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LABORATORY EFFECTS IN BEACH STUDIES. VOLUME VI. MOVABLE-BED EXP--ETC(U)

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Laboratory Effects in Beach Studies

Volume VI

Movable-Bed Experiments with H_o/L_o=0.004

by

Charles B. Chesnutt and Robert P. Stafford

MISCELLANEOUS REPORT NO. 77-7 (VI)
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Two experiments with long low waves on 0.2-millimeter sand slopes in tanks 6 and 10 feet wide showed very different profile development, apparently because current circulation, present only in the 6-foot tank, was more effective in distributing sand in the onshore-offshore direction. In the 6-foot tank, the profile developed a more distinct shelf separated by two relatively steep seaward-facing slopes. The clockwise circulation pattern occurred over the shelf between the foreshore and the first seaward antinode of the standing

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wave envelope, a distance approximately twice the tank width. This current pattern in the 6-foot tank began to disintegrate after about 70 hours.

The profile in the 6-foot tank was still changing at 135 hours when the experiment ended; in the 10-foot tank, the profile had reached approximate equilibrium after 25 hours. In the 6-foot tank, the foreshore eroded throughout the test, but in the 10-foot tank it quickly stabilized. In the 6-foot tank, the offshore consisted of an almost flat shelf and a steep seaward slope as long as the circulation prevailed, but became more gently sloping after the circulation disappeared. In the 10-foot tank, the offshore was less steep and stabilized after about 50 hours.

Reflection coefficient, K_R, varied from 0.17 to 0.31 in the 6-foot tank, increasing as the shelf developed during the time of active circulation. K_R then began decreasing as the steep offshore slope began flattening. In the 10-foot tank, K_R was higher, varying from 0.24 to 0.37 and tended to increase with steepening of the foreshore.

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 work was carried out under the CERC coastal processes program.

This report (Vol. VI of a series of eight volumes) provides coastal engineers who conduct or interpret model studies with an analysis of two similar movable-bed experiments that produced different beach changes. The analysis suggests that a combination of tank width and wave conditions caused wave-driven currents to dominate in one experiment but not in the other, even though the wave and sand conditions of both experiments were the same. The currents dominated the experiment run in the narrower of two tanks, causing that beach to erode long after the shore had stabilized in the wider tank.

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Volume I of this series describes the procedures used in the 10 LEBS experiments, and also serves as a guide for conducting realistic coastal engineering laboratory studies. Volumes II to VII are data reports on the ten 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 two experiments, under the general supervision of Dr. C.J. Galvin, Jr., Chief, Coastal Processes Branch.

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.

for Wilson P. Andrews LTC
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 VI. MOVABLE-BED EXPERIMENTS
WITH H_o/L_o = 0.004

by
Charles B. Chesnutt and *Robert P. Stafford*

I. INTRODUCTION

1. Background.

Standing waves in movable-bed profile experiments can affect the transport of sediment and alter the development of the profile, particularly when the reflection coefficient is large. In addition, critical combinations of tank width and standing wave envelope length appear to generate circulation cells between wave envelope antinodes.

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. These LEBS experiments are reported in a series of eight volumes. This report (Vol. VI) describes the two experiments conducted with H_o/L_o = 0.004. Volumes II, III, and IV (Chesnutt and Stafford, 1977a, 1977b, 1977c) discuss the experiments conducted with H_o/L_o = 0.021; Volume V (Chesnutt and Stafford, 1977d) discusses the experiment with H_o/L_o = 0.039. The last two experiments are discussed in Volume VII. 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 describe four experiments with an initial slope of 0.10 and wave steepness of 0.021. 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; (b) examine the approach to equilibrium profile shape, on the assumption that wave height variability would be significantly reduced when the profile was at equilibrium; and (c) examine the effect of tank width by running identical experiments in tanks 6 and 10 feet wide.

The two experiments discussed in this study were a direct consequence of the earlier experiments. All controllable variables in these experiments are the same as the variables in Volume III, except that the wave steepness was reduced to 0.004 in an attempt to determine how much the wave reflection and the reflection variability would be increased by a longer wave on the same initial profile.

2. Experimental Procedures.

The experimental procedures used in the LEBS experiments are described in Volume I, 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 experiments 72A-06 and 72A-10 in this study are documented in the Appendix. The conditions of these two experiments are summarized in Table 1. The table shows that the initial slope, water depth, wave period, wave height, and sand size were the same in both experiments.

Table 1. Summary of experimental conditions.

Experiment[1]	Initial test length (ft)	Initial slope	Wave period (s)	Generated wave height[2] (ft)
72A-06	93.0	0.10	3.75	0.31
72A-10	54.7	0.10	3.75	0.31

[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 so that the generated wave energy flux, computed from linear theory, had a constant value of 5.8 foot-pounds per second-foot.

NOTE.--Constant: Initial d_{50} (by dry sieve analysis) was 0.22 millimeter.

Two experimental facilities were used (see Figs. 3 and 4 in Vol. I and Fig. A-1 in the App. to this volume). Each facility consisted of two side-by-side wave tanks, one with a 0.10 concrete slope and the other a sand slope. A generator was common to each pair of 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 (bench-mark value) for the varying reflection measured in the neighboring tank with the movable bed.

The basic difference between the two facilities was the tank width. One pair of tanks, each 6 feet (1.8 meters) wide, was used for experiment 72A-06; the other pair, each 10 feet (3.0 meters) wide, was used for experiment 72A-10. The initial test length (the horizontal distance from the initial stillwater level (SWL) intercept on the beach to the mean position of the wave generator) on the sand side was 93 feet (28.3 meters) in experiment 72A-06 and 54.7 feet (16.7 meters) in experiment 72A-10 (Table 1). This length was 7 feet (2.1 meters) greater on the concrete side in both tanks.

The initial grading of the sand slope in experiment 72A-06 was on 17 April 1972. The first run was on 24 April 1972, the last run was on

7 July 1972 after 135 hours, and the data collection was completed 11 July 1972. Experiment 72A-10 was begun 17 May 1972, was stopped on 7 July 1972 after 80 hours, and the data collection was completed 12 July 1972. The dates are important because the experiments were run in outdoor facilities with water temperature varying with ambient air temperature. The major events of each 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 experiments 72A-06 and 72A-10.

Event	Time within runs (hr:min)
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 morning and afternoon of each day of testing	

3. Scope.

This report describes and analyzes the reduced data from LEBS experiments 72A-06 and 72A-10. The original data are available in an unpublished laboratory memorandum (No. 5) (Leffler and Chesnutt, 1978) filed in the CERC library.

Wave height variability, profile surveys, sediment-size distribution, breaker characteristics, water temperature, and current observations are discussed in the following section. Section III discusses the interrelation of changes in wave reflection, profile shape, sediment-size distribution, breaker characteristics, water temperature, and currents. Section IV discusses the results of wave height variability, profile equilibrium, and other laboratory effects.

Table 2. Schedule for experiments 72A-06 and 72A-10.

Cumulative time[1] (hr:min)	Wave record No.	Survey No.	Special data collected
		Experiment 72A-06	
0:00		1	Sand samples
0:10	1	2	
0:40	2	3	
1:30	3	4	
3:00	4	5	
5:00	5	6	
10:00	6	7	
------[2]	--[3]	------[3]	
30:00	10	11	Wave reflection
------[2]	--[3]	------[3]	
50:00	14	15, S1	Sand samples, profile surveys, ripple photos
55:00	15	16	Wave reflection
------[2]	--[3]	------[3]	
80:00	20	21	Wave reflection
------[2]	--[3]	------[3]	
100:00	24	25, S2	Sand samples, profile surveys, ripple photos
105:00	25	26	Wave reflection
------[2]	--[3]	------[3]	
130:00	30	31	Wave reflection
135:00	31	32, S3	Sand samples, profile surveys, ripple photos
		Experiment 72A-10	
0:00		1	Sand samples
0:10	1	2	
0:40	2	3	
1:30	3	4	
3:00	4	5	
5:00	5	6	
10:00	6	7	
-----[2]	--[3]	------[3]	
30:00	10	11	Wave reflection
-----[2]	--[3]	------[3]	
50:00	14	15, S1	Sand samples, profile surveys, ripple photos
55:00	15	16	Wave reflection
-----[2]	--[3]	------[3]	
80:00	20	21, S2	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.

The conclusions and recommendations (Sec. V) are directed toward the problems of the laboratory researcher or engineer in charge of a model study. Field engineers should be aware of these conclusions and recommendations when discussing and analyzing model studies of their 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. After an analysis of the scale and laboratory effects, the field engineer may use these data to determine generalized profile adjustment rates.

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 during the first 10 minutes of each experiment are shown in Table 4. The wave heights in the movable-bed tanks varied from 0.29 to 0.46 foot (8.8 to 14.0 centimeters) in experiment 72A-06, and from 0.17 to 0.33 foot (5.2 to 10.1 centimeters) in experiment 72A-10. Ignoring the first group of waves, the range of wave heights within the first 10 minutes was 0.15 foot (4.6 centimeters) in both experiments. In the fixed-bed tanks, again ignoring the first group, the range of wave height variation was 0.09 foot (2.7 centimeters) in experiment 72A-06 and 0.10 foot (3.0 centimeters) in experiment 72A-10. The range of wave height variation was greater in the movable-bed tanks than in the fixed-bed tanks.

The average wave height in the movable-bed tanks for each record (Table 4) was determined by averaging the average of the last 10 waves in each of the 40-second intervals after 40 seconds. In experiment 72A-06 the average wave height was 0.39 foot (11.9 centimeters); in experiment 72A-10 the height was 0.24 foot (7.3 centimeters). Because the waves were recorded at the same distance from the movable-bed profiles, and assuming that the initial reflectivity was the same, the difference in the average wave height was not due to reflection from the profile, but likely due to the secondary waves and re-reflection from the wave generator, which can be affected by differences in initial test length. In the fixed-bed tanks the average wave height was 0.31 foot (9.4 centimeters) in experiment 72A-06 and 0.36 foot (11.0 centimeters) in experiment 72A-10. The difference between the two fixed-bed tanks was also likely due to differences in initial test length, because the gages were the same distance from the concrete slopes.

The average wave height in the fixed-bed tank was 0.08 foot (2.4 centimeters) greater than in the movable-bed tank for experiment 72A-06, and 0.12 foot (3.7 centimeters) less than in the movable-bed tank for experiment 72A-10.

Table 4. Wave heights during first 10 minutes of experiments 72A-06 and 72A-10.

Cumulative time (min:s)	Wave height (ft)											
	Experiment 72A-06						Experiment 72A-10					
	Movable-bed tank			Fixed-bed tank			Movable-bed tank			Fixed-bed tank		
	(avg)	(max)	(min)	(avg)	(max)	(min)	(avg)	(max)	(min)	(avg)	(max)	(min)
0:00 to 0:20	0.305[1]	0.329	0.285	0.306[1]	0.332	0.288	0.301[2]	0.332	0.276	0.310[2]	0.339	0.293
0:20 to 0:40	0.335[3]	0.362	0.312	0.315[3]	0.345	0.290	0.261[4]	0.318	0.170	0.367[4]	0.398	0.336
0:40 to 1:20	0.382	0.405	0.356	0.313	0.342	0.285	0.222	0.257	0.183	0.357	0.380	0.327
1:40 to 2:20	0.398	0.428	0.371	0.319	0.339	0.302	0.222[5]	0.240	0.200	0.356[5]	0.381	0.336
2:40 to 3:20	0.424	0.462	0.386	0.312	0.356	0.272	0.244	0.273	0.224	0.348	0.392	0.328
3:40 to 4:20	0.397	0.425	0.371	0.309	0.341	0.282	0.256	0.305	0.215	0.355	0.389	0.335
4:40 to 5:20	0.398	0.453	0.356	0.309	0.339	0.266	0.239	0.272	0.213	0.357	0.413	0.315
5:40 to 6:20	0.407	0.434	0.357	0.319	0.342	0.290	0.236	0.285	0.203	0.339	0.359	0.311
6:40 to 7:20	0.380	0.401	0.357	0.305	0.339	0.272	0.258	0.297	0.216	0.366	0.398	0.323
7:40 to 8:20	0.390	0.408	0.378	0.301	0.339	0.276	0.248	0.272	0.201	0.378	0.407	0.333
8:40 to 9:20	0.382	0.399	0.365	0.304	0.315	0.291	0.245	0.281	0.203	0.369	0.393	0.342
9:20 to 10:00	0.374[6]	0.389	0.350	0.294[6]	0.306	0.279	0.251	0.291	0.210	0.364	0.395	0.336
Avg[7]	0.393			0.309			0.242			0.359		

[1]First full trough-crest face is the second wave in this group which includes waves 2 to 5. These waves show no reflection or solitons; shapes are good.

[2]First wave a full trough-crest advancing front; only waves 1, 2, and 3 in this group. These waves have no reflection, but are not of optimum shape.

[3]Waves 6 to 11 with some "jaggedness" on waveform, but not appreciable; cannot be determined if reflection or soliton.

[4]Waves 6 to 11; shows buildup of reflection and solitons.

[5]Reflection-soliton buildup to full extent in this interval. Waveform very jagged and entire wave deformed; movable bed much worse than fixed bed.

[6]Jagged shape buildup to maximum for the 10-minute interval; fixed bed appears slightly worse than movable bed.

[7]Excludes averages for cumulative times 0:00 to 0:20 and 0:20 to 0:40.

Some of the difference may have been due to the gages in the fixed-bed tanks being 7 feet farther from the profile (see Fig. A-1 in the App.) and thus the gages may have been at different positions between nodes and antinodes. For example, on the envelopes recorded beginning at 20 minutes (10 minutes after the data given in Table 1) in experiment 72A-06, an antinode is at station 25 in the fixed-bed tank and a node in the movable-bed tank (Fig. 1).

Table 5 shows the average incident wave heights in both tanks from the two experiments. These heights were determined by the automated method for determining the reflection coefficient, K_R (see Vol. I). The range of variation in the fixed-bed tank was 0.07 foot (2.1 centimeters) in experiment 72A-06 and 0.04 foot (1.2 centimeters) in experiment 72A-10. This variation was probably caused by generator operation variation, measurement errors, and all errors not caused by a changing profile.

The range of wave heights in the movable-bed tank was 0.10 foot in experiment 72A-06 and 0.11 foot (3.3 centimeters) in experiment 72A-10. The difference in range of variation between the two tanks was due to the changing shape and position of the profile which caused a varying re-reflection from the wave generator. The re-reflected wave superposing with the generated wave created an incident wave which varied in time. Thus, a measure of the variation due to re-reflection is the difference in range of heights on fixed and movable beds: 0.03 foot (0.9 centimeter) in experiment 72A-06 and 0.07 foot in experiment 72A-10.

b. Wave Reflection. The reflection coefficient, K_R, from experiments 72A-06 and 72A-10 as determined by the manual and automated methods, is given in Table 6. The two methods are described in Volume I. A plot of K_R versus time for the fixed-bed tanks of both experiments is shown in Figure 2. In experiment 72A-06 the range of K_R was only 0.02 with no long-term trends; in experiment 72A-10 the mean K_R was lower and the range of K_R was 0.05, with a decrease in K_R to the minimum near the beginning of the experiment, followed by a long-term rise to the maximum. This variation was not seen in the incident wave height data in Table 5. An explanation for the variation in K_R in the fixed-bed tank of experiment 72A-10 is not apparent. As with the incident wave heights, the range of K_R variation in the fixed-bed tanks is a measure of all the errors and variations not due to the changing profile in the movable-bed tanks. Thus, the accuracy of the reflection measurement in the movable-bed tanks is about ±0.01 in experiment 72A-06 and ±0.025 in experiment 72A-10.

A plot of K_R versus time in the movable-bed tanks for three ranges in experiment 72A-10 and the center range in experiment 72A-06, compares the data reduced by the two methods (Fig.3). The same temporal variation in K_R occurred in both tanks. A scatter plot of K_R values for the manual method versus the automated method for those wave records reduced by both methods is shown in Figure 4. This indicates that the manual

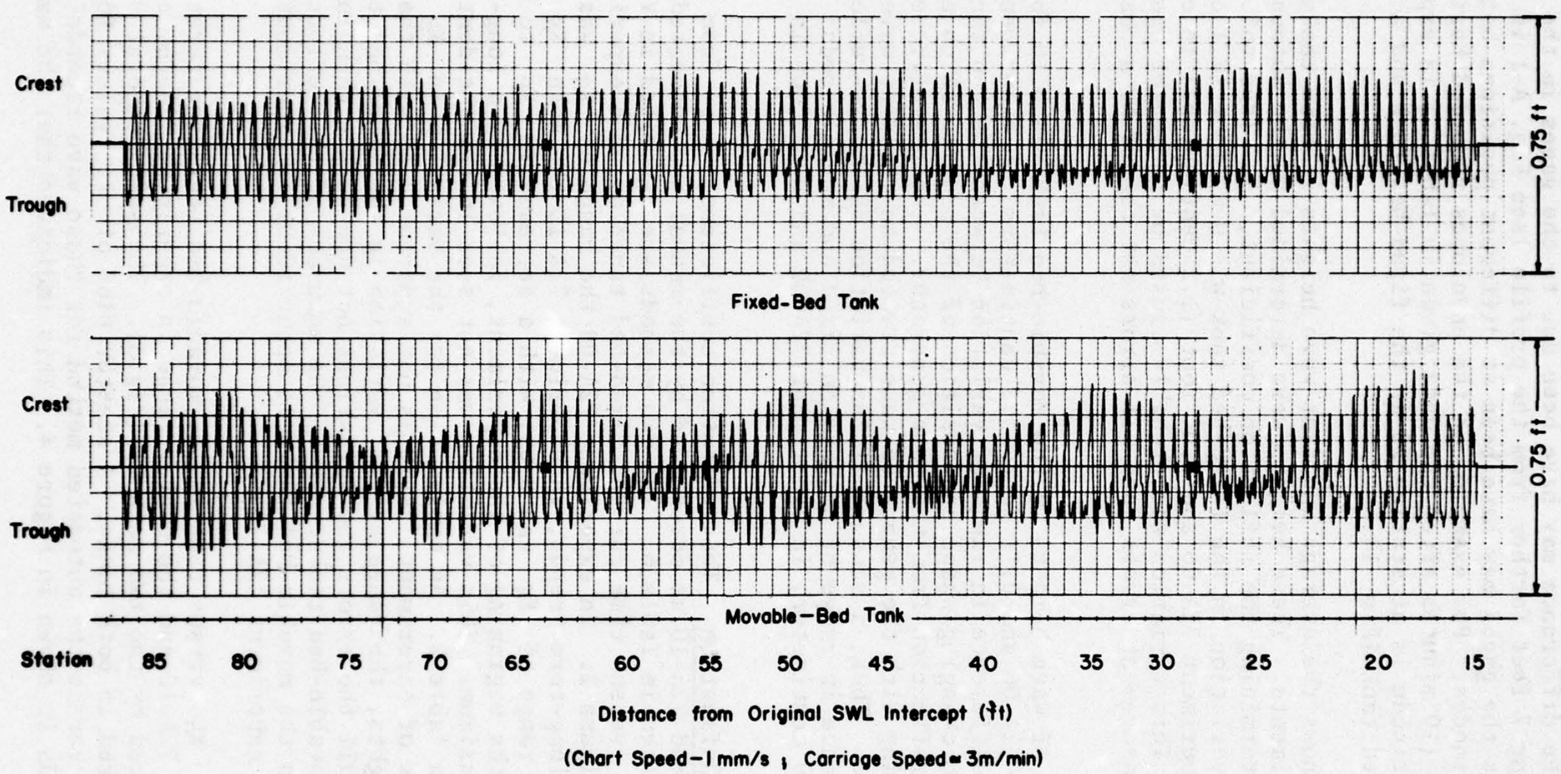


Figure 1. Standing wave envelopes at 20 minutes in experiment 72A-06 (range 3).

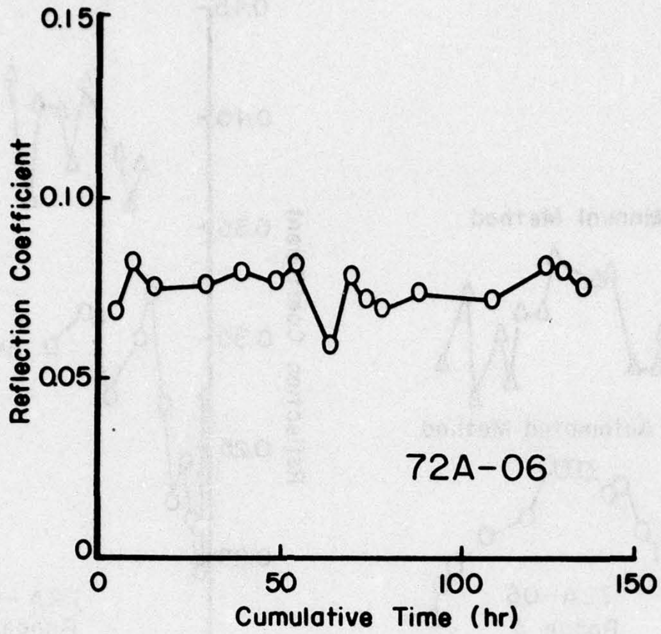
Table 5. Incident wave heights in fixed- and movable-bed tanks for experiments 72A-06 and 72A-10.

Time (hr)	Incident wave height (ft)			
	Fixed bed		Movable bed	
	Expt. 72A-06	Expt. 72A-10	Expt. 72A-06	Expt. 72A-10
0.66	----[1]	0.34	----	0.32
1.5	----	0.34	----	0.30
3.0	----	0.35	----	0.33
5.0	0.34	0.35	0.34	0.31
10.0	0.34	0.37	0.33	0.38
15.0	0.34	0.36	0.33	0.36
20.0	----	0.35	----	0.35
25.0	----	0.36	----	0.38
30.0	0.37	0.37	0.38	0.38
40.0	0.35	----	0.36	----
45.0	----	0.33	----	0.34
50.0	0.35	0.36	0.38	0.31
55.0	0.35	0.35	0.37	0.37
60.0	----	0.36	----	0.42
65.0	0.35	----	0.40	----
70.0	0.34	0.34	0.36	0.36
75.0	0.35	----	0.40	----
80.0	0.36	----	0.39	----
90.0	0.41	----	0.41	----
110.0	0.36	----	0.40	----
125.0	0.37	----	0.40	----
130.0	0.36	----	0.43	----
135.0	0.36	----	0.41	----
Avg	0.36	0.35	0.38	0.35

[1]Data for these times were not reduced.

Table 6. Reflection coefficients, manual and automated methods.

Cumulative time	Manual method						Automated method							
	Movable bed						Movable bed			Fixed bed	Movable bed			Fixed bed
	Experiment 72A-06			Experiment 72A-10			Experiment 72A-06				Experiment 72A-10			
	Range			Range			Range			Range	Range			Range
(hr)	1	3	5	1	5	9	1	3	5	3	1	5	9	5
0.66	0.336	0.323	0.340								0.237	0.329	0.226	0.05
1.5		0.256									0.27	0.325	0.257	0.041
3.0		0.250									0.193	0.262	0.265	0.052
5.0								0.221		0.069	0.215	0.338	0.250	0.044
10.0								0.202		0.082	0.244	0.313	0.227	0.016
15.0								0.224		0.075	0.226	0.314	0.240	0.032
20.0		0.308									0.270	0.329	0.279	0.042
25.0		0.378									0.318	0.369	0.258	0.034
30.0	0.376	0.352	0.352	0.375	0.393	0.336	0.273	0.253	0.260	0.076	0.299	0.326	0.234	0.043
35.0		0.336		0.359	0.409	0.388								
40.0				0.382	0.423	0.342		0.263		0.080				
45.0		0.336									0.273	0.378	0.286	0.049
50.0								0.284		0.077	0.308	0.341	0.282	0.071
55.0	0.385	0.380	0.353	0.412	0.436	0.371	0.273	0.280	0.262	0.082	0.310	0.401	0.322	0.072
60.0		0.376		0.375		0.350						0.355		0.066
65.0				0.400	0.467	0.371		0.290		0.059				
70.0								0.291		0.078	0.295	0.387	0.280	0.069
75.0				0.402	0.492	0.397		0.291		0.072				
80.0	0.391	0.385	0.388	0.360	0.471	0.357	0.301	0.292	0.289	0.070				
85.0		0.361												
90.0								0.259		0.074				
95.0		0.360												
100.0		0.328												
105.0		0.351												
110.0								0.259		0.072				
115.0		0.321												
120.0		0.370												
125.0								0.247		0.081				
130.0	0.351	0.337	0.300				0.247	0.238	0.212	0.080				
1.35								0.222		0.075				



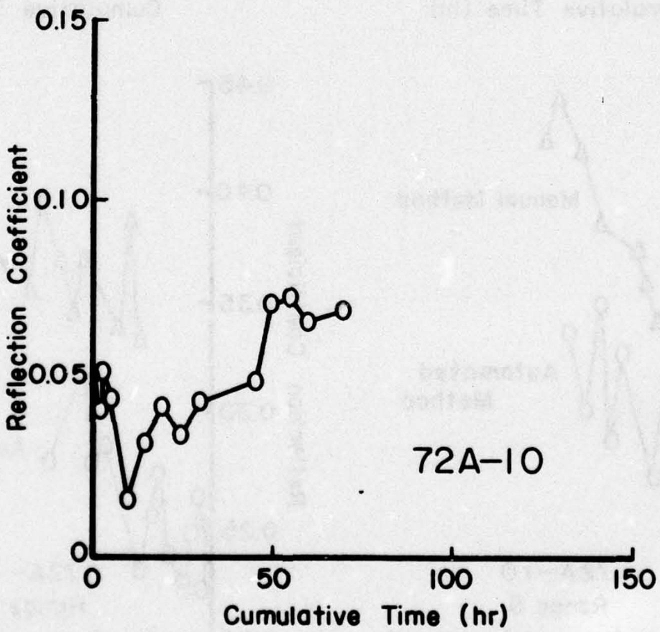


Figure 2. Reflection coefficient variation in fixed-bed tanks.

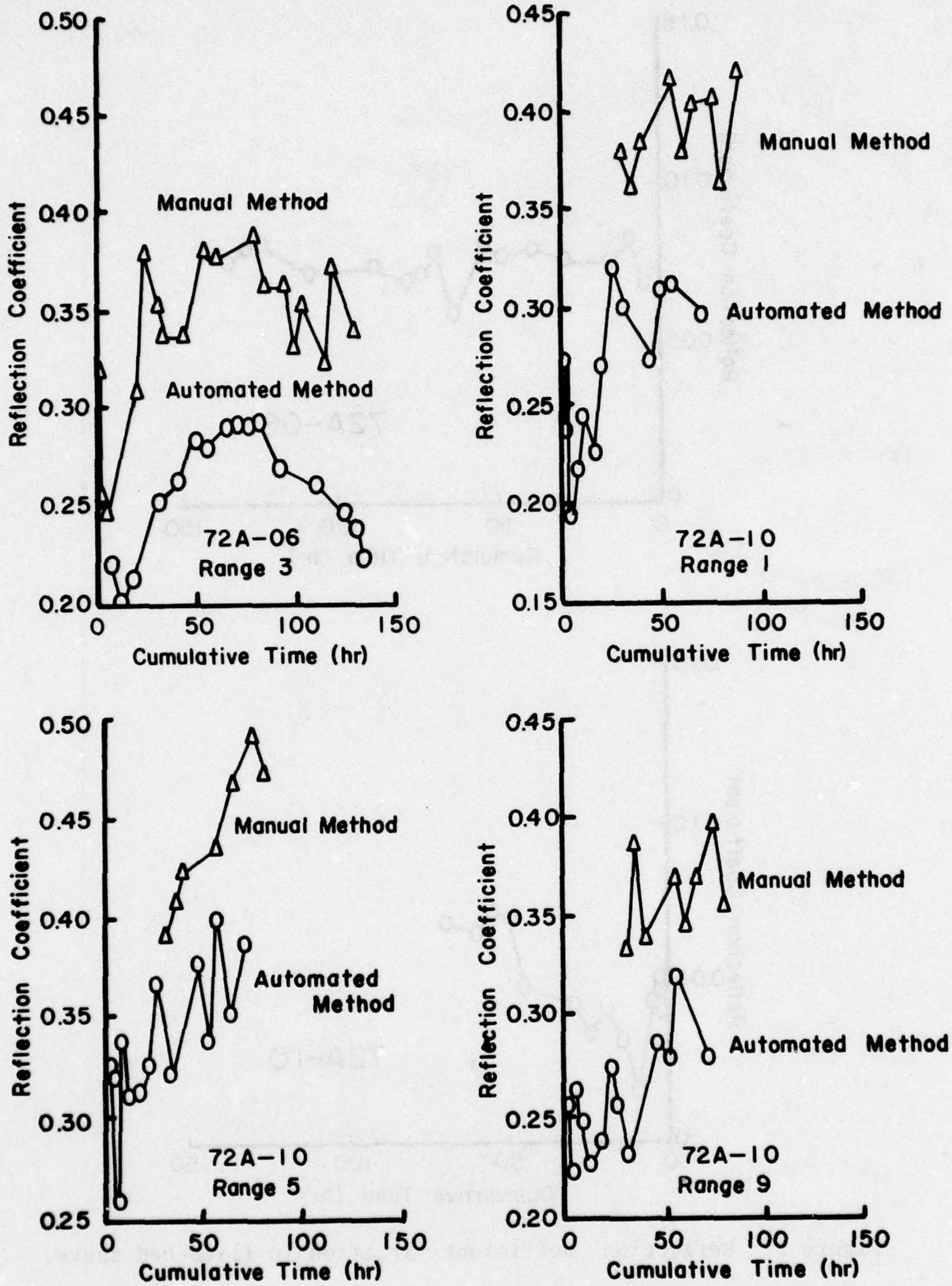


Figure 3. Comparison of manual and automated reflection coefficients.

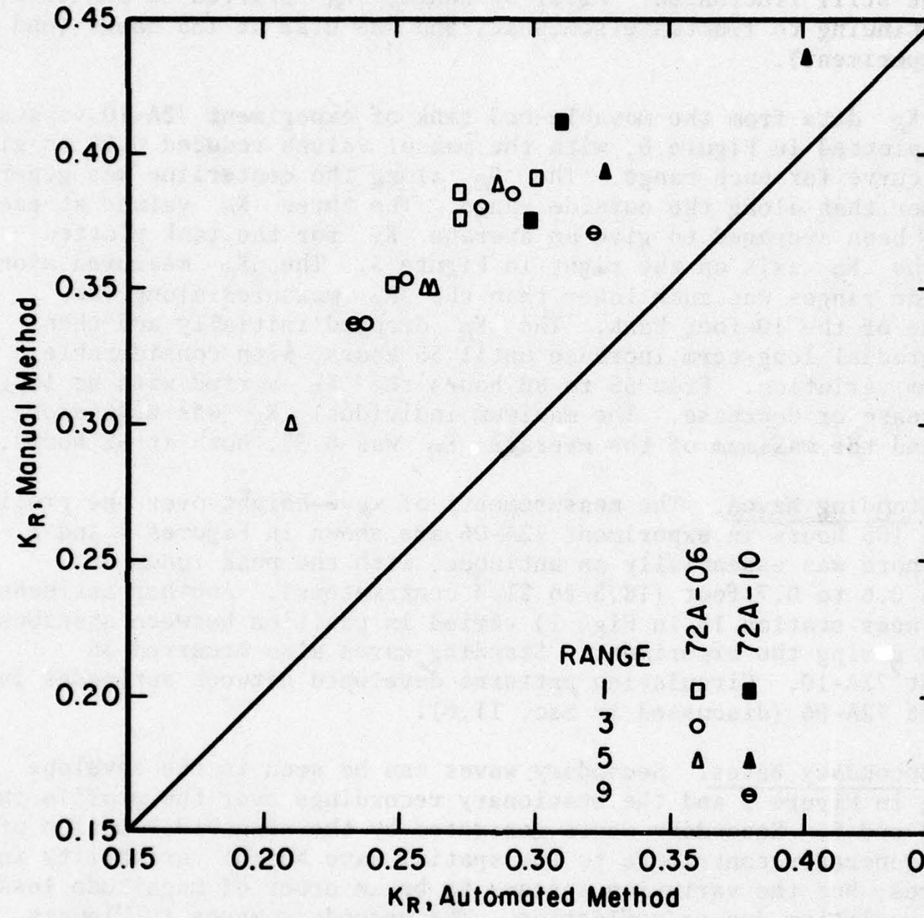


Figure 4. Correlation of manual and automated reflection coefficients.

method values were higher than the automated method values by an average of 0.08.

All data from the movable-bed tank for experiment 72A-06 versus time are plotted in Figure 5, with the manual method values reduced 0.08 to give a single curve. The K_R dropped from an initial value of 0.24 to 0.18, then to 0.17 at 3 hours and began to increase, reaching 0.30 at 25 hours. From 25 to 80 hours, K_R remained high (between 0.25 and 0.30), but still fluctuated. After 80 hours, K_R started to decrease, while continuing to fluctuate somewhat, and was 0.22 at 135 hours (end of the experiment).

All K_R data from the movable-bed tank of experiment 72A-10 versus time are plotted in Figure 6, with the manual values reduced 0.08 to give a single curve for each range. The K_R along the centerline was generally higher than along the outside range. The three K_R values at each time have been averaged to give an average K_R for the tank plotted against the K_R axis on the right in Figure 5. The K_R measured along the outside ranges was much lower than the K_R measured along the centerline of the 10-foot tank. The K_R dropped initially and then began a gradual long-term increase until 55 hours, with considerable short-term variation. From 55 to 80 hours the K_R varied with no long-term increase or decrease. The maximum individual K_R was 0.46 along range 5 and the maximum of the average K_R was 0.37, both at 55 hours.

c. Standing Waves. The measurements of wave height over the profile at 55 and 105 hours in experiment 72A-06 are shown in Figures 7 and 8. The foreshore was essentially an antinode, with the peak runup at elevation 0.6 to 0.7 foot (18.3 to 21.3 centimeters). Another antinode (located near station 18 in Fig. 1) varied in position between stations 16 and 20 during the experiment. Standing waves also occurred in experiment 72A-10. Circulation patterns developed between antinodes in experiment 72A-06 (discussed in Sec. II,6).

d. Secondary Waves. Secondary waves can be seen in the envelope recording in Figure 1 and the stationary recordings over the profile in Figures 7 and 8. Secondary waves generated by the sinusoidal motion of the wave generator contribute to the spatial wave height variability in the figures, but the variation appears to be an order of magnitude less than the variation due to reflection. The secondary waves in Figures 7 and 8 could have been generated by both the sinusoidal motion of the generator and the shoaling of the wave over the profile. The variation in wave heights at a given location makes quantification of the secondary wave heights in this area difficult.

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 experiments. The CONPLT method for

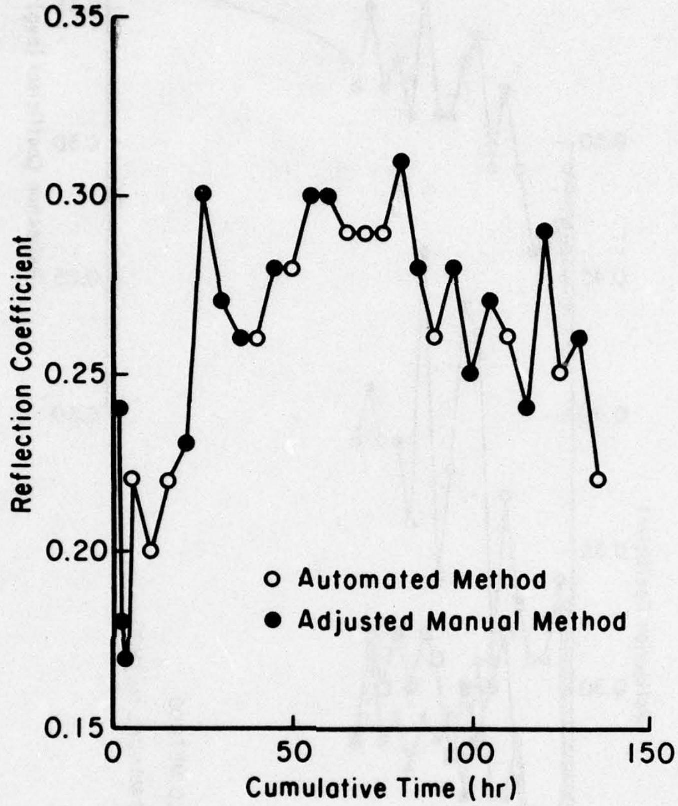


Figure 5. Reflection coefficient variation in experiment 72A-06.

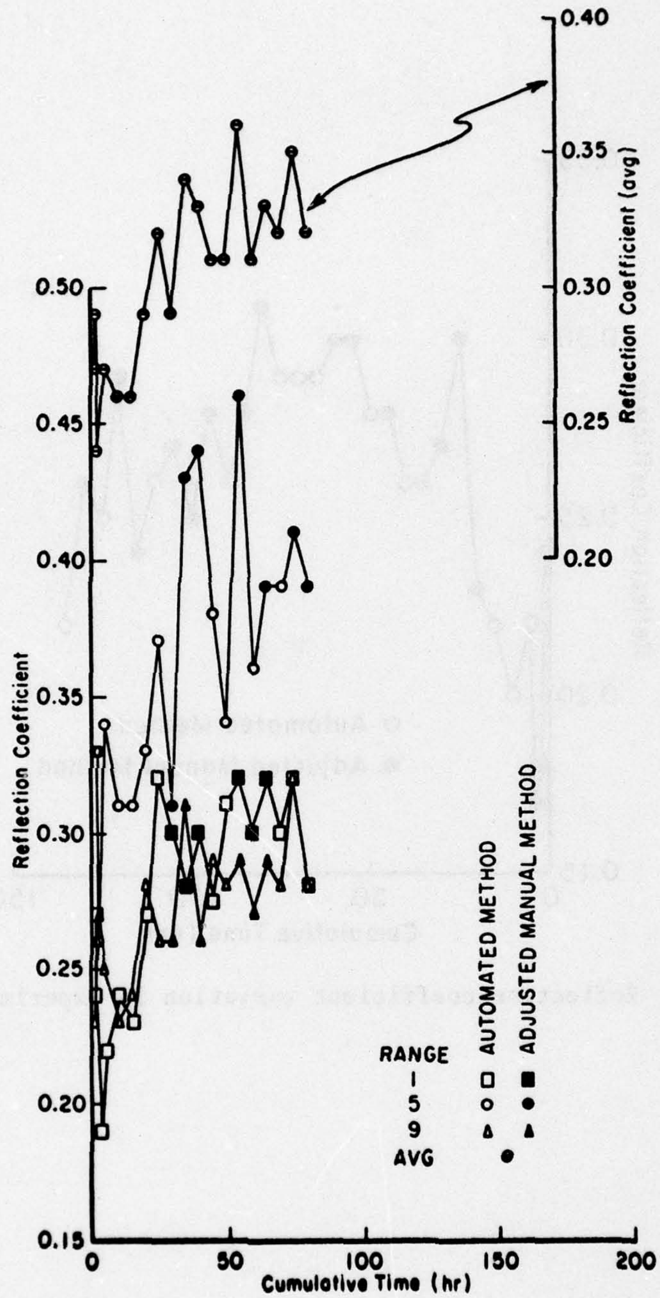


Figure 6. Reflection coefficient variation in experiment 72A-10.

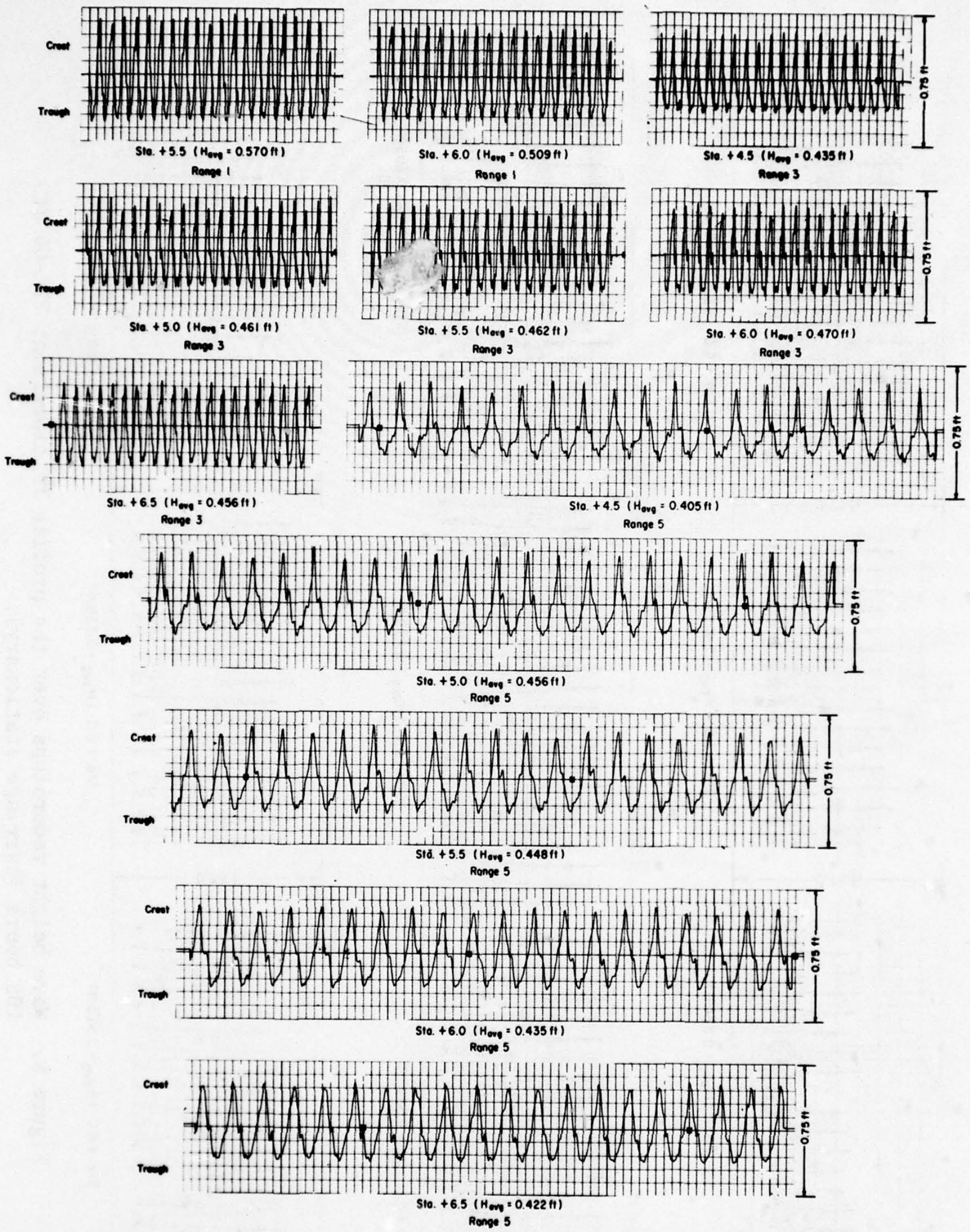


Figure 7. Wave height recordings over the profile in experiment 72A-06 at 55 hours (carriage stationary).

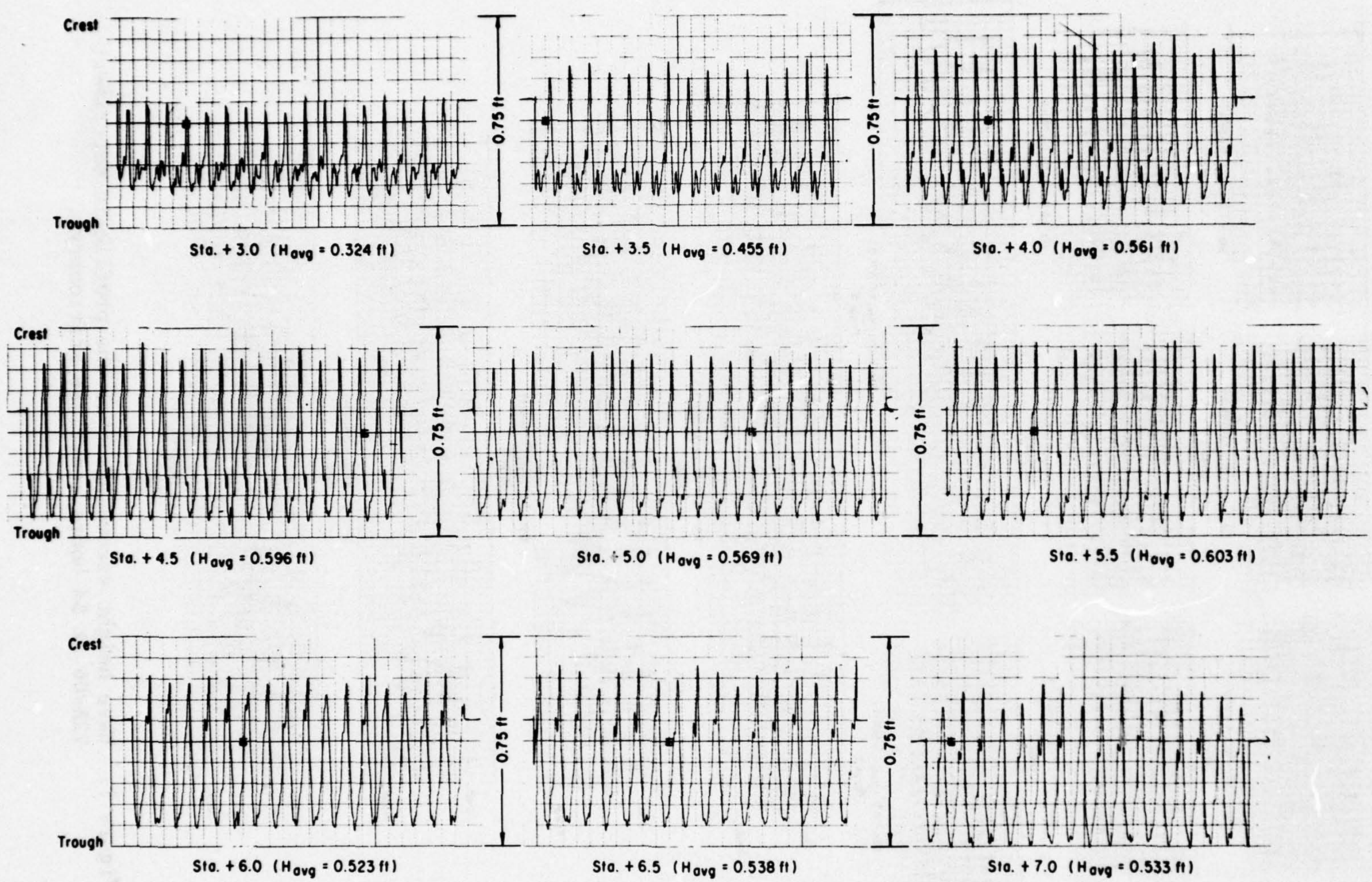


Figure 8. Wave height recordings over the profile in experiment 72A-06 at 105 hours (carriage stationary).

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 9(a). These contour positions from each survey are then plotted against time (Fig. 9,b).

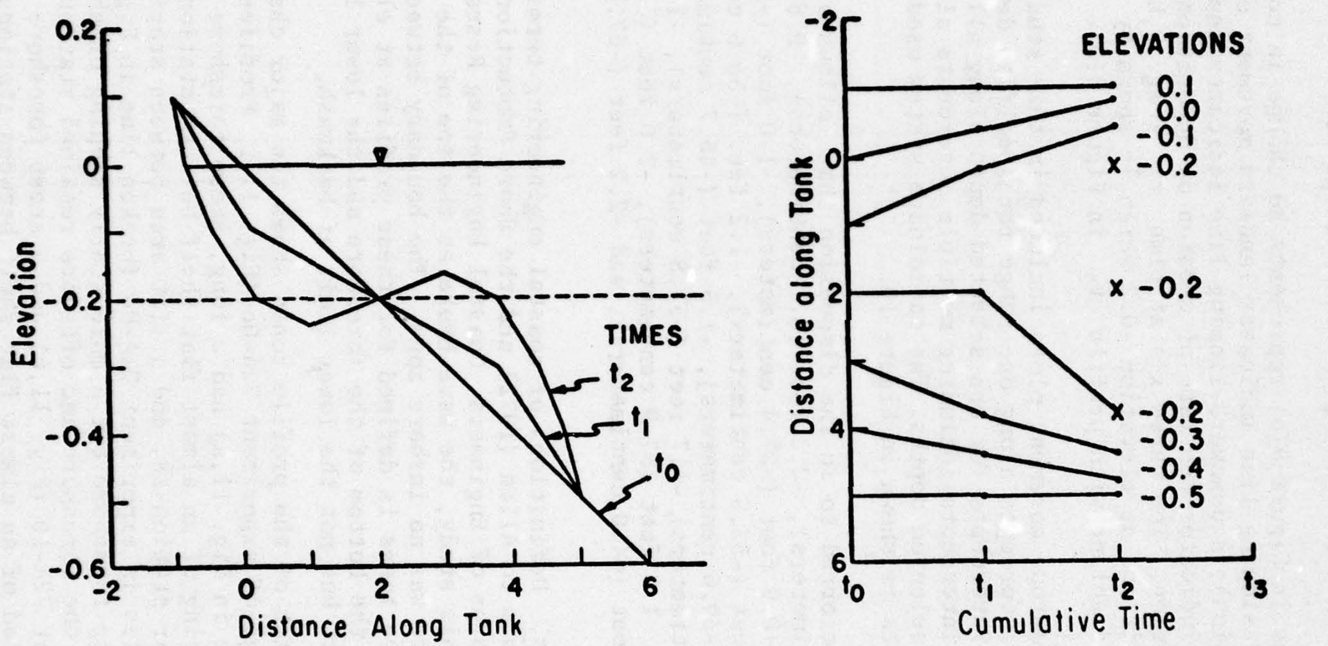
A horizontal line in Figure 9(b) represents no change in contour position. An upward-sloping line indicates landward movement of contour position (i.e., erosion); a downward-sloping line indicates deposition. The slope of a line indicates the rate of erosion or deposition (horizontally) at that elevation. The three x's at time t_2 (Fig. 9,b) indicate multiple contour positions at elevation -0.2 which is shown by the intersection of the dashline with profile t_2 in Figure 9(a).

Three types of contour movement plots included in this study are: (a) The seawardmost intercepts along one range for specified 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 10.

The elevations referred to in the discussion that follows are: -0.1 foot (-3.0 centimeters), -0.2 foot (6.1 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), -1.2 feet (-36.6 centimeters), -1.3 feet (-39.6 centimeters), -1.5 feet (-45.7 centimeters), -1.6 feet (-48.8 centimeters), -1.7 feet (-51.8 centimeters), -1.8 feet (-54.9 centimeters), -1.9 feet (57.9 centimeters), -2.0 feet (61.0 centimeters), -2.1 feet (64.0 centimeters), and -2.2 feet (-67.1 centimeters).

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, 1977). In this study, the wave broke at the toe of the foreshore and, thus, there was no inshore zone. The boundary between the foreshore and offshore zones is defined for these profiles at elevation -0.9 foot, which was the bottom of the foreshore and the lower limit of the backwash effect but not the lower limit of backwash.

A definition sketch of the profile zones shows the major changes along the center range of experiment 72A-06 (Fig. 11). Profiles up to 100 hours (solid line in Fig. 11,a) had a long, steep foreshore and an offshore zone consisting of an almost flat shelf between stations 8 and 18, a steep slope near station 18, and a flat area between stations 22 and 30. Later profiles in experiment 72A-06 (broken line in Fig. 11,a) also had a long, steep foreshore but a more gently sloping offshore. The boundary between the foreshore and offshore remained stationary. Profiles in experiment 72A-10 (Fig. 11,b) had a steep foreshore and an offshore that consisted of an almost flat shelf between stations 5 and 12 and a flatter seaward slope, but no offshore flat area.



a. Profile Line

b. Movement of Contour Position

Figure 9. Interpretation of contour movement plots.

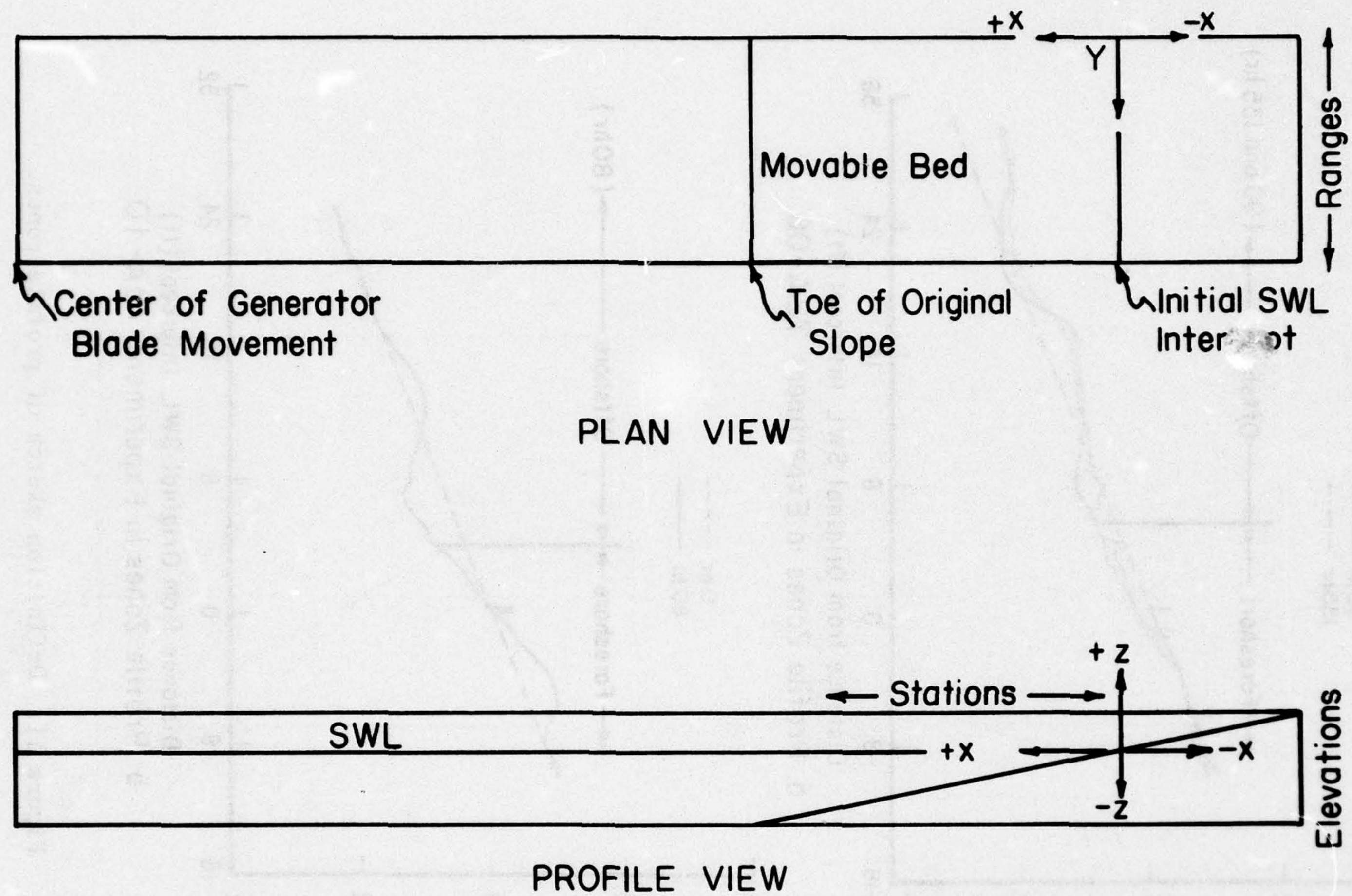


Figure 10. Definition of coordinate system.

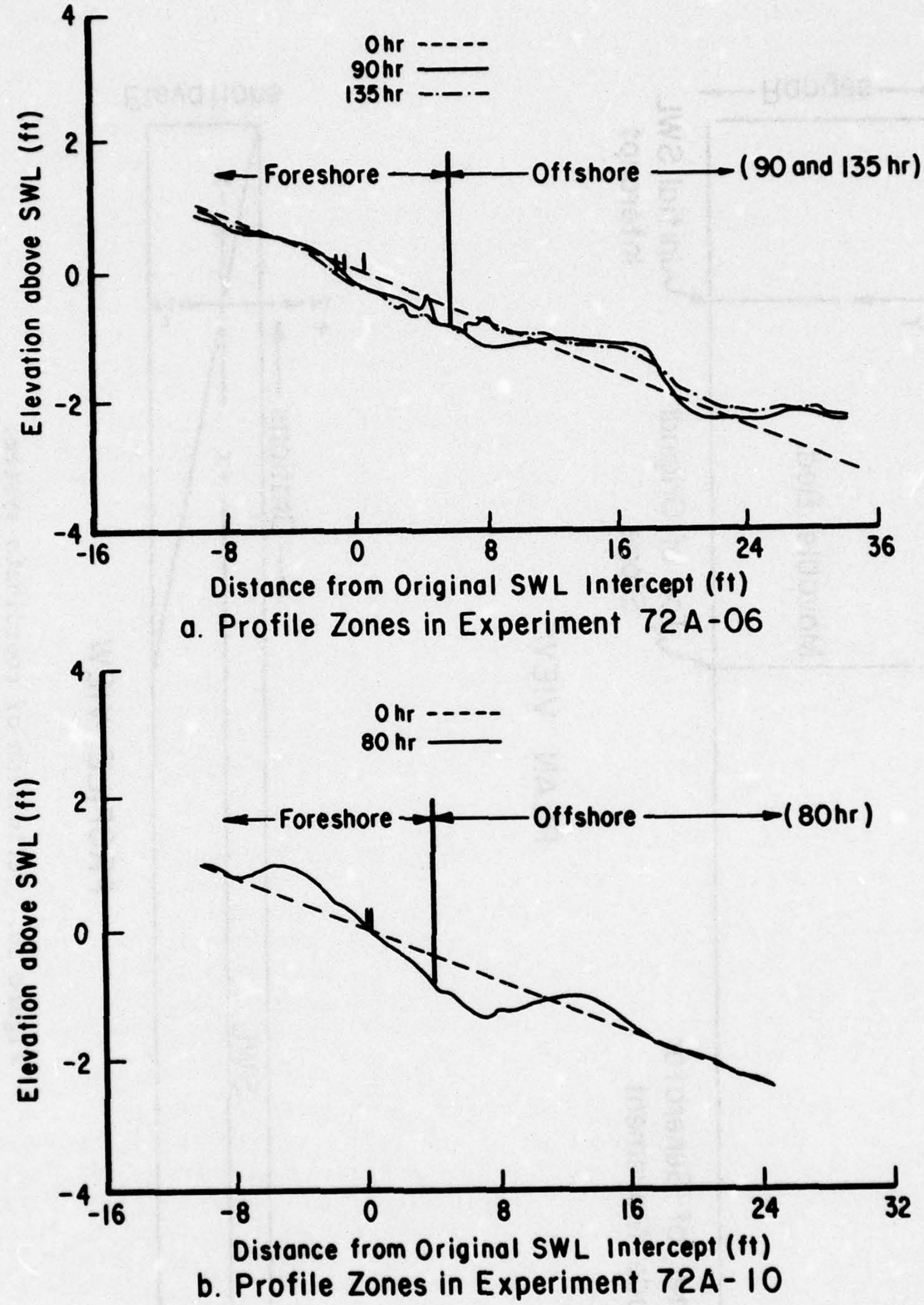


Figure 11. Definition sketch of profile zones.

Profile development is shown by contour movement plots (Figs. 12 to 19) 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 -0.9-foot contour distinguish the boundary between the foreshore and the offshore in the figures.

(1) Foreshore Zone.

(a) Experiment 72A-06. Within the first 5 hours the foreshore developed an equilibrium shape, as shown in the contour movement plots of the foreshore during the first 10 hours of experiment 72A-06 (Fig. 20). Along each of the ranges, material eroded from the elevations below the SWL (-0.1 to -0.7 foot) and deposited above the SWL (+0.1 to +0.7 foot) to form a steeper beach face. The steepness of the beach face varied across the tank, as indicated by the close spacing (steep slope) along range 5 and the increased spacing (flatter slopes) along the other ranges. At 3 hours the -0.2- to -0.8-foot contours moved shoreward along range 1, indicating erosion, and seaward along ranges 3 and 5, indicating deposition; at 5 hours these contours moved back to approximately their position at 1.5 hours.

The foreshore along each range retreated almost continually throughout this experiment, when examined on the time scale of Figures 12, 13, and 14. These figures show that although the foreshore maintained the same shape along each range, the slopes varied across the tank, increasing from range 1 to 5, but no long-term changes in slope occurred. The slope at the SWL intercept along each range is given in Table 7. The difference in foreshore slope along the ranges at 90 hours is shown in Figure 21.

Figure 22 is a photo of the wave runup on the foreshore at 130 hours in this experiment. The lateral variation in the slope of the foreshore developed as a result of a concentration of backwash along range 1, which created the flatter slope. Along range 5 the uprush that washed over the berm crest proceeded laterally across the tank and then washed back along range 1. The greater volume of backwash along range 1 interfered to a greater extent with the incident wave and thus reduced the uprush along range 1.

The movements of the shoreline (or 0 contour) along the three ranges of experiment 72A-06 are compared in Figure 23. During the first 5 hours the foreshore advanced 0.5 foot (15.2 centimeters) seaward as the foreshore developed and then began a gradual landward movement at an average rate of 0.015 foot per hour (0.46 centimeter per hour). Between 110 and 115 hours the shoreline along range 1 moved 1.3 feet in the seaward direction, and then between 115 and 125 hours moved 1.5 feet in the landward direction.

(b) Experiment 72A-10. The foreshore shape developed as the result of erosion just below the SWL and deposition above the SWL (see Fig. 24, which compares the contour movements in the foreshore zone

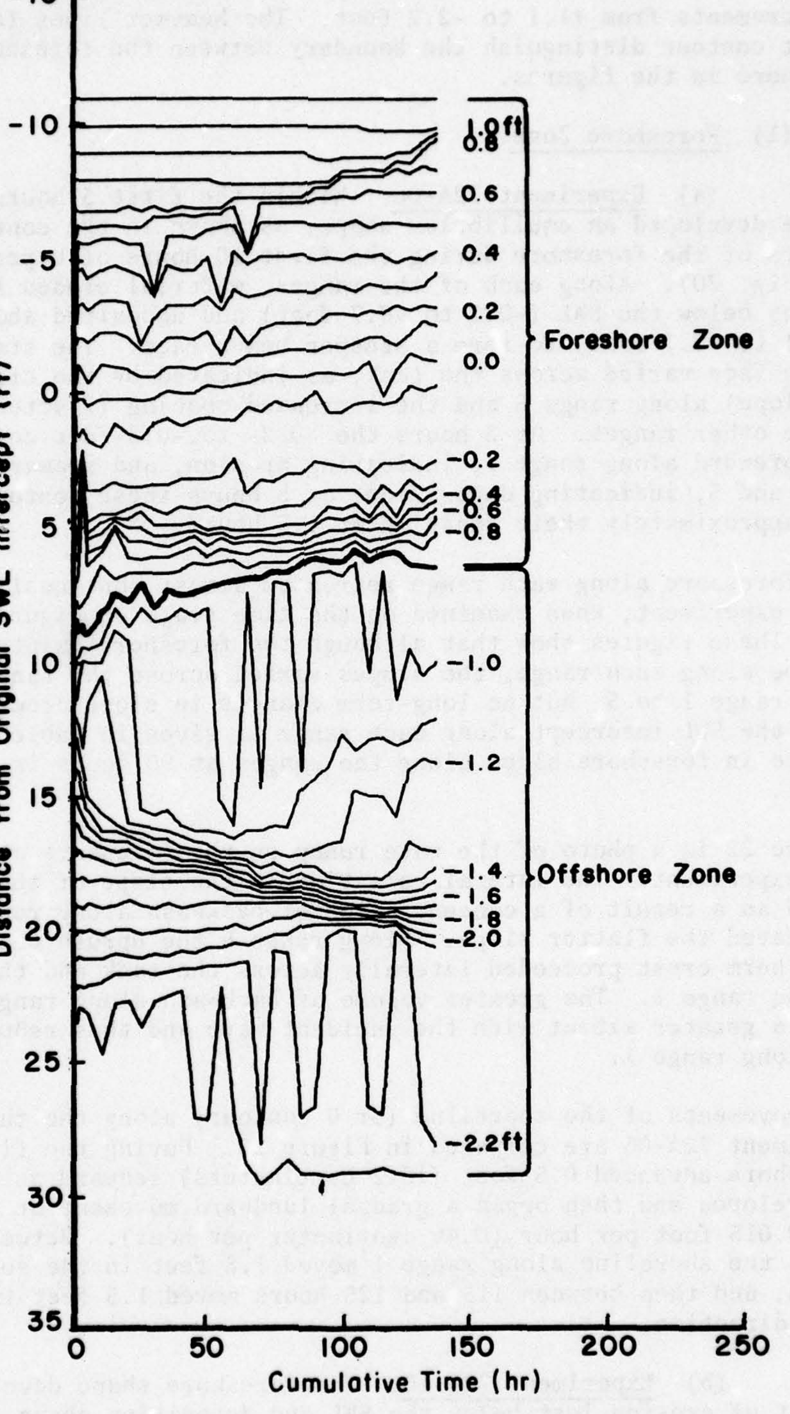


Figure 12. Profile changes along range 1, experiment 72A-06.

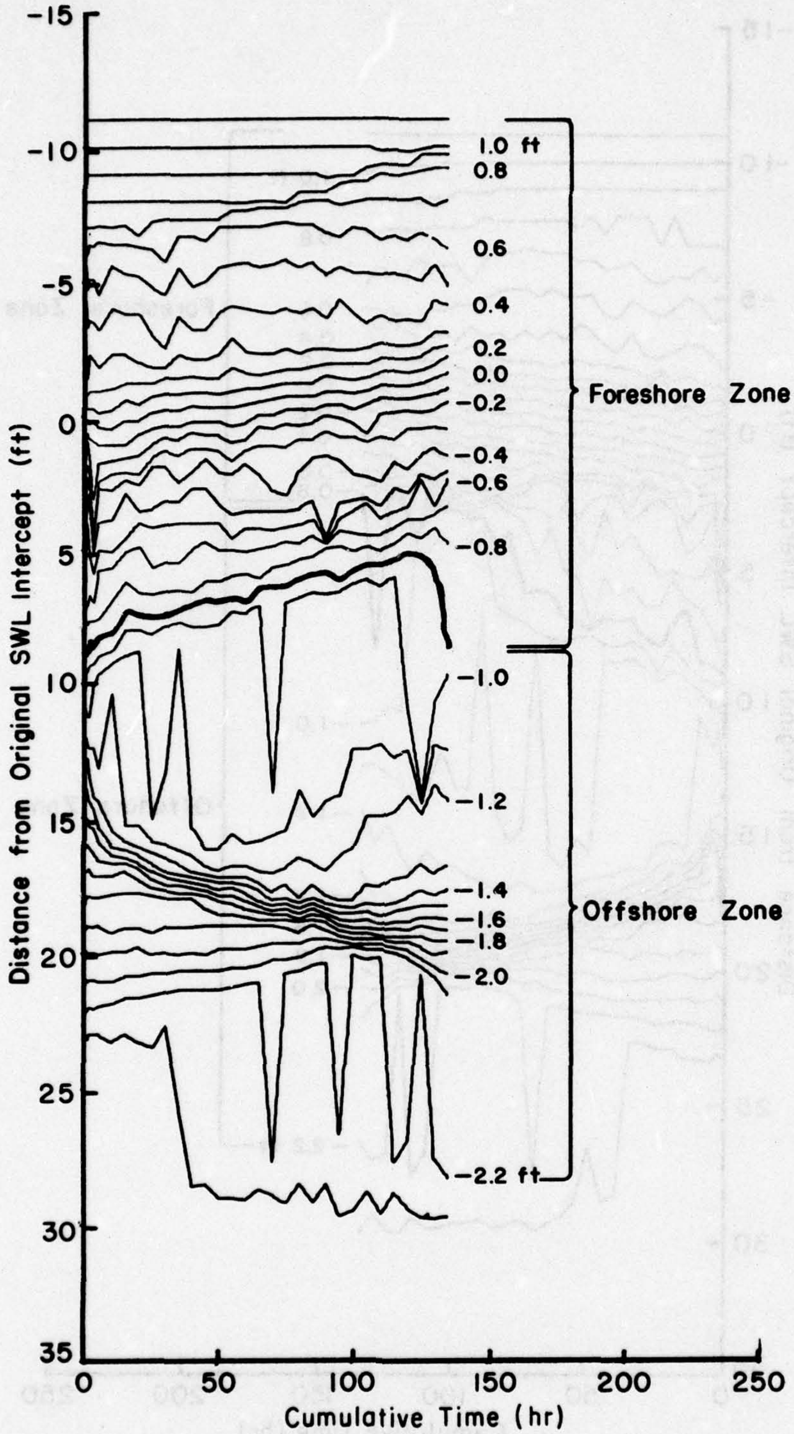


Figure 13. Profile changes along range 3, experiment 72A-06.

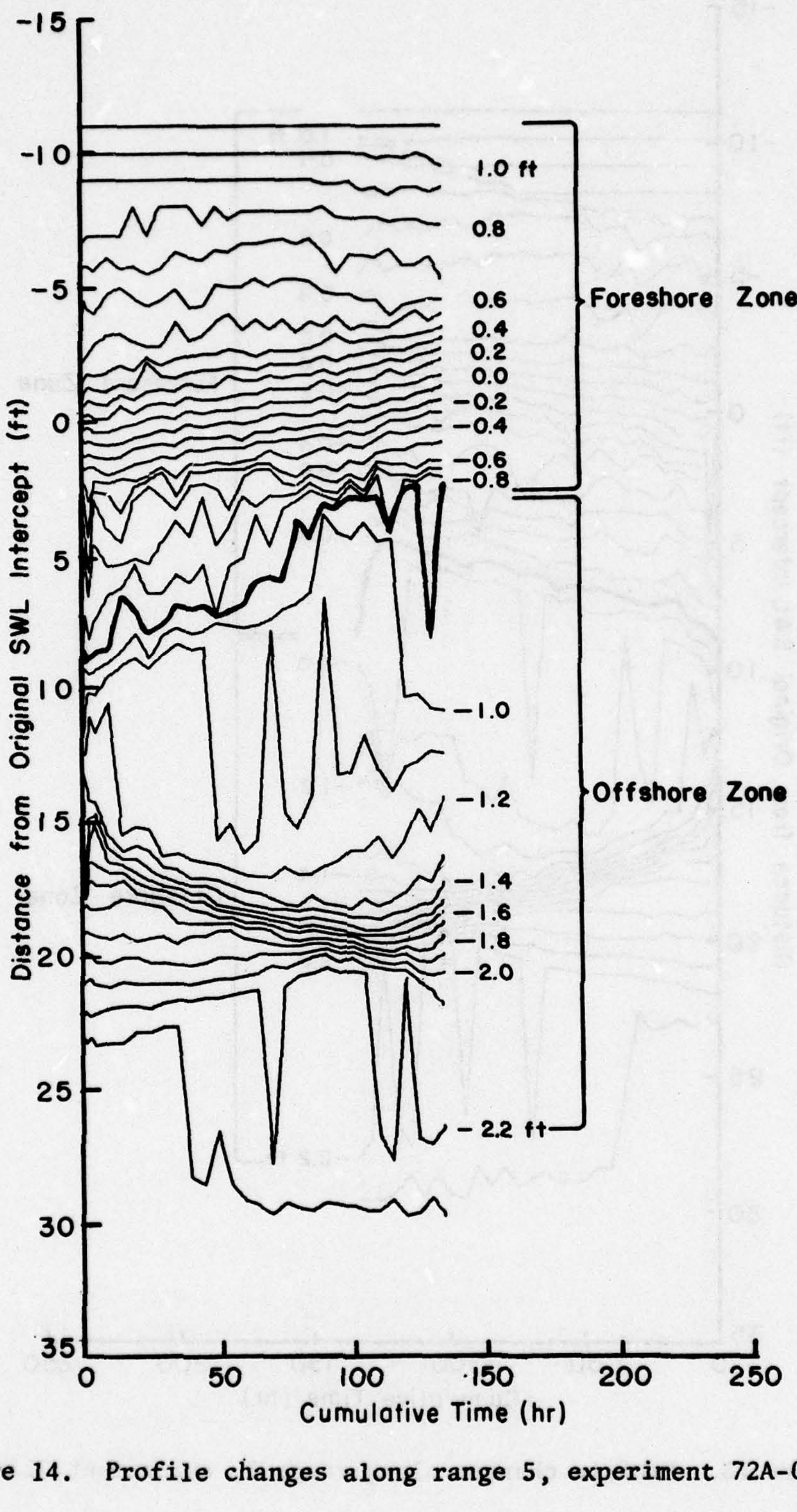


Figure 14. Profile changes along range 5, experiment 72A-06.

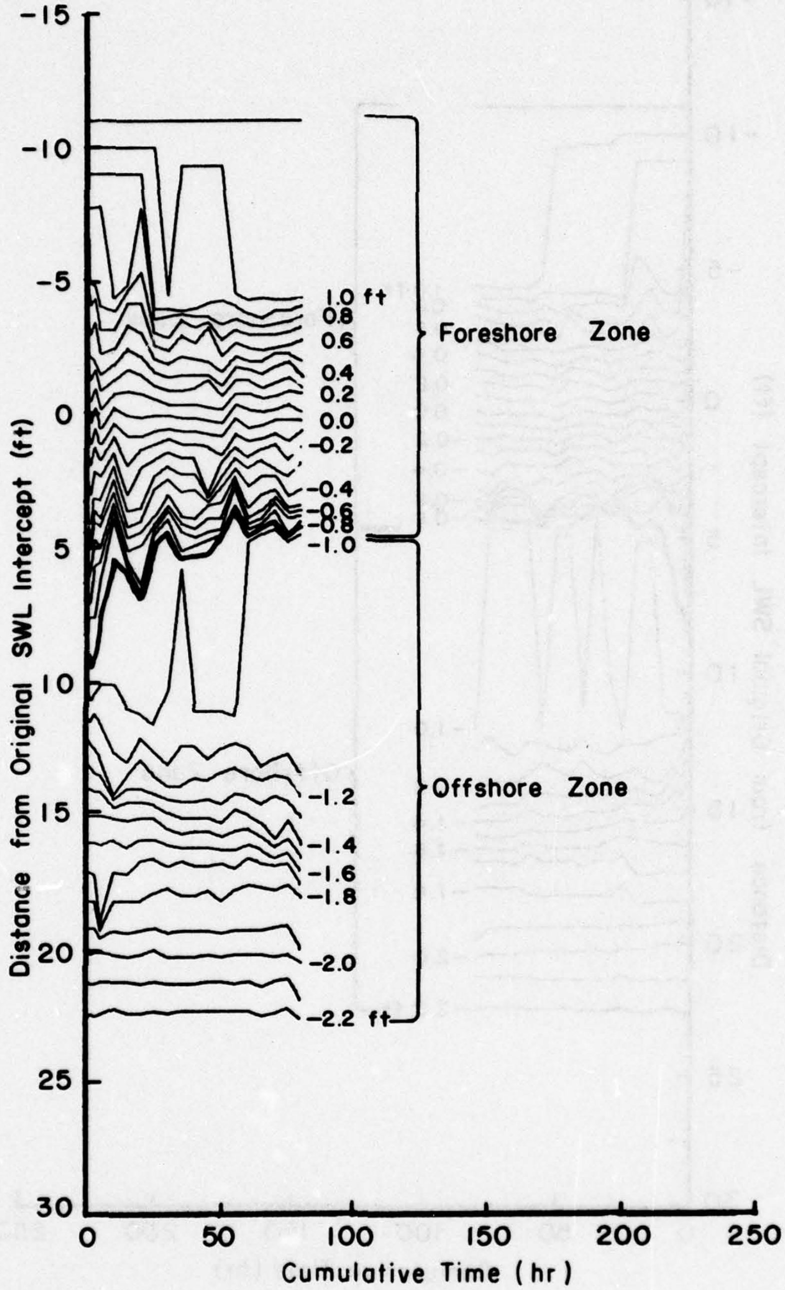


Figure 15. Profile changes along range 1, experiment 72A-10.

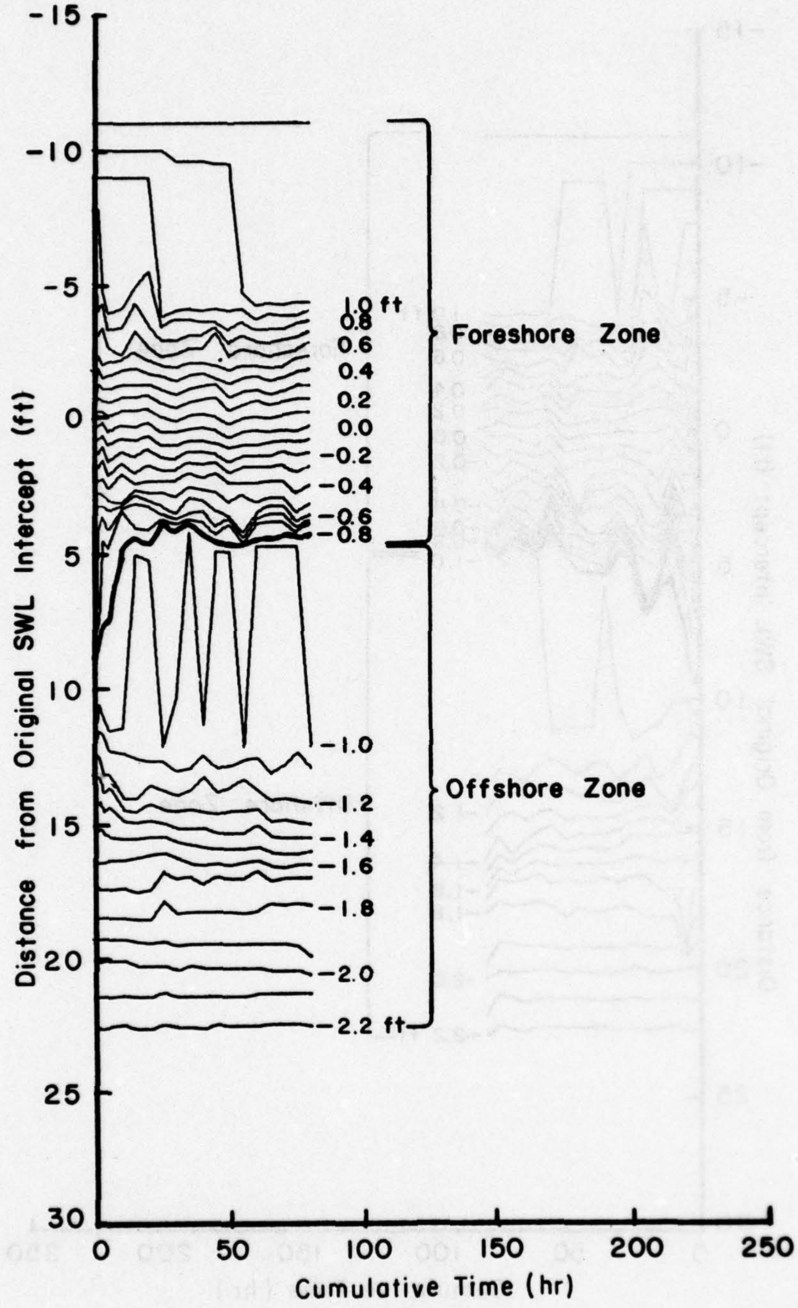


Figure 16. Profile changes along range 3, experiment 72A-10.

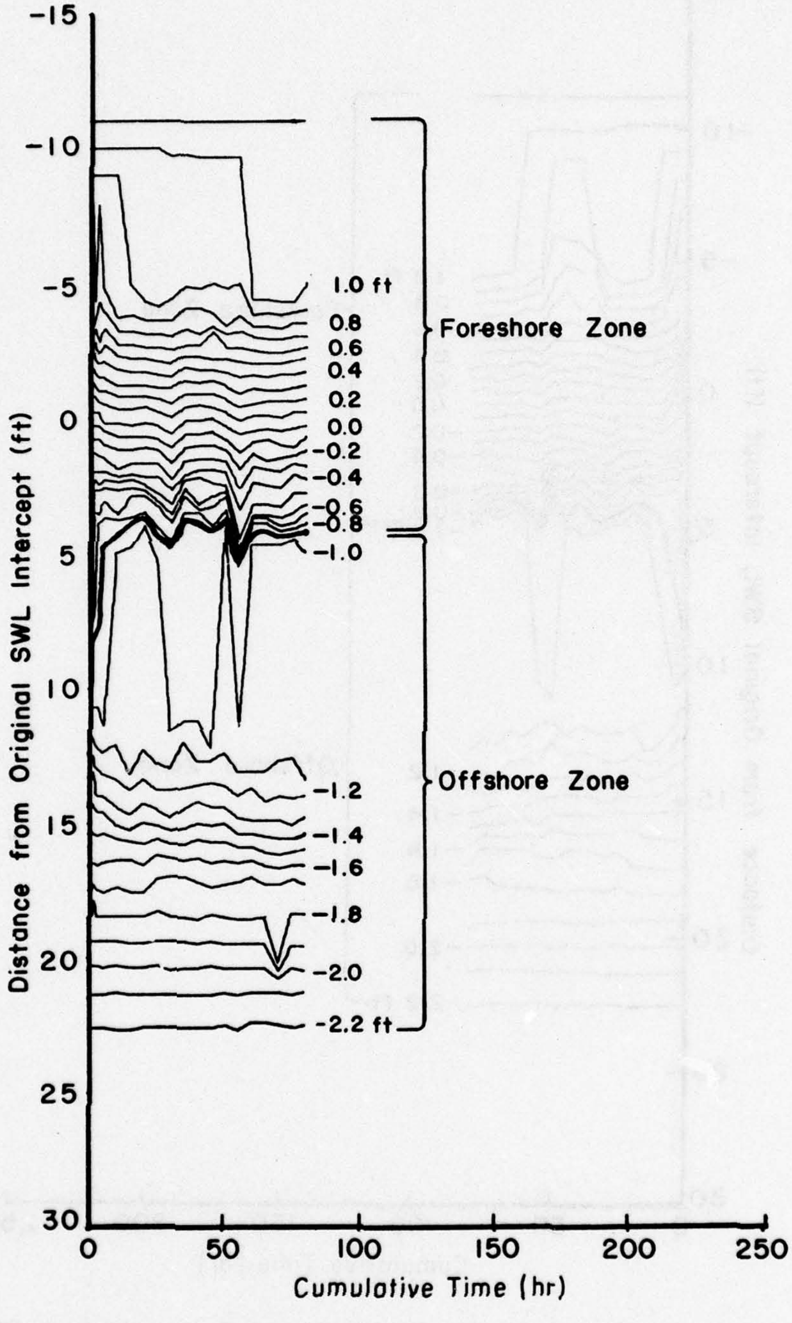


Figure 17. Profile changes along range 5, experiment 72A-10.

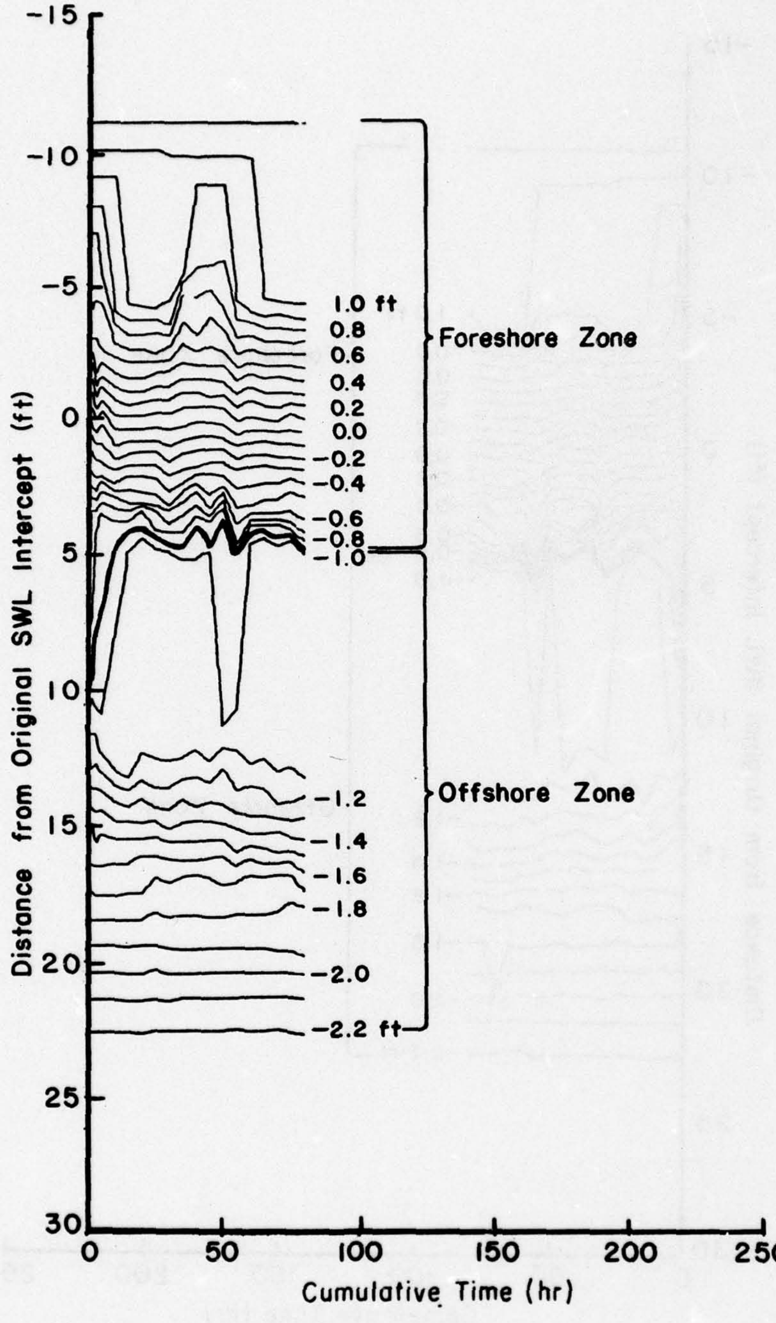


Figure 18. Profile changes along range 7, experiment 72A-10.

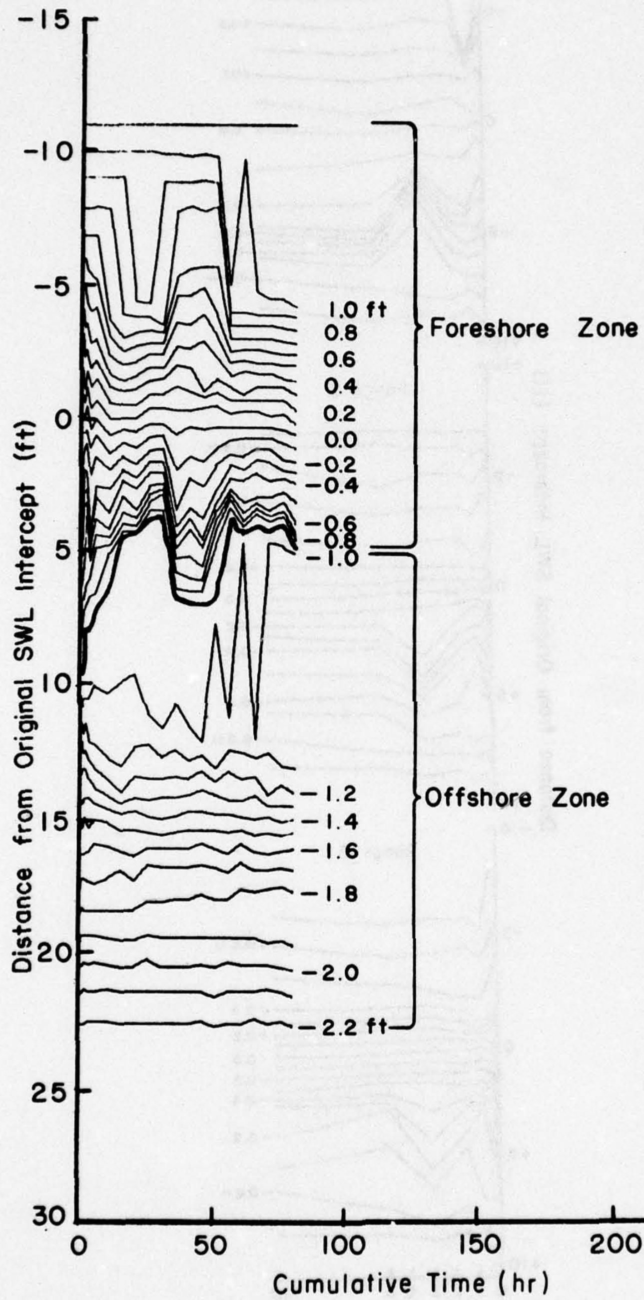


Figure 19. Profile changes along range 9, experiment 72A-10.

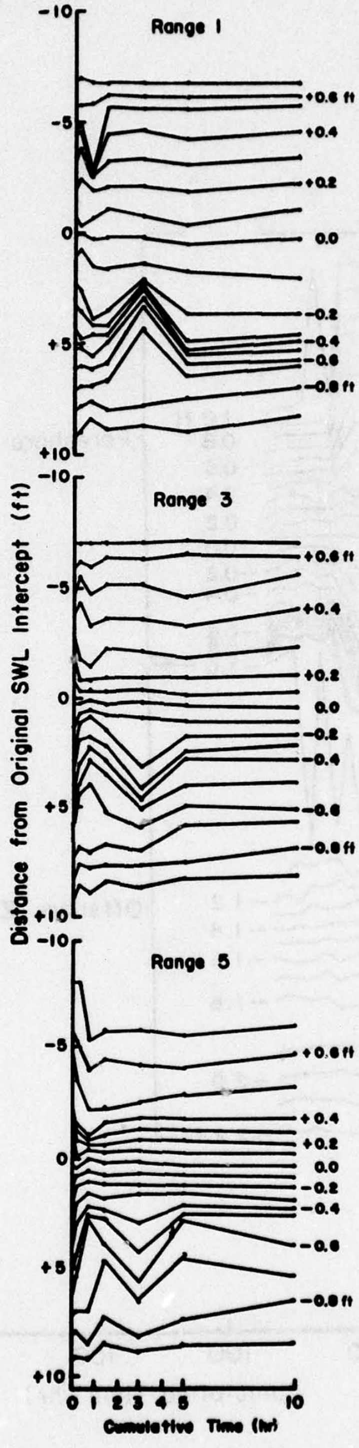


Figure 20. Foreshore contour movement during first 10 hours of experiment 72A-06.

Table 7. Slope of the beach face at the SWL intercept in experiments' 72A-06 and 72A-10.

Cumulative time (hr:min)	Tangent of the slope							
	Range 1		Range 3		Range 5		Range 7	Range 9
	72A-06	72A-10	72A-06	72A-10	72A-06	72A-10	72A-10	72A-10
0:00	0.10	0.06	0.10	0.10	0.10	0.10	0.14	0.12
0:10	0.30	0.16	0.20	0.20	0.30	0.22	0.24	0.18
0:40	0.16	0.14	0.20	0.24	0.18	0.14	0.18	0.20
1:30	0.06	0.12	0.18	0.22	0.18	0.18	0.18	0.12
3:00	0.12	0.16	0.18	0.20	0.20	0.20	0.22	0.12
5:00	0.08	0.18	0.22	0.18	0.24	0.36	0.22	0.14
10:00	0.08	0.16	0.14	0.20	0.18	0.20	0.18	0.16
15:00	0.10	0.16	0.12	0.20	0.12	0.22	0.22	0.22
20:00	0.12	0.16	0.18	0.20	0.20	0.18	0.20	0.16
25:00	0.14	0.22	0.16	0.22	0.16	0.18	0.18	0.20
30:00	0.12	0.22	0.12	0.20	0.16	0.18	0.16	0.18
35:00	0.14	0.20	0.16	0.22	0.18	0.20	0.10	0.12
40:00	0.10	0.20	0.16	0.20	0.18	0.18	0.16	0.16
45:00	0.12	0.20	0.16	0.20	0.18	0.20	0.18	0.12
50:00	0.12	0.20	0.18	0.22	0.18	0.20	0.18	0.14
55:00	0.06	0.18	0.16	0.22	0.22	0.14	0.22	0.18
60:00	0.12	0.24	0.14	0.20	0.20	0.16	0.18	0.18
65:00	0.14	0.24	0.22	0.26	0.22	0.18	0.20	0.18
70:00	0.16	0.20	0.20	0.24	0.22	0.24	0.26	0.26
75:00	0.12	0.12	0.22	0.14	0.22	0.18	0.18	0.18
80:00	0.10	0.30	0.18	0.22	0.20	0.22	0.22	0.22
85:00	0.14		0.18		0.22			
90:00	0.14		0.20		0.22			
95:00	0.18		0.20		0.18			
100:00	0.14		0.20		0.24			
105:00	0.12		0.22		0.20			
110:00	0.12		0.24		0.24			
115:00	0.14		0.14		0.20			
120:00	0.12		0.20		0.20			
125:00	0.16		0.24		0.24			
130:00	0.08		0.14		0.22			
135:00	0.14		0.16		0.18			
Avg at 80 hr	0.123	0.188	0.174	0.209	0.197	0.198	0.193	0.171
at 135 hr	0.127		0.187		0.203			

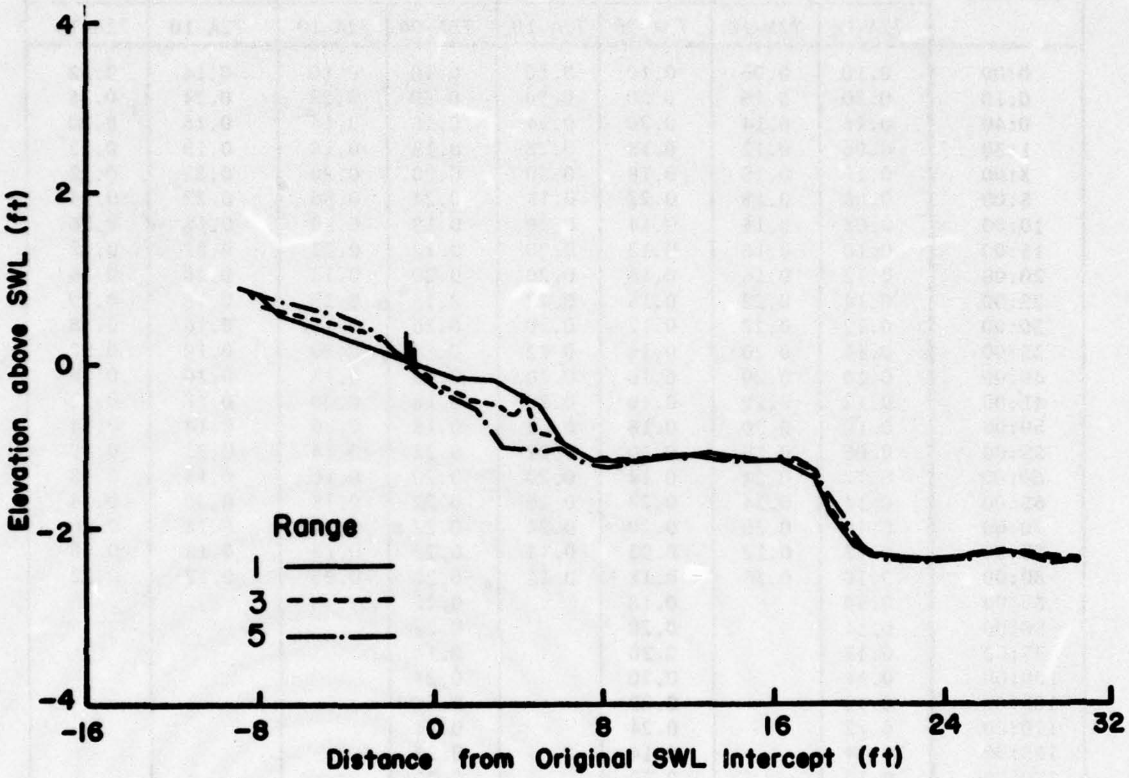


Figure 21. Comparison of profiles along ranges 1, 3, and 5 at 90 hours in experiment 72A-06.

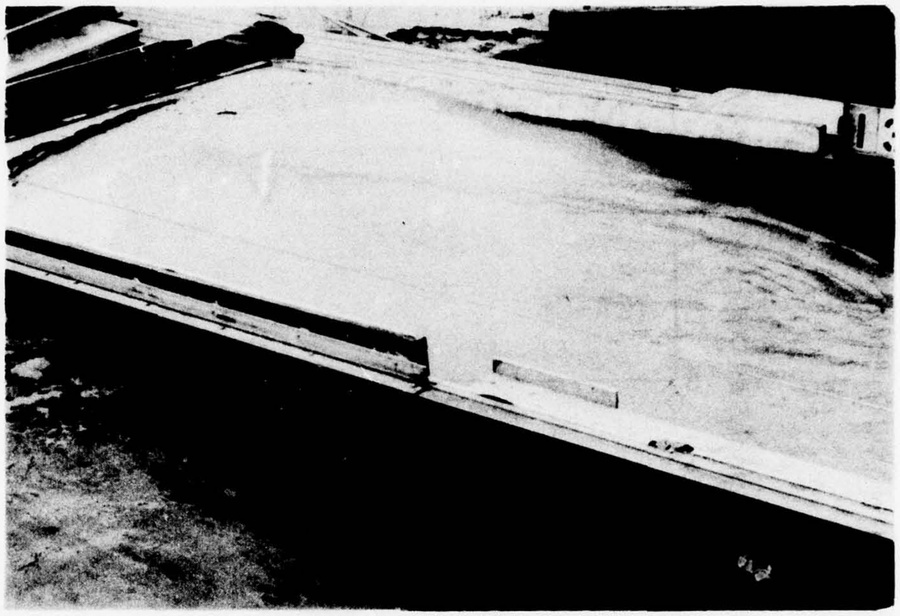


Figure 22. Shape of the foreshore zone in experiment 72A-06.

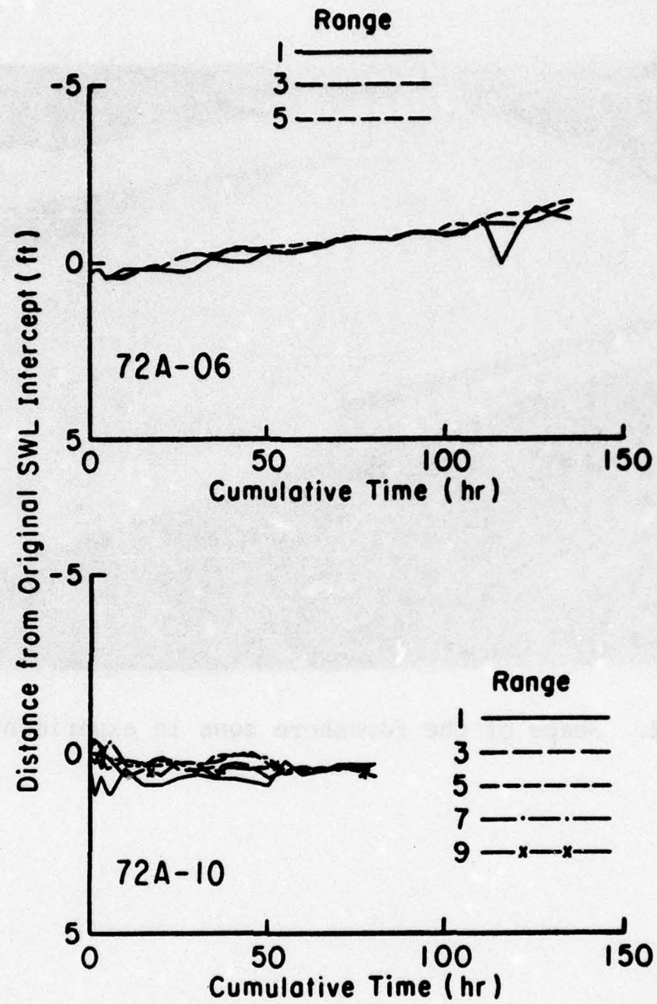


Figure 23. Shoreline (0 contour) movement.

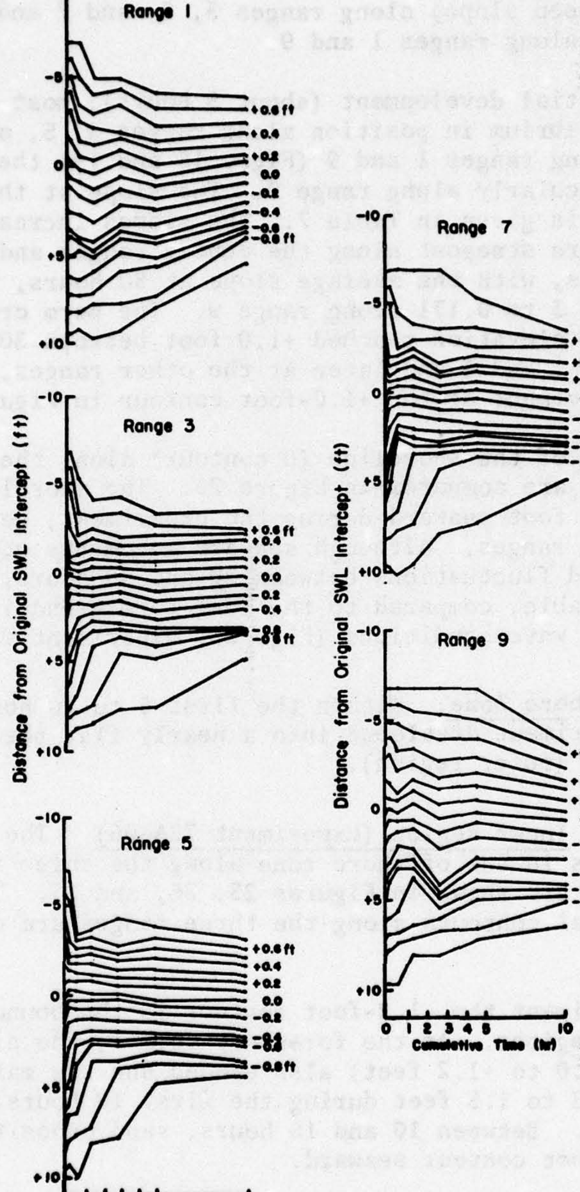


Figure 24. Foreshore contour movement during first 10 hours of experiment 72A-10.

along the five ranges during the first 10 hours of experiment 72A-10). The steepness of the beach varied across the tank, as indicated by the close spacing (steep slope) along ranges 3, 5, and 7 and wider spacing (flatter slopes) along ranges 1 and 9.

After the initial development (about 5 hours), most of the foreshore zone was at equilibrium in position along ranges 3, 5, and 7 (Figs. 16, 17, and 18). Along ranges 1 and 9 (Figs. 15 and 19) the position fluctuated, particularly along range 9. The slope at the SWL intercept along each range is given in Table 7. The slopes increased, in general, with time, and were steepest along the center ranges and flattest along the outside ranges, with the average slope at 80 hours, varying from 0.209 along range 3 to 0.171 along range 9. The berm crest marking the maximum foreshore elevation reached +1.0 foot between 30 and 70 hours, earlier at ranges 1 and 3 and later at the other ranges, as indicated by the seaward movement of the +1.0-foot contour in Figures 15 to 19.

The movements of the shoreline (0 contour) along the five ranges of experiment 72A-10 are compared in Figure 23. The shoreline advanced approximately 0.5 foot seaward during the experiment, beginning first along the outside ranges. Although seaward movements occurred between 0 and 25 hours and fluctuations between 30 and 50 hours, the shoreline was relatively stable, compared to the long-term trend in the 6-foot tank for the same wave conditions (Fig. 23, experiment 72A-06).

(2) Offshore Zone. Within the first 5 to 10 hours the offshore zone in each experiment developed into a nearly flat shelf (inner region) and a steep slope (outer region).

(a) Inner Region (Experiment 72A-06). The movements of all contour intercepts in the offshore zone along the three ranges for experiment 72A-06 are shown in Figures 25, 26, and 27. The movements of selected individual contours along the three ranges are compared in Figure 28.

In this experiment the -1.2-foot contour is the boundary between the inner and outer regions. As the foreshore formed, the area just below the foreshore (-1.0 to -1.2 feet) also eroded and the material deposited at depths from 1.3 to 1.5 feet during the first 10 hours, forming the nearly flat shelf. Between 10 and 15 hours, sand deposited on the shelf, moving the -1.2-foot contour seaward.

For the next 55 hours (until 70 hours) the shelf continued to grow in both directions; the depth over the shelf varied from -1.0 to -1.3 feet, as shown by the widening of the distance between the -0.9- and -1.2-foot contours and the multiple intercepts for all depths of -1.0 to -1.3 feet in Figures 24, 25, and 26. The multiple intercepts indicate that the shelf developed into a bar and trough, with the crest of the bar at about station +15 and the bottom of the trough between stations +10 and +12.

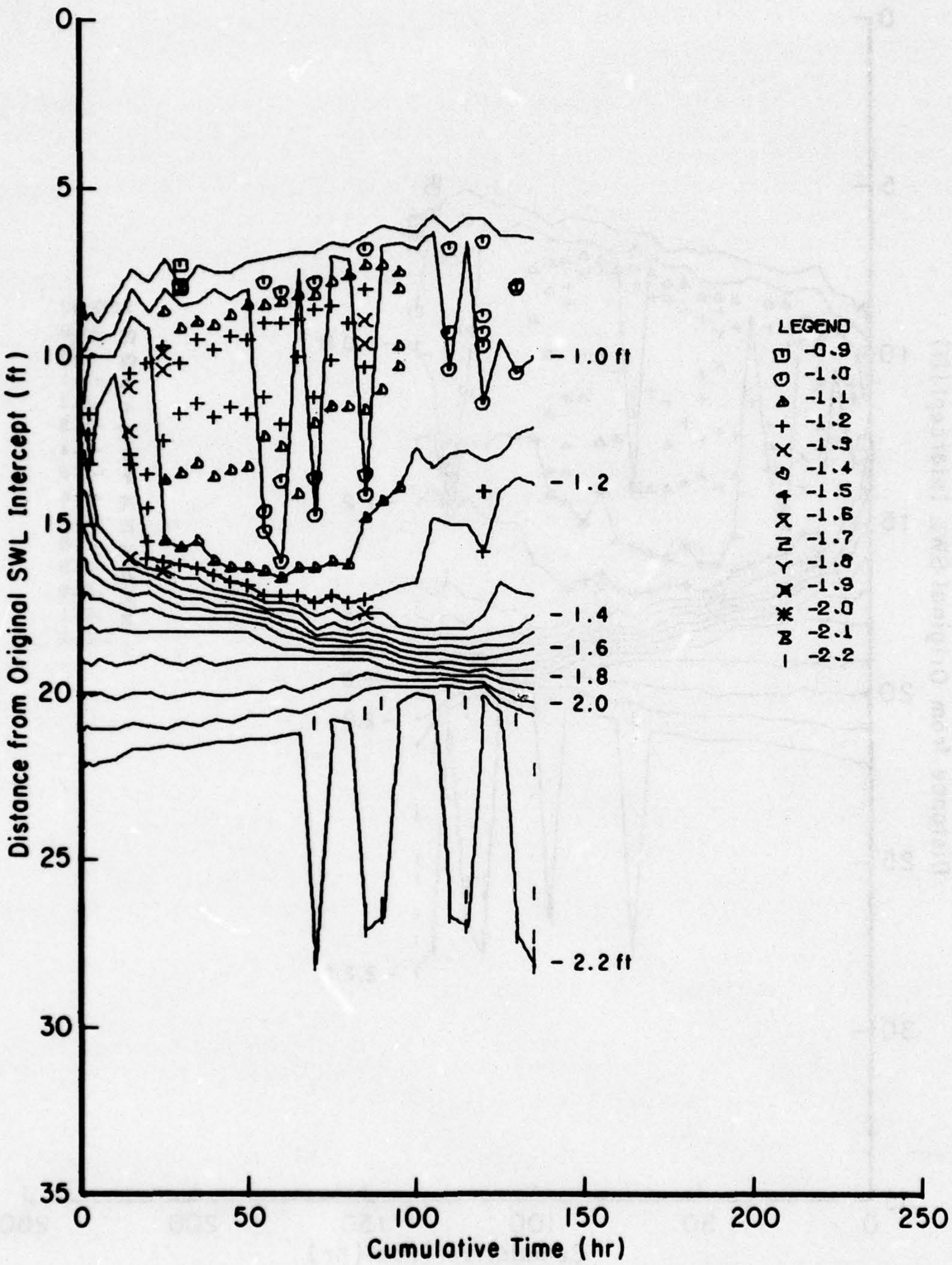


Figure 25. Changes in the offshore zone along range 1, experiment 72A-06.

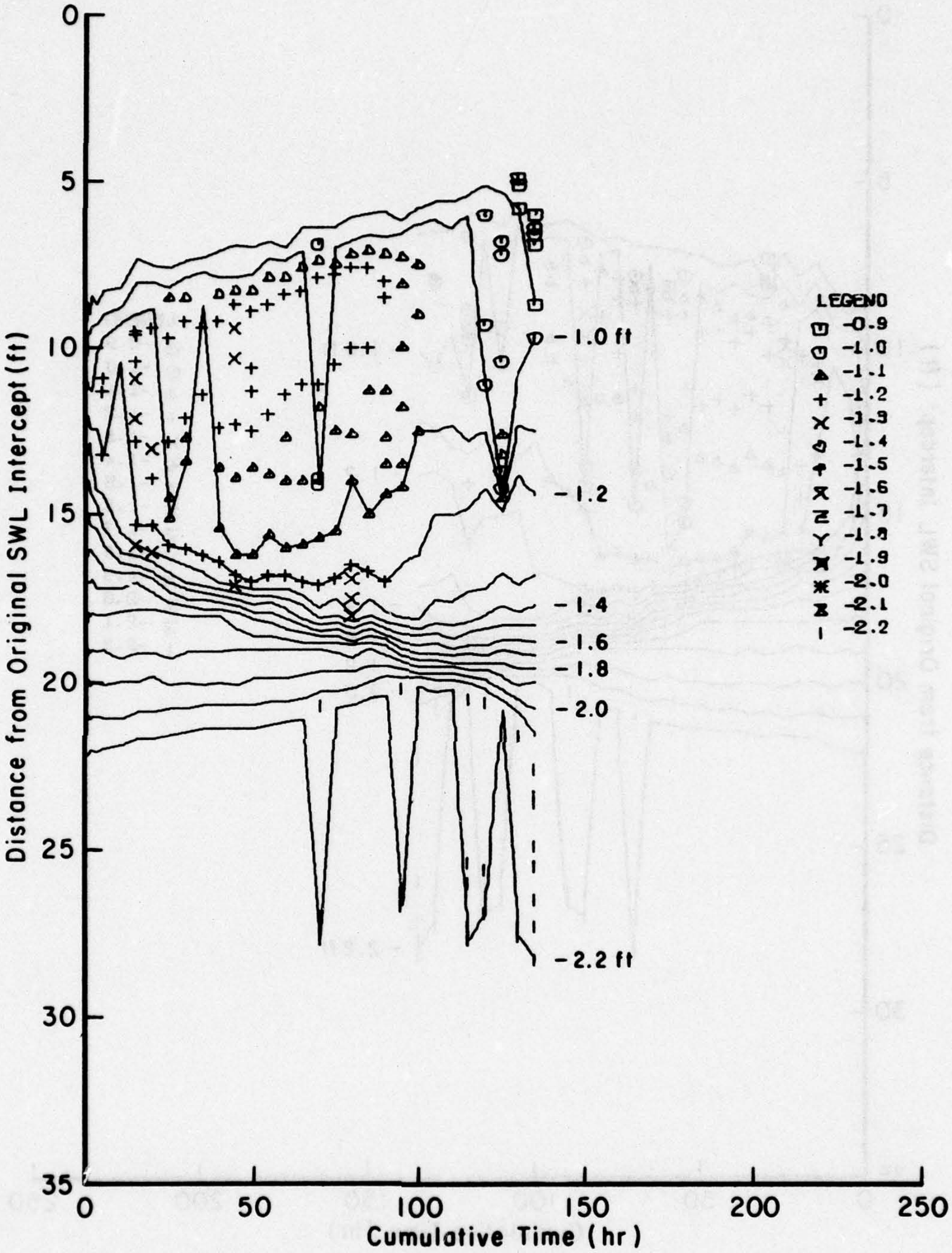


Figure 26. Changes in the offshore zone along range 3, experiment 72A-06.

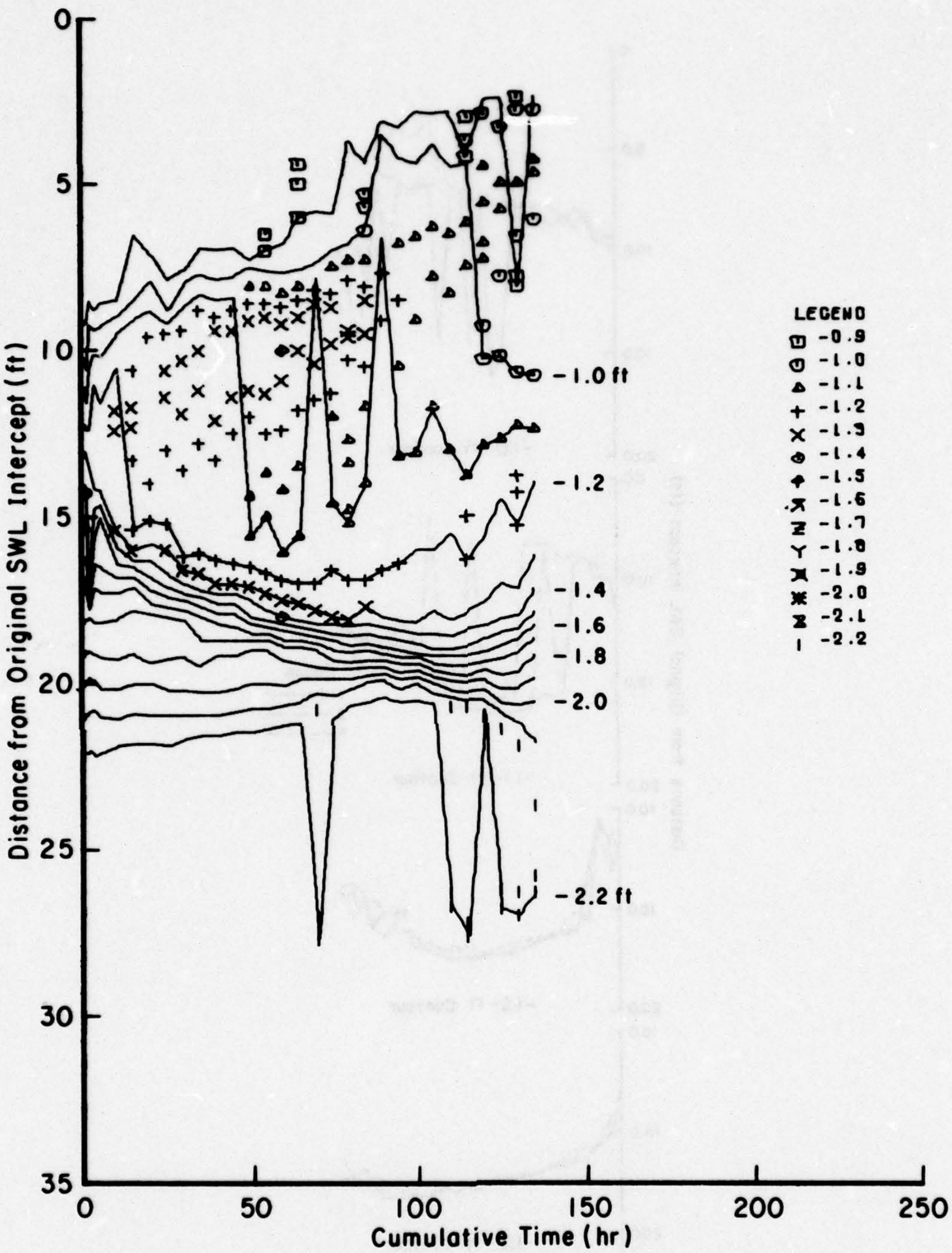


Figure 27. Changes in the offshore zone along range 5, experiment 72A-06.

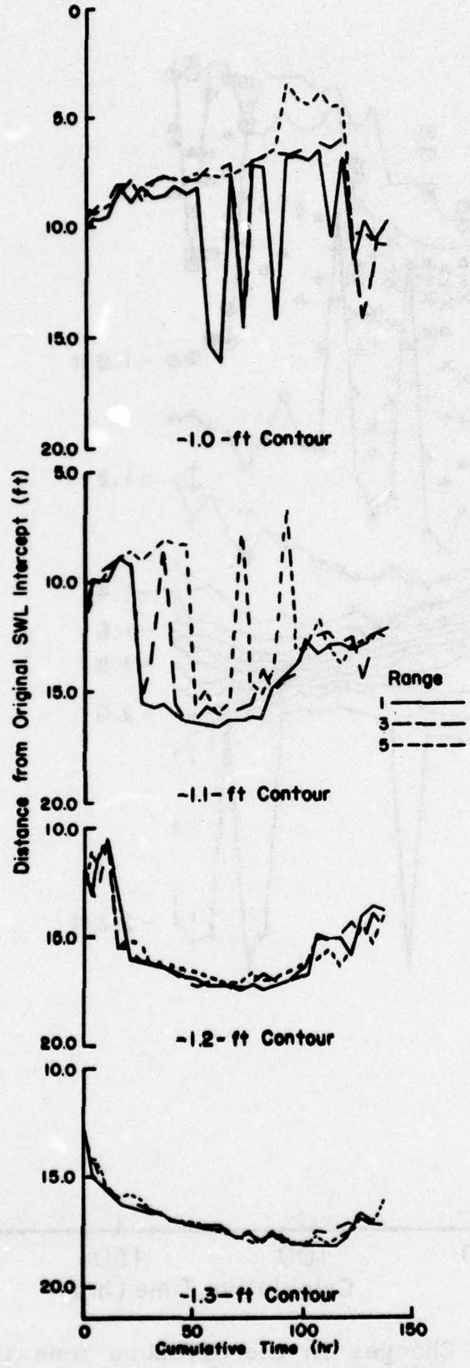


Figure 28. Movement of the offshore zone in experiment 72A-06; comparison of the -1.0-, -1.1-, -1.2-, and -1.3-foot contours.

After 70 hours the seaward edge of the shelf (-1.2-foot contour) began to move in the shoreward direction. By 100 hours the bar had been mostly eroded and the trough was only 0.1 foot or less below the elevation of the rest of the shelf, thus making the inner region a gently sloping area rather than a shelf.

Only slight lateral variations occurred in the movement of the -1.2-foot contour (Fig. 28), indicating that the boundary between the two regions was normal to the direction of wave propagation. At the -1.0- and -1.1-foot elevations there were lateral variations in contour position. The -1.0-foot contour movement (Fig. 28) indicates that the bar crest near station 15 reached an elevation of -1.0 foot, three times along range 1 and once along range 3. The -1.1-foot contour movement (Fig. 28) indicates that the depth over the shelf edge permanently reached -1.1 feet first along range 1, then range 3, and then range 5.

(b) Outer Region (Experiment 72A-06). Changes in the outer region occurred uniformly across the tank. This is indicated by the lack of lateral variation in the position of the -1.3-foot contour in Figure 28, but these changes were unusual in that the slope reached a maximum and then began to decrease, as shown by the spacing between -1.3- to -2.1-foot contours in Figures 25, 26, and 27.

During the first 15 hours, most of the deposition in this outer region occurred at elevations -1.3 to -1.6 feet, where a steep slope quickly formed (e.g., Fig. 26). This was representative of changes along the other ranges. As more material deposited at the shoreward edge of the slope and slid down, other contours began moving seaward, the -1.7-foot contour at 15 hours, the -1.8-foot contour at 40 hours, and the -1.9-foot contour at 85 hours. At the base of the slope, erosion began first at the -2.2-foot contour from the beginning and then at the -2.1-foot contour at 10 hours and continued until 100 hours. The eroded material deposited on a bar which formed seaward of the profile (between stations +26 and +28) at 40 hours. The bar crest elevation reached -2.2 feet at times which differed across the tank (see Fig. 29).

The initial offshore slope was 0.10. At 100 hours the offshore slope was 0.36; after 100 hours the offshore slope became milder as the seaward edge of the shelf eroded shoreward and material was deposited at depths below 1.7 feet. At 135 hours, the offshore slope was 0.175. The area from station +23.5 to +28.2 had an elevation of -2.2 feet.

(c) Inner Region (Experiment 72A-10). The -1.1-foot contour is the boundary between the inner region (shelf) and the outer region (steep slope) in this experiment.

With the first 10 hours the nearly flat shelf formed, as evidenced by the shoreward movement of the -1.0-foot contour in Figures 30 to 34. The edge of the shelf (-1.1-foot contour) moved to station +12 at 10 hours and to station +13 at 15 hours, remaining between those two stations for the remainder of the experiment.

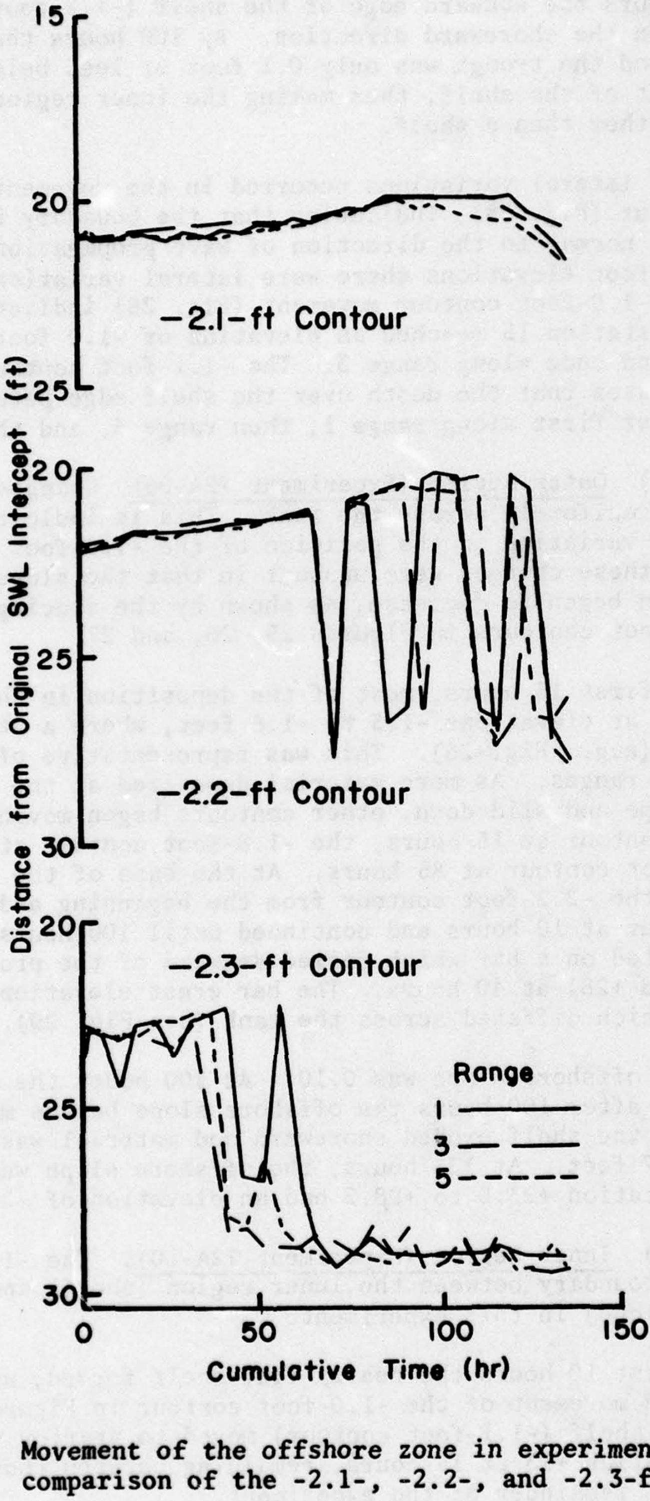


Figure 29. Movement of the offshore zone in experiment 72A-06; comparison of the -2.1-, -2.2-, and -2.3-foot contours.

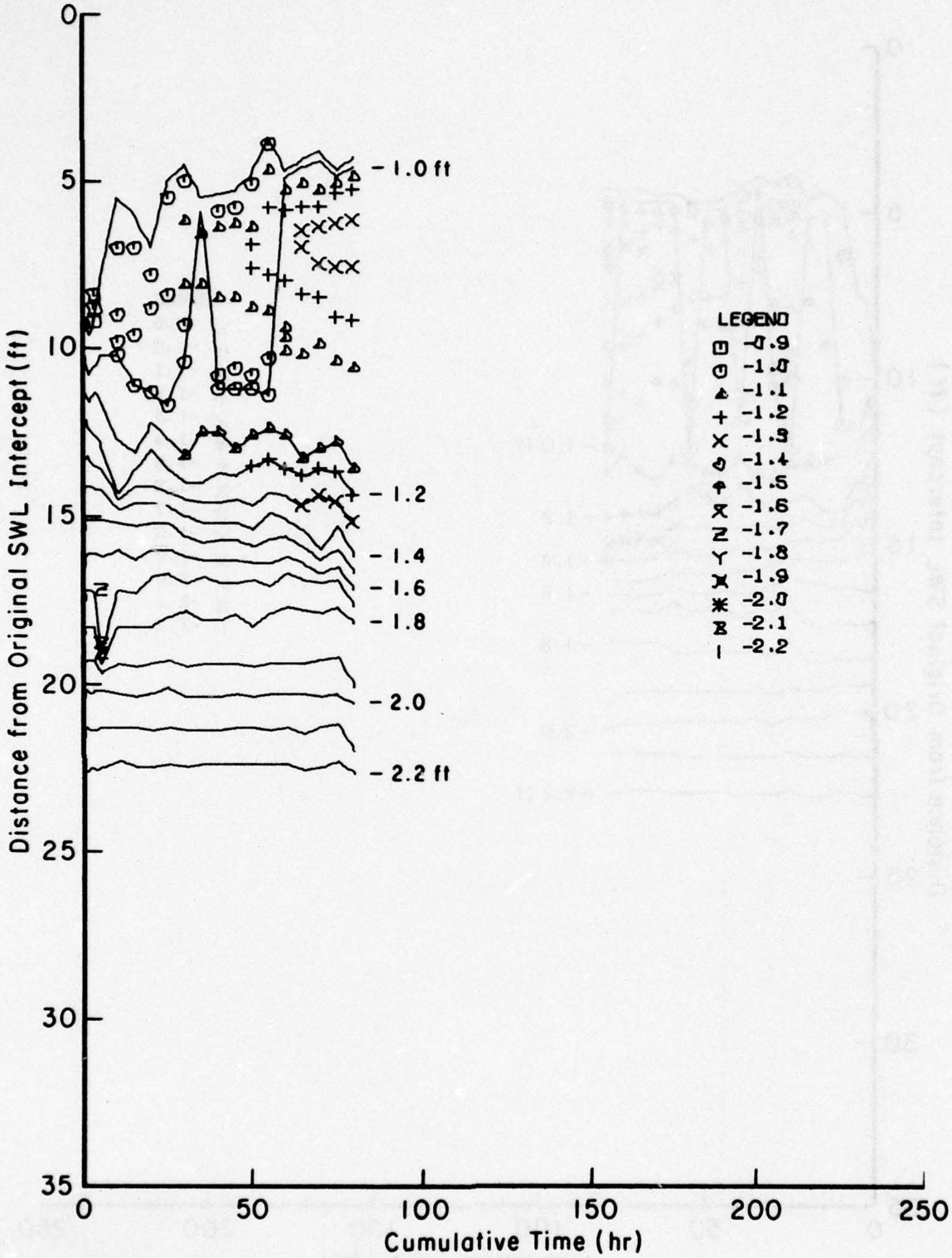


Figure 30. Changes in the offshore zone along range 1, experiment 72A-10.

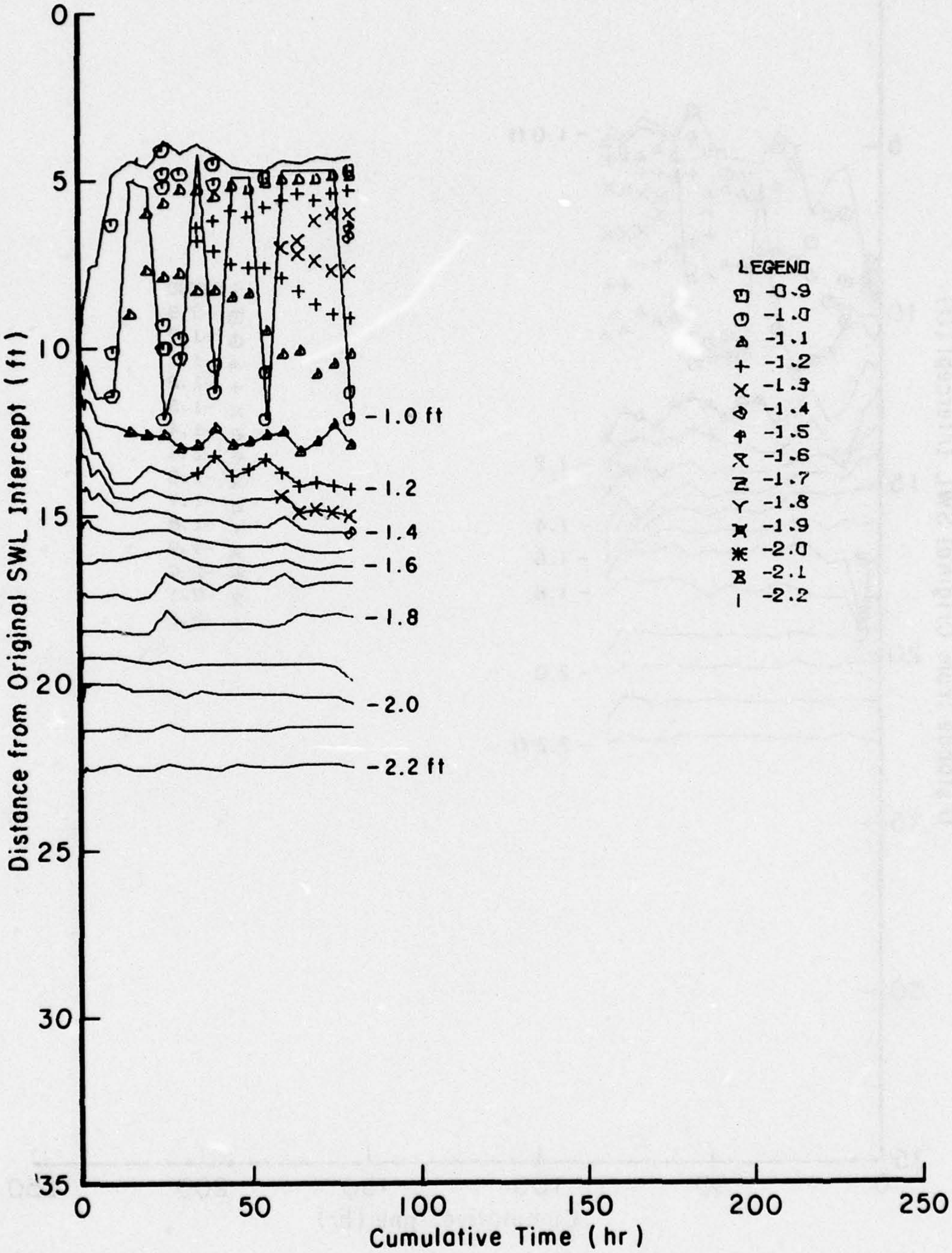


Figure 31. Changes in the offshore zone along range 3, experiment 72A-10.

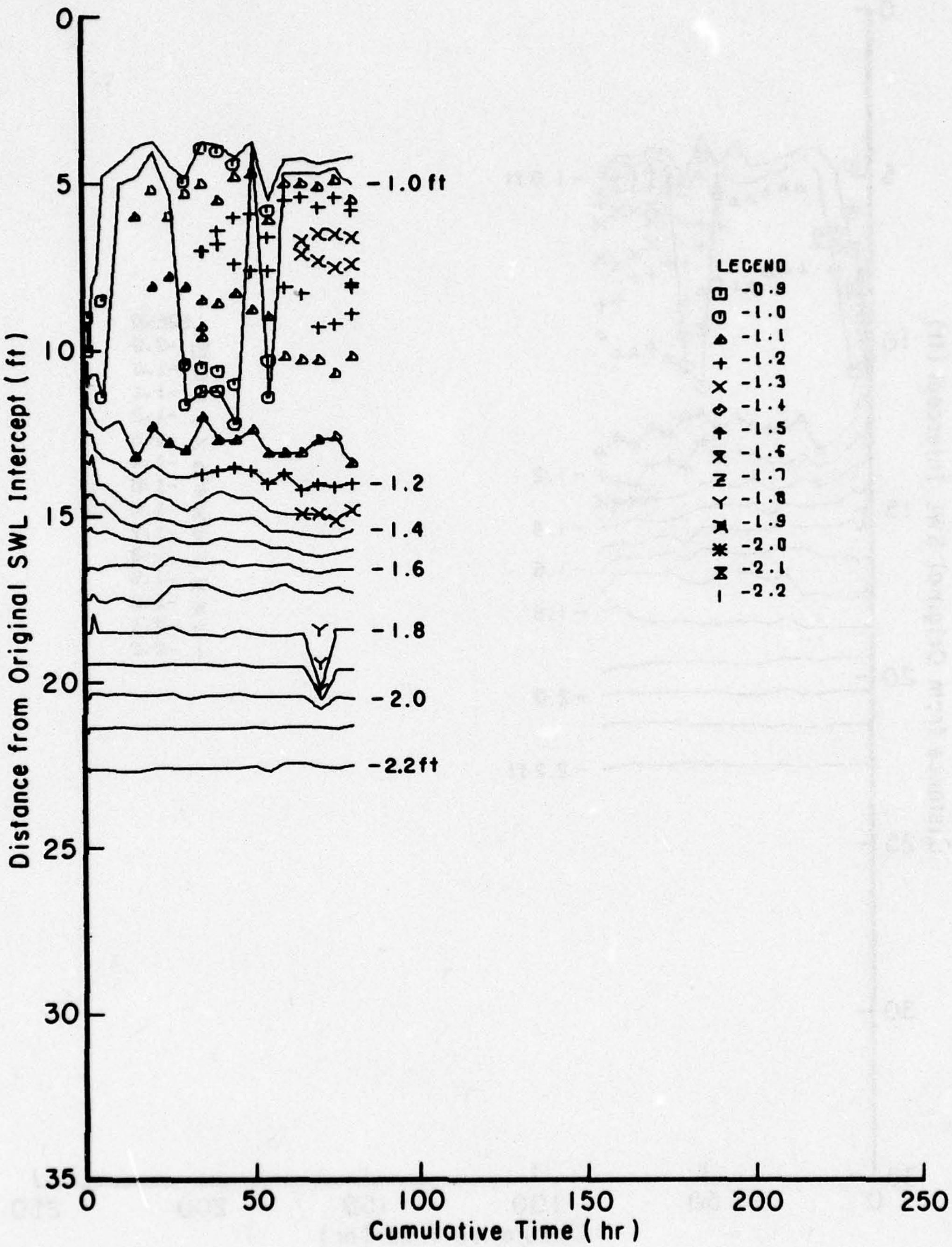


Figure 32. Changes in the offshore zone along range 5, experiment 72A-10.

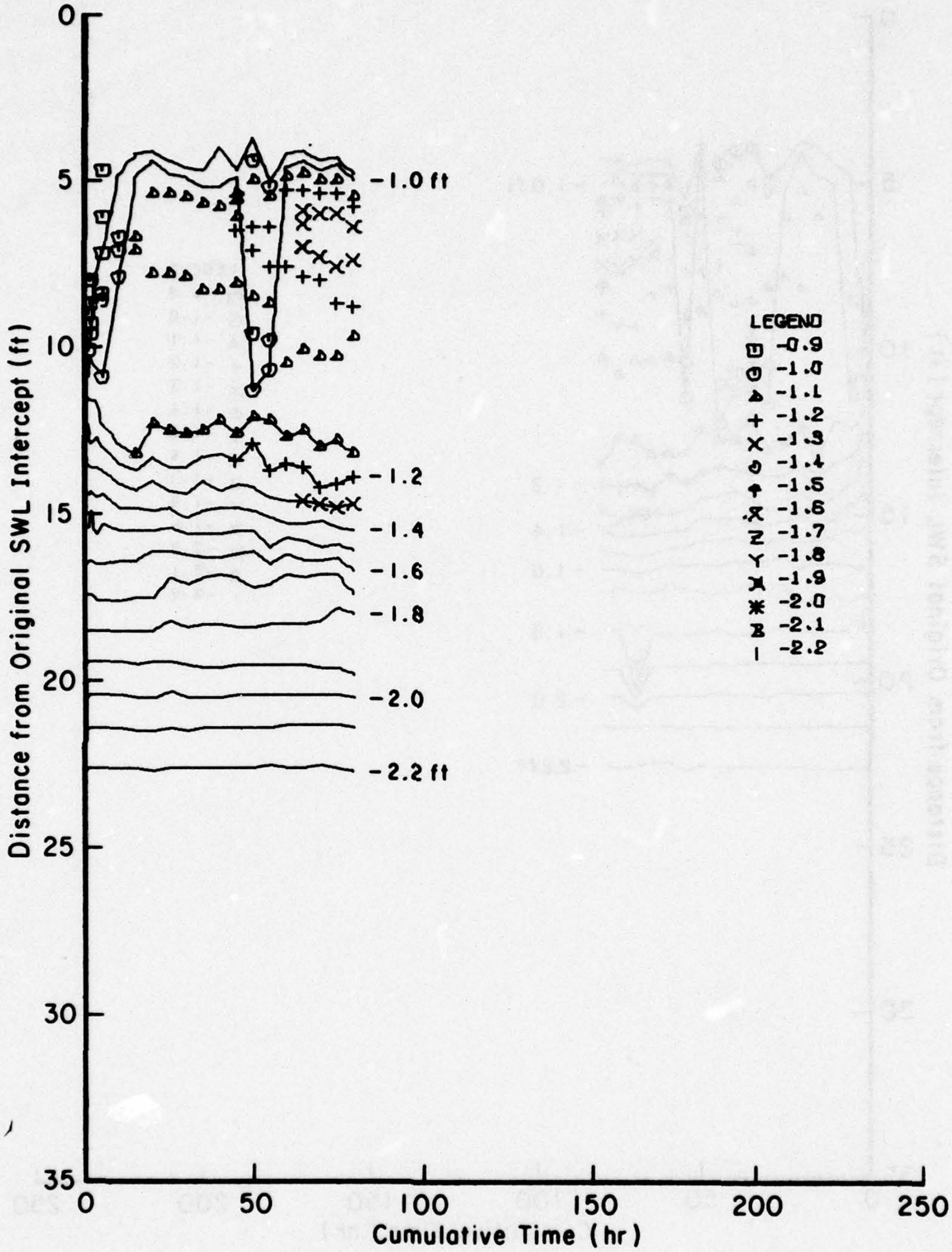


Figure 33. Changes in the offshore zone along range 7, experiment 72A-10

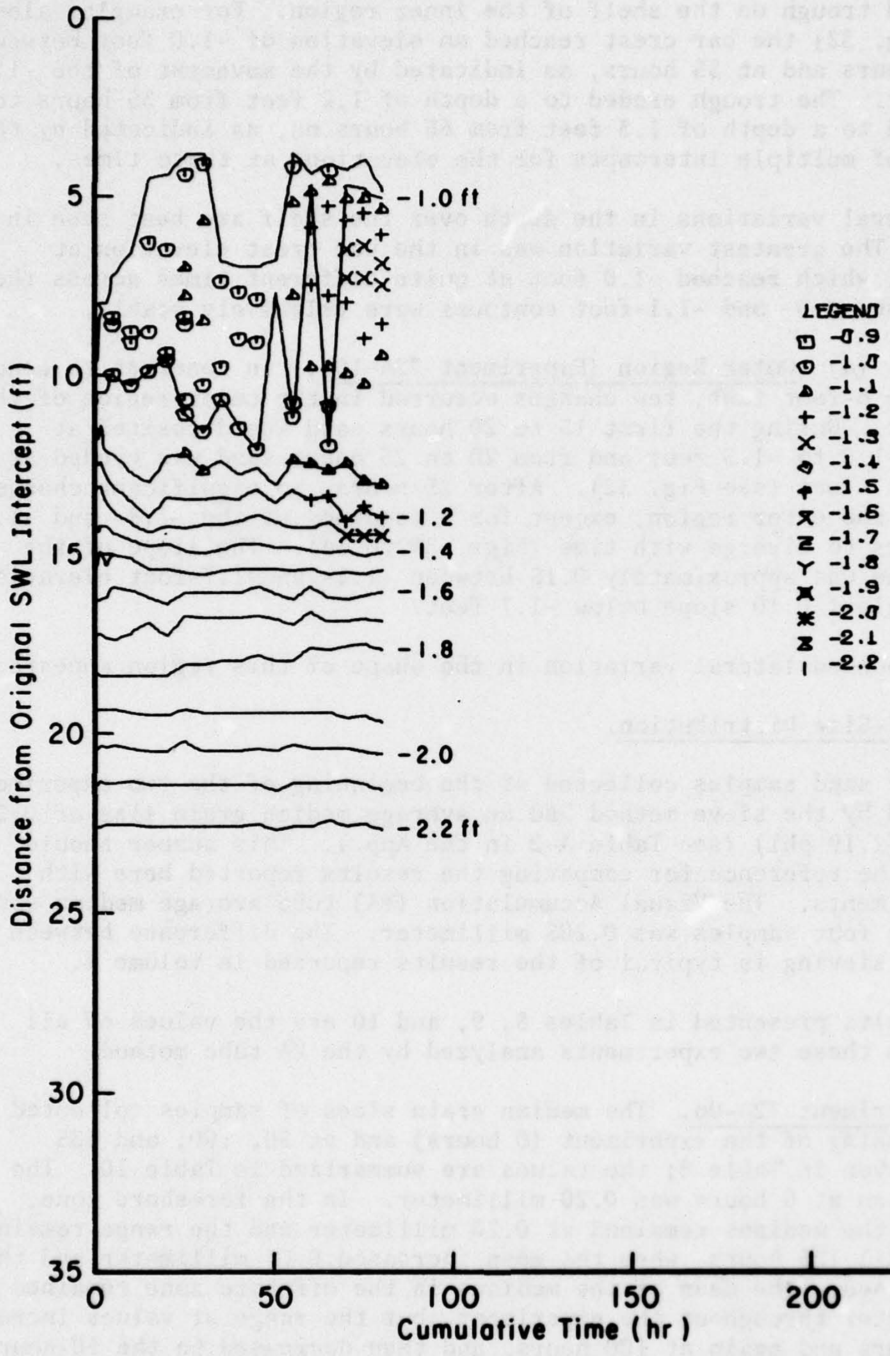


Figure 34. Changes in the offshore zone along range 9, experiment 72A-10.

The multiple intercepts in Figures 30 to 34 indicate the development of a bar and trough on the shelf of the inner region. For example, along range 5 (Fig. 32) the bar crest reached an elevation of -1.0 foot between 30 and 45 hours and at 55 hours, as indicated by the movement of the -1.0-foot contour. The trough eroded to a depth of 1.2 feet from 35 hours to 65 hours and to a depth of 1.3 feet from 65 hours on, as indicated by the appearance of multiple intercepts for the elevations at those times.

The lateral variations in the depth over the shelf are best seen in Figure 35. The greatest variation was in the bar crest elevation at station +12, which reached -1.0 foot at quite different times across the tank when the -0.9- and -1.1-foot contours were relatively stable.

(d) Outer Region (Experiment 72A-10). In contrast to conditions in the 6-foot tank, few changes occurred in the outer region of the 10-foot tank. During the first 15 to 20 hours sand was deposited at elevations -1.2 to -1.5 feet and from 20 to 25 hours sand was eroded at -1.6 and -1.7 feet (see Fig. 32). After 25 hours, no significant change occurred in the outer region, except for a tendency of the -1.8- and -1.9-foot contours to diverge with time (Figs. 30 to 34). The slope of the offshore zone was approximately 0.15 between -1.1- and-1.7-foot elevations and the original 0.10 slope below -1.7 feet.

No pronounced lateral variation in the shape of this region appeared.

3. Sediment-Size Distribution.

The four sand samples collected at the beginning of the two experiments and analyzed by the sieve method had an average median grain size of 0.22 millimeter (2.19 phi) (see Table A-2 in the App.). This number should be used as the reference for comparing the results reported here with other experiments. The Visual Accumulation (VA) tube average median size for the same four samples was 0.205 millimeter. The difference between VA tube and sieving is typical of the results reported in Volume I.

The results presented in Tables 8, 9, and 10 are the values of all samples from these two experiments analyzed by the VA tube method.

a. Experiment 72A-06. The median grain sizes of samples collected at the beginning of the experiment (0 hours) and at 50, 100, and 135 hours are given in Table 8; the values are summarized in Table 10. The average median at 0 hours was 0.20 millimeter. In the foreshore zone, the mean of the medians remained at 0.20 millimeter and the range remained the same until 135 hours, when the mean increased 0.01 millimeter and the range increased. The mean of the medians in the offshore zone remained at 0.20 millimeter throughout the experiment, but the range of values increased at 50 hours and again at 100 hours, and then decreased to the 50-hour range at 135 hours. There was no significant change in sediment-size distribution, compared to the other LEBS experiments.

b. Experiment 72A-10. The median grain sizes of samples collected at the beginning of the experiment (0 hours) and at 50 and 80 hours are

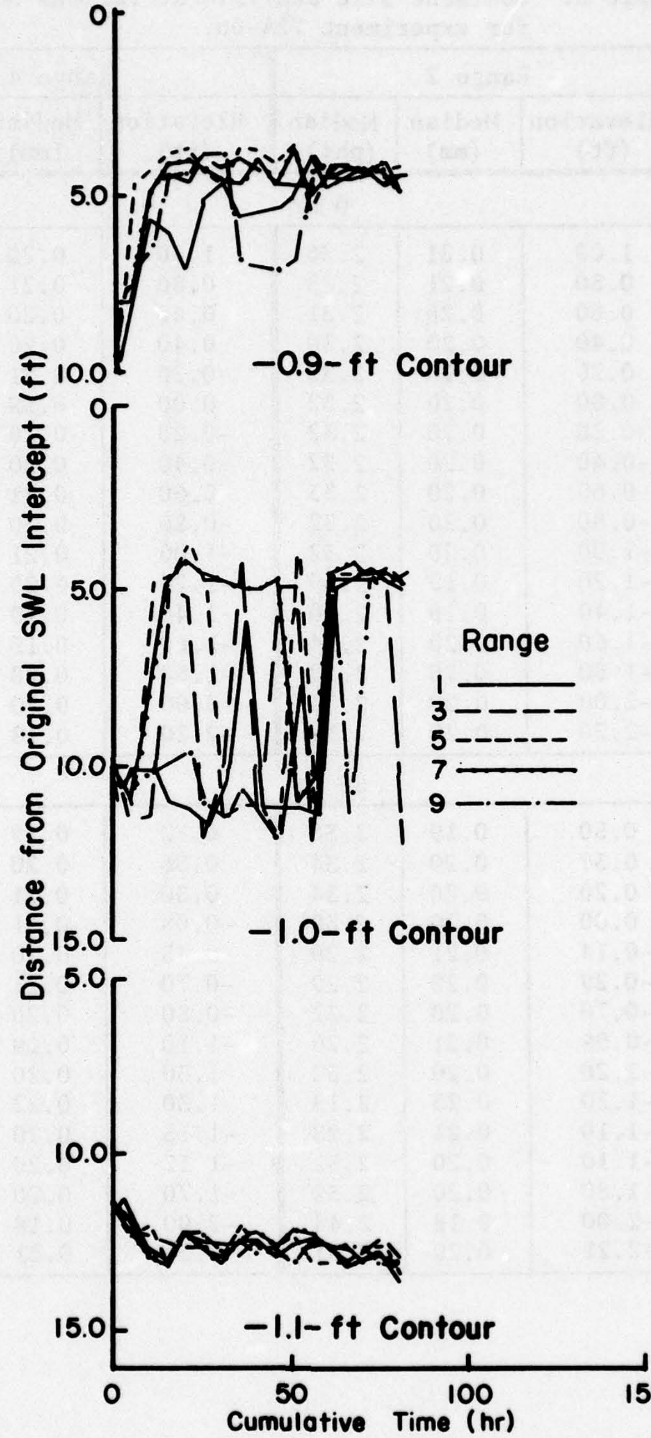


Figure 35. Movement of the offshore zone in experiment 72A-10; comparison of the -0.9-, -1.0-, and -1.1-foot contours.

Table 8. Sediment-size analysis at various hours for experiment 72A-06.

Station (ft)	Range 2 Elevation (ft)	Range 2 Median (mm)	Range 2 Median (phi)	Range 4 Elevation (ft)	Range 4 Median (mm)	Range 4 Median (phi)
0 Hr						
-10	1.00	0.21	2.26	1.00	0.20	2.36
-8	0.80	0.21	2.28	0.80	0.21	2.27
-6	0.60	0.20	2.31	0.60	0.20	2.32
-4	0.40	0.20	2.30	0.40	0.20	2.34
-2	0.20	0.20	2.32	0.20	0.21	2.29
0	0.00	0.20	2.32	0.00	0.19	2.38
2	-0.20	0.20	2.32	-0.20	0.20	2.32
4	-0.40	0.20	2.32	-0.40	0.20	2.35
6	-0.60	0.20	2.33	-0.60	0.21	2.29
8	-0.80	0.20	2.32	-0.80	0.20	2.31
10	-1.00	0.20	2.32	-1.00	0.21	2.25
12	-1.20	0.19	2.39	-1.20	0.20	2.33
14	-1.40	0.19	2.40	-1.40	0.19	2.38
16	-1.60	0.20	2.34	-1.60	0.19	2.38
18	-1.80	0.20	2.30	-1.80	0.20	2.36
20	-2.00	0.20	2.32	-2.00	0.20	2.32
22	-2.20	0.20	2.35	-2.20	0.18	2.44
50 Hr						
-6	0.50	0.19	2.38	0.72	0.19	2.38
-4	0.37	0.20	2.34	0.56	0.20	2.36
-2	0.20	0.20	2.34	0.30	0.21	2.29
0	0.00	0.20	2.30	-0.08	0.21	2.25
2	-0.14	0.21	2.29	-0.45	0.20	2.29
4	-0.29	0.20	2.29	-0.70	0.21	2.27
6	-0.70	0.20	2.32	-0.80	0.20	2.31
8	-0.95	0.21	2.26	-1.10	0.19	2.37
10	-1.20	0.20	2.32	-1.30	0.20	2.32
12	-1.20	0.23	2.13	-1.30	0.22	2.18
14	-1.10	0.21	2.28	-1.15	0.20	2.32
16	-1.10	0.20	2.32	-1.12	0.20	2.36
18	-1.80	0.20	2.32	-1.70	0.20	2.31
20	-2.00	0.18	2.44	-2.00	0.18	2.48
22	-2.21	0.20	2.31	-2.21	0.21	2.27

Table 8. Sediment-size analysis at various hours for experiment 72A-06.-Continued

Station (ft)	Range 1 Elevation (ft)	Range 1 Median (mm)	Range 1 Median (phi)	Range 5 Elevation (ft)	Range 5 Median (mm)	Range 5 Median (phi)
			100 Hr			
-10	1.00	0.20	2.32	1.00	0.20	2.29
-8	0.80	0.20	2.31	0.83	0.21	2.28
-6	0.47	0.19	2.40	0.73	0.19	2.40
-4	0.32	0.20	2.34	0.58	0.21	2.26
-2	0.15	0.19	2.43	0.22	0.20	2.31
0	-0.03	0.21	2.29	-0.10	0.21	2.26
2	-0.17	0.21	2.27	-0.50	0.21	2.27
4	-0.24	0.21	2.28	-1.00	0.20	2.29
6	-0.75	0.21	2.28	-1.05	0.20	2.35
8	-1.10	0.24	2.07	-1.10	0.25	2.01
10	-1.10	0.20	2.31	-1.10	0.23	2.11
12	-1.10	0.21	2.25	-1.10	0.21	2.29
14	-1.12	0.20	2.32	-1.11	0.19	2.38
16	-1.17	0.19	2.40	-1.19	0.19	2.38
18	-1.22	0.20	2.29	-1.40	0.18	2.51
20	-2.00	0.20	2.34	-2.00	0.18	2.51
22	-2.30	0.20	2.33	-2.30	0.21	2.24
24	-2.30	0.20	2.31	-2.30	0.22	2.20
26	-2.30	0.20	2.34	-2.30	0.22	2.22
28	-2.30	0.20	2.32	-2.30	0.20	2.31
30	-2.33	0.16	2.64	-2.33	0.19	2.41
			135 Hr			
-10	1.01	0.20	2.32	1.12	0.22	2.18
-8	0.68	0.19	2.38	0.86	0.19	2.41
-6	0.47	0.20	2.34	0.73	0.21	2.24
-4	0.29	0.22	2.21	0.55	0.21	2.24
-2	0.08	0.22	2.18	0.05	0.20	2.31
0	-0.10	0.24	2.06	-0.21	0.22	2.18
2	-0.17	0.22	2.21	-0.60	0.20	2.32
4	-0.28	0.24	2.06	-1.06	0.20	2.35
6	-0.84	0.22	2.16	-1.00	0.21	2.25
8	-0.93	0.23	2.13	-1.00	0.23	2.11
10	-0.99	0.22	2.20	-1.00	0.21	2.25
12	-1.06	0.20	2.31	-1.05	0.20	2.31
14	-1.20	0.20	2.34	-1.18	0.19	2.41
16	-1.25	0.20	2.34	-1.28	0.19	2.38
18	-1.60	0.20	2.34	-1.60	0.19	2.39
20	-1.90	0.20	2.34	-1.90	0.18	2.47
22	-2.20	0.20	2.32	-2.10	0.19	2.39
24	-2.30	0.22	2.18	-2.20	0.20	2.34
26	-2.20	0.20	2.31	-2.20	0.20	2.32
28	-2.20	0.19	2.39	-2.27	0.19	2.39
30	-2.33	0.19	2.42	-2.33	0.19	2.43

Table 9. Sediment-size analysis at various hours for experiment 72A-10.

Station (ft)	Range 1 Elevation (ft)	Range 1 Median (mm)	Range 1 Median (phi)	Range 5 Elevation (ft)	Range 5 Median (mm)	Range 5 Median (phi)	Range 9 Elevation (ft)	Range 9 Median (mm)	Range 9 Median (phi)
				0 Hr					
-6	0.60	0.20	2.31	0.60	0.21	2.26	0.60	0.20	2.29
-4	0.40	0.21	2.24	0.40	0.20	2.32	0.40	0.21	2.29
-2	0.20	0.20	2.32	0.20	0.21	2.29	0.20	0.21	2.27
0	0.00	0.20	2.31	0.00	0.21	2.27	0.00	0.20	2.31
2	-0.20	0.19	2.37	-0.20	0.20	2.35	-0.20	0.20	2.32
4	-0.40	0.20	2.32	-0.40	0.21	2.29	-0.40	0.20	2.32
6	-0.60	0.20	2.30	-0.60	0.20	2.32	-0.60	0.20	2.34
8	-0.80	0.20	2.32	-0.80	0.20	2.36	-0.80	0.21	2.29
10	-1.00	0.21	2.25	-1.00	0.21	2.25	-1.00	0.20	2.33
12	-1.20	0.20	2.35	-1.20	0.20	2.32	-1.20	0.19	2.38
14	-1.40	0.20	2.29	-1.40	0.20	2.31	-1.40	0.20	2.31
16	-1.60	0.20	2.30	-1.60	0.20	2.32	-1.60	0.20	2.32
18	-1.80	0.20	2.31	-1.80	0.21	2.29	-1.80	0.21	2.26
20	-2.00	0.20	2.32	-2.00	0.21	2.29	-2.00	0.21	2.25
22	-2.20	0.21	2.26	-2.20	0.21	2.26	-2.20	0.20	2.32
				50 Hr					
-8	1.00	0.25	2.03	0.90	0.20	2.29	0.95	0.21	2.22
-6	1.00	0.21	2.32	0.90	0.21	2.31	0.75	0.22	2.17
-4	0.90	0.30	1.76	0.85	0.20	2.32	0.60	0.20	2.32
-2	0.50	0.21	2.27	0.45	0.20	2.32	0.35	0.21	2.29
0	0.10	0.22	2.19	0.05	0.23	2.13	0.07	0.23	2.11
2	-0.20	0.25	2.02	-0.40	0.26	1.94	-0.20	0.24	2.06
4	-0.55	0.23	2.12	-1.00	0.23	2.13	-0.35	0.21	2.25
6	-1.10	0.20	2.32	-1.20	0.19	2.41	-0.95	0.22	2.20
8	-1.20	0.22	2.18	-1.26	0.22	2.18	-1.00	0.20	2.36
10	-1.05	0.21	2.26	-1.10	0.22	2.16	-1.03	0.21	2.27
12	-1.05	0.21	2.29	-1.10	0.21	2.26	-1.08	0.19	2.38
14	-1.21	0.20	2.34	-1.25	0.20	2.32	-1.25	0.20	2.35
16	-1.50	0.20	2.35	-1.52	0.18	2.45	-1.58	0.15	2.72
18	-1.76	0.11	3.20	-1.75	0.14	2.83	-1.80	0.15	2.71
20	-1.95	0.19	2.38	-1.95	0.21	2.26	-1.96	0.20	2.31
22	-2.18	0.21	2.29	-2.16	0.21	2.27	-2.15	0.20	2.31
				80 Hr					
-10	1.02	0.20	2.29	1.00	0.20	2.29	1.00	0.21	2.24
-8	0.92	0.24	2.07	0.90	0.23	2.13	0.90	0.22	2.22
-6	1.00	0.21	2.22	1.02	0.21	2.27	1.00	0.21	2.29
-4	1.00	0.20	2.32	0.90	0.20	2.36	0.95	0.20	2.29
-2	0.50	0.28	1.84	0.47	0.20	2.32	0.49	0.21	2.26
0	0.05	0.20	2.32	0.05	0.20	2.32	0.16	0.21	2.22
2	-0.20	0.22	2.22	-0.39	0.23	2.13	-0.21	0.27	1.90
4	-0.60	0.21	2.29	-0.85	0.22	2.21	-0.52	0.22	2.18
6	-1.20	0.19	2.38	-1.20	0.20	2.29	-1.20	0.18	2.47
8	-1.20	0.20	2.31	-1.20	0.21	2.24	-1.20	0.19	2.37
10	-1.15	0.21	2.27	-1.10	0.24	2.06	-1.10	0.20	2.31
12	-1.10	0.20	2.32	-1.10	0.21	2.25	-1.10	0.18	2.44
14	-1.12	0.19	2.41	-1.20	0.20	2.31	-1.19	0.19	2.41
16	-1.40	0.18	2.47	-1.50	0.20	2.34	-1.59	0.16	2.61
18	-1.75	0.19	2.43	-1.75	0.17	2.56	-1.81	0.20	2.32
20	-1.89	0.19	2.38	-1.95	0.17	2.52	-1.94	0.18	2.46
22	-2.13	0.21	2.26	-2.16	0.22	2.20	-2.14	0.19	2.38

Table 10. Summary of median grain sizes within profile zones for experiments 72A-06 and 72A-10.

Cumulative time (hr)	Profile zones					
	Foreshore[1]			Offshore		
	Mean (mm)	Range (mm)	No.	Mean (mm)	Range (mm)	No.
Expt. 72A-06						
50	0.20	0.19 to 0.21	14	0.20	0.18 to 0.23	16
100	0.20	0.19 to 0.21	16	0.20	0.16 to 0.25	26
135	0.21	0.19 to 0.24	16	0.20	0.18 to 0.23	26
Expt. 72A-10						
50	0.22	0.20 to 0.30	20	0.20	0.11 to 0.23	28
80	0.22	0.20 to 0.28	24	0.19	0.16 to 0.24	27

[1]Samples collected on the backshore not included.

Note.--The mean of the median sizes at 0 hours in both experiments was 0.205 millimeter.

given in Table 9; the values are summarized in Table 10. The average median at 0 hours was 0.20 millimeter. In the foreshore zone, the mean median increased to 0.22 millimeter at 50 hours and remained at 0.22 millimeter at 80 hours. The range of values increased from a range of 0.02 millimeter at 0 hours to 0.10 millimeter (including coarser values) at 50 hours and then decreased to a range of 0.08 millimeter at 80 hours. In the offshore zone, the mean median remained at 0.20 millimeter during the first 50 hours and then decreased to 0.19 millimeter at 80 hours. The range of values increased from a range of 0.02 millimeter at 0 hours to 0.12 millimeter (including finer values) at 50 hours and then decreased to a range of 0.08 millimeter at 80 hours.

In general, the foreshore became coarser and included more coarse samples, and the offshore maintained the same mean median but had more fine samples.

4. Breaker Characteristics.

A plot of breaker position (dashline) superimposed on a plot of contour movement along range 3 in experiment 72A-06 is shown in Figure 36. The wave broke mainly by surging or collapsing, and occasionally by spilling, near the base of the foreshore.

A similar plot of breaker position along range 5 in experiment 72A-10 is shown in Figure 37. The wave broke mainly by collapsing, and occasionally by plunging, near the base of the foreshore.

5. Water Temperature.

Figure 38 gives data on daily average water temperature versus both cumulative test time and dates for experiments 72A-06 and 72A-10.

6. Wave-Generated Currents.

a. Experiment 72A-06. Observations of wave-generated surface currents were collected during each run up to 85 hours and during runs between 125 and 135 hours. As pointed out in Section II,1,c (see Figs. 1, 7, and 8), antinodes of the standing wave envelope occurred near stations 5 and 18. During the first 70 hours a repeatable circulation pattern developed in the foreshore zone and between the first two antinodes of the standing wave envelope. The various pathlines followed by the bobs are indicated by the numbered lines in Figure 39. Table 11 gives the maximum, minimum, and average velocities, path lengths, and number of velocity measurements for each of the pathlines in this experiment. Path number 0-1 in Figure 39 indicates the only path taken by bobs passing from the foreshore zone to the offshore zone, and path number F-8 the only path taken from the offshore to the foreshore. The antinode near station 18 was a complete barrier during the first 70 hours; i.e., all bobs that moved seaward from station +5 returned, and no bobs moved seaward of station +16.

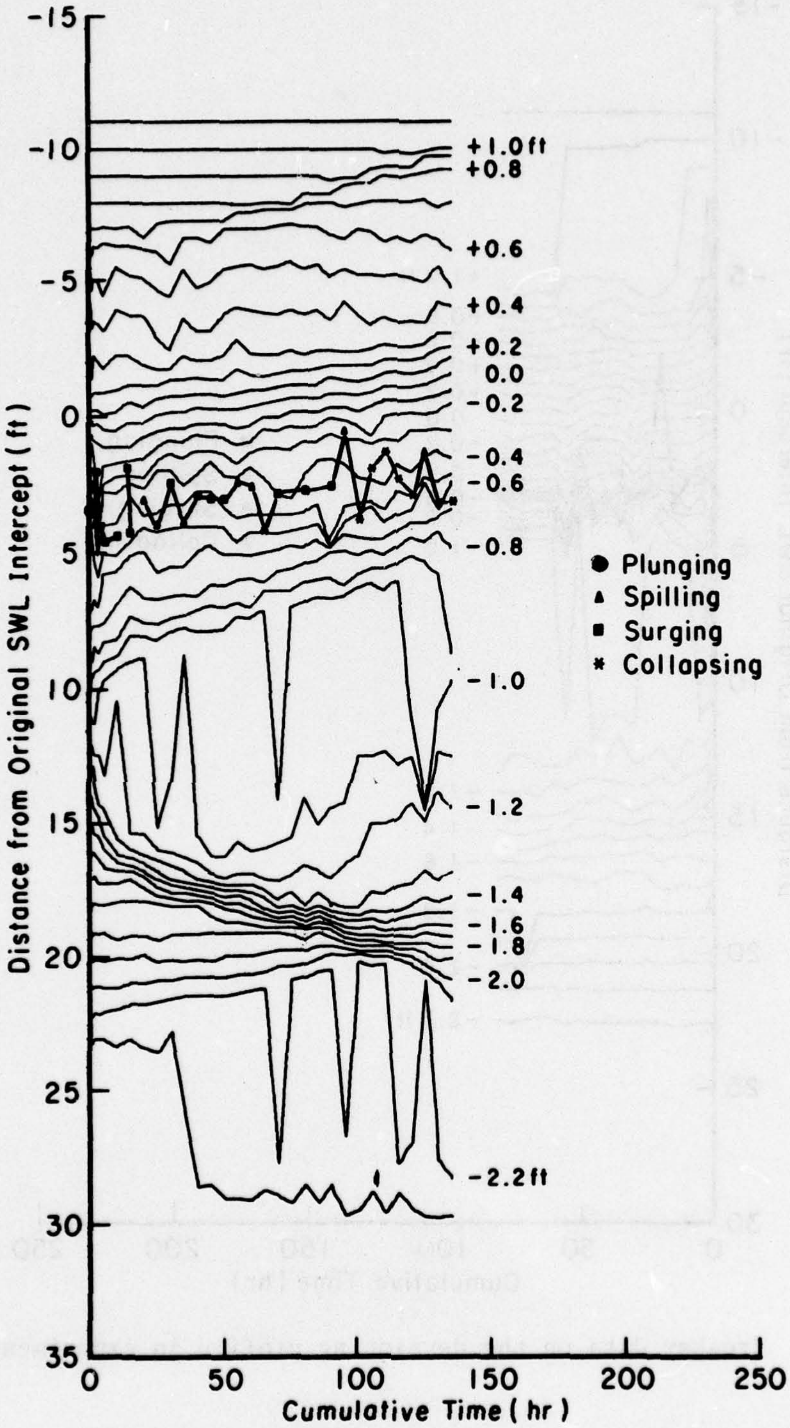


Figure 36. Breaker data on the developing profile in experiment 72A-06.

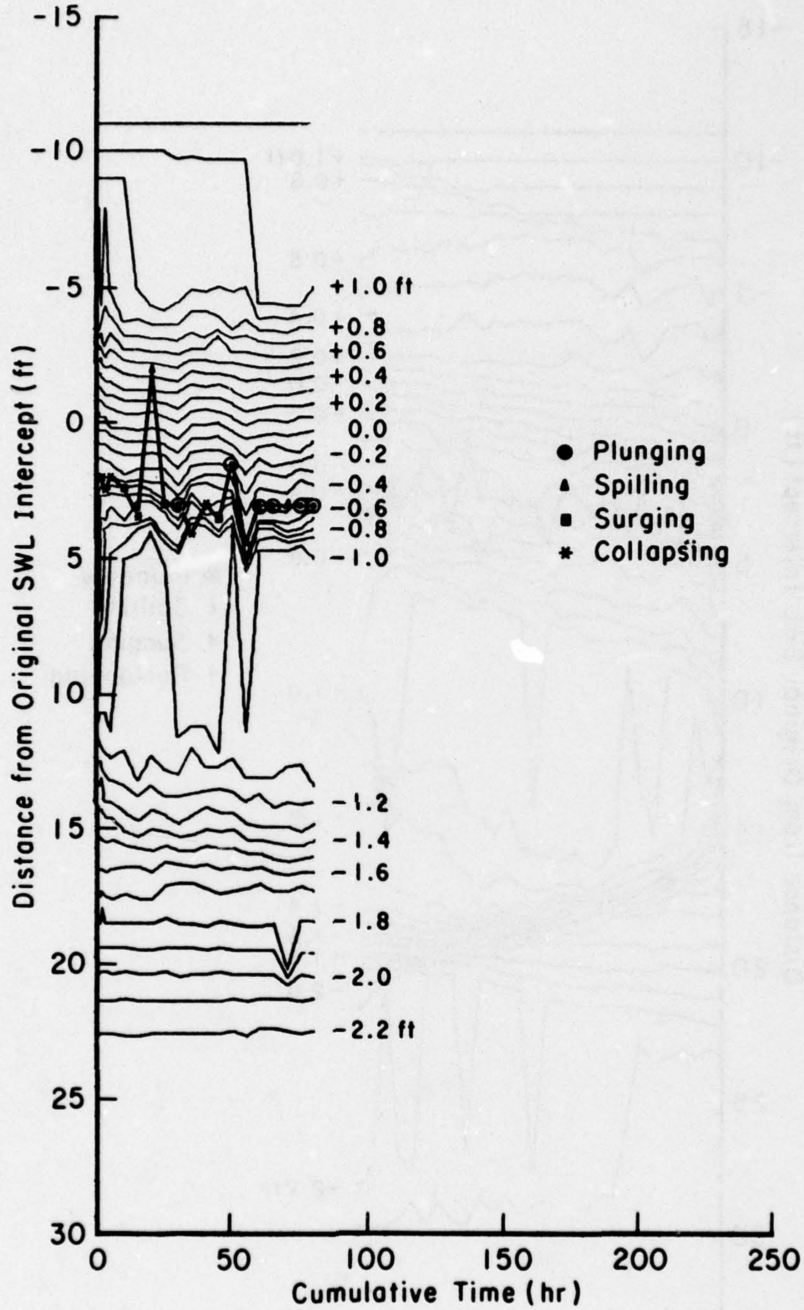


Figure 37. Breaker data on the developing profile in experiment 72A-10.

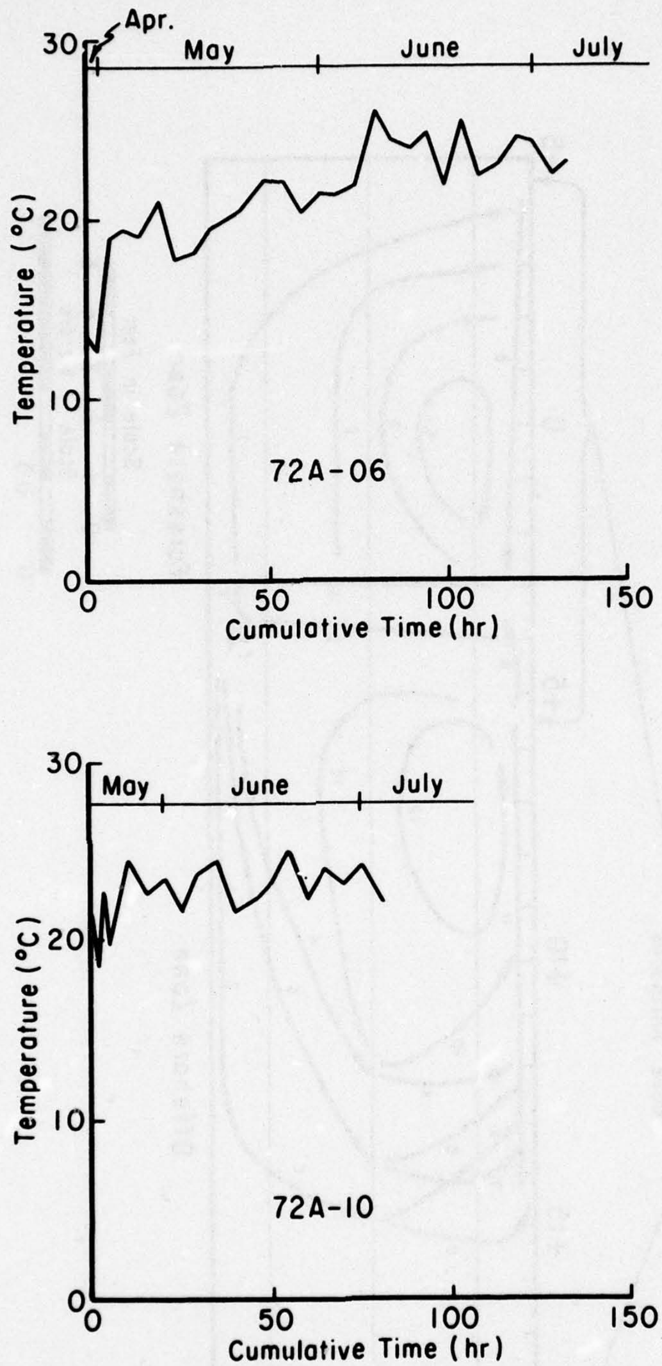


Figure 38. Water temperature data (1972).

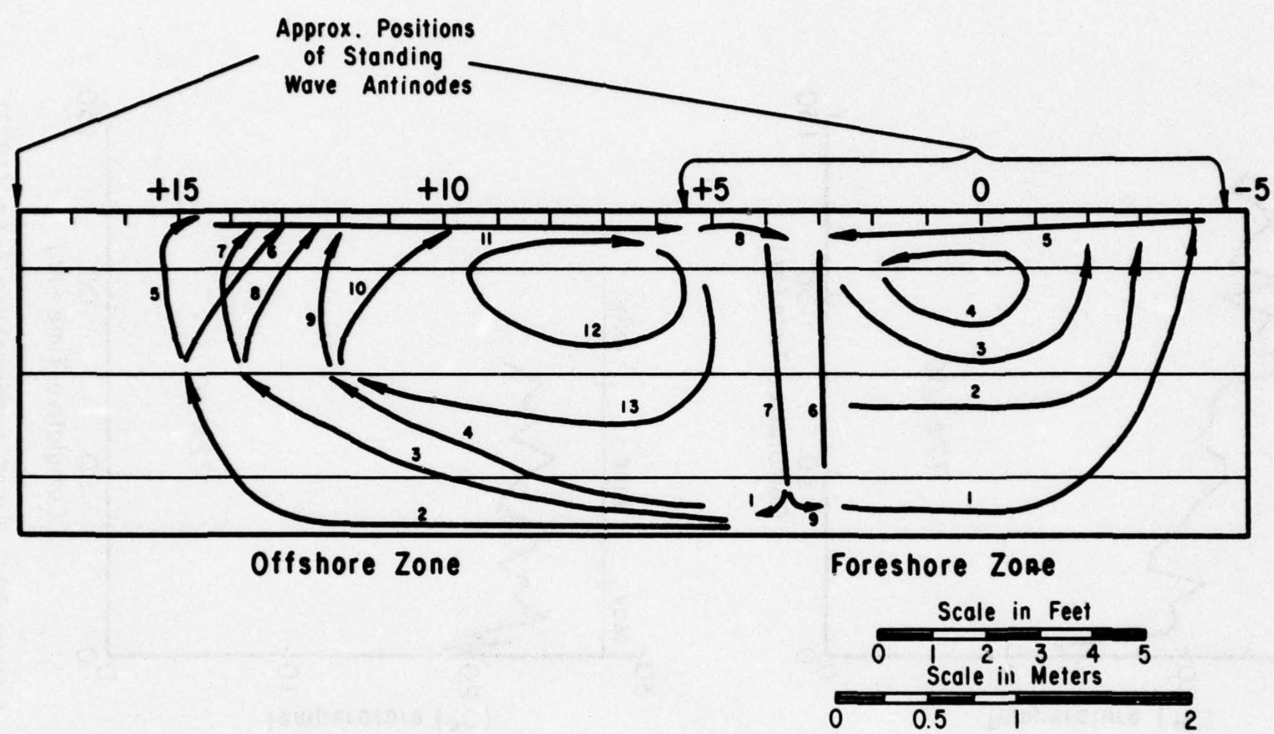


Figure 39. Wave-generated current pathlines during first 70 hours of experiment 72A-06.

Table 11. Current velocities along pathlines in experiment 72A-06.

Pathline No.	Length of pathline (ft)	Average velocity (ft/s)	Maximum velocity (ft/s)	Minimum velocity (ft/s)	Observations (No.)
Foreshore					
1	11.0	0.26	0.37	0.18	18
2	9.0	0.31	0.36	0.30	14
3	7.5	0.47	0.50	0.38	19
4	9.0	1.36	1.80	0.90	32
5	6.0	1.67	2.00	1.50	12
6	5.0	0.33	0.50	0.25	15
7	5.5	0.24	0.28	0.18	13
8	Movement from offshore to foreshore zone				
9[1]					
Offshore					
1[1]					
2	11.0	0.15	0.27	0.09	6
3	9.5	0.13	0.23	0.10	19
4	8.0	0.13	0.27	0.08	11
5	3.0	0.04	0.10	0.02	5
6	4.0	0.07	0.08	0.07	4
7	3.0	0.07	0.10	0.05	5
8	4.0	0.10	0.10	0.10	4
9	3.0	0.12	0.20	0.08	4
10	4.0	0.09	0.10	0.07	3
11	9.0	0.08	0.15	0.05	28
12	9.5	0.09	0.16	0.05	9
13	9.0	0.08	0.13	0.06	6

[1]Bobs moving along pathline F-7 either remained in foreshore by moving along F-9 or moved offshore along 0-1.

Note.--See Figure 39.

After 70 hours, the current pattern began to disintegrate and become quite confused. Between 70 and 75 hours, only 67 percent of the bobs which moved seaward from station +5 returned; the other 33 percent moved past station +16. Between 75 and 80 hours, 33 percent of the bobs returned, between 80 and 85 hours, 25 percent returned, and between 125 and 130 hours only 20 percent returned.

Flourescein dye was introduced on either side of the antinode near station 18 and in all cases (all before 70 hours) the dye moved away from the antinode and did not diffuse across this boundary.

b. Experiment 72A-10. A few observations of currents were made in this experiment during the first 30 hours and no repeatable current pattern was observed. There was never any indication that a pronounced current pattern existed during the experiment.

III. PROFILE DEVELOPMENT AND REFLECTIVITY

This section discusses the interdependence of changes in profile shape, sediment-size distribution, breaker characteristics, current patterns, water temperature, and the reflection coefficient.

1. Experiment 72A-06.

Profile development is summarized in Table 12 which tabulates, as a function of time, the important changes in the foreshore and offshore zones, the breaker and current conditions, median grain size, and water temperature during this experiment. Figure 40 compares the shoreline movement with water temperature changes for experiment 72A-06; Figure 41 compares the -1.2-foot contour movement, which represents the boundary between the inner and outer offshore regions with K_R changes.

The important changes in the various parameters and their interrelationships occurred as follows. In the first 5 hours the foreshore developed an equilibrium shape, which was steep along range 5 and quite flat along range 1 as a result of the counterclockwise pattern of flow of the wave uprush and backwash. Since the waves broke on the foreshore, it received most of the wave energy, and as the foreshore became steeper the K_R increased, except at 1.5 and 3 hours. At those times, the erosion and deposition patterns at the base of the foreshore (-0.2 to -0.9 foot) were reversed and the K_R reached its lowest values.

An almost flat shelf developed during the first 10 hours in the inner offshore region, caused by the erosion at the toe of the foreshore and deposition in the outer offshore at depths from -1.3 to -1.6 feet. As the foreshore eroded landward at a rate of 0.015 foot per hour and the outer offshore slope steepened and prograded seaward with deposition at the higher elevations, the shelf in the inner offshore grew in length in both directions and a bar and trough developed. During this period of greatest profile development the K_R rose sharply, reaching a maximum at 25 hours. As a result of the high reflection, a significantly large standing wave

Table 12. Summary of profile development for experiment 72A-06.

Time (hr)	Foreshore	Inner offshore	Outer offshore	Breakers	Currents	Water temperature (°C)
0 to 5	Developed equilibrium shape	An almost flat shelf developed	Deposition at -1.3 to -1.6 ft	Surging or collapsing, breaking on lower part of foreshore	Counterclockwise circulation on foreshore; clockwise circulation between first 2 antinodes of standing wave envelope	13 to 19
5 to 10	Retreated landward					20
10 to 15		Shelf grew in length in both directions; bar and trough developed				19
15 to 70	Mean d_{50} = 0.20 mm		Deposition at -1.3 to -1.9 ft; erosion at -2.0 to -2.1 ft Mean d_{50} = 0.20 mm			18 to 22
70 to 100	At rate of 0.015 ft/hr Mean d_{50} = 0.20 mm	Seaward edge of shelf began moving shoreward; bar eroded, trough filled in	Causing slope to steepen Mean d_{50} = 0.20 mm		Clockwise circulation on foreshore; circulation between first 2 antinodes breaks down, and becomes confused	22 to 26
100 to 135	Mean d_{50} = 0.21 mm	Gently sloping region; seaward edge moving shoreward Shoreward edge stationary except along range 3	Erosion at -1.2 to -1.5 ft; deposition at -1.7 to -2.2 ft, causing slope to decrease in steepness Mean d_{50} = 0.20 mm			23 to 26

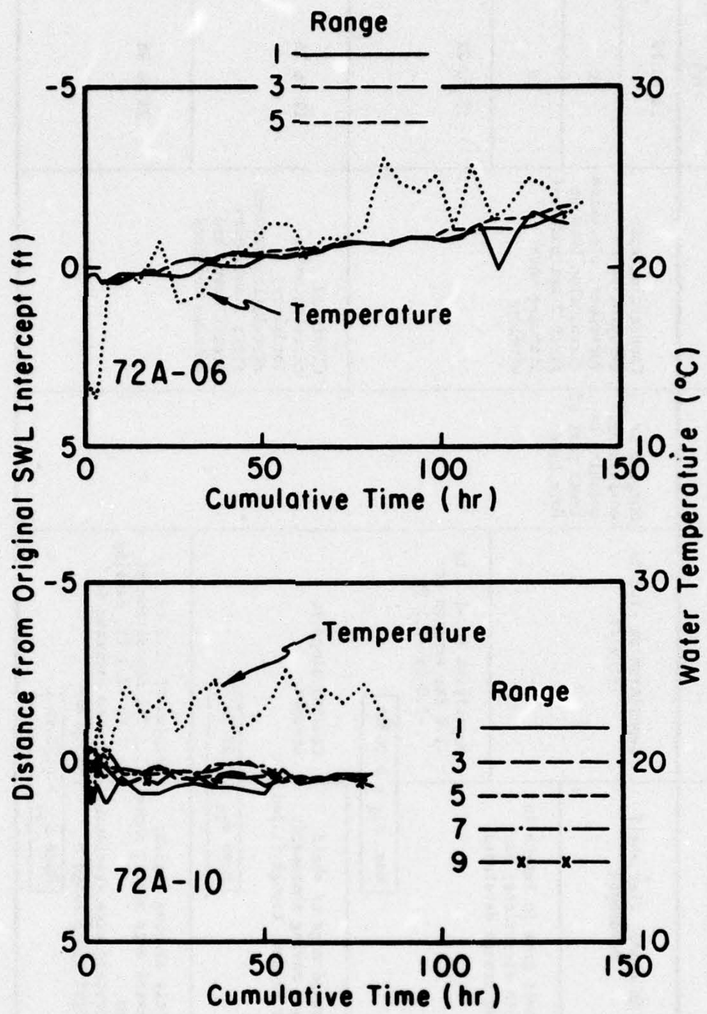


Figure 40. Comparison of water temperature and shoreline position.

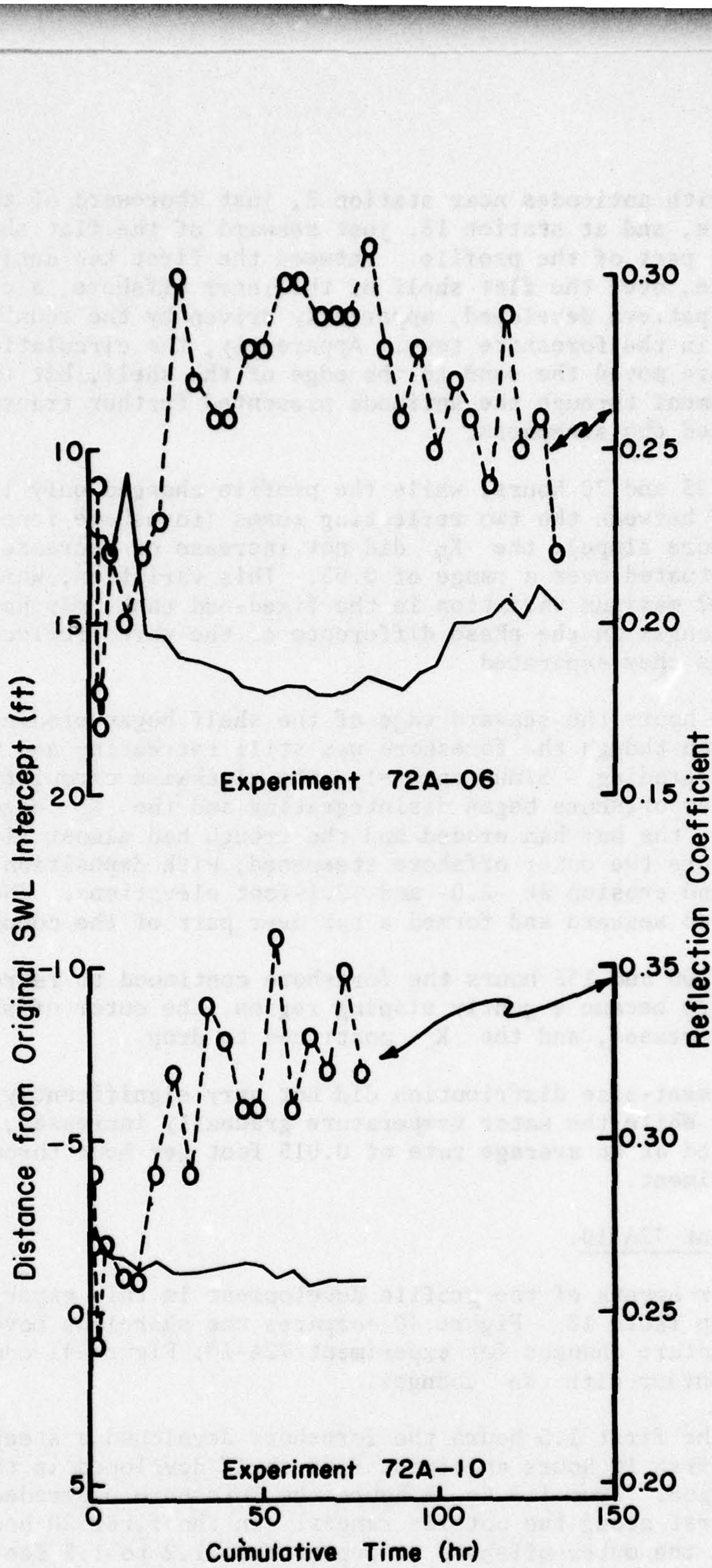


Figure 41. Comparison of the -1.2-foot contour position and K_R.

developed, with antinodes near station 5, just shoreward of the base of the foreshore, and at station 18, just seaward of the flat shelf over the steepest part of the profile. Between the first two antinodes of the standing wave, over the flat shelf of the inner offshore, a clockwise circulation pattern developed, apparently driven by the counterclockwise circulation in the foreshore zone. Apparently, the circulation over the inner offshore moved the sand to the edge of the shelf, but the lack of current movement through the antinode prevented further transport and thus increased the steepness.

Between 25 and 70 hours, while the profile changed only in the length of the shelf between the two reflecting zones (foreshore zone and submerged offshore slope), the K_R did not increase or decrease significantly, but fluctuated over a range of 0.05. This variation, which was greater than the 0.02 maximum variation in the fixed-bed tank, may have been caused by changes in the phase difference of the waves reflected from the two slopes as they separated.

After 70 hours the seaward edge of the shelf began eroding, moving landward, even though the foreshore was still retreating and the offshore was still prograding. Simultaneously, the clockwise circulation pattern over the inner offshore began disintegrating and the K_R began decreasing. By 100 hours, the bar had eroded and the trough had almost filled. From 15 to 100 hours the outer offshore steepened, with deposition at the upper elevations and erosion at -2.0- and -2.1-foot elevations. The eroded material moved seaward and formed a bar over part of the concrete bottom.

Between 100 and 135 hours the foreshore continued to retreat, the inner offshore became a gently sloping region, the outer offshore slope steepness decreased, and the K_R continued to drop.

The sediment-size distribution did not vary significantly during the experiment. While the water temperature gradually increased, the shoreline retreated at an average rate of 0.015 foot per hour throughout most of the experiment.

2. Experiment 72A-10.

The major events of the profile development in this experiment are summarized in Table 13. Figure 40 compares the shoreline movement with water temperature changes for experiment 72A-10; Figure 41 compares the -1.2-foot contour with K_R changes.

During the first 1.5 hours the foreshore developed a steep slope, and within the first 10 hours an almost flat shelf developed in the inner offshore region. From 1.5 to 25 hours the foreshore prograded 0.5 foot, beginning first along the outside ranges. In the first 20 hours, sand deposited in the outer offshore at depths from 1.2 to 1.5 feet; from 20 to 25 hours, sand eroded at depths of 1.6 and 1.7 feet, thus forming a slightly steeper slope on the upper part of the outer offshore. During this initial profile development, the K_R rose sharply.

Table 13. Summary of profile development for experiment 72A-10.

Time (hr)	Foreshore	Inner offshore	Outer offshore	Currents and breakers	Temperature (°C)
0 to 1.5	Developed equilibrium shape	An almost flat shelf developed	Deposition at -1.2 to -1.5 ft	No discernible pattern of wave-generated currents developed	18 to 21
1.5 to 10	Advanced seaward 0.5 ft, beginning along outside ranges first				20 to 24
10 to 20		No significant changes occurred; some minor lateral variations in elevation of bar crest		Breaker was surging or collapsing on lower part of foreshore	23 to 24
20 to 25			Erosion at -1.6 and -1.7 ft		22
25 to 80	In equilibrium in shape and position		No major change		22 to 25
	50 hr: Mean d_{50} = 0.22 mm	Mean d_{50} = 0.20 mm			
	80 hr: Mean d_{50} = 0.22 mm	Mean d_{50} = 0.19 mm			

After 25 hours the only profile changes were a slight general increase in the foreshore slope and a gradual increase in the foreshore berm crest elevation. The K_R continued to increase, but at a slower rate. The variation in K_R after 35 hours was ±0.03, on the order of ±0.025 variation in the fixed-bed tank.

Throughout the experiment the foreshore slope was slightly flatter and the K_R was significantly lower along the outside ranges.

Other than the minor changes in the foreshore shape after 25 hours, the profile appeared to be quite close to equilibrium (Fig. 42).

The range of median grain sizes increased in the coarser fractions in the foreshore zone and increased in the finer fractions in the offshore zone.

The temperature did not vary significantly and the shoreline (and the profile) reached equilibrium within 25 hours (see Fig. 40).

3. Comparison of the Two Experiments.

Although the general shape of the profiles and the sequence of events during the development of the profiles were similar, there were significant differences between the two tanks.

a. Foreshore Zone. The foreshore zone in experiment 72A-06 was dominated by the counterclockwise circulation of the swash, forming a steep beach face (0.197) along range 5 and a flat beach face (0.123) along range 1. This circulation pattern did not develop in experiment 72A-10 where the foreshore shape was more uniform laterally, varying from 0.171 to 0.209. There were slightly flatter slopes along the outside ranges than along the center ranges.

Although the shoreline advanced 0.5 foot and became stationary in the 10-foot tank, the shoreline in the 6-foot tank retreated at an average rate of 0.015 foot per hour after the initial development.

b. Inner Offshore Zone. In experiment 72A-06, a clockwise circulation pattern developed over the inner offshore shelf between the first two antinodes of the standing wave. This circulation pattern did not develop in the wider tank. After the inner offshore shelf developed in the 10-foot tank, the boundaries remained fixed and a bar and trough developed. A similar shelf developed in the narrower tank, but was later eroded and transformed into a gently sloping area while the circulation pattern disintegrated.

c. Outer Offshore Zone. The slope of the outer offshore became quite steep in experiment 72A-06, with the steepest part between elevations -1.2 and -2.2 feet. In the wider tank (experiment 72A-10) the area between elevations -1.1 and -1.8 feet became slightly steeper (than 0.10), but no change occurred below -1.9 feet. The strong circulation pattern in the narrower tank is the most likely cause of these differences.

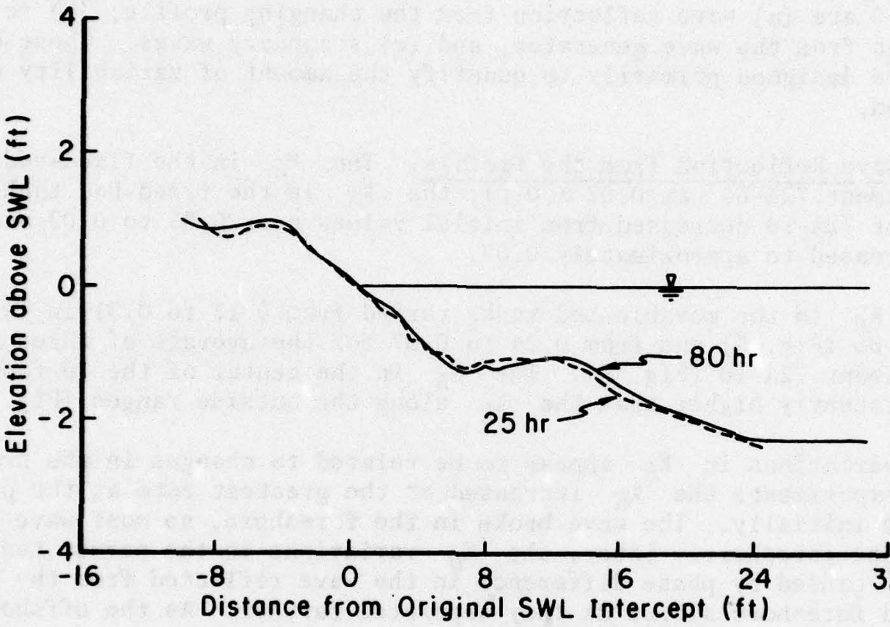


Figure 42. Equilibrium profile for 3.75-second wave.

d. Sand-Size Distribution. In experiment 72A-06, with the strong circulation pattern over the profile, the sediment sizes remained well mixed and basically unchanged. In experiment 72A-10, where no circulation pattern was observed, the sediment sizes became more sorted.

IV. DISCUSSION OF RESULTS

1. Wave Height Variability.

Three probable causes of wave height variability in experiments 72A-06 and 72A-10 are (a) wave reflection from the changing profile, (b) re-reflection from the wave generator, and (c) secondary waves. These experiments were designed primarily to quantify the amount of variability due to reflection.

a. Wave Reflection from the Profile. The K_R in the fixed-bed tank of experiment 72A-06 was 0.07 ± 0.01; the K_R in the fixed-bed tank of experiment 72A-10 decreased from initial values near 0.05 to 0.02 and then increased to approximately 0.07.

The K_R in the movable-bed tanks varied from 0.17 to 0.31 in experiment 72A-06 (Fig. 5) and from 0.24 to 0.37 for the average of three ranges in experiment 72A-10 (Fig. 6). The K_R in the center of the 10-foot tank was consistently higher than the K_R along the outside ranges (Fig. 6).

The variations in K_R appear to be related to changes in the profile. In both experiments the K_R increased at the greatest rate as the profile developed initially. The wave broke in the foreshore, so most wave energy reached the foreshore. Later, the K_R variations in the narrow tank may have been caused by phase difference in the wave reflected from the offshore and foreshore slopes as they separated farther. As the offshore slope became more gently sloping in the narrower tank, the K_R decreased.

The K_R was greater in the wider tank. The difference could have been caused by the slightly steeper slope and higher berm crest in the foreshore zone. The lower K_R in the narrow tank may have been due to more energy being consumed in driving the strong circulation currents. However, this is difficult to prove since the currents decreased simultaneously with significant changes in the shape of the offshore zone.

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, varied from 0.33 to 0.43 foot (10.1 to 13.1 centimeters) in experiment 72A-06 and from 0.30 to 0.42 foot (9.1 to 12.8 centimeters) in experiment 72A-10 (Table 5). Part of that variation (0.07 foot in experiment 72A-06 and 0.03 foot in experiment 72A-10) can be attributed to measurement errors, variations in the generated wave, and all other errors not caused by a changing profile. The remainder of the variation (0.03 and 0.09 foot) is likely due to varying re-reflection.

c. Secondary Waves. Along the length of the tank, between the generator and the toe of the profile, wave heights on a given recording varied as the result of the presence of secondary waves (Galvin, 1972; Hulsbergen, 1974). Wave height variation due to secondary waves appears to be an order of magnitude less than variation due to reflection (see Figs. 1, 7, and 8).

2. Profile Equilibrium.

The profile in experiment 72A-10 appeared to be in equilibrium after 25 hours. As the depths over the inner offshore shelf were fluctuating along any one range and varying from one range to the next, the profile was nevertheless close to, if not at, equilibrium (see Fig. 42).

In experiment 72A-06 the profile was still changing, even after 135 hours (see Fig. 11). Apparently, the circulation of the swash continued to erode the foreshore causing the shoreline to retreat. This continual change prevented the remainder of the profile from reaching equilibrium.

3. Other Laboratory Effects.

The differences in tank width and initial test length provide possible explanations for the differences in profile shape between the two tanks.

a. Initial Test Length. Two phenomena are affected by varying tank length: re-reflection and secondary waves.

The difference in initial test length between the two tanks, which would have caused the phase difference between primary and secondary waves at the toe of the profile to be different and thus caused the velocity profile at the toe of the profile to be different, may possibly account for some of the difference in the development of the toe of the outer offshore profile. In experiment 72A-10 the slope below -1.9 feet was essentially unchanged; in experiment 72A-06, significant changes occurred in this area.

The re-reflected wave, which is affected by tank length, may also account for some of the difference. The average incident wave height in experiment 72A-06 was 0.38 foot (11.6 centimeters) and in experiment 72A-10 was 0.35 foot (10.7 centimeters) (Table 5). This difference (0.03 foot) due to re-reflection may account for some but not all of the difference.

b. Tank Width. The development of the circulation patterns in the foreshore and inner offshore zones in the 6-foot tank, which did not develop in the wider tank, was a most significant difference. Some minor perturbation on the foreshore may have triggered an initial lateral variation in runup and the counterclockwise circulation. The distance between antinodes was approximately 12 feet (3.7 meters), which meant that the wavelength over the shelf was 24 feet (7.3 meters). The tank width of 6 feet was obviously a critical width (1/4 wavelength) and thus susceptible to this form of disturbance.

c. Water Temperature. In experiment 72A-06 the shoreline retreated at a constant rate, which means that the volume rate of erosion was continually increasing as the water temperature gradually rose. In experiment 72A-10 the shoreline and the profile reached equilibrium, but the water temperature remained fairly constant. This suggests a possible temperature effect on the rate of sediment transport and profile adjustment; however, this is opposite to the effect reported in Volume II.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions.

(a) In two experiments with a water depth of 2.33 feet, a wave period of 3.75 seconds, and a generator stroke of 0.35 foot (generated wave height of 0.31 foot), the average incident wave height was 0.38 foot in experiment 72A-06 and 0.35 foot in experiment 72A-10 (Table 5). Reflection measurements in the control tanks with a fixed-bed profile varied from 0.06 to 0.08 in experiment 72A-06 and from 0.02 to 0.07 in experiment 72A-10. This variation is taken as the inherent measurement error in determining K_R from the movable-bed profile (Table 6).

(b) K_R varied from 0.17 to 0.31 in experiment 72A-06 (Fig. 5) and from 0.24 to 0.37 for the average of three ranges in experiment 72A-10 (Fig. 6). The variation in K_R correlates well with profile changes. K_R increased as the profiles developed. As profile changes in experiment 72A-10 decreased, the increases in K_R slowed but K_R continued to vary for the remainder of the experiment. In experiment 72A-06 the K_R remained high while the offshore zone consisted of a flat shelf and steep seaward slope, but started declining as the offshore zone developed into a more gently sloping zone (Fig. 41).

(c) The profile in the 10-foot tank developed an approximate equilibrium profile during the first 25 hours (Fig. 17). The profile in the narrower tank developed a profile similar to the wide tank except that the offshore slope was much steeper; however, the profile continued to change and never appeared close to equilibrium (Fig. 13).

(d) A strong circulation pattern developed in the narrow tank which did not develop in the wider tank. In the foreshore zone a counterclockwise circulation developed, causing significant lateral variation in the shape of the foreshore zone. Over the flat shelf in the inner offshore zone, a strong clockwise circulation developed between the antinodes of the standing wave envelope (Fig. 39). The circulation in the inner offshore disintegrated coincidentally with the change of the offshore profile from a steep slope and flat shelf to a gently sloping region.

(e) The difference in slope in the outer offshore zone may have been the result of secondary wave or re-reflection effects due to the difference in initial test length (Figs. 12 to 19), but were most likely due to the strong circulation pattern in the narrower tank.

(f) Reflection coefficient variation, development and disintegration of current patterns, and profile development in experiment 72A-06 were strongly interrelated.

2. Recommendations.

(a) The final profile shape in experiment 72A-10 could be used as an approximation to an equilibrium profile for these wave, sediment, and initial slope conditions (Fig. 42), provided the critical conditions leading to circulation (as in Fig. 39) can be avoided.

(b) More research should be conducted on the effect of initial test length on re-reflection and secondary waves and the resulting effects on profile development.

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APPENDIX

EXPERIMENTAL PROCEDURES FOR 72A-06 AND 72A-10

This appendix documents those aspects of the experimental procedures unique to experiments 72A-06 and 72A-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 experiments 71Y-06 and 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 in each experiment, a wave gage recorded the water surface elevation at station +25 near the toe of the movable-bed profiles and 7 feet farther from the toe of the fixed-bed slopes. During all subsequent runs, wave envelopes were recorded with wave gages moving along the center of the two tanks in experiment 72A-06 from station +15 to +85 and return, and along the center of the fixed-bed tank and ranges 1, 5, and 9 in the movable-bed tank of experiment 72A-10 from station +15 to +50 and return.

(2) Wave-Generated Current Data. Observations of wave-generated surface currents were made during the first 85 hours and from 125 to 135 hours in experiment 72A-06. Also, observations of bottom currents using bobs and fluorescein dye were made intermittently during the first 75 hours in experiment 72A-06. Several observations were made during the first 30 hours of experiment 72A-10.

b. Special Data. Four types of special data were collected at less frequent intervals, and Table A-1 indicates the time 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 the grade I data, which had no quality control 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 speed, or (c) off-scale values. Twenty percent of the grade I envelopes were also reduced manually to provide a comparison of the two methods.

b. Sand-Size Distribution. All samples were analyzed using the VA tube method by the U.S. Army Engineer Division, Missouri River, laboratory.

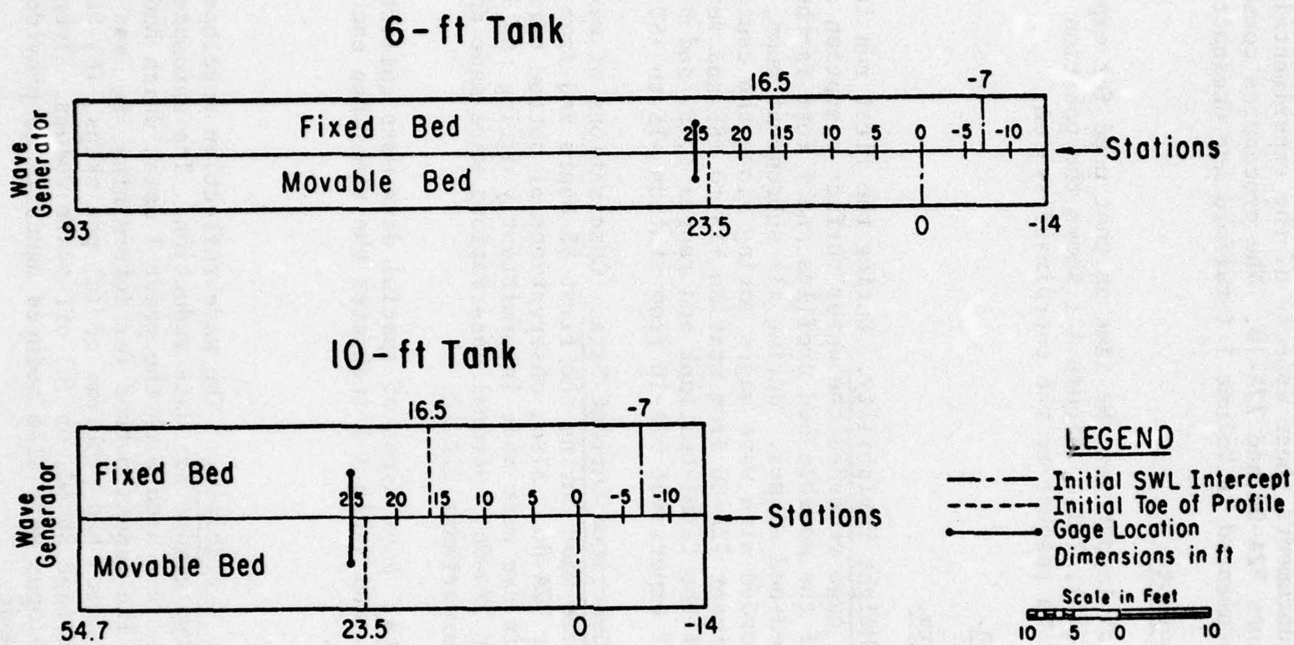

Figure A-1. Experimental setup.

Table A-1. Summary of special data collection.

Time (hr)	Limits (ft)			
	Profile survey[1]	Photo survey	Sand sample[2]	Wave envelope[3]
	Experiment 72A-06			
0	Not taken	Not taken	-10 to +22	Not taken
3	Not taken	-10 to +23	Not taken	Not taken
30	Not taken	Not taken	Not taken	Envelope: +75 to +20 Stands: +5 to +12 +12 to +8
50	-8.0 to +29.0	-9 to +27	-6 to +22	
55				Envelope: +80 to +25 Stands: +7 to +3
75	Not taken	Not taken	Not taken	Envelope: +80 to +25
80	Not taken	Not taken	Not taken	Stands: +7 to +2
100	-9.0 to +30.5	-9 to +27	-10 to +30	Not taken
105	Not taken	Not taken	Not taken	Envelope: +80 to +25 Stands: +6 to +3 +19 to +8
130	Not taken	Not taken	Not taken	Envelope: +80 to +25
135	-10.0 to +29.0	-9 to +31	-10 to +22	Not taken
	Experiment 72A-10			
	Profile survey[1]	Photo survey	Sand sample[4]	Wave envelope[5]
0	Not taken	Not taken	-6 to +22	
30	Not taken	Not taken	Not taken	Envelope: +15 to +45 Stands: +7 to +4
50	-10.0 to +24.5	-10 to +26	-8 to +22	
55	Not taken	Not taken	Not taken	Envelope: +15 to +45 Stands: +7 to +4
80	-10.0 to +24.0	-10 to +23	-10 to +22	Envelope: +15 to +45 Stands: +7 to +4

[1]Elevation measurements made at 0.5-foot intervals between the given stations along ranges 0.5-foot apart.

[2]Samples collected at 2-foot intervals along ranges 1 foot on either side of centerline at 0 and 50 hours, and along ranges 1 and 5 at 100 and 135 hours.

[3]One-minute stands were recorded at 0.5-foot intervals along ranges 1, 3, and 5 at 50, 80, and 105 hours and on ranges 1 and 3 at 30 hours; the special wave envelopes were recorded along ranges 1, 3, and 5 in the movable-bed tank.

[4]Samples collected at 2-foot intervals on ranges 1, 5, and 9 at 0, 50, and 80 hours.

[5]One-minute stands were recorded at 0.5-foot intervals at 30, 55, and 80 hours on ranges 1, 5, and 9; the special wave envelopes were recorded on ranges 1, 5, and 9 on the movable-bed tank.

Approximately 10 percent of the samples were also analyzed by project personnel using the dry sieve method as a quality control measure. Table A-2 presents the results from the dry sieve mehtod.

c. Breaker Characteristics. Breaker type and position were determined from the visual observation form.

Table A-2. Sediment-size analysis by dry sieve method.

Station	Experiment 72A-06												Experiment 72A-10								
	Range 1			Range 2			Range 4			Range 5			Range 1			Range 5			Range 9		
	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)
	0 Hr																				
4																			-0.40	0.21	2.22
8				-0.80	0.22	2.19															
10							-1.00	0.23	2.14												
20				-2.00	0.22	2.19															
	50 Hr																				
-2				0.20	0.21	2.25										0.45	0.19	2.42			
4																-1.00	0.21	2.23			
10																			-1.03	0.23	2.11
16													-1.50	0.22	2.19						
18				-1.80	0.22	2.17	-1.70	0.20	2.50												
	80 Hr																				
-4													1.00	0.21	2.23						
2																-0.39	0.23	2.10			
8																			-1.20	0.21	2.23
16													-1.40	0.20	2.34						
20																			-1.84	0.21	2.27
	100 Hr																				
-4	0.32	0.21	2.27							0.58	0.22	2.18									
18	-1.22	0.22	2.20							-1.40	0.19	2.39									
	135 Hr																				
-2										0.05	0.22	2.16									
8										-1.00	0.24	2.06									
18										-1.60	0.20	2.35									
28										-2.27	0.20	2.30									

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