U. S. Army
Coastal Engineering Research Center

BEHAVIOR OF BEACH FILL AND BORROW AREA AT SHERWOOD ISLAND STATE PARK WESTPORT, CONNECTICUT

TECHNICAL MEMORANDUM NO. 20
MAY, 1967

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

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by
William H. Vesper

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ABSTRACT

In 1957, to restore and stabilize the beach of Sherwood Island State Park, sand was pumped to the shore from an offshore borrow area by a hydraulic pipeline dredge. In addition, two training walls were constructed to confine the inlet at the east end (updrift) and a groin built at the west end of the park. The entire beach was widened and raised, and in addition, an extra amount of sand was placed on Sherwood Point to act as a feeder beach. The material from the borrow area proved to be suitable beach fill. In 1962, surveys showed that while the actual net loss of sand from the project area was slight, losses from the tidal zone in the updrift and central parts of the area were major. These losses indicate that maintenance fill is now required and that the construction of several short groins west of Sherwood Point (downdrift) may be desirable. Data, in graphic form, show comparative profiles of the area, changes in shoreline, and composite size-distribution curves for sand samples. Tables show quantitative volume changes and sand sample data. Initial and annual cost figures are given.

FOREWORD

A basic effort under the general investigations program at the Coastal Engineering Research Center (CERC) is to follow the behavior of selected works with the view of developing new or improved design criteria and techniques for application to future works. This report describes results of the sand beach fill placed at Sherwood Island State Park, Connecticut, in accordance with a plan developed by the U. S. Army Corps of Engineers. This is one of a series of reports of its type. The most recent, which dealt with Seaside Park, Bridgeport, Connecticut, was published as CERC Technical Memorandum No. 11. Study results pertaining to the effectiveness of these operations will, at a subsequent time, be correlated with results from other beach fill operations, and hopefully, more positive design criteria can be derived through empirical consideration.

This report was prepared by William H. Vesper, Hydraulic Engineer, Engineering Development Division, Coastal Engineering Research Center. At the time of completion of this report, Colonel F. O. Diercks was Director of the Center and J. M. Caldwell was Technical Director. Field data utilized herein were obtained through the U. S. Army Engineer Division, New England.

NOTE: Comments on this publication are invited. Discussion will be published in the next issue of the CERC Bulletin.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945, as supplemented by Public Law 172, 88th Congress, approved November 7, 1963.

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Figure 1. Aerial View of Sherwood Point Looking Northeastward; taken May 1957 before Fill Placement

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Section I INTRODUCTION

1. General

Sherwood Island State Park is located in the town of Westport, Connecticut (see Figure 2). Its shoreline extends generally northeast and northwest from Sherwood Point and is about 6,000 feet in length. In 1949, the U. S. Army Corps of Engineers, in cooperation with the State of Connecticut, completed a beach erosion control study of the Connecticut shore from Ash Creek to Saugatuck River which included Sherwood Island State Park.* The purpose of the cooperative study was to determine the most suitable methods of stabilizing and improving the shoreline. The study revealed that a natural source of supply of littoral material no longer existed within the area and that improvement of the shore could best be accomplished by artificial replenishment of the beaches. The most logical source of sand for this purpose was deemed to be offshore. A plan for improvement was developed and recommended which involved pumping sand onto the beach from an offshore borrow area, employing a hydraulic pipeline dredge. The plan, authorized as a Federal project under the 1950 River and Harbor Act, provided for widening approximately 6,000 feet of beach to a 150-foot width above mean high water by direct placement of sand, creation of a stockpile by placement of sand to an additional width of 100 feet over a distance of 1,000 feet both east and west from Sherwood Point, construction of two training walls 400 and 500 feet in length at Burial Hill Creek, construction of an impermeable rubble groin 500 feet long at the west end of the park, and maintenance of the improved beach by periodic nourishment.

The purpose of a stockpile at Sherwood Point was to feed the beach areas east and west of it. The purpose of the groin and training walls was to catch and hold littoral material and thereby stabilize the beach to project dimensions at the extremities of the park fill area. Intermediate structures were not recommended because it was believed that they would interfere with the feeding of sand to the adjacent beaches by natural movement away from the point. For this reason it was also recommended that a proposed fishing pier should be an open-pile structure.

The restored beach was to have a berm elevation of 3 feet above mean high water and a berm width generally about 80 feet increasing to 180 feet

* Area I - Ash Creek to Saugatuck River, Connecticut, Beach Erosion Control Study, published as House Document No. 454/81/2.

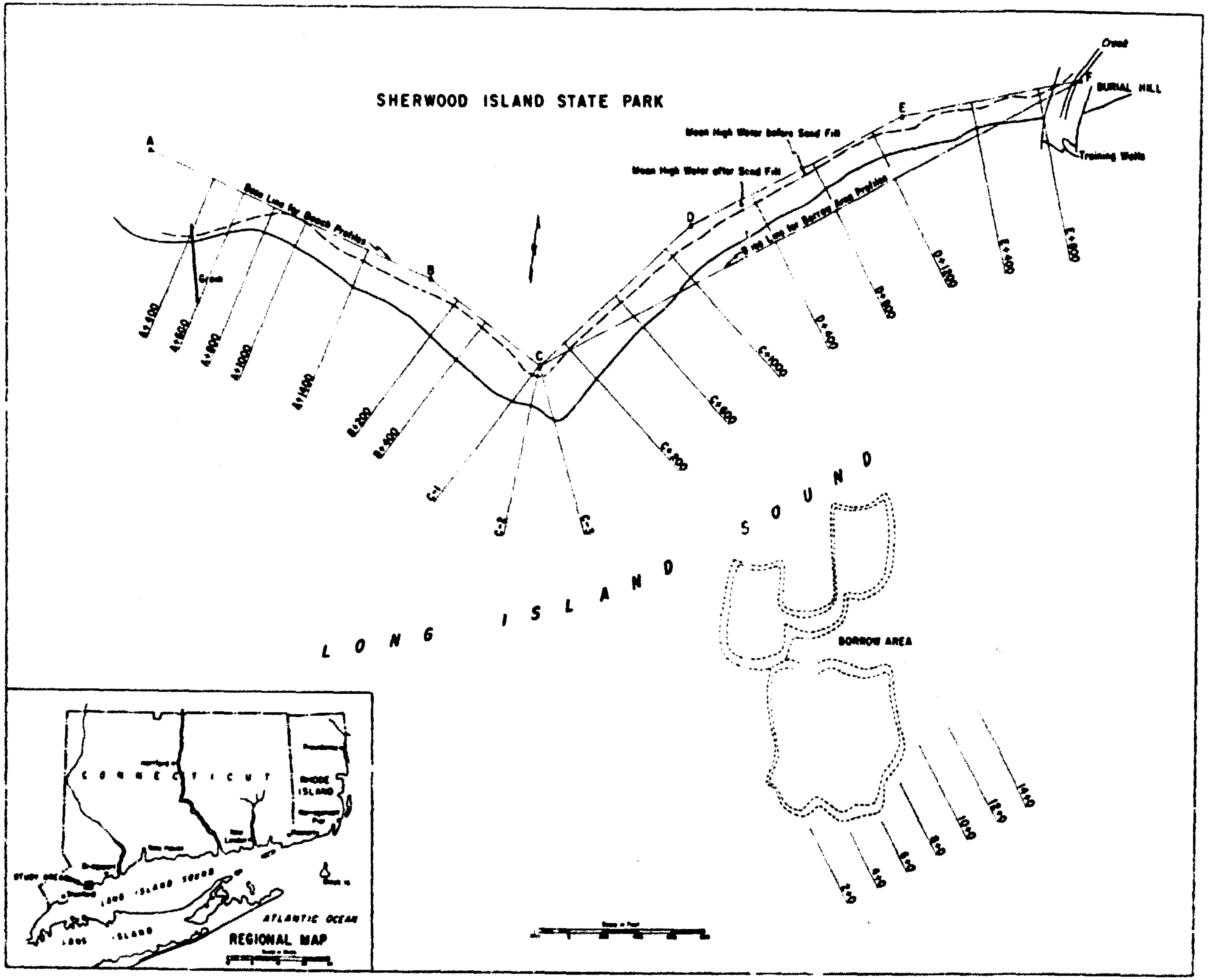

Figure 2. Location of Study Area Showing Profiles and Borrow Area

at Sherwood Point. The anticipated foreshore slope after natural shaping by wave action was 1 on 20 above and 1 on 30 below mean high water. The estimated quantity of sand required to provide a beach of these project dimensions and the stockpile at Sherwood Point was 460,000 cubic yards for the initial fill, and an average requirement of about 4,600 cubic yards annually for nourishment.

2. Summary of Physical Data

Sherwood Island State Park is a State-owned public park located at Westport. The shoreline of the park extends generally in a southeasterly direction from the Compo Mill Beach Association development for about 2,500 feet to Sherwood Point, thence northeasterly about 3,500 feet to Burial Hill Creek. The area is sheltered from waves from the Atlantic Ocean by Long Island which serves as a natural breakwater for most of the Connecticut shore. It is exposed to waves which are generated in Long Island Sound and these can approach the park shore from the east through the southwest.

There is a seasonal variation in littoral transport along the Connecticut shore; it varies in quantity and direction as well as from place to place. Sherwood Point is probably a nodal zone as the direction of littoral movement appears to be both northeast and northwest away from Sherwood Point; however, the northeastward movement is not too clearly indicated by physical evidence. Tides in the area are semidiurnal with mean and spring ranges of 7.0 and 8.3 feet. There are no continuous stormtide records for any locality between Ash Creek and Saugatuck River; however, during the hurricane of September 1938 tide stages of 13.4 and 13.8 feet above MLW were recorded at Southport and Bridgeport, respectively. These tides are the highest tides of record for the area.

Before improvement, the shore area consisted generally of low lands and marshes. The shore from Sherwood Point northeast to Burial Hill Creek consisted of a narrow beach of mixed sand and cobbles backed by a low dune and the marsh. Northwest from Sherwood Point the shore consisted of marsh areas bordered by a narrow beach of coarse material ranging from shingle to cobbles extending along more than half its length. The remainder of the beach to the northwest was composed of medium sand. The original beach slope was steep between high and low water and averaged about 1 on 10. The slope flattened near mean low water, except in the vicinity of Sherwood Point where the flattening occurred at depths between 10 and 20 feet.

Prior to the improvement project, public conveniences such as parking areas, bathhouses, sanitary facilities, lifeguards, fireplaces and tables, were limited. As part of the general beach erosion control and improvement program for the shoreline of Connecticut, extensive improvements for this park, comprising a pavilion, pleasure-boat development, and fishing pier, were included in the State plans.

3. Project Construction

The State of Connecticut initiated the Sherwood Island project in July 1956 when construction began on the rubble groin at the west end of the park. The groin required placement of about 4,000 tons of stone and was completed in October of the same year at a cost of about $58,000. Between September 1956 and February 1957 the Burial Hill training walls were built at a cost of approximately $60,000, and during June 1957, about 535,000 cubic yards of sand were placed on the beach, at a cost of about $440,800, completing the authorized work under the project.

4. Survey Data

In March 1955, about 21 months before fill placement, 31 profiles of the shore and offshore bottom were surveyed generally at 200-foot intervals (ranges A+600 to E+800 - see Figure 2). All ranges were resurveyed immediately after the fill placement in June 1957 and the surveys were repeated again in November 1957 and June 1958. A condition survey of Sherwood Island was made in June 1962; however, during this survey, only 17 selected ranges were resurveyed because of limited funds. The borrow area was sounded along 13 ranges in August 1957 after dredging at 100-foot intervals (ranges 2+00 to 14+00, inclusive, Figure 2). These soundings were compared with those taken along the even-numbered ranges earlier in 1957 before dredging. During the June 1962 survey, the borrow area was again sounded along the seven even-numbered ranges (2+00 to 14+00).

Only three sand samples of pre-fill beach material at the project site are available and these were taken from midtide level in 1948. Fifteen core borings were made in the borrow area in March 1957 before dredging. During the repeat survey of June 1962, 36 surface samples were taken from the beach and nearshore zones and 16 subsurface samples were taken in the borrow area. The sand sample data are given in Table 2.

Section II ANALYSIS OF DATA

1. Profiles

Comparative profiles obtained from 5 surveys from 1955 through 1962 are shown in Figures 3 through 6. Successive profiles of the same range either close or approach to within one foot of closure from 600 to 800 feet offshore of the baseline. Profiles of the four ranges in the western sector (ranges A+600 to A+1400) close at about 600 to 750 feet offshore of the baseline and, except for range A+600, in depths of 3.0 to 3.5 feet. Range A+600 extends through the impounding area of the stone groin at the western end of the park and profiles of this range close at about mean low water. Profiles of the remaining ranges at Sherwood Park do not completely close; however, they do converge to within one foot of closing. Except for range C-3, profiles of ranges located at Sherwood Point and in its vicinity (ranges B+200 to C+600) approach closure from 650 to 850 feet offshore of the baseline in depths of from 7 to 12 feet. Range C-3 extends through Sherwood Point and profiles of this range converge to within one foot of closing at about 540 feet offshore of the baseline in a depth of from 4 to 5 feet.

Volume changes were computed for the 17 selected ranges resurveyed in 1962. Since profile adjustments creating the greatest volume change appeared to be between the planes of mean high water and mean low water, the beach and nearshore area were arbitrarily divided into three zones for analysis as follows:

1. Above mean high water (between MHW and baseline).

2. Between mean high and mean low water lines.

3. Below mean low water (between MLW and the point where comparative profiles approximately close or terminate in the nearshore area).

2. Volume Computation

The data in Table I indicate that during the 5-year period since fill placement, the trend of shore processes over the project shore has been accretion in the western sector and erosion at the Point and in the eastern sector. Accretion in the western sector was general in all zones except in the tidal zone near the Point, and the total gains amounted to over 50,000 cubic yards. At Sherwood Point losses amounted to 11,100 cubic yards above mean high water and 31,300 cubic yards in the tidal zone. Below mean low water 5,300 cubic yards of material accreted which produced a net loss of 37,100 cubic yards. In the eastern sector there was accretion of 22,700 cubic yards above mean high water, erosion of 66,400 cubic yards between mean high water and mean low water and accretion of 31,100 cubic yards below mean low water for a net loss of only 12,600 cubic yards. Thus, for the entire project shore at Sherwood Island State Park (6,000 feet), the effect of the material movement has been a gain of 33,800 cubic yards of material above mean high water, loss of 95,900 cubic yards from the tidal zone and a gain of 57,400 cubic yards below mean low water. The net result then (without regard to accuracy of survey measurements) is a loss of 4,700 cubic yards out of the project area or net losses at the rate of about 940 cubic yards per year. However, net losses from the eroding sectors of the project beach approach 10,000 cubic yards per year over the full profile, or about 17,500 cubic yards per year if only profile zones above MLW are considered.

3. Shoreline Changes

Changes in the mean high water and mean low water shoreline are shown graphically in Figures 8 and 9. There was little change in the position of the high water line from July 1957 (immediately after filling) to June 1958 except in the vicinity of Sherwood Point where the shoreline receded. East of the Point the high water shoreline was more or less stable, while west of the Point there was a small advance. Between June 1958 and June 1962 the high water shoreline receded at Sherwood Point and east of the Point, while it advanced in the area west of the Point. The net change in the high water shoreline by June 1962 was one of recession at Sherwood Point, advance in the western sector and little or no change in the eastern sector. Erosion at Sherwood Point was anticipated, however, and additional fill had been placed along the Point to create a stockpile to nourish the beach on either side. Although the high water shoreline had receded about 120 feet since fill placement, nowhere along the beach had it receded to its position before improvement. Changes in the low water line followed a pattern similar to that for the high water line; however, the net change was one of recession at Sherwood Point accompanied by little or no change in the eastern or western sectors.

4. Borrow Area Behavior

Prior to initial dredging in 1957, the borrow area was sounded along thirteen ranges spaced at intervals of 100 feet (ranges 2+00 to 14+00, inclusive) and again sounded in August 1957 after dredging. A line connecting Station C and Station F (Figure 2) was used as the base line of reference. These two sets of soundings were compared and the quantity of material excavated from the borrow area was computed to be 557,200 cubic yards. Of this quantity, 535,000 cubic yards were deposited on Sherwood Island Beach and 17,000 cubic yards were placed on Burial Hill Beach; the remaining 5,200, which represents a little less than one percent, can be accounted for by probable error in procedures used for measurement and computation, or losses during pumping.

The seven even-numbered ranges (2+00 to 14+00, inclusive) over the borrow area were sounded again in July 1962 to obtain an indication of the rate of natural refilling or shoaling. Comparative profiles plotted from these surveys are shown in Figure 7. Computations therefrom indicate that between August 1957 and July 1962 the borrow area shoaled 43,900 cubic yards or an average of about 8,800 cubic yards annually.

5. Sand-size Analysis

Sand sample data given in Table 2 show the results of sieve analyses. One of the midtide samples was taken in the western sector and two in the eastern sector. The sample from the western sector was about 90 percent gravel with a median diameter of 26 mm. The two samples from the eastern sector were about 70 percent gravel and had median diameters approximating 5 mm. Samples taken from the beach zone in July 1962 had median diameters ranging from 0.16 mm to 720 mm with an average median diameter of about 1 mm. The median diameters of samples from borings obtained from the offshore borrow area in March 1957 ranged from 0.215 to 0.621 mm with an average median diameter of about 0.40 mm. Analysis of core samples taken from the borrow area in July 1962 shows an average of about 90 percent of the shoaling material in the bottom of the pits to be finer than 0.062 mm. The material composing the bottom adjacent to the borrow pits averaged 60 percent finer than 0.062 mm. Cumulative frequency curves for particle-size distribution and computed composite curves therefor have been constructed for midtide samples taken in 1948, the samples taken in July 1962 and for the borrow area samples taken in March 1957, using the method given by Krumbein.* Phi-unit values are used for convenience in the statistical analysis, and phi-unit equivalents for standard sieve-mesh openings in the range of particle-sizes commonly found in beach sands are given in Table 3. Data for the observed composite size

* Krumbein, W. C., A METHOD FOR SPECIFICATION OF SAND FOR BEACH FILLS, Beach Erosion Board Technical Memorandum No. 102, October 1957.

frequency and computed composite curves for the beach, borrow and midtide samples are shown in Tables 4 and 5, respectively, and plots of the curves are shown on Figure 10. The phi standard deviations for the computed curves for the 1962 beach, 1957 borrow and 1948 midtide samples, respectively, are 2.58, 1.41 and 0.88. The differences between these values are relatively large which indicates the variance in sorting between the beach material, borrow material and the midtide samples, the 1962 beach material being by far the most poorly sorted. A comparison of median diameter for the 1962 beach samples and samples of the borrow material (Figure 10) shows that the composite median diameter of the beach samples is much larger. This would indicate that there had been mixing of the fill material with the coarser material composing the original native beach and that also much of the finer size material may have been lost from the fill during placement or by subsequent action of littoral forces. Normally, when entire class fractions are removed from the size-class distribution of a mixture of material, the remaining material exhibits better sorting. For the 1962 beach samples, the indicated poor sorting, as well as coarseness (in some degree), are believed to be derived from the mixing of the fill material with the coarser native beach material.

Section III RESULTS AND CONCLUSIONS

1. Interpretation of Profile Changes

If the assumption is made that the computed volume changes shown in Table 1 do truly reflect the quantitative results of changes in the available sand on the shore, the following interpretations might be placed thereon. During the 5-year period immediately following placement of beach fill, 37,100 cubic yards of material were eroded from approximately 600 linear feet of shore at Sherwood Point and 12,600 cubic yards were eroded from the 3,400-foot sector east of the Point. During this period accretion amounting to 45,000 cubic yards occurred in the 2,000-foot western sector, indicating a net loss of material from the project area of 4,700 cubic yards. If the data are examined over various segments of the profile, deficits created by movement of beach material are indicated to be predominantly between mean high water and mean low water and almost entirely confined to Sherwood Point and the eastern sector. Most of the losses can be accounted for by accretion in the zones above and below the tidal zone and by the general accretion which occurred in the western sector thereby indicating only a relatively small actual net loss of material from the project area. However, the loss of approximately 96,000 cubic yards of material from the tidal zone of the project beach between Sherwood Point and the eastern extremity indicates that at least 18 percent of the original 535,000 cubic yards of beach fill placed in 1957 has been repositioned by wave forces from its initial zone of placement. Actually only 4,700 cubic yards of fill is indicated as having been entirely removed from the project area, which would represent net losses of less than 1 percent for the 5-year period. Undoubtedly the littoral forces have moved and redistributed gross quantities of material substantially greater than the cited figures indicated by net quantities.

2. Interpretation of Beach Areal Changes

Before construction of the beach improvement project, the shore at Sherwood Island had beach widths above mean high water ranging from 5 to 65 feet. The average above-MHW width at Sherwood Point was about 50 feet. In the sector east of the Point this width averaged about 45 feet while in the western sector the width was much less, averaging only about 20 feet. The comparative high water shoreline changes (Figure 8) developed from the survey data show that beach widths greater than project dimensions (150 feet wide above MHW) were attained throughout the area by the fill placed in June 1957. The average width above mean high water was about 208 feet in the western sector, 265 feet at the Point and 190 feet in the eastern sector. Minor adjustments occurred in the beach fill during the 5 months from June to November 1957. Along the western sector there were alternate short segments of shore respectively exhibiting advance and recession of the high water line which about equalled one another. At Sherwood Point the high water shoreline receded and along the eastern sector there was a small general advance. During the next survey period, November 1957 to June 1958, the high water shoreline advanced along the western sector, receded at the Point and was generally stable along the eastern sector. During the last survey period, the four years from June 1958 to June 1962, the greatest changes in the high water shoreline occurred. The greatest shift was in the vicinity of Sherwood Point where the shoreline receded somewhat more than 100 feet. At the western end of the Park, the high water shoreline advanced about 100 feet while receding about 50 feet the eastern end. The net result of these fluctuations in position of the high water shoreline over the 5-year period following fill placement, was that there had been an advance of about 100 feet at the west end of the western sector, recession at Sherwood Point of about 150 feet and slight recession along the eastern sector.

By June 1962 the average beach width above mean high water had increased in the western sector and decreased in the eastern sector and at Sherwood Point. In the western sector the beach width had increased from the average of 210 feet immediately after fill placement to about 245 feet. At Sherwood Point the average width had decreased from 265 feet to 110 feet and in the eastern sector the decrease was from about 190 feet to 170 feet. Changes in beach widths in the 5 years since fill placement represent an average annual increase in the width in the western sector of 7 feet and average annual decreases of 4 feet in the eastern sector and 30 feet at the Point. However, beach widths of specified minimum project dimensions or greater still existed at this time along most of the project are at Sherwood Island. It was only at Sherwood Point and along a 400-foot stretch of shore at the easternmost limit of the Park adjacent to Burial Hill Creek that beach widths were less than the project width of 150 feet. The narrowest width at Sherwood Point was about 90 feet, and in the vicinity of Burial Hill Creek, 75 feet.

A beach of project width existed throughout most of the area even though no maintenance fill was placed since completion of the project and beach slopes in the foreshore zone had become significantly steeper due to natural removal of material from this zone. The authorized project for Sherwood Island provided for the construction and maintenance of a 150-foot beach width above mean high water. It is probable that the rate of movement from the beach zone at Sherwood Point may decrease if a flatter and more stable slope develops in the inshore zone. However, a maintenance program should be initiated whenever the beach is significantly less than project dimensions.

3. Discussion of Nourishment Requirements

Volume changes computed for Sherwood Island indicate that practically all of the sand-fill losses were from the stockpiled beach at Sherwood Point and the beach zone between mean high water and mean low water and in the eastern sector of the park. These losses were relatively large, amounting to approximately 97,700 cubic yards or an average annual loss of about 19,500 cubic yards. While presumably accretion offshore of the mean low water line will cause the future rate of erosion to diminish, it is probable that losses will continue to be heavier than initially estimated due to the relative alignment of the projecting Sherwood Point with the adjacent shores. Possibly the installation of several short groins of low profile to retard movement from the zone between mean high water and mean low water would reduce the erosion rate to a degree more than sufficient to justify their construction. The groins envisioned at this time would terminate at the mean low water line and be low enough to permit the passage of some sand over their tops to maintain uniform berm width as well as to nourish the downdrift beaches. It is estimated that stone groins of this type could be constructed at an initial cost of about $8,000 each. Considering maintenance, interest and amortization over a 50-year period, the annual cost per groin would be about $400. This cost would be about equal to the cost of placing 275 cubic yards of material on the beach each year at $1.45 per yard and it seems reasonable to assume from data available at this time that suitably designed groins could reduce the rate of erosion by a much greater amount. As the losses are principally westward from the Point, groins located west of the Point would probably be most effective.

Survey data of June 1957 show that approximately 557,200 cubic yards of material were initially dredged from the offshore borrow pits. A comparison of the June 1957 and June 1962 surveys indicates that approximately 43,900 cubic yards of material had collected in the borrow pits during that period or an average of 8,800 cubic yards annually. Particle size analysis of the material accumulated in the borrow pits shows that an average of about 92 percent of that material was finer than 0.062 mm in diameter. Samples taken in June 1962 indicate about 63 percent of the surface material on the natural bottom adjacent to the borrow pits was finer than 0.062 mm in diameter. It thus appears that perhaps none of the coarser fractions (beach-size) of the material pumped onto the beach in 1957 moved as far seaward as the borrow area. It may be assumed that the material that has collected in the borrow pits is composed of sediments from the natural bottom adjacent to the pits and perhaps some of the finer fractions of those particles composing the beach fill placed in 1957.

The borrow pits are refilling very slowly at 8,800 cubic yards per year; at this rate it would take about 63 years for the holes to fill. The toe of the original beach fill initially averaged about 1100 feet distant from the shoreward edge of the borrow holes, and during the 5 years since fill placement the average advance of the toe toward the pits has been less than 70 feet. If the toe of the fill continues to move seaward, the rate of shoaling in the pits could eventually increase very rapidly. However, conclusions regarding such an event from present data are purely speculative. The slow rate of shoaling and the fact that coarser beach materials have not collected in the pits are indications that the borrow area was located far enough seaward to preclude inducement of the beach fill to move back into the borrow pits.

4. Project Economics

a. First Cost

The first cost of the improvement project was about $559,200 which includes contract cost, cost of engineering and supervision, and a Federal share of one-third. A breakdown of costs is given below:

Item	Cost
Sand fill	$440,800
Training Walls	60,346
Groin	58,054
Total	$559,200

b. Annual Charges

Estimated annual charges for the project based on a useful life of 50 years and with the originally estimated maintenance charges adjusted to the 1957 cost index are shown below:

Interest on Investment:			
Federal	3%	$ 5,600	
Non-Federal	3½%	13,050	$18,650
Amortization 50 years:			
Federal	3%	$ 1,650	
Non-Federal	3½%	2,850	4,500
Maintenance:			
Sand fill 4,600 cu yds @ $1.45		$ 6,670	
Training wall repair		605	
Groin repair		435	7,710
Total annual charges			$30,860

Annual sand maintenance requirement is presently estimated at 16,000 cubic yards, which is 11,400 cubic yards greater than originally estimated. This represents an increase in the estimated annual cost of $16,530, resulting in a total estimated annual cost of $47,390.

The cost figures indicate that under the above conditions for estimation, a beach of project dimensions can be established and maintained along 6,000 feet of shoreline at Sherwood Island State Park for a cost of about $7.90 per linear foot per year. Even though a beach of project width existed along most of the shore in June 1962, the foreshore slopes have greatly steepened and material losses from between mean high water and mean low water have been much greater than anticipated. Although there had been no program of periodic maintenance, it is apparent that under present conditions annual maintenance costs will be much greater than originally estimated.

5. Conclusions

The fill placed under the authorized project for Sherwood Island State Park initially provided a beach of greater than project dimensions.

Although actual net loss of material from the project area was only about 1,000 cubic yards per year, losses from the tidal zone in the updrift and central parts of the project area averaged about 19,500 cubic yards per year.

Consideration could be given to the construction of several short stone groins of low profile to retard the erosion rate at and west of Sherwood Point.

A maintenance program should be initiated to replenish losses from the tidal zone if project widths above mean high water are to be retained.

The material borrowed from offshore was suitable beach fill.

The annual cost to provide and maintain a beach of the authorized project dimensions will apparently be about $8.00 per linear foot of shore when considered over an estimated 50-year amortization period.

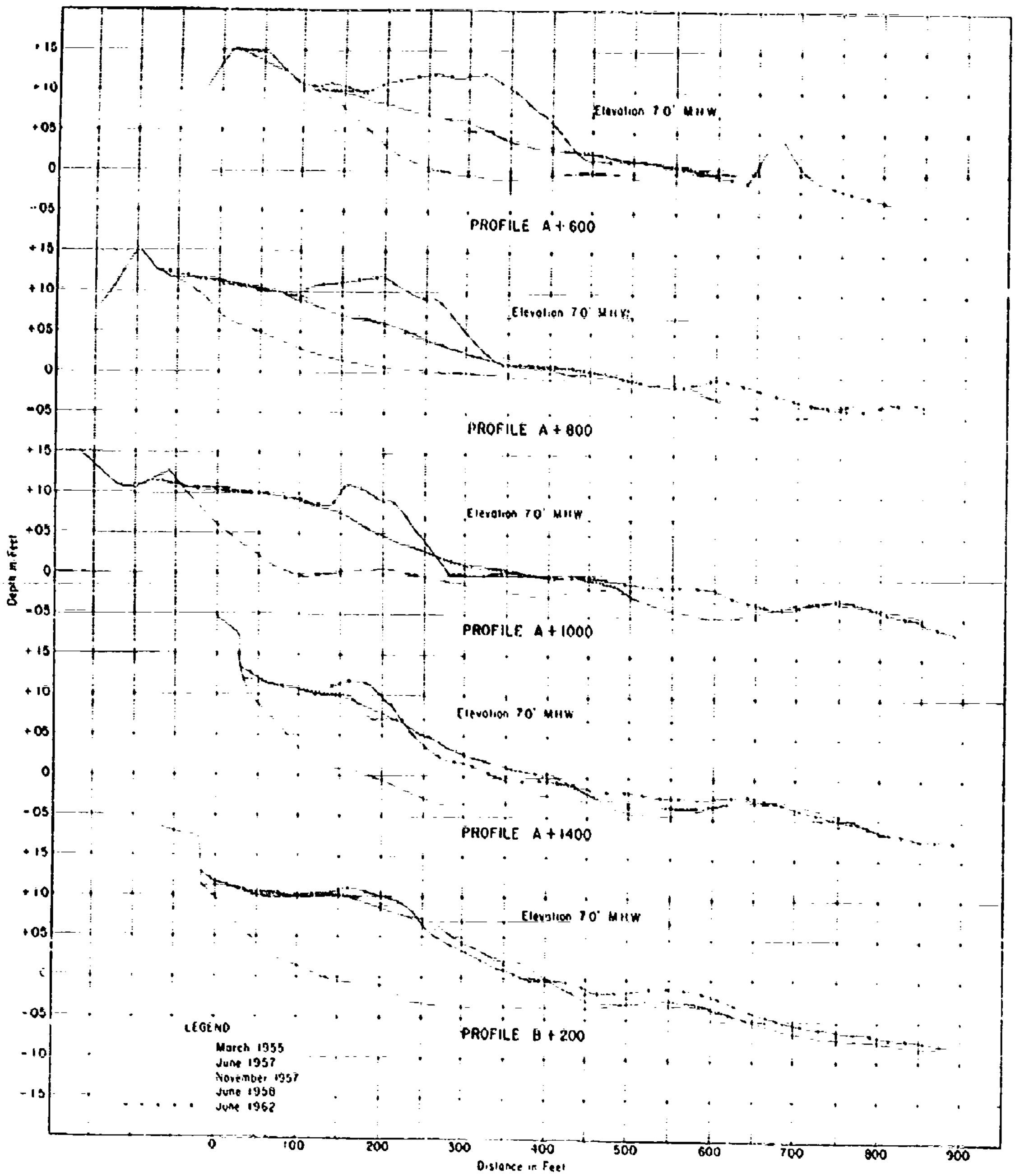

Figure 3. Comparative Profiles A+600 Through B+200

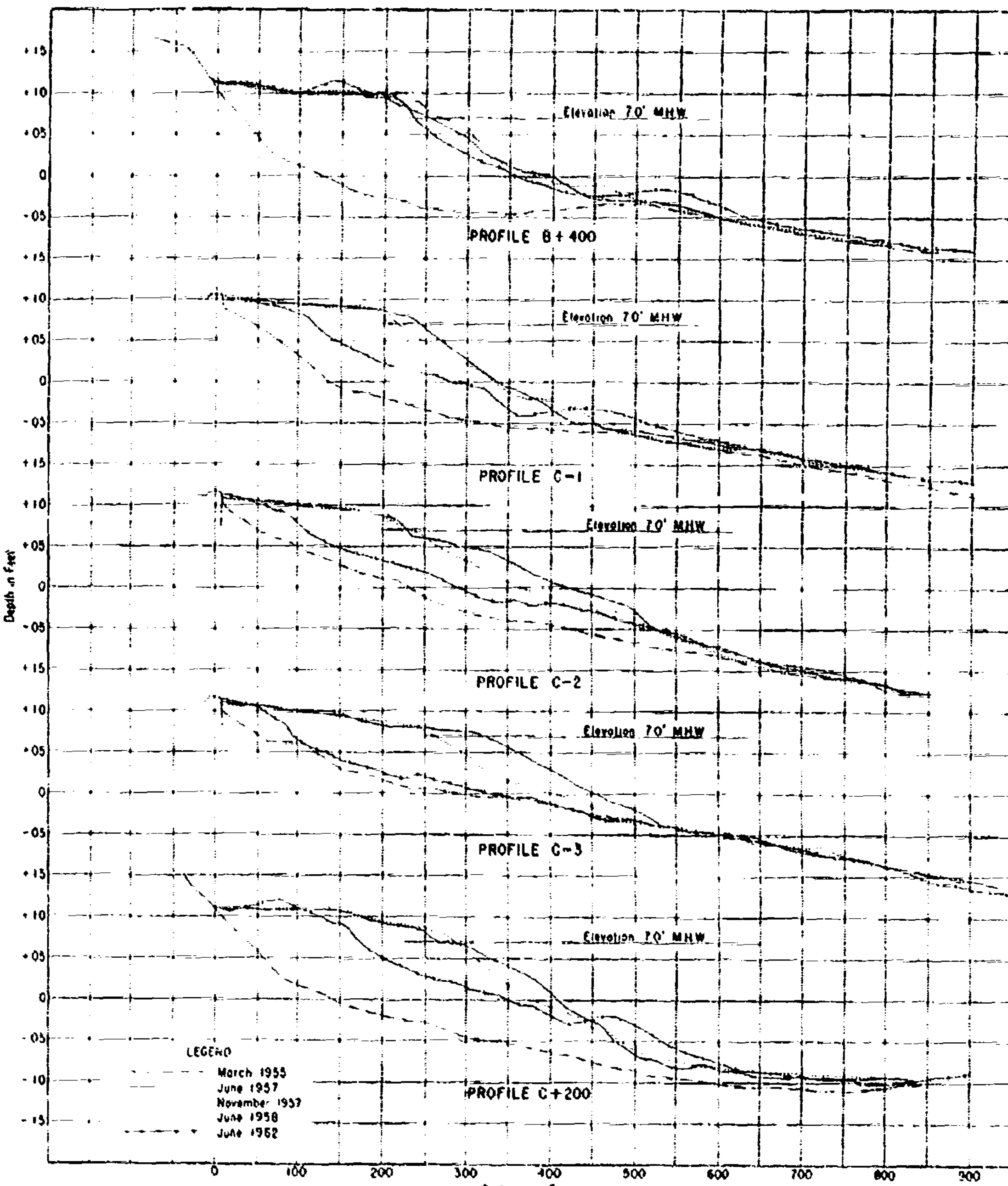

Figure 4. Comparative Profiles B+400 Through C+200

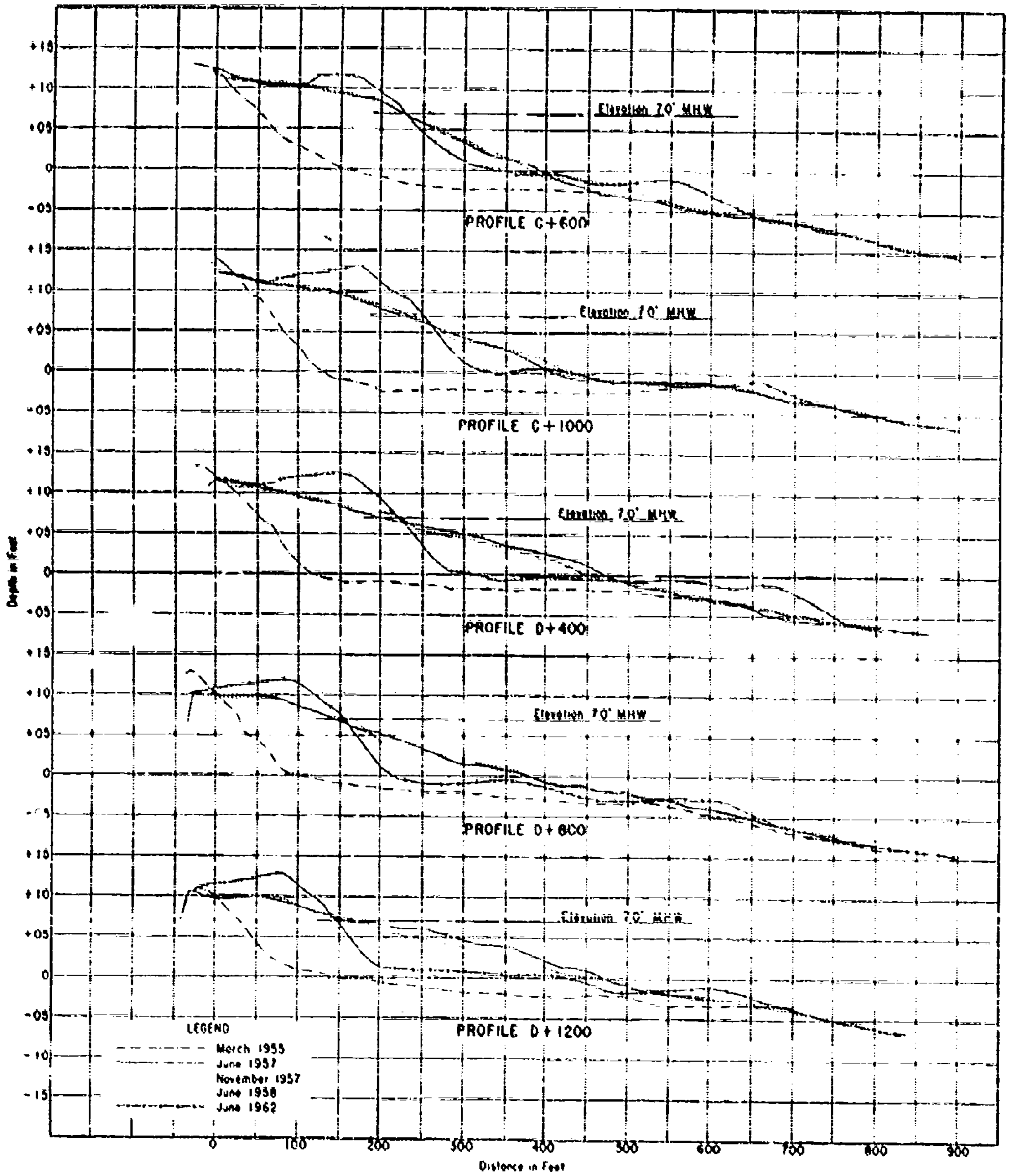

Figure 5. Comparative Profiles C+600 Through D+1200

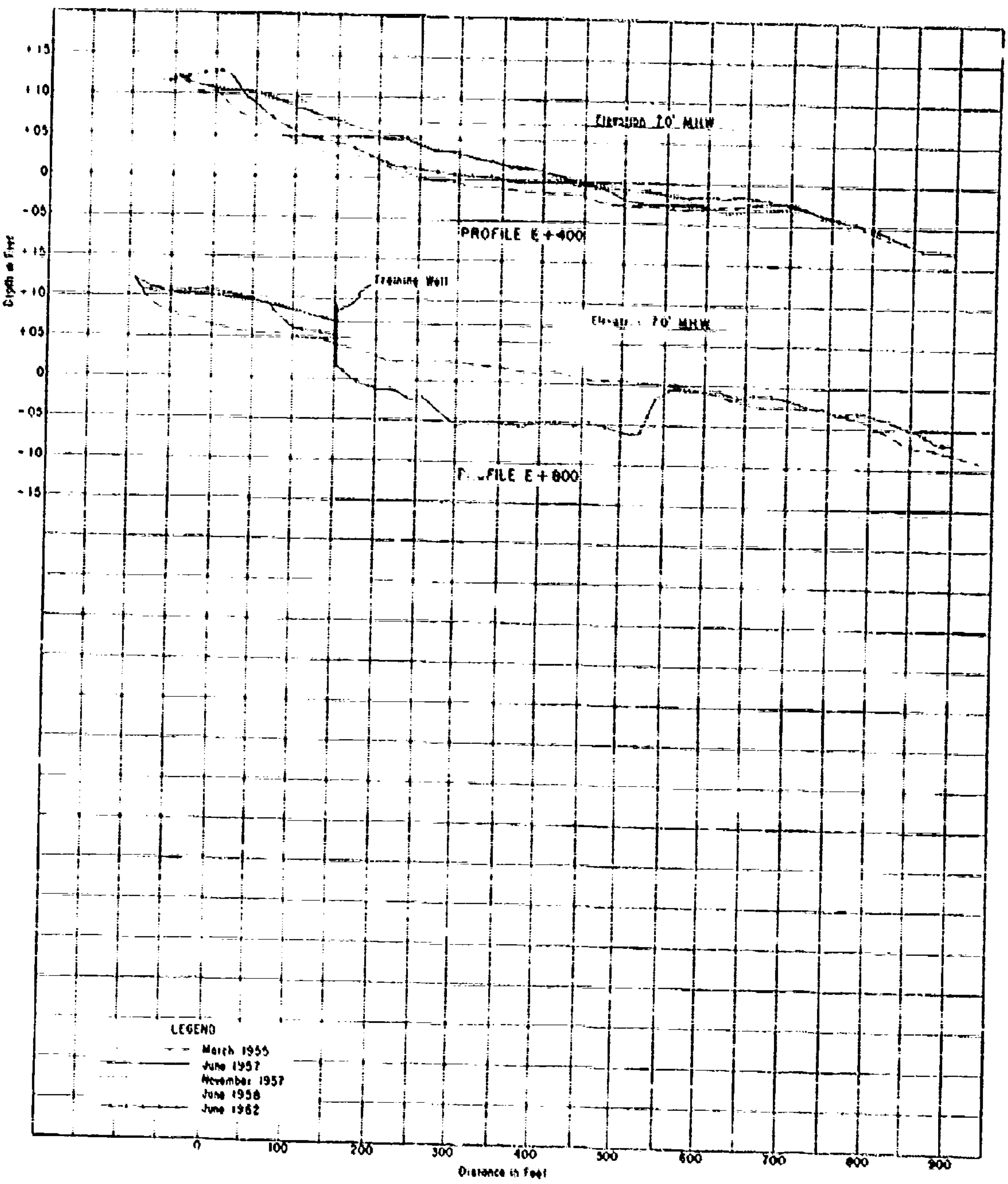

Figure 6. Comparative Profiles E+400 and E+800

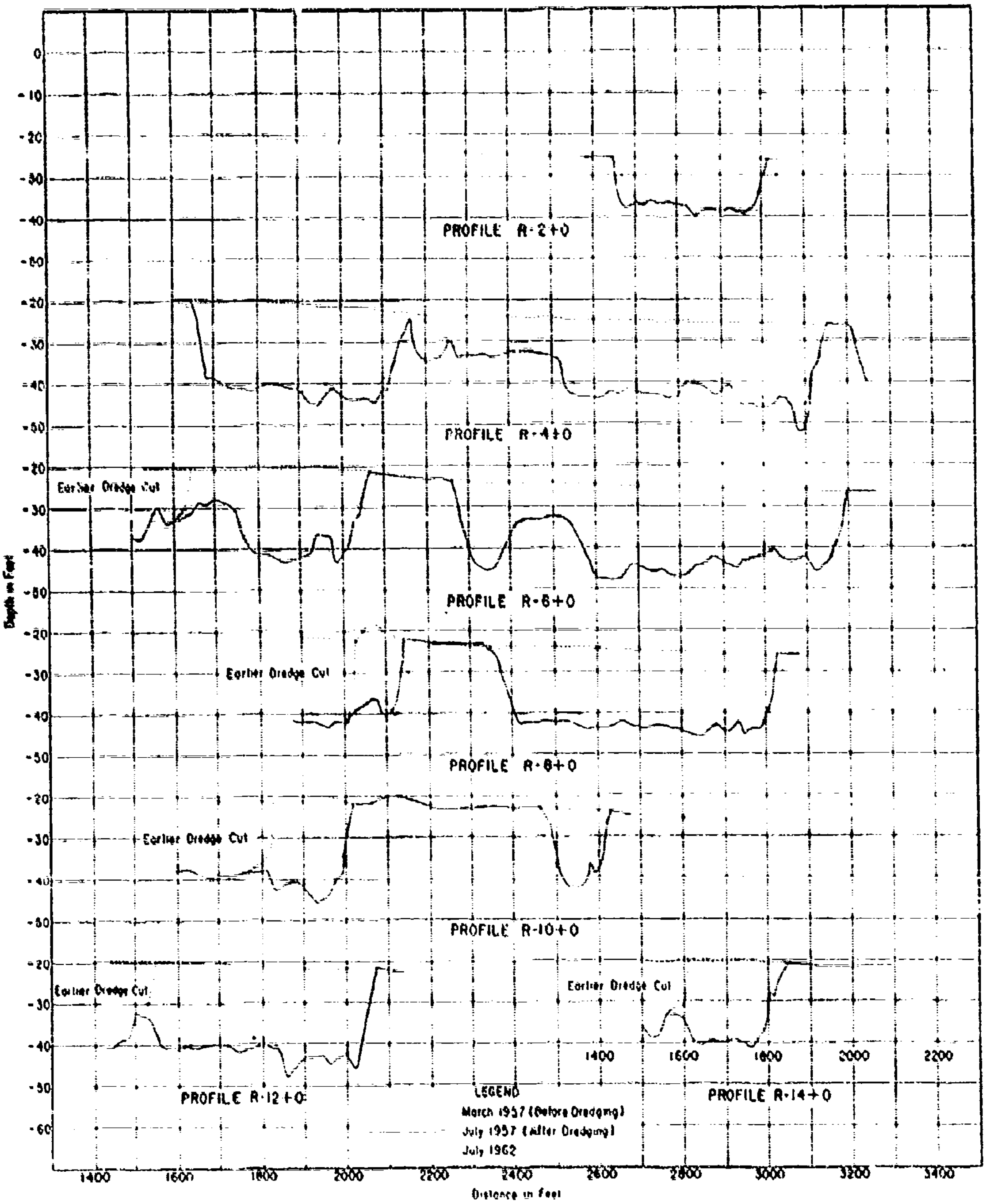

Figure 7. Comparative Ranges at Borrow Area

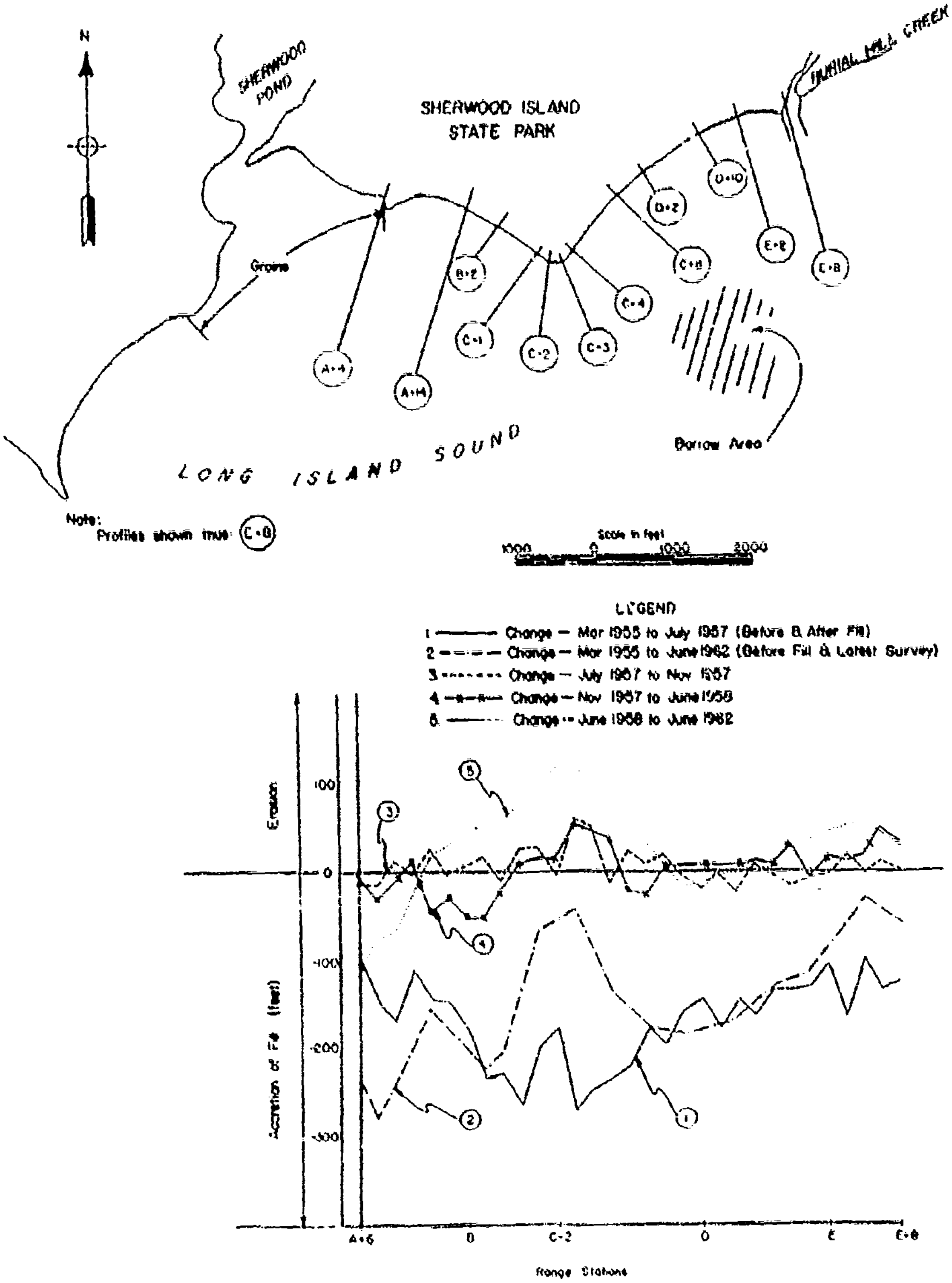

Figure 8. High Water Shoreline Changes

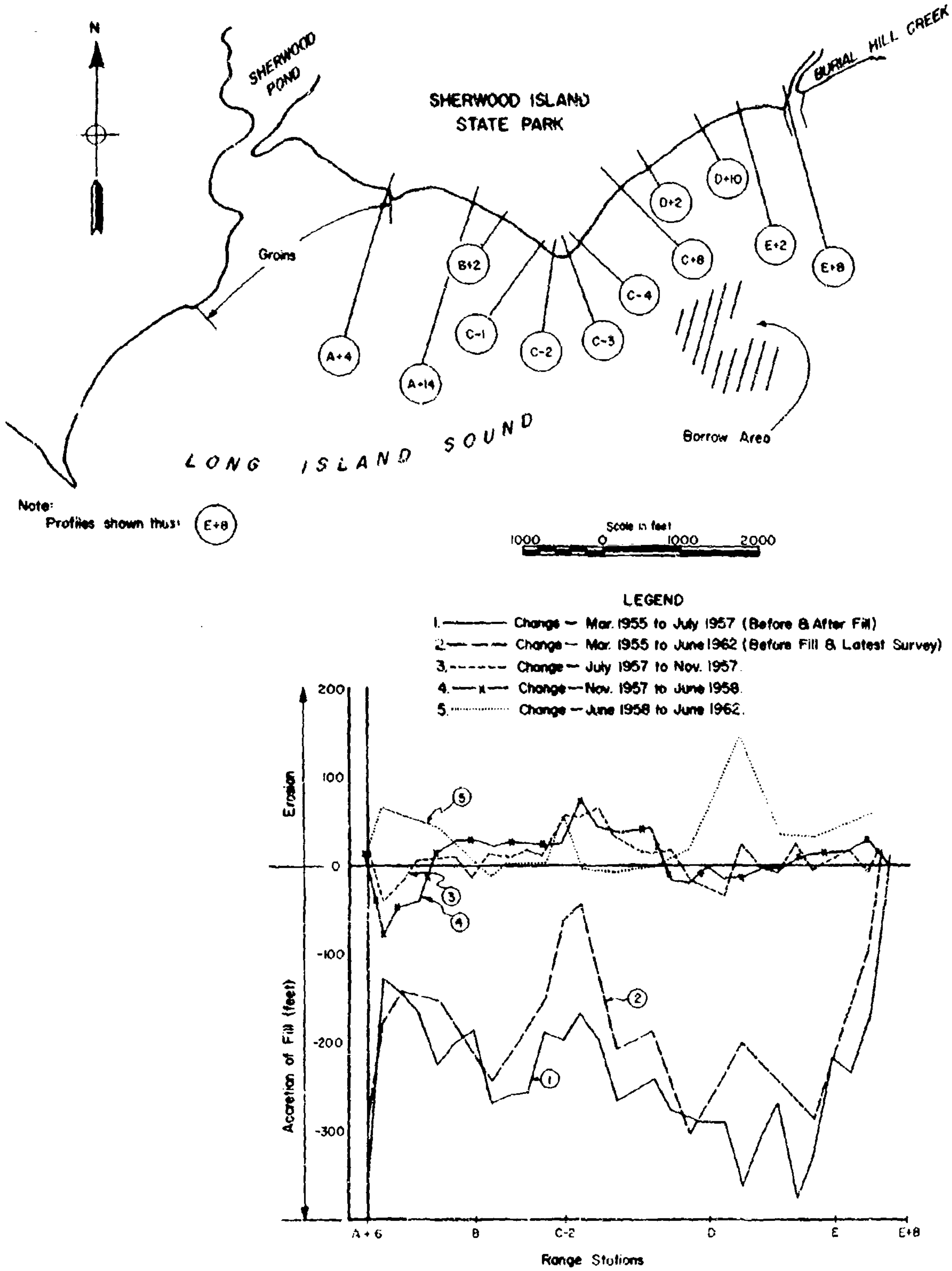

Figure 9. Low Water Shoreline Changes

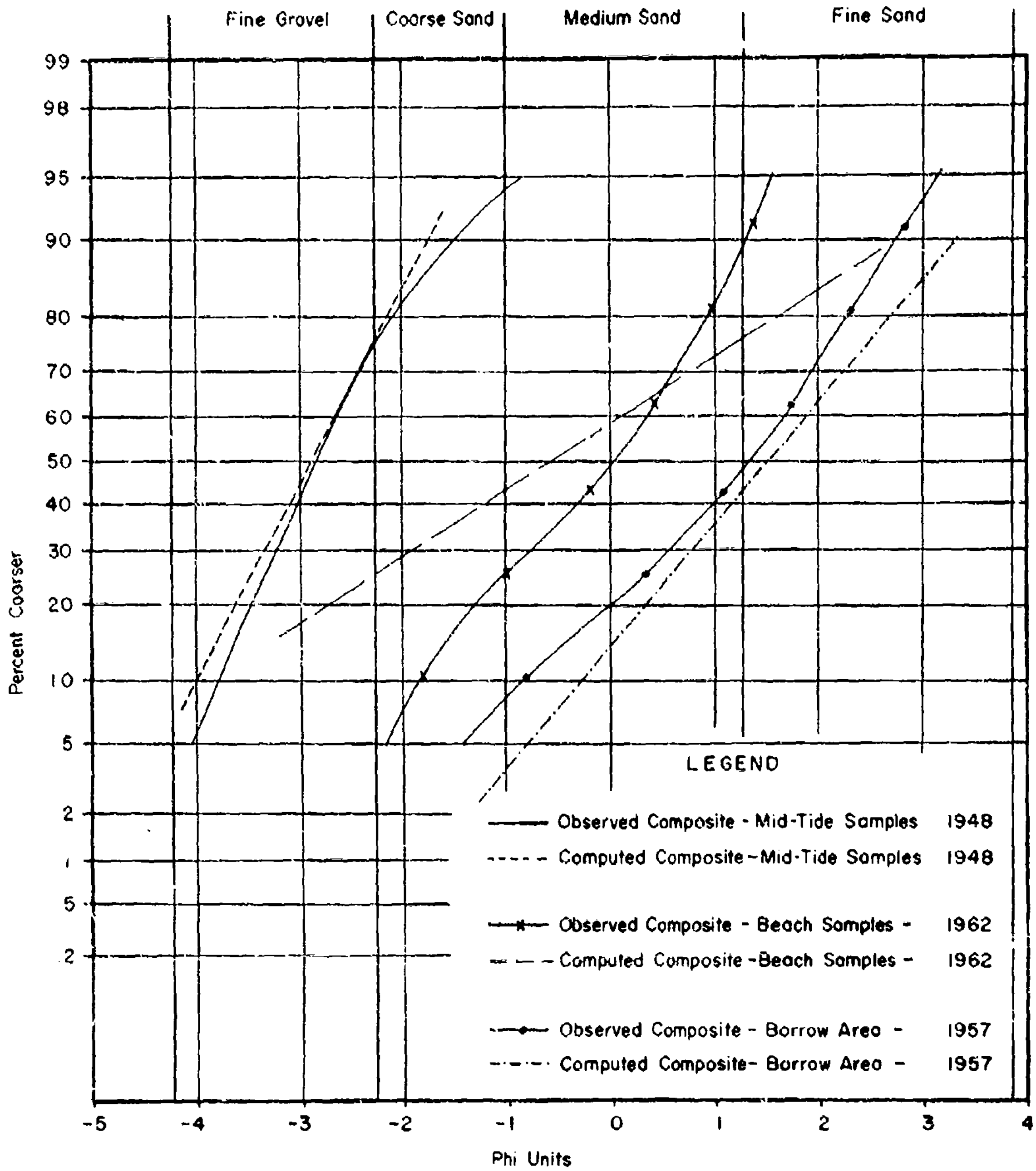

Figure 10. Composite Curves for Sand Samples

TABLE I

SHERWOOD ISLAND STATE PARK, CONNECTICUT
VOLUME CHANGE - THOUSAND CUBIC YARDS

PROFILES	June 1957 to Nov. 1957				Nov. 1957 to June 1958				June 1958 to June 1962				June 1957 to June 1962			
	Above MHW	MLW to MHW	Below MLW	Net	Above MHW	MLW to MHW	Below MLW	Net	Above MHW	MLW to MHW	Below MLW	Net	Above MHW	MLW to MHW	Below MLW	Net
A + 4																
	0.5	-0.3	0.3	0.5	0.4	-0.3	0.1	0.2	3.8	2.2	-0.1	5.9	4.7	1.6	0.3	6.6
A + 6																
	0.6	0.2	0.6	1.4	0.7	0.0	0.1	0.8	4.2	2.4	-0.2	6.4	5.5	2.6	0.5	8.6
A + 8																
	0.1	0.2	0.5	0.8	0.7	-0.5	0.2	0.4	2.2	2.0	0.2	4.4	3.0	1.7	0.9	5.6
A + 10																
	0.1	0.9	0.0	1.0	0.1	-1.0	1.6	0.7	3.0	1.3	2.2	6.5	3.2	1.2	3.8	8.2
A + 14																
	0.7	-0.7	1.9	1.9	1.7	0.2	1.0	2.9	2.3	-3.4	8.3	7.2	4.7	-3.9	11.2	12.0
B + 2																
	0.4	0.1	0.6	1.1	0.9	0.1	-0.1	0.9	-0.2	-1.6	3.8	2.0	1.1	-1.4	4.3	4.0
B + 4																
Subtotal	2.4	0.4	3.9	6.7	4.5	-1.5	2.9	5.9	15.3	2.9	14.2	32.4	22.2	1.8	21.0	45.0
B + 4																
	0.1	-0.7	0.2	-0.4	-0.1	-2.6	-0.1	-2.8	-2.7	-4.0	6.0	-0.7	-2.7	-7.3	6.1	-3.9
C + 1																
	-0.2	-0.9	-0.8	-1.9	0.1	-1.1	-0.9	-1.9	-1.8	-2.4	2.1	-2.1	-1.9	-4.4	0.4	-5.9
C + 2																
	-0.1	-1.8	-1.0	-2.9	0.3	-1.5	-1.2	-2.4	-2.0	-2.5	2.0	-2.5	-1.3	-5.8	-0.2	-7.8
C + 3																
	-0.5	-4.8	-1.2	-6.5	0.1	-4.2	-6.0	-10.1	-4.3	-4.8	6.2	-2.9	-4.7	13.8	-1.0	19.5
C + 200																
Subtotal	-0.7	-8.2	-2.8	-11.7	0.4	-9.4	-8.2	-17.2	-10.8	-13.7	16.3	-8.2	-11.1	-31.3	5.3	-37.1
C + 200																
	-0.2	-0.6	2.0	1.2	0.9	-2.0	-3.0	-4.1	-1.1	-3.9	8.0	3.0	-0.4	-6.5	7.0	0.1
C + 600																
	-0.1	-0.5	1.4	0.8	0.0	-1.0	0.9	-0.1	3.4	-3.1	3.7	4.0	3.3	-4.6	6.0	4.7
C + 1000																
	-0.3	0.5	0.6	0.8	1.6	-1.7	0.8	0.7	6.9	-7.0	4.6	4.5	8.2	-8.2	6.0	6.0
D + 4																
	0.0	-0.8	0.8	0.0	0.8	-2.2	-0.5	-1.9	4.1	-6.4	4.6	2.3	4.9	-9.4	4.9	0.4
D + 8																
	0.5	-1.4	0.0	-1.9	0.5	-2.2	-1.0	-2.7	3.4	-7.2	1.9	-1.9	4.4	-10.8	0.9	-5.5
D + 12																
	0.1	-3.6	0.7	-2.2	2.5	-3.2	0.0	-2.7	0.5	-12.2	3.3	-8.4	3.1	-19.0	4.0	-11.9
E + 4																
	0.4	-1.7	0.2	-1.1	0.3	-1.6	0.2	-1.1	-1.5	-4.6	1.9	-4.2	-0.8	-7.9	2.3	-6.4
E + 8																
Subtotal	0.4	-8.1	5.7	-2.0	6.6	-13.9	-2.6	-9.9	15.7	-44.4	28.0	-0.7	22.7	-66.4	31.1	-12.6
TOT	2.1	-15.9	6.8	-7.0	11.5	-24.8	-7.9	-21.2	20.2	-55.2	58.5	23.5	33.8	-95.9	57.4	-4.7

TABLE 4

SHERWOOD ISLAND STATE PARK SAND SAMPLES
SIEVE ANALYSIS - PERCENT COARSER

$M\phi = (\phi 84 + \phi 16)/2$ = Phi Mean
$\sigma\phi = (\phi 84 - \phi 16)/2$ = Std Dev.
$\alpha\phi = (M\phi - Md\phi)/\sigma\phi$ = Skew.

Beach Samples - July 1962

Sample No.	Range	Location	φ5	φ16	φ25	φ50	φ75	φ84	φ95	[illegible]	Phi Mean Mφ	σφ	σφ²	αφ
1	A+600	Berm	[illegible]	-3.82	-3.50	[illegible]	1.04	2.16	2.40	-	Bimodal	-	-	-
2	"	MHW	[illegible]	-2.90	-1.70	0.49	1.36	1.61	2.00	-	"	-	-	-
3	"	MLW	1.75	1.98	[illegible]	2.37	2.61	2.69	3.00	1.46	2.54	0.36	0.1296	0.47
4	A+1400	Berm	-2.83	-1.96	-1.37	0.45	1.16	1.46	1.64	-	-0.26	[illegible]	0.9241	-0.41
5	"	MHW	-2.76	-1.45	-0.67	0.71	1.27	1.54	1.99	0.78	0.04	1.49	2.2201	-0.45
6	"	MLW	1.60	2.04	2.24	2.58	3.04	3.27	3.64	-	2.66	0.62	0.3844	0.13
7	"	Offshore	0.60	1.30	1.84	2.87	3.54	3.76	-	10.00	2.54	1.24	1.5376	-0.27
8	C-3	Berm	-3.50	-2.97	-2.07	0.47	1.18	1.42	1.83	-	Bimodal	-	-	-
9	"	MHW	-2.78	-1.45	-0.95	0.74	1.44	1.75	2.36	1.92	0.15	1.60	2.5600	-0.37
10	"	MLW	-2.73	-1.22	-0.25	2.02	2.46	2.77	-	5.24	0.78	2.00	4.000	-0.62
11	"	Offshore	-6.09	-5.98	-5.93	-5.83	-5.72	-5.67	-5.57	-	-5.83	0.16	0.0256	0.00
12	"	Offshore	-5.10	-4.93	-4.83	-4.40	-3.30	-1.47	-	5.55	-3.19	1.74	3.0276	0.70
13	C-1000	Berm	-2.32	-0.23	0.56	1.25	1.75	2.12	2.50	-	Bimodal	-	-	-
14	"	MHW	-3.70	-3.37	-3.21	-1.90	0.15	1.30	2.43	0.50	"	-	-	-
15	"	MLW	1.67	2.03	2.18	2.53	2.85	2.99	3.25	1.19	2.51	0.48	0.2304	-0.04
16	"	Offshore	-5.66	-5.57	-5.53	-5.42	-5.11	-2.05	-4.96	-	-5.29	0.30	0.0900	0.43
17	D+1200	Berm	-2.90	-2.27	-1.75	0.10	1.42	1.87	2.53	0.60	Bimodal	-	-	-
18	"	MHW	-4.25	-3.82	-3.53	-2.00	0.50	1.50	2.38	0.20	"	-	-	-
19	"	MLW	1.92	2.22	2.34	2.62	2.82	2.90	3.20	2.10	2.56	0.34	0.1156	-0.18
20	"	Offshore	1.77	2.43	2.71	3.66	wet sieved	-	-	45.30	-	-	-	-
Total			-43.09	-30.23	-21.11	0.46	14.46	22.96	24.82				17.2450	-0.22
Average			-2.15	-1.51	-1.06	0.02	0.76	1.21	1.55				1.4371	-0.0183

Borrow Area Samples - March 1957

Sample No.	Location	φ5	φ16	φ25	φ50	φ75	φ84	φ95	Mφ	σφ	σφ²	αφ
1	Borrow area	-0.33	0.81	1.33	2.13	2.76	3.02	3.40	1.91	1.10	1.21	-0.20
2	"	-1.73	-0.96	-0.50	0.69	1.53	1.85	2.58	0.45	1.40	1.96	-0.17
3	"	-2.96	-1.17	-0.32	1.07	1.97	2.36	3.32	0.60	1.77	3.13	-0.27
4	"	-2.26	-1.32	-0.65	0.80	1.71	2.07	2.71	0.37	1.69	2.86	-0.25
5	"	-1.34	-0.40	0.08	1.04	1.75	2.05	2.59	0.82	1.22	1.49	-0.18
6	"	-2.09	-0.90	-0.14	1.53	2.39	2.69	3.28	0.89	1.79	3.20	-0.36
7	"	-1.51	-0.42	0.22	1.11	1.72	2.00	2.57	0.79	1.21	1.46	-0.26
8	"	-0.59	0.40	0.83	1.50	2.11	2.37	2.97	1.38	0.98	0.96	-0.12
9	"	-2.58	-0.74	-0.11	1.10	1.84	2.16	2.93	0.71	1.06	1.12	-0.37
10	"	-0.15	0.55	0.89	1.47	2.09	2.40	3.12	1.47	0.92	0.85	0.00
11	"	-0.77	0.01	0.44	1.39	2.25	2.44	2.95	1.24	1.21	1.46	-0.12
12	"	-1.87	-0.48	0.46	1.22	2.00	2.51	4.06	1.01	1.50	2.25	-0.14
13	"	-0.61	0.56	1.07	1.91	2.62	3.06	3.95	1.81	1.25	1.56	-0.08
14	"	-1.23	0.05	0.98	2.22	2.69	2.93	3.38	1.49	1.44	2.07	-0.51
Total		-20.02	-4.01	4.58	19.16	29.14	33.91	43.81			25.58	-3.35
Average		-1.43	-0.29	0.32	1.37	2.08	2.42	3.15			1.83	-0.24

Mid-Tide Samples - 1948

Sample No.	Location	φ5	φ16	φ25	φ50	φ75	φ84	φ95	Mφ	σφ	σφ²	αφ
22	Mid-Tide	-3.50	-3.10	-2.95	-2.55	-2.05	-1.60	-0.55	-2.35	0.75	0.5625	0.27
23	"	-3.95	-3.45	-3.20	-2.70	-2.15	-1.70	-0.55	-2.57	0.88	0.7744	0.15
24	"	-4.65	-4.10	-3.85	-3.20	-2.65	-2.35	-1.35	-3.24	0.88	0.7744	-0.05
Total		-12.10	-10.65	-10.00	-8.45	-6.85	-5.65	-2.45			2.1113	0.37
Average		-4.03	-3.55	-3.33	-2.82	-2.28	-1.88	-0.82			0.7038	0.12

TABLE 3

PHI VALUES OF STANDARD SIEVE MESHES

(ASTM Sieve Scale)

Mesh Number	Opening, Millimeters	Phi-Unit Value
5	4.00	-2.00
6	3.36	-1.75
7	2.83	-1.50
8	2.38	-1.25
10	2.00	-1.00
12	1.68	-0.75
14	1.41	-0.50
16	1.19	-0.25
18	1.00	0.00
20	0.84	0.25
25	0.71	0.50
30	0.59	0.75
35	0.50	1.00
40	0.42	1.25
45	0.35	1.50
50	0.297	1.75
60	0.250	2.00
70	0.210	2.25
80	0.177	2.50
100	0.149	2.75
120	0.125	3.00
140	0.105	3.25
170	0.088	3.50
200	0.074	3.75
230	0.062	4.00
270	0.053	4.25
325	0.044	4.50

TABLE 4

SUMMARY OF DATA FOR OBSERVED COMPOSITE SAND SAMPLES

Percent Coarser	Beach Samples July 1962 φ Values	Borrow Samples March 1957 φ Values	Mid-Tide Samples 1949 φ Values
5	-2.15	-1.43	-4.03
16	-1.51	-0.29	-3.55
25	-1.06	0.32	-3.33
50	0.02	1.37	-2.82
75	0.76	2.08	-2.28
84	1.21	2.42	-1.88
95	1.55	3.13	-0.82

TABLE 5

COMPILATION OF COMPUTED COMPOSITE CURVE

$$\sigma^2_{comp} = \sigma^2 + \frac{(B-A)^2}{12} + \frac{(B-A)^2}{6(n-1)}$$

$$\phi_{50} = \frac{B+A}{2}$$

$$\phi_{16} = \frac{B+A}{2} - \sigma_{comp}$$

$$\phi_{84} = \frac{B+A}{2} + \sigma_{comp}$$

where σ^2_{comp} is the variance of the computed composite curve, σ^2 is the mean variance of the individual distributions. A and B are the extreme phi means and n is the number of samples in the set.

Beach Samples - July 1962

Sample No.	Phi Mean B	A	B-A	$\frac{B+A}{2}$	σ^2
7	2.87				
1		-2.85	5.72	0.01	
20	3.66				
11		-5.83	3 9.49	-1.08	
Average			7.60	-0.54	1.44

$$\sigma^2_{comp} = \sigma^2 + \frac{(B-A)^2}{12} + \frac{(B-A)^2}{6(n-1)} = 1.44 + \frac{57.76}{12} + \frac{57.76}{114}$$

$$= 1.44 + 4.813 + 0.506 = 6.76$$

$$\sigma_{comp} = \sqrt{6.76} = 2.58 \text{ Std Deviation}$$

$$\phi_{50} = \frac{B+A}{2} = -0.54$$

$$\phi_{16} = \frac{B+A}{2} - \sigma_{comp} = -0.54 - 2.58 = -3.12$$

$$\phi_{84} = \frac{B+A}{2} + \sigma_{comp} = -0.54 + 2.58 = 2.04$$

TABLE 5 (Continued)

Borrow Area Samples - March 1957

Sample No.	Phi Mean B	A	B-A	$\frac{B+A}{2}$	σ^2
1	2.13				
2		0.69	1.44	1.41	
14	2.22				
9		1.10	1.12	1.66	
Average			1.28	1.53	1.83

$$\sigma^2_{comp} = \sigma^2 + \frac{(B-A)^2}{12} + \frac{(B-A)^2}{6(n-1)} = 1.83 + \frac{1.64}{12} + \frac{1.64}{78}$$

$$= 1.83 + .137 + .021 = 1.988$$

$$\sigma_{comp} = \sqrt{1.988} = 1.41 \text{ Std Deviation}$$

$$\phi_{50} = \frac{B+A}{2} = 1.53$$

$$\phi_{16} = \frac{B+A}{2} - \sigma_{comp} = 1.53 - 1.41 = 0.12$$

$$\phi_{84} = \frac{B+A}{2} + \sigma_{comp} = 2.94$$

Mid-Tide Samples

Sample No.	Phi Mean B	A	B-A	$\frac{B+A}{2}$	σ^2
S-22	-2.55				
S-24		-3.20	+0.65	-2.88	.7038

$$\sigma^2_{comp} = \sigma^2 + \frac{(B-A)^2}{12} + \frac{(B-A)^2}{6(n-1)} = .7038 + \frac{.4225}{12} + \frac{.4225}{12}$$

$$= .7038 + .0352 + .0352 = .7742$$

$$\sigma_{comp} = 0.88 = \text{Std Deviation}$$

$$\phi_{50} = \frac{B+A}{2} = -2.88$$

$$\phi_{16} = \frac{B+A}{2} - \sigma_{comp} = -2.88 - 0.88 = -3.76$$

$$\phi_{84} = \frac{B+A}{2} + \sigma_{comp} = -2.88 + 0.88 = -2.00$$