TECHNICAL REPORT H-69-6

DESIGN FOR EXPANSION OF PORT SAN LUIS, CALIFORNIA

Hydraulic Model Investigation

by

C. E. Chatham, Jr.
C. W. Brasfeild

April 1969

Sponsored by

U. S. Army Engineer District
Los Angeles

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U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

A request for the U. S. Army Engineer Waterways Experiment Station (WES) to conduct a hydraulic model investigation of Port San Luis (San Luis Obispo Harbor), California, was initiated by the District Engineer, U. S. Army Engineer District, Los Angeles (LAD), in a letter to the WES dated 24 November 1965, subject, "Model Study for Port San Luis, California." Authority to conduct the study was granted by the Office, Chief of Engineers (OCE), on 24 January 1966 by the 4th indorsement to this letter.

The model study was conducted during the period from October 1967 to September 1968 in the Harbor Wave Action Section, Wave Dynamics Branch, Hydraulics Division, under the direction of Mr. E. P. Fortson, Jr., Chief of the Hydraulics Division, and Mr. R. Y. Hudson, Chief of the Wave Dynamics Branch. The tests were conducted by Mr. C. E. Chatham, Jr., Project Engineer, assisted by Mr. E. H. Brasfield, under the supervision of Mr. C. W. Brasfeild. This report was prepared by Messrs. Chatham and C. W. Brasfeild.

Liaison was maintained during the course of the investigation between the LAD and the WES by means of conferences, telephone communications, and monthly progress reports.

The following personnel visited the WES to observe model operation and participate in conferences: Mr. C. E. Lee of the OCE; Mr. O. F. Weymouth of the South Pacific Division; COL N. E. Pehrson, District Engineer, and Messrs. W. J. Herron, Jr., C. H. Fisher, G. D. Ward, F. J. Buchholz, and H. D. Converse of the LAD; Mr. O. T. Magoon of the San Francisco District; Dr. F. R. Raichlen of the California Institute of Technology; Messrs. R. P. Lundin and Tom Heatfield of Koebig and Koebig, Inc.; Messrs. L. A. Brisco,

N. W. Strother, G. L. Parsons, E. J. Fabbri, and D. D. Law of the Port San Luis Harbor Commission; and Mr. Ken Jenkins, Port San Luis Harbor Manager.

COL John R. Oswalt, Jr., CE, and COL Levi A. Brown, CE, were Directors of the WES during the conduct of the model study and the preparation of this report. Messrs. J. B. Tiffany and F. R. Brown were Technical Directors.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles	1.609344	kilometers
square feet	0.092903	square meters
square miles	2.58999	square kilometers
pounds	0.45359237	kilograms
tons	907.185	kilograms

SUMMARY

A 1:100-scale model of Port San Luis (formerly known as San Luis Obispo Harbor), California, and sufficient offshore area to permit generation of the required test waves was used to investigate the arrangement and design of certain proposed harbor improvements with respect to wave action. The proposed harbor improvements consisted of (a) an 1150-ft-long south breakwater extending east-northeast from Smith Island, with a 370-ft-long breakwater wing extending northward from this structure; (b) a 3515-ft-long detached breakwater with a north-northeast to south-southwest alignment, located approximately 500 ft seaward of the Port San Luis Wharf; (c) a 1300-ft-long north breakwater extending from a point on shore southward toward the north end of the detached breakwater; and (d) development of the inner harbor by constructing landfill areas and boat slips for the anchorage of small pleasure craft. A 60-ft-long wave machine and electrical wave height measuring and recording apparatus were utilized in model operation.

Base tests were conducted with existing prototype conditions installed in the model. Results of tests involving the various improvement plans were compared with base test results to determine the relative effectiveness of the respective plans. Of the plans tested, the optimum configuration appears to be that designated as plan 12.

It was concluded from the test results that (a) the proposed 1300-ft-long north breakwater and the 370-ft-long south breakwater wing can be replaced by revetted fills; (b) the length of the south breakwater should be increased by 400 ft; (c) the northern end of the proposed harbor should be redesigned to prevent excessive wave heights in that area; (d) the optimum harbor improvement plan (plan 12) will provide sufficient protection to the inner harbor from storm waves most of the time; however, when exceptionally high storm waves from the south-southwest deepwater direction occur simultaneously with high tide conditions, wave heights in the northern part of the harbor will reach magnitudes of approximately 3 ft; and (e) installation of the proposed breakwater and other harbor structures will not adversely affect wave conditions at the Union Oil Company Pier.

DESIGN FOR EXPANSION OF PORT SAN LUIS, CALIFORNIA

Hydraulic Model Investigation

PART I: INTRODUCTION

Description of Prototype

Existing conditions

1. Port San Luis (formerly known as San Luis Obispo Harbor) is located at the western end of San Luis Obispo Bay on the coast of southern California, and is about 190 miles* northwest of Los Angeles and 245 miles southeast of San Francisco (plate 1). San Luis Obispo Bay is a broad bight extending about 3.6 miles eastward from Point San Luis, with a north-south width of about 1 mile. The shore consists of high rocky bluffs west and north of the bay, about 0.5 mile of sand beach at the mouth of San Luis Obispo Creek, and irregular cliffs and tableland on the east. Depths in the bay range from about 18 ft at the Port San Luis fishing pier to about 50 ft at the approach from the ocean.

2. The existing Federal breakwater, completed in 1913, extends 336 ft from Point San Luis to Whaler Island, then 1820 ft southeast from the island for a total length of approximately 2400 ft, including the width of the island. Terminal facilities in the harbor consist of (a) an 1827-ft-long commercial pier at which fish are unloaded and small boats are repaired and serviced; (b) a 3082-ft-long oil pier used for petroleum and petroleum products shipping operations; (c) a 1463-ft-long county pier used as a landing for fishing and recreational boats and as a recreational fishing pier; and (d) a 200-ft-long lighthouse pier formerly used as a landing by the U. S. Coast Guard.

Proposed improvements

3. It is proposed that the existing harbor at Port San Luis be modified to provide a safe small-craft mooring area for approximately 1500

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* A table of factors for converting British units of measurement to metric units is presented on page vii.

pleasure craft and 240 commercial fishing boats.[1] The proposed mooring area would be protected from adverse wave action by: (a) an 1150-ft-long south breakwater extending east-northeast from Smith Island, with a 370-ft-long wing extending northward from this structure; (b) a 3515-ft-long detached breakwater with a north-northeast to south-southwest alignment, located approximately 500 ft seaward of Port San Luis Wharf; and (c) a 1300-ft-long north breakwater extending from a point on shore southward toward the north end of the detached breakwater. Access to the proposed harbor would be gained through two 400-ft-wide entrances located at the ends of the detached breakwater. The inner harbor would be developed by the construction of landfill areas, terminal facilities, boat mooring slips, utility installations, and other service facilities.

The Problem

4. Port San Luis is exposed to short-period wind waves (sea and swell) from all deepwater directions from south clockwise to southwest, the limits being Point Arguello to the south and Point San Luis to the north. In addition, the harbor is exposed to locally generated waves (sea) from the southeast to south directions. The waves approaching Port San Luis average about 3 ft in height, but they may range as high as 19 ft. Wave periods range from about 3 to 21 sec, with the more common ones ranging from about 7 to 16 sec. Adverse winds and wave action have often caused damage to small craft in the harbor, and all recreational small craft must be taken out of the water each fall because of the danger from winter storms. This situation restricts the recreational boating season to about eight months per year. Because of the difficulty in determining the effects of the proposed improvements and revisions on wave action in the harbor, it was recommended that a hydraulic model investigation be conducted.

Purpose of Model Study

5. The purpose of the model study was to (a) study wave action in the harbor for existing conditions and following the proposed harbor

revisions; (b) develop remedial plans for alleviation of undesirable wave action and navigation conditions in the inner harbor and entrance channels as necessary; (c) determine whether suitable design modifications of the proposed plans could be made that would reduce construction costs significantly and still provide adequate protection from wave action; and (d) study the effects of the proposed revisions on wave conditions at the Union Oil Company Pier.

Wave Height Criteria

6. At the present time, completely reliable criteria have not been developed for ensuring that satisfactory navigation and mooring conditions will obtain in small-craft harbors for short-period waves. However, it is known that when resonant conditions occur for small craft moored in present-day marinas, relatively small wave heights can result in the breaking of lines if the craft are not moored correctly. For the study reported herein, the U. S. Army Engineer District, Los Angeles (LAD), specified that for an improvement plan to be acceptable, maximum wave heights in the harbor should not exceed 4.0 ft in the entrances, 2.5 ft in the boat mooring area, and 1.5 ft in the slip areas.

Motion Picture

7. At the request of the LAD, several motion picture sequences were secured in connection with the Port San Luis model study. These film sequences, which depict the various phases of harbor development and the effects of wave action on model boats, floating boat slips, breakwaters, and inner-harbor configurations, were furnished the LAD in September 1968.

PART II: THE MODEL

Design of Model

8. The Port San Luis model (plate 2) was constructed to a linear scale of 1:100, model to prototype. Scale selection was based on such factors as the (a) depth of water required in the model to prevent excessive bottom friction effects; (b) absolute size of model waves; (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; and (f) cost of model construction. A geometrically undistorted model was necessary to ensure accurate reproduction of short-period wave patterns. Following selection of the linear scale, the model was designed and operated in accordance with Froude's model law.[2] The scale relations used for design and operation of the model were as follows:

Characteristics	Dimensions*	Model:Prototype Scale Relation
Length	L	$L_r = 1:100$
Area	L^2	$A_r = L_r^2 = 1:10,000$
Volume	L^3	$\forall_r = L_r^3 = 1:1,000,000$
Time	T	$T_r = L_r^{1/2} = 1:10$
Velocity	L/T	$V_r = L_r^{1/2} = 1:10$

* Dimensions are in terms of length and time.

9. The proposed plans of improvement for Port San Luis included the use of rubble-mound breakwaters. Past experience and experimental research have shown that considerable wave energy passes through the interstices of this type of structure; thus, the transmission of wave energy became a matter of concern in the design of the 1:100-scale model. In small-scale harbor models, rubble-mound structures reflect relatively more and absorb or

dissipate relatively less wave energy than geometrically similar prototype structures.[3] Too, the transmission of energy through the breakwater is less (relatively) for the small-scale model than for the prototype. Consequently, some adjustment in small-scale-model rubble-mound structures is needed to ensure satisfactory reproduction of wave-transmission characteristics. In recent investigations[4,5] at the U. S. Army Engineer Waterways Experiment Station (WES), this adjustment was accomplished as follows. The wave-energy transmission characteristics of the proposed structure were determined in a two-dimensional model using a scale large enough to ensure negligible scale effect. Then a breakwater section was developed for the small-scale three-dimensional model that would provide essentially the same relative transmission of wave energy. However, this procedure was not used for the Port San Luis model, because it was believed that the proposed structures and the incident wave characteristics at Port San Luis were sufficiently similar to those of the other harbors for which the procedure had been used to allow application of the results of the tests conducted therein to the Port San Luis case. Therefore, from previous findings for cases similar to that at Port San Luis, it was determined that a close approximation of the correct wave-energy transmission characteristics could be obtained by increasing the size of the rock used in the 1:100-scale model to approximately 1.5 times that required for geometric similarity. Accordingly, in constructing the breakwater structures in the Port San Luis model, the rock sizes were computed linearly by scale, then multiplied by 1.5 to arrive at the actual sizes used in the model.

Description of Model and Appurtenances

10. The model was molded in cement mortar and reproduced the entire harbor area and underwater contours to an offshore depth of 60 ft. Sufficient additional offshore area was included to permit generation of test waves from all critical directions. The total area reproduced in the model was approximately 12,250 sq ft, representing about 4.4 square miles in the prototype. Photograph 1 shows a general view of the model with existing conditions installed. Model construction was based on the mean lower low

water datum (mllw), and all elevations used in this report refer to mllw. A local prototype grid system was used for horizontal control in the model.

11. Model waves were generated to scale by a 60-ft-long wave machine with a trapezoidal-shaped, vertical-motion plunger. The vertical movement of the plunger caused a periodic displacement of water incident to this motion. The length of stroke and the period of the vertical motion were infinitely 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 directions. Wave heights at selected locations in the model were recorded on chart paper by an electrically operated oscillograph. The input to the oscillograph was the output of electrical wave height gages that measured the changes in the water-surface elevation with respect to time. The electrical output of each wave height gage was directly proportional to the submergence depth of the gage in the water.

PART III: TEST CONDITIONS AND PROCEDURES

Selection of Test Conditions

Still-water level

12. Still-water levels (swl) for harbor wave-action models are selected so that the various wave-induced phenomena that are dependent upon water depths are accurately reproduced in the model. These phenomena include the refraction of waves in the harbor area, the overtopping of harbor structures by the waves, the reflection of wave energy from breakwater structures, and the transmission of wave energy through porous structures. Some of the more important factors contributing to selection of the optimum swl are (a) the maximum amount of wave energy that can reach a coastal area will ordinarily do so during the period of a severe storm that coincides in time with the higher high-water phase of the astronomical tide cycle; (b) severe storms are usually accompanied by some additional increase in the normal water level due to wind tide and mass transport; and (c) a relatively high swl in the model is beneficial in minimizing the effects of bottom friction, which can be excessive in shallow areas of small-scale models. Therefore, with consideration for the various factors contributing to and affected by the static water level in the prototype, and in view of the tendency toward more conservative results from the model investigation, it was desirable that a model swl be selected that closely approximated the higher water stages that normally prevail during severe storms in the prototype. This entailed the study of tide height records in the prototype locality, with due attention being given to the higher levels experienced in the area in the past.

13. The water level at the Port San Luis project site varies not only with the stage of the astronomical tide and wind tide, but also with tsunami action in the area. During the tsunami caused by the Alaskan earthquake of March 1964, the water level in San Luis Obispo Bay exceeded the limits of the United States Coast and Geodetic Survey (USC&GS) tide gage at the county pier in Avila, and eyewitnesses estimated a 16-ft wave height. There was relatively little damage, however, and since the

occurrence of such tsunamis is rare, it appeared reasonable to disregard any increase in the model swl due to tsunami action.

14. From USC&GS records,[6] the mean tide level at Avila on the north side of the bay is +2.8 ft, mean high water is +4.6 ft, and mean higher high water is +5.3 ft. The highest tide of record, which occurred January 25-26, 1948, was +7.5 ft. Because of the low probability that an extreme wind tide, a high astronomical tide, and extreme storm waves will occur simultaneously, a swl of +6.0 ft was selected for use in the model, which represents the mean higher high water level of +5.3 ft plus an assumed wind tide of 0.7 ft.

Wave dimensions and directions

15. Factors influencing selection of test-wave characteristics. 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 of the proposed improvement plans and allow an accurate evaluation of the elements of the various proposals. Surface wind waves are generated by the tangential shear force of the wind blowing along the water surface and the normal force of the wind against the wave crests. The magnitude of the maximum wave that can be 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. 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 navigation entrance to the harbor; (d) the alignments, lengths, and locations of the various reflecting surfaces inside the harbor; and (e) the refraction of waves caused by differentials in depth in the area seaward of the harbor, which may create either a concentration or a diffusion of wave energy at the harbor site.

16. Wave refraction. When wind waves move into water of gradually decreasing depth, transformations take place in all wave characteristics

except wave period. 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. The changes in wave height and direction can be determined by plotting refraction diagrams and calculating refraction coefficients. For this study, refraction diagrams were prepared by personnel of the LAD and National Marine Consultants[7] for representative wave periods for the critical directions of approach. These diagrams were constructed by plotting the positions 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, the ratio between the wave height in deep water (H_o) and the wave height in shallow water (H) will be inversely proportional to the square root of the ratio of the corresponding orthogonal spacings (b_o and b) or $H/H_o = K\ (b_o/b)^{1/2}$. The quantity $(b_o/b)^{1/2}$ is the refraction coefficient; K 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 8.

17. Prototype wave data and selection of test waves. Based on the information contained in reference 7, it was concluded that model test waves could be chosen from those storms with significant wave heights in deep water of 10 ft or greater and which approached Port San Luis from southeast clockwise to southwest. Of 407 storms analyzed for the period 1899-1959, 22 met these criteria. Pertinent characteristics of the deepwater waves associated with these 22 storms were then modified by refraction and shoaling considerations to yield corresponding shallow-water values for use in the model. The results of this analysis are presented in table 1. For additional verification of the selected test waves, reference was made to wave hindcast data by National Marine Consultants[9] for stations 4 and 5, located approximately 75 and 50 nautical miles west-northwest and south-southwest, respectively, from Port San Luis. To these hindcast data, which were computed in accordance with the theory of wave spectra and statistics as presented by Pierson, Neumann, and James,[10] refraction

coefficients from reference 7 and shoaling coefficients from reference 8 were applied to derive shallow-water wave characteristics applicable to the model study. A comparison of the results of the two analyses showed that, for all directions of approach, the test-wave heights derived from the storm-wave analysis were equal to or greater than the corresponding heights derived from the hindcast data analysis. It was therefore concluded that use of the test-wave characteristics shown in table 1 would provide more conservative results from the model study. In addition to the test waves given in table 1, the LAD requested that model test waves include the largest 9-sec wave from the south 15° east test direction that could break on the proposed detached breakwater. Preliminary model tests revealed that a 9-sec, 20-ft shallow-water wave (height at model wave generator) would produce the desired breaking wave at the location of the detached breakwater; therefore, this test wave was added to those selected from table 1. Toward the latter part of the model study, the LAD also requested that 14-sec, 8- and 11-ft test waves from the south 16° west test direction be included in the testing program. The 14-sec, 14-, 16-, and 18-ft waves from this direction have a low frequency of occurrence, and the 8- and 11-ft waves would represent more frequent storm-wave conditions.

Analysis of Model Data

18. The relative merits of the various plans tested were evaluated by (a) comparison of wave heights at selected locations in the harbor, and (b) visual observations and photographs. In the wave height data analysis, the average height of the highest one-third of the waves recorded at each gage location was selected. All wave heights thus selected were then adjusted to compensate for the greater rate of wave height attenuation in the model, as compared with the prototype, by the application of Keulegan's equation.[11] From this equation, the reduction of wave heights in the model due to bottom friction can be calculated as a function of water depth, width of wave front, wave period, water viscosity, and distance of wave travel.

PART IV: TESTS AND RESULTS

Description of Tests

Base test

19. The term "base test" as used herein denotes a test performed with existing prototype conditions (plate 3) installed in the model. Prior to tests of the various improvement plans, comprehensive base test wave height data were obtained in the existing harbor area, with particular emphasis placed on the entrance channels and inner mooring areas of the proposed harbor. The base test wave height data were secured for all test waves and test directions shown in table 1. Specific wave height gage locations for base test conditions and for each improvement plan tested are included in plates 3-12, which show the elements of the plans involved, although in several instances during the model tests, various gages were shifted slightly to obtain the maximum wave height values in the immediate area.

20. Analysis of the base test data showed that the most critical direction of wave approach, with respect to wave action in the entrances and inner harbor areas, was the shallow-water test direction of south 16° west, which corresponded to the south-southwest direction of deepwater wave approach. Consequently, tests involving relatively minor modifications of some of the proposed improvement plans were limited to this test direction only.

Improvement plans

21. Wave height tests were conducted for 26 variations in design elements of the proposed plans of improvement to the harbor. The plans tested included (a) various combinations of the proposed breakwater structures; (b) variations in length, porosity, and crown elevation of the proposed structures; (c) variations in the location, the revetment protection, and the number of interior harbor fill areas; and (d) combinations of several of these design features. Brief descriptions of the plan elements are given in the following subparagraphs; dimensioned details are presented in the referenced plates.

a. Plan 1 (plate 4) entailed the installation of only one structure in the existing harbor area. This structure was a 3515-ft-long detached breakwater with a north-northeast to south-southwest alignment, generally parallel to the shoreline, located approximately 500 ft seaward of the Port San Luis Wharf. The crown elevation of the structure was +16 ft from sta 0+00 (the south end) to 6+50, and +20 ft from sta 6+50 to 35+15 (the north end).

b. Plan 2 (plate 5) consisted of the detached breakwater and an 1150-ft-long south breakwater extending east-northeast from Smith Island, with a 370-ft-long breakwater arm extending northward from this structure. The crown elevation of the south breakwater was +16 ft; the crown elevation of the breakwater arm structure was +14 ft. Also, plans 2 through 6A included a breakwater structure between Smith Island and the shore, the crown elevation of which was +14 ft.

c. Plan 3 (plate 6) included the detached breakwater, the south breakwater, and a 1300-ft-long L-shaped north breakwater extending from a point on shore southward toward the north end of the detached breakwater. The crown elevation of the north breakwater was +14 ft.

d. Plans 3A and 3B (plate 6) involved raising the crown elevation of the south breakwater from +16 to +18 and +20 ft, respectively.

e. Plans 3C and 3D (plate 6) entailed reductions in the length of the south breakwater from 1150 to 950 and 750 ft, respectively, with the crown elevation of that structure being +16 ft.

f. Plan 4 (plate 7) involved straightening the north breakwater so that it joined the detached breakwater at sta 31+75 to form one continuous structure. The south breakwater was the same structure that was used with plan 3.

g. Plans 5 and 5A (plate 8) included the north and south breakwaters of plan 3. However, for plans 5 and 5A, the north end of the detached breakwater was shortened by 200 and 400 ft, resulting in overall breakwater lengths of 3315 and 3115 ft, respectively.

h. Plans 6 and 6A (plate 8) also included the north and south breakwaters of plan 3, and the detached breakwater was reconstructed to its original 3515-ft length, with the crown of this structure between sta 0+00 and 6+50 remaining at the original elevation of +16 ft. Then, for plan 6, the crown elevation was lowered from +20 to +18 ft between sta 6+50 and 25+00. For plan 6A, the crown elevation was +18 ft between sta 6+50 and 35+15.

i. Plan 7 (plate 9) consisted of the plan 6A breakwater system tested in conjunction with the phase II interior harbor development. For plan 7 and all subsequent plans, the breakwater structure between the shore and Smith Island was removed, being replaced by the proposed landfill. The seaward perimeter of all landfill areas was protected by a stone revetment (see plate 13 for section details). For plans 7 through 10, the revetment was placed from the base of the fill up to an elevation of +5 ft. Also, for plan 7 and all subsequent plans, the 1300-ft-long north breakwater and the 370-ft-long breakwater wing extending from the south breakwater were redesigned as revetted fills.

j. Plan 8 (plate 10) consisted of the plan 6A breakwater system tested in conjunction with the phase IV interior harbor development.

k. Plans 8A and 8B (plate 10) utilized the same model configurations as plan 8, but plan 8A included an impervious core in the crown armor-stone layer of the south breakwater, and plan 8B included a similar impervious core in both the south and the detached breakwaters.

l. Plans 8C-8G (plate 10) included the basic model configuration of plan 8, with the following revisions to the south breakwater. For plans 8C, 8D, and 8G, this structure was lengthened by successive 200-ft increments, resulting in overall breakwater lengths of 1350, 1550, and 1750 ft, respectively. For plan 8E, an impervious core was installed in the crown armor-stone layer of the plan 8C south breakwater, and for plan 8F, a similar installation was made in the plan 8D structure.

m. Plans 9 and 9A (plate 11) included the phase IV landfill areas and the plan 8D south breakwater. For plan 9, the crown elevation of the detached breakwater was +16 ft from sta 0+00 to 25+00, and +18 ft from sta 25+00 to 35+15. For plan 9A, the crown elevation of this structure was +16 ft from sta 0+00 to 20+00, and +18 ft from sta 20+00 to 35+15.

n. Plan 10 (plate 12) consisted of the basic plan 9A harbor configuration with the northern corner of the interior harbor redesigned as a curved beach with a slope of approximately 6:1.

o. Plan 11 (plate 12) consisted of the plan 10 configuration with the revetment on the interior harbor perimeter raised from +5 to +10 ft.

p. Plan 12 (plate 12) consisted of the plan 11 configuration with the crown elevation of the detached breakwater between sta 0+00 and 6+50 lowered from +16 to +14 ft.

22. Wave height tests for the various improvement plans were conducted using test waves from one or more of the test directions listed in

table 1. As previously stated, tests involving relatively minor modifications of some of the improvement plans were limited to the most critical direction of wave approach, i.e., the south 16° west test direction. Tests involving certain other plans were limited to the two most critical directions of wave approach, i.e., south 16° west and south 15° east test directions. This procedure is a model expedient used when base test results show a marked difference among the test directions. However, all of the major proposed plans of improvement were tested comprehensively for all test conditions listed in table 1 to establish a complete comparison with base test.

Test Results

23. In the evaluation of test results, the relative efficiency of each of the improvement plans tested was assessed on the basis of an analysis of measured wave heights in the harbor and the entrances thereto. The model wave height data were tabulated to show the measured wave heights at the various gage locations for base test and for each of the improvement plans. An additional comparison among the various plans tested was made by selecting wave height data for corresponding gage locations for the various plans and computing a numerical average of the selected data for each plan, then comparing these average values as percentages of wave height increase or reduction among the various plans. Results of these comparisons are referred to as general or overall wave height variations in the harbor area in the discussion of test results.

Base test

24. The results of tests with the existing prototype conditions installed in the model are presented in tables 2-5. These data reveal that wave heights up to about 19 ft were recorded in the proposed mooring area, indicating that considerable protection is needed to make this area suitable for the safe anchorage of small craft. Wave heights up to about 21 ft were recorded in the vicinity of the proposed detached breakwater.

Improvement plans

25. The results of tests with the four basic breakwater

configurations (plans 1, 2, 3, and 4) installed in the model are compared with corresponding base test data in tables 2-5. These data show that the installation of the detached breakwater alone (plan 1) effected an overall reduction in wave heights of about 61 percent inside the harbor. The successive addition of the south breakwater (plan 2) and the north breakwater (plan 3), and the relocation of the outer portion of the north breakwater to close the northern harbor entrance (plan 4) resulted in general wave height reductions of about 83, 85, and 85 percent, respectively, when compared with base test conditions. Since wave conditions inside the harbor were approximately the same with plans 3 and 4 installed in the model, and since two entrances were highly desirable from a navigation standpoint, the plan 3 breakwater system was selected for further modification and testing.

26. Visual observations made while the harbor was under attack by 14-sec waves from the south 16° west test direction revealed that standing waves of considerable magnitude obtained in the northern end of the inner harbor, apparently caused by reflections from the adjacent shoreline. Accordingly, additional wave gages were installed in this area for plan 3 and all subsequent plans tested. These gages were positioned in loop areas of the standing wave patterns, and, as stated in paragraph 19, repositioned where necessary to obtain the maximum wave height values.

27. The results of tests with plans 3A and 3B installed in the model are presented in table 6. These data reveal that raising the crown elevation of the south breakwater from +16 to +18 ft did not significantly reduce overall wave heights inside the harbor. However, when the crown elevation was raised to +20 ft, a general reduction in wave heights of about 11 percent was noted in the harbor as compared with the plan 3 test results.

28. The results of tests to determine the feasibility of reducing the length of the south breakwater (plans 3C and 3D) are presented in table 7. These data show that reducing the length of the south breakwater by 200 and 400 ft increased overall wave heights in the harbor about 6 and 23 percent, respectively, over those noted with plan 3 installed.

29. Table 8 presents the results of tests to determine the feasibility of reducing the length of the detached breakwater at the north end. These data indicate that the 200-ft length reduction (plan 5) increased

wave heights in the harbor slightly (about 6 percent) for test waves from the south 16° west test direction; however, a slight decrease was noted in wave heights in the harbor for test waves from the south 15° east test direction. The 400-ft length reduction (plan 5A) resulted in a significant increase in wave heights (about 26 percent) inside the harbor for test waves from both test directions.

30. The results of tests with plans 6 and 6A installed in the model are presented in table 9. These data reveal that lowering the crown elevation of the detached breakwater from +20 to +18 ft from sta 6+50 to 25+00 (plan 6) or to 35+15 (plan 6A) effected no significant increase in wave heights inside the harbor.

31. Since plan 6A was the most economical of the various modifications of the basic plan 3 breakwater system that did not increase wave heights inside the harbor, this breakwater configuration was selected for tests involving the installation of the proposed interior harbor development.

32. The results of tests with plan 7 (phase II development) and plan 8 (phase IV development) installed in the model are presented in table 10. These data show that the installation of plans 7 and 8 resulted in overall increases in wave heights inside the harbor of about 8 and 19 percent, respectively, over those experienced with plan 6A installed. The magnitudes of standing waves that obtained in the northern end of the harbor during all tests of the proposed breakwater system were substantially increased by the installation of the interior harbor landfill areas and reached a maximum value of about 5 ft at gage 31 with either plan 7 or plan 8 installed. No overtopping of the interior harbor perimeter was observed with plans 7 and 8 installed in the model. However, the seaward perimeter of the landfill area between Smith Island and the existing Coast Guard pier was overtopped by all test waves.

33. Since the selected model swl of +6.0 ft represented an extreme high-tide condition, tests were conducted to determine the effects of a swl representative of low-tide stages. Accordingly, tests were conducted with plan 8 installed in the model and with the model swl set at 0.0 ft. The results of these tests are presented in table 11, which consists of

corresponding wave height data for swl's of +6.0 and 0.0 ft with plan 8 installed in the model. These data reveal that lowering the swl to 0.0 ft effected a general reduction in wave heights in the harbor of approximately 50 percent.

34. Table 12 presents the results of tests with plans 8A and 8B installed in the model. These data show that sealing the armor layer of the south breakwater reduced wave heights inside the harbor about 17 percent, and sealing the armor layer of both the south and detached breakwaters reduced wave heights about 19 percent.

35. The results of tests with plans 8C, 8D, 8E, 8F, and 8G installed in the model are presented in tables 13 and 14. The data for plans 8C, 8D, and 8G (table 13), when compared with corresponding test data for plan 8, reveal that increasing the length of the south breakwater to 1350, 1550, and 1750 ft resulted in overall reductions in wave heights in the harbor of about 21, 25, and 32 percent, respectively. The data for plans 8E and 8F (table 14), when compared with corresponding data for plan 8, indicate that sealing the armor layer of the south breakwater in conjunction with the 200- and 400-ft-long additions reduced overall wave heights in the harbor about 23 and 30 percent, respectively.

36. Following a review of the test data for plans 8 through 8G by personnel of the LAD, the 1550-ft-long south breakwater structure (plan 8D) was selected as being the optimum with respect to cost of construction and degree of protection afforded; therefore, this structure was used in all subsequent testing.

37. The results of tests to determine the effects of additional revisions in the crown elevation of portions of the detached breakwater are presented in table 15. These data indicate that when the crown elevation was lowered from +18 to +16 ft between sta 6+50 and 20+00 (plan 9A), there resulted an overall increase in wave heights of only about 1 percent above those experienced with plan 8D installed. Also, when the crown elevation was constructed to +16 ft to sta 25+00 (plan 9), the general increase in wave heights was about 5 percent above corresponding plan 8D wave heights. However, wave heights in the northern corner of the harbor (gage 31)

reached magnitudes of about 5 ft for plans 9 and 9A as compared with 3.5 ft for plan 8D.

38. From visual observations of test waves from the south 16° west test direction, the extreme standing wave heights that occurred in the vicinity of gage 31 with the proposed interior harbor configuration installed appeared to be caused by the focusing of the energy of waves that entered the harbor (a) by overtopping of the breakwaters; (b) by transmission through the breakwater structures; and (c) through the north and south entrances. In order to alleviate the effects of this concentration of energy, the northern corner of the harbor was redesigned as a curved beach with a slope of approximately 6:1 and tested in conjunction with the plan 9A breakwater system. The results of tests with this configuration (plan 10) installed in the model are presented in table 16. These data, when compared with corresponding data for plan 9A, reveal that the redesign effected an overall reduction in wave heights in the harbor of about 16 percent. Wave heights in the vicinity of the beach (gage 34) reached a maximum value of about 2 ft as compared with almost 5 ft in this area (gage 31) for plan 9A.

39. The results of tests conducted to determine the effects of extending the interior perimeter revetment from +5 to +10 ft (plan 11) in conjunction with the plan 10 harbor configuration are also presented in table 16. These data indicate that the revetment revision effected an overall reduction in wave heights in the harbor of about 5 percent below those noted for plan 10. Also, maximum wave heights in the slip areas were reduced to 3.0 from 3.5 ft.

40. Test results with plan 12 installed in the model are presented in tables 16 and 17. The data in table 16 indicate that lowering the crown elevation of the detached breakwater from +16 to +14 ft between sta 0+00 and 6+50 resulted in a general increase in wave heights in the harbor of about 10 percent over those that obtained with plan 11 installed, although maximum wave heights were slightly reduced.

41. A comparison of the base test and plan 12 data (table 17) for gages 18, 19, 20, 21, and 22 reveals that the installation of the proposed breakwaters and other harbor structures will not adversely affect wave

conditions in the vicinity of the Union Oil Company Pier.

42. During model testing, overhead photographs of wave patterns in the harbor area were secured for base test and for several of the proposed improvement plans. Photographs 2-14 present a comparison of wave patterns for base test and plans 1, 2, 3, 4, 6A, 7, 8, 8D, 10, and 12 for representative test waves.

Discussion of test results

43. The proposed plans of improvement that represented major changes in the harbor design and that were used, by comparison of test results, to assess the relative merits of lesser design modifications are listed in the following tabulation. Also shown are the percentages by which the overall wave heights in the harbor area were reduced by the installation of each of these plans as compared with those that obtained with the existing harbor conditions (base test) installed in the model.

Plan No.	Percent* Reduction of Overall Wave Heights Compared with Base Test Results
3	85
6A	86
8	81
8D	85
9A	85
10	87
11	88
12	87

* Only those wave heights at corresponding gage locations were used in computing the percentage values.

44. The percentages shown in the preceding tabulation reveal no great differences among the plans included therein; however, as previously noted, these values are based on numerical averages of wave heights in the harbor area. Therefore, they do not take into account the wave height criteria established for judging plan acceptability. By referring to the actual wave heights measured in the harbor area (tables 2-17), it can be seen that only plans 10, 11, and 12, all of which included the redesign of the northern corner of the harbor, approach the optimum with respect to wave heights in the harbor and the entrances. The tabulated wave heights also

show that plans 11 and 12 offer better protection to the harbor than plan 10 because of the increased wave absorption occasioned by the additional height of the stone perimeter revetment included in plans 11 and 12. Since either plan 11 or 12 would afford practically the same degree of protection to the harbor, plan 12 was selected as the optimum because of the savings in construction costs that would accrue by lowering the crown elevation of a portion of the detached breakwater. With the exception of one or two isolated cases, maximum wave heights with plan 12 installed met the specified wave height criteria (4.0 ft in the harbor entrances, 2.5 ft in the anchorage areas behind the detached breakwater, and 1.5 ft in the boat slip areas) for test waves from south 25° east, south 15° east, and south. For the larger test waves from south 16° west, the specified criteria were exceeded in several cases. However, these larger waves have a low frequency of occurrence, and most of the time, wave conditions in the harbor will be acceptable. Plan 12 differed from the originally proposed plan of improvement as follows: (a) the length of the south breakwater was increased by 400 ft; (b) the crown elevation of the detached breakwater was lowered from +16 to +14 ft between sta 0+00 and 6+50, from +20 to +16 ft between sta 6+50 and 20+00, and from +20 to +18 ft between sta 20+00 and 35+15; (c) the 1300-ft-long north breakwater and the 370-ft-long breakwater wing extending northward from the south breakwater were redesigned as revetted fills; (d) the north corner of the harbor was redesigned as a curved beach with a slope of 6:1; and (e) the top elevation of the interior harbor revetment was raised from +5 to +10 ft.

PART V: CONCLUSIONS

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

- a. The most critical shallow-water direction of wave approach with respect to extreme wave heights in the proposed harbor is south 16° west (the corresponding direction of deepwater wave approach is south 22°30' west).
- b. The proposed 1300-ft-long north breakwater and the 370-ft-long south breakwater wing can be replaced by revetted fills.
- c. At high-tide stages, the seaward perimeter (el +10) of the proposed landfill area between Smith Island and the existing Coast Guard Pier will be overtopped by waves larger than about 5 ft in height. Therefore, additional perimeter protection is needed in this area.
- d. The relatively high standing waves observed in the north end of the proposed harbor can be effectively reduced by the installation of a curved beach in this area.
- e. With respect to the degree of protection afforded and the cost of construction, the model configuration designated as plan 12 appears to be the optimum combination of the various elements of the improvement plans tested.
- f. Plan 12 offers a significant improvement over existing conditions in all sections of the proposed harbor and, except for a small percent of the time, wave conditions in the harbor will be acceptable. However, during periods of attack by exceptionally high storm waves from the south-southwest deepwater direction, wave heights in the northern part of the harbor will reach magnitudes of approximately 3 ft.
- g. Installation of the proposed breakwaters and other harbor structures will not adversely affect wave conditions at the Union Oil Company Pier.

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Table 1

Results of Refraction and Shoaling Analysis* of 22 Representative Storms Approaching Port San Luis During the Period 1899-1959 (Shallow-Water Depth = -60 ft)

Wave Period sec	Deepwater Wave Direction	Corresponding Shallow-Water Wave Direction	Deepwater Wave Height ft	Shallow-Water Wave Height ft	Selected Shallow-Water Test Direction	Selected Test Periods sec	Selected Test Heights ft
8.0	S45°E	S25°E	12 to 12.9	8.5	S25°E	9.0	8, 10
9.0	S45°E	S25°E	14 to 14.9	9.5			
7.5	S22°30'E	S15°E	9 to 10.9	7.5			
7.5	↓	↓	11 to 11.9	8.5			
8.5	↓	↓	14 to 14.9	10.5	S15°E	9.0	8, 12
9.5	↓	↓	14 to 14.9	10.5			
9.5	↓	↓	16 to 16.9	11.5			
9.5	↓	↓	16 to 16.9	11.5			
8.0	South	S01°E	11 to 11.9	10.5			
8.5	↓	↓	13 to 13.9	12.0			
8.5	↓	↓	13 to 13.9	12.0	South	10.0	8, 11, 14
9.5	↓	South	14 to 14.9	12.0			
9.5	↓	↓	16 to 16.9	13.5			
9.5	↓	↓	16 to 16.9	13.5			
9.0	S22°30'W	S17°W	15 to 15.9	13.0			
11.0	↓	S17°W	16 to 16.9	14.0			
13.0	↓	S16°W	17 to 17.9	16.0	S16°W	14.0	14, 16, 18
14.0	↓	↓	15 to 15.9	15.5			
14.0	↓	↓	18 to 18.9	18.0			
14.0	↓	↓	18 to 18.9	18.0			
11.0	S45°W**	S33°W	16 to 16.9	14.0			
14.0	S45°W	S25°W	17 to 17.9	15.5			

* Analysis conducted by the U. S. Army Engineer District, Los Angeles, using data from reference 7.

** Because refraction analysis showed that waves from this direction will be greatly reduced in height by the time they reach the harbor proper, no test waves were selected for this direction.

Table 2

Wave Heights (in feet) for Test Waves from South 25° East Test Direction for Base Test and Plans 1-4

Wave Gage No.	9-sec, 8-ft Test Wave Base Test	Plan 1	Plan 2	Plan 3	Plan 4	9-sec, 10-ft Test Wave Base Test	Plan 1	Plan 2	Plan 3	Plan 4
1	3.8	5.1	7.1	6.0	6.8	4.9	4.9	7.4	5.9	6.0
2	8.8	9.0	8.5	9.0	8.2	10.3	10.8	10.6	10.6	10.8
3	7.9	8.5	3.1	2.8	3.1	9.3	10.5	3.6	3.1	3.0
4	4.9	5.6	0.9	0.8	0.7	5.3	6.4	0.9	0.9	0.8
5	9.7	1.3	1.4	0.9	1.3	10.6	1.3	1.4	1.0	1.3
6	6.0	2.3	1.7	1.1	1.5	9.2	3.2	1.6	1.4	1.4
7	6.5	2.1	1.2	0.7	1.1	6.9	2.3	1.2	0.8	1.1
8	5.8	2.5	1.8	0.8	1.1	9.8	3.1	1.6	1.0	1.7
9	3.1	1.6	1.6	1.0	0.4	6.6	2.2	1.5	1.2	0.8
10	4.9	5.2	6.1	5.4	6.0	6.4	7.2	7.0	7.6	7.2
11	7.1	1.5	1.0	0.9	1.1	10.2	1.7	1.7	1.1	1.2
12	8.2	11.5	11.6	10.0	11.0	11.1	13.3	13.2	12.0	13.1
13		9.1	7.8	8.0	8.6		9.2	10.6	9.8	8.9
14	4.0	5.2	6.6	5.1	4.8	5.3	6.9	6.6	6.6	6.2
17	6.2	2.0	1.1	0.5	1.5	7.4	2.0	1.4	0.6	1.7

Note: Wave gage locations are shown in plates 3-7.

Table 3

Wave Heights (in feet) for Test Waves from South 15° East Test

Direction for Base Test and Plans 1-4

Wave Gage No.	9-sec, 8-ft Test Wave Base Test	Plan 1	Plan 2	Plan 3	Plan 4	9-sec, 12-ft Test Wave Base Test	Plan 1	Plan 2	Plan 3	Plan 4	9-sec, 20-ft Test Wave Base Test	Plan 1	Plan 2	Plan 3	Plan 4
1	6.2	5.5	6.6	6.1	7.1	9.1	8.1	9.6	7.8	8.2	11.6	14.3	10.4	11.1	12.2
2	7.8	6.3	7.0	7.4	7.6	10.6	11.2	11.3	11.5	12.5	19.0	23.6	17.5	15.5	14.3
3	8.2	7.3	2.1	1.7	2.2	10.0	10.3	2.2	1.9	3.1	12.9	12.5	3.5	4.5	5.4
4	5.3	5.6	0.9	1.0	0.8	7.1	8.5	1.0	1.3	1.4	14.0	11.7	1.8	3.0	3.4
5	8.4	0.9	0.8	0.7	0.8	9.9	1.3	1.0	0.9	1.0	18.4	2.2	1.9	2.0	2.0
6	5.3	2.0	0.9	0.8	1.2	6.1	3.2	1.2	1.6	1.3	11.4	3.4	2.1	1.3	2.0
7	13.6	1.9	1.2	1.2	0.9	14.4	2.4	1.3	1.8	1.3	18.7	3.6	1.6	1.9	1.5
8	7.8	1.7	0.7	0.8	0.7	14.1	2.9	0.8	1.0	1.0	14.6	3.3	1.7	1.5	1.8
9	9.2	1.3	1.1	1.8	0.8	11.4	2.8	1.9	1.9	1.1	17.5	3.5	2.8	2.6	1.4
10	5.4	5.3	5.9	4.6	3.6	14.4	13.5	14.3	11.8	12.5	15.2	17.3	16.2	14.4	16.0
11	11.5	1.5	1.8	1.6	1.2	12.1	2.9	1.7	1.4	1.3	13.4	3.4	1.6	1.7	1.6
12	8.6	5.1	5.3	5.5	5.9	11.3	5.7	5.3	5.5	6.2	20.0	18.6	16.5	16.7	15.6
13	8.3	5.5	6.4	7.1	6.5	9.2	10.5	11.0	10.0	9.8	15.4	11.2	17.3	18.0	13.5
14	7.1	6.2	7.0	6.4	4.9	6.4	6.7	7.1	6.3	6.5	6.1	7.8	7.2	5.8	6.3
17	10.7	1.3	1.8	0.3	1.5	13.9	2.2	2.5	0.8	1.8	13.6	3.8	3.2	0.8	1.7

Note: Wave gage locations are shown in plates 3-7.

Table 4

Wave Heights (in feet) for Test Waves from South Test Direction

for Base Test and Plans 1-4

Wave Gage No.	10-sec, 8-ft Test Wave					10-sec, 11-ft Test Wave					10-sec, 14-ft Test Wave				
	Base Test	Plan 1	Plan 2	Plan 3	Plan 4	Base Test	Plan 1	Plan 2	Plan 3	Plan 4	Base Test	Plan 1	Plan 2	Plan 3	Plan 4
1	5.5	5.3	4.3	4.4	4.1	6.7	7.5	9.0	7.3	6.2	10.2	6.7	9.3	8.2	7.4
2	5.6	4.6	3.8	4.6	4.5	8.5	7.1	6.2	7.0	7.2	11.7	9.1	8.7	10.0	8.1
3	6.8	7.6	1.6	1.0	1.9	8.2	9.5	1.9	1.4	2.0	12.6	16.0	2.4	3.0	2.6
4	3.3	4.2	1.0	0.6	0.6	8.1	8.4	1.5	0.8	0.8	8.9	10.9	1.6	1.0	1.2
5	6.7	1.8	0.8	0.8	0.8	7.9	2.0	0.9	0.9	1.2	10.8	2.4	0.9	1.1	1.2
6	4.0	2.7	1.4	0.8	0.6	7.6	2.0	1.0	1.1	0.9	7.6	4.0	1.3	1.8	1.0
7	8.1	1.5	0.8	0.8	0.6	11.6	2.5	0.9	1.0	0.9	11.9	2.7	1.4	1.2	1.4
8	4.3	1.4	1.0	0.8	0.6	5.6	2.0	1.0	1.5	0.8	8.4	4.3	1.4	1.3	0.8
9	9.0	1.8	1.5	1.6	0.6	14.2	2.6	1.4	1.9	1.0	15.9	2.9	1.8	2.0	1.3
10	10.0	9.8	10.5	10.8	10.7	14.4	12.5	12.2	13.2	13.4	14.4	16.9	16.9	15.1	16.6
11	6.9	2.3	1.1	0.6	1.1	8.3	2.1	2.2	1.3	1.6	13.9	4.8	2.6	1.7	1.9
12	7.3	7.2	5.9	5.5	5.4	8.7	11.1	9.6	10.4	8.8	13.0	14.3	12.9	13.3	13.9
13		6.1	8.9	8.2	8.3		5.6	10.8	8.1	8.8		10.0	12.0	12.6	13.3
14	5.4	4.4	4.0	3.6	4.0	7.8	6.4	7.3	6.5	4.7	8.0	6.1	6.2	6.5	5.1
17	9.5	1.8	2.5	0.4	1.1	12.0	2.5	2.5	0.7	1.8	14.9	3.4	2.9	1.0	2.0

Note: Wave gage locations are shown in plates 3-7.

Table 5

Wave Heights (in feet) for Test Waves from South 16° West Test

Direction for Base Test and Plans 1-4

Wave Gage No.	14-sec, 14-ft Test Wave					14-sec, 16-ft Test Wave					14-sec, 18-ft Test Wave				
	Base Test	Plan 1	Plan 2	Plan 3	Plan 4	Base Test	Plan 1	Plan 2	Plan 3	Plan 4	Base Test	Plan 1	Plan 2	Plan 3	Plan 4
1	5.8	7.2	7.0	6.0	7.8	6.5	6.6	8.5	7.2	7.8	7.1	7.4	11.5	9.6	12.6
2	10.4	11.2	10.9	11.6	11.6	16.4	13.5	13.4	10.8	13.5	10.2	9.1	10.5	9.7	9.9
3	10.7	9.4	3.0	3.7	4.1	8.0	11.3	3.1	2.8	3.5	11.4	10.7	4.5	4.5	3.3
4	9.4	10.3	1.8	2.0	1.8	7.9	8.5	1.8	1.6	1.7	8.1	8.6	2.1	1.7	1.8
5	14.3	1.2	1.4	1.2	1.0	17.3	1.8	1.8	1.4	1.4	15.2	1.4	1.5	1.1	1.4
6	9.4	4.3	2.6	2.2	2.4	10.2	4.2	2.4	2.1	2.3	11.9	3.7	2.3	1.8	2.0
7	14.8	3.0	1.6	1.6	1.3	16.6	2.5	2.1	1.6	1.9	18.0	2.2	1.6	1.7	1.3
8	8.2	2.9	1.5	1.2	0.8	11.3	3.0	1.7	2.4	1.3	15.6	3.3	1.9	2.3	1.8
9	13.7	2.8	2.7	3.6	2.1	16.2	3.0	3.2	3.7	2.4	18.0	3.2	3.0	3.6	2.6
10	14.8	12.0	10.5	11.9	12.5	17.2	12.0	12.4	12.3	13.6	17.4	14.5	14.0	13.6	18.0
11	16.3	3.4	2.3	2.2	1.7	19.2	2.7	2.0	3.5	2.3	16.5	3.7	2.3	3.2	2.5
12	11.0	10.5	9.0	9.4	9.6	17.1	15.9	16.0	11.4	15.4	20.4	12.4	11.4	12.4	14.4
13		10.4	10.4	11.4	10.7		10.8	9.5	11.6	9.5		10.5	10.7	13.2	10.8
14	6.7	6.2	6.0	6.9	6.6	7.1	7.2	5.7	4.8	5.1	7.2	5.6	4.1	6.9	5.7
17	13.3	3.6	3.0	1.1	2.3	11.8	2.9	2.4	0.7	2.3	14.6	3.5	2.9	1.3	2.9

Note: Wave gage locations are shown in plates 3-7.

Table 6

Wave Heights (in feet) for Test Waves from South 16° West Test Direction for Plans 3, 3A, and 3B

Wave Gage No.	14-sec, 14-ft Test Wave			14-sec, 16-ft Test Wave			14-sec, 18-ft Test Wave		
	Plan 3	Plan 3A	Plan 3B	Plan 3	Plan 3A	Plan 3B	Plan 3	Plan 3A	Plan 3B
1	6.0	7.5	7.7	7.2	6.3	5.9	9.6	8.4	8.5
2	11.6	11.9	11.3	10.8	14.0	13.5	9.7	11.0	11.6
3	3.7	3.3	2.9	2.8	3.3	3.0	4.5	3.2	3.0
4	2.0	1.7	1.2	1.6	1.4	1.3	1.7	1.6	1.5
5	1.2	1.3	1.2	1.4	1.4	1.2	1.1	1.4	1.3
6	2.2	2.2	2.3	2.1	2.2	2.1	1.8	1.8	1.5
7	1.6	1.4	1.5	1.6	1.8	1.8	1.7	1.6	1.9
8	1.2	1.6	1.7	2.4	2.1	1.7	2.3	2.0	1.9
9	3.6	3.5	3.6	3.7	3.1	3.2	3.6	4.3	3.3
10	11.9	11.7	11.4	12.3	14.2	15.7	13.6	14.7	16.9
11	2.2	2.5	1.8	3.5	3.2	2.5	3.2	3.2	2.7
12	9.4	10.4	10.2	11.4	13.4	13.4	12.4	15.8	14.2
13	11.4	14.0	12.2	11.6	12.4	10.7	13.2	10.5	10.2
14	6.9	5.4	7.9	4.8	5.1	8.5	6.9	4.8	8.0
17	1.1	0.8	0.7	0.7	0.8	0.8	1.3	0.7	0.7
23	2.3	3.0	2.4	2.2	2.9	2.5	1.7	2.8	1.9
24	1.7	1.6	1.4	1.5	1.9	1.0	1.6	1.7	1.0
25	0.9	0.9	1.0	1.4	1.4	1.2	2.0	1.9	1.7
26	3.2	3.2	2.7	3.4	3.7	3.0	3.5	3.6	3.1
27	2.7	2.2	2.1	2.0	2.2	2.3	2.7	2.1	2.0
28	1.0	1.5	1.5	1.5	1.7	1.6	2.0	2.3	1.7

Note: Wave gage locations are shown in plate 6.

Table 7

Wave Heights (in feet) for Plans 3C and 3D

Wave Gage No.	South 15° East Test Direction						South 16° West Test Direction					
	9-sec, 8-ft Test Wave		9-sec, 12-ft Test Wave		9-sec, 20-ft Test Wave		14-sec, 14-ft Test Wave		14-sec, 16-ft Test Wave		14-sec, 18-ft Test Wave	
	Plan 3C	Plan 3D	Plan 3C	Plan 3D	Plan 3C	Plan 3D	Plan 3C	Plan 3D	Plan 3C	Plan 3D	Plan 3C	Plan 3D
3	1.6	3.2	2.1	4.0	4.7	8.7	2.1	4.5	2.3	4.3	3.0	5.9
4	1.1	1.7	1.7	2.6	3.7	4.9	1.7	3.9	1.6	3.2	1.8	3.5
5	0.9	0.9	1.1	0.9	3.3	2.1	1.6	1.6	1.6	1.6	1.2	1.5
6	0.8	1.1	1.5	1.4	2.1	2.2	2.3	2.5	2.4	2.0	2.0	2.4
7	1.2	1.3	1.3	1.7	2.0	2.2	1.9	1.5	1.8	1.7	2.4	2.4
8	1.2	0.9	1.0	1.1	1.9	1.6	1.6	1.6	1.6	1.7	1.8	1.6
9	1.9	1.1	2.2	1.7	2.7	2.4	2.5	3.5	3.2	3.8	3.2	3.7
11	1.3	1.8	1.4	1.6	2.3	1.5	1.9	1.7	2.1	1.8	2.1	2.3
17	0.4	0.7	0.9	0.8	0.8	1.2	1.0	1.4	1.1	1.2	0.9	0.9
23	1.1	0.5	1.2	0.9	1.7	1.7	2.3	2.9	2.0	2.9	1.2	2.6
24	0.7	0.9	1.1	1.3	1.5	1.6	2.2	1.5	2.2	1.4	1.6	1.3
25	2.5	1.6	2.8	1.8	3.1	2.3	2.0	1.1	1.8	0.9	1.7	1.5
26	1.5	1.3	2.4	2.2	2.2	1.9	3.5	3.3	3.9	3.5	5.0	3.1
27	1.4	1.3	2.1	1.7	1.8	2.2	2.5	3.8	2.2	3.5	2.7	3.5
28	1.4	1.1	1.4	1.6	1.8	1.6	2.0	2.5	2.0	2.0	2.5	2.1

Note: Wave gage locations are shown in plate 6.

Table 8

Wave Heights (in feet) for Plans 5 and 5A

Wave Gage No.	South 15° East Test Direction: 9-sec, 8-ft Test Wave, Plan 5	9-sec, 8-ft Test Wave, Plan 5A	9-sec, 12-ft Test Wave, Plan 5	9-sec, 12-ft Test Wave, Plan 5A	9-sec, 20-ft Test Wave, Plan 5	9-sec, 20-ft Test Wave, Plan 5A
4	1.1	0.6	1.6	1.1	1.8	2.4
5	0.5	0.6	0.7	0.9	1.7	2.3
6	1.1	0.8	1.6	1.2	1.6	2.1
7	0.9	1.2	1.5	1.5	1.7	1.9
8	0.7	0.9	1.2	1.2	1.3	2.1
9	1.7	4.0	2.1	4.7	2.4	5.6
10	6.8	6.7	12.7	13.8	13.6	17.7
11	1.3	1.9	1.6	2.7	1.3	2.8
17	0.7	0.8	0.8	1.1	0.7	1.2
23	0.9	1.3	0.8	1.8	1.1	1.7
24	1.0	0.8	1.1	1.1	1.5	2.0
25	1.7	2.4	2.4	3.2	2.6	4.2
26	1.0	1.1	1.6	1.5	1.4	2.4
27	1.6	1.4	1.0	1.8	1.8	1.9
28	0.8	1.3	1.4	1.6	1.3	2.8

Wave Gage No.	South 16° West Test Direction: 14-sec, 14-ft Test Wave, Plan 5	14-sec, 14-ft Test Wave, Plan 5A	14-sec, 16-ft Test Wave, Plan 5	14-sec, 16-ft Test Wave, Plan 5A	14-sec, 18-ft Test Wave, Plan 5	14-sec, 18-ft Test Wave, Plan 5A
4	1.9	1.6	1.6	1.4	1.9	1.7
5	1.2	1.3	1.7	1.7	1.5	1.6
6	2.8	2.8	3.0	2.6	2.3	2.8
7	1.2	1.1	1.5	1.1	1.4	1.5
8	1.4	2.1	1.7	1.8	2.1	2.1
9	2.4	4.5	3.3	4.4	2.9	4.5
10	13.0	14.1	14.6	14.6	15.4	15.8
11	1.5	2.1	2.4	2.3	2.5	2.3
17	1.2	1.2	1.0	1.3	0.9	1.5
23	2.4	1.7	2.7	2.1	2.5	2.0
24	2.0	2.5	2.5	2.7	2.0	1.6
25	1.4	2.2	1.4	2.4	1.1	1.7
26	4.1	3.5	4.3	4.8	4.4	3.7
27	2.9	2.9	3.2	3.2	2.7	2.4
28	2.1	3.4	2.3	3.5	2.3	3.0

Note: Wave gage locations are shown in plate 8.

Table 9

Wave Heights (in feet) for Plans 6 and 6A

Wave Gage No.	South 15° East Test Direction						South 16° West Test Direction					
	9-sec, 8-ft Test Wave		9-sec, 12-ft Test Wave		9-sec, 20-ft Test Wave		14-sec, 14-ft Test Wave		14-sec, 16-ft Test Wave		14-sec, 18-ft Test Wave	
	Plan 6	Plan 6A	Plan 6	Plan 6A	Plan 6	Plan 6A	Plan 6	Plan 6A	Plan 6	Plan 6A	Plan 6	Plan 6A
4	1.1	1.0	1.7	1.3	2.1	1.8	1.9	2.2	1.6	1.7	1.7	1.6
5	0.8	0.8	1.4	1.2	2.4	2.4	1.6	1.6	1.6	1.9	1.4	1.5
6	0.7	1.0	1.4	1.2	2.0	2.6	2.7	2.5	2.4	2.5	2.1	1.2
7	1.3	1.3	1.4	1.2	1.7	1.8	1.1	1.3	1.5	1.5	1.7	2.0
8	1.2	1.2	1.1	1.0	1.5	1.9	1.5	1.3	1.9	1.8	2.2	1.9
9	2.2	1.1	2.5	2.4	2.1	2.2	2.3	3.2	3.1	3.9	3.3	4.0
10	5.4	5.4	12.4	13.6	13.8	14.0	11.4	10.1	14.0	12.4	15.5	14.8
11	1.2	1.6	1.3	1.2	1.7	1.7	1.4	1.6	1.9	2.2	2.2	2.3
17	0.3	0.5	0.7	0.5	0.9	0.9	1.0	0.9	0.9	0.9	0.9	0.9
23	0.7	0.5	1.2	1.2	2.3	2.3	2.8	2.4	2.3	2.2	1.7	1.9
24	0.8	0.7	1.0	1.2	1.6	1.6	2.6	2.3	1.8	1.8	1.6	2.2
25	2.0	2.6	3.2	2.3	2.9	2.8	1.2	0.9	1.1	1.3	1.3	1.7
26	1.2	1.0	1.3	1.5	2.0	2.0	3.6	3.7	3.0	3.5	3.3	3.5
27	1.4	1.7	1.8	2.0	1.8	2.0	2.7	3.0	2.7	2.8	2.6	2.6
28	0.9	1.4	1.2	1.3	1.6	2.2	1.3	1.4	1.5	1.4	2.0	1.9

Note: Wave gage locations are shown in plate 8.

Table 10

Wave Heights (in feet) for Plans 7 and 8

Wave Gage No.	South 25° East Test Direction				South 15° East Test Direction					
	9-sec, 8-ft Test Wave		9-sec, 10-ft Test Wave		9-sec, 8-ft Test Wave		9-sec, 12-ft Test Wave		9-sec, 20-ft Test Wave	
	Plan 7	Plan 8	Plan 7	Plan 8	Plan 7	Plan 8	Plan 7	Plan 8	Plan 7	Plan 8
3	2.0	2.3	2.2	2.5	1.7	1.8	3.0	3.3	4.6	5.3
4	1.2	1.2	1.3	1.1	1.1	1.3	1.7	1.8	2.5	3.0
5	0.8	1.9	1.0	2.3	0.9	0.9	1.4	1.3	2.9	3.2
6	1.2	1.1	1.4	1.7	0.8	0.5	1.5	1.3	2.6	3.6
7	1.1	1.7	1.4	1.8	1.4	1.5	1.8	1.8	2.1	2.3
8	0.8	0.5	1.1	0.9	1.7	2.8	1.8	3.6	2.0	1.9
9	0.8	0.6	0.9	0.9	1.6	0.9	1.4	1.1	1.7	2.0
11	1.9	1.9	1.9	2.1	2.1	2.3	2.5	2.9	3.1	2.8
23	0.8	0.5	1.0	0.7	0.6	0.7	1.3	0.7	2.2	1.7
24	1.1	1.4	1.2	1.5	1.1	1.3	1.4	1.7	1.6	1.7
28	0.6	0.7	0.6	0.7	0.6	1.3	1.4	1.8	1.2	1.7
29	0.4		0.5		0.7		0.8		0.7	
30	0.3	0.7	0.4	1.0	1.1	1.2	1.1	1.5	1.4	1.8
31	0.3	0.5	0.5	0.6	0.6	0.4	1.0	0.7	0.9	0.9
32	0.7	0.6	1.0	1.2	0.5	0.7	1.2	0.9	2.2	2.7
33		0.5		0.7		0.7		1.0		1.7

Wave Gage No.	South Test Direction						South 16° West Test Direction							
	10-sec, 8-ft Test Wave		10-sec, 11-ft Test Wave		10-sec, 14-ft Test Wave		14-sec, 8-ft Test Wave	14-sec, 11-ft Test Wave	14-sec, 14-ft Test Wave		14-sec, 16-ft Test Wave		14-sec, 18-ft Test Wave	
	Plan 7	Plan 8	Plan 7	Plan 8	Plan 7	Plan 8	Plan 8	Plan 8	Plan 7	Plan 8	Plan 7	Plan 8	Plan 7	Plan 8
3	1.8	1.9	2.4	2.6	2.4	3.2	2.1	3.5	3.1	4.6	3.1	4.7	3.0	4.4
4	0.4	1.5	0.8	1.3	1.1	1.5	0.7	1.2	2.5	1.6	2.4	1.3	1.9	1.5
5	0.8	1.5	1.0	1.8	1.3	1.7	1.3	1.4	1.4	1.6	1.4	2.0	1.4	1.7
6	0.7	1.1	1.1	1.5	1.5	1.6	0.8	1.6	2.3	2.0	2.3	1.8	2.1	1.6
7	0.6	1.0	0.8	1.1	1.1	1.4	0.7	0.9	1.4	1.3	1.6	1.7	1.9	2.2
8	0.6	0.6	0.7	0.8	1.1	1.2	1.0	1.9	1.5	2.1	1.6	2.1	2.0	2.5
9	1.7	1.9	2.0	2.0	2.3	2.8	2.8	3.5	3.0	4.1	3.5	4.3	3.8	5.3
11	0.7	1.6	1.6	2.0	2.2	2.1	1.0	1.3	1.8	1.7	1.9	1.9	1.5	2.2
23	0.8	0.7	1.1	0.6	1.2	0.7	0.9	1.6	1.4	1.9	1.8	1.8	2.2	1.6
24	0.5	1.1	1.0	1.0	1.5	1.2	1.0	1.2	1.9	1.9	2.5	2.3	2.9	2.4
28	1.5	2.0	2.8	2.3	3.1	2.5	0.9	1.6	1.8	2.6	2.2	3.1	3.4	4.4
29	0.5		0.6		0.7				1.6		1.9		2.4	
30	1.2	1.3	1.5	1.6	1.4	2.0	1.4	1.6	1.8	1.8	2.2	2.4	2.6	3.0
31	0.6	0.8	0.9	1.0	1.0	1.2	3.3	4.5	4.4	5.2	4.8	5.0	3.9	5.1
32	1.3	0.7	1.3	0.7	1.2	1.1	0.5	0.6	0.7	0.6	0.7	0.7	0.9	0.9
33		0.6		0.8		1.3	1.9	2.4		2.5		2.9		2.9

Note: Wave gage locations are shown in plates 9 and 10.

Table 11

Wave Heights (in feet) for Plan 8 with Two Still-Water Levels

Wave Gage No.	South 15° East Test Direction: 9-sec, 8-ft Test Wave, swl +6.0	swl 0.0	9-sec, 12-ft Test Wave, swl +6.0	swl 0.0	9-sec, 20-ft Test Wave, swl +6.0	swl 0.0	South 16° West Test Direction: 14-sec, 8-ft Test Wave, swl +6.0	swl 0.0	14-sec, 11-ft Test Wave, swl +6.0	swl 0.0	14-sec, 14-ft Test Wave, swl +6.0	swl 0.0	14-sec, 16-ft Test Wave, swl +6.0	swl 0.0	14-sec, 18-ft Test Wave, swl +6.0	swl 0.0
3	1.8	1.3	3.3	1.8	5.3	3.0	2.1	1.3	3.5	1.7	4.6	1.7	4.7	2.3	4.4	2.3
4	1.3	1.3	1.8	1.5	3.0	1.6	0.7	0.3	1.2	0.4	1.6	0.4	1.3	0.5	1.5	0.5
5	0.9	0.5	1.3	0.8	3.2	0.9	1.3	0.4	1.4	0.5	1.6	0.8	2.0	0.9	1.7	0.8
6	0.5	0.5	1.3	0.7	3.6	0.8	0.8	0.8	1.6	0.8	2.0	1.1	1.8	1.2	1.6	1.2
7	1.5	0.5	1.8	0.6	2.3	0.9	0.7	0.6	0.9	0.7	1.3	0.8	1.7	0.8	2.2	1.0
8	2.8	0.9	3.6	0.8	1.9	0.7	1.0	1.0	1.9	1.4	2.1	1.6	2.1	1.8	2.5	1.7
9	0.9	0.5	1.1	1.3	2.0	1.2	2.8	1.5	3.5	1.7	4.1	1.8	4.3	2.1	5.3	2.7
11	2.3	1.1	2.9	1.3	2.8	1.1	1.0	0.4	1.3	0.5	1.7	0.7	1.9	0.8	2.2	0.7
23	0.7	0.4	0.7	0.6	1.7	0.8	0.9	0.8	1.6	1.0	1.9	1.2	1.8	1.3	1.6	1.1
24	1.3	0.6	1.7	0.8	1.7	0.7	1.0	1.2	1.2	1.3	1.9	1.7	2.3	1.7	2.4	1.6
28	1.3	0.6	1.8	1.0	1.7	1.0	0.9	0.6	1.6	0.9	2.6	1.3	3.1	1.5	4.4	1.4
30	1.2	0.5	1.5	0.9	1.8	0.7	1.4	0.5	1.6	0.9	1.8	1.2	2.4	1.4	3.0	1.8
31	0.4	0.3	0.7	0.3	0.9	0.4	3.3	1.3	4.5	1.9	5.2	2.3	5.0	2.5	5.1	2.5
32	0.7	0.5	0.9	0.6	2.7	1.4	0.5	0.4	0.6	0.4	0.6	0.5	0.7	0.6	0.9	0.6
33	0.7	0.4	1.0	0.5	1.7	1.0	1.9	1.1	2.4	1.0	2.5	1.3	2.9	1.3	2.9	1.4

Note: Wave gage locations are shown in plate 10.

Table 12

Wave Heights (in feet) for Test Waves from South 16° West Test Direction for Plans 8A and 8B

Wave Gage No.	14-sec, 8-ft Test Wave		14-sec, 11-ft Test Wave		14-sec, 14-ft Test Wave		14-sec, 16-ft Test Wave		14-sec, 18-ft Test Wave	
	Plan 8A	Plan 8B	Plan 8A	Plan 8B	Plan 8A	Plan 8B	Plan 8A	Plan 8B	Plan 8A	Plan 8B
3	1.5	1.5	2.6	2.2	3.6	3.4	3.3	4.0	2.9	3.5
4	0.4	0.5	0.6	0.6	0.9	0.8	1.0	0.8	0.7	0.7
5	1.0	1.1	1.2	1.3	1.6	1.5	1.6	1.7	1.5	1.4
6	0.5	0.5	0.8	0.9	1.3	1.3	1.3	1.3	1.2	1.2
7	0.5	0.6	1.0	0.8	1.3	1.2	1.6	1.6	1.6	1.6
8	1.0	1.1	1.4	1.3	1.7	1.6	1.9	1.9	2.2	2.1
9	2.2	2.3	3.4	3.1	3.7	3.6	4.2	3.8	4.3	4.5
11	0.6	0.6	0.7	1.0	1.1	1.2	1.5	1.3	1.7	1.9
23	0.6	0.6	1.1	1.0	1.5	1.5	1.5	1.5	1.5	1.2
24	1.0	1.0	0.8	0.9	1.3	1.1	1.6	1.8	1.7	1.9
28	1.0	0.9	1.5	1.1	2.4	1.8	3.7	2.5	3.9	3.7
30	1.0	1.1	1.4	1.2	1.8	1.2	2.7	2.3	3.0	2.6
31	2.6	2.9	3.8	4.1	5.0	5.1	4.9	5.1	3.8	4.0
32	0.5	0.5	0.6	0.6	0.8	0.6	0.8	0.9	0.7	1.0
33	2.0	2.2	2.3	2.4	2.2	2.4	1.8	2.2	1.7	1.5

Note: Wave gage locations are shown in plate 10.

Table 13

Wave Heights (in feet) for Test Waves from South 16° West Test Direction for Plans 8C, 8D, and 8G

Wave Gage No.	14-sec, 8-ft Test Wave			14-sec, 11-ft Test Wave			14-sec, 14-ft Test Wave			14-sec, 16-ft Test Wave			14-sec, 18-ft Test Wave		
	Plan 8C	Plan 8D	Plan 8G	Plan 8C	Plan 8D	Plan 8G	Plan 8C	Plan 8D	Plan 8G	Plan 8C	Plan 8D	Plan 8G	Plan 8C	Plan 8D	Plan 8G
3	1.3	1.3	1.0	1.4	2.1	1.5	1.9	2.8	2.0	2.3	3.6	2.4	2.6	3.7	2.4
4	0.6	0.5	0.6	0.7	0.7	0.8	0.9	0.8	0.7	1.0	1.0	0.8	0.9	1.0	0.9
5	0.9	0.6	0.4	1.0	0.7	0.6	1.0	0.7	0.7	1.1	0.9	0.6	1.3	1.1	0.6
6	0.5	1.1	1.1	1.4	1.7	1.8	2.2	2.4	1.9	1.6	2.0	1.8	1.6	1.6	1.8
7	0.5	0.9	0.7	0.8	0.9	0.8	1.2	1.1	0.9	1.7	1.5	1.3	2.0	1.9	1.6
8	0.9	1.0	0.8	1.1	1.4	1.1	1.7	2.0	1.5	2.1	2.1	1.9	2.3	2.4	1.9
9	1.9	1.8	1.8	2.3	2.1	2.2	3.2	3.4	2.8	4.0	3.8	4.3	4.7	4.6	4.4
11	0.6	0.5	0.6	0.7	1.0	0.9	1.0	1.4	1.5	1.4	1.6	1.5	1.9	1.6	1.4
23	0.9	1.0	0.9	1.3	1.3	1.0	1.5	1.5	0.9	1.7	1.6	1.1	1.4	1.5	1.2
24	0.8	0.7	0.8	0.8	0.9	1.2	1.1	1.5	1.8	1.4	1.5	1.7	1.8	1.5	1.4
28	0.8	0.7	0.6	1.2	1.2	1.4	1.9	1.6	2.0	2.4	2.4	2.4	2.8	2.9	3.1
30	1.5	1.4	1.0	1.8	1.2	0.8	2.2	1.3	1.0	3.0	1.9	1.0	3.1	1.9	1.2
31	3.5	1.9	2.0	4.4	2.6	2.9	5.0	3.1	3.5	4.9	3.5	4.0	5.0	3.6	4.3
32	0.5	0.4	0.3	0.6	0.5	0.4	0.7	0.6	0.5	0.8	0.8	0.7	0.8	0.9	0.6
33	1.4	1.1	1.1	1.3	1.3	1.2	1.4	2.0	1.5	1.9	1.8	1.7	2.5	2.3	1.4

Note: Wave gage locations are shown in plate 10.

Table 14

Wave Heights (in feet) for Test Waves from South 16° West Test Direction for Plans 8E and 8F

Wave Gage No.	14-sec, 8-ft Test Wave Plan 8E	14-sec, 8-ft Test Wave Plan 8F	14-sec, 11-ft Test Wave Plan 8E	14-sec, 11-ft Test Wave Plan 8F	14-sec, 14-ft Test Wave Plan 8E	14-sec, 14-ft Test Wave Plan 8F	14-sec, 16-ft Test Wave Plan 8E	14-sec, 16-ft Test Wave Plan 8F	14-sec, 18-ft Test Wave Plan 8E	14-sec, 18-ft Test Wave Plan 8F
3	1.3	1.0	1.8	1.6	2.1	2.2	2.4	2.9	2.5	3.0
4	0.6	0.4	0.7	0.6	0.8	0.6	0.9	0.8	0.9	0.8
5	0.8	0.5	0.8	0.6	0.9	0.6	1.0	1.0	1.3	1.1
6	0.8	0.9	1.5	1.5	2.0	2.1	1.4	1.5	1.8	1.2
7	0.6	0.8	0.9	1.0	1.2	1.0	1.8	1.4	1.7	1.6
8	1.0	0.7	1.3	1.2	1.7	1.7	1.9	2.0	2.1	2.1
9	1.9	1.6	2.4	2.3	3.3	3.1	3.9	3.6	3.8	4.2
11	0.6	0.4	0.6	0.8	1.2	1.1	1.5	1.3	1.7	1.6
23	0.9	0.8	1.2	1.1	1.5	1.3	1.6	1.6	1.5	1.4
24	0.7	0.6	0.8	0.9	1.4	1.6	1.1	1.4	1.8	1.4
28	1.0	0.6	1.2	1.3	1.9	1.8	2.2	2.3	2.8	3.0
30	1.3	1.2	1.5	1.2	1.8	1.5	2.3	2.0	2.5	1.8
31	3.6	2.6	4.5	3.5	4.9	3.9	5.1	4.0	4.4	4.0
32	0.4	0.3	0.5	0.4	0.7	0.4	0.6	0.7	0.6	0.6
33	1.3	0.9	1.1	1.2	1.6	1.8	2.3	2.0	2.4	2.2

Note: Wave gage locations are shown in plate 10.

Table 15

Wave Heights (in feet) for Test Waves from South 16° West Test Direction for Plans 9 and 9A

Wave Gage No.	14-sec, 8-ft Test Wave		14-sec, 11-ft Test Wave		14-sec, 14-ft Test Wave		14-sec, 16-ft Test Wave		14-sec, 18-ft Test Wave	
	Plan 9	Plan 9A	Plan 9	Plan 9A	Plan 9	Plan 9A	Plan 9	Plan 9A	Plan 9	Plan 9A
3	1.0	0.9	2.2	1.7	2.7	2.5	3.3	2.6	3.5	3.3
4	0.6	0.6	0.8	0.7	0.8	1.0	1.0	0.9	1.1	1.0
5	0.5	0.5	0.6	0.7	0.8	0.8	1.1	1.0	1.4	1.1
6	1.1	1.0	1.9	1.6	2.2	2.3	1.7	2.3	1.8	1.6
7	0.7	0.8	1.1	0.9	1.3	1.2	1.8	1.3	2.0	1.9
8	0.8	0.8	1.3	1.3	1.9	1.8	2.4	1.9	2.3	2.1
9	1.5	1.7	2.5	2.4	3.0	3.4	3.7	3.3	3.9	4.5
11	0.5	0.4	1.0	0.9	1.4	1.5	1.8	1.4	1.9	1.6
23	0.9	0.9	1.2	1.1	1.1	1.3	1.2	1.4	1.3	1.1
24	0.6	0.6	1.1	1.0	1.7	1.7	1.6	1.9	1.7	1.4
28	0.7	0.6	1.2	1.4	2.1	1.9	2.8	2.1	3.1	3.1
30	1.4	1.6	1.4	1.6	1.7	1.6	2.5	2.3	2.7	2.1
31	2.8	2.5	3.9	3.6	4.7	4.3	4.8	4.7	5.1	4.8
32	0.4	0.3	0.6	0.4	0.6	0.5	0.7	0.6	0.6	0.8
33	0.8	1.0	1.4	1.1	1.6	1.6	1.6	1.7	1.6	1.6

Note: Wave gage locations are shown in plate 11.

Table 16

Wave Heights (in feet) for Test Waves from South 16° West Test Direction for Plans 10, 11, and 12

Wave Gage No.	14-sec, 8-ft Test Wave			14-sec, 11-ft Test Wave			14-sec, 14-ft Test Wave			14-sec, 16-ft Test Wave			14-sec, 18-ft Test Wave		
	Plan 10	Plan 11	Plan 12	Plan 10	Plan 11	Plan 12	Plan 10	Plan 11	Plan 12	Plan 10	Plan 11	Plan 12	Plan 10	Plan 11	Plan 12
3	1.0	0.9	1.0	2.2	1.8	1.7	2.5	2.5	2.5	3.1	2.0	2.8	3.2	1.8	2.7
4	0.8	0.7	0.7	1.0	0.9	1.0	1.0	1.0	1.1	0.9	1.2	1.0	1.0	1.1	1.1
5	0.4	0.4	0.5	0.5	0.7	0.5	0.6	0.5	0.6	1.0	0.9	1.0	1.2	1.2	1.3
6	0.7	0.8	1.0	1.2	1.1	1.4	2.0	1.3	1.9	1.5	1.2	1.9	1.3	1.4	1.3
7	0.5	0.6	0.9	0.9	0.6	1.0	1.0	0.9	0.9	1.3	1.2	1.3	1.9	1.5	1.6
8	0.5	0.5	0.5	0.5	0.5	0.9	1.1	1.0	1.0	1.2	1.4	1.3	1.7	1.8	1.5
9	1.7	1.0	1.6	2.2	1.9	2.3	3.4	3.0	2.9	3.5	3.7	3.2	3.5	3.8	4.4
11	0.5	0.5	0.6	0.9	0.8	0.8	1.4	1.0	1.3	1.4	1.3	1.3	1.9	1.6	1.6
23	0.8	0.8	0.8	1.2	1.0	1.0	1.1	1.1	1.5	1.3	1.0	1.4	1.2	1.5	1.7
24	0.7	0.6	0.5	0.7	0.7	0.8	1.2	1.1	1.2	1.4	1.3	1.5	2.0	1.7	1.4
28	0.7	0.9	0.9	1.1	1.0	1.1	1.1	1.2	1.5	2.0	1.6	2.0	2.5	2.1	2.1
30	1.1	0.8	1.0	1.2	1.2	1.7	2.2	2.2	2.6	2.7	2.5	2.6	3.5	3.0	2.5
32	0.2	0.2	0.3	0.3	0.2	0.4	0.4	0.3	0.4	0.5	0.3	0.6	0.6	0.5	0.5
33	0.8	0.7	0.9	1.0	0.9	1.0	1.7	1.5	1.2	1.5	2.0	2.0	1.2	1.9	2.6
34	1.1	1.5	1.5	1.5	1.9	2.0	1.6	2.2	2.6	1.7	2.5	2.7	2.0	2.8	2.5

Note: Wave gage locations are shown in plate 12.

Table 17

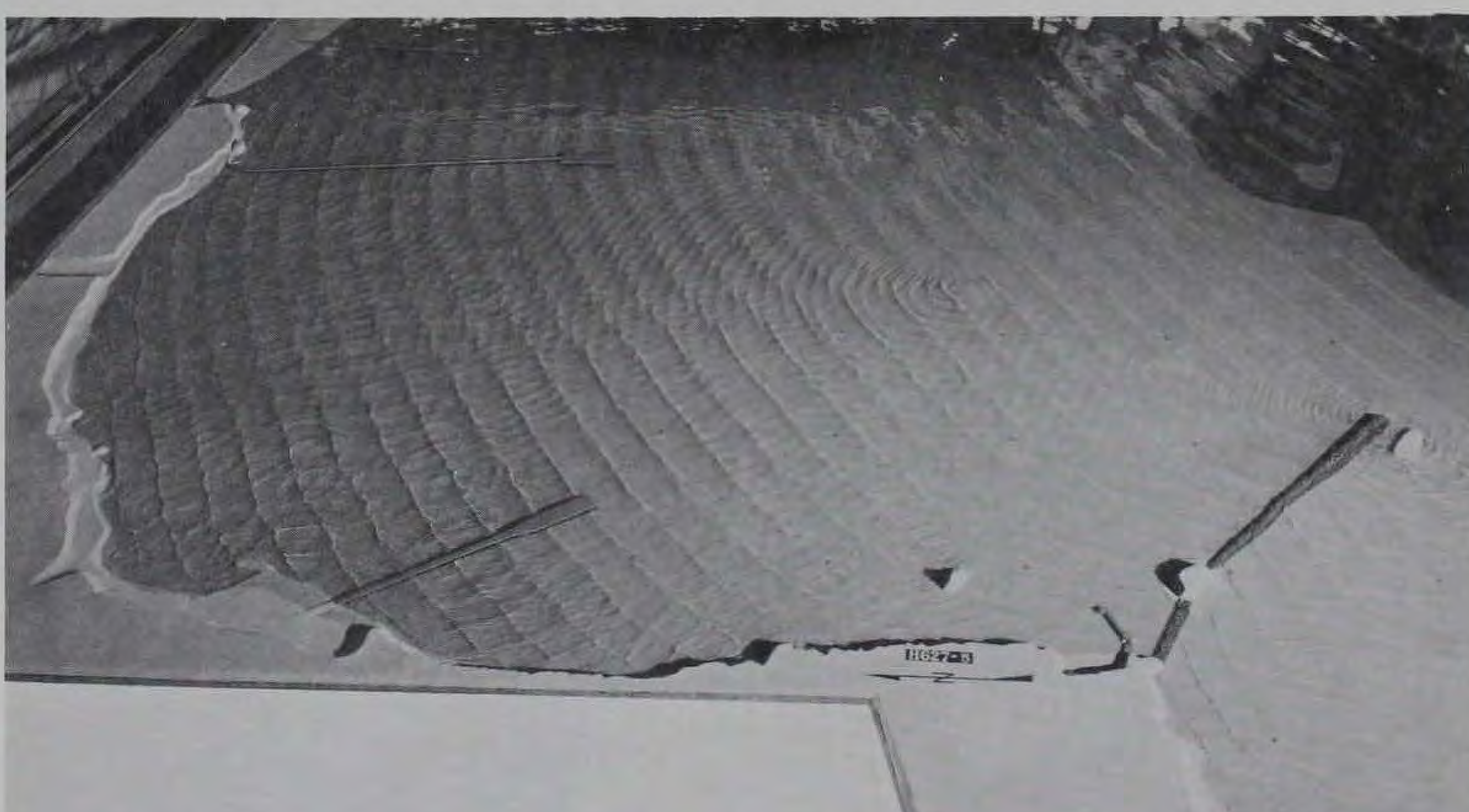
Wave Heights (in feet) for Base Test and Plan 12

Wave Gage No.	South 25° East Test Direction: 9-sec, 8-ft Test Wave, Base Test	Plan 12	9-sec, 10-ft Test Wave, Base Test	Plan 12	South 15° East Test Direction: 9-sec, 8-ft Test Wave, Base Test	Plan 12	9-sec, 12-ft Test Wave, Base Test	Plan 12	9-sec, 20-ft Test Wave, Base Test	Plan 12
1	3.8	--	4.9	--	6.2	--	9.1	--	11.6	--
2	8.8	--	10.3	--	7.8	--	10.6	--	19.0	--
3	7.9	1.5	9.3	2.0	8.2	1.1	10.0	1.5	12.9	3.6
4	4.9	1.1	5.3	1.4	5.3	0.9	7.1	0.9	14.0	2.5
5	9.7	0.6	10.6	0.7	8.4	0.8	9.9	1.0	18.4	1.7
6	6.0	0.8	9.2	1.1	5.3	0.7	6.1	0.8	11.4	2.0
7	6.5	1.1	6.9	1.1	13.6	0.4	14.4	0.8	18.7	1.1
8	5.8	0.7	9.8	1.2	7.8	0.8	14.1	0.5	14.6	1.8
9	3.1	1.3	6.6	1.3	9.2	1.2	11.4	1.2	17.5	1.9
10	4.9	--	6.4	--	5.4	--	14.4	--	15.2	--
11	7.1	0.8	10.2	1.0	11.5	1.3	12.1	1.4	13.4	1.4
12	8.2	--	11.1	--	8.6	--	11.3	--	20.0	--
14	4.0	--	5.3	--	7.1	--	6.4	--	6.1	--
15	6.6	--	8.7	--	5.2	--	7.8	--	16.8	--
16	7.5	--	9.4	--	5.4	--	8.3	--	17.8	--
17	6.2	--	7.4	--	10.7	--	13.9	--	13.6	--
18	4.9	6.3	6.3	7.4	8.5	6.2	9.1	7.5	16.5	14.0
19	7.4	6.5	8.8	9.2	8.4	4.1	13.0	8.7	20.6	18.4
20	9.0	6.3	9.5	6.9	6.2	4.7	12.8	6.1	20.7	16.0
21	7.0	5.2	7.7	5.2	6.1	3.8	10.6	5.7	18.6	14.9
22	6.3	7.4	6.6	8.6	6.8	5.4	9.9	7.5	19.8	13.3
23	--	0.7	--	0.8	--	0.2	--	0.4	--	1.1
24	--	0.5	--	0.7	--	0.4	--	0.3	--	0.5
28	--	1.0	--	1.2	--	1.2	--	1.4	--	2.5
30	--	0.7	--	0.9	--	0.9	--	1.1	--	1.0
32	--	0.7	--	1.0	--	0.9	--	0.5	--	1.6
33	--	0.4	--	0.4	--	0.2	--	0.3	--	0.4
34	--	2.0	--	2.0	--	0.9	--	1.1	--	2.0

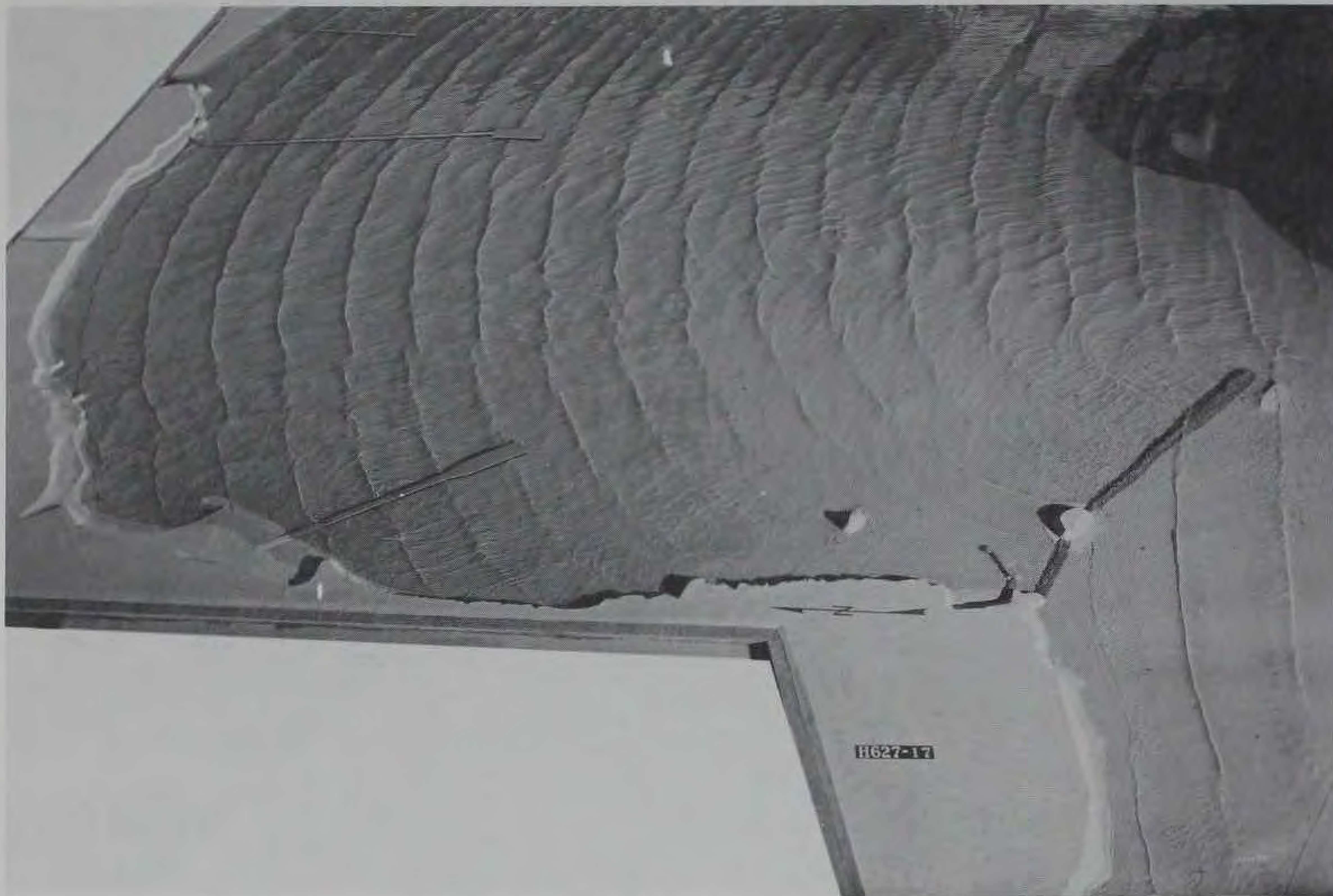
Wave Gage No.	South Test Direction: 10-sec, 8-ft Test Wave, Base Test	Plan 12	10-sec, 11-ft Test Wave, Base Test	Plan 12	10-sec, 14-ft Test Wave, Base Test	Plan 12	South 16° West Test Direction: 14-sec, 14-ft Test Wave, Base Test	Plan 12	14-sec, 16-ft Test Wave, Base Test	Plan 12	14-sec, 18-ft Test Wave, Base Test	Plan 12
1	5.5	--	6.7	--	10.2	--	5.8	--	6.5	--	7.1	--
2	5.6	--	8.5	--	11.7	--	10.4	--	16.4	--	10.2	--
3	6.8	1.4	8.2	1.6	12.6	1.5	10.7	2.5	8.0	2.8	11.4	2.7
4	3.3	0.8	8.1	1.0	8.9	0.9	9.4	1.1	7.9	1.0	8.1	1.1
5	6.7	0.9	7.9	0.9	10.8	1.2	14.3	0.6	17.3	1.0	15.2	1.3
6	4.0	0.7	7.6	1.0	7.6	1.0	9.4	1.9	10.2	1.9	11.9	1.3
7	8.1	0.8	11.6	1.0	11.9	0.7	14.8	0.9	16.6	1.3	18.0	1.6
8	4.3	0.8	5.6	0.8	8.4	1.1	8.2	1.0	11.3	1.3	15.6	1.5
9	9.0	1.9	14.2	2.0	15.9	1.6	13.7	2.9	16.2	3.2	18.0	4.4
10	10.0	--	14.4	--	14.4	--	14.8	--	17.2	--	17.4	--
11	6.9	0.7	8.3	0.8	13.9	0.8	16.3	1.3	19.2	1.3	16.5	1.6
12	7.3	--	8.7	--	13.0	--	11.0	--	17.1	--	20.4	--
14	5.4	--	7.8	--	8.0	--	6.7	--	7.1	--	7.2	--
15	6.5	--	8.8	--	10.8	--	11.4	--	8.7	--	12.0	--
16	7.0	--	9.9	--	15.1	--	12.6	--	16.3	--	16.4	--
17	9.5	--	14.4	--	14.9	--	13.3	--	14.2	--	14.6	--
18	11.3	7.0	14.2	11.1	14.5	11.9	15.4	10.4	20.4	12.4	22.2	15.0
19	4.3	6.0	9.7	8.3	9.2	8.9	13.0	9.5	18.4	11.0	21.4	14.1
20	5.9	4.6	9.6	7.2	9.7	8.6	14.0	10.9	15.9	14.3	19.0	15.0
21	4.9	3.5	6.5	5.6	9.3	6.8	9.0	6.6	10.9	9.1	14.4	12.4
22	5.5	4.4	6.5	5.9	8.3	6.1	13.6	9.9	13.6	9.4	18.7	13.0
23	--	0.4	--	0.5	--	0.8	--	1.5	--	1.4	--	1.7
24	--	0.3	--	0.4	--	0.6	--	1.2	--	1.5	--	1.4
28	--	0.8	--	1.3	--	2.0	--	1.5	--	2.0	--	2.1
30	--	1.4	--	1.7	--	1.9	--	2.6	--	2.6	--	2.5
32	--	0.6	--	0.6	--	1.3	--	0.4	--	0.6	--	0.5
33	--	0.4	--	0.4	--	0.6	--	1.2	--	2.0	--	2.6
34	--	0.5	--	0.8	--	1.2	--	2.6	--	2.7	--	2.5

Note: Wave gage locations are shown in plates 3 and 12.

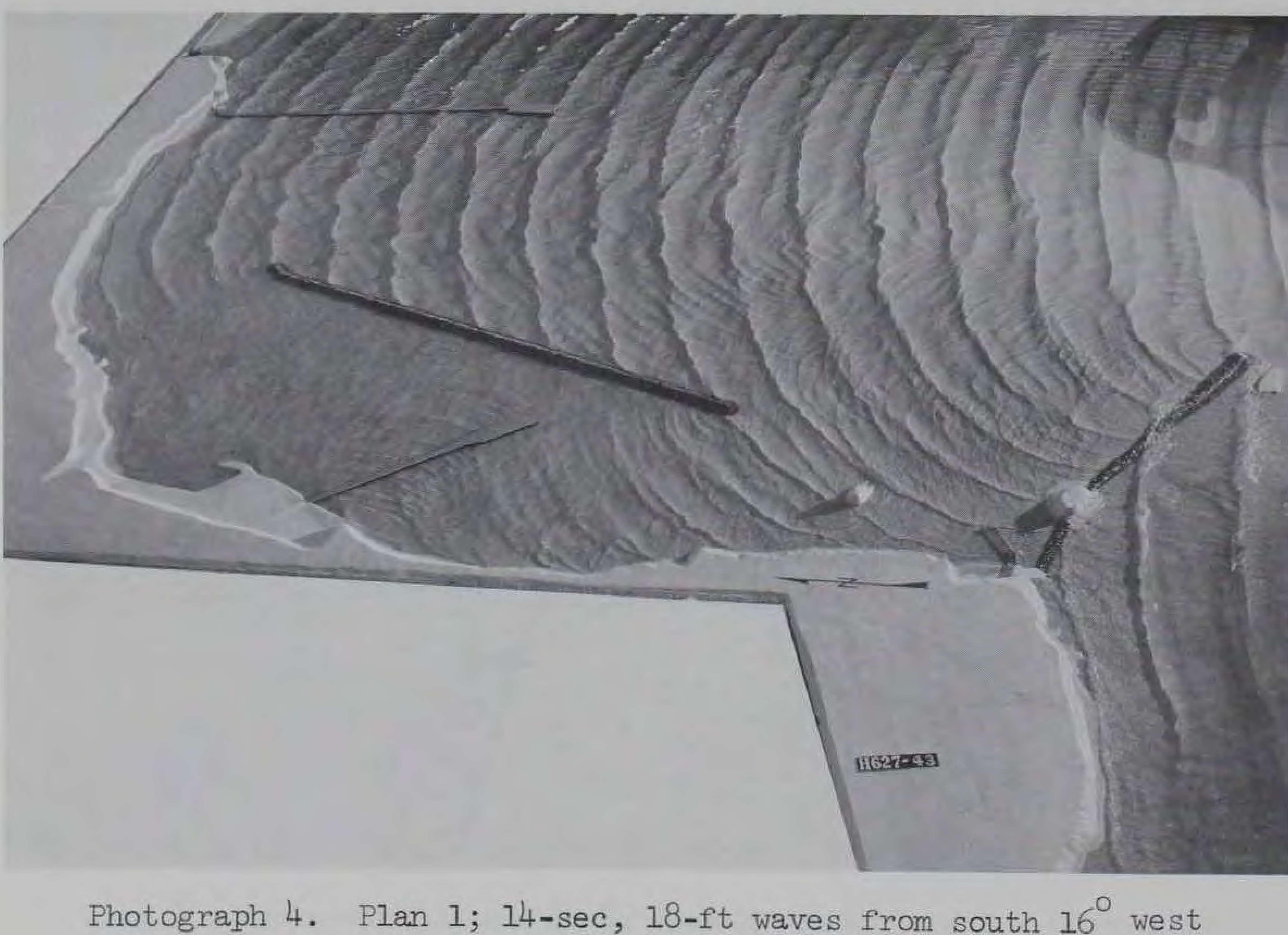
Photograph 1. General view of model; existing prototype conditions



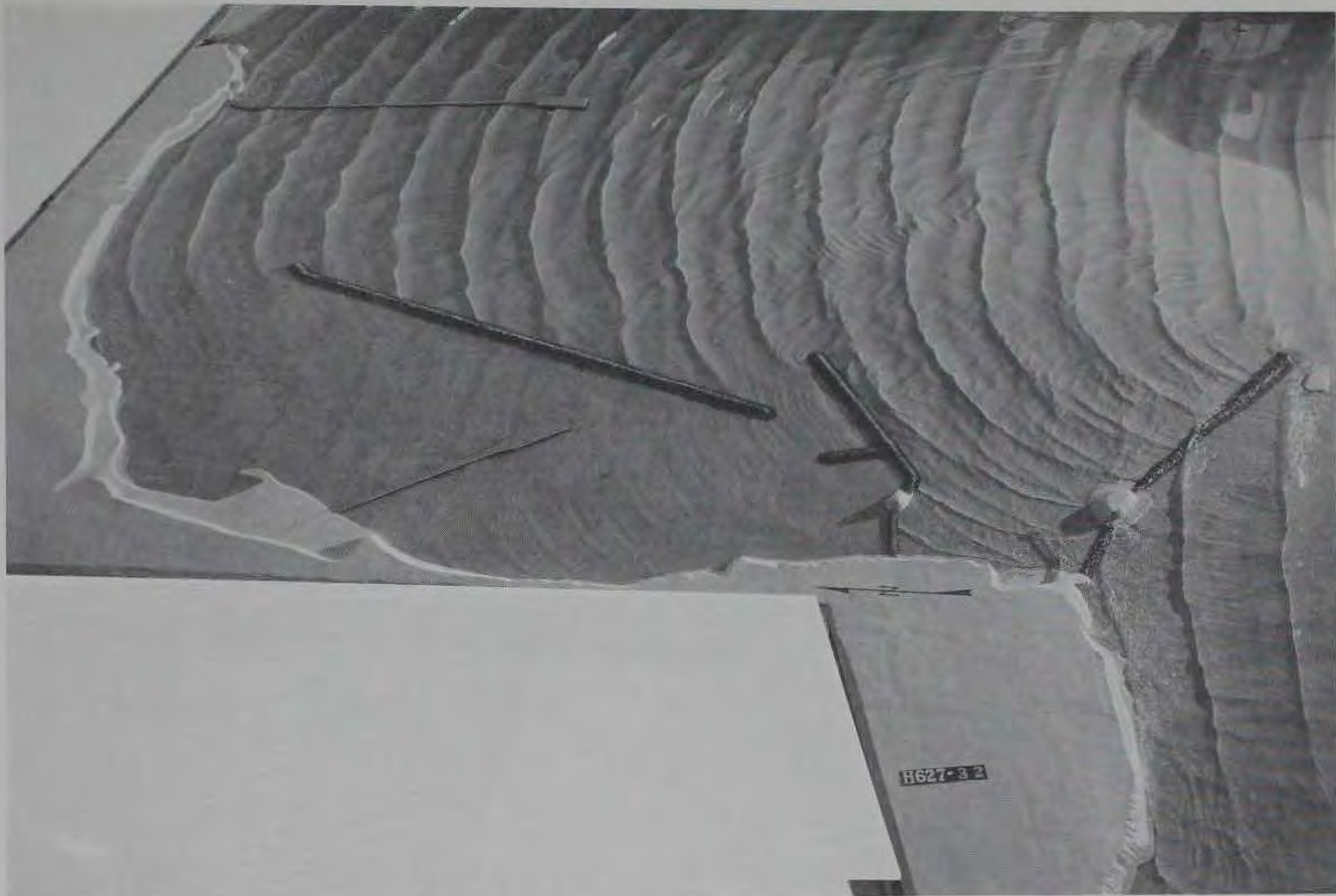
Photograph 2. Base test; 9-sec, 10-ft waves from south 25° east



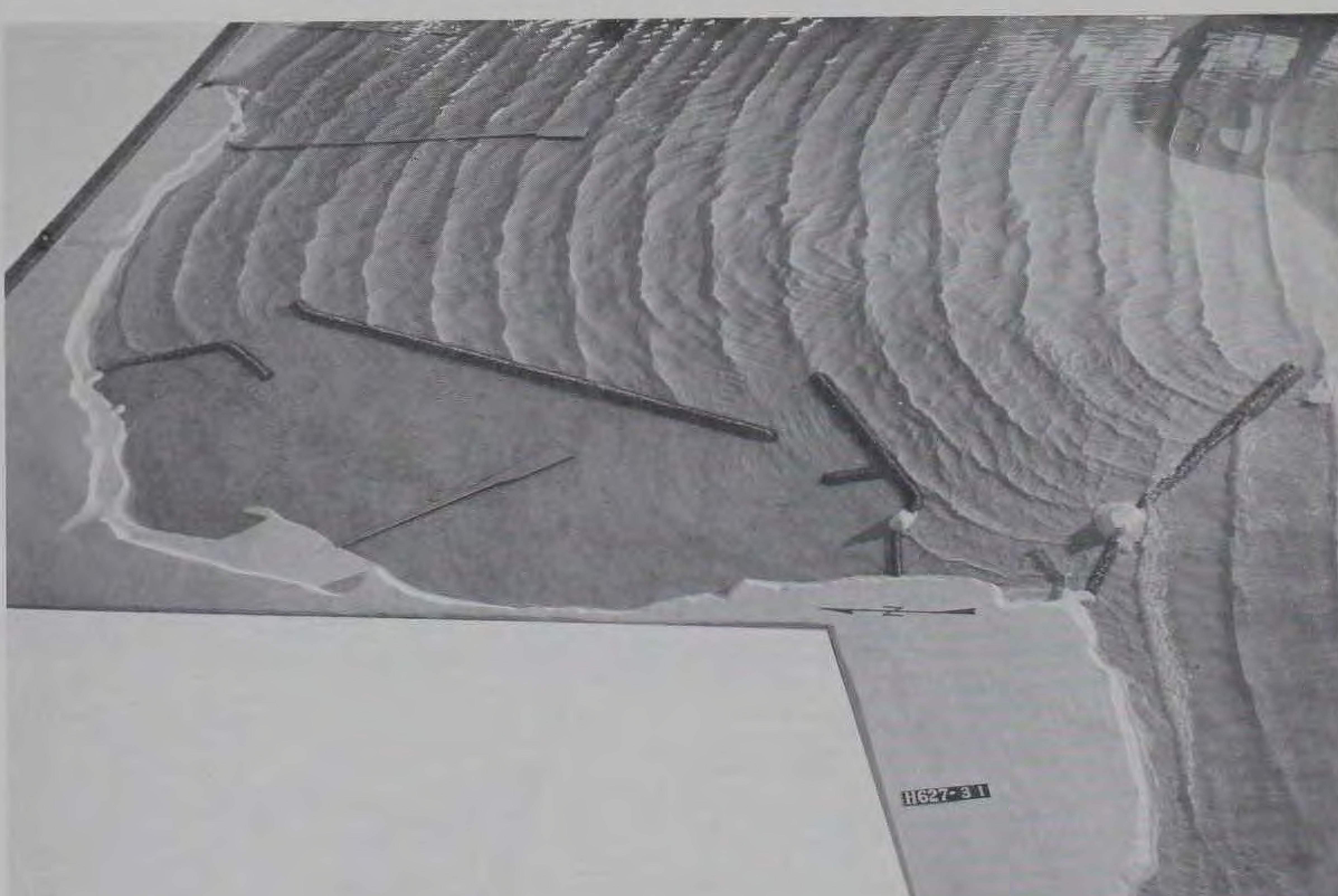
Photograph 3. Base test; 14-sec, 18-ft waves from south 16° west



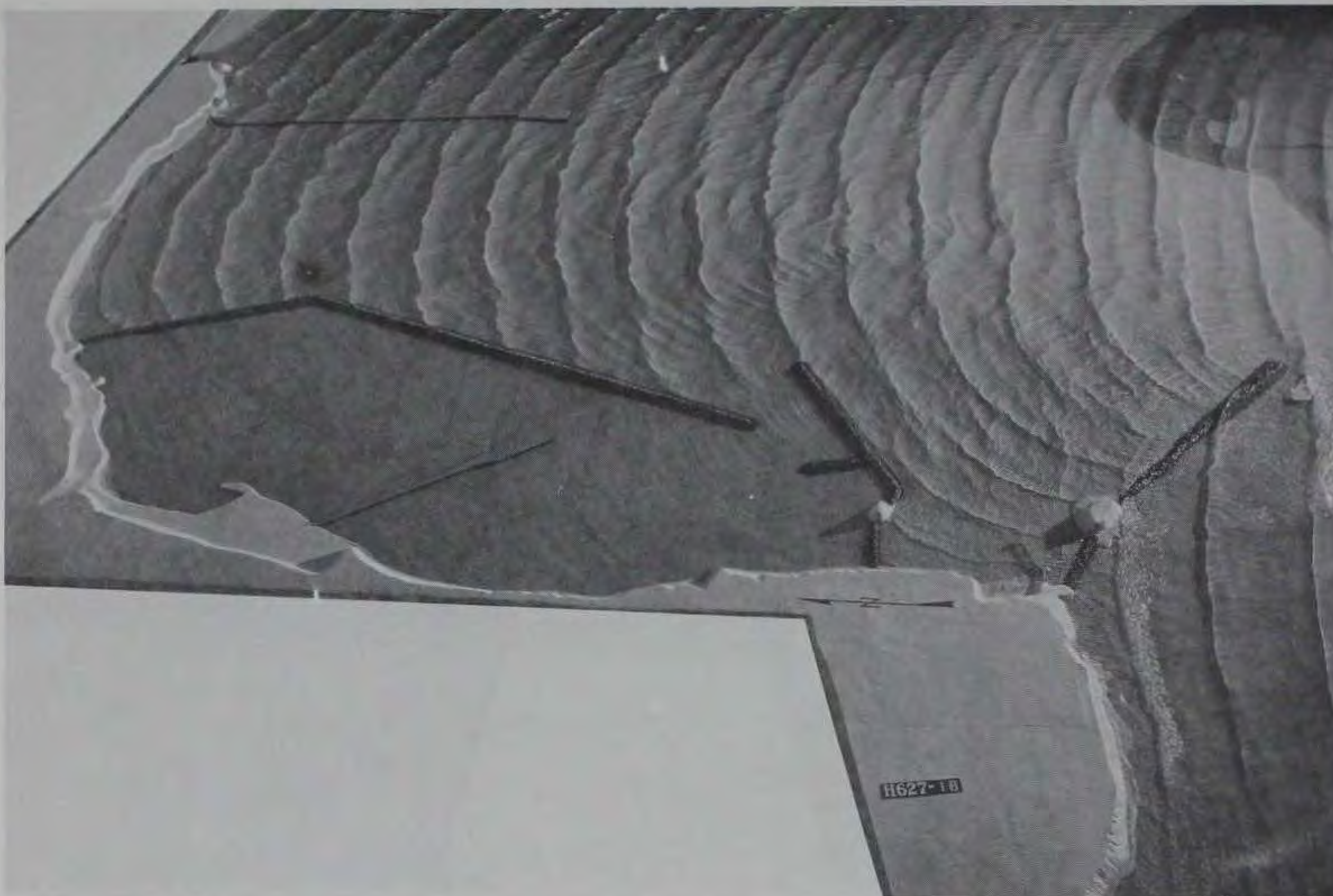
Photograph 4. Plan 1; 14-sec, 18-ft waves from south 16° west



Photograph 5. Plan 2; 14-sec, 18-ft waves from south 16° west



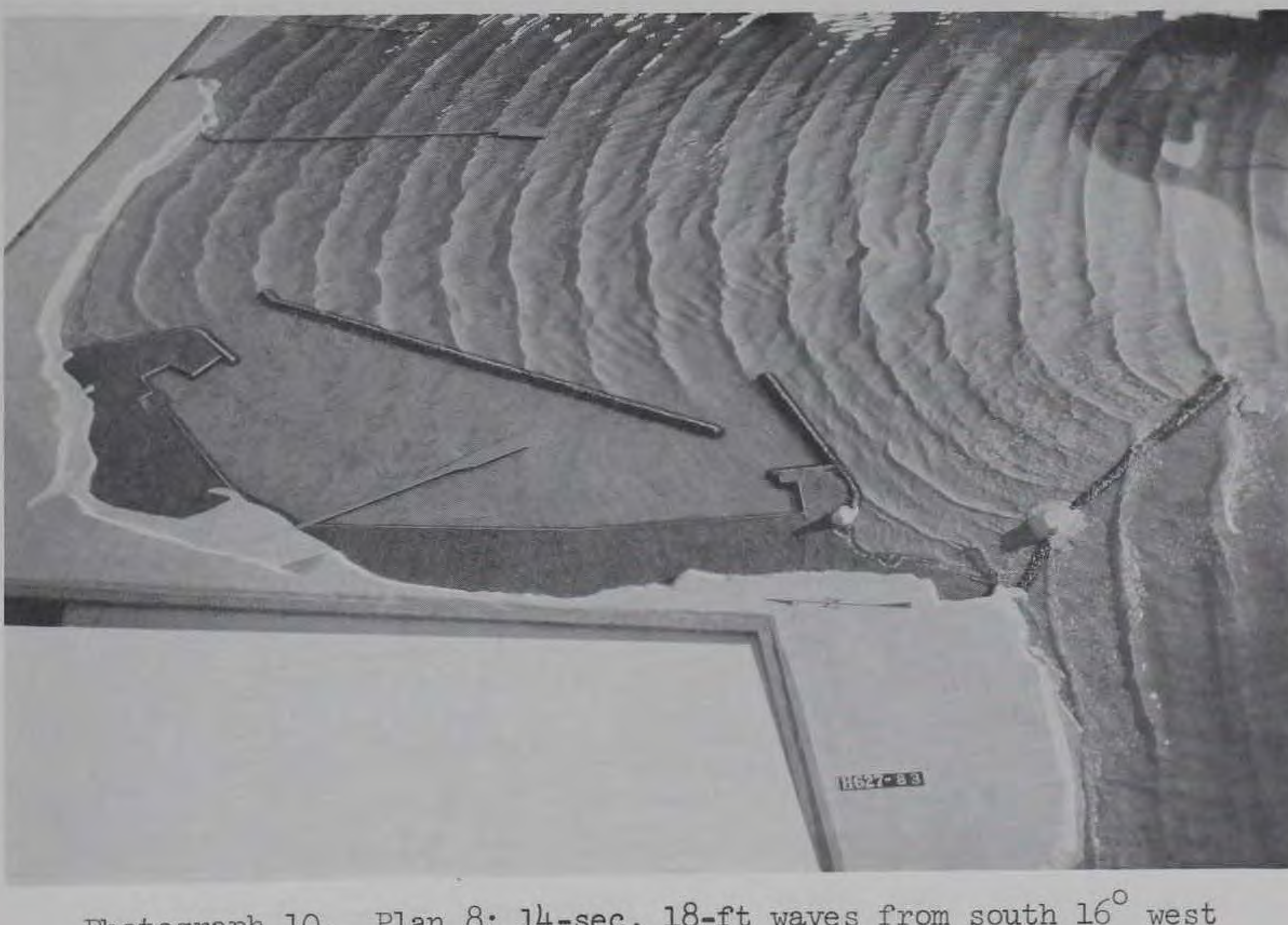
Photograph 6. Plan 3; 14-sec, 18-ft waves from south 16° west



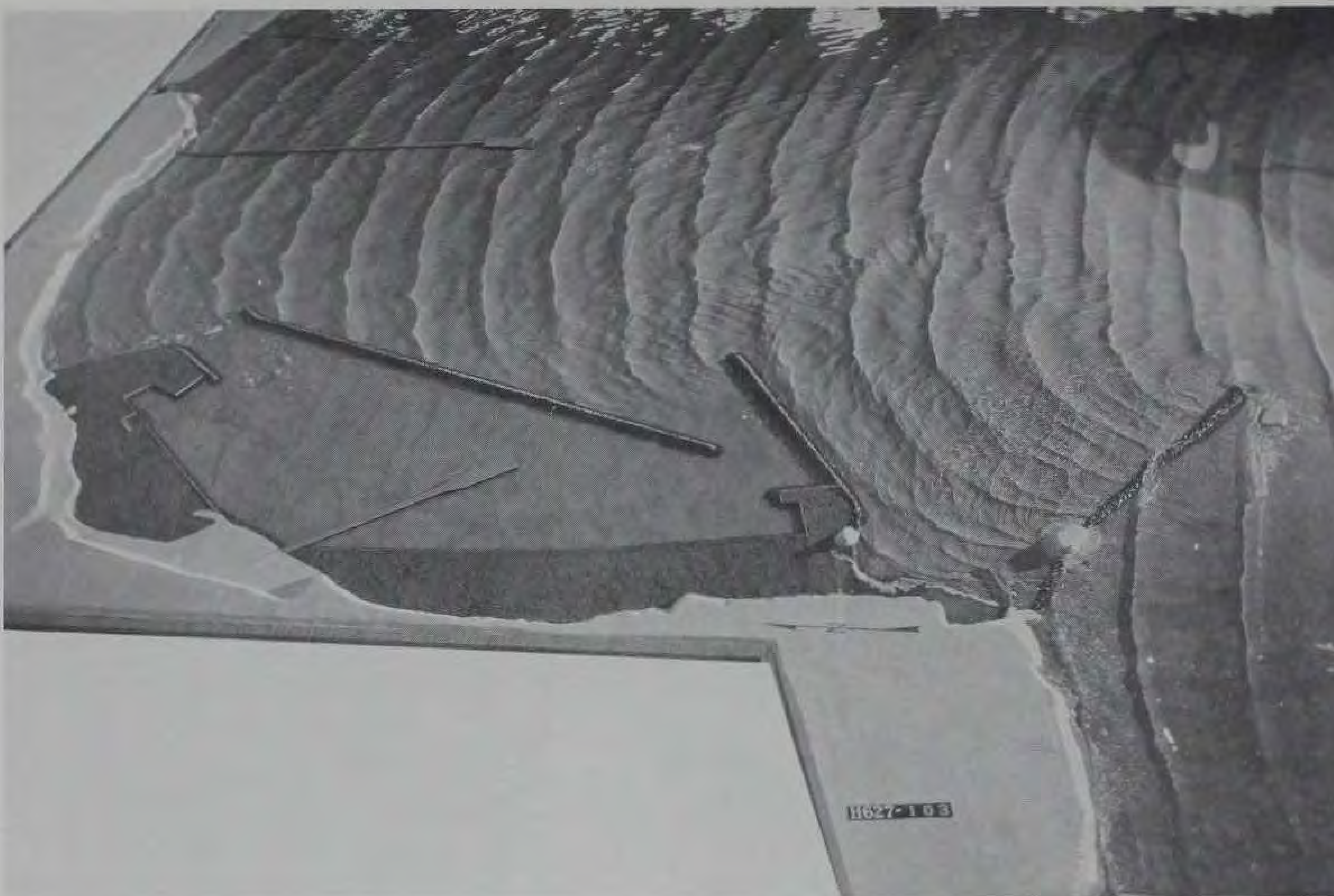
Photograph 7. Plan 4; 14-sec, 18-ft waves from south 16° west

Photograph 8. Plan 6A; 14-sec, 18-ft waves from south 16° west

Photograph 9. Plan 7; 14-sec, 18-ft waves from south 16° west



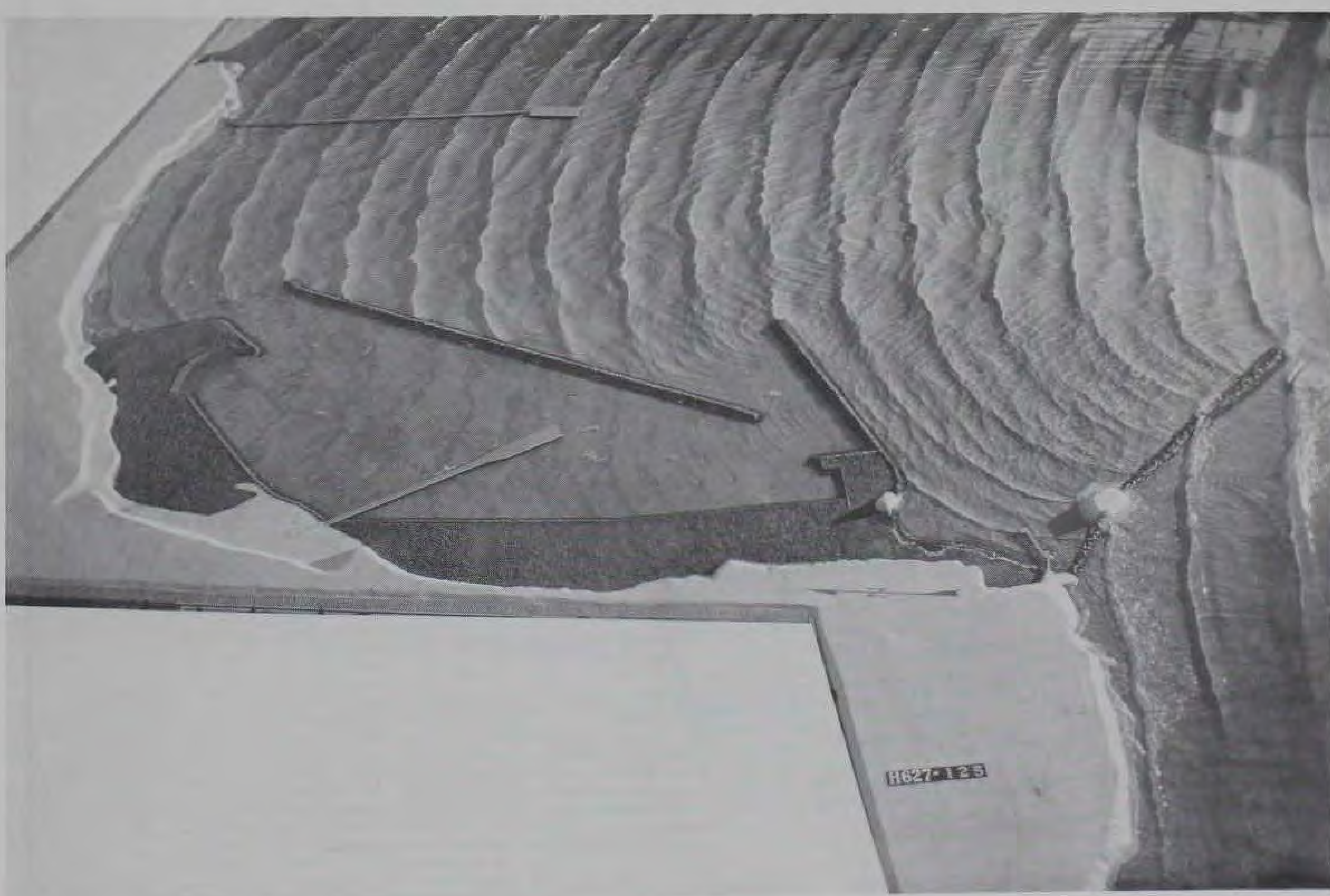
Photograph 10. Plan 8; 14-sec, 18-ft waves from south 16° west



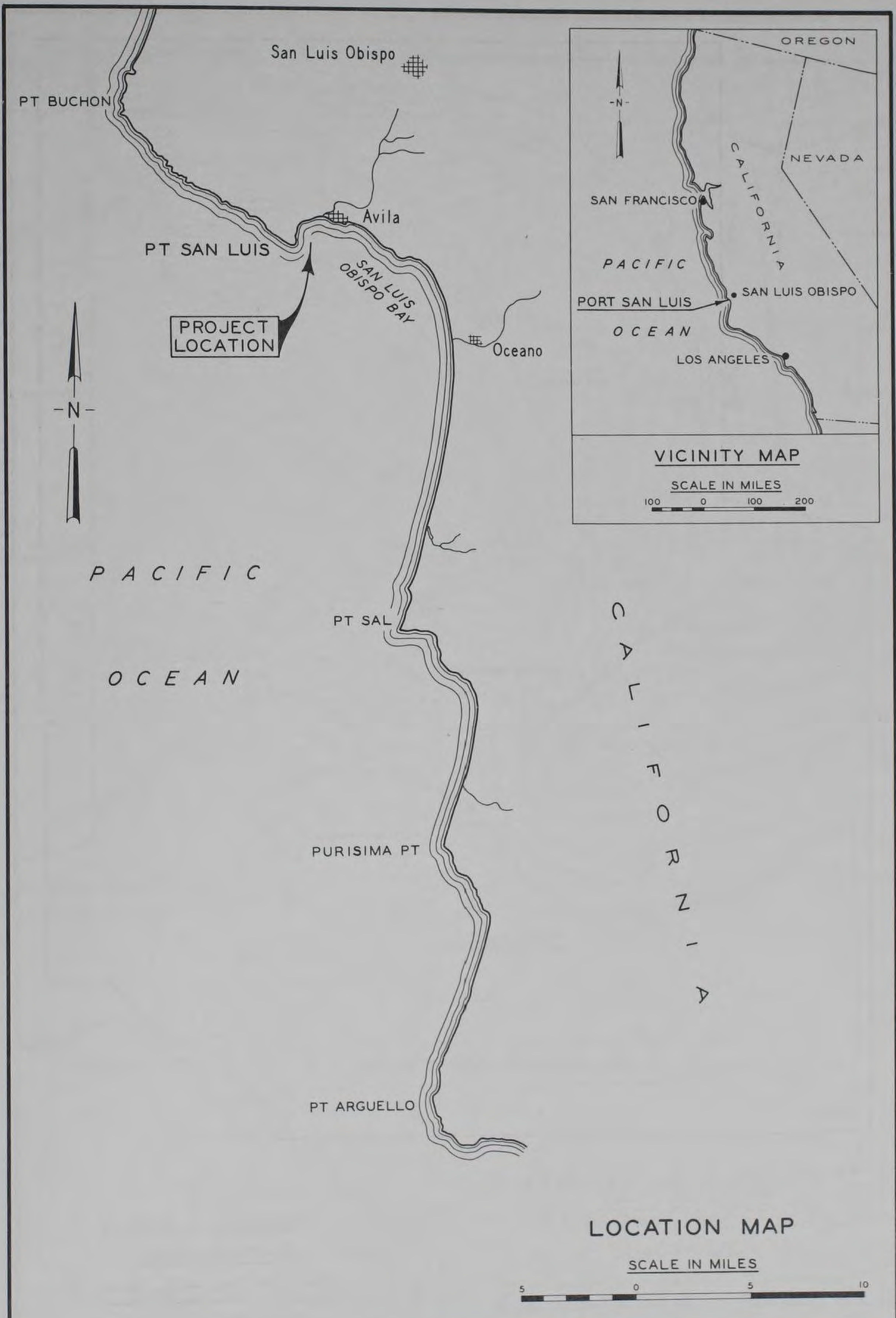
Photograph 11. Plan 8D; 14-sec, 18-ft waves from south 16° west

Photograph 12. Plan 10; 14-sec, 18-ft waves from south 16° west

Photograph 13. Plan 12; 9-sec, 10-ft waves from south 25° east



Photograph 14. Plan 12; 14-sec, 18-ft waves from south 16° west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Avila
PT SAN LUIS
SAN LUIS OBISPO BAY
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Oceano
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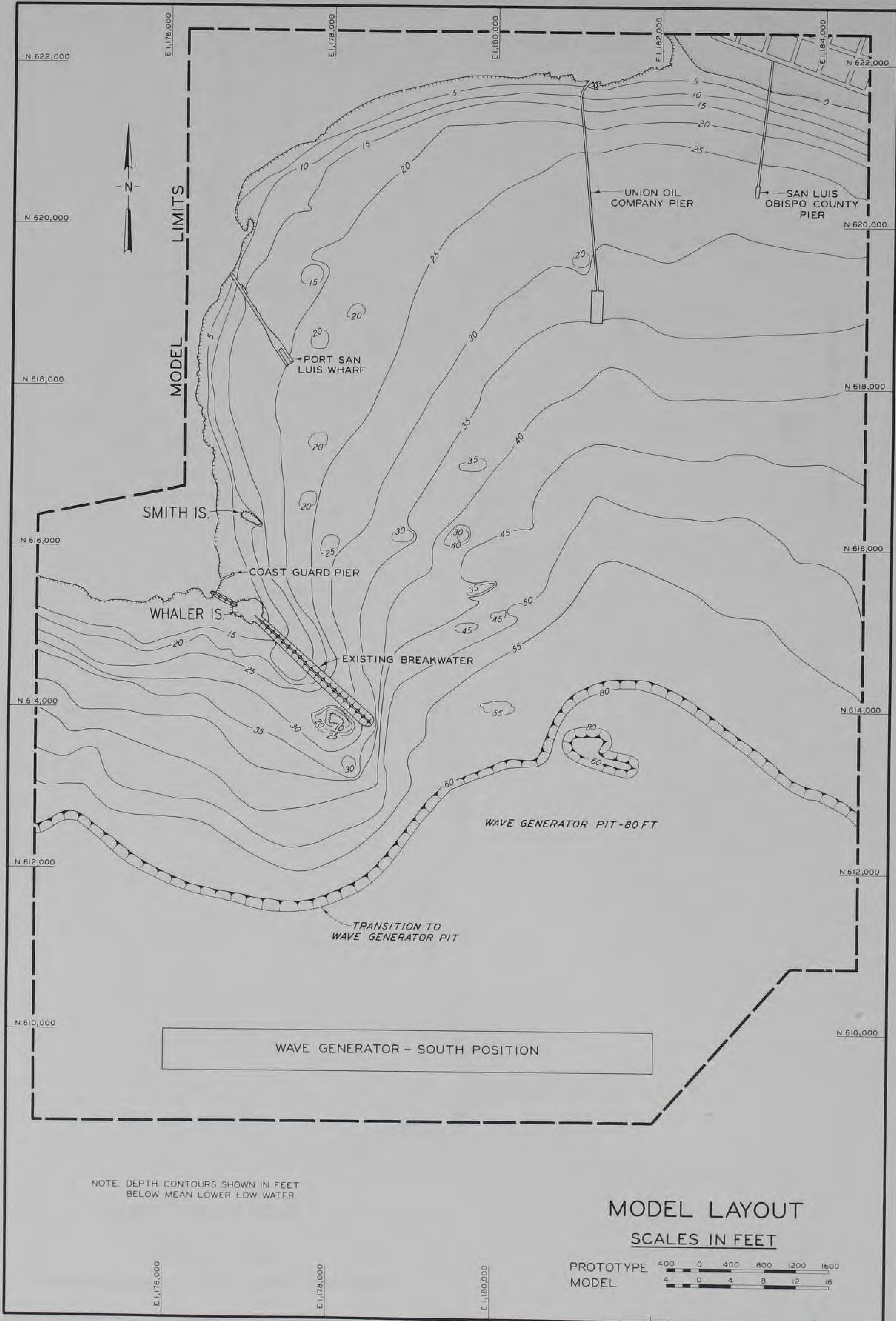
PACIFIC
OCEAN
PT SAL
CALIFORNIA
PURISIMA PT
PT ARGUELLO
OREGON
NEVADA
CALIFORNIA
SAN FRANCISCO
PACIFIC
OCEAN
PORT SAN LUIS
SAN LUIS OBISPO
LOS ANGELES
VICINITY MAP
SCALE IN MILES
100 0 100 200
LOCATION MAP
SCALE IN MILES
5 0 5 10

PLATE I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E 1,180,000
E 1,182,000
E 1,184,000
UNION OIL COMPANY PIER
SAN LUIS OBISPO COUNTY PIER
PORT SAN LUIS WHARF
SMITH IS.
COAST GUARD PIER
WHALER IS.
EXISTING BREAKWATER
WAVE GENERATOR PIT - 80 FT
TRANSITION TO WAVE GENERATOR PIT
WAVE GENERATOR - SOUTH POSITION
NOTE: DEPTH CONTOURS SHOWN IN FEET BELOW MEAN LOWER LOW WATER
MODEL LAYOUT
SCALES IN FEET
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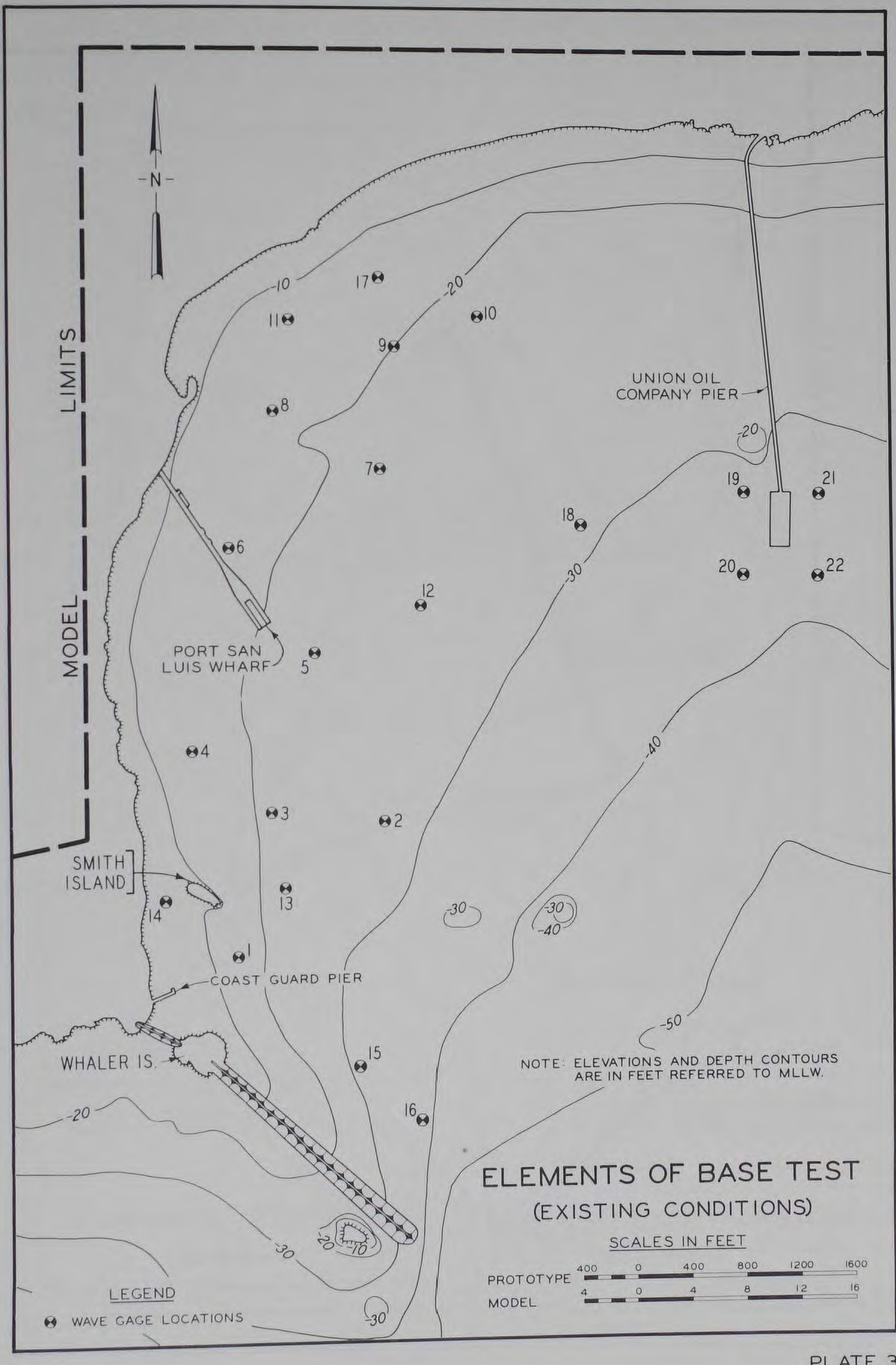
MODEL 4 0 4 8 12 16

PLATE 2


N
MODEL LIMITS
-10
-20
-30
-40
-50
UNION OIL COMPANY PIER
PORT SAN LUIS WHARF
SMITH ISLAND
COAST GUARD PIER
WHALER IS.
NOTE: ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.
ELEMENTS OF BASE TEST
(EXISTING CONDITIONS)
SCALES IN FEET
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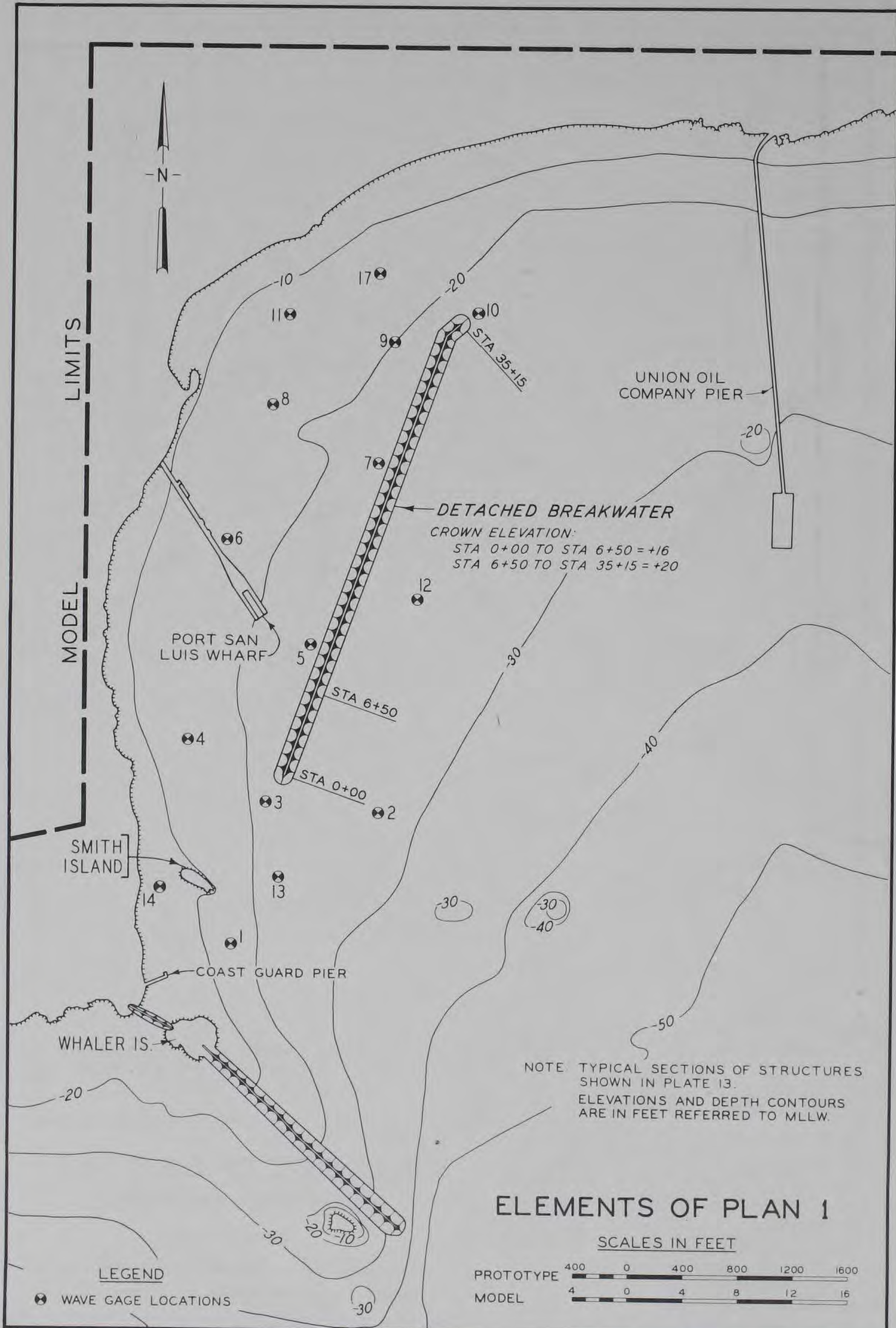
MODEL 4 0 4 8 12 16
LEGEND
WAVE GAGE LOCATIONS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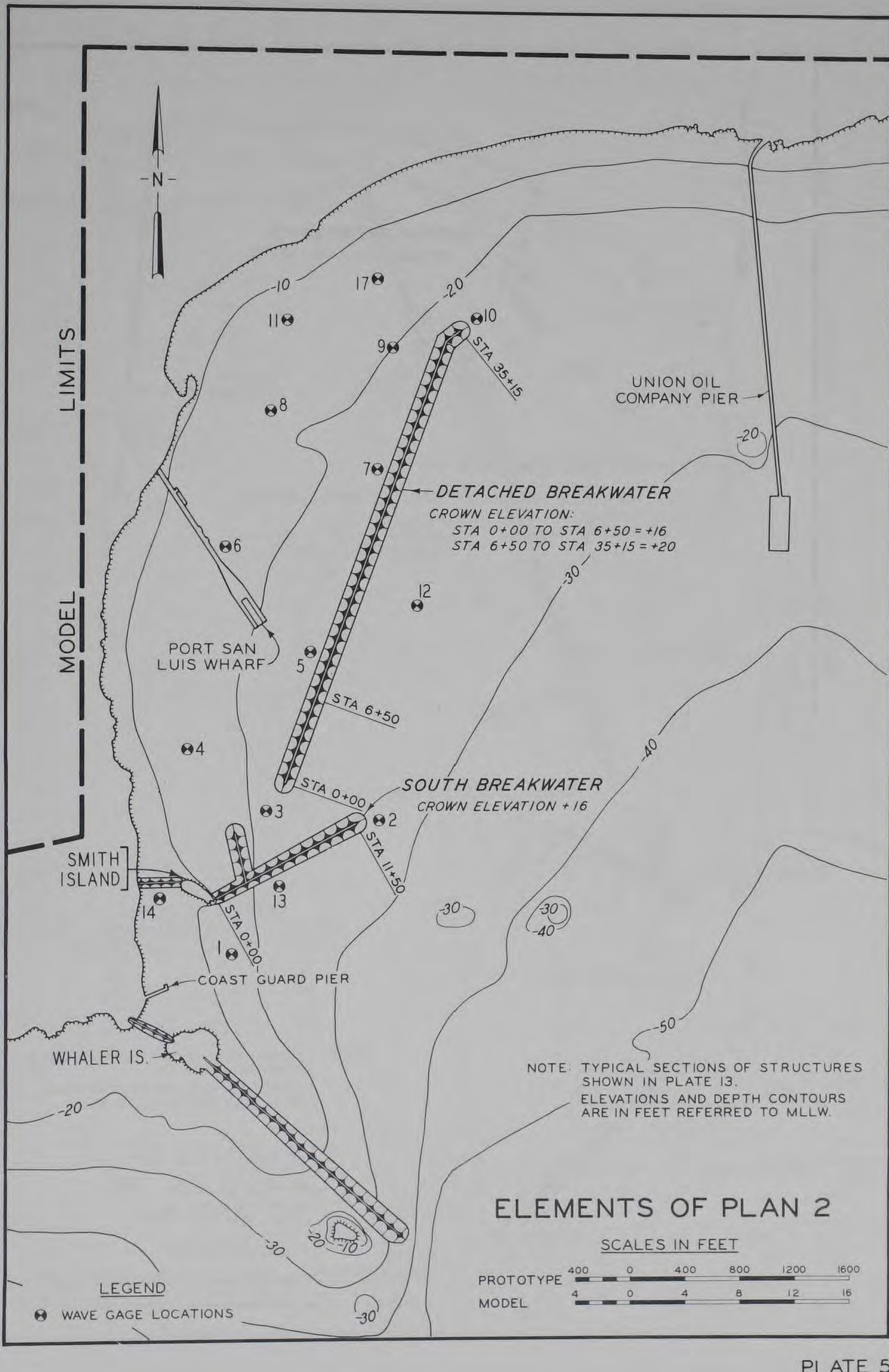
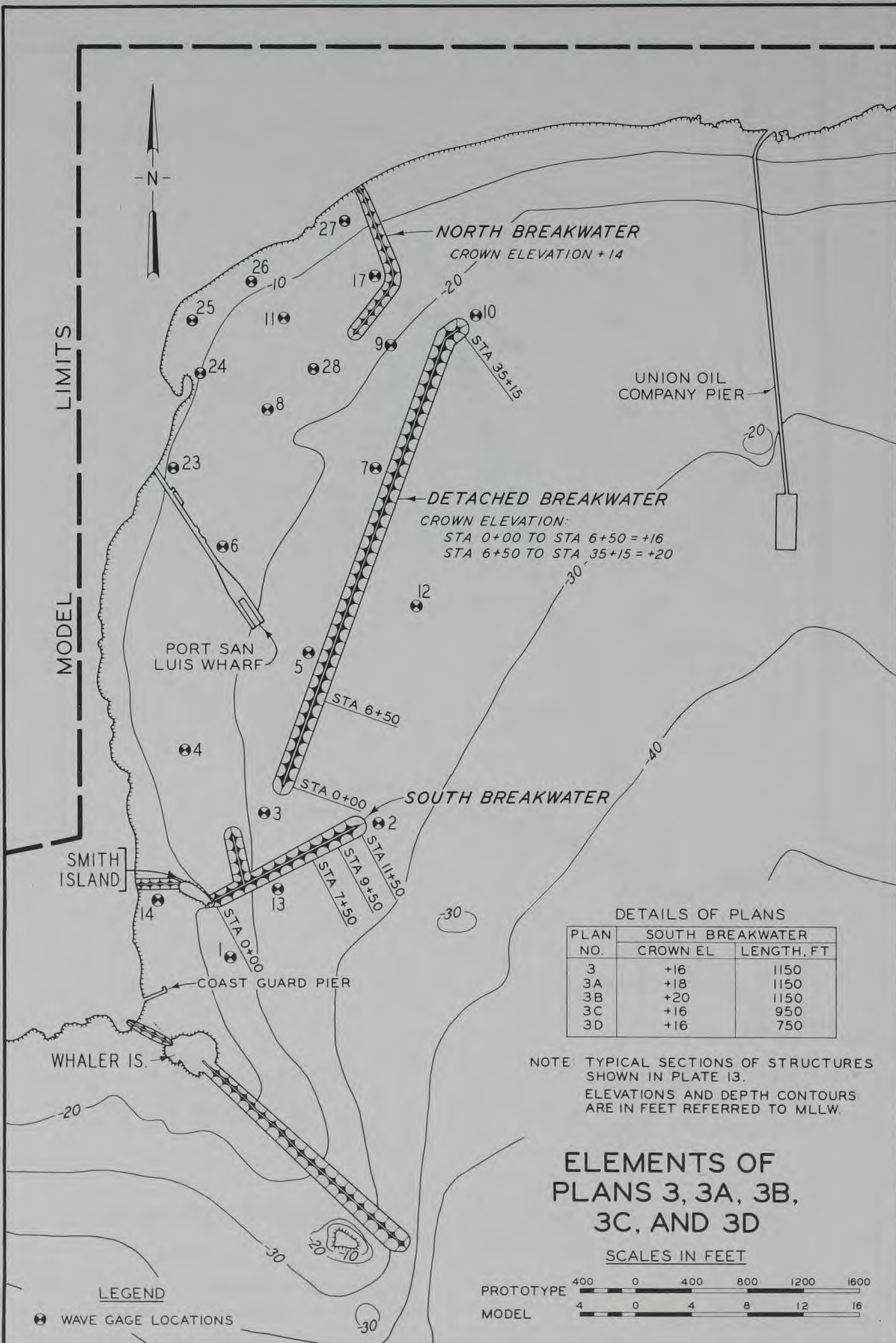
COMPANY PIER
DETACHED BREAKWATER
CROWN ELEVATION:
STA 0+00 TO STA 6+50 = +16
STA 6+50 TO STA 35+15 = +20
STA 35+15
STA 6+50
STA 0+00
PORT SAN
LUIS WHARF
SMITH
ISLAND
COAST GUARD PIER
WHALER IS.
-10
-20
-30
-40
-50
NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.
ELEMENTS OF PLAN 1
SCALES IN FEET
PROTOTYPE 400 0 400 800 1200 1600
MODEL 4 0 4 8 12 16
LEGEND
WAVE GAGE LOCATIONS



N
MODEL LIMITS
UNION OIL COMPANY PIER
DETACHED BREAKWATER
CROWN ELEVATION:
STA 0+00 TO STA 6+50 = +16
STA 6+50 TO STA 35+15 = +20
SOUTH BREAKWATER
CROWN ELEVATION +16
PORT SAN LUIS WHARF
SMITH ISLAND
WHALER IS.
COAST GUARD PIER
STA 35+15
STA 6+50
STA 0+00
STA 11+50
STA 0+00
-10
-20
-30
-40
-50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
17
NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.
ELEMENTS OF PLAN 2
SCALES IN FEET
PROTOTYPE 400 0 400 800 1200 1600
MODEL 4 0 4 8 12 16
LEGEND
WAVE GAGE LOCATIONS

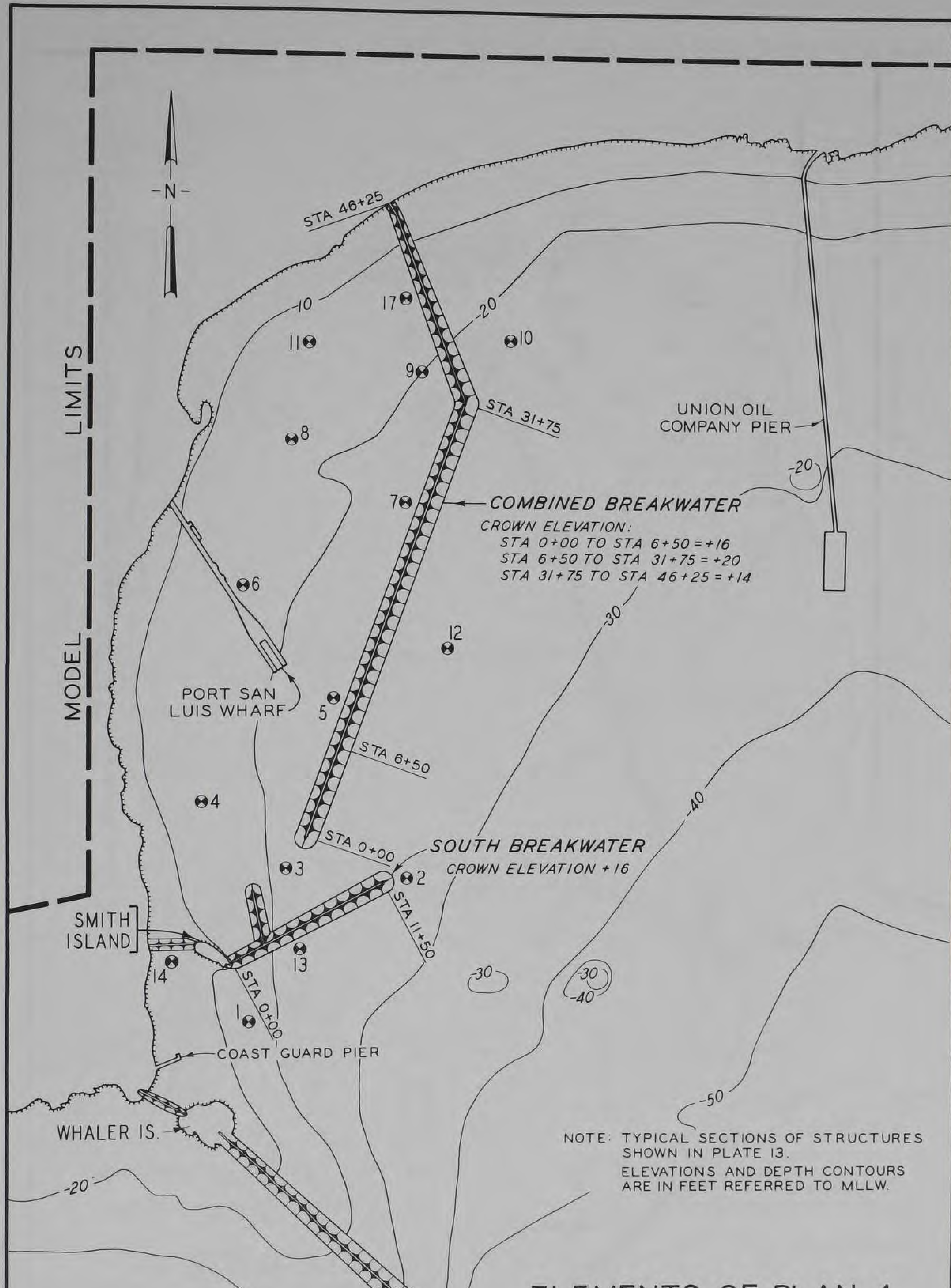


DETAILS OF PLANS

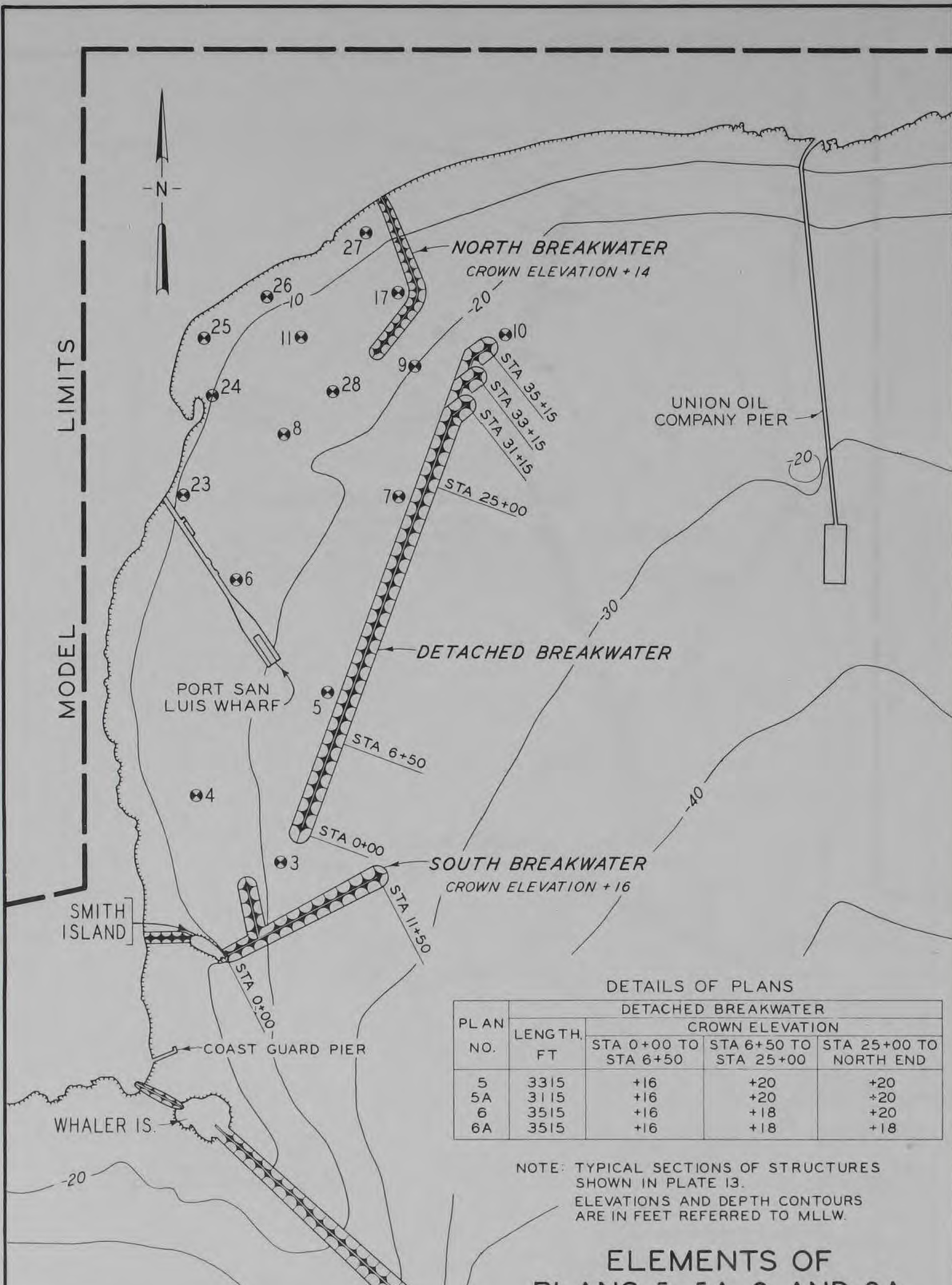
PLAN NO.	SOUTH BREAKWATER CROWN EL	LENGTH, FT
3	+16	1150
3A	+18	1150
3B	+20	1150
3C	+16	950
3D	+16	750

NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.

ELEMENTS OF PLANS 3, 3A, 3B, 3C, AND 3D



ELEMENTS OF PLAN 4

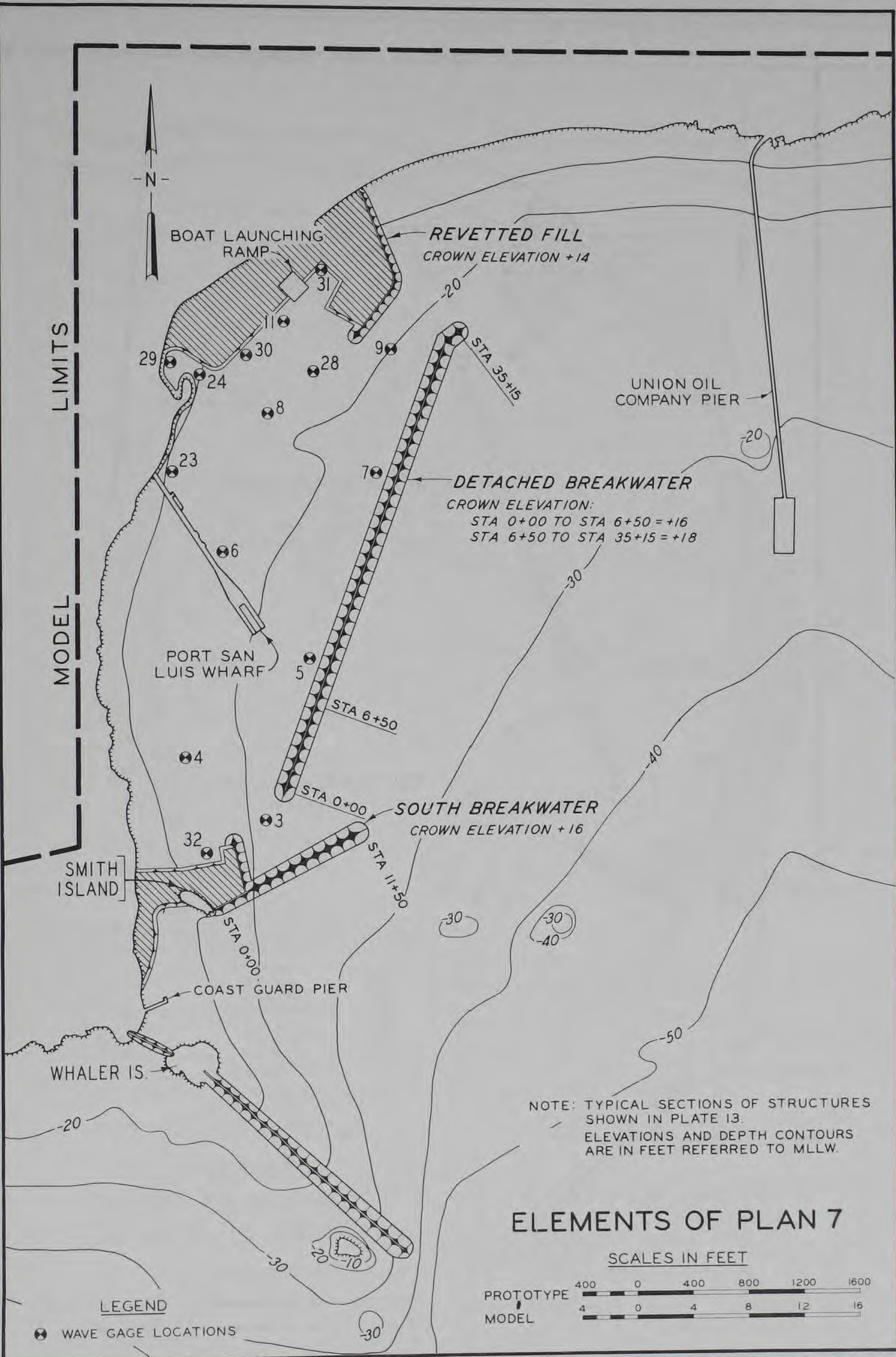


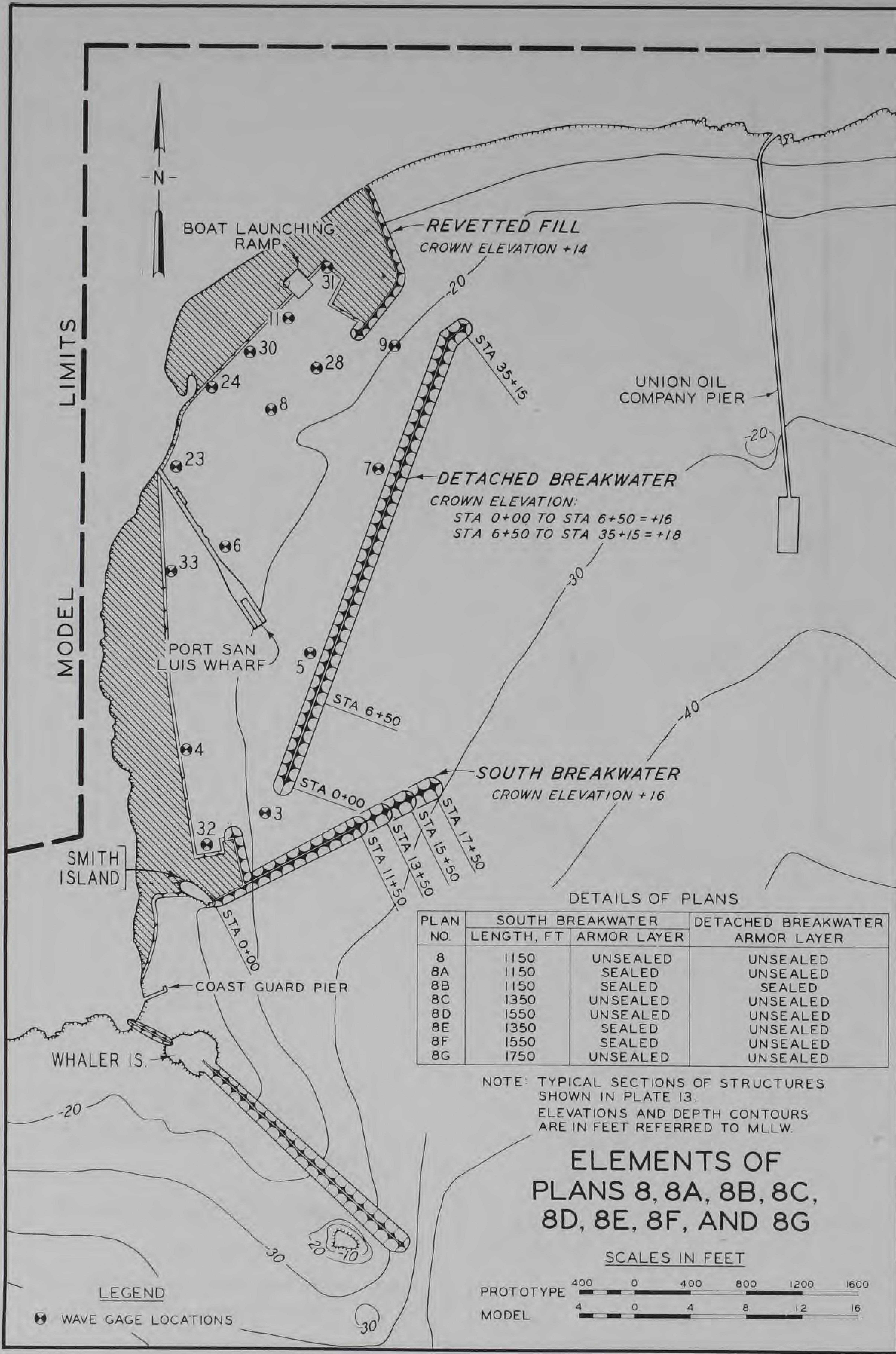
DETAILS OF PLANS

PLAN NO.	DETACHED BREAKWATER			
	LENGTH, FT	CROWN ELEVATION		
		STA 0+00 TO STA 6+50	STA 6+50 TO STA 25+00	STA 25+00 TO NORTH END
5	3315	+16	+20	+20
5A	3115	+16	+20	+20
6	3515	+16	+18	+20
6A	3515	+16	+18	+18

NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.

ELEMENTS OF PLANS 5, 5A, 6, AND 6A


MODEL LIMITS
N
BOAT LAUNCHING RAMP
REVETTED FILL
CROWN ELEVATION +14
31
11
30
29
24
28
9
8
23
7
6
5
4
3
32
-20
STA 35+15
UNION OIL COMPANY PIER
DETACHED BREAKWATER
CROWN ELEVATION:
STA 0+00 TO STA 6+50 = +16
STA 6+50 TO STA 35+15 = +18
-30
PORT SAN LUIS WHARF
STA 6+50
-40
STA 0+00
SOUTH BREAKWATER
CROWN ELEVATION +16
STA 11+50
SMITH ISLAND
STA 0+00
COAST GUARD PIER
WHALER IS.
-50
-10
LEGEND
WAVE GAGE LOCATIONS
NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.
ELEMENTS OF PLAN 7
SCALES IN FEET
PROTOTYPE
400 0 400 800 1200 1600
MODEL
4 0 4 8 12 16

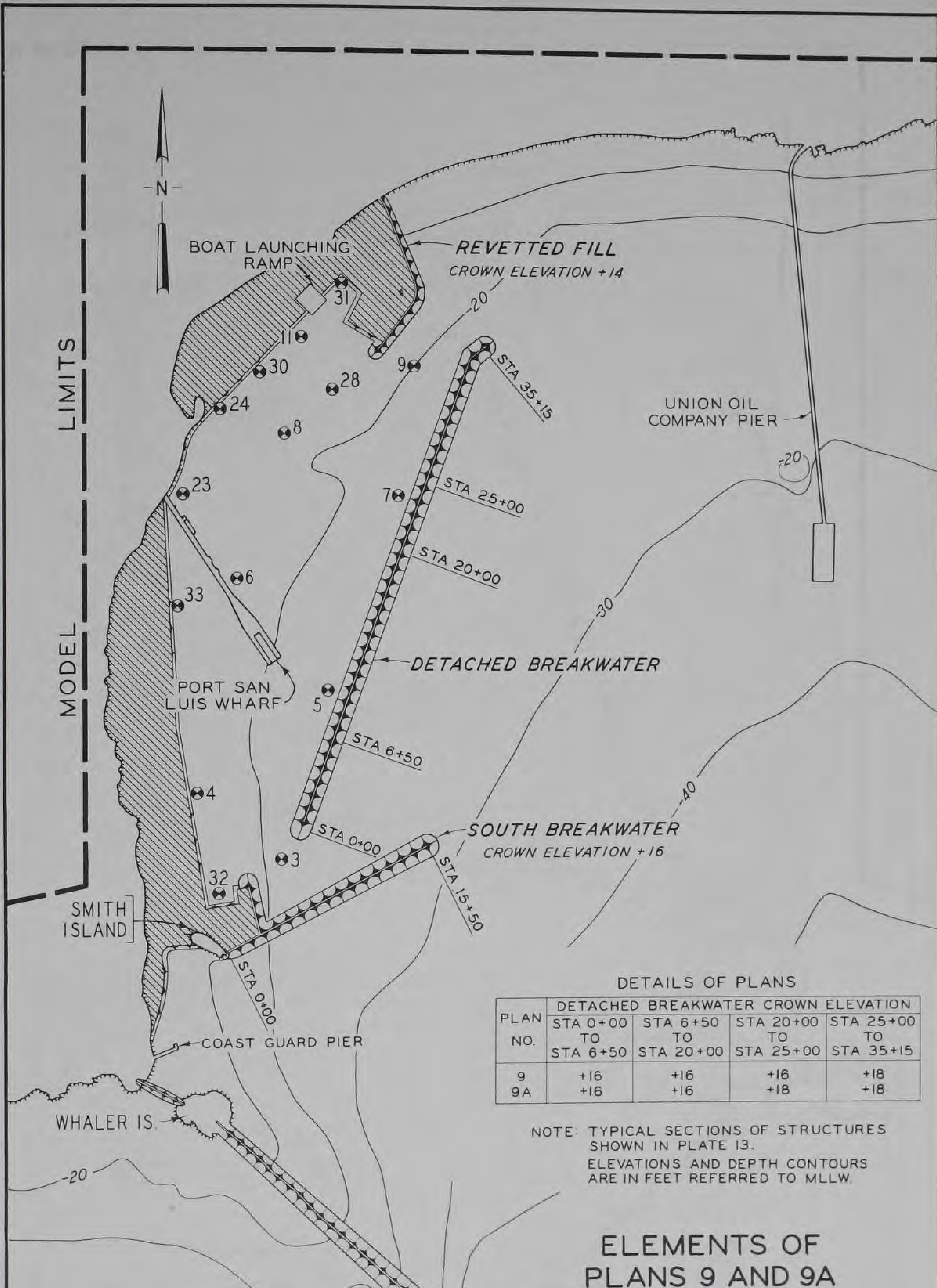


DETAILS OF PLANS

PLAN NO.	SOUTH BREAKWATER LENGTH, FT	SOUTH BREAKWATER ARMOR LAYER	DETACHED BREAKWATER ARMOR LAYER
8	1150	UNSEALED	UNSEALED
8A	1150	SEALED	UNSEALED
8B	1150	SEALED	SEALED
8C	1350	UNSEALED	UNSEALED
8D	1550	UNSEALED	UNSEALED
8E	1350	SEALED	UNSEALED
8F	1550	SEALED	UNSEALED
8G	1750	UNSEALED	UNSEALED

NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.

ELEMENTS OF PLANS 8, 8A, 8B, 8C, 8D, 8E, 8F, AND 8G

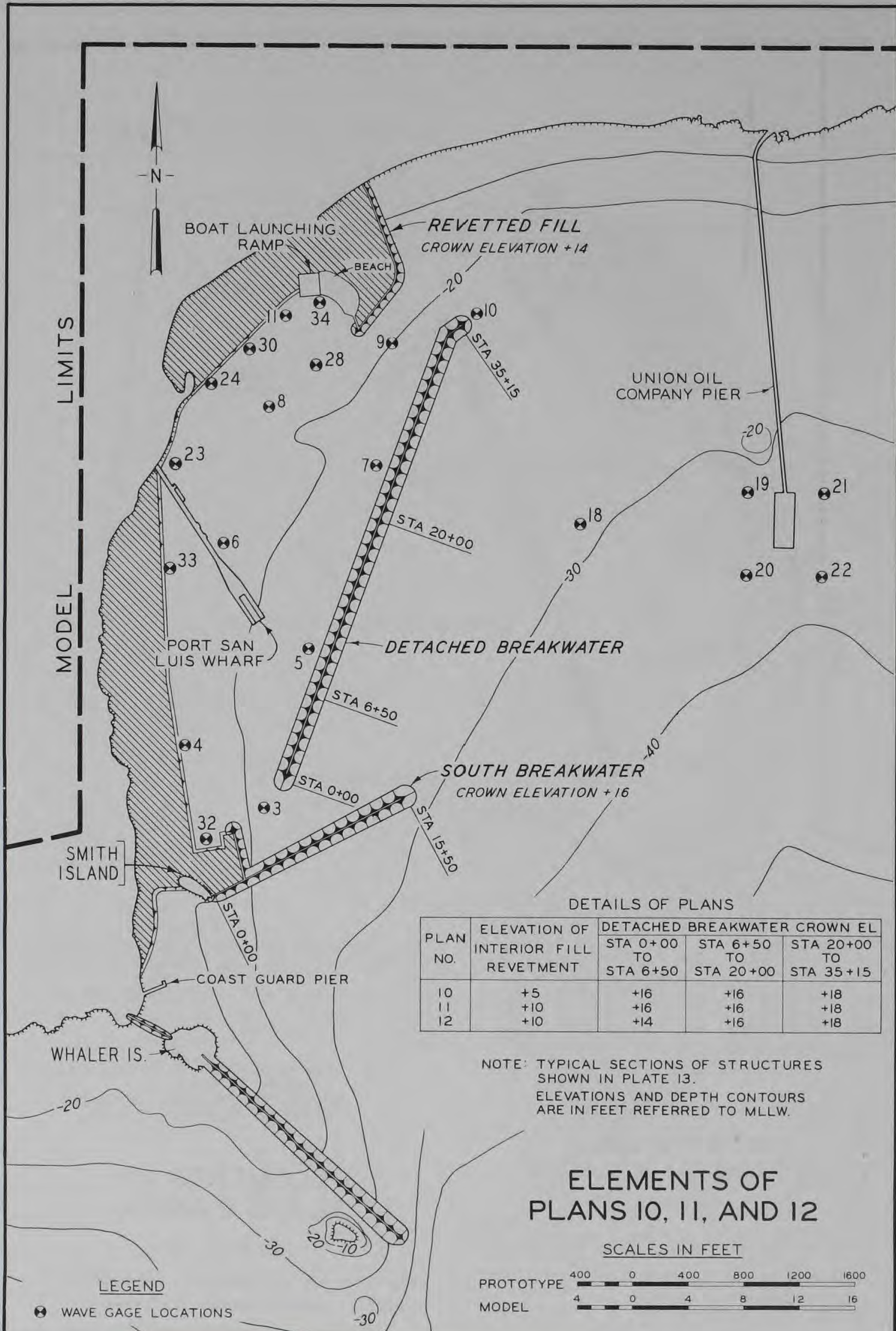


DETAILS OF PLANS

PLAN NO.	DETACHED BREAKWATER CROWN ELEVATION			
	STA 0+00 TO STA 6+50	STA 6+50 TO STA 20+00	STA 20+00 TO STA 25+00	STA 25+00 TO STA 35+15
9	+16	+16	+16	+18
9A	+16	+16	+18	+18

NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.

ELEMENTS OF PLANS 9 AND 9A



DETAILS OF PLANS

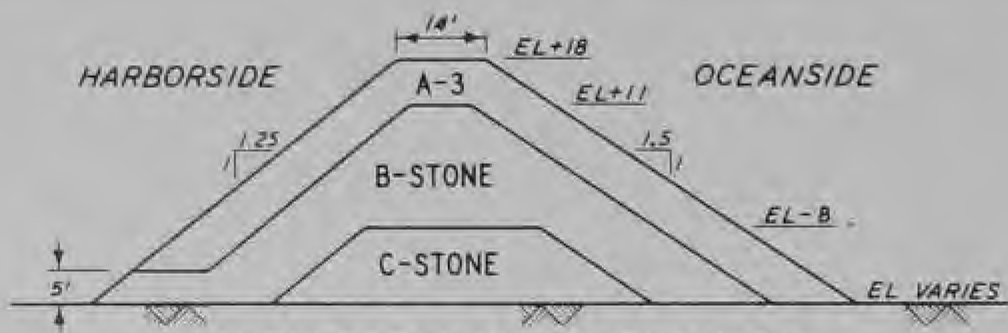
PLAN NO.	ELEVATION OF INTERIOR FILL REVETMENT	DETACHED BREAKWATER CROWN EL STA 0+00 TO STA 6+50	STA 6+50 TO STA 20+00	STA 20+00 TO STA 35+15
10	+5	+16	+16	+18
11	+10	+16	+16	+18
12	+10	+14	+16	+18

NOTE: TYPICAL SECTIONS OF STRUCTURES SHOWN IN PLATE 13.
ELEVATIONS AND DEPTH CONTOURS ARE IN FEET REFERRED TO MLLW.

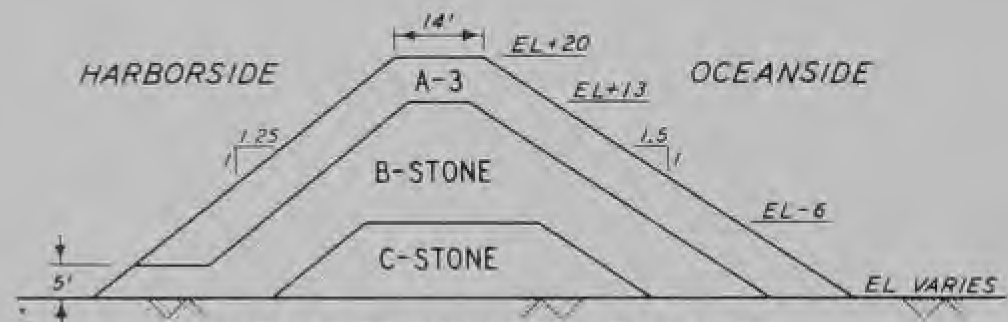
ELEMENTS OF PLANS 10, 11, AND 12

SCALES IN FEET

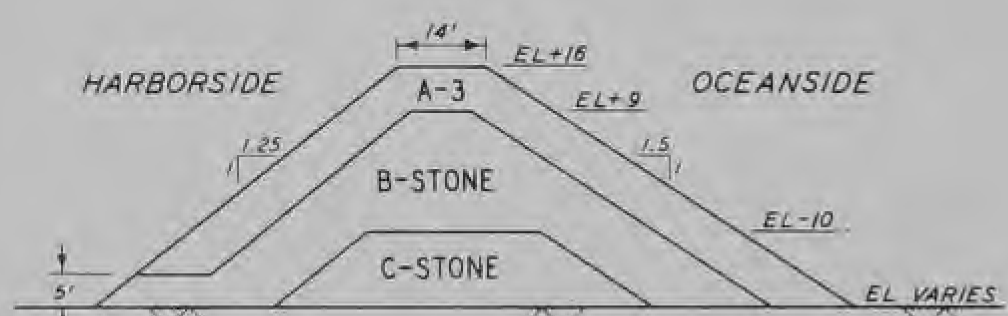
PROTOTYPE 400 0 400 800 1200 1600
MODEL 4 0 4 8 12 16



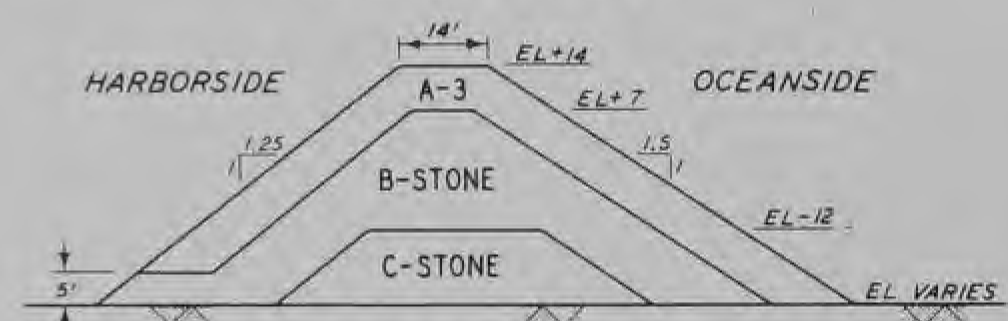
SOUTH BREAKWATER-PLAN 3A



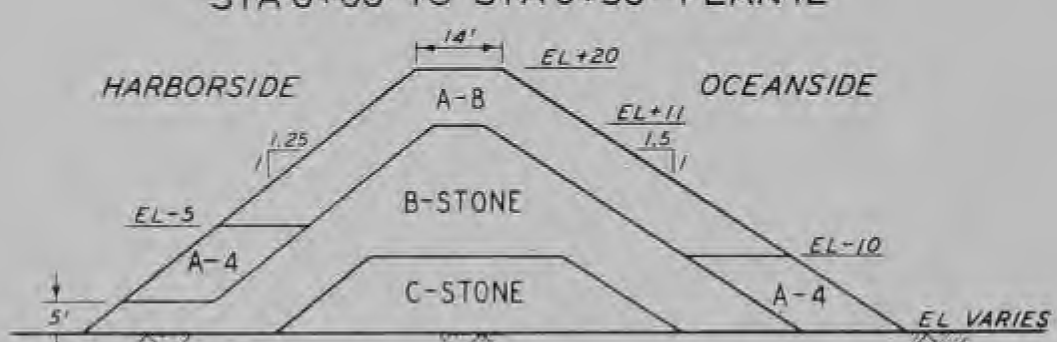
SOUTH BREAKWATER-PLAN 3B



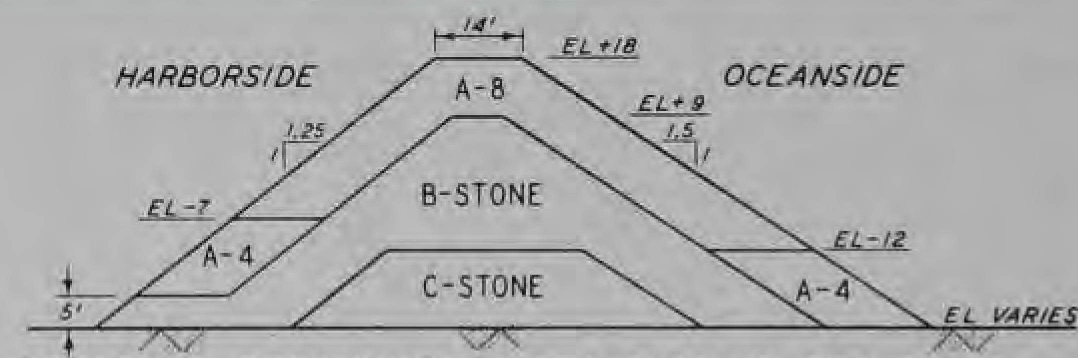
DETACHED BREAKWATER; STA 0+00 TO STA 6+50
ALL PLANS EXCEPT PLAN 12
SOUTH BREAKWATER-ALL PLANS EXCEPT
PLANS 1, 3A, AND 3B



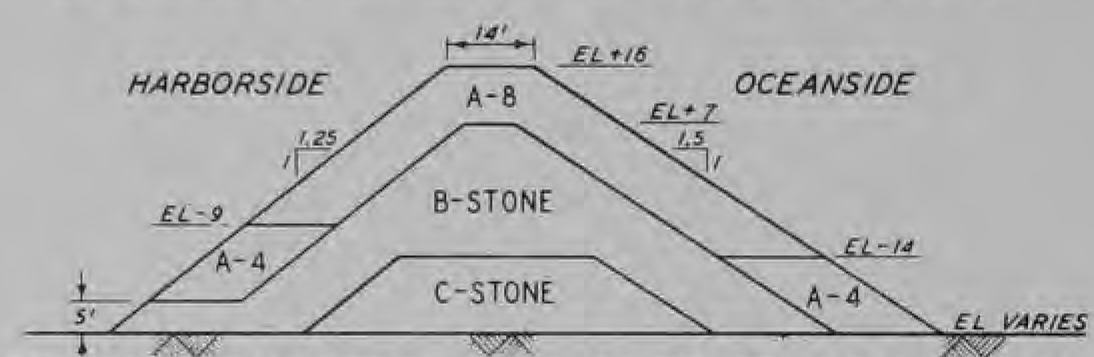
DETACHED BREAKWATER;
STA 0+00 TO STA 6+50-PLAN 12



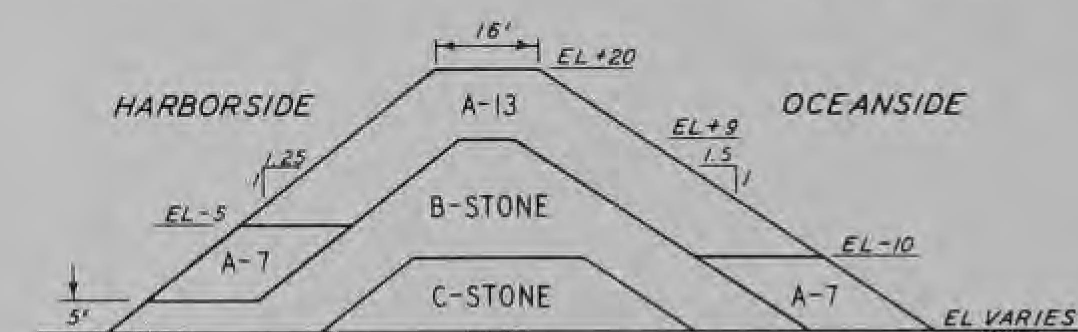
DETACHED BREAKWATER, STA 6+50 TO STA 25+00
PLANS 1, 2, 3, 3A, 3B, 3C, 3D, 4, 5, AND 5A



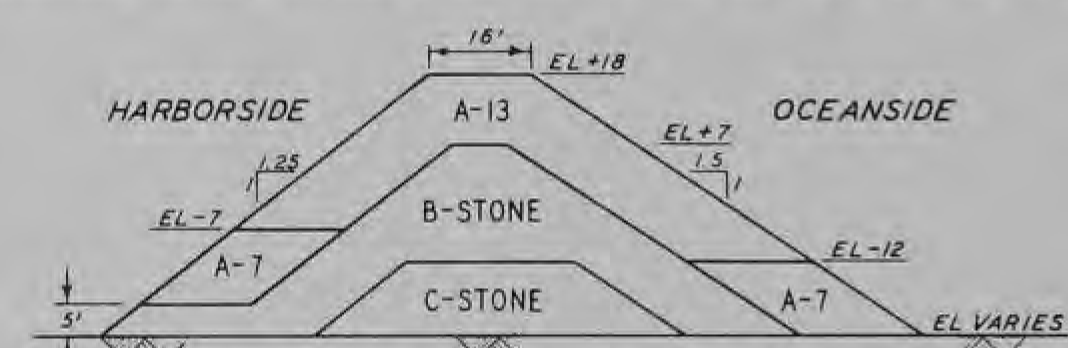
DETACHED BREAKWATER; STA 6+50 TO STA 25+00
PLANS 6, 6A, 7, 8, 8A, 8B, 8C, 8D, 8E, 8F, AND 8G
STA 20+00 TO STA 25+00-PLANS 9A, 10, 11, AND 12



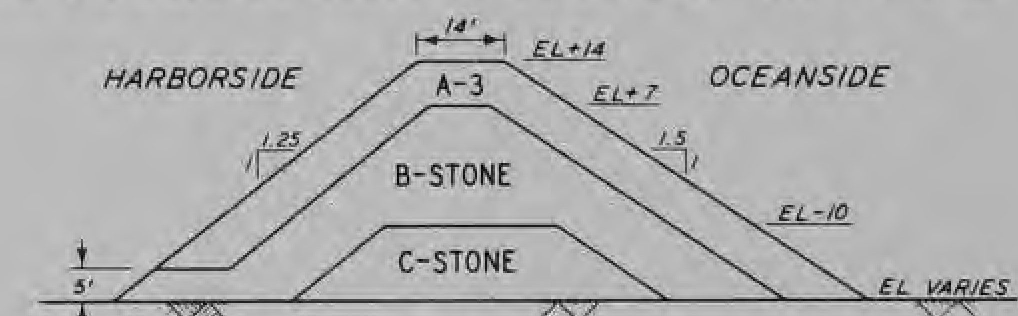
DETACHED BREAKWATER; STA 6+50 TO STA 25+00-PLAN 9
STA 6+50 TO STA 20+00-PLANS 9, 9A, 10, 11, AND 12



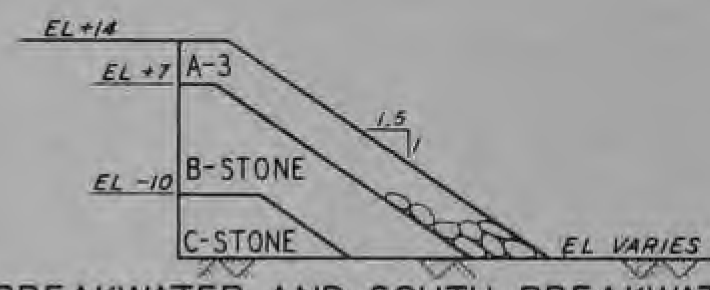
DETACHED BREAKWATER; STA 25+00 TO STA 35+15
PLANS 1, 2, 3, 3A, 3B, 3C, 3D, 5, 5A, AND 6
COMBINED BREAKWATER; STA 25+00 TO STA 31+75-PLAN 4



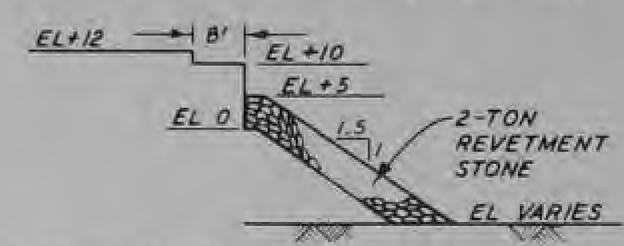
DETACHED BREAKWATER; STA 25+00 TO STA 35+15
PLANS 6A, 7, 8, 8A, 8B, 8C, 8D, 8E, 8F, 8G, 9, 9A, 10, 11 AND 12



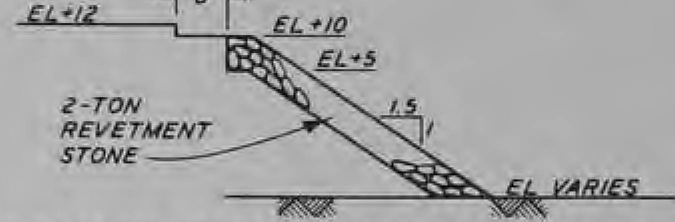
NORTH BREAKWATER AND SOUTH BREAKWATER WING
PLANS 2, 3, 3A, 3B, 3C, 3D, 5, 5A, 6, AND 6A
COMBINED BREAKWATER; STA 31+75 TO STA 46+25-PLAN 4



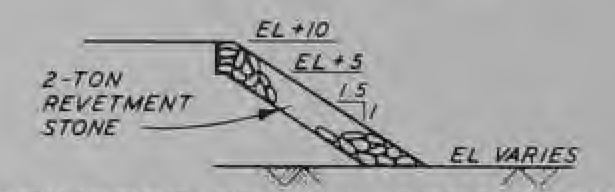
NORTH BREAKWATER AND SOUTH BREAKWATER WING
PLANS 7, 8, 8A, 8B, 8C, 8D, 8E, 8F, 8G, 9, 9A, 10, 11, AND 12



PERIMETER OF INTERIOR HARBOR FILL AREAS
PLANS 7, 8, 8A, 8B, 8C, 8D, 8E, 8F, 8G, 9, 9A, AND 10



PERIMETER OF INTERIOR HARBOR FILL AREAS
PLANS 11 AND 12



PERIMETER OF FILL AREA BETWEEN
SMITH ISLAND AND COAST GUARD PIER
PLANS 7, 8, 8A, 8B, 8C, 8D, 8E, 8F, 8G, 9, 9A, 10, 11, AND 12

STONE SPECIFICATIONS	
CLASS	PROTOTYPE WEIGHT RANGE
A-13	7-20 TONS; 50% ≥ 13 TONS
A-8	4-13 TONS; 50% ≥ 8 TONS
A-7	4-10 TONS; 50% ≥ 7 TONS
A-4	3-8 TONS; 50% ≥ 4 TONS
A-3	2-6 TONS; 50% ≥ 3 TONS
B	1 LB-4 TONS; 100% < 4 TONS 50% < 1000 LBS 30% < 200 LBS 15% < 20 LBS 5% < 1 LB
C	1 LB-4 TONS; 100% < 4 TONS 60% < 200 LBS 40% < 20 LBS 25% < 1 LB

NOTE: ELEVATIONS ARE IN FEET REFERRED TO MLLW

TYPICAL SECTIONS OF PROPOSED STRUCTURES

SCALE IN FEET

Unclassified

Security Classification

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

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Charles W. Brasfeild

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11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

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Los Angeles

13. ABSTRACT

A 1:100-scale model of Port San Luis (formerly known as San Luis Obispo Harbor), California, and sufficient offshore area to permit generation of the required test waves was used to investigate the arrangement and design of certain proposed harbor improvements with respect to wave action. The proposed harbor improvements consisted of (a) an 1150-ft-long south breakwater extending east-northeast from Smith Island, with a 370-ft-long breakwater wing extending northward from this structure; (b) a 3515-ft-long detached breakwater with a north-northeast to south-southwest alignment, located approximately 500 ft seaward of the Port San Luis Wharf; (c) a 1300-ft-long north breakwater extending from a point on shore southward toward the north end of the detached breakwater; and (d) development of the inner harbor by constructing landfill areas and boat slips for the anchorage of small pleasure craft. A 60-ft-long wave machine and electrical wave height measuring and recording apparatus were utilized in model operation. Base tests were conducted with existing prototype conditions installed in the model. Results of tests involving the various improvement plans were compared with base test results to determine the relative effectiveness of the respective plans. Of the plans tested, the optimum configuration appears to be that designated as plan 12. It was concluded from the test results that (a) the proposed 1300-ft-long north breakwater and the 370-ft-long south breakwater wing can be replaced by revetted fills; (b) the length of the south breakwater should be increased by 400 ft; (c) the northern end of the proposed harbor should be redesigned to prevent excessive wave heights in that area; (d) the optimum harbor improvement plan (plan 12) will provide sufficient protection to the inner harbor from storm waves most of the time; however, when exceptionally high storm waves from the south-southwest deepwater direction occur simultaneously with high tide conditions, wave heights in the northern part of the harbor will reach magnitudes of approximately 3 ft; and (e) installation of the proposed breakwater and other harbor structures will not adversely affect wave conditions at the Union Oil Company Pier.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

Security Classification

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Harbors						
Hydraulic models						
Port San Luis, Calif.						
Water waves						