ENGINEERING RESEARCH INSTITUTE
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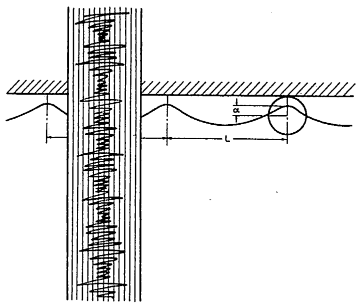
# *MODEL STUDY OF MILWAUKEE OUTER HARBOR*

by

E.F. Brater and L.D. Stair



Technical Report No. 5
Lake Hydraulics Laboratory
Department of Civil Engineering

Project 2039
Board of Harbor Commissioners
Milwaukee, Wisconsin

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

# MODEL STUDY OF MILWAUKEE

# OUTER HARBOR

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Project 2039

BOARD OF HARBOR COMMISSIONERS
MILWAUKEE, WISCONSIN

August 15, 1952

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# MODEL STUDY OF MILWAUKEE

# OUTER HARBOR

## INTRODUCTION

The primary purpose of this model study is to determine effective and economical methods of alleviating or preventing damaging wave conditions produced by certain northeasterly storms in Slip 1 of the outer harbor at Milwaukee, Wisconsin. It was also proposed to investigate the conditions which may be expected to occur in Slip 2 after the construction of the proposed pier 2. The Milwaukee harbor area is shown in Drawing 1, p. 3. The objectionable conditions in Slip 1 are caused by waves which enter the harbor through the 500-foot opening in the breakwaters. Waves entering Slip 1 with certain combinations of direction and frequency combine with waves reflected from Pier 1 and cause damaging overtopping at the inner end of the slip, as illustrated in Figures 1 and 2. It was also desired to determine whether or not objectionable conditions would be caused by a southeasterly storm after the construction of the proposed Pier 2.

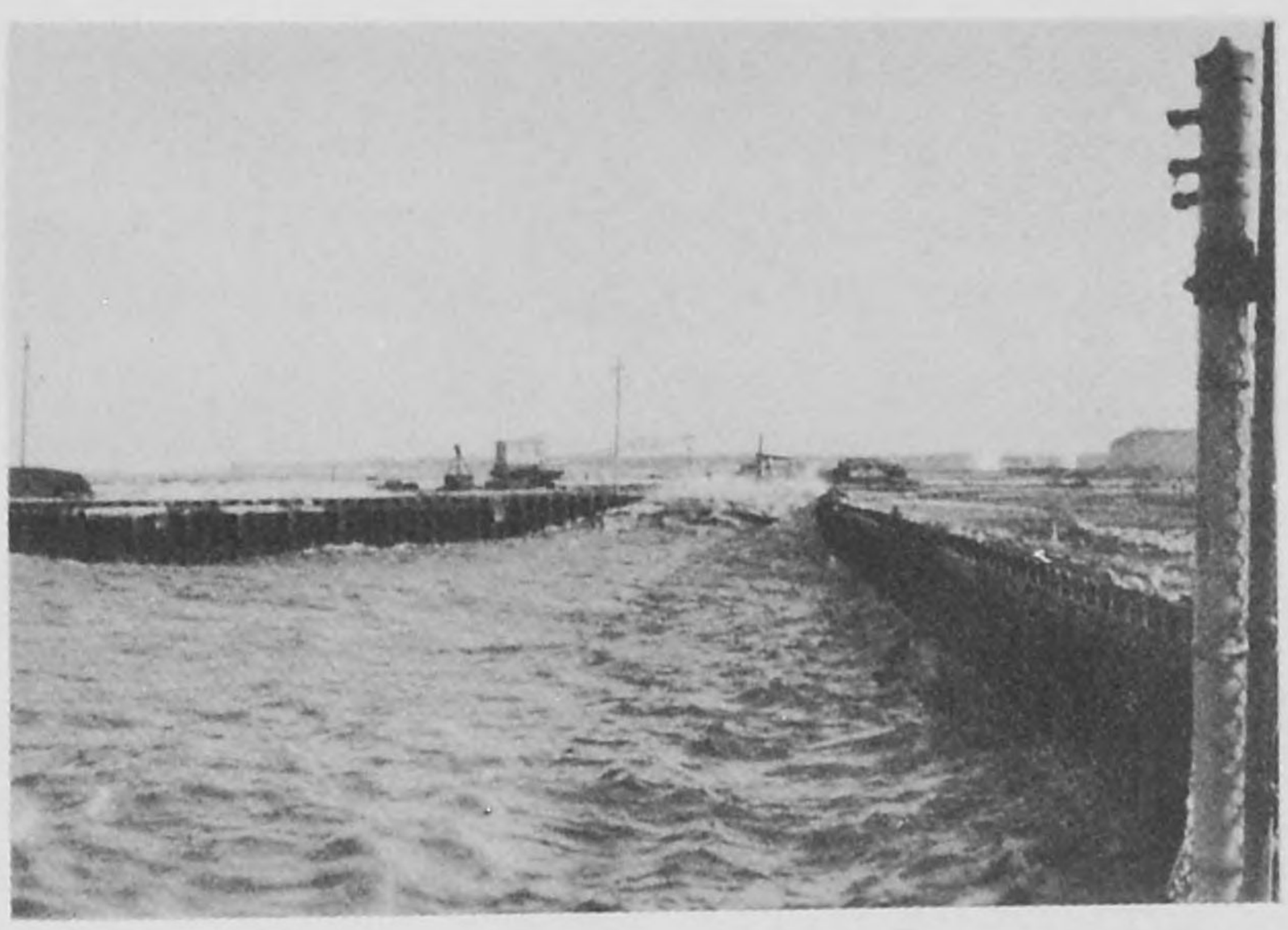

Figure 1

Figure 2

Overtopping at Southwest Corner of Slip 1.

The Milwaukee model study was conducted in accordance with a contract, dated March 6, 1952, between the University of Michigan, Engineering Research Institute, Ann Arbor, Michigan, and the City of Milwaukee, Board of Harbor Commissioners, Milwaukee, Wisconsin. The tests were made in the University of Michigan Lake Hydraulics Laboratory[1].

Mr. H. C. Brockel, Municipal Port Director of the City of Milwaukee, made available the services of his staff in providing the data needed for constructing the model and reproducing prototype conditions. Frequent consultations were held with Mr. John T. Weldon, Civil Engineer of the Milwaukee Board of Harbor Commissioners. His cooperation and suggestions were most helpful in planning the testing program.

## PROTOTYPE CONDITIONS

The Port of Milwaukee is located on the western shore of Lake Michigan, approximately 100 miles north of the south end of the lake. The port consists of an inner and an outer harbor with the outer harbor protected by a system of breakwaters as shown in Drawing 1. The portion of the outer harbor area which is the subject of these studies is shown in greater detail in Drawing 2, p. 5.

The most severe storm waves are produced by winds ranging from the northeast to the southeast. The overtopping which has been experienced in Slip 1 was produced by northeasterly storms. During one such storm, that of November 6-7, 1951, the wave period during the overtopping was observed to be approximately five seconds. The wind records taken during this storm by the U.S. Weather Bureau at Milwaukee indicated that wave periods may have varied from four seconds to more than six seconds during this storm. It was also found from the fetch, duration, and average velocity of the wind that deep water wave heights as great as ten feet occurred on those dates in the vicinity of Milwaukee. Computations for wave periods and wave heights were based on the

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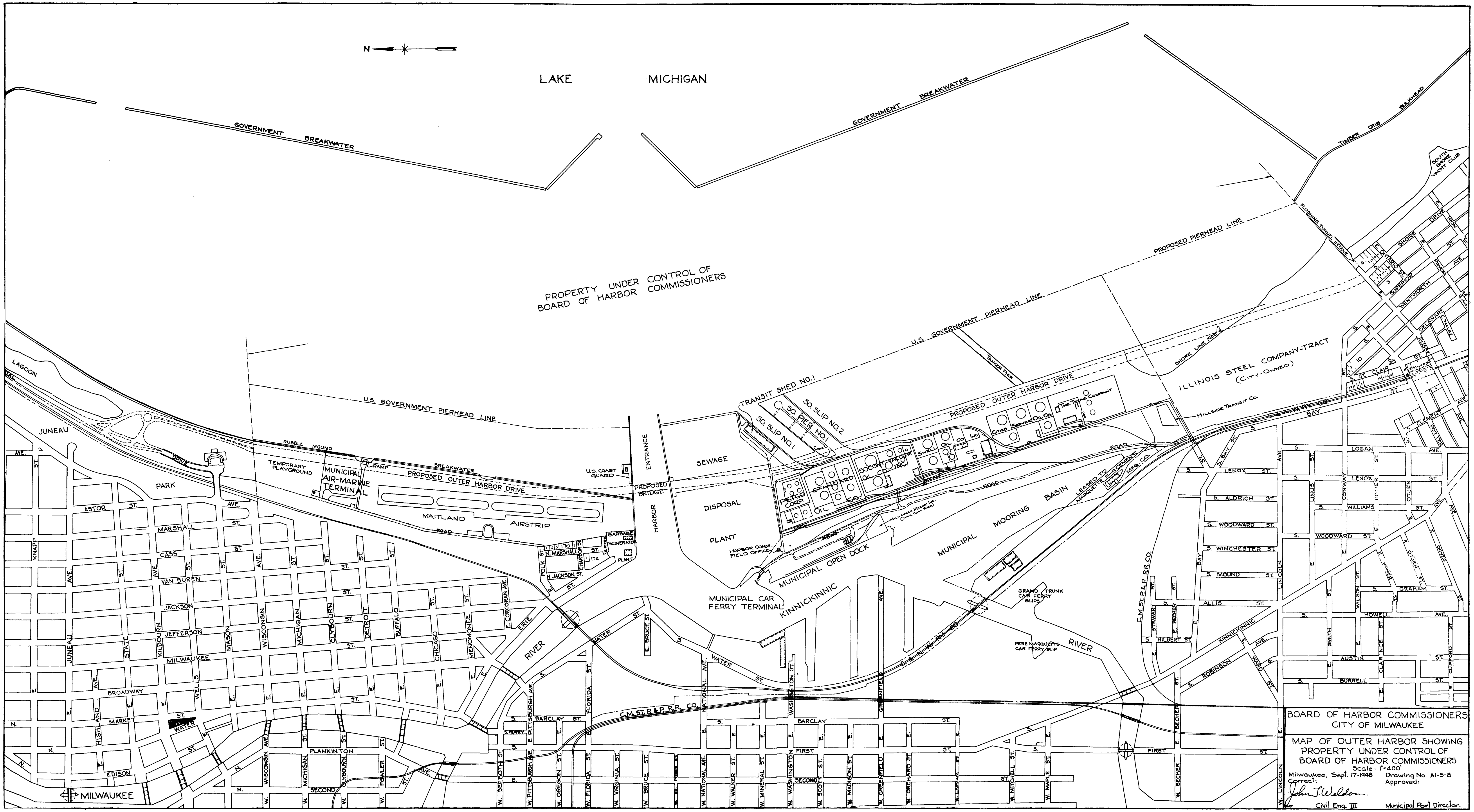
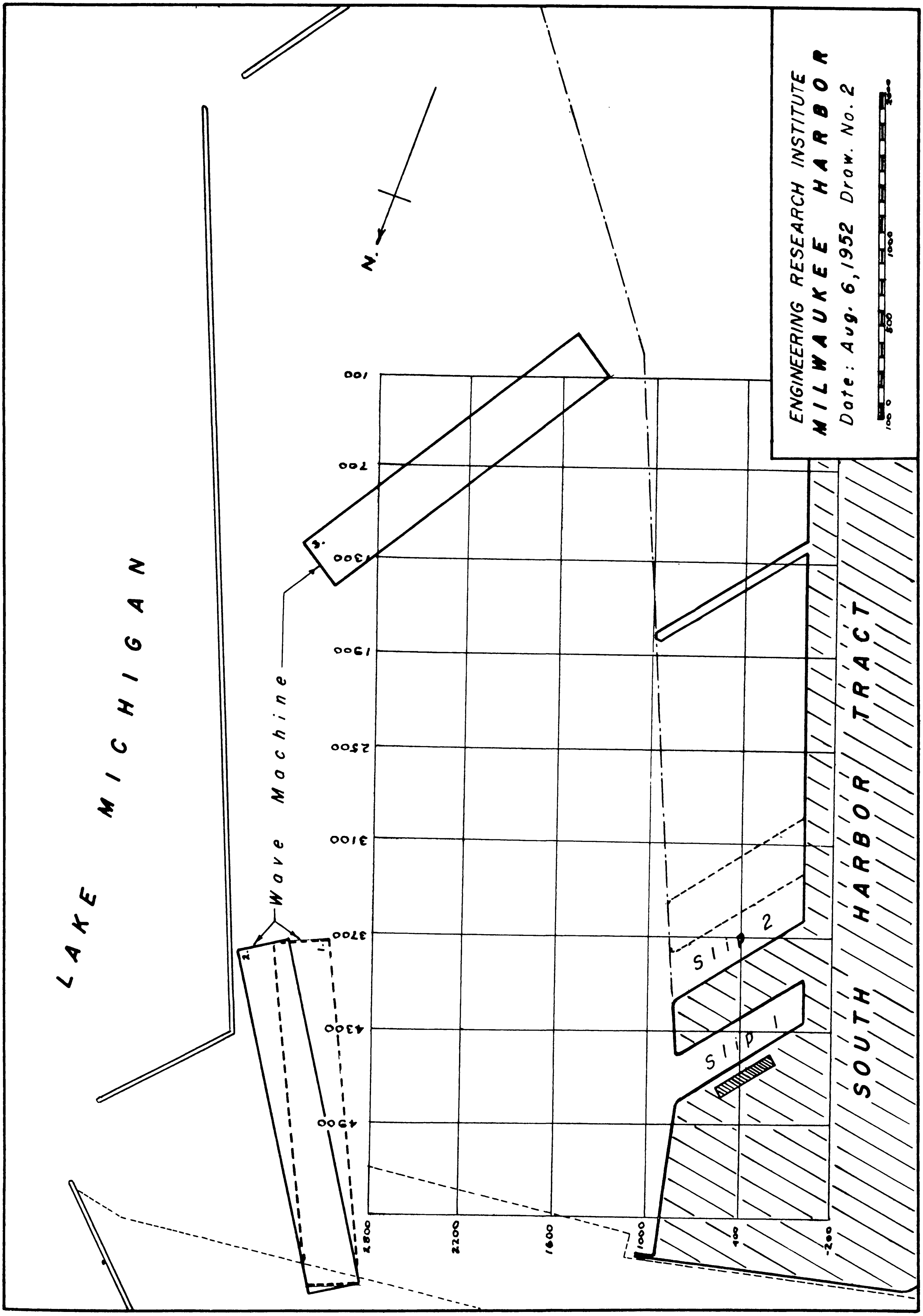
[1] The University of Michigan Lake Hydraulics Laboratory is a facility of the Engineering Research Institute and the Department of Civil Engineering of the College of Engineering. Professor A. E. White is Director of the Engineering Research Institute. Dr. George G. Brown is Dean of the College of Engineering and Professor Earnest Boyce is Chairman of the Department of Civil Engineering. The laboratory is under the direction of Dr. E. F. Brater, Professor of Hydraulic Engineering. Mr. L. D. Stair, Research Associate, was in charge of the construction and operation of the model.




**DRAWING 1**

*REPRODUCED FROM A PUBLICATION OF THE MILWAUKEE BOARD OF HARBOR COMMISSIONERS.*


ENGINEERING RESEARCH INSTITUTE
MILWAUKEE HARBOR
Date: Aug. 6, 1952 Draw. No. 2
LAKE MICHIGAN
Wave Machine
N.
SOUTH HARBOR TRACT
Slip 1
Slip 2
100
700
1300
1900
2500
3100
3700
4300
4900
2800
2200
1600
1000
400
-200

Sverdrup-Munk Curves[1,2]. Photographs of the conditions in the southwest corner of Slip 1 during the storm of November 6-7, 1951, are shown in Figures 1 and 2.

## THE MODEL

The model was constructed to an undistorted linear scale of 1:75. This scale provided for depths and waves of sufficient magnitude to minimize the effect of surface tension and viscous damping. The Froude law was used as a basis for determining model wave periods.

The model was constructed in a tank 90 feet long and 54 feet wide. The harbor area, reproduced in the model, extended from a location inside the breakwaters to the land area of the South Harbor Tract and included about one mile of shore line. A plan of the harbor area, showing the location of the tank and model limits, is shown in Drawing 3.

Water depths used in reproducing the topography of the outer harbor were taken from charts of the United States Lake Survey and from data supplied by engineers of the Board of Harbor Commissioners. The lake elevation simulated in the model was +1.0 foot with respect to the Milwaukee datum or 582.2 feet above mean tide at New York. During the summer of 1952, Lake Michigan reached a level approximately 0.4 foot higher than this elevation. A limited number of tests were made with the lake elevation at +1.4 feet.

The model was built by cutting templates from 3/8 inch plywood to conform to the harbor depths at various locations. The template layout is shown in Drawing 3. The templates were placed at intervals of four feet and set at the proper elevations by means of an engineer's level. For areas of rapidly changing elevation the template spacing was reduced to two feet. The space between the templates was filled with well-compacted sand to within an inch of the upper edges and the remaining space filled with low strength mortar, using the edges of the templates as screeds. Photographs of the model under construction are shown in Figures 3 and 4, p. 8.

Elevations of the templates were checked before and after placing the cement mortar. As a final check on the accuracy of the model construction, the tank was filled to a number of water surface elevations and the contours

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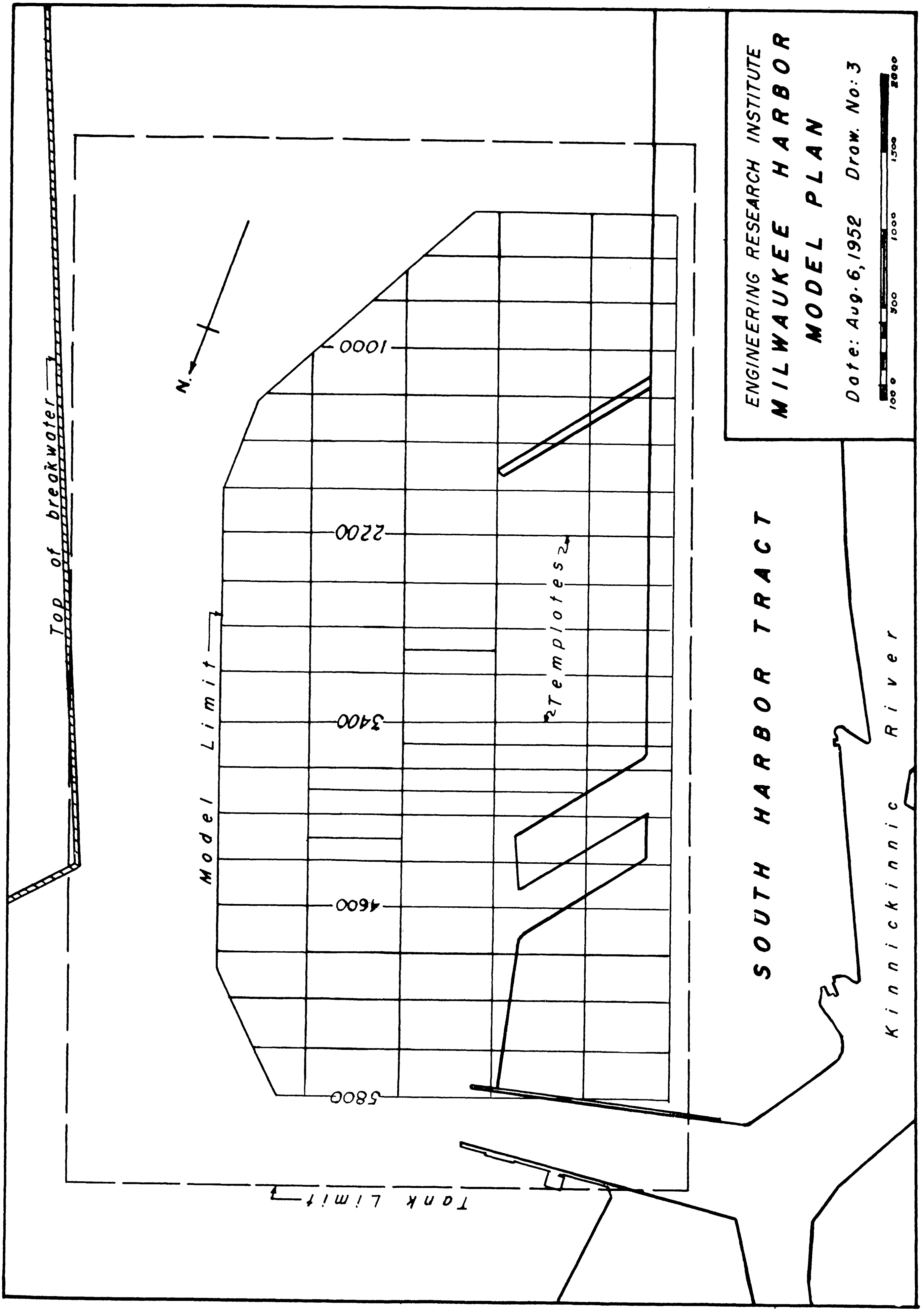
1 "Wind Waves and Swell, Principles in Forecasting," U.S. Hydrographic Office Publ., Misc. 11,275, (1943).

2 R. L. Wiegel, "Bulletin of the Beach Erosion Board," Special Issue No. 1, (1948).


ENGINEERING RESEARCH INSTITUTE
MILWAUKEE HARBOR
MODEL PLAN
Date: Aug. 6, 1952
Draw. No: 3
Top of breakwater
Model Limit
Templates
N.
1000
2200
3400
4600
5800
Tank Limit
SOUTH HARBOR TRACT
Kinnickinnic River

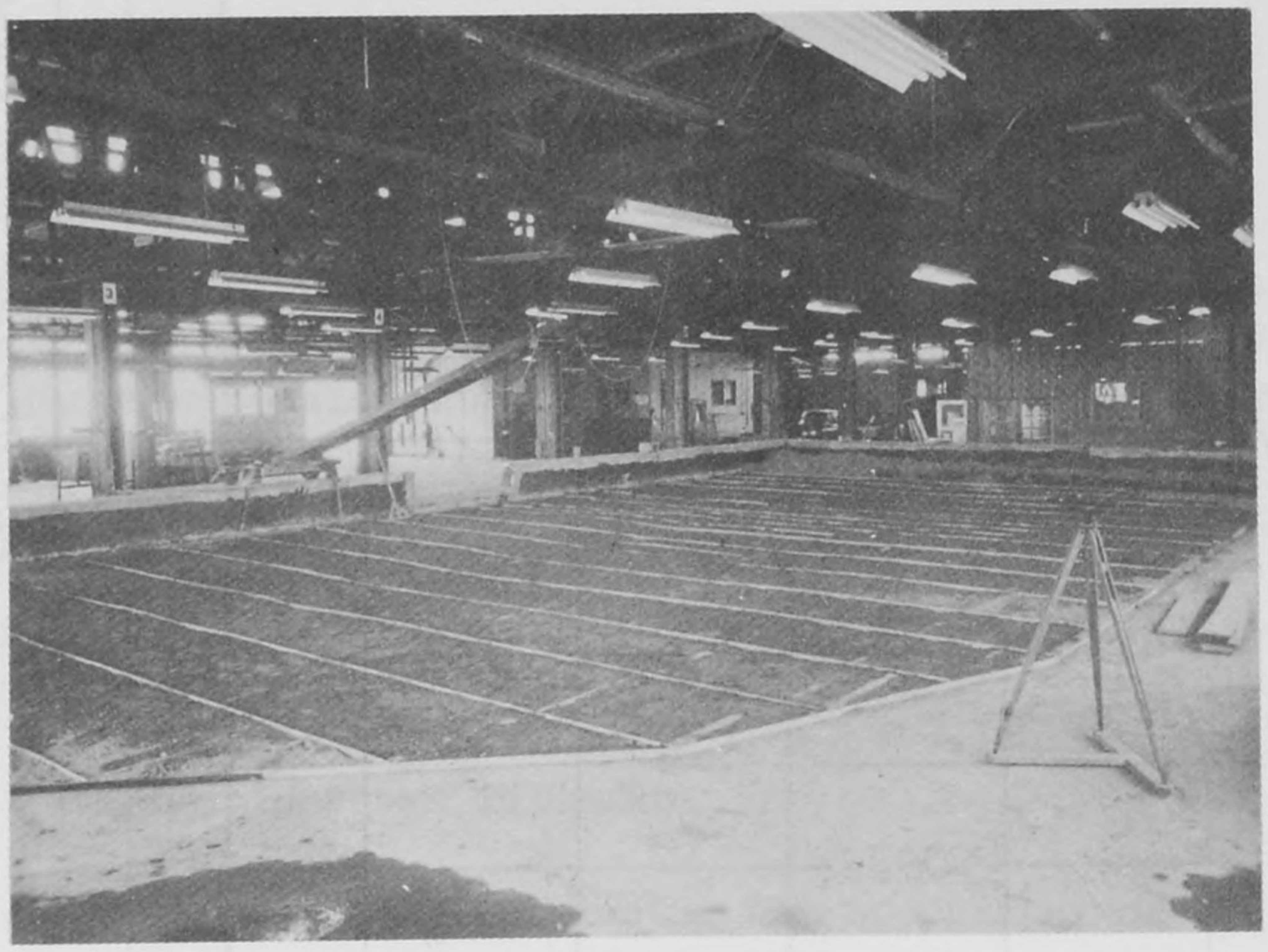


Figure 3. Model under Construction - Templates in Place.

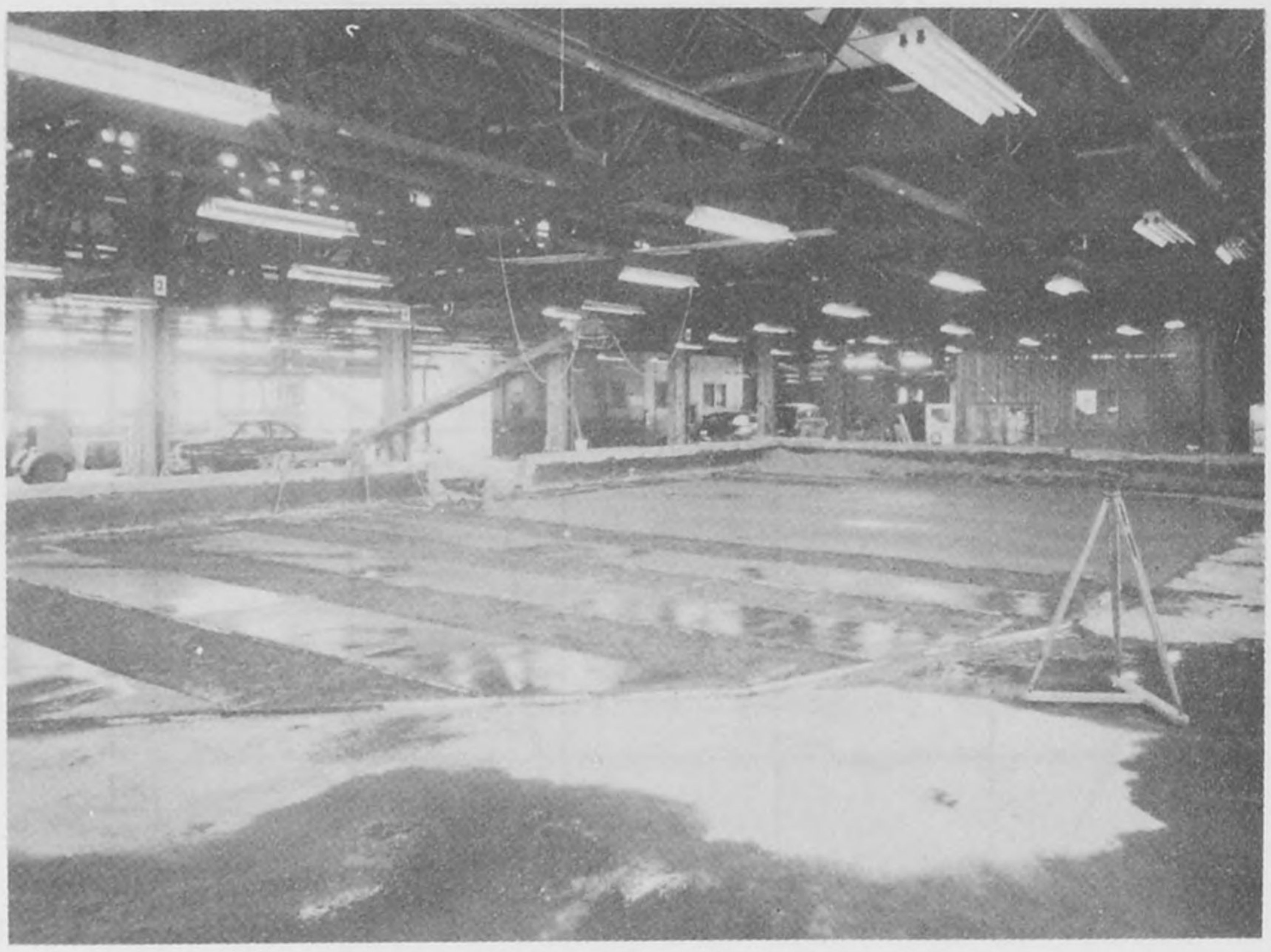


Figure 4. Model under Construction - Cement Mortar Partially in Place.

established by the edges of the water were compared with corresponding contours on the topographic charts.

## TESTING EQUIPMENT AND PROCEDURE

A portable, plunger-type wave machine, 30 feet long, was used to generate waves. Waves of the desired height were produced by selecting the proper eccentricity of the plunger arms. Wave periods were varied by changing the frequency of the wave machine.

The wave heights were measured by means of an electrical resistance gage. Variations in depth due to passing waves caused the voltage across the gage terminals to vary, and the variations in voltage were amplified and recorded by means of an oscillograph. The instruments were calibrated by raising and lowering the gage by specific increments in still water and recording the corresponding oscillograph fluctuations. A photograph of the wave machine and resistance gage is shown in Figure 5.

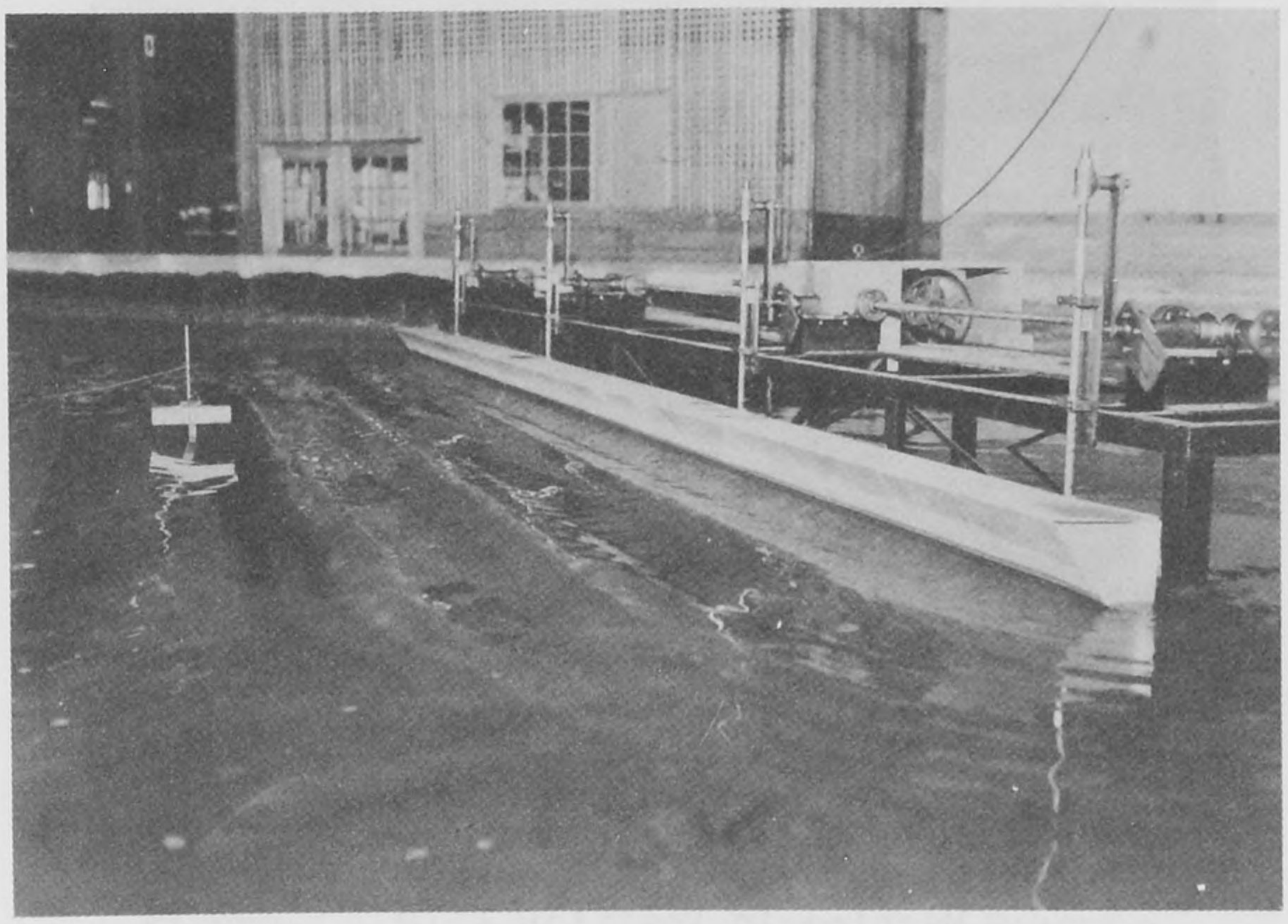


Figure 5. Wave Machine and Resistance Gage.

The elevations of the water surface in the model were determined by means of a hook gage installed in a stilling well at one side of the tank.

## MODEL VERIFICATION OF SLIP 1

The ability of the model to simulate prototype conditions was checked by reproducing the surging in Slip 1 that had been observed during the storm of November 6-7, 1951. The observed wave period of five seconds was used, and the characteristics of the waves as they approached the harbor entrance were determined from deep water conditions by means of refraction diagram[1]. The wave height and wave directions at the gage location were estimated by considering the effect of diffraction as the waves passed through the breakwater opening. The wave characteristics were then varied slightly until the desired conditions were reproduced. The similarity between model and prototype conditions was verified by Mr. John T. Weldon, Civil Engineer, Board of Harbor Commissioners, and Mr. H. C. Brockel, Municipal Port Director. The particular wave which produced conditions similar to those of November 6-7, 1951, had a period of 5.5 seconds and was produced with the wave machine in the location shown as (1) in Drawing 2, p. 5. A photograph of Slip 1 during model operation under these conditions is shown in Figure 6.

Figure 6. Slip 1 Wave Period 5.5 Seconds - Wave Machine in Position 1.

Further experimentation through a wide range of frequencies, with the wave machine in position (1), showed that overtopping also occurred at

[1] "Breakers and Surf," U.S. Hydrographic Office Publ. No. 234, 1949.

wave periods of 4.8, 4.95, 5.2, 6.1, and 6.5 seconds. Most of these frequencies produced overtopping to some degree in the southwest corner of the slip, but many of them also produced overtopping at various points along or near the inner end of the slip. Conditions in Slip 1 were also studied with the wave machine in the location shown as (2) in Drawing 2, p. 5.

## CONDITIONS IN SLIP 2

The wave action is Slip 2, with the proposed Pier 2 in place, was observed for the various wave frequencies studied for Slip 1. It was found that overtopping occurred at various points at the inner end of Slip 2 for some of these frequencies, as well as for some frequencies which were not objectionable in the case of Slip 1. However, the most severe overtopping in Slip 2 occurred with the wave machine in the location shown as (2) in Drawing 2, p. 5. The most violent conditions in Slip 2, with the wave machine in position (2), occurred for a wave period of 4.8 seconds. A photograph of Slip 2 under these conditions is shown in Figure 7. Various other troublesome frequencies were also found and used as part of the testing program.

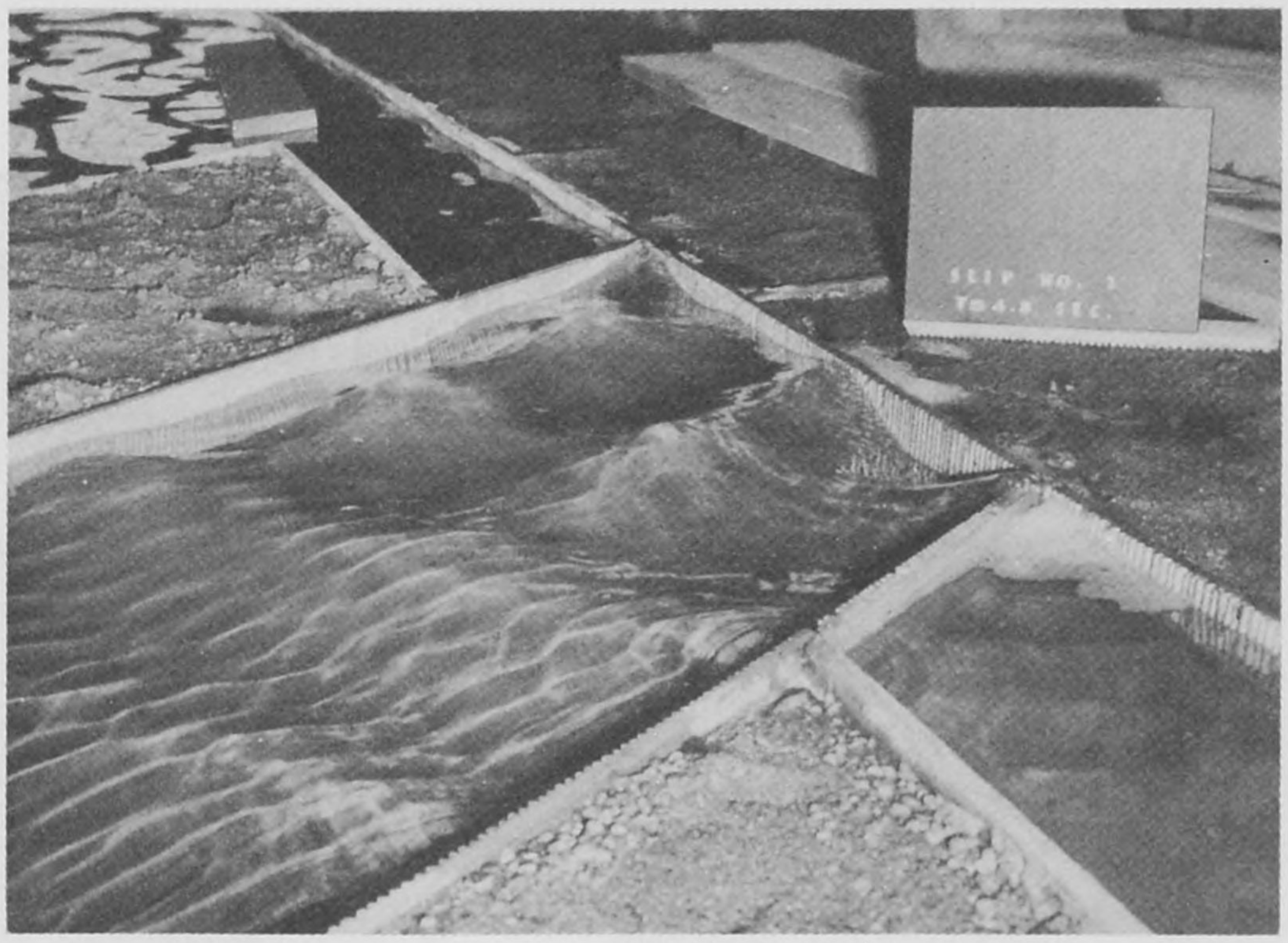


Figure 7. Slip 2 - Wave Period 4.8 Seconds - Wave Machine in Position 2.

On the basis of the studies described above, it was decided that the most suitable protective device should stop overtopping at all locations for the various wave periods and directions, even though the most serious conditions observed to date in the prototype occured in the southwest corner.

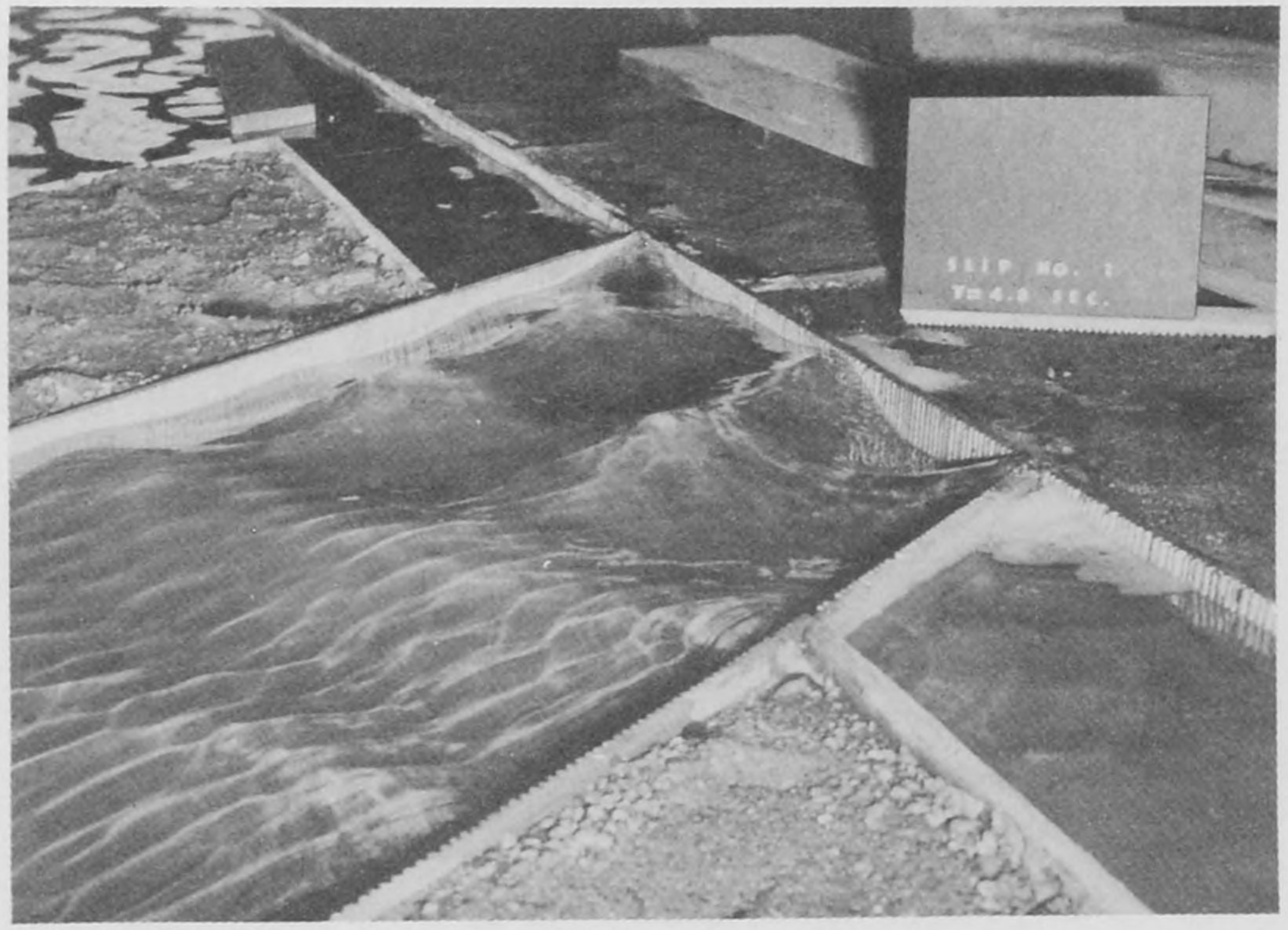
Some observations were made with the wave machine in the location designated as (3) in Drawing 2, p. 5. The waves generated with the machine in this position simulated those produced by a southeasterly storm. Observed prototype conditions were reproduced in the model. Pier 2 was then installed and it was found that its presence caused no serious wave conditions during southeasterly storms.

## TESTS OF REMEDIAL METHODS

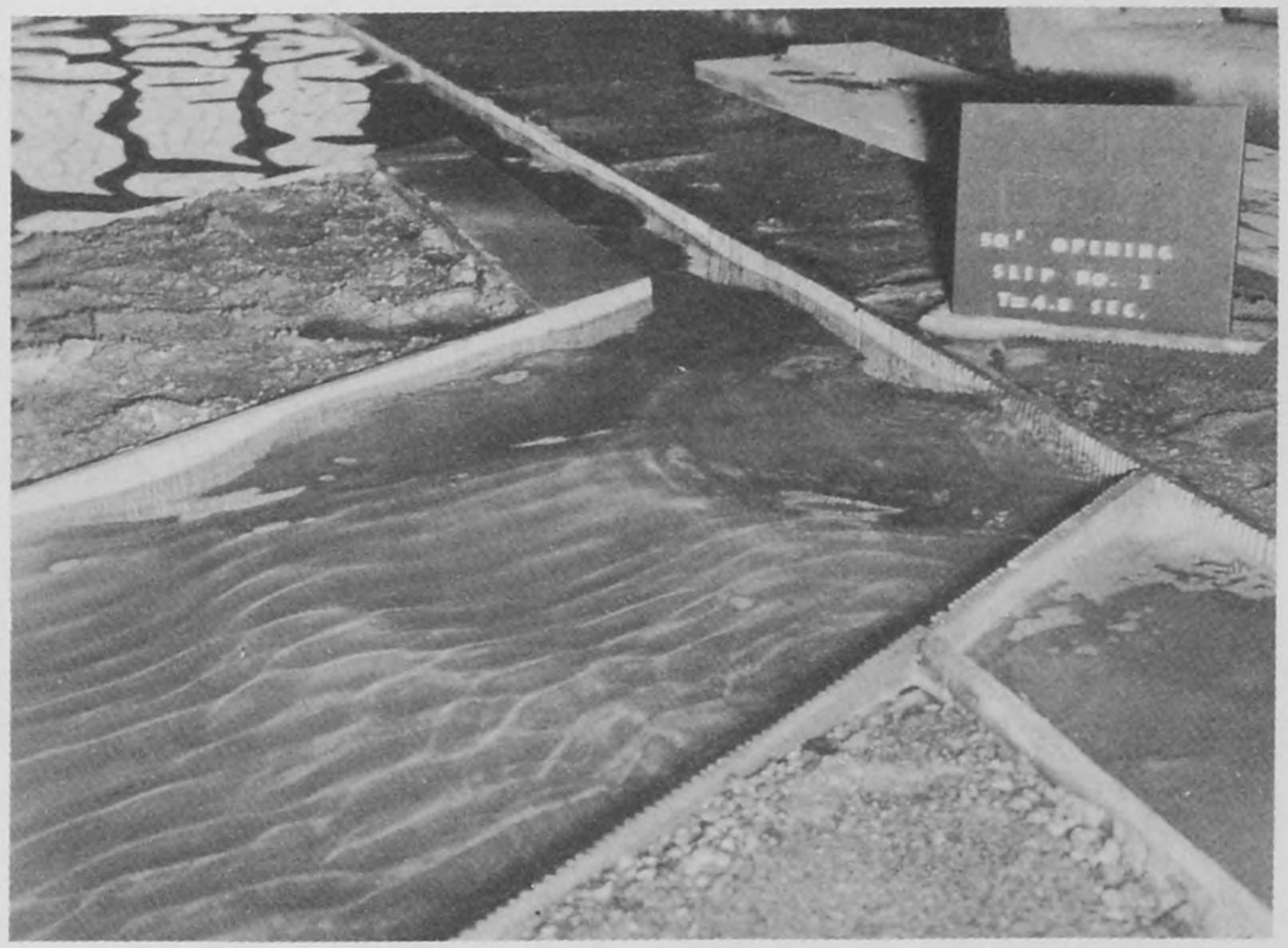
The methods which were given serious study were those that could be constructed within the slips without interfering to any great extent with the operation of port facilities. Changing the breakwater arrangement, realigning the slips, or constructing an additional breakwater were not considered as possibilities, either because of the tremendous expense involved or because of other practical reasons. The methods tried consisted of channels cut through the inner ends of the piers, underwater barriers placed near the inner ends of the slip, baffles at the sides of the slip, and compressed air.

### Channels in Piers

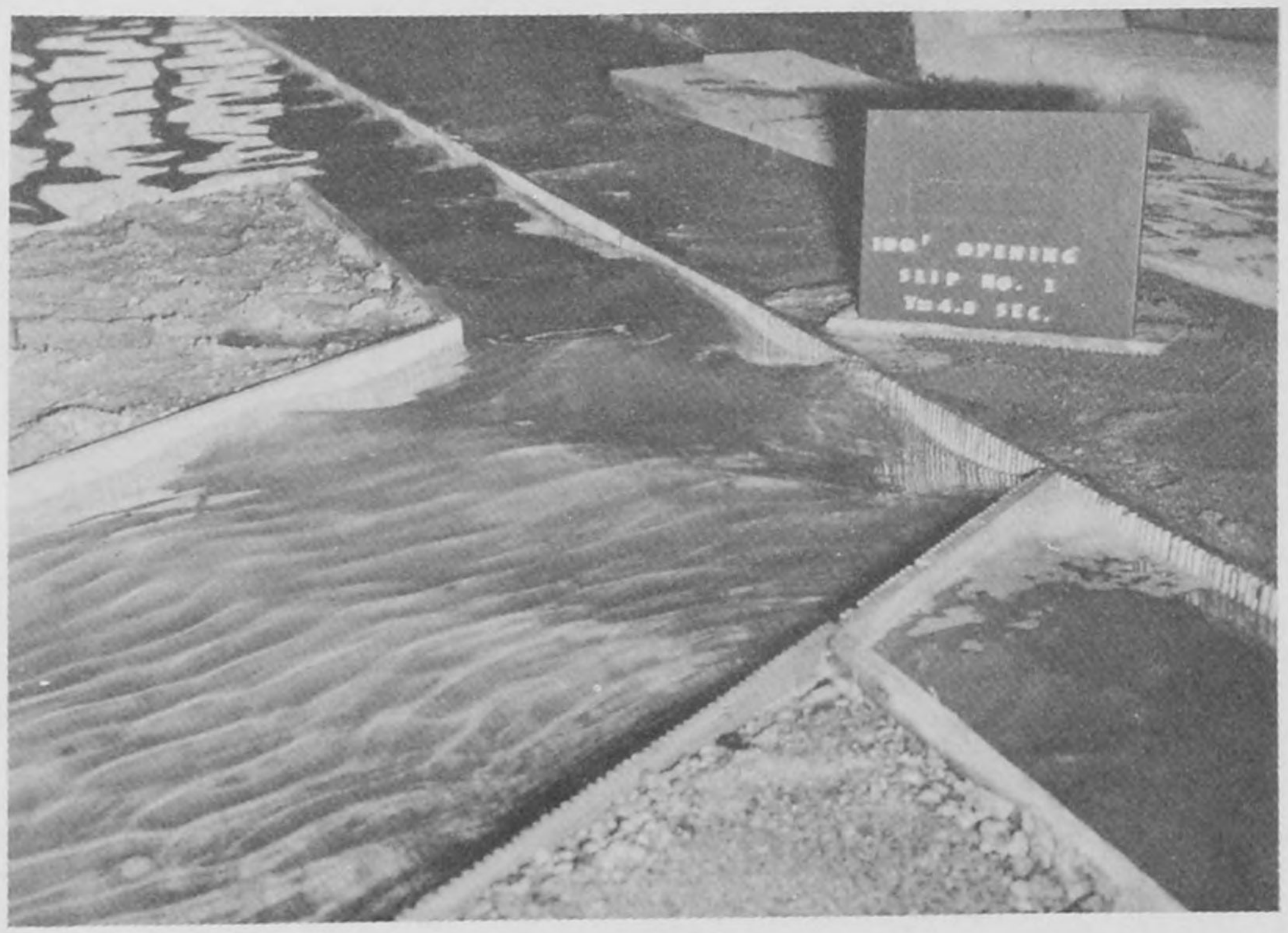
One of the methods which was proposed for study by the Milwaukee authorities was the construction of channels through the inner ends of the piers to allow some of the wave energy to pass out of the slips. It was proposed to study the effect of channels of various sizes in Pier 1 alone, in Pier 2 alone, and with channels in both piers. Channels of 25-, 50-, 75-, and 100-foot widths were tried. The 25-foot channel was found to be ineffective, and the 75 foot channel was found to produce results differing only slightly from those of the 50- and 100-foot channels. Therefore, the 50- and 100-foot channels were chosen for more extensive study. Various combinations of 50- and 100-foot channels were tried in the two piers. They were tested for two wave periods with the wave machine in position (1) and for two wave periods with the wave machine in position (2). The effectiveness of the channels was judged by their ability to reduce or stop the overtopping which occurred under the original conditions. Satisfactory results were obtained by the use of channels of certain widths for some wave periods and directions. However, no channel of a particular width prevented overtopping at all locations for all wave conditions. Photographs showing wave conditions during some of these tests are presented in Figure 8, p. 13. The detailed results of all of the tests with channels in the piers are shown in Drawings 4 through 11, in the Appendix, (p. 23 37).



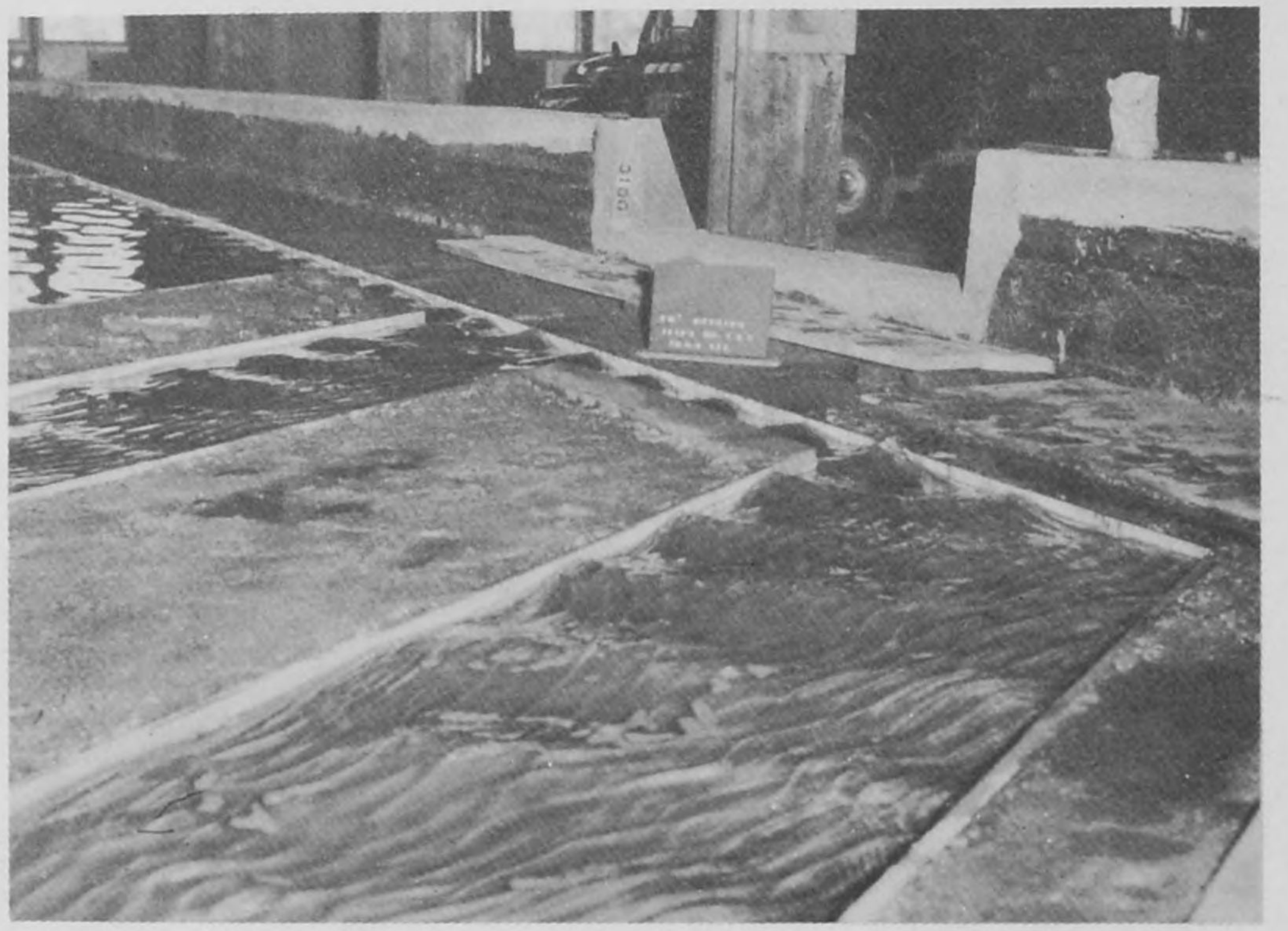
Original Condition Slip 2



50-Foot Channel in Pier 2



100-Foot Channel in Pier 2



50-Foot Channels in Pier 1 and Pier 2

Figure 8

The Effect of Channels through Piers on Wave Conditions in Slips - Wave Period 4.8 Seconds - Wave Machine in Position 2.

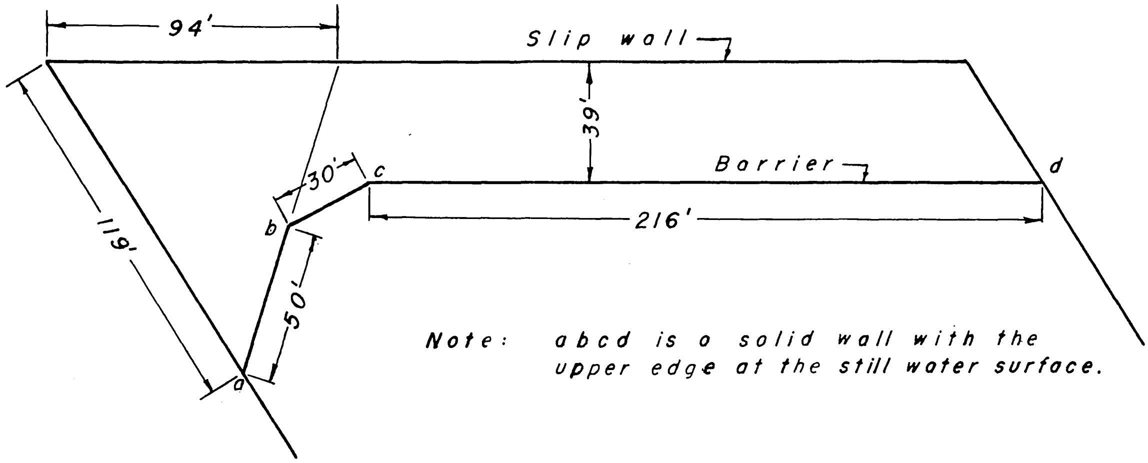
## Submerged Barriers

A second method of preventing the overtopping consisted of dissipating the wave energy in turbulence by means of barriers placed near the ends of the slips. Many different types were tried, and the results obtained from the more important ones are shown in Table I, in the Appendix (p. 39).

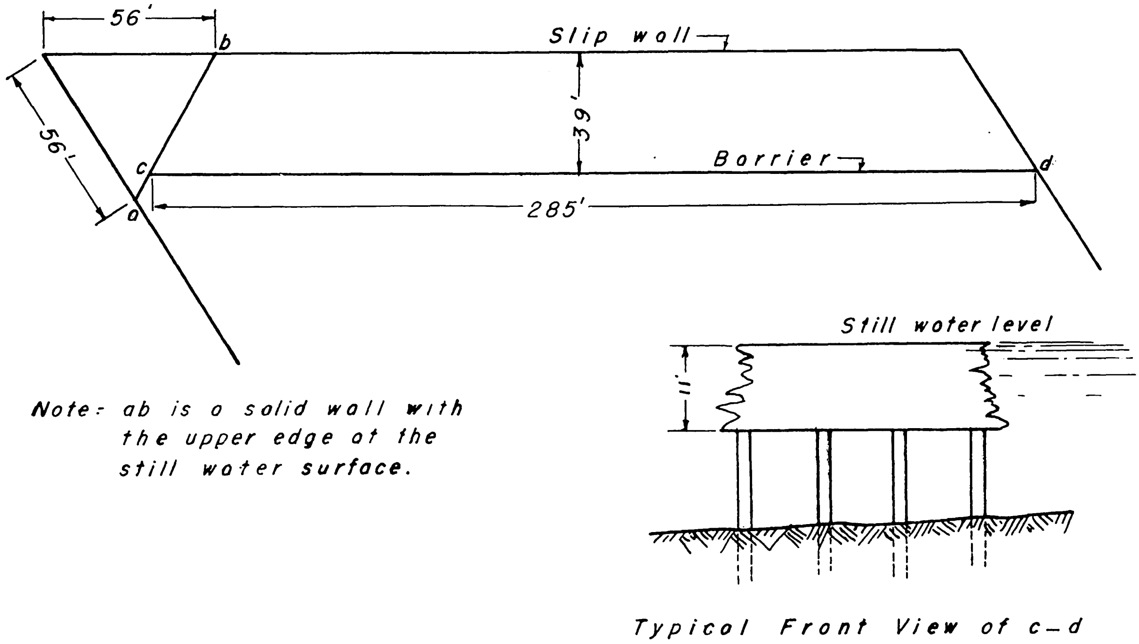
The two most effective barriers are shown in Figure 9. Each of these stopped overtopping under all conditions of wave period and wave direction in each slip. Solid barriers were tried with varying widths, heights, and locations. A thin wall was found to be nearly as effective as a wide one. The best height was found to be with the top edge of the barrier at the water surface. Higher walls caused overtopping at the points where they joined the sides of the slip. Type A simulated a tight steel sheet piling wall with the top edge at the water surface. The location shown in Figure 9 was the most effective one. However, the dimensions showing the location of Type A may be considered as approximate, because variations of several feet in the location caused no noticeable difference in the results.

Because of the greater economy of construction, it was suggested by Mr. Weldon that an open or permeable wall be tried. It was found that no wall open at the bottom for its full length would stop overtopping in the southwest corners of the slips. Various combinations of open and tight walls were tried. The one designated as Type B in Figure 9 was found to give the best results. This structure consisted of a tight wall (a-b) across the southwest corner combined with an open wall (c-d) parallel to the end of the slip. This barrier (Type B) was only slightly less effective than Type A and stopped overtopping under all conditions. The solid portion alone, a-b, in Figure 9, greatly reduced the overtopping in the southwest corner. The addition of the permeable portion, c-d, made Type B effective against overtopping at all locations. Type B barrier simulates tight steel sheet piling construction for the corner wall, a-b, and piling spaced at intervals with a tight wall extending down 11.0 feet from the water surface for the portion parallel to the end of the slip.

Barriers A and B were tested with more than 70 combinations of wave period and wave direction as well as with the water surface raised to +1.4 feet with respect to the Milwaukee Datum. Photographs of the wave action in Slip 1 before and after the installation of these barriers are shown for four sets of conditions in Figures 10, 11, 12, and 13, on pages 16, 17, 18, and 19.




SOLID BARRIER TYPE A




PERMEABLE BARRIER TYPE B

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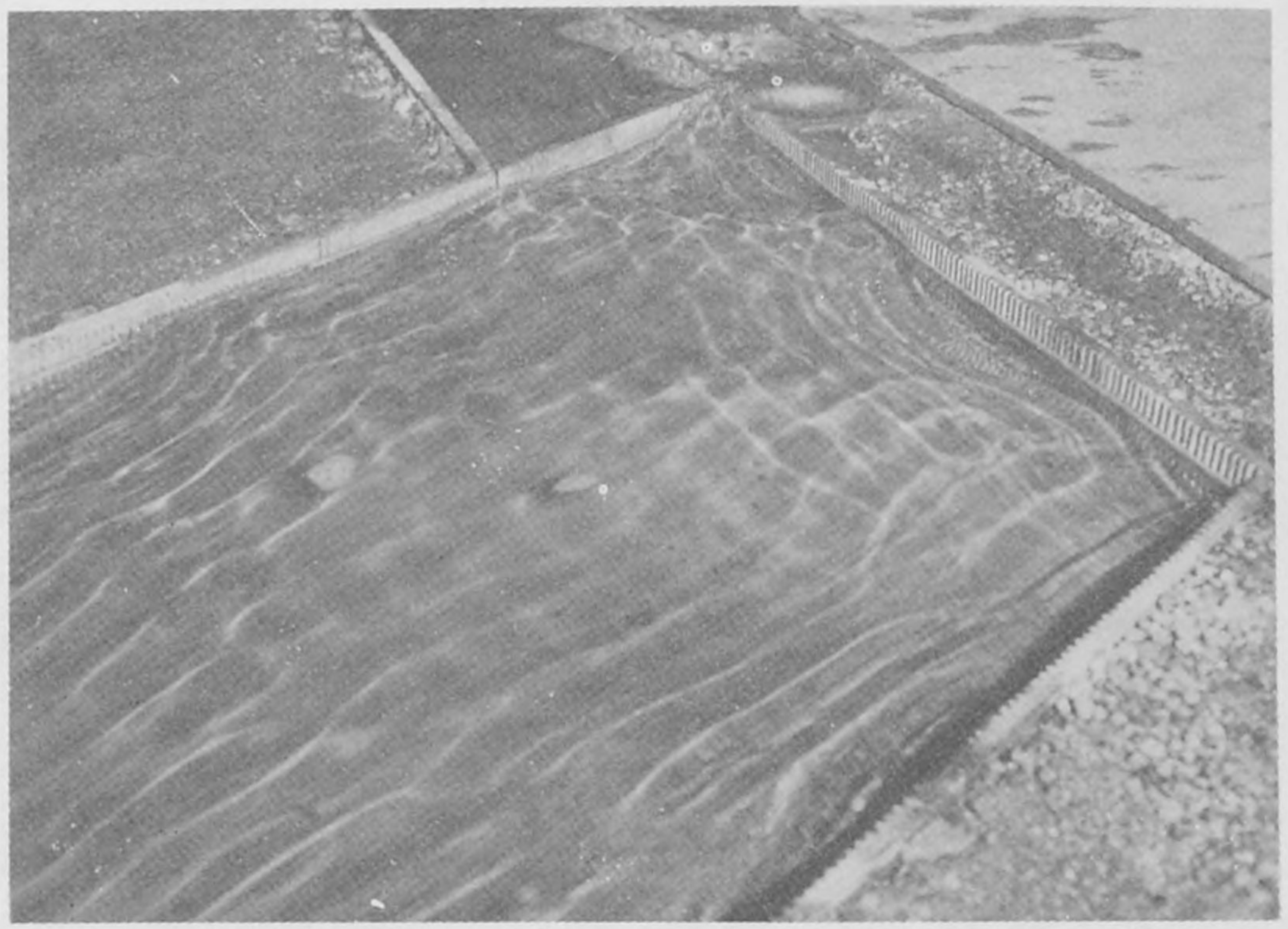
SUBMERGED BARRIERS

Date: Aug. 6, 1952 Fig. 9

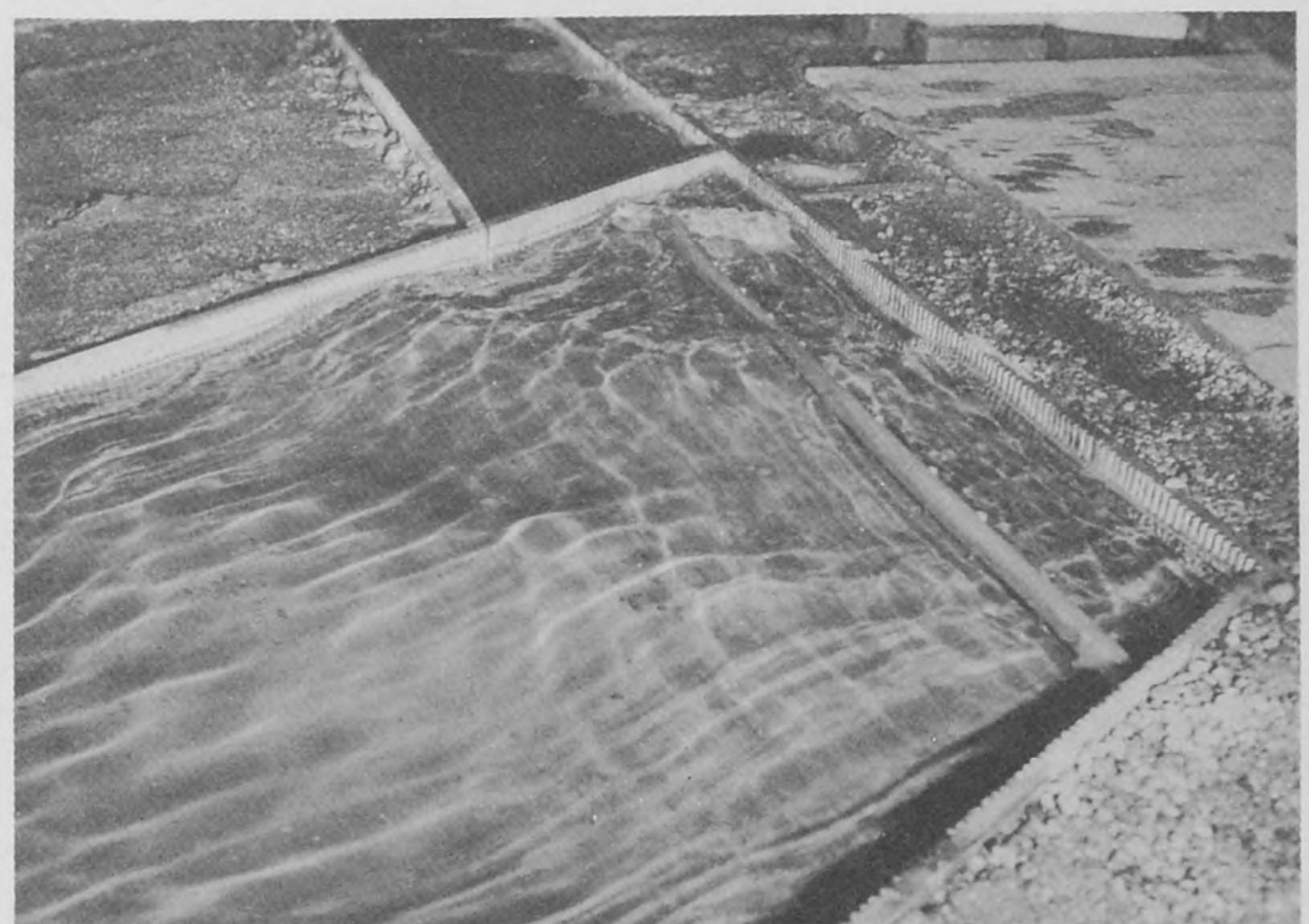
Figure 10

The Effect of Submerged Barriers on Conditions in Slip 1
Wave Period 5.5 Seconds
Wave Machine in Position 1

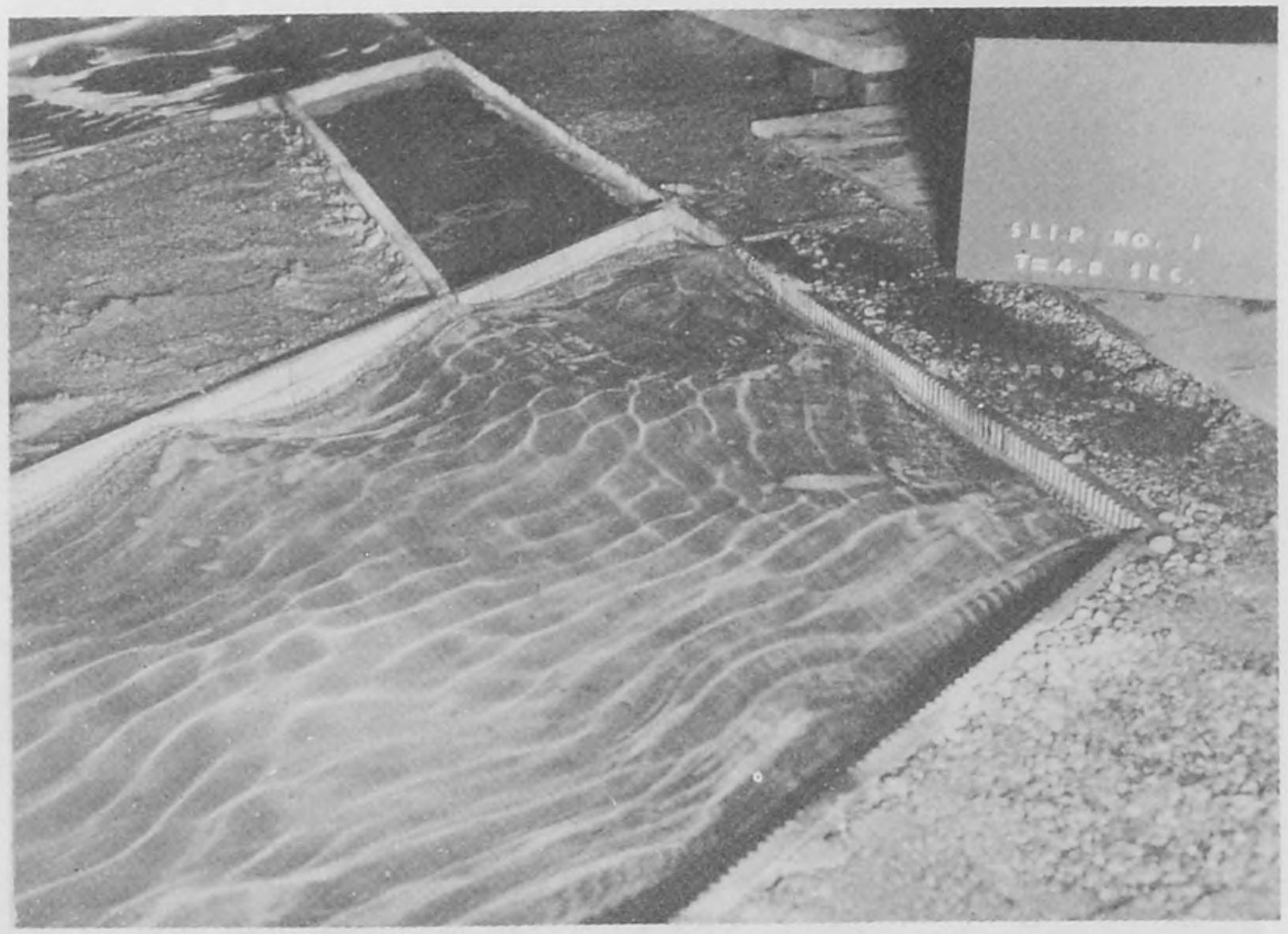


Original Condition

Solid Barrier-Type A



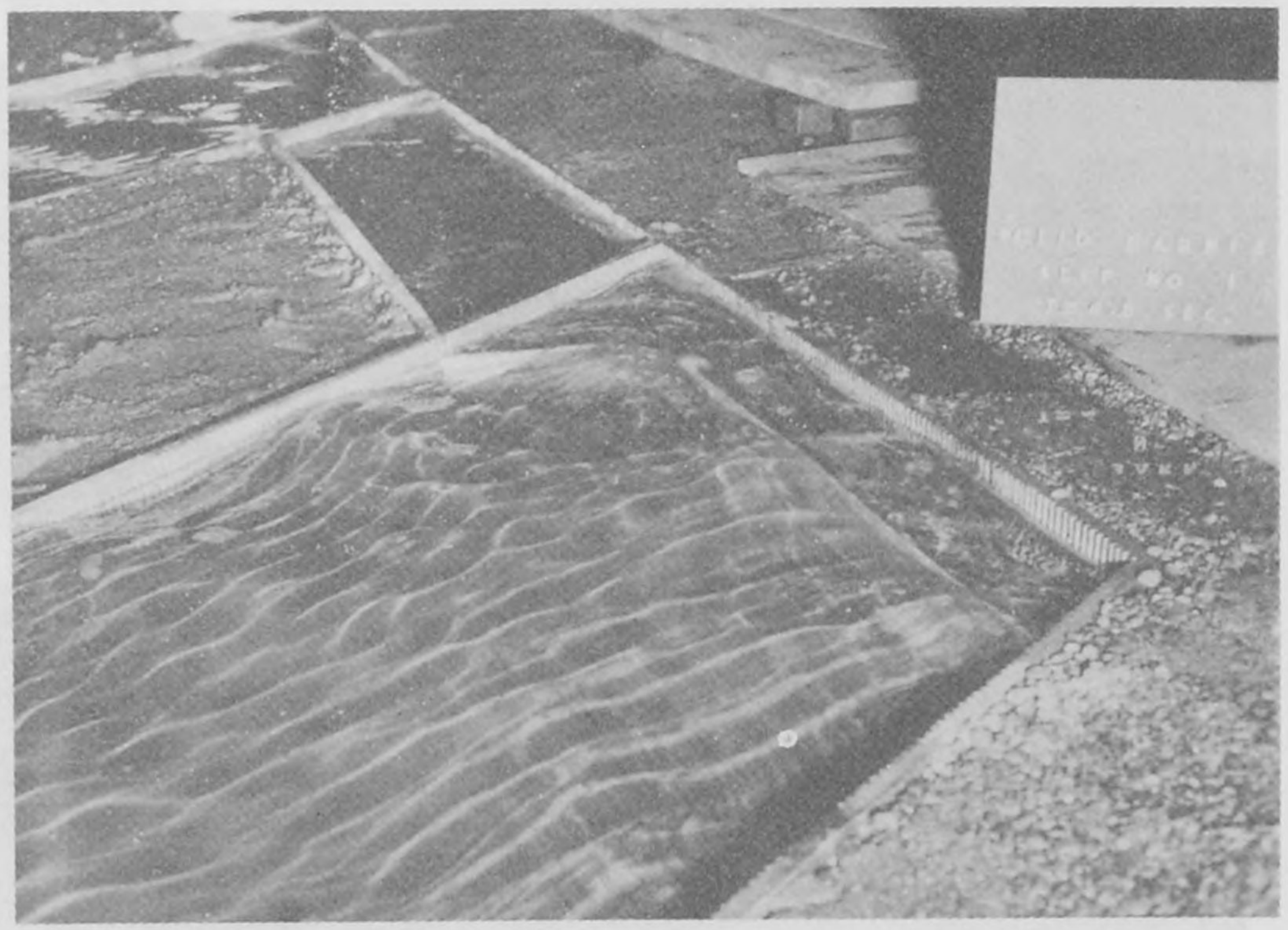
Permeable Barrier-Type B



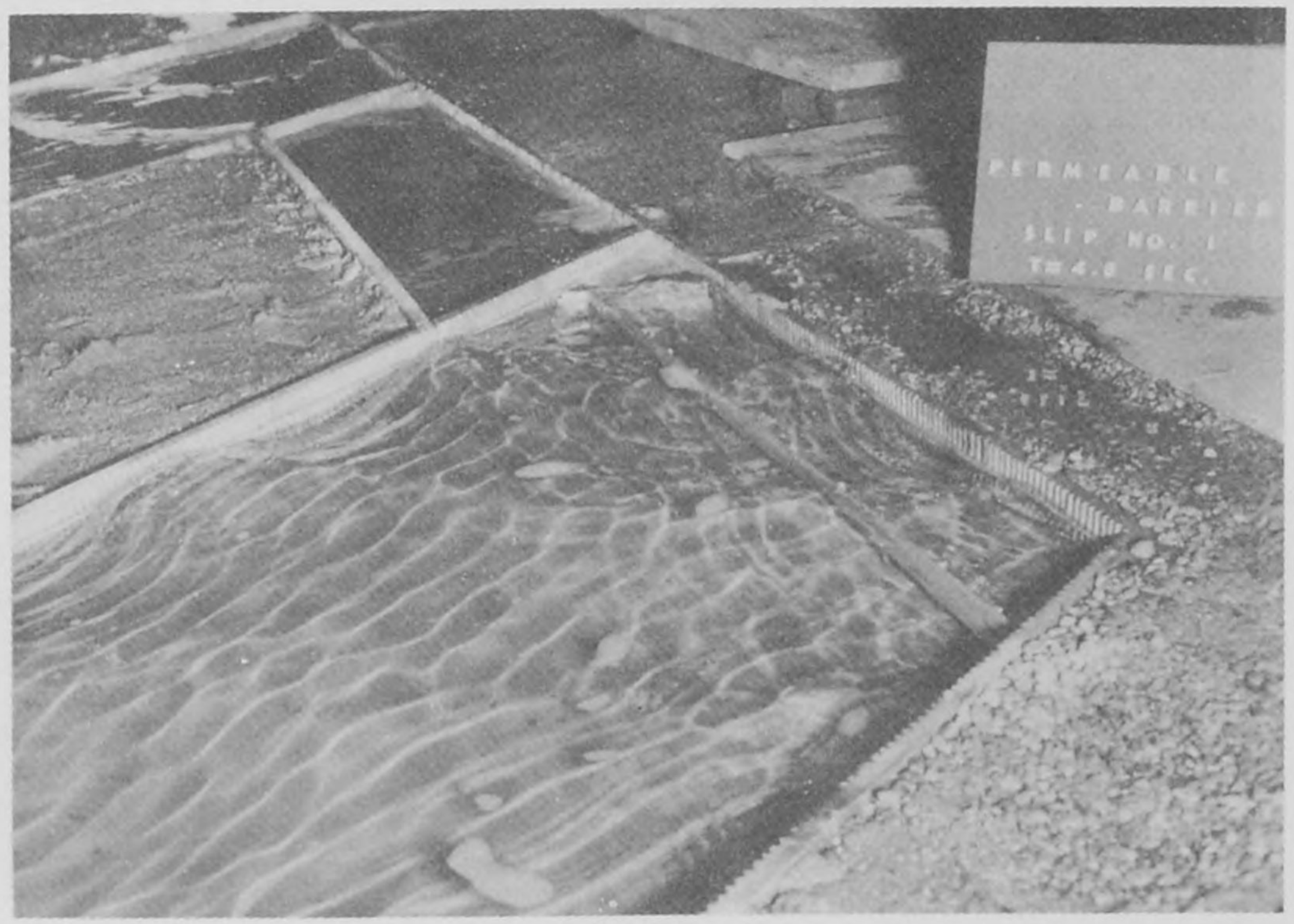

Original Condition

Figure 11

The Effect of Submerged Barriers on Conditions in Slip 1
Wave period 4.8 Seconds
Wave Machine in Position 2



Solid Barrier-Type A



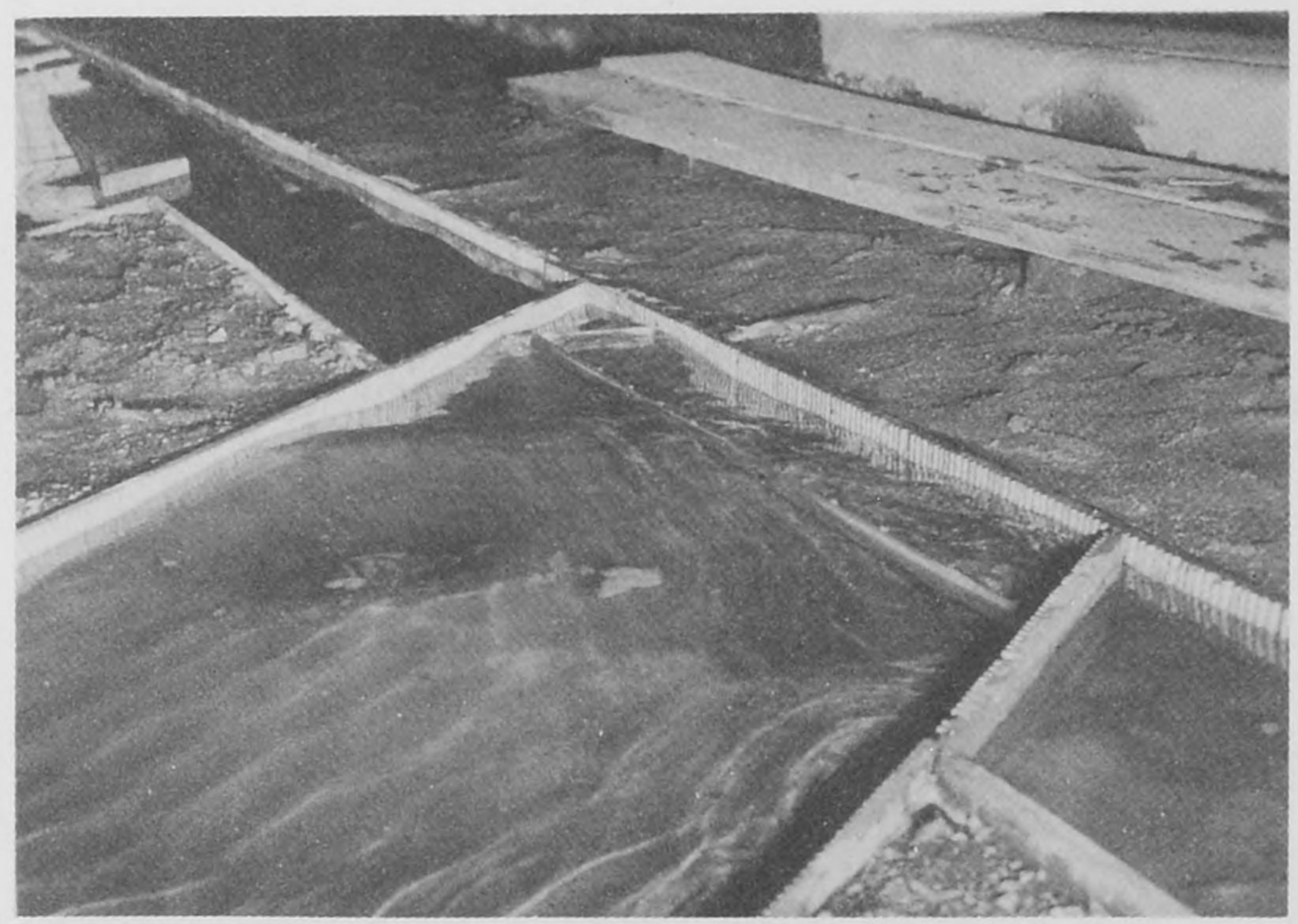

Permeable Barrier-Type B

Figure 12

The Effect of Submerged Barriers on Conditions in Slip 2
Wave Period 5.5 Seconds
Wave Machine in Position 2

Original Condition

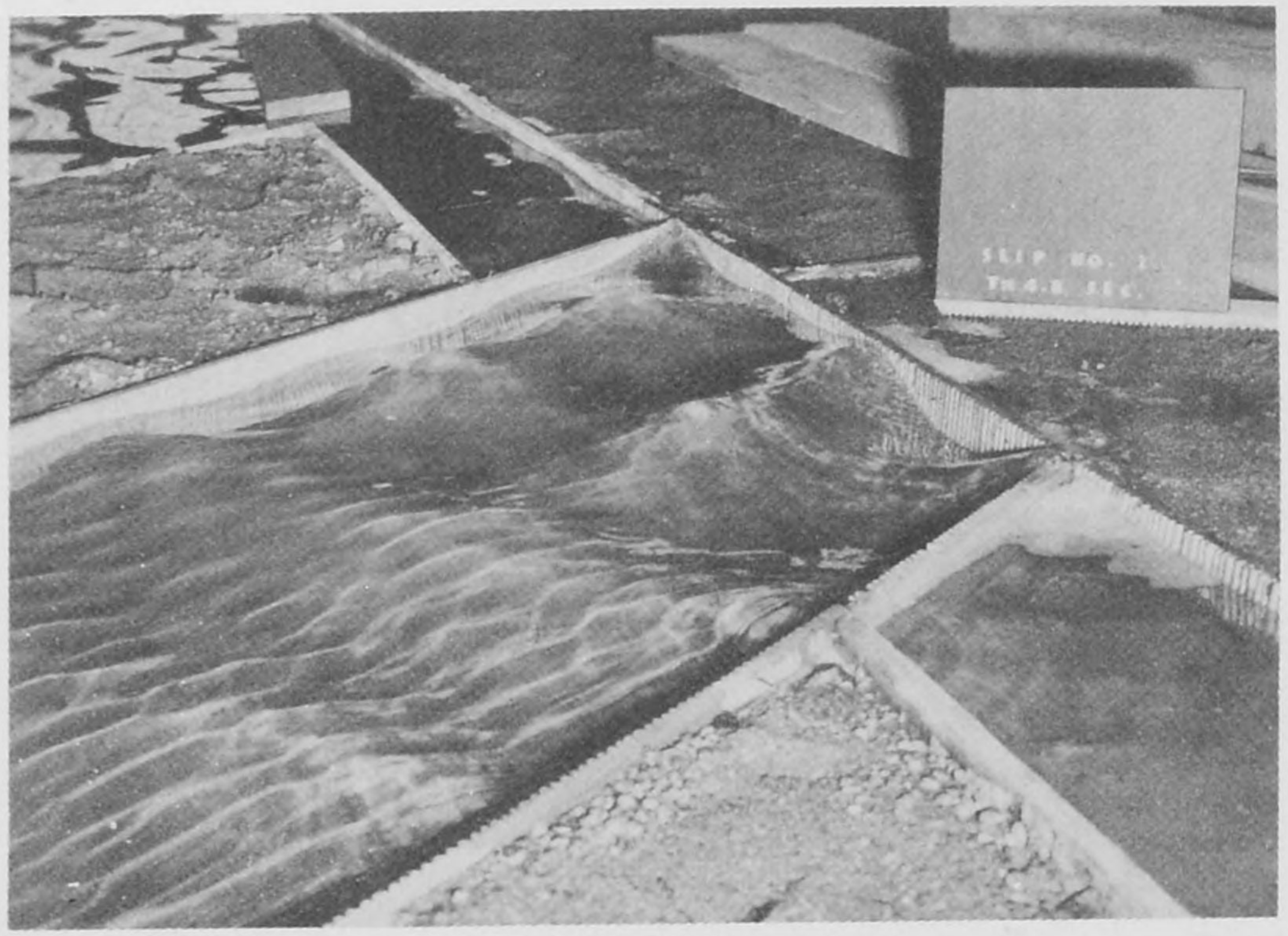
Solid Barrier-Type A



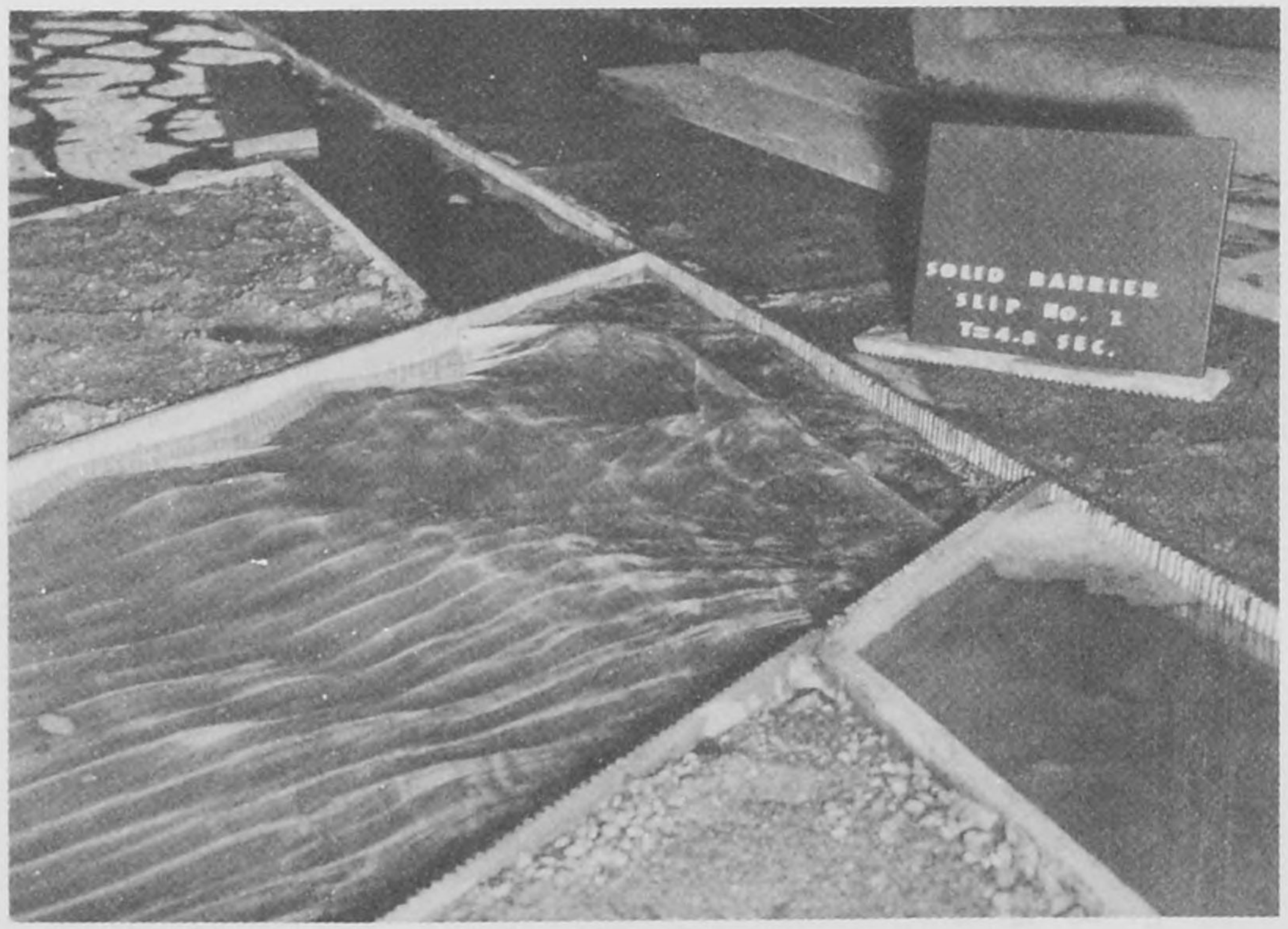
Permeable Barrier-Type B

Figure 13

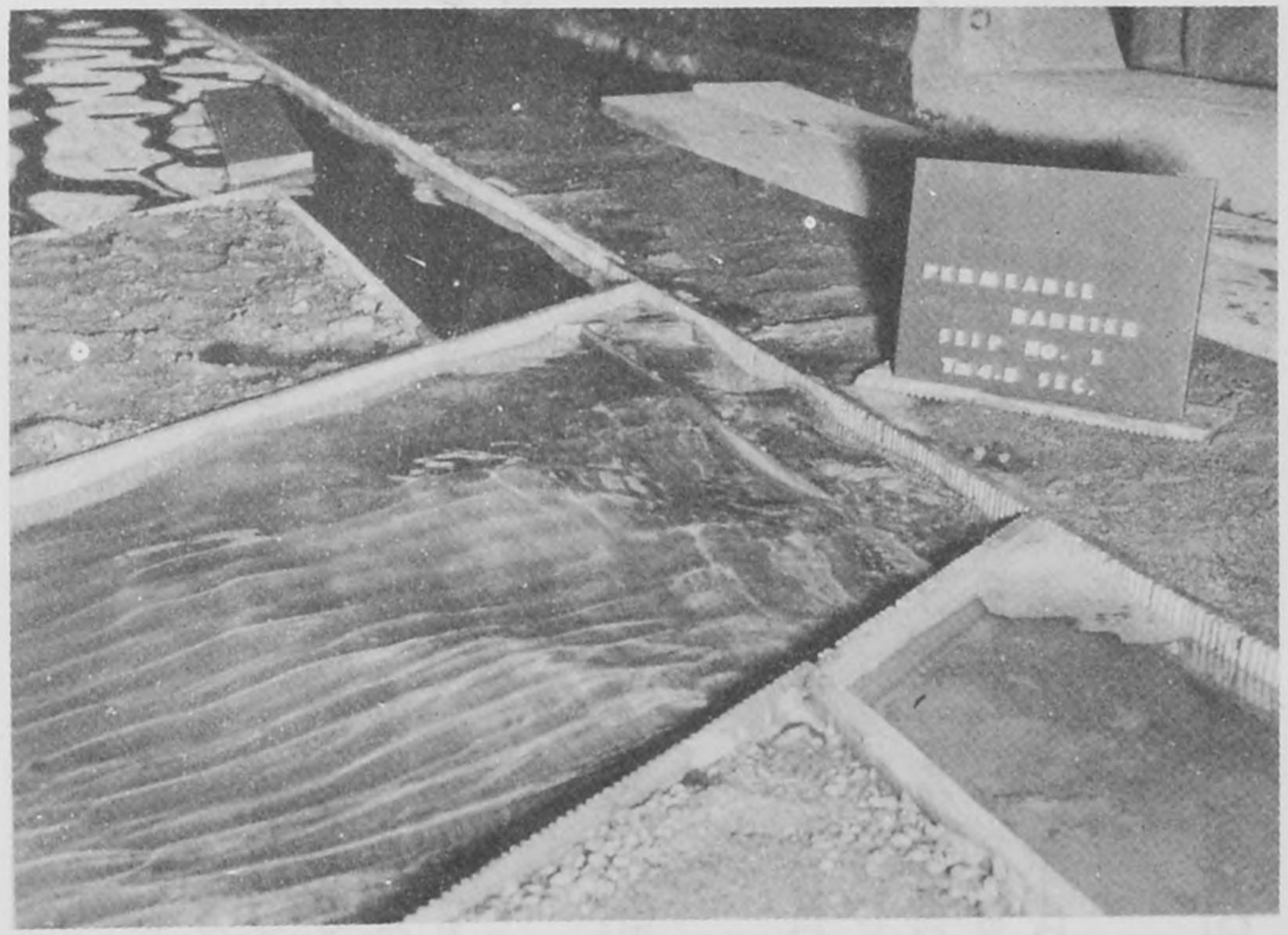
The Effect of Submerged Barriers on Conditions in Slip 2
Wave Period 4.8 Seconds
Wave Machine in Position 2




Original Condition




Solid Barrier-Type A




Permeable Barrier-Type B

### Compressed Air

Compressed air was discharged at various rates from a submerged pipe placed in Slip 1. The air was discharged across the entire entrance to the slip and at various other locations in the slip, both parallel to the end and parallel to the sides. In no case was there any noticeable decrease in the overtopping. On the basis of the model tests, this method of solving the problem is not feasible.

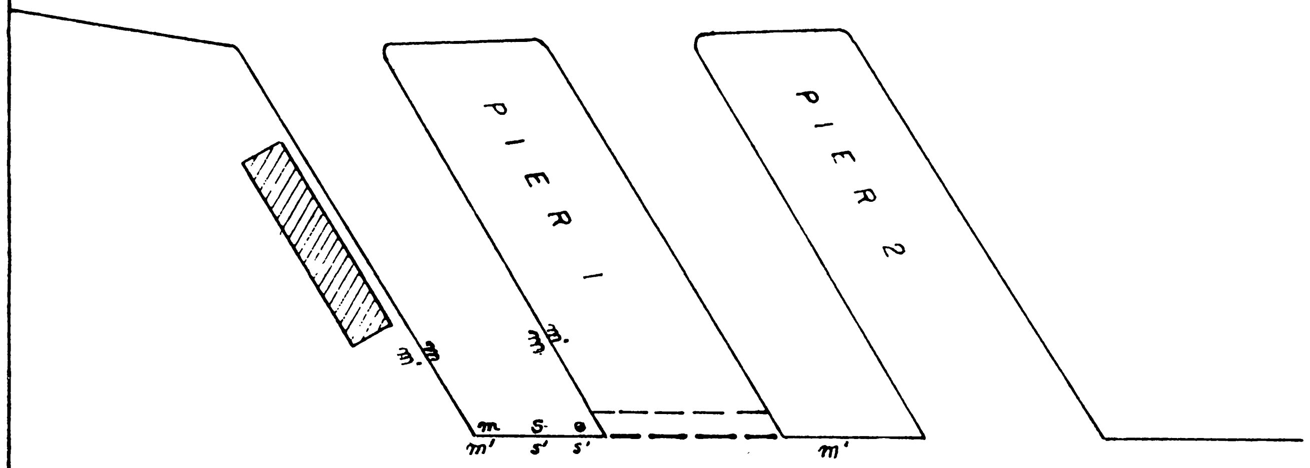
### Baffles at the Side of the Slip

It was found that the entire slip could be calmed and the overtopping stopped by constructing baffles on the north side of the slip as shown at the bottom of Table I, p. 39. These baffles stopped the reflected wave which combined with the original wave to cause the overtopping. This method was not considered to be practical because of its interference with the use of the dock, but it was of interest because it demonstrated the basic cause of the overtopping.

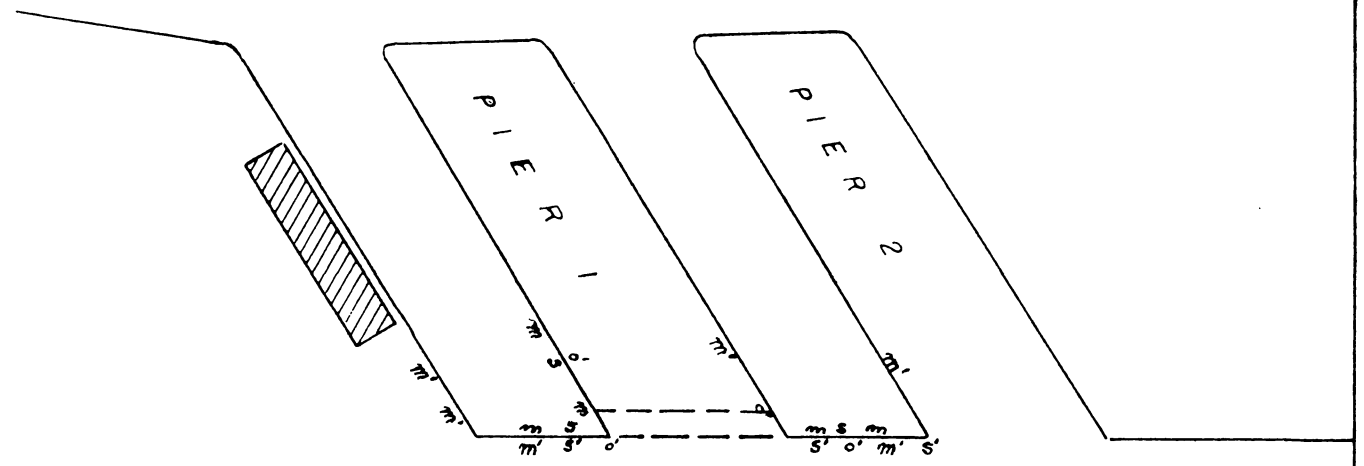
## RECOMMENDATIONS

The barriers shown in Figure 9, p. 15, gave excellent results. The solid barrier, designated as Type A, gave the best results. However, Type B, which is mostly of permeable construction, gave results that were nearly as good as Type A. Type B is recommended because of the greater economy of construction.

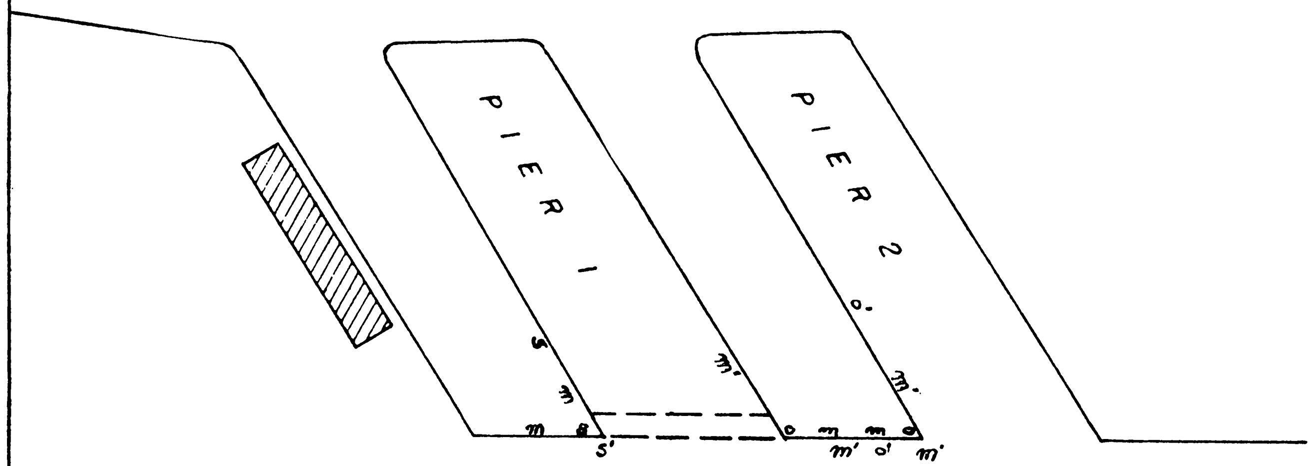
APPENDIX



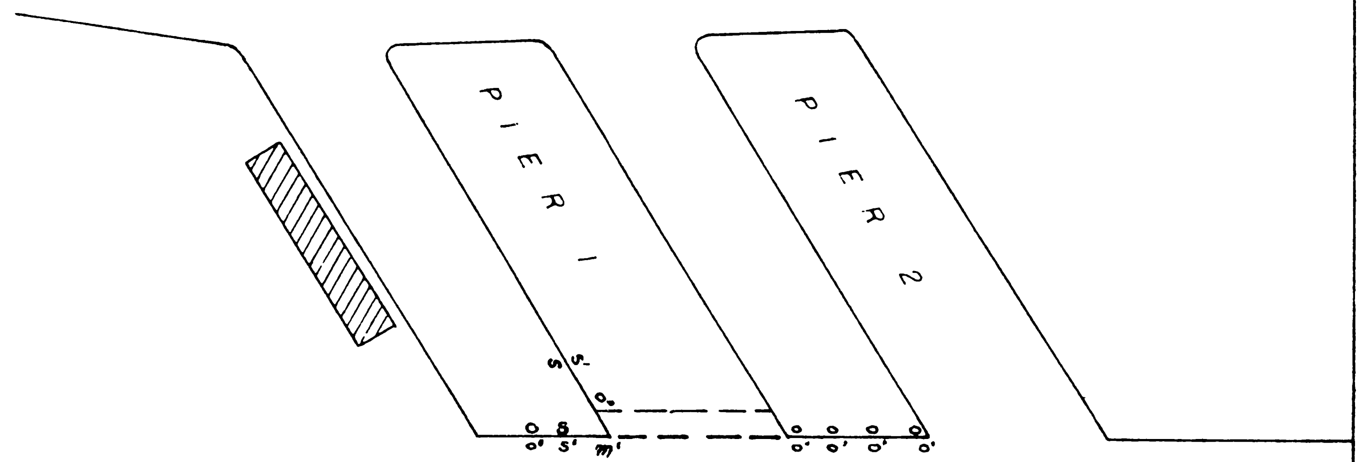

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

SYMBOLS

o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

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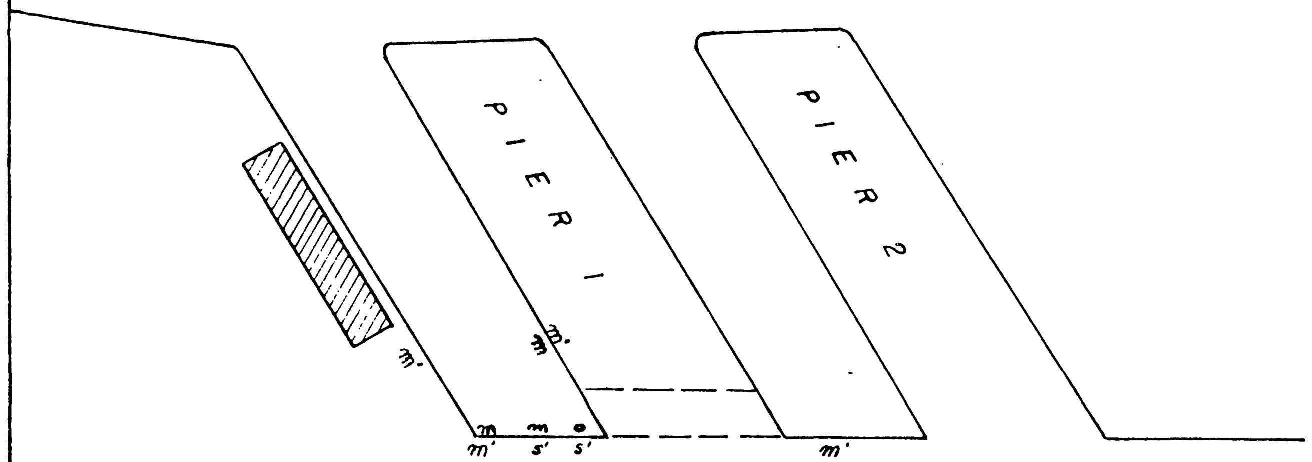
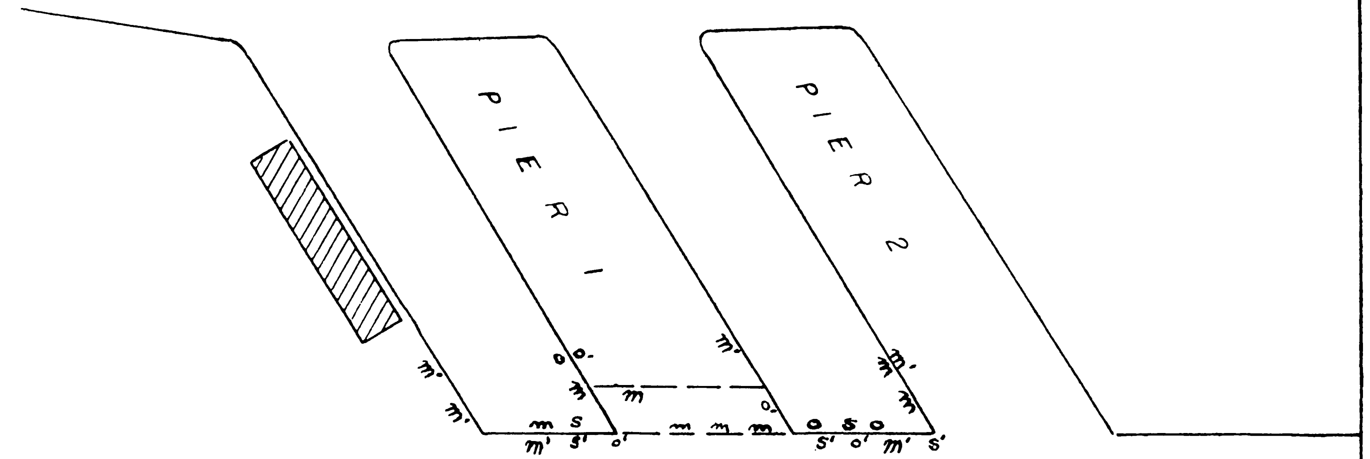
**MILWAUKEE HARBOR**
EFFECT OF CHANNELS

50' channel in Pier 1
No channel in Pier 2

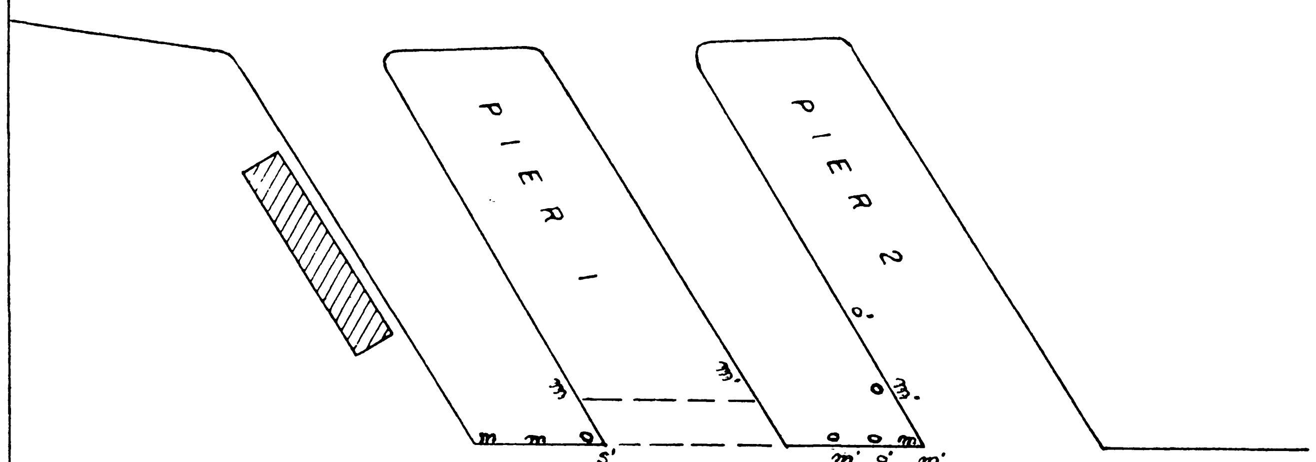
Drawing No. 4



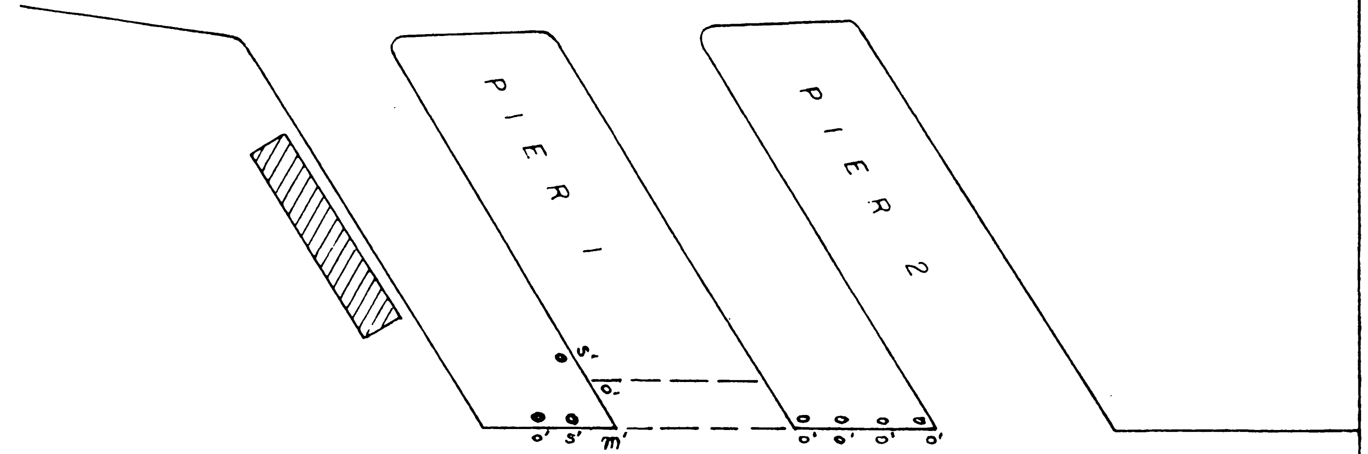

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1

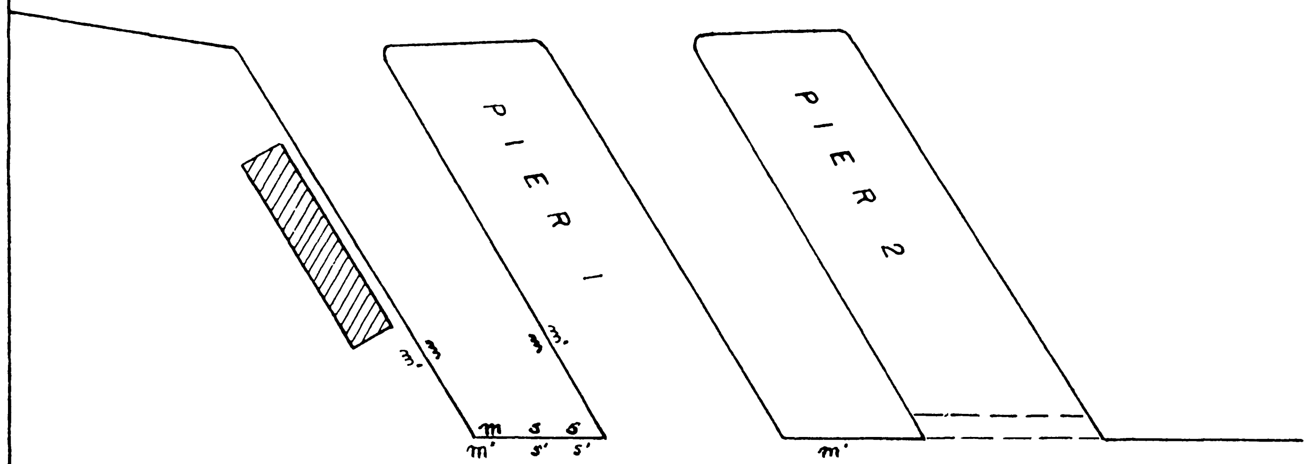



FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

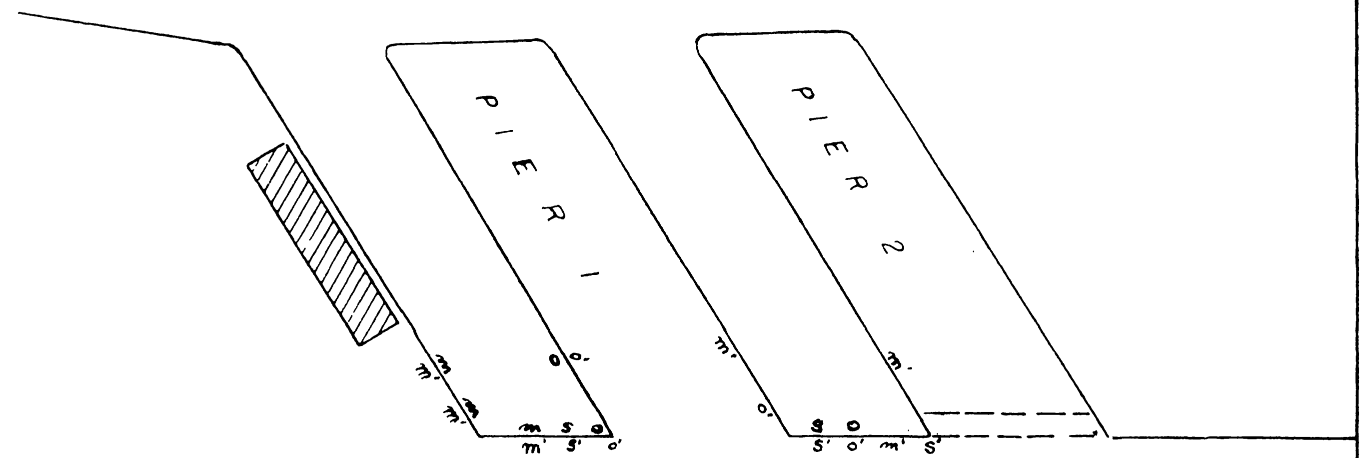
SYMBOLS

o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

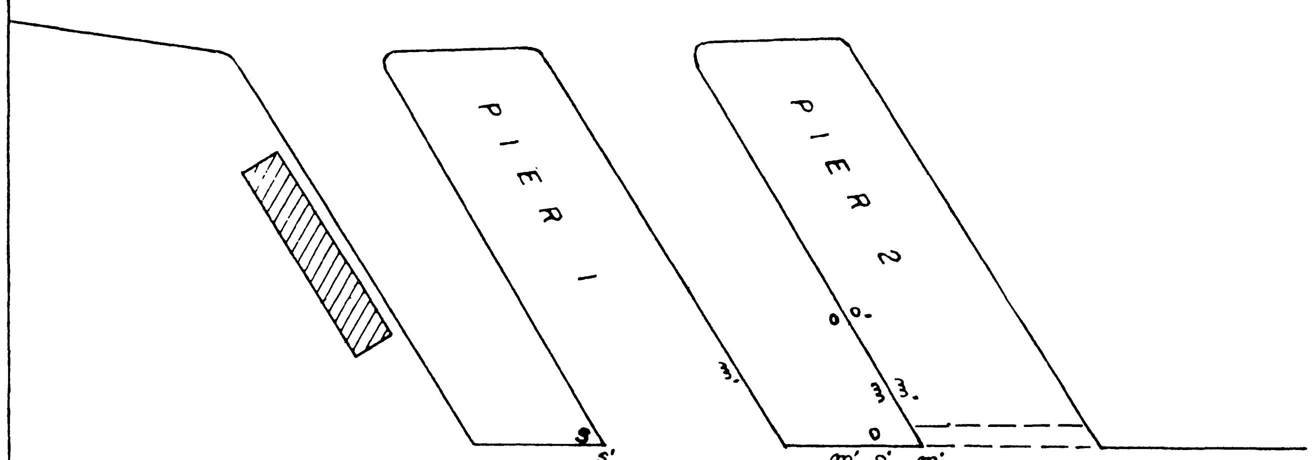
ENGINEERING RESEARCH INSTITUTE
**MILWAUKEE HARBOR**
EFFECT OF CHANNELS
100' channel in Pier 1
No channel in Pier 2
Drawing No. 5



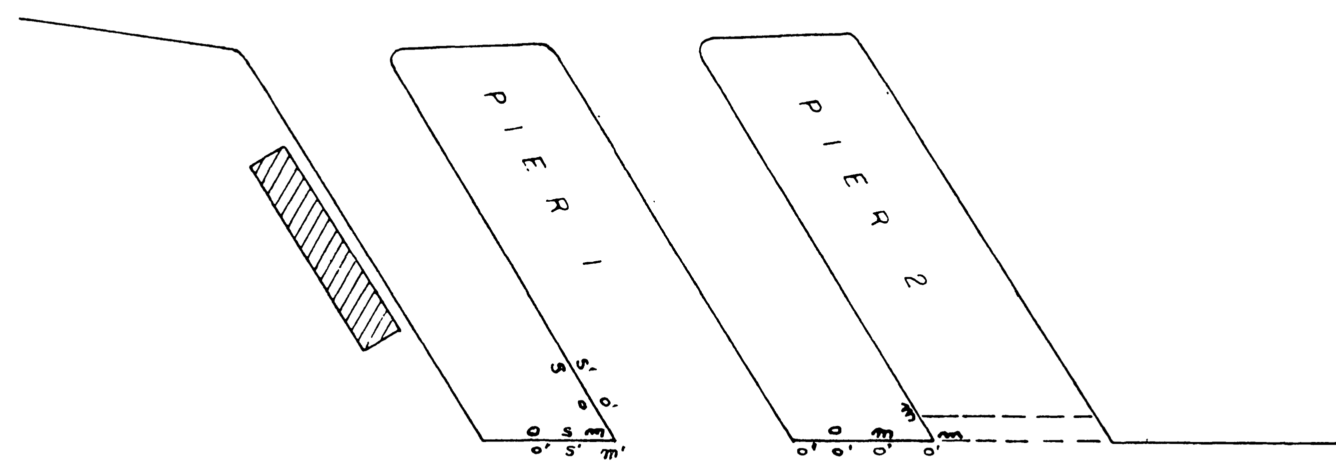

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

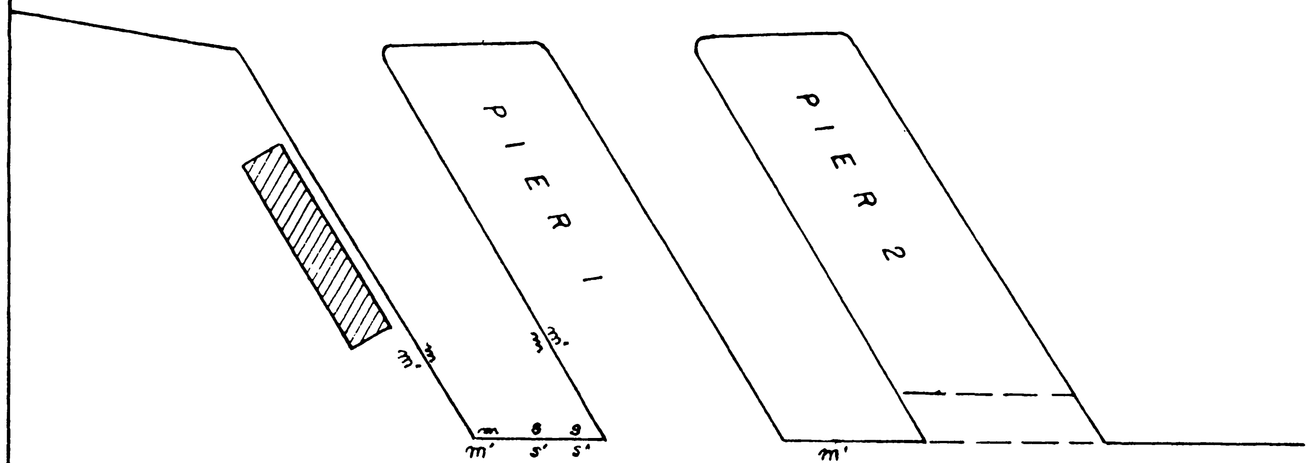
SYMBOLS

o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

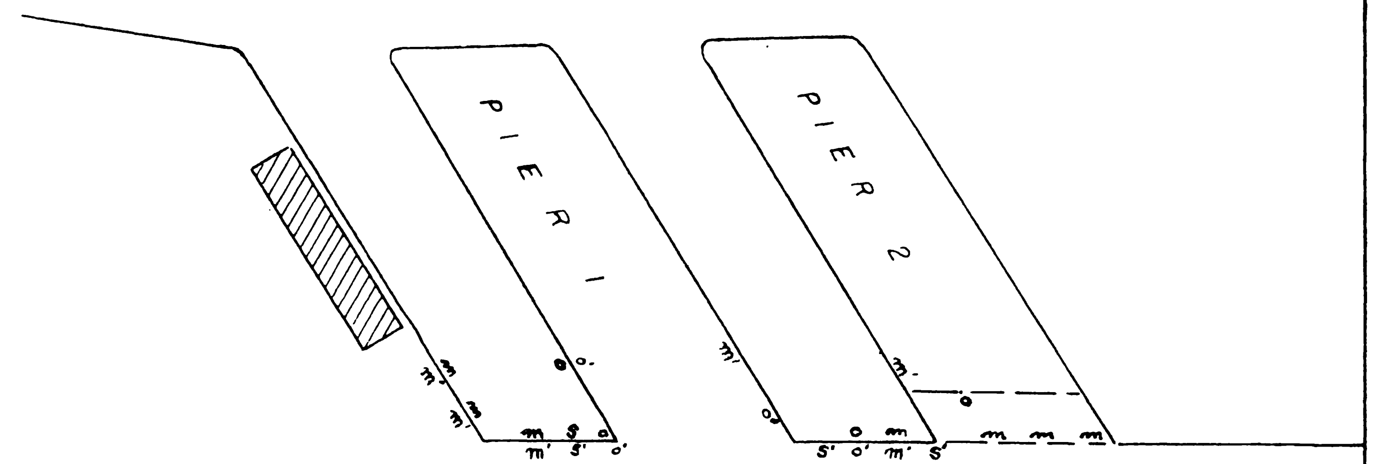
ENGINEERING RESEARCH INSTITUTE
**MILWAUKEE HARBOR**
EFFECT OF CHANNELS

**No** channel in Pier 1
**50'** channel in Pier 2

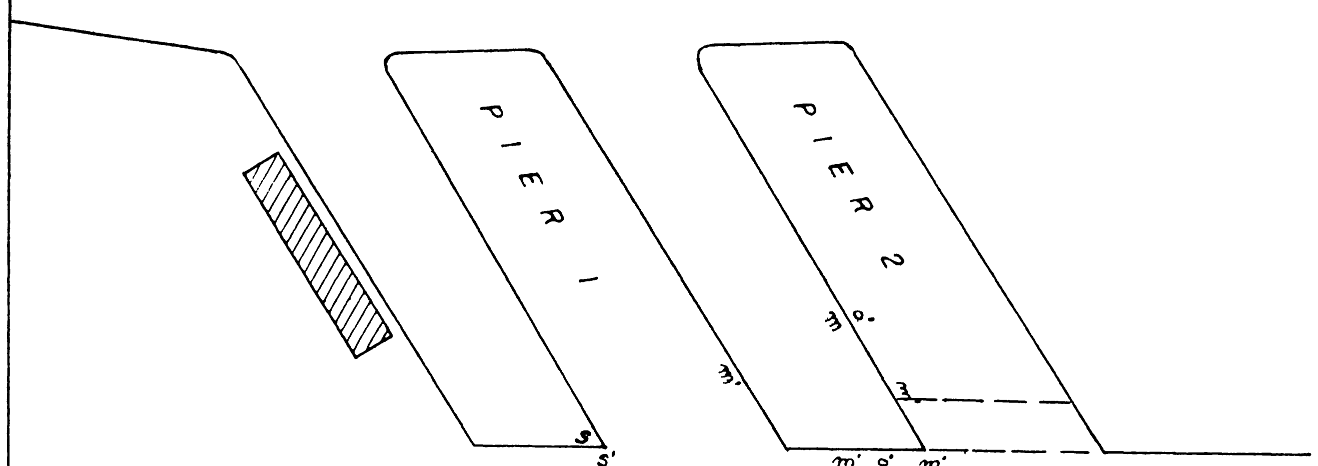
Drawing No. 6



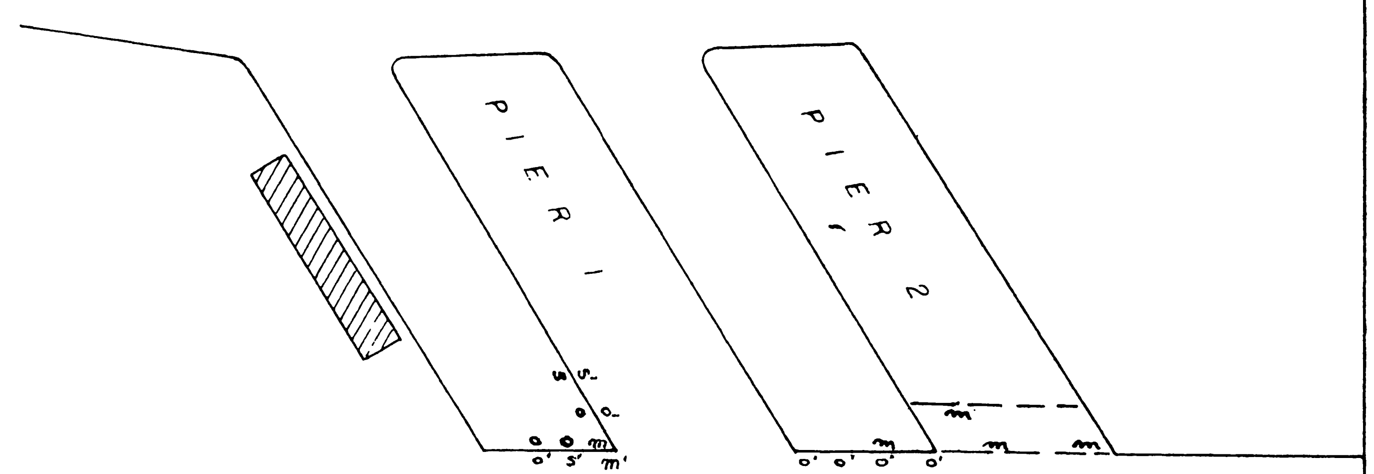

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1

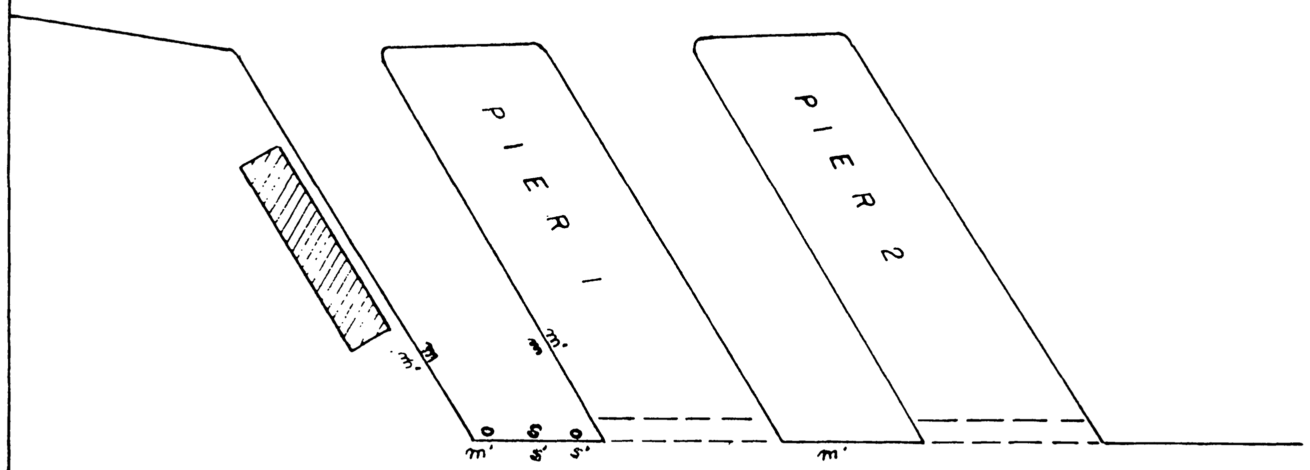



FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

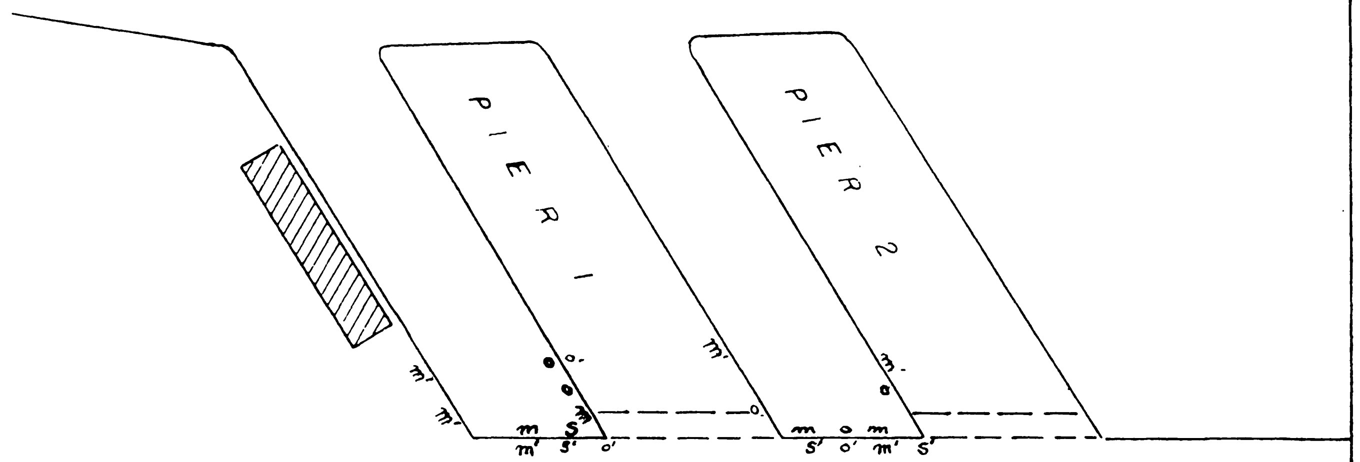
SYMBOLS

o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

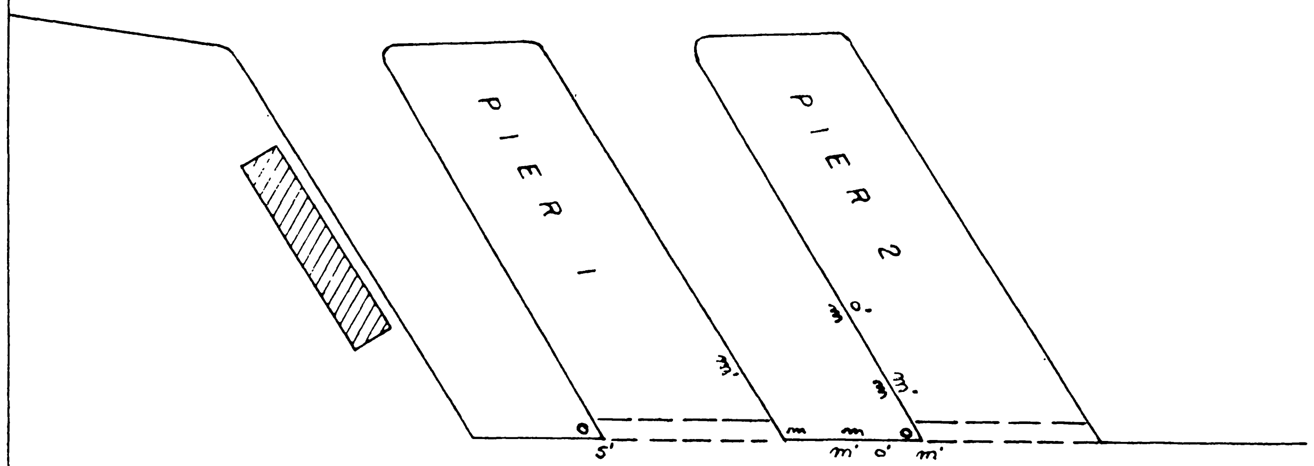
ENGINEERING RESEARCH INSTITUTE
**MILWAUKEE HARBOR**
EFFECT OF CHANNELS
No channel in Pier 1
100' channel in Pier 2
Drawing No. 7



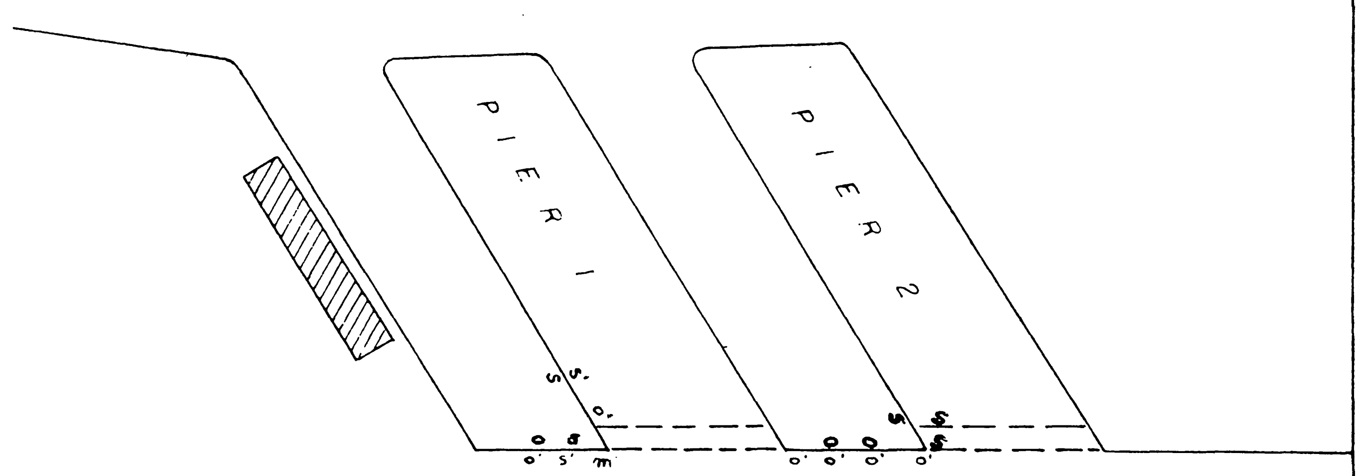

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

SYMBOLS

o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

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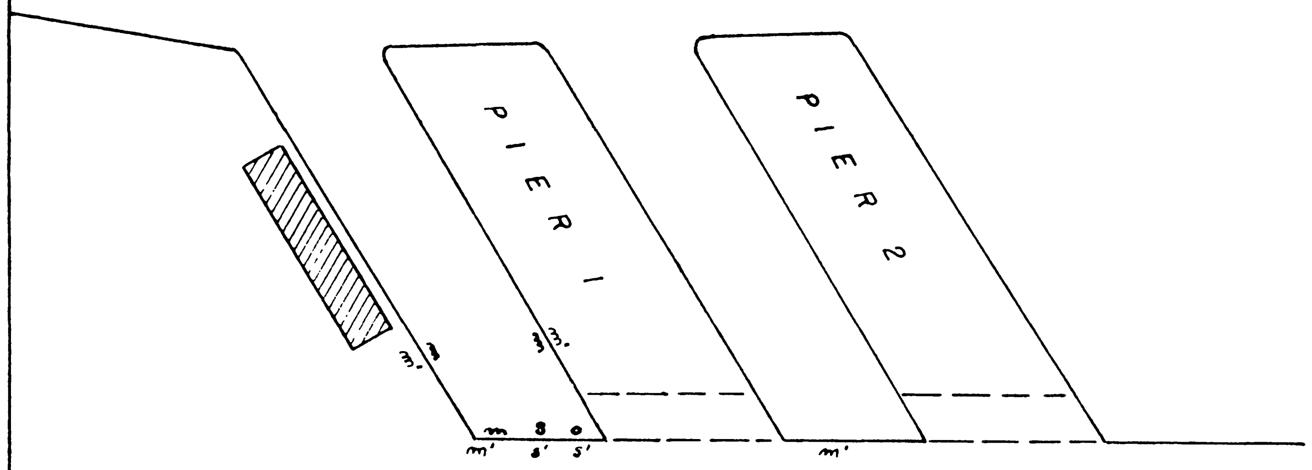
**MILWAUKEE HARBOR**

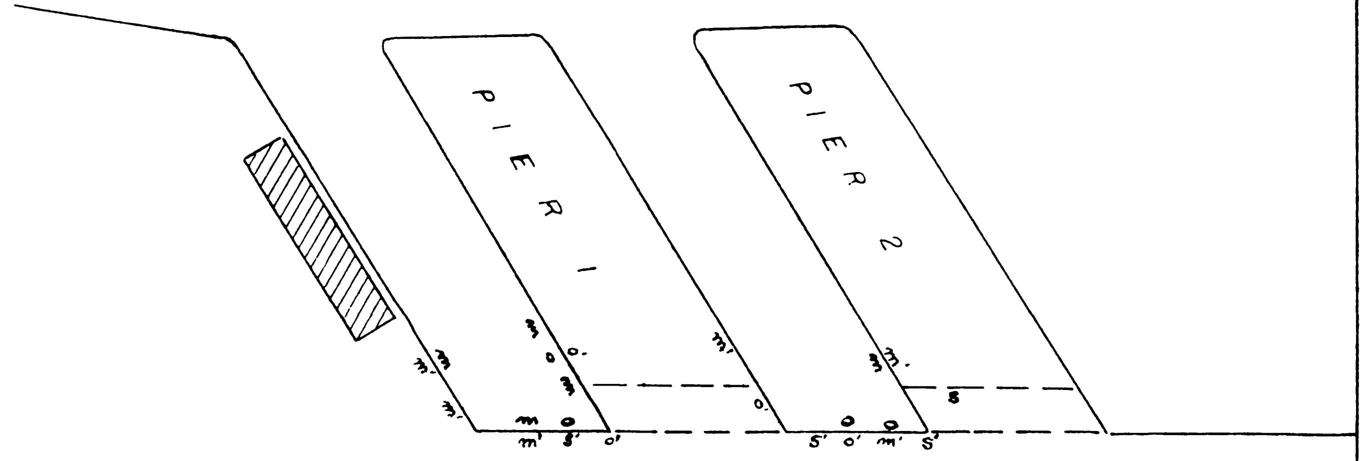
EFFECT OF CHANNELS

**50'** channel in Pier 1
**50'** channel in Pier 2

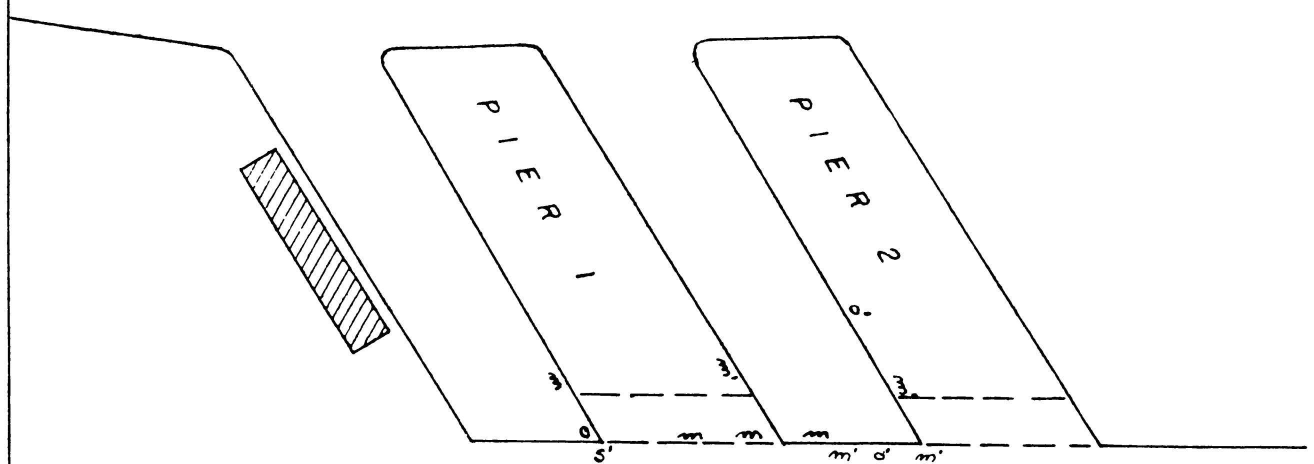
Drawing No. 8



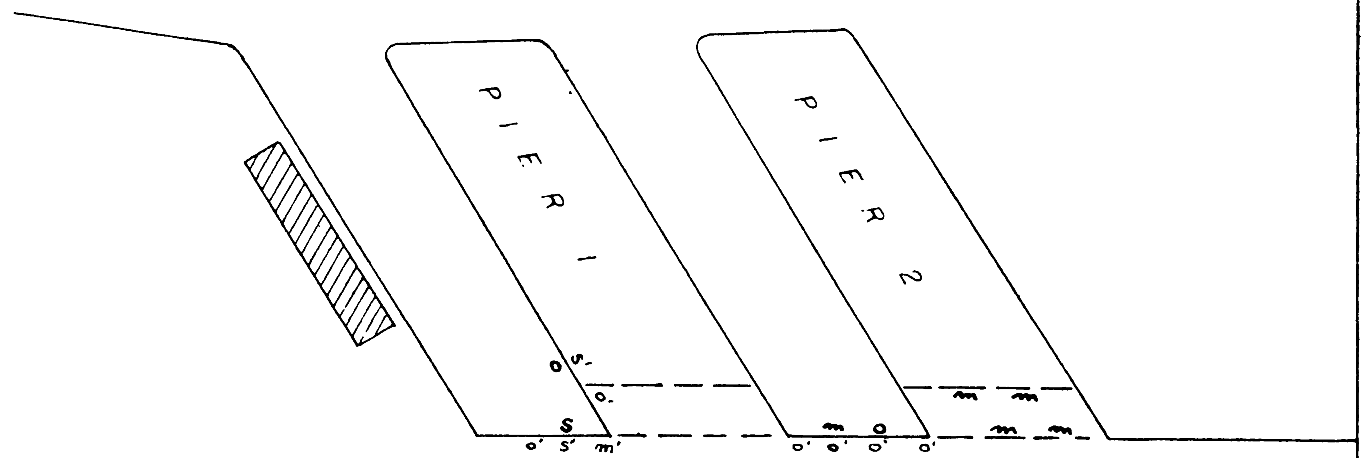

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

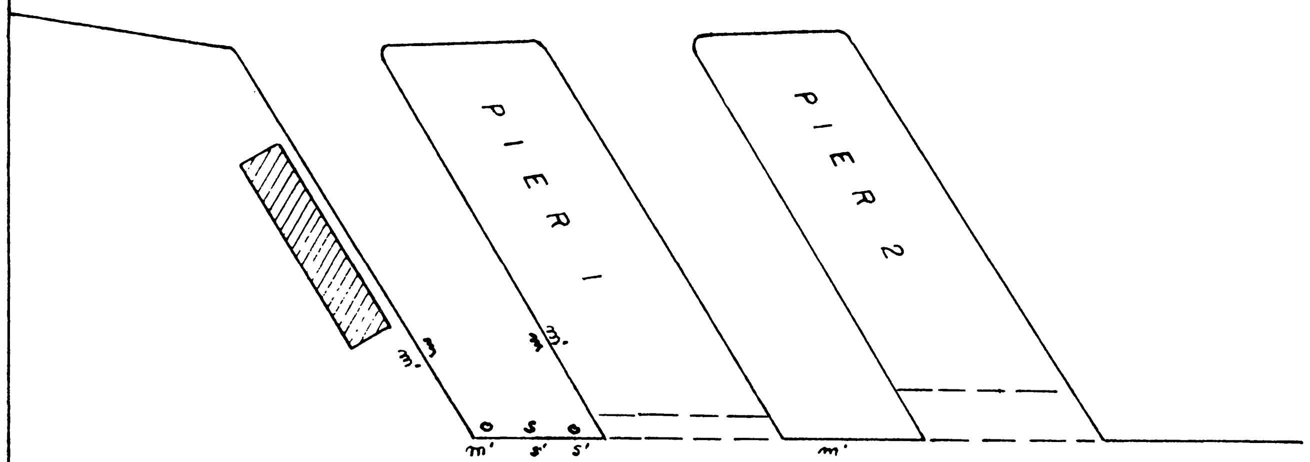
SYMBOLS

o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

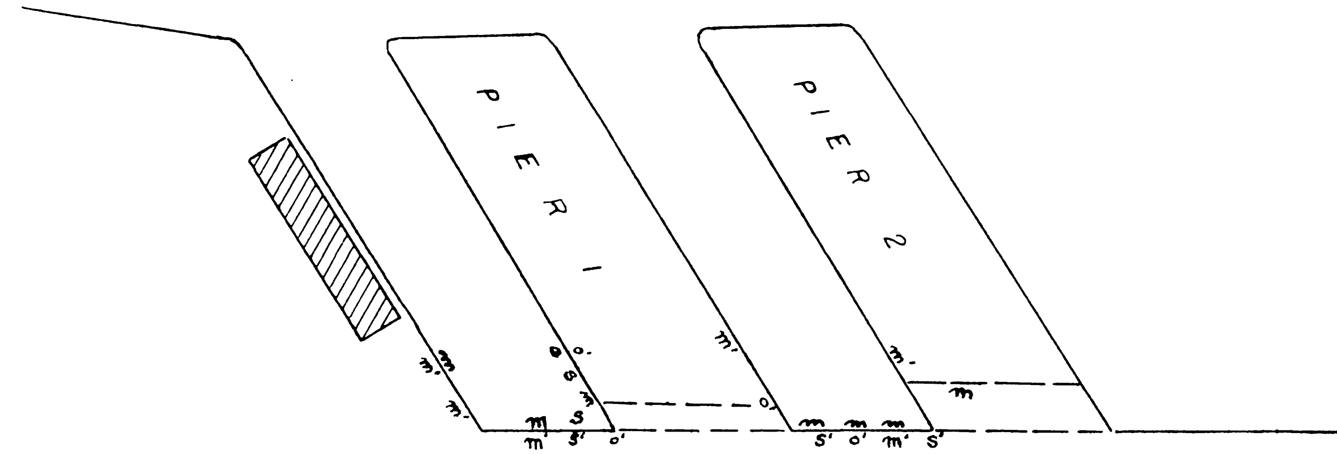
ENGINEERING RESEARCH INSTITUTE
**MILWAUKEE HARBOR**
EFFECT OF CHANNELS

100' channel in Pier 1
100' channel in Pier 2

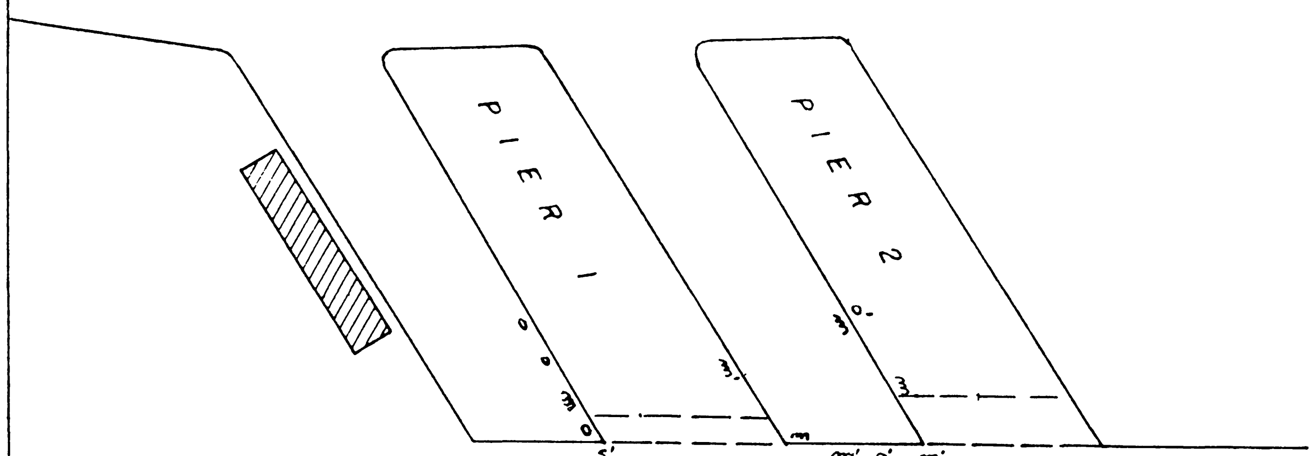
Drawing No. 9



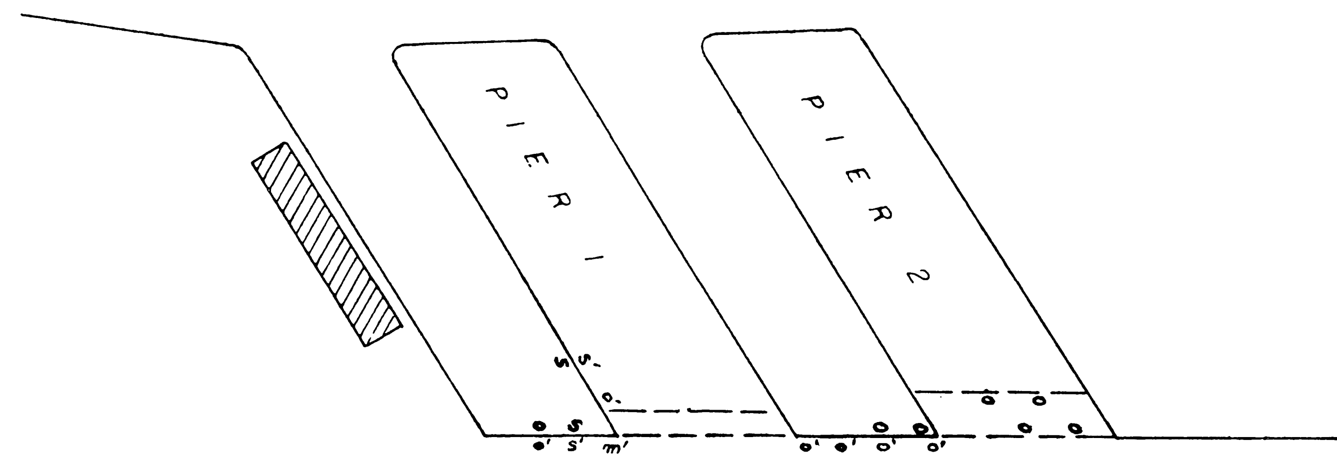

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

SYMBOLS

o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

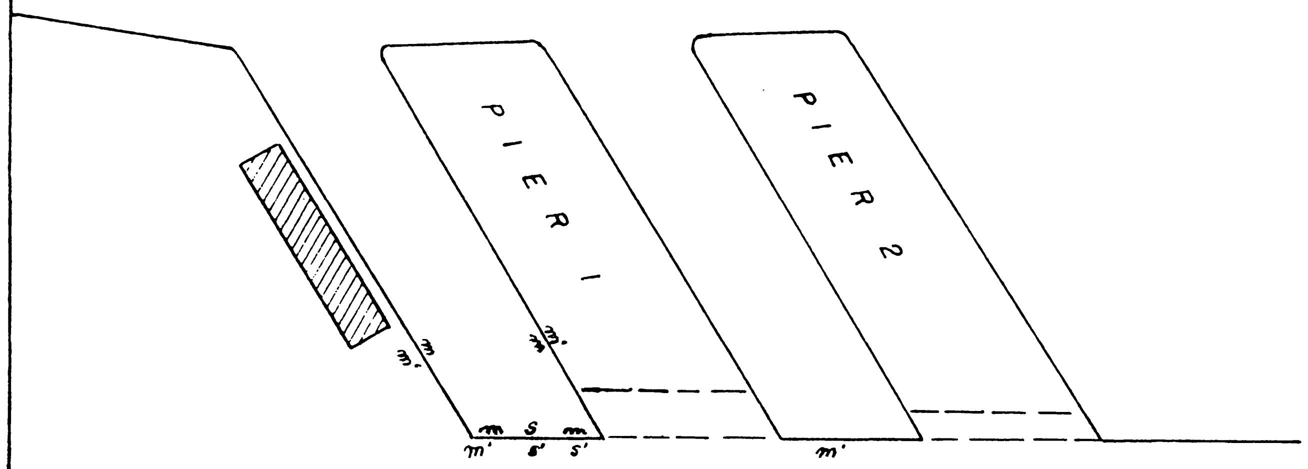
ENGINEERING RESEARCH INSTITUTE

**MILWAUKEE HARBOR**

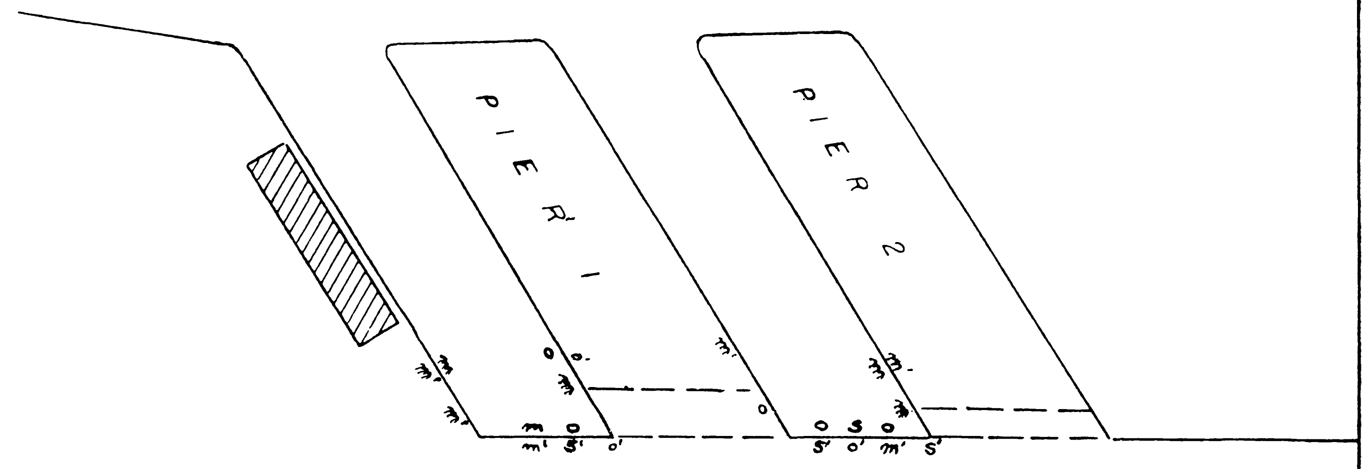
EFFECT OF CHANNELS

**50'** channel in Pier I
**100'** channel in Pier 2

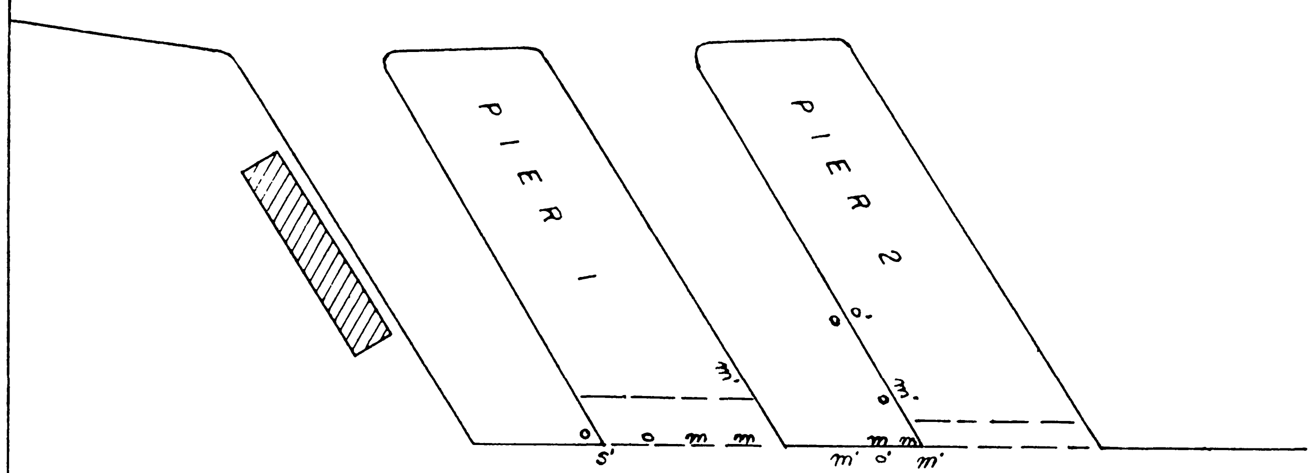
Drawing No. 10



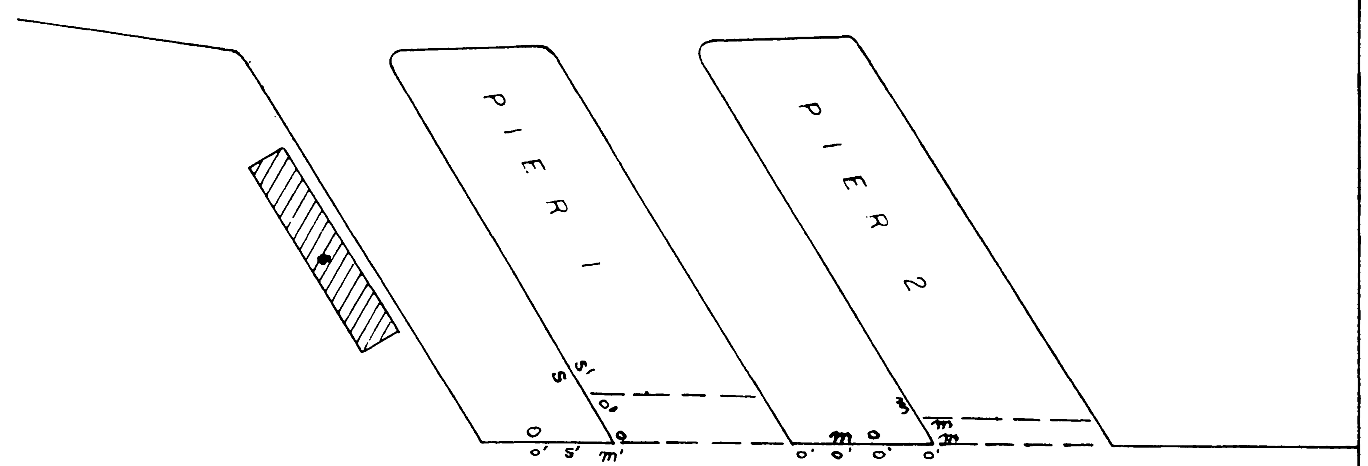

FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 4.8 SECONDS
WAVE MACHINE POSITION 2




FREQUENCY 5.5 SECONDS
WAVE MACHINE POSITION 1




FREQUENCY 5.0 SECONDS
WAVE MACHINE POSITION 2

SYMBOLS

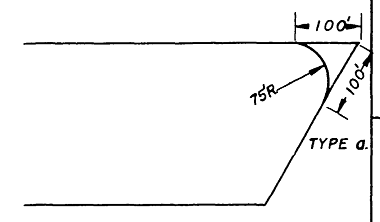
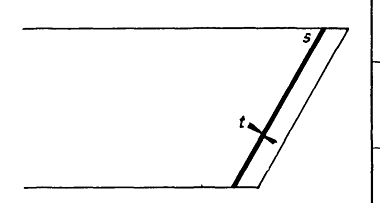
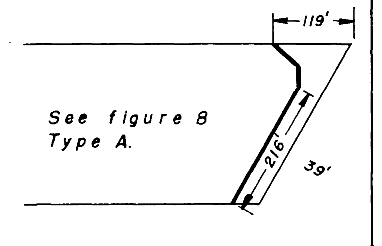
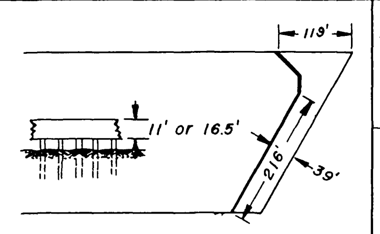
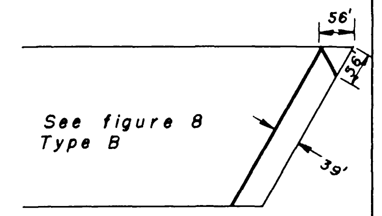
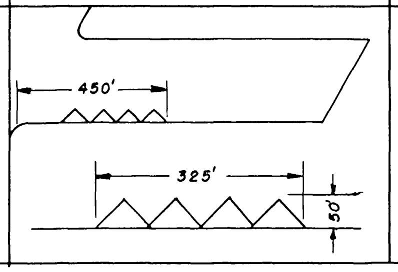
o - Location of overtopping.
s - Location of strong overtopping.
m - Location of mild overtopping.
Original condition designated as o', s', m'.
Final condition designated as o, s, m.

ENGINEERING RESEARCH INSTITUTE
**MILWAUKEE HARBOR**
EFFECT OF CHANNELS

100' channel in Pier 1
50' channel in Pier 2

Drawing No. 11

# TABLE I. THE EFFECT OF BARRIERS ON WAVE CONDITIONS

| BARRIER DESCRIPTION | BARRIER DRAWING | PERIOD OF WAVE IN SECONDS 4.8 | 4.95 | 5.1 | 5.5 | 5.9 | 6.1 | 6.5 | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| The conditions described are the original conditions in the slip produced by waves of the various frequencies. | | Overtopping occurs over the entire end of the slip including the northwest corner<br>Overtopping is not severe in the southwest corner. | Overtopping occurs in the southwest corner and at two other locations along the inner wall of the slip. | Overtopping occurs in the southwest corner and also approximately 50 feet north of the corner. | Spills over violently in southwest corner. | Overtops in southwest corner and at two other locations. | Overtops in southwest corner and at a point 50 feet north of southwest corner. | Spills over 75 feet north of southwest corner and nearly spills in northwest corner. | A small change in the period produces surging in the slip in various localities within the limits from 4.8 to 6.5 seconds. |
| Type "a" consists of a solid curved barrier, as shown on the drawing, having its upper edge at the still water surface.<br>Type "b" is the same as type "a" except the radius of curvature is shortened to make the barrier become tangent 75' from the corner. |  | Of practically no effect<br>a | Stops spilling except for one place. | Stops corner location only.<br>Stops both locations if elevated 3'. | Fairly effective. | | Quite effective. | Not effective. | Stops corner spilling but has little effect at other locations. |
| | | Of practically no effect<br>b | Stops spilling except for one place. | Very good. | Very effective. | | Quite effective. | Not effective. | Same as "a" but slightly more effective. |
| A solid barrier with the top edge at the still water surface, parallel to the rear wall, at a distance 25 to 35 feet from it.<br>For "a", dimension t is 1.5'<br>For "b", dimension t is 4.5'<br>For "c", dimension t is 22.0' |  | Quite effective but spilling occurs at s. Waves run from N. to S. behind wall.<br>a | Very effective. | Fairly effective but still spills at "s". | Only partially effective. | Nearly stops overtopping in corner but spills at s. | Still spills in southwest corner. | Quite effective. | Prevents spilling along rear wall but causes a poor condition at s. |
| | | Same as for "a".<br>b | Very effective. | Same as "a". | Same as "a". | Same as "a". | Same as "a". | Same as "a". | Variation of width of barrier has little effect. |
| | | Same as for "a".<br>c | Very effective. | Same as "a". | Same as "a". | Same as "a". | Same as "a". | Same as "a". | Same as "b". |
| A solid curved barrier with the top edge at the still water surface. The parallel portion is located 39' from the rear wall.<br>Enlarged drawings and photographs of this device are shown elsewhere in this report. | See figure 8 Type A.<br> | Very effective.<br>No overtopping. | Very effective. | Very effective. | Very effective. | Very effective. | Very effective | Very effective. | Gives effective results for all frequencies. Good both at corner and along rear wall.<br>Location of parallel wall should be about 1/4 wave-length from rear wall. |
| A permeable, curved barrier of the same shape and dimension as that above.<br>Type "a" has a solid section extending 11' below the still water surface.<br>Type "b" has a solid section extending 16.5' below the still water surface. |  | Overtops in southwest corner and along wall. A short solid barrier added across the corner prevents overtopping there.<br>a | Nearly stops all except corner spilling. | Still spills in southwest corner. | Not effective. | | | | Does not give protection to the corner. Narrow wall is not as effective as the wider one. |
| | | Overtops only in the southwest corner. A short solid barrier added across the corner prevents overtopping there.<br>b | Only corner spills. | Same as "a". | Same as "a". | | | | |
| A short straight solid barrier extends across the acute angle, and a permeable barrier 11' in depth parallels the rear wall.<br>Enlarged drawings and photographs are shown elsewhere in this report. | See figure 8 Type B<br> | Effective.<br>No overtopping. | Very effective. | Very effective. | Very effective. | Very effective. | Very effective. | Very effective. | Gives effective results for all frequencies.<br>Small solid barrier in the corner in combination with a narrow permeable barrier across rear wall gives effective protection. |
| This device consists of four small triangular stilling wells located along the north wall of the slip. The top edges are at the still water surface, the walls are solid and extend to the bottom of the slip. |  | Effective.<br>Quiets slip. | Effective.<br>Quiets entire slip. | Effective.<br>Quiets slip. | Effective.<br>Quiets slip. | Effective. | Effective.<br>Quiets slip. | Effective. | This device calms the entire slip and reduces the wave height therein. No overtopping occurs but the location of the barrier is detrimental to the operation of the slip. |

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# AIIM SCANNER TEST CHART # 2

## Spectra

4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
8 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
10 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789

## Times Roman

4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
8 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
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## **Century Schoolbook Bold**

**4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789**
**6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789**
**8 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789**
**10 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789**

## News Gothic Bold Reversed

4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
8 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789
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## *Bodoni Italic*

*4 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789*
*6 PT ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz;:",./?$0123456789*
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## Greek and Math Symbols

4 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋗⋖≡
6 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋗⋖≡
8 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋗⋖≡
10 PT ΑΒΓΔΕΞΘΗΙΚΛΜΝΟΠΦΡΣΤΥΩΧΨΖαβγδεξθηικλμνοπφρστυωχψζ≧∓",./≦±=≠°><⊁⊀⋗⋖≡

White

Black

Isolated Characters

| | | | | | |
|---|---|---|---|---|---|
| e | m | 1 | 2 | 3 | a |
| 4 | 5 | 6 | 7 | o | • |
| 8 | 9 | 0 | h | I | B |

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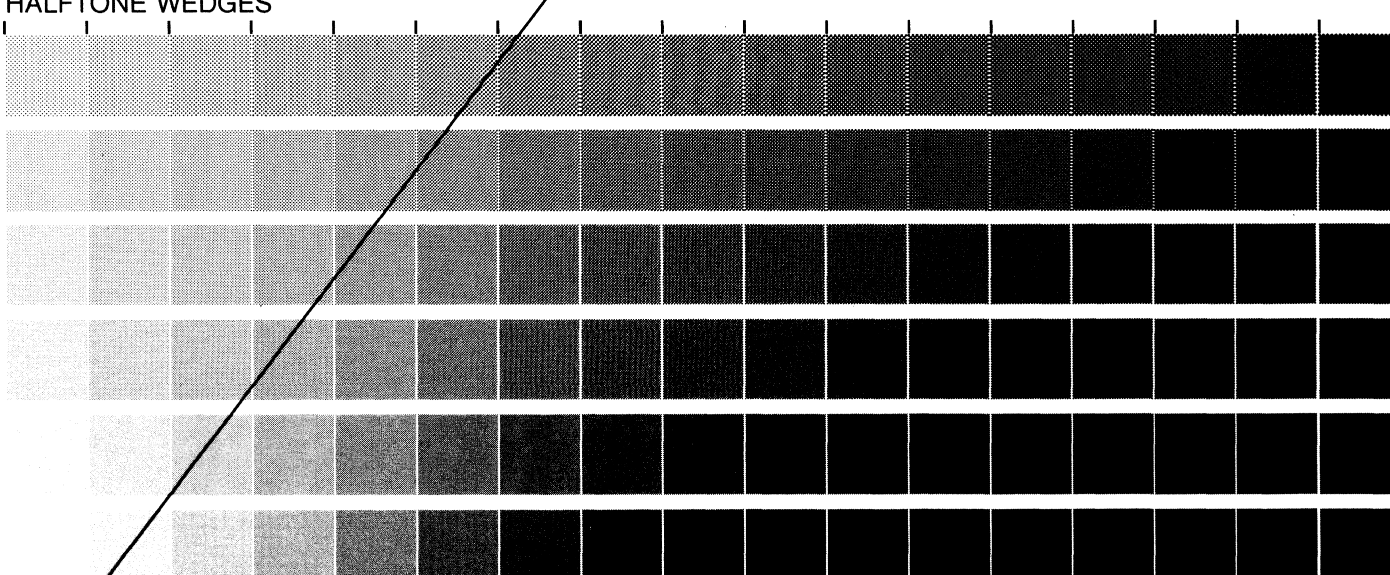
MESH HALFTONE WEDGES

65
85
100
110
133
150



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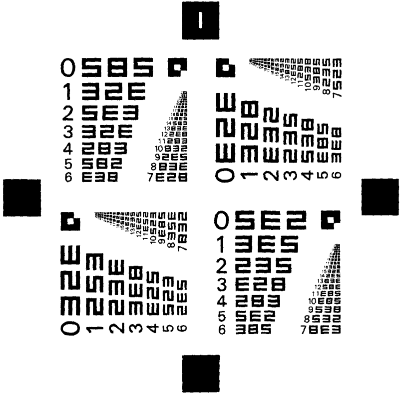
RIT ALPHANUMERIC RESOLUTION TEST OBJECT, RT-1-71

PRODUCED BY GRAPHIC ARTS RESEARCH CENTER



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MEMORIAL DRIVE, ROCHESTER, NEW YORK 14623