TECHNICAL REPORT H-68-6

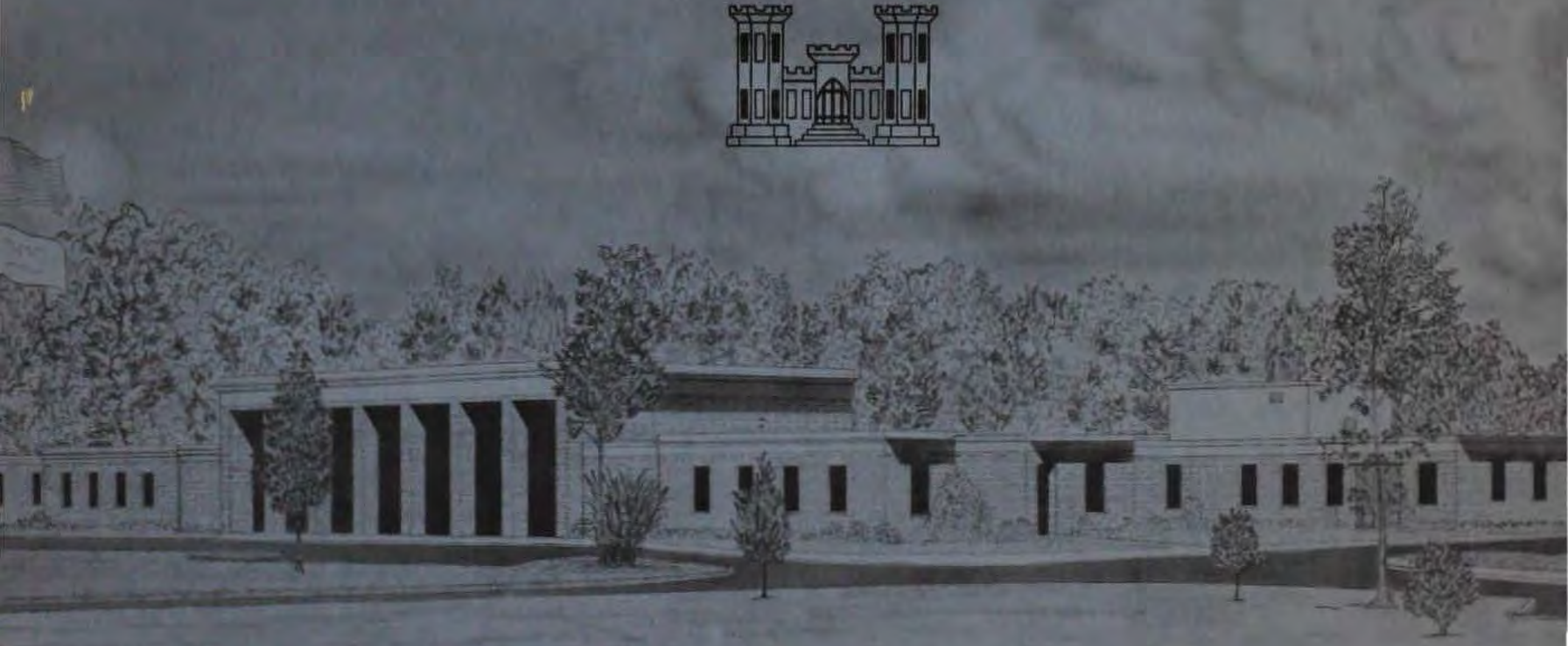
DESIGN FOR OPTIMUM WAVE CONDITIONS CRESCENT CITY HARBOR CRESCENT CITY, CALIFORNIA

APPENDIX A: RESULTS OF SUPPLEMENTAL TESTS

Hydraulic Model Investigation

by

P. K. Senter



June 1971

Sponsored by U. S. Army Engineer District, San Francisco

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

Request for continuation of testing on the Crescent City Harbor model was initiated by the District Engineer, U. S. Army Engineer District, San Francisco, in a letter to the Division Engineer, U. S. Army Engineer Division, South Pacific, dated 17 March 1969. Authorization for the U. S. Army Engineer Waterways Experiment Station to perform the study was granted on 27 March 1969 by the Office, Chief of Engineers. The tests were conducted from July through August 1969.

Corps of Engineers personnel who visited the Waterways Experiment Station to attend a conference and witness model demonstrations were: BG W. M. Glasgow, Jr., Division Engineer, and Mr. O. T. Magoon of the South Pacific Division; and COL C. R. Roberts, District Engineer, Messrs. G. P. Reilly, P. L. Vredenburg, and R. L. Sloan of the San Francisco District. Others who visited the Waterways Experiment Station in connection with the study were: Honorable Donald Clausen, U. S. House of Representatives, from the First Congressional District of California; Mr. W. Hight, Supervisor, Del Norte County, Calif.; Messrs. J. S. Nicholson and R. E. Mouritsen, Councilmen, Crescent City, Calif.; Messrs. F. E. Finley, President, C. A. Brower, Director, R. C. Magnuson, Director, B. Wilson, Director, D. G. Richcreek, Harbor Master, and T. J. Murray, Consultant, Board of Harbor Commissioners, Crescent City Harbor District; and Mr. M. Noble, representative of Dames and Moore Consulting Engineering Firm, Consultants to Tri-Agency (City, County, and Harbor District).

The investigation was conducted in the Hydraulics Division of the Waterways Experiment Station under the direction of Mr. E. P. Fortson, Jr., Chief of the Hydraulics Division, and Mr. R. Y. Hudson, Chief of the Wave Dynamics Branch. The model tests were conducted by Mr. P. K. Senter,

Project Engineer, assisted by Mr. J. B. Stratton, Electronics Technician. The report was prepared by Mr. Senter.

COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE, were Directors of the Waterways Experiment Station during the conduct of the model study and the preparation and publication of this report. Mr. F. R. Brown was Technical Director.

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SUMMARY

Additional tests were conducted in an existing hydraulic model of Crescent City Harbor to determine the optimum length and location of a breakwater system for providing sufficient protection for an expansion to the small-craft harbor capacity.

It was concluded that of the several plans tested a breakwater beginning at the +7.5 contour about 900 ft east of Elk Creek and extending southerly into the harbor for approximately 1050 ft, then angling southeasterly and continuing for an additional 900 ft, in conjunction with a northwesterly extension to the existing inner breakwater of 400 ft, would provide the best protection for the problem area.

DESIGN FOR OPTIMUM WAVE CONDITIONS, CRESCENT CITY HARBOR CRESCENT CITY, CALIFORNIA

APPENDIX A: RESULTS OF SUPPLEMENTAL TESTS

Hydraulic Model Investigation

PART I: INTRODUCTION

1. A hydraulic model investigation of Crescent City Harbor, Calif., was conducted to determine the optimum length and location of an extension, or extensions, to the existing breakwater system that would reduce to a tolerable level the adverse effects of storm waves on navigation and mooring conditions in the harbor. Near the end of that study, the San Francisco District requested that a few tests be conducted to determine if adequate protection could be provided for an expansion of small-craft harbor capacity. The breakwater plan tested in this regard did substantially decrease wave heights in the area in the lee of the structure but not enough to warrant the use of the area for small-craft mooring. Because these tests had not been included in the planned testing program, funds were not available to pursue the tests any further at that time.

2. After the report on the results of the tests referred to above was published,* additional tests were requested to ascertain the optimum length and location of a breakwater system for providing protection for an expanded small-craft harbor capacity.

3. The tests conducted in connection with the study referred to in paragraph 1 and the report presenting the results of these tests are referred to herein as the basic tests and the basic report, respectively. This report, which constitutes an appendix to the basic report, presents the results of the supplemental tests.

4. The Crescent City Harbor model and its appurtenances as used in

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* P. K. Senter and C. W. Brasfeild, "Design for Optimum Wave Conditions, Crescent City Harbor, Crescent City, California; Hydraulic Model Investigation," Technical Report H-68-6, Sept 1968, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

the basic tests was reactivated, with minor revisions, for use in conduct of the supplemental tests.

PART II: THE TEST PROGRAM

Test Conditions

5. The test conditions used in the basic study were applicable to the supplemental tests and were used in these tests unless otherwise stated.

6. Wave height and period characteristics for the waves in the supplemental tests were selected from the tabulation in paragraph 16 of the basic report. Two to four test wave heights were selected for representative wave periods for three deepwater wave directions. These test waves were considered to be the most critical on the basis of the test results from the basic study. The characteristics of the test waves selected are as follows:

Wave	Deepwater Waves		Selected Shallow-Water Test Waves	
Period, sec	Direction	Height, ft*	Direction	Height, ft
9.0	South	8, 14, 16, 20	S10°22'W	6, 12, 14, 18
12.0	South-southwest	6, 14, 20	S35°45'W	6, 12, 18
14.0		14, 20	S35°40'W	12, 18
9.0	Southwest	8, 14	S49°15'W	8, 14
12.0		10, 16	S49°15'W	10, 16
14.0		8, 14, 18	S49°15'W	10, 16, 22
16.0		4, 8, 16	S49°15'W	6, 12, 22

* To convert feet to meters, multiply by 0.3048.

Test Data

7. The data obtained during the testing program included (a) wave height measurements at several locations inside and outside the harbor, (b) photographs showing wave-front patterns, and (c) visual observations. The locations of the wave height gages used during the course of the supplemental tests are shown in fig. A1. These wave gage locations were selected to determine the wave heights that would obtain in the proposed areas of expansion and revisions and in the outer harbor when the test structures were installed. Since data had already been obtained for base test (existing)

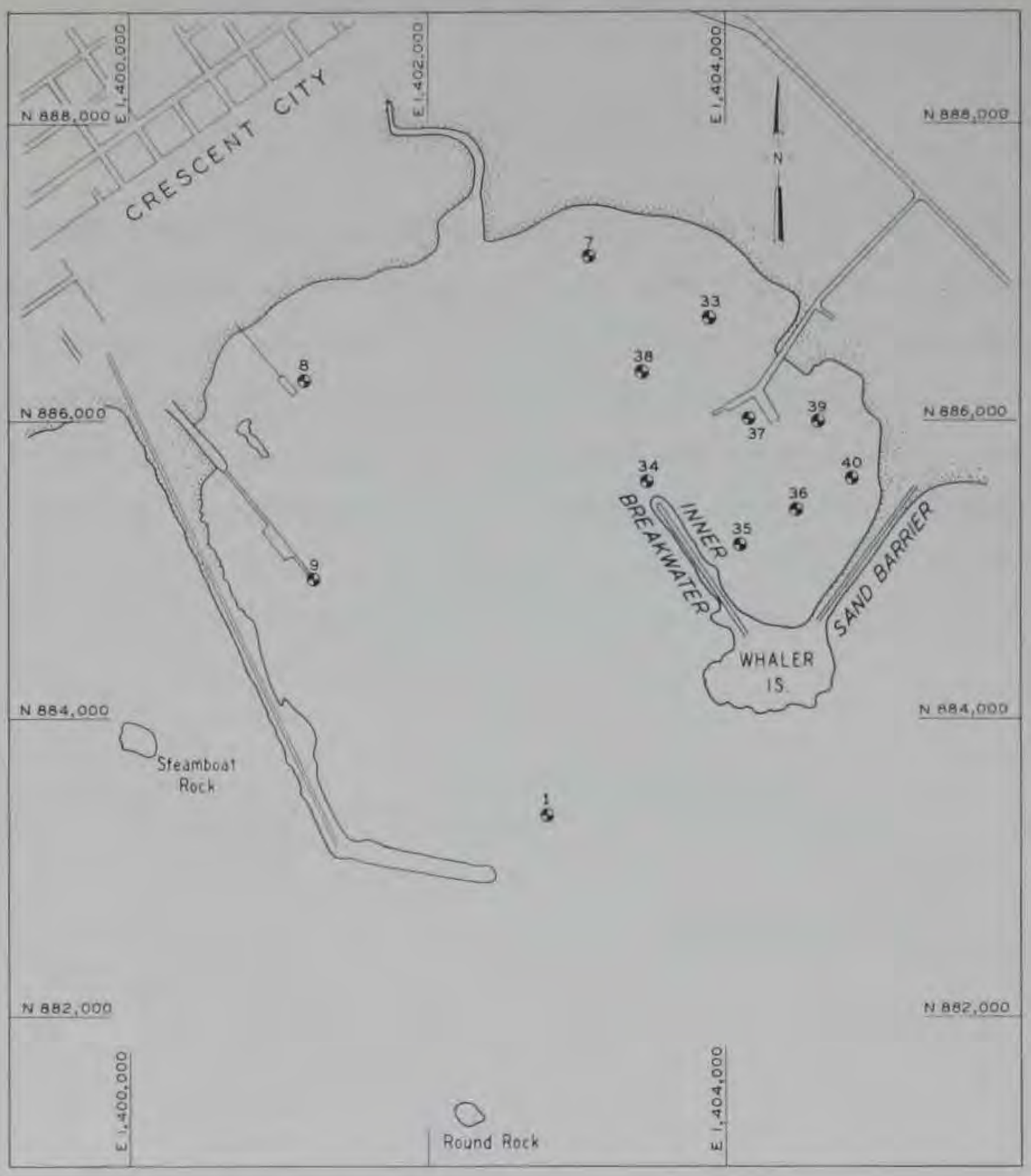


Fig. A1. Location of wave gages

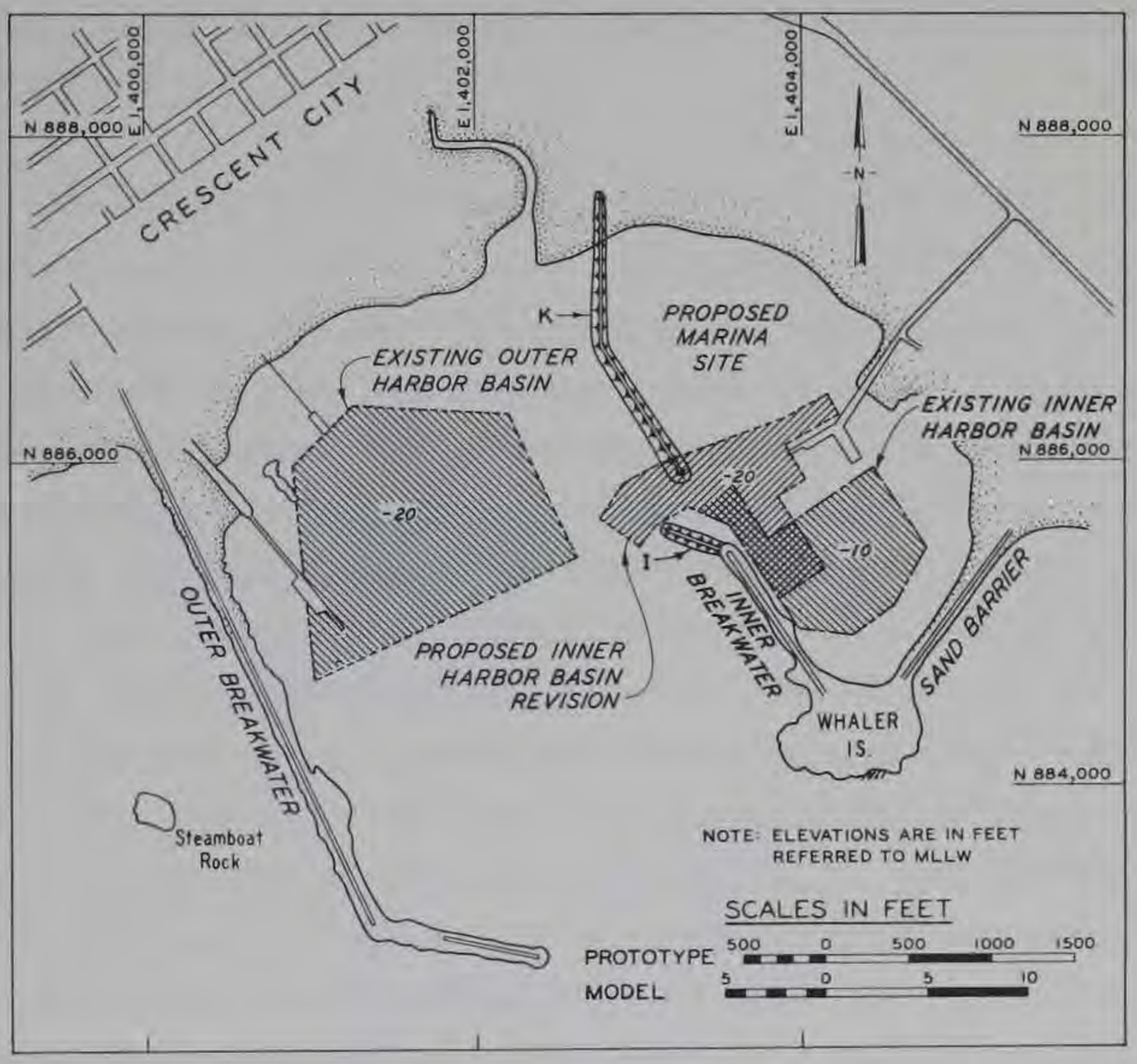
conditions, the supplemental tests were devoted to obtaining data with the proposed improvement plans. As in the basic tests, comparison of the wave height data obtained from the various tests with the selected wave height criteria (paragraph 8) permitted evaluation of the effectiveness of each proposed improvement plan and provided a basis for selecting the optimum plan. Also, wave heights measured in the model were corrected to compensate for the increased rate of wave height attenuation in the model, due to bottom friction, compared with the amount of attenuation in the prototype.

8. The wave height criterion suggested by local interests was that waves in the proposed marina site (see fig. A2) not exceed 1 ft in height.

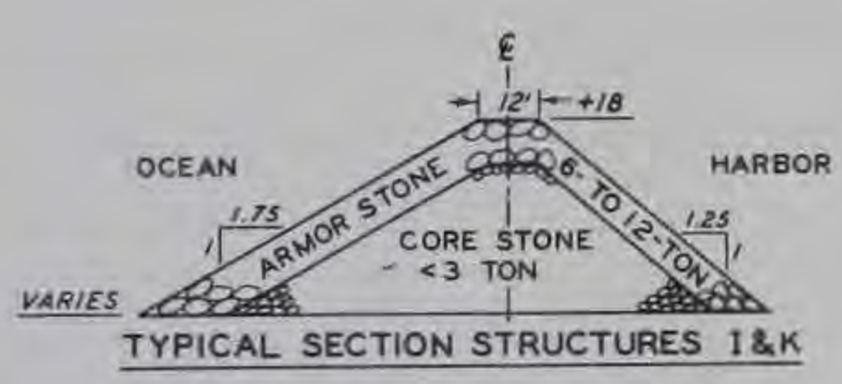
PART III: PLANS TESTED AND TEST RESULTS

Description of Plans

9. Tests were conducted for several breakwater plans to determine protection for planned new construction in the existing inner harbor basin and the area immediately east of the proposed new north-south aligned breakwater (structure K, plans 10 and 11, fig. A2). The latter area would be used to provide additional small-craft mooring capacity. Details of the various plans are described in the following paragraphs and all of the plan elements described are shown in fig. A2.



PLAN	STRUCTURES INCLUDED	CROWN LENGTH, FT
10	K	2050
10A	K	2150
11	I	400
	K	1950
11A	I	500
	K	1950



TYPICAL SECTION STRUCTURES I&K

Fig. A2. Elements of breakwater plans

Plans 10 and 10A

10. Plans 10 and 10A entailed the construction of a breakwater beginning at the +7.5* contour about 900 ft east of Elk Creek and extending southerly into the harbor for approximately 1050 ft, then angling southeasterly and continuing for an additional 1000 and 1100 ft, respectively. Navigation openings of 300 and 200 ft, respectively, were thus formed with the existing inner breakwater.

Plans 11 and 11A

11. Plans 11 and 11A consisted of the plans 10 and 10A breakwaters with the southeasterly portions being 900 ft long in conjunction with a northwesterly extension to the existing inner breakwater of 400 and 500 ft, respectively. A 300-ft-wide navigation entrance to the inner harbor was thus formed.

Test Results

12. The test results are presented in table A1, which shows the estimated duration of waves of various heights and periods that can be expected to occur at selected locations inside and outside the harbor for the plans tested. Photographs A1-A9 show wave patterns within the harbor for the various plans and test waves. As explained in the basic report, wave height duration data were prepared by using model wave heights to compute wave reduction coefficients. The reduction coefficients were then applied to the shallow-water wave duration values contained in table 2 of the basic report. However, in the supplemental tests, wave heights were obtained only for selected wave conditions; therefore, reduction coefficients could not be obtained from measured data for all the shallow-water wave values. The remainder of the reduction coefficients were obtained by interpolation or extrapolation of measured values guided by past model performance.

Plan 10

13. Results of the wave height tests of plan 10 (table A1) indicate

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* All elevations used in this report are in feet referred to mean lower low water (at Crescent City, mllw is 3.8 ft below mean sea level).

that the wave action in the existing harbor and in the proposed area for expansion of small-craft mooring would be reduced considerably over base test conditions but not sufficiently to warrant installation of the plan. Photographs A1 and A2 depict the wave action that obtained in the problem area with plan 10 installed in the model.

Plan 10A

14. Results of the wave height tests of plan 10A (table A1) indicate that installation of the plan would decrease wave action some in the problem areas as compared with plan 10. However, neither the criterion suggested by local interests nor the criteria used in the basic study are met by installation of this plan. Photographs A3 and A4 show the wave conditions that occurred for two of the test conditions with plan 10A installed in the model.

Plan 11

15. Results of the wave height tests (table A1) reveal that plan 11 would provide more protection for the problem area than would plan 10 or 10A. However, it is estimated that with plan 11 installed in the prototype, waves equal to or greater than 2 ft high would obtain in the problem area about 20 hr/yr, and waves equal to or greater than 1 ft high would occur approximately 240 hr/yr. Thus, the design criterion is still not met. A comparison of the plan 11 and plan 6A test results was made for the southern part of the existing inner harbor (the area between the sand barrier and Citizens' Dock). The elements of plan 6A and results of tests are described in paragraph 21 and table 4, respectively, of the basic report. The comparison was made on the basis of wave heights measured at gage 6 for plan 6A and at gage 37 for plan 11. The results of this comparison show that waves equal to or greater than 1 ft high would occur approximately 450 hr/yr with plan 6A installed and approximately 295 hr/yr with plan 11 installed. Also, a comparison of the results of the plan 11 tests with the results of the base test data presented in table 3 of the basic report indicates that installation of plan 11 would not have any detrimental effects on the outer harbor. Photographs A5-A7 depict the effectiveness of plan 11 in providing additional protection for the existing inner harbor and the proposed expansion area.

Plan 11A

16. Results of the wave height tests of plan 11A (table A1 and photographs A8 and A9) reveal that this plan would not be more effective than plan 11 in reducing wave heights. Also, this plan consists of an additional 100 ft of breakwater and thus would cost more to construct than plan 11.

PART IV: CONCLUSIONS

17. Based on results of the hydraulic model study presented in this report it is concluded that of the several plans tested plan 11 would provide the most protection at least cost for the existing inner harbor and the area proposed for a possible marina site. However, with this plan installed in the prototype, wave heights 1 ft or higher would still obtain in the problem area approximately 240 hr/yr.

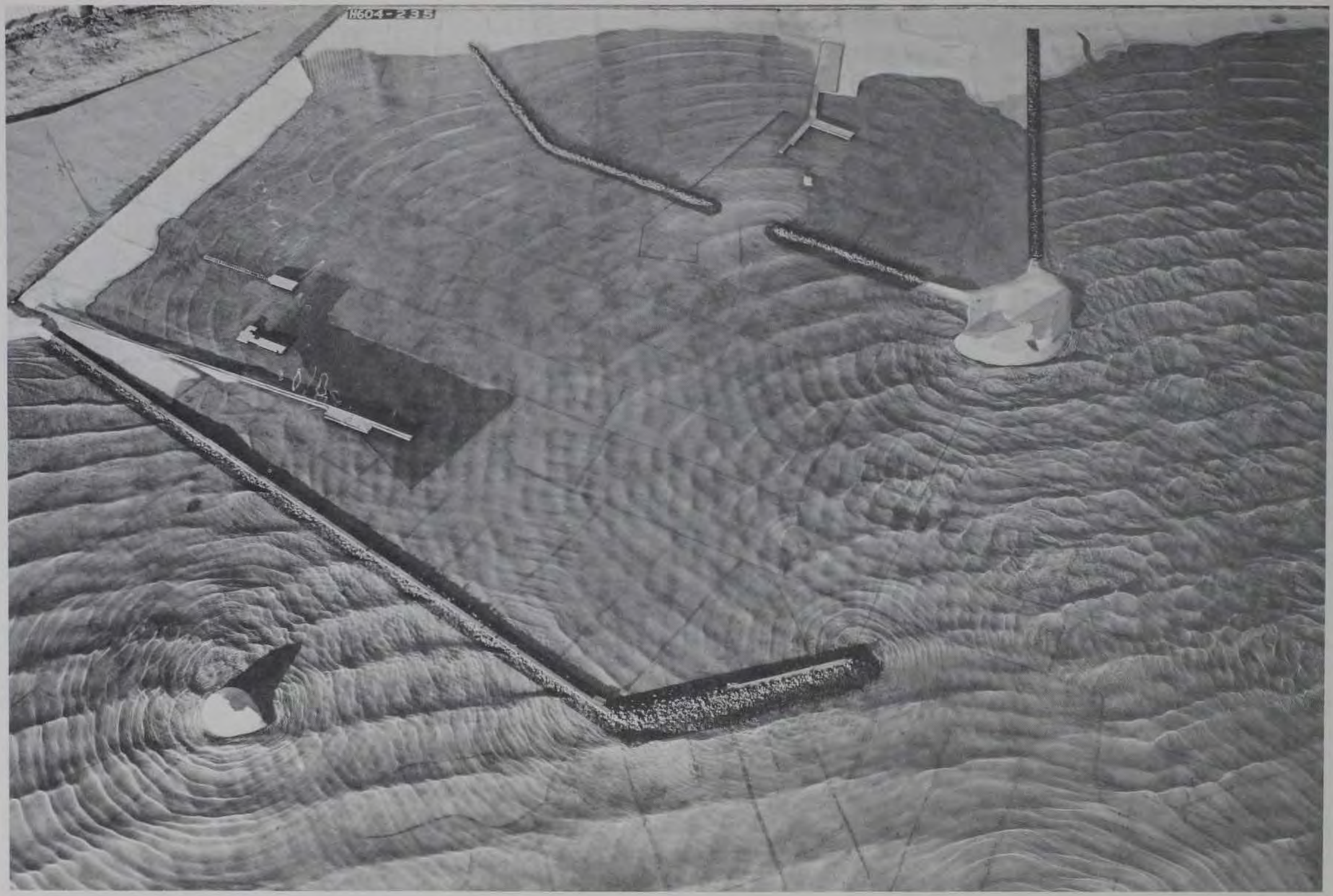
Table A1

Estimated Duration of Wave Heights for All Tests, Directions Combined, Plans 10, 10A, 11, and 11A

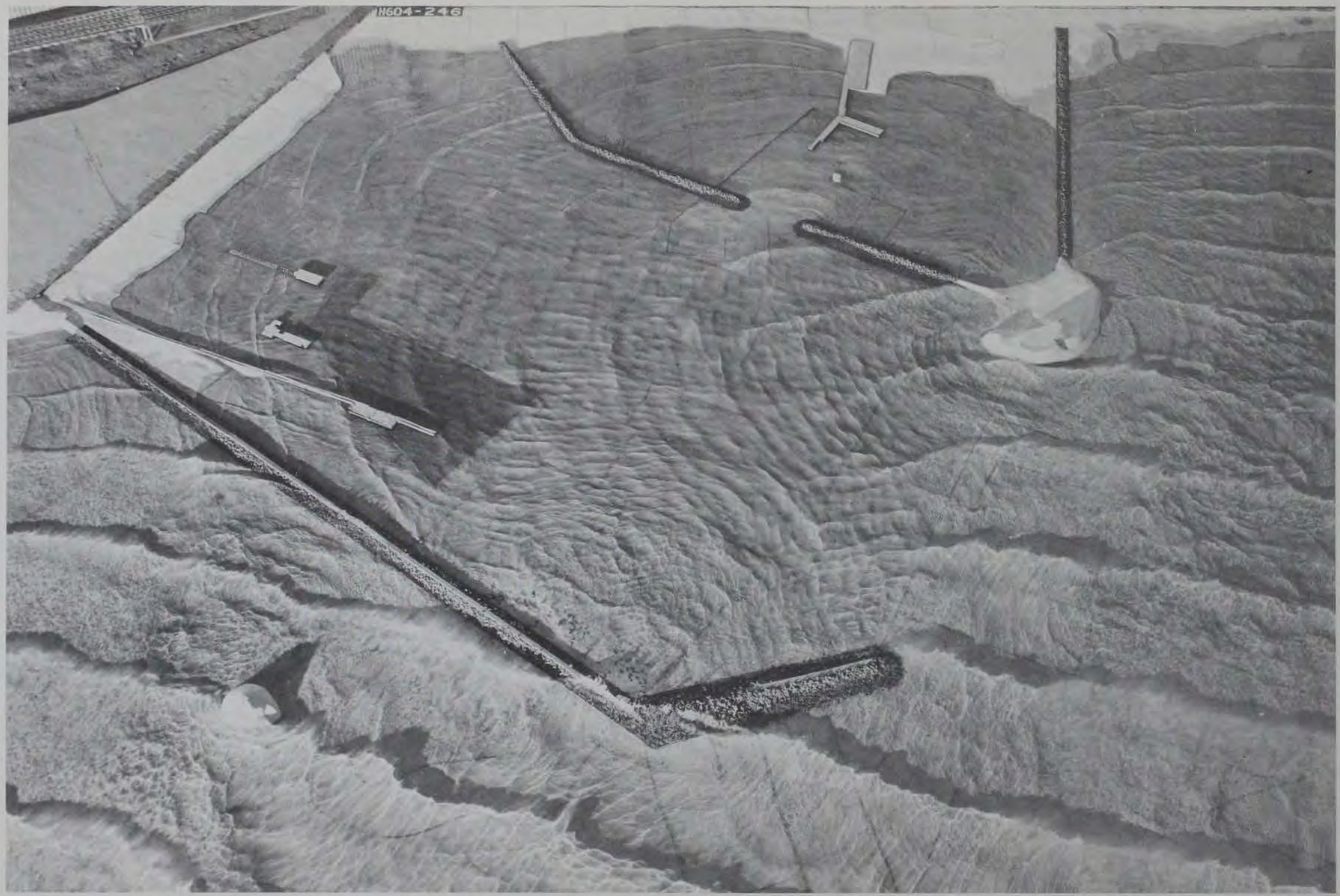
Wave Height* ft	Estimated Duration of Wave Heights at Gage Locations, hr/yr									
	Gage 1	Gage 7	Gage 8	Gage 9	Gage 33	Gage 34	Gage 35	Gage 36	Gage 37	Gage 38
					Plan 10					
0 to 1	136	3595	2723	1979	2330	1650	3469	3579	3301	2522
1 to 2	1120	168	783	928	1112	855	282	194	454	961
2 to 3	701	41	158	414	230	649	42	31	43	134
3 to 4	572		104	323	105	265	11		6	107
4 to 5	519		34	133	6	176				80
5 to 6	159		--	21	21	95				
6 to 7	198		2	6		81				
7 to 8	139					12				
8 to 9	47					--				
9 to 10	110					21				
10 to 11	12									
11 to 12	18									
12 to 13	8									
13 to 14	16									
14 to 15	--									
15 to 16	16									
16 to 17	6									
17 to 18	10									
18 to 19	6									
19 to 20	--									
20 to 21	11									
					Plan 10A					
0 to 1	136	3662	2405	2196	2769	1077	3612	3593	2967	3277
1 to 2	1163	112	1029	849	749	1328	145	181	805	379
2 to 3	675	30	253	282	209	713	27	30	16	118
3 to 4	811		67	358	56	324	20		10	30
4 to 5	198		38	81	21	157			6	
5 to 6	195		10	38		81				
6 to 7	112		2			32				
7 to 8	180					74				
8 to 9	192					12				
9 to 10	10					--				
10 to 11	41					6				
11 to 12	12									
12 to 13	12									
13 to 14	4									
14 to 15	20									
15 to 16	14									
16 to 17	2									
17 to 18	10									
18 to 19	--									
19 to 20	11									
20 to 21	6									

Wave Height ft	Estimated Duration of Wave Heights at Gage Locations, hr/yr											
	Gage 1	Gage 7	Gage 8	Gage 9	Gage 33	Gage 34	Gage 35	Gage 36	Gage 37	Gage 38	Gage 39	Gage 40
					Plan 11							
0 to 1	136	3794	2558	1893	3573	2667	3555	3634	3509	3563	3359	3571
1 to 2	1163	10	937	1355	231	983	208	139	263	221	396	231
2 to 3	1213		155	285		111	35	31	26	20	49	2
3 to 4	273		107	176		43	6		6			
4 to 5	391		35	46								
5 to 6	172		10	49								
6 to 7	122		--									
7 to 8	124		2									
8 to 9	50											
9 to 10	16											
10 to 11	59											
11 to 12	8											
12 to 13	12											
13 to 14	--											
14 to 15	36											
15 to 16	--											
16 to 17	6											
17 to 18	12											
18 to 19	--											
19 to 20	11											
					Plan 11A							
0 to 1	--	3781	1982	1334	3713	2922	3522	3630	3457	3601	3388	3488
1 to 2	1334	23	1339	1545	91	689	241	154	327	197	396	310
2 to 3	471		343	591		191	31	20	20	6	20	6
3 to 4	738		93	215		2						
4 to 5	279		39	80								
5 to 6	324		6	33								
6 to 7	120		2	6								
7 to 8	216											
8 to 9	162											
9 to 10	29											
10 to 11	54											
11 to 12	8											
12 to 13	26											
13 to 14	27											
14 to 15	6											
15 to 16	--											
16 to 17	--											
17 to 18	10											

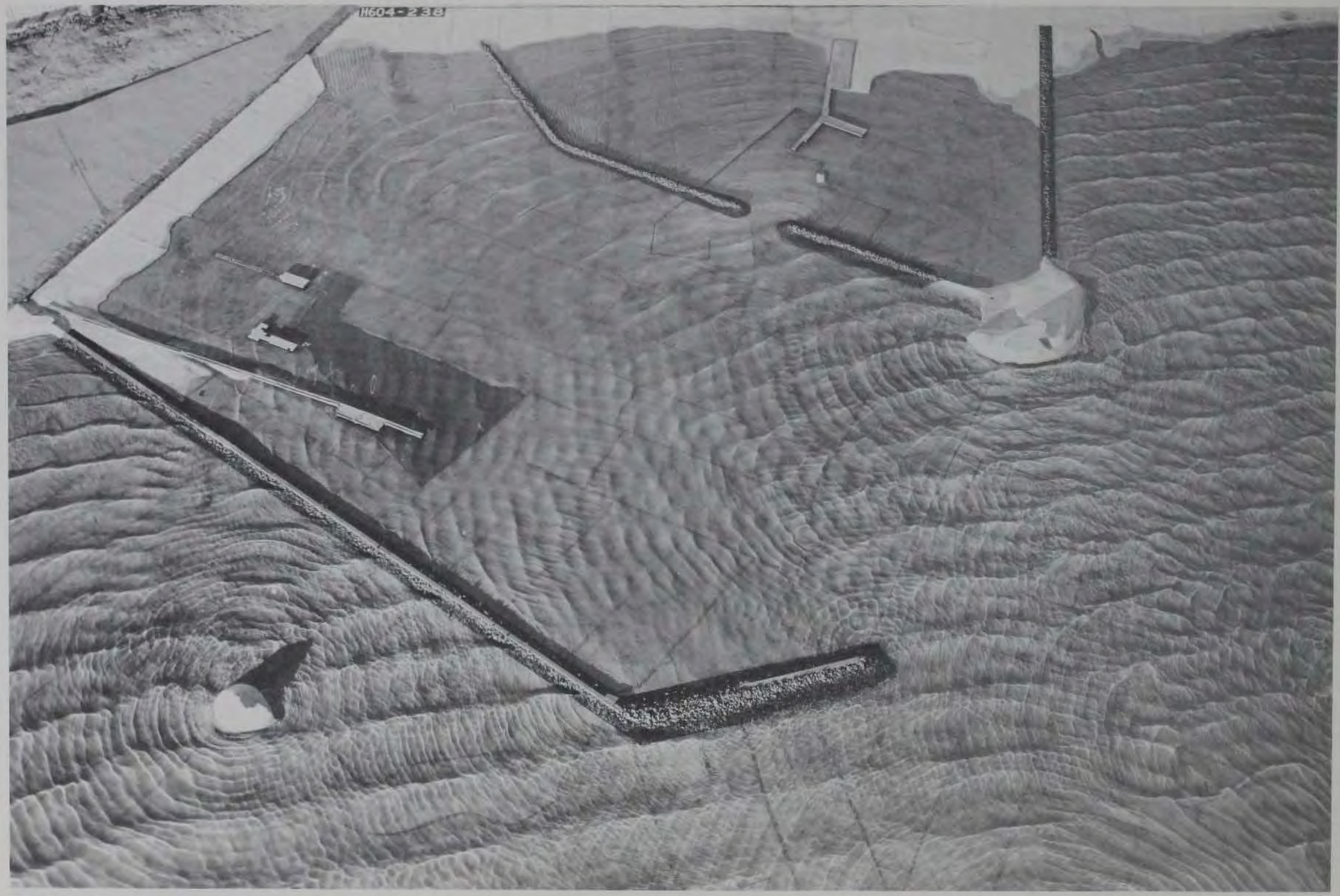
* Wave height groupings include the lower but not the upper values.



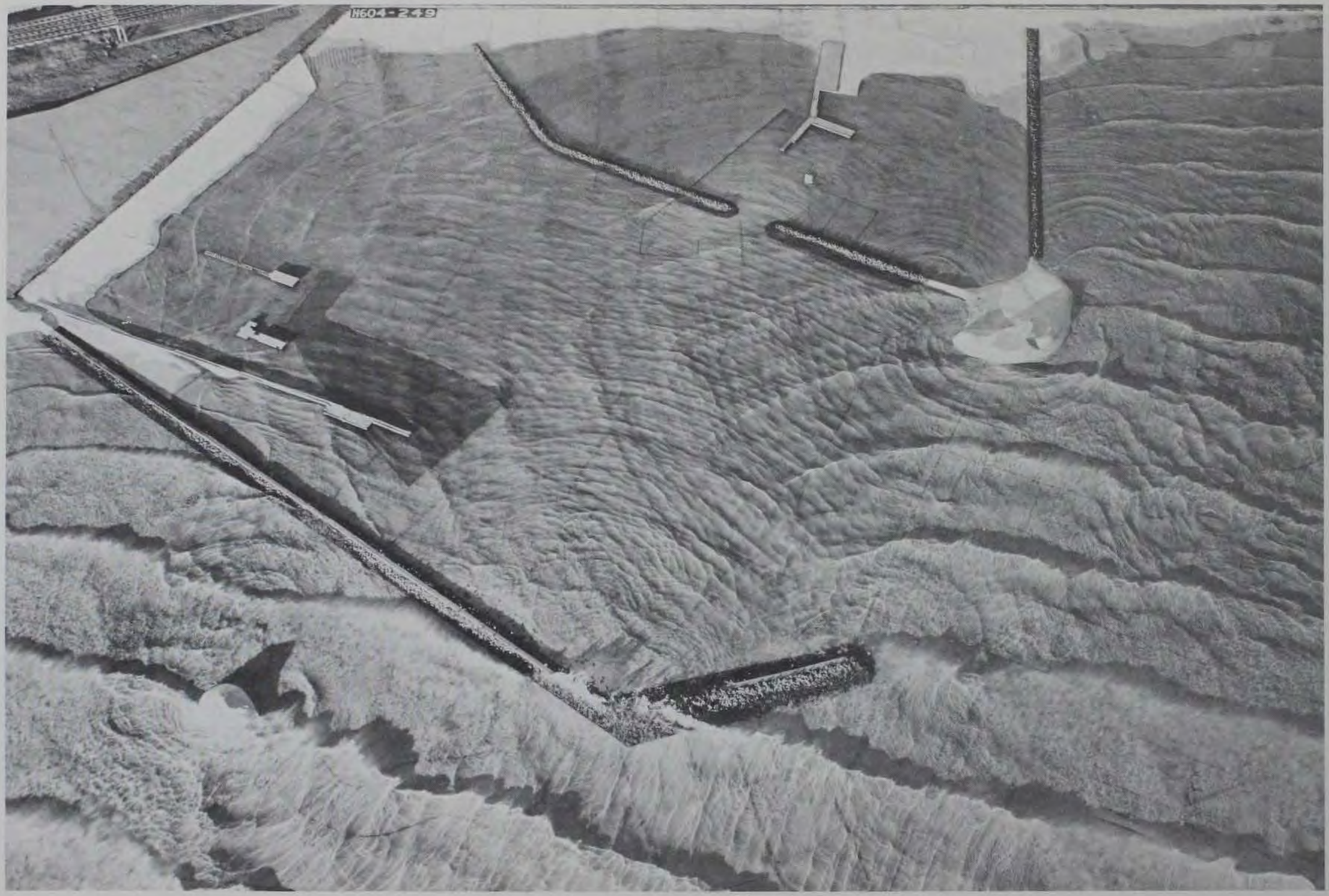
Photograph A1. Wave patterns, plan 10; 9-sec, 12-ft shallow-water waves from S10°22'W



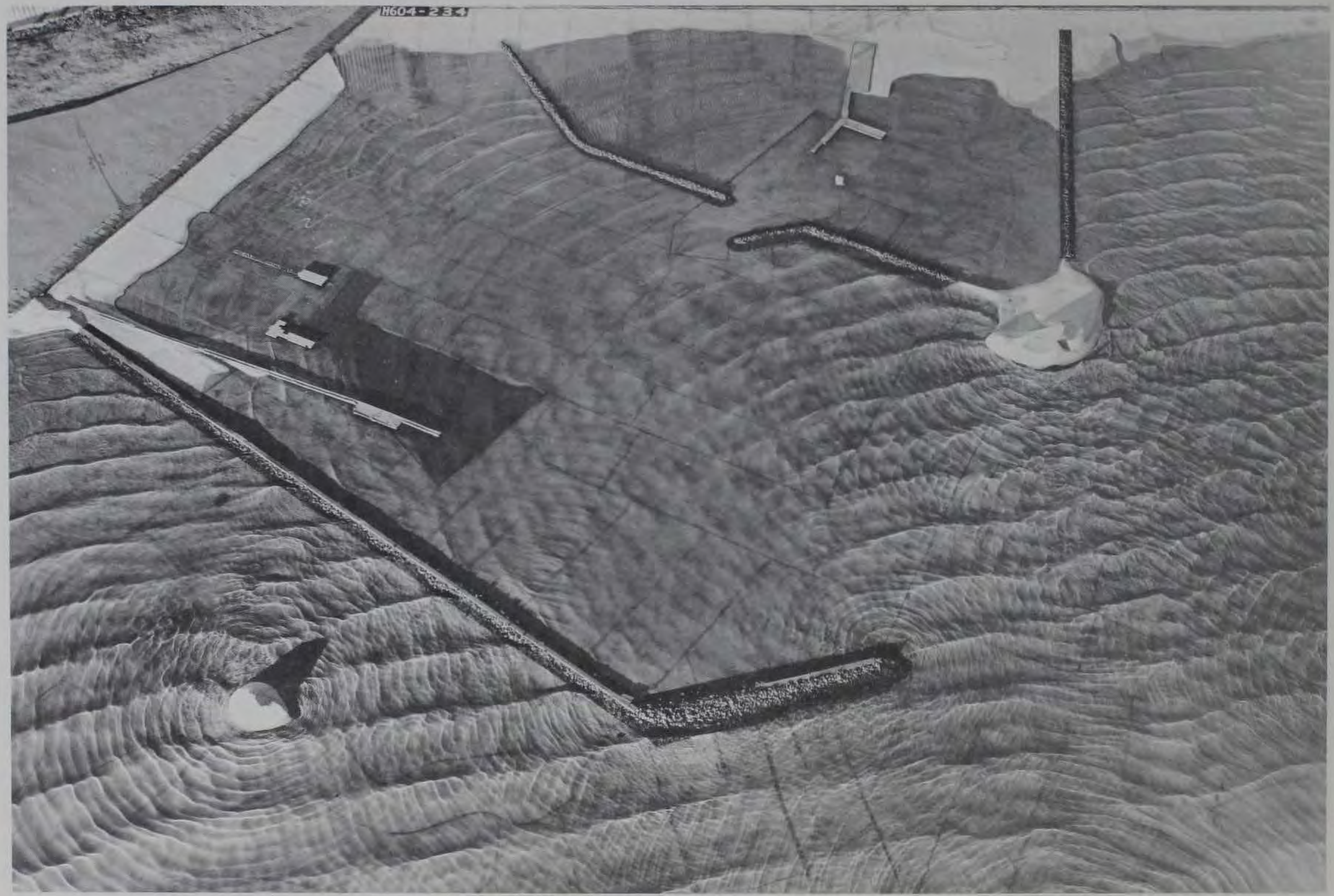
Photograph A2. Wave patterns, plan 10; 16-sec, 22-ft shallow-water waves from S49°15'W



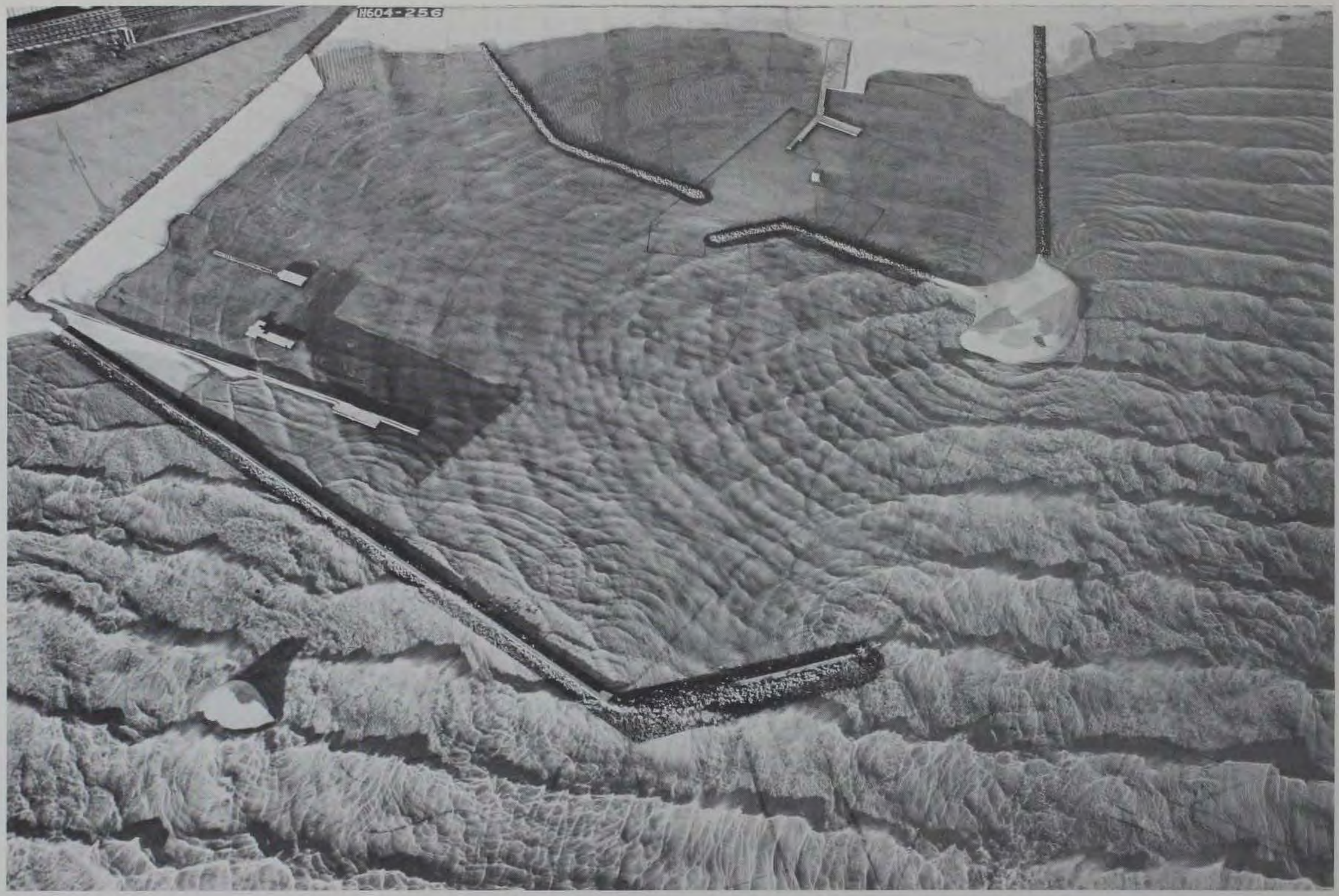
Photograph A3. Wave patterns, plan 10A; 9-sec, 12-ft shallow-water waves from S10°22'W



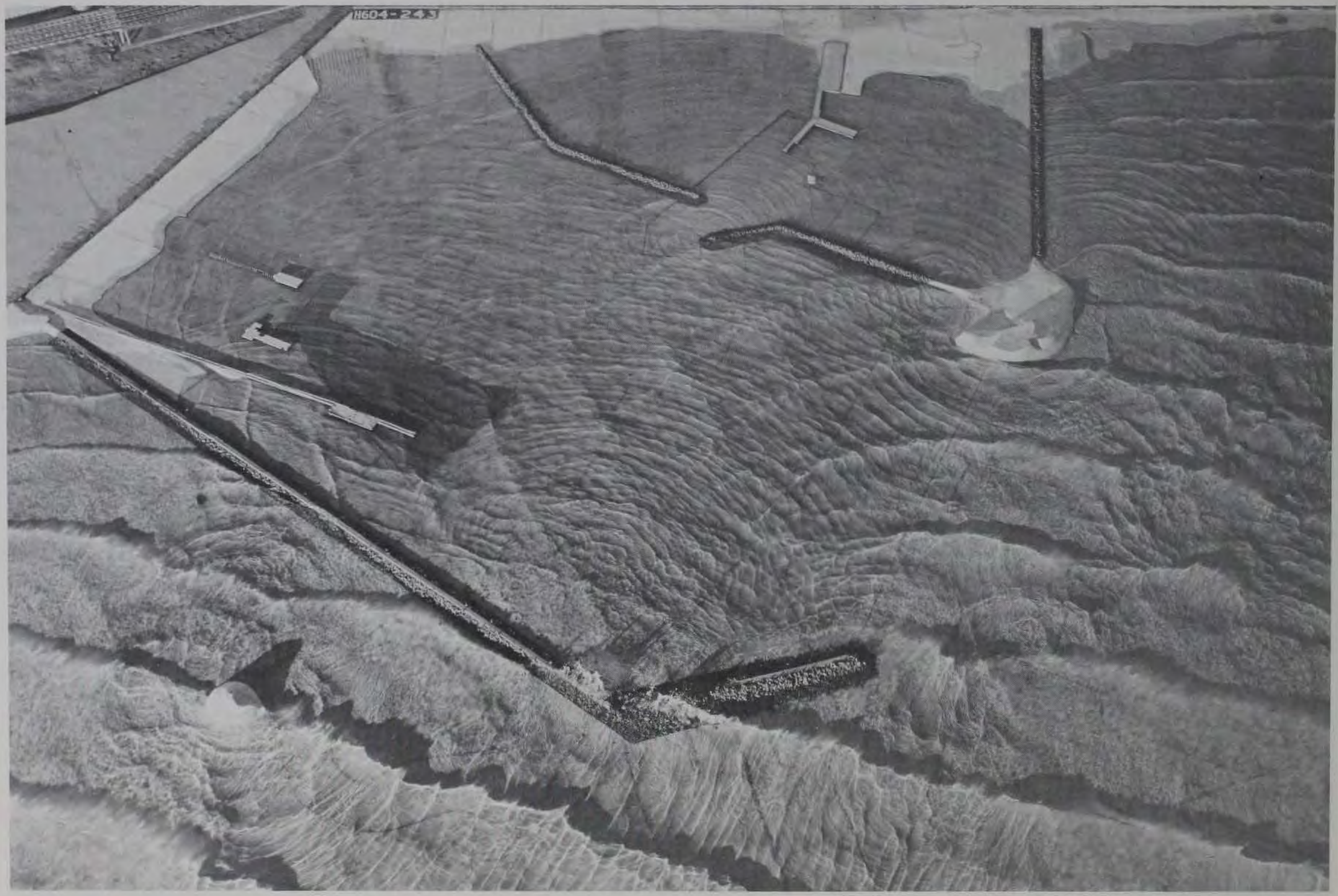
Photograph A4. Wave patterns, plan 10A; 16-sec, 22-ft shallow-water waves from S49°15'W



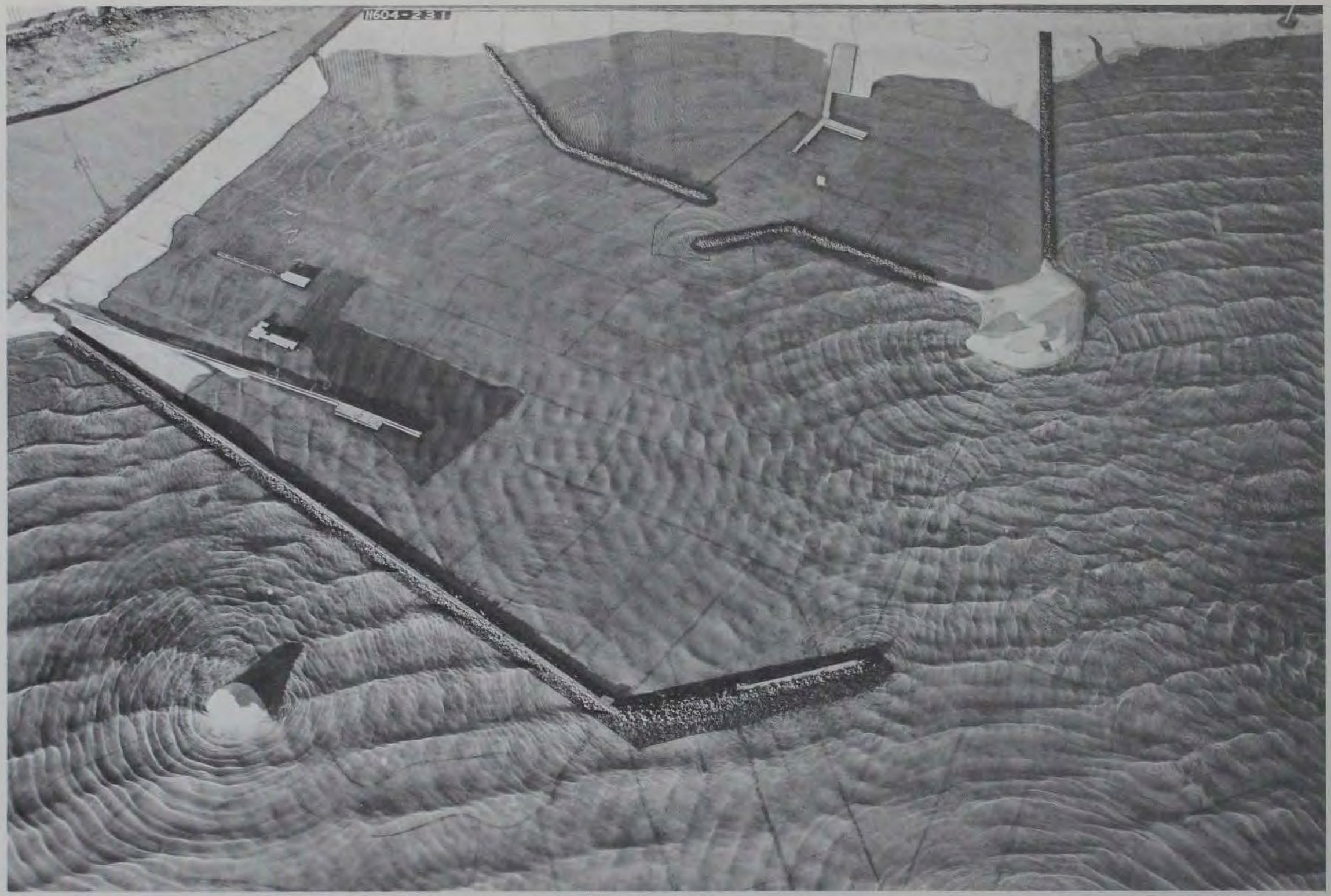
Photograph A5. Wave patterns, plan 11; 9-sec, 12-ft shallow-water waves from S10°22'W



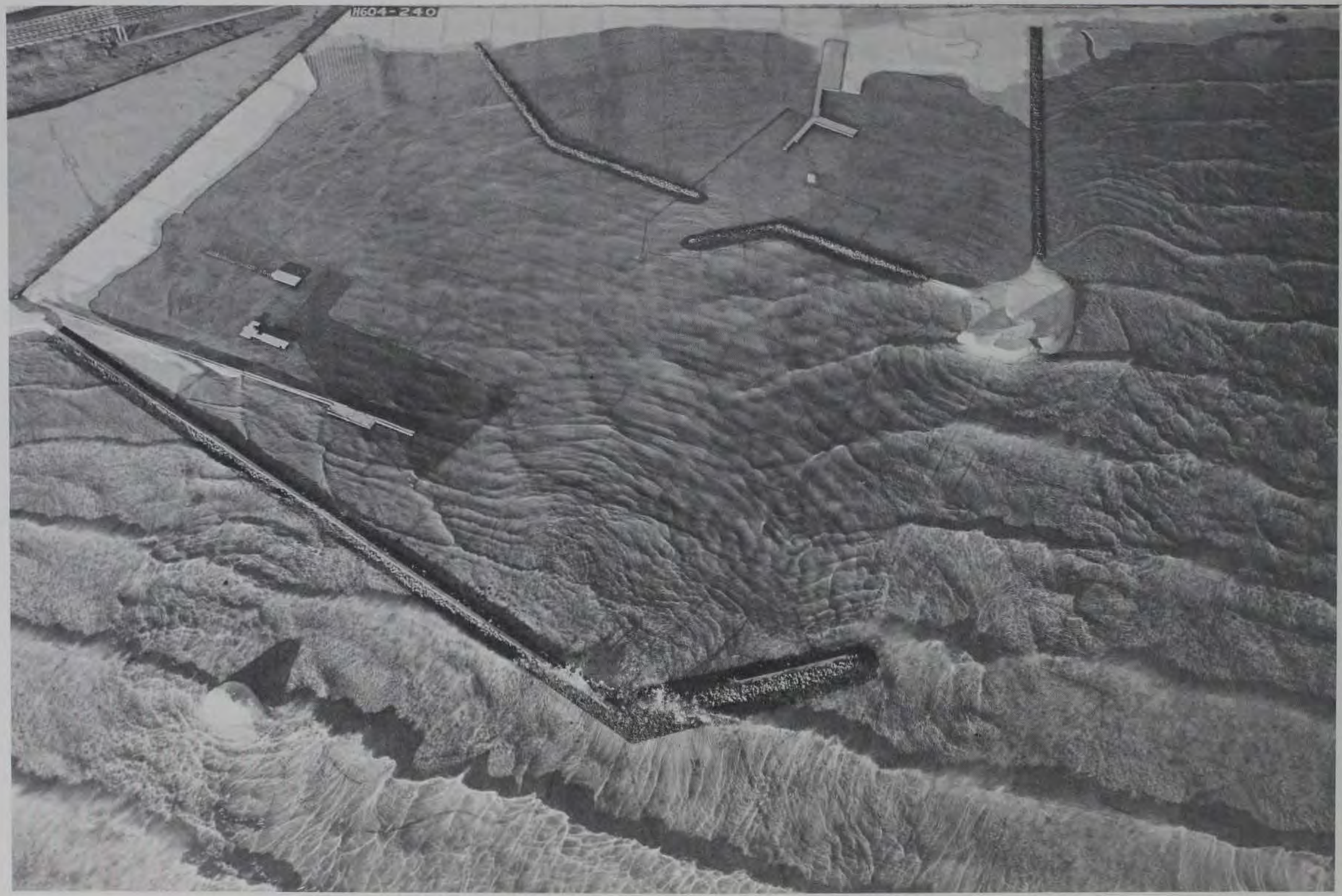
Photograph A6. Wave patterns, plan 11; 12-sec, 18-ft shallow-water waves from S35°40'W



Photograph A7. Wave patterns, plan 11; 16-sec, 22-ft shallow-water waves from S49°15'W



Photograph A8. Wave patterns, plan 11A; 9-sec, 12-ft shallow-water waves from S10° 22'W



Photograph A9. Wave patterns, plan 11A; 16-sec, 22-ft shallow-water waves from S49°15'W

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13. ABSTRACT

Additional tests were conducted in an existing hydraulic model of Crescent City Harbor to determine the optimum length and location of a breakwater system for providing sufficient protection for an expansion to the small-craft harbor capacity. It was concluded that of the several plans tested a breakwater beginning at the +7.5 contour about 900 ft east of Elk Creek and extending southerly into the harbor for approximately 1050 ft, then angling southeasterly and continuing for an additional 900 ft, in conjunction with a northwesterly extension to the existing inner breakwater of 400 ft, would provide the best protection for the problem area.

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