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SHORE EFFECT MODEL, ATLANTIC GENERATING STATION

Hydraulic Model Investigation

by

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A distorted-scale hydraulic model investigation was performed to determine the potential effect, if any, of a proposed offshore nuclear power plant on shoreline evolution. Model measurements of current patterns with and without the breakwater were directly compared and measurements of breaking wave characteristics (height, depth, and angle to shoreline) with and without the breakwater were used to calculate and compare longshore transport rates in the potentially affected areas. It was concluded that the proposed construction would have a negligible effect on future shoreline evolution.

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PREFACE

The model investigation reported herein was requested by Public Service Electric and Gas Company (PSE&G) in a letter to the U. S. Army Engineer Waterways Experiment Station (WES) dated 29 June 1972. The investigation was authorized by the Office, Chief of Engineers (OCE), U. S. Army, in the 1st indorsement dated 20 July 1972 to WES letter dated 11 July 1972 and extended in the 1st indorsement dated 5 June 1974 to WES letter dated 16 May 1974. The tests were conducted during the period October 1973 to December 1974 by personnel of the Hydraulics Laboratory (HL), WES, under the general direction of Mr. H. B. Simmons, Chief of HL, and Dr. R. W. Whalin, Chief of the Wave Dynamics Division. The research on the morphology of the inlets was conducted by 1LT J. H. Barwis, and the model tests were conducted by Mr. R. D. Carver, Research Hydraulic Engineer, with the assistance of Messrs. C. Lewis and W. G. Dubose, Engineering Technicians, under the immediate supervision of Mr. D. D. Davidson, Chief of the Wave Research Branch. This report was prepared by Messrs. Carver and Davidson, and Dr. Whalin. 1LT Barwis prepared Appendix A.

Directors of WES during this investigation and the preparation and publication of this report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
square miles (U. S. statute)	2.589988	square kilometres
cubic yards	0.7645549	cubic metres
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
foot-pounds (force)	1.355818	joules
feet per second	0.3048	metres per second
miles per hour	1.609344	kilometres per hour
degrees (angle)	0.01745329	radians

SHORE EFFECT MODEL, ATLANTIC GENERATING STATION

Hydraulic Model Investigation

PART I: INTRODUCTION

The Problem

1. A nuclear power plant is proposed to be located approximately 3 miles* seaward of Little Egg Inlet, New Jersey, at longitude 74°15'20" W and latitude 39°28'20" N (New Jersey coordinate of N 232, 959 ft and E 2, 116, 060 ft). A concern is the effect, if any, of this offshore structure on shoreline evolution in the vicinity of the inlet. Will the breakwater used to protect the power plant alter wave conditions (breaking locations, heights, and angles) near the shoreline, thereby producing a change in the longshore transport rates and causing erosion or accretion of the shoreline? This is a difficult question to answer. It is impossible to answer by purely analytical techniques due to the complicated dynamics of wave, tide, and sediment interaction. Some factors which must be considered are: the existence of caustics in the local wave refraction patterns, the diffraction of wave energy around the breakwater and along the wave crests, and the nonlinear interaction of wave-induced currents and tidal flows.

Geomorphological Evaluation of the Prototype

2. The Beach Haven-Little Egg Inlet area has, since the existence of records, undergone dynamic changes as a result of tidal and wave interaction with the regional longshore transport. It is realized that any type of study to show that the construction of an offshore structure would cause morphology changes over and above those presently being

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

experienced is very difficult. To emphasize the historical configurational changes, a brief morphology study of the inlets was conducted and is presented in Appendix A as background information.

Feasibility Investigation

3. Since all the dynamic problems involved could not be determined analytically, it was felt that the only realistic way to evaluate the potential effects of the proposed power plant was to conduct a distorted-scale hydraulic model investigation. Even a distorted hydraulic model of these phenomena is a state-of-the-art investigation and requires special feasibility considerations. Whalin and Hudson[1] address the feasibility of this model in detail, whereas the next few paragraphs of this report contain only the highlights of the factors affecting the model feasibility. Factors considered in determining the feasibility of such an investigation were:

- a. Wave height attenuation due to viscous friction.
- b. Wave refraction.
- c. Wave diffraction.
- d. Wave reflection.
- e. Wave breaking location and angle to shoreline.
- f. Simulation of tidal flow velocities.

4. Due to the large area of relatively shallow water encompassed by the model, the viscous dissipation of energy at the bottom became an important consideration. If the model had been constructed to an undistorted scale, this excessive energy dissipation would probably have prevented accurate reproduction of wave phenomena. The selection of a horizontal-scale ratio which was numerically larger than the vertical-scale ratio and the scaling of model wave heights and periods by the vertical-scale ratio resulted in a reduction in the energy dissipation due to the relatively shorter propagation distance of the test waves.

5. In a distorted-scale model investigation it is impossible for both wave refraction and diffraction to be properly scaled

simultaneously. Refraction is a function of the relative depth (d/L)* only; therefore, if the wavelength is scaled according to the vertical scale, refraction patterns will be modeled correctly. Diffraction is a function of the ratio of a horizontal distance to the wavelength (X/L); consequently, if the wavelength is scaled according to the horizontal scale, diffraction will be properly modeled. In the investigation under consideration, diffraction around the breakwater is an important effect in the immediate area of the power plant; however, the closer to shore the wave progresses, the less important diffraction effects are and the more important refraction becomes. Since attention was focused on current patterns and wave characteristics near the shoreline, it was most advantageous to model refraction correctly (test waves were modeled on the vertical scale). Even though this induced some errors in the diffraction patterns around the breakwater, construction of diffraction diagrams[1] revealed these errors to be minimal near the shoreline.

6. Two types of wave reflection merited consideration: cumulative reflection from bottom slopes as waves propagated from the area of the power plant to the shoreline, and reflection from the sloping breakwater. Calculations using the theory of M. Rosseau[2] revealed that excess bottom slope reflections for horizontal-scale ratios up to five times numerically larger than the vertical-scale ratio were only one to two percent of the incident wave height. The magnitude of bottom-slope reflections in this model (distortion 4:1) can be considered negligible. However, reflections from the relatively steep breakwater slopes (1:2) were considered a problem. It was decided that two-dimensional (2-D) flume tests should be conducted to determine optimum construction materials and techniques for the three-dimensional (3-D) model breakwater.

7. Scaling test waves by the vertical-scale ratio resulted in proper similitude of relative wave heights (H/d) and relative wave steepness (H/L); therefore, proper breaking depth was assured. Similitude of

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* For convenience, symbols and unusual abbreviations are listed and defined in the Notation (Appendix C).

refraction and consequently similitude of angle of wave crests relative to the shoreline also were assured by this scaling technique.

8. An important part of the model study was the interaction of tidal and wave-induced currents. Based on the study of requirements to reproduce the entire tidal cycle (reproduction of a large tidal prism, artificial roughness, extensive prototype surveys, etc.), it was decided the model could use steady-state ebb and flood flows produced by a manifold system.

Object and Approach

9. The objective of the model study was to determine qualitatively the effect, if any, of the proposed offshore nuclear power plant breakwater on shoreline evolution. Model measurements to be made across and along the shoreline north and south of the inlet, with and without the proposed breakwater, consisted of current patterns and breaking wave characteristics such as height, depth, and angle to the shoreline. Current patterns and calculated longshore transport rates with and without the proposed breakwater would then be compared. From these comparisons a judgment would be made as to the effect, if any, of the proposed breakwater on shoreline evolution.

PART II: THE MODEL

Description of the Model

10. The shore effect model (Plate 1 and Photos 1 and 2) was constructed to a distorted scale of 1:75 vertically and 1:300 horizontally, model to prototype. The model was molded in cement mortar (fixed-bed) and an artificial transition was constructed from the -40 ft mean sea level (msl) contour to the wave generator pit (-69.2 ft msl). The model was approximately 113 by 115 ft and covered a total area of 9800 sq ft, of which about 6600 sq ft was contoured area. This reproduced, in nature, 34,000 ft of coastline and the bathymetry for a seaward distance of 18,000 ft. The model was operated in accordance with Froude's model law.[3] Scale relations used in the transference from model to prototype were as follows:

Characteristics	Dimensions*	Model:Prototype Scale Relation
Horizontal distance	L	$X_r = 1:300$
Vertical distance	L	$Y_r = 1:75$
Volume	L^3	$Vol_r = X_r Y_r^2 = 1:1,687,500$
Time	T	$T_r = Y_r^{1/2} = 1:8.66$
Velocity	L/T	$Vel_r = Y_r^{1/2} = 1:8.66$
Volumetric flow rate	L^3/T	$Q_r = X_r Y_r^{3/2} = 1:194,586$
Wave period	T	$Per_r = Y_r^{1/2} = 1:8.66$
Wavelength	L	$L_r = Y_r = 1:75$
Wave height	L	$H_r = Y_r = 1:75$

* Dimensions are in terms of length (L) and time (T).

11. A pump and manifold system[4] were used to reproduce tidal currents. A differential manometer was installed in the discharge line of the pump and was used in conjunction with a control valve and pipe

arrangement to regulate both the flood and ebb volumetric flow rates through the inlet. The pipe system around the inner perimeter of the model was fitted with a series of openings; each opening was equipped with a sliding metal sleeve which could be used to vary the effective area of the opening. This system allowed the reproduction of a quite variable combination of flow rates.

Design of Model Breakwater

12. During the construction phase of the 3-D model, large-scale 2-D flume tests were conducted to determine reflection coefficients of the proposed breakwater at an undistorted scale. A representative range of wave periods and heights were tested with the incident and reflected wave heights being measured by a mobile wave gage (Photo 3) for each test wave. This information was used to calculate reflection coefficients representative of the prototype structure. By using these data it was determined, by a trial and error procedure, that a distorted structure composed of wire mesh covered with fibrous wave absorber (rubberized hair) would reflect about the same amount of wave energy as the prototype structure.

Test Equipment

13. A vertical-displacement, 60-ft-long wave generator was used to produce the model waves (Photo 2). The vertical motion of the plunger produced a periodic oscillation of the water normal to it. Test waves of the required characteristics were generated by varying the frequency and amplitude of the plunger motion. The wave generator was equipped with retractable jacks and wheels which enabled it to be positioned to generate waves from various wave directions. Changes in water-surface elevation as a function of time were measured by electrical wave-height gages at selected locations in the model and recorded on chart paper by an electrically operated oscillograph (Photo 4). The

electrical output of each wave gage was directly proportional to the submergence depth of the gage.

14. A gravity-feed dye injection system was used to inject a tracer for measuring current patterns. The system consisted of an elevated well connected by flexible tubing to portable injection stands. This arrangement allowed simultaneous injection at a variety of locations across the inlet and along the coastline. Two 16mm motion picture cameras were mounted above the model and used to record current patterns and wave motion. A still-picture camera also was used to obtain instantaneous current pattern and wave motion records.

Verification of Tidal Velocities

15. Prototype tidal velocity data, collected and furnished by E. G. and G. International, Environmental Services Division,[5] were used to calibrate the model manifold system. A trial and error procedure was employed during which various combinations of control valve settings and sliding collar positions were tested. For each trial, tidal velocities were measured using weighted surface floats and a stopwatch at stations selected across the inlet to correspond with the given prototype data. Tests were conducted until settings were obtained which adequately reproduced mean steady-state flood and ebb tide flows through the inlet.

PART III: TEST CONDITIONS AND PROCEDURES

Wave Dimensions and Directions

16. In planning a test program for a model investigation involving wave action, it is necessary to select dimensions and directions for test waves that will allow the model to accurately reproduce the prototype wave climate. Surface-wind waves are generated by the tangential shear force of the wind blowing along the water surface and the normal force of the wind against the wave crests. Selection of test wave conditions entails evaluation of such factors as:

- a. The frequency and duration of waves of different periods from different directions.
- b. The refraction of waves caused by depth differentials.
- c. The dissipation of wave energy due to viscous friction.

17. Wave refraction occurs when waves propagate over water of variable depth (provided the depth is less than about one-half the deepwater wavelength). Changes take place in all wave characteristics except wave period. The most important changes affecting test wave characteristics are the alteration of wave height and direction of travel. Changes in wave height and direction can be obtained by calculating refraction coefficients and plotting refraction diagrams. The diagrams are constructed by plotting orthogonals (lines drawn perpendicular to wave crests). Linear wave refraction theory assumes the waves do not break and there is no lateral flow of energy between wave orthogonals. The ratio between the wave height in deep water (H_o) and the wave height in shallow water (H) will be inversely proportional to the square root of the ratio of the corresponding orthogonal spacings (b_o and b) or $H/H_o = K(b_o/b)^{1/2}$ where K is the shoaling coefficient and $(b_o/b)^{1/2}$ is the refraction coefficient. Therefore, the quantity $K(b_o/b)^{1/2}$ serves as a conversion factor for transforming deepwater wave heights to shallow-water wave heights. The shoaling coefficient, a function of wavelength and water depth, can be obtained from Reference 6.

18. Wave refraction diagrams were prepared for selected wave directions and periods. Two sets of diagrams were prepared from the wave generator pit to the shoreline. In the first set the natural contours were used and in the second set the model contours with the sloping transition to the wave generator pit were substituted. A comparison of the diagrams showed the model accurately reproduced wave fronts near the shoreline. Diagrams for the southeast wave direction are presented in Appendix B.

19. Even though the model was built to a distorted scale, the large area of extremely shallow water reproduced by it made the excessive dissipation of energy at the bottom a problem worthy of correction. The effect of this energy dissipation on wave height is given by[7]

$$H_2 = H_1 e^{-\left[\frac{5\pi(\pi\nu T)^{1/2}}{L^2\left(\sinh\frac{4\pi d}{L} + \frac{4\pi d}{L}\right)}\right]\Delta X}$$

where

H_2 = the wave height after the wave has propagated a distance ΔX

H_1 = the incident wave height

ν = kinematic viscosity

T = wave period

d = water depth

L = wavelength

ΔX = an incremental distance

Energy dissipation was calculated along orthogonals from the wave generator to the breaker zone; wave heights at the wave generator were increased by an appropriate amount to compensate for the viscous-friction scale effects.

20. Model test wave conditions were selected from wave hindcast data obtained by A. H. Glenn[8] and Associates (Table 1). These data represent an estimated yearly wave climate in terms of magnitude and duration of waves approaching the proposed Atlantic Generating Station from the various directions.

Test Series I

21. Model measurements, with and without the proposed breakwater, consisted of measuring currents at selected locations across the mouth of the inlet and along the north and south coastline (test series I), breaking wave characteristics (test series II), and average longshore currents (test series III). Selected test conditions for test series I are presented in Table 2. Velocity stations (Plate 2) were positioned across the inlet and along the shoreline both north and south. For each test condition, the currents were allowed to develop, dye was injected as a tracer, and the current and wave patterns were recorded on motion picture film. Still photos also were taken to give an instantaneous record of current and wave patterns.

Test Series II

22. The breaking wave characteristic tests (test series II) involved measuring the height and depth of breaking and the angle of breaking relative to the shoreline. Two longshore transport zones were selected, one north and one south of the inlet, in which the measurements were taken. These zones and baselines for referencing the angle of breaking are shown in Plate 3. Selected test conditions are presented in Table 3. Breaking-wave heights were obtained by placing electrical wave gages across the zones at the breaker line. Uneven breaking of the wave front within a selected zone required the placement of up to four wave gages to adequately define the wave front. The depth of breaking was obtained directly from the model using an engineer's level. The angle of breaking relative to the assumed baseline was obtained from visual observation, still photos, and the motion picture film gathered in test series I.

Test Series III

23. Average longshore current measurements (test series III) were

made by injecting a line of dye perpendicular to the assumed baseline of the selected zone (Plate 3). The currents were allowed to develop; the general direction of the dye was observed and its rate of travel timed with a stopwatch. Selected conditions for test series III are given in Table 4. These average current measurements were taken at the same time as the data in test series II, simply to augment the current data collected in test series I and to provide an overall look at the current regime within the selected zones rather than at specific stations as measured in test series I.

PART IV: DATA ANALYSES AND DISCUSSION OF RESULTS

Test Series I

24. The motion picture film obtained for each test condition was analyzed with the aid of a stop-action movie projector. Current velocities and directions were extracted from the film for sta 1A-4B for the south wave direction, 2A-6B for the southeast wave direction, and 4A-7B for the east wave direction (see Plate 2 for stations). Photos 5-22 illustrate model current patterns for selected test conditions.

25. All current data obtained in test series I are given in Table 5. In some instances, an azimuth or both a velocity and azimuth value may be left blank. These omissions resulted from either the current pattern having such a broad range of flow directions that a pronounced direction was not definable or the complete loss of the data at a station due to some mechanical malfunction. Plates 4-29 present the data from Table 5 in a comparative graphical form. Careful scrutiny of these plates reveals some changes in current patterns with the breakwater installed; however, the majority of the data indicate no predominant trends either in decrease or increase of velocity or shift of direction. It is felt that most of the differences shown are reasonably within the limits of experimental error. Repeat tests of selected wave conditions indicated current velocities were reproducible within ±10 percent on a comparative basis.

26. Since the data presented in Plates 4-29 are quite detailed, it was believed averaging the data would result in a clearer picture of the overall current measurement results. Table 6 presents average current velocities and directions for a given wave period. To obtain this table, the values of velocity and azimuth for all wave heights at a given station for a given period, wave direction, and tidal condition (Table 5) were averaged. The data from Table 6 also are presented in a graphical manner in Plates 30-56. These data again fail to indicate any significant changes in current patterns (velocity or direction).

Test Series II

27. Data obtained from the breaking-wave height tests are presented in Tables 7 through 18. Photos 23-32 illustrate the simultaneous measurement of breaking-wave heights and longshore currents (test series III) for selected wave conditions.

28. Extensive correlation of model and prototype wave and sediment transport data by other researchers has yielded several longshore transport equations. In all these studies, the transport rate is some function of the breaking-wave characteristics. Three of the more common equations relating breaking-wave characteristics to the longshore transport rate, Q_L , are:

$$Q_L = 118.9E'_L \quad \text{(CERC)}^{6} \tag{1}$$

$$Q_L = 210E'^{0.8}_L \quad \text{(Caldwell)}^{9} \tag{2}$$

$$Q_L = 548\bar{H}_b^2 \quad \text{(Galvin)}^{10} \tag{3}$$

where

E'_L = total longshore energy per foot of beach per day

$\bar{H}_b$ = average breaking-wave height for all waves considered

29. In order to use Equations 1 and 2, the total longshore energy per foot of beach per wave must be calculated and the total number of waves per day approaching the coastline under consideration must be known. The total longshore energy per foot of beach per wave is given by[6]

$$E_L = \frac{\gamma H_b^2 L_b}{8}\left[1 - \frac{\pi^2}{2\tanh^2\left(\frac{2\pi d_b}{L_b}\right)}\left(\frac{H_b^2}{L_b^2}\right)\right]\sin\alpha\cos\alpha \tag{4}$$

where

γ = specific weight of water

H_b = wave height at breaking

L_b = wavelength at breaking

d_b = depth of water a wave breaks in, ft

α = angle between breaking-wave crest and shoreline

To determine the total number of waves per day the wave hindcast data (Table 1) were regrouped to make the selected test waves representative of the average wave climate. Tables 19-21 illustrate this regrouping procedure for waves approaching the south zone. The same objective is accomplished for the north zone in Tables 22 and 23. Since the original wave climate was only divided into 45-deg wave direction groups and tests were conducted at selected 22.5-deg intervals, it became necessary to redistribute the wave occurrence frequencies. To accomplish this, it was assumed that each 22.5-deg interval would receive 25 percent of the total waves from each of the two major directions adjacent to it. Tables 24, 25, and 26 illustrate this final regrouping procedure.

30. The information required to calculate transport rates in the two longshore transport zones is summarized in Tables 27 and 28. The "Breaking Height Squared" column is the average height at breaking, squared, for all wave gages considered for a particular test wave. The "Transport Direction" column was determined by the orientation of the breaking-wave crest relative to the assumed baseline. The "Longshore Energy per Foot of Beach per Wave" was obtained by applying the longshore energy Equation 4 to the measured breaking-wave characteristics at each of the gages in a zone (Tables 7 through 19) and then averaging the individual longshore energy calculated for each test wave. The "Longshore Energy per Foot of Beach per Wave per Day" was determined by multiplying the longshore energy per wave by the number of waves per day.

31. Table 29 lists calculated transport rates, with and without the proposed breakwater, for all wave directions considered in test series II. It should be mentioned that the "Average Breaking Height Squared" column was obtained by taking a weighted average of the breaking heights (Tables 27 and 28) for a particular wave direction and tidal condition. The weighted average was obtained by multiplying the individual values of $\overline{H}_b^2$ by their respective occurrences in waves per day and dividing by the total number of waves per day from a given test

direction. This procedure can best be illustrated by an example. The data from Table 27 for the northeast wave direction for the case with the structure out can be used to obtain $\overline{H}_b^2$ as follows:

$$\overline{H}_b^2 = \Big[(11.50)(209) + (30.91)(115) + (98.19)(17) + (22.85)(137)$$

$$+ 128.24(83) + 59.19(11) + 197.411(23)\Big] \div (209 + 115$$

$$+ 17 + 137 + 33 + 11 + 23)$$

$$\overline{H}_b^2 = \frac{26,593.27}{595} = 44.69 \text{ ft}^2$$

The same procedure was followed to obtain values of $\overline{H}_b^2$ for the other test directions.

32. Table 30 presents calculated transport rates for the major transport directions (north and south). When more than one tidal condition per wave direction (south, southeast, and east) was tested it was assumed that slack tide occurred 50 percent of the time and flood and ebb tide 25 percent each. It should be observed that all the calculated longshore transport rate changes are 7 percent or less except for a 19 percent change obtained by applying Galvin's equation to the south zone. In this particular case, the relatively small reduction in wave height (approximately 9.5 percent) is amplified because Galvin's method only considers wave height squared rather than wave height, breaking depth, and breaking angle to the shoreline as used in the energy calculations. It should be emphasized that the most important consideration in the present investigation is not the absolute value of the predicted transport rates or the relative merits of the different equations, but the comparative predicted transport rates (with and without the breakwater). The three equations considered give widely different predicted transport rates; however, they are all similar in that they indicated little change with the proposed breakwater installed. When one considers the small experimental error involved in obtaining such data, the differences become even more minimal. Repeat tests of selected wave conditions indicated breaking characteristics (height,

depth, and angle) to be reproducible to the extent that calculated transport rates on a comparative basis have an accuracy of ±8 percent.

Test Series III

33. Comparative average current velocities and directions of flow are given in Table 31. These data indicate little difference in velocity and no directional changes with the proposed breakwater installed. These data are not presented graphically since they are of an auxiliary nature and were obtained only to give an overall view of the current regime within a general area.

PART V: CONCLUSIONS

34. Based on the results of the hydraulic model study described herein, it appears that:

a. The construction of the proposed power plant will not:

   (1) Significantly alter current patterns shoreward of it.

   (2) Significantly alter longshore current velocities or transport rates north and south of the inlet.

   (3) Have a detrimental effect on shoreline evolution in the area under consideration.

b. The Little Egg Inlet area is historically one of very dynamic geomorphological change and any changes produced by the construction of the breakwater protecting the offshore nuclear power plant would certainly be masked by the natural changes at the inlet.

c. The distorted-scale model provided adequate information to reach the conclusions set forth in this investigation.

PART VI: GENERAL KNOWLEDGE GAINED AND FUTURE APPLICATIONS

35. Results of this investigation have an extremely wide application. The present energy crisis makes it a virtual certainty that offshore nuclear power plants, offshore deepwater oil terminals, and perhaps entire offshore energy-related industrial complexes will be constructed. The impact of this construction on coastal evolution must be reliably evaluated. The methodology developed in this investigation can be very beneficial in evaluating possible effects of other proposed offshore structures.

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Table 1

Estimated Magnitude and Duration of Waves Approaching Proposed Atlantic Generating Station from the Indicated Directions

Wave Period sec	Percentage of Total Wave Climate per Wave Height Group, ft															
	0-1	1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	17-19	19-21	21-23	23-25	25-27	>27	Total
								South								
0-5	1.20	1.50	0.80	0.30	0	0	0	0	0	0	0	0	0	0	0	3.80
5-7	1.20	1.50	0.65	0.45	0.12	0.04	0.04	0	0	0	0	0	0	0	0	4.00
7-9	0.30	0.70	0.80	0.60	0.45	0.11	0.04	0.05	0.04	0.03	0.02	0.01	0	0	0	3.15
9-11	0.18	0.38	0.37	0.43	0.38	0.30	0.11	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0	2.28
11-13	0.02	0.10	0.16	0.16	0.18	0.19	0.10	0.10	0.05	0.05	0.03	0.02	0.02	0.01	0.02	1.21
13-15	0	0.02	0.01	0.06	0.06	0.06	0.08	0.05	0.04	0.03	0.01	0.01	0.01	0.01	0.02	0.47
>15	0	0	0	0.01	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0	0.01	0	0.02	0.19
Total	2.90	4.20	2.79	2.01	1.22	0.73	0.40	0.25	0.18	0.14	0.09	0.05	0.05	0.03	0.06	15.10
								Southeast								
0-5	1.90	1.70	0.40	0.08	0.02	0	0	0	0	0	0	0	0	0	0	4.10
5-7	0.30	0.75	0.53	0.18	0.24	0	0	0	0	0	0	0	0	0	0	2.00
7-9	0.25	0.42	0.50	0.35	0.31	0.19	0.03	0.01	0.02	0	0.01	0.01	0	0	0	2.10
9-11	0.10	0.23	0.27	0.29	0.27	0.26	0.10	0.02	0.01	0.01	0.01	0.01	0.02	0	0	1.60
11-13	0.09	0.07	0.05	0.09	0.16	0.17	0.08	0.03	0.02	0.02	0.01	0.02	0.03	0	0	0.84
13-15	0.02	0.03	0.04	0.03	0.05	0.05	0.06	0.04	0.02	0.01	0.01	0	0.02	0	0	0.38
>15	0	0	0.01	0	0.01	0.02	0.02	0.02	0.01	0.01	0	0	0.02	0	0	0.12
Total	2.66	3.20	1.80	1.02	1.06	0.69	0.29	0.12	0.08	0.05	0.04	0.04	0.09	0	0	11.14
								East								
0-5	3.18	2.10	0.42	0.18	0	0	0	0	0	0	0	0	0	0	0	5.88
5-7	0.25	0.75	0.68	0.16	0.08	0.06	0.02	0	0	0	0	0	0	0	0	2.00
7-9	0.26	0.55	0.39	0.37	0.39	0.13	0.04	0.02	0.01	0.02	0.01	0	0.01	0	0	2.20
9-11	0.07	0.22	0.29	0.28	0.27	0.23	0.10	0.05	0.02	0.02	0	0.02	0.03	0	0	1.60
11-13	0.04	0.07	0.09	0.11	0.16	0.15	0.12	0.05	0.04	0.02	0.02	0.01	0.04	0	0	0.92
13-15	0	0.01	0.03	0.03	0.05	0.07	0.05	0.04	0.02	0.02	0.02	0	0.02	0	0	0.36
>15	0	0	0	0.01	0.01	0.02	0.02	0.03	0.02	0.01	0	0.01	0.01	0	0	0.14
Total	3.80	3.70	1.90	1.14	0.96	0.66	0.35	0.19	0.11	0.09	0.05	0.04	0.11	0	0	13.10
								Northeast								
0-5	0.70	1.30	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	3.00
5-7	0.50	0.70	0.70	0.35	0.17	0.06	0.01	0.01	0	0	0	0	0	0	0	2.50
7-9	0.10	0.51	0.56	0.64	0.44	0.12	0.03	0.01	0.02	0.01	0.02	0	0.01	0	0	2.47
9-11	0.94	0.34	0.39	0.36	0.45	0.14	0.06	0.03	0.02	0.02	0	0.02	0.02	0	0	2.79
11-13	0.03	0.03	0.12	0.18	0.22	0.13	0.05	0.04	0.03	0.02	0.03	0	0.05	0	0	0.93
13-15	0.02	0	0.03	0.04	0.05	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.03	0	0	0.34
>15	0	0	0	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0	0.01	0.02	0	0	0.14
Total	2.29	2.88	2.55	1.84	1.35	0.52	0.21	0.13	0.10	0.07	0.06	0.04	0.13	0	0	12.17
								North								
0-5	2.39	3.97	1.93	0.23	0.02	0	0	0	0	0	0	0	0	0	0	8.54
5-7	0.41	0.43	0.36	0.44	0.15	0.03	0.01	0	0	0	0	0	0	0	0	1.83
7-9	0	0	0.01	0.10	0.06	0.07	0.01	0.01	0	0	0	0	0	0	0	0.26
>9	0	0	0	0	0.02	0.03	0.01	0.01	0	0	0	0	0	0	0	0.07
Total	2.80	4.40	2.30	0.77	0.25	0.13	0.03	0.02	0	0	0	0	0	0	0	10.70
								Northwest								
0-5	3.79	5.42	0.94	0.06	0.03	0.01	0.01	0.01	0	0	0	0	0	0	0	10.27
>5	0.21	0.43	0.39	0.06	0.02	0.01	0	0	0	0	0	0	0	0	0	1.12
Total	4.00	5.85	1.33	0.12	0.05	0.02	0.01	0.01	0	0	0	0	0	0	0	11.39
								West								
0-5	4.47	1.34	0.58	0.76	0.77	0.57	0.29	0.11	0.03	0.01	0	0	0	0	0	8.93
>5	0.23	0.46	0.32	0.04	0.01	0	0	0	0	0.01	0	0	0	0	0	1.07
Total	4.70	1.80	0.90	0.80	0.78	0.57	0.29	0.11	0.03	0.02	0	0	0	0	0	10.00
								Southwest								
0-5	2.96	5.24	3.30	1.05	0.05	0	0	0	0	0	0	0	0	0	0	12.60
5-7	1.05	0.07	0.07	0.35	0.17	0.06	0.01	0.01	0	0	0	0	0	0	0	1.79
7-9	0.11	0.51	0.56	0.64	0.44	0.12	0.03	0.01	0.02	0.01	0.02	0	0.01	0	0	2.48
9-11	0.94	0.34	0.39	0.36	0.45	0.14	0.06	0.03	0.02	0.02	0	0.02	0.02	0	0	2.79
11-13	0.03	0.03	0.12	0.18	0.22	0.13	0.05	0.04	0.03	0.02	0.03	0	0.05	0	0	0.93
13-15	0.04	0	0.03	0.04	0.05	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.03	0	0	0.36
>15	0	0	0	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0	0.01	0.02	0	0	0.14
Total	5.13	6.19	4.47	2.64	1.40	0.52	0.21	0.13	0.10	0.07	0.06	0.04	0.13	0	0	21.09

Table 2

Selected Conditions for Test Series I

Stillwater Level = 0.0 (msl)

Wave Direction					
East		Southeast		South	
Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft
6	2	6	2	6	2
6	4	6	4	6	4
6	7	6	7	6	7
6	10	6	10	6	10
10	4	10	4	10	4
10	10	10	10	10	10
10	14	10	14	10	14
10	18	10	18	10	18
14	4	14	4	14	4
14	10	14	10	14	10
14	14	14	14	14	14
14	18	14	18	14	18

Note: All wave conditions for all wave directions conducted for slack, flood, and ebb tide with and without proposed breakwater in place.

Table 3

Selected Conditions for Test Series II

Stillwater Level = 0.0 (msl)

Tidal Condition and Wave Direction													
Slack Tide										Slack, Flood, and Ebb Tide			
Northeast		E22.5°N		E22.5°S		Southeast		E22.5°E		East		South	
Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft
						South Zone*							
6	4	6	4	6	4	6	4			6	4		
6	7	6	7	6	7	6	7			6	7		
6	10	6	10	6	10	6	10			6	10		
10	4	10	4	10	4	10	4			10	4		
10	10	10	10	10	10	10	10			10	10		
14	4	14	4	14	4	14	4			14	4		
14	10	14	10	14	10	14	10			14	10		
						North Zone*							
						6	10	6	10			6	10
						10	10	10	10			10	10
						10	14	10	14			10	14
						14	10	14	10			14	10
						14	14	14	14			14	14

* Zones are defined in Plate 3.

Table 4

Selected Conditions for Test Series III, Slack Tide

Stillwater Level = 0.0 (msl)

Wave Direction									
Northeast		E22.5°N		E22.5°S		Southeast		S22.5°E	
Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft	Wave Period sec	Wave Height ft
				South Zone*					
6	4	6	4	6	4	6	4		
6	7	6	7	6	7	6	7		
6	10	6	10	6	10	6	10		
10	4	10	4	10	4	10	4		
10	10	10	10	10	10	10	10		
14	4	14	4	14	4	14	4		
14	10	14	10	14	10	14	10		
				North Zone*					
						6	10	6	10
						10	10	10	10
						10	14	10	14
						14	10	14	10
						14	14	14	14

* Zones are defined in Plate 3.

Table 5

Comparison of Test Series I Current Measurements

Current Velocities in fps and Direction* at Indicated Stations**

Wave Period sec	Wave Height ft	Breakwater† Status	1A Vel	1A Az	1B Vel	1B Az	2A Vel	2A Az	2B Vel	2B Az	3A Vel	3A Az	3B Vel	3B Az	4A Vel	4A Az	4B Vel	4B Az
		South Wave Direction--Slack Tide																
6	2	Without	0.38		0.57	165	0.34	30	0.51	90	0.88	330	0.34		0.43		0.32	60
		With	0.50	240	0.57	165	0.69	30	0.64	60	1.06	330	0.56	330	0.37	315	0.70	
6	4	Without	0.33		0.58	180	0.44		0.83	90	1.72	300	0.96	60	0.53		0.73	60
		With	0.39	135	0.58	150	0.65		0.88	90	1.70	285	0.97	75	0.56		0.74	90
6	7	Without	0.38		0.49	150	0.57	105	1.01	75	2.12	315	1.19	30	1.26	60		
		With	0.48	180	0.39		0.99	90	1.51	75	2.75	315	1.39	15	1.44	30	0.96	60
6	10	Without			0.38	45	0.67	120	1.83	60	1.50	315	0.67	315	0.91	0	0.67	90
		With	0.69	75	0.57	75	0.94	120	1.65	60	1.80	330	0.67	315	0.91	45	1.00	90
10	4	Without	0.36		0.66	195	0.57	210	0.37		1.49	345	0.47	0	0.58	315	0.87	45
		With	0.97	45	0.66	75	0.57	30	0.99	60	2.48	345	0.94	0	0.58	0	0.87	60
10	10	Without	0.69	75	1.15	45	0.49	60	2.00	60	1.90	315	0.67	330	0.92	60	0.76	90
		With	1.15	60	0.81	60	0.74	105	1.74	60	2.53	315	0.78	315	1.03	60	0.76	90
10	14	Without			1.74	45	3.24	0	1.94	45	1.47	330	0.67	330	0.90	45	0.81	120
		With			0.87	90	2.43	315	1.73	45	1.64	15	0.89	60	0.90	60	0.68	120
10	18	Without	2.71	345	1.24	60	2.76	15	1.23	75	1.73	270	0.69	300	0.64	75	0.67	135
		With	2.11	135	1.86	60	2.55	15	2.45	60	2.38	285	0.57	315	0.64	45	0.89	105
14	4	Without	0.91	60	0.49	60	0.74	60	1.56	60	2.01	0	1.05	30	0.69	0	0.99	75
		With	1.00	60	0.29		1.17	30	1.47	60	1.38	345	1.05	30	0.96	30	0.66	60
14	10	Without	0.87	120	1.03	75	0.80	0	2.43	60	1.79	285	0.46	315	1.01	30	0.68	150
		With	1.21	60	1.37	60	1.60	345	3.18	45	2.44	0	0.80	0	0.74	0	0.90	105
14	14	Without			2.27	45	1.08	60	1.88	75	2.00	270	1.16	180	0.80	90	1.39	105
		With			1.96	60	1.08	210	1.00	45	2.21	345	0.57		0.80	30	1.08	120
14	18	Without	1.76	60	1.73	45	0.68		1.44	60	2.04	315	1.03	315	0.65	0	0.41	
		With	2.06	90	1.73	45	2.08	60	1.85	75	2.05	0	0.80	0	0.81	45	0.68	120
		South Wave Direction--Flood Tide																
6	2	Without	0.87	225	1.61	210	1.66	255	2.39	240	3.41	315	2.77	315	4.06	270	2.26	315
		With													3.34	270	3.44	315
6	4	Without	0.66	210	1.35	210	1.48	255	2.68	240	4.32	315	2.63	330	3.19	285	2.88	315
		With	0.65	225	1.48	210	1.53	225	2.54	240	4.09	315	2.22	330	2.92	285	2.54	315
6	7	Without	0.58	225	1.22	210	1.19	225	1.68	240	4.44	315	3.65	330	2.46	300	2.68	315
		With	0.49	210	1.35	210	1.31	255	1.75	240	4.79	315	3.19	330	2.46	300	3.03	315
6	10	Without	0.60	180	1.01	180	1.16	255	1.82	240	4.25	330	3.02	315	2.65	285	2.64	315
		With	0.56	195	1.21	195	1.07	240	1.27	240	5.16	330	3.45	330	2.72	300	2.97	315
10	4	Without	0.82	210	1.54	210	1.74	255	2.26	240	3.80	315	3.23	330	2.87	285	2.47	315
		With	0.70	225	1.50	210	1.63	255	2.26	240	3.80	315	2.77	330	2.67	285	2.47	315
10	10	Without			0.33		1.66	285	1.13	60	4.96	330	2.93	315	2.39	285	2.68	315
		With	0.79	0	0.71	180	0.92	255	0.84	60	4.58	330	2.49	330	2.19	285	2.68	315
10	14	Without	0.93		1.25	60	2.07	315	2.80	240	3.44	315	2.15	315	2.14	285	2.08	300
		With	0.95	60	0.38		1.84	315	2.56	240	3.63	330	2.47	315	2.32	285	2.08	315
10	18	Without	1.56	150	1.35	150	1.63	210	2.15	240	3.67	300	1.24	300	3.20	270	2.38	315
		With	2.01	180	1.35	135	1.43	255	2.31	240	3.67	315	0.75		3.41	270	2.53	315
14	4	Without	0.22		0.55	195	0.96	255	1.00	240	4.86	330	2.48	330	2.48	300	3.06	315
		With	0.29		1.18	210	0.83	255	1.50	240	4.22	315	2.93	330	3.38	300	2.80	315
14	10	Without	0.26		1.43	75	1.25	225	1.21	75	5.02	330	3.13	330	2.64	300	2.46	315
		With	0.84	165	1.04	105	1.04	180	0.39		4.14	345	2.69	330	3.13	285	2.46	315
14	14	Without	1.18	60	1.36	75	1.19	255	1.73	240	5.00	315	2.23	315	2.61	285	2.26	300
		With	1.42	180	1.03	45	0.86	255	1.92	240	4.12	330	2.69	315	3.00	285	1.44	315
14	18	Without	1.26	60	0.91	60	1.70	180	2.43	240	5.00	330	2.24	315	2.32	285	2.56	315
		With	1.28	180	1.13	90	1.72	165	2.40	240	4.46	330	2.25	315	2.06	300	2.05	315
		South Wave Direction--Ebb Tide																
6	2	Without	0.65	60	0.43	180	0.90	120	1.05	45	1.83	75	2.32	135	3.14	120	4.31	135
		With	0.33		0.65	180	0.45	180	0.45		1.83	90	2.99	150	2.58	120	4.00	135
6	4	Without	0.68	195	1.02	195	0.85	120	0.53	240	1.83	60	2.29	165	2.43	120	3.26	120
		With	1.69	120	1.47	180	0.96	75	0.64	270	1.68	15	1.99	135	2.02	135	3.30	135
6	7	Without	0.21		0.68	180	0.43	45	0.75	240	2.05	75	1.79	150	2.99	105	4.41	120
		With	0.45		0.68	180	0.43	120	0.54	240	2.82	60	1.41	135	2.99	90	3.61	120
6	10	Without	1.32	90	0.96	180	1.73	90	1.61	60	1.89	60	1.45	180	2.49	90	3.92	120
		With	1.32	135	1.56	180	1.52	120	1.27	60	2.32	60	2.03	150	2.49	90	3.00	135
10	4	Without	0.42	0	0.42	180	0.74	135	1.15	105	1.41	30	0.58	300	2.41	105	2.85	135
		With	0.53	180	0.53	180	0.42	210	0.58	105	2.11	105	2.08	135	2.61	150	2.85	135
10	10	Without			1.07	60	1.22	60	2.47	60	2.04	210	2.21	165	2.26	90	3.64	135
		With			0.61	60	2.13		2.14	60	1.36	210	2.04	150	2.26	120	3.64	135
10	14	Without	1.72	30	1.15	90	2.51	30	1.84	120	1.77	60	2.31	165	2.63	135	3.65	150
		With			1.35	120	1.40	30	1.73	105	1.37	60	2.31	150	2.63	120	3.43	150

(Continued)

* Direction in the azimuth measured clockwise from New Jersey grid north.
** Station locations given in Plate 2.
† Without means breakwater is not installed. With means breakwater is installed.

Table 5 (Continued)

Wave Period sec	Wave Height ft	Breakwater Status	1A Vel	1A Az	1B Vel	1B Az	2A Vel	2A Az	2B Vel	2B Az	3A Vel	3A Az	3B Vel	3B Az	4A Vel	4A Az	4B Vel	4B Az
		South Wave Direction--Ebb Tide (Continued)																
10	18	Without	2.07	15	1.38	60	4.58	45	2.31	90	3.19	240	2.71	195	2.77	105	3.67	135
		With	1.15		1.38	30	3.60	90	1.61	60	1.24	30	2.87	180	2.31	135	3.67	135
14	4	Without	0.80	180	1.38	165	1.66	120	1.11	60	2.07	45	1.43	165	2.98	105	3.14	135
		With	0.45		0.58	195	0.78	90	0.54	90	3.18	75	1.59	120	1.58	120	2.46	135
14	10	Without			1.59	75	2.68	60	3.13	90	2.57	225	3.13	180	2.85	105	3.96	135
		With			0.80	120	4.02	60	3.13	60	1.65	345	0.55		1.42	120	3.08	135
14	14	Without	0.89	285	2.32	45	2.27	15	1.28	75	1.85	300			3.69	90	3.92	135
		With	1.11	270	1.67	135	2.78	60	1.26	90	1.03	90			1.58	120	3.26	135
14	18	Without			3.90	30	2.01	15	2.56	75	2.30	30			3.33	120	4.16	135
		With			1.73	60	1.10	135	1.40	135	4.36	45			2.56	105	3.74	135

Wave Period sec	Wave Height ft	Breakwater Status	2A Vel	2A Az	2B Vel	2B Az	3A Vel	3A Az	3B Vel	3B Az	4A Vel	4A Az	4B Vel	4B Az	5A Vel	5A Az	5B Vel	5B Az	6A Vel	6A Az	6B Vel	6B Az
		Southeast Wave Direction--Slack Tide																				
6	2	Without	0.35		0.61	120	1.73	0	0.52	330	0.35		0.35		0.26		0.26		0.61	270	0.61	165
		With																				
6	4	Without	0.20		0.78	60	2.18	285	0.78	300	0.49	330	1.05	330	0.49	180	0.26		2.52	285	0.96	195
		With	0.26		0.95	90	2.50	300	0.98	300	0.26		0.66	345	0.26		0.17		2.68	285	1.04	195
6	7	Without	0.95	180	1.91	60	1.91	300	0.95	285	0.78	75	1.47	315	0.52	180	0.52	150	1.99	285	1.47	180
		With	1.04	180	1.73	60	2.34	270	1.04	285	1.04	60	1.30	315	0.52	150	0.61	135	2.60	285	1.91	180
6	10	Without	1.47	255	2.25	60	3.12	300	1.04	300	1.56	60	1.13	300	0.52	180	0.52	150	2.77	285	1.47	180
		With	1.47	270	3.12	60	2.86	255	1.13	255	1.91	90	1.04	285	0.61	165	0.61	150	3.12	270	2.77	180
10	4	Without	0.78	135	1.39	75	3.20	270	0.61	0	1.04	75	0.78		0.43		0.43	135	3.38	285	1.04	180
		With	0.69	150	1.56	75	2.51	270	0.69	30	0.69	270	1.21	120	0.52	315	0.26		3.38	270	0.87	195
10	10	Without	2.25	0	3.03	60	2.68	270	0.52	30	0.61	300	0.69	120	1.13	180	0.96	150	1.47	240	1.73	180
		With	3.46	0	3.48	60	2.09	285	0.61	30	0.69	330	1.26	120	0.78	210	0.52	180	2.34	255	2.00	195
10	14	Without	2.60	345	2.42	60	3.03	285	0.61	15	0.69	330	0.87	120	1.21	180	1.13	150	2.77	255	2.34	180
		With	2.25	330	2.86	60	2.77	270	0.52	15	0.52	315	0.95	120	1.13	180	1.21	150	2.77	255	3.12	195
10	18	Without	3.38	0	1.99	60	2.94	285	0.69	360	1.30	60	1.39	150	1.13	180	1.21	150	3.12	255	2.25	180
		With	2.78	0	2.25	60	2.68	255	0.52		1.04	90	1.56	135	1.21	165	1.30	135	2.77	255	2.94	195
14	4	Without	0.87	150	2.77	60	3.12	300	0.78	15	2.08	45	1.21	180	0.52	180	0.52	150	2.60	270	2.08	195
		With	0.43	135	1.30	75	4.16	300	0.95	300	2.48	300	0.87	150	0.26		0.69	135	2.25	285	1.30	195
14	10	Without	1.39	15	5.11	60	1.56	300	1.39	315			0.95	165	1.73	180	1.39	165	3.12	255	3.46	195
		With	1.21	15	5.37	60	1.91	300	1.04	45	1.21	270	1.13	150	1.65	180	1.13	165	2.77	240	3.03	195
14	14	Without	1.73	15	3.98	60	3.20	270	1.21	315	0.69	345	1.30	165	1.73	180	1.47	150	3.98	240	3.55	195
		With	3.20	0	3.03	60	2.77	270	1.39	330	0.95	285	0.87	120	1.47	180	1.21	150	3.29	270	2.86	195
14	18	Without	2.08	30	3.64	60	2.68	300	1.30	45	0.87	285	1.04	165	1.39	195	1.39	165	3.46	240	2.86	195
		With	2.17	30	3.12	60	1.82	195	1.39	30	0.61	270	1.39	150	1.04	195	1.04	165	3.20	225	2.60	195
		Southeast Wave Direction--Flood Tide																				
6	2	Without	1.32	240	2.37	240	2.96	300	2.22	315	2.22	285	2.21	315	1.44	330	1.52	315	1.38	345	1.44	15
		With	1.38	240	2.76	240	2.96	300	2.07	315	1.92	285	1.93	315	1.24	330	1.60	315	1.30	345	1.24	15
6	4	Without	1.38	240	2.27	240	3.57	300	2.27	315	1.92	285	2.29	300	1.66	330	1.60	315	1.60	345	0.58	15
		With	1.46	240	2.47	240	3.27	300	2.47	315	2.00	285	2.13	315	1.52	330	1.80	315	1.55	330	0.46	30
6	7	Without	1.21	225	1.02	75	3.91	300	2.81	315	1.36	315	2.29	315								
		With	1.40	225	0.68	75	4.38	300	4.15	300	1.42	315	2.13	315	1.23	315	1.60	330	3.05	300	1.67	195
6	10	Without	1.41	240	1.56	60	4.37	285	2.68	300	1.58	300	1.81	315	1.63	315	1.39	315	2.49	285	1.36	210
		With	1.58	240	1.36	60	4.77	270	2.46	300	1.36	315	1.65	315	1.51	315	1.27	315	2.70	285	1.51	195
10	4	Without	1.54	255	2.15	240	4.22	300	3.12	315	2.55	285	2.44	315	2.02	315	1.90	315	2.32	0	0.63	30
		With	1.34	270	2.01	240	4.55	300	3.38	315	2.84	285	2.63	315	2.32	330	2.11	315	2.53	345	1.60	15
10	10	Without	1.77	185	3.08	60	3.63	300	2.31	315	1.35	0	2.06	315	1.38	300	1.07	300	0.99	255	1.89	195
		With	2.10	210	3.08	60	2.72	270	2.67	300	1.13	30	2.25	315	1.38	300	1.38	315	2.07	270	1.44	195
10	14	Without	3.62	345	2.07	45	3.58	330	2.46	315	1.73	300	1.78	315	0.97	240	0.93	300	1.95	240	2.56	195
		With	4.52	345	1.56	60	2.69	315	2.82	315	1.90	315	1.57	315	0.84	300	1.09	315	3.76	300	3.08	195
10	18	Without			1.77	45	1.31	15	2.05	315	2.05	285										
		With	3.15	345	1.36	60	1.58	345	2.00	315	2.50	270	1.47	300	0.62	300	0.65	300	1.66	225	2.34	195
14	4	Without	0.60	345	0.36		5.78	315	2.88	315	2.62	300	1.96	315	1.51	330	1.01	330	1.70	300	0.93	195
		With	0.51	240	0.73	210	6.02	300	2.88	315	2.10	300	1.64	315	1.70	330	1.20	315	2.23	330	0.74	195
14	10	Without	1.42	240	3.46	60	4.19	300	2.97	315	3.98	285	1.54	315	0.91	270	0.87	300	2.56	300	1.90	195
		With	2.00	240	2.88	60	4.52	300	2.84	315	3.79	285	1.69	315								
14	14	Without	2.42	300	3.83	45	4.33	315	2.98	315	3.36	285	1.35	315	0.94	255	0.77	300	1.49	270	2.20	195
		With	3.18	330	3.38	45	3.36	315	2.81	315	3.27	285	1.27	315	0.79	285	0.61	300	2.20	270	1.92	195
14	18	Without	2.80	0	1.89	60	5.18	300	2.65	315	3.48	285	1.53	315	1.11	285	1.09	300	3.50	240	2.28	180
		With	3.02	30	2.97	60	4.23	300	3.03	315	3.79	285	1.67	315	1.07	285	0.97	315	3.95	240	2.83	195

(Continued)

Wave Period sec	Wave Height ft	Breakwater Status	2A Vel	2A Az	2B Vel	2B Az	3A Vel	3A Az	3B Vel	3B Az	4A Vel	4A Az	4B Vel	4B Az	5A Vel	5A Az	5B Vel	5B Az	6A Vel	6A Az	6B Vel	6B Az
										Southeast Wave Direction--Ebb Tide												
6	2	Without	0.85	180	0.62	90	3.48	120	6.63	135	2.76	120	3.42	150	1.07	165	1.09	135	0.36		0.54	195
		With	0.31		0.52		4.72	135	2.79	120	2.70	135	4.02	135	1.42	165	0.99	150	0.39		0.60	
6	4	Without	1.19	120	1.26	60	1.65	90	4.31	135	1.72	135	3.97	135	0.94	150	1.03	135	0.80	195	1.23	180
		With	0.43	45	1.22	75	2.29	150	5.65	135	1.49	120	2.98	135	1.38	165	0.94	135	1.88	270	1.91	180
6	7	Without	1.97	195	2.21	45	1.28	15	3.36	135	1.22	75	1.07	150	1.32	150	1.28	150	1.17	255	1.70	195
		With	0.44				1.37	90	3.11	150	2.22	120	3.93	135	1.25	150	0.95	135	2.22	255	0.91	210
6	10	Without	1.80	75	2.13	45	2.44	30	3.36	150	1.90	105	5.41	135	1.65	165	1.29	150	2.18	255	2.70	195
		With	1.23	135	3.37	60	2.24	105	4.38	135	3.05	120	3.53	135	1.30	180	1.08	150	2.13	240	1.78	210
10	4	Without	0.95	120	1.21	75	2.18	45	3.02	150	1.71	135	5.09	135	1.30	165	0.96	150	1.04	255	1.10	195
		With	0.65	45	0.86	60	2.77	150	5.06	135	2.14	135	5.15	135	0.83	150	0.96	150	0.51	270	1.12	195
10	10	Without	3.12	15	5.45	45	1.48	60	2.91	135			3.99	165	2.47	180	1.66	150	3.95	225	3.47	195
		With	3.12	15	5.28	45	1.81	150	5.00	135	2.33	135	4.60	150	1.72	180	1.11	165	2.70	225	2.63	195
10	14	Without	3.53	330	3.89	45	1.75	300	2.01	120	1.75	180	4.46	150	2.68	180	1.62	165	3.91	240	3.68	195
		With	1.77	330			2.73	75	4.08	135	4.13	150	4.05	150	1.80	180	1.34	165	5.69	240	1.75	195
10	18	Without	3.72	45	5.77	60	2.57	30	2.95	120	0.42		3.95	165	3.99	165	2.14	165	5.08	210	4.16	195
		With	4.16	60	1.87	60	2.16	150	5.53	135	1.74	105	5.23	150	1.65	180	1.64	150	4.34	210	2.87	195
14	4	Without	2.10	120	2.98	75	2.65	30	3.83	120	0.67	90	4.88	195	2.02	165	1.49	150	2.82	285	3.00	195
		With	0.72	60	2.47	45	1.97	90	6.30	135	1.72	105	5.00	150	1.74	165	1.21	150	2.20	225	2.63	195
14	10	Without	1.24		3.90	45	1.55	45	2.97	135	1.86	90	4.81	165	2.82	165	1.70	150	3.68	210	3.53	195
		With	1.86	30	4.68	45	1.06	45	5.20	120	1.06	15	4.59	165	1.65	165	1.33	150	3.39	210	3.53	195
14	14	Without	2.36	0	5.46	60	0.68		4.22	135	0.68		4.77	165	2.81	180	1.82	165	4.74	240	3.42	195
		With	3.30	15	3.71	60	1.81		4.43	120	1.13	75	4.24	165	2.18	180	1.19	165	3.79	240	2.66	195
14	18	Without	3.04	30	4.38	60	2.00	270	3.77	135	0.66	270	4.13	150	2.87	180	1.86	165	4.08	210	3.98	195
		With									0.85	210	4.66	165	2.51	180	1.76	165	4.55	210	3.60	195

Wave Period sec	Wave Height ft	Breakwater Status	4A Vel	4A Az	4B Vel	4B Az	5A Vel	5A Az	5B Vel	5B Az	6A Vel	6A Az	6B Vel	6B Az	7A Vel	7A Az	7B Vel	7B Az
								East Wave Direction--Slack Tide										
6	2	Without	1.01	270	0.85	165	0.69	300	0.30		0.50	195	0.89	165	0.36		0.75	0
		With	0.40		0.34		0.21		0.19		0.56	225	0.61	120	0.25		0.41	180
6	4	Without	0.93	285	0.55	135	0.62	330	0.80	300	1.56	315	0.69	30	0.43	30	0.26	
		With	1.17	300	0.68	105	0.32		0.54	210	1.21	270	0.61	15	0.35	30	0.35	195
6	7	Without	0.61	30	1.07	180	0.43		0.52		1.99	270	1.04	15	0.52	105	1.13	165
		With	0.87	60	1.80	330	0.52	300	0.69	300	2.17	300	0.95	15	0.61	90	0.87	165
6	10	Without	1.92	75	1.42	150	0.43	195	0.80	135	4.33	285	1.13	195	2.08	255	1.48	180
		With	1.32	45	1.13	300	0.52	195	0.74	120	4.85	300	1.30	195	2.34	270	0.93	195
10	4	Without	0.51	75	1.13	105	0.43	300	0.44		0.87	180	1.09	165	0.60	45	0.74	180
		With	0.57	60	1.30	135	0.52	300	0.76	315	1.13	270	1.12	15	0.36		0.30	
10	10	Without	2.04	90	1.75	270	0.75	300	0.43		2.62	240	2.84	195	2.37	225	1.78	195
		With	2.68	60	1.21	285	0.95	270	0.26		2.42	255	0.87	210				
10	14	Without	1.76	60	0.92	300	1.39	315	1.11	315	2.44	270	1.26	195	2.27	240	1.21	180
		With	1.99	60	0.69		1.13	300			2.34	210	1.56	210				
10	18	Without	1.91	45	0.61	165	0.35		0.61	135	2.66	240	1.65	180	1.39	180	1.73	195
		With	1.56	60	0.78	150	0.35		0.69	135	3.86	255	1.82	180	1.47	180	1.39	180
14	4	Without	1.30	45	1.47	105	0.95	300	0.96	15	3.98	270	1.13	0	0.78	195	1.21	180
		With	1.04	45	1.21	90	0.71	180	0.36		2.93	270	1.24	195	0.69	180	1.13	180
14	10	Without	2.34	45	2.08	165	0.61		1.01	330	2.25	285	1.04	180	2.59	210	1.99	195
		With	2.42	75	1.82	150	0.52		0.46		1.73	255	1.39	180	2.63	195	2.22	210
14	14	Without	1.09	60	0.61		1.24	315	1.07	315	3.06	285	1.14	180	1.39	195	1.51	165
		With	2.18	75	0.91	195	0.78	270	0.61		2.82	255	2.64	180	1.91	195	1.91	180
14	18	Without	1.79	75	1.14	240	1.12	315	0.35		2.86	255	0.67	180	1.50	165	2.42	195
		With	2.12	90	1.53	285	0.39		0.35		2.34	240	3.18	180	2.43	195	2.68	210
								East Wave Direction--Ebb Tide										
6	2	Without	1.28	135	3.47	135	1.21	150	0.91	135	0.94	210	0.68	180	1.02	255	0.73	195
		With	3.08	120	5.72	135	1.82	165	1.21	150	1.17		0.39		0.91	240	1.28	195
6	4	Without	1.69	135	3.92	135	1.64	165	1.24	150	2.26	255	0.96	15	0.79	240	1.01	180
		With	3.09	120	6.53	135	1.39	165	1.52	150	2.07	255	1.21	0	1.12	270	0.90	210
6	7	Without	1.65	150	4.67	150	1.77	165	1.16	165	2.17	270	0.52		0.92	240	2.81	180
		With	3.02	105	5.70	150	1.98	165	1.52	165	2.17	270	0.94	15	0.81	240	3.38	195
6	10	Without	2.85	105	2.15	150	1.54	165	1.13	135	3.27	240	0.97	195	2.41	225	2.03	195
		With	2.38	105	4.00	150	1.63	150	1.34	135	4.08	270	0.85	195	2.42	225	1.69	210
10	4	Without	3.78	105	6.00	135	2.13	180	1.31	150	2.07	195	2.69	180	0.95	225	1.64	195
		With	2.61	120	5.19	135	2.13	150	1.47	135	1.66	195	0.83	210	0.85	240	1.56	195

(Continued)

Table 5 (Concluded)

Wave Period sec	Wave Height ft	Breakwater Status	4A Vel	4A Az	4B Vel	4B Az	5A Vel	5A Az	5B Vel	5B Az	6A Vel	6A Az	6B Vel	6B Az	7A Vel	7A Az	7B Vel	7B Az
		East Wave Direction--Ebb Tide (Continued)																
10	10	Without	2.20	90	3.65	150	1.42	180	1.08	135	2.92	225	1.25	180	2.71	225	2.26	210
		With	2.20	90	3.98	135	1.42	150	1.14	120	1.46	225	1.88	195	1.81	225	2.04	210
10	14	Without	1.74	90	4.15	150	1.59	180	1.01	150	2.42	240	1.67	180	2.90	225	2.60	210
		With	3.05	90	3.96	150	1.59	180	1.19	135	2.86	240	1.98	195	3.47	225	2.38	210
10	18	Without	1.61	90	3.62	150	1.62	180	1.16	150	5.13	255	2.30	195	2.57	225	2.57	210
		With	1.85	105	3.87	150	1.53	180	1.38	150	4.27	270	1.94	195	2.23	225	2.40	210
14	4	Without	1.75	105	4.35	135	1.42	180	1.04	150	3.94	270	1.32	210	1.13	225	2.28	210
		With	1.97	120	4.88	150	1.63	165	1.48	150	2.53	240	1.10	210	1.37	225	1.83	210
14	10	Without	2.90	105	4.03	150	1.25	180	1.06	135	3.08	225	0.84	180	2.95	210	2.37	210
		With	3.32	90	4.03	150	1.46	180	0.93	150	3.42	225	0.72	195	5.17	225	2.30	210
14	14	Without	1.32	75	4.14	150	1.58	150	1.03	135	2.94	225	2.12	195	2.12	210	2.23	210
		With	2.21	90	4.14	150	1.76	150	1.46	150	3.23	240	1.82	195	2.27	225	2.35	210
14	18	Without	1.72	90	4.33	150	1.94	180	1.21	150	3.79	225	2.20	195	2.35	210	2.24	210
		With	1.51	135	5.05	135	1.75	150	1.35	150	3.15	210	2.03	195	2.80	240	2.24	210
		East Wave Direction--Flood Tide																
6	2	Without	4.07	285	3.55	315	2.42	315	2.42	315	2.25	345	2.60	15	1.04	30	0.69	75
		With	3.55	285	3.20	315	2.25	315	2.08	315	1.91	345	2.34	15	0.78	0	0.52	75
6	4	Without	2.77	285	2.77	315	1.91	315	2.08	315	1.73	330	1.73	15	0.61	15	0.52	75
		With	2.94	285	2.94	315	2.08	315	2.17	315	1.73	330	1.99	15	0.69	15	0.52	90
6	7	Without	2.68	315	2.17	270	2.08	315	1.47	315	2.42	300	1.56	15	0.52	45	0.52	165
		With	3.12	285	2.68	315	2.34	315	1.91	315	2.08	330	2.08	15	0.43	60	0.61	165
6	10	Without	1.65	300	1.82	300	1.91	330	1.65	315	1.91	300	1.65	15	0.52		0.61	165
		With	2.42	300	3.12	315	2.08	330	2.08	315	2.51	300	2.34	15	1.47	240	0.61	180
10	4	Without	3.38	285	2.77	315	1.99	315	2.51	315	2.17	345	2.42	15	0.87	15	0.43	
		With	3.20	285	2.94	315	2.08	315	2.34	315	1.91	330	2.42	15	0.69	15	0.35	
10	10	Without	3.03	315	3.12	300	1.91	330	2.51	315	3.38	300	1.82	15	1.13	225	1.04	180
		With	2.77	300	3.29	315	2.17	315	2.17	330	3.12	300	1.99	15	1.39	240	1.21	195
10	14	Without	1.39	345	2.25	315	1.82	315	2.08	315	1.65	270	0.69	195	1.47	270	1.65	195
		With	1.56	330	2.08	315	2.08	330	1.82	315	2.68	270	1.13	0	1.30		1.21	210
10	18	Without	1.21	330	2.08	330	1.82	315	1.56	330	1.30	285	1.04	15	1.65	180	1.56	195
		With	1.73	315	1.56	315	1.99	330	1.56	330	2.42	270	0.78		2.08	225	1.56	195
14	4	Without	2.17	285	2.60	315	1.99	315	1.47	330	2.08	300	3.64	0	0.52		1.04	135
		With	1.99	300	2.34	315	1.82	315	1.47	315	2.60	300	2.51	0	0.17		0.87	195
14	10	Without	1.65	345	2.17	315	2.60	330	2.51	330	2.25	300	1.04	180	1.39	195	1.65	195
		With	1.65	345	1.47	330	2.08	330	2.34	330	1.99	315	1.21	180	1.56	180	1.65	210
14	14	Without	1.82	330	1.39	315	2.17	315	1.91	315	2.51	300	0.61	195	1.21	180	1.56	195
		With	2.17	330	2.17	315	1.73	315	1.65	330	2.68	270	0.78	210	1.39	210	1.30	210
14	18	Without	1.21	360	1.47	315	1.91	330	1.65	330	3.03	300	1.13	195	1.04	195	1.73	195
		With	1.04	45	2.08	315	1.47	330	1.65	330	2.08	270	1.04	180	1.56	210	2.08	210

Table 6

Average Current Velocities Within a Wave Period, Test Series I

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth* deg	Breakwater In Velocity fps	Breakwater In Azimuth* deg	Δ Velocity** fps	Δ Velocity† %
		South Wave Direction, 6-Sec Wave Period					
Slack	1A	0.36	††	0.46	††	+0.10	+28
	1B	0.51	130	0.53	130	+0.02	+4
	2A	0.51	113	0.82	105	+0.31	+61
	2B	1.05	79	1.16	71	+0.11	+10
	3A	1.56	315	1.83	315	+0.27	+17
	3B	0.79	15	0.90	15	+0.11	+14
	4A	0.78	30	0.82	38	+0.04	+5
	4B	0.70	75	0.87	90	+0.17	+24
Flood	1A	0.61	205	0.57	210	-0.04	-7
	1B	1.19	200	1.35	205	+0.16	+13
	2A	1.28	255	1.30	250	+0.02	+2
	2B	2.06	240	1.85	240	-0.21	-10
	3A	4.34	320	4.68	320	+0.34	+8
	3B	3.10	325	2.95	330	-0.15	-5
	4A	3.09	285	2.86	289	-0.23	-7
	4B	2.62	315	3.00	315	+0.38	+15
Ebb	1A	0.72	††	0.95	††	+0.23	+32
	1B	0.77	184	1.09	180	+0.32	+42
	2A	0.98	110	0.84	105	-0.14	-14
	2B	0.96	240	0.82	255	-0.14	-15
	3A	1.90	68	2.16	56	+0.26	+14
	3B	1.96	158	2.11	143	+0.15	+8
	4A	2.76	109	2.52	109	-0.24	-9
	4B	4.05	124	3.48	131	-0.57	-14

(Continued)

Note: Station locations given in Plate 2, velocities and azimuths are average values obtained from all test waves within the designated wave periods.

* Azimuth is measured clockwise from New Jersey grid north.

** Δ velocity (fps) = $velocity_{in} - velocity_{out}$.

† Δ velocity (%) = ($velocity_{in} - velocity_{out}/velocity_{out}$) (100).

†† No predominant direction can be defined.

(Sheet 1 of 8)

Table 6 (Continued)

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth deg	Breakwater In Velocity fps	Breakwater In Azimuth deg	Δ Velocity fps	Δ Velocity %
			South Wave Direction, 10-Sec Wave Period				
Slack	1A	1.25	††	1.41	††	+0.16	+13
	1B	1.20	86	1.05	71	-0.15	-13
	2A	2.16	8	1.91	345	-0.25	-12
	2B	1.72	60	1.97	55	+0.25	+15
	3A	1.65	315	2.26	330	+0.61	+37
	3B	0.61	330	0.76	330	+0.15	+25
	4A	0.84	34	0.79	41	-0.05	-6
	4B	0.73	98	0.80	94	+0.07	+10
Flood	1A	1.19	180	1.36	203	+0.17	+14
	1B	1.12	180	0.99	173	-0.13	-12
	2A	1.82	285	1.46	275	-0.36	-20
	2B	2.09	240	1.99	240	-0.10	-5
	3A	3.97	319	3.92	323	-0.05	-1
	3B	2.38	320	2.12	325	-0.26	-11
	4A	2.11	281	1.98	281	-0.13	-6
	4B	2.40	311	2.44	315	+0.04	+2
Ebb	1A	Lost	Lost	Lost	Lost	--	--
	1B	1.01	98	0.97	98	-0.04	-4
	2A	3.55	45	2.50	60	-1.05	-30
	2B	1.94	94	1.52	83	-0.42	-22
	3A	1.91	††	1.37	††	-0.54	-28
	3B	2.41	175	2.41	160	0	0
	4A	2.55	109	2.40	131	-0.15	-6
	4B	3.45	139	3.40	139	-0.05	-1
			South Wave Direction, 14-Sec Wave Period				
Slack	1A	1.34	60	1.53	75	+0.19	+14
	1B	1.38	55	1.34	55	-0.04	-3
	2A	0.77	30	1.38	8	+0.61	+79
	2B	1.83	64	1.88	56	+0.05	+3
	3A	1.94	290	2.02	353	+0.08	+4
	3B	0.85	340	0.88	10	+0.03	+4
	4A	0.79	30	0.83	26	+0.04	+5
	4B	1.02	110	0.89	115	-0.13	-13

(Continued)

†† No predominant direction can be defined.

Table 6 (Continued)

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth deg	Breakwater In Velocity fps	Breakwater In Azimuth deg	Δ Velocity fps	Δ Velocity %
			South Wave Direction, 14-Sec Wave Period (Continued)				
Flood	1A	1.22	60	1.18	175	-0.04	-3
	1B	1.06	101	1.10	112	+0.04	+4
	2A	1.27	229	1.11	214	-0.16	-13
	2B	1.72	240	1.94	240	+0.22	+13
	3A	4.97	326	4.24	330	-0.73	-15
	3B	2.52	323	2.64	323	+0.12	+5
	4A	2.51	293	2.89	293	+0.38	+15
	4B	2.59	311	2.19	315	-0.40	-15
Ebb	1A	Lost	Lost	Lost	Lost	--	--
	1B	2.30	79	1.20	113	-1.10	-48
	2A	2.16	53	2.17	86	+0.01	0
	2B	2.02	75	1.58	94	-0.44	-22
	3A	2.20	††	2.56	††	+0.36	+16
	3B	1.43	173	1.59	††	+0.16	+11
	4A	3.21	105	1.79	116	-1.42	-44
	4B	3.80	135	3.14	135	-0.66	-17
			Southeast Wave Direction, 6-Sec Wave Period				
Slack	2A	0.87	218	0.92	225	+0.05	+6
	2B	1.65	60	1.93	70	+0.28	+16
	3A	2.40	295	2.57	275	+0.17	+7
	3B	0.92	295	1.05	280	+0.13	+14
	4A	0.94	68	1.07	75	+0.13	+14
	4B	1.22	315	1.00	315	-0.22	-18
	5A	0.51	180	0.46	158	-0.05	-10
	5B	0.43	150	0.46	143	+0.03	+7
	6A	2.43	285	2.80	280	+0.37	+15
	6B	1.30	185	1.91	185	+0.61	+47
Flood	2A	1.33	236	1.46	236	+0.13	+9
	2B	1.81	††	1.82	††	+0.01	+1
	3A	3.70	296	3.85	293	+0.15	+4
	3B	2.50	311	2.79	307	+0.29	+12
	4A	1.77	296	1.68	300	-0.09	-5
	4B	2.15	311	1.96	315	-0.19	-9
	5A	1.58	325	1.42	325	-0.16	-10
	5B	1.50	315	1.56	315	+0.06	+4
	6A	1.82	325	1.85	320	+0.03	+2
	6B	1.13	††	1.07	††	-0.06	-5

(Continued)

†† No predominant direction can be defined.

Table 6 (Continued)

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth deg	Breakwater In Velocity fps	Breakwater In Azimuth deg	Δ Velocity fps	Δ Velocity %
		Southeast Wave Direction, 6-Sec Wave Period (Continued)					
Ebb	2A	1.20	††	0.60	††	-0.60	-50
	2B	1.56	60	1.70	68	+0.14	+9
	3A	2.21	116	2.66	120	+0.45	+20
	3B	4.42	139	3.98	135	-0.44	-10
	4A	1.90	109	2.37	124	+0.47	+25
	4B	3.47	143	3.62	135	+0.15	+4
	5A	1.25	158	1.33	165	+0.08	+6
	5B	1.17	143	0.99	143	-0.18	-15
	6A	1.13	235	1.66	255	+0.53	+47
	6B	1.54	191	1.30	200	-0.24	-16
		Southeast Wave Direction, 10-Sec Wave Period					
Slack	2A	2.74	355	2.83	350	+0.09	+3
	2B	2.21	64	2.54	64	+0.33	+15
	3A	2.96	278	2.51	270	-0.45	-15
	3B	0.61	11	0.59	25	-0.02	-3
	4A	0.87	††	0.75	305	-0.12	-14
	4B	0.98	130	1.25	124	+0.27	+28
	5A	1.16	180	1.04	185	-0.12	-10
	5B	0.93	146	0.82	155	-0.11	-12
	6A	2.69	259	2.82	259	+0.13	+5
	6B	1.84	180	2.23	195	+0.39	+21
Flood	2A	2.31	††	2.65	††	+0.34	+15
	2B	2.31	50	2.00	60	-0.31	-13
	3A	3.19	310	2.89	295	-0.30	-9
	3B	2.49	315	2.72	311	+0.23	+9
	4A	1.92	290	2.11	290	+0.19	+10
	4B	2.09	315	2.15	315	+0.06	+3
	5A	1.46	308	1.51	310	+0.05	+3
	5B	1.30	305	1.52	315	+0.22	+17
	6A	1.75	248	2.50	265	+0.75	+43
	6B	2.23	195	2.26	195	+0.03	+1

(Continued)

†† No predominant direction can be defined.

Table 6 (Continued)

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth deg	Breakwater In Velocity fps	Breakwater In Azimuth deg	Δ Velocity fps	Δ Velocity %
		Southeast Wave Direction, 10-Sec Wave Period (Continued)					
Ebb	2A	3.46	††	3.02	††	-0.44	-13
	2B	3.33	56	3.07	55	-0.26	-8
	3A	2.08	45	2.25	150	+0.17	+8
	3B	2.72	131	4.92	135	+2.20	+81
	4A	1.29	158	2.67	131	+1.38	+107
	4B	4.37	154	4.78	146	+0.41	+9
	5A	2.61	173	1.50	173	-1.11	-42
	5B	1.60	158	1.26	158	-0.34	-21
	6A	4.31	225	4.24	225	-0.07	-2
	6B	3.10	195	2.09	195	-1.01	-32
		Southeast Wave Direction, 14-Sec Wave Period					
Slack	2A	1.52	28	1.75	15	+0.23	+15
	2B	3.88	60	3.20	64	-0.68	-18
	3A	2.63	290	2.95	290	+0.32	+12
	3B	1.17	353	1.19	356	+0.02	+2
	4A	1.21	††	1.33	281	+0.12	+10
	4B	1.13	169	1.07	143	-0.06	-5
	5A	1.34	185	1.11	184	-0.23	-17
	5B	1.19	158	1.02	154	-0.17	-14
	6A	3.29	251	2.88	255	-0.41	-12
	6B	2.99	195	2.45	195	-0.54	-18
Flood	2A	2.21	††	2.73	††	+0.52	+24
	2B	3.06	55	3.08	55	+0.02	+1
	3A	4.87	308	4.53	304	-0.34	-7
	3B	2.87	315	2.89	315	+0.02	+1
	4A	3.36	289	3.24	289	-0.12	-4
	4B	1.60	315	1.56	315	-0.04	-3
	5A	1.19	290	1.19	300	0	0
	5B	0.96	310	0.93	310	-0.03	-3
	6A	2.23	270	2.79	280	+0.56	+25
	6B	1.80	190	1.83	195	+0.03	+2

(Continued)

†† No predominant direction can be defined.

Table 6 (Continued)

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth deg	Breakwater In Velocity fps	Breakwater In Azimuth deg	Δ Velocity fps	Δ Velocity %
			Southeast Wave Direction, 14-Sec Wave Period (Continued)				
Ebb	2A	1.90	15	1.96	35	+0.06	+3
	2B	4.11	60	3.62	50	-0.49	-12
	3A	1.63	38	1.61	68	-0.02	-1
	3B	3.67	130	5.31	125	+1.64	+44
	4A	1.06	††	1.21	††	+0.15	+14
	4B	4.65	169	4.62	161	-0.03	-1
	5A	2.63	173	2.02	173	-0.61	-23
	5B	1.72	158	1.37	158	-0.35	-20
	6A	3.83	220	3.48	221	-0.35	-9
	6B	3.48	195	3.11	195	-0.37	-11
			East Wave Direction, 6-Sec Wave Period				
Slack	4A	1.15	††	1.12	††	-0.03	-3
	4B	0.97	158	0.99	††	+0.02	+2
	5A	0.49	263	0.45	248	-0.04	-8
	5B	0.71	††	0.66	††	-0.05	-7
	6A	2.63	290	2.74	290	+0.11	+4
	6B	0.95	††	0.95	††	0	0
	7A	1.01	††	1.10	††	+0.09	+9
	7B	1.30	173	0.90	184	-0.40	-31
Flood	4A	2.79	296	3.00	289	+0.21	+8
	4B	2.71	310	3.09	315	+0.38	+14
	5A	2.08	319	2.19	319	+0.11	+5
	5B	1.91	315	2.06	315	+0.15	+8
	6A	2.08	319	2.06	326	-0.02	-1
	6B	1.89	15	2.19	15	+0.30	+16
	7A	0.72	30	0.63	25	-0.09	-13
	7B	0.59	120	0.57	128	-0.02	-3
Ebb	4A	1.94	125	2.85	115	+0.91	+47
	4B	3.55	143	5.49	143	+1.94	+55
	5A	1.54	161	1.71	161	+0.17	+11
	5B	1.11	146	1.40	150	+0.29	+26
	6A	2.57	255	2.77	265	+0.20	+8
	6B	0.78	††	0.85	††	+0.07	+9
	7A	1.29	240	1.32	244	+0.03	+2
	7B	1.65	188	1.81	203	+0.16	+10

(Continued)

†† No predominant direction can be defined.

Table 6 (Continued)

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth deg	Breakwater In Velocity fps	Breakwater In Azimuth deg	Δ Velocity fps	Δ Velocity %
			East Wave Direction, 10-Sec Wave Period				
Slack	4A	1.56	68	1.70	60	+0.14	+9
	4B	1.10	††	1.00	††	-0.10	-9
	5A	0.73	305	0.74	290	+0.01	+1
	5B	0.49	††	0.57	††	+0.08	+16
	6A	2.15	233	2.44	248	+0.29	+13
	6B	1.71	184	1.42	200	-0.29	-17
	7A	1.00	††	0.92	††	-0.08	-8
	7B	1.37	188	1.39	180	+0.02	+2
Flood	4A	2.25	319	2.32	308	+0.07	+3
	4B	2.56	315	2.48	315	-0.08	-3
	5A	1.89	319	2.08	323	+0.19	+10
	5B	2.17	319	1.97	323	-0.20	-9
	6A	2.13	300	2.53	293	+0.40	+19
	6B	1.76	15	1.58	10	-0.18	-10
	7A	1.28	††	1.37	††	+0.09	+7
	7B	1.17	190	1.08	200	-0.09	-8
Ebb	4A	2.33	94	2.43	101	+0.10	+4
	4B	4.36	146	4.25	143	-0.11	-3
	5A	1.69	180	1.67	165	-0.02	-1
	5B	1.14	146	1.30	135	+0.16	+14
	6A	3.14	229	2.56	233	-0.58	-18
	6B	1.98	184	1.66	199	-0.32	-16
	7A	2.28	225	2.09	229	-0.19	-8
	7B	2.27	206	2.10	206	-0.17	-7
			East Wave Direction, 14-Sec Wave Period				
Slack	4A	1.63	56	1.94	71	+0.31	+19
	4B	1.33	††	1.37	††	+0.04	+3
	5A	1.10	310	0.75	225	-0.35	-32
	5B	0.85	340	0.45	††	-0.40	-47
	6A	3.04	274	2.46	255	-0.58	-19
	6B	0.95	180	2.11	184	+1.16	+122
	7A	1.57	191	1.91	191	+0.34	+22
	7B	1.78	184	1.99	195	+0.21	+12

†† No predominant direction can be defined.

(Sheet 7 of 8)

Tidal Condition	Station	Breakwater Out Velocity fps	Breakwater Out Azimuth deg	Breakwater In Velocity fps	Breakwater In Azimuth deg	Δ Velocity fps	Δ Velocity %
East Wave Direction, 14-Sec Wave Period (Continued)							
Flood	4A	1.71	330	1.71	345	0	0
	4B	1.91	315	2.02	319	+0.11	+6
	5A	2.17	323	1.78	323	-0.39	-18
	5B	1.89	326	1.78	326	-0.11	-5
	6A	2.47	300	2.34	289	-0.13	-5
	6B	0.93	190	1.01	190	+0.08	+9
	7A	1.04	190	1.17	200	+0.13	+13
	7B	1.65	195	1.68	210	+0.03	+2
Ebb	4A	1.92	94	2.25	109	+0.33	+17
	4B	4.21	146	4.53	146	+0.32	+8
	5A	1.55	173	1.65	161	+0.10	+6
	5B	1.09	143	1.31	150	+0.22	+20
	6A	3.44	236	3.08	229	-0.36	-10
	6B	1.62	195	1.42	199	-0.20	-12
	7A	2.14	214	2.90	229	+0.76	+36
	7B	2.28	210	2.18	210	-0.10	-4

Table 7

Breaking Wave Data for South Zone, Northeast Wave Direction--Slack Tide

Test Wave			Breaking Characteristics					
Period sec	Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	4	Without	2,102,150	235,000	3.75	8.00	32	South
		With	2,102,150	235,000	3.73	8.00	33	South
		Without	2,105,865	234,000	2.17	8.00	32	South
		With	2,105,865	234,000	2.15	8.00	34	South
		Without	2,103,060	233,000	3.97	7.50	33	South
		With	2,103,060	233,000	4.38	7.50	31	South
6	7	Without	2,108,000	235,000	5.56	12.50	41	South
		With	2,108,000	235,000	6.23	12.50	39	South
		Without	2,108,000	234,000	6.63	13.00	41	South
		With	2,108,000	234,000	6.37	13.00	39	South
		Without	2,107,375	233,000	6.19	13.00	35	South
		With	2,107,375	233,000	6.23	13.00	36	South
		Without	2,103,000	232,000	3.24	7.00	33	South
		With	2,103,000	232,000	3.68	7.00	32	South
6	10	Without	2,109,000	235,000	8.00	19.00	43	South
		With	2,109,000	235,000	8.44	19.00	43	South
		Without	2,108,300	234,000	10.26	16.00	43	South
		With	2,108,300	234,000	10.41	16.00	42	South
		Without	2,108,000	233,000	10.95	16.50	36	South
		With	2,108,000	233,000	11.10	16.50	34	South
		Without	2,108,000	232,000	10.18	17.00	36	South
		With	2,108,000	232,000	9.86	17.00	34	South
10	4	Without	2,102,120	235,000	5.17	8.50	33	South
		With	2,102,120	235,000	4.75	8.50	33	South
		Without	2,101,835	234,000	4.59	7.00	33	South
		With	2,101,835	234,000	4.15	7.00	38	South
		Without	2,103,105	233,000	5.15	7.50	28	South
		With	2,103,105	233,000	5.45	7.50	28	South
		Without	2,102,850	232,000	4.14	5.50	28	South
		With	2,102,850	232,000	3.82	5.50	28	South
10	10	Without	2,109,595	235,000	11.71	21.00	40	South
		With	2,109,595	235,000	12.00	21.00	42	South
		Without	2,109,595	234,000	11.01	21.00	40	South
		With	2,109,595	234,000	10.56	21.00	42	South
		Without	2,109,000	233,000	11.82	20.50	34	South
		With	2,108,700	233,000	12.00	19.50	34	South
		Without	2,108,775	232,000	10.72	20.50	34	South
		With	2,108,550	232,000	11.00	19.00	34	South
14	4	Without	2,107,700	235,000	8.77	11.00	28	South
		With	2,107,700	235,000	7.83	11.00	28	South
		Without	2,107,700	234,000	8.46	10.50	28	South
		With	2,107,700	234,000	8.93	10.50	28	South
		Without	2,107,700	233,000	7.07	12.50	28	South
		With	2,107,700	233,000	6.55	12.50	27	South
		Without	2,103,300	232,000	6.19	10.00	23	South
		With	2,103,300	232,000	6.59	10.00	21	South
14	10	Without	2,110,000	235,000	14.12	22.50	36	South
		With	2,110,000	235,000	14.42	22.50	36	South
		Without	2,108,255	234,000	14.51	16.00	36	South
		With	2,108,255	234,000	14.22	16.00	36	South
		Without	2,108,150	233,000	14.29	18.00	35	South
		With	2,108,000	233,000	14.57	17.00	36	South
		Without	2,108,225	232,000	13.25	17.50	35	South
		With	2,108,225	232,000	13.86	17.50	36	South

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 8

Breaking Wave Data for South Zone, E22.5°N Wave Direction--Slack Tide

Test Wave			Breaking Characteristics					
Period	Height	Breakwater	Coordinates*		Height	Depth	Angle	Transport
sec	ft	Status	E, ft	N, ft	ft	ft	deg	Direction
6	4	Without	2,105,150	234,000	3.51	8.00	17	South
		With	2,105,360	234,000	2.47	7.50	17	South
		Without	2,102,501	233,000	2.46	5.00	18	South
		With	2,102,060	233,000	2.94	4.50	17	South
6	7	Without	2,107,501	235,000	5.61	9.50	18	South
		With	2,107,501	235,000	5.45	9.50	18	South
		Without	2,107,501	234,000	6.42	9.50	18	South
		With	2,107,501	234,000	5.21	9.50	18	South
		Without	2,103,240	233,000	6.31	7.50	11	South
		With	2,103,000	233,000	4.06	7.00	12	South
		Without	2,103,000	232,000	5.22	6.50	12	South
		With	2,103,000	232,000	3.96	6.50	12	South
6	10	Without	2,108,000	235,000	7.36	12.50	18	South
		With	2,107,850	235,000	8.28	11.00	18	South
		Without	2,107,850	234,000	6.23	11.50	18	South
		With	2,107,850	234,000	8.69	11.50	18	South
		Without	2,107,300	233,000	8.20	12.00	18	South
		With	2,107,300	233,000	8.81	12.00	18	South
		Without	2,107,000	232,000	8.65	15.00	18	South
		With	2,103,000	232,000	5.19	6.50	16	South
10	4	Without	2,102,240	234,000	4.40	7.00	13	South
		With	2,102,240	234,000	5.74	7.00	13	South
		Without	2,102,300	233,000	6.71	4.50	13	South
		With	2,102,300	233,000	4.17	4.50	13	South
		Without	2,102,150	232,000	5.82	5.50	13	South
		With	2,102,700	232,000	6.64	5.50	13	South
10	10	Without	2,107,700	235,000	8.46	10.50	17	South
		With	2,107,700	235,000	8.91	10.50	16	South
		Without	2,107,850	234,000	10.47	11.50	17	South
		With	2,107,850	234,000	12.53	11.50	16	South
		Without	2,107,850	233,000	8.89	15.50	17	South
		With	2,107,501	233,000	11.70	13.00	16	South
		Without	2,108,700	232,000	14.97	19.50	13	South
		With	2,106,300	232,000	9.12	14.50	14	South
14	4	Without	2,102,210	235,000	5.23	8.00	8	South
		With	2,107,501	235,000	6.88	9.50	7	South
		Without	2,105,195	234,000	5.99	8.00	7	South
		With	2,107,300	234,000	8.46	10.00	7	South
		Without	2,106,501	233,000	9.69	12.50	7	South
		With	2,103,150	233,000	7.36	7.50	7	South
		Without	2,106,501	232,000	11.27	15.50	7	South
		With	2,102,850	232,000	6.32	5.50	8	South
14	10	Without	2,108,000	235,000	9.60	12.50	12	South
		With	2,108,501	235,000	13.53	17.00	12	South
		Without	2,108,501	234,000	12.82	16.50	12	South
		With	2,108,150	234,000	16.20	14.50	12	South
		Without	2,108,300	233,000	16.33	19.00	12	South
		With	2,107,000	233,000	11.35	12.50	12	South
		Without	2,109,000	232,000	15.63	21.00	12	South
		With	2,107,700	232,000	13.55	16.50	12	South

Note: Zones and baselines for angles are defined in Plate 3; without means breakwater is not installed, with means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 9

Breaking Wave Data for South Zone, East Wave Direction--Slack Tide

Test Wave			Breaking Characteristics						
Period sec	Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	4	Without	2,103,000	233,000	3.23	7.50	5	North
		With	2,102,501	233,000	4.28	5.20	1	North
		Without	2,103,000	232,000	3.86	7.00	7	South
		With	2,102,842	232,000	3.68	5.50	7	South
6	7	Without	2,108,000	235,000	8.74	12.50	6	South
		With	2,107,501	235,000	6.79	10.00	11	South
		Without	2,107,700	234,000	7.62	10.00	1	South
		With	2,106,000	234,000	7.14	10.50	10	South
		Without	2,103,501	233,000	5.62	9.50	1	North
		With	2,103,150	233,000	5.96	7.50	3	North
		Without	2,104,000	232,000	8.61	12.50	7	South
		With	2,103,150	232,000	5.33	8.50	3	North
6	10	Without	2,108,501	235,000	10.05	17.50	3	South
		With	2,108,000	235,000	9.32	12.50	19	South
		Without	2,108,501	234,000	8.55	16.50	3	South
		With	2,107,700	234,000	4.65	10.50	4	South
		Without	2,108,000	233,000	10.63	16.50	7	South
		With	2,107,300	233,000	8.46	12.50	1	North
		Without	2,108,000	232,000	11.53	17.00	1	North
		With	2,107,501	232,000	8.89	16.00	8	North
10	4	Without	2,107,700	235,000	7.04	10.50	0	--
		With	2,107,000	235,000	4.76	10.00	3	South
		Without	2,107,700	234,000	7.88	10.00	0	--
		With	2,105,700	234,000	5.61	8.00	2	North
		Without	2,103,300	233,000	6.25	8.00	15	South
		With	2,103,000	233,000	4.71	7.50	12	South
		Without	2,103,000	232,000	4.46	7.00	7	South
		With	2,103,000	232,000	4.72	7.00	7	South
10	10	Without	2,111,000	235,000	16.30	25.50	2	South
		With	2,109,000	235,000	10.79	19.50	10	South
		Without	2,110,000	234,000	16.65	24.50	4	South
		With	2,108,501	234,000	13.76	16.50	7	South
		Without	2,109,000	233,000	16.59	20.50	7	South
		With	2,107,700	233,000	10.74	14.50	2	North
		Without	2,108,000	232,000	13.46	17.00	3	North
		With	2,108,000	232,000	13.21	17.00	2	North
14	4	Without	2,108,000	235,000	9.26	9.50	1	South
		With	2,107,501	235,000	8.67	10.00	7	South
		Without	2,108,000	234,000	9.79	11.00	1	South
		With	2,107,700	234,000	8.07	10.50	5	North
		Without	2,107,501	233,000	10.14	12.50	1	North
		With	2,103,000	233,000	6.19	7.50	21	South
		Without	2,103,499	232,000	7.95	10.50	7	North
		With	2,103,150	232,000	7.09	8.50	6	North
14	10	Without	2,112,000	235,000	21.52	29.50	1	North
		With	2,108,700	235,000	12.86	18.00	12	South
		Without	2,111,000	234,000	17.89	26.50	1	North
		With	2,108,700	234,000	14.69	17.50	5	South
		Without	2,110,300	233,000	20.69	24.50	6	South
		With	2,109,000	233,000	16.56	20.50	5	South
		Without	2,109,150	232,000	17.03	21.50	1	South
		With	2,108,850	232,000	12.68	20.50	20	North

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 10

Breaking Wave Data for South Zone, East Wave Direction--Flood Tide

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Breaking Height ft	Breaking Depth ft	Breaking Angle deg	Transport Direction
6	4	Without	2,105,700	234,000	5.42	8.00	5	North
		With	2,102,000	234,000	3.36	7.00	7	South
		Without	2,102,700	233,000	4.00	7.00	6	South
		With	2,102,501	233,000	4.36	5.50	7	South
		Without	2,102,700	232,000	4.09	5.50	6	South
		With	2,102,150	232,000	3.54	6.00	7	South
6	7	Without	2,108,000	235,000	8.75	12.50	4	South
		With	2,107,700	235,000	6.62	10.50	7	South
		Without	2,107,700	234,000	7.33	10.00	4	South
		With	2,106,000	234,000	5.65	10.50	4	North
		Without	2,103,501	233,000	6.92	9.00	7	South
		With	2,103,150	233,000	5.05	7.50	7	South
		Without	2,103,300	232,000	7.33	9.50	7	South
		With	2,103,150	232,000	6.38	8.50	7	South
6	10	Without	2,108,000	235,000	9.47	12.50	7	South
		With	2,107,850	235,000	8.81	11.50	7	South
		Without	2,108,000	234,000	9.19	12.50	7	South
		With	2,107,501	234,000	7.10	10.00	7	South
		Without	2,108,000	233,000	10.68	16.50	7	South
		With	2,106,000	233,000	6.74	13.00	17	North
		Without	2,108,000	232,000	10.93	16.50	7	South
		With	2,106,501	232,000	9.31	14.50	1	North
10	4	Without	2,107,300	235,000	7.76	9.50	3	South
		With	2,107,000	235,000	5.14	9.50	2	South
		Without	2,107,300	234,000	7.21	9.50	3	South
		With	2,105,700	234,000	5.50	8.00	7	South
		Without	2,102,700	233,000	4.59	5.50	43	South
		With	2,103,000	233,000	4.83	7.50	3	South
		Without	2,103,000	232,000	5.00	6.50	7	South
		With	2,103,000	232,000	5.96	7.00	3	South
10	10	Without	2,111,300	235,000	15.64	26.50	7	South
		With	2,109,000	235,000	10.30	19.50	14	South
		Without	2,110,000	234,000	15.50	24.00	7	South
		With	2,108,300	234,000	12.81	15.50	7	South
		Without	2,109,000	233,000	15.59	20.50	3	North
		With	2,108,000	233,000	9.63	16.50	0	--
		Without	2,108,000	232,000	12.44	17.00	7	South
		With	2,108,000	232,000	13.19	17.00	8	North
14	4	Without	2,108,000	235,000	9.48	12.50	8	South
		With	2,107,499	235,000	7.64	10.00	7	South
		Without	2,108,000	234,000	9.56	13.00	1	South
		With	2,107,499	234,000	8.11	10.00	4	North
		Without	2,107,501	233,000	10.37	13.50	7	North
		With	2,103,000	233,000	6.20	7.50	7	South
		Without	2,103,300	232,000	8.60	9.50	12	South
		With	2,102,850	232,000	7.18	5.50	7	South
14	10	Without	2,112,000	235,000	18.87	29.00	5	South
		With	2,109,300	235,000	15.04	20.50	12	South
		Without	2,111,000	234,000	17.21	26.50	2	South
		With	2,108,700	234,000	13.71	17.50	5	South
		Without	2,110,499	233,000	16.95	25.00	1	North
		With	2,108,300	233,000	15.45	19.00	5	South
		Without	2,109,499	232,000	16.60	23.00	1	North
		With	2,107,000	232,000	11.60	15.00	20	North

Note: Zones and baselines for angles are defined in Plate 3; without means breakwater is not installed, with means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 11

Breaking Wave Data for South Zone, East Wave Direction--Ebb Tide

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	4	Without	2,102,000	235,000	3.84	8.00	3	South
		With	2,102,000	235,000	3.59	8.00	7	South
		Without	2,108,000	234,000	7.34	12.50	2	South
		With	2,102,000	234,000	3.67	6.50	7	South
		Without	2,103,150	233,000	5.00	7.50	4	South
		With	2,102,499	233,000	4.79	5.00	2	North
		Without	2,103,000	232,000	3.42	6.50	4	South
		With	2,102,799	232,000	4.61	6.50	2	North
6	7	Without	2,108,000	235,000	9.08	12.00	7	South
		With	2,108,000	235,000	8.94	12.00	3	South
		Without	2,108,000	234,000	6.51	12.50	7	South
		With	2,105,700	234,000	5.20	8.00	7	South
		Without	2,108,000	233,000	8.63	16.00	7	South
		With	2,103,000	233,000	4.08	7.00	7	North
		Without	2,107,000	232,000	9.71	14.50	2	South
		With	2,103,000	232,000	4.91	6.50	15	North
6	10	Without	2,109,000	235,000	11.26	18.50	7	South
		With	2,108,000	235,000	10.33	12.00	3	South
		Without	2,109,000	234,000	9.76	19.00	7	South
		With	2,107,850	234,000	6.74	11.50	15	South
		Without	2,108,501	233,000	12.30	19.50	2	South
		With	2,107,501	233,000	8.30	12.50	4	South
		Without	2,108,501	232,000	9.46	18.50	2	South
		With	2,107,501	232,000	6.53	15.50	5	North
10	4	Without	2,107,700	235,000	6.41	10.00	5	South
		With	2,102,150	232,000	4.84	7.50	4	North
		Without	2,107,501	234,000	7.97	9.50	5	North
		With	2,105,700	234,000	4.12	8.00	1	North
		Without	2,103,000	233,000	5.24	7.00	8	North
		With	2,102,700	233,000	4.66	5.00	9	South
		Without	2,103,000	232,000	6.30	6.50	8	North
		With	2,102,700	232,000	5.32	5.50	7	South
10	10	Without	2,110,501	235,000	14.26	22.50	3	South
		With	2,109,000	235,000	10.65	18.50	10	South
		Without	2,110,501	234,000	15.48	25.50	3	South
		With	2,108,499	234,000	11.82	16.50	2	South
		Without	2,110,501	233,000	15.25	24.50	3	South
		With	2,108,000	233,000	9.15	16.50	7	South
		Without	2,108,501	232,000	14.02	18.50	1	South
		With	2,107,700	232,000	11.23	16.50	5	North
14	4	Without	2,107,850	235,000	11.37	11.00	1	North
		With	2,107,499	235,000	8.55	9.50	13	South
		Without	2,107,700	234,000	11.57	9.50	1	North
		With	2,107,625	234,000	7.59	9.50	2	North
		Without	2,107,700	233,000	10.75	14.00	10	North
		With	2,103,150	233,000	7.07	7.50	17	North
		Without	2,103,150	232,000	8.80	8.00	7	South
		With	2,103,150	232,000	8.07	8.00	7	North
14	10	Without	2,112,000	235,000	20.34	29.50	7	South
		With	2,109,700	235,000	13.99	20.50	18	South
		Without	2,111,000	234,000	16.91	26.00	5	South
		With	2,108,700	234,000	11.75	17.00	9	South
		Without	2,110,501	233,000	18.90	24.50	5	South
		With	2,109,000	233,000	16.27	20.00	2	South
		Without	2,109,501	232,000	19.07	22.50	1	North
		With	2,109,000	232,000	12.67	16.50	4	North

Note: Zones and baselines for angles are defined in Plate 3; without means breakwater is not installed, with means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 12

Breaking Wave Data for South Zone, E22.5°S Wave Direction--Slack Tide

Test Wave		Breakwater	Breaking Characteristics					
Period sec	Height ft	Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	4	Without	2,105,679	234,000	4.08	8.00	14	North
		With	2,105,679	234,000	4.75	8.00	14	North
		Without	2,102,586	233,000	3.75	5.00	15	North
		With	2,102,586	233,000	4.11	5.00	13	North
		Without	2,102,865	232,000	4.57	5.50	15	North
		With	2,102,865	232,000	4.57	5.50	15	North
6	7	Without	2,107,568	235,000	6.78	9.50	16	North
		With	2,107,568	235,000	6.14	9.50	16	North
		Without	2,107,661	234,000	8.63	10.00	16	North
		With	2,107,661	234,000	6.89	10.00	16	North
		Without	2,107,000	233,000	6.62	12.00	16	North
		With	2,107,000	233,000	7.84	12.00	16	North
		Without	2,104,655	232,000	5.50	14.50	16	North
		With	2,104,655	232,000	6.26	14.50	16	North
6	10	Without	2,108,069	235,000	9.46	12.50	15	North
		With	2,107,889	235,000	7.27	11.50	15	North
		Without	2,108,105	234,000	9.90	14.00	15	North
		With	2,108,000	234,000	8.73	12.50	15	North
		Without	2,107,486	233,000	10.07	12.00	15	North
		With	2,107,679	233,000	10.79	14.50	15	North
		Without	2,107,000	232,000	9.43	14.50	15	North
		With	2,106,895	232,000	9.90	14.50	15	North
10	4	Without	2,105,820	234,000	5.96	7.50	12	North
		With	2,106,000	234,000	5.74	10.00	11	North
		Without	2,103,000	233,000	5.07	7.00	10	North
		With	2,102,835	233,000	4.49	6.50	9	North
		Without	2,103,000	232,000	5.62	6.50	8	North
		With	2,103,000	232,000	5.84	6.50	9	North
10	10	Without	2,108,135	235,000	10.92	13.50	13	North
		With	2,108,000	235,000	9.78	12.00	15	North
		Without	2,108,850	234,000	14.15	18.00	13	North
		With	2,108,679	234,000	14.13	17.00	15	North
		Without	2,109,000	233,000	13.12	20.00	16	North
		With	2,108,000	233,000	13.40	16.50	16	North
		Without	2,108,240	232,000	13.82	17.00	16	North
		With	2,108,240	232,000	14.45	17.00	16	North
14	4	Without	2,107,610	235,000	7.09	9.50	13	North
		With	2,107,000	235,000	6.30	9.50	13	North
		Without	2,107,685	234,000	9.53	10.00	13	North
		With	2,107,685	234,000	9.00	10.00	13	North
		Without	2,107,225	233,000	10.71	12.00	13	North
		With	2,107,225	233,000	10.78	12.00	13	North
		Without	2,105,225	232,000	7.26	14.50	13	North
		With	2,105,000	232,000	8.74	14.50	13	North
14	10	Without	2,110,300	235,000	15.79	18.00	18	North
		With	2,108,300	235,000	11.72	14.50	13	North
		Without	2,109,300	234,000	13.19	20.50	18	North
		With	2,109,000	234,000	12.89	19.00	19	North
		Without	2,109,000	233,000	16.04	20.00	18	North
		With	2,109,500	233,000	18.74	22.00	19	North
		Without	2,108,700	232,000	16.76	19.50	18	North
		With	2,109,000	232,000	16.06	21.00	19	North

Note: Zones and baselines for angles are defined in Plate 3; <u>without</u> means breakwater is not installed, <u>with</u> means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 13

Breaking Wave Data for South Zone, Southeast Wave Direction--Slack Tide

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Breaking Height ft	Breaking Depth ft	Breaking Angle deg	Transport Direction
6	4	Without	2,105,835	234,000	3.86	8.00	32	North
		With	2,105,835	234,000	3.79	8.00	31	North
		Without	2,103,375	233,000	6.66	8.00	28	North
		With	2,103,375	233,000	5.07	8.00	28	North
		Without	2,103,180	232,000	4.67	8.50	28	North
		With	2,103,180	232,000	6.21	8.50	28	North
6	7	Without	2,108,000	235,000	6.88	12.50	31	North
		With	2,108,000	235,000	6.46	12.50	31	North
		Without	2,107,730	234,000	6.74	10.00	31	North
		With	2,107,730	234,000	7.56	10.00	31	North
		Without	2,107,000	233,000	6.68	12.00	31	North
		With	2,107,000	233,000	7.73	12.00	31	North
		Without	2,106,105	232,000	8.01	14.50	31	North
		With	2,106,105	232,000	8.38	14.50	31	North
6	10	Without	2,108,105	235,000	8.71	13.00	31	North
		With	2,108,105	235,000	9.34	13.00	33	North
		Without	2,108,000	234,000	9.62	12.50	31	North
		With	2,108,000	234,000	10.07	12.50	33	North
		Without	2,107,769	233,000	10.60	15.00	34	North
		With	2,107,901	233,000	10.98	15.50	34	North
		Without	2,106,904	232,000	8.52	14.50	34	North
		With	2,107,481	232,000	9.84	15.50	34	North
10	4	Without	2,105,835	234,000	5.06	8.00	29	North
		With	2,105,835	234,000	4.92	8.00	29	North
		Without	2,103,375	233,000	7.32	8.00	29	North
		With	2,103,375	233,000	7.46	8.00	29	North
		Without	2,103,180	232,000	6.47	8.50	29	North
		With	2,103,679	232,000	7.33	13.00	29	North
10	10	Without	2,108,625	235,000	12.45	17.50	30	North
		With	2,108,625	235,000	12.45	17.50	30	North
		Without	2,108,556	234,000	12.77	16.50	30	North
		With	2,108,556	234,000	14.12	16.50	30	North
		Without	2,108,135	233,000	12.36	17.50	31	North
		With	2,108,135	233,000	10.44	17.50	30	North
		Without	2,108,544	232,000	11.98	18.50	31	North
		With	2,108,300	232,000	14.00	17.50	33	North
14	4	Without	2,107,700	235,000	8.51	10.50	31	North
		With	2,107,775	235,000	8.66	11.00	31	North
		Without	2,107,820	234,000	8.26	11.00	31	North
		With	2,107,820	234,000	8.25	11.00	31	North
		Without	2,106,000	233,000	8.95	12.50	31	North
		With	2,106,000	233,000	9.54	12.50	31	North
		Without	2,106,321	232,000	10.97	14.00	31	North
		With	2,106,321	232,000	10.44	14.00	31	North
14	10	Without	2,110,000	235,000	16.08	21.50	33	North
		With	2,110,000	235,000	14.45	21.50	32	North
		Without	2,109,369	234,000	15.47	21.00	33	North
		With	2,110,000	234,000	16.31	24.00	32	North
		Without	2,109,135	233,000	16.43	20.50	33	North
		With	2,109,435	233,000	16.53	22.00	32	North
		Without	2,109,225	232,000	15.90	21.50	34	North
		With	2,109,225	232,000	15.44	21.50	34	North

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 14

Breaking Wave Data for North Zone, Southeast Wave Direction--Slack Tide

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	10	Without	2,111,881	246,119	8.66	13.50	12	North
		With	2,111,678	246,322	9.25	12.00	12	North
		Without	2,112,000	247,000	10.13	11.50	12	North
		With	2,112,000	247,000	10.15	11.50	12	North
10	10	Without	2,111,756	246,244	11.05	12.50	11	North
		With	2,112,038	245,962	11.06	15.50	12	North
		Without	2,112,182	246,818	12.45	14.50	11	North
		With	2,112,182	246,818	11.72	14.50	12	North
		Without	2,112,085	247,915	12.16	14.00	11	North
		With	2,112,085	247,915	10.83	14.00	12	North
10	14	Without	2,114,000	244,000	15.80	25.00	9	North
		With	2,114,000	244,000	17.13	25.00	9	North
		Without	2,113,000	246,000	16.73	21.00	14	North
		With	2,113,000	246,000	16.67	21.00	13	North
		Without	2,113,000	247,000	14.84	19.00	14	North
		With	2,113,000	247,000	13.42	19.00	13	North
		Without	2,114,000	247,000	17.93	21.50	14	North
		With	2,114,000	247,000	16.70	21.50	13	North
14	10	Without	2,112,160	245,840	14.59	16.50	9	North
		With	2,112,160	245,840	15.63	16.50	9	North
		Without	2,112,160	246,840	10.43	14.00	9	North
		With	2,112,160	246,840	9.53	14.00	9	North
		Without	2,112,265	247,735	13.64	14.50	10	North
		With	2,112,265	247,735	13.16	14.50	10	North
14	14	Without	2,114,000	244,000	18.69	25.50	13	North
		With	2,114,000	244,000	18.40	32.00	14	North
		Without	2,112,788	246,212	13.25	19.00	13	North
		With	2,112,788	246,212	13.71	19.00	13	North
		Without	2,112,875	247,125	15.91	18.50	13	North
		With	2,113,000	247,000	15.51	19.00	13	North
		Without	2,114,000	247,000	17.47	21.50	13	North
		With	2,114,000	247,000	17.58	21.50	13	North

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 15

Breaking Wave Data for North Zone, S22.5°E Wave Direction--Slack Tide

Test Wave			Breaking Characteristics						
Period sec	Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	10	Without	2,112,000	247,000	8.98	11.50	30	North
		With	2,112,000	247,000	8.98	11.50	30	North
10	10	Without	2,112,000	246,000	12.59	15.50	26	North
		With	2,112,000	246,000	12.89	15.50	26	North
		Without	2,113,000	246,664	13.63	19.50	26	North
		With	2,113,000	246,664	13.48	19.50	26	North
10	14	Without	2,112,000	238,000	16.99	24.50	23	North
		With	2,112,000	240,000	19.87	22.50	25	North
		Without	2,113,000	239,000	17.11	27.00	23	North
		With	2,113,000	242,408	18.59	24.00	25	North
		Without	2,114,000	240,171	14.50	29.00	22	North
		With	2,114,000	241,500	17.20	26.50	25	North
		Without	2,115,000	240,721	16.34	31.50	26	North
		With	2,115,000	241,000	17.09	30.50	25	North
14	10	Without	2,112,000	246,000	13.01	15.50	22	North
		With	2,112,000	246,112	12.86	14.50	22	North
		Without	2,113,000	247,000	11.74	19.00	22	North
		With	2,113,000	247,000	13.41	19.00	22	North
14	14	Without	2,112,000	237,510	17.10	25.50	24	North
		With	2,112,000	239,550	16.03	23.50	27	North
		Without	2,113,000	238,000	20.61	28.50	24	North
		With	2,113,000	244,000	14.94	23.50	25	North
		Without	2,114,000	238,000	22.42	32.50	24	North
		With	2,114,000	244,000	19.29	25.50	25	North
		Without	2,115,000	243,000	16.18	31.00	24	North
		With	2,115,000	243,000	16.46	31.00	25	North

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.
* Coordinates are referred to New Jersey grid system.

Table 16

Breaking Wave Data for North Zone, South Wave Direction--Slack Tide

Test Wave			Breaking Characteristics					
Period sec	Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	10	Without	2,113,000	251,000	8.02	11.50	30	North
		With	2,113,000	251,000	5.56	11.50	34	North
		Without	2,114,000	252,000	8.18	15.00	30	North
		With	2,114,000	252,000	7.80	15.00	34	North
10	10	Without	2,111,000	244,000	8.46	13.50	23	North
		With	2,113,000	250,500	6.90	9.00	20	North
		Without	2,113,000	250,000	11.28	14.50	23	North
		With	2,111,000	245,000	9.62	12.50	31	North
10	14	Without	2,115,000	248,000	16.82	19.50	23	North
		With	2,113,000	246,000	10.34	20.50	24	North
		Without	2,116,000	248,500	17.14	21.00	23	North
		With	2,116,000	249,000	13.78	23.00	24	North
		Without	2,113,000	246,000	10.53	20.50	23	North
		With	2,115,000	248,000	14.14	19.50	24	North
14	10	Without	2,113,000	247,000	14.48	19.50	33	North
		With	2,114,000	251,000	12.03	16.50	37	North
		Without	2,114,000	250,700	11.40	17.00	40	North
		With	2,113,000	248,000	11.69	18.75	37	North
14	14	Without	2,113,000	243,000	17.85	25.00	22	North
		With	2,113,000	246,000	12.69	22.00	21	North
		Without	2,116,000	250,000	11.89	26.50	26	North
		With	2,116,000	249,000	14.49	23.50	21	North
		Without	2,115,000	247,000	16.17	26.50	24	North
		With	2,115,000	248,000	13.46	20.00	21	North
		Without	2,114,000	246,000	13.91	26.50	24	North
		With	2,114,000	247,000	15.52	22.50	21	North

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 17

Breaking Wave Data for North Zone, South Wave Direction--Flood Tide

Test Wave			Breaking Characteristics					
Period sec	Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	10	Without	2,112,000	247,000	6.61	12.50	28	North
		With	2,112,000	247,000	4.45	12.50	31	North
		Without	2,114,000	252,000	7.53	15.00	22	North
		With	2,114,000	252,000	7.80	15.00	26	North
		Without	2,113,000	251,000	7.54	12.50	22	North
		With	2,113,000	251,000	3.87	12.50	26	North
10	10	Without	2,112,000	246,000	9.05	15.50	20	North
		With	2,112,000	247,000	7.20	12.00	21	North
		Without	2,114,000	248,000	10.25	19.00	27	North
		With	2,113,000	250,000	8.54	14.50	28	North
		Without	2,115,000	248,500	10.54	19.00	27	North
		With	2,115,000	248,000	11.99	19.50	26	North
		Without	2,113,000	250,000	9.80	14.50	26	North
		With	2,114,000	248,000	10.07	19.00	26	North
10	14	Without	2,114,000	247,000	20.03	22.50	26	North
		With	2,116,000	246,000	16.45	29.50	32	North
		Without	2,116,000	246,000	15.05	30.00	33	North
		With	2,115,000	248,000	15.84	19.50	25	North
		Without	2,115,000	248,000	14.96	20.00	26	North
		With	2,114,000	247,500	12.53	20.50	25	North
14	10	Without	2,113,000	247,500	13.77	18.50	24	North
		With	2,112,500	248,500	11.21	17.50	18	North
		Without	2,114,000	251,000	9.69	17.00	28	North
		With	2,114,000	250,000	11.42	18.50	26	North
14	14	Without	2,114,000	246,000	15.56	26.00	25	North
		With	2,115,000	247,000	10.90	26.50	27	North
		Without	2,116,000	249,000	10.33	23.50	28	North
		With	2,115,000	249,000	12.75	23.50	26	North
		Without	2,115,000	247,000	12.99	26.50	25	North
		With	2,114,000	245,000	12.28	26.50	27	North

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.
* Coordinates are referred to New Jersey grid system.

Table 18

Breaking Wave Data for North Zone, South Wave Direction--Ebb Tide

Test Wave			Breaking Characteristics					
Period sec	Height ft	Breakwater Status	Coordinates* E, ft	Coordinates* N, ft	Height ft	Depth ft	Angle deg	Transport Direction
6	10	Without	2,114,000	252,000	5.19	15.00	24	North
		With	2,113,000	251,000	7.89	12.50	24	North
		Without	2,113,000	251,000	6.67	12.50	24	North
		With	2,114,000	252,000	4.85	15.00	24	North
10	10	Without	2,113,000	250,330	10.03	13.00	26	North
		With	2,115,000	248,000	14.32	20.00	26	North
		Without	2,115,000	248,000	11.46	19.50	30	North
		With	2,114,000	248,000	11.01	19.00	26	North
		Without	2,114,000	247,500	11.64	20.00	30	North
		With	2,113,000	250,000	7.24	14.50	25	North
10	14	Without	2,112,000	246,000	13.29	16.00	28	North
		With	2,114,000	247,000	13.87	22.50	28	North
		Without	2,114,000	247,000	10.11	22.50	28	North
		With	2,116,000	246,000	18.00	30.00	34	North
		Without	2,116,000	246,000	17.41	29.50	32	North
		With	2,112,000	246,000	10.42	16.00	28	North
		Without	2,115,000	248,000	15.23	19.50	28	North
		With	2,115,000	248,000	13.73	20.00	28	North
14	10	Without	2,115,000	248,000	10.47	19.50	24	North
		With	2,115,000	248,500	11.33	19.50	24	North
		Without	2,113,000	246,500	12.64	20.50	22	North
		With	2,113,000	250,000	13.49	14.50	19	North
		Without	2,112,000	246,000	11.20	15.50	20	North
		With	2,112,000	247,000	10.31	12.00	21	North
14	14	Without	2,115,000	248,000	13.43	19.50	28	North
		With	2,113,000	247,000	14.53	19.50	24	North
		Without	2,114,000	245,000	14.94	26.50	30	North
		With	2,114,000	247,500	13.46	20.00	24	North
		Without	2,116,000	249,000	14.65	23.50	28	North
		With	2,115,000	248,500	15.56	19.50	24	North
		Without	2,113,000	246,000	16.29	21.50	30	North
		With	2,116,000	249,000	14.49	23.50	24	North

Note: Zones and baselines for angles are defined in Plate 3; _without_ means breakwater is not installed, _with_ means breakwater is installed.

* Coordinates are referred to New Jersey grid system.

Table 19

Consolidation of Waves Approaching South Zone* from the Northeast

Wave Period sec	Percentage of Total Wave Climate per Wave Height Group, ft 1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	Total
					Selected Portion of Northeast Wave Climate				
5-7	0.70	0.70	0.35	0.17	0.06	0.01	0.01	0	2.00
7-9	0.51	0.56	0.64	0.44	0.12	0.03	0.01	0.02	2.33
9-11	0.34	0.39	0.36	0.45	0.14	0.06	0.03	0.02	1.79
11-13	0.03	0.12	0.18	0.22	0.13	0.05	0.04	0.03	0.80
13-15	0	0.03	0.04	0.05	0.05	0.04	0.03	0.02	0.26
>15	0	0	0.02	0.02	0.02	0.02	0.01	0.01	0.10
Total	1.58	1.80	1.59	1.35	0.52	0.21	0.13	0.10	7.28
					Eliminating 7-9 Sec Wave Period Group				
5-7	0.96	0.98	0.67	0.39	0.12	0.02	0.01	0.01	3.16
9-11	0.59	0.67	0.68	0.67	0.20	0.08	0.04	0.03	2.96
11-13	0.03	0.12	0.18	0.22	0.13	0.05	0.04	0.03	0.80
13-15	0	0.03	0.04	0.05	0.05	0.04	0.03	0.02	0.26
>15	0	0	0.02	0.02	0.02	0.02	0.01	0.01	0.10
Total	1.58	1.80	1.59	1.35	0.52	0.21	0.13	0.10	7.28
					Eliminating 11-13 and >15 Sec Wave Period Groups				
5-7	0.96	0.98	0.67	0.39	0.12	0.02	0.01	0.01	3.16
9-11	0.61	0.73	0.77	0.78	0.27	0.11	0.06	0.05	3.38
13-15	0.01	0.09	0.15	0.18	0.13	0.08	0.06	0.04	0.74
Total	1.58	1.80	1.59	1.35	0.52	0.21	0.13	0.10	7.28

Wave Period sec	Wave Height, ft 4	7	10	Total
	Reducing to Test Waves			
6	1.94	1.06	0.16	3.16
10	2.11		1.27	3.38
14	0.25		0.49	0.74
Total	4.30	1.06	1.92	7.28

Wave Period sec	Wave Height ft	Occurrence %	Sec/Day	Waves/Day
		Obtain Number of Waves per Day		
6	4	1.94	1676	279
6	7	1.06	916	153
6	10	0.16	138	23
10	4	2.11	1823	182
10	10	1.27	1097	110
14	4	0.25	216	15
14	10	0.49	423	30

* Zones are defined in Plate 3.

Table 20

Consolidation of Waves Approaching South Zone* from the East

Wave Period sec	Percentage of Total Wave Climate per Wave Height Group, ft 1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	Total
	Selected Portion of East Wave Climate								
5-7	0.75	0.68	0.16	0.08	0.06	0.02	0	0	1.75
7-9	0.55	0.39	0.37	0.39	0.13	0.04	0.02	0.01	1.90
9-11	0.22	0.29	0.28	0.27	0.23	0.10	0.05	0.02	1.46
11-13	0.07	0.09	0.11	0.16	0.15	0.12	0.05	0.04	0.79
13-15	0.01	0.03	0.03	0.05	0.07	0.05	0.04	0.02	0.30
>15	0	0	0.01	0.01	0.02	0.02	0.03	0.02	0.11
Total	1.60	1.48	0.96	0.96	0.66	0.35	0.19	0.11	6.31
	Eliminating 7-9 Sec Wave Period Group								
5-7	1.03	0.88	0.34	0.27	0.12	0.04	0.01	0	2.69
9-11	0.49	0.48	0.47	0.47	0.30	0.12	0.06	0.03	2.42
11-13	0.07	0.09	0.11	0.16	0.15	0.12	0.05	0.04	0.79
13-15	0.01	0.03	0.03	0.05	0.07	0.05	0.04	0.02	0.30
>15	0	0	0.01	0.01	0.02	0.02	0.03	0.02	0.11
Total	1.60	1.48	0.96	0.96	0.66	0.35	0.19	0.11	6.31
	Eliminating 11-13 and >15 Sec Wave Period Groups								
5-7	1.03	0.88	0.34	0.27	0.12	0.04	0.01	0	2.69
9-11	0.53	0.53	0.53	0.55	0.38	0.18	0.09	0.05	2.84
13-15	0.04	0.07	0.09	0.14	0.16	0.13	0.09	0.06	0.78
Total	1.60	1.48	0.96	0.96	0.66	0.35	0.19	0.11	6.31

Wave Period sec	Wave Height, ft 4	7	10	Total
	Reducing to Test Waves			
6	1.91	0.61	0.17	2.69
10	1.59		1.25	2.84
14	0.20		0.58	0.78
Total	3.70	0.61	2.00	6.31

Wave Period sec	Wave Height ft	Occurrence %	Sec/Day	Waves/Day
		Obtain Number of Waves per Day		
6	4	1.91	1650	275
6	7	0.61	527	88
6	10	0.17	147	24
10	4	1.59	1374	138
10	10	1.25	1080	108
14	4	0.20	173	12
14	10	0.58	501	36

* Zones are defined in Plate 3.

Table 21

Consolidation of Waves Approaching South Zone* from the Southeast

Wave Period, sec	Percentage of Total Wave Climate per Wave Height Group, ft 1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	Total
				Selected Portion of Southeast Wave Climate					
5-7	0.75	0.53	0.18	0.24	0	0	0	0	1.70
7-9	0.42	0.50	0.35	0.31	0.19	0.03	0.01	0.02	1.83
9-11	0.23	0.27	0.29	0.27	0.26	0.10	0.02	0.01	1.45
11-13	0.07	0.05	0.09	0.16	0.17	0.08	0.03	0.02	0.67
13-15	0.03	0.04	0.03	0.05	0.05	0.06	0.04	0.02	0.32
>15	0	0.01	0	0.01	0.02	0.02	0.02	0.01	0.09
Total	1.50	1.40	0.94	1.04	0.69	0.29	0.12	0.08	6.06
				Eliminating 7-9 Sec Wave Period Group					
5-7	0.96	0.78	0.35	0.39	0.09	0.01	0	0.01	2.59
9-11	0.44	0.52	0.47	0.43	0.36	0.12	0.03	0.02	2.39
11-13	0.07	0.05	0.09	0.16	0.17	0.08	0.03	0.02	0.67
13-15	0.03	0.04	0.03	0.05	0.05	0.06	0.04	0.02	0.32
>15	0	0.01	0	0.01	0.02	0.02	0.02	0.01	0.09
Total	1.50	1.40	0.94	1.04	0.69	0.29	0.12	0.08	6.06
				Eliminating 11-13 and >15 Sec Wave Period Groups					
5-7	0.96	0.78	0.35	0.39	0.09	0.01	0	0.01	2.59
9-11	0.48	0.55	0.52	0.51	0.45	0.16	0.04	0.03	2.74
13-15	0.06	0.07	0.07	0.14	0.15	0.12	0.08	0.04	0.73
Total	1.50	1.40	0.94	1.04	0.69	0.29	0.12	0.08	6.06

Wave Period sec	Wave Height, ft 4	7	10	Total
	Reducing to Test Waves			
6	1.74	0.74	0.11	2.59
10	1.55		1.19	2.74
14	0.20		0.53	0.73
Total	3.49	0.74	1.83	6.06

Wave Period sec	Wave Height ft	Occurrence %	Sec/Day	Waves/Day
	Obtain Number of Waves per Day			
6	4	1.74	1,503	250
6	7	0.74	639	107
6	10	0.11	95	16
10	4	1.55	1,339	134
10	10	1.19	1,028	103
14	4	0.20	173	12
14	10	0.53	458	33

* Zones are defined in Plate 3.

Table 22

Consolidation of Waves Approaching North Zone* from the South

Wave Period sec	Percentage of Total Wave Climate per Wave Height Group, ft 1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	Total
				Selected Portion of Northeast Wave Climate					
5-7	1.50	0.65	0.45	0.12	0.04	0.04	0	0	2.80
7-9	0.70	0.80	0.60	0.45	0.11	0.04	0.05	0.04	2.79
9-11	0.38	0.37	0.43	0.38	0.30	0.11	0.03	0.03	2.03
11-13	0.10	0.16	0.16	0.18	0.19	0.10	0.10	0.05	1.04
13-15	0.02	0.01	0.06	0.06	0.06	0.08	0.05	0.04	0.38
>15	0	0	0.01	0.03	0.03	0.03	0.02	0.02	0.14
Total	2.70	1.99	1.71	1.22	0.73	0.40	0.25	0.18	9.18
				Eliminating 7-9 Sec Wave Period Group					
5-7	1.85	1.05	0.75	0.34	0.09	0.06	0.02	0.02	4.18
9-11	0.73	0.77	0.73	0.61	0.36	0.13	0.06	0.05	3.44
11-13	0.10	0.16	0.16	0.18	0.19	0.10	0.10	0.05	1.04
13-15	0.02	0.01	0.06	0.06	0.06	0.08	0.05	0.04	0.38
>15	0	0	0.01	0.03	0.03	0.03	0.02	0.02	0.14
Total	2.70	1.99	1.71	1.22	0.73	0.40	0.25	0.18	9.18
				Eliminating 11-13 and >15 Sec Wave Period Groups					
5-7	1.85	1.05	0.75	0.34	0.09	0.06	0.02	0.02	4.18
9-11	0.78	0.85	0.81	0.70	0.46	0.18	0.11	0.08	3.97
13-15	0.07	0.09	0.15	0.18	0.18	0.16	0.12	0.08	1.03
Total	2.70	1.99	1.71	1.22	0.73	0.40	0.25	0.18	9.18

Wave Period sec	Wave Height, ft 10	14	Total
	Reducing to Test Waves		
6	4.18		4.18
10	3.69	0.28	3.97
14	0.75	0.28	1.03
Total	8.62	0.56	9.18

Wave Period sec	Wave Height ft	Occurrence %	Sec/Day	Waves/Day
		Obtain Number of Waves per Day		
6	10	4.18	3612	602
10	10	3.69	3188	319
10	14	0.28	242	24
14	10	0.75	648	46
14	14	0.28	242	17

* Zones are defined in Plate 3.

Table 23

Consolidation of Waves Approaching North Zone* from the Southeast

Wave Period sec	Percentage of Total Wave Climate per Wave Height Group, ft 1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	Total
	Selected Portion of Southeast Wave Climate								
5-7	0.75	0.53	0.18	0.24	0	0	0	0	1.70
7-9	0.42	0.50	0.35	0.31	0.19	0.03	0.01	0.02	1.83
9-11	0.23	0.27	0.29	0.27	0.26	0.10	0.02	0.01	1.45
11-13	0.07	0.05	0.09	0.16	0.17	0.08	0.03	0.02	0.67
13-15	0.03	0.04	0.03	0.05	0.05	0.06	0.04	0.02	0.32
>15	0	0.01	0	0.01	0.02	0.02	0.02	0.01	0.09
Total	1.50	1.40	0.94	1.04	0.69	0.29	0.12	0.08	6.06
	Eliminating 7-9 Sec Wave Period Group								
5-7	0.96	0.78	0.35	0.39	0.09	0.01	0	0.01	2.59
9-11	0.44	0.52	0.47	0.43	0.36	0.12	0.03	0.02	2.39
11-13	0.07	0.05	0.09	0.16	0.17	0.08	0.03	0.02	0.67
13-15	0.03	0.04	0.03	0.05	0.05	0.06	0.04	0.02	0.32
>15	0	0.01	0	0.01	0.02	0.02	0.02	0.01	0.09
Total	1.50	1.40	0.94	1.04	0.69	0.29	0.12	0.08	6.06
	Eliminating 11-13 and >15 Sec Wave Period Groups								
5-7	0.96	0.78	0.35	0.39	0.09	0.01	0	0.01	2.59
9-11	0.48	0.55	0.52	0.51	0.45	0.16	0.04	0.03	2.74
13-15	0.06	0.07	0.07	0.14	0.15	0.12	0.08	0.04	0.73
Total	1.50	1.40	0.94	1.04	0.69	0.29	0.12	0.08	6.06

Wave Period sec	Wave Height, ft 10	14	Total
	Reducing to Test Waves		
6	2.59		2.59
10	2.59	0.15	2.74
14	0.55	0.18	0.73
Total	5.73	0.33	6.06

Wave Period sec	Wave Height ft	Occurrence %	Sec/Day	Waves/Day
		Obtain Number of Waves per Day		
6	10	2.59	2238	373
10	10	2.59	2238	224
10	14	0.15	130	13
14	10	0.55	475	34
14	14	0.18	156	11

* Zones are defined in Plate 3.

Table 24

Determination of Number of Waves Approaching North Zone* from S22.5°E

Wave Period sec	Wave Height ft	Waves per Day from Indicated Direction Southeast	South	S22.5°E
6	10	373	602	244
10	10	224	319	136
10	14	13	24	9
14	10	34	46	20
14	14	11	17	7

* Zones are defined in Plate 3.

Table 25

Determination of Number of Waves Approaching South Zone* from E22.5°N

Wave Period sec	Wave Height ft	Waves per Day from Indicated Direction Northeast	East	E22.5°N
6	4	279	275	139
6	7	153	88	60
6	10	23	24	12
10	4	182	138	80
10	10	110	108	55
14	4	15	12	7
14	10	30	36	17

* Zones are defined in Plate 3.

Table 26

Determination of Number of Waves Approaching South Zone* from E22.5°S

Wave Period sec	Wave Height ft	Waves per Day from Indicated Directions East	Southeast	E22.5°S
6	4	275	250	131
6	7	88	107	49
6	10	24	16	10
10	4	138	134	68
10	10	108	103	53
14	4	12	12	6
14	10	36	33	17

* Zones are defined in Plate 3.

Table 27

Summary of Data Used in Determining Longshore Transport Rates in South Zone*

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Waves per Day	Breaking Height Squared, ft^2	Transport Direction	Longshore Energy per Foot of Beach: Per Wave $\times 10^4$ ft-lb/ft	Longshore Energy per Foot of Beach: Per Wave Per Day $\times 10^4$ ft-lb/ft-day
			Northeast Wave Direction--Slack Tide				
6	4	Without	209	11.50	South	0.365	76.29
		With		12.57	South	0.394	82.35
6	7	Without	115	30.91	South	1.277	146.86
		With		32.93	South	1.343	154.45
6	10	Without	17	98.19	South	4.492	76.36
		With		100.00	South	4.514	76.74
10	4	Without	137	22.85	South	1.134	155.36
		With		21.01	South	1.042	142.75
10	10	Without	83	128.24	South	11.596	962.47
		With		131.12	South	11.610	963.63
14	4	Without	11	59.19	South	4.655	51.21
		With		56.84	South	4.367	48.04
14	10	Without	23	197.41	South	22.933	527.46
		With		203.62	South	23.543	541.49
			E22.5°N Wave Direction--Slack Tide				
6	4	Without	138	9.19	South	0.174	24.19
		With		7.37	South	0.124	17.24
6	7	Without	60	34.94	South	0.600	36.00
		With		22.25	South	0.421	25.26
6	10	Without	12	58.76	South	1.468	17.62
		With		62.16	South	1.386	16.63
10	4	Without	80	32.75	South	0.604	48.32
		With		31.48	South	0.641	51.28
10	10	Without	55	121.08	South	4.744	260.92
		With		114.12	South	4.044	222.42
14	4	Without	7	71.04	South	1.796	12.57
		With		53.25	South	1.066	7.46

(Continued)

Note: Without means breakwater is not installed. With means breakwater is installed.
* Zones are defined in Plate 3.

Table 27 (Continued)

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Waves per Day	Breaking Height Squared, ft^2	Transport Direction	Longshore Energy per Foot of Beach: Per Wave $\times 10^4$ ft-lb/ft	Longshore Energy per Foot of Beach: Per Wave Per Day $\times 10^4$ ft-lb/ft-day
			E22.5°N Wave Direction--Slack Tide (Continued)				
14	10	Without	17	191.87	South	9.486	161.26
		With		189.48	South	8.291	140.95
			East Wave Direction--Slack Tide				
6	4	Without	138	12.66	South	0.028	3.86
		With		15.93	South	0.039	5.38
6	7	Without	44	60.94	South	0.356	15.66
		With		40.25	South	0.274	12.06
6	10	Without	12	105.01	South	0.480	5.76
		With		64.77	South	0.292	3.50
10	4	Without	69	42.65	South	0.350	24.15
		With		24.65	South	0.214	14.77
10	10	Without	54	249.83	South	2.517	135.92
		With		148.90	South	1.426	77.00
14	4	Without	6	86.90	North	0.305	1.83
		With		57.22	South	0.425	2.55
14	10	Without	18	375.31	South	2.363	42.53
		With		204.04	South	1.257	22.63
			East Wave Direction--Flood Tide				
6	4	Without	138	20.70	South	0.009	1.24
		With		14.28	South	0.105	14.49
6	7	Without	44	57.98	South	0.398	17.51
		With		35.49	South	0.195	8.58
6	10	Without	12	101.92	South	1.079	12.95
		With		65.04	South	0.012	0.14
10	4	Without	69	39.57	South	0.515	35.54
		With		28.88	South	0.224	15.46
10	10	Without	54	220.67	South	3.191	172.31
		With		134.23	South	0.935	50.49

(Continued)

Table 27 (Continued)

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Waves per Day	Breaking Height Squared, ft^2	Transport Direction	Longshore Energy per Foot of Beach: Per Wave $\times 10^4$ ft-lb/ft	Longshore Energy per Foot of Beach: Per Wave Per Day $\times 10^4$ ft-lb/ft-day
			East Wave Direction--Flood Tide (Continued)				
14	4	Without	6	96.27	South	0.029	0.17
		With		54.19	South	0.399	2.39
14	10	Without	18	303.78	South	2.489	44.80
		With		196.86	South	2.846	51.23
			East Wave Direction--Ebb Tide				
6	4	Without	138	26.33	South	0.095	13.11
		With		17.64	South	0.032	4.42
6	7	Without	44	73.40	South	0.591	26.00
		With		36.93	South	0.014	0.62
6	10	Without	12	115.71	South	0.869	10.43
		With		65.93	South	0.351	4.21
10	4	Without	69	42.94	North	0.293	20.22
		With		22.53	South	0.098	6.76
10	10	Without	54	218.03	South	1.910	103.14
		With		115.74	South	1.044	56.38
14	4	Without	6	114.04	North	0.907	5.44
		With		61.45	North	0.233	1.40
14	10	Without	18	355.14	South	7.501	135.02
		With		189.76	South	5.007	90.13
			E22.5°S Wave Direction--Slack Tide				
6	4	Without	131	17.20	North	0.253	33.14
		With		20.11	North	0.286	37.47
6	7	Without	49	48.63	North	1.004	49.20
		With		46.46	North	0.992	48.61
6	10	Without	10	94.46	North	1.957	19.57
		With		85.87	North	1.816	18.16

(Continued)

Table 27 (Concluded)

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Waves per Day	Breaking Height Squared, ft²	Transport Direction	Longshore Energy per Foot of Beach: Per Wave × 10^4 ft-lb/ft	Longshore Energy per Foot of Beach: Per Wave Per Day × 10^4 ft-lb/ft-day
		E22.5°S Wave Direction--Slack Tide (Continued)					
10	4	Without	68	30.94	North	0.581	39.51
		With		29.07	North	0.566	38.49
10	10	Without	53	170.65	North	6.958	368.77
		With		170.92	North	7.017	371.90
14	4	Without	6	77.13	North	3.255	19.53
		With		78.32	North	3.373	20.24
14	10	Without	17	240.37	North	17.638	299.85
		With		228.16	North	17.519	297.82
		Southeast Wave Direction--Slack Tide					
6	4	Without	188	27.02	North	0.779	146.45
		With		26.21	North	0.765	143.82
6	7	Without	80	50.39	North	1.869	149.52
		With		57.21	North	2.092	167.36
6	10	Without	12	88.34	North	3.420	41.04
		With		101.02	North	3.988	47.86
10	4	Without	101	40.35	North	1.991	201.09
		With		44.53	North	2.443	246.74
10	10	Without	77	153.59	North	11.375	875.88
		With		164.84	North	12.051	927.93
14	4	Without	9	85.27	North	7.626	68.63
		With		85.77	North	7.699	69.29
14	10	Without	25	255.16	North	30.778	769.45
		With		246.61	North	30.465	761.63

Table 28

Summary of Data Used in Determining Longshore Transport Rates in North Zone*

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Waves per Day	Breaking Height Squared, ft^2	Transport Direction	Longshore Energy per Foot of Beach: Per Wave $\times 10^4$ ft-lb/ft	Longshore Energy per Foot of Beach: Per Wave Per Day $\times 10^4$ ft-lb/ft-day
			Southeast Wave Direction--Slack Tide				
6	10	Without	280	88.81	North	1.439	402.92
		With		94.29	North	1.477	413.56
10	10	Without	168	141.66	North	3.877	651.34
		With		125.66	North	3.949	663.43
10	14	Without	10	267.82	North	10.543	105.43
		With		257.88	North	9.543	95.43
14	10	Without	26	169.24	North	5.934	154.28
		With		169.44	North	5.930	154.18
14	14	Without	8	270.80	North	15.694	125.55
		With		269.04	North	16.858	134.86
			S22.5°E Wave Direction--Slack Tide				
6	10	Without	244	80.64	North	2.711	661.48
		With		80.64	North	2.711	661.48
10	10	Without	136	172.14	North	11.428	1554.21
		With		172.93	North	11.512	1565.63
10	14	Without	9	264.67	North	20.638	185.74
		With		332.08	North	25.280	227.52
14	10	Without	20	153.54	North	12.714	254.27
		With		172.60	North	14.032	280.64
14	14	Without	7	370.40	North	43.196	302.37
		With		280.80	North	32.127	224.89
			South Wave Direction--Slack Tide				
6	10	Without	452	65.62	North	2.435	1100.62
		With		45.88	North	1.886	852.47
10	10	Without	239	99.41	North	5.442	1300.64
		With		70.08	North	3.900	932.10

(Continued)

Note: Without means breakwater is not installed. With means breakwater is installed.
* Zones are defined in Plate 3.

Table 28 (Concluded)

Test Wave Period sec	Test Wave Height ft	Breakwater Status	Waves per Day	Breaking Height Squared, ft^2	Transport Direction	Longshore Energy per Foot of Beach: Per Wave $\times 10^4$ ft-lb/ft	Longshore Energy per Foot of Beach: Per Wave Per Day $\times 10^4$ ft-lb/ft-day
			South Wave Direction--Slack Tide (Continued)				
10	14	Without	18	229.19	North	14.620	263.16
		With		165.58	North	11.481	206.66
14	10	Without	35	169.82	North	19.874	695.59
		With		140.69	North	16.583	580.41
14	14	Without	13	228.74	North	24.993	324.91
		With		198.26	North	18.208	236.70
			South Wave Direction--Flood Tide				
6	10	Without	452	52.41	North	1.671	755.29
		With		31.87	North	1.161	524.77
10	10	Without	239	98.52	North	6.540	1563.06
		With		84.49	North	6.263	1496.86
10	14	Without	18	283.83	North	22.487	404.77
		With		226.17	North	18.207	327.73
14	10	Without	35	141.76	North	13.522	473.27
		With		128.04	North	11.082	387.87
14	14	Without	13	172.52	North	20.185	262.41
		With		144.06	North	17.397	226.16
			South Wave Direction--Ebb Tide				
6	10	Without	452	35.72	North	1.176	531.55
		With		42.89	North	1.378	622.86
10	10	Without	239	122.47	North	9.006	2152.43
		With		126.23	North	8.804	2104.16
10	14	Without	18	203.47	North	16.658	299.84
		With		203.37	North	17.501	315.02
14	10	Without	35	131.61	North	11.598	405.93
		With		138.88	North	10.434	365.19
14	14	Without	13	220.89	North	26.092	339.20
		With		211.09	North	20.575	267.48

Table 29

Longshore Transport Rates for South and North Zones*

Wave Direction	Tidal Condition	Transport Direction	Longshore Energy Per Foot of Beach Per Day $\times 10^6$ ft-lb/ft-day		Average Breaking Height Squared, ft^2		Shore Protection Manual Equation Longshore Transport Rate, yd^3/day			Caldwell Equation Longshore Transport Rate, yd^3/day			Galvin Equation Longshore Transport Rate, yd^3/day		
			Breakwater Out	Breakwater In	Breakwater Out	Breakwater In	Breakwater Out	Breakwater In	ΔQ** %	Breakwater Out	Breakwater In	ΔQ** %	Breakwater Out	Breakwater In	ΔQ** %
South Zone*															
Northeast	Slack	South	19.960	20.095	44.69	45.69	2373	2389	+1	2303	2316	+1	24,000	25,000	+4
E22.5°N	Slack	South	5.609	4.812	46.26	41.88	667	572	-14	834	738	-12	25,000	23,000	-8
East	Slack	South	2.261	1.379	86.21	54.26	269	164	-39	403	272	-33	47,000	30,000	-36
East	Flood	South	2.845	1.428	80.13	51.09	338	170	-50	485	279	-42	44,000	28,000	-36
East	Ebb	South	2.620	1.611	88.17	48.21	312	192	-38	454	308	-32	48,000	26,000	-46
E22.5°S	Slack	North	8.296	8.327	63.71	63.34	986	990	0	1141	1144	0	35,000	35,000	0
Southeast	Slack	North	22.521	23.646	67.52	70.82	2678	2812	+5	2537	2638	+4	37,000	39,000	+5
North Zone*															
Southeast	Slack	North	14.395	14.615	117.70	115.14	1712	1738	+2	1773	1795	+1	64,000	63,000	-2
S22.5°E	Slack	North	29.581	29.602	122.92	124.04	3517	3520	0	3155	3157	0	67,000	68,000	+1
South	Slack	North	36.849	28.083	87.80	63.37	4381	3339	-24	3761	3027	-20	48,000	35,000	-27
South	Flood	North	34.588	29.634	78.66	59.48	4113	3523	-14	3576	3160	-12	43,000	33,000	-23
South	Ebb	North	37.290	36.747	74.71	80.34	4434	4369	-1	3797	3753	-1	41,000	44,000	+7

* Zones are defined in Plate 3.

** $\Delta Q = (\text{transport rate}_{in} - \text{transport rate}_{out} / \text{transport rate}_{out})(100)$.

Table 30

Changes in Longshore Transport Rates for South and North Zones*

Transport Direction	Zone*	Longshore Energy Per Foot of Beach Per Day $\times 10^6$ ft-lb/ft-day: Breakwater Out	Longshore Energy Per Foot of Beach Per Day $\times 10^6$ ft-lb/ft-day: Breakwater In	Average Breaking Height Squared, ft^2: Breakwater Out	Average Breaking Height Squared, ft^2: Breakwater In	Shore Protection Manual Equation, Longshore Transport Rate, yd^3/day: Breakwater Out	Shore Protection Manual Equation, Longshore Transport Rate, yd^3/day: Breakwater In	ΔQ** %
South	South	28.066	26.356	55.71	46.25	3337	3134	-6
North	South	30.817	31.973	65.98	67.80	3664	3801	+4
North	North	80.370	74.854	102.88	95.31	9556	8900	-7

Transport Direction	Zone*	Caldwell Equation, Longshore Transport Rate, yd^3/day: Breakwater Out	Caldwell Equation, Longshore Transport Rate, yd^3/day: Breakwater In	Caldwell ΔQ** %	Galvin Equation, Longshore Transport Rate, yd^3/day: Breakwater Out	Galvin Equation, Longshore Transport Rate, yd^3/day: Breakwater In	Galvin ΔQ** %
South	South	3025	2877	-5	31,000	25,000	-19
North	South	3260	3358	+3	36,000	37,000	+3
North	North	7019	6613	-6	56,000	52,000	-7

* Zones are defined in Plate 3.

** ΔQ = (transport rate$_{in}$ - transport rate$_{out}$/transport rate$_{out}$)(100).

Table 31

Comparison of Test Series III Current Measurements

Wave Direction	Test Wave Period sec	Test Wave Height ft	Breakwater Out Velocity fps	Breakwater Out Direction of Flow	Breakwater In Velocity fps	Breakwater In Direction of Flow	Δ Velocity* fps	Δ Velocity** %
				South Zone†				
Northeast	6	4	0.83	South	0.80	South	-0.03	-4
	6	7	0.75	South	0.69	South	-0.06	-8
	6	10	0.73	South	0.69	South	-0.04	-5
	10	4	0.73	South	0.79	South	+0.06	+8
	10	10	0.32	South	0.38	South	+0.06	+19
	14	4	0.63	South	0.58	South	-0.05	-8
	14	10	0.63	South	0.65	South	+0.02	+3
E22.5°N	6	4	0.61	South	0.61	South	0	0
	6	7	0.95	South	1.21	South	+0.26	+27
	6	10	1.21	South	1.21	South	0	0
	10	4	0.61	South	0.43	South	-0.18	-30
	10	10	1.21	South	1.73	South	+0.52	+43
	14	4	1.21	South	1.21	South	0	0
	14	10	0.78	South	1.21	South	+0.43	+55
E22.5°S	6	4	1.15	North	1.07	North	-0.08	-7
	6	7	1.88	North	1.88	North	0	0
	6	10	1.49	North	1.60	North	+0.11	+7
	10	4	1.48	North	1.40	North	-0.08	-5
	10	10	1.74	North	1.76	North	+0.02	+1
	14	4	1.83	North	2.04	North	+0.21	+11
	14	10	2.13	North	2.04	North	-0.09	-4
Southeast	6	4	1.97	North	2.09	North	+0:12	+6
	6	7	1.77	North	1.65	North	-0.12	-7
	6	10	1.22	North	1.32	North	+0.10	+8
	10	4	1.97	North	2.12	North	+0.15	+8
	10	10	1.54	North	1.70	North	+0.16	+10
	14	4	1.52	North	1.42	North	-0.10	-7
	14	10	1.27	North	1.12	North	-0.15	-12
				North Zone†				
Southeast	6	10	1.92	North	1.83	North	-0.09	-5
	10	10	2.33	North	2.06	North	-0.27	-12
	10	14	3.53	North	3.74	North	+0.21	+6
	14	10	2.24	North	2.38	North	+0.14	+6
	14	14	3.33	North	3.13	North	-0.20	-6
S22.5°E	6	10	1.86	North	1.59	North	-0.27	-15
	10	10	2.89	North	3.04	North	+0.15	+5
	10	14	2.69	North	2.73	North	+0.04	+1
	14	10	2.69	North	2.53	North	-0.16	-6
	14	14	2.84	North	2.71	North	-0.13	-5

* Δ velocity (fps) = $velocity_{in} - velocity_{out}$.

** Δ velocity (%) = $[(velocity_{in} - velocity_{out})/velocity_{out})]$ (100).

† Zones are defined in Plate 3.

Photo 1. Setting templates and finishing concrete during model construction

Photo 2. General view of model looking north with wave generator on the right and instrumentation building on the left

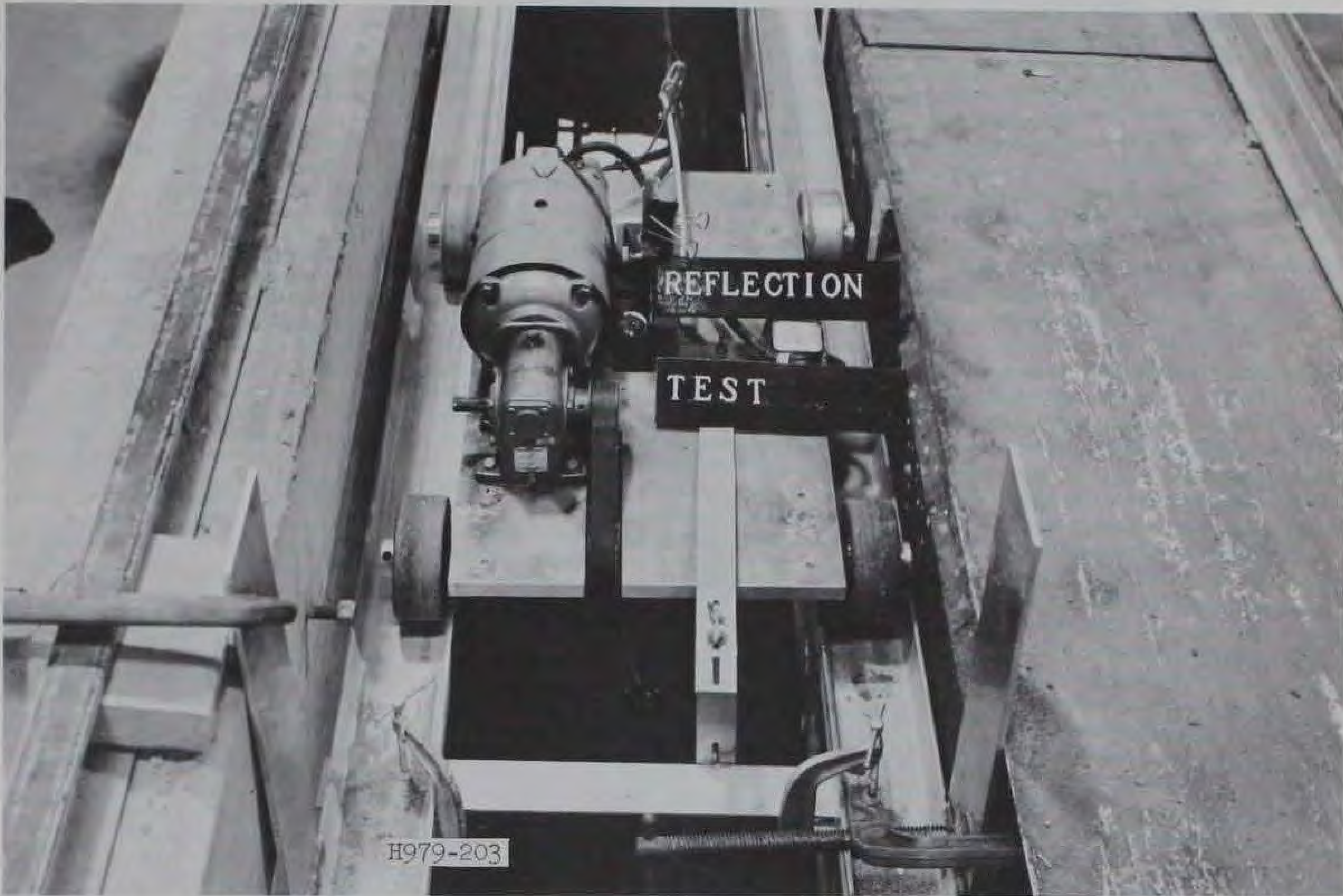


Photo 3. Mobile wave gage used in two-dimensional reflection tests

Photo 4. Recording equipment used in measuring wave heights

Photo 5. Test series I, south wave direction, slack tide,
6-sec wave period, 10-ft wave height

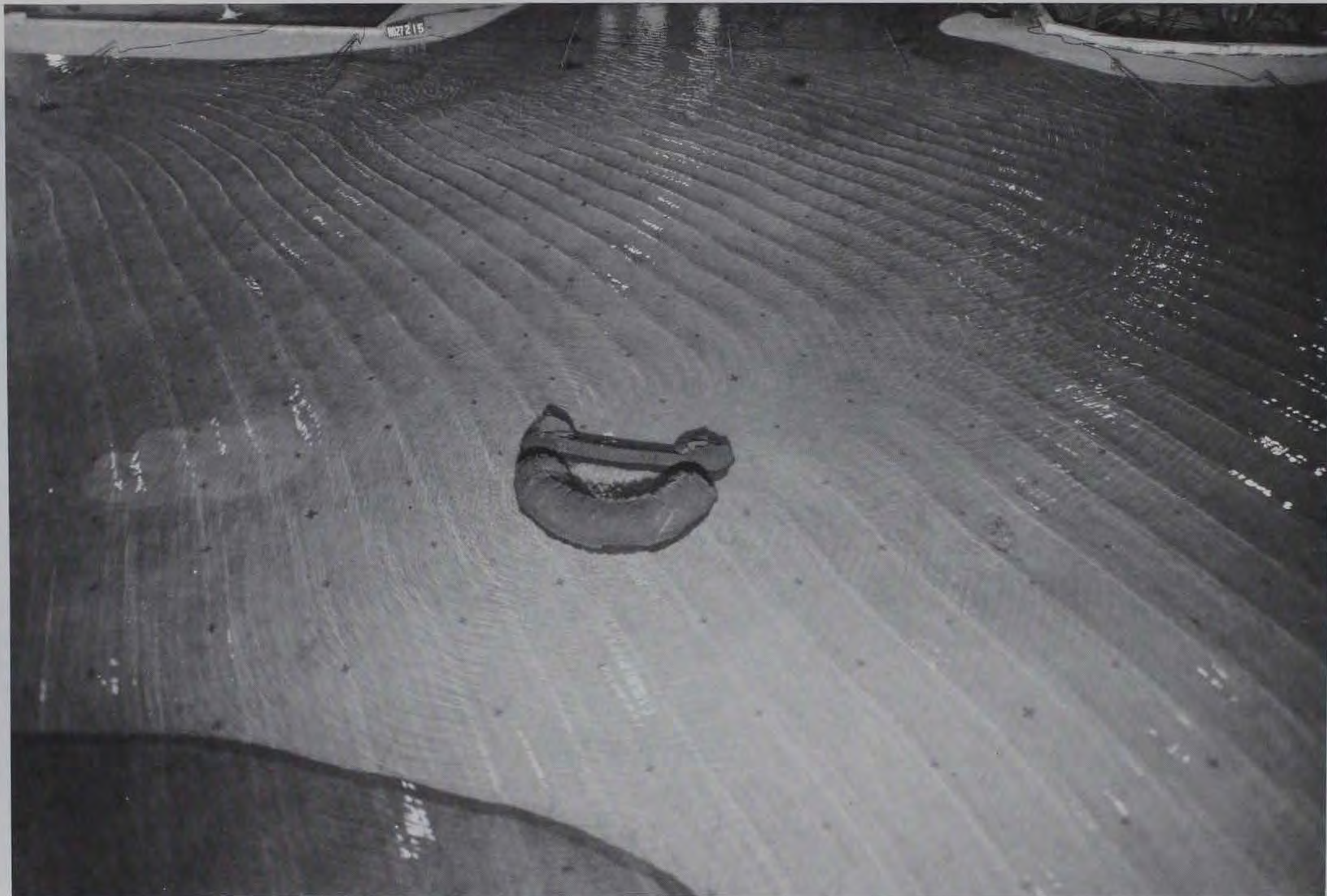


Photo 6. Test series I, south wave direction, slack tide, 6-sec wave period, 10-ft wave height, proposed breakwater installed

Photo 7. Test series I, south wave direction, flood tide, 10-sec wave period, 10-ft wave height

Photo 8. Test series I, south wave direction, flood tide, 10-sec wave period, 10-ft wave height, proposed breakwater installed

Photo 9. Test series I, south wave direction, ebb tide, 14-sec wave period, 18-ft wave height

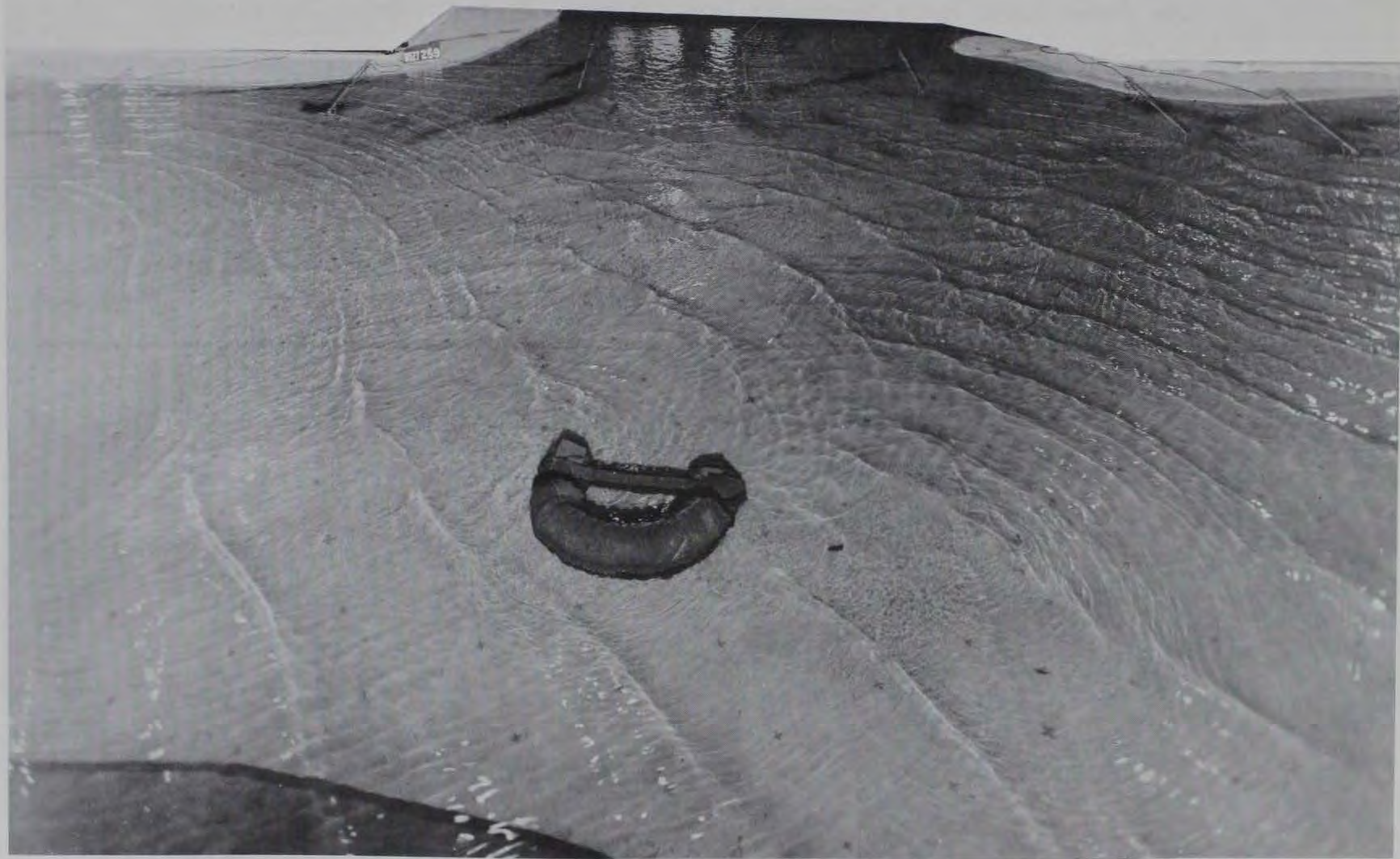


Photo 10. Test series I, south wave direction, ebb tide, 14-sec wave period, 18-ft wave height, proposed breakwater installed

Photo 11. Test series I, southeast wave direction, slack tide, 10-sec wave period, 4-ft wave height

Photo 12. Test series I, southeast wave direction, slack tide, 10-sec wave period, 4-ft wave height, proposed breakwater installed

Photo 13. Test series I, southeast wave direction, flood tide, 10-sec wave period, 4-ft wave height

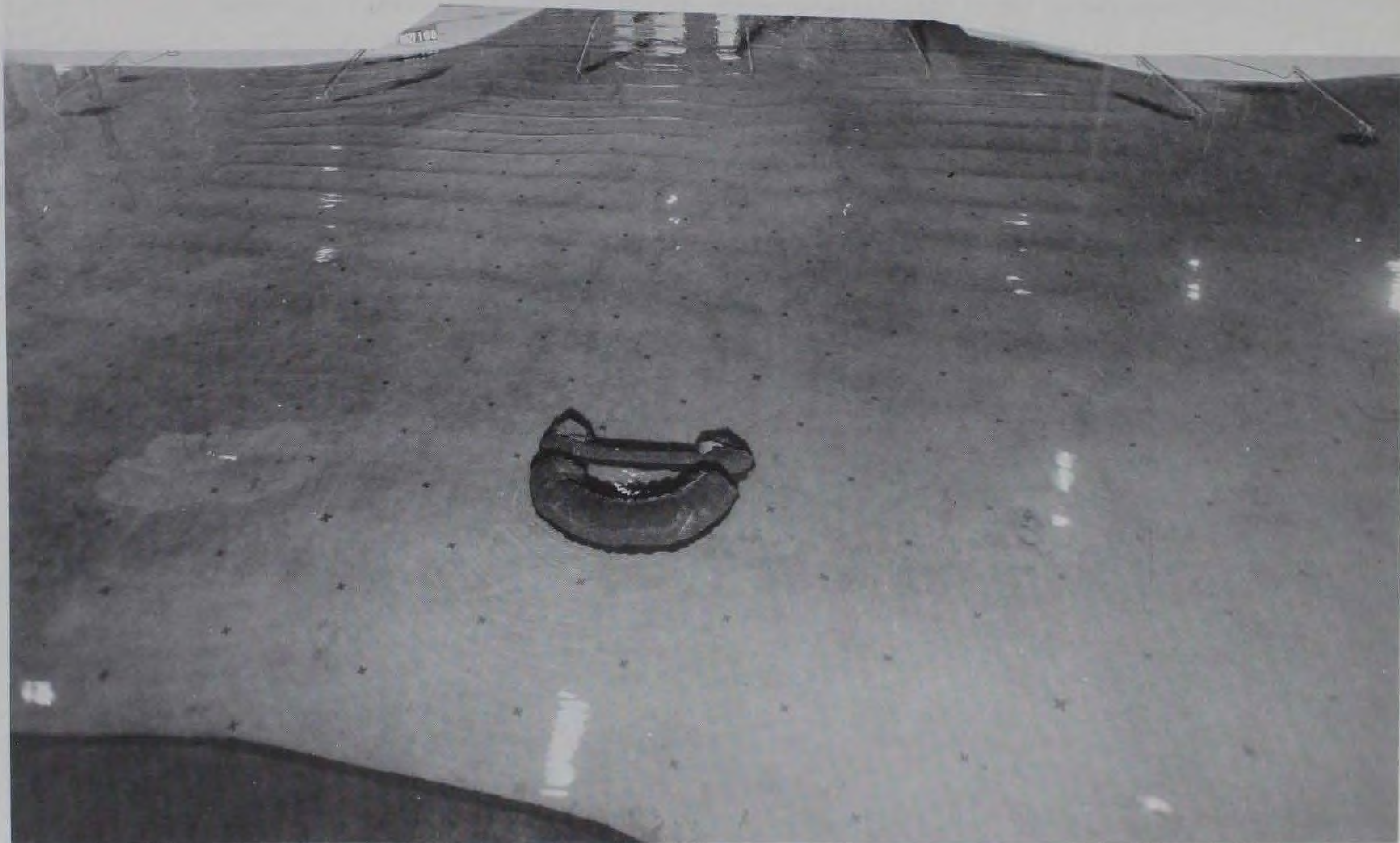


Photo 14. Test series I, southeast wave direction, flood tide, 10-sec wave period, 4-ft wave height, proposed breakwater installed

Photo 15. Test series I, southeast wave direction, ebb tide, 6-sec wave period, 2-ft wave height

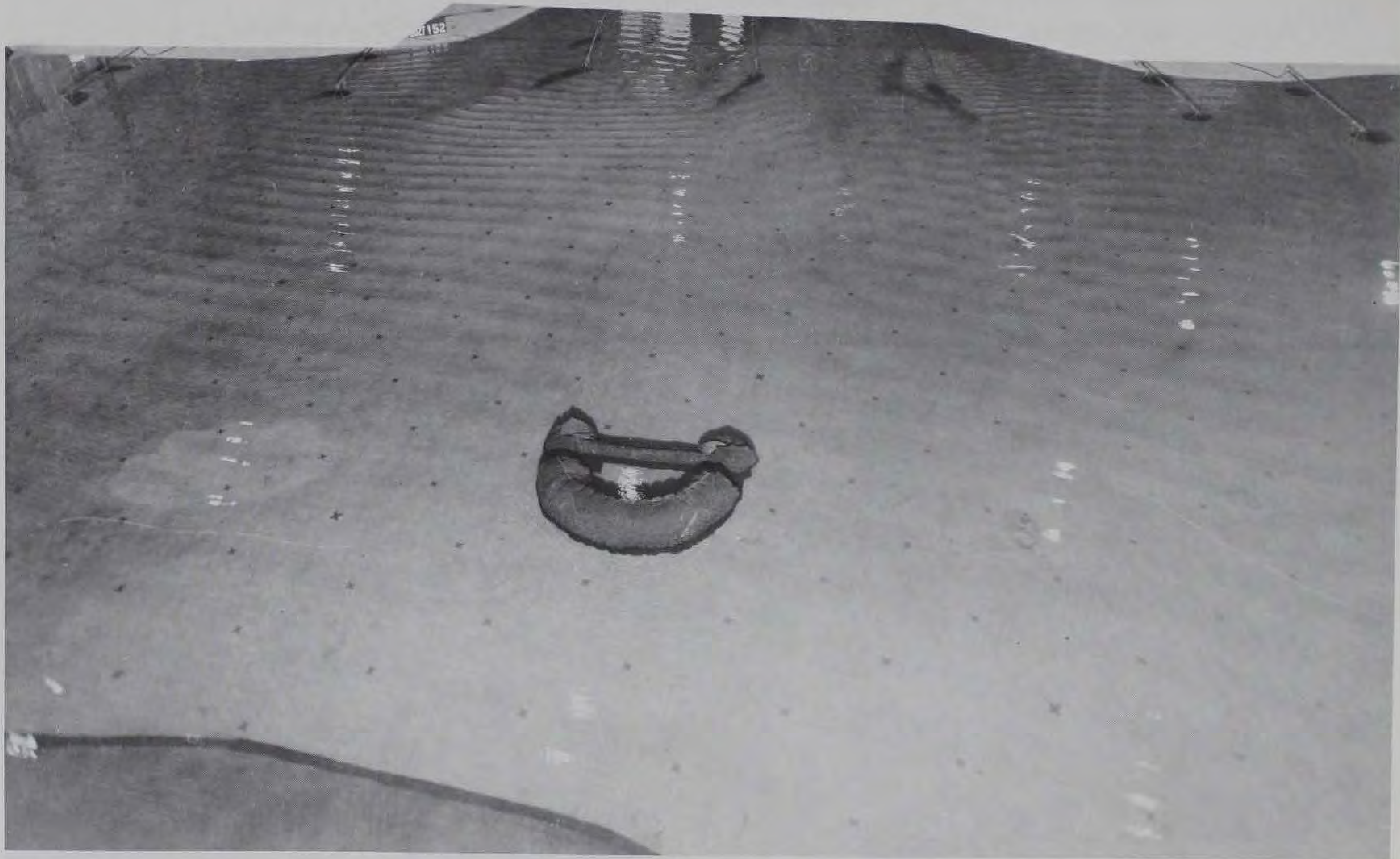


Photo 16. Test series I, southeast wave direction, ebb tide, 6-sec wave period, 2-ft wave height, proposed breakwater installed

Photo 17. Test series I, east wave direction, slack tide, 14-sec wave period, 14-ft wave height

Photo 18. Test series I, east wave direction, slack tide, 14-sec wave period, 14-ft wave height, proposed breakwater installed

Photo 19. Test series I, east wave direction, flood tide, 6-sec wave period, 7-ft wave height

Photo 20. Test series I, east wave direction, flood tide, 6-sec wave period, 7-ft wave height, proposed breakwater installed

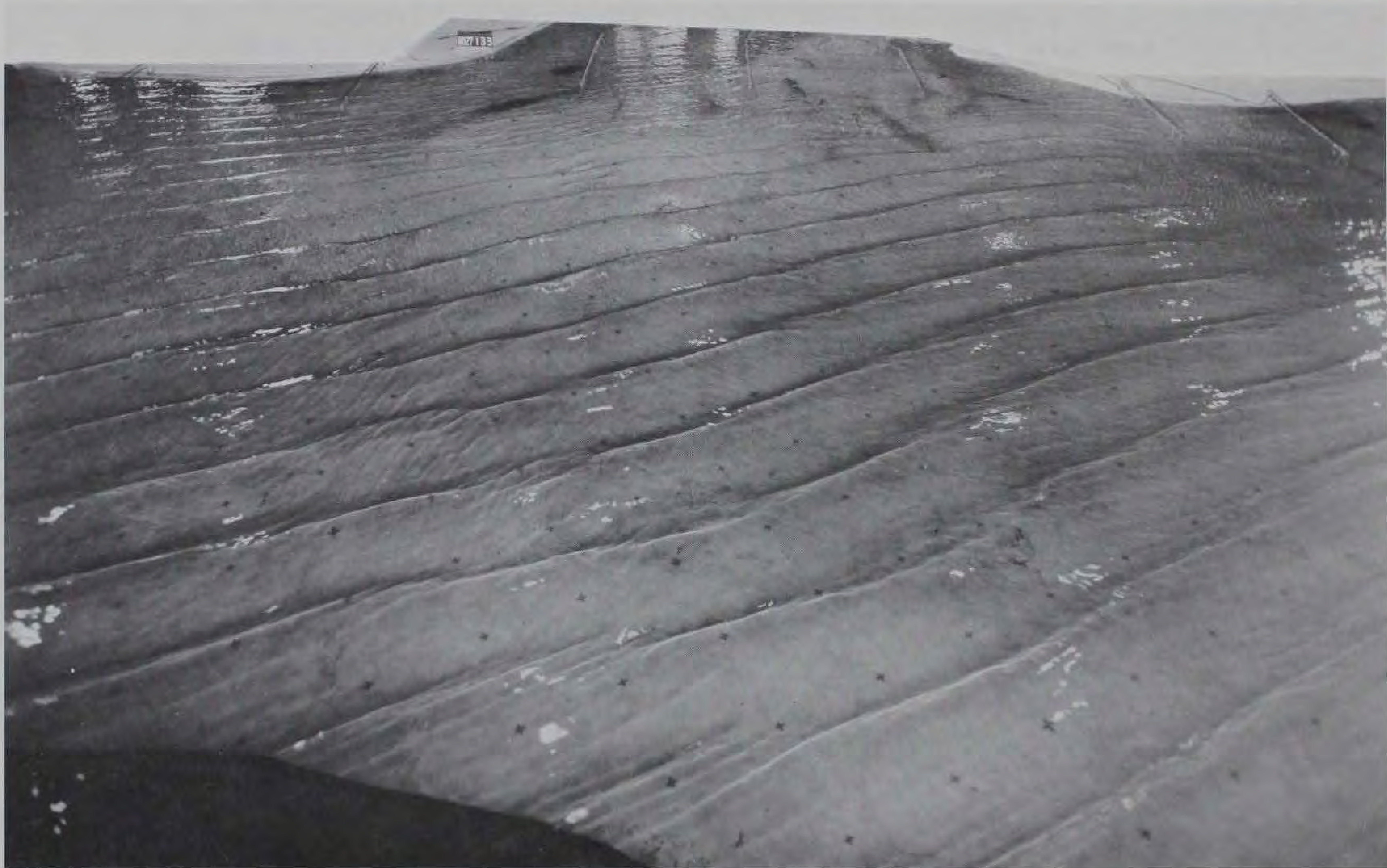


Photo 21. Test series I, east wave direction, ebb tide, 10-sec wave period, 14-ft wave height

Photo 22. Test series I, east wave direction, ebb tide, 10-sec wave period, 14-ft wave height, proposed breakwater installed

Photo 23. Test series II and III, south zone, southeast wave direction, slack tide, 6-sec wave period, 7-ft wave height

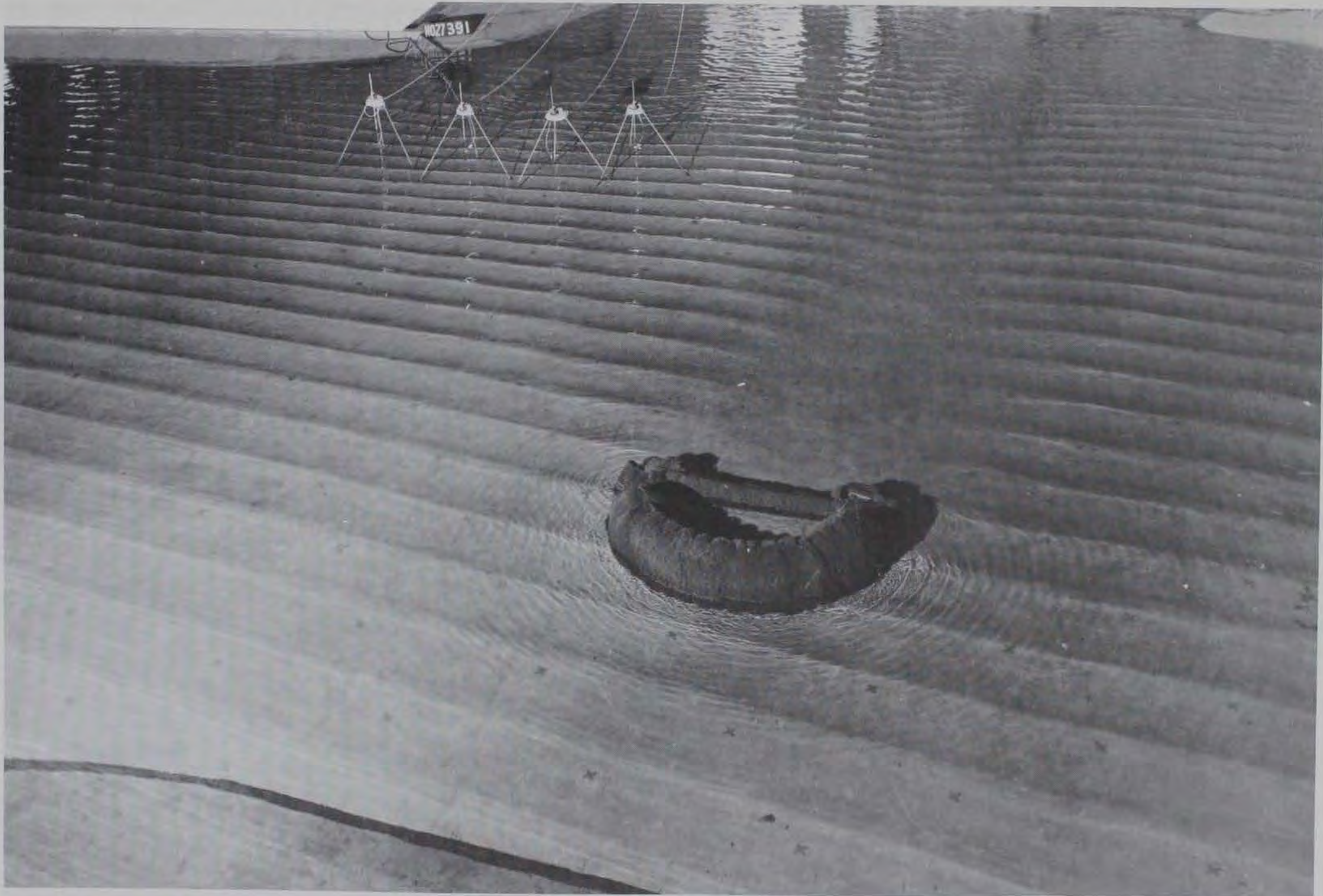


Photo 24. Test series II and III, south zone, southeast wave direction, slack tide, 6-sec wave period, 7-ft wave height, proposed breakwater installed

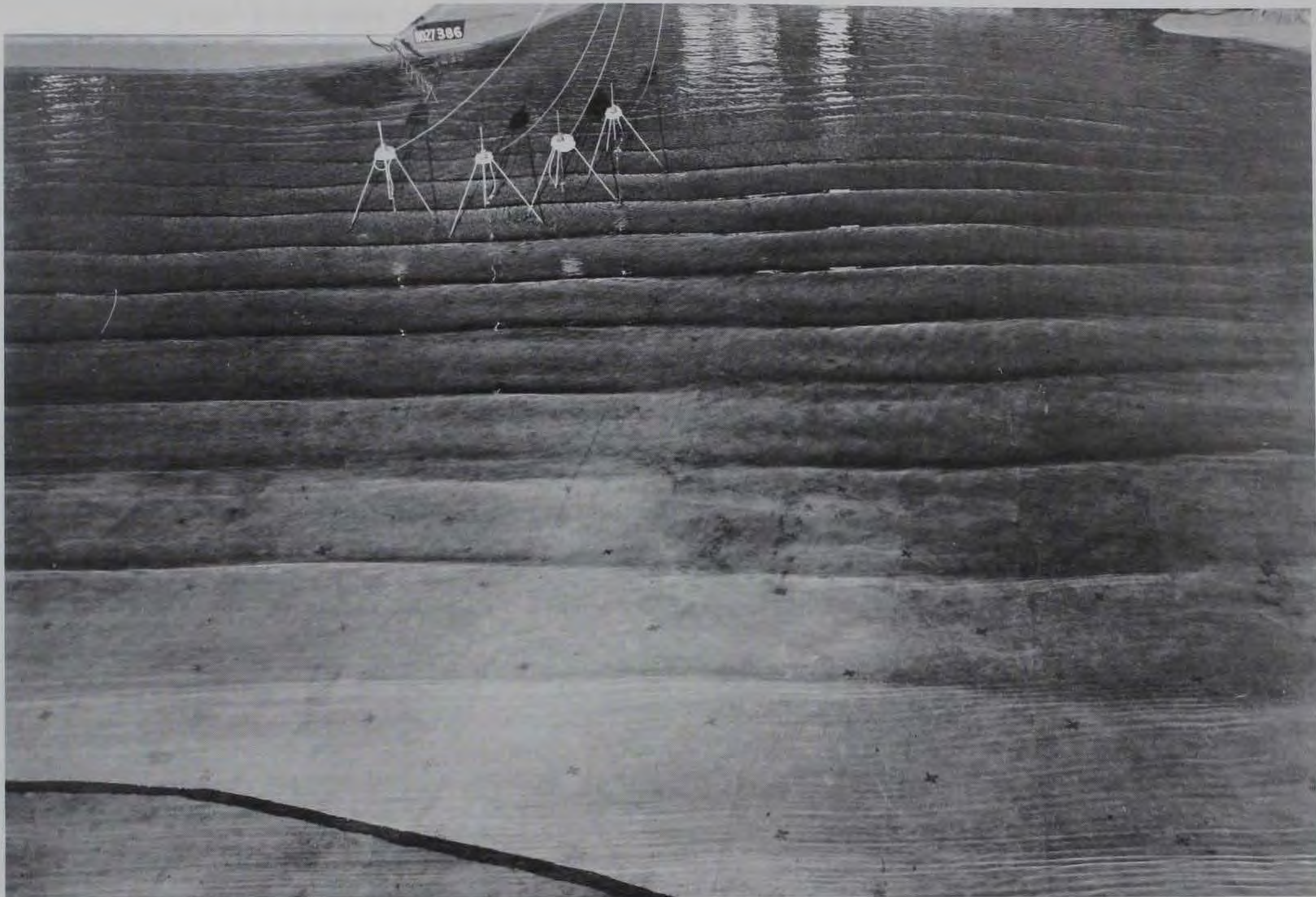


Photo 25. Test series II and III, south zone, E 22°30' S wave direction, slack tide, 10-sec wave period, 10-ft wave height

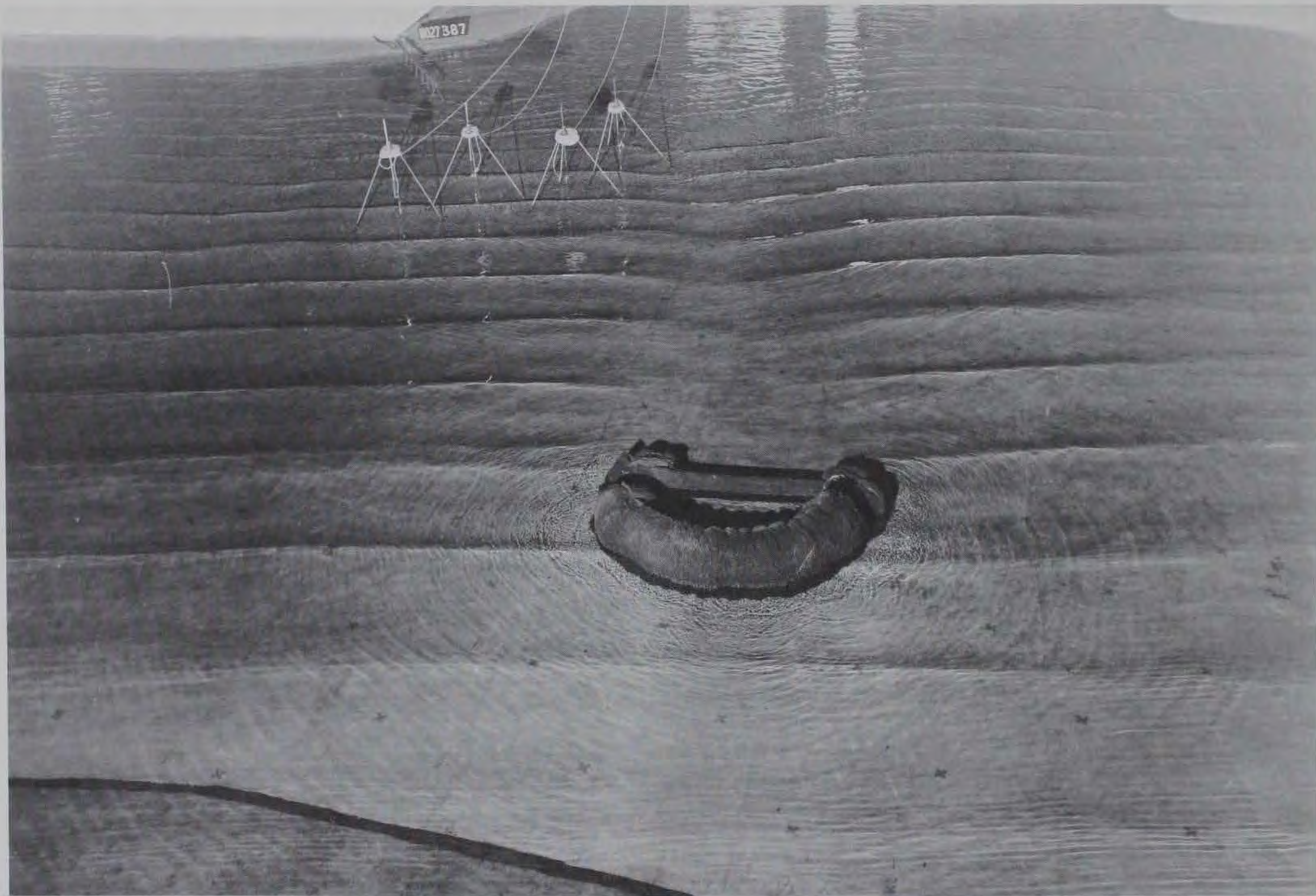


Photo 26. Test series II and III, south zone, E 22°30' S wave direction, slack tide, 10-sec wave period, 10-ft wave height, proposed breakwater installed

Photo 27. Test series II and III, south zone, E 22°30' N wave direction, slack tide, 14-sec wave period, 10-ft wave height

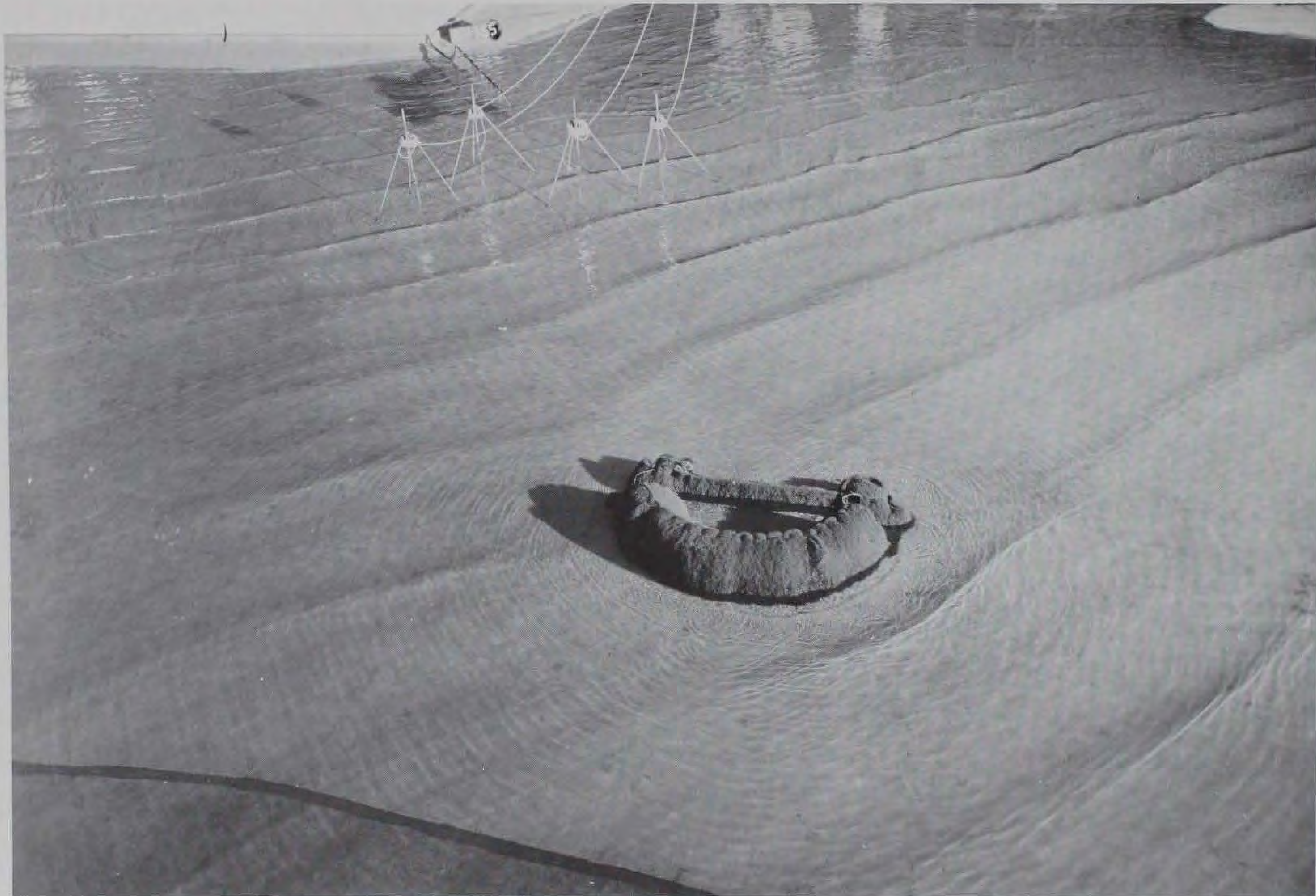


Photo 28. Test series II and III, south zone, E 22°30' N wave direction, slack tide, 14-sec wave period, 10-ft wave height, proposed breakwater installed

Photo 29. Test series II and III, north zone, S 22°30' E wave direction, slack tide, 10-sec wave period, 10-ft wave height

Photo 30. Test series II and III, north zone, S 22°30' E wave direction, slack tide, 10-sec wave period, 10-ft wave height, proposed breakwater installed

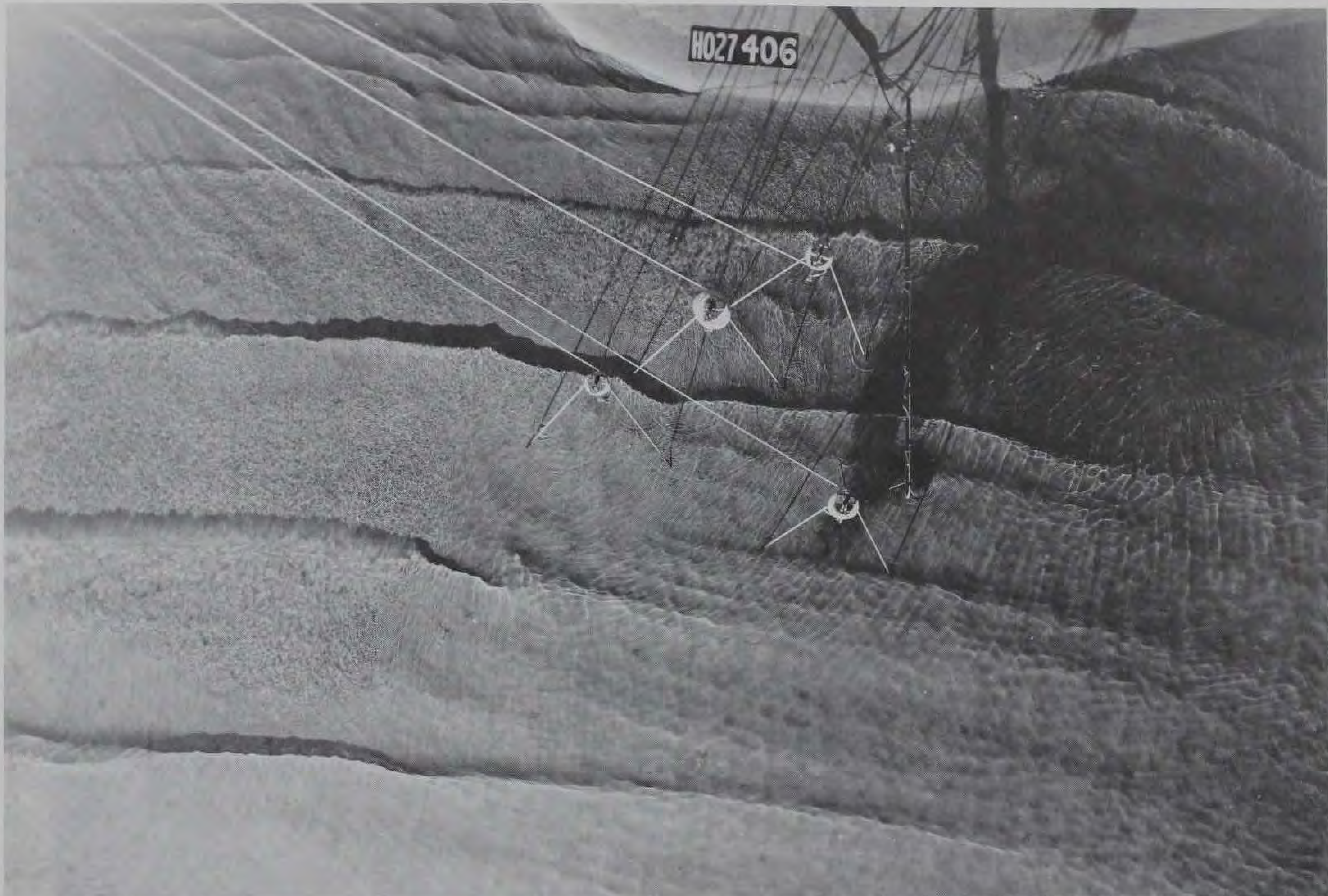


Photo 31. Test series II and III, north zone, southeast wave direction, slack tide, 14-sec wave period, 10-ft wave height

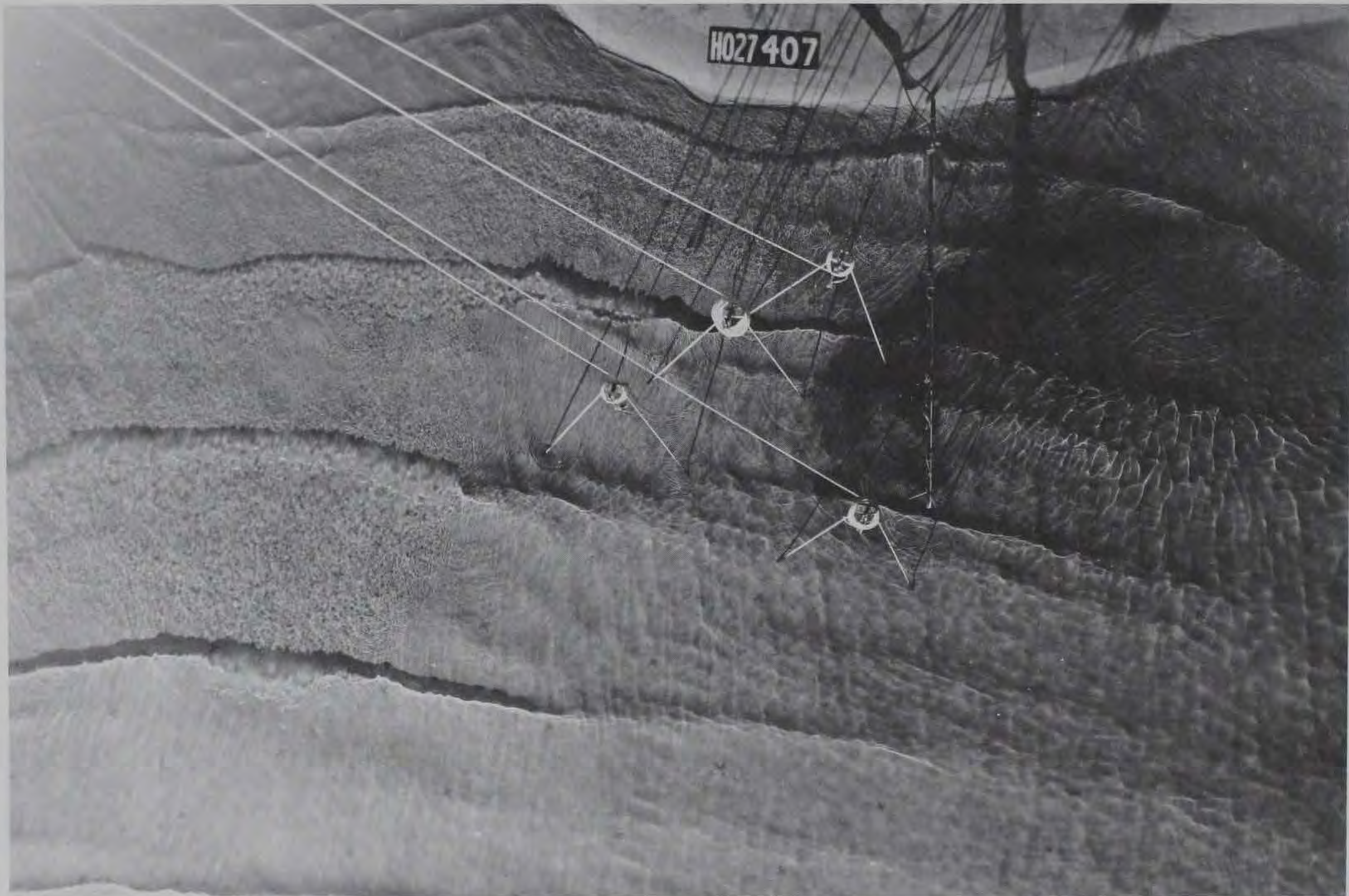
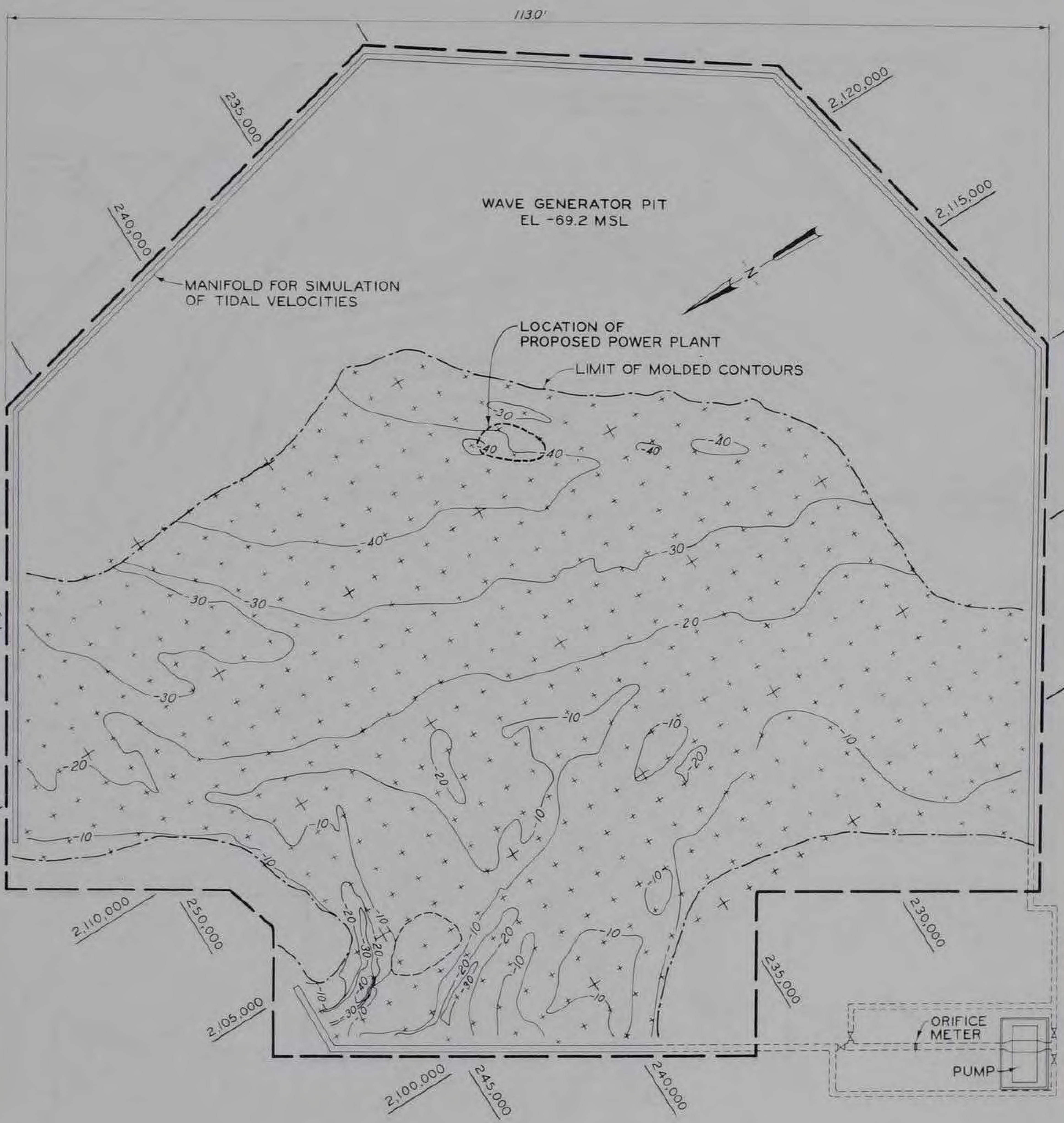


Photo 32. Test series II and III, north zone, southeast wave direction, slack tide, 14-sec wave period, 10-ft wave height, proposed breakwater installed



NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

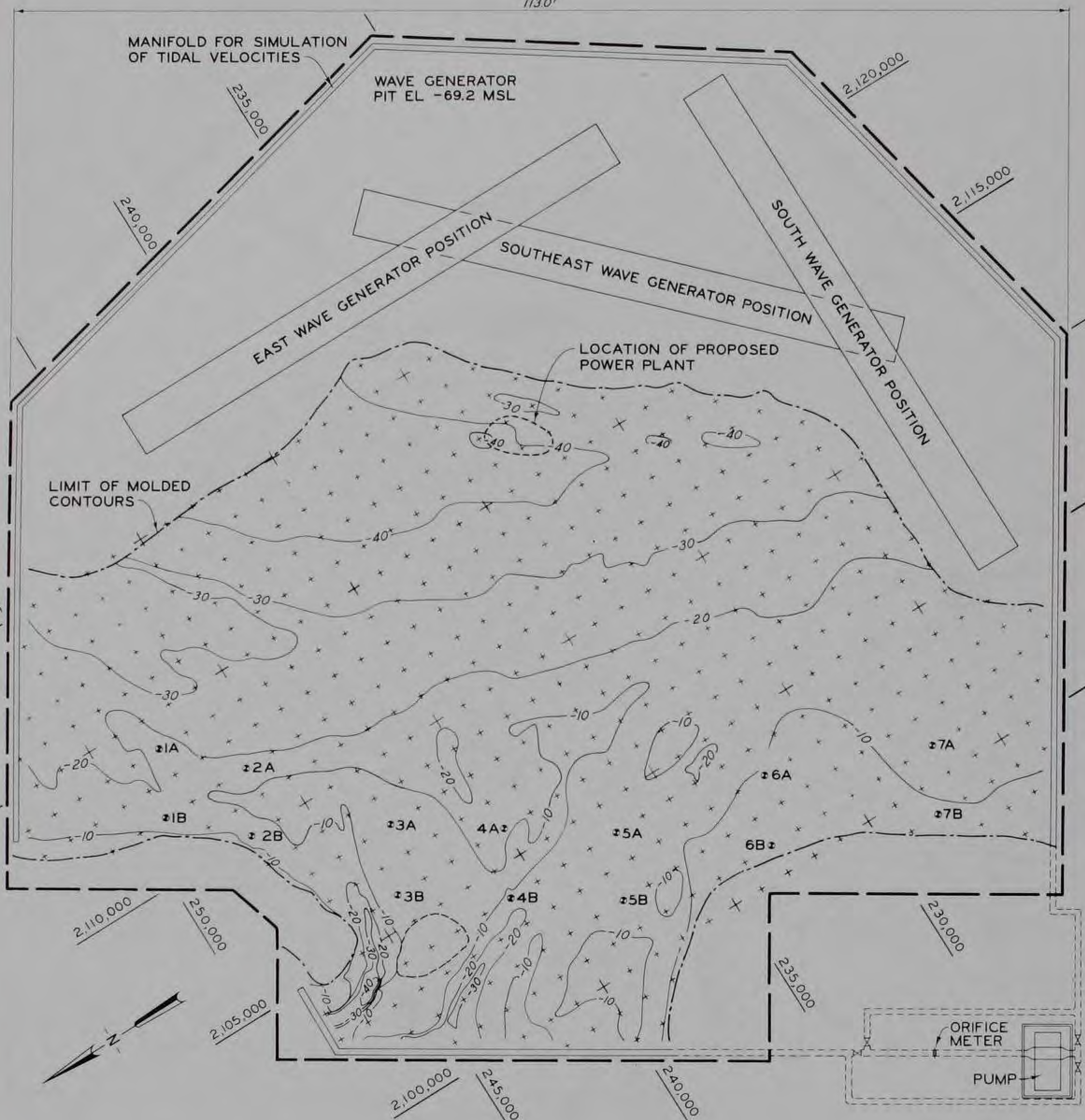
MODEL LAYOUT

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500

MODEL 5 0 5 10 15

PLATE 1



ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

VELOCITY STATION LOCATIONS

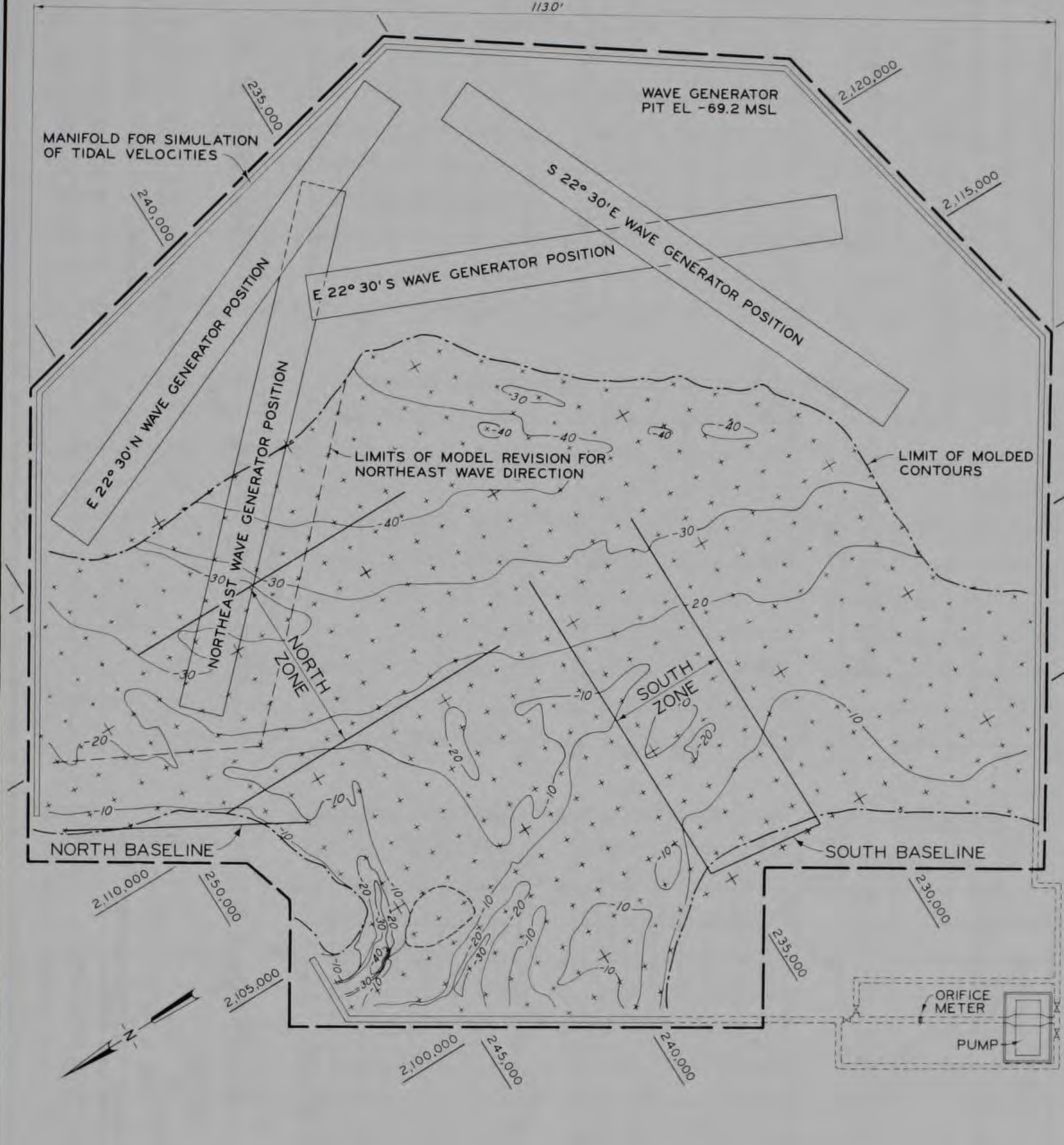
SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500

MODEL 5 0 5 10 15

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

PLATE 2



ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

LOCATION OF ZONES AND BASELINES

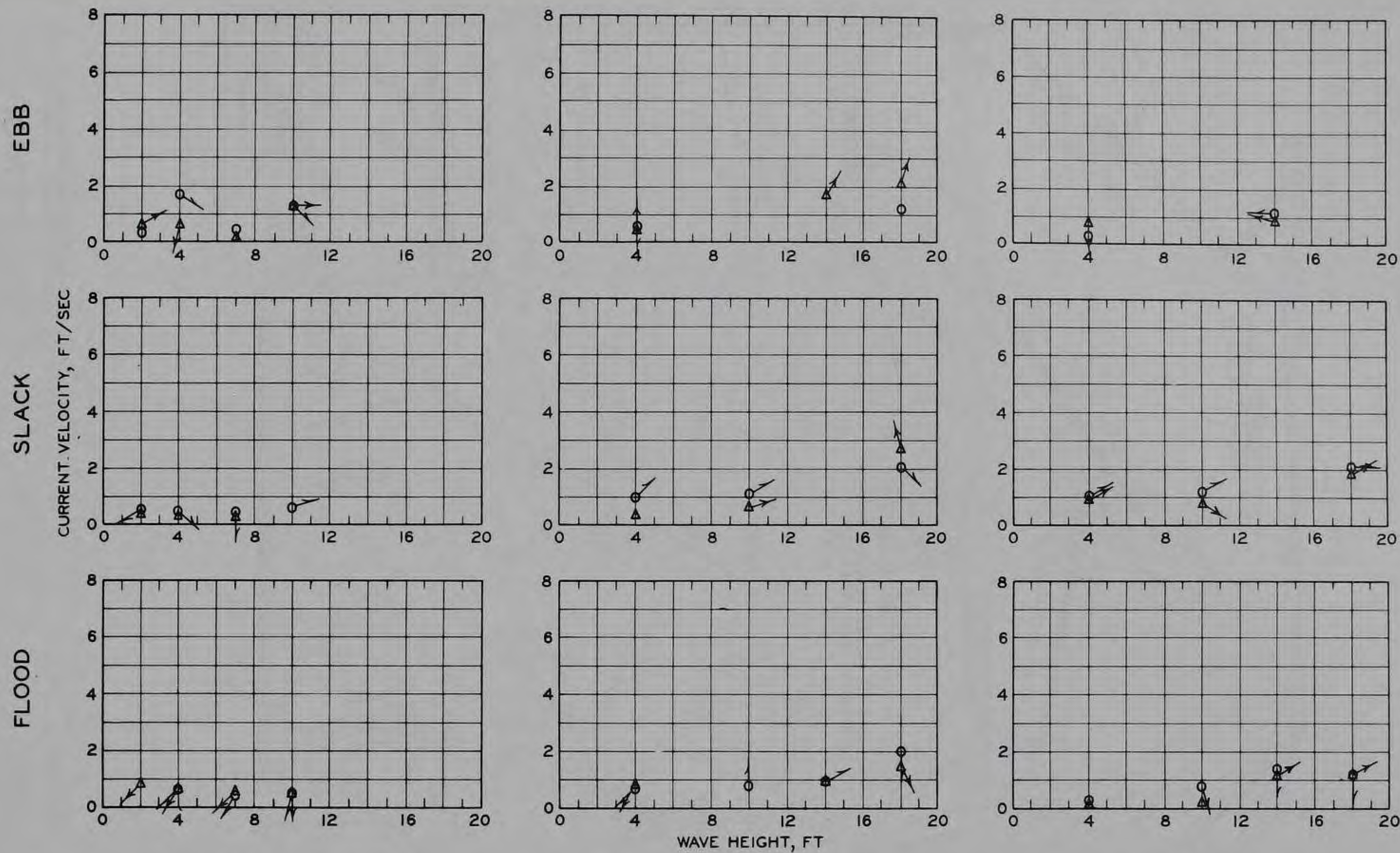
SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500

MODEL 5 0 5 10 15

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

PLATE 3



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

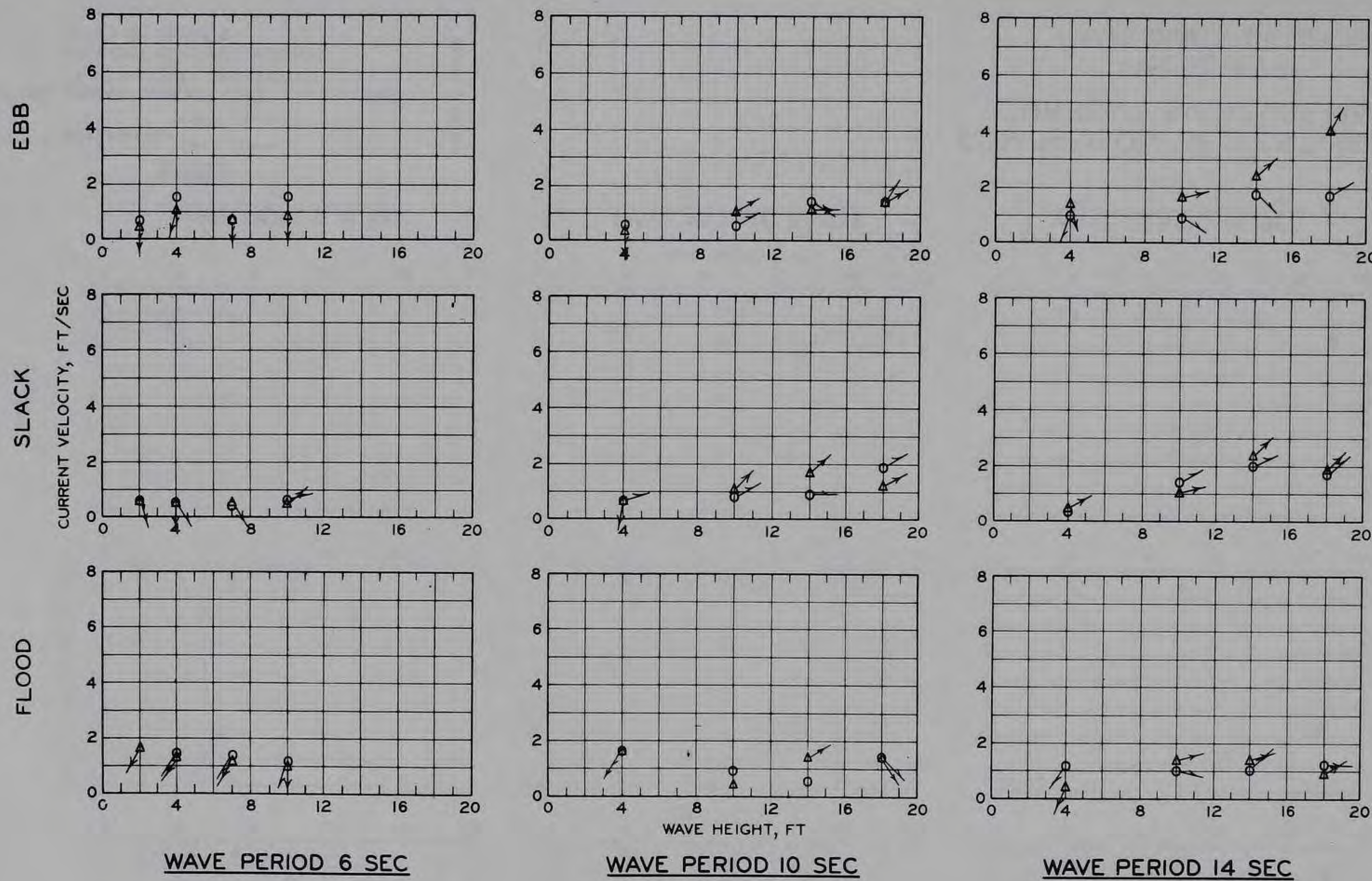
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 1A

WAVE DIRECTION : SOUTH



LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

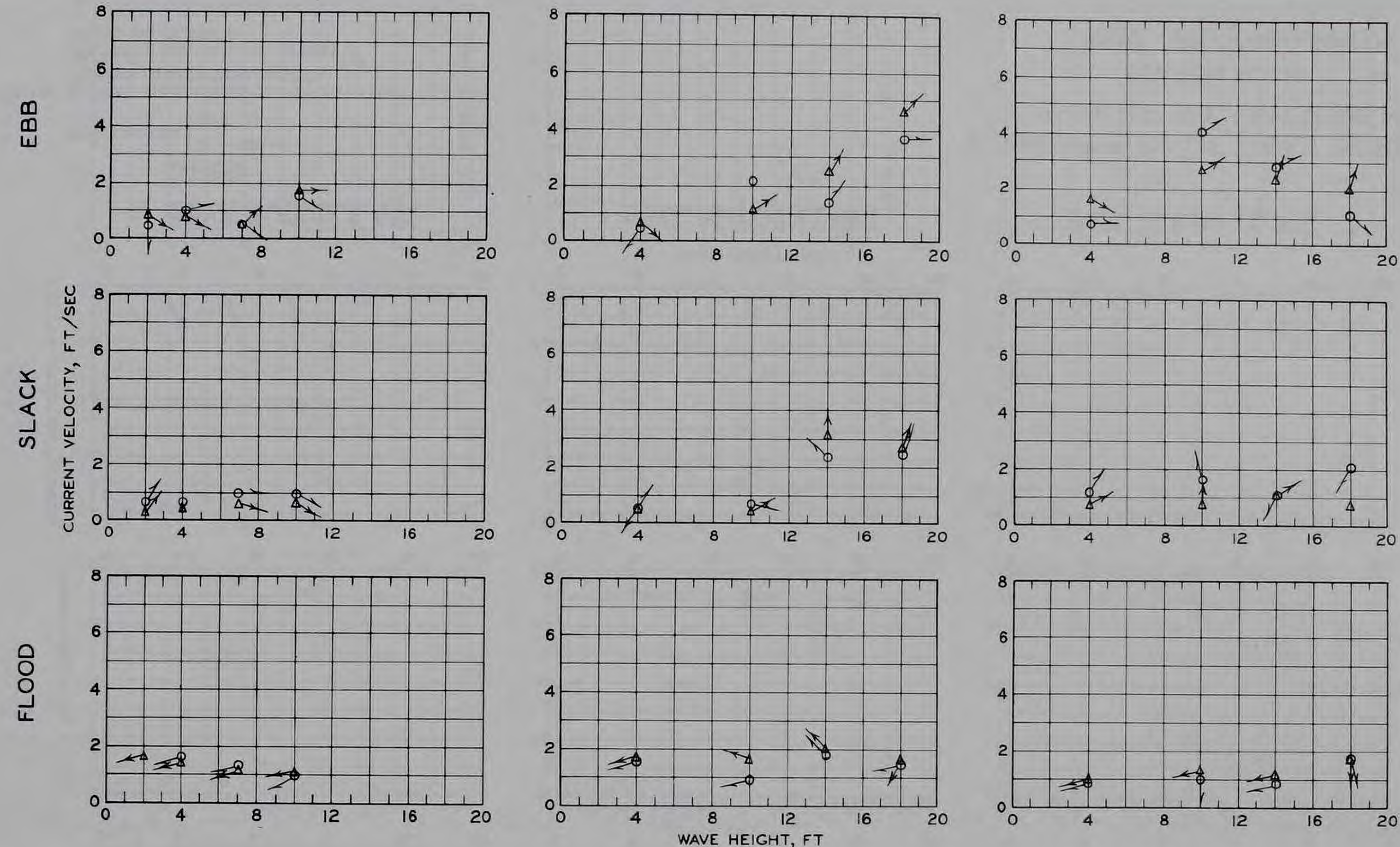
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 1B

WAVE DIRECTION: SOUTH



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

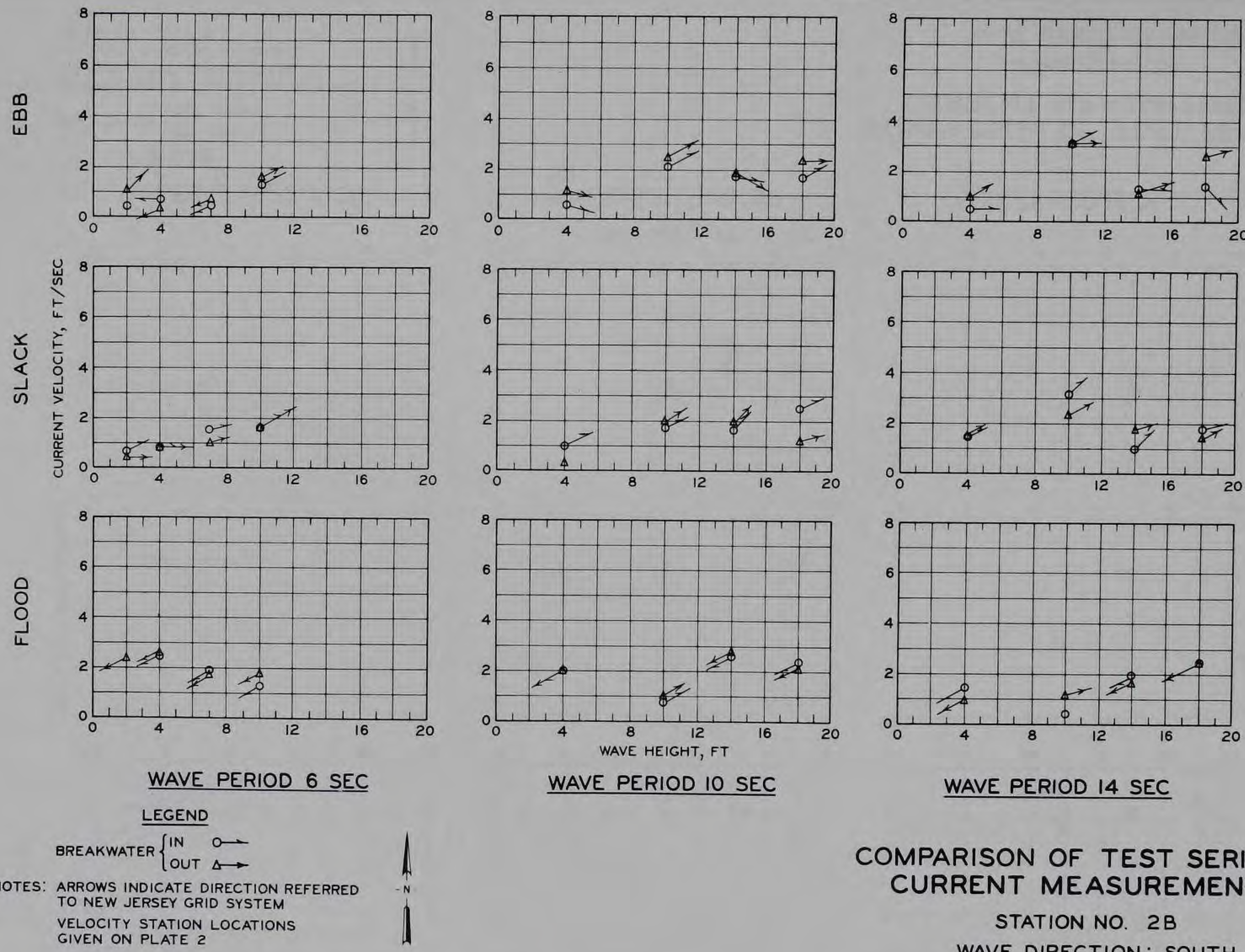
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 2A

WAVE DIRECTION: SOUTH



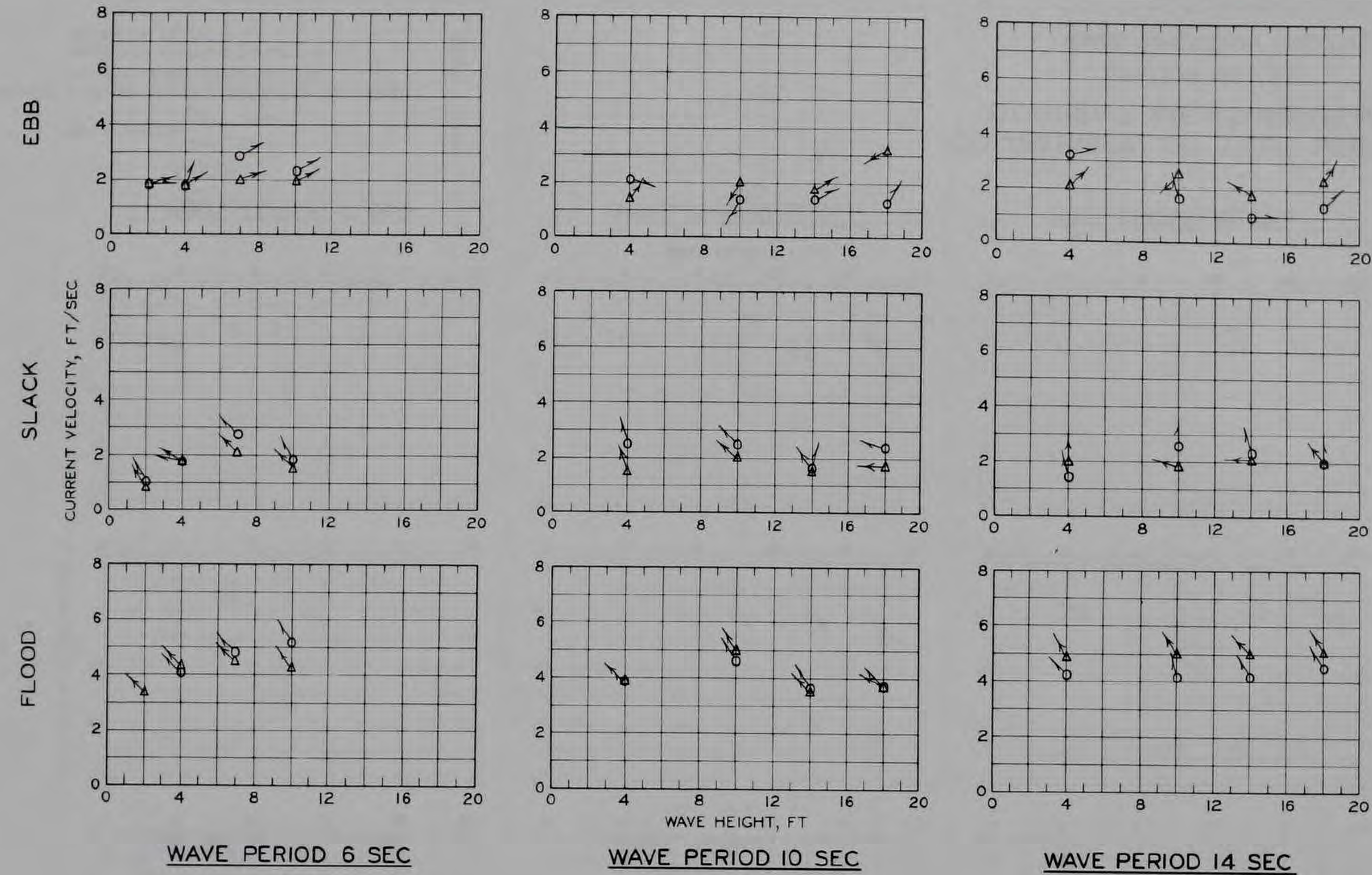
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 2B

WAVE DIRECTION: SOUTH



LEGEND

BREAKWATER { IN ○⟶ ; OUT △⟶ }

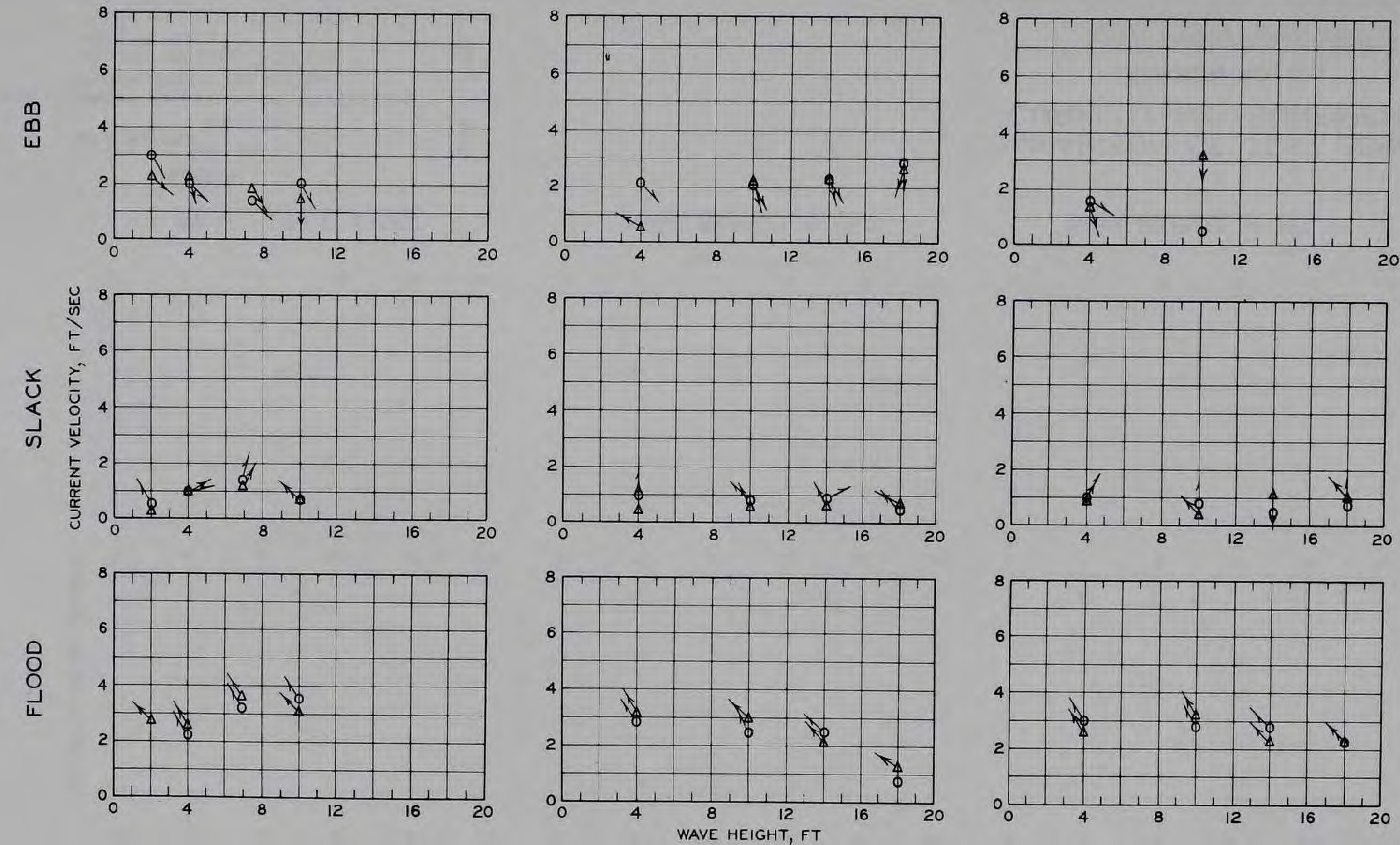
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 3A

WAVE DIRECTION: SOUTH



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

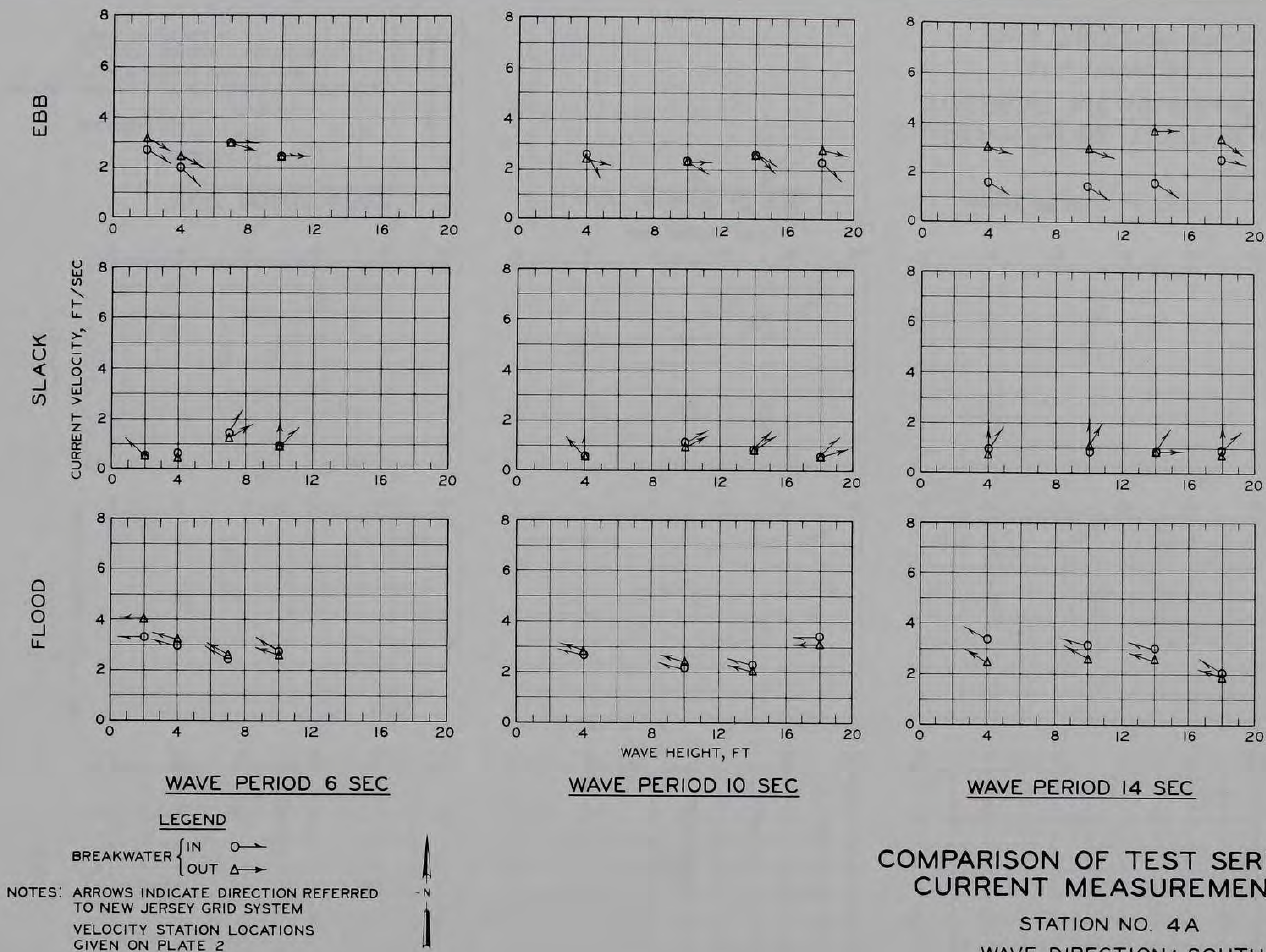
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 3B

WAVE DIRECTION: SOUTH



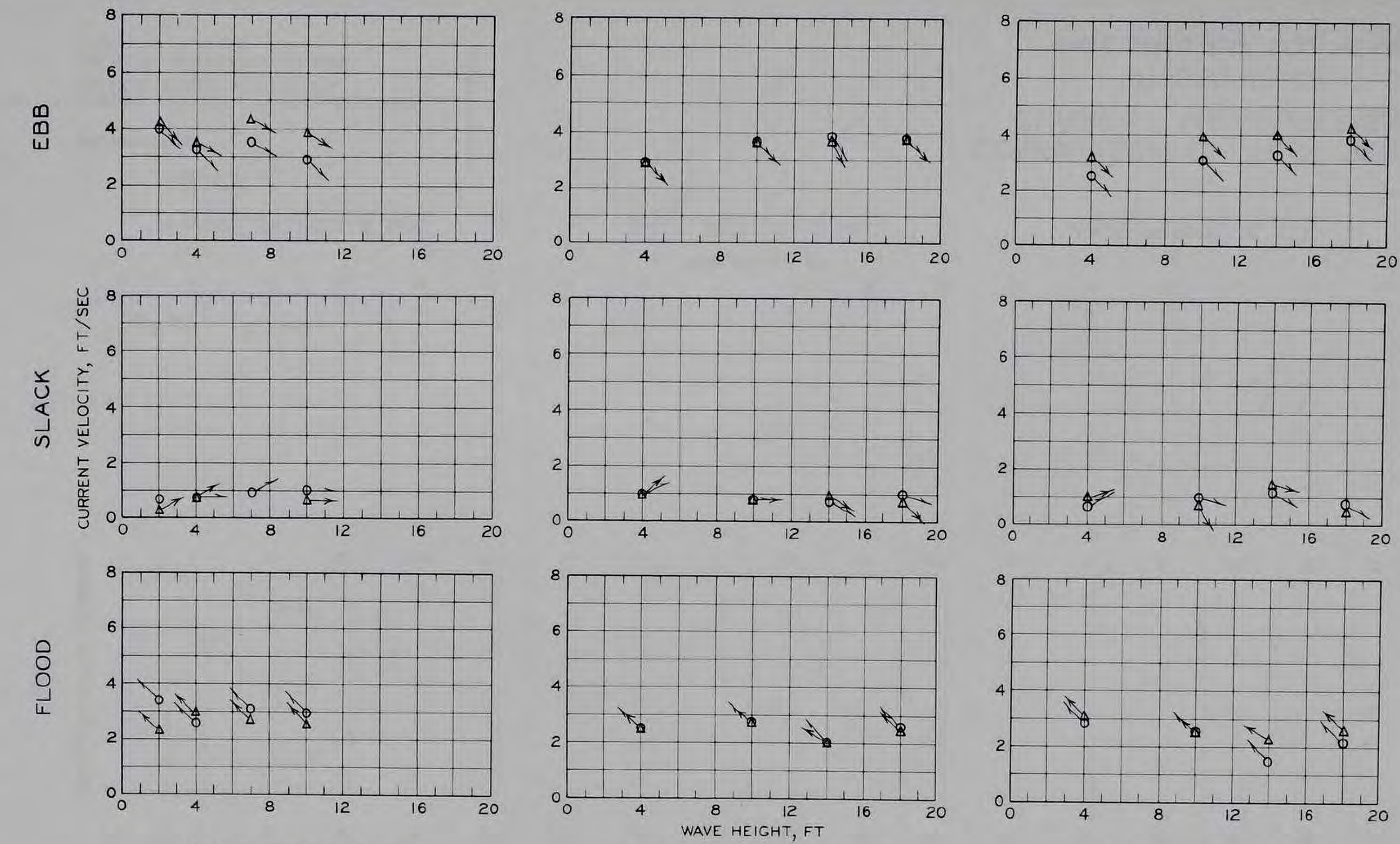
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 4A

WAVE DIRECTION: SOUTH



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○→ ; OUT △→

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

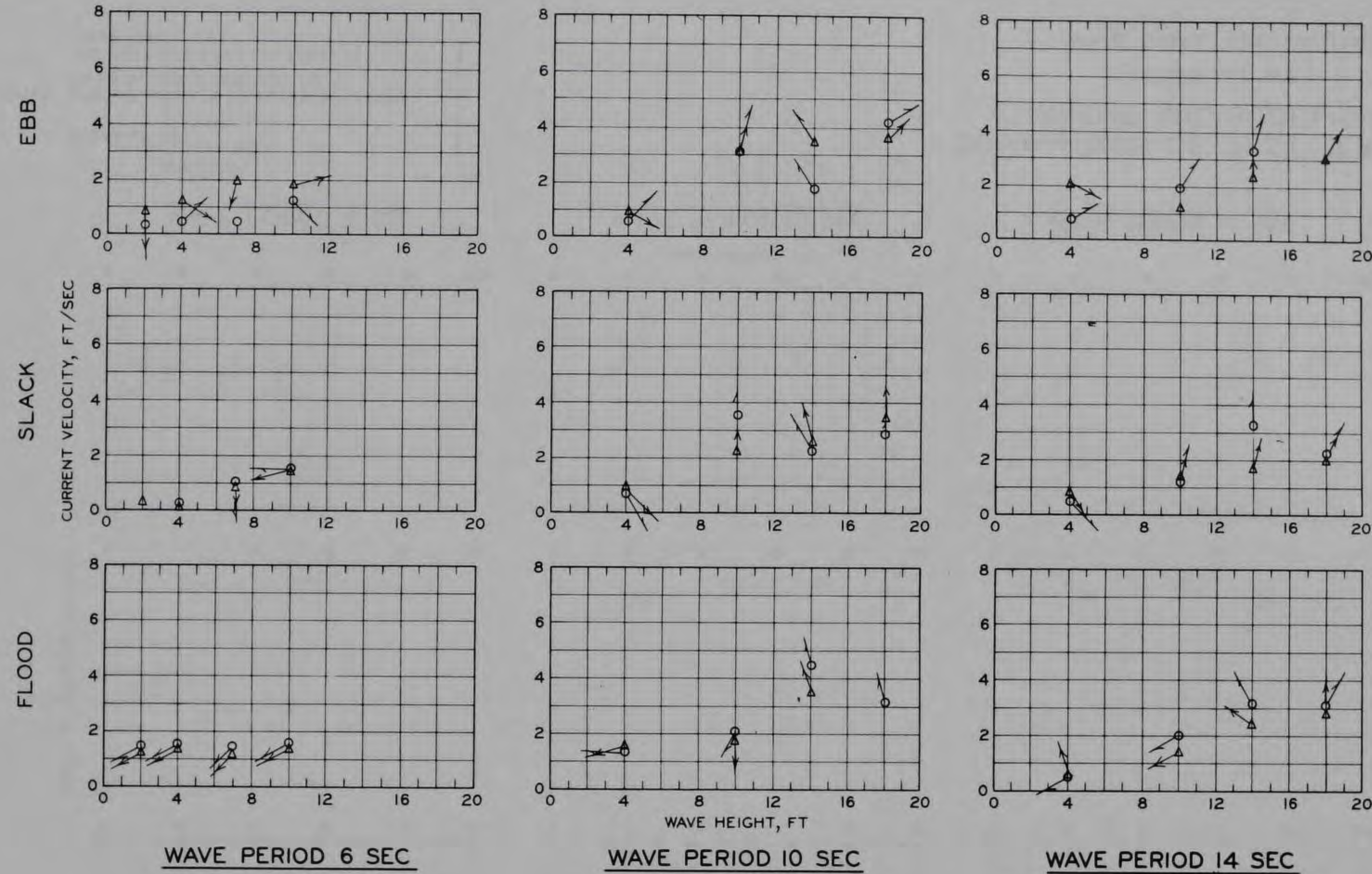
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 4B

WAVE DIRECTION: SOUTH



LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

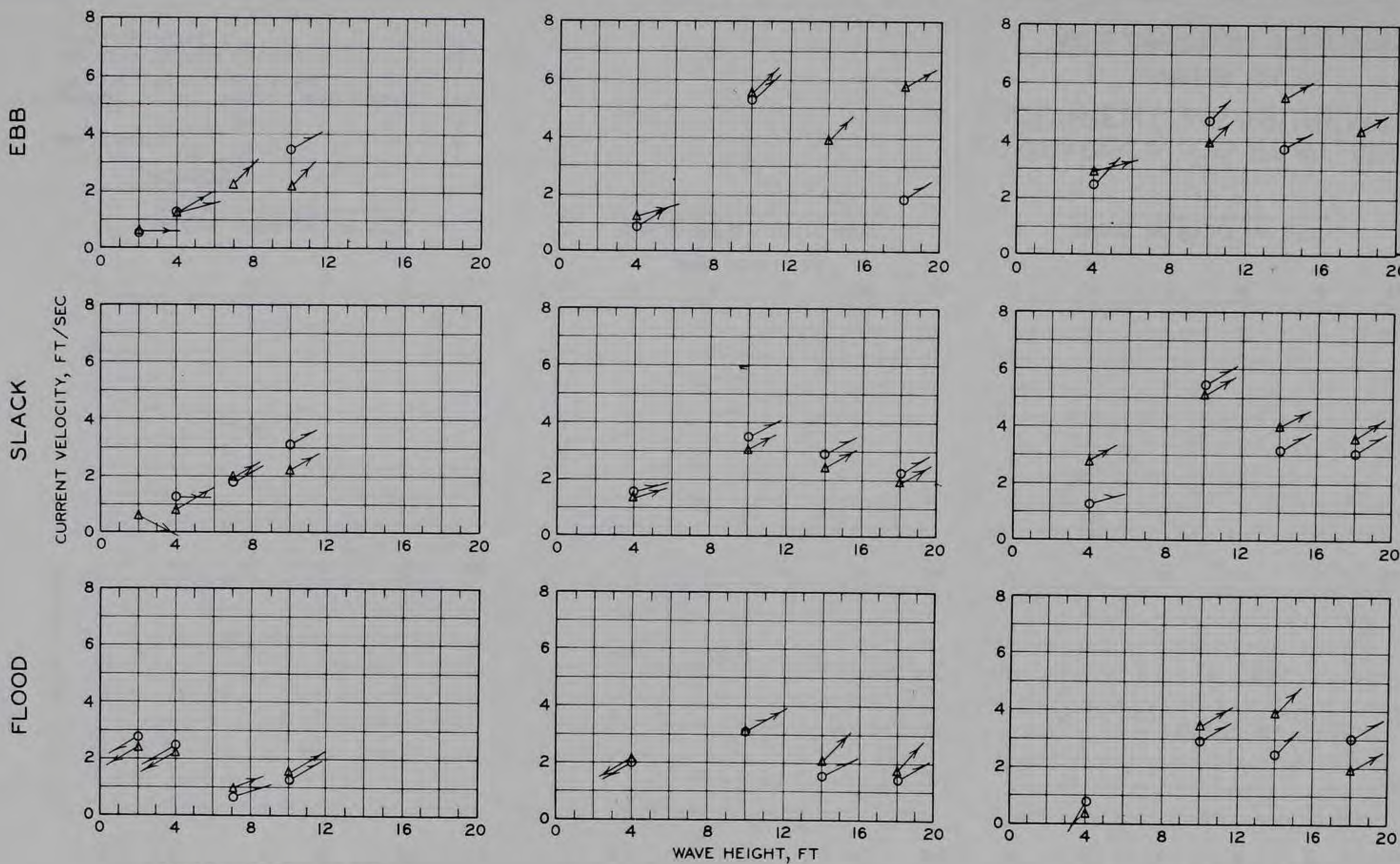
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 2A

WAVE DIRECTION: SOUTHEAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○⟶ ; OUT △⟶ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

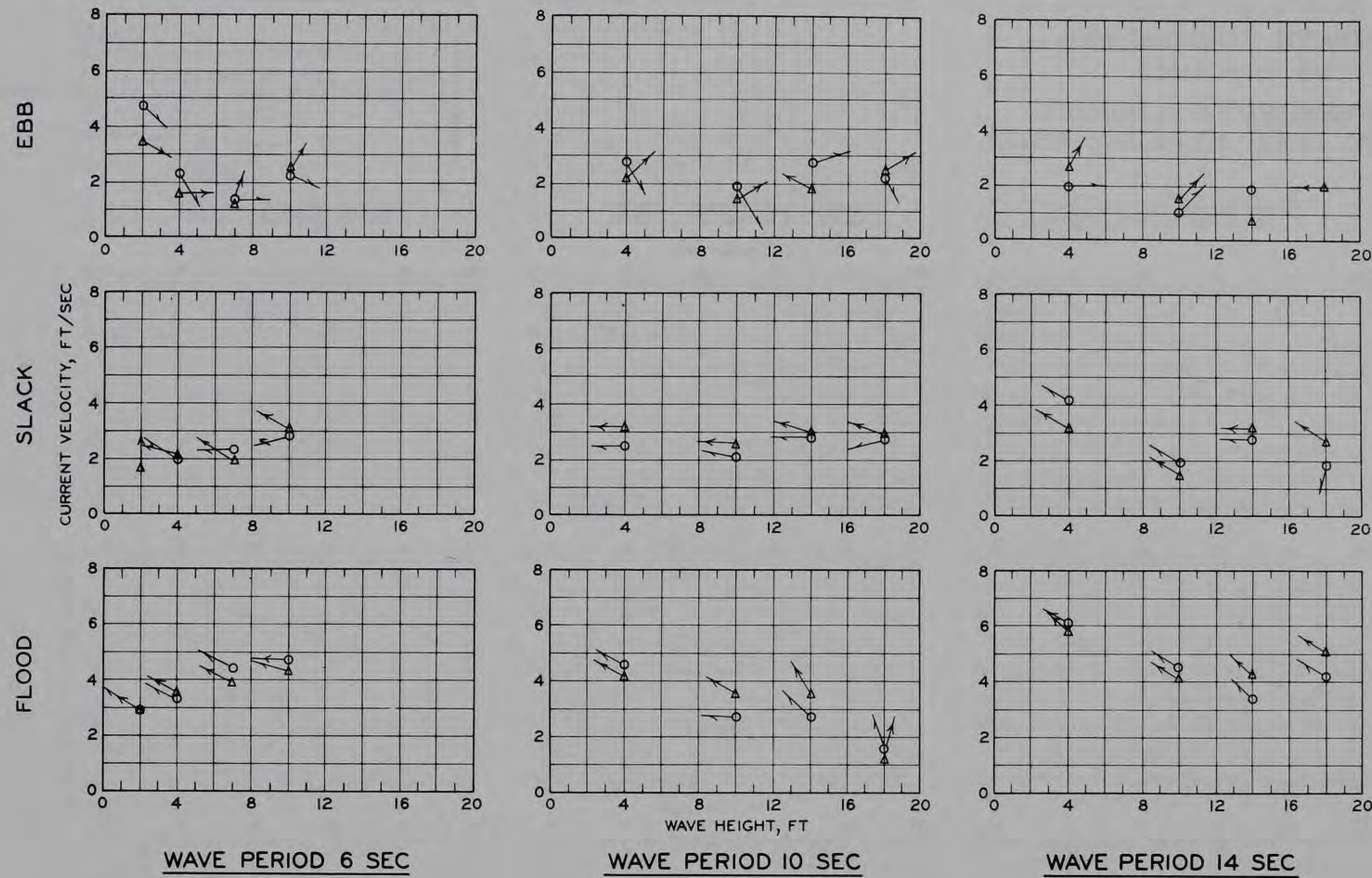
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 2B

WAVE DIRECTION : SOUTHEAST



LEGEND

BREAKWATER { IN ○⟶ ; OUT △⟶ }

N

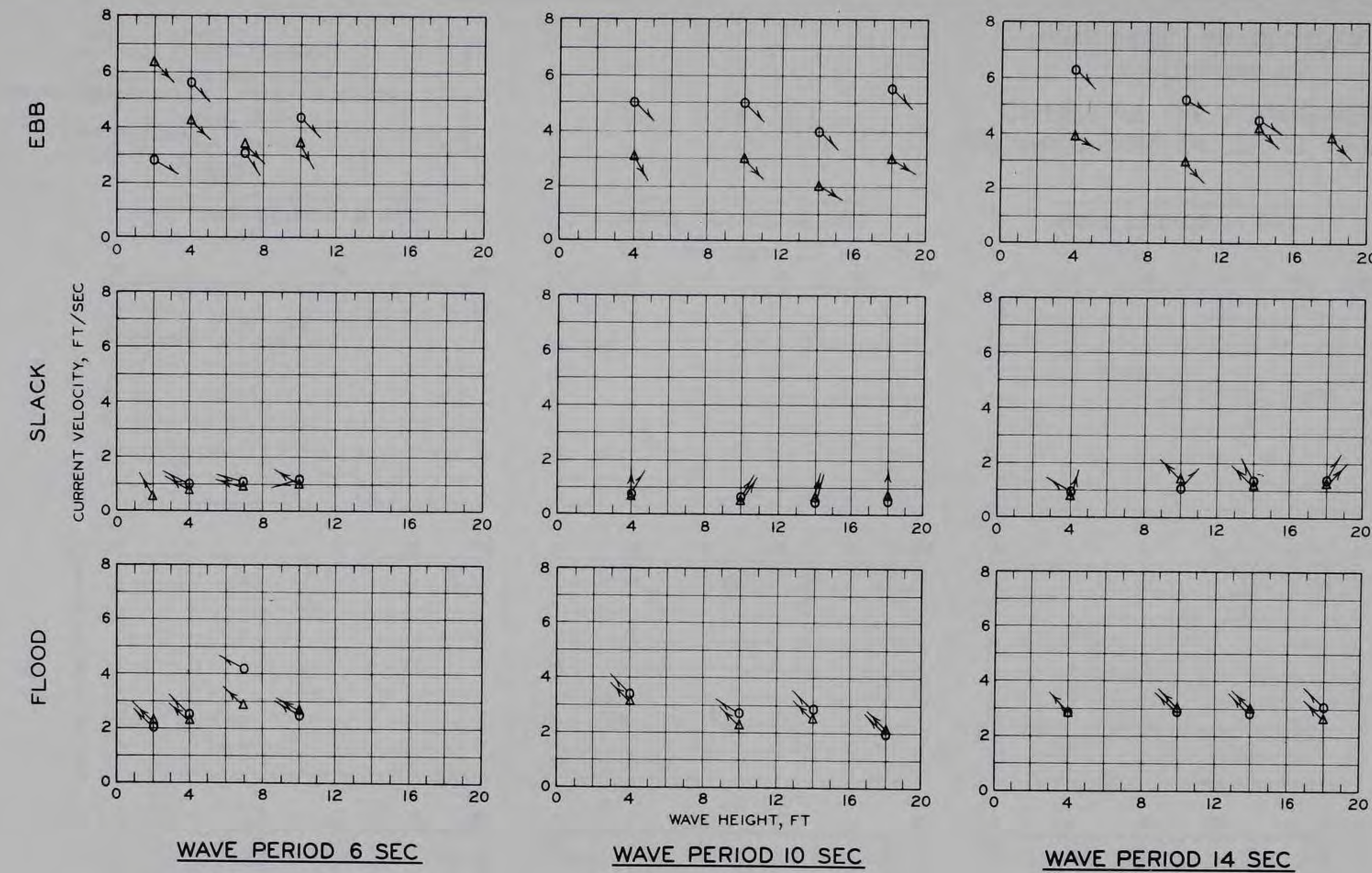
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 3A

WAVE DIRECTION: SOUTHEAST



LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

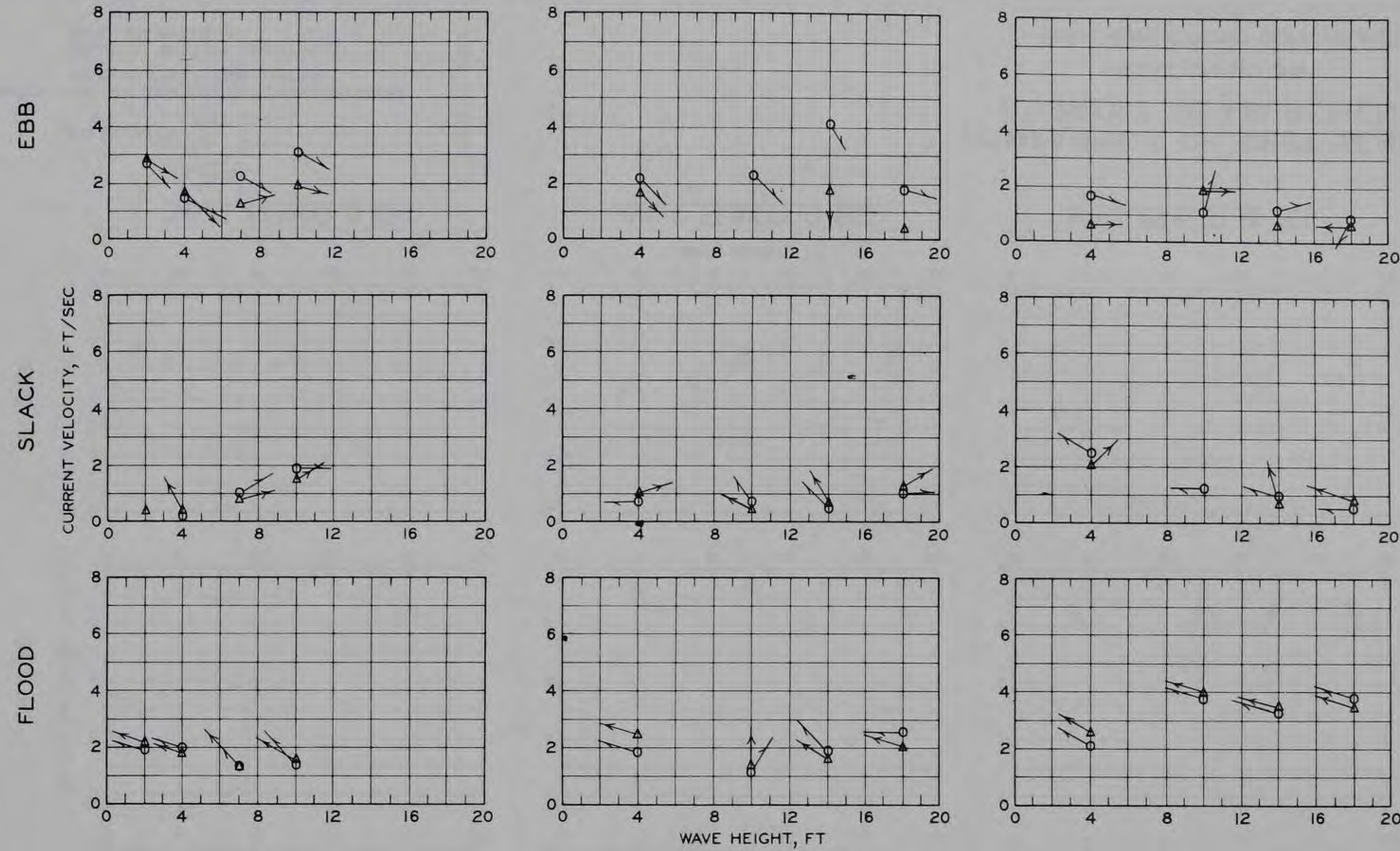
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 3B

WAVE DIRECTION: SOUTHEAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○⟶ ; OUT △⟶ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

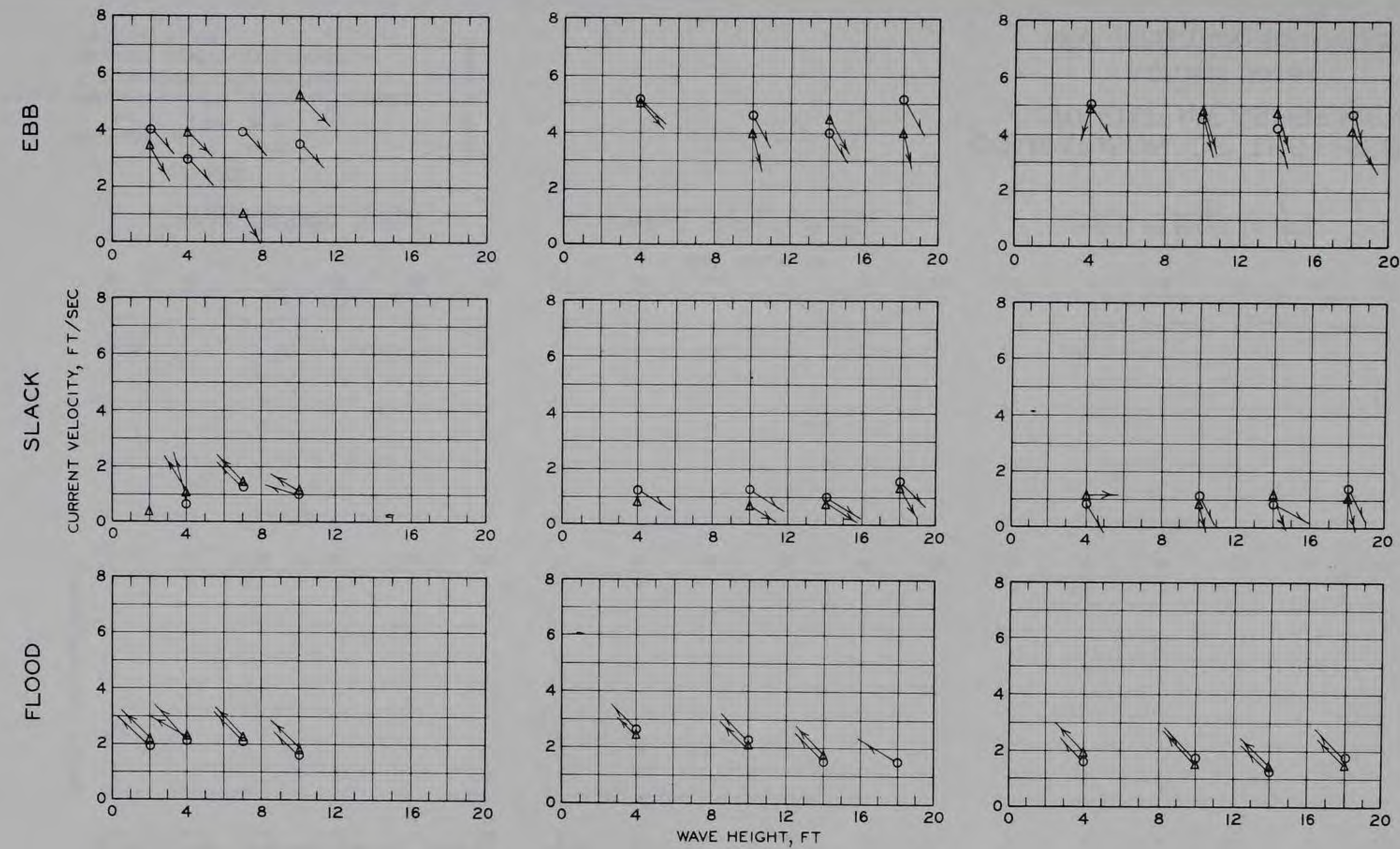
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 4A

WAVE DIRECTION: SOUTHEAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN O⟶ ; OUT Δ⟶ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

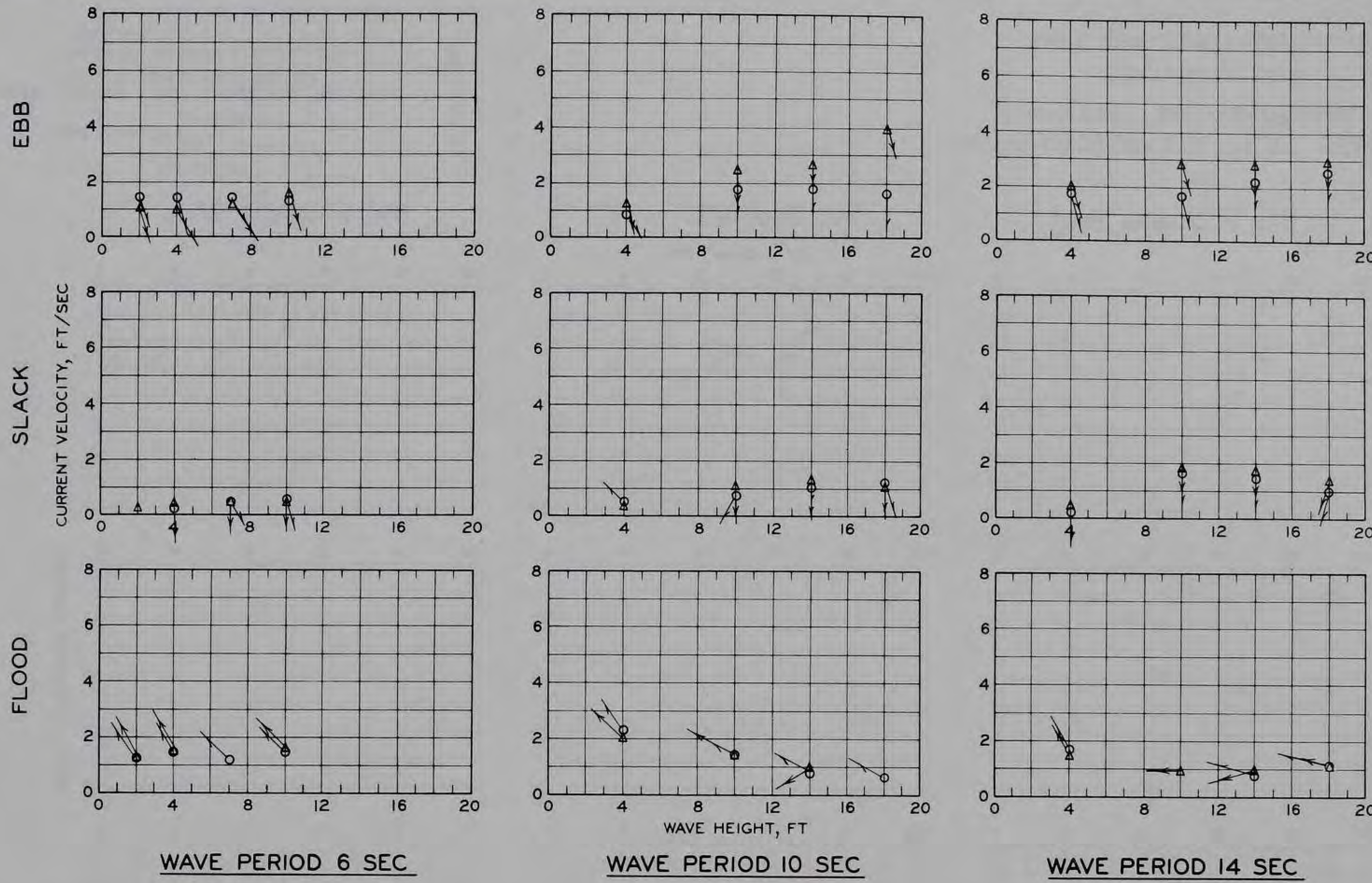
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 4B

WAVE DIRECTION : SOUTHEAST



LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

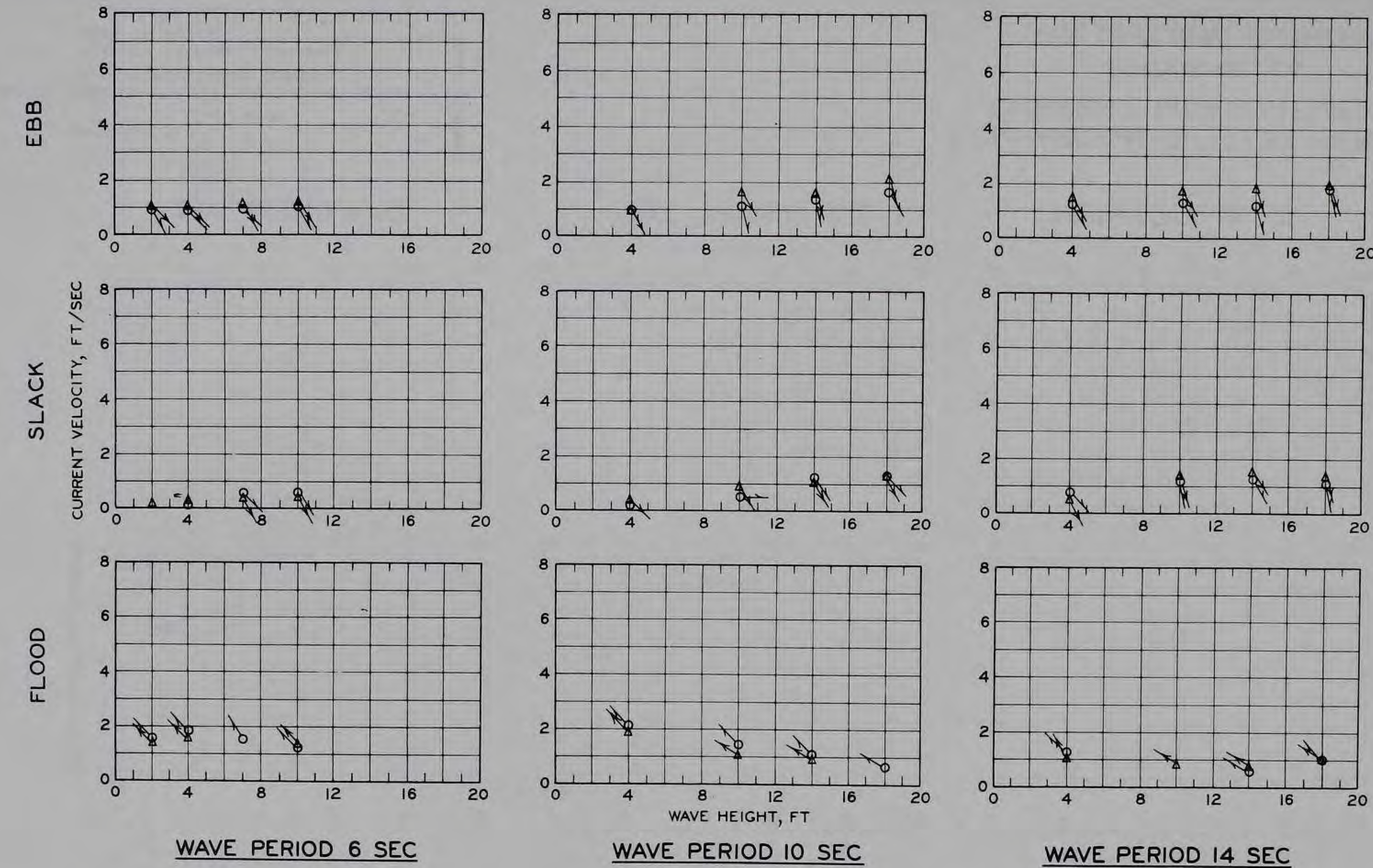
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 5A

WAVE DIRECTION: SOUTHEAST



LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

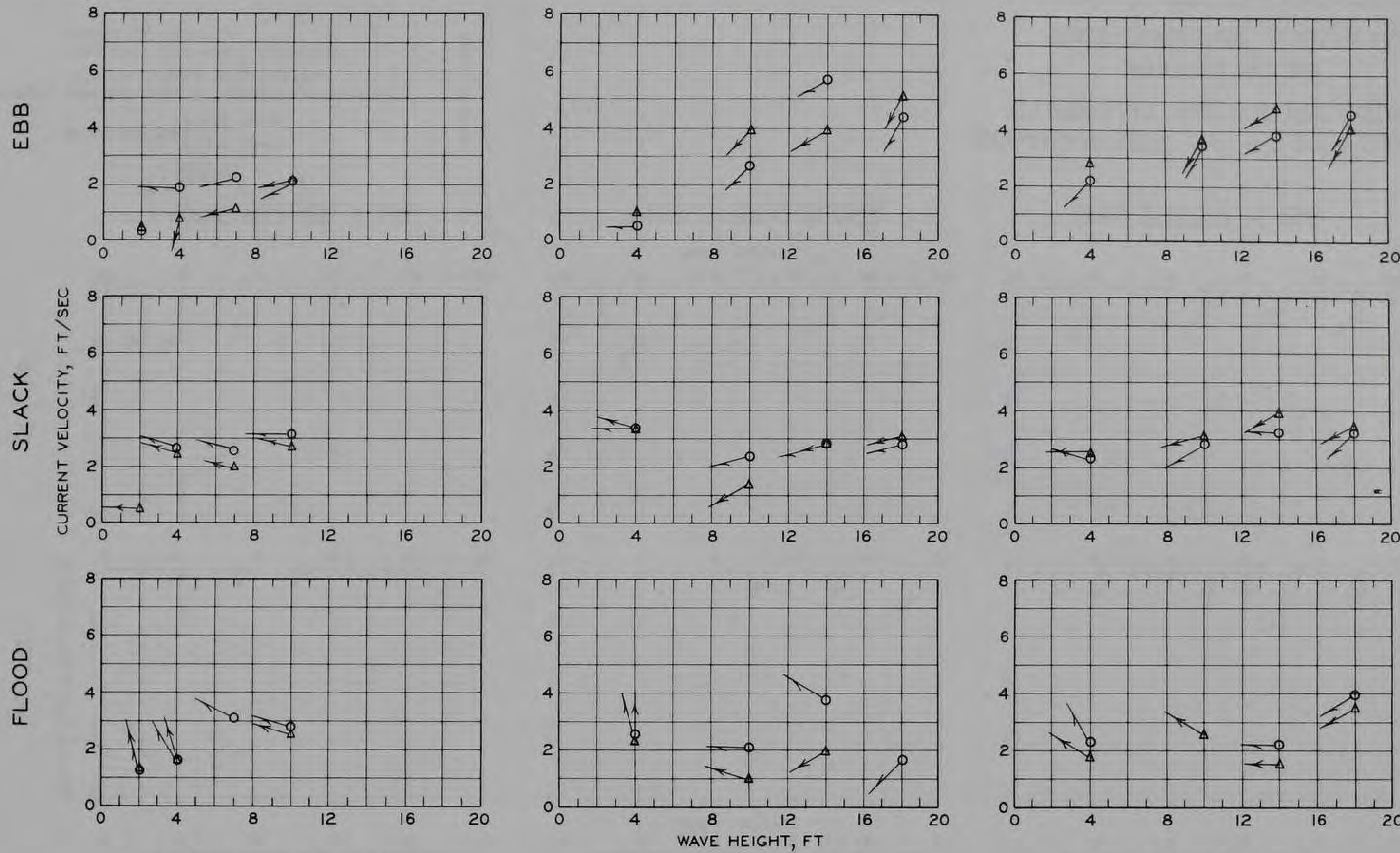
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 5B

WAVE DIRECTION : SOUTHEAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

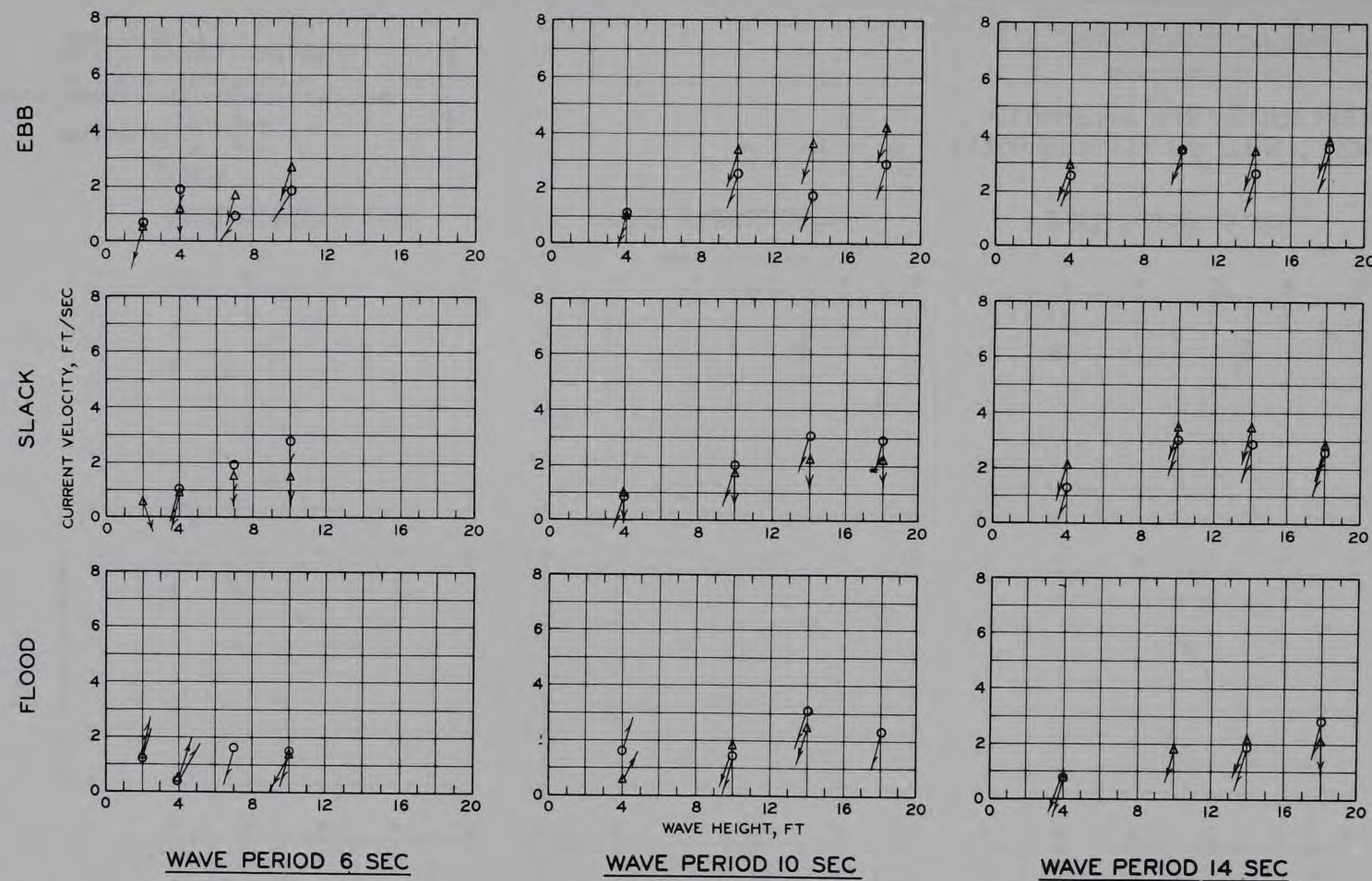
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 6A

WAVE DIRECTION: SOUTHEAST

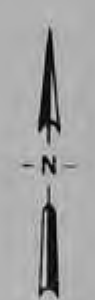


LEGEND

BREAKWATER { IN ○→ ; OUT △→

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

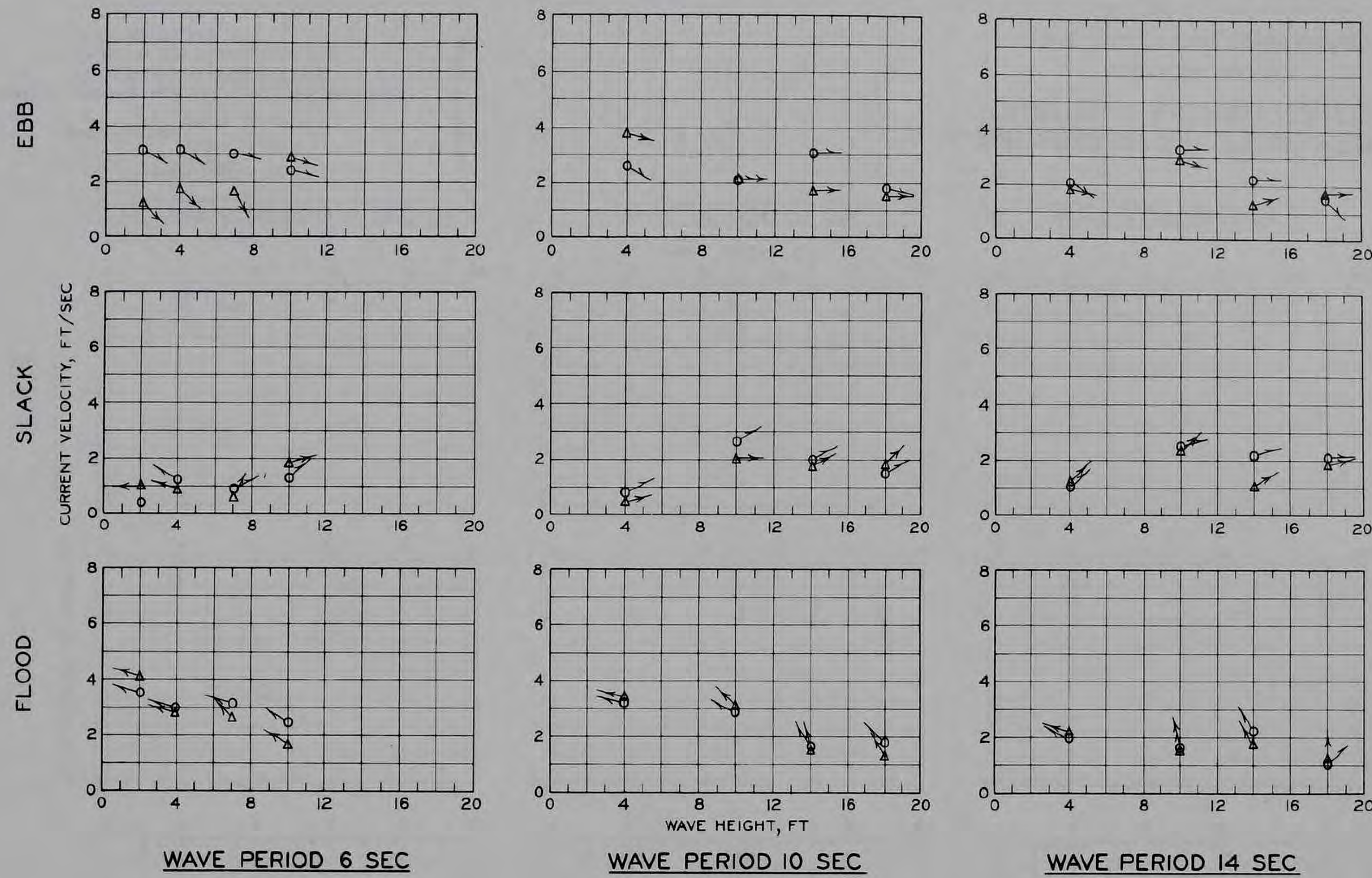
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2



COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 6B

WAVE DIRECTION : SOUTHEAST



LEGEND

BREAKWATER { IN ○⟶ / OUT △⟶ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

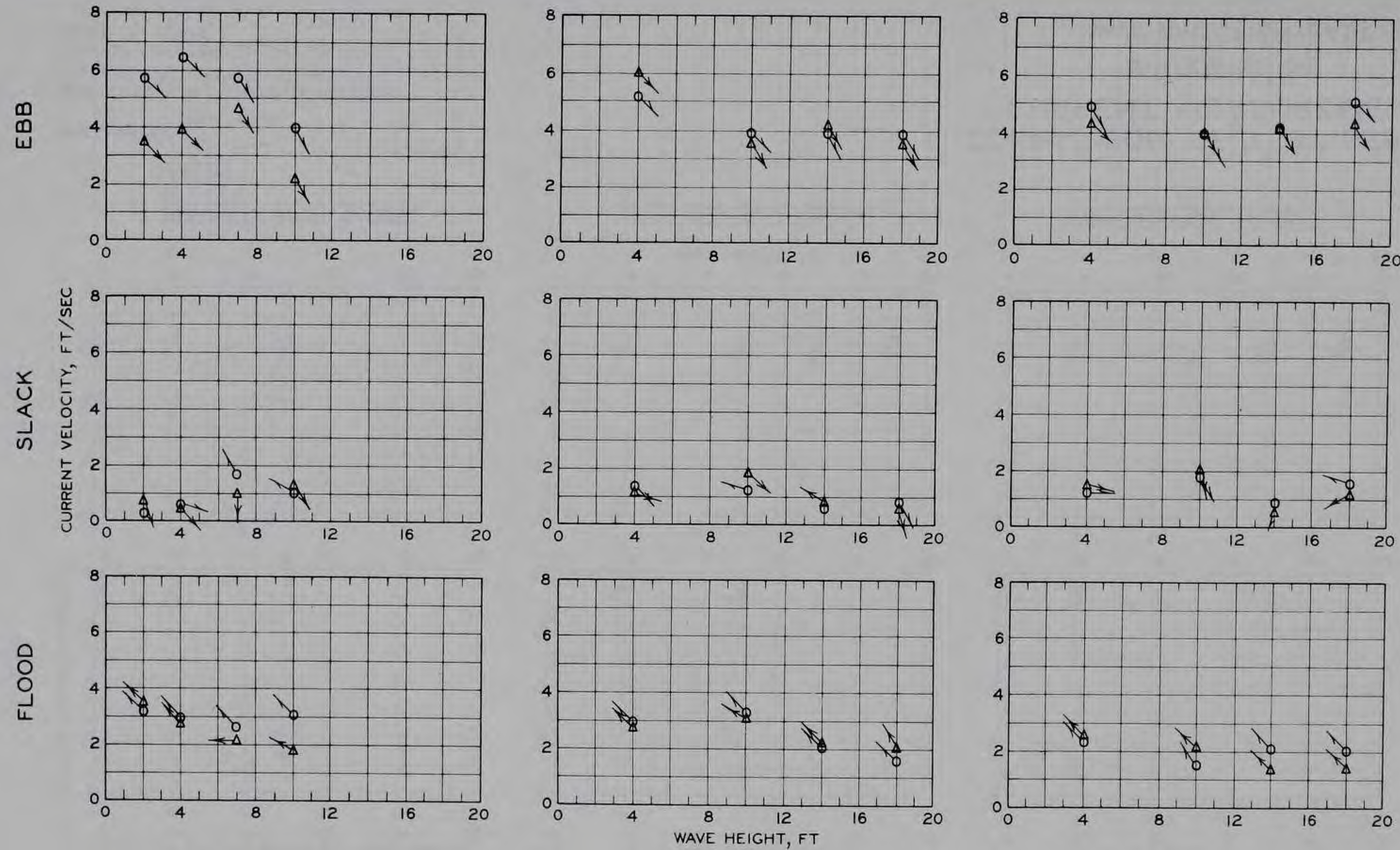
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 4A

WAVE DIRECTION: EAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○⟶ ; OUT △⟶ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

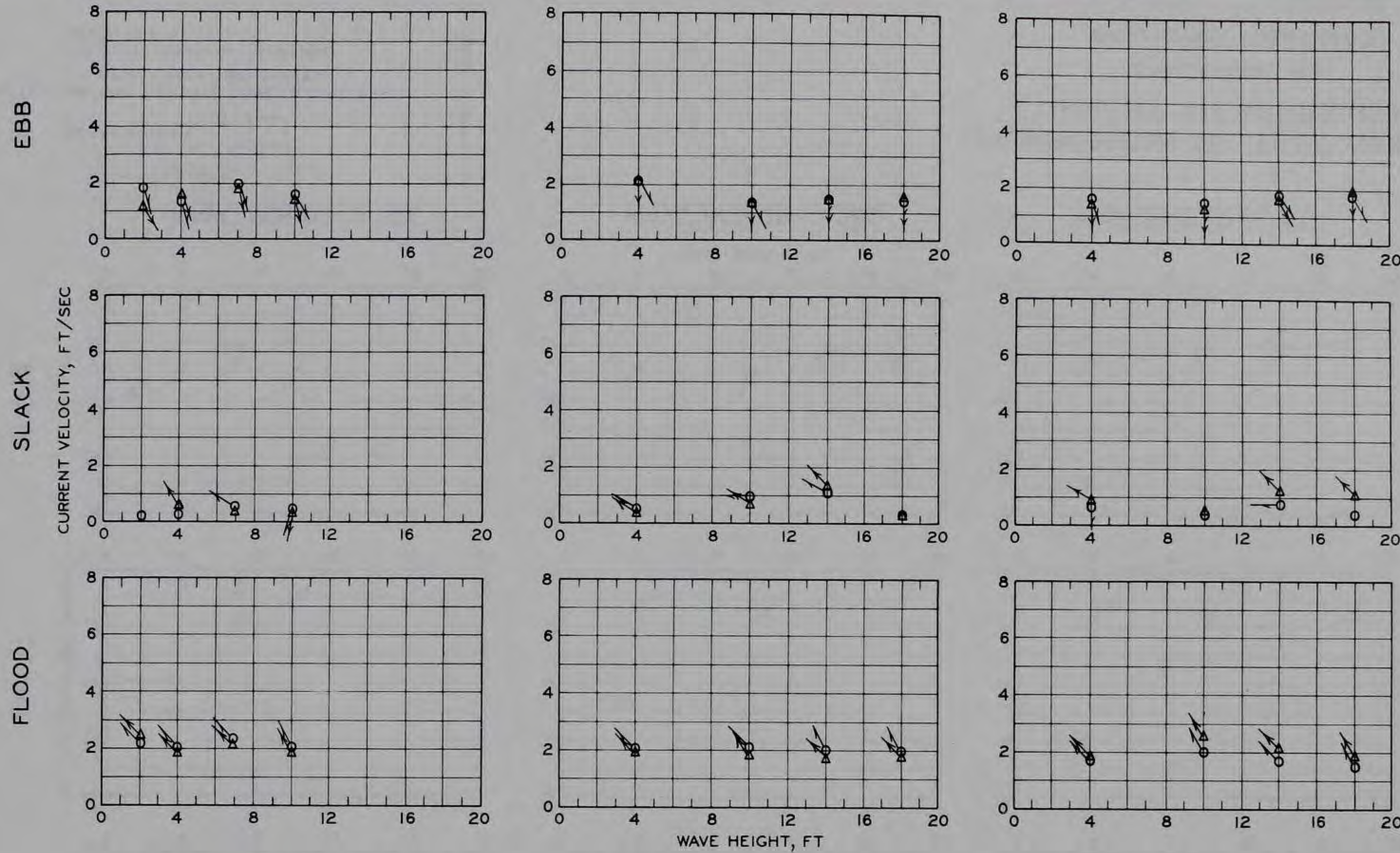
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 4B

WAVE DIRECTION: EAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○⟶ / OUT △⟶ }

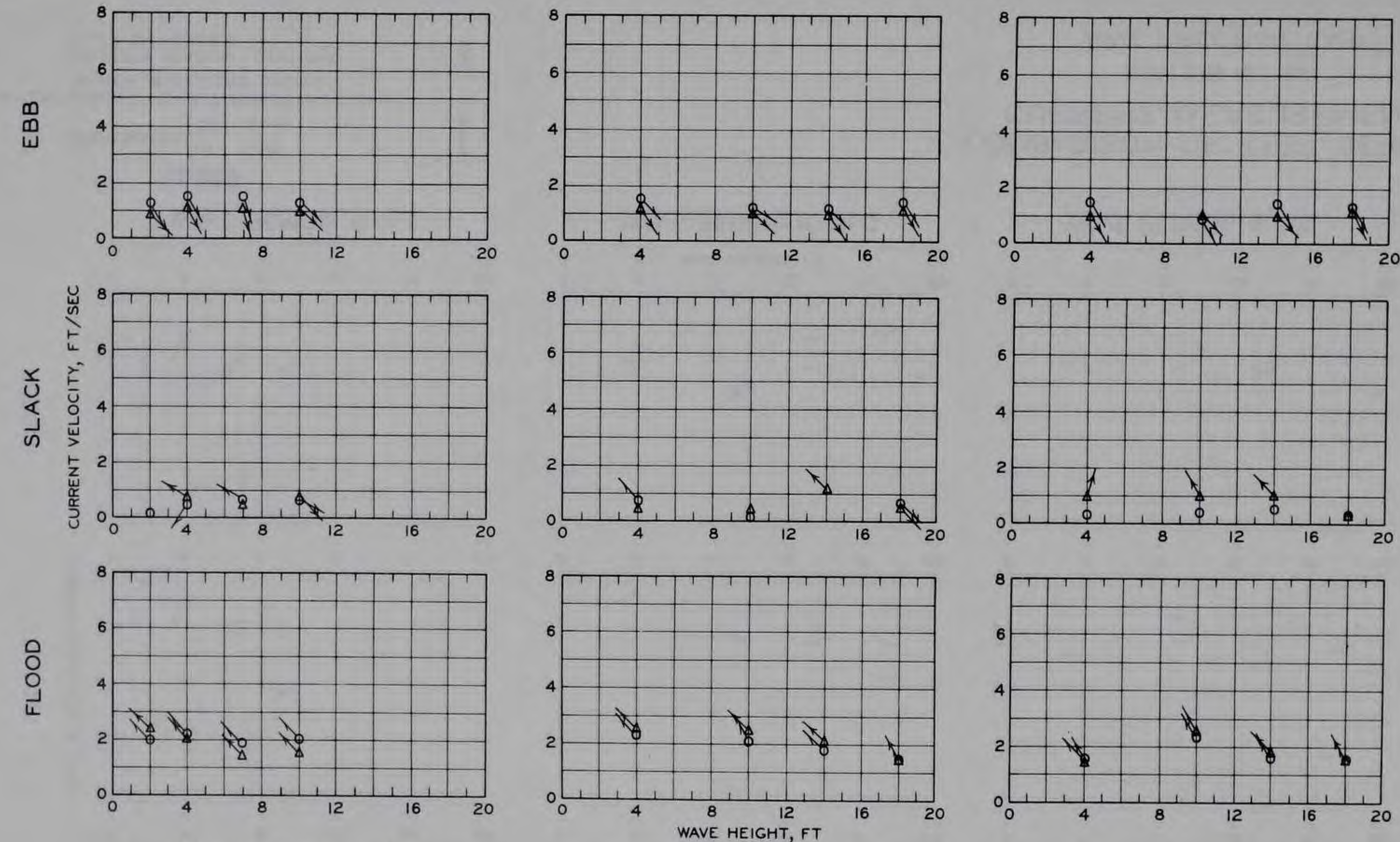
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 5A

WAVE DIRECTION: EAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○⟶ ; OUT △⟶ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

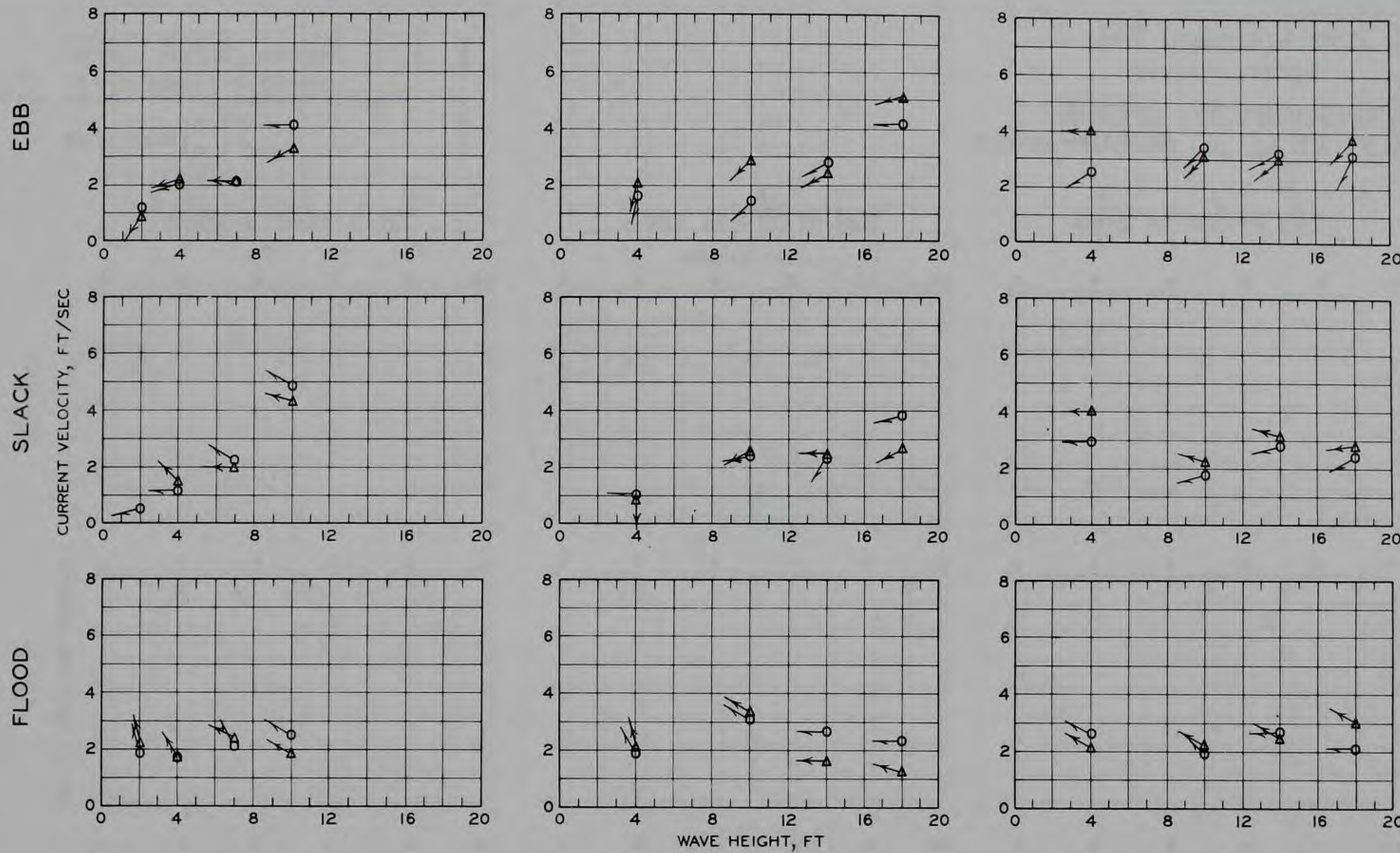
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 5B

WAVE DIRECTION : EAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

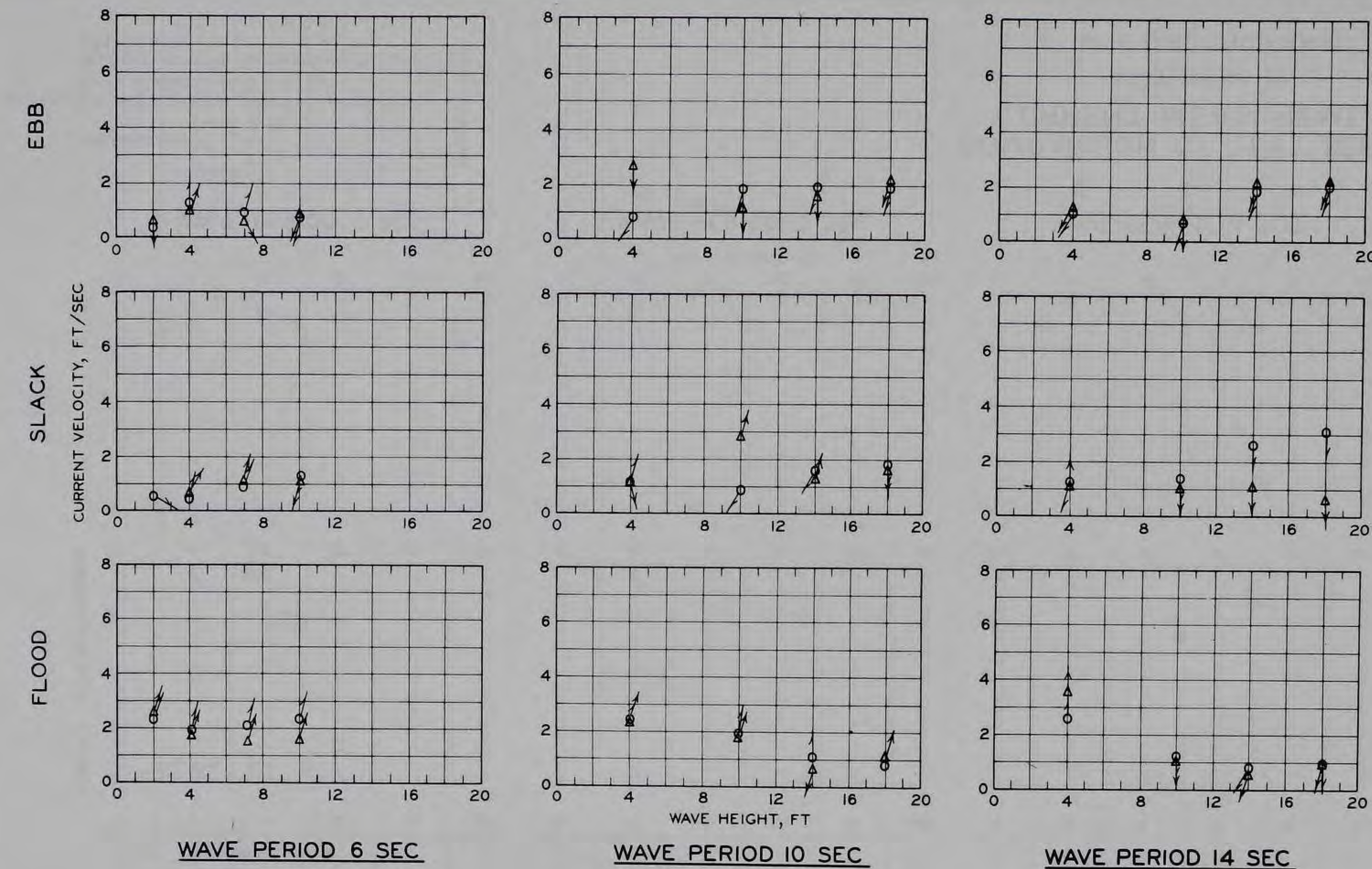
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

N

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 6A

WAVE DIRECTION : EAST



LEGEND

BREAKWATER { IN ○→ ; OUT △→

N

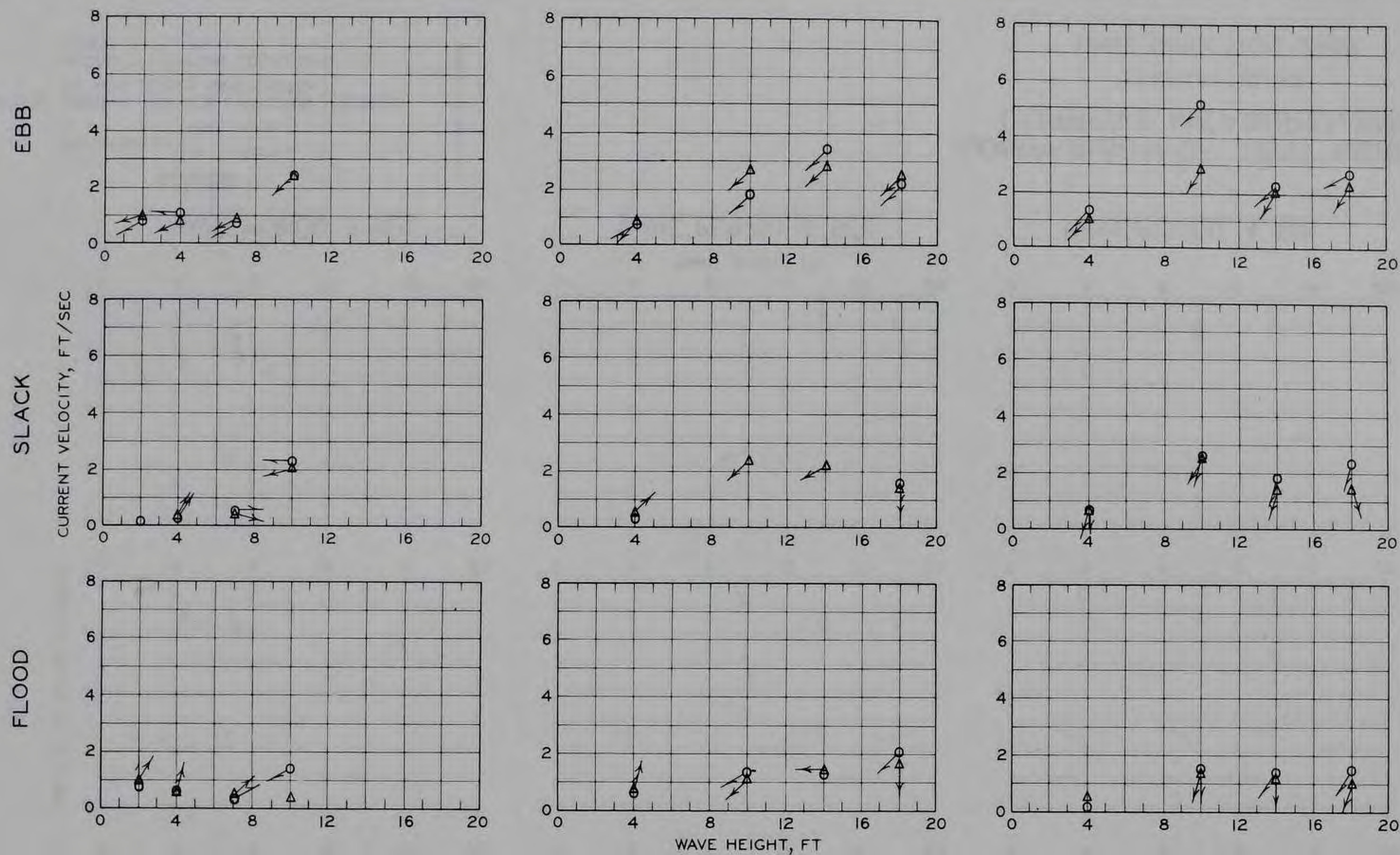
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 6B

WAVE DIRECTION : EAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN O→ ; OUT Δ→ }

N

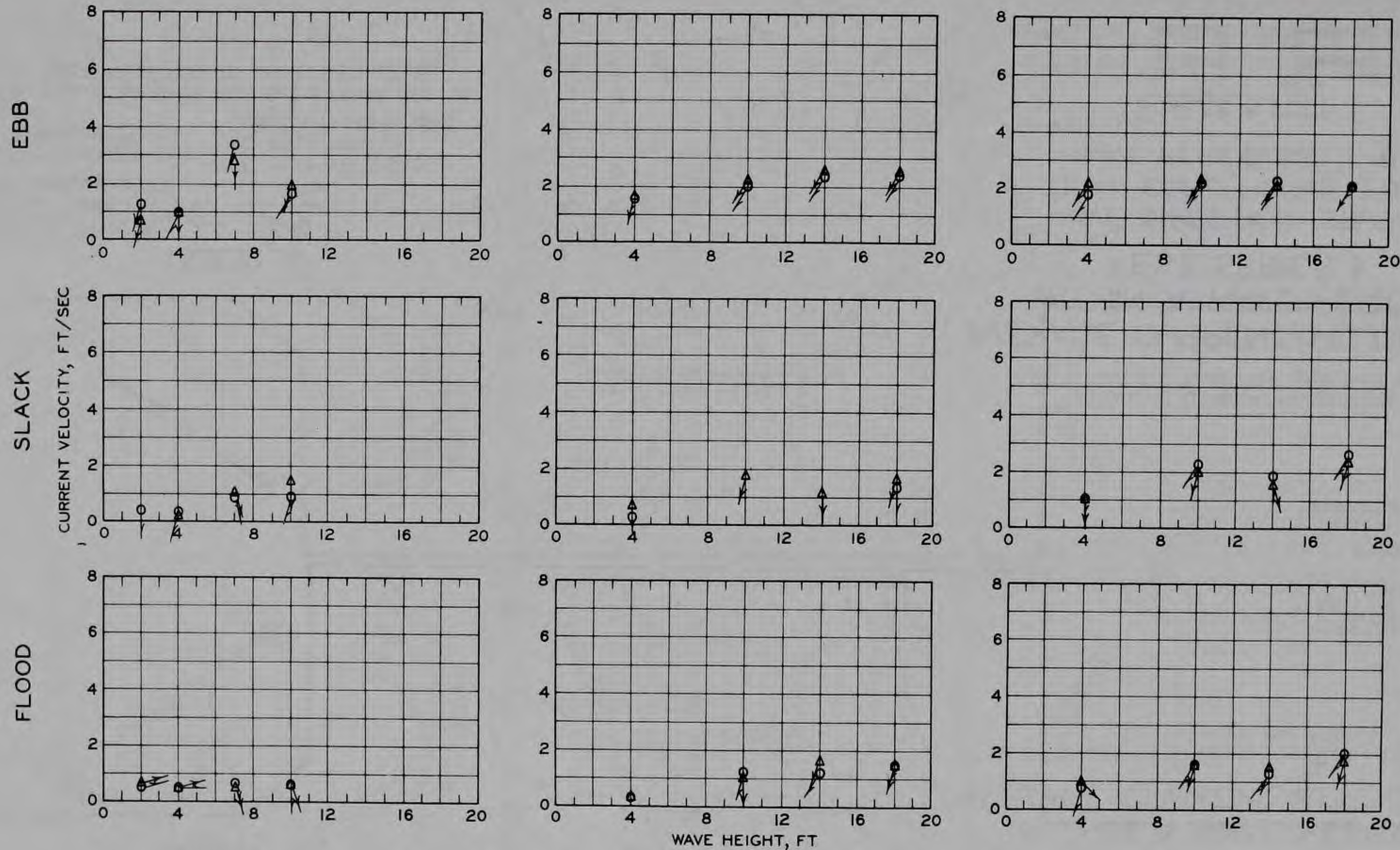
NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

VELOCITY STATION LOCATIONS GIVEN ON PLATE 2

COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 7A

WAVE DIRECTION: EAST



WAVE PERIOD 6 SEC

WAVE PERIOD 10 SEC

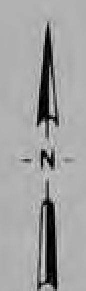
WAVE PERIOD 14 SEC

LEGEND

BREAKWATER { IN ○→ ; OUT △→ }

NOTES: ARROWS INDICATE DIRECTION REFERRED TO NEW JERSEY GRID SYSTEM

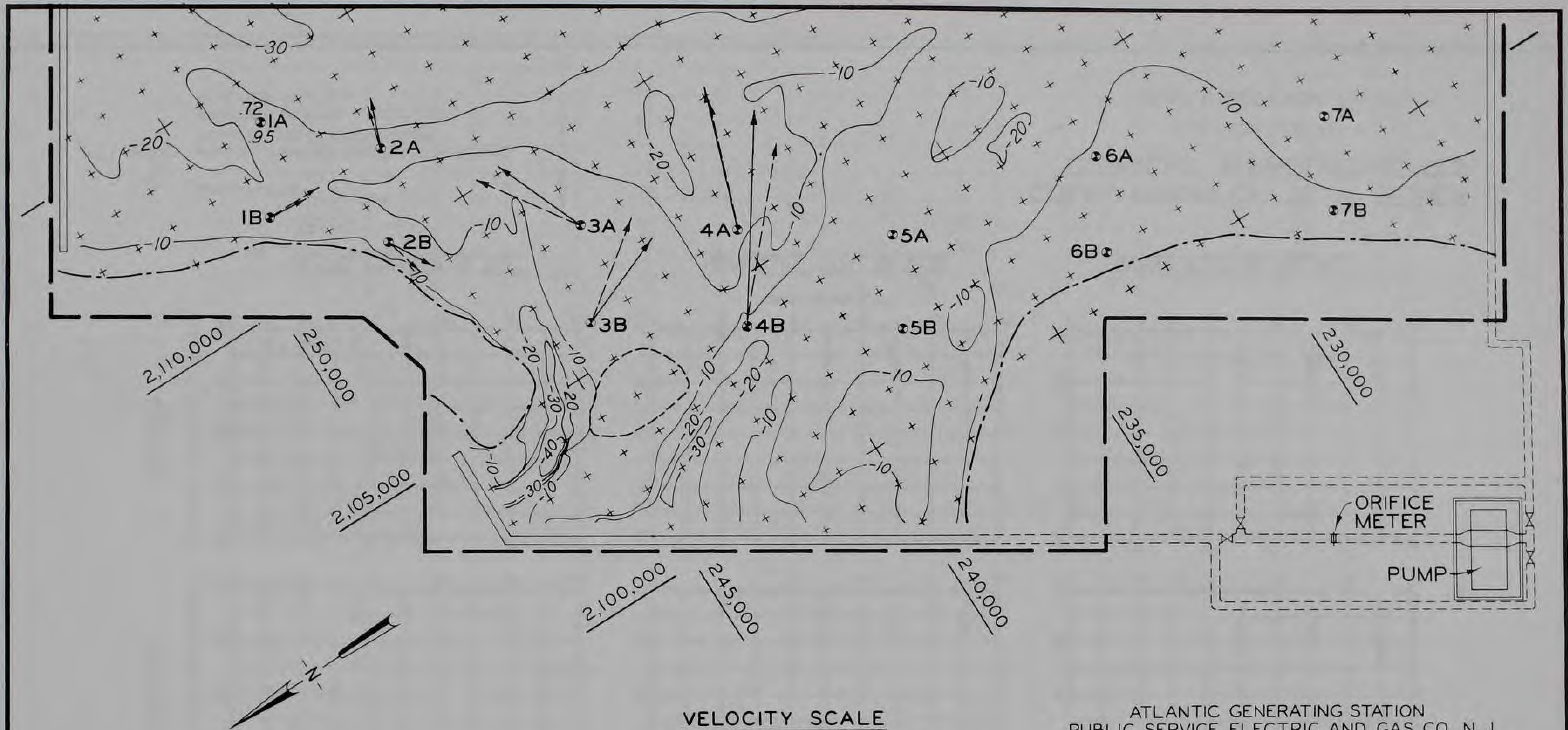
VELOCITY STATION LOCATIONS GIVEN ON PLATE 2



COMPARISON OF TEST SERIES I CURRENT MEASUREMENTS

STATION NO. 7B

WAVE DIRECTION: EAST



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 6

LEGEND

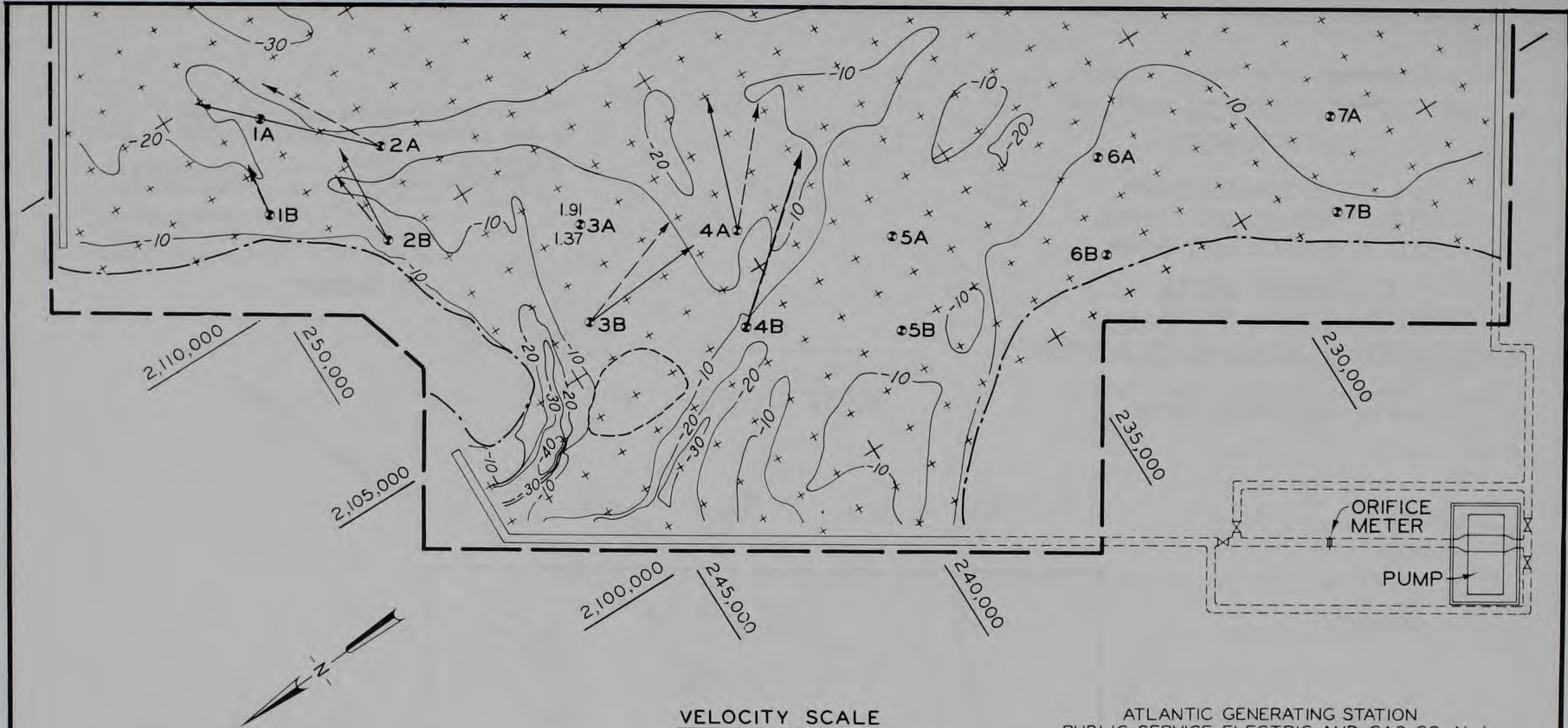
WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE
1.65 BREAKWATER IN

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 10

LEGEND

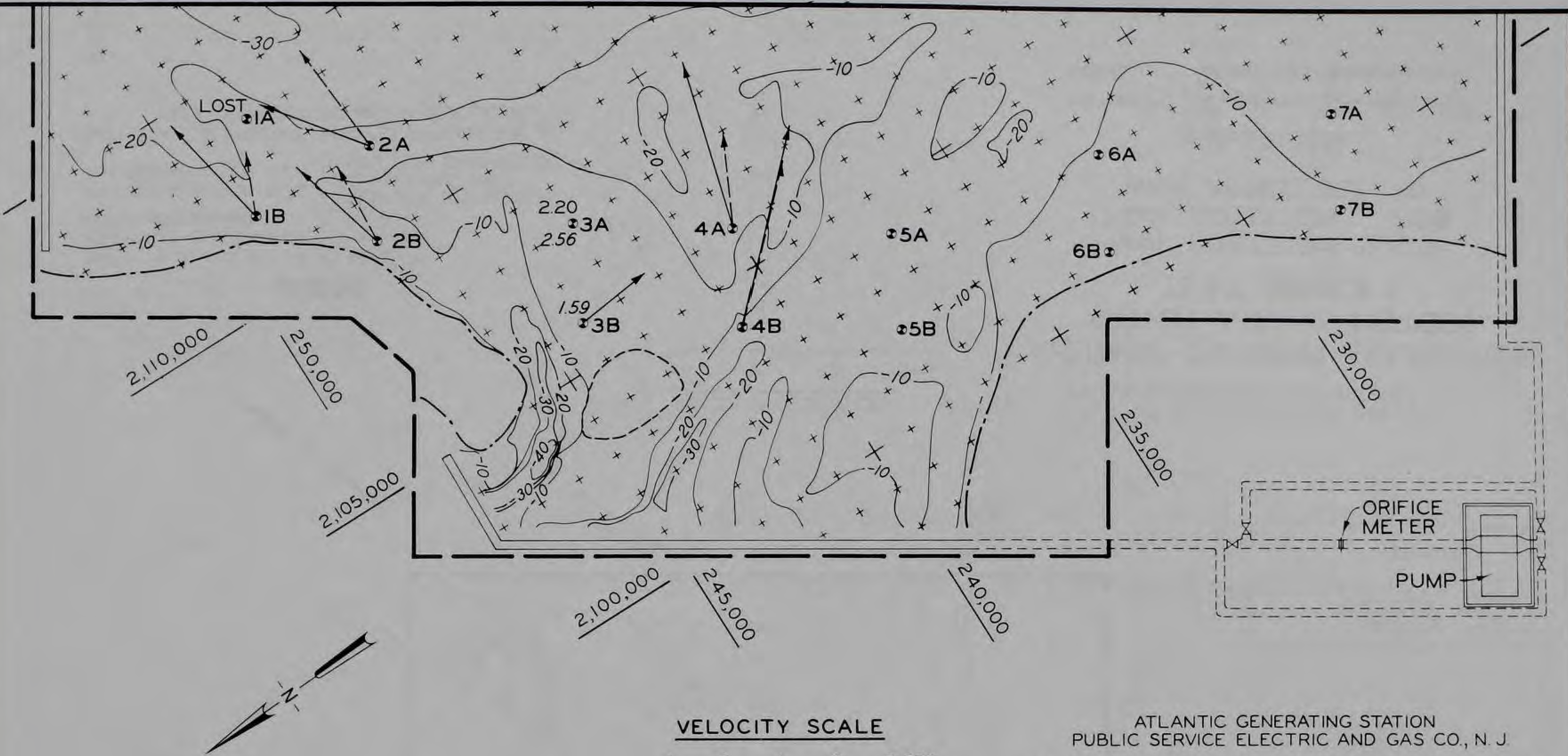
WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER – – –→

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

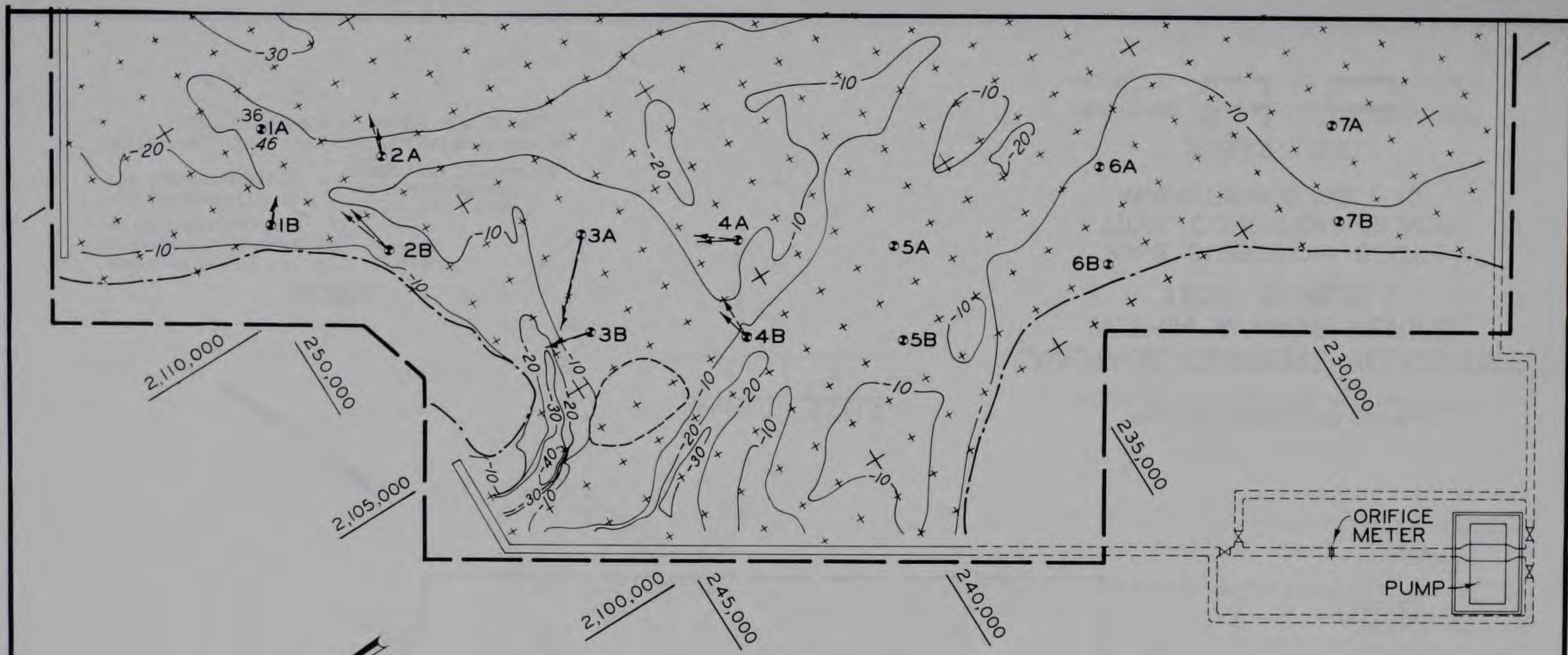
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 14

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ———→
WITH BREAKWATER – – –→
1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

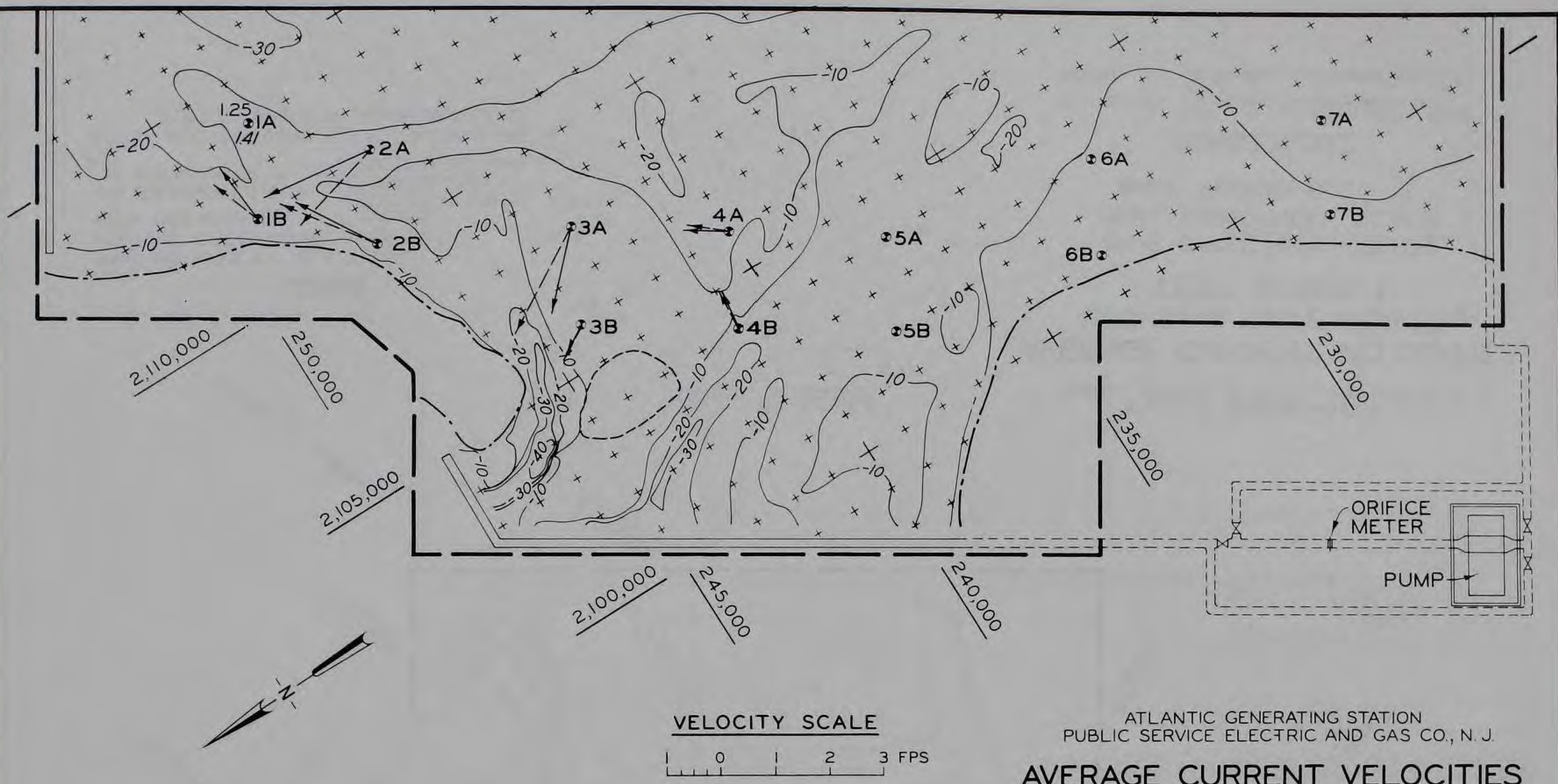
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 6

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 10

SCALES IN FEET

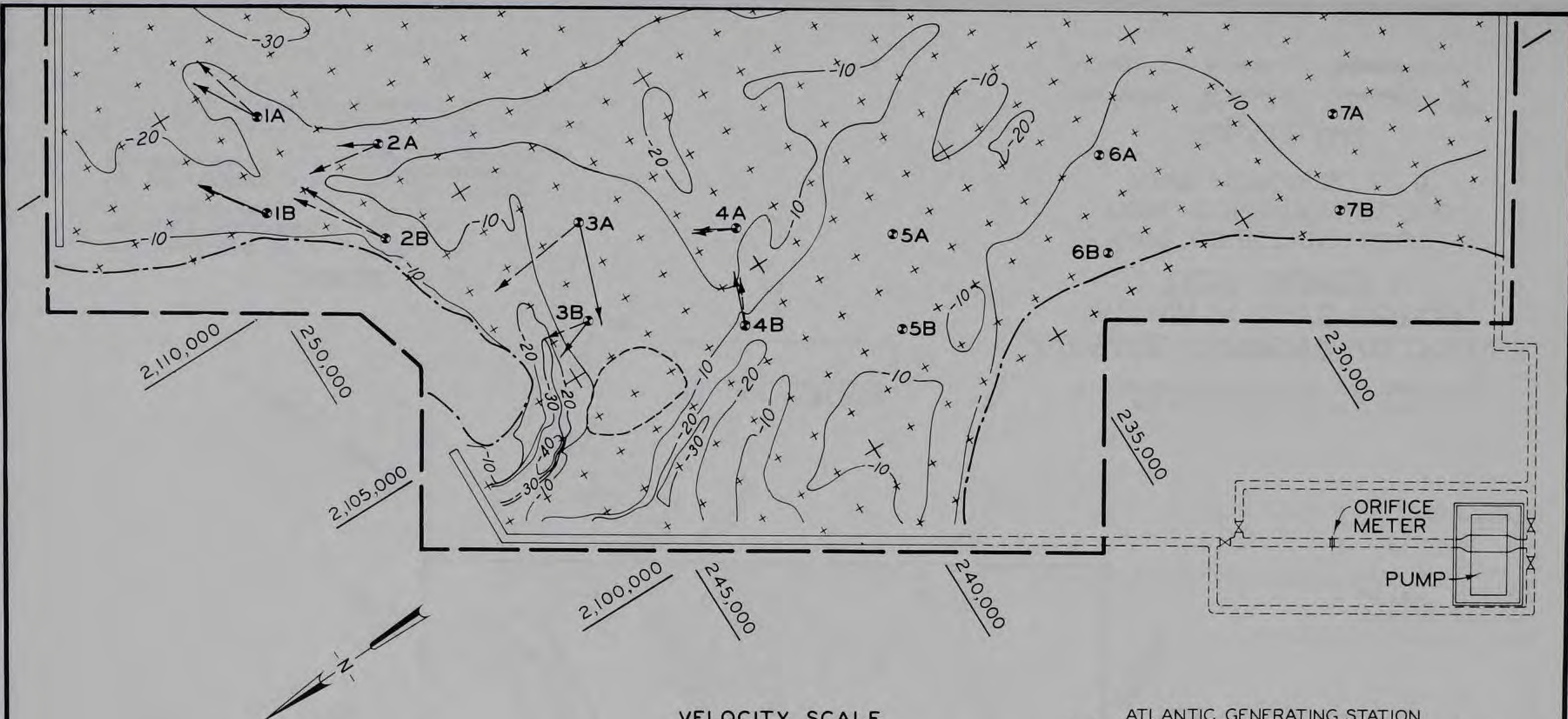
PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE
1.65 BREAKWATER IN

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

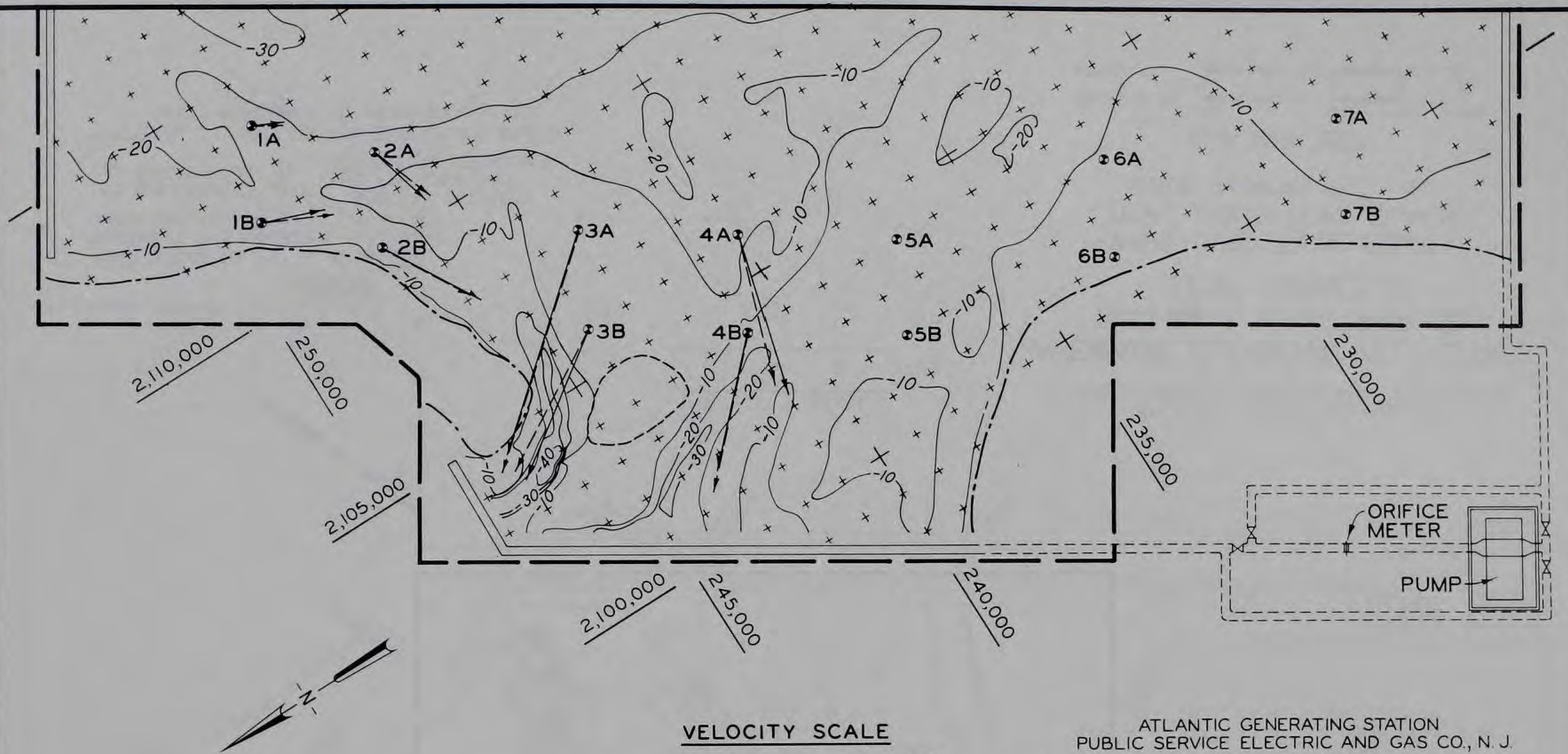
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 14

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 6

SCALES IN FEET

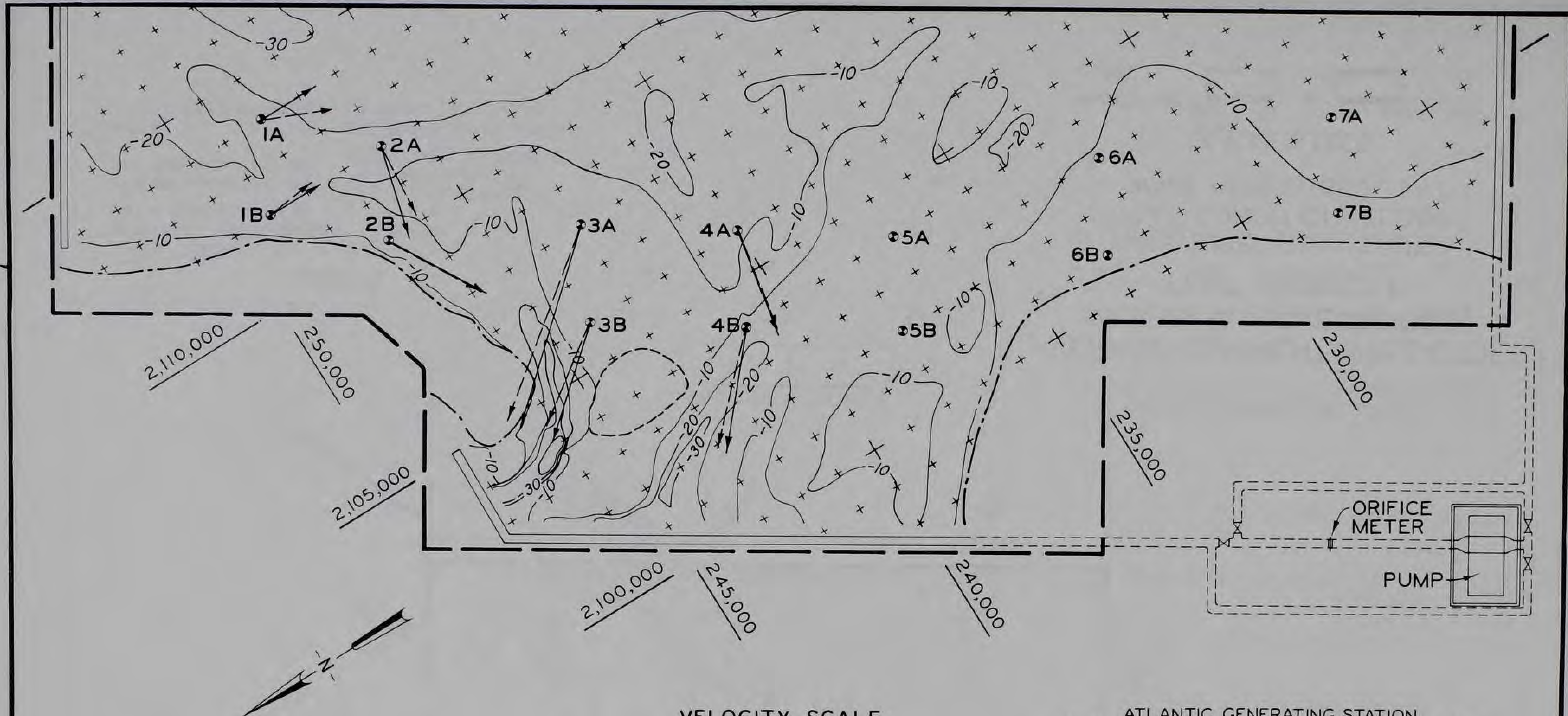
PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15

LEGEND

WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 10

LEGEND

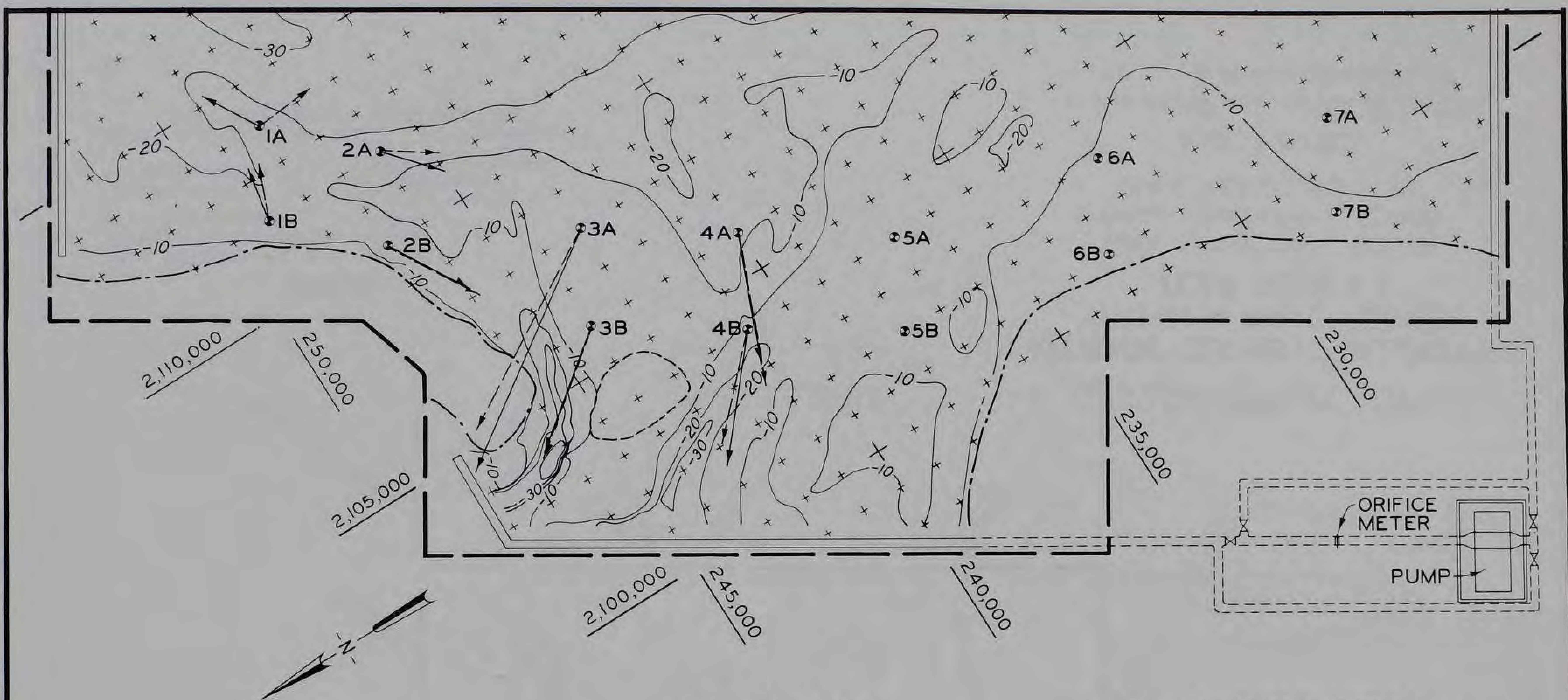
WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTH
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 14

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — —→

1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15

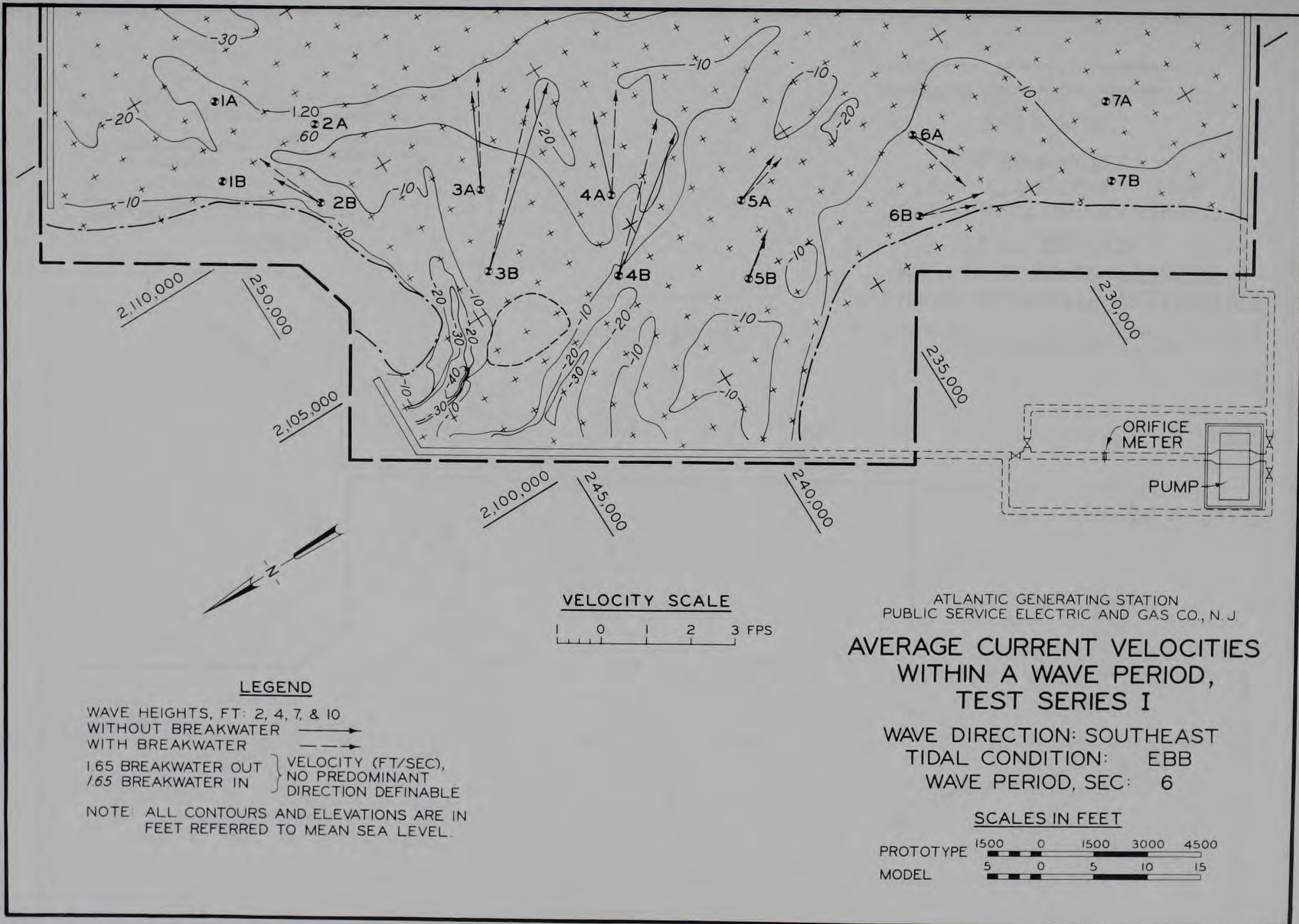
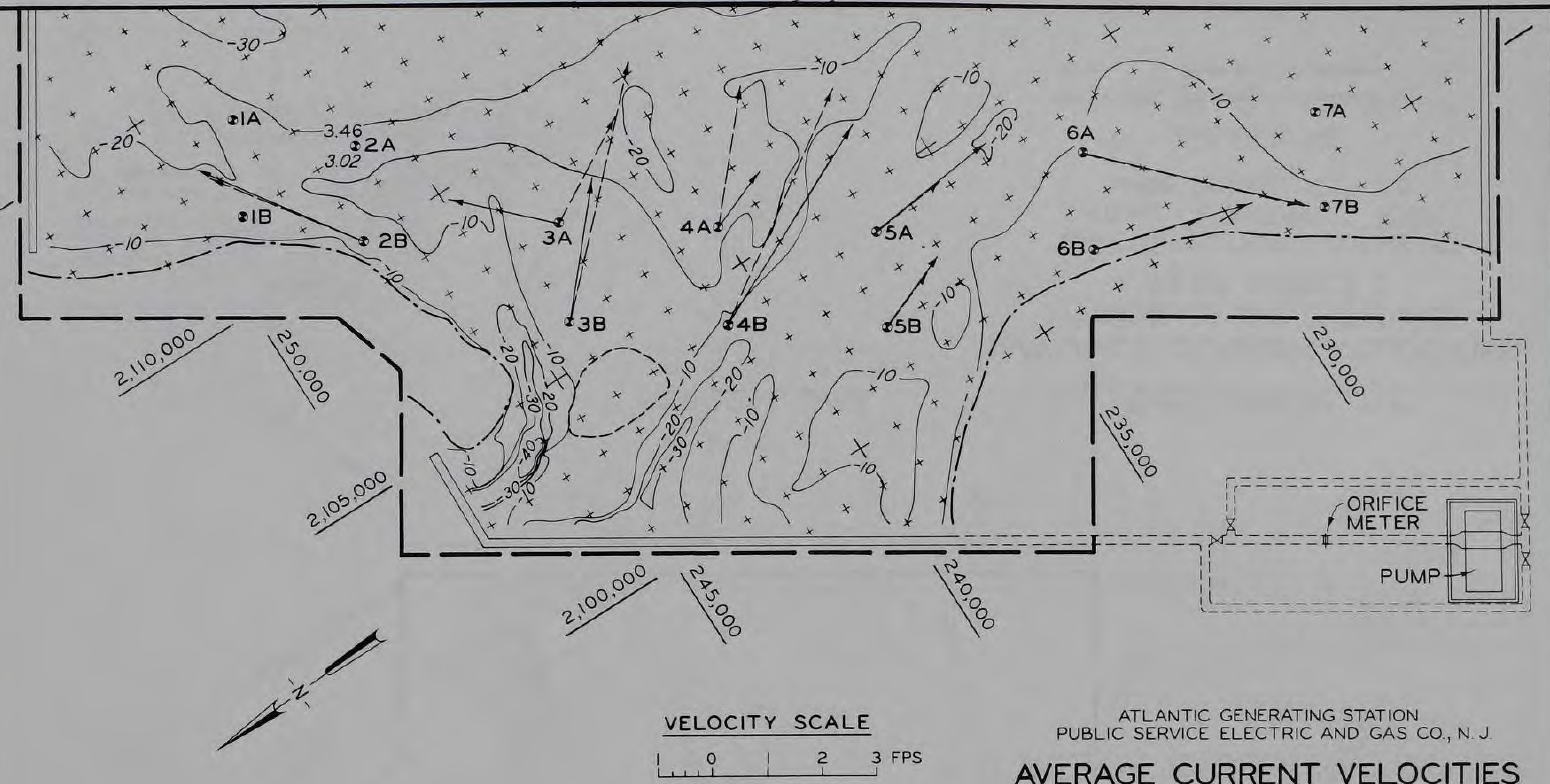

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.
AVERAGE CURRENT VELOCITIES
WITHIN A WAVE PERIOD,
TEST SERIES I
WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 6
SCALES IN FEET
PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15
VELOCITY SCALE
1 0 1 2 3 FPS
LEGEND
WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER
WITH BREAKWATER
1.65 BREAKWATER OUT
1.65 BREAKWATER IN
VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE
NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.
ORIFICE METER
PUMP
N
1A
1B
2A
2B
3A
3B
4A
4B
5A
5B
6A
6B
7A
7B
1.20
.60
2,110,000
2,105,000
2,100,000
250,000
245,000
240,000
235,000
230,000

PLATE 39

PLATE 40



ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 10

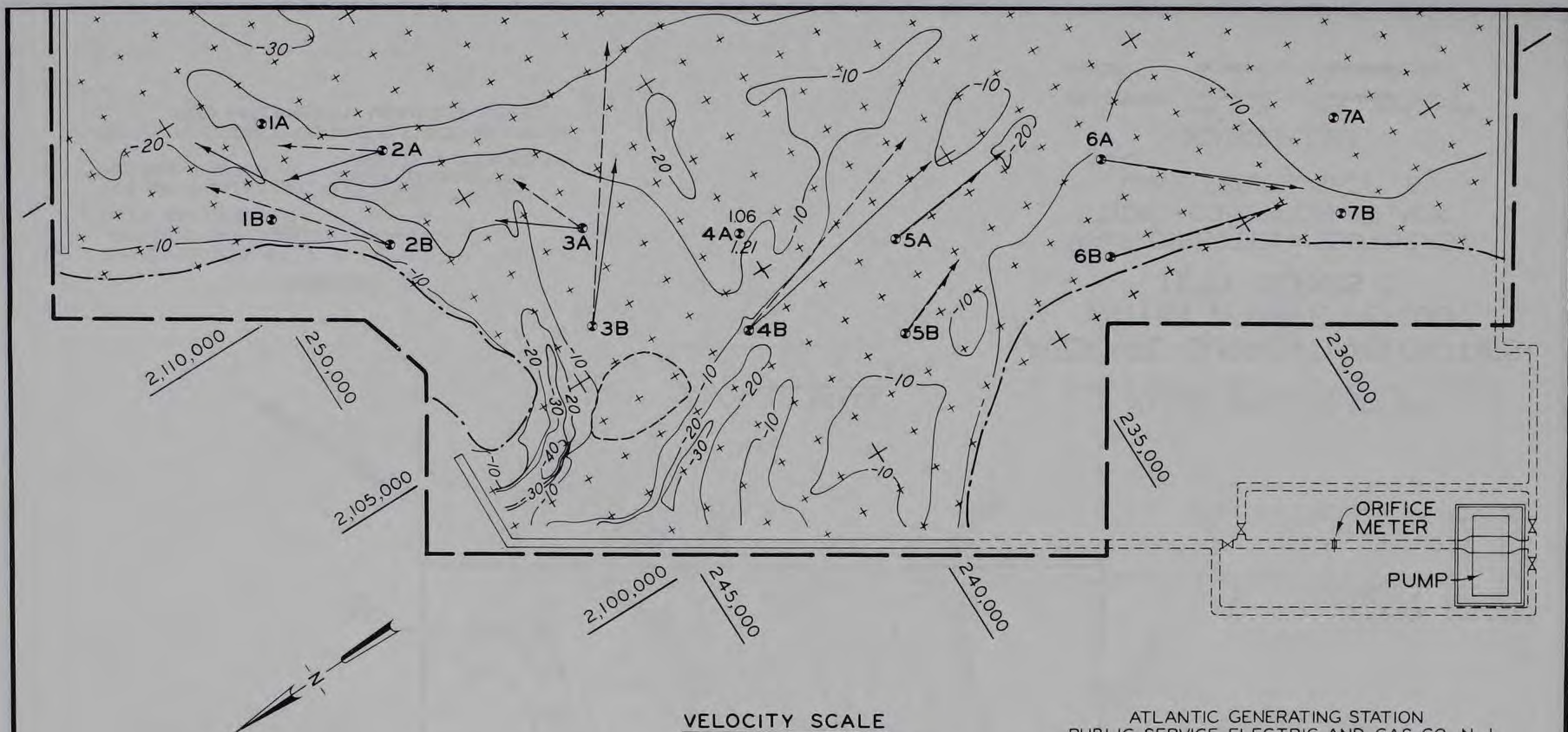
SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →
1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 14

LEGEND

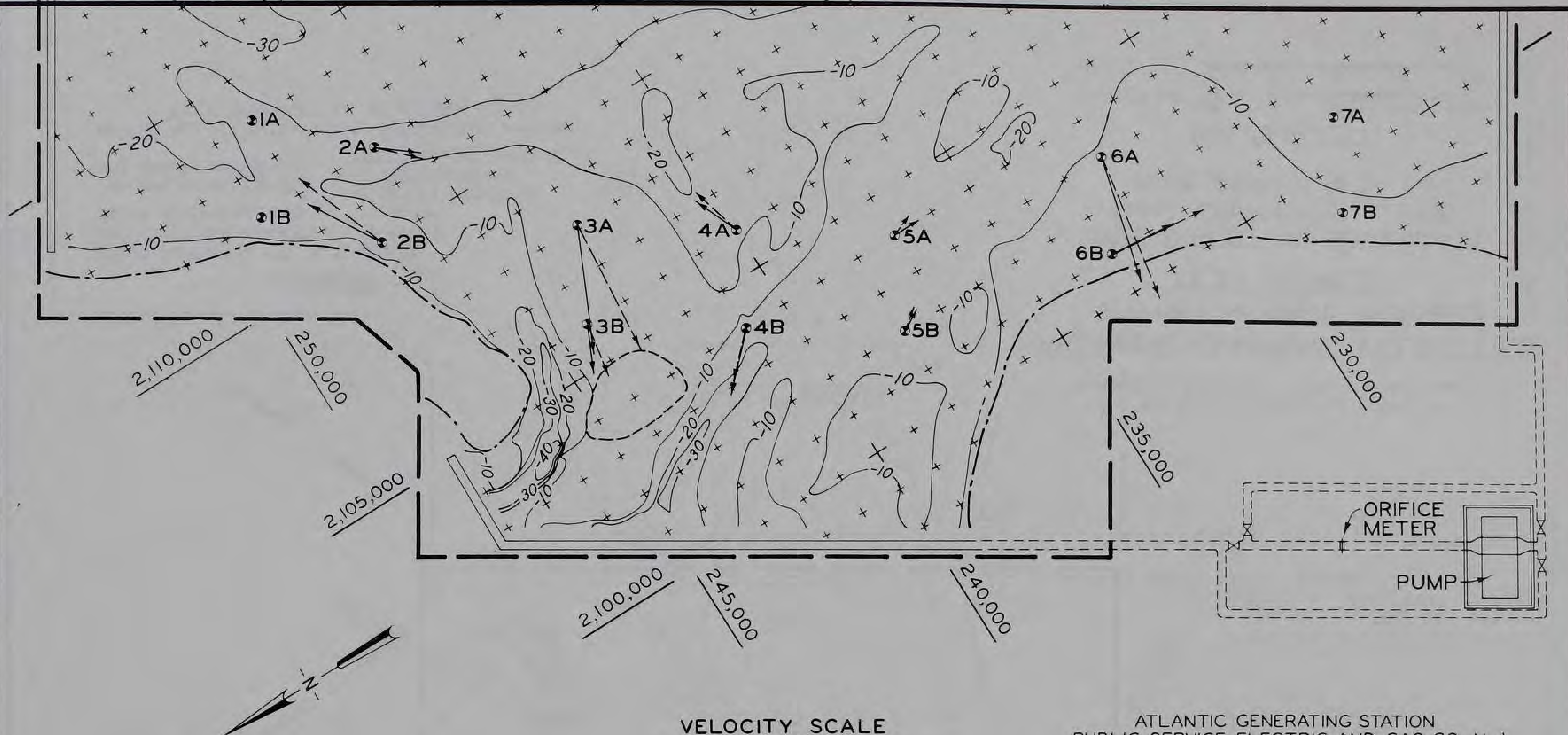
WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

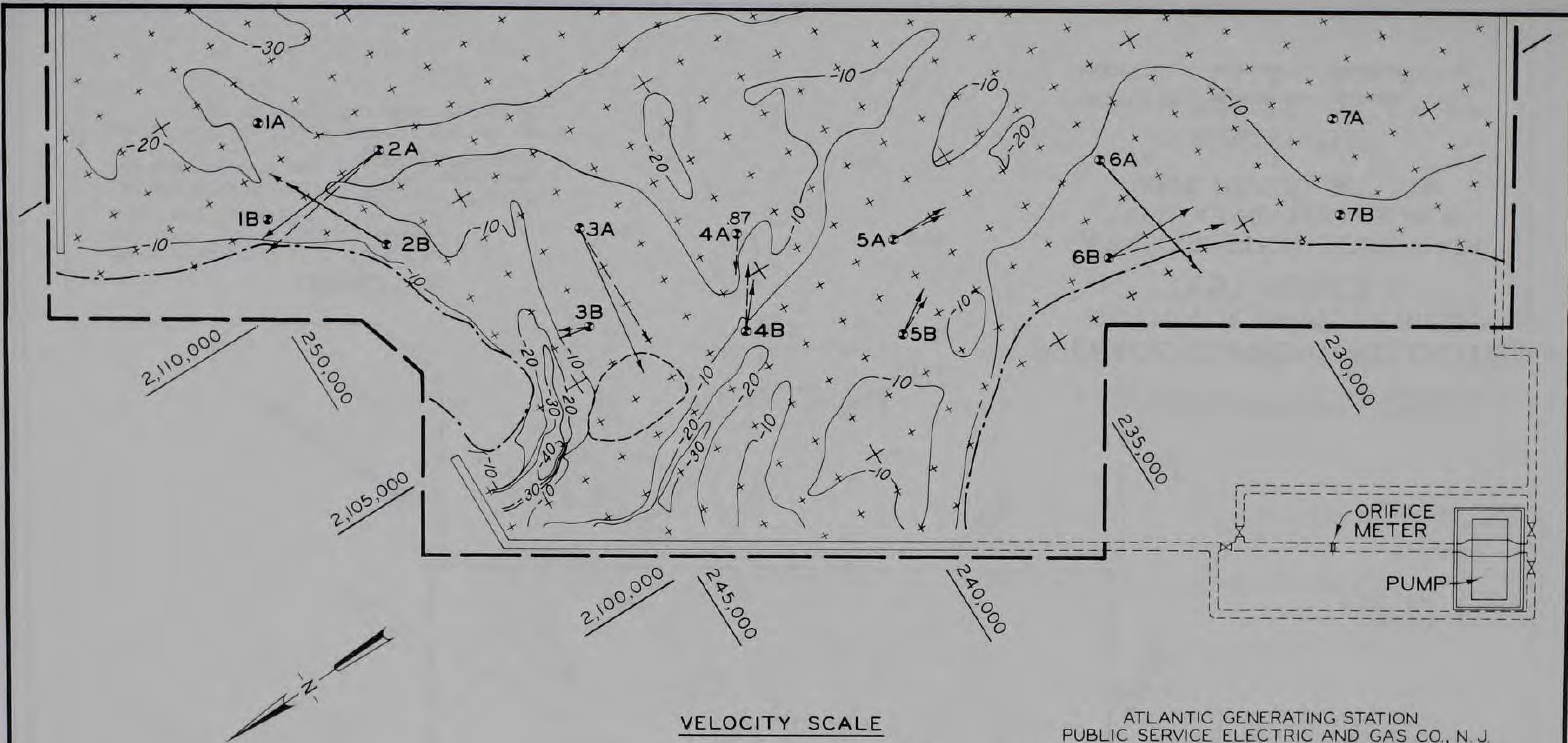
AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 6

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500

MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

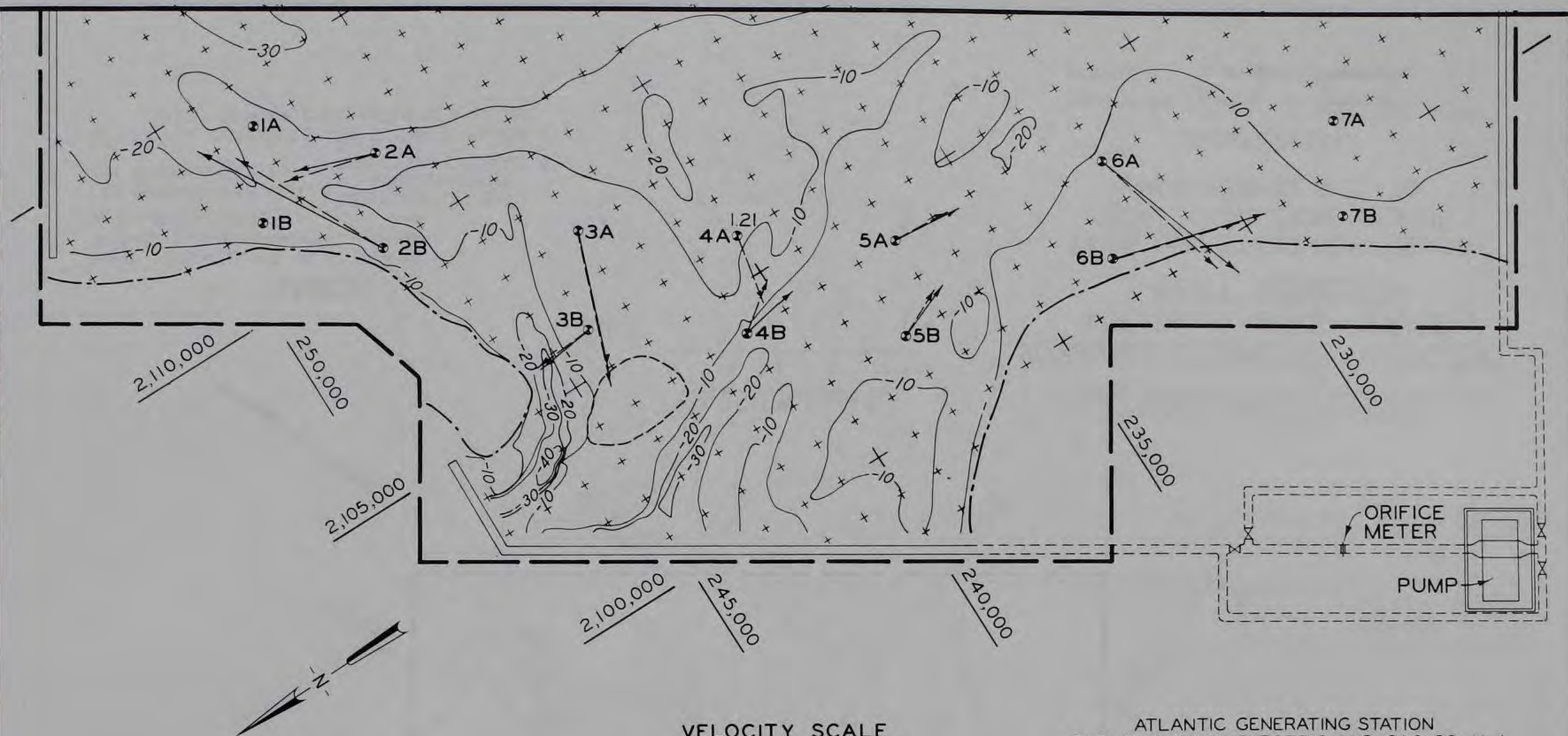
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 10

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →
1.65 BREAKWATER OUT
1.65 BREAKWATER IN } VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

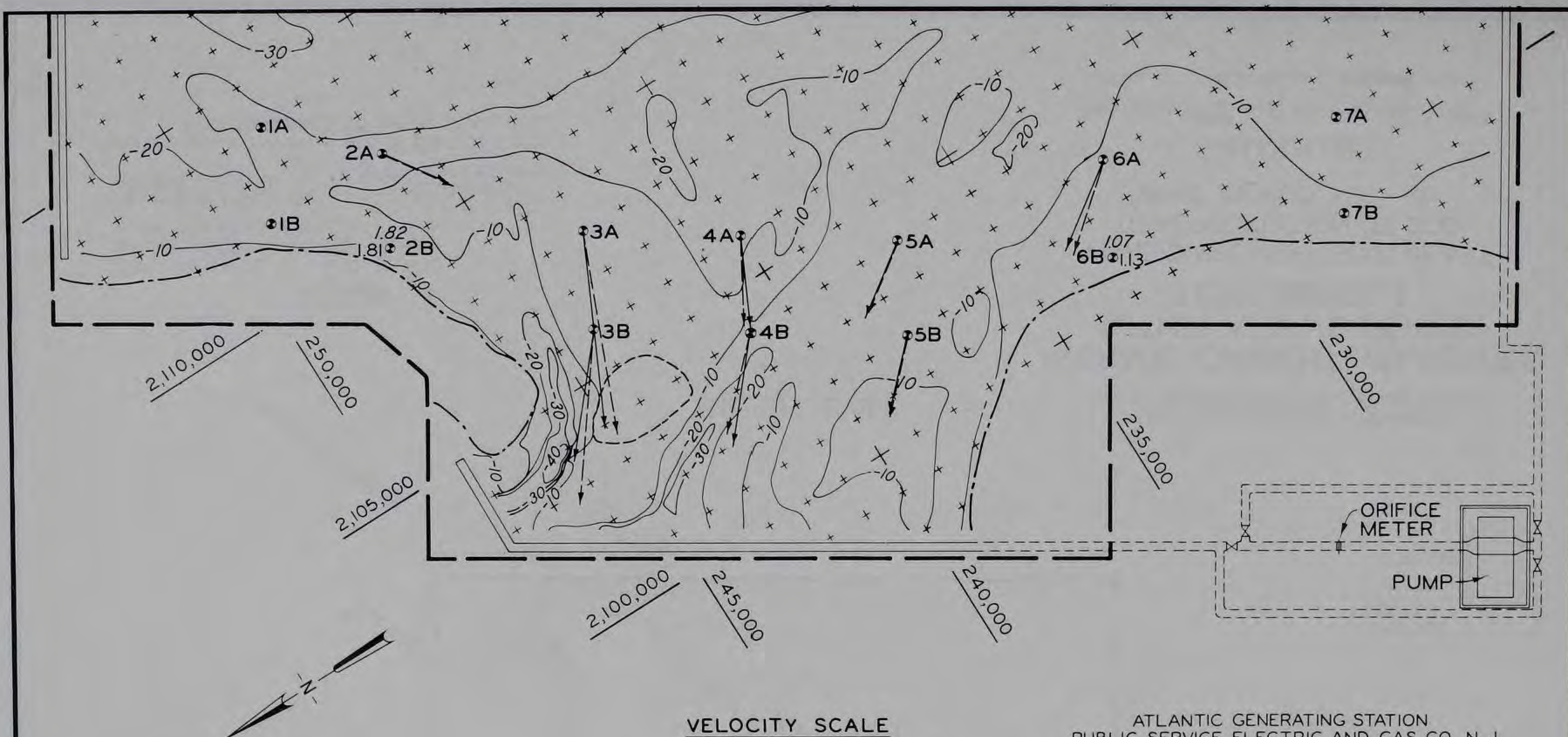
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 14

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ————→
WITH BREAKWATER — — —→

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

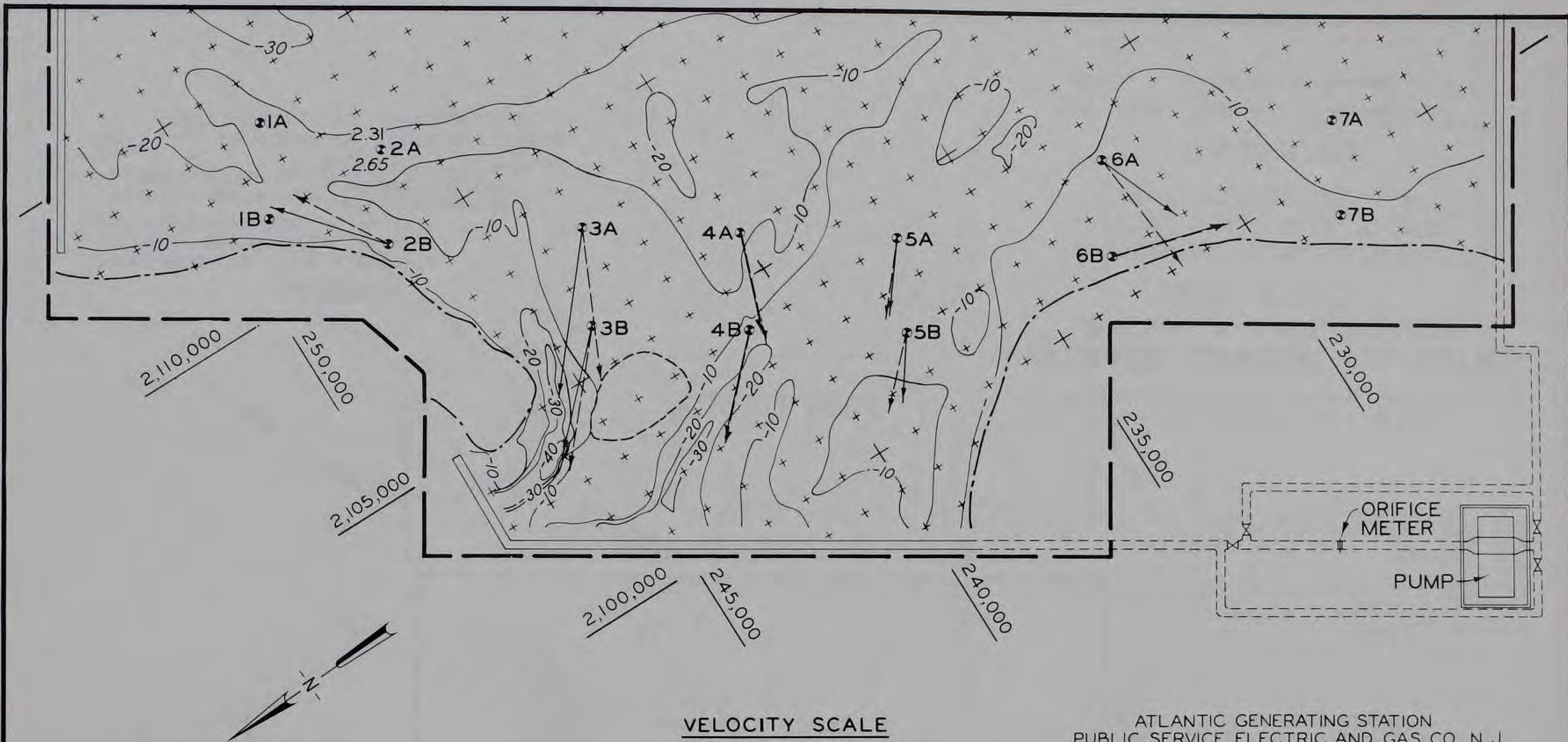
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 6

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

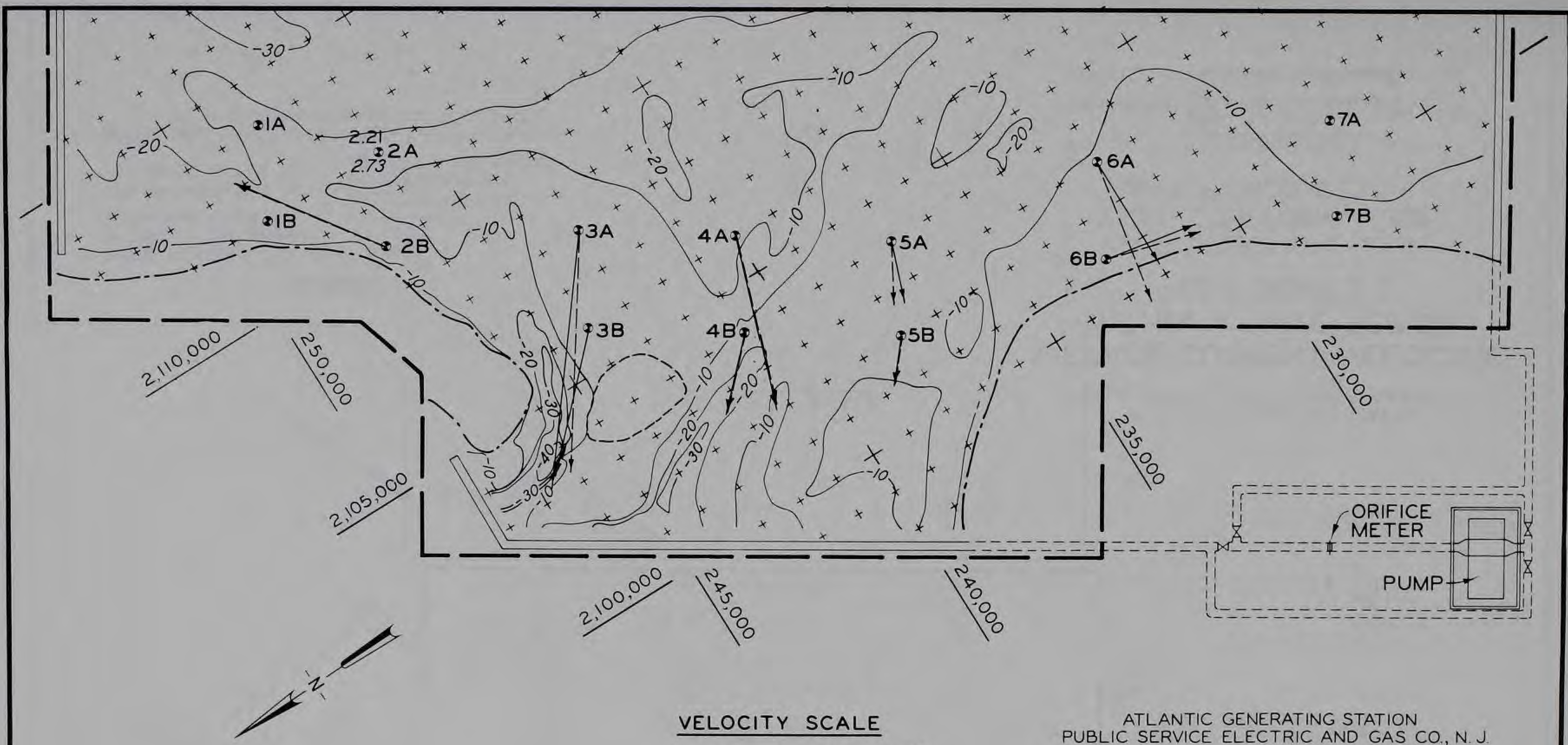
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 10

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →
1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

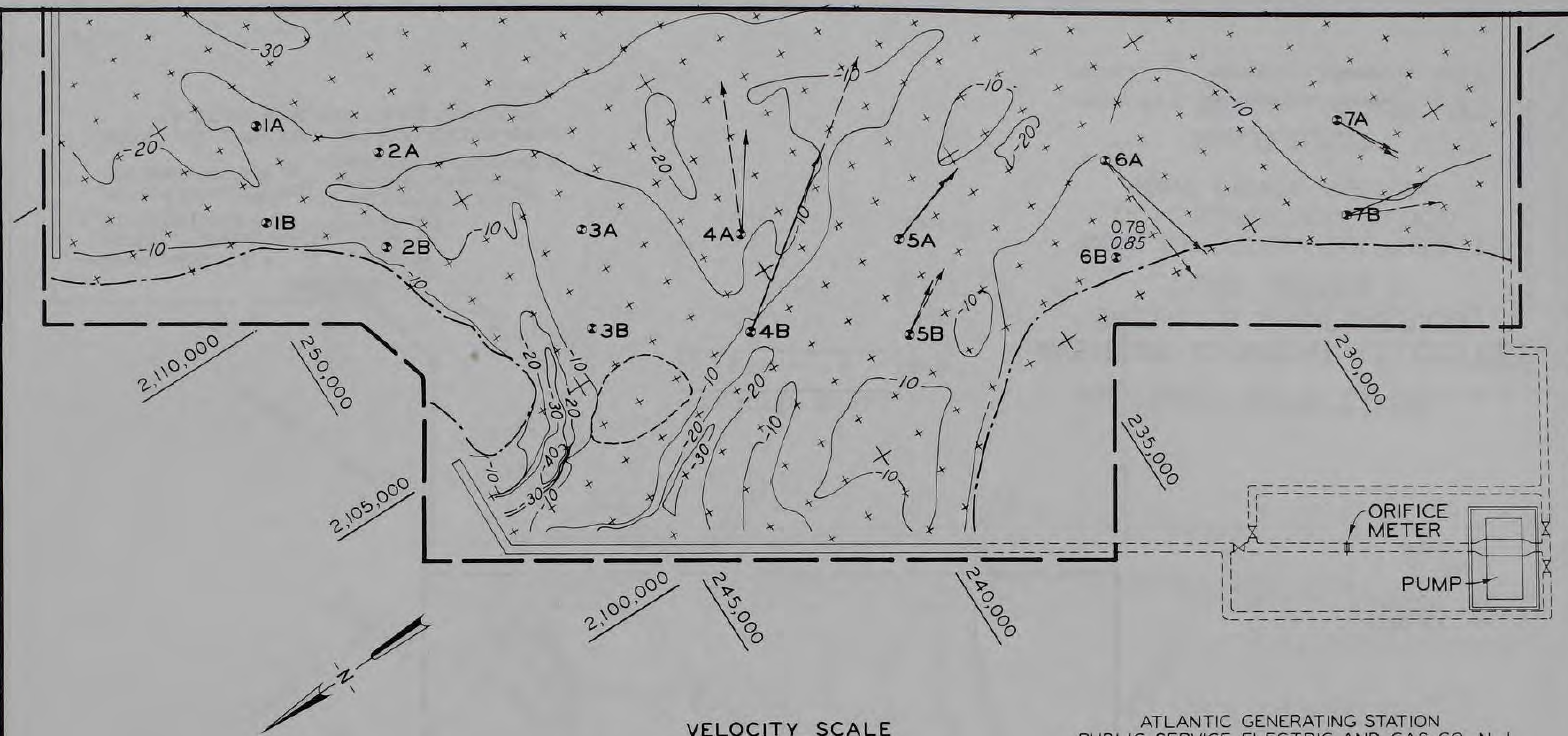
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: SOUTHEAST
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 14

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT } VELOCITY (FT/SEC),
1.65 BREAKWATER IN } NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

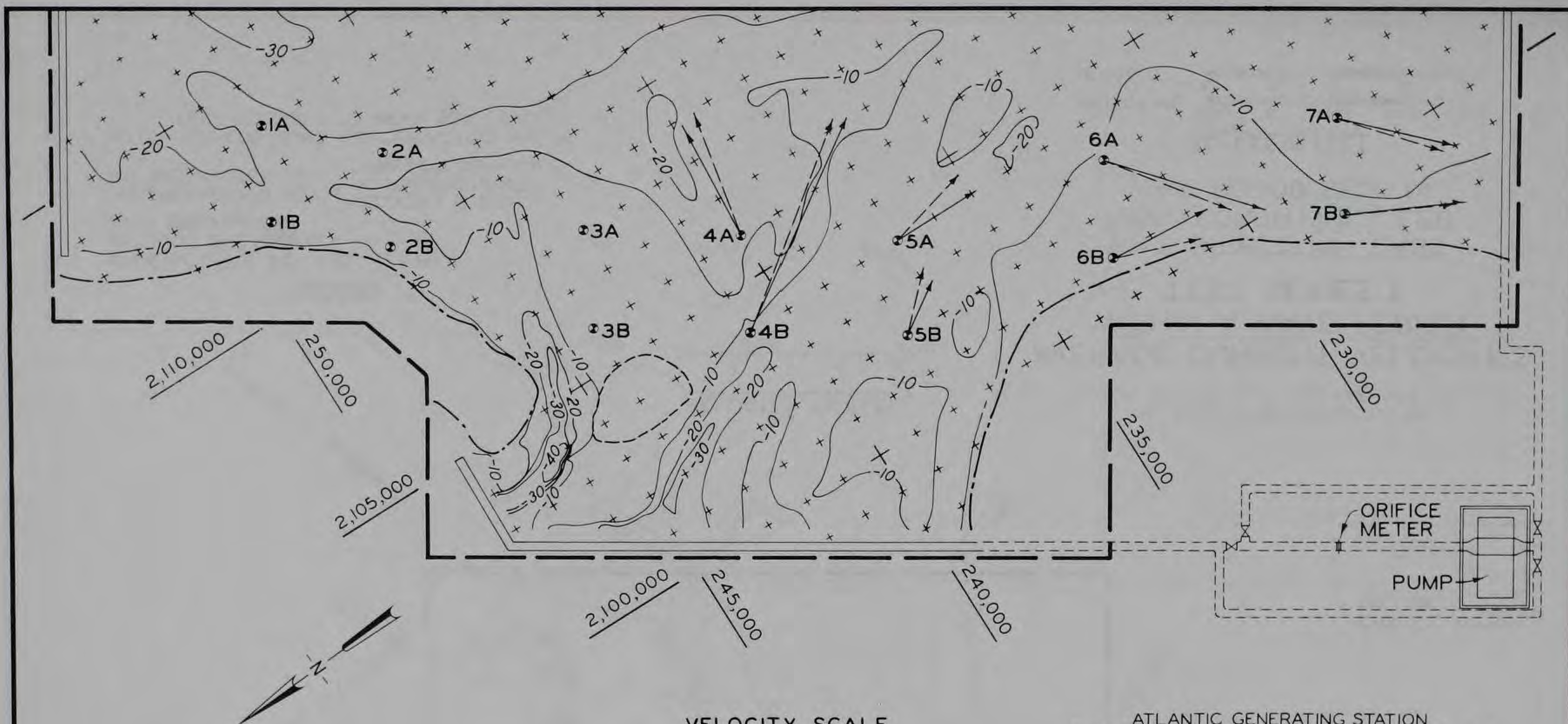
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 6

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18

WITHOUT BREAKWATER ———→

WITH BREAKWATER — — →

1.65 BREAKWATER OUT, *1.65* BREAKWATER IN } VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

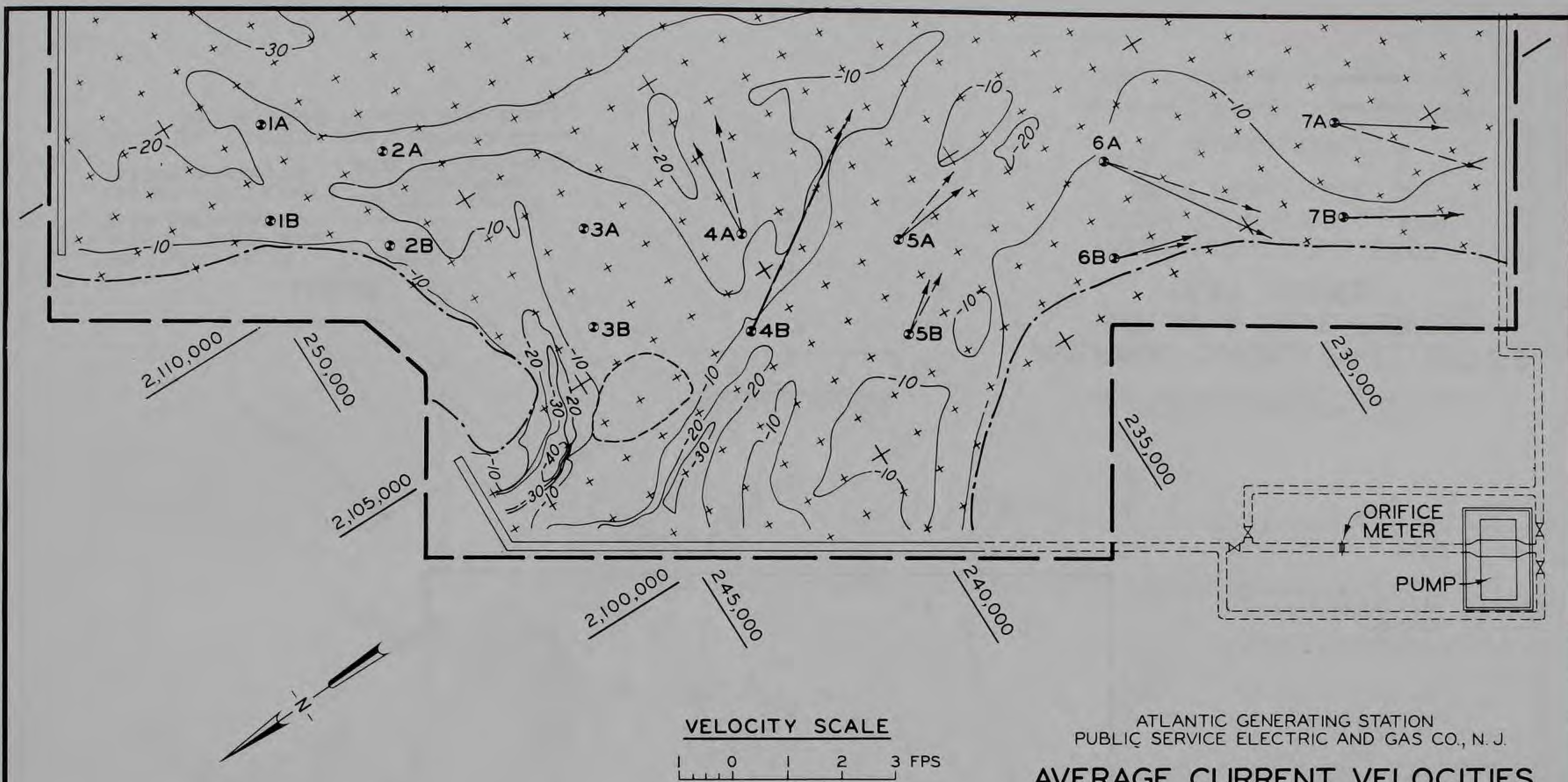
AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 10

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500

MODEL 5 0 5 10 15



LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

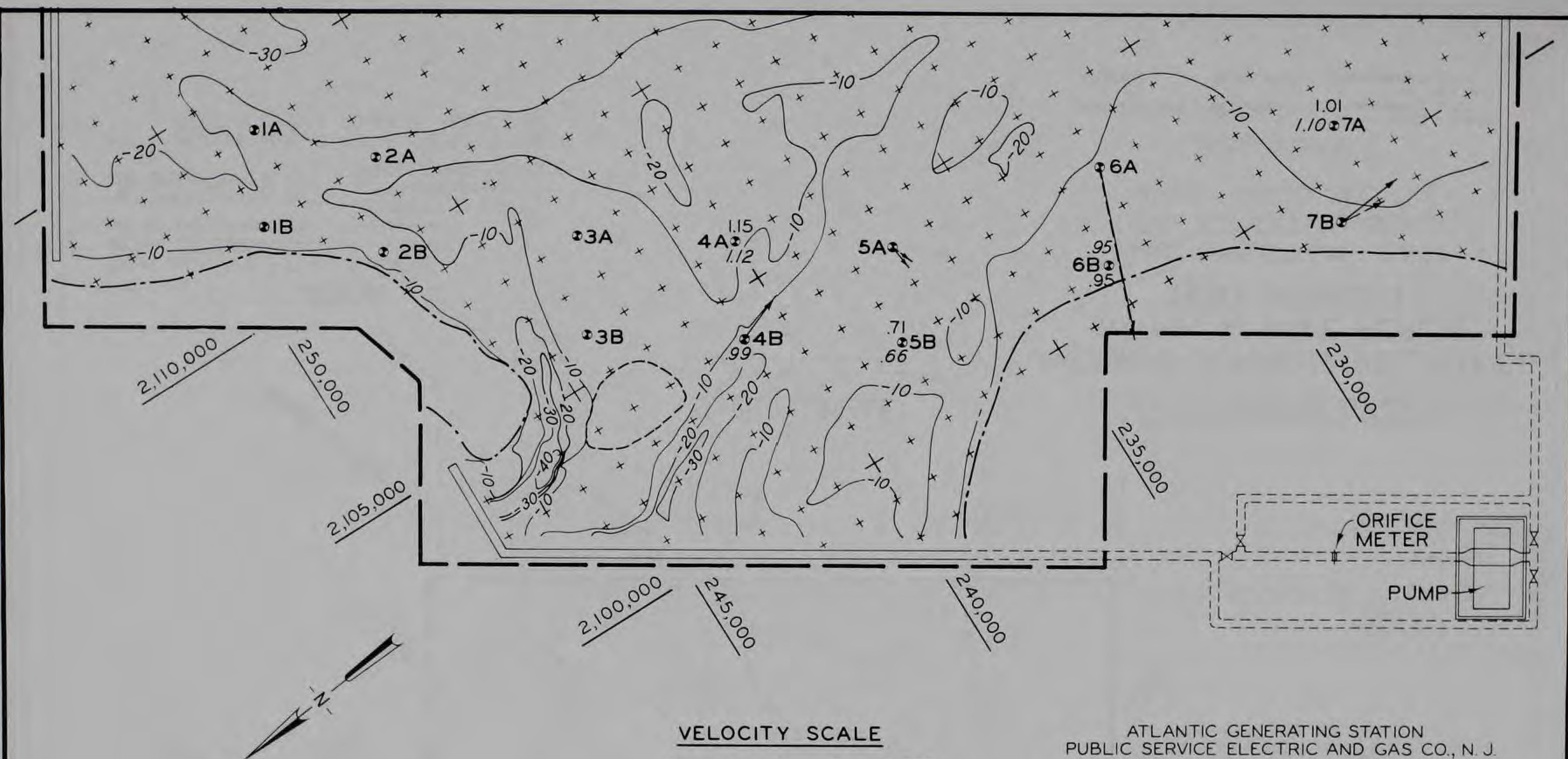
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: EBB
WAVE PERIOD, SEC: 14

SCALES IN FEET

PROTOTYPE	1500	0	1500	3000	4500
MODEL	5	0	5	10	15



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 6

LEGEND

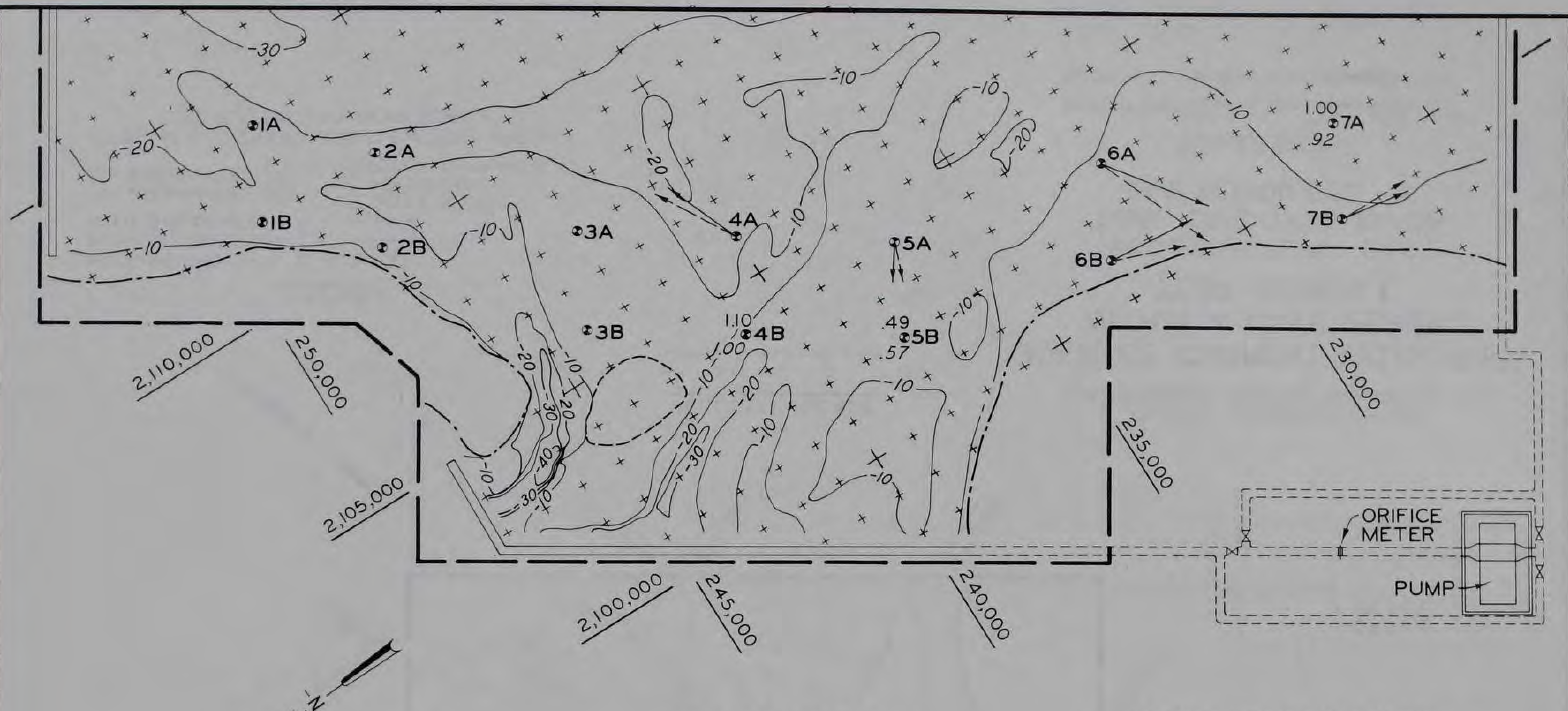
WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — —→

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

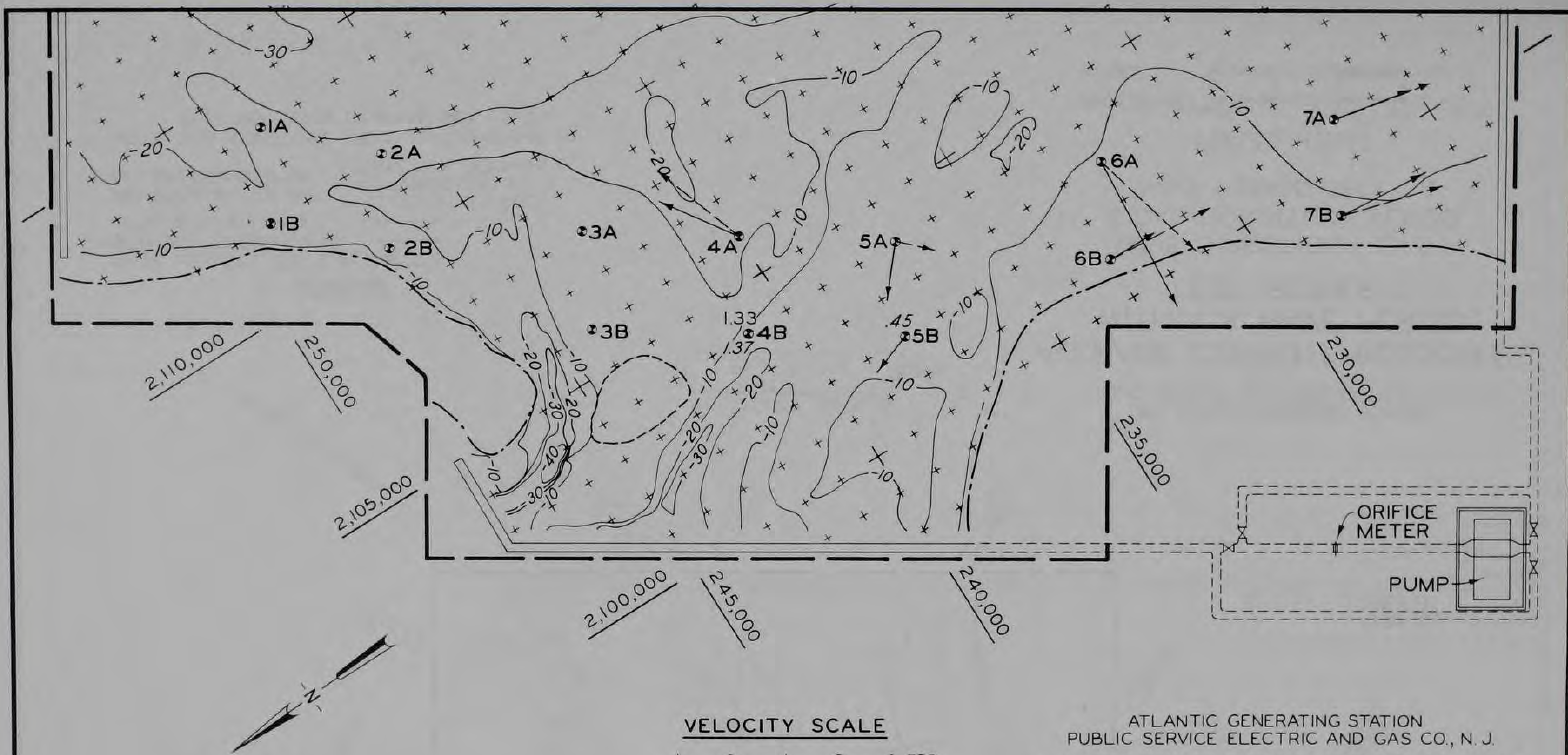
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 10

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: SLACK
WAVE PERIOD, SEC: 14

SCALES IN FEET

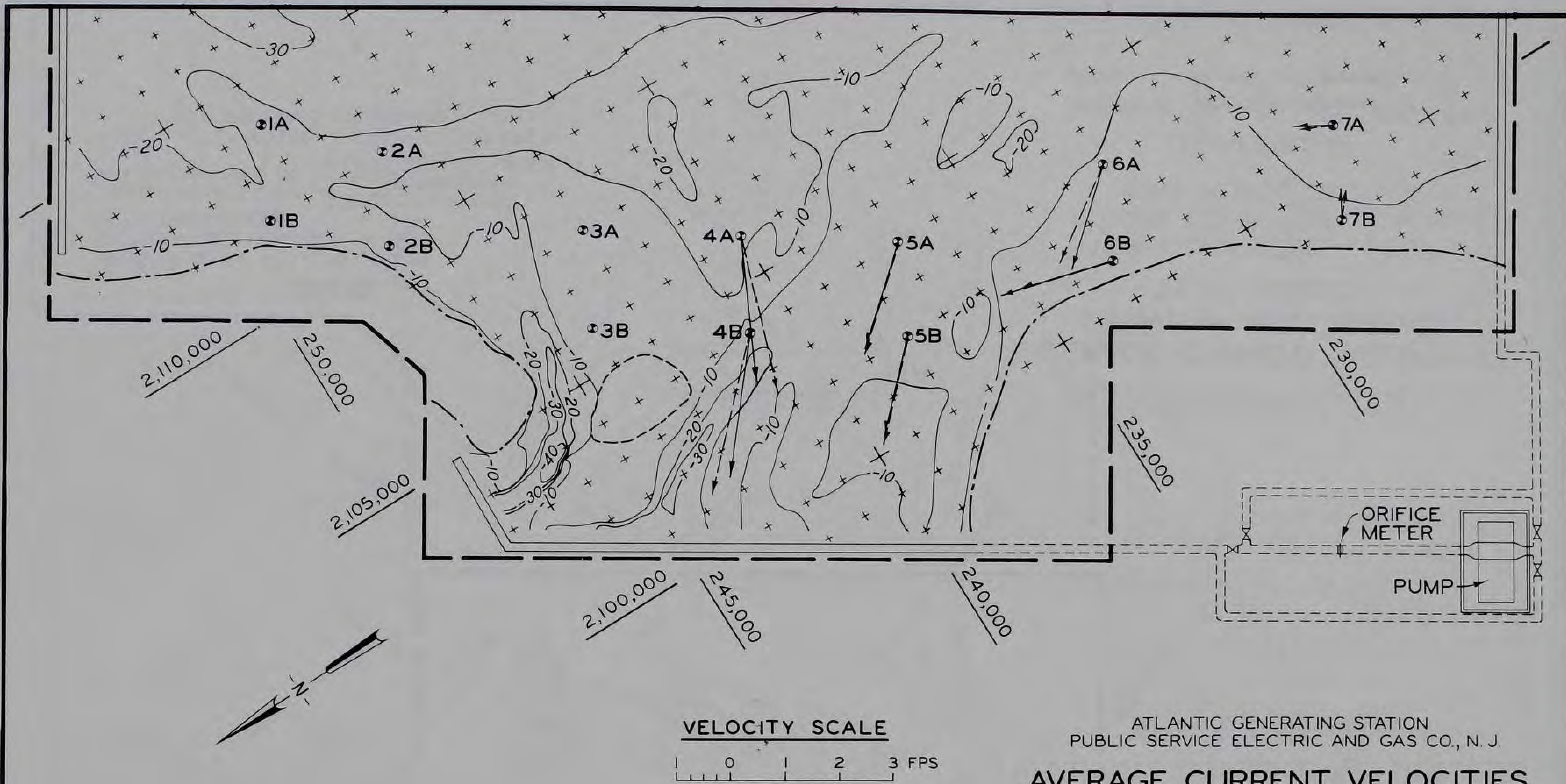
PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT }
1.65 BREAKWATER IN } VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.



ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 6

SCALES IN FEET

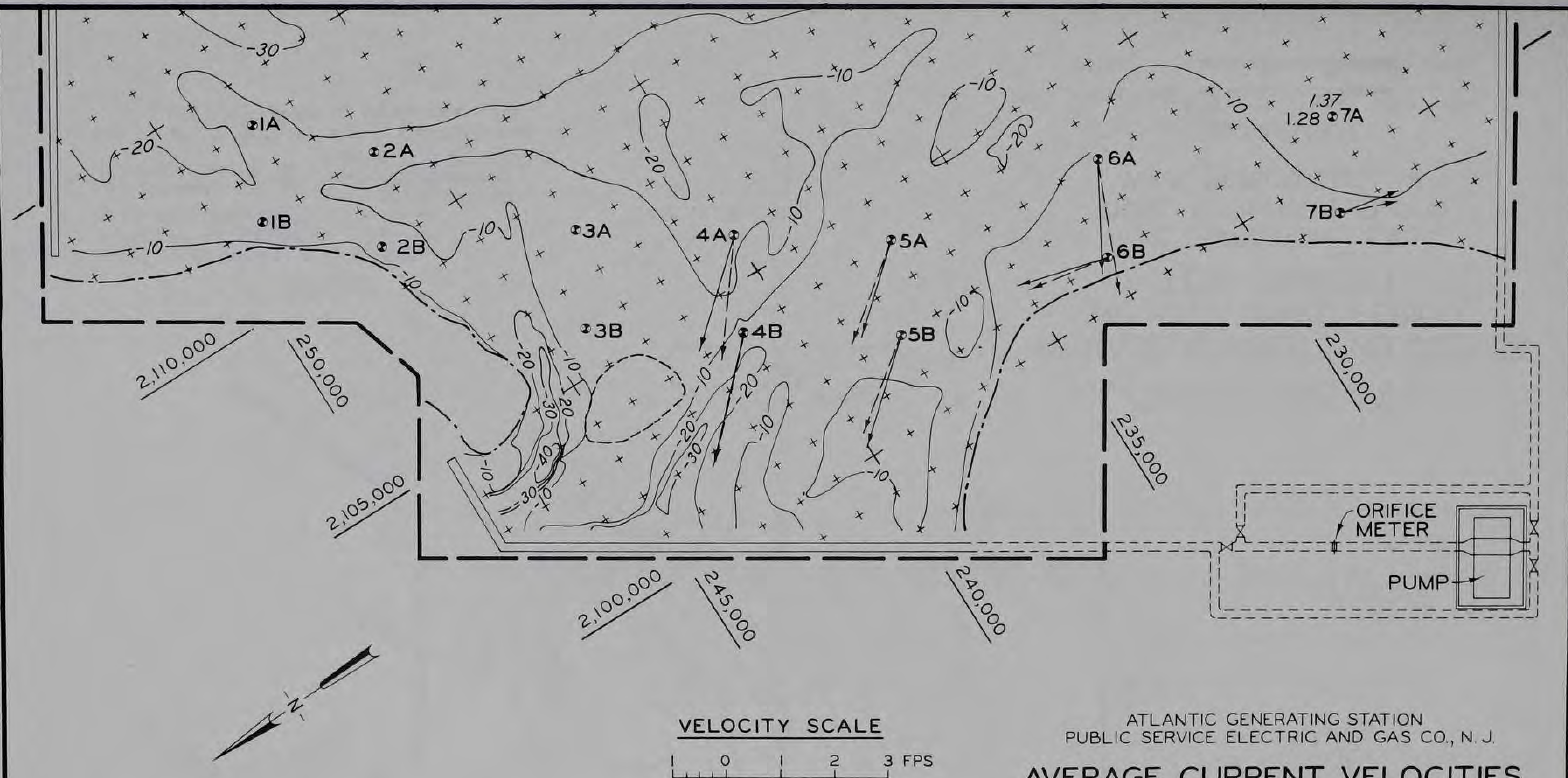
PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15

LEGEND

WAVE HEIGHTS, FT: 2, 4, 7, & 10
WITHOUT BREAKWATER ————→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.



LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ——→
WITH BREAKWATER — — →
1.65 BREAKWATER OUT
1.65 BREAKWATER IN
} VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

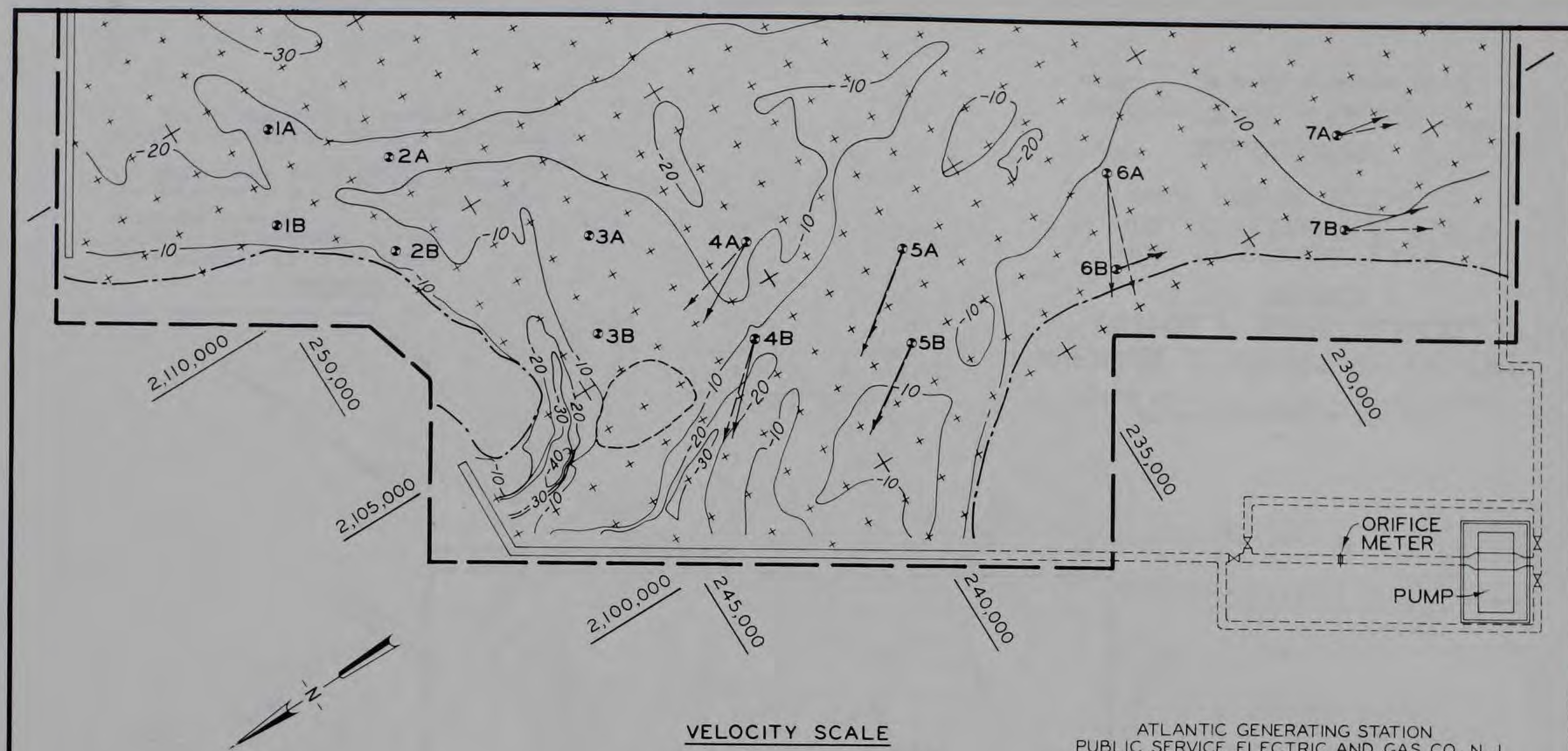
ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 10

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15



VELOCITY SCALE

1 0 1 2 3 FPS

LEGEND

WAVE HEIGHTS, FT: 4, 10, 14, & 18
WITHOUT BREAKWATER ———→
WITH BREAKWATER — — →

1.65 BREAKWATER OUT
1.65 BREAKWATER IN } VELOCITY (FT/SEC), NO PREDOMINANT DIRECTION DEFINABLE

NOTE: ALL CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

ATLANTIC GENERATING STATION
PUBLIC SERVICE ELECTRIC AND GAS CO., N. J.

AVERAGE CURRENT VELOCITIES WITHIN A WAVE PERIOD, TEST SERIES I

WAVE DIRECTION: EAST
TIDAL CONDITION: FLOOD
WAVE PERIOD, SEC: 14

SCALES IN FEET

PROTOTYPE 1500 0 1500 3000 4500
MODEL 5 0 5 10 15

APPENDIX A: BEACH HAVEN-LITTLE EGG INLET MORPHOLOGY STUDY

Historical Inlet Changes

1. A crude British map published in 1769 (Figure A1) shows Beach Haven and Little Egg Inlets as a single opening, "Little Egg Harbour," in the barrier island adjacent to the mouth of the "Mullicus River."[11*] The inlet separated "Old Barnigate Beach" (now Long Beach Island) and "Barnigate Inlet" to the north from "Mikannow Shoal" and "Brigantine Inlet" to the south. Mikannow Shoal was breached in 1800 and the subsequent new channel called "New Inlet." The two resulting islands were renamed, the northern to "Tucker's Island" and the southern to "Little Beach." The single original entrance, Little Egg Harbour, also was renamed, and became "Old Inlet." Plusquellac[11] suggests that the opening of New Inlet compensated for a reduction of tidal flow into "Flat Bay," the area now occupied by both Little Egg Harbour and Great Bay, caused both by a pre-1800 closing of Brigantine Inlet and choking of Old Inlet by southerly spit growth at the tip of Old Barnigate Beach.

2. The first detailed map of the area was published in 1840. Geomorphic changes between then and 1932, outlined in Shepard and Wanless,[12] are reproduced herein (Figure A2). Configurational changes of shorelines and tidal deltas have been so extensive and complex that the inlet history is best understood by an analysis of smaller areas. Consider first the vicinity of Old Inlet near the southern end of Long Beach Island (Old Barnigate Beach). Between 1840 and 1885, the tip of Long Beach migrated approximately 3 miles southward, overlapping the seaward edge of Tucker Island, and in effect eliminating Old Inlet (Figure A2a-c). During the same time, Tucker Island had lost half of its 2-mile length, such that its southern tip lay adjacent to the tip of Long Beach. By 1885, Long Beach and Tucker Island had welded together and extended an additional mile southward. This spit growth continued until sometime after the 1904 survey when, sometime prior to 1932, Long Beach Island was breached near the site of the original Old Inlet (d in

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* Raised numbers refer to similarly numbered items in "References" at end of main text.

Figure A1. Ratzer's map of southeastern New Jersey in 1769 (from Plusquellac[11])

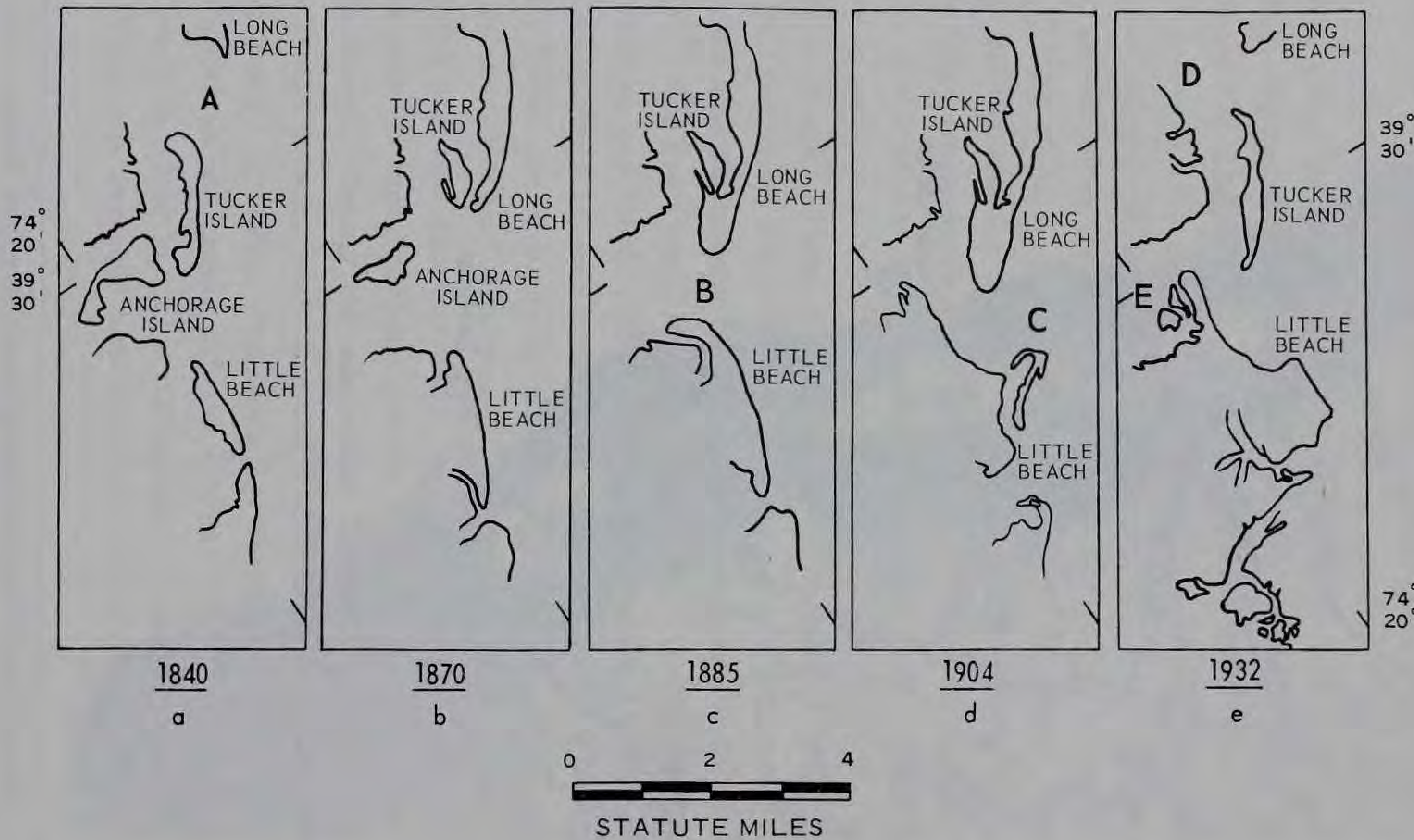


Figure A2. Morphological changes at Beach Haven-Little Egg Inlets, 1840-1932 (after Shepard and Wanless[12])

Figure A2e). Tucker Island was thereby reestablished by the new Beach Haven Inlet, although its seaward shoreline was approximately 0.5 mile west of the welded Long Beach-Tucker Island shoreline. The southerly longshore transport sediment supply was cut off by the opening of Beach Haven Inlet and by 1940 the Tucker Island area had eroded to a little more than 0.5 mile in length (A in Figure A3). Tucker Island had nearly disappeared by 1950[12] as longshore transport being delivered to the area was deposited primarily on the tip of the lengthening Long Beach and on a flood-tidal delta in the southern end of Little Egg Harbor.

3. By 1962, although Tucker Island had been eroded completely away, Long Beach had accreted to nearly the position previously occupied by the island (Figure A4). The Ash Wednesday storm of March 1962 created considerable overwash on the southern end of Long Beach and caused a slight shortening of the spit but did not breach the island. The spit had continued to grow and was associated with a small proximal ebb-tidal delta (A in Figure A4). Although flood-tidal delta configurations had changed considerably, the overall size of the Beach Haven Inlet flood-tidal delta had remained essentially constant since 1940.

4. Photographs taken in 1965 reveal a major redistribution of sediments at Beach Haven Inlet; the large recurved spit evident in the 1962 photographs had completely disappeared (Figure A5). At least part of this material undoubtedly contributed to substantial ebb-tidal delta growth (A in Figure A5), as well as to accretion on the long channel-margin shoal just inside the inlet. The smaller, more seaward spit, visible only as a slight bulge in the 1962 photograph, had by 1965 lengthened and begun to recurve to the position of the 1962 spit. Spit growth continued to 1973 and was accompanied by an apparent decrease in the volume of material on the flood-tidal delta (Figure A6).

5. Since the opening of New Inlet about 1800, Little Beach (the area between New Inlet and Brigantine Inlet) has exhibited significant accretion and associated configurational changes. Between 1840 and 1885, the north end of Little Beach occupied approximately the same position. The two islands shown on the 1840 survey were welded together and capped with a northeastward-growing recurved spit (Figure A2). By 1904 Little

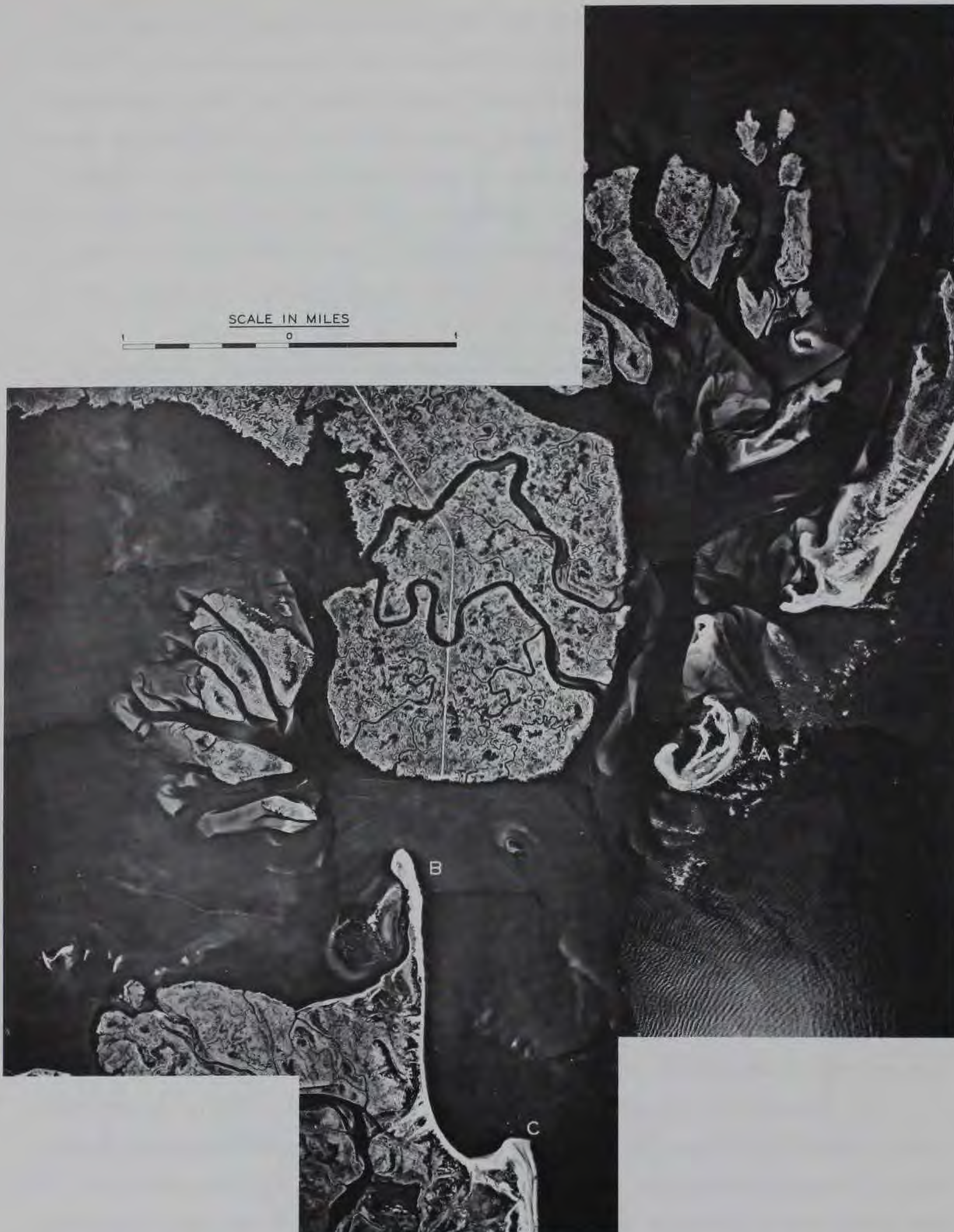


Figure A3. Coastal morphology of Beach Haven-Little Egg Inlets in April 1940 (photography by Aero Service Corp., Philadelphia, Pa.)

Figure A4. Coastal morphology of Beach Haven-Little Egg Inlets in January 1962; notice ice cover in marsh areas (photography by Aero Service Corp., Philadelphia, Pa.)

Figure A5. Coastal morphology of Beach Haven-Little Egg Inlets in April 1965 (photography by Aero Service Corp., Philadelphia, Pa.)

Figure A6. Coastal morphology of Beach Haven-Little Egg Inlets in March 1973 (photography by NASA)

Beach had continued its northward growth (B in Figure A2c). The shoreline was reoriented considerably, exhibiting a seaward concavity, the trend of which was truncated by a large offshore bar (C in Figure A2d). Northeastward progradation continued; by 1932, the 1904 offshore bar was incorporated into the main beach, and two islands had formed behind the beach's northern end.

6. Morphologic changes of Little Beach since 1932 have mostly been consumed in northward spit growth along two fronts. The northernmost spit (B in Figure A3) lengthened and by 1950 had curved around the two marsh islands. The southern spit (C in Figure A3) grew approximately 1 mile to the north by 1950, and by recurving to the west, created a small embayment.[12] The embayment-enclosing spit continued its northward accretion, and in 1962 had reached the same latitude as the original northward spit, which, along with the associated two marsh islands, had nearly disappeared (Figure A4). The embayment was fed by a small inlet with an associated flood-tidal delta (B in Figure A5).

7. Little Beach has continued to reflect localized northward longshore transport. By 1973 the embayment behind the Little Beach spit had been extensively modified both by addition of sand to the small embayment flood-tidal delta and by continued northward spit growth (Figure A6). Shoreline concavity had been eliminated and the beach became essentially two-linear elements. In addition, the ebb-tidal delta system appears to have been better developed.

Present Processes

Tides

8. New Jersey tides are semidiurnal with little diurnal inequality. The accepted mean tidal heights are based on a 19-yr period (1924-1942) of observations at the Atlantic City Steel Pier.[13] Referred to ocean mean low water (mlw), the mean tidal heights are: mean high water (mhw), 4.08 ft; msl, 2.06 ft. Normally tide range varies from 3.2 ft (neap) to 5.0 ft (spring), with a mean tide range of 4.1 ft. Tidal durations, referred to lower and upper transits of the moon at Greenwich, are 6.12 hr (low water) and 12.24 hr (high water).[14] Mean

sea level has been increasing in the study area since at least 1912 by 0.014 ft/yr, and since 1953 at a possibly even greater rate.[13]

Winds

9. Prevailing winds are from the south and west and of moderate speed (14-28 mph), although northeast winds have the greatest average velocity (19-20 mph). For speeds greater than 28 mph, northeast winds are more than twice as frequent as winds from any other direction.[13] Prevailing winds are generally southerly from April to September, and westerly to northwesterly during the rest of the year. High-velocity northeast winds usually occur in August through October.

Waves

10. In addition to the study of Glenn,[8] deepwater wave hindcasting was done by Saville[15] and Neumann and James[16] for Atlantic Coast locations that bracket the study area. The highest waves approach from the east-northeast. Fewer than one percent of the deepwater waves approach from counterclockwise of north-northeast; fewer than one percent approach from clockwise of south-southwest.[17] Because Long Island, New York, provides a sheltering effect from northeast waves along the northern New Jersey coast, the area south of the Barnegat Inlet vicinity is relatively more affected by northeasterly waves than is northern New Jersey. This results in a net southerly longshore transport for southern New Jersey.[14,18]

11. Wave observations in 1935-1957 at Atlantic City and Brigantine indicate a median wave height of 1.9 ft, and a maximum of 12.8 ft.[19] Median wavelength was 105 ft (maximum 312 ft); median wave speed was 14.7 fps (maximum 25 fps). Only 6 percent of the waves observed approached normal to the beach; 61 percent approached from the north, and 33 percent from the south. Observations made from 1955-1959[20] are summarized in Reference 21. In general, the frequency of occurrence of high, short-period storm waves increased to a maximum in early autumn. Breakers approached from the southeast (nearly normal to the shoreline) 60.7 percent of the time, and from the northeast 16.8 percent of the time. Charlesworth[21] also reports on wave observations made at Atlantic City by the Coastal Engineering Research Center from 1960 to 1965; the

mean significant wave height was 3.05 ft.

Storms

12. Hurricanes and extratropical storms are frequent in southern New Jersey. The Corps of Engineers[13] lists 18 severe storms that significantly affected the area between 1933 and 1964. Increased wave heights and higher tides often associated with these storms may cause significant changes in the normal sedimentary processes and the resultant coastal geomorphology. Storm waves may reach heights of 12 ft once a year; during the Ash Wednesday storm of March 1962, 15-ft wave heights were recorded at the Atlantic City Steel Pier.

Currents

13. In 1936 and 1937 nontidal longshore currents averaged 0.22 fps southwest (downcoast). During this time westerly winds prevailed (19.2 percent of the time; average speed, 16.4 mph), but the predominant winds were northeasterly (14.7 percent at an average of 17.7 mph). Greaser and Wicker[19] suggested that during an "average" year, longshore currents are most likely to flow downcoast at an average speed of 0.3 fps, as opposed to an average upcoast speed of 0.2 fps. Maximum expected speeds are 4.5 fps upcoast and 0.8 fps downcoast. A downcoast speed of 5 fps occurred during the 66-mph winds of the November 1935 storm, which generated 12.5-ft waves and caused tides 3.6 ft above those predicted.

14. Beach Haven-Little Egg Inlet tidal current velocities have been documented by Charlesworth[21] in his study of local sedimentary processes. Four current stations were occupied, and velocity versus depth was plotted for one tidal cycle. In the throats of both inlets, phase lags between ocean-bay tidal extremes and inlet slack water were essentially 30 deg. For Little Egg Inlet, this value is comparable to that used by Jarrett[22] in computing the repletion coefficient, K ,[23] for the Beach Haven-Little Egg system. Computed phase lags for Beach Haven Inlet,[22] however, were somewhat higher than those measured by Charlesworth.[21] Jarrett's computations place Beach Haven and Little Egg Inlets into two hydraulically distinct classes. Beach Haven Inlet, with longer phase lag and a repletion coefficient (K = 0.31), is associated with open, shallow bays fed by relatively small inlets. In effect,

inlets of this type are less "competent" in transmitting the tidal wave into their adjoining bays. On the other hand, Little Egg Inlet's shorter phase lag and higher repletion coefficient (K = 0.78) make it intermediate between inlets like Beach Haven and inlets feeding deeper, more channelized bays with bay-tidal phase ranges closer to ocean tides.

Longshore transport

15. The net alongshore component of wave energy increases in either direction from a point near Barnegat Inlet,[24] changing from 3.34×10^8 ft-lb/ft/yr southward at Barnegat to 65.29×10^8 ft-lb/ft/yr southward at Cape May. Charlesworth,[21] in a linear interpolation between these two points, suggests that the total net wave energy at Beach Haven-Little Egg Inlet is 24×10^8 ft-lb/ft/yr southward. Estimates of net longshore transport rates in the area vary from 400,000 yd^3/yr south[25] to 50,000 yd^3/yr south.[18]

Process-Response Relationships and Future Changes

16. The Beach Haven-Little Egg Inlet shoal-shoreline configurational history accurately reflects local and regional sedimentologic processes superimposed on the larger scale process of marine transgression. The major geomorphic features of the inlet are the result of an interaction of tidal flow with a regional net southerly longshore transport of sand. These features are modified by local variations caused by wave refraction and current diversion.

17. Since at least 1840, Beach Haven Inlet has undergone a cyclic migration process. As the southern end of Long Beach migrated southward by accretion of littoral drift, the inlet entrance channel was forced to migrate also. Storms eventually opened a shorter, more efficient channel, whether by overwash or lagoonal storm surge, through the comparatively new portion of Long Beach as yet unstabilized by dune vegetation. Remains of resultant cutoff portions of Long Beach have formed the islands and shoals occupying the position of Tucker Island. Although considerable quantities of sand are transported to the flood tidal delta behind the inlet, aerial photographs indicate no long-term net influx.

18. Spit accretion in the Little Beach area reflects a local northward transport probably caused by wave refraction around an often sizeable ebb-tidal delta. The absolute quantity of this accretion is limited both by the ability of the offshore bar to protect the area from direct wave attack, and by the erosive capability of Little Egg Inlet tidal currents, e.g., Figure A2. The concave-outward shoreline of point C reflects significant erosion over the 1885 conditions (Figure A2c). This erosion was in all probability caused by Beach Haven Inlet ebb-tidal currents impinging directly on Little Beach as a result of the channel being forced southward by accretion at the tip of Long Beach. The reopening of a more northern Beach Haven Inlet channel after 1904 and the subsequent elimination of Tucker Island relieved this erosive tendency allowing the progradation by spit development as shown by the 1962 and 1965 photographs (Figures A4 and A5). Similarly, the disappearance of the two marsh islands behind the northern tip of Little Beach spit, although possibly caused by subsidence,[12] is due more probably to erosion by Little Egg Inlet ebb-tidal currents.

19. Shepard and Wanless[12] suggest three possibilities for future geomorphic developments of the inlets:

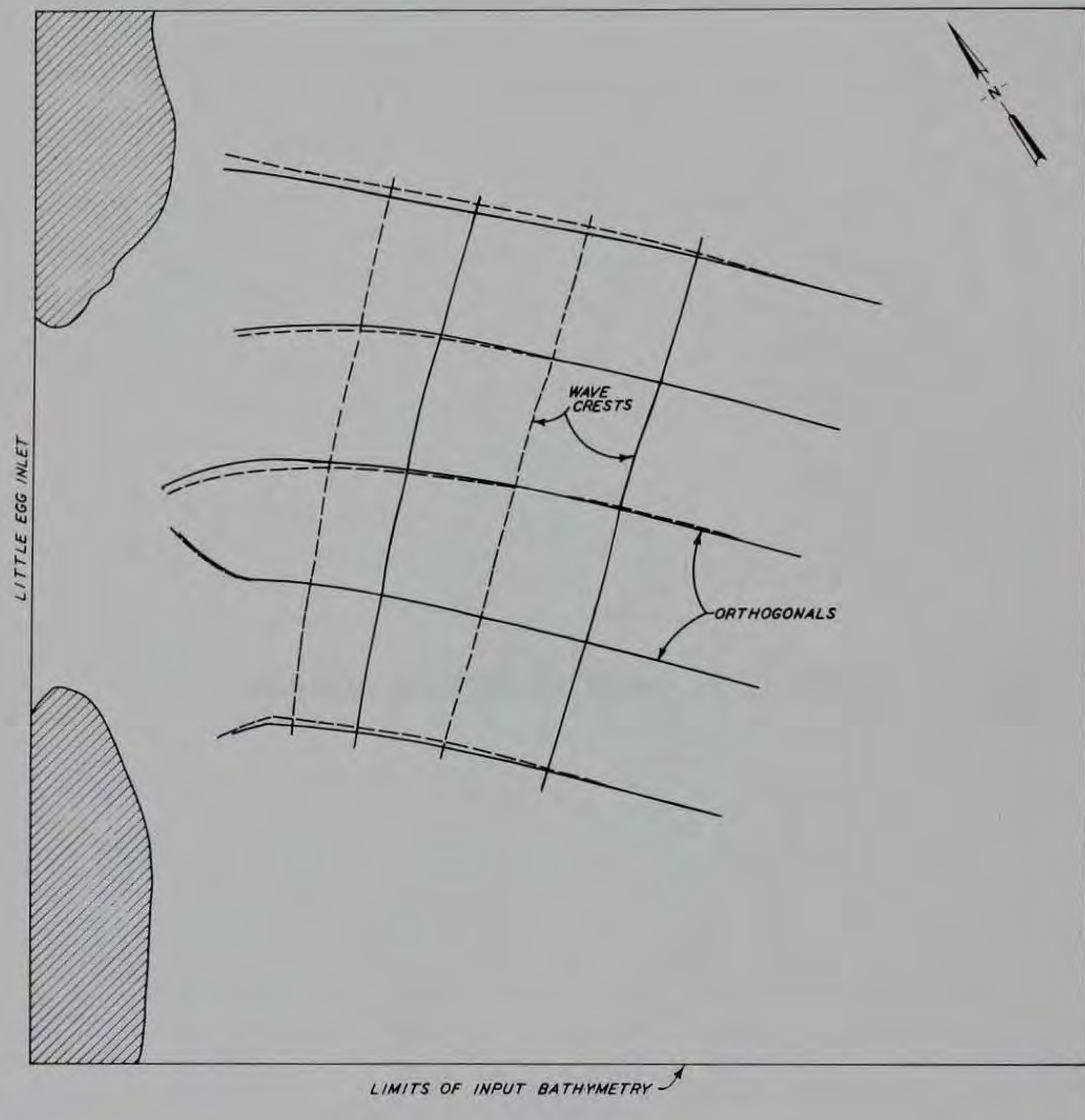
- a. Tidal currents will probably maintain the inlets in some form for a long time, although further filling of the bays by tidal deltas will decrease the tidal prism and may eventually allow the inlets to be closed.
- b. A succession of new spits is likely to develop from Little Beach growth to the north, becoming wrapped around earlier spits by hooking to the west.
- c. New inlets are likely to develop on the southern end of Long Beach, particularly if it grows to the south.

20. It is doubtful that, under the present conditions of marine transgression, the tidal prisms associated with Beach Haven and Little Egg Inlets will ever be decreased significantly to allow closing of the inlets. Any net influx of sediment to the bays is extremely small, and could be more than offset by the presently rising sea level. New spit growth on Little Beach does appear to be a likelihood, but may be halted should the channels of the two inlets become too proximal by extensive Long Beach spit growth. Should a future attempt be made to stabilize

Long Beach to a point below 39°40' latitude, Little Beach will more than likely resemble the pre-1932 conditions.

21. It should be emphasized that over the relatively short span of 100 yr and even though its geographic position has been relatively constant, Beach Haven-Little Egg Inlet has displayed a very low configurational stability. To show that the construction of any offshore structure had caused any changes in geomorphology over and above those presently being experienced, one would have to demonstrate that wave conditions were altered in an amount necessary to significantly reduce the net longshore transport rate.

APPENDIX B: WAVE REFRACTION DIAGRAMS



LEGEND

——— NATURAL BATHYMETRY

– – – – TRANSITION INSTALLED

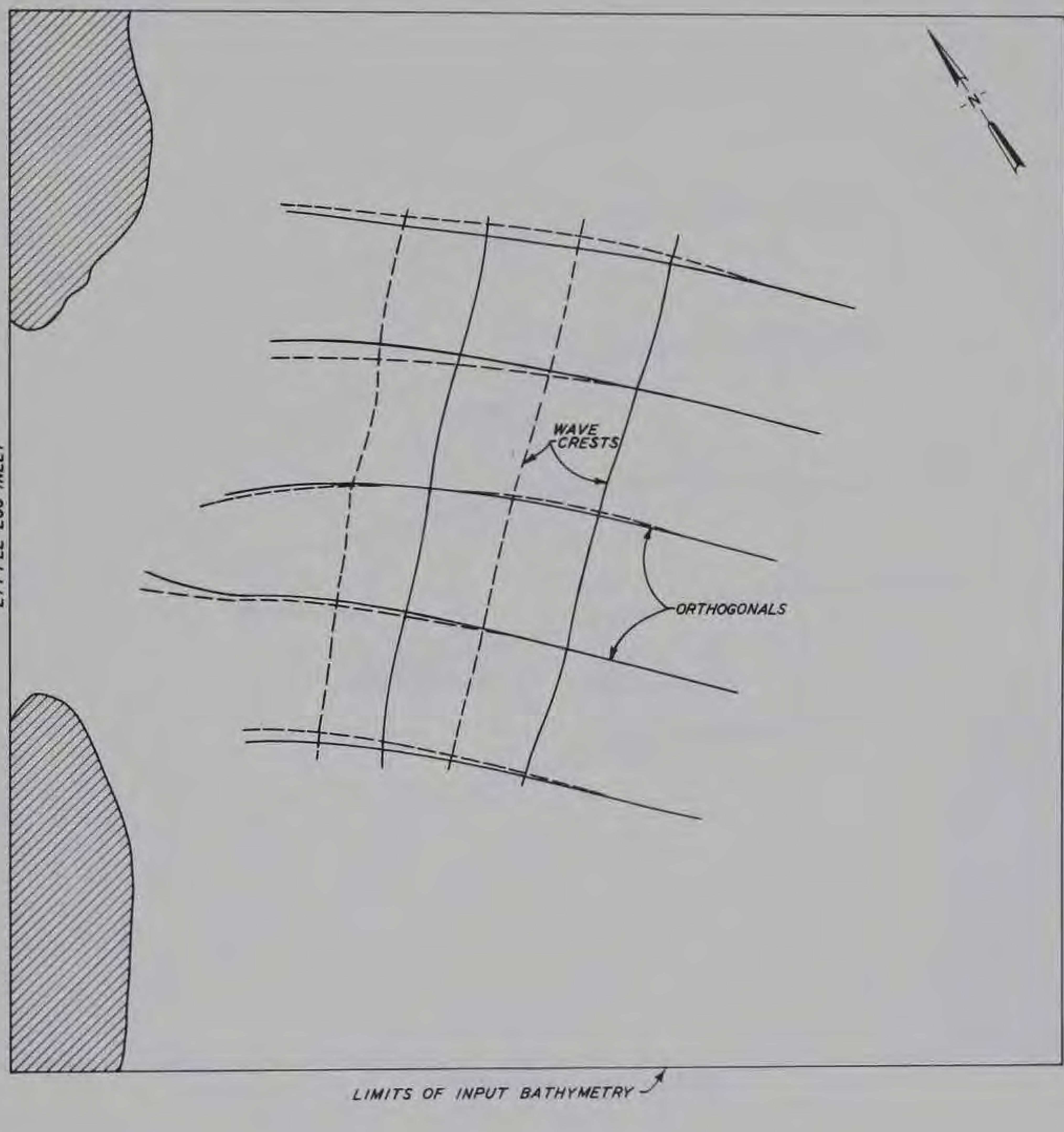
WAVE REFRACTION DIAGRAM

RAYS ORIGINATING FROM SOUTHEAST WAVE GENERATOR POSITION

6-SEC WAVE PERIOD

SCALE IN FEET

2500 0 2500 5000 7500 10,000



LEGEND

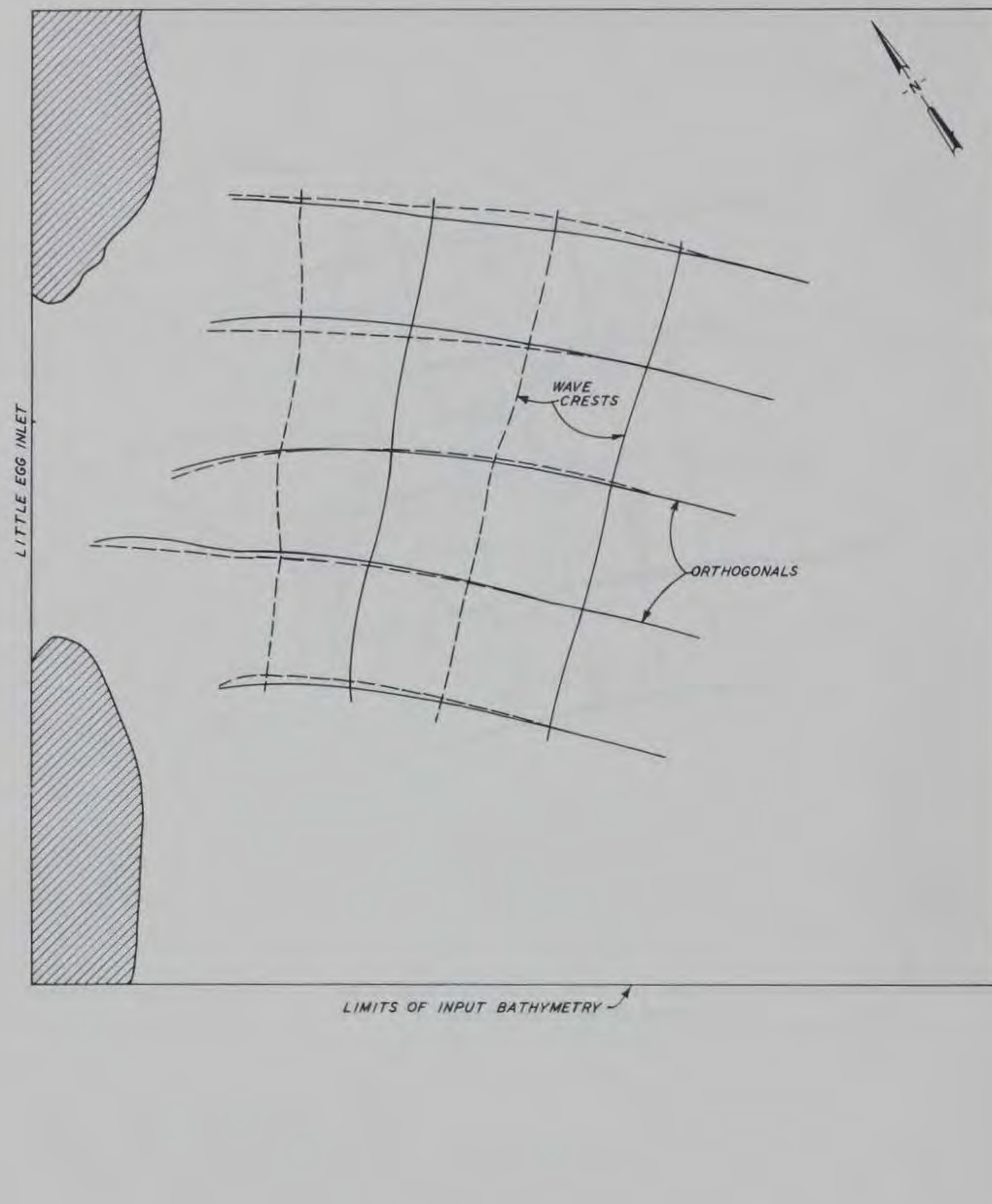
——— NATURAL BATHYMETRY

– – – – – TRANSITION INSTALLED

WAVE REFRACTION DIAGRAM
RAYS ORIGINATING FROM SOUTHEAST WAVE GENERATOR POSITION
10-SEC WAVE PERIOD

SCALE IN FEET

2500 0 2500 5000 7500 10,000



LEGEND

——— NATURAL BATHYMETRY

– – – – TRANSITION INSTALLED

WAVE REFRACTION DIAGRAM

RAYS ORIGINATING FROM SOUTHEAST WAVE GENERATOR POSITION

14-SEC WAVE PERIOD

SCALE IN FEET

2500 0 2500 5000 7500 10,000

APPENDIX C: NOTATION

b	Orthogonal spacing in shallow water, ft
b_o	Orthogonal spacing in deep water, ft
$(b_\sigma/b)^{1/2}$	Refraction coefficient (dimensionless)
d	Depth, ft
d_b	Depth of water a wave breaks in, ft
E_L	Total longshore energy per foot of beach, ft-lb/ft
E_L'	Total longshore energy per foot of beach per day, ft-lb/ft/day
H	Wave height at a given location, ft
H_b	Wave height at breaking, ft
$\bar{H}_b$	Average breaking wave height for all waves considered, ft
H_o	Wave height in deep water, ft
H_r	Ratio of wave heights (model to prototype)
H/d	Relative wave height (dimensionless)
H/L	Relative wave steepness (dimensionless)
H_1	Incident wave height, ft
H_2	Wave height after wave has propagated a distance ΔX
K	Shoaling coefficient (dimensionless)
L	Wavelength at a given location, ft
L_b	Wavelength at breaking, ft
L_r	Ratio of wavelengths (model to prototype)
Per_r	Ratio of wave periods (model to prototype)
Q_L	Volumetric longshore transport rate, yd^3/day
Q_r	Ratio of volumetric flow rates (model to prototype)
T	Wave period, sec
T_r	Ratio of times (model to prototype)
Vel_r	Ratio of velocities (model to prototype)
Vol_r	Ratio of volumes (model to prototype)
X	A horizontal distance, ft
X_r	Ratio of horizontal distances (model to prototype)
Y_r	Ratio of vertical distances (model to prototype)
α	Angle between breaking-wave crest and shoreline, deg
γ	Specific weight of water, lb/ft^3
ΔX	An incremental distance, ft
ν	Kinematic viscosity, ft^2/sec