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TECHNICAL REPORT H-77-22

BREAKWATER STABILITY STUDY
IMPERIAL BEACH, CALIFORNIA

Hydraulic Model Investigation

by

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A hydraulic model investigation was conducted at a geometrically undistorted scale of 1:16, model to prototype, to design stable rubble-mound breakwater sections to protect a beach nourishment area at Imperial Beach, California. Both the -5.0 ft mllw contour (shallow-water location) and -10.0 ft mllw contour (deeper water location) were given as proposed construction sites. Twenty-one plans were tested, resulting in two adequate breakwater designs for each of the two proposed sites. A constant high-sill structure, using

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20. ABSTRACT (Continued).

3-ton graded armor stone, and an alternating high- and low-sill structure, using 5- and 0.5-ton armor stone, were stable for the design conditions at the shallow-water location. Two alternating high- and low-sill structures proved adequate for the design condition at the deeper water location. One used 5- and 3-ton graded armor stone on the breakwater trunks and 7-ton capstone on the ends of the breakwater system on 1V-on-3H side slopes while the other design used trunk sections of 7- and 5-ton graded armor stone on 1V-on-2H side slopes and 7-ton capstone on the head section with 1V-on-3H side slopes.

PREFACE

The model investigation reported herein was initially requested by the U. S. Army Engineer District, Los Angeles (SPL) in a letter to the Division Engineer, U. S. Army Engineer Division, South Pacific, dated 19 August 1974.

Funding authorization by SPL was granted on 23 December 1974, with subsequent installments authorized through 23 March 1977. Model tests of the breakwater stability were conducted at the U. S. Army Engineer Waterways Experiment Station (WES) during the period November 1976 to July 1977 under the general direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, Dr. R. W. Whalin, Chief of the Wave Dynamics Division, and Mr. D. D. Davidson, Chief of the Wave Research Branch. Tests were conducted by Messrs. R. D. Carver and D. G. Markle, Hydraulic Research Engineers, assisted by Mr. C. Lewis, engineering technician. This report was prepared by Messrs. Carver and Markle.

Liaison was maintained during the course of the investigation by means of conferences, progress reports, and telephone conversations.

Director of WES during the conduct of this study and the preparation and publication of this report was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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

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

Multiply	By	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms
tons (2000 lb, mass)	907.1847	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
degrees (angle)	0.01745329	radians

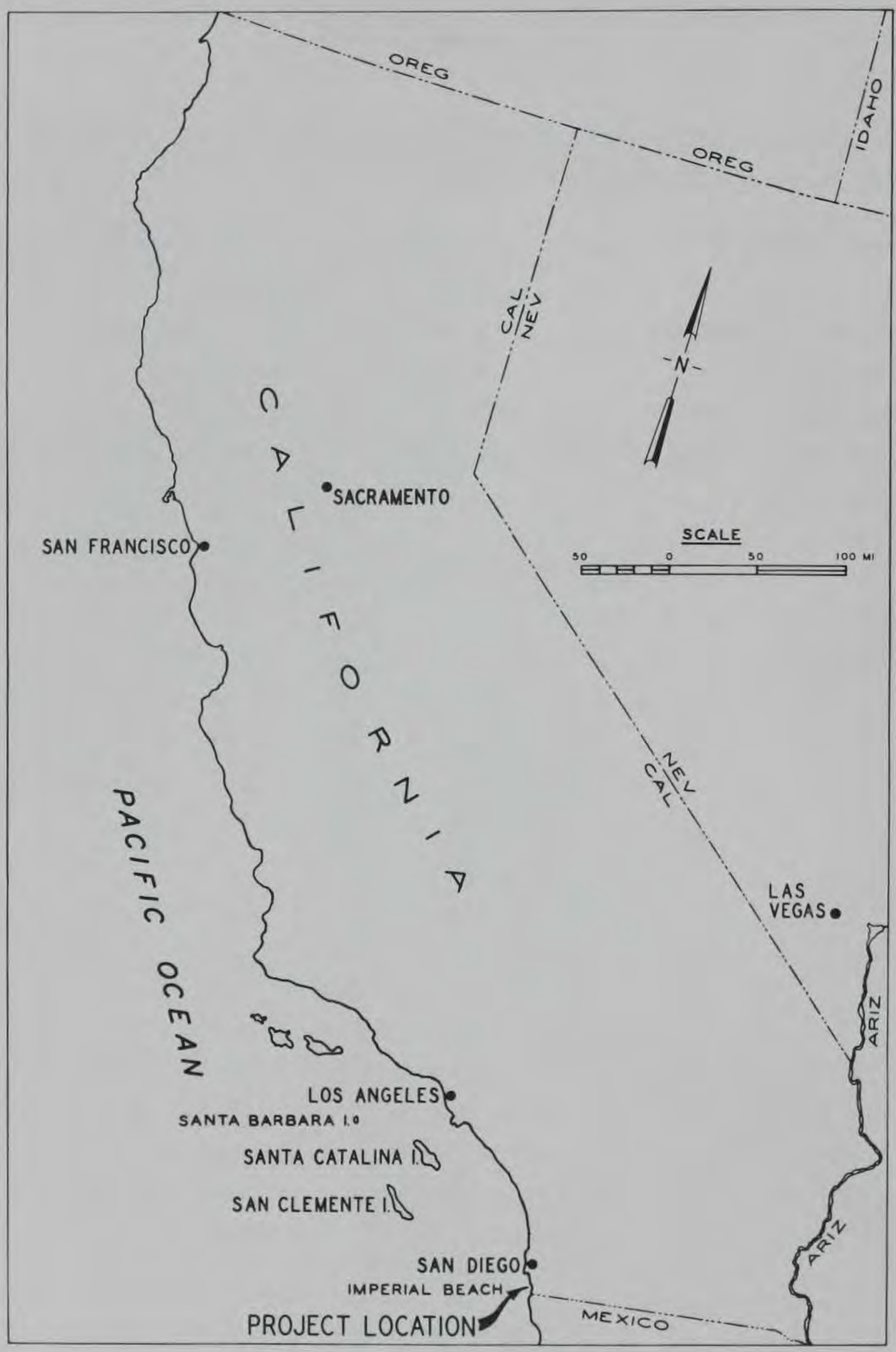

Figure 1. Vicinity map

BREAKWATER STABILITY STUDY, IMPERIAL BEACH, CALIFORNIA

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Imperial Beach is located on the Pacific Ocean about 3 miles* north of the Mexican border and 11 miles south of San Diego, California (Figure 1). It is primarily a recreational beach with a 1200-ft-long fishing pier located at its approximate center. Offshore bathymetry is characterized by gentle slopes with contours approximately parallel to the shoreline; consequently, most waves approach nearly normal to beach.

2. The Tijuana River has probably been the main source of sediment for Imperial Beach; however, a lack of significant floods since 1944 has caused a shortage of sediment at the river mouth, resulting in a decreased quantity of sand available for longshore transport to Imperial Beach. Erosion problems became critical during the winter of 1952-1953 when wave action caused rapid shoreline recession and property damage. Winter storms during the next several years necessitated the construction of a stone revetment by local interests. Between 1959 and 1963, the Corps of Engineers constructed two groins in the area; however, these have proven ineffective in restoring the beach, and additional stone revetments have been installed by local interests.

3. The Corps of Engineers recently completed nourishing the beach with sand dredged from San Diego Bay (summer 1977). It is planned that the new beach fill will be protected by an offshore submerged, or near-submerged, breakwater approximately 5000 ft long and positioned parallel to the shoreline at either the -5.0 ft mean lower low water (mllw) contour or the -10.0 ft mllw contour. Preliminary analysis of various

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

available breakwater materials dictated that the breakwater be constructed of stone and that the crown elevation be at or below the range of normal water levels. This would necessitate the structure being subjected to breaking waves which either strike the structure directly or are tripped by the structure, causing major turbulence and overtopping. Although model tests conducted at U. S. Army Engineer Waterways Experiment Station (WES) in connection with the OCE Research and Development Program[1,2,3] have provided considerable data for design of rubble mound, the majority of the data addresses nonovertopping structures subject to nonbreaking waves. Other specific studies, such as those conducted for Perched Beach, Santa Monica, California,[4] and Jetty Stability, Oregon Inlet, North Carolina,* provide limited data on submerged structures and overtopping breaking wave conditions; but the results are not directly applicable to the Imperial Beach design conditions. Thus, since there is no applicable design criteria for submerged structures subject to breaking waves, it was considered necessary to conduct stability tests of the proposed Imperial Beach breakwater to assure adequate design of the structure.

Purpose of Model Study

4. Three-dimensional (3-D) model tests conducted by WES during 1975-1976 to determine the optimum breakwater alignment and positioning relative to the shoreline,[5] indicated that several alternative plans constructed parallel to the shoreline at either the -5.0 or -10.0 ft mllw contour would provide the protection needed by the beach. The purpose of the present investigation was to design alternative breakwater sections (determine armor weights, slopes, crown widths, etc.) that would be stable at the -5.0 and -10.0 ft mllw contours.

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* Jetty Stability, Oregon Inlet, N. C. (unpublished, study presently being conducted at WES).

PART II: THE MODEL

Design of Model

5. Tests were conducted at a geometrically undistorted linear scale of 1:16, model to prototype. Scale selection was determined by the absolute size of the model breakwater sections necessary to ensure the preclusion of stability scale effects,[6] capabilities of the available wave generator, and depth of water at the toe of the breakwater. Based on Froude's model law[7] and a linear scale of 1:16, the following model-prototype relations were derived. Dimensions are in terms of length (L) and time (T).

Characteristics	Dimensions	Model-Prototype Scale Relations
Length	L	$L_r = 1:16$
Area	L^2	$A^r = L_r^2 = 1:256$
Volume	L^3	$V_r = L^3 = 1:4096$
Time	T	$T_r = L_r^{1/2} = 1:4$

6. The specific weight of water used in the model was assumed to be 62.4 pcf, that of seawater is 64.0 pcf. Specific gravities of model breakwater construction materials were the same as their prototype counterparts. The difference in specific gravity of model fresh water and the prototype seawater was accounted for by use of the following transference equation:

$$\frac{(W_r)_m}{(W_r)_p} = \frac{(\gamma_r)_m}{(\gamma_r)_p}\left(\frac{L_m}{L_p}\right)^3\left[\frac{(S_r)_p - 1}{(S_r)_m - 1}\right]^3$$

where

subscripts m and p = model and prototype quantities, respectively

W_r = weight of an individual stone, lb

γ_r = specific weight of an individual stone, pcf

L_m/L_p = linear scale of the model

S_r = specific gravity of an individual stone relative to the water in which the breakwater is constructed, i.e., $S_r = \gamma_r/\gamma_w$

γ_w = the specific weight of water, pcf

Method of Constructing Test Sections

7. Model breakwater lengths representing 64 to 96 ft of the proposed prototype breakwater sections were constructed to reproduce, as closely as possible, the usual methods of constructing prototype breakwaters. The filter material, dampened as it was dumped by bucket or shovel into the flume, was compacted with hand trowels to simulate natural consolidation resulting from wave action during construction of the prototype structure. Once the filter material was in place, it was sprayed with a low-velocity water hose to ensure adequate compaction of the material. Armor stone used in the cover layers was placed in a random manner (i.e., laid down in such a way that no intentional interlocking of the stone was obtained). Model elevations were controlled with an engineers level to a tolerance of $\pm$0.005 ft.

Test Facilities and Equipment

8. All stability tests were conducted in a flume 19 ft wide and approximately 80 ft long located within a large L-shaped concrete flume 250 ft long, 50 and 80 ft wide at the top and bottom of the L, respectively, and 4.5 ft deep. To simulate local prototype bathymetry, the bottom of the 19-ft-wide flume was molded to a 1V-on-35H slope for a simulated prototype distance of approximately 300 ft seaward of the test sections. The flume was equipped with a paddle-type wave generator capable of producing sinusoidal waves of various periods and heights. Changes in water-surface elevation, as a function of time, were measured by electrical wave-height gages and recorded on chart paper by an electrically operated oscillograph. The electrical output of each wave gage was directly proportional to its submergence depth.

PART III: TESTS AND RESULTS

Selection of Test Conditions

9. It was desired to design alternative breakwater sections that would be stable for water depths at the -5.0 and -10.0 ft mllw contours. From here on, the -5.0 and -10.0 ft mllw contours will be referred to as the shallow-water location and deeper water location, respectively. For both locations, it was desired that the structures be stable for wave periods of 7, 10, and 14 sec at still-water levels (swl's) of 0.0 and +5.4 ft mllw. Model observations indicated that for swl's and wave periods considered at both locations, the corresponding maximum breaking wave was always more damaging than any lesser wave height. Observations of incident wave forms at the structures showed the worst breaking waves that could be made experimentally to attack the sections for the selected conditions as follows:

Depth, ft mllw	swl, ft mllw	Wave Period, sec	Worst Breaking Wave Height, ft
-5.0	0.0	7	3.9
-5.0	0.0	10	4.1
-5.0	0.0	14	4.5
-5.0	+5.4	7	7.5
-5.0	+5.4	10	8.3
-5.0	+5.4	14	8.5
-10.0	0.0	7	7.3
-10.0	0.0	10	8.0
-10.0	0.0	14	8.3
-10.0	+5.4	7	10.0
-10.0	+5.4	10	11.4
-10.0	+5.4	14	12.1

Model observations also indicated that for a given location and swl, the 14-sec period wave produced the most damage to the structure. Therefore, subsequent full-length stability tests were conducted using only the 14-sec wave period. The testing time reported for each wave condition throughout this report is given in prototype time.

Development of Plans

10. A total of 21 plans were tested. Two plans were tested for both the shallow-water and deeper water locations, while the other 19 plans were only tested for the deeper water location. All plans tested, except for Plans 5, 6, 8, and 9, employed an alternating high- and low-sill concept. Plans 1-4 (Plates 1-4) used uniform size primary armor stone, while the remaining 17 plans used graded armor stone mixes. Graded armor stone mixes were used in an effort to obtain a stable design that would fit within the limiting geometry required to maintain (as nearly as possible) a totally submerged structure in the deeper water location for all swl's equal to or greater than 0.0 ft mllw. Uniform size armor stone was used to cap (one layer) areas on some of the heads and groins where instability of the graded armor stone mixes occurred. The gradation by weight of the graded armor stone mixes, directed by the sponsoring district and used in the model tests, are given in Table 1 and on their respective test plans (Plates 5-21). The initial plans (Plans 2-6) incorporated a 2-ft thick, 25-lb stone filter layer, whereas later plans (Plans 7-12D) deleted this filter stone on the assumption that the prototype structure would be constructed on filter cloth. Table 2 gives a listing of all plans and the test conditions to which they were exposed.

Description of Test Plans and Discussion of Results

11. Plans 1 and 2 were constructed on a sand bed in an attempt to qualitatively determine if erosion at the toe of the breakwater would be a problem. The sand was of approximate prototype size; and it was felt, therefore, that if scouring was observed in the model it would certainly be a prototype problem. However, the converse may or may not be true (i.e., if scour is not a problem in the model, it may still occur in the prototype). During the testing of Plans 1 and 2, some scour was observed along the seaward edge of the structure; however, the apron stone tended to migrate into the eroded area and stabilize the slope. Also, a

bar tended to form immediately seaward of the eroded area. The model armor stone was not undermined; thus it was concluded that the erosion was probably not extensive enough to have a significant effect on stability of the breakwater and that the bar formed was of sufficient height that waves reaching the structure were no more severe than they would have been if the structure had been built on a fixed surface. Therefore, to assure uniformity of test waves between tests of Plans 2 and 3, the sand pit was capped with concrete. Details of plans tested, test conditions, and test results are given in the following paragraphs.

12. Plan 1 (Plate 1 and Photo 1) was constructed in the deeper water location to high-sill and low-sill elevations of +0.4 and -5.0 ft mllw, respectively. The high sill was armored with 3.0-ton stone and the low sill used 300-lb stone. Armor slopes of 1V on 1.5H were used on both the sea side and beach side. Attack of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw for 1.5 hr produced moderate damage to both the low- and high-sill sections of the breakwater (Photo 2). Test conditions were changed to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, and 2.0 hr of wave attack produced extensive damage to all portions of the breakwater (Photo 3).

13. Plan 2 (Plate 2 and Photo 4) was similar to Plan 1 except a 2.0-ft-thick blanket of 25-lb filter material was added to the bottom of the structure. Crown elevations of +2.4 and -5.2 ft mllw were used for the deeper water location. Attack of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw for 1.5 hr produced moderate damage to both the low- and high-sill sections of the breakwater (Photo 5). Attack of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw for 1.0 hr produced extensive damage to all portions of the breakwater (Photo 6).

14. Plan 3 (Plate 3 and Photo 7) used 5.0-ton stone on the high sill and 0.5-ton stone on the low sill and was tested in both the deeper water and shallow-water locations. Armor slopes of 1V on 1.5H were used both sea side and beach side. The high-sill section of the structure was constructed to a crown elevation of +5.2 ft mllw in the deeper water location (equivalent to +10.2 ft mllw in the shallow-water location). The low-sill section of the structure was constructed to a crown

elevation of -3.8 ft mllw in the deeper water location (equivalent to +1.2 ft mllw in the shallow-water location). Testing in the deeper water location with 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw for 2.0 hr produced only minor damage (Photo 8); however, 2.0 hr of attack by 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw produced extensive damage (Photo 9). The breakwater was rebuilt in the shallow-water location and 2.0 hr of 14.0-sec, 4.5-ft waves at an swl of 0.0 ft mllw and 2.0 hr of 14.0-sec, 8.5-ft waves at an swl of -5.4 ft mllw produced only minor damage (Photos 10-13).

15. Plan 4 (Plate 4 and Photo 14) was constructed in the deeper water location to high- and low-sill elevations of +6.0 ft and -3.0 ft mllw, respectively. The high sill was armored with 5.0-ton stone and the low sill used 1750-lb stone. The 5.0-ton and 1750-lb stone were built to slopes of 1V on 2H and 1V on 1.5H, respectively. Attack of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw for 1.5 hr produced only minor damage (Photo 15); however, test conditions were changed to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw and 2.0 hr of wave attack produced extensive damage to both the low- and high-sill sections of the structure (Photo 16).

16. Plan 5 (Plate 5 and Photo 17) was a substantial departure from the alternating low- and high-sill concept employed in Plans 1-4. Plan 5 was constructed to a constant crown elevation of 0.0 ft mllw in the deeper water location and +5.0 ft mllw in the shallow-water location. The armor stone was graded by weight percentage from a maximum of 3.0 tons to a minimum of less than 6.0 lb (3-ton graded armor stone as given in Plate 5 or Table 1). Armor slopes of 1V on 3H were used both sea side and beach side. Testing in the deeper water location with 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw produced only minor damage after 1.5 hr of exposure (Photo 18); however, exposure to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw for 2.0 hr resulted in extensive damage (Photo 19). It was deemed advantageous to test Plan 5 in the shallow-water location since it was thought it might prove to be more economical than Plan 3. After rebuilding the breakwater, testing in the shallow-water location with 14.0-sec, 4.5-ft waves at an swl of

0.0 ft mllw produced significant toe stone movement, but only minor damage to the primary armor mix (Photo 20). Wave attack was continued for 2.0 hr using 14.0-sec, 8.5-ft waves at an swl of +5.4 ft mllw and this resulted in minor to moderate damage to all sections of the breakwater (Photo 21).

17. Plan 6 (Plate 6 and Photo 22) was constructed on a 2-ft-thick layer of 25-lb filter stone to a constant crown elevation of +1.0 ft mllw in the deeper water location. The trunk portion of the breakwater was constructed with 1V on 3H slopes using graded armor stone that ranged from a maximum of 5.0 tons to a minimum of less than 6.0 lb (5-ton graded armor stone as given in Plate 6 or Table 1). Maximum and minimum porosity of the 5-ton graded armor stone as determined by model measurement was 44 percent and 40 percent, respectively. The breakwater head and the adjacent 50 ft of trunk incorporated this same graded armor stone in a 4.5-ft-thick core and was capped with one layer of 5.0-ton armor stone placed on 1V-on-3H slopes. Attack by 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw for 1.5 hr produced only minor damage (Photo 23). The swl was then raised to +5.4 ft mllw; and after 2.0 hr of attack by 14.0-sec, 12.1-ft waves, the breakwater showed moderate damage (Photo 24). After 4.0 hr more of wave attack (a total of 6.0 hr) by 14-sec, 12.1-ft waves, the damage to the trunk section increased slightly while the damage to the head was significant (Photo 25). An additional 2 hr (a total of 8.0 hr) of exposure to the same wave condition resulted in extensive but stabilized damage to the entire test section (Photo 26).

18. Plan 7 (Plate 7 and Photo 27) returned to the alternating high- and low-sill concept for the deeper water location, but removed the 25-lb stone filter layer with the assumption that the rock filter would be replaced with filter cloth. The high sill was constructed with 1V-on-3H slopes to a crown elevation of 0.0 ft mllw using 5.0-ton graded armor stone. Using 3.0-ton graded armor stone, the low sill was constructed with 1V-on-3H slopes to a crown elevation of -5.0 ft mllw. After experiencing 1.5 hr of attack by 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw, the structure had sustained very minor damage (Photo 28) and was considered stabilized for this test condition. The test

condition was changed to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. After 2.0 hr of exposure to this wave condition, the high-sill and low-sill trunk had experienced very little displacement; however, the low-sill head section showed significant damage (Photo 29) and had not stabilized.

19. Plan 7A (Plate 8 and Photo 30) was the same as Plan 7, except that the last 15 ft of the trunk and the entire head of the low sill were replaced with 5.0-ton graded armor stone identical with that used on the high sill in Plan 7. The high-sill section was not rebuilt after testing Plan 7, but the low-sill trunk was rebuilt for Plan 7A testing. After 2.0 hr of exposure to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, the high-sill section and the low-sill trunk experienced very little movement while the 5.0-ton graded armor on the head of the low sill sustained significant damage (Photo 31). The identical test conditions were extended for an additional 2.0 hr to determine if the damage to the head section would stabilize. The head section continued to deteriorate and did not stabilize (Photo 32). The high-sill section and low-sill trunk (6.0 hr and 4.0 hr, cumulative testing at +5.4 ft mllw swl, respectively) remained in acceptable condition.

20. Plan 7B (Plate 9 and Photo 33) consisted of rebuilding the last 15 ft of trunk and adjacent head of Plan 7A's low sill using one layer of 5.0-ton armor stone. The remaining portions of the breakwater were not rebuilt after testing Plan 7A. After 2.0 hr of exposure to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, the 5.0-ton armor layer on the low-sill head had accrued extensive damage (Photo 34) and did not appear to be stabilized. Stability of the high-sill section and low-sill trunk (8.0 hr and 6.0 hr cumulative testing at a +5.4 ft mllw swl, respectively) remained acceptable.

21. Plan 7C (Plate 10 and Photo 35) was constructed in the deeper water location using the alternating high- and low-sill concept. Like Plans 7, 7A, and 7B, the 25-lb stone filter layer was not used on the assumption that it would be replaced by filter cloth. Slopes of 1V on 3H were used in constructing the high sill to a crown elevation of 0.0 ft mllw. Construction material in the high-sill section consisted of

5.0-ton graded armor stone. A 3.0-ton graded armor stone was placed on 1V-on-3H slopes in construction of the low-sill trunk (except for the last 15 ft adjacent to low-sill head) to a crown elevation of a -5.0 ft mllw. The low-sill head and 15 ft of the adjacent low-sill trunk consisted of one layer of 7.0-ton armor stone at a crown elevation of -5.0 ft mllw. After 1.0 hr of exposure to 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw, the breakwater had sustained no damage (Photo 36). Test conditions were then changed to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. Very minor damage had occurred after 2.0 hr of wave attack at this test condition (Photo 37). The identical test condition was extended for 2.0 hr of additional wave attack. This resulted in minor but stabilized damage to both the high- and low-sill sections of the breakwater (Photos 38-40). In this plan, as well as others, a few stones were completely displaced off the test section as shown in the photographs. This displacement did not deteriorate the effective stability of the structure; and it is surmised that since the model bottom was hard-surface concrete, the stone displaced in the prototype will not travel as far as indicated in the photographs but will settle into the sand bottom immediately behind the breakwater. This test was repeated and it verified results of the first testing of Plan 7C.

22. Plan 8 (Plate 11 and Photo 41) was tested to find a stable high-sill head for the deeper water location in the event that the breakwater sections were to end with a high sill. Except for the 15 ft adjacent to the high-sill head, the high-sill trunk was constructed identical with Plan 7C (paragraph 21). This 15 ft of trunk and the entire head were constructed with 1V-on-3H slopes to a crown elevation of -5.0 ft mllw using 5.0-ton graded armor stone. One layer of 7.0-ton armor stone was then used to cap this portion of the breakwater, bringing the crown elevation to 0.0 ft mllw. After experiencing 2.0 hr of attack by 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, the structure showed no damage (Photo 42). A repeat test verified the findings of this first test.

23. Plan 9 (Plate 12 and Photo 43) was run in an effort to steepen the breakwater slopes and thus reduce construction costs by

minimizing the amount of construction material. Plan 9, in the deeper water location, consisted of two high-sill trunk sections with 1V-on-3H and 1V-on-2H slopes, respectively, and a high-sill head with 1V-on-2H slopes; 5.0-ton graded armor stone was used on both trunk sections. Except for the steeper 1V-on-2H slopes, the Plan 9 head section was identical with the Plan 8 head section described in paragraph 22. A crown elevation of 0.0 ft mllw was used for the entire breakwater test section. After 4.0 hr of exposure to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, very minor damage could be seen on the 1V-on-3H slope trunk section, minor damage on the 1V-on-2H slope trunk section, and moderate damage to the 7.0-ton capstone on the head section of the breakwater (Photo 44).

24. Plan 10 (Plate 13 and Photo 45) was initiated based on the marginally acceptable test results of Plan 9. Like Plan 7C, Plan 10, in the deeper water location, consisted of alternating high- and low-sill sections with 1V-on-2H side slopes constructed of 5.0- and 3.0-ton graded armor stone, respectively. A 2-ft-thick, 5-ft-wide berm of 25-lb filter stone was placed at the beach-side and sea-side toes of the high-sill section and low-sill trunk. The purpose of this material would be to hold the exposed filter cloth in place and to help prevent undermining of toe areas in the prototype. The low-sill head's 7.0-ton armor stone (one layer) was placed on a 2-ft-thick bed of 25-lb filter stone which was to be underlaid by filter cloth in the prototype. This filter layer prevented the direct placement of 7.0-ton armor stone on the filter cloth. Crown elevations of 0.0, -5.0, and -3.0 ft mllw were used on the high-sill section, low-sill trunk, and low-sill head, respectively. After 2.0 hr of attack by 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw caused minor instability of the breakwater (Photo 46). The test condition was changed to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. After 2.0 hr of exposure, the high-sill section and low-sill trunk showed moderate damage and the low-sill head had accrued extensive damage (Photo 47).

25. Plan 10A (Plate 14) consisted of rebuilding the low-sill head section of Plan 10. Migration of 25-lb filter stone had added to the

extensive damage of the low-sill head of Plan 10. For this reason it was replaced by one layer (2 ft thick) of 1000-lb stone. The remainder of the structure was not rebuilt after testing Plan 10. After 2.0 hr more of attack by 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, the low-sill head and trunk showed extensive damage. Movement on the high-sill section had lowered the crown elevation significantly. Damage had not stabilized but had exceeded the allowable amount when the test was stopped (Photo 48).

26. Plan 11 (Plate 15 and Photo 49) used the alternating high- and low-sill concept. Results of Plans 10 and 10A (paragraphs 24 and 25) had shown that the 5.0- and 3.0-ton graded armor stone mixes constructed to 1V-on-2H slopes on the high and low sills, respectively, were unstable for the design condition of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. Plan 11 incorporated the same design geometry for the high-sill section and low-sill trunk as used for Plans 10 and 10A; however, the weight of the graded armor stone mixes was increased. The 7-ton graded armor stone (given in Plate 15 and Table 1) was used on the high-sill section and 5.0-ton graded armor stone was used on the low-sill trunk. Maximum and minimum porosity of the 7-ton-graded armor stone as determined in the model was 47 and 40 percent, respectively. Like Plan 10A, a 6-ft-wide and 2-ft-high berm of 1000-lb stone was placed on both the sea-side and beach-side toe of the structure. The low-sill head and adjacent 15 ft of trunk were constructed using one layer of 7.0-ton armor stone placed on a 2-ft-thick layer of 1000-lb stone, except for the outer perimeter where 7.0-ton stones were to be placed directly on the filter cloth to stabilize the toe of the low-sill head which had proved unstable during testing of Plan 10A. Crown elevations were 0.0, -5.0, and -3.0 ft mllw for the high-sill section, low-sill trunk, and low-sill head, respectively. After 1.0 hr of exposure to 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw, minor displacement of the beach-side berm had occurred (Photo 50). The condition was changed to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. After 2.0 hr of wave attack, displacement of some of the beach-side toe stone behind the low-sill trunk section had occurred, but it is believed that the

displacement of this stone on a prototype sand bottom would not be as severe as shown in the model. The remainder of the structure suffered minor damage (Photo 51). The identical wave attack was extended for 2.0 hr more, resulting in very little change to the breakwater (Photos 52-54). Moderate damage had occurred on the low-sill head and minor damage on the remainder of the structure after a total of 6.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw (Photos 55-57).

27. Plan 11A (Plate 16 and Photo 58) was identical with Plan 11 (paragraph 26) except for the addition of the 5-ft-high beach-connected groin, constructed at a 90° angle to and connected to the low-sill head. The 5-ton graded armor stone mix, identical with that used on the low-sill trunk, was placed on 1V-on-2H slopes with a constant crown width of 10 ft. The groin crown elevation was not held constant but instead the structure height was maintained at 5 ft. In changing from Plan 11 to Plan 11A, only the low-sill head was rebuilt. In order to observe the result of extended wave attack, the remaining sections of the breakwater were not rebuilt during the change to Plan 11A. After 1.0 hr of attack by 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, the entire breakwater showed only minor damage which had stabilized before conclusion of the test (Photo 59).

28. Plan 12 (Plate 17 and Photo 60) was a repeat test for the high-sill section and low-sill trunk of Plan 11. The alternating high and low sills of Plan 11 were reversed during construction of Plan 12 so that a 1V-on-3H slope high-sill head could be constructed at the end of the 1V-on-2H slope high-sill trunk. Construction of the high-sill head was identical with Plan 8 (paragraph 22) except that in Plan 8 the head had been attached to a high-sill trunk with 1V-on-3H slopes. Crown elevations were identical with those of Plan 11. After 1.0 hr of exposure to 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw, the structure had experienced very minor damage (Photo 61). The test condition was changed to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw and after 2.0 hr of wave attack, only minor damage was observed (Photo 62). The identical test conditions were extended and after a total of 4.0 hr of wave attack the breakwater had accrued minor to moderate damage (Photos 63-65).

29. Plan 12A (Plate 18 and Photo 66) consisted of rebuilding the high-sill head and adding a 5-ft-high, beach-connected groin to Plan 12. The groin was constructed with 1V-on-2H slopes using 5.0-ton graded armor stone and connected at a 90° angle to the beach side of the high-sill head. In order to observe the effect of extended wave attack on the high-sill and low-sill trunk, these sections of the Plan 12 breakwater were not rebuilt before testing was initiated on Plan 12A. After 2.0 hr of attack by 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw caused minor damage on the high-sill head and groin. Little change occurred to those portions of the structure which were not rebuilt after testing Plan 12 (Photos 67-69). The breakwater was then exposed to 1.0 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw to check for any possible stability problems on the 5-ft-high groin when exposed to this low-water wave attack. No instability was observed on the groin and the remainder of the breakwater showed very little change.

30. Plan 12B (Plate 19 and Photo 70) consisted of the addition of a 10-ft-high, 5.0-ton graded armor stone, beach-connected groin and rebuilding of the high-sill head on Plan 12A. The remainder of the breakwater, the high- and low-sill trunks, was once again not rebuilt in order to observe the results of extended wave attack. After 2.0 hr of exposure to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, the intersection between the high-sill head and groin showed significant damage and the remainder of the breakwater showed minor to moderate damage (Photos 71-73).

31. Plan 12C (Plate 20 and Photos 74 and 75) was identical with Plan 12B except that the first 40 ft of the 10-ft-high groin adjacent to the high-sill head was capped with one layer of 7.0-ton armor stone. Like Plans 12A and 12B, the high-sill head was rebuilt, but the remainder of the breakwater was not. The breakwater was then exposed to 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. At the conclusion of the test all damage had stabilized. Minor damage had occurred on the high-sill head and groin. The high- and low-sill trunk sections had been exposed for a total of 10.0 hr to 14.0-sec, 12.1-ft waves at an swl

of +5.4 ft mllw since its initial building and had sustained minor to moderate damage (Photos 76-78).

32. Plan 12D (Plate 21 and Photo 79) consisted of rebuilding a breakwater identical with Plan 12B except that 7.0-ton graded armor stone was used in the 10-ft-high groin instead of 5.0-ton graded armor stone. This plan was tested to determine if larger graded armor stone could be used as an alternative to capping the first 40 ft of the groin with 7.0-ton armor stone as was done in Plan 12C. After 2.0 hr of exposure to 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw, the high-sill and low-sill trunk had accrued minor damage. The high-sill head had sustained moderate damage, very similar to previous test results. The connecting area between the high-sill head and the 10-ft-high groin showed moderate damage at the conclusion of the test (Photos 80-82). Damage in this area was somewhat less than that of Plan 12B but more than that sustained by Plan 12C when exposed to the identical test conditions.

PART IV: CONCLUSIONS

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

a. For the shallow-water location (-5.0 ft mllw contour) tested for the design conditions of 14.0-sec, 4.5-ft waves at an swl of 0.0 ft mllw and 14.0-sec, 8.3-ft waves at an swl of +5.4 ft mllw:

(1) Plan 3 showed only minor instability and should therefore be an adequate alternating high- and low-sill design for this location. Even though the structure was tested on a 2-ft-thick layer of filter stone, lowering the structure 2 ft by constructing on filter cloth should not cause armor stone stability problems.

(2) Moderate, but repairable, damage occurred in Plan 5 due to the displacement of some of the smaller stone contained in the 3.0-ton graded armor stone. This plan would be an acceptable constant high-sill structure for this location if it is kept in mind that some damage may occur and that intermittent maintenance may be necessary. Like Plan 3, replacement of the 2-ft-thick filter layer with filter cloth should not result in any more armor stone instability than that observed for Plan 5 constructed on the stone filter blanket.

b. For the deeper water location (-10.0 ft mllw contour) tested for the design conditions of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw and 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw:

(1) Plans 1-6 are inadequate designs due to high instability that resulted in extensive damage.

(2) Plans 7, 7A, 7B, and 7C used the same designs for the high-sill section and low-sill trunk but differing designs for the low-sill head. The designs for the high-sill section and low-sill trunk showed very minor damage. Only the Plan 7C design for the low-sill head proved adequate. Plan 7C would be a very acceptable alternating high- and low-sill design.

(3) For a breakwater ending with a high-sill head, Plan 8 would be an acceptable design if the head section were connected to a high-sill trunk constructed with 1V-on-3H side slopes.

(4) Plans 9, 10, and 10A were run in an effort to steepen the breakwater slopes and thus reduce construction costs by minimizing the amount of construction material. The 5- and 3-ton graded armor stone used on

the high-sill section and low-sill trunk, respectively, were unstable with the 1V-on-2H side slopes. Extensive damage occurred for the low-sill head designs used in Plans 10 and 10A. Thus Plans 9, 10, and 10A are inadequate designs for the deeper water location.

(5) Due to the nature of the 7.0- and 5.0-ton graded armor stone, some spot damage occurred on the high- and low-sill trunks and the transition between them in Plans 11 and 12 when exposed to the design conditions of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. This damage is mainly due to displacement of some of the lighter stone. This results in some reduction (on the average, approximately 1 ft with extremes up to 2 ft) of the high- and low-sill section crown elevation at various points. Since the entire breakwater consists of alternating high- and low-sill sections, which will be totally submerged for all water levels above 0.0 ft mllw swl, this minor lowering of the high-sill crown elevation at various locations should not alter the functional integrity of the structure (i.e., minimize the wave energy and contain the sand in the nourished beach area behind the breakwater). Therefore, even though the high- and low-sill trunks and the transition between them in Plans 11 and 12 do not meet the no-damage criterion of minor stone movement that is usually used for breakwaters which are designed for the safety of life and property, they should function adequately for this particular application.

(6) The low-sill head tested in Plan 11 showed very little damage when subjected to design conditions; thus one layer of 7.0-ton armor stone on a slope of approximately 1V on 2.5H is an adequate low-sill head design.

(7) The Plan 12 high-sill head sustained moderate, but reparable, damage when exposed to the 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw. Like the damage that resulted on the high-sill trunk of this plan, this moderate damage does not appreciably alter the design function of the high-sill head; thus one layer of 7.0-ton armor stone on a slope of 1V on 3H is an adequate high-sill head design.

(8) The connecting areas of the 5-ft-high groins with the low- and high-sill heads tested in Plans 11A and 12A, respectively, showed some minor instability but appear to be suitable designs if 5-ft-high beach-connected groins are selected for construction in the prototype.

(9) The Plan 12B 10-ft-high groin proved to be unstable and thus inadequate at the intersection of the high-sill head and groin.

(10) Capping the first 40 ft of the 10-ft-high, 5.0-ton graded armor stone groin adjacent to the high-sill head with one layer of 7.0-ton armor stone (Plan 12C) resulted in a stable connecting area between the high-sill head and groin.

(11) Plan 12D sustained moderate damage in the region connecting the 10-ft-high groin and the high-sill head when exposed to design conditions. The Plan 12C design for this area is, therefore, recommended over the Plan 12D design; but Plan 12D could be used if it is kept in mind that it would require more maintenance than the 7.0-ton capstone used in Plan 12C.

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4. Chatham, C. E., Jr., Davidson, D. D., and Whalin, R. W., "Study of Beach Widening by the Perched Beach Concept, Santa Monica Bay, California; Hydraulic Model Investigation," Technical Report H-73-8, Jun 1973, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

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Table 1

Gradations of Graded Armor Stone

Percent by Weight	Prototype Weights
	3.0-ton Graded Armor Stone
100	≤6,000 lb
50	<3,000 lb
25	<2,000 lb
10	<6 lb
	5.0-ton Graded Armor Stone
100	≤10,000 lb
50	<6,000 lb
25	<5,000 lb
12.5	<2,000 lb
5	<6 lb
	7.0-ton Graded Armor Stone
100	≤14,000 lb
50	<10,000 lb
25	<6,000 lb
12.5	<3,000 lb
6.25	<2,000 lb
2.5	<6 lb

Table 2

Summary of Plans Tested, Test Conditions, and Test Duration

Plan	Test Area	Test Condition	Duration hr
1	Entire breakwater	1*	1.5
1	Entire breakwater	2**	2.0
2	Entire breakwater†	1	1.5
2	Entire breakwater	2	1.0
3	Entire breakwater	1	2.0
3	Entire breakwater	2	2.0
3	Entire breakwater†	3††	2.0
3	Entire breakwater	4‡	2.0
4	Entire breakwater†	1	1.5
4	Entire breakwater	2	2.0
5	Entire breakwater†	1	1.5
5	Entire breakwater	2	2.0
5	Entire breakwater†	3	1.5
5	Entire breakwater	4	2.0
6	Entire breakwater†	1	1.5
6	Entire breakwater	2	8.0
7	Entire breakwater†	1	1.5
7	Entire breakwater	2	2.0

(Continued)

* Test Condition 1 - 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw in the deeper water location.

** Test Condition 2 - 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw in the deeper water location.

† Indicates test area was changed, rebuilt, and/or added since the last test condition was run.

†† Test Condition 3 - 14.0-sec, 4.5-ft waves at an swl of 0.0 ft mllw in the shallow-water location.

‡ Test Condition 4 - 14.0-sec, 8.5-ft waves at an swl of +5.4 ft mllw in the shallow-water location.

Table 2 (Concluded)

Plan	Test Area	Test Condition	Duration hr
7A	High-sill section	2	4.0
7A	Low-sill head and trunk†	2	4.0
7B	High-sill section and low-sill trunk	2	2.0
7B	Low-sill head†	2	2.0
7C	Entire breakwater†	1	1.0
7C	Entire breakwater	2	4.0
8	Entire breakwater†	2	2.0
9	Entire breakwater†	2	4.0
10	Entire breakwater†	1	2.0
10	Entire breakwater	2	2.0
10A	High-sill section and low-sill trunk	2	2.0
10A	Low-sill head†	2	2.0
11	Entire breakwater†	1	1.0
11	Entire breakwater	2	6.0
11A	High-sill section and low-sill trunk	2	1.0
11A	Low-sill head and 5-ft-high groin†	2	1.0
12	Entire breakwater†	1	1.0
12	Entire breakwater	2	4.0
12A	High- and low-sill trunks	2	2.0
12A	High-sill head and 5-ft-high groin†	2	2.0
12B	High- and low-sill trunks	2	2.0
12B	High-sill head and 10-ft-high groin†	2	2.0
12C	High- and low-sill trunks	2	2.0
12C	High-sill head and 10-ft-high groin†	2	2.0
12D	Entire breakwater and groin†	2	2.0

† Indicates test area was changed, rebuilt, and/or added since the last test condition was run.

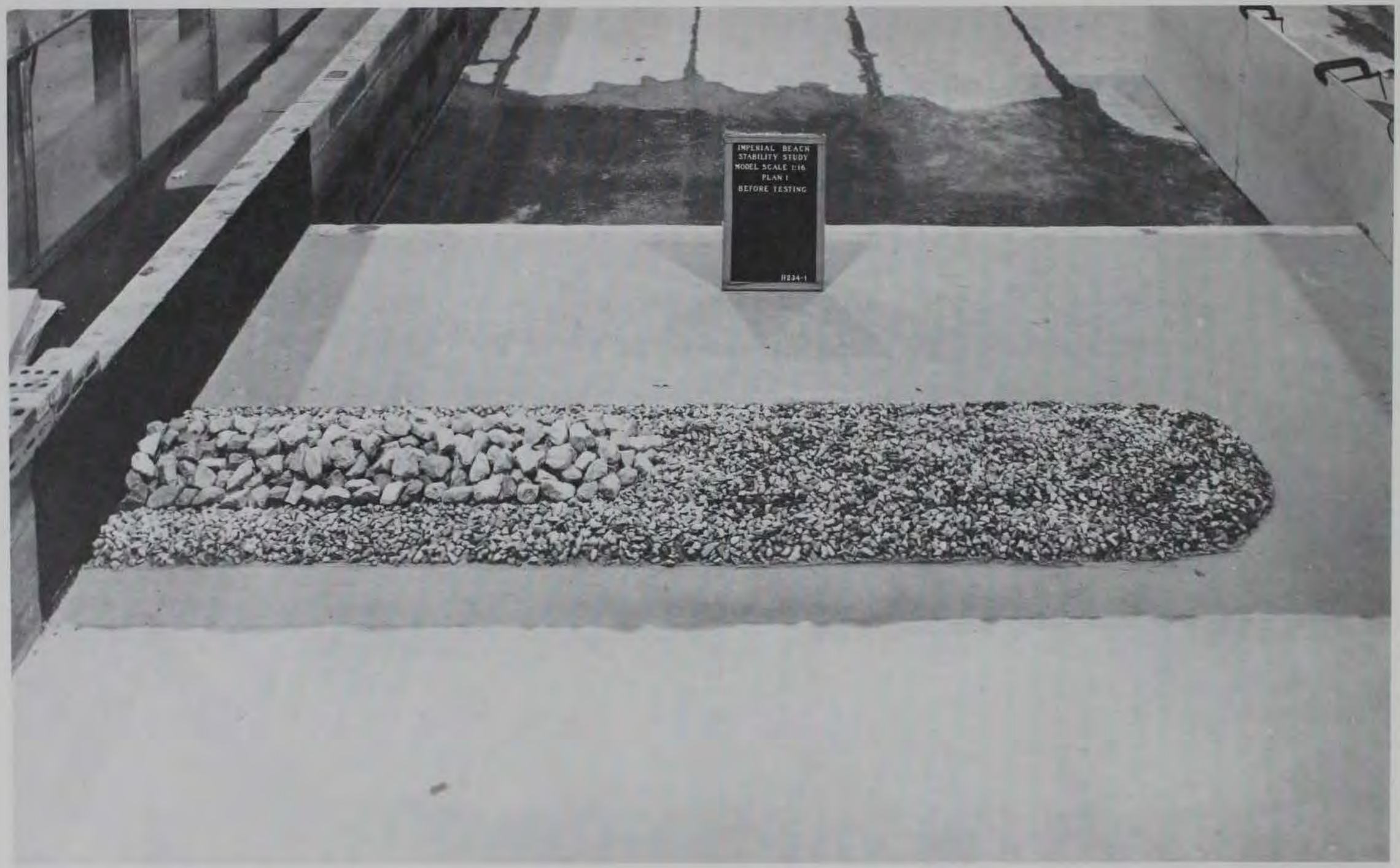


Photo 1. Sea-side view of Plan 1 before wave attack

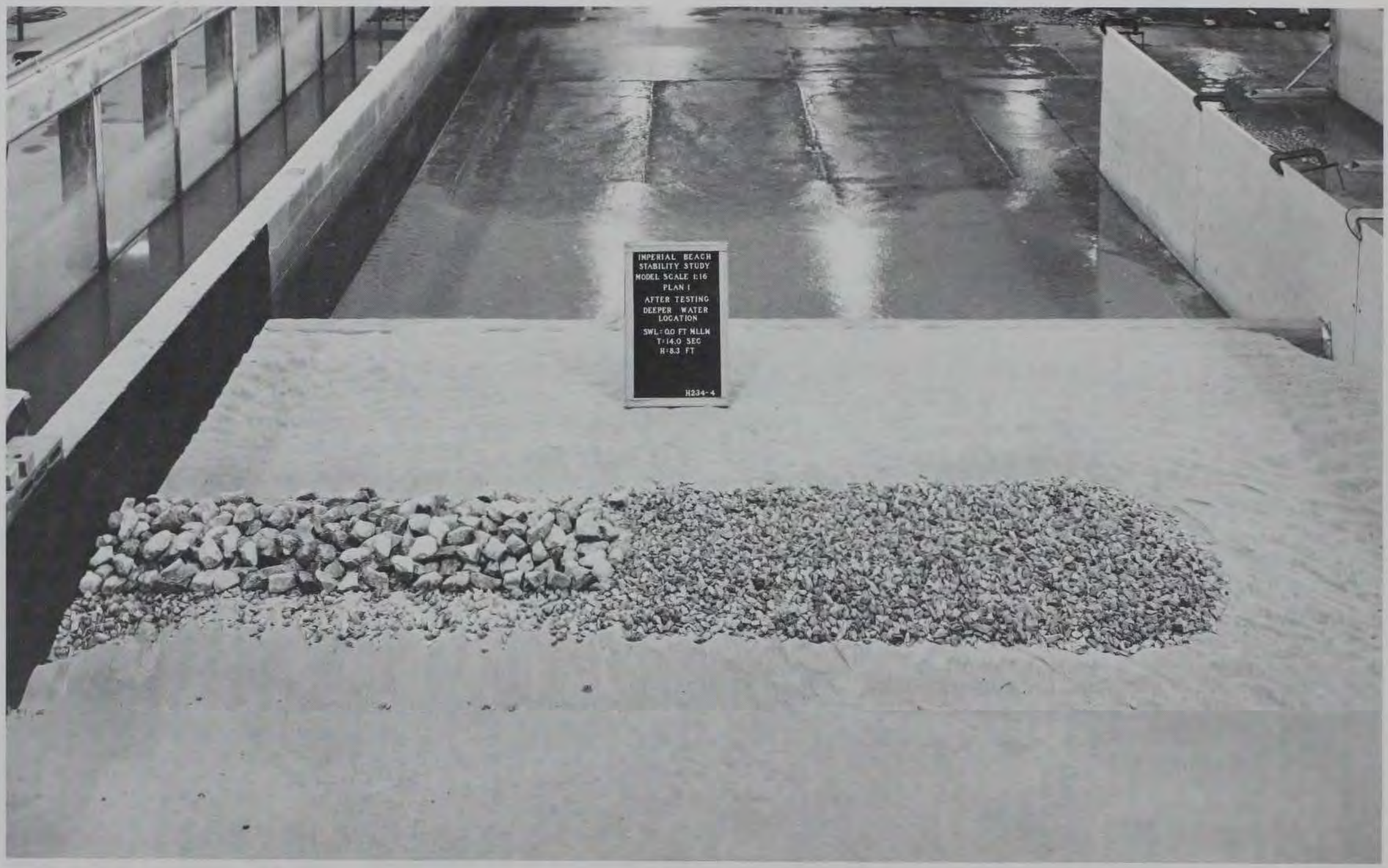


Photo 2. Sea-side view of Plan 1 in the deeper water location after 1.5 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

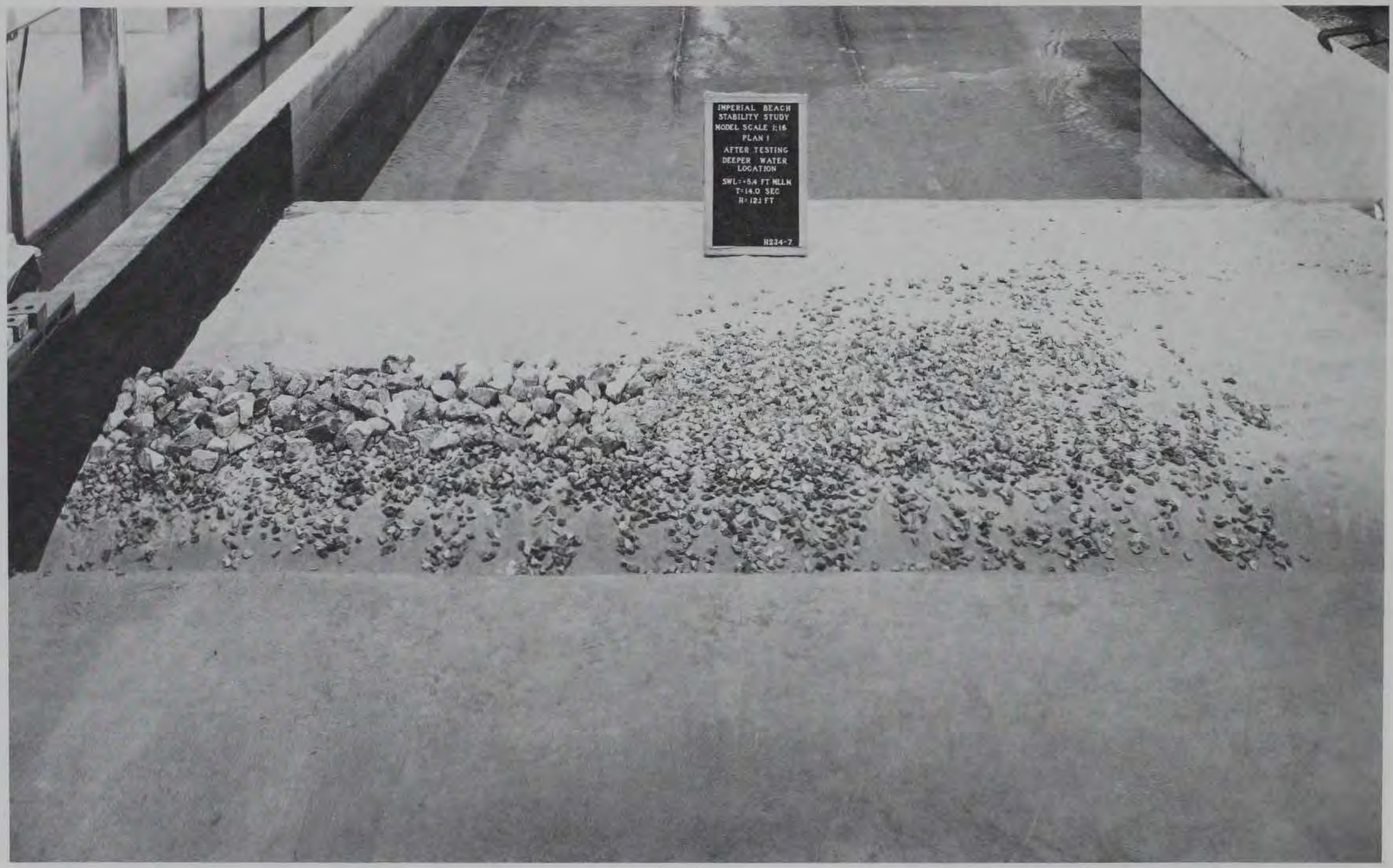


Photo 3. Sea-side view of Plan 1 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

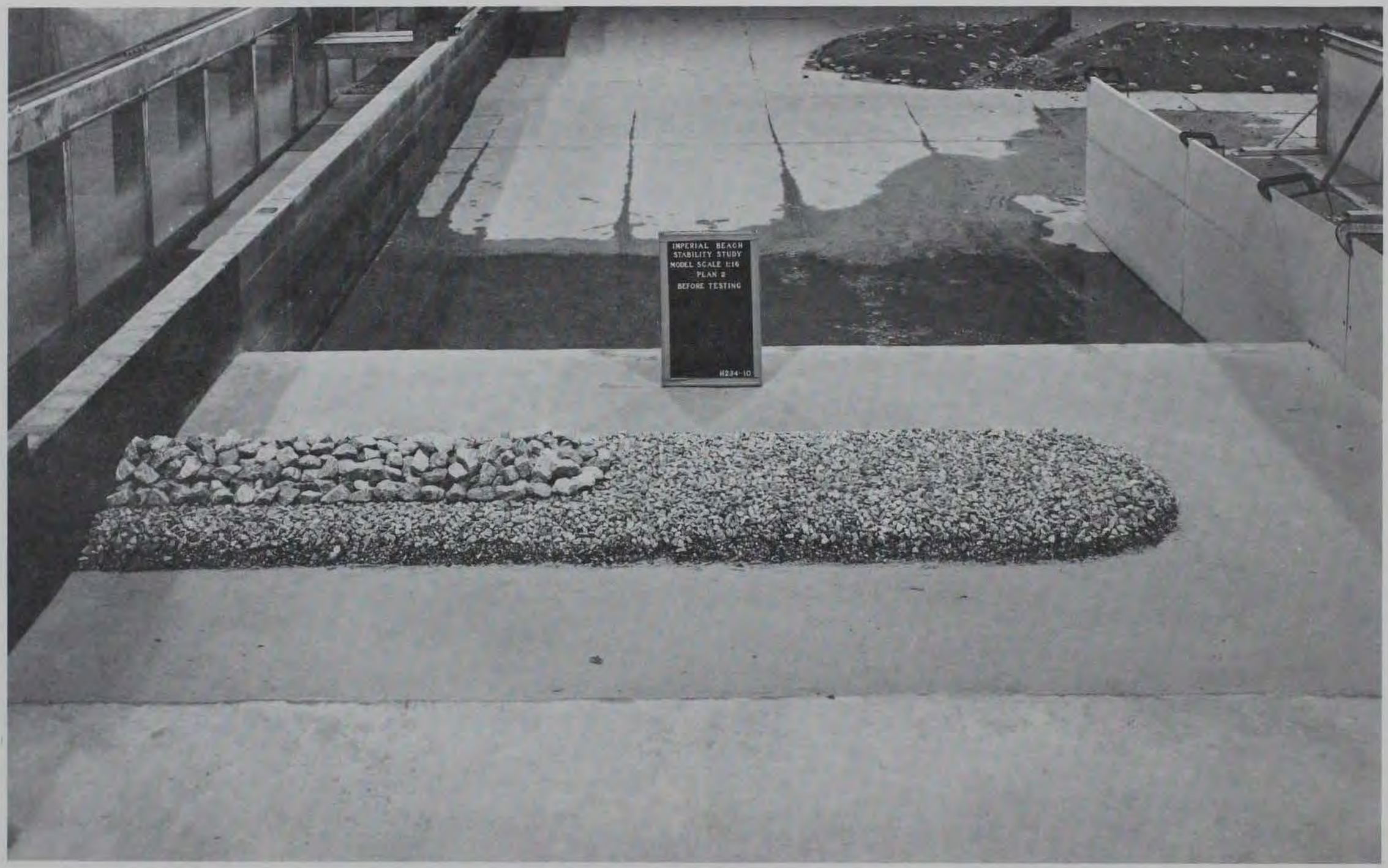


Photo 4. Sea-side view of Plan 2 before wave attack

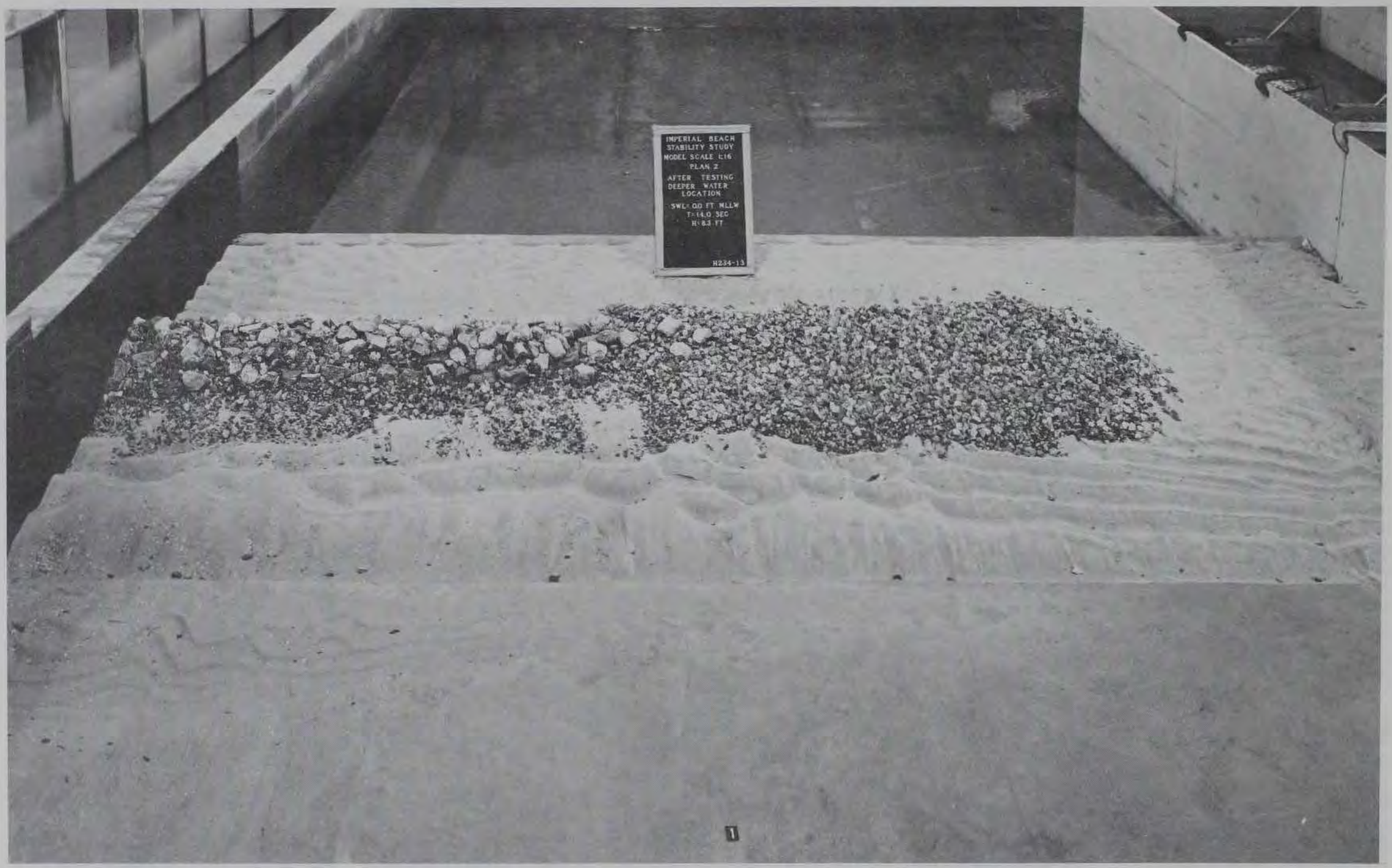


Photo 5. Sea-side view of Plan 2 in the deeper water location after 1.5 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

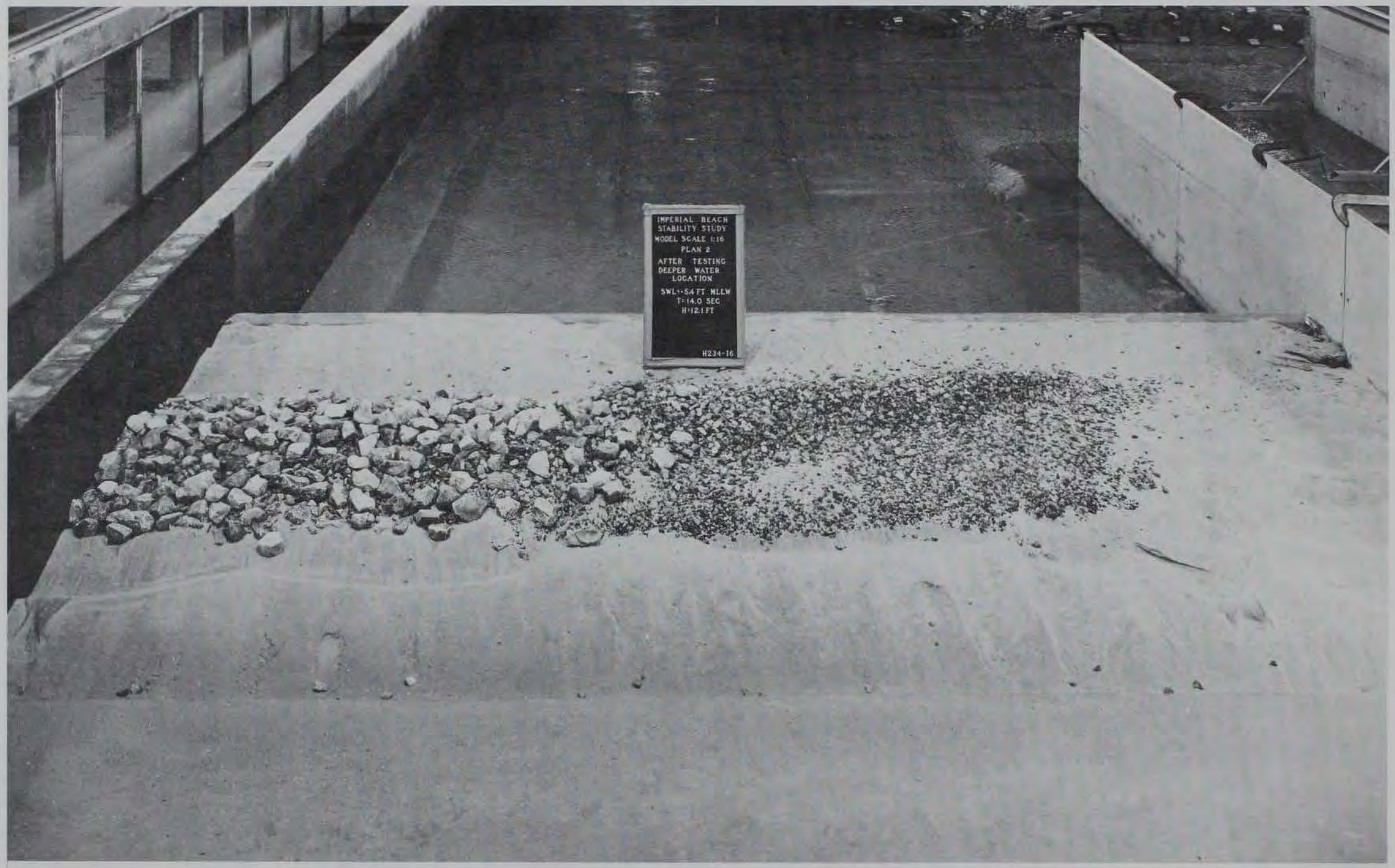


Photo 6. Sea-side view of Plan 2 in the deeper water location after 1.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

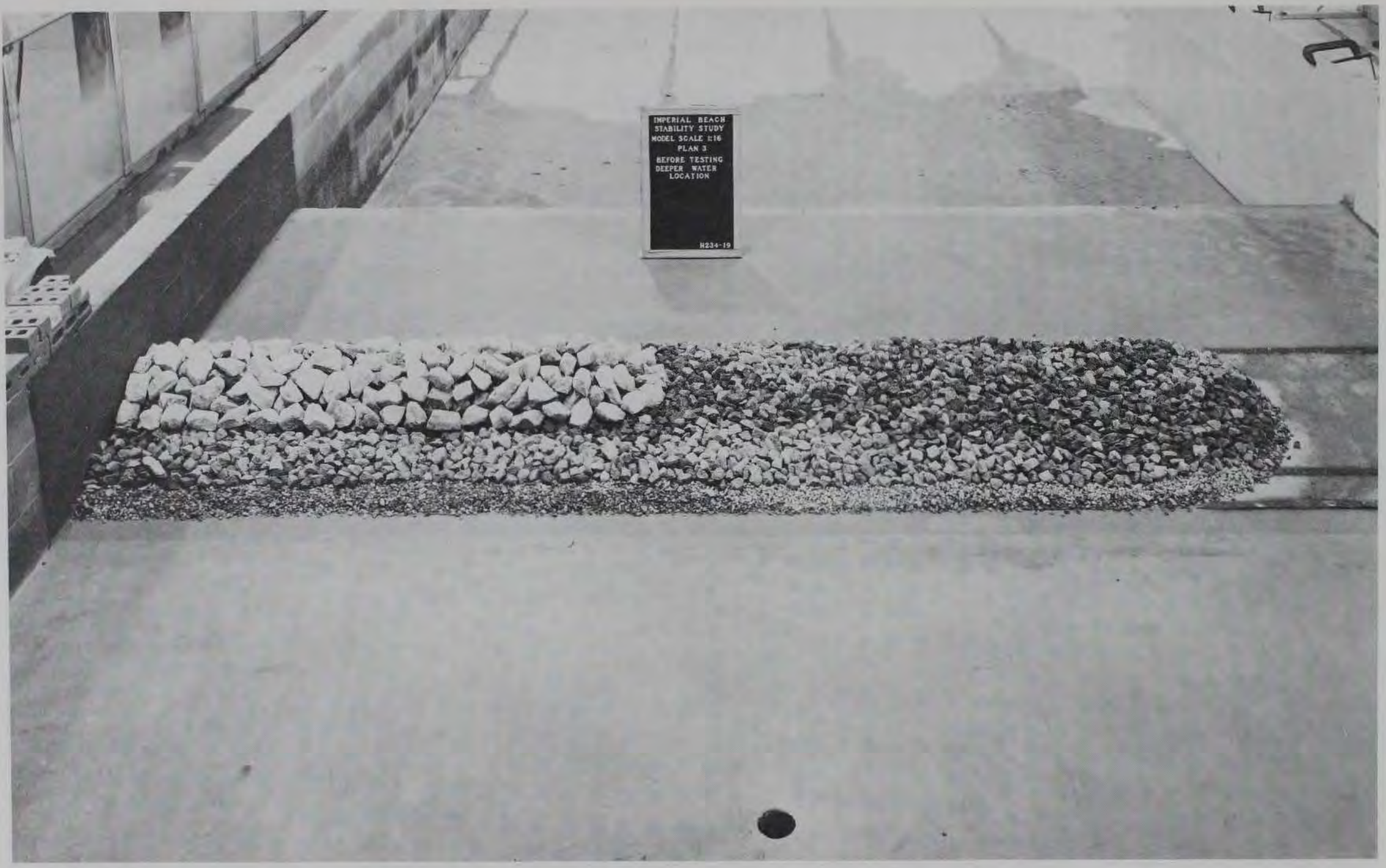


Photo 7. Sea-side view of Plan 3 before wave attack

Photo 8. Sea-side view of Plan 3 in the deeper water location after 2.0 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

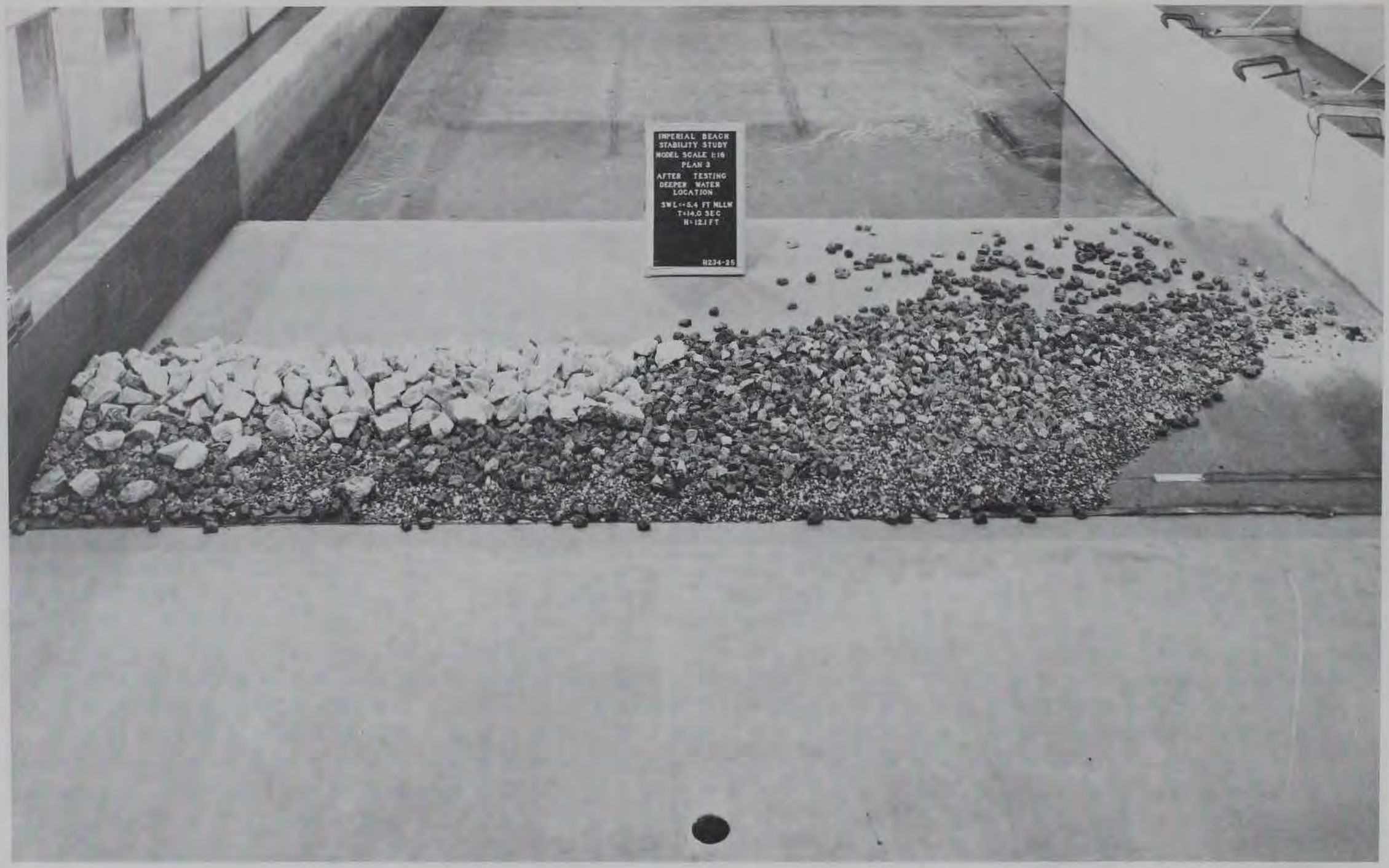


Photo 9. Sea-side view of Plan 3 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

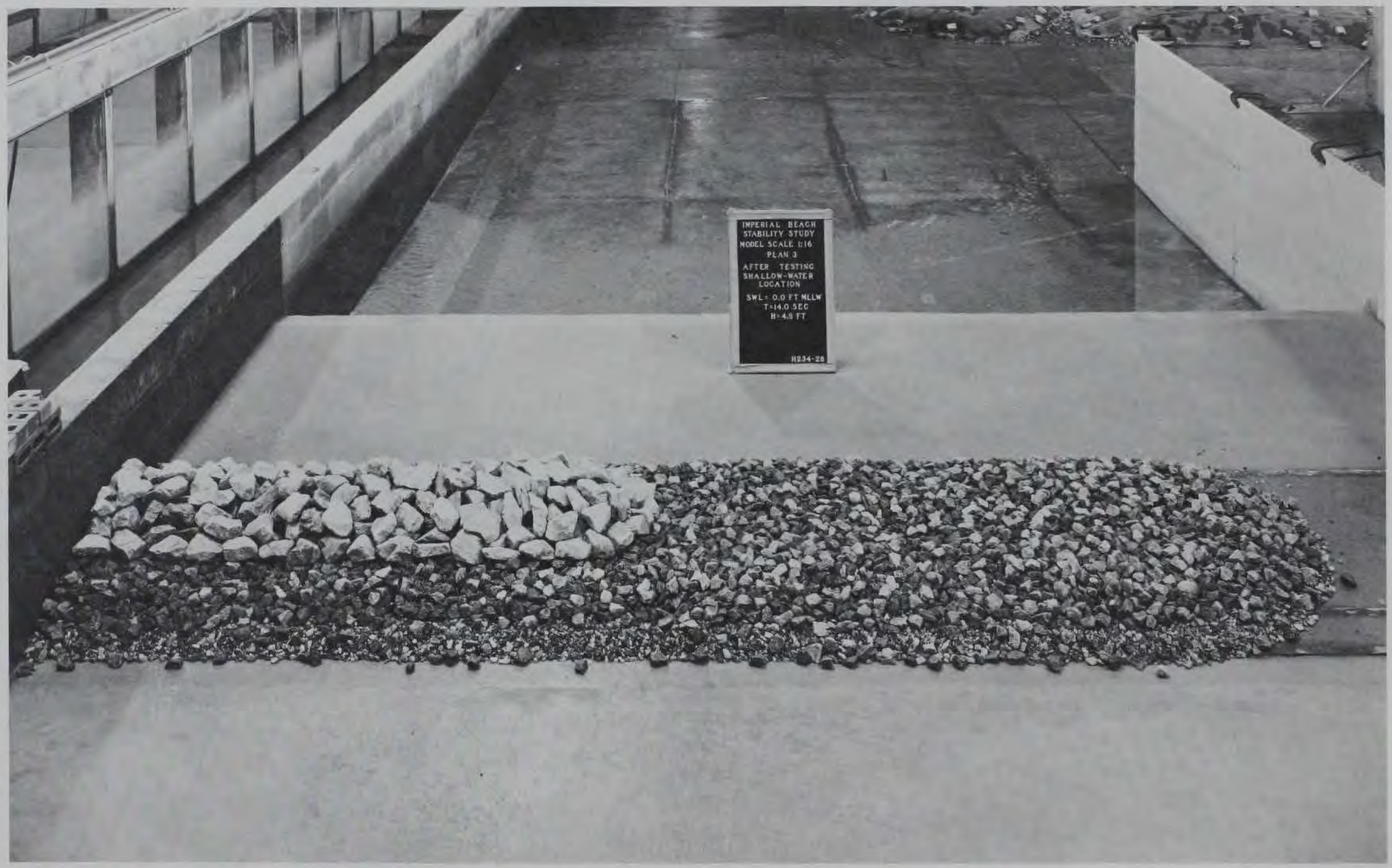


Photo 10. Sea-side view of Plan 3 in the shallow-water location after 2.0 hr of 14.0-sec, 4.5-ft waves at an swl of 0.0 ft mllw

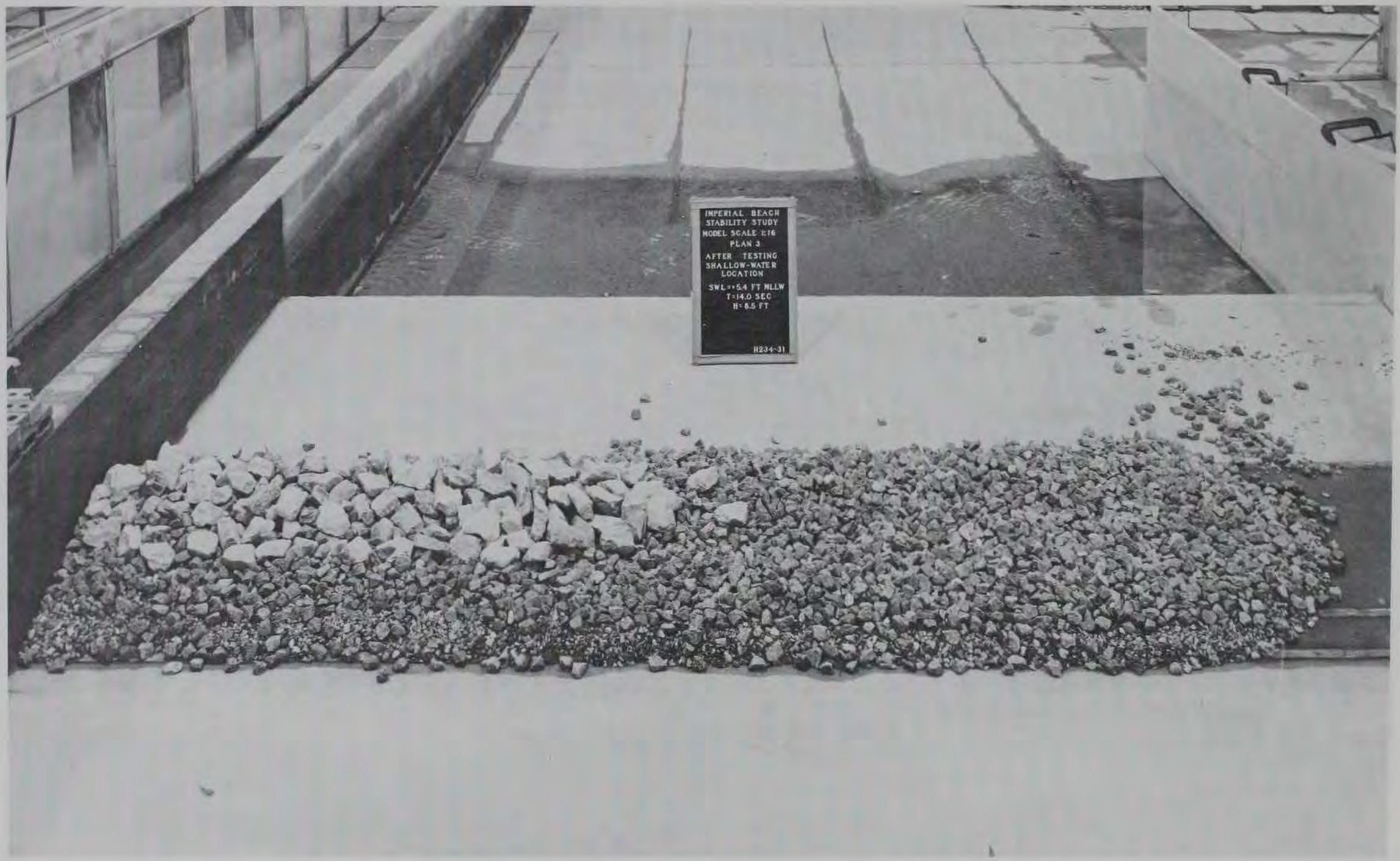


Photo 11. Sea-side view of Plan 3 in the shallow-water location after 2.0 hr of 14.0-sec, 8.5-ft waves at an swl of +5.4 ft mllw

Photo 12. Sea-side view of low-sill section of Plan 3 in the shallow-water location after 2.0 hr of 14.0-sec, 8.5-ft waves at an swl of +5.4 ft mllw

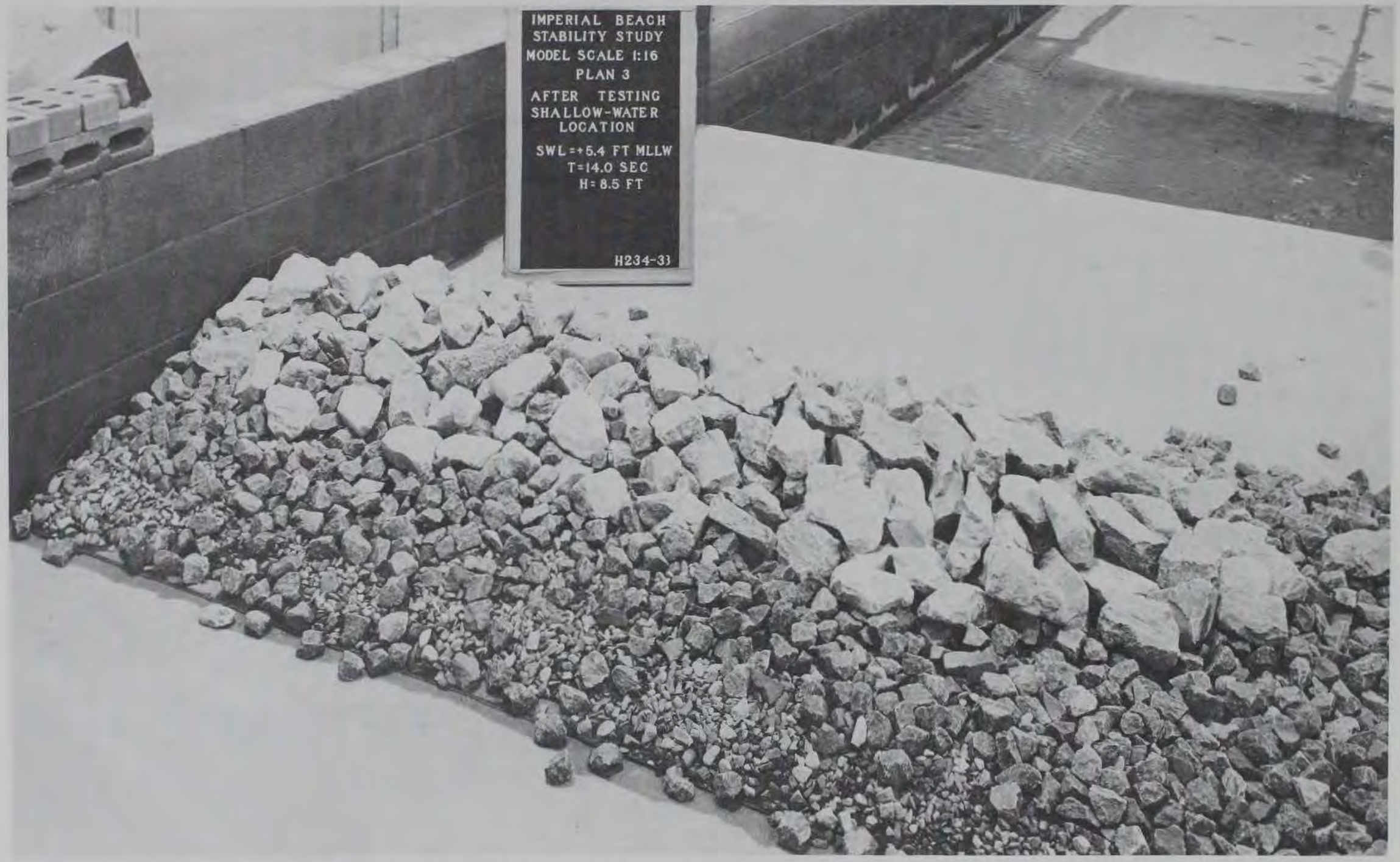


Photo 13. Sea-side view of high-sill section of Plan 3 in the shallow-water location after 2.0 hr of 14.0-sec, 8.5-ft waves at an swl of +5.4 ft mllw

Photo 14. Sea-side view of Plan 4 before wave attack

Photo 15. Sea-side view of Plan 4 in the deeper water location after 1.5 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

Photo 16. Sea-side view of Plan 4 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 17. Sea-side view of Plan 5 before wave attack

Photo 18. Sea-side view of Plan 5 in the deeper water location after 1.5 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

Photo 19. Sea-side view of Plan 5 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

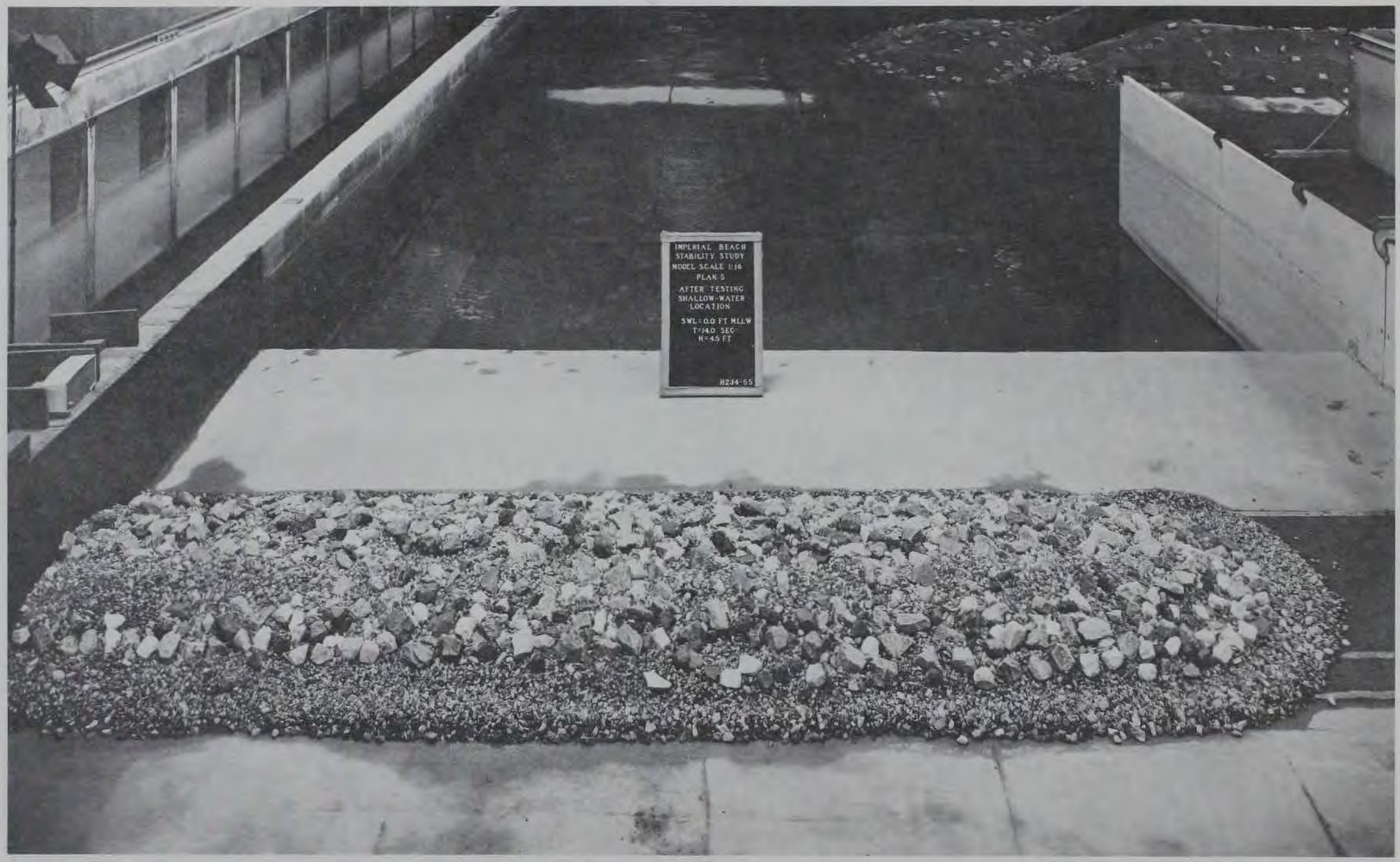


Photo 20. Sea-side view of Plan 5 in the shallow-water location after 1.5 hr of 14.0-sec, 4.5-ft waves at an swl of 0.0 ft mllw

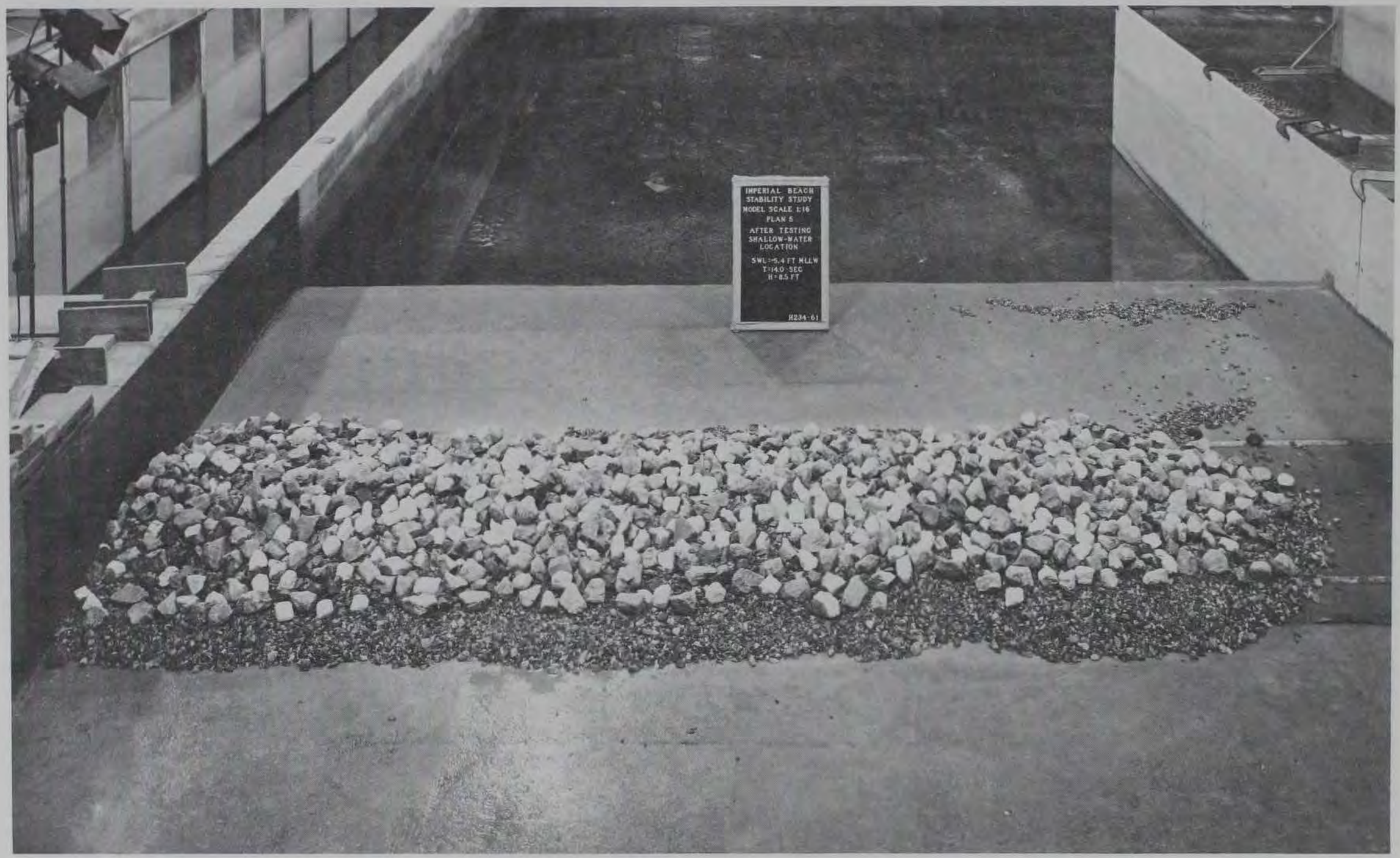


Photo 21. Sea-side view of Plan 5 in the shallow-water location after 2.0 hr of 14.0-sec, 8.5-ft waves at an swl of +5.4 ft mllw

Photo 22. Sea-side view of Plan 6 before wave attack

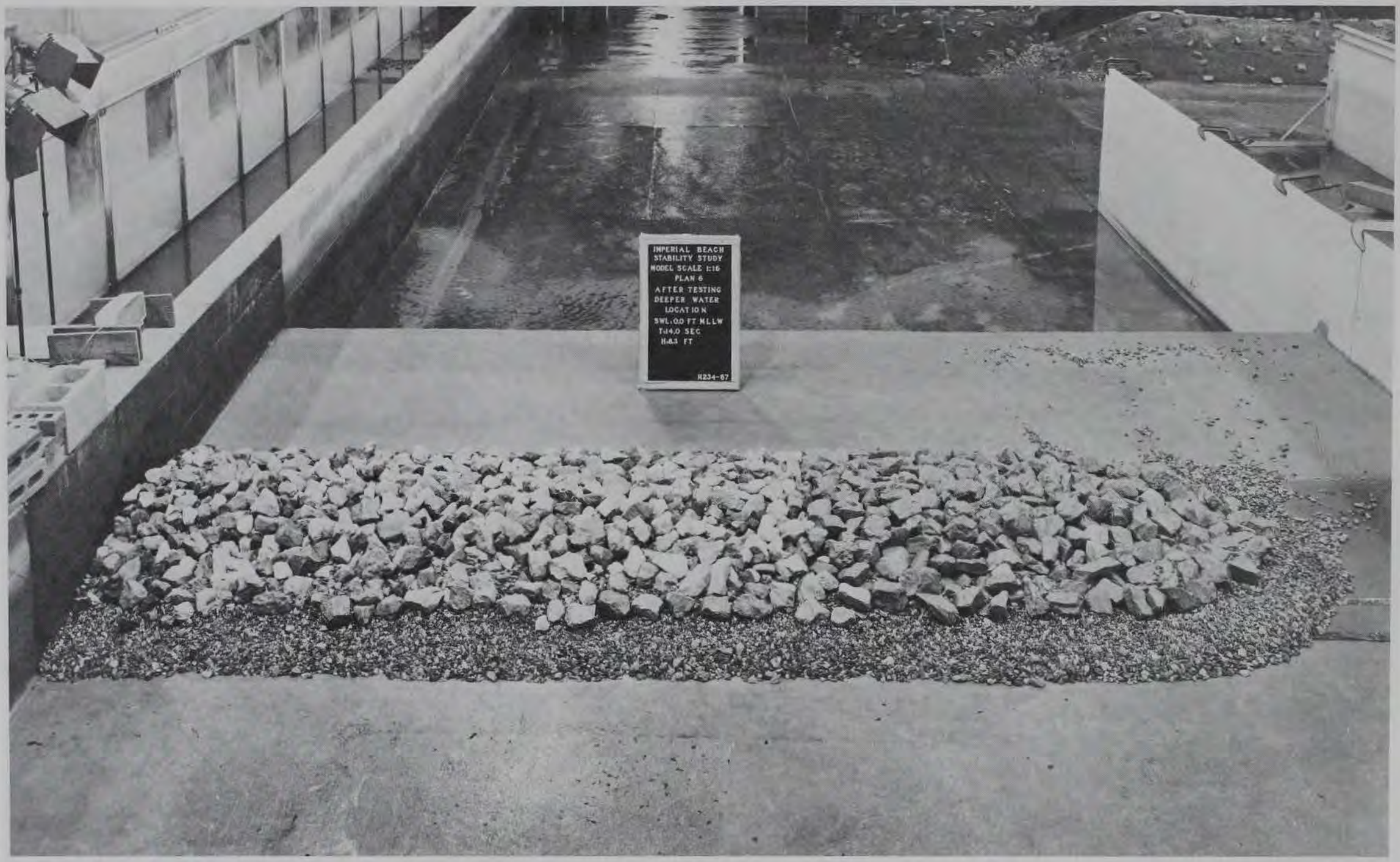


Photo 23. Sea-side view of Plan 6 in the deeper water location after 1.5 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

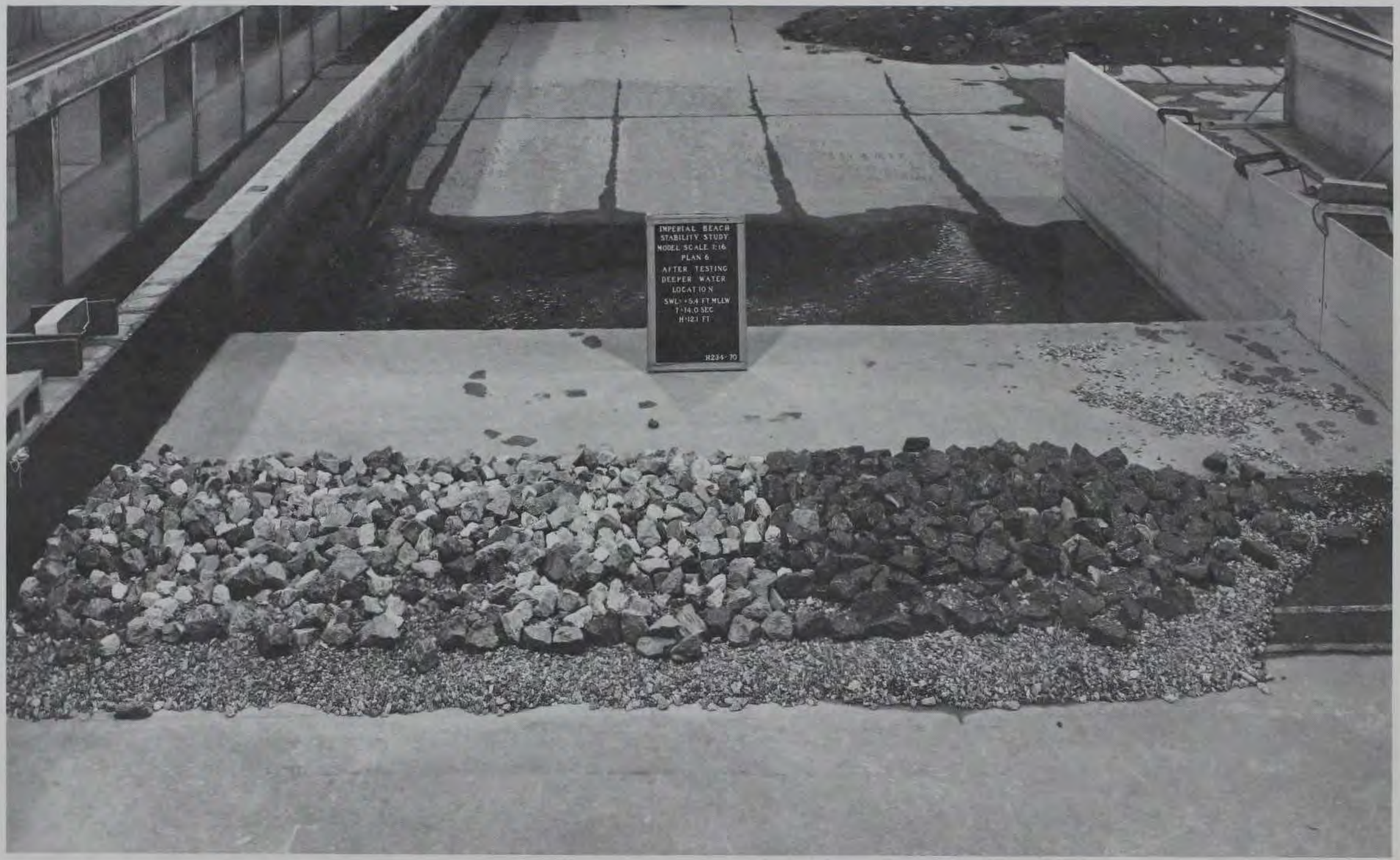


Photo 24. Sea-side view of Plan 6 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 25. Sea-side view of Plan 6 in the deeper water location after 6.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 26. Sea-side view of Plan 6 in the deeper water location after 8.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

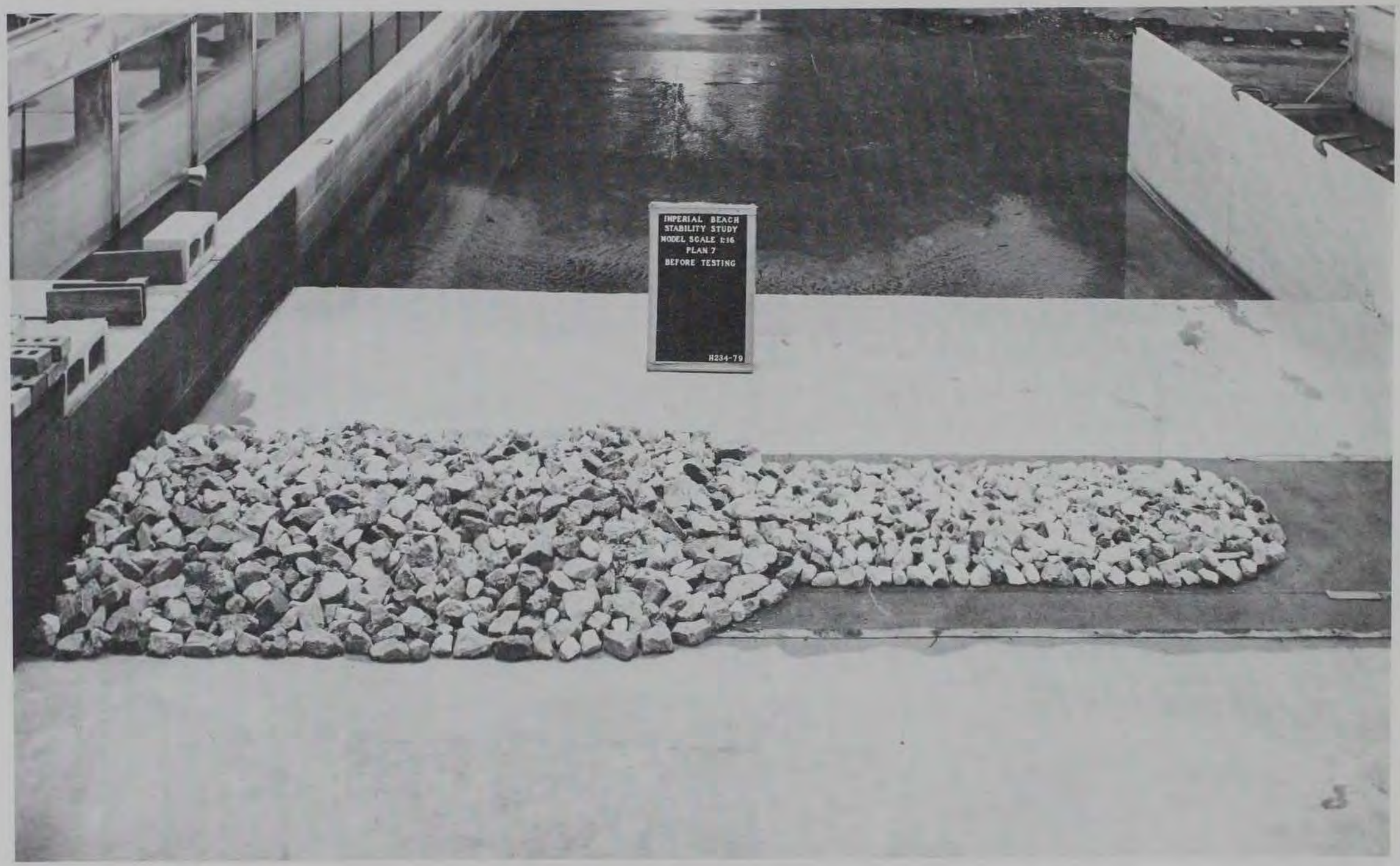


Photo 27. Sea-side view of Plan 7 before wave attack

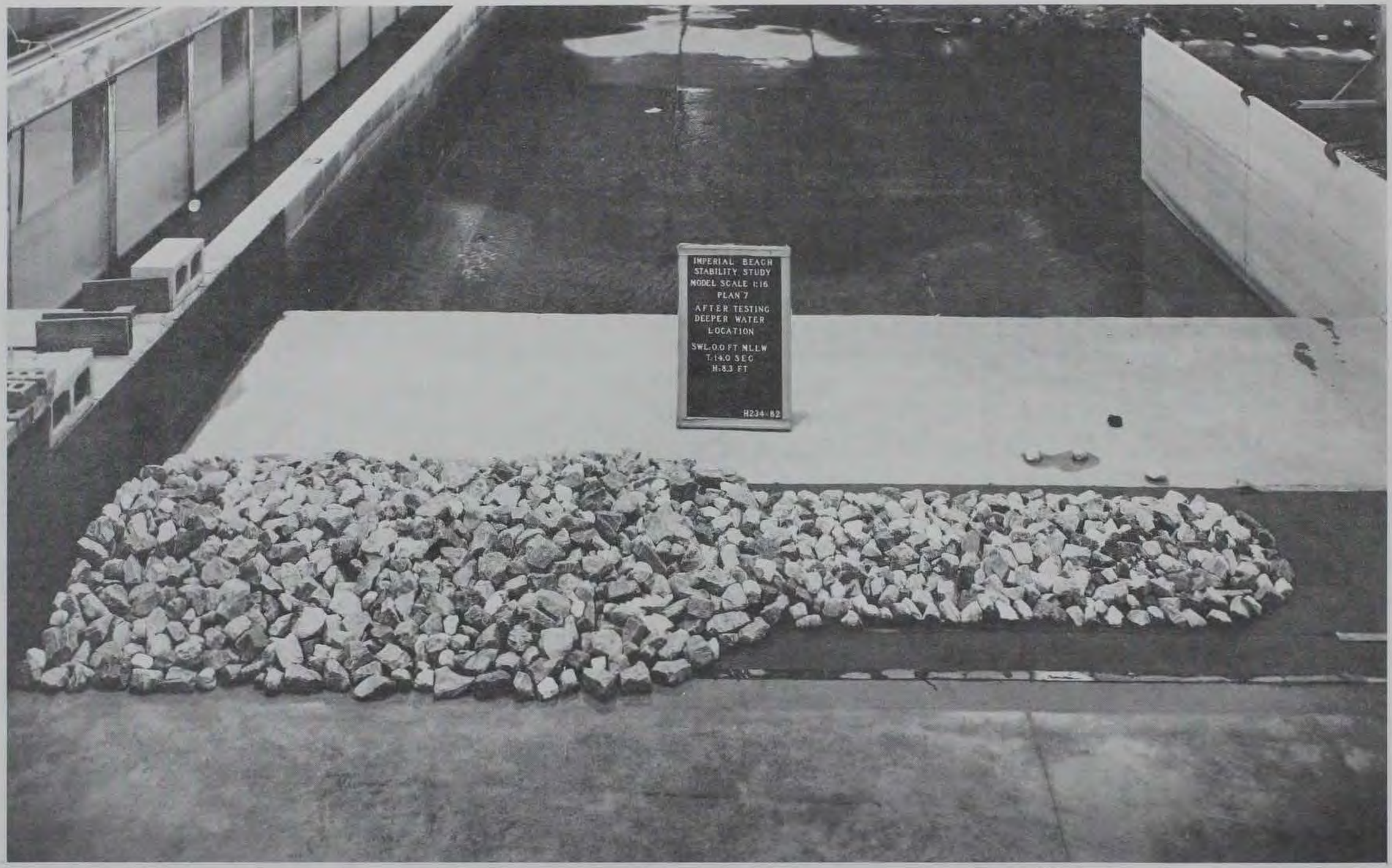


Photo 28. Sea-side view of Plan 7 in the deeper water location after 1.5 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

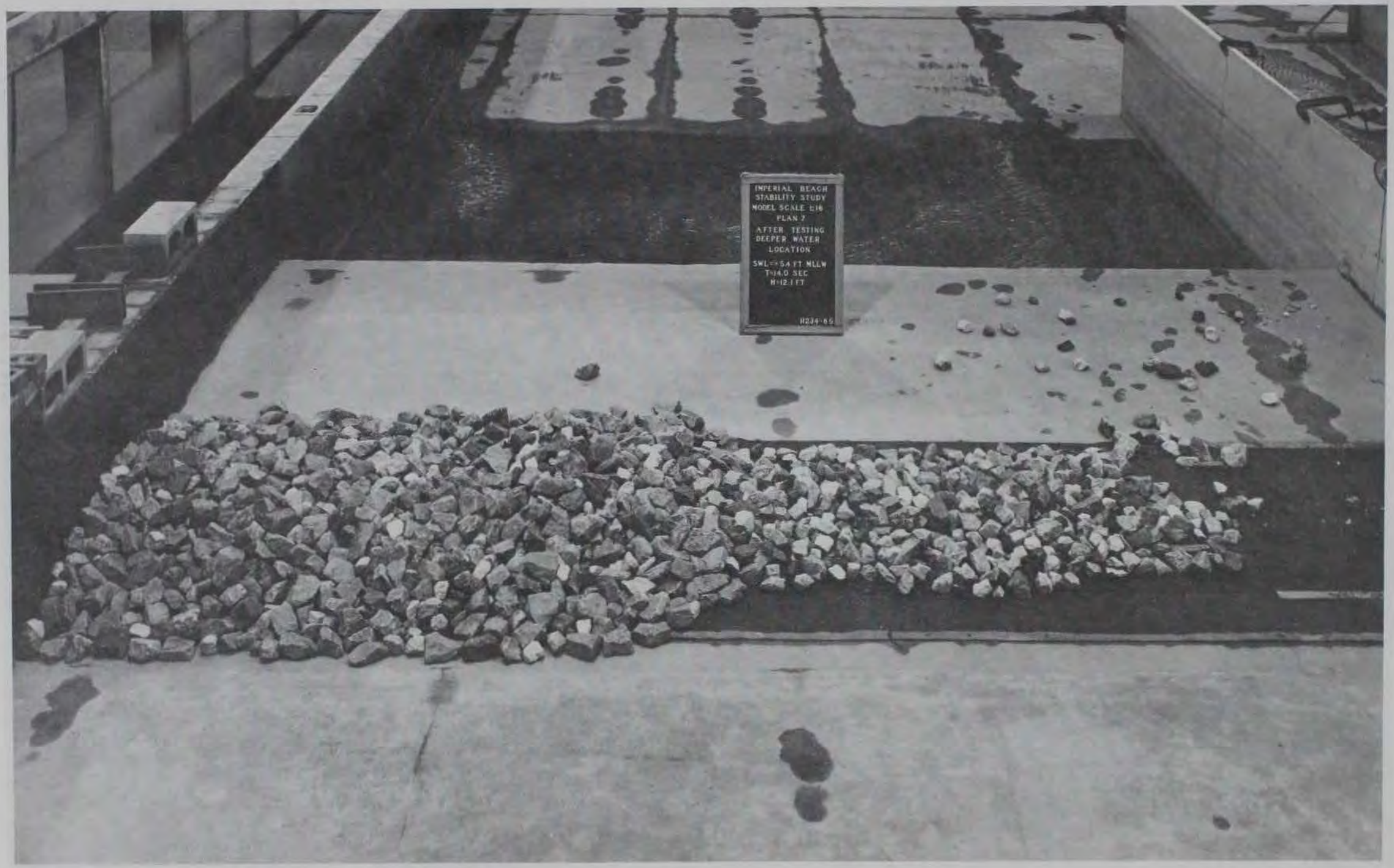


Photo 29. Sea-side view of Plan 7 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

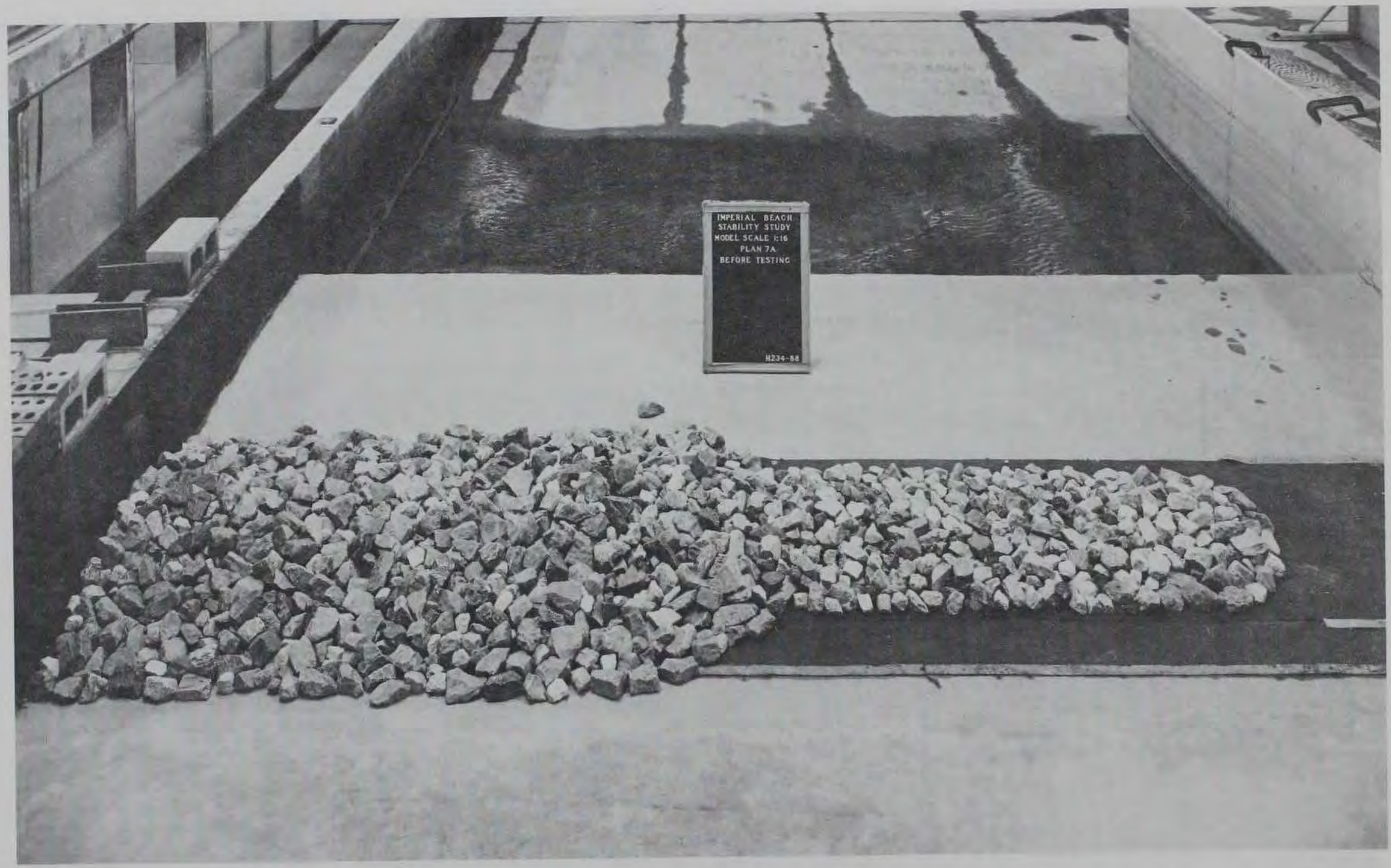


Photo 30. Sea-side view of Plan 7A before wave attack

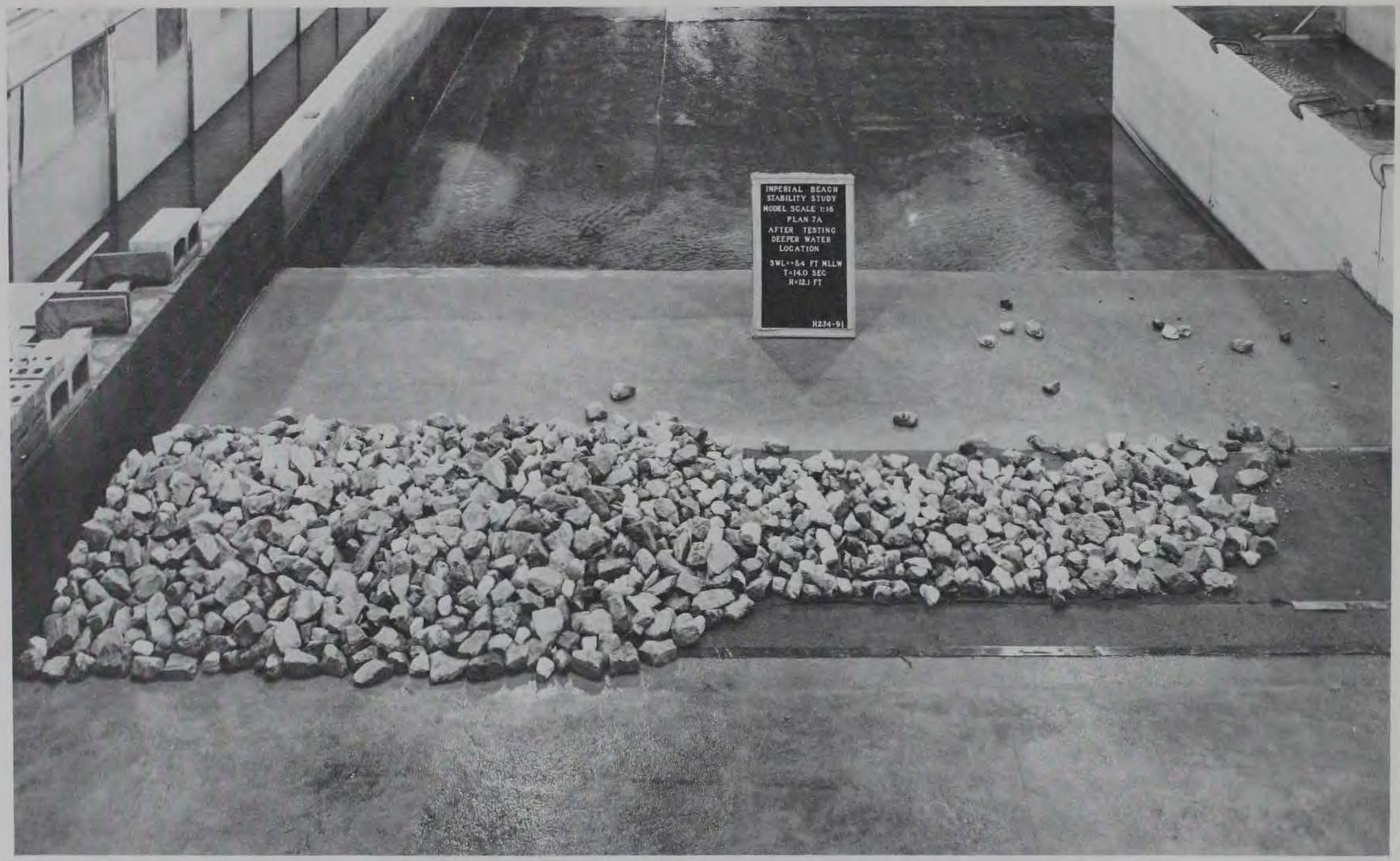


Photo 31. Sea-side view of Plan 7A in the deeper water location after 2.0 hr on the low sill and 4.0 hr on the high sill of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

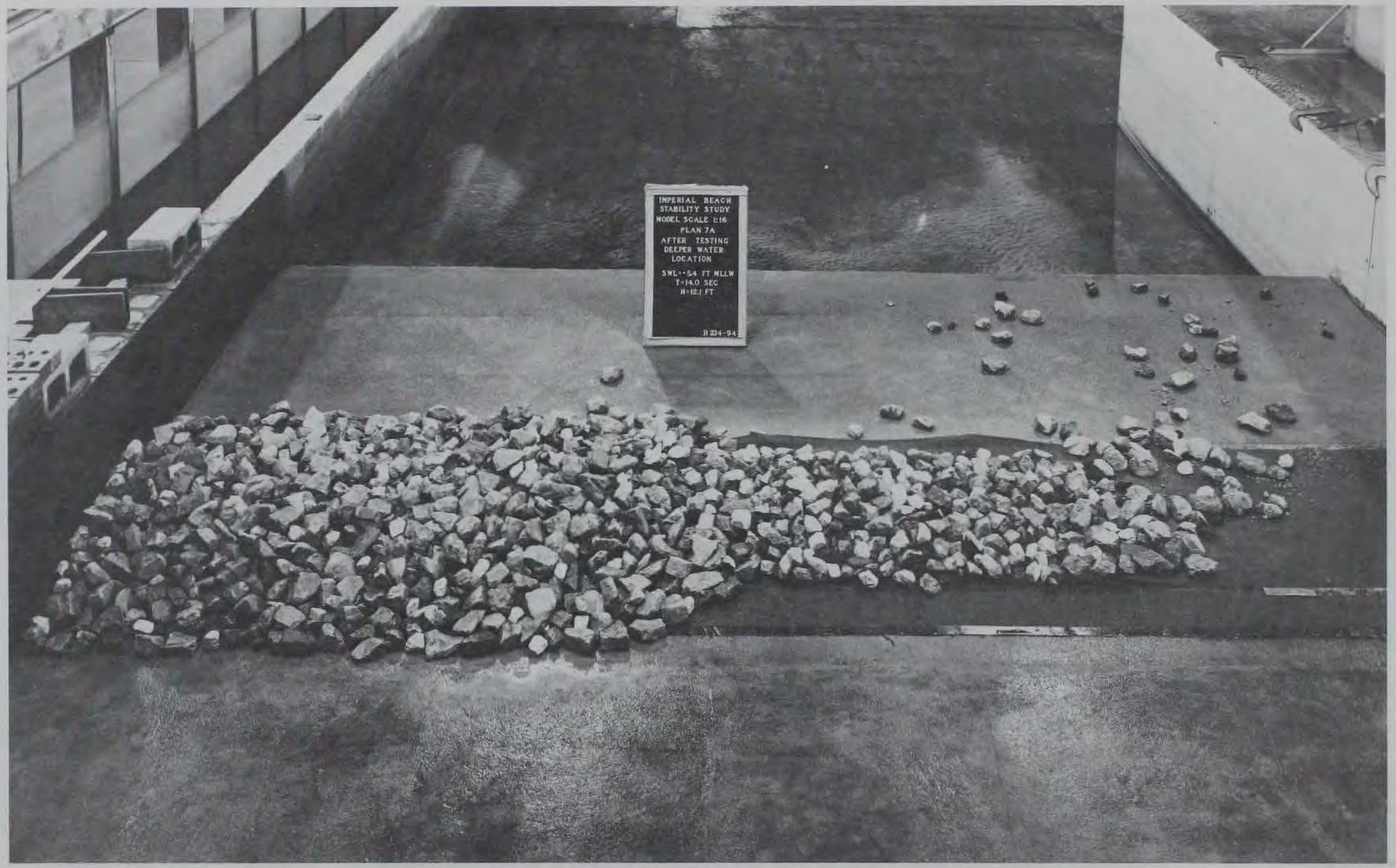


Photo 32. Sea-side view of Plan 7A in the deeper water location after 4.0 hr on the low sill and 6.0 hr on the high sill of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

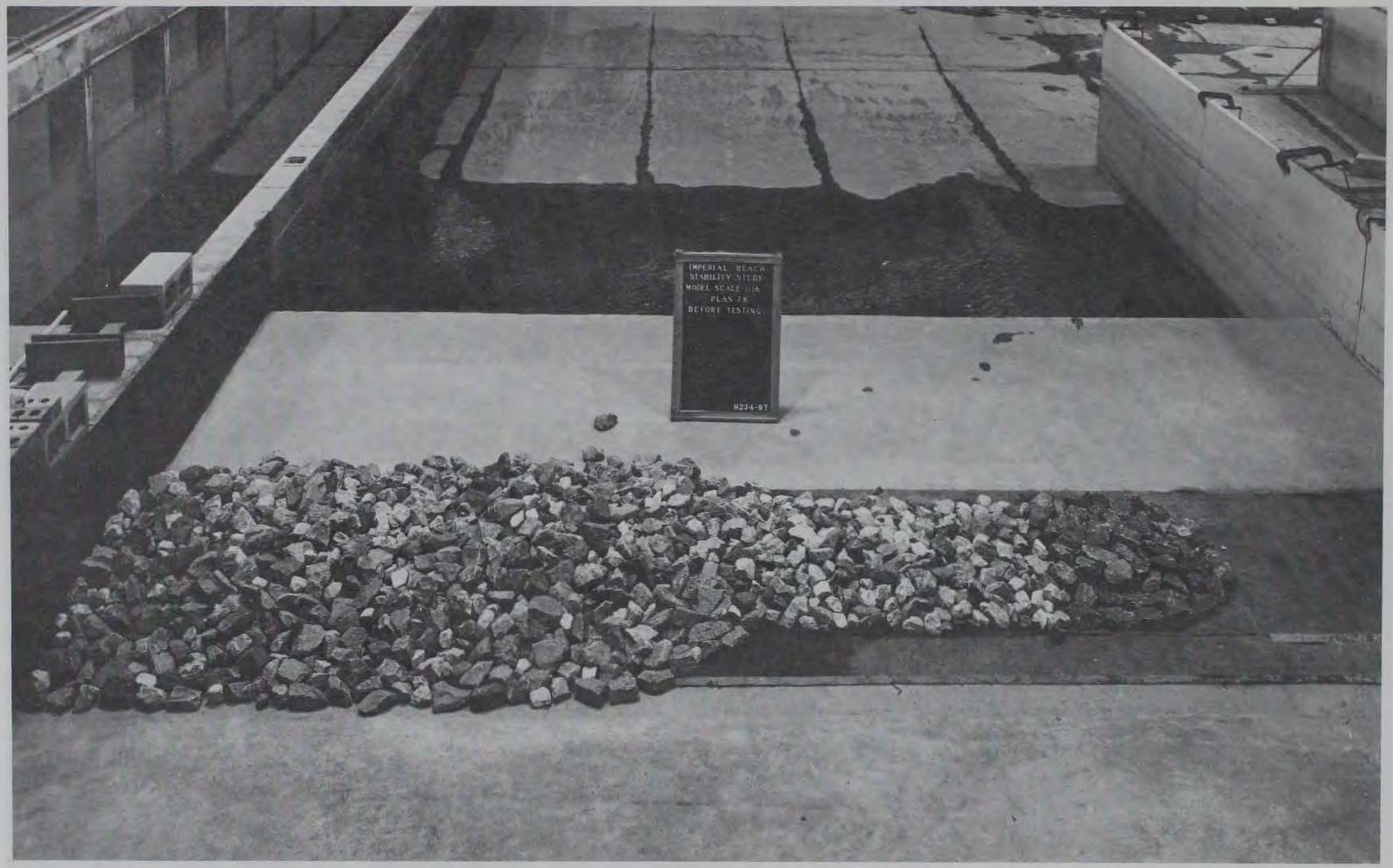


Photo 33. Sea-side view of Plan 7B before wave attack

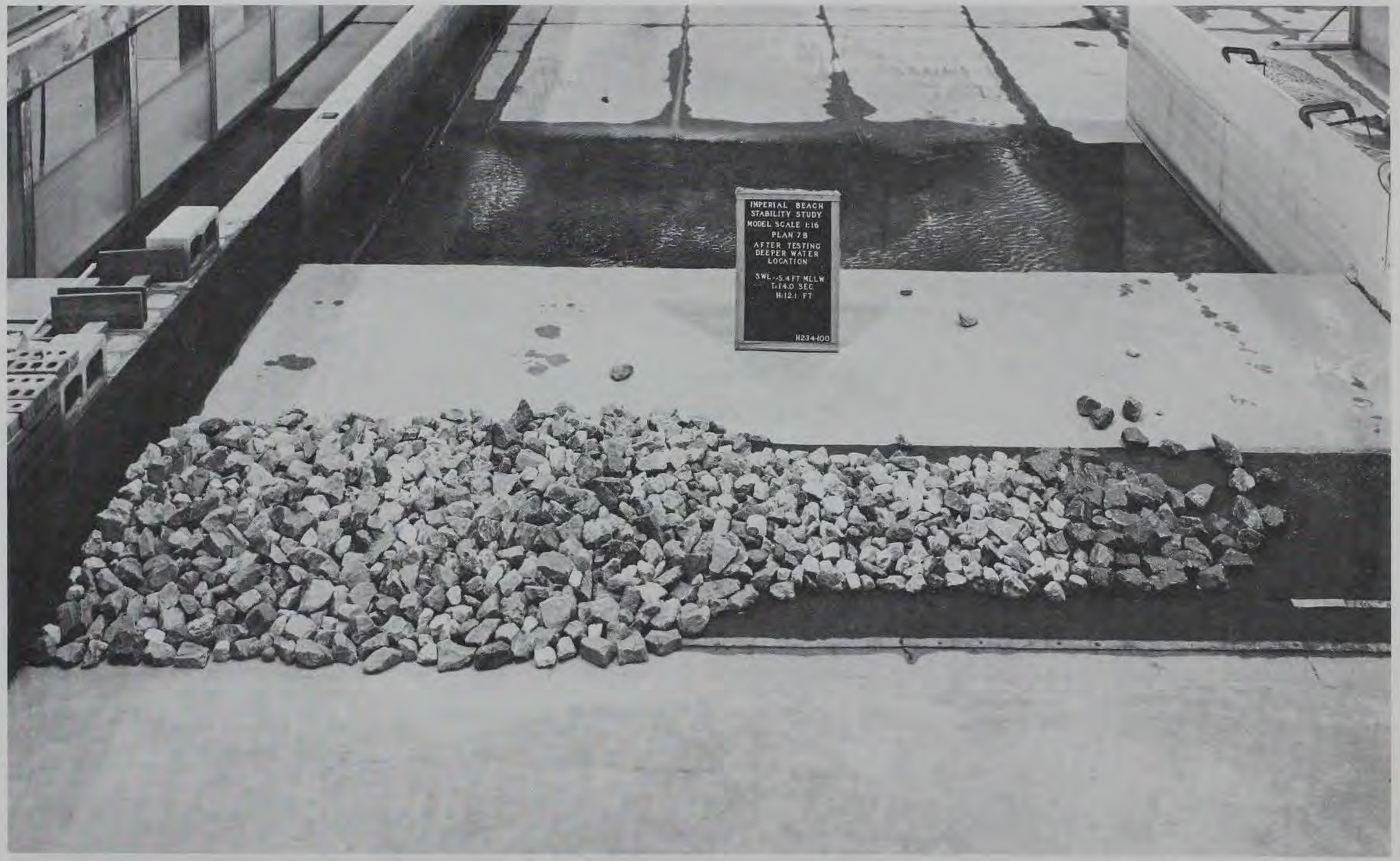


Photo 34. Sea-side view of Plan 7B in the deeper water location after 2.0 hr on low-sill head section and 15 ft of adjacent trunk, 6.0 hr on remainder of low sill, and 8.0 hr on high sill of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

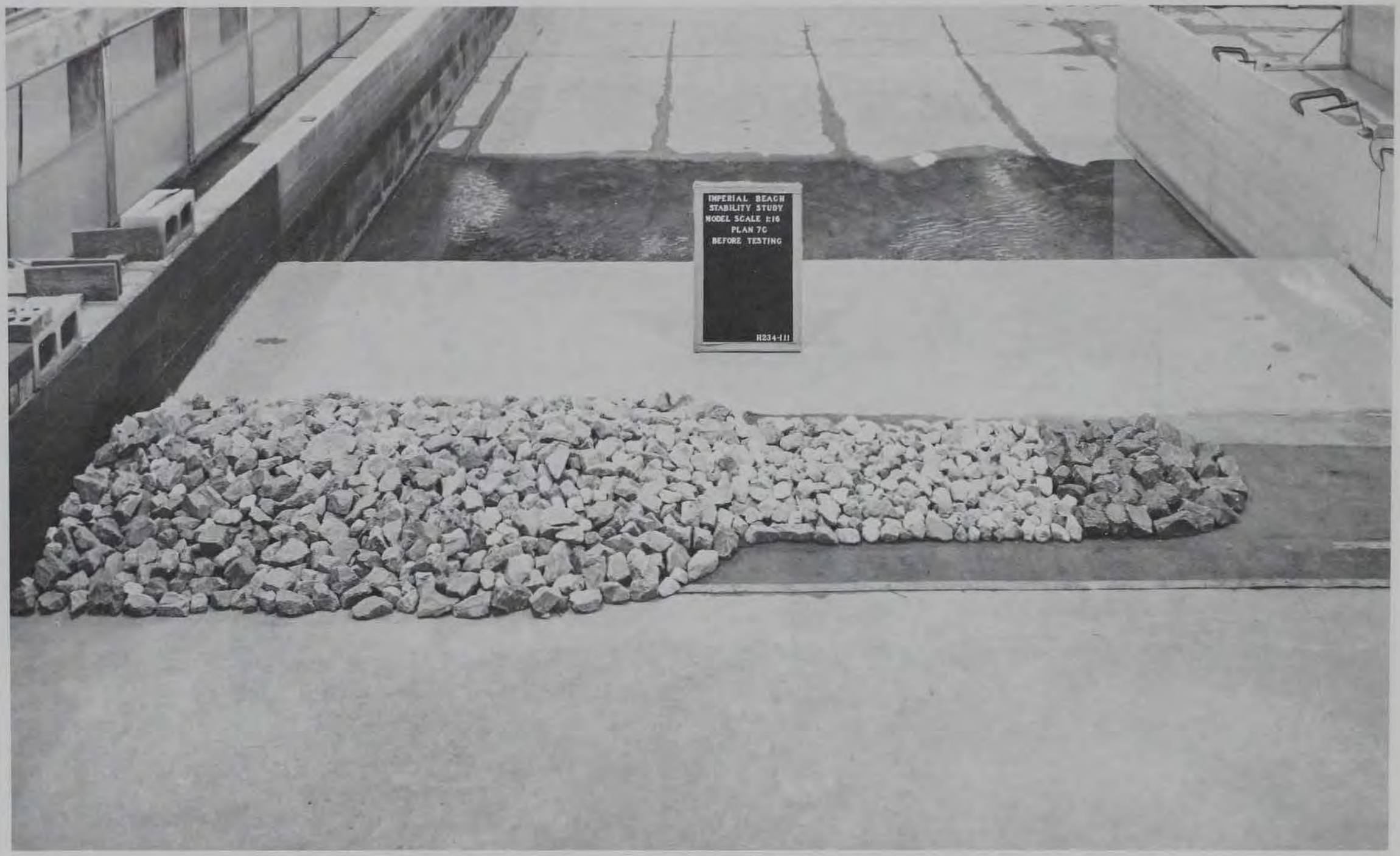


Photo 35. Sea-side view of Plan 7C before wave attack

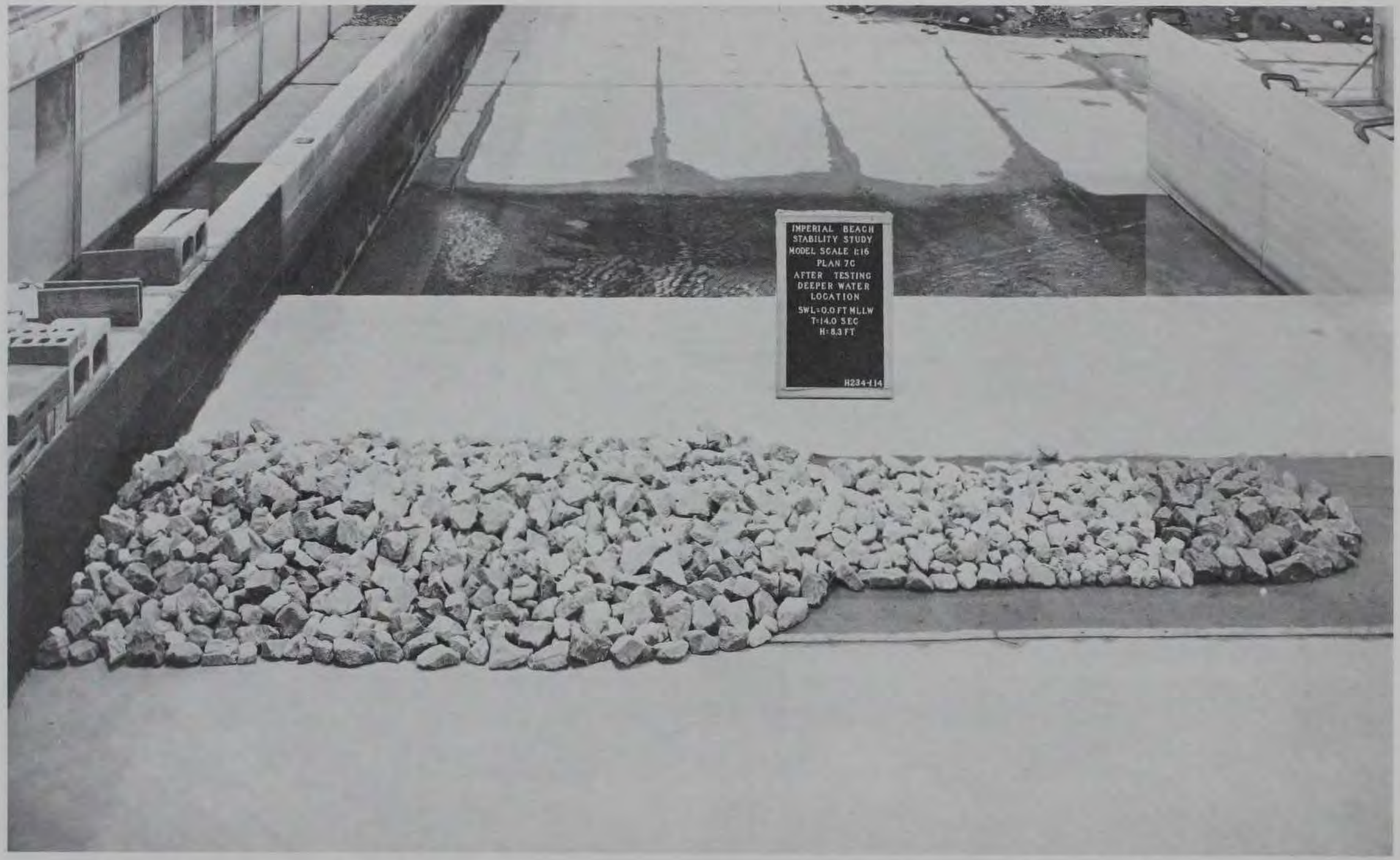


Photo 36. Sea-side view of Plan 7C in the deeper water location after 1.0 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

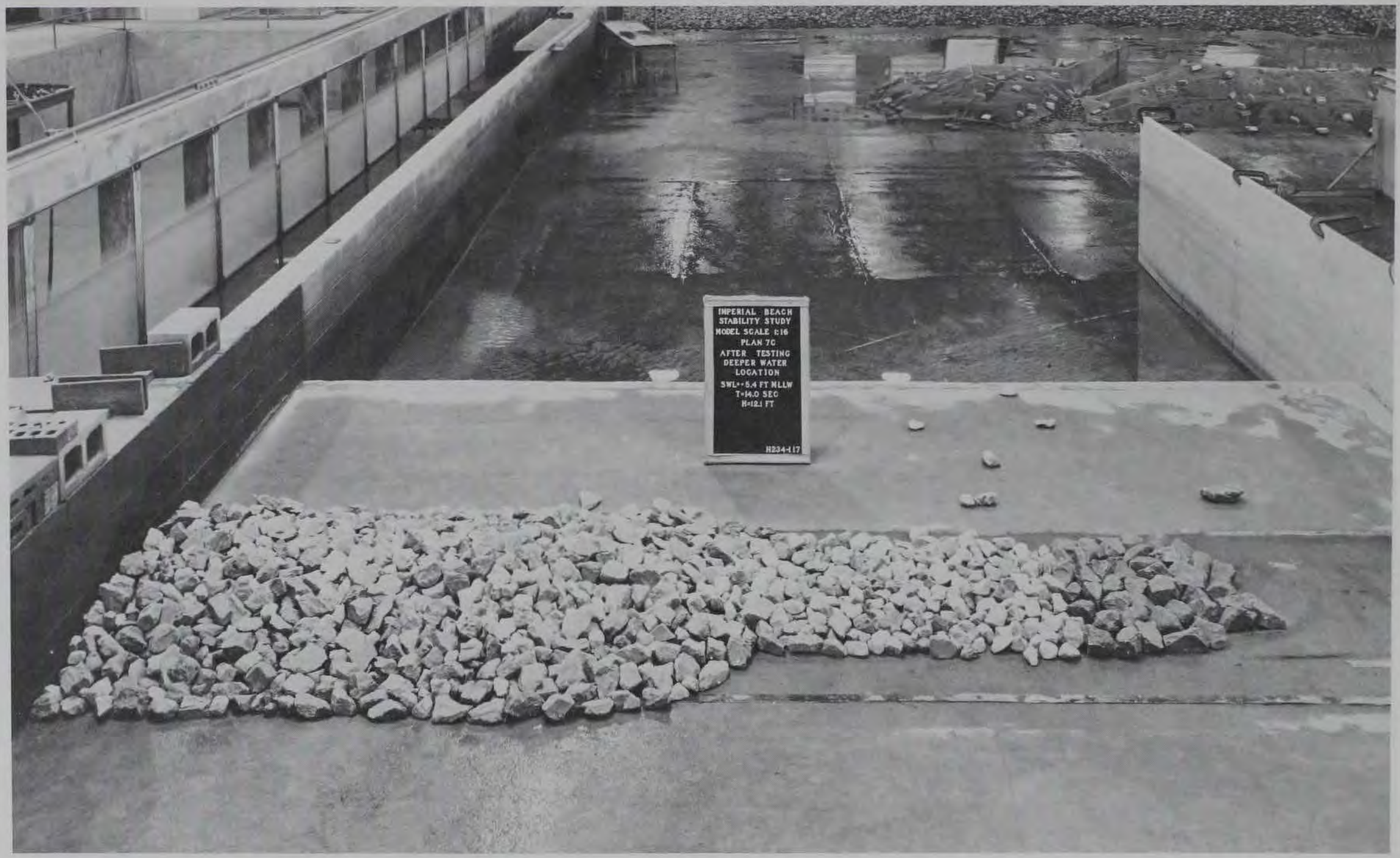


Photo 37. Sea-side view of Plan 7C in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 38. Sea-side view of Plan 7C in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

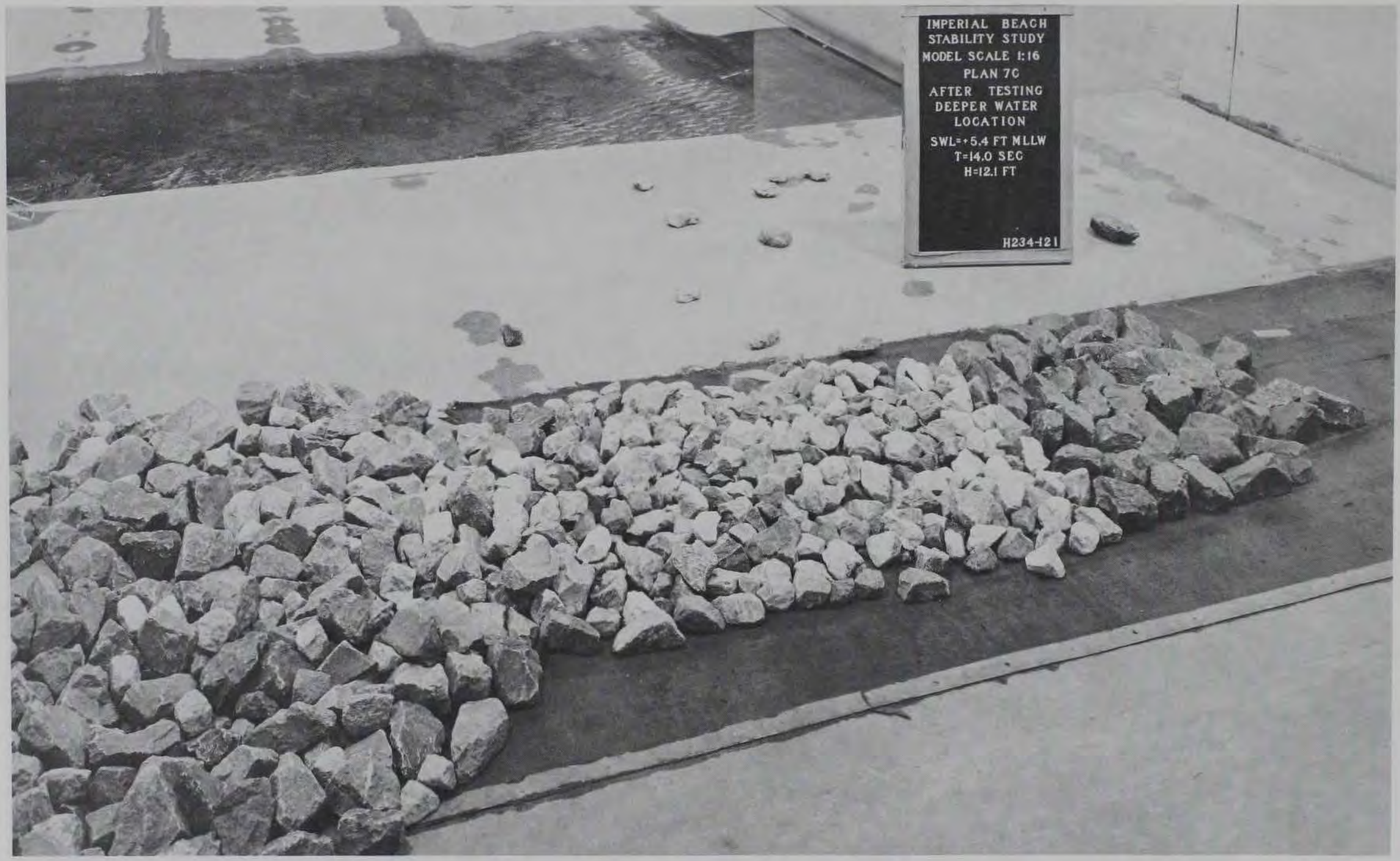


Photo 39. Sea-side view of low-sill section of Plan 7C in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 40. Sea-side view of high-sill section of Plan 7C in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 41. Sea-side view of Plan 8 before wave attack

Photo 42. Sea-side view of Plan 8 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 43. Sea-side view of Plan 9 before wave attack

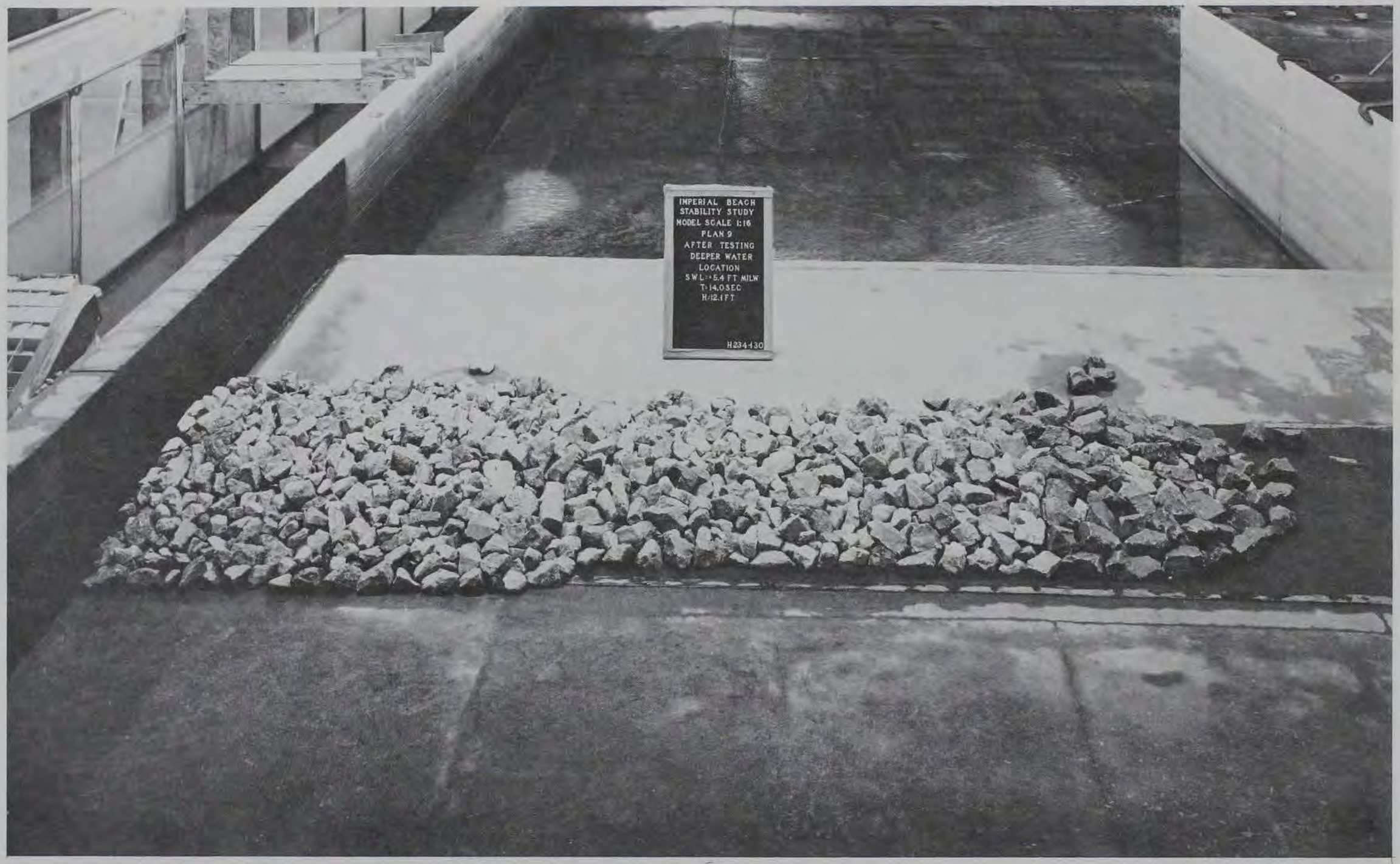


Photo 44. Sea-side view of Plan 9 in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

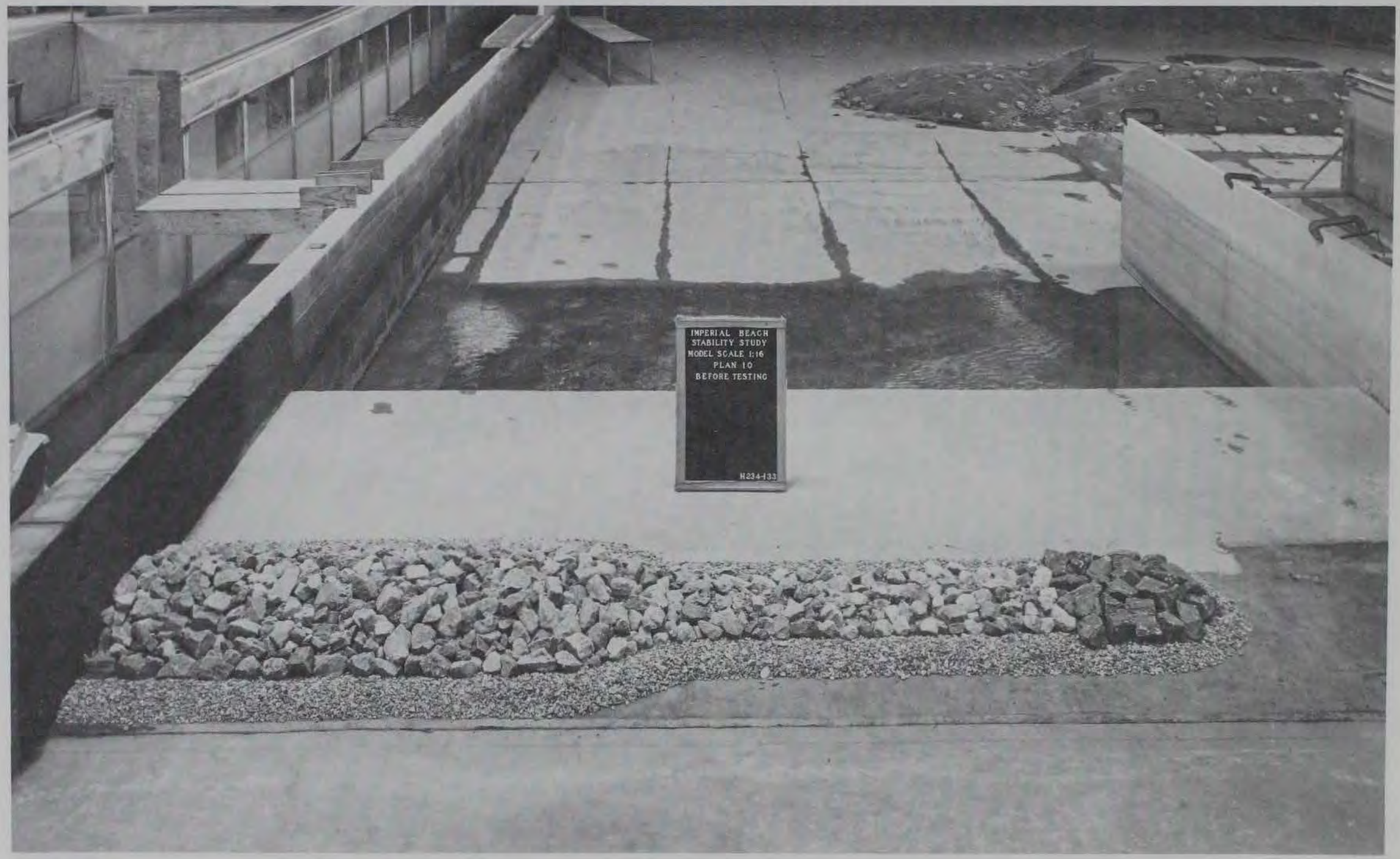


Photo 45. Sea-side view of Plan 10 before wave attack

Photo 46. Sea-side view of Plan 10 in the deeper water location after 2.0 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

Photo 47. Sea-side view of Plan 10 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 48. Sea-side view of Plan 10A in the deeper water location after 2.0 hr on the low-sill head and 4.0 hr on the remainder of the breakwater of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 49. Sea-side view of Plan 11 before wave attack

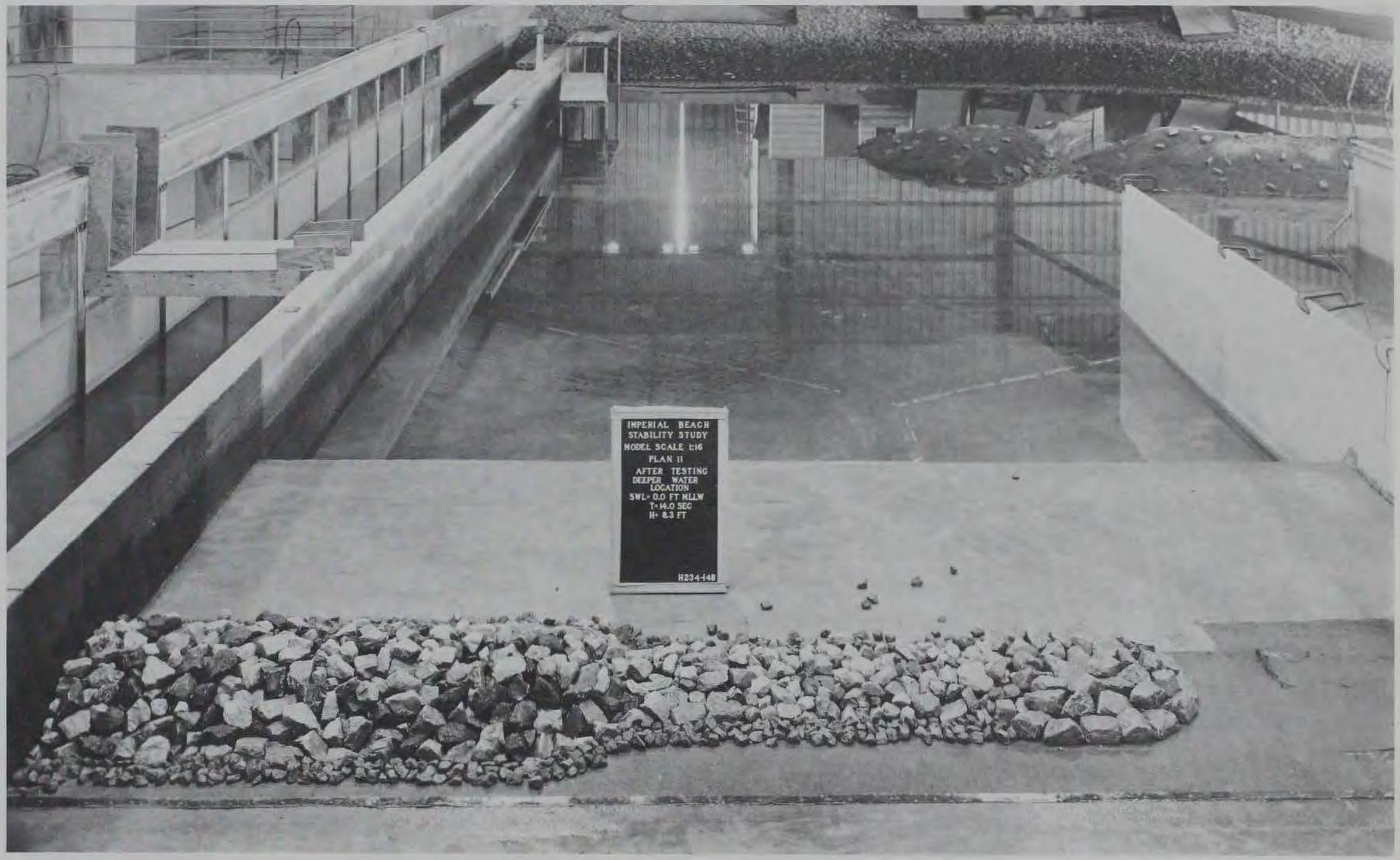


Photo 50. Sea-side view of Plan 11 in the deeper water location after 1.0 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

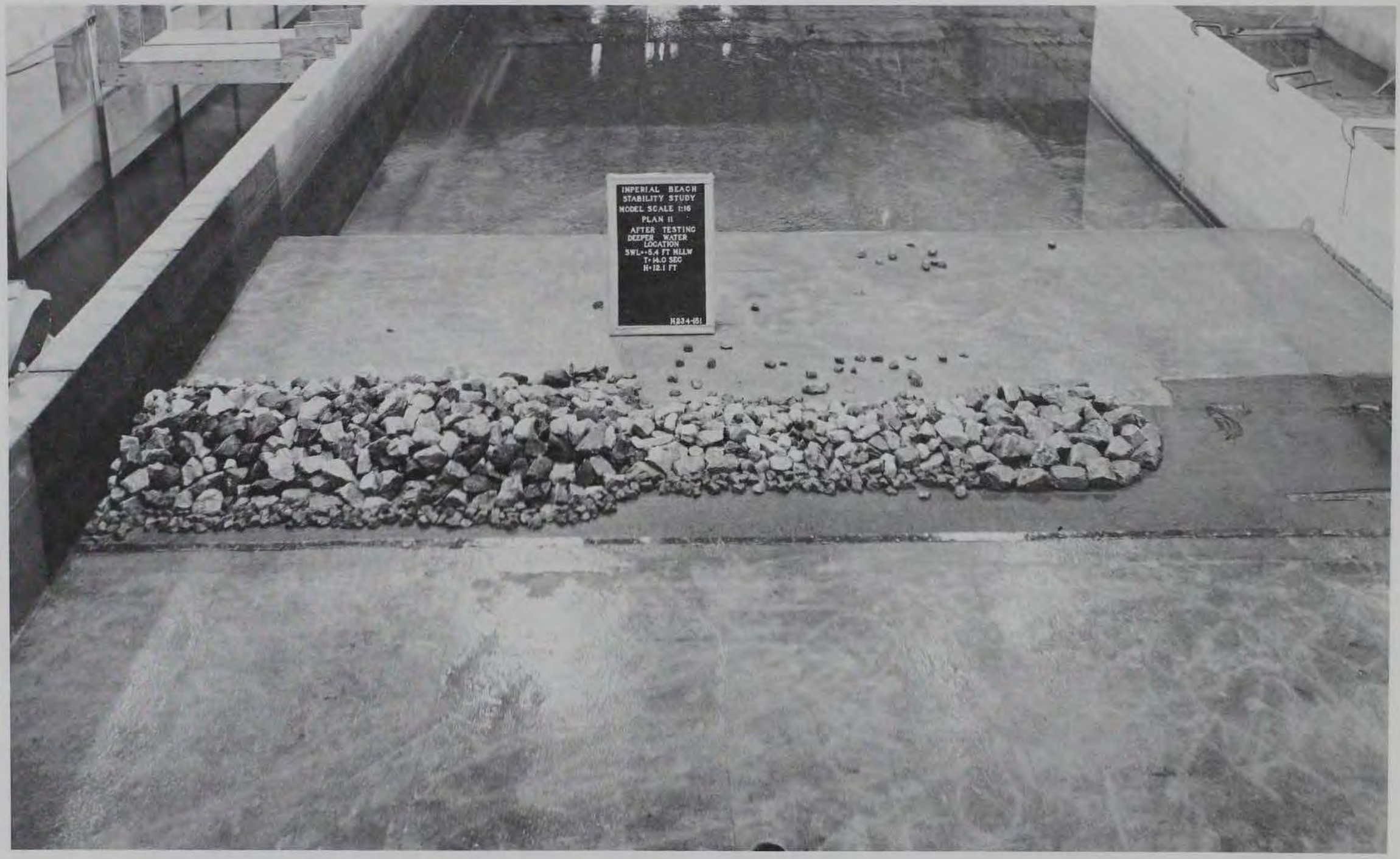


Photo 51. Sea-side view of Plan 11 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 52. Sea-side view of Plan 11 in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

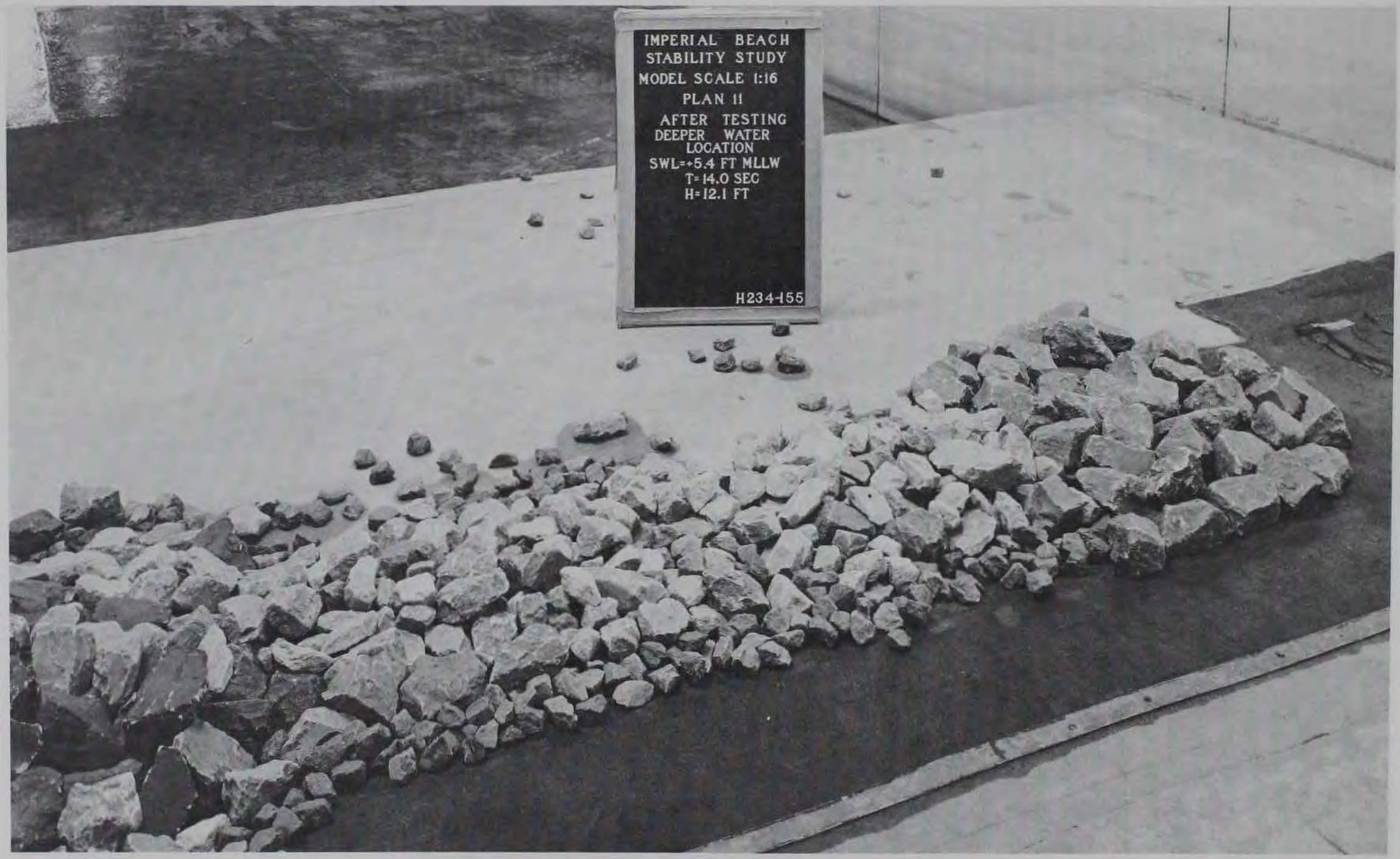


Photo 53. Sea-side view of low-sill section of Plan 11 in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 54. Sea-side view of high-sill section of Plan 11 in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

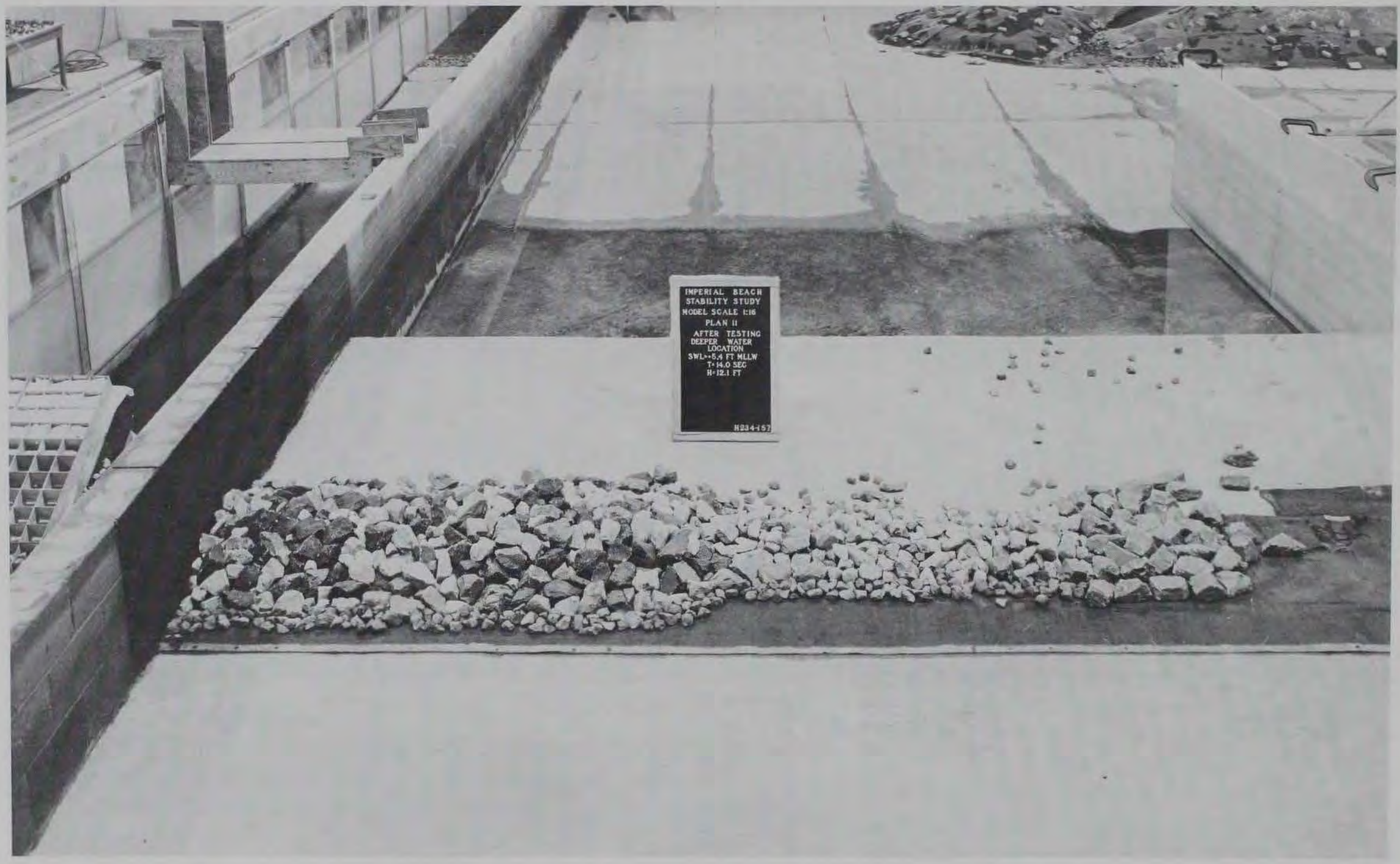


Photo 55. Sea-side view of Plan 11 in the deeper water location after 6.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

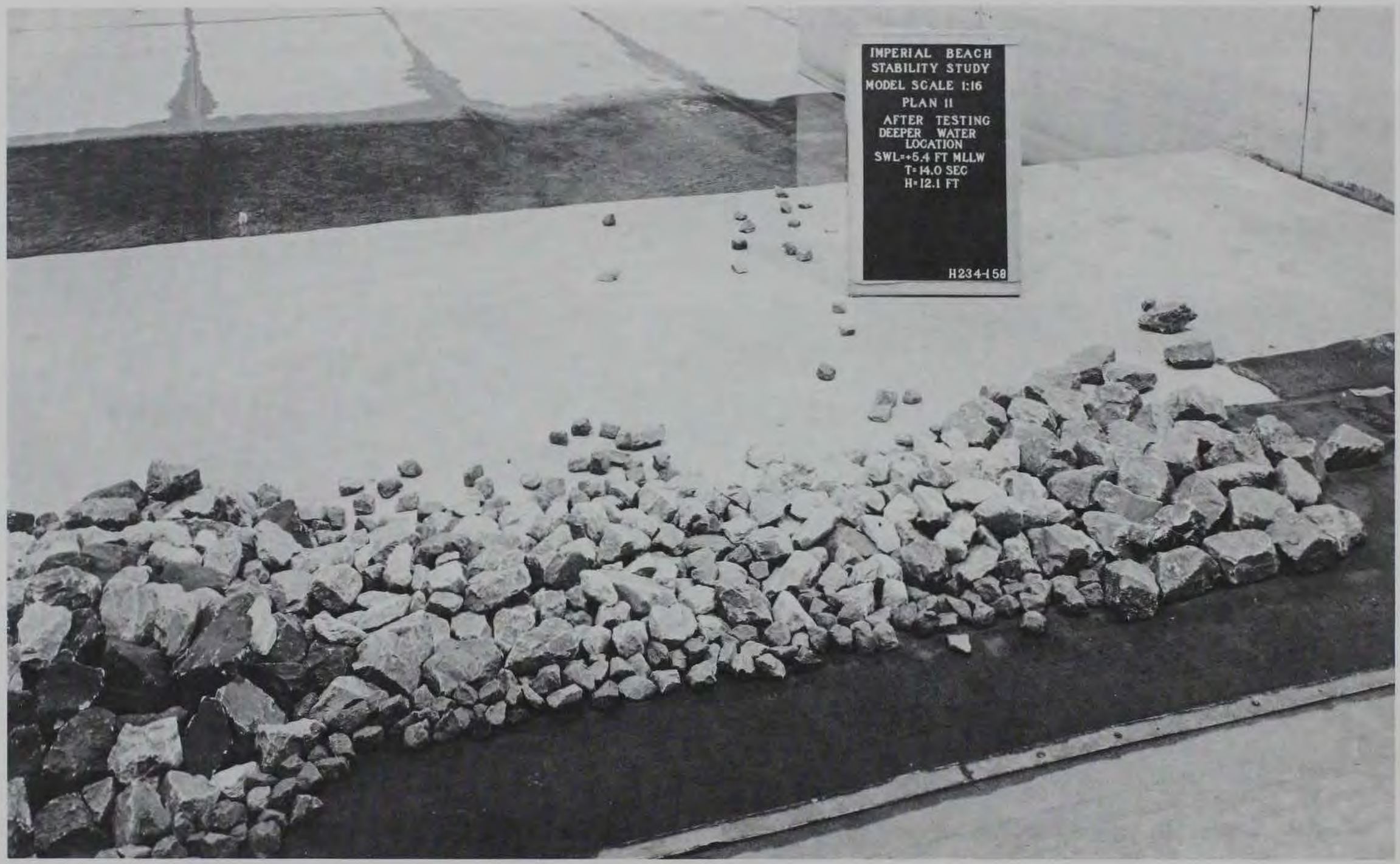


Photo 56. Sea-side view of low-sill section of Plan 11 in the deeper water location after 6.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 57. Sea-side view of high-sill section of Plan 11 in the deeper water location after 6.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

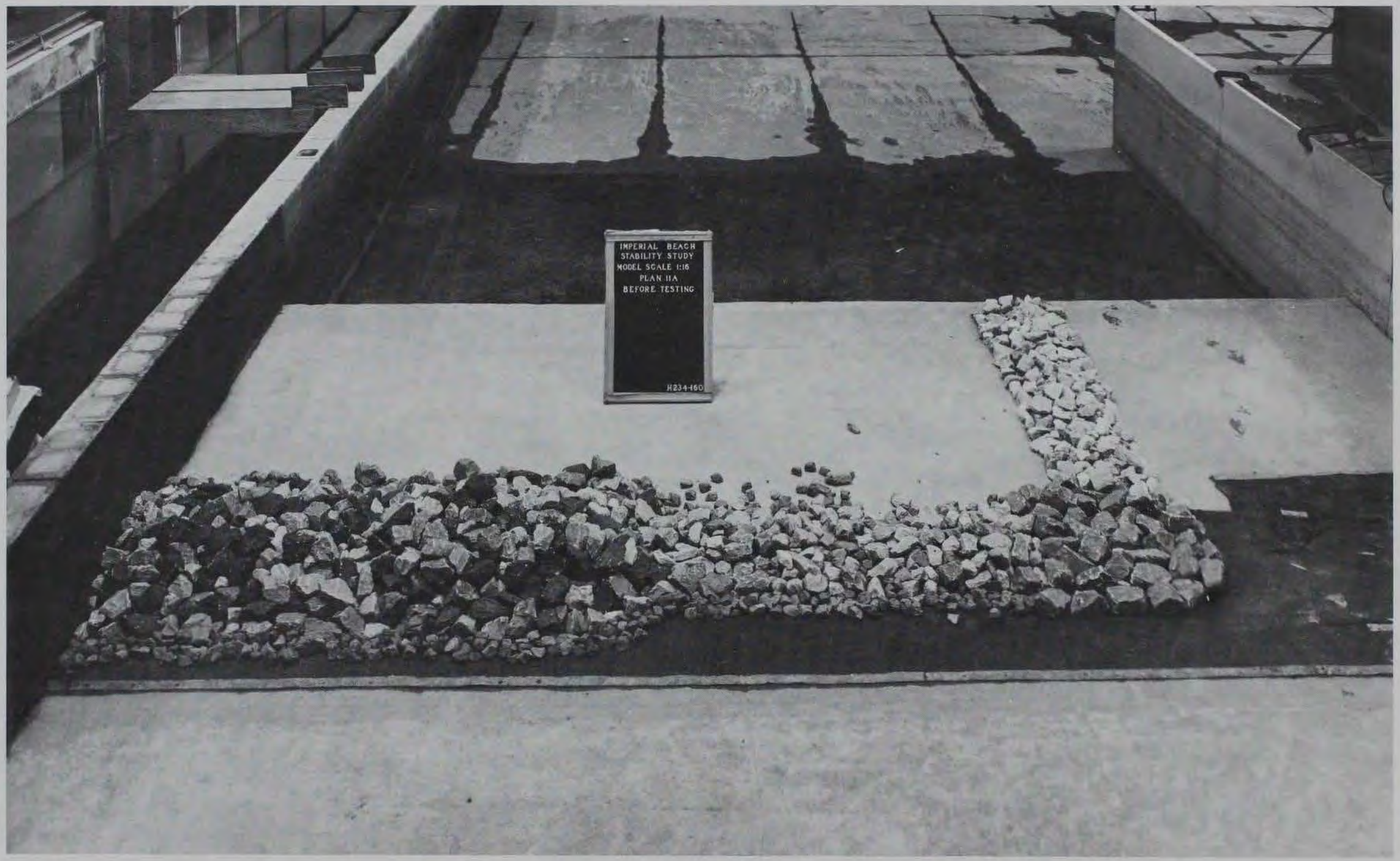


Photo 58. Sea-side view of Plan 11A before wave attack

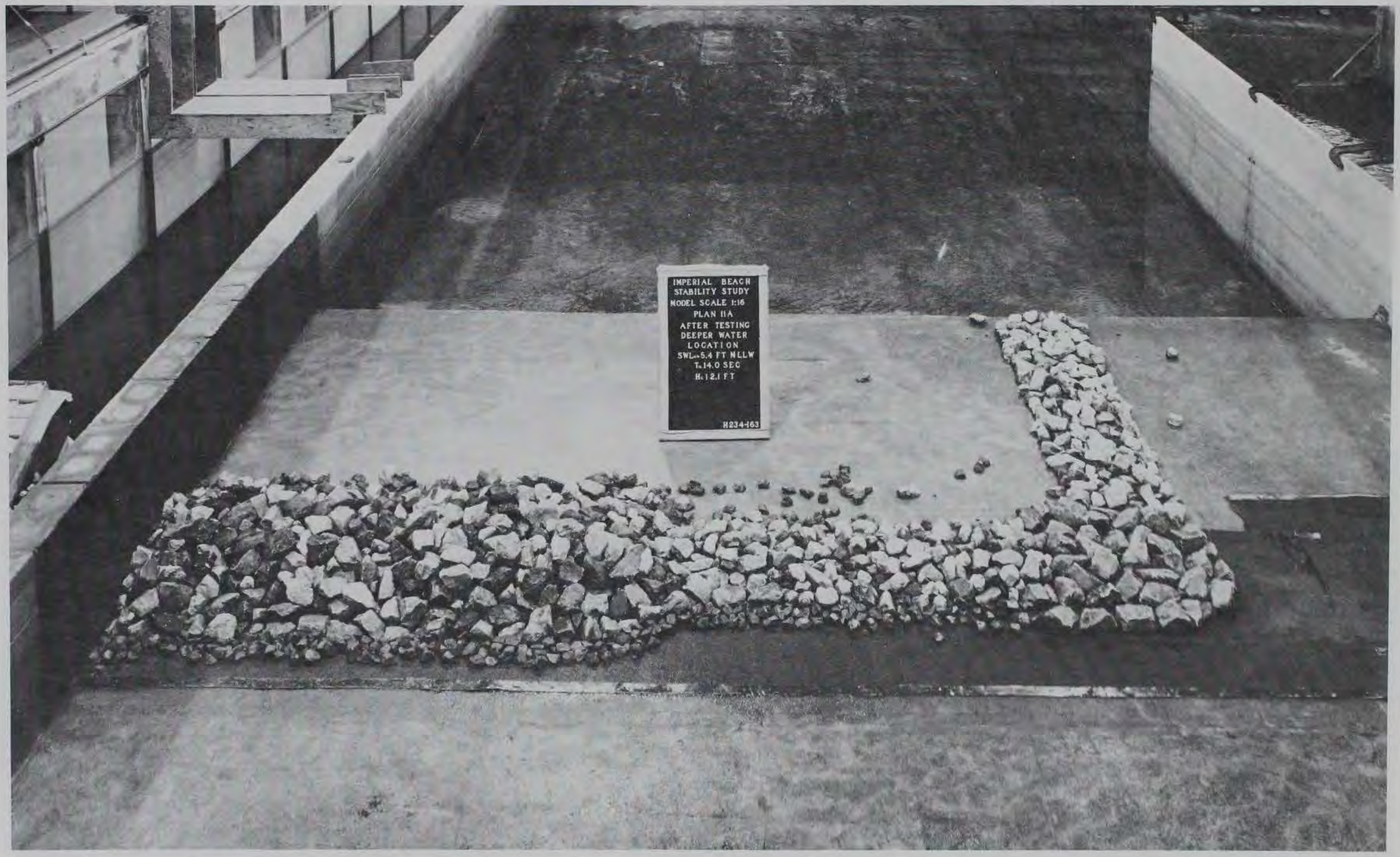


Photo 59. Sea-side view of Plan 11A in the deeper water location after 1.0 hr on 5-ft-high groin and low-sill head and 7.0 hr on remainder of breakwater of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

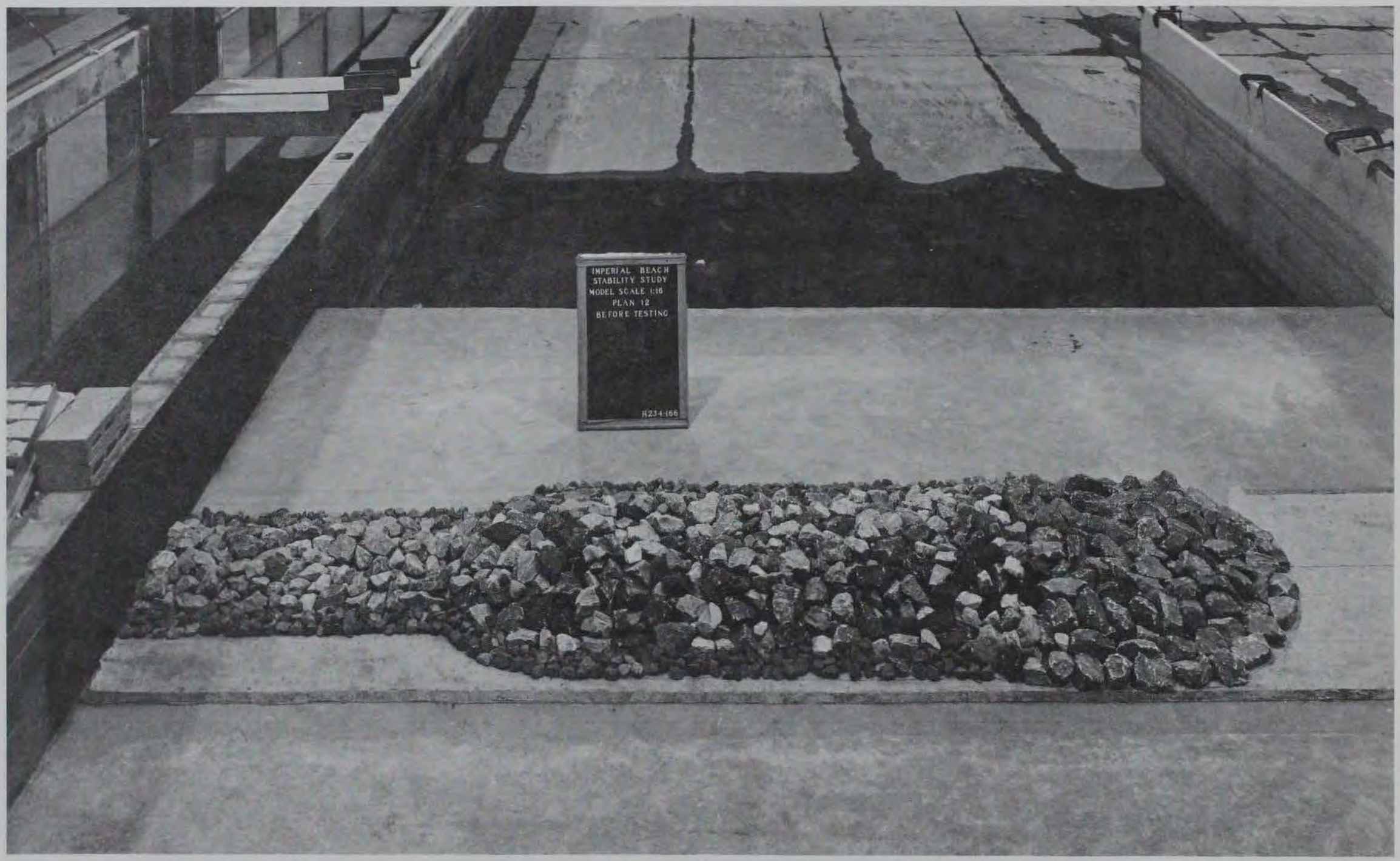


Photo 60. Sea-side view of Plan 12 before wave attack

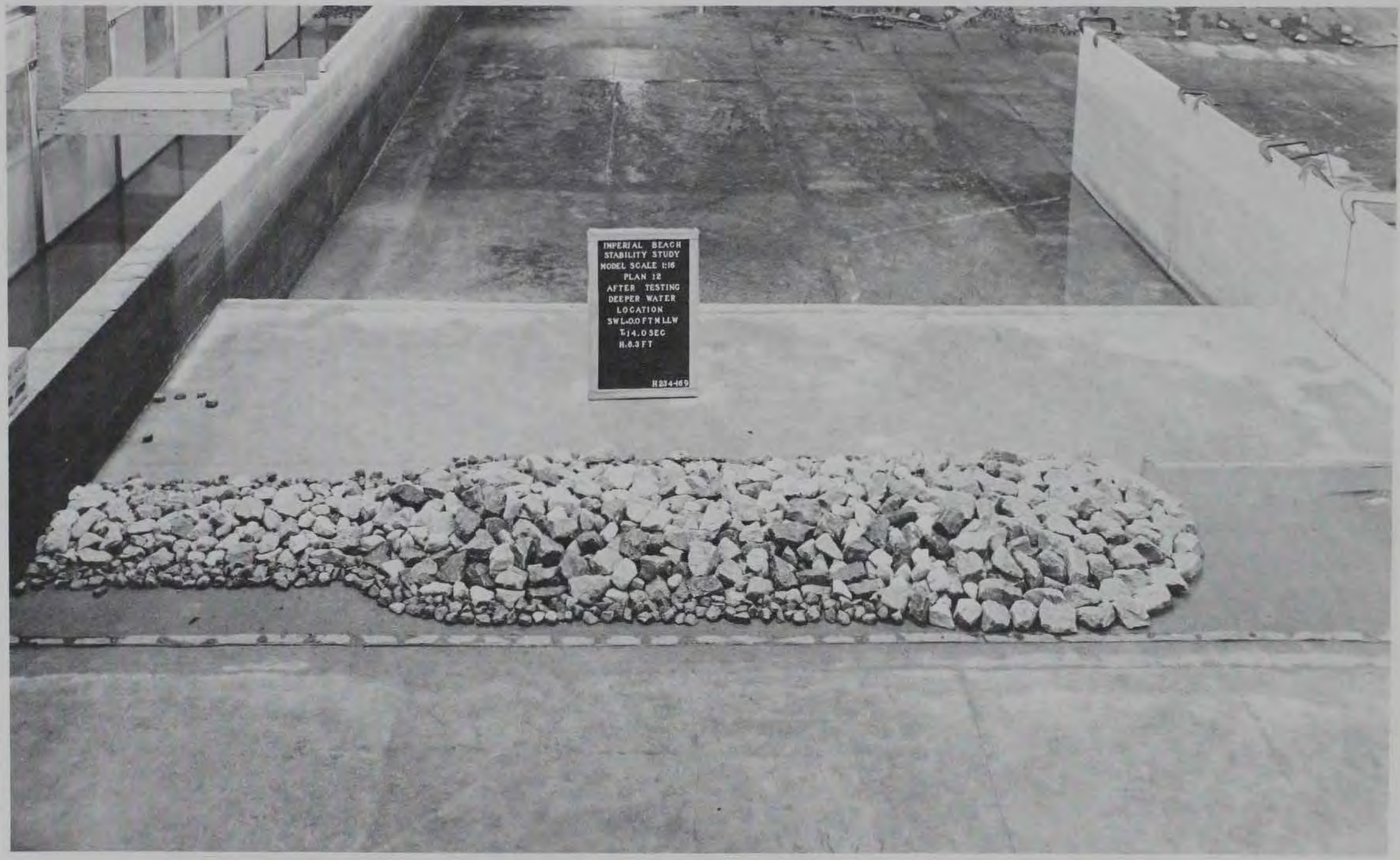


Photo 61. Sea-side view of Plan 12 in the deeper water location after 1.0 hr of 14.0-sec, 8.3-ft waves at an swl of 0.0 ft mllw

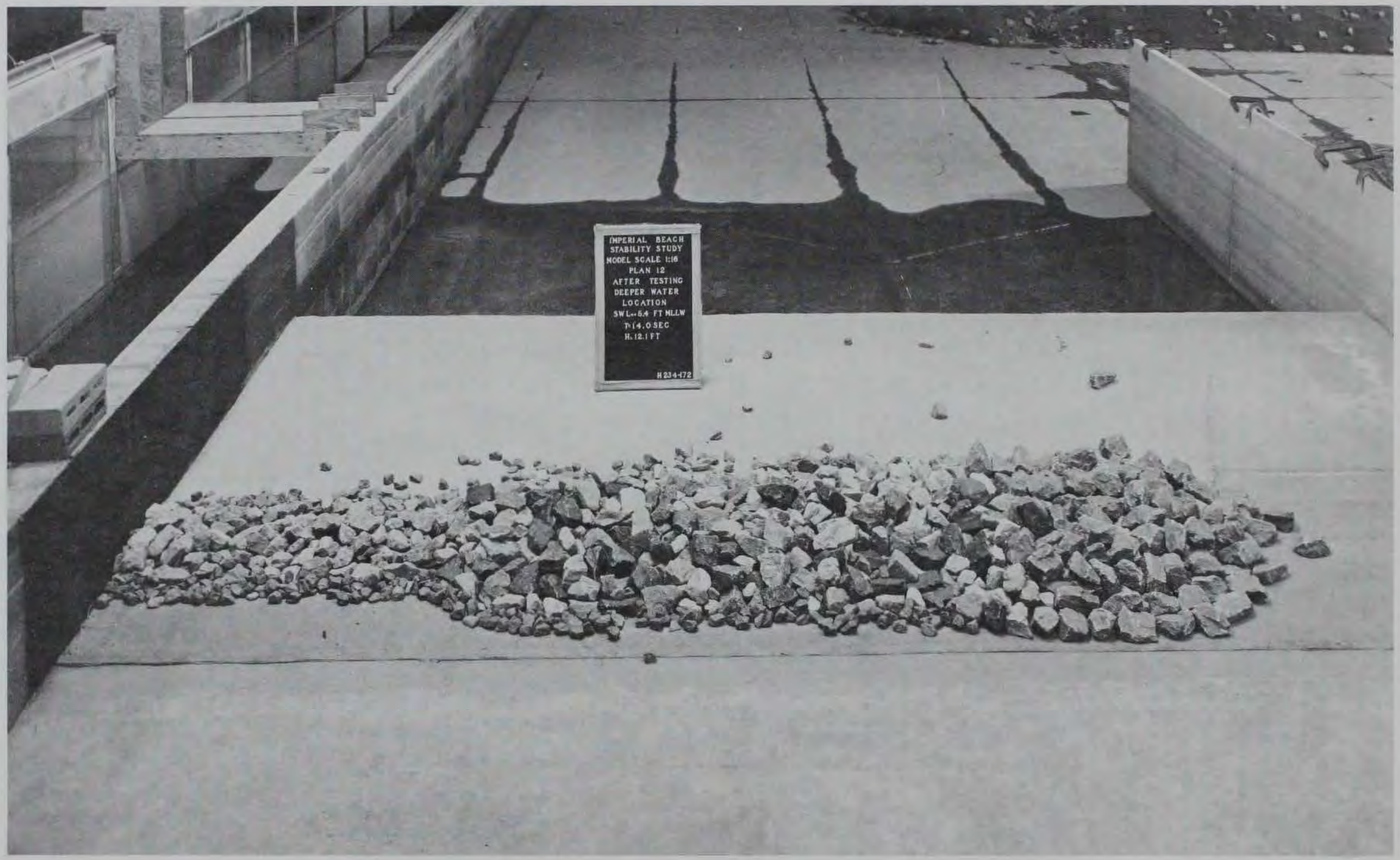


Photo 62. Sea-side view of Plan 12 in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

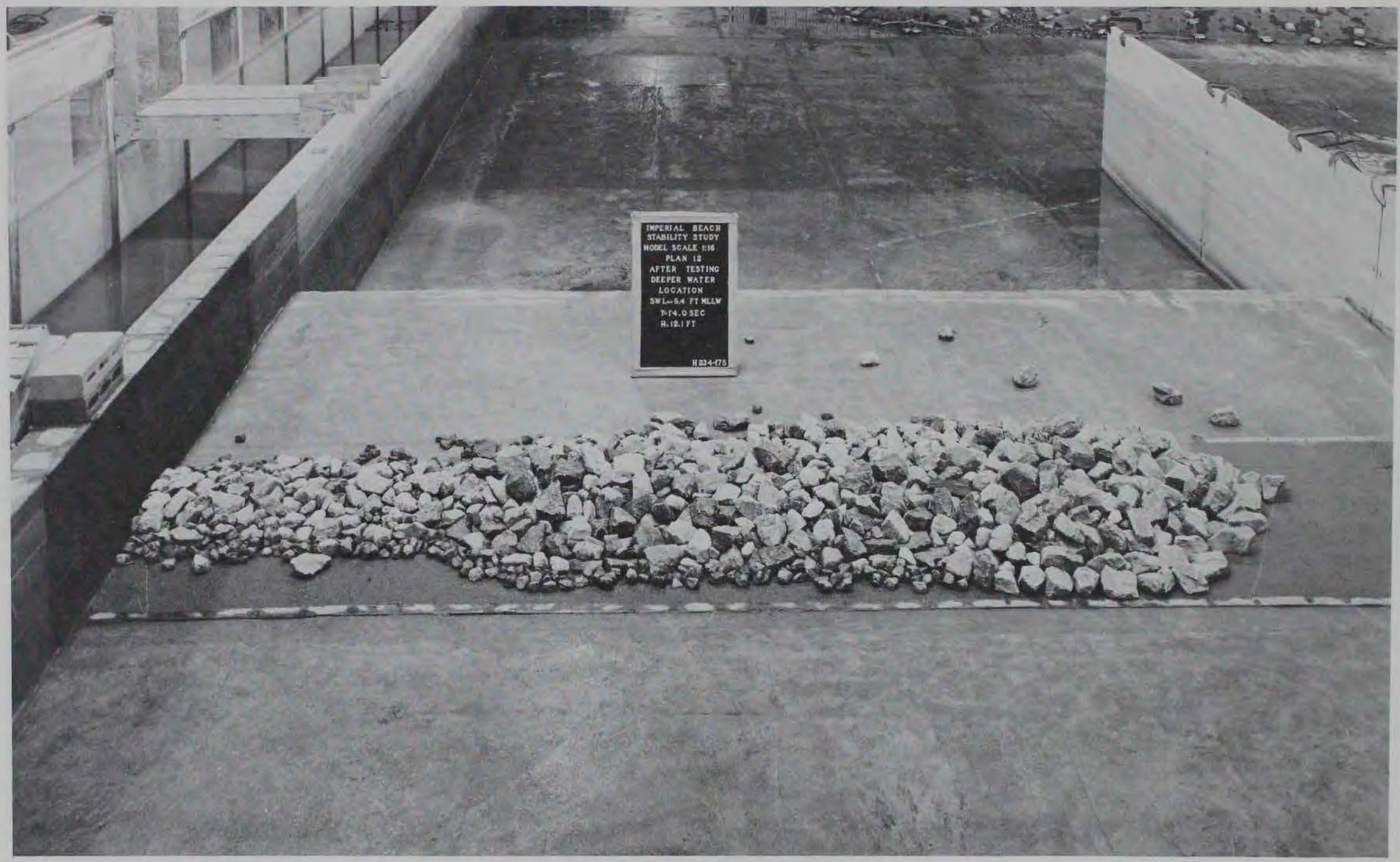


Photo 63. Sea-side view of Plan 12 in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 64. Sea-side view of high-sill section of Plan 12 in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 65. Sea-side view of low-sill section of Plan 12 in the deeper water location after 4.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 66. Sea-side view of Plan 12A before wave attack

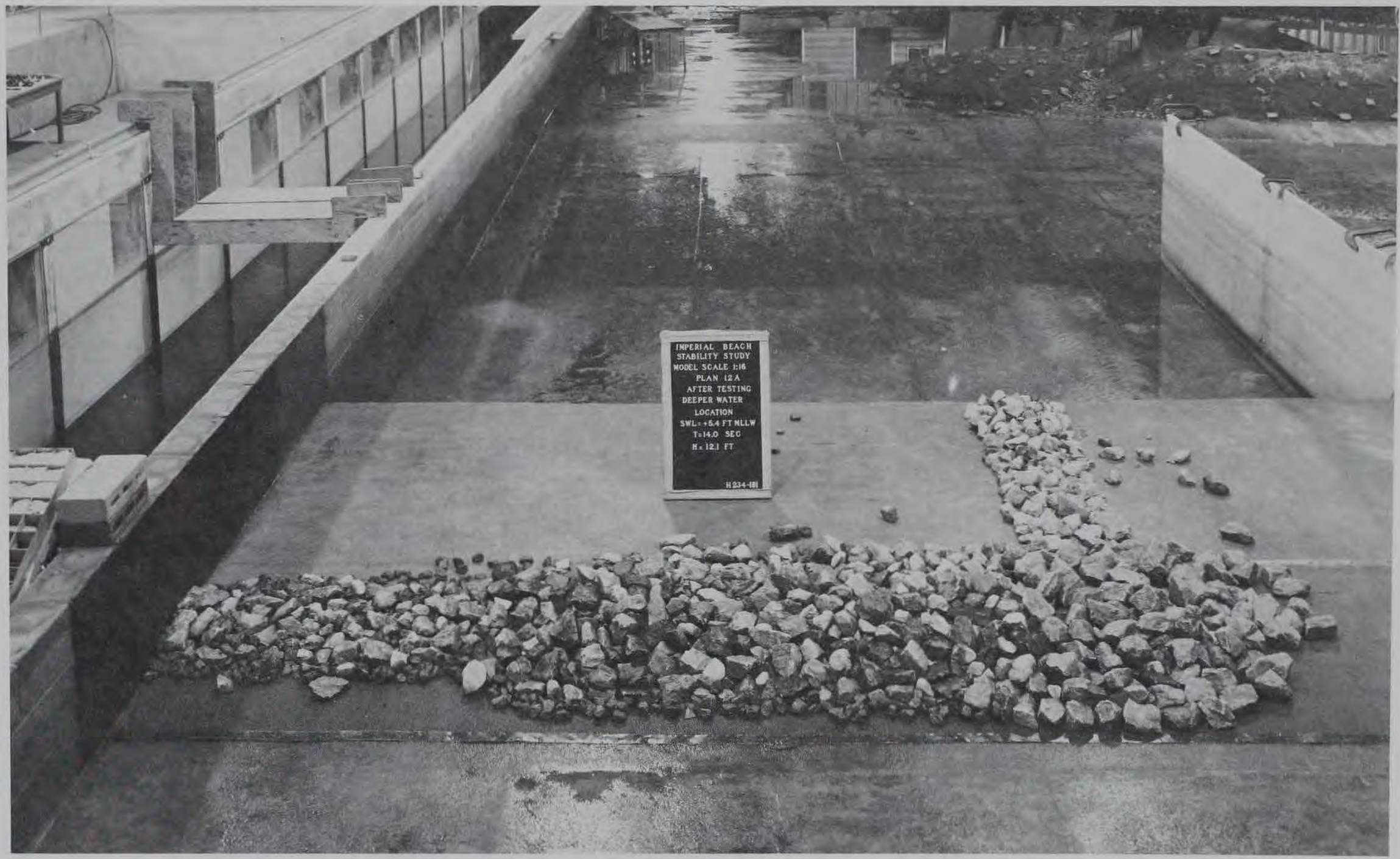


Photo 67. Sea-side view of Plan 12A in the deeper water location after 2.0 hr on high-sill head and 5-ft-high groin and 6.0 hr on remainder of breakwater of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 68. Sea-side view of high-sill section and 5-ft-high groin of Plan 12A in the deeper water location after 2.0 hr on high-sill head and groin and 6.0 hr on remainder of high-sill of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 69. Sea-side view of low-sill section of Plan 12A in the deeper water location after 6.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 70. Sea-side view of Plan 12B before wave attack

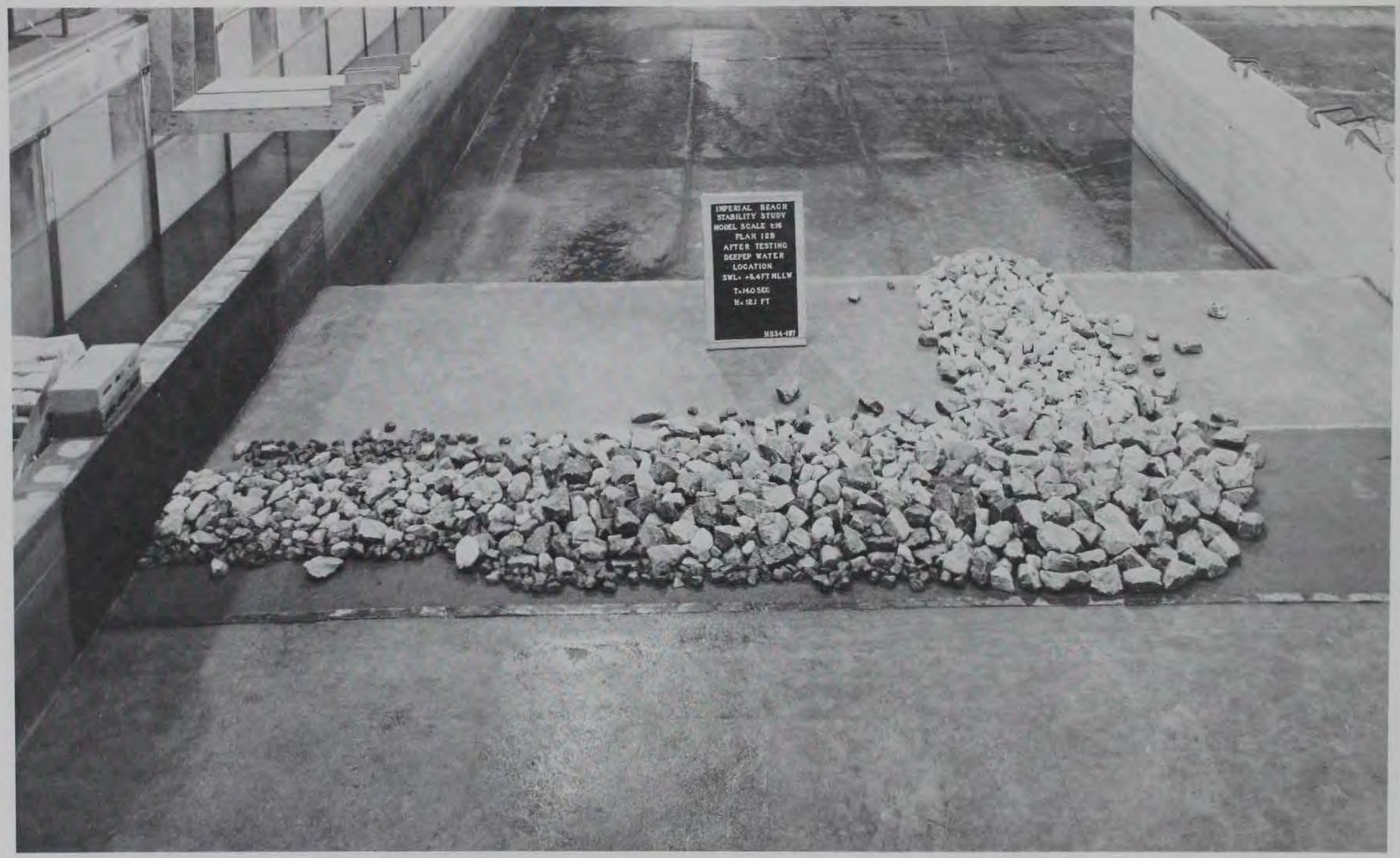


Photo 71. Sea-side view of Plan 12B in the deeper water location after 2.0 hr on high-sill head and 10-ft-high groin and 8.0 hr on remainder of breakwater of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 72. Sea-side view of high-sill section and 10-ft-high groin of Plan 12B in the deeper water location after 2.0 hr on high-sill head and groin and 8.0 hr on remainder of high-sill of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 73. Sea-side view of low-sill section of Plan 12B in the deeper water location after 8.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

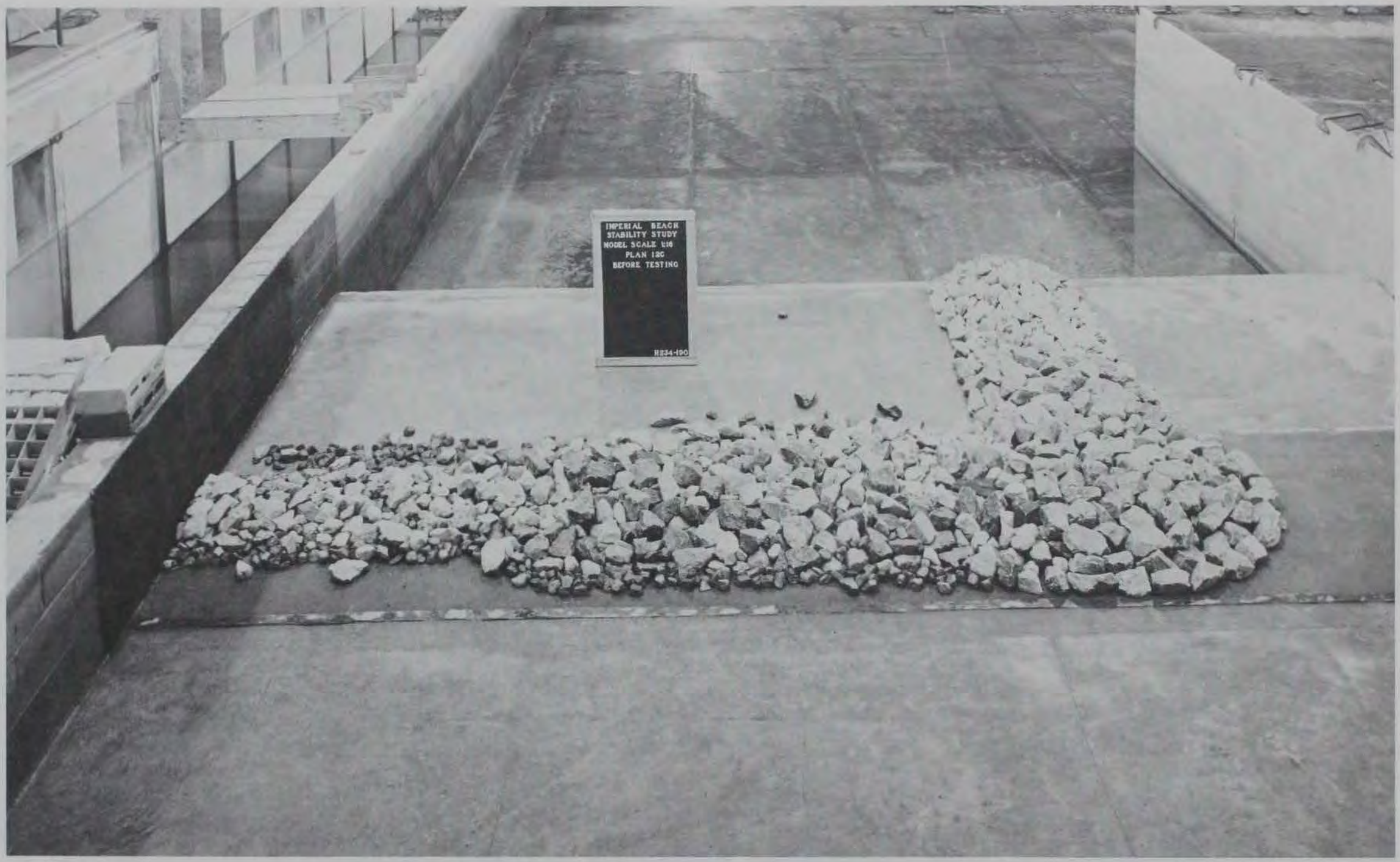


Photo 74. Sea-side view of Plan 12C before wave attack

Photo 75. Sea-side view of high-sill section and 10-ft-high groin of Plan 12C before wave attack; groin modified and rebuilt and only high-sill head of remaining breakwater rebuilt in changing from Plan 12B to Plan 12C

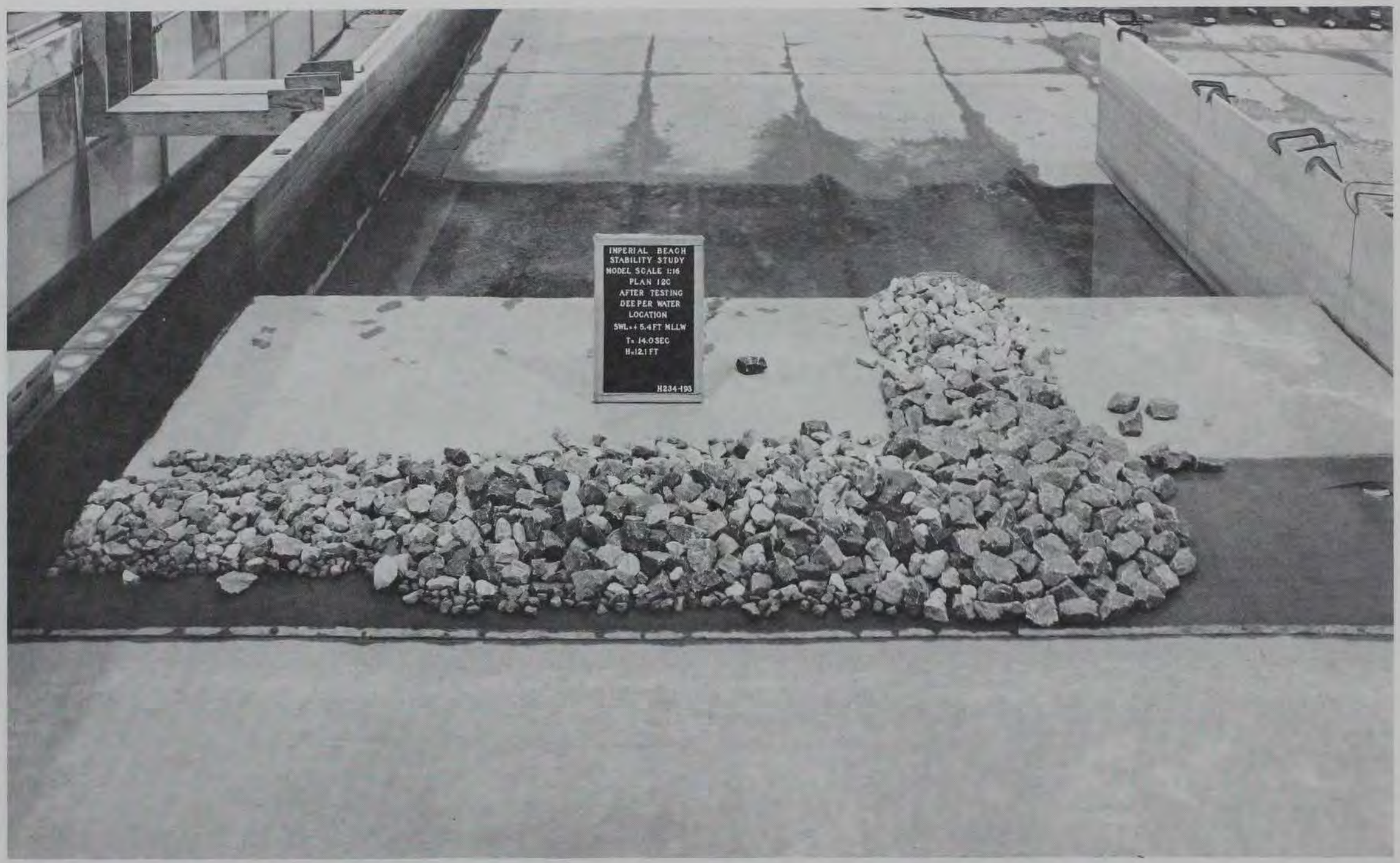


Photo 76. Sea-side view of Plan 12C in the deeper water location after 2.0 hr on high-sill head and 10-ft-high groin and 10.0 hr on remainder of breakwater of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 77. Sea-side view of high-sill section and 10-ft-high groin of Plan 12C in the deeper water location after 2.0 hr on high-sill head and groin and 10.0 hr on remainder of high-sill of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

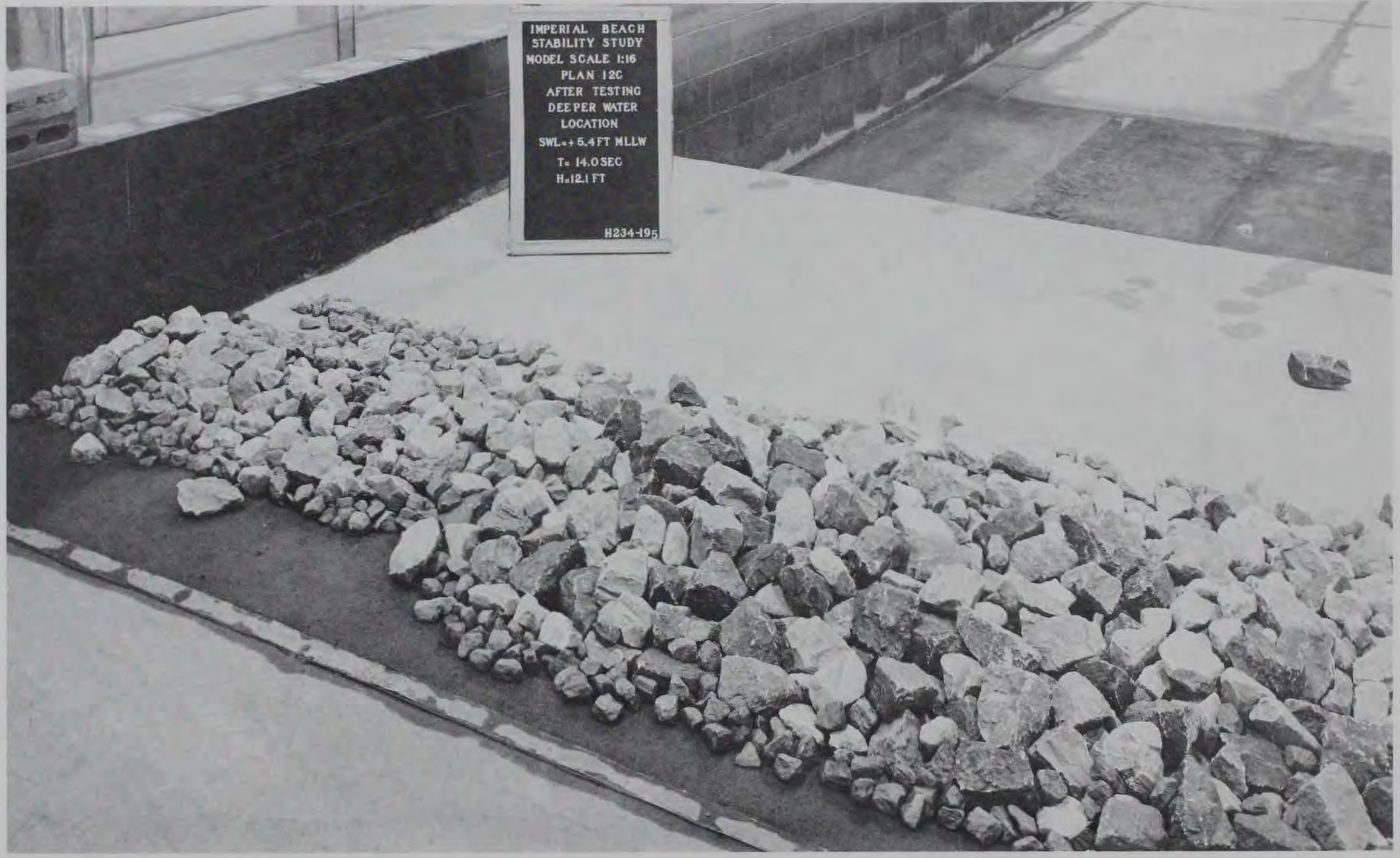


Photo 78. Sea-side view of low-sill section of Plan 12C in the deeper water location after 10.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 79. Sea-side view of Plan 12D before wave attack

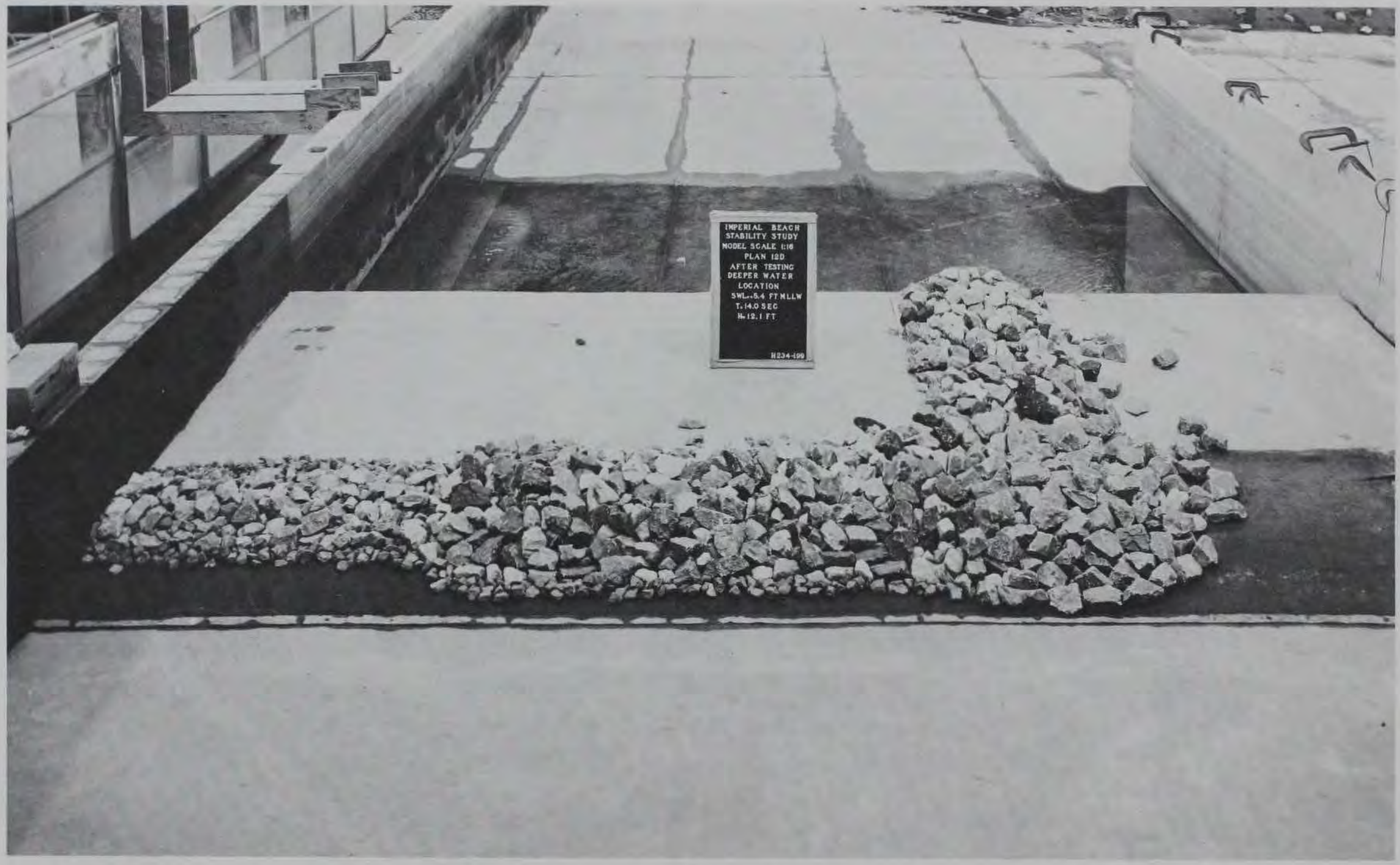
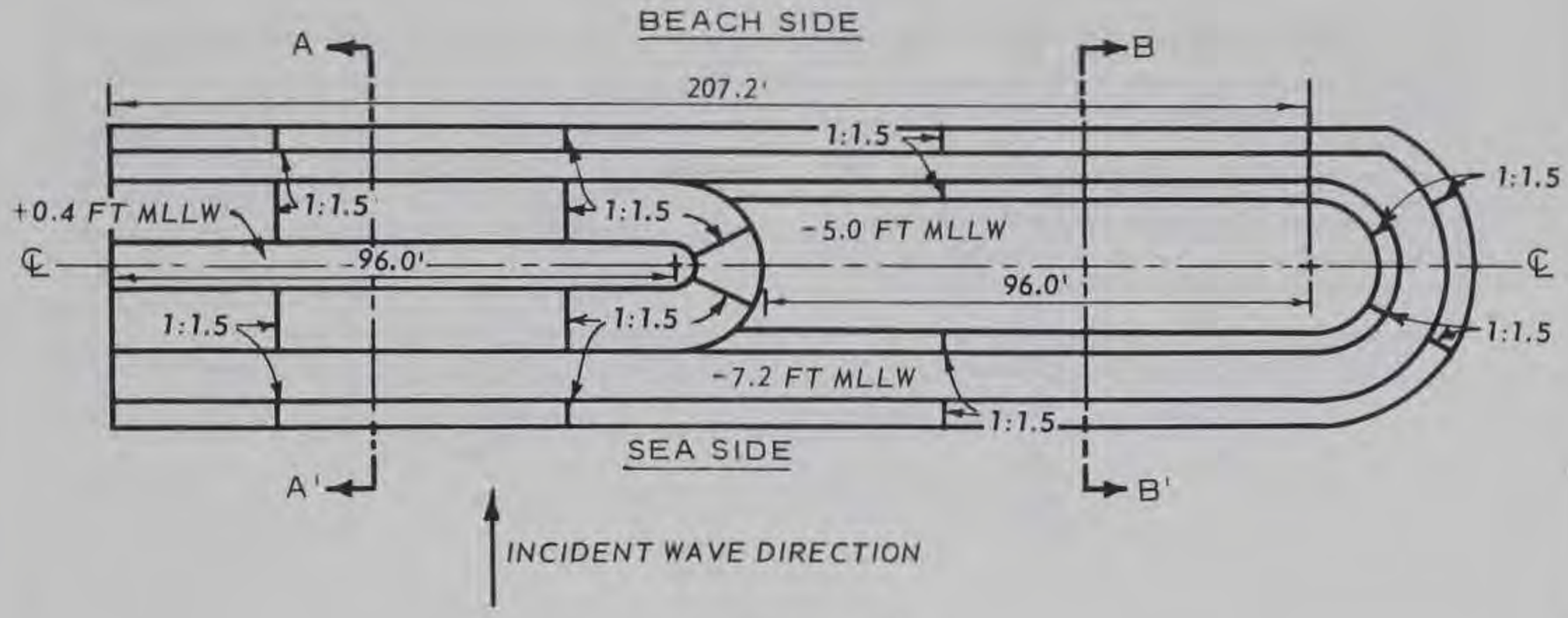


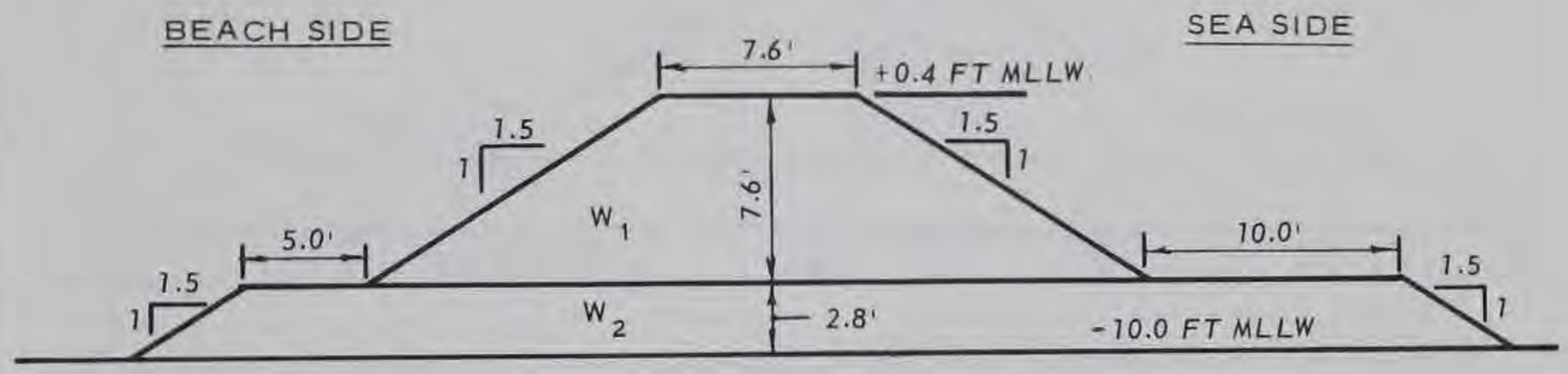
Photo 80. Sea-side view of Plan 12D in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

Photo 81. Sea-side view of high-sill section and 10.0-ft-high groin of Plan 12D in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw

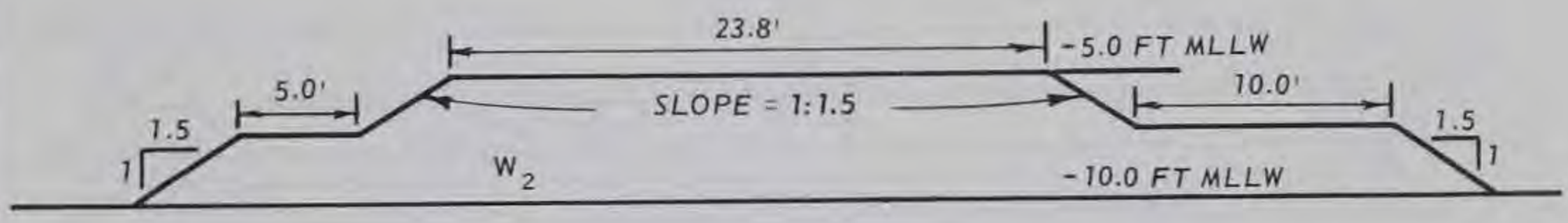
Photo 82. Sea-side view of low-sill section of Plan 12D in the deeper water location after 2.0 hr of 14.0-sec, 12.1-ft waves at an swl of +5.4 ft mllw



PLAN VIEW



SECTION A-A'



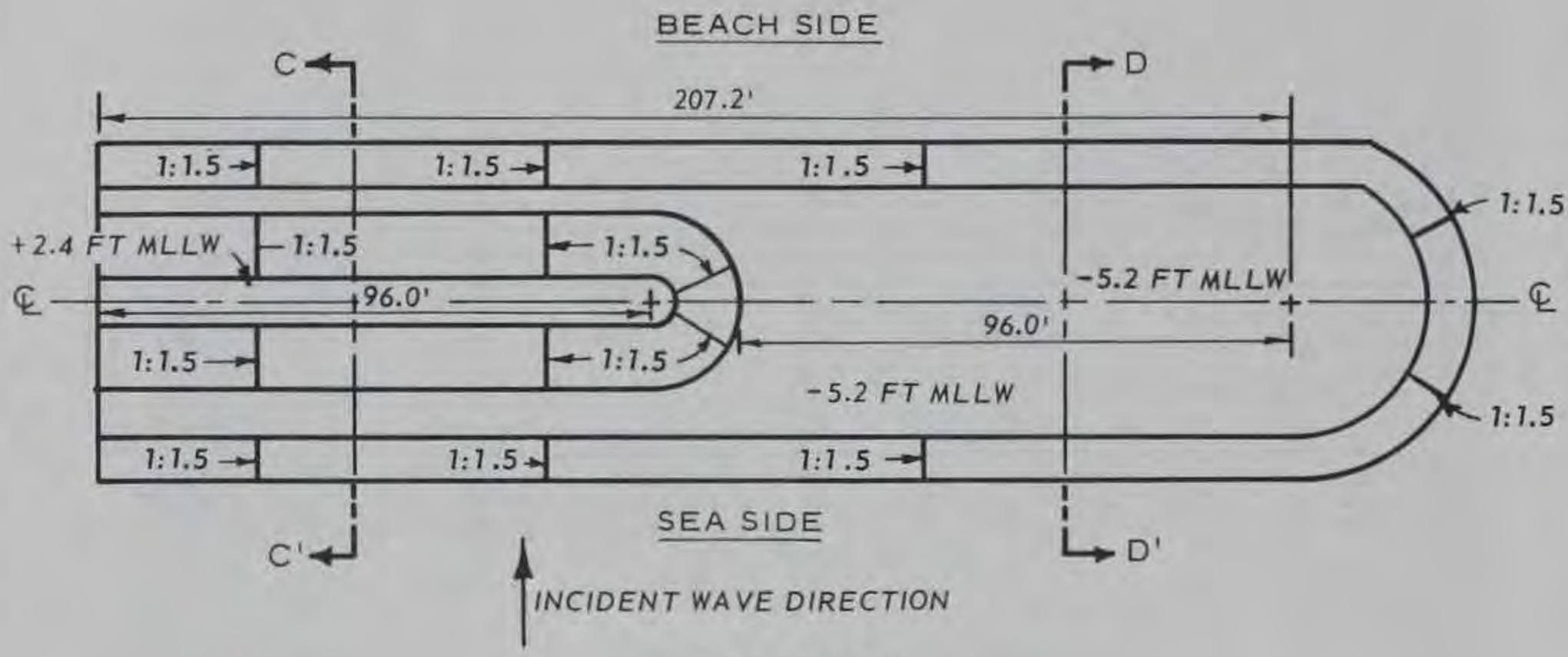
SECTION B-B'

MATERIAL CHARACTERISTICS

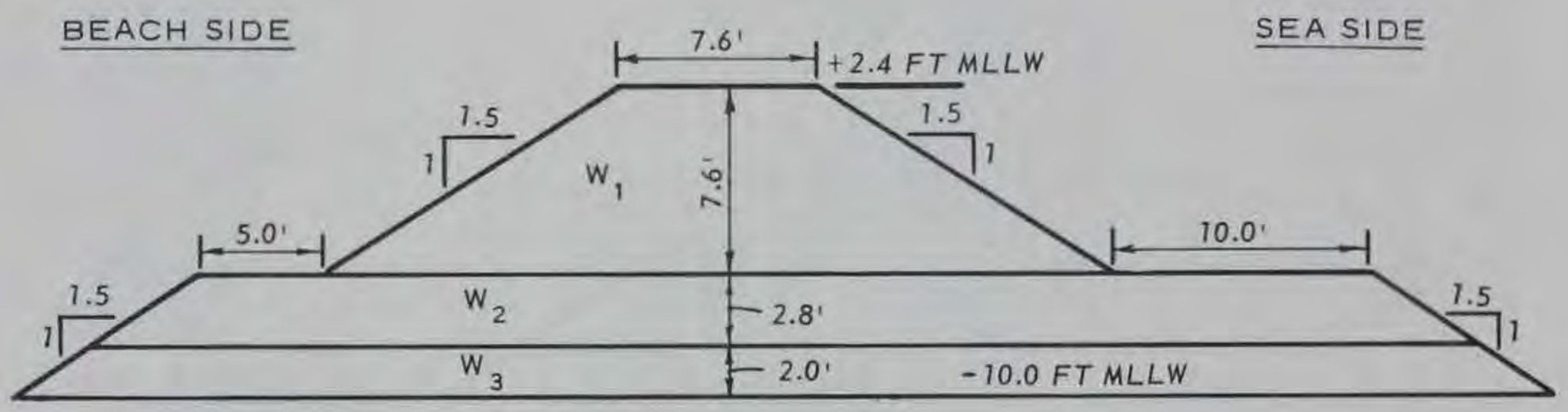
MODEL	PROTOTYPE
W_1 = 1.295-LB ROCK @ 165 PCF	W_1 = 3.0-TON ROCK @ 165 PCF
W_2 = 0.065-LB ROCK @ 165 PCF	W_2 = 0.15-TON ROCK @ 165 PCF

DEEPER WATER LOCATION
PLAN 1

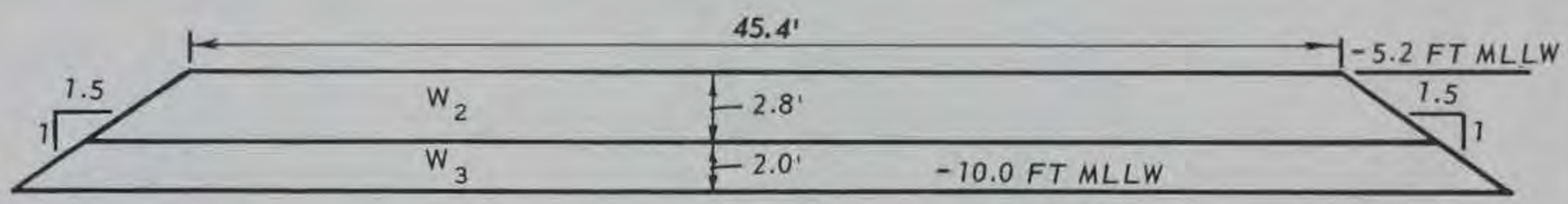
PLATE 1



PLAN VIEW



SECTION C-C'



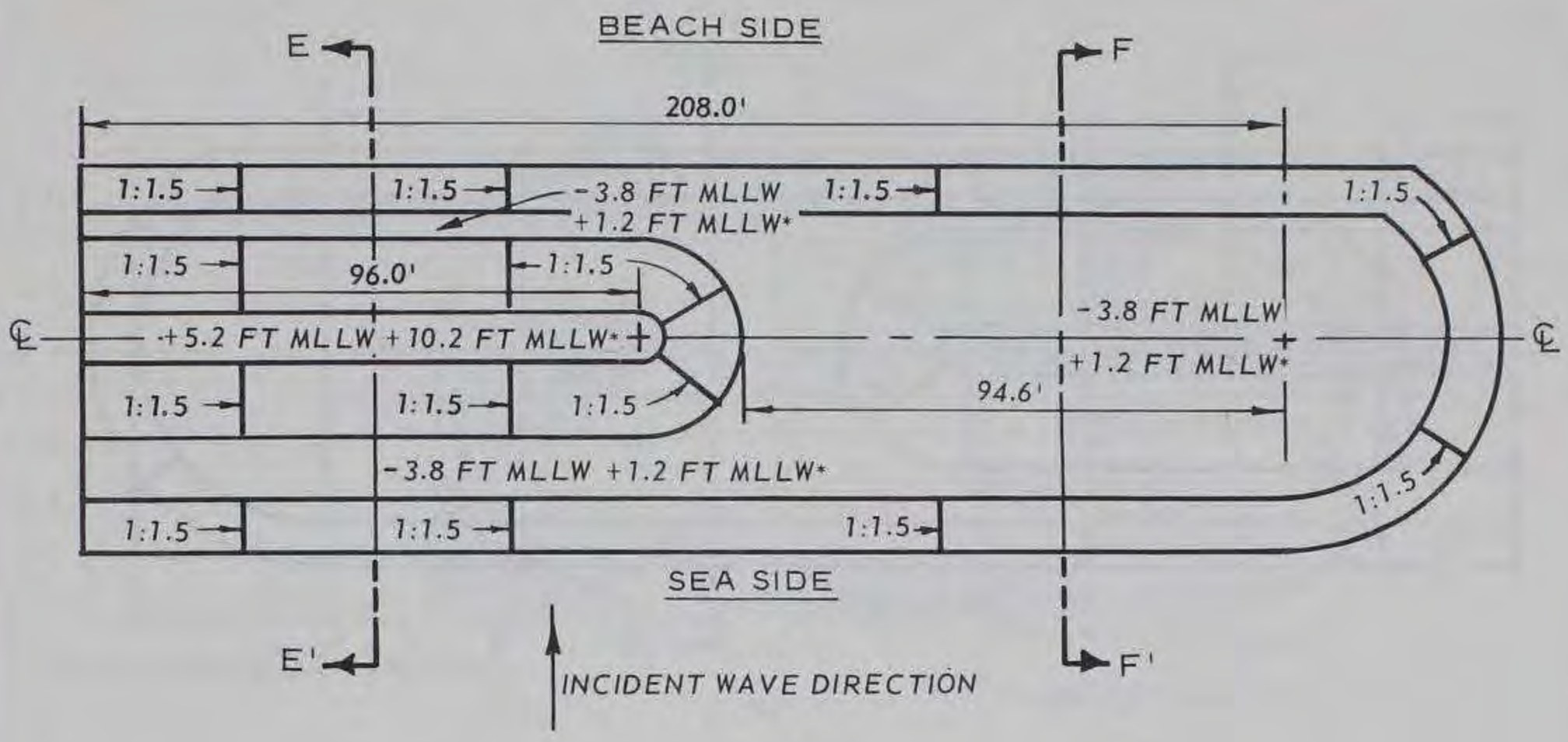
SECTION D-D'

MATERIAL CHARACTERISTICS

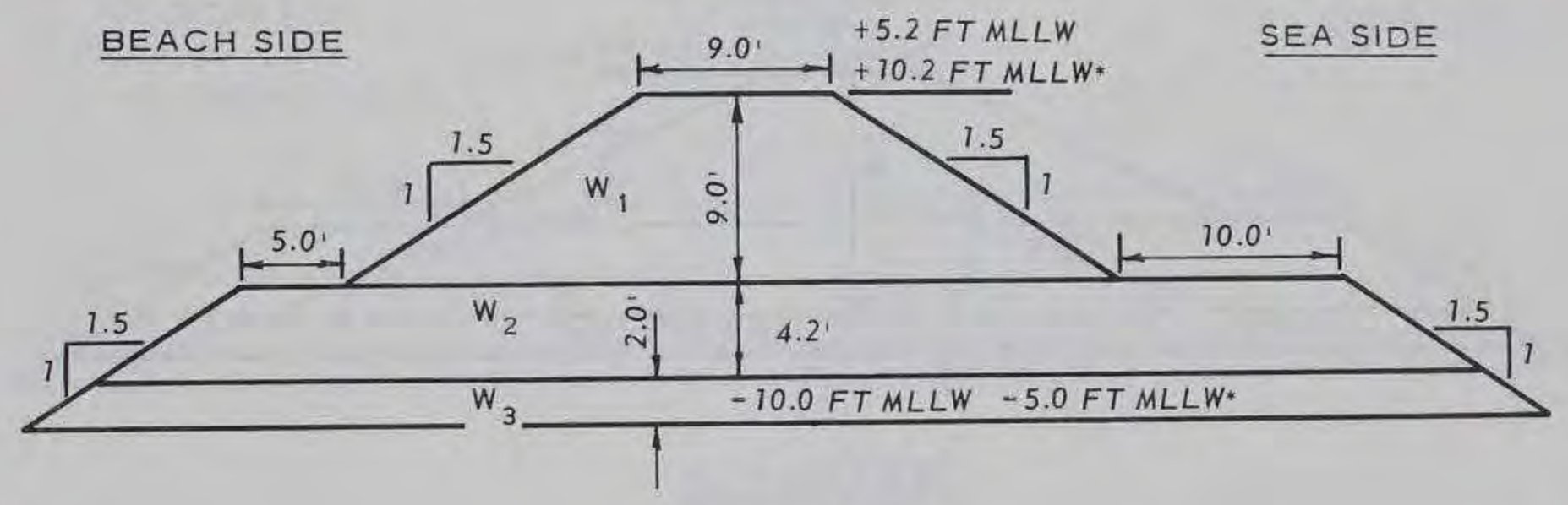
MODEL	PROTOTYPE
W_1 = 1.295-LB ROCK @ 165 PCF	W_1 = 3.0-TON ROCK @ 165 PCF
W_2 = 0.065-LB ROCK @ 165 PCF	W_2 = 0.15-TON ROCK @ 165 PCF
W_3 = 0.0054-LB ROCK @ 165 PCF	W_3 = 25.0-LB ROCK @ 165 PCF

DEEPER WATER LOCATION
PLAN 2

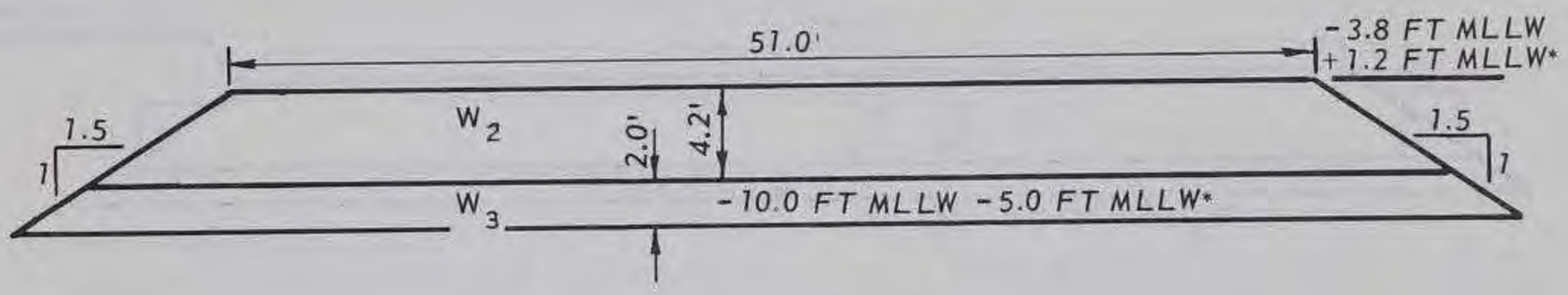
PLATE 2



PLAN VIEW



SECTION E-E'



SECTION F-F'

* INDICATES SHALLOW-WATER LOCATION

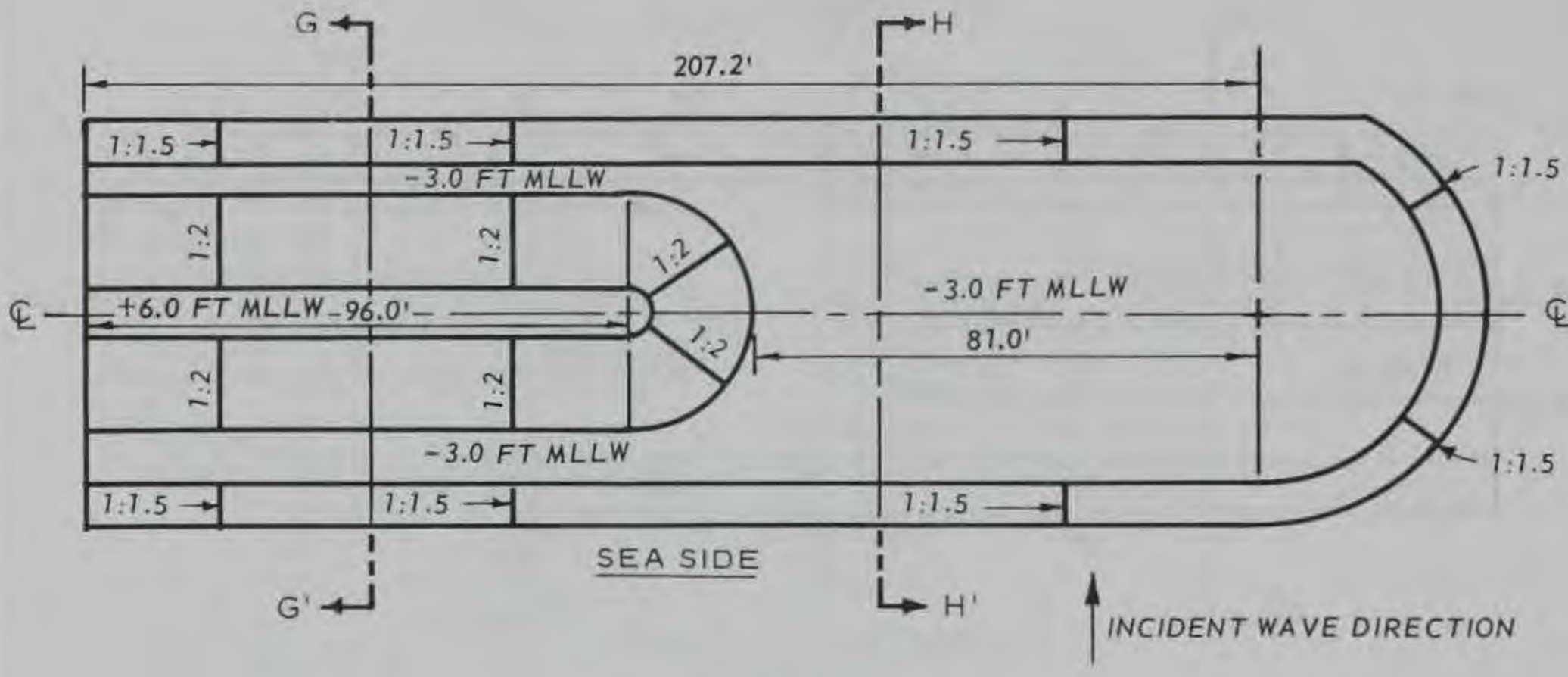
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 = 2.16-LB ROCK @ 165 PCF	W_1 = 5.0-TON ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 0.5-TON ROCK @ 165 PCF
W_3 = 0.0054-LB ROCK @ 165 PCF	W_3 = 25.0-LB ROCK @ 165 PCF

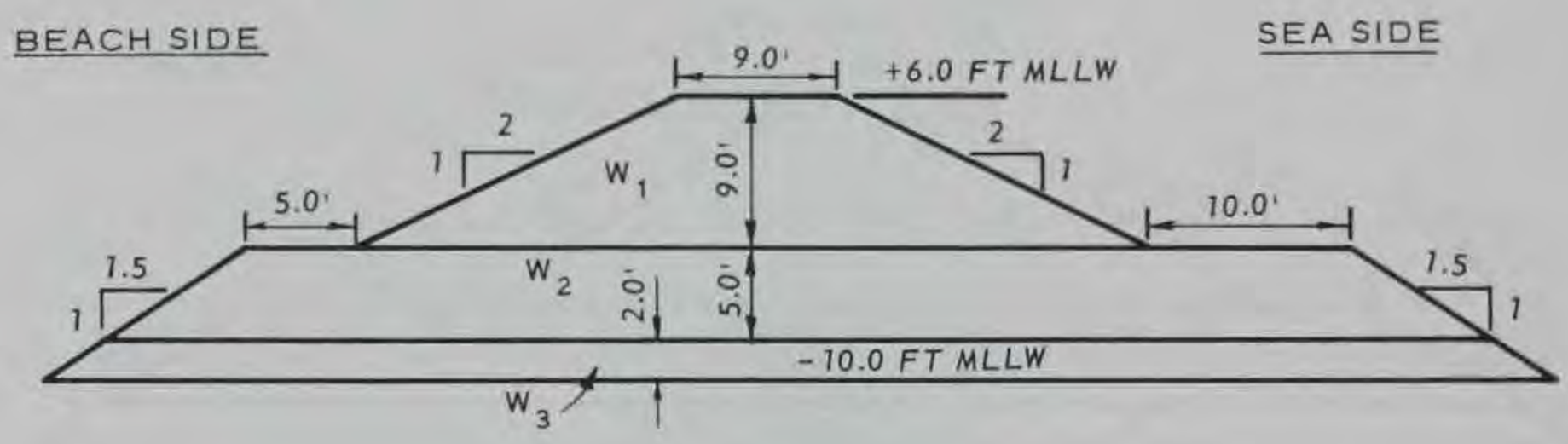
DEEPER WATER LOCATION AND
SHALLOW-WATER LOCATION
PLAN 3

PLATE 3

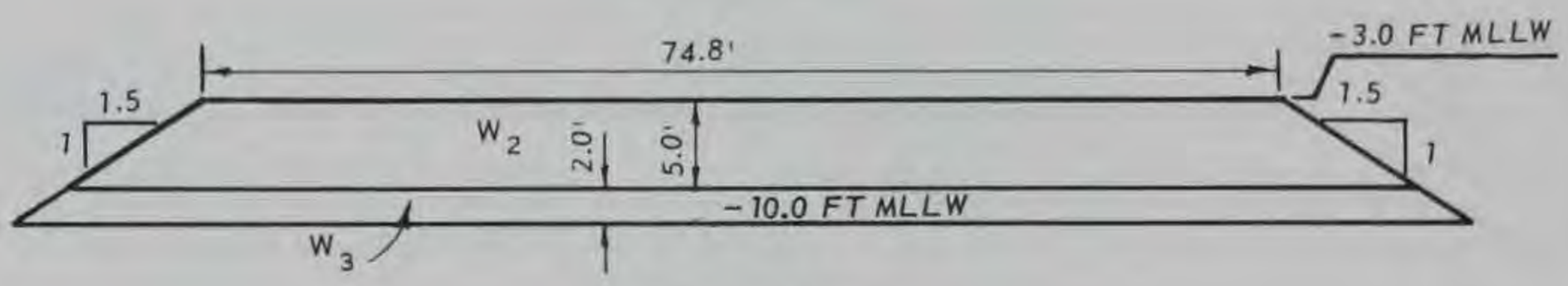
BEACH SIDE



PLAN VIEW



SECTION C–C'



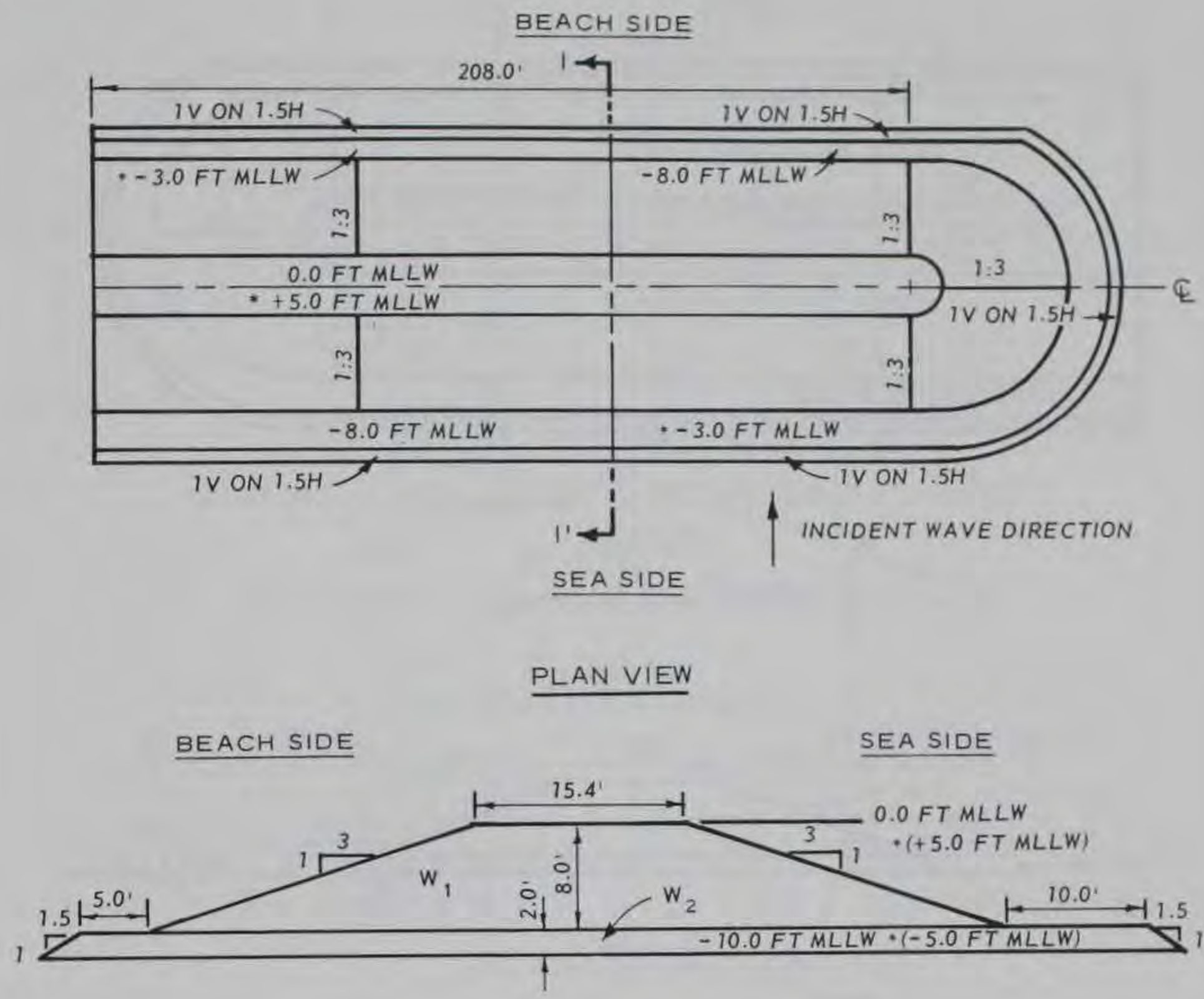
SECTION H–H'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 = 2.16-LB ROCK @ 165 PCF	W_1 = 5.0-TON ROCK @ 165 PCF
W_2 = 0.38-LB ROCK @ 165 PCF	W_2 = 1750.0-LB ROCK @ 165 PCF
W_3 = 0.0054-LB ROCK @ 165 PCF	W_3 = 25.0-LB ROCK @ 165 PCF

DEEPER WATER LOCATION
PLAN 4

PLATE 4



PLAN VIEW

SECTION 1-1'

* INDICATES SHALLOW-WATER LOCATION

MATERIAL CHARACTERISTICS

MODEL

W_1, GRADED % BY WEIGHT

100% ≤ 1.295-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF
10% < 0.001-LB ROCK @ 165 PCF

W_2 = 0.0054-LB ROCK @ 165 PCF

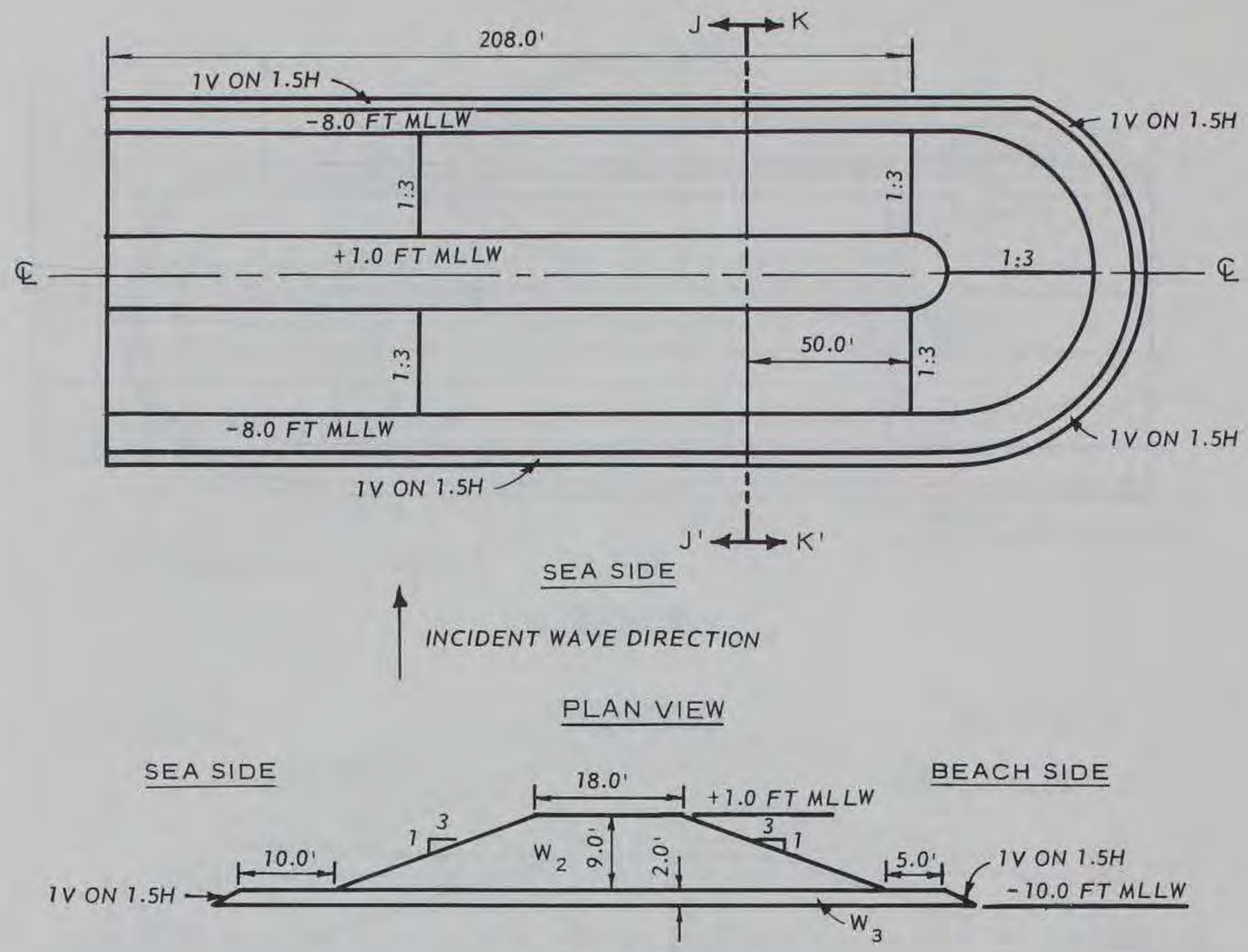
PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 6000-LB ROCK @ 165 PCF
50% < 3000-LB ROCK @ 165 PCF
25% < 2000-LB ROCK @ 165 PCF
10% < 6-LB ROCK @ 165 PCF

W_2 = 25.0-LB ROCK @ 165 PCF

DEEPER WATER LOCATION AND
SHALLOW-WATER LOCATION
PLAN 5

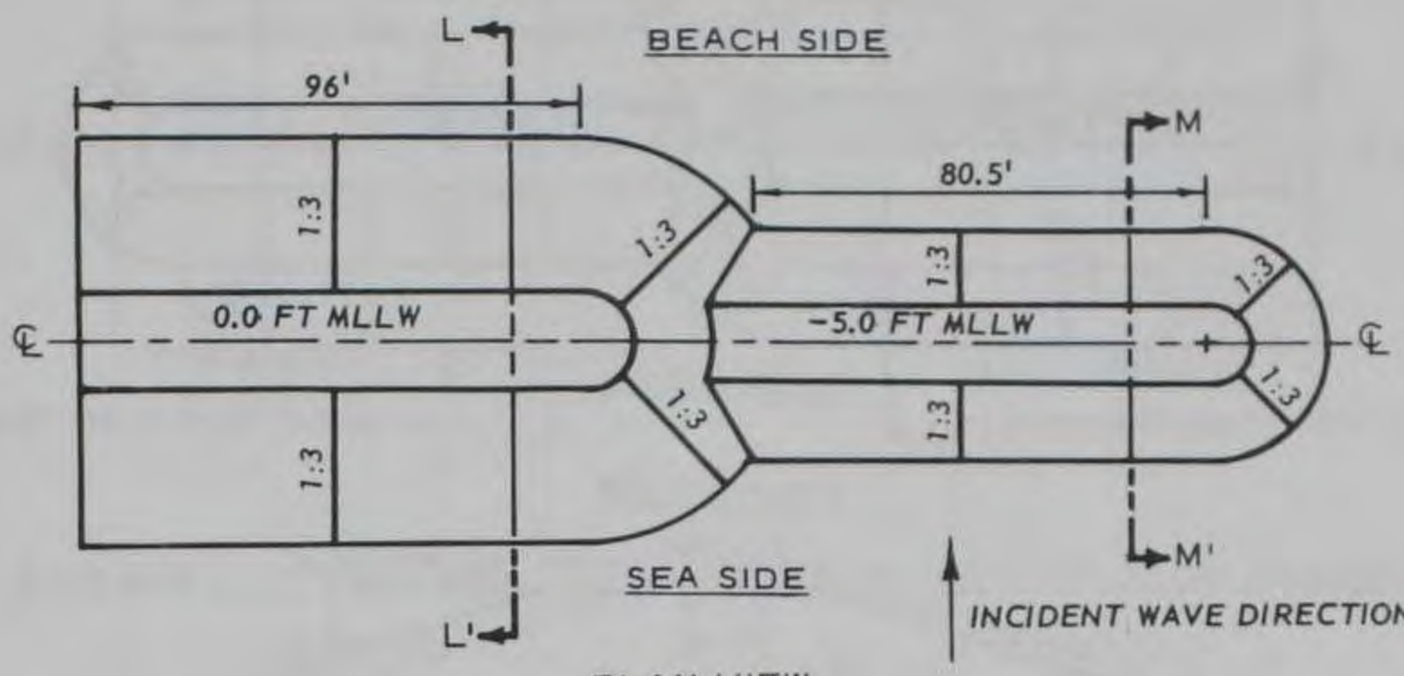


MATERIAL CHARACTERISTICS

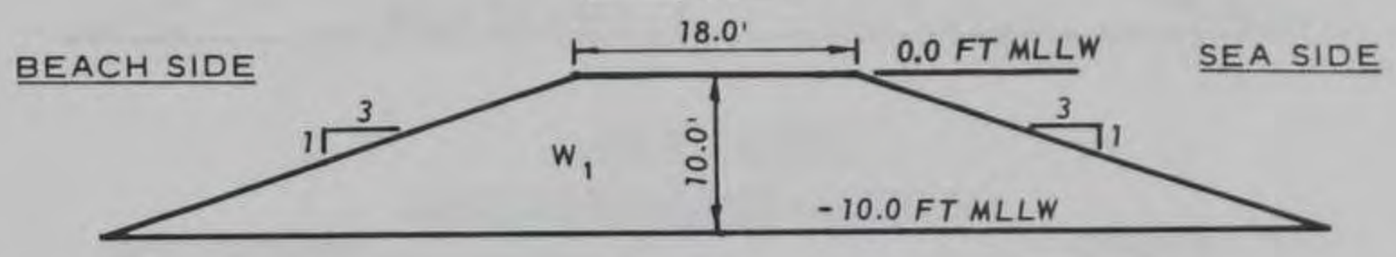
MODEL	PROTOTYPE
W_1 = 2.159-LB ROCK @ 165 PCF	W_1 = 10,000-LB ROCK @ 165 PCF
W_2, GRADED % BY WEIGHT	W_2, GRADED % BY WEIGHT
100% ≤ 2.159-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_3 = 0.0054-LB ROCK @ 165 PCF	W_3 = 25.0-LB ROCK @ 165 PCF

DEEPER WATER LOCATION
PLAN 6

PLATE 6



PLAN VIEW



SECTION L-L'

MATERIAL CHARACTERISTICS

MODEL

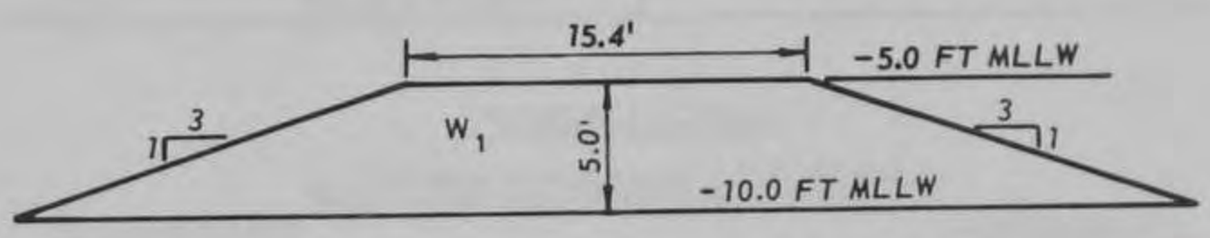
W_1, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF



SECTION M-M'

MATERIAL CHARACTERISTICS

MODEL

W_1, GRADED % BY WEIGHT

100% ≤ 1.295-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF
10% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

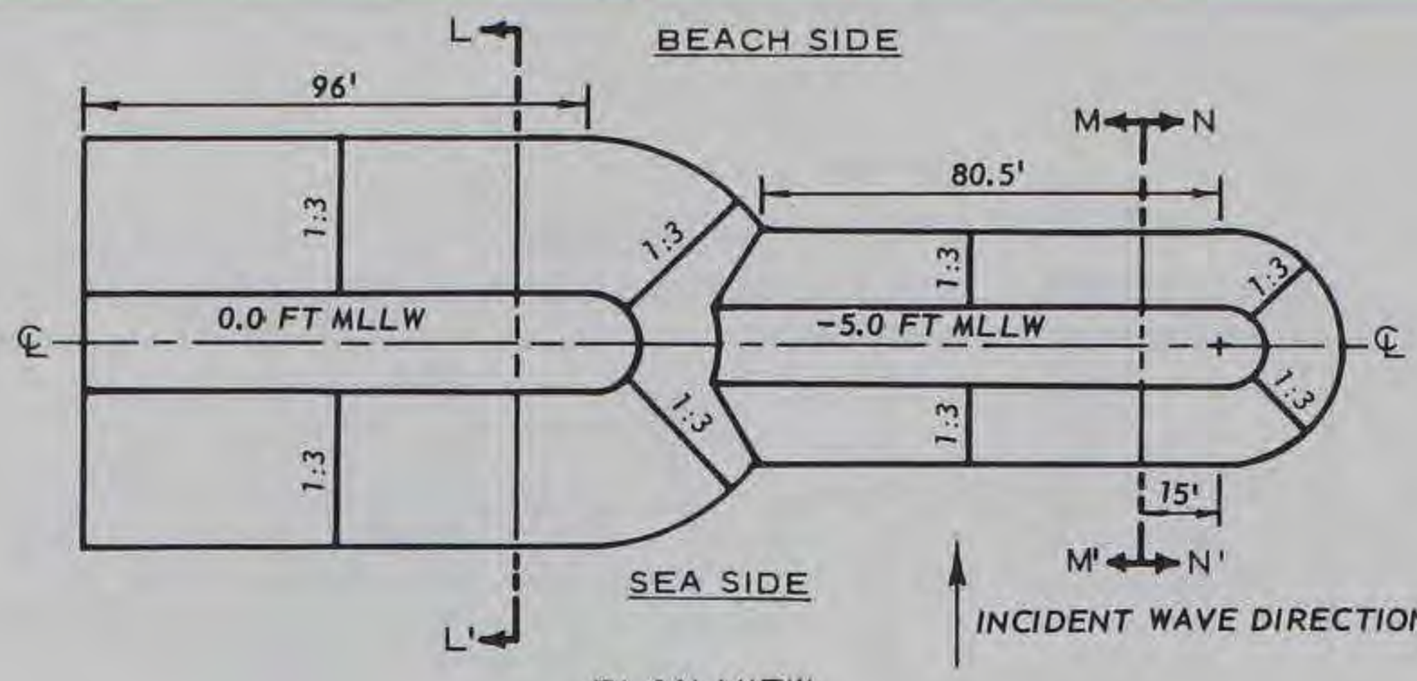
W_1, GRADED % BY WEIGHT

100% ≤ 6,000-LB ROCK @ 165 PCF
50% < 3,000-LB ROCK @ 165 PCF
25% < 2,000-LB ROCK @ 165 PCF
10% < 6-LB ROCK @ 165 PCF

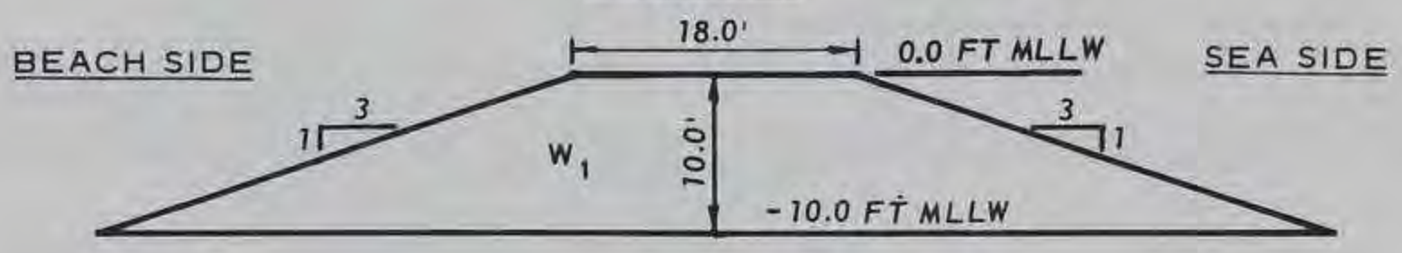
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 7

PLATE 7



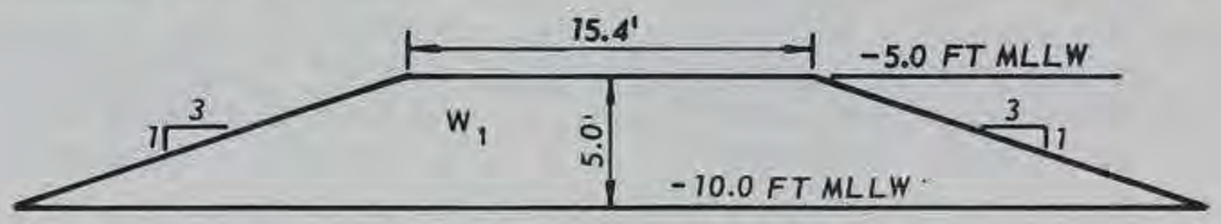
PLAN VIEW



SECTION L-L'

MATERIAL CHARACTERISTICS

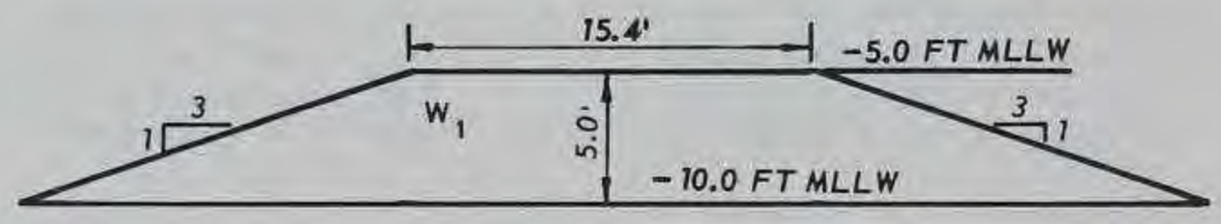
MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF



SECTION M-M'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 1.295-LB ROCK @ 165 PCF	100% ≤ 6,000-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF	50% < 3,000-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF	25% < 2,000-LB ROCK @ 165 PCF
10% < 0.001-LB ROCK @ 165 PCF	10% < 6-LB ROCK @ 165 PCF



SECTION N-N'

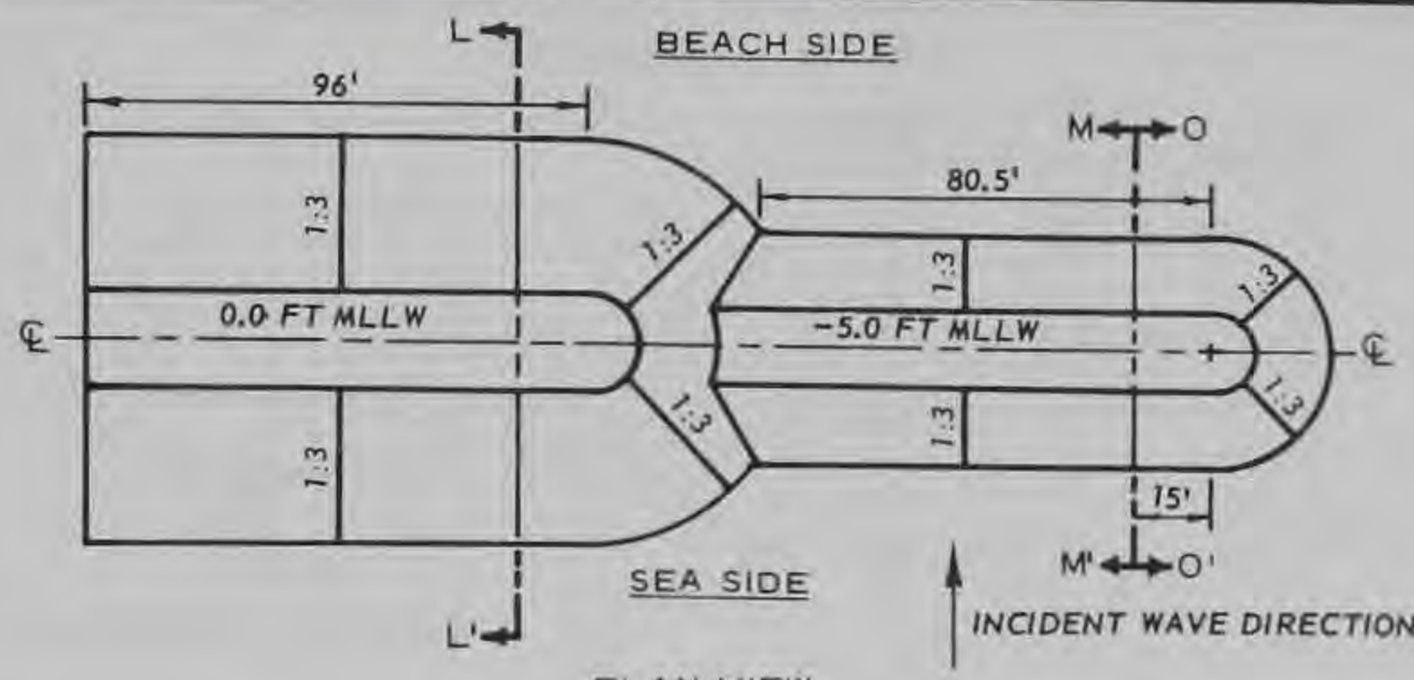
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.296-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF

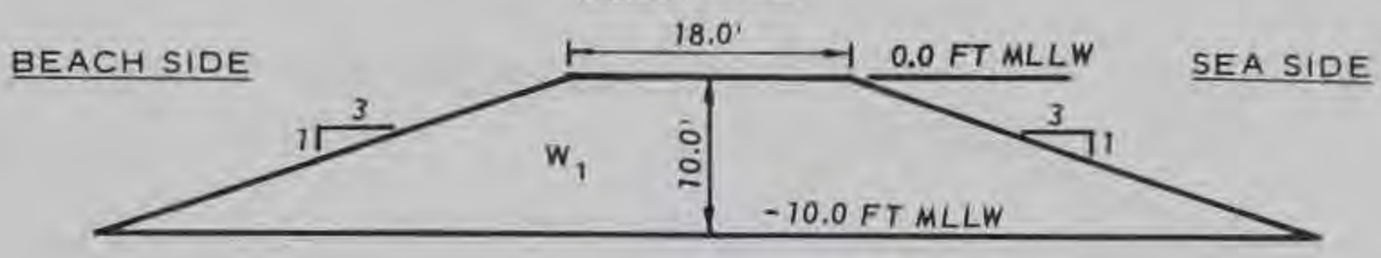
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 7A

PLATE 8



PLAN VIEW



SECTION L-L'

MATERIAL CHARACTERISTICS

MODEL

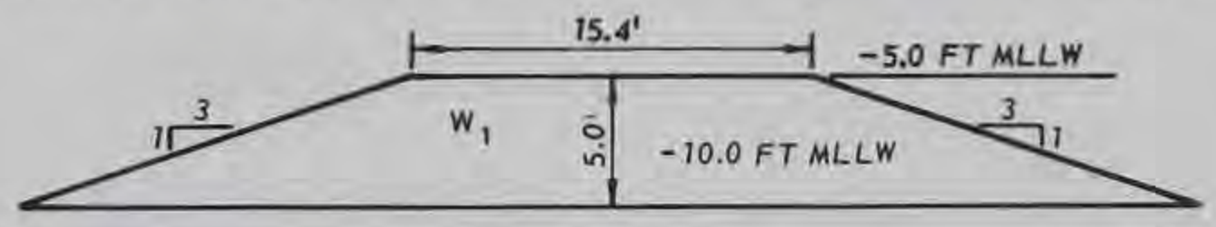
W_1, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF



SECTION M-M'

MATERIAL CHARACTERISTICS

MODEL

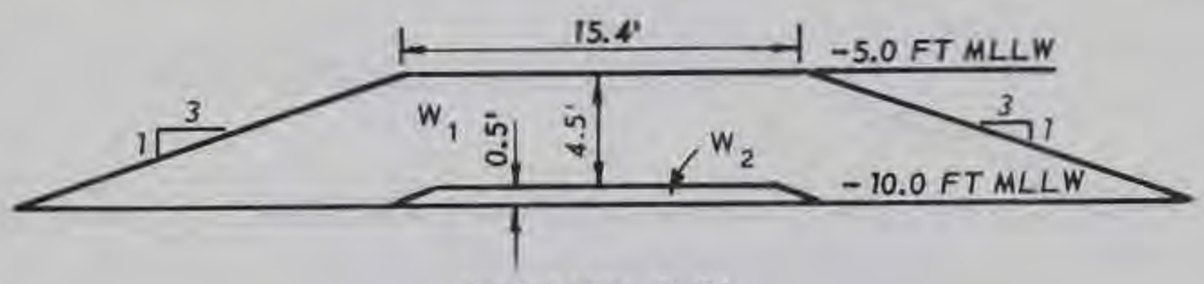
W_1, GRADED % BY WEIGHT

100% ≤ 1.295-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF
10% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 6,000-LB ROCK @ 165 PCF
50% < 3,000-LB ROCK @ 165 PCF
25% < 2,000-LB ROCK @ 165 PCF
10% < 6-LB ROCK @ 165 PCF



SECTION O-O'

MATERIAL CHARACTERISTICS

MODEL

W_1 = 2.158-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

100% ≤ 1.295-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF
10% < 0.001-LB ROCK @ 165 PCF

NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

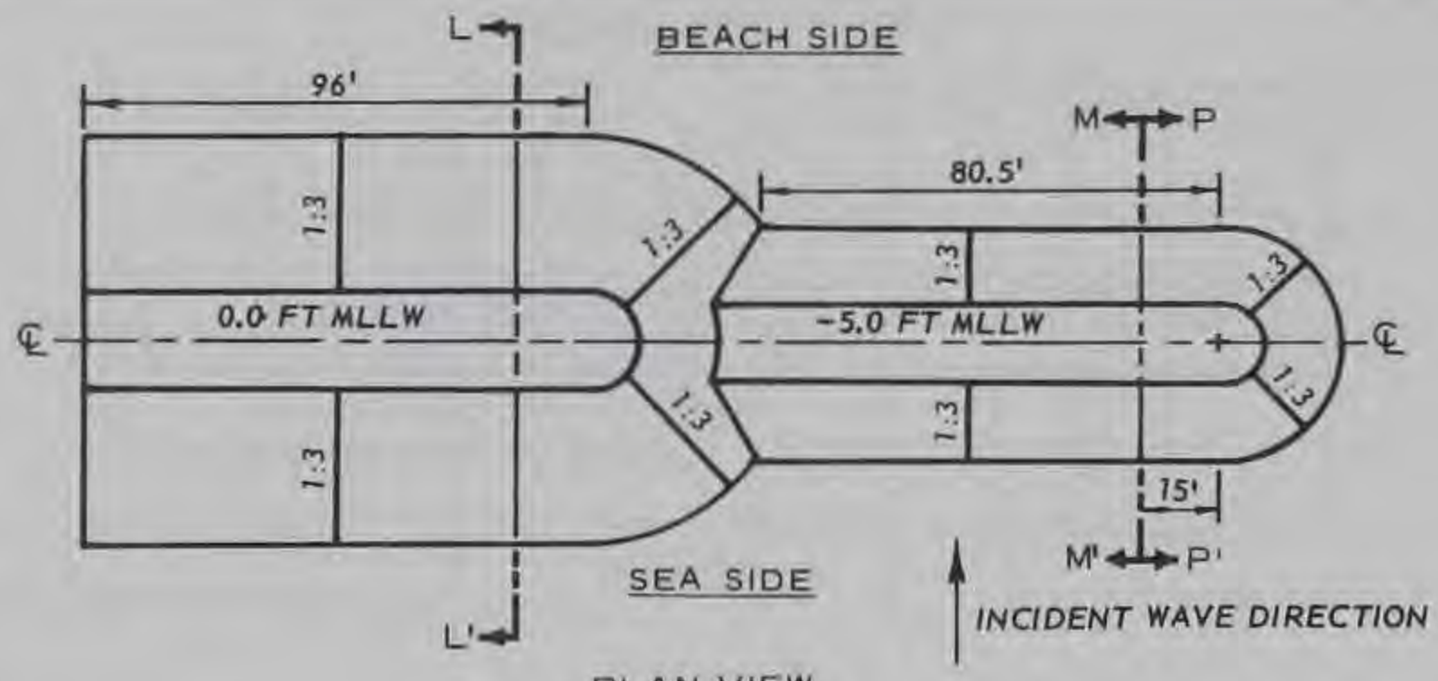
PROTOTYPE

W_1 = 10,000-LB ROCK @ 165 PCF

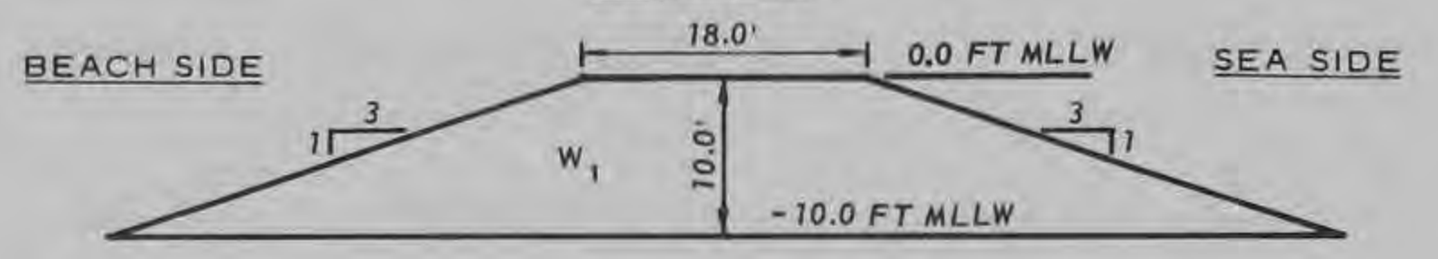
W_2, GRADED % BY WEIGHT

100% ≤ 6,000-LB ROCK @ 165 PCF
50% < 3,000-LB ROCK @ 165 PCF
25% < 2,000-LB ROCK @ 165 PCF
10% < 6-LB ROCK @ 165 PCF

DEEPER WATER LOCATION
PLAN 7B



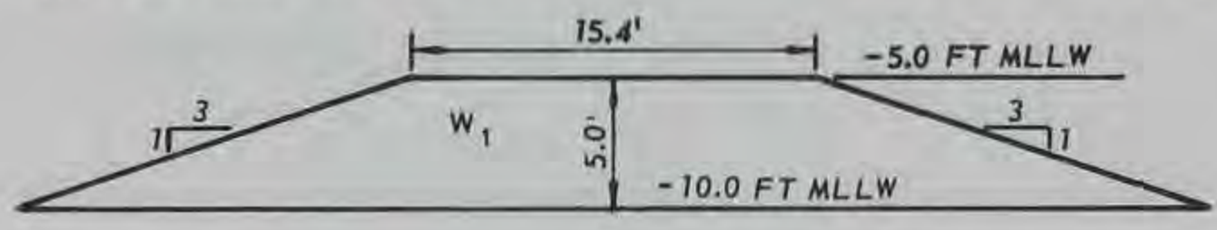
PLAN VIEW



SECTION L-L'

MATERIAL CHARACTERISTICS

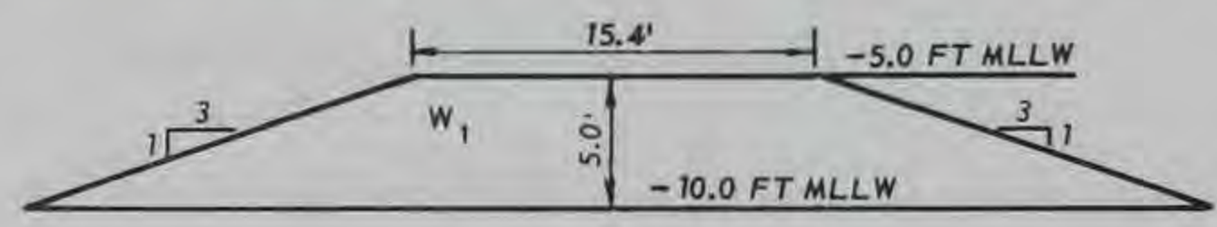
MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF



SECTION M-M'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 1.295-LB ROCK @ 165 PCF	100% ≤ 6,000-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF	50% < 3,000-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF	25% < 2,000-LB ROCK @ 165 PCF
10% < 0.001-LB ROCK @ 165 PCF	10% < 6-LB ROCK @ 165 PCF



SECTION P-P'

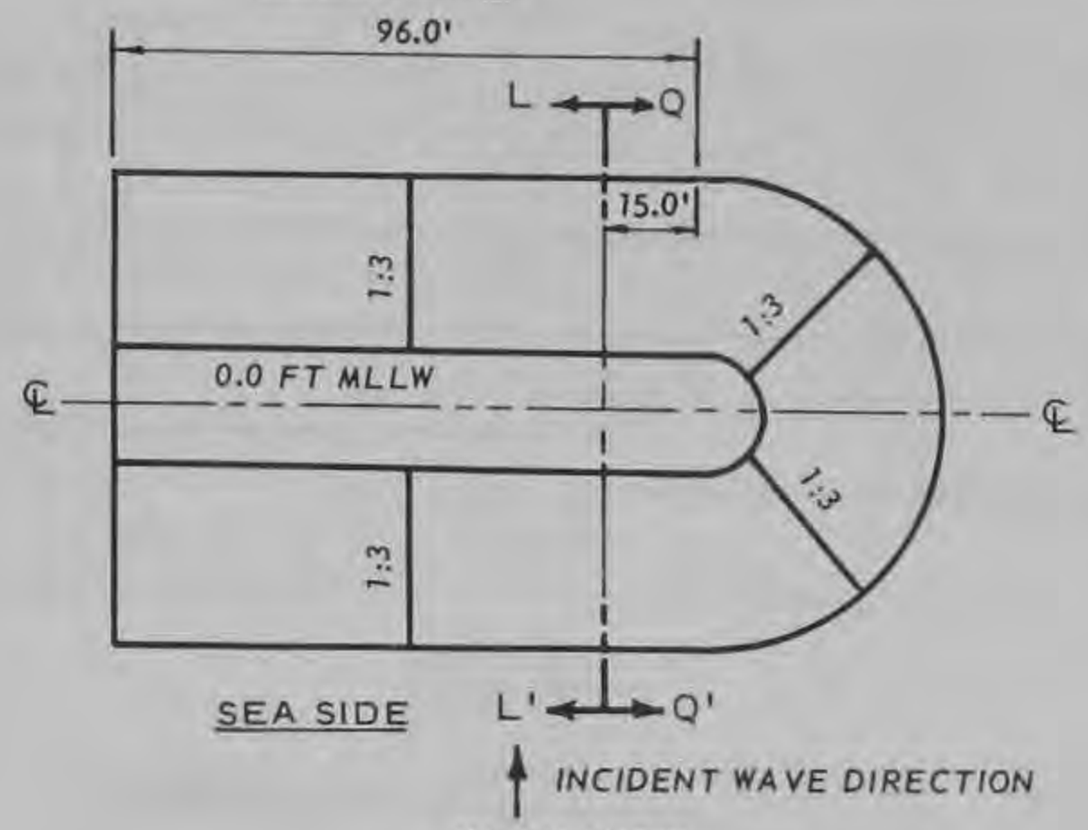
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 = 3.023-LB ROCK @ 165 PCF	W_1 = 14,000-LB ROCK @ 165 PCF

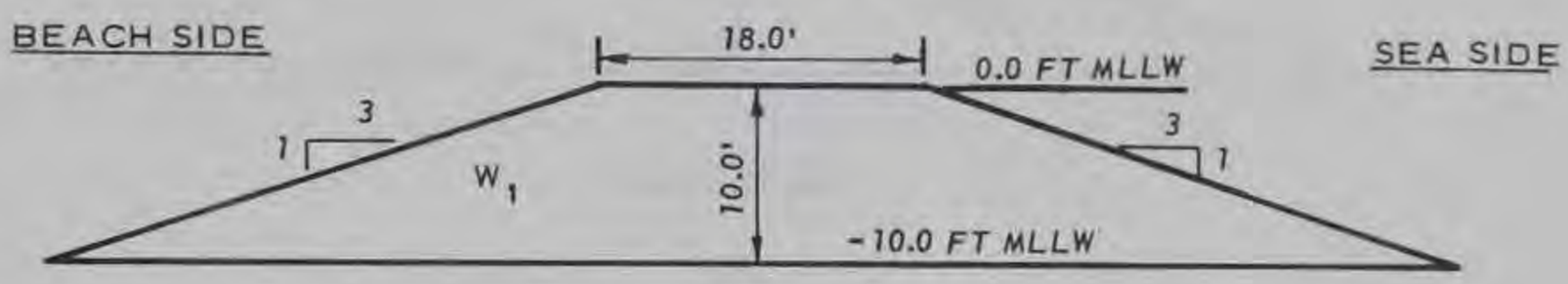
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 7C

PLATE 10



PLAN VIEW



SECTION L-L'

MATERIAL CHARACTERISTICS

MODEL

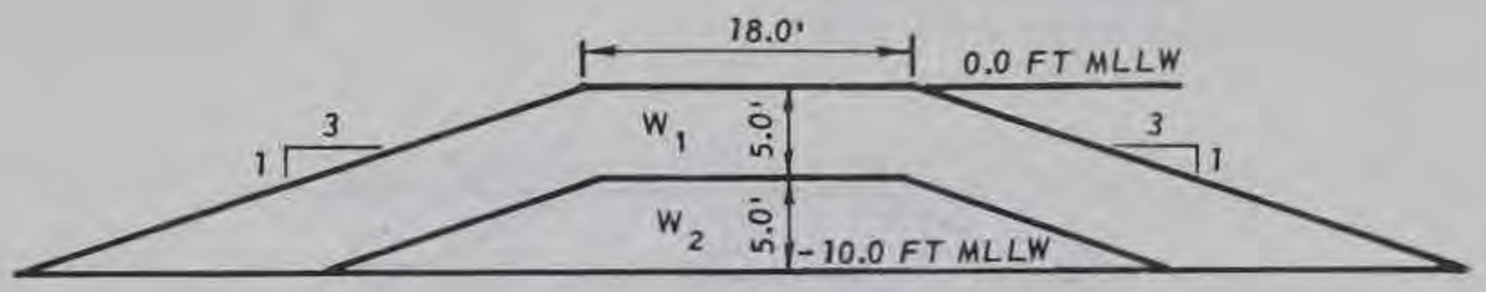
W_1, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF



SECTION Q-Q'

MATERIAL CHARACTERISTICS

MODEL

W_1 = 3.023-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

PROTOTYPE

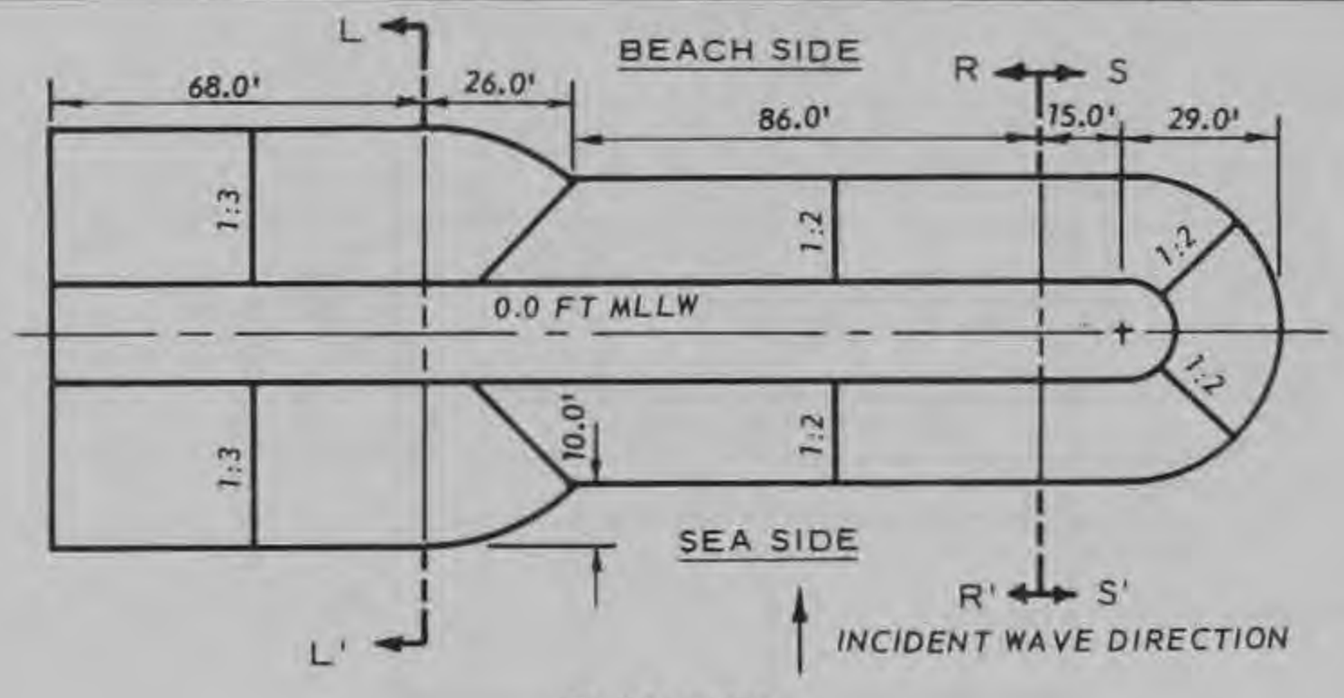
W_1 = 14,000-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

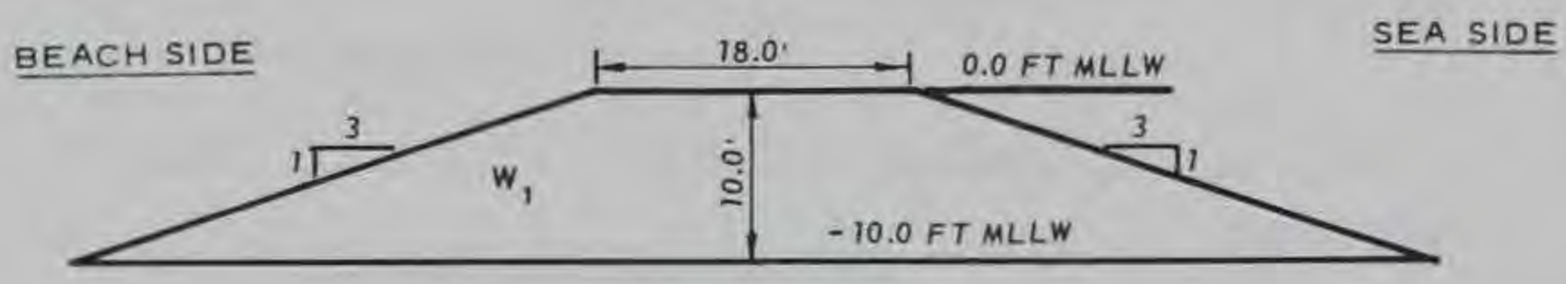
100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF

DEEPER WATER LOCATION
PLAN 8

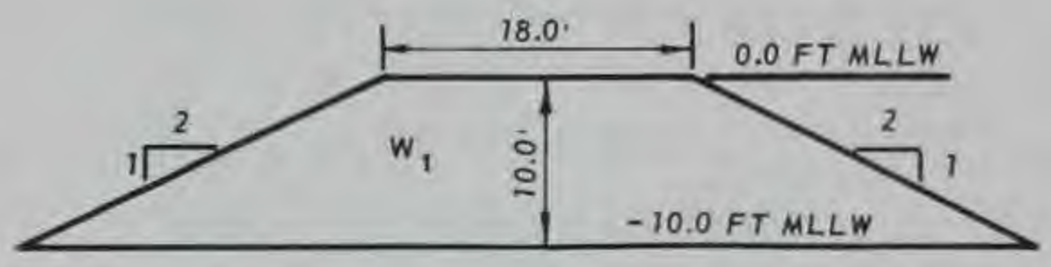
PLATE 11



PLAN VIEW



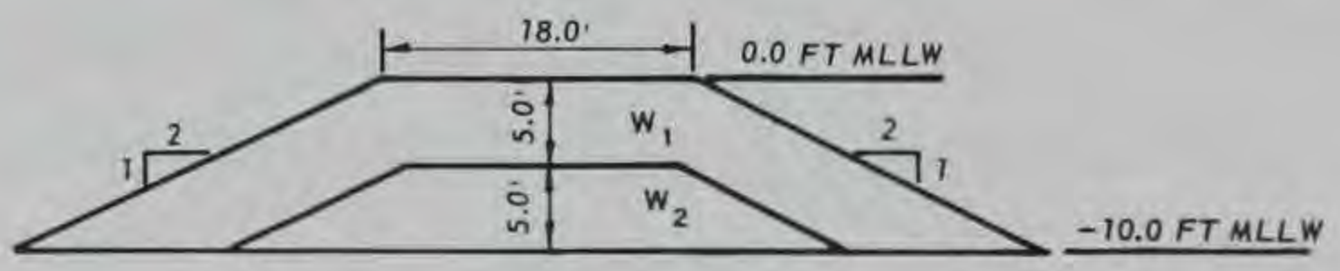
SECTION L-L'



SECTION R-R'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF



SECTION S-S'

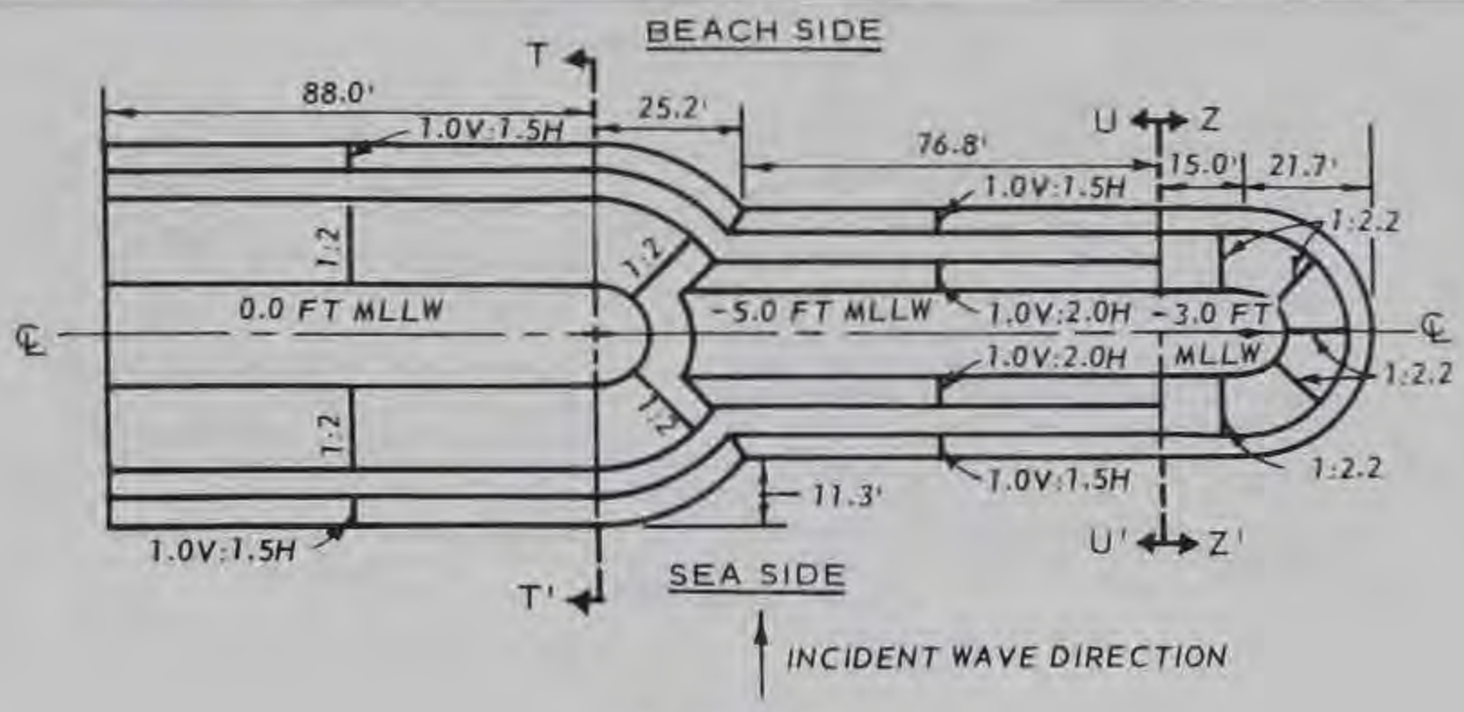
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 = 3.023-LB ROCK @ 165 PCF	W_1 = 14,000-LB ROCK @ 165 PCF
W_2, GRADED % BY WEIGHT	W_2, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF

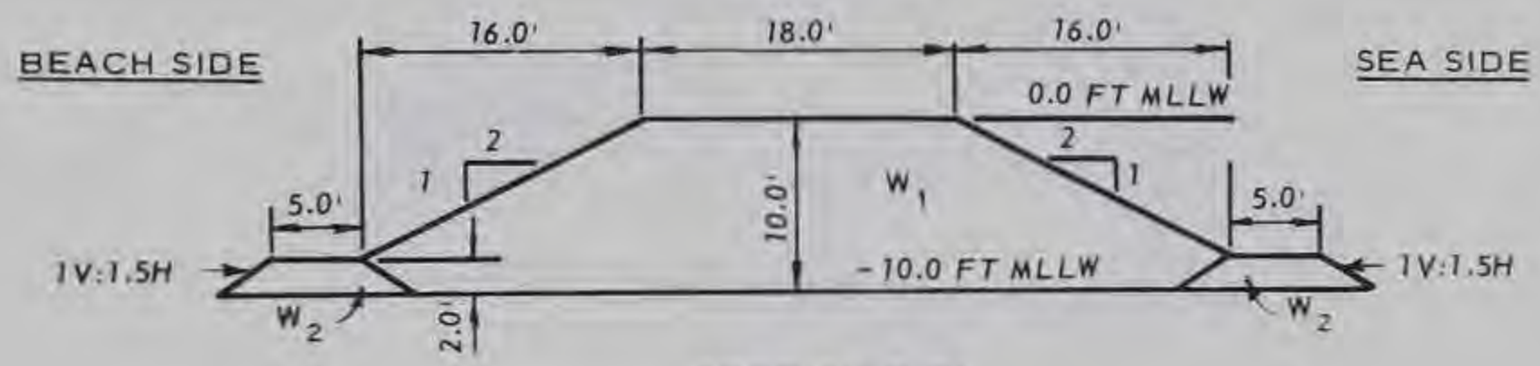
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 9

PLATE 12



PLAN VIEW



SECTION T-T'

MATERIAL CHARACTERISTICS

MODEL

W_1, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

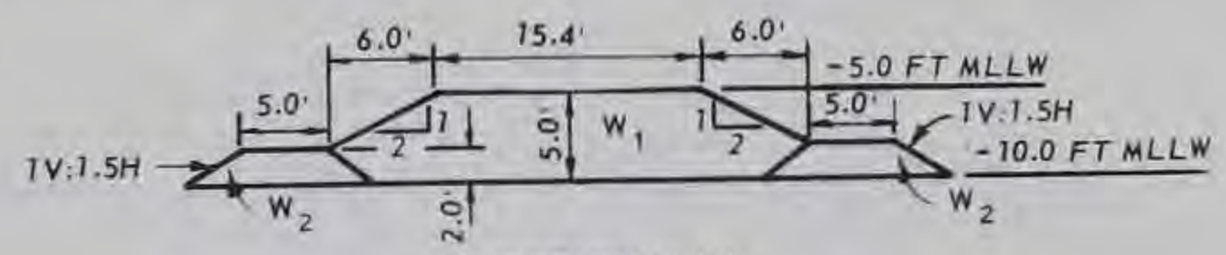
W_2 = 0.0054-LB ROCK @ 165 PCF

PROTOTYPE

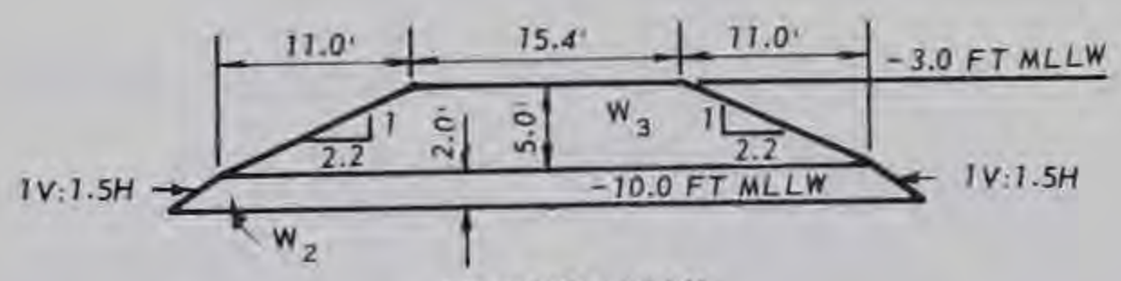
W_1, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF

W_2 = 25.0-LB ROCK @ 165 PCF



SECTION U-U'



SECTION V-V'

MATERIAL CHARACTERISTICS

MODEL

W_1, GRADED % BY WEIGHT

100% ≤ 1.295-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

W_2 = 0.0054-LB ROCK @ 165 PCF

W_3 = 3.023-LB ROCK @ 165 PCF

PROTOTYPE

W_1 GRADED % BY WEIGHT

100% ≤ 6,000-LB ROCK @ 165 PCF
50% < 3,000-LB ROCK @ 165 PCF
25% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF

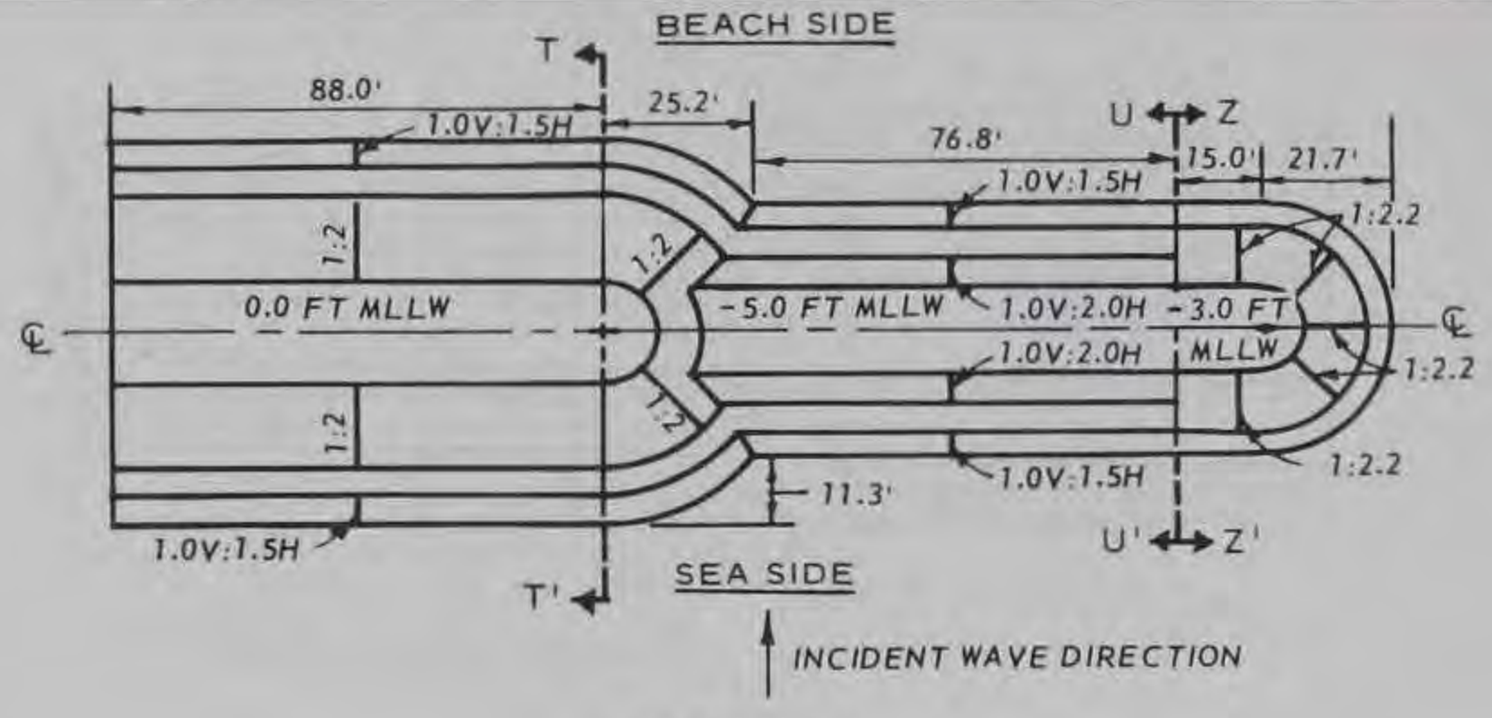
W_2 = 25.0-LB ROCK @ 165 PCF

W_3 = 14,000-LB ROCK @ 165 PCF

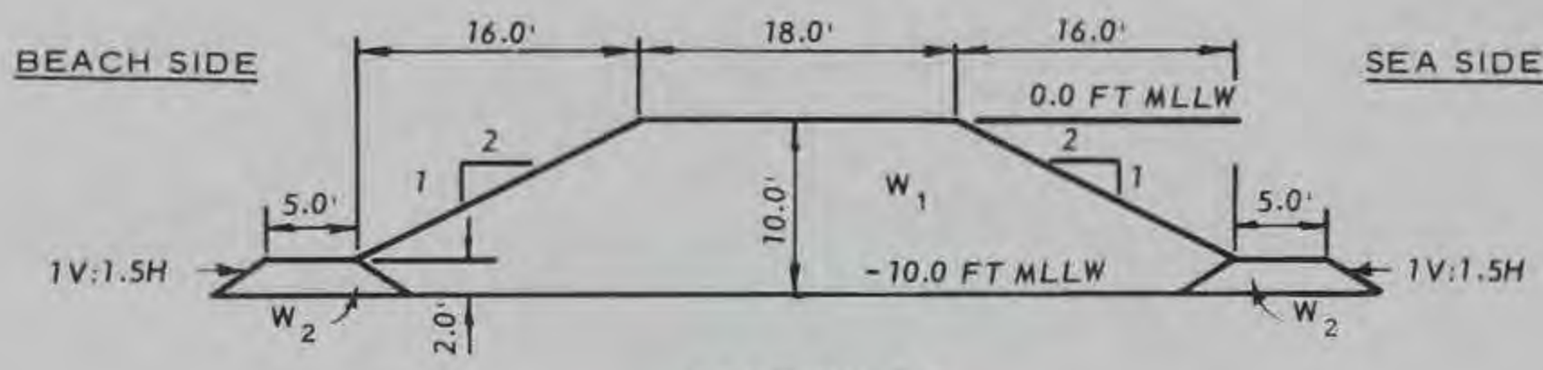
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 10

PLATE 13



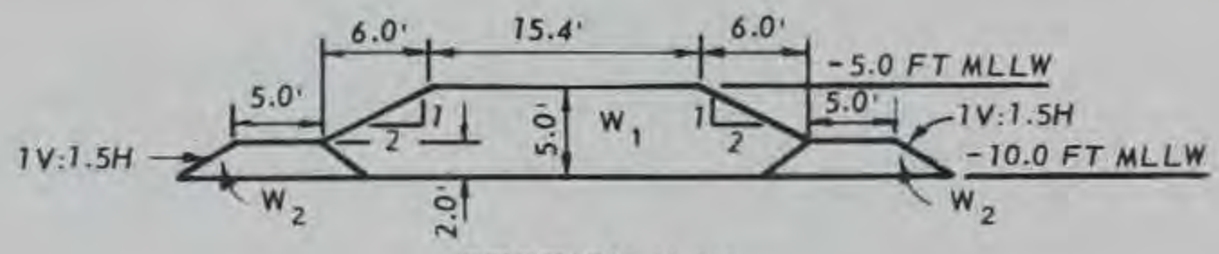
PLAN VIEW



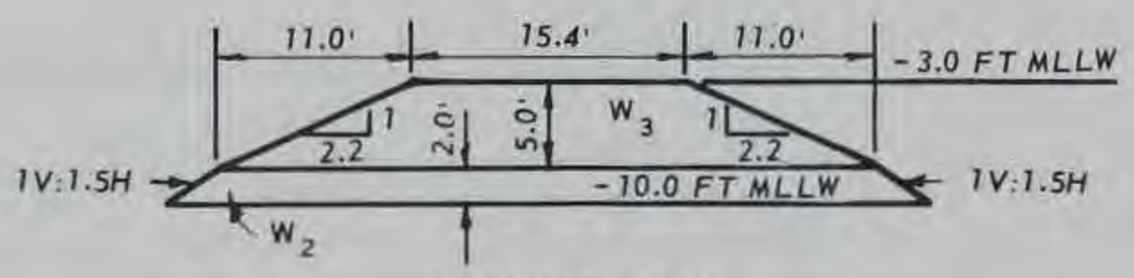
SECTION T-T'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.0054-LB ROCK @ 165 PCF	W_2 = 25.0-LB ROCK @ 165 PCF



SECTION U-U'



SECTION Z-Z'

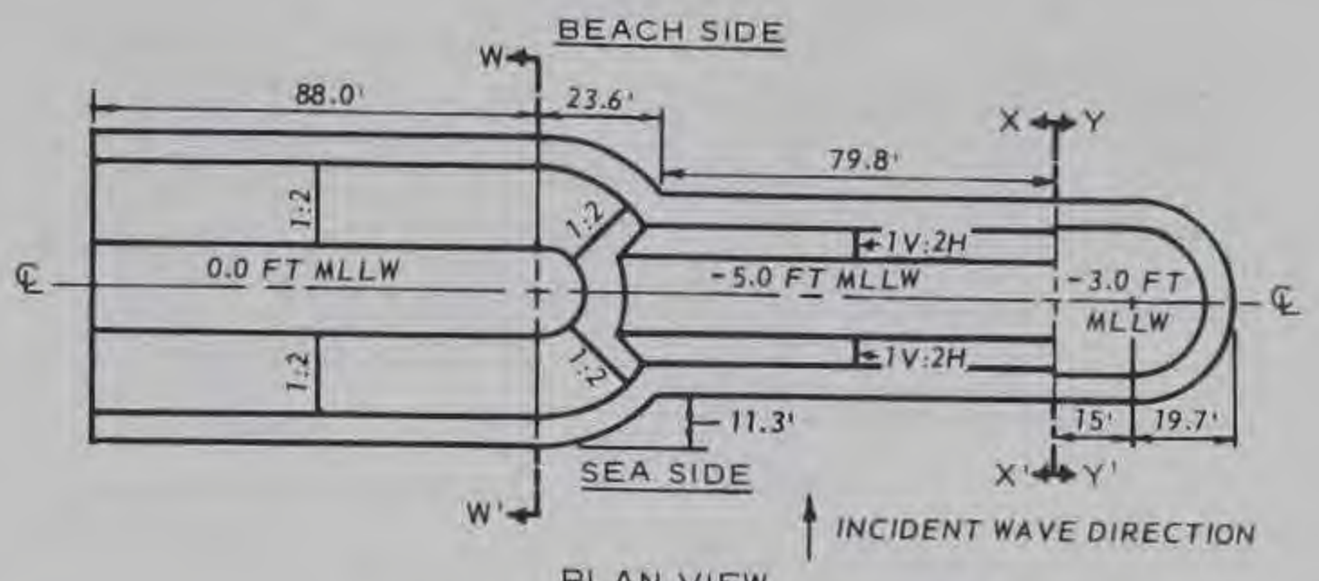
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 1.295-LB ROCK @ 165 PCF	100% ≤ 6,000-LB ROCK @ 165 PCF
50% < 0.648-LB ROCK @ 165 PCF	50% < 3,000-LB ROCK @ 165 PCF
25% < 0.432-LB ROCK @ 165 PCF	25% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF
W_3 = 3.023-LB ROCK @ 165 PCF	W_3 = 14,000-LB ROCK @ 165 PCF

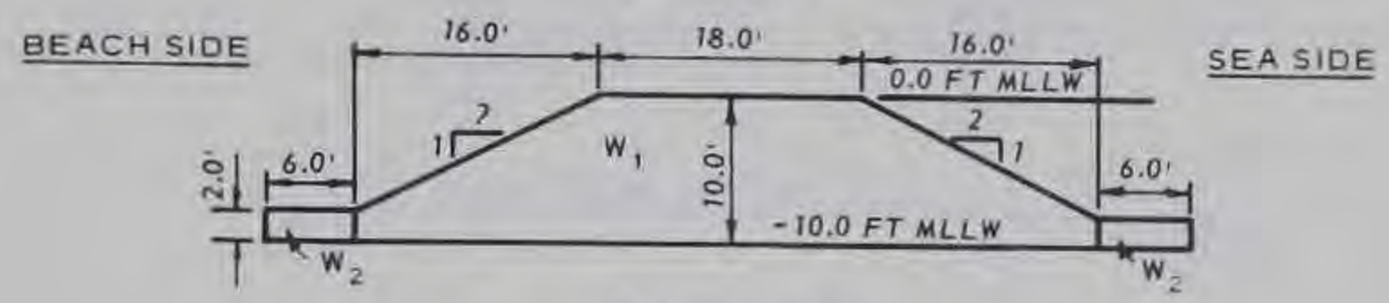
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 10A

PLATE 14



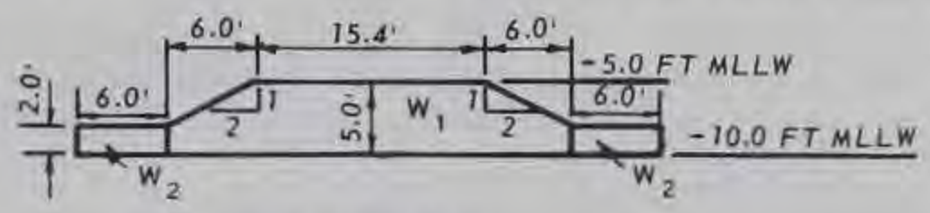
PLAN VIEW



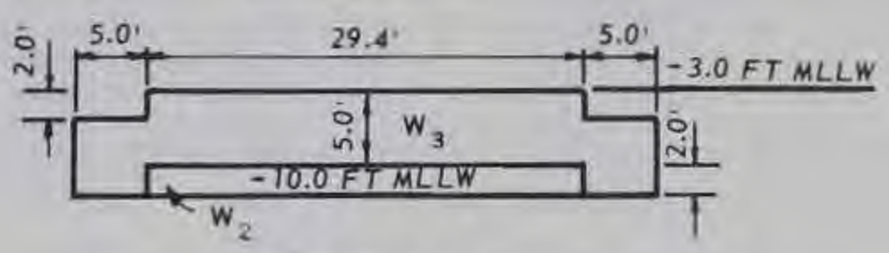
SECTION W-W'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF



SECTION X-X'



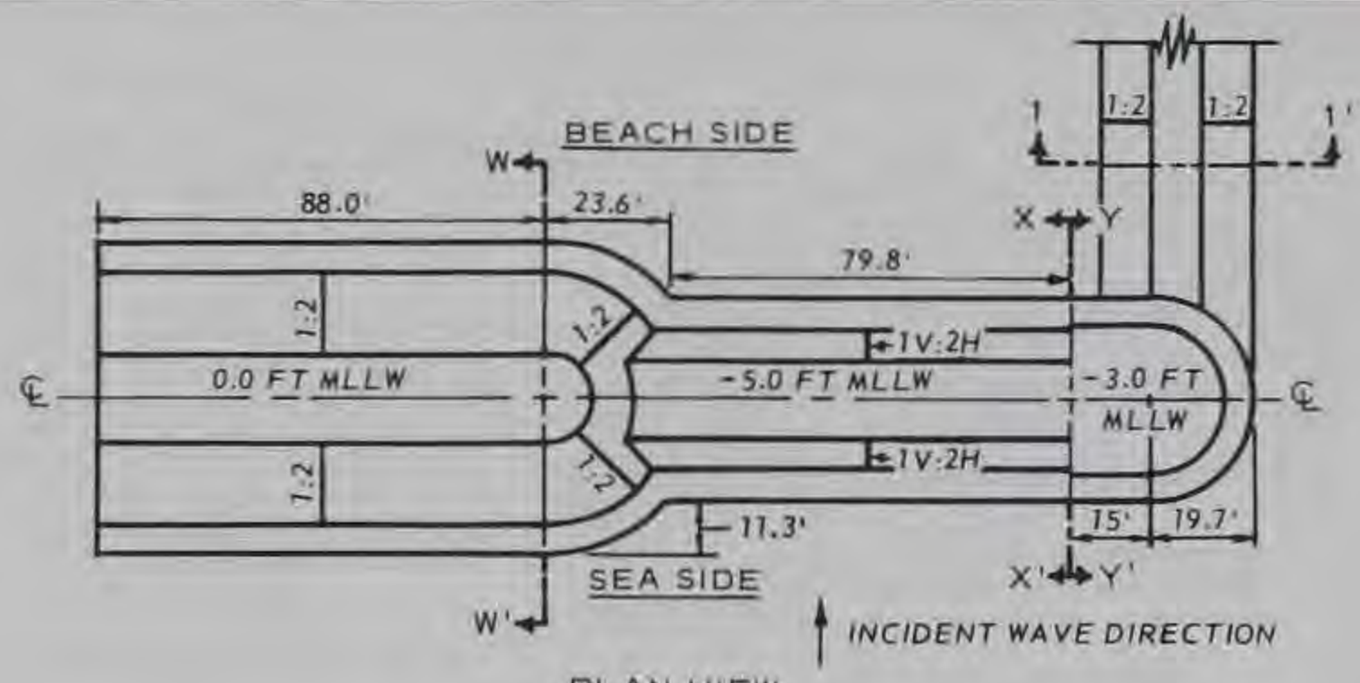
SECTION Y-Y'

MATERIAL CHARACTERISTICS

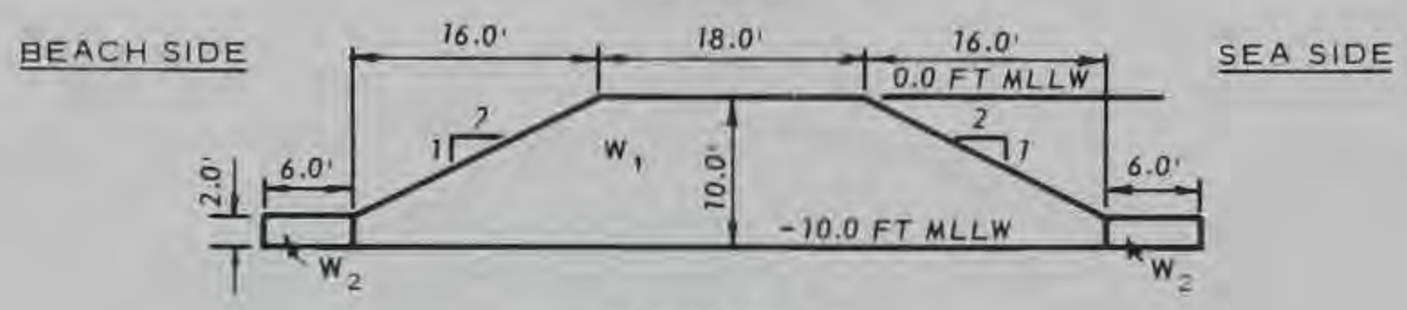
MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF
W_3 = 3.023-LB ROCK @ 165 PCF	W_3 = 14,000-LB ROCK @ 165 PCF

NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 11



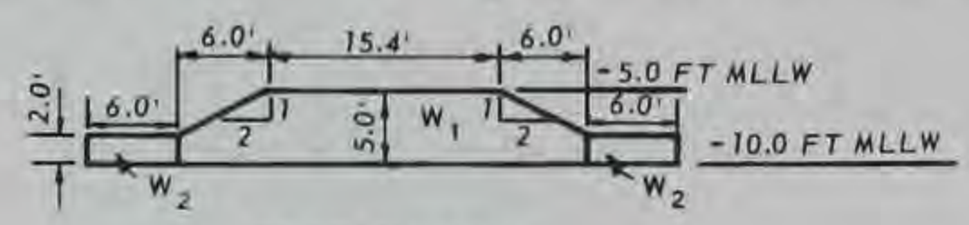
PLAN VIEW



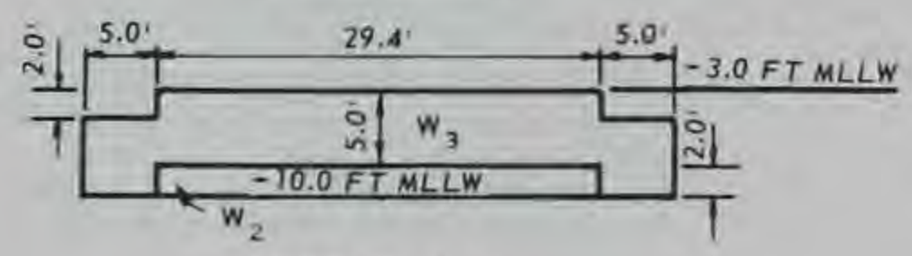
SECTION W-W'

MATERIAL CHARACTERISTICS

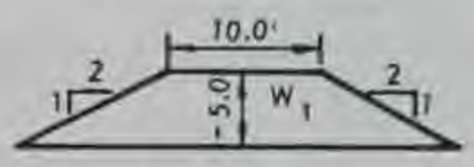
MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF



SECTION X-X'



SECTION Y-Y'



SECTION 1-1'

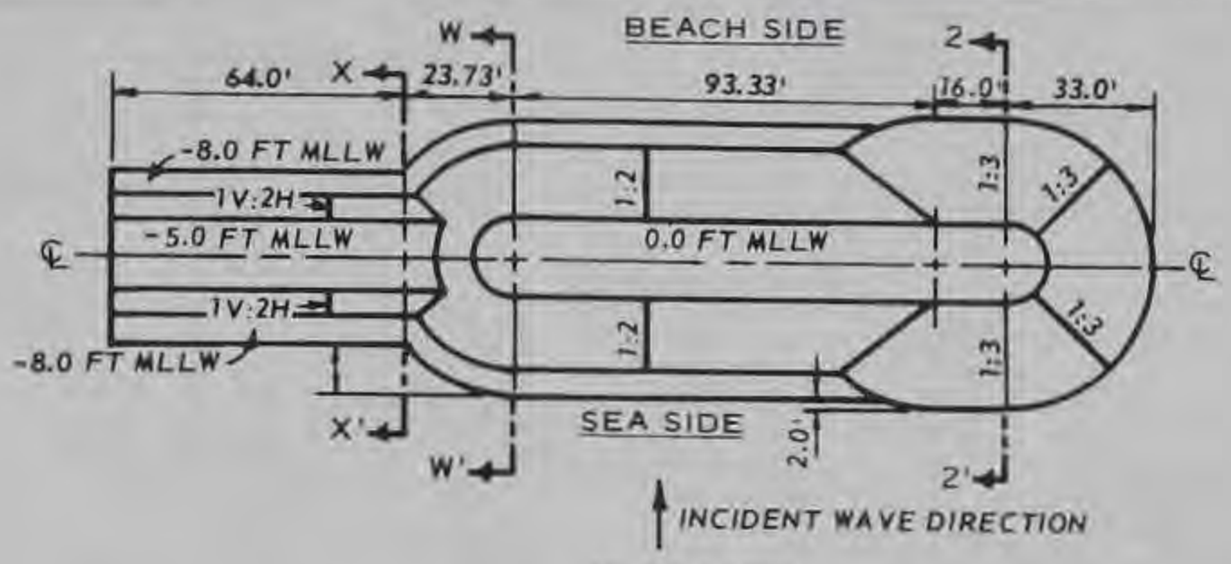
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF
W_3 = 3.023-LB ROCK @ 165 PCF	W_3 = 14,000-LB ROCK @ 165 PCF

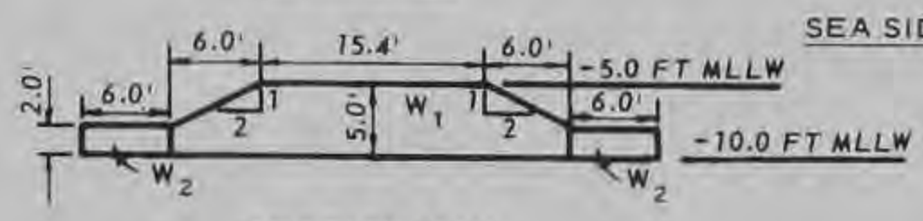
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 11A

PLATE 16



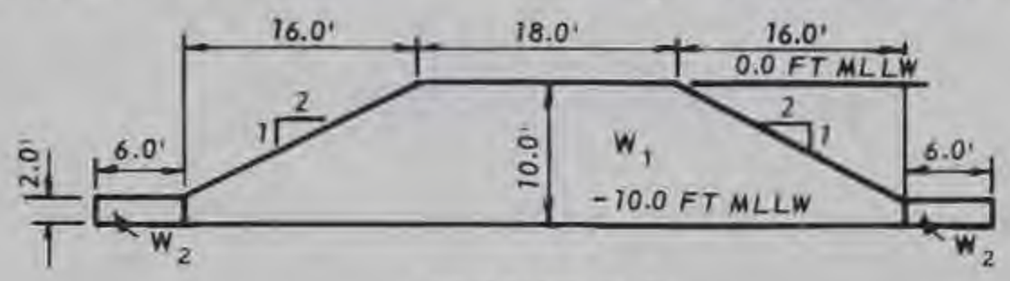
PLAN VIEW



SECTION X-X'

MATERIAL CHARACTERISTICS

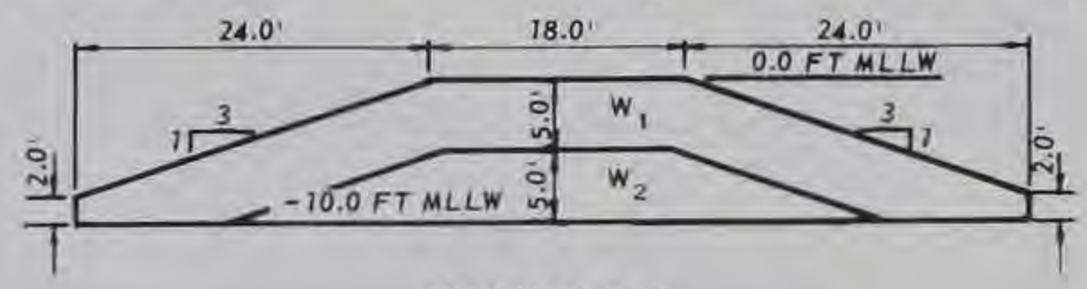
MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF



SECTION W-W'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF

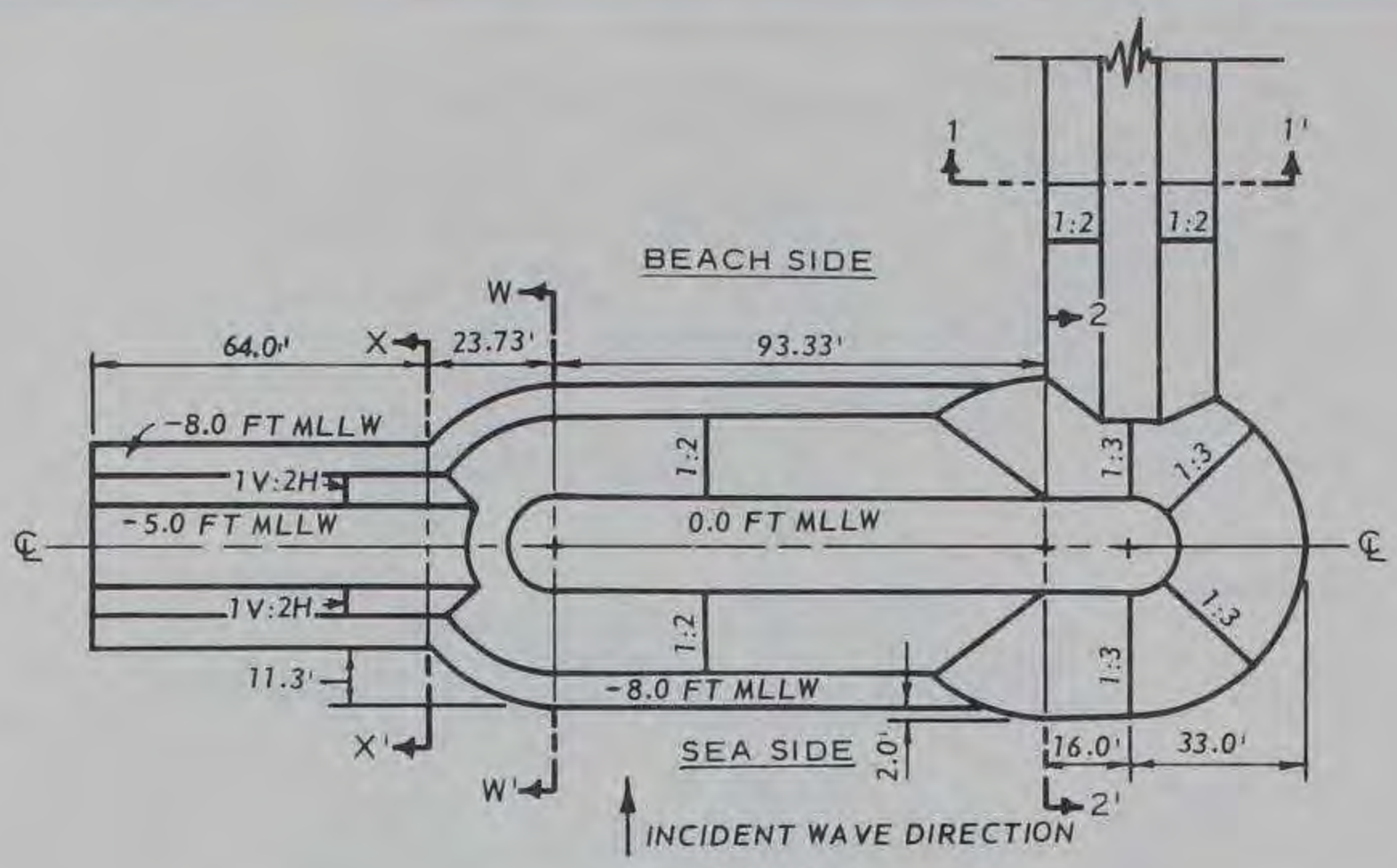


SECTION 2-2'

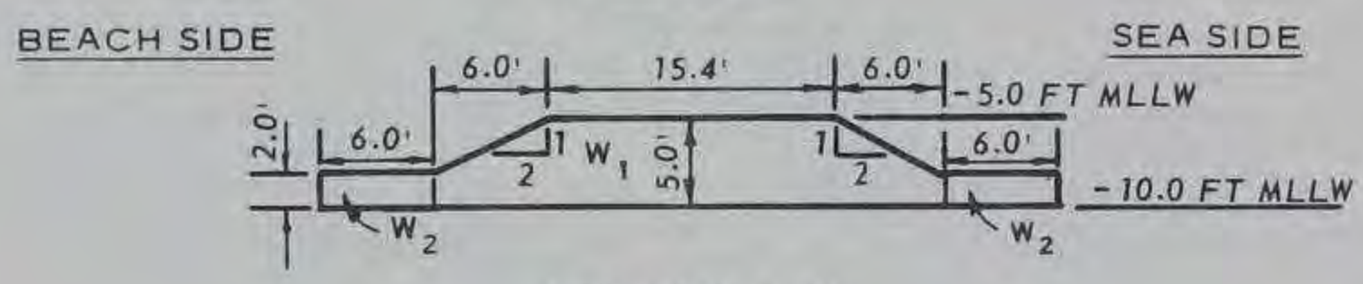
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 = 3.023-LB ROCK @ 165 PCF	W_1 = 14,000-LB ROCK @ 165 PCF
W_2, GRADED % BY WEIGHT	W_2, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.	

DEEPER WATER LOCATION
PLAN 12



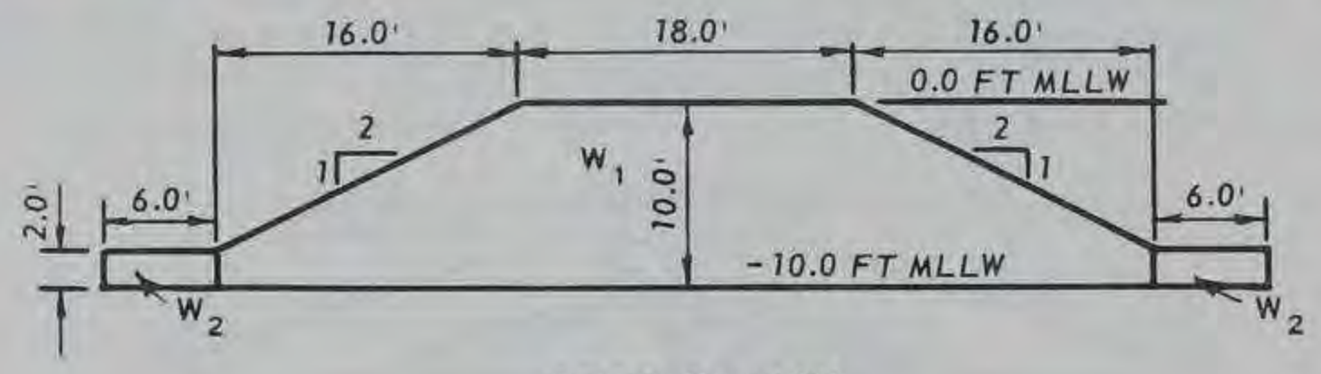
PLAN VIEW



SECTION X-X'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF
W_3 = 3.023-LB ROCK @ 165 PCF	W_3 = 14,000-LB ROCK @ 165 PCF



SECTION W-W'

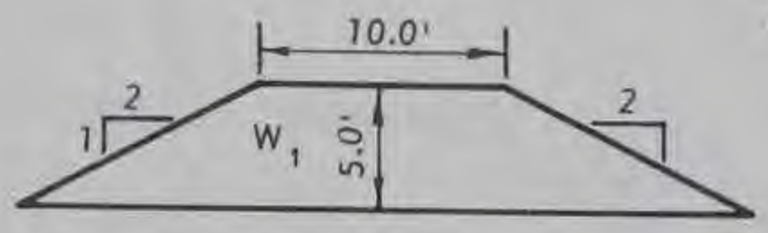
MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF

NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12A

PLATE 18



SECTION 1-1'

MATERIAL CHARACTERISTICS

MODEL

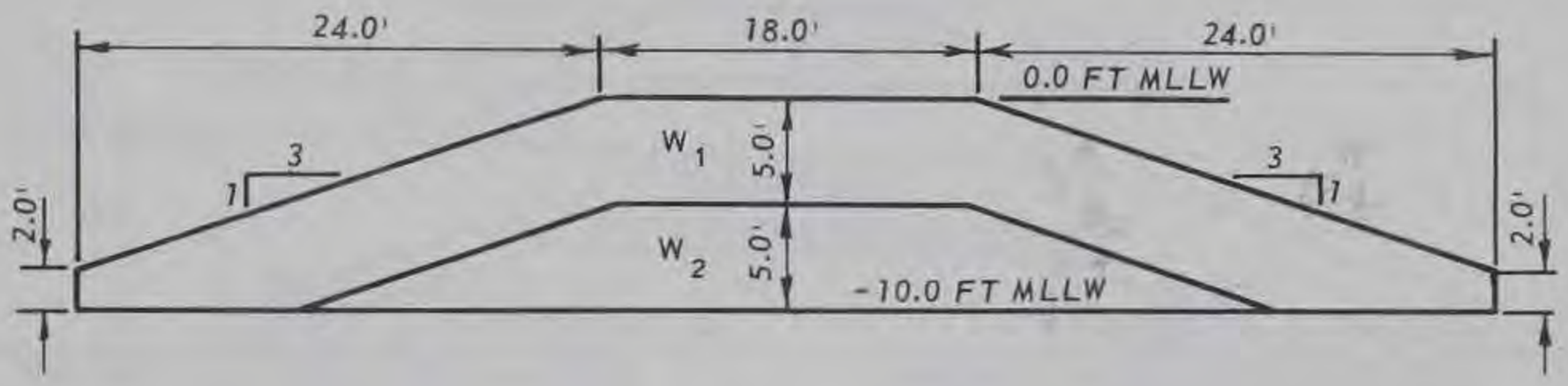
W_1, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF



SECTION 2-2'

MATERIAL CHARACTERISTICS

MODEL

W_1 = 3.023-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

100% ≤ 3.023-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1 = 14,000-LB ROCK @ 165 PCF

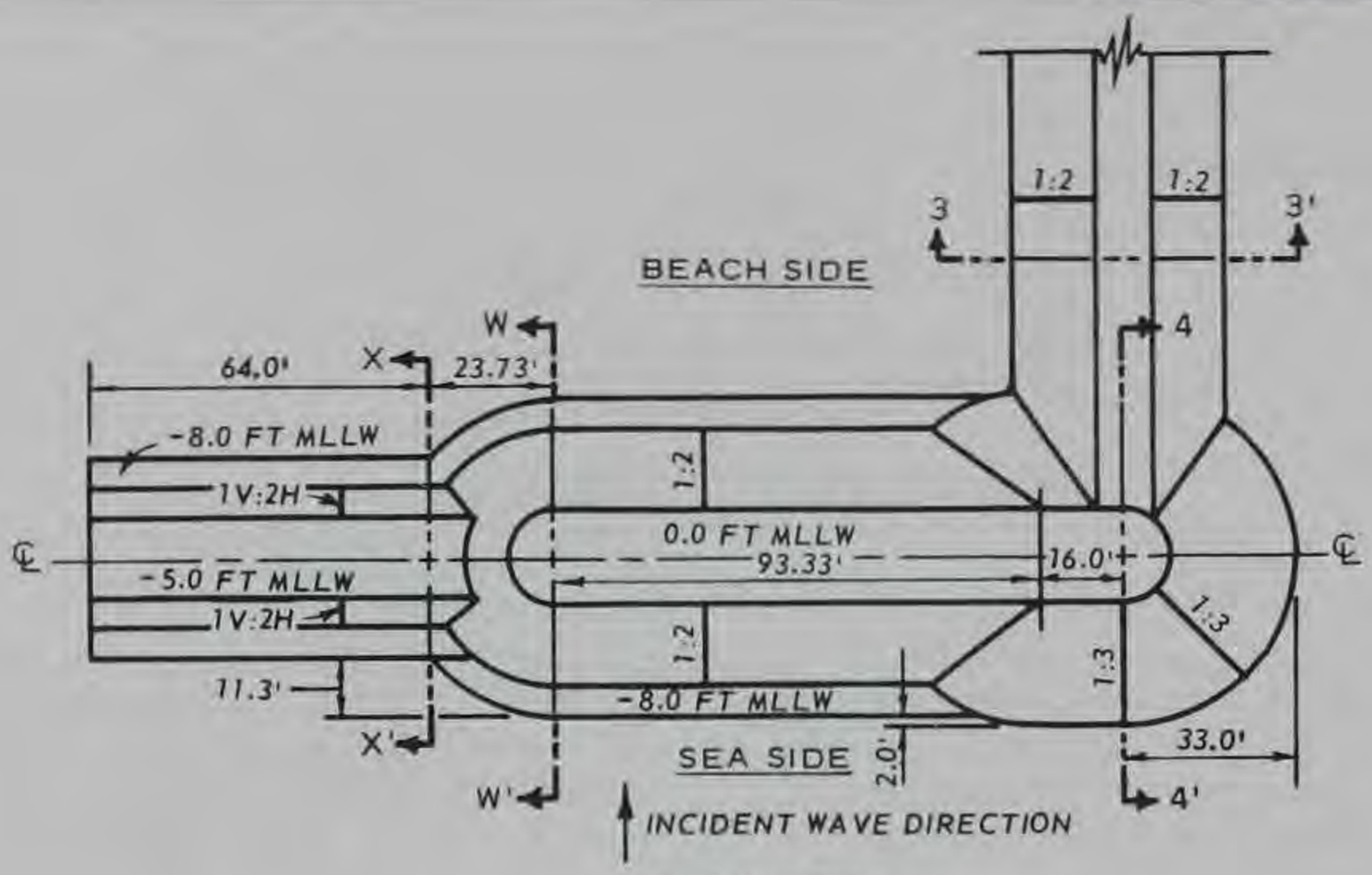
W_2, GRADED % BY WEIGHT

100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 10,000-LB ROCK @ 165 PCF
25% < 6,000-LB ROCK @ 165 PCF
12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 6-LB ROCK @ 165 PCF

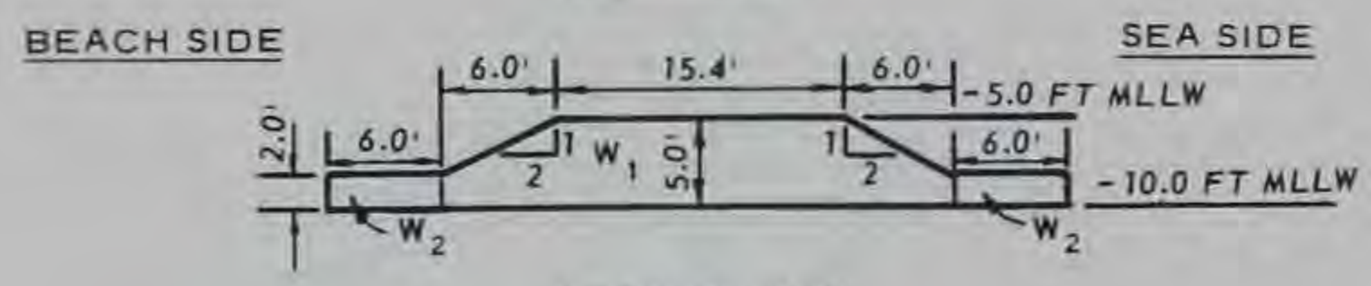
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12A

PLATE 18 (CONTINUED)



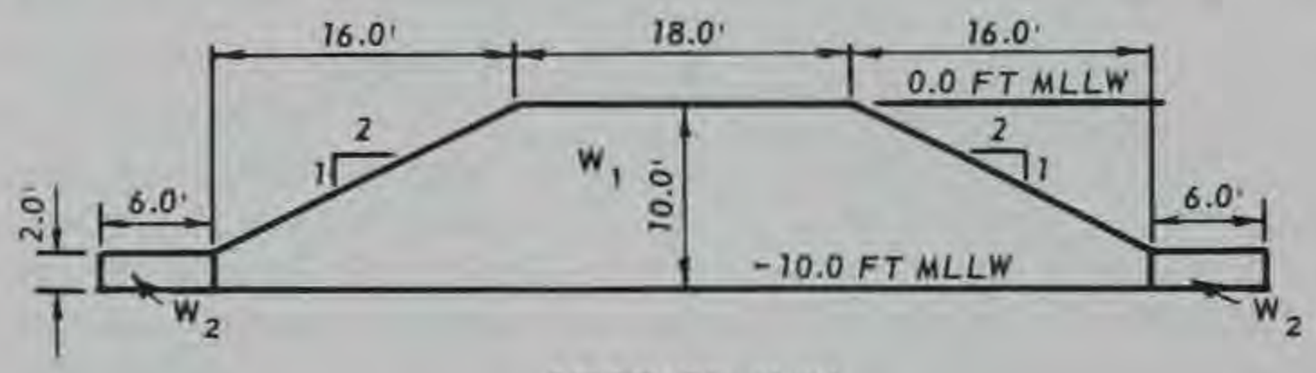
PLAN VIEW



SECTION X-X'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF



SECTION W-W'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF

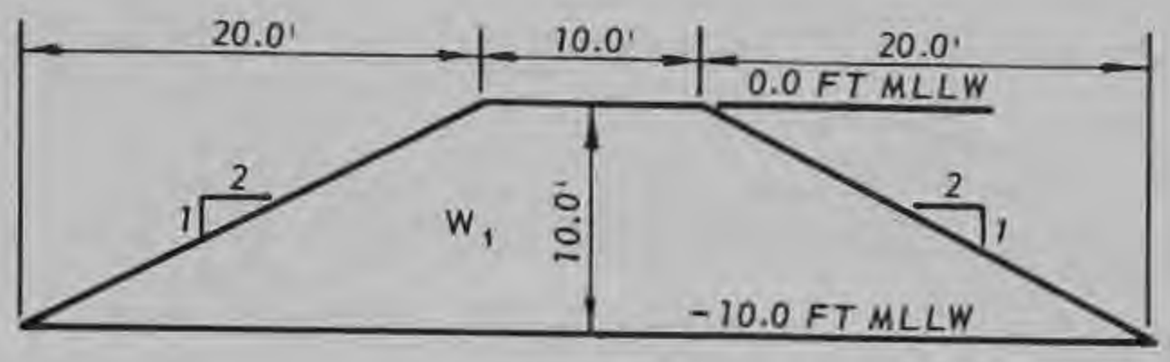
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12B

PLATE 19

BEACH SIDE

SEA SIDE



SECTION 3-3'

MATERIAL CHARACTERISTICS

MODEL

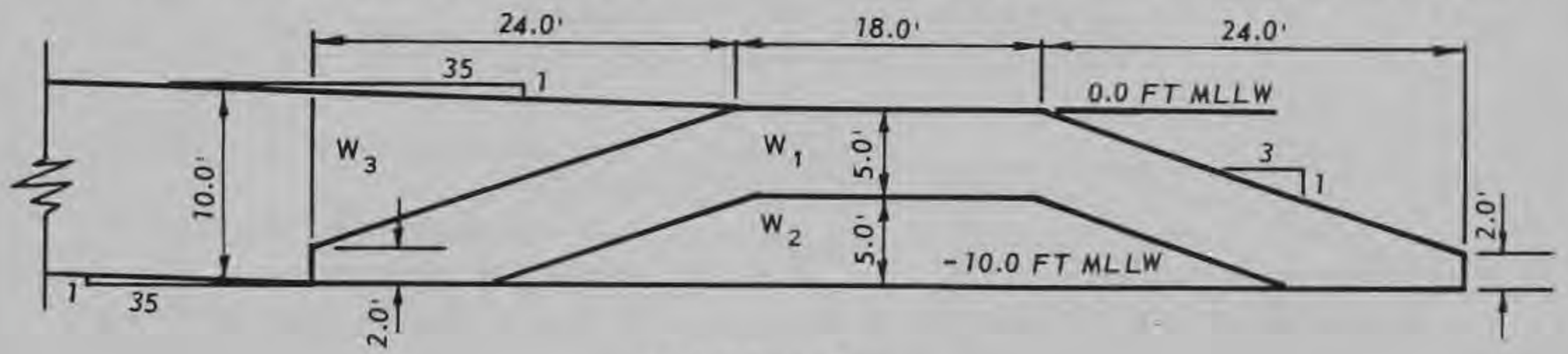
W_1, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF



SECTION 4-4'

MATERIAL CHARACTERISTICS

MODEL

W_1 = 3.023-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

100% ≤ 3.023-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF

W_3, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1 = 14,000-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 10,000-LB ROCK @ 165 PCF
25% < 6,000-LB ROCK @ 165 PCF
12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 6-LB ROCK @ 165 PCF

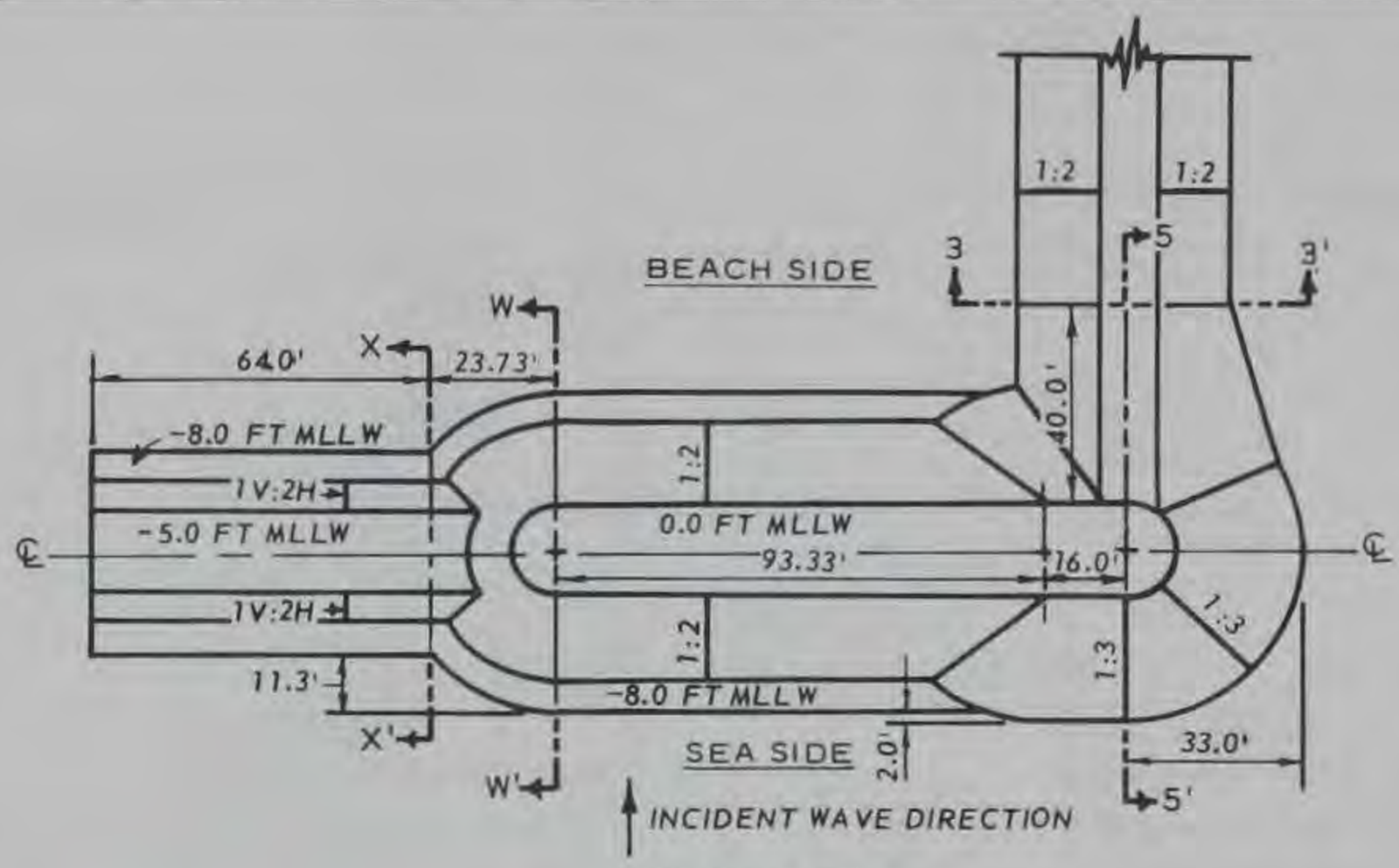
W_3, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF

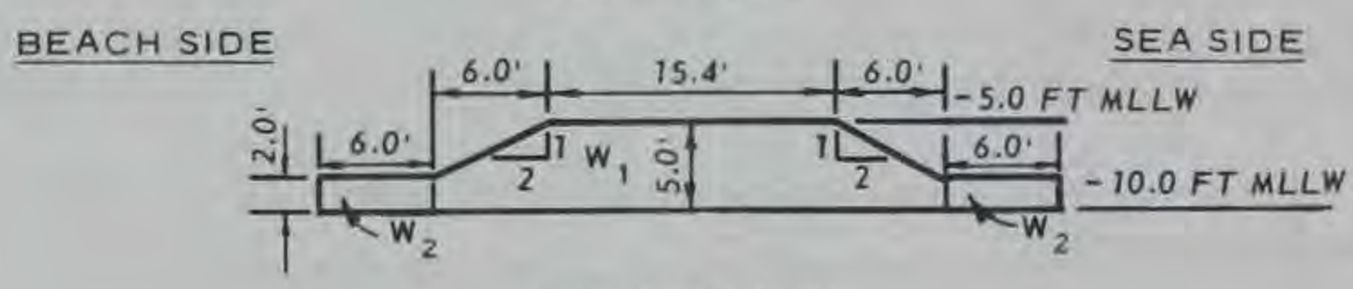
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12B

PLATE 19 (CONTINUED)



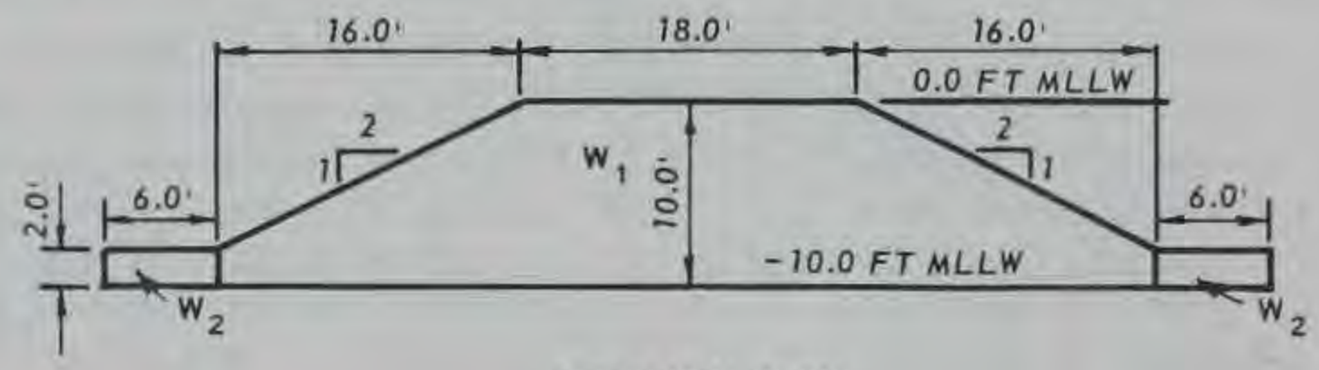
PLAN VIEW



SECTION X-X'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF



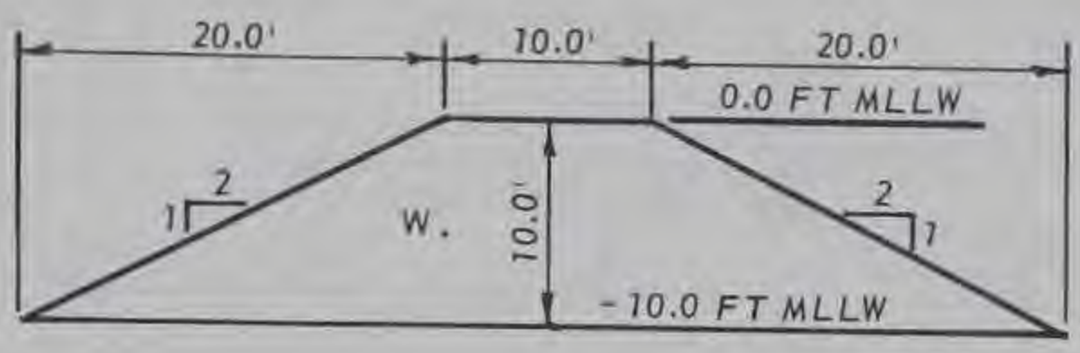
SECTION W-W'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF

NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12C



SECTION 3-3'

MATERIAL CHARACTERISTICS

MODEL

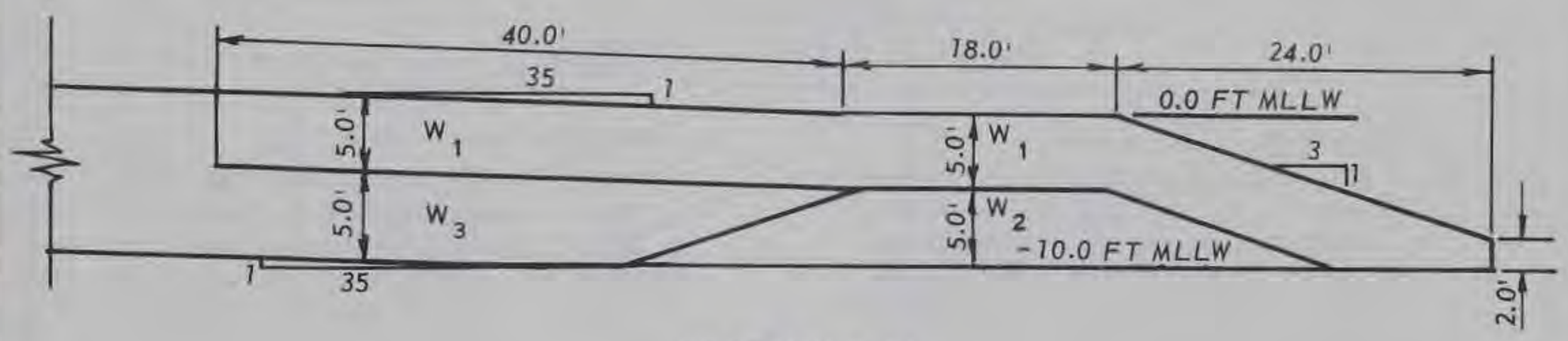
W_1, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF



SECTION 5-5'

MATERIAL CHARACTERISTICS

MODEL

W_1 = 3.023-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

100% ≤ 3.023-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF

W_3, GRADED % BY WEIGHT

100% ≤ 2.158-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF

PROTOTYPE

W_1 = 14,000-LB ROCK @ 165 PCF

W_2, GRADED % BY WEIGHT

100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 10,000-LB ROCK @ 165 PCF
25% < 6,000-LB ROCK @ 165 PCF
12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 6-LB ROCK @ 165 PCF

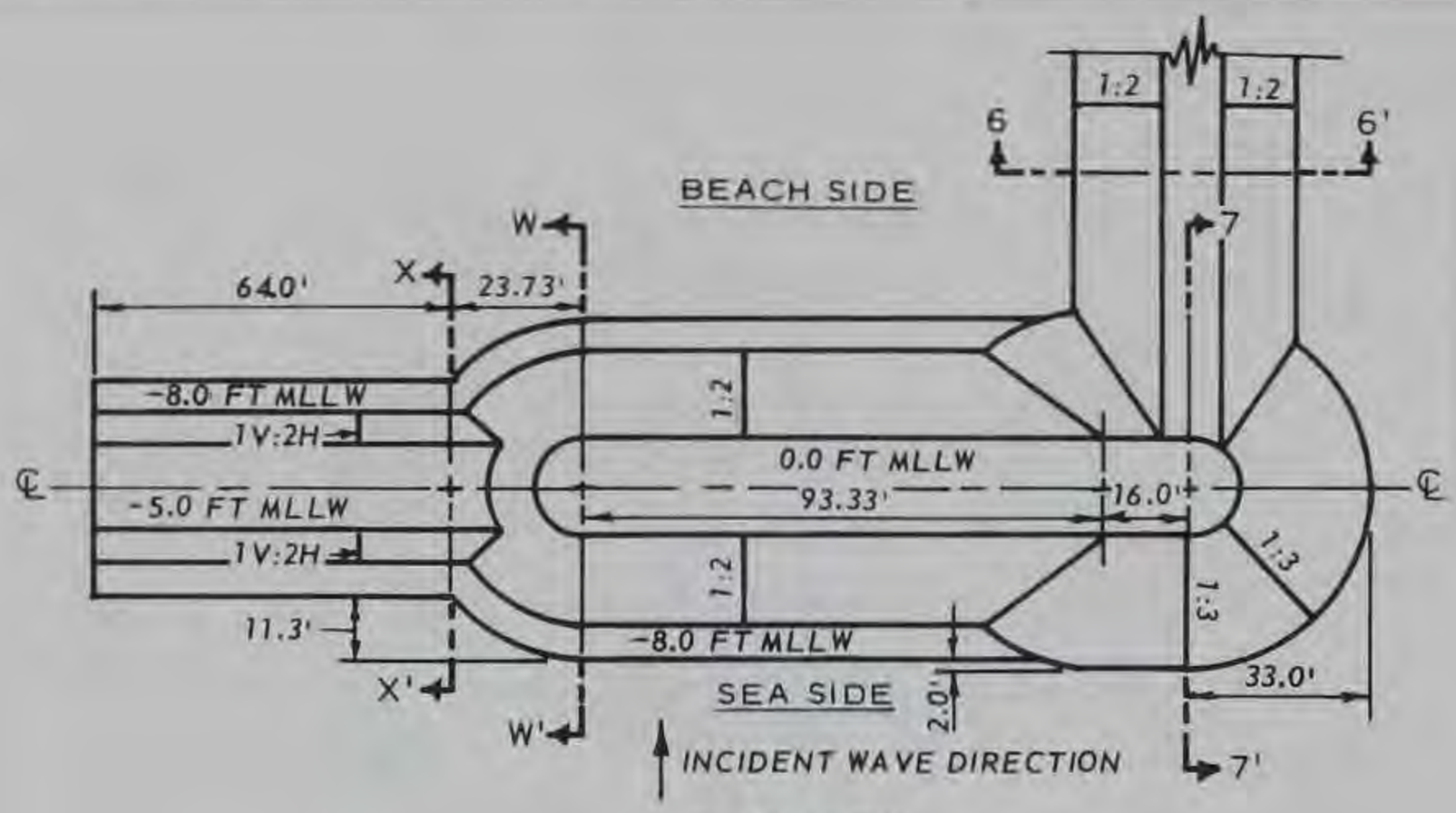
W_3, GRADED % BY WEIGHT

100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 6,000-LB ROCK @ 165 PCF
25% < 3,000-LB ROCK @ 165 PCF
12.5% < 2,000-LB ROCK @ 165 PCF
5% < 6-LB ROCK @ 165 PCF

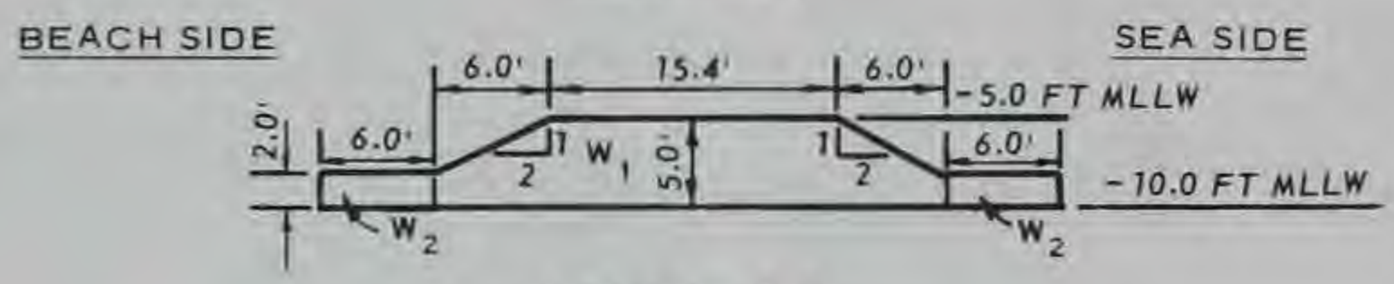
NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12C

PLATE 20 (CONTINUED)



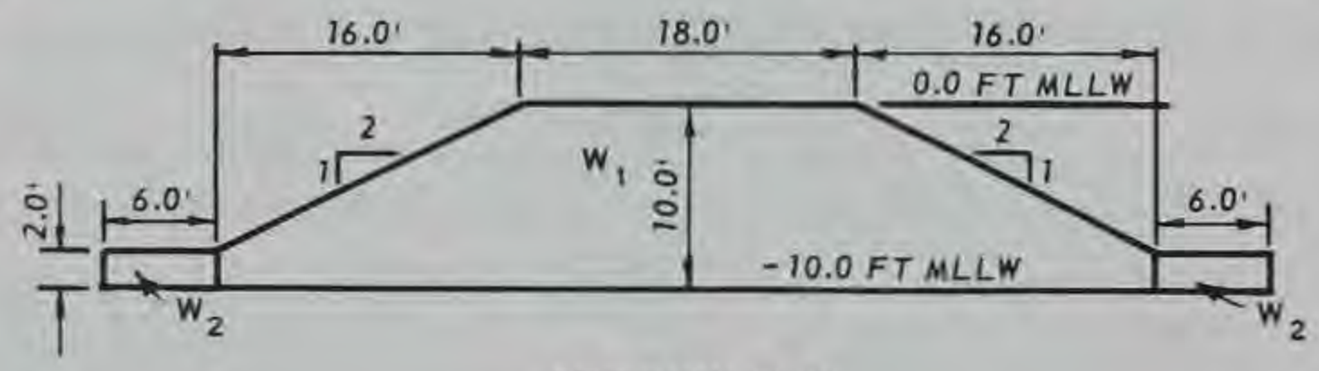
PLAN VIEW



SECTION X-X'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 2.158-LB ROCK @ 165 PCF	100% ≤ 10,000-LB ROCK @ 165 PCF
50% < 1.295-LB ROCK @ 165 PCF	50% < 6,000-LB ROCK @ 165 PCF
25% < 0.648-LB ROCK @ 165 PCF	25% < 3,000-LB ROCK @ 165 PCF
12.5% < 0.432-LB ROCK @ 165 PCF	12.5% < 2,000-LB ROCK @ 165 PCF
5% < 0.001-LB ROCK @ 165 PCF	5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF



SECTION W-W'

MATERIAL CHARACTERISTICS

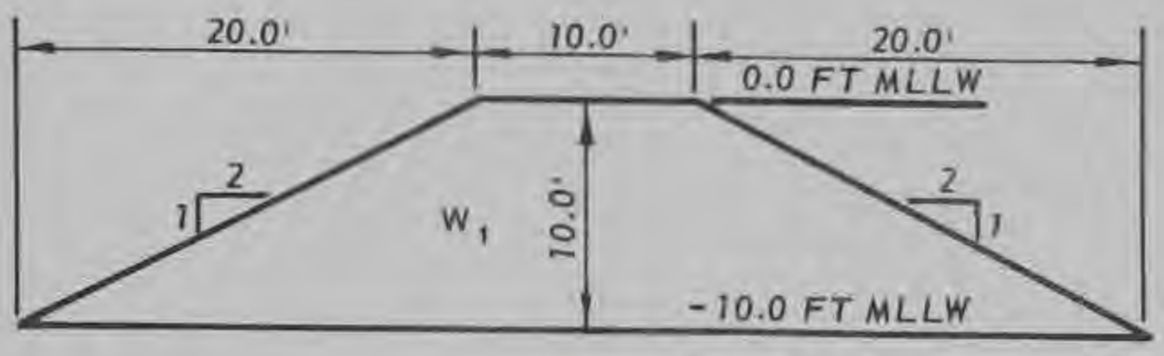
MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF
W_2 = 0.22-LB ROCK @ 165 PCF	W_2 = 1,000-LB ROCK @ 165 PCF

NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12D

BEACH SIDE

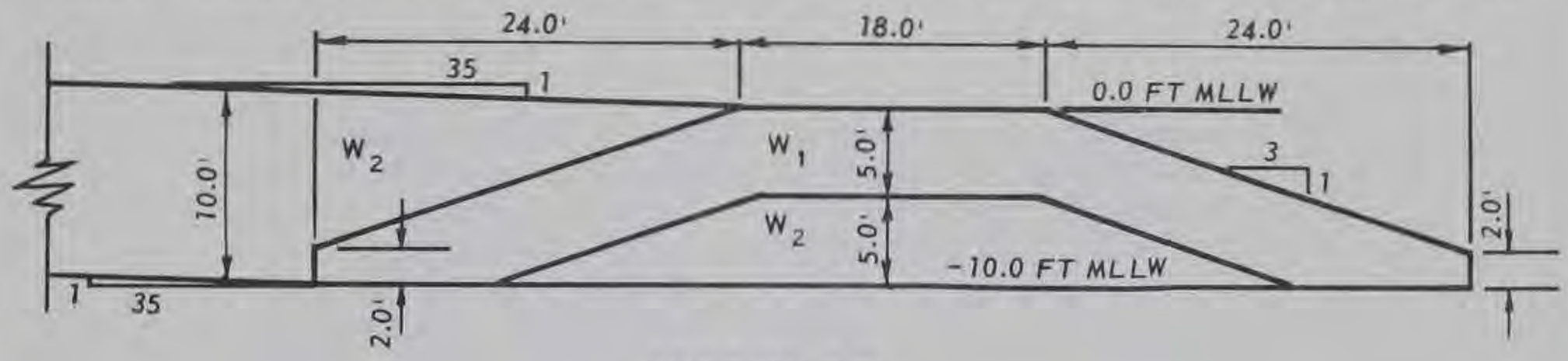
SEA SIDE



SECTION 6 6'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1, GRADED % BY WEIGHT	W_1, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF



SECTION 7-7'

MATERIAL CHARACTERISTICS

MODEL	PROTOTYPE
W_1 = 3.023-LB ROCK @ 165 PCF	W_1 = 14,000-LB ROCK @ 165 PCF
W_2, GRADED % BY WEIGHT	W_2, GRADED % BY WEIGHT
100% ≤ 3.023-LB ROCK @ 165 PCF	100% ≤ 14,000-LB ROCK @ 165 PCF
50% < 2.158-LB ROCK @ 165 PCF	50% < 10,000-LB ROCK @ 165 PCF
25% < 1.295-LB ROCK @ 165 PCF	25% < 6,000-LB ROCK @ 165 PCF
12.5% < 0.648-LB ROCK @ 165 PCF	12.5% < 3,000-LB ROCK @ 165 PCF
6.25% < 0.432-LB ROCK @ 165 PCF	6.25% < 2,000-LB ROCK @ 165 PCF
2.5% < 0.001-LB ROCK @ 165 PCF	2.5% < 6-LB ROCK @ 165 PCF

NOTE: ASSUMES USE OF FILTER CLOTH UNDER ENTIRE BREAKWATER.

DEEPER WATER LOCATION
PLAN 12D

PLATE 21 (CONTINUED)