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ANN ARBOR

MODEL STUDY FOR HARBOR OF REFUGE FOR LIGHT DRAFT VESSELS AT PORT SANILAC, MICHIGAN

Technical Report No. 1
Lake Hydraulics Laboratory
Department of Civil Engineering

JULY 1, 1949

BY: E.F. BRATER

APPROVED BY: C.O. WISLER

Project M 804 - Contract W-20-064-eng-1774
Detroit District, Corps of Engineers,
United States Army

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FOR

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E. F. BRATER
Associate Professor of Civil Engineering

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INTRODUCTION

Port Sanilac, Michigan is located approximately 30 miles from the southern end of Lake Huron as shown by the map in Drawing 1. It is proposed to construct breakwaters and to dredge areas within the breakwaters in order to create a harbor of refuge for light draft vessels at this location. The primary purpose of the model study was to determine the breakwater arrangement which would afford the maximum protection from wave action in the harbor area. As an additional basis for comparison, currents were measured within the harbor and near the harbor entrance for each of the plans. The effect of the size of the harbor opening was investigated by constructing one of the plans with a larger opening than those of the others. The effect of the shape of the breakwaters was studied by reconstructing one of the plans with vertical-walled breakwaters. Rubble mound breakwaters were simulated in all other plans.

The study was made as a result of a contract dated November 8, 1948, between the University of Michigan Engineering Research Institute and the Detroit District, Corps of Engineers, U. S. Army. The initiation of the work was expedited by the interest and financial support of the Michigan State

Waterways Commission.

Throughout the model study frequent consultations were held with the following personnel of the Detroit District: Colonel Louis J. Rumaggi, District Engineer, Tom C. Trelfa, Harley F. Lawhead and Charles E. Lee. Colonel E. W. Nelson and W. H. Booth, Jr. of the Great Lakes Division Office, Corps of Engineers, visited the laboratory in connection with the work. Mr. R. Y. Hudson of the Waterways Experiment Station, Vicksburg, Mississippi, visited the laboratory at various stages of the work, as did Colonel H. D. Vogel, District Engineer of the Buffalo District.

Members of the Michigan State Waterways Commission visited the laboratory at various times. E. W. Kiefer, Chairman, and Leonard H. Thomson, Secretary, were in close touch with the work throughout the tests.

The University of Michigan Lake Hydraulics Laboratory where the tests were made 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. Professor Earnest Boyce is Chairman of the Department of Civil Engineering and Ivan C. Crawford is Dean of the College of Engineering. The laboratory is under the general direction of C. O. Wisler, Professor of Hydraulic Engineering, and the model tests were conducted under the supervision of E. F. Brater, Associate Professor of Civil Engineering. The following men took an active part in conducting the tests: John H. Boeckerman, Jerome Pepper, Leslie D. Stair and Dah C. Woo.

THE MODEL

The model was built to an undistorted linear scale of 1 to 75. Templates were cut from 3/8-inch waterproof plywood according to sounding data supplied by the Corps of Engineers. The templates were spaced at 1.5-foot intervals in and near the harbor area and at 3-foot intervals in the more remote regions. A plan of the model and wave tank is shown in Drawing 2. The space between the templates was packed with sand to within an inch of their upper edges. The model was then surfaced with cement mortar which was screeded to conform with the edges of the templates. The accuracy of the model was checked by means of an engineer's level and again by checking contours of the lake bottom against locations of the shore line for various water surface elevations. Plate 1 shows the templates in place before the concrete was poured.

METHOD OF CONDUCTING TESTS

The waves were generated by means of a plunger-type wave machine 30 feet long. The wave machine is shown in Plate 1. The amplitude and period of the plunger may be varied to produce waves of any required height, length and period. The wave machine is portable, so that any desired wind direction can be simulated.

Wave heights were measured with electric resistance gages arranged so that variations in water level were recorded by means of oscillographs. The calibrations of the resistance gages were checked systematically during the tests. The wave height at any point was determined by computing the average of the highest one-third of 180 successive waves. The instruments described above are shown in Plate 2.

Surface currents were measured by timing the movements of small floats with reference to coordinate lines on the model.

The elevation of the water surface in the tank was checked by means of a hook gage mounted on one of the tank walls. It was necessary to add small amounts of water occasionally to compensate for evaporation and leakage.

THE TESTING PROGRAM

Five breakwater arrangements designated as Plans 1, 2, 3, 4 and 5 were tested. Each of these was constructed to simulate the shape of a rubble mound breakwater as shown in Drawing 1. In each of these the outer 200 feet of the north breakwater had the shape designated in Drawing 1 as Type A, whereas the remainder was of Type B. Plan 6 consisted of vertical-walled breakwaters placed in the same position as those of Plan 3. Typical sections through these breakwaters are also shown in Drawing 1.

For all plans, except Plan 4, the width of the dredged entrance channel was 150 feet and the distance from toe to toe of rubble mound breakwaters was 185 feet. Plan 4 was constructed with a dredged entrance channel 200 feet wide and a distance from toe to toe of rubble mound breakwaters of 235 feet. The clear distance between the vertical faces of breakwaters of Plan 6 was 210 feet at the harbor entrance.

The harbor arrangement designated as Plan 1 may be seen in Drawings 3-9 and 11-13 and Plate 2. Plan 1a, shown in Drawing 10, consisted of the same breakwater arrangement as Plan 1 with the elevation of the north breakwater raised to prevent overtopping by waves from the NNE.

Plan 2 differed from Plan 1 only in having the outer 100 feet of the south breakwater rotated toward the lake as shown in Drawings 14-22 and Plates 3 and 4.

For Plan 3, the south breakwater was in the same position as for Plan 1. The entire north breakwater was rotated in a clockwise direction to the position shown in Drawings 23-31 and Plates 4, 5 and 6.

Plan 4 was similar to Plan 3 except that the south breakwater was moved southward a distance sufficient to increase the size of the opening by 50 feet. Plan 4 is illustrated in Drawings 32-40 and Plates 7 and 8.

Plan 5 consisted of curved breakwaters placed in the same general location as for Plan 3. Plan 5 is shown in Drawings 41-49 and Plates 9 and 10.

The breakwater arrangement for Plan 6 was exactly the same as for Plan 3, the only difference being in the nature of the cross section of the breakwaters as previously described. The drawings for Plan 6 are numbered 50-56 and 58-60, and photographs are shown in Plates 10, 11 and 12.

Plan 6a consisted of the breakwaters of Plan 6 with spurs added to the inner face of the north breakwater as shown in Drawing 57.

TEST CONDITIONS

The basic wave data were prepared by H. F. Lawhead and C. E. Lee of the Detroit District Office. Deep water wave heights were computed from the records of wind velocity and duration for the following four wind directions: N, NNE, E and SSE. Refraction diagrams were then prepared for each wind direction. It was found from these diagrams that the wave action at Port Sanilac resulting from a north wind was similar to but less severe than that produced by a wind from the NNE. Consequently no tests were run for the north direction. The refraction diagrams for the three wind directions used in the tests are reproduced in Appendix C at the end of this report.

For Plan 6 one additional wind direction was tested. This direction was approximately SE. It was determined in the wave tank by trial so that the resulting wave would be projected directly into the harbor entrance; i.e., the waves moved in a direction parallel to the north breakwater as they approached the harbor. This same wind direction was used in the test on Plan 6a.

For each wind direction a "large" wave and a "small" wave was projected against the harbor. The large wave was one that would be produced by a severe storm. The small wave would be produced by less severe storms of more frequent occurrence. A summary of the characteristics of the waves used in the tests is given in Table I. The frequencies shown in the table were determined from curves given in Appendix C.

TABLE I

SUMMARY OF WAVE DATA

Wave Characteristic	Small Wave			Large Wave		
	SSE	E	NNE	SSE	E	NNE
Deep Water Wave Height (Ft.)	4.5	4.5	4.5	8.7	7.0	13.0
Deep Water Wave Length (Ft.)	81.9	81.9	81.9	90.3	81.9	190.5
Wave Period (Sec.)	4.0	4.0	4.0	4.2	4.0	6.1
Frequency *	75	45	272	1	5	4

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

It is believed that the larger waves would 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 would occur more frequently and might be thought to represent the 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. Finally, the smaller waves permit a comparison of the various harbor arrangements under conditions of virtually no overtopping of the breakwaters by storm waves, whereas in the case of the larger waves the conditions inside the harbor are affected by overtopping to some extent for the SSE and E winds and to a greater degree for the NNE wind.

Low-water datum for Lake Huron is at elevation 578.5. The crests of the breakwaters were set 8 feet above low-water datum. Throughout the tests the lake elevation was kept 3 feet above low-water. Thus, the crests of the breakwaters were 5 feet above the still water level of the lake. Such a high water condition is primarily the result of a prolonged westerly wind which tends to cause some Lake Michigan water to enter Lake Huron through the Straits of Mackinac. A change in wind direction will then produce the conditions simulated in the tests. 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.

PRESENTATION OF RESULTS

All of the data obtained from the tests are presented in Drawings 3-60. The successive plans are presented in numerical order. For each plan the drawings showing measured values of harbor wave heights are presented first. These are followed by drawings giving the results of current measurements. Photographs showing harbor conditions during large wave tests are presented in Plates 1-12.

Wave Heights

Wave heights were measured at from 25 to 30 locations for each test. The measured values are recorded on the drawings at the gage locations. With these values as a basis, lines of equal wave height were drawn. The regions where the wave heights were less than 1.5 feet and where they were greater than 5.0 feet were hatched. The direction in which the predominant wave was moving is indicated at each gage location by means of an arrow. The wave height drawings for Plans 1, 3, 4 and 6 were also reproduced on single sheets for each wind direction. These are shown on Pages 81 through 91 following Drawing 61.

Some numerical averages were found to be useful in analyzing the test data. In Table II are shown three groups of averages for each wind direction and for both the large and small waves. The first group consists of the measurements made near the harbor entrance. The second group comprises those inside the harbor. The dividing line between the two groups is shown as a dotted line in Drawing 61. A third group designated in Table II as the "mooring area" consisted of eleven measuring stations located in the quietest portion of the harbor. This region is outlined by the dashed line in Drawing 61.

Currents

The magnitude and direction of velocities in and around the harbor are shown on the drawings by means of arrows. The lengths of the arrows were made proportional to the velocities according to a scale shown on the drawings. Paths followed by the floats are shown by means of dotted lines. In some locations the velocities varied with time, so that occasionally different paths may be seen to emanate from the same point. A summary of the maximum

TABLE II

AVERAGE WAVE HEIGHTS

	Plan	Entrance			Harbor			Mooring Area		
		SSE	E	NNE	SSE	E	NNE	SSE	E	NNE
Small Wave	1	4.6	2.0	0.9	0.9	0.5	0.1	0.6	0.6	0.1
	2	4.5	1.2	1.4	1.8	0.4	0.4	1.4	0.5	0.5
	3	4.0	2.1	1.6	1.2	0.2	0.3	0.6	0.3	0.2
	4	3.9	2.6	0.9	1.4	0.6	0.2	0.6	0.7	0.2
	5	4.8	2.2	1.3	1.2	0.6	0.2	0.6	0.8	0.2
	6	4.9	4.3	0.9	1.2	1.1	0.1	0.6	0.7	0.1
Large Wave	1	5.6	5.2	5.1	1.4	1.6	1.7	1.0	1.3	1.8
	2	7.0	3.8	4.2	2.1	1.4	1.6	1.6	1.1	1.4
	3	5.5	4.6	3.6	1.4	0.6	1.2	0.9	0.6	1.1
	4	6.1	4.2	2.8	1.6	0.8	1.6	0.8	0.8	1.5
	5	6.0	4.1	3.9	1.5	0.9	1.6	0.8	0.7	1.6
	6	6.7	5.2	2.2	2.0	1.6	0.6	1.2	1.0	0.6

velocities found in various locations is given in Table III.

TABLE III

MAXIMUM CURRENTS FOUND IN VARIOUS HARBOR LOCATIONS

Values are in mi. per hr.

Plan	Entrance			Harbor			Mooring Area			Between Shore and Inner End of Breakwater		
	SSE	E	NNE	SSE	E	NNE	SSE	E	NNE	SSE	E	NNE
1	3.1	2.8	2.5	3.3	1.8	2.4	0.9	0.9	2.4	3.3	---	2.0
2	1.2	2.0	3.2	1.0	3.5	2.2	1.1	3.5	2.2	1.0	1.0	2.5
3	0.8	2.3	3.0	0.6	1.0	2.6	0.4	0.7	2.6	0.8	---	---
4	1.7	2.6	2.4	3.1	1.8	1.5	0.8	1.8	1.5	1.7	---	0.5
5	2.4	1.1	3.2	3.1	1.6	1.6	1.3	1.4	1.6	1.9	1.2	1.1
6	2.1	1.5	3.6	2.5	0.9	1.6	1.1	0.9	1.5	2.0	1.6	2.0

CONCLUSIONS

The model tests provided data which permit the evaluation of the effectiveness of the various plans in regard to wave heights inside the harbor, wave heights in the vicinity of the entrance and currents. The final selection of a plan will require the consideration of other factors, such as the costs of the various plans, the availability of construction materials, desirable entrance size and suitability for mooring and docking purposes.

On the basis of an inspection and comparison of the wave height drawings, Table IV was prepared, showing the best plans for various conditions. Where two or more plans have been tabulated, it was for the reason that several seemed to be so nearly equal that it would have been misleading to select only one. It will be noted that Plan 3 appears 10 times in Table IV, whereas the

the others appear only 4 or 5 times.

TABLE IV

PLANS GIVING THE MOST FAVORABLE RESULTS FOR VARIOUS CONDITIONS

Wind Direction	Small Wave Entrance	Small Wave Harbor	Large Wave Entrance	Large Wave Harbor
SSE	3,4	1,3,4,5,6	3	3
E	1,2,3	2,3,5	3,4	3
NNE	1,2,3,4,5,6	1,2,3,4,5,6	5,6	6

In Table V is given a set of values obtained by numbering the average wave heights of Table II from 1 to 6 in order of ascending size. Thus, the best plan for any region and wind direction is given the value 1, the next best 2, and so on. The sum of the values for each wave size is given for all of the plans. Plan 3 is again indicated as being better than the others. A more detailed method of summarizing the values in Table V is shown in Table VI. Here the values for a particular plan are added for each wind direction and wave size. This tabulation indicates that Plan 3 is as good or better than the others for waves from the SSE and E, but for the NNE direction Plan 6 is very good for both the large and small waves. For the large wave this is due in part to the fact that harbor waves resulting from the NNE wind were affected to a considerable degree by the overtopping of the north breakwater. The rectangular shape of the breakwaters of Plan 6 broke up the overtopping waves much more than the sloping shape of the other breakwaters. In this connection it should be noted that harbor waves resulting from overtopping cannot be determined as confidently from model tests as those entering through openings in the breakwaters. It can be assumed that harbor waves will be worse in the model than for comparable conditions in the prototype because the surface of the model breakwater is relatively smoother than the prototype surfaces. It is also probable that the wind action may tend to break up some of the overtopping waves in the prototype.

TABLE V

NUMERICAL EVALUATION OF THE VARIOUS PLANS

	Plan	Entrance			Harbor			Mooring Area			Summation
		SSE	E	NNE	SSE	E	NNE	SSE	E	NNE	
Small Wave	1	4	2	2	1	3	1.5	3	3	1.5	21
	2	3	1	5	6	2	6	6	2	6	37
	3	2	4	6	3	1	5	3	1	4	29
	4	1	3	2	5	4.5	3.5	3	4.5	4	30.5
	5	5	5	4	3	4.5	3.5	3	6	4	38
	6	6	6	2	3	6	1.5	3	4.5	1.5	33.5
Large Wave	1	2	5.5	6	1.5	5.5	6	4	6	6	42.5
	2	6	1	5	6	4	4	6	5	3	40
	3	1	4	3	1.5	1	2	3	1	2	18.5
	4	4	3	2	4	2	4	1.5	3	4	27.5
	5	3	2	4	3	3	4	1.5	2	5	27.5
	6	5	5.5	1	5	5.5	1	5	4	1	33

The results shown in Tables V and VI fail to take into account the magnitude of the differences between various plans. This is also true to some extent of the evaluations shown in Table IV. Consequently, these summaries can only be considered as a guide and constant reference must be made to the original wave height drawings and the wave height averages of Table II in evaluating the various plans.

TABLE VI

SUMMARY OF THE NUMERICAL EVALUATION OF THE VARIOUS PLANS

Plan	Small Wave			Large Wave		
	SSE	E	NNE	SSE	E	NNE
1	8	8	5	7.5	17	18
2	15	5	17	18	10	12
3	8	6	15	5.5	6	7
4	9	12	9.5	9.5	8	10
5	11	15.5	11.5	7.5	7	13
6	12	16.5	5	15	15	3

The following evaluations of the various plans are based entirely on wave heights. However, the results of the current measurements shown in the drawings and summarized in Table III are generally in accord with the conclusions reached.

Plan 1

This breakwater arrangement gave good results for the small waves. However, the large wave tests indicated that Plan 3 has definite advantages over Plan 1. Therefore, barring other considerations, Plan 3 should be chosen in preference to Plan 1.

Plan 1a

Overtopping of the north breakwater was prevented in the model by placing bricks on the breakwater. Tests were run only for the large NNE wave.

The results of the tests, given in Drawing 10, may be compared with those obtained under the same conditions with the normal breakwater elevation, as shown in Drawing 7, to obtain an indication of the effect of overtopping on the harbor conditions. With overtopping prevented, the waves in the harbor were less than one-third of the height of those during overtopping. However, the results are not entirely comparable with those that would occur if the sloping faces of the breakwater were carried high enough to prevent overtopping. This is because the sloping face would absorb some of the energy which was reflected by the vertical face of the bricks.

Plan 2

This plan gave the least satisfactory results of any of the plans tested. It can be eliminated from further discussion.

Plan 3

This plan gave very good results. Its relative advantages and disadvantages will be discussed in more detail as a basis for comparison with Plans 4 and 6.

Plan 4

In general, the average wave heights inside the harbor were found to be from 0.2 feet to 0.4 feet higher for Plan 4 than for Plan 3. The choice between Plans 3 and 4 depends upon whether the advantages of the larger entrance of Plan 4 outweigh the more comfortable mooring conditions provided by Plan 3.

Plan 5

The tests showed that the curved breakwaters of this plan provided no advantages over several of the other plans.

Plan 6

Plan 6 is better than Plan 3 during NNE wind storms, but Plan 3 provides much better protection during storms from the SSE and E. The frequencies given in Table I indicate that for every 4 occurrences of the large wave from the NNE, the combined number of occurrences from the SSE and E will be 6. However, in the case of the small waves, there will be more than twice as many occurrences from the NNE as the combined number from the SSE and E. Consequently, from a statistical point of view the large wave tests would lead to the conclusion that Plan 3 is the better one, whereas the reverse would be indicated by the small wave tests. However, the statistical importance of the small wave from the NNE is nearly nullified by the fact that actual wave heights in the harbor and at the entrance are only a small amount greater for Plan 3 than for Plan 6. This may be seen by comparing Drawings 28 and 55. In contrast, the small waves from the east result in much greater differences between the two plans, as shown by Drawings 26 and 53. Moreover, the vertical-walled breakwaters of Plan 6 produce regions of large wave height near the entrance and in the northeastern portion of the harbor during both the large and the small waves from the SSE. Therefore, unless other considerations favor the use of the rectangular-shaped breakwater, the tests indicate that Plan 3 should be selected.

Plan 6: Intermediate Wind Direction

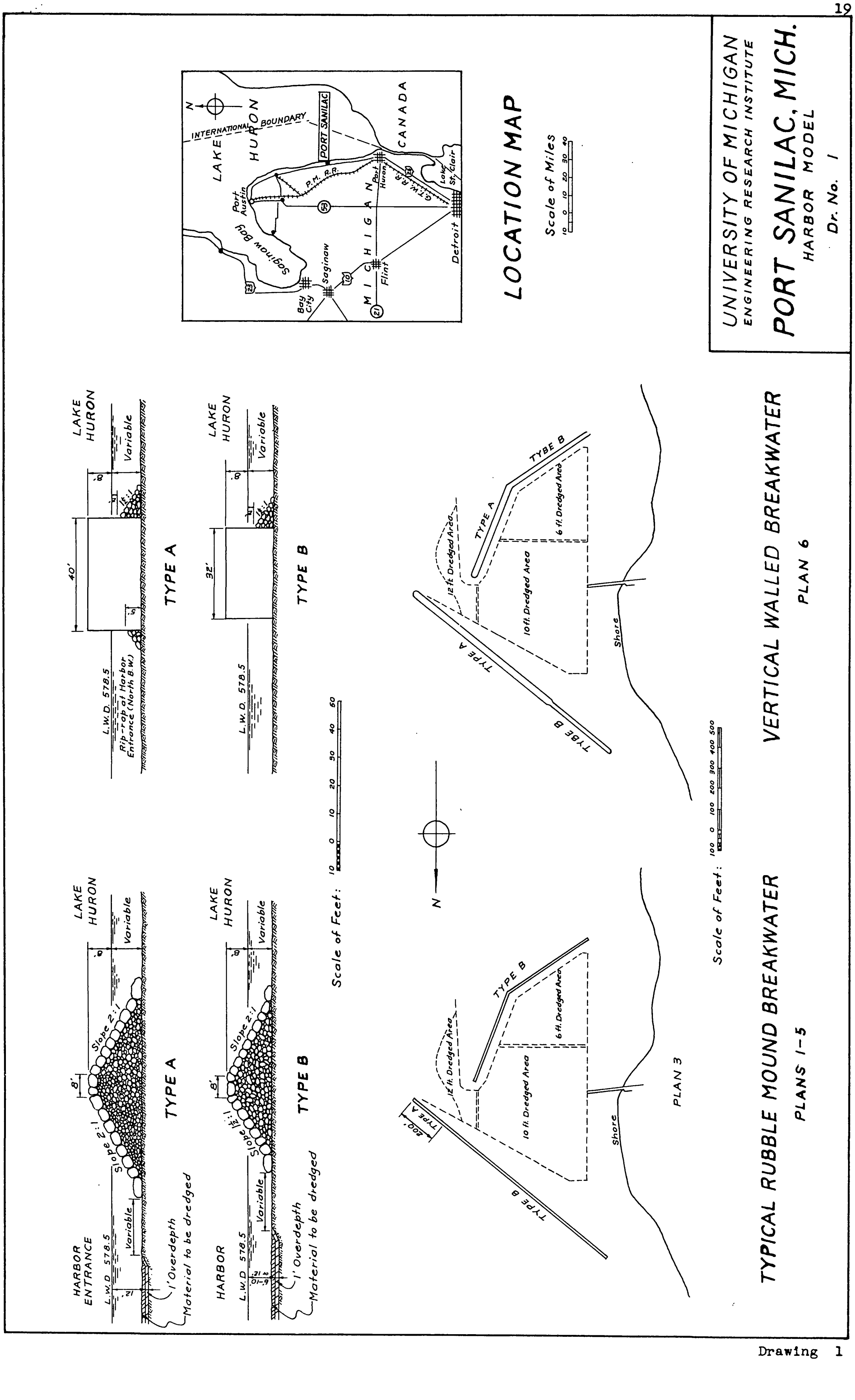
The conditions for this test would be produced by a wind from approximately the SE direction. The deep water wave height used in the test was 8.0 feet, as compared with values of 8.7 feet for the SSE and 7.0 feet for the E. The results of the test shown in Drawing 56 may be compared with those of the SSE (Drawing 50) and E(Drawing 52). It will be seen that the harbor and harbor entrance wave heights were somewhat higher than those from the E and lower than those from the SSE. The test provided assurance that an intermediate wind direction would not cause unusually bad harbor conditions.

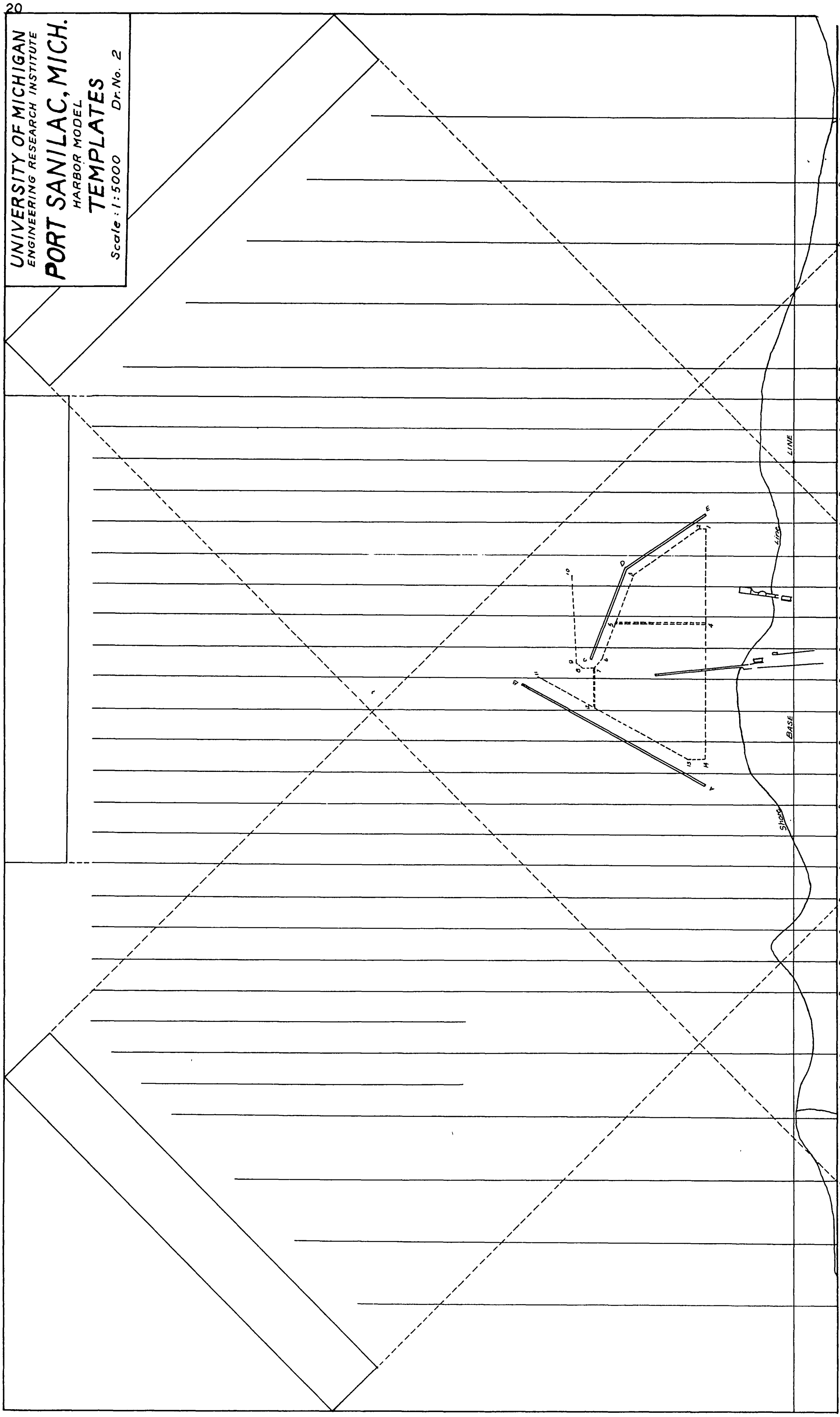
Plan 6a

A limited number of measurements were taken with spurs on the inner face of the north breakwater. The wind direction was SE and the deep water wave height was 8.0 as in the test described in the previous paragraph. The results are shown in Drawing 57. The spurs were found to have little effect at the entrance and in the northerly portion of the harbor. However, they caused reflections which more than doubled the wave height in the mooring area.

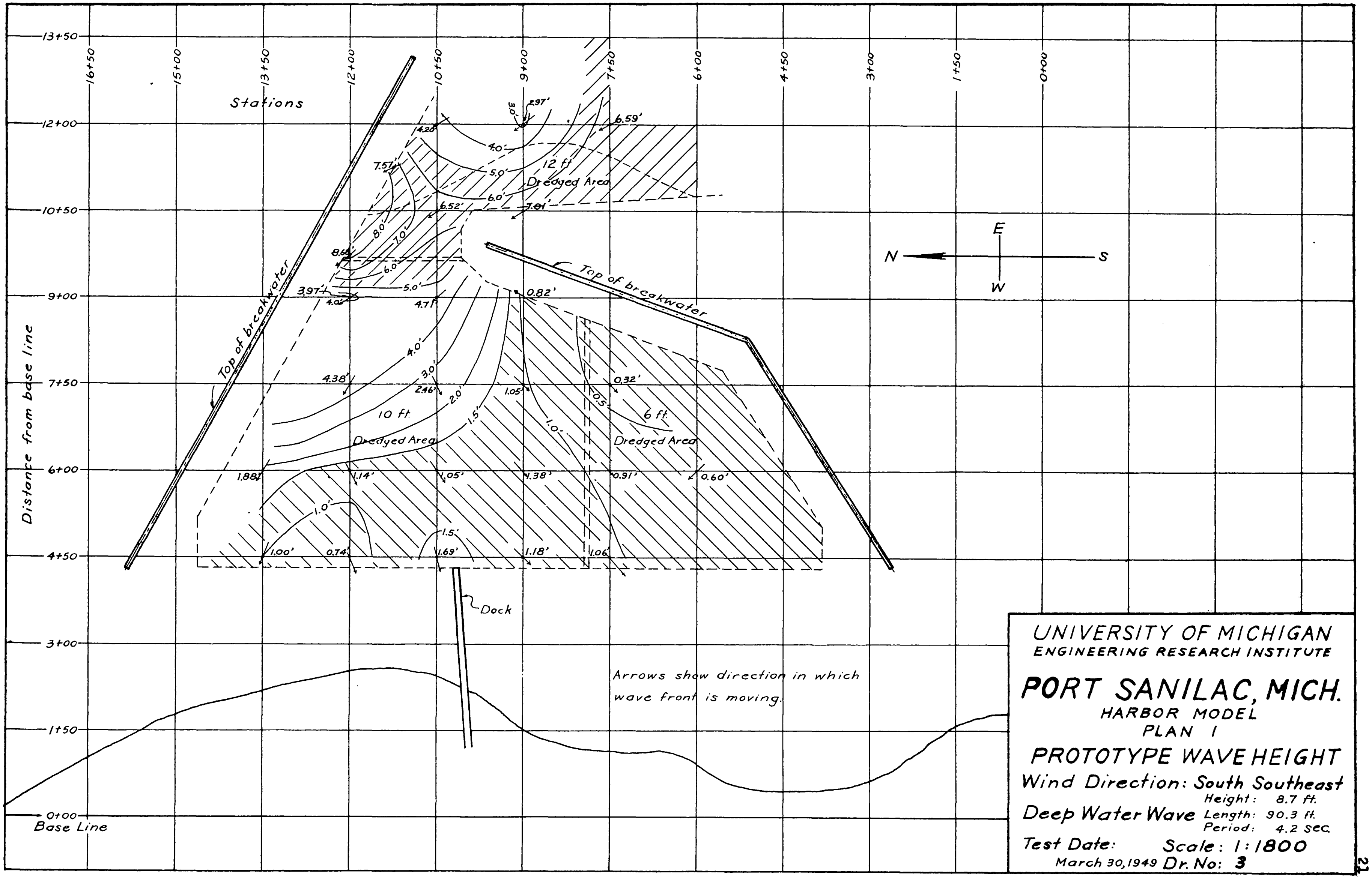
APPENDIX A

DRAWINGS


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
Dr. No. 1
LOCATION MAP
Scale of Miles
LAKE HURON
INTERNATIONAL BOUNDARY
PORT SANILAC
CANADA
MICHIGAN
Saginaw Bay
Port Austin
P.M. R.R.
G.T.W. R.R.
Port Huron
Lake St. Clair
Detroit
Flint
Saginaw
Bay City
TYPICAL RUBBLE MOUND BREAKWATER
PLANS 1-5
VERTICAL WALLED BREAKWATER
PLAN 6
HARBOR ENTRANCE
HARBOR
LAKE HURON
L.W.D. 578.5
Variable
Slope 2:1
Slope 1½:1
1' Overdepth
Material to be dredged
Rip-rap at Harbor Entrance (North B.W.)
TYPE A
TYPE B
40'
32'
8'
Scale of Feet:
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Shore
PLAN 3
N


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
TEMPLATES
Scale : 1:5000
Dr. No. 2
BASE LINE

Drawing 2


Stations
Distance from base line
Base Line
Top of breakwater
Top of breakwater
Dock
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Arrows show direction in which wave front is moving.
N
S
E
W
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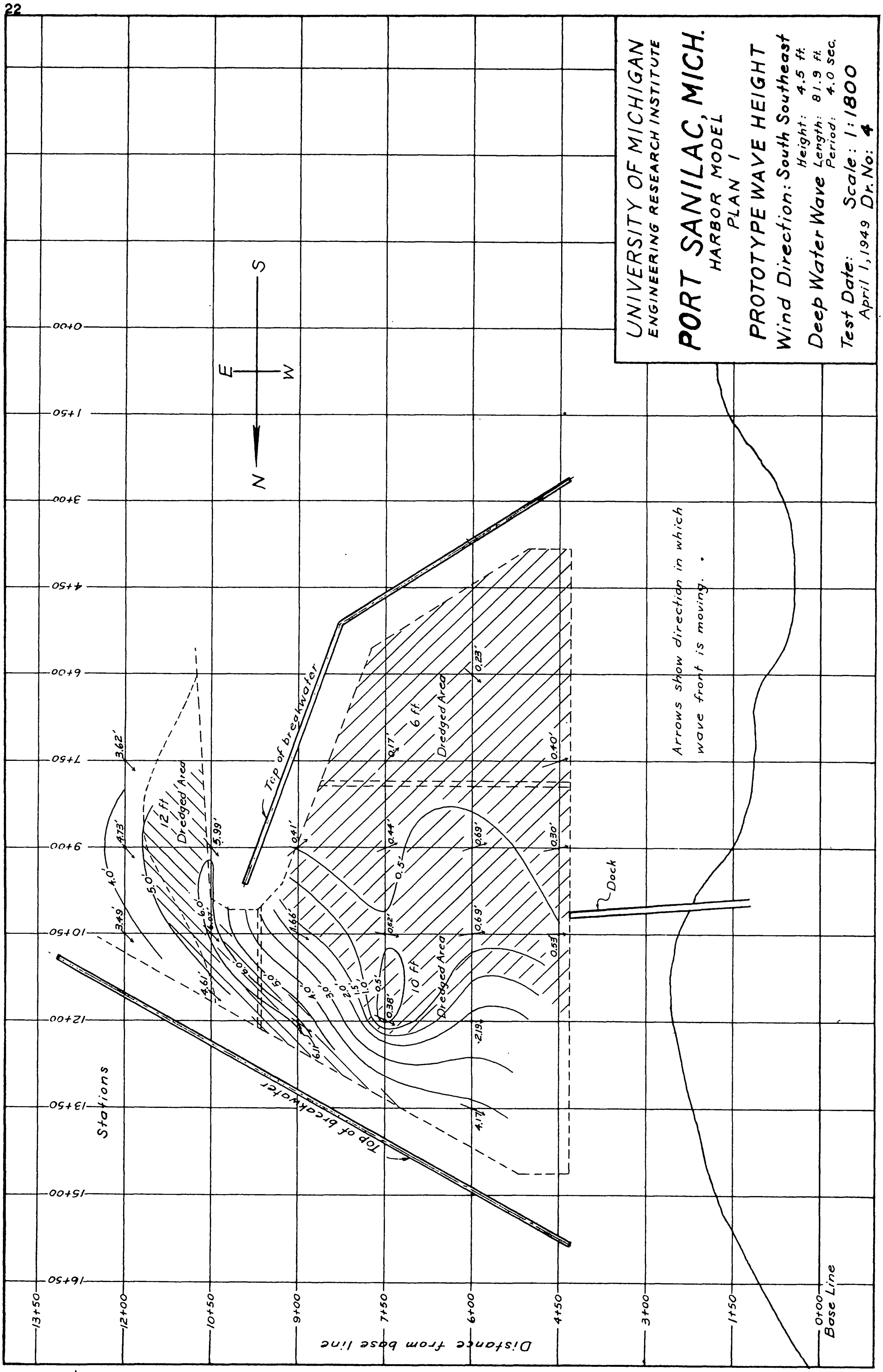
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: March 30, 1949
Scale: 1:1800
Dr. No: 3

Drawing 3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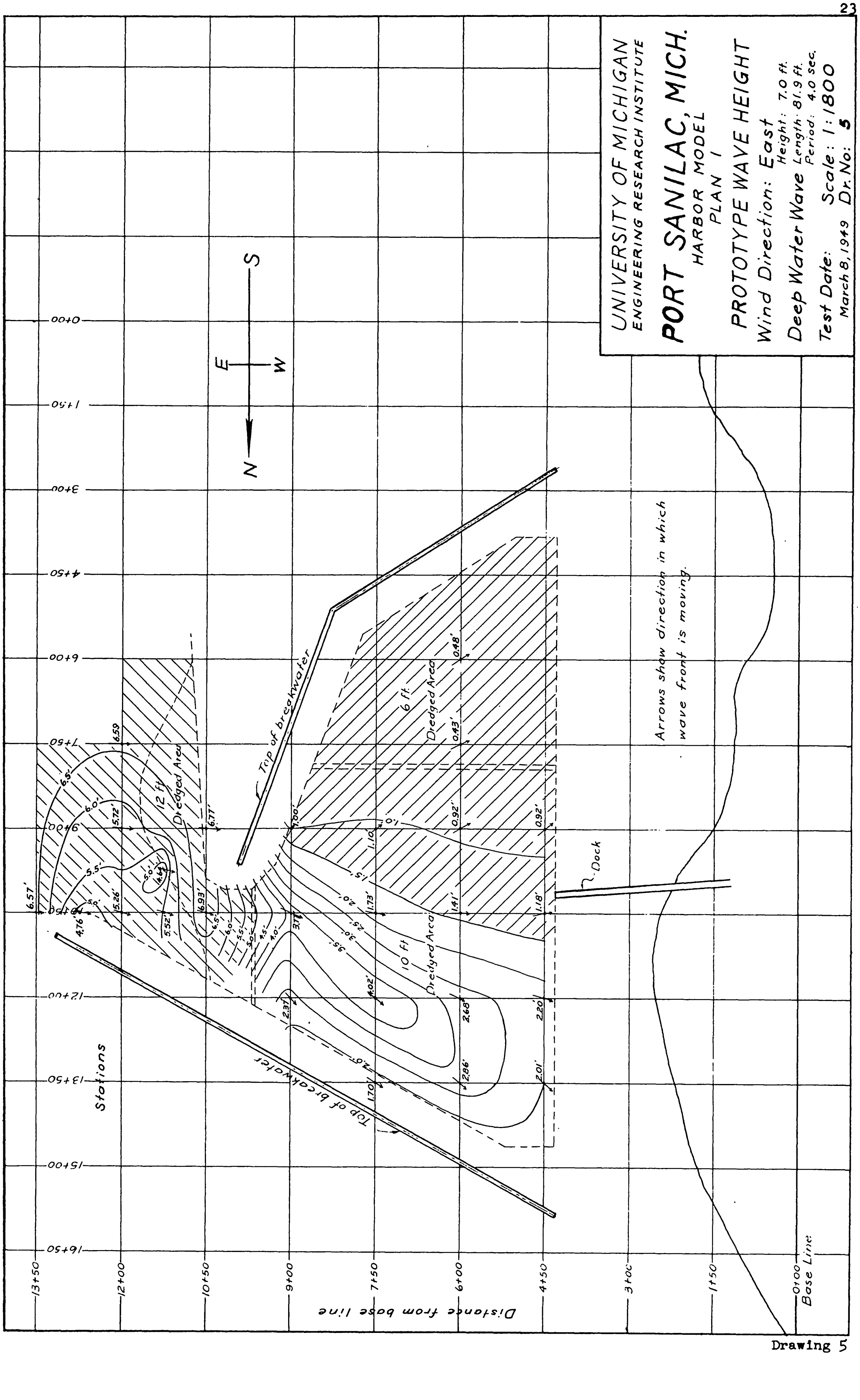
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 1, 1949
Scale: 1:1800
Dr. No: 4
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
6 ft. Dredged Area
12 ft Dredged Area
10 ft Dredged Area
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 4



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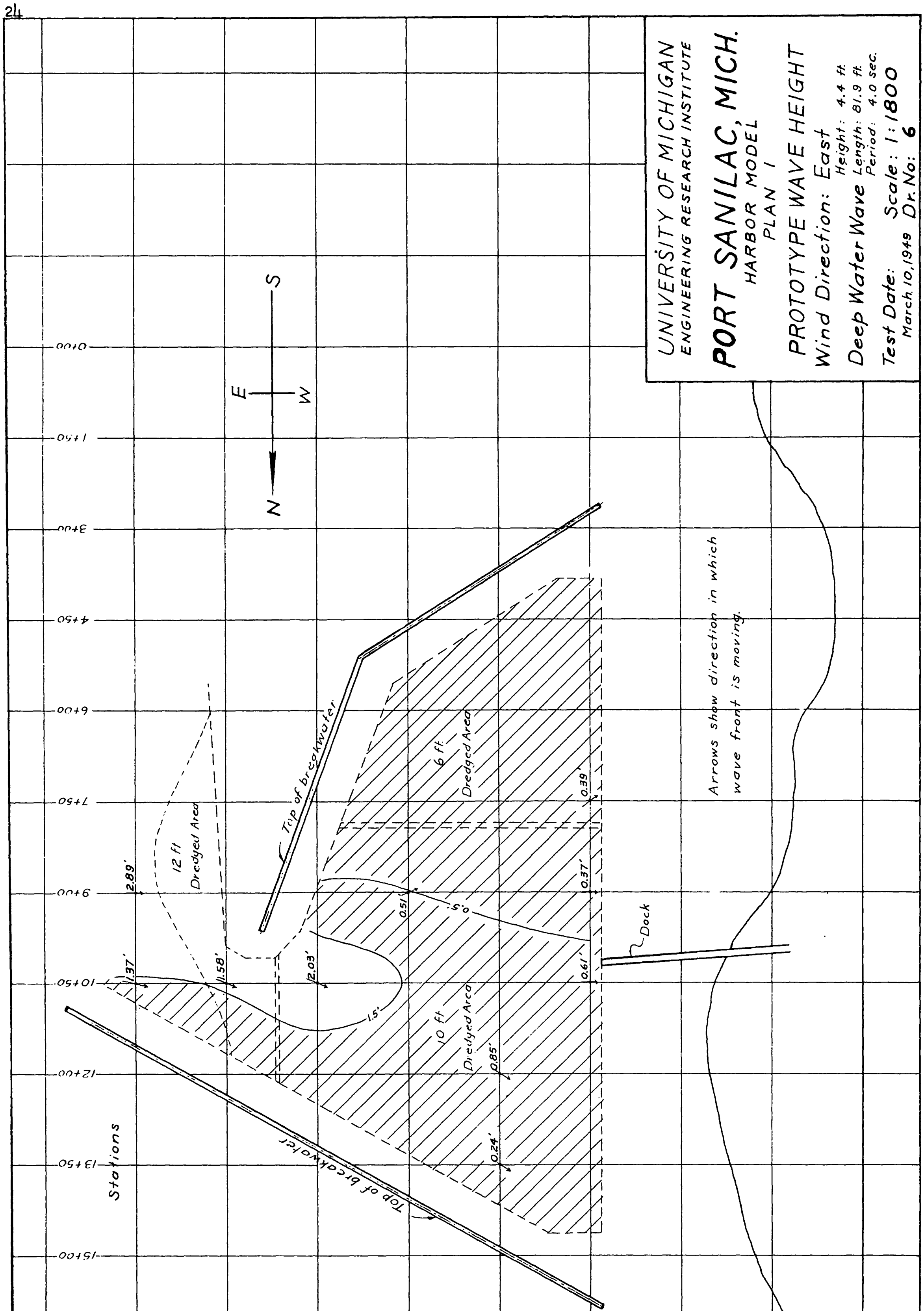
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: March 8, 1949
Scale: 1:1800
Dr. No: 5
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Dock
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 5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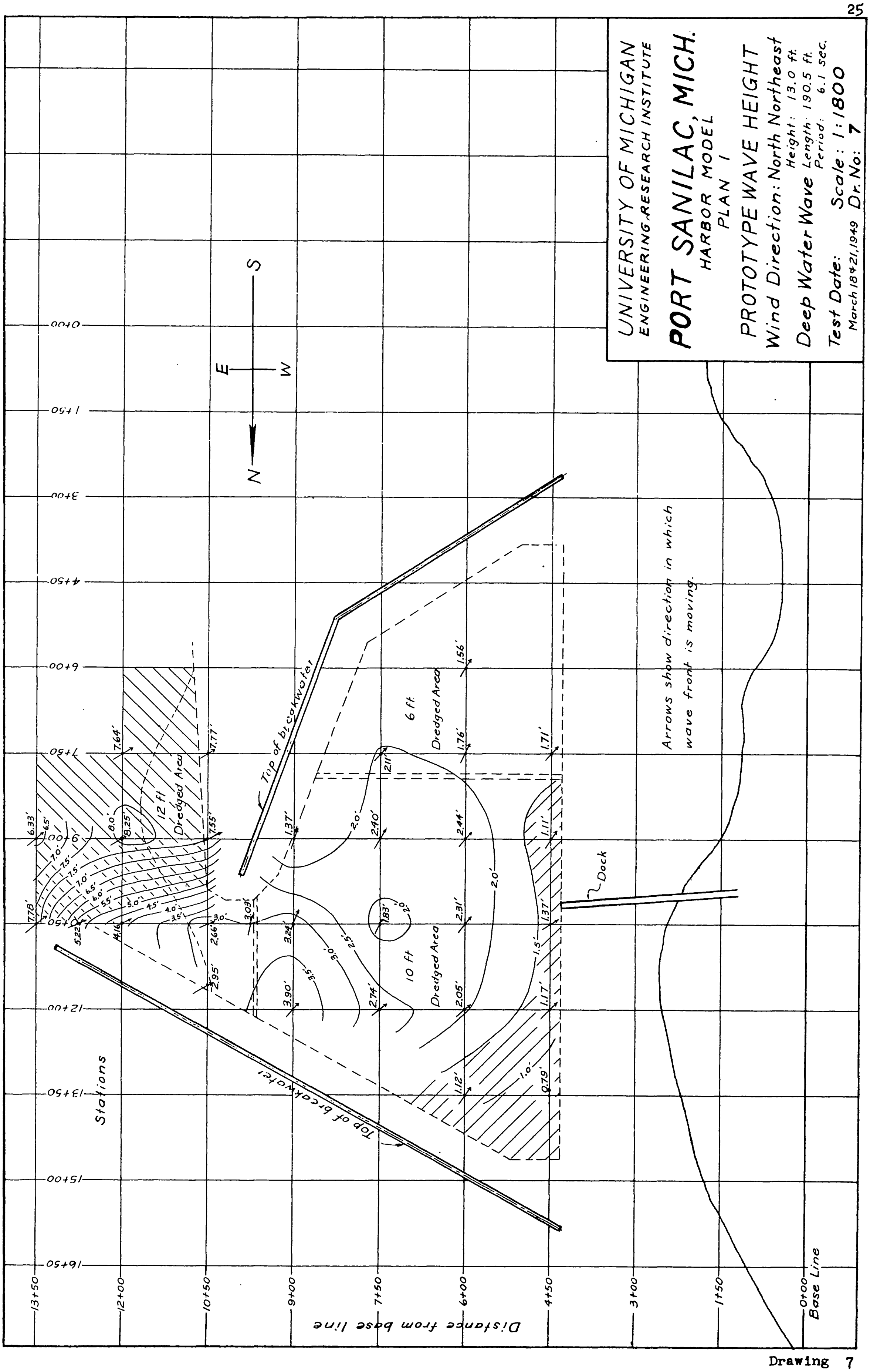
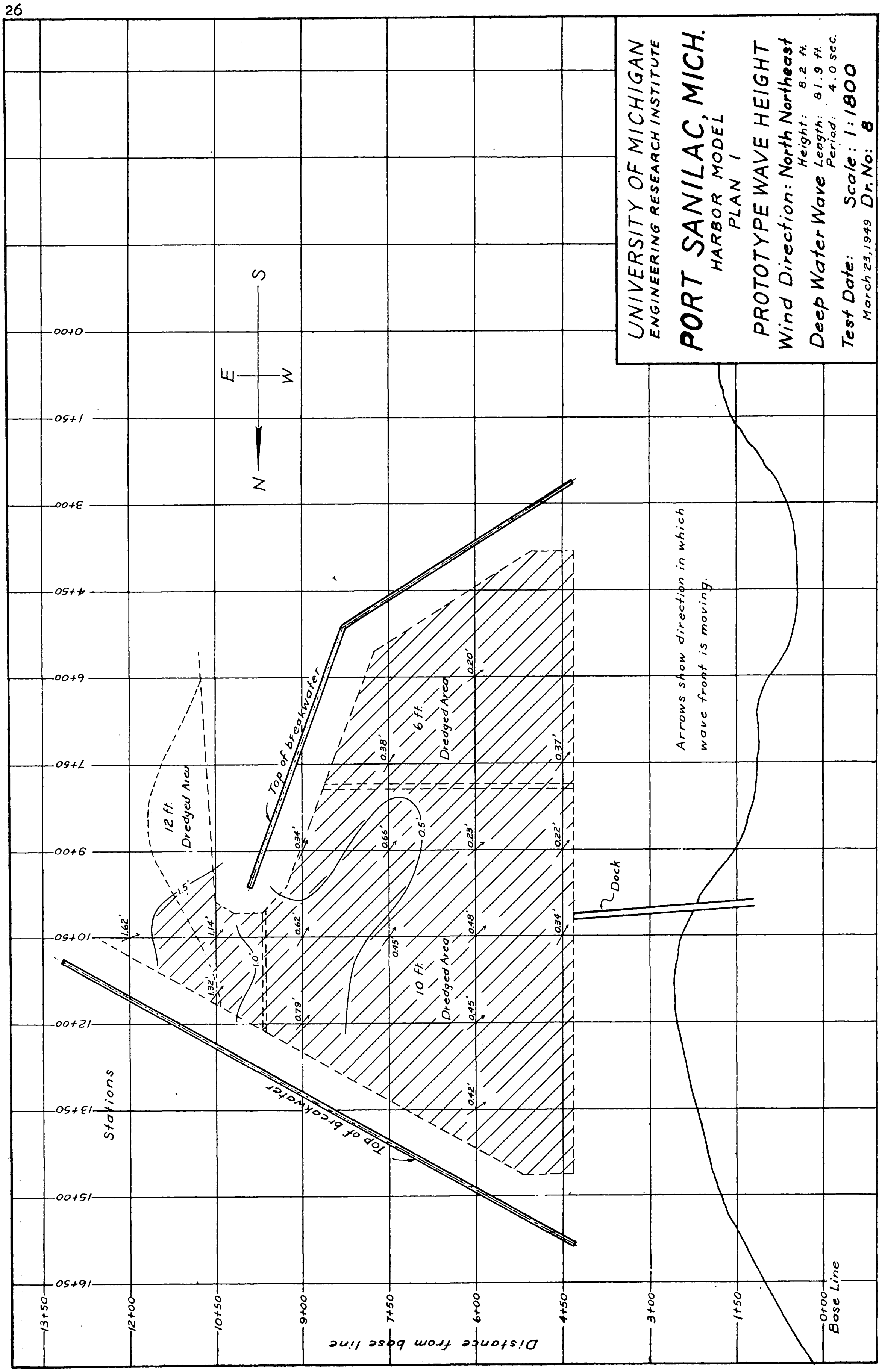
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave
Height: 4.4 ft.
Length: 81.9 ft.
Period: 4.0 sec.
Test Date: March 10, 1949
Scale: 1:1800
Dr. No: 6
N
E
W
S
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft. Dredged Area
10 ft. Dredged Area
Dock
Arrows show direction in which wave front is moving.
2.89'
1.37'
1.58'
2.03'
1.5'
0.51'
0.5'
0.37'
0.39'
0.61'
0.85'
0.24'
Stations
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
Distance from base line
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
Base Line

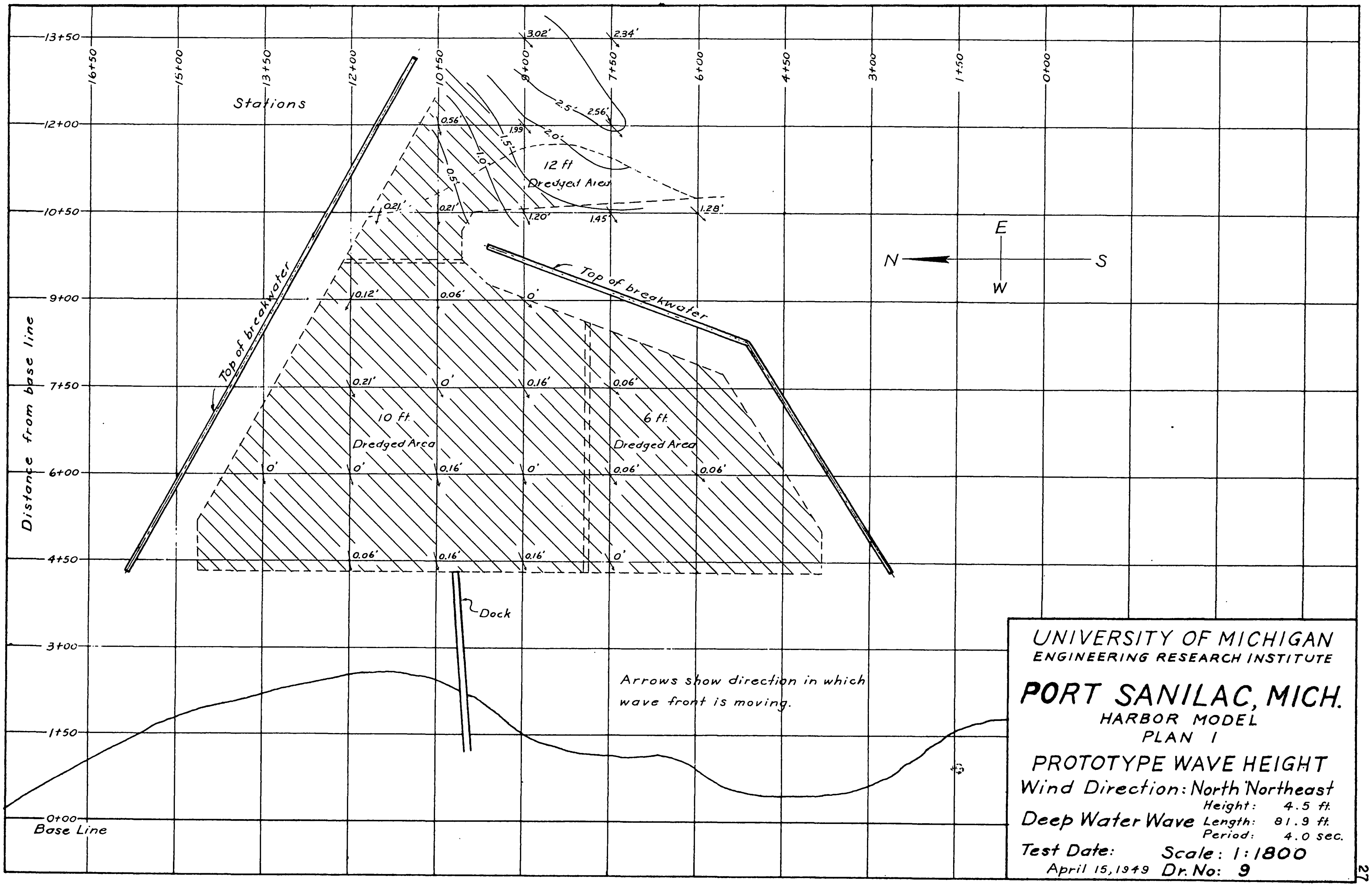
Drawing 6


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 Sec.
Test Date: March 18 & 21, 1949
Scale: 1:1800
Dr. No: 7
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 7


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 8.2 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: March 23, 1949
Scale: 1:1800
Dr. No: 8
N
S
E
W
Top of breakwater
Top of breakwater
12 ft. Dredged Area
6 ft. Dredged Area
10 ft. Dredged Area
Dock
Arrows show direction in which wave front is moving.
Stations
Distance from base line
Base Line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50

Drawing 8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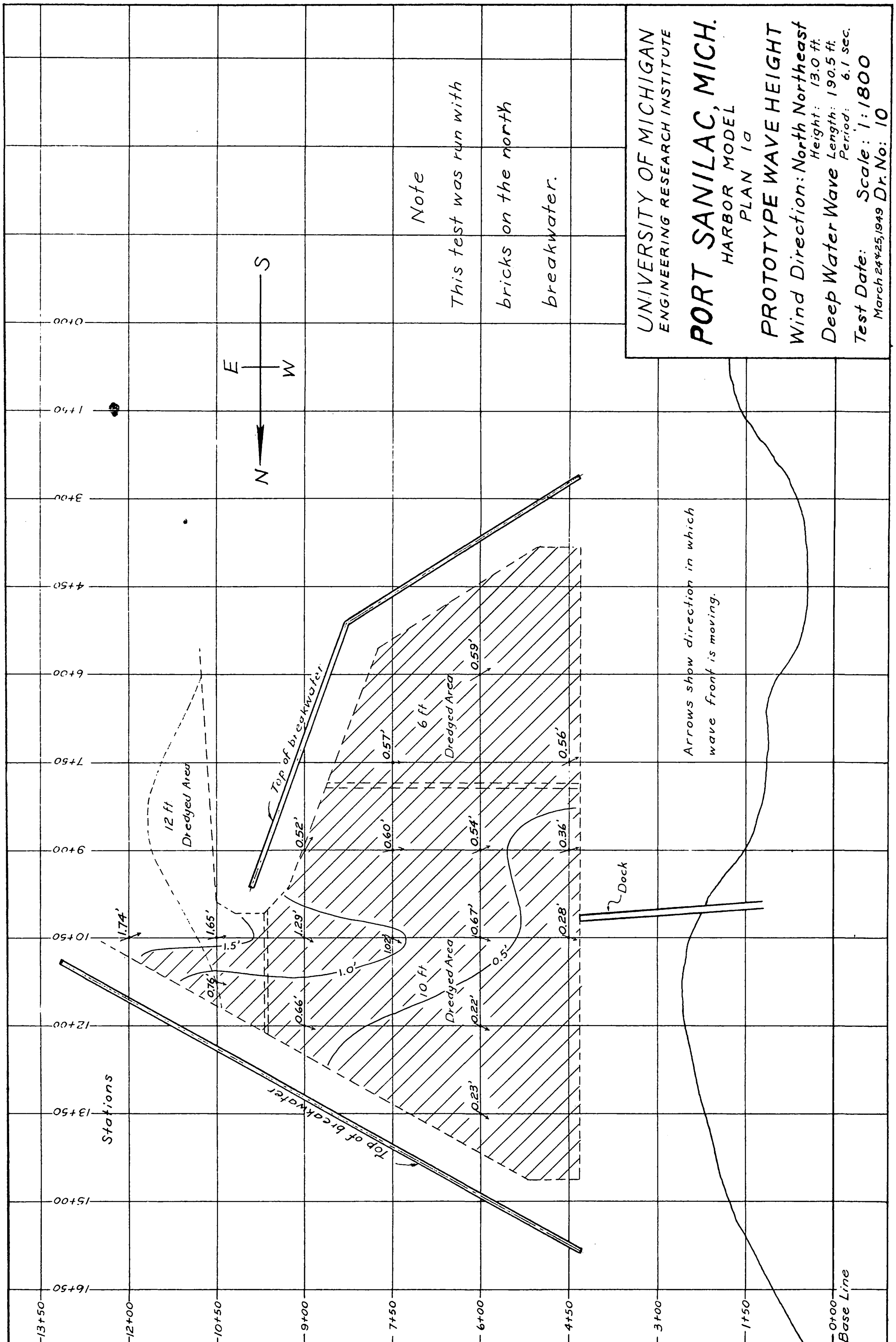
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 15, 1949
Scale: 1:1800
Dr. No: 9
Arrows show direction in which wave front is moving.
Stations
Distance from base line
Base Line
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
N
S
E
W

Drawing 9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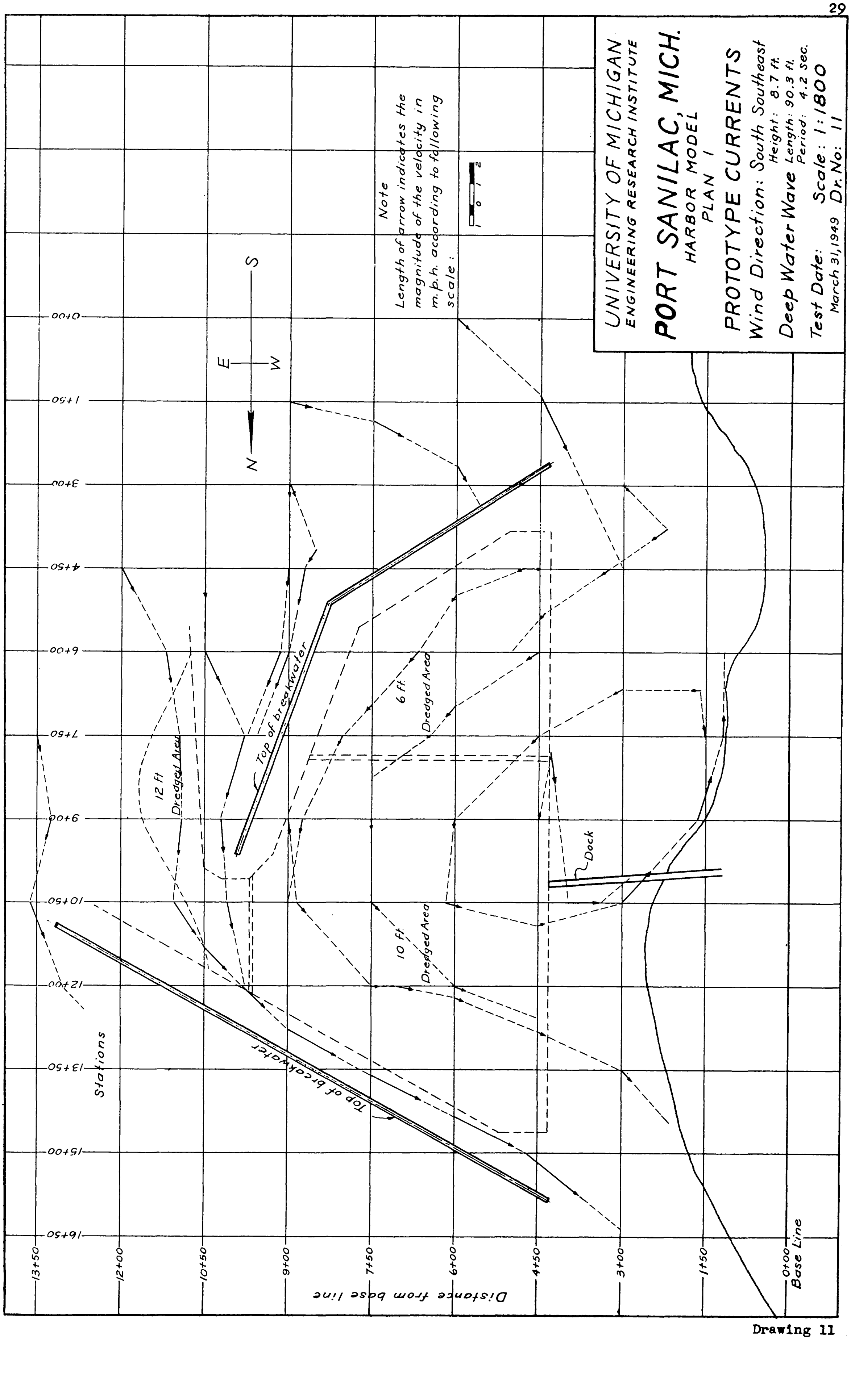
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 1a
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: March 24&25, 1949
Scale: 1:1800
Dr. No: 10
Note
This test was run with bricks on the north breakwater.
Arrows show direction in which wave front is moving.
S
E
W
N
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Distance from base line
Base Line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
1.74'
1.65'
1.5'
1.29'
1.02'
1.0'
0.76'
0.66'
0.67'
0.5'
0.28'
0.22'
0.23'
0.52'
0.60'
0.54'
0.36'
0.57'
0.56'
0.59'

Drawing 10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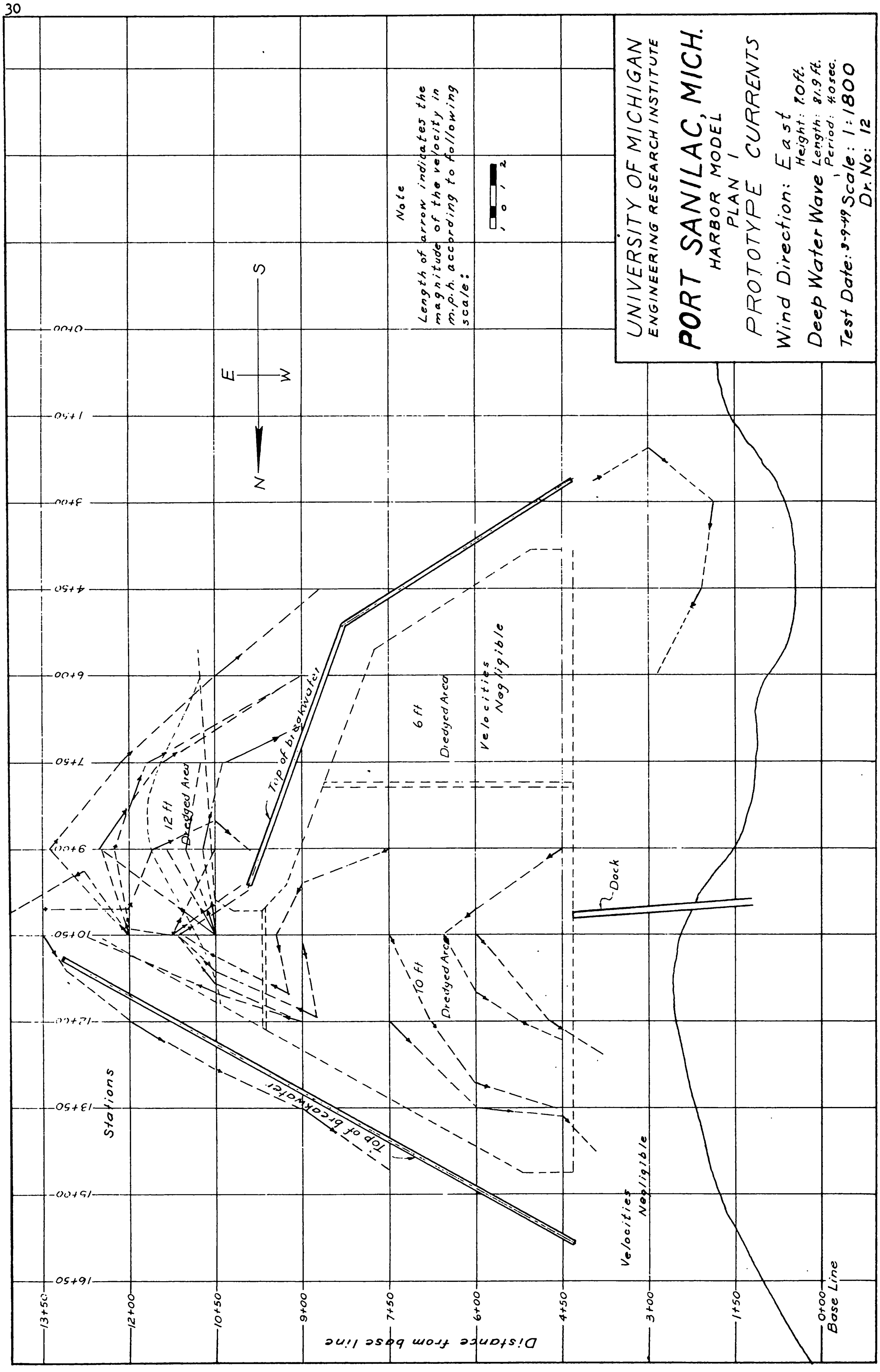
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 1
PROTOTYPE CURRENTS
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 Sec.
Test Date: March 31, 1949
Scale: 1:1800
Dr. No: 11
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
S
E
W
N
Top of breakwater
Top of breakwater
6 ft. Dredged Area
12 ft Dredged Area
10 ft. Dredged Area
Dock
Stations
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
Base Line
Distance from base line

Drawing 11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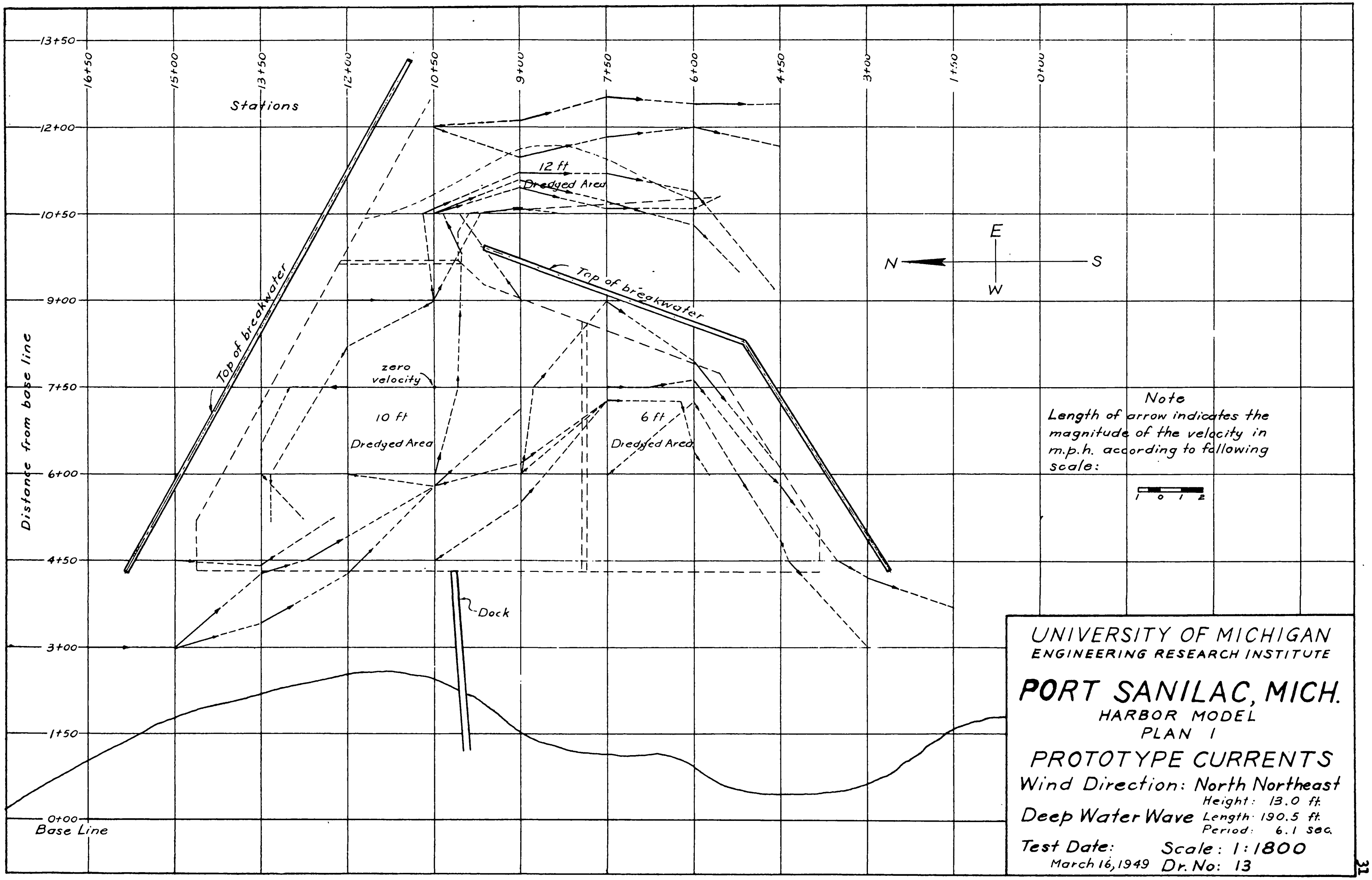
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 1
PROTOTYPE CURRENTS
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: 3-9-49 Scale: 1:1800
Dr. No: 12
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
S
E
W
N
Top of breakwater
6 ft Dredged Area
Velocities Negligible
12 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Velocities Negligible
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
Base Line

Drawing 12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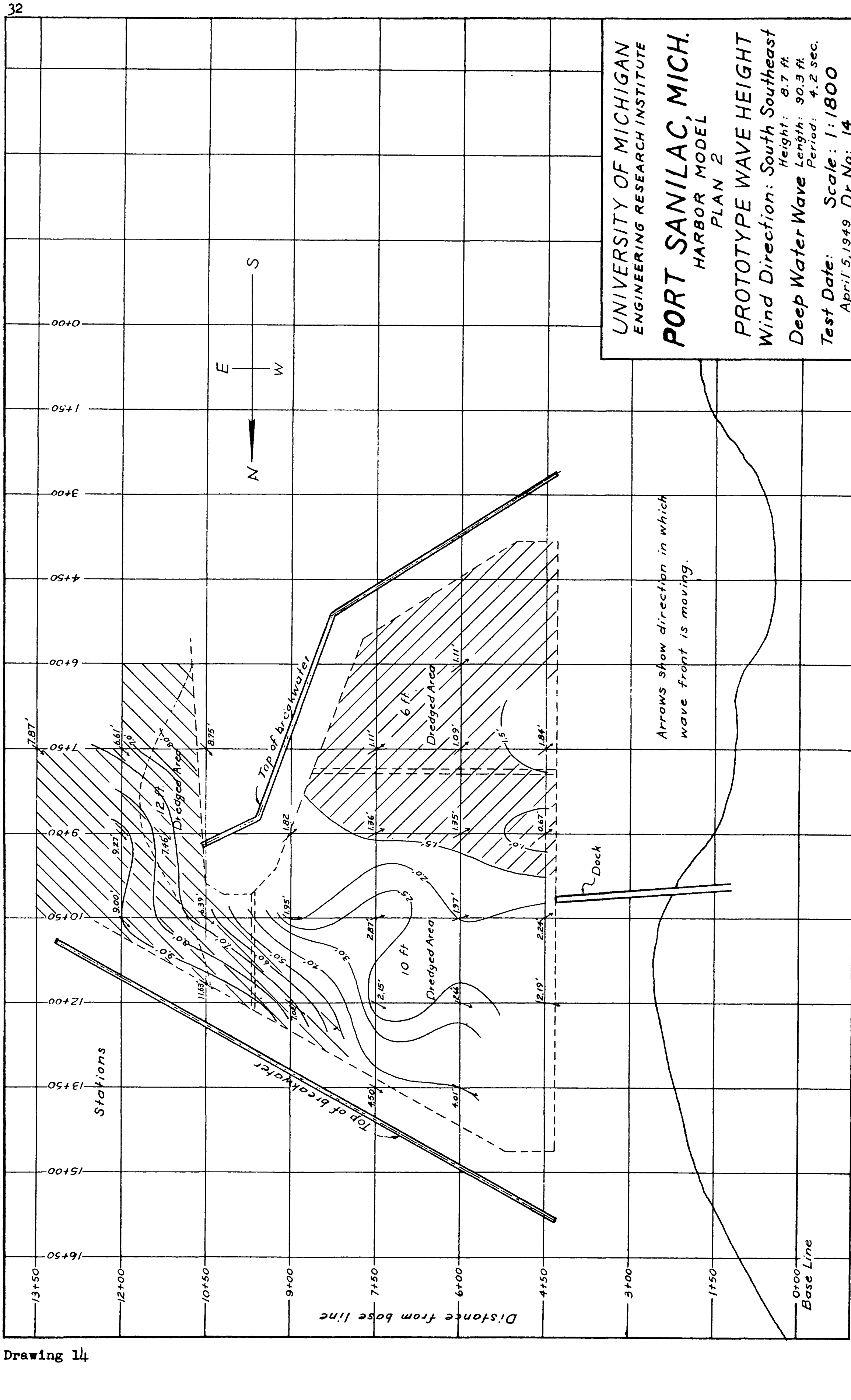
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN I
PROTOTYPE CURRENTS
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: March 16, 1949
Scale: 1:1800
Dr. No: 13
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
N
S
E
W
Stations
Distance from base line
Base Line
Top of breakwater
Top of breakwater
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
zero velocity
Dock
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 13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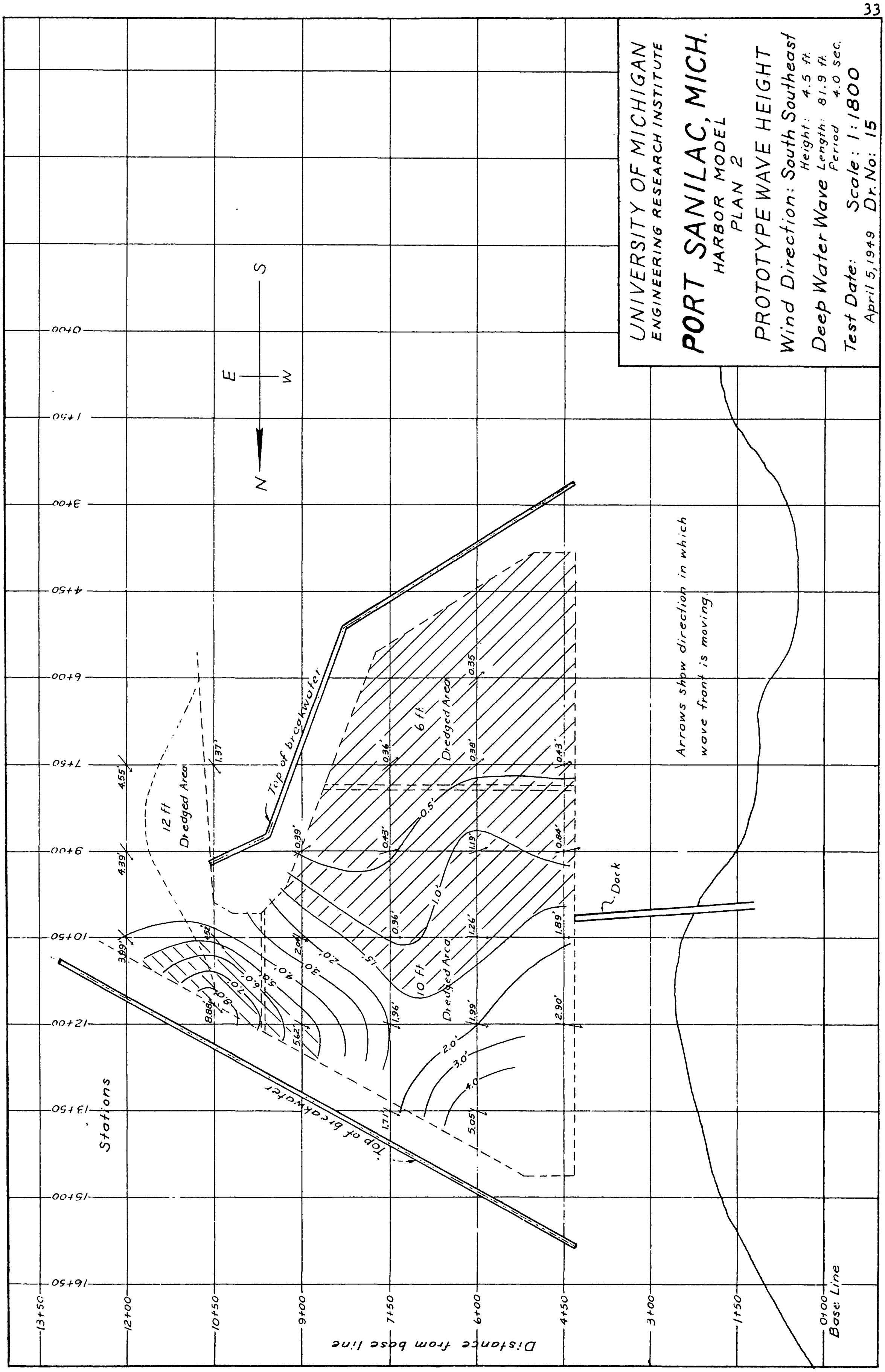
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: April 5, 1949
Scale: 1:1800
Dr. No: 14
Top of breakwater
Top of breakwater
6 ft Dredged Area
12 ft Dredged Area
10 ft Dredged Area
Dock
Arrows show direction in which wave front is moving.
Stations
Distance from base line
Base Line

Drawing 14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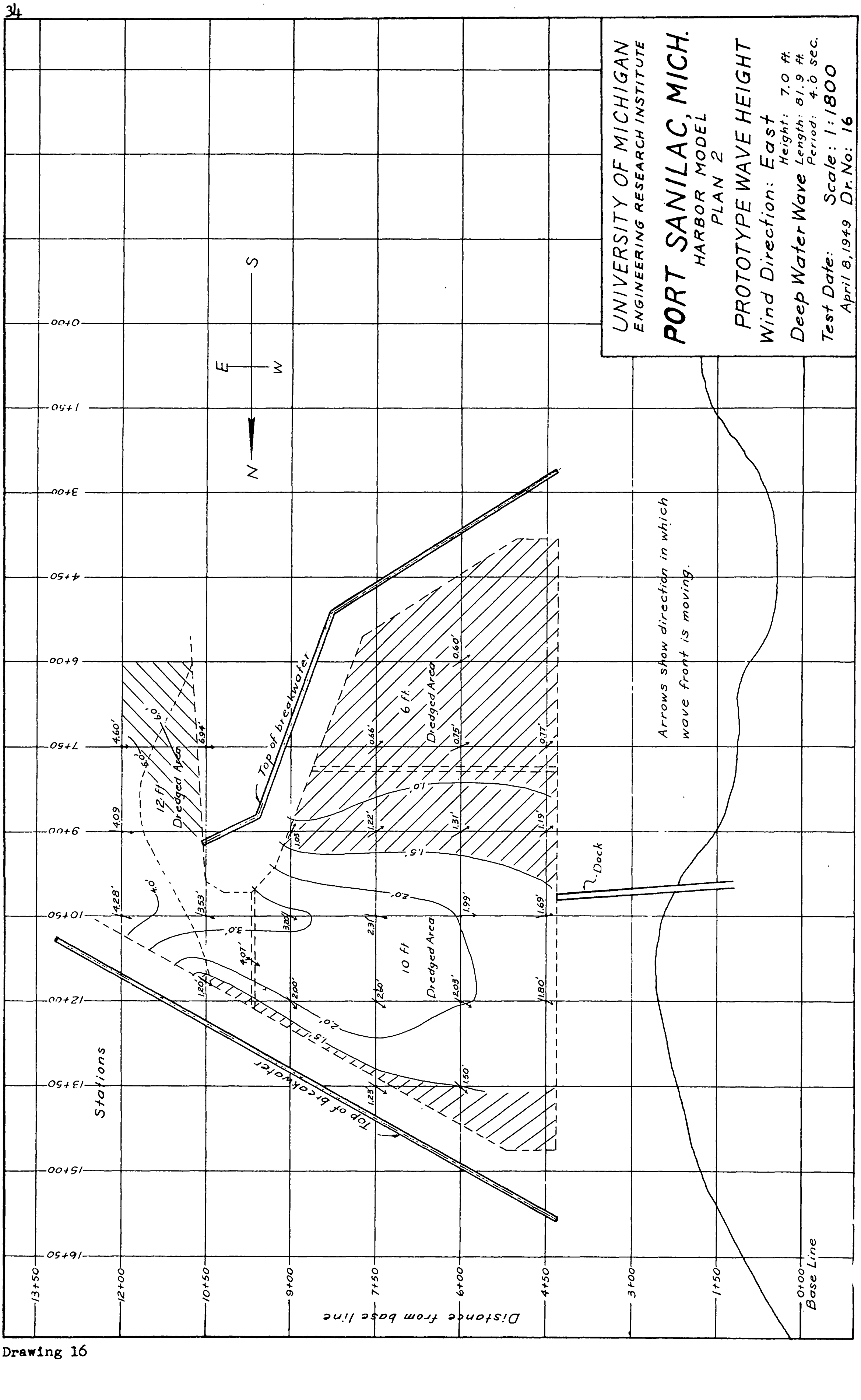
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period 4.0 sec.
Test Date: April 5, 1949
Scale: 1:1800
Dr. No: 15
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
6 ft. Dredged Area
10 ft Dredged Area
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 15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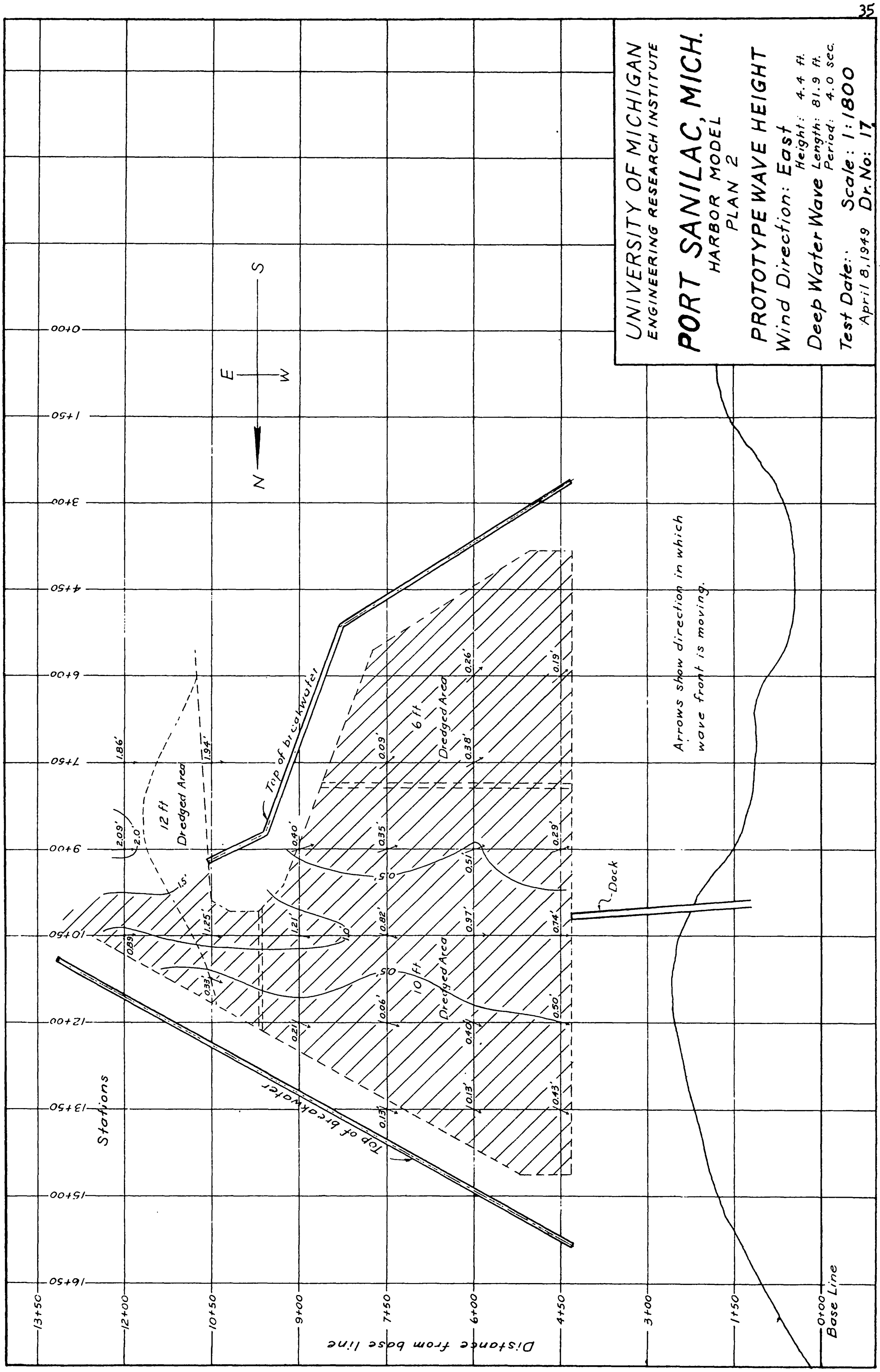
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 8, 1949
Scale: 1:1800
Dr. No: 16
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 16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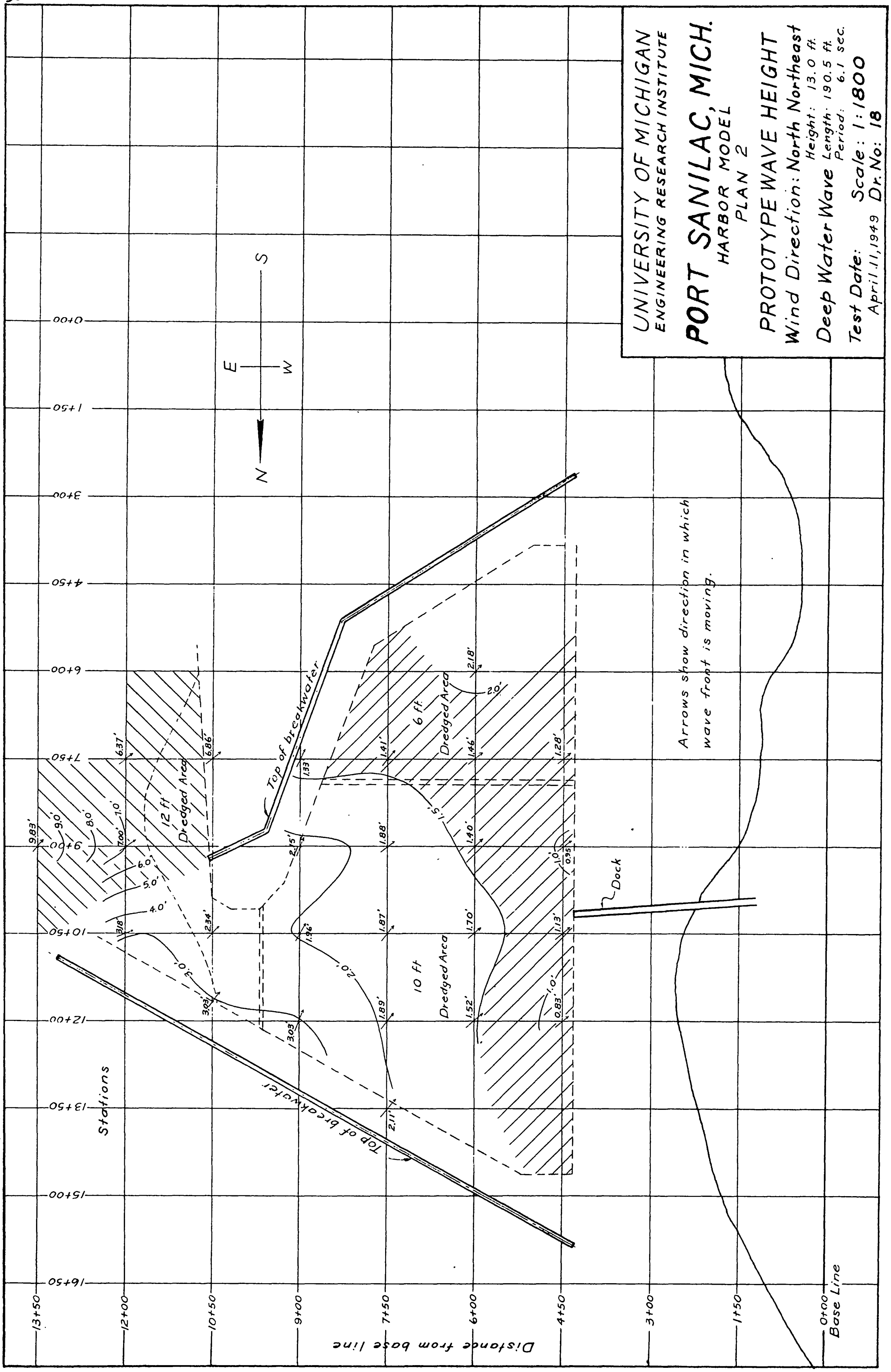
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.4 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 8, 1949
Scale: 1:1800
Dr. No: 17
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 17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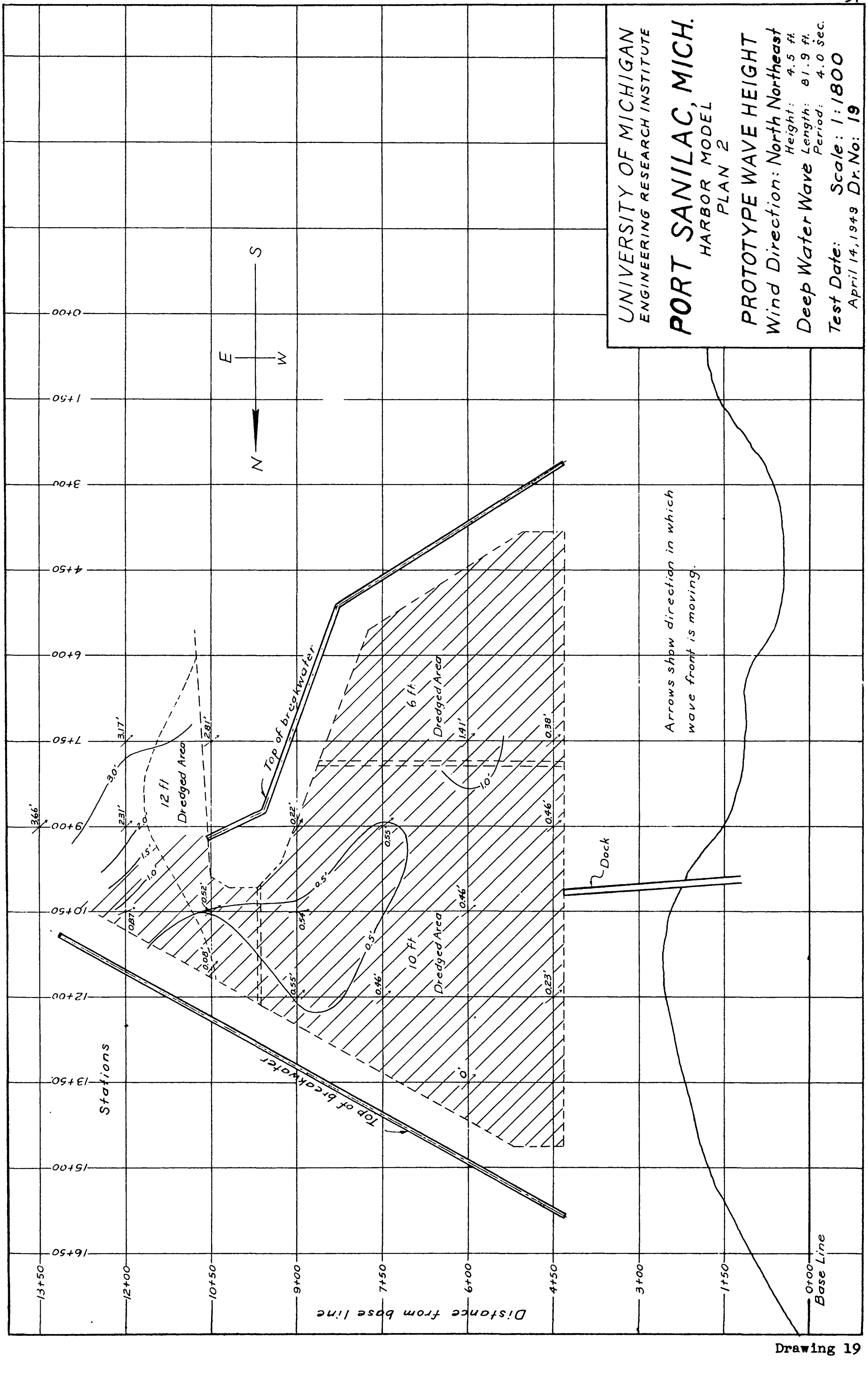
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: April 11, 1949
Scale: 1:1800
Dr. No: 18
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Distance from base line
Base Line

Drawing 18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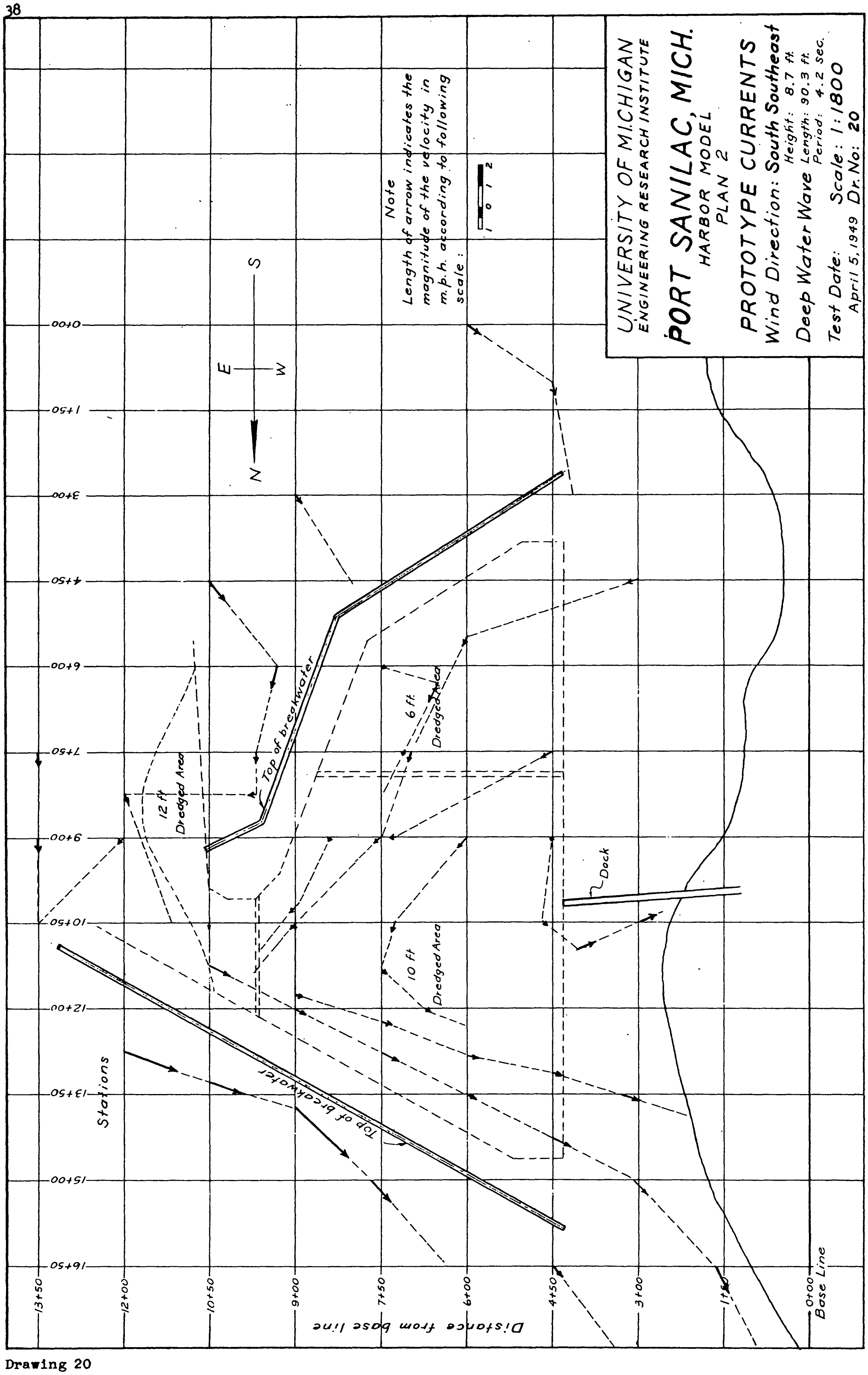
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 14, 1949
Scale: 1:1800
Dr. No: 19
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 19



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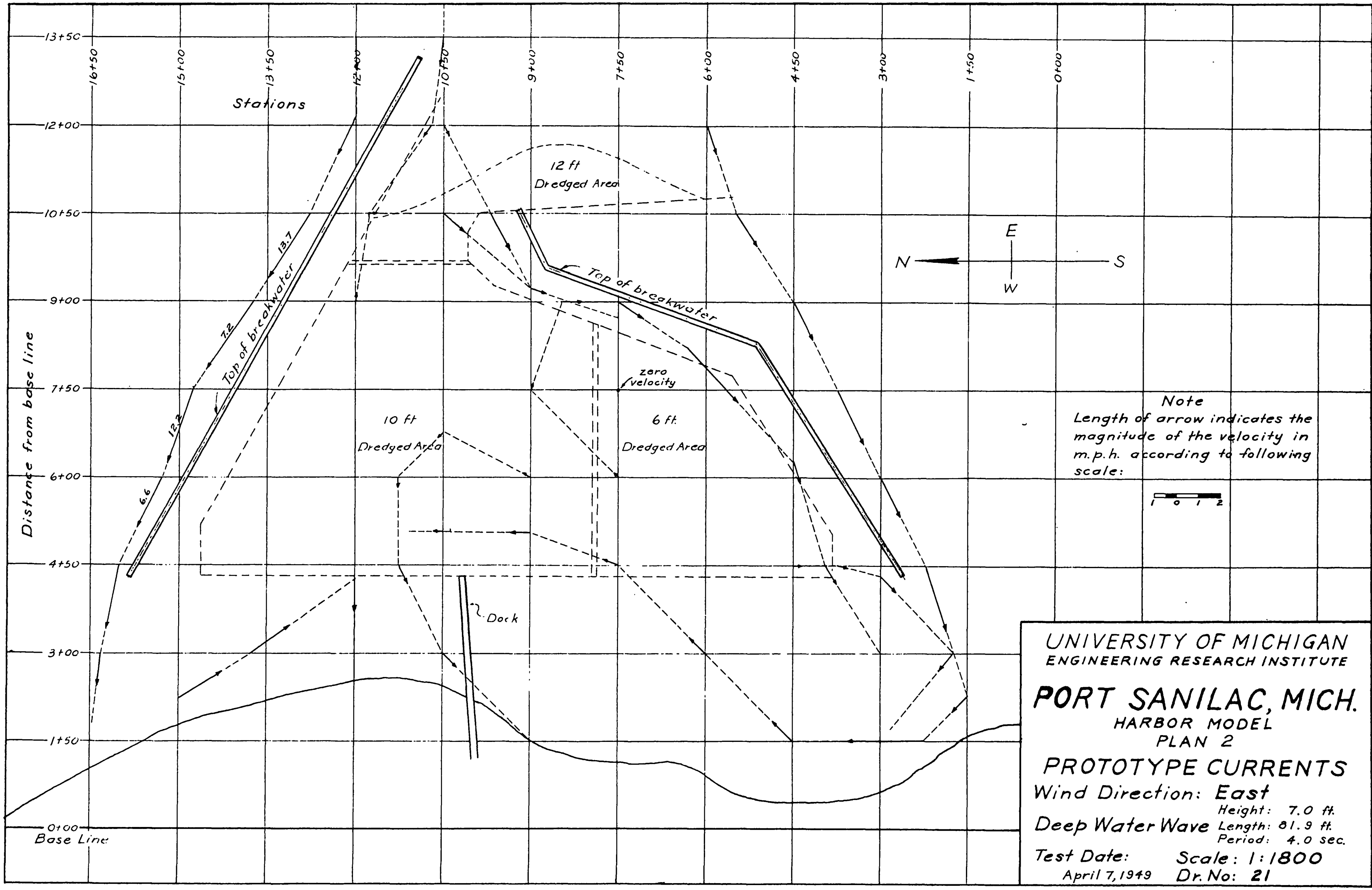
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE CURRENTS
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: April 5, 1949
Scale: 1:1800
Dr. No: 20
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
S
E
W
N
Top of breakwater
6 ft. Dredged Area
12 ft Dredged Area
10 ft Dredged Area
Dock
Top of breakwater
Stations
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00 Base Line
Distance from base line

Drawing 20



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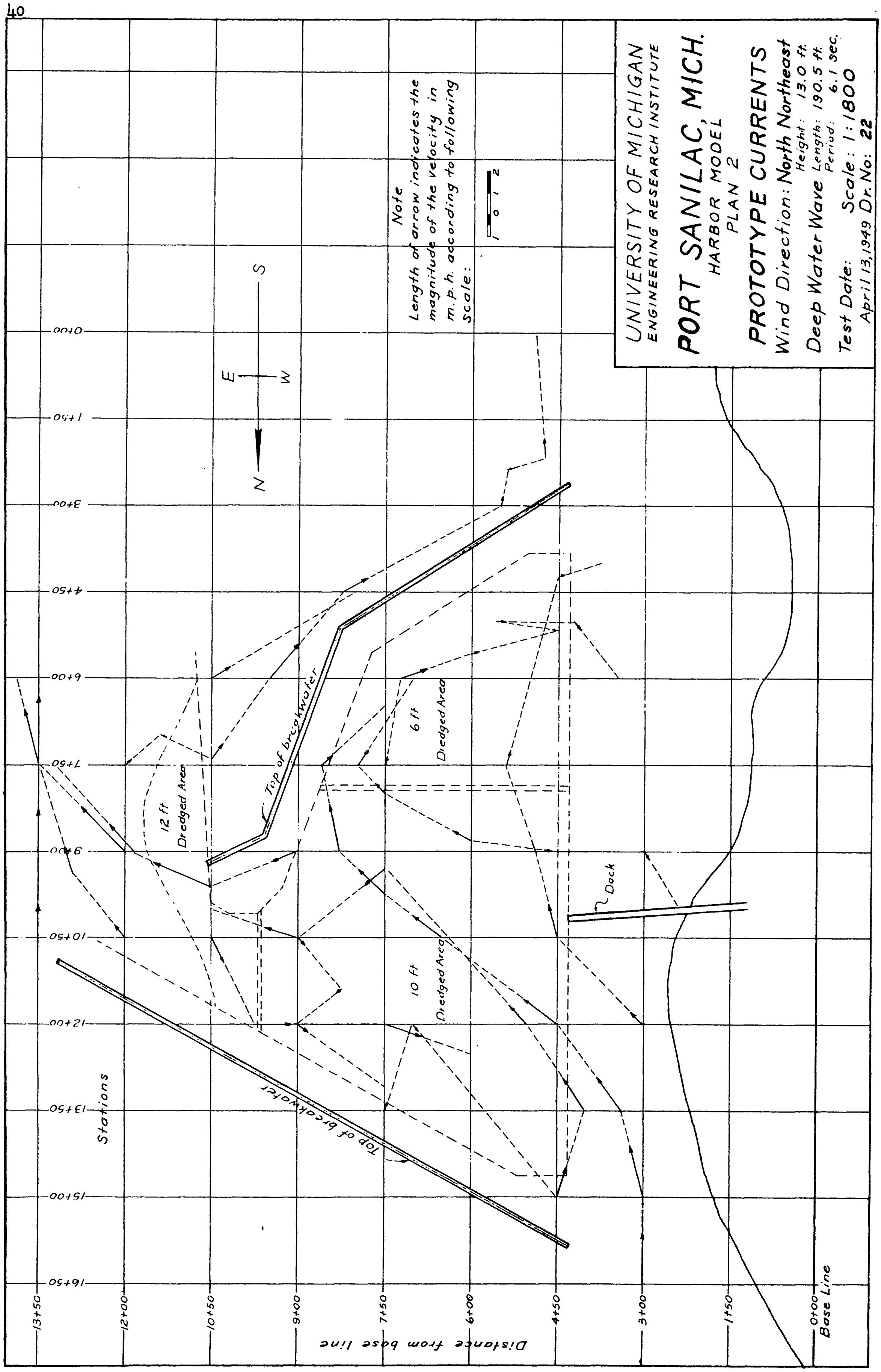
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE CURRENTS
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 7, 1949
Scale: 1:1800
Dr. No: 21
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
N
S
E
W
Stations
Distance from base line
Base Line
Top of breakwater
Top of breakwater
12 ft Dredged Area
10 ft Dredged Area
6 ft. Dredged Area
zero velocity
Dock
13.7
7.2
12.2
6.6
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 21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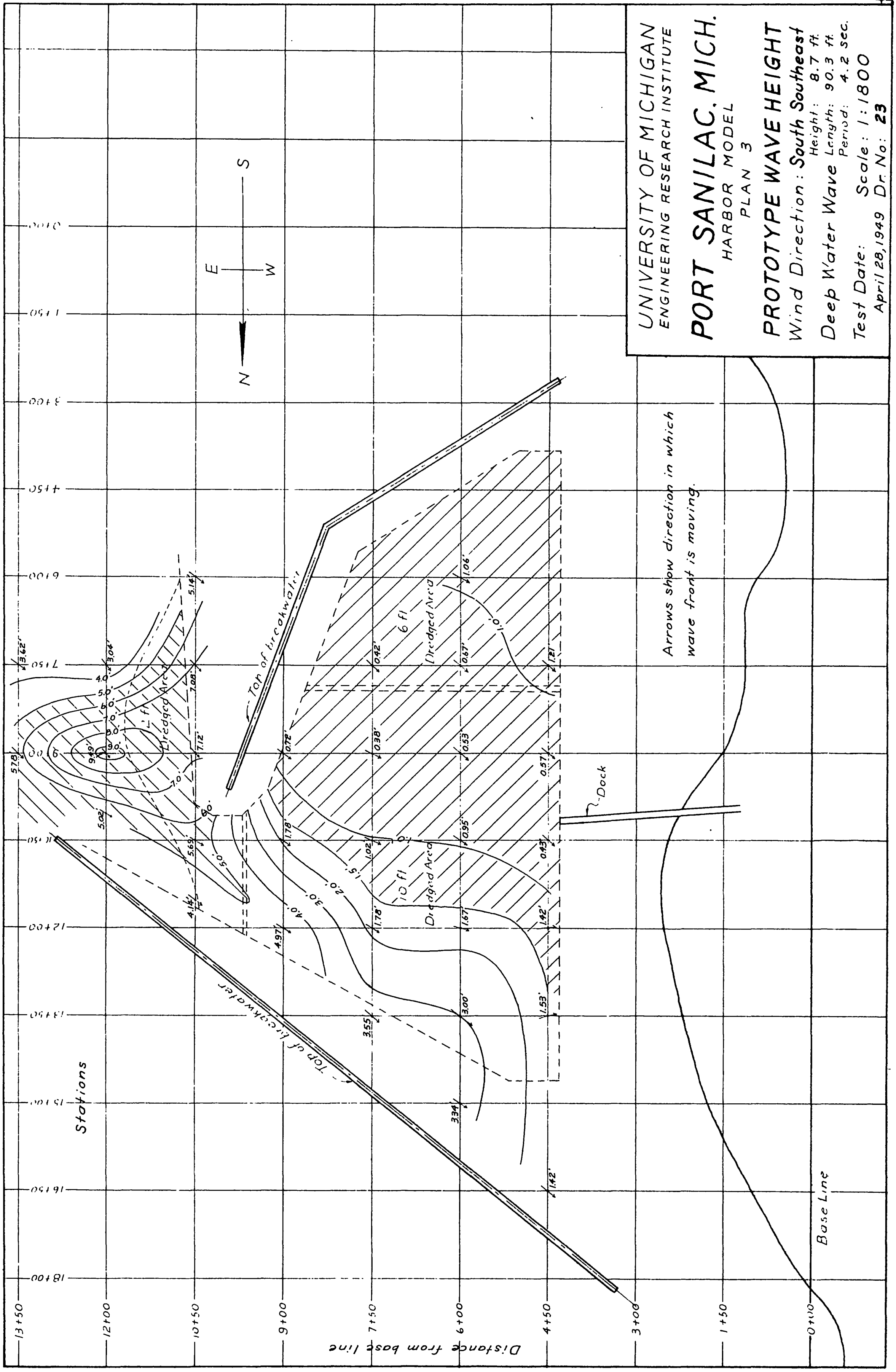
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 2
PROTOTYPE CURRENTS
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: April 13, 1949
Scale: 1:1800
Dr. No: 22
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
0 1 2
S
E W
N
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Top of breakwater
Stations
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00 Base Line
Distance from base line

Drawing 22



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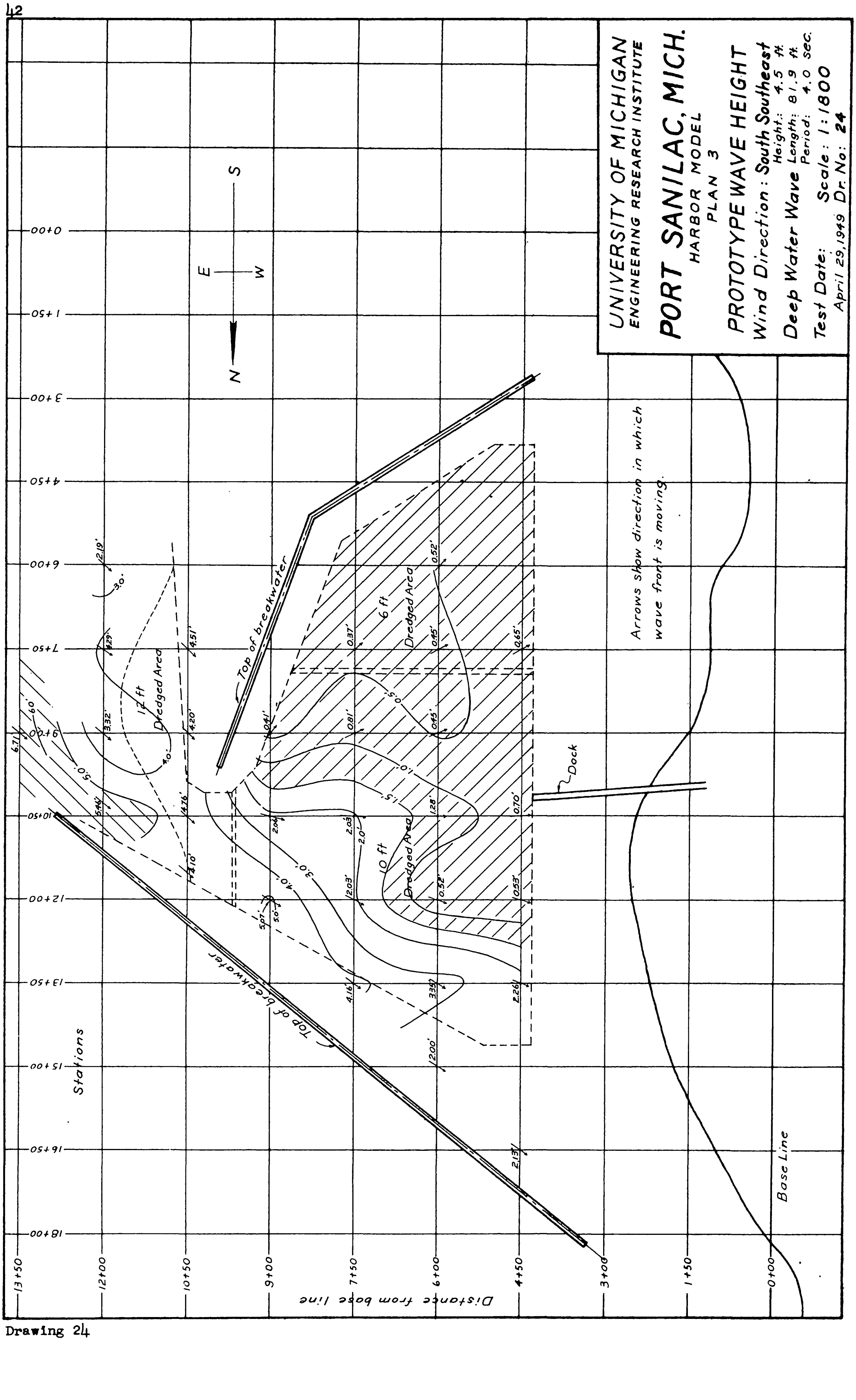
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: April 28, 1949
Scale: 1:1800
Dr. No: 23
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 23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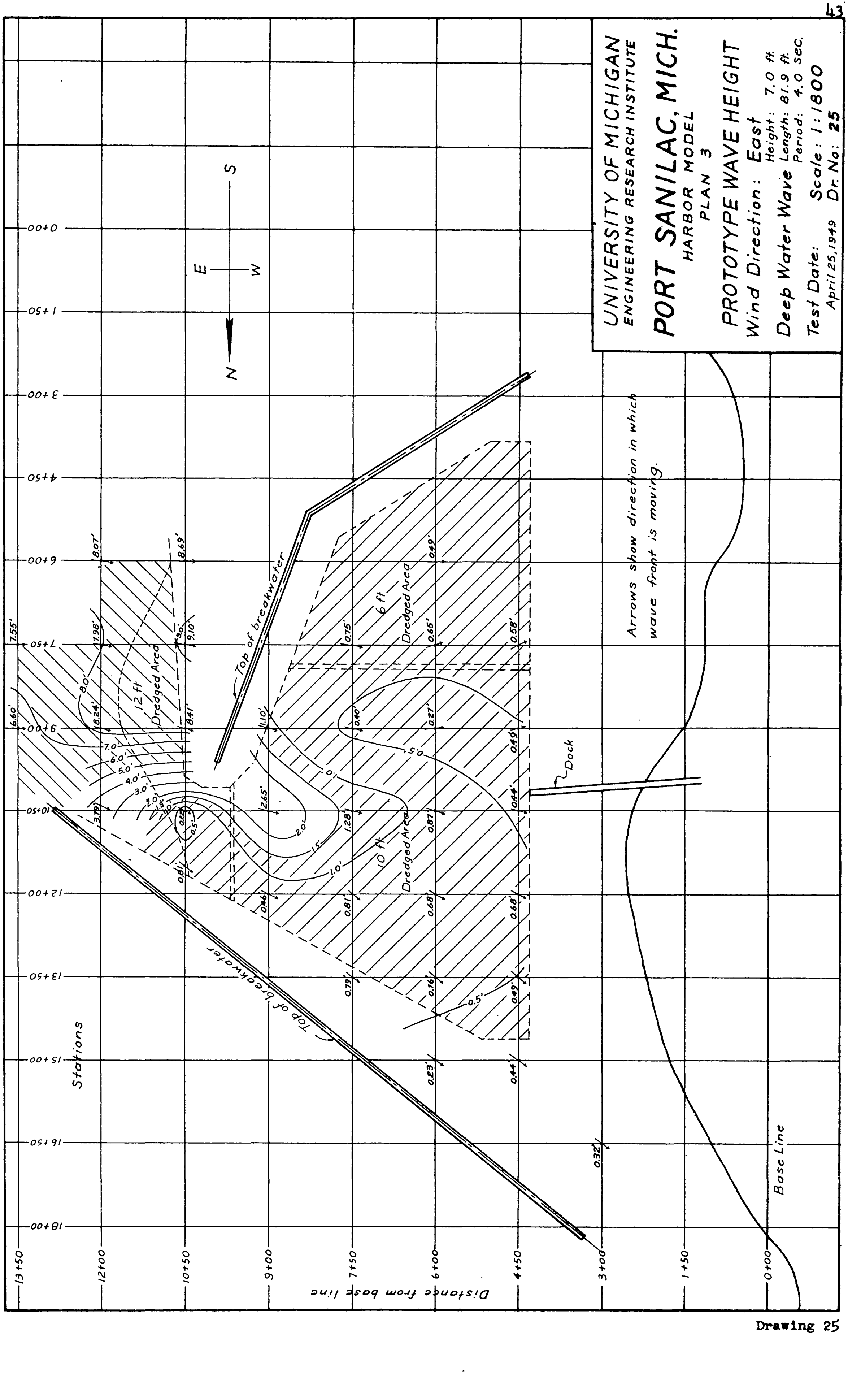
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 29, 1949
Scale: 1:1800
Dr. No: 24
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
6 ft Dredged Area
12 ft Dredged Area
10 ft Dredged Area
Dock
Base Line
Stations
Distance from base line
N
S
E
W
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 24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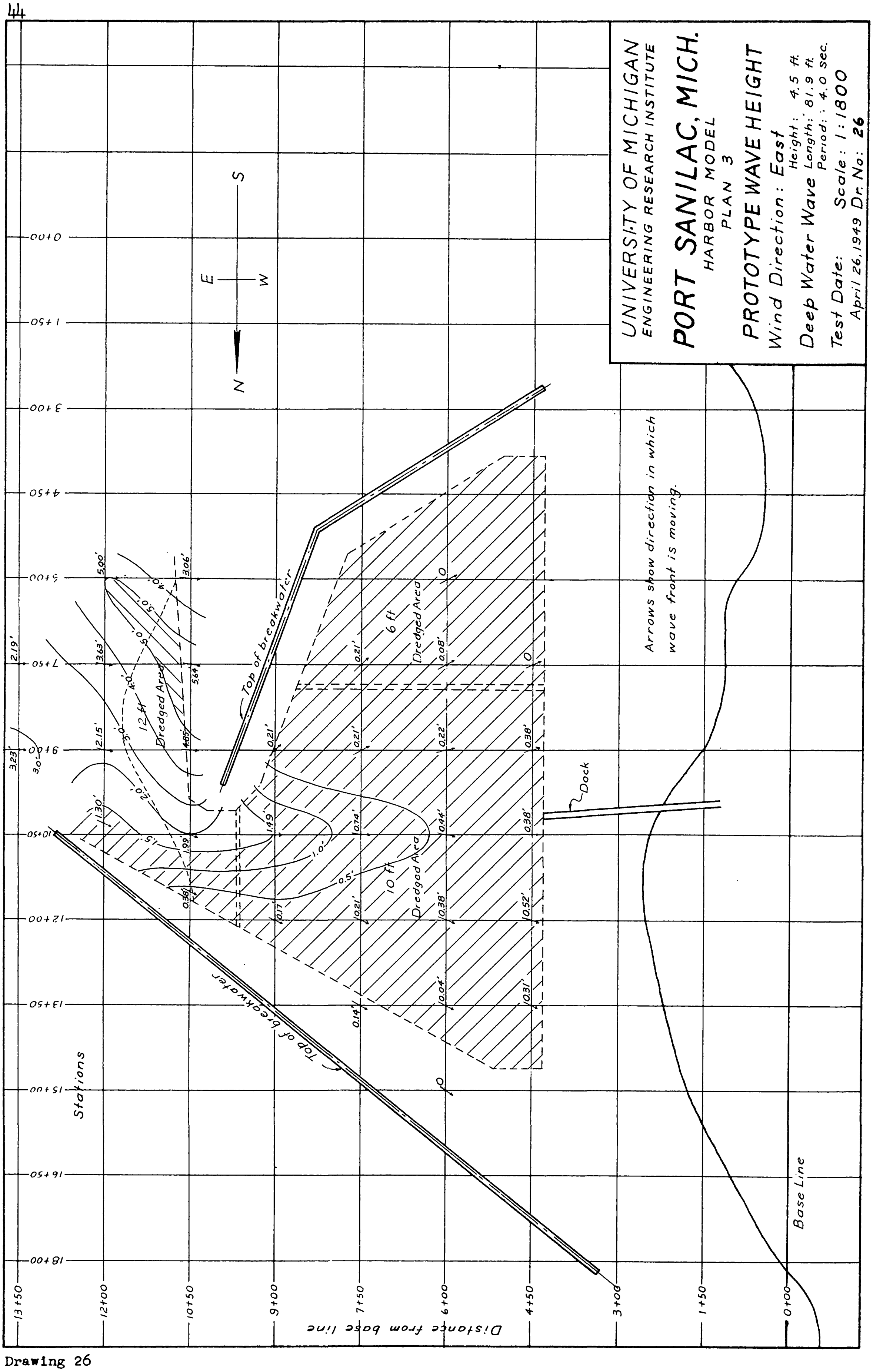
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 25, 1949
Scale: 1:1800
Dr. No: 25
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Distance from base line
Base Line
N
S
E
W
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 25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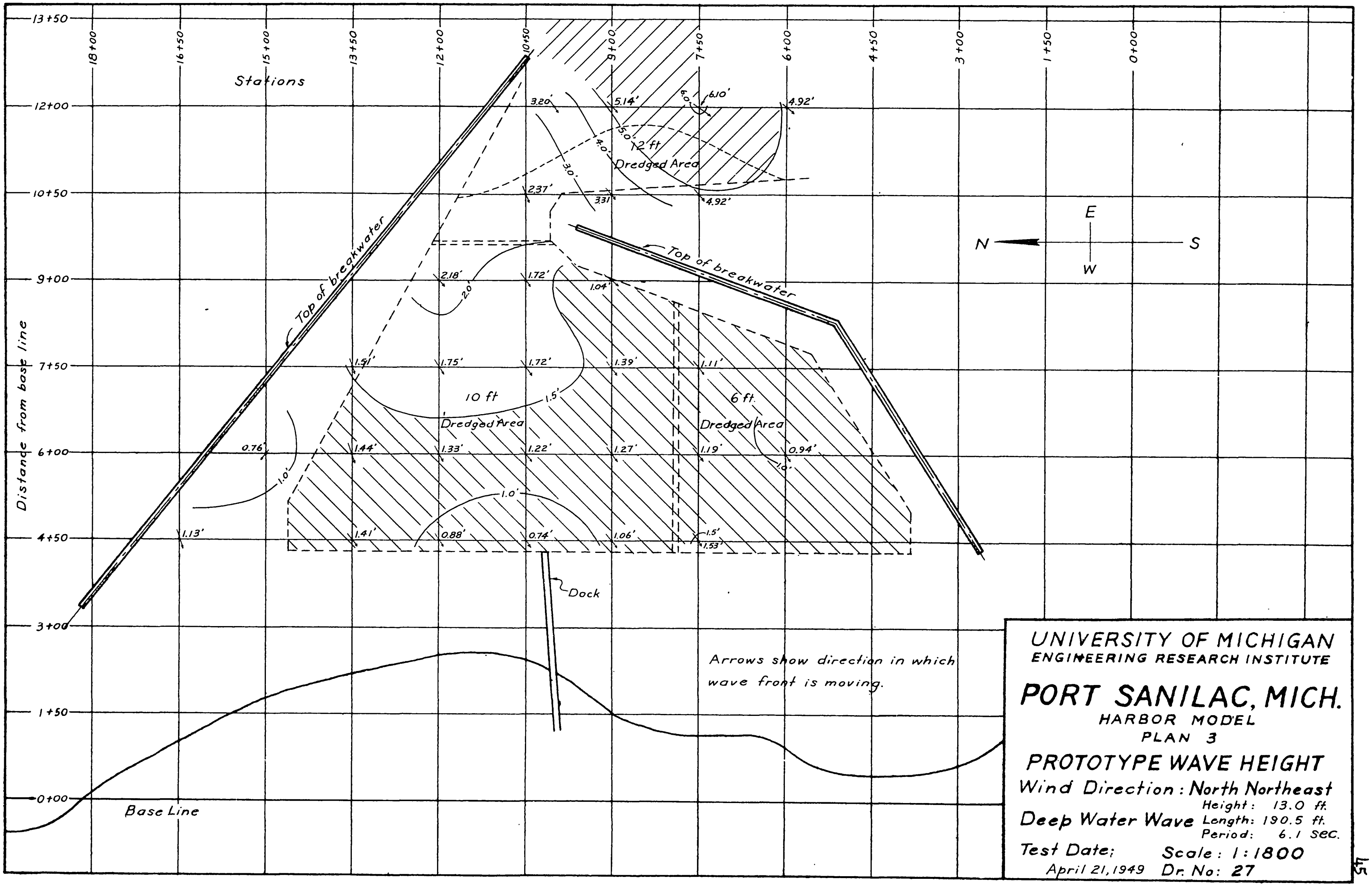
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 26, 1949
Scale: 1:1800
Dr. No: 26
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dredged Area 12 ft
Dredged Area 6 ft
Dredged Area 10 ft
Dock
Stations
Distance from base line
Base Line
N
S
E
W
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00

Drawing 26



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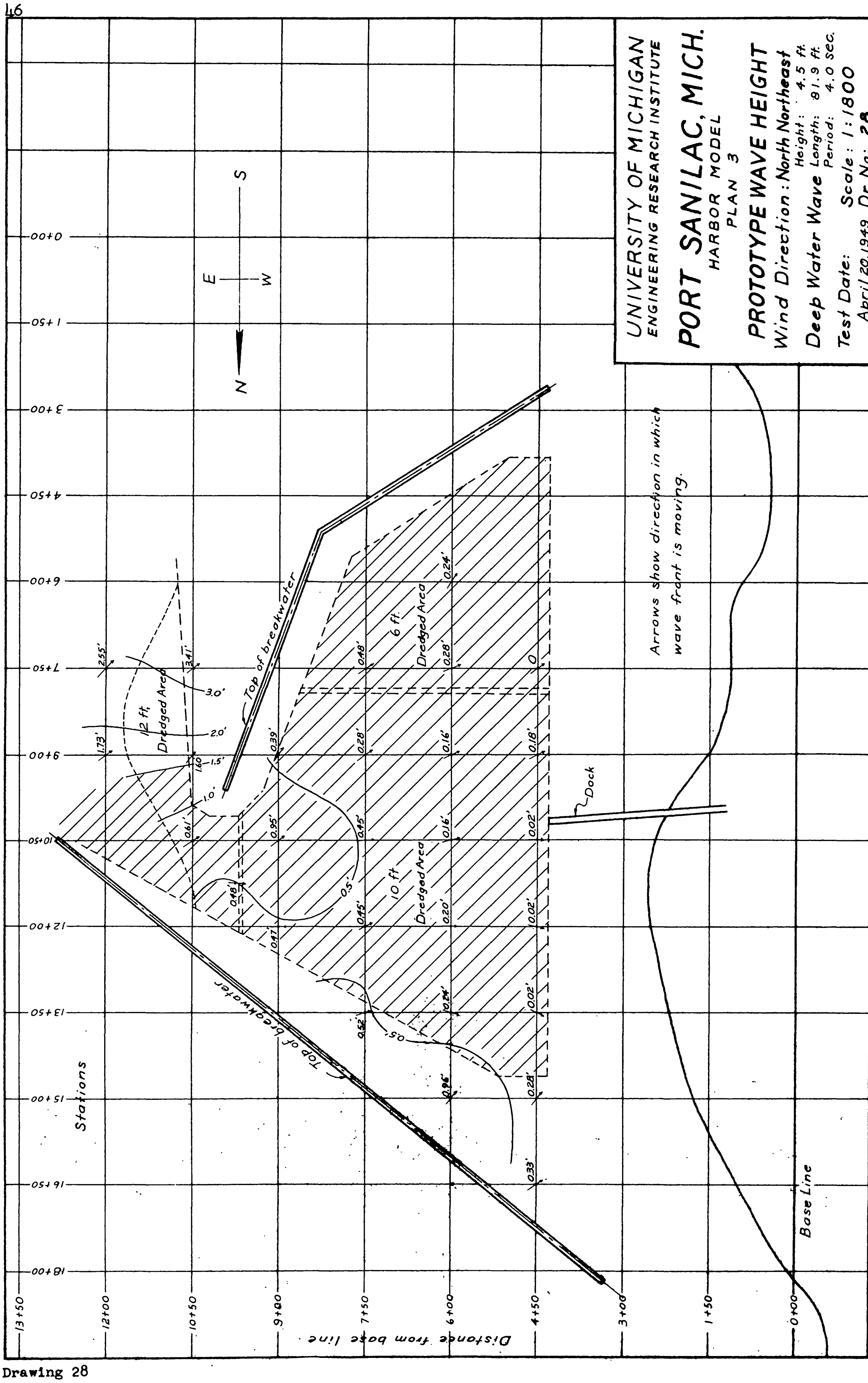
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 Sec.
Test Date; April 21, 1949
Scale: 1:1800
Dr. No: 27
Arrows show direction in which wave front is moving.
Stations
Distance from base line
Base Line
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
10 ft Dredged Area
6 ft. Dredged Area
N
S
E
W
18+00
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
3.20'
5.14'
6.0'
6.10'
4.92'
4.92'
5.0'
4.0'
3.0'
2.37'
3.31
2.18'
2.0
1.72'
1.04'
1.51'
1.75'
1.72'
1.39'
1.11'
1.5'
0.76'
1.44'
1.33'
1.22'
1.27'
1.19'
0.94'
1.0'
1.0'
1.0'
1.13'
1.41'
0.88'
0.74'
1.06'
1.5'
1.53'

Drawing 27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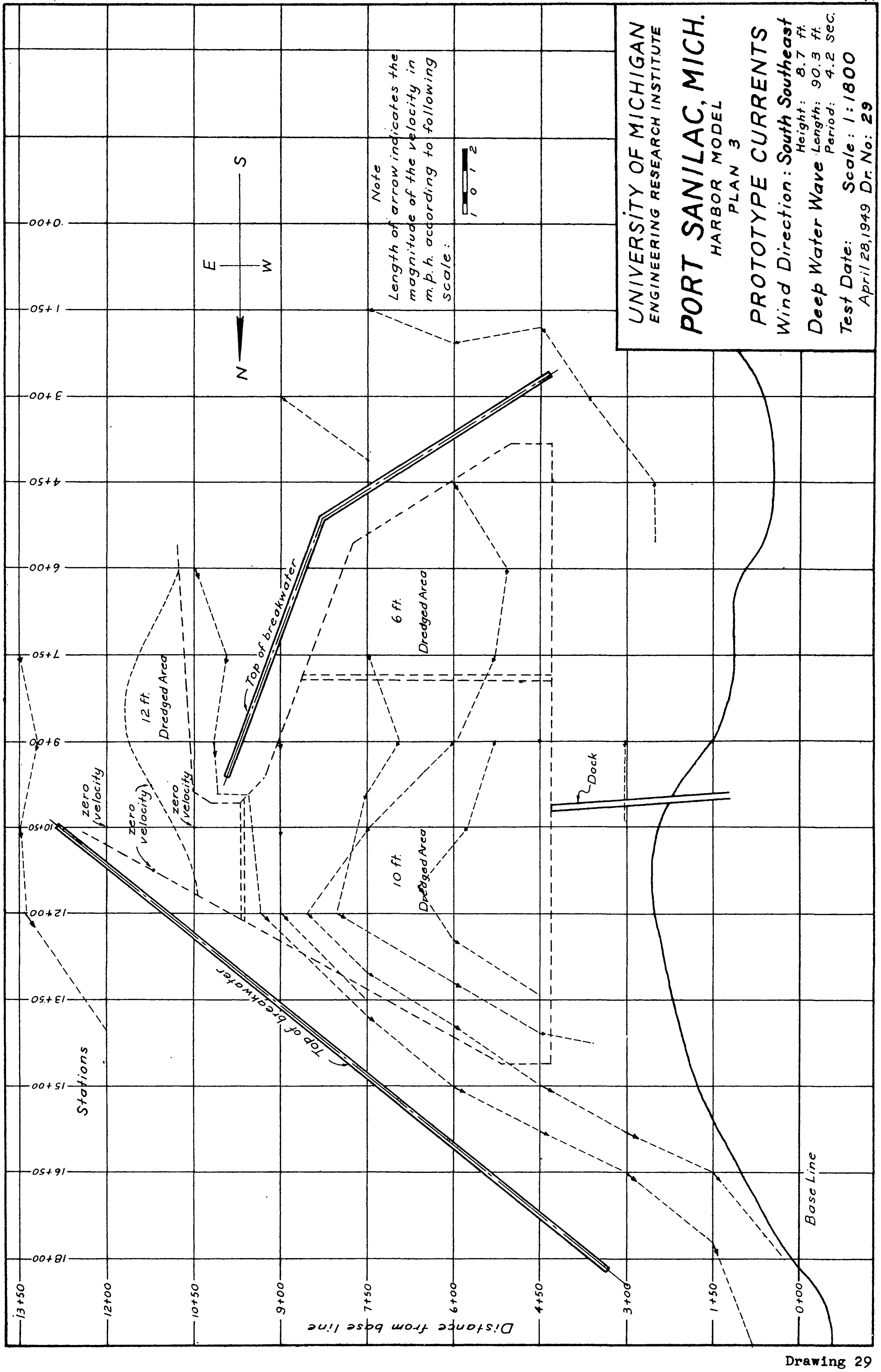
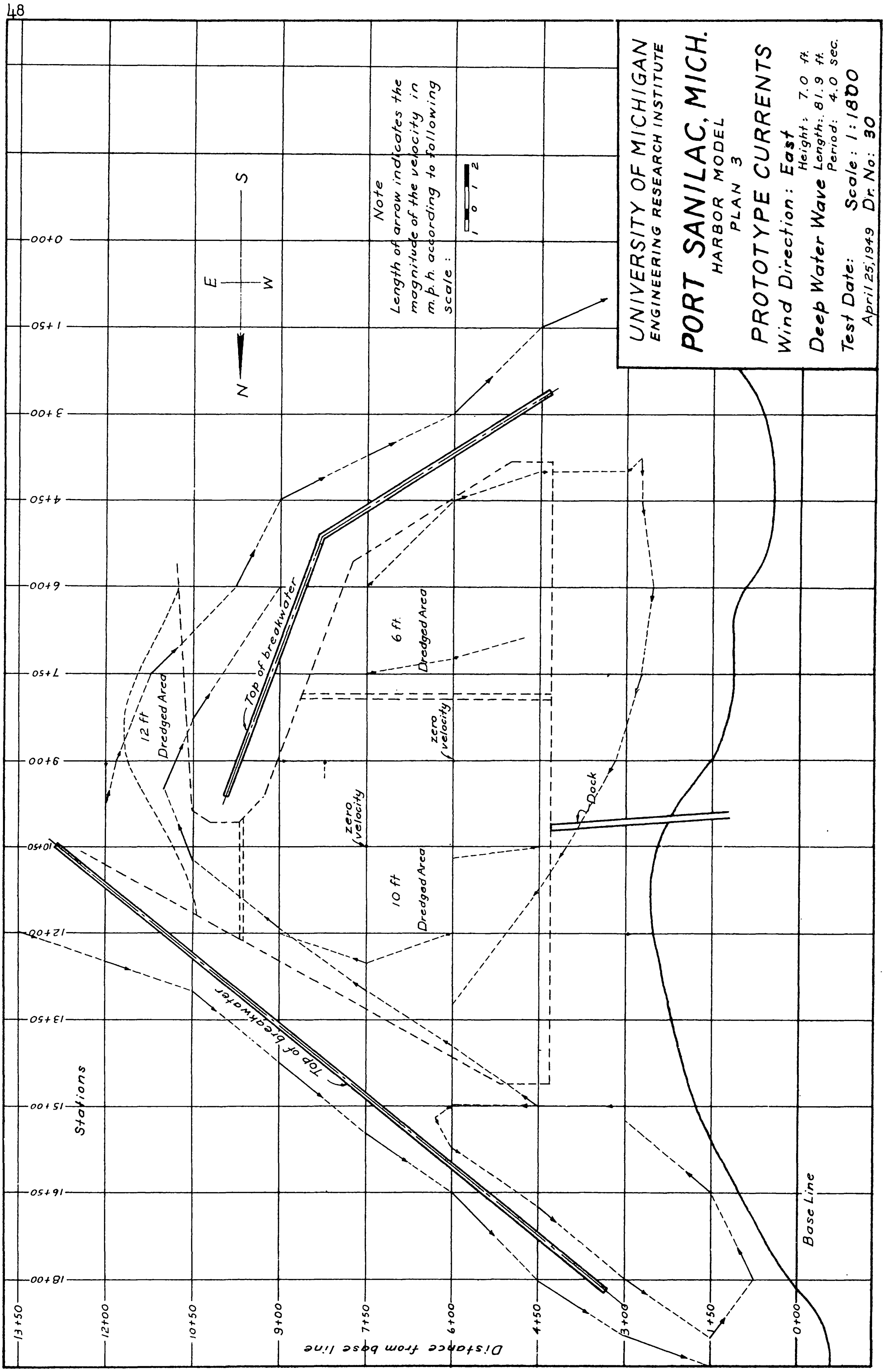
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 20, 1949
Scale: 1:1800
Dr. No: 28
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
12 ft. Dredged Area
6 ft. Dredged Area
10 ft. Dredged Area
Base Line
Stations
Distance from base line
N
S
E
W

Drawing 28


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE CURRENTS
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: April 28, 1949
Scale: 1:1800
Dr. No: 29
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
0 1 2
N
S
E
W
Top of breakwater
Top of breakwater
6 ft. Dredged Area
12 ft. Dredged Area
10 ft. Dredged Area
zero velocity
zero velocity
zero velocity
Dock
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00

Drawing 29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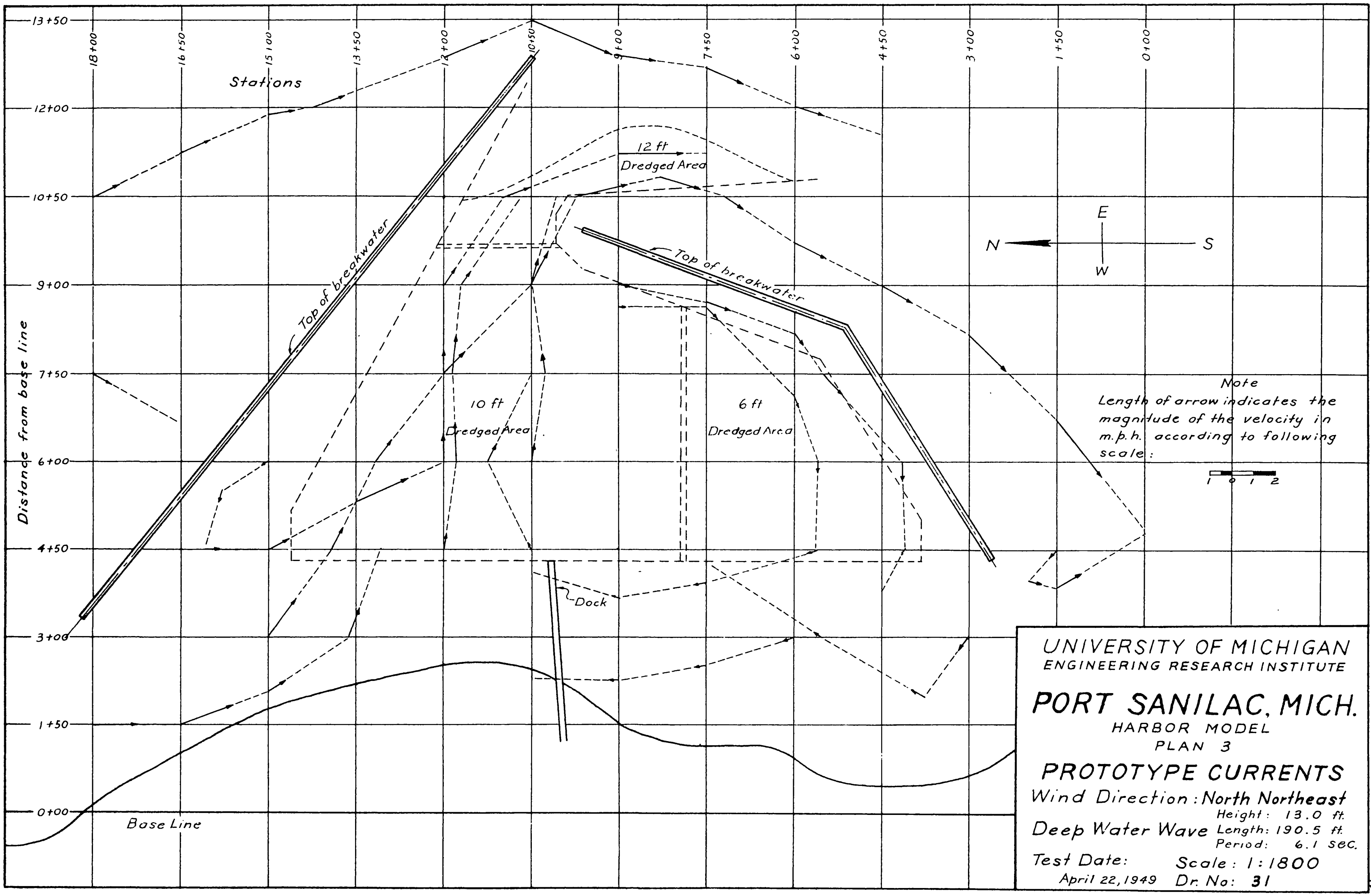
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE CURRENTS
Wind Direction: East
Deep Water Wave Height: 7.0 ft.
Length: 81.9 ft.
Period: 4.0 sec.
Test Date: April 25, 1949
Scale: 1:1800
Dr. No: 30
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
N
S
E
W
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
zero velocity
zero velocity
Dock
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 30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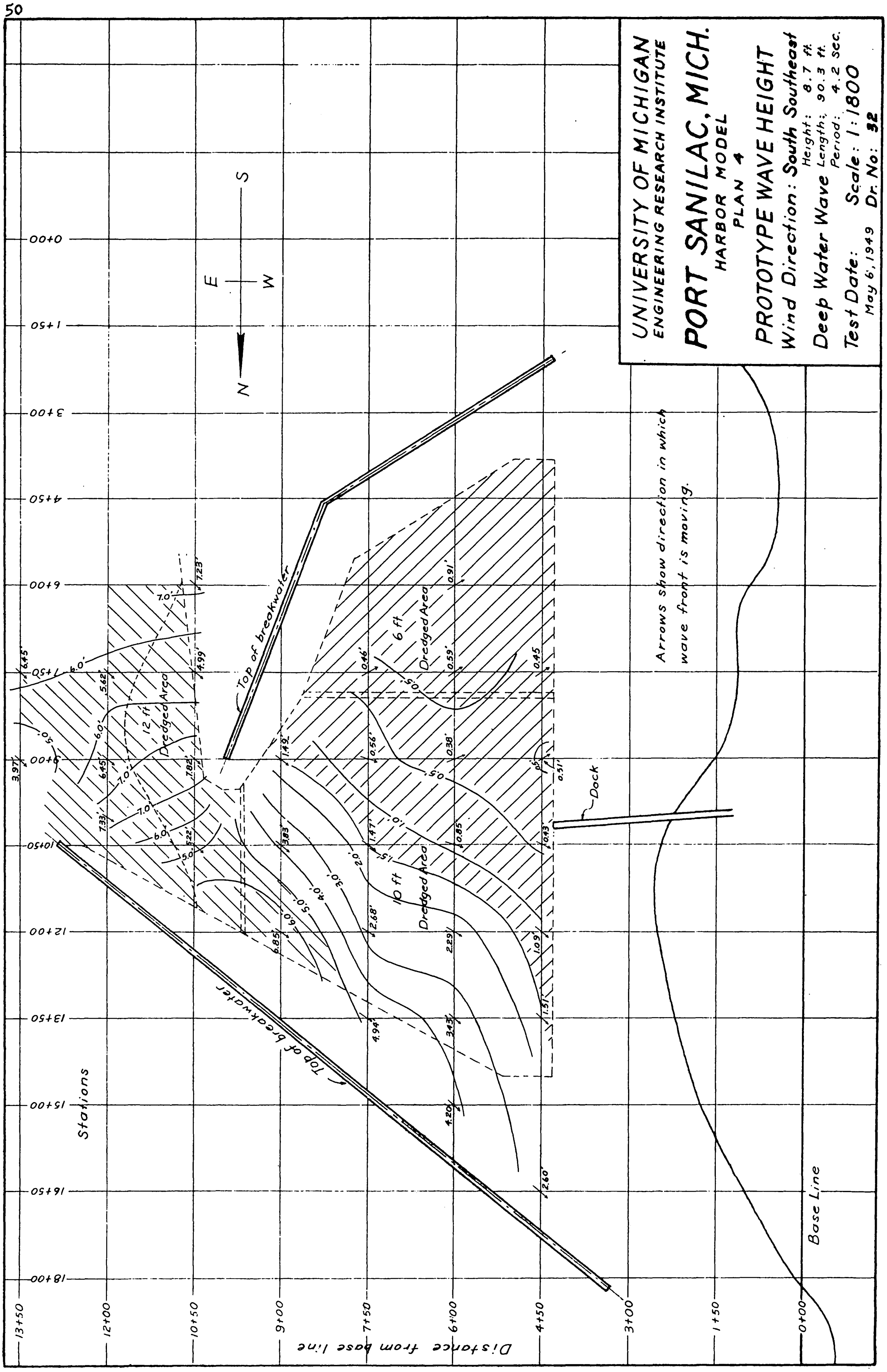
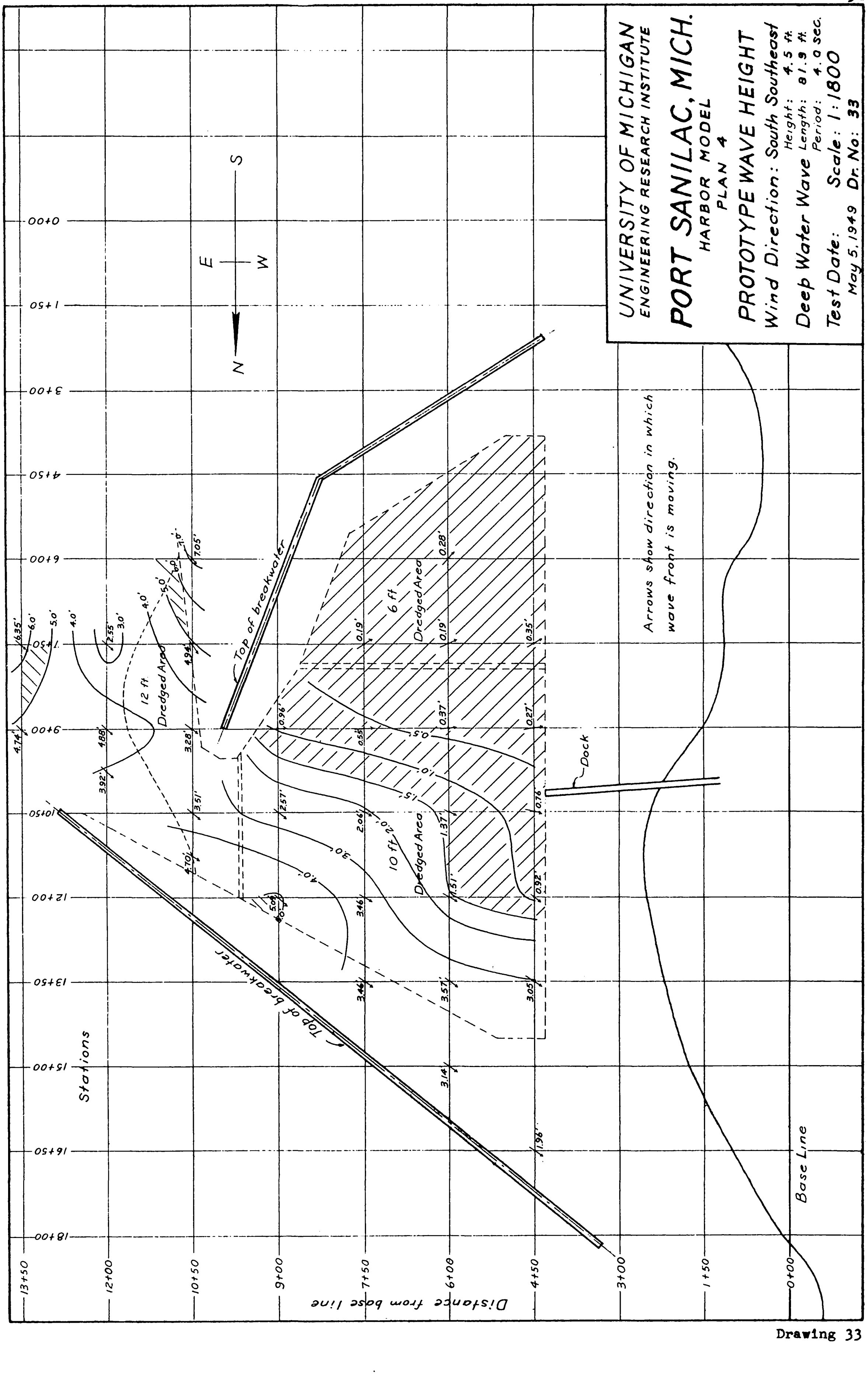
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE CURRENTS
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: April 22, 1949
Scale: 1:1800
Dr. No: 31
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
N
S
E
W
Stations
18+00
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
Distance from base line
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
Top of breakwater
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Base Line

Drawing 31


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 Sec.
Test Date: May 6, 1949
Scale: 1:1800
Dr. No: 32
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Base Line
Stations
Distance from base line

Drawing 32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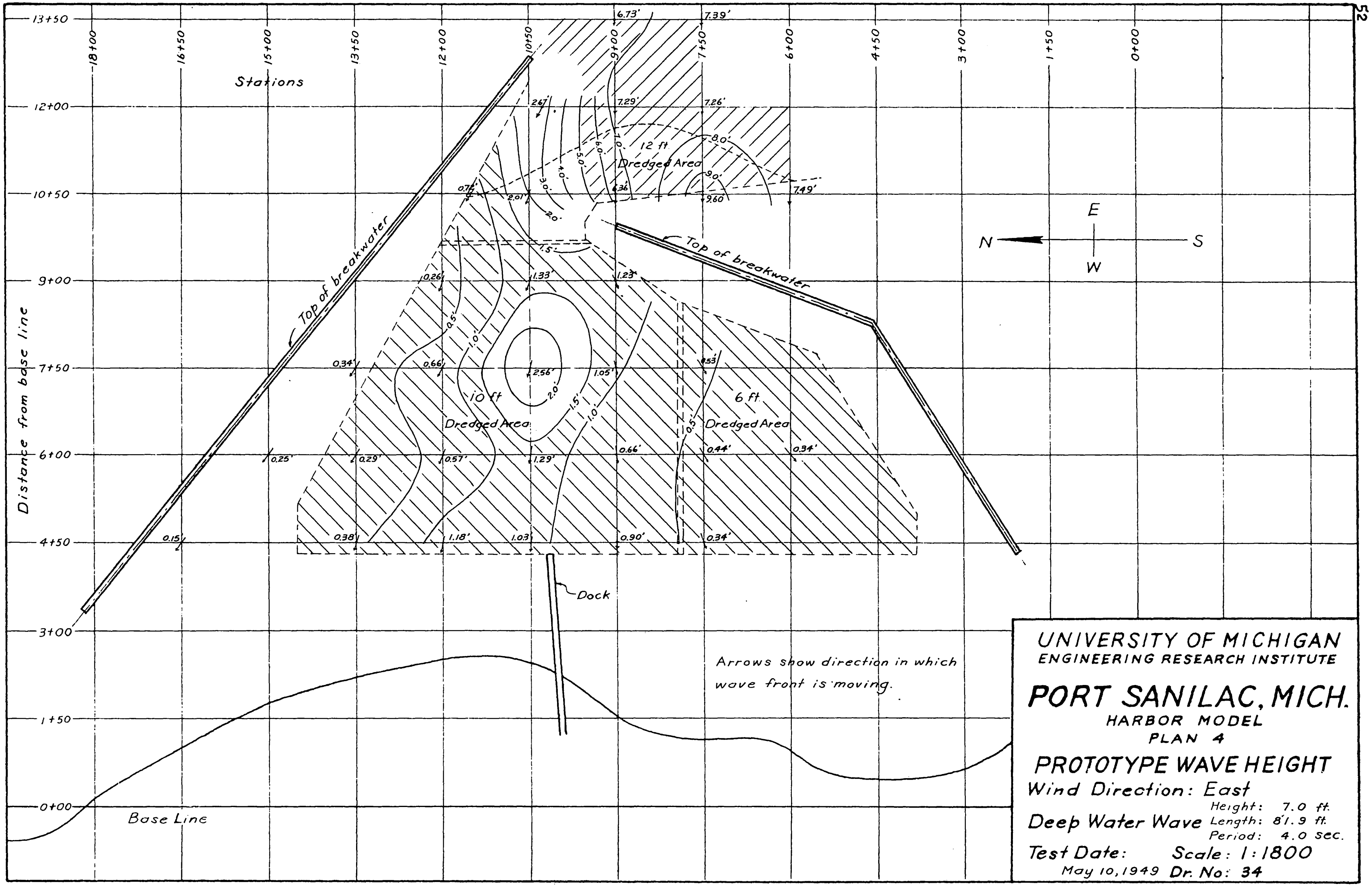
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: May 5, 1949
Scale: 1:1800
Dr. No: 33
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Stations
Distance from base line
Base Line
N
S
E
W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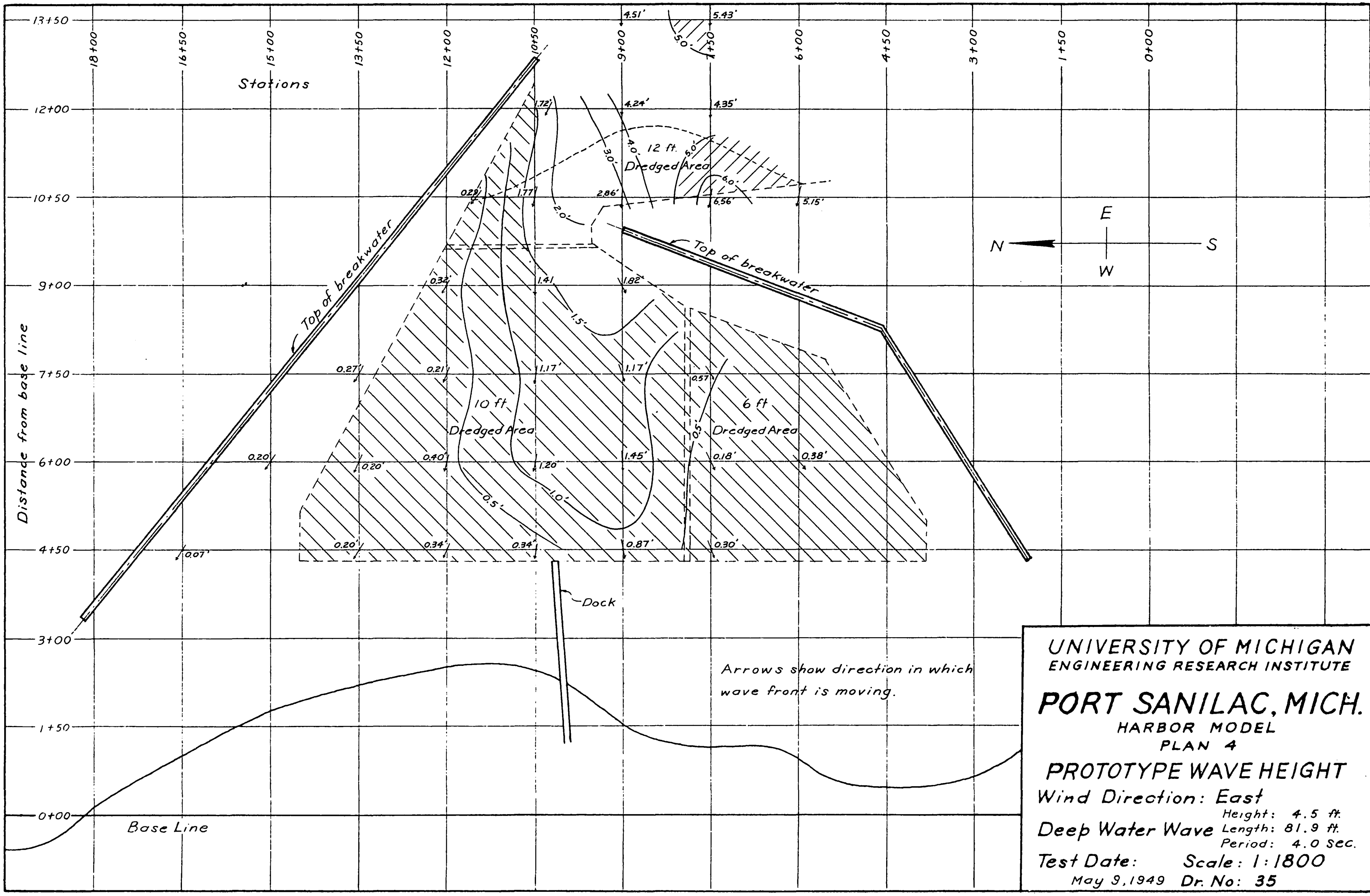
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 Sec.
Test Date: May 10, 1949
Scale: 1:1800
Dr. No: 34
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 34


UNIVERSITY OF MICHIGAN
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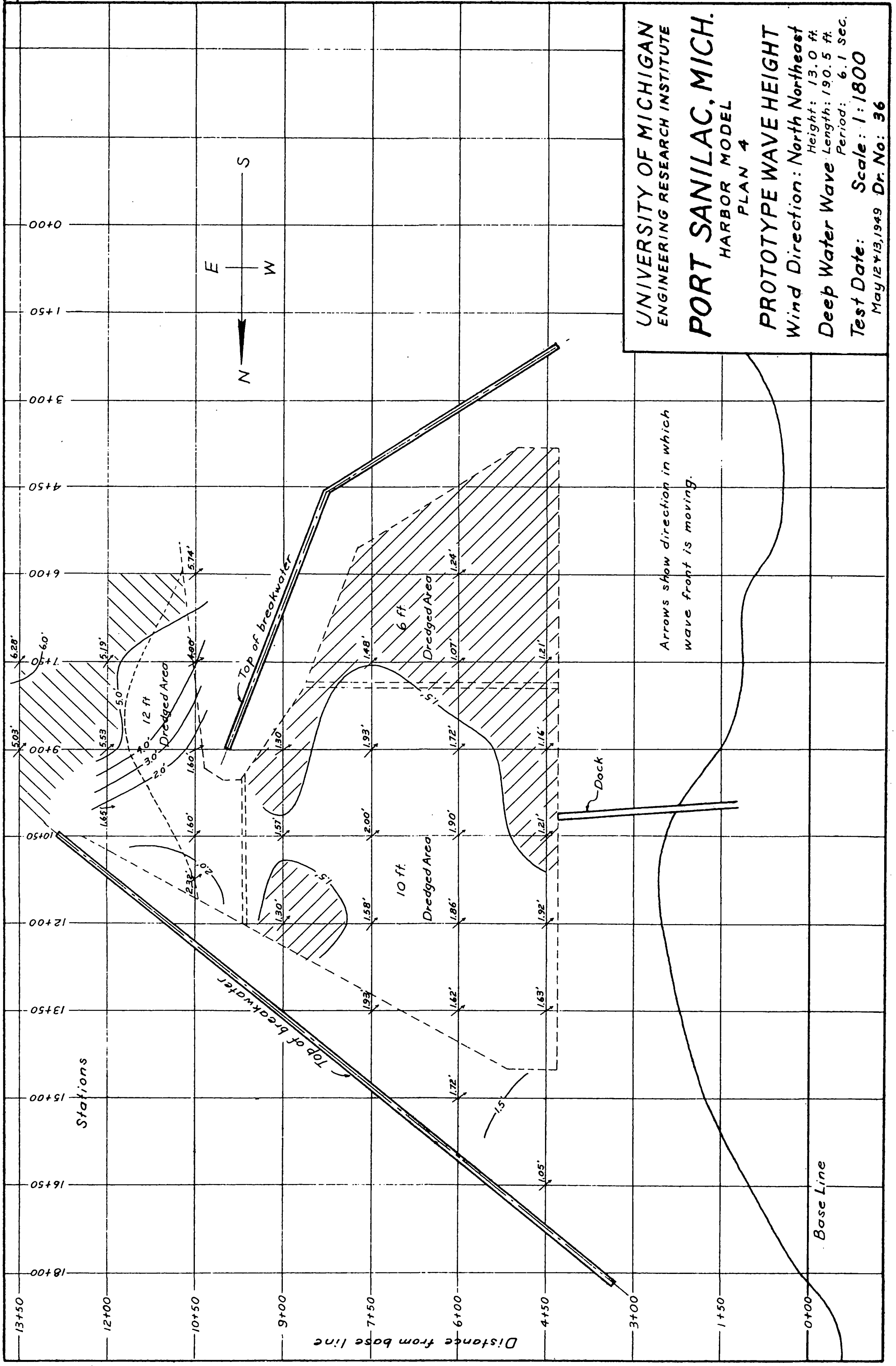
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 Sec.
Test Date: May 9, 1949
Scale: 1:1800
Dr. No: 35
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
Base Line
Stations
Distance from base line
12 ft. Dredged Area
10 ft Dredged Area
6 ft Dredged Area
N
S
E
W
18+00
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
4.51'
5.43'
4.24'
4.35'
1.72'
2.86'
6.56'
5.15'
0.29'
1.77'
0.32'
1.41
1.82'
0.27'
0.21'
1.17'
1.17'
0.57'
0.20'
0.20'
0.40'
1.20'
1.45'
0.18'
0.38'
0.07'
0.20'
0.34'
0.34'
0.87'
0.30'
5.0'
4.0'
3.0'
6.0'
2.0'
1.5'
1.0'
0.5'
.5'

Drawing 35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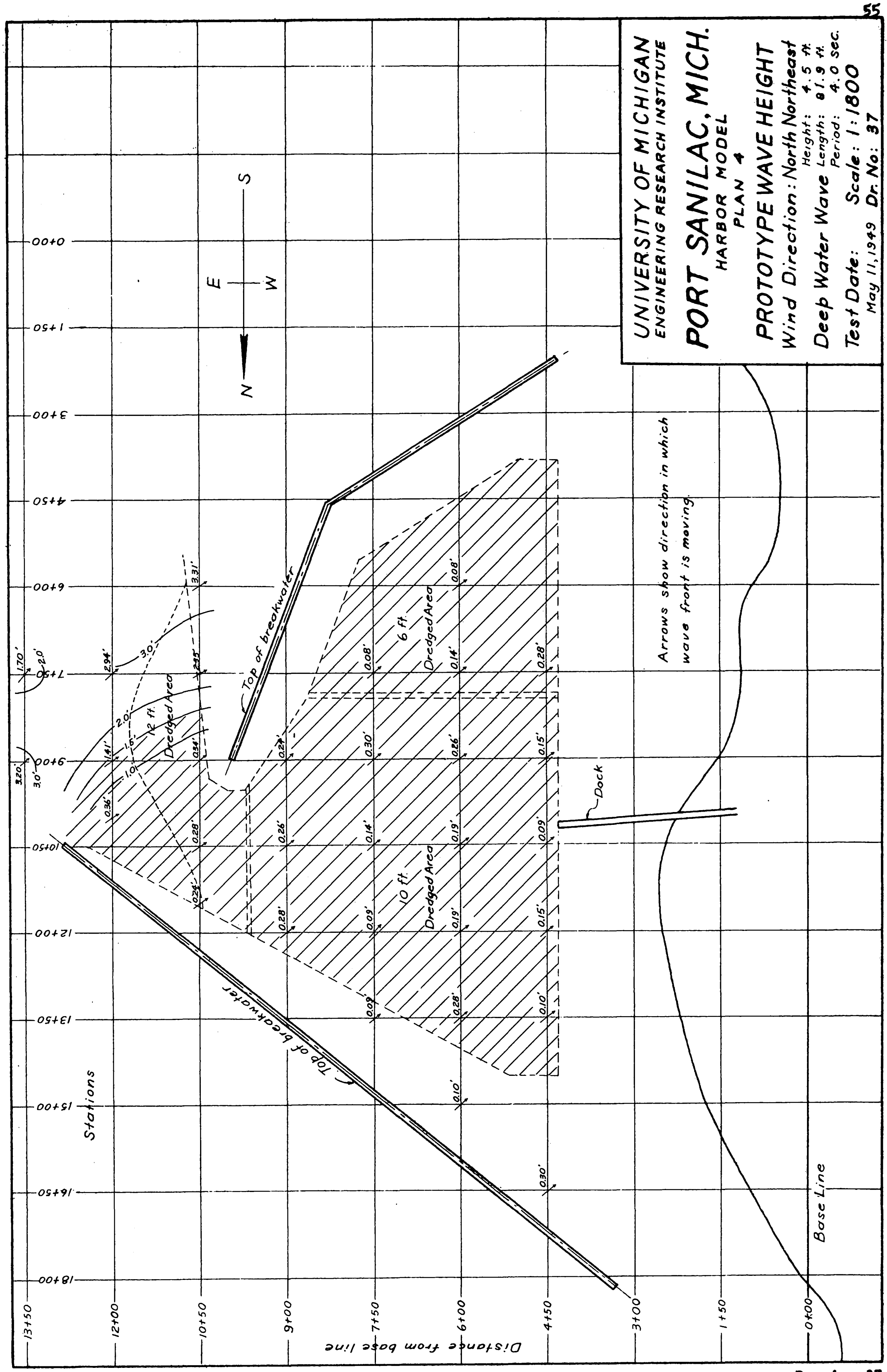
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: May 12 & 13, 1949
Scale: 1:1800
Dr. No: 36
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Stations
Base Line
Distance from base line
N
S
E
W
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 36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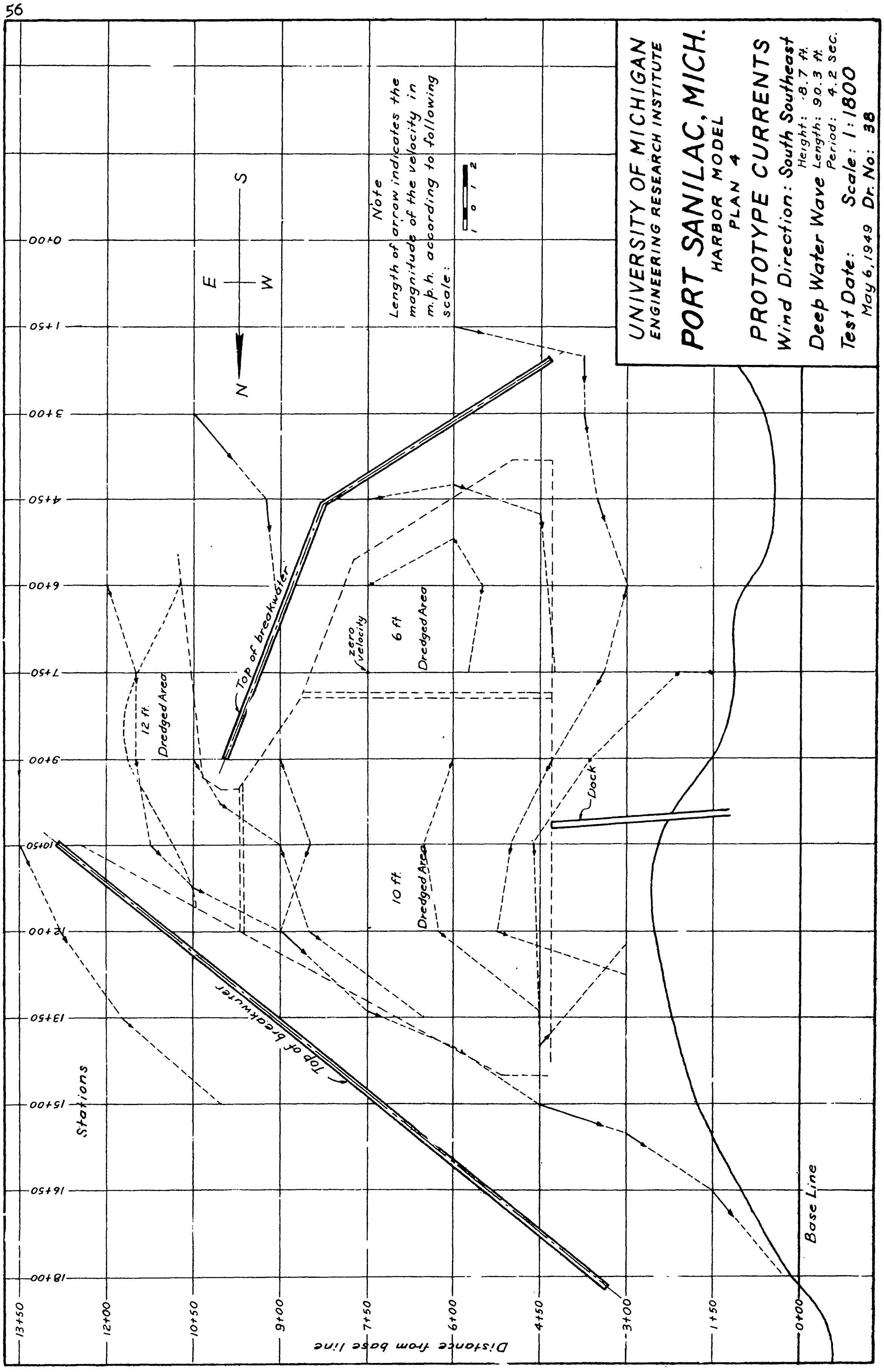
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 Sec.
Test Date: May 11, 1949
Scale: 1:1800
Dr. No: 37
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
6 ft. Dredged Area
10 ft. Dredged Area
12 ft. Dredged Area
Stations
Base Line
Distance from base line
N
S
E
W
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
0.08'
0.08'
0.14'
0.28'
0.30'
0.26'
0.15'
0.24'
0.14'
0.19'
0.09'
0.28'
0.26'
0.28'
0.09'
0.19'
0.15'
0.09'
0.28'
0.10'
0.10'
0.30'
0.36'
0.24'
0.34'
1.41'
2.94'
2.85'
3.31'
1.70'
3.20'
1.0
1.5
2.0
3.0'
2.0'
3.0'

Drawing 37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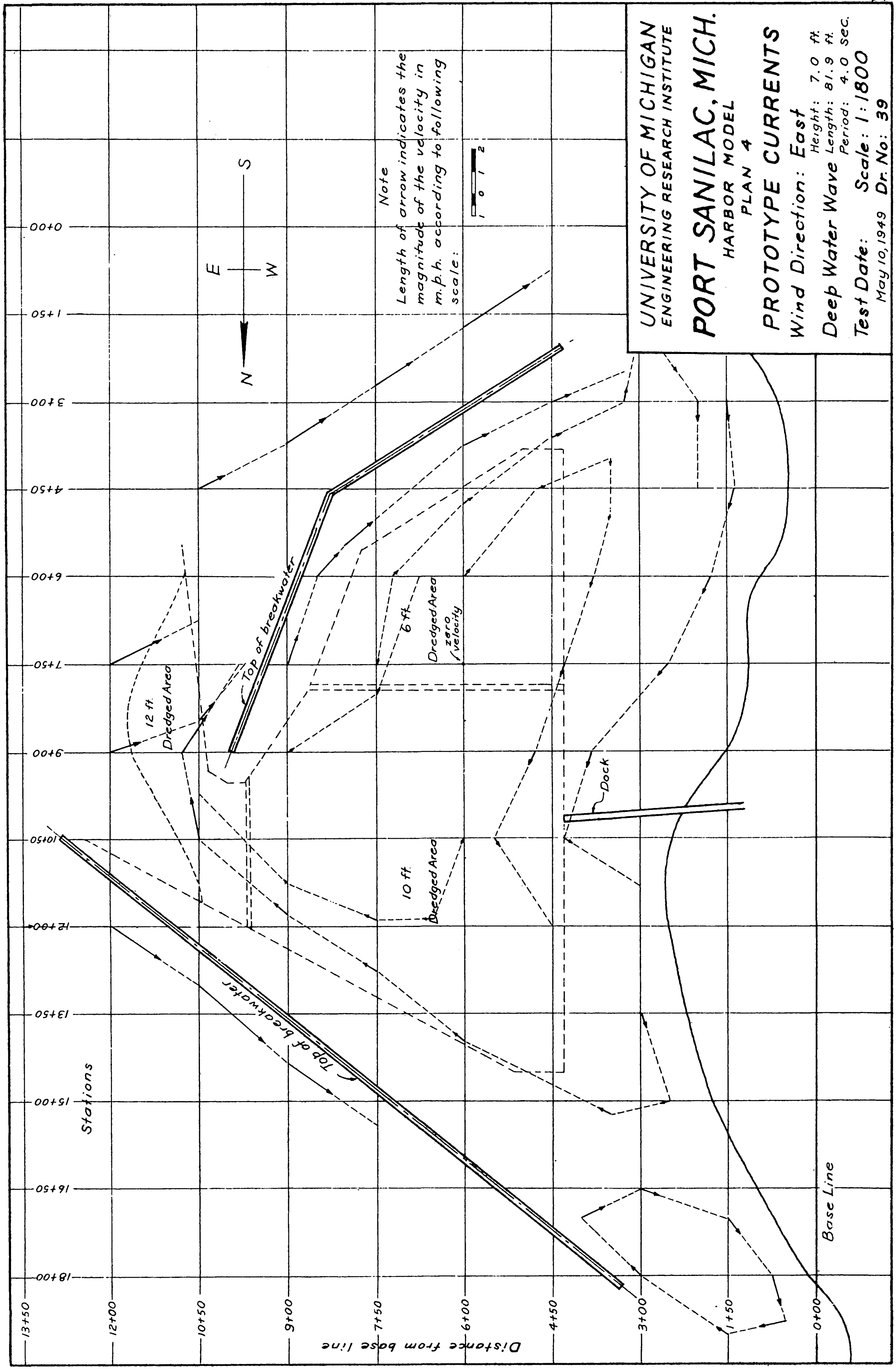
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE CURRENTS
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: May 6, 1949
Scale: 1:1800
Dr. No: 38
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
E
W
N
S
Top of breakwater
Top of breakwater
12 ft. Dredged Area
6 ft Dredged Area
zero velocity
10 ft. Dredged Area
Dock
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 38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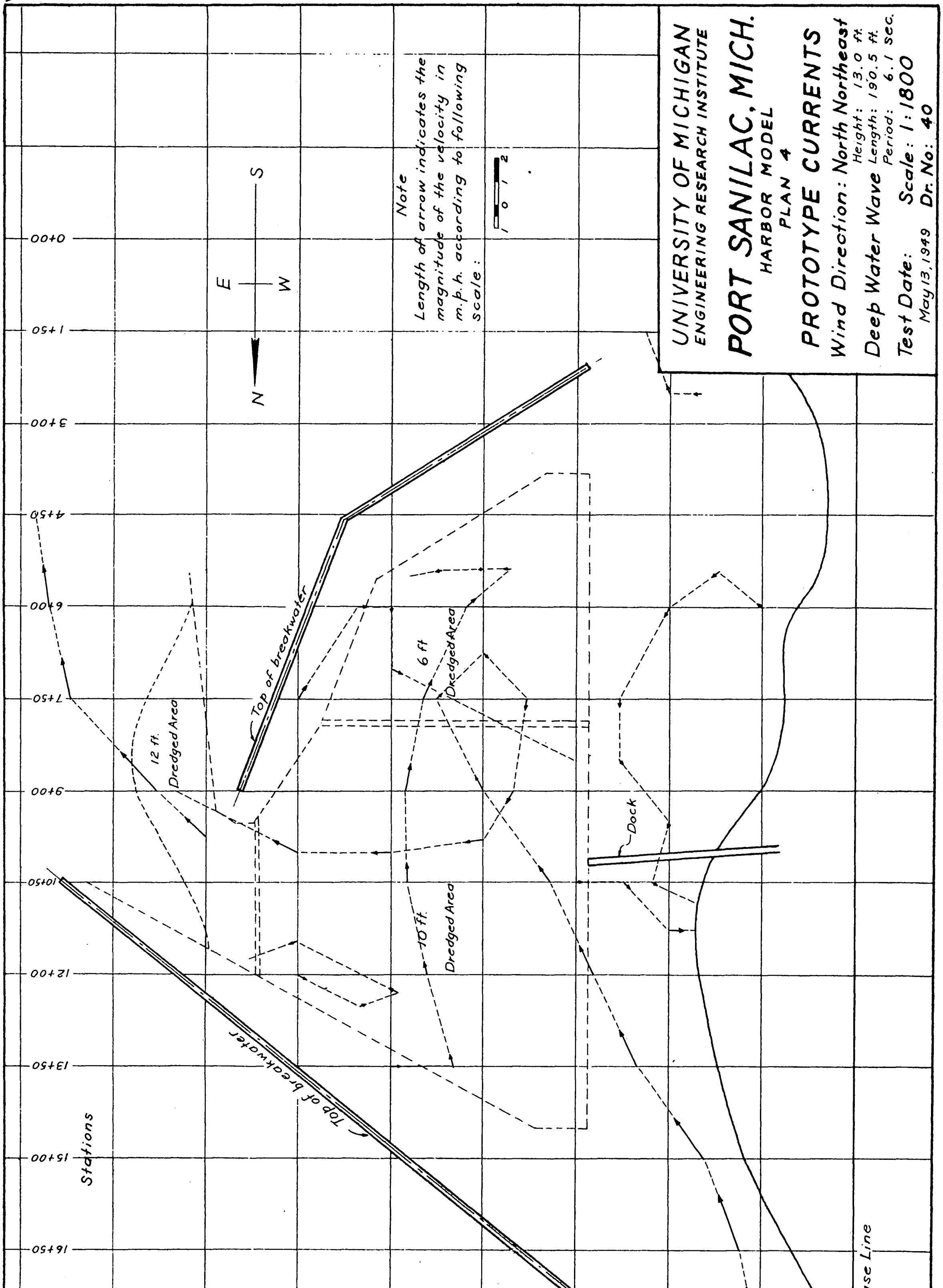
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE CURRENTS
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 Sec.
Test Date: May 10, 1949
Scale: 1:1800
Dr. No: 39
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
0 1 2
N
S
E
W
Top of breakwater
Top of breakwater
12 ft. Dredged Area
6 ft. Dredged Area zero velocity
10 ft. Dredged Area
Dock
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00

Drawing 39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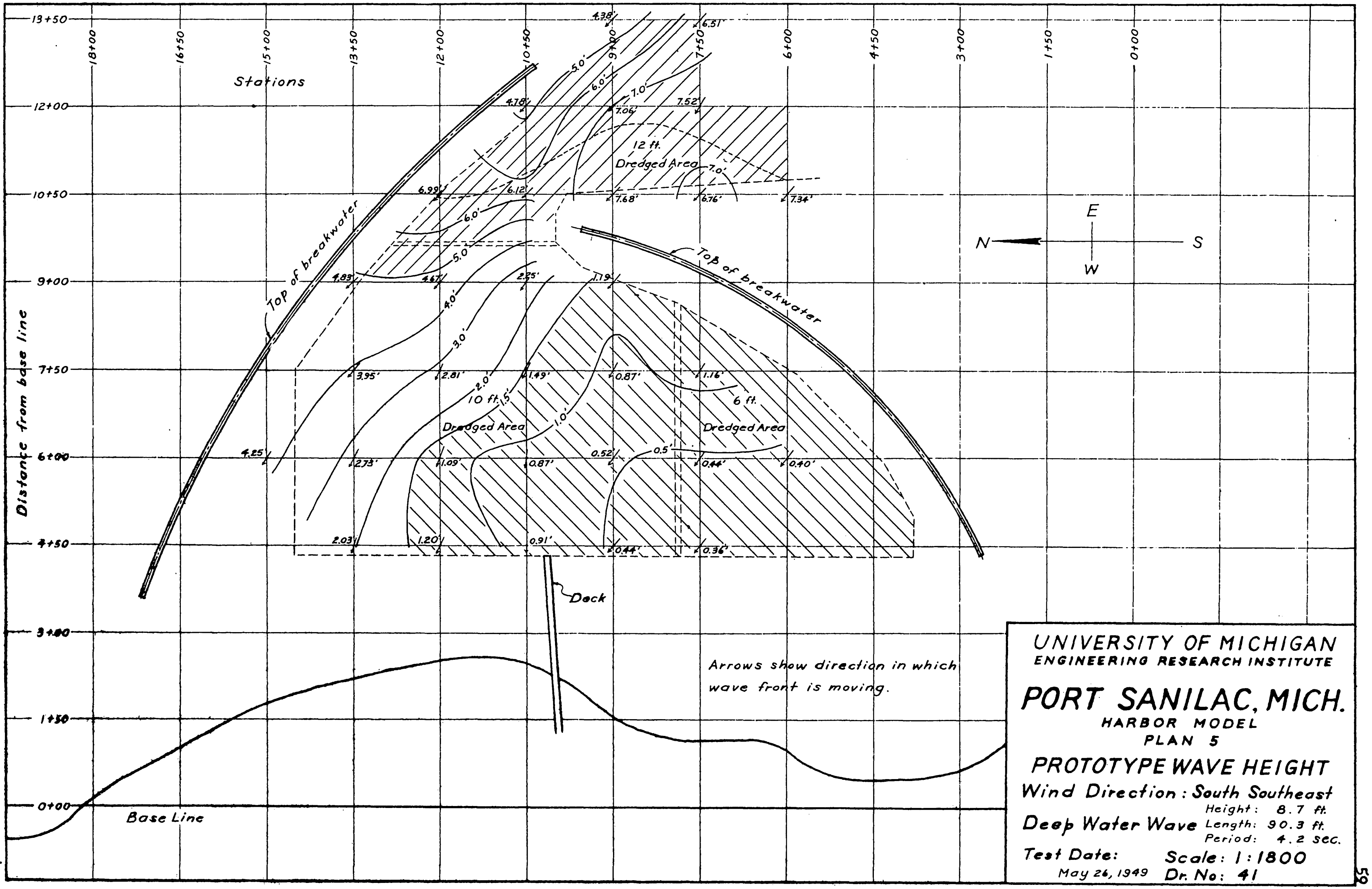
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE CURRENTS
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 Sec.
Test Date: May 13, 1949
Scale: 1:1800
Dr. No: 40
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
0 1 2
N
S
E
W
Top of breakwater
Top of breakwater
12 ft. Dredged Area
6 ft. Dredged Area
10 ft. Dredged Area
Dock
Base Line
Stations
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50

Drawing 40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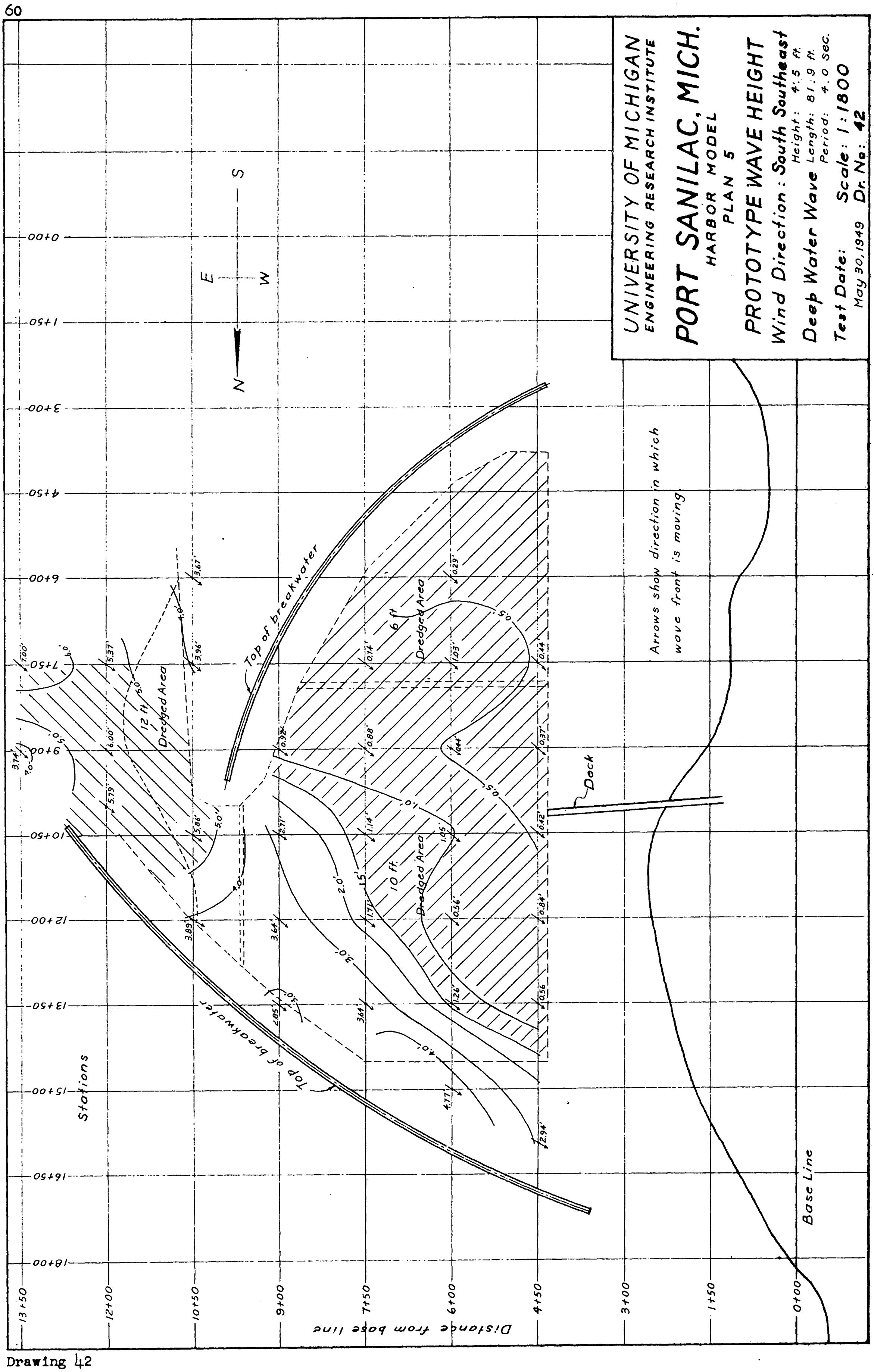
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: May 26, 1949
Scale: 1:1800
Dr. No: 41
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Dock
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 41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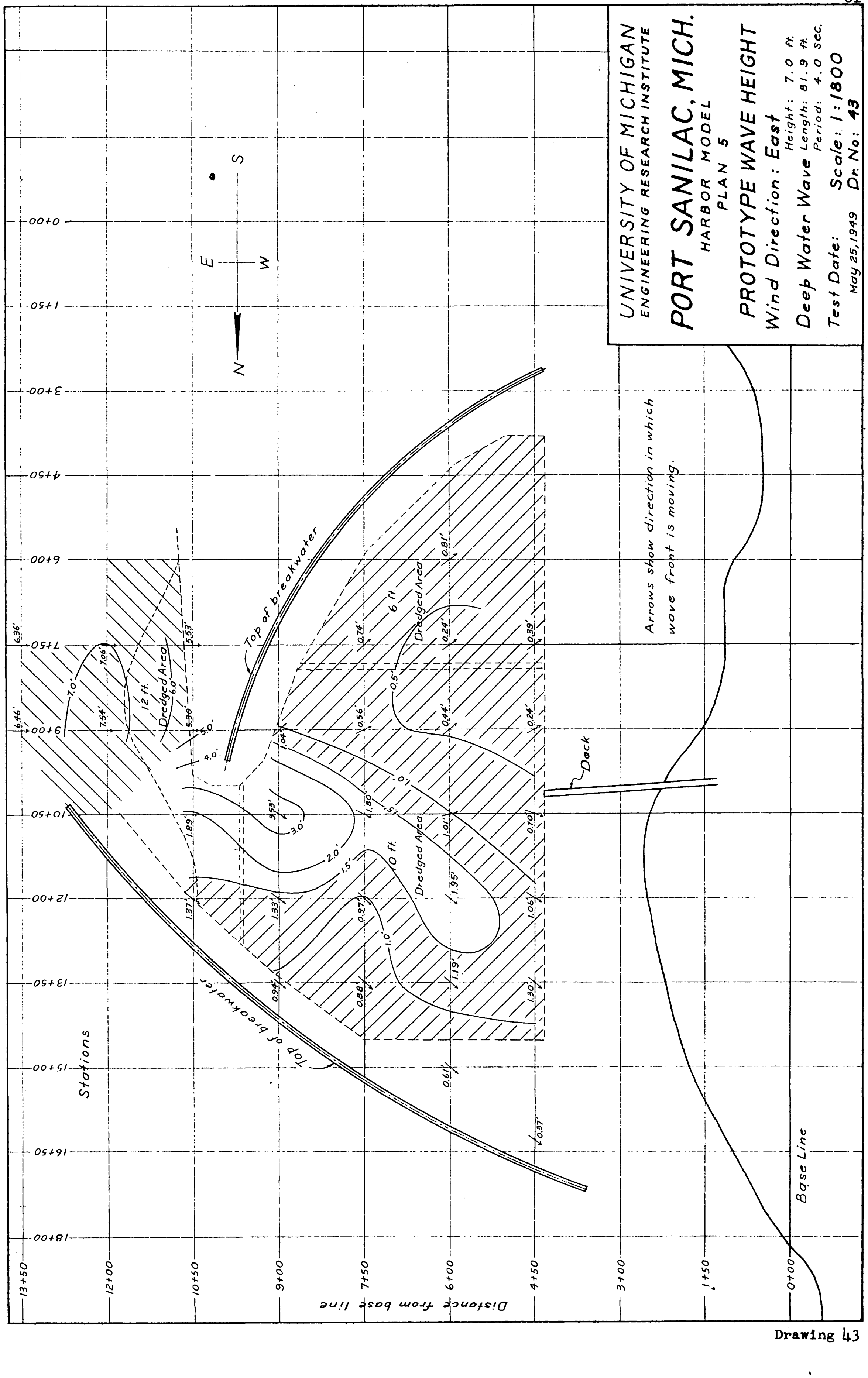
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave
Height: 4.5 ft.
Length: 81.9 ft.
Period: 4.0 Sec.
Test Date:
May 30, 1949
Scale: 1:1800
Dr. No. 42
Arrows show direction in which wave front is moving
Top of breakwater
Top of breakwater
Dock
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Stations
Base Line
Distance from base line

Drawing 42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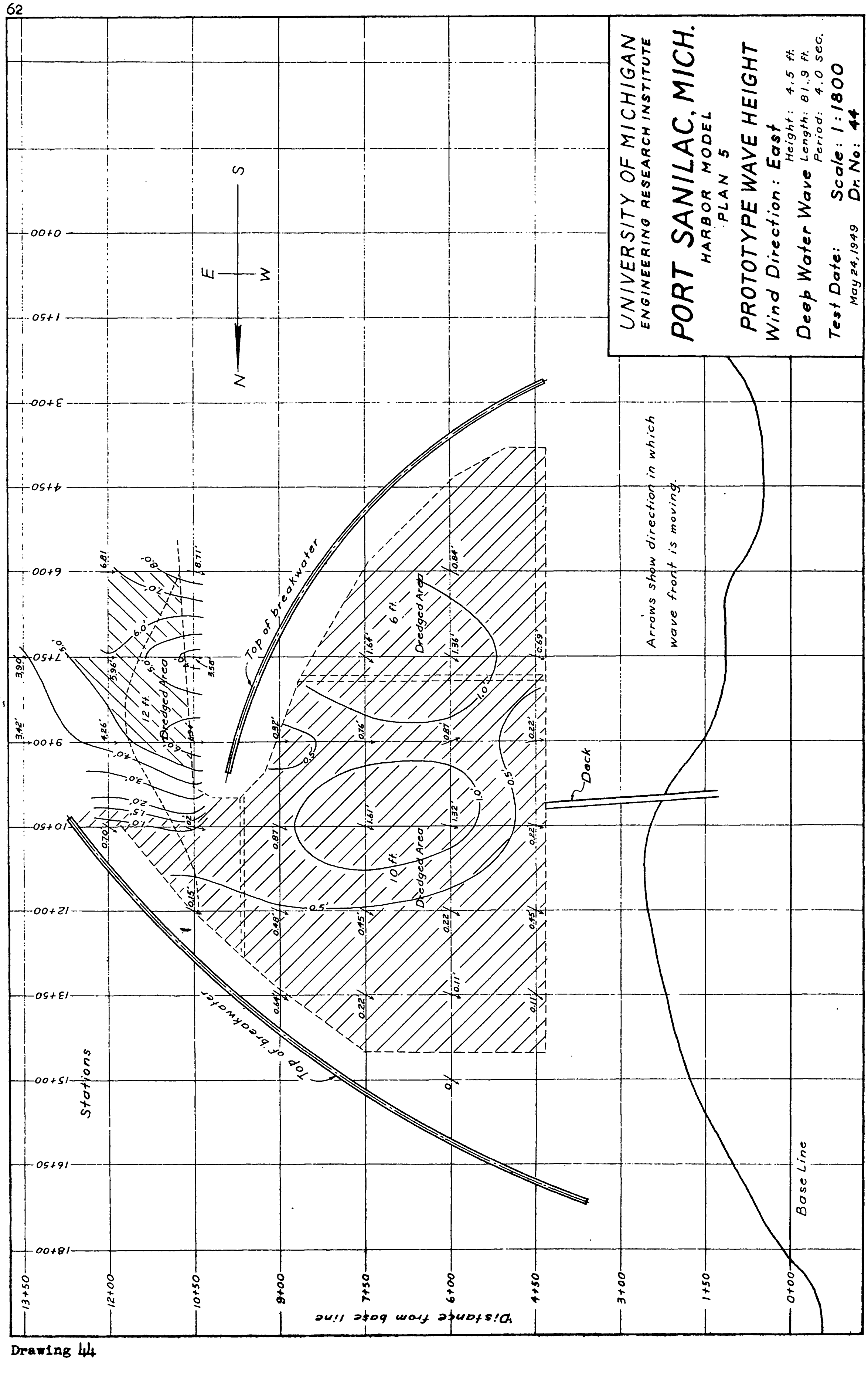
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 Sec.
Test Date: May 25, 1949
Scale: 1:1800
Dr. No: 43
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
12 ft. Dredged Area
6 ft. Dredged Area
10 ft. Dredged Area
Stations
Distance from base line
Base Line
N
S
E
W

Drawing 43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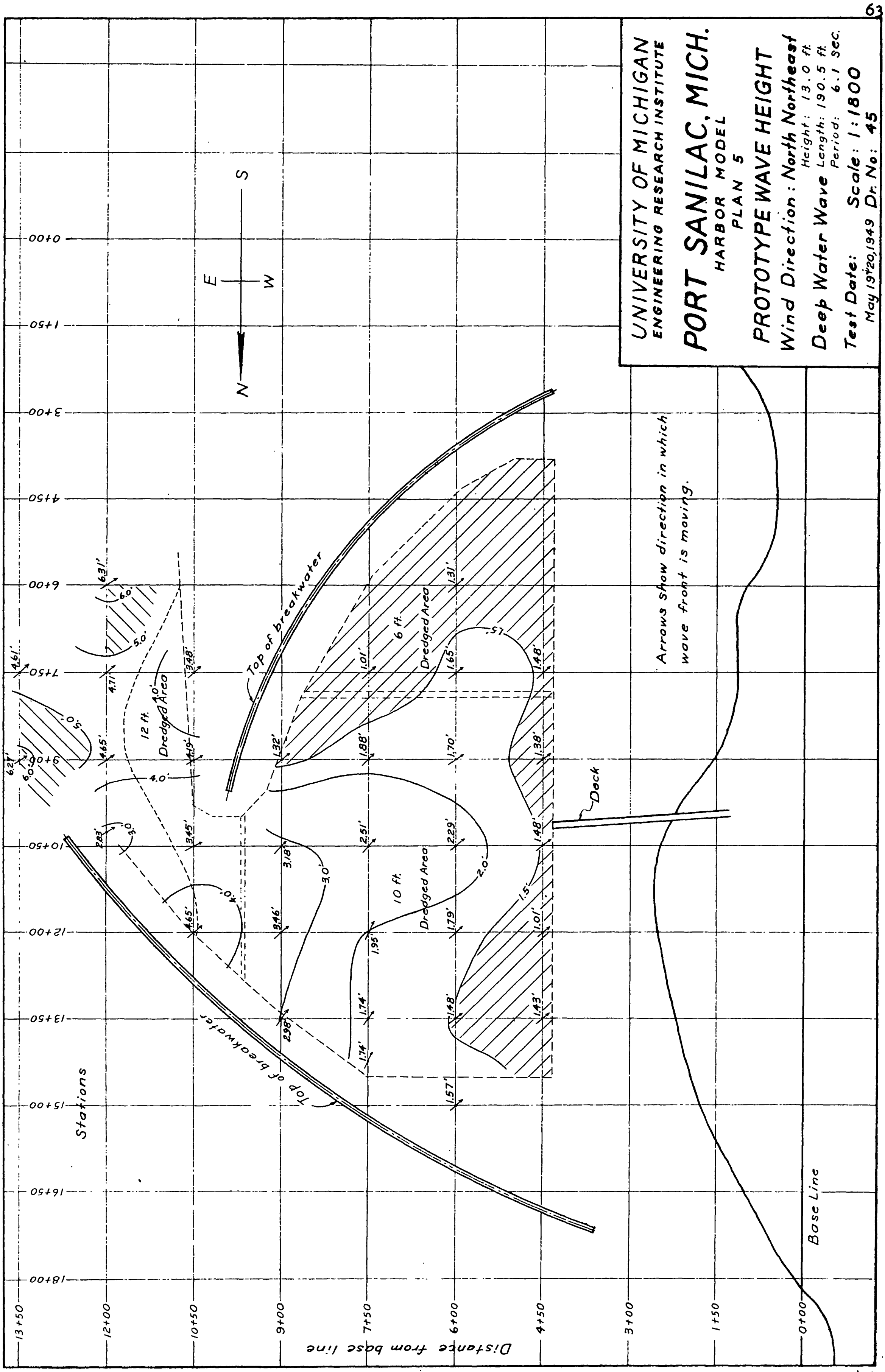
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: May 24, 1949
Scale: 1:1800
Dr. No: 44
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dredged Area
Dredged Area
Dredged Area
12 ft.
6 ft.
10 ft.
Dock
Stations
Base Line
Distance from base line

Drawing 44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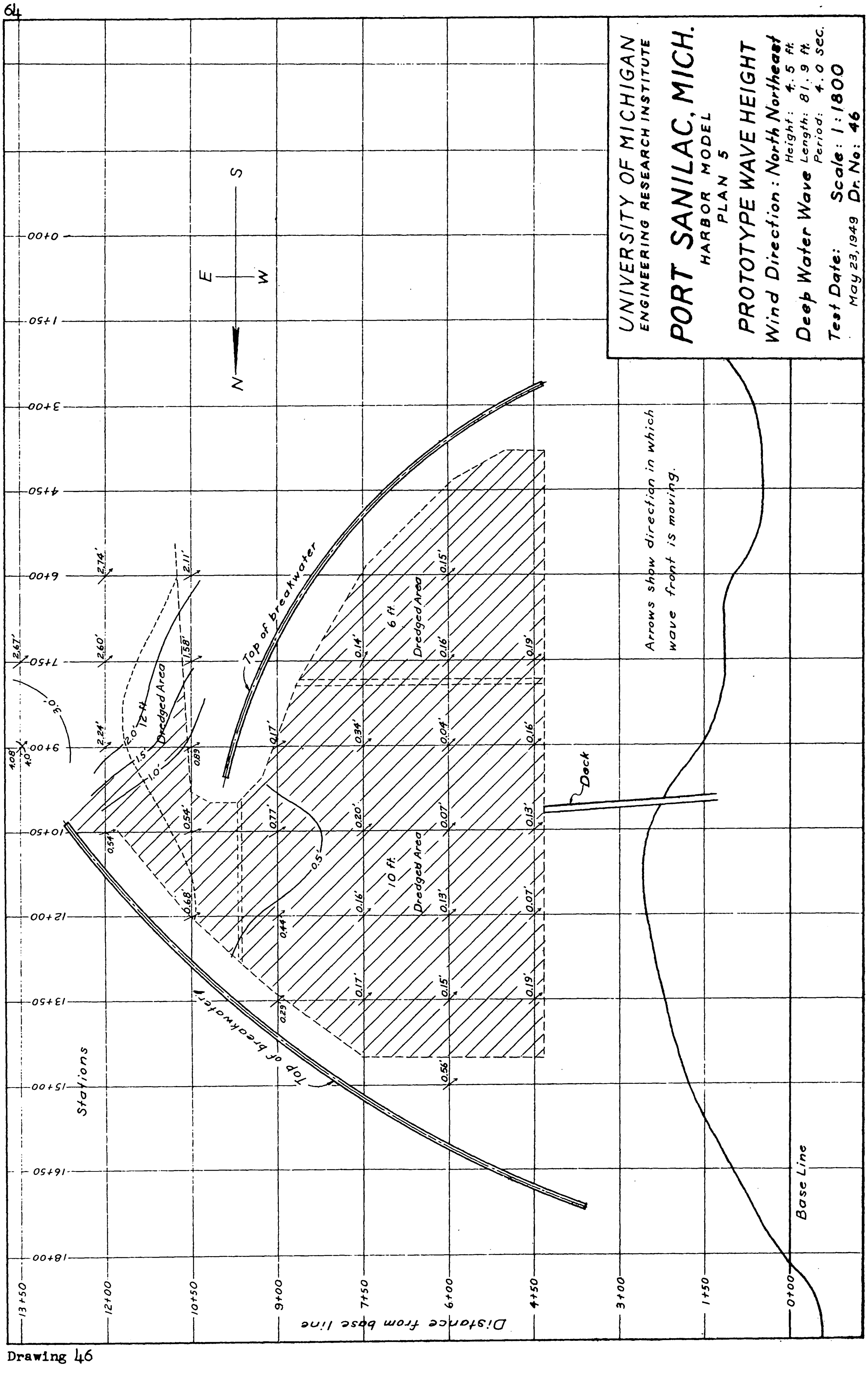
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft.
Length: 190.5 ft.
Period: 6.1 Sec.
Test Date: May 19 & 20, 1949
Scale: 1:1800
Dr. No: 45
Arrows show direction in which wave front is moving.
Top of breakwater
Dredged Area
6 ft.
10 ft.
12 ft.
Dock
Stations
Base Line
Distance from base line
N
S
E
W

Drawing 45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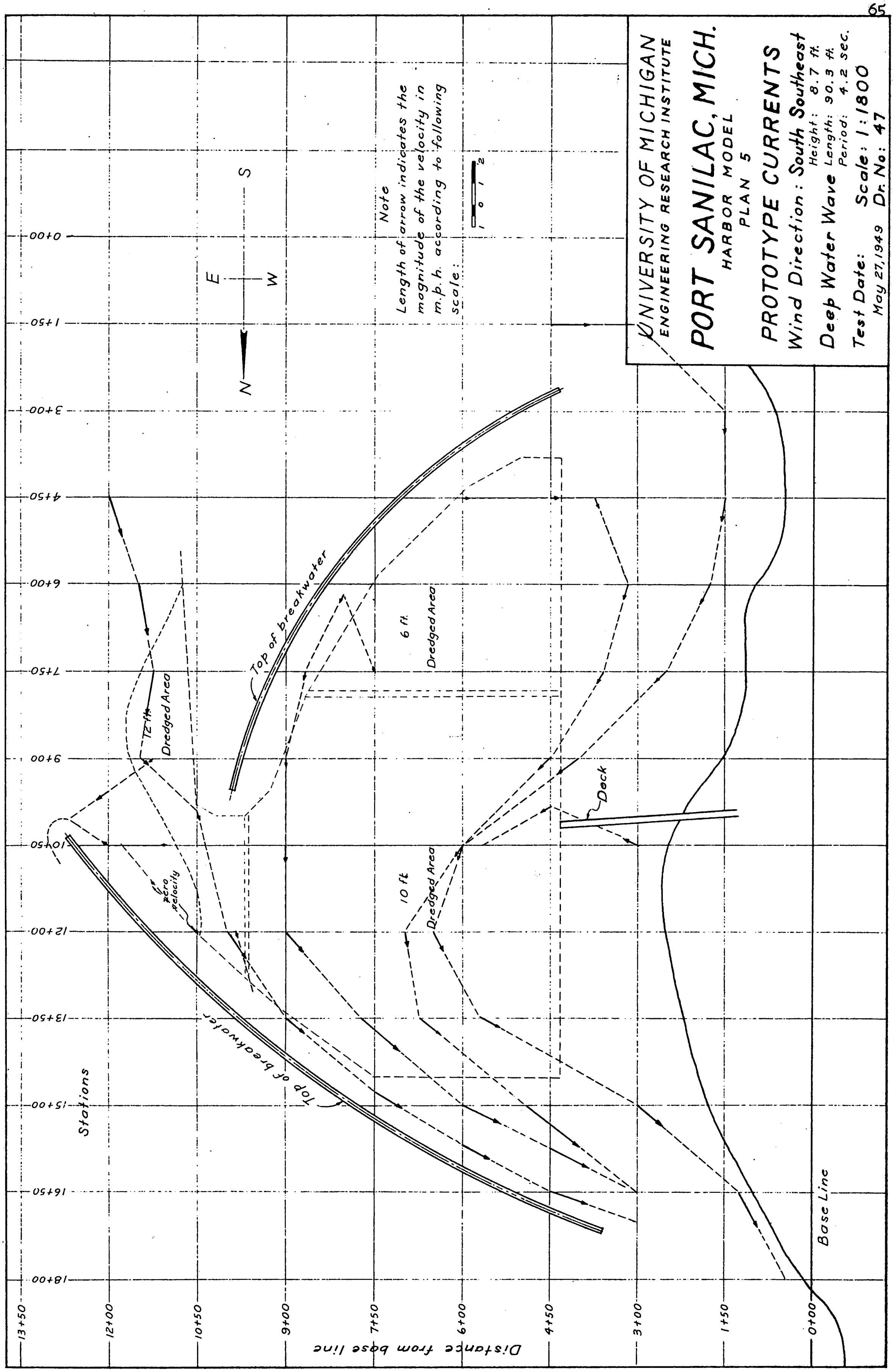
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: May 23, 1949
Scale: 1:1800
Dr. No: 46
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dredged Area 12 ft
6 ft. Dredged Area
10 ft. Dredged Area
Dock
Base Line
Stations
Distance from base line
N
S
E
W

Drawing 46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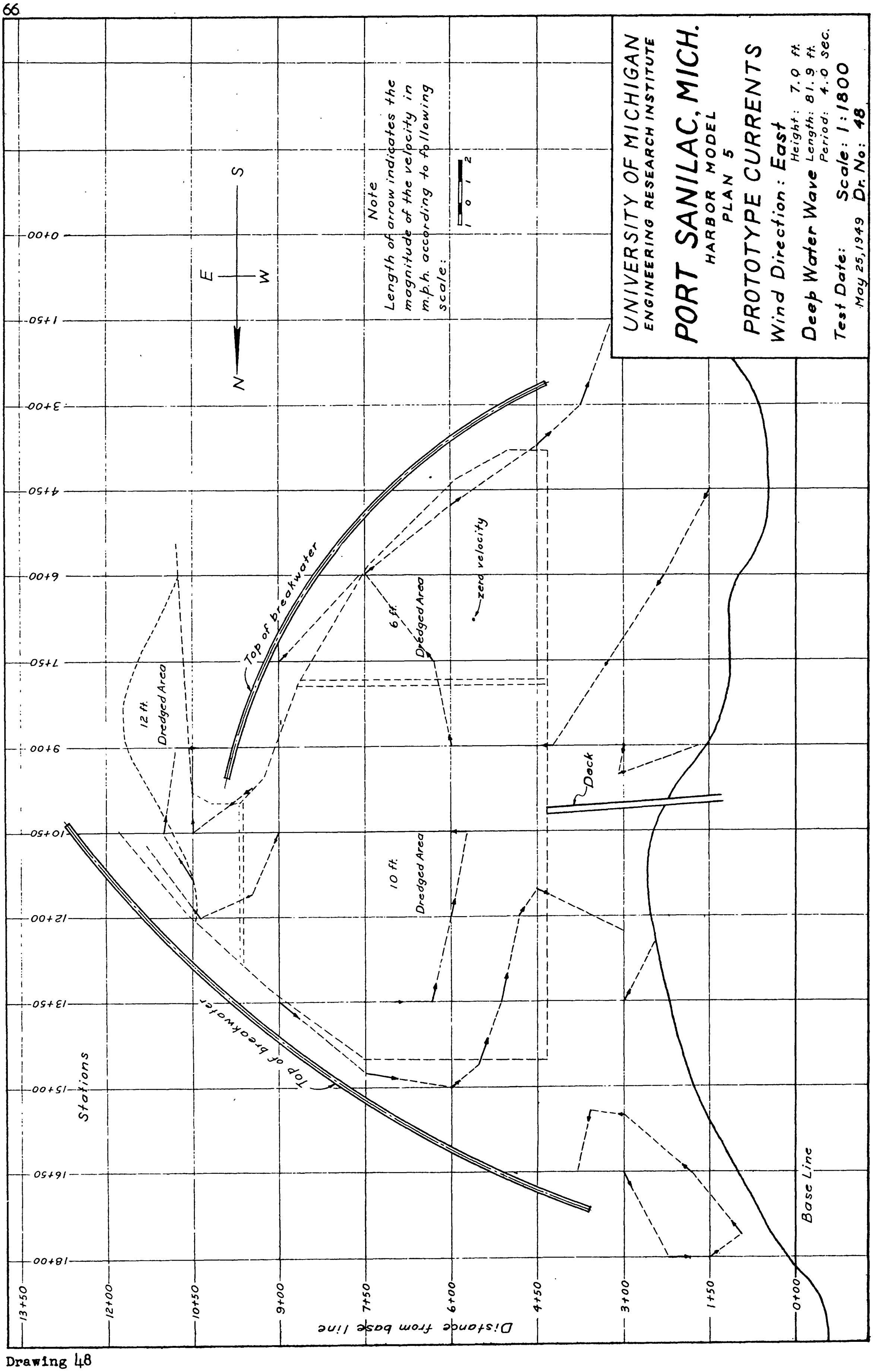
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE CURRENTS
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: May 27, 1949
Scale: 1:1800
Dr. No: 47
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
0 1 2
N
S
E
W
Top of breakwater
Top of breakwater
6 ft. Dredged Area
10 ft. Dredged Area
12 ft. Dredged Area
zero velocity
Dock
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00

Drawing 47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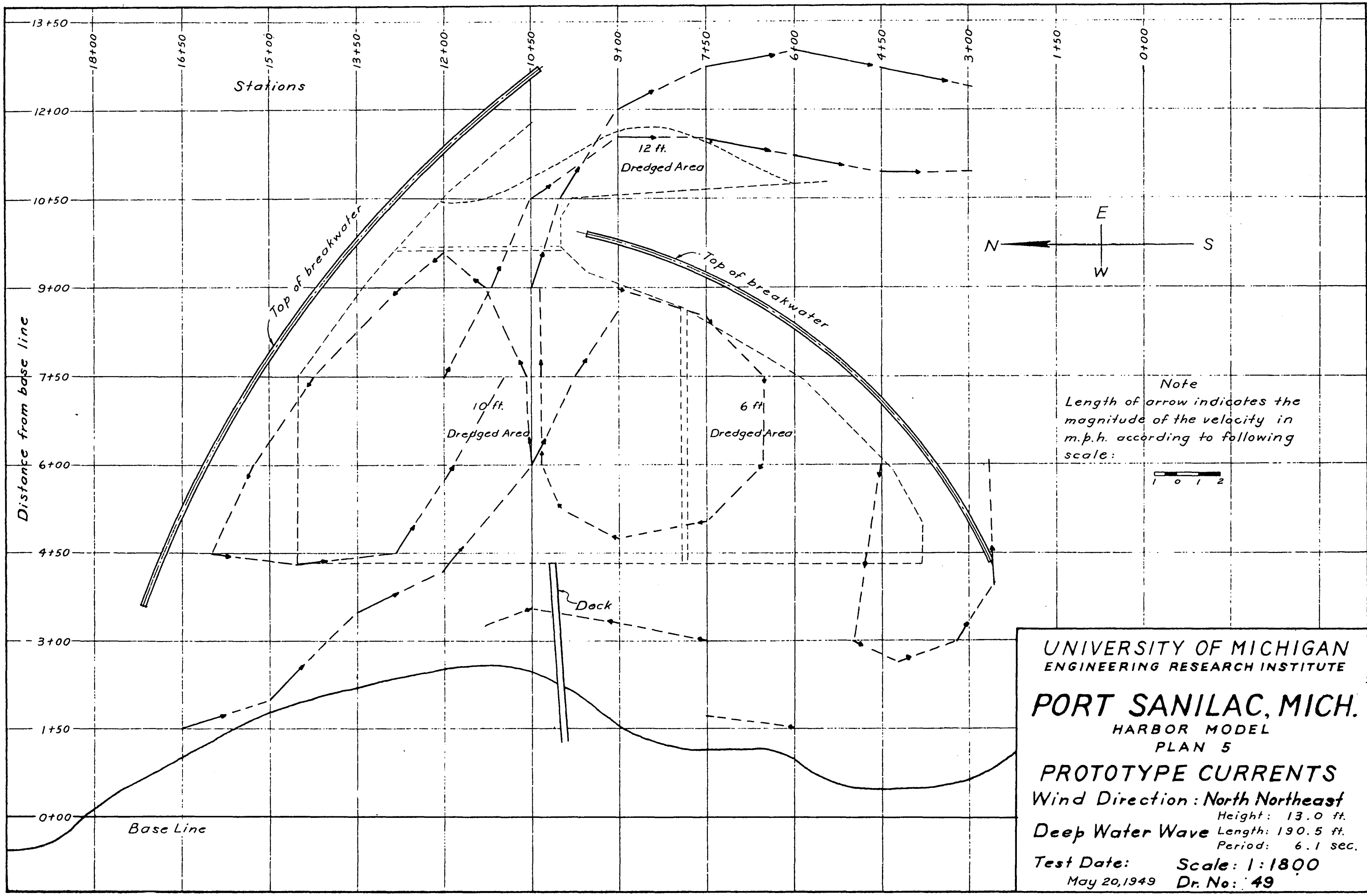
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE CURRENTS
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 Sec.
Test Date: May 25, 1949
Scale: 1:1800
Dr. No: 48
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
0 1 2
N
E W
S
Top of breakwater
Top of breakwater
6 ft. Dredged Area
zero velocity
12 ft. Dredged Area
10 ft. Dredged Area
Dock
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 48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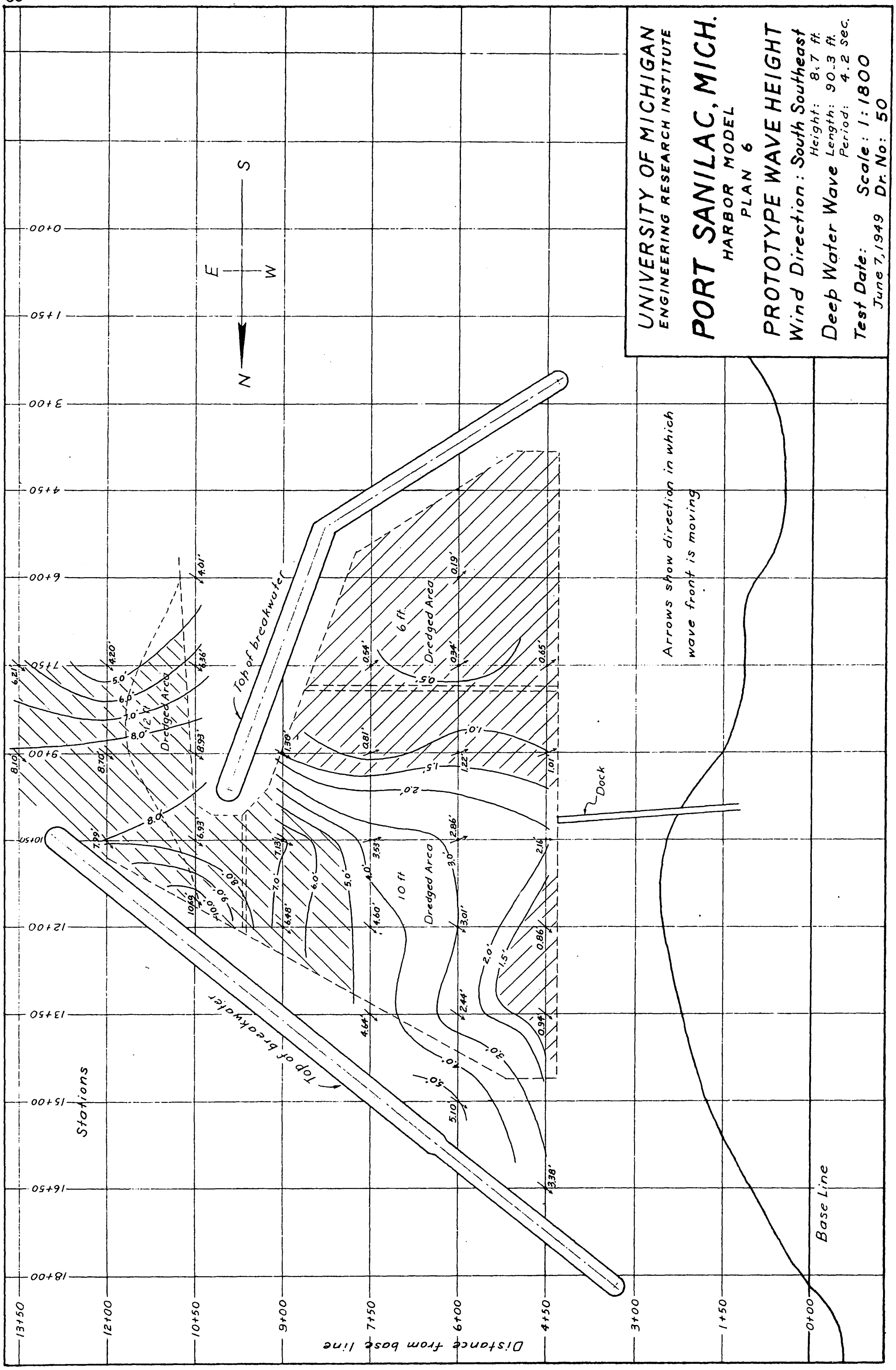
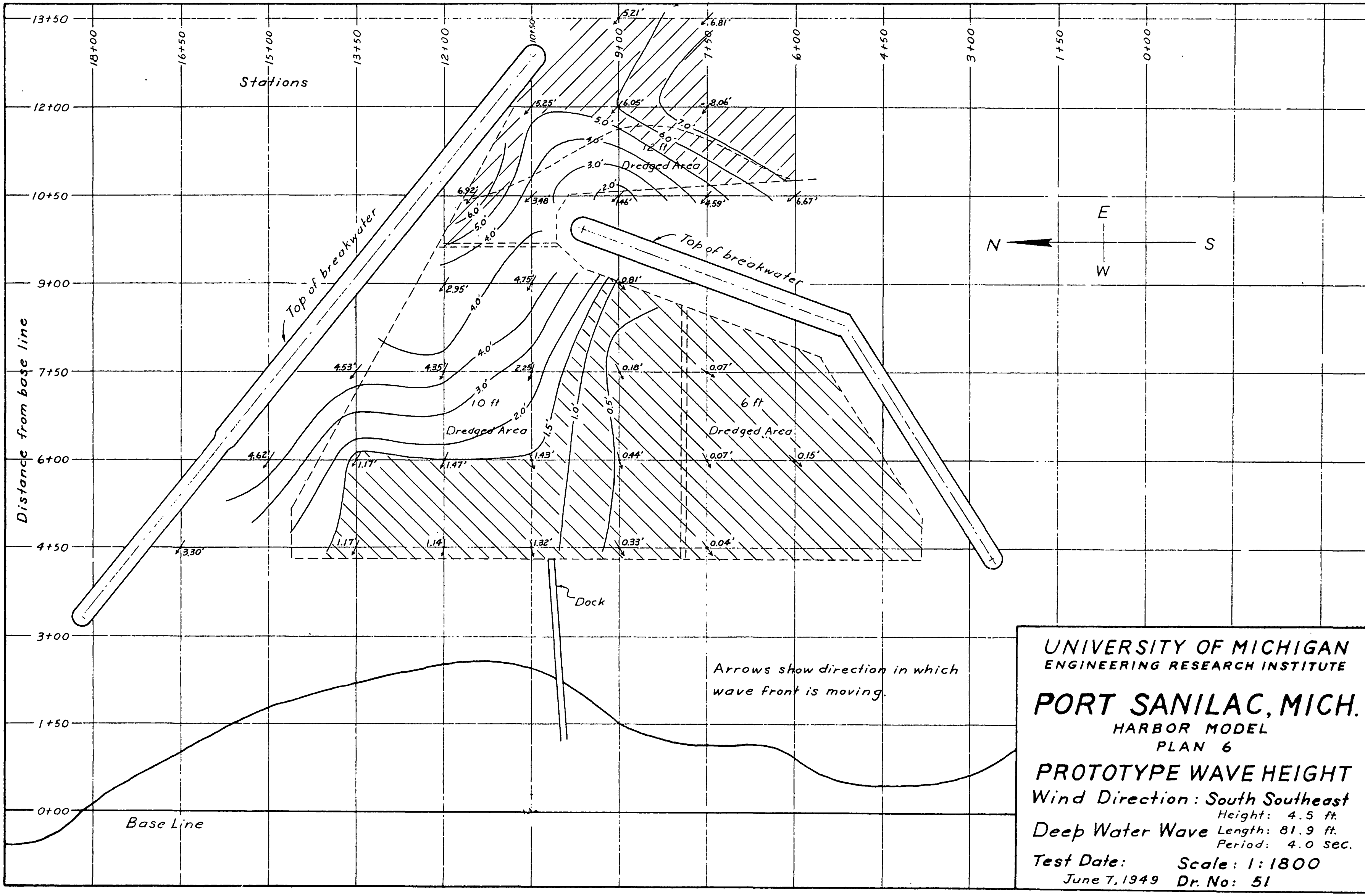
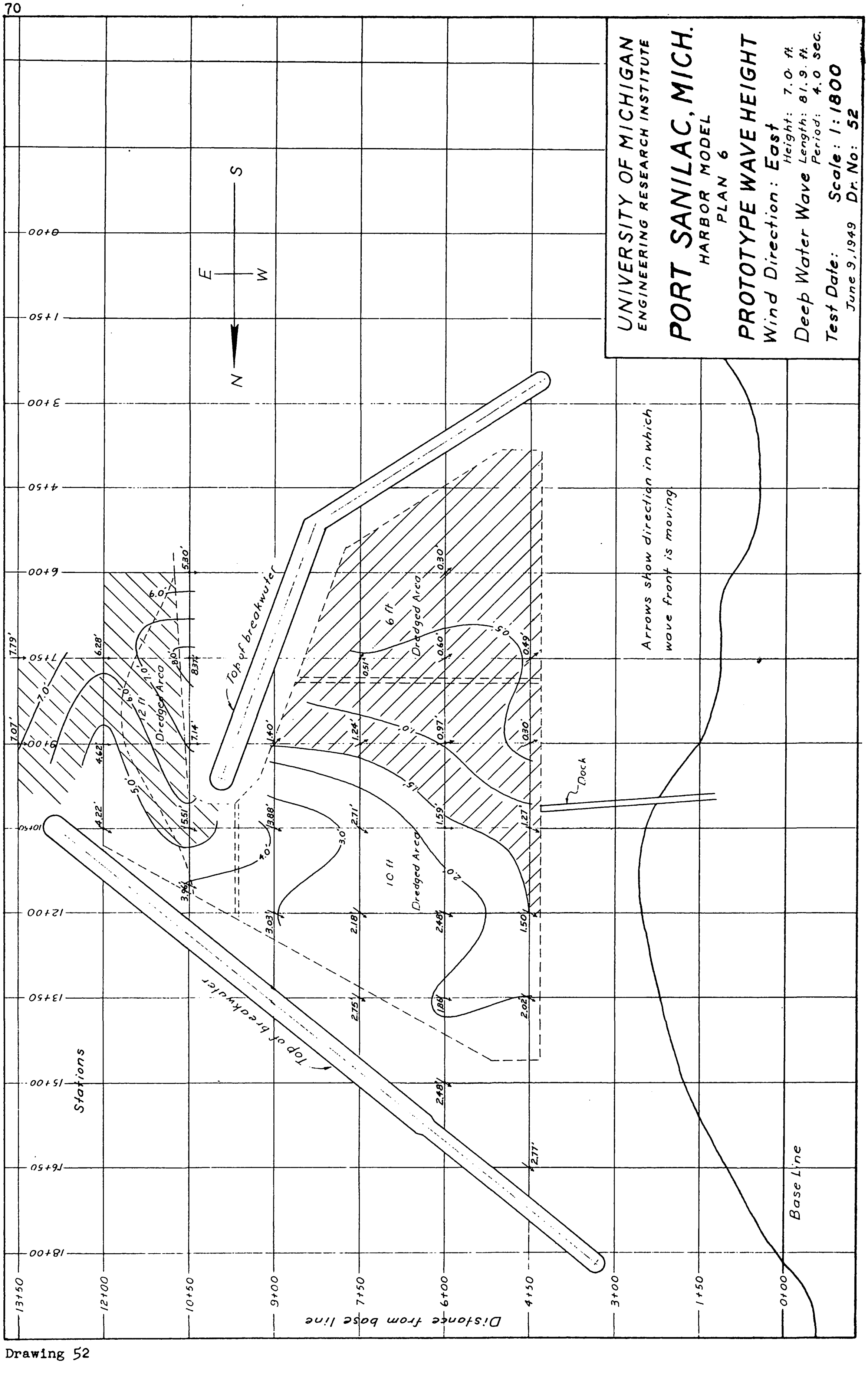
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 5
PROTOTYPE CURRENTS
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: May 20, 1949
Scale: 1:1800
Dr. No: 49
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
N
S
E
W
Stations
Distance from base line
Base Line
Top of breakwater
Top of breakwater
12 ft. Dredged Area
10 ft. Dredged Area
6 ft. Dredged Area
Dock
18+00
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 49

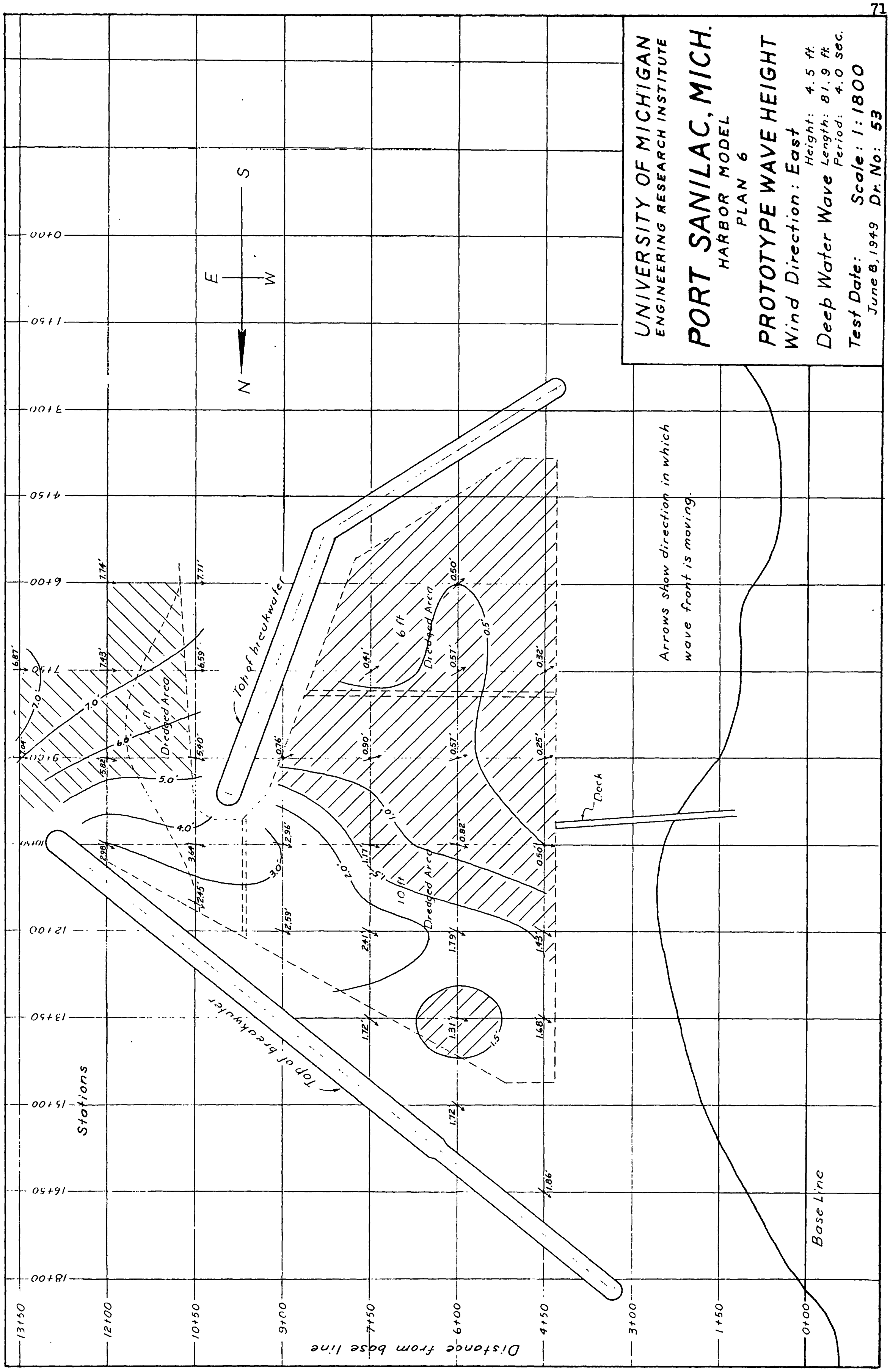

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 Sec.
Test Date: June 7, 1949
Scale: 1:1800
Dr. No: 50
Arrows show direction in which wave front is moving
Top of breakwater
Dredged Area
6 ft.
10 ft
12 ft
Dock
Stations
Base Line
Distance from base line

Drawing 50

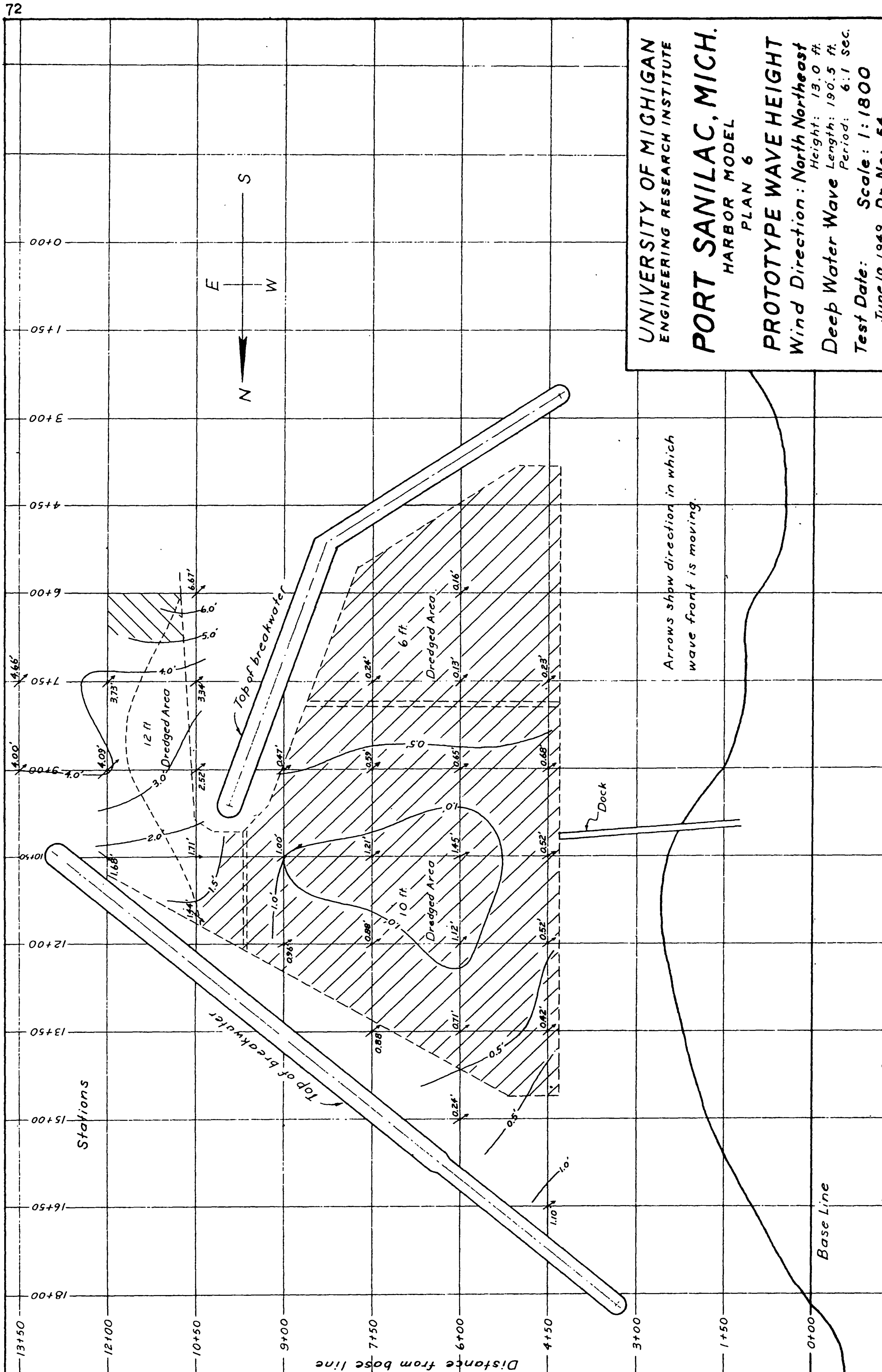

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: June 7, 1949
Scale: 1:1800
Dr. No: 51
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dredged Area
Dredged Area
Dredged Area
12 ft
10 ft
6 ft
Dock
Stations
Distance from base line
Base Line
N
S
E
W
18+00
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
5.21'
6.81'
5.25'
6.05'
8.06'
6.92'
3.48
1.46'
4.59'
6.67'
0.81'
2.95'
4.75'
4.53'
4.35'
2.25'
0.18'
0.07'
4.62'
1.17'
1.47'
1.43'
0.44'
0.07'
0.15'
3.30'
1.17
1.14
1.32'
0.33'
0.04'
7.0'
6.0'
5.0'
4.0'
3.0'
2.0'
6.0'
5.0'
4.0'
4.0'
4.0'
3.0'
2.0'
1.5'
1.0'
0.5'


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: June 9, 1949
Scale: 1:1800
Dr. No: 52
Arrows show direction in which wave front is moving
Top of breakwater
Top of breakwater
Dredged Area
Dredged Area
Dredged Area
12 ft
6 ft
10 ft
Dock
Base Line
Stations
Distance from base line
N
S
E
W

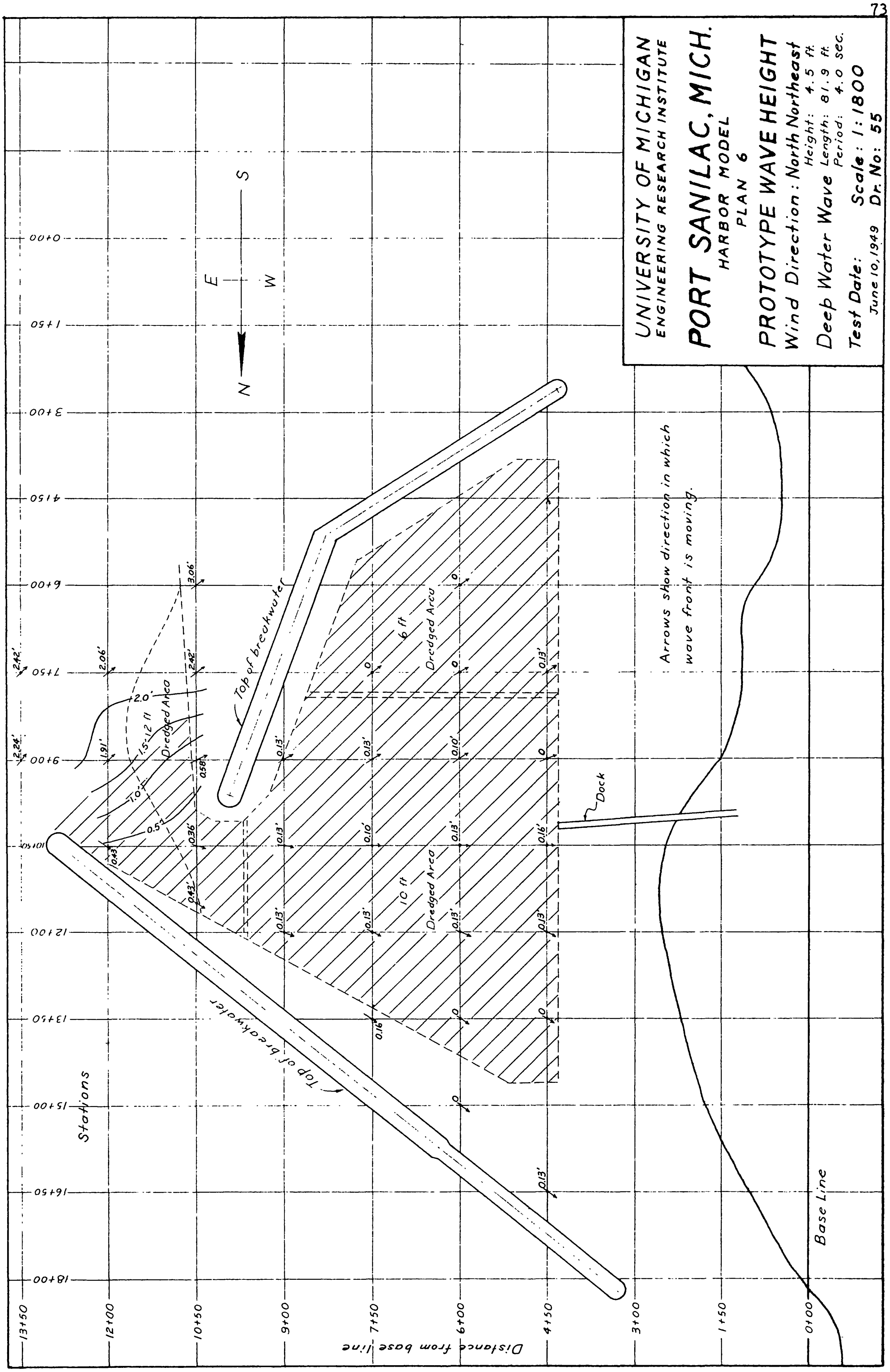
Drawing 52


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: June 8, 1949
Scale: 1:1800
Dr. No: 53
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dredged Area
Dredged Area
Dredged Area
Dock
Base Line
Stations
Distance from base line
N
S
E
W

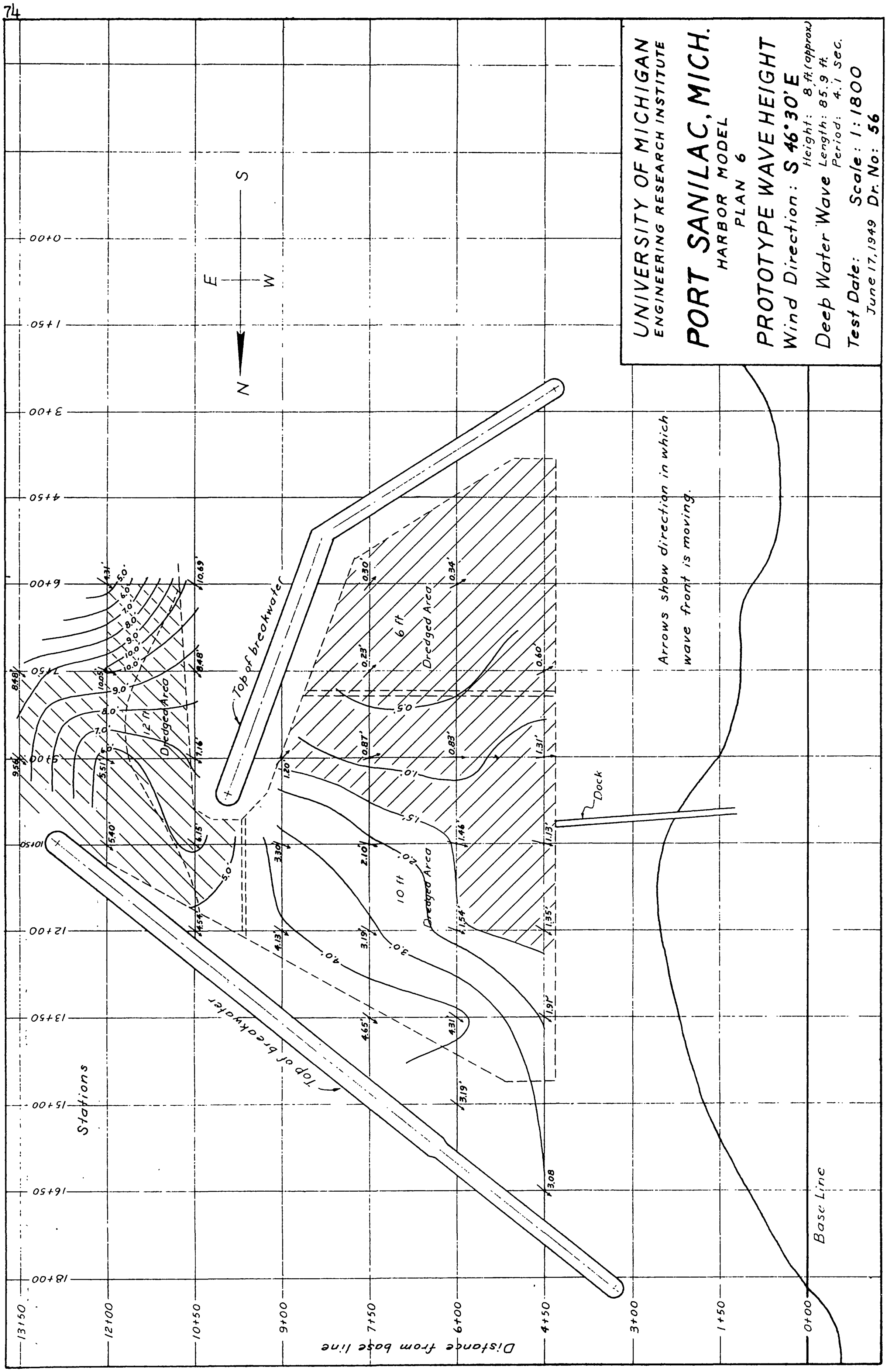
Drawing 53


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 Sec.
Test Date: June 10, 1949
Scale: 1:1800
Dr. No: 54
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft. Dredged Area
10 ft. Dredged Area
Dock
Stations
Base Line
Distance from base line
N
S
E
W

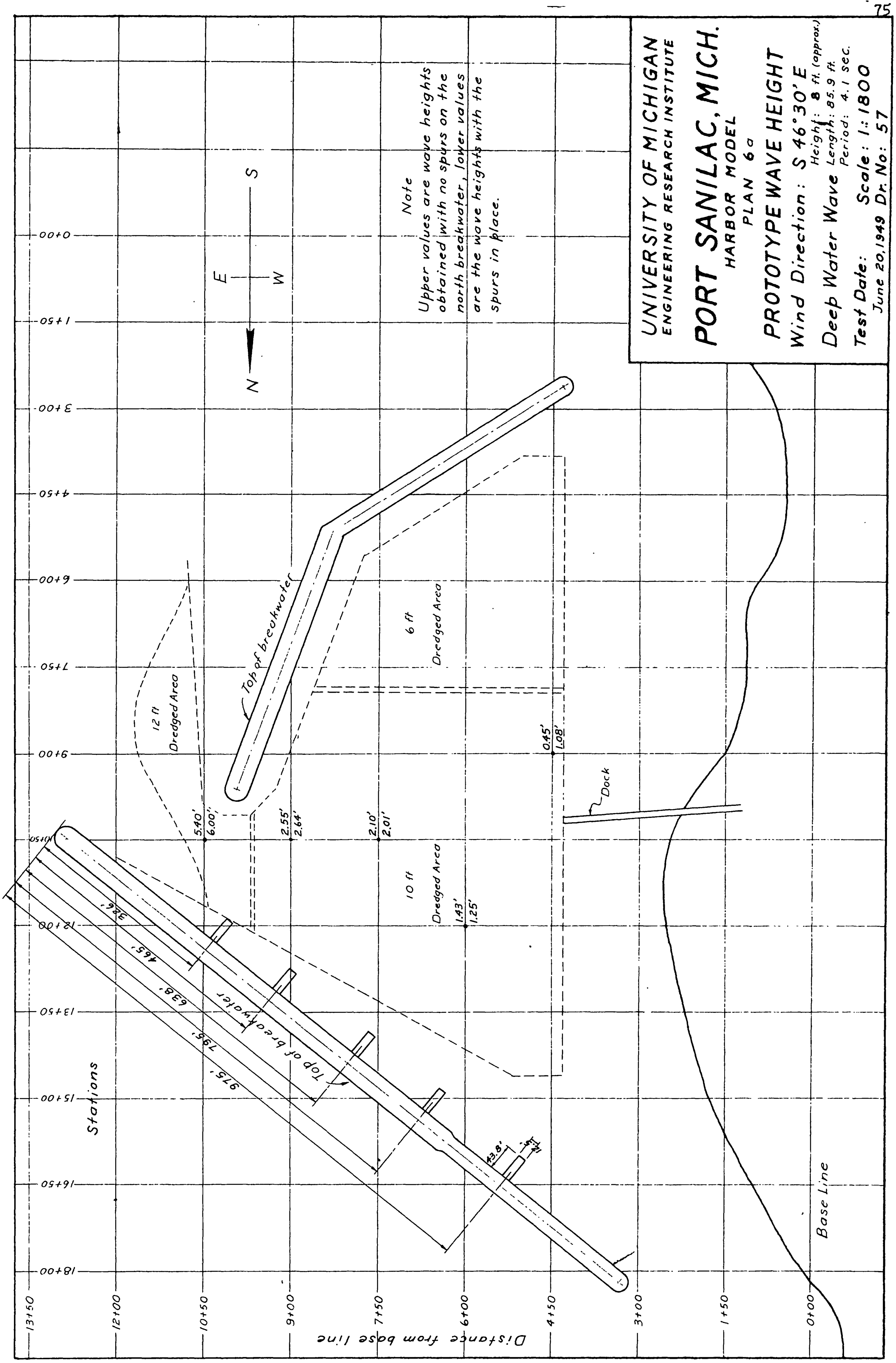
Drawing 54


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: June 10, 1949
Scale: 1:1800
Dr. No: 55
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dock
6 ft Dredged Area
10 ft Dredged Area
1.5-12 ft Dredged Area
Stations
Distance from base line
Base Line
N
S
E
W

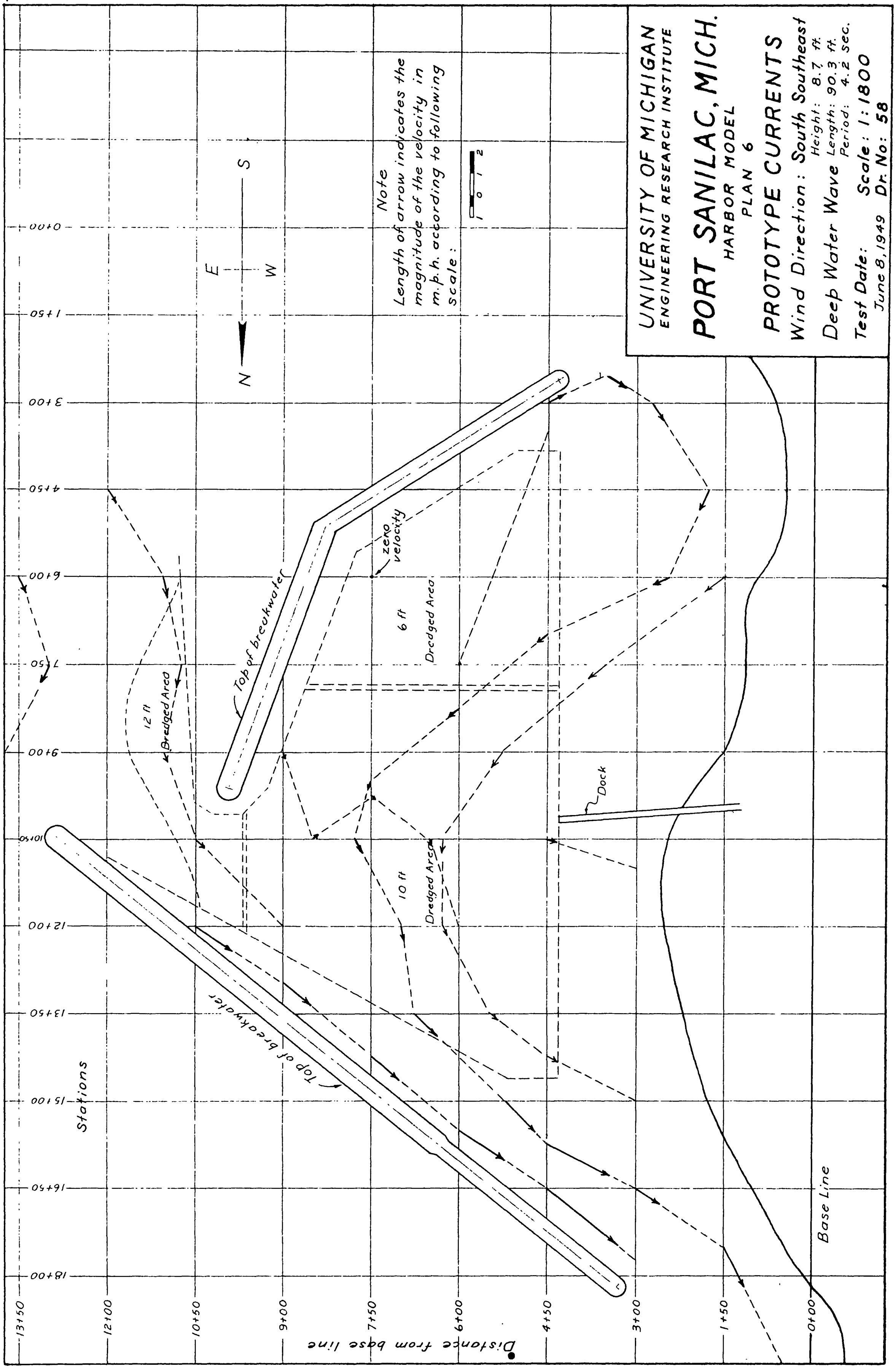
Drawing 55


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: S 46°30' E
Deep Water Wave Height: 8 ft.(approx.)
Length: 85.9 ft.
Period: 4.1 sec.
Test Date: June 17, 1949
Scale: 1:1800
Dr. No: 56
Arrows show direction in which wave front is moving.
Top of breakwater
Top of breakwater
Dredged Area
12 ft
Dredged Area
6 ft
Dredged Area
10 ft
Dock
Stations
Base Line
Distance from base line
N
S
E
W

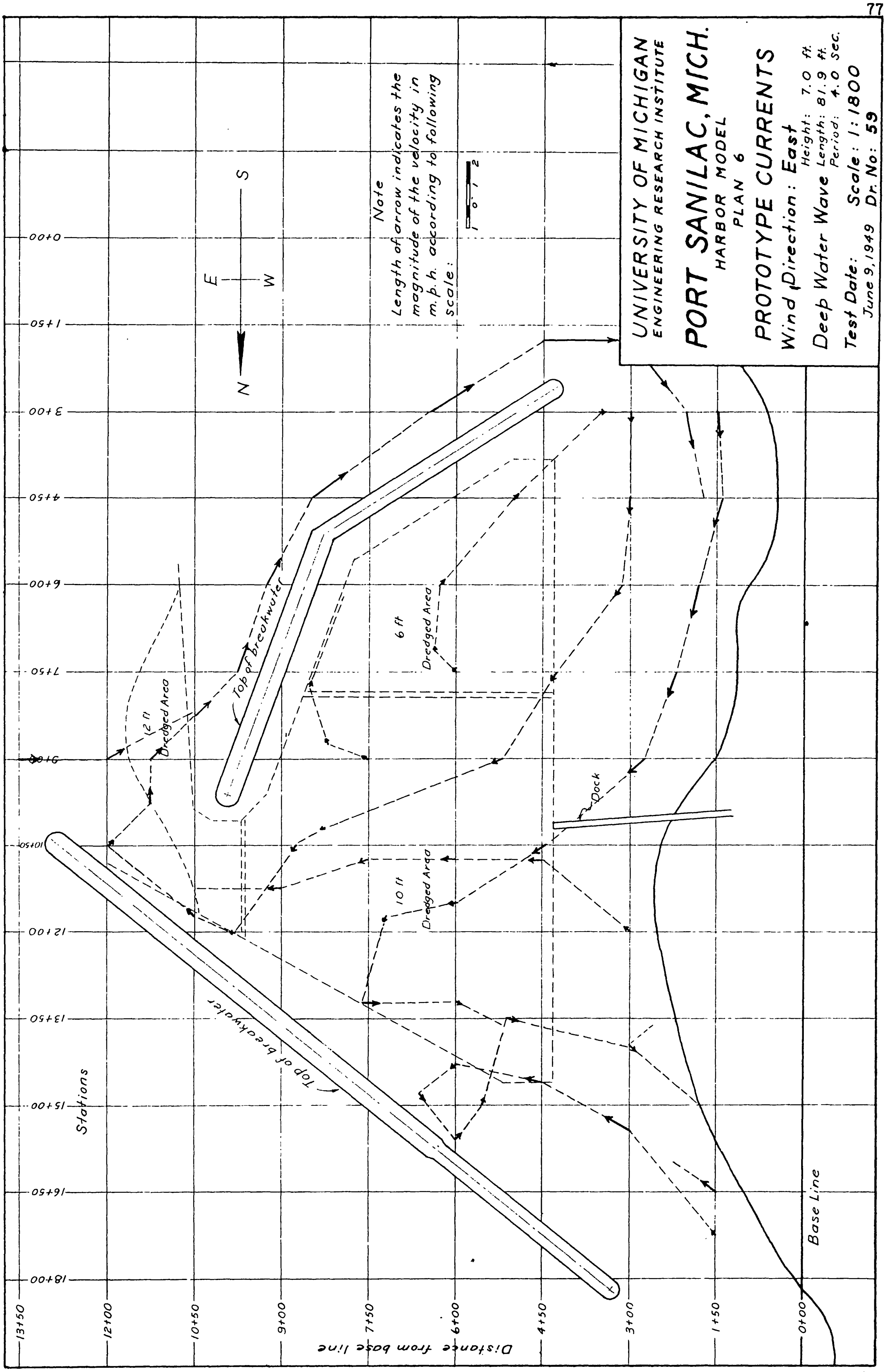
Drawing 56


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6a
PROTOTYPE WAVE HEIGHT
Wind Direction: S 46°30' E
Deep Water Wave Height: 8 ft. (approx.) Length: 85.9 ft. Period: 4.1 sec.
Test Date: June 20, 1949
Scale: 1:1800
Dr. No: 57
Note
Upper values are wave heights obtained with no spurs on the north breakwater, lower values are the wave heights with the spurs in place.
N
E
W
S
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
0.45'
1.08'
5.40'
6.00'
2.55'
2.64'
2.10'
2.01'
1.43'
1.25'
326'
465'
638'
795'
975'
43.8'
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00

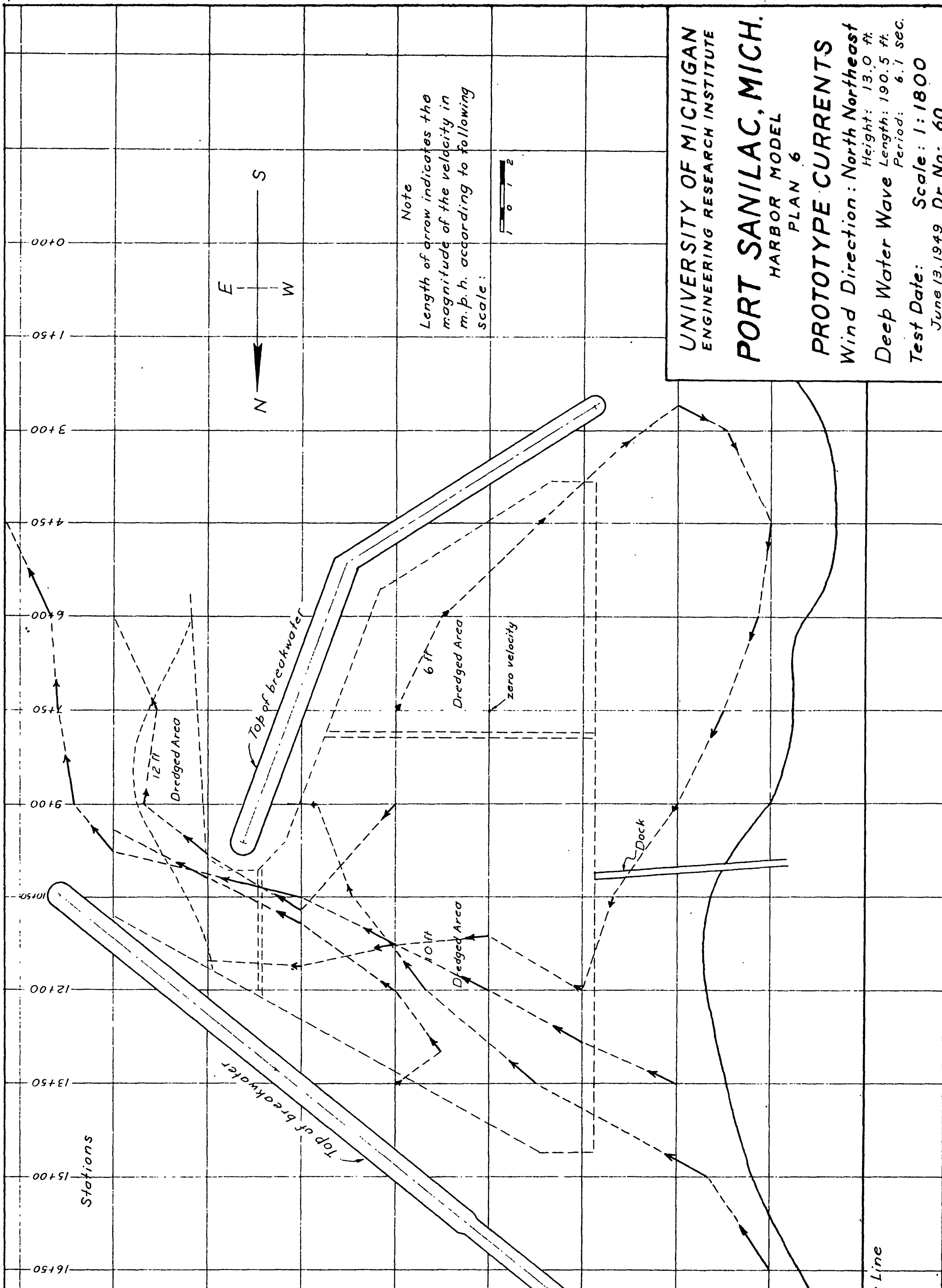
Drawing 57


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE CURRENTS
Wind Direction: South Southeast
Height: 8.7 ft.
Deep Water Wave Length: 90.3 ft.
Period: 4.2 sec.
Test Date: June 8, 1949
Scale: 1:1800
Dr. No: 58
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
0 1 2
N
S
E
W
zero velocity
Top of breakwater
6 ft
Dredged Area
12 ft
Dredged Area
10 ft
Dredged Area
Dock
Top of breakwater
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

Drawing 58

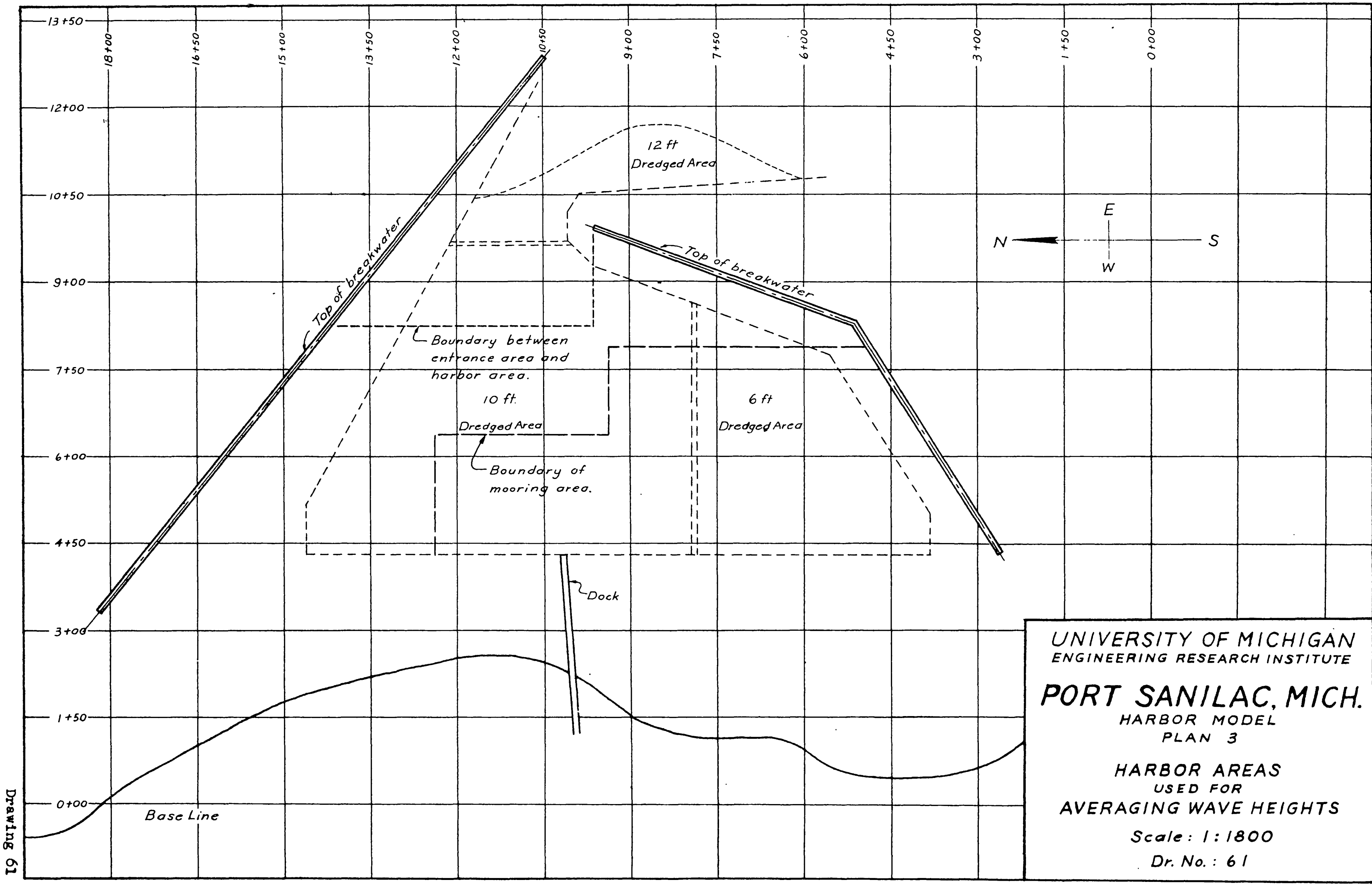

UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE CURRENTS
Wind Direction: East
Deep Water Wave Height: 7.0 ft. Length: 81.9 ft. Period: 4.0 Sec.
Test Date: June 9, 1949
Scale: 1:1800
Dr. No: 59
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
N
S
E
W
Top of breakwater
Top of breakwater
12 ft Dredged Area
6 ft Dredged Area
10 ft Dredged Area
Dock
Base Line
Stations
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50

Drawing 59

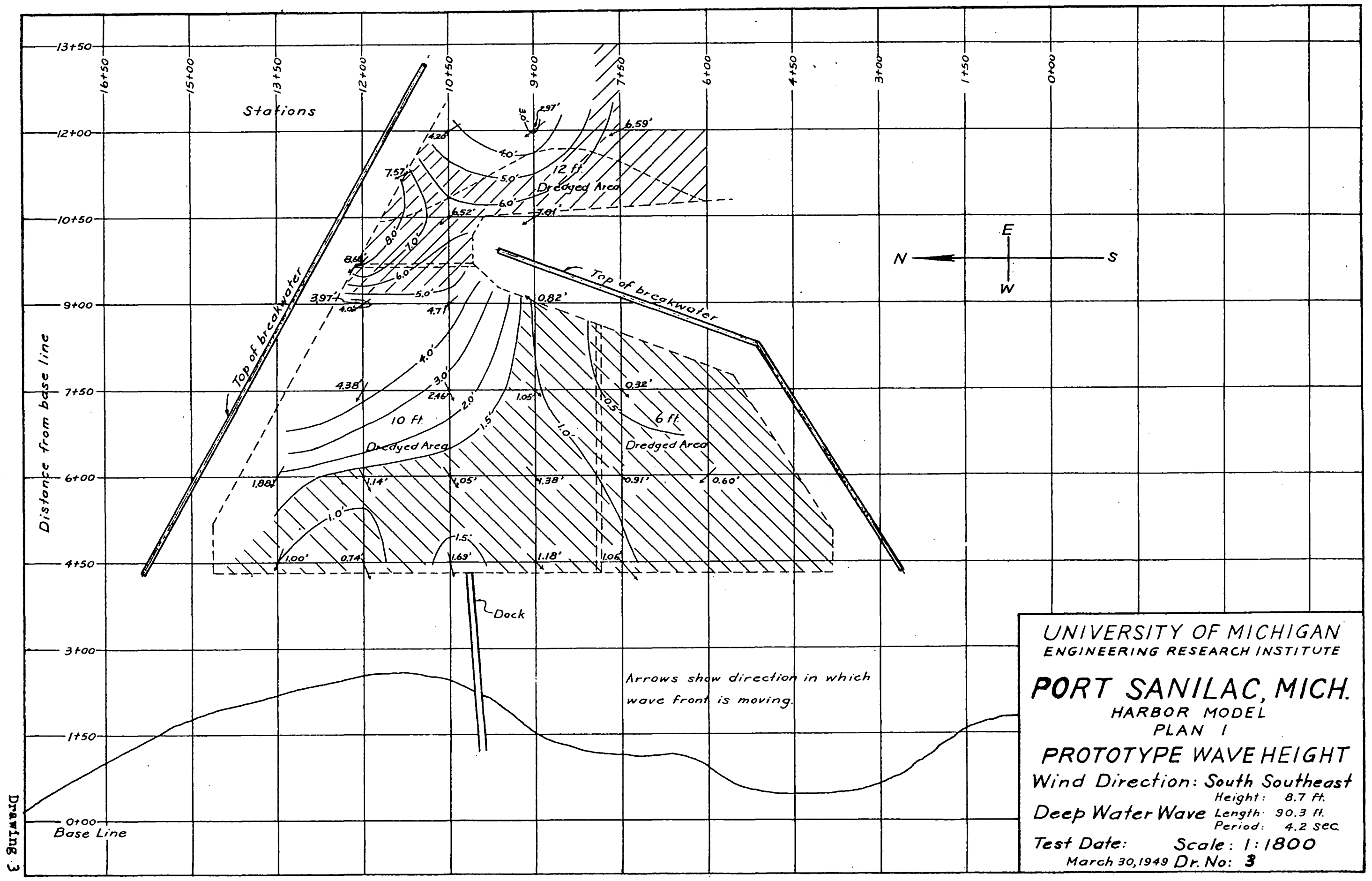


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE CURRENTS
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: June 13, 1949
Scale: 1:1800
Dr. No: 60
Note
Length of arrow indicates the magnitude of the velocity in m.p.h. according to following scale:
1 0 1 2
N
S
E
W
Top of breakwater
Top of breakwater
Dredged Area
12 ft
Dredged Area
6 ft
zero velocity
Dredged Area
10 ft
Dock
Stations
Base Line
Distance from base line
0+00
1+50
3+00
4+50
6+00
7+50
9+00
10+50
12+00
13+50
15+00
16+50
18+00

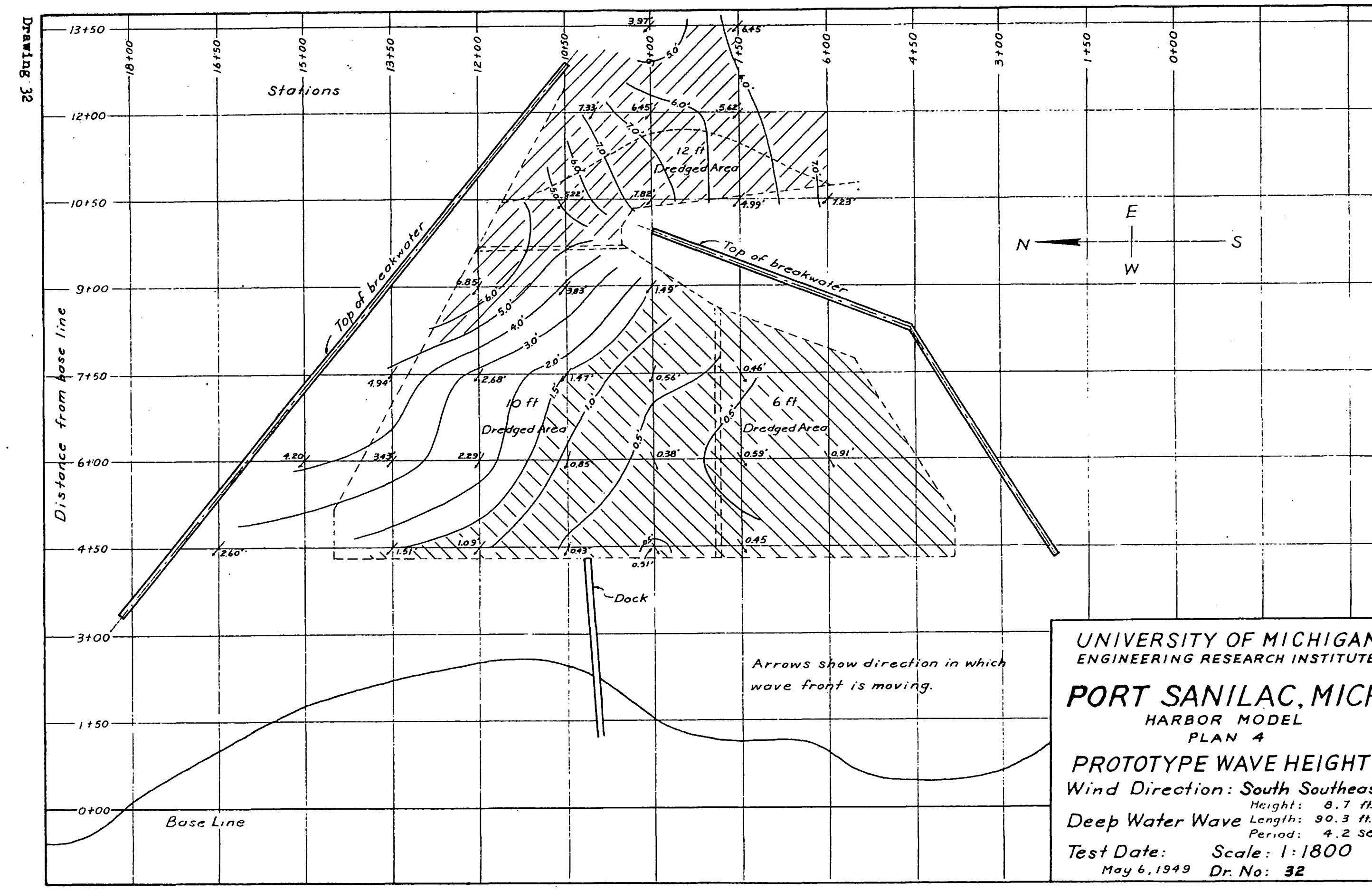
Drawing 60


UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
HARBOR AREAS
USED FOR
AVERAGING WAVE HEIGHTS
Scale: 1:1800
Dr. No.: 61
Top of breakwater
Top of breakwater
12 ft
Dredged Area
10 ft.
Dredged Area
6 ft
Dredged Area
Boundary between
entrance area and
harbor area.
Boundary of
mooring area.
Dock
Base Line
N
S
E
W
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00
18+00
16+50
15+00
13+50
12+00
10+50
9+00
7+50
6+00
4+50
3+00
1+50
0+00

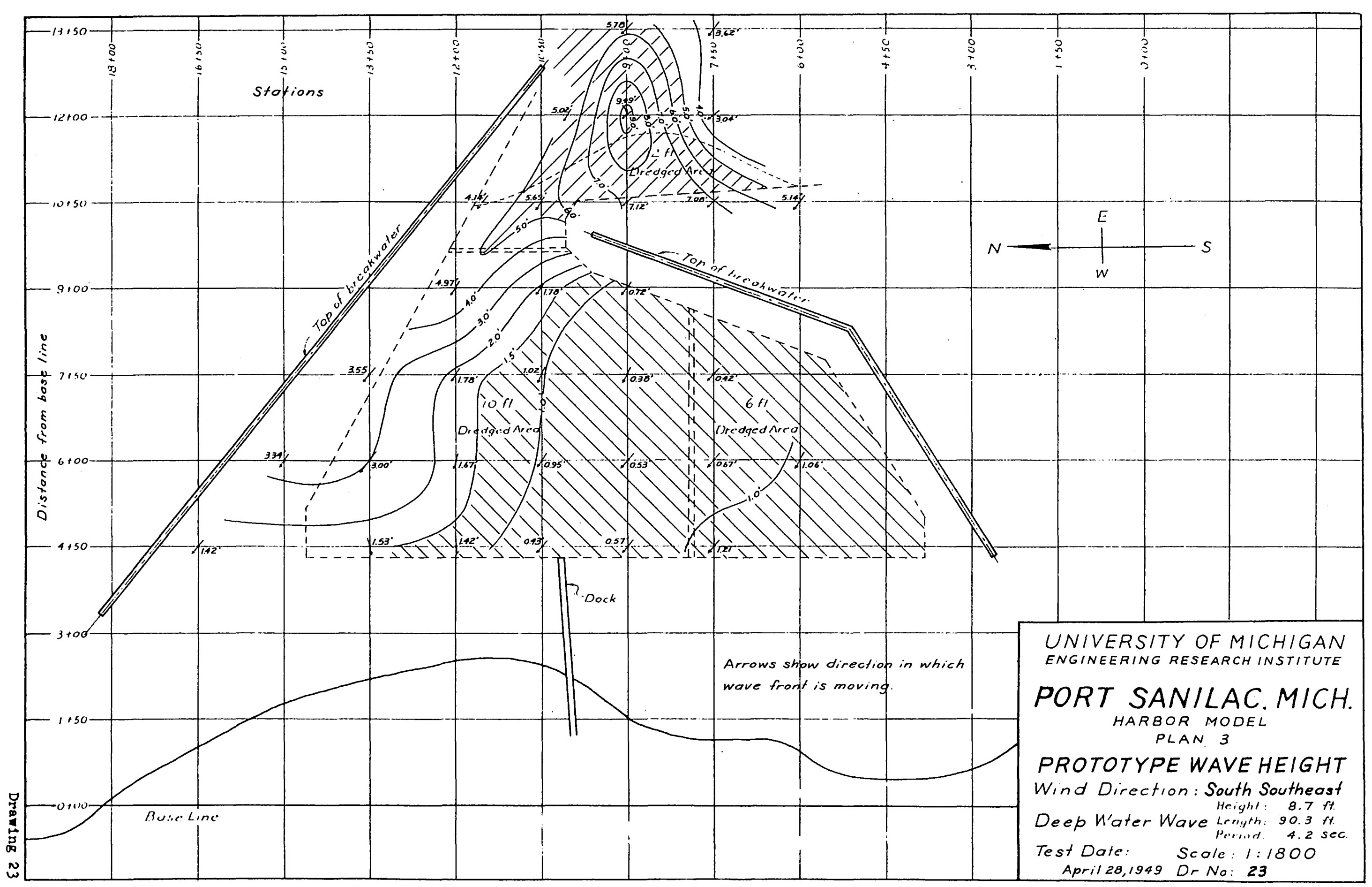
Drawing 61



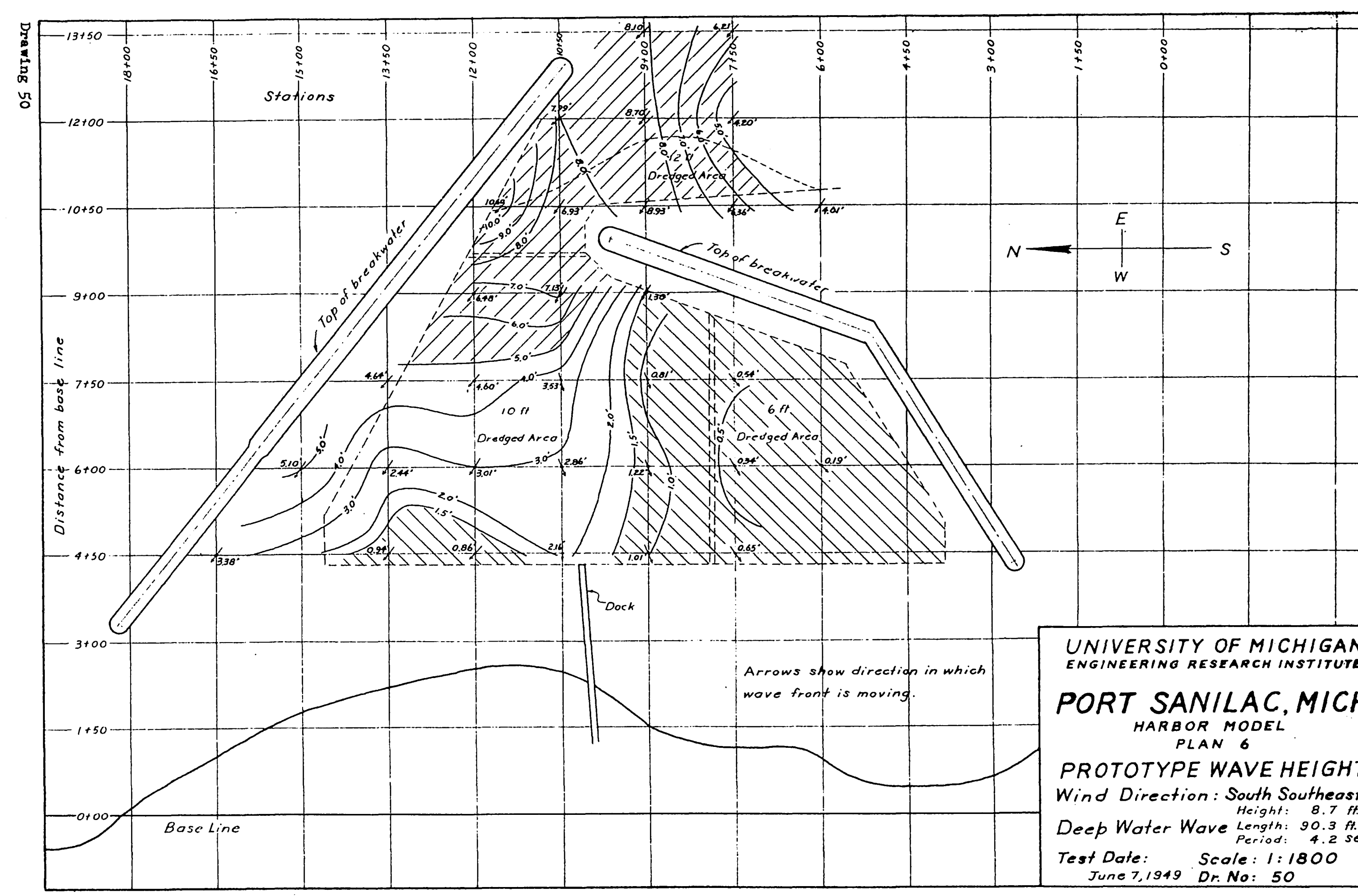
Drawing 3
Stations
Top of breakwater
Top of breakwater
12 ft.
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
N
E
W
S
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 1
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: March 30, 1949
Scale: 1:1800
Dr. No: 3



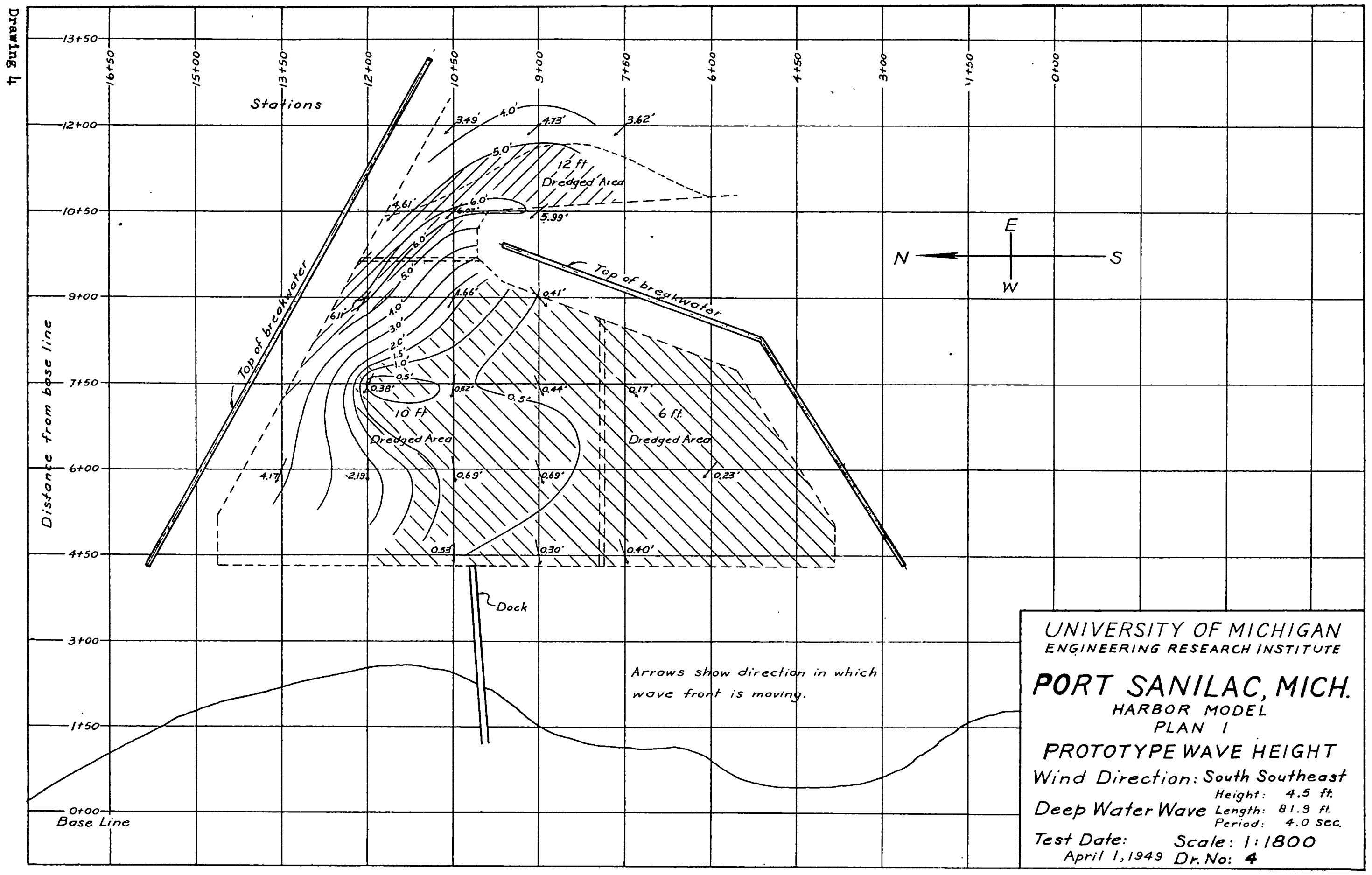
Drawing 32
Stations
Top of breakwater
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
N
E
W
S
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: May 6, 1949
Scale: 1:1800
Dr. No: 32

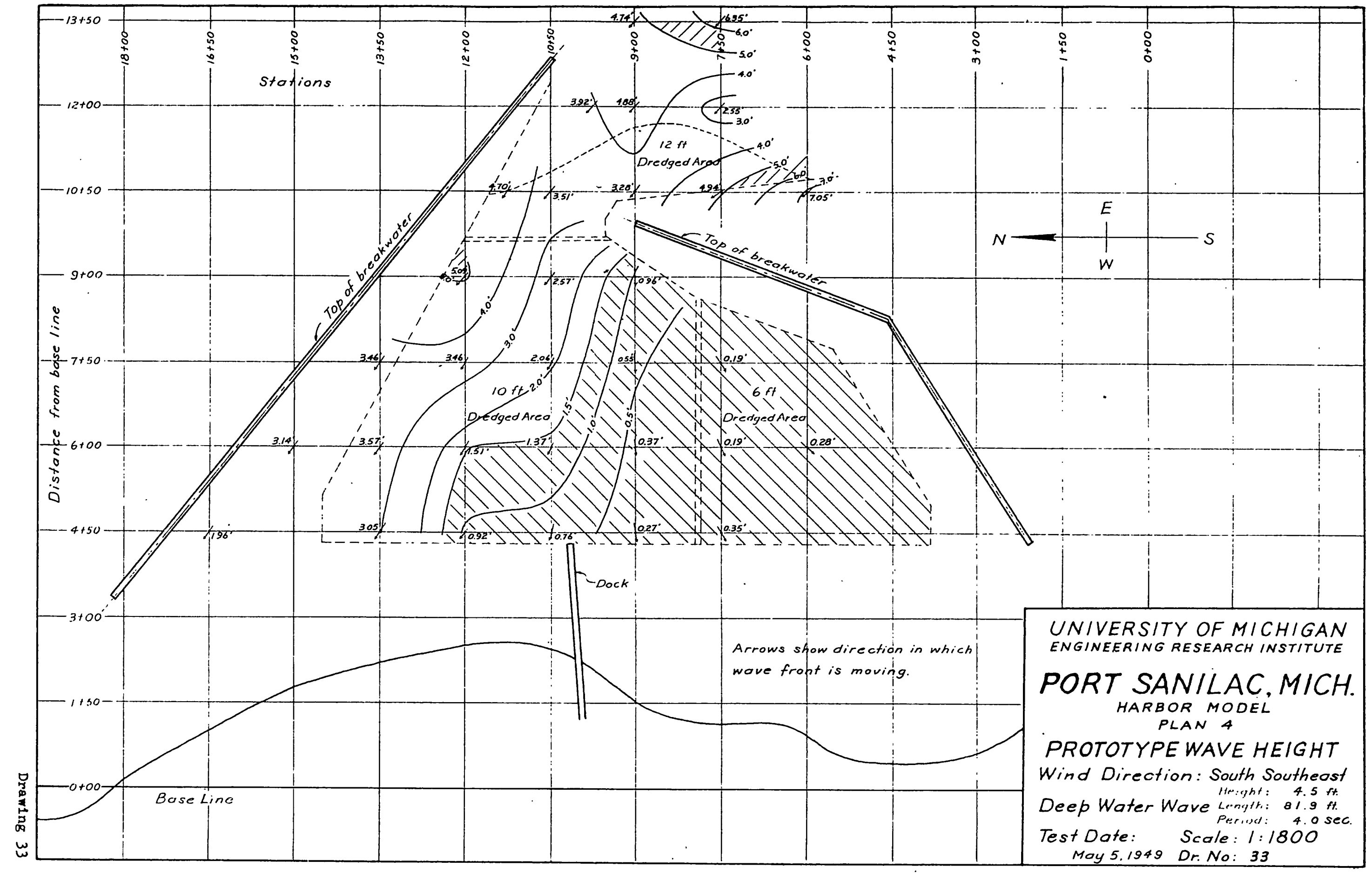


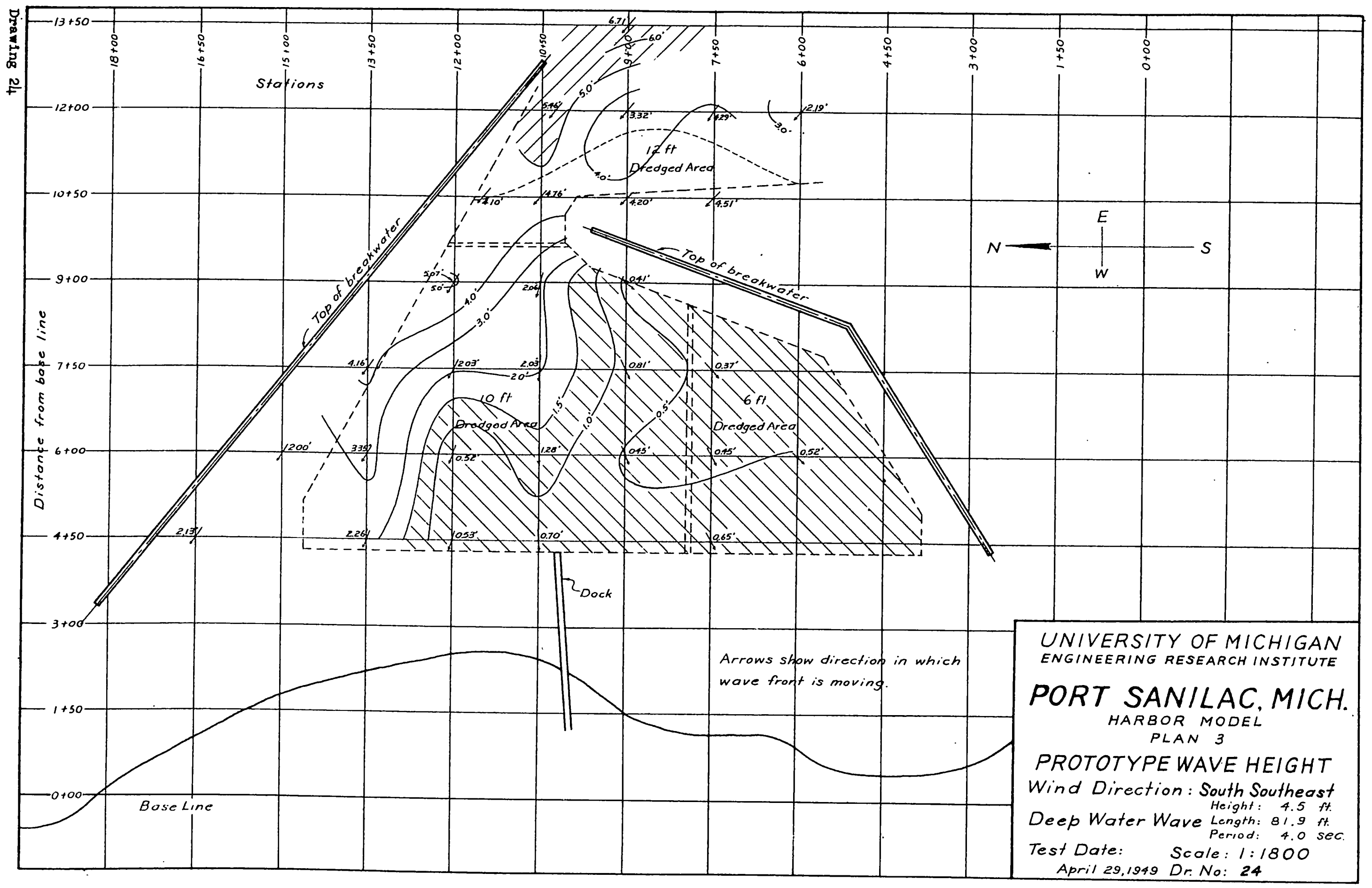
Drawing 23
Stations
Top of breakwater
Top of breakwater
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
N
E
W
S
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: April 28, 1949
Scale: 1:1800
Dr. No: 23

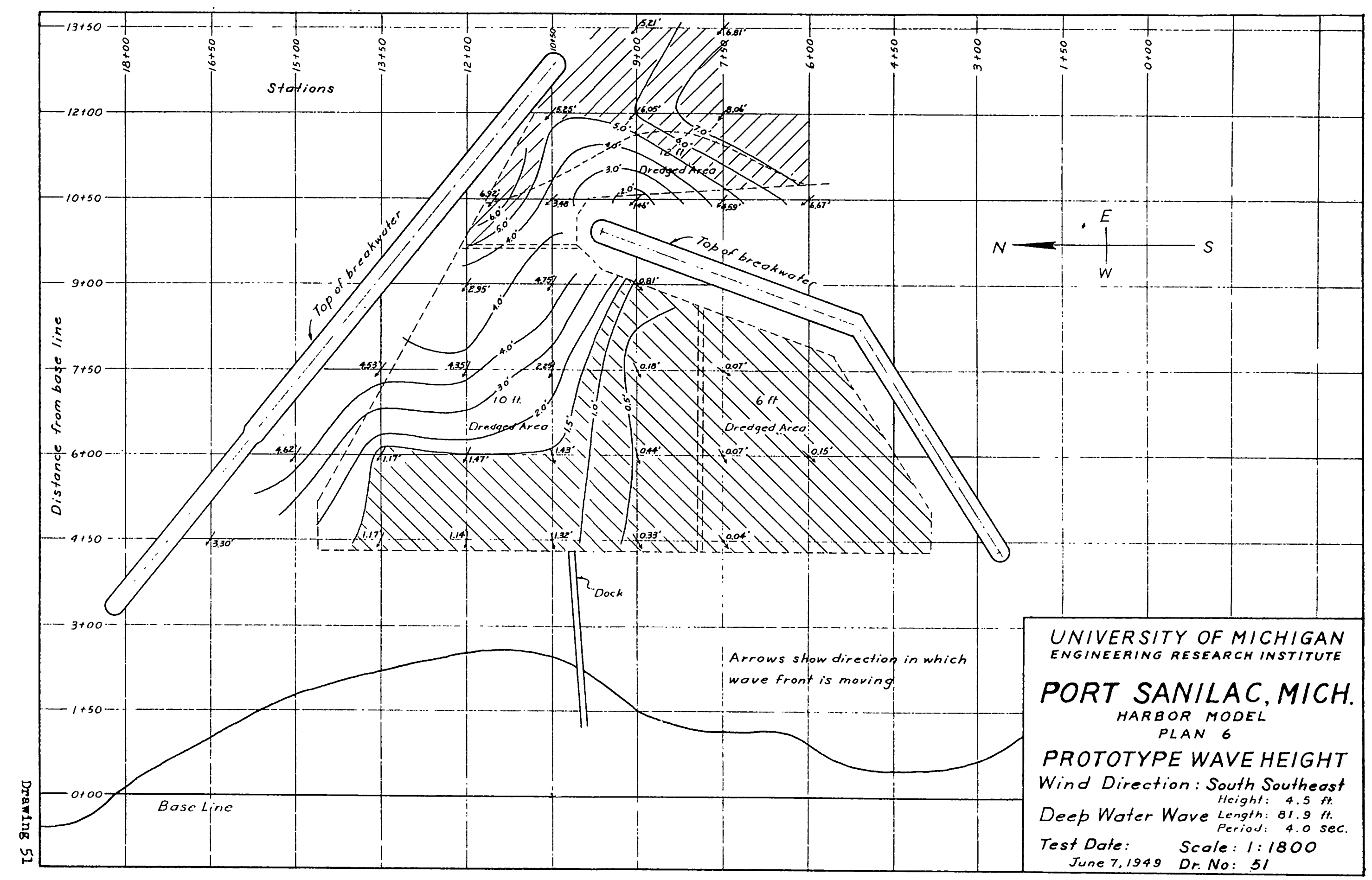


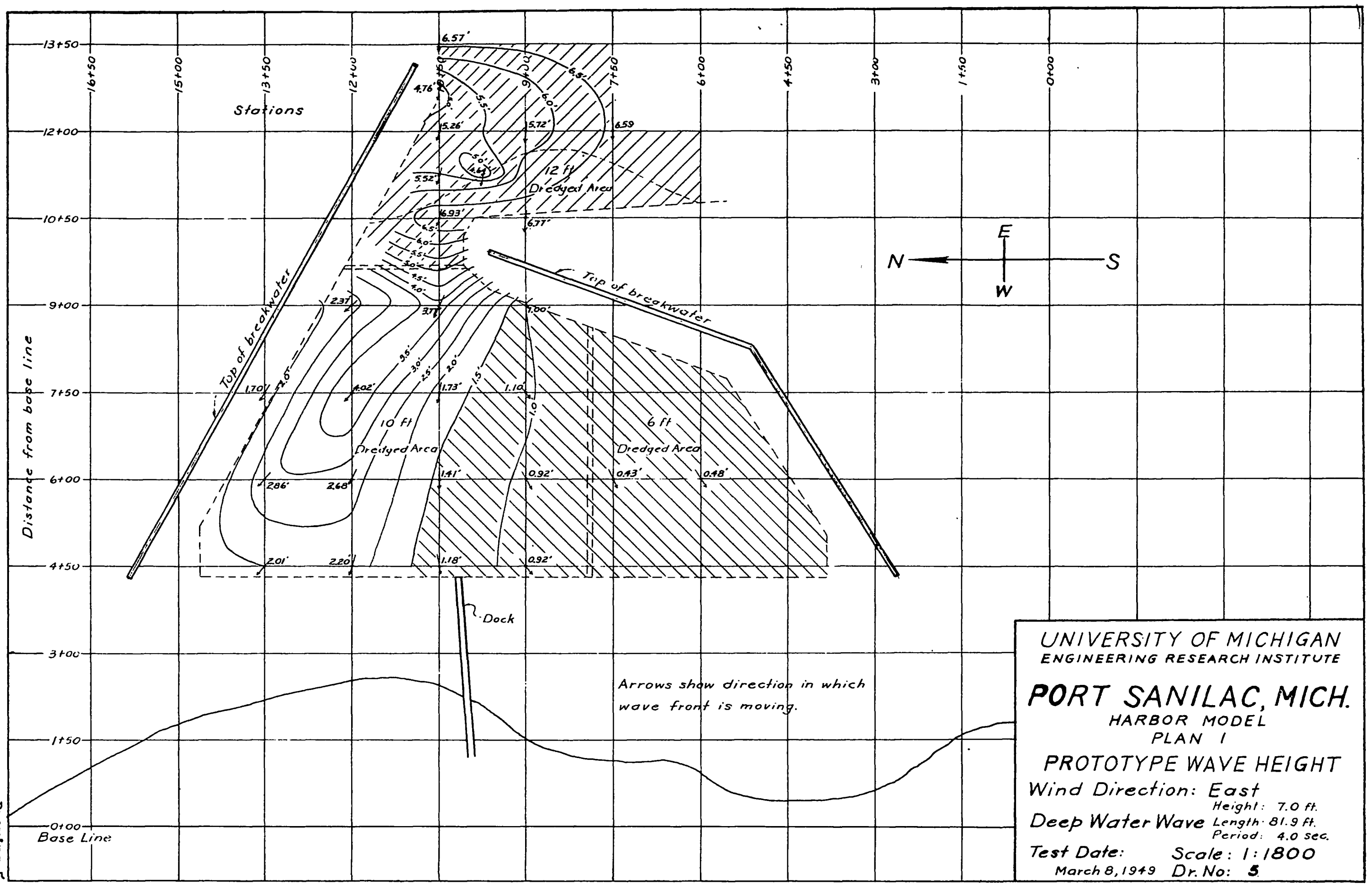
Drawing 50
Stations
Top of breakwater
Top of breakwater
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
N
E
W
S
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 8.7 ft. Length: 90.3 ft. Period: 4.2 sec.
Test Date: June 7, 1949
Scale: 1:1800
Dr. No: 50


Drawing 4
Stations
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 1
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 1, 1949
Scale: 1:1800
Dr. No: 4


Drawing 33
Stations
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: May 5, 1949
Scale: 1:1800
Dr. No: 33

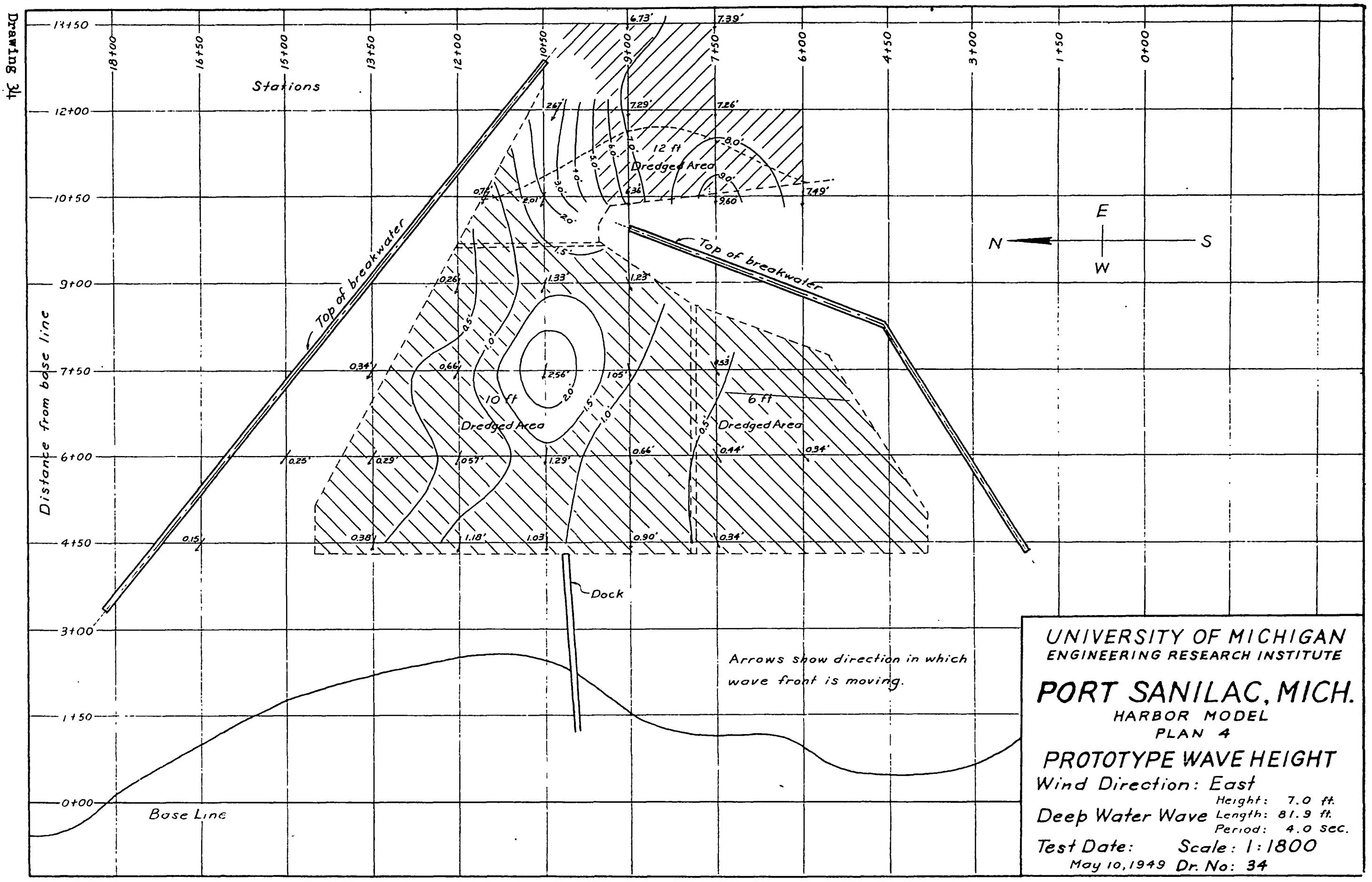

Drawing 24
Stations
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 29, 1949
Scale: 1:1800
Dr. No: 24

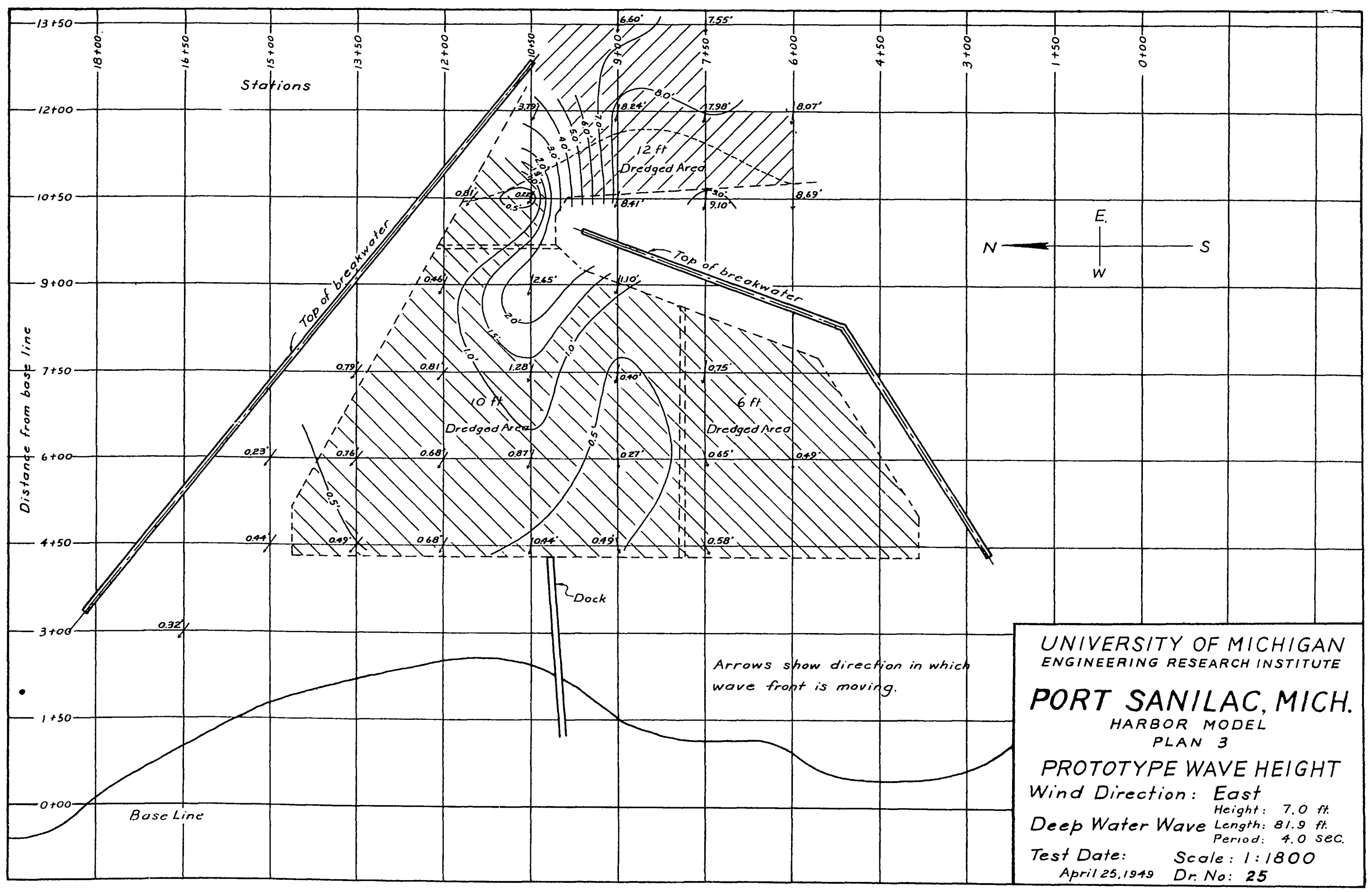

Drawing 51
Stations
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: South Southeast
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: June 7, 1949
Scale: 1:1800
Dr. No: 51



Drawing 5

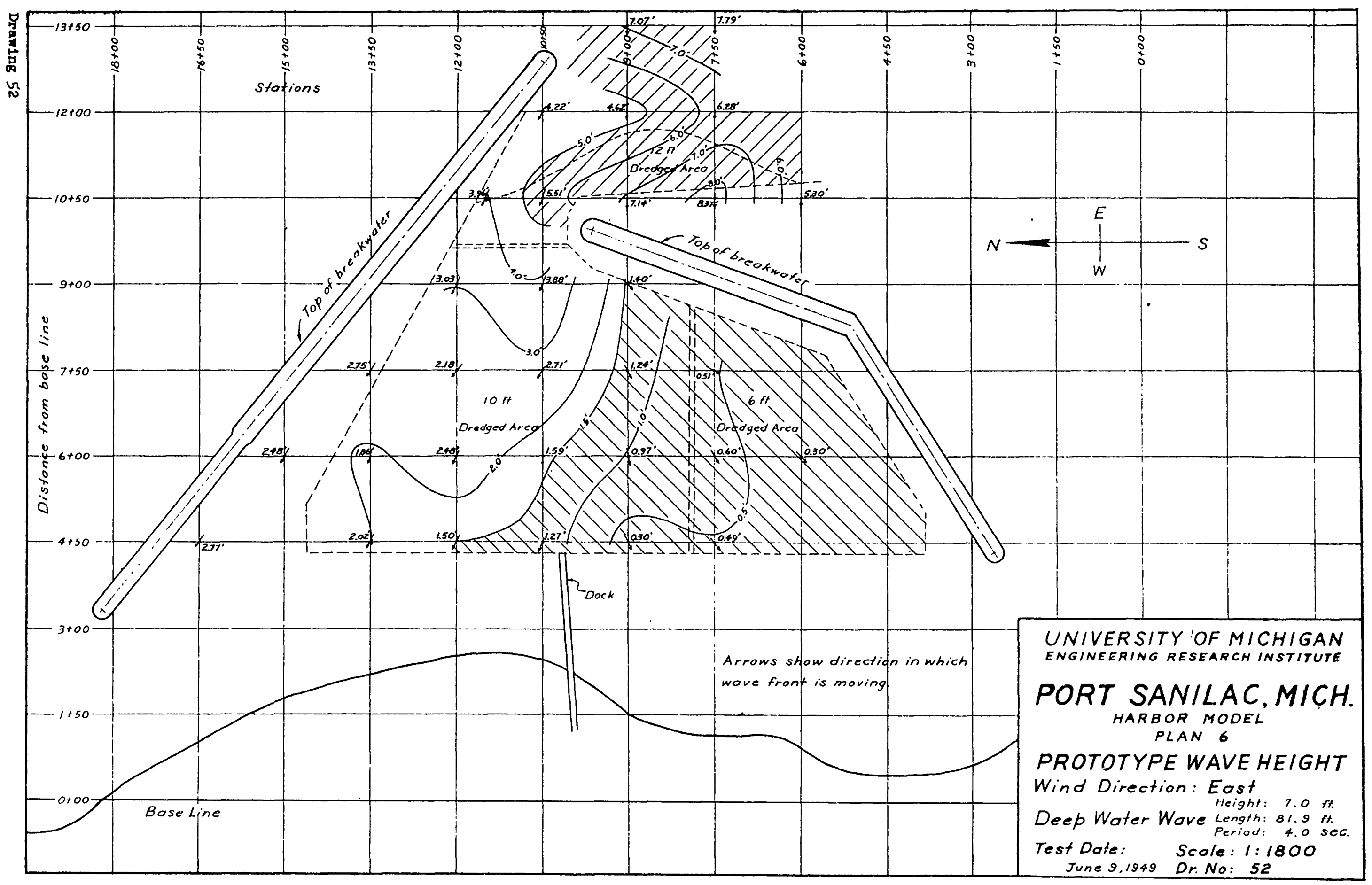
Drawing 34

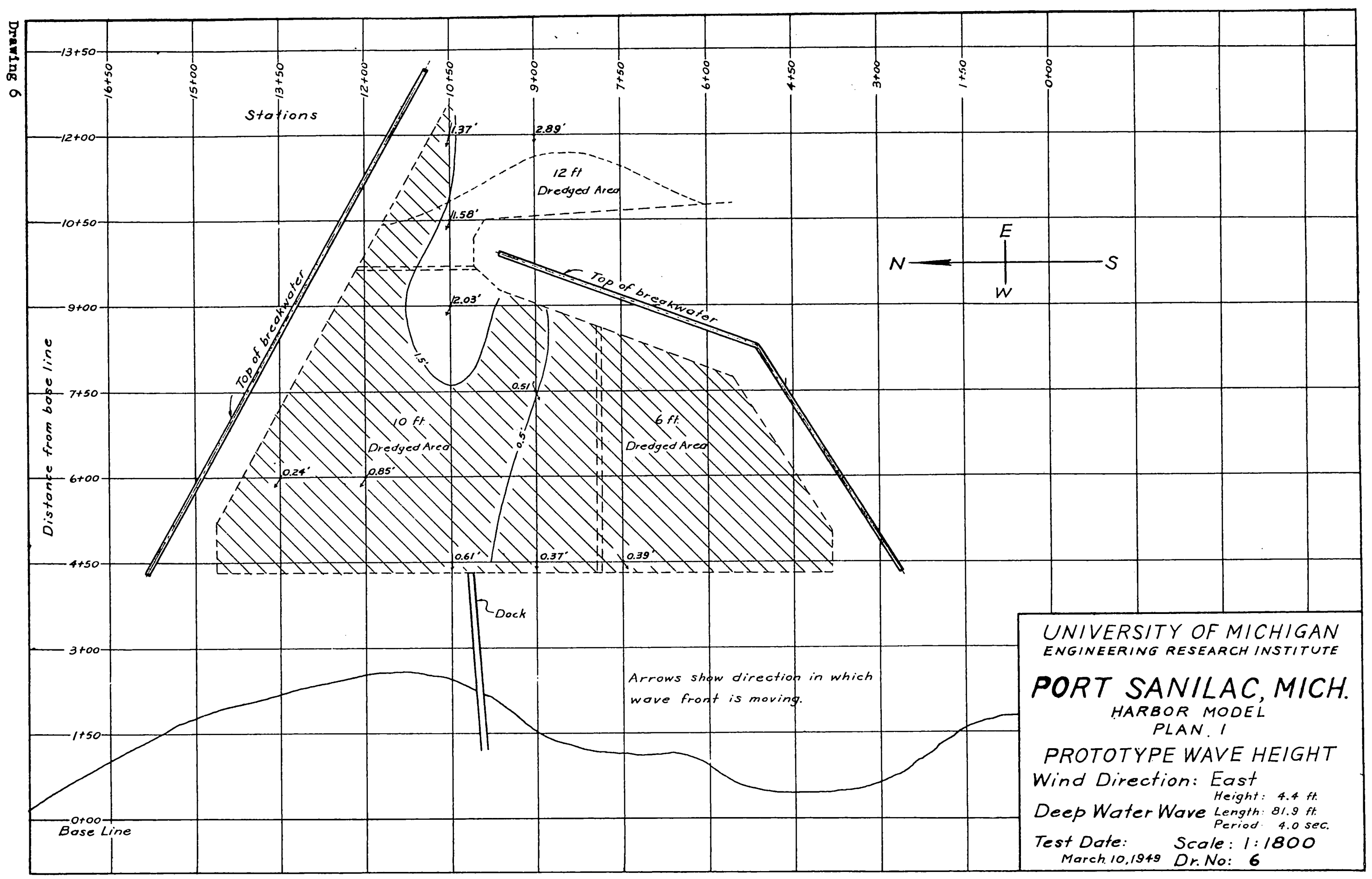




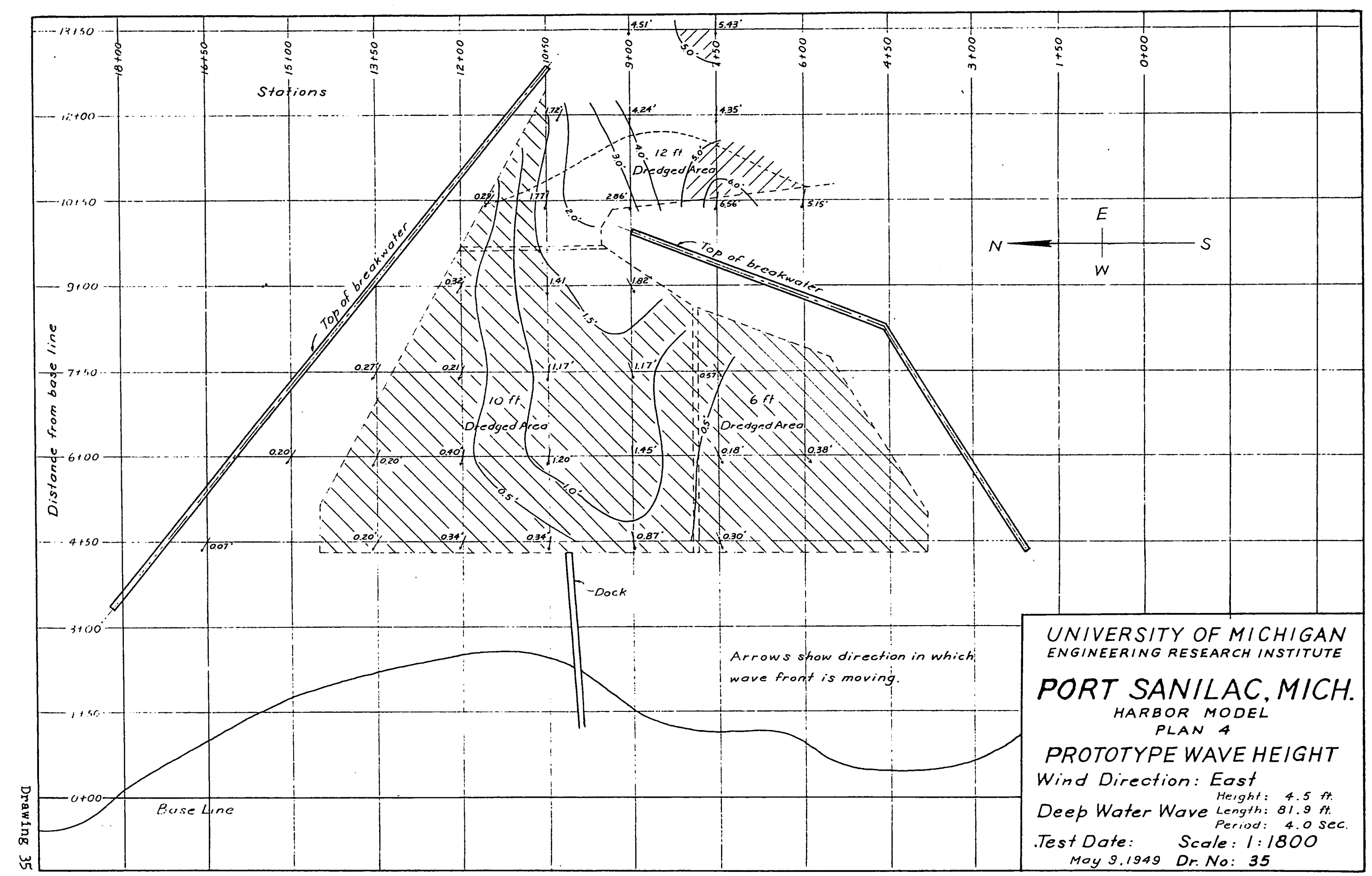
Drawing 25

Drawing 52

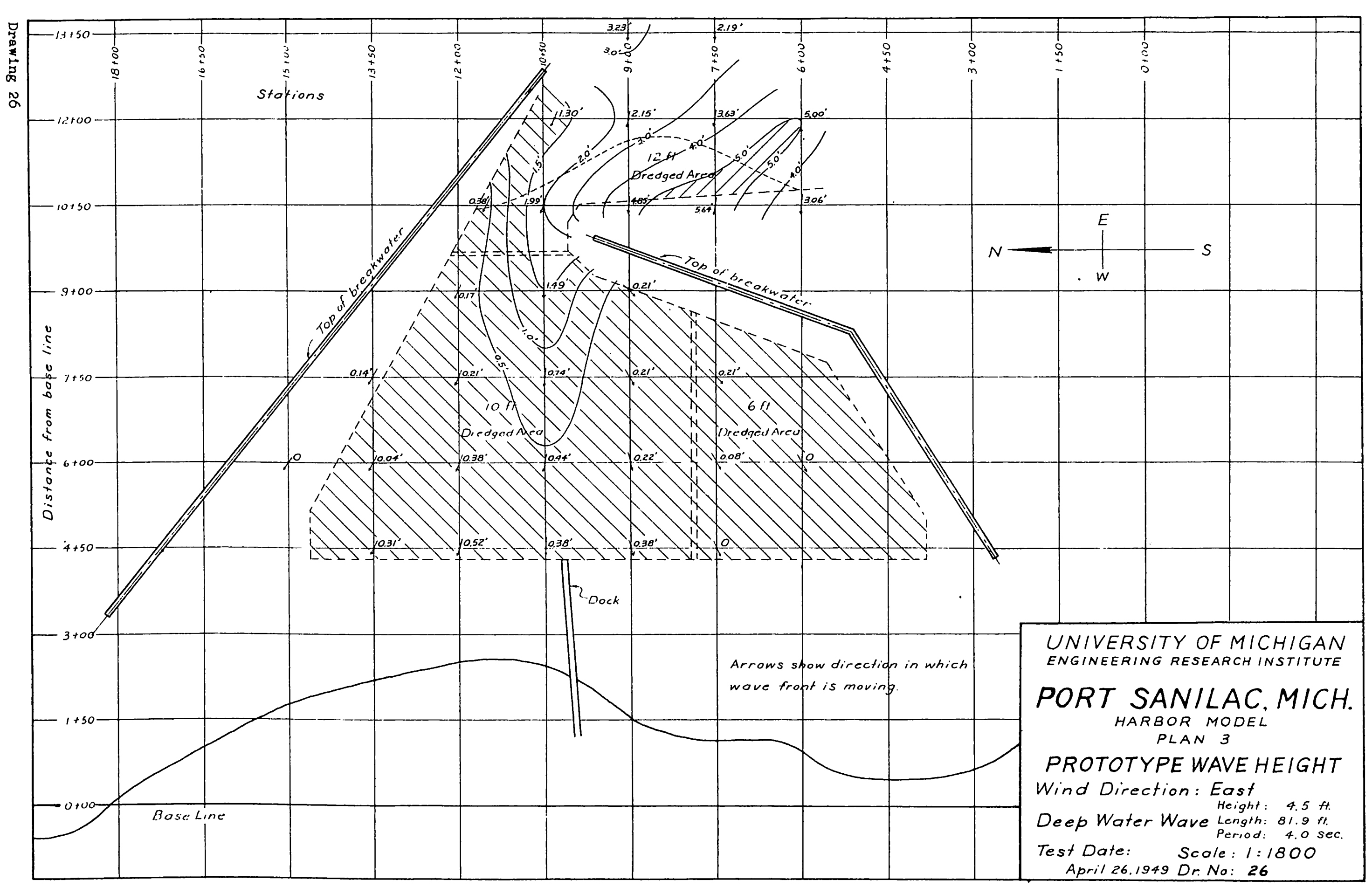




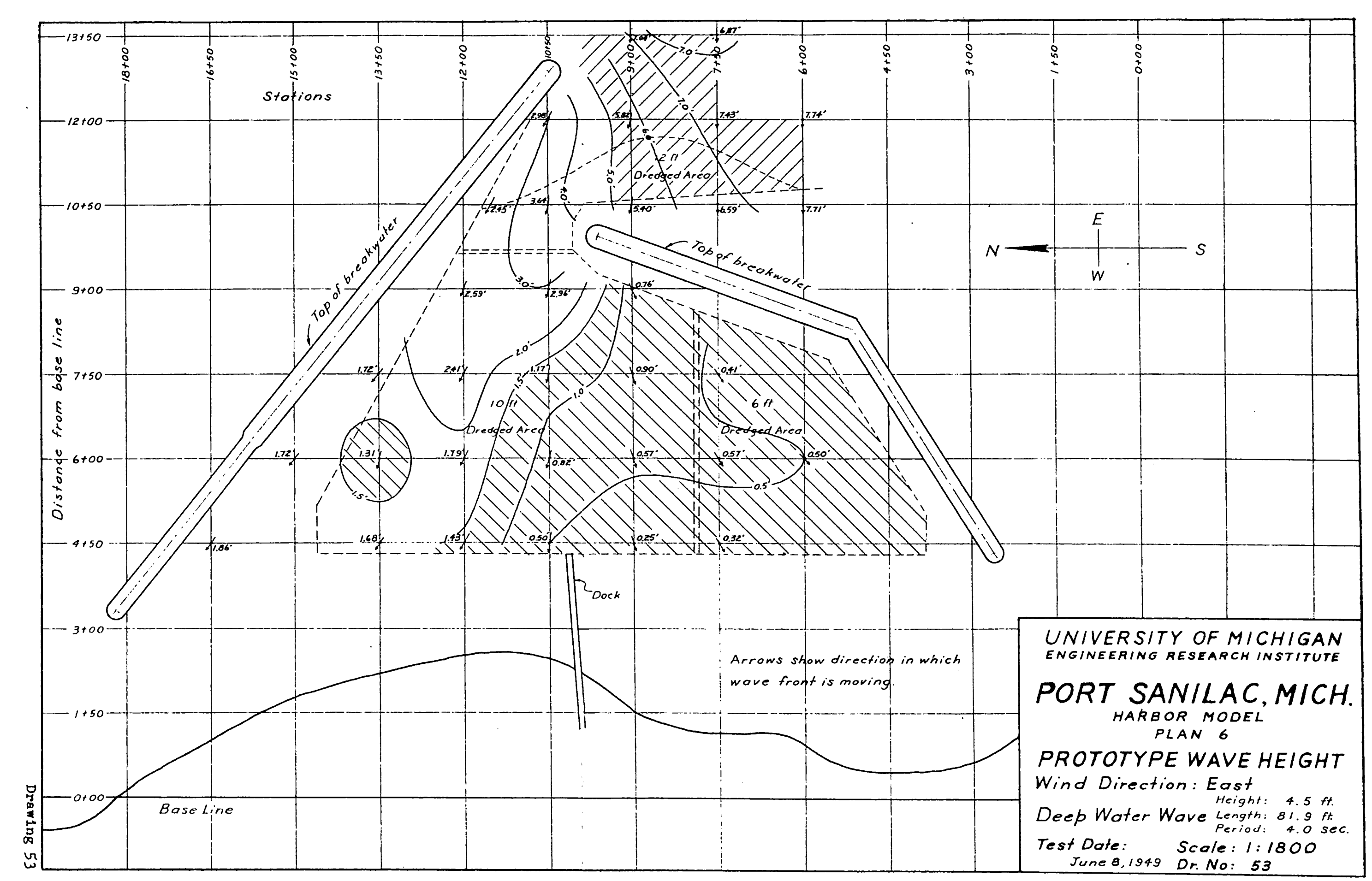
Drawing 6
Stations
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Top of breakwater
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 1
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.4 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: March 10, 1949
Scale: 1:1800
Dr. No: 6



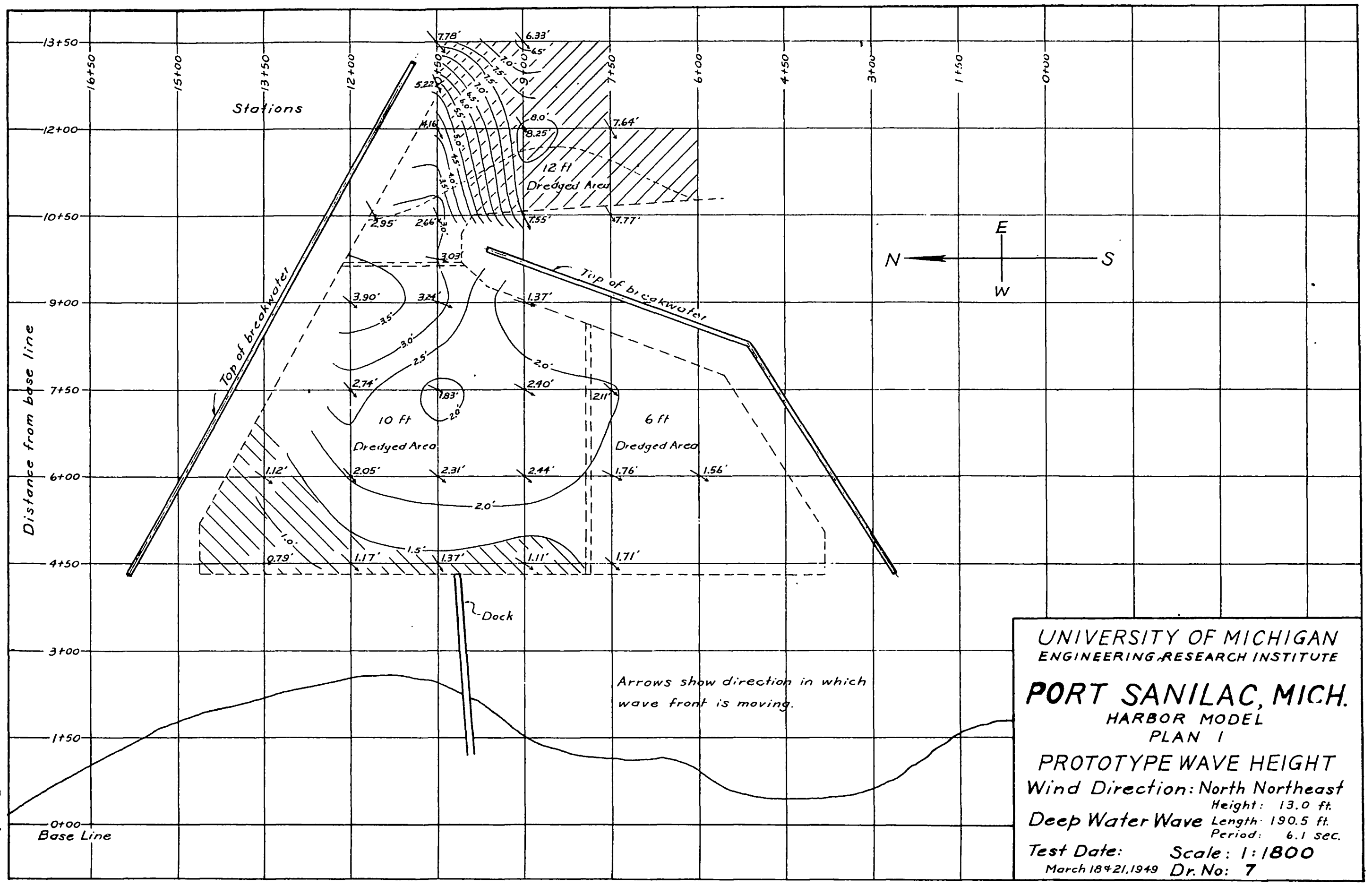
Drawing 35
Stations
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Top of breakwater
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: May 3, 1949
Scale: 1:1800
Dr. No: 35

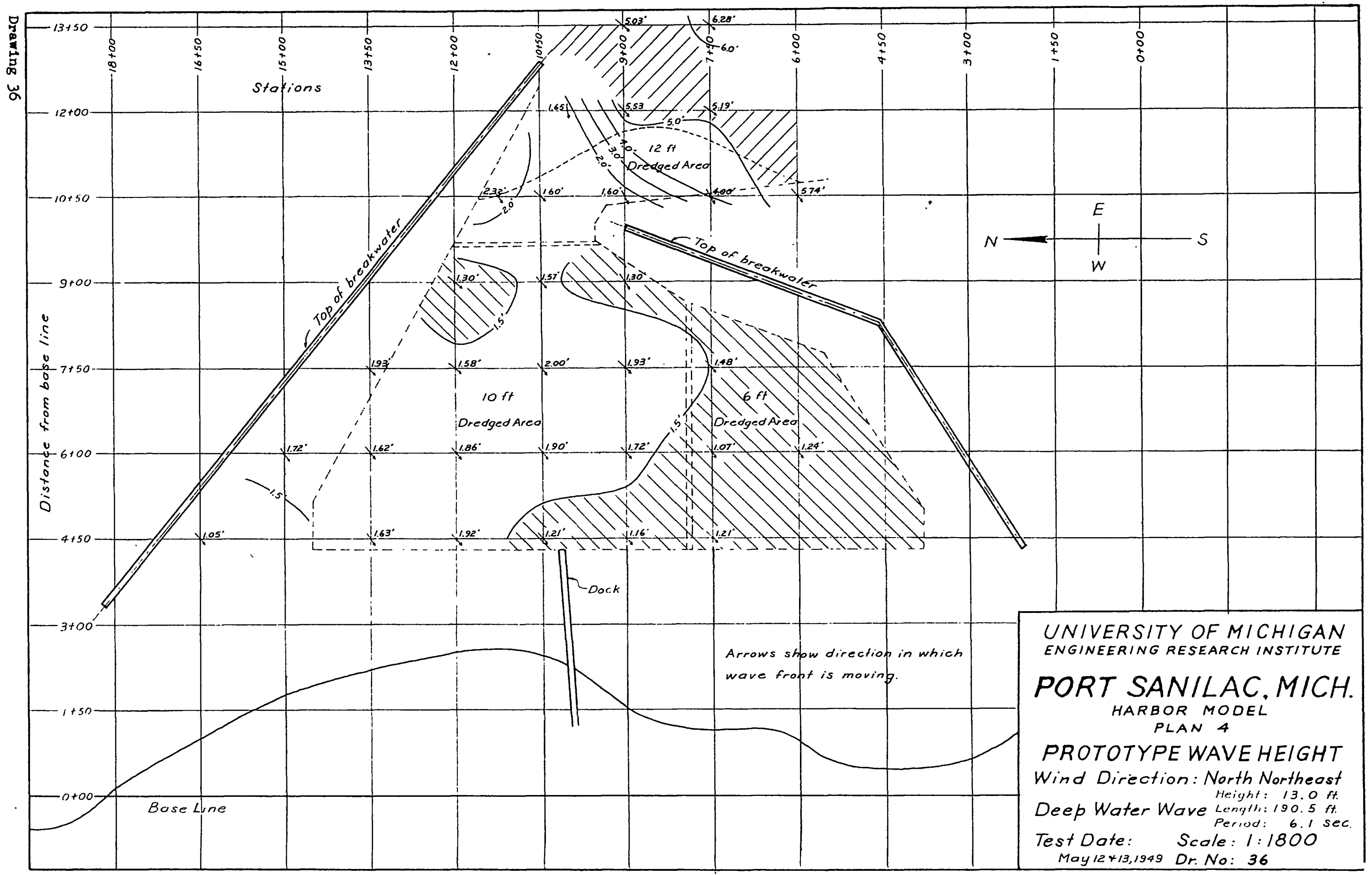


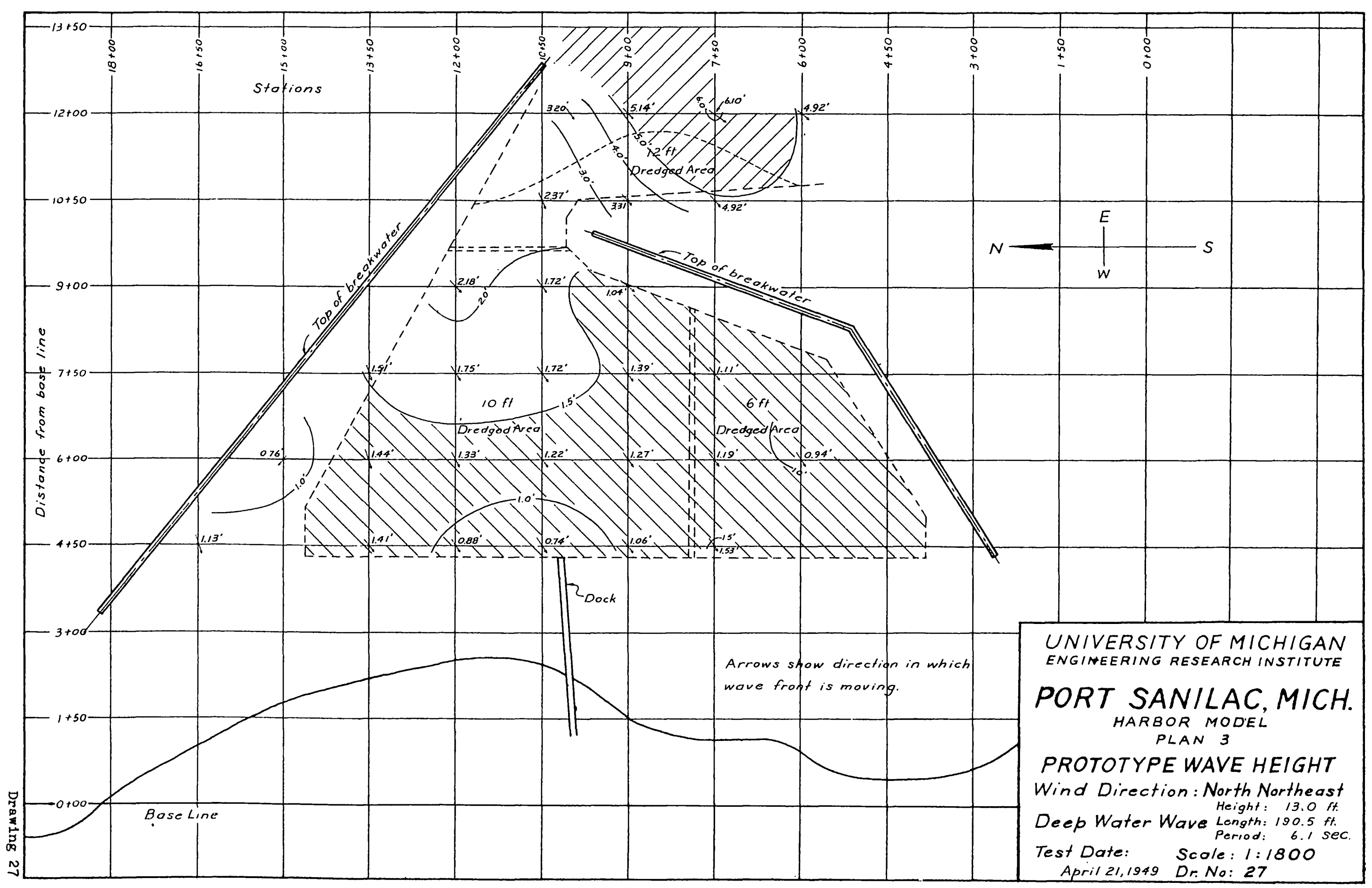
Drawing 26
Stations
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Top of breakwater
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: April 26, 1949
Scale: 1:1800
Dr. No: 26

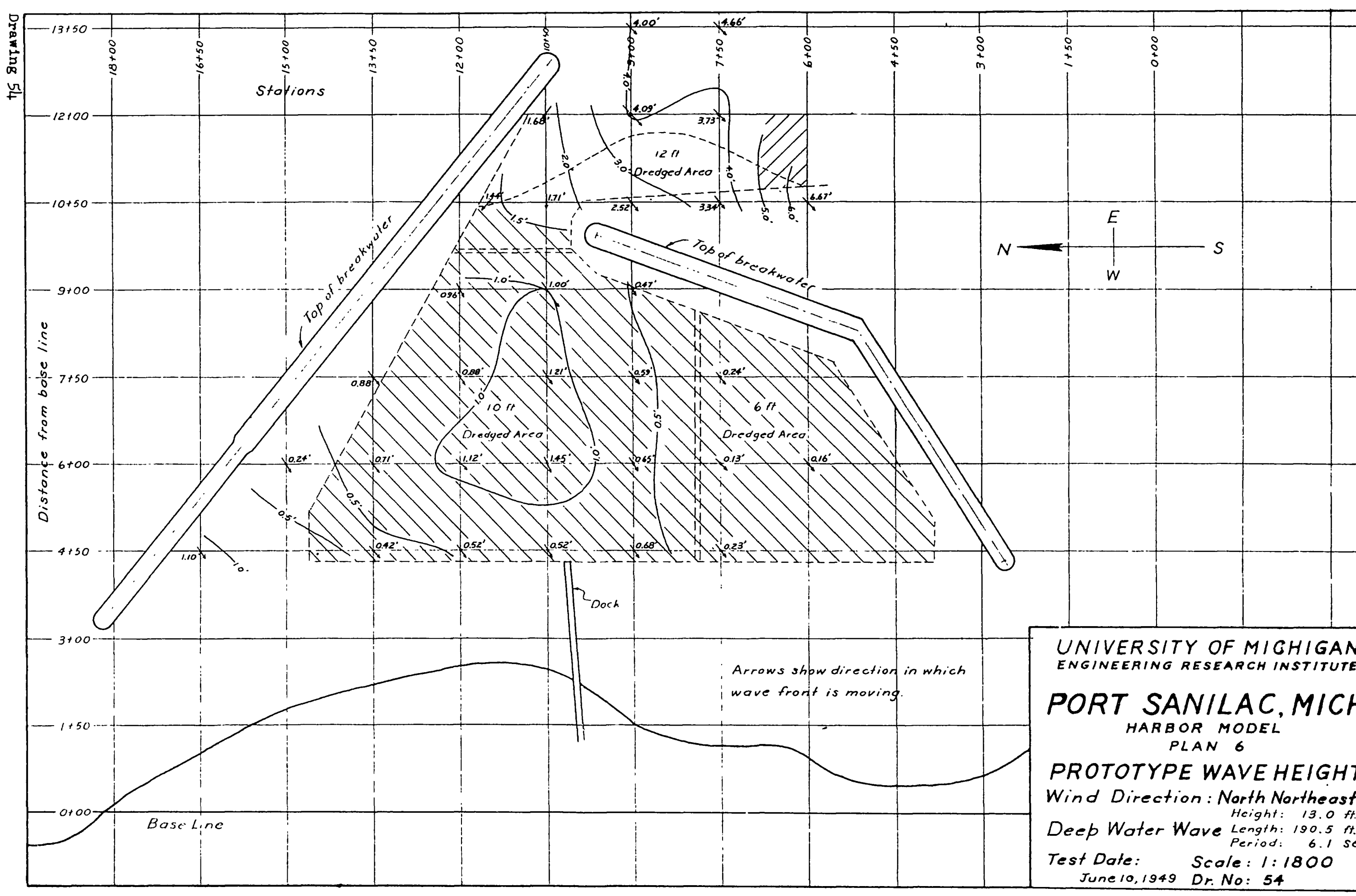


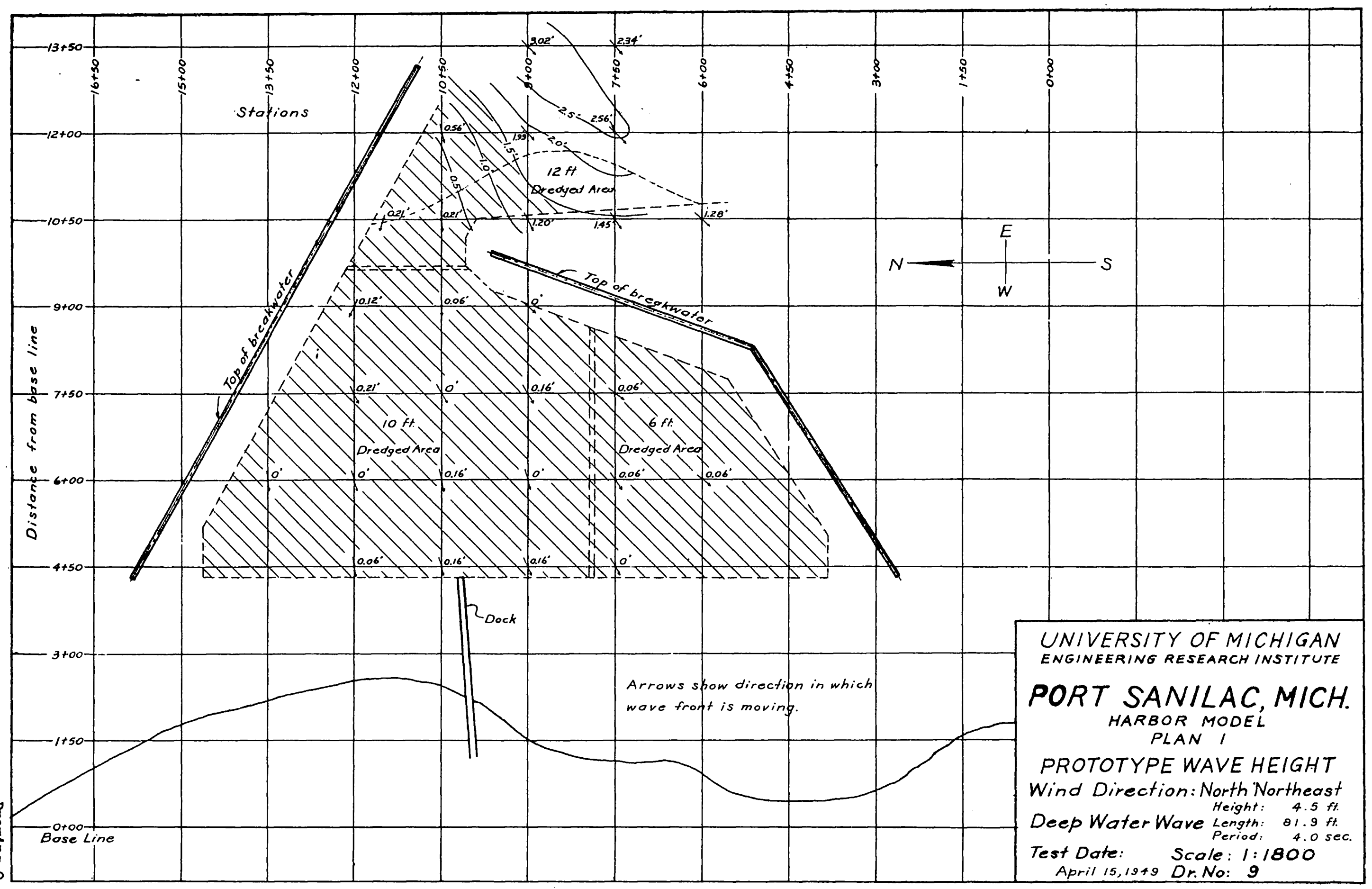
Drawing 53
Stations
12 ft Dredged Area
10 ft Dredged Area
6 ft Dredged Area
Top of breakwater
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: East
Deep Water Wave Height: 4.5 ft. Length: 81.9 ft. Period: 4.0 sec.
Test Date: June 8, 1949
Scale: 1:1800
Dr. No: 53


Stations
Top of breakwater
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 1
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: March 18 & 21, 1949
Scale: 1:1800
Dr. No: 7
Drawing 7

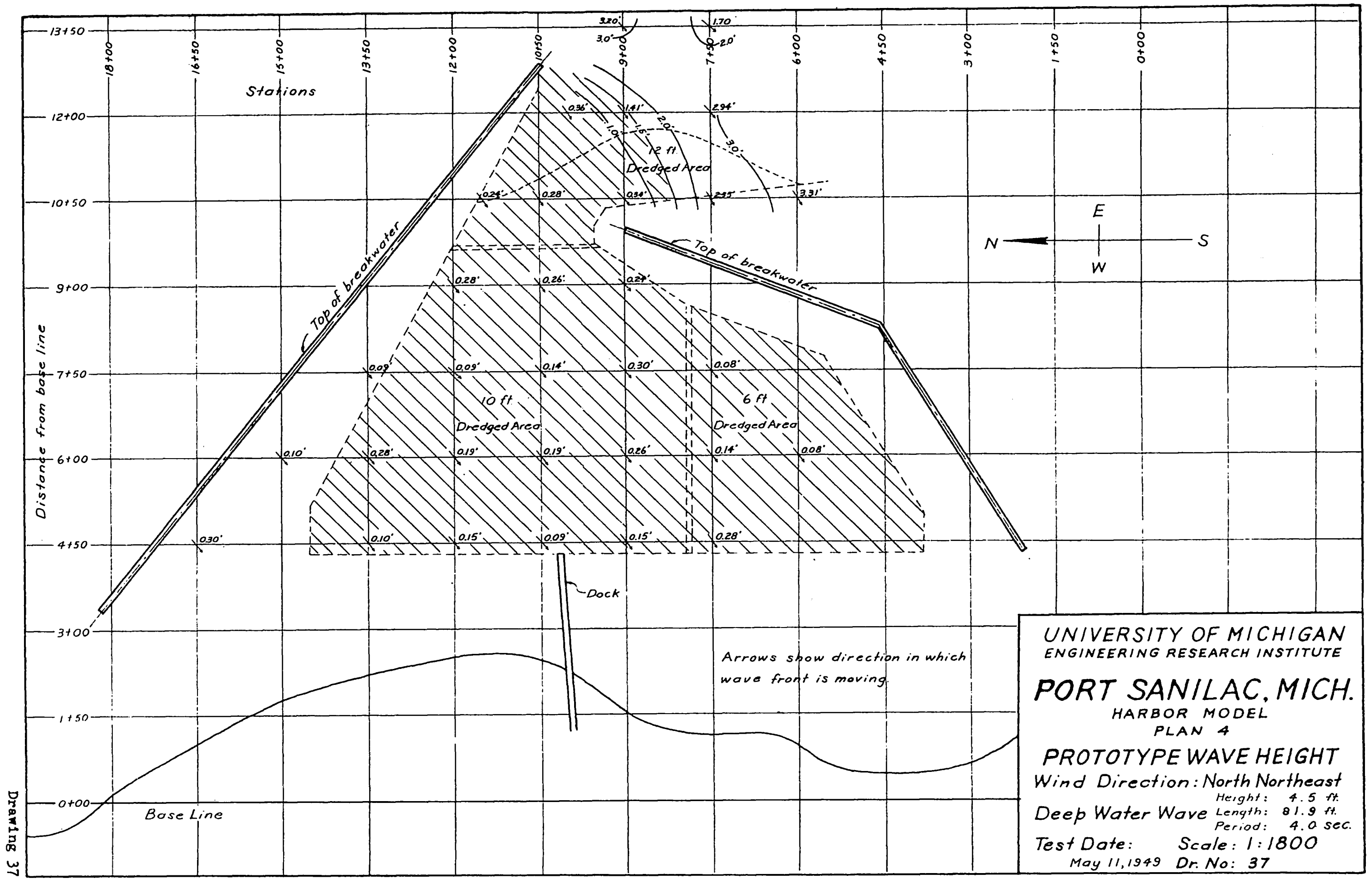

Drawing 36
Stations
Top of breakwater
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 4
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: May 12 & 13, 1949
Scale: 1:1800
Dr. No: 36


Stations
Top of breakwater
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 3
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: April 21, 1949
Scale: 1:1800
Dr. No: 27
Drawing 27

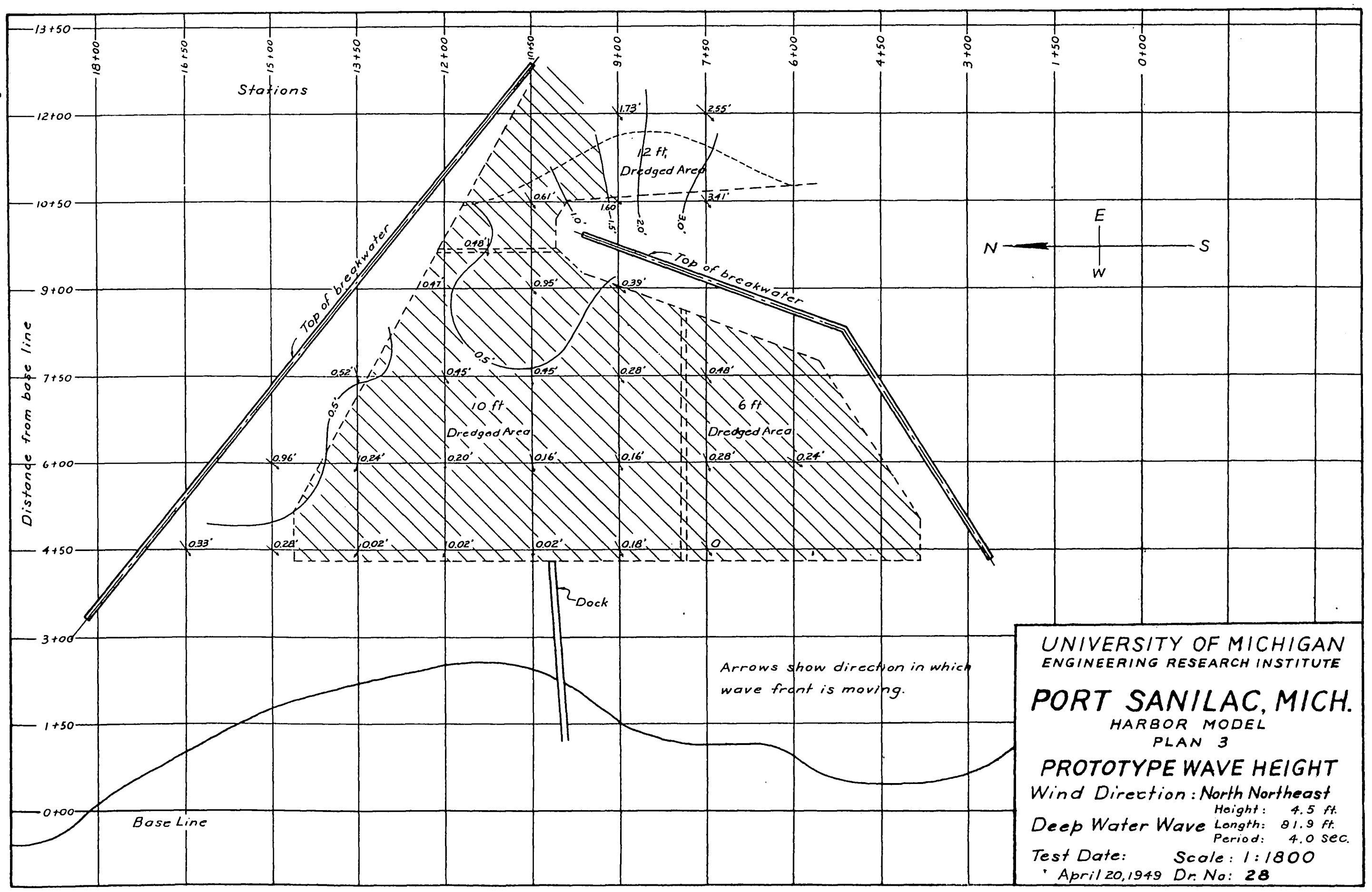

Drawing 54
Stations
Top of breakwater
Top of breakwater
12 ft
Dredged Area
10 ft
Dredged Area
6 ft
Dredged Area
Dock
Distance from base line
Base Line
Arrows show direction in which wave front is moving.
UNIVERSITY OF MICHIGAN
ENGINEERING RESEARCH INSTITUTE
PORT SANILAC, MICH.
HARBOR MODEL
PLAN 6
PROTOTYPE WAVE HEIGHT
Wind Direction: North Northeast
Deep Water Wave Height: 13.0 ft. Length: 190.5 ft. Period: 6.1 sec.
Test Date: June 10, 1949
Scale: 1:1800
Dr. No: 54



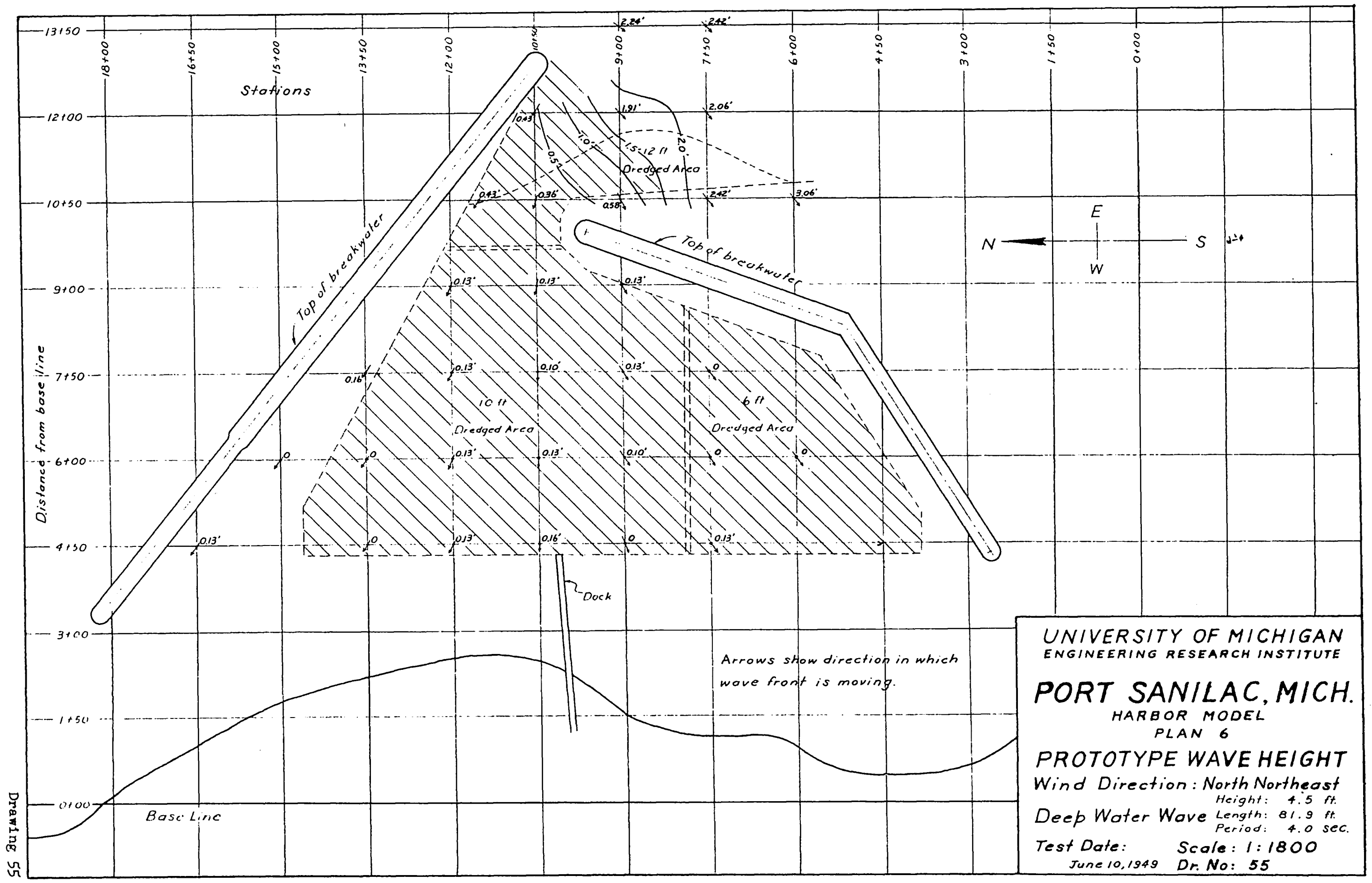
Drawing 9



Drawing 37



Drawing 28

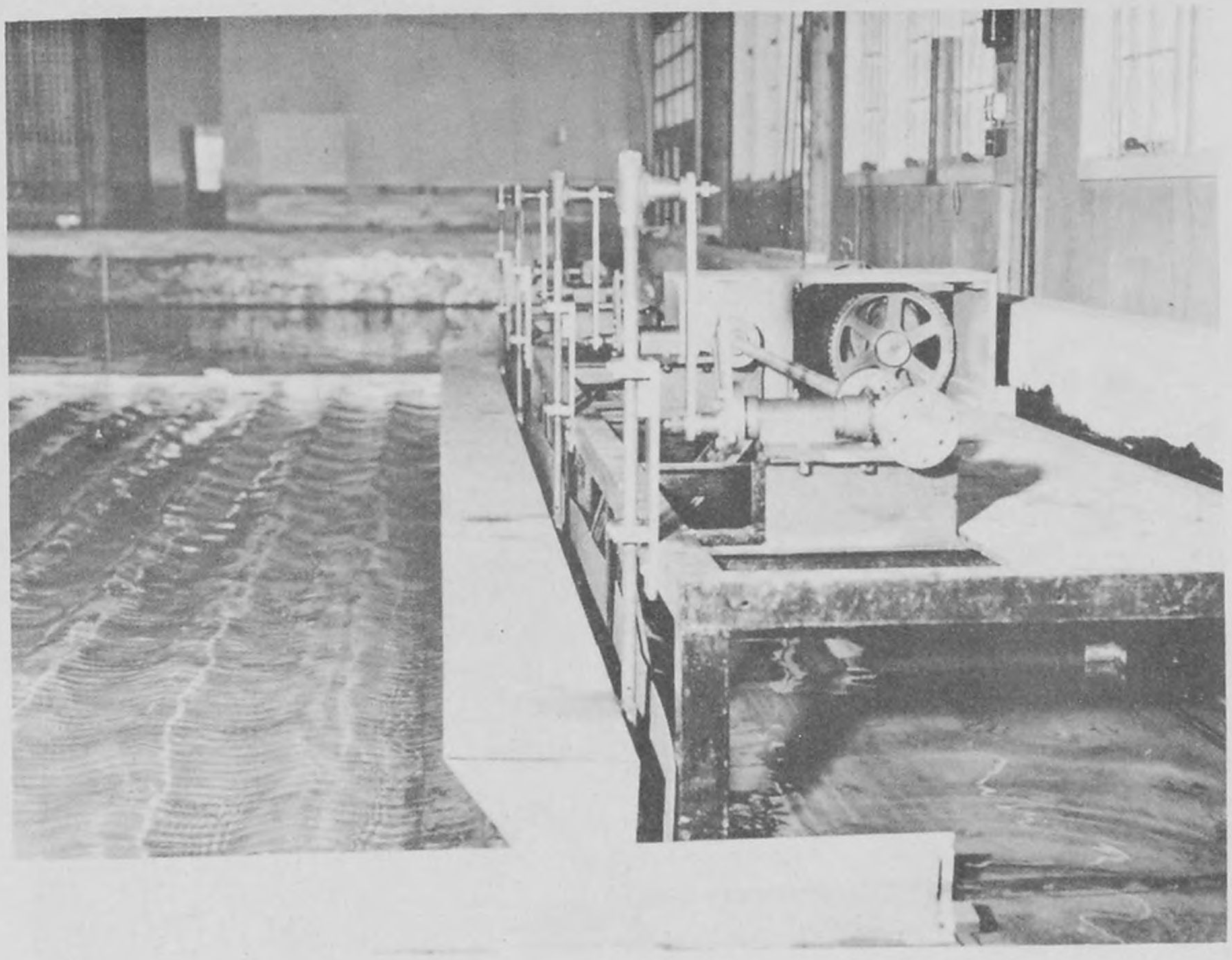


Drawing 55

APPENDIX B

PHOTOGRAPHS

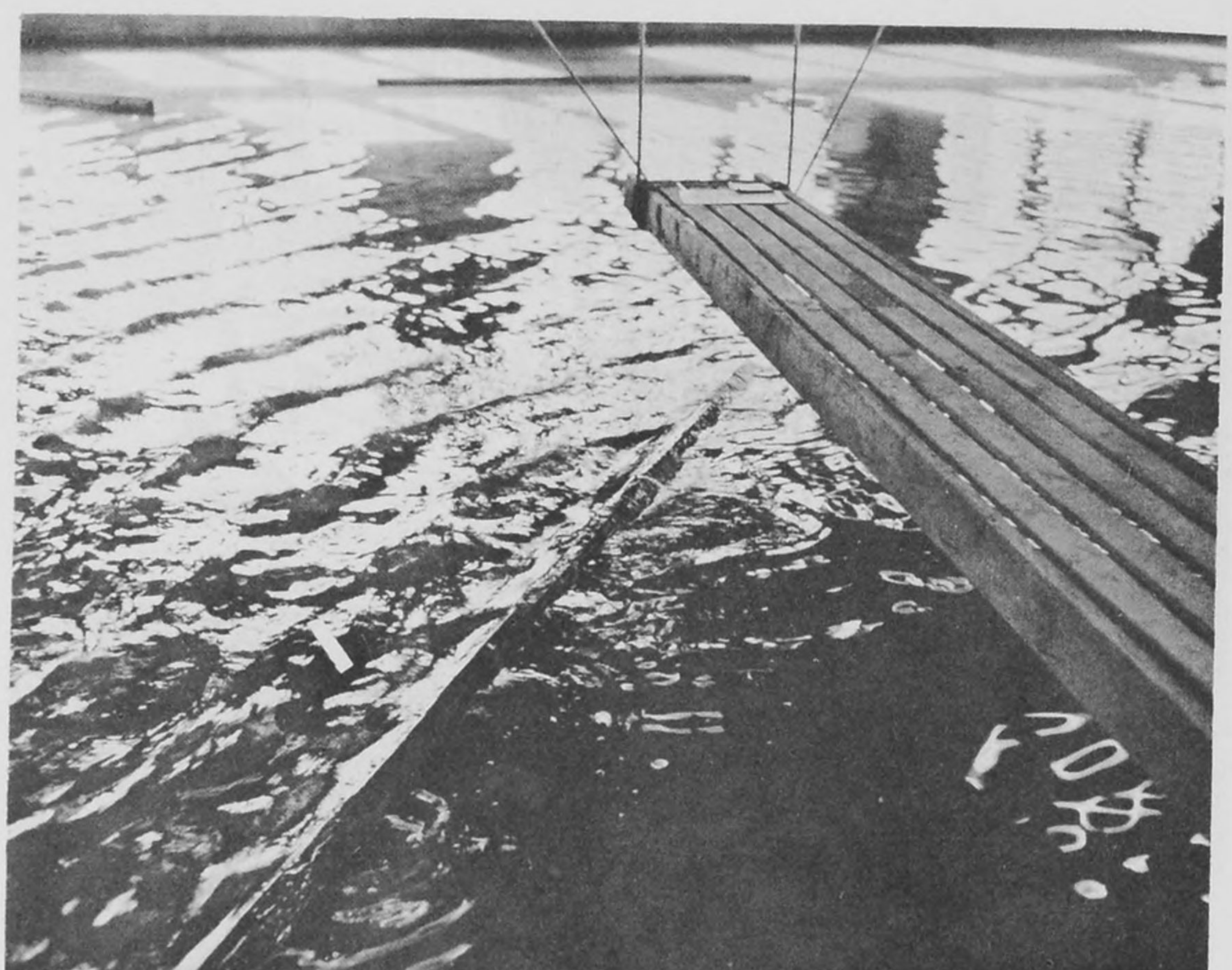
TEMPLATES



WAVE MACHINE

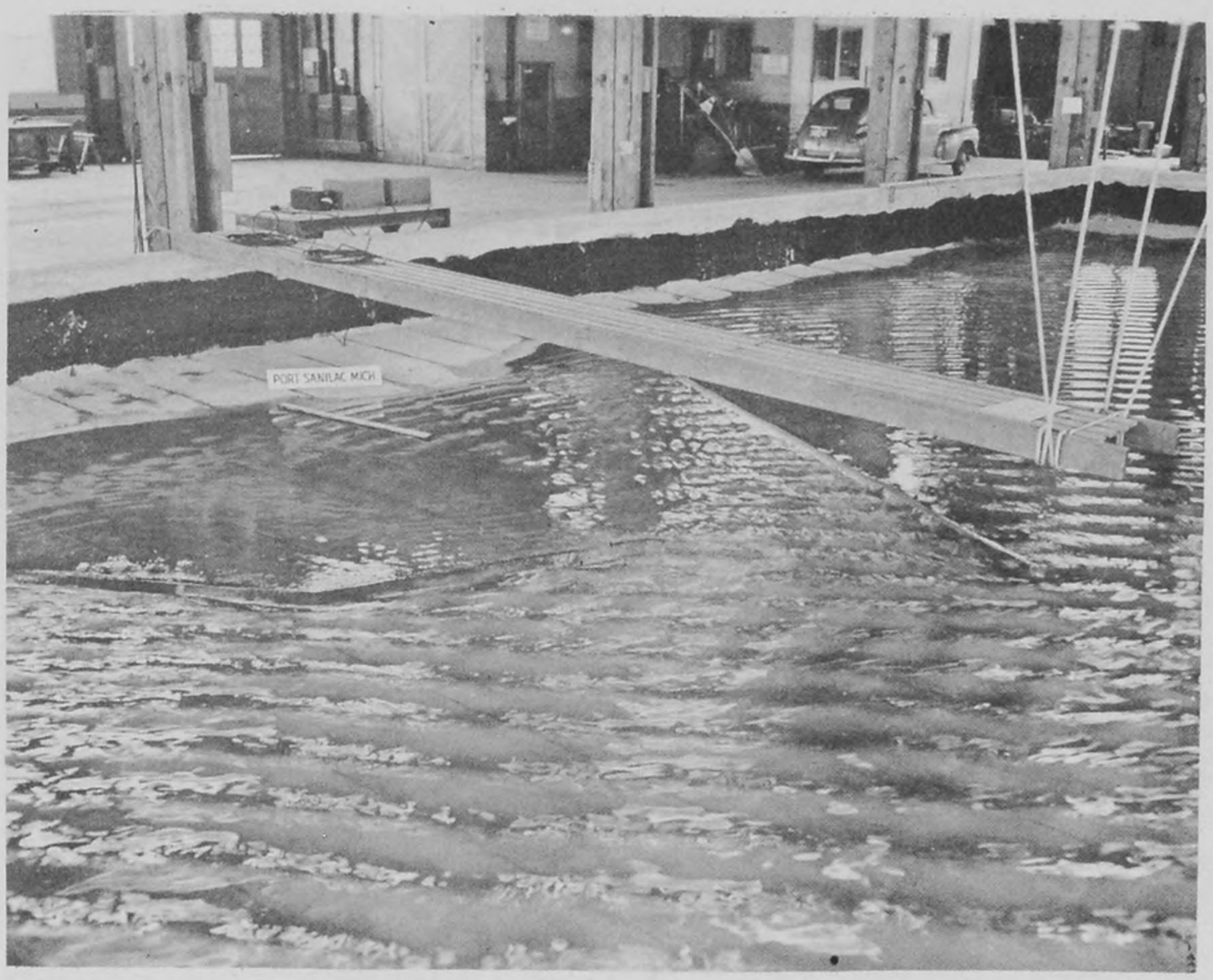
PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 1.

PLAN 1 - E WIND



PLAN 1 - NNE WIND

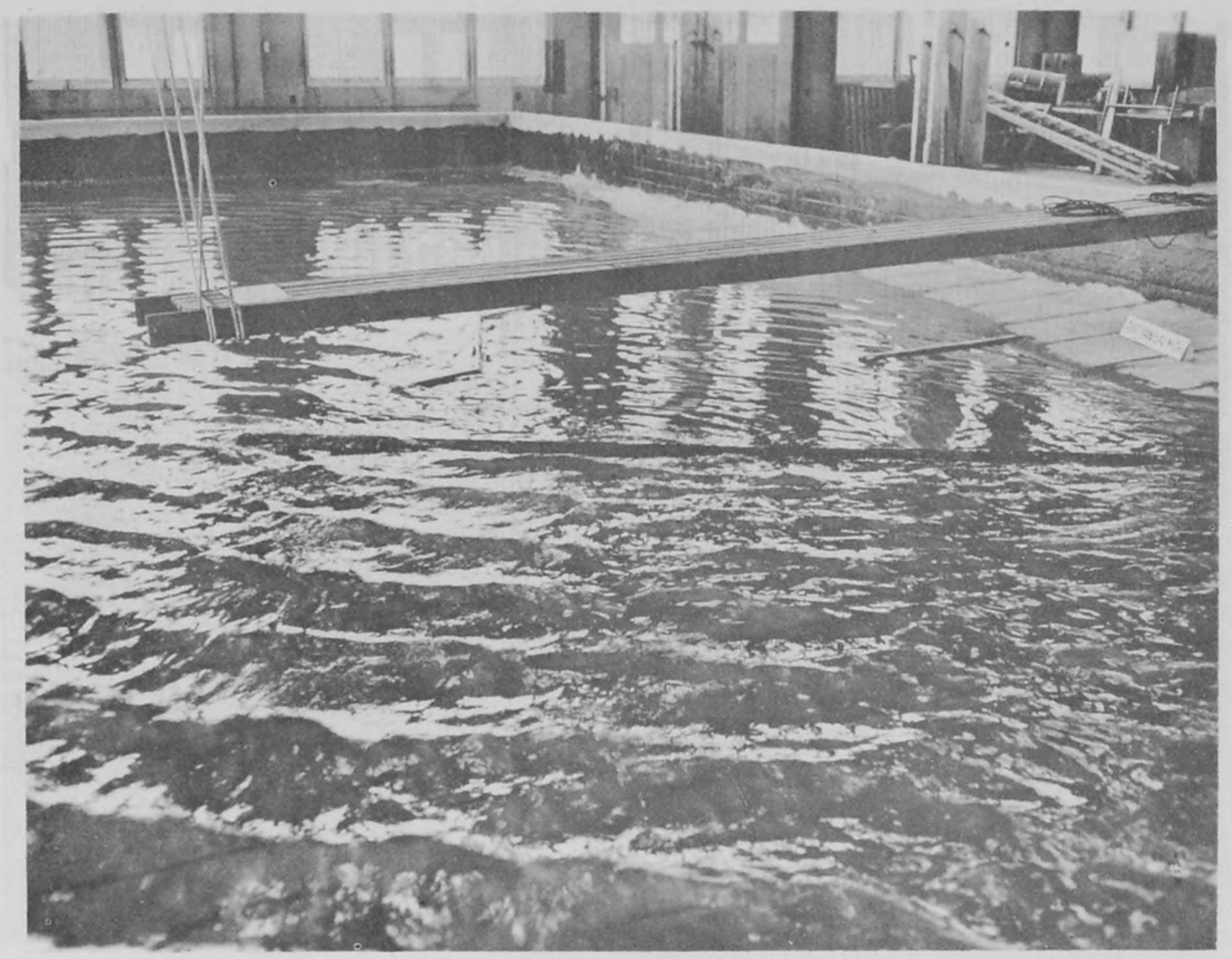
PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 2.



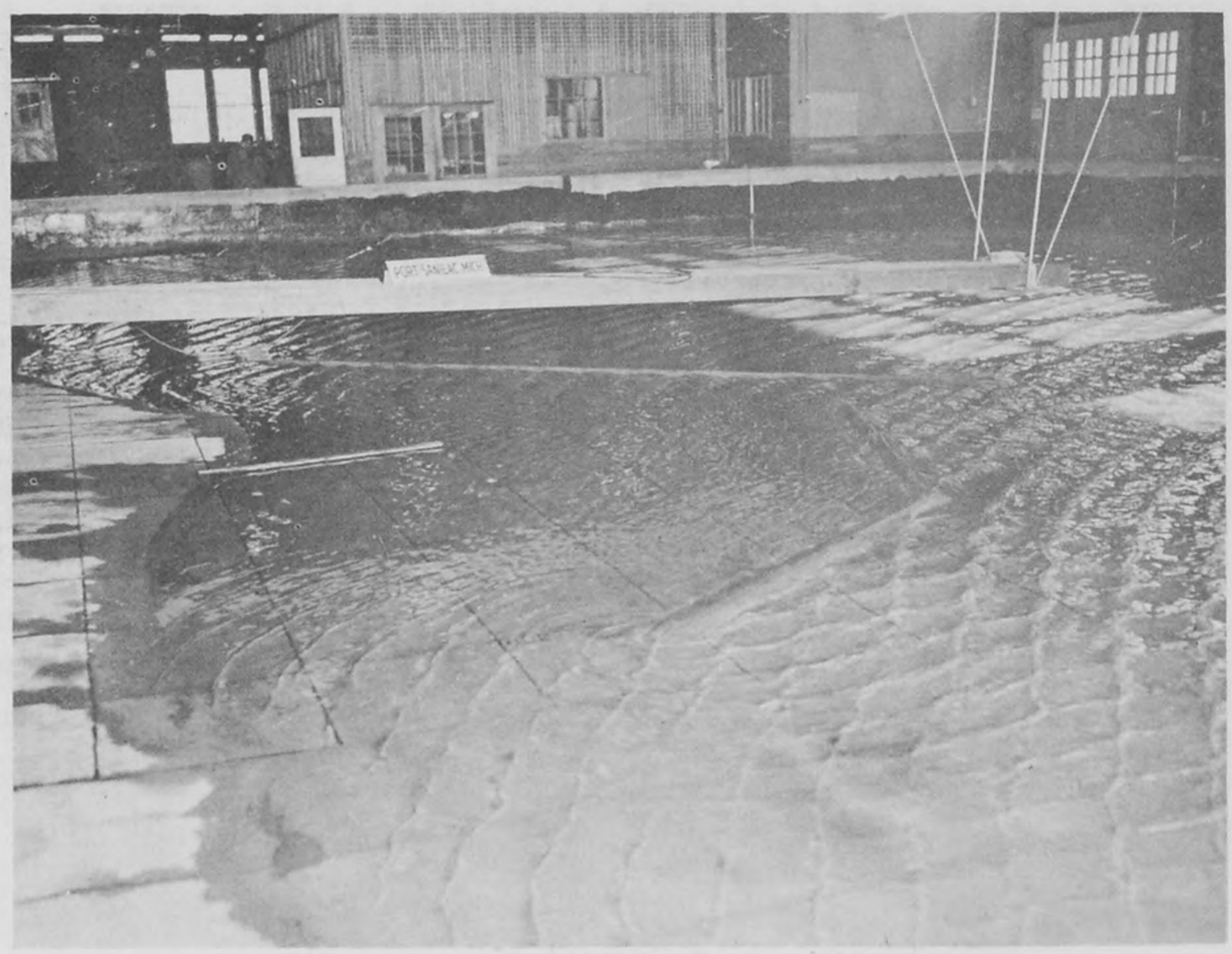
PLAN 2 - SSE WIND

PLAN 2 - SSE WIND

PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 3.

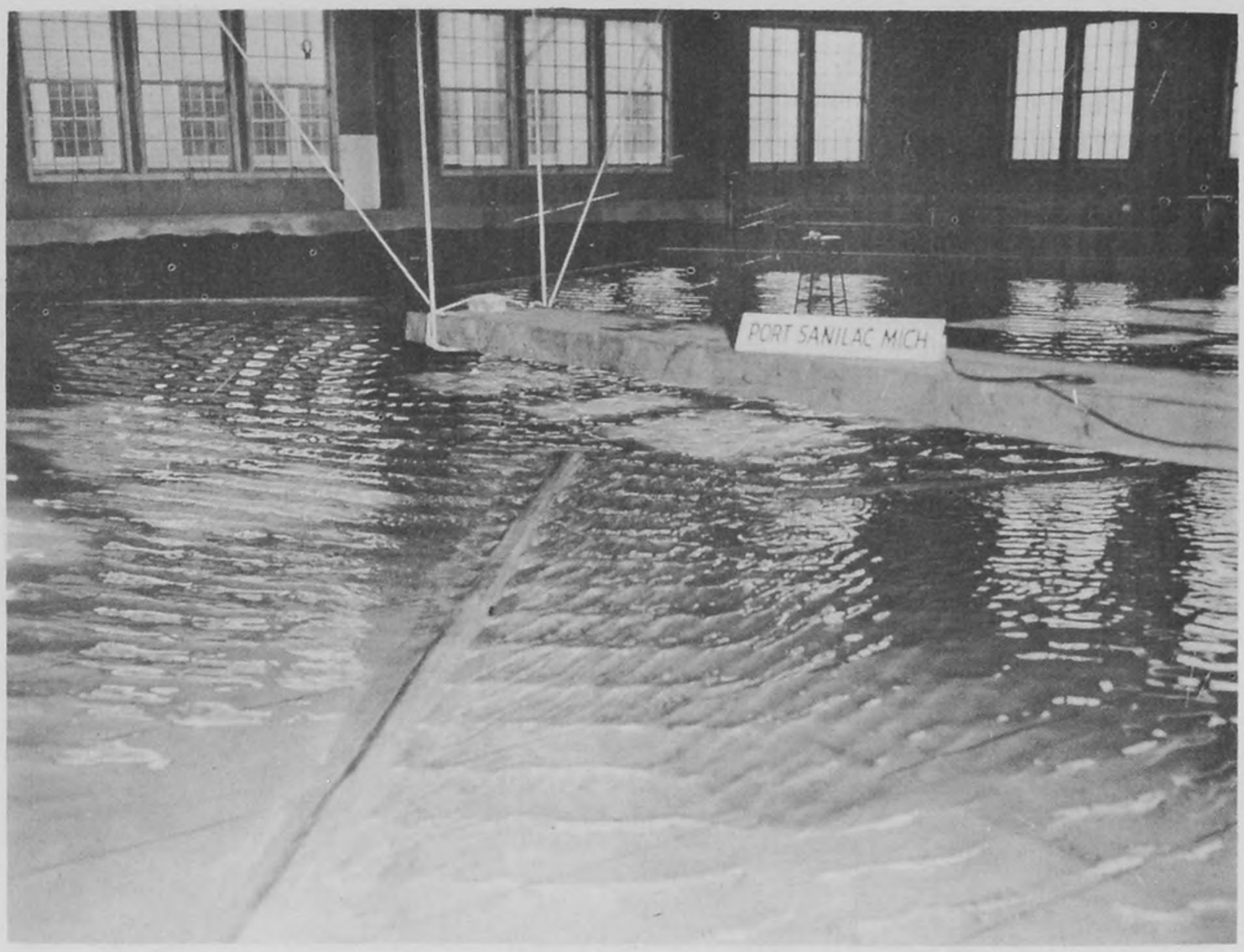


PLAN 2 - NNE WIND

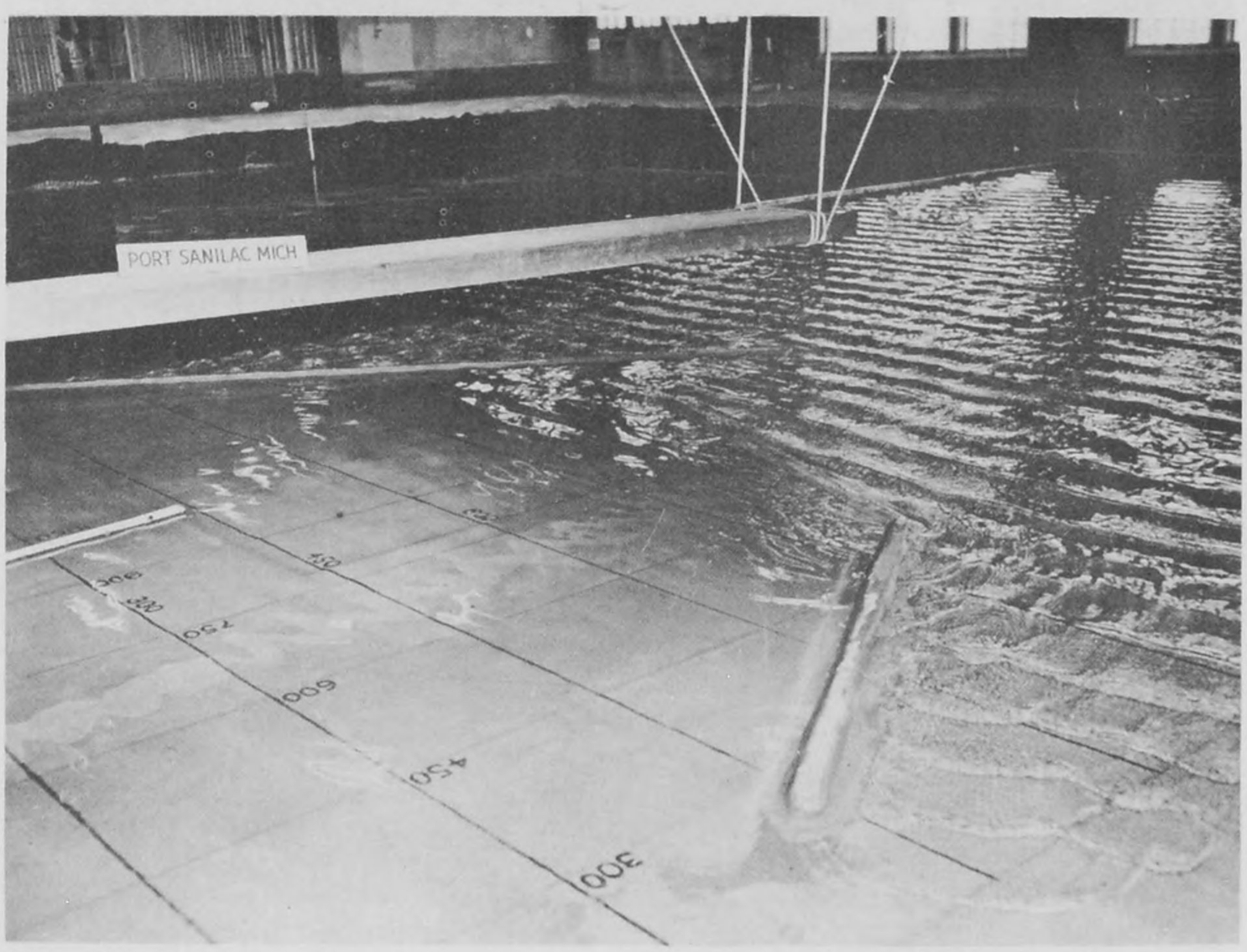


PLAN 3 - SSE WIND

PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 4.



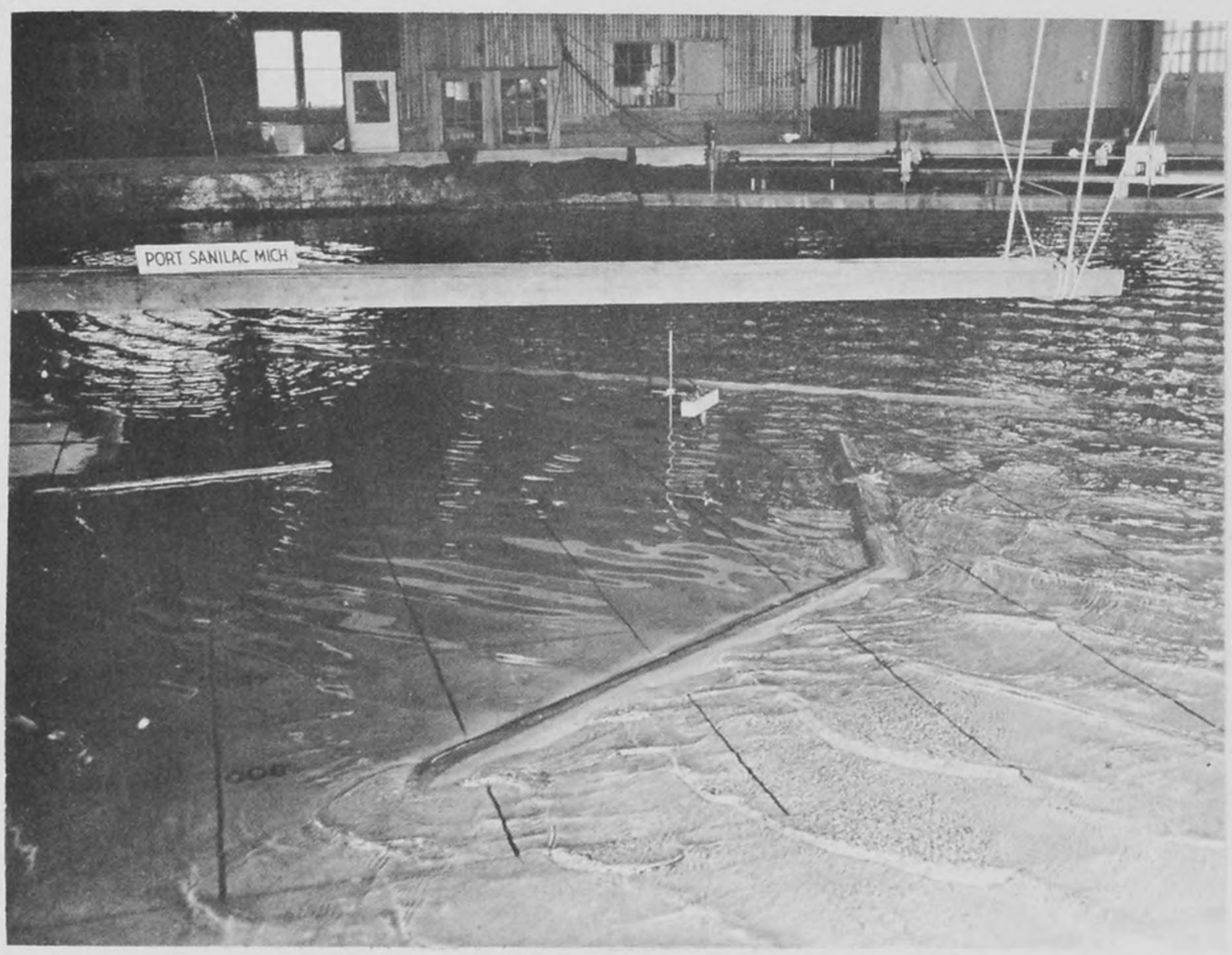
PLAN 3 - SSE WIND



PLAN 3 - E WIND

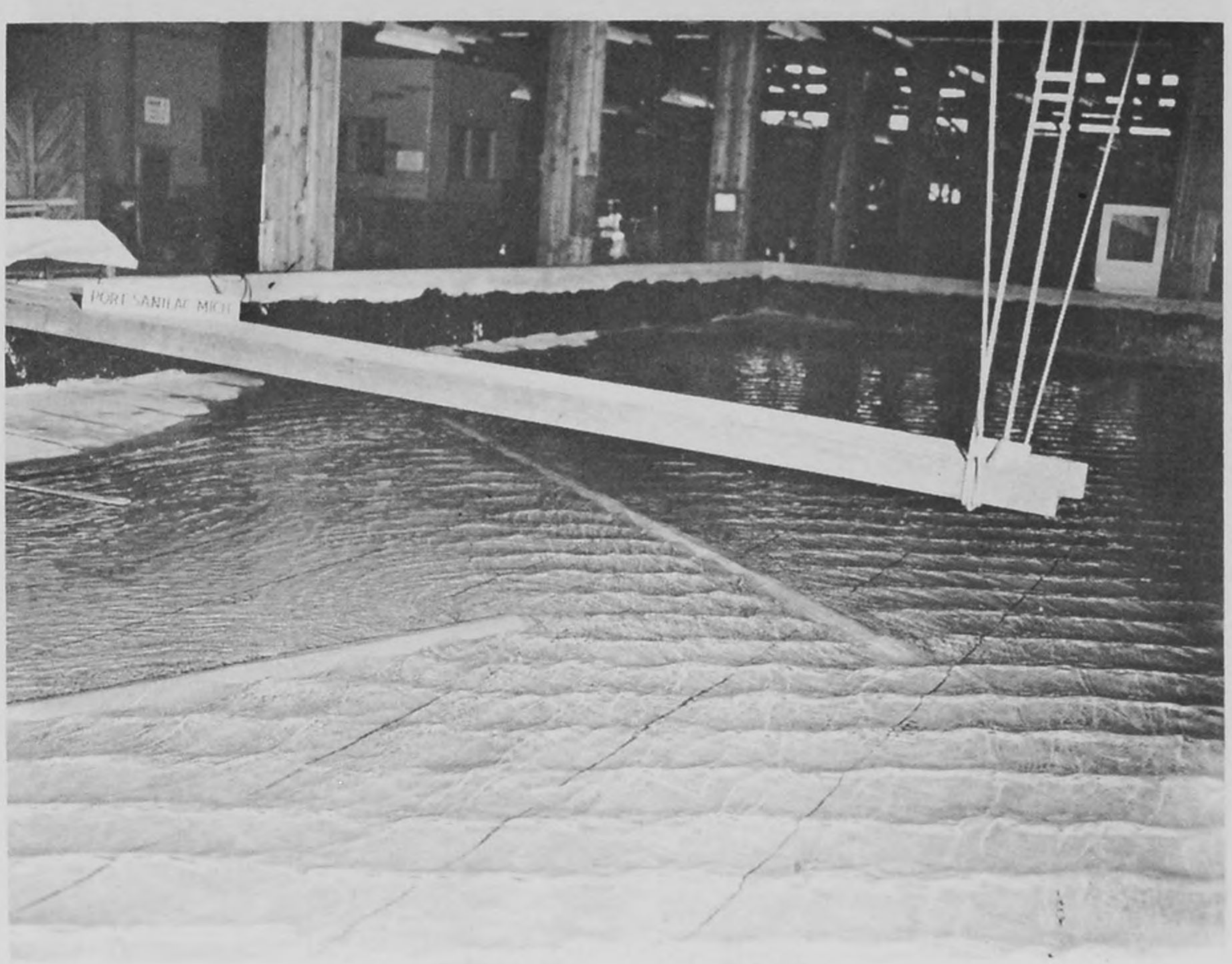
PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 5.

PLAN 3 - E WIND



PLAN 3 - NNE WIND

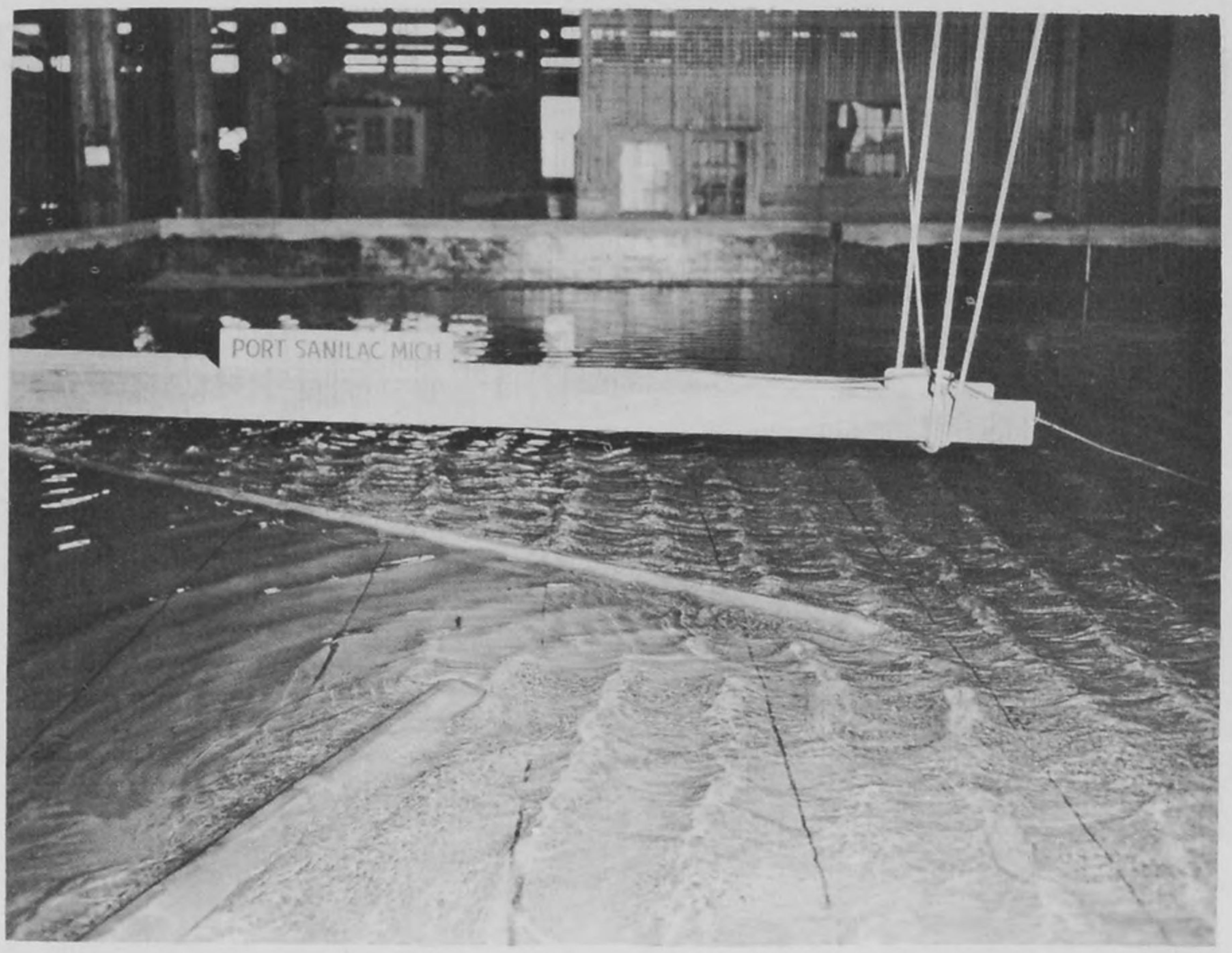
PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 6.



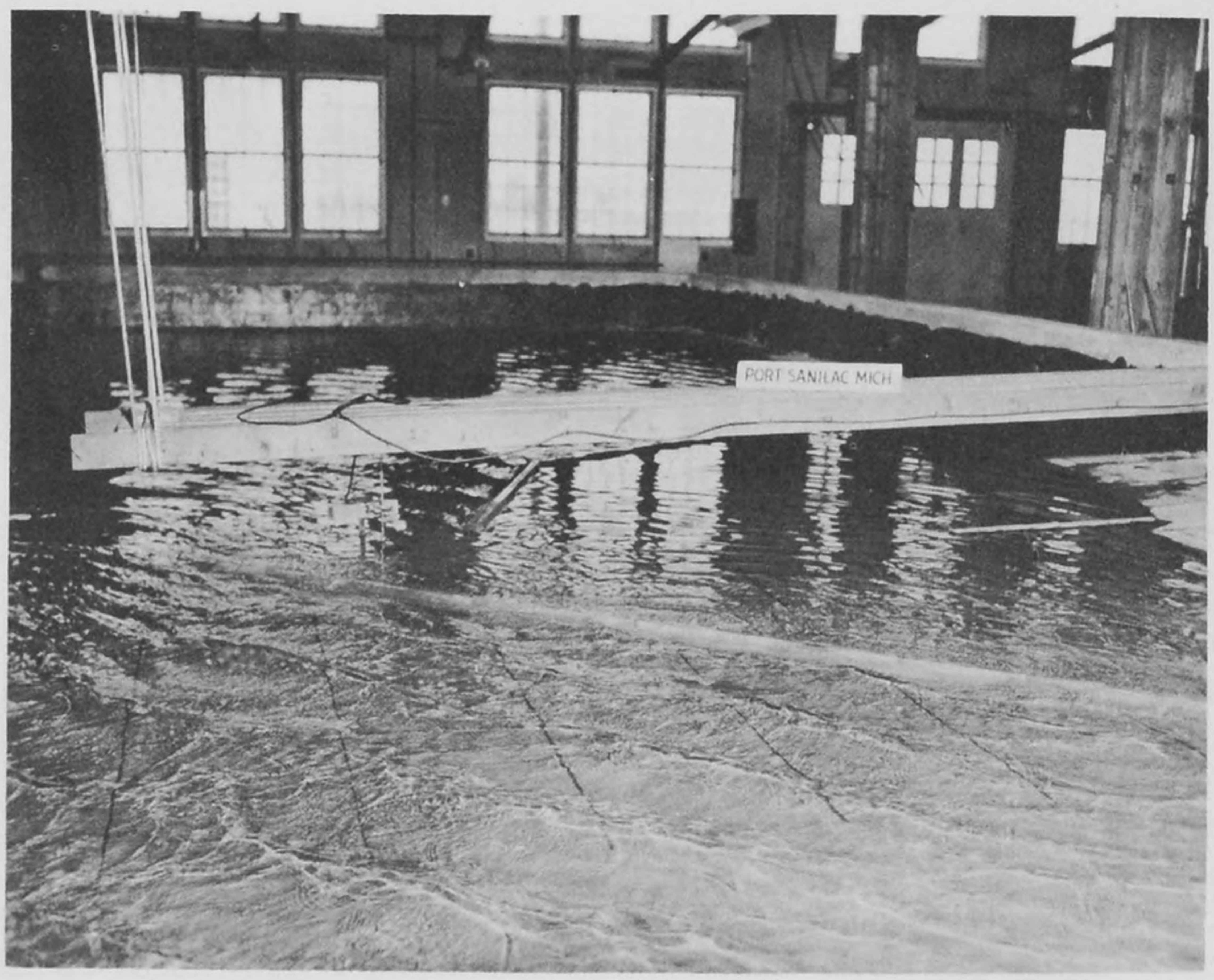
PLAN 4 - SSE WIND

PLAN 4 - E WIND

PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 7.

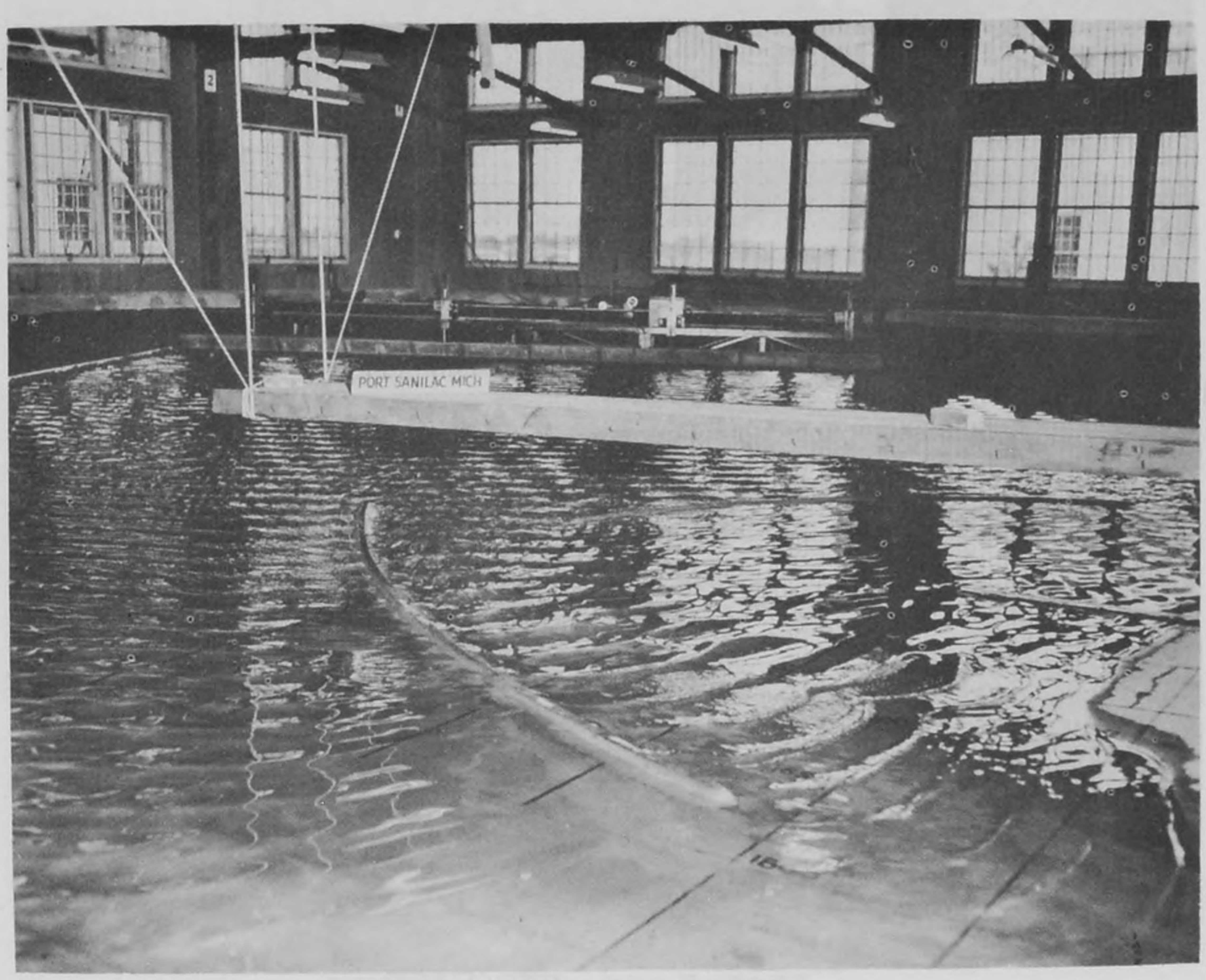


PLAN 4 - E WIND

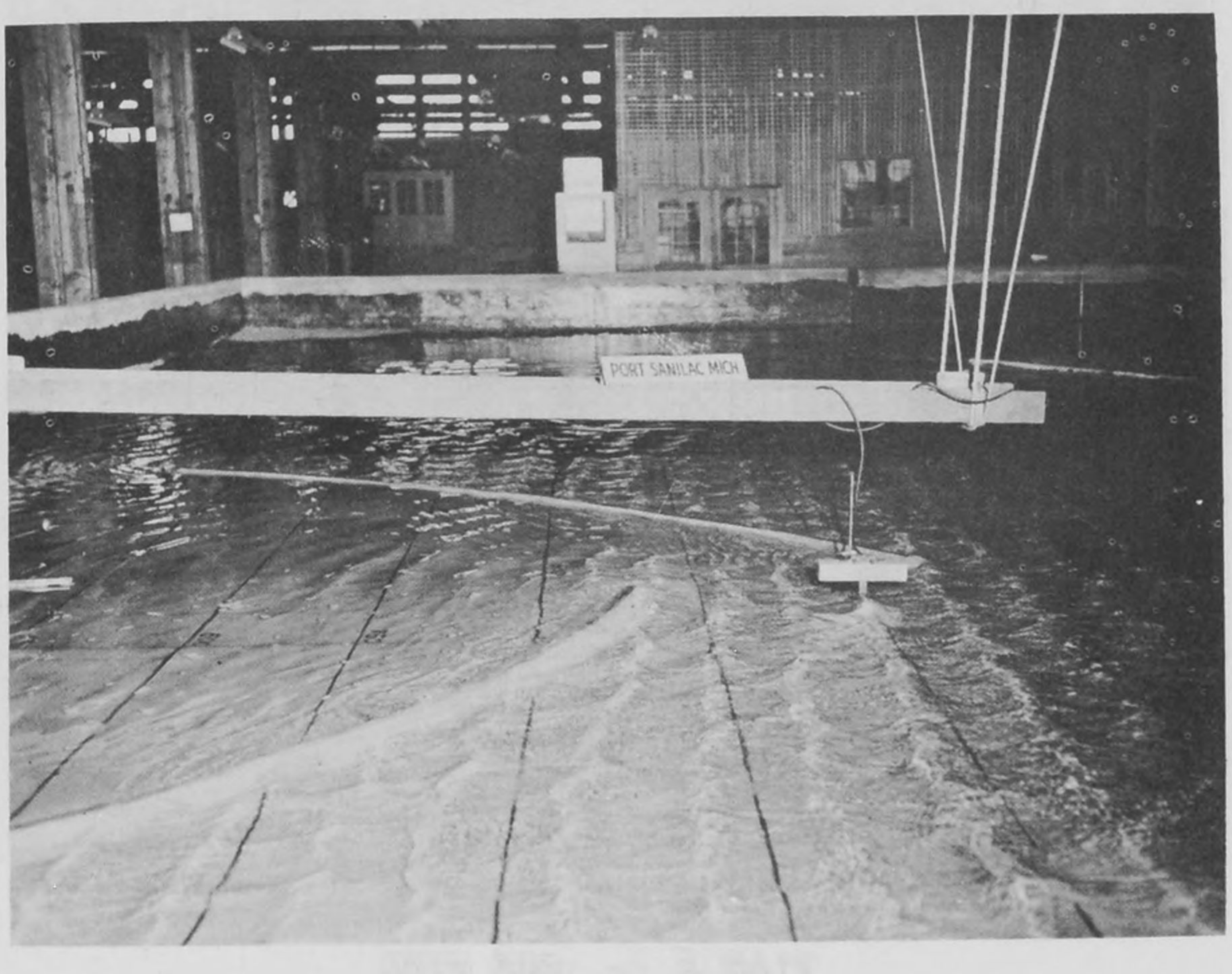


PLAN 4 - NNE WIND

PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 8.

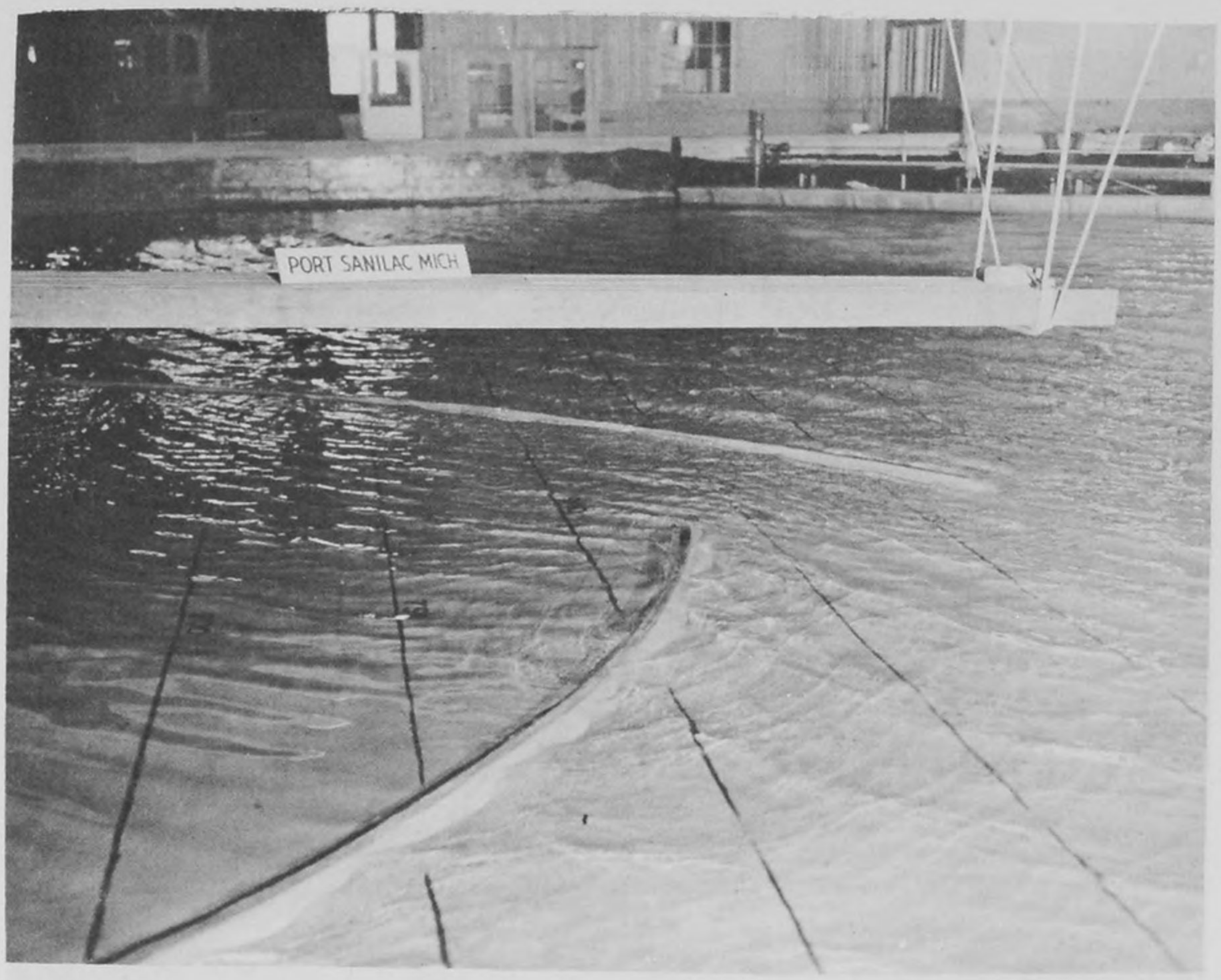


PLAN 5 - SSE WIND



PLAN 5 - E WIND

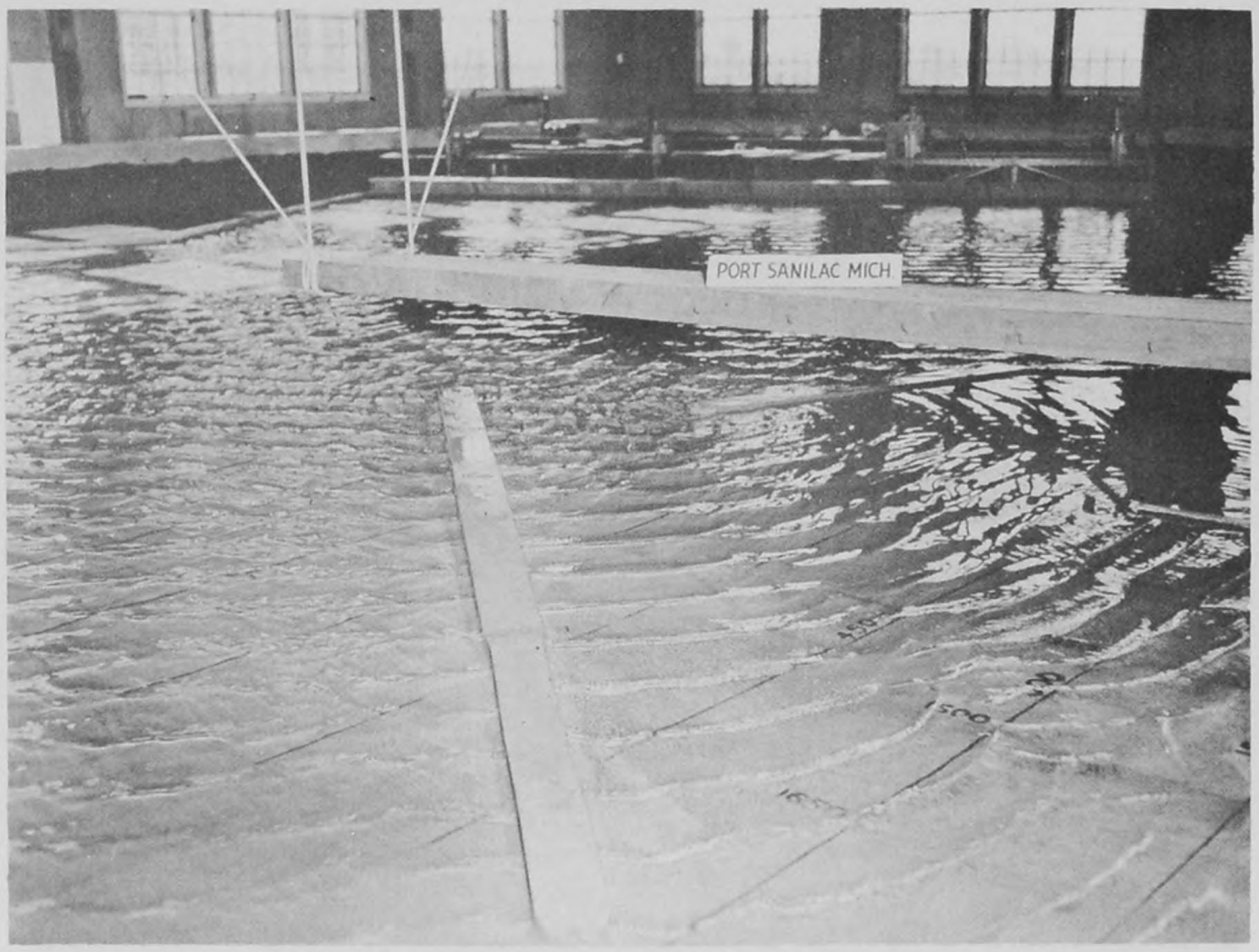
PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 9.



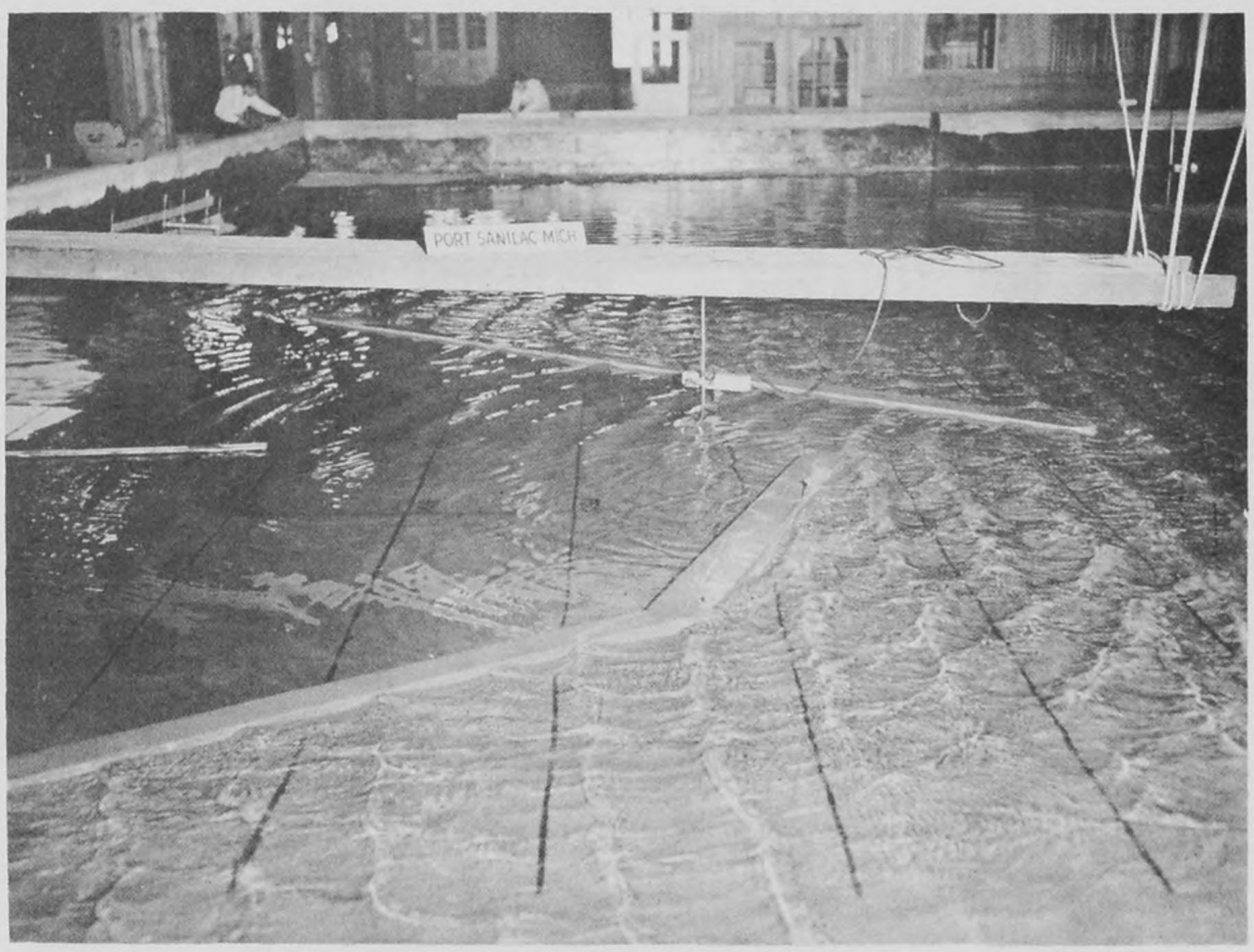
PLAN 5 - NNE WIND

PLAN 6 - SSE WIND

PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 10.

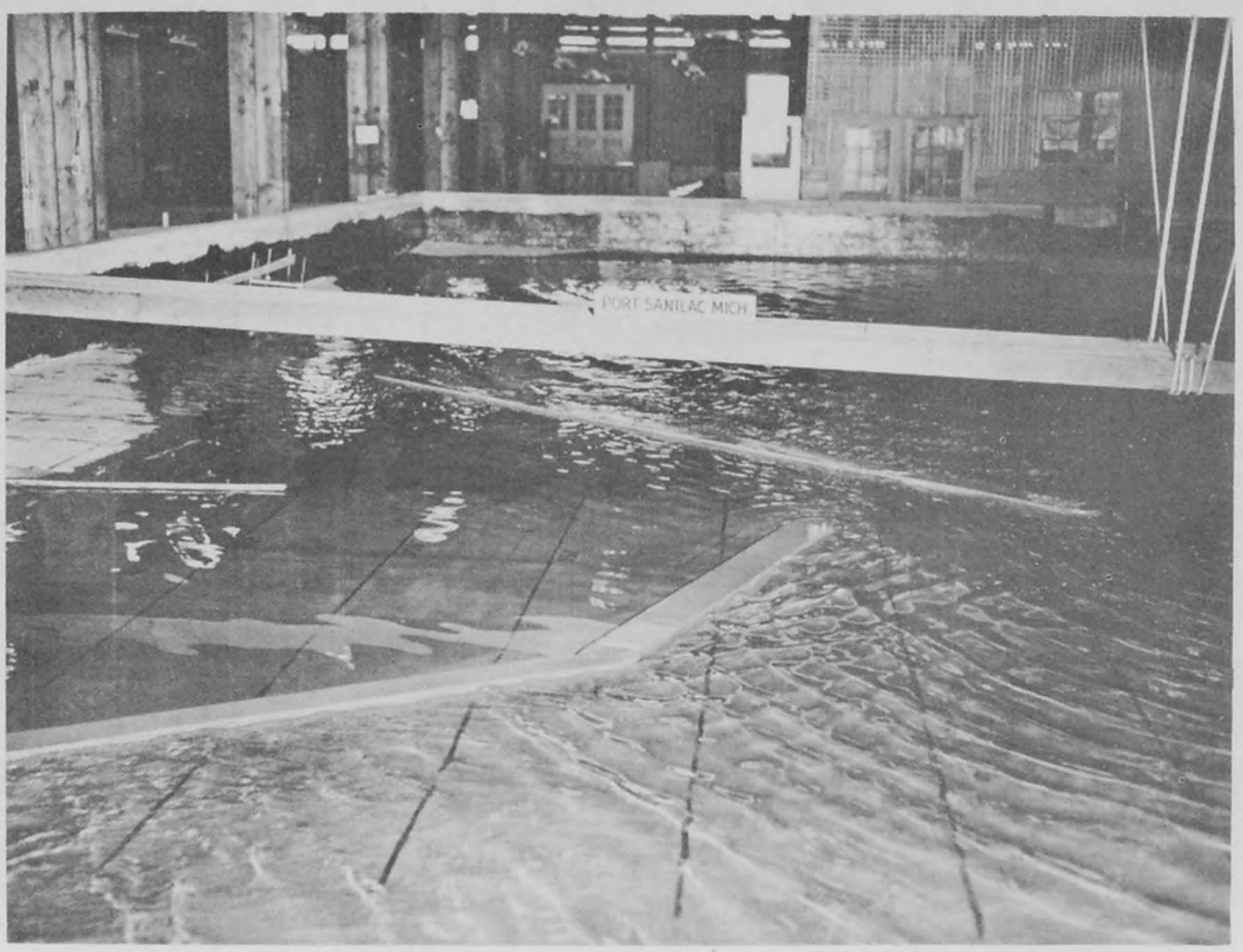


PLAN 6 - SSE WIND

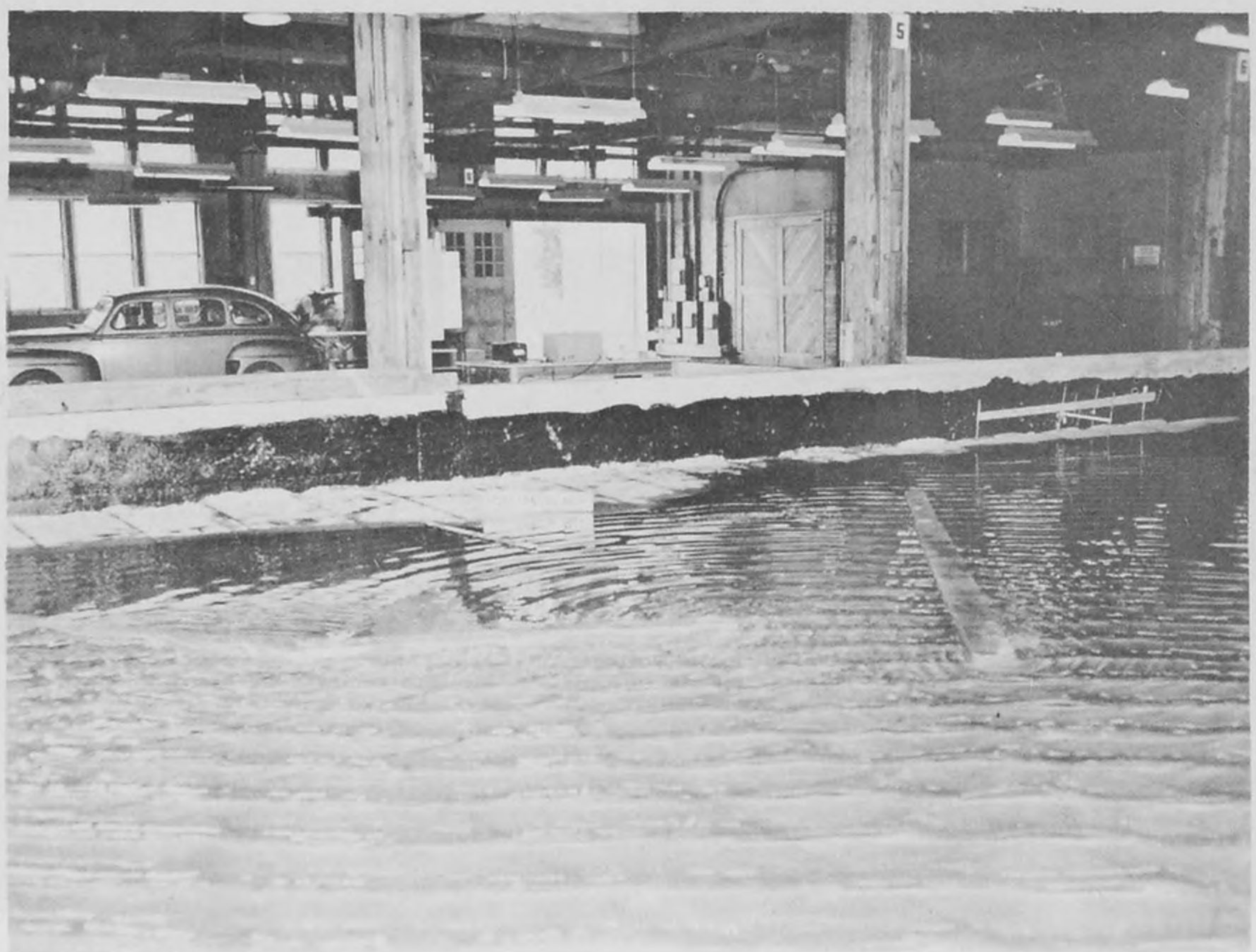


PLAN 6 - E WIND

PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 11.



PLAN 6 - NNE WIND



PLAN 6 - SE WIND

PORT SANILAC, MICHIGAN
HARBOR MODEL
PLATE 12.

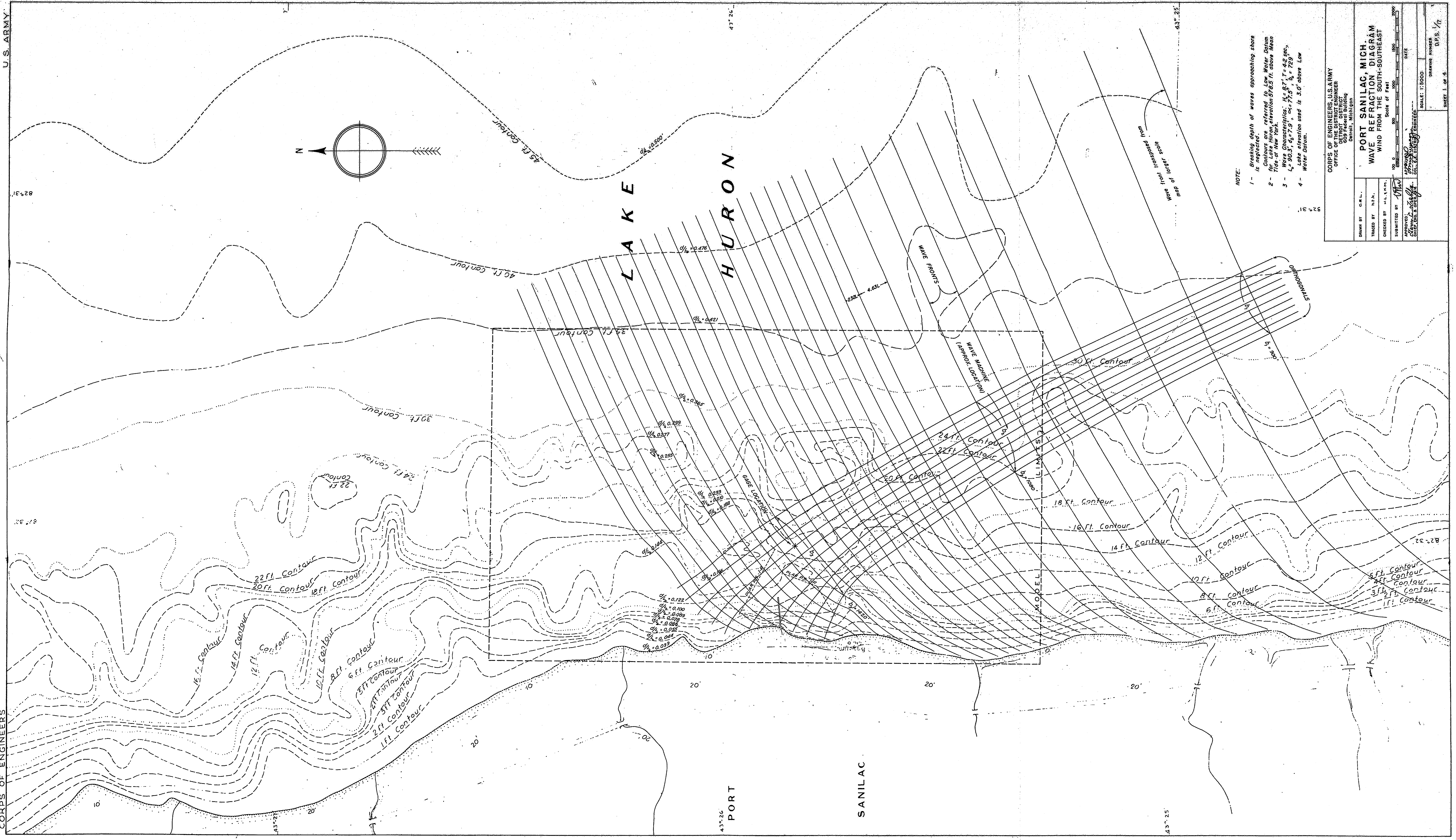
APPENDIX C

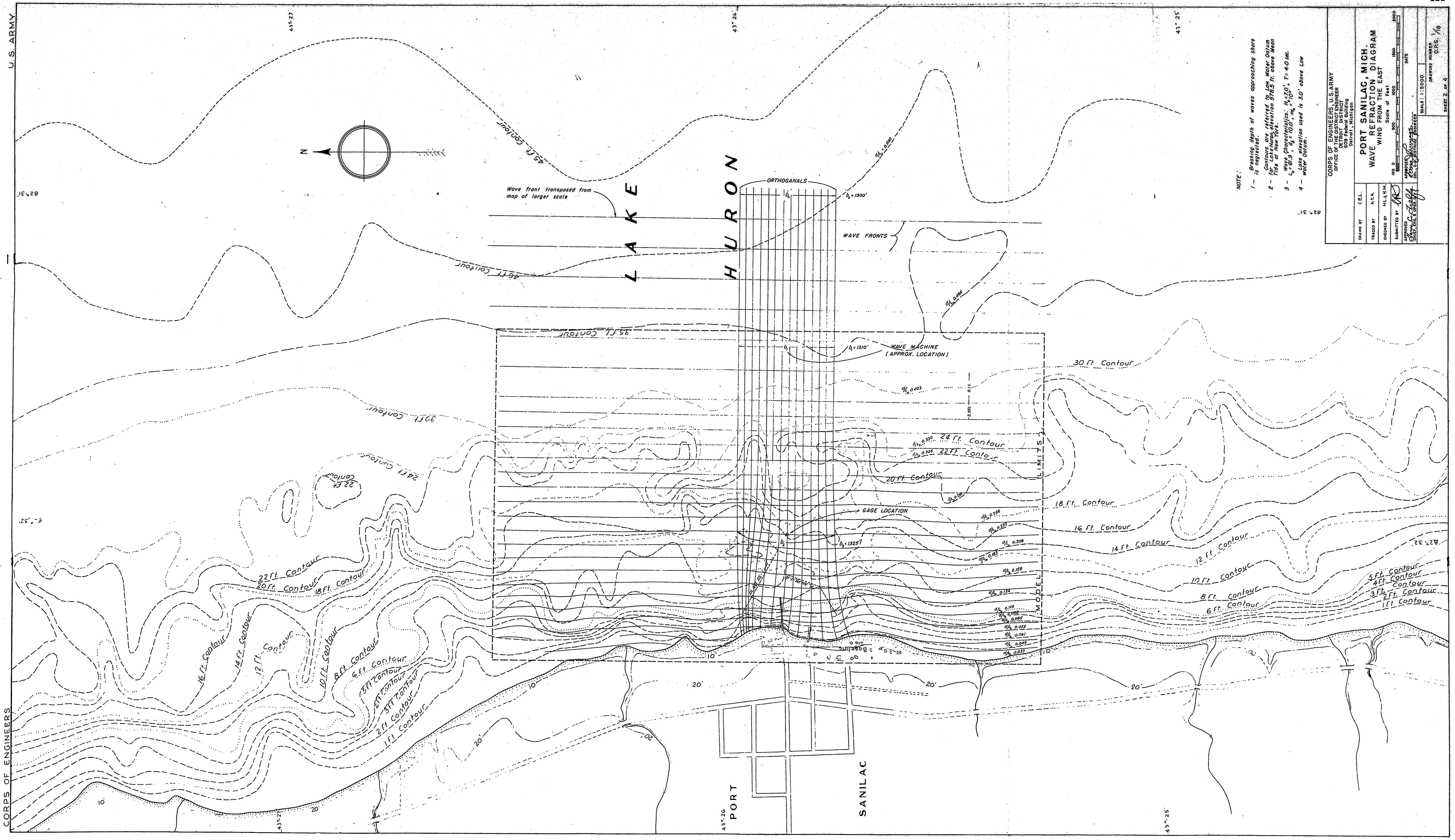
DRAWINGS SUPPLIED

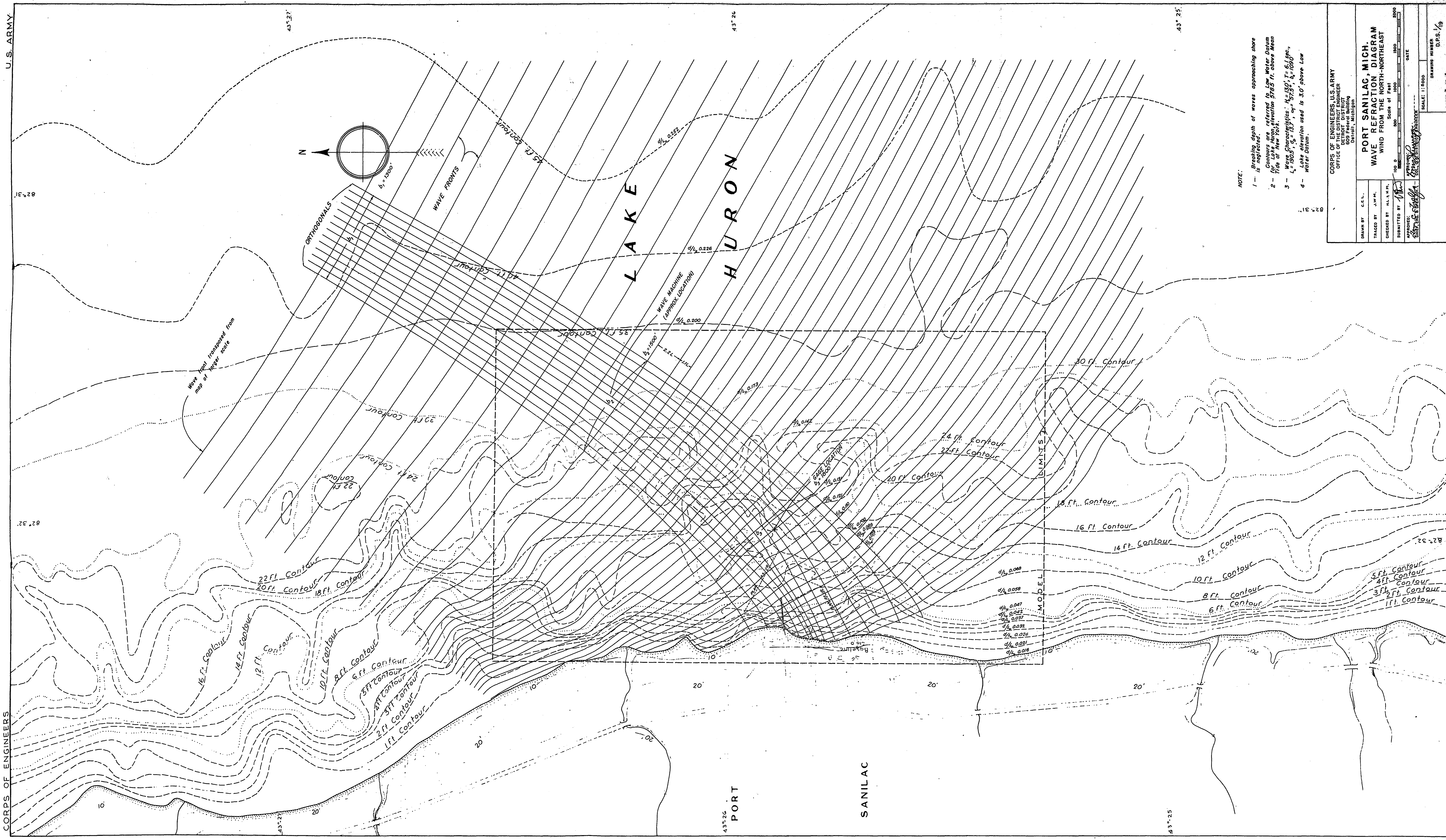
BY

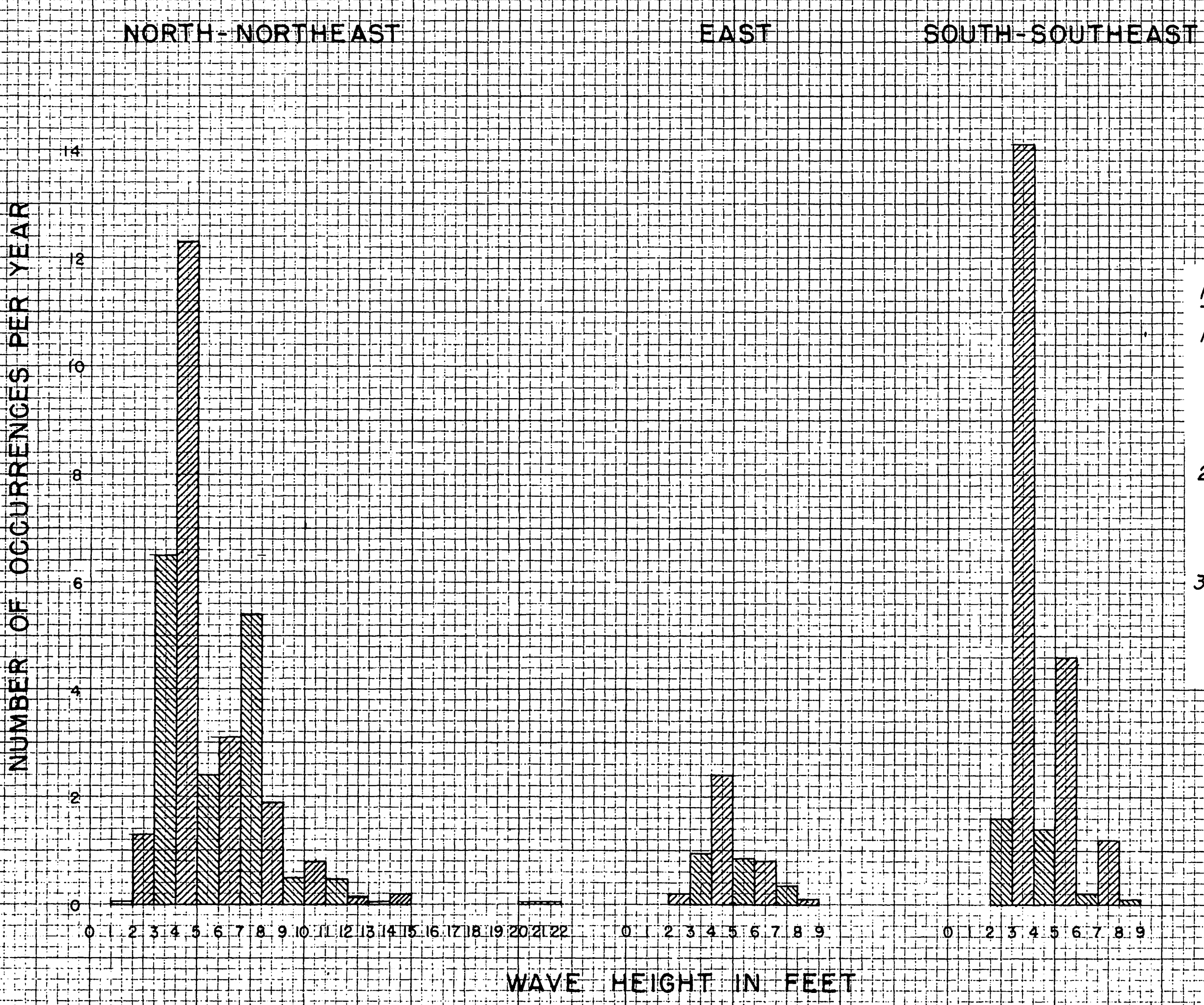
THE DETROIT DISTRICT,

CORPS OF ENGINEERS, U. S. ARMY


U.S. ARMY
CORPS OF ENGINEERS
LAKE HURON
PORT SANILAC
N
45 ft. Contour
40 ft. Contour
35 ft. Contour
30 ft. Contour
24 ft. Contour
22 ft. Contour
20 ft. Contour
18 ft. Contour
16 ft. Contour
14 ft. Contour
12 ft. Contour
10 ft. Contour
8 ft. Contour
6 ft. Contour
5 ft. Contour
4 ft. Contour
3 ft. Contour
2 ft. Contour
1 ft. Contour
WAVE FRONTS
ORTHOGONALS
WAVE MACHINE (APPROX. LOCATION)
GAGE LOCATION
MODEL LIMITS
Wave front transposed from map of larger scale
NOTE:
1 - Breaking depth of waves approaching shore is neglected.
2 - Contours are referred to Low Water Datum for Lake Huron, elevation 578.5 ft. above Mean Tide at New York.
3 - Wave Characteristics: $H_o = 8.7'$, $T = 4.2$ sec., $L_o = 90.3'$, $d_b = 7.9'$, $\alpha = 77.5°$, $b_o = 729'$
4 - Lake elevation used is 3.0' above Low Water Datum.
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
DETROIT DISTRICT
609 Federal Building
Detroit, Michigan
PORT SANILAC, MICH.
WAVE REFRACTION DIAGRAM
WIND FROM THE SOUTH-SOUTHEAST
Scale of Feet
DRAWN BY C.E.L.
TRACED BY H.T.K.
CHECKED BY H.L. & K.M.
SUBMITTED BY
APPROVED: CHIEF, ENG. & OPER. DIV.
APPROVED: COL., C.E., DISTRICT ENGINEER.
DATE
SCALE: 1:5000
DRAWING NUMBER D.P.S. 1/17
SHEET 1 OF 4


NOTE:
1 — Breaking depth of waves approaching shore is neglected.
2 — Contours are referred to Low Water Datum for Lake Huron, elevation 578.5 ft. above Mean Tide at New York.
3 — Wave Characteristics: $H_o = 7.0'$, $T = 4.0$ sec. $L_o = 81.9$, $d_b = 10.0$, $\alpha_o = 10°$
4 — Lake elevation used is 3.0' above Low Water Datum.
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
DETROIT DISTRICT
609 Federal Building
Detroit, Michigan
PORT SANILAC, MICH.
WAVE REFRACTION DIAGRAM
WIND FROM THE EAST
Scale of Feet
100 0 500 1000 1500 2000
DRAWN BY C.E.L.
TRACED BY h.t.k.
CHECKED BY H.L. & K.M.
SUBMITTED BY
APPROVED CHIEF, ENG. & OPER. DIV.
APPROVED COL., C.E. DISTRICT ENGINEER
DATE
SCALE: 1:5000
DRAWING NUMBER D.P.S. 1/18
SHEET 2 OF 4
U.S. ARMY
CORPS OF ENGINEERS
LAKE HURON
N
ORTHOGANALS
Wave front transposed from map of larger scale
WAVE FRONTS
WAVE MACHINE (APPROX. LOCATION)
GAGE LOCATION
MODEL LIMITS
45 ft. Contour
40 ft. Contour
35 ft. Contour
30 ft. Contour
24 ft. Contour
22 ft. Contour
20 ft. Contour
18 ft. Contour
16 ft. Contour
14 ft. Contour
12 ft. Contour
10 ft. Contour
8 ft. Contour
6 ft. Contour
5 ft. Contour
4 ft. Contour
3 ft. Contour
2 ft. Contour
1 ft. Contour
$b_o = 1300'$
$b_1 = 1310'$
$b_2 = 1325'$
PORT SANILAC
43° 26'
43° 25'
43° 27'
82° 31'
82° 32'


U.S. ARMY
CORPS OF ENGINEERS
LAKE HURON
PORT SANILAC
ORTHOGONALS
WAVE FRONTS
Wave front transposed from map of larger scale
WAVE MACHINE (APPROX. LOCATION)
GAGE LOCATION
MODEL LIMITS
45 ft. Contour
40 ft. Contour
35 ft. Contour
30 ft. Contour
27 ft. Contour
24 ft. Contour
22 ft. Contour
20 ft. Contour
18 ft. Contour
16 ft. Contour
14 ft. Contour
12 ft. Contour
10 ft. Contour
8 ft. Contour
6 ft. Contour
5 ft. Contour
4 ft. Contour
3 ft. Contour
2 ft. Contour
1 ft. Contour
$b_1 = 1300'$
$b_2 = 1500$
$b_3 = 1600$
d/L_o 0.252
d/L_o 0.226
d/L_o 0.200
d/L_o 0.173
d/L_o 0.142
d/L_o 0.068
d/L_o 0.058
d/L_o 0.047
d/L_o 0.042
d/L_o 0.037
d/L_o 0.032
d/L_o 0.026
d/L_o 0.021
d/L_o 0.016
N
NOTE:
1 — Breaking depth of waves approaching shore is neglected.
2 — Contours are referred to Low Water Datum for Lake Huron, elevation 578.5 ft. above Mean Tide at New York.
3 — Wave Characteristics: $H_o = 13.0'$, $T = 6.1$ sec., $L_o = 190.5'$, $d_b = 13.7$, $\alpha = 57.5°$, $b_o = 1090'$
4 — Lake elevation used is 3.0' above Low Water Datum.
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
DETROIT DISTRICT
609 Federal Building
Detroit, Michigan
PORT SANILAC, MICH.
WAVE REFRACTION DIAGRAM
WIND FROM THE NORTH-NORTHEAST
Scale of Feet
100 0 500 1000 1500 2000
DRAWN BY C.E.L.
TRACED BY J.W.M.
CHECKED BY H.L. & K.M.
SUBMITTED BY
APPROVED: CHIEF, ENG. & OPER. DIV.
APPROVED: COL. C.E. DISTRICT ENGINEER
DATE
SCALE: 1:5000
DRAWING NUMBER D.P.S. 1/19
SHEET 3 OF 4
43° 27'
43° 26'
43° 25'
82° 31'
82° 32'



NOTE

1— The wave heights were computed from the winds in excess of 15 miles per hour that occurred during the 20 year period of 1905-1924, recorded at the U.S. Weather Bureau station at Port Huron, Mich.

2— The direction NNE contains winds from North to Northeast; East contains the winds from E.N.E. to E.S.E.; S.S.E. contains the winds from S.E. to South.

3— The graphs show the times per year that wind velocity and duration conditions occurred which would produce a maximum wave of the height shown.

PORT SANILAC, MICHIGAN

WAVE FREQUENCY STUDY

CORPS OF ENGINEERS, DETROIT DISTRICT

15 JULY 1949

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

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

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

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

Bodoni Italic

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

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

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

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

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	l	B

MESH HALFTONE WEDGES

65

85

100

110

133

150

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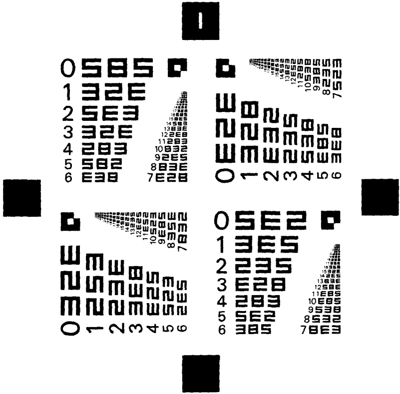
RIT ALPHANUMERIC RESOLUTION TEST OBJECT, RT-1-71



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