLE NUMBER			
∅	1 100 (%)	4 200 (%)	4 325 (%)	6 200 (%)
-2.25	0.50	0.00	0.00	0.00
-2.00	0.62	0.00	0.00	0.00
-1.75	0.79	0.00	0.00	0.00
-1.50	1.58	0.00	0.00	0.00
-1.25	1.66	0.00	0.00	0.00
-1.00	1.93	0.00	0.00	0.00
-0.75	2.51	0.00	0.00	0.00
-0.50	3.43	0.00	0.00	0.00
-0.25	4.06	0.00	0.02	0.02
0.00	4.83	0.00	0.05	0.04
0.25	6.10	0.11	0.29	0.12
0.50	7.16	0.21	0.52	0.27
0.75	6.95	0.23	0.89	0.76
1.00	7.53	0.37	1.82	2.33
1.25	11.98	0.67	4.33	6.61
1.50	11.45	1.03	6.52	7.83
1.75	10.31	2.21	10.78	11.89
2.00	6.21	4.65	14.57	13.25
2.25	4.90	7.07	11.07	11.87
2.50	1.97	15.67	15.41	12.68
2.75	0.87	16.07	11.12	14.92
3.00	0.31	24.32	13.15	10.90
3.25	0.19	17.79	6.23	4.66
3.50	0.07	8.53	2.86	1.42
3.75	0.05	0.76	0.16	0.17
4.00	0.03	0.44	0.13	0.16
4.25	1.64	0.04	0.06	0.07
4.50	0.39	0.00	0.00	0.00
M_Z (∅)	1.56	2.89	2.47	2.43
σ_I (∅)	1.14	0.50	0.63	0.69
% Gravel	7.08	0.00	0.00	0.00
% Silt	2.03	0.04	0.06	0.07

Table VII

Replicate Sampling, Pre-Storm Conditions

Sample	Standard Deviation	Mean Phi
4- 90 A	0.81	1.90
B	0.91	2.01
6-100 A	1.33	1.66
B	1.28	1.73
4-550 A	0.68	3.25
B	0.67	3.26
2-100 A	0.45	3.11
B	0.56	2.99
1-100 A	1.14	1.41
B	0.81	1.90

Composite samples taken 3 feet from initial sample in Table IV, Appendix A.

A represents Appendix A sample
B represents Appendix B replicate sample

Raw data for replicate samples follows

SIZE	SAMPLE NUMBER			
Ø	4 90 (%)	6 100 (%)	4 550 (%)	2 100 (%)
-1.75	0.00	1.20	0.00	0.00
-1.50	0.00	1.19	0.00	0.00
-1.25	0.00	0.78	0.00	0.00
-1.00	0.00	1.22	0.00	0.00
-0.75	0.00	1.95	0.00	0.00
-0.50	0.00	2.39	0.00	0.00
-0.25	0.42	2.88	0.00	0.00
0.00	0.93	3.30	0.00	0.00
0.25	1.78	3.20	0.00	0.00
0.50	2.39	2.91	0.00	0.00
0.75	3.89	2.83	0.00	0.00
1.00	6.29	2.72	0.00	0.08
1.25	7.67	3.86	0.01	0.11
1.50	7.17	3.50	0.40	0.88
1.75	8.84	5.36	0.69	1.07
2.00	11.20	6.90	1.31	2.69
2.25	9.88	7.80	3.79	5.03
2.50	13.56	10.78	8.05	8.28
2.75	11.88	15.18	9.22	10.21
3.00	9.77	11.99	9.71	18.26
3.25	3.37	4.44	14.34	22.36
3.50	0.86	2.24	18.03	15.64
3.75	0.05	0.31	10.93	6.80
4.00	0.03	0.33	9.51	4.30
4.25	0.01	0.73	8.09	3.20
4.50	0.00	0.00	5.81	1.09
4.75	0.00	0.00	0.01	0.00
M_Z(Ø)	2.01	1.73	3.26	2.99
σ_I(Ø)	0.91	1.28	0.67	0.56
% Gravel	0.00	4.39	0.00	0.00
% Silt	0.01	0.73	13.91	4.29

SIZE ϕ	SAMPLE NUMBER 1 100 (%)
-0.25	0.49
0.00	0.98
0.25	1.77
0.50	2.38
0.75	3.86
1.00	6.21
1.25	7.64
1.50	7.14
1.75	8.78
2.00	11.14
2.25	9.88
2.50	13.52
2.75	11.91
3.00	10.08
3.25	3.30
3.50	0.80
3.75	0.03
4.00	0.07
4.25	0.01
M_Z (ϕ)	1.90
σ_I (ϕ)	0.81
% Gravel	0.00
% Silt	0.00

APPENDIX C

Hydraulic Equivalence Data

Pre-Storm 10-19-73 Table VIII A

Beach Building 4-14-74 Table VIII B

The data for the hydraulic equivalence are presented in the next two tables VIII A and VIII B. The method of Lowright (1973) and Hand (1967) was used as explained in the text. Log values were taken from standard log tables.

The delta value is defined as the log of the median settling velocity of the heavy mineral minus the log of the median settling velocity of the associated light minerals.

TABLE VIIIA

Hydraulic Equivalence Data

Pre-Storm Samples

		Median Settling Velocity cm/sec		Log Value	
Sample Number	Delta Value	Garnet Minerals	Light Minerals	Garnet Minerals	Light Minerals
6 650	.0289	4.35	4.07	.6385	.6096
4 -10	.1931	2.48	1.59	.3945	.2014
6 15	.4610	11.90	10.67	.7550	.2940
4 325	.1512	3.98	2.81	.5999	.4487
4 90	.0267	1.85	1.74	.2672	.2405
1 100	-.0909	1.59	1.96	.2014	.2923
2 300	.0148	0.80	1.19	.0903	.0755
2 600	.0305	0.97	1.17	.0987	.0682
1 50	.0157	0.89	1.20	.0949	.0792

TABLE VIIIB

Hydraulic Equivalence Data

Beach Building Samples

Sample Number	Delta Value	Median Settling Velocity cm/sec Garnet Minerals	Median Settling Velocity cm/sec Light Minerals	Log Value Garnet Minerals	Log Value Light Minerals
2 OS	-.0892	1.00	0.78	.0000	.0892
3 OS	-.0432	1.12	0.84	.0492	.0924
4 OS	.0512	1.53	1.36	.1847	.1335
5 OS	.0702	1.81	1.54	.2577	.1875
6 OS	.0523	2.82	2.50	.4502	.3979
7 OS	.0170	3.92	3.77	.5933	.5763

APPENDIX D

Wave Induced Current Data

Table IX

Shoaling waves approaching a shoreline produce a net shoreward component of velocity at the bottom. The depth to which this velocity acts is dependent upon the ratio of wave height to water depth (H/h). Waves affecting the region of study are placed in the range of solitary wave form, best described as an isolated crest moving in relatively shallow water. Velocity at the bottom under the wave crest is then expressed as:

$$Um = \frac{1}{2} H/h\ C$$

where Um is the maximum shoreward velocity, H/h is the ratio of wave height to water depth, and C is the wave phase velocity expressed as $C = \sqrt{g(H+h)}$. This form holds for $H/h < \frac{1}{4}$. When $H/h > \frac{1}{4}$ the velocity at the bottom is expressed as:

$$Um = 1/3\ H/h\ C$$

This is due to increased drag at the bottom and a return flow from breaking waves.

TABLE IX

A

Mild Conditions

Wave Height 1 foot; Wave Length 6-8 feet; period 3-5 seconds.

Distance From Shore (ft)	10	15	45	85	120	170	185	220
H/h	1/4	1/5	1/7	1/10	1/11	1/14	1/15	1/18
Vel. (ft/sec)	1.58	1.39	1.14	0.94	0.89	0.78	0.75	0.69

$U_m = \frac{1}{2} H/h\ C$

B

Intermediate Conditions

Wave Height 1-3 feet; Wave Length 10-15 feet; Period 4 seconds.

Distance From Shore (ft)	10	15	45	85	120	170	185	220
H/h	1/1		1/2	1/2	1/3		1/6	1/7
Vel. (ft/sec)	4.62		2.67	2.98	2.18		2.11	1.98

$U_m = 1/3\ H/h\ C$ (45–120 ft) $\qquad U_m = \frac{1}{2} H/h\ C$ (185–220 ft)

C

Local Storm Conditions

Wave Height 2-4 feet; Wave Length 10-20 feet; Period 6-8 seconds.

Distance From Shore (ft)	10	45	85	120	145	185	220
H/h	2	1/2	1/3	1/4	1/4	1/5	1/5
Vel. (ft/sec)	9.24	3.12	2.51	3.08	3.24	2.71	2.77

$U_m = 1/3 \; H/h \; C$ $\qquad$ $U_m = \frac{1}{2} \; H/h \; C$

D

Value Of C For Above Computations

$$C = \sqrt{g \; (H+h)}$$

EXA

Distance From Shore (ft)	10	15	45	85	120	170	185	220
C	12.65	13.86		18.76	19.60	21.91	22.63	24.22

D

(continued)

IXB

Distance From Shore (ft)	10	45	85	120	185	220
C	13.86	16.00	17.89	19.60	25.30	27.71

IXC

Distance From Shore (ft)	10	45	85	120	145	185	220
C	13.86	18.76	22.63	24.66	25.92	27.13	27.71

APPENDIX E

Condensed Weather Data

1950 - 1964 & 1966

Table X

SW, W, and NW winds occur 69.59% of the time. NE, SE, S, and N winds 30.41% of the time. Westerly beach drift occurs 1/3 of the time, when it occurs, it reinforces the westward movement caused by tidal forces.

Conversion Of mph To Knots

$$\frac{\text{mph}}{1.15} = \text{Knots}$$

Wave Data

(From U.S. Army Coastal Eng. Res. Center, 1966)

Wind Direction	Duration	Speed	Fetch Distance	Wave Period	Wave Height
SW	8-13 hrs	5-8 mph	27 miles	3.5 sec	2 ft
SW	12-24 hrs	8-12 mph	27 miles	6 sec	5 ft
SE	15-18 hrs	13-17 mph	unknown	6.5 sec	5 ft
*SE	Decaying	Swells	unknown	10 sec	9 ft

*passing Nor'easters

TABLE X

Weather Data

1950 - 1964 & 1966

Direction	Occurrance (%)	Wind Speed (mph) Percent Occurance* 4-8	8-12	12-16
N	12.89	0	72	28
NE	5.15	10	90	0
E	0	0	0	0
SE	2.58	20	80	0
S	9.79	0	78.95	21.05
SW	37.11	9.72	73.61	16.67
W	4.64	0	77.78	22.22
NW	27.84	3.70	72.22	24.08

*percent occurrance indicates percent of time wind was that speed from that direction.

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