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LABORATORY EFFECTS IN BEACH STUDIES. VOLUME V. MOVABLE-BED EXPE--ETC(U)
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Laboratory Effects in Beach Studies

Volume V

Movable-Bed Experiment with $H_o/L_o=0.039$

by

Charles B. Chesnutt and Robert P. Stafford

MISCELLANEOUS REPORT NO. 77-7 (V)

DECEMBER 1977

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In an experiment with a wavelength of 10.26 feet (wave period = 1.50 seconds) on an initial movable-bed slope of 0.10 in a tank 10 feet wide with waves directed normal to the initial shoreline, the foreshore and inshore changes of the profile were three-dimensional to such an extent that a longshore current developed at the base of the foreshore. Comparable experiments in the same facility, but with a longer wavelength, did not show three-dimensional effects to as great an extent. As a working hypothesis, it is (continued)

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proposed that the shorter the wavelength in a movable-bed experiment relative to a given tank width, the greater the likelihood of three-dimensional effects in profile development.

The wave steepness was higher than the wave steepness in the comparable earlier experiments (0.039 versus 0.021 in Vols. II, III, and IV of the series), and the reflection coefficient was lower, as would be expected from increased breaker dissipation of steeper waves and for a shorter wave on the same slope. Variations in the reflection coefficient may have been caused by the change in phase difference between the waves reflected from the offshore slope and the foreshore slope as those two zones moved farther apart on the developing profile.

The profile appeared to have almost attained an equilibrium shape after 150 hours, in contrast to the comparable experiments with lower wave steepness, which were not approaching equilibrium after a much longer time in the same facility.

PREFACE

Ten experiments were conducted at the Coastal Engineering Research Center (CERC) from 1970 to 1972 as part of an investigation of the Laboratory Effects in Beach Studies (LEBS), to relate wave height variability to wave reflection from a movable-bed profile in a wave tank. The investigation also identified the effects of other laboratory constraints. The LEBS project is directed toward the solution of problems facing the laboratory researcher or engineer in charge of a model study; ultimately, the results will be of use to field engineers in the analysis of model studies. The work was carried out under the CERC coastal processes program.

This report (Vol. V), the fifth in a series of eight volumes on the LEBS experiments, analyzes a movable-bed experiment which shows that wave height variability depends on a complex relationship between profile changes and wave reflection. The experiment, when compared to earlier tests, suggests that the tank width is an important parameter affecting profile development.

Volume I of this series documents the procedures used in the 10 movable-bed laboratory experiments, and also serves as a guide for conducting realistic coastal engineering laboratory studies. Volumes II to VII are data reports for the other experiments; Volume VIII is a final analysis report.

This report was prepared by Charles B. Chesnutt, principal investigator, and Robert P. Stafford, senior technician in charge of the experiment. Dr. C.J. Galvin, Jr., Chief, Coastal Processes Branch, provided general supervision.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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

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

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: C = (5/9) (F -32).

To obtain Kelvin (K) readings, use formula: K = (5/9) (F -32) + 273.15.

LABORATORY EFFECTS IN BEACH STUDIES

Volume V. Movable-Bed Experiment With H_o/L_o = 0.039

by

Charles B. Chesnutt and *Robert P. Stafford*

I. INTRODUCTION

1. Background.

Wave reflection has been shown to vary significantly as a movable-bed profile changes from an initial planar slope to one closer to equilibrium (Chesnutt and Galvin, 1974). Wave reflection from a profile of a given slope is expected to decrease with increasing wave steepness.

The Laboratory Effects in Beach Studies (LEBS) project was initiated at the Coastal Engineering Research Center (CERC) in 1966 to investigate the causes of wave height variability and other problems associated with movable-bed coastal engineering laboratory studies. Ten movable-bed laboratory experiments were conducted from 1970 to 1972 in the CERC Shore Processes Test Basin (SPTB) to measure the variation in reflection as the profile developed toward equilibrium. This report (Vol. V) discusses the experiment conducted with H_o/L_o = 0.039; Volumes II, III, and IV (Chesnutt and Stafford, 1977a, 1977b, 1977c) discussed the experiments conducted with H_o/L_o = 0.021. The other four experiments are covered in Volumes VI and VII, part of a series of eight reports on LEBS. Volume I of the series (Stafford and Chesnutt, 1977) discusses the contents and primary purposes of these reports.

Volumes II and III in this series (Chesnutt and Stafford, 1977a, 1977b) describe four experiments with initial slopes of 0.10 and wave steepness of 0.021, which led directly to the experiment described in this report. Those experiments were conducted primarily to (a) relate the variation of wave height to the variation in wave reflection caused by changes in the movable-bed profile, and (b) define the equilibrium profile shape, at which point it was assumed that the wave height variability would be significantly reduced.

The experiment discussed in this study had an initial slope of 0.10, but wave steepness was increased from 0.021 to 0.039, in an attempt to determine how much the wave reflection and the reflection variability would be reduced by increased wave steepness.

Experiment 72D-06 (Vol. IV; Chesnutt and Stafford, 1977c) was conducted concurrently with this experiment. Results will also be compared with that experiment, which had a wave period of 1.90 seconds, but had an initial slope of 0.05.

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2. Experimental Procedures.

The experimental procedures used in the LEBS experiments are described in Volume I (Stafford and Chesnutt, 1977) which provides the necessary details on the equipment, quality control, data collection, and data reduction for all 10 experiments. Data collection and reduction procedures unique to the experiment in this study are documented in the Appendix.

The conditions of experiment 72C-10 (the subject of this report) and experiment 71Y-10 (discussed in Vol. III and compared with experiment 72C-10 in this volume) are summarized in Table 1. The table shows that initial test length, initial slope, water depth, and sand size were the same in both experiments. Although the wave period, height, steepness, and energy density differed, the wave energy flux was the same. The wavelength was 10.26 feet (3.13 meters).

Table 1. Summary of experimental conditions.

Experiment[1]	Initial test length (ft)	Initial slope	Wave period (s)	Generated[2] wave height (ft)	Initial[3] median grain size (mm)
72C-10	54.7	0.10	1.50	0.41	0.21
71Y-10	54.7	0.10	1.90	0.36	0.23

[1]Refer to Volume I (Stafford and Chesnutt, 1977) for relation between these experiments and the other eight LEBS experiments.
[2]Determined for the given wave period and constant water depth of 2.33 feet (0.7 meter) so that the generated wave energy flux, computed from linear theory, had a constant value of 5.8 foot-pounds per foot-second.
[3]Initial d_{50} by dry sieve analysis.

NOTE.--Constants: water depth = 2.33 feet, wave energy flux = 5.8 foot-pounds per foot-second.

The experimental facility used is shown in Volume I (Fig. 4) and in the Appendix (Fig. A-1). The facility consisted of two side-by-side 10-foot-wide (3 meters) wave tanks, one with a 0.10 concrete slope and the other a sand slope. A generator was common to both tanks so that each had identical wave energy input. The operation of the generators is described in Section IV and Appendix B of Volume I. The concrete slope provided a control (a bench-mark value) for the varying reflection measured in the neighboring tank with the movable bed. The initial test length was 7 feet (2.1 meters) greater on the concrete side.

The initial grading of the sand slope was 27 September 1972. The first run was on 3 October 1972, the last run was on 7 December 1972 after 140 hours, and the data collection was completed 14 December 1972. The dates are important because the experiments were run in outdoor facilities

Table 2. Experimental schedule for experiment 72C-10.

Cumulative time[1] (hr:min)	Wave record No.	Survey No.	Special data collected
0:00	--	1	Sand samples
0:10	55	2	
0:40	56	3	
1:30	57	4	
3:00	58	5	
5:00	59	6	
10:00	60	7	
------[2]	--[3]	------[3]	
30:00	64	11	Wave reflection
------[2]	--[3]	------[3]	
50:00	68	15, S1	Sand samples, profile surveys, ripple photos
------[2]	--[3]	------[3]	
60:00	70	17	Wave reflection
------[2]	--[3]	------[3]	
80:00	74	21	Wave reflection
------[2]	--[3]	------[3]	
100:00	78	25, S2	Sand samples, profile surveys, ripple photos
------[2]	--[3]	------[3]	
140:00	86	33, S3	Sand samples, profile surveys, ripple photos

[1]Wave records were taken *during* run ending at cumulative time shown; surveys, sand samples, and ripple photos were taken *after* the run ending at the cumulative time shown (see also Table 3).

[2]Increments of 5.

[3]Increments of 1.

with water temperatures varying with ambient air temperature. The major events of the experiment and the cumulative time at the end of each run are summarized in Table 2.

Table 3 gives the data collection schedule within each 5-hour run. During the first 5 hours when the runs varied in length, the same data were collected, with the schedule depending on the length of the run.

Table 3. Data collection schedule within runs for experiment 72C-10.

Event	Time within runs
Photo of SWL intercept and upper slope, if damaged since last run	Before start
Current data	Throughout run
Recording of wave envelope	4:40
Preparation of visual observation form	4:55
Photos of runup and breaker	4:59
Photo of SWL intercept and upper slope, after water had calmed	5:00
Profile survey	5:00
Water temperature data collected in the morning and afternoon of each day of testing	

3. Scope.

This report describes and analyzes the reduced data from LEBS experiment 72C-10. The original data are available in an unpublished laboratory memorandum (No. 4) filed in the CERC library (Leffler and Chesnutt, 1977).

Wave reflection, profile surveys, sediment-size distribution, breaker characteristics, water temperature, and current observations are discussed in Section II. Section III discusses (a) profile development, which examines the interrelation of changes in profile shape, sediment-size distribution, breaker characteristics, water temperature, and currents; and (b) profile reflectivity, which examines the interrelation of changes in profile shape, breaker characteristics, currents, and wave reflection. Section IV summarizes the results on wave height variability, profile equilibrium, and other laboratory effects.

The conclusions and recommendations (Sec. V) are aimed directly at the problems of the laboratory researcher or engineer in charge of a model study. Field engineers should be aware of these results when analyzing model studies for projects.

The data in this study (particularly the profiles) may have other uses. The researcher can use these data, after consideration of the laboratory effects, to analyze short- and long-term changes in profile shape. The field engineer may use these data, after an analysis of the laboratory and scale effects, to determine generalized shoreline recession rates for this very steep wave.

II. RESULTS

1. Wave Height Variability.

a. Incident Wave Heights. Wave height measurements from the continuous recording of water surface elevation along the center range at station +25 in both tanks during the first 10 minutes for experiment 72C-10 are shown in Table 4. The wave heights in both tanks varied from 0.37 to 0.48 foot (11.3 to 14.6 centimeters) during the first 20 seconds. Ignoring the first group of waves, the range was 0.07 foot (2.1 centimeters) in the movable-bed tank and 0.12 foot (3.7 centimeters) in the fixed-bed tank.

The average wave height in each tank was determined by averaging the average of the 10 waves nearest each full minute. The average wave height was 0.38 foot (11.6 centimeters) in the movable-bed tank and 0.43 foot (13.1 centimeters) in the fixed-bed tank. The initial height differences are assumed to occur primarily because the gages were different distances from the profile and thus at different points in the standing wave envelope.

Table 5 shows the computed average incident wave heights in the two tanks during 140 hours of testing. These heights were determined by the automated method for determining the reflection coefficient, K_R (see Vol. I), which assumes that the incident wave is a single sine wave. The range of values for the fixed-bed tank was 0.03 foot (0.9 centimeter). This variation is probably caused by generator operation variation, measurement errors, and all errors not caused by a changing profile. The range of values in the movable-bed tank was 0.09 foot (2.7 centimeters). The difference between the two tanks indicates that 0.06 foot (1.8 centimeters) of the variation in the movable-bed tank was due to the changing profile which caused a variation in the reflected and re-reflected wave heights. The re-reflected wave superposing with the generated wave created an incident wave which varied in time.

b. Wave Reflection. The reflection coefficient, K_R, data determined by the manual and automated methods are given in Table 6. The two methods are described in Volume I. A plot of K_R versus time comparing the two methods for ranges 1, 5, and 9 in the movable-bed tank (Fig. 1), indicates that the manual method gave higher values. A scatter plot of K_R values for the manual method versus the automated method (Fig. 2) for those wave records reduced by both methods also shows that the manual values were higher than the automated values. The generalized region in Figure 2 is where equivalent data for the 1.90-second wave plotted and is the justification for assuming that the average difference between the two methods (0.09 for the 1.50-second wave) is constant.

All K_R data from the movable-bed tank versus time are plotted in Figure 3, with the manual method values reduced by 0.09 to give a single curve for each of the three ranges. The three K_R values at each time have been averaged to give a single curve. The outside ranges show a greater variation in K_R than the center range, but the maximum and

Table 4. Wave heights during first 10 minutes for experiment 72C-10.

Cumulative time (min:s)	Wave height (ft)					
	Movable-bed tank			Fixed-bed tank		
	(avg)	(max)	(min)	(avg)	(max)	(min)
0:00 to 0:20	0.413	0.477	0.368	0.418	0.480	0.368
0:20 to 0:40	0.401	0.420	0.375	0.393	0.437	0.342
0:50 to 1:10	0.407	0.422	0.390	0.449	0.456	0.431
1:50 to 2:10	0.364	0.374	0.350	0.436	0.453	0.425
2:50 to 3:10	0.378	0.389	0.369	0.416	0.405	0.432
3:50 to 4:10	0.367	0.375	0.357	0.427	0.453	0.420
4:50 to 5:10	0.393	0.402	0.383	0.425	0.438	0.411
5:50 to 6:10	0.378	0.395	0.363	0.427	0.441	0.413
6:50 to 7:10	-----[1]	-----	-----	0.440	0.458	0.426
7:50 to 8:10	0.392	0.410	0.384	0.420	0.449	0.402
8:50 to 9:10	0.394	0.405	0.378	0.432	0.449	0.419
9:40 to 10:00	0.378	0.395	0.366	0.425	0.458	0.407
Avg [2]	0.383			0.430		

[1]Data missing due to pen skip.
[2]Excludes averages for cumulative times 0:00 to 0:20 and 0:20 to 0:40.

Table 5. Incident wave heights in experiment 72C-10.

Time (hr)	Incident wave height (ft)	
	Movable bed	Fixed bed
1.50	0.39[1]	0.43
3.00	0.43	0.44
5.00	0.41[1]	----
15.00	0.42[1]	0.46
20.00	0.37[1]	0.43
25.00	0.43[1]	0.44
30.00	0.45	0.46
35.00	0.44	0.43
40.00	0.46	0.45
45.00	0.43	0.43
60.00	0.46	0.45
75.00	0.45	0.45
80.00	0.44	0.45
100.00	0.44	0.45
110.00	0.41[1]	0.45
125.00	0.45	0.45
130.00	0.45[1]	0.45
135.00	0.45	0.44
140.00	0.44[1]	0.44
Avg	0.43	0.44

[1]Includes data from ranges 1 and 9.

Table 6. Reflection coefficients, manual and automated methods for experiment 72C-10.

Cumulative time	Manual method				Automated method			
	Movable bed			Fixed bed	Movable bed			Fixed bed
	Range			Range	Range			Range
(hr)	1	5	9	5	1	5	9	5
0.16	-----[1]	-----	-----	-----	-----	-----	-----	-----
0.66	0.136	0.128	0.119	-----	-----	-----	-----	-----
1.50	-----	-----	-----	-----	0.104	0.122	0.067	0.026
3.00	0.229	-----	0.148	-----	-----	0.084	-----	0.009
5.00	-----	-----	-----	-----	0.052	0.048	0.042	-----
10.00	0.163	0.121	0.113	-----	-----	-----	-----	-----
15.00	-----	-----	-----	-----	0.053	0.044	0.037	0.016
20.00	-----	-----	-----	-----	0.087	0.055	0.071	0.007
25.00	-----	-----	-----	-----	0.131	0.083	0.032	0.024
30.00	0.115	0.119	0.113	-----	0.028	0.027	0.017	0.008
35.00	0.095	-----	0.083	-----	-----	0.049	-----	0.006
40.00	0.098	-----	0.108	-----	-----	0.077	-----	0.019
45.00	0.111	-----	0.121	-----	-----	0.043	-----	0.019
50.00	0.126	0.167	0.132	-----	-----	-----	-----	-----
55.00	0.169	0.196	0.196	-----	-----	-----	-----	-----
60.00	0.112	0.174	-----	-----	-----	0.027	-----	0.009
65.00	0.132	0.173	0.141	-----	-----	-----	-----	-----
70.00	0.135	0.156	0.166	-----	-----	-----	-----	-----
75.00	0.156	-----	0.166	-----	-----	0.066	-----	0.020
80.00	0.155	0.114	-----	-----	-----	0.074	-----	0.007
85.00	0.157	0.160	0.156	-----	-----	-----	-----	-----
90.00	0.124	0.142	0.111	-----	-----	-----	-----	-----
95.00	0.090	0.150	0.123	-----	-----	-----	-----	-----
100.00	0.176	-----	0.165	-----	-----	0.015	-----	0.014
105.00	-----	0.163	-----	-----	0.147	-----	0.142	-----
110.00	-----	-----	-----	-----	0.067	0.077	0.112	0.009
115.00	-----	0.164	-----	-----	0.067	-----	0.053	-----
120.00	0.109	0.123	0.115	-----	-----	-----	-----	-----
125.00	0.113	-----	0.135	-----	-----	0.057	-----	0.010
130.00	-----	-----	-----	-----	0.054	0.034	0.022	0.020
135.00	0.109	-----	0.123	-----	-----	0.047	-----	0.013
140.00	-----	-----	-----	-----	0.037	0.029	0.054	0.014

[1]Data either not reduced by this method or not available.

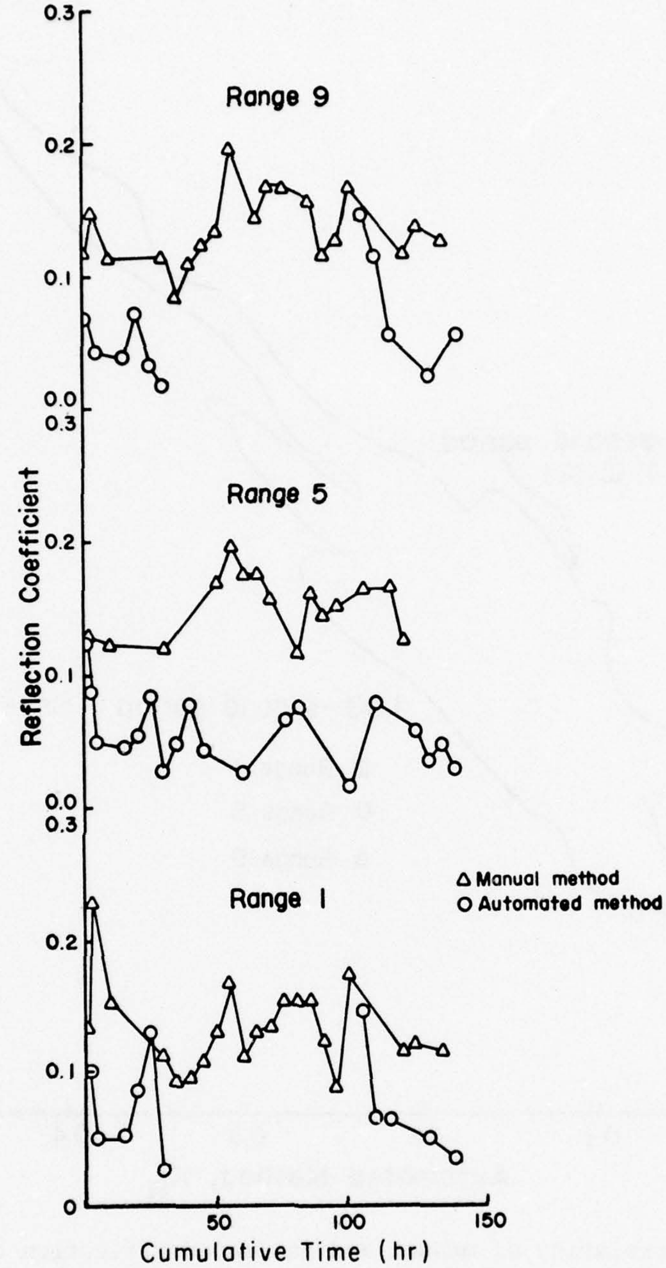


Figure 1. Comparison of manual and automated reflection coefficients.

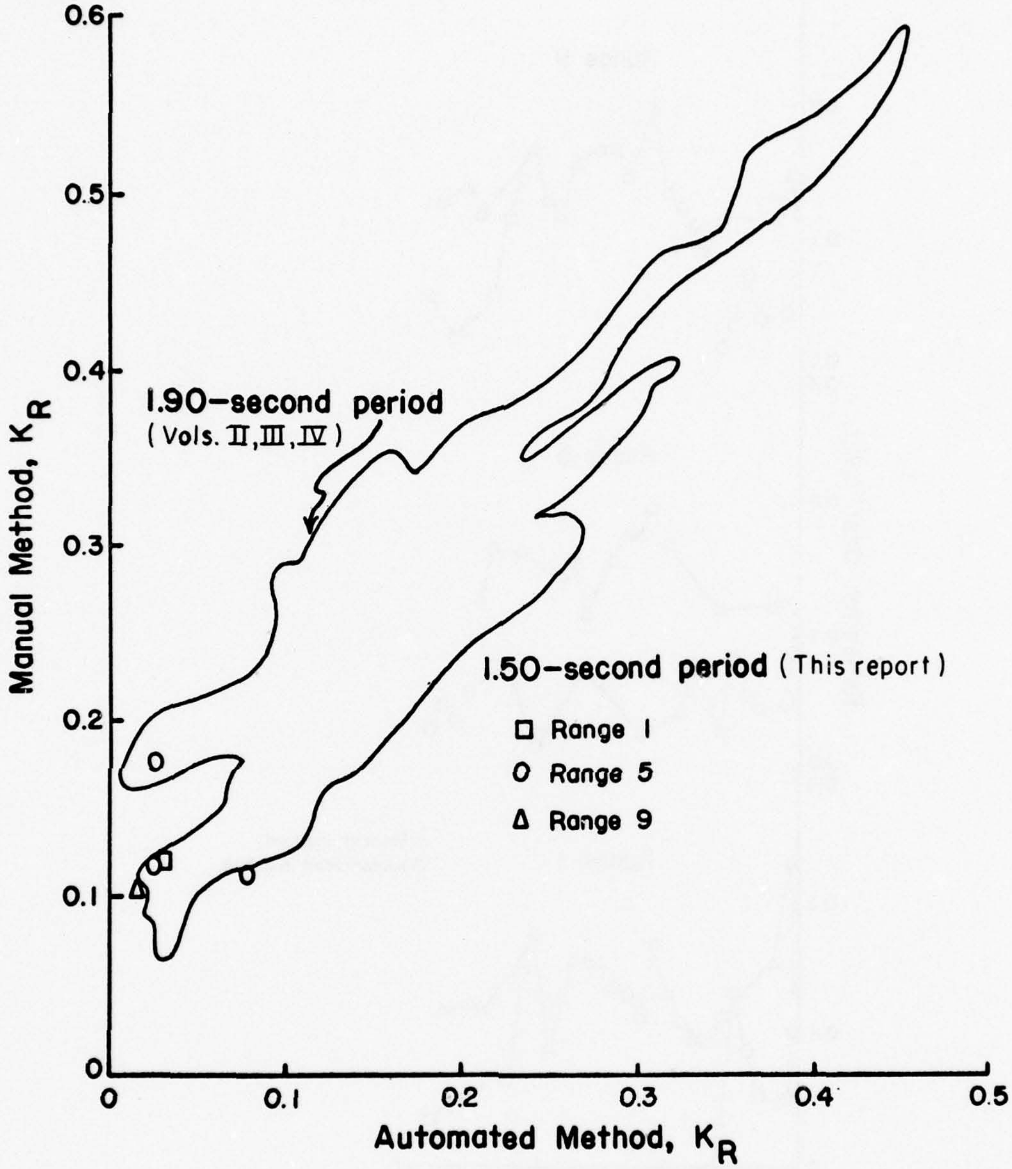


Figure 2. Correlation of manual and automated reflection coefficients.

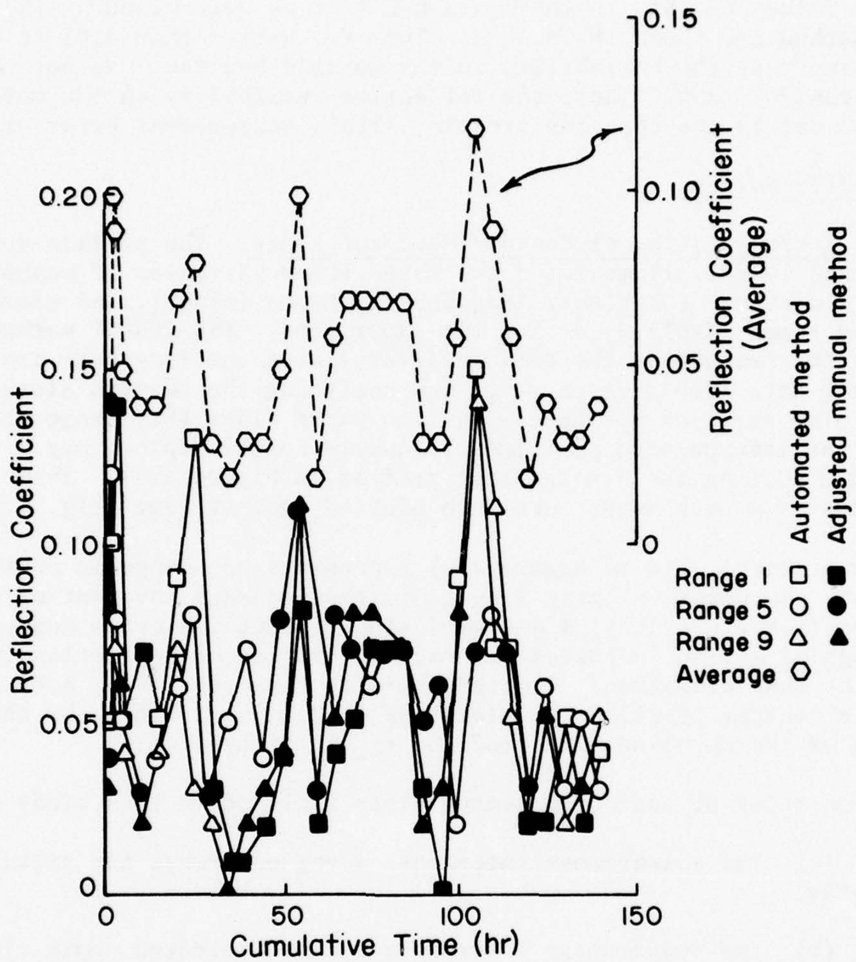


Figure 3. Reflection coefficient variation in experiment 72C-10.

minimum values occur at the same times on the three ranges. Maximum values occur at 1.5, 25, 55, and 105 hours; minimum values occur at 35, 60, 90, 95, and 120 hours. Long-term variations are not apparent.

The values of K_R in the fixed-bed tank as determined by the automated method are shown in Table 6. The K_R varied from 0.01 to 0.03, indicating that the variability in the movable-bed tank was not observed in the control tank. Thus, the reflection variability in the movable-bed tank was due to the changing profile, with a measurement error of ±0.01.

2. Profile Surveys.

a. Interpretation of Contour Movement Plots. The profile surveys (discussed in Vol. I) measured the three space variables of onshore-offshore distance (station), longshore distance (range), and elevation at fixed times (Table 2) during the experiment. The CONPLT method (see Vol. I) for presenting the data involves fixing the longshore distance by selecting data from a given range and analyzing the surveys along that range. The surveyed distance-elevation pairs along that range are used to obtain the interpolated position of equally spaced depths; e.g., -0.1, -0.2, and -0.3 on the hypothetical profile in Figure 4(a). These contour positions from each survey are then plotted against time (Fig. 4,b).

A horizontal line in Figure 4(b) represents no change in contour position. An upward-sloping line indicates landward movement of contour position (i.e., erosion); a downward-sloping line indicates deposition. The slope of a line indicates the rate of erosion or deposition (horizontally) at that elevation. The three x's at time t_2 (Fig. 4,b) indicate multiple contour positions at elevation -0.2 which is shown by the intersection of the dashline with profile t_2 in Figure 4(a).

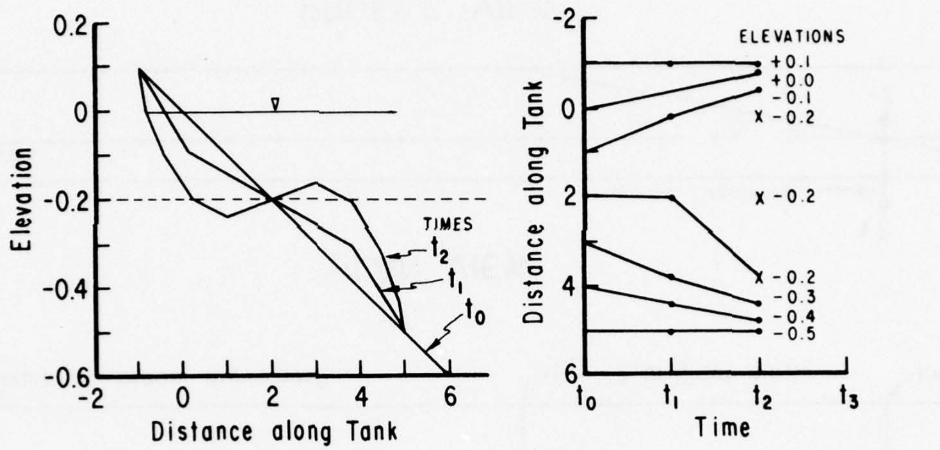
Three types of contour movement plots included in this study are:

(a) The seawardmost intercepts along one range for selected depths;

(b) the seawardmost intercepts for one selected depth along all ranges; and

(c) all contour intercepts including multiple intercepts along one range, for up to 12 selected depths.

The coordinate system used for the contour movement plots is shown in Figure 5. The elevations referred to in the discussion that follows are: 0.1 foot (3.0 centimeters), 0.3 foot (9.1 centimeters), 0.4 foot (12.2 centimeters), 0.5 foot (15.2 centimeters), 0.6 foot (18.3 centimeters), 0.8 foot (24.4 centimeters), 0.9 foot (27.4 centimeters), 1.0 foot (30.5 centimeters), 1.1 feet (33.5 centimeters), 1.3 feet (39.6 centimeters), 1.4 feet (42.7 centimeters), 2.1 feet (64.0 centimeters), and 2.2 feet (67.1 centimeters).



a. Profile line

b. Movement of contour positions

Figure 4. Interpretation of contour movement plots.

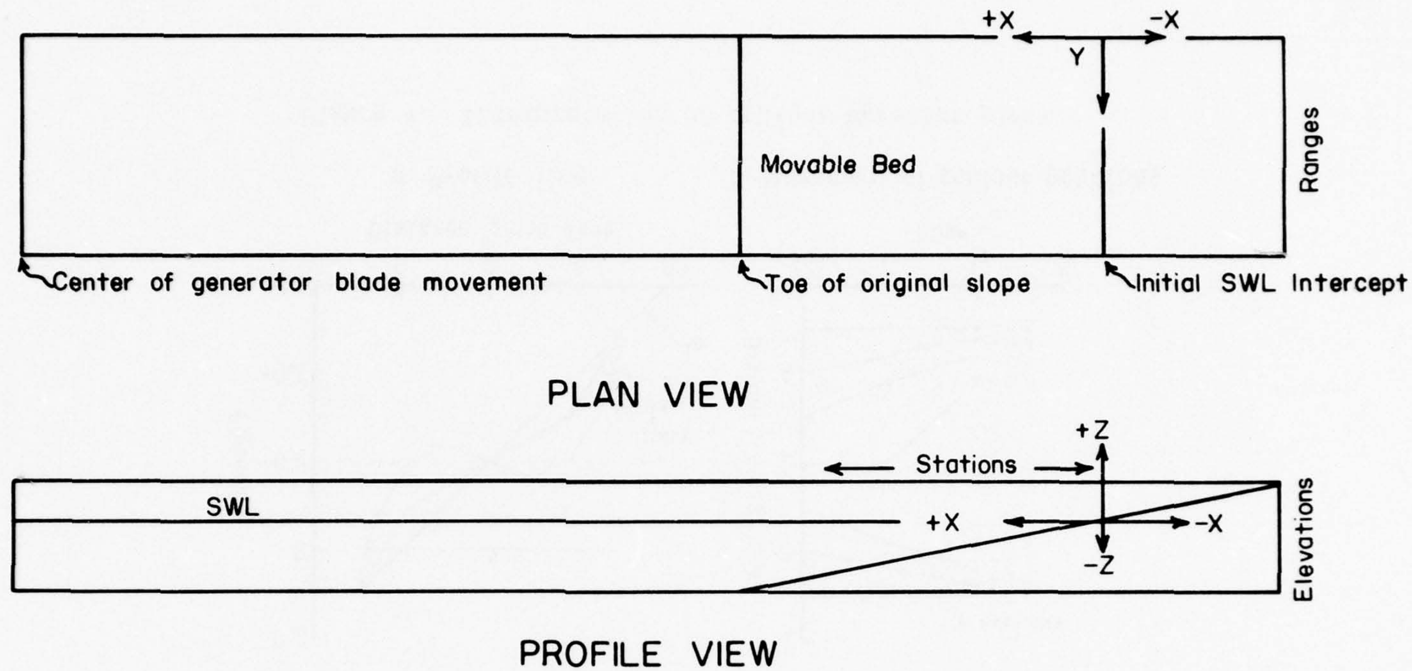


Figure 5. Definition of coordinate system.

b. Profile Zones. Definitions of coastal engineering terms used in LEBS reports conform to Allen (1972) and the Shore Protection Manual (SPM) (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975). For the profile zones in this study, the boundary between the foreshore and inshore zones, the lower limit of backrush (low water line), is at elevation -0.1 foot. The seaward edge of the inshore zone is defined as extending through the breaker zone. The boundary between the inshore and offshore zones for this experiment is at elevation -0.9 foot.

A definition sketch of the profile zones is shown in Figure 6. The profile at 55 hours (dashline) had a very narrow foreshore zone with a steep beach face and a high scarp, an inshore zone consisting of two almost flat regions separated by a gentle slope, and a steep offshore zone. The profile at 140 hours (broken line) was similar. The foreshore and offshore zones had roughly the same shapes, but the foreshore had retreated landward and the offshore had prograded seaward. The inshore zone had a longer inner shelf, a sloping region in the same position, and more of a bar and trough at the outer end. This development is shown by contour movement plots (Figs. 7 to 11) of the seawardmost contour intercepts for elevations at 0.1-foot depth increments from +1.1 to -2.2 feet. The heavier lines for the -0.1- and -0.9-foot contours distinguish the three profile zones in the figures. In the foreshore and offshore zones the contour lines are close together, indicating steeper slopes; in the inshore zone the lines are generally spaced farther apart, indicating flatter slopes.

(1) Foreshore Zone. Within the first 40 minutes the foreshore zone developed the basic shape which it maintained throughout the experiment. This is indicated by the parallel lines after *40 minutes* in Figure 12, which compares the contour movements in the foreshore zone along the five ranges during the first 10 hours. The foreshore maintained basically this shape as it retreated in the erosion process (upward-sloping lines for -0.1 foot and higher contours in Figs. 7 to 11).

Although contours of the foreshore moved together, the lines were not always parallel (Figs. 7 to 11), indicating some variation in foreshore slope with time at each range. Slope values at the stillwater level (SWL) intercept (Table 7) were determined by measuring the slope between survey points on either side of the shoreline. The steepest slope was 0.56 and the flattest slope was 0.10, indicating that although the slope varied, the values were all fairly steep. The average slope was 0.204.

The shoreline (0 contour) movement along the five ranges is compared in Figure 13. After 5 hours the shoreline along the different ranges varied as much as 2.5 feet (0.76 meter) in position at a given time. This is further illustrated by the photos in Figure 14. At 50 hours (Fig. 14,a) the shoreline and scarp on the near side (ranges 1 and 3) were farther landward than the shoreline along the far side (ranges 7 and 9), indicating that the backshore and scarp were probably eroding along

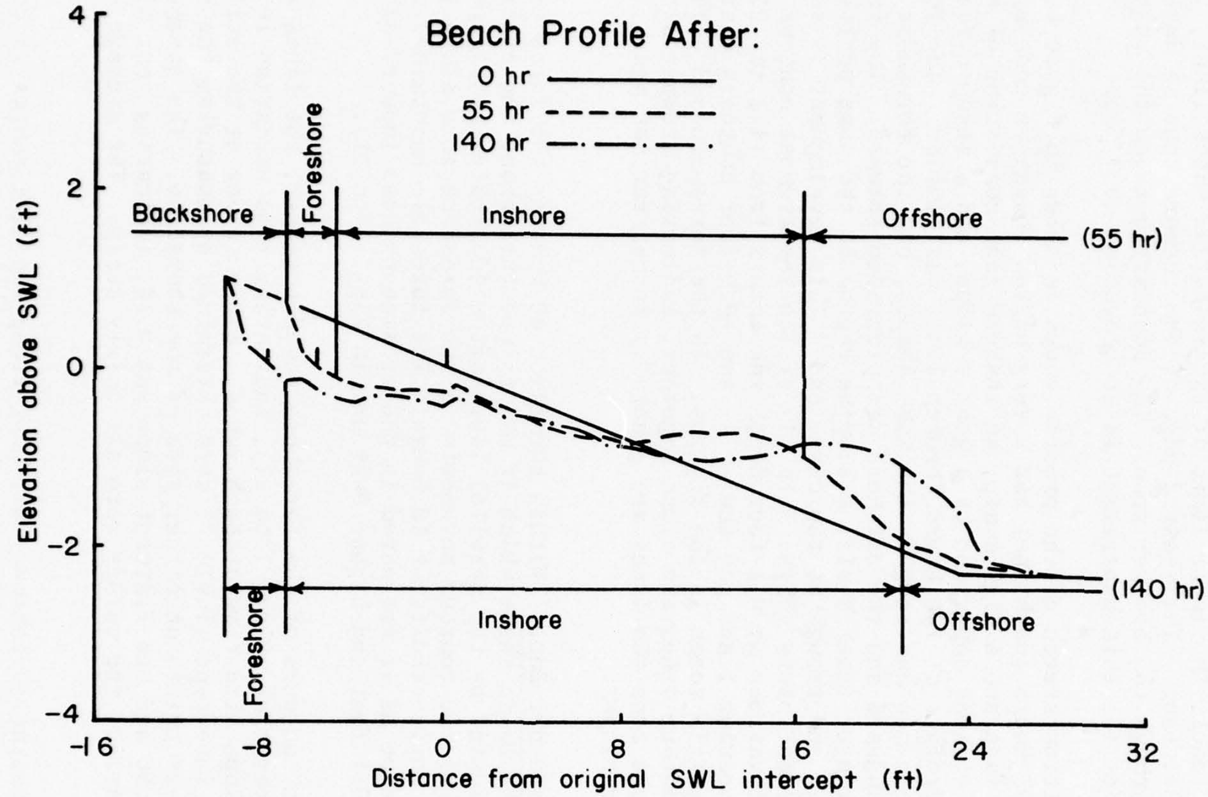


Figure 6. Definition sketch of profile zones.

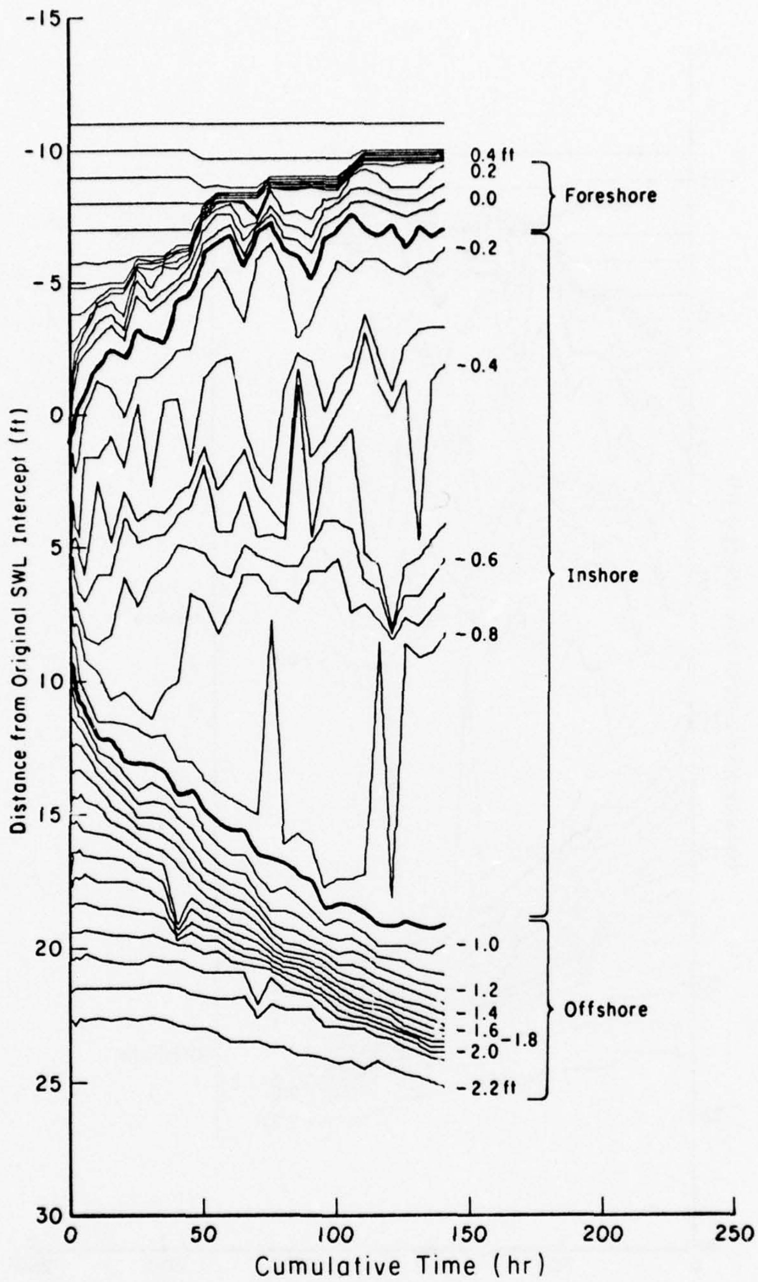


Figure 7. Profile changes along range 1.

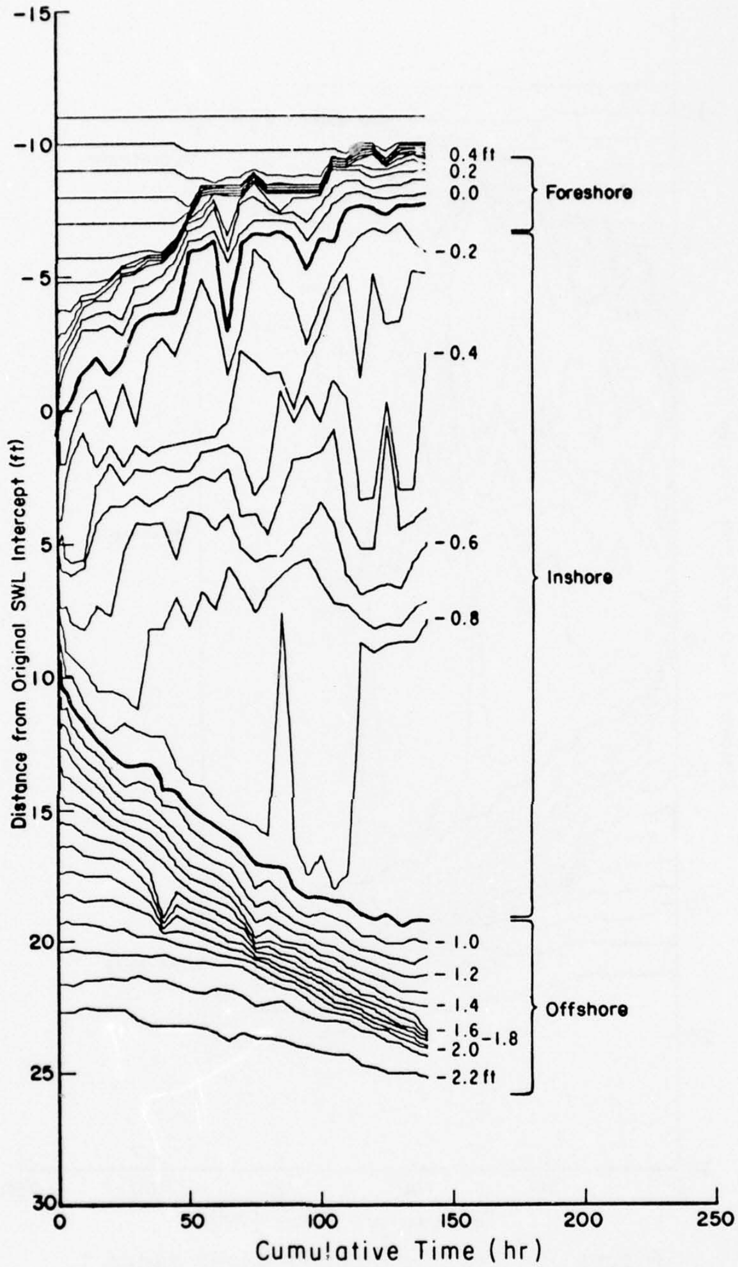


Figure 8. Profile changes along range 3.

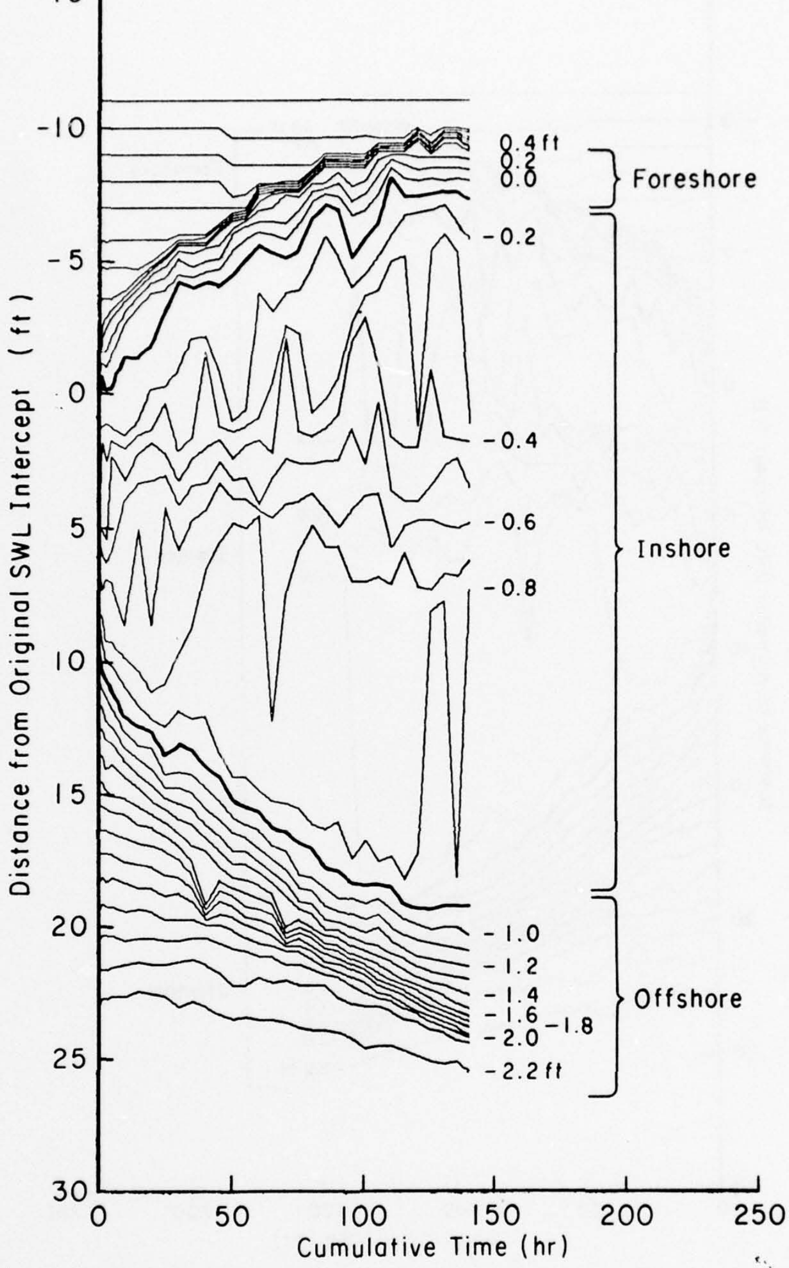


Figure 9. Profile changes along range 5.

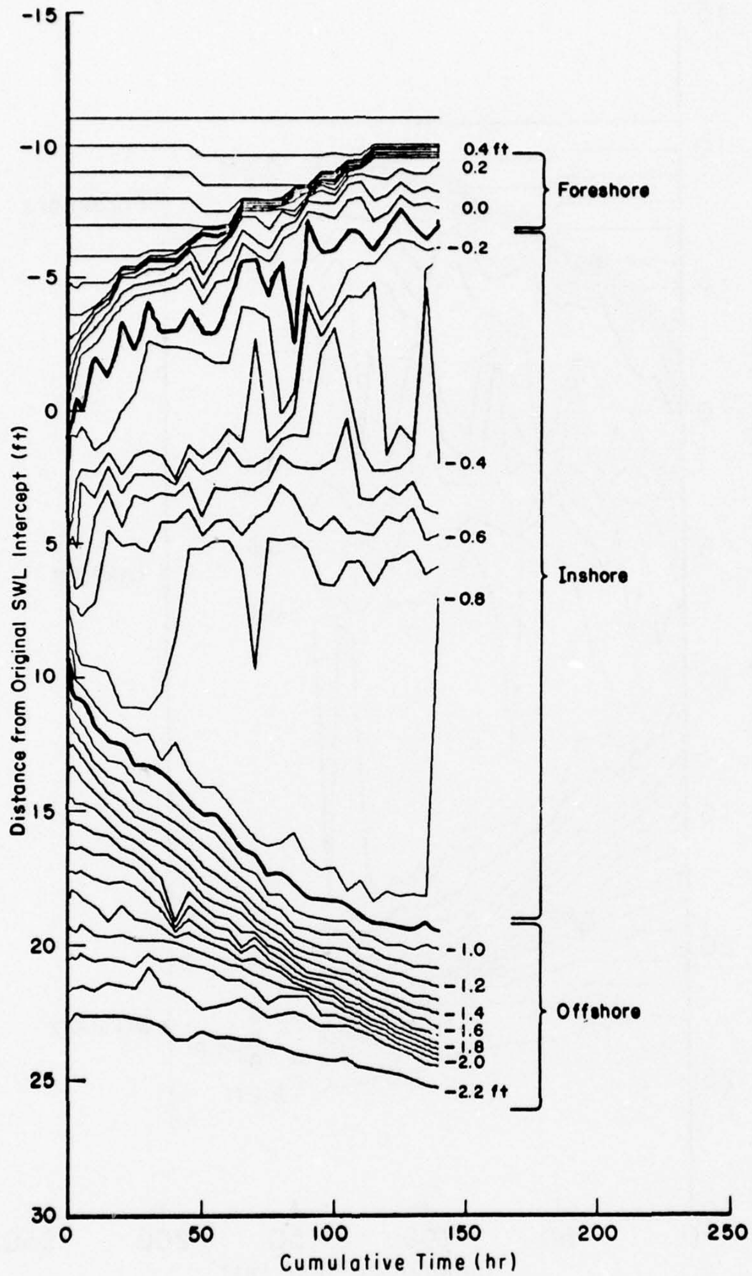


Figure 10. Profile changes along range 7.

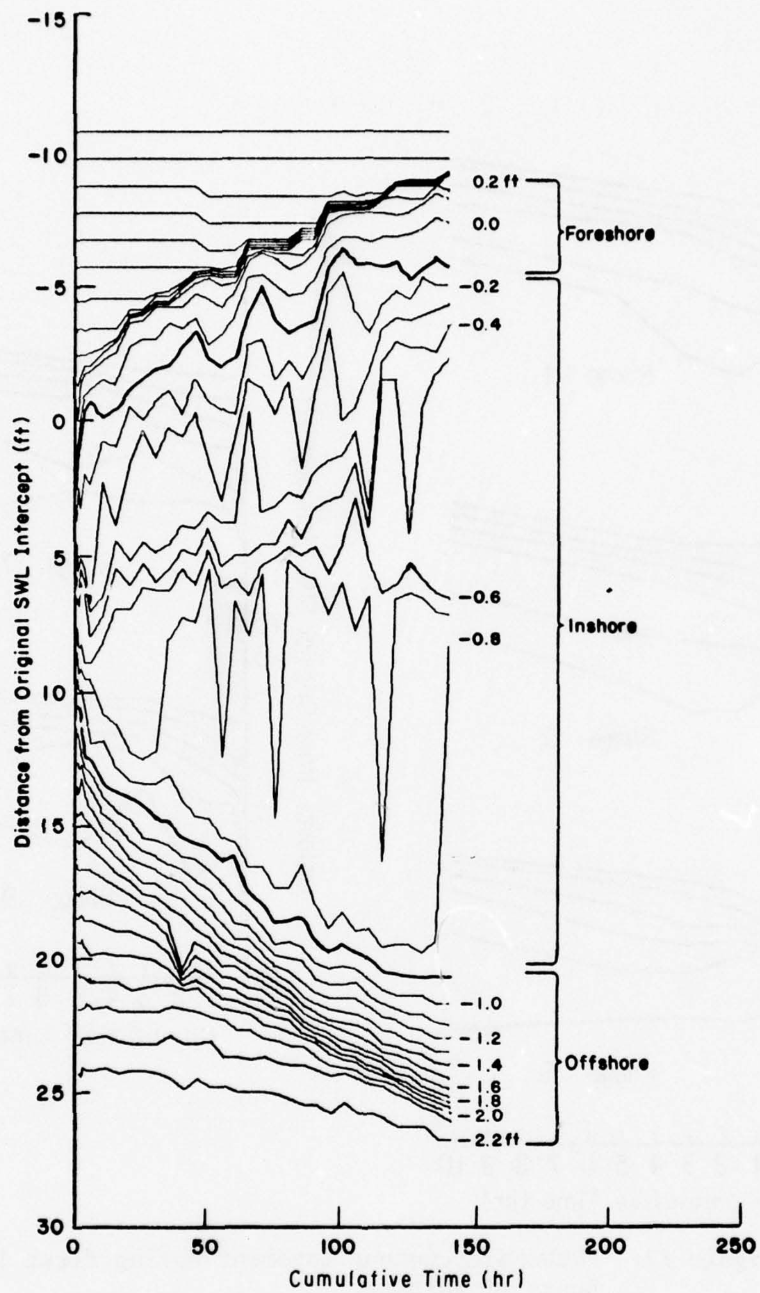


Figure 11. Profile changes along range 9.

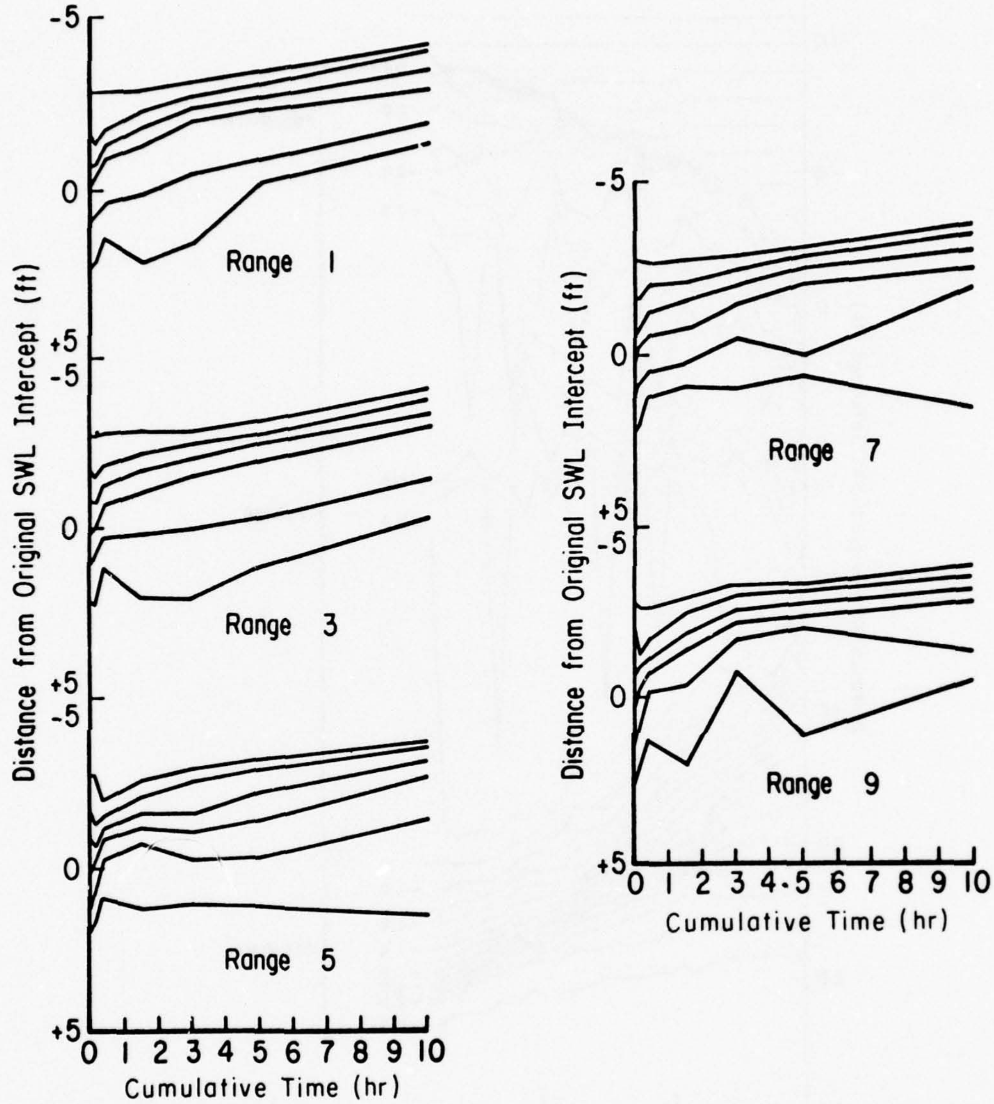


Figure 12. Foreshore contour movement during first 10 hours of testing.

Table 7. Slope of the beach face at the SWL intercept in experiment 72C-10.

Cumulative time (hr)	Range 1	Range 3	Range 5	Range 7	Range 9
0:00	0.08	0.10	0.08	0.12	0.10
0:10	0.20	0.12	0.20	0.14	0.16
0:40	0.20	0.18	0.20	0.16	0.18
1:30	0.18	0.12	0.20	0.16	0.14
3:00	0.26	0.16	0.18	0.12	0.18
5:00	0.24	0.22	0.12	0.20	0.28
10:00	0.18	0.22	0.14	0.18	0.28
15:00	0.20	0.16	0.26	0.28	0.18
20:00	0.24	0.18	0.30	0.20	0.18
25:00	0.22	0.16	0.16	0.24	0.16
30:00	0.22	0.16	0.16	0.30	0.22
35:00	0.22	0.14	0.24	0.24	0.24
40:00	0.30	0.16	0.20	0.18	0.28
45:00	0.22	0.16	0.24	0.16	0.18
50:00	0.22	0.26	0.20	0.18	0.14
55:00	0.26	0.24	0.18	0.10	0.22
60:00	0.22	0.22	0.20	0.16	0.20
65:00	0.26	0.24	0.22	0.20	0.30
70:00	----	0.20	0.16	0.46	0.20
75:00	0.30	0.18	0.20	0.20	0.16
80:00	0.20	0.18	0.20	0.18	0.26
85:00	0.18	0.54	0.56	0.18	0.20
90:00	0.14	0.24	0.24	0.28	0.12
95:00	0.20	0.12	0.18	0.22	0.20
100:00	0.22	0.14	0.14	0.18	0.26
105:00	0.20	0.16	0.14	0.18	0.18
110:00	0.16	0.16	0.26	0.16	0.14
115:00	0.14	0.20	0.20	0.14	0.18
120:00	0.22	0.28	0.20	0.18	0.18
125:00	0.18	0.22	0.22	0.20	0.20
130:00	0.20	0.28	0.20	0.18	0.16
135:00	0.18	0.16	0.22	0.30	0.18
140:00	0.16	0.22	0.30	0.18	0.22
Avg	0.21	0.20	0.21	0.20	0.20

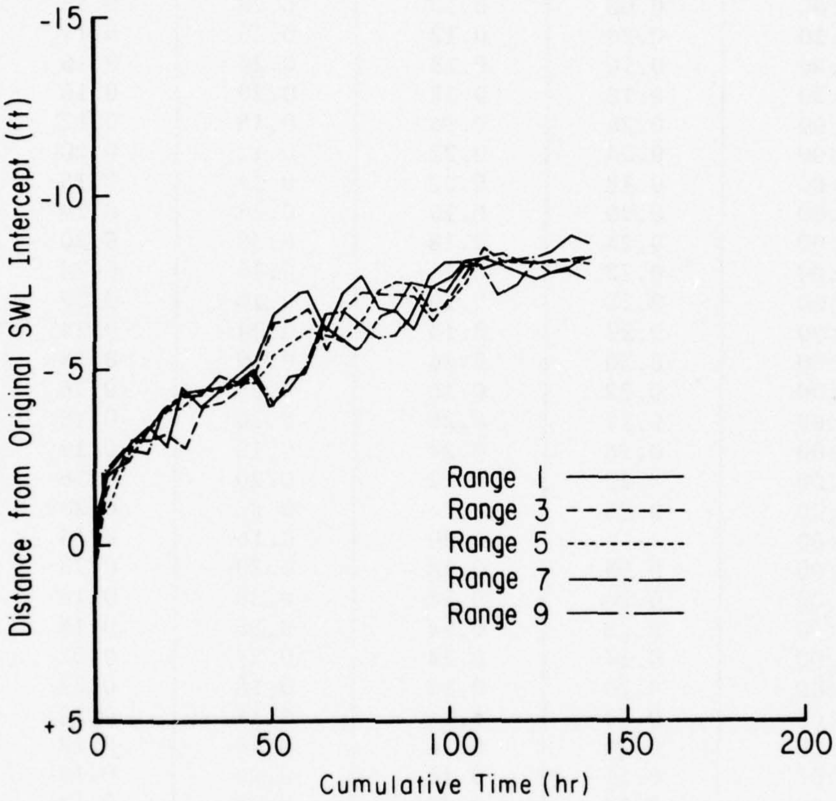
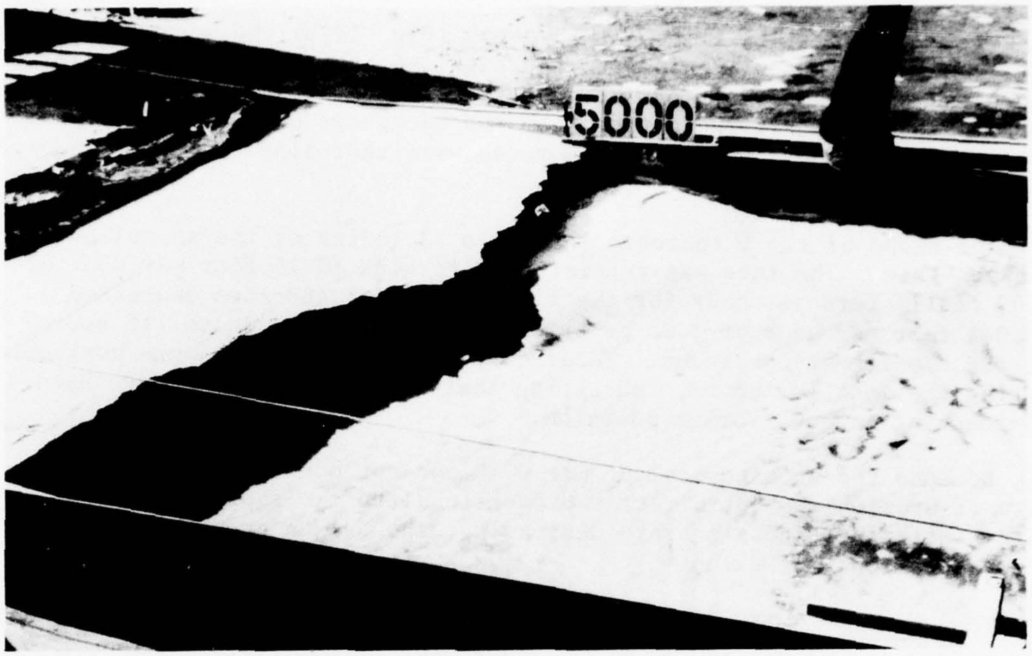
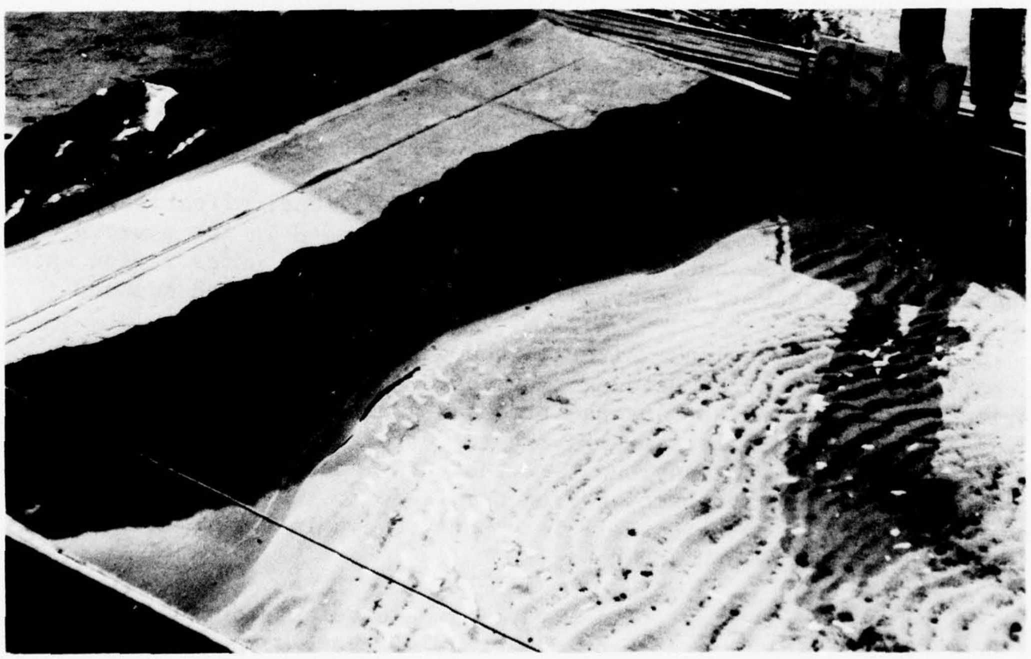


Figure 13. Shoreline (0 contour) movement at five ranges.



At 50 hr



At 85 hr

Figure 14. Shape of the foreshore zone.

ranges 1 and 3 at this time. At 85 hours (Fig. 14,b) the scarp was fairly uniform in position across the tank, but the position of the shoreline was seawardmost on the near side (range 1) and landwardmost in the middle (range 5), indicating that the backshore and scarp were probably eroding along range 5. The more seaward shoreline positions appeared to be areas of deposition.

The slope of the 0 contours in Figure 13 indicates the shoreline recession rate. The rate was initially quite high (0.15 foot per hour or 4.62 centimeters per hour for the first 30 hours) and then decreased (0.041 foot per hour or 1.25 centimeters per hour from 30 to 115 hours) as the experiment continued. Three of the five 0 contours were horizontal during the last few hours, indicating that the foreshore may have been approaching an equilibrium position.

Because the backshore slope was 0.10 and not horizontal, the volume rate of erosion was not directly proportional to the shoreline recession rate. With the recession rate decreasing, the volume erosion was likely close to a constant value.

(2) Inshore Zone. The movement of all contour intercepts in the inshore zone along the five ranges is shown in Figures 15 to 19; the movement of selected contours along the five ranges is compared in Figure 20.

Within the first hour a longshore bar and trough developed in the inshore zone, as indicated by the seaward movement of the -0.5- and -0.4-foot contours and the many multiple contour intercepts at those elevations in Figures 15 to 19. By 15 hours the bar had eroded (shoreward movement of the -0.4- and -0.5-foot contours). The inshore developed into two fairly flat shelves separated by a gently sloping area.

The -0.6-foot contour, in the middle of the slope, effectively divides the inshore zone into an inner region which expanded in the shoreward direction as the foreshore retreated landward, and an outer region which expanded in the seaward direction as the offshore prograded seaward.

(a) Inner Region. After 15 hours the inner region was essentially a flat shelf between two slopes. The depth over the shelf varied across the tank at any one time and generally increased with time. The lateral variation is shown in Figure 20 for contours at elevation -0.3 and -0.4 foot. At any one time the -0.3- and -0.4-foot contours varied several feet in position from one range to the next. The increasing depth over the inshore shelf is clearly shown in Figure 6, which compares profiles at 55 and 140 hours.

(b) Outer Region. The outer region developed during the first 50 hours as a flat shelf between the steep offshore slope and the inner inshore zone as indicated by the -0.6- and -0.7-foot contours and lack of many multiple intercepts for elevations -0.6 to -0.9 foot (see Figs. 15 to 19).

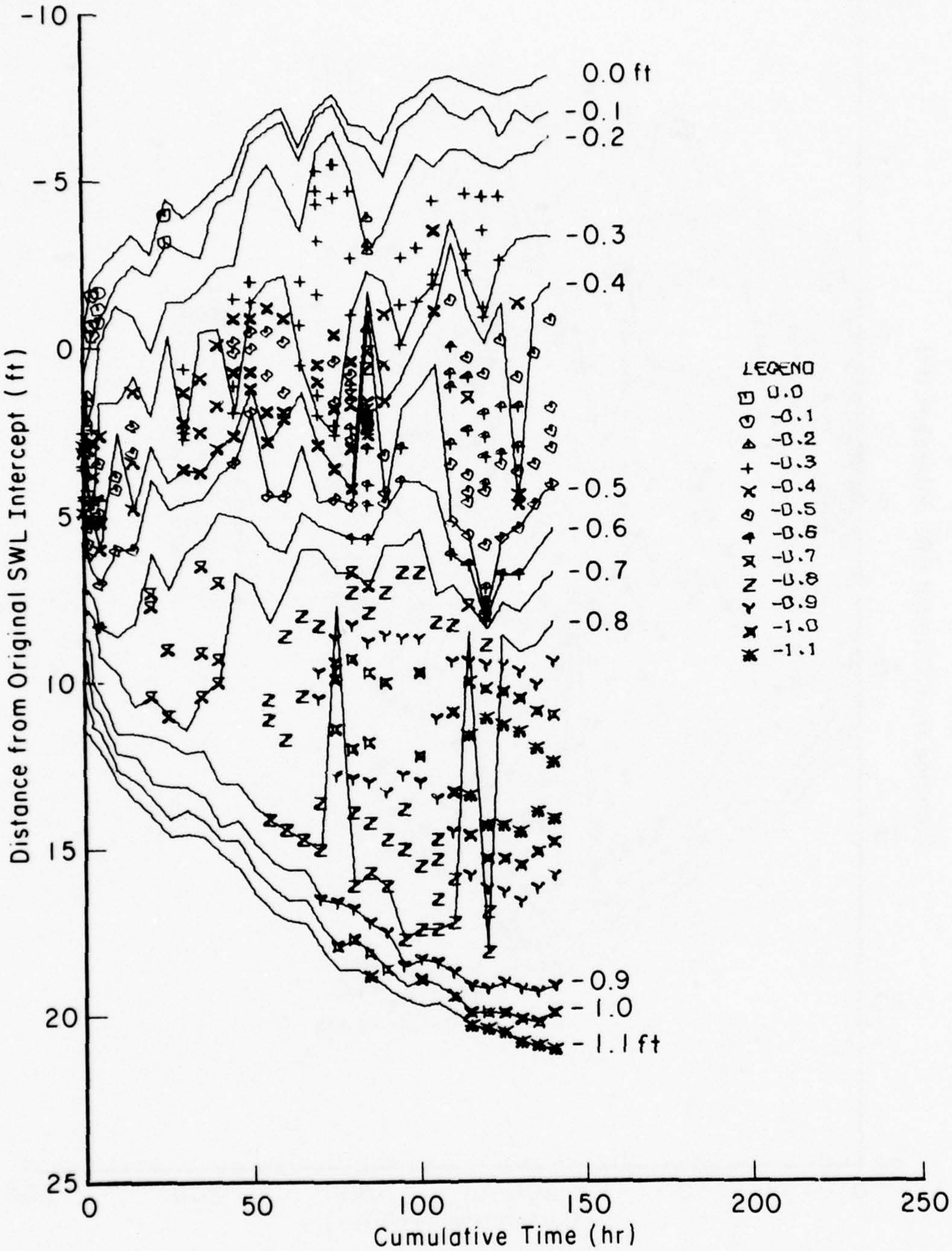


Figure 15. Changes in the inshore zone along range 1.

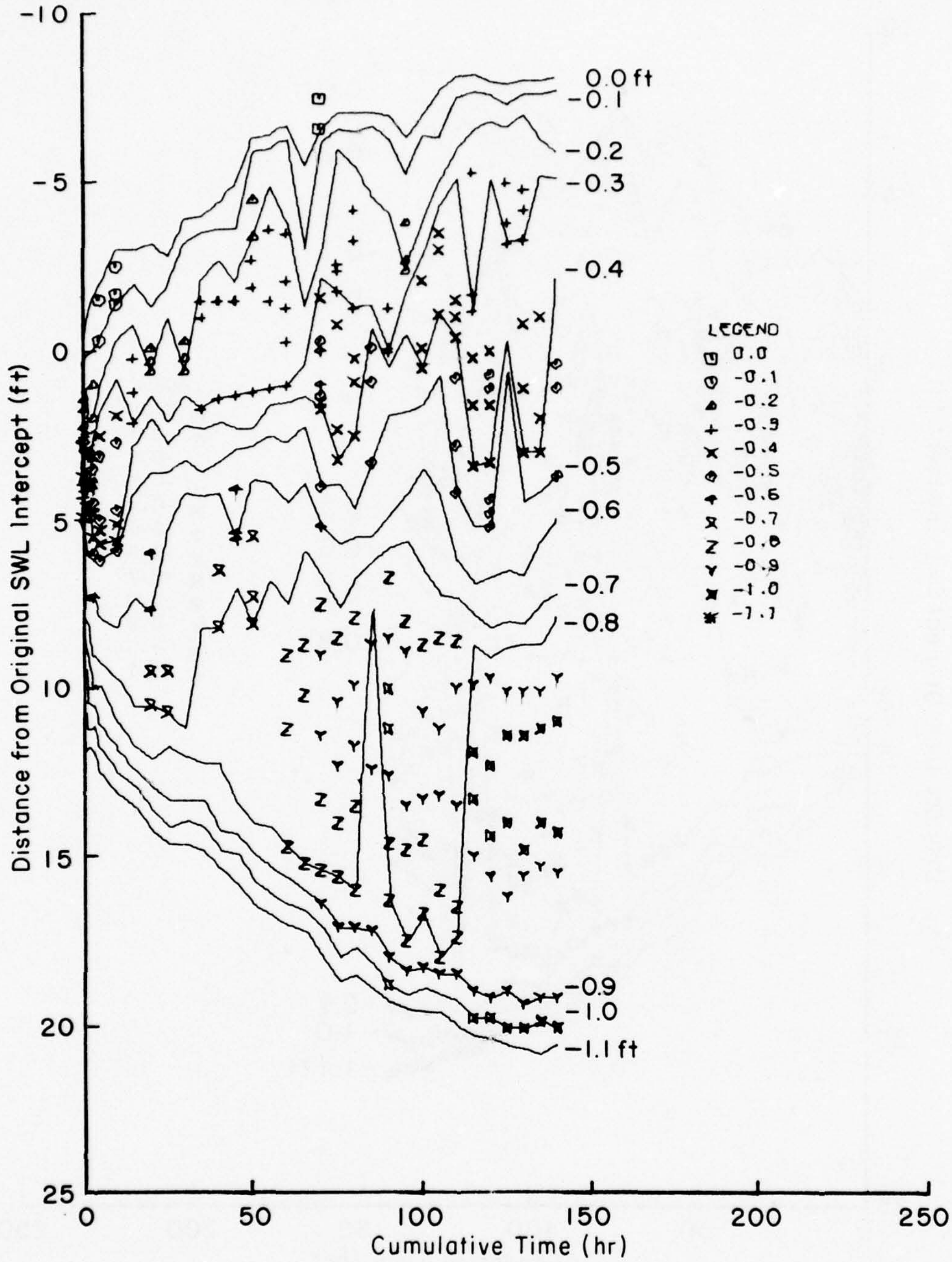


Figure 16. Changes in the inshore zone along range 3.

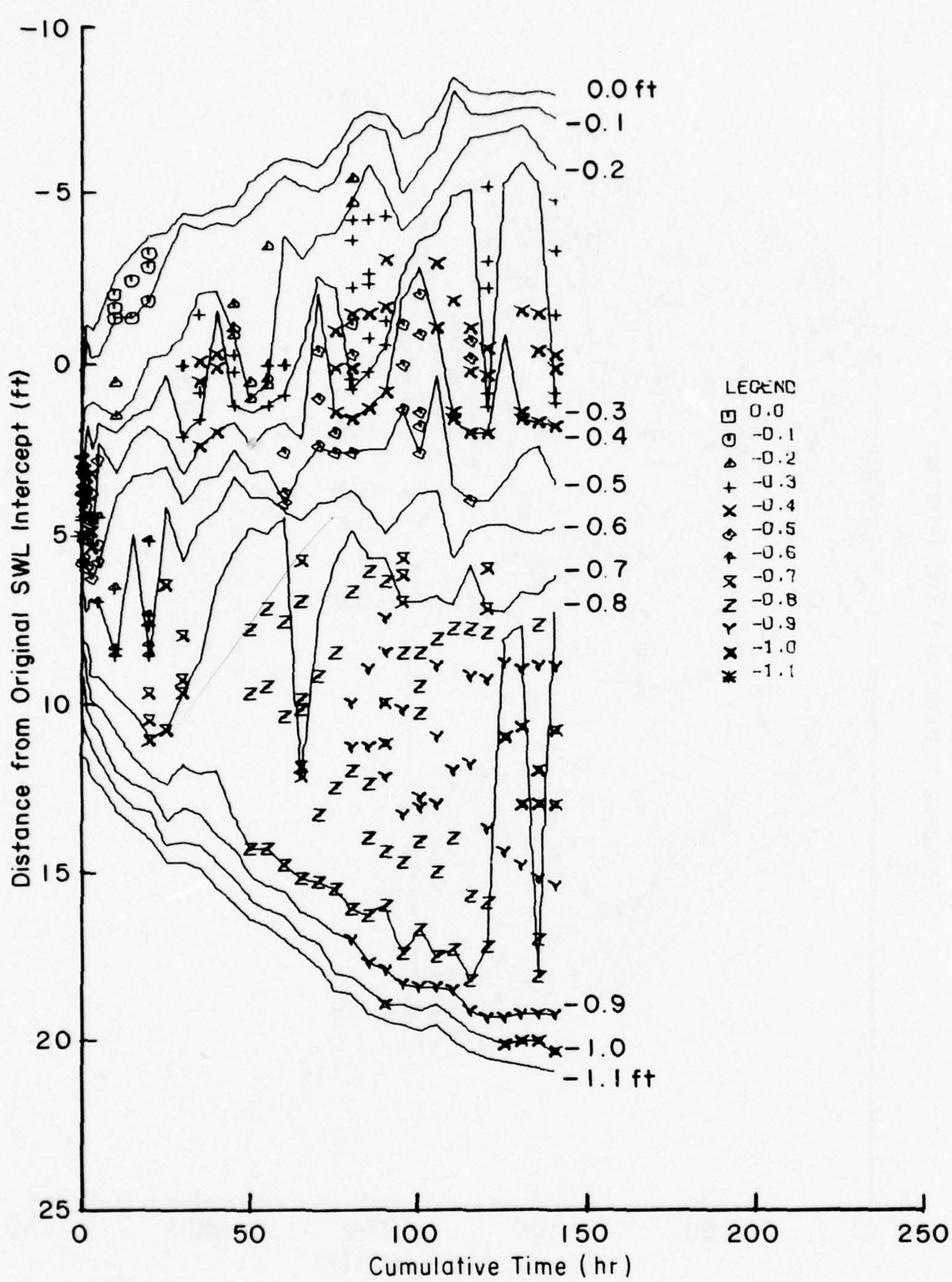


Figure 17. Changes in the inshore zone along range 5.

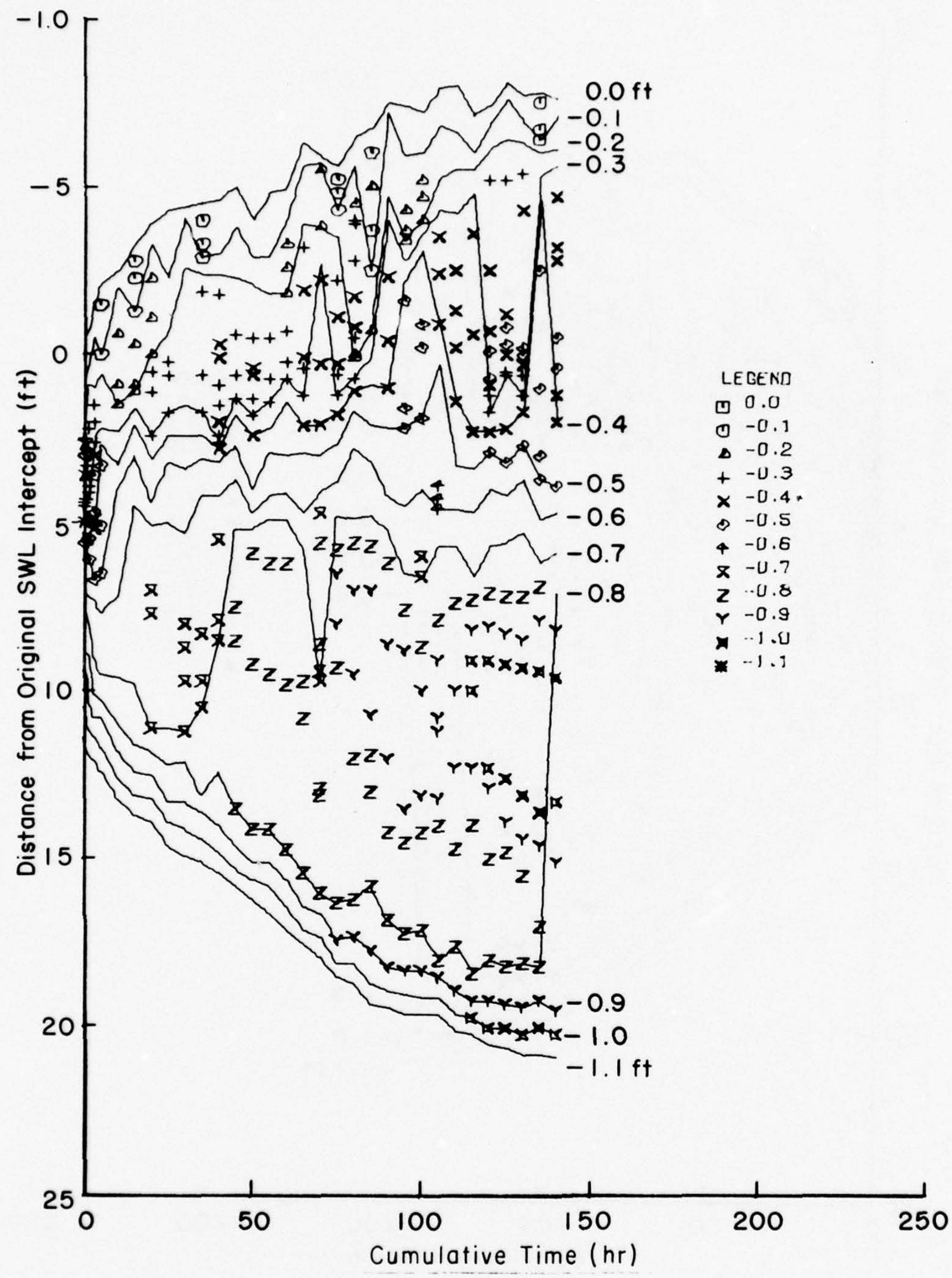


Figure 18. Changes in the inshore zone along range 7.

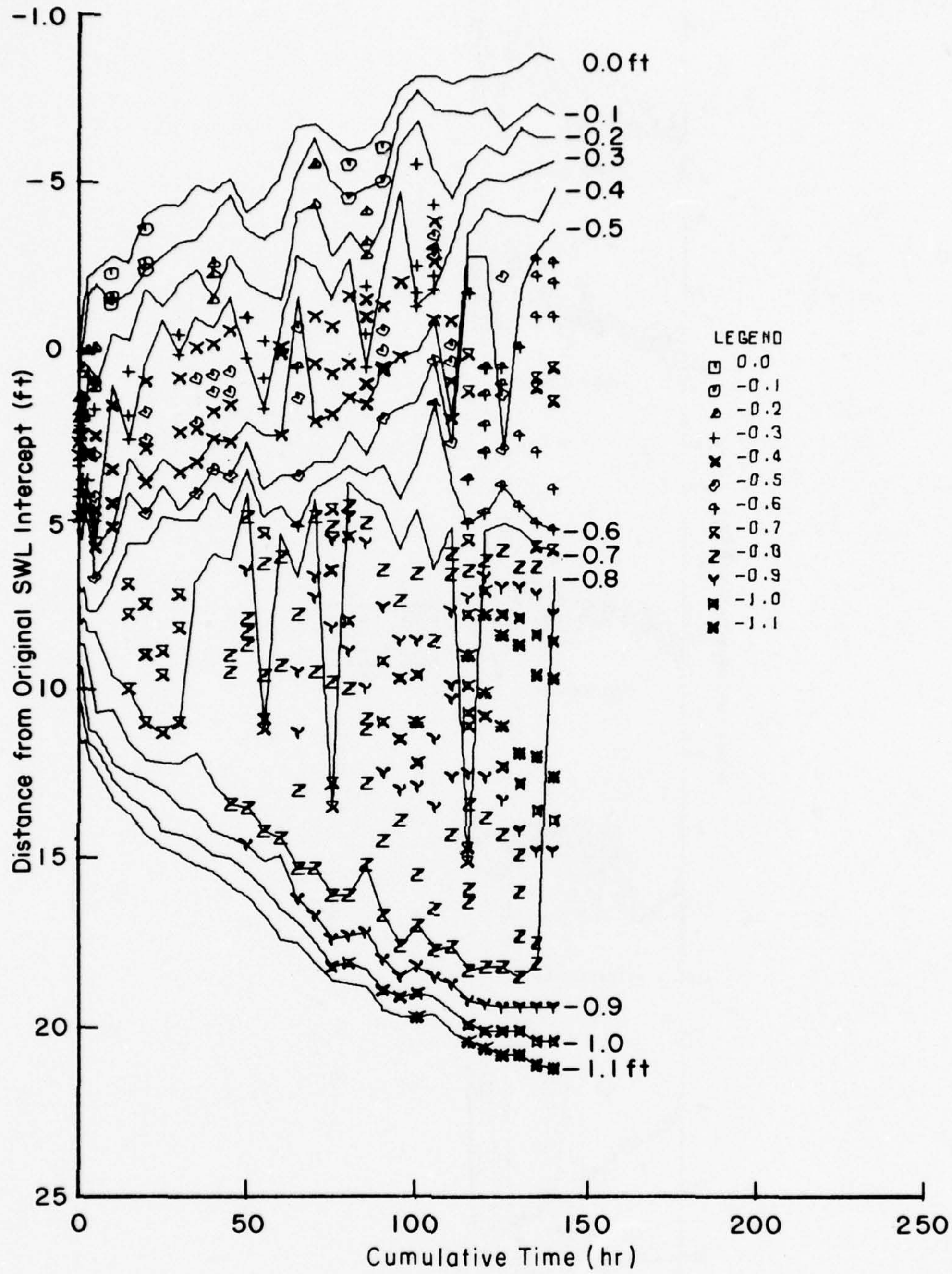


Figure 19. Changes in the inshore zone along range 9.

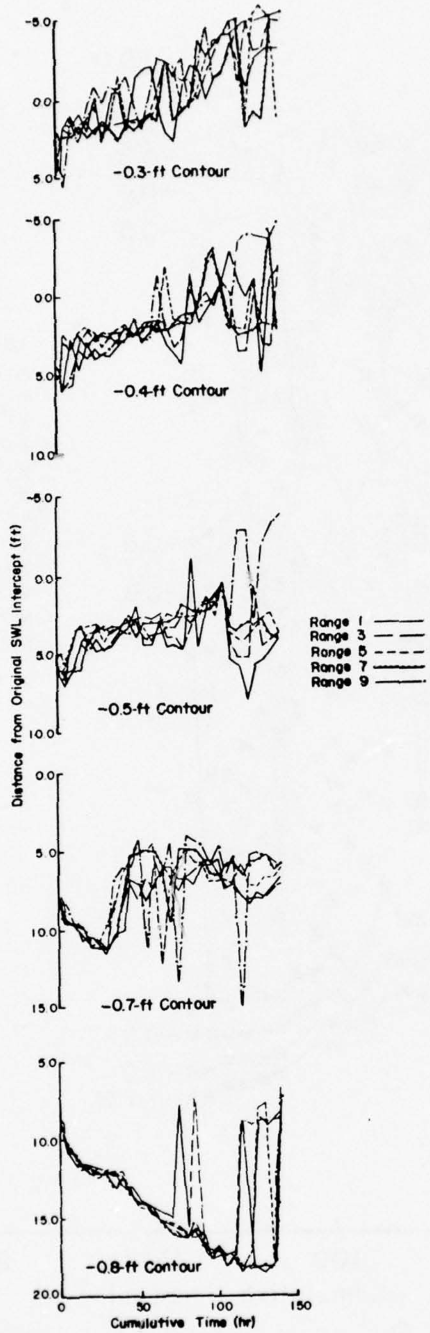


Figure 20. Movement of the inshore zone at five ranges: Comparison of the -0.3-, -0.4-, -0.5-, -0.7-, and -0.8-foot contour movements.

Beginning at 50 hours along range 5 (slightly earlier along ranges 7 and 9, and later along ranges 1 and 3) the outer inshore became more undulating; i.e., a bar developed at the outer end of the outer inshore region and a fairly deep trough developed between the bar and the inner inshore region. The depth of the trough increased as the experiment continued. The trough developed first along ranges 7 and 9 at 45 hours, along range 5 at 50 hours, along range 1 at 55 hours, and along range 3 at 60 hours. This is indicated by the multiple intercepts at -0.8 foot in Figures 15 to 19.

The trough eroded to elevation -0.9 foot at 50 hours along range 9, at 70 hours along ranges 1 and 3, at 75 hours along range 7, and at 80 hours along range 5. Elevation -1.0 was reached first along ranges 1 and 9, and last along range 5. Along ranges 1 and 9 the trough reached elevation -1.1 at 115 hours. Thus, the erosion of the trough started first along the outside ranges and progressed toward the center.

(3) Offshore Zone. The offshore zone was a zone of deposition, as indicated by the downward-sloping lines for contours deeper than -0.8 foot in Figures 7 to 11. The deposition began first at the higher elevations (-0.9 to -1.4 feet) with the greatest rates at the higher of these elevations. The deposition began after 10 hours at the lower elevations, extending progressively from -1.4 to -2.2 feet, as shown by the closer spacing of the deeper contours in Figures 7 to 11 as the experiment continued.

The deposition rate at -1.0 foot, for example, was high initially and then began to decrease. The contours for -0.9 to -1.3 feet were approaching horizontal during the last 5 to 10 hours, indicating that the shoreward edge of the offshore zone may also have been approaching an equilibrium position.

Movement of the -0.9-, -1.4-, and -2.1-foot contours along the five ranges is compared in Figure 21. At all three elevations, the lines for the five ranges are fairly close together (within 0.5 foot), indicating no significant lateral variation in the amount or rate of deposition in the offshore zone.

3. Sediment-Size Distribution.

The sand for these experiments was the same sand used by Savage (1959, 1962) and Fairchild (1970). In Volumes II and III, the median grain size (sieve method) for the sand was reported to be 0.23 millimeter. A total of 16 samples was collected along the full length of the profile before the start of this experiment. Four of the samples were analyzed by the sieve method; the average median grain size was 0.21 millimeter, 0.02 millimeter less than the earlier experiments. The sieving results are given in the Appendix.

All samples collected for this experiment were analyzed by the Visual Accumulation (VA) tube method, and 10 percent of the samples were also

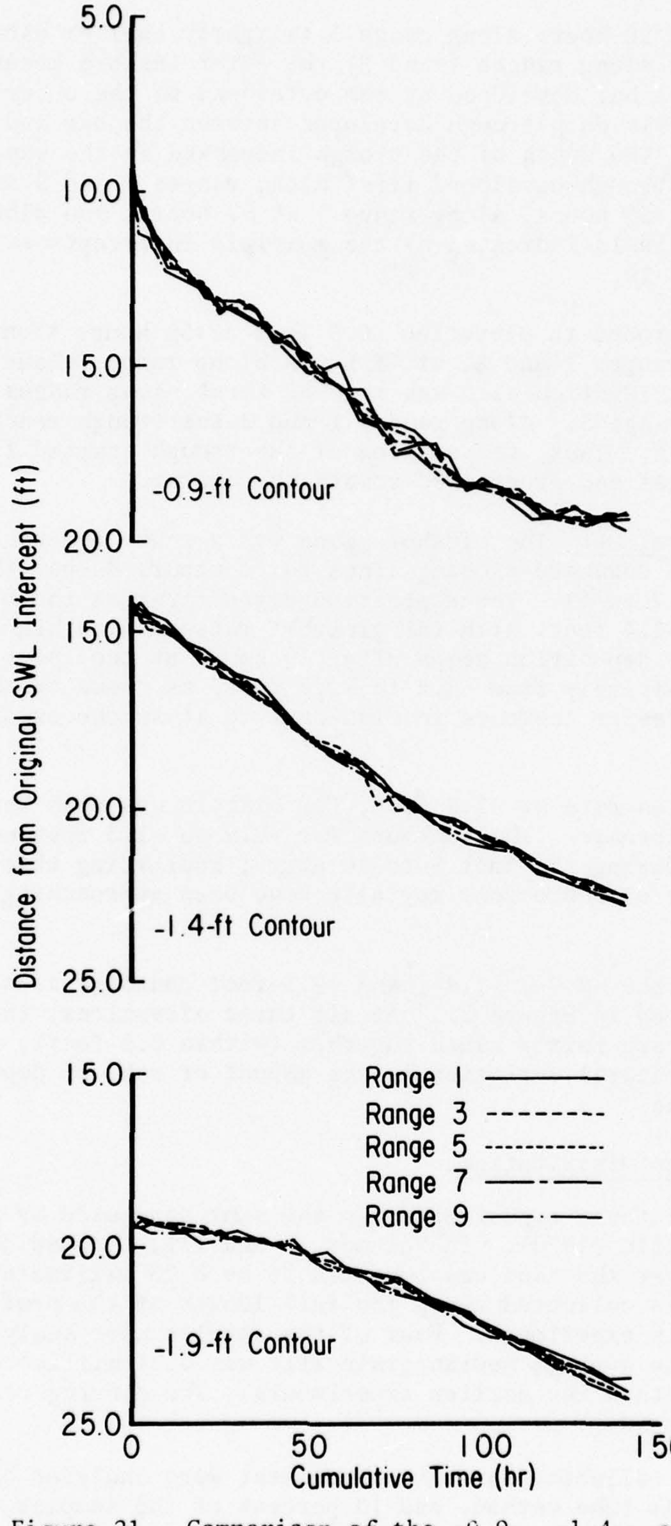


Figure 21. Comparison of the -0.9-, -1.4-, and -1.9-foot contour movements.

analyzed by the sieve method for quality control (described in Vol. I). The values reported here are the VA tube values, which are generally 0.015 millimeter less than the sieve median.

Tables 8 and 9 give the median grain-size results, including values at the beginning of the experiment (Table 8). The initial average median grain size by the VA tube method was 0.195 millimeter.

A summary of the mean and range of the median grain sizes, and the number of samples within each profile zone are given in Table 10. In the foreshore zone, the mean of the median sizes increased as the finer sand preferentially eroded. The range of median size also increased. In the inshore zone, the mean of the median sizes increased slightly. In the offshore zone, the mean of the medians increased between 100 and 140 hours and the range of medians gradually increased throughout the experiment. At the end of the experiment, the mean median was 0.25 millimeter in the foreshore zone, 0.22 millimeter in the inshore zone, and 0.21 millimeter in the offshore zone. This type of variation is expected on an eroding profile. However, the mean of the medians in any zone was never less than the initial mean median, indicating that the finer fractions were eroded from the profile surface.

4. Breaker Characteristics.

A plot of breaker type and position superimposed on a plot of contour movement along range 5 is shown in Figure 22. During the first 30 hours the wave broke by plunging and moved seaward as the seaward edge of the inshore zone moved seaward. Between 30 and 80 hours the breaker position varied across the inshore zone and the breaker type varied between plunging and spilling. At 60 hours the wave broke twice. From 85 hours until the end of the experiment the wave broke twice, generally by spilling and occasionally by plunging near the seaward edge of the inshore zone (elevation -0.8 foot) and breaking by plunging near the seaward edge of the inner inshore region (elevation -0.4 to -0.5 foot). The position of the secondary breaker varied across the tank between stations 0 and 8.

At 56 hours the breaker height (at station 12.5) was 0.47 foot (14.3 centimeters) along range 1, 0.60 foot along range 5, and 0.52 foot (15.8 centimeters) along range 9. At 77 hours the breaker height was 0.46 foot (14.0 centimeters) at station 5.5 along range 1, 0.54 foot (16.5 centimeters) at station 12.5 along range 5, and 0.45 foot (13.7 centimeters) at station 13.0 along range 9.

5. Wave-Generated Currents.

The procedures for collecting current data are described in Volume I.

a. Surface Currents. During the first 35 hours, a circulation pattern developed between the breaker zone and the shoreline (Fig. 23), apparently as the result of the longshore current which developed at the base of the foreshore. The current flowed from landwardmost point of

Table 8. Sediment-size analysis at 0 hours for experiment *72C-10*.

Station	Range 4			Range 6		
	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)
-4	0.45	0.22	2.21	0.45	0.21	2.27
0	0.00	0.20	2.30	-0.05	0.20	2.35
4	-0.40	0.19	2.40	-0.40	0.20	2.32
8	-0.75	0.19	2.38	-0.75	0.19	2.40
12	-1.12	0.19	2.38	-1.10	0.19	2.43
16	-1.55	0.19	2.37	-1.55	0.18	2.46
20	-1.95	0.19	2.40	-1.95	0.19	2.37
23	-2.20	0.20	2.32	-2.20	0.19	2.38

Table 9. Sediment-size analysis at 50, 100, and 140 hours for experiment 72C-10.

Station	Range 1			Range 5			Range 9		
	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)
				50 hr					
-10	1.02	0.21	2.27	1.02	0.20	2.32	1.02	0.20	2.32
-8	0.85	0.20	2.30	0.84	0.20	2.32	0.90	0.20	2.32
-6	0.00	0.20	2.33	0.20	0.20	2.31	0.25	0.21	2.22
-4	-0.20	0.22	2.17	-0.11	0.20	2.33	0.00	0.22	2.18
-2	-0.30	0.25	2.00	-0.16	0.21	2.24	-0.20	0.20	2.30
0	-0.50	0.27	1.89	-0.18	0.27	2.89	-0.30	0.20	2.32
2	-0.40	0.23	2.10	-0.30	0.25	2.03	-0.35	0.21	2.24
4	-0.55	0.21	2.24	-0.60	0.21	2.25	-0.50	0.21	2.24
6	-0.62	0.20	2.32	-0.71	0.21	2.27	-0.80	0.19	2.37
8	-0.72	0.20	2.32	-0.80	0.21	2.24	-0.80	0.21	2.26
10	-0.80	0.20	2.33	-0.80	0.20	2.36	-0.80	0.17	2.60
12	-0.80	0.21	2.25	-0.80	0.20	2.36	-0.80	0.20	2.34
14	-0.86	0.20	2.31	-0.80	0.21	2.26	-0.85	0.20	2.32
16	-1.15	0.21	2.27	-1.10	0.20	2.32	-1.15	0.20	2.36
18	-1.55	0.21	2.24	-1.50	0.20	2.30	-1.50	0.20	2.32
20	-1.90	0.21	2.25	-1.90	0.20	2.32	-1.88	0.19	2.41
22	-2.08	0.21	2.27	-2.15	0.21	2.28	-2.09	0.21	2.28
24	-2.33	0.19	2.37	-2.30	0.21	2.24	-2.25	0.20	2.32
				100 hr					
-10	1.03	0.21	2.29	1.02	0.20	2.31	1.02	0.21	2.29
-8	0.20	0.21	2.27	0.20	0.22	2.20	0.02	0.28	1.84
-6	-0.15	0.23	2.13	-0.05	0.27	1.89	-0.20	0.23	2.11
-4	-0.22	0.26	1.94	-0.18	0.26	1.93	-0.30	0.28	1.83
-2	-0.30	0.27	1.89	-0.50	0.22	2.20	-0.30	0.28	1.86
0	-0.36	0.27	1.90	-0.50	0.20	2.32	-0.39	0.27	1.90
2	-0.45	0.22	2.19	-0.50	0.21	2.24	-0.50	0.22	2.20
4	-0.56	0.20	2.32	-0.60	0.20	2.32	-0.61	0.20	2.31
6	-0.65	0.20	2.36	-0.70	0.20	2.33	-0.80	0.21	2.29
8	-0.80	0.21	2.27	-0.75	0.21	2.26	-0.88	0.23	2.15
10	-0.90	0.21	2.24	-0.80	0.21	2.25	-0.80	0.21	2.24
12	-0.90	0.21	2.26	-0.85	0.20	2.31	-0.80	0.22	2.22
14	-0.80	0.20	2.35	-0.88	0.22	2.18	-0.85	0.20	2.34
16	-0.80	0.23	2.15	-0.80	0.21	2.27	-0.80	0.22	2.18
18	-0.95	0.21	2.25	-0.90	0.20	2.30	-0.95	0.20	2.31
20	-1.20	0.20	2.31	-1.20	0.20	2.34	-1.25	0.20	2.33
22	-1.80	0.20	2.36	-1.75	0.19	2.40	-1.69	0.19	2.38
24	-2.25	0.19	2.38	-2.17	0.21	2.24	-2.20	0.21	2.27
26	-2.33	0.20	2.19	-2.30	0.22	2.16	-2.33	0.21	2.24
				140 hr					
-12	1.20	0.20	2.29	1.20	0.21	2.29	1.20	0.20	2.31
-10	1.00	0.20	2.31	1.02	0.21	2.26	0.75	0.27	1.89
-8	0.05	0.20	2.32	0.00	0.28	1.86	-0.02	0.28	1.85
-6	-0.20	0.24	2.29	-0.16	0.26	1.93	-0.20	0.24	2.10
-4	-0.24	0.24	2.29	-0.30	0.21	2.27	-0.40	0.21	2.24
-2	-0.35	0.23	2.15	-0.30	0.21	2.28	-0.60	0.21	2.26
0	-0.50	0.23	2.14	-0.38	0.21	2.26	-0.65	0.22	2.18
2	-0.50	0.21	2.24	-0.30	0.20	2.35	-0.70	0.22	2.22
4	-0.50	0.20	2.30	-0.52	0.20	2.32	-0.68	0.22	2.16
6	-0.60	0.20	2.31	-0.68	0.20	2.35	-0.70	0.22	2.22
8	-0.80	0.21	2.29	-0.80	0.22	2.17	-0.90	0.22	2.20
10	-0.90	0.21	2.27	-0.90	0.20	2.32	-0.90	0.23	2.15
12	-0.90	0.20	2.29	-0.90	0.20	2.30	-0.90	0.22	2.80
14	-0.90	0.21	2.27	-0.90	0.20	2.30	-0.90	0.21	2.26
16	-0.90	0.26	1.97	-0.90	0.21	2.27	-0.90	0.22	2.18
18	-0.90	0.23	2.13	-0.90	0.22	2.18	-0.90	0.22	2.22
20	-1.05	0.22	2.20	-1.00	0.20	2.29	-1.05	0.21	2.27
22	-1.30	0.20	2.30	-1.30	0.21	2.27	-1.30	0.20	2.32
24	-2.12	0.20	2.32	-2.00	0.20	2.32	-2.00	0.20	2.31
26	-2.33	0.23	2.11	-2.22	0.22	2.18	-2.25	0.24	2.07

Table 10. Summary of median grain-size values within profile zones.

Cumulative time (hr)	Profile zones								
	Foreshore[1]			Inshore			Offshore		
	Mean (mm)	Range (mm)	No.	Mean (mm)	Range (mm)	No.	Mean (mm)	Range (mm)	No.
50	0.20	0.20 to 0.21	3	0.21	0.17 to 0.27	30	0.20	0.19 to 0.21	15
100	0.25	0.21 to 0.28	4	0.22	0.20 to 0.28	36	0.20	0.19 to 0.22	14
140	0.25	0.20 to 0.28	4	0.22	0.20 to 0.28	39	0.21	0.20 to 0.24	12

[1]Samples collected *from the* backshore not included.

NOTE.--Mean of the median sizes at 0 hours was 0.195 millimeter.

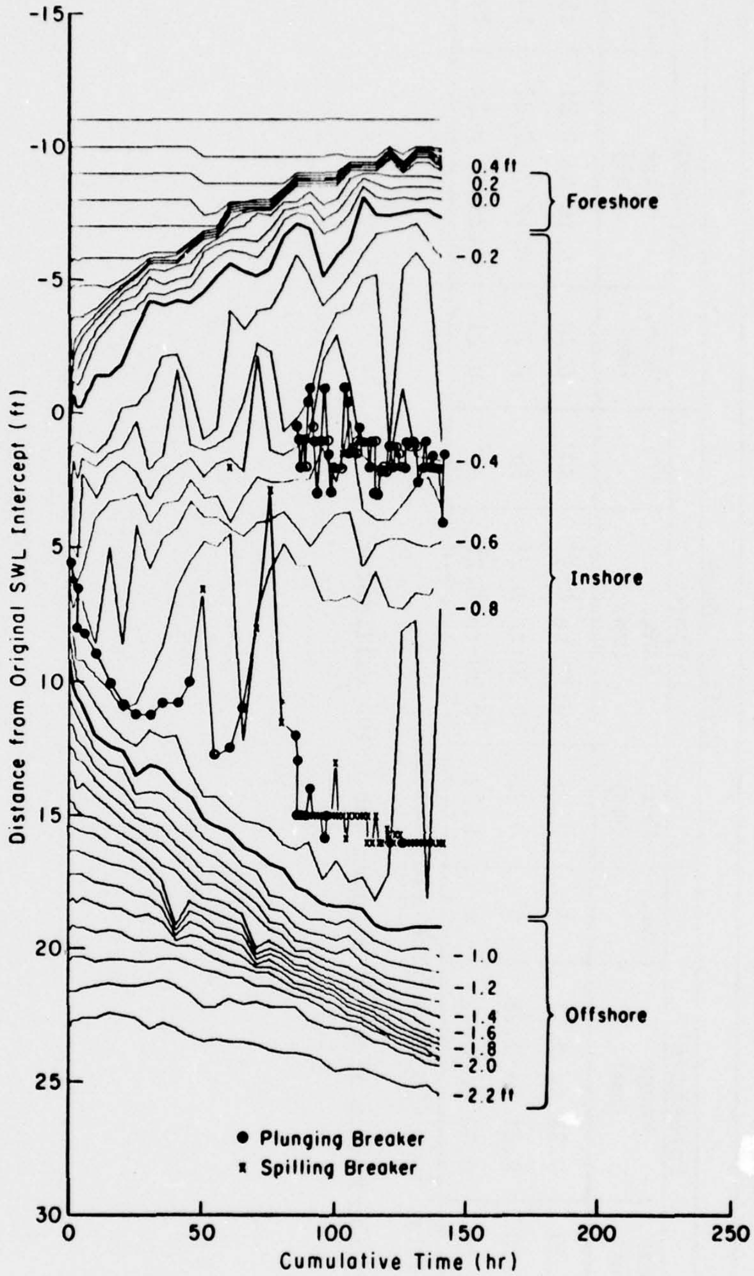


Figure 22. Breaker data on the developing sand profile.

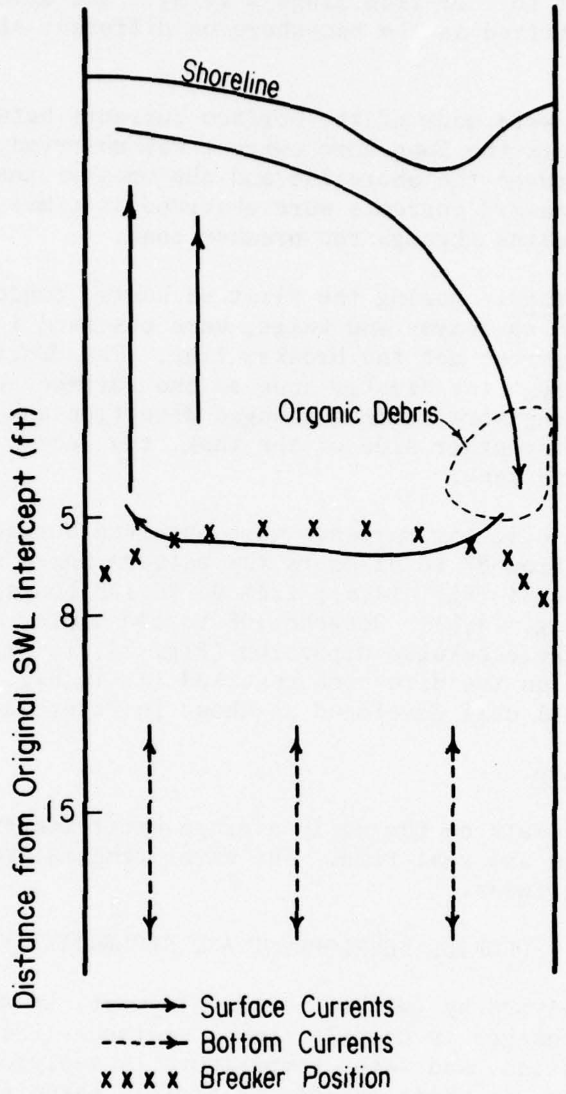


Figure 23. Typical current patterns.

the shoreline toward the seawardmost point of the shoreline (generally flowing from range 1 to 7 or from range 9 to 3). The direction of the longshore current shifted as the backshore on different sides of the tank eroded.

No observations were made of the surface currents between 35 and 85 hours. After 85 hours the longshore current was observed, but the circulation pattern between the shoreline and the breaker zone was more confused. Strong seaward currents were observed at times along the tank walls from the shoreline through the breaker zone.

b. Bottom Currents. During the first 95 hours, concentrations of organic debris, such as leaves and twigs, were observed in the area where the seaward current met the breaker line. The debris did not move across the tank through the breaker zone as the surface currents did. However, when the longshore current changed direction and the seaward current shifted to the other side of the tank, the debris also moved to the other side of the tank.

After 85 hours, circular currents were observed between stations -6 and +8 (Fig. 24). From 87 to 91 hours the pattern was a single counterclockwise circular cell (Fig. 14,a); from 92 to 108 hours, two circular patterns existed (Fig. 24,b). Between 108 to 140 hours, a single cell again occurred in the clockwise direction (Fig. 24,c), except between 110 and 111 hours when the direction reversed (as in Fig. 24,a), and at 139 hours when a dual cell developed as shown in Figure 24(d).

6. Water Temperature.

Figure 25 gives data on the daily average water temperature versus cumulative test time and real time. The water temperature decreased throughout the experiment.

III. PROFILE DEVELOPMENT AND REFLECTIVITY

Results are analyzed by (a) Profile development, in which the interdependence of the changes in profile shape, sediment-size distribution, breaker characteristics, and water temperature is analyzed; and (b) profile reflectivity, in which changes in profile shape and breaker characteristics are related to the variability of the reflection coefficient. Profile development is discussed first to provide an introduction to profile reflectivity.

1. Profile Development.

The important changes in the foreshore, inshore, and offshore zones, the breaker conditions, median grain size, and water temperature during this experiment are summarized and tabulated as a function of time in Table 11.

The profile development discussed previously and condensed in Table 11 occurred as follows. In the first 1.5 hours the plunging breaker

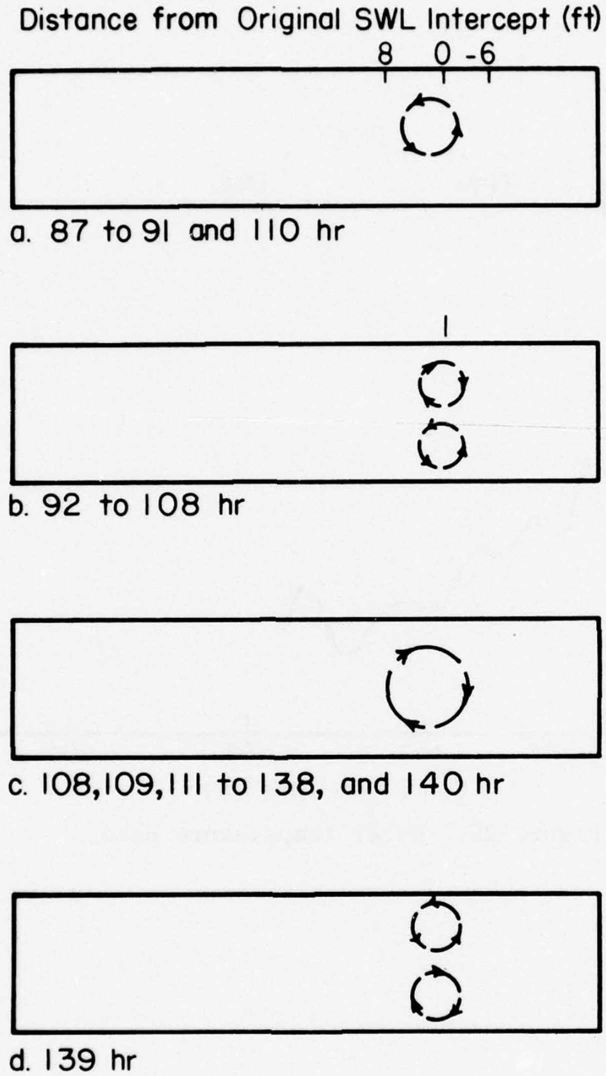


Figure 24. Bottom current patterns near end of experiment 72C-10.

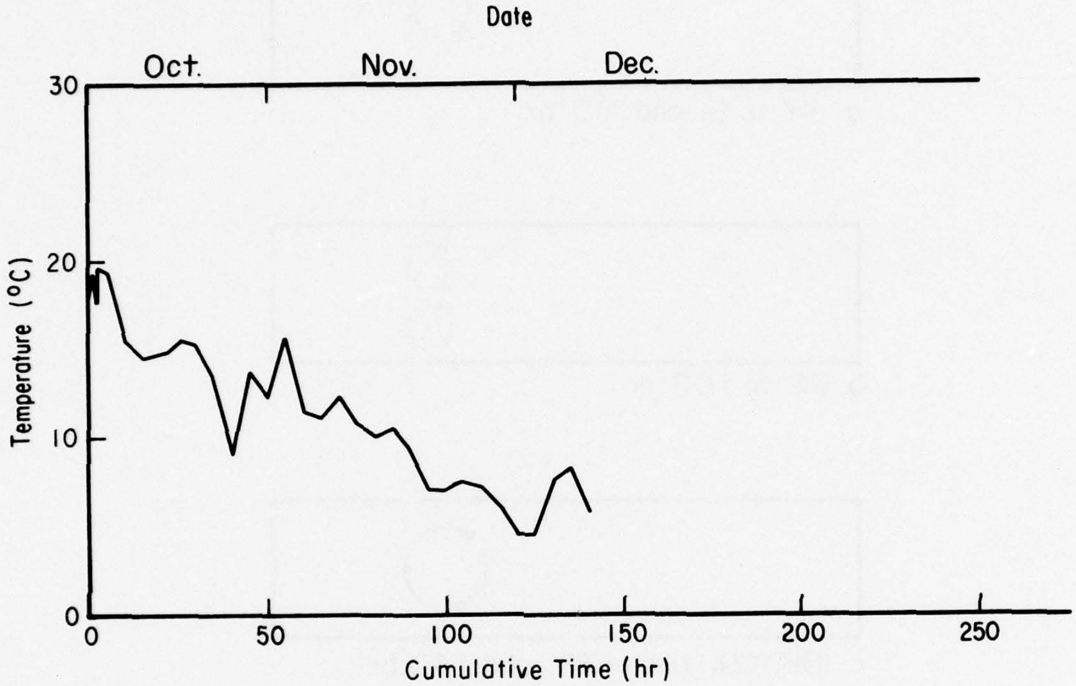


Figure 25. Water temperature data.

Table 11. Summary of profile development in experiment 72C-10.

Time (hr)	Foreshore	Inner inshore	Outer inshore	Offshore	Breaker conditions Position	Breaker conditions Type	Water temperature (°C)
0 to 0.67	Developed basic shape	Longshore bar developed	Flat shelf developed, and grew in seaward direction; shoreward edge stable	Deposition at -0.9 to -1.4 ft	Moving seaward with outer edge of inshore	P[1]	19
0.67 to 1.5	Eroded at rate of 0.15 ft/hr						20
1.5 to 5		Bar stable					15
5 to 15		Bar eroded; shelf developed		Deposition throughout			15 to 16
15 to 30		Shelf grew in shoreward direction			Varied across outer inshore		9 to 14
30 to 50	Eroded at rate of 0.041 ft/hr $\boxed{d_{50} = 0.20\ \mathrm{mm}}$	$\boxed{\text{mean } d_{50} = 0.21\ \mathrm{mm}}$		$\boxed{d_{50} = 0.20\ \mathrm{mm}}$		P,S[2]	10 to 16
50 to 85		Seaward edge stable	Bar and trough developed				6 to 9
85 to 115	100 hr: $\boxed{d_{50} = 0.25\ \mathrm{mm}}$	$\boxed{\text{mean } d_{50} = 0.22\ \mathrm{mm}}$		$\boxed{d_{50} = 0.20\ \mathrm{mm}}$	Two breaker positions; outer edge of outer inshore	S[3]	5 to 8
115 to 130	Approaching equilibrium		Depth over trough increasing beginning along outside walls and progressing toward center				
130 to 140	$\boxed{\text{mean } d_{50} = 0.25\ \mathrm{mm}}$	$\boxed{\text{mean } d_{50} = 0.22\ \mathrm{mm}}$		Deposition at -0.9 to -1.3 ft decreasing. Continuing at other elevations $\boxed{\text{mean } d_{50} = 0.21\ \mathrm{mm}}$	Outer edge of inner inshore	P	6 to 8

[1]P = plunging.
[2]P,S = plunging and spilling.
[3]S = spilling.

formed a longshore bar in the inner inshore. A shelf developed in the outer inshore as sand was deposited just seaward of the breaker position. Between 5 and 15 hours the breaker moved seaward with the development of the outer inshore shelf and the longshore bar in the inner inshore eroded. Longshore currents developed at the base of the foreshore as three-dimensional changes in the foreshore occurred.

At 30 hours the breaker began moving shoreward, and between 50 and 85 hours the breaker type varied between plunging and spilling and the breaker position varied across the inshore zone. The foreshore and shoreward edge of the inner inshore moved landward, and the offshore and seaward edge of the outer inshore moved seaward, at rates which varied from high (initially) to almost zero near the end of the experiment.

At 85 hours, the length of the shelf in the outer inshore had increased enough for the wave to break twice, by spilling at the outer edge of the outer inshore and by plunging at the outer edge of the inner inshore. The erosion of the trough in the outer inshore started along the sides and progressed toward the center.

The movement of the shoreline with the change in water temperature is compared in Figure 26. The water temperature dropped throughout the experiment. The shoreline recession rate gradually decreased, indicating that the volume rate of erosion was fairly constant.

2. Profile Reflectivity.

The profile shapes which evolved during the profile development are shown in Figure 6. Steep foreshore and offshore slopes developed almost immediately and then began to separate. The distance between the two slopes increased as the foreshore retreated landward with the erosion of sand from the foreshore and backshore, and the offshore advanced seaward with the deposition of the sand seaward of the breaker.

Figure 3 shows the variability of the reflection coefficient in this experiment. At 1.5, 25, 55, and 105 hours, maximum values occurred; at 35, 60, 90, 95, and 120 hours, minimum values occurred. No long-term increase or decrease is apparent.

With the development of the two reflecting zones separated by a growing distance of fairly gradual slope, the measured reflected wave may have been composed of two reflected waves. A change in phase or amplitude of either reflected wave would change the phase and amplitude of the measured wave. Perhaps the K_R variability can be attributed to the change in phase difference between these two reflected waves as the foreshore retreated landward and the offshore advanced seaward.

With the depth over the inshore zone an average of 0.6 foot, the average wavelength was 6.23 feet (1.90 meters). An increase of 3.12 feet (0.95 meter) in the distance between the two reflecting zones would cause a change in phase difference of 360°. The distance between the 0- and -1.0-foot contours increased from 10 to 28.5 feet (3.0 to 8.7 meters),

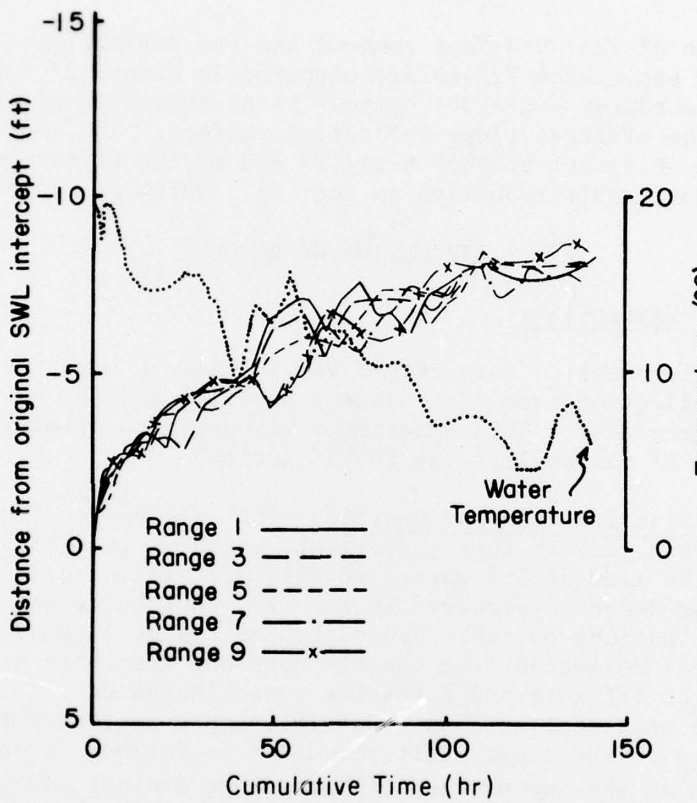


Figure 26. Comparison of water temperature changes and shoreline movement.

indicating that the maximum number of cycles of 360° phase-difference change possible was five. If the cycle started with the two waves 180° out of phase, four in-phase values are possible.

This hypothesis cannot be proven with the data presented here, because neither the foreshore nor the offshore reflection was measured separately.

Near the end of the experiment when the profile appeared to have been close to equilibrium, the K_R did not vary significantly, possibly verifying the original premise that reflection variability, and thus wave height variability, would be eliminated as the profile reached equilibrium.

The position of the -0.8-foot contour and the reflection coefficient versus time for experiment 72C-10 are compared in Figure 27. The movement of the seawardmost -0.8-foot contour is an indicator of the depth at the top of the offshore slope reflecting surface. The shoreward movement of the -0.8-foot contour near the end of the experiment did not cause any noticeable reduction in the K_R, which was already low.

IV. DISCUSSION OF RESULTS

1. Wave Height Variability.

Two possible causes of wave height variability in experiment 72C-10 are (a) wave reflection from the changing profile, and (b) re-reflection from the wave generator. This experiment was designed primarily to quantify the amount of variability due to reflection.

a. Wave Reflection from the Profile. The K_R varied from 0 to 0.15 in the movable-bed tank in this experiment, which is generally lower than in tests with the 1.90-second wave (see Vols. II, III, and IV). No long-term increase or decrease occurred in the K_R, but there was a series of short-term fluctuations possibly caused by the change in phase difference between the waves reflected from the offshore and foreshore as the distance between the offshore and foreshore zones increased. This kind of fluctuation had been mentioned as a possible cause of long-term reflection variability in the experiments discussed in Volumes II and III. The depth variation at the top of the offshore slope did not cause a variation in K_R, as was observed in the experiments with the 1.90-second wave (Vols. II, III, and IV), probably because the K_R value was already small.

b. Re-Reflection from the Generator. The reflected wave advanced to the generator and was re-reflected. As the height of the reflected wave varied, the height of the re-reflected wave varied. As the phase difference between the re-reflected wave and the generator motion varied with changes in the profile, the height and phase of the incident wave varied. The height of the wave incident to the profile, which was measured by averaging wave heights along the full tank length, had a range

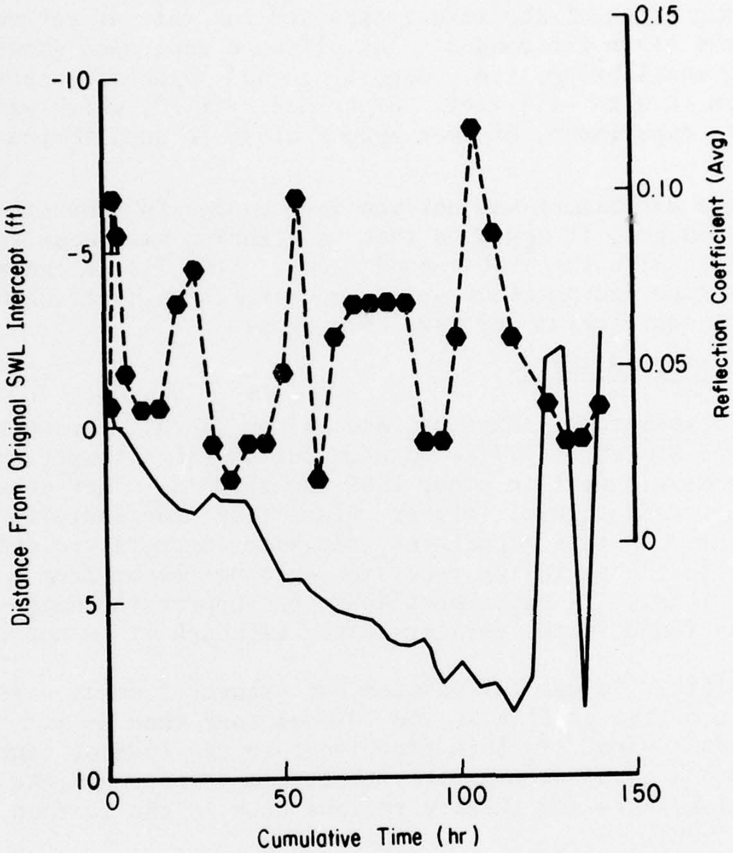


Figure 27. Comparison of the -0.8-foot contour position and K_R.

of 0.09 foot. Part of that variation (0.03 foot) was due to measurement and other errors; the remainder of the variation (0.06 foot) was due to variation in the height and phase (at the generator) of the re-reflected wave.

2. Profile Equilibrium.

The profile in experiment 72C-10 appeared to be approaching an equilibrium shape after 33,600 waves. The shoreline and foreshore had stopped retreating along three of the five ranges and the rate of retreat had slowed along the other two ranges. The offshore zone also showed signs of approaching equilibrium, i.e., deposition had apparently ceased at elevations from -0.9 to -1.3 feet. Experiment 71Y-10, which was most similar to this experiment, did not appear close to equilibrium after 63,474 waves.

Although the experiment was not run long enough to prove that equilibrium had been reached, it appeared that equilibrium was close (at least closer than tests with the 1.90-second wave). Also little change occurred in the breaker type and position or in the reflection coefficient, further indicating that equilibrium may have been close.

3. Other Laboratory Effects.

a. Water Temperature. Chesnutt and Galvin (1974), Chesnutt (1975), and Chesnutt and Stafford (1977a) pointed out possible temperature effects in the profile development in other LEBS experiments. They observed that with lower water temperatures (higher viscosities) the shoreline recession rate was greater. In this experiment, the water temperature decreased throughout, while the shoreline recession rate decreased from a high rate to near zero. Thus, this experiment does not support the suggested temperature effect found in the earlier tests, although it is not ruled out.

b. Tank Width. Volume III pointed out greater lateral variation in the development of the profile in the 10-foot tank than in the 6-foot tank for the 1.9-second wave. In this experiment in the 10-foot tank with the shorter 1.5-second wave, even greater three-dimensional effects were observed in the foreshore and inshore regions than in the 10-foot tank with the 1.9-second wave.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions.

(a) In experiment 72C-10 with a water depth of 2.33 feet (0.71 meter), a wave period of 1.50 seconds, and a generator stroke of 0.325 foot (9.9 centimeters), the nominal generated wave height was 0.41 foot (12.5 centimeters) and the average incident wave height was 0.43 foot. Reflection measurements in the control tank with a fixed-bed profile varied from 0.01 to 0.03, indicating that the wave generators were operating uniformly and that the measurement error in determining K_R was ±0.01 (Tables 5 and 6).

(b) K_R varied from 0 to 0.15. The variations were possibly caused by the change in phase difference between the waves reflected from the offshore slope and the foreshore slope as those two zones moved farther apart on the developing profile (Figs. 3 and 9). In this experiment the top of the offshore zone did not vary significantly in slope or depth at the same time that K_R varied (Fig. 27), in contrast to observations reported in Volumes II, III, and IV for the longer 1.90-second waves with the same wave energy flux.

(c) The profile appeared to have almost attained an equilibrium shape. This apparent equilibrium was attained for the 1.5-second wave, although the 1.90-second wave in the same facility with the same energy flux did not approach equilibrium after twice the number of waves had been run (see Figs. 7 to 11 and Vol. III).

(d) Even though this experiment was conducted in a wave tank with the direction of wave approach normal to the initial shoreline, the shoreline became skewed and a longshore current developed at the base of the foreshore. The greater three-dimensional development of the beach in this experiment compared with experiment 71Y-10 (Vol. III) is consistent with the working hypothesis that the shorter the wavelength relative to a given tank width, the greater the likelihood of three-dimensional effects in profile shape and profile development (see Figs. 7 to 11 and 14 and Vol. III).

(e) Measured changes in the median grain-size distribution gave results typical of an eroding profile: from a d_{50} of 0.195 millimeter on the initial profile, the mean d_{50} everywhere became coarser, so that after 140 hours the d_{50} was 0.25 millimeter on the foreshore, 0.22 millimeter on the inshore, and 0.21 millimeter on the offshore (Table 10).

2. Recommendations.

(a) Experimenters should expect three-dimensional effects to become significant in otherwise two-dimensional experiments when the wavelength decreases to near the tank width.

(b) Additional research on the interaction of waves reflected from two or more segments of the profile is recommended to prove or disprove the hypothesis in conclusion (b) above.

(c) The final profile shape (at 140 hours in Fig. 6) could be used as an approximation to an equilibrium profile for the wave, sediment, and slope conditions.

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APPENDIX

EXPERIMENTAL PROCEDURES FOR 72C-10

This appendix documents those aspects of the experimental procedures unique to experiment 72C-10. The procedures common to all experiments are documented in Volume I (Stafford and Chesnutt, 1977).

1. Experimental Layout.

The experimental layout was the same as that used for experiment 71Y-10 (Vol. III). Figure A-1 shows the position of the initial profiles with respect to the coordinate system.

2. Data Collection.

a. Regular Data.

(1) Wave Height Variability. During the first run (to 10 minutes), a continuous water surface elevation was recorded at station 25 near the toe of the movable-bed profile and 7 feet from the toe of the fixed-bed slope. During all subsequent runs, wave envelopes were recorded with wave gages moving along the center of the fixed-bed tank and along ranges 1, 5, and 9 in the movable-bed tank from station +15 to +50.

(2) Breaker Data. Breaker data were collected for the first 85 hours according to the schedule in Table 3. After 85 hours, the visual observation form, including breaker data, was prepared hourly.

(3) Wave-Generated Current Data. For the first 85 hours, wave-generated current data were collected using the methods described in Volume I; however, the frequency of collection varied, as surface current data were not collected between 35 and 85 hours.

After 85 hours the current data were collected hourly and recorded on the visual observation form. Current patterns were determined by observing the movement of organic debris in the water.

b. Special Data. Four types of special data were collected at less frequent intervals, and Table A-1 indicates the times when each type of data was collected.

3. Data Reduction.

a. Wave Height Variability. The wave reflection envelope recordings were divided into two grades for data reduction. The automated method for determining K_R was used with a Grade I data, which had no data quality problems. The manual method for determining K_R was used with the grade II data, which had problems of (a) pen skips, (b) highly variable instrument carriage velocity, or (c) off-scale values. Twenty percent of the grade I envelopes were also reduced manually to provide a comparison of the two methods.

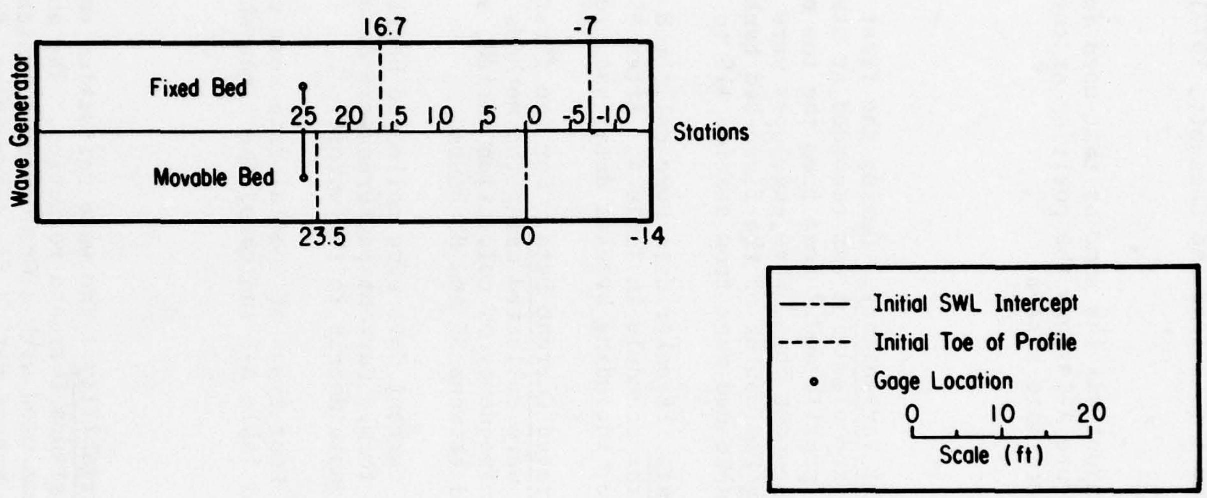

Figure A-1. Experimental setup.

Table A-1. Summary of special data collection.

Time (hr)	Profile survey limits[1] (ft)	Photo survey limits (ft)	Sand sample limits[2] (ft)	Wave envelope limits[3] (ft)
0	Not taken	Not taken	-4 to +23	Not taken
30	Not taken	Not taken	Not taken	Envelope: +15 to +50
50	-10.0 to +27.0	-10 to +26	-10 to +24	Not taken
60	Not taken	Not taken	Not taken	Envelope: +15 to +50 Stands: +45 to +18 +18 to +6
80	Not taken	Not taken	Not taken	Envelope: +20 to +50 Stands: +48 to +25 +20 to +5
100	-10.0 to +27.0	-10 to +26	-10 to +26	Not taken
140	-11.0 to +28.0	-10 to +29	-12 to +26	Not taken

[1]Elevations measured at 0.5-foot intervals between the given stations along ranges 0.5 foot apart.
[2]Samples collected at 4-foot intervals at 0 hours along ranges 1 foot either side of centerline. Samples collected at 2-foot intervals at 50, 100, and 140 hours along ranges 4 feet either side of centerline and on centerline.
[3]One-minute stands recorded at 0.5-foot intervals at both 60 and 80 hours. Special wave envelopes were recorded along ranges 1, 3, and 5 in the movable-bed tank.

The water surface elevation data collected with a stationary gage, during the first 10 minutes and the two runs indicated in Table A-1, were reduced manually to determine average wave heights.

b. Sand-Size Distribution. All samples were analyzed using the VA tube method by the U.S. Army Engineer Division, Missouri River, laboratory. Approximately 10 percent of the samples were also analyzed by project personnel in the CERC Petrology Laboratory using the dry sieve method as a quality control measure. Tables A-2 and A-3 give the results from the dry sieve method.

Table A-2. Sediment-size analysis (dry sieve method), at 0 hours for experiment 72C-10.

Station	Range 4			Range 6		
	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)
-4	0.45	0.23	2.12	0.45	0.22	2.16
12	-1.12	0.19	2.37	-1.10	0.20	2.36

c. Breaker Characteristics. Breaker type and position data were determined from the visual observation form. Breaker height data were determined from the stationary recordings of water surface elevation in the inshore zone at 56 and 77 hours.

Table A-3. Sediment-size analysis (dry sieve method) at 50, 100, and 140 hours for experiment 72C-10.

Station	Range 1			Range 5			Range 9		
	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)
				50 hr					
-8	-----	----	----	0.84	0.22	2.18	-----	----	----
-4	-----	----	----	-0.11	0.21	2.25	-----	----	----
0	-0.50	0.28	1.82	-----	----	----	-----	----	----
8	-----	----	----	-----	----	----	-0.80	0.23	2.12
14	-----	----	----	-0.80	0.23	2.13	-----	----	----
22	-2.08	0.22	2.18	-----	----	----	-----	----	----
				100 hr					
-2	-0.30	0.29	1.78	-0.50	0.23	2.12	-0.30	0.30	1.75
18	-0.95	0.23	2.11	-0.90	0.23	2.15	-0.95	0.22	2.17
				140 hr					
-2	-0.35	0.24	2.06	-0.30	0.22	2.19	-0.40	0.23	2.11
18	-0.90	0.24	2.06	-0.90	0.24	2.07	-0.90	0.23	2.11

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