TA7
W34
No. H-76-2
Cop. 2

US-CE-C Property of the United States Government

REFERENCE

TECHNICAL REPORT H-76-2

DESIGN OF JUBAIL HARBOR, SAUDI ARABIA, ROYAL SAUDI NAVAL EXPANSION PROGRAM

Hydraulic Model Investigation

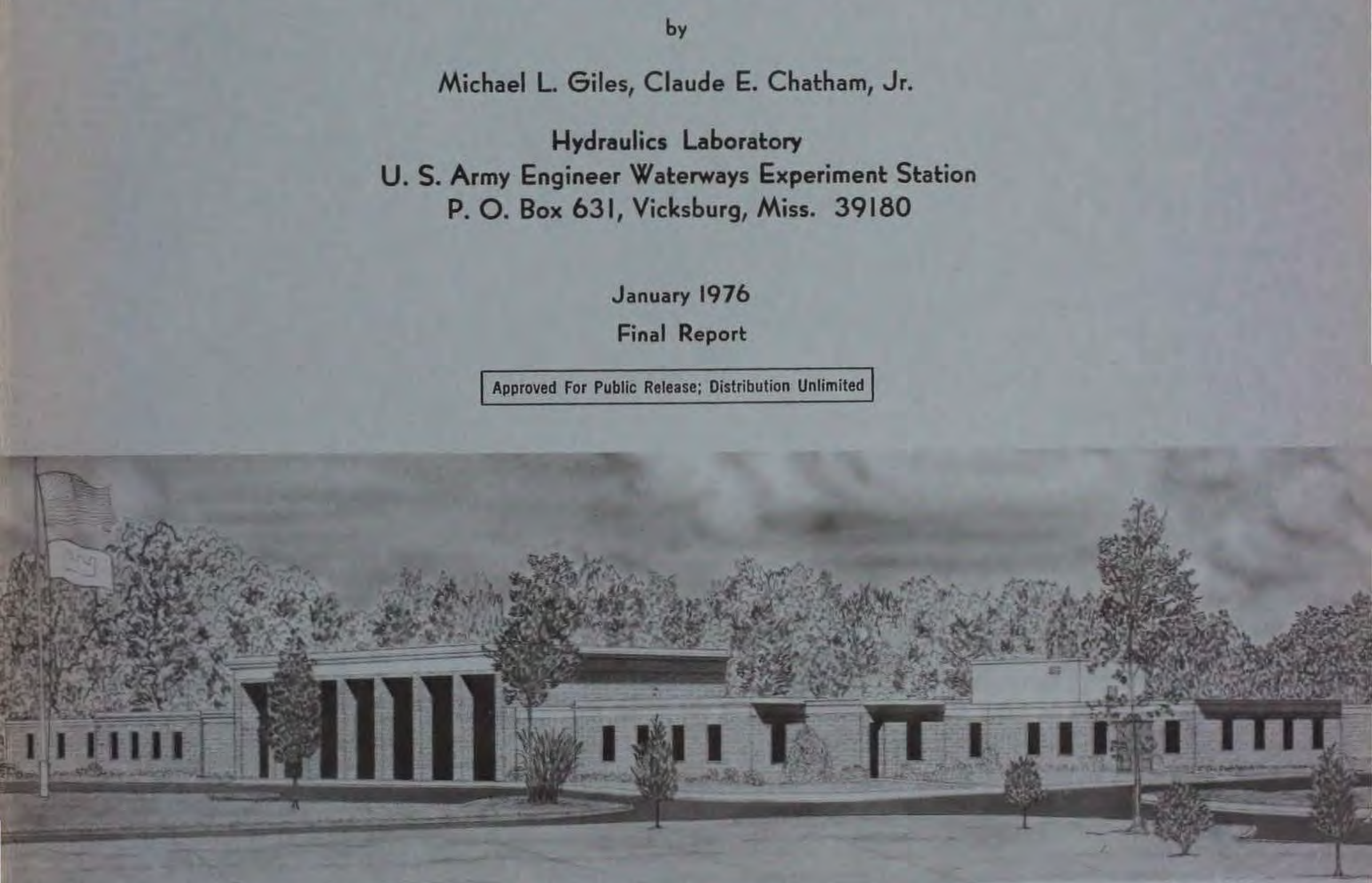
by

Michael L. Giles, Claude E. Chatham, Jr.

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

January 1976
Final Report

Approved For Public Release; Distribution Unlimited



Prepared for U. S. Army Engineer Division, Mediterranean
Livorno, Italy

LIBRARY BRANCH
TECHNICAL INFORMATION CENTER
US ARMY ENGINEER WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report H-76-2

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE *(and Subtitle)*: DESIGN OF JUBAIL HARBOR, SAUDI ARABIA, ROYAL SAUDI NAVAL EXPANSION PROGRAM; Hydraulic Model Investigation

5. TYPE OF REPORT & PERIOD COVERED: Final report

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): Michael L. Giles
Claude E. Chatham, Jr.

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
U. S. Army Engineer Waterways Experiment Station
Hydraulics Laboratory
P. O. Box 631, Vicksburg, Miss. 39180

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:

11. CONTROLLING OFFICE NAME AND ADDRESS:
U. S. Army Engineer Division, Mediterranean
Livorno, Italy

12. REPORT DATE: January 1976

13. NUMBER OF PAGES: 195

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*:

15. SECURITY CLASS. *(of this report)*: Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT *(of this Report)*:
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*:

18. SUPPLEMENTARY NOTES:

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*:
Harbor design
Hydraulic models
Jubail Harbor, Saudi Arabia
Royal Saudi Naval Expansion Program

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*:

A 1:120-scale (undistorted) hydraulic model of the proposed Jubail Harbor site and sufficient offshore area to permit generation of the required test waves was used to investigate the arrangement and design of the proposed offshore structures with respect to wave heights at critical locations within the harbor complex. The basic harbor consisted of an offshore island connected to shore by a causeway, north and east breakwaters

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

20. ABSTRACT (Continued).

to provide protection for the island, and an ammunition pier connected to shore by a causeway. Variations to the basic configuration included: (a) realigning the breakwaters, (b) varying the crown elevation of the breakwaters, (c) lengthening and shortening the breakwaters, (d) adding various inner breakwaters and revetted slopes, (e) relocating the island, (f) relocating the ammunition pier, (g) additional dredging, and (h) relocating the entire harbor complex to a more shoreward location. A 24.4-m-long wave generator and electrical wave-height measuring and recording apparatus were utilized in model operation.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

PREFACE

The U. S. Army Engineer Waterways Experiment Station (WES) was requested to conduct a hydraulic model investigation of Jubail Harbor, Saudi Arabia, by the U. S. Army Engineer Division, Mediterranean (MDD), in a telephone conversation on 20 June 1973 and during a subsequent visit to WES by MDD personnel on 4 September 1973. The study was authorized by the Office, Chief of Engineers (OCE), U. S. Army, on 24 October 1973, and funds were authorized by MDD on 9 October 1973.

The model study was conducted during the period January 1974 to May 1975 by personnel of the Harbor Wave Action Branch (HWAB), Wave Dynamics Division (WDD), Hydraulics Laboratory (HL), WES, under the direction of Mr. H. B. Simmons, Chief of HL, Dr. R. W. Whalin, Chief of WDD, and Mr. C. E. Chatham, Jr., Chief of HWAB. The tests were conducted by Mr. M. L. Giles, Project Engineer, with the assistance of Mr. E. J. Irby. This report was prepared by Messrs. Giles and Chatham.

During the course of the investigation, liaison was maintained between MDD and WES by means of conferences, telephone and teletype communications, and monthly progress reports.

Visitors to WES to observe model operation and participate in conferences included: COL L. L. Heimerl, MAJ Peter LoPresti, and Messrs. C. N. Dunnam, Willie Voelker, and William Boyers, MDD; Mr. J. M. Caldwell, MDD Consultant; Messrs. J. F. Warwar, R. L. Groeneveld, Al Steenmeyer, Herman Bomze, and E. F. Sanborn, F. R. Harris, Inc.; LT Saad Al-Ahmadi, Royal Saudi Navy; CDR H. H. Harrell, U. S. Navy; MG G. A. Rebh and Mr. Norman Howard, OCE; and Dr. J. I. Collins, Tetra Tech, Inc.

Director of WES during this study and the preparation of this report was COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

	Page
PREFACE	2
CONVERSION FACTORS, METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENT	4
PART I: INTRODUCTION	5
The Prototype	5
Purpose of the Model Study	7
Wave-Height Criteria	7
PART II: THE MODEL	8
Scale Selection	8
Design of Model Breakwaters	11
The Model and Appurtenances	13
PART III: TEST CONDITIONS AND PROCEDURES	17
Selection of Test Conditions	17
Analysis of Model Data	20
PART IV: TESTS AND RESULTS, ORIGINAL HARBOR LOCATION	21
Description of Tests	21
Test Results	24
PART V: TESTS AND RESULTS, ALTERNATE HARBOR CONFIGURATION	33
Description of Tests	33
Modifications to the Alternate Configuration	33
Test Results	36
Discussion of Test Results	42
PART VI: CONCLUSIONS	50
REFERENCES	52
TABLES 1-31	
PHOTOS 1-54	
PLATES 1-38	
APPENDIX A: WAVE REFRACTION ANALYSIS FOR JUBAIL HARBOR LOCATION	
TABLES A1-A2	
PLATES A1-A12	
APPENDIX B: NOTATION	

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

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

Multiply	By	To Obtain
millimeters	0.0393701	inches
centimeters	0.0393701	inches
meters	3.28083	feet
kilometers	0.621371	miles (U. S. statute)
kilometers	0.539665	miles (U. S. nautical)
square meters	10.76391	square feet
square kilometers	0.386101	square miles
metric tons	1.10231	tons (2000 lb)
meters per second	3.28083	feet per second
meters per second	1.9438	knots (international)
kilograms per cubic meter	0.06242	pounds per cubic foot

DESIGN OF JUBAIL HARBOR, SAUDI ARABIA, ROYAL SAUDI NAVAL EXPANSION PROGRAM

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The proposed site for Jubail Harbor (part of the Royal Saudi Naval Expansion Program) is immediately south of Jubail, Saudi Arabia (see Figure 1). The community of Jubail is approximately 80 km* north of Dhahran (the leading oil-producing center of Saudi Arabia) and is situated along the western coastline of the Arabian Gulf in the eastern province of the Arabian Peninsula.

2. The primary mission of the Jubail Naval Base facilities is to provide berthing and supplies for the Saudi Naval East Flotilla Force operating in the Arabian Gulf. Major activities of the naval base are the operation, service, maintenance, and repair of the ships. In addition, berthing facilities for visiting naval ships as well as commercial and supply ships are provided. The naval station has the capability to provide temporary services for ships in port, and has provisions for fueling, loading of supplies, and the disposal of sewage and contaminated fuels. Ship repair facilities at Jubail will consist of repair piers, dry-docking berths (employing a Syncrolift dry-docking system), and shop facilities.

3. The proposed harbor consisted of: an offshore island (to contain the ship berthing, repair, and servicing facilities) connected to shore by a landfill causeway; two protective breakwaters with a primary entrance allowing approach from the northwest and an emergency

---

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

Figure 1. Project location

secondary entrance; and an ammunition (ammo) pier connected to shore by a landfill causeway.

4. Two breakwater configurations and harbor locations were proposed. The original harbor configuration consisted of two detached breakwaters, forming an "open" harbor on the shoreward side. An alternate design consisted of a breakwater and revetted landfill arrangement attached to shore, forming a "closed" harbor. Both the original and alternate harbor configurations had entrances aligned in the same direction but they had different orientations of the offshore island. Wave conditions within the harbor under design storm conditions were a function of variations in the opening geometry of the harbor entrances and were affected by overtopping and transmission through the breakwaters.

Purpose of the Model Study

5. The purposes of the model study were to (a) determine wave heights at critical areas within the harbor, (b) optimize the length, alignment, and crown elevation of the breakwaters, (c) compare the original and alternate harbor concepts under design wave conditions, and (d) evaluate changes made during harbor design.

Wave-Height Criteria

6. For this harbor, the U. S. Army Engineer Division, Mediterranean (MDD), specified that, for an improvement plan to be acceptable, no exceptionally large waves should be present in the entrance channel and turning basin, and maximum wave heights should not exceed those indicated below for the various areas of concern.

Location	Incident Test Wave Period sec	Incident Test Wave Height m	Maximum Acceptable Wave Height cm
Front of island	9	3.0	60.0
Floating pier location	9	3.0	30.0
Ammunition pier	9	2.1	60.0

PART II: THE MODEL

Scale Selection

7. The Jubail Harbor model (Figures 2 and 3) was constructed to a linear scale of 1:120, model to prototype. Scale selection was based on:

a. The depth of water required in the model to prevent excessive bottom friction.

b. The absolute dimensions of model wave heights and periods.

c. Available shelter dimensions and the area required for constructing the model.

d. Efficiency of model operation.

e. Capabilities of available wave-generating and wave-measuring equipment.

f. Cost of model construction.

A geometrically undistorted model was necessary to ensure accurate reproduction of short-period wave patterns. After selection of the linear scale, the model was designed and operated in accordance with Froude's model law.[1] Scale relations used for design and operation of the model were as follows:

Characteristic	Dimension*	Model:Prototype Scale Relation
Length	L**	$L_r = 1:120$
Area	L^2	$A_r = L_r^2 = 1:14,400$
Volume	L^3	$\forall_r = L_r^3 = 1:1,728,000$
Time	T	$T_r = L_r^{1/2} = 1:10.95$
Velocity	L/T	$V_r = L_r^{1/2} = 1:10.95$

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

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

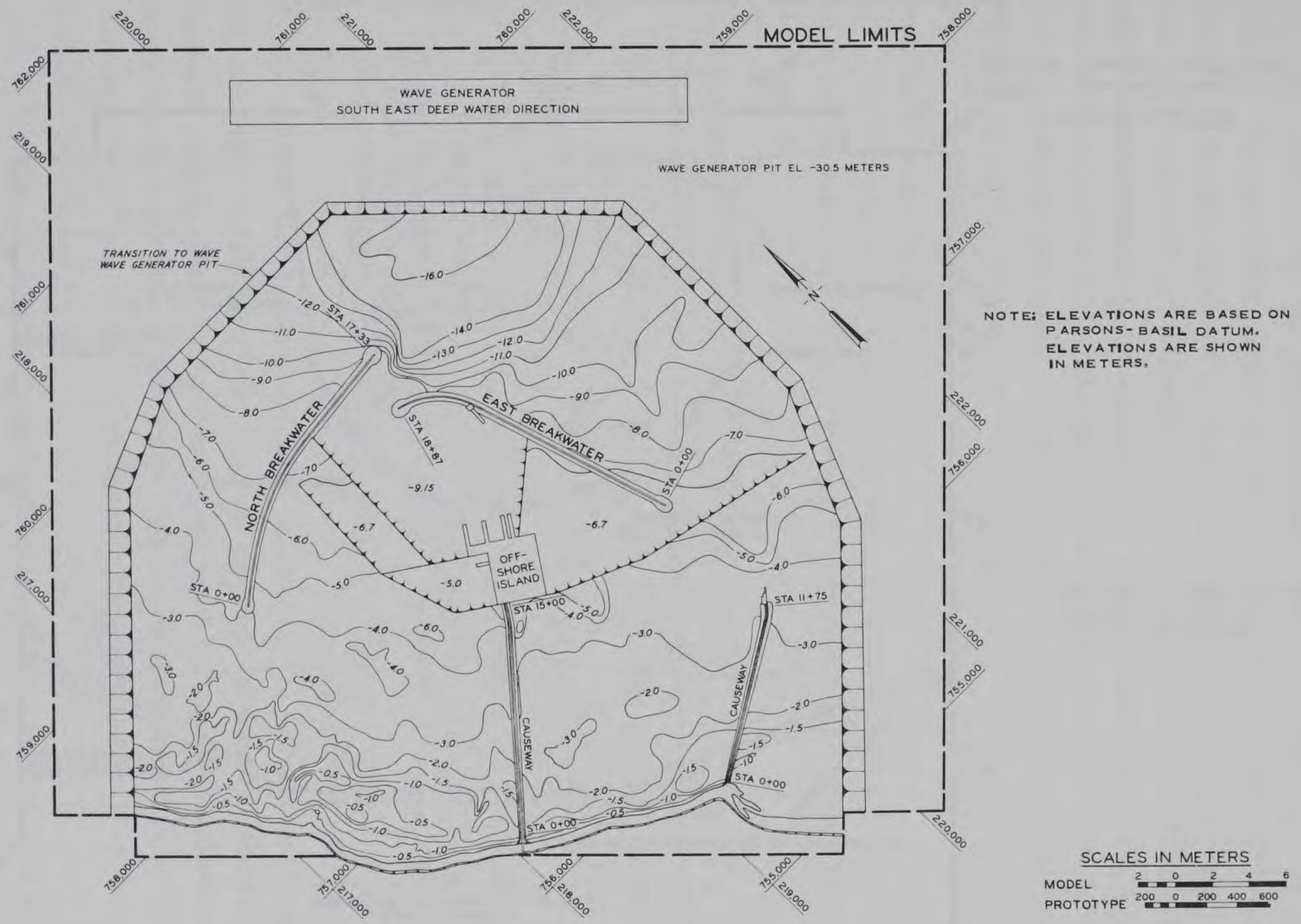


Figure 2. Model layout (original harbor installed)

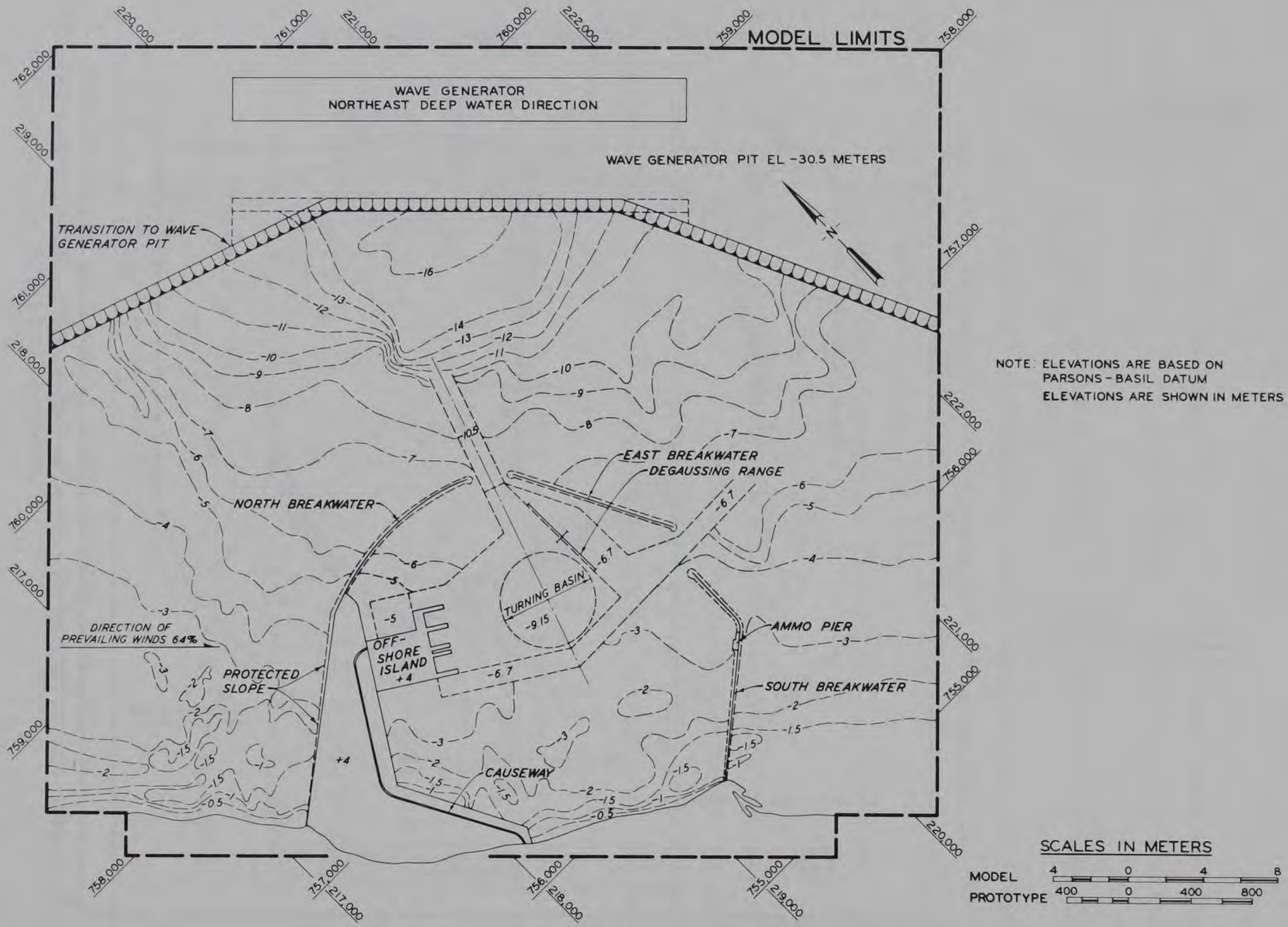


Figure 3. Model layout (alternate harbor installed)

Design of Model Breakwaters

8. Some of the proposed breakwater sections (Plate 1) for the original and alternate harbor layouts included the use of concrete armor units. Since the porosity of these armor units differs from that of rock, and since the units could not be reproduced to scale (due to cost and time requirements), two-dimensional wave-transmission tests were conducted at scales large enough to have negligible scale effects (i.e. 1:27 to 1:30) to determine the correct transmission through the proposed structures. This transmission then was duplicated at a scale of 1:120 using rock cross sections, and the three-dimensional model structures were built accordingly.

9. Transmitted waves for the various structures in 11.3 m of water while under attack by 9 sec, 4-m waves (proposed design wave) are given below:

Proposed Breakwater Armor Protection	Incident Wave H_i, m	Transmitted Wave H_t, m	$C_T = H_t/H_i$
5-ton (4.5-metric-ton) dolosse	4.1	0.204	0.049
7-ton (6.4-metric-ton) tribars	4.1	0.222	0.054
9.5-ton (8.6-metric-ton) cubes	4.1	0.228	0.055
7-ton (6.4-metric-ton) tribars with concrete cap	4.1	0.164	0.040

Curves showing the transmitted wave height H_t as a function of the incident wave height H_i for the four proposed breakwater sections are compared with a curve for the structure built in the three-dimensional model (Figure 4). These data show that the model breakwater is slightly conservative (i.e., it allows slightly more transmission than any of the proposed breakwater sections).

10. Some of the proposed improvement plans included rock wave absorbers and/or rock slopes around the island perimeter and along the

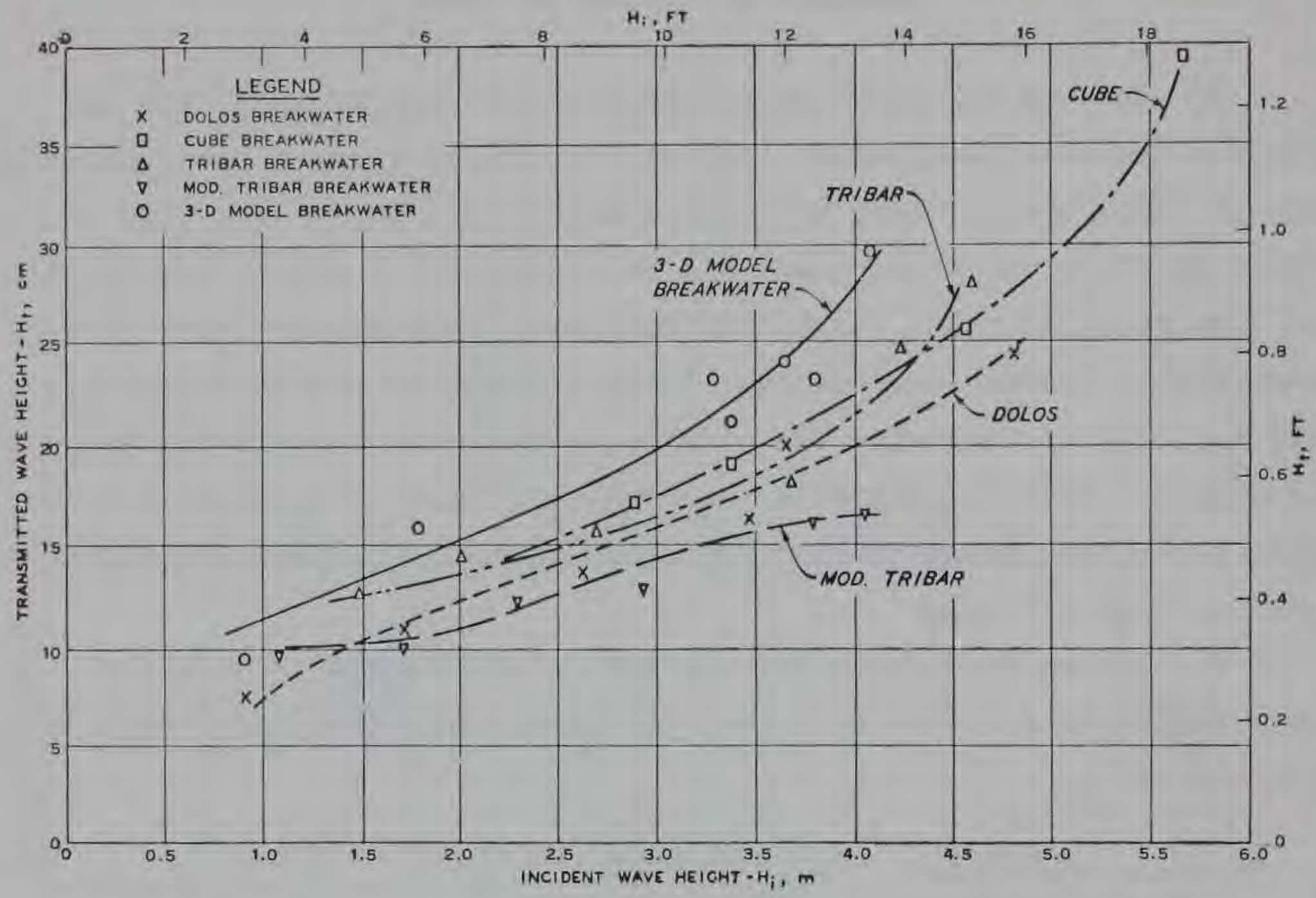


Figure 4. Transmission curves for various breakwater sections, wave period = 9 sec, depth = 11.3 m

landfill and the causeways. In small-scale models, geometrically scaled rock structures reflect relatively more and absorb or dissipate relatively less wave energy than their prototype counterparts.[2] Consequently, some adjustment in small-scale model rubble structures is required to ensure satisfactory reproduction of wave absorption and transmission characteristics. Past experience has shown that for similar wave conditions a close approximation of the correct energy dissipation and transmission could be obtained by increasing the size of the rock used in the 1:120-scale model to approximately two times that required for geometric similarity. Accordingly, in constructing the rock structures (except for the breakwaters) in the Jubail Harbor model, the rock sizes were computed linearly by scale, then multiplied by 2.0 to arrive at the actual sizes used in the model.

The Model and Appurtenances

11. The model, which was molded in cement mortar, reproduced approximately 4.8 km of shoreline along the Jubail Naval Base site and underwater contours out to 16 m* with a 1V on 5H sloping transition to a wave-generator pit elevation of -30.5 m. The total area reproduced in the model was approximately 29 sq km in the prototype. Figure 5 is a general view of the model with the original harbor configuration installed; and Figure 6 is a general view of the model with the alternate harbor configuration installed. Vertical control for the model was based on the Parsons-Basil datum. Horizontal control was referenced to the local prototype coordinate system.

12. Model waves were generated by a 24.4-m-long, piston-type wave generator. The horizontal movement of the plunger caused a periodic displacement of water incident to this motion. The length of stroke and the period of horizontal motion were variable over the range necessary to generate waves with the required characteristics. In addition, the wave machine was mounted on retractable casters which enabled it to be positioned to generate waves from the required test directions.

13. A 20-channel wave-height measuring system was used to secure wave-height data during test operations. Each channel consisted of a wave rod to detect the water level, a remote-control, motor-driven assembly to raise and lower the wave rod in the water during calibration, and related cable circuitry connecting the wave rod to a power supply and to a 20-channel, light-beam oscillograph recorder. The resistance-type wave rods consisted of two 2-mm-diam parallel wires which formed the legs of an electrical circuit that was closed when the wave rods were partially submerged. During calibration of the system, which was performed in still water prior to each series of test runs (usually about twice daily), each wave rod was moved up and down in the water by the remote-controlled, motor-driven rod assembly, and the resulting

---

* All elevations (el) cited herein are in meters referred to the Parsons-Basil datum.

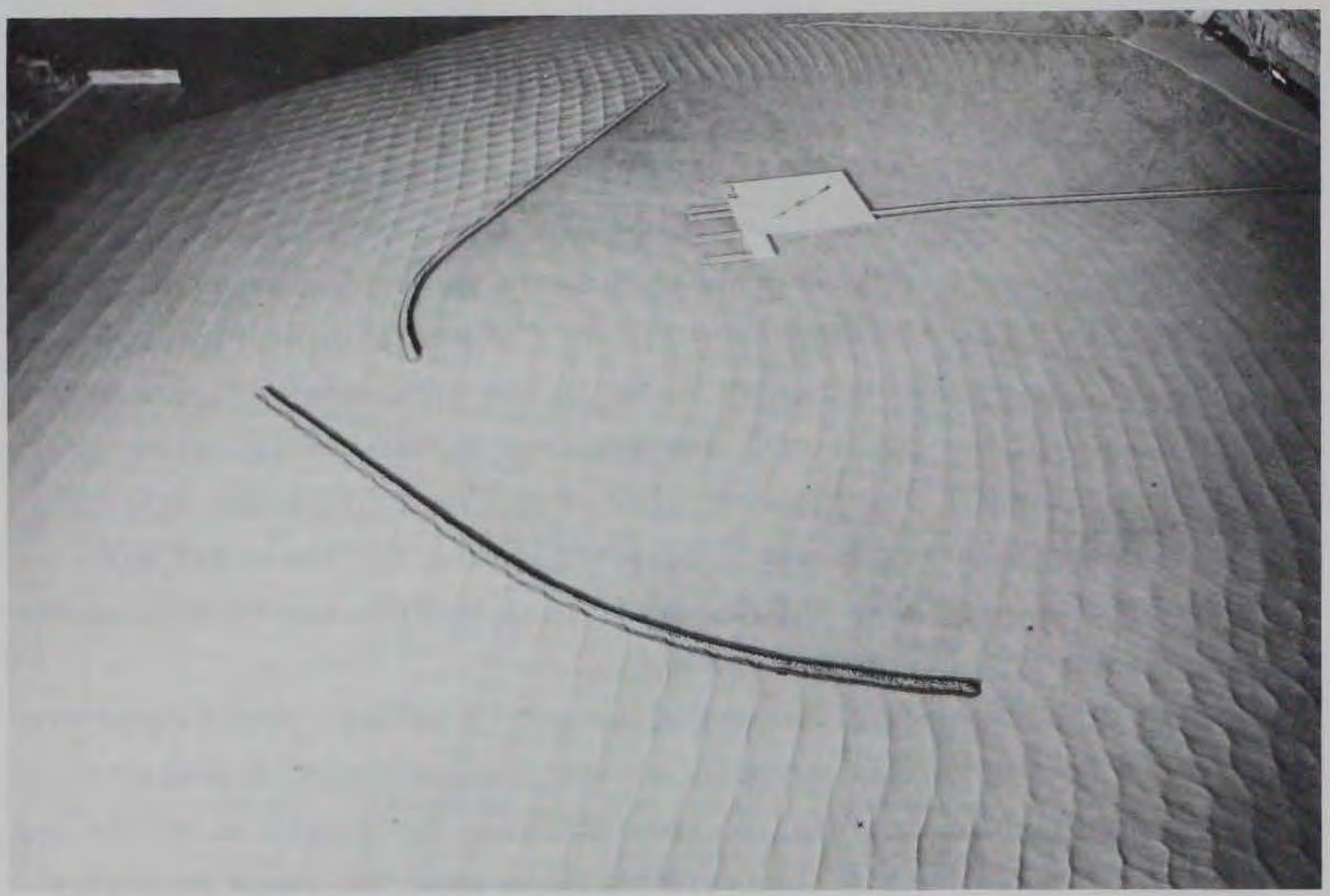


Figure 5. General view of model with original harbor installed

Figure 6. General view of model with alternate harbor installed

light-beam deflection was recorded for calibration data. Vertical travel of each rod was monitored by a linear potentiometer in the mechanical linkage from which the rod was suspended. The travel distance of each potentiometer, which was used as the calibration standard for the attached wave rod, was accurately measured and did not vary throughout the testing period. A capability of doubling the amplitude of the deflection of the light beam was incorporated to facilitate data reduction of the smaller amplitude waves in the more protected areas of the model. In all cases, the wave-trace deflections were directly proportional to the submergence of the respective wave rods in the water. All of the controls for calibration of the wave rods, adjustment and activation of the recorder, and control of the wave machine were located in an instrumentation room adjacent to the model.

14. During the latter part of the model study, an Automated Data Acquisition and Control System (ADACS) was completed and used to obtain wave-height data on the Jubail model. This new system was more stable, less sensitive to temperature changes, utilized a faster and more accurate calibration procedure, and included more exact analysis programs. Basically, through the use of a minicomputer, ADACS recorded the data on magnetic tape which was then analyzed by computer. A schematic diagram of ADACS is shown in Figure 7. Relative comparisons of plans using data taken with the previous system are certainly valid. The main difference is in the absolute magnitude of some of the larger wave heights (data taken with ADACS were usually lower). All final plans being considered for Jubail were rerun using ADACS.

15. A 60-cm (horizontal) solid layer of fiber wave absorber was placed around the inside perimeter of the model to dampen wave energy that might otherwise be reflected from the model walls. In addition, guide vanes were placed along the side of the wave generator in the pit area to ensure proper formation of the wave train incident to the model contours.

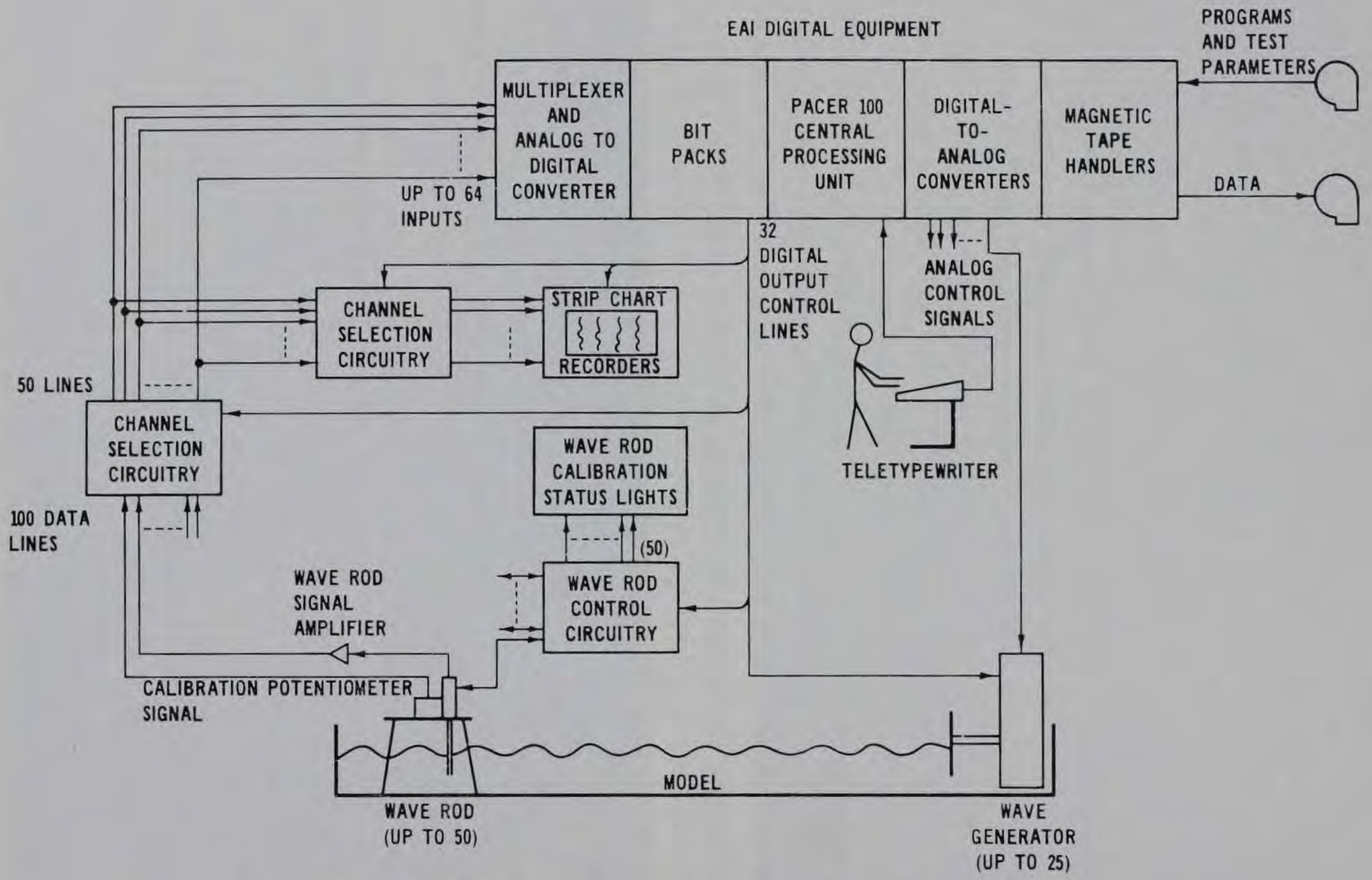


Figure 7. Automated data acquisition and control system (ADACS)

PART III: TEST CONDITIONS AND PROCEDURES

Selection of Test Conditions

Still-water level

16. Still-water levels (swl's) for harbor wave-action models are selected so that various wave-induced phenomena dependent on water depth are accurately reproduced in the model. Included among these phenomena are refraction of waves in the harbor area, reflection of wave energy from harbor structures, transmission of wave energy through porous structures, and overtopping of structures by waves. The maximum amount of wave energy reaching a coastal area will normally occur during the higher water phase of the local tide cycle. In addition, most storms moving onshore are characteristically accompanied by a higher water level due to wind tide and shoreward mass transport. Also, a high swl helps minimize model scale effects due to viscous friction at the bottom. Therefore, considering the factors which contribute to and are affected by the static water level in the model, and the desire to ensure that the model data do not underestimate potential problems (while yielding representative data), it was desirable to select a model swl that closely approximated the higher water stages which normally occur in the prototype.

17. There is no tidal station at Jubail. However, tidal data secured for MDD[3] during master planning are summarized below:

	meters
Maximum probable tide at the shoreline	2.64
Maximum probable tide at the island	2.35
Mean monthly high tide	1.90
Mean high water, mhw	1.48
Mean sea level, msl	0.88
Mean low water, mlw	0.20
Parsons-Basil datum	0.00
Indian Springs low water	-0.50

The maximum probable tide at the island (+2.35 m) was selected as representative of swl conditions that might reasonably occur and thus was used for most model wave-height and current tests. An swl of 0.0 m also was selected for some of the wave-height tests to determine the effect of different water levels on wave heights at the island.

Factors influencing selection of test-wave characteristics

18. In planning the test program for a model investigation of harbor wave-action problems, it is necessary to select dimensions and directions for the test waves that will afford a realistic test for the proposed improvement plans and allow an accurate evaluation of the elements of the proposed plans. Surface-wind waves are primarily generated by the interactions of tangential stresses of wind flowing over water, resonance between the ocean surface and atmospheric turbulence, and interactions of individual wave components. The magnitude of the maximum wave generated by a given storm depends upon the wind speed, the length of time that wind of a given speed continues to blow, and the water distance (fetch) over which the wind blows. For a given wind speed, the ultimate wave growth in the Arabian Gulf (semiclosed basin) will be duration limited or fetch limited. Selection of test-wave conditions entails evaluation of such factors as:

a. The fetch and decay distances (the latter being the distance over which waves travel after leaving the generating area) for the various directions from which waves can attack the problem area.

b. The frequency of occurrence and duration of storm winds from the different directions.

c. The alignment, width, and relative geographic position of the harbor.

d. The alignments, lengths, and locations of the various structures in the harbor.

e. The refraction of waves caused by differentials in depth in areas seaward of the harbor; refraction may cause either a convergence or a divergence of wave energy at the harbor site.

Wave refraction

19. When waves move into water of gradually decreasing depth, transformations occur in all wave characteristics except wave period (to the first order of approximation). The most important transformations with respect to the selection of test-wave characteristics are the changes in wave height and direction of travel due to the phenomenon referred to as wave refraction. Changes in wave height and direction can be determined by plotting refraction diagrams and calculating refraction coefficients. These diagrams are constructed by plotting the position of wave orthogonals (lines drawn perpendicular to wave crests) from deep water into shallow water. If it is assumed that the waves do not break and that there is no lateral flow of energy along the wave crest, 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 $H/H_o = K_s(b_o/b)^{1/2}$. The quantity $(b_o/b)^{1/2}$ is the refraction coefficient; K_s is the shoaling coefficient. Thus, the refraction coefficient multiplied by the shoaling coefficient gives a conversion factor for transfer of deepwater wave heights to shallow-water values. The shoaling coefficient, which is a function of wavelength and water depth, can be obtained from Reference 4. For this study, wave refraction diagrams were prepared for representative wave periods from the critical directions of approach using computer facilities at the U. S. Army Engineer Waterways Experiment Station (WES) and are detailed in Appendix A.

Prototype wave data
and selection of test waves

20. Measured wave data necessary to conduct a comprehensive statistical analysis of wave conditions were unavailable for the Jubail Harbor site. Wave hindcast data were obtained by representatives of MDD, however, and representative wave periods and significant wave heights (H_s) were determined for deepwater waves approaching Jubail from northwest clockwise to southeast. The refraction and shoaling analysis described in paragraph 19 was used to transform wave characteristics from deep water to shallow water (-16 m contour) for use in the model.

The shallow-water wave directions used in the model were the average directions of the refracted waves for the significant wave periods noted from each deepwater wave direction. Characteristics of model test waves selected are shown in the following tabulation:

Deepwater Wave Direction	Selected Shallow-Water Test Direction, deg (radians)	Selected Test Wave Period, sec	Selected Test Wave Height, H_s, m
Northwest	315 (5.5)	7	0.9-1.8
North	14.7 (0.25)	7	0.9-1.8
		9	1.2-4.9
		11	1.2-4.9
Northeast	45 (0.79)	7	1.5-3.4
		9	1.2-5.8
		11	1.2-4.9
East-southeast	64.2 (1.12)	7	1.5-4.3
		9	1.8-4.6
		11	1.8-6.4
Southeast	135 (2.36)	7	1.2-2.1

Analysis of Model Data

21. The relative merits of the various plans tested were evaluated by (a) comparing wave heights at selected locations in the harbor, (b) visual observations and photos, and (c) comparing current patterns and magnitudes. Analysis of the wave-height data was based on significant wave height (the average height of the highest one-third of the waves recorded at each gage location). All wave heights thus computed were then adjusted by the application of Keulegan's equation,[5] to compensate for the greater rate of attenuation in the model relative to the prototype. From this equation, the reduction of wave heights in the model due to viscous friction at the bottom can be calculated as a function of water depth, width of wave front, wave period, water viscosity, and distance of wave travel. Current magnitudes were obtained by timing the progress of an injected dye trace relative to a model grid system.

PART IV: TESTS AND RESULTS, ORIGINAL HARBOR LOCATION

Description of Tests

Maximum breakwater wave heights

22. Prior to tests of various improvement plans, maximum wave heights along the center lines of the proposed breakwaters were obtained and are shown in Plates 2-6. The curves drawn through the upper limits of the data points represent the maximum possible wave height along that given section of breakwater for a +2.35 m swl and a given wave at the wave generator. It should be noted that all of the curves show that wave heights are higher at the breakwater than at the wave generator; this is due to refraction, shoaling, and peaking of the waves prior to breaking.

Proposed harbor plans

23. Tests were conducted for the originally proposed harbor configuration (Plan 1) and various modifications. As originally proposed, the berthing, repair, and support facilities would be located on a 150,000-sq-m offshore island connected to shore by a 1,500-m-long causeway. This island would be protected by north and east breakwaters with a total length of 3,620 m. An ammo pier connected to shore by an 1,175-m-long causeway would be located about 1,400 m to the southeast of the island. Project depths would be -9.15 m in the main entrance and harbor area, and -6.7 m in the secondary entrance. Initial tests were conducted with the model layout shown in Figure 2, so that waves could be generated from the northwest and southeast directions. Following these tests, the model contours were altered as shown in Plate 7 so that waves from the deepwater directions (north to east-southeast) could be more accurately reproduced. Details of Plan 1 are shown in Plate 8. Brief descriptions of the various modifications to Plan 1 are given in the following subparagraphs; dimensional details and various gage locations for each plan are illustrated in the referenced plates.

a. Plan 2 (Plate 8) consisted of the originally proposed harbor (Plan 1) with a 2V on 3H rock slope (30-cm diam) around the island.

b. Plan 3 (Plate 9) consisted of elements of Plan 2 with the removal of 100 m from the north end of the east breakwater.

c. Plan 4 (Plate 9) consisted of elements of Plan 2 with the removal of 200 m from the north end of the east breakwater.

d. Plan 5 (Plate 10) consisted of elements of Plan 2 with the removal of 100 m from the shoreward end of the north breakwater.

e. Plan 6 (Plate 10) consisted of elements of Plan 2 with the removal of 200 m from the shoreward end of the north breakwater.

f. Plan 7 (Plate 10) consisted of elements of Plan 2 with removal of 300 m from the shoreward end of the north breakwater.

g. Plan 8 (Plate 10) consisted of elements of Plan 2 with the removal of 400 m from the shoreward end of the north breakwater.

h. Plan 9 (Plate 11) consisted of elements of Plan 2 with 300 m removed from the shoreward end of the north breakwater (Plan 7) and 100 m removed from the seaward end of the north breakwater.

i. Plan 10 (Plate 11) consisted of elements of Plan 7 with the removal of 200 m from the seaward end of the north breakwater.

j. Plan 11 (Plate 12) consisted of elements of Plan 9 with the removal of 100 m from the north end of the east breakwater.

k. Plan 12 (Plate 12) consisted of elements of Plan 9 with the removal of 100 m from the south end of the east breakwater.

l. Plan 13 (Plate 13) consisted of elements of Plan 9 with a 30-cm-diam rock slope placed 1V on 3H around the island.

m. Plan 14 (Plate 13) consisted of elements of Plan 9 with a 90-cm-diam rock slope placed 1V on 3H around the island.

n. Plan 15 (Plate 14) involved elements of Plan 9 with the north breakwater crown lowered to +5.5 m (previously set at +6.5 m).

o. Plan 16 (Plate 14) involved elements of Plan 9 with the north and east breakwater crowns lowered to +5.5 m.

p. Plan 17 (Plate 15) consisted of elements of Plan 16 with 100 m added to the seaward end of the north breakwater and 100 m added to the north end of the east breakwater.

24. Analysis of wave data at the ammo pier resulted in the following modifications to the causeway alignment and ammo pier location. Dimensional details are shown in Plates 16-19 (all modifications were tested with Plan 17 installed).

a. Plan 17A involved extending the ammo pier causeway 75 m to sta 12+50 and adding 100 m at a 90-deg (1.6-radian) angle toward the island.

b. Plan 17B involved extending the causeway to sta 12+50 and adding 200 m at a 90-deg (1.6-radian) angle toward the island.

c. Plans 17C, D, and E involved extending the causeway to sta 12+50 and adding 100, 200, and 300 m, respectively, at an angle toward the east breakwater.

d. Plan 17F involved elements of Plan 17C with an additional 100 m at a 90-deg (1.6-radian) angle toward the shore.

e. Plan 17I involved forming a 115-deg (2.0-radian) angle at sta 10+50 and extending the causeway to sta 12+50. The ammo pier was located at sta 11+20.

f. Plans 17H and G involved elements of Plan 17I with an additional 100 and 200 m of causeway (to sta 13+50 and 14+50, respectively).

25. To determine the effect of moving the island and changing the alignment of the breakwaters, various modifications to Plan 17 were installed as follows:

a. Plan 18 (Plate 20) involved elements of Plan 17 with the island extended one-half the island width to the northwest.

b. Plan 19 (Plate 21) involved elements of Plan 17 with the north breakwater curved to the north.

c. Plan 20 (Plate 21) involved elements of Plan 17 with the north breakwater removed.

26. Wave-height tests for the various improvement plans described above were conducted using test waves from one or more of the directions listed in paragraph 20. After an examination of initial model test results, some of the subsequent tests were limited to the most critical directions of approach and most critical test waves. This procedure is a model expedient used when initial tests show a marked difference among the results for various test directions.

Test Results

27. The relative efficiency of each of the proposed harbor configurations was evaluated on the basis of satisfying the wave-height criteria specified in paragraph 6 and repeated here for convenience:

Location	Incident Test Wave Period sec	Incident Test Wave Height m	Maximum Acceptable Wave Height cm
Front of island	9	3.0	60.0
Floating pier location	9	3.0	30.0
Ammo pier	9	2.1	60.0

28. Wave-height measurements were obtained for the following gage locations (shown for each plan on corresponding plates).

Gage	Location
1	Outside primary entrance
2	Primary entrance
3, 3A	Seaward side of east breakwater
4, 4A	Seaward side of north breakwater
5, 6, 7	Between piers of offshore island
9	West side of offshore island
10, 11	Turning basin
12	Secondary entrance
13	Ammo pier

29. Results of wave-height measurements obtained for test waves from the northeast with the original harbor (Plan 1) installed are presented in Table 1. A maximum wave height of 1.34 m was recorded at the offshore island for a 9-sec, 3-m test wave. Wave patterns obtained with Plan 1 installed are shown in Photos 1-3. Since visual observations indicated a standing wave occurred at the island (due to the vertical walls) a rock slope consisting of 30-cm-diam (prototype) stone was placed 2V on 3H around the island (Plan 2). Wave patterns from various directions with Plan 2 installed are shown in Photos 4-12.

Wave heights obtained at various gage locations with Plan 2 installed are shown in Table 2. The maximum wave height obtained at the island for a 9-sec, 3-m test wave was 85 cm. Even though this exceeds the wave-height criterion, a comparison of the data for Plans 1 and 2 indicates that the rock slope substantially reduces the standing wave amplitude at the front of the island.

30. Next, 100- and 200-m lengths were removed from the north end of the east breakwater (Plans 3 and 4) to determine the effect of increasing the primary entrance opening to allow a more direct approach to the berthing areas. Wave heights obtained at various gage locations for 9-sec test waves from northeast with Plans 3 and 4 installed are presented in Table 3. Maximum wave heights recorded at the island for 9-sec, 3-m test waves were 1.13 and 1.40 m for Plans 3 and 4, respectively. While both plans provide a wider entrance, the significant increase in wave heights at the island relative to Plan 2 (85 cm) indicates that little, if any, length can be removed from the north end of the east breakwater.

31. A fetch-limited wave period of 7 sec and wave height of 1.8 m were determined as the maximum obtainable from the northwest. Calculations were then made which indicated that with the original harbor configuration installed, a 90-cm wave could be generated between the north breakwater and the offshore island (regardless of the length of the north breakwater). This value, therefore, was taken as the limiting criterion at the island for this particular test direction, and lengths of breakwater were removed from the shoreward end of the north breakwater (Plans 5-8) until the maximum wave at the island exceeded 90 cm. Wave heights obtained at various gage locations with Plans 5-8 installed are presented in Table 4. The maximum wave height obtained at the island was at gage 9 (proposed floating pier) for all test plans. These wave heights were 70, 82, 88, and 116 cm for Plans 5-8, respectively. The maximum wave heights recorded between the fixed piers at the front of the island for Plans 5-8 were 55, 36, 49, and 73 cm. Plans 5-8 are compared with Plan 2 in Figure 8. These data show that Plan 7 approaches the 90-cm limit (88 cm at gage 9) and therefore 300 m was considered the

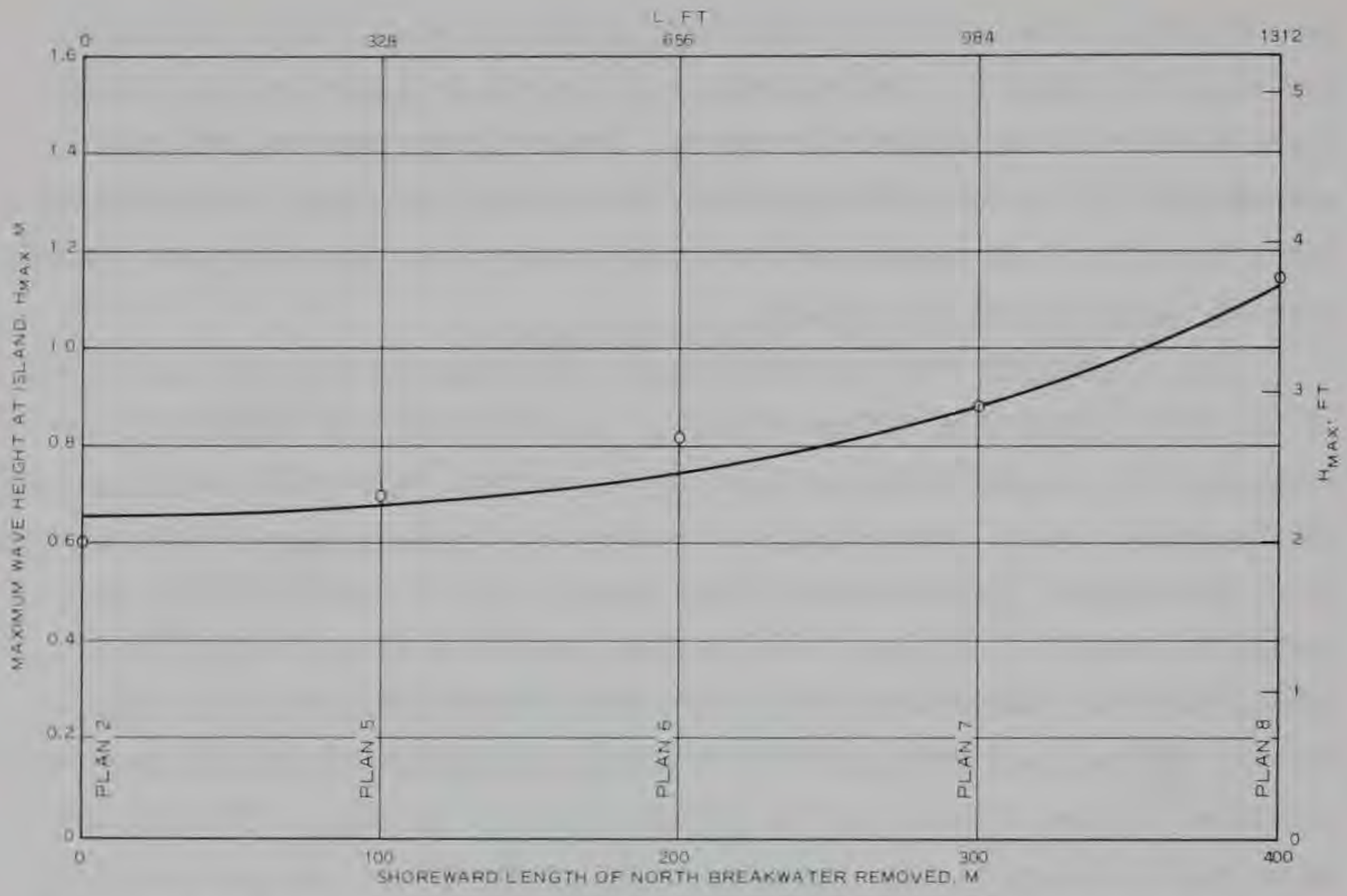


Figure 8. Maximum wave heights at the offshore island (floating pier location) for Plans 2, 5, 6, 7, and 8 (waves from northwest)

maximum allowable reduction in the shoreward end of the north breakwater.

32. Wave heights obtained at various gage locations with Plan 9 installed are presented in Table 5. Maximum wave heights of 88, 64, and 73 cm were recorded at the front of the island for waves from the north, northeast, and east-southeast test directions. It should be noted that spilling and breaking wave conditions were observed in the entrance channel for some of the larger incident waves. Wave patterns for typical test waves are shown in Photos 13-18. No overtopping at the island was noted for any test wave condition; however, a very slight amount of overtopping did occur on portions of the piers. Results of a special test with a 9-sec, 9.1-m test wave from the northeast indicated a maximum wave height of 7.19 m in the entrance channel and 2.07 m at the front of the island.

33. Typical current patterns and magnitudes for 9-sec waves from the northeast with Plan 9 installed are shown in Photo 17. All current

patterns were similar to those in Photo 17. Current magnitudes were as follows:

Test Wave Height m	Prototype Velocity (m/sec) at Seaward Side of North Breakwater	Head of North Breakwater	Entrance Channel	Seaward Side of East Breakwater
4.0	0.21	0.42	0.18	0.27
4.9	0.51	0.45	0.24	0.33
5.8	0.64	0.73	0.45	0.76

Currents of these magnitudes should not produce navigational hazards.

34. Results of wave-height tests with Plan 9 installed and using an swl of 0.0 for test waves from the northeast are shown in Table 6. A 64-cm wave height was recorded at the island for a 9-sec, 3-m test wave and maximum wave heights of 34, 88, and 79 cm were recorded at the island for 7-sec, 3.4-m; 9-sec, 5.8-m; and 11-sec, 4.9-m test waves, respectively.

35. Results of wave-height tests with Plans 10, 11, and 12 (modifications of Plan 9) installed are presented in Table 7. Maximum wave heights of 1.48, 1.82, and 0.95 m (this value interpolated from Table 7) were recorded at the island for a 9-sec, 3-m test wave, indicating that the length of either the north or east breakwaters could not be further reduced without significantly exceeding the specified wave-height criterion of 60 cm at the front of the offshore island.

36. Wave heights with a 1V on 3H slope around the island constructed of 30-cm rock (Plan 13) and 90-cm rock (Plan 14) are presented in Table 8. The maximum wave heights at the island for a 9-sec, 3-m incident wave were 70 cm for both plans. Comparison of these data with corresponding data for Plan 9 indicated that changing the slope or rock size around the island would not significantly change wave heights at the island.

37. Wave heights obtained at various gage locations with the north breakwater crown elevation lowered from +6.5 to +5.5 m (Plan 15) and with both the north and east breakwater crown elevations lowered to +5.5 m (Plan 16) are presented in Tables 9 and 10. For 9-sec, 3-m test

waves, maximum wave heights recorded at the island for Plans 15 and 16 were 112 and 94 cm for the north test direction and 73 and 64 cm for the northeast test direction. Lowering the north breakwater crown elevation to +5.5 m (Plan 15) increased wave heights at the island an average of about 15 cm (relative to Plan 9) for the larger test waves (3 m or greater) from the north but had little effect on waves approaching from the northeast. Lowering both the north and east breakwater crown elevations to +5.5 m (Plan 16) significantly increased wave heights recorded at the island for the larger waves from the northeast. These waves have a low frequency of occurrence and for the smaller, more frequent waves (less than 3 m), the lower crown elevation did not significantly increase wave heights.

38. During the technical review conference in Livorno, Italy, on 1-3 October 1974, considerable concern was expressed over the fact that, while the original harbor layout provided relatively good protection for large waves, wave heights in excess of 60 cm still occurred at the island for incident waves of 1.2 m to 2.1 m. Additional tests then were conducted with various main entrance modifications in an effort to reduce wave heights at the island. All tests were conducted with a breakwater crown elevation of +5.5 m. Plans tested included (a) lengthening the seaward end of the north breakwater, (b) lengthening the north end of the east breakwater (parallel to the north breakwater), (c) combining (a) and (b), and (d) installing a spending beach (1:11 slope) inside the east breakwater.

39. Comparison of wave heights at the island for all the above indicated that the most promising plan was the addition of 100 m to the north end of the east breakwater and 100 m to the seaward end of the north breakwater (back to its original length). This configuration was designated as Plan 17, and wave heights at various gage locations are presented in Table 11. Maximum wave heights at the island were 45 and 54 cm for 9-sec, 3-m test waves from the north and northeast, respectively. A comparison of Plan 17 with the original harbor layout (Plan 2) for 9-sec waves from all test directions is shown in Figure 9.

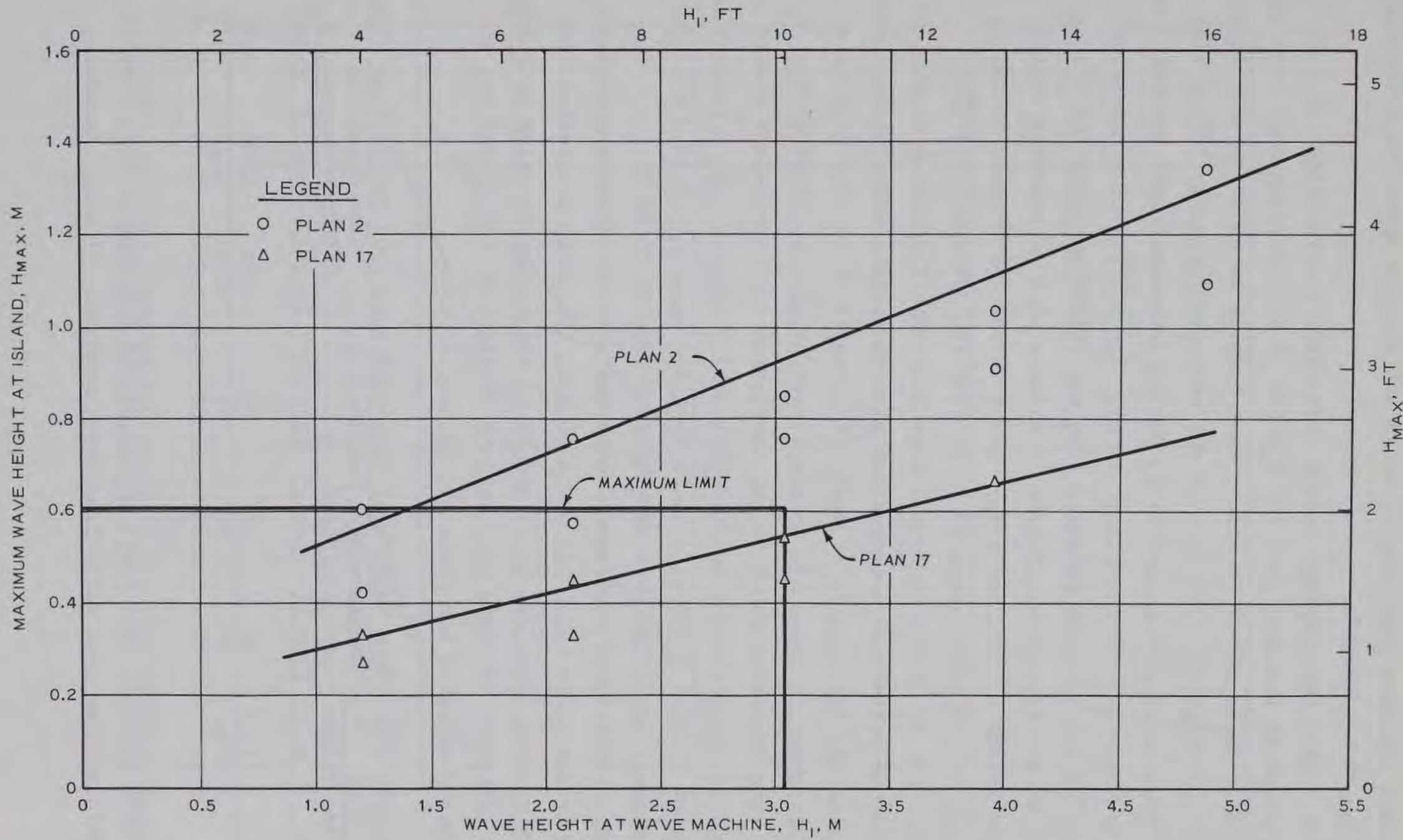


Figure 9. Wave heights at offshore island for Plans 2 and 17 (wave period = 9 sec)

These data indicate that Plan 17 would satisfy the specified wave-height criterion at the island.

40. With the original design installed, a wave height of 1.49 m was measured at the ammo pier for a 9-sec, 2.1-m incident wave from the northeast. In an effort to reduce wave heights to an acceptable level, various modifications were made to the ammo pier causeway (Plans 17A-17I). Results of wave-height tests for the northeast test direction are shown in Table 12. Of the plans tested, Plan 17G (a 400-m extension at an angle of 115 deg (2.0 radians) from sta 10+50) provided the best protection at the ammo pier. Figure 10 shows a plot of causeway length versus wave height at the ammo pier. These curves can be used to select the length of causeway required to provide the desired protection.

41. In an effort to obtain more favorable foundation conditions, the offshore island was extended one-half the island width to the northwest (Plan 18) and results of wave-height tests at various gage locations are shown in Table 13. Maximum wave heights recorded at the island were increased about 30 cm, indicating that the island should not be moved to the northwest unless absolutely necessary from a foundation standpoint. Gages 5 and 6 indicate that moving a full-island width to the northwest would increase wave heights from 30 to 60 m.

42. Additional tests were conducted with the north breakwater curved to the north (Plan 19) and also with the north breakwater completely removed (Plan 20) in an effort to reduce any focusing of energy at the entrance. Maximum wave heights obtained at the island and in the primary entrance for Plans 17, 19, and 20 are:

Northeast Test Wave		Wave Heights at Indicated Locations for Various Plans					
		Maximum Wave Height at Island, cm			Wave Height in Entrance Channel, m		
Period sec	Height m	Plan 17	Plan 19	Plan 20	Plan 17	Plan 19	Plan 20
9	2.1	46	51	60	1.83	2.01	2.52
	3.0	54	67	64	2.44	2.71	3.16
	4.0	67	85	60	2.96	3.84	3.96

These data indicate that Plans 19 and 20 did not improve wave conditions at the island for test waves from the northeast. It was, therefore,

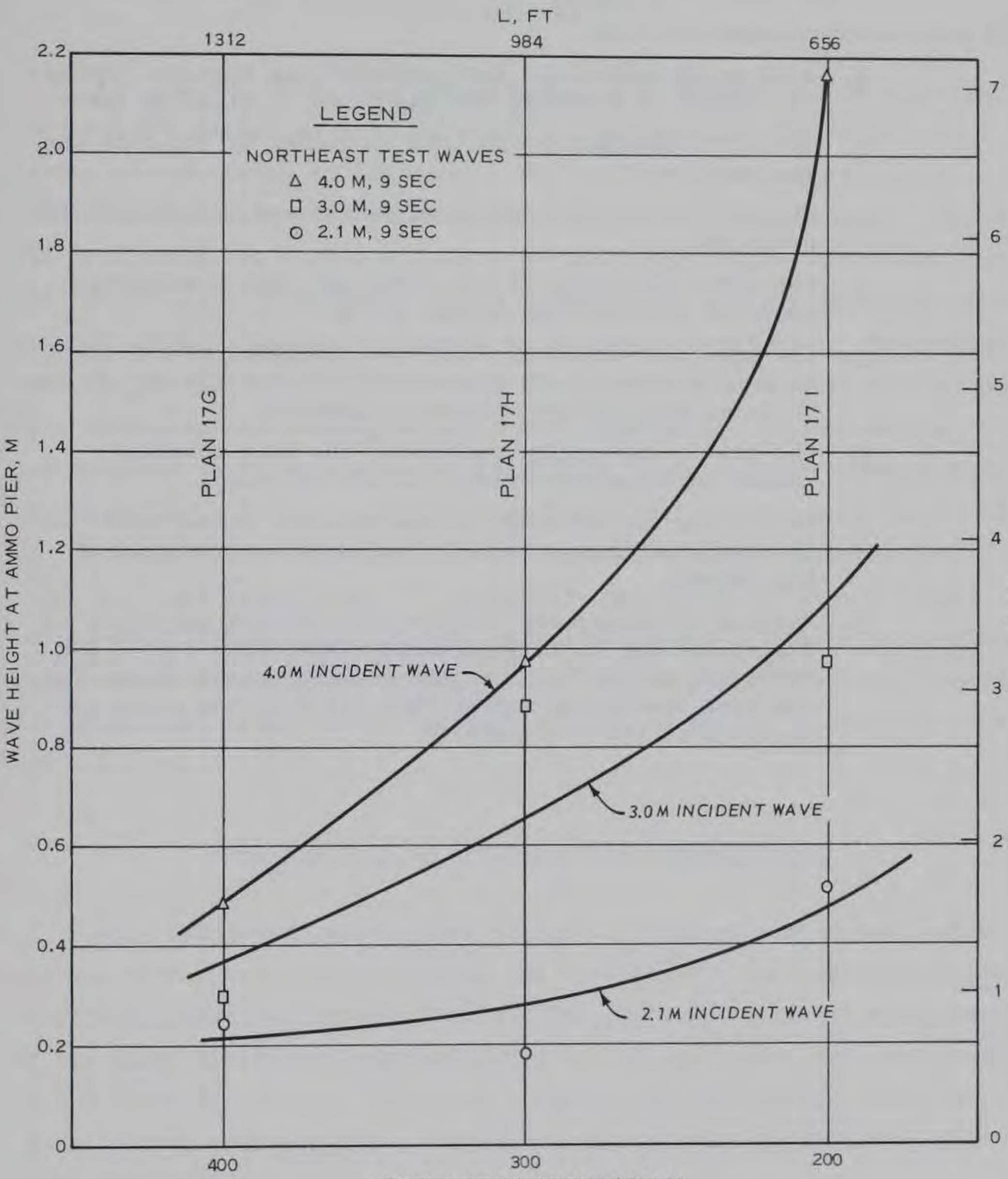


Figure 10. Wave heights at ammo pier for various causeway arm lengths (Plans 17G, 17H, 17I)

concluded that realignment of the north breakwater was not warranted and that Plan 17 would offer the optimum open harbor configuration.

43. In summary, test results for the original harbor layout and its modifications revealed that:

a. A 2V on 3H rock-slope wave absorber was required around the island to minimize the amplitude of standing waves.

b. The north breakwater could be shortened by 300 m at the shoreward end.

c. The east breakwater should be lengthened by 100 m on the north end.

d. The crown elevation of the north and east breakwaters could be reduced from 6.5 to 5.5 m.

e. The ammo pier-causeway should be realigned at sta 10+50 to form a 200- to 400-m outer arm at an angle of 115 deg (2.0 radians) to the original alignment.

f. The bottom topography seaward of the main entrance tended to focus wave energy in the entrance.

g. Relocating the offshore island one-half island width to the northwest substantially increased wave heights at the island.

h. Maximum breaking wave heights (without the structure in place) for the north breakwater varied from 6 m at the shoreward end to 8.3 m at the seaward end and those for the east breakwater varied from 5.9 m at the south end to 8.2 m at the north end.

PART V: TESTS AND RESULTS, ALTERNATE HARBOR CONFIGURATION

Description of Tests

44. In an effort to further reduce wave heights and to minimize construction costs, an alternate harbor configuration (Plate 22) was installed and tested in the model. Basically, the alternate harbor consisted of moving the breakwaters and offshore island closer to shore and realigning the island and piers so that ships would be berthing into the prevailing northwesterly winds. Access to the offshore island would be provided by a landfill causeway at an elevation of +4 m. The island would be protected by a 1050-m-long north breakwater extending from the fill and by an 1100-m-long detached east breakwater. A 1450-m-long causeway and south breakwater would provide access to and protection for the ammo pier. Access to the turning basin and berthing area (-9.15 m) was provided by a 140-m-wide entrance channel (-10.5 m) between the north and east breakwaters. A 120-m-wide secondary entrance (-6.3 m) was located between the south and east breakwaters. Details and various gage locations for the alternate harbor (Plan 21) are shown in Plate 23. All breakwater crown elevations were +5.0 m; an swl of +2.35 m was used for all tests.

Modifications to the Alternate Configuration

45. All modifications were designed to reduce wave energy entering the harbor and minimize costs, and consisted of various inner breakwater configurations, modifications to the primary entrance, realignment of the south breakwater and relocation of the ammo pier, and realignment of the north breakwater. The plan elements are briefly described in the following subparagraphs; dimensional details are presented in the referenced plates.

a. Plan 22 (Plate 24) entailed the installation of a 400-m-long inner breakwater (+5.0 m crown elevation) extending from sta 23+50 on the north breakwater to the intersection of the basin and channel dredge lines.

b. Plan 22A (Plate 24) consisted of elements of Plan 22 with 100 m removed from the end of the inner breakwater.

c. Plan 23 (Plate 25) involved installation of a 600-m-long, straight inner breakwater (+5 m crown elevation), approximately parallel to the north breakwater and adjacent to the basin dredge line.

d. Plan 23A (Plate 25) consisted of elements of Plan 23 with 100 m removed from the channel end of the inner breakwater.

e. Plan 23B (Plate 25) consisted of elements of Plan 23 with 200 m removed from the channel end of the inner breakwater.

f. Plan 23C (Plate 25) consisted of elements of Plan 23 with 300 m removed from the channel end of the inner breakwater.

g. Plan 23D (Plate 26) consisted of elements of Plan 23 with 100 m removed from the island end of the inner breakwater.

h. Plan 23E (Plate 26) consisted of elements of Plan 23 with 200 m removed from the island end of the inner breakwater.

i. Plan 24 (Plate 27) entailed the installation of a 500-m-long inner breakwater (+5.0 m crown elevation) extending from sta 21+50 on the north breakwater to the intersection of the basin and channel dredge lines.

j. Plan 24A (Plate 27) consisted of elements of Plan 24 with 100 m removed from the end of the inner breakwater.

k. Plan 25 (Plate 28) involved realignment of the south breakwater (crown elevation +5.0) to form a 115-deg (2.0 radians) angle at sta 10+00 and relocation of the ammo pier at sta 10+70.

l. Plan 25A (Plate 28) was the same as Plan 25 with 100 m removed from the south breakwater.

m. Plan 25B (Plate 28) was the same as Plan 25 with 200 m removed from the south breakwater.

n. Plan 26 (Plate 29) involved elements of the Plan 22 inner breakwater and the Plan 25 south breakwater with 50 m removed from the north breakwater and 50 m added to the east breakwater at the primary entrance.

o. Plan 26A (Plate 29) was the same as Plan 26 except that the Plan 24 inner breakwater was used.

p. Plan 27 (Plate 30) consisted of the elements of Plan 24 (a 500-m-long inner breakwater) and Plan 25A (a 1350-m-long south breakwater).

q. Plan 28 (Plate 31) consisted of elements of Plan 27 with the island moved 100 m to the northwest.

r. Plan 29 (Plate 32) consisted of elements of Plan 28 with a possible future harbor expansion to the southeast of the offshore island.

s. Plan 30 (Plate 33) consisted of elements of Plan 28 with a possible future harbor expansion to the southeast and northeast of the offshore island.

t. Plan 30A (Plate 33) consisted of elements of Plan 30 with a 1V on 3H seaward slope on the inner breakwater.

u. Plan 30B (Plate 33) consisted of elements of Plan 30 with a 1V on 20H seaward slope on the inner breakwater.

v. Plan 30C (Plate 34) consisted of elements of Plan 30 with a 400-m inner breakwater (Plan 22) with a 1V on 3H seaward slope.

w. Plan 30D (Plate 34) consisted of elements of Plan 30 with no inner breakwater installed.

x. Plan 31 (Plate 35) involved elements of Plan 30A with the primary entrance channel dredging (-10.5 m) extended to the turning basin.

y. Plan 31A (Plate 35) consisted of elements of Plan 31 with 300 m removed from the north breakwater.

z. Plan 32 (Plate 36) consisted of elements of Plan 31 with the north breakwater realigned to the south forming an offset breakwater primary entrance.

aa. Plan 32A (Plate 36) consisted of elements of Plan 32 with an additional 200 m added to the east breakwater parallel to the entrance channel.

46. Wave-height tests for the various improvement plans described above were conducted using test waves from one or more of the directions listed in paragraph 20. As previously stated, tests involving certain improvement plans were limited to the most critical direction of wave approach (in most cases, the northeast deepwater direction). Tests involving some improvement plans were limited to the two most critical directions of wave approach, i.e., the northeast and east-southeast deepwater directions. However, all of the major plans of improvement were tested comprehensively for three test directions, the north, northeast, and east-southeast.

Test Results

47. The relative efficiency of each of the proposed harbor configurations was evaluated on the basis of satisfying the wave-height criteria specified in paragraph 6 and repeated here for convenience:

Location	Incident Test Wave Period sec	Incident Test Wave Height m	Maximum Acceptable Wave Height cm
Front of island	9	3.0	60.0
Floating pier location	9	3.0	30.0
Ammo pier	9	2.1	60.0

Various gage locations for each plan are shown in the corresponding plates.

48. Results of wave-height tests with the basic alternate harbor configuration installed (Plan 21) are shown in Table 14. These data show that a maximum wave height of 3.11 m was recorded at the island for the 9-sec, 4.6-m test wave from east-southeast, and maximum wave heights of 0.79 and 1.19 m were recorded at the island for 9-sec, 3.0-m waves from north and northeast. Wave heights at the floating pier (gage 10) and at the ammo pier (gage 13) also exceeded the specified criteria. Maximum wave heights of 4.39 and 4.11 m were recorded in the entrance channel for 9-sec, 4.0-m test waves and 9-sec, 3.6-m test waves from northeast and east-southeast, respectively. The wave patterns in Photos 19-24 show a considerable amount of wave energy being diffracted through the primary entrance toward the offshore island. Overtopping of the north and east breakwaters was observed for the larger test waves. These data indicated that some type of inner breakwater was needed to reduce wave heights at the island.

49. Table 15 shows results of wave-height tests for a 400-m (Plan 22) and a 300-m (Plan 22A) inner breakwater with a +5.0 m crown elevation. Maximum wave heights of 58 and 73 cm were recorded at the island for a 9-sec and 3-m (or smaller) incident wave with Plans 22 and 22A installed. Wave heights of 40 cm (slightly exceeding the 30-cm criterion) were recorded at the floating pier with Plan 22 installed.

Photos 25 and 26 show wave patterns in the harbor for Plans 22 and 22A.

50. Results of wave-height tests with various lengths of a detached inner breakwater (Plans 23-23E) approximately parallel to the north breakwater and adjacent to the basin dredge line are presented in Tables 16 and 17. Maximum wave heights obtained at the front of the island and at the floating pier for incident waves of 3.0 m or less were:

Plan	Maximum Wave Height at Island cm	Maximum Wave Height at Floating Pier cm
23	55	61
23A	58	76
23B	64	52
23C	116	46
23D	67	67
23E	70	64

Photos 27-32 show wave patterns obtained with Plans 23-23E installed for 9-sec, 4-m incident waves from the northeast.

51. Typical wave patterns obtained for a 500-m (Plan 24) and a 400-m (Plan 24A) inner breakwater extending from sta 21+50 on the north breakwater to the intersection of the basin and channel dredge lines are shown in Photos 33 and 34. Results of wave-height tests with Plans 24 and 24A installed are presented in Table 18. For a 9-sec, 3-m incident wave, maximum wave heights of 58 and 88 cm, respectively, were recorded at the island and a maximum wave height of 36 cm was recorded at the floating pier for both plans.

52. In an effort to reduce wave heights at the ammo pier, the south breakwater was realigned and the ammo pier relocated (Plan 25). The total length of the south breakwater was 1450 m: the first 1070 m was a causeway; the last 380 m, a rubble-mound breakwater. Results of wave-height tests for this configuration and for 100-m (Plan 25A) and 200-m (Plan 25B) reductions in length of the south breakwater are presented in Tables 19-21. The maximum wave heights recorded at the ammo pier for 9-sec, 2.1-m incident waves were 55, 60, and 67 cm for Plans 25, 25A, and 25B, respectively.

53. In an effort to improve wave conditions at the island, the length of the east breakwater was increased by 50 m and the length of the north breakwater was reduced by 50 m (at the primary entrance). Table 22 shows wave heights obtained at various gage locations with Plans 26 (400-m-long inner breakwater) and 26A (500-m-long inner breakwater) installed. Maximum wave heights of 61 and 82 cm at the island, and 3.26 and 4.08 m in the entrance channel, were recorded for a 9-sec, 3-m incident wave with Plans 26 and 26A installed.

54. Since the revised entrance (Plans 26 and 26A) did not improve wave conditions at the island, the original entrance was reinstalled, along with the Plan 24 inner breakwater and the Plan 25A south breakwater. This configuration was designated Plan 27 and wave heights obtained at various gage locations are shown in Table 23. The maximum wave height at the front of the island for a 9-sec, 3-m test wave from any test direction was 55 cm; the maximum wave height at the floating pier was 43 cm. Average wave heights at the island for various 9-sec test waves are shown in the following tabulation:

Test Wave Height m	Average Wave Heights, cm at the Island for Test Directions		
	North	Northeast	East-Southeast
1.2	15	24	
1.8			26
2.1	30	38	
2.7			42
3.0	43	41	
3.6			59
4.0	57	58	
4.6			92
4.9	54	76	

55. Photos 35-40 show wave patterns obtained with Plan 27 installed. Photo 38 shows a typical wave-induced current pattern. Current velocities induced by waves were appreciable only in the primary and secondary entrances, and the magnitudes for various test waves are as follows:

Test Direction	Test Wave Period, sec	Test Wave Height, m	Maximum Velocity (Prototype), m/sec Primary Entrance	Maximum Velocity (Prototype), m/sec Secondary Entrance
North	7	1.8	<0.15	0.30
	9	2.1	0.33	<0.15
	9	4.0	0.42	0.42
	11	3.0	0.27	0.42
Northeast	7	2.4	<0.15	0.21
	9	2.1	<0.15	<0.15
	9	4.0	0.36	0.45
	11	3.0	0.36	<0.15
East-southeast	7	3.4	0.30	0.24
	9	1.8	<0.15	<0.15
	9	3.6	0.51	0.30
	11	2.7	0.18	0.18

56. In an effort to further improve wave conditions at the offshore island, the entire island complex was moved 100 m to the northwest (Plan 28); resulting wave heights obtained at various gage locations are shown in Table 24. The maximum wave height recorded at the offshore island for a 9-sec, 3.0-m test wave was 51 cm. Some overtopping of the north breakwater was observed and a maximum wave height of 39 cm was recorded at the floating pier for a 9-sec, 3.0-m incident wave from the north. Wave patterns obtained with Plan 28 installed are shown in Photos 41-49.

57. Wave heights obtained with a possible future harbor expansion to the southwest of the offshore island (Plan 29) are presented in Table 25. In general, this plan resulted in increased wave heights at the island (i.e., the 9-sec, 2.7-m test wave from east-southeast resulted in a maximum wave height of 73 cm relative to 45 cm for Plan 28), and concentrations of wave energy were noted along the shoreward landfill wall. Wave patterns obtained with Plan 29 installed are shown in Photos 50 and 51.

58. It was felt that a more favorable future harbor expansion might be to the northeast of the offshore island. Therefore, about half of the proposed future landfill was located in this area (Plan 30); resulting wave heights are presented in Table 26. These data show that

Plan 30 offers a much better future expansion than did Plan 29. In an effort to determine if flattening the inner breakwater slope would decrease the peaking and breaking wave condition in the entrance channel, wave heights were obtained with the inner breakwater seaward slope flattened to 1V on 3H (Plan 30A) and to 1V on 20H (Plan 30B); these data are presented in Tables 27 and 28. Four additional gages (gages 2, 3, 5, and 6) were installed in the entrance channel for these tests. For an 11-sec, 4.9-m incident wave, maximum wave heights of 7.97, 8.05, and 7.16 m were recorded in the channel for Plans 30, 30A and 30B, respectively. These data, plus visual observations, indicate that flattening the inner breakwater slopes had little effect on entrance wave heights. Maximum wave heights at the island for a 9-sec, 3.0-m test wave were 61, 58, and 58 cm with Plans 30, 30A, and 30B installed, respectively. Wave heights still exceeded the criterion of 30 cm at the floating pier for these plans. Photo 52 illustrates typical wave patterns obtained with Plan 30B installed.

59. Since flattening the seaward slope of the inner breakwater did not significantly reduce peaking and breaking waves in the entrance channel, additional wave gages were installed to better define wave conditions, and tests were conducted with a 500-m inner breakwater (Plan 30A), a 400-m inner breakwater (Plan 30C), no inner breakwater (Plan 30D), the -10.5 m channel dredging extended (Plan 31), and 300 m of the north breakwater removed (Plan 31A). It was specified that wave heights in the channel should not exceed 1.2 times the incident test wave. The new ADACS described in paragraph 14 was used during these tests; the results are presented in Table 29. Maximum wave heights obtained in the channel (gages 1-2C) and the ratios of maximum (H_{max}) to incident (H_i) wave height for a 9-sec, 4-m incident wave were as follows:

Plan	H_{max} m	H_{max}/H_i
30A	4.8	1.20
30C	4.6	1.15

(Continued)

Plan	H_{max} m	H_{max}/H_i
30D	4.8	1.20
31	4.7	1.18
31A	5.1	1.28

Maximum wave heights obtained at the offshore island for a 9-sec, 3-m incident wave were 55, 70, 101, 58, and 55 cm for Plans 30A, 30C, 30D, 31, and 31A, respectively. These data indicate that Plans 30A and 31 were the only plans that satisfied both wave-height criteria: (a) Wave heights in the channel are not to exceed 1.2 times the incident wave heights, and (b) maximum wave heights at the island are not to exceed 60 cm for a 9-sec, 3-m incident wave. Extending the -10.5 m channel dredging (Plan 31) did not significantly affect wave heights in the harbor. Removing the outer 300 m of the north breakwater (Plan 31A) increased maximum entrance channel wave heights about 30 cm and did not significantly increase wave heights at the island.

60. In an effort to improve entrance conditions and reduce construction costs, the inner breakwater was removed and the north breakwater was relocated to form an offset breakwater entrance (Plan 32). This plan also was tested with a 200-m extension to the east breakwater, parallel to the entrance channel (Plan 32A). Wave heights obtained at various wave gage locations with Plans 32 and 32A installed are presented in Table 30. Maximum channel wave heights for a 9-sec, 4-m wave were 5.1 and 4.9 m, and maximum wave heights at the island for a 9-sec, 3-m wave were 70 cm for both plans (slightly exceeding the 60-cm criterion). Typical wave patterns for Plans 32 and 32A are shown in Photos 53 and 54, respectively.

61. Maximum wave heights along the center lines of all alternate harbor breakwaters without the structures in place were obtained for 9-sec test waves from the north, northeast, and east-southeast test directions. Wave gage locations are shown in Plate 37 and the recorded wave heights are presented in Table 31. As discussed in paragraph 21, all nonbreaking wave heights measured in the model were adjusted to compensate for attenuation due to viscous friction at the bottom (i.e., the

measured value multiplied by the attenuation factor equals the adjusted value). However, this procedure cannot be applied to breaking waves because the adjusted value would be higher than the possible wave height due to either depth or wave-steepness limitations. In such cases, the measured value was recorded and the incident wave height was adjusted by the attenuation factor (i.e., the incident wave height H_i was divided by the attenuation factor, k_f, or H_i/k_f = adjusted incident wave height). Since the purpose of the present tests was to obtain maximum breaking wave heights, the values shown in Table 30 are the actual measured values, and the incident wave height shown in the first column can be divided by the attenuation factor for a given gage to obtain the adjusted incident wave height for that gage. Maximum wave heights recorded for various adjusted incident wave heights from all test directions for the north, east, and south breakwaters are shown in Plate 38. By using the refraction and shoaling coefficients in Appendix A, the data in Plate 38 can be related back to deepwater values, and a frequency of occurrence can be estimated.

Discussion of Test Results

62. Test results of the basic alternate harbor configuration (Plan 21) indicated that excessive wave energy entered the harbor through the primary entrance and wave heights exceeded the wave-height criteria at all locations (i.e. in front of the island, at the floating pier, and at the ammo pier).

63. Of the various inner breakwaters tested, Plans 22 and 24 were the most promising. A graphical comparison of maximum wave heights at the island for these plans is shown in Figure 11. It can be seen that Plan 24 offers more protection (particularly for the larger wave heights); this plan was selected as the optimum inner breakwater.

64. Since wave heights at the original ammo pier location significantly exceeded the specified criterion of 60 cm for a 2.1-m incident wave, the south breakwater was realigned and the ammo pier relocated in the lee of this structure (Plan 25). A comparison of data for different

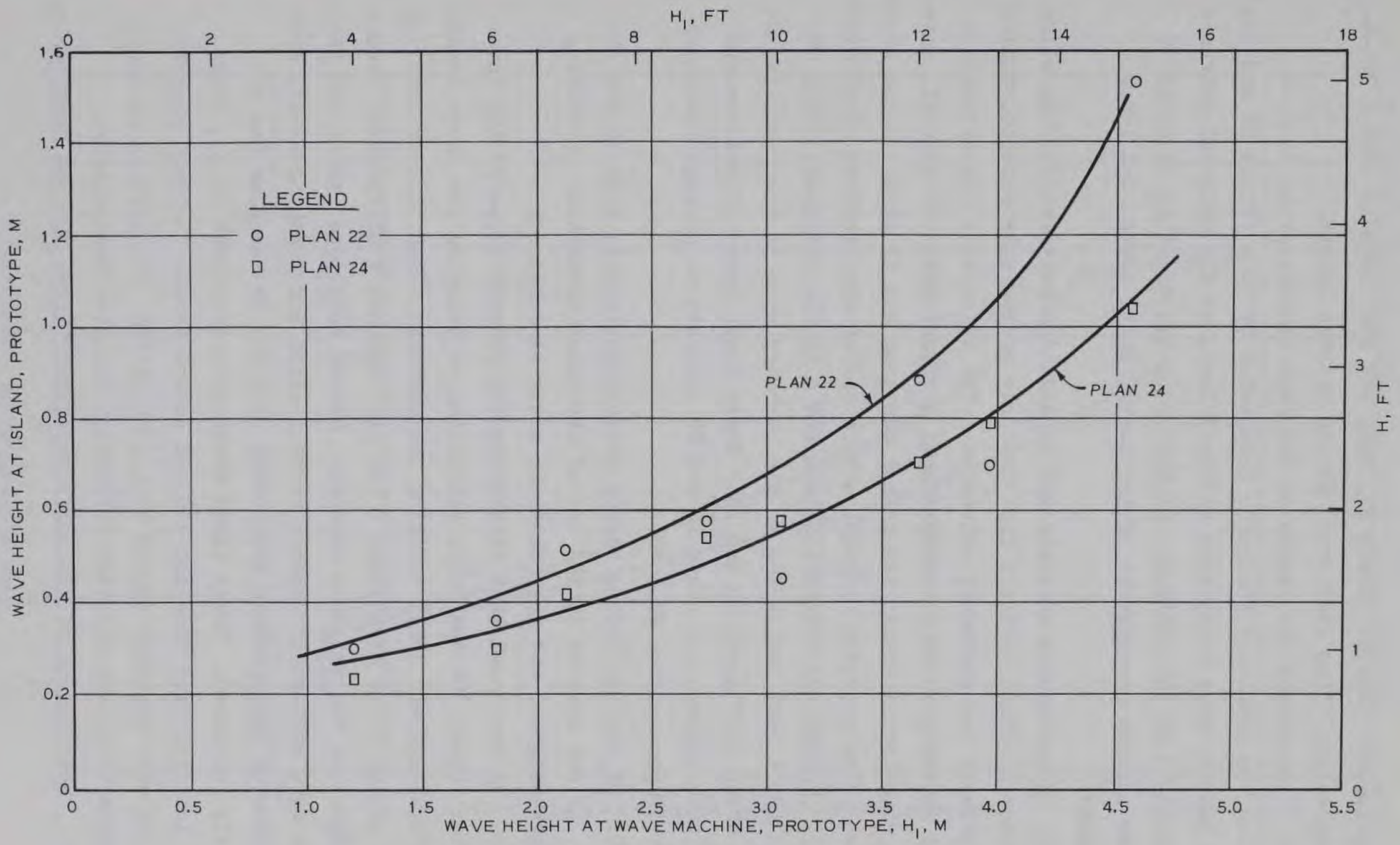


Figure 11. Maximum wave heights (9-sec period) at offshore island for Plans 22 and 24

south breakwater lengths (Plans 25, 25A, and 25B) reveals that a 300-m-long seaward arm (Plan 25A) would be the optimum length.

65. Increasing the length of the east breakwater by 50 m and decreasing the length of the north breakwater by 50 m (Plans 26 and 26A) did not improve wave conditions at the island, so the original entrance was assumed to be the optimum. Of the plans tested, Plan 27 appeared to be the optimum arrangement of the north, east, south, and inner breakwaters.

66. Wave-induced currents and circulation patterns for the alternate harbor location indicate that the only appreciable velocities were in the primary and secondary entrances. The relatively low velocities obtained should present no navigational difficulties. In general, wave-induced circulation inside the harbor was poor and flushing of the harbor will have to be provided by tidal action and/or wind-induced circulation.

67. Moving the offshore island 100 m to the northwest (Plan 28) provided additional sheltering to the berthing area in front of the island as shown in Figures 12 and 13. These comparisons of maximum and average wave heights for Plans 27 and 28 indicate an average reduction of about 10 percent for Plan 28.

68. Of the two future harbor expansions tested, Plan 30 was the better. It was located in the lee of the inner breakwater (resulting in lower wave heights) and less dredging would be required.

69. It was found that flattening the seaward slope of the inner breakwater (Plans 30A and 30B), relocating or removing the inner breakwater (Plans 30C and 30D), dredging the entrance (Plan 31), or removing the end of the north breakwater (Plan 31A) did not significantly reduce wave heights in the entrance channel. Use of additional gages and the ADACS to more accurately measure these peaking and breaking waves, however, revealed that maximum magnitudes were not as large as had been originally indicated. These large waves were transient (i.e., they changed location with time and did not extend across the full channel width) and were probably caused by a combination of refraction, shoaling, diffraction, and possibly reflection from the breakwaters.

70. Realignment of the north breakwater (Plan 32) and lengthening

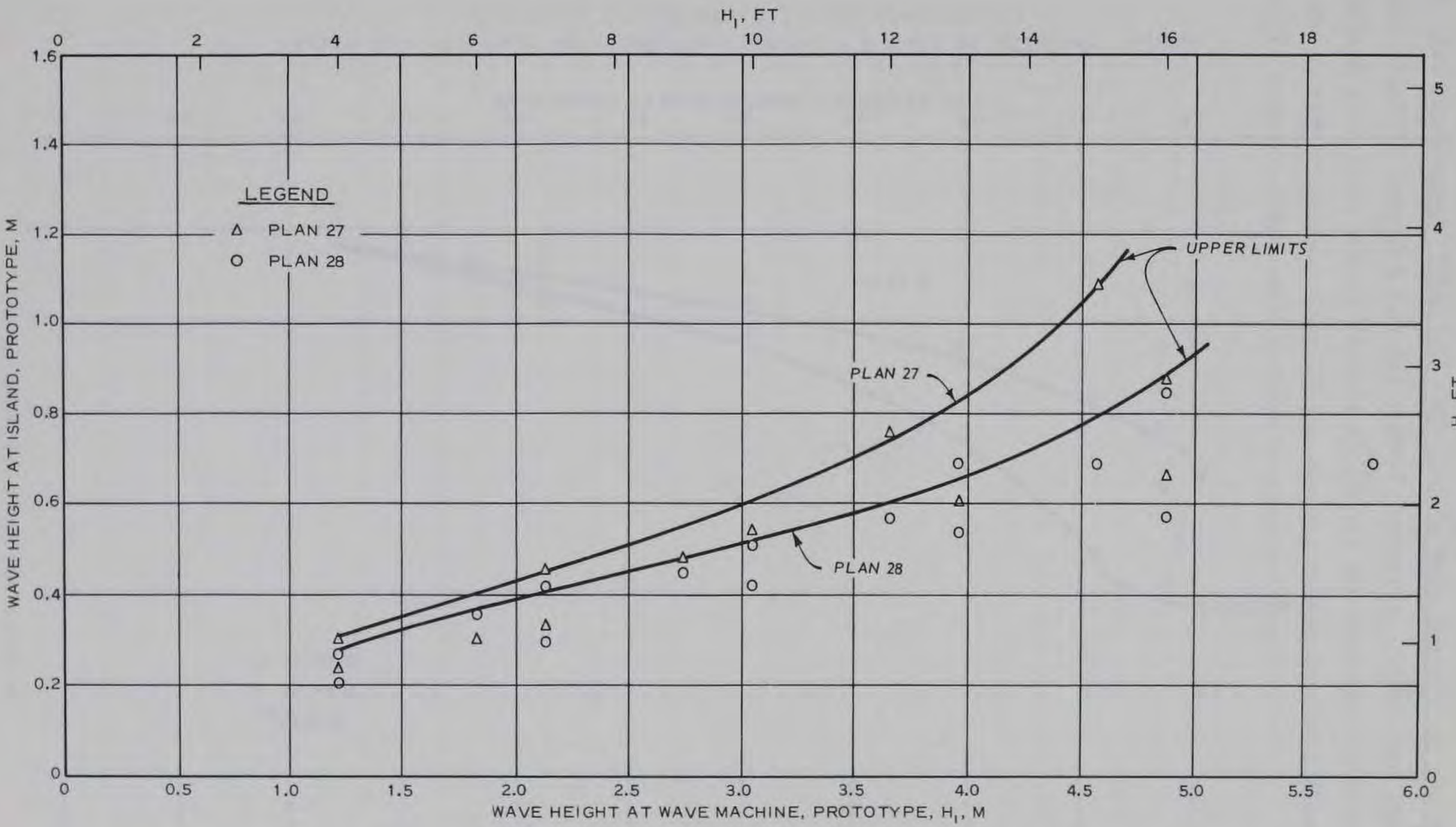


Figure 12. Maximum wave heights (period = 9 sec) at offshore island for Plans 27 and 28 (all test directions)

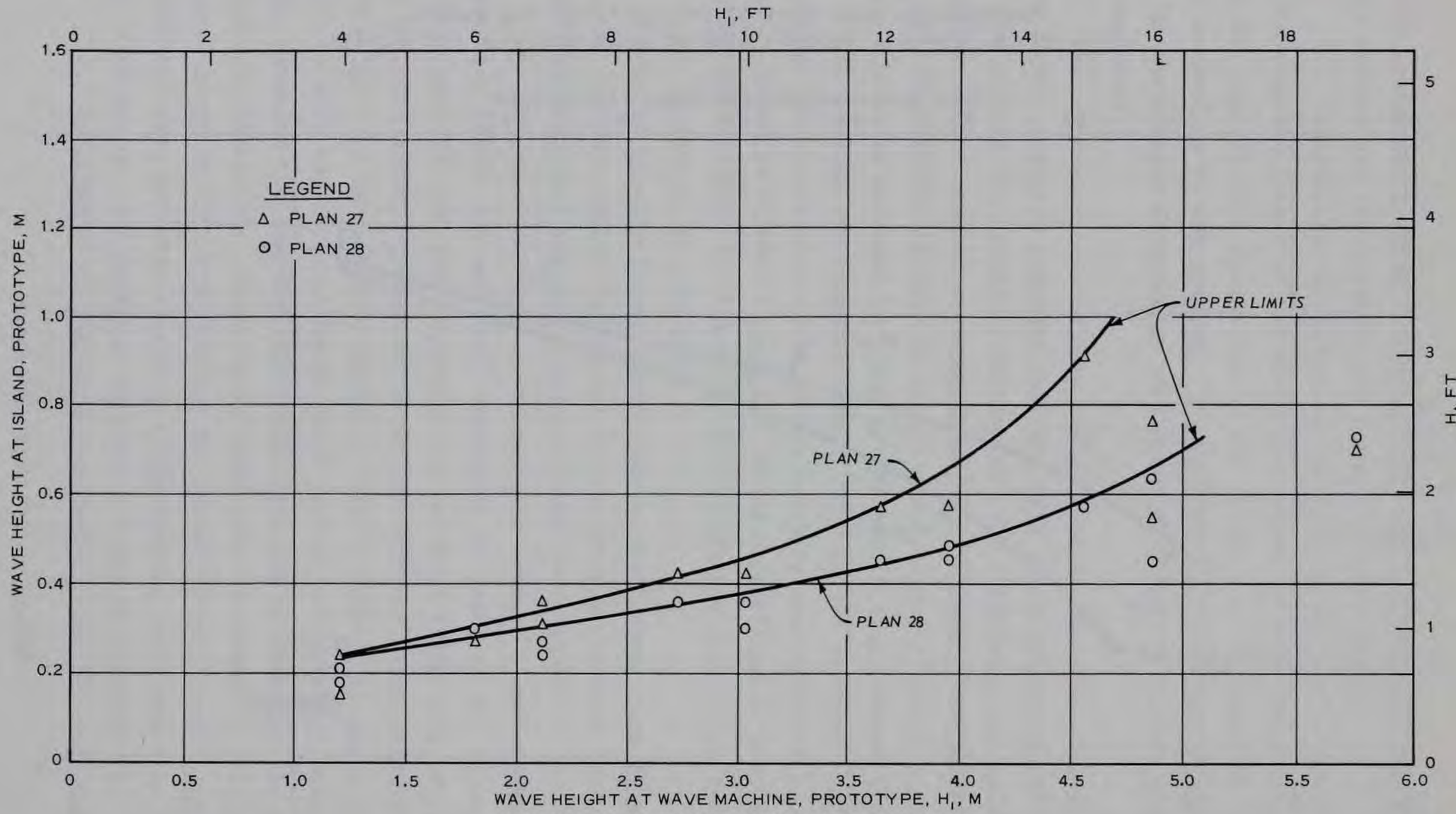


Figure 13. Average wave heights (period = 9 sec) at offshore island for Plans 27 and 28 (all test directions)

the east breakwater (Plan 32A) resulted in wave heights at the island which slightly exceeded the designated criterion. These two plans are compared with Plan 30A in Figures 14 and 15 for maximum and average wave heights, respectively. Plan 30A is clearly better but both Plans 32 and 32A require substantially less breakwater length.

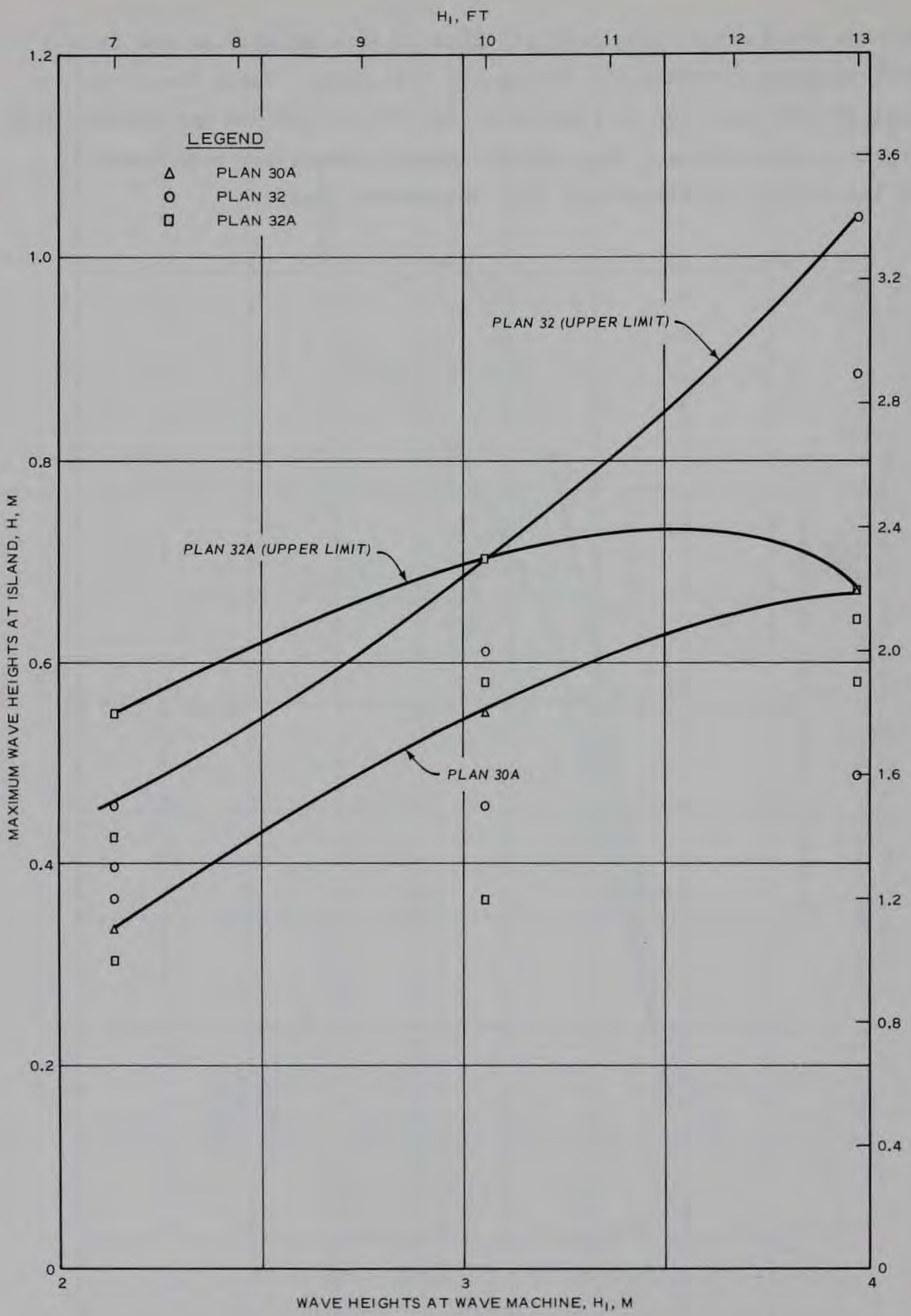


Figure 14. Maximum wave heights (period = 9 sec) at the offshore island for Plans 30A, 32, and 32A (all test directions)

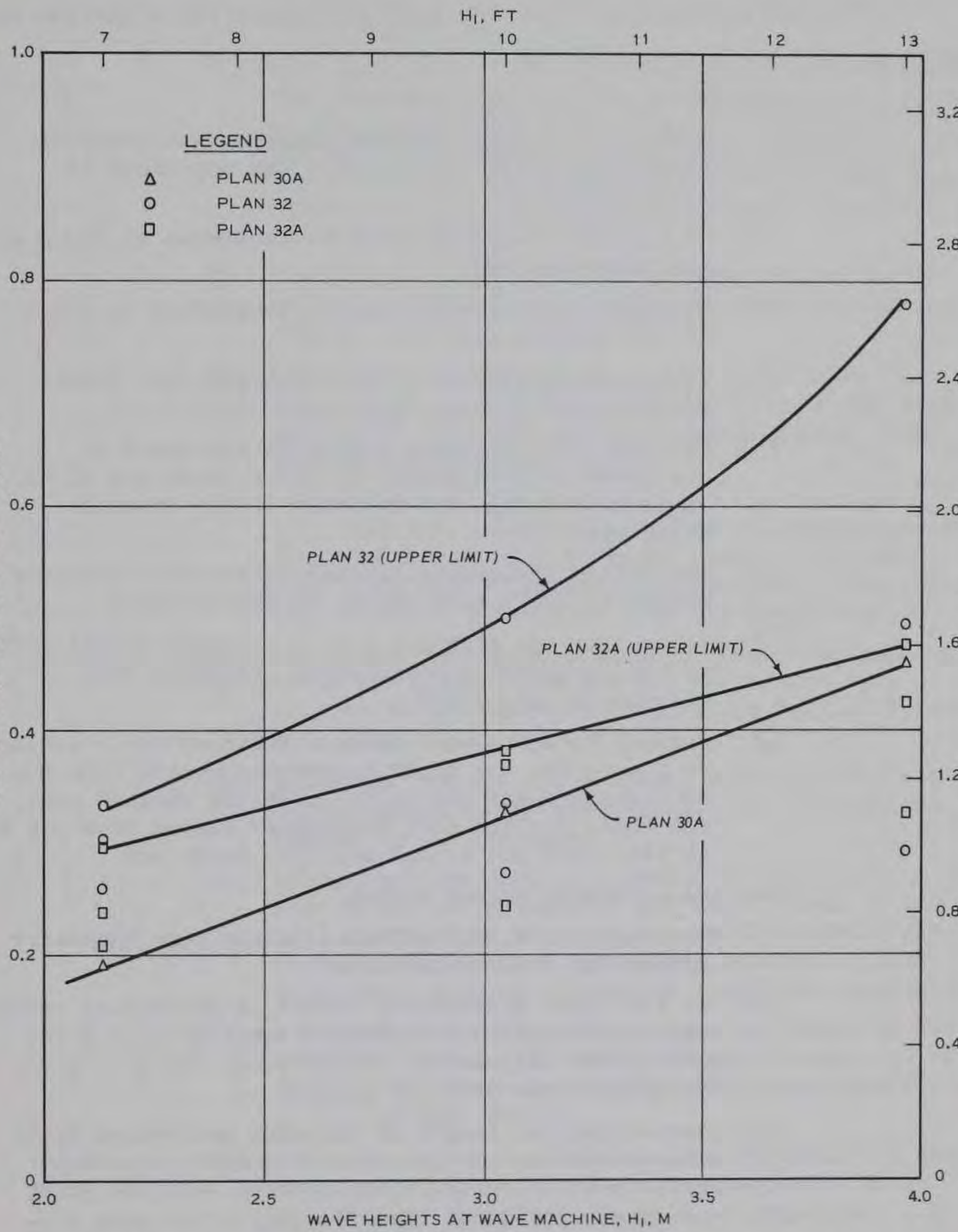


Figure 15. Average wave heights (period = 9 sec) at the offshore island for Plans 30A, 32, and 32A (all test directions)

PART VI: CONCLUSIONS

71. Based on the results of the hydraulic model investigation reported herein, it is concluded that:

a. For the original harbor layout:

(1) A 2V on 3H rock-slope wave absorber was required around the island to minimize the amplitude of standing waves.

(2) The north breakwater could be shortened by 300 m at the shoreward end.

(3) The east breakwater should be lengthened by 100 m on the north end.

(4) The crown elevation of the north and east breakwaters could be reduced from 6.5 to 5.5 m.

(5) The ammo pier causeway should be realigned at sta 10+50 to form a 200- to 400-m outer arm at an angle of 115 deg (2.0 radians) to the original alignment.

(6) The bottom topography seaward of the main entrance tended to focus wave energy in the entrance.

(7) Relocating the offshore island one-half island width to the northwest substantially increased wave heights at the island.

(8) Maximum breaking wave heights (without the structure in place) for the north breakwater varied from 6 m at the shoreward end to 8.3 m at the seaward end, and those for the east breakwater varied from 5.9 m at the south end to 8.2 m at the north end.

b. For the alternate harbor layout:

(1) Wave heights at the offshore island were excessive without an inner breakwater.

(2) Of the inner breakwaters tested, a 500-m-long structure connected to the north breakwater at a point 350 m from the seaward end provided the best protection to the offshore island.

(3) Increasing the length of the east breakwater by 50 m and decreasing the length of the north breakwater by 50 m (to provide better overlap with the inner breakwater) did not significantly alter wave conditions at the island.

(4) Moving the offshore island 100 m to the northwest reduced wave heights at the island about 10 percent.

(5) The length of the south breakwater could be reduced 100 m by realigning the outer arm to form an angle of 115 deg (2.0 radians) at sta 10+00 and relocating the ammo pier at sta 10+70.

(6) Wave heights at the floating pier location exceeded the desired wave-height criterion due to overtopping of the north breakwater. However, large-scale two-dimensional flume tests conducted in connection with the breakwater stability model indicated that the overtopping might not be as serious as indicated in the three-dimensional model.

(7) Maximum wave-induced currents measured in the entrance channels should not cause serious navigational problems.

(8) Wave-induced circulation in the harbor area was poor, indicating that flushing of the harbor will have to be provided by tidal action and/or wind-induced circulation.

(9) Large peaking and spilling waves (up to about 1.2 times the incident height at the wave generator) occurred in the main entrance channel for some test waves due to refraction, shoaling, diffraction, and possibly reflections from the breakwaters.

(10) Flattening the seaward slope of the inner breakwater to 1V on 3H and 1V on 20H did not reduce wave heights in the entrance channel and had little effect on waves at the island.

(11) Extending the -10.5 m dredging southward did not significantly alter wave heights in the entrance channel or at the island.

(12) Relocating the north breakwater to the south to form an offset breakwater entrance (Plans 32 and 32A) resulted in wave heights which slightly exceeded the specified criterion; however, a substantially shorter breakwater length was required.

(13) A future harbor expansion to the southwest of the offshore island will result in wave heights in excess of the desired criterion (60 cm maximum for a 3.0-m incident wave).

(14) A future harbor expansion to the northeast of the offshore island will result in acceptable wave heights and less dredging will be required.

(15) Maximum breaking wave heights for the north, east, and south breakwaters were 6.4, 5.9, and 3.5 m, respectively.

REFERENCES

1. Stevens, J. C. et al., "Hydraulic Models," Manuals of Engineering Practice No. 25, 1942, American Society of Civil Engineers, New York.

2. LeMéhaute, B., "Wave Absorbers in Harbors," Contract Report No. 2-122, Jun 1965, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.; prepared by National Engineering Science Co., Pasadena, Calif., under Contract No. DA-22-079-CIVENG-64-81.

3. U. S. Army Engineer Division, Mediterranean, "Coastal and Waterfront Surveys at Jubail," Report No. 2, Apr 1973, Livorno, Italy.

4. Wiegel, R. L., "Gravity Waves; Tables of Functions," 1954, Engineering Foundation, Council on Wave Research, Berkeley, Calif.

5. Keulegan, G. H., "The Gradual Damping of a Progressive Oscillatory Wave with Distance in a Prismatic Rectangular Channel" (unpublished), May 1950, National Bureau of Standards, Washington, D. C.

6. Dobson, R. S., Some Applications of a Digital Computer to Hydraulic Engineering Problems, M.S. Thesis, Stanford University, Stanford, Calif., 1967.

7. Whalin, R. W., "The Limit of Applicability of Linear Wave Refraction Theory in a Convergence Zone," Research Report H-71-3, Dec 1971, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

8. Bretschneider, C. L., "Revisions in Wave Forecasting: Deep and Shallow Water," Look Lab Quarterly, Vol 1, No. 3, Jul 1970, Look Laboratory, University of Hawaii, Honolulu, Hawaii.

Table 1

Wave Heights with Plan 1 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northeast	7	1.50	1.86	1.25	1.58	1.68	2.13	--	1.28	1.04	0.70	--	0.52	0.52	0.52	0.46	--
		2.40	2.86	1.74	2.32	2.38	2.92	--	1.77	1.19	0.58	--	0.49	0.79	0.79	0.55	--
		3.40	3.87	2.13	2.83	2.74	3.44	--	2.16	1.34	0.70	0.43	0.73	0.79	0.91	0.49	--
	9	1.20	1.62	1.25	1.31	2.10	1.46	--	0.98	1.13	0.73	--	0.36	0.58	0.46	0.52	--
		2.10	2.90	2.10	2.44	3.11	2.53	--	1.04	1.19	0.70	--	0.36	0.64	0.52	0.58	--
		3.00	3.87	2.86	3.84	4.08	3.75	--	1.10	1.34	0.64	--	0.49	0.70	0.82	0.79	--
		4.00	4.60	3.93	4.85	7.38	4.94	--	1.46	1.58	0.79	0.61	0.52	1.31	1.16	0.82	--
		4.90	5.33	4.21	5.24	8.32	5.97	--	1.77	1.77	1.13	0.61	0.79	1.31	1.40	0.70	--
		5.80	5.55	5.00	6.49	7.19	6.98	--	2.38	2.22	1.28	0.64	0.98	1.83	1.92	0.82	--
	11	1.20	1.52	0.98	0.85	1.31	1.28	--	0.64	0.85	0.46	0.30	0.27	0.55	0.67	0.52	--
		2.10	2.68	1.55	1.46	2.04	2.50	--	0.91	0.91	0.36	0.40	0.34	0.73	0.98	0.52	--
		3.00	3.66	2.86	2.13	3.63	3.20	--	0.79	1.04	0.46	0.49	0.43	0.91	1.10	0.73	--
		4.00	4.66	3.29	3.05	6.22	4.08	--	1.37	1.43	0.79	0.52	0.67	1.19	1.34	0.88	--
		4.90	5.97	4.88	3.69	5.61	5.79	--	2.01	2.01	1.31	0.52	1.07	1.46	1.77	0.82	--

Table 2

Wave Heights with Plan 2 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters: Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northwest	7	0.90	0.15	0.09	--	--	0.46	0.58	0.15	0.30	0.21	--	0.43	0.24	0.18	0.27	--
		1.20	0.18	0.18	--	--	0.30	0.91	0.21	0.30	0.24	--	0.52	0.24	0.15	0.27	--
		1.80	0.12	0.15	--	--	0.55	1.34	0.34	0.36	0.27	--	0.61	0.36	0.24	0.34	--
North	7	0.90	0.94	0.70	1.16	--	0.73	0.52	0.34	0.21	0.27	0.18	0.18	0.64	0.30	0.40	--
		1.80	1.40	1.13	1.80	--	1.40	0.85	0.52	0.21	0.34	0.21	0.21	0.98	0.36	0.52	--
		2.70	2.13	1.40	2.56	--	2.26	1.92	0.58	0.34	0.36	0.24	0.21	1.22	0.34	0.46	--
	9	1.20	0.82	1.00	0.98	--	1.74	0.76	0.40	0.36	0.43	0.24	--	0.82	0.46	0.40	--
		2.10	1.52	1.55	1.74	--	3.17	1.10	0.52	0.40	0.58	0.34	--	1.13	0.55	0.52	--
		3.00	2.28	2.22	2.77	--	5.24	1.74	0.55	0.58	0.76	0.43	0.24	1.31	0.70	0.43	--
		4.00	2.56	2.62	3.69	--	6.34	2.90	0.58	0.58	0.91	0.40	0.30	1.52	0.88	0.52	--
		4.90	4.18	2.41	5.21	--	8.35	3.20	0.64	0.76	1.10	0.49	0.46	1.77	1.07	0.64	--
	11	1.20	1.07	0.70	0.49	--	1.55	0.43	0.24	0.24	0.15	0.12	--	0.98	0.30	0.27	--
		2.10	2.01	1.34	0.76	--	3.54	1.00	0.36	0.36	0.21	0.24	--	1.46	0.40	0.40	--
		3.00	3.08	1.95	1.25	--	5.42	2.77	0.40	0.46	0.27	0.27	0.15	1.74	0.49	0.49	--
		4.00	3.50	2.50	1.83	--	5.33	2.80	0.49	0.49	0.34	0.34	0.18	2.10	0.61	0.52	--
		4.90	4.45	2.96	2.90	--	6.46	2.65	0.55	0.61	0.55	0.43	0.24	2.47	0.85	0.79	--
Northeast	7	1.50	1.89	1.52	1.80	1.71	1.98	--	0.30	0.64	0.64	--	0.70	0.64	0.58	0.58	1.07
		2.40	3.20	2.44	2.96	2.80	3.05	--	0.46	0.64	0.55	--	0.67	1.00	0.64	0.61	2.41
		3.40	3.81	2.71	3.81	3.44	3.66	--	0.49	0.76	0.70	--	0.67	1.16	0.85	0.49	2.56
	9	1.20	1.95	1.40	1.77	1.80	1.46	--	0.43	0.55	0.61	0.43	0.61	0.52	0.67	0.52	1.40
		2.10	3.23	2.44	2.80	3.29	2.44	--	0.58	0.76	0.64	0.64	0.55	0.94	0.64	0.61	1.49
		3.00	4.05	3.29	3.69	4.02	4.11	--	0.85	0.76	0.61	0.76	0.61	1.22	0.73	0.76	2.74
		4.00	5.18	4.33	5.52	7.28	4.91	--	1.04	1.00	0.82	0.64	1.04	1.40	0.98	1.37	4.48
		4.90	6.89	4.88	6.46	7.62	6.03	--	1.34	1.28	0.94	0.98	1.16	2.01	1.07	1.13	3.96
		5.80	8.41	5.97	8.05	6.89	6.98	--	1.46	1.52	0.73	1.40	0.88	2.01	1.31	1.07	2.83
	11	1.20	1.43	1.25	1.19	1.10	1.22	--	0.49	0.76	0.58	0.40	0.64	0.70	0.73	0.52	1.00
		2.10	2.74	2.22	2.26	2.32	2.32	--	0.58	1.00	0.67	0.76	0.70	0.91	1.07	0.88	2.10
		3.00	5.24	3.66	4.42	4.66	3.75	--	0.64	1.19	0.52	0.67	0.76	1.58	0.91	0.88	3.54
		4.00	6.13	4.24	5.21	5.64	5.18	--	1.00	1.40	0.85	0.88	1.04	1.86	1.22	1.25	3.69
		4.90	7.31	5.39	6.89	6.40	7.25	--	1.46	1.68	0.79	0.85	0.91	1.92	1.62	1.10	3.78
Southeast	7	0.90	0.15	0.30	0.30	0.73	--	--	0.21	0.27	0.34	0.27	--	--	--	0.34	0.67
		1.20	0.27	0.36	0.43	1.00	--	--	0.27	0.36	0.40	0.73	--	0.18	0.21	0.55	1.07
		2.10	0.49	0.49	0.64	1.68	--	--	0.55	0.73	1.13	0.94	--	0.30	0.55	1.49	1.64

Table 3

Wave Heights with Plans 3 and 4 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 3										
Northeast	9	1.20	1.64	1.19	1.58	1.71	1.62	--	0.70	0.79	0.73	--	--	0.79	0.94	0.76	--
		2.10	2.83	2.13	3.08	2.74	2.71	--	0.94	0.85	0.64	--	0.76	1.19	0.76	0.94	--
		3.00	3.84	2.86	4.18	3.66	4.02	--	1.13	1.07	0.58	0.76	0.76	1.68	0.76	0.85	--
		4.00	4.91	3.66	5.18	5.55	5.52	--	1.04	1.13	0.64	0.85	0.76	2.38	0.76	1.10	--
		4.90	5.82	4.54	7.01	6.77	6.43	--	1.46	1.49	0.82	0.94	0.91	3.17	1.10	1.22	--
		5.80	7.59	5.33	8.84	5.33	7.01	--	1.25	1.49	0.98	1.22	1.07	4.42	1.46	1.28	--
							Plan 4										
Northeast	9	1.20	1.74	1.28	1.77	1.92	1.83	--	0.49	0.98	0.61	--	0.67	1.22	0.61	0.67	--
		2.10	3.05	1.95	3.02	3.35	3.23	--	0.76	1.22	0.61	0.64	0.79	1.86	0.61	0.94	--
		3.00	4.27	2.80	4.94	4.30	3.17	--	0.98	1.40	0.61	0.73	1.00	2.68	0.85	1.04	--
		4.00	5.27	4.02	5.46	6.67	5.97	--	1.13	1.40	0.67	0.76	0.85	3.66	0.85	1.10	--
		4.90	6.10	4.57	7.31	8.05	6.64	--	1.64	1.40	0.79	0.94	0.79	5.03	1.46	0.94	--
		5.80	7.62	5.79	9.02	6.55	7.53	--	1.98	2.13	1.22	1.04	1.00	6.00	2.07	1.10	--

Table 4

Wave Heights with Plans 5, 6, 7, and 8 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 5										
Northwest	7	0.90	0.12	--	--	--	0.15	0.58	0.18	0.21	0.18	--	0.36	0.18	0.12	0.24	--
		1.20	0.15	0.12	--	--	0.40	0.85	0.27	0.30	0.21	--	0.55	0.18	0.21	0.27	--
		1.80	0.21	0.21	--	--	0.61	1.46	0.55	0.36	0.30	--	0.70	0.24	0.21	0.36	--
							Plan 6										
Northwest	7	0.90	0.21	0.12	--	--	0.18	0.58	0.24	0.30	0.24	--	0.43	0.21	0.18	0.30	--
		1.20	0.15	0.12	--	--	0.58	0.88	0.21	0.34	0.27	--	0.49	0.27	0.30	0.40	--
		1.80	0.15	0.15	0.15	--	0.61	1.37	0.36	0.36	0.27	--	0.82	0.34	0.36	0.40	--
							Plan 7										
Northwest	7	0.90	--	0.12	--	--	0.46	0.76	0.18	0.21	0.24	--	0.43	0.24	0.21	0.30	--
		1.20	0.18	0.18	0.18	--	0.40	1.04	0.36	0.21	0.27	--	0.43	0.30	0.27	0.30	--
		1.80	0.30	0.15	0.24	--	0.55	1.55	0.49	0.43	0.27	0.27	0.88	0.34	0.36	0.34	--
							Plan 8										
Northwest	7	0.90	0.18	0.18	--	--	0.40	0.76	0.24	0.34	0.34	--	0.55	0.24	0.18	0.34	--
		1.20	0.24	0.15	0.15	--	0.24	1.10	0.46	0.40	0.52	--	0.55	0.27	0.27	0.30	--
		1.80	0.24	0.18	0.21	--	0.64	1.71	0.64	0.73	0.55	0.18	1.16	0.30	0.40	0.36	--

Table 5

Wave Heights with Plan 9 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
North	7	0.90	1.31	0.79	1.22	--	1.13	0.34	0.36	0.43	0.18	--	0.24	0.64	0.46	--	--
		1.80	1.98	1.34	2.38	--	2.47	0.98	0.52	0.64	0.43	0.18	0.36	1.16	0.55	0.21	--
		2.70	2.80	2.32	3.48	--	3.60	1.74	0.34	0.79	0.49	0.21	0.49	1.64	0.76	0.73	--
	9	1.20	1.04	1.04	1.07	--	2.22	0.67	0.64	0.52	0.52	0.18	0.18	1.04	0.43	0.46	--
		2.10	1.71	1.77	1.89	--	3.75	0.85	0.85	0.79	0.73	0.34	0.24	1.71	0.61	0.43	--
		3.00	2.19	2.65	2.83	--	5.39	1.13	0.85	0.88	0.82	0.40	0.30	2.01	0.70	0.43	--
		4.00	3.54	3.50	4.78	--	6.40	3.14	1.04	1.00	0.82	0.36	0.30	2.44	0.94	0.73	--
		4.90	4.11	4.11	5.09	--	8.23	3.35	1.07	0.49	0.61	0.52	0.30	2.68	0.98	0.67	--
	11	1.20	1.34	1.25	0.67	--	0.82	0.67	0.30	0.40	0.90	0.18	0.18	0.91	0.55	0.40	--
		2.10	2.44	2.80	1.13	--	1.40	0.94	0.46	0.58	0.36	0.24	0.18	1.43	0.85	0.30	--
		3.00	2.71	3.96	1.92	--	2.56	1.86	0.49	0.55	0.52	0.24	0.30	2.07	0.91	0.49	--
		4.00	3.20	4.51	2.74	--	3.56	2.86	0.55	0.46	0.58	0.55	0.43	2.41	0.82	0.58	--
		4.90	3.99	5.18	3.72	--	5.55	2.65	0.85	0.76	0.85	0.36	0.49	3.47	0.94	0.67	--
Northeast	7	1.50	1.49	2.13	1.25	1.43	1.16	--	0.15	0.27	0.34	0.34	0.18	0.58	0.58	0.46	--
		2.40	2.44	3.23	2.07	1.89	2.38	--	0.12	0.30	0.12	0.18	0.15	0.76	0.64	0.55	--
		3.40	3.38	4.27	3.23	2.62	3.69	--	0.24	0.27	0.21	0.46	0.24	1.31	0.79	0.64	--
	9	1.20	1.49	1.49	1.19	2.41	0.61	--	--	0.46	0.30	0.27	0.12	0.58	0.43	0.55	--
		2.10	2.68	2.62	2.35	3.60	1.34	--	0.27	0.58	0.43	0.43	0.21	0.98	0.43	0.85	--
		3.00	3.44	3.56	3.23	4.14	1.95	--	0.43	0.64	0.49	0.40	0.21	1.55	0.73	0.98	--
		4.00	4.18	5.03	4.24	6.10	3.84	--	0.61	0.88	0.43	0.73	0.21	1.55	0.70	0.85	--

(Continued)

Table 5 (Concluded)

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northeast (cont'd)	9	4.90	5.36	5.70	5.42	7.34	4.36	--	0.55	0.73	0.52	0.58	0.34	2.01	1.04	1.07	--
		5.80	6.43	6.70	7.92	7.65	4.72	--	0.91	1.04	0.61	0.49	0.30	2.83	1.65	1.16	--
		9.10	6.67	7.19	7.56	6.25	4.24	--	2.07	1.55	1.10	0.88	0.73	3.63	1.92	1.13	--
	11	1.20	1.10	1.00	0.67	1.37	0.55	--	0.21	0.27	0.21	0.18	0.18	0.55	0.49	0.36	--
		2.10	2.13	2.35	1.46	2.68	1.25	--	0.36	0.49	0.27	0.30	0.24	0.94	0.70	0.30	--
		3.00	3.05	3.72	2.04	4.08	1.98	--	0.36	0.55	0.34	0.46	0.27	1.55	0.88	0.49	--
		4.00	3.66	5.06	1.74	4.94	3.44	--	0.43	0.49	0.49	0.55	0.30	2.19	1.10	0.67	--
		4.90	3.50	6.31	3.99	6.83	6.46	--	0.79	0.85	0.79	0.52	0.36	3.41	1.00	0.98	--
East-southeast	7	1.50	0.58	0.30	1.07	1.22	--	--	0.18	0.15	0.21	0.49	0.12	0.36	0.36	0.40	1.16
		2.40	1.28	0.58	1.77	2.07	--	--	0.27	0.21	0.34	0.58	0.15	0.64	0.36	0.46	1.52
		3.40	1.46	0.85	2.26	3.44	--	--	0.30	0.27	0.46	0.55	0.21	0.58	0.36	0.43	3.84
		4.30	1.98	1.40	2.90	4.21	--	--	0.36	0.27	0.46	0.82	0.18	0.52	0.52	0.67	3.72
	9	1.80	0.43	0.43	1.55	2.83	--	--	0.46	0.34	0.40	0.79	0.18	0.34	0.46	0.52	1.46
		2.70	0.79	0.55	2.44	4.91	--	--	0.73	0.55	0.43	0.79	0.24	0.40	0.55	0.73	2.56
		3.60	0.94	0.79	3.23	6.43	--	--	0.70	0.64	0.82	0.88	0.21	0.52	0.58	1.19	4.36
		4.60	1.40	1.40	3.99	7.96	--	--	0.61	0.55	1.31	1.68	0.24	0.64	0.61	2.16	3.50
	11	1.80	0.79	0.55	1.07	2.59	--	--	0.21	0.27	0.18	0.49	0.18	0.46	0.52	0.36	2.07
		2.70	1.07	0.70	1.55	3.87	--	--	0.30	0.43	0.49	0.52	0.15	0.52	0.52	0.64	4.72
		3.60	1.49	0.55	1.92	6.22	--	--	0.46	0.49	0.91	1.28	0.18	0.64	0.64	1.04	4.24
		4.60	1.86	0.67	2.83	6.49	--	--	0.82	0.67	1.40	1.74	0.18	0.79	0.67	1.95	4.33
		5.50	2.22	1.55	3.72	5.42	--	--	1.10	0.82	1.10	1.00	0.24	1.04	1.52	1.49	5.76
		6.40	2.07	1.71	4.42	7.16	--	--	1.13	0.91	1.52	1.71	0.24	1.28	1.71	1.71	4.63

Table 6

Wave Heights with Plan 9 Installed; swl = 0.0 ft

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northeast	7	1.50	1.46	1.83	1.19	1.86	1.34	--	0.18	0.21	0.15	0.24	--	0.30	0.36	0.49	--
		2.40	2.86	2.71	2.26	2.68	2.32	--	0.24	0.21	0.27	0.27	0.18	0.52	0.43	0.55	--
		3.40	3.63	3.47	3.69	3.38	3.08	--	0.27	0.15	0.34	0.30	0.18	0.76	0.52	0.55	--
	9	1.20	0.91	1.86	1.04	2.32	0.61	--	0.27	0.30	0.15	0.24	--	0.34	0.30	0.36	--
		2.10	1.65	3.26	1.80	3.47	1.37	--	0.49	0.36	0.18	0.30	0.18	0.58	0.30	0.64	--
		3.00	2.50	3.93	2.74	3.87	2.16	--	0.64	0.43	0.21	0.30	0.18	1.10	0.36	0.79	--
		4.00	3.54	4.08	4.06	6.13	3.75	--	0.67	0.40	0.24	0.40	0.21	1.34	0.52	0.64	--
		4.90	4.36	4.91	5.82	5.06	4.91	--	0.67	0.52	0.24	0.58	0.40	1.89	0.52	0.98	--
		5.80	5.97	6.58	6.06	5.30	3.84	--	0.79	0.88	0.36	0.43	0.24	2.35	1.00	0.67	--
	11	1.20	0.98	0.79	0.58	1.65	0.55	--	0.18	0.24	0.18	--	--	0.30	0.34	0.30	--
		2.10	2.19	1.77	1.13	2.83	1.28	--	0.15	0.30	0.18	0.24	0.15	0.34	0.30	0.43	--
		3.00	3.17	2.96	2.07	2.71	2.35	--	0.24	0.43	0.34	0.43	0.21	0.91	0.46	0.55	--
		4.00	4.66	4.85	3.32	5.33	4.57	--	0.24	0.49	0.43	0.49	0.24	1.74	0.58	0.91	--
		4.90	5.67	4.91	4.11	5.30	4.30	--	0.79	0.40	0.49	0.30	0.27	1.74	0.67	0.73	--

Table 7

Wave Heights with Plans 10, 11, and 12 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 10										
North	9	1.20	1.34	1.37	0.88	--	1.95	0.94	0.73	0.46	0.43	0.27	0.24	1.28	0.34	0.55	--
		2.10	2.07	2.38	1.46	--	3.41	0.88	1.13	0.70	0.64	0.30	0.34	1.98	0.49	0.58	--
		3.00	2.77	3.54	2.32	--	4.57	1.40	1.48	1.10	0.73	0.34	0.40	2.68	0.73	0.55	--
		4.00	2.77	4.45	3.81	--	6.31	2.65	1.92	1.43	0.70	0.27	0.55	2.93	1.10	0.82	--
		4.90	4.51	5.52	4.11	--	8.59	3.05	2.13	1.43	1.31	0.36	0.52	3.41	1.13	0.64	--
							Plan 11										
North	9	1.20	1.25	1.10	1.58	--	1.37	0.58	0.30	0.27	0.30	0.21	0.24	1.28	0.40	0.49	--
		2.10	2.01	2.01	2.59	--	2.50	1.31	0.82	0.61	0.34	0.36	0.36	2.41	0.85	0.67	--
		3.00	2.77	3.32	3.50	--	3.38	1.55	1.82	1.07	0.61	0.52	0.58	3.14	1.22	0.73	--
		4.00	3.50	4.39	3.87	--	4.45	3.81	2.59	1.37	1.07	0.46	0.55	3.87	1.62	0.82	--
		4.90	4.39	5.36	4.51	--	5.97	2.99	2.74	0.91	1.43	0.36	0.82	4.66	2.16	1.22	--
							Plan 12										
East-southeast	9	1.80	0.46	0.30	1.40	3.14	--	--	0.40	0.34	0.30	0.55	0.18	0.40	0.46	0.82	1.22
		2.70	0.79	0.49	2.56	5.30	--	--	0.64	0.64	0.58	0.64	0.18	0.49	0.70	1.74	3.84
		3.60	1.07	0.88	3.44	7.04	--	--	0.55	0.55	0.73	1.58	0.21	0.55	0.61	3.78	2.96
		4.60	1.58	1.16	4.30	9.08	--	--	0.82	0.79	1.55	1.95	0.21	0.64	0.52	3.99	3.41

Table 8

Wave Heights with Plans 13 and 14 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
							Plan 13										
Northeast	9	1.20	1.34	1.28	1.31	2.44	0.61	--	0.18	0.46	0.18	--	0.18	0.49	0.43	0.58	--
		2.10	1.89	2.16	2.26	3.84	1.34	--	0.15	0.64	0.18	0.49	0.24	0.76	0.61	0.58	--
		3.00	2.56	3.14	3.02	5.94	2.01	--	0.24	0.70	0.24	0.67	0.24	1.22	0.67	1.13	--
		4.00	3.63	4.21	4.30	6.74	3.38	--	0.34	0.79	0.30	0.73	0.24	1.37	0.76	1.22	--
		4.90	4.88	4.94	5.52	7.53	4.78	--	0.61	0.79	0.49	0.85	0.34	1.74	1.10	1.19	--
		5.80	6.31	6.95	6.58	8.50	6.06	--	0.94	0.73	0.67	0.76	0.34	2.44	1.37	1.22	--
							Plan 14										
Northeast	9	1.20	1.16	1.16	1.34	2.26	0.49	--	0.21	0.46	0.24	0.30	0.15	0.46	0.34	0.30	--
		2.10	1.89	2.29	2.22	3.63	1.16	--	0.34	0.58	0.27	0.36	0.18	0.73	0.67	0.49	--
		3.00	2.77	3.60	3.26	5.03	2.04	--	0.43	0.70	0.34	0.55	0.18	1.13	0.79	0.61	--
		4.00	4.27	3.81	4.42	5.73	3.63	--	0.55	0.76	0.36	0.55	0.18	1.46	0.82	0.64	--
		4.90	5.58	6.13	5.52	7.10	4.75	--	0.88	0.73	0.55	0.73	0.36	2.16	1.16	1.31	--
		5.80	6.64	7.68	6.77	7.74	6.04	--	1.00	0.73	0.67	0.73	0.49	2.74	1.37	1.13	--

Table 9

Wave Heights with Plan 15 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
North	7	0.90	0.79	0.67	1.19	--	0.76	0.49	0.18	0.27	0.18	0.18	0.18	0.55	0.49	0.43	--
		1.80	1.64	1.28	1.92	--	1.86	1.43	0.21	0.49	0.30	0.21	0.21	0.91	0.61	0.64	--
		2.70	2.71	2.26	3.17	--	2.26	2.07	0.27	0.61	0.36	0.30	0.30	1.46	0.85	0.76	--
	9	1.20	1.19	0.85	1.64	--	1.43	1.00	0.30	0.61	0.46	0.24	0.30	0.91	0.73	0.49	--
		2.10	1.89	1.25	2.59	--	2.26	1.40	0.40	0.91	0.55	0.27	0.21	1.46	0.91	0.70	--
		3.00	2.71	1.86	3.69	--	3.26	2.07	0.46	1.12	0.58	0.34	0.21	1.86	1.16	0.82	--
		4.00	4.02	3.17	4.14	--	5.58	3.17	0.67	0.94	0.34	0.34	0.43	2.26	1.10	0.85	--
		4.90	5.24	4.60	5.67	--	7.95	5.49	1.40	1.25	0.61	0.43	0.82	3.32	1.22	1.31	--
	11	1.20	0.85	0.94	0.64	--	1.58	0.46	0.12	0.18	0.12	0.18	--	0.76	0.55	0.52	--
		2.10	1.49	2.10	1.22	--	2.99	0.94	0.21	0.34	0.15	0.21	0.18	1.46	0.76	0.55	--
		3.00	1.46	3.08	2.35	--	4.54	2.22	0.27	0.43	0.30	0.18	0.24	2.04	0.88	0.64	--
		4.00	2.01	4.27	3.41	--	5.42	3.29	0.91	0.64	0.55	0.30	0.40	2.96	1.22	0.79	--
		4.90	3.72	4.45	4.75	--	8.20	3.35	1.13	0.98	0.88	0.49	0.64	3.60	1.64	0.88	--
Northeast	7	1.50	1.28	1.16	1.43	1.89	1.16	--	0.15	0.21	0.15	0.21	0.18	0.70	0.24	0.46	--
		2.40	2.10	2.41	2.32	2.77	2.22	--	0.18	0.24	0.21	0.27	0.18	1.10	0.30	0.64	--
		3.40	3.17	3.63	3.38	4.05	3.02	--	0.24	0.30	0.21	0.52	0.18	1.68	0.49	0.67	--
	9	1.20	1.19	1.37	1.46	2.50	1.28	--	0.24	0.40	0.27	--	0.21	0.73	0.36	0.43	--
		2.10	2.13	2.77	2.65	4.18	2.62	--	0.43	0.58	0.36	0.30	0.24	1.22	0.61	0.58	--
		3.00	3.20	3.41	3.54	5.42	3.93	--	0.40	0.73	0.43	0.46	0.27	1.68	0.64	0.64	--
		4.00	3.66	4.94	4.14	5.91	6.46	--	0.58	0.64	0.43	0.76	0.30	2.13	0.88	0.85	--
		4.90	4.14	6.31	6.28	7.50	8.11	--	0.88	0.61	0.58	0.70	0.46	3.02	1.07	0.91	--
		5.80	5.03	7.56	7.86	6.40	8.53	--	1.10	0.79	0.61	0.73	0.52	3.32	1.71	1.10	--
	11	1.20	1.04	0.91	0.67	1.13	0.79	--	--	0.21	--	0.24	0.21	0.58	0.36	0.49	--
		2.10	2.32	2.26	1.77	2.56	1.98	--	0.18	0.34	0.15	0.52	0.24	1.07	0.46	0.61	--
		3.00	3.17	3.56	2.19	3.05	3.26	--	0.18	0.43	0.30	0.52	0.27	1.58	0.49	0.46	--
		4.00	4.51	4.75	3.08	3.87	4.66	--	0.36	0.49	0.27	0.64	0.40	2.47	0.79	0.49	--
		4.90	5.97	7.13	4.88	6.89	6.25	--	0.73	0.82	0.43	0.88	0.46	3.14	1.46	0.88	--

Table 10

Wave Heights with Plan 16 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
North	7	0.90	1.04	0.73	1.07	--	0.85	0.46	0.21	0.21	0.24	--	0.24	0.61	0.43	0.55	--
		1.80	1.83	1.62	2.26	--	1.52	1.52	0.36	0.40	0.30	0.21	0.24	1.25	0.55	0.82	--
		2.70	2.41	2.50	2.96	--	1.83	1.86	0.34	0.52	0.46	0.24	0.34	1.62	0.82	1.04	--
	9	1.20	1.22	0.85	1.58	--	1.86	0.85	0.43	0.61	0.52	0.24	0.18	0.98	0.73	0.55	--
		2.10	1.64	1.25	2.50	--	3.02	1.46	0.82	0.88	0.67	0.36	0.24	1.52	0.98	0.73	--
		3.00	1.92	1.62	3.32	--	4.14	2.35	0.88	0.94	0.70	0.46	0.36	1.83	1.07	0.82	--
		4.00	3.14	3.44	4.48	--	5.39	3.35	1.10	1.04	0.58	0.61	0.43	2.80	1.16	1.16	--
		4.90	5.18	5.03	6.13	--	6.46	3.26	1.64	1.04	0.64	0.46	0.76	3.60	1.07	1.58	--
	11	1.20	0.70	1.00	0.67	--	0.88	0.40	0.18	0.24	0.15	0.18	0.18	0.79	0.61	0.52	--
		2.10	1.13	1.92	1.13	--	3.11	0.91	0.27	0.24	0.21	0.18	0.24	1.37	0.73	0.55	--
		3.00	1.58	2.59	1.64	--	4.24	1.77	0.30	0.34	0.24	0.36	0.27	2.04	0.82	0.64	--
		4.00	2.32	3.29	2.41	--	5.85	1.58	0.91	0.67	0.64	0.46	0.43	2.96	0.82	0.82	--
		4.90	3.32	4.30	3.32	--	7.98	3.29	1.04	1.22	0.94	0.64	0.58	3.75	1.68	0.67	--
Northeast	7	1.50	1.16	1.40	1.55	1.77	1.28	--	0.30	0.24	0.18	0.34	--	0.88	0.61	0.55	--
		2.40	2.32	2.56	2.59	3.20	2.28	--	0.30	0.24	0.15	0.46	0.18	1.19	0.49	0.76	--
		3.40	3.44	3.75	3.60	3.60	3.44	--	0.34	0.24	0.15	0.58	0.21	1.83	0.52	0.52	--
	9	1.20	0.94	1.43	1.64	2.32	1.37	--	0.24	0.40	0.21	0.30	0.15	0.58	0.43	0.61	--
		2.10	2.07	2.96	2.99	3.47	2.90	--	0.49	0.46	0.34	0.30	0.18	1.07	0.55	0.70	--
		3.00	3.02	4.27	4.14	5.30	4.11	--	0.64	0.43	0.40	0.34	0.18	1.68	0.70	0.73	--
		4.00	3.63	5.36	4.75	6.61	5.61	--	1.00	0.40	0.58	0.55	0.24	2.44	0.91	0.67	--
		4.90	3.96	7.13	6.55	8.66	7.59	--	1.40	0.55	0.85	0.94	0.34	3.41	1.28	0.88	--
		5.80	4.24	7.71	7.68	8.81	9.26	--	1.43	1.55	0.79	0.85	0.40	2.86	1.55	1.37	--

(Continued)

Table 10 (Concluded)

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northeast (cont'd)	11	1.20	0.85	1.04	0.27	1.31	0.91	--	--	0.18	0.18	0.36	0.12	0.58	0.49	0.52	--
		2.10	1.74	2.32	1.28	2.19	2.38	--	0.18	0.43	0.30	0.46	0.24	1.22	0.70	0.49	--
		3.00	2.50	3.02	2.26	2.96	3.66	--	0.27	0.55	0.27	0.67	0.27	1.95	0.82	0.61	--
		4.00	2.56	3.44	2.96	4.85	4.97	--	0.30	0.49	0.24	1.07	0.30	2.01	1.22	0.67	--
		4.90	3.38	4.75	3.75	7.22	6.55	--	0.64	0.76	0.36	1.13	0.36	2.35	1.40	1.04	--
East-southeast	7	1.50	0.43	0.34	1.22	1.22	--	--	0.18	0.12	0.12	0.30	--	0.24	0.30	0.52	0.67
		2.40	0.94	0.67	2.10	2.07	--	--	0.18	0.12	0.15	0.46	--	0.27	0.34	0.52	0.76
		3.40	0.91	0.82	2.59	3.78	--	--	0.21	0.24	0.36	0.40	--	0.27	0.40	0.52	2.68
		4.30	1.40	1.16	3.69	4.91	--	--	0.34	0.34	0.34	0.58	0.15	0.46	0.46	0.58	5.00
	9	1.80	0.91	0.30	2.26	2.71	--	--	0.43	0.24	0.40	0.64	0.15	--	0.46	0.61	0.79
		2.70	1.40	0.46	3.41	4.91	--	--	0.58	0.36	0.49	0.82	0.15	0.30	0.40	0.61	2.47
		3.60	1.52	1.04	4.33	6.80	--	--	0.49	0.43	0.43	0.98	0.15	0.40	0.49	0.67	3.11
		4.60	1.77	1.46	5.06	7.44	--	--	0.64	0.58	1.25	1.58	0.24	0.40	0.64	0.88	3.50
	11	1.80	0.52	0.55	1.22	2.10	--	--	0.21	0.24	0.09	0.15	0.30	0.30	0.34	0.55	2.65
		2.70	0.82	1.00	1.89	3.35	--	--	0.30	0.36	0.27	0.18	0.43	0.36	0.43	0.55	2.22
		3.60	1.04	1.16	2.80	4.57	--	--	0.46	0.46	0.67	0.21	0.79	0.43	0.55	0.76	3.96
		4.60	1.34	1.00	3.56	5.94	--	--	0.79	0.73	1.04	0.18	1.07	0.64	0.79	1.22	4.24
		5.50	2.22	1.34	4.51	5.27	--	--	1.07	1.10	1.34	0.21	1.37	1.10	2.04	1.49	3.66
		6.40	2.83	2.07	6.52	5.21	--	--	1.13	1.13	1.00	0.27	1.68	1.13	1.80	1.10	3.20

Table 11

Wave Heights with Plan 17 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 3A	Gage 4	Gage 4A	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
North	7	0.90	0.79	0.70	0.91	--	0.58	0.46	0.09	0.18	0.24	--	0.12	0.43	0.34	0.46	--
		1.80	1.52	1.37	1.46	--	1.07	0.85	0.21	0.24	0.21	--	0.21	0.55	0.30	0.70	--
		2.70	2.01	2.04	2.56	--	1.89	2.22	0.15	0.30	0.30	--	0.21	0.67	0.43	0.79	--
	9	1.20	0.98	0.70	2.01	--	1.43	0.55	0.27	0.21	0.24	--	0.21	0.67	0.30	0.52	--
		2.10	1.25	1.31	2.90	--	2.44	0.64	0.36	0.27	0.34	--	0.21	0.73	0.36	0.52	--
		3.00	1.77	1.83	3.90	--	4.45	1.52	0.45	0.30	0.36	--	0.24	0.88	0.49	0.61	--
		4.00	2.65	2.92	4.94	--	5.64	1.92	0.67	0.34	0.36	--	0.30	1.25	0.46	0.82	--
Northeast	7	1.50	1.28	0.91	0.79	--	1.83	--	0.18	0.18	0.18	0.18	--	0.52	0.36	0.46	--
		2.40	2.28	1.74	1.52	--	2.86	--	0.30	0.21	0.27	0.21	0.09	0.52	0.40	0.46	--
		3.40	3.41	2.50	1.92	--	3.54	--	0.34	0.27	0.27	0.27	0.15	0.67	0.52	0.55	--
	9	1.20	1.43	1.16	1.49	--	1.80	--	0.21	0.34	0.18	0.18	--	0.34	0.43	0.52	--
		2.10	2.07	1.83	2.47	--	3.72	--	0.30	0.46	0.21	0.27	--	0.58	0.58	0.73	--
		3.00	2.90	2.44	3.29	--	5.15	--	0.27	0.54	0.40	0.36	--	0.79	0.67	0.70	--
		4.00	3.84	2.96	4.97	--	7.16	--	0.43	0.67	0.36	0.30	--	1.04	0.79	0.70	--

Table 12

Northeast Wave Heights at the

Ammo Pier for Plans 17-17I

Test Wave		Wave Heights for Indicated Plan, Prototype, meters									
Period sec	Height meters	Plan 17	Plan 17A	Plan 17B	Plan 17C	Plan 17D	Plan 17E	Plan 17F	Plan 17G	Plan 17H	Plan 17I
9	2.10	1.49	0.52	0.40	0.52	0.27	0.27	0.30	0.24	0.18	0.52
	3.00	2.74	0.76	0.34	1.13	0.52	0.49	0.43	0.30	0.88	0.98
	4.00	4.48	1.55	0.82	2.71	2.47	1.58	1.16	0.49	0.98	2.26

Table 13

Wave Heights with Plan 18 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7
North	9	2.10	0.27	0.34	0.64	0.43	0.91	1.07	0.24
		3.00	0.36	0.49	0.79	0.55	1.13	1.19	0.30
		4.00	0.43	0.58	0.79	0.98	1.25	1.22	0.40
Northeast	9	2.10	0.52	0.40	0.30	0.73	0.46	0.67	0.24
		3.00	0.67	0.36	0.43	0.73	0.67	0.88	0.30
		4.00	0.67	0.55	0.55	0.91	0.67	0.98	0.27

Table 14

Wave Heights with Plan 21 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
North	7	0.90	0.61	0.73	0.34	0.30	0.15	0.15	0.27	0.27	0.24	0.12	0.55	0.36	0.40
		1.80	1.06	1.16	0.55	0.36	0.18	0.24	0.40	0.27	0.43	0.21	0.64	0.49	0.34
		2.70	1.55	1.55	0.82	0.67	0.46	0.49	0.27	0.40	0.49	0.27	0.85	0.73	0.61
	9	1.20	0.49	0.88	0.43	0.46	0.52	0.46	0.49	0.24	0.36	0.27	0.58	0.46	0.64
		2.10	1.25	1.46	0.88	0.49	0.88	0.79	0.34	0.27	0.46	0.15	0.85	0.79	0.88
		3.00	1.98	2.04	1.04	0.70	0.79	0.61	0.43	0.43	0.46	0.27	1.07	1.00	1.04
		4.00	2.53	1.98	1.10	0.73	0.67	0.82	0.58	0.58	0.73	0.43	1.22	1.04	1.58
		4.90	2.13	2.71	1.83	1.13	1.40	1.04	0.85	0.82	1.07	0.52	1.71	1.83	2.07
Northeast	7	1.50	1.40	1.40	0.82	0.98	0.34	0.24	0.36	0.43	0.49	0.15	0.58	1.04	0.30
		2.40	2.44	2.19	1.22	1.58	0.64	0.52	0.64	0.88	0.55	0.18	1.04	1.37	0.43
		3.40	3.35	2.83	1.62	2.13	0.98	1.10	0.88	0.67	0.58	0.34	0.98	2.53	0.61
	9	1.20	1.16	1.22	0.64	0.76	0.34	0.24	0.27	0.43	0.49	0.15	0.67	0.70	0.67
		2.10	2.04	2.10	0.91	1.37	0.73	0.64	0.67	0.70	0.85	0.24	0.91	1.10	1.07
		3.00	3.11	3.38	1.49	1.89	1.16	1.19	0.79	0.79	1.04	0.43	0.94	1.80	1.25
		4.00	4.39	4.75	2.04	2.62	1.64	1.62	1.10	1.00	0.94	0.52	1.89	2.86	1.16
		4.90	5.12	4.45	2.47	2.47	1.98	1.98	1.62	1.37	1.71	0.52	1.37	3.90	1.34
		5.80	4.14	3.11	1.46	1.28	1.55	1.71	1.77	1.80	2.74	1.13	2.25	3.66	1.68
East-southeast	7	1.50	1.28	0.73	0.67	0.40	0.18	0.27	0.67	0.58	0.67	0.40	0.30	1.46	0.36
		2.40	2.38	0.98	0.98	0.58	0.70	0.79	1.22	0.88	1.04	0.40	0.36	1.83	0.43
		3.40	2.99	1.10	1.13	0.58	0.85	1.00	1.52	1.13	1.68	0.27	0.43	2.74	0.58
		4.30	4.20	1.89	1.64	0.73	0.98	1.28	2.07	1.22	2.41	0.64	0.76	3.47	0.49
	9	1.80	2.04	0.55	0.64	0.73	1.00	0.88	0.43	0.46	0.70	0.49	0.85	2.04	0.43
		2.70	3.08	1.46	1.19	1.28	1.55	1.43	0.91	0.91	1.52	0.52	0.79	3.08	0.70
		3.60	4.11	1.83	1.40	1.28	2.19	1.49	1.77	1.13	1.98	0.67	1.49	3.87	1.07
		4.60	5.55	2.77	2.32	1.13	3.11	2.41	2.26	1.10	2.47	1.98	1.74	3.50	0.85

Table 15

Wave Heights with Plans 22 and 22A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
			Wave Heights at Indicated Gage Locations, Prototype, meters												
			Plan 22												
Northeast	9	1.20	0.94	1.22	1.04	0.40	0.15	0.12	0.24	0.30	0.27	0.27	0.55	1.04	0.15
		2.10	1.77	2.26	1.58	0.73	0.27	0.30	0.36	0.52	0.30	0.40	0.94	1.95	0.40
		3.00	2.44	2.96	2.41	0.73	0.46	0.46	0.46	0.46	0.43	0.30	1.19	2.65	0.73
		4.00	3.66	4.36	3.35	1.40	0.58	0.61	0.70	0.49	0.55	0.40	1.77	2.96	0.70
East-southeast	9	1.80	1.83	1.43	0.76	0.49	0.34	0.30	0.36	0.30	0.27	0.24	0.58	1.62	0.18
		2.70	2.90	1.89	1.07	0.94	0.49	0.58	0.46	0.30	0.46	0.24	0.52	2.32	0.55
		3.60	3.81	3.26	1.16	1.46	0.76	0.67	0.73	0.88	0.64	0.27	1.10	2.96	0.67
		4.60	5.61	5.12	1.10	1.71	1.00	0.91	1.52	1.13	0.76	0.49	1.13	3.81	0.70
			Plan 22A												
Northeast	9	1.20	0.98	1.22	1.13	0.43	0.18	0.15	0.24	0.40	0.36	0.24	0.70	1.07	0.40
		2.10	1.80	1.98	1.86	0.79	0.40	0.27	0.43	0.82	0.40	0.34	1.04	1.71	0.70
		3.00	2.71	3.47	2.32	1.34	0.61	0.64	0.67	0.73	0.36	0.36	1.28	2.74	0.79
		4.00	3.69	4.60	3.72	1.92	1.28	0.82	1.37	1.28	0.91	0.46	1.83	3.81	0.79

Table 16

Wave Heights with Plans 23 and 23A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						Plan 23									
Northeast	9	1.20	0.88	1.00	0.82	0.43	0.18	0.21	0.12	0.18	0.24	0.40	0.70	0.98	0.30
		2.10	1.49	2.01	1.68	0.58	0.27	0.30	0.18	0.15	0.24	0.52	1.07	1.40	0.70
		3.00	2.59	2.86	2.04	0.58	0.36	0.52	0.18	0.18	0.24	0.61	1.55	2.19	1.00
		4.00	4.84	4.24	3.29	0.73	0.49	0.49	0.36	0.30	0.21	0.79	1.52	3.23	0.88
East-southeast	9	1.80	1.68	1.49	0.79	0.49	0.24	0.30	0.12	0.24	0.18	0.43	0.82	1.46	0.21
		2.70	2.92	2.32	1.10	0.88	0.36	0.55	0.36	0.34	0.43	0.61	1.00	2.22	0.58
		3.60	3.66	2.96	1.46	1.31	0.79	0.49	0.61	0.82	0.58	0.82	0.98	3.05	0.58
		4.60	5.24	4.69	1.52	1.52	0.73	0.94	1.00	0.85	0.67	1.22	1.68	4.11	0.85
						Plan 23 A									
Northeast	9	1.20	1.04	1.16	1.13	0.61	0.18	0.15	0.21	0.15	0.21	0.30	0.85	0.70	0.52
		2.10	1.86	2.13	1.83	0.88	0.36	0.27	0.30	0.30	0.21	0.49	1.22	1.04	0.88
		3.00	2.71	3.32	2.50	0.98	0.46	0.52	0.34	0.36	0.58	0.46	1.37	2.53	1.04
		4.00	3.75	4.57	3.56	1.52	0.85	0.55	0.98	0.73	0.43	0.55	1.95	3.54	1.13
East-southeast	9	1.80	1.64	1.37	0.73	0.64	0.34	0.24	0.30	0.43	0.30	0.67	0.94	1.58	0.30
		2.70	2.74	2.13	1.10	1.22	0.55	0.34	0.43	0.49	0.40	0.76	0.94	2.04	0.40
		3.60	3.72	2.86	1.52	1.31	0.70	0.85	0.79	0.70	0.70	1.00	1.04	3.14	0.43
		4.60	5.27	4.63	1.52	1.92	1.34	1.10	1.22	1.34	1.00	1.62	1.34	3.81	0.64

Table 17

Wave Heights with Plans 23B, 23C, 23D, and 23E Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						Plan 23B									
Northeast	9	1.20	0.82	1.13	1.28	0.43	0.21	0.18	0.21	0.24	0.21	0.30	0.85	1.04	0.40
		2.10	1.71	2.04	1.68	0.64	0.49	0.40	0.27	0.34	0.18	0.52	1.49	1.34	0.85
		3.00	2.56	2.99	2.53	0.73	0.64	0.55	0.36	0.61	0.30	0.34	2.07	3.20	0.88
		4.00	3.81	4.36	3.50	1.68	1.07	1.10	0.61	0.94	0.76	0.34	1.98	3.96	0.88
						Plan 23C									
Northeast	9	1.20	0.76	1.22	1.10	0.34	0.36	0.18	0.15	0.18	0.24	0.34	0.94	0.88	0.40
		2.10	1.55	1.98	1.46	0.64	0.82	0.30	0.24	0.49	0.27	0.43	1.37	1.31	0.70
		3.00	2.44	3.38	2.41	0.91	1.16	0.64	0.49	0.52	0.36	0.46	1.64	2.41	0.79
		4.00	3.54	4.42	3.47	1.58	1.43	0.82	0.73	0.91	0.64	0.43	1.80	3.72	0.98
						Plan 23D									
Northeast	9	1.20	0.85	1.71	1.07	0.40	0.21	0.24	0.18	0.21	0.12	0.34	0.58	0.79	0.40
		2.10	1.83	2.99	1.83	0.67	0.40	0.30	0.34	0.27	0.15	0.58	1.00	1.77	0.64
		3.00	2.80	4.30	2.35	0.94	0.55	0.43	0.67	0.43	0.27	0.67	1.77	3.11	0.55
		4.00	4.08	6.55	3.56	1.64	0.85	0.76	0.70	0.46	0.36	0.64	2.07	3.75	1.07
						Plan 23E									
Northeast	9	1.20	0.82	1.49	1.13	0.18	0.18	0.21	0.27	0.21	0.18	0.30	0.61	0.85	0.40
		2.10	1.77	2.96	1.77	0.58	0.40	0.34	0.52	0.36	0.21	0.49	1.04	1.83	0.67
		3.00	2.71	3.54	2.41	0.94	0.49	0.43	0.70	0.49	0.30	0.64	1.46	3.08	0.64
		4.00	3.81	6.22	3.26	1.74	0.85	0.64	0.88	0.61	0.46	0.55	2.22	3.63	1.19

Table 18

Wave Heights with Plans 24 and 24A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						Plan 24									
Northeast	9	1.20	0.85	1.64	1.13	0.30	0.21	0.24	0.24	0.18	0.15	0.21	0.55	0.94	0.43
		2.10	1.83	2.99	1.95	0.55	0.36	0.30	0.43	0.30	0.18	0.24	1.00	1.95	0.64
		3.00	2.90	4.39	2.59	1.00	0.36	0.40	0.58	0.27	0.27	0.36	1.46	3.08	0.55
		4.00	3.96	6.03	3.81	1.68	0.79	0.76	0.79	0.55	0.30	0.49	2.38	3.84	1.28
East-southeast	9	1.80	1.77	1.40	0.73	0.88	0.30	0.24	0.24	0.30	0.21	0.15	0.88	1.55	0.21
		2.70	2.83	2.01	0.98	1.46	0.55	0.55	0.43	0.36	0.34	0.24	1.16	2.19	0.46
		3.60	3.87	2.96	1.40	1.64	0.70	0.70	0.64	0.49	0.46	0.30	1.07	3.05	0.46
		4.60	5.33	4.88	2.59	1.19	1.04	0.73	0.79	0.91	0.52	0.55	1.07	4.36	0.64
						Plan 24A									
Northeast	9	1.20	0.91	1.43	0.73	0.40	0.36	0.21	0.24	0.21	0.21	0.27	0.61	0.55	0.34
		2.10	1.74	2.77	1.74	0.82	0.58	0.49	0.34	0.46	0.30	0.27	1.22	1.98	0.55
		3.00	2.83	4.02	2.41	1.49	0.85	0.70	0.76	0.88	0.30	0.36	2.04	3.29	0.73
		4.00	4.14	6.00	3.66	2.16	1.34	1.16	1.16	0.82	0.46	0.58	2.50	3.90	0.98

Table 19

Wave Heights with Plan 25 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northeast	9	1.20	0.88	1.16	1.16	0.24	0.24	0.30	0.30	0.30	0.27	0.21	0.79	0.88	0.24
		2.10	1.89	2.19	2.04	0.46	0.43	0.36	0.52	0.36	0.34	0.30	1.22	1.95	0.55
		3.00	3.08	3.23	2.47	0.88	0.61	0.52	0.79	0.46	0.49	0.43	1.52	3.14	0.76
		4.00	4.63	4.60	2.99	1.31	0.79	0.64	0.70	0.85	0.49	0.61	2.19	3.60	0.64
East-southeast	9	1.80	1.58	1.43	0.98	0.34	0.34	0.21	0.30	0.27	0.24	0.27	0.52	1.71	0.34
		2.70	2.80	2.35	1.25	0.64	0.64	0.52	0.30	0.43	0.52	0.30	0.61	2.10	0.55
		3.60	3.99	4.08	1.25	1.28	0.94	0.52	0.58	0.94	0.64	0.40	0.94	3.60	1.22
		4.60	5.61	5.52	1.74	1.55	0.85	0.91	1.10	0.94	0.79	0.61	1.64	4.30	1.28

Table 20

Wave Heights with Plan 25A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northeast	9	1.20	0.94	1.43	1.28	0.34	0.30	0.30	0.34	0.34	0.27	0.27	0.64	1.10	0.24
		2.10	1.95	2.38	1.83	0.67	0.40	0.43	0.67	0.52	0.36	0.34	1.13	2.16	0.60
		3.00	3.23	3.32	2.41	0.88	0.58	0.43	0.91	0.49	0.46	0.30	1.58	2.62	0.67
		4.00	4.72	4.45	3.05	1.34	0.91	0.67	0.82	0.70	0.49	0.61	2.04	3.02	0.58
East-southeast	9	1.80	1.64	1.40	1.00	0.36	0.36	0.24	0.30	0.30	0.30	0.34	0.67	1.58	0.52
		2.70	2.74	2.26	1.58	0.67	0.55	0.46	0.36	0.36	0.52	0.27	0.64	1.83	0.67
		3.60	3.99	4.48	1.77	1.00	0.73	0.76	0.49	0.88	0.67	0.43	0.94	3.08	1.10
		4.60	5.42	5.12	1.37	1.71	1.04	1.16	0.94	1.07	1.07	0.64	1.37	4.24	1.25

Table 21

Wave Heights with Plan 25B Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
Northeast	9	1.20	0.98	1.28	1.16	0.34	0.30	0.21	0.30	0.36	0.21	0.24	0.70	0.98	0.27
		2.10	0.83	2.28	1.98	0.46	0.49	0.46	0.67	0.49	0.40	0.34	1.28	2.01	0.67
		3.00	3.11	3.26	2.50	0.83	0.67	0.49	0.85	0.58	0.52	0.30	1.71	3.02	0.73
		4.00	4.54	4.75	2.99	1.46	0.88	0.64	0.76	0.79	0.52	0.76	2.35	3.23	0.98
East-southeast	9	1.80	1.46	1.52	1.00	0.36	0.36	0.18	0.34	0.30	0.24	0.30	0.58	1.46	0.55
		2.70	2.74	1.92	1.28	0.61	0.52	0.34	0.36	0.34	0.40	0.24	0.52	1.74	0.88
		3.60	4.21	3.78	1.52	1.00	0.67	0.70	0.46	0.70	0.58	0.43	0.76	3.20	1.07
		4.60	5.49	5.61	1.46	1.77	0.88	0.85	1.07	1.10	0.94	0.52	1.52	4.33	1.07

Table 22

Wave Heights with Plans 26 and 26A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
						Plan 26									
Northeast	9	1.20	0.91	1.43	1.00	0.30	0.24	0.30	0.36	0.27	0.27	0.21	0.61	1.19	0.76
		2.10	1.77	2.32	1.55	0.58	0.52	0.43	0.55	0.27	0.34	0.34	1.07	1.98	0.43
		3.00	2.90	3.26	2.32	0.94	0.58	0.49	0.82	0.43	0.55	0.36	1.28	2.28	0.79
		4.00	3.81	4.57	2.56	1.31	0.70	0.49	0.85	0.49	0.43	0.49	1.55	2.92	0.52
						Plan 26 A									
Northeast	9	1.20	1.10	1.49	0.98	0.34	0.24	0.21	0.27	0.34	0.18	0.18	0.82	1.13	0.43
		2.10	2.01	2.92	1.58	0.79	0.43	0.40	0.40	0.55	0.27	0.40	0.91	2.01	0.58
		3.00	2.92	4.08	2.19	1.04	0.52	0.52	0.52	0.61	0.21	0.46	1.07	3.38	0.79
		4.00	4.39	4.51	2.62	1.22	0.98	0.82	1.04	0.49	0.34	0.49	1.89	3.63	0.82

Table 23

Wave Heights with Plan 27 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
North	7	0.90	0.88	0.82	0.46	0.18	0.09	0.21	0.21	0.21	0.12	0.24	0.27	0.34	0.30
		1.80	1.43	1.04	0.73	0.21	0.18	0.21	0.24	0.27	0.18	0.30	0.64	0.70	0.43
		2.70	2.22	1.64	0.61	0.30	0.30	0.24	0.36	0.27	0.24	0.34	0.67	0.85	0.55
	9	1.20	0.88	0.94	0.58	0.24	0.24	0.12	0.12	0.15	0.12	0.27	0.49	0.52	0.27
		2.10	1.34	1.37	0.73	0.49	0.34	0.24	0.30	0.30	0.30	0.30	0.67	0.70	0.40
		3.00	1.95	1.62	1.00	0.82	0.36	0.30	0.43	0.55	0.49	0.43	1.19	1.55	0.64
		4.00	2.65	1.89	1.25	0.91	0.61	0.52	0.55	0.61	0.58	0.49	1.31	1.83	0.82
		4.90	2.32	2.65	1.80	0.88	0.40	0.36	0.58	0.67	0.70	0.55	1.64	2.04	1.04
	11	1.20	0.79	0.52	0.21	0.18	0.12	0.12	0.18	0.18	0.18	0.18	0.43	0.55	0.21
		2.10	1.22	1.04	0.43	0.36	0.27	0.30	0.27	0.30	0.34	0.73	0.61	0.46	0.27
		3.00	1.89	1.40	1.04	0.52	0.36	0.30	0.34	0.52	0.55	1.28	0.88	1.10	0.70
		4.00	2.38	2.01	1.68	0.67	0.34	0.36	0.61	0.76	0.67	1.77	1.31	1.52	0.79
		4.90	3.35	2.99	2.41	1.00	0.67	0.55	0.73	0.85	1.00	1.13	1.31	2.35	0.98
Northeast	7	1.50	1.25	1.71	1.07	0.49	0.34	0.30	0.18	0.18	0.24	0.18	0.34	0.91	0.34
		2.40	2.04	2.86	1.64	0.67	0.40	0.46	0.36	0.21	0.24	0.24	0.70	1.64	0.40
		3.40	2.83	3.72	1.95	0.98	0.36	0.43	0.58	0.34	0.40	0.34	1.19	2.59	0.67
	9	1.20	0.94	1.43	0.85	0.27	0.27	0.24	0.30	0.24	0.18	0.15	0.43	1.22	0.30
		2.10	1.89	2.80	1.58	0.61	0.46	0.27	0.46	0.40	0.30	0.18	0.67	2.01	0.43
		3.00	2.77	3.69	2.32	0.82	0.46	0.34	0.55	0.36	0.36	0.27	1.04	2.38	0.52
		4.00	3.69	5.00	2.96	1.22	0.70	0.64	0.55	0.52	0.49	0.40	1.52	2.77	0.67
		4.90	5.30	4.78	2.74	1.34	0.73	0.73	0.88	0.73	0.73	0.61	1.58	2.38	0.76
		5.80	6.19	4.94	3.14	1.07	0.88	0.82	0.79	0.76	0.58	0.49	1.71	3.05	0.67
	11	1.20	0.85	1.40	0.76	0.24	0.27	0.24	0.24	0.27	0.15	0.18	0.67	1.40	0.30
		2.10	1.80	2.96	1.58	0.52	0.49	0.49	0.46	0.49	0.24	0.40	1.49	2.77	0.64
		3.00	2.96	4.45	2.35	0.76	0.67	0.67	0.49	0.30	0.30	0.88	1.86	3.08	0.67
		4.00	3.90	6.00	3.14	1.43	1.00	0.88	0.73	0.67	0.55	1.10	1.71	2.77	0.79
		4.90	4.82	6.13	2.62	1.83	1.04	0.94	1.04	0.94	0.58	1.22	1.83	4.08	1.16
East-Southeast	7	1.50	1.52	1.00	0.21	0.36	0.21	0.30	0.30	0.21	0.12	0.34	0.46	1.49	0.49
		2.40	2.96	2.16	1.00	0.73	0.30	0.40	0.46	0.34	0.15	0.36	0.46	1.83	0.36
		3.40	3.56	2.56	0.82	0.91	0.30	0.34	0.52	0.49	0.43	0.36	0.61	2.65	0.79
		4.30	4.33	3.63	1.52	1.25	0.46	0.40	0.85	0.76	0.40	0.49	0.73	3.08	0.79
	9	1.80	1.83	0.98	1.10	0.43	0.27	0.24	0.30	0.27	0.21	0.24	0.70	1.74	0.49
		2.70	2.96	1.34	1.28	0.85	0.49	0.36	0.43	0.46	0.36	0.21	0.91	1.95	0.43
		3.60	4.14	2.68	1.22	1.10	0.73	0.49	0.76	0.61	0.34	0.30	0.88	3.50	0.79
		4.60	6.00	4.27	1.37	1.98	1.10	0.79	1.07	1.07	0.58	0.67	1.31	4.39	0.88
	11	1.80	2.50	1.55	0.46	0.36	0.55	0.43	0.34	0.21	0.30	0.36	1.04	1.95	0.61
		2.70	3.90	2.65	1.40	0.61	0.55	0.43	0.49	0.27	0.55	0.67	1.31	2.44	0.85
		3.60	6.37	4.72	2.68	1.74	1.07	0.91	0.76	0.70	0.64	0.79	2.13	3.20	0.82
		4.60	7.31	5.73	2.13	1.89	1.28	1.10	0.82	0.85	1.07	1.10	1.58	4.48	1.25
		5.50	5.79	7.25	3.14	1.98	1.64	1.34	1.04	0.88	1.13	1.00	2.35	3.63	1.16
		6.40	6.10	5.70	2.35	2.10	1.28	0.98	0.85	1.07	1.07	1.00	2.04	4.63	1.13

Table 24

Wave Heights with Plan 28 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
North	7	0.90	0.91	0.73	0.45	0.21	0.18	0.15	0.12	0.21	0.30	0.18	0.39	0.33	0.27
		1.80	1.49	1.09	0.67	0.33	0.21	0.18	0.18	0.21	0.39	0.21	0.60	0.51	0.30
		2.70	2.07	1.40	0.76	0.36	0.27	0.18	0.18	0.30	0.48	0.27	0.79	0.82	0.45
	9	1.20	1.09	0.67	0.48	0.24	0.12	0.18	0.21	0.21	0.15	0.21	0.36	0.60	0.45
		2.10	1.49	0.91	0.67	0.33	0.27	0.24	0.30	0.24	0.27	0.27	0.60	0.60	0.45
		3.00	2.04	1.58	0.88	0.79	0.36	0.24	0.42	0.21	0.30	0.39	1.46	1.21	0.67
		4.00	2.34	2.01	1.49	0.85	0.42	0.48	0.42	0.54	0.45	0.51	1.55	2.01	0.85
		4.90	4.35	2.34	1.61	0.76	0.54	0.36	0.39	0.39	0.57	0.60	1.03	1.85	0.60
Northeast	7	1.50	1.28	1.79	1.03	0.39	0.30	0.27	0.24	0.21	0.12	0.30	0.45	1.00	0.30
		2.40	2.16	2.86	1.46	0.76	0.42	0.39	0.33	0.27	0.18	0.33	0.73	1.82	0.36
		3.40	2.77	3.56	1.79	0.97	0.51	0.48	0.42	0.27	0.15	0.39	1.24	1.82	0.42
	9	1.20	1.21	1.64	0.97	0.39	0.27	0.30	0.15	0.21	0.09	0.12	0.48	0.82	0.24
		2.10	2.16	2.83	1.49	0.60	0.42	0.30	0.18	0.21	0.15	0.21	1.00	1.98	0.54
		3.00	2.74	4.26	2.49	0.79	0 51	0.39	0.33	0.30	0.27	0.33	1.46	3.32	0.60
		4.00	3.84	5.18	2.89	1.24	0.70	0.51	0.36	0.36	0.51	0.42	1.58	2.56	0.82
		4.90	5.54	4.87	2.52	1.82	0.85	0.60	0.51	0.54	0.73	0.67	1.43	3.26	0.67
		5.80	5.21	3.44	2.31	1.28	0.57	0.42	0.67	0.60	0.70	0.33	2.43	3.96	0.97
East-southeast	7	1.50	1.40	0.91	0.67	0.33	0.24	0.18	0.21	0.15	0.09	0.12	0.36	1.37	0.33
		2.40	2.49	1.95	0.67	0.60	0.39	0.21	0.30	0.18	0.18	0.18	0.73	1.73	0.45
		3.40	3.38	2.34	0.70	0.73	0.33	0.39	0.45	0.36	0.15	0.30	0.82	1.76	0.51
		4.30	3.80	3.13	0.64	0.94	0.54	0.45	0.48	0.39	0.24	0.36	1.00	3.29	0.45
	9	1.80	1.76	1.12	0.85	0.45	0.30	0.30	0.21	0.36	0.33	0.21	0.42	1.15	0.21
		2.70	2.74	1.92	1.09	0.79	0.45	0.42	0.21	0.30	0.42	0.18	0.51	2.19	0.54
		3.60	3.77	3.07	1.06	1.31	0.57	0.67	0.36	0.39	0.27	0.21	0.79	2.71	0.79
		4.60	4.87	4.60	1.43	1.34	0.70	0.64	0.64	0.39	0.45	0.36	1.09	3.84	0.97

Table 25

Wave Heights with Plan 29 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 2	Gage 3	Gage 4	Gage 4A	Gage 5	Gage 5A	Gage 5B	Gage 5C	Gage 5D	Gage 6	Gage 7	Gage 8	Gage 12	Gage 13
Northeast	7	1.50	1.28	1.64	1.10	0.43	0.49	0.18	0.12	0.24	0.18	0.52	0.27	0.27	0.30	0.46	0.24
		2.40	2.13	2.71	1.46	0.73	0.73	0.40	0.58	0.30	0.21	0.76	0.30	0.49	0.40	1.68	0.40
		3.40	2.80	3.81	2.04	1.04	1.07	0.52	0.79	0.43	0.46	1.40	0.49	0.79	0.58	2.38	0.64
	9	1.20	0.98	1.13	0.82	0.40	0.30	0.30	0.21	0.36	0.30	0.36	0.27	0.24	0.21	0.82	0.43
		2.10	1.80	2.13	1.25	0.52	0.30	0.34	0.15	0.52	0.52	0.46	0.30	0.24	0.21	1.80	0.76
		3.00	2.68	3.29	2.19	0.79	0.79	0.67	0.36	0.61	0.67	0.46	0.43	0.36	0.34	2.62	0.91
		4.00	4.18	5.67	3.08	1.40	1.40	1.07	0.67	1.46	1.89	0.94	0.67	0.58	0.61	3.17	0.67
		4.90	5.97	6.70	2.53	1.46	1.16	1.28	1.04	2.07	2.32	1.16	0.67	0.85	0.79	2.68	1.04
		5.80	6.64	3.93	2.10	1.16	1.37	0.82	0.85	1.10	1.13	1.04	0.61	0.64	0.64	3.17	0.94
East-southeast	7	1.50	1.22	0.73	0.36	0.24	0.52	0.24	0.27	0.30	0.43	0.67	0.30	0.34	0.18	1.07	0.52
		2.40	2.28	1.62	0.52	0.61	0.82	0.15	0.30	0.36	0.58	1.10	0.55	0.43	0.30	1.64	0.67
		3.40	3.44	2.62	0.85	0.91	0.88	0.27	0.61	0.55	0.58	1.37	0.46	0.61	0.46	1.89	0.76
		4.30	4.75	3.29	1.10	1.19	1.25	0.49	0.67	0.76	0.67	1.58	0.85	0.79	0.49	2.86	0.64
	9	1.80	2.04	1.04	0.82	0.46	0.40	0.34	0.21	0.46	0.43	0.43	0.34	0.27	0.61	1.68	0.64
		2.70	3.35	1.52	0.98	0.70	0.91	0.67	0.46	0.52	0.40	0.67	0.58	0.21	0.73	1.83	0.55
		3.60	4.97	2.56	1.28	1.19	1.58	1.16	0.73	1.07	0.85	1.19	0.76	0.43	0.82	3.17	0.94
		4.60	5.06	4.82	1.64	1.83	2.26	1.55	1.13	2.19	1.83	2.04	0.98	0.70	0.70	4.05	0.98

Table 26

Wave Heights with Plan 30 Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 1A	Gage 1B	Gage 2	Gage 2A	Gage 2B	Gage 4B	Gage 4C	Gage 5	Gage 5A	Gage 6	Gage 7	Gage 8	Gage 9	Gage 9A	Gage 10A
Northeast	9	2.10	2.04	3.08	1.22	2.74	2.53	1.49	0.64	0.67	0.27	0.34	0.15	0.43	0.34	0.21	0.36	0.49
		3.00	3.32	4.36	1.89	3.63	4.27	1.98	0.82	1.10	0.34	0.46	0.18	0.43	0.43	0.36	0.46	0.49
		4.00	5.46	5.76	2.90	5.58	6.19	3.11	1.04	1.58	0.46	0.82	0.27	0.67	0.55	0.46	0.61	0.55
		4.90	6.06	7.74	5.18	6.25	6.80	4.27	1.68	2.19	0.64	1.25	0.36	0.98	0.70	0.79	1.19	0.82
	11	2.10	2.22	2.71	0.91	2.07	2.53	1.62	0.64	0.64	0.49	0.27	0.34	0.24	0.27	0.18	0.27	0.27
		3.00	3.23	4.42	1.74	3.56	3.60	2.22	0.85	1.22	0.36	0.55	0.36	0.49	0.40	0.43	0.40	0.30
		4.00	4.72	5.91	2.65	5.79	6.06	3.60	1.40	1.68	0.43	0.73	0.64	0.70	0.73	0.58	1.00	0.43
		4.90	7.97	7.50	5.30	6.49	6.98	5.64	1.49	2.53	0.79	1.10	0.98	0.61	1.00	0.67	0.79	0.61
East-southeast	9	2.10	2.50	2.62	1.74	1.34	1.64	2.13	0.55	0.64	0.40	0.43	0.27	0.34	0.30	0.15	0.46	0.40
		3.00	3.02	3.29	2.68	1.46	1.83	2.68	0.85	0.98	0.61	0.55	0.34	0.40	0.40	0.18	0.52	0.55
		4.00	3.35	3.75	3.29	2.38	3.08	3.17	1.19	1.71	0.82	0.73	0.58	0.55	0.55	0.46	0.64	0.61
		4.09	5.15	6.49	5.12	3.87	5.61	5.79	1.62	1.83	0.79	0.94	0.49	0.82	0.61	0.79	0.79	0.64
	11	2.10	2.47	2.71	2.32	1.62	1.77	2.35	0.55	0.43	0.61	0.34	0.24	0.27	0.30	0.21	0.30	0.21
		3.00	4.39	4.51	3.56	2.96	3.78	4.02	0.79	1.19	0.64	0.98	0.43	0.40	0.55	0.61	0.36	0.40
		4.00	5.85	5.73	4.69	4.54	5.24	5.49	1.10	2.04	1.00	1.31	0.85	0.64	0.85	0.76	0.49	0.43
		4.90	7.86	7.74	6.70	5.24	6.89	6.34	1.58	2.13	1.52	1.40	0.85	0.64	1.00	0.88	0.64	0.49

Table 27

Wave Heights with Plan 30A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 1A	Gage 1B	Gage 2	Gage 2A	Gage 2B	Gage 4B	Gage 4C	Gage 5	Gage 5A	Gage 6	Gage 7	Gage 8	Gage 9	Gage 9A	Gage 10A
Northeast	9	2.10	2.62	3.14	1.83	3.35	3.29	1.55	0.64	0.55	0.30	0.30	0.12	0.21	0.27	0.24	0.40	0.40
		3.00	3.50	4.08	2.38	4.72	4.33	1.80	0.76	0.79	0.34	0.40	0.18	0.30	0.36	0.30	0.52	0.49
		4.00	3.04	4.94	2.74	5.91	5.85	2.56	1.04	1.10	0.46	0.55	0.27	0.34	0.36	0.36	0.55	0.85
		4.90	6.34	6.49	5.42	6.06	4.45	3.99	1.31	1.34	0.43	0.55	0.36	0.46	0.46	0.60	0.64	0.55
	11	2.10	2.01	2.50	1.43	2.62	3.05	1.95	0.36	0.30	0.30	0.24	0.18	0.27	0.36	0.34	0.27	0.30
		3.00	3.78	4.11	2.28	4.51	3.99	2.68	0.79	0.91	0.52	0.55	0.27	0.46	0.49	0.64	0.43	0.43
		4.00	5.52	5.94	3.05	7.34	6.92	4.18	1.83	1.86	0.73	0.67	0.49	0.58	0.67	0.73	0.49	0.55
		4.90	5.09	8.05	4.66	6.03	7.01	5.09	1.46	2.10	0.85	0.82	0.49	0.70	0.70	1.13	0.88	0.79
East-southeast	9	2.10	2.44	3.26	2.59	1.49	1.34	1.83	0.46	0.27	0.30	0.27	0.27	0.30	0.15	0.18	0.34	0.52
		3.00	2.68	3.56	2.99	1.95	1.80	1.95	0.94	0.49	0.46	0.58	0.43	0.40	0.27	0.34	0.55	0.61
		4.00	4.05	3.87	4.60	3.02	2.68	2.80	1.46	1.10	0.79	0.88	0.61	0.43	0.46	0.49	0.64	0.67
		4.90	5.49	6.98	5.91	5.67	6.28	5.76	1.83	1.52	0.76	0.82	0.58	0.58	0.55	0.52	0.61	0.79
	11	2.10	2.53	3.08	2.38	1.83	1.86	2.10	0.64	0.49	0.58	0.30	0.27	0.24	0.36	0.18	0.40	0.34
		3.00	3.60	4.57	3.87	3.02	2.80	2.65	0.70	0.70	0.36	0.85	0.43	0.55	0.43	0.55	0.55	0.36
		4.00	4.88	5.91	5.49	5.52	4.36	4.78	1.04	1.25	0.73	1.52	0.88	1.04	0.76	0.73	0.49	0.49
		4.90	6.13	7.50	6.40	6.28	6.37	6.37	1.28	1.52	1.00	1.19	0.67	0.67	0.67	0.79	0.61	0.61

Table 28

Wave Heights with Plan 30B Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters Gage 1	Gage 1A	Gage 1B	Gage 2	Gage 2A	Gage 2B	Gage 4B	Gage 4C	Gage 5	Gage 5A	Gage 6	Gage 7	Gage 8	Gage 9	Gage 9A	Gage 10A
Northeast	9	2.10	2.77	3.08	1.43	3.20	2.92	--	0.58	0.82	0.30	0.36	0.27	0.30	0.30	0.24	0.43	0.36
		3.00	3.72	4.08	2.16	3.87	4.05	--	0.79	1.04	0.49	0.49	0.40	0.34	0.30	0.36	0.55	0.40
		4.00	5.67	5.82	2.59	4.75	5.21	--	1.04	1.25	0.52	0.67	0.36	0.36	0.36	0.43	0.58	0.67
		4.90	5.88	6.16	2.99	6.16	5.85	--	1.58	1.89	0.67	0.88	0.43	0.43	0.46	0.67	0.61	0.67
	11	2.10	2.26	2.68	1.37	2.50	2.53	--	0.30	0.43	0.30	0.36	0.30	0.30	0.34	0.24	0.36	0.30
		3.00	3.75	4.08	1.86	4.08	3.93	--	0.79	0.91	0.64	0.70	0.49	0.34	0.55	0.67	0.52	0.55
		4.00	5.18	5.73	2.59	6.25	6.34	--	1.86	2.16	0.98	0.94	0.52	0.61	0.70	0.79	0.98	0.67
		4.90	5.00	7.13	4.27	5.12	5.58	--	1.10	1.58	0.73	0.98	0.46	0.58	0.70	1.31	1.10	0.61
East-southeast	9	2.10	1.95	2.44	1.95	1.83	1.58	--	0.46	0.40	0.24	0.34	0.24	0.36	0.24	0.24	0.52	0.55
		3.00	2.56	3.32	3.11	2.26	1.68	--	1.10	0.82	0.30	0.36	0.27	0.58	0.34	0.40	0.58	0.64
		4.00	3.05	3.69	3.63	3.14	2.44	--	1.40	1.25	0.52	0.98	0.49	1.00	0.52	0.46	0.64	0.64
		4.90	4.69	6.31	4.75	4.85	5.30	--	1.25	1.22	0.70	0.79	0.52	0.98	0.76	0.58	0.76	0.73
	11	2.10	1.95	2.53	2.13	1.65	1.40	--	0.36	0.27	0.36	0.34	0.21	0.27	0.40	0.27	0.43	0.43
		3.00	3.05	4.11	3.35	3.32	2.77	--	1.31	0.98	0.46	0.70	0.30	0.58	0.61	0.46	0.52	0.55
		4.00	5.33	5.24	4.85	4.27	4.42	--	1.55	2.16	1.10	1.34	0.64	1.13	1.00	0.73	0.91	0.76
		4.90	6.00	7.16	6.70	6.16	5.97	--	2.04	2.04	1.13	1.49	0.79	1.10	0.94	1.00	1.00	0.91

Table 29

Wave Heights with Plans 30A, 30C, 30D, 31, and 31A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters: Entrance Channel Gages Gage 1	Gage 1A	Gage 1C	Gage 2	Gage 2A	Gage 2C	Turning Basin Gage 4B	Gage 4C	Island Gages Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Floating Pier Gage 10A	Degaussing Range Gage 11	Ammo Pier Gage 13
Plan 30A (Plan 24 Inner Breakwater)																		
Northeast	9	2.10	1.92	1.92	1.82	2.01	2.13	1.73	0.21	0.39	0.21	0.06	0.12	0.27	0.33	0.18	0.94	0.12
		3.00	2.86	3.04	3.01	3.35	3.23	2.89	0.54	0.54	0.18	0.18	0.27	0.48	0.54	0.36	1.00	0.30
		4.00	2.62	4.51	4.35	4.75	4.63	4.20	0.85	0.79	0.30	0.30	0.48	0.67	0.57	0.33	1.46	0.67
Plan 30C (Plan 22 Inner Breakwater)																		
Northeast	9	2.10	2.04	2.07	1.88	2.10	2.25	1.82	0.15	0.42	0.12	0.09	0.12	0.24	0.42	0.18	0.64	0.18
		3.00	3.92	3.04	2.83	3.07	3.16	2.71	0.48	0.51	0.18	0.15	0.36	0.45	0.70	0.36	1.12	0.27
		4.00	3.74	4.51	4.51	4.63	4.35	4.35	0.85	0.85	0.39	0.21	0.36	0.67	0.54	0.33	1.70	1.82
Plan 30D (No Inner Breakwater)																		
Northeast	9	2.10	2.07	2.10	1.92	2.13	2.40	1.85	0.57	1.28	0.67	0.30	0.12	0.42	0.24	0.18	0.67	0.12
		3.10	2.95	3.26	3.16	3.53	3.41	2.83	1.18	1.88	0.97	0.54	0.27	1.00	0.54	0.27	1.00	0.36
		4.00	3.87	4.75	4.51	4.57	4.54	3.96	1.73	2.46	1.06	0.79	0.67	1.24	1.00	0.36	1.58	0.54
Plan 31 (-10.5 m Dredging Extended)																		
Northeast	9	2.10	2.13	2.07	2.07	1.98	2.34	1.70	0.36	0.64	0.42	0.18	0.09	0.18	0.24	0.21	0.94	0.24
		3.00	3.01	3.10	3.20	3.20	3.62	2.59	0.57	0.85	0.42	0.21	0.15	0.39	0.57	0.33	1.31	0.39
		4.00	3.77	4.66	4.51	4.69	4.54	3.87	0.97	1.06	0.57	0.27	0.42	0.73	0.79	0.36	2.01	0.73
Plan 31A (Outer 300 m of North Breakwater Removed)																		
Northeast	9	2.10	2.04	2.25	2.13	2.37	2.49	1.88	0.30	0.60	0.24	0.18	0.24	0.27	0.27	0.27	0.79	0.18
		3.00	2.83	3.23	3.20	3.47	3.65	2.56	0.67	0.79	0.30	0.24	0.36	0.48	0.54	0.39	1.24	0.51
		4.00	3.71	4.44	4.20	4.90	5.05	3.90	1.21	1.12	0.45	0.33	0.48	0.91	0.60	0.42	1.88	0.88

Table 30

Wave Heights with Plans 32 and 32A Installed

Test Direction	Test Wave Period sec	Test Wave Height meters	Wave Heights at Indicated Gage Locations, Prototype, meters: Gage 1	Gage 1A	Gage 1C	Gage 2	Gage 2A	Gage 2C	Gage 4B	Gage 4C	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10A	Gage 11	Gage 13
Plan 32																		
North	9	2.10	1.00	0.70	0.79	0.88	0.54	1.15	0.36	0.12	0.21	0.12	0.21	0.15	0.36	0.18	1.09	0.51
		3.00	1.76	1.00	1.00	1.12	0.97	1.43	0.60	0.24	0.21	0.18	0.24	0.30	0.45	0.24	1.43	0.67
		4.00	2.37	1.79	1.79	1.64	1.79	1.70	0.45	0.73	0.27	0.24	0.21	0.27	0.48	0.24	1.49	0.94
Northeast	9	2.10	2.01	2.07	2.04	2.07	2.25	1.73	0.33	0.48	0.45	0.24	0.27	0.30	0.27	0.15	1.09	0.27
		3.00	3.16	3.07	2.68	3.04	3.29	2.56	0.57	0.88	0.45	0.24	0.18	0.21	0.60	0.24	1.31	0.42
		4.00	3.77	4.54	4.17	4.78	4.57	3.93	1.06	0.97	0.39	0.30	0.42	0.88	0.51	0.30	1.64	0.67
East-southeast	9	2.10	2.16	2.43	2.16	0.97	1.18	0.94	0.24	0.59	0.39	0.33	0.27	0.36	0.33	0.18	1.00	0.36
		3.00	3.20	3.71	2.98	2.01	2.19	1.98	0.82	0.45	0.48	0.36	0.33	0.67	0.70	0.24	1.21	0.67
		4.00	4.29	5.05	4.63	2.95	3.90	2.16	1.12	1.03	0.88	0.57	0.60	1.03	0.88	0.33	0.79	0.91
Plan 32A																		
North	9	2.10	1.03	0.67	0.67	0.39	0.36	0.33	0.12	0.27	0.18	0.21	0.12	0.24	0.30	0.15	0.24	0.21
		3.00	1.43	1.06	1.58	0.79	0.97	0.45	0.18	0.27	0.18	0.15	0.24	0.36	0.30	0.24	0.64	0.30
		4.00	2.40	2.52	1.73	2.68	3.32	2.22	0.73	0.97	0.21	0.27	0.33	0.27	0.57	0.21	1.34	0.57
Northeast	9	2.10	2.13	2.34	2.34	2.10	2.25	1.43	0.27	0.57	0.27	0.12	0.21	0.18	0.42	0.18	0.91	0.27
		3.00	3.13	3.35	3.41	2.89	3.35	2.01	0.45	0.67	0.24	0.27	0.33	0.39	0.70	0.30	1.61	0.45
		4.00	3.71	4.90	4.81	3.71	4.29	2.49	0.70	1.00	0.39	0.27	0.39	0.64	0.54	0.33	2.01	0.42
East-southeast	9	2.10	2.28	2.71	1.67	0.76	0.85	0.79	0.70	0.24	0.30	0.12	0.24	0.30	0.54	0.21	0.51	0.15
		3.00	3.56	3.90	2.83	1.52	1.61	1.58	0.88	0.64	0.33	0.18	0.30	0.48	0.57	0.30	0.76	0.73
		4.00	4.69	4.75	3.96	2.80	2.65	2.28	0.97	1.18	0.39	0.42	0.48	0.67	0.45	0.30	1.61	1.12

Table 31

Wave Heights Along Center Lines of Various Proposed Structures for 9-sec Incident Test Waves

Incident Wave Height* H_i, meters	Wave Heights at Indicated Gage Locations for Various Test Directions, Prototype, meters																
	North Breakwater								East Breakwater							South Breakwater	
	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15	Gage 16	Gage 17
North Test Direction																	
(k_f)** →	1.18	1.17	1.14	1.14	1.11	1.17	1.18	1.15	1.10	1.10	1.11	1.11	1.12	1.13	1.15	1.20	1.22
1.20	0.88	1.58	0.33	1.28	0.21	0.39	0.91	0.06	1.92	1.88	0.21	0.30	0.48	0.82	0.39	1.24	0.51
2.10	1.64	2.74	0.94	1.92	0.30	1.49	1.58	0.27	2.98	2.89	0.57	1.15	1.34	1.28	0.91	1.15	1.37
3.00	2.92	3.62	2.62	2.68	0.54	2.56	1.85	0.51	3.87	3.77	1.58	2.25	2.56	2.01	1.40	1.82	1.76
4.00	2.68	4.14	4.11	2.80	1.37	3.16	3.35	2.16	4.81	5.02	3.71	3.65	3.01	2.65	1.82	3.47	1.98
4.90	3.77	3.26	3.07	4.32	4.93	3.68	4.54	3.29	5.33	3.99	5.08	5.15	4.96	4.08	3.04	3.07	1.92
5.80	2.95	3.74	4.78	4.08	4.11	3.90	3.80	3.56	4.84	4.69	4.41	4.54	3.84	3.65	3.26	2.74	1.98
Northeast Test Direction																	
(k_f)** →	1.15	1.13	1.10	1.10	1.10	1.13	1.13	1.13	1.08	1.09	1.10	1.11	1.12	1.14	1.13	1.19	1.19
1.20	0.60	0.42	0.76	0.76	0.45	1.21	0.24	0.36	0.51	0.27	1.24	0.97	1.85	0.73	0.76	0.67	0.60
2.10	1.64	0.57	1.55	1.43	0.76	1.88	0.36	0.70	0.85	0.33	2.16	1.88	3.07	1.37	1.76	2.31	0.76
3.00	2.83	0.64	2.37	2.22	1.24	2.28	1.18	1.18	1.49	0.82	3.01	2.86	4.26	2.28	3.01	2.95	2.34
4.00	3.44	3.16	3.20	3.35	1.98	3.04	3.32	2.13	2.65	2.62	4.54	3.77	4.87	3.26	3.65	2.86	2.80
4.90	3.90	4.72	3.71	3.93	3.77	3.68	4.57	3.20	4.44	5.45	5.15	4.41	4.14	4.11	3.53	3.07	2.92
5.80	3.56	3.59	3.84	6.37	6.00	5.21	3.68	4.17	4.69	4.26	4.63	4.41	4.75	3.38	3.90	3.01	3.41
East Southeast Test Direction																	
(k_f)** →	1.15	1.14	1.13	1.11	1.11	1.15	1.14	1.16	1.11	1.12	1.13	1.13	1.14	1.14	1.15	1.24	1.25
1.20	0.24	0.45	0.76	0.36	0.70	0.57	0.82	0.48	0.70	0.39	1.24	1.24	1.09	0.91	1.43	0.97	0.39
2.10	0.42	1.09	1.40	0.88	1.58	1.43	1.64	0.97	1.43	0.94	2.34	2.07	2.04	1.61	2.37	1.21	1.58
3.00	1.18	1.85	1.98	1.46	2.28	2.25	2.34	0.91	2.07	2.01	3.47	3.13	3.59	2.83	3.35	2.25	1.34
4.00	1.67	2.04	2.98	2.52	3.53	3.20	3.38	3.59	3.23	4.69	4.05	4.44	3.44	3.84	4.14	2.31	2.49
4.90	3.44	3.74	4.38	4.32	5.85	5.18	3.77	4.02	4.69	4.14	5.88	4.78	4.38	3.80	3.80	2.59	3.26
5.80	3.41	3.68	4.14	3.99	4.41	3.80	3.74	4.08	5.45	4.72	4.60	4.63	4.20	4.26	3.65	2.31	2.83

* Actual wave height at wave machine.

** Model viscous friction correction factor (i.e. adjusted incident wave height = H_i/k_f).

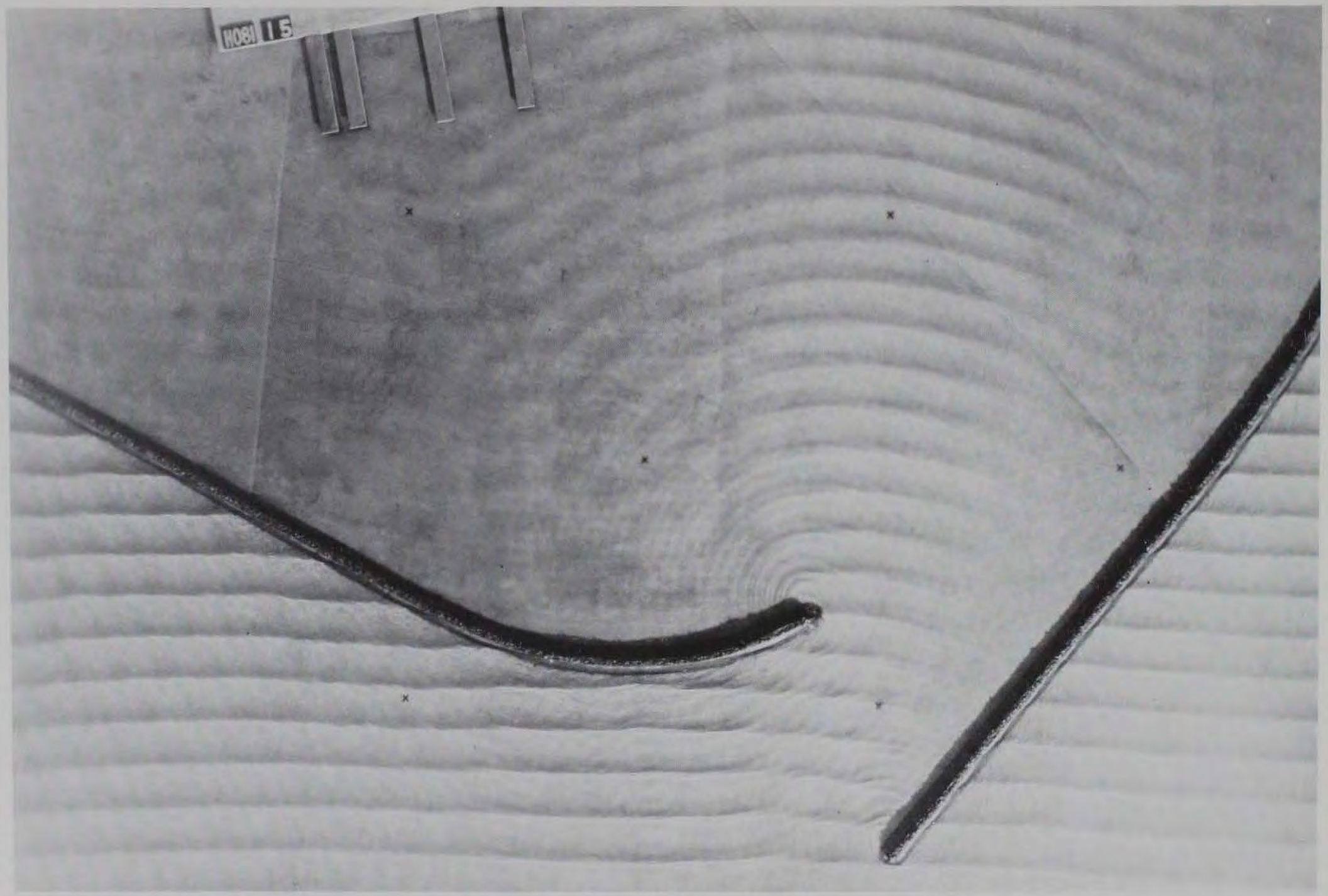


Photo 1. Plan 1; 7-sec, 3.4-m waves from northeast

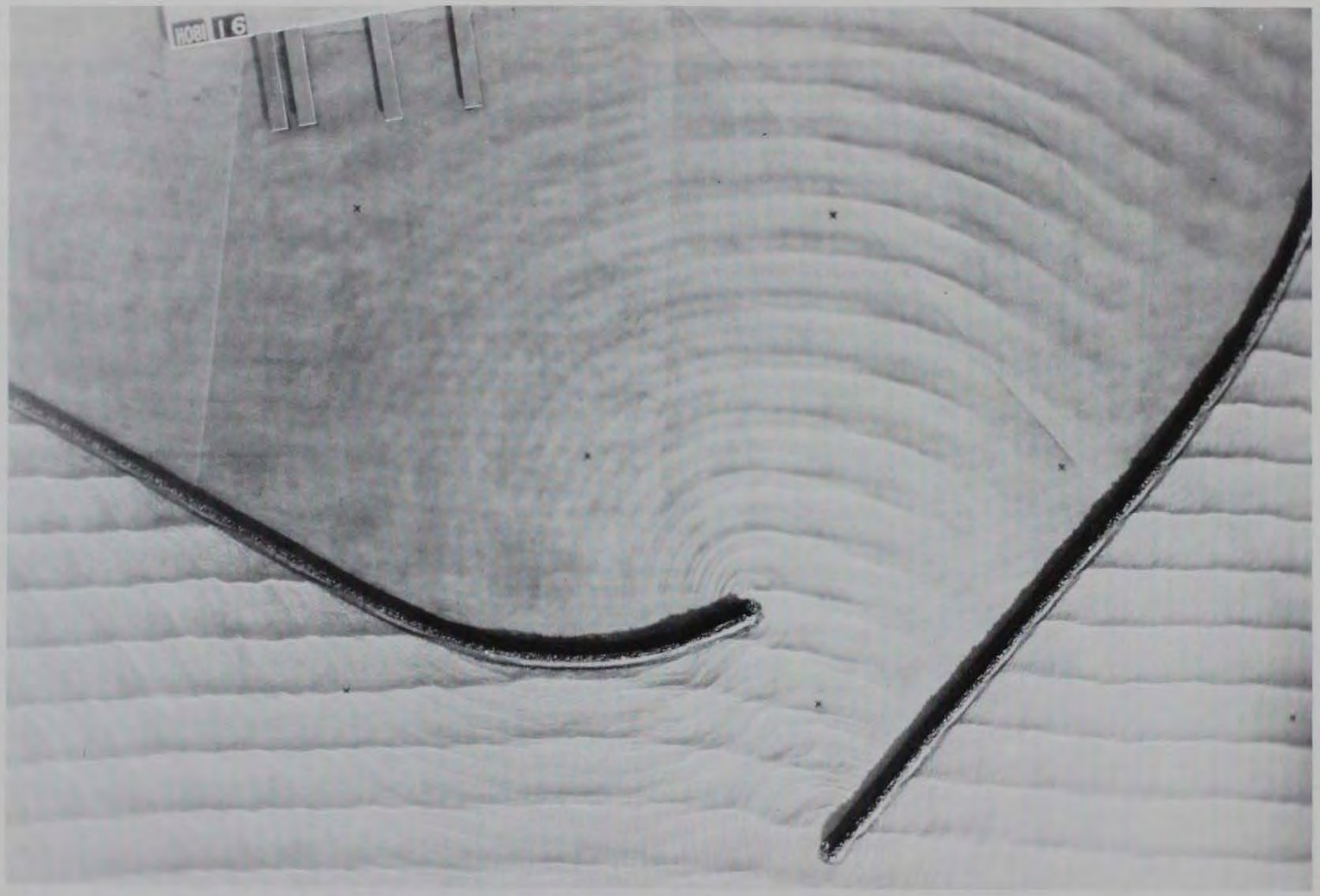


Photo 2. Plan 1; 9-sec, 4.0-m waves from northeast

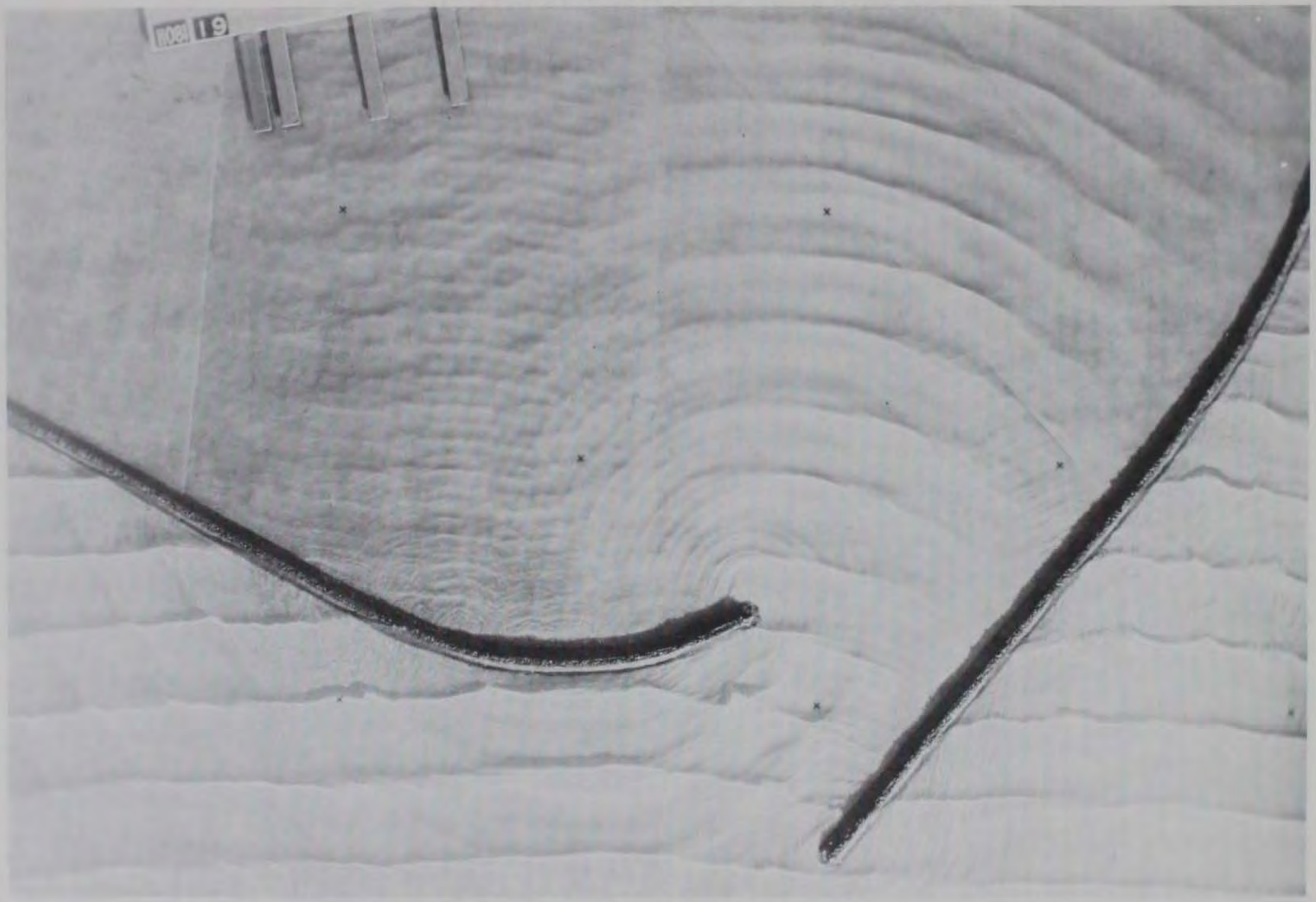


Photo 3. Plan 1; 11-sec, 4.9-m waves from northeast

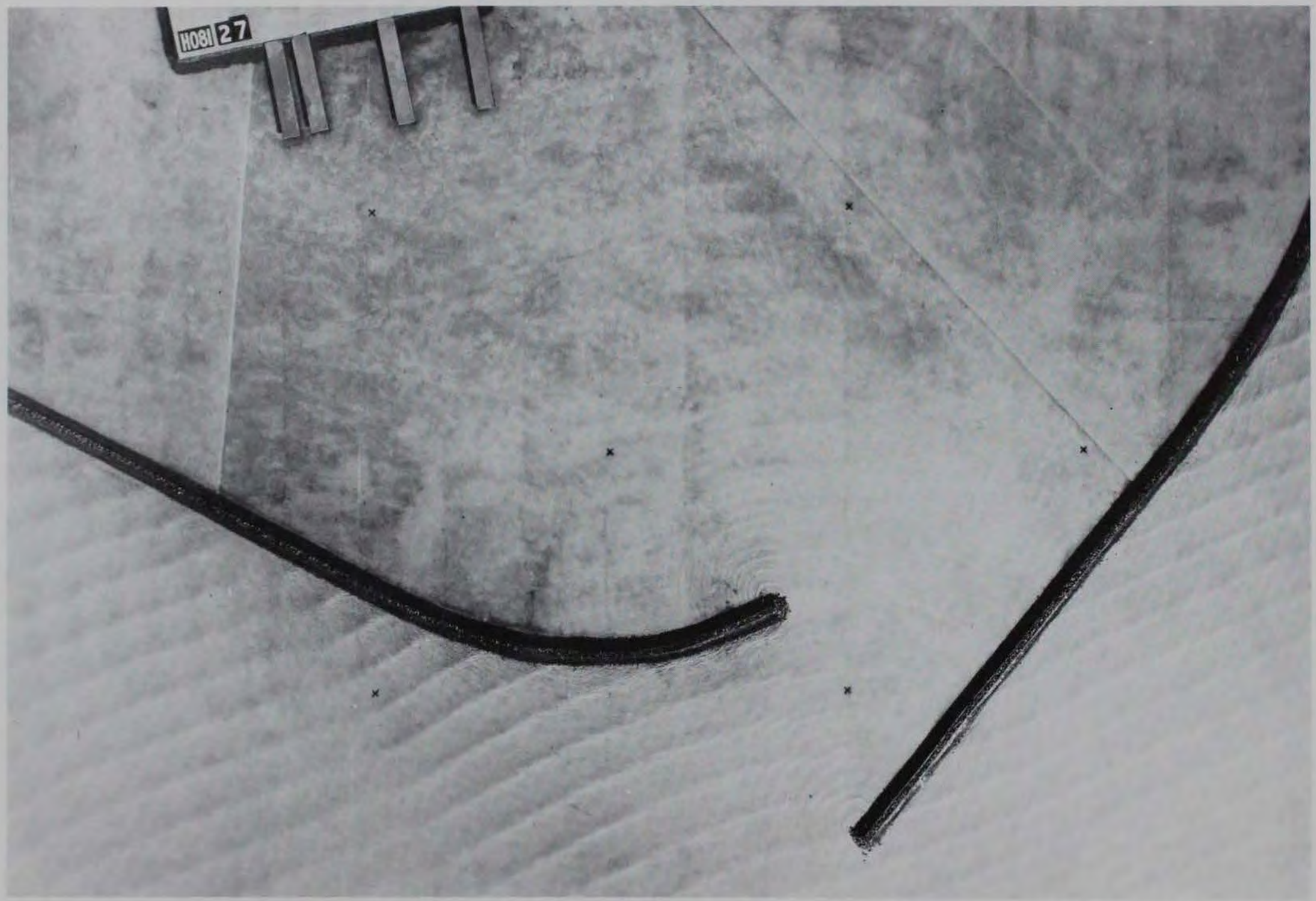


Photo 4. Plan 2; 7-sec, 2.7-m waves from north

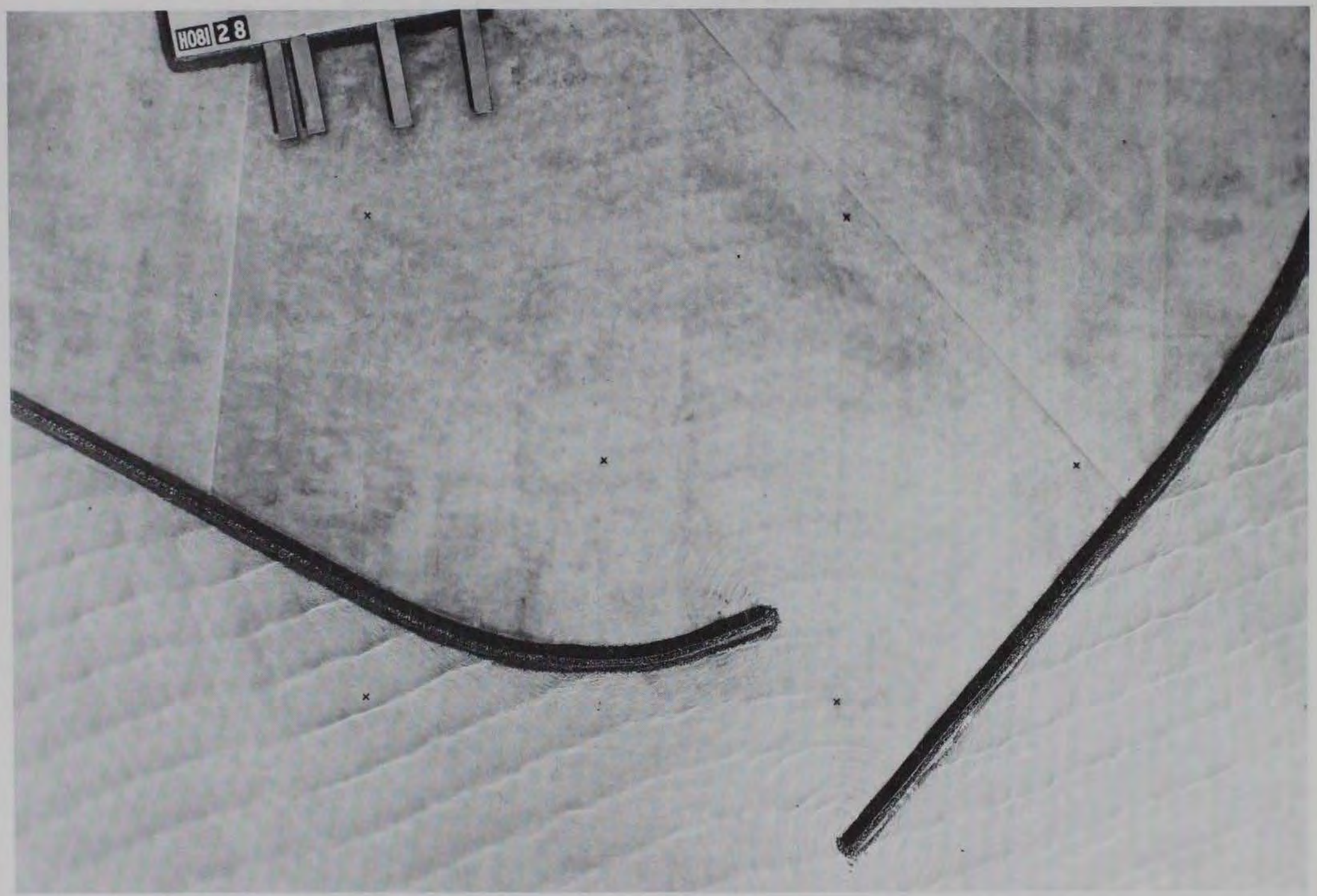


Photo 5. Plan 2; 9-sec, 4.0-m waves from north

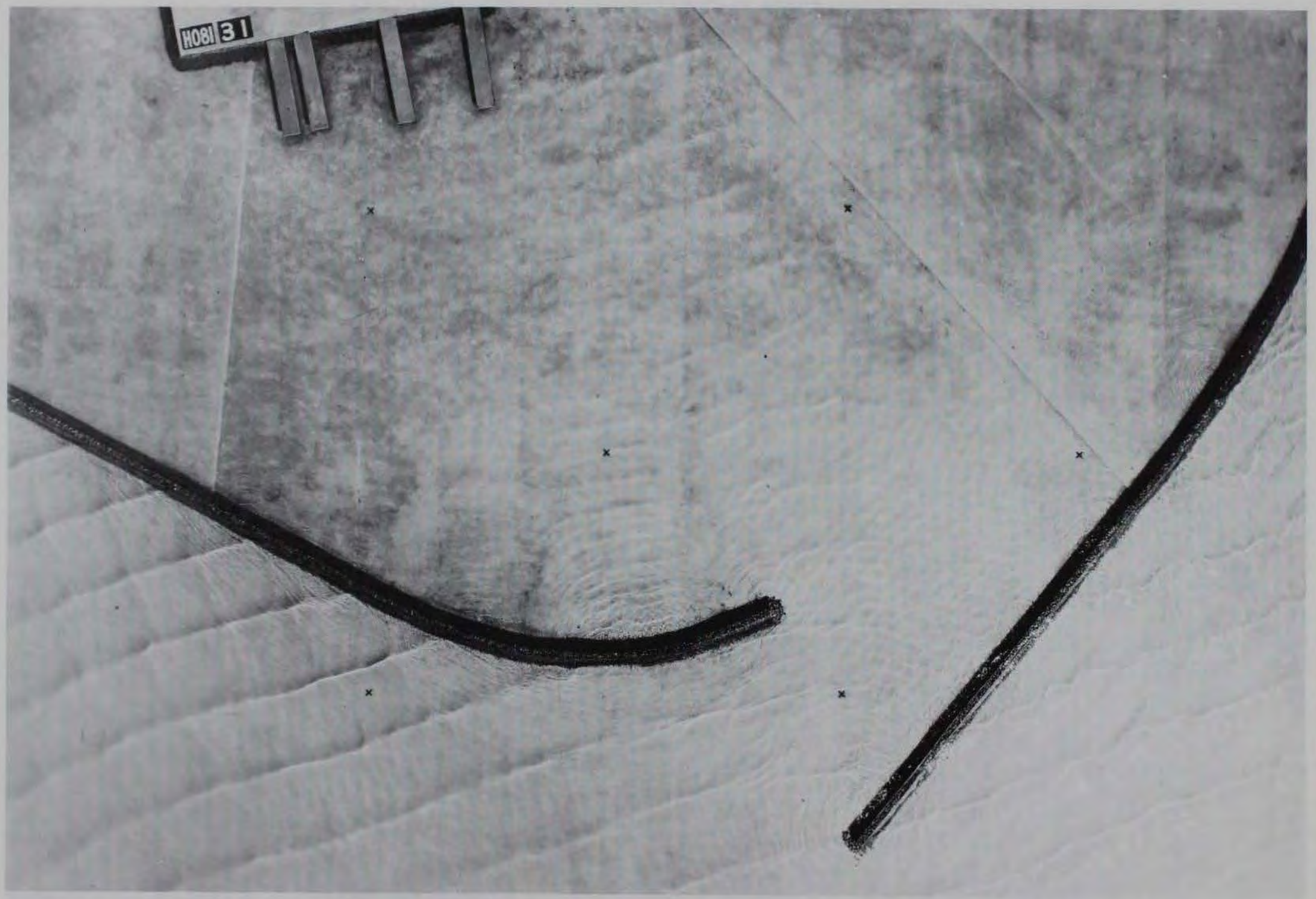


Photo 6. Plan 2; 11-sec, 4.9-m waves from north

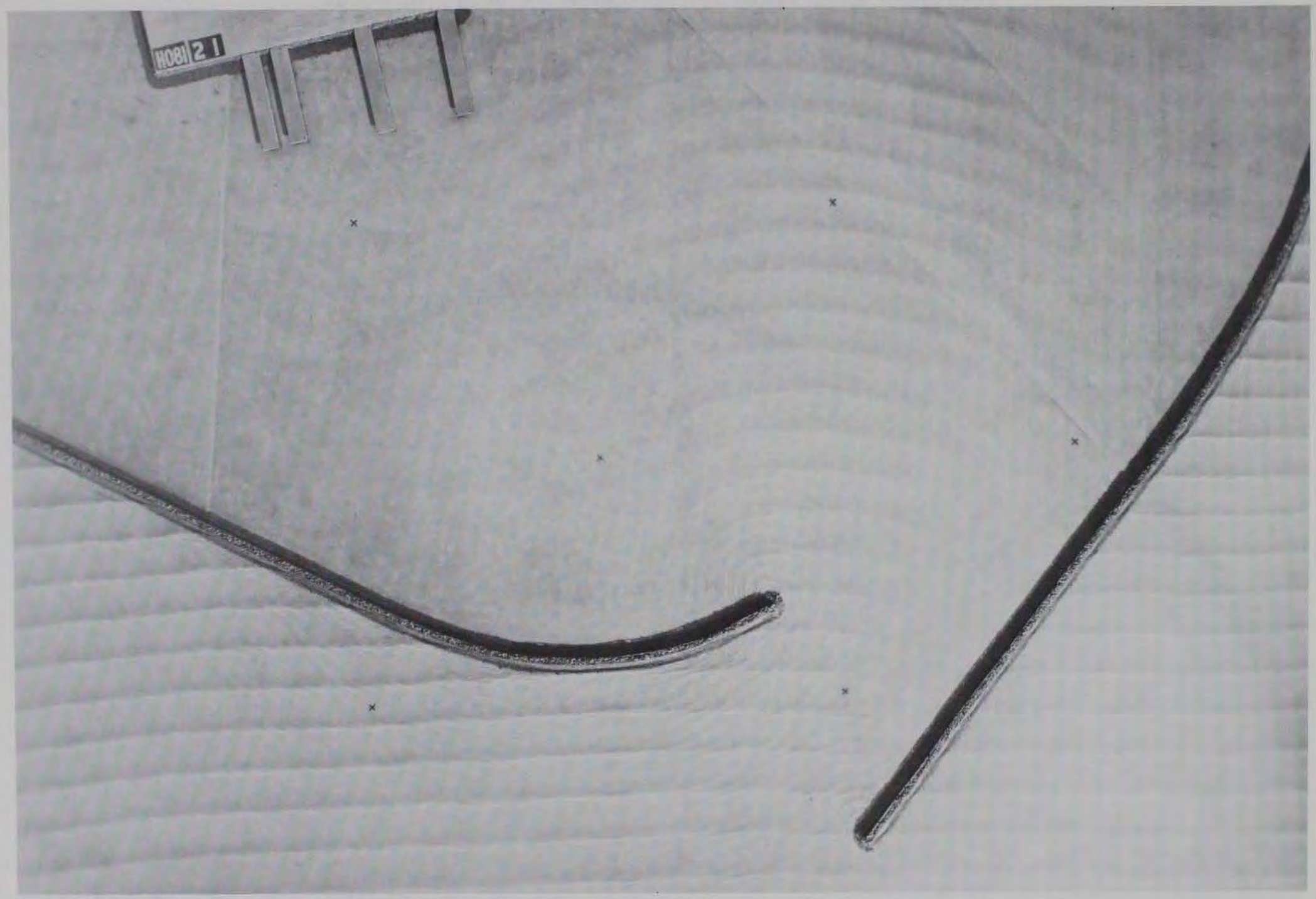


Photo 7. Plan 2; 7-sec, 3.4-m waves from northeast

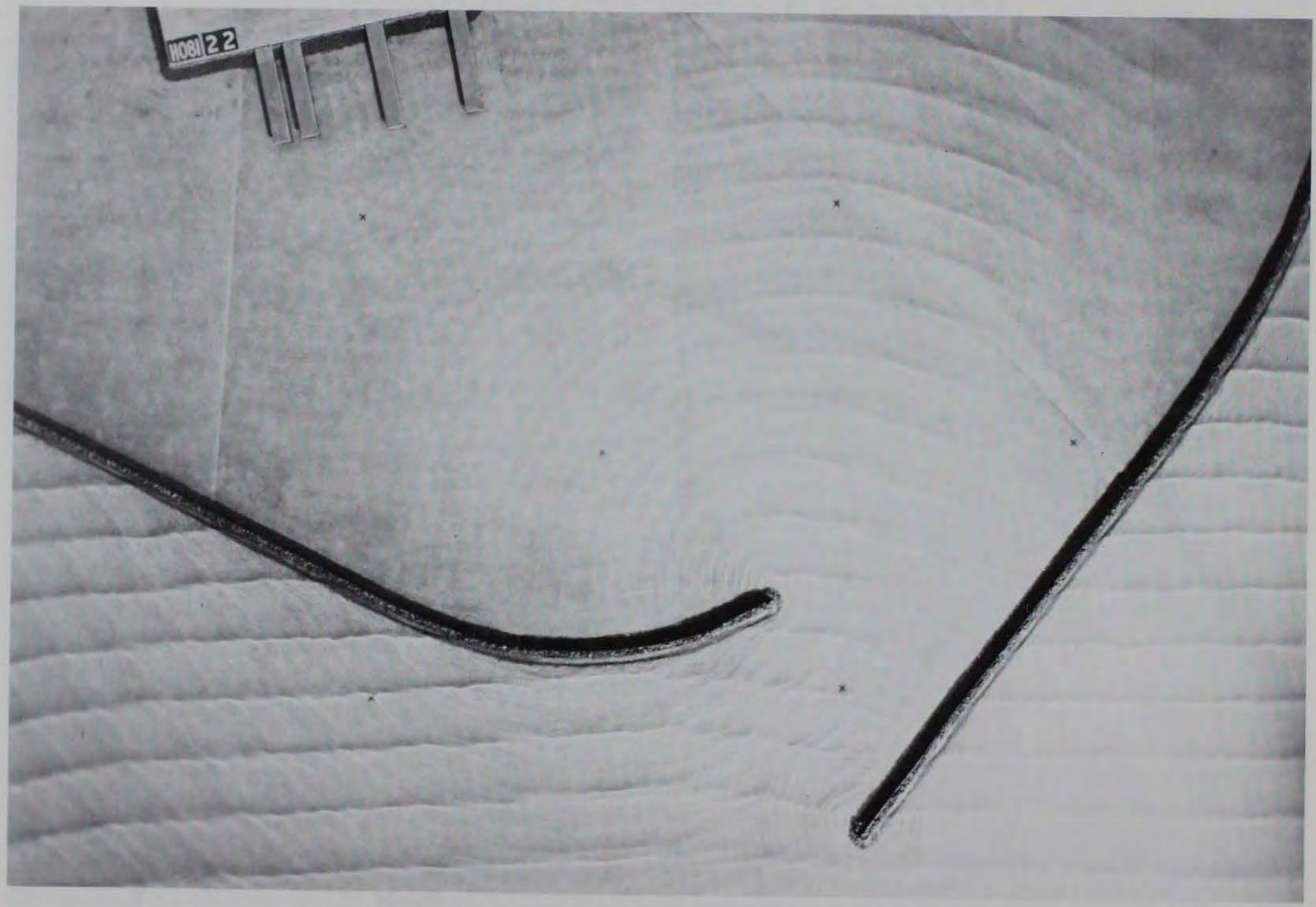


Photo 8. Plan 2; 9-sec, 4.0-m waves from northeast

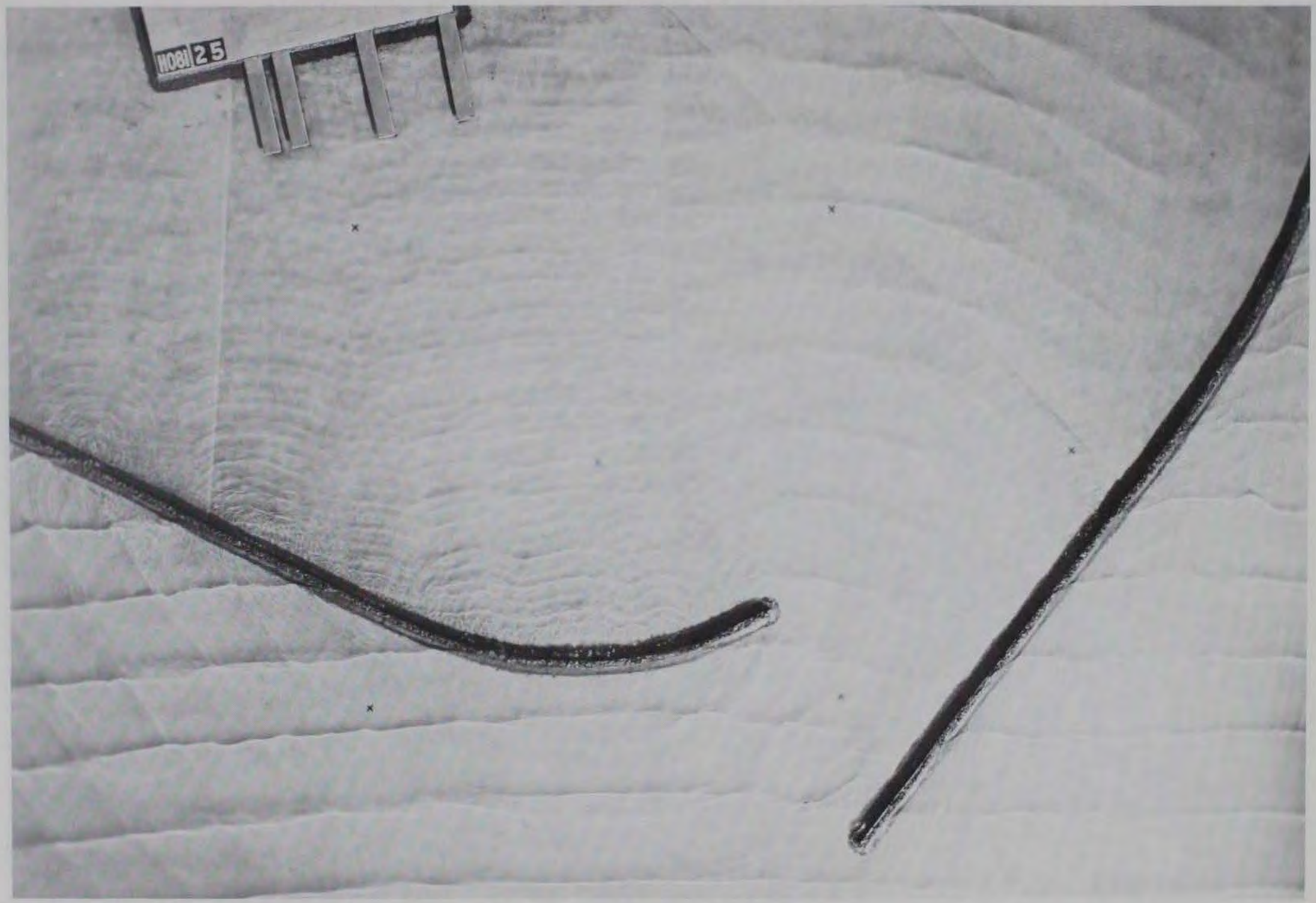


Photo 9. Plan 2; 11-sec, 4.9-m waves from northeast

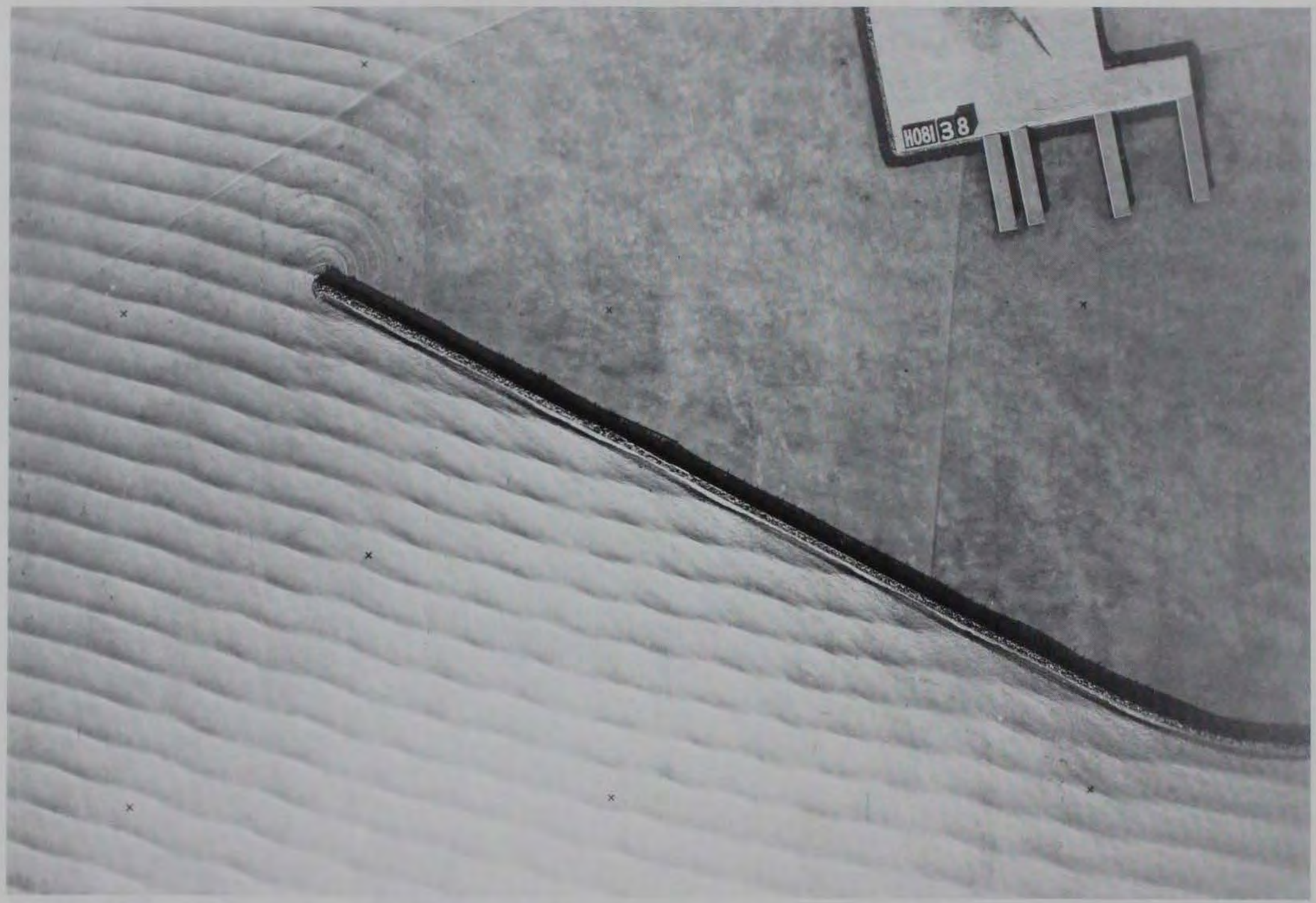


Photo 10. Plan 2; 7-sec, 2.4-m waves from east-southeast

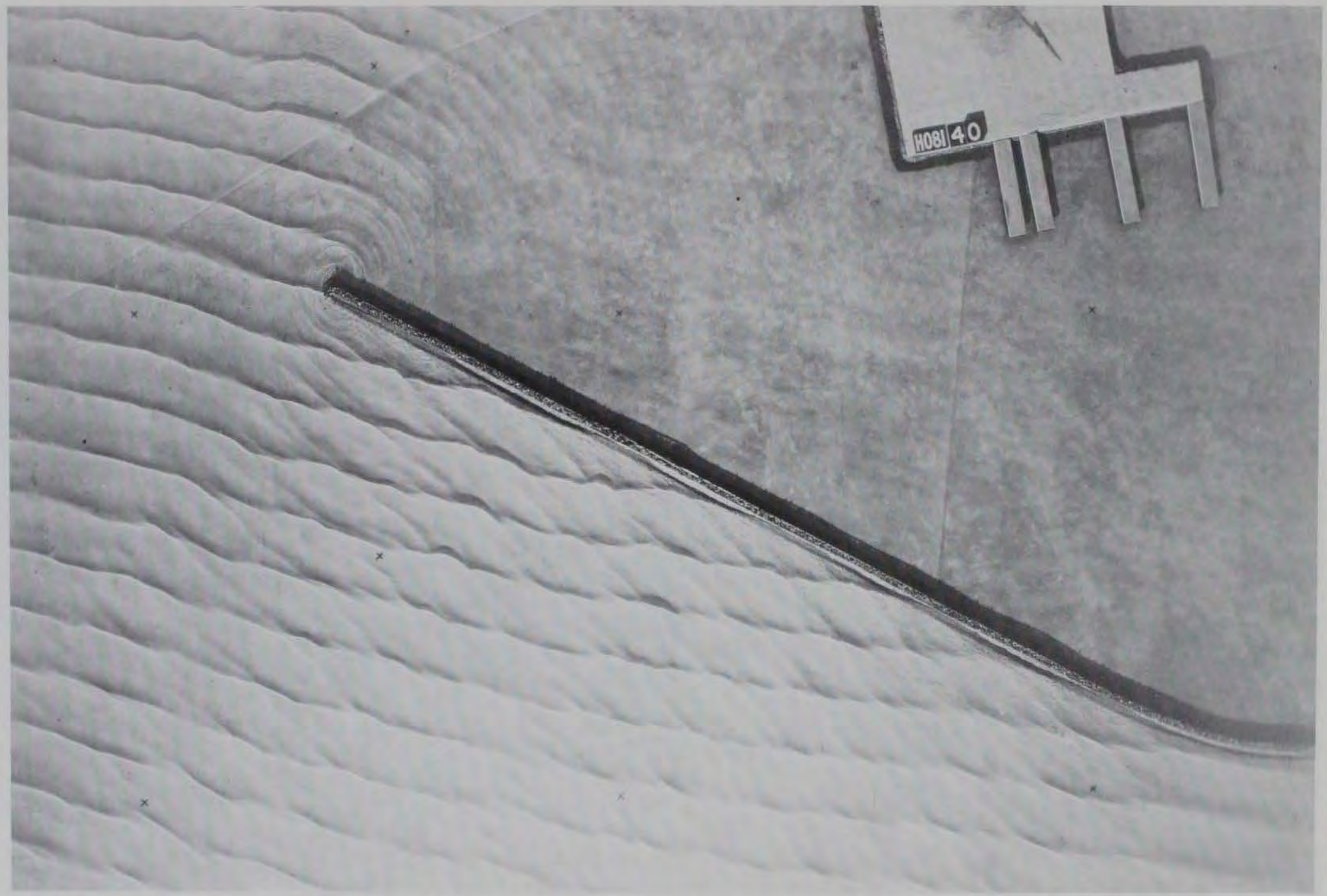


Photo 11. Plan 2; 9-sec, 3.6-m waves from east-southeast

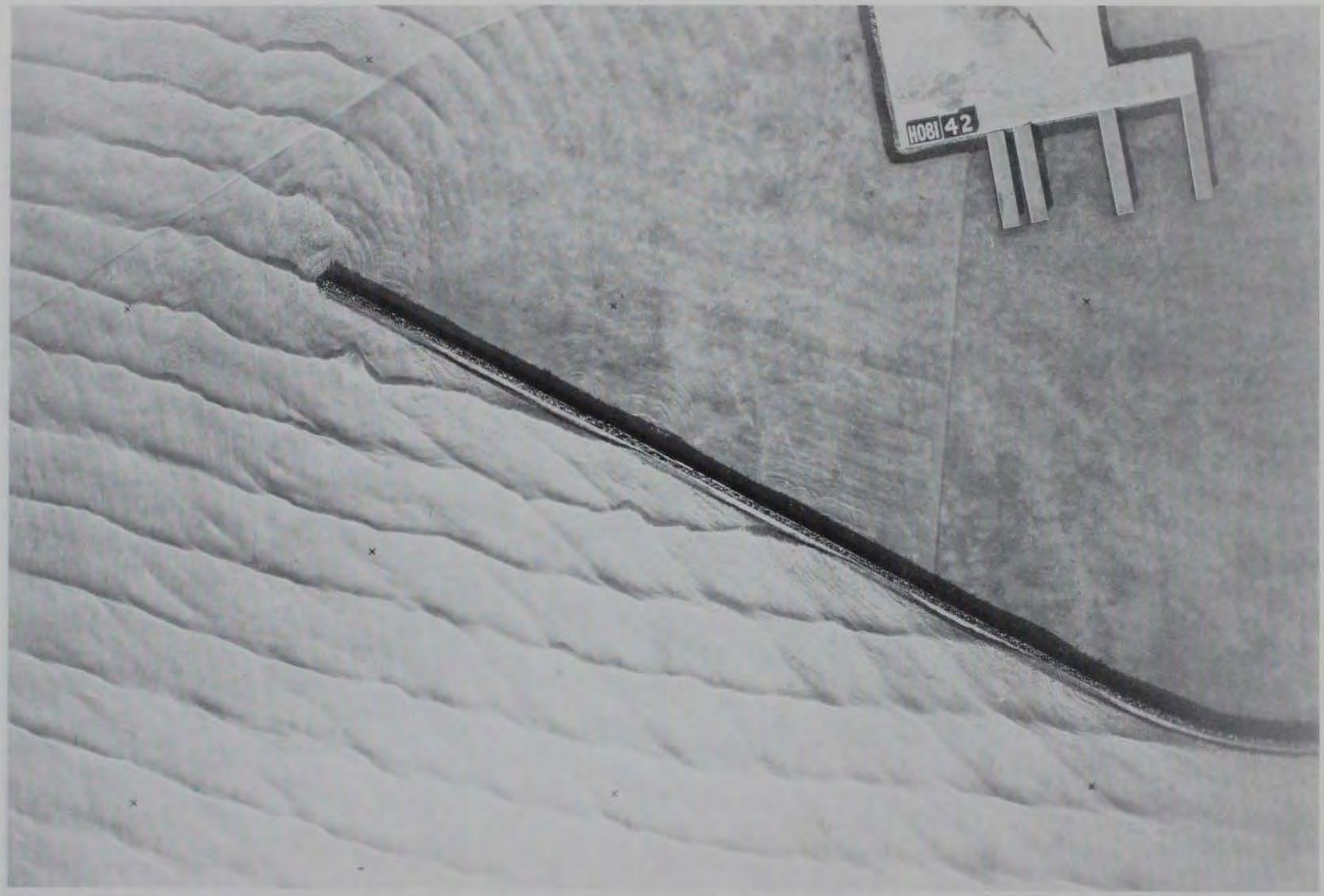


Photo 12. Plan 2; 11-sec, 3.6-m waves from east-southeast

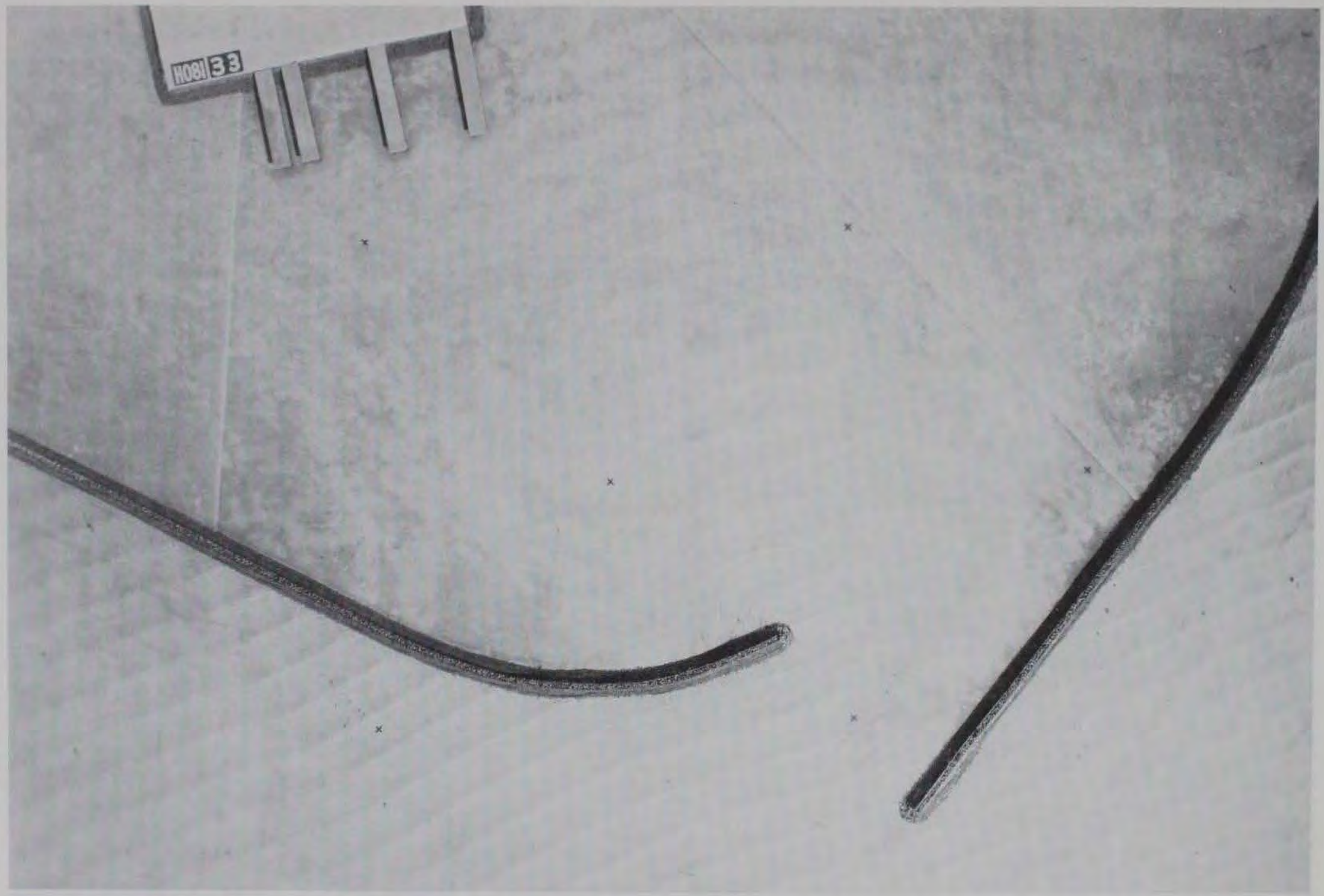


Photo 13. Plan 9; 7-sec, 2.7-m waves from north

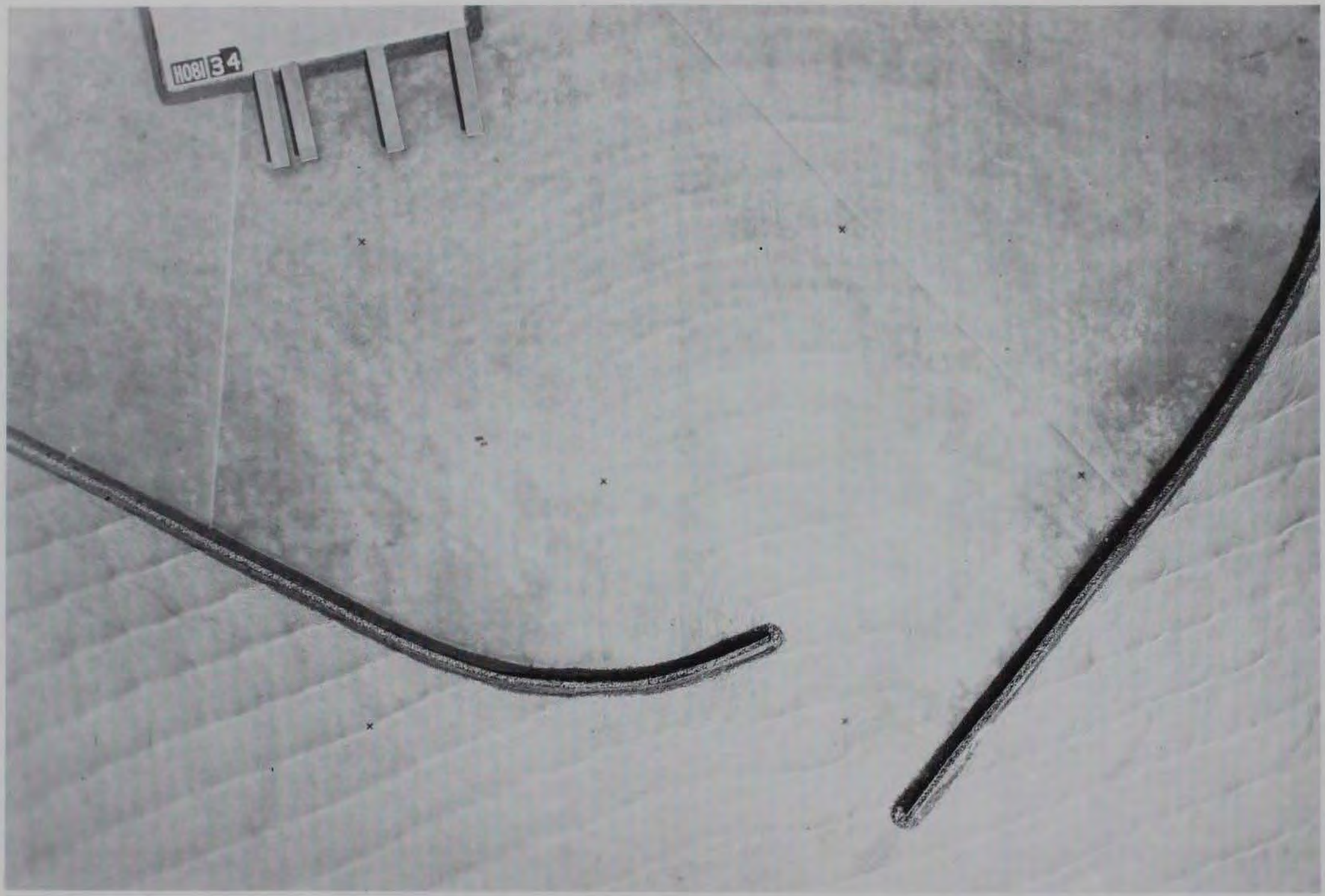


Photo 14. Plan 9; 9-sec, 3.0-m waves from north

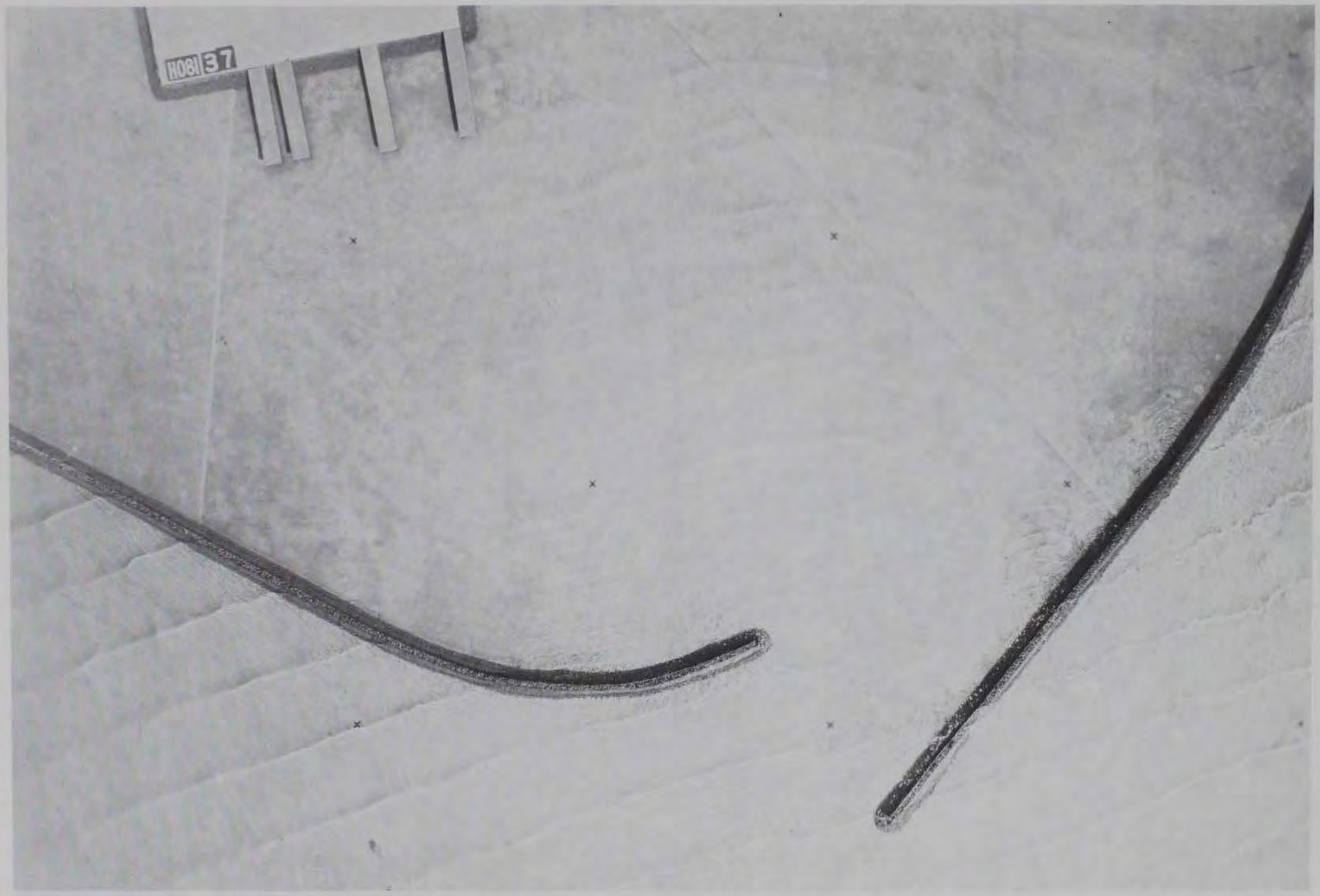


Photo 15. Plan 9; 11-sec, 4.9-m waves from north

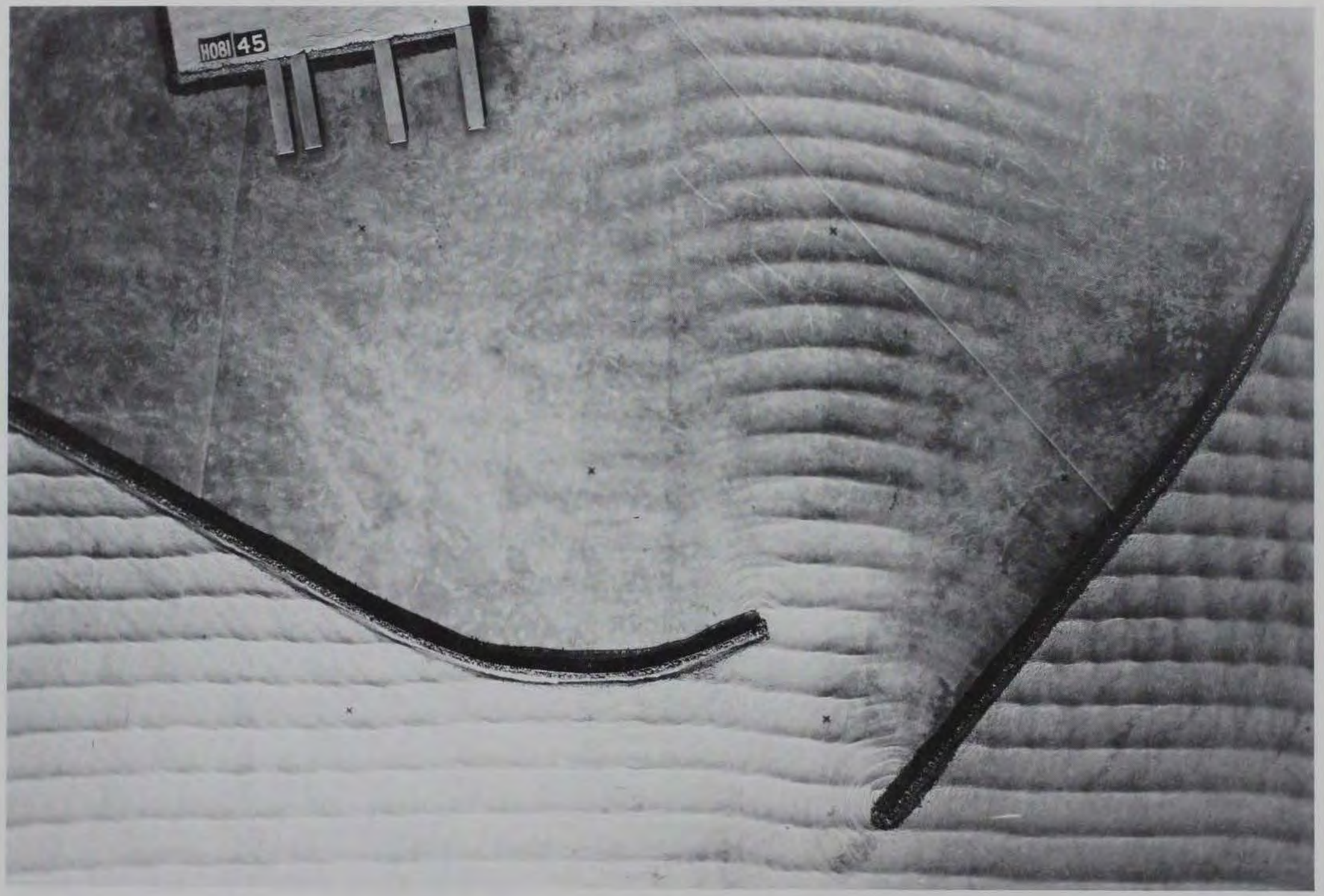


Photo 16. Plan 9; 7-sec, 3.4-m waves from northeast

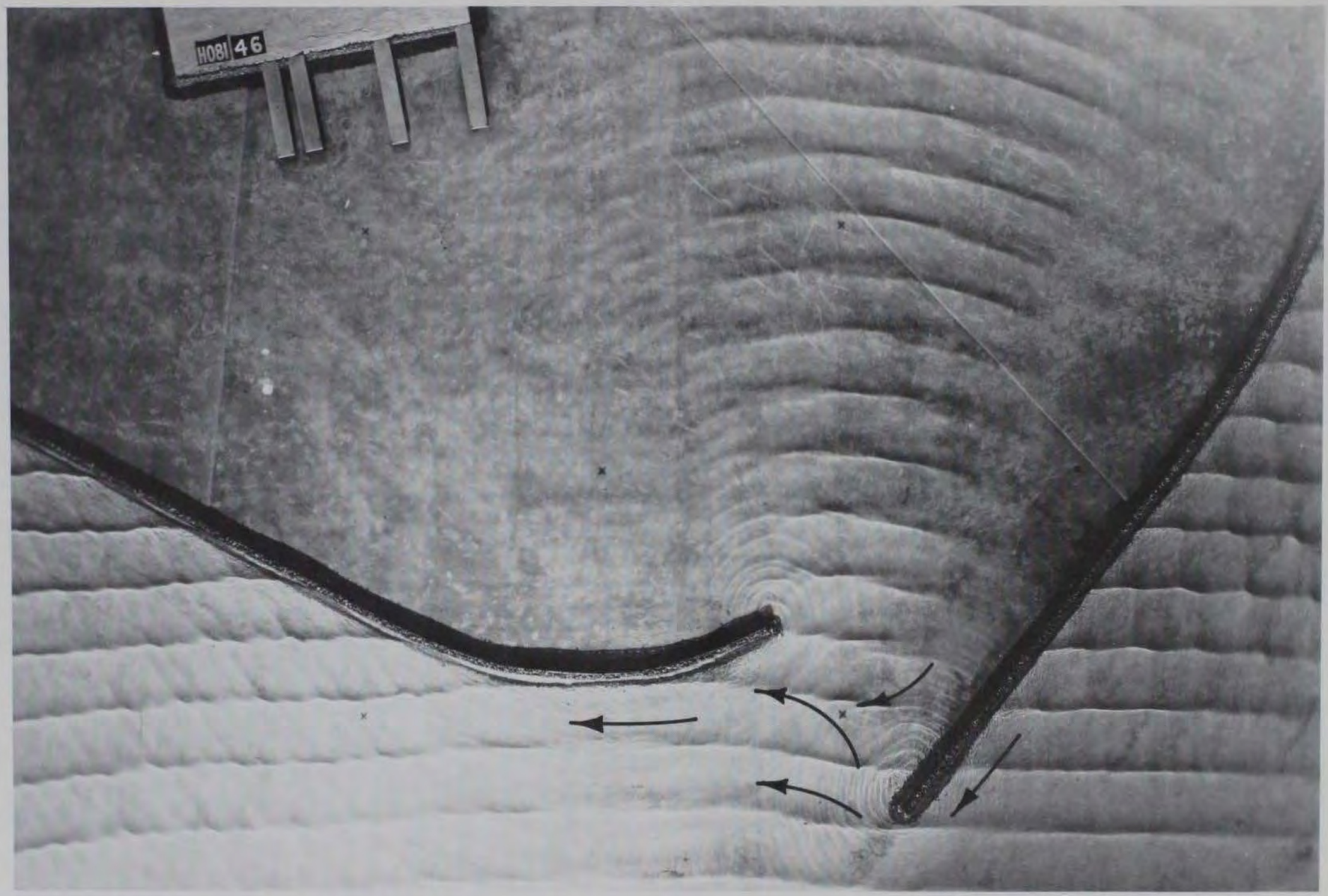


Photo 17. Plan 9; typical current patterns for 9-sec, 4.0-m waves from northeast

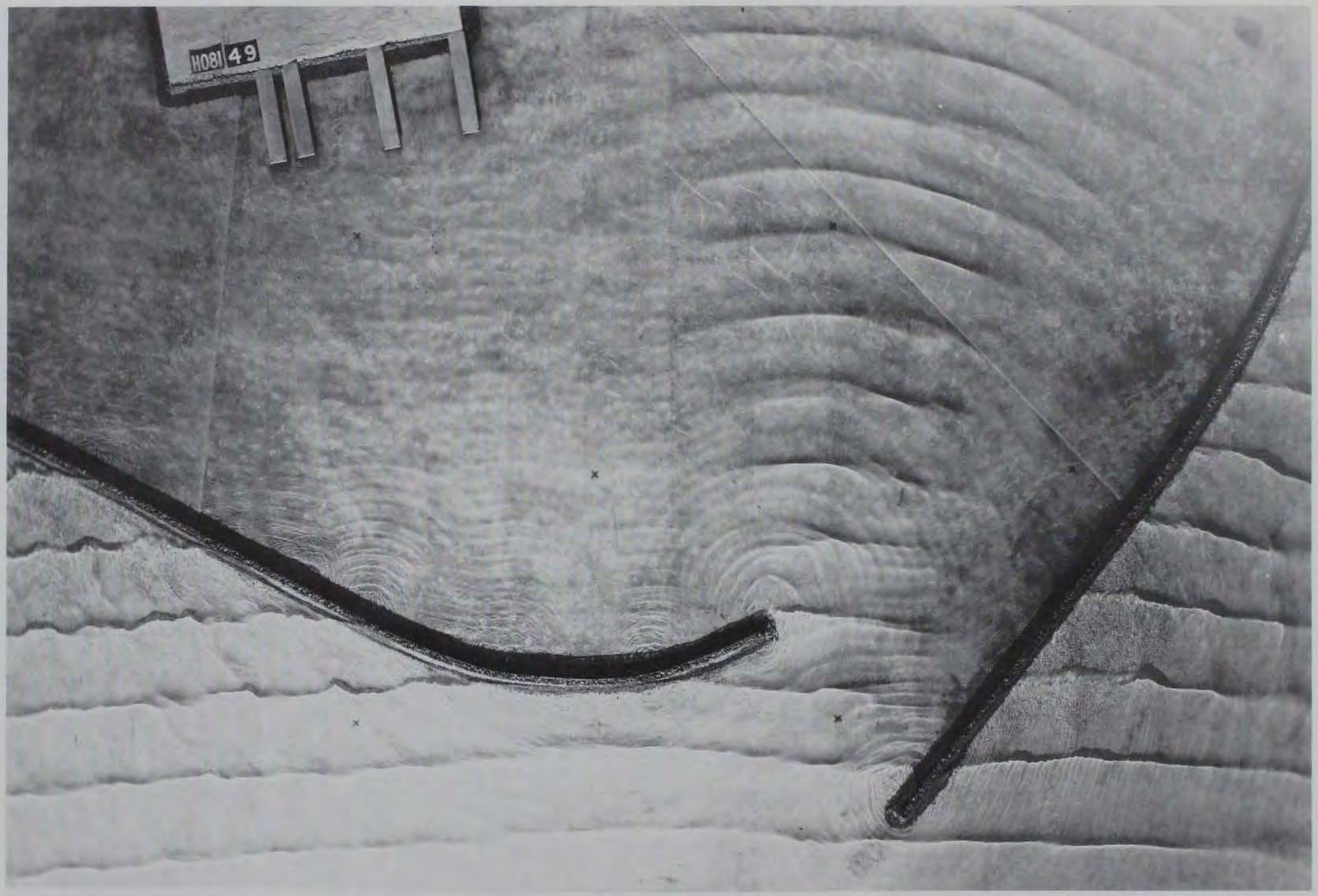


Photo 18. Plan 9; 11-sec, 4.9-m waves from northeast

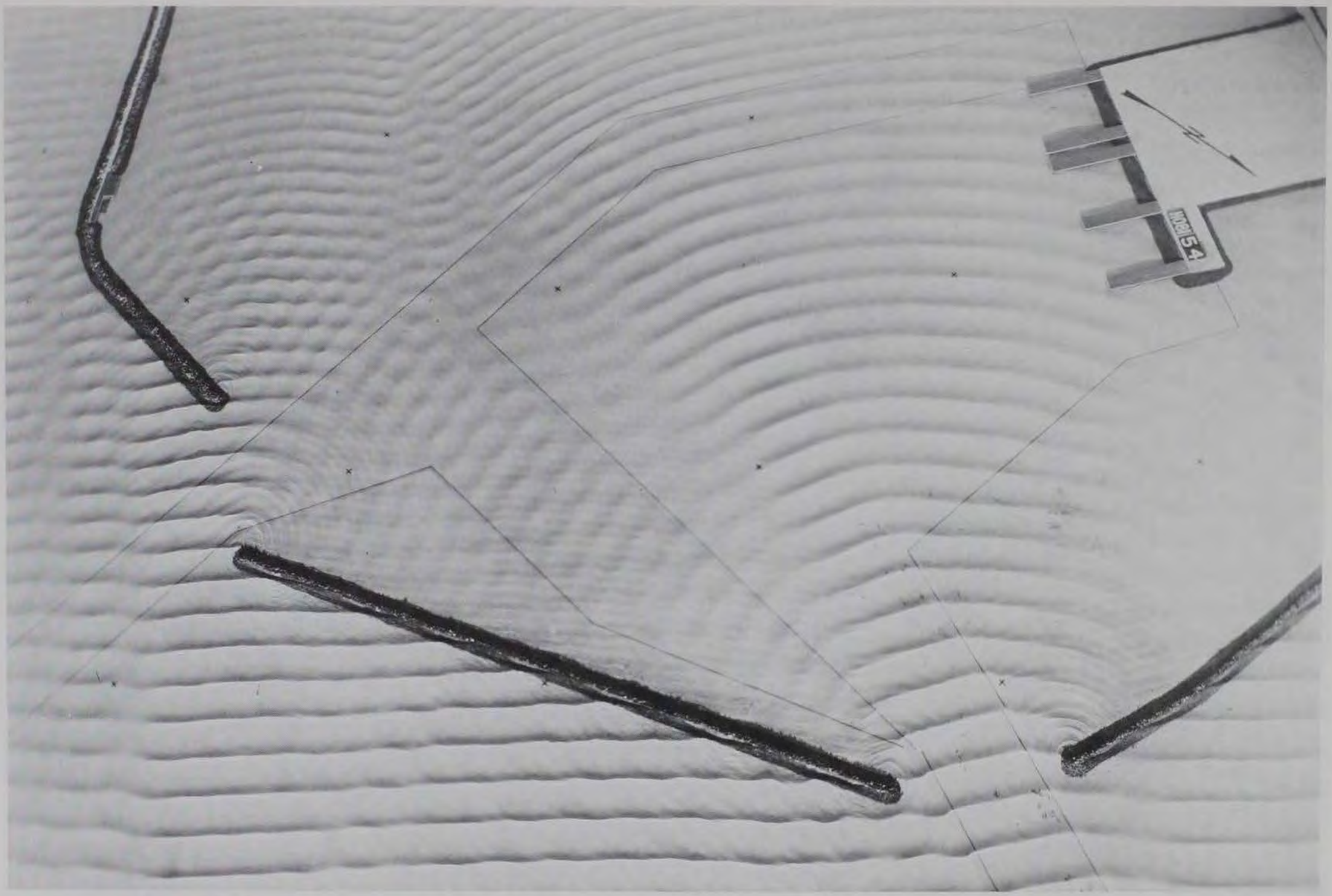


Photo 19. Plan 21; 7-sec, 3.4-m waves from northeast

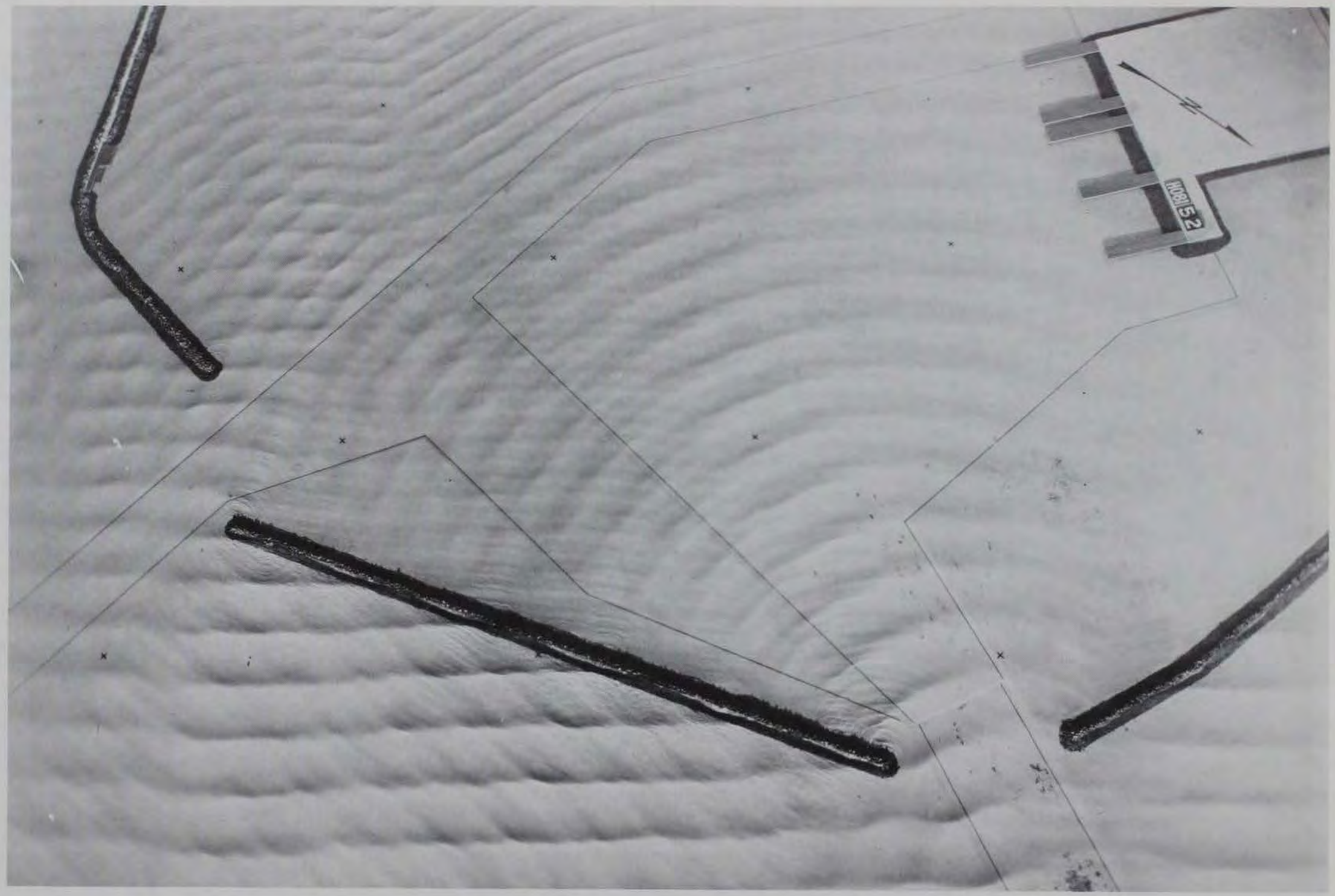


Photo 20. Plan 21; 9-sec, 2.1-m waves from northeast

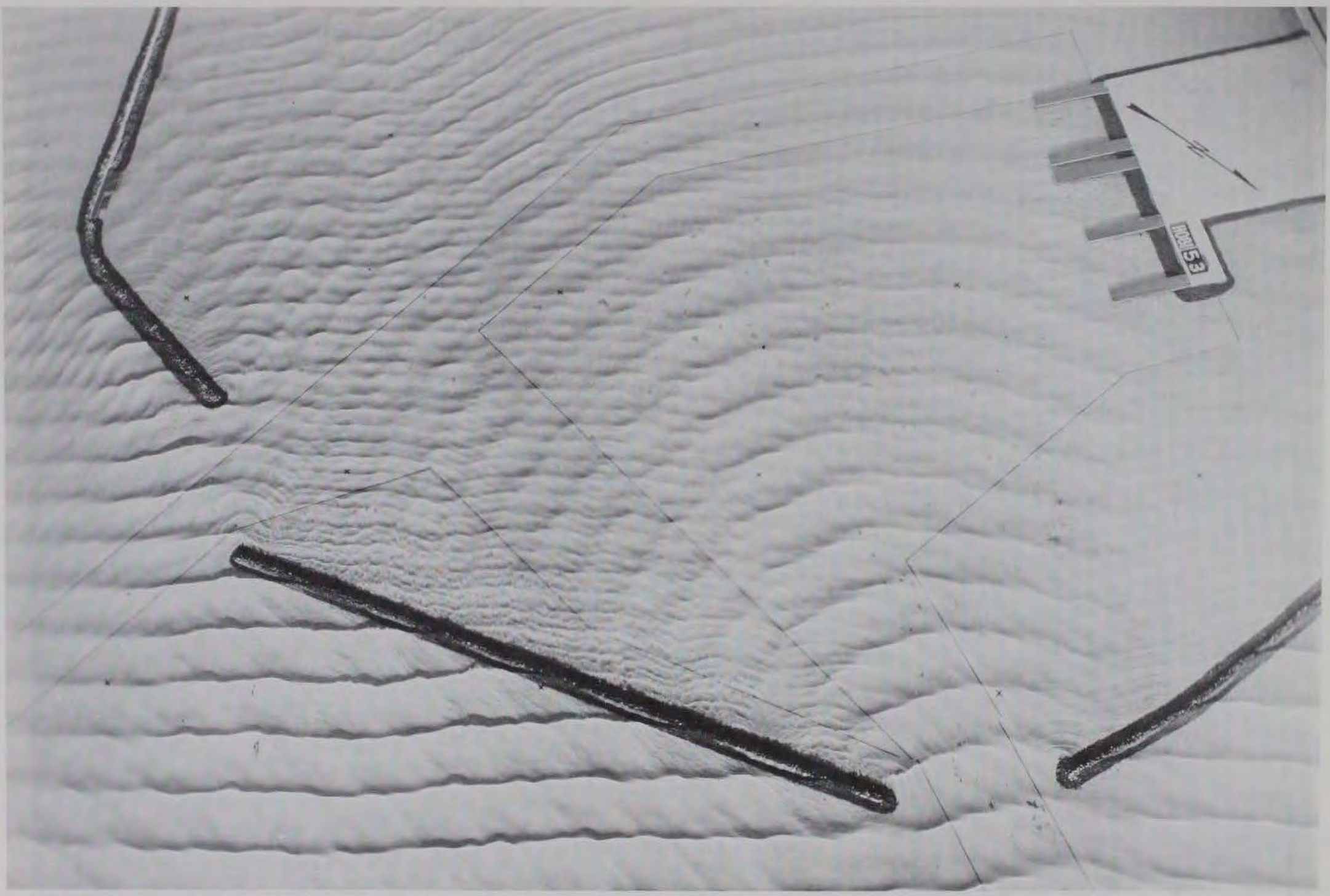


Photo 21. Plan 21; 9-sec, 4.0-m waves from northeast

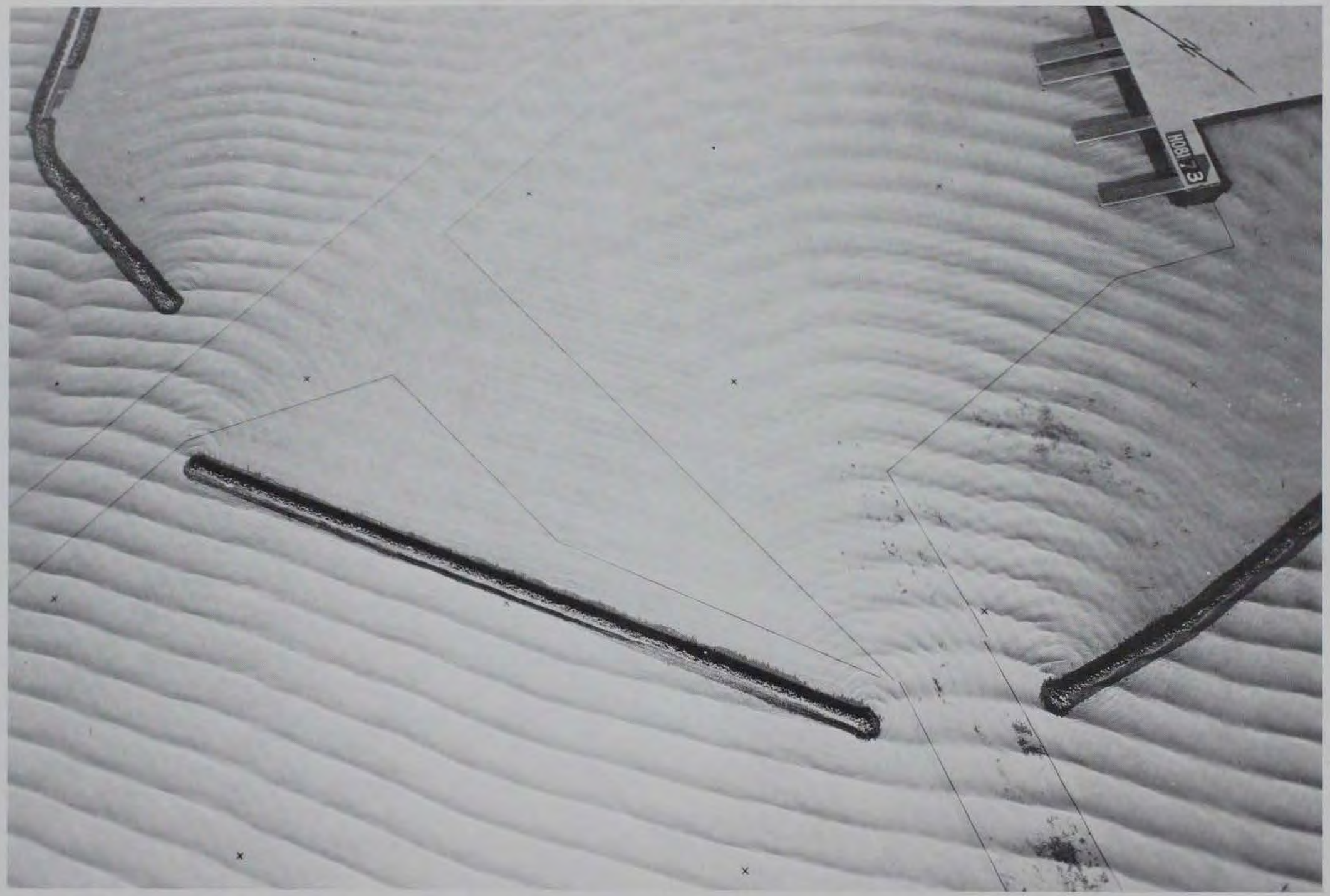


Photo 22. Plan 21; 7-sec, 3.4-m waves from east-southeast

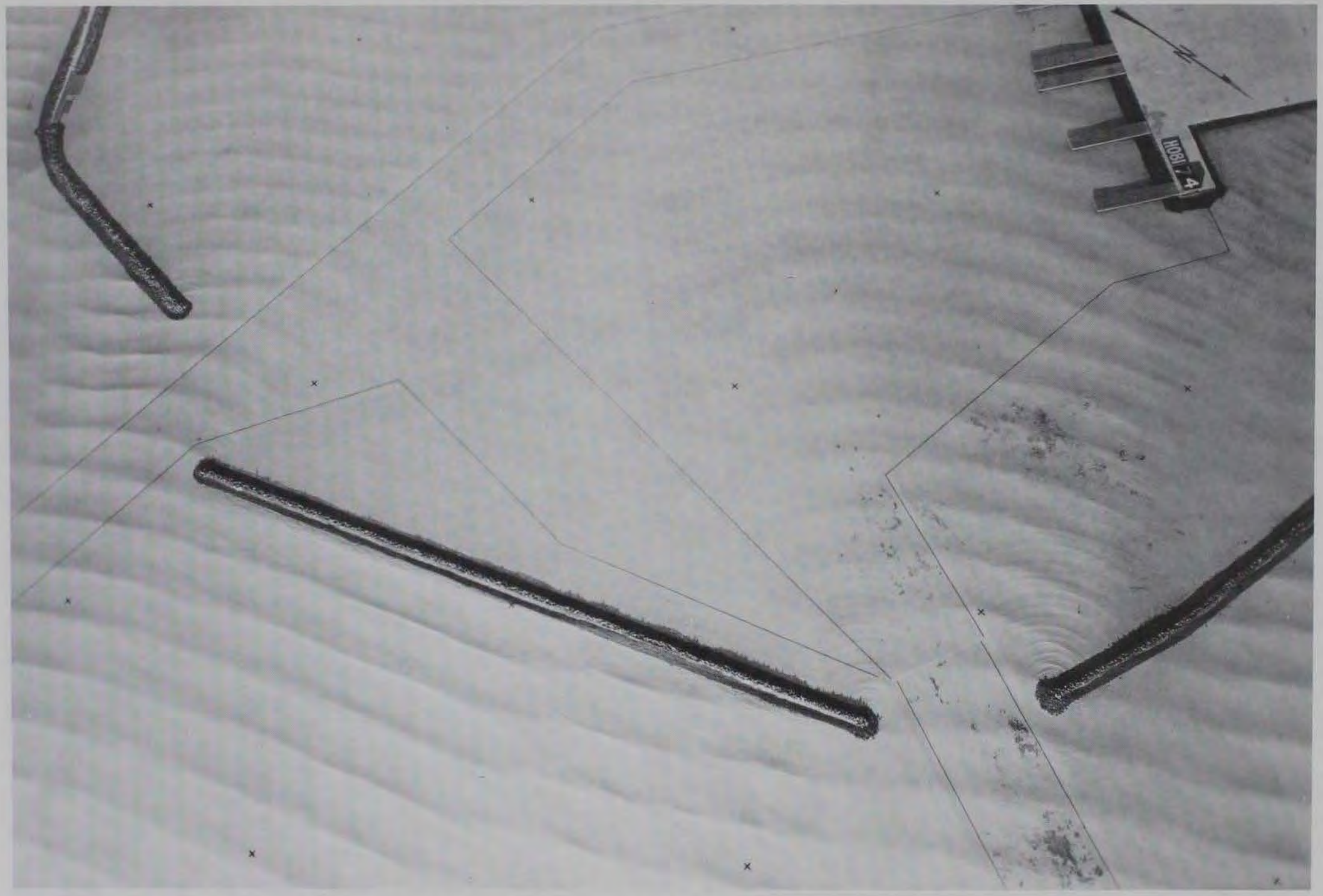


Photo 23. Plan 21; 9-sec, 1.8-m waves from east-southeast

Photo 24. Plan 21; 9-sec, 3.6-m waves from east-southeast

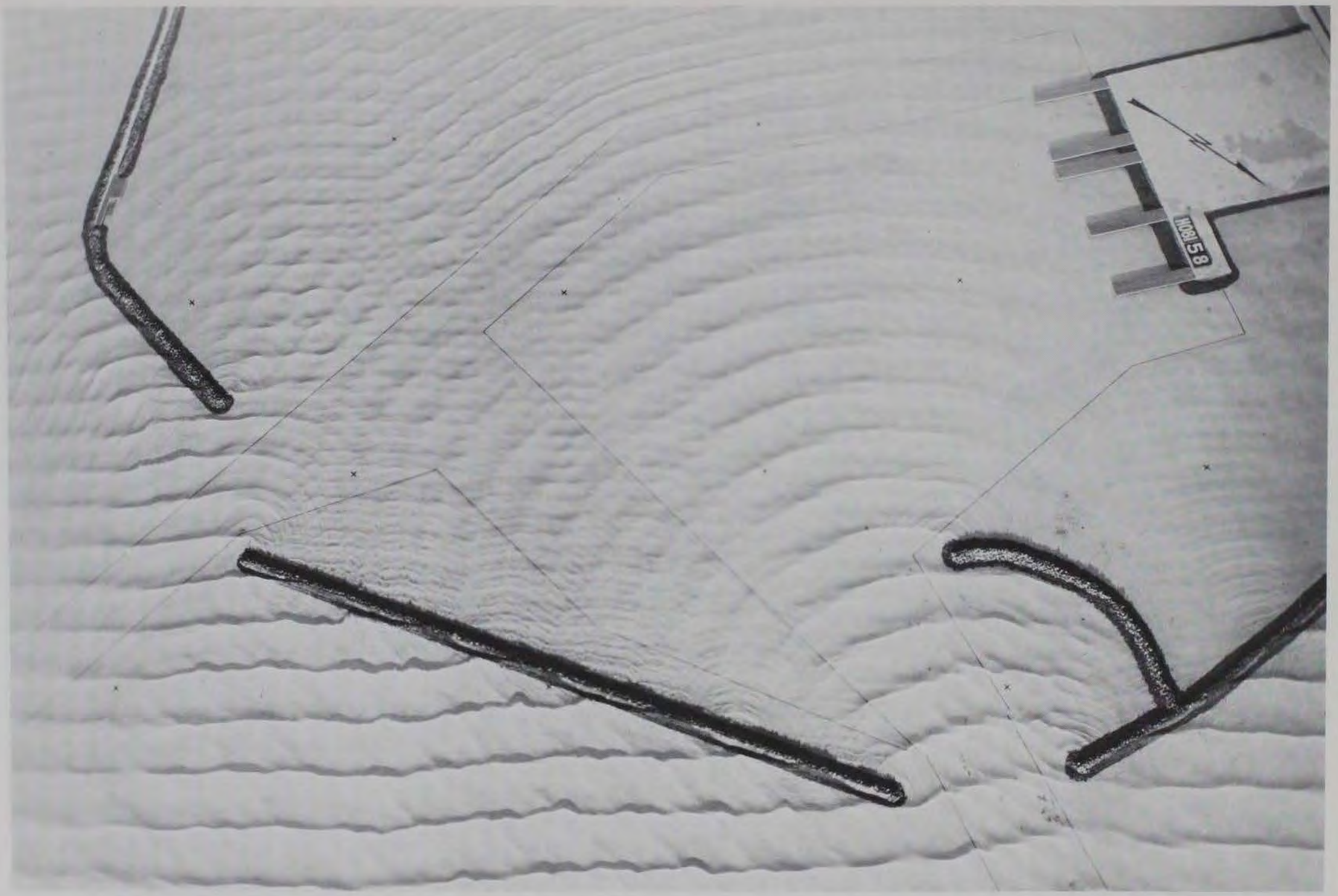


Photo 25. Plan 22; 9-sec, 4.0-m waves from northeast

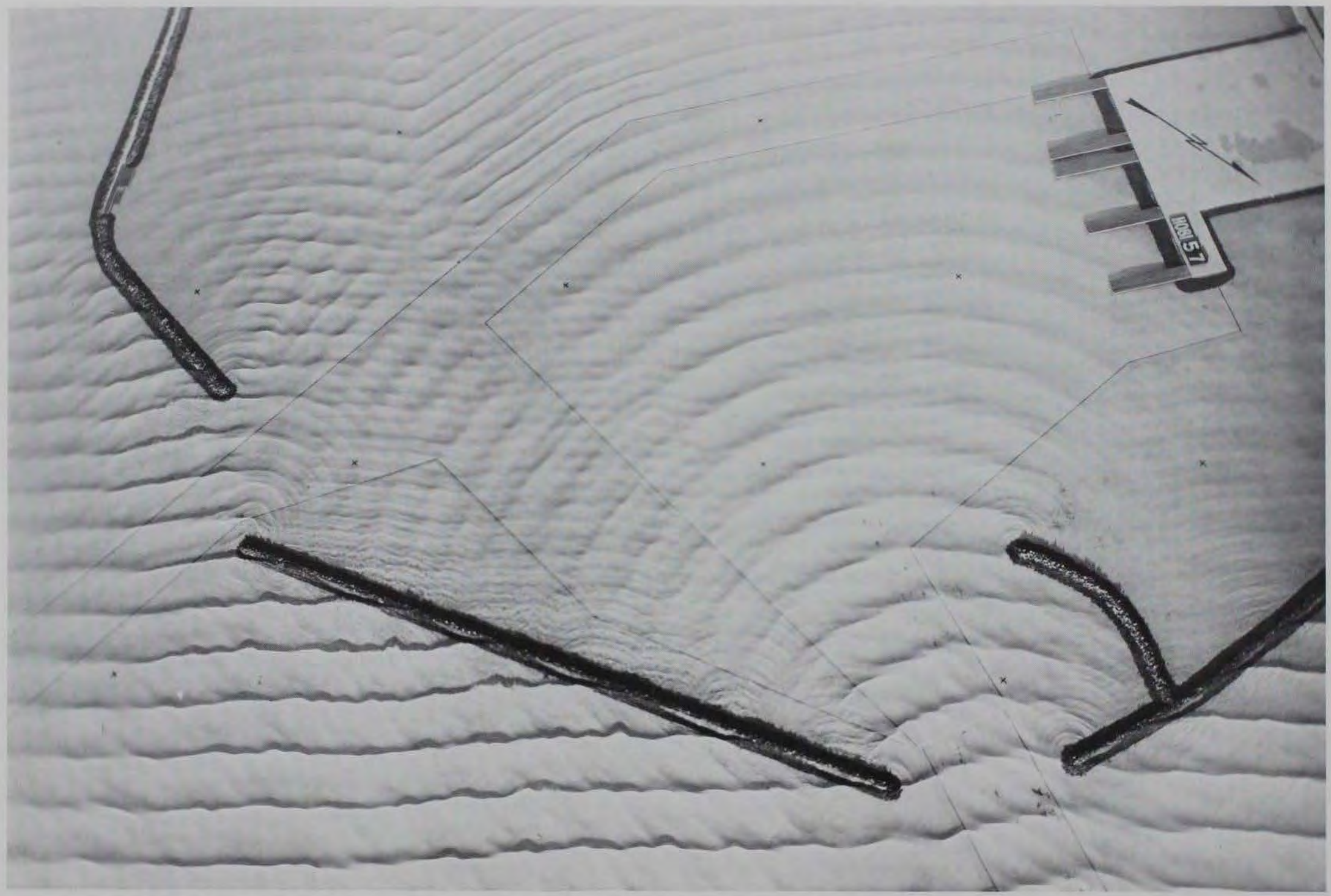


Photo 26. Plan 22A; 9-sec, 4.0-m waves from northeast

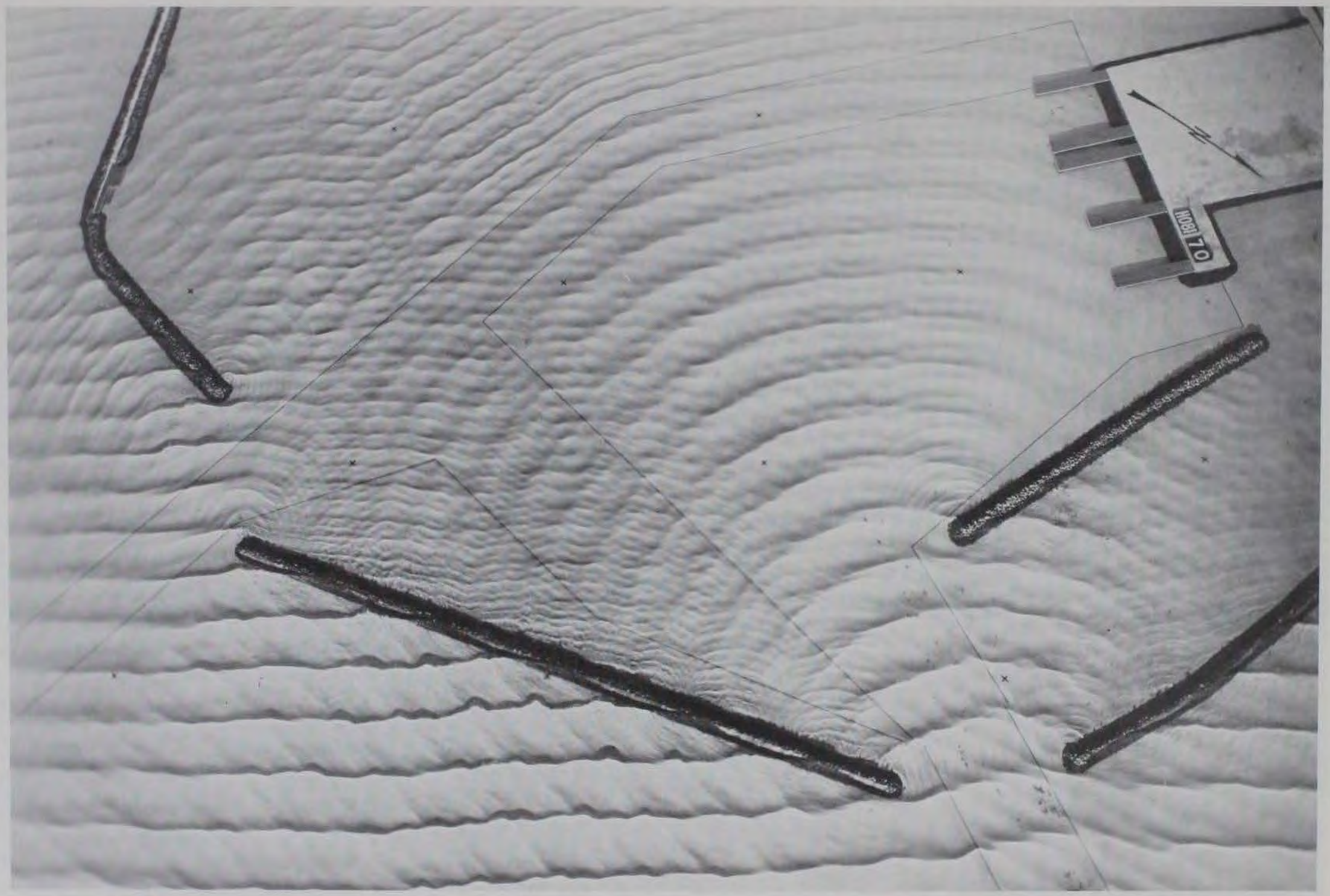


Photo 27. Plan 23; 9-sec, 4.0-m waves from northeast

Photo 28. Plan 23A; 9-sec, 4.0-m waves from northeast

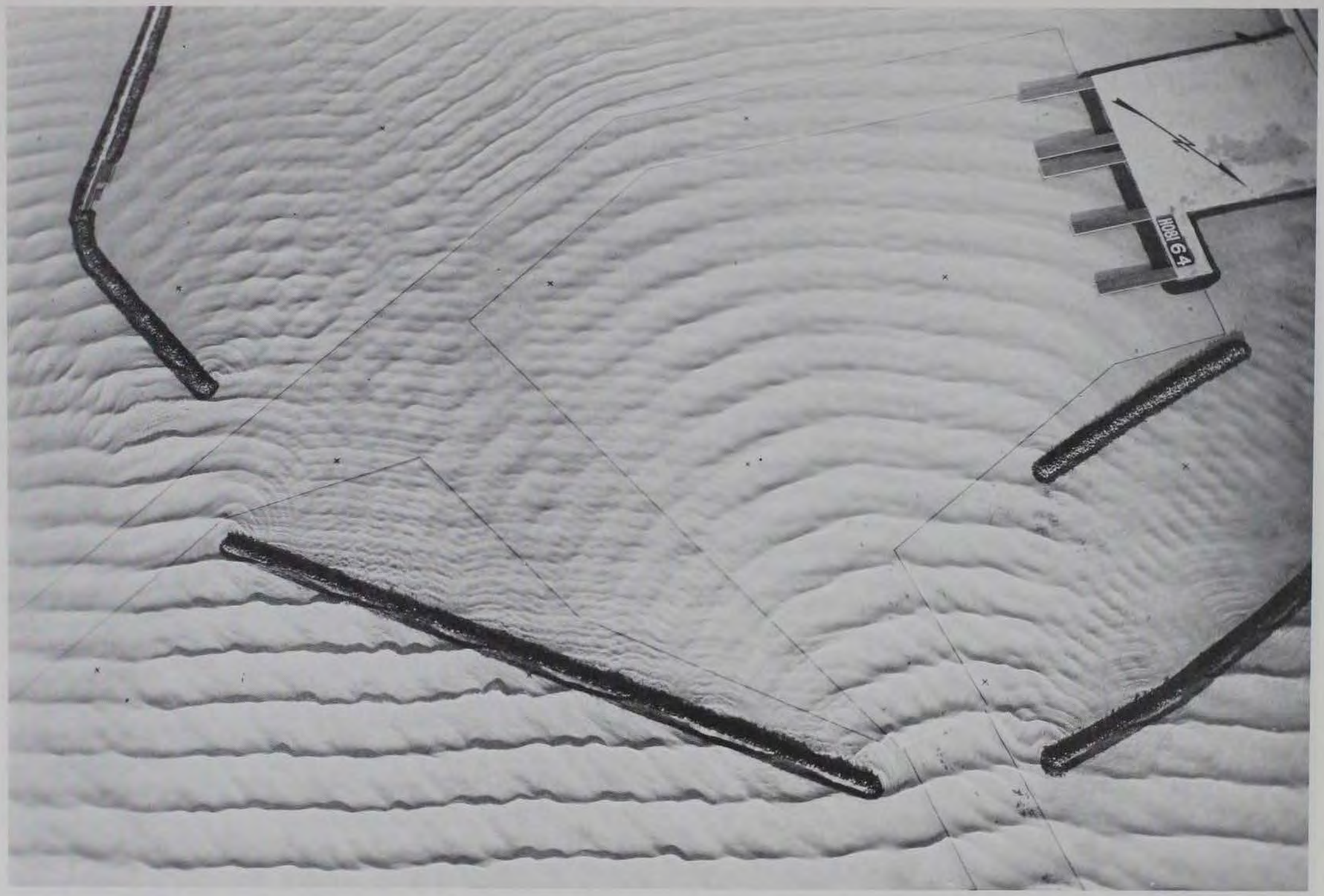


Photo 29. Plan 23B; 9-sec, 4.0-m waves from northeast

Photo 30. Plan 23C; 9-sec, 4.0-m waves from northeast

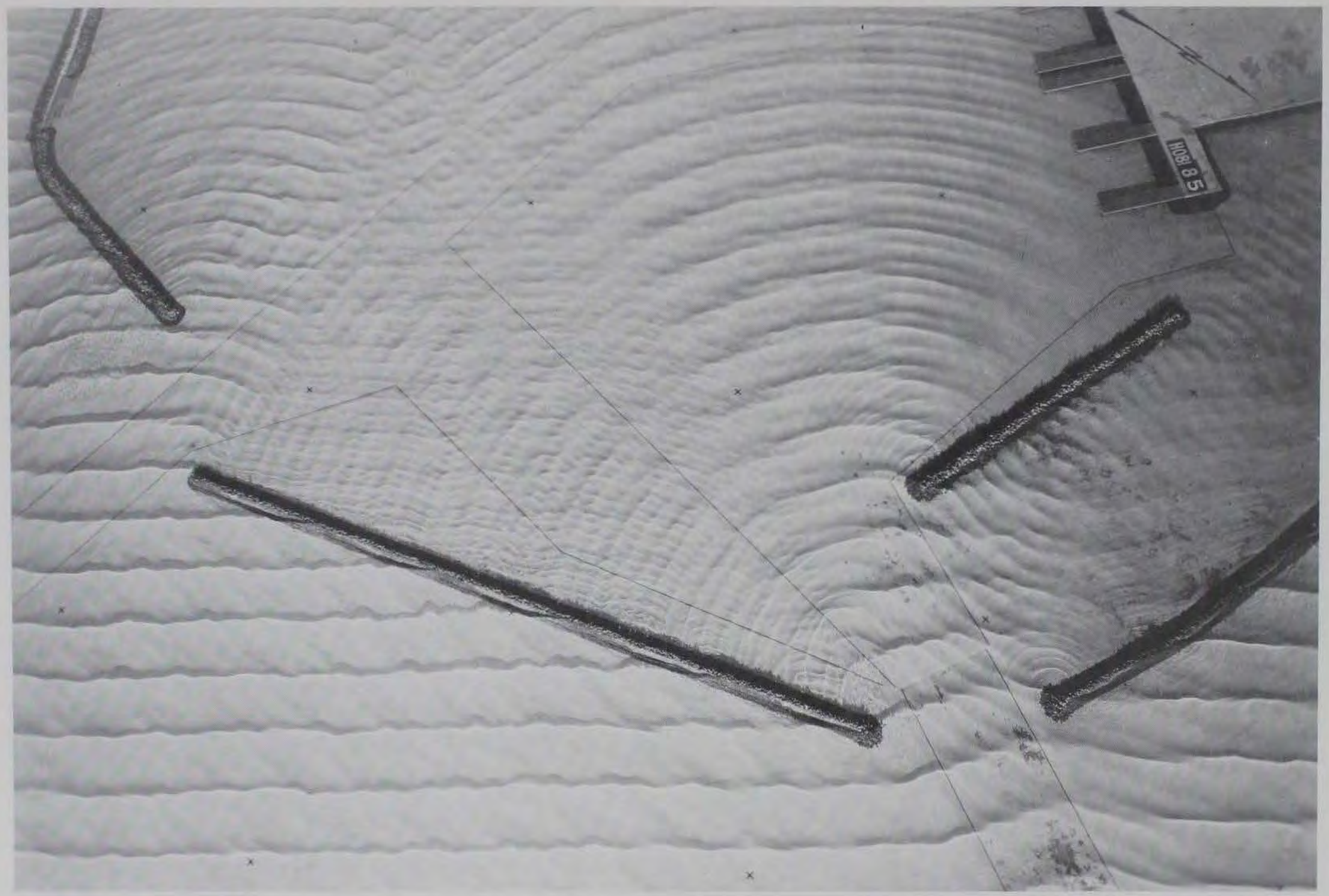


Photo 31. Plan 23D; 9-sec, 4.0-m waves from northeast

Photo 32. Plan 23E; 9-sec, 4.0-m waves from northeast

Photo 33. Plan 24; 9-sec, 4.0-m waves from northeast

Photo 34. Plan 24A; 9-sec, 4.0-m waves from northeast

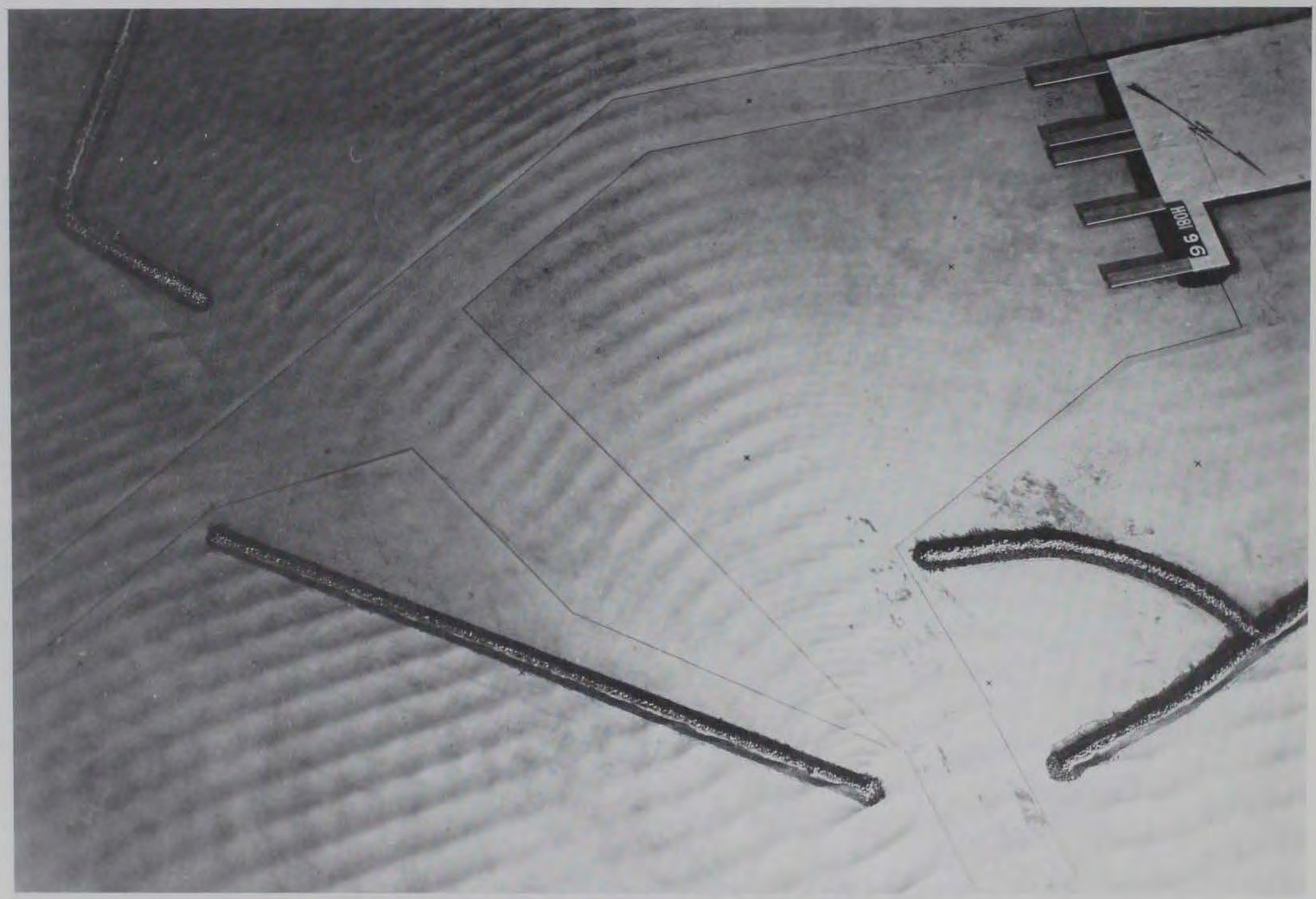


Photo 35. Plan 27; 7-sec, 1.8-m waves from north

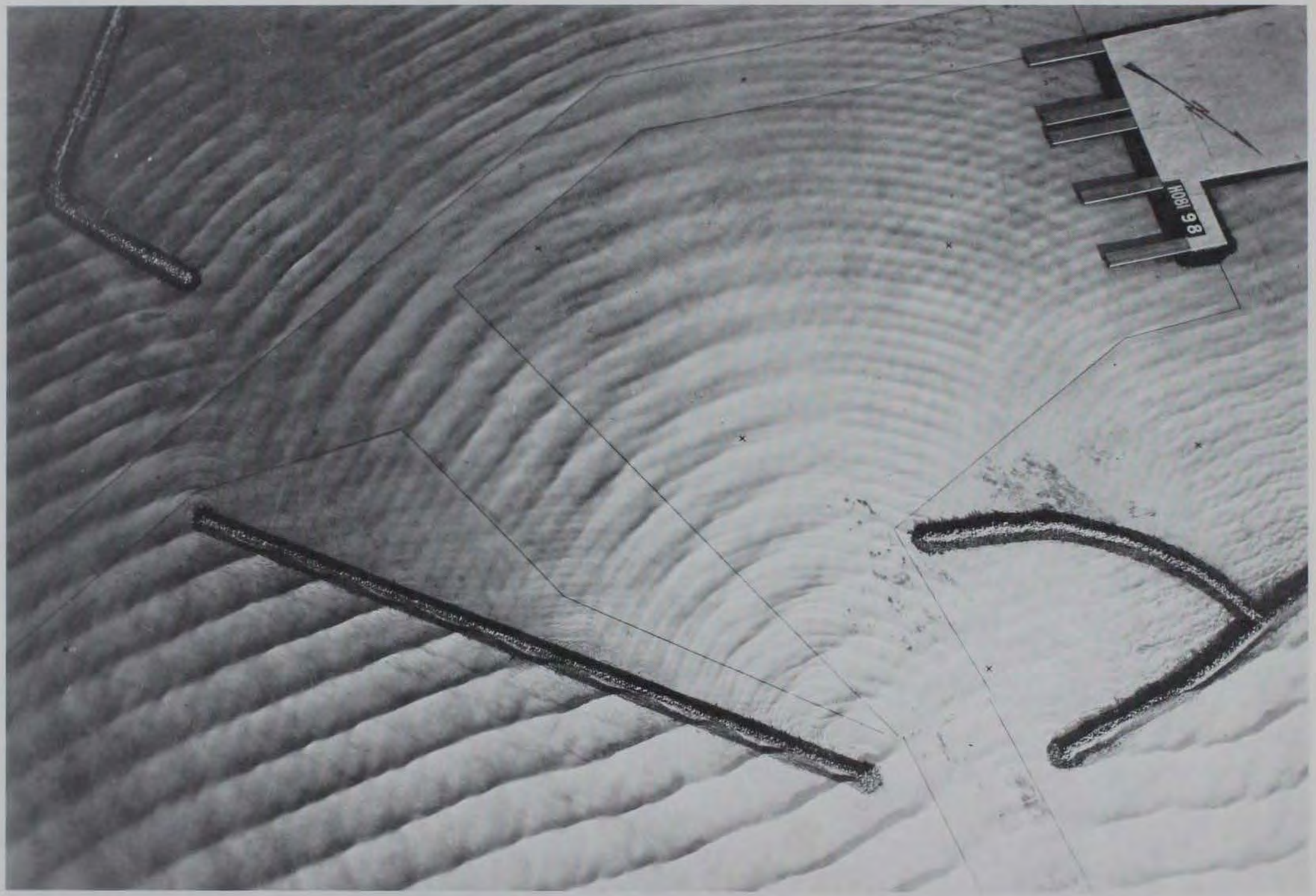


Photo 36. Plan 27; 9-sec, 4.0-m waves from north

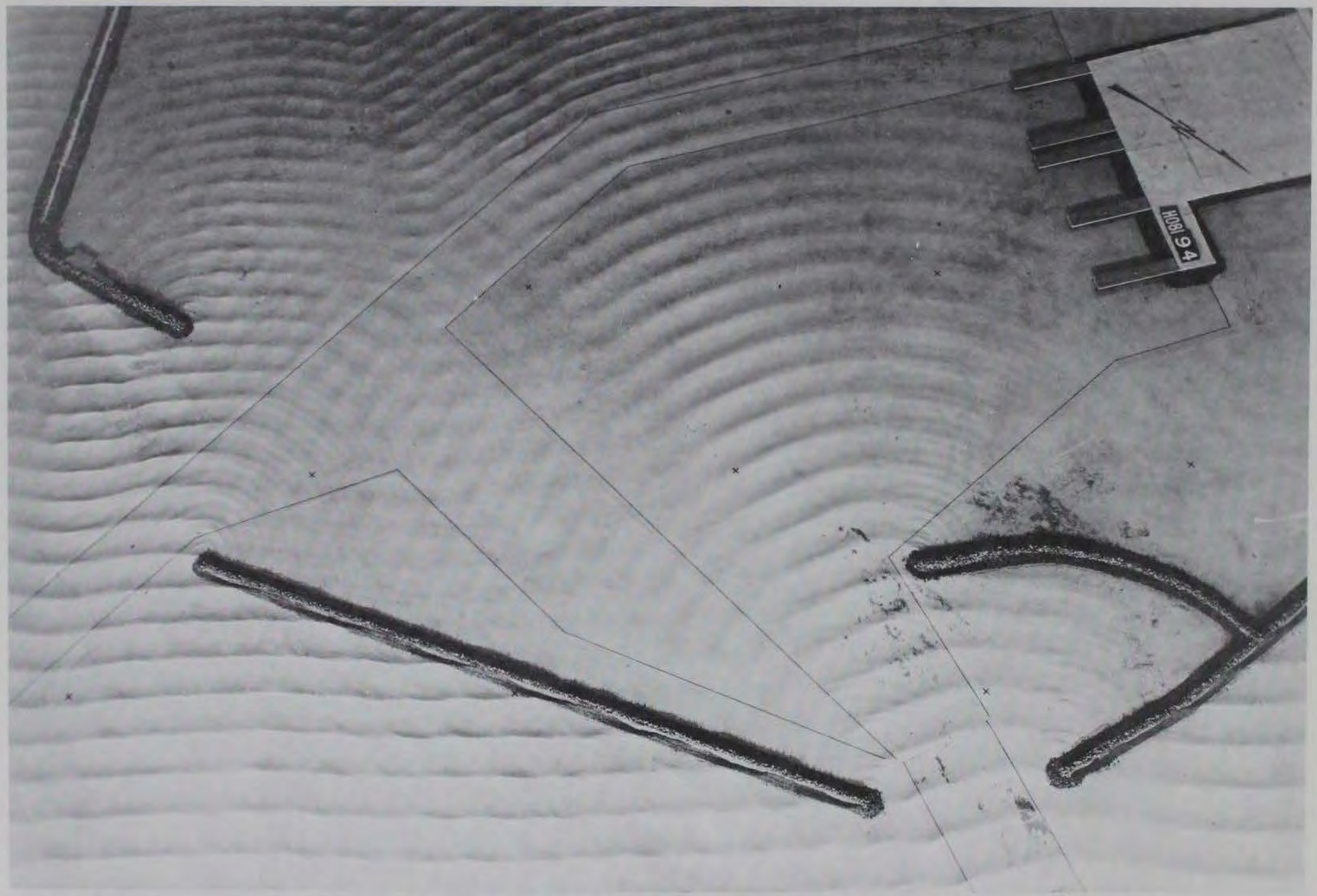


Photo 37. Plan 27; 7-sec, 2.4-m waves from northeast

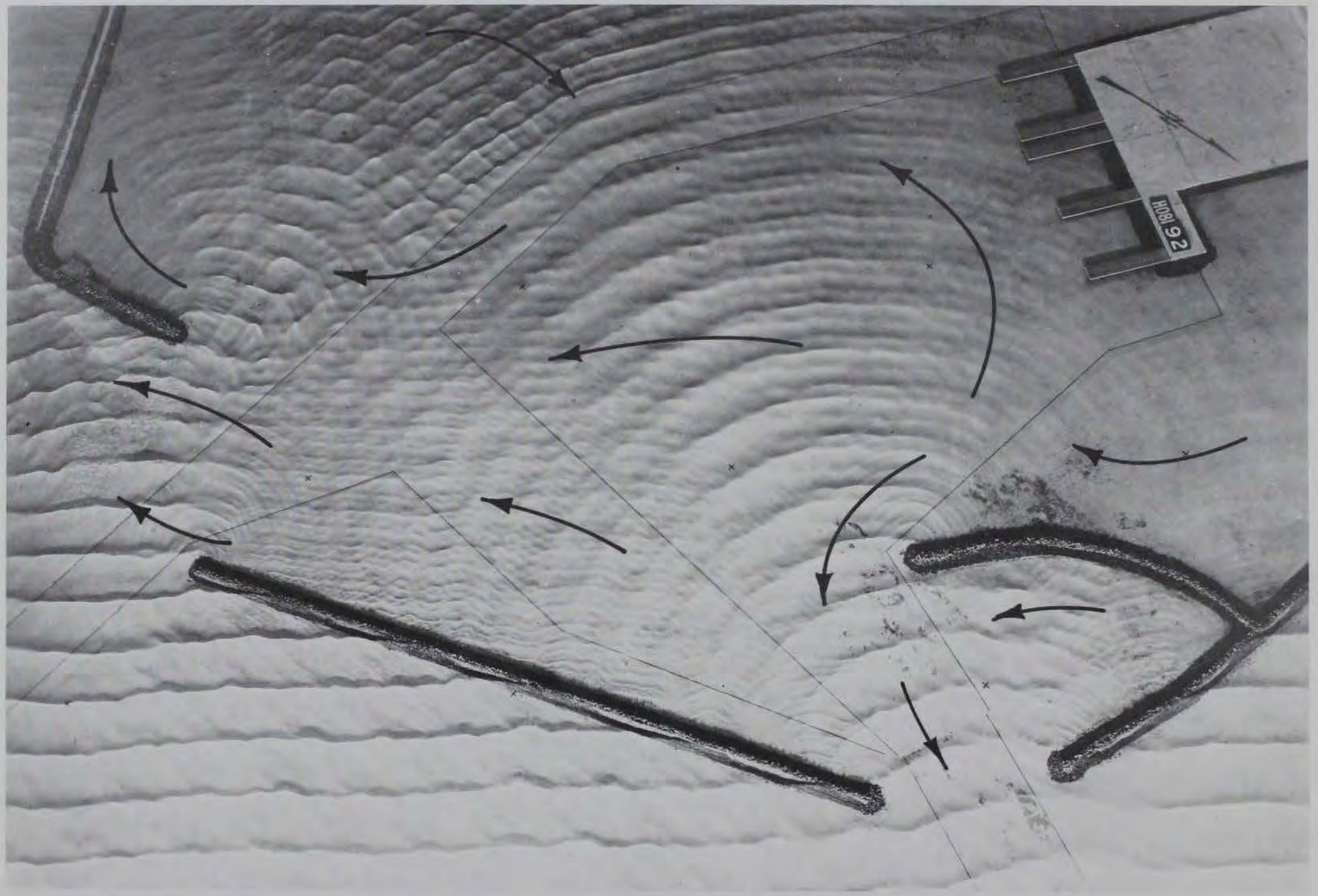


Photo 38. Plan 27; typical current patterns for 9-sec, 4.0-m waves from northeast

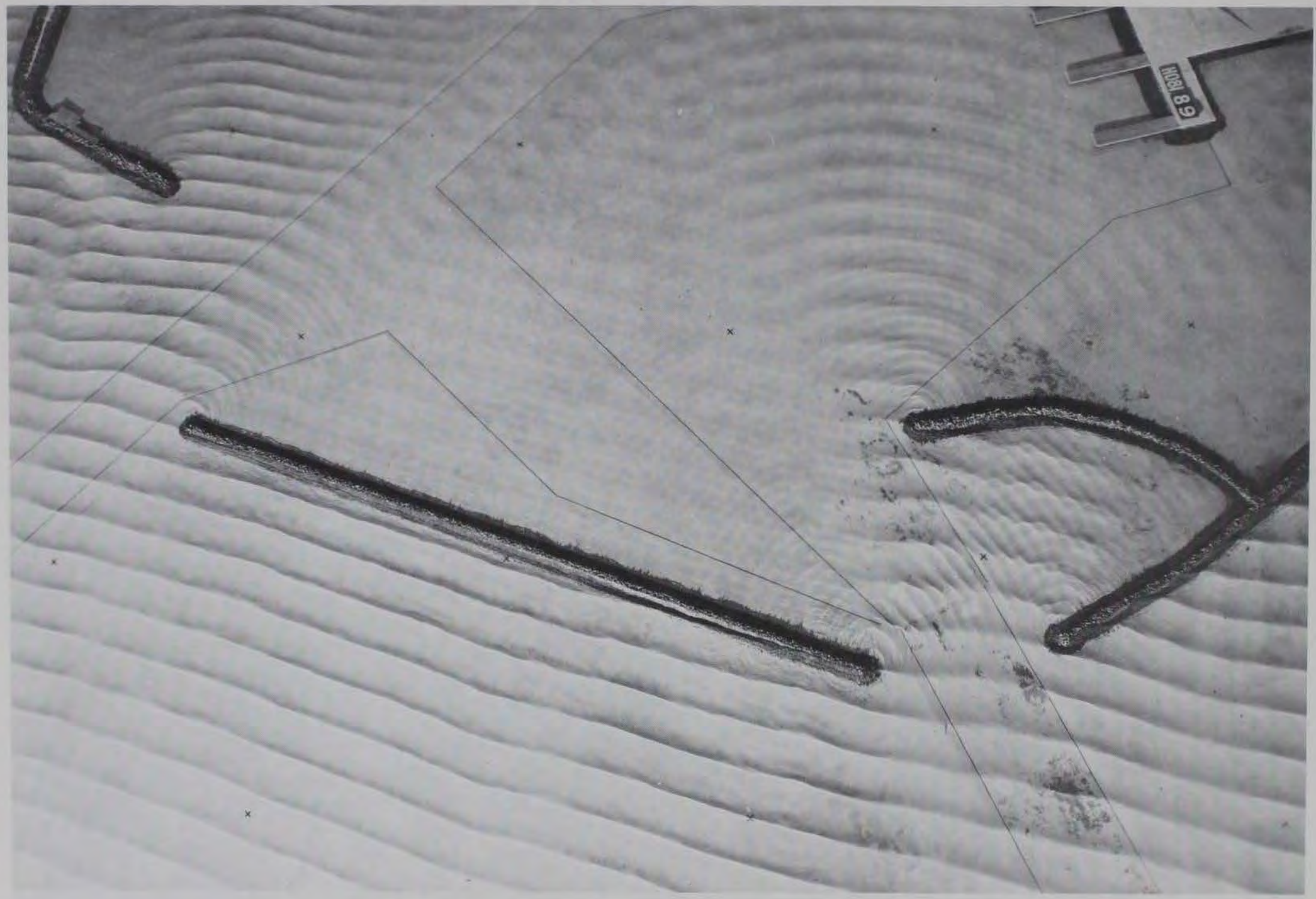


Photo 39. Plan 27; 7-sec, 3.4-m waves from east-southeast

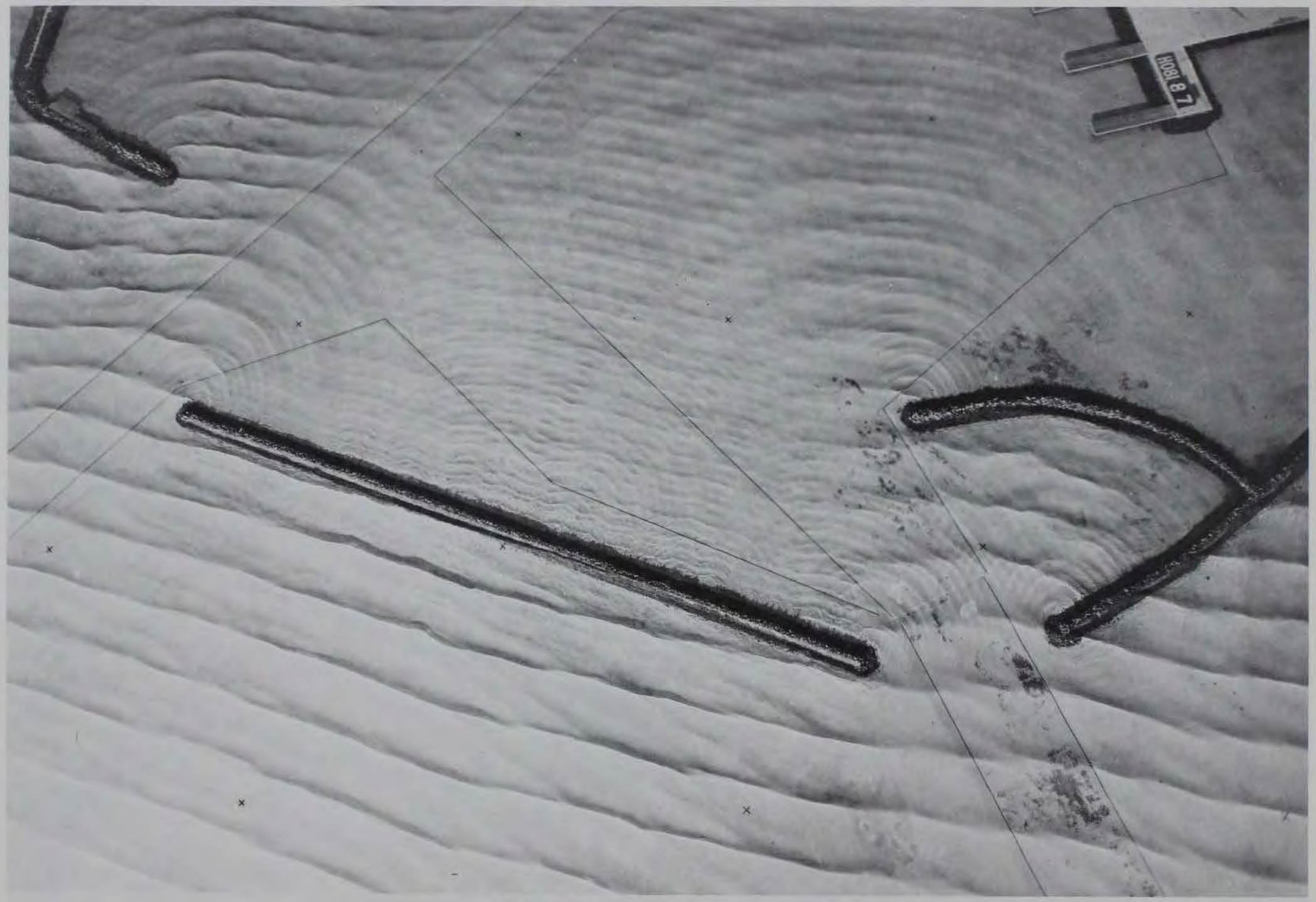


Photo 40. Plan 27; 9-sec, 3.6-m waves from east-southeast

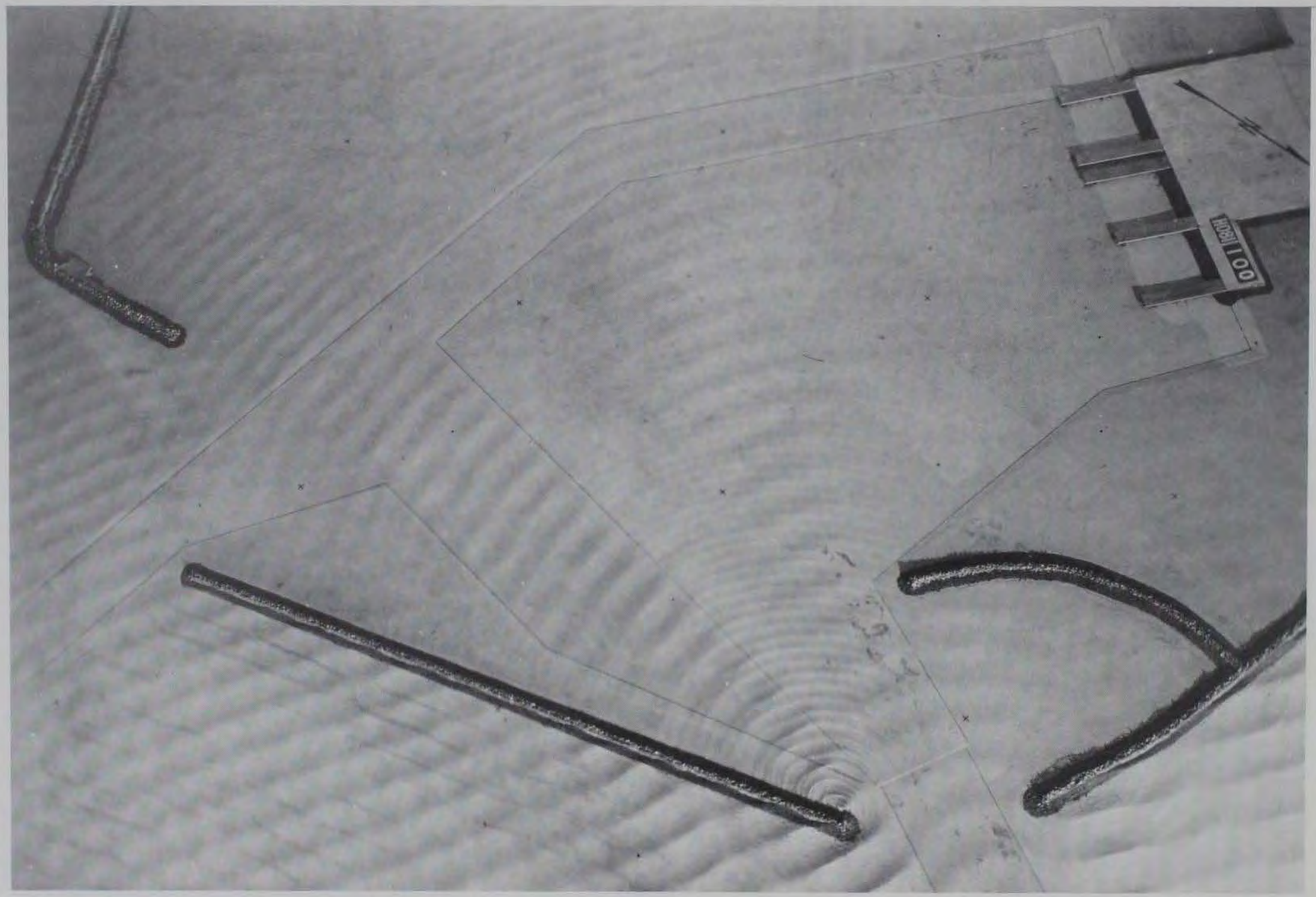


Photo 41. Plan 28; 7-sec, 1.8-m waves from north

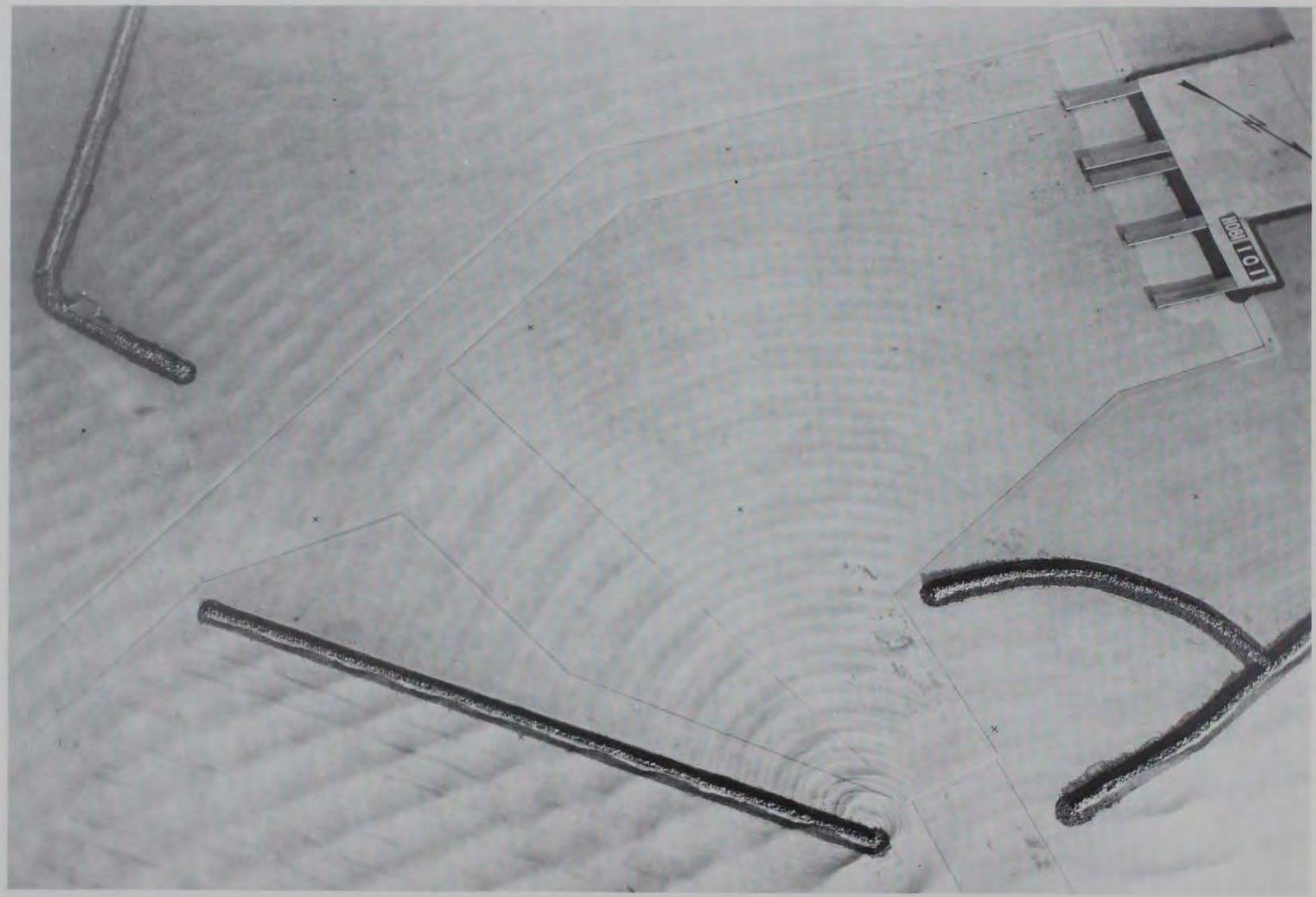


Photo 42. Plan 28; 9-sec, 2.1-m waves from north

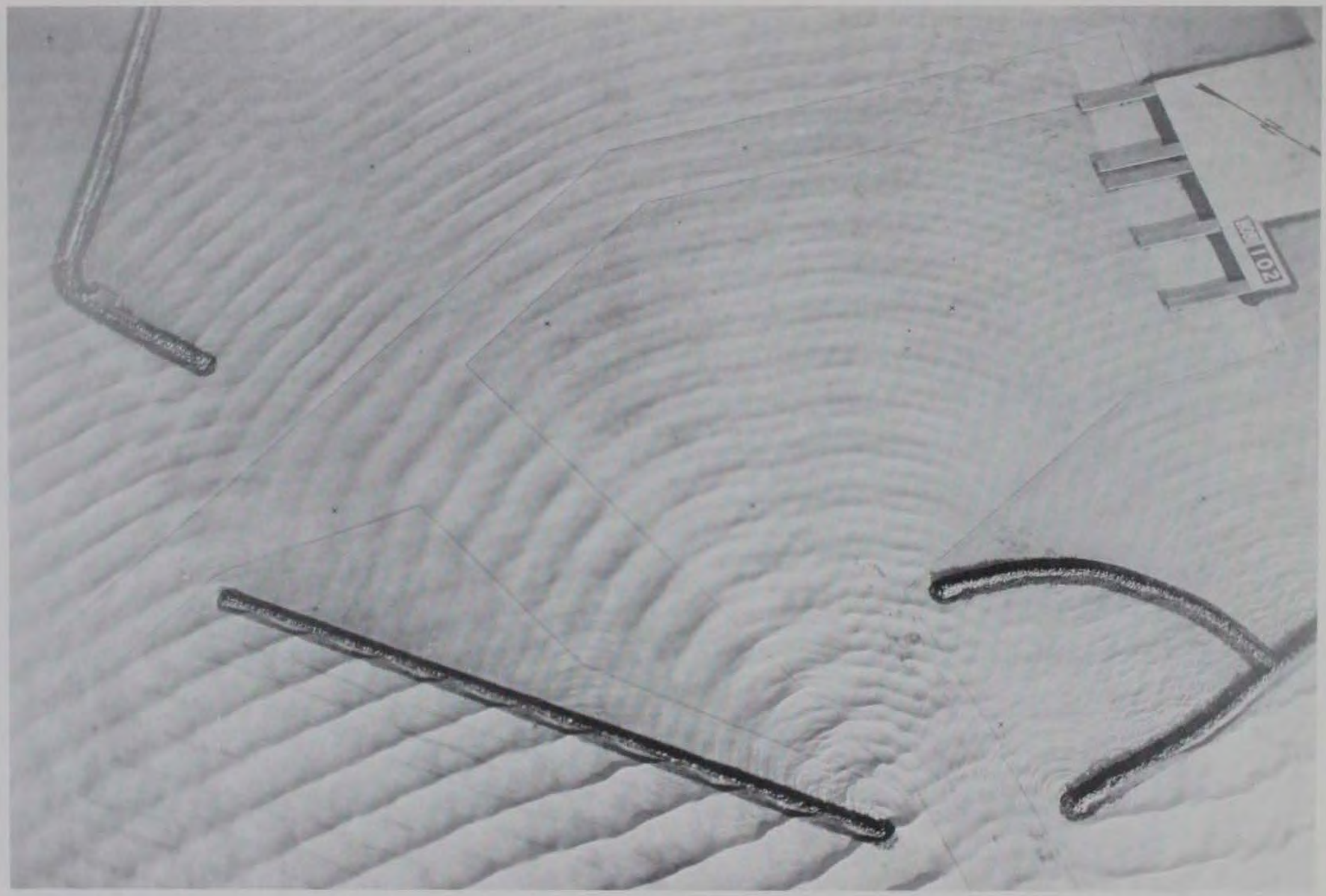


Photo 43. Plan 28; 9-sec, 4.0-m waves from north

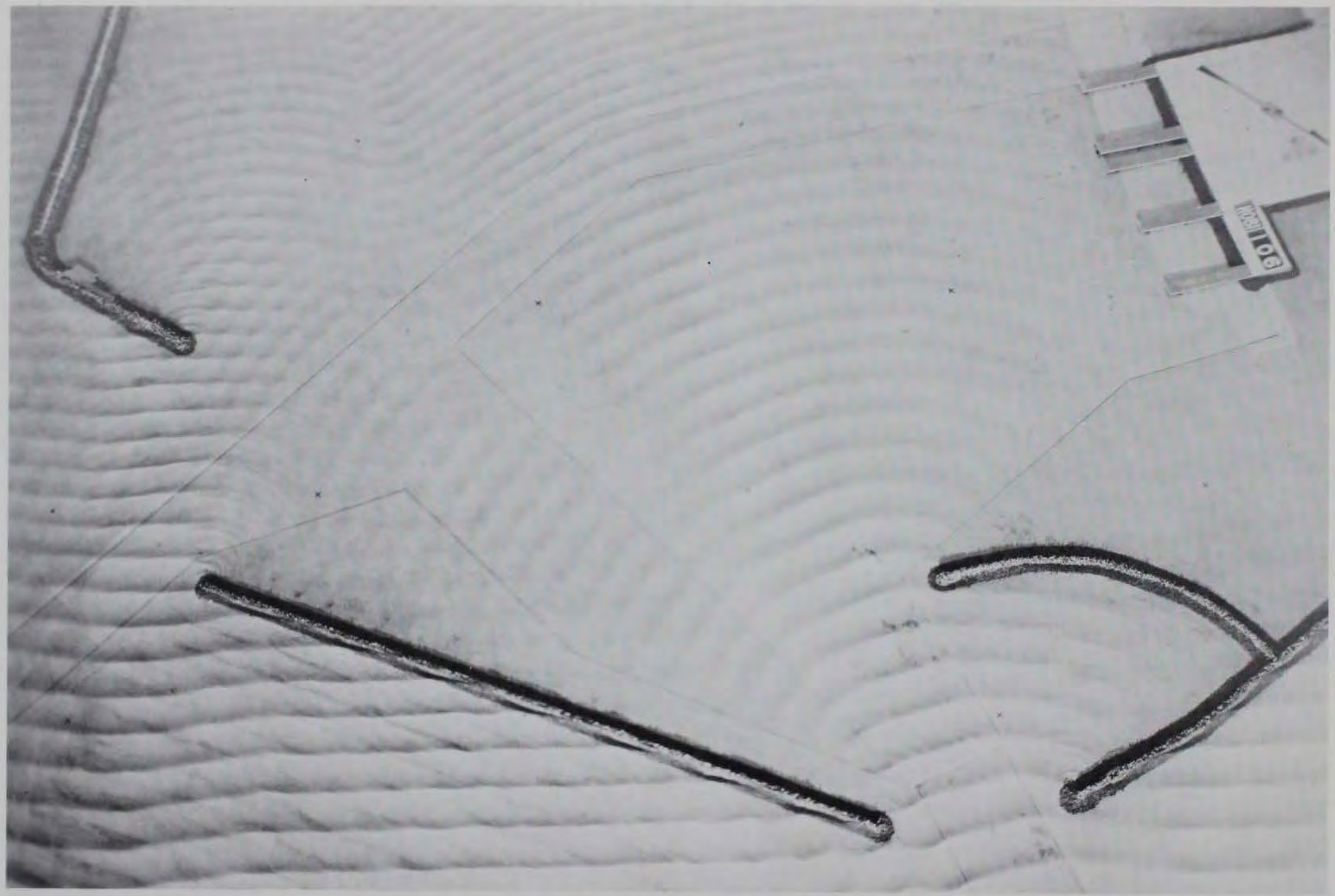


Photo 44. Plan 28; 7-sec, 2.4-m waves from northeast

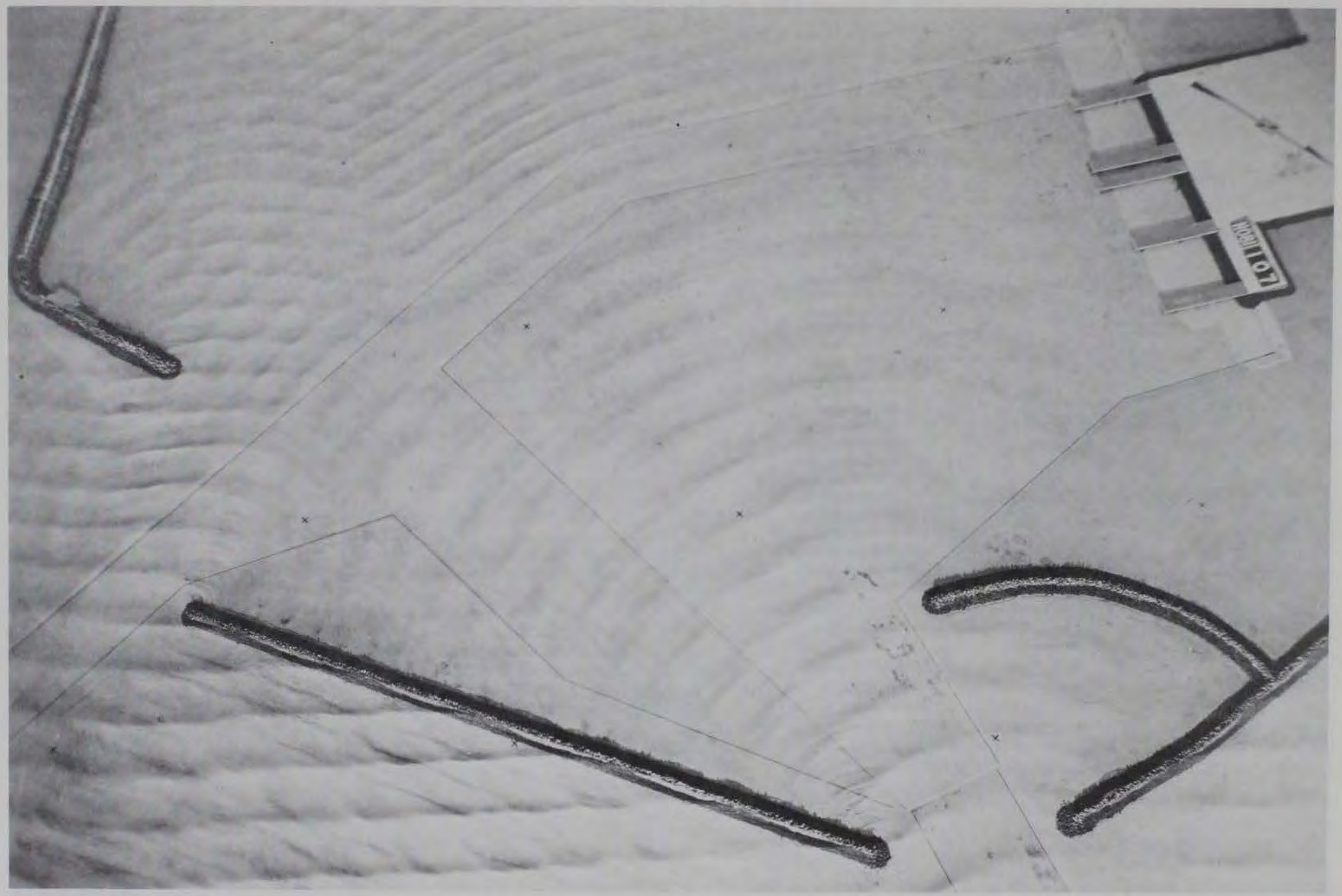


Photo 45. Plan 28; 9-sec, 2.1-m waves from northeast

Photo 46. Plan 28; 9-sec, 4.0-m waves from northeast

Photo 47. Plan 28; 7-sec, 3.4-m waves from east-southeast

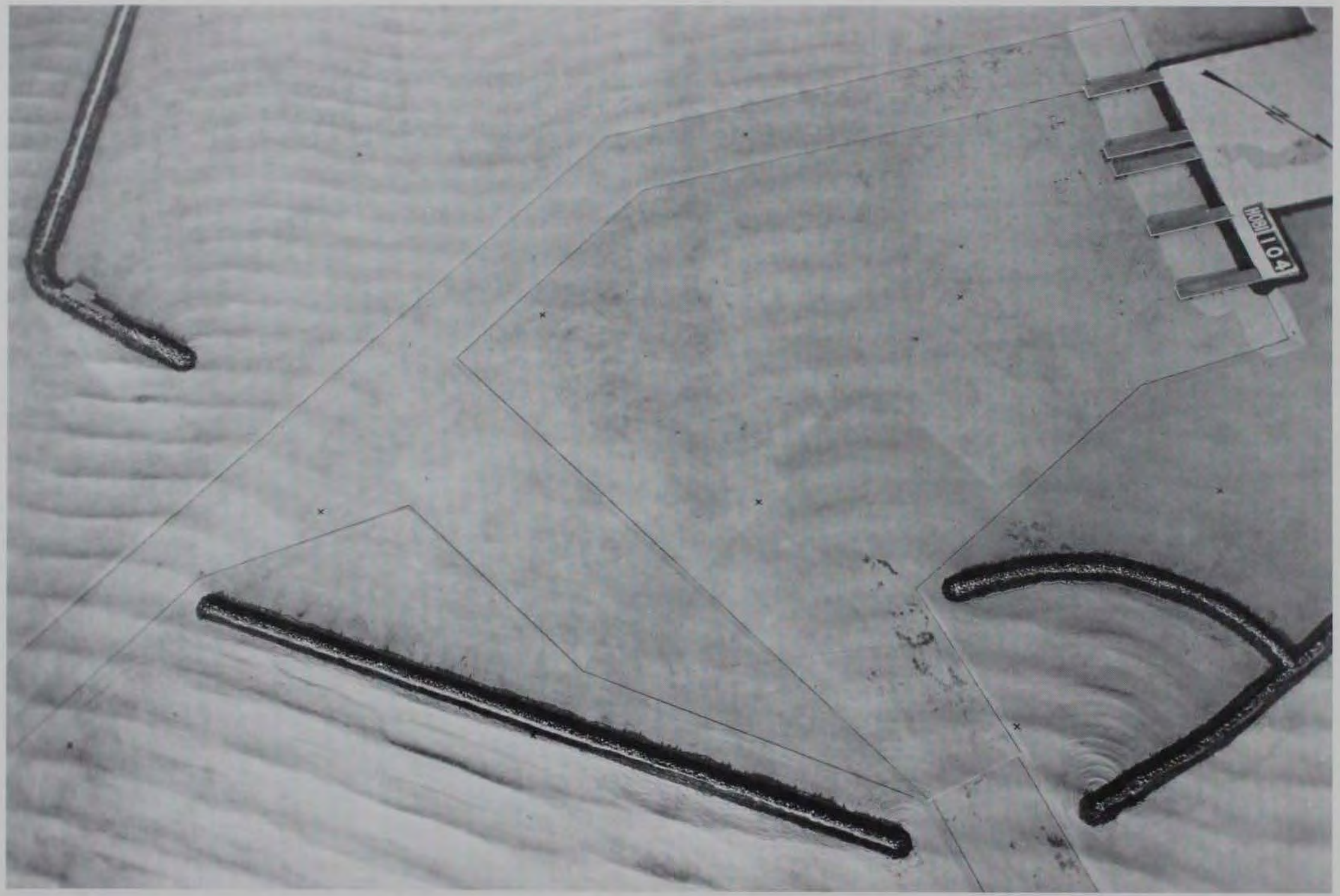


Photo 48. Plan 28; 9-sec, 1.8-m waves from east-southeast

Photo 49. Plan 28; 9-sec, 3.6-m waves from east-southeast

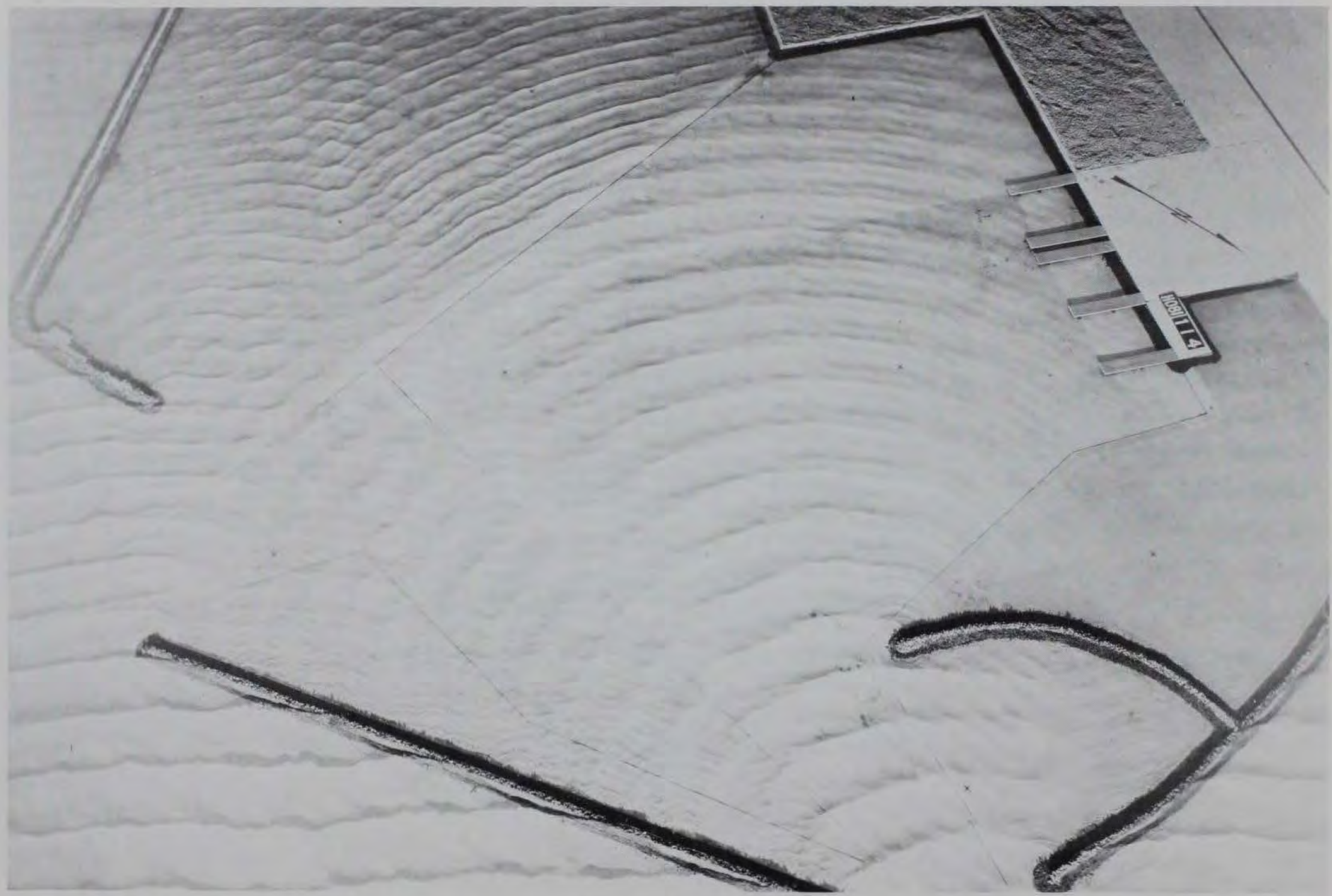


Photo 50. Plan 29; 9-sec, 4.0-m waves from northeast

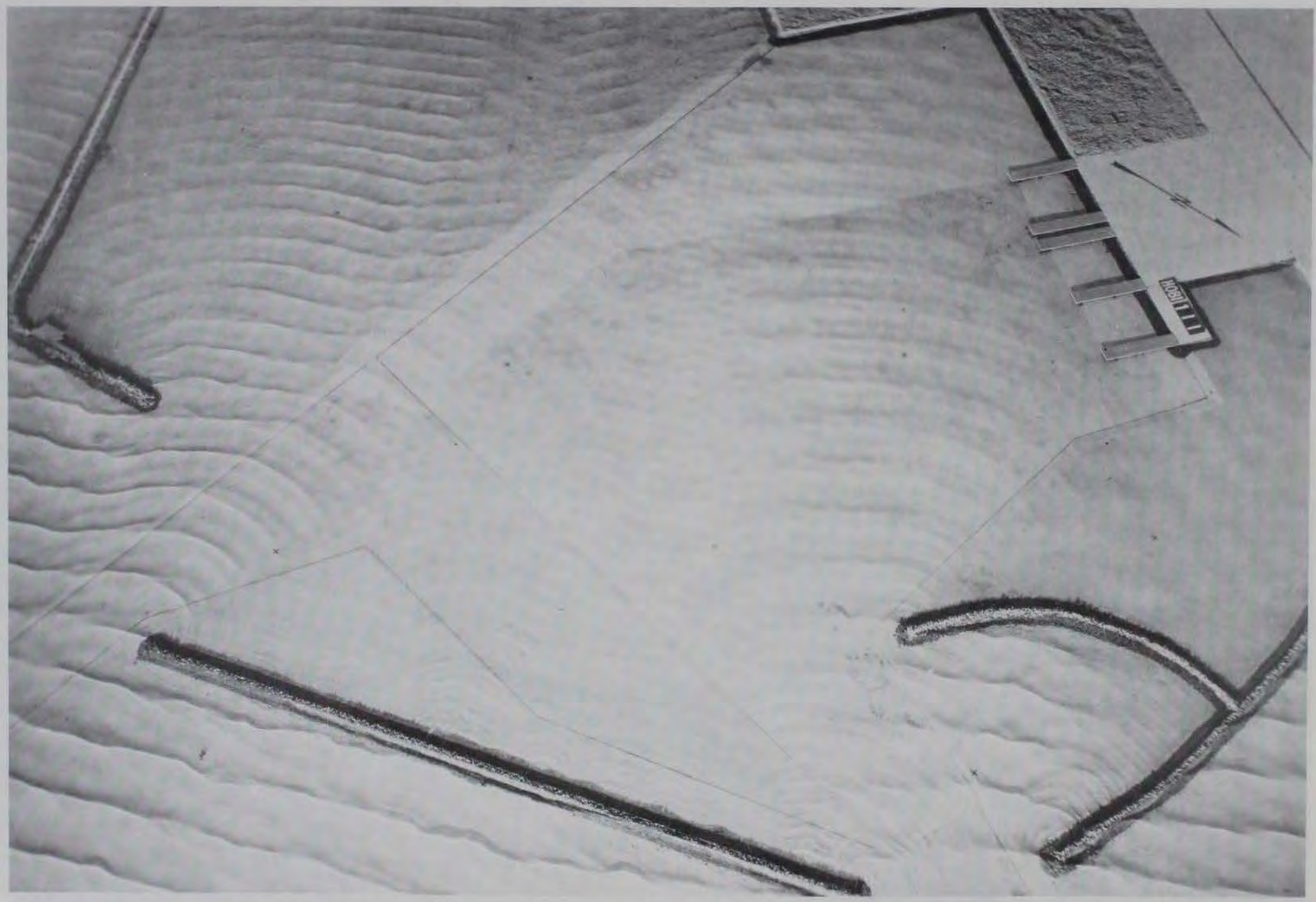


Photo 51. Plan 29; 9-sec, 3.6-m waves from east-southeast

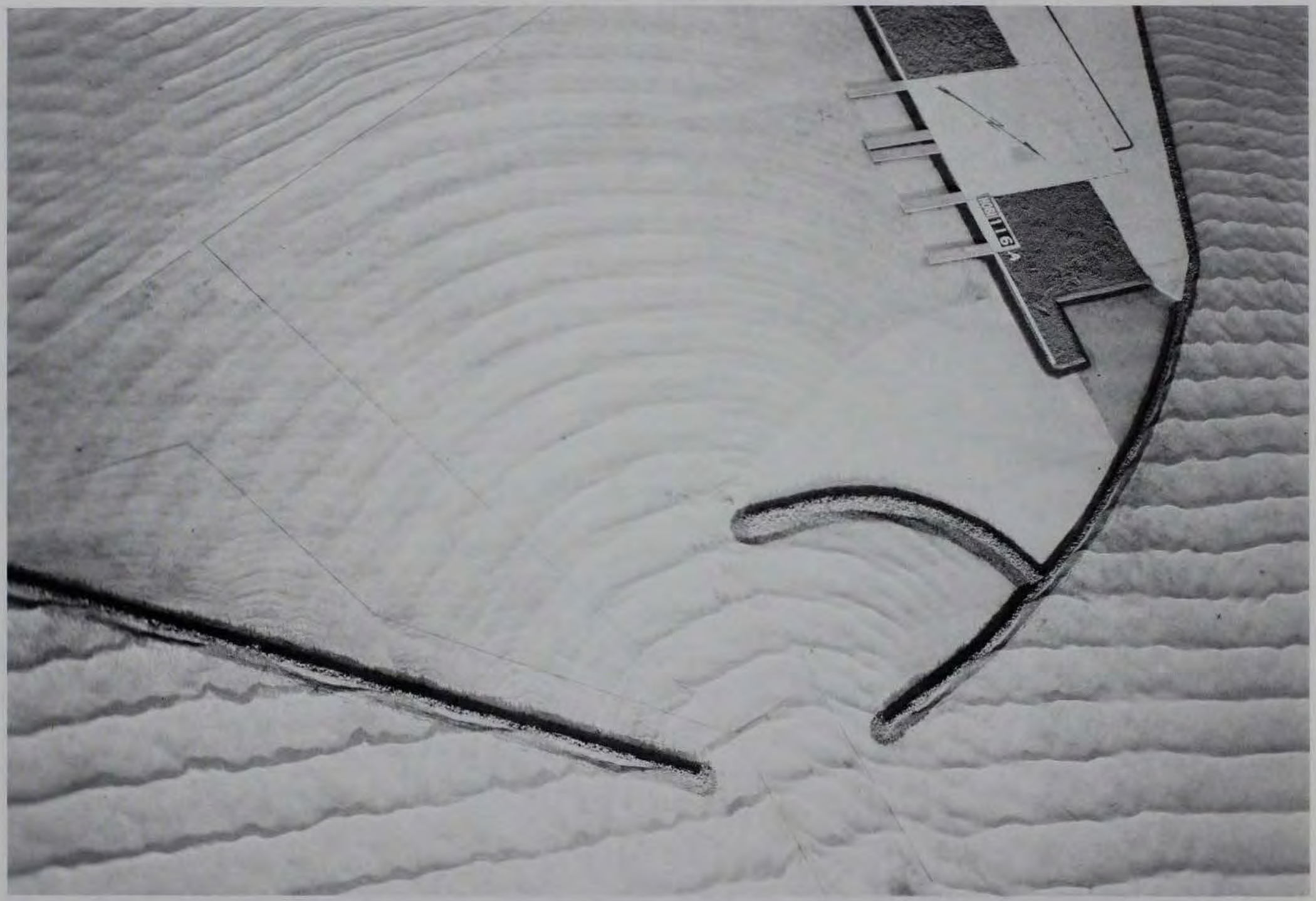


Photo 52. Plan 30B; 9-sec, 3.0-m waves from northeast

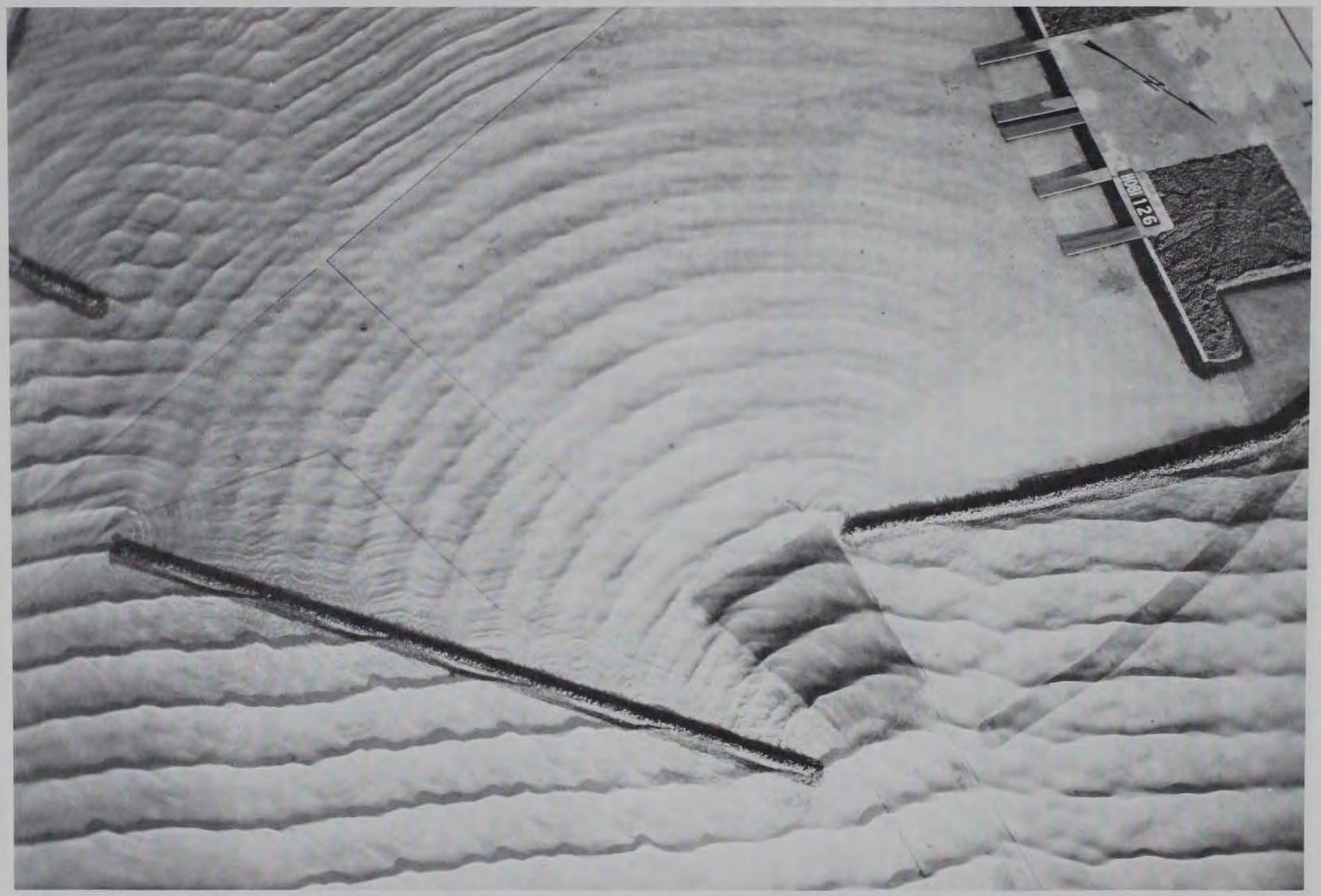


Photo 53. Plan 32; 9-sec, 4.0-m waves from northeast

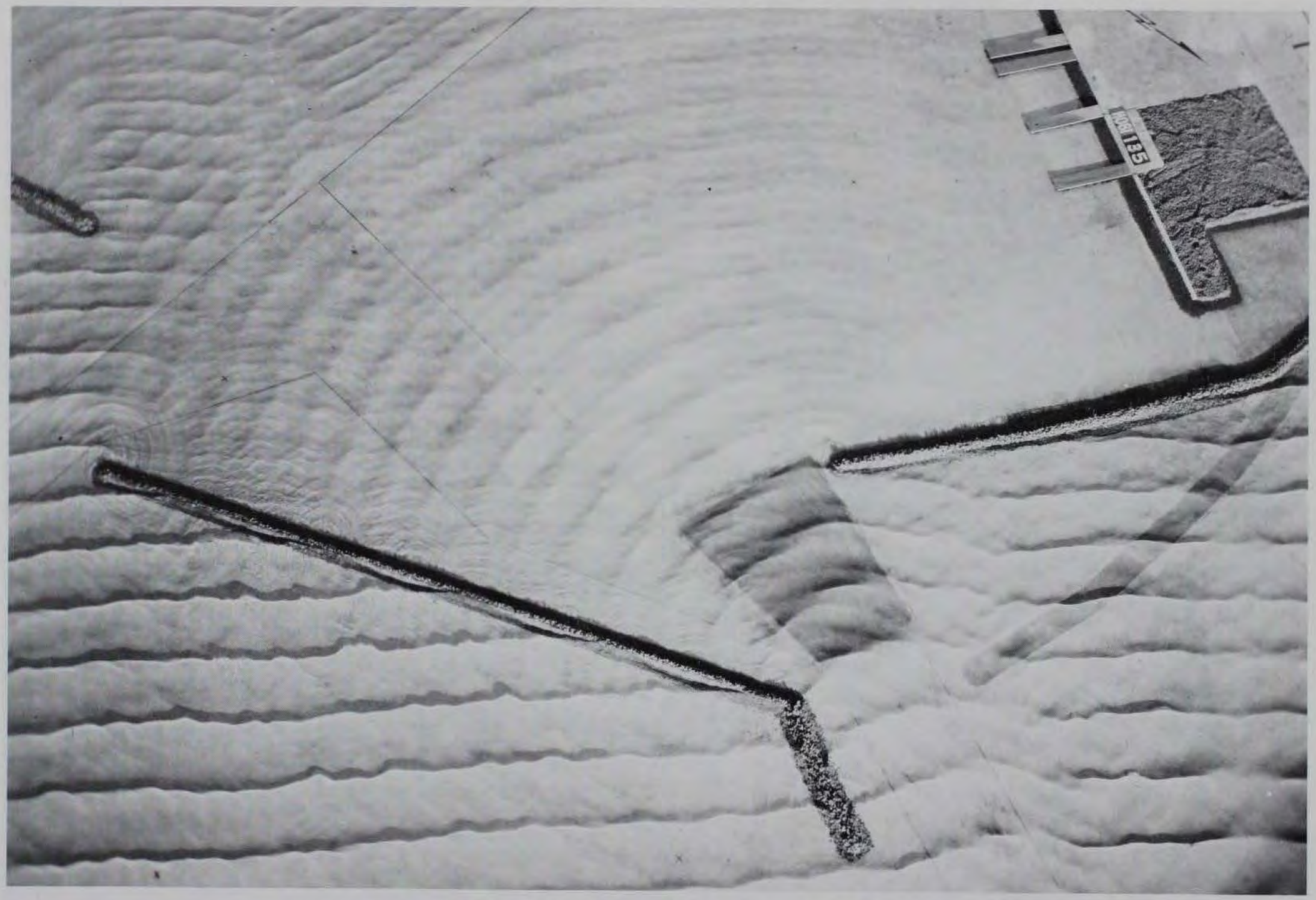
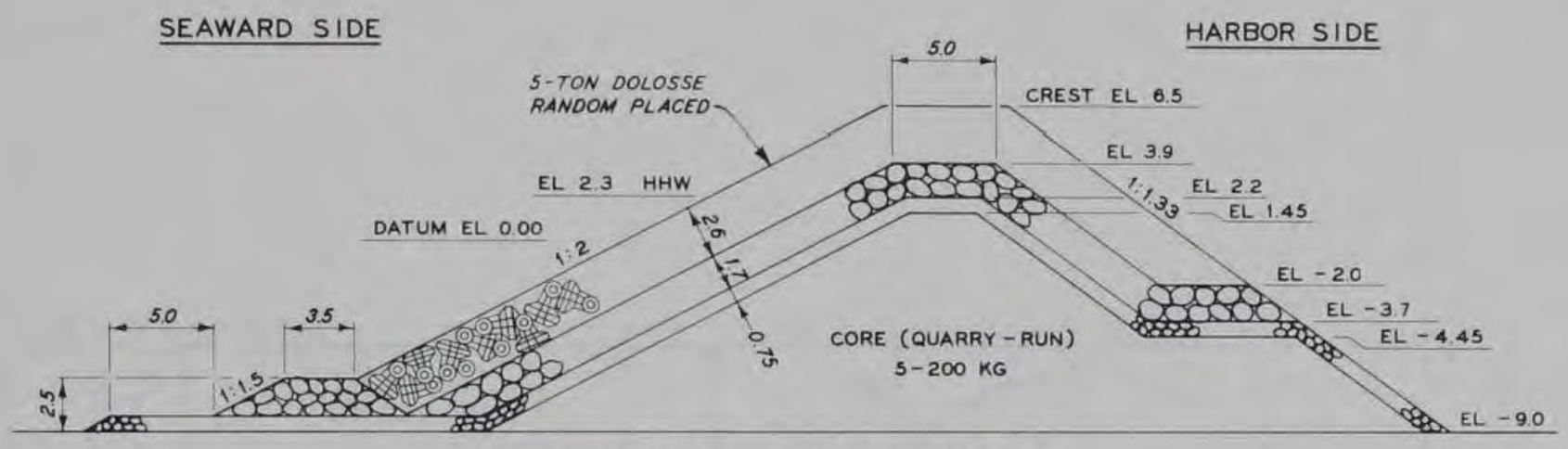
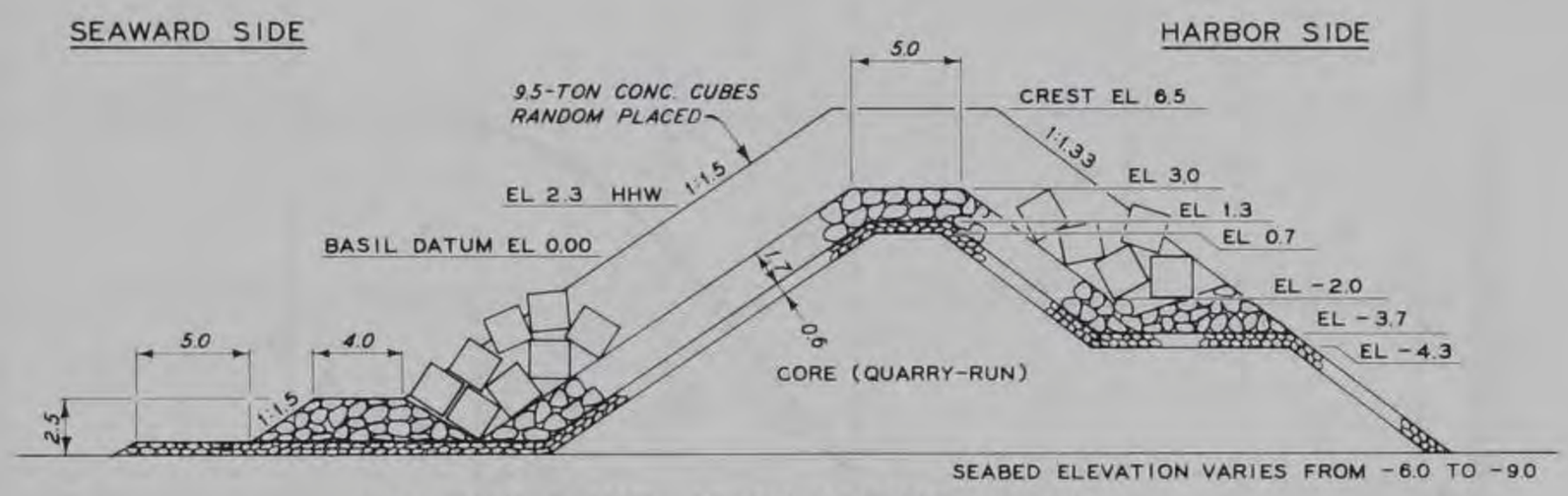


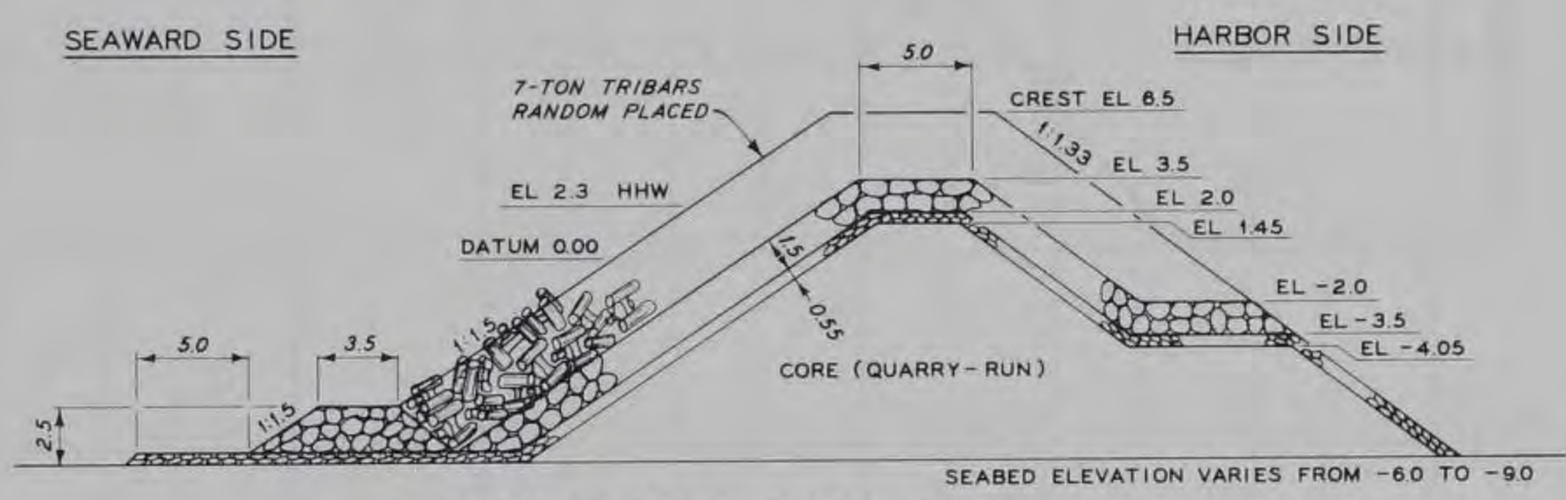
Photo 54. Plan 32A; 9-sec, 4.0-m waves from northeast



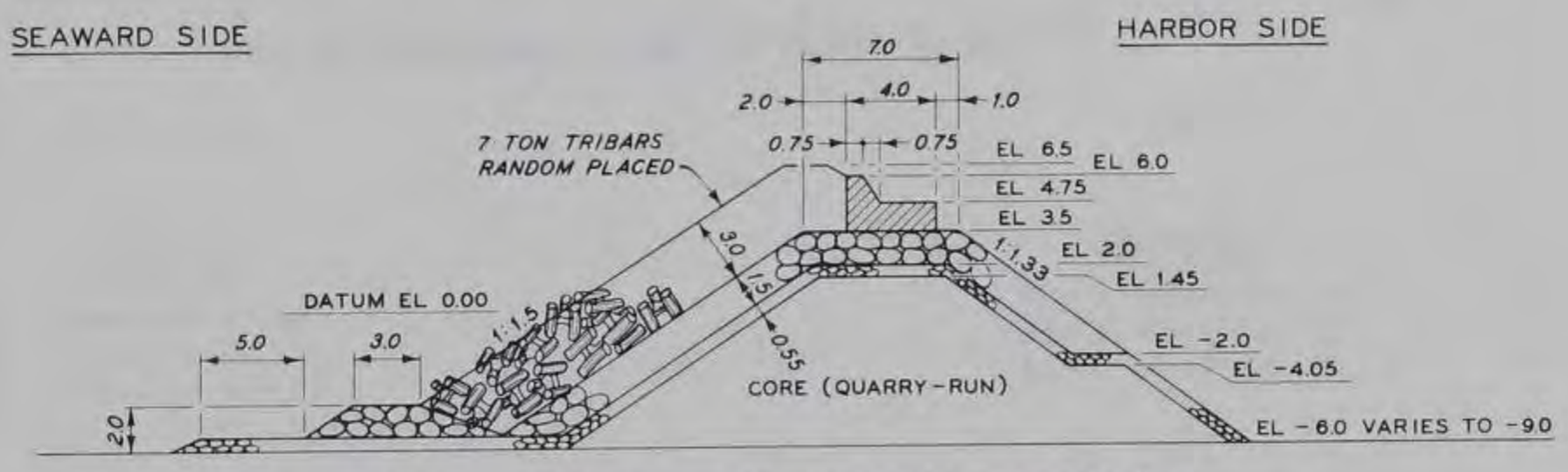
5-TON DOLOS ARMOR UNITS



9.5-TON CONC. CUBE ARMOR UNITS



7-TON TRIBAR ARMOR UNITS



7-TON TRIBAR ARMOR UNITS W/CONC. PARAPET

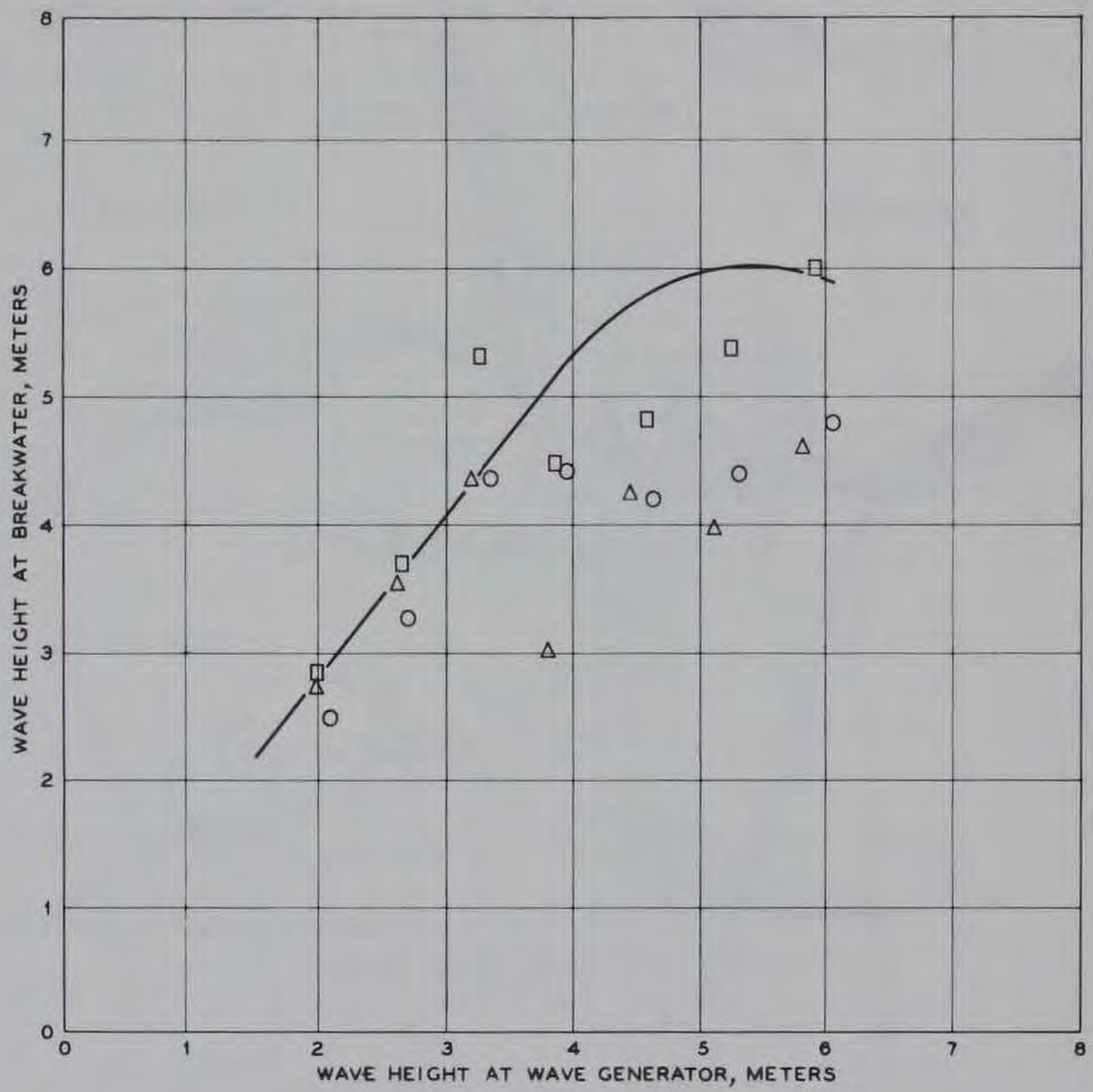
NOTE: DIMENSIONS ARE IN METERS

PROPOSED BREAKWATER CROSS SECTIONS

SCALE IN METERS

10 0 10 20

PLATE 1



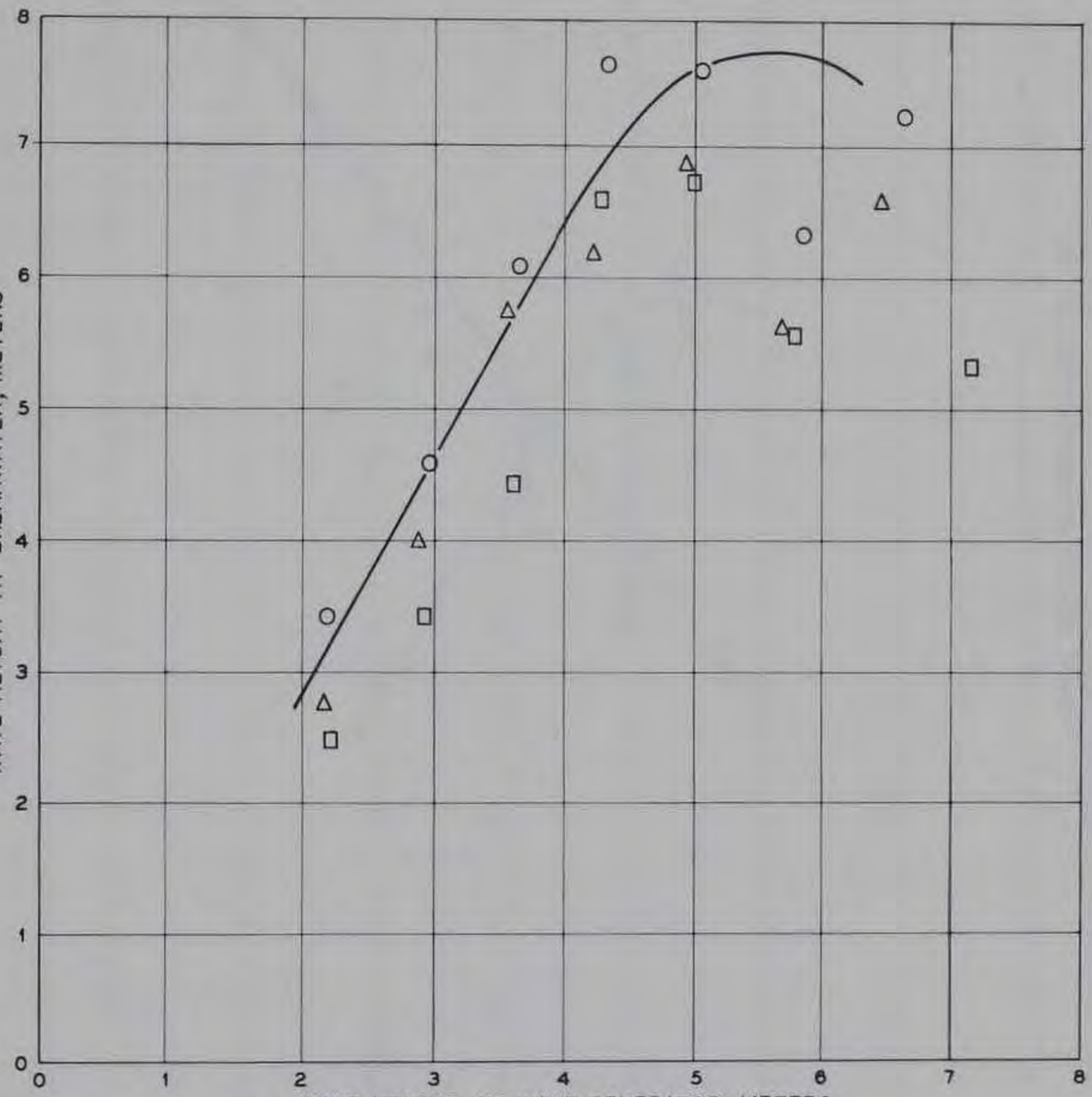
LEGEND

△ STATION 0+00
□ STATION 2+33
○ STATION 4+33

WAVE HEIGHTS

STA 0+00, 2+33, AND 4+33
NORTH BREAKWATER
9-SEC WAVES
STILL-WATER LEVEL +2.35 METERS

PLATE 2

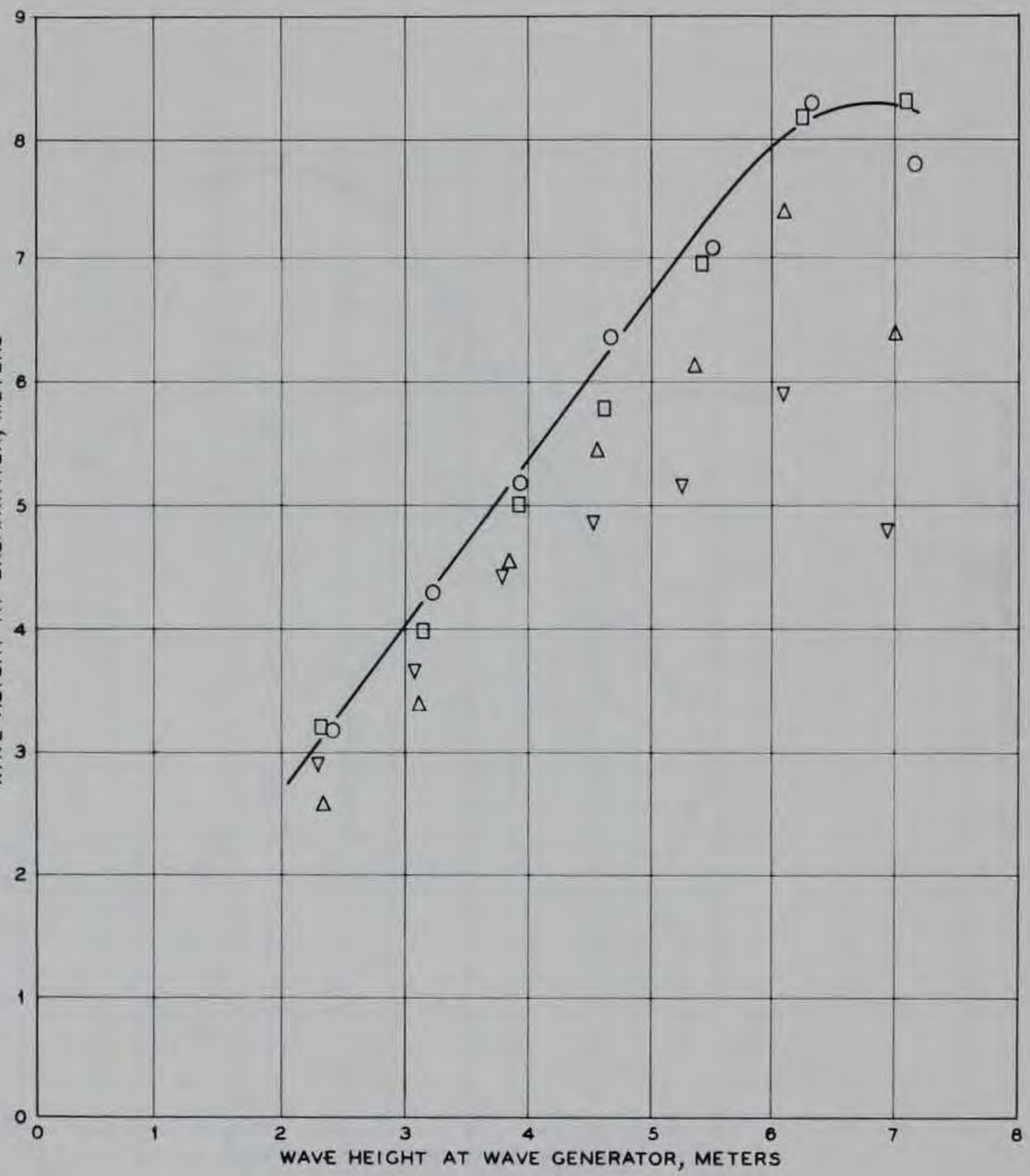


LEGEND

△ STATION 6+33
□ STATION 8+33
○ STATION 10+33

WAVE HEIGHTS

STA 6+33, 8+33, AND 10+33
NORTH BREAKWATER
9-SEC WAVES
STILL-WATER LEVEL +2.35 METERS



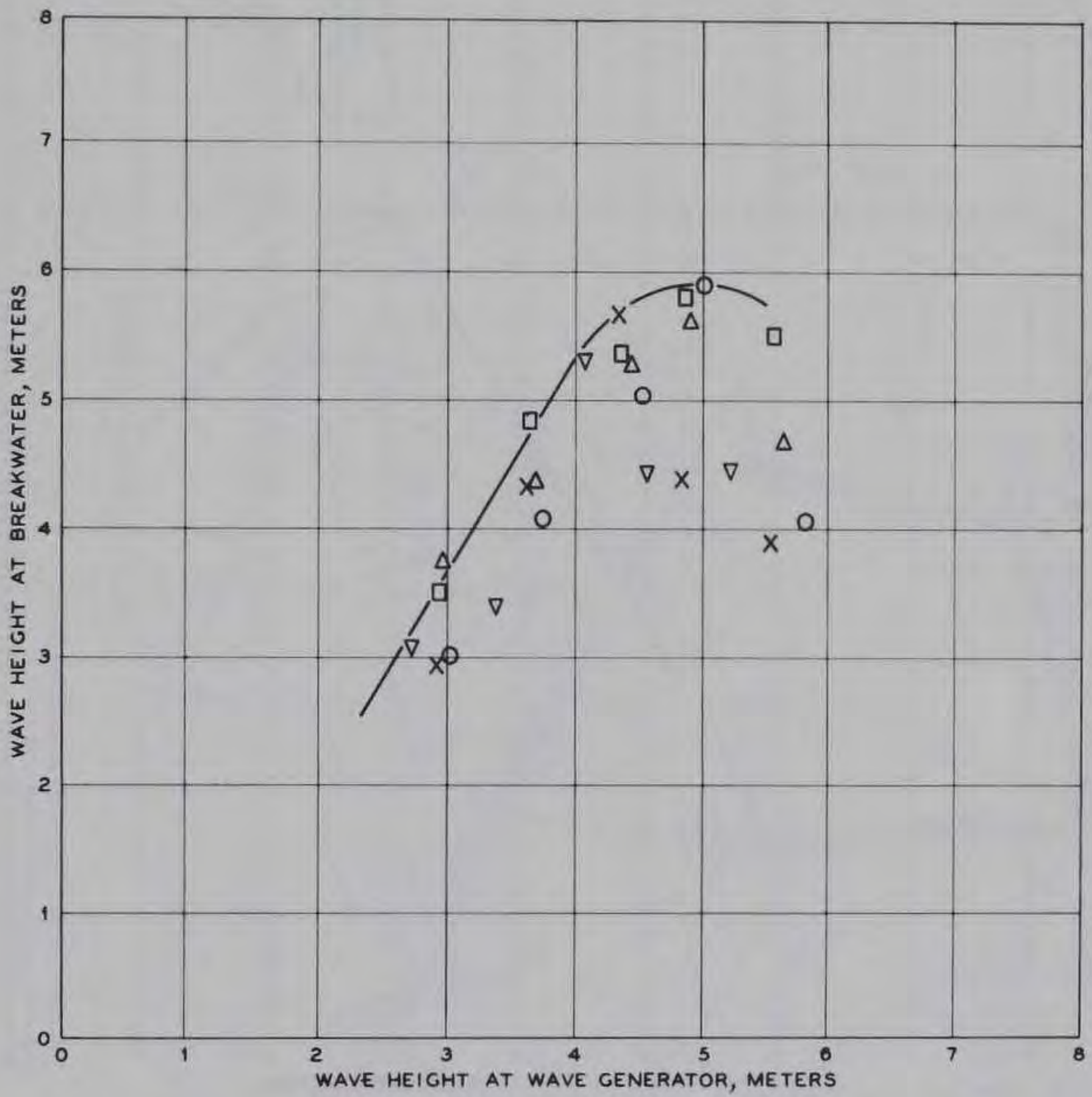
LEGEND

▽ STATION 12+33
□ STATION 14+33
△ STATION 16+33
○ STATION 17+33

WAVE HEIGHTS

STA 12+33, 14+33, 16+33, AND 17+33
NORTH BREAKWATER
9-SEC WAVES
STILL-WATER LEVEL +2.35 METERS

PLATE 4



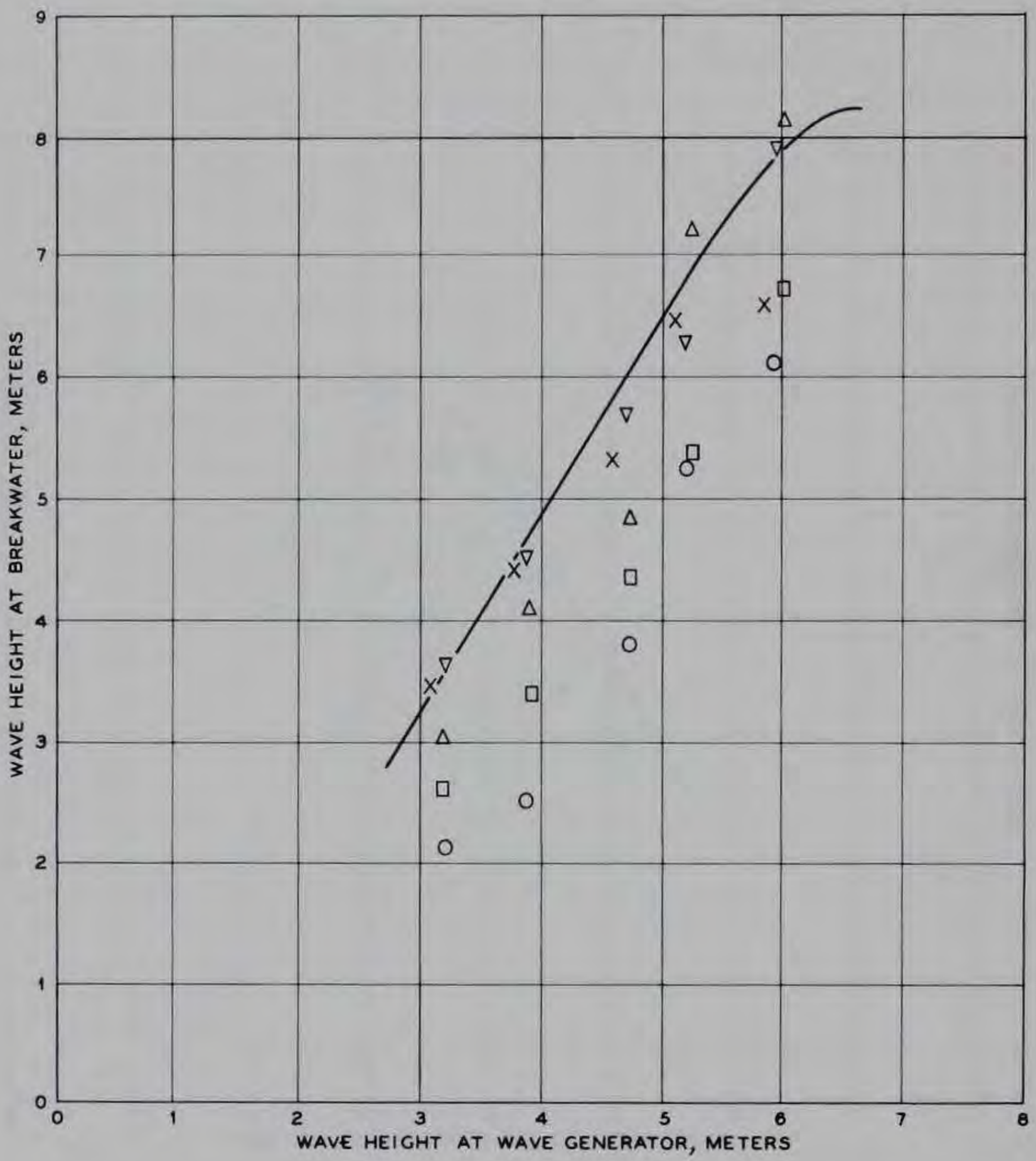
LEGEND

- ▽ STATION 0+00
- X STATION 2+87
- □ STATION 4+87
- △ STATION 6+87
- O STATION 8+87

WAVE HEIGHTS

STA 0+00, 2+87, 4+87, 6+87, AND 8+87
EAST BREAKWATER
9-SEC WAVES
STILL-WATER LEVEL +2.35 METERS

PLATE 5



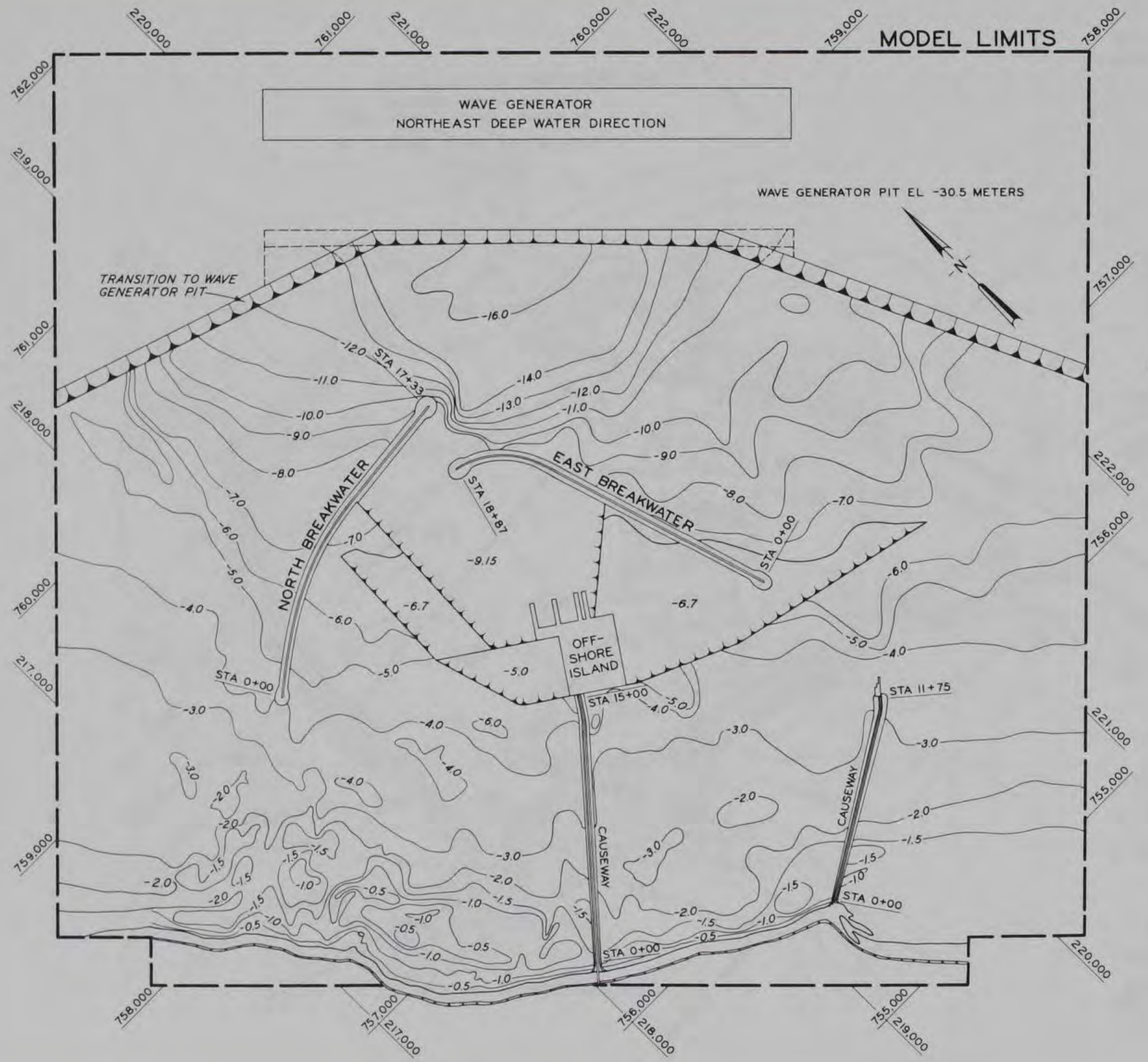
LEGEND

X STATION 10+87
▽ STATION 12+87
△ STATION 14+87
□ STATION 16+87
○ STATION 18+87

WAVE HEIGHTS

STA 10+87, 12+87, 14+87, 16+87, AND 18+87
EAST BREAKWATER
9-SEC WAVES
STILL-WATER LEVEL, +2.35 METERS

PLATE 6



NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

MODEL LAYOUT

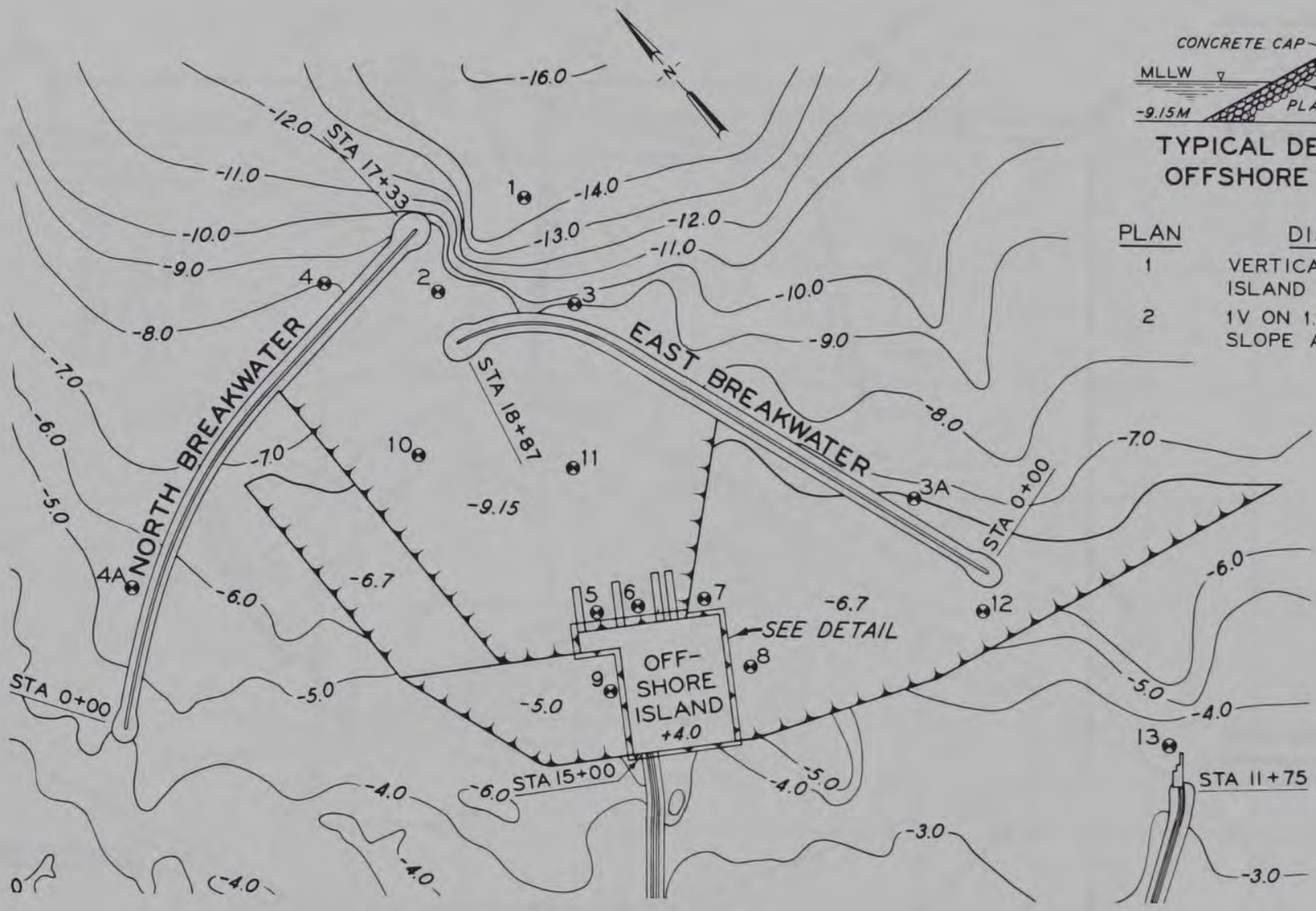
SCALES IN METERS

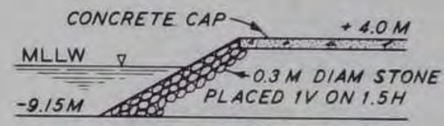
MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600

PLATE 7

PLATE 8





TYPICAL DETAIL OF OFFSHORE ISLAND

PLAN	DISCRIPTION
1	VERTICAL CONCRETE ISLAND WALLS
2	1V ON 1.5H ROCK SLOPE AROUND ISLAND

LEGEND

● WAVE GAGE LOCATION

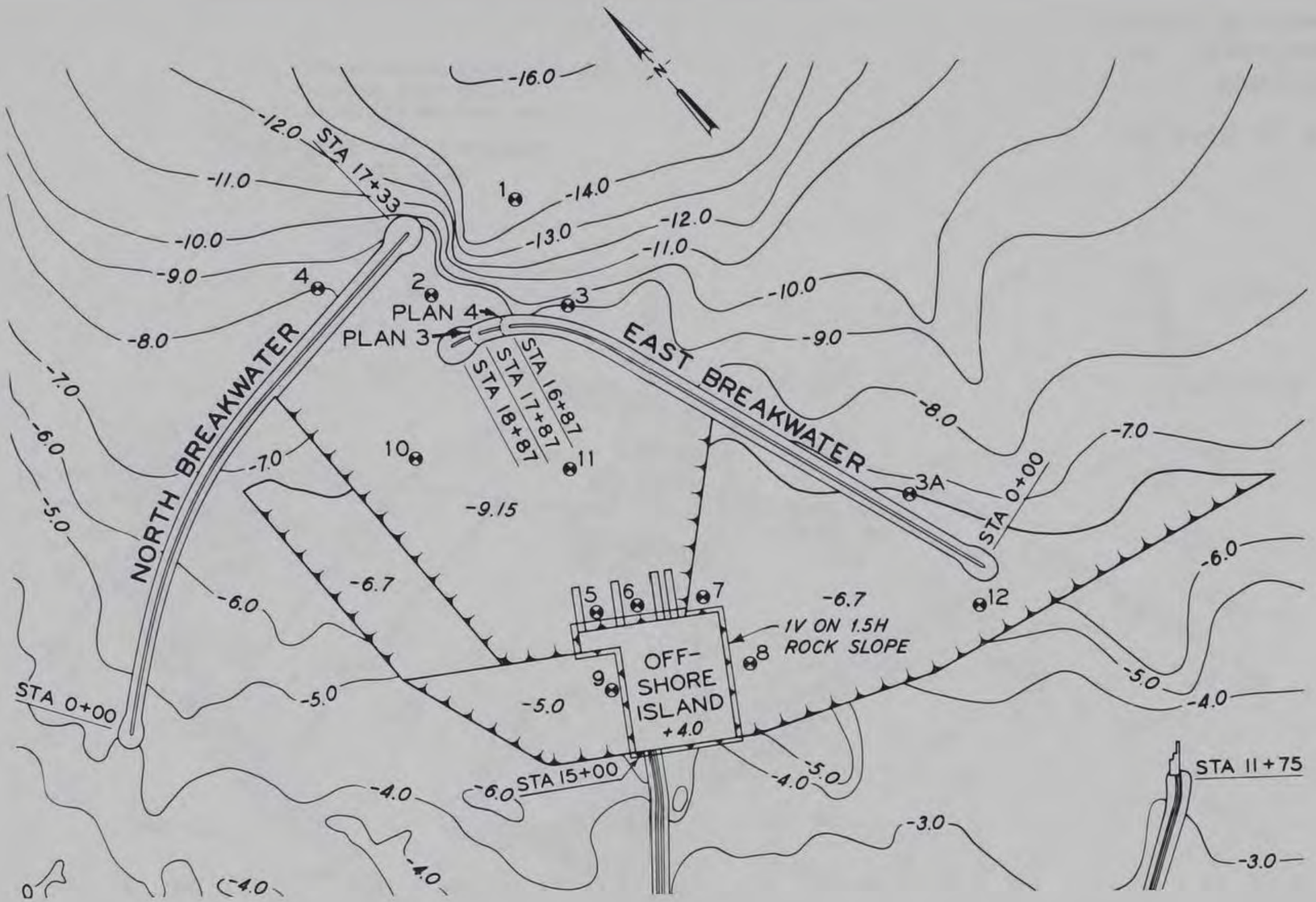
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 1 AND 2

SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 3 AND 4

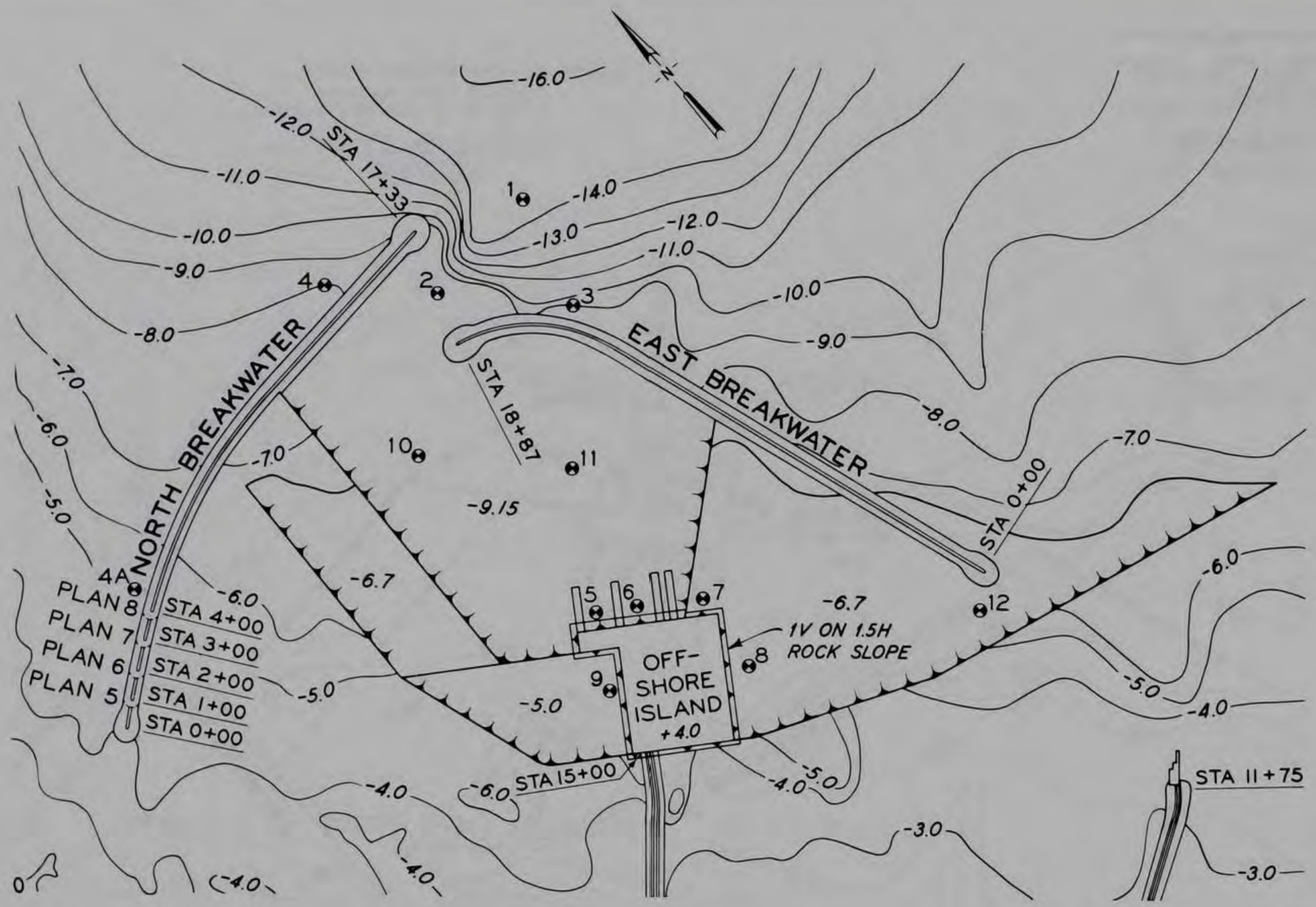
SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600

PLATE 9

PLATE 10



LEGEND

● WAVE GAGE LOCATION

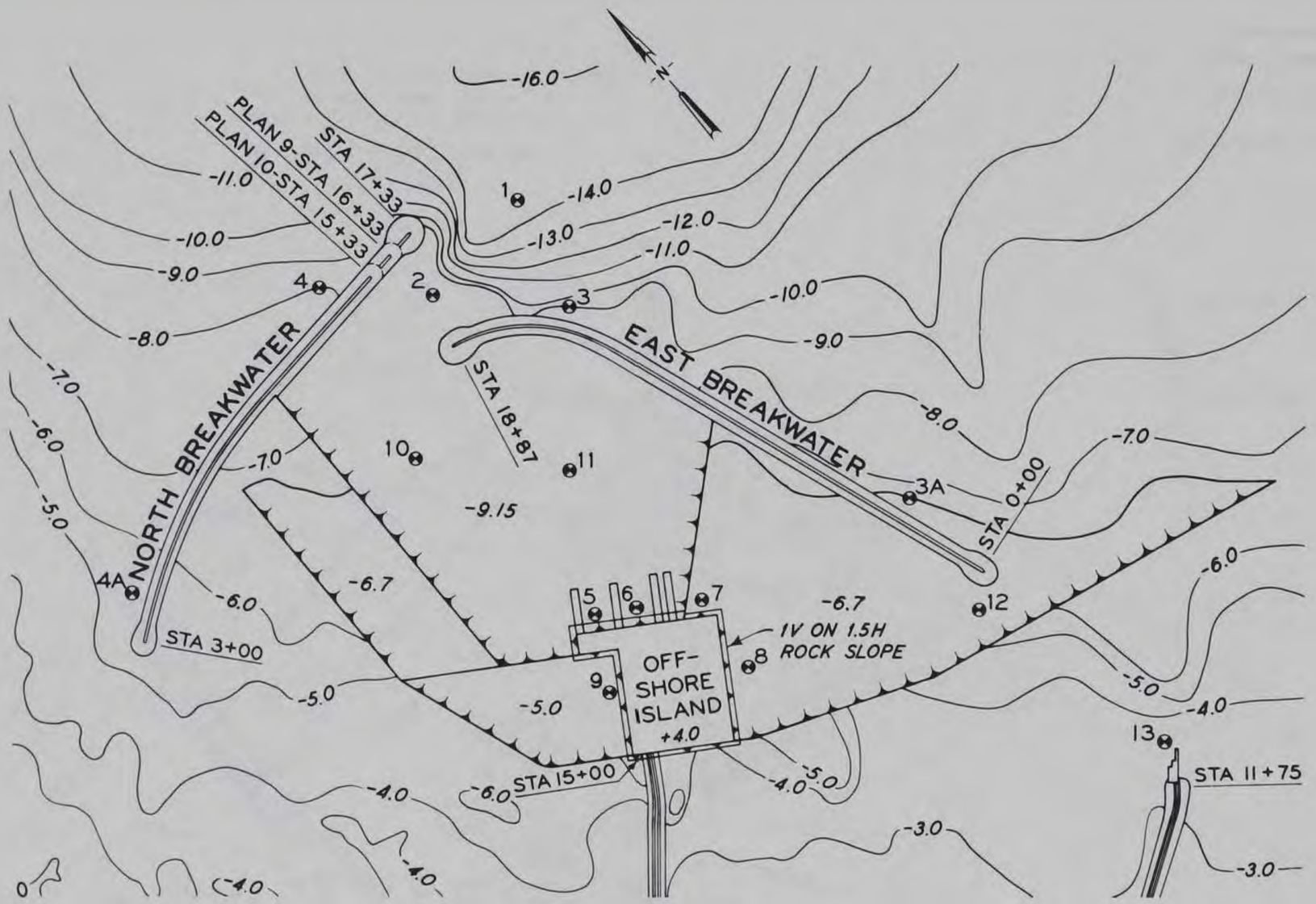
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 5, 6, 7, AND 8

SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

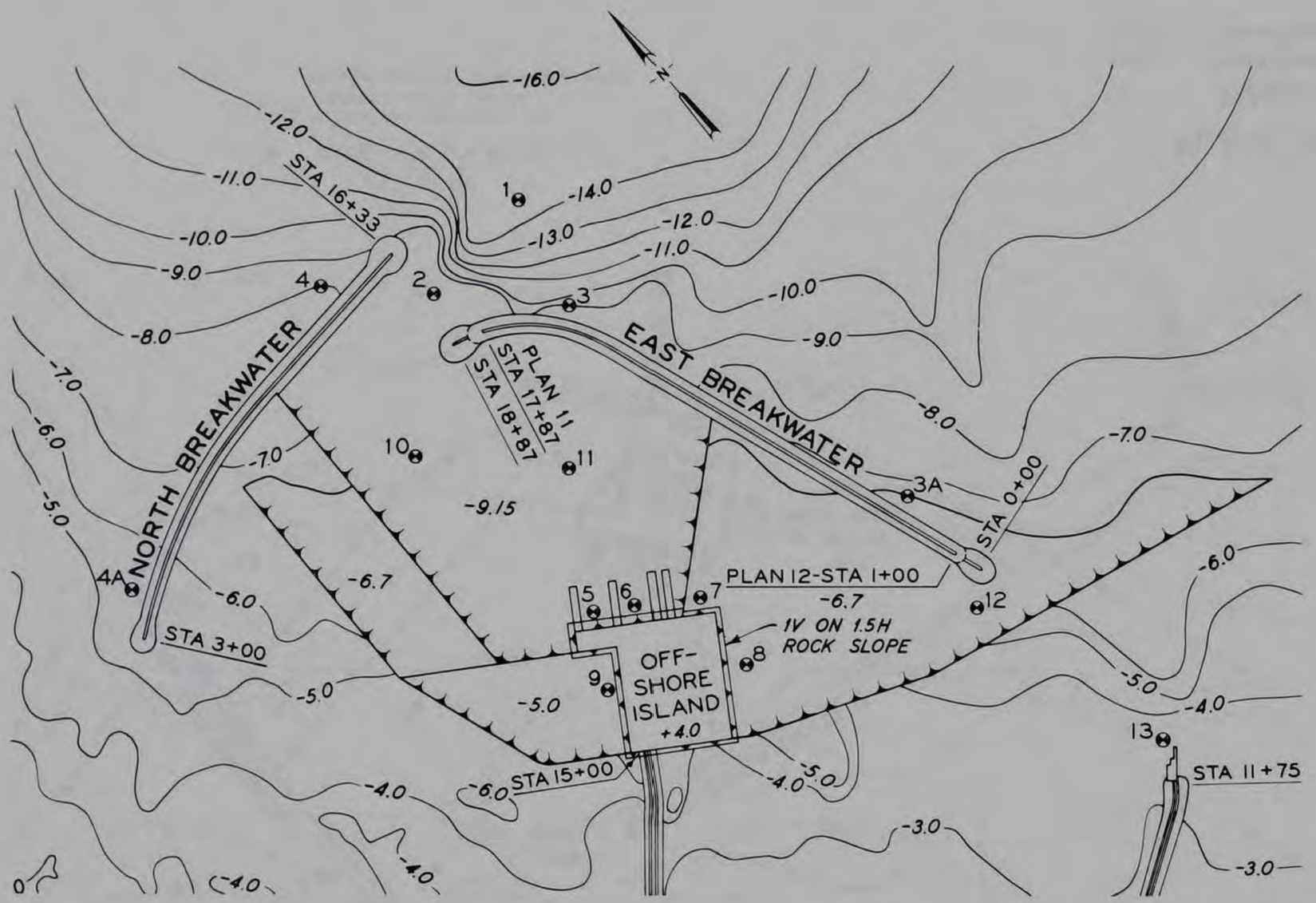
PLANS 9 AND 10

SCALE IN METERS

MODEL	2	0	2	4	6	
PROTOTYPE	200	0	200	400	600	

PLATE 11

PLATE 12



LEGEND

⊗ WAVE GAGE LOCATION

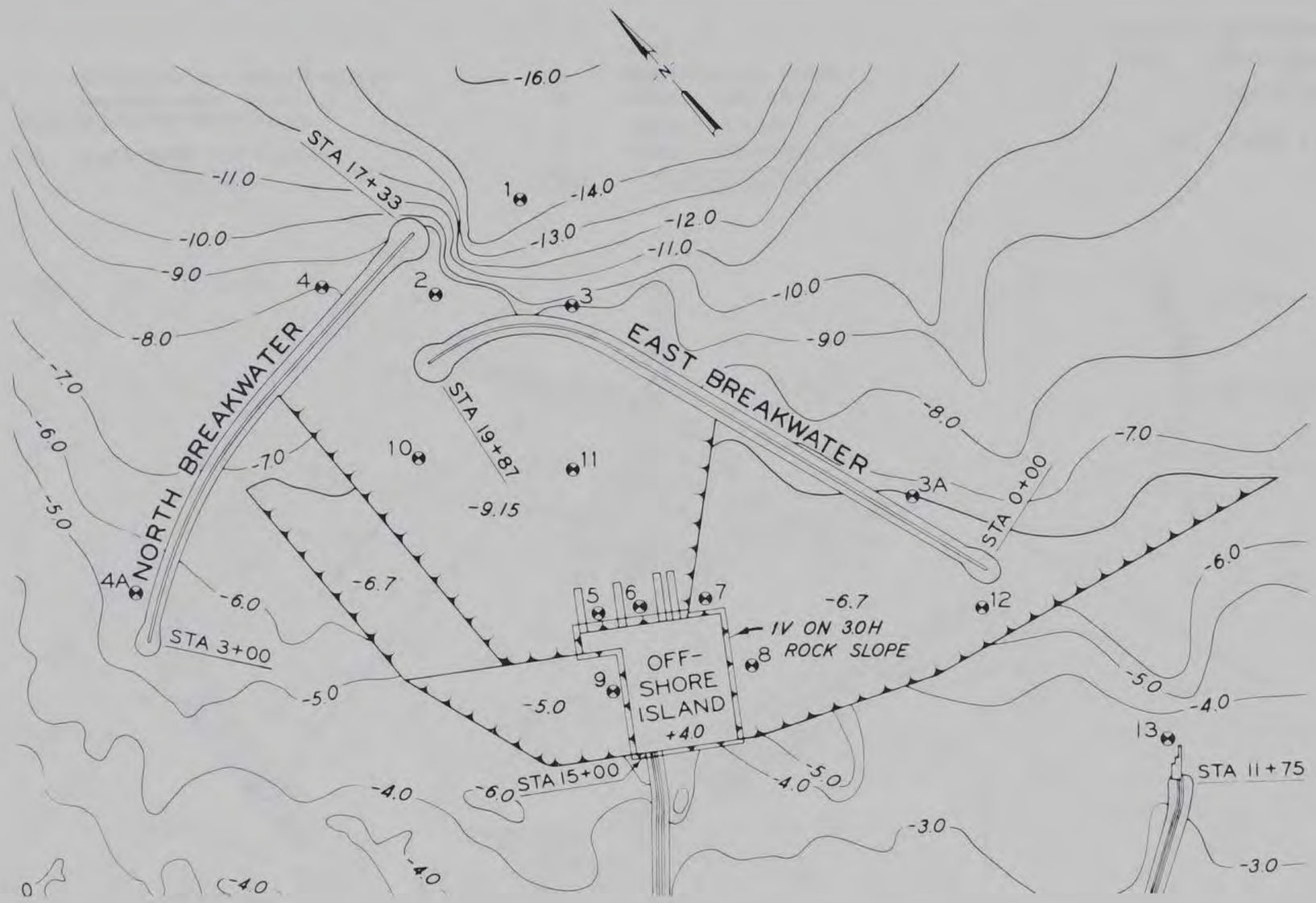
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 11 AND 12

SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLAN	ROCK DIAMETER AROUND ISLAND
13	30 - CENTIMETERS
14	90 - CENTIMETERS

PLANS 13 AND 14

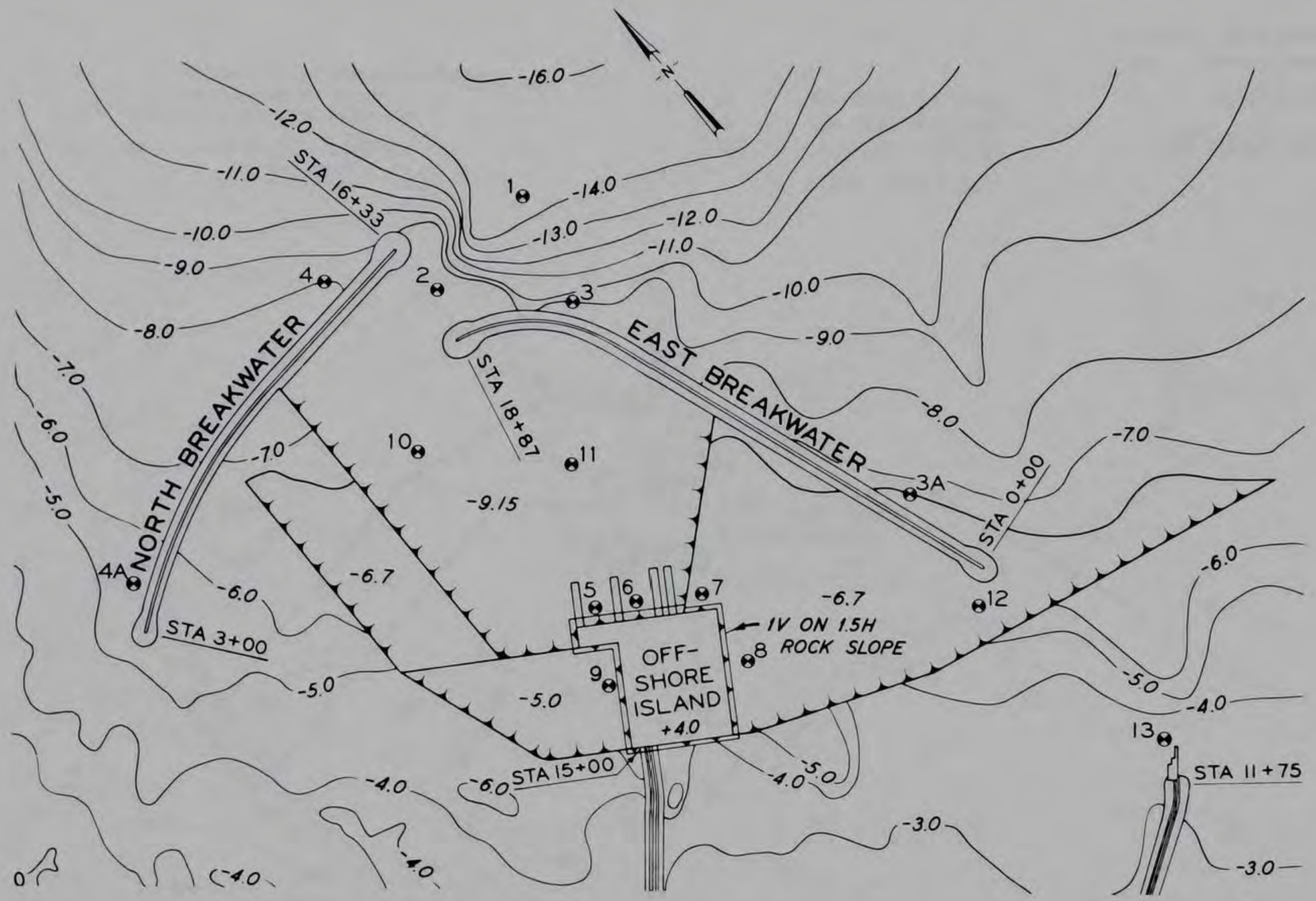
SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600

PLATE 13

PLATE 14



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

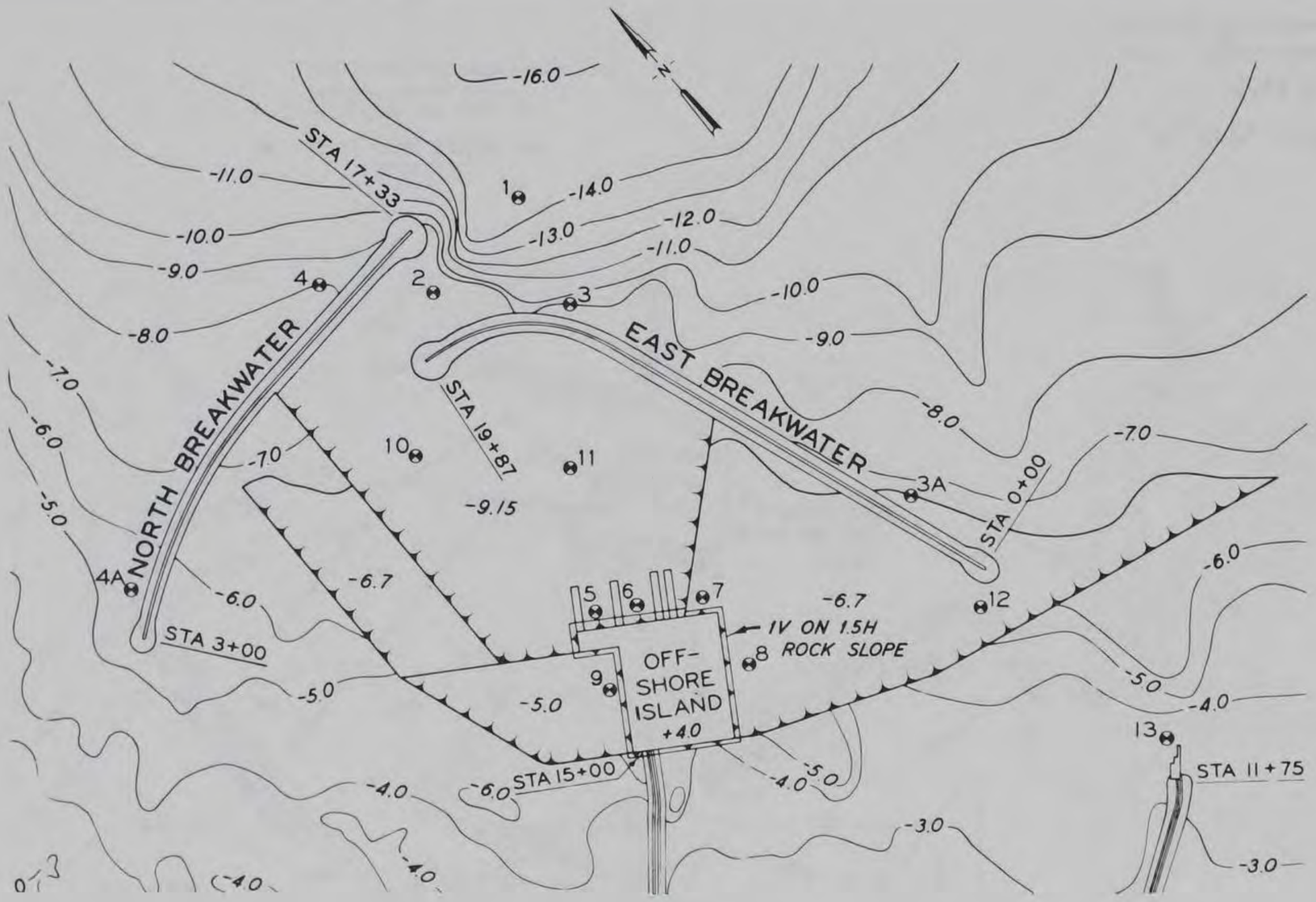
PLAN	DESCRIPTION
15	NORTH BREAKWATER CROWN + 5.5 m
16	NORTH AND EAST BREAKWATER CROWN +5.5 m

PLANS 15 AND 16

SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

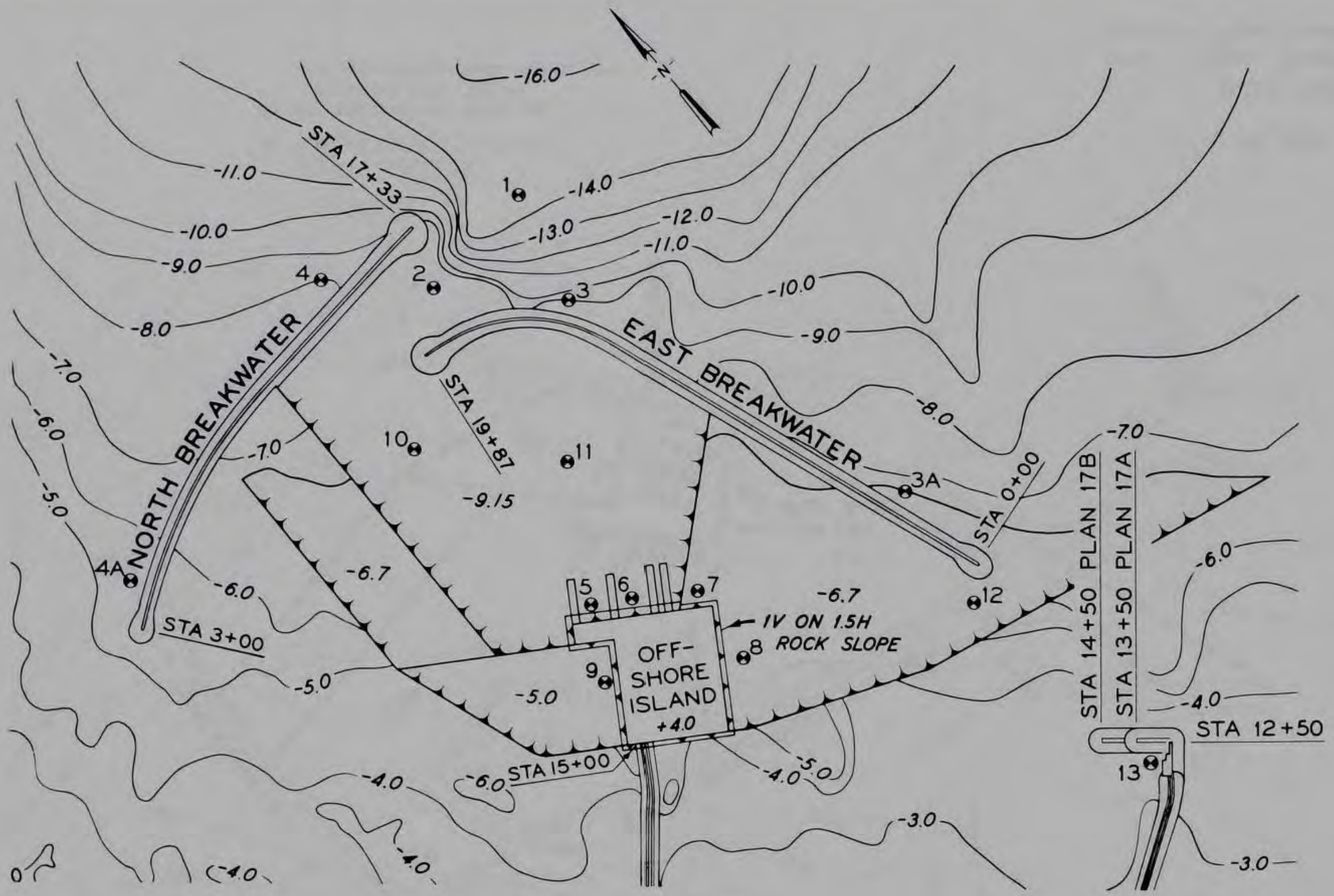
PLAN 17

SCALE IN METERS

MODEL	2	0	2	4	6	
PROTOTYPE	200	0	200	400	600	

PLATE 15

PLATE 16



LEGEND

● WAVE GAGE LOCATION

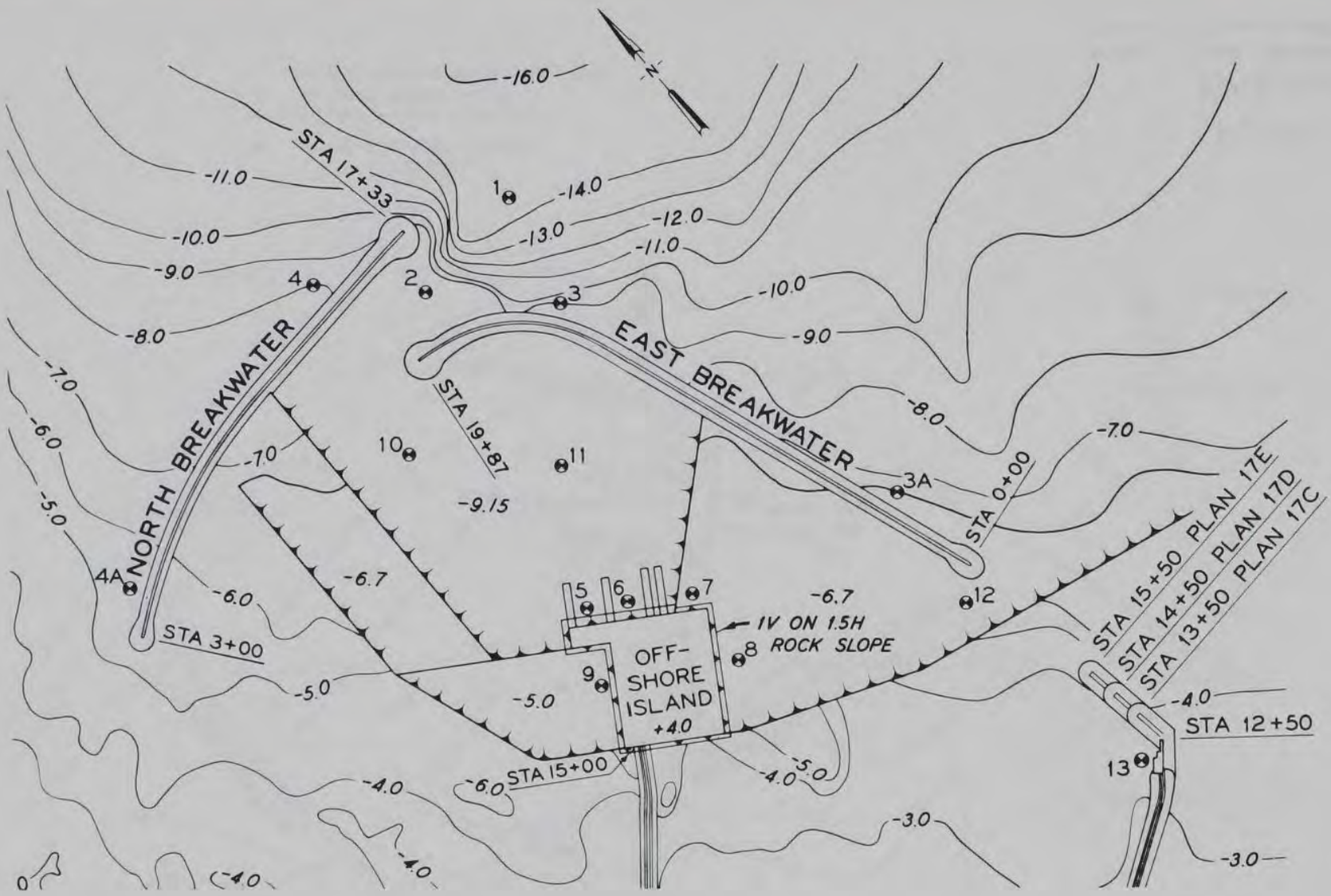
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 17A AND 17B

SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 17C, 17D, AND 17E

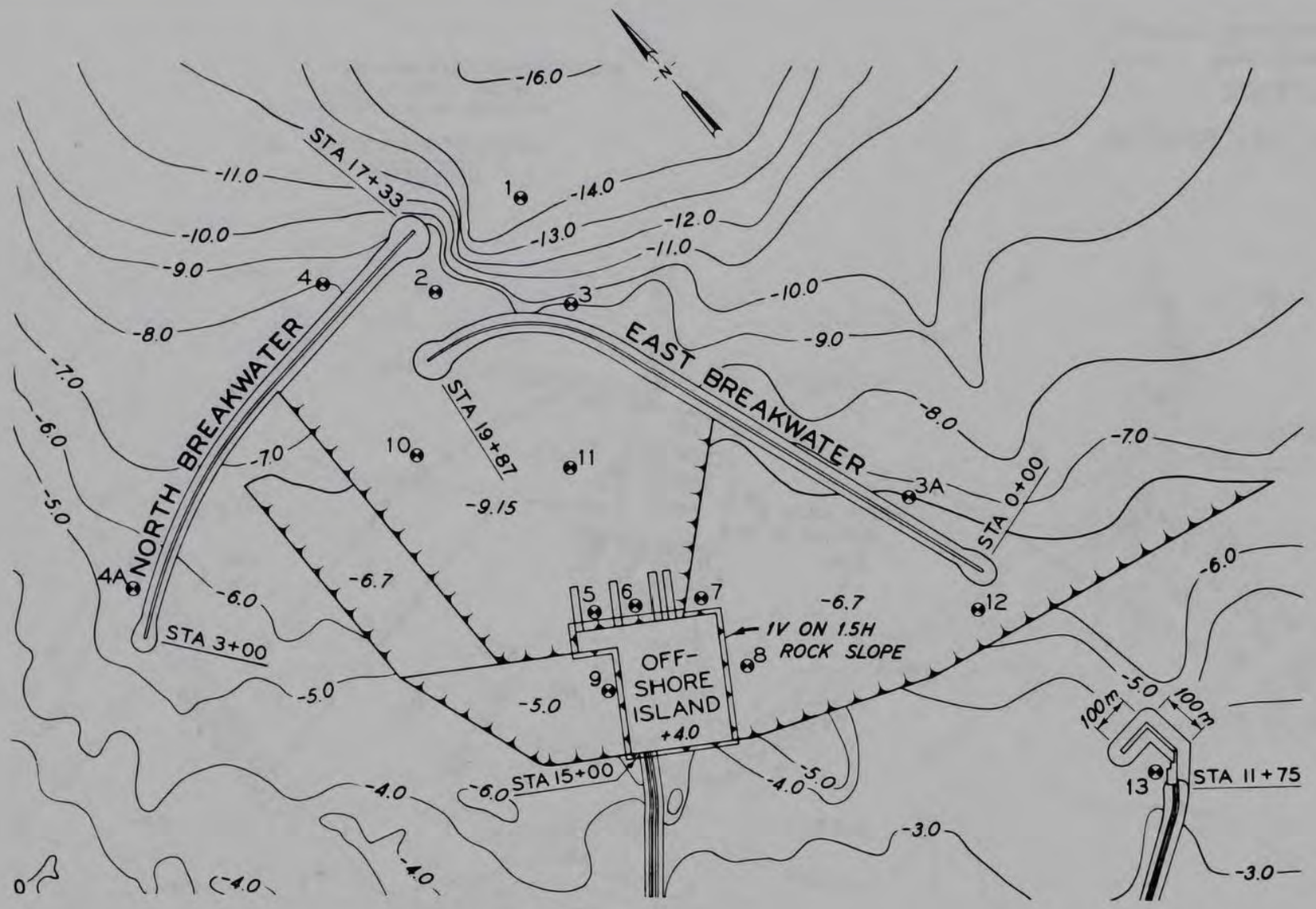
SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600

PLATE 17

PLATE 18



LEGEND

● WAVE GAGE LOCATION

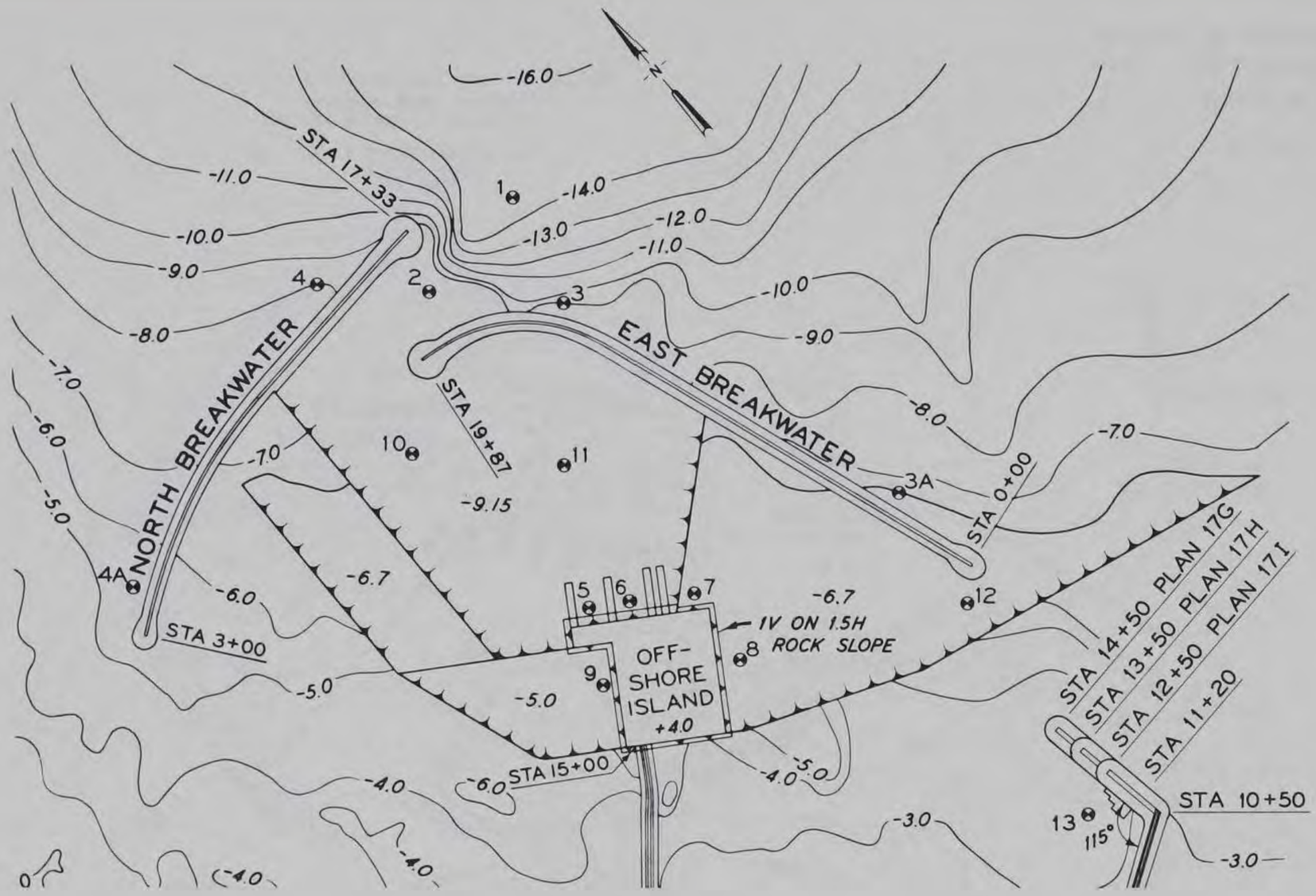
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLAN 17F

SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 17G, 17H, AND 17I

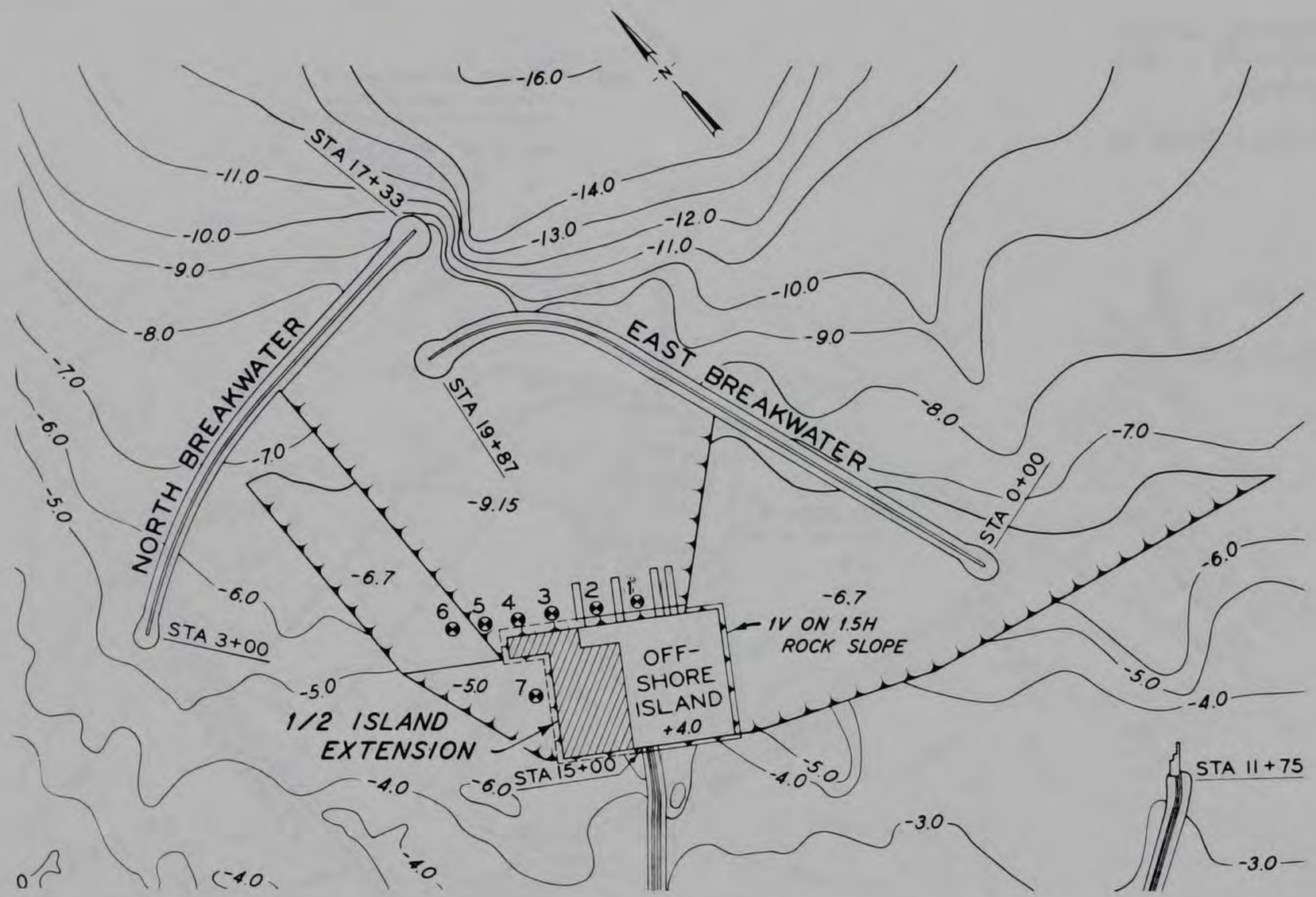
SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600

PLATE 19

PLATE 20



LEGEND

⊗ WAVE GAGE LOCATION

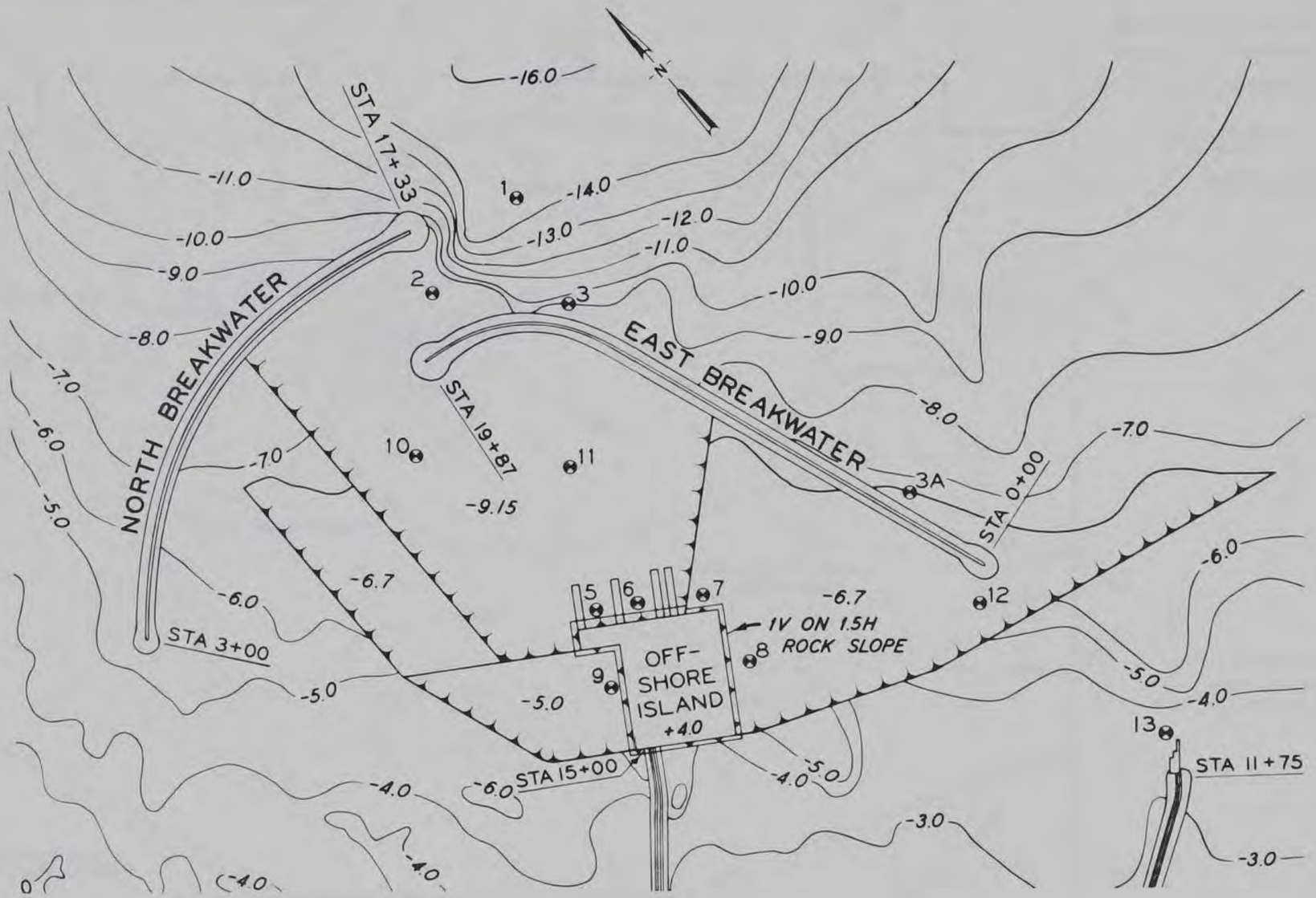
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLAN 18

SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600



LEGEND	
⊗	WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLAN	DESCRIPTION
19	NORTH BREAKWATER CURVED TO THE NORTH
20	NORTH BREAKWATER REMOVED COMPLETELY

PLANS 19 AND 20

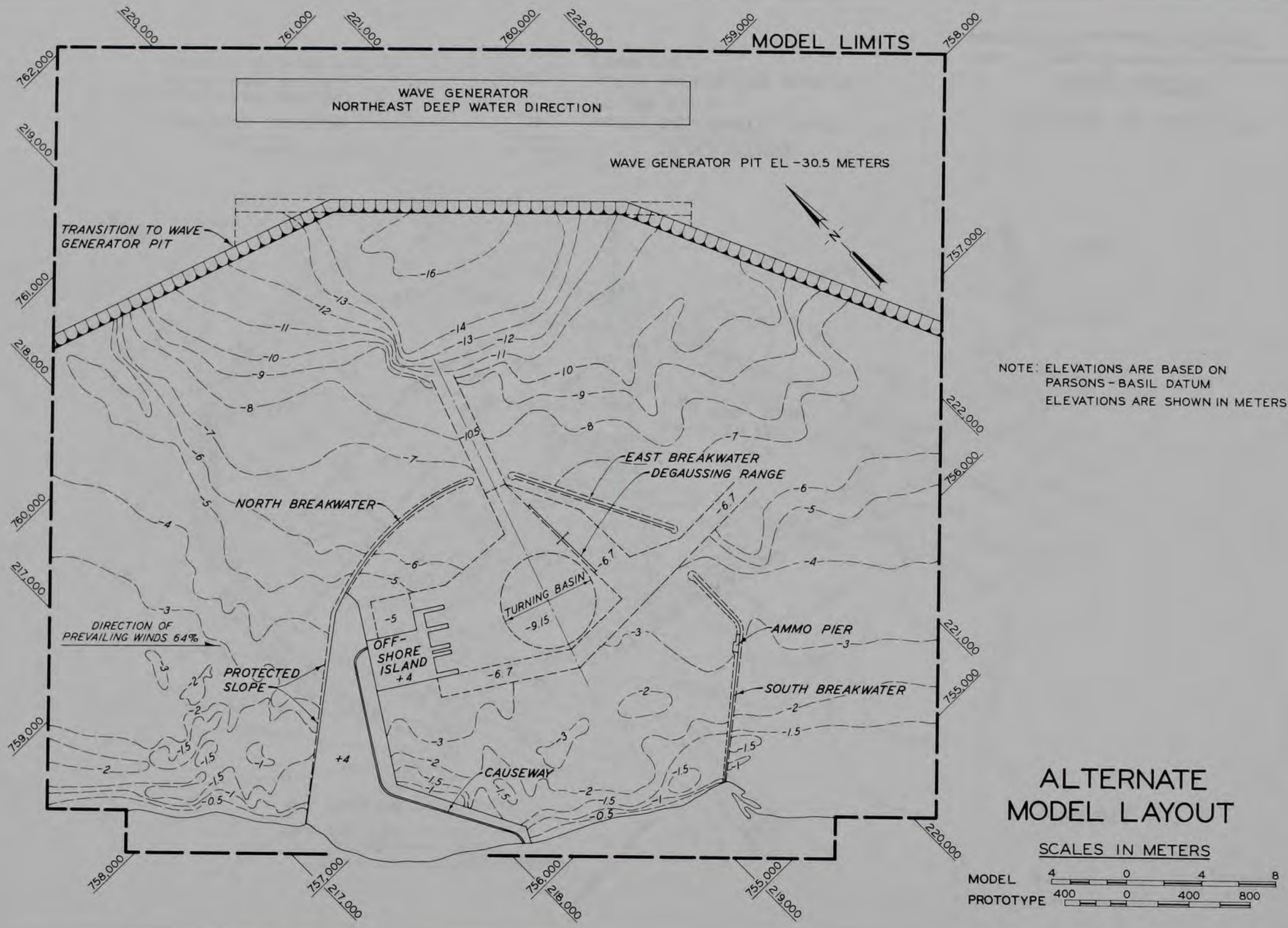
SCALE IN METERS

MODEL 2 0 2 4 6

PROTOTYPE 200 0 200 400 600

PLATE 21

PLATE 22



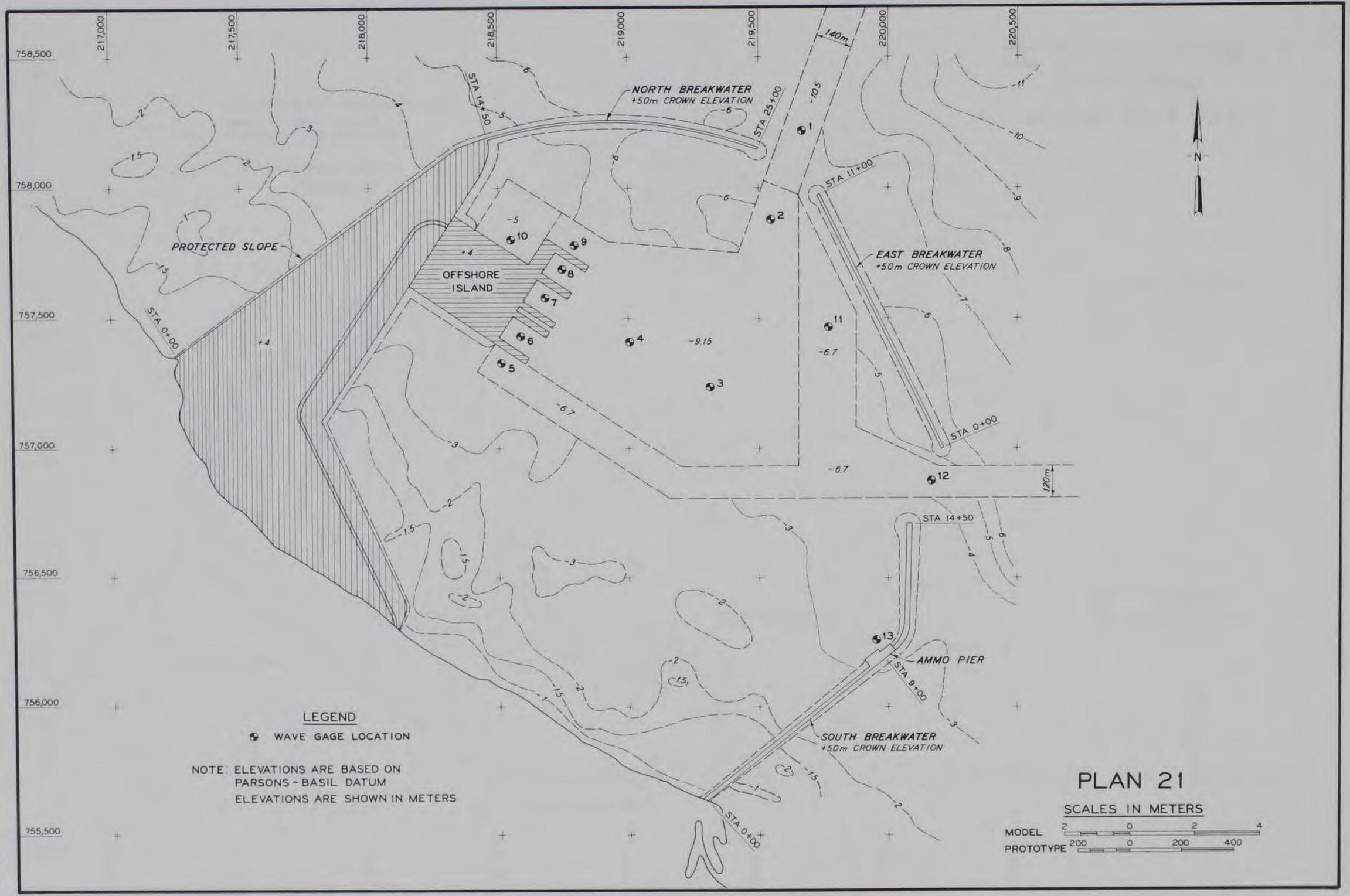
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

ALTERNATE MODEL LAYOUT

SCALES IN METERS

MODEL 4 0 4 8

PROTOTYPE 400 0 400 800



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS-BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLAN 21

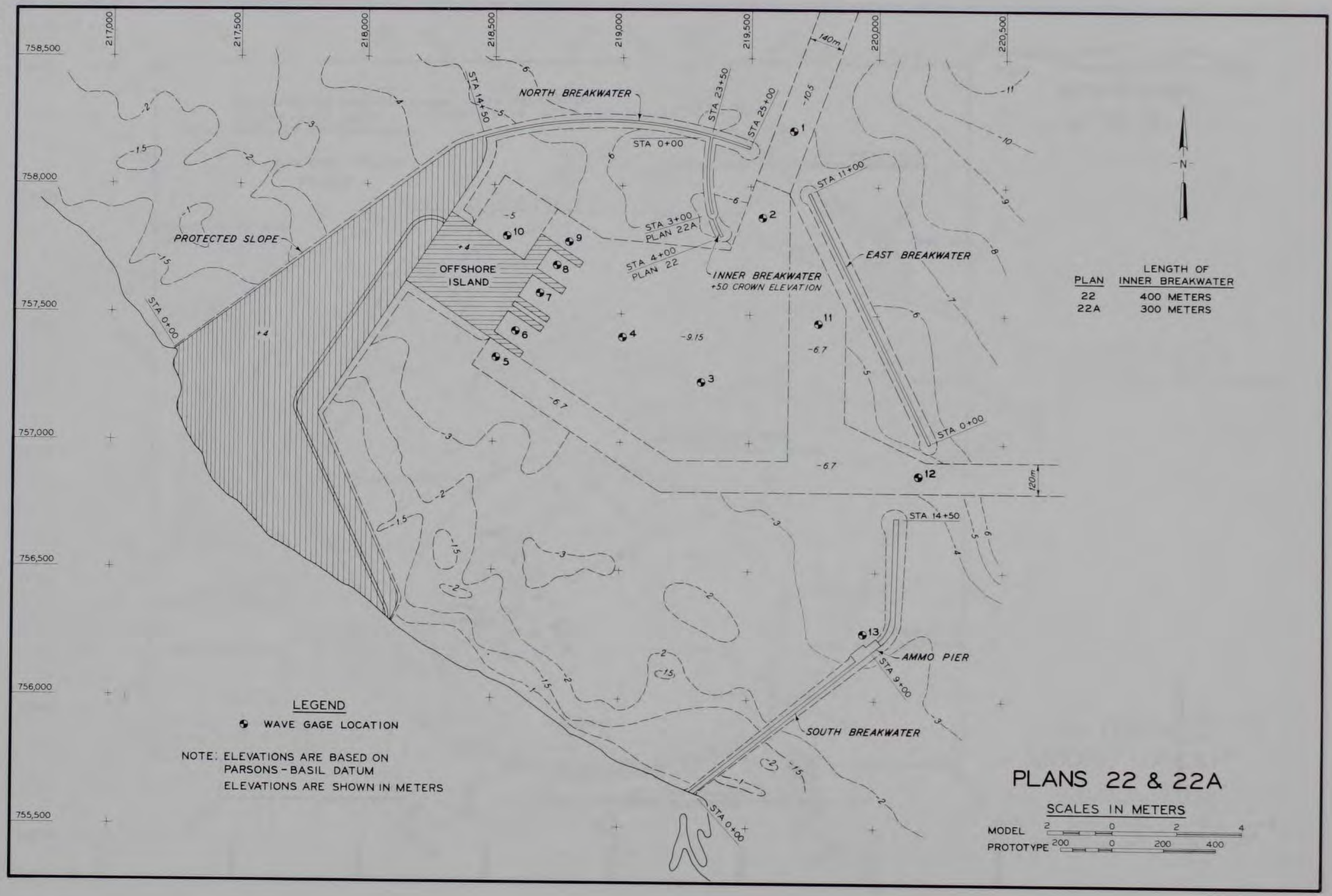
SCALES IN METERS

MODEL 2 0 2 4

PROTOTYPE 200 0 200 400

PLATE 23

PLATE 24



PLAN	LENGTH OF INNER BREAKWATER
22	400 METERS
22A	300 METERS

LEGEND

● WAVE GAGE LOCATION

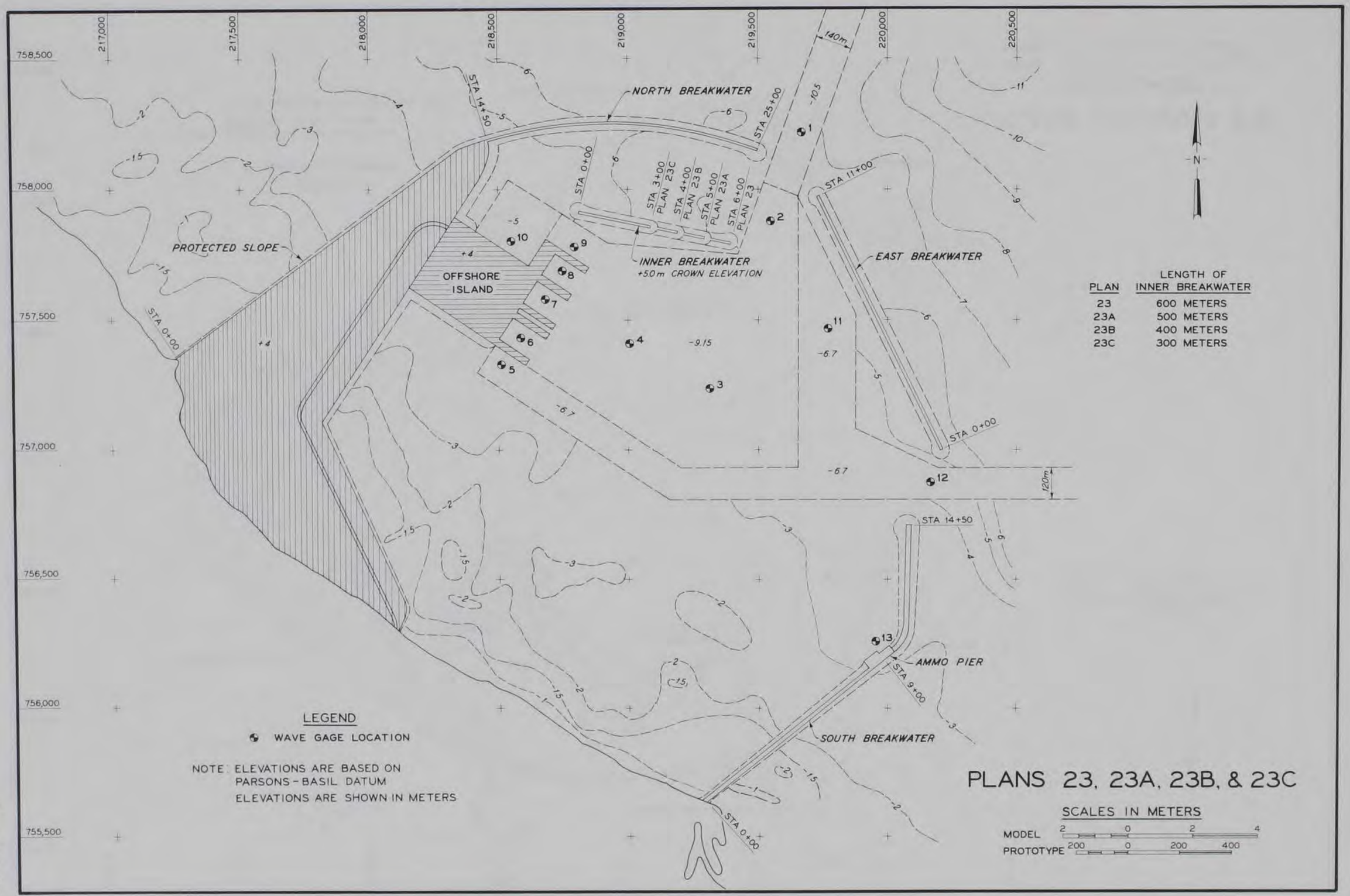
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 22 & 22A

SCALES IN METERS

MODEL 2 0 2 4

PROTOTYPE 200 0 200 400



PLAN	LENGTH OF INNER BREAKWATER
23	600 METERS
23A	500 METERS
23B	400 METERS
23C	300 METERS

LEGEND

WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 23, 23A, 23B, & 23C

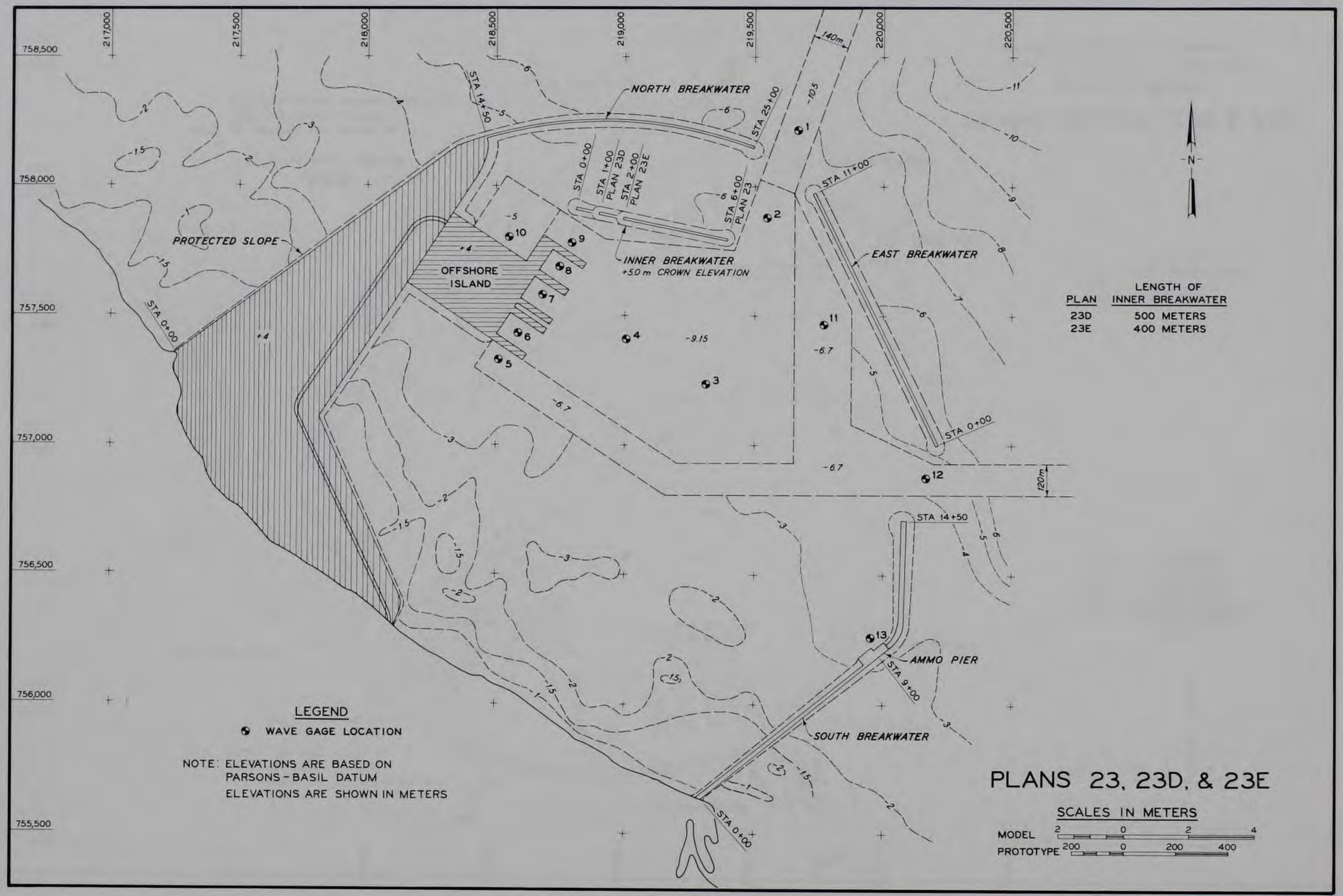
SCALES IN METERS

MODEL 2 0 2 4

PROTOTYPE 200 0 200 400

PLATE 25

PLATE 26



PLAN	LENGTH OF INNER BREAKWATER
23D	500 METERS
23E	400 METERS

LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 23, 23D, & 23E

SCALES IN METERS

MODEL 2 0 2 4

PROTOTYPE 200 0 200 400

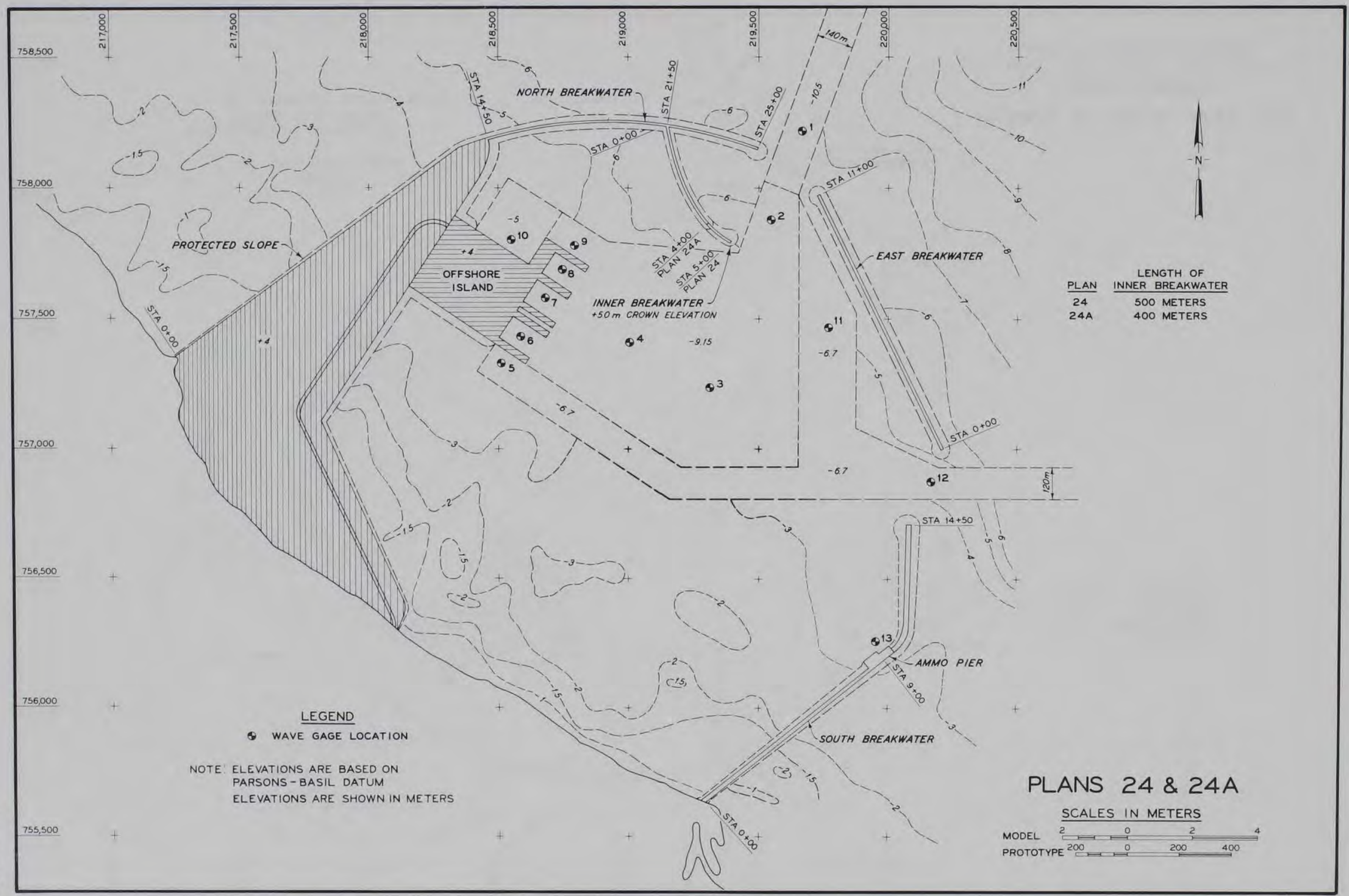
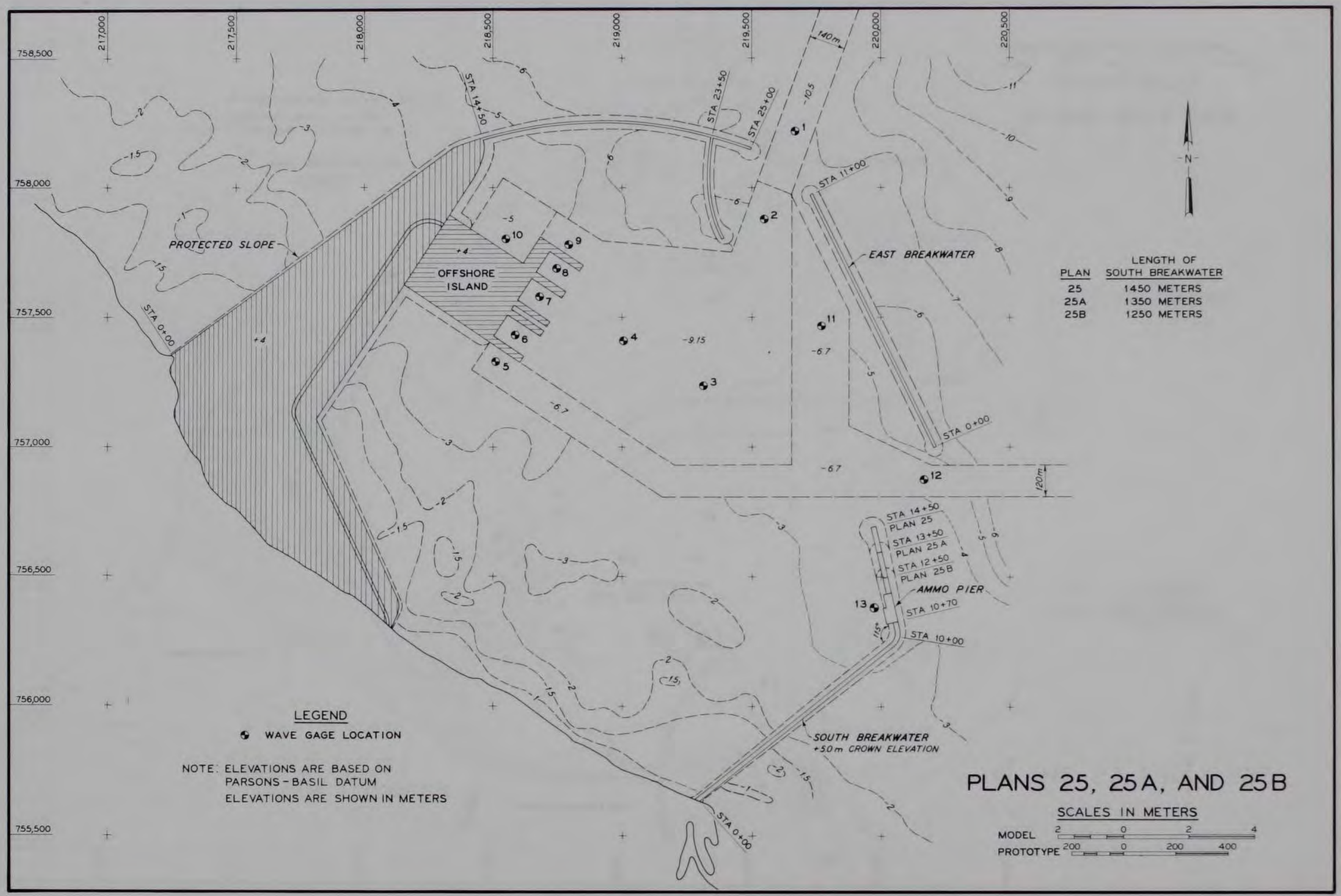

217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
758,500
758,000
757,500
757,000
756,500
756,000
755,500
NORTH BREAKWATER
STA 14+50
STA 21+50
STA 25+00
STA 0+00
140m
STA 11+00
EAST BREAKWATER
PROTECTED SLOPE
OFFSHORE ISLAND
INNER BREAKWATER
+50 m CROWN ELEVATION
STA 4+00 PLAN 24A
STA 5+00 PLAN 24
-9.15
-6.7
120m
STA 14+50
AMMO PIER
STA 9+00
SOUTH BREAKWATER
STA 0+00
N
PLAN
LENGTH OF INNER BREAKWATER
24
500 METERS
24A
400 METERS
LEGEND
WAVE GAGE LOCATION
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
PLANS 24 & 24A
SCALES IN METERS
MODEL 2 0 2 4
PROTOTYPE 200 0 200 400

PLATE 27

PLATE 28


758,500
758,000
757,500
757,000
756,500
756,000
755,500
217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
STA 14+50
STA 23+50
STA 25+00
140m
STA 11+00
PROTECTED SLOPE
OFFSHORE ISLAND
EAST BREAKWATER
STA 0+00
120m
STA 14+50 PLAN 25
STA 13+50 PLAN 25A
STA 12+50 PLAN 25B
AMMO PIER
STA 10+70
STA 10+00
SOUTH BREAKWATER
+5.0m CROWN ELEVATION
N
LEGEND
WAVE GAGE LOCATION
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
PLAN | LENGTH OF SOUTH BREAKWATER
25 | 1450 METERS
25A | 1350 METERS
25B | 1250 METERS
PLANS 25, 25A, AND 25B
SCALES IN METERS
MODEL 2 0 2 4
PROTOTYPE 200 0 200 400

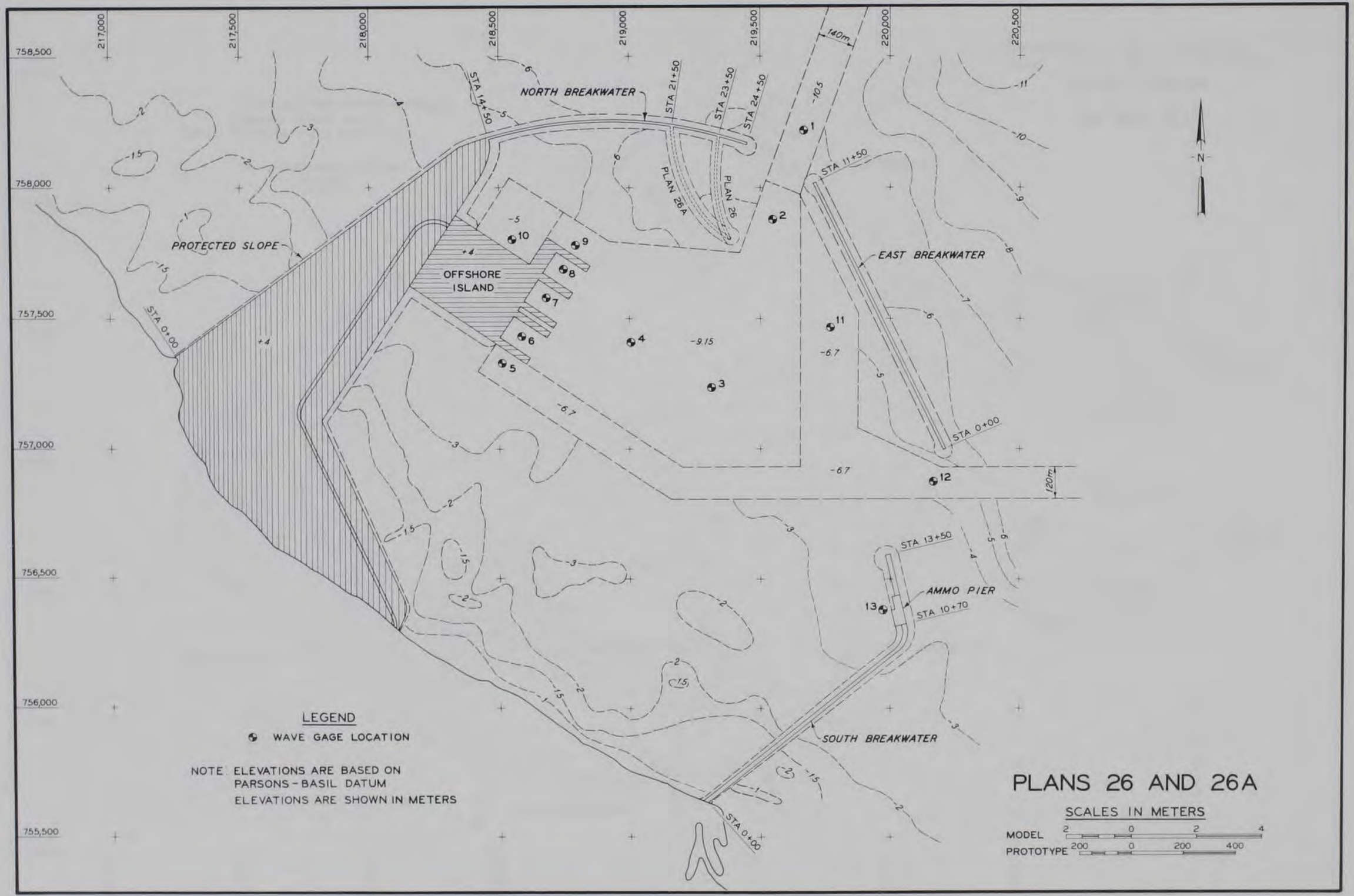
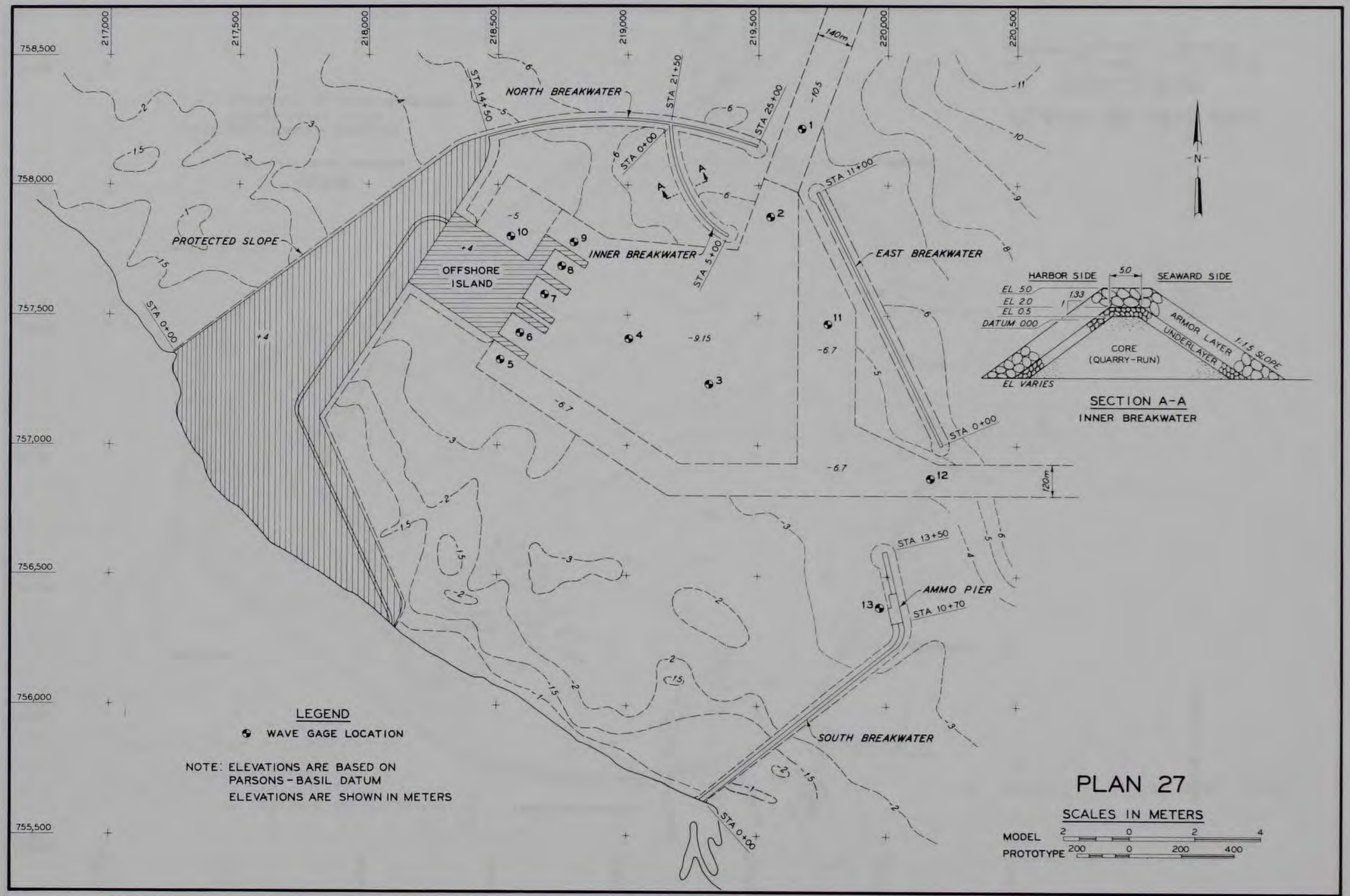

217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
758,500
758,000
757,500
757,000
756,500
756,000
755,500
NORTH BREAKWATER
STA 14+50
STA 21+50
STA 23+50
STA 24+50
PLAN 26A
PLAN 26
140m
STA 11+50
EAST BREAKWATER
PROTECTED SLOPE
OFFSHORE ISLAND
STA 0+00
STA 0+00
120m
STA 13+50
AMMO PIER
STA 10+70
SOUTH BREAKWATER
STA 0+00
N
1
2
3
4
5
6
7
8
9
10
11
12
13
-10.5
-9.15
-6.7
-6.7
LEGEND
WAVE GAGE LOCATION
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
PLANS 26 AND 26A
SCALES IN METERS
MODEL 2 0 2 4
PROTOTYPE 200 0 200 400

PLATE 29

PLATE 30



SECTION A-A
INNER BREAKWATER

LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLAN 27

SCALES IN METERS

MODEL 2 0 2 4
PROTOTYPE 200 0 200 400

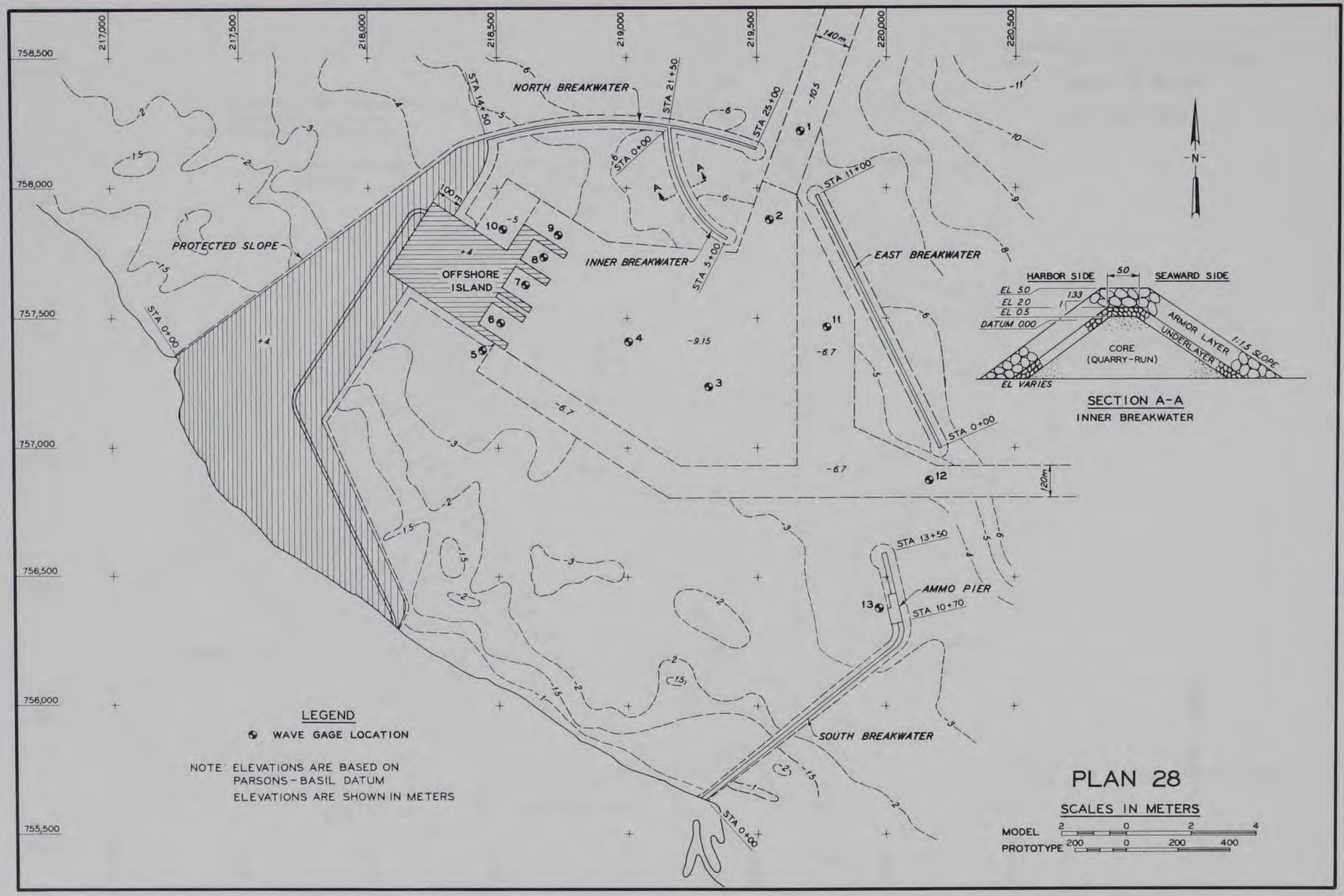
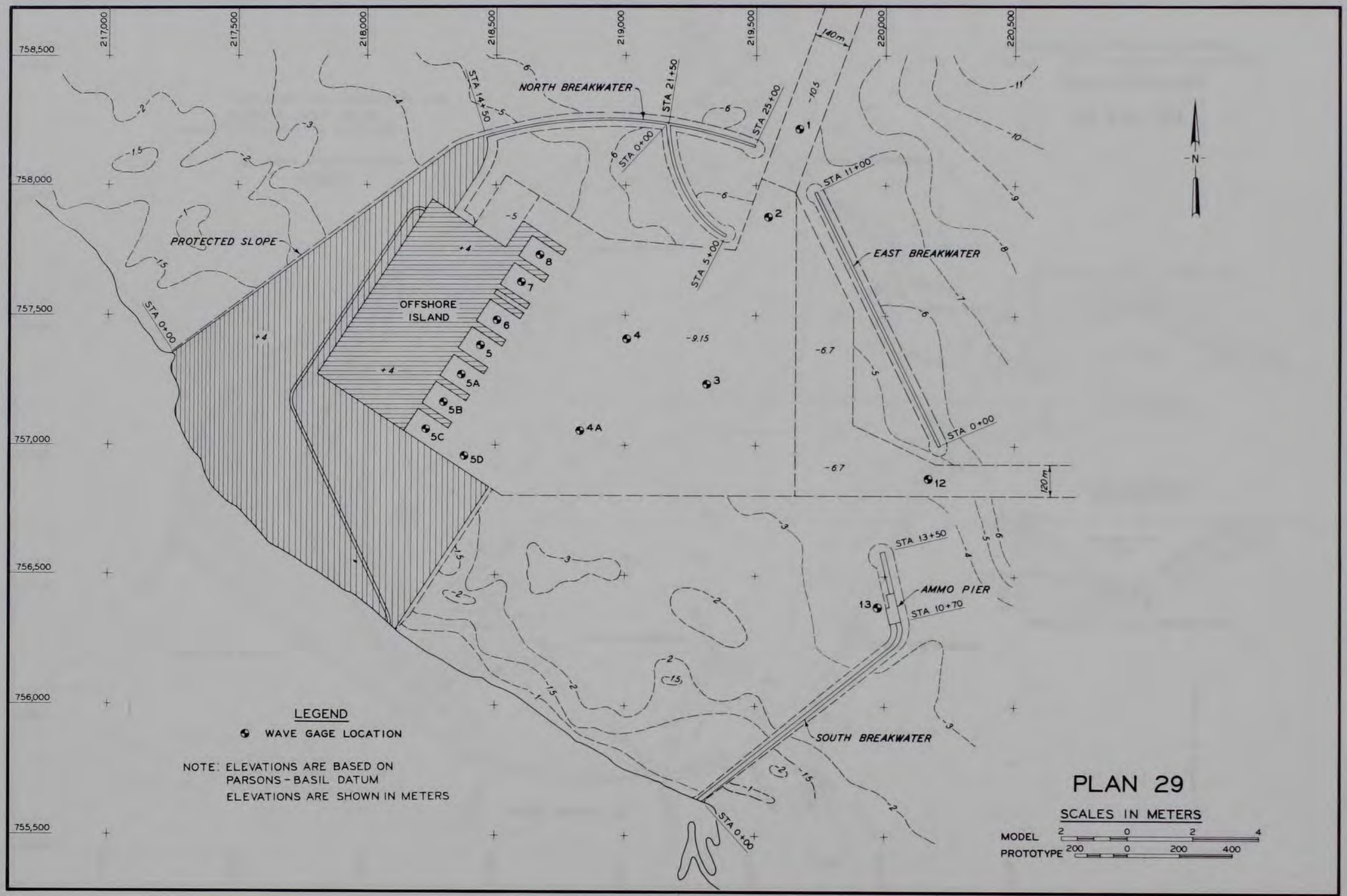

NORTH BREAKWATER
INNER BREAKWATER
EAST BREAKWATER
SOUTH BREAKWATER
PROTECTED SLOPE
OFFSHORE ISLAND
AMMO PIER
STA 14+50
STA 21+50
STA 25+00
STA 0+00
STA 5+00
STA 11+00
STA 13+50
STA 10+70
140m
120m
100m
N
HARBOR SIDE
SEAWARD SIDE
EL 5.0
EL 2.0
EL 0.5
DATUM 0.00
ARMOR LAYER
UNDERLAYER
1:1.5 SLOPE
CORE (QUARRY-RUN)
EL VARIES
SECTION A-A
INNER BREAKWATER
LEGEND
WAVE GAGE LOCATION
NOTE: ELEVATIONS ARE BASED ON PARSONS-BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
PLAN 28
SCALES IN METERS
MODEL
PROTOTYPE

PLATE 31

PLATE 32



LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLAN 29

SCALES IN METERS

MODEL 2 0 2 4

PROTOTYPE 200 0 200 400

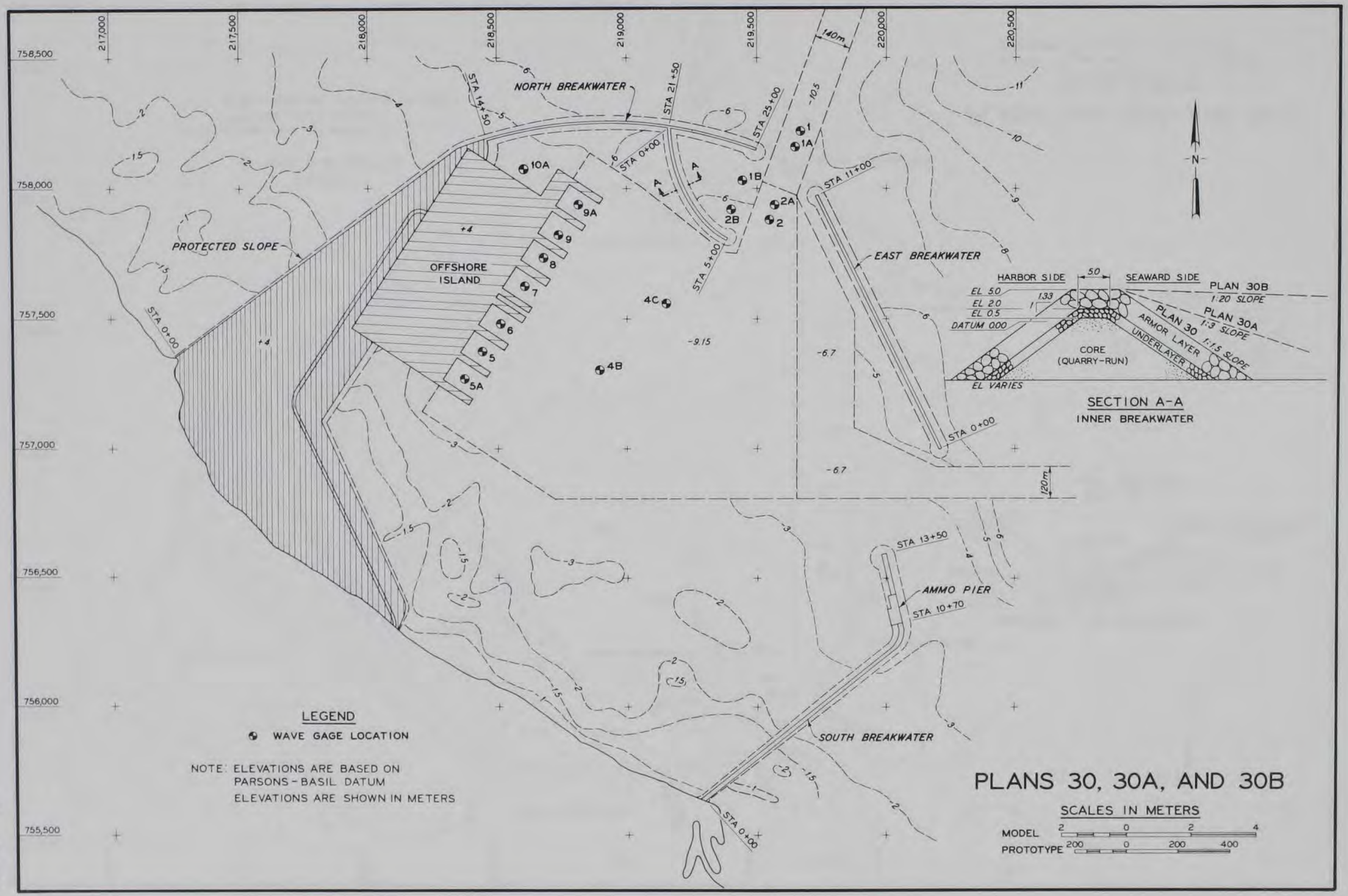
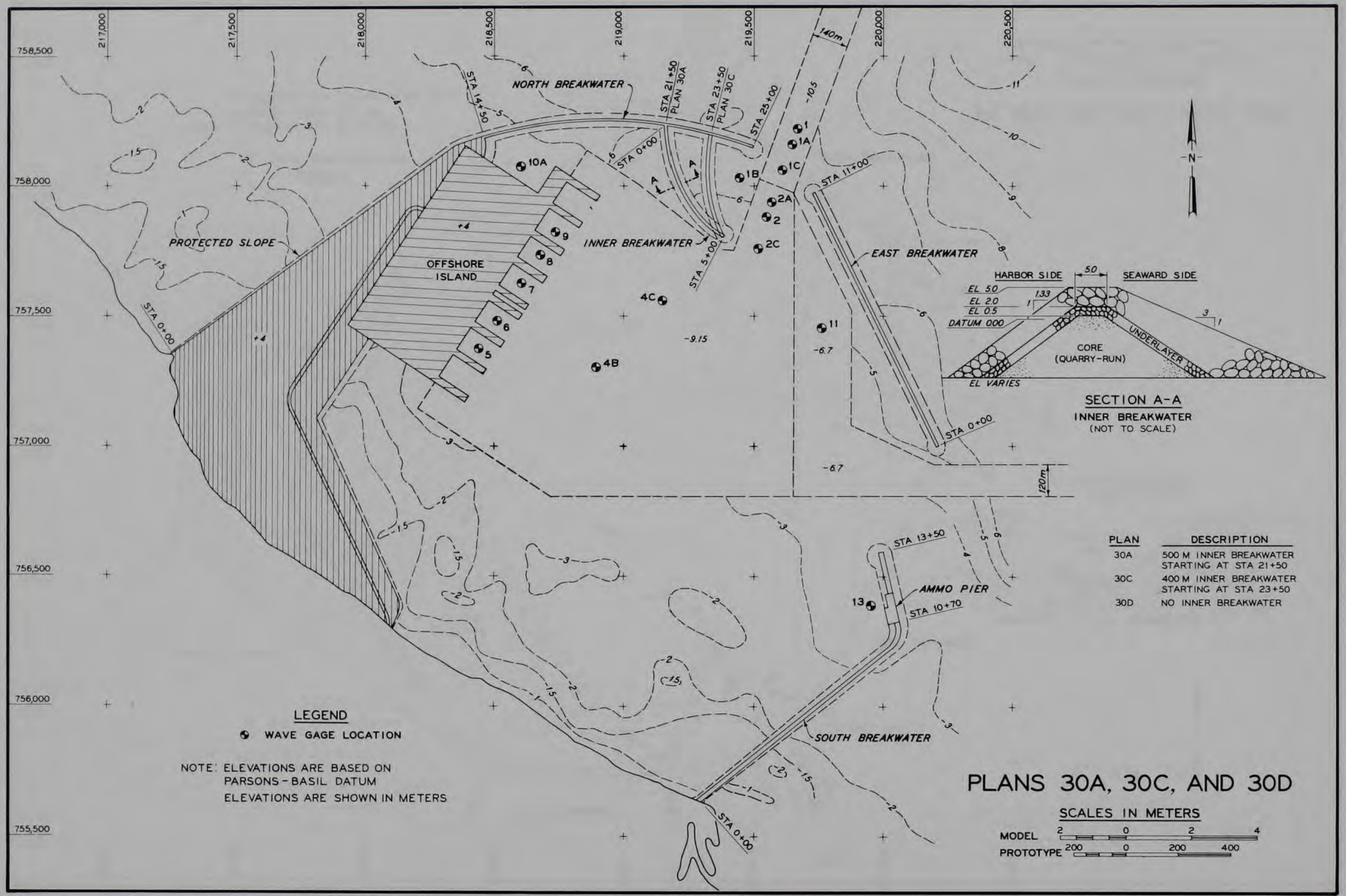

758,500
758,000
757,500
757,000
756,500
756,000
755,500
217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
NORTH BREAKWATER
STA 14+50
STA 21+50
STA 25+00
STA 0+00
STA 11+00
STA 5+00
EAST BREAKWATER
140m
PROTECTED SLOPE
OFFSHORE ISLAND
+4
-9.15
-6.7
-10.5
1
1A
1B
2
2A
2B
4B
4C
5
5A
6
7
8
9
9A
10A
N
HARBOR SIDE
5.0
SEAWARD SIDE
EL 5.0
EL 2.0
EL 0.5
DATUM 0.00
1.33
1
PLAN 30B
1:20 SLOPE
PLAN 30A
1:3 SLOPE
PLAN 30 1:15 SLOPE
ARMOR LAYER
UNDERLAYER
CORE
(QUARRY-RUN)
EL VARIES
SECTION A-A
INNER BREAKWATER
120m
STA 13+50
AMMO PIER
STA 10+70
SOUTH BREAKWATER
STA 0+00
LEGEND
WAVE GAGE LOCATION
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
PLANS 30, 30A, AND 30B
SCALES IN METERS
MODEL 2 0 2 4
PROTOTYPE 200 0 200 400

PLATE 33

PLATE 34



SECTION A-A
INNER BREAKWATER
(NOT TO SCALE)

PLAN	DESCRIPTION
30A	500 M INNER BREAKWATER STARTING AT STA 21+50
30C	400 M INNER BREAKWATER STARTING AT STA 23+50
30D	NO INNER BREAKWATER

LEGEND

● WAVE GAGE LOCATION

NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS

PLANS 30A, 30C, AND 30D

SCALES IN METERS

MODEL 2 0 2 4

PROTOTYPE 200 0 200 400

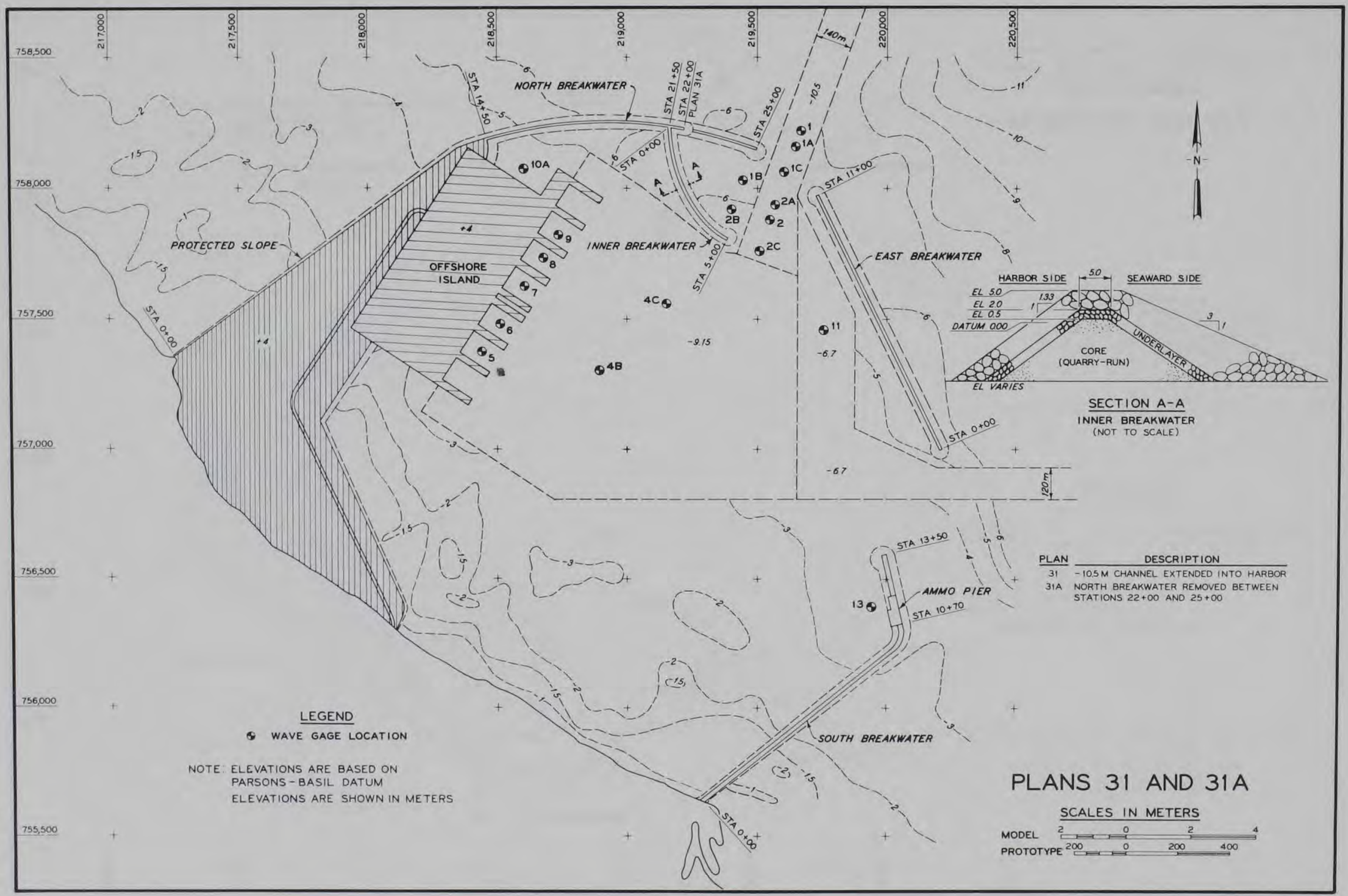
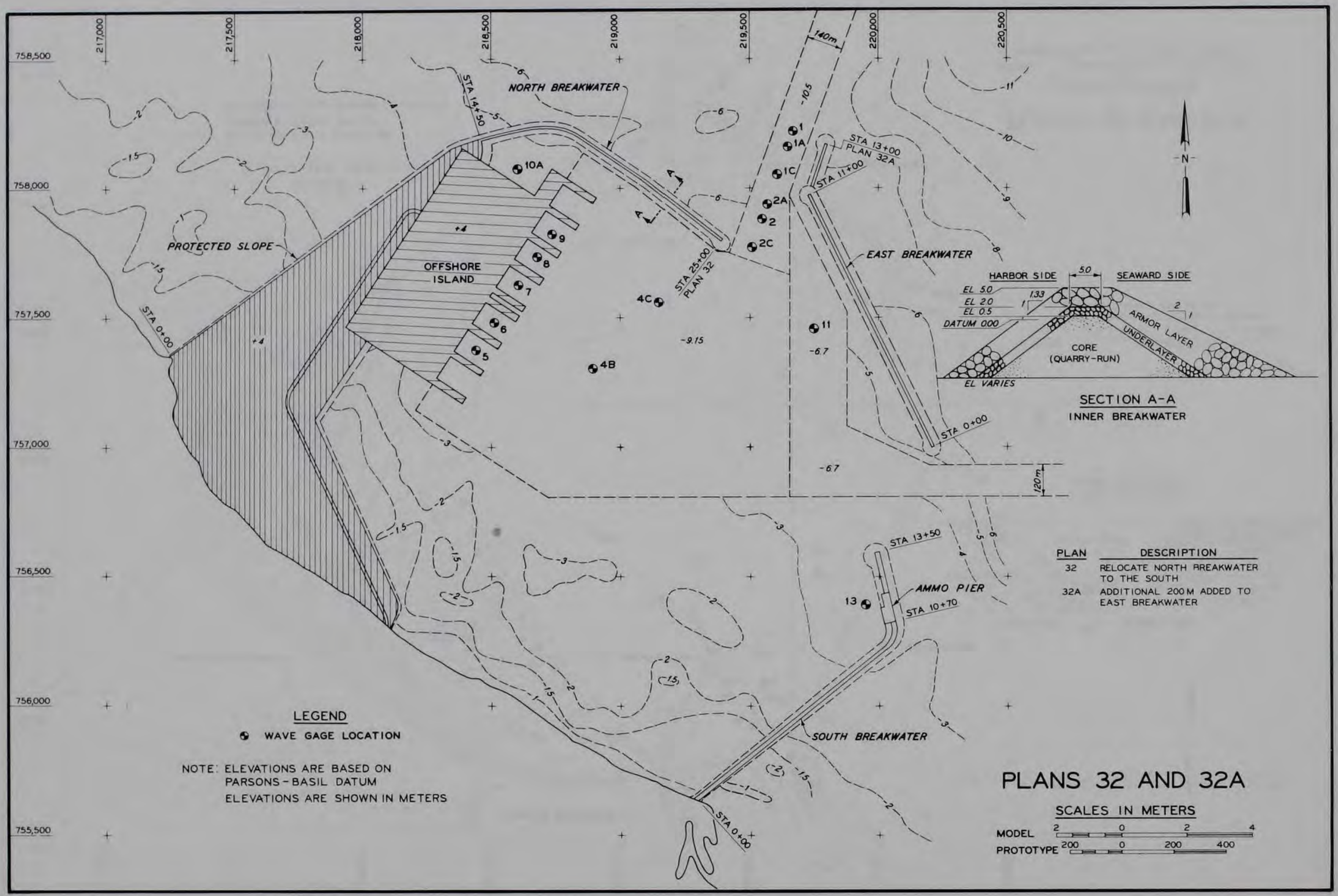

217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
758,500
758,000
757,500
757,000
756,500
756,000
755,500
NORTH BREAKWATER
STA 14+50
STA 21+50
STA 22+00
PLAN 31A
STA 25+00
140m
-10.5
STA 0+00
STA 11+00
INNER BREAKWATER
STA 5+00
EAST BREAKWATER
PROTECTED SLOPE
OFFSHORE ISLAND
+4
-9.15
-6.7
10A
1
1A
1B
1C
2A
2B
2
2C
4C
4B
11
5
6
7
8
9
N
HARBOR SIDE
5.0
SEAWARD SIDE
EL 5.0
EL 2.0
EL 0.5
DATUM 000
1.33
1
3
1
CORE
(QUARRY-RUN)
UNDERLAYER
EL VARIES
SECTION A-A
INNER BREAKWATER
(NOT TO SCALE)
120m
STA 13+50
AMMO PIER
STA 10+70
13
SOUTH BREAKWATER
LEGEND
WAVE GAGE LOCATION
NOTE: ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
PLAN
DESCRIPTION
31
-10.5 M CHANNEL EXTENDED INTO HARBOR
31A
NORTH BREAKWATER REMOVED BETWEEN STATIONS 22+00 AND 25+00
PLANS 31 AND 31A
SCALES IN METERS
MODEL
2
0
2
4
PROTOTYPE
200
0
200
400

PLATE 35

PLATE 36


758,500
758,000
757,500
757,000
756,500
756,000
755,500
217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
NORTH BREAKWATER
EAST BREAKWATER
SOUTH BREAKWATER
PROTECTED SLOPE
OFFSHORE ISLAND
AMMO PIER
STA 14+50
STA 0+00
STA 25+00 PLAN 32
STA 13+00 PLAN 32A
STA 11+00
STA 0+00
STA 13+50
STA 10+70
STA 0+00
140m
120m
1
1A
1C
2A
2
2C
4B
4C
5
6
7
8
9
10A
11
13
HARBOR SIDE
SEAWARD SIDE
EL 5.0
EL 2.0
EL 0.5
DATUM 000
EL VARIES
ARMOR LAYER
UNDERLAYER
CORE
(QUARRY-RUN)
SECTION A-A
INNER BREAKWATER
N
LEGEND
WAVE GAGE LOCATION
NOTE: ELEVATIONS ARE BASED ON PARSONS-BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
PLAN
DESCRIPTION
32 RELOCATE NORTH BREAKWATER TO THE SOUTH
32A ADDITIONAL 200 M ADDED TO EAST BREAKWATER
PLANS 32 AND 32A
SCALES IN METERS
MODEL 2 0 2 4
PROTOTYPE 200 0 200 400

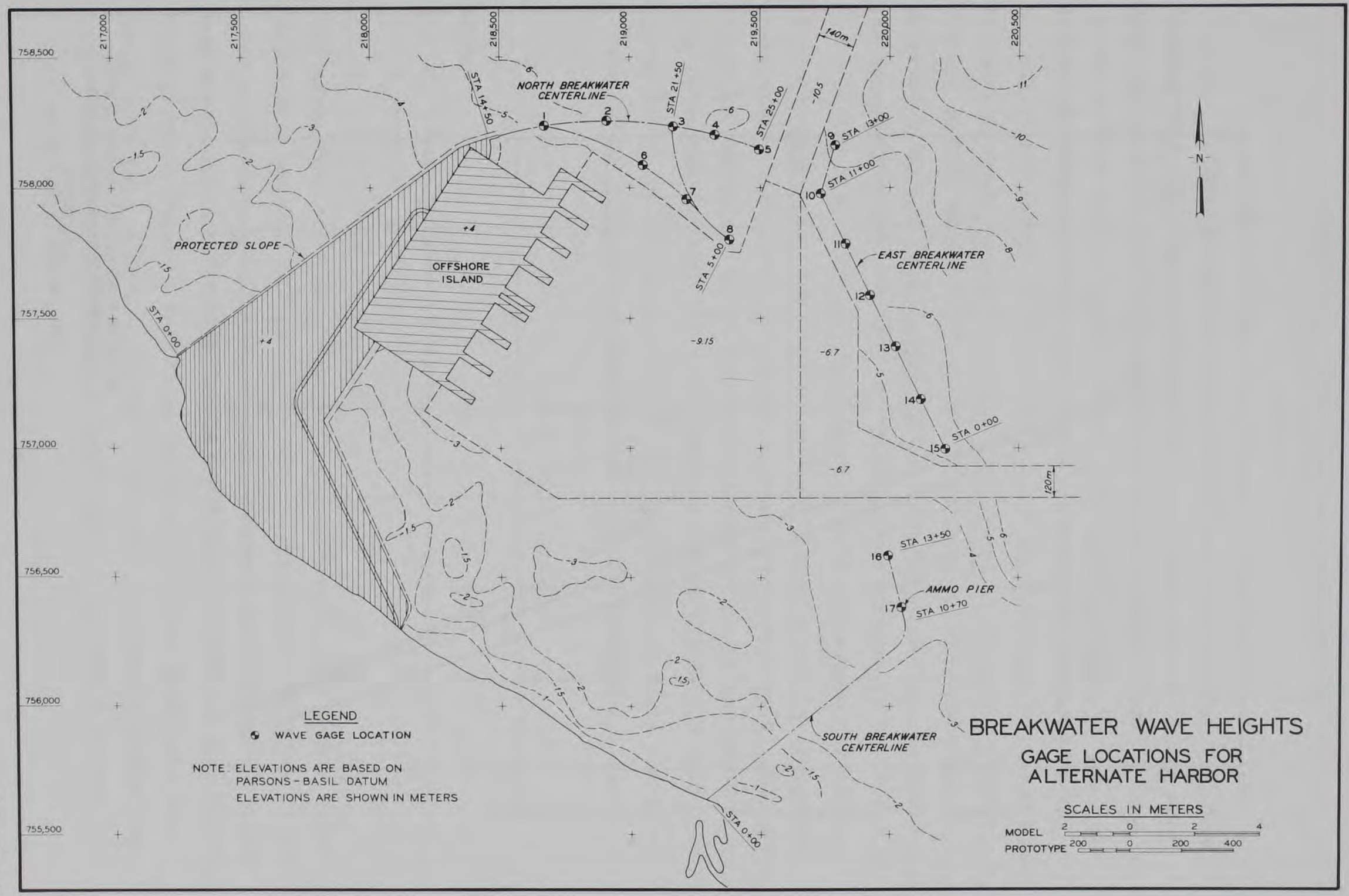
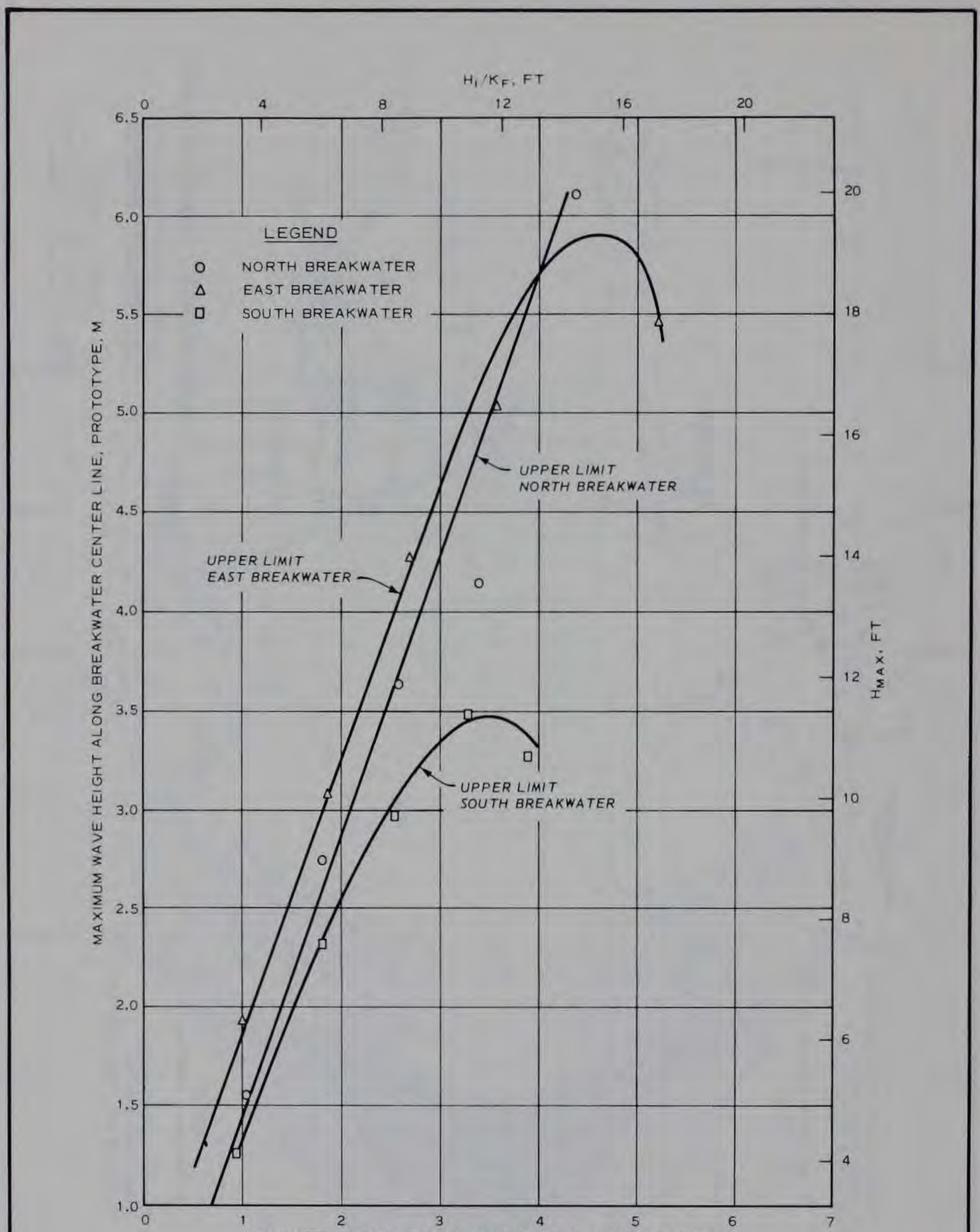

217,000
217,500
218,000
218,500
219,000
219,500
220,000
220,500
758,500
758,000
757,500
757,000
756,500
756,000
755,500
NORTH BREAKWATER CENTERLINE
STA 14+50
STA 21+50
STA 25+00
STA 5+00
STA 0+00
140m
PROTECTED SLOPE
OFFSHORE ISLAND
+4
-9.15
-10.5
STA 13+00
STA 11+00
EAST BREAKWATER CENTERLINE
-6.7
STA 0+00
120m
STA 13+50
AMMO PIER
STA 10+70
SOUTH BREAKWATER CENTERLINE
STA 0+00
N
LEGEND
WAVE GAGE LOCATION
NOTE. ELEVATIONS ARE BASED ON PARSONS - BASIL DATUM
ELEVATIONS ARE SHOWN IN METERS
BREAKWATER WAVE HEIGHTS
GAGE LOCATIONS FOR ALTERNATE HARBOR
SCALES IN METERS
MODEL 2 0 2 4
PROTOTYPE 200 0 200 400

PLATE 37



MAXIMUM WAVE HEIGHTS ALONG CENTER LINE OF PROPOSED BREAKWATERS

9 - SEC WAVES
STILL-WATER LEVEL = +2.35m

PLATE 38

APPENDIX A: WAVE REFRACTION ANALYSIS FOR JUBAIL HARBOR LOCATION

1. During the course of the Jubail Model Study, the U. S. Army Engineer Division, Mediterranean (MDD), indicated that a 12.2-m wave might be possible from directions of north clockwise to east-southeast in the Arabian Gulf. A wave refraction analysis, therefore, was conducted to determine the maximum wave possible at the model site for 7-, 9-, and 11-sec waves. This analysis was conducted using a linear wave refraction theory program originally developed at Stanford University by Dobson[6] in 1967 and modified by the U. S. Army Engineer Waterways Experiment Station (WES). All computations and plotting were done using the Honeywell GE 635 computer and Calcomp drum plotter at WES.

2. In this analysis the effects of both reflection and diffraction are neglected. These assumptions are valid except in convergence areas where caustics occur and linear theory does not apply. Therefore, the major assumption in determining the wave height at any point on a wave orthogonal, within the limits of the linear theory, is that no energy is transmitted perpendicular to the orthogonal along the wave crest, in which case the height at any point is given by:

$$H = H_o K_s K_r$$

where

H_o = wave height in deep water

K_s = shoaling coefficient

K_r = refraction coefficient

This assumption has been shown to be reasonable for mild slopes which induce only gradual bending of the wave orthogonals. For areas of extreme refraction, the failure to consider the flow of energy along the wave crests can lead to significant errors in the computed wave height. Since previous research at WES by Whalin (1971)[7] has shown that wave energy will tend to flow along the wave crest in areas of energy concentration, a maximum refraction coefficient of 1.4 and a minimum

refraction coefficient of 0.15 were selected as reasonable values.

3. All wave orthogonals were produced using a grid spacing of 1.89 km bounded by latitudes 26°35' and 28°00' and by longitudes 49°30' and 51°00'. Depths were taken from the latest available hydrographic survey maps (scale 1:150,000). The grid spacing was refined to 0.94 km near the harbor site. Storm tide conditions were represented by superimposing a mean water level of 2.35 m on the depth grid.

4. Wave orthogonals were started in a water depth of approximately 73.1 m (considered to be deep water) for deepwater directions from north clockwise to east-southeast. Wave periods of 7, 9, and 11 sec were used for each direction. In addition, a 7-sec locally generated wave front from the north was started at Ra's Abu Ali and refracted to the proposed harbor site.

5. Plates A1-A12 show 9-sec wave rays (wave orthogonals) for deepwater directions from north to east-southeast and are considered representative of the various plots obtained. Refraction coefficients and shallow-water wave front directions obtained for three periods and 12 deepwater wave directions are presented in Table A1. These values represent an average of the orthogonals in the immediate vicinity of the harbor site (approximately the location of the wave generator in the model). Shoaling coefficients of 0.98, 0.94, and 0.91 for 7, 9, and 11 sec, respectively, were computed for a 32.85-m water depth corresponding to the simulated depth at the model wave generator. The wave-height adjustment factor is obtained by multiplying K_r by K_s and can be applied to any deepwater wave height to obtain the corresponding shallow-water value.

6. It was found that deepwater waves approaching from the north diverge or break on the shoals in the vicinity of Abu Ali resulting in a net divergence of energy at the harbor site. The maximum refraction coefficient from north (0.46) was obtained for the waves generated locally between Abu Ali and the harbor site. Refraction coefficients for waves approaching from deepwater directions between N 16.8° E and N 73.1° E vary from 0.71 to 1.25 for 7 sec, 0.30 to 1.15 for 9 sec, and 0.43 to 1.09 for 11 sec. The energy concentrations were due to the general

shape of the contours and the shoals seaward of the harbor. Due to the numerous shoals located to the east and east-southeast, wave energy from these deepwater directions is significantly reduced at the harbor site for 9- and 11-sec waves. Maximum refraction coefficients of 1.15, 0.39, and 0.23 were obtained for 7, 9, and 11 sec, respectively.

7. Using wind data furnished by MDD and Bretschneider's revised deepwater forecasting curves,[8] the following deepwater wave heights were obtained:

Period Sec	H_{max} m	H_{10} m	H_s m
7	6.3	4.3	3.4
9	9.9	6.7	5.3
11	12.2	8.3	6.6

In addition, a locally generated significant wave of 7 sec, 3.4 m is possible between Abu Ali and the proposed harbor site (fetch = 28 km) for a wind of 50 knots (97 mps).

8. Table A2 presents the significant wave heights at the wave generator for the corresponding deepwater wave heights shown above. Three wave generator positions (refracted direction of 9-sec waves) were selected representing deepwater directions of north, northeast, and east-southeast.

9. The following tabulation shows the deepwater directions, selected shallow-water test directions, the refracted directions included within each test direction, and the largest significant wave from each test direction.

Deepwater Direction	Shallow-Water Test Direction deg (radians)	Refracted Directions Included deg (radians)	Period sec	Largest H_s m
North	14.67 (0.26)	10.3-30 (0.18-0.53)	7	2.6
			9	4.8
			11	5.0
Northeast	45.0 (0.79)	30.0-55 (0.53-0.96)	7	3.4
			9	5.7
			11	5.0
East-southeast	64.20 (1.12)	55.0-91.4 (0.96-1.60)	7	4.2
			9	4.7
			11	6.5

Table A1

Summary of Refraction and Shoaling Analysis for Mediterranean Division Harbor

Wave Period sec	Deepwater Azimuth deg	Shallow-Water Azimuth deg	Refraction Coefficient	Shoaling Coefficient*	Wave Height Adjustment Factor
7	0**	14.67	0.46	0.98	0.45
7	0	19.47	0.21	0.98	0.21
9	0	10.32	0.20	0.94	0.19
11	0	35.51	0.17	0.91	0.15
7	16.875	14.68	0.79	0.98	0.77
9	16.875	22.62	0.30	0.94	0.28
11	16.875	26.92	0.78	0.91	0.71
7	22.5	24.54	0.71	0.98	0.70
9	22.5	35.83	0.96	0.94	0.90
11	22.5	17.91	0.84	0.91	0.76
7	28.125	33.57	0.84	0.98	0.82
9	28.125	28.28	0.97	0.94	0.91
11	28.125	30.17	0.52	0.91	0.47
7	39.375	35.63	1.00	0.98	0.98
9	39.375	35.67	1.15	0.94	1.08
11	39.375	40.22	0.43	0.91	0.39
7	45.0	41.96	0.93	0.98	0.91
9	45.0	40.70	0.65	0.94	0.61
11	45.0	40.78	0.83	0.91	0.76
7	50.625	46.77	1.04	0.98	1.02
9	50.625	46.36	0.92	0.94	0.86
11	50.625	43.57	0.70	0.91	0.64
7	61.875	56.64	0.94	0.98	0.92
9	61.875	51.79	1.01	0.94	0.95
11	61.875	50.51	0.78	0.91	0.71
7	67.5	64.55	0.98	0.98	0.96
9	67.5	56.42	0.90	0.94	0.85
11	67.5	66.40	0.57	0.91	0.52

(Continued)

* Shoaling coefficient at wave generator position (-30.5 m contour plus 2.35 m swl = 32.85 m water depth).

** Locally generated waves.

Table A1 (Concluded)

Wave Period sec	Deepwater Azimuth deg	Shallow-Water Azimuth deg	Refraction Coefficient	Shoaling Coefficient	Wave Height Adjustment Factor
7	73.125	69.26	1.25	0.98	1.23
9	73.125	79.80	0.94	0.94	0.88
11	73.125	83.22	1.09	0.91	0.99
7	90.0	66.91	1.15	0.98	1.13
9	90.0	49.97	0.22	0.94	0.21
11	90.0	44.19	0.22	0.91	0.20
7	112.5	91.43	9.90	0.98	0.88
9	112.5	64.20	0.39	0.94	0.37
11	112.5	61.22	0.23	0.91	0.21

Table A2

Model Study of Mediterranean Division Harbor Significant Wave Heights at the Wave Generator

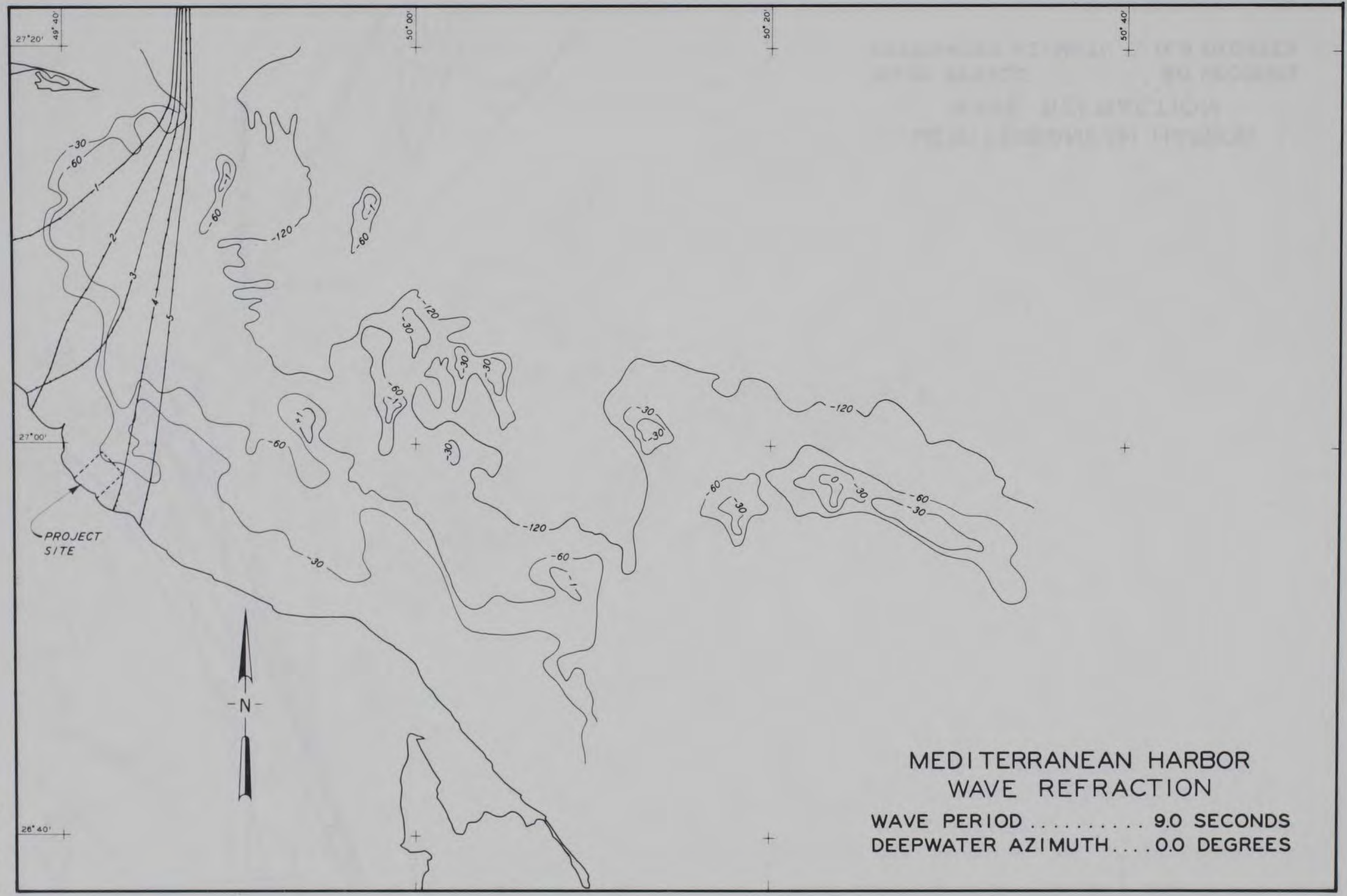
Wave Period sec	Deepwater Azimuth deg	Shallow-Water Azimuth deg	Wave Height Adjustment Factor	Deepwater H_s, m	H_s at Wave Generator, m
7	0*	14.67	0.45	3.4	1.5
7	0	19.47	0.21	3.4	0.7
9	0	10.32	0.19	5.3	1.0
11	0	35.51	0.15	6.6	1.0
7	16.875	14.68	0.77	3.4	2.6
9	16.875	22.62	0.28	5.3	1.5
11	16.875	26.92	0.71	6.6	4.7
7	22.5	24.54	0.70	3.4	2.4
9	22.5	35.83	9.90	5.3	4.8
11	22.5	17.91	0.76	6.6	5.0
7	28.125	33.57	0.82	3.4	2.8
9	28.125	28.28	0.91	5.3	4.8
11	28.125	30.17	0.47	6.6	3.1
7	39.375	35.63	0.98	3.4	3.3
9	39.375	35.67	1.08	5.3	5.7
11	39.375	40.22	0.39	6.6	2.6
7	45.0	41.96	0.91	3.4	3.1
9	45.0	40.70	0.61	5.3	3.2
11	45.0	40.78	0.76	6.6	5.0
7	50.625	46.77	1.02	3.4	3.4
9	50.625	46.36	0.86	5.3	4.6
11	50.625	43.57	0.64	6.6	4.2
7	61.875	56.64	0.92	3.4	3.1
9	61.875	51.79	0.95	5.3	5.0
11	61.875	50.51	0.71	6.6	4.7
7	67.5	64.55	0.96	3.4	3.3
9	67.5	56.42	0.85	5.3	4.5
11	67.5	66.40	0.52	6.6	3.4
7	73.125	69.26	1.23	3.4	4.2
9	73.125	79.80	0.88	5.3	4.7
11	73.125	83.22	0.99	6.6	6.5

(Continued)

* Locally generated.

Table A2 (Concluded)

Wave Period sec	Deepwater Azimuth deg	Shallow-Water Azimuth deg	Wave Height Adjustment Factor	Deepwater H_s, m	H_s at Wave Generator, m
7	90.0	66.91	1.13	3.4	3.8
9	90.0	49.97	0.21	5.3	1.1
11	90.0	44.19	0.20	6.6	1.3
7	112.5	91.43	0.88	3.4	3.0
9	112.5	64.20	0.37	5.3	2.0
11	112.5	61.22	0.21	6.6	1.4

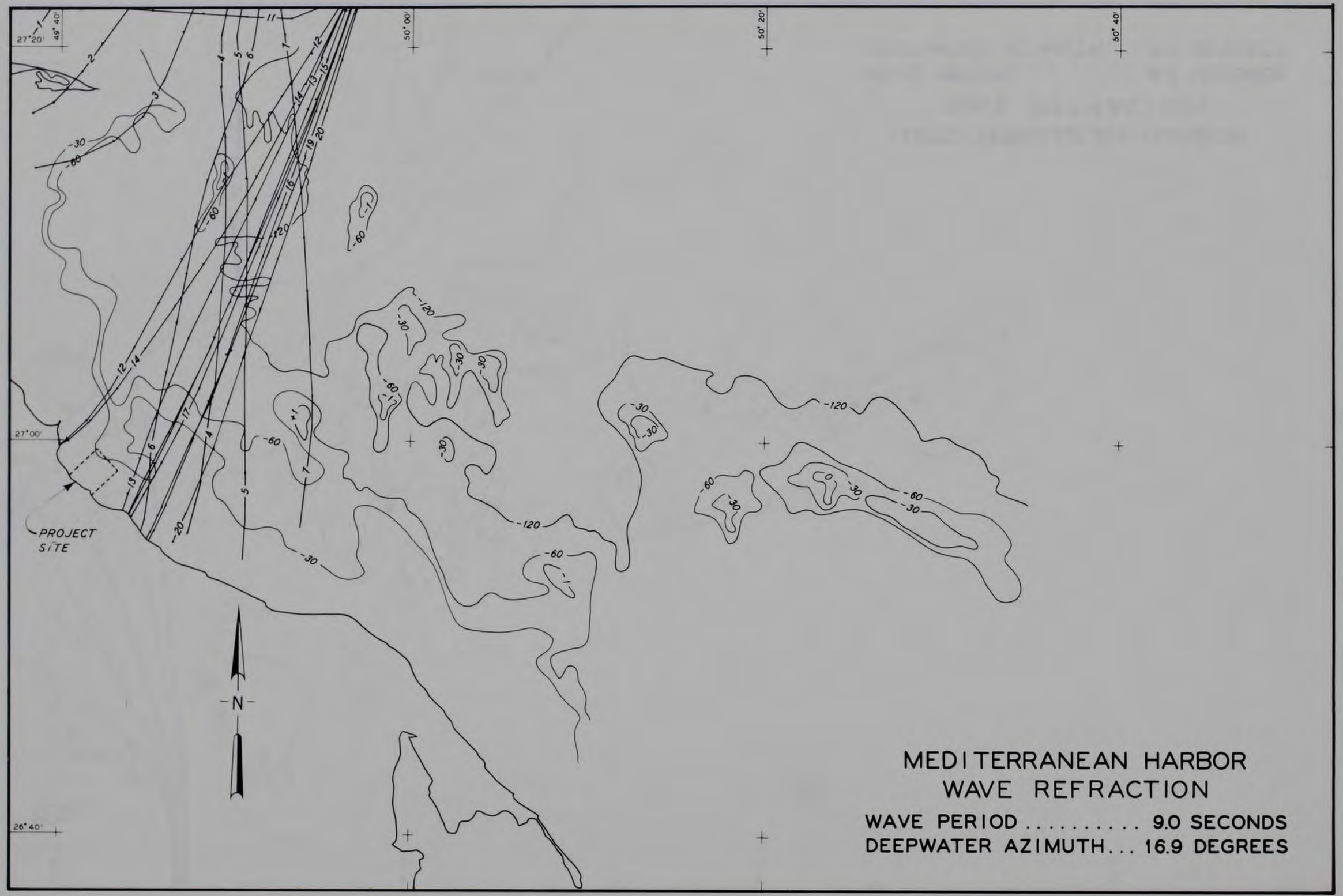


MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH....0.0 DEGREES

PLATE A1

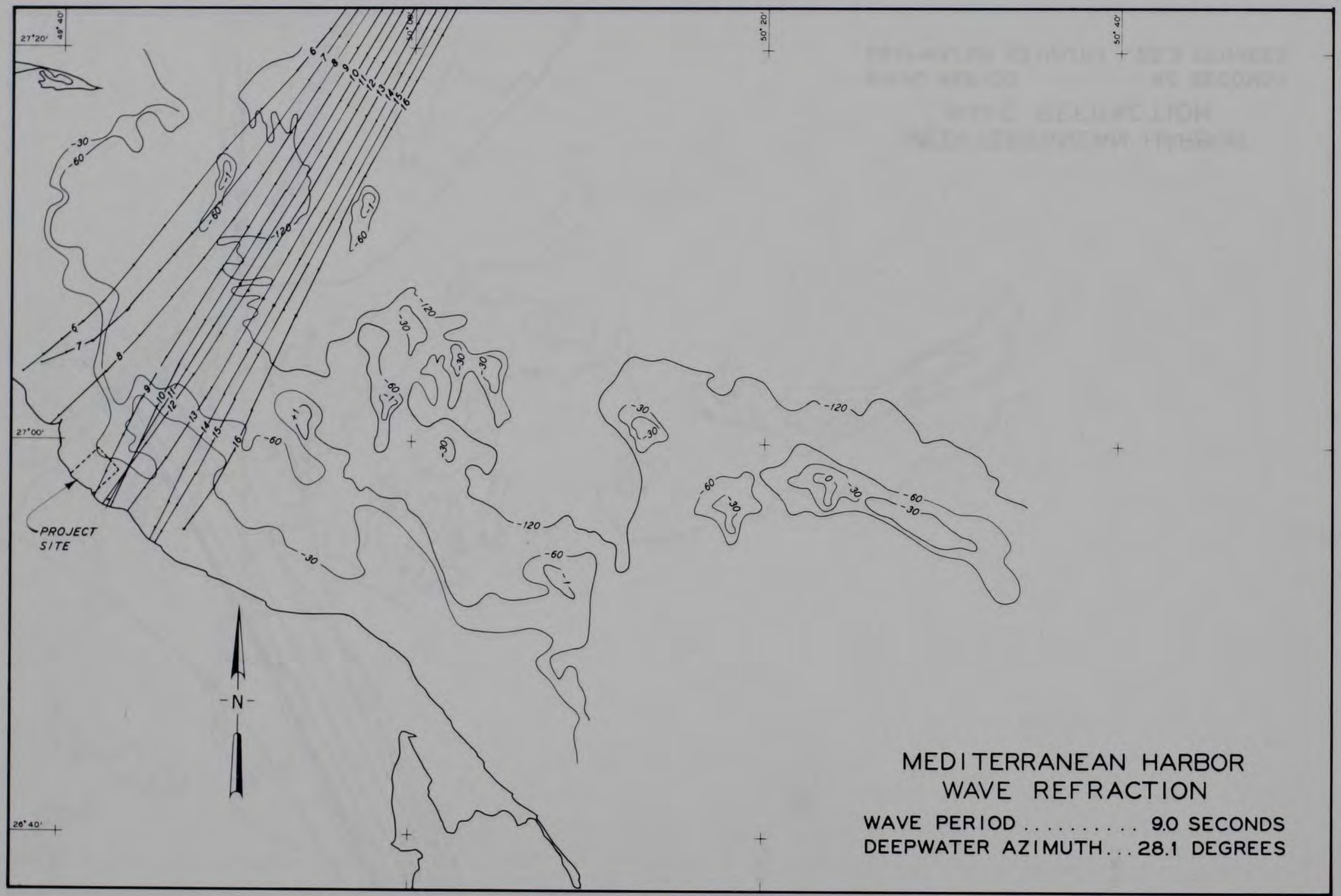
PLATE A2


27°20'
49° 40'
50° 00'
50° 20'
50° 40'
27°00'
26° 40'
PROJECT SITE
N
MEDITERRANEAN HARBOR
WAVE REFRACTION
WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 16.9 DEGREES

27°20'
49° 40'
50° 00'
50° 20'
50° 40'
27°00'
26°40'
PROJECT SITE
N
MEDITERRANEAN HARBOR
WAVE REFRACTION
WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH...22.5 DEGREES

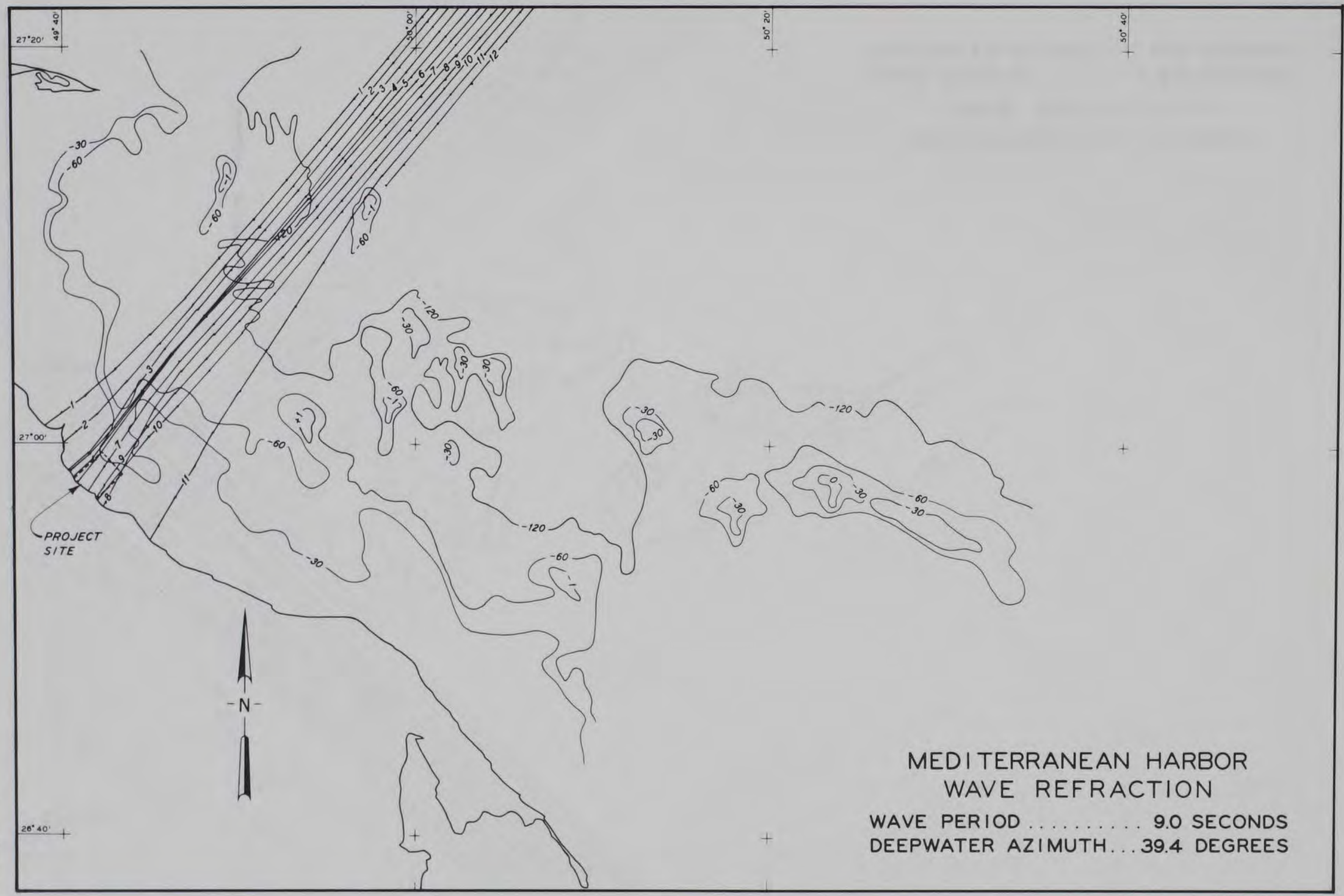
PLATE A3

PLATE A4



MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 28.1 DEGREES

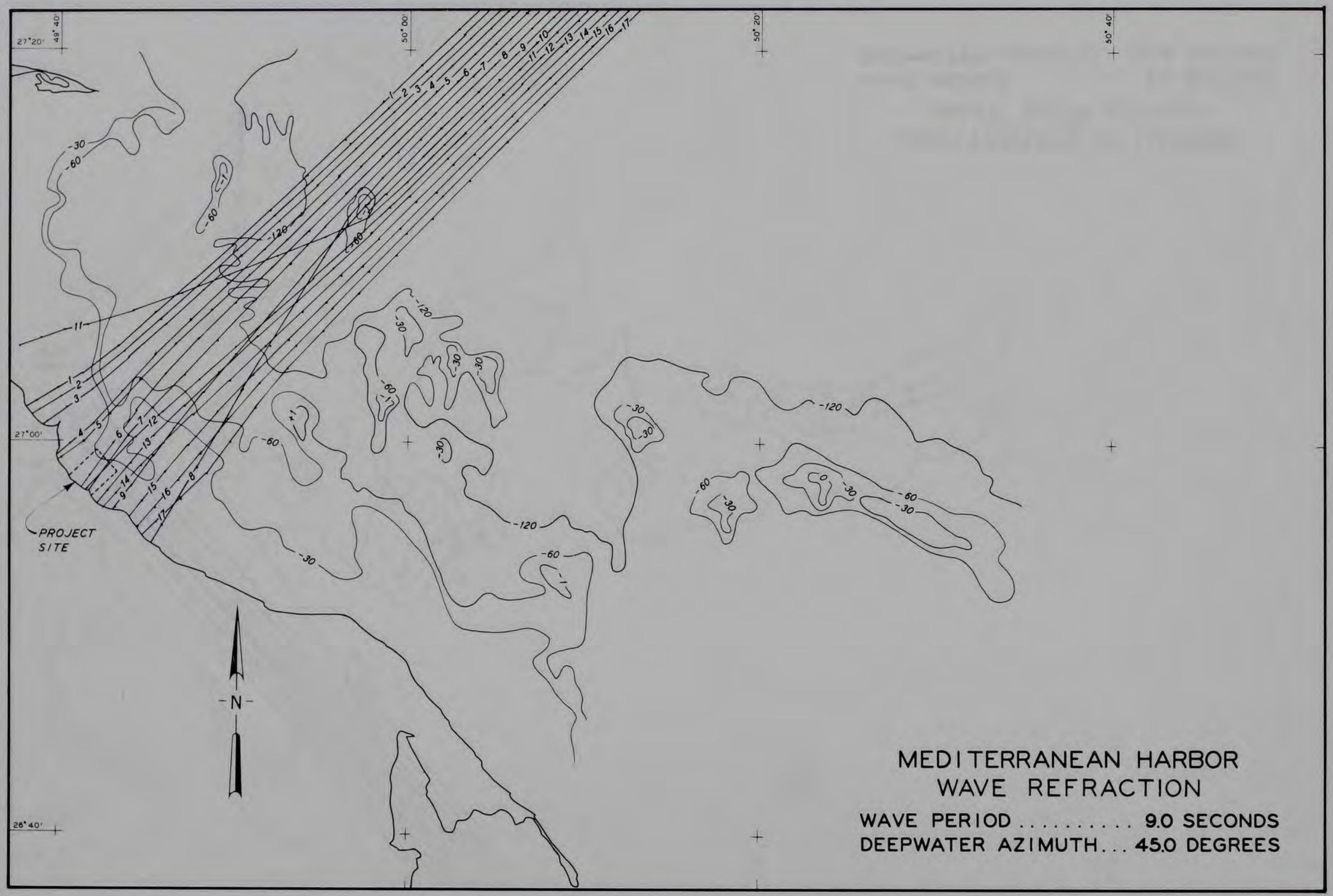


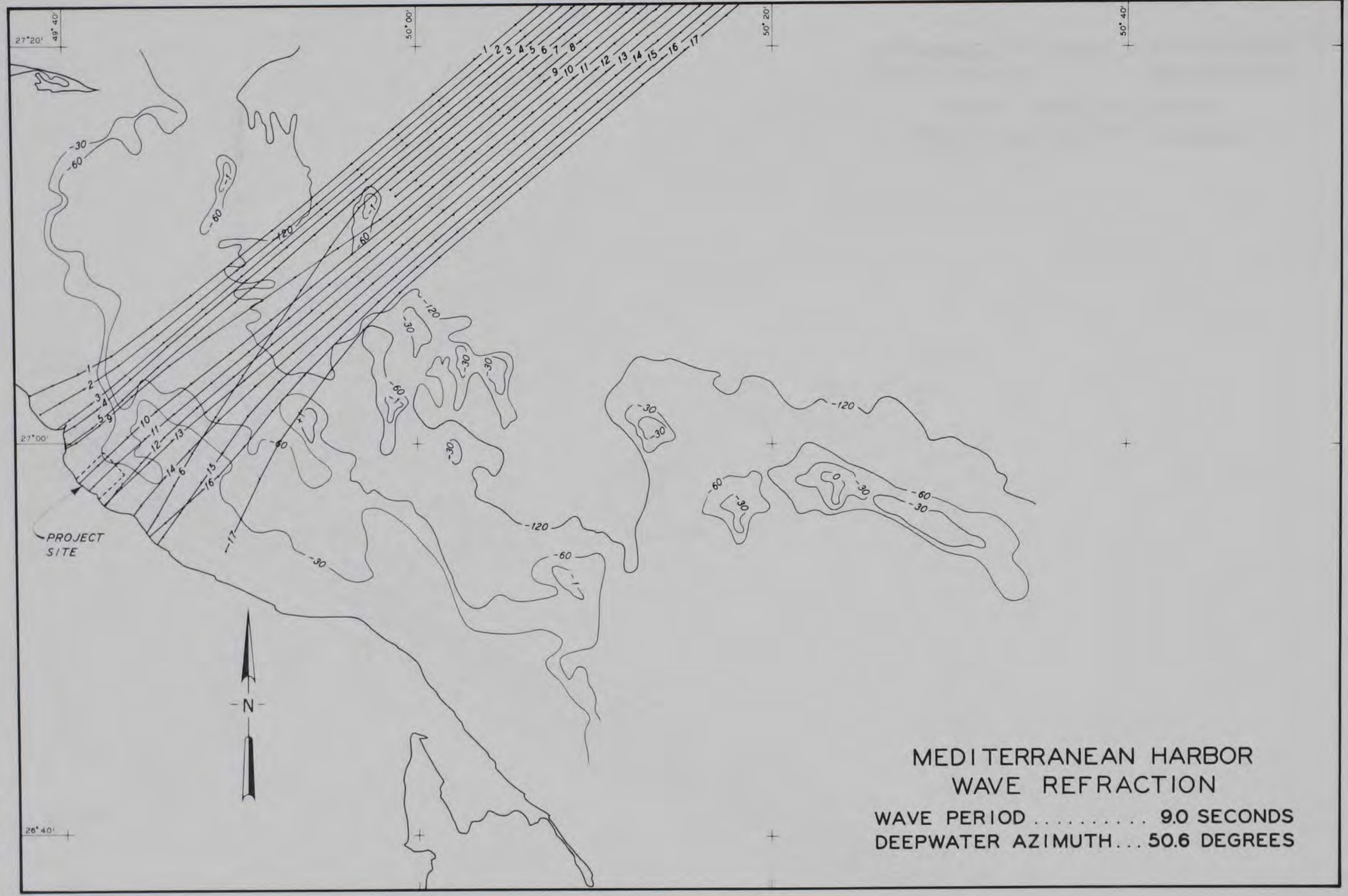
MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH...39.4 DEGREES

PLATE A5

PLATE A6


27°20'
49° 40'
50° 00'
50° 20'
50° 40'
27°00'
26° 40'
PROJECT SITE
N
MEDITERRANEAN HARBOR
WAVE REFRACTION
WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 45.0 DEGREES

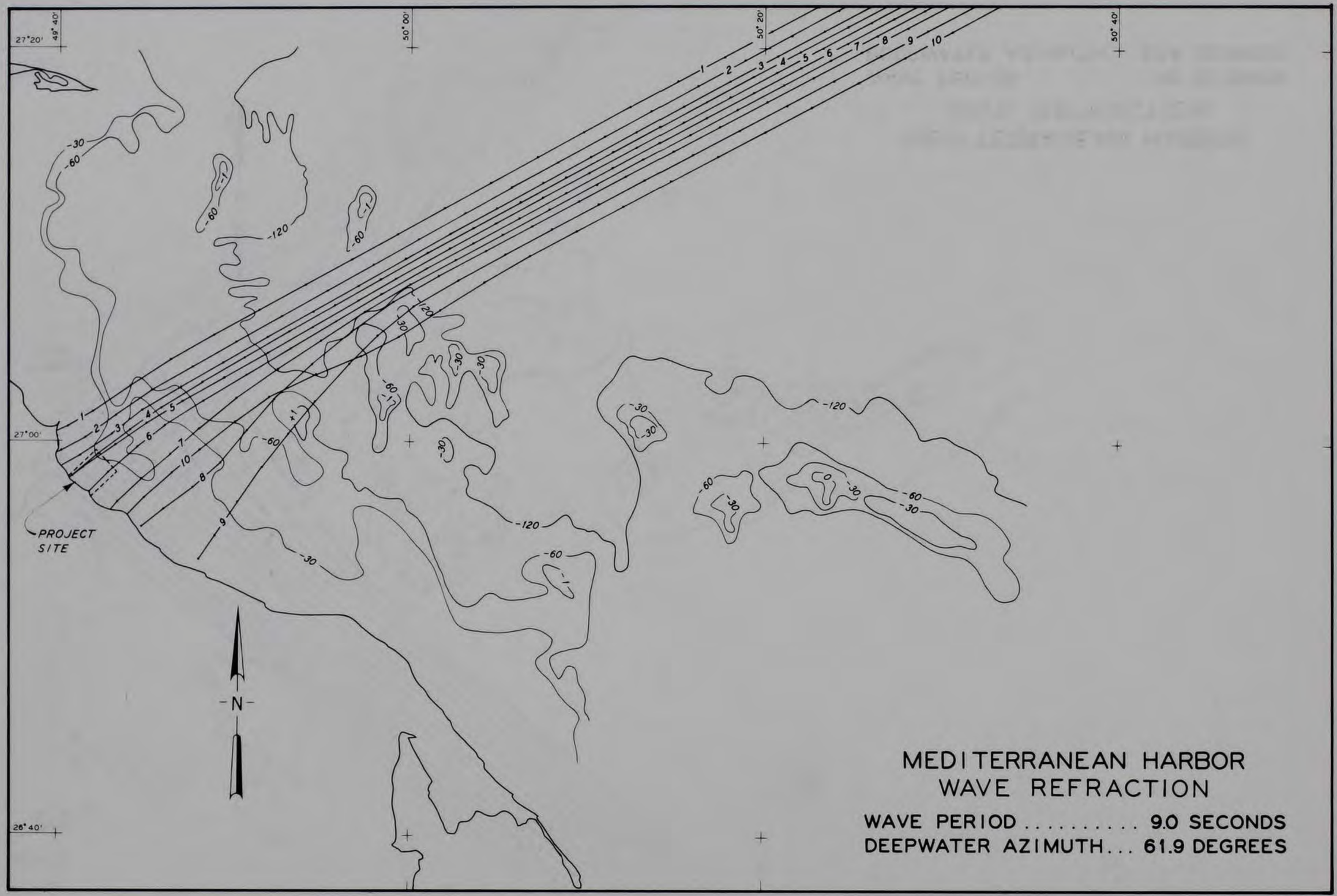


MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 50.6 DEGREES

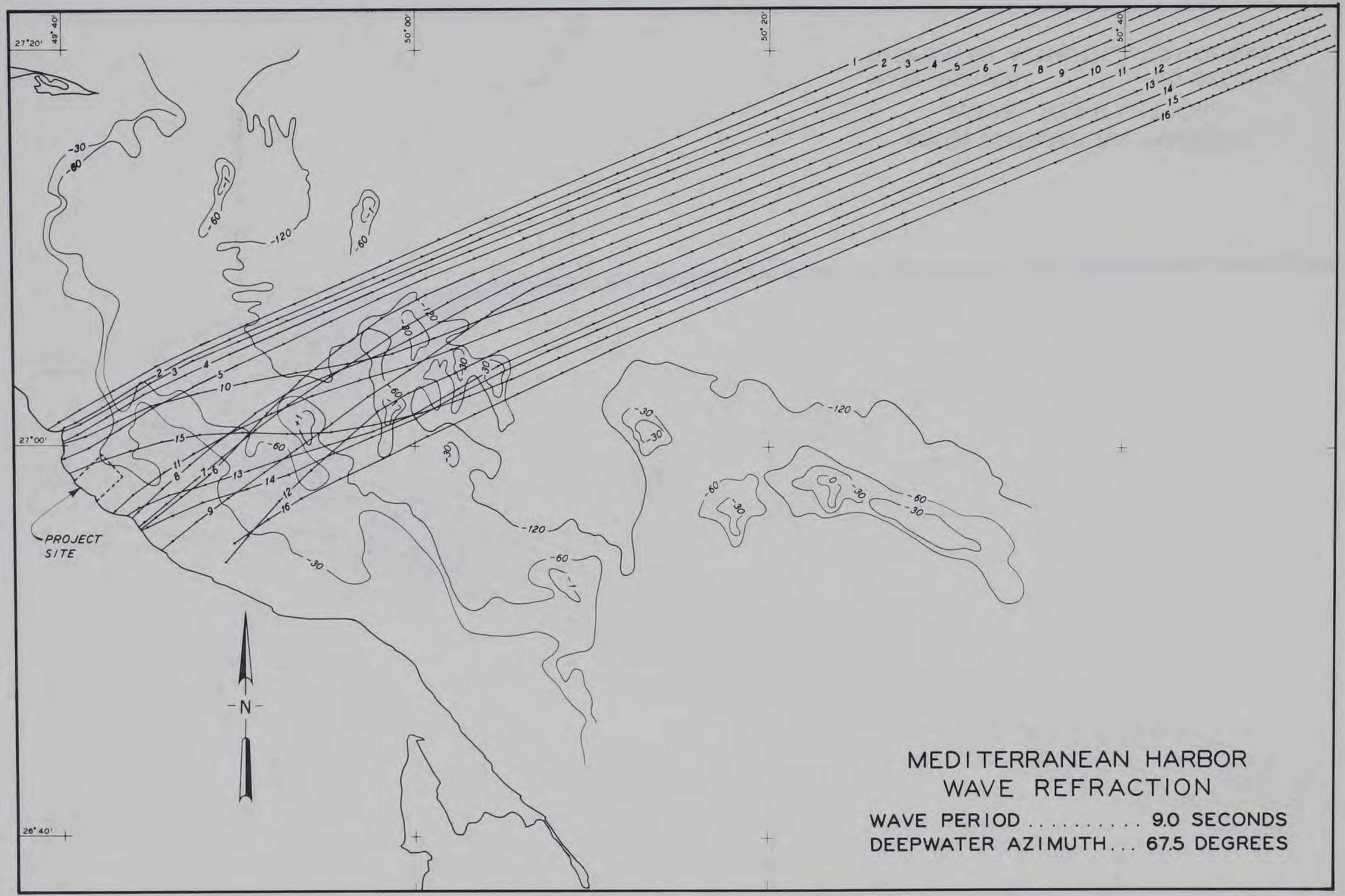
PLATE A7

PLATE A8



MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 61.9 DEGREES

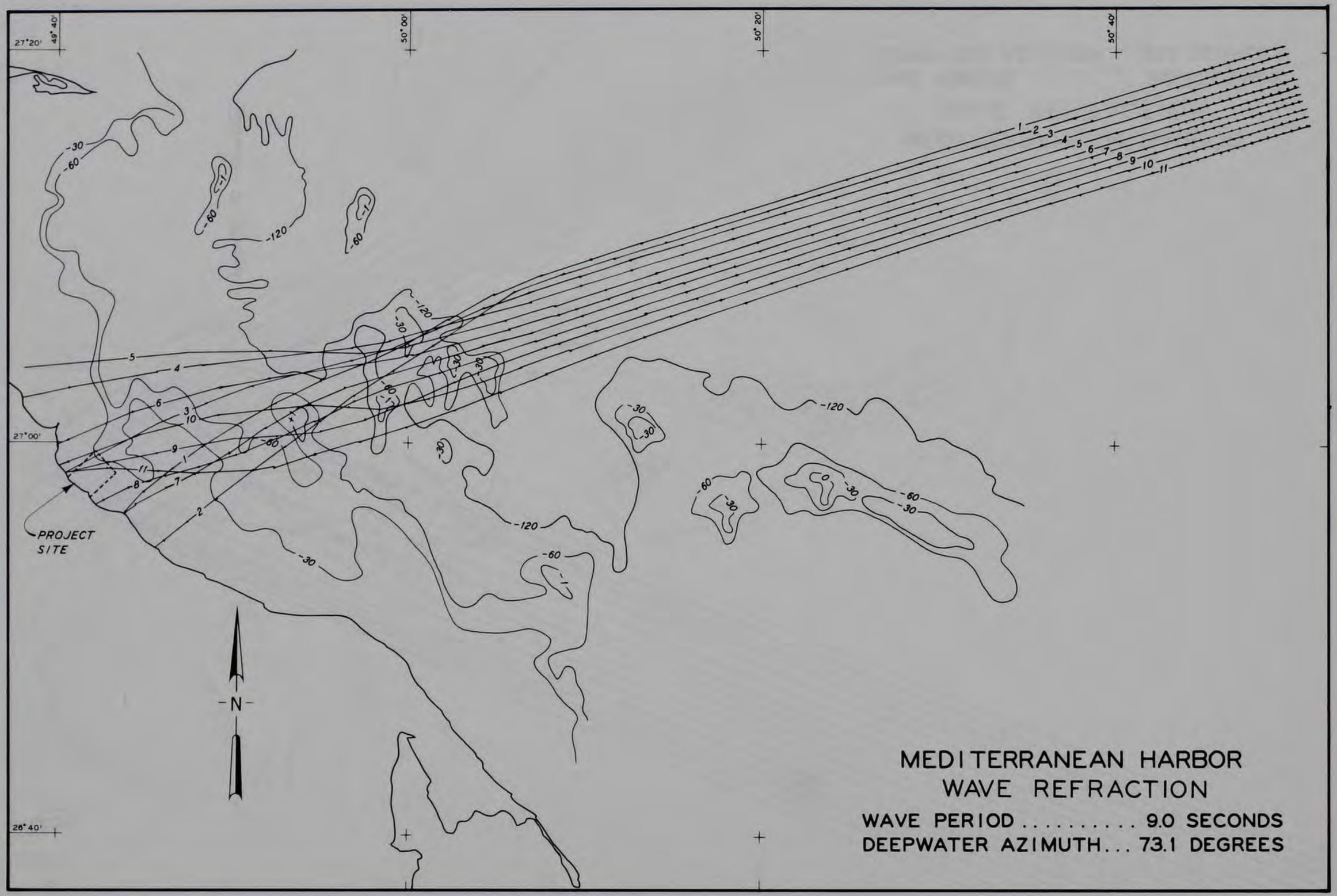


MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 67.5 DEGREES

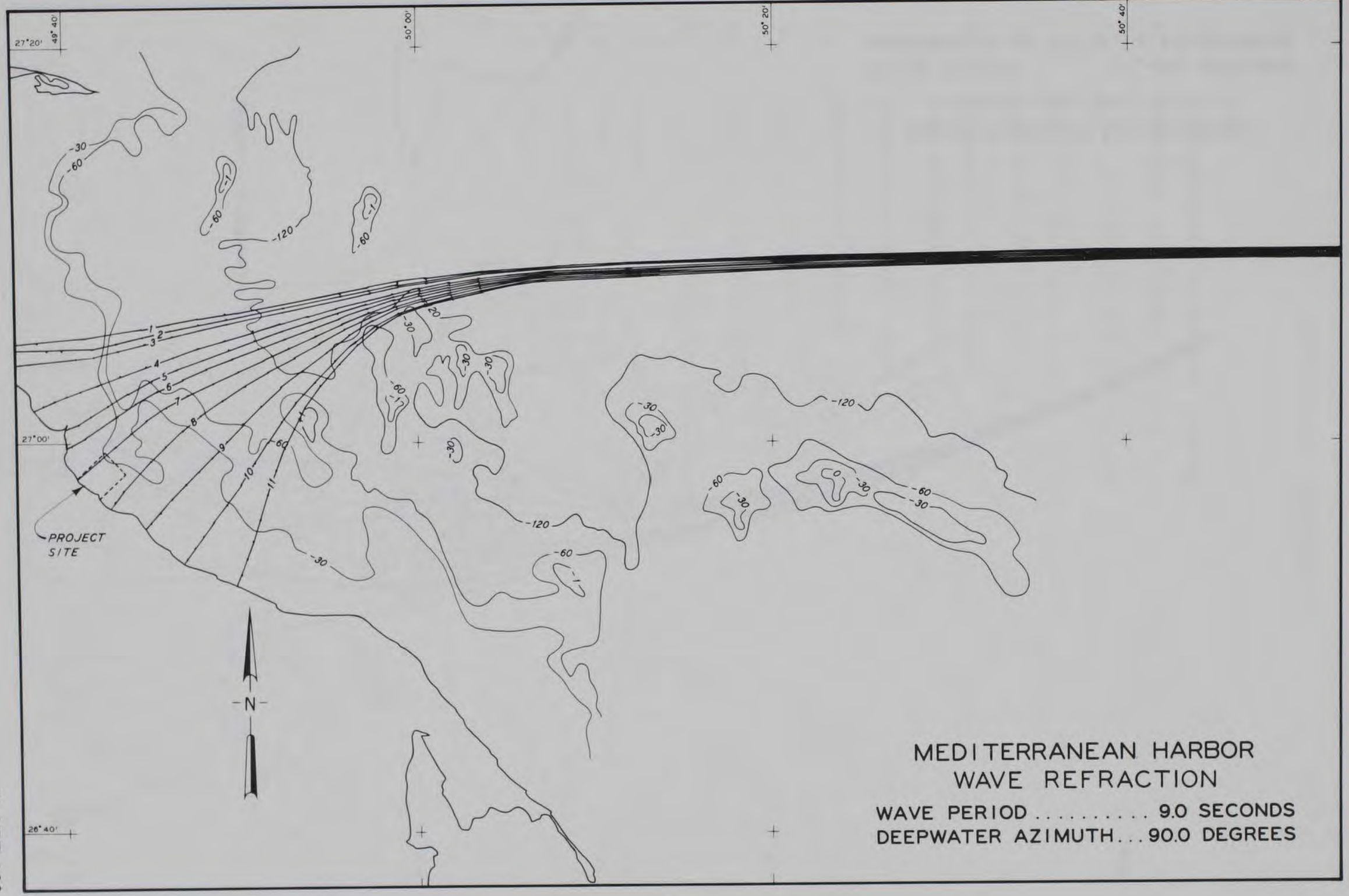
PLATE A9

PLATE A10



MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 73.1 DEGREES

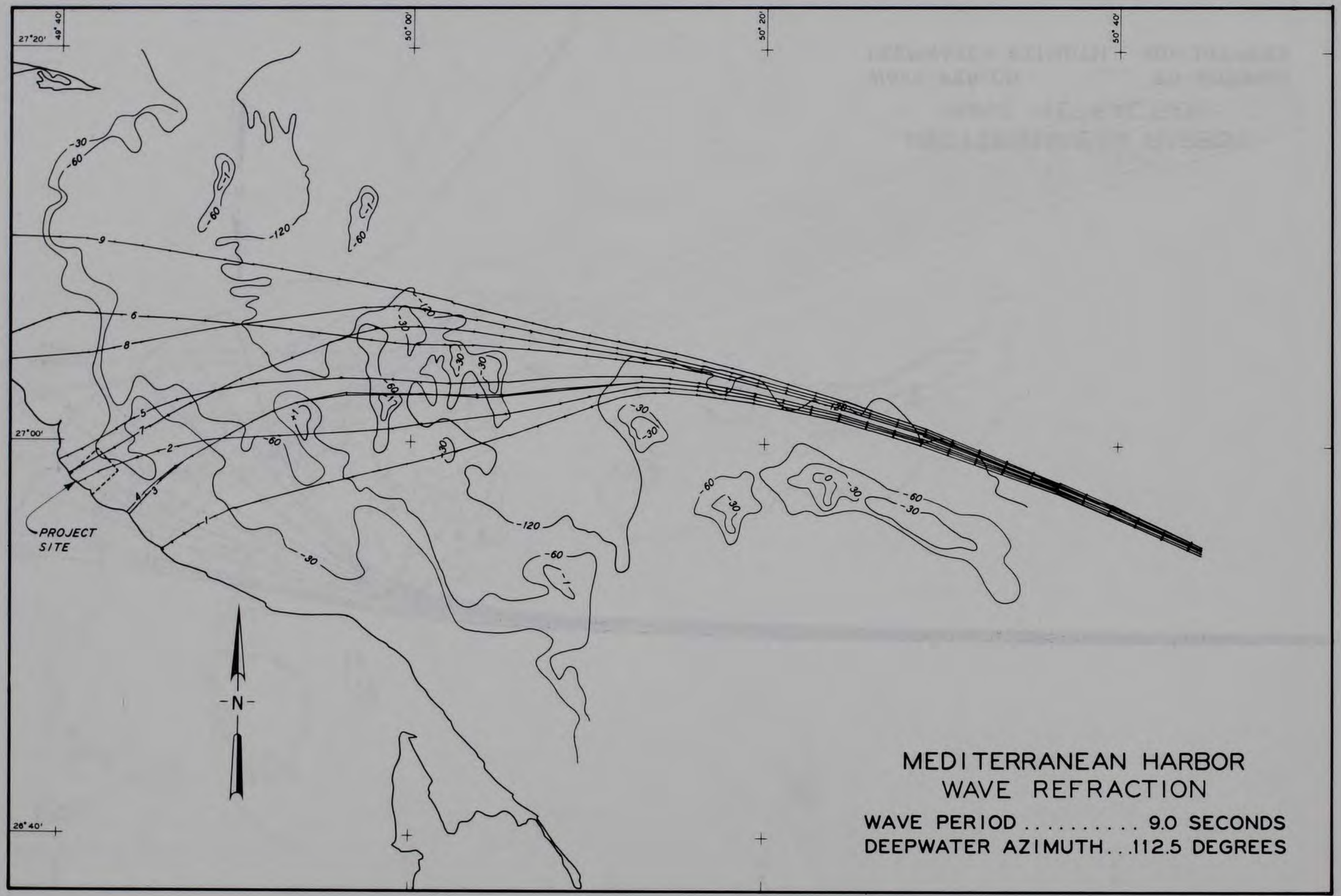


MEDITERRANEAN HARBOR
WAVE REFRACTION

WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH... 90.0 DEGREES

PLATE A11

PLATE A12


27°20'
49°40'
50°00'
50°20'
50°40'
27°00'
26°40'
-30
-60
-120
-1
9
6
8
5
7
2
3
4
1
PROJECT SITE
N
MEDITERRANEAN HARBOR
WAVE REFRACTION
WAVE PERIOD ..... 9.0 SECONDS
DEEPWATER AZIMUTH...112.5 DEGREES

APPENDIX B: NOTATION

A	Area
b	Shallow-water orthogonal spacing
b_o	Deepwater orthogonal spacing
C_T	H_t/H_i = transmission coefficient
H	Shallow-water wave height
H_o	Deepwater wave height
H_t	Transmitted wave height
H_i	Incident wave height
H_s	Significant wave height
H_{max}	Maximum wave height
k_f	Attenuation factor
K_s	Shoaling coefficient
K_r	$(b_o/b)^{1/2}$ = refraction coefficient
L	Length
T	Time
V	Velocity
$\forall$	Volume