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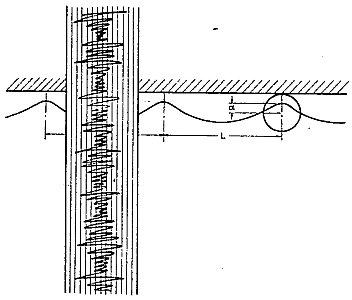
MODEL STUDY FOR HARBOR OF REFUGE FOR LIGHT DRAFT VESSELS AT HAMMOND BAY, MICHIGAN



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LAKE HYDRAULICS LABORATORY
DEPARTMENT OF CIVIL ENGINEERING
BY: E.F. BRATER

PROJECT M869 CONTRACT DA-22-079-ENG-10
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
UNITED STATES ARMY

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MODEL STUDY FOR HARBOR OF REFUGE

FOR

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BY

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MODEL STUDY FOR HARBOR OF REFUGE
FOR
LIGHT DRAFT VESSELS AT HAMMOND BAY, MICHIGAN

Hammond Bay is located on Lake Huron approximately forty miles southeast of the northern tip of Michigan's lower peninsula, as shown in Drawing 1, page 23. The harbor area is exposed to fetches varying from thirty miles to fifty-nine miles in a northerly sector extending approximately from the northwest to the east. The model study was made to determine the breakwater arrangement which will produce the most satisfactory conditions for vessels moored in, or entering the harbor. The most effective plan is determined primarily on the basis of wave conditions. However, the magnitudes of the currents were also determined for the various plans and they served as an additional basis for comparison. The final selection of the plan to be constructed will require a consideration of the relative costs of the various arrangements.

The study was made as a result of a contract, dated February 3, 1950, between the University of Michigan Engineering Research Institute and the Waterways Experiment Station, Corps of Engineers, U. S. Army.

Mr. R. Y. Hudson, Chief of the Wave Action Section of the Waterways Experiment Station, Corps of Engineers, visited the laboratory on two occasions and was kept informed regarding the results of the tests as the work progressed. Throughout the model study frequent consultations were held with

Messrs. H. F. Lawhead and C. E. Lee of the Hydraulics Branch of the Detroit District, Corps of Engineers. Mr. W. H. Booth, Jr., of the Great Lakes Division, Corps of Engineers, visited the laboratory on several occasions and kept in close touch with the progress of the work. Other personnel of the Detroit District, Corps of Engineers, who visited the project are Colonel Louis J. Rumaggi, former District Engineer, Lt. Colonel John D. Bristor, District Engineer, and Messrs. Tom C. Trelfa and Charles R. Dickinson.

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 and Professor C. W. Good is Assistant Director of the Engineering Research Institute. Ivan C. Crawford is Dean of the College of Engineering and Earnest Boyce is Chairman of the Department of Civil Engineering. The laboratory is under the supervision of Ernest F. Brater, Associate Professor of Civil Engineering. L. D. Stair was in charge of the construction and operation of the model. Other members of the staff who took part in the work are D. C. Woo, H. R. Bachman, and C. C. Young.

THE MODEL

The model was constructed in a tank having the dimensions 90 feet by 54 feet. An undistorted linear scale of 1 to 75 was used. This scale ratio provided a model of sufficient size to minimize the effects of the surface tension and viscosity forces. Consequently, the model results were interpreted on the basis of the Froude law. The corresponding scale ratio for time and velocity was 1 to 8.66. The model included an area which, in the prototype, extended somewhat over one mile in the east-west direction and approximately one-half mile in the north-south direction. A plan view of the wave tank showing the model limits is presented in Drawing 2, page 24. Templates were cut from 3/8-inch waterproof plywood in accordance with sounding data and topographic charts supplied by the Corps of Engineers. The templates were spaced at intervals of 1.33 feet in the vicinity of the harbor and at intervals of 4.00 feet in the more remote regions. The template layout is shown in Drawing 2. The space between the templates was filled with well compacted sand to within an inch of their top edges. A photograph of the model at this stage in the construction is shown in Plate 1, page 71. The upper inch was then filled with low-strength cement mortar which was finished by using the top edges of the templates as screeds. The model breakwaters were built to simulate vertical wall construction with a rip-rap fillet at the base. Typical cross sections are shown in Drawing 4, page 27. The vertical portion of the model breakwater was constructed of low-stress concrete and the rip-rap was made of selected gravel bonded with mortar.

The templates were cut so that their bottom edges would fall on a single horizontal plane surface. They were set in place at the proper elevation by means of an engineer's level. The completed model was checked by leveling. The accuracy of the model was given a much more rigorous check by filling the tank to various water surface elevations, and checking the shore lines formed in this manner with the positions of the corresponding contours of the lake bottom.

METHOD OF CONDUCTING TESTS

The waves were generated by means of a plunger-type wave machine, 30 feet long. A photograph of the wave machine in operation is shown in Plate I, page 71. The wave machine is portable, which permitted waves to be generated from any desired direction. The proper wave period and wave height were obtained by regulating the speed and amplitude of the plunger.

Wave heights were measured by means of electric resistance gages. The voltage on the gage terminals, which varies with the depth of the water, was amplified and recorded by means of an oscillograph. The instruments were calibrated by raising and lowering the resistance gages known amounts in still water and noting the corresponding oscillograph fluctuation. Calibrations were checked systematically during the tests. The instruments are shown in operation in Plate I, page 71.

Surface currents were measured by timing the movements of small wooden floats with reference to coordinate lines on the model. The elevation of the water surface in the model was checked by means of hook gages on the walls of the wave tank.

TEST CONDITIONS

The basic wave data were prepared by Messrs. H. F. Lawhead and C. E. Lee of the Detroit District, Corps of Engineers. Deep-water wave heights were computed from records of the wind velocity and duration, based on the corresponding fetches.[1,2*] The following three wind directions were selected for the tests: N 56°15' E, N 11°15' E, and N 33°45'W. The frequencies of waves of various sizes from these directions are shown in Appendix C, page 97. For each wind direction a "large" wave and a "small" wave were projected against the various harbor arrangements. A summary of the characteristics of all the waves used in the tests is given in Table I.

The values of wave height and wave length shown in Table I apply to deep water. As the waves enter water having depths less than approximately

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*Numbers refer to items in the list of references given on page 20.

one-half the deep-water wave length, the height, length and orientation of the waves are changed. Because the model limits did not extend to depths greater than one-half the wave length, it was necessary to compute the wave height at selected gaging stations and to determine the orientation of the waves at the location of the wave machine. The wave machine was then aligned with the computed wave orientation. The refraction diagrams[3,4] which were needed to make the computations were prepared by Detroit District Office, Corps of Engineers. These diagrams are shown in Appendix C, pages 91, 93, and 95.

TABLE I

SUMMARY OF WAVE DATA

	"Small" Wave			"Large" Wave		
	N56°15'E	N11°15'E	N33°45'W	N56°15'E	N11°15'E	N33°45'W
Deep-Water Wave Height (Feet)	4.5	4.5	4.5	11.0	9.0	10.0
Deep-Water Wave Length (Feet)	81.9	81.9	81.9	128.0	95.0	113.0
Wave Period (Seconds)	4.0	4.0	4.0	5.0	4.3	4.7
Frequency*	14.0	23.0	64.0	0.9	1.35	0.9

*Number of times wave height will be equaled or exceeded in three years.

It is believed that the larger waves used in the tests give an indication of the disturbance inside the harbor when severe Lake Huron storms have reached their full intensity and are producing near maximum waves at the harbor site. The smaller waves occur more frequently and might be thought of as representing conditions that would commonly exist when small boats are entering the harbor to seek refuge from a major storm before it has reached its full intensity. The "small" wave tests permit the comparisons of the effectiveness of the various harbor arrangements under conditions of no overtopping of the breakwaters by storm waves. In the case of the "large" waves, the overtopping effect is considerable.

Low-water datum for Lake Huron is at elevation 578.5 feet above mean tide at New York. The crests of the breakwaters were set eight feet above low-water datum. Throughout the tests the lake elevation was kept three feet above low-water datum. Thus, the crests of the breakwaters were five feet above the still-water level of the lake. The lake stage used in the tests was determined from a consideration of the records of the U. S. Lake Survey's water-level recorder at Harbor Beach, Michigan, covering a number of storm periods. The records show that the rise in stage at this locality due to storm conditions is not a very significant factor, and that during the past sixty years a stage of 581.5 has been exceeded infrequently and then only for relatively short periods and to a minor extent.

THE TESTING PROGRAM

Four principal breakwater arrangements together with some modifications of three of them were tested. The principal arrangements were designated as Plans 1, 2, 3, and 4. The modifications were given the designations 1a, 2a, 3a, and 3b. A number of minor variations in the plans were also tested for particular purposes. These were not given special designations. In all cases the entrance was dredged to twelve feet below low-water datum and the harbor was provided with a ten-foot dredged area near the entrance and a six-foot area nearer the shore. The various breakwater arrangements and the locations of the dredged areas are presented in Drawing 3, page 25. The breakwater cross sections used in the various plans are shown in Drawing 4, page 27. The riprap fillets shown in Drawing 4 extended the full length of the lake side of the breakwaters and along the exposed portions near the entrance on the harbor side.

Plan 1 consisted of two straight breakwaters with the east breakwater overlapping the west breakwater as shown in Drawing 3. At the entrance, the width of the twelve-foot channel was 150 feet, the distance from toe to toe of rip-rap was 210 feet, and the distance from face to face of the breakwaters was 250 feet. The total length of the breakwaters was 1595 feet. Plan 1a consisted of the same arrangement as Plan 1, but the east breakwater was raised 2.33 feet. Plan 1a was tested only for the "large" wave from the direction N 33°45' W.

Plan 2 was composed of two straight breakwaters, with the west breakwater overlapping the east breakwater, as shown in Drawing 3. Both the width of the twelve-foot channel at the entrance and the distance from toe to toe of the rip-rap were 150 feet. The distance between vertical faces of the breakwaters was 195 feet at the entrance. The total length of the breakwaters was 1665 feet. Plan 2a consisted of the same arrangement as Plan 2, but the rip-rap near the harbor entrance was built up to the top surfaces of the breakwaters. The distance from toe to toe of rip-rap was kept the same as for Plan 2. Plan 2a was tested only for the "large" wave from the direction N 56°15' E.

Plan 3 consisted of a single breakwater composed of two straight segments arranged as shown in Drawing 3. The width of the entrance channel, having depths of twelve feet or more, was 290 feet. The total length of the breakwater was 1085 feet. Plan 3a was formed by extending the deep-water end of the Plan 3 breakwater 100 feet toward shore, thus increasing the length of the breakwater to 1185 feet. Some additional area was dredged on the shoreward side of the entrance so that the width of the entrance channel for Plan 3a was 345 feet. Plan 3a was not tested for the direction N56°15' E because it was believed that results would be at least as good as those for Plan 3 for this direction.

Plan 3b differed from Plan 3a only in having a shallow area lying on the lakeward side of the outer end of the breakwater, dredged to depths varying from 16 to 18 feet, as shown in Drawing 3. The original depths in this area varied from slightly less than 14 feet to 16 feet. Plan 3b was tested for the "large" and "small" waves for only the one direction, N 11°15' E.

Plan 4 consisted of a single straight breakwater with the end points located in the same position as those of Plan 3a. The dredged area and entrance width of Plan 4 was kept the same as that for Plan 3a. The length of the breakwater was 1100 feet.

PRESENTATION OF RESULTS

The data obtained from the tests, converted to prototype values on the basis of the Froude law, are presented graphically in Appendix A, Drawings 5 to 51, pages 29 to 67. Photographs showing harbor conditions during tests with the large waves are presented in Appendix B, Plates II to XVII, pages 72 to 87. In Appendix A the wave-height data are presented first. These are followed by the drawings showing the results of the surface-current measurements. All drawings are numbered in the order in which the tests were run. They may be located by referring to the List of Illustrations which follows the Table of Contents at the beginning of this report.

Wave Heights

The wave-height drawings are presented in groups to facilitate the comparison of the various plans. The first group consists of the results from Plans 1 and 2. These drawings are shown on pages 29 to 33. The results from

Plan 1a are presented with the corresponding drawing for Plan 1 on page 35. The next group, shown on pages 37 to 47, contains the wave heights determined for Plans 1, 3, 3a, and 4 to permit the comparison of these four plans. Corresponding test data for Plans 2 and 2a are shown on page 49. The results obtained from Plan 3b with corresponding values from Plan 3a are shown on page 51.

Wave heights were measured at from 25 to 35 locations for each test. The results are recorded on the drawings at the gage locations. An arrow at each gage location shows the direction in which the predominant wave was traveling. With these values as a basis, lines of equal wave height were drawn. As an aid in evaluating the effectiveness of the various plans, the harbor area in which the wave height was less than 1.5 feet was hatched. The region in which the wave height was greater than 5.0 feet was hatched with lines having the opposite slope.

The wave-height data are also presented in the form of numerical averages. In Table II, page 10, are shown three groups of averages for each wind direction, for both the "large" and "small" waves. The first group consists of measurements made at stations near the harbor entrance. The second group comprises those made inside the harbor and the third consists of the results obtained in the area near the docks. The boundaries of these areas are shown in Drawing 3, page 25, by lines consisting of alternate dots and dashes. The boundaries of the lake side of the "entrance" areas were determined by scribing a segment of a circle having its center at the middle of the harbor entrance and a radius of 500 feet, as shown in Drawing 3.

Currents

The drawings showing the results of surface-current measurements are presented in the order in which the tests were made on pages 53 to 67. The

TABLE II

AVERAGE WAVE HEIGHTS

Values are in feet

	Plan	Entrance			Harbor			Dock Area		
		North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West
"Large" Wave	1	3.3	4.9	6.0	0.1	0.4	1.0	0.1	0.4	0.7
	2	5.8	6.8	5.9	1.4	1.7	1.0	0.5	0.6	0.4
	2a	5.8	---	---	1.3	---	---	0.4	---	---
	3	2.1	5.5	6.4	0.2	0.6	1.6	0.2	0.4	1.0
	3a	---	4.9	5.6	---	0.7	1.2	---	0.6	0.6
	3b	---	4.7	---	---	0.5	---	---	0.3	---
	4	2.8	6.0	7.2	0.1	0.4	1.1	0.0	0.2	0.4
"Small" Wave	1	1.0	3.8	3.3	0.1	0.1	0.3	0.0	0.1	0.2
	2	3.5	3.9	2.8	0.8	0.8	0.2	0.2	0.1	0.1
	3	1.5	3.6	3.4	0.0	0.4	0.5	0.0	0.3	0.3
	3a	---	3.3	3.5	---	0.3	0.3	---	0.4	0.1
	3b	---	3.1	---	---	0.2	---	---	0.1	---
	4	1.1	3.8	3.8	0.0	0.2	0.2	0.0	0.2	0.1

magnitude and direction of the currents are shown by means of arrows. The lengths of the arrows are proportional to the velocities in accordance with the scale provided on the drawings. Paths followed by the floats are shown by means of dotted lines. In some locations the directions of the currents varied somewhat with time, so that occasionally the paths of the floats may be seen to converge and cross. The maximum velocities found in various portions of the harbor are tabulated in Table III. The maximum velocity does not always occur at the same point for each plan.

Other Observations

The results of all the major tests on waves and currents are presented in the manner just described. The results of other minor observations, taken for special purposes, are not included in this report. They are available in the files of the laboratory. Most such observations were made for the purpose of determining whether small changes in the breakwaters would affect the wave height. When it was indicated that conditions were being improved, the change was usually incorporated into the next plan. The change from Plan 3 to Plan 3a was made as the result of such observations.

Another series of tests was conducted to determine whether an intermediate wave size, between the "large" and "small" waves, would produce more troublesome conditions than the "large" wave itself. It was believed that such a condition might exist because of a shift in the location of the area in which breakers occurred. Careful checks were made for Plan 1, and it was found that no more severe condition existed than that produced by the "large" wave. The other plans were also checked for this effect.

During the tests on Plan 2a, a number of additional observations were made on currents. Some measurements were made with the east breakwater

TABLE III

MAXIMUM CURRENTS FOUND IN VARIOUS LOCATIONS

Values are in miles per hour

Plan	Approach			Entrance			Harbor			Dock Area		
	North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West
1	4.0	2.8	1.0	1.3	2.3	1.6	1.8	2.0	1.4	2.1	2.9	1.0
2	4.3	3.0	3.6	2.7	1.9	4.2	1.0	1.2	0.3	1.7	1.2	0.2
3	2.8	2.0	3.2	0.7	1.2	1.9	2.0	2.6	1.6	2.3	2.9	1.2
3a	---	2.2	3.9	---	0.6	1.5	---	2.2	1.5	---	2.3	1.4
3b	---	2.8	---	---	1.0	---	---	2.5	---	---	2.2	---
4	4.0	2.5	4.1	1.8	2.1	1.9	1.9	2.5	1.8	1.4	2.9	1.0

extended 100 feet toward shore. It was found that the currents in some portions of the dock area were reduced approximately 40 percent under these conditions. The currents in the region outside of the east-breakwater location were measured after the breakwaters were removed. It was found that currents in this region were approximately 20 percent larger than the values obtained with the breakwaters in place. The water surface gradients in the wave tank were also measured during these observations. The gradient across the model area was found to be approximately 0.00015. This gradient would produce a velocity in excess of 2 miles per hour. This velocity, when combined with a wave velocity of approximately 2.5 miles per hour, accounts for some of the larger velocities observed in the model.

Some special wave-height observations were made for the direction N 11°15' E in the case of Plan 4. In this test, waves reflected from the breakwater were returned to the wave machine and then reflected back to the model for the second time. Although these returning waves were quite small, it was feared that they might influence conditions at the harbor. To determine this effect, a number of stations were observed during the short interval from the beginning of fully established wave motion until these reflected waves returned to the harbor. These measurements were compared with results obtained in the usual fashion. It was found that at the harbor entrance, some stations showed an increase, whereas others showed a decrease in wave height. This change amounted to as much as 10 percent of the wave height. Inside the harbor the effect disappeared. It was concluded that the effect at the entrance would not influence the evaluations of the results, especially in view of the fact that increases at some points were largely balanced by decreases at other points.

ANALYSIS OF RESULTS

The most dependable method of determining the relative effectiveness of the plans tested is to compare the results shown on the wave-height and current drawings and the values given in Tables II and III. However, an appraisal of the various plans, based on the results of the wave-height measurements, may be obtained from a consideration of Table IV, page 15, and Table V, page 16. In Table IV is given a set of values obtained by numbering the average wave heights shown in Table II from 1 to 5 in the order of increasing magnitude. Thus, the best plan for any wind direction and wave size is numbered 1, the next best 2, and so on. In the right-hand column is shown the sum of the values for each plan. These summaries indicate that Plans 1, 3a, and 4 are more effective than Plans 2 and 3. It is of interest that the results from both the "large" and "small" waves lead to the same conclusion. In preparing these values it was assumed that the results from Plan 3a were the same as those obtained from Plan 3 for the direction N 56°15' E. Plan 3a was not tested for that wind direction because the results from Plan 3 were very good and it was believed that Plan 3a would be equally or more effective. Plan 2a was not included in Tables IV and V because only one wind direction was tested and because the results differed only slightly from those of Plan 2. Plan 2 gave the poorest results of all the plans tested. Plan 3b was not included in Tables IV and V because the results for the direction tested can be compared readily with corresponding values for Plan 3a by observing the drawings given on page 51 and the wave-height averages given in Table II.

Table V was prepared to provide a ready comparison of the different harbor plans for particular wind directions. The values in this table were obtained from Table IV by adding the three values for each wind direction for

TABLE IV

NUMERICAL EVALUATION OF THE VARIOUS PLANS

	Plan	Entrance			Harbor			Dock Area			Summation
		North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West	
"Large" Wave	1	4	1.5	3	1.5	1.5	1.5	2	2.5	4	21.5
	2	5	5	2	5	5	1.5	5	4.5	1.5	34.5
	3	1.5	3	4	3.5	3	5	3.5	2.5	5	31.0
	3a	1.5	1.5	1	3.5	4	4	3.5	4.5	3	26.5
	4	3	4	5	1.5	1.5	3	1	1	1.5	21.5
"Small" Wave	1	1	3.5	2	4	1	3.5	2.5	1.5	4	23.0
	2	5	5	1	5	5	1.5	5	1.5	2	31.0
	3	3.5	2	3	2	4	5	2.5	4	5	31.0
	3a	3.5	1	4	2	3	3.5	2.5	5	2	26.5
	4	2	3.5	5	2	2	1.5	2.5	3	2	23.5

the various plans. Considering the "large" and "small" waves separately, Table V provides six conditions for comparison. Plans 1, 2, and 4 each gave the best results for two conditions. Plan 2 gave the poorest results in four cases, and Plan 3 gave the poorest results for the other two cases. Therefore, Table IV points to Plans 1 and 4 as the most effective breakwater arrangements.

TABLE V

SUMMARY OF THE NUMERICAL EVALUATION OF THE VARIOUS PLANS

Plan	"Large" Wave			"Small" Wave		
	North 56°15' East	North 11°15' East	North 33°45' West	North 56°15' East	North 11°15' East	North 33°45' West
1	7.5	5.5	8.5	7.5	6.0	9.5
2	15.0	14.5	5.0	15.0	11.5	4.5
3	8.5	8.5	14.0	8.0	10.0	11.0
3a	8.5	10.0	8.0	8.0	9.0	9.5
4	5.5	6.5	9.5	6.5	8.5	8.5

Although Tables IV and V are very useful in providing an appraisal of the relative merits of the various plans, the values shown in the table do not indicate the extent of the advantage of one plan over another. Two plans may differ in wave height by amounts less than the experimental error and still be rated differently by this method. Frequently, the average wave height in any area is influenced by the presence of a small region of unusually large wave height. The relative importance of such regions of large wave height depends upon whether they occur in a critical area, as for example in the center of the entrance channel. Only by reference to the original data can such situations be found and properly evaluated. A discussion of the results obtained from the individual plans is given in the following paragraphs.

The currents observed in the various plans did not differ sufficiently to indicate that any particular arrangement was either inferior or superior in this respect.

Plan 1: This breakwater arrangement provided very good conditions inside of the harbor. However, a small region of relatively large wave height occurred in the entrance channel for the wind direction N 11°15' E.

Plan 1a: Wave heights were determined at a limited number of points for the direction N 33°45' W in order to determine the difference in overtopping effect on wave height inside the harbor after raising the east breakwater 2.33 feet. The difference was found to be small. It should be noted that the overtopping was not stopped by raising the breakwater this amount.

Plan 2: This plan gave excellent results for the direction N 33°45' W. However, Plan 2 gave the poorest results for the other two wind directions.

Plan 2a: This plan was tested for the direction N 56°15' E to determine the effect of using sloping walled breakwaters instead of vertical walled breakwaters near the harbor entrance. Conditions inside the harbor were improved somewhat as shown by the corresponding drawings of Plans 2 and 2a on page 49. This improvement occurred in spite of the fact that, due to the sloping walls of the breakwaters, the opening at the entrance was somewhat larger than for Plan 2. However, the greatest improvement resulting from the presence of the sloping rip-rap was in the more orderly wave motion in the entrance. This may be seen from corresponding photographs of the two conditions shown in Plate XVIII, page 88. The severe cross wave which appeared at the entrance in Plan 2 was eliminated in Plan 2a.

Plan 3: Good results were obtained except for the direction N 33°45' W. For this direction relatively large waves occurred in a considerable portion of the harbor.

Plan 3a: This plan gave very good results for all wind directions.

Plan 3b: This plan was tested for the direction N 11°15' E to determine the effect of dredging a relatively shallow area on the lakeward side of the breakwaters. A comparison of the wave height drawings for Plans 3a and 3b, shown on page 51, indicates that conditions were improved to some extent by the dredging. This is also shown by the wave height averages given in Table II, page 10. However, the amount of improvement probably would not warrant the expense of the additional dredging.

Plan 4: Plan 4 gave very good results for all wind directions.

CONCLUSIONS

Plans 1, 3a, and 4 would provide good harbors. It may be seen from a comparison of the wave-height drawings on pages 37, 39, 41, and 43 that Plans 3a and 4 provide better entrance conditions than Plan 1 for the wind directions N 56°15' E and N 11°15' E, even though the values given in Tables III and IV indicate that the opposite is true. For the direction N 33°45' W, Plan 1 provides slightly better entrance conditions. Plan 3a or 4 would provide a wider entrance channel and would be more economical to construct than Plan 1. For these reasons, Plan 3a or 4 would be preferred over Plan 1.

The results from Plans 3a and 4 were almost equally good. Plan 3a provided slightly better entrance conditions and somewhat more mooring space, especially in the ten-foot dredged area. Plan 4 would be less expensive. The choice between Plans 3a and 4 will depend upon whether the advantages of Plan 3a are considered to justify the difference in cost.

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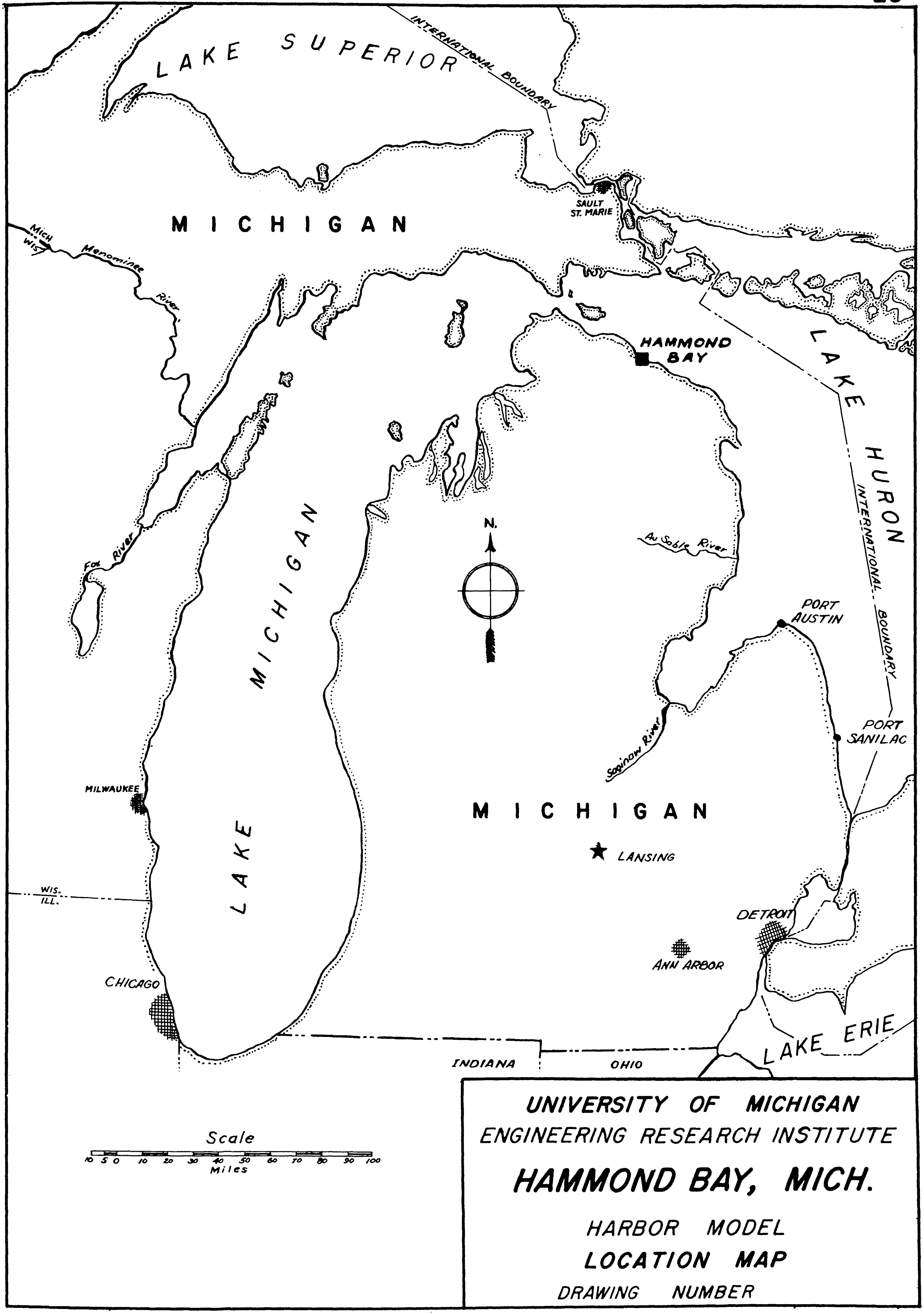
APPENDIX A

DRAWINGS



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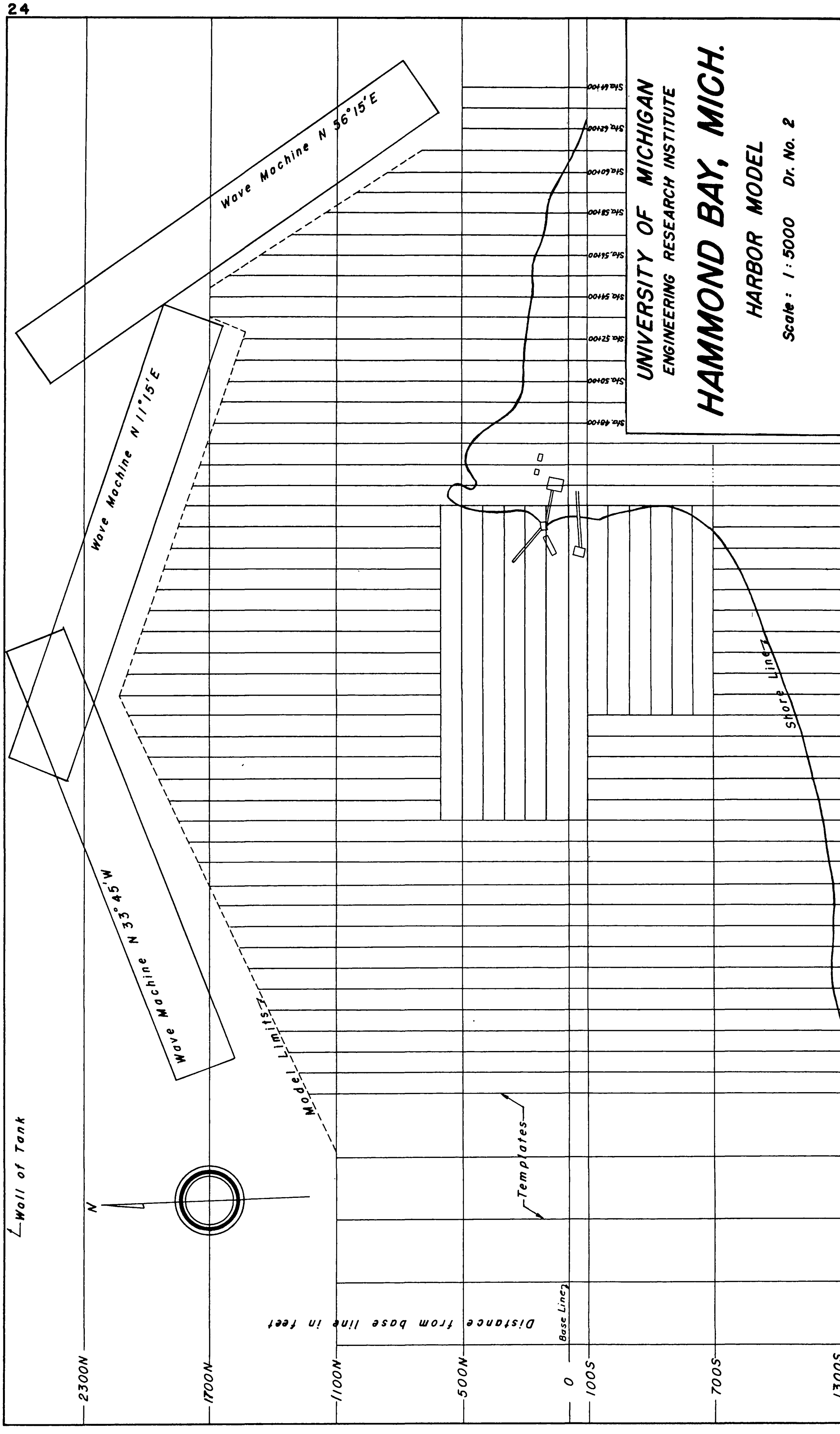
HARBOR MODEL

LOCATION MAP

DRAWING NUMBER


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL
Scale : 1 : 5000
Dr. No. 2
Wave Machine N 56°15'E
Wave Machine N 11°15'E
Wave Machine N 33°45'W
Model Limits
Shore Line
Templates
Wall of Tank
N
Base Line
Distance from base line in feet
2300N
1700N
1100N
500N
0
100S
700S
1300S
Sta. 4+00
Sta. 7+00
Sta. 10+00
Sta. 13+00
Sta. 16+00
Sta. 18+00
Sta. 20+00
Sta. 22+00
Sta. 24+00
Sta. 26+00
Sta. 28+00
Sta. 30+00
Sta. 32+00
Sta. 34+00
Sta. 36+00
Sta. 38+00
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Sta. 42+00
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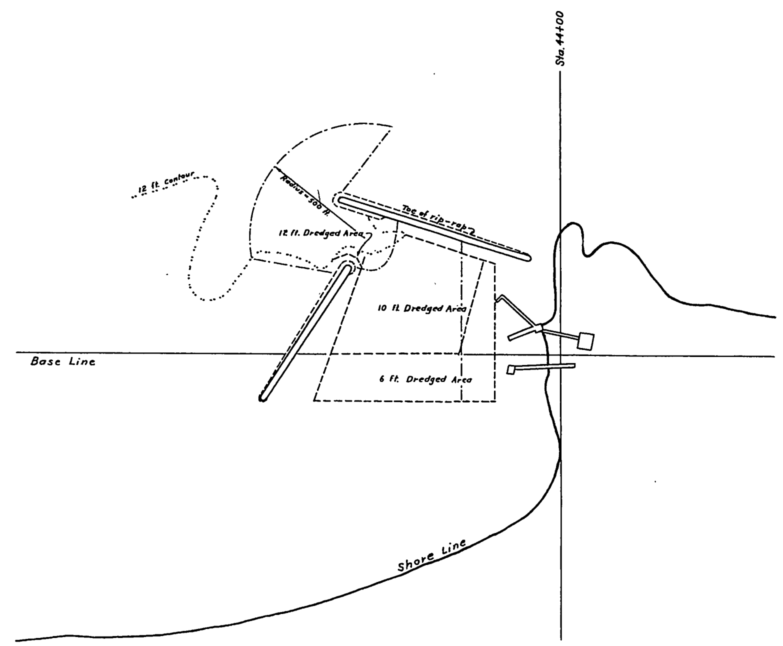
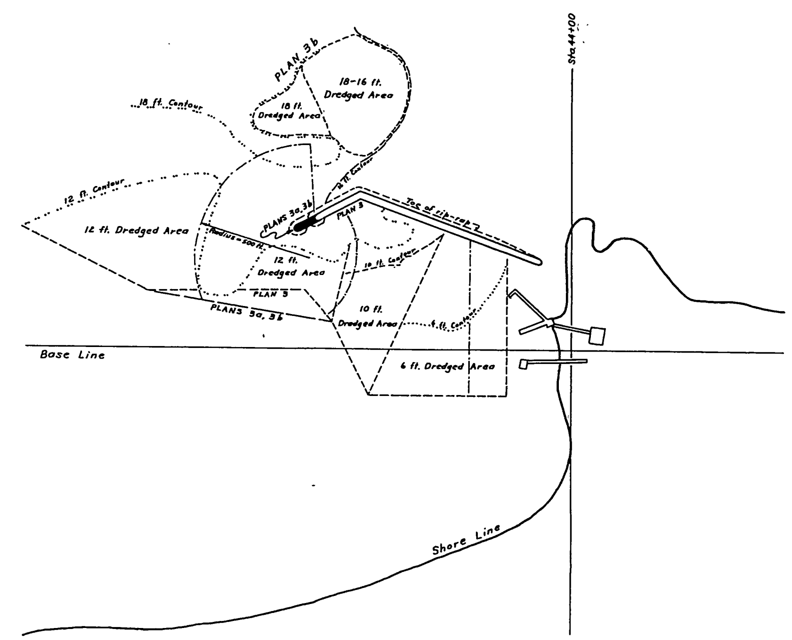
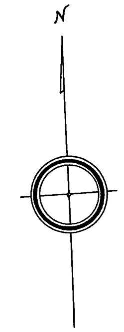
Sta. 62+00
Sta. 64+00

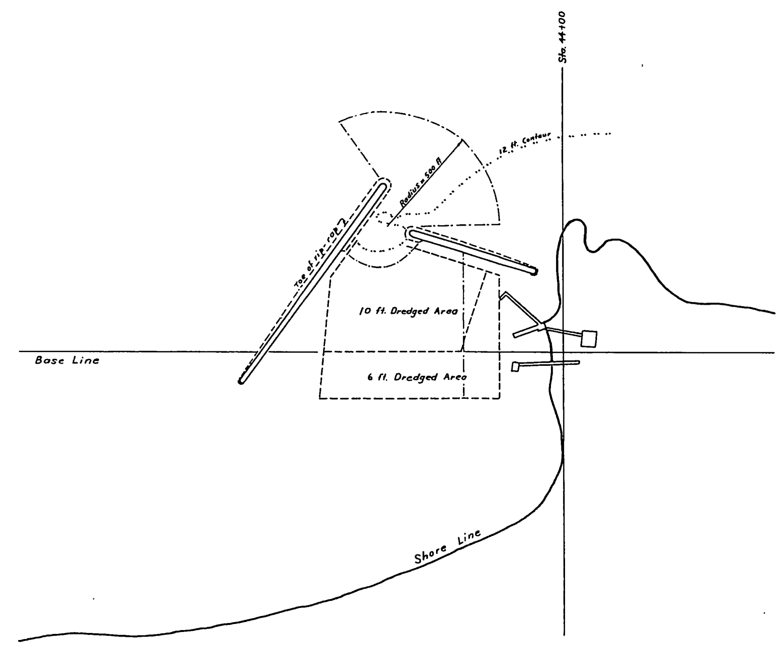


PLAN— 1

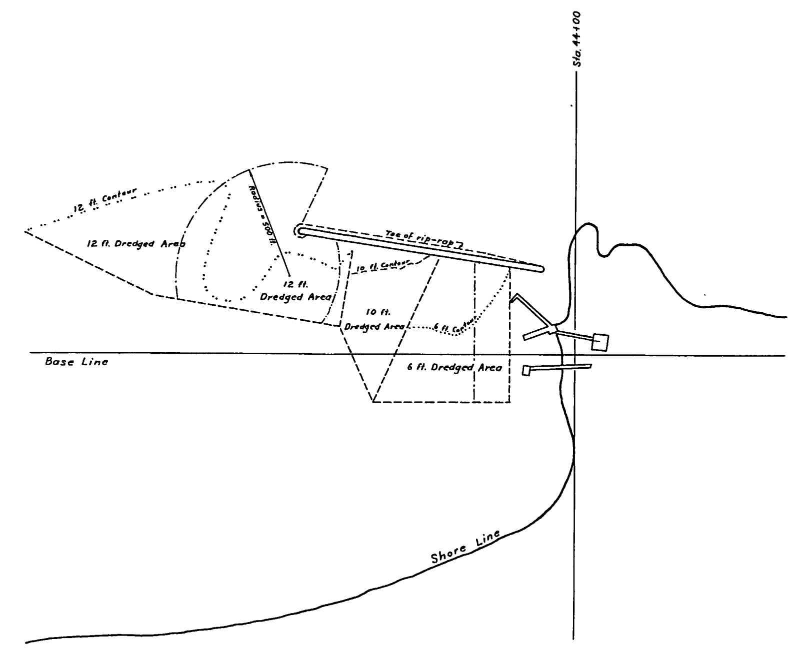


PLANS—3, 3a, 3b





PLAN— 2



PLAN— 4

SCALE
100 0 100 200 300 400 500
Feet

Note
The boundaries of the areas, designated in Tables II and IV as ENTRANCE, HARBOR and DOCK, are shown thus —·—·—·—.
The boundaries of the dredged areas are shown thus - - - - - - .

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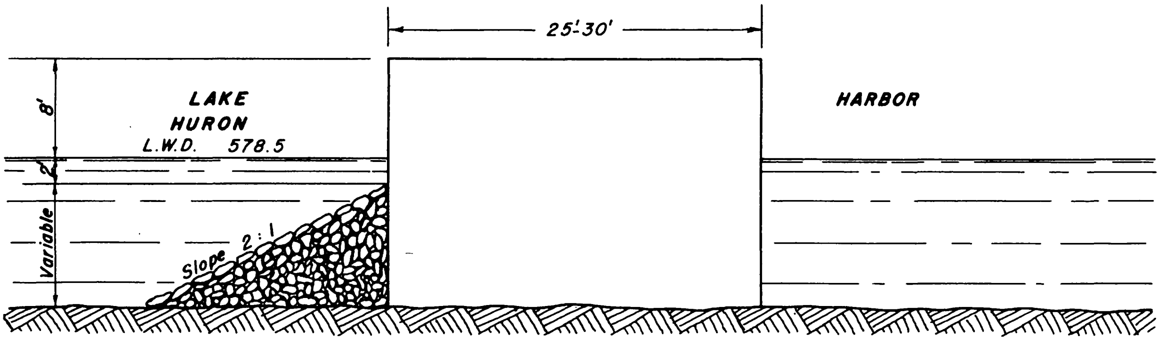
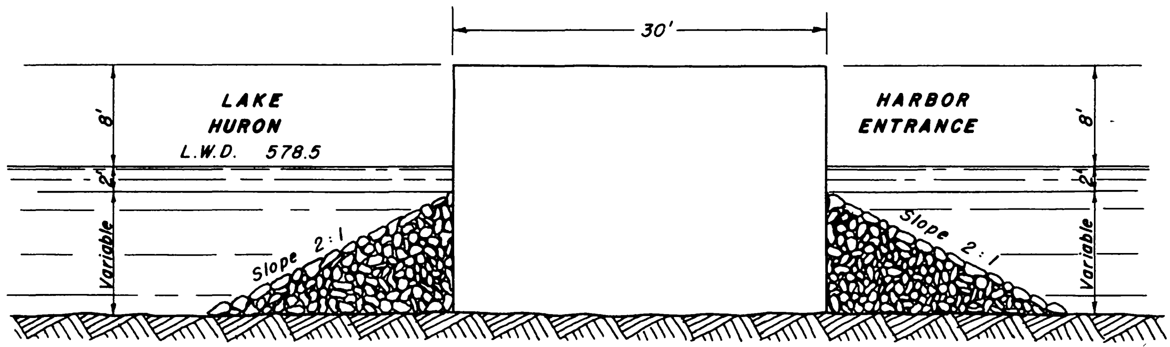
HAMMOND BAY, MICH.
HARBOR MODEL

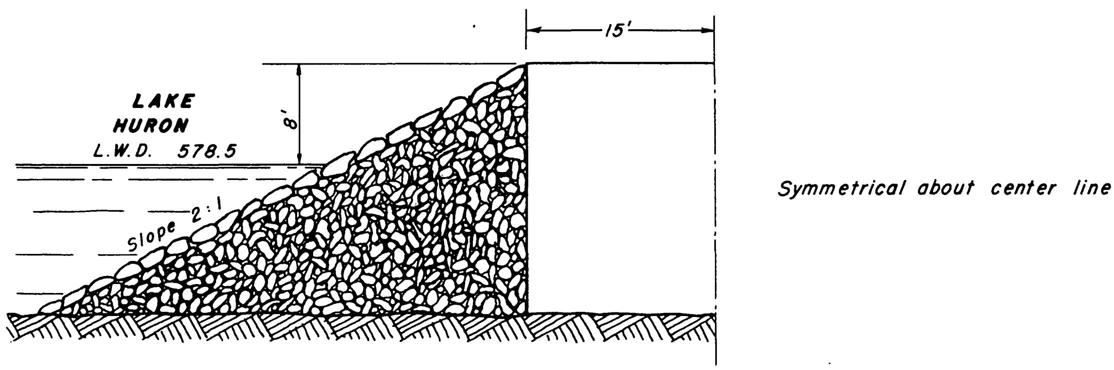
BREAKWATER ARRANGEMENTS
DRAWING NUMBER 3



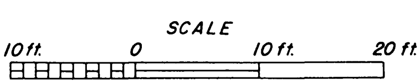
TYPICAL BREAKWATER SECTION



NEAR ENTRANCE



NEAR ENTRANCE PLAN 2a



Note

The width of the breakwater was 30 feet at the outer end and 25 feet at the shoreward end. The change was made in a 100 foot transition reach located at the 6 foot contour.

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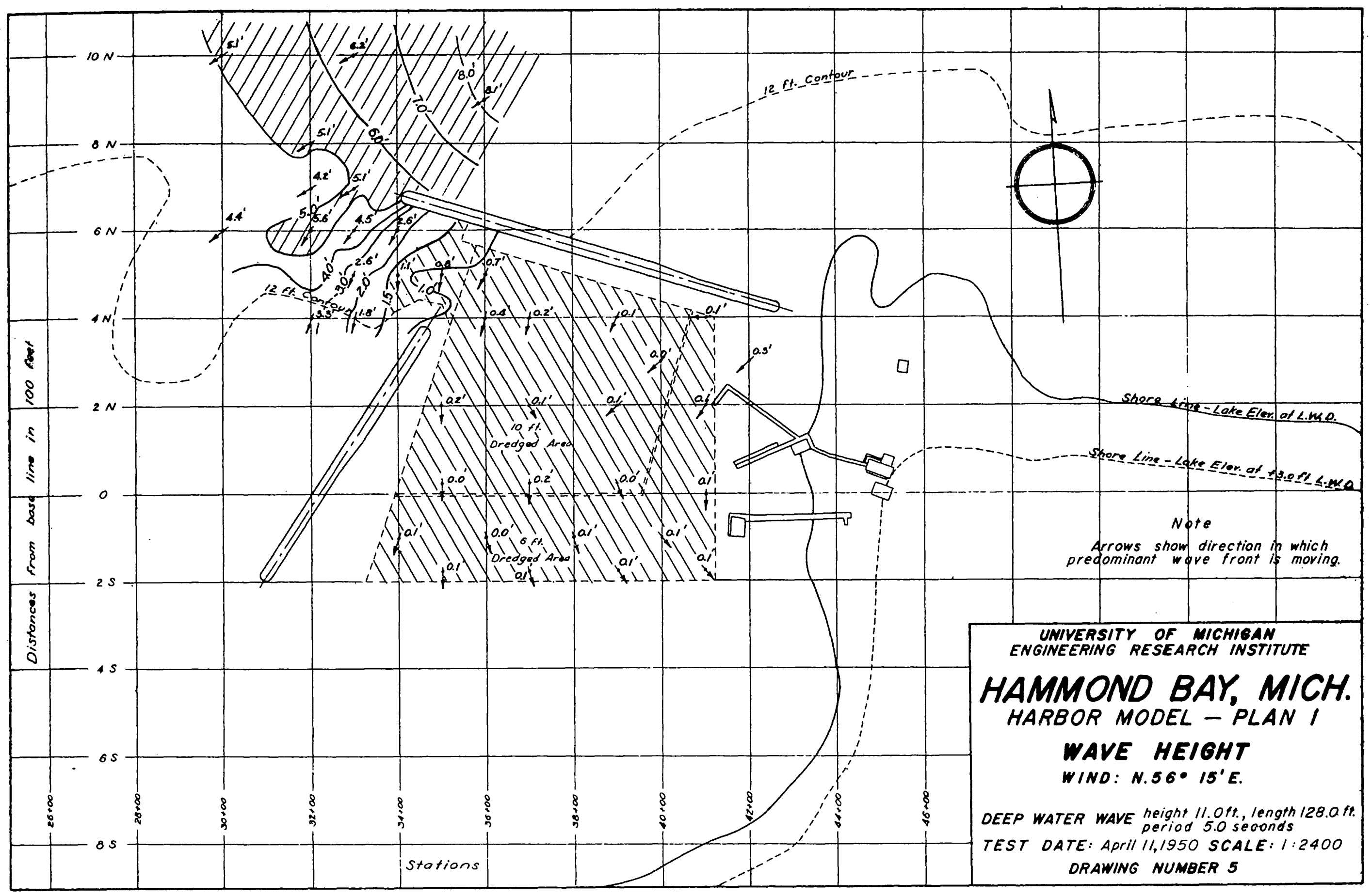
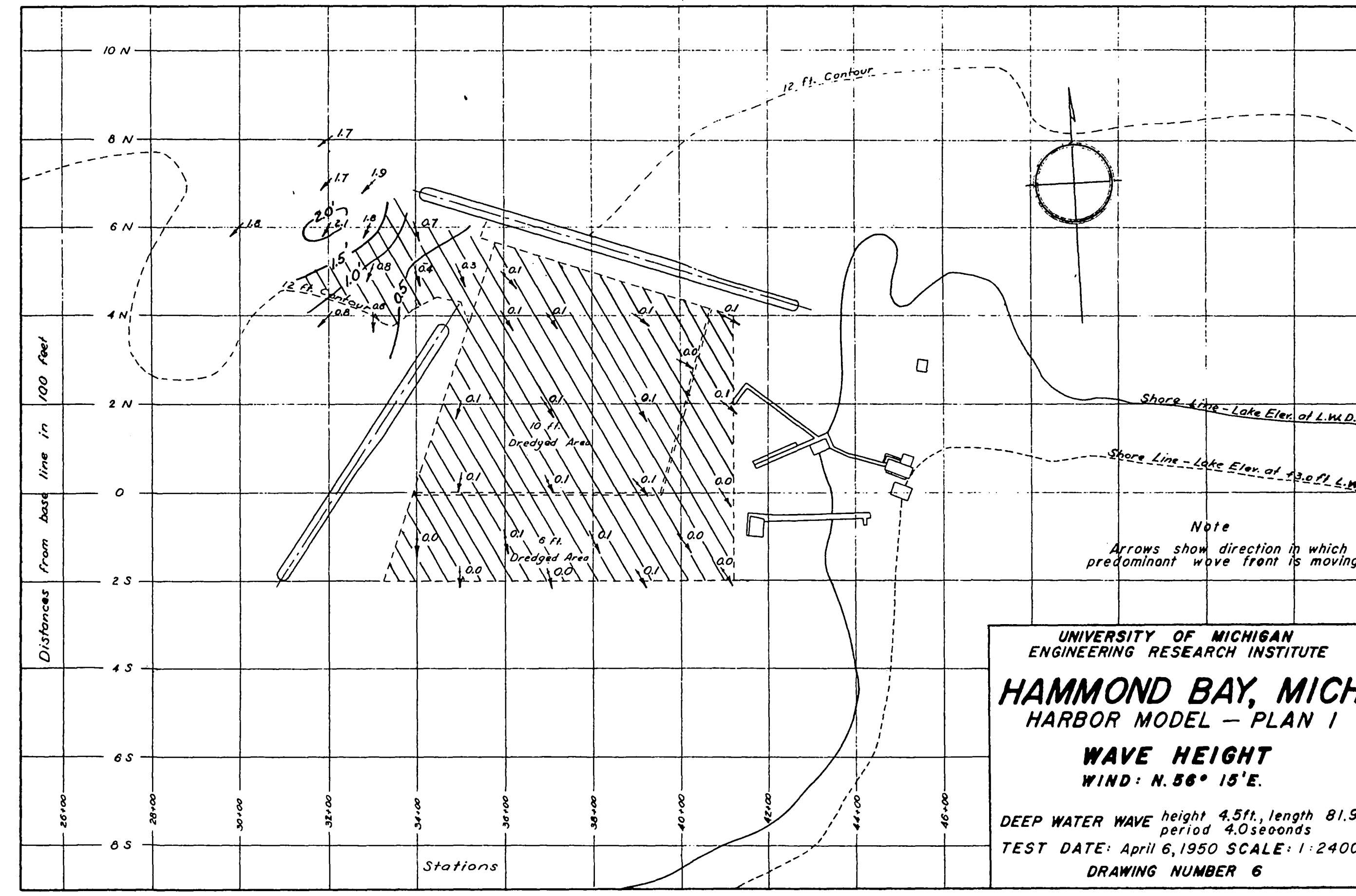
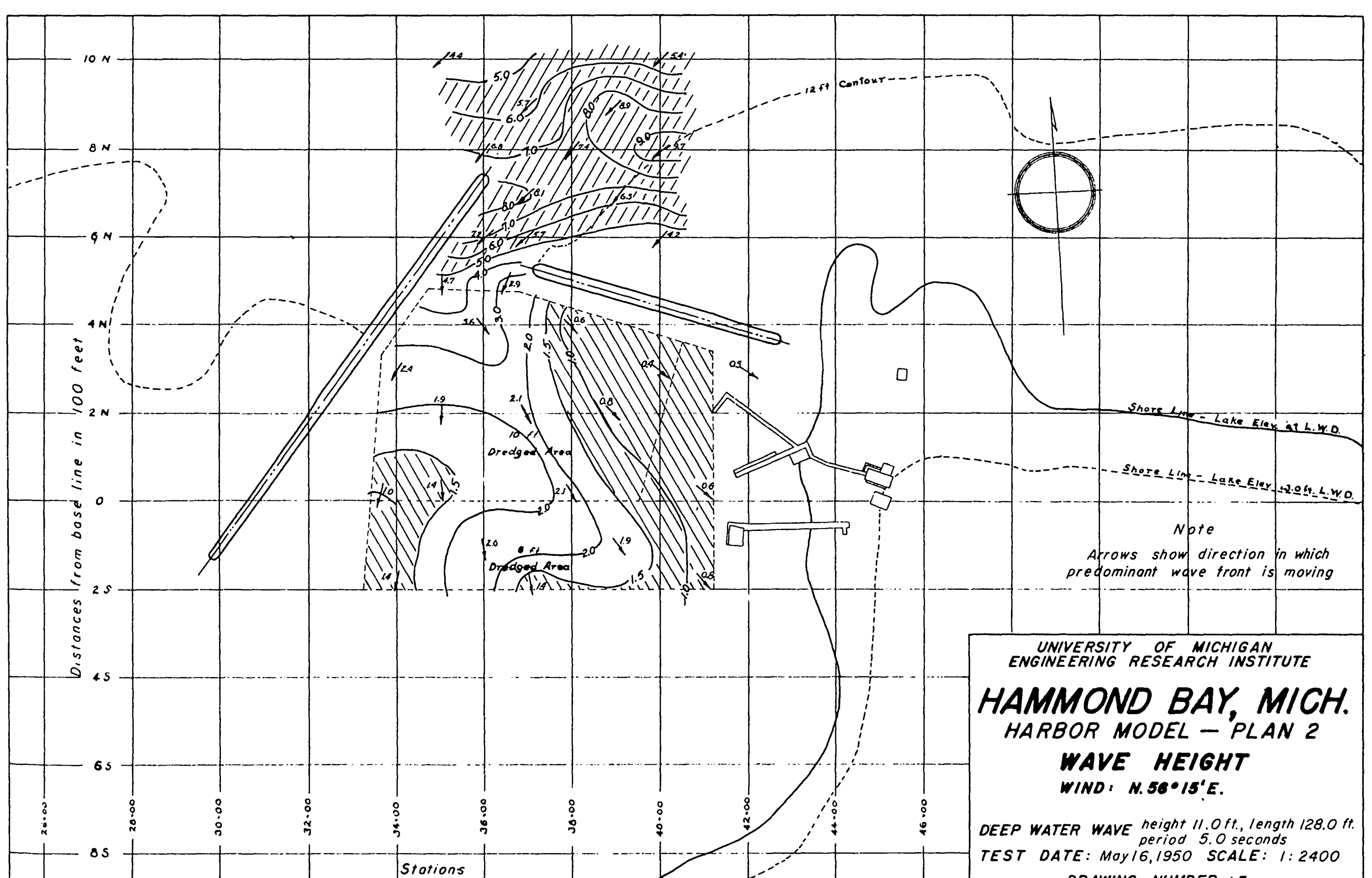
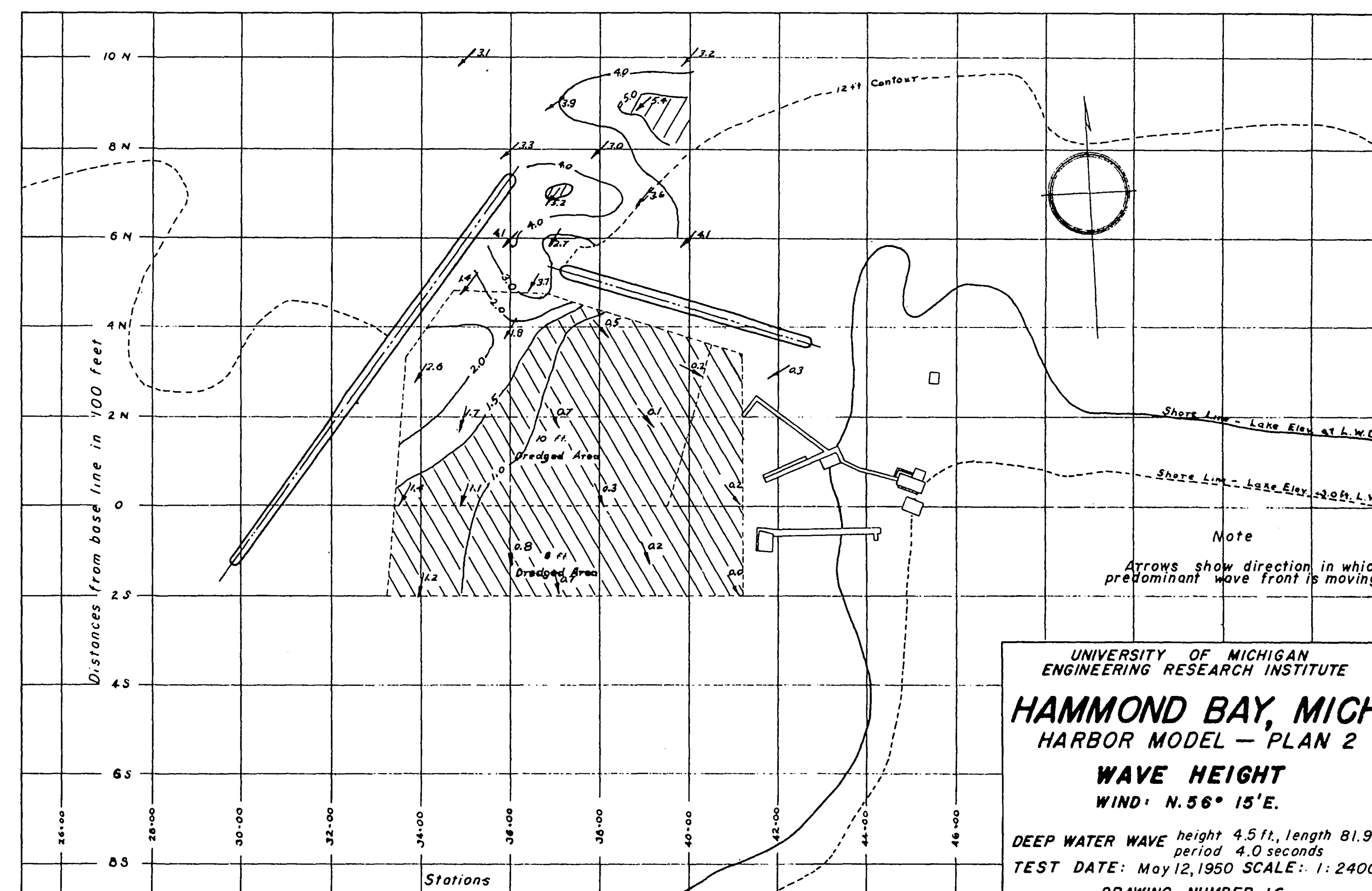
HAMMOND BAY, MICH.
HARBOR MODEL

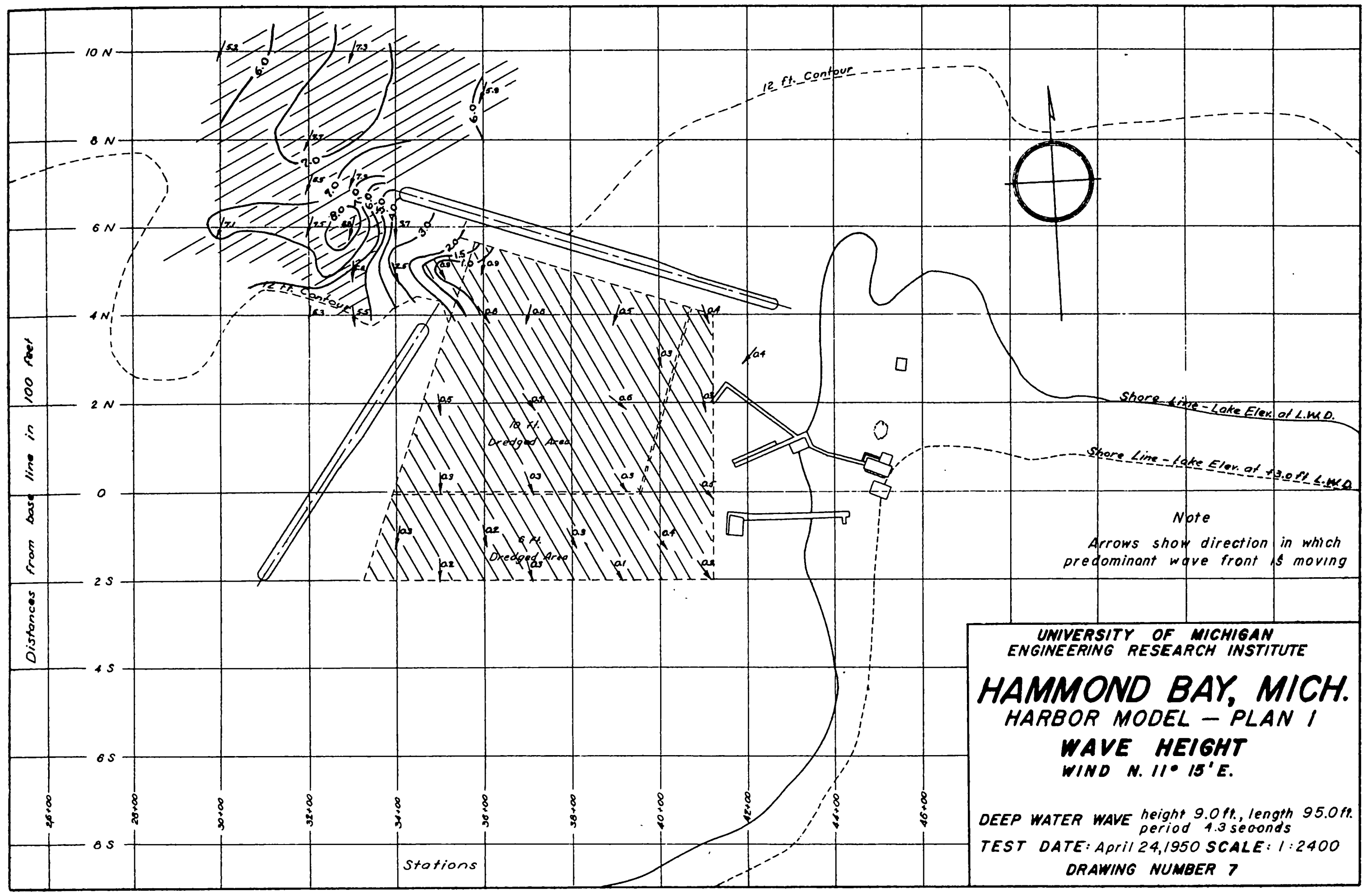
BREAKWATER SECTIONS
DRAWING NUMBER 4


12 ft. Contour
12 ft. Contour
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N.56° 15'E.
DEEP WATER WAVE height 11.0 ft., length 128.0 ft. period 5.0 seconds
TEST DATE: April 11, 1950 SCALE: 1:2400
DRAWING NUMBER 5


12 ft. Contour
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N.56° 15'E.
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: April 6, 1950 SCALE: 1:2400
DRAWING NUMBER 6


12 ft Contour
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. +3.0 ft. L.W.D.
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
WAVE HEIGHT
WIND: N.56° 15'E.
DEEP WATER WAVE height 11.0 ft., length 128.0 ft. period 5.0 seconds
TEST DATE: May 16, 1950 SCALE: 1:2400
DRAWING NUMBER 15


12 ft Contour
10 ft. Dredged Area
8 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. +3.0 ft. L.W.D.
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
WAVE HEIGHT
WIND: N.56° 15'E.
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: May 12, 1950 SCALE: 1:2400
DRAWING NUMBER 16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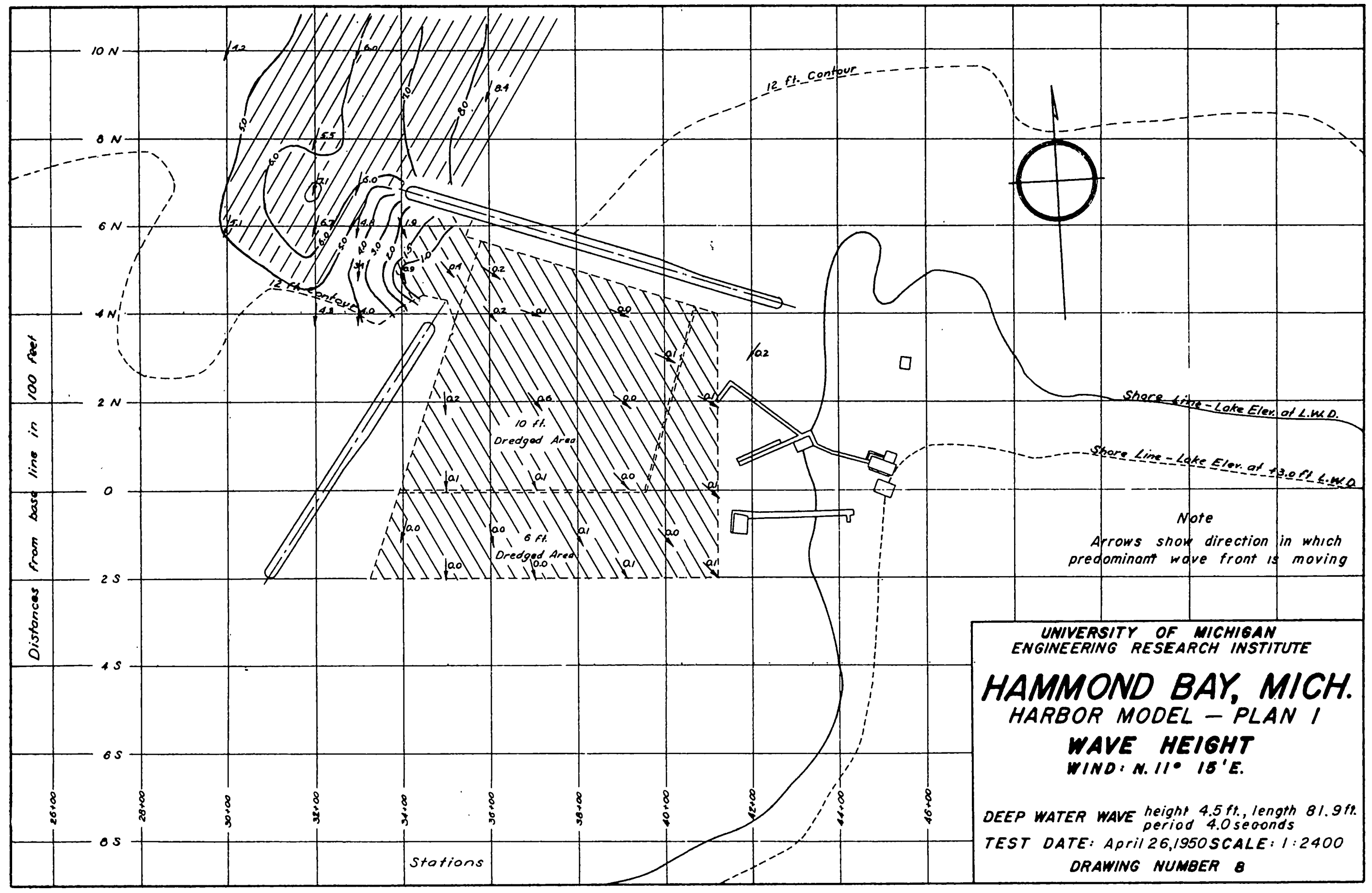
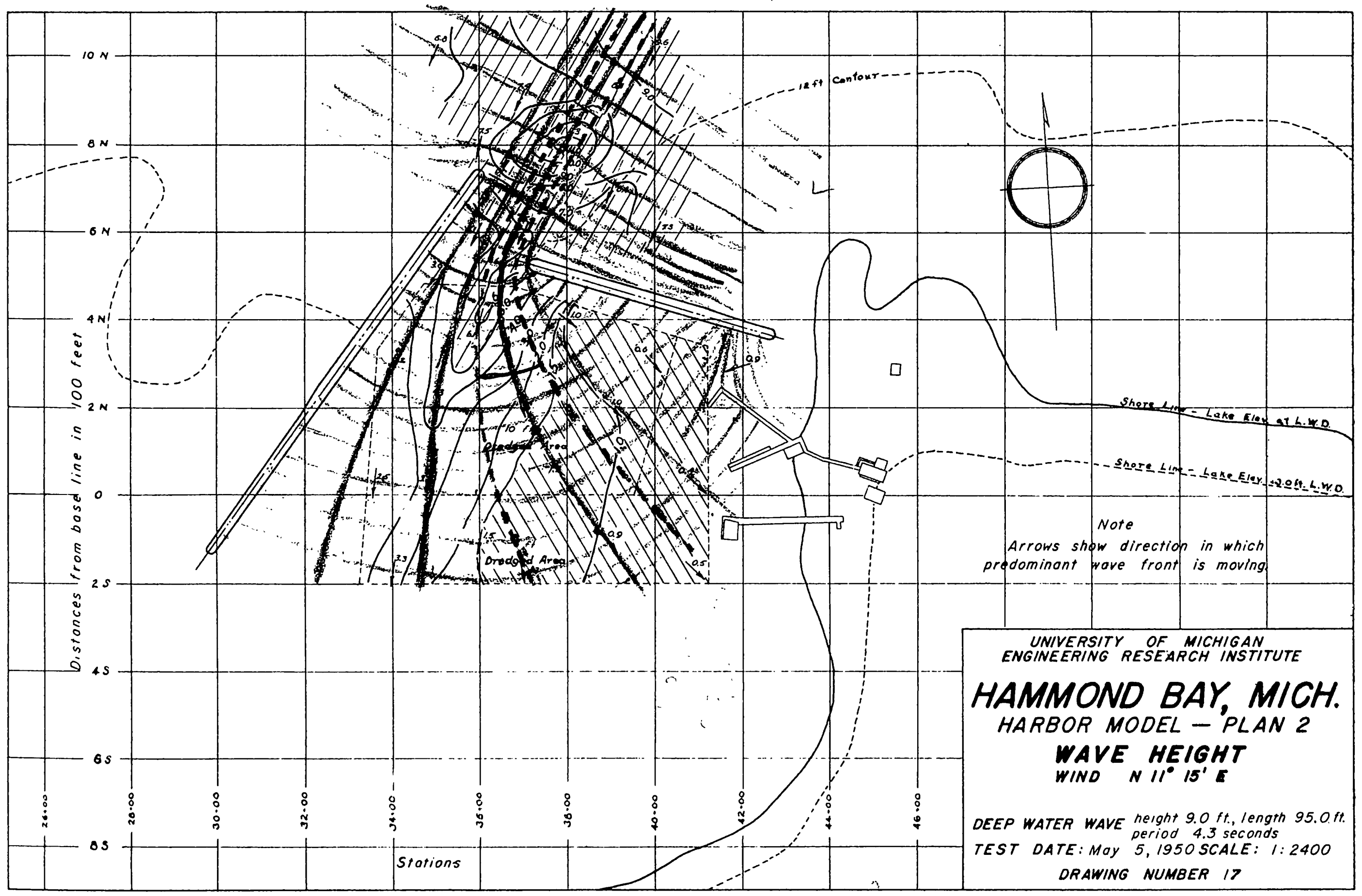
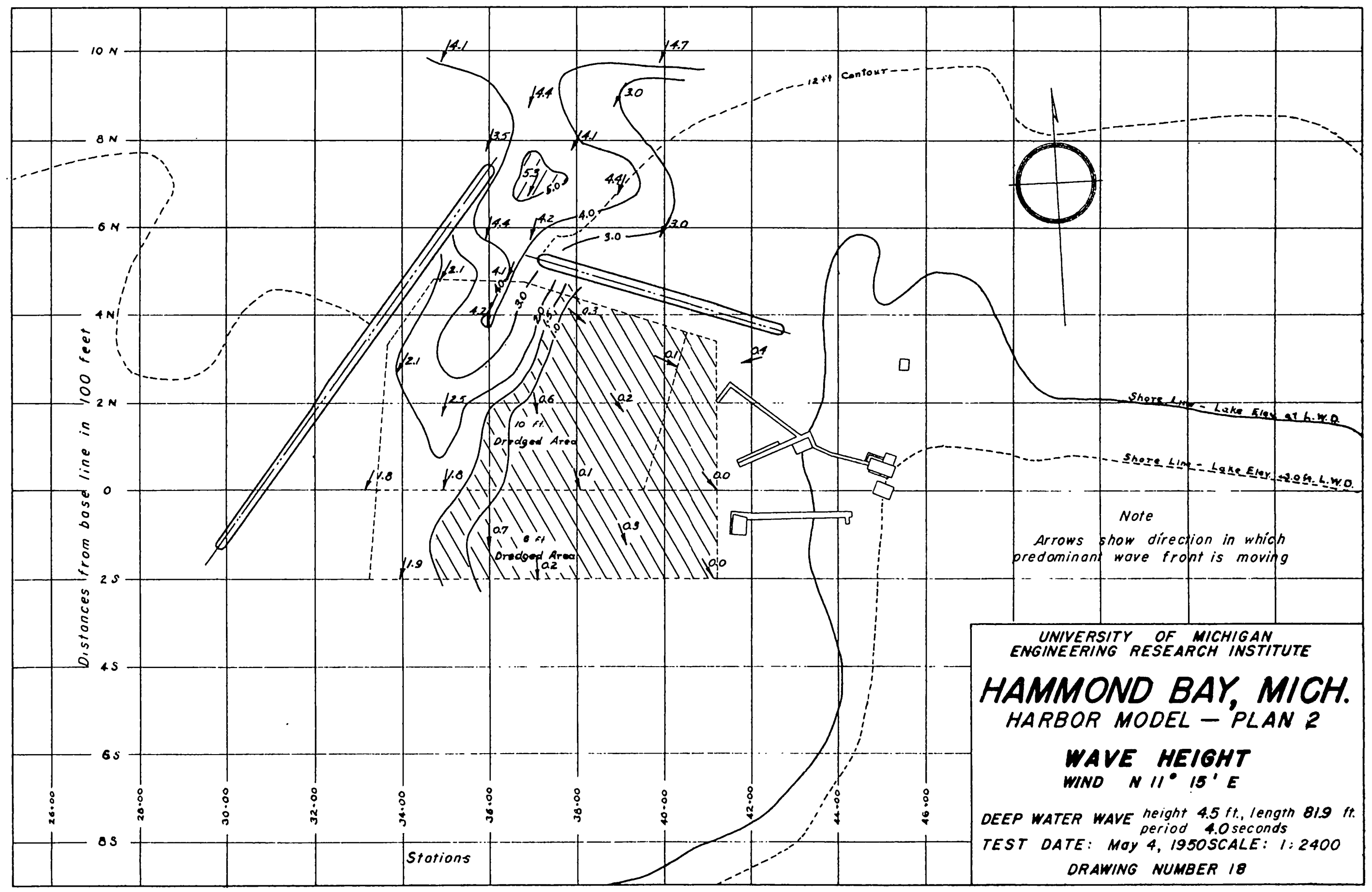
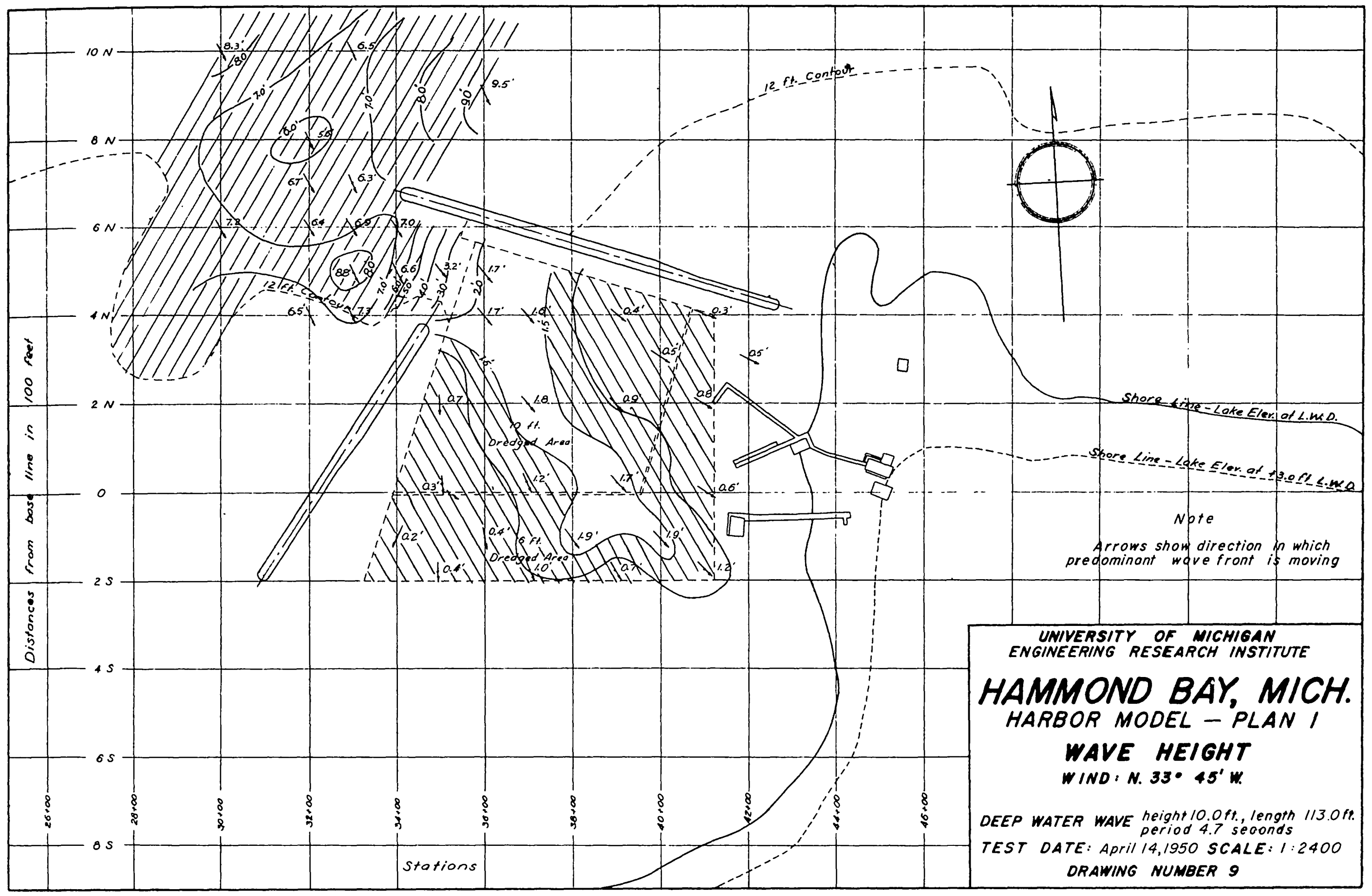
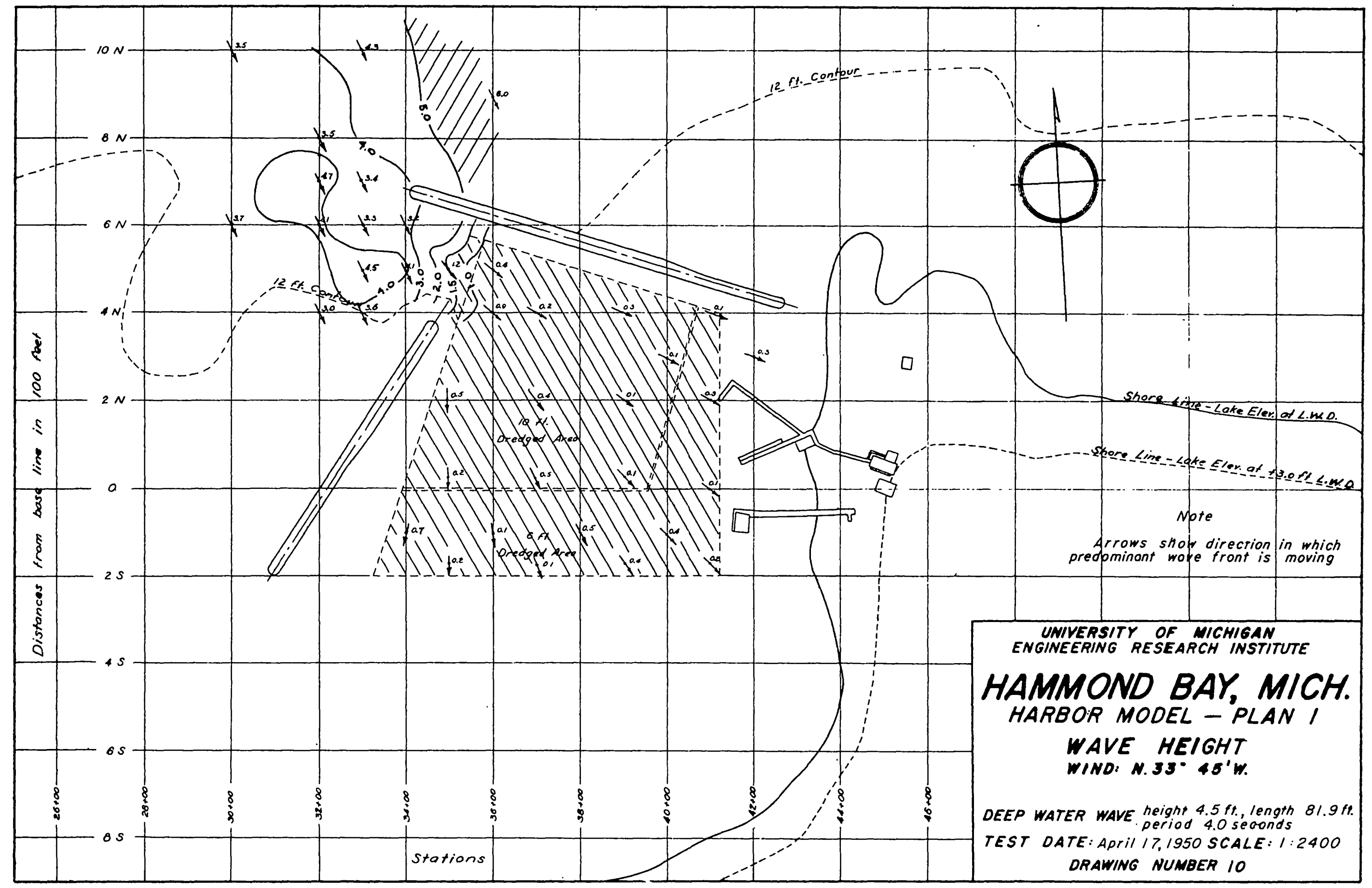
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN I
WAVE HEIGHT
WIND N. 11° 15' E.
DEEP WATER WAVE height 9.0 ft., length 95.0 ft. period 4.3 seconds
TEST DATE: April 24, 1950 SCALE: 1:2400
DRAWING NUMBER 7
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at 13.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area

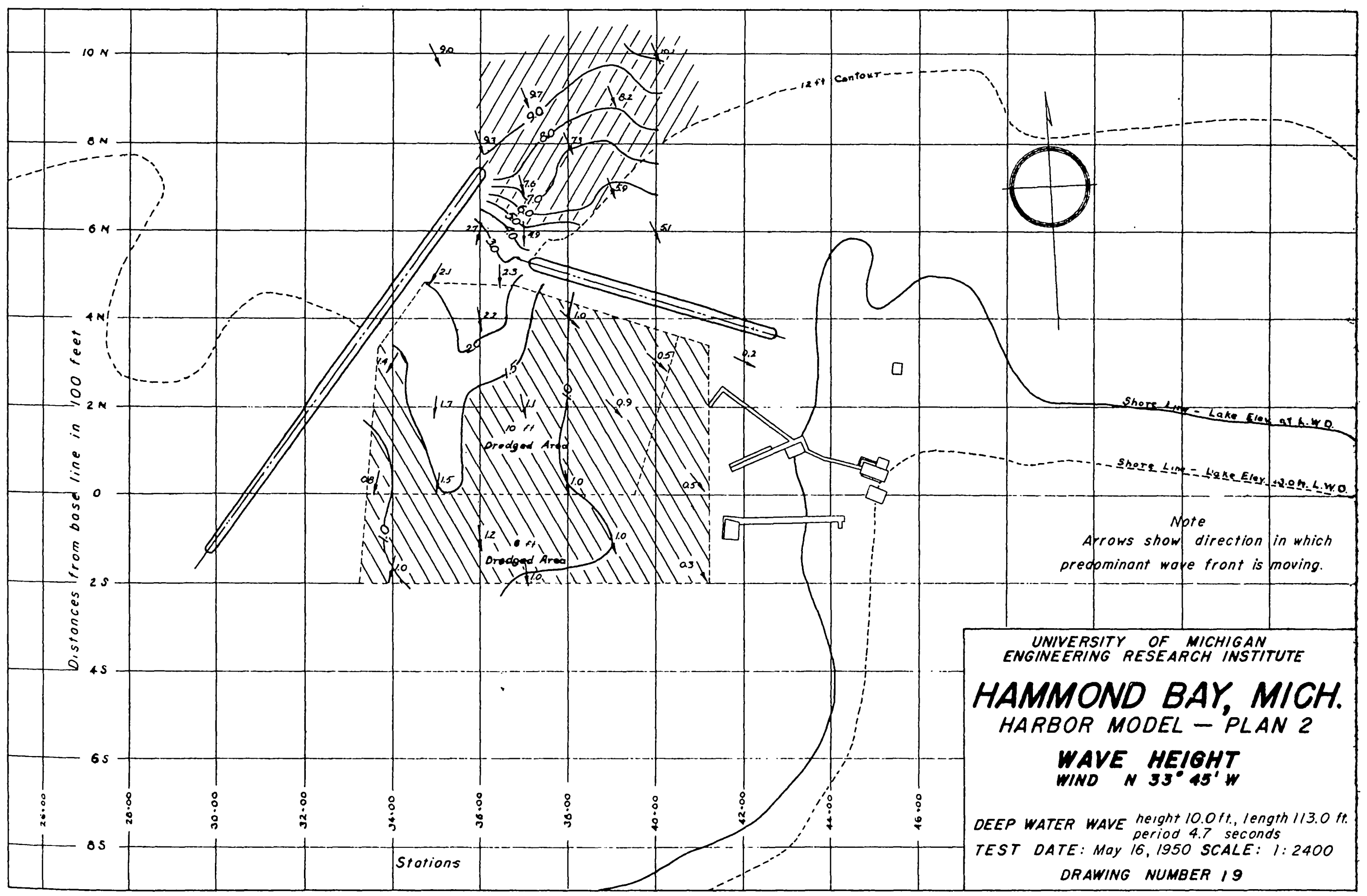

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN I
WAVE HEIGHT
WIND: N. 11° 15' E.
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: April 26, 1950 SCALE: 1:2400
DRAWING NUMBER 8
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at 13.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area

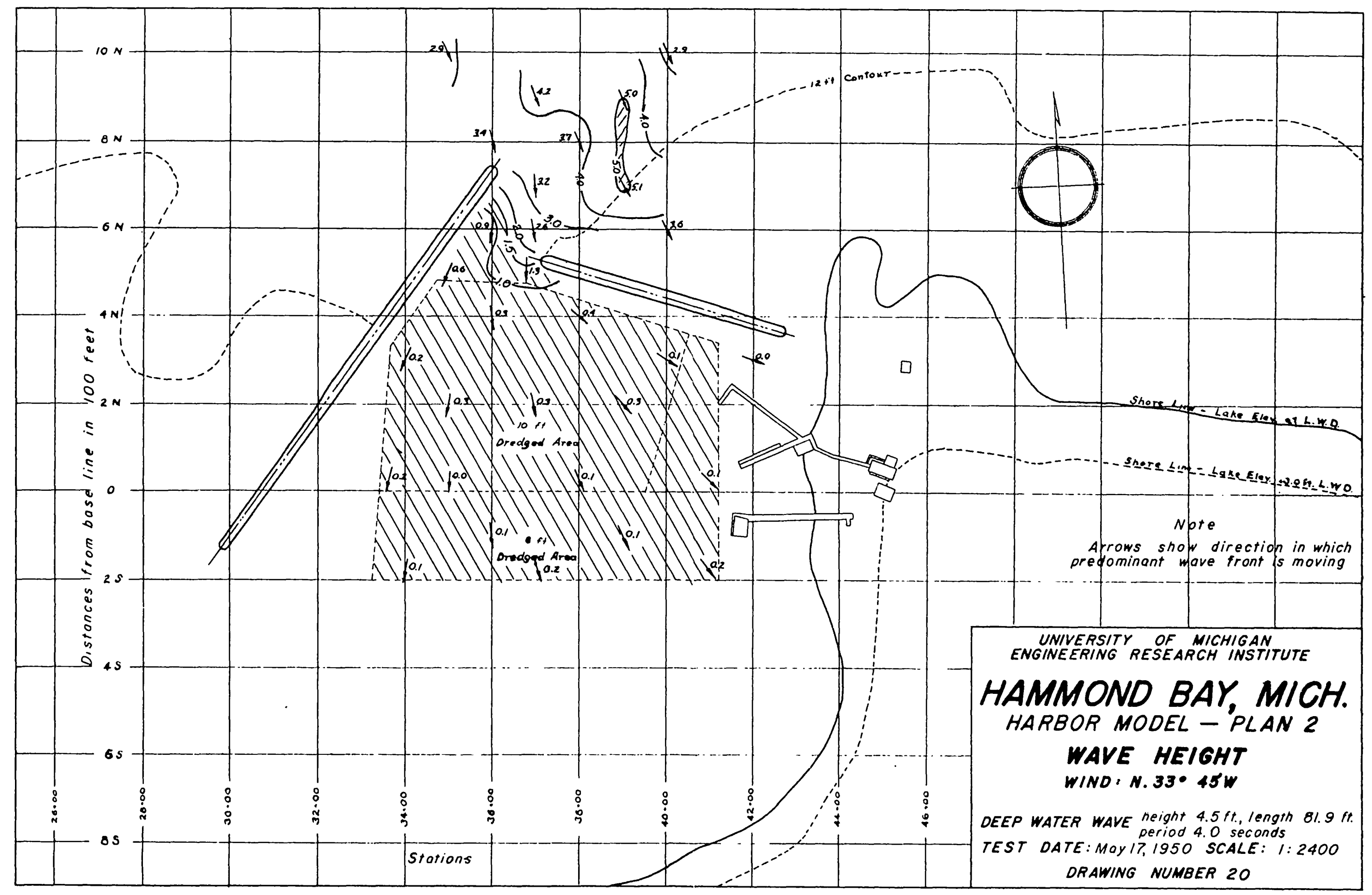

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
WAVE HEIGHT
WIND N 11° 15' E
DEEP WATER WAVE height 9.0 ft., length 95.0 ft. period 4.3 seconds
TEST DATE: May 5, 1950 SCALE: 1:2400
DRAWING NUMBER 17
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
12 ft Contour
Shore Line - Lake Elev. at L.W.D.
Dredged Area

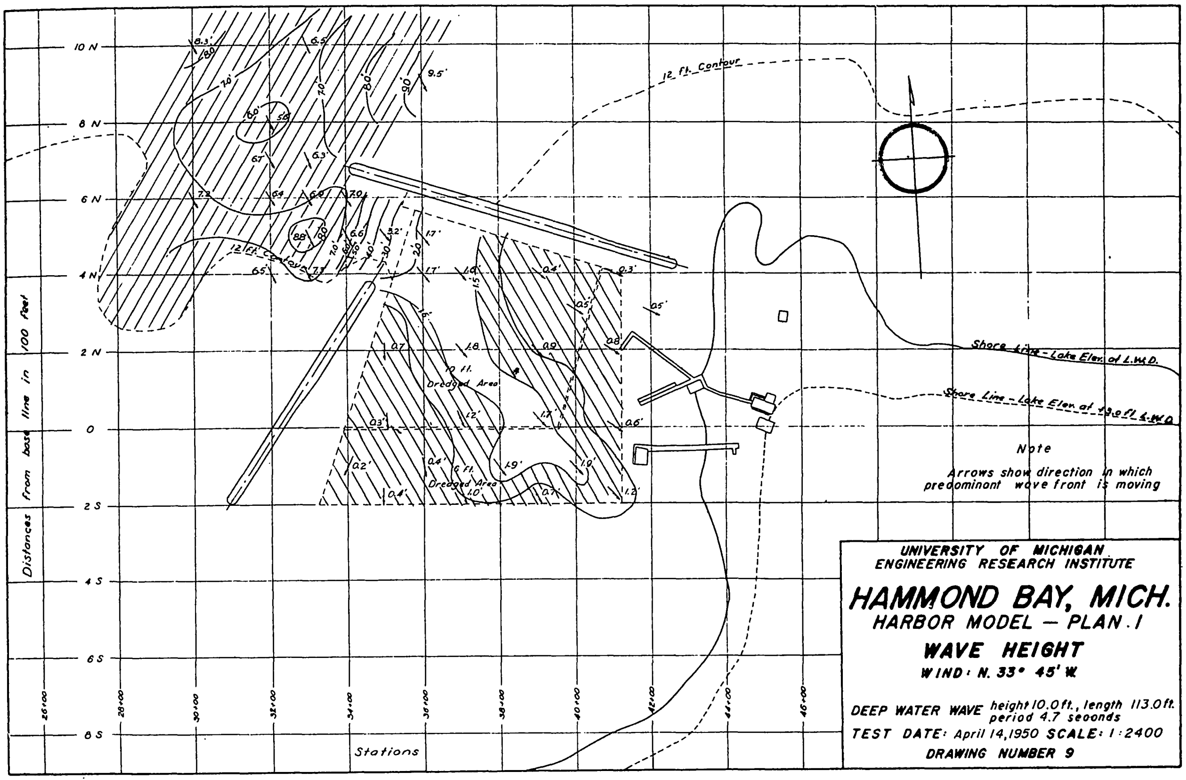

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
WAVE HEIGHT
WIND N 11° 15' E
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: May 4, 1950 SCALE: 1:2400
DRAWING NUMBER 18
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
12 ft Contour
Shore Line - Lake Elev. at L.W.D.
10 ft Dredged Area
6 ft Dredged Area

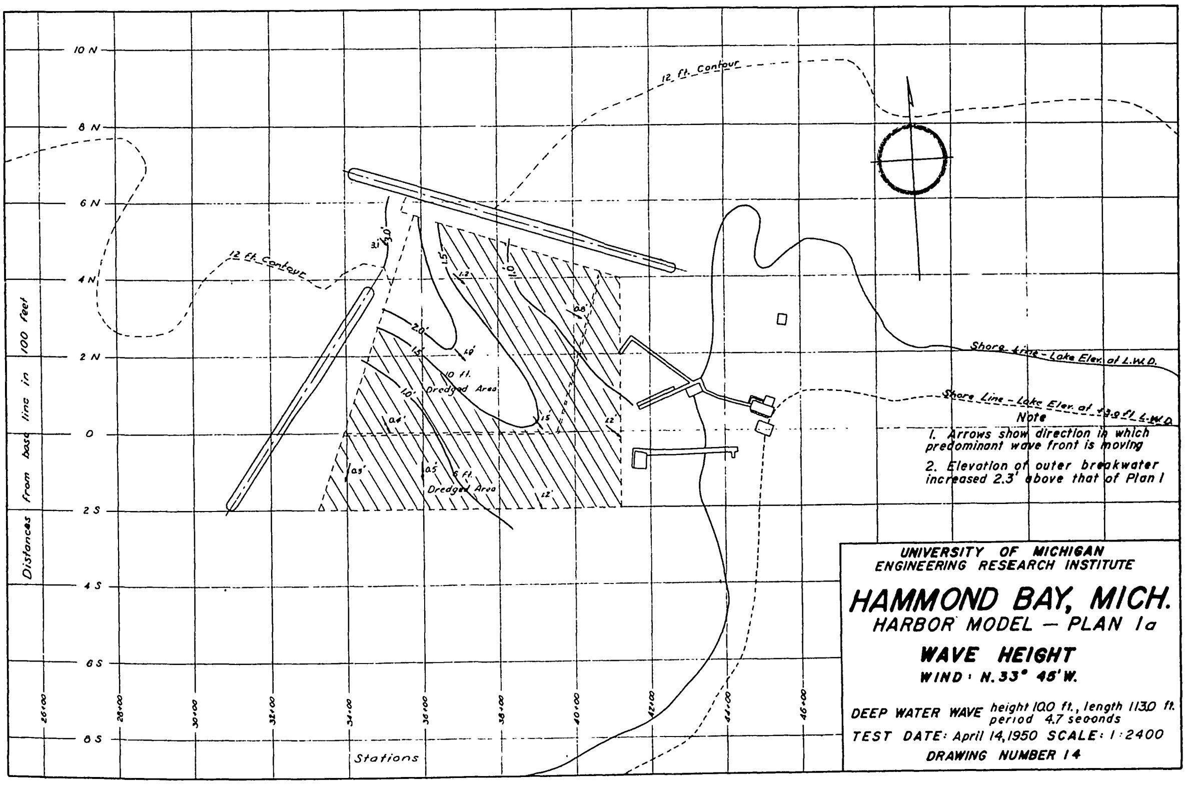

12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at 13.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N. 33° 45' W.
DEEP WATER WAVE height 10.0 ft., length 113.0 ft. period 4.7 seconds
TEST DATE: April 14, 1950 SCALE: 1:2400
DRAWING NUMBER 9

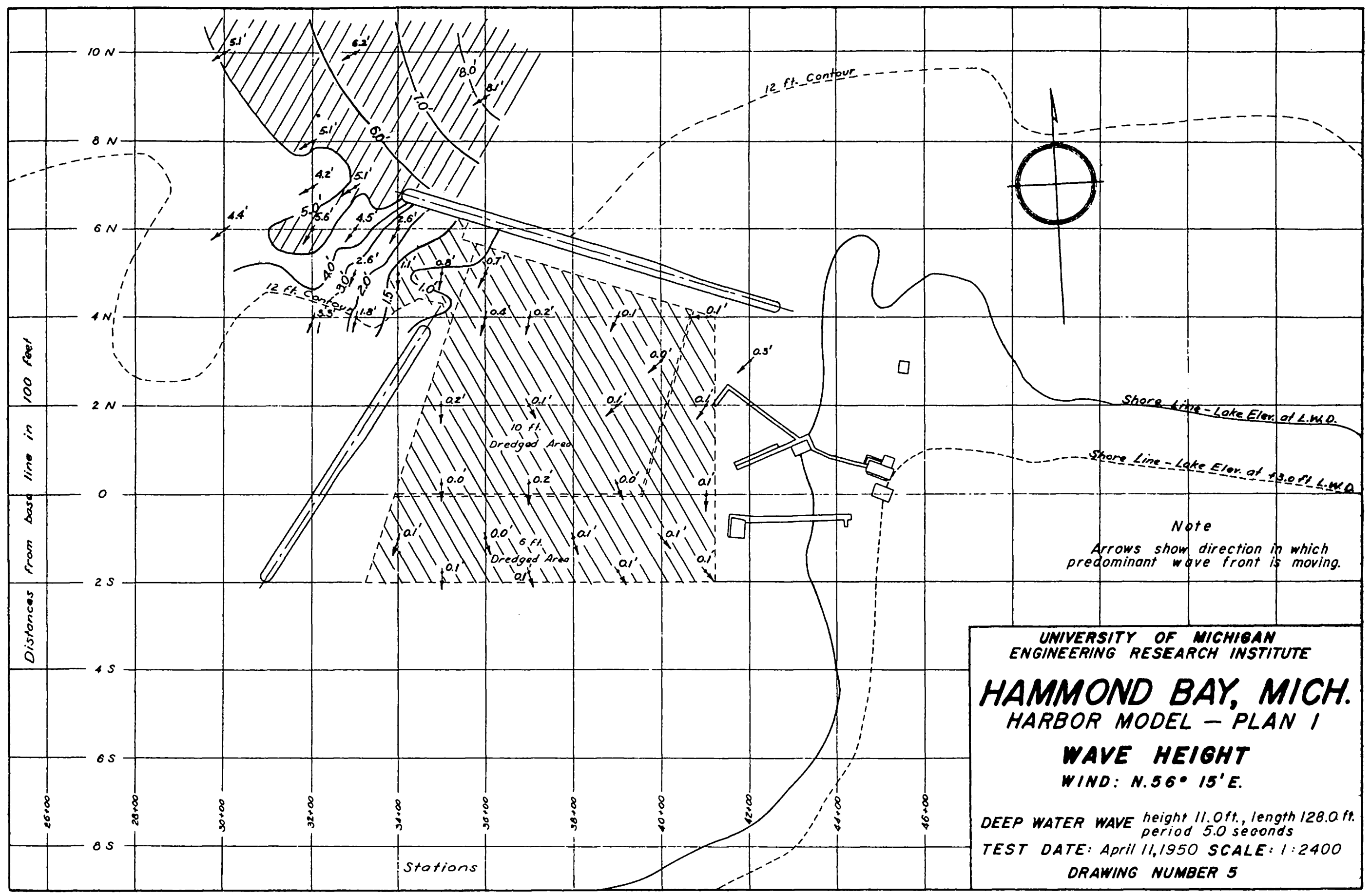

12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at 13.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N. 33° 45' W.
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: April 17, 1950 SCALE: 1:2400
DRAWING NUMBER 10

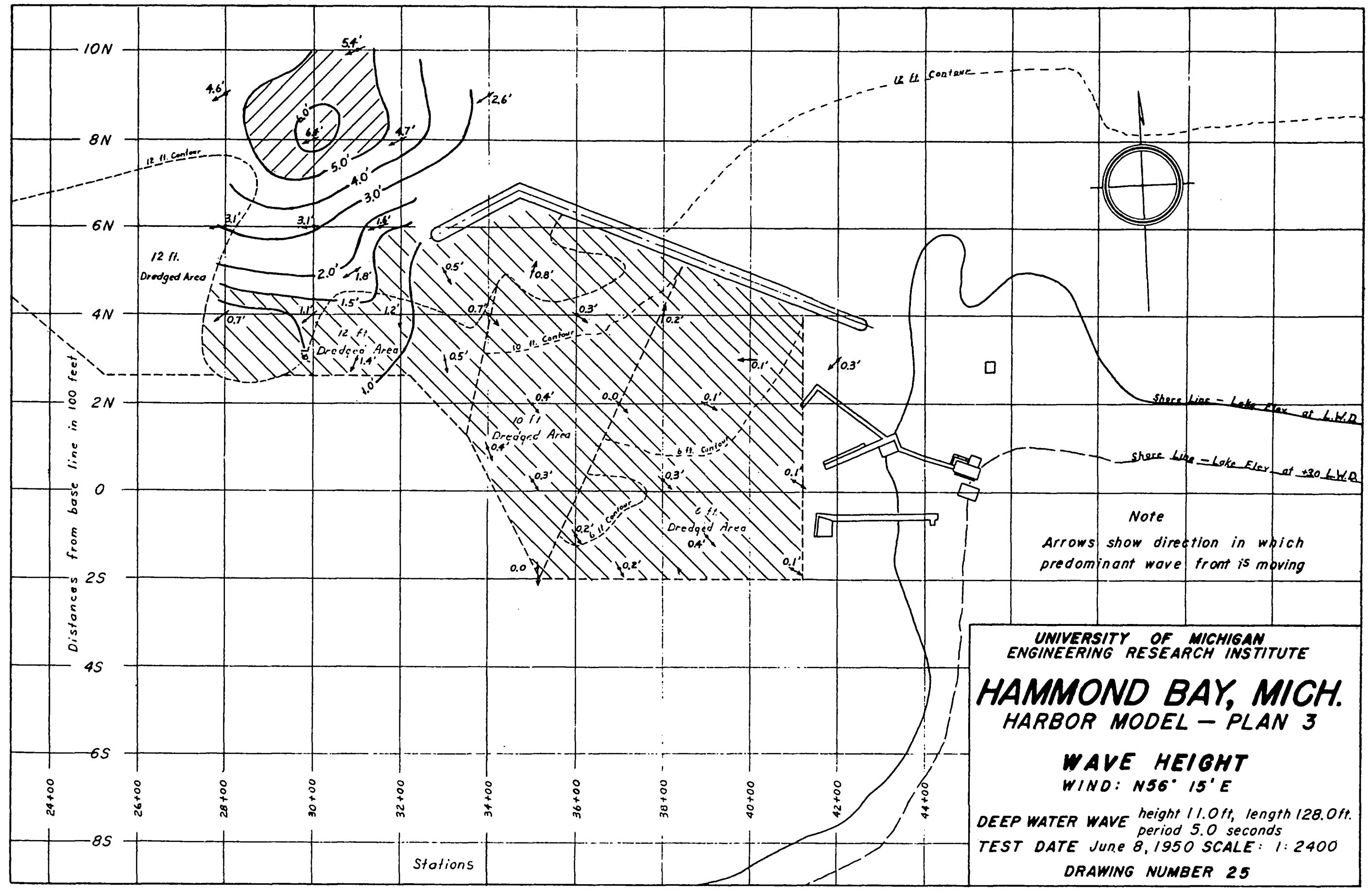

12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. 3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
WAVE HEIGHT
WIND N 33° 45' W
DEEP WATER WAVE height 10.0 ft., length 113.0 ft. period 4.7 seconds
TEST DATE: May 16, 1950 SCALE: 1:2400
DRAWING NUMBER 19

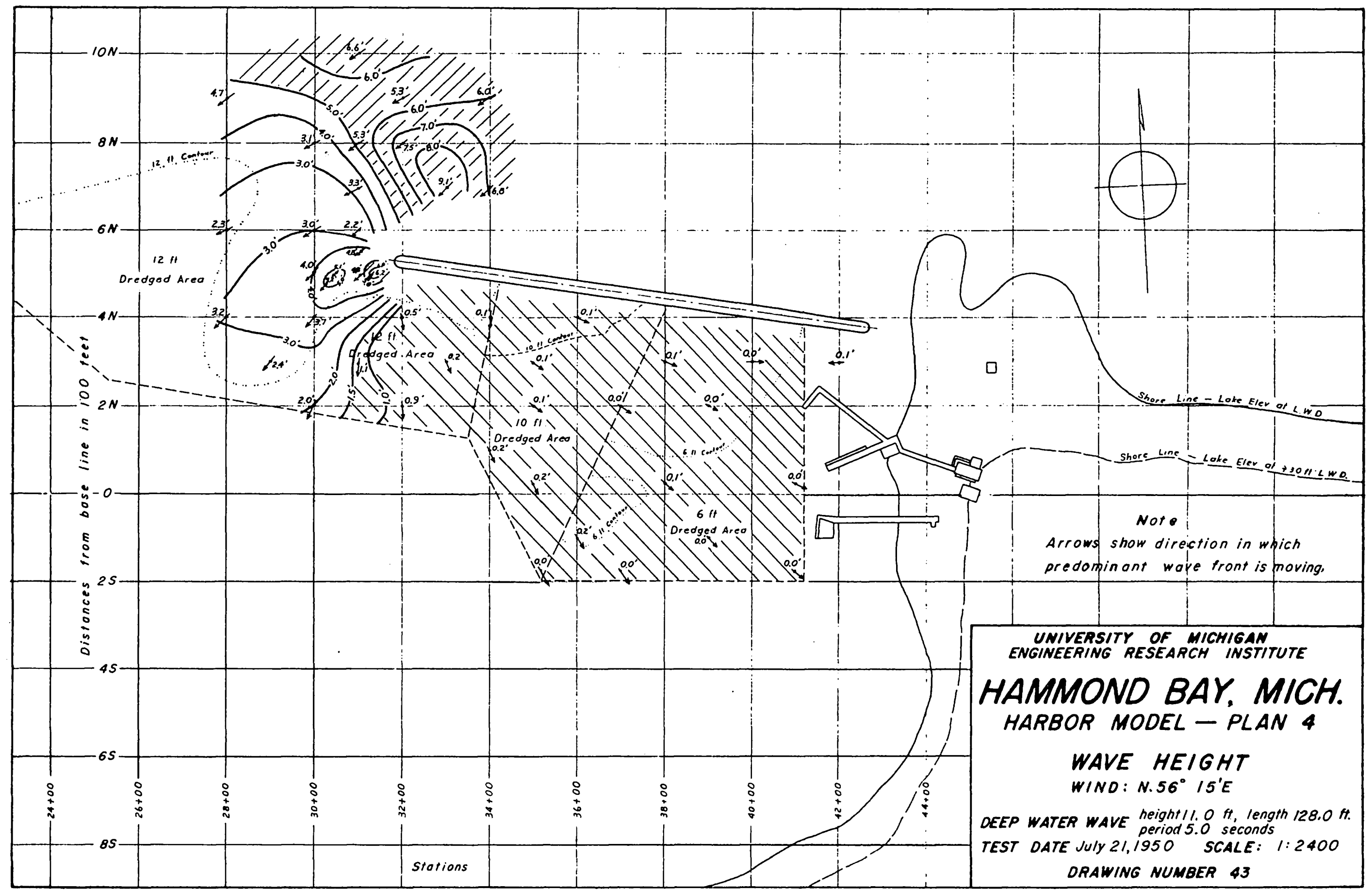

12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. 3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
WAVE HEIGHT
WIND: N. 33° 45' W
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: May 17, 1950 SCALE: 1:2400
DRAWING NUMBER 20

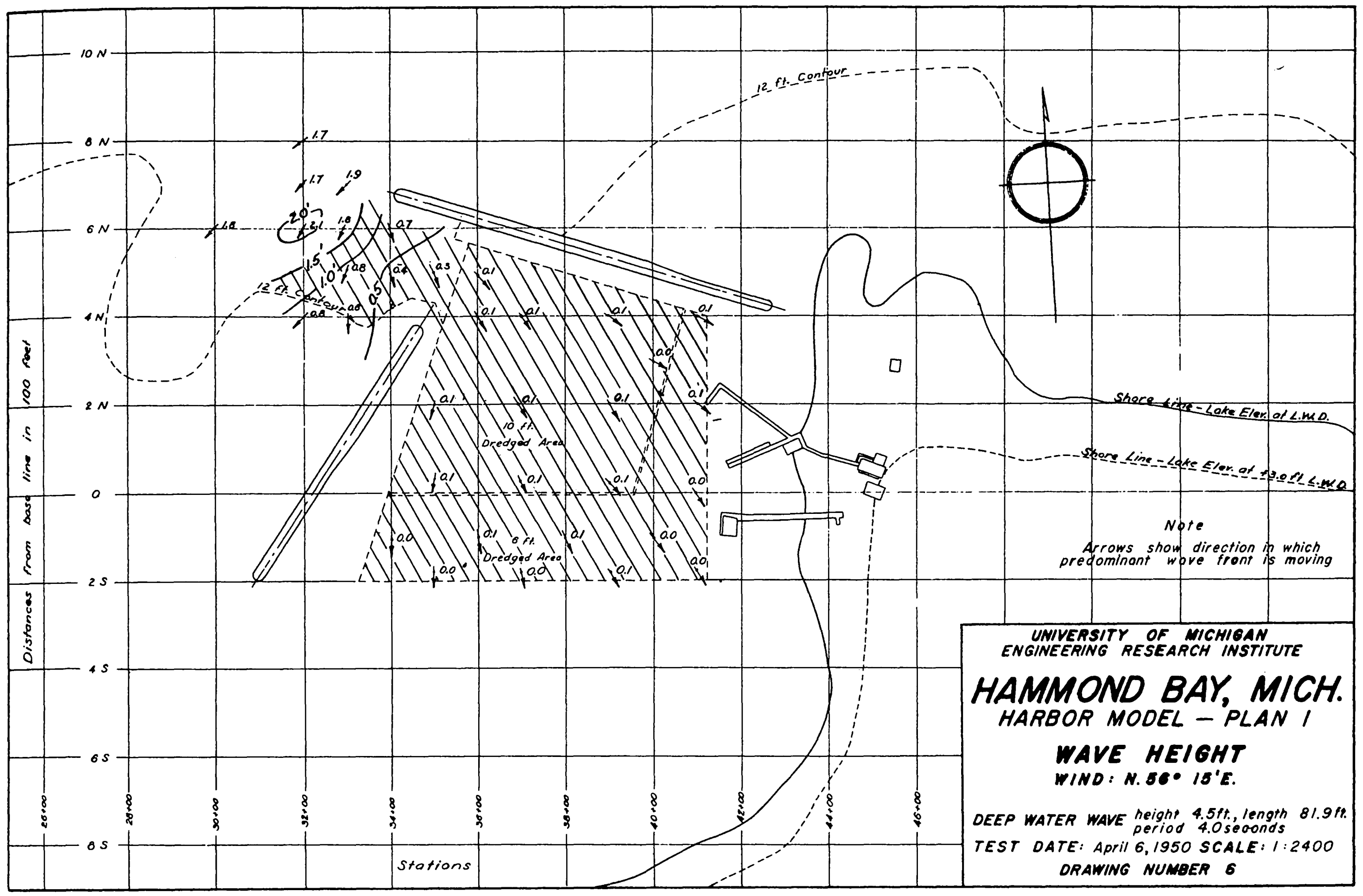

12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN I
WAVE HEIGHT
WIND: N. 33° 45' W.
DEEP WATER WAVE height 10.0 ft., length 113.0 ft. period 4.7 seconds
TEST DATE: April 14, 1950 SCALE: 1:2400
DRAWING NUMBER 9

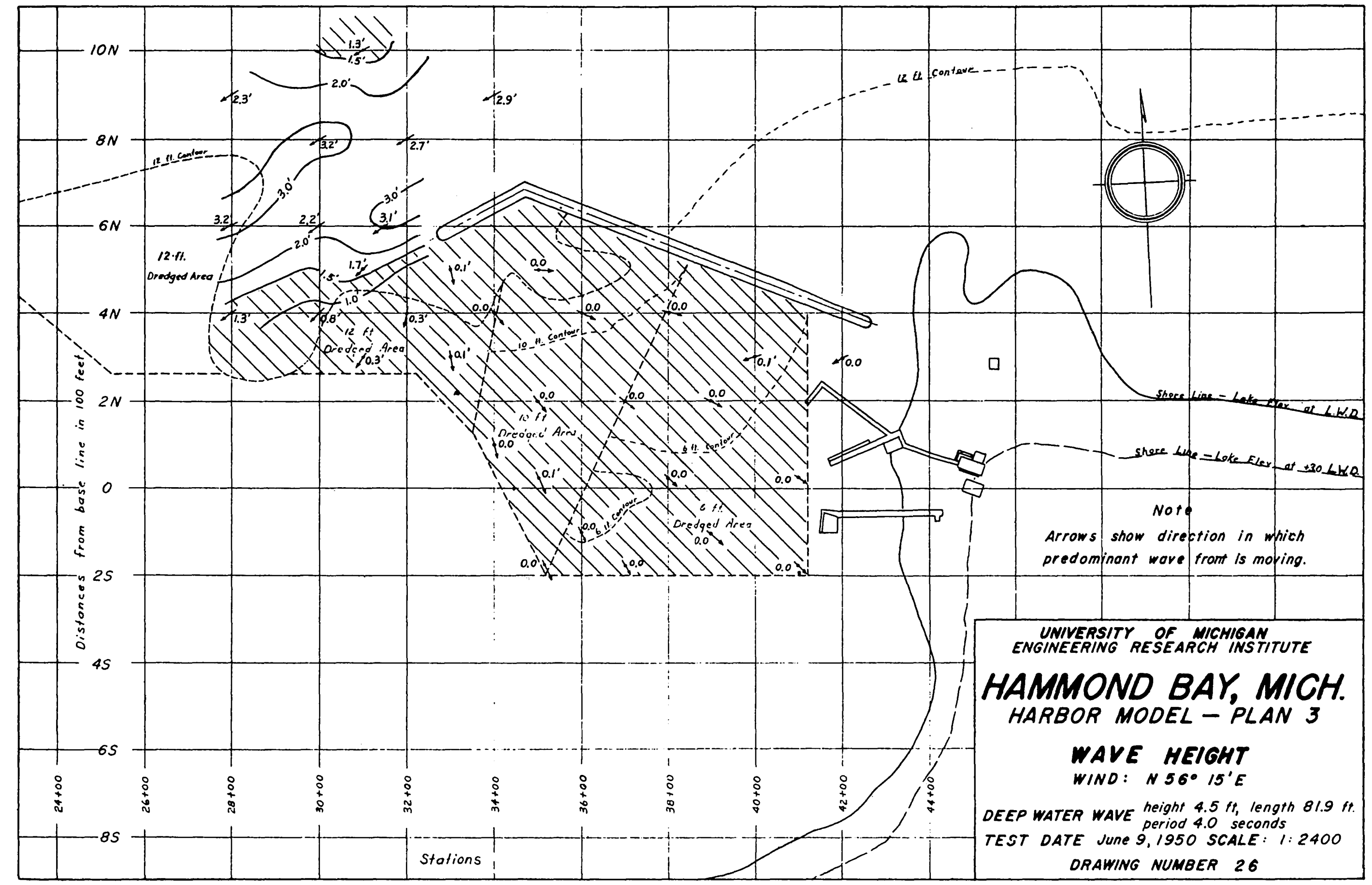

12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Note
1. Arrows show direction in which predominant wave front is moving
2. Elevation of outer breakwater increased 2.3' above that of Plan I
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN Ia
WAVE HEIGHT
WIND: N. 33° 45' W.
DEEP WATER WAVE height 10.0 ft., length 113.0 ft. period 4.7 seconds
TEST DATE: April 14, 1950 SCALE: 1:2400
DRAWING NUMBER 14

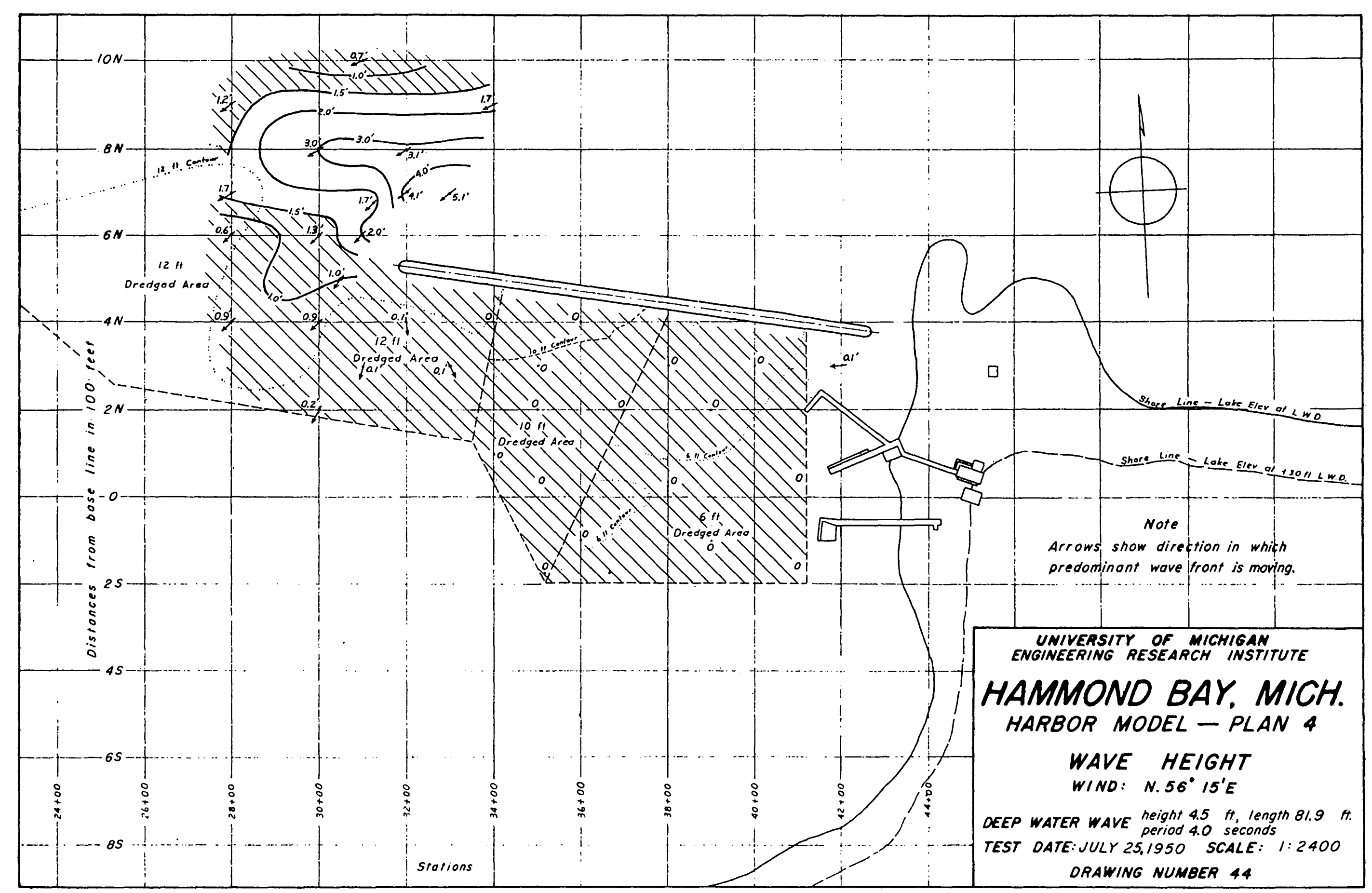

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N.56° 15'E.
DEEP WATER WAVE height 11.0 ft., length 128.0 ft. period 5.0 seconds
TEST DATE: April 11, 1950 SCALE: 1:2400
DRAWING NUMBER 5
Note
Arrows show direction in which predominant wave front is moving.
12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Distances from base line in 100 feet
Stations

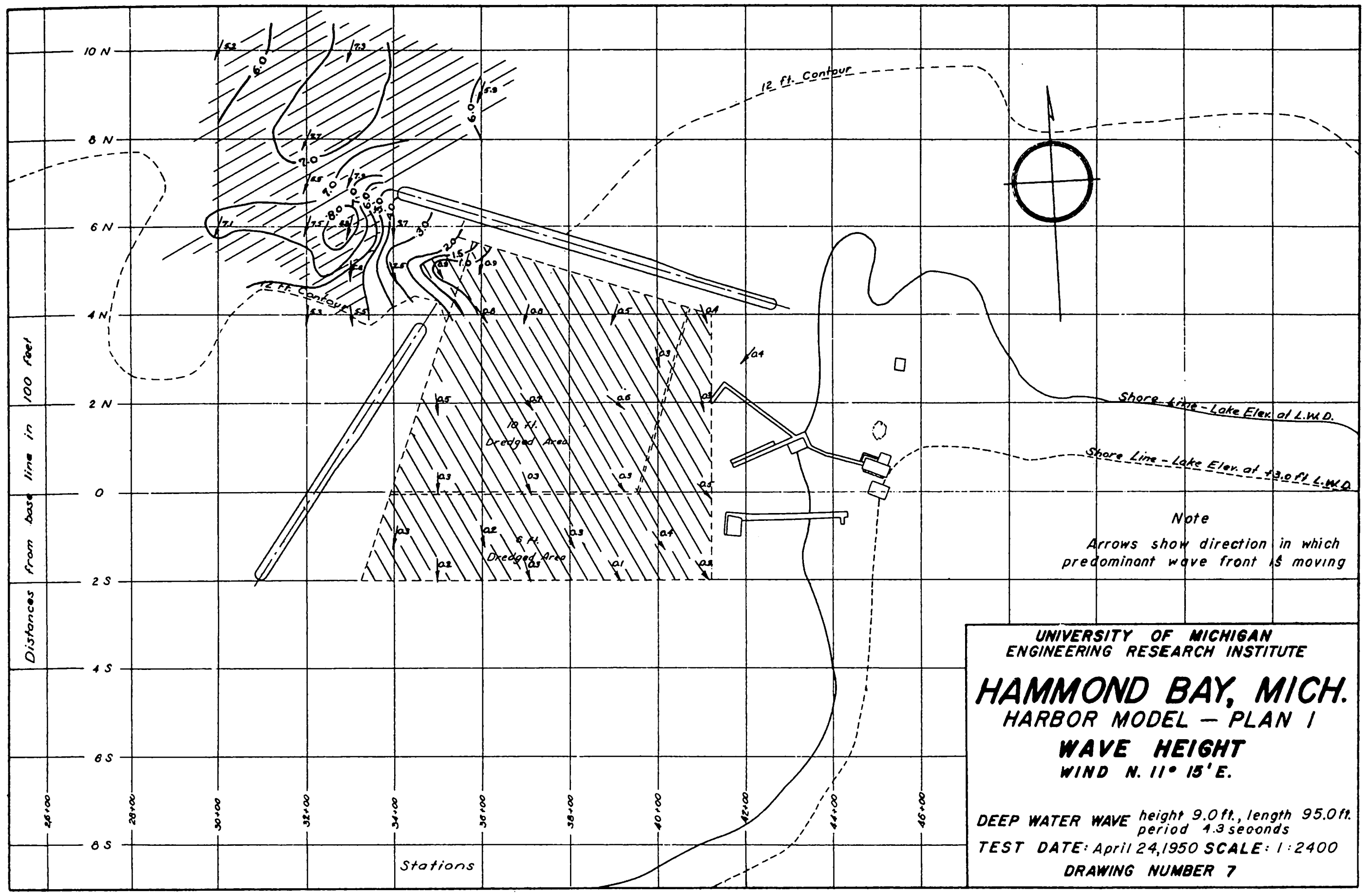

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
WAVE HEIGHT
WIND: N56° 15'E
DEEP WATER WAVE height 11.0 ft, length 128.0 ft. period 5.0 seconds
TEST DATE June 8, 1950 SCALE: 1:2400
DRAWING NUMBER 25
Note
Arrows show direction in which predominant wave front is moving
12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 L.W.D.
12 ft. Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Distances from base line in 100 feet
Stations

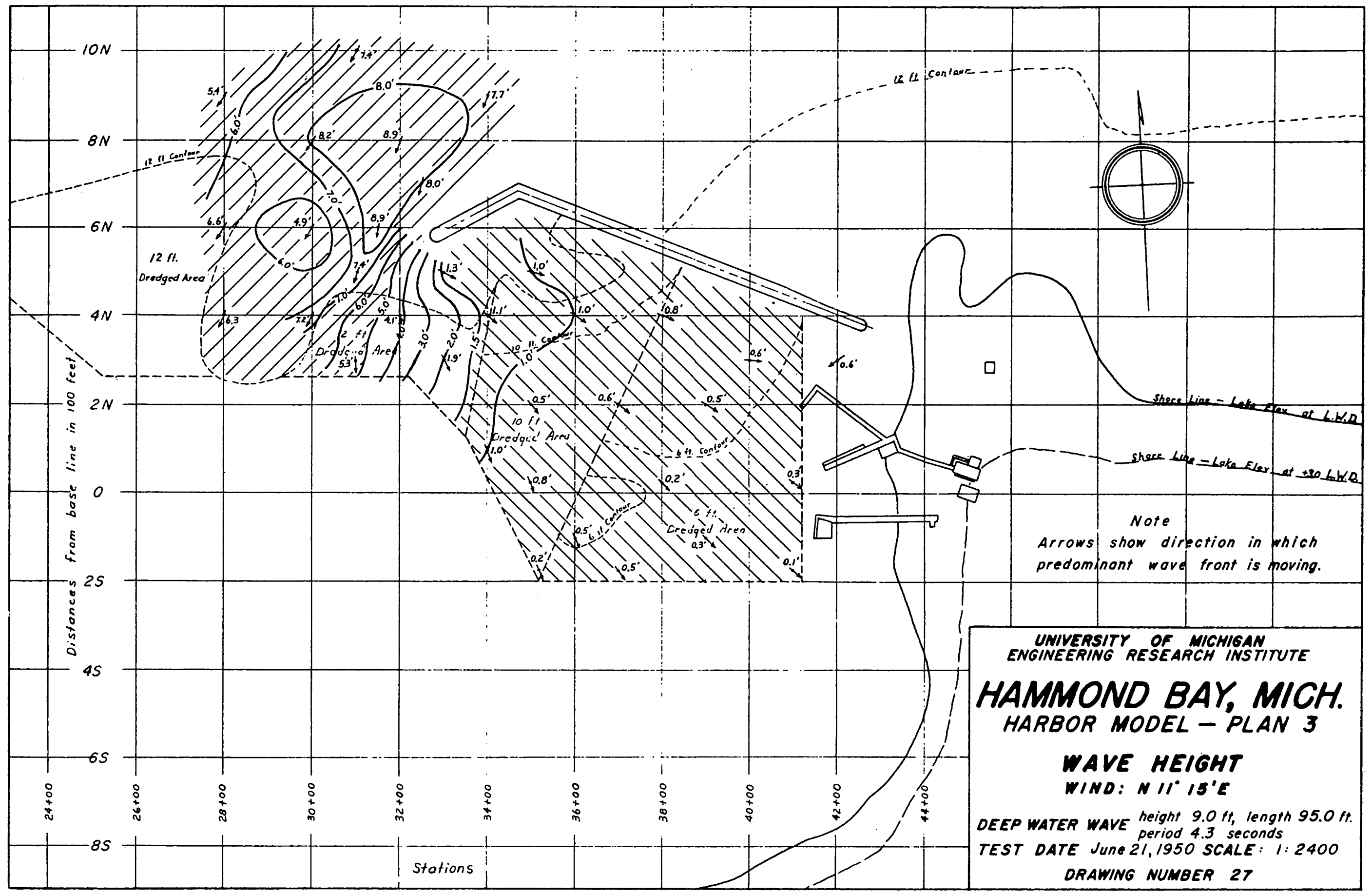

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
WAVE HEIGHT
WIND: N.56° 15'E
DEEP WATER WAVE height 11.0 ft, length 128.0 ft. period 5.0 seconds
TEST DATE July 21, 1950 SCALE: 1:2400
DRAWING NUMBER 43
Note
Arrows show direction in which predominant wave front is moving.
12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Distances from base line in 100 feet
Stations

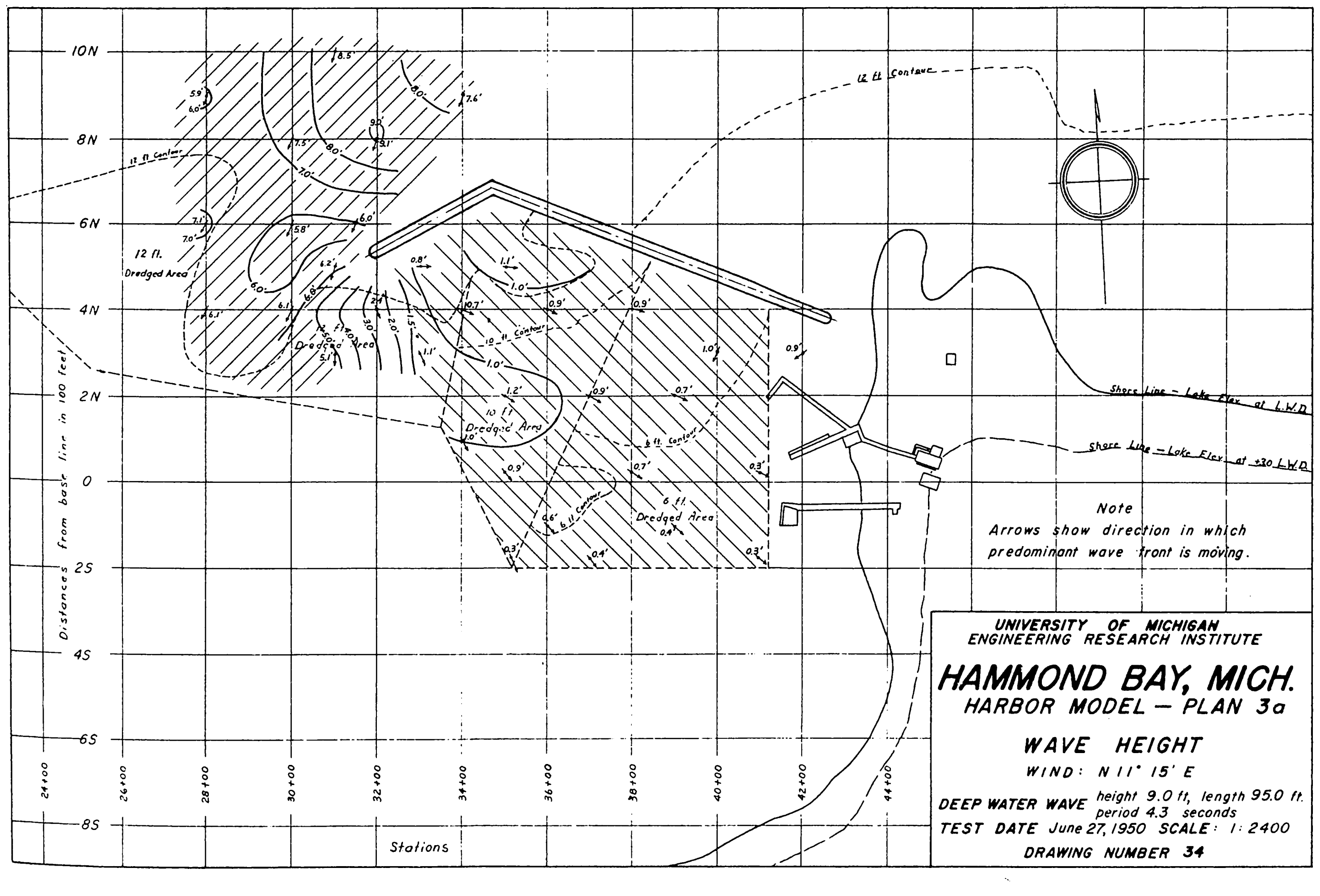

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N. 56° 15'E.
DEEP WATER WAVE height 4.5ft., length 81.9ft. period 4.0seconds
TEST DATE: April 6,1950 SCALE: 1:2400
DRAWING NUMBER 6
Note
Arrows show direction in which predominant wave front is moving
12 ft. Contour
Shore Line - Lake Elev. of L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Stations
Distances from base line in 100 feet


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
WAVE HEIGHT
WIND: N 56° 15'E
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE June 9, 1950 SCALE: 1:2400
DRAWING NUMBER 26
Note
Arrows show direction in which predominant wave front is moving.
12 ft. Dredged Area
Stations
Distances from base line in 100 feet


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
WAVE HEIGHT
WIND: N. 56° 15'E
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE: JULY 25,1950 SCALE: 1:2400
DRAWING NUMBER 44
Note
Arrows show direction in which predominant wave front is moving.
12 ft Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Stations
Distances from base line in 100 feet


12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND N. 11° 15' E.
DEEP WATER WAVE height 9.0 ft., length 95.0 ft. period 4.3 seconds
TEST DATE: April 24, 1950 SCALE: 1:2400
DRAWING NUMBER 7


12 ft. Contour
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 L.W.D.
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft. period 4.3 seconds
TEST DATE June 21, 1950 SCALE: 1:2400
DRAWING NUMBER 27


12 ft. Contour
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 L.W.D.
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
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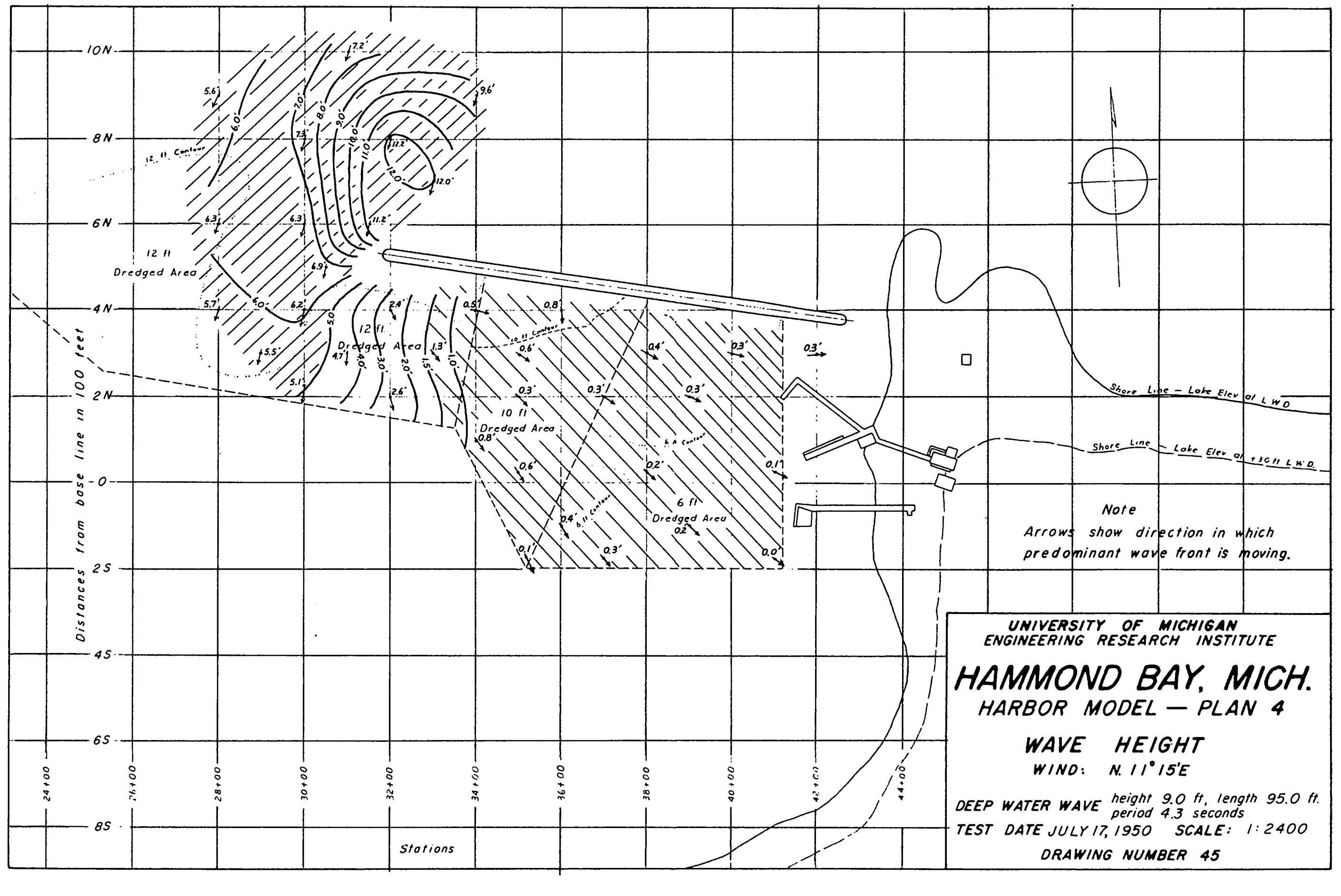
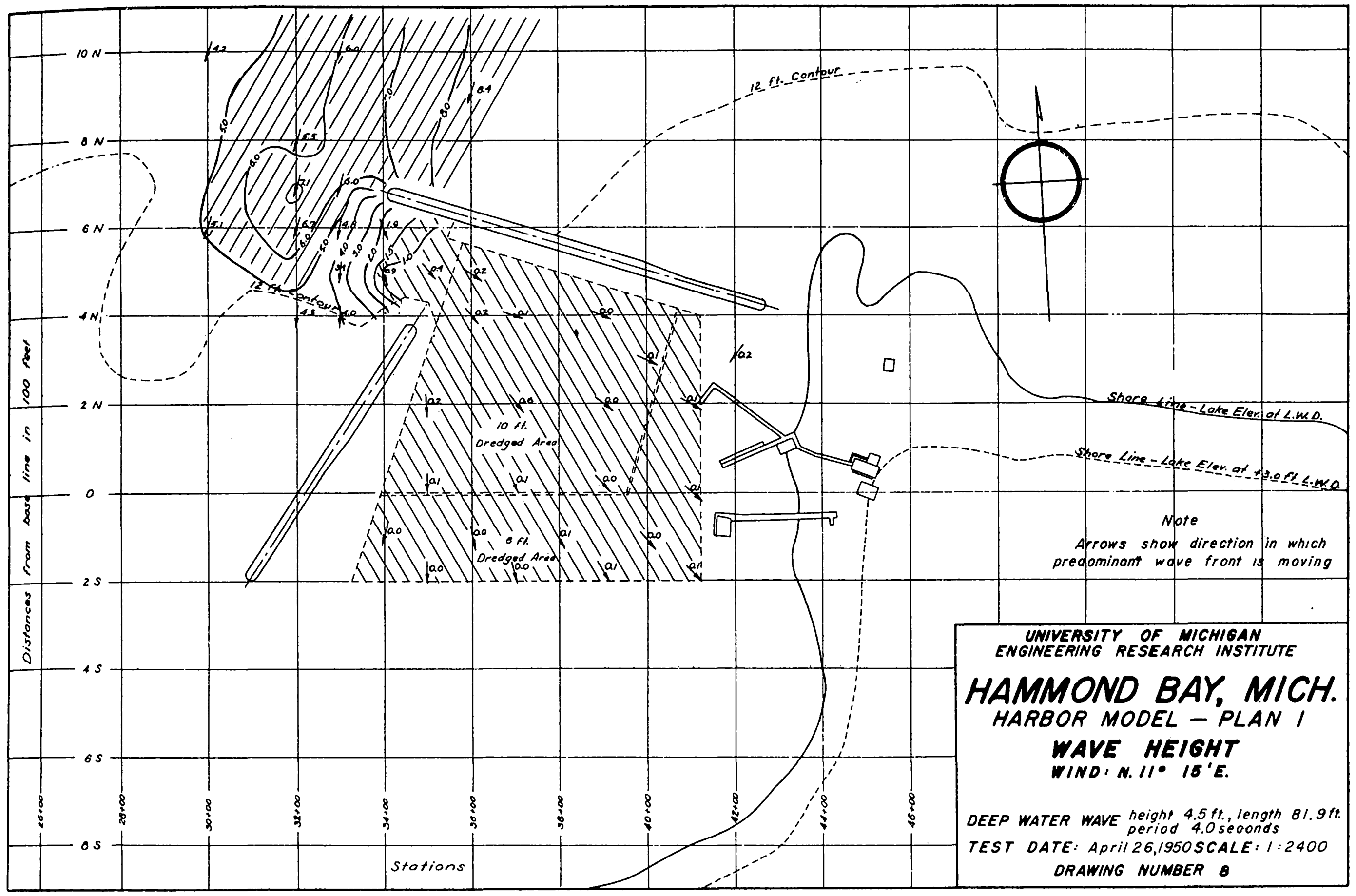
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft. period 4.3 seconds
TEST DATE June 27, 1950 SCALE: 1:2400
DRAWING NUMBER 34


12 ft. Contour
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
WAVE HEIGHT
WIND: N. 11° 15'E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft. period 4.3 seconds
TEST DATE JULY 17, 1950 SCALE: 1:2400
DRAWING NUMBER 45


12 ft. Contour
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
10 ft. Dredged Area
6 ft. Dredged Area
Distances from base line in 100 feet
Stations
Note
Arrows show direction in which predominant wave front is moving
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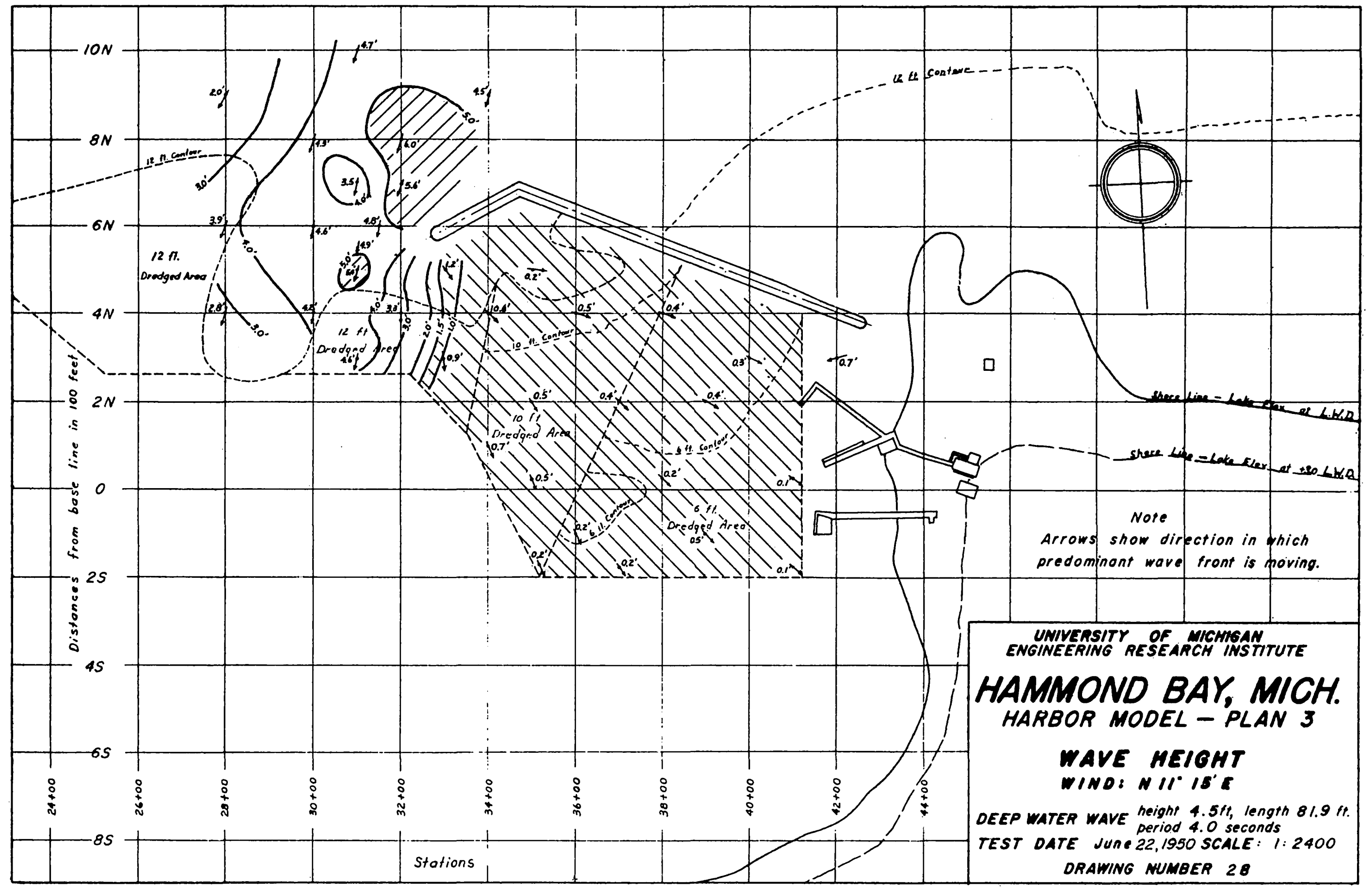
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N. 11° 15' E.
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: April 26, 1950 SCALE: 1:2400
DRAWING NUMBER 8


12 ft. Contour
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 L.W.D.
Distances from base line in 100 feet
Stations
Note
Arrows show direction in which predominant wave front is moving.
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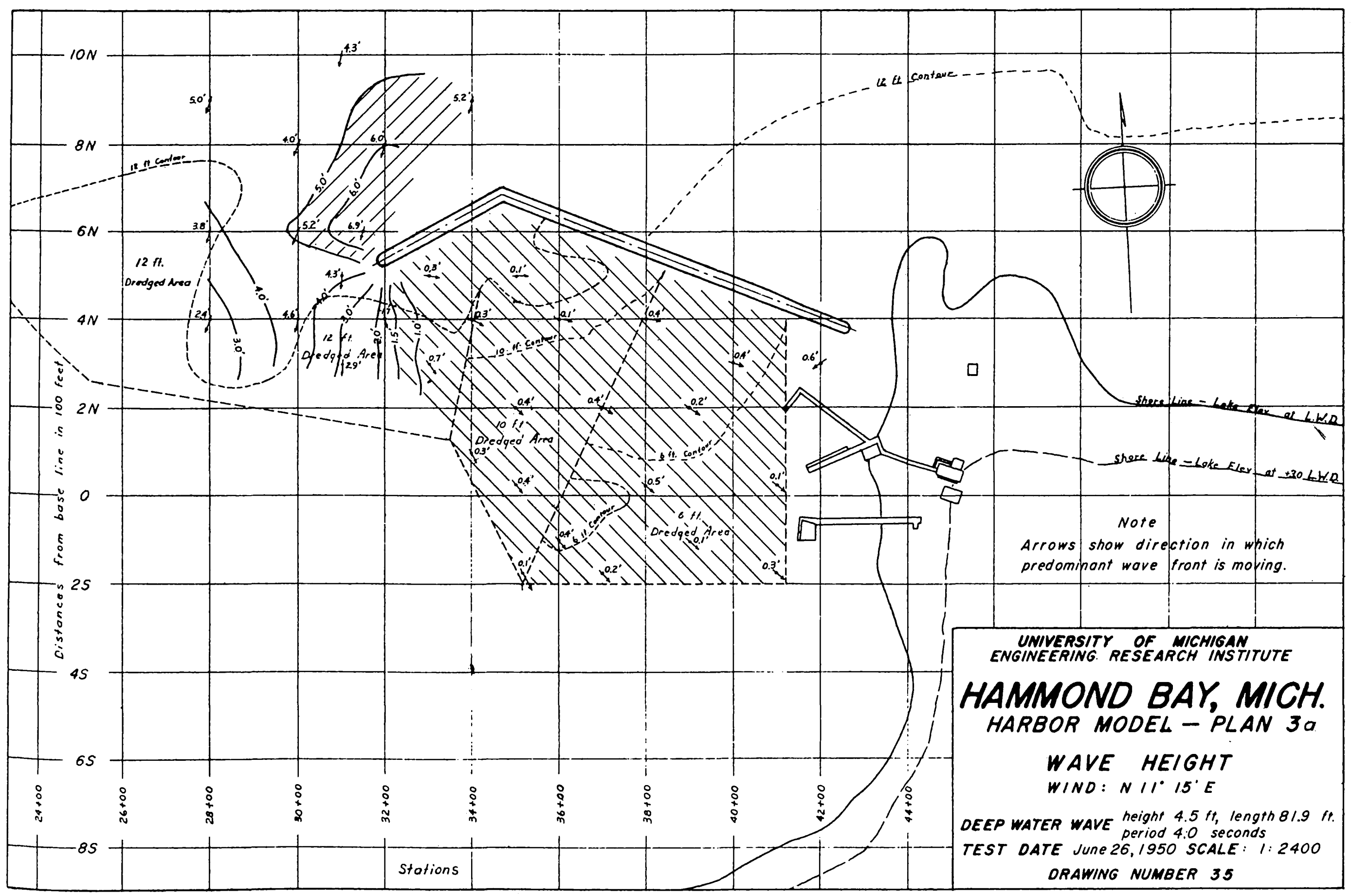
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE June 22, 1950 SCALE: 1:2400
DRAWING NUMBER 28


12 ft. Contour
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 L.W.D.
Distances from base line in 100 feet
Stations
Note
Arrows show direction in which predominant wave front is moving.
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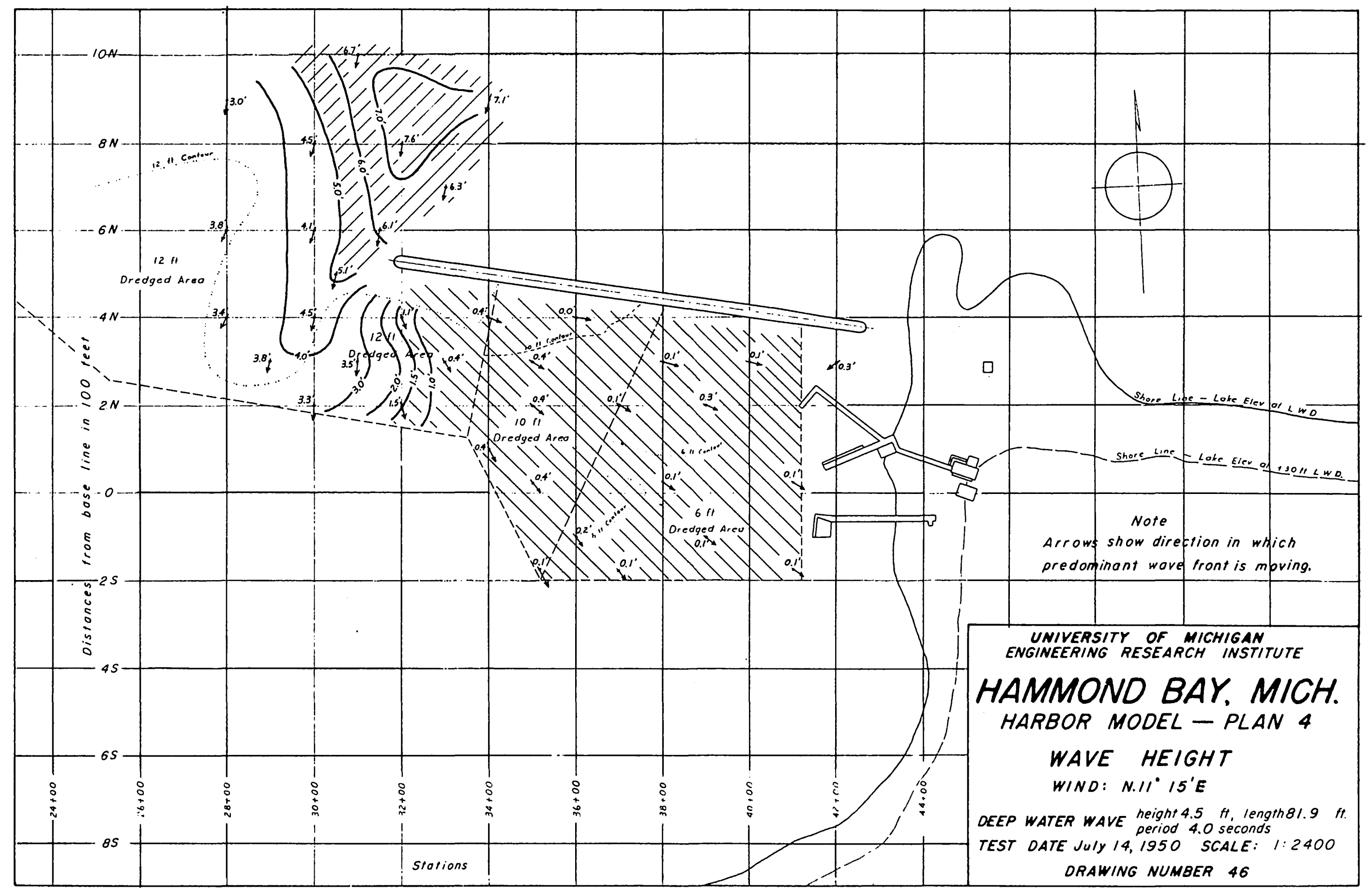
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE June 26, 1950 SCALE: 1:2400
DRAWING NUMBER 35


12 ft. Contour
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Shore Line - Lake Elev at L.W.D.
Shore Line - Lake Elev. at +3.0 ft L.W.D.
Distances from base line in 100 feet
Stations
Note
Arrows show direction in which predominant wave front is moving.
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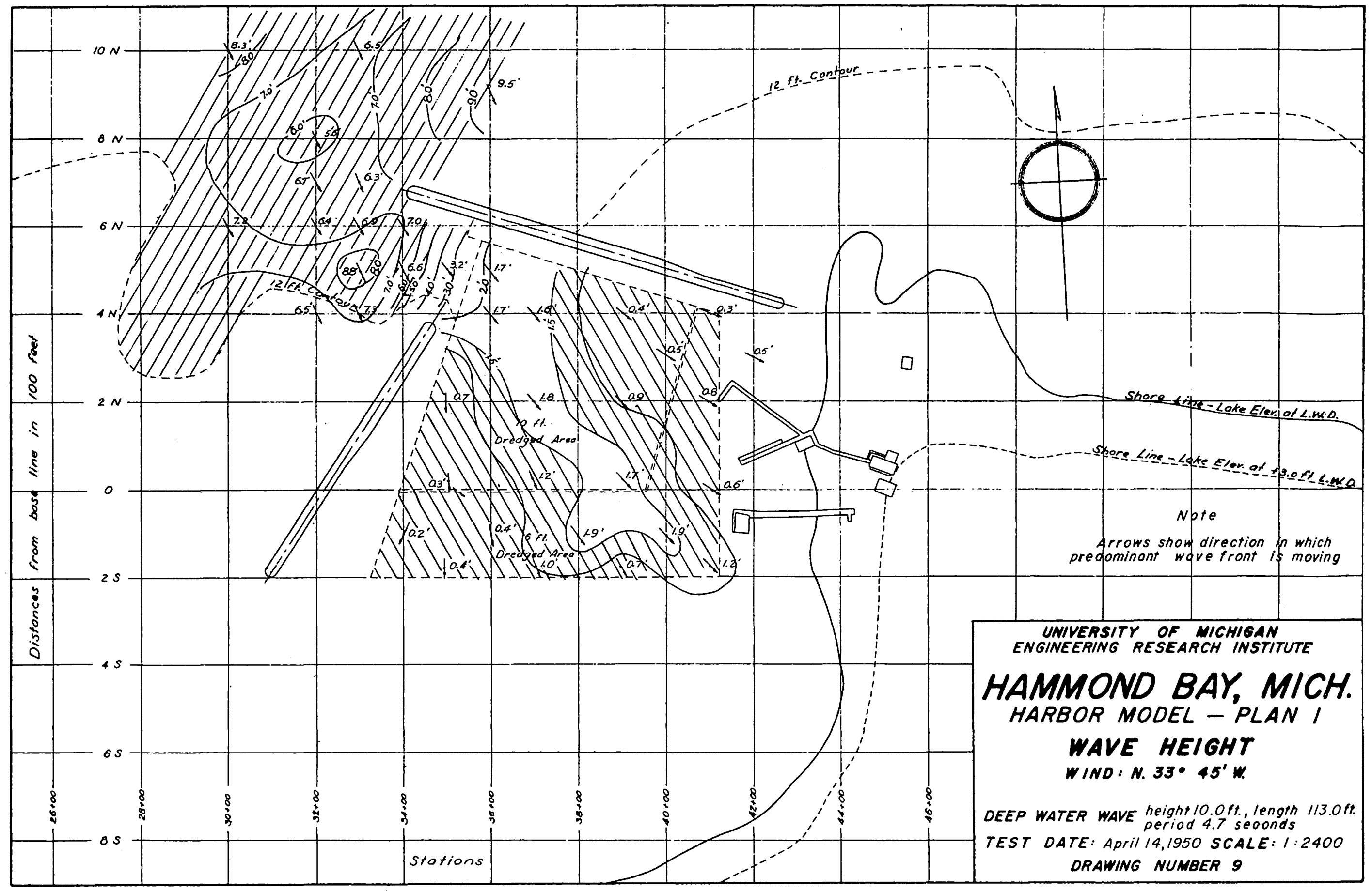
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
WAVE HEIGHT
WIND: N. 11° 15' E
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE July 14, 1950 SCALE: 1:2400
DRAWING NUMBER 46



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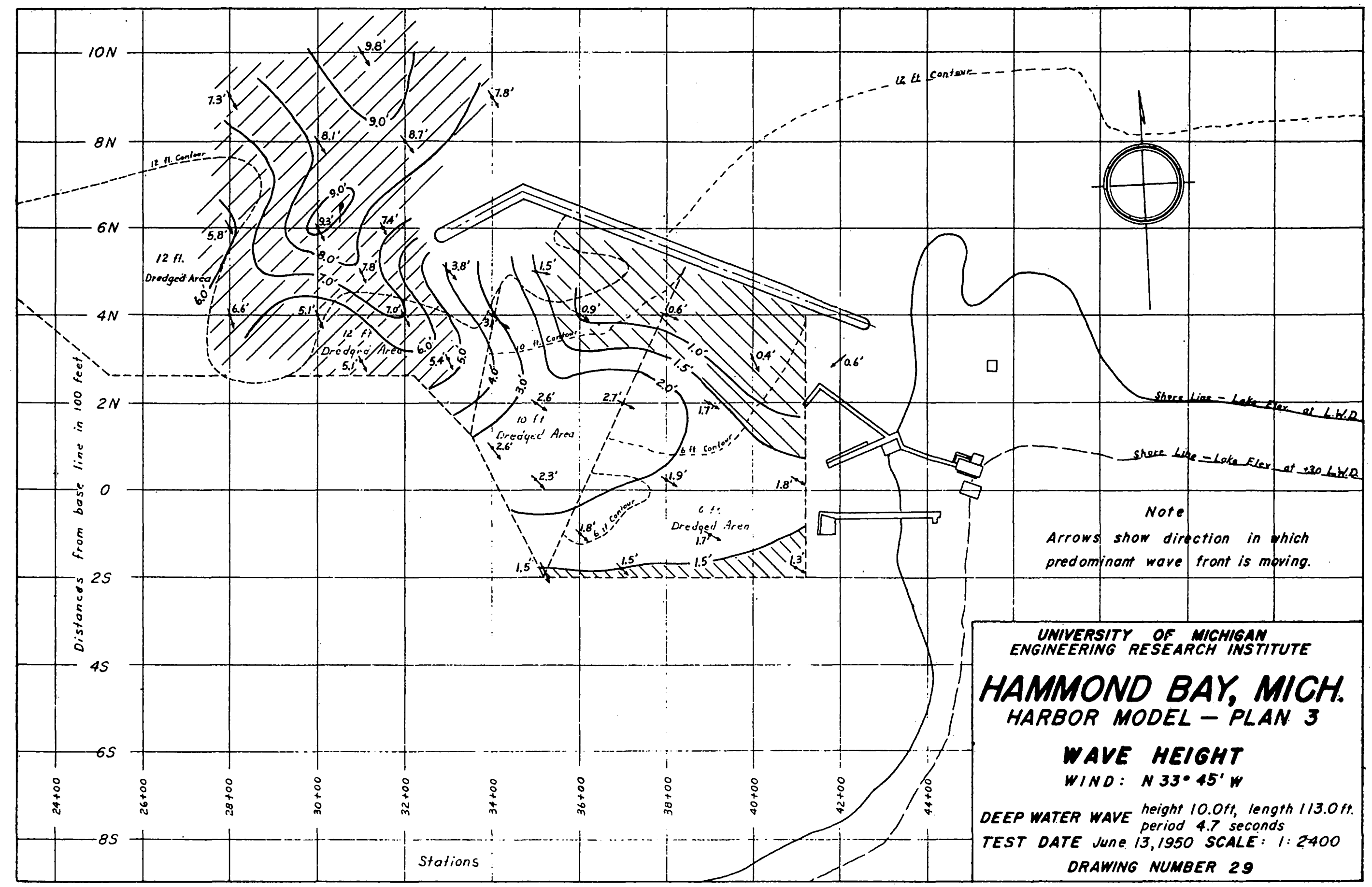
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N. 33° 45' W.
DEEP WATER WAVE height 10.0 ft., length 113.0 ft. period 4.7 seconds
TEST DATE: April 14, 1950 SCALE: 1:2400
DRAWING NUMBER 9
Note
Arrows show direction in which predominant wave front is moving
Stations
Distances from base line in 100 feet
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
12 ft. Contour



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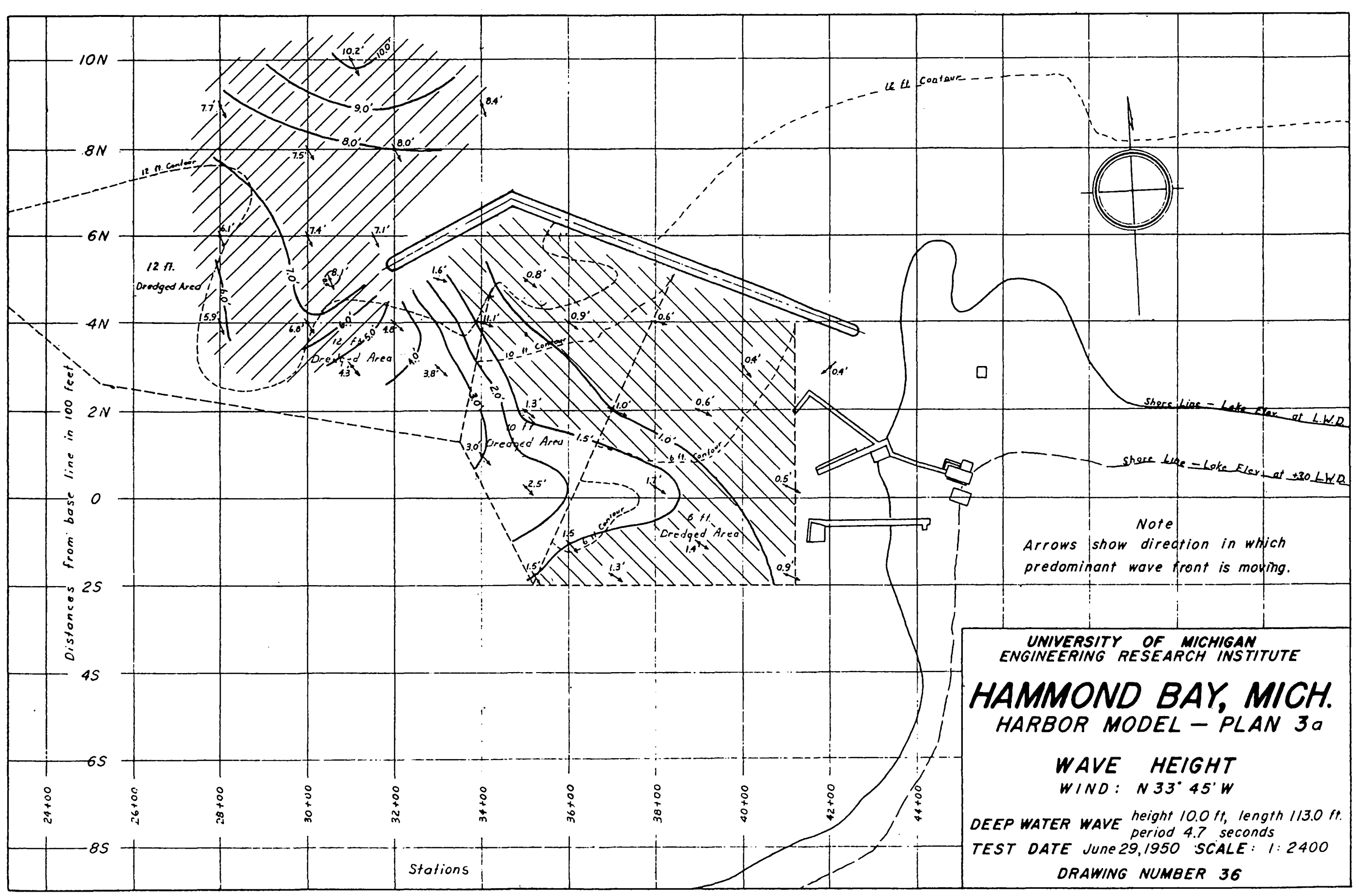
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
WAVE HEIGHT
WIND: N 33° 45' W
DEEP WATER WAVE height 10.0 ft, length 113.0 ft. period 4.7 seconds
TEST DATE June 13, 1950 SCALE: 1:2400
DRAWING NUMBER 29
Note
Arrows show direction in which predominant wave front is moving.
Stations
Distances from base line in 100 feet



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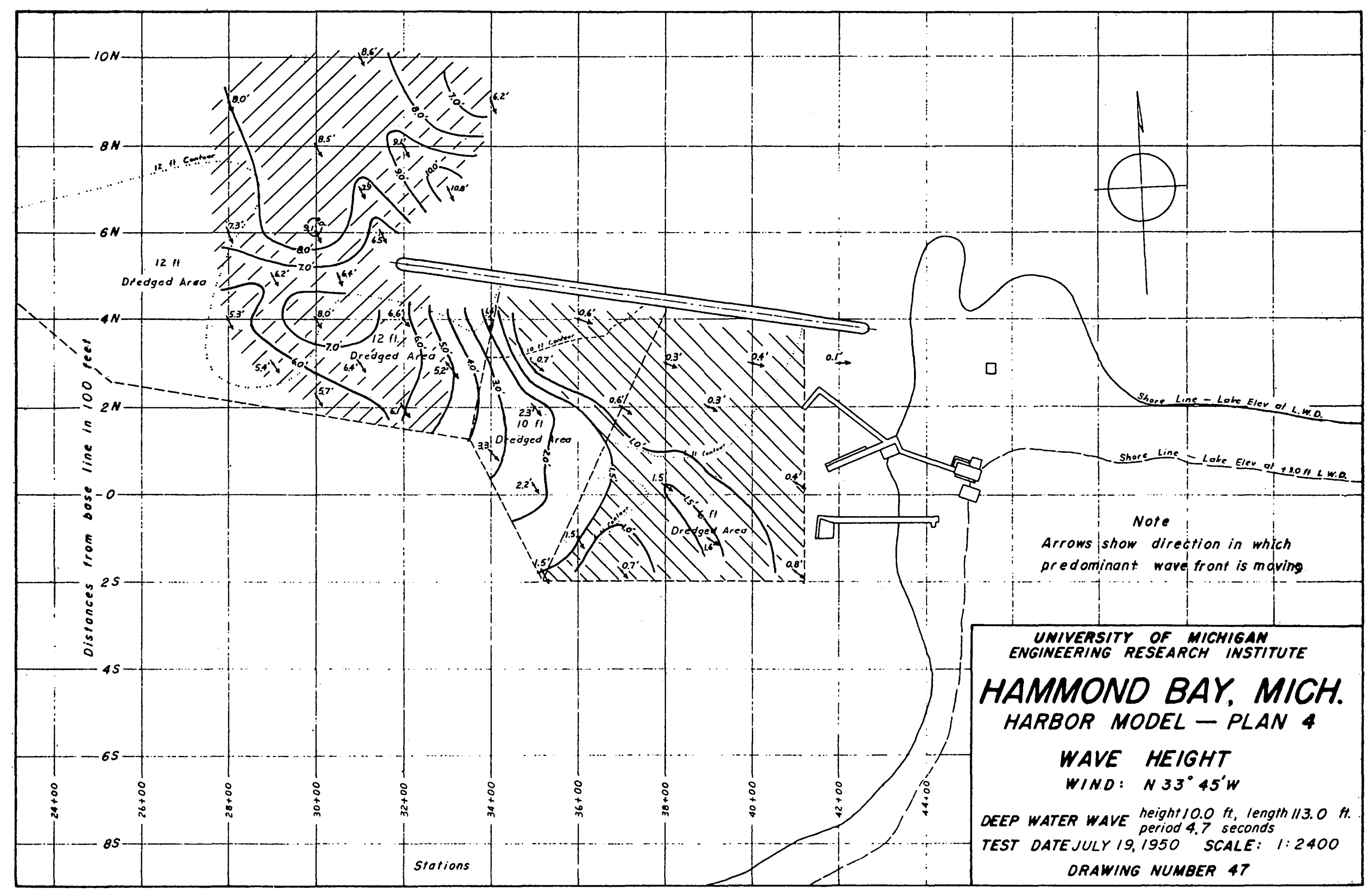
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
WAVE HEIGHT
WIND: N 33° 45' W
DEEP WATER WAVE height 10.0 ft, length 113.0 ft. period 4.7 seconds
TEST DATE June 29, 1950 SCALE: 1:2400
DRAWING NUMBER 36
Note
Arrows show direction in which predominant wave front is moving.
Stations
Distances from base line in 100 feet



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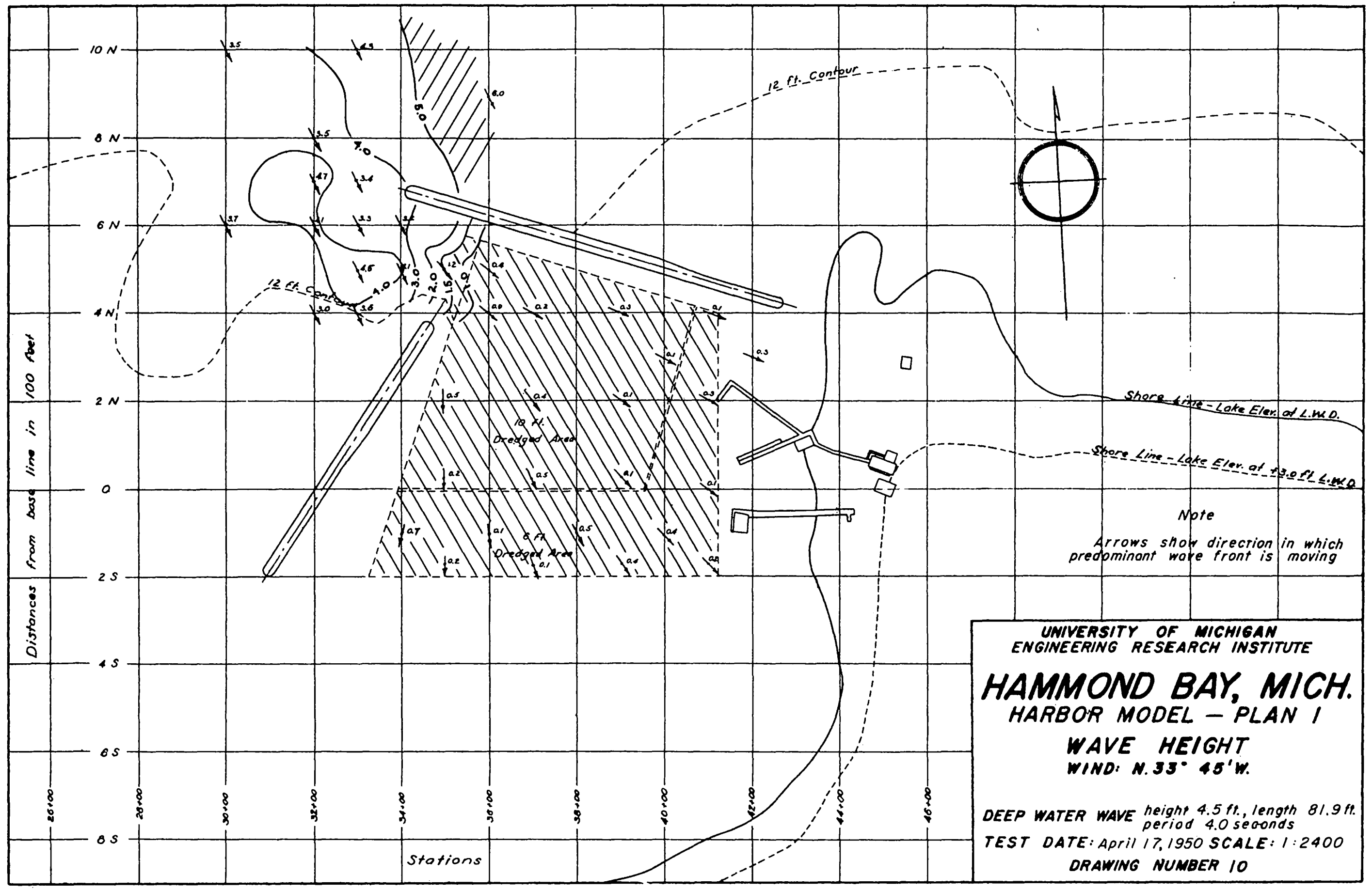
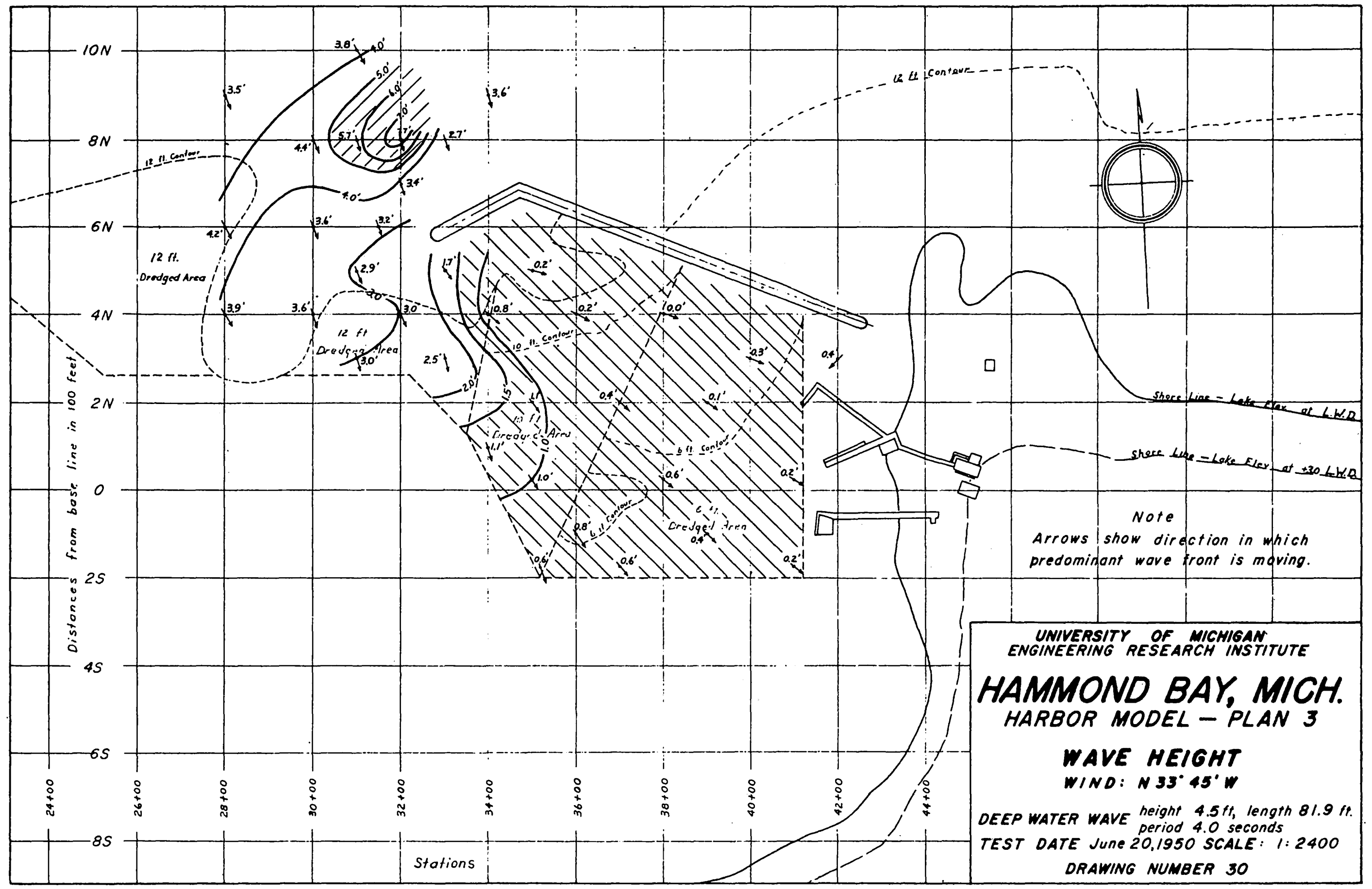
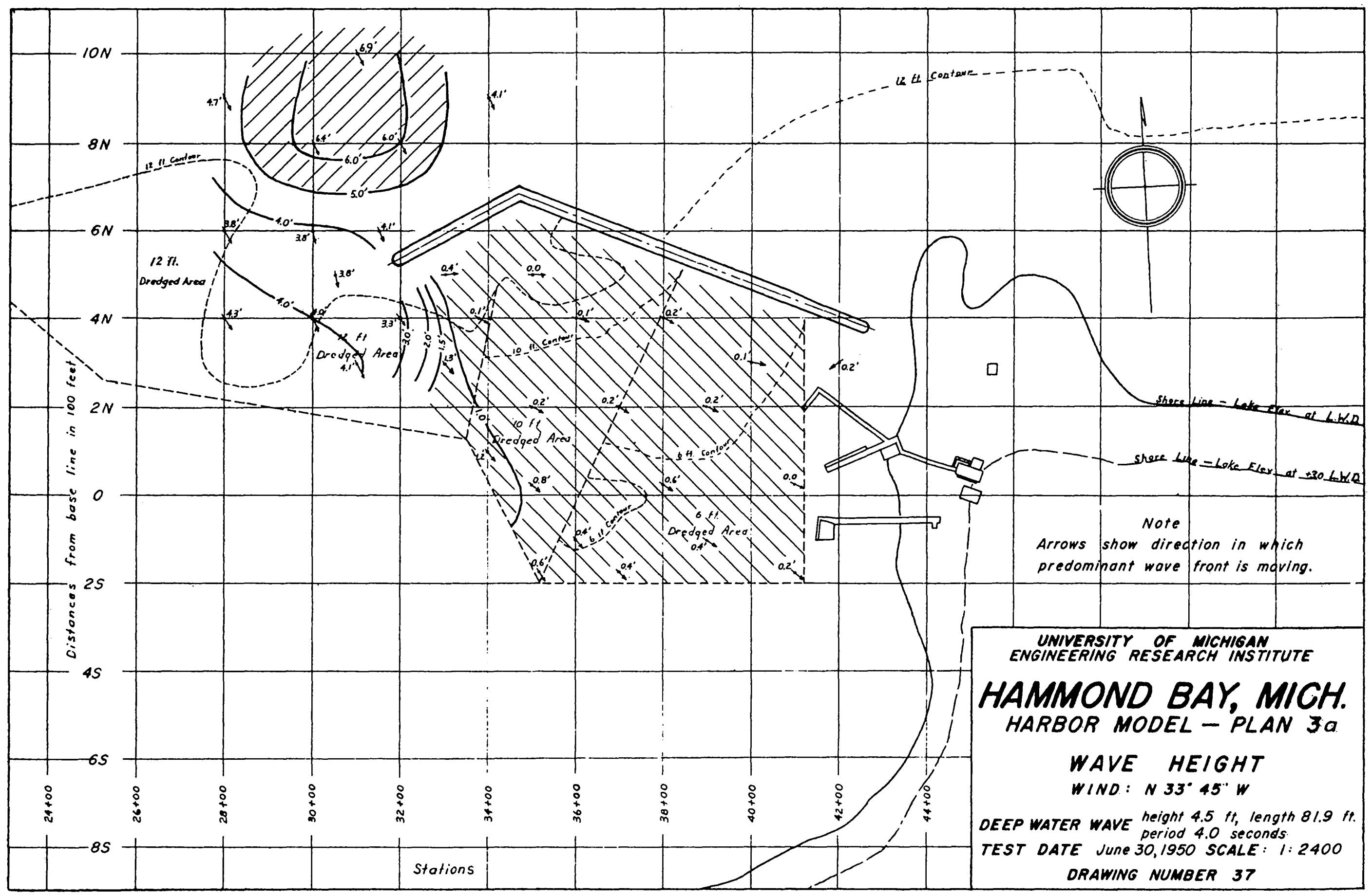
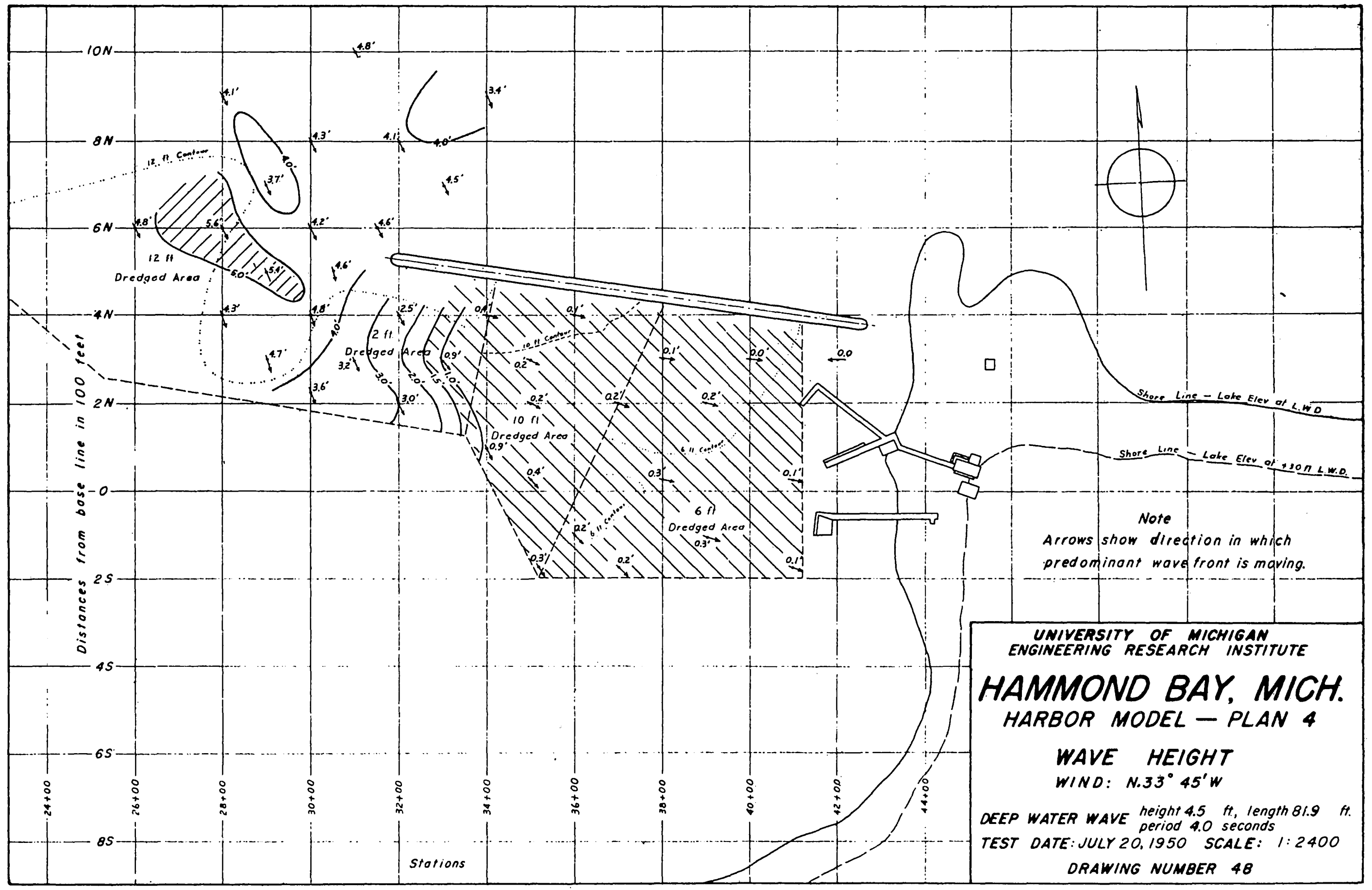
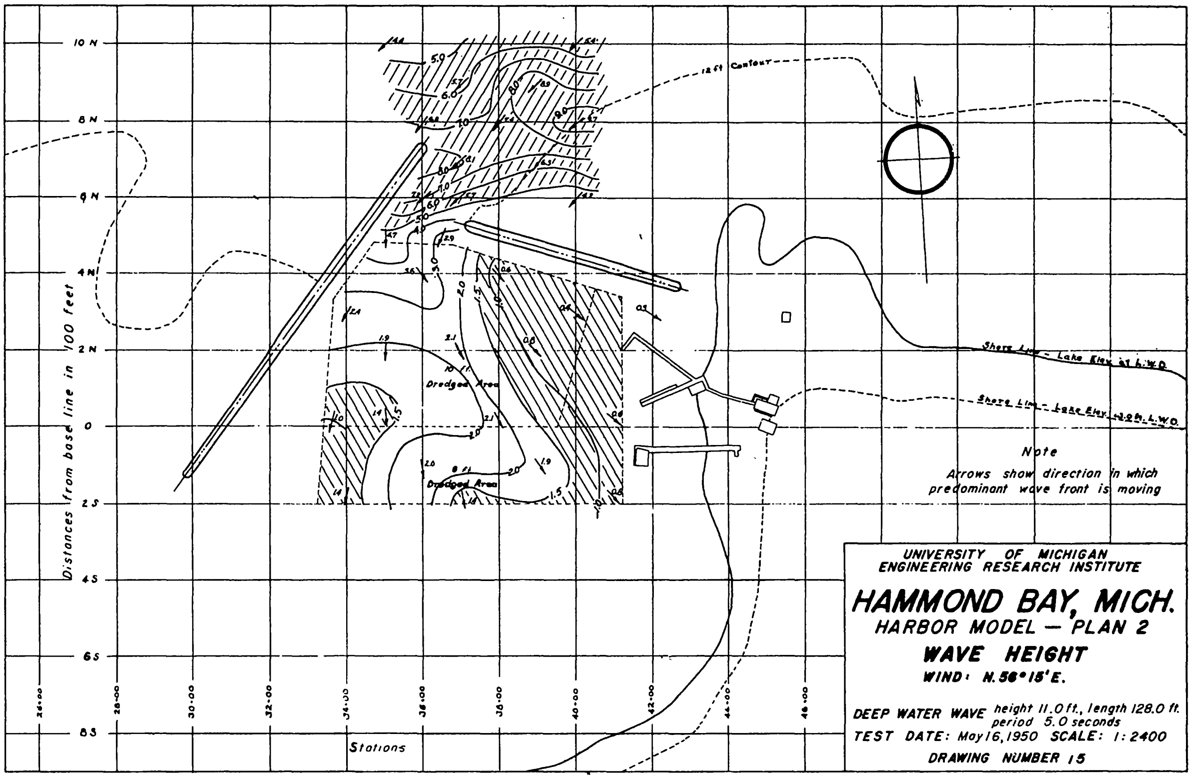
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
WAVE HEIGHT
WIND: N 33° 45' W
DEEP WATER WAVE height 10.0 ft, length 113.0 ft. period 4.7 seconds
TEST DATE JULY 19, 1950 SCALE: 1:2400
DRAWING NUMBER 47
Note
Arrows show direction in which predominant wave front is moving
Stations
Distances from base line in 100 feet

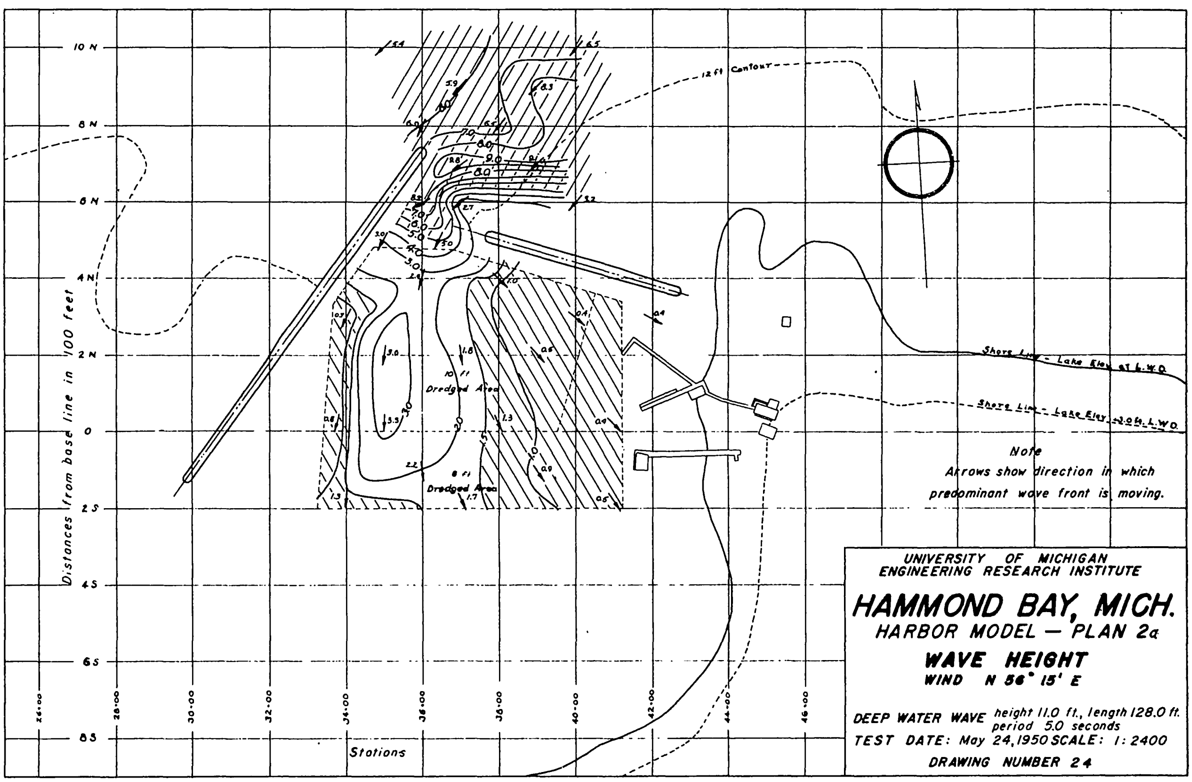

12 ft. Contour
12 ft. Contour
10 ft. Dredged Area
6 ft. Dredged Area
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
WAVE HEIGHT
WIND: N.33° 45'W.
DEEP WATER WAVE height 4.5 ft., length 81.9 ft. period 4.0 seconds
TEST DATE: April 17, 1950 SCALE: 1:2400
DRAWING NUMBER 10

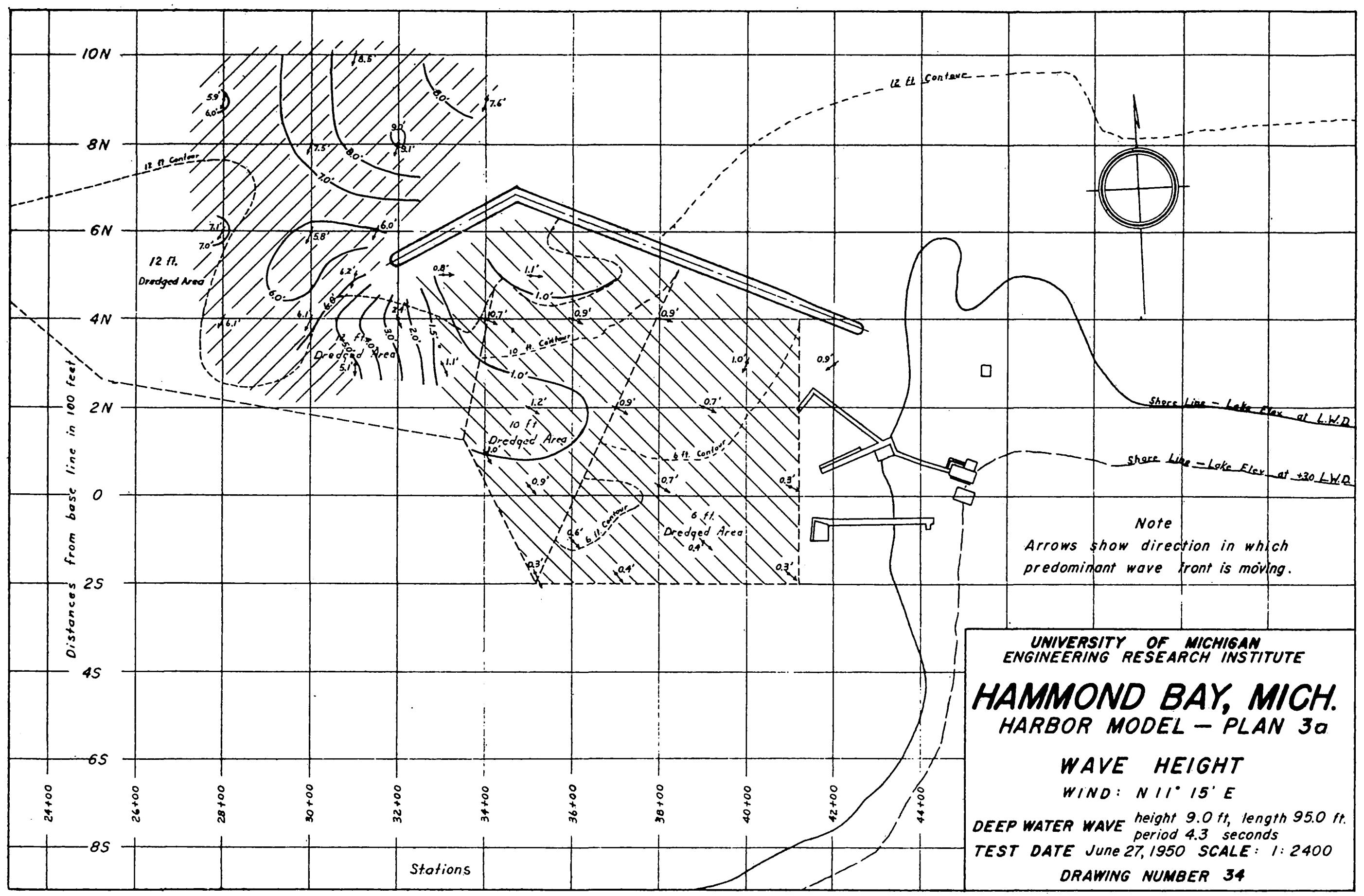

12 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
WAVE HEIGHT
WIND: N 33° 45' W
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE June 20, 1950 SCALE: 1:2400
DRAWING NUMBER 30

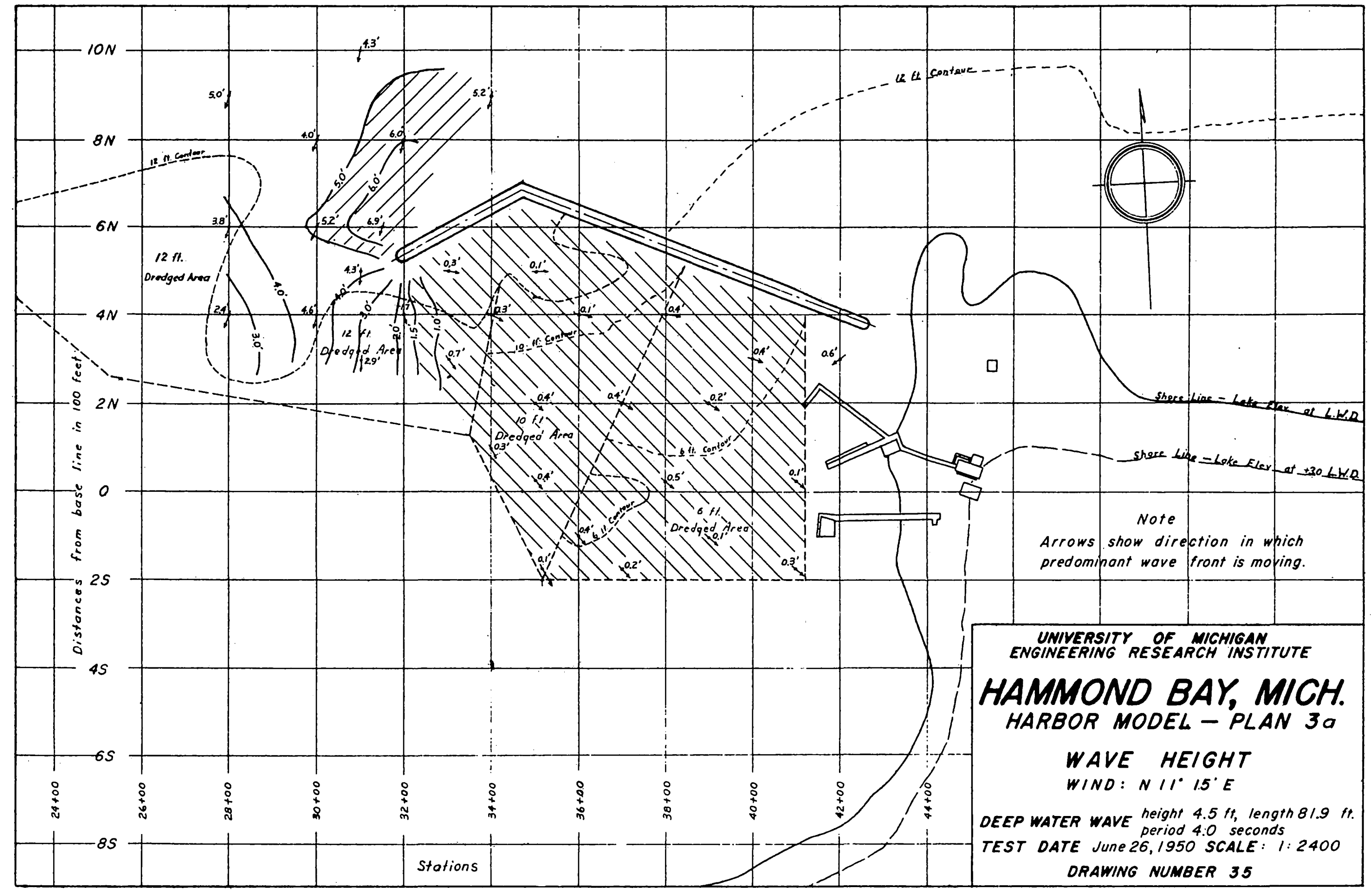

12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
WAVE HEIGHT
WIND: N 33° 45' W
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE June 30, 1950 SCALE: 1:2400
DRAWING NUMBER 37


12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
WAVE HEIGHT
WIND: N.33° 45'W
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE: JULY 20, 1950 SCALE: 1:2400
DRAWING NUMBER 48


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
WAVE HEIGHT
WIND: N.56°15'E.
DEEP WATER WAVE height 11.0 ft., length 128.0 ft. period 5.0 seconds
TEST DATE: May 16, 1950 SCALE: 1:2400
DRAWING NUMBER 15
Note
Arrows show direction in which predominant wave front is moving
Distances from base line in 100 feet
Stations
Dredged Area
12 ft Contour
Shore Line - Lake Elev. at L.W.D.


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2a
WAVE HEIGHT
WIND N 56° 15' E
DEEP WATER WAVE height 11.0 ft., length 128.0 ft. period 5.0 seconds
TEST DATE: May 24, 1950 SCALE: 1:2400
DRAWING NUMBER 24
Note
Arrows show direction in which predominant wave front is moving.
Distances from base line in 100 feet
Stations
Dredged Area
12 ft Contour
Shore Line - Lake Elev. at L.W.D.


Note
Arrows show direction in which predominant wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft. period 4.3 seconds
TEST DATE June 27, 1950 SCALE: 1:2400
DRAWING NUMBER 34
Distances from base line in 100 feet
Stations


Note
Arrows show direction in which predominant wave front is moving.
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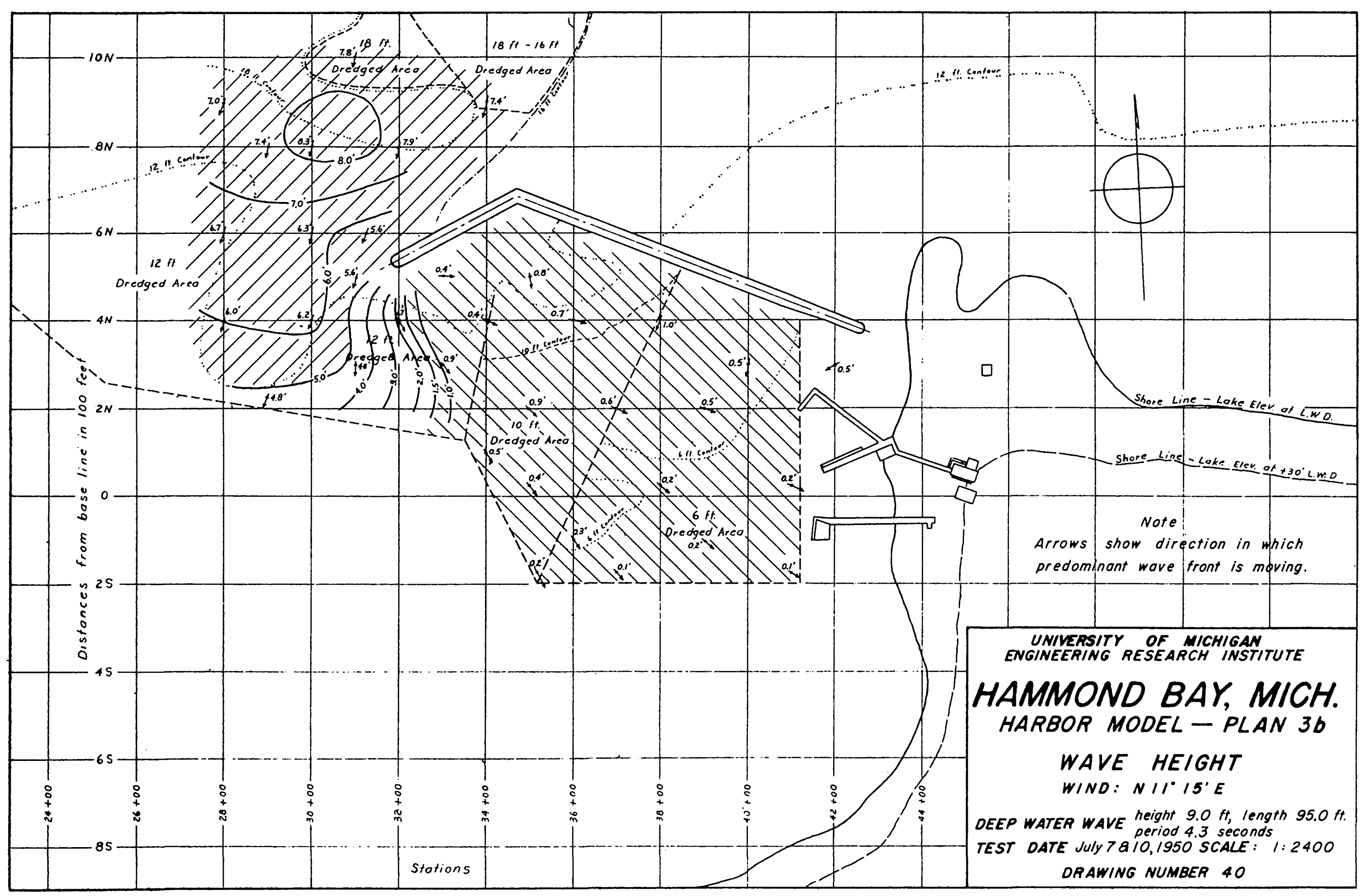
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE June 26, 1950 SCALE: 1:2400
DRAWING NUMBER 35
Distances from base line in 100 feet
Stations


Note
Arrows show direction in which predominant wave front is moving.
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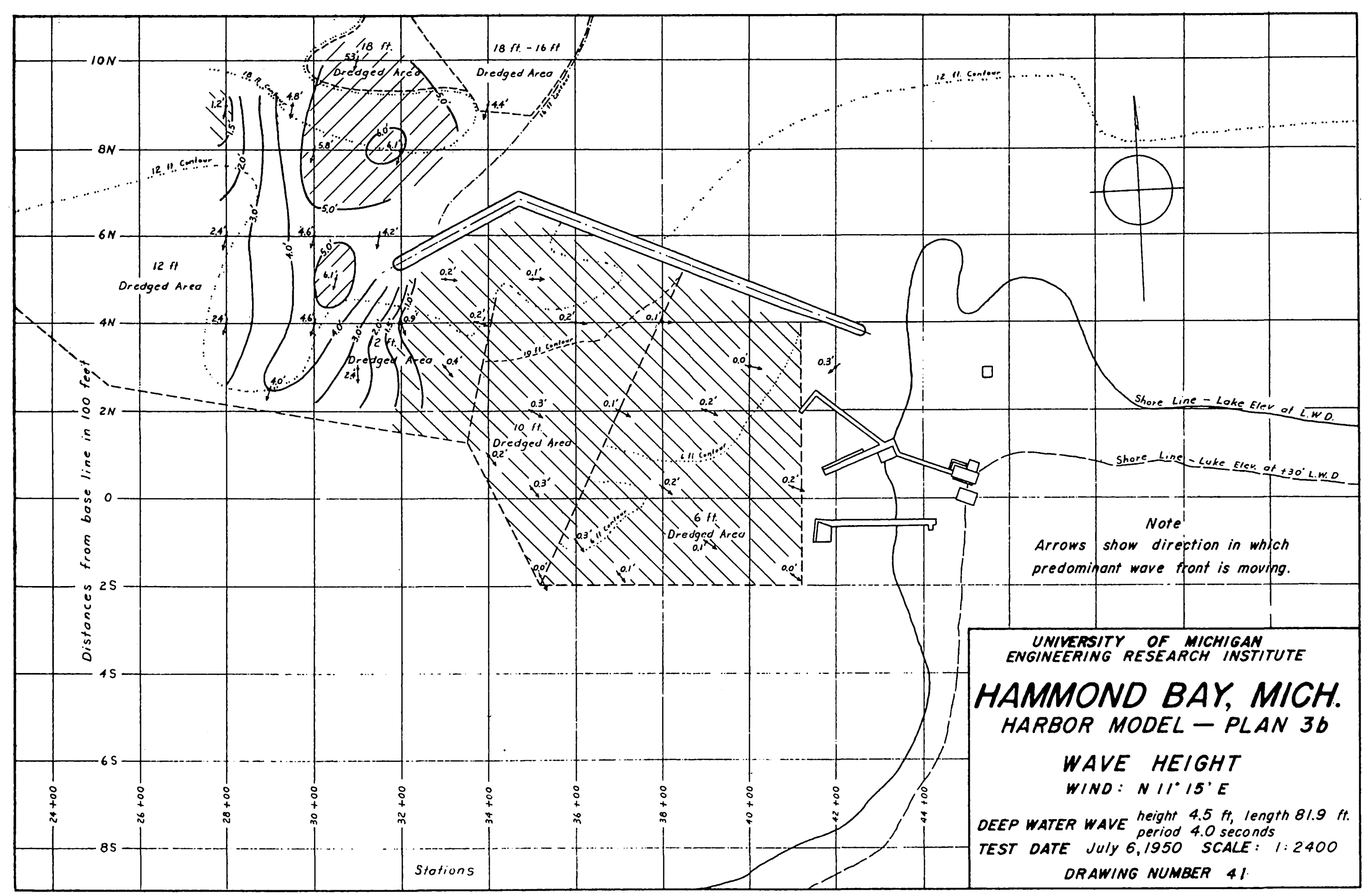
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3b
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft. period 4.3 seconds
TEST DATE July 7 & 10, 1950 SCALE: 1:2400
DRAWING NUMBER 40
Distances from base line in 100 feet
Stations


Note
Arrows show direction in which predominant wave front is moving.
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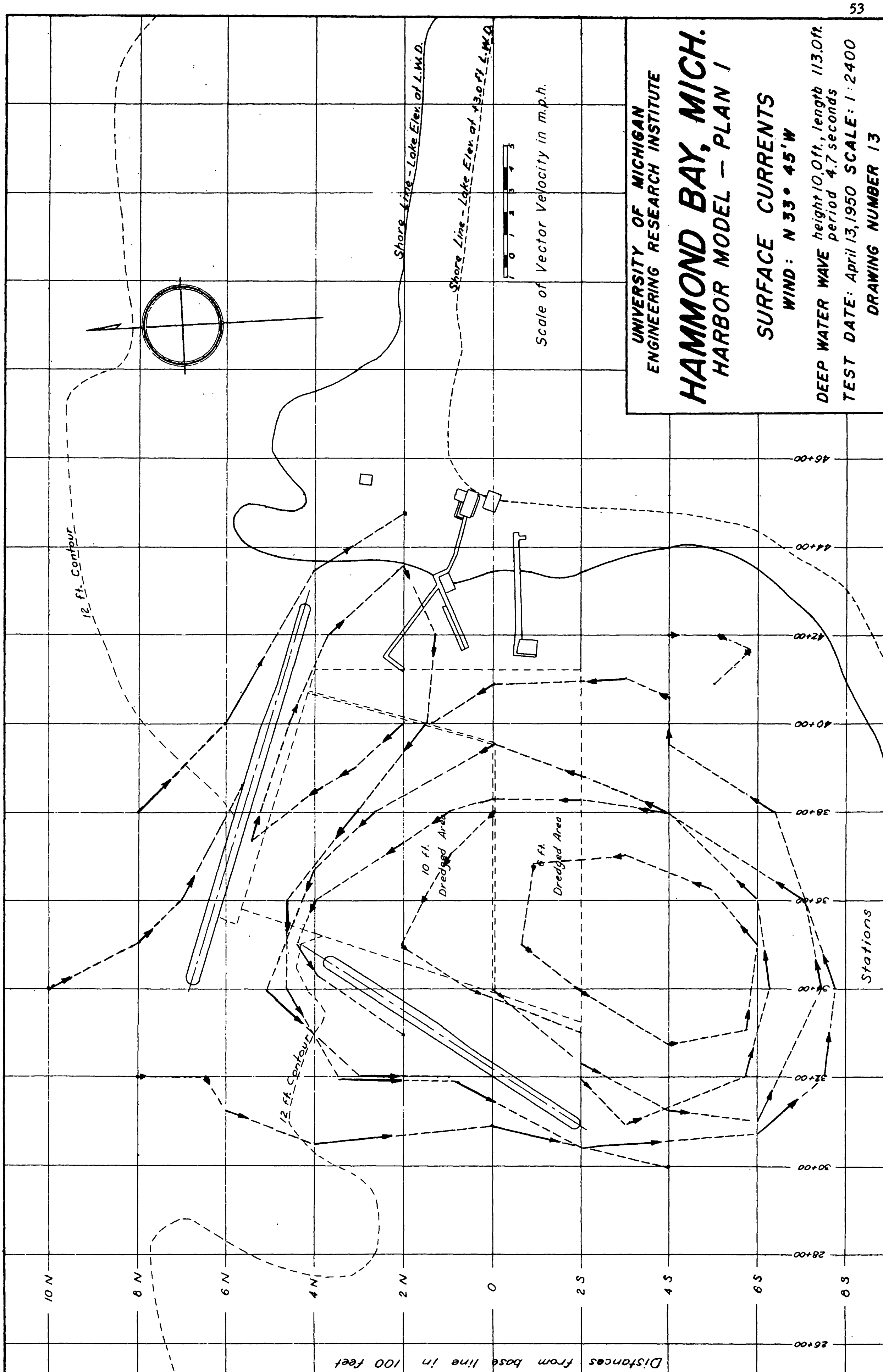
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3b
WAVE HEIGHT
WIND: N 11° 15' E
DEEP WATER WAVE height 4.5 ft, length 81.9 ft. period 4.0 seconds
TEST DATE July 6, 1950 SCALE: 1:2400
DRAWING NUMBER 41
Distances from base line in 100 feet
Stations


UNIVERSITY OF MICHIGAN
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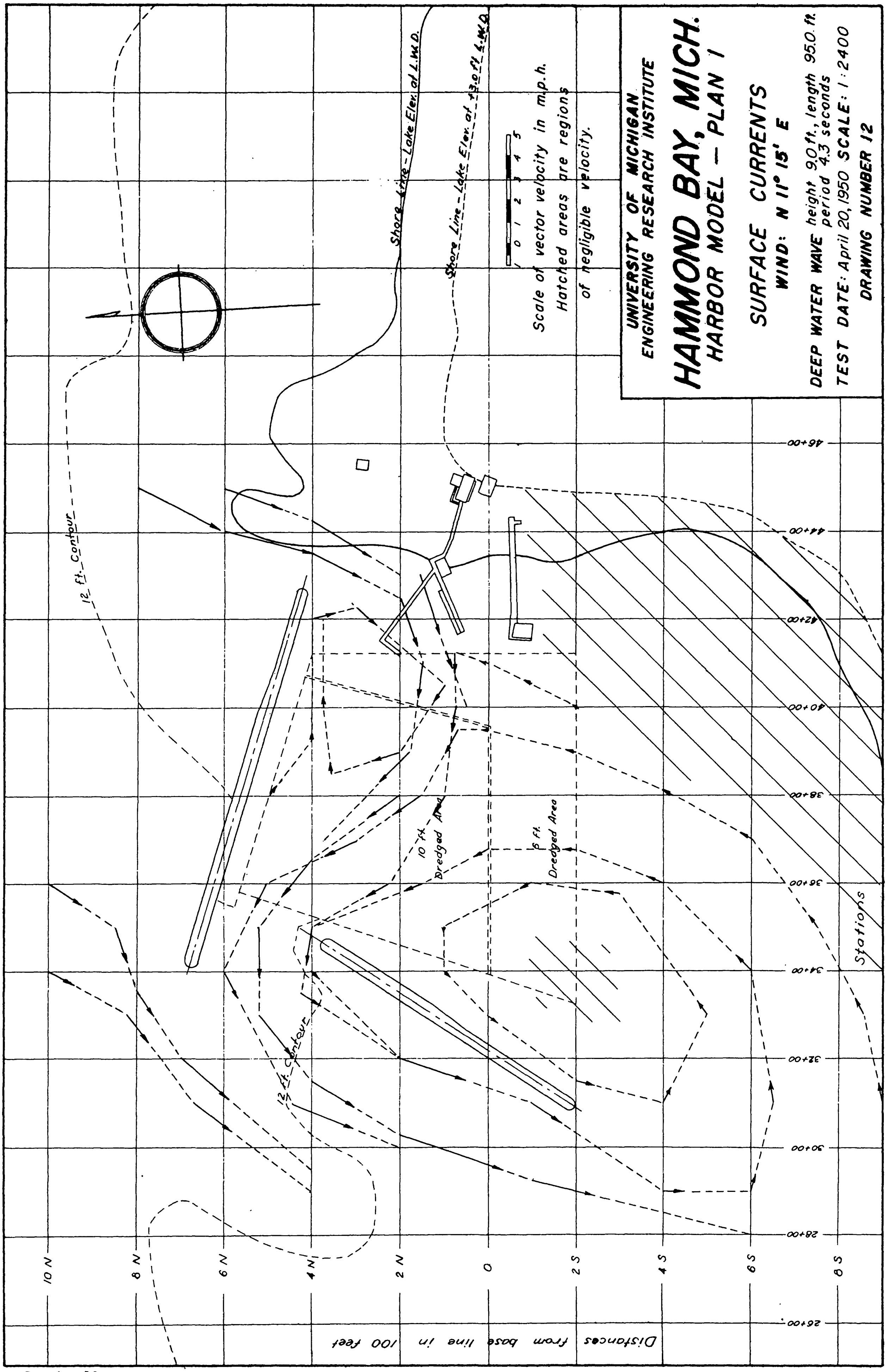
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN I
SURFACE CURRENTS
WIND: N 33° 45' W
DEEP WATER WAVE height 10.0 ft., length 113.0 ft.
period 4.7 seconds
TEST DATE: April 13, 1950 SCALE: 1:2400
DRAWING NUMBER 13
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
Scale of Vector Velocity in m.p.h.
0 1 2 3 4 5
12 ft. Contour
10 ft. Dredged Area
6 ft. Dredged Area
Stations
46+00
44+00
42+00
40+00
38+00
36+00
34+00
32+00
30+00
28+00
26+00
10 N
8 N
6 N
4 N
2 N
0
2 S
4 S
6 S
8 S
Distances from base line in 100 feet

Drawing 13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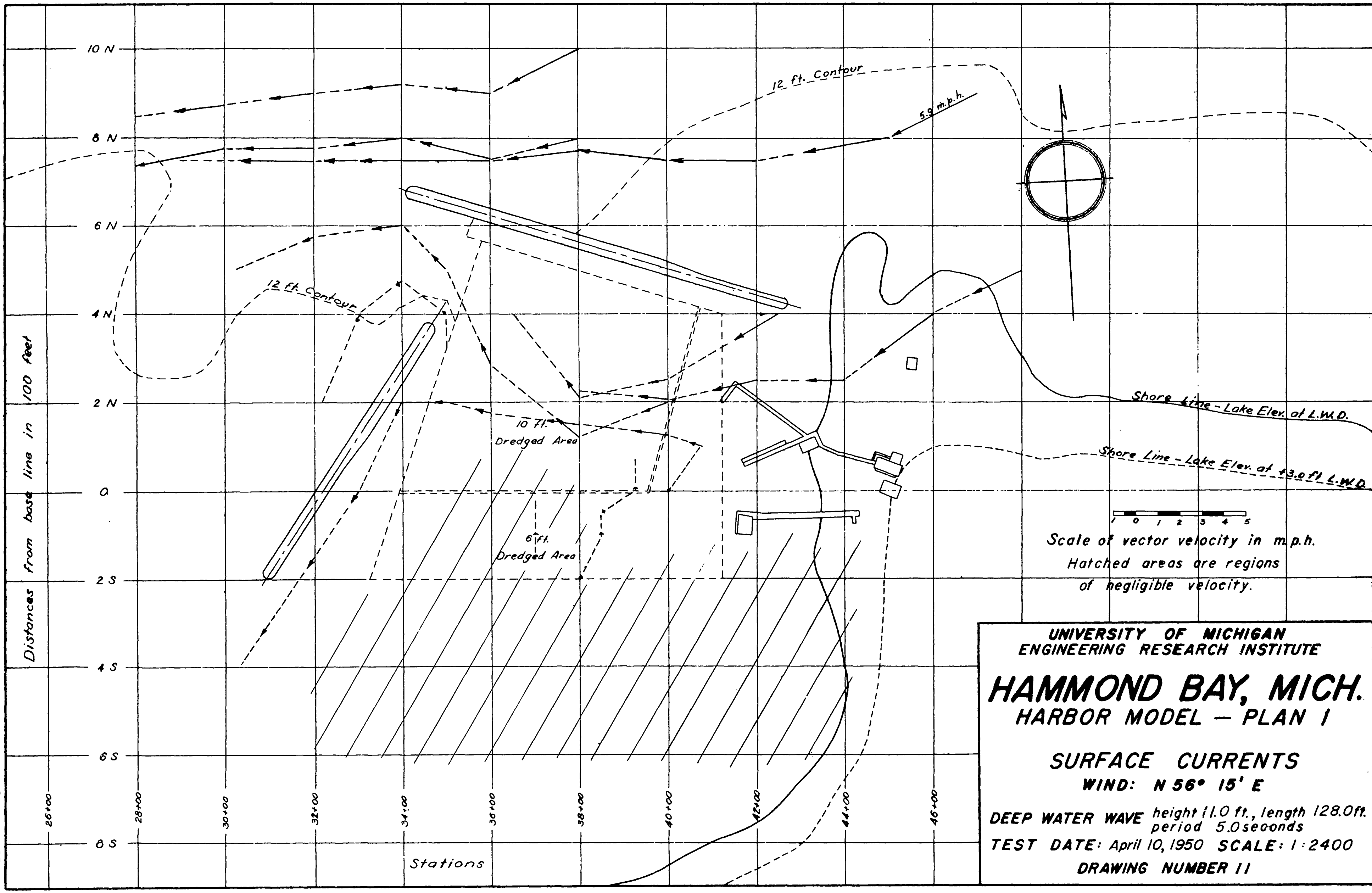
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 1
SURFACE CURRENTS
WIND: N 11° 15' E
DEEP WATER WAVE height 9.0 ft., length 95.0 ft.
period 4.3 seconds
TEST DATE: April 20, 1950 SCALE: 1:2400
DRAWING NUMBER 12
0 1 2 3 4 5
Scale of vector velocity in m.p.h.
Hatched areas are regions
of negligible velocity.
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft L.W.D.
12 ft. Contour
12 ft. Contour
10 ft. Dredged Area
6 ft. Dredged Area
Stations
46+00
44+00
42+00
40+00
38+00
36+00
34+00
32+00
30+00
28+00
26+00
10 N
8 N
6 N
4 N
2 N
0
2 S
4 S
6 S
8 S
Distances from base line in 100 feet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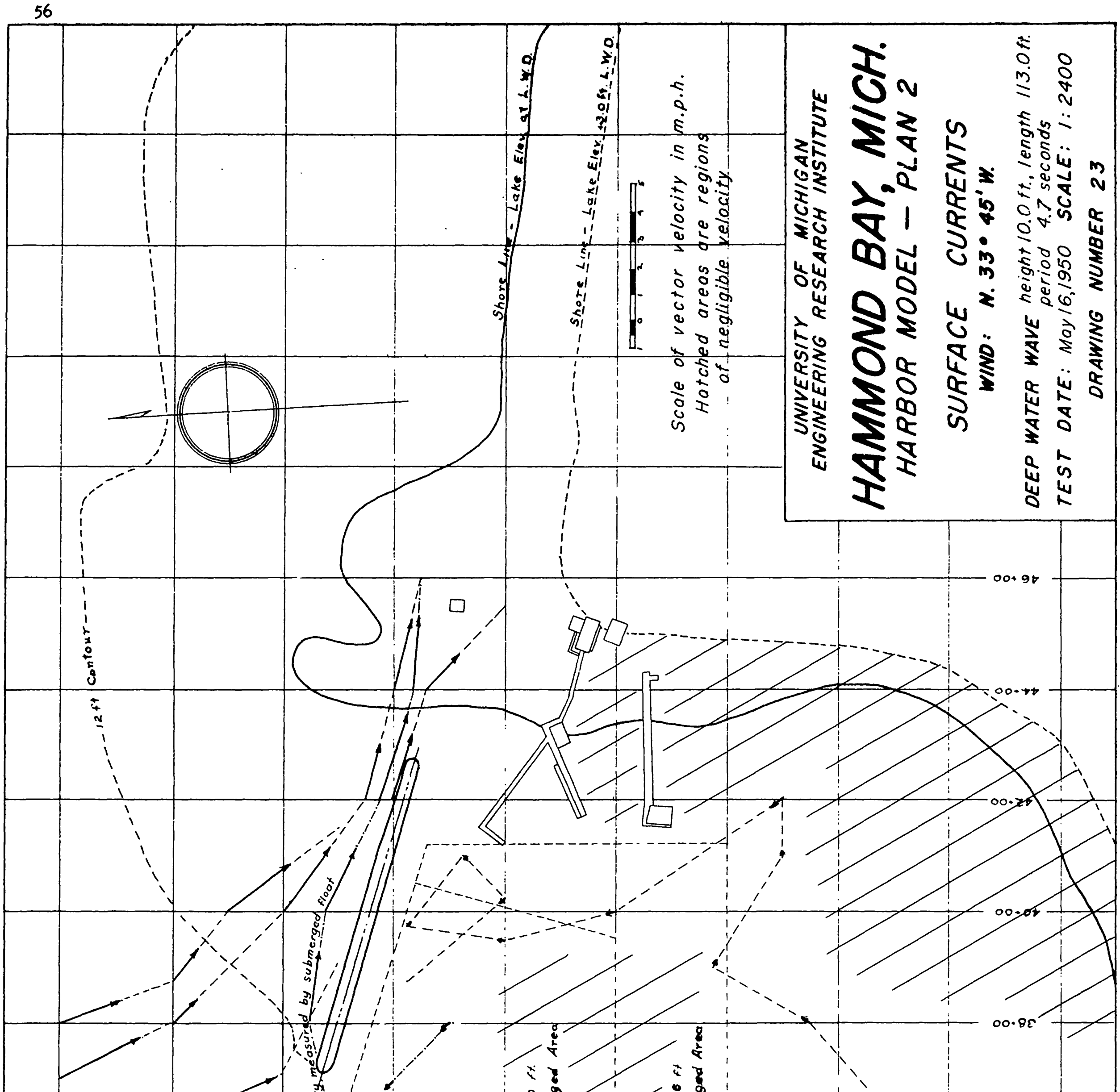
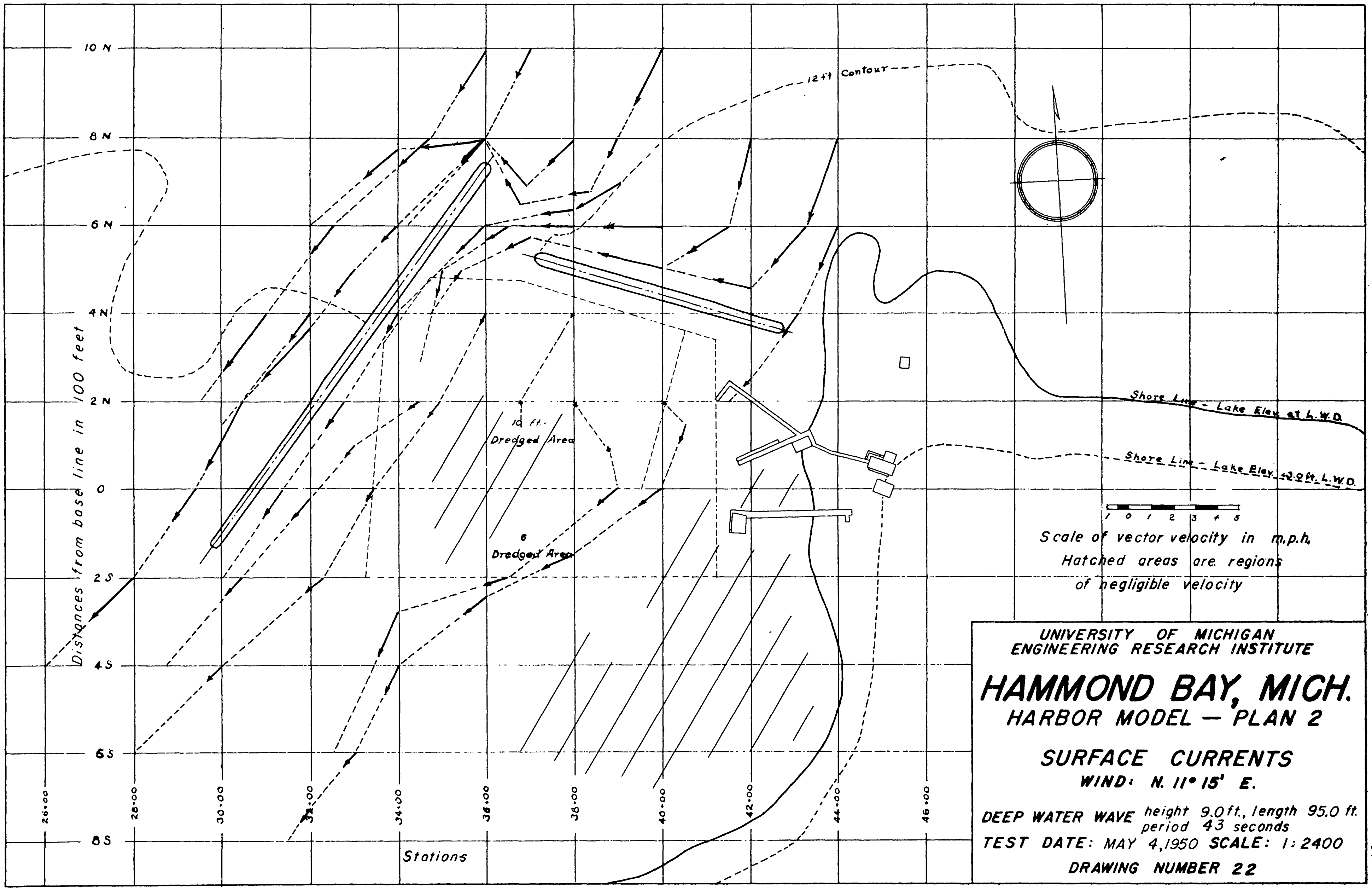
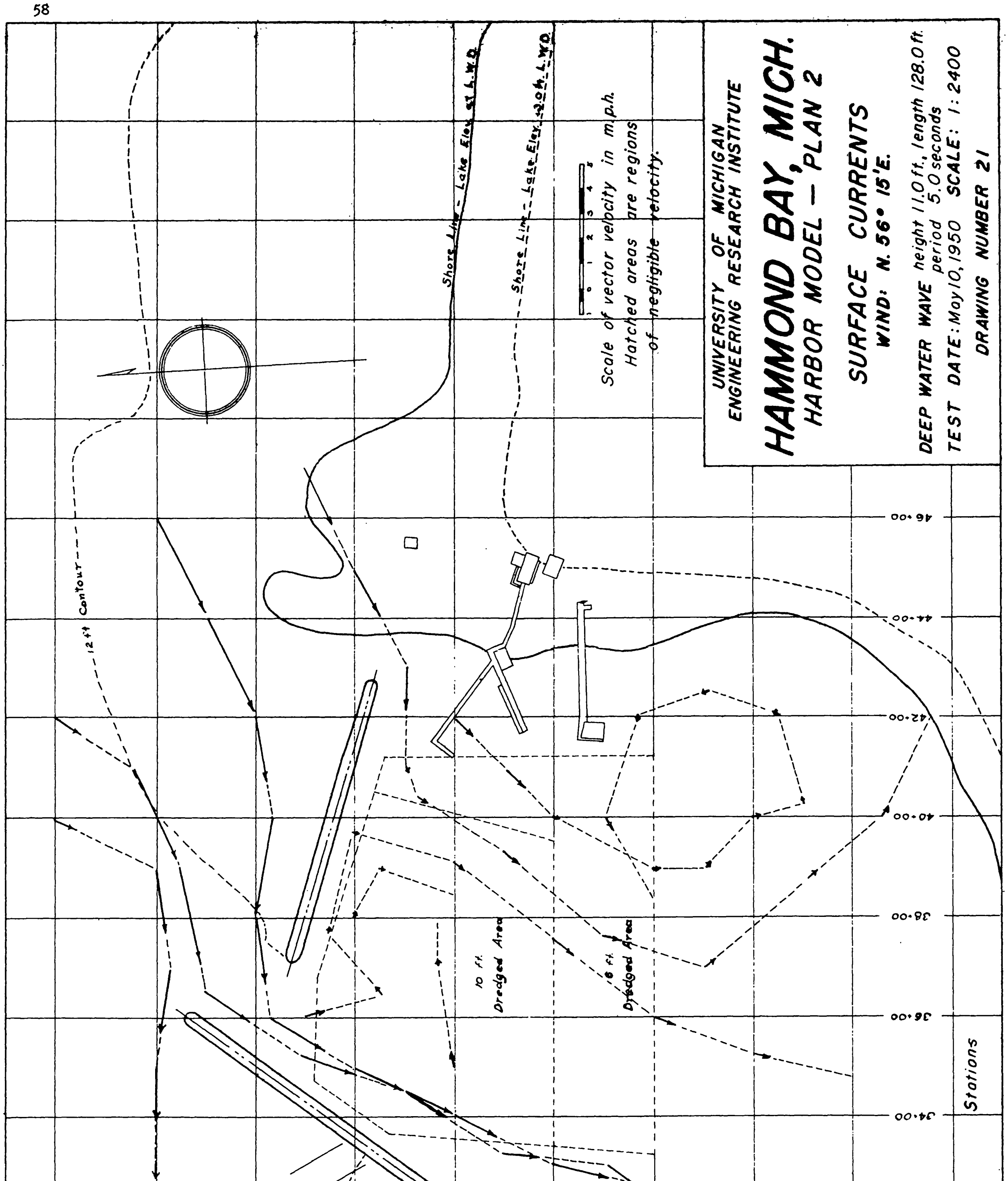
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN I
SURFACE CURRENTS
WIND: N 56° 15' E
DEEP WATER WAVE height 11.0 ft., length 128.0 ft. period 5.0 seconds
TEST DATE: April 10, 1950 SCALE: 1:2400
DRAWING NUMBER 11
Scale of vector velocity in m.p.h.
Hatched areas are regions
of negligible velocity.
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +3.0 ft. L.W.D.
12 ft. Contour
12 ft. Contour
5.9 m.p.h.
10 ft. Dredged Area
6 ft. Dredged Area
Distances from base line in 100 feet
Stations
10 N
8 N
6 N
4 N
2 N
0
2 S
4 S
6 S
8 S
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00
46+00


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
SURFACE CURRENTS
WIND: N. 33° 45' W.
DEEP WATER WAVE height 10.0 ft., length 113.0 ft.
period 4.7 seconds
TEST DATE: May 16, 1950 SCALE: 1:2400
DRAWING NUMBER 23
Scale of vector velocity in m.p.h.
Hatched areas are regions of negligible velocity
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. +2.0 ft. L.W.D.
12 ft Contour
Velocity measured by submerged float
10 ft. Dredged Area
6 ft Dredged Area
Stations
Distances from base line in 100 feet
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00
46+00
10 N
8 N
6 N
4 N
2 N
0
2 S
4 S
6 S
8 S

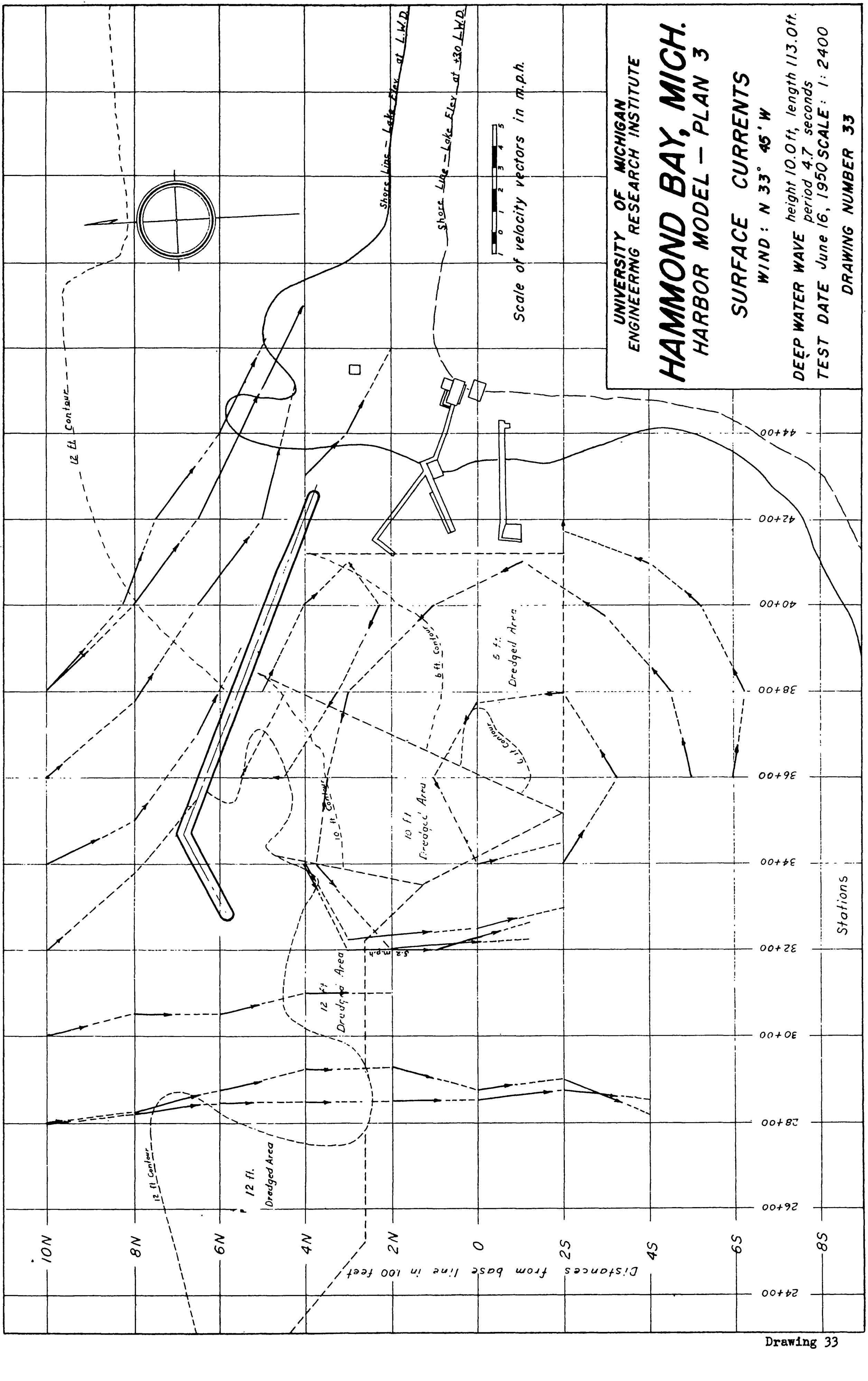
Drawing 23

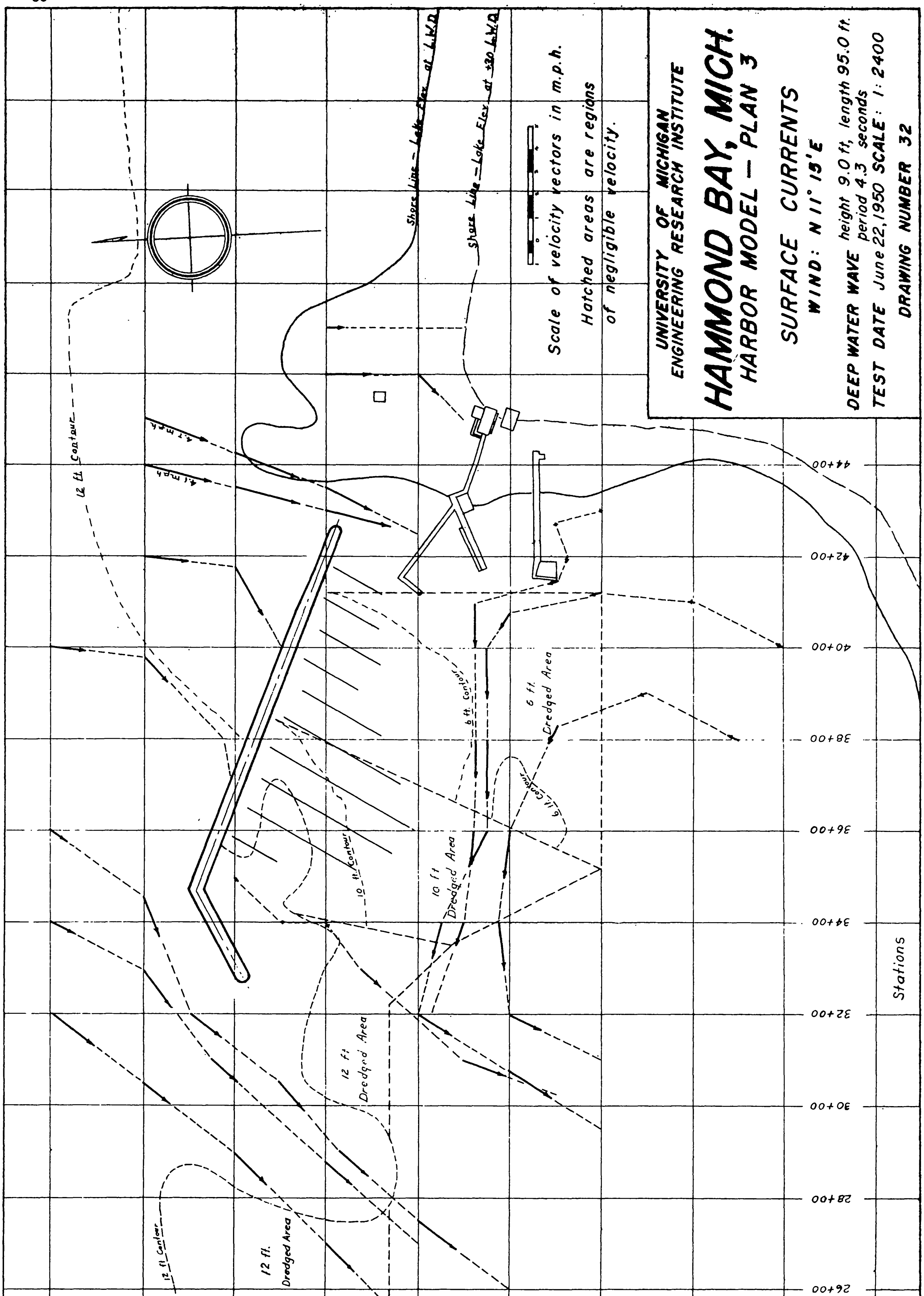

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
SURFACE CURRENTS
WIND: N. 11° 15' E.
DEEP WATER WAVE height 9.0 ft., length 95.0 ft. period 43 seconds
TEST DATE: MAY 4, 1950 SCALE: 1:2400
DRAWING NUMBER 22
Scale of vector velocity in m.p.h.
Hatched areas are regions of negligible velocity
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. +3.0 ft. L.W.D.
12 ft Contour
10 ft. Dredged Area
6 Dredged Area
Distances from base line in 100 feet
Stations
10 N
8 N
6 N
4 N
2 N
0
2 S
4 S
6 S
8 S
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00
46+00

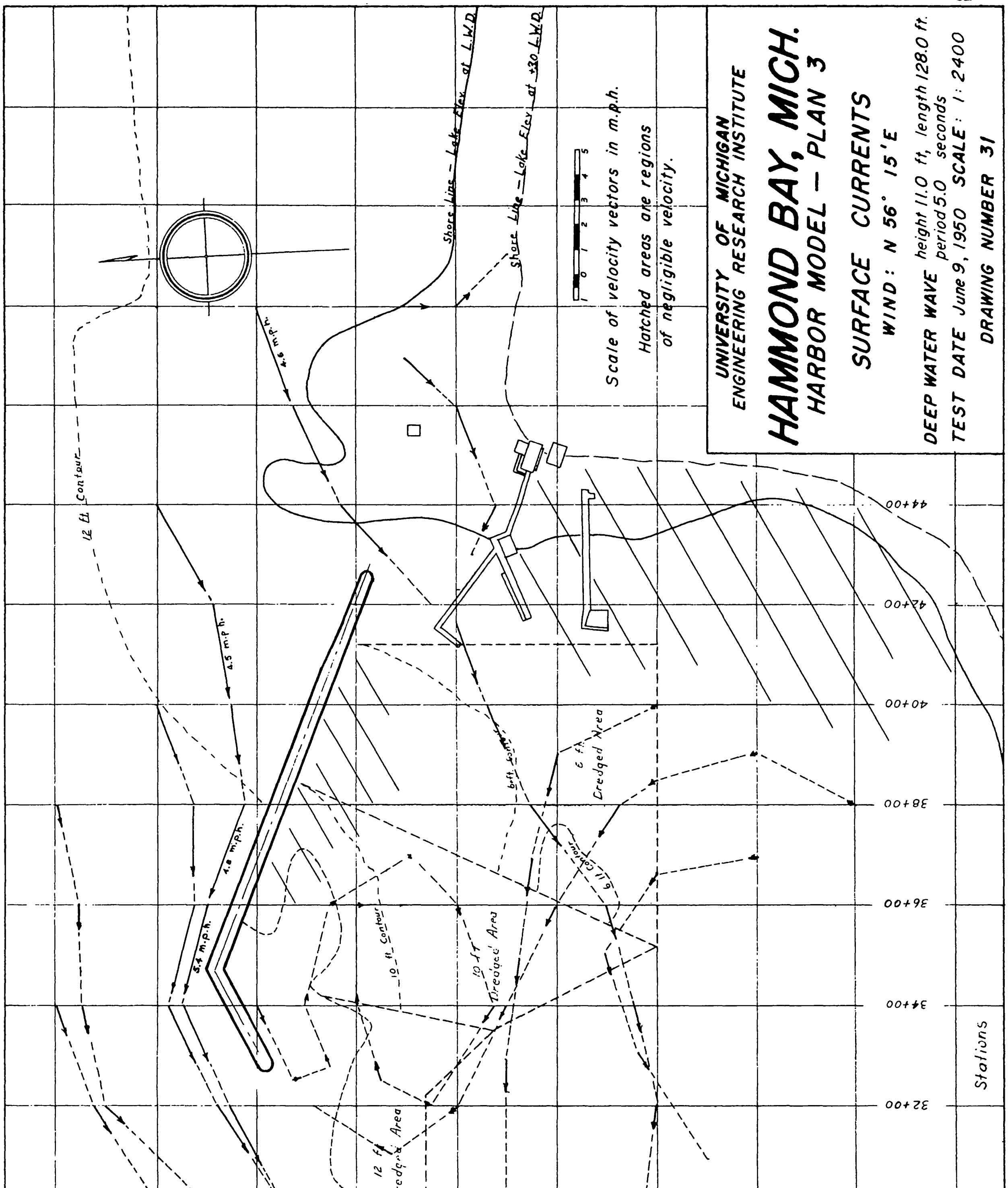
Drawing 22


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 2
SURFACE CURRENTS
WIND: N. 56° 15'E.
DEEP WATER WAVE height 11.0 ft., length 128.0 ft. period 5.0 seconds
TEST DATE: May 10, 1950 SCALE: 1:2400
DRAWING NUMBER 21
Scale of vector velocity in m.p.h.
Hatched areas are regions of negligible velocity.
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. +20 ft. L.W.D.
12 ft Contour
10 ft. Dredged Area
6 ft. Dredged Area
Stations
Distances from base line in 100 feet
10 N
8 N
6 N
4 N
2 N
0
2 S
4 S
6 S
8 S
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00
46+00

Drawing 21


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL - PLAN 3
SURFACE CURRENTS
WIND: N 33° 45' W
DEEP WATER WAVE height 10.0 ft, length 113.0 ft. period 4.7 seconds
TEST DATE June 16, 1950 SCALE: 1: 2400
DRAWING NUMBER 33
Scale of velocity vectors in m.p.h.
0 1 2 3 4 5
Shore Line - Lake Elev. at L.W.D.
Shore Line - Lake Elev. at +30 L.W.D.
12 ft Contour
6 ft Contour
5 ft. Dredged Area
10 ft Contour
10 ft Dredged Area
12 ft Dredged Area
12 ft Contour
12 ft. Dredged Area
Stations
44+00
42+00
40+00
38+00
36+00
34+00
32+00
30+00
28+00
26+00
24+00
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
Distances from base line in 100 feet


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
SURFACE CURRENTS
WIND: N 11° 15'E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft.
period 4.3 seconds
TEST DATE June 22, 1950 SCALE: 1:2400
DRAWING NUMBER 32
Scale of velocity vectors in m.p.h.
Hatched areas are regions of negligible velocity.
Shore Line — Lake Elev. at L.W.D.
Shore Line — Lake Elev. at +3.0 L.W.D.
12 ft Contour
6 ft. Contour
6 ft. Dredged Area
10 ft Dredged Area
10 ft Contour
12 ft Dredged Area
12 ft Contour
6 ft Contour
Stations
Distances from base line in 100 feet
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
24+00
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00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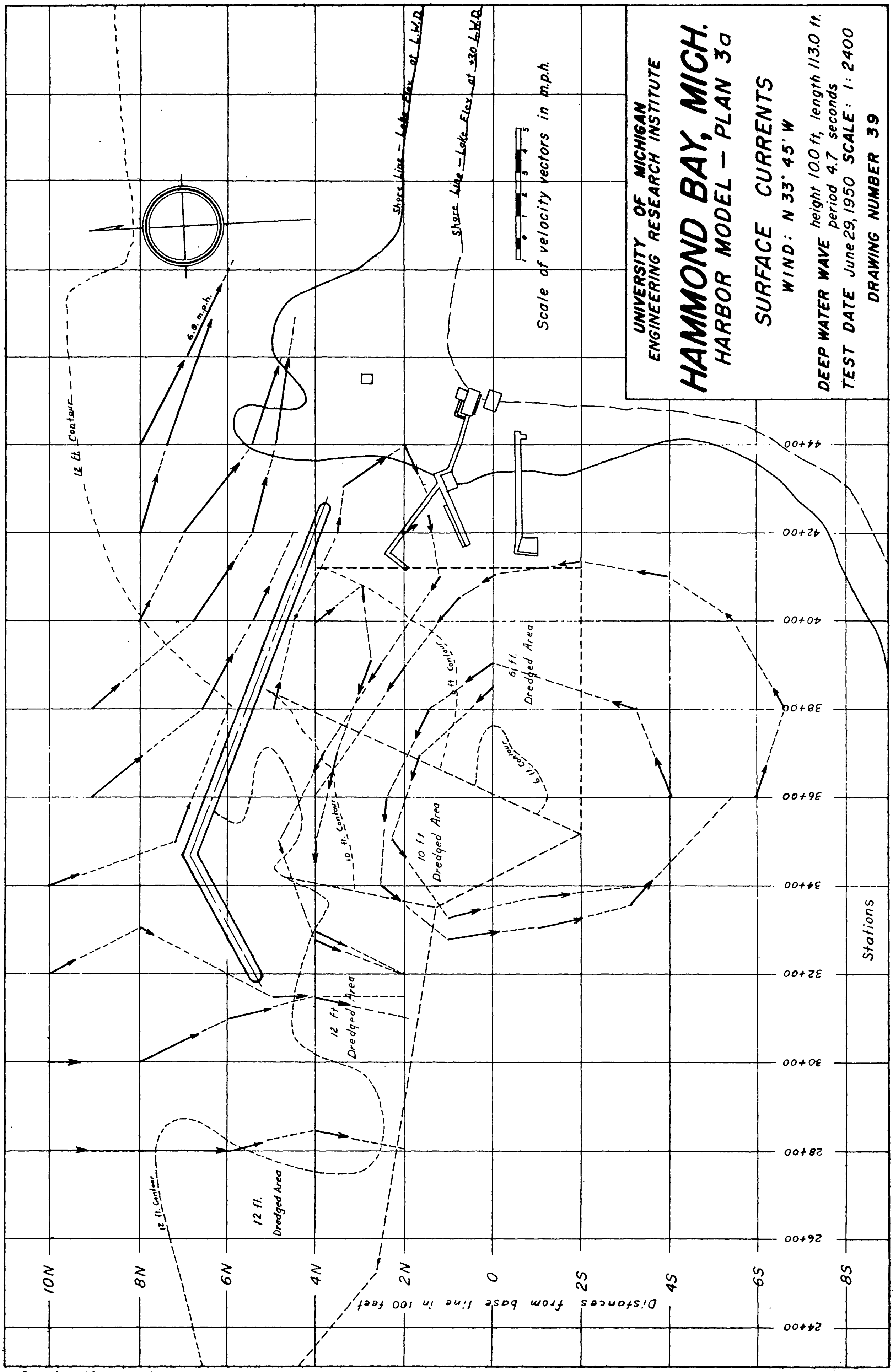
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3
SURFACE CURRENTS
WIND: N 56° 15'E
DEEP WATER WAVE height 11.0 ft, length 128.0 ft.
period 5.0 seconds
TEST DATE June 9, 1950 SCALE: 1:2400
DRAWING NUMBER 31
Scale of velocity vectors in m.p.h.
Hatched areas are regions of negligible velocity.
Shore Line — Lake Elev. at L.W.D.
Shore Line — Lake Elev. at +3.0 L.W.D.
12 ft Contour
12 ft. Dredged Area
10 ft Contour
10 ft Dredged Area
6 ft Contour
6 ft Dredged Area
4.6 m.p.h.
4.5 m.p.h.
4.8 m.p.h.
5.4 m.p.h.
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
Distances from base line in 100 feet
Stations
24+00
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00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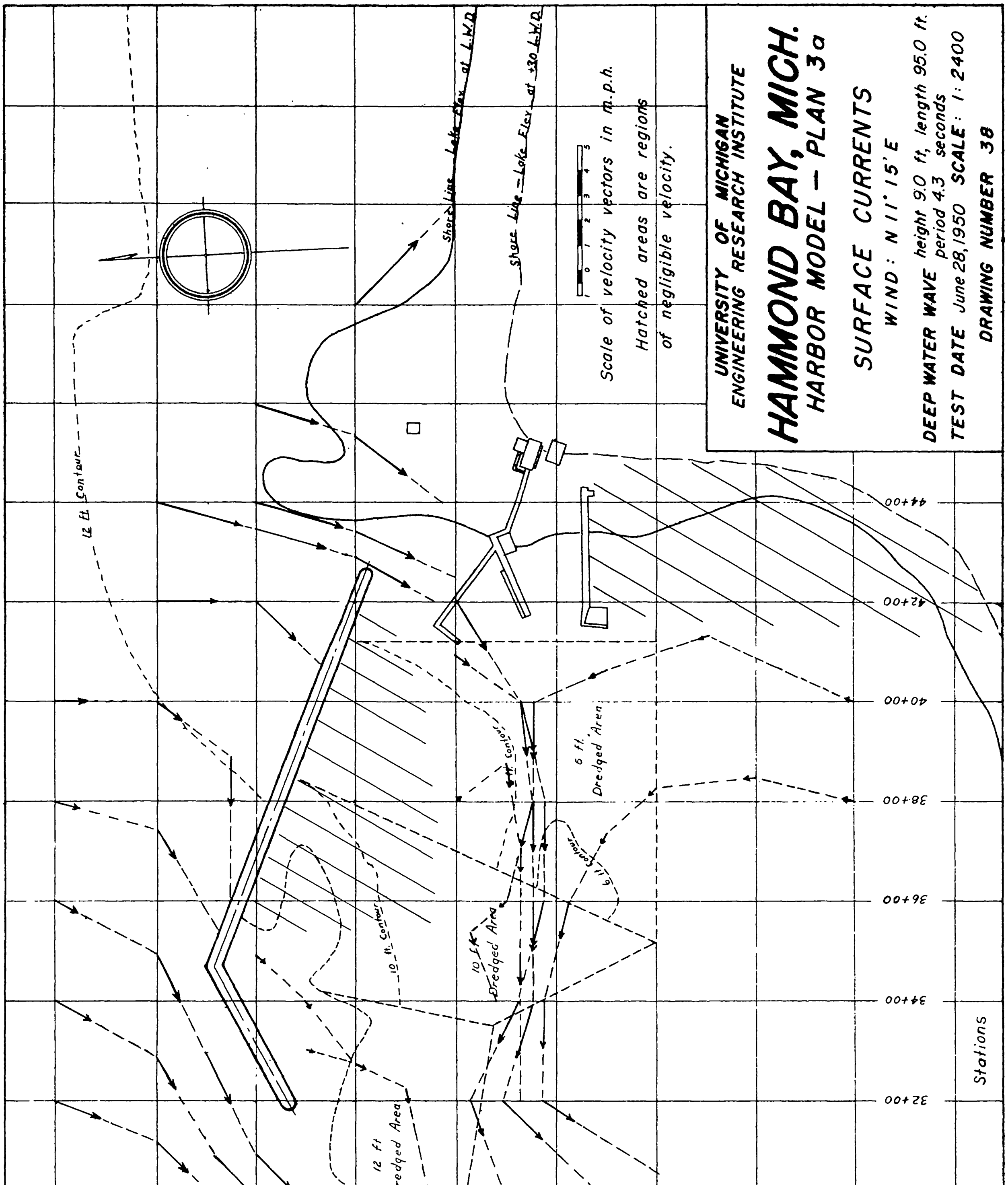
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
SURFACE CURRENTS
WIND: N 33° 45' W
DEEP WATER WAVE height 10.0 ft, length 113.0 ft.
period 4.7 seconds
TEST DATE June 29, 1950 SCALE: 1:2400
DRAWING NUMBER 39
Scale of velocity vectors in m.p.h.
Shore Line — Lake Elev. at L.W.D.
Shore Line — Lake Elev. at +3.0 L.W.D.
6.0 m.p.h.
12 ft Contour
6 ft. Dredged Area
9 ft Contour
6 ft Contour
10 ft Contour
10 ft Dredged Area
12 ft Dredged Area
12 ft Contour
12 ft. Dredged Area
44+00
42+00
40+00
38+00
36+00
34+00
32+00
30+00
28+00
26+00
24+00
Stations
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
Distances from base line in 100 feet

Drawing 39



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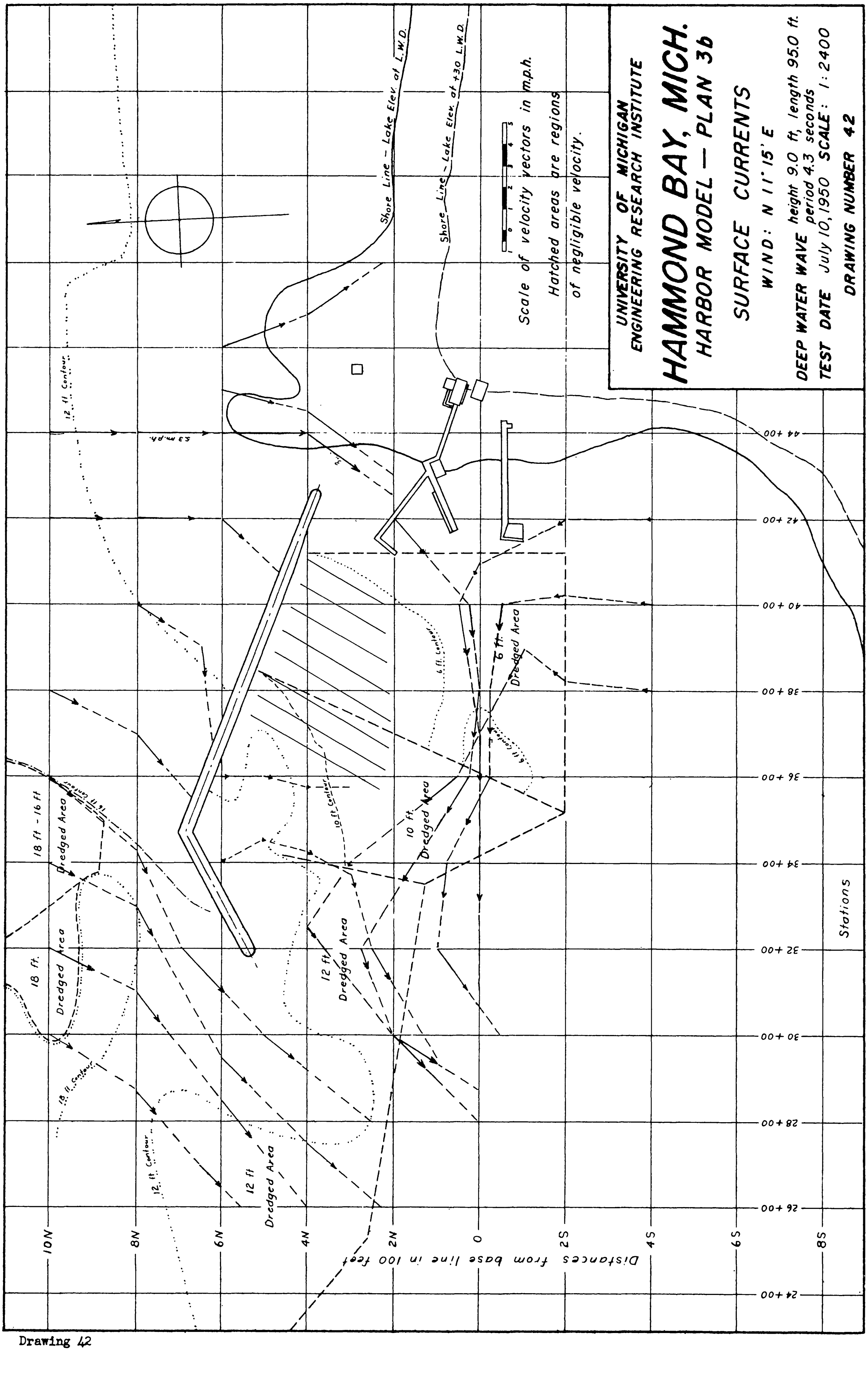
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3a
SURFACE CURRENTS
WIND: N 11° 15' E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft.
period 4.3 seconds
TEST DATE June 28, 1950 SCALE: 1:2400
DRAWING NUMBER 38
Scale of velocity vectors in m.p.h.
Hatched areas are regions of negligible velocity.
Shore Line — Lake Elev. at L.W.D.
Shore Line — Lake Elev. at +3.0 L.W.D.
12 ft. Contour
6 ft. Dredged Area
10 ft. Dredged Area
10 ft. Contour
12 ft. Dredged Area
Stations
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
Distances from base line in 100 feet
24+00
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00

Drawing 38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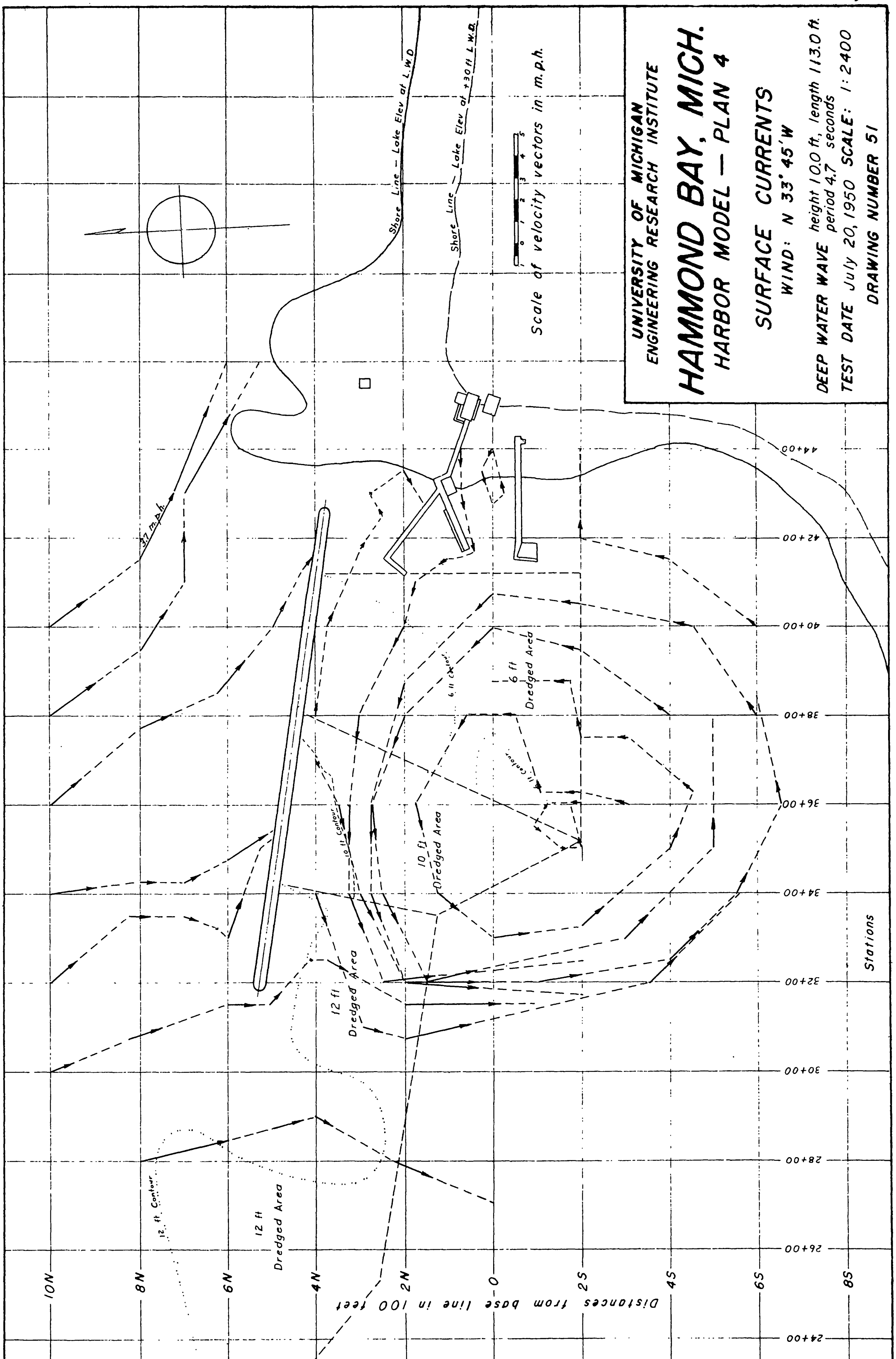
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 3b
SURFACE CURRENTS
WIND: N 11° 15' E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft.
period 4.3 seconds
TEST DATE July 10, 1950 SCALE: 1:2400
DRAWING NUMBER 42
Scale of velocity vectors in m.p.h.
Hatched areas are regions
of negligible velocity.
Shore Line - Lake Elev of L.W.D.
Shore Line - Lake Elev. at +30 L.W.D.
12 ft Contour
6 ft Dredged Area
10 ft Dredged Area
12 ft Dredged Area
18 ft Dredged Area
18 ft - 16 ft Dredged Area
18 ft Contour
10 ft Contour
6 ft Contour
12 ft. Contour
Stations
Distances from base line in 100 feet
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
24+00
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00

Drawing 42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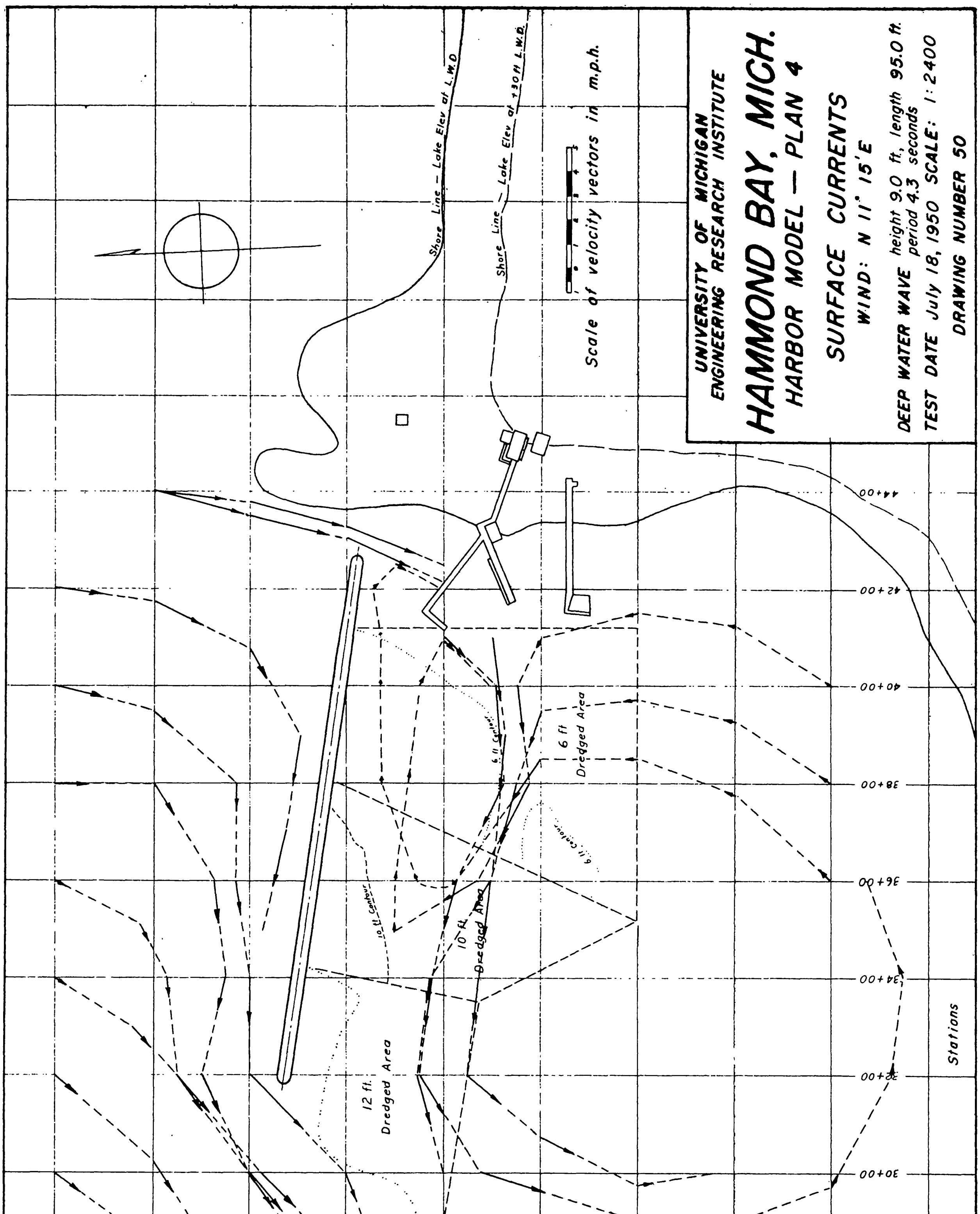
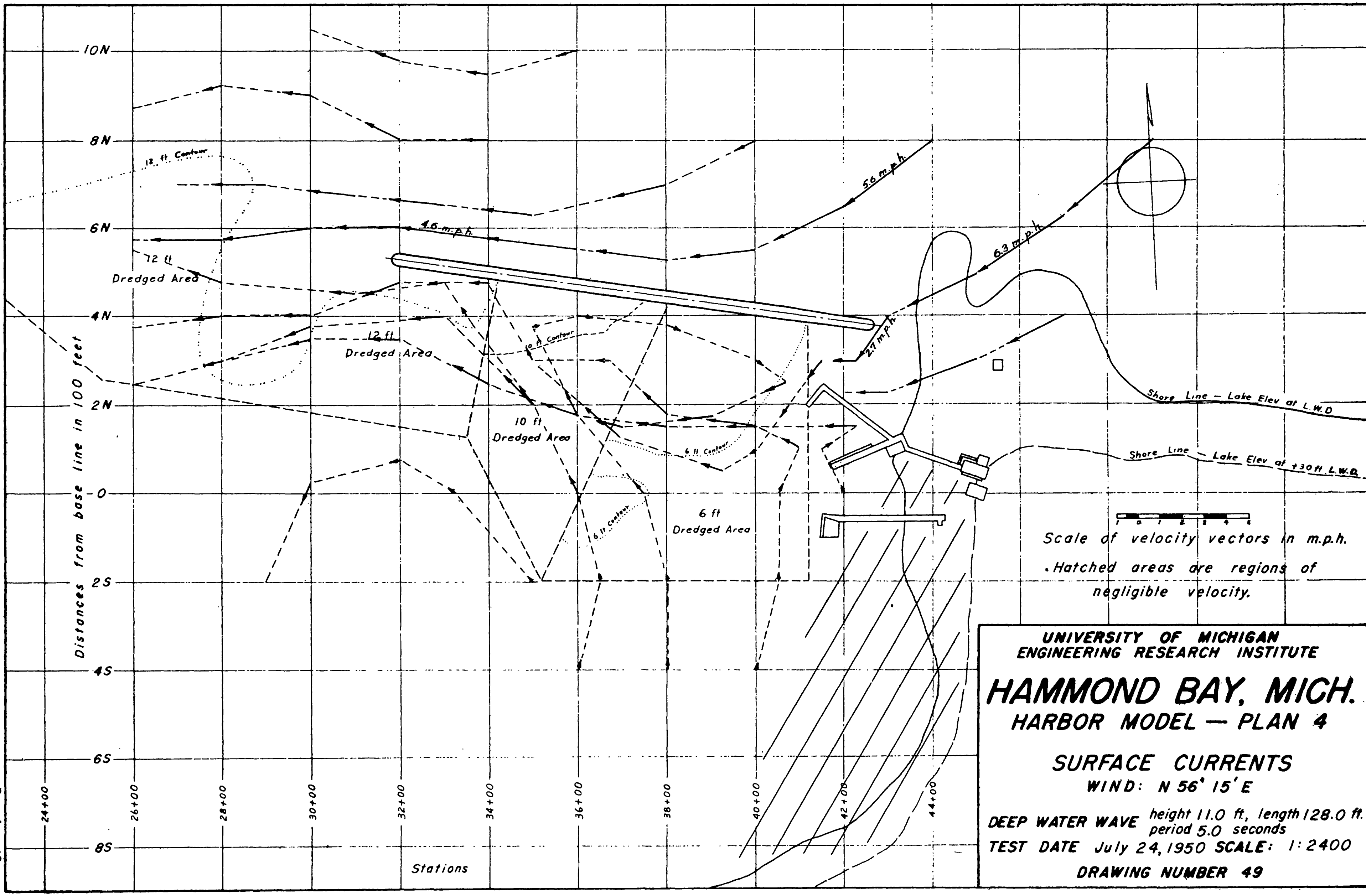
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
SURFACE CURRENTS
WIND: N 33° 45' W
DEEP WATER WAVE height 10.0 ft, length 113.0 ft.
period 4.7 seconds
TEST DATE July 20, 1950 SCALE: 1:2400
DRAWING NUMBER 51
Scale of velocity vectors in m.p.h.
Shore Line — Lake Elev at L.W.D
Shore Line — Lake Elev at +3.0 ft L.W.D.
3.7 m.p.h.
6 ft Dredged Area
10 ft Dredged Area
12 ft Dredged Area
12 ft Dredged Area
Stations
Distances from base line in 100 feet
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
24+00
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00

Drawing 51


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
SURFACE CURRENTS
WIND: N 11° 15'E
DEEP WATER WAVE height 9.0 ft, length 95.0 ft, period 4.3 seconds
TEST DATE July 18, 1950 SCALE: 1:2400
DRAWING NUMBER 50
Scale of velocity vectors in m.p.h.
Shore Line – Lake Elev at L.W.D.
Shore Line – Lake Elev at +3.0 ft L.W.D.
6 ft Dredged Area
6 ft Contour
10 ft Contour
10 ft Dredged Area
12 ft Dredged Area
12 ft Contour
12 ft Dredged Area
Stations
24+00
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
Distances from base line in 100 feet

Drawing 50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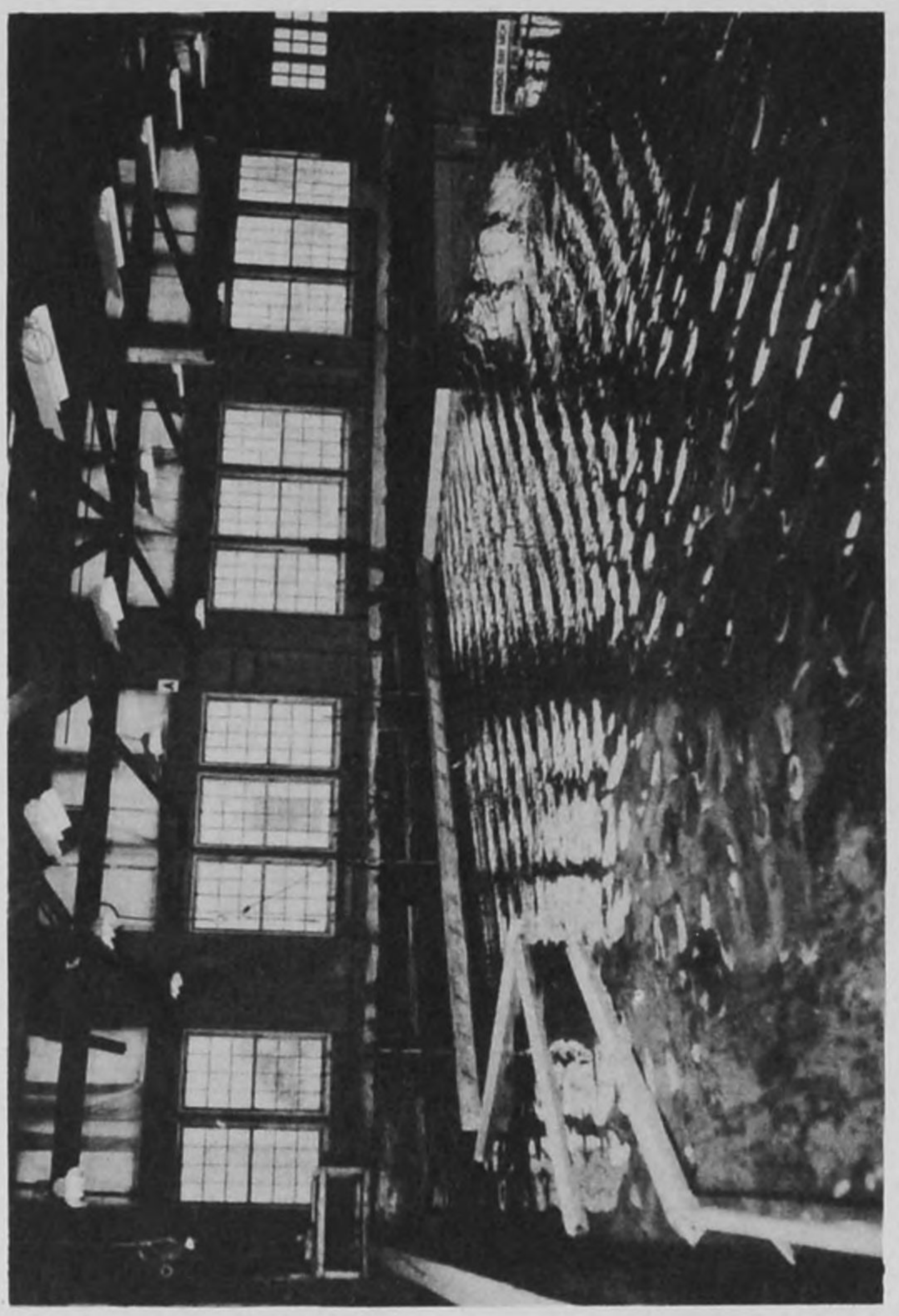
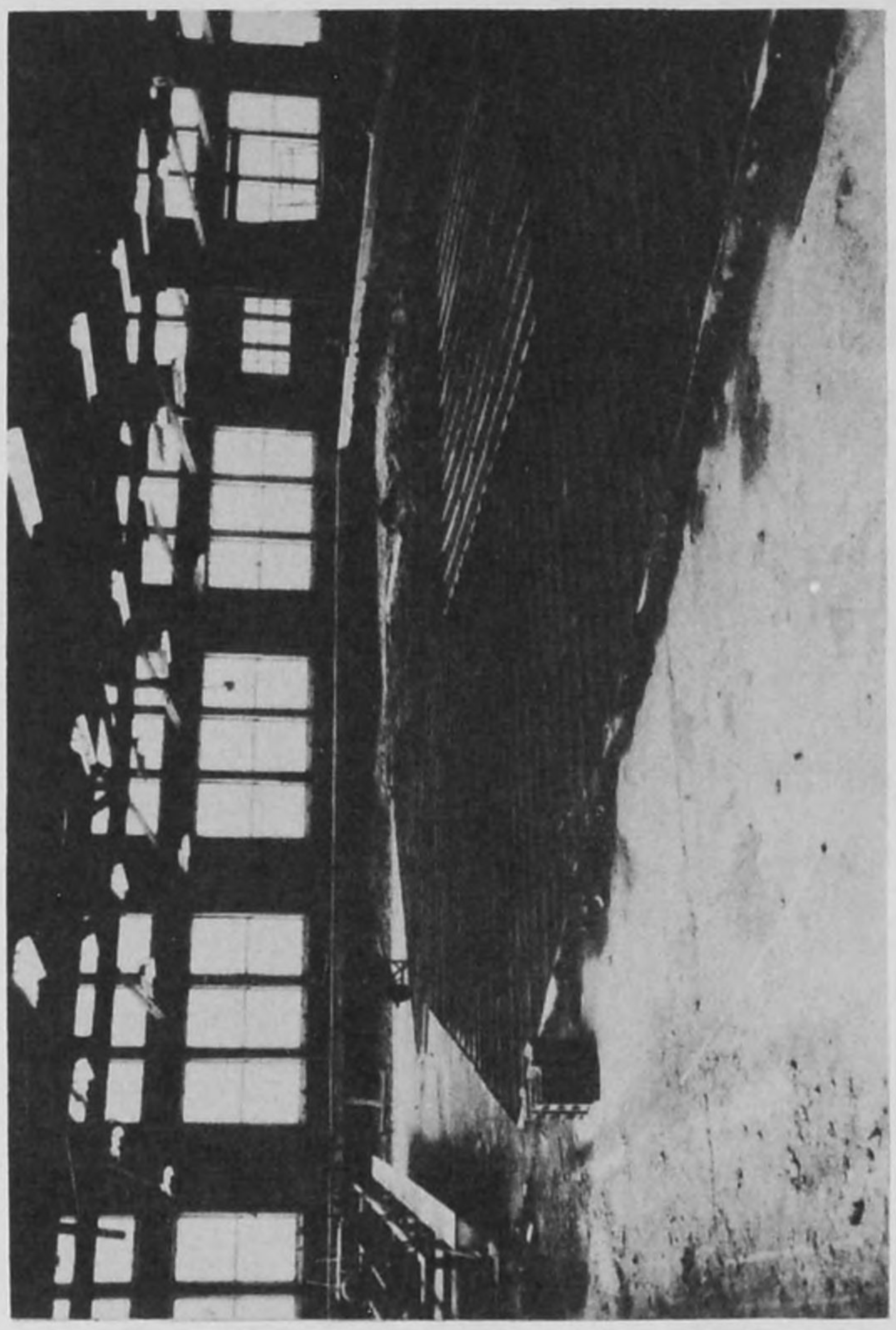
HAMMOND BAY, MICH.
HARBOR MODEL — PLAN 4
SURFACE CURRENTS
WIND: N 56° 15' E
DEEP WATER WAVE height 11.0 ft, length 128.0 ft. period 5.0 seconds
TEST DATE July 24, 1950 SCALE: 1:2400
DRAWING NUMBER 49
Scale of velocity vectors in m.p.h.
.Hatched areas are regions of negligible velocity.
Shore Line — Lake Elev at L.W.D
Shore Line — Lake Elev at +3.0 ft L.W.D
6.3 m.p.h.
5.6 m.p.h.
4.6 m.p.h.
2.7 m.p.h.
12 ft Dredged Area
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
12 ft Contour
6 ft Contour
6 ft Contour
10N
8N
6N
4N
2N
0
2S
4S
6S
8S
Distances from base line in 100 feet
24+00
26+00
28+00
30+00
32+00
34+00
36+00
38+00
40+00
42+00
44+00
Stations

APPENDIX B

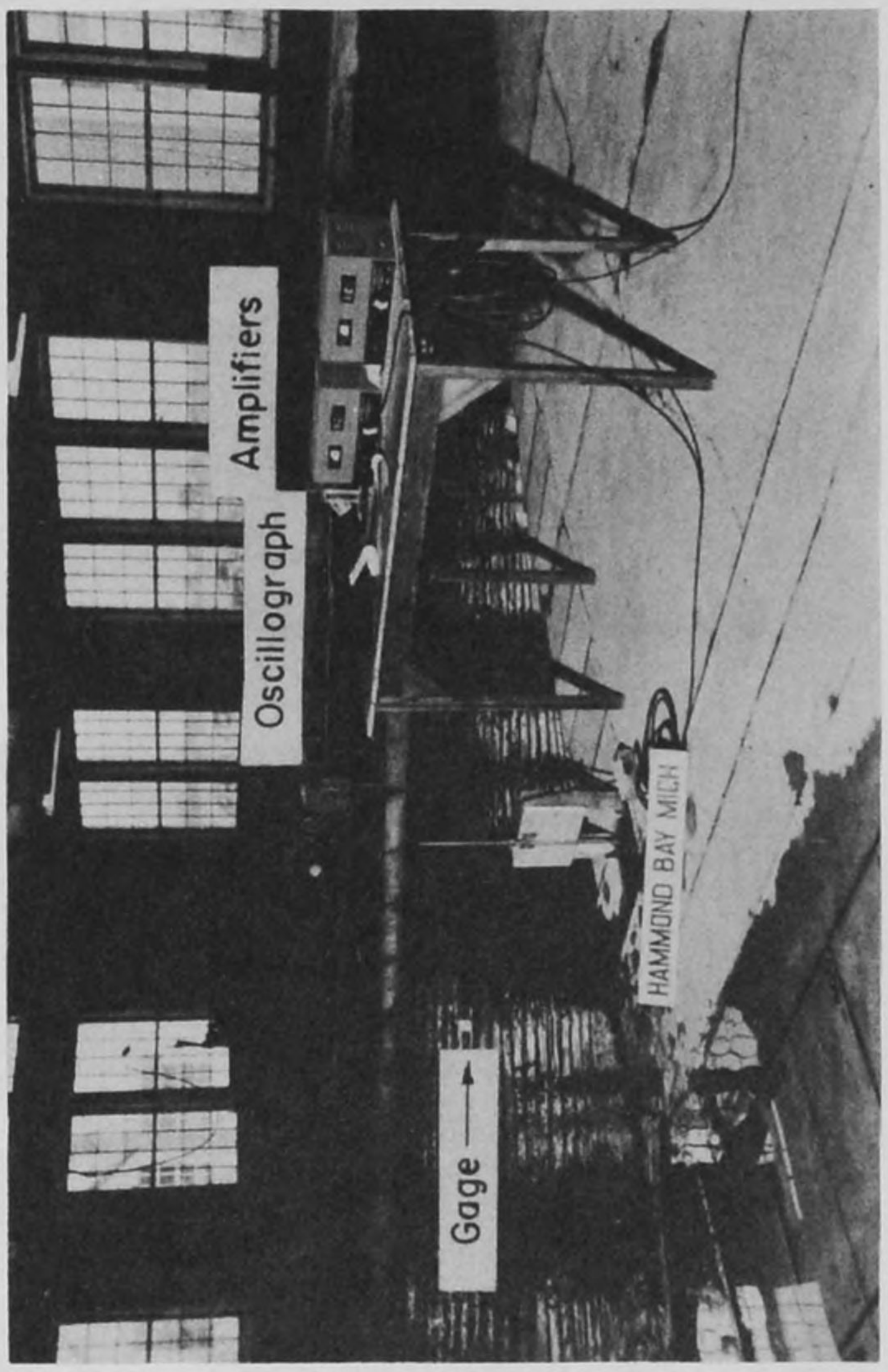
PHOTOGRAPHS



WAVE MACHINE

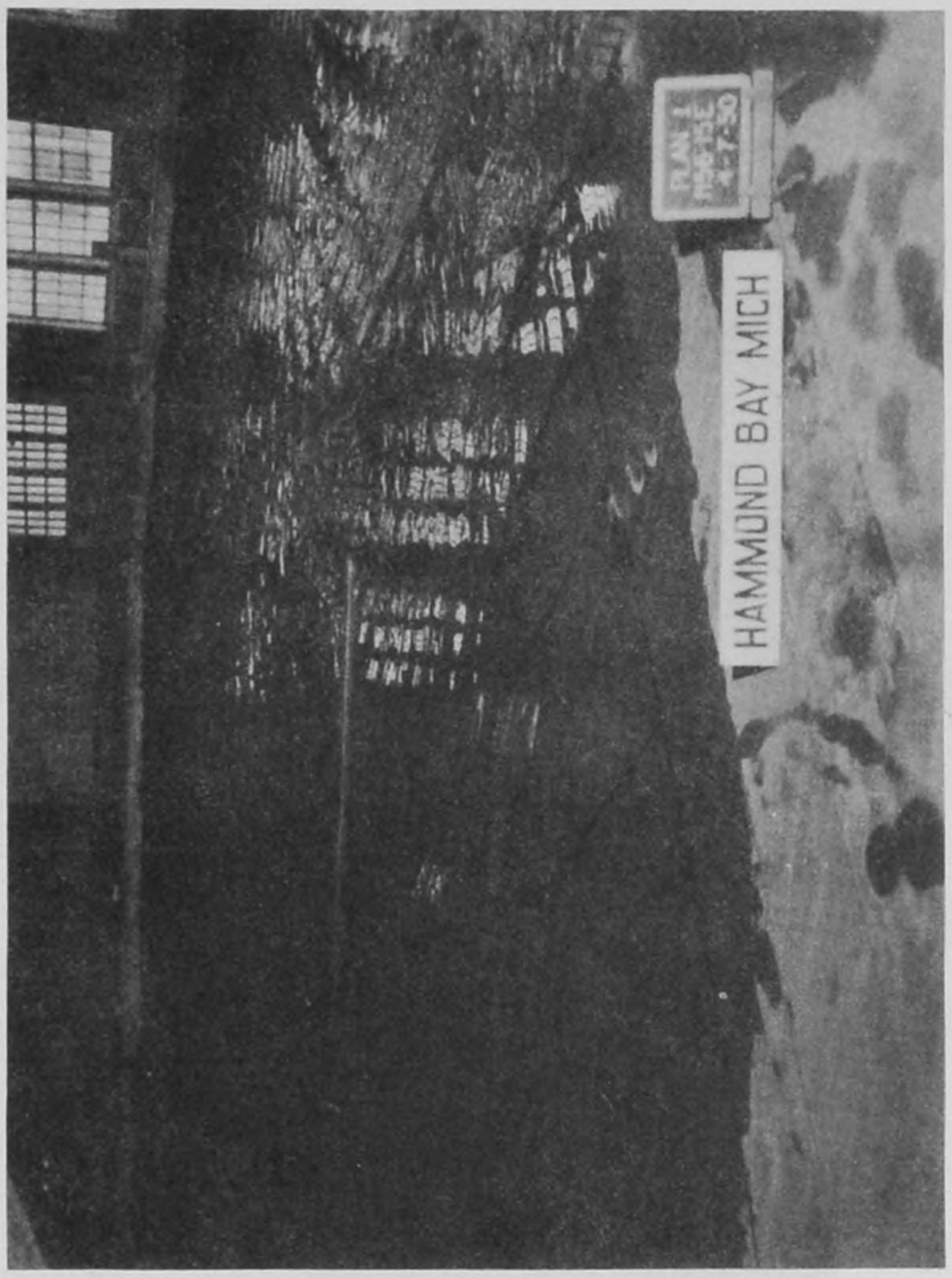


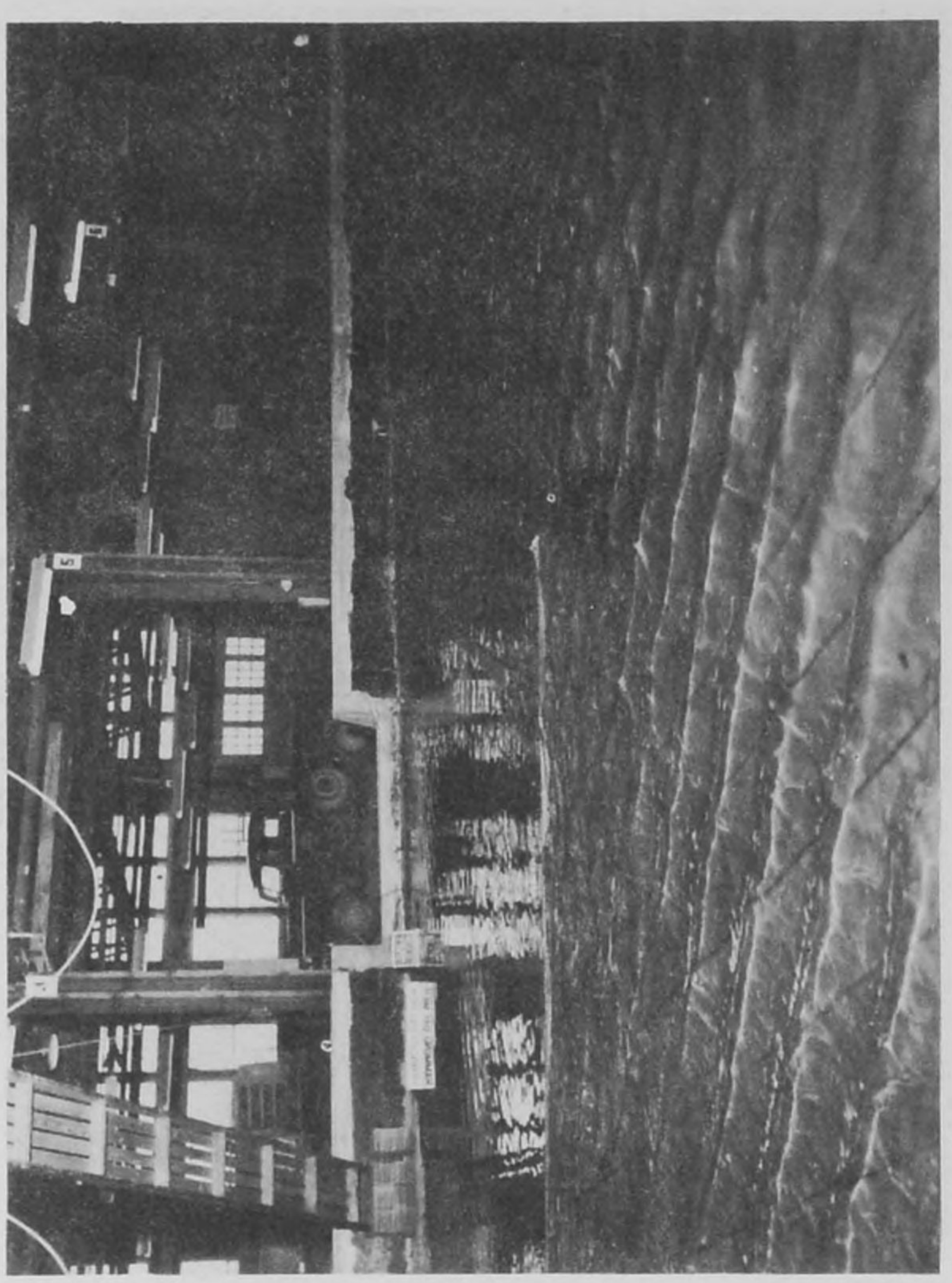
MODEL UNDER CONSTRUCTION

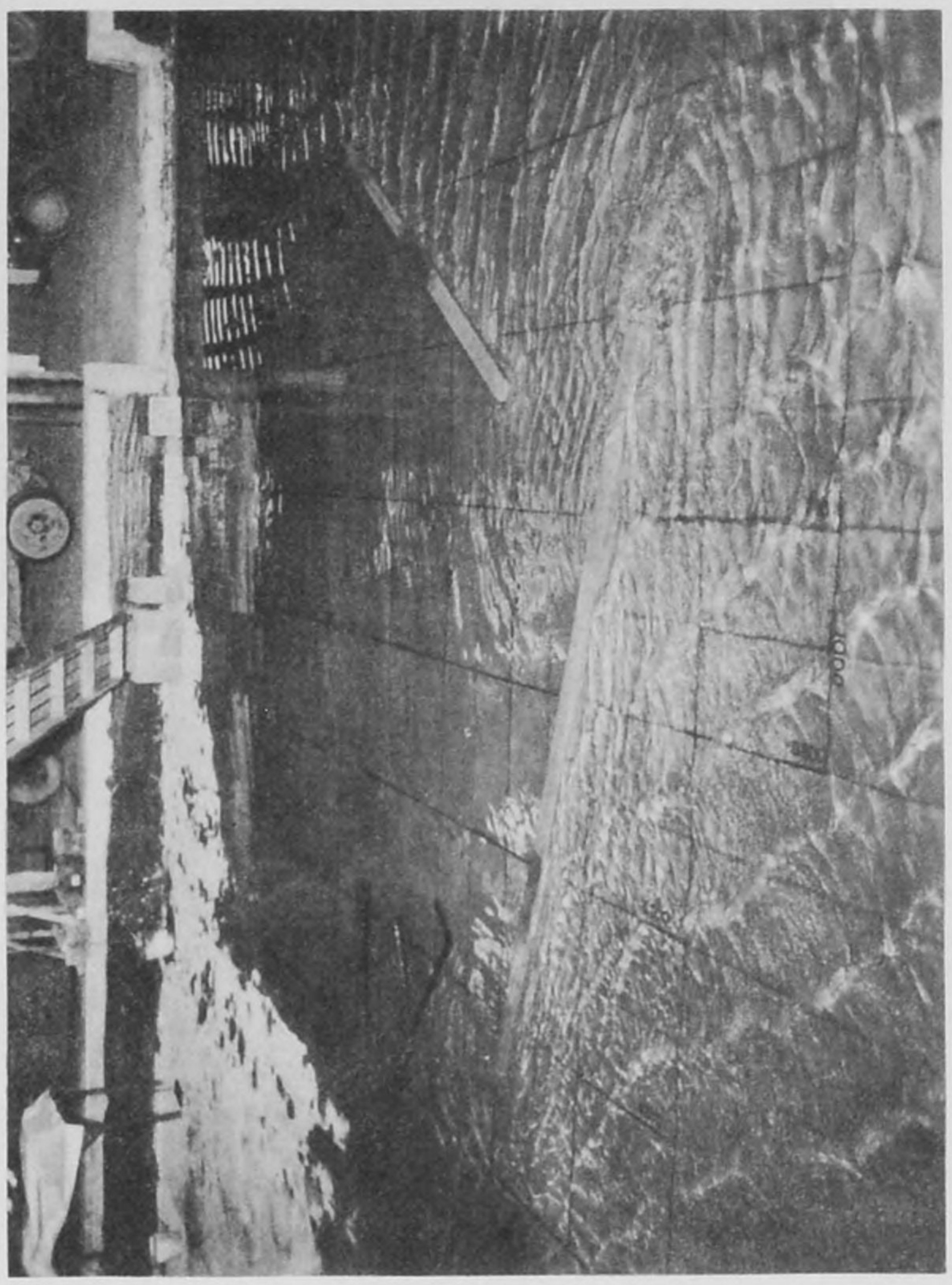


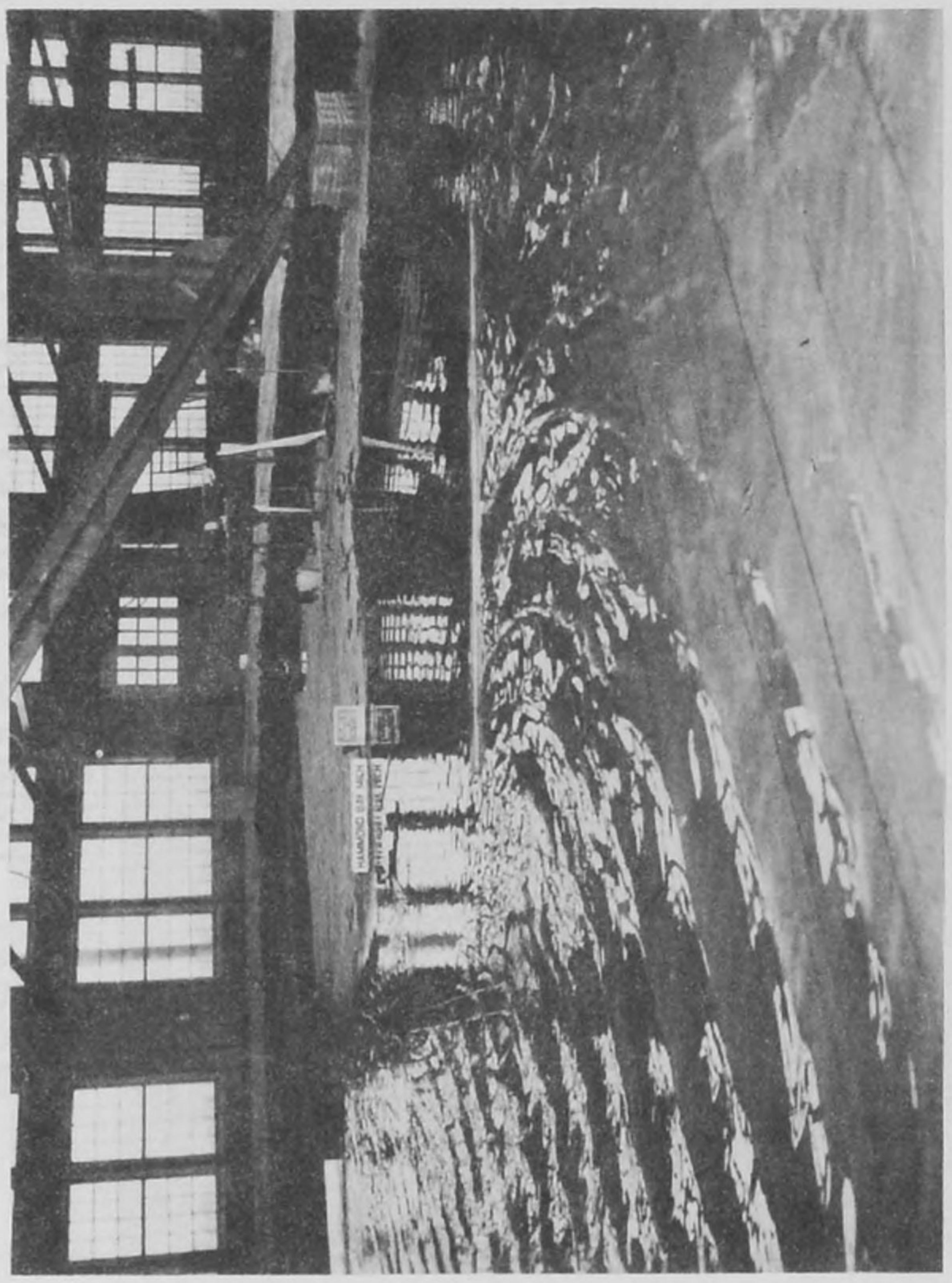
INSTRUMENTS

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 1



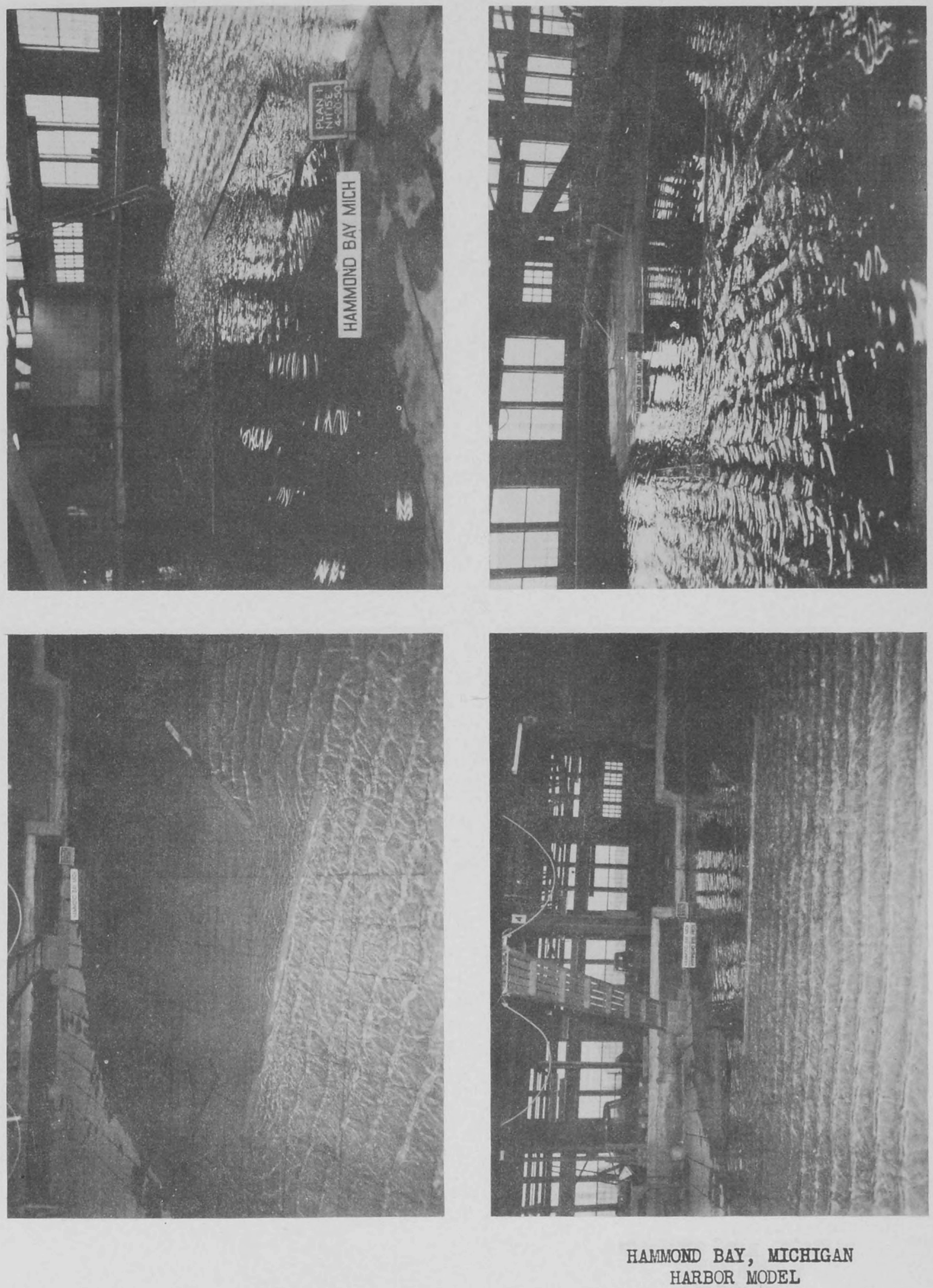






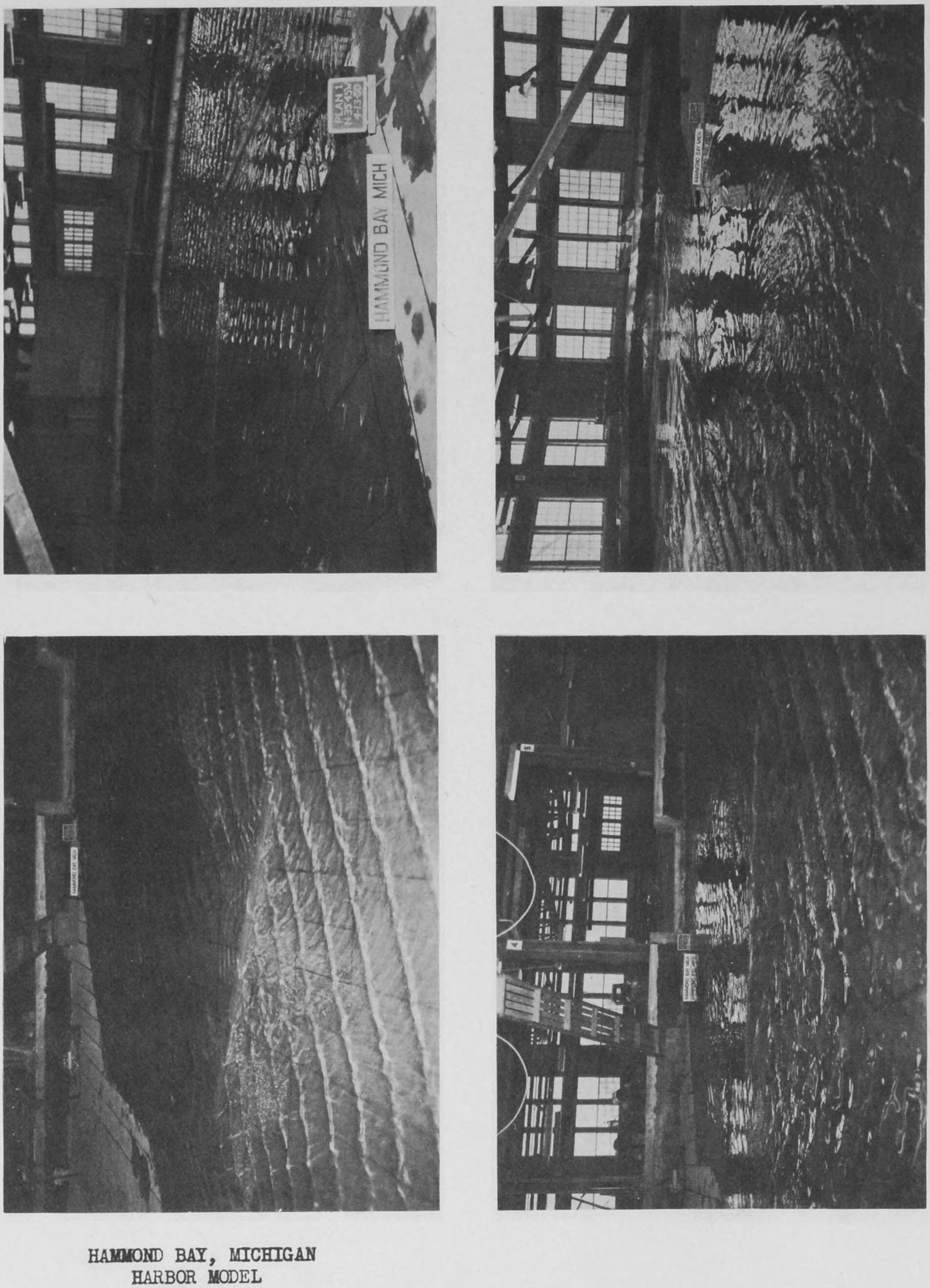
PLAN 1-WIND N. 56°15'E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 2



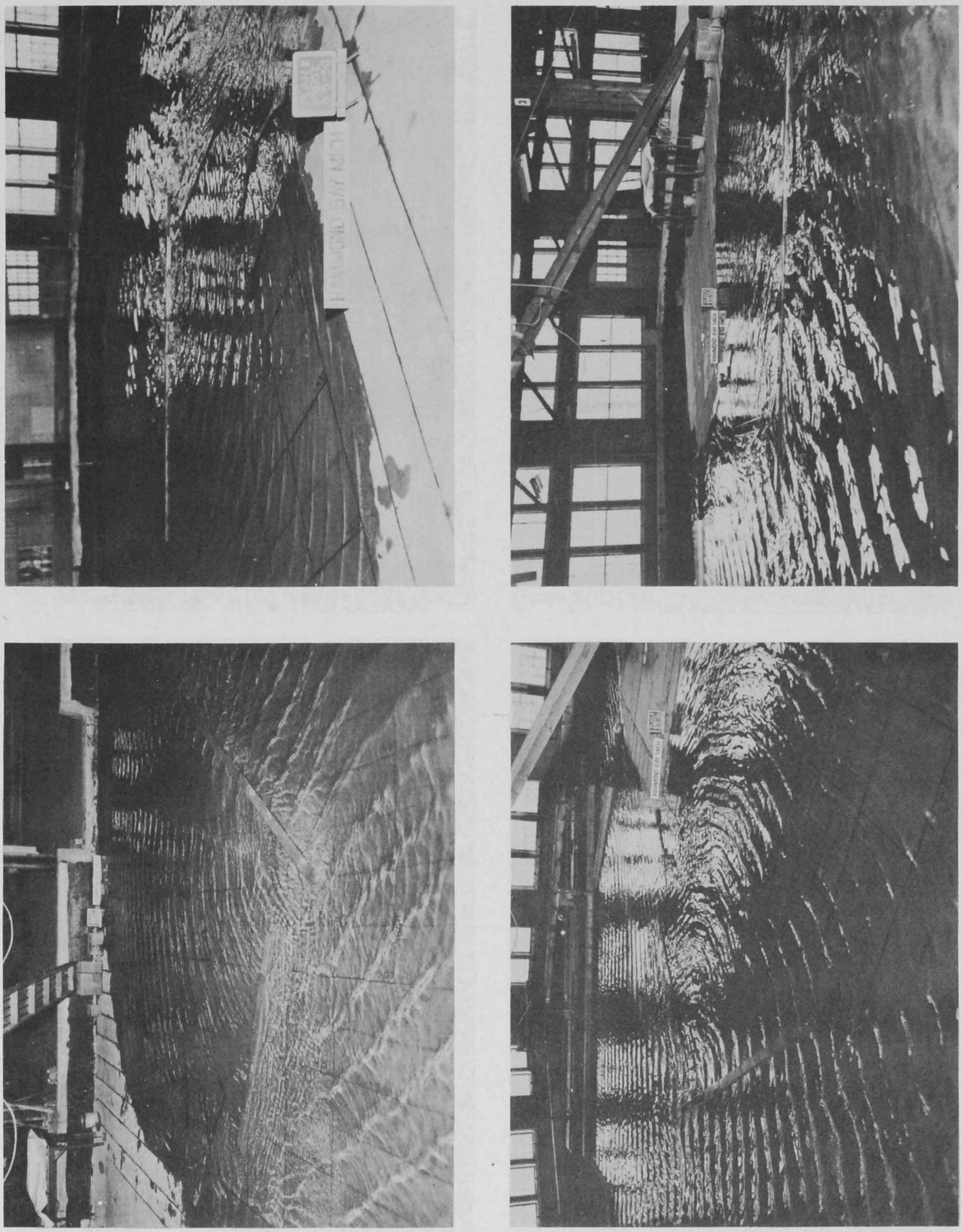
PLAN I-WIND N. 11° 15' E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 3



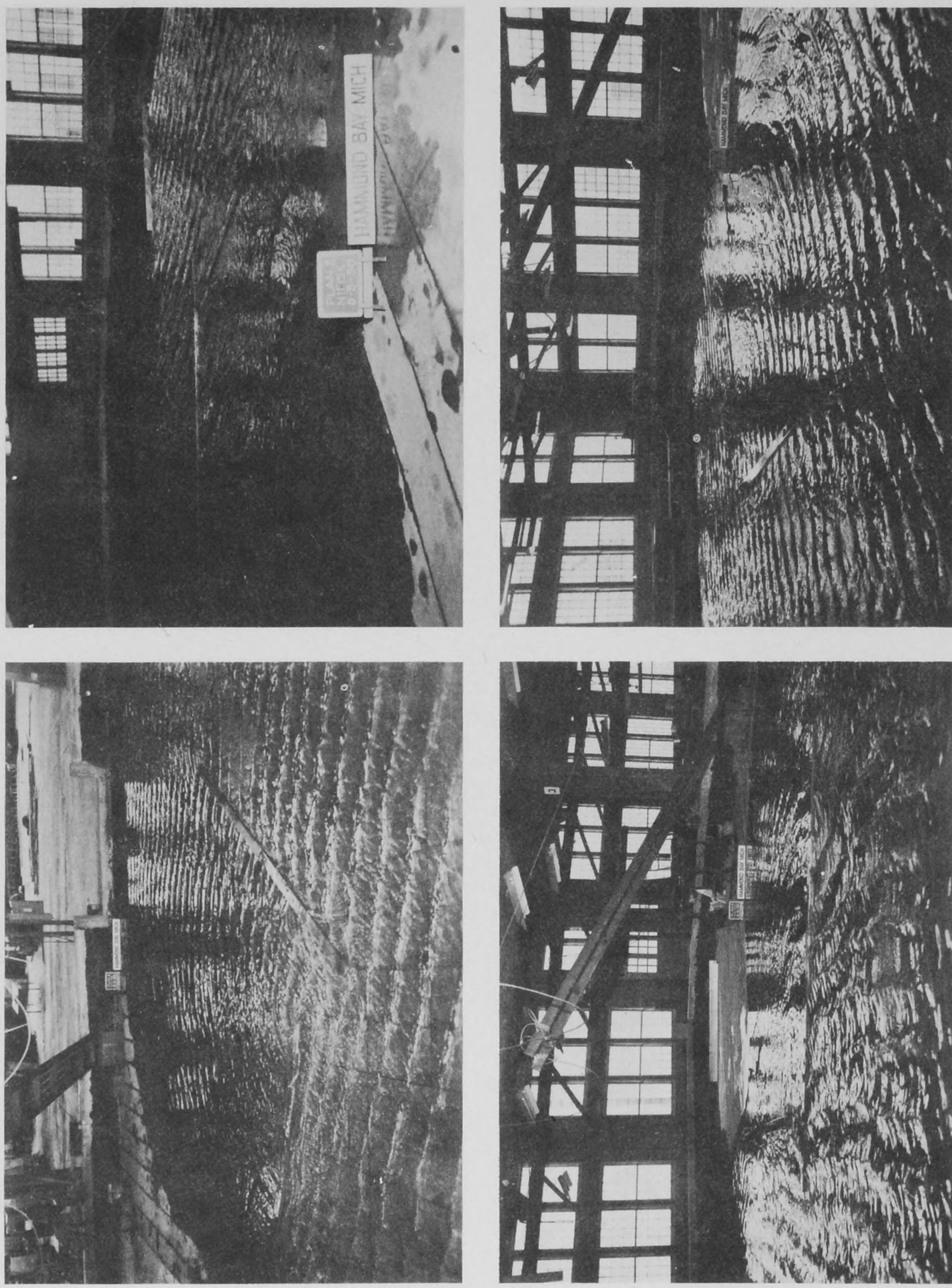
PLAN I-WIND N.33° 45' W.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 4



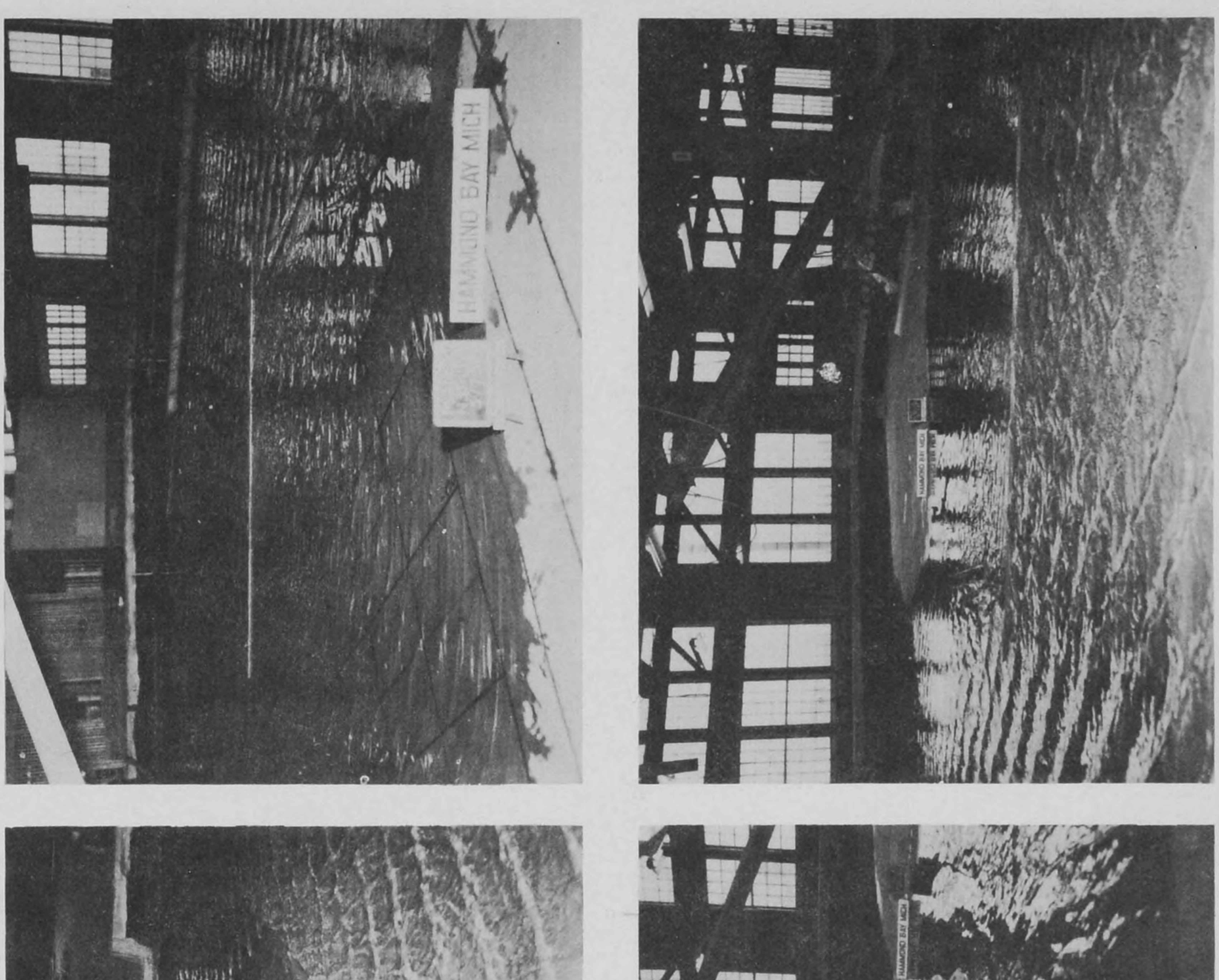
PLAN 2-WIND N. 56°15'E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 5



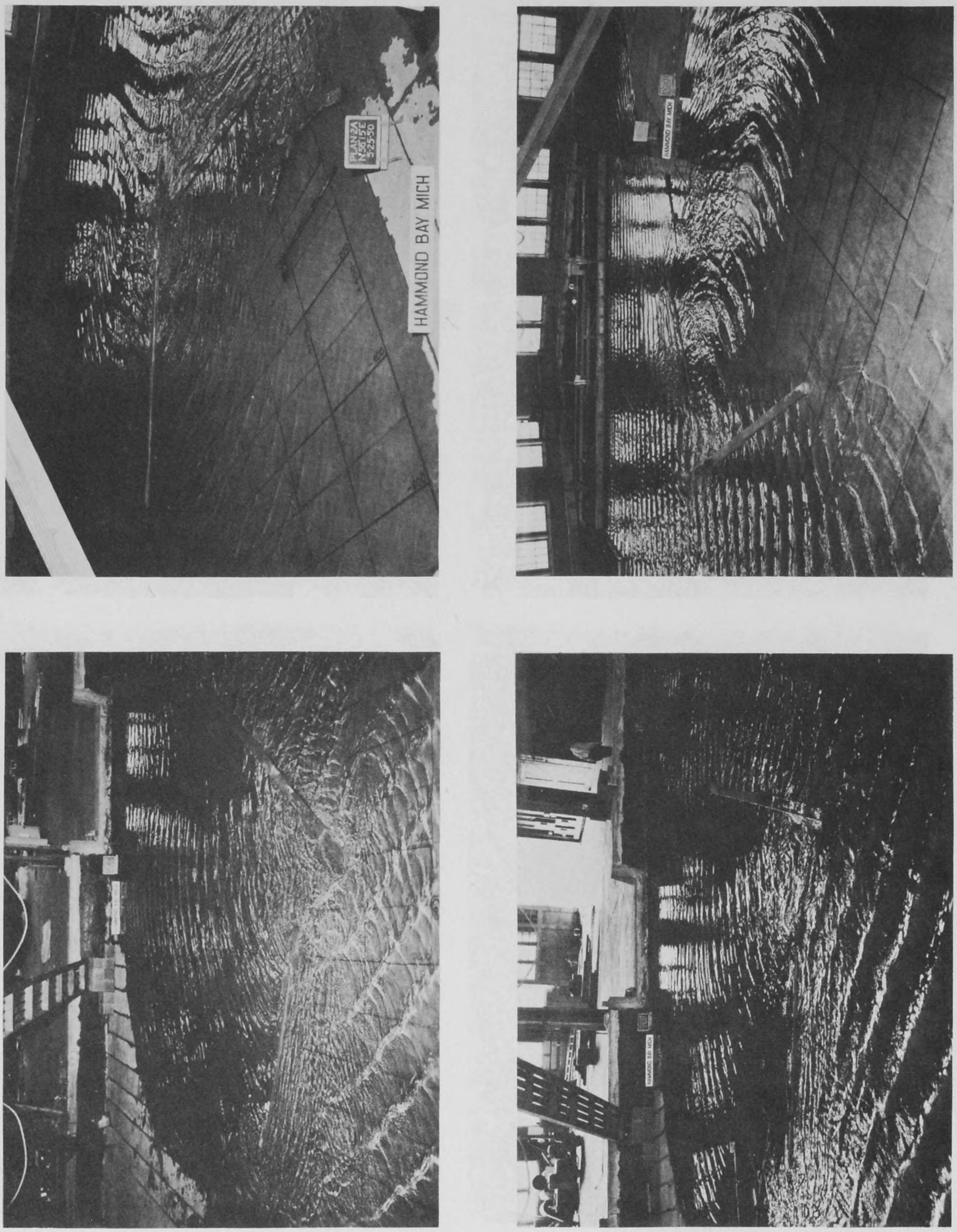
PLAN 2-WIND N. 11° 15' E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 6



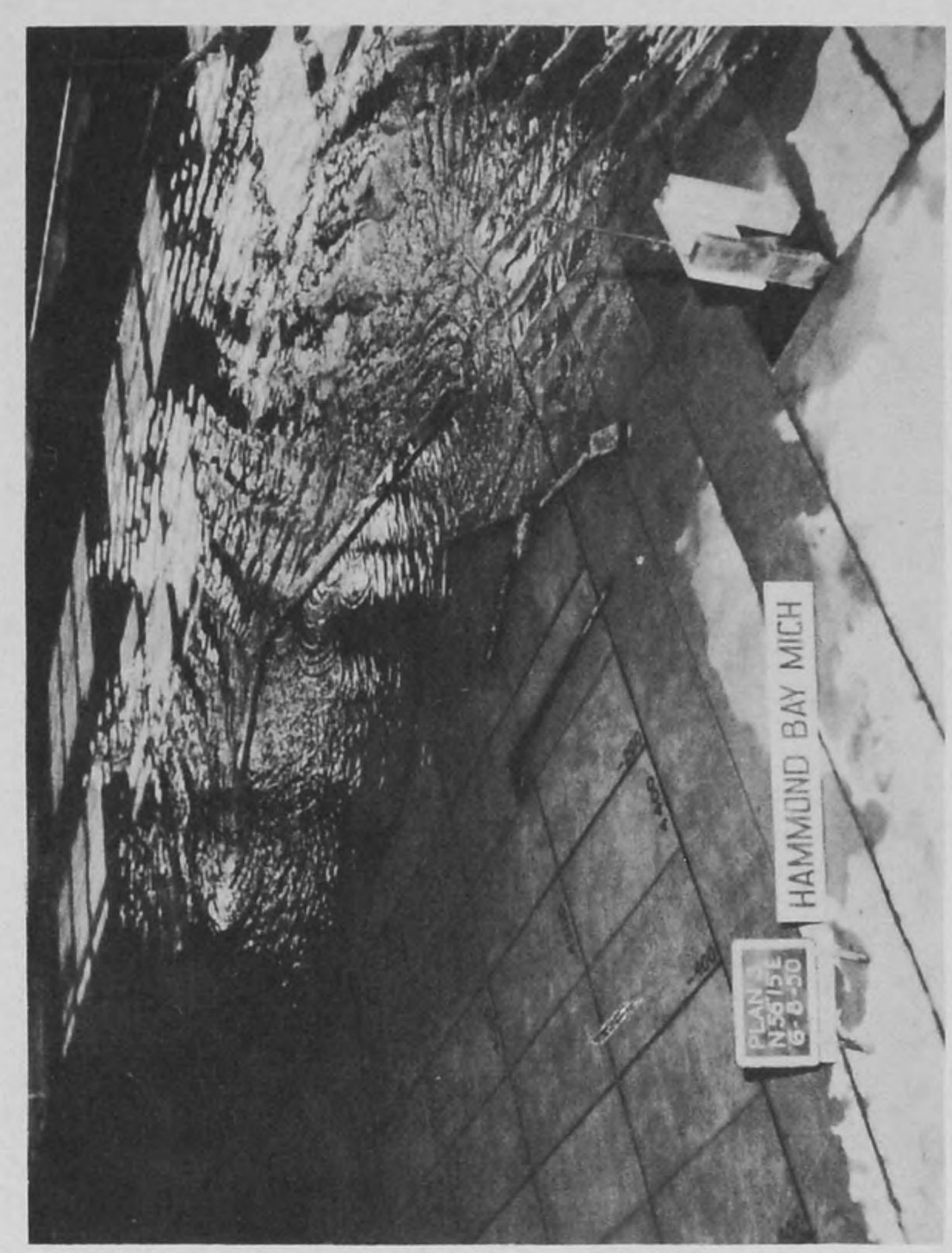
PLAN 2-WIND N. 33° 45' W.

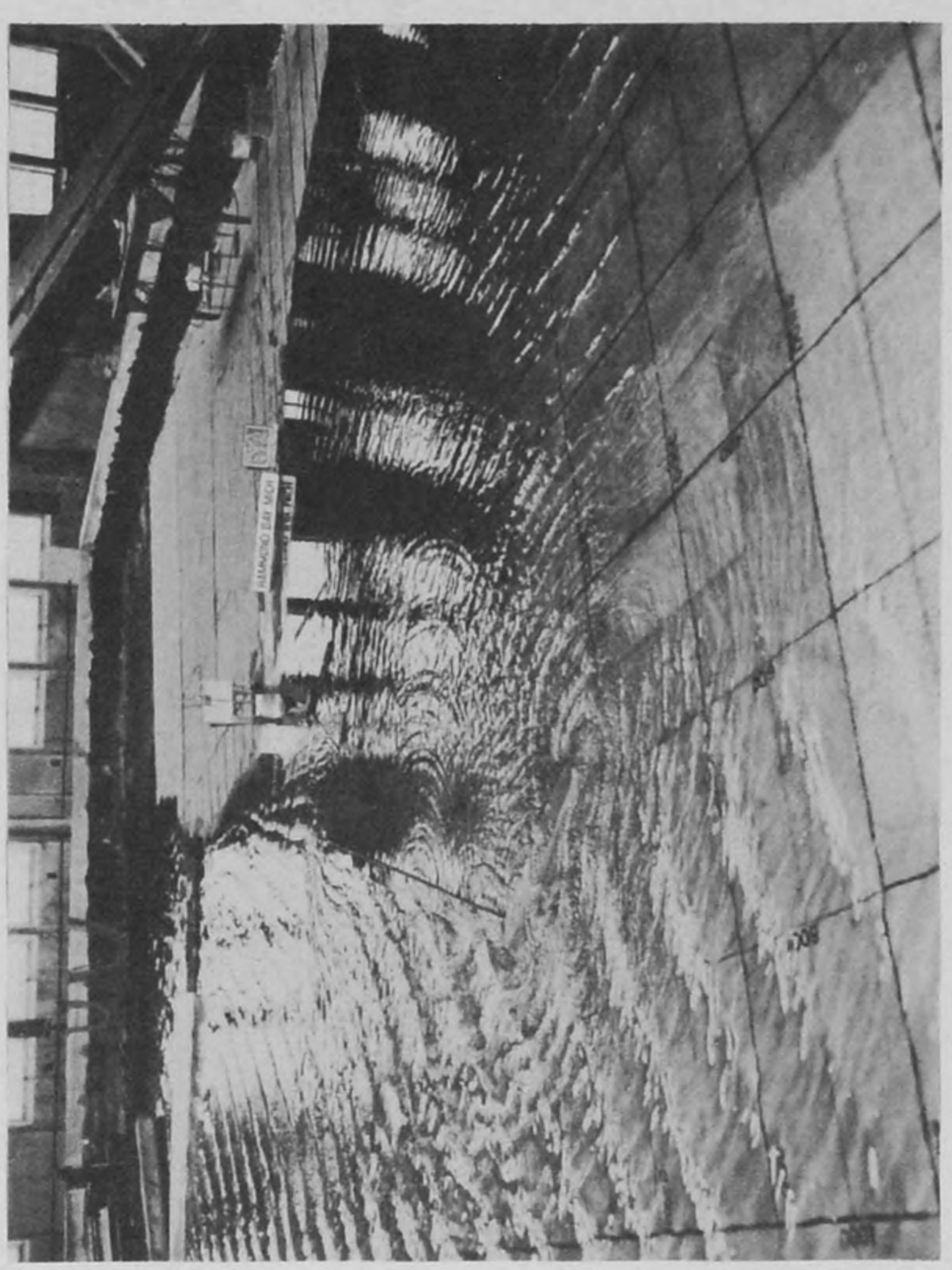
HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 7

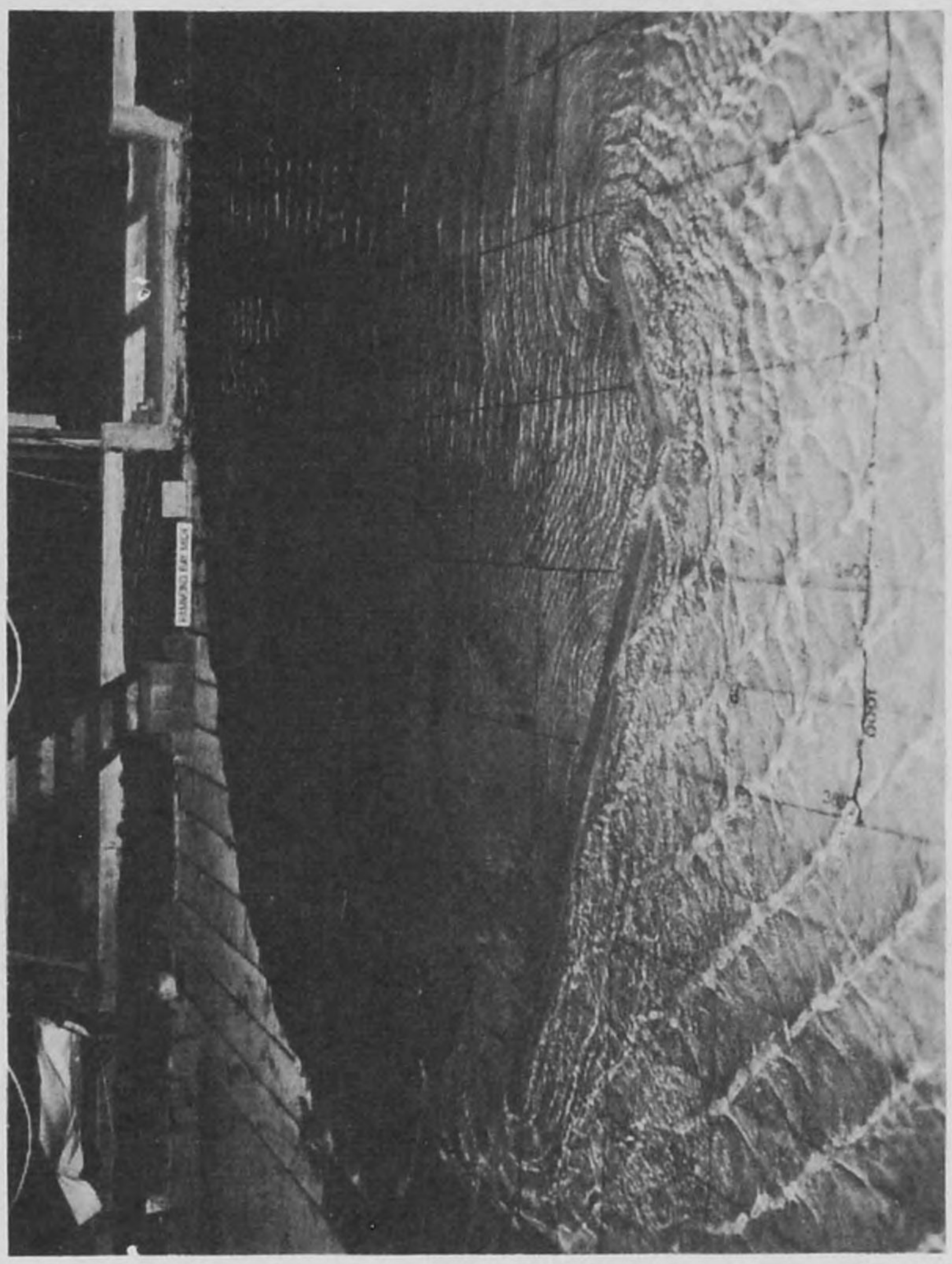


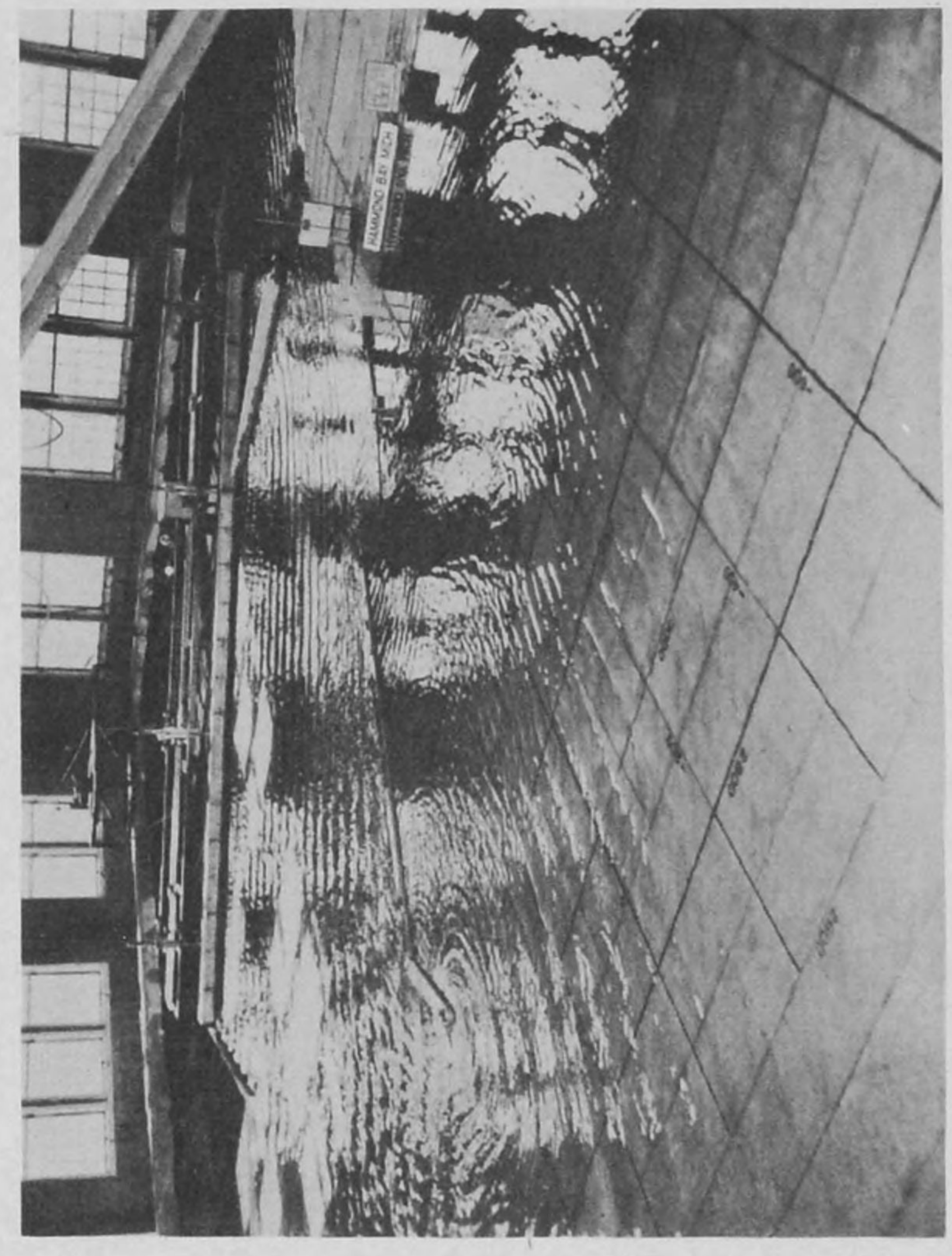
PLAN 2a-WIND N. 56° 15'E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 8



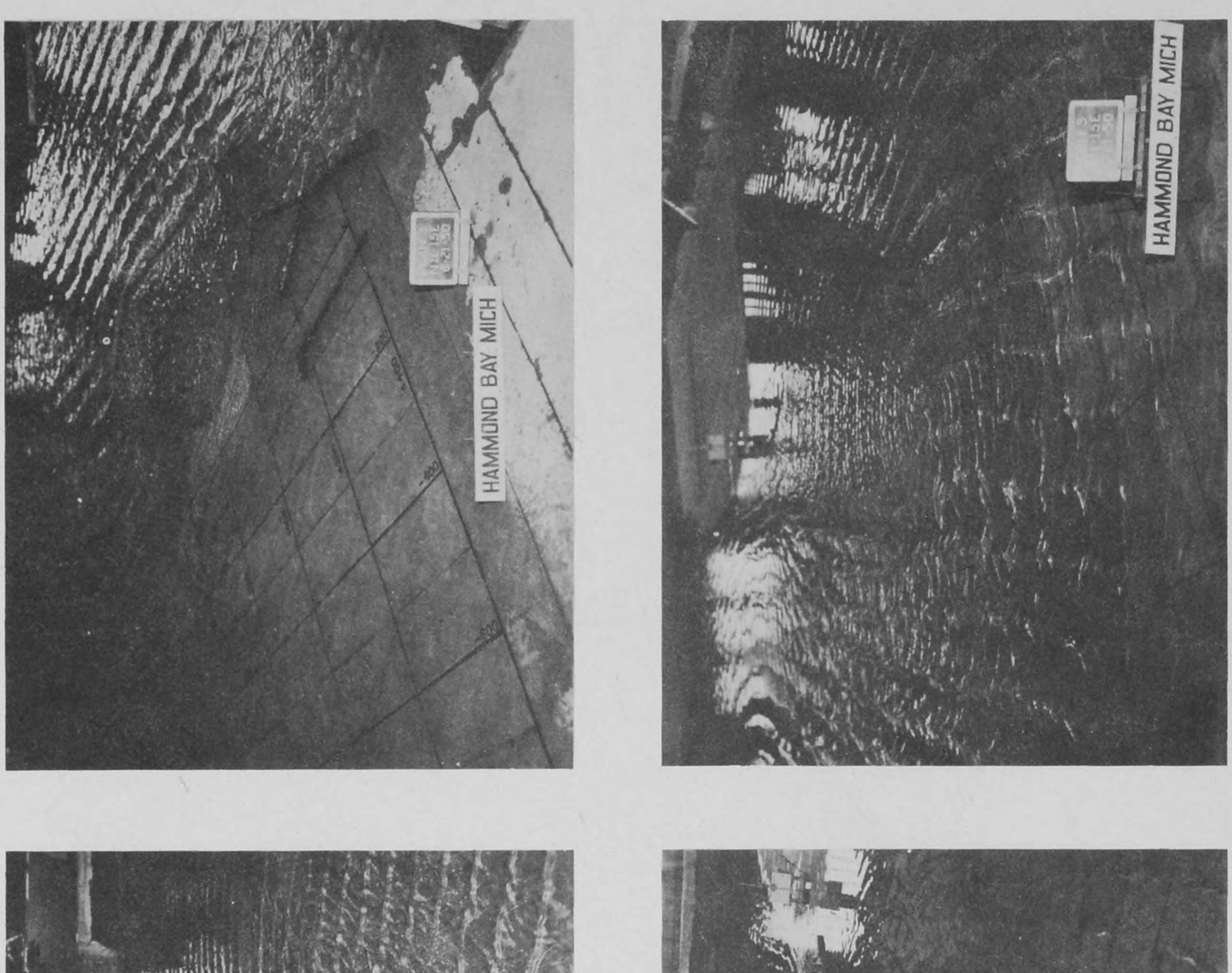






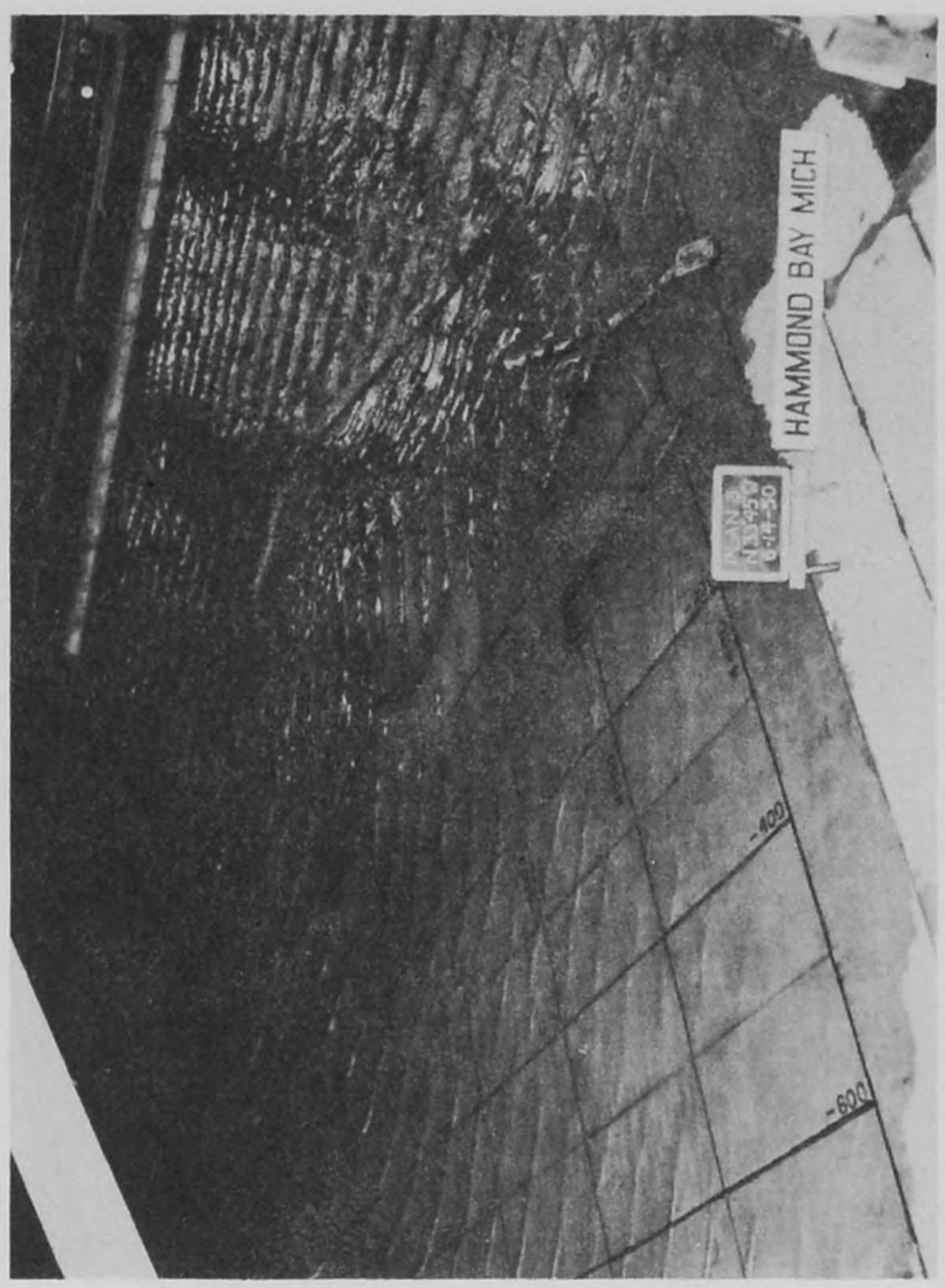
PLAN 3-WIND N. 56°15'E.

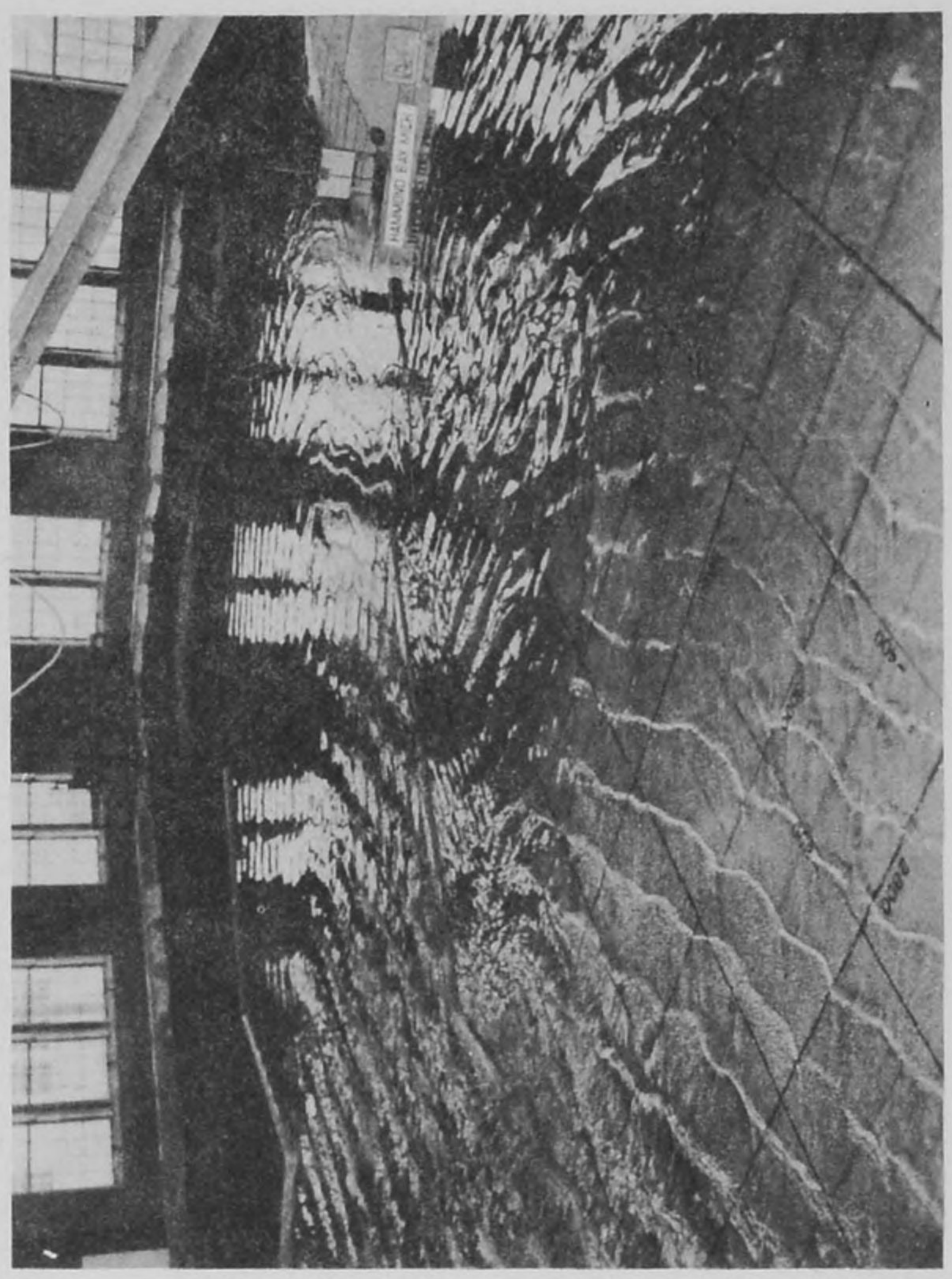
HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 9

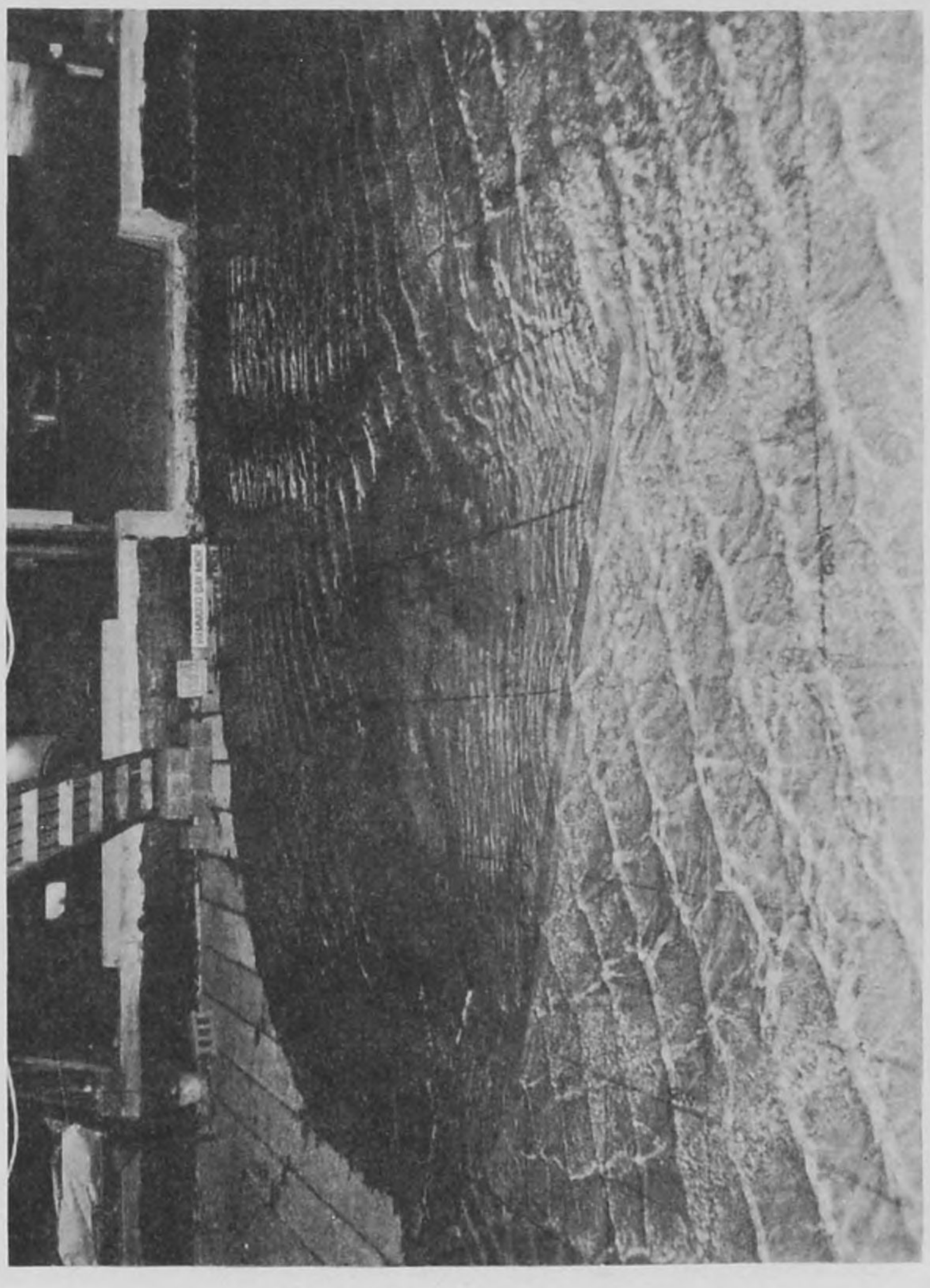


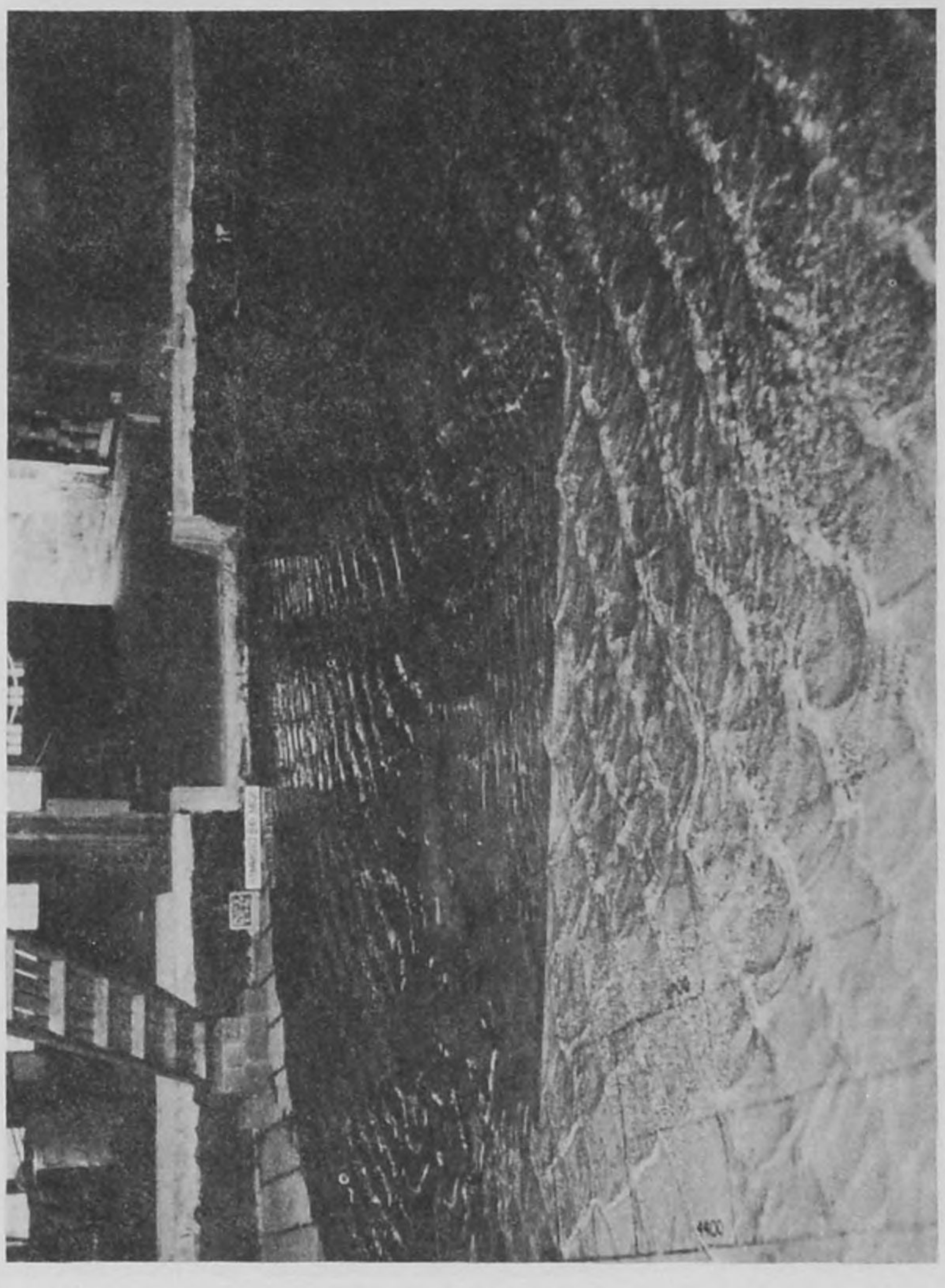
PLAN 3-WIND N. 11°15'E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 10



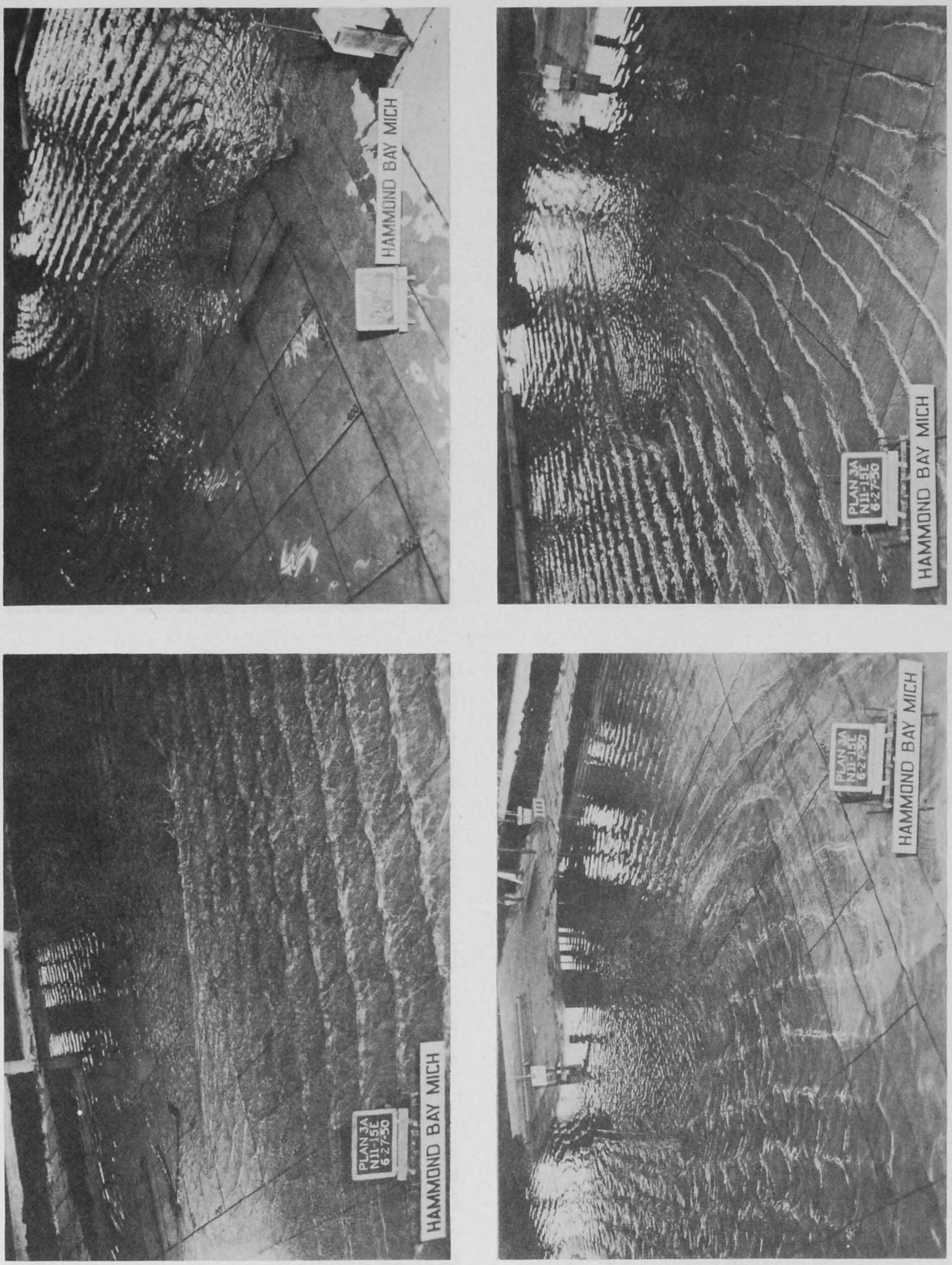






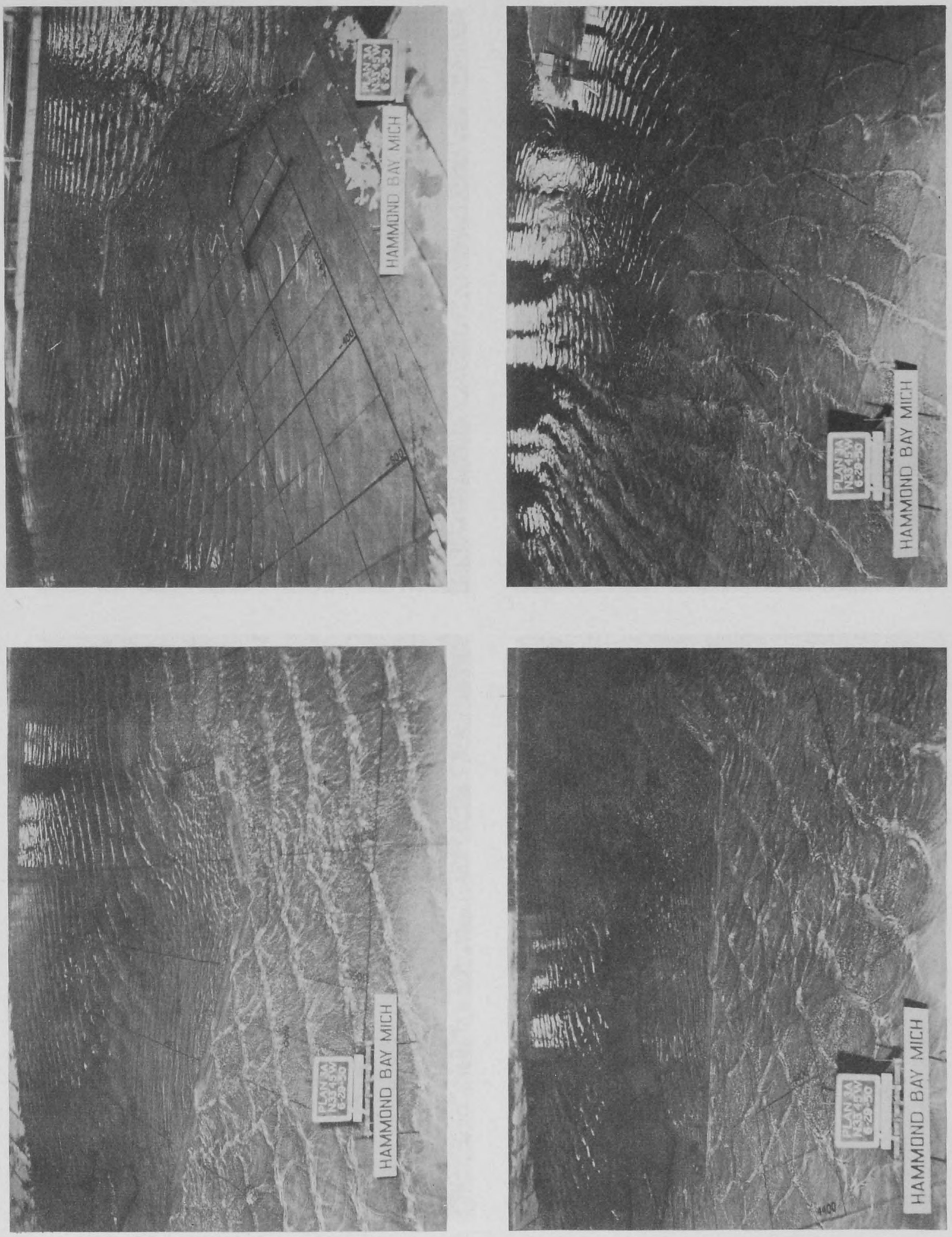
PLAN 3-WIND N. 33° 45′ W.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 11



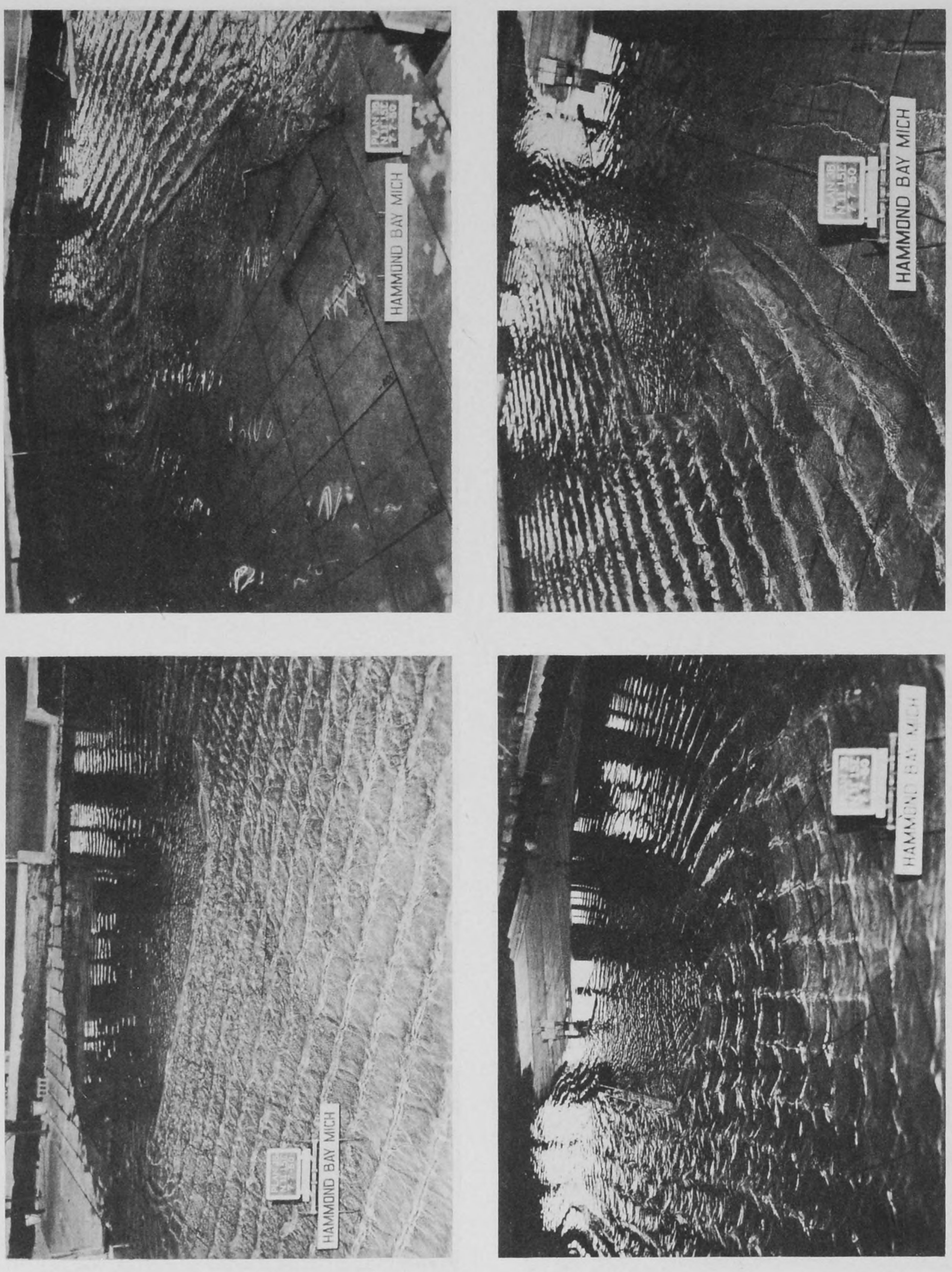
PLAN 3a-WIND N. 11° 15' E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 12



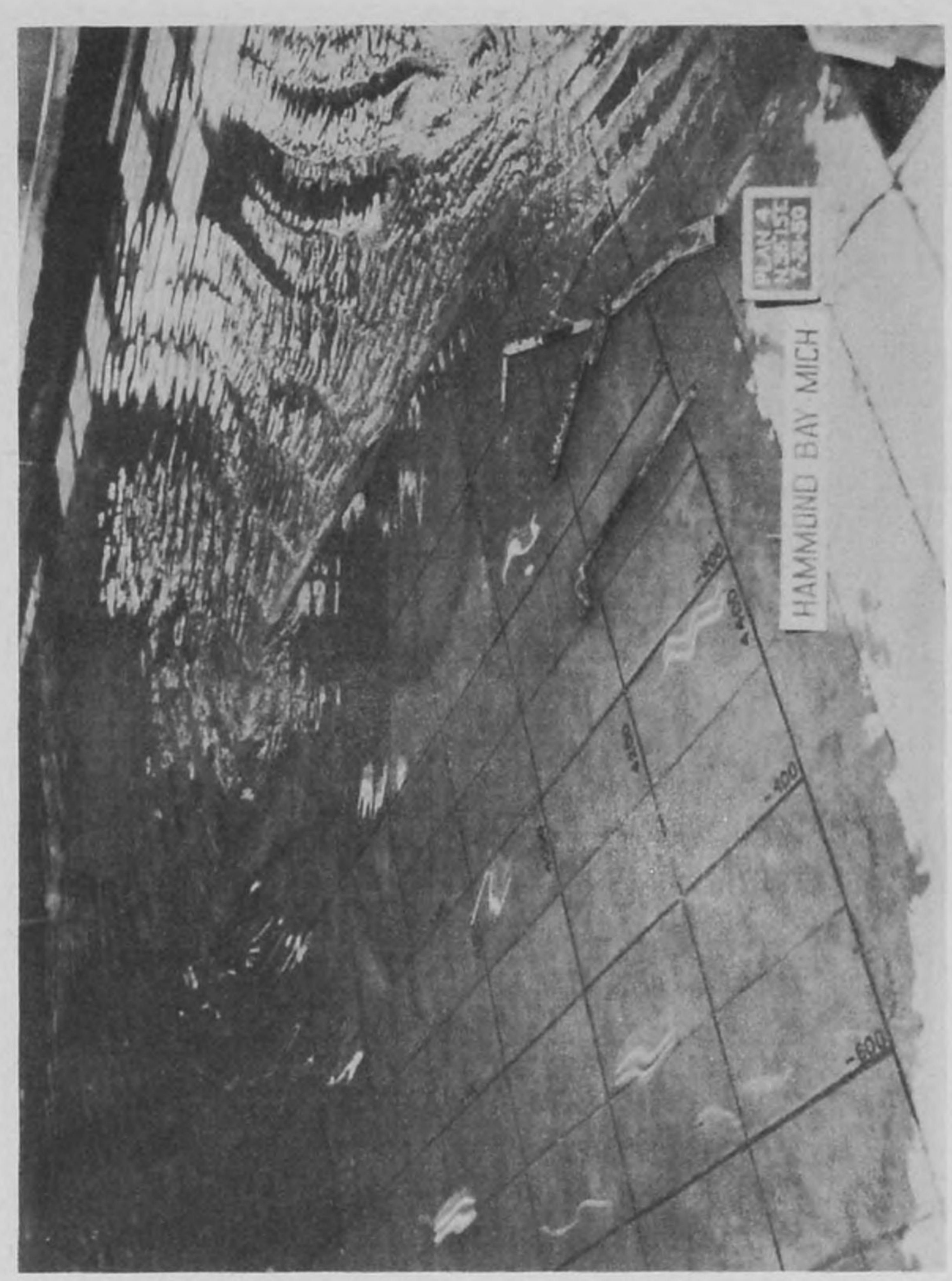
PLAN 3a-WIND N. 33° 45' W.

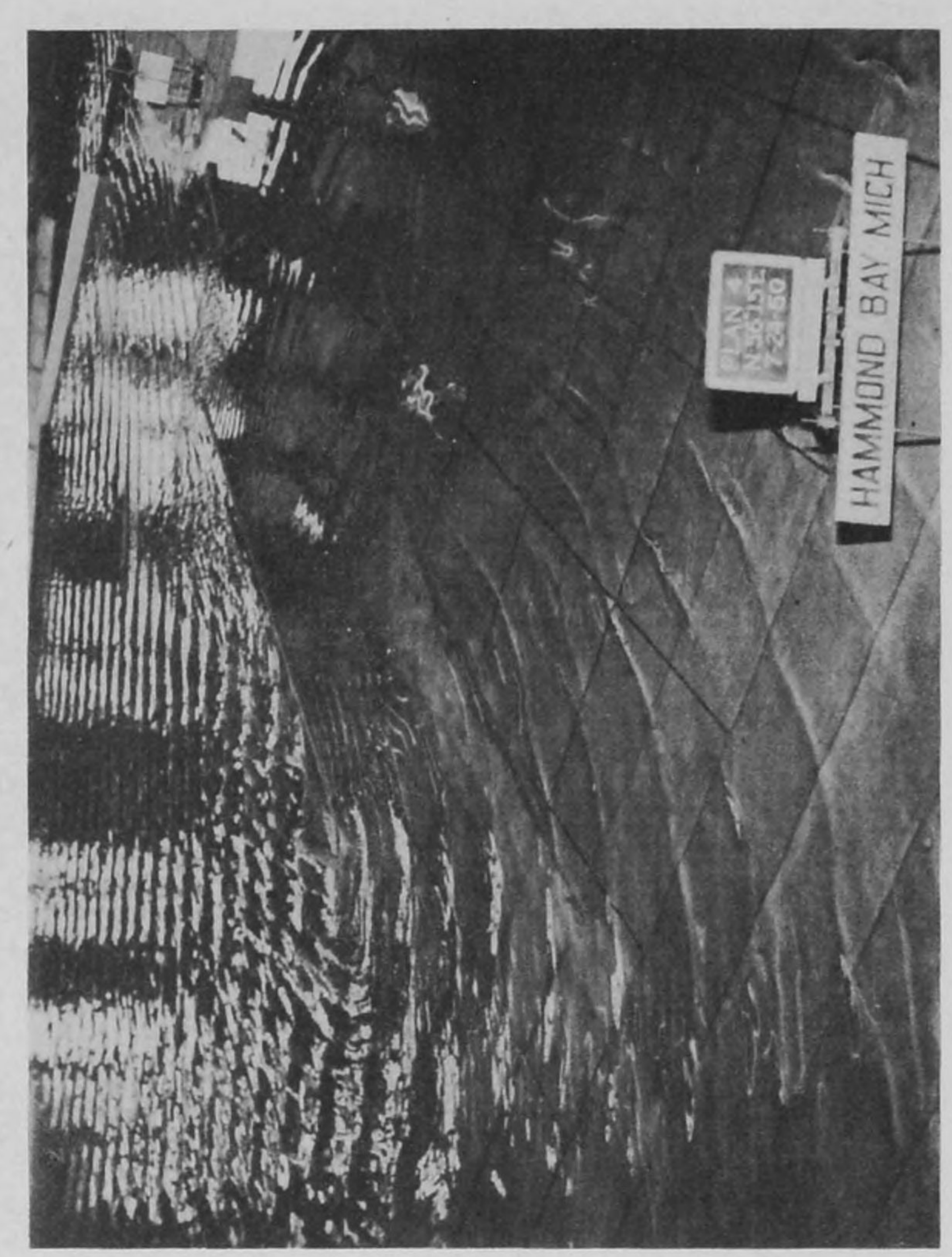
HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 13

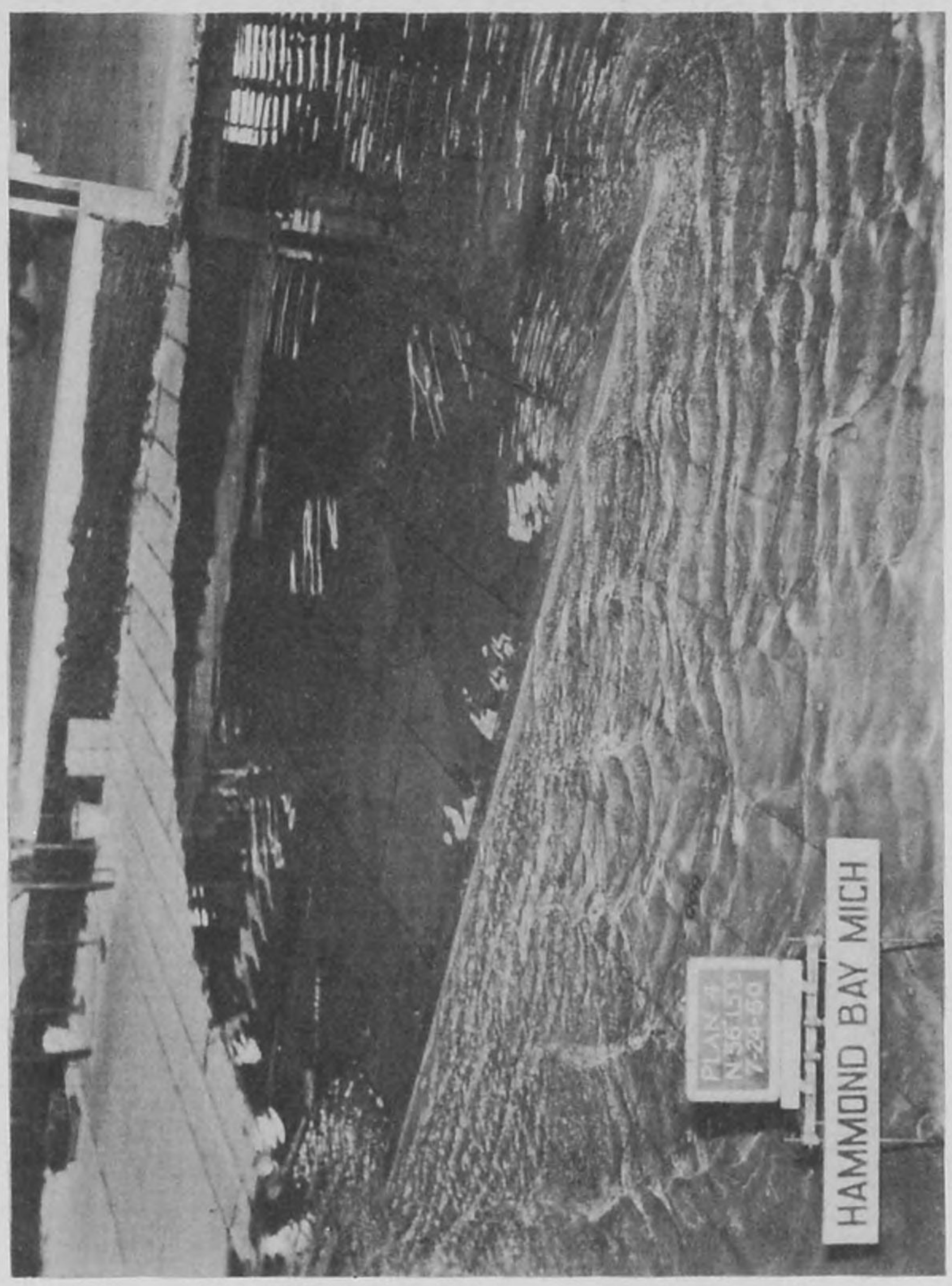


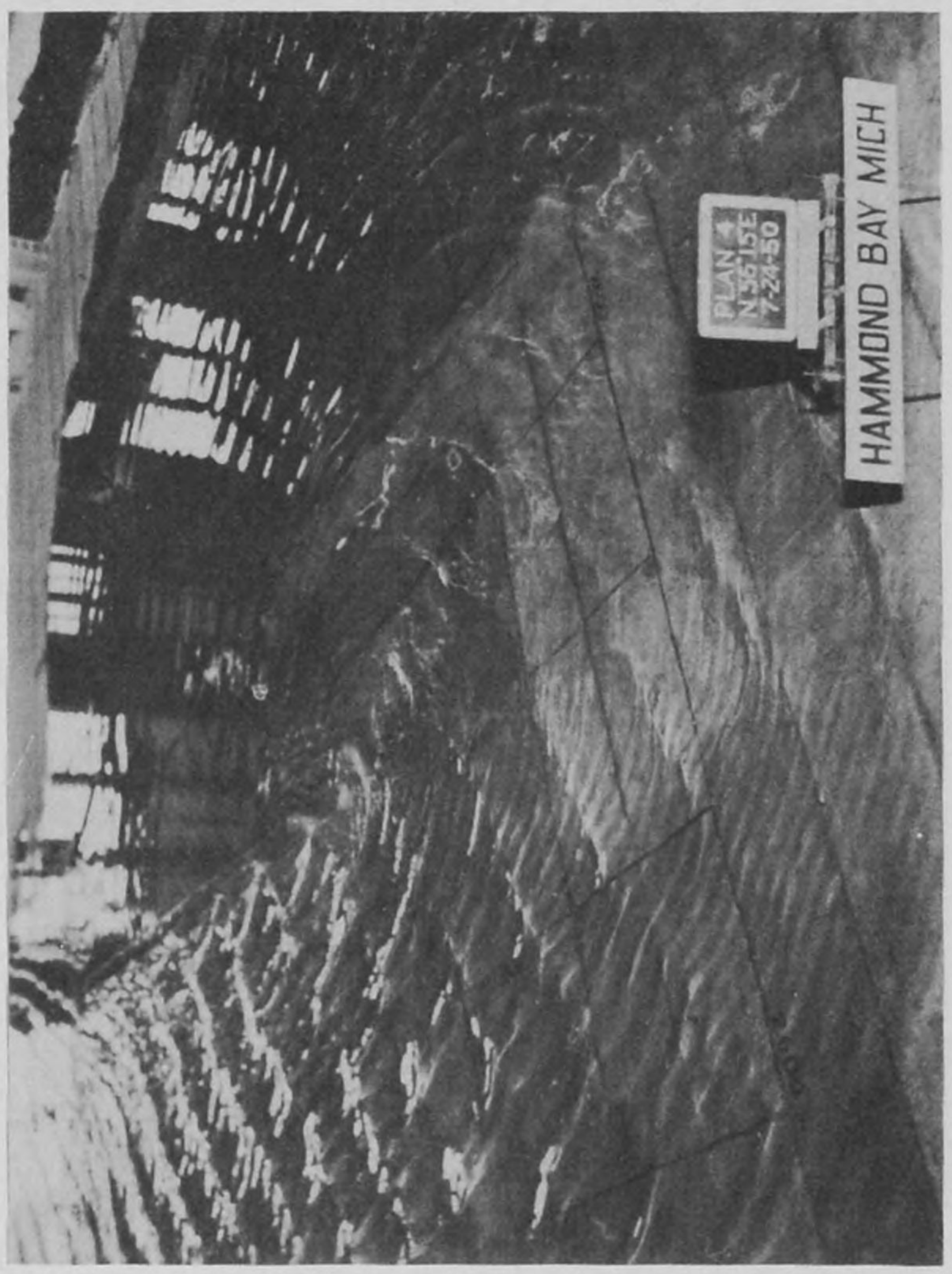
PLAN 3b-WIND N. 11° 15' E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 14



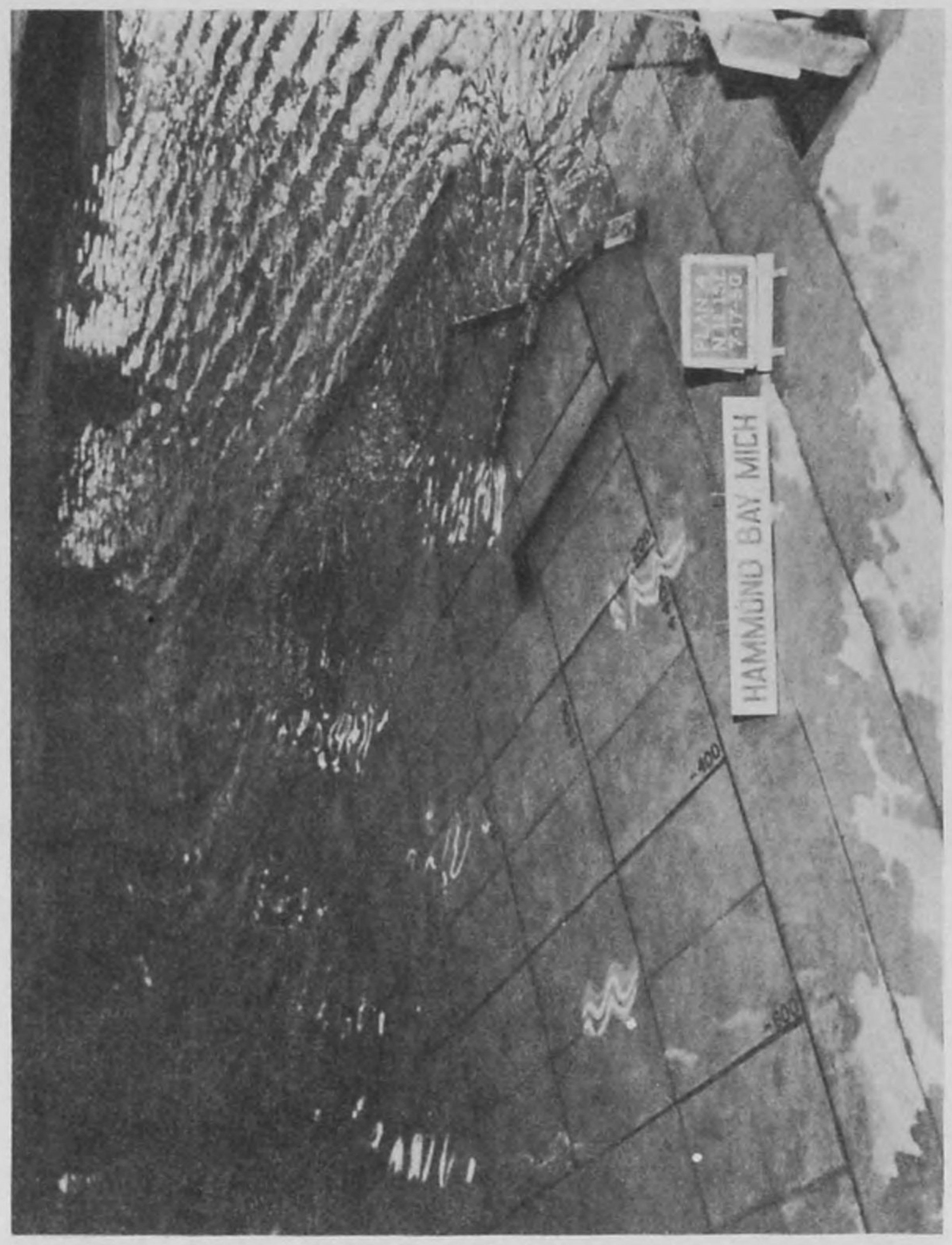


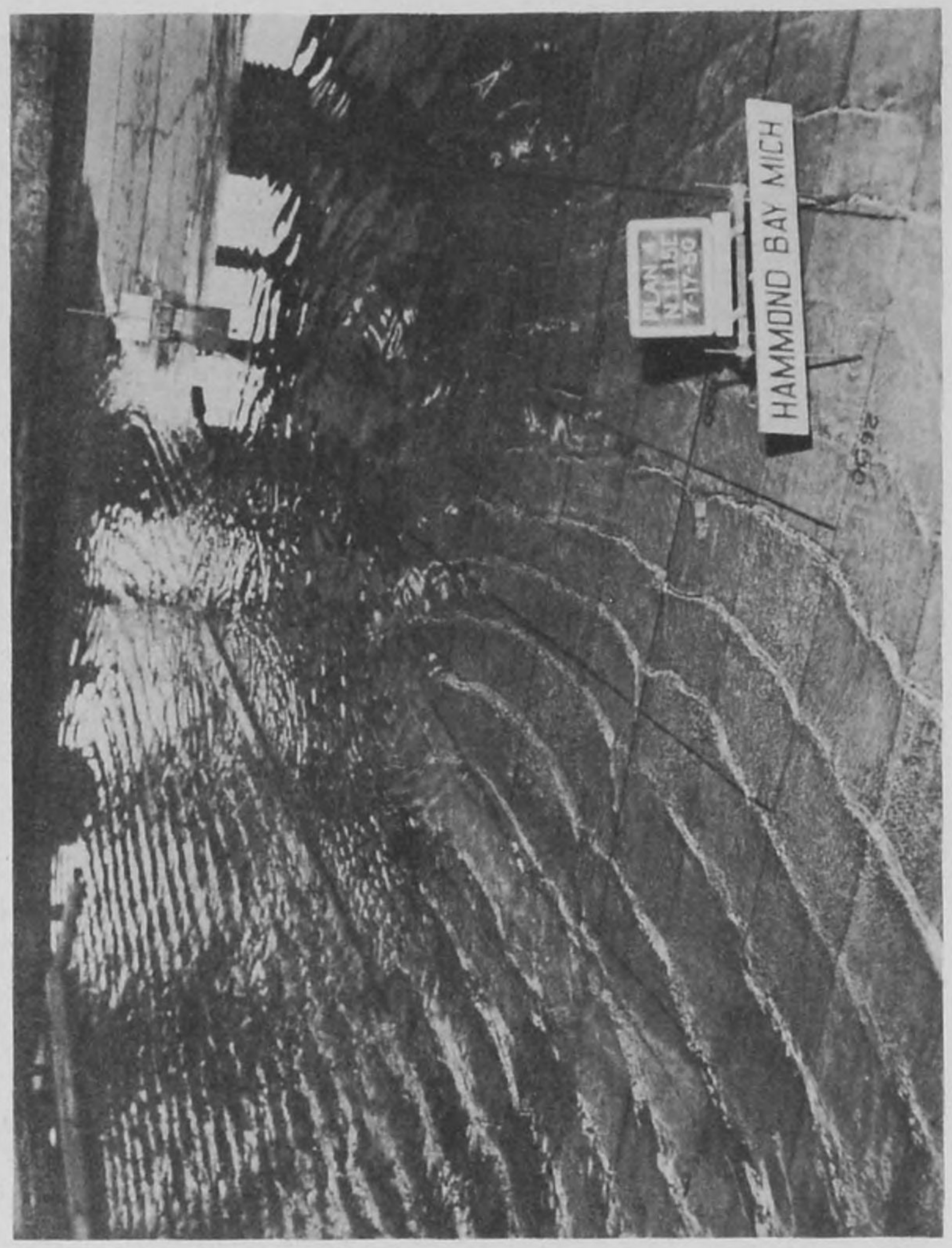


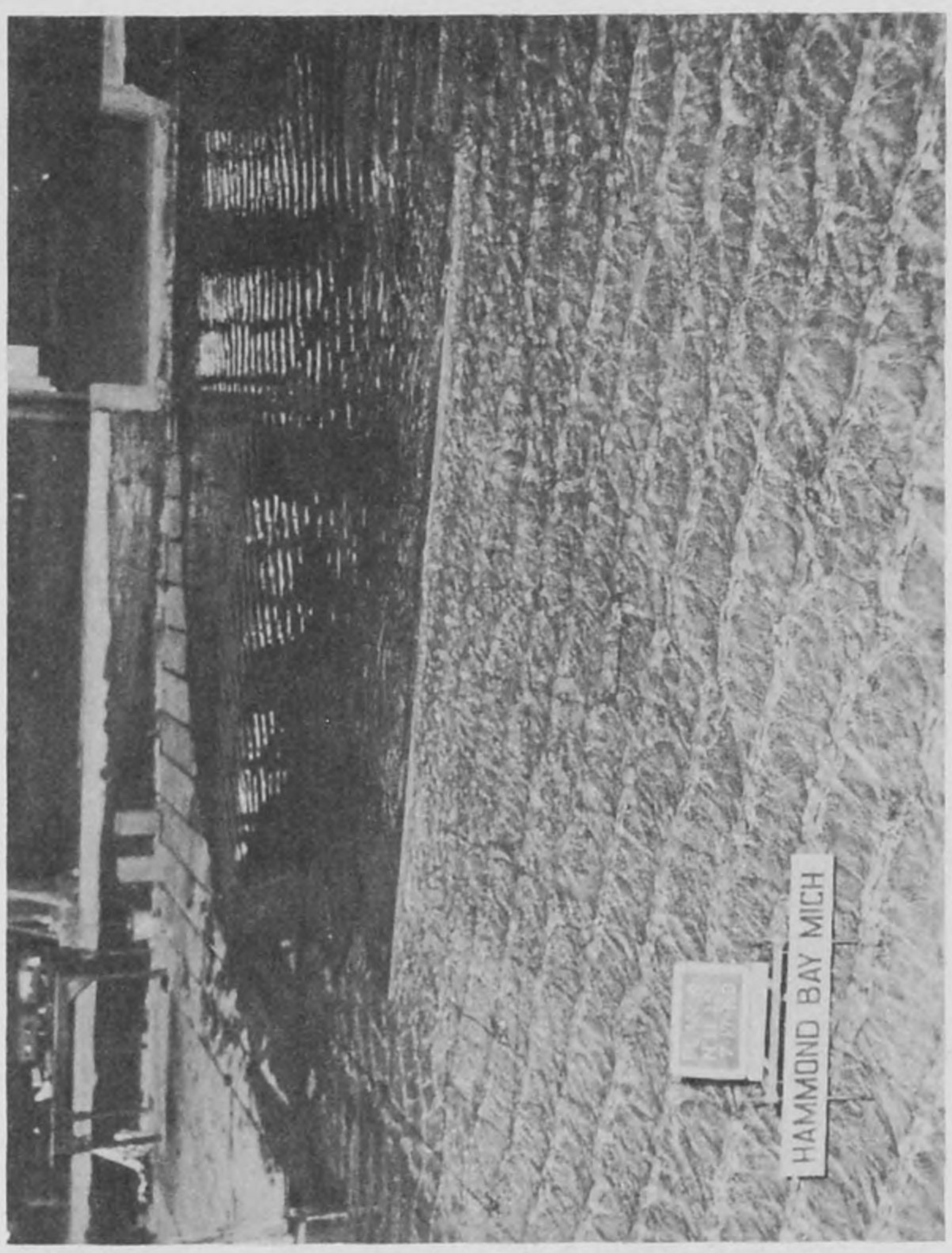


PLAN 4-WIND N. 56° 15′ E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 15

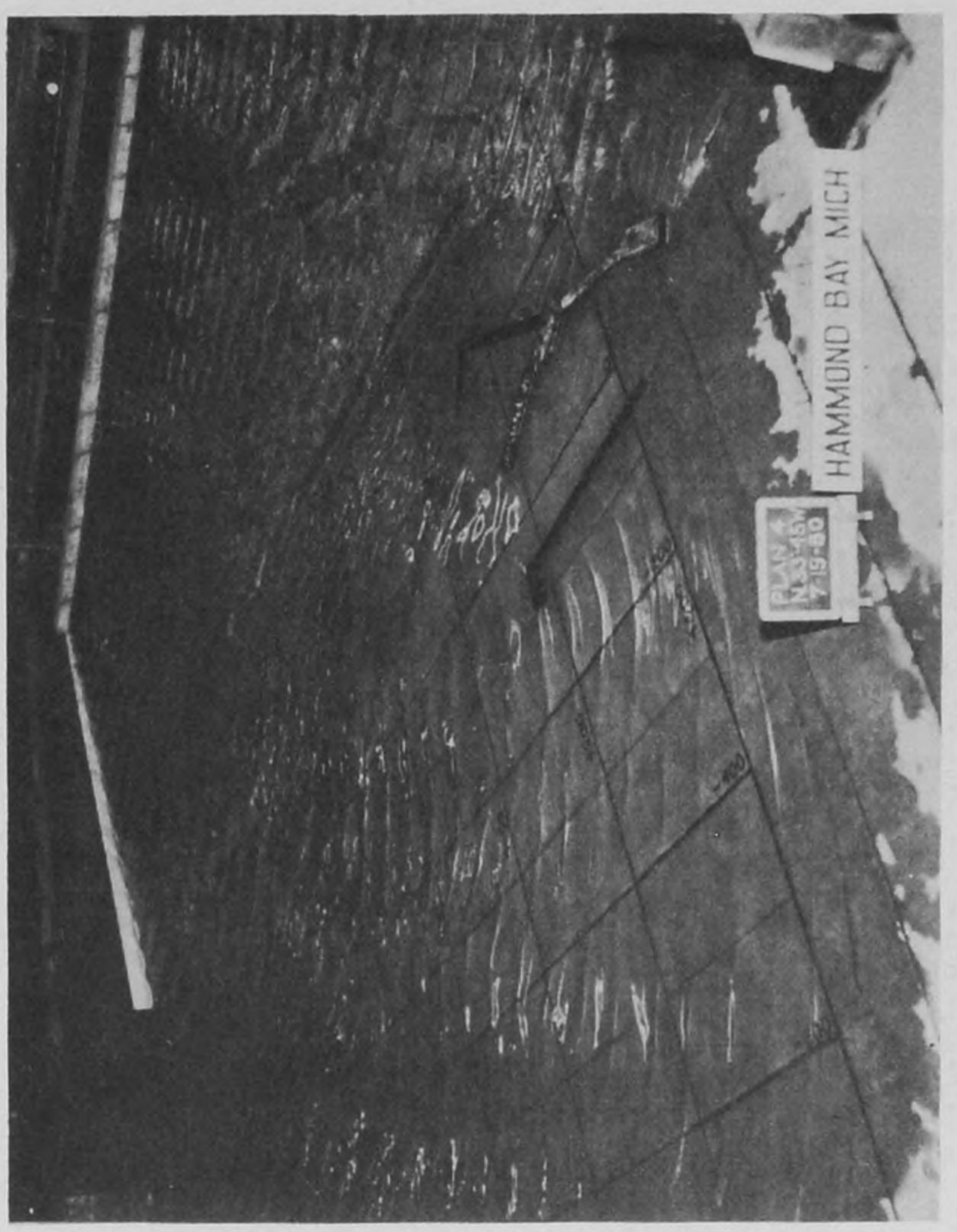


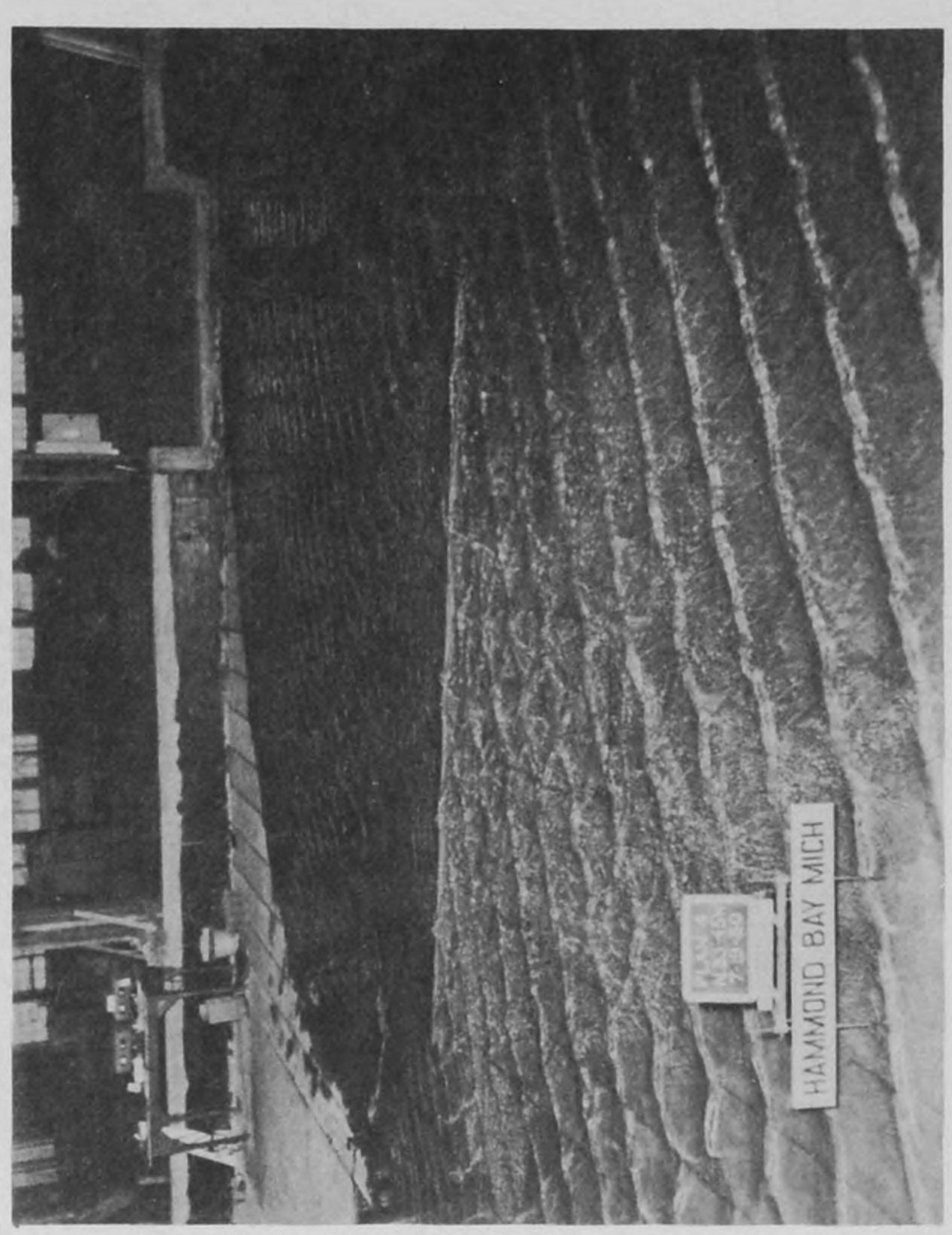


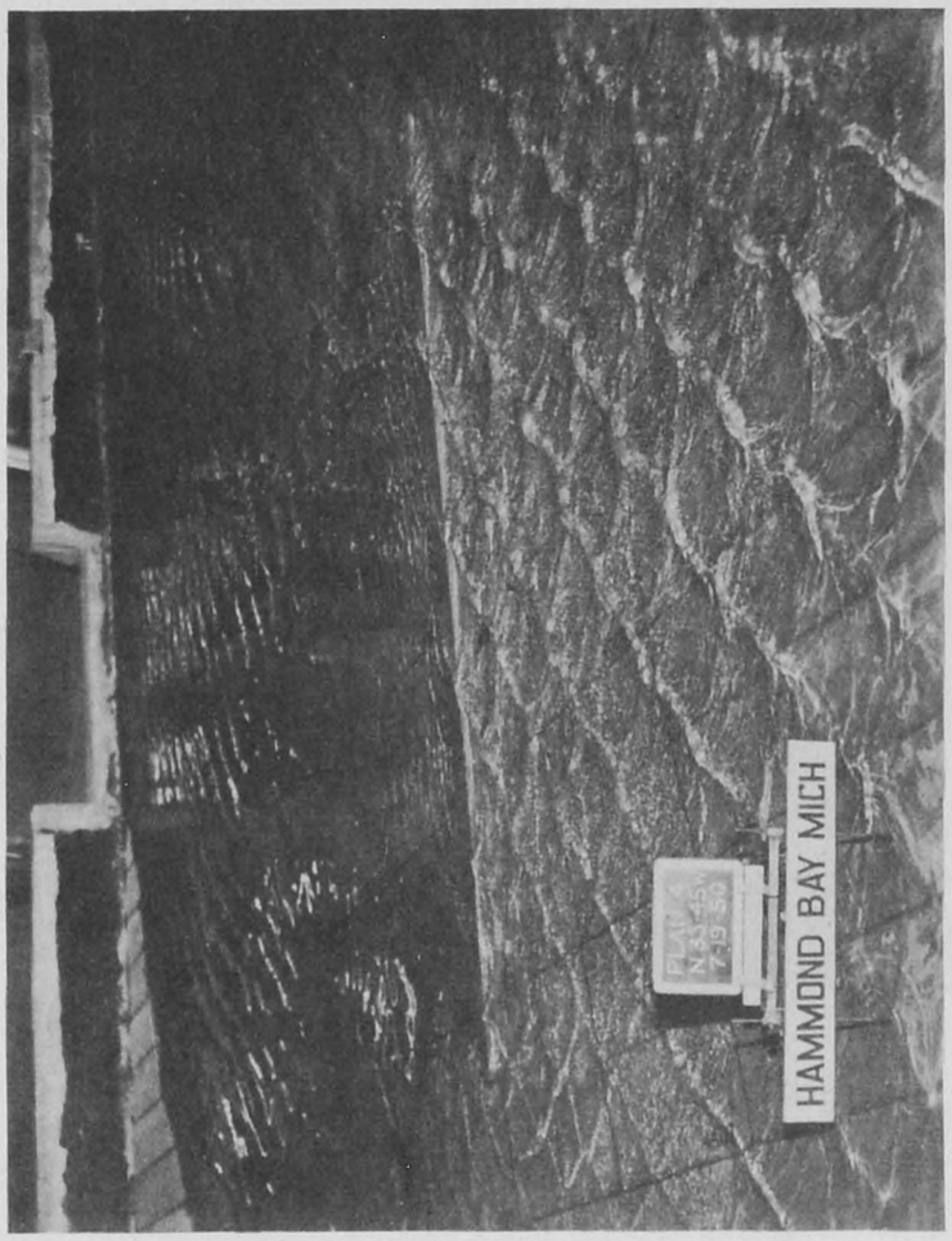


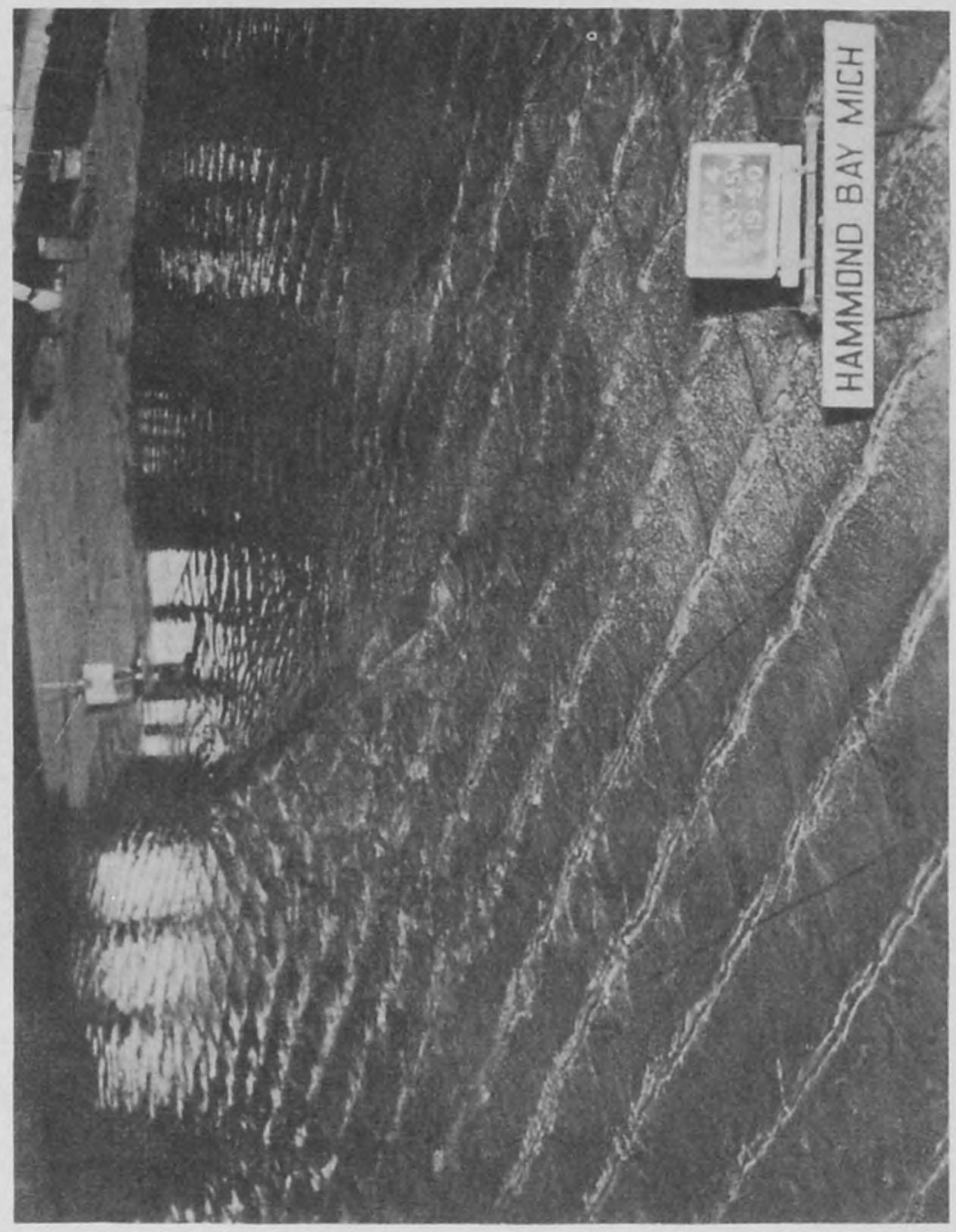
PLAN 4-WIND N. 11° 15' E.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 16



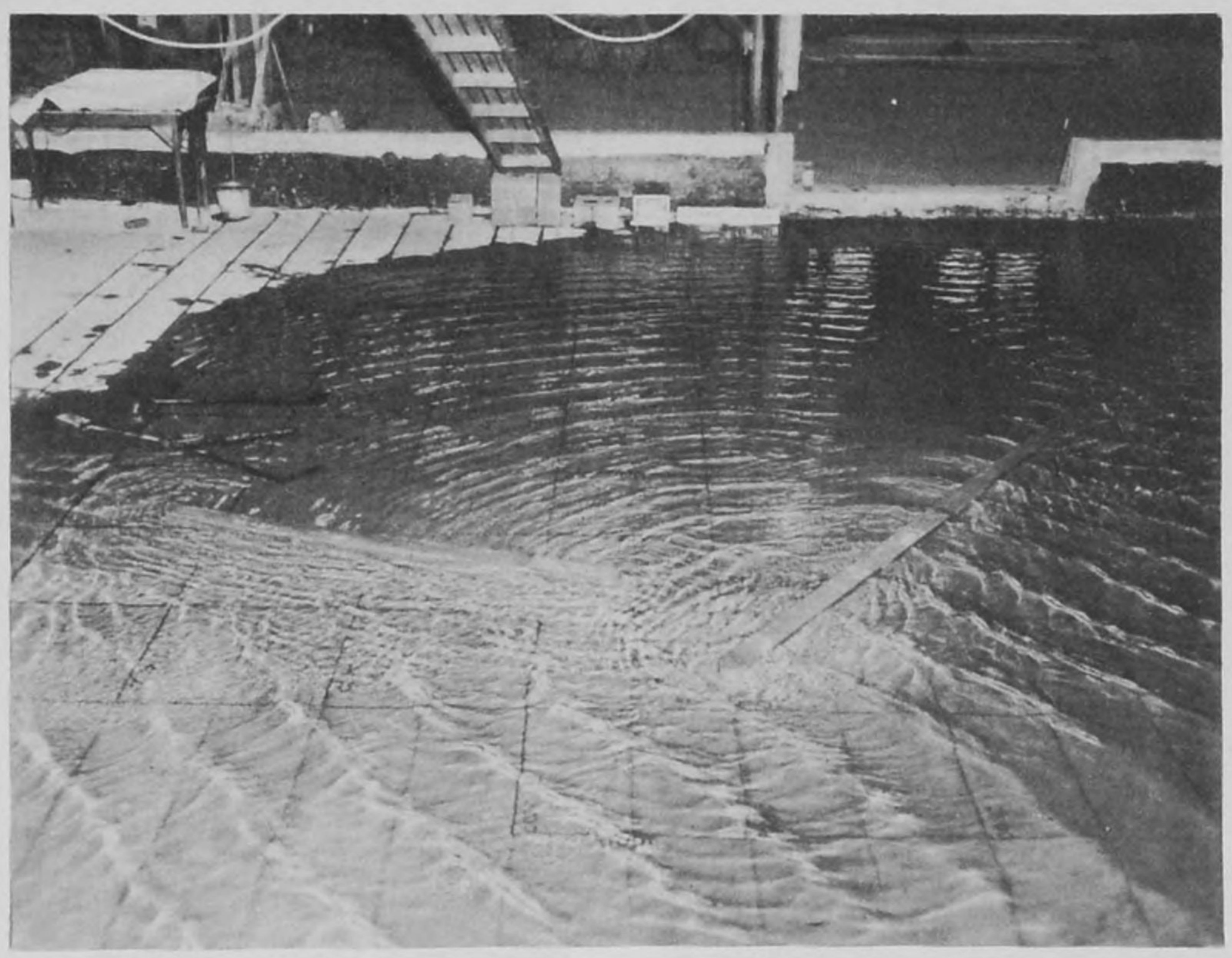




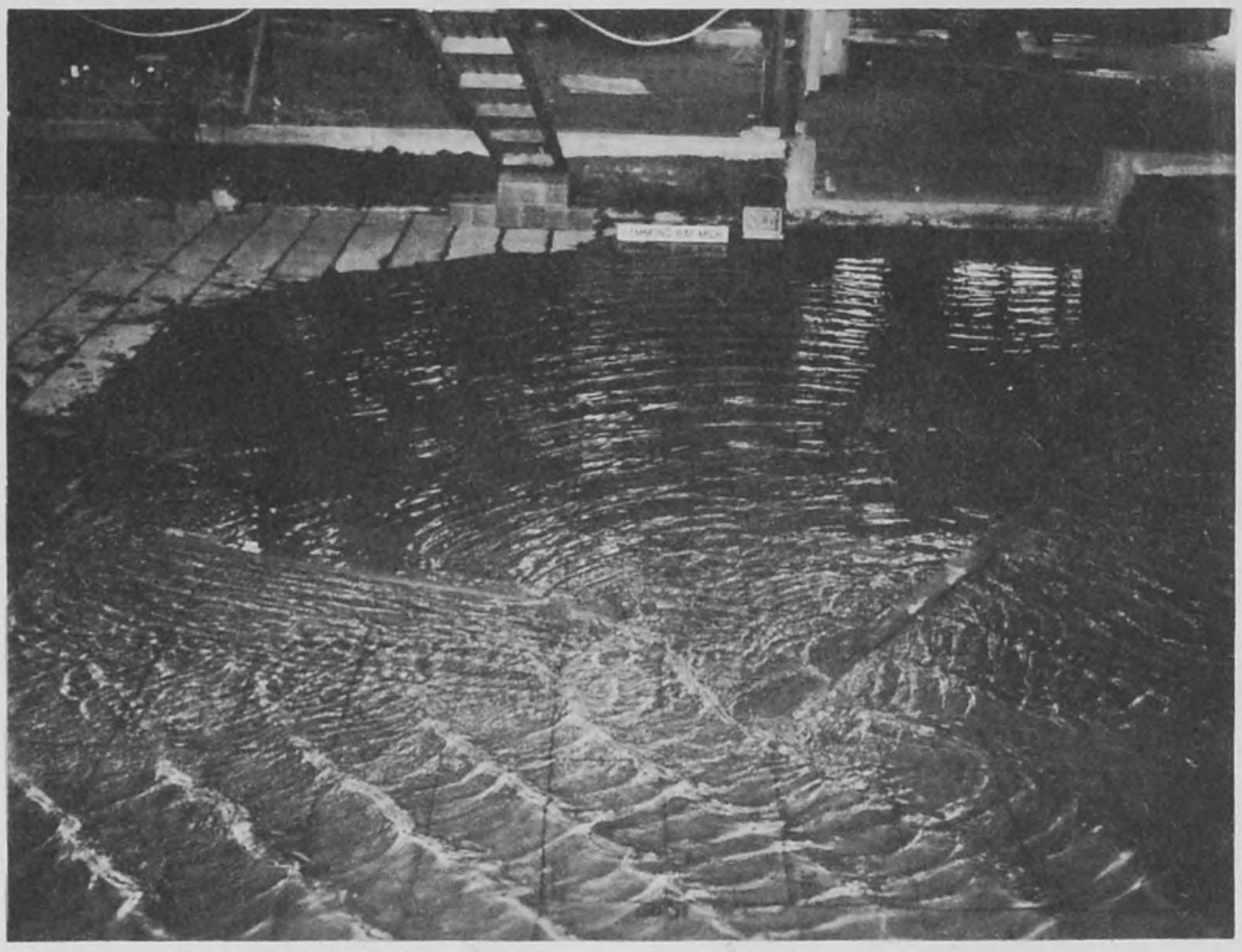


PLAN 4-WIND N. 33° 45' W.

HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 17



PLAN 2-WIND N. 56° 15′ E

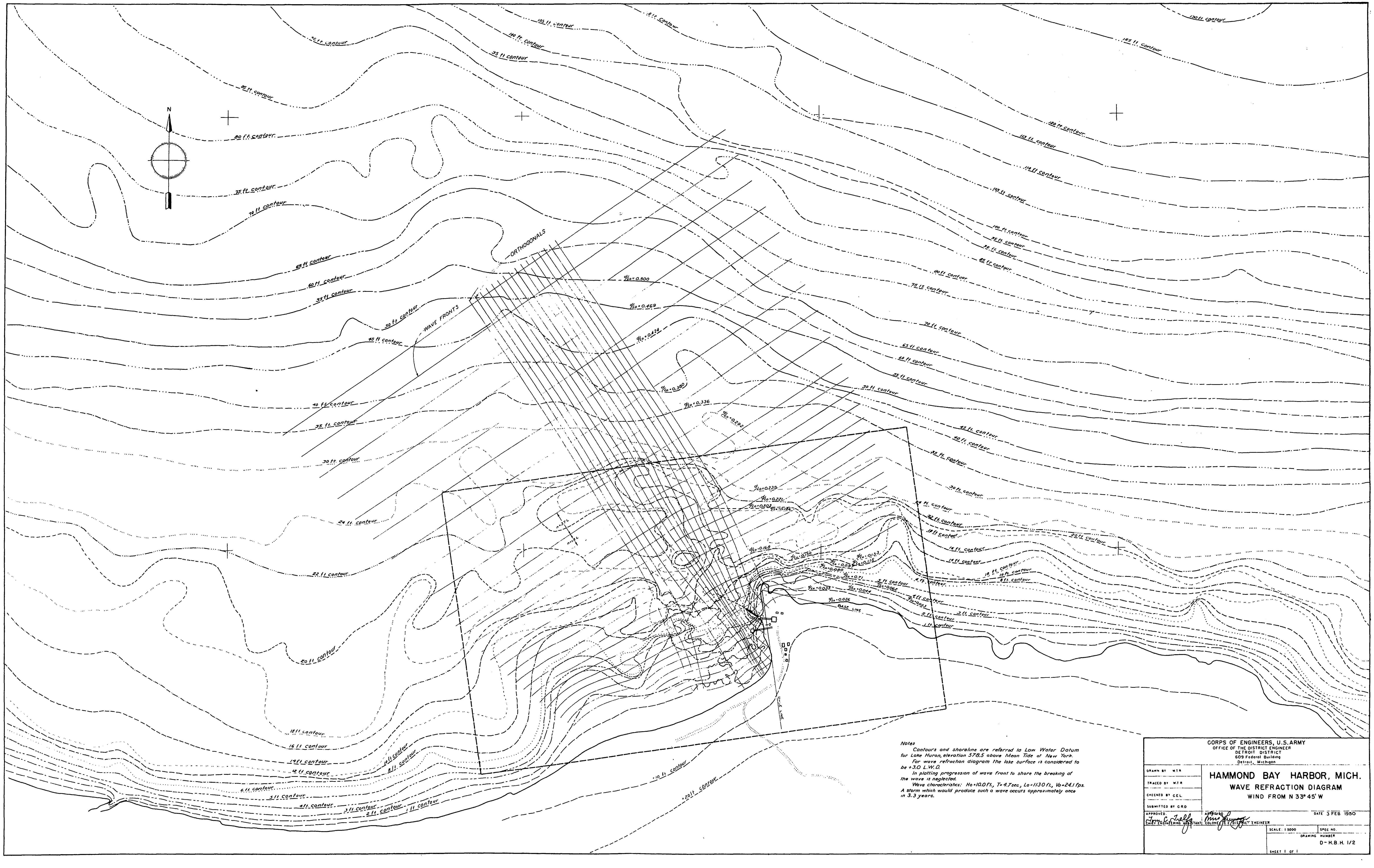


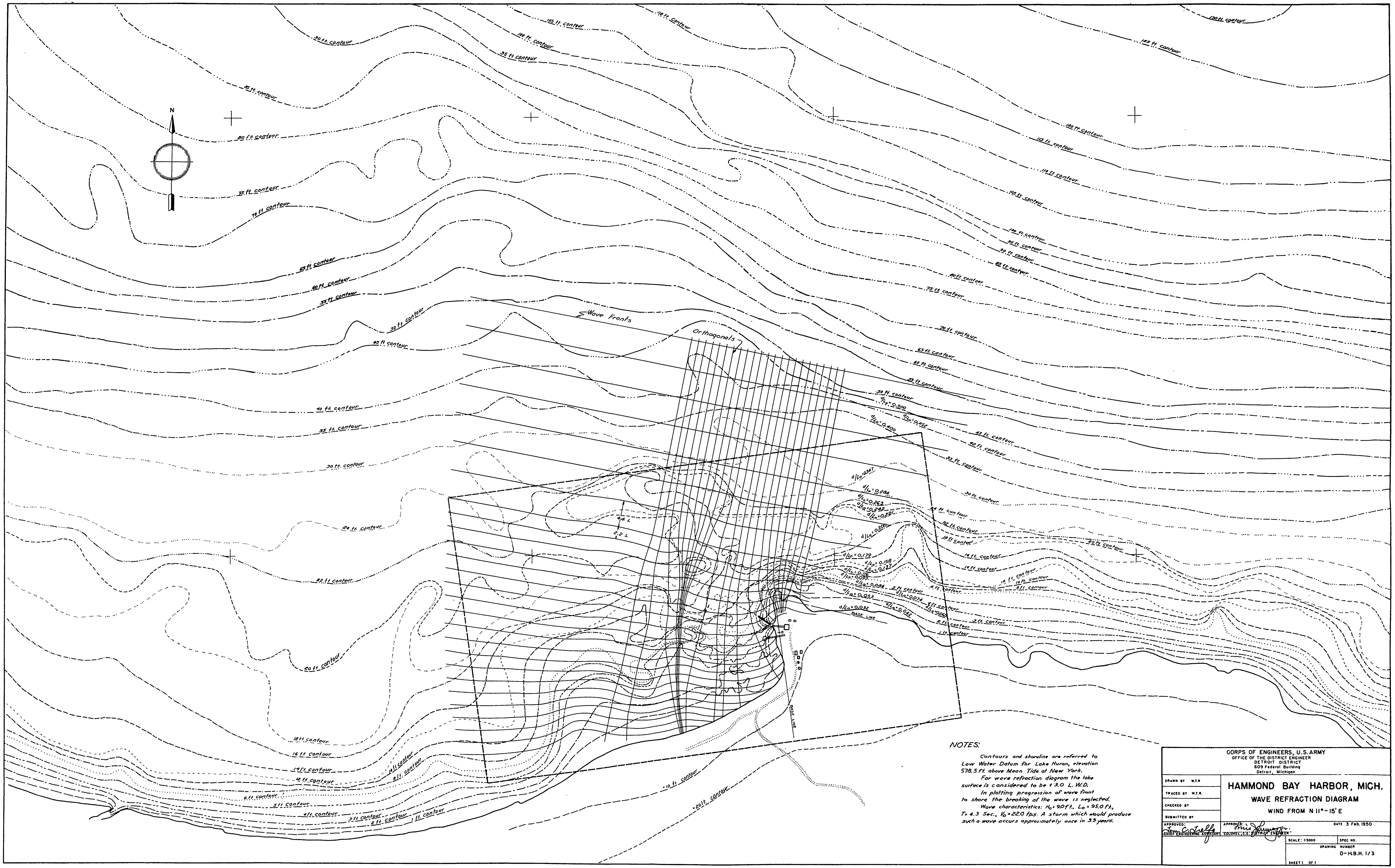
PLAN 2a-WIND N. 56° 15′ E

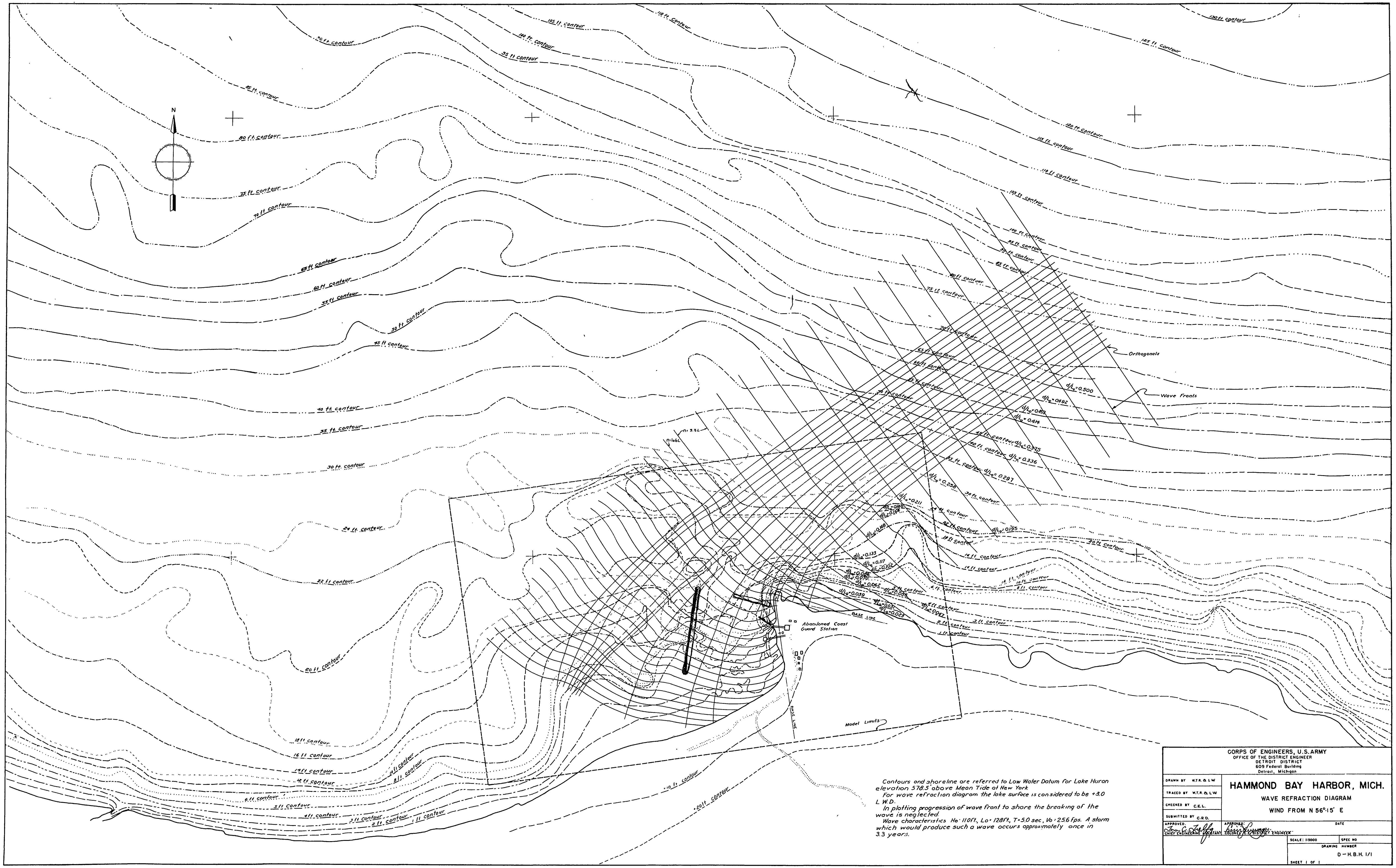
HAMMOND BAY, MICHIGAN
HARBOR MODEL
PLATE 18

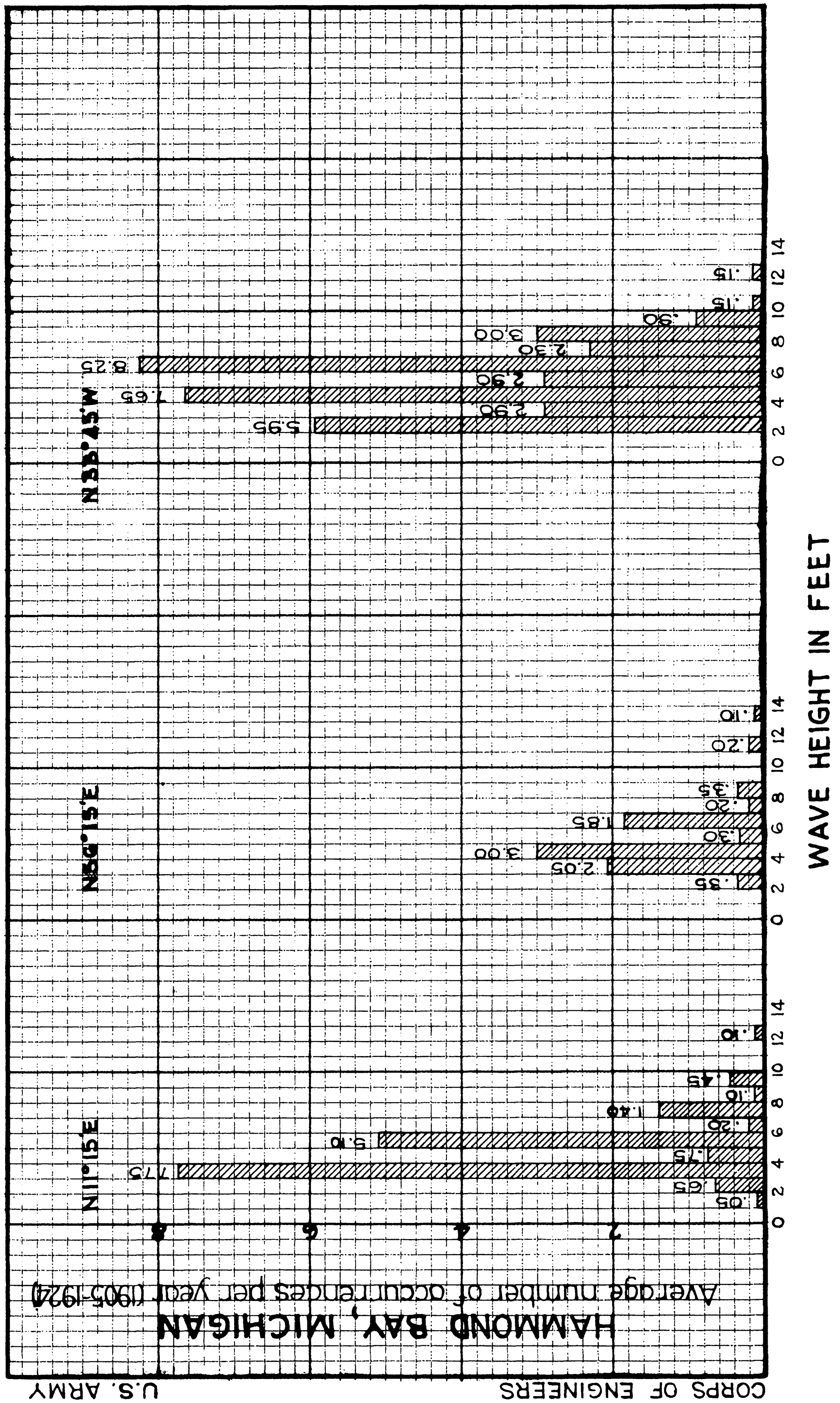
APPENDIX C

DRAWINGS SUPPLIED
BY
THE DETROIT DISTRICT,
CORPS OF ENGINEERS, U. S. ARMY


ORTHOGONALS
WAVE FRONTS
Notes
Contours and shoreline are referred to Low Water Datum for Lake Huron, elevation 578.5 above Mean Tide of New York.
For wave refraction diagram the lake surface is considered to be +3.0 L.W.D.
In plotting progression of wave front to shore the breaking of the wave is neglected.
Wave characteristics: Ho=10.0 ft., T=4.7 sec., Lo=1130 ft., Vo=24.1 fps. A storm which would produce such a wave occurs approximately once in 3.3 years.
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
DETROIT DISTRICT
609 Federal Building
Detroit, Michigan
DRAWN BY W.T.R
TRACED BY W.T.R
CHECKED BY C.E.L.
SUBMITTED BY C.R.D
HAMMOND BAY HARBOR, MICH.
WAVE REFRACTION DIAGRAM
WIND FROM N 33° 45' W
APPROVED.
CHIEF ENGINEERING ASSISTANT
APPROVED.
COLONEL C.E. DISTRICT ENGINEER
DATE 3 FEB 1950
SCALE: 1:5000
SPEC NO.
DRAWING NUMBER
D-H.B.H. 1/2
SHEET 1 OF 1


N
Wave Fronts
Orthogonals
BASE LINE
NOTES:
Contours and shoreline are referred to Low Water Datum for Lake Huron, elevation 578.5 ft. above Mean Tide at New York.
For wave refraction diagram the lake surface is considered to be +3.0 L.W.D.
In plotting progression of wave front to shore the breaking of the wave is neglected.
Wave characteristics: H_0 = 9.0 ft., L_0 = 95.0 ft., T = 4.3 Sec., V_0 = 22.0 fps. A storm which would produce such a wave occurs approximately once in 3.3 years.
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
DETROIT DISTRICT
609 Federal Building
Detroit, Michigan
DRAWN BY W.T.R
TRACED BY W.T.R.
CHECKED BY
SUBMITTED BY
HAMMOND BAY HARBOR, MICH.
WAVE REFRACTION DIAGRAM
WIND FROM N 11° - 15' E
APPROVED:
CHIEF ENGINEERING ASSISTANT
APPROVED:
COLONEL, C.E. DISTRICT ENGINEER
DATE 3 Feb. 1950
SCALE: 1:5000
SPEC NO.
DRAWING NUMBER
D-H.B.H. 1/3
SHEET 1 OF 1


N
Orthogonals
Wave Fronts
Abandoned Coast Guard Station
BASE LINE
Model Limits
Contours and shoreline are referred to Low Water Datum for Lake Huron elevation 578.5' above Mean Tide at New York
For wave refraction diagram the lake surface is considered to be +3.0 L.W.D.
In plotting progression of wave front to shore the breaking of the wave is neglected.
Wave characteristics Ho· 110ft., Lo· 128ft., T=5.0 sec, Vo=25.6 fps. A storm which would produce such a wave occurs approximately once in 3.3 years.
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
DETROIT DISTRICT
609 Federal Building
Detroit, Michigan
DRAWN BY W.T.R. & L.W.
TRACED BY W.T.R. & L.W.
CHECKED BY C.E.L.
SUBMITTED BY C.R.D.
HAMMOND BAY HARBOR, MICH.
WAVE REFRACTION DIAGRAM
WIND FROM N 56°-15' E
APPROVED.
CHIEF ENGINEERING ASSISTANT
APPROVED:
COLONEL, C.E. DISTRICT ENGINEER
DATE
SCALE: 1:5000
SPEC NO
DRAWING NUMBER
D-H.B.H. 1/1
SHEET 1 OF 1


HAMMOND BAY, MICHIGAN
Average number of occurrences per year (1905-1924)
WAVE HEIGHT IN FEET
N11°15'E
CORPS OF ENGINEERS
U.S. ARMY

OTHER PUBLICATIONS OF THE

LAKE HYDRAULICS LABORATORY

1. MODEL STUDY FOR HARBOR OF REFUGE FOR LIGHT DRAFT VESSELS AT PORT SANILAC, MICHIGAN, Tech. Rept. no. 1, 1949.

2. MODEL STUDY FOR HARBOR OF REFUGE FOR LIGHT DRAFT VESSELS AT PORT AUSTIN, MICHIGAN, Tech. Rept. no. 2, 1949.

3. BIBLIOGRAPHY ON BEACH EROSION AND RELATED SUBJECTS, Research Publ. no. 1, 1950.

AIIM SCANNER TEST CHART # 2

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Century Schoolbook Bold

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Greek and Math Symbols

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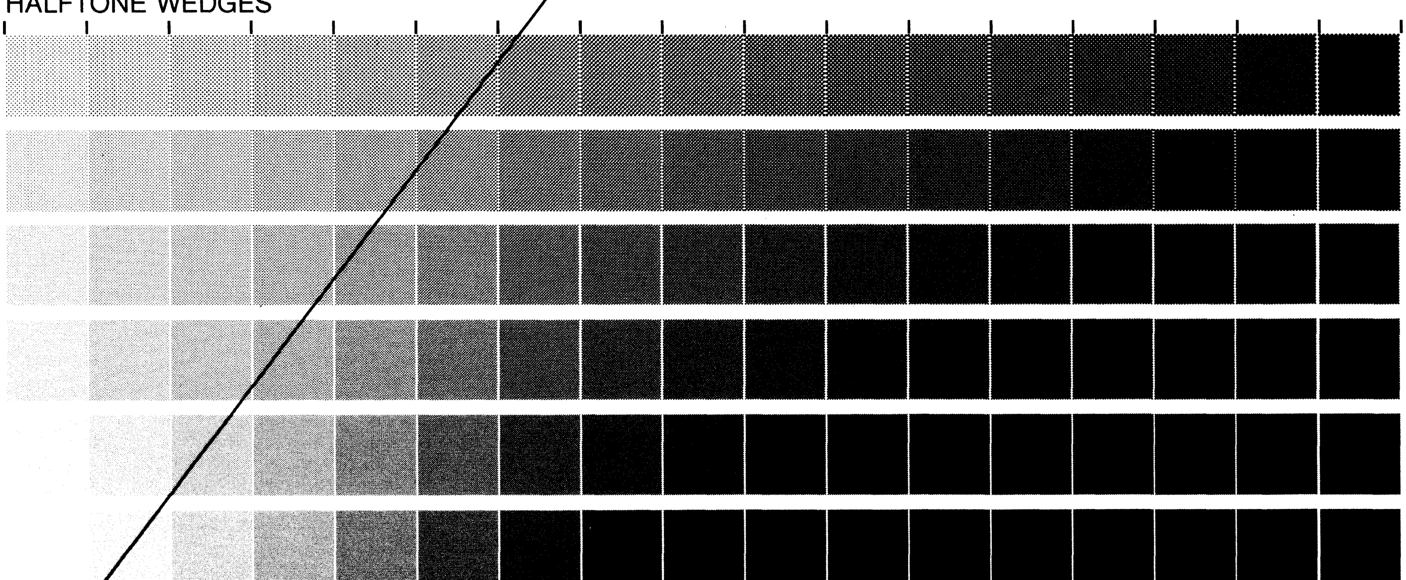

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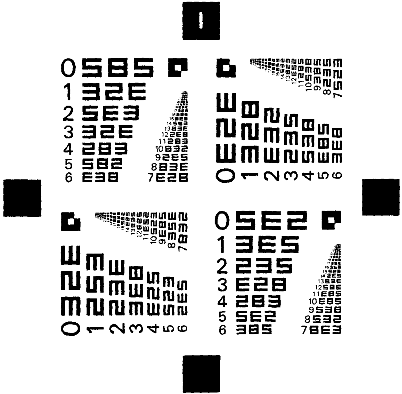

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