DEPARTMENT OF THE ARMY CORPS OF ENGINEERS

BEACH EROSION BOARD
OFFICE OF THE CHIEF OF ENGINEERS

CHANGES IN CONFIGURATION OF POINT REYES BEACH, CALIFORNIA 1955-1956

TECHNICAL MEMORANDUM NO. 91

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NOVEMBER 1956

FOREWORD

The design of shore protection measures, including the artificial nourishment of beaches, is governed to a significant degree by the characteristics of the beach material in the problem area. These characteristics usually vary with time at any given point and also vary from point to point along and across the beach face. The securing and interpretation of a set of beach samples can be done more intelligently if the cause and probable extent of these variations in beach characteristics are understood.

This report presents a summary of sand sample data obtained at one beach over a year's period, and a type of statistical analysis of this data. To supplement the data and analysis in this memorandum, the user would probably find it to be of interest to refer to prior reports by other workers in the field of statistical interpretation of beach parameters, e.g., Krumbein on Statistical Significance of Beach Sampling Methods, Beach Erosion Board Technical Memorandum No. 50; Trask and Johnson on Sand Variation at Point Reyes, California, Beach Erosion Board Technical Memorandum No. 65; and Krumbein on Relative Efficiency of Beach Sampling Methods, Beach Erosion Board Technical Memorandum No. 90. The report in addition presents certain data on beach cut and fill over this period, and also, as an appendix, over the previous 18-month period. This latter portion was prepared a year before the main body of the report, and is included (unrevised in light of later findings) as an appendix to afford ready reference and to extend the period of published data.

The report was prepared at the Waves Research Laboratory of the Institute of Engineering Research at the University of California in Berkeley in pursuance of contract DA-49-055-eng-8 with the Beach Erosion Board which provides in part for the study of beach materials. The author of this report, Parker D. Trask, is a Research Geologist at that institution. The appendix was prepared under the same contract by P. D. Trask, C. A. Johnson, and T. Scott, all Geologists with the University of California.

Views and conclusions expressed in this report are not necessarily those of the Beach Erosion Board.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945.

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Appendix A - Cut and Fill on Point Reyes Beach, California (June 1953 - March 1954)

CHANGES IN CONFIGURATION OF POINT REYES BEACH, CALIFORNIA 1955-1956

by
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ABSTRACT

Point Reyes Beach is a highly variable beach, characterized by steep slopes, high berms and prominent cusps. It has been surveyed in the present study 8 times between August 1955 and June 1956. The sands are coarse, ranging from a mean of 560 microns (0.38 phi units) in February to 770 microns (0.84 phi units) in October. Intervening months have intermediate grain sizes. The general variation or standard deviation of the samples on the beach ranges generally from 0.30 to 0.35 phi units, which indicates that the median diameter of two-thirds of the samples on the beach at any one time ranges within 20 to 25 percent on either side of the mean for the beach. At times the beach is more variable than indicated above, and gravels with phi diameters of minus 3 (8 millimeters) are found on the beach. The sediments at all times are more poorly sorted than normal beach sands, as the mean coefficient of sorting ranges generally between 1.27 and 1.30, in contrast with 1.20 or less for many beaches. No distinctive difference in sorting is observed between seasons. The sediments are evenly skewed.

The sediments on the lower foreshore are more coarse grained and better sorted than the sediments on the upper foreshore or berm. The deposits in the swales or bays between cusp points are more fine grained than on the foreshore or on the berm adjacent to the cusp points. The cusps range in height from 12 to 17 feet above mean low water and average 15 feet. The horizontal interval between cusps ranges between 60 and 250 feet, with an average of 160 feet. The cusps change location on the beach from time to time. The average position of the cusps ranges within an interval of 50 feet measured normal to the coast line, and the maximum variation in position occurred within a period of 6 weeks between May and June 1956. Individual cusps or parts of the beach may advance or retreat a maximum distance of 160 feet. The cusps are actively eroded at times, particularly when low berms form on which the waves cut scarps as much as 5 feet in height in the preceding berm. At other times the cusps and beach are built up rapidly. As much as 8 inches of fill in 4 hours and 12 inches in 18 hours has been observed. The maximum fill at any one place in an

interval of 6 weeks is 7 feet and the maximum cut is 10 feet. The winter months are periods of active cutting and summer months a period of fill. The slopes on the beach are generally steep. In the swales between cusps the slopes are commonly 4 to 8 degrees, and on the slopes off the points of the cusps, from 6 to 15 degrees, with an average of about 10 degrees on the upper foreshore near the "Reference Point". Where the berm is being actively eroded slopes greater than 45 degrees or 100 percent have been observed.

INTRODUCTION

Point Reyes Beach is a highly variable beach on the Pacific coast of California, 35 miles northwest of San Francisco (Figure 1). The beach continually changes in configuration and in grain size. At times each succeeding wave brings up sand of appreciably different dimensions than that brought up by the preceding wave. The sand is coarse, ranging mainly in grain size from 500 to 750 microns. The foreshore is steep, commonly sloping 10 degrees and in places where cusps are being eroded, slopes as steep as 45 degrees have been observed. The beach outline is irregular, though the general beach trend is remarkably straight for a distance of 10 miles. The beach at times is characterized by a series of alternating protuberances and embayments 1500 to 3000 feet in length and ranging up to 200 feet in width. Superimposed on the protuberances and embayments are a series of cusps 60 to 250 feet apart. Both the cusps and protuberances change position with time. Rip tides are observed opposite many of the embayments. The beach is exposed to the full force of the waves, which strike it straight on. One or more bars lie off-shore. The prevailing drift is from north to south. The general location and setting of the beach are shown in Figures 1 and 2.

The variability and irregularity of the beach have lead to an intensive study of it by the Waves Research Laboratory of the University of California in cooperation with the Beach Erosion Board. Since June, 1953 the beach has been occupied at intervals of 4 to 15 weeks, except for a period between March, 1954 and May, 1955. In the first 18 months, of the investigation, two stations 5 miles apart on the beach were studied, but owing to the poor accessibility of one of the stations and the general similarity of the beach at this station to the beach at the other station, only one station has been investigated during the past 18 months. The results of the first 18 months investigation have been reported in two articles(1,2)*. Reference 2 is included as appendix A to this report. The results of the second 18-month period form the basis for the present paper.

The two previous reports show that the texture of the beach is highly variable. The standard deviation, sigma, of the groups of samples taken at each sampling interval ranged from 0.15 to 0.41 phi units. Series of samples collected within a circle with radius of 15 feet on

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*Numbers in parentheses refer to References listed on page 49.

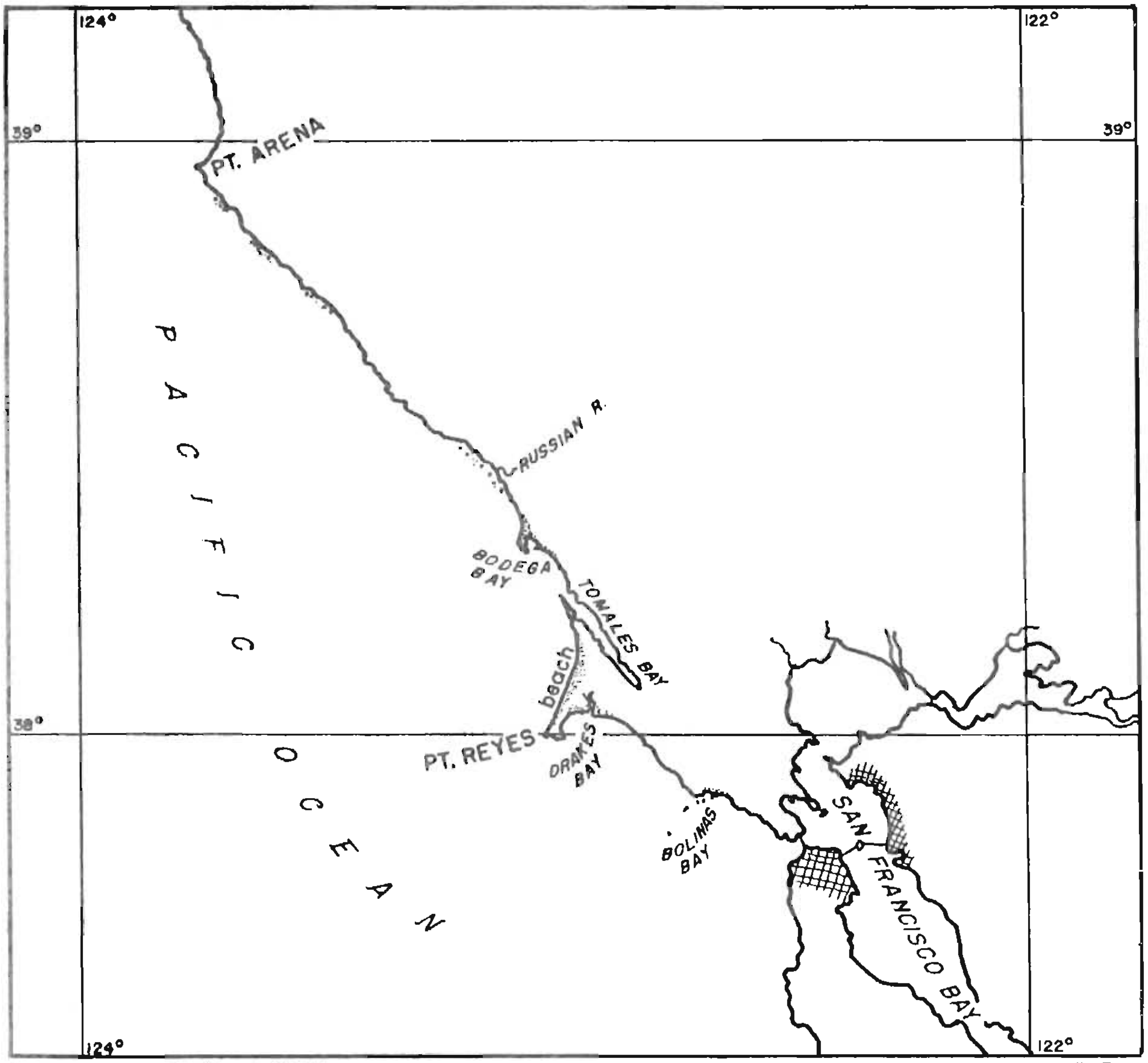

FIGURE 1. LOCATION OF POINT REYES BEACH

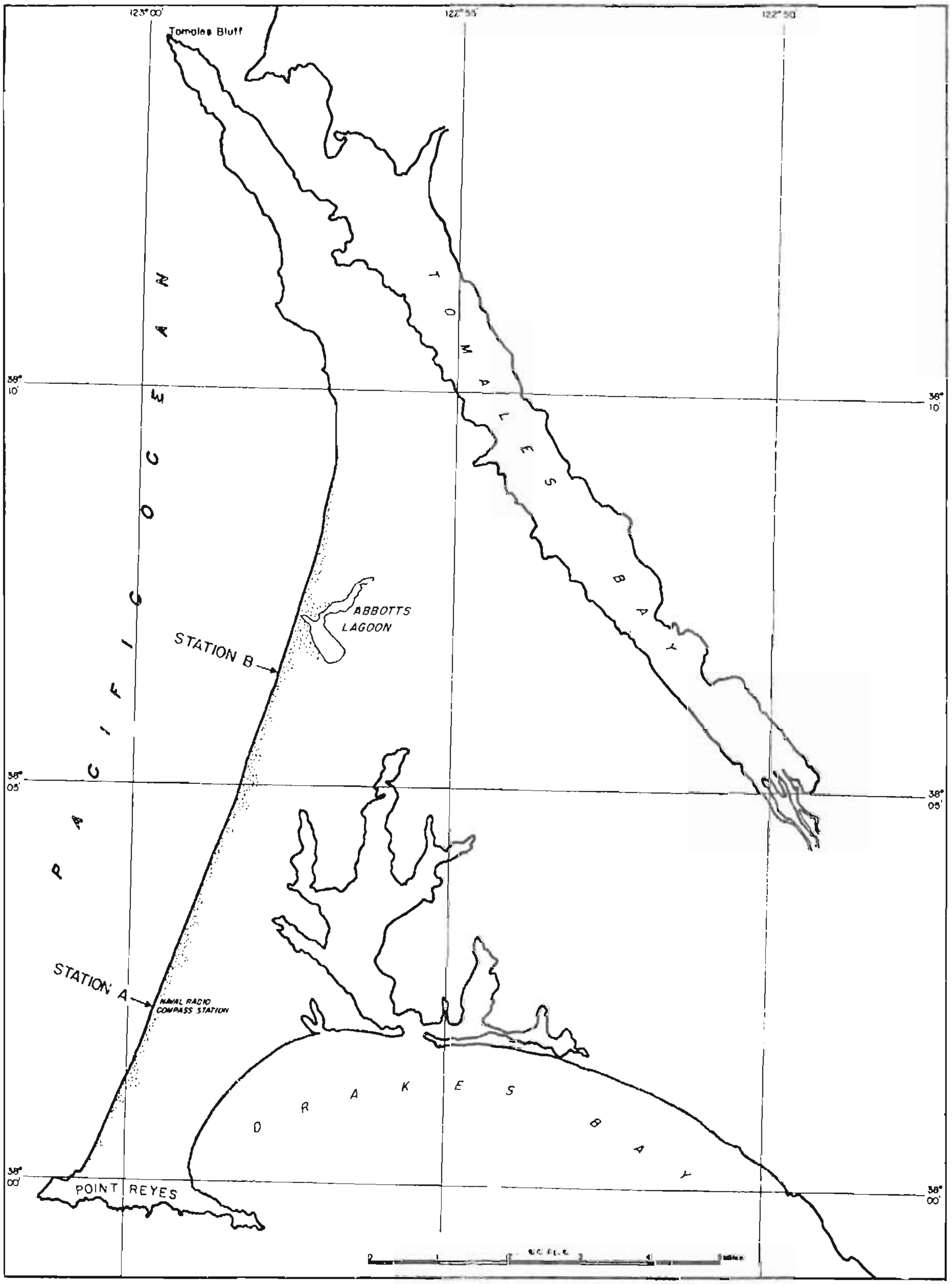

FIGURE 2. LOCATION OF STATIONS A AND B

the average had 60 percent of the variation of the total area sampled on the beach. This area had a lineal extent of more than 500 feet and a width of more than 200 feet (See Figures 3 to 10). The sediments were distinctly finer in the early fall (October) at the end of the summer season than at other times. The lower foreshore was consistently more coarse-grained than the upper foreshore or berm. The coefficient of sorting was moderately high for an ocean beach, averaging 1.28 at one station and 1.45 at the other. The position of cusps changed between sampling intervals, such that some places on the beach had been cut or filled as much as 6 feet between intervals of study. No relationship between grain size and amount of cut or fill was indicated by the studies made.

In order to understand better the nature of the variations on Point Reyes Beach, the beach has been occupied at intervals of 6 to 8 weeks from August 1955 to June 1956. The beach was visited 8 times in this period. At each time a plane table map was made with alidade, stadia, and chain. The survey was made at Station A, 3 miles north of Point Reyes (Figure 2). The same sampling interval as in the first 18 months' study and the same sampling stations were occupied. These stations are located along five lines normal to the beach on a center line and at a distance of 64 and 256 feet on either side of the center line (Figures 3-10). Sample intervals along the individual lines are 1, 4, 16, 32, 48, 64, 96 and 128 feet north (seaward) and south (landward) of the zero point, which was arbitrarily picked at the time of the first sampling in June 1953. Occasional samples were taken at other places, notably, on the crests of cusps and in places where particularlv coarse or fine sediments had been laid down. During the August, 1955-period of sampling, lines of samples were taken at right angles to each of the cusps and in the embayments between the cusps if one of the regular sample lines did not pass through such positions. The zero point lies 103 feet seaward from a reference stake, which is taken as the point of reference for the beach survey. This stake is 19 feet east (parallel to the beach) from the fence corner, just west of the mouth of the creek that lies west of the old Coast Guard building. In March, 1956 this reference stake was washed away in a storm and it has been replaced by a new stake lying 2 feet north of the old stake. The elevation of the ground at the point of the reference stake has arbitrarily been taken as 30 feet. The basis for this elevation is readings taken of water level during the first occupation of the station.

The individual times studies are indicated by letter symbols. Thus A represents the samples collected in August 1955, B, those collected in October, 1955 and so on through H, representing those procured in June, 1956. The letter X refers to samples collected in March, 1954 and reported in the previous publication on sand variations at Point Reyes Beach[1]. The letter Y represents a small suite of samples collected on May 31, 1955 along the same sampling grid as the other samples, but at this time no contour map of the beach was made. The individual samples are designated by a coordinate system. Thus sample 25W, 64N represents the samples taken on the line of samples 25 feet west and 64 feet north (seaward) of the zero point, as indicated on the accompanying contour maps of the beach.

MECHANICAL ANALYSES

The mechanical analyses of the samples were made by the customary procedure of sieving with approximate ratio between sieves of one-half the square root of two. The samples were sieved for 10 minutes in the standard rotap sieving machine, and the samples were dried before sieving. The entire sample of 100 to 250 grams was sieved. The usual parameters were computed from the weight accumulation curve. The basic results are presented in Table 1 which shows median diameter in phi units, coefficient of sorting, $\log_{10}$ of the skewness, and the 10 and 90 percentiles, D_{10} and D_{90}, measured in microns. The data are grouped according to date of sampling and to sample station, starting with line 256 west and going from north to south. The analyses were made by J. Peter Berge and Patrick O'Malley. The statistical studies of the results have been made by Sigrid Woodson.

The standard deviation of the method of analysis is 0.02 phi unit, which for the range in grain size generally found on Point Reyes Beach corresponds to about 10 microns. Each of two samples was analyzed 9 times to determine the variation inherent in the method of analysis. The average median of one sample was 711 microns and of the other 522 microns. The standard deviation of these two samples was 0.020 and 0.022 phi units, respectively, corresponding to standard deviations of 11 and 7 microns. As the standard deviation of the samples as distributed on the beach ranges generally between 0.30 and 0.35 phi units, the variation caused by the method of measurement is small, about 6 or 7 percent of the total variation.

STATISTICAL PROCEDURES

The statistical methods used in this report are based upon the assumption that the various parameters examined are taken for a normally distributed population and, in particular, that the median diameter (D_{50}) expressed in phi units is normally distributed. Many statistical comparisons among groups of samples have been made. The results of the great majority of such calculations do not appear in the tables but have been used as a guide in writing the text. All of the tests and procedures used in this report are described in greater detail by Hoel[3]. If, in making a statistical study of a group of samples we let x_i be the value of the parameter for the i^{th} sample and let n_x be the number of samples in the group under consideration, the mean, or arithmetic average is given by $\bar{x} = \sum x_i/n_x$. The standard deviation of the group, σ_x is given by $\sigma_x = \sqrt{\sum (x_i - \bar{x})^2/n_x}$. This is the interval on either side of the mean value which contains approximately 68 percent of the sample values (that is, on the average, 34 percent on either side of the mean). It is therefore a measure of the spread of the data about the mean. The standard deviation of the mean, $\sigma_x/\sqrt{n_x}$, is a measure of the reliability of the mean. If z groups of random samples from a population, x, are averaged, yielding z means, the chances are even that 68 percent of these means will lie within the interval of $\sigma_x/\sqrt{n_x}$

from the mean of the entire population.

The significance of a relationship between two variables x and y is determined by the standard method using the symbol t where

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{\sigma_x^2}{n_x} + \frac{\sigma_y^2}{n_y}}}$$

In the above equation the probability that the difference in means is real and not due to random variations, or in other words, the probability that both groups of samples could have been taken from the same population is indicated by

$$\left[1 - \int_{-t}^{+t} \phi(t)\,dt\right] \qquad \text{where } \phi(t) = \frac{1}{\sqrt{2\pi}} e^{-t^2/2}$$

and is the normal curve of error. The probabilities as calculated by this equation are computed in terms of ratios, but are reported in Tables 3 and 5 in terms of percent, or 100 times the ratio. Thus a probability given as 5 percent, which corresponds to a value of "t" of 1.96 means that the chances are 5/100 or one in twenty that the difference is due to random causes. In other words, the probabilities are 20 to 1 that the difference between the two means is real and not anomalous owing to vagaries of sampling. A probability of 1 percent, corresponding to a "t" of 2.58, indicates the chances are 100 to 1 that the difference is real. Figures given in Tables 3 and 5 as 0.00 indicate a percentage probability of less than 0.005; that is, the chances are greater than 20,000 to 1 that the difference is real.

It should be borne in mind that the statistical theory for investigating groups of samples taken from a normally distributed population can be developed for the case in which the number of samples in the group is small, as well as for the more commonly used techniques in which the number of samples is supposed to be essentially infinite; i.e., the entire population has been included. For ordinary purposes small sample and large sample theories give identical results where the number of samples is equal to or greater than 30. In the present paper the significance of a difference has been developed for the large sample theory and the number of samples usually ranged between 30 and 50.

A method of detecting the significance of the difference between two means is available in both theories. For a qualitative measurement of "significant" or "nonsignificant" the large sample test is far easier to apply where large numbers of such tests must be performed. For this reason large sample theory has been used throughout for the comparison of means, even when the size of the group would indicate the use of small sample theory. This procedure invariably indicates a higher degree of significance than that given by small sample theory. The cases where this error becomes of importance are those mentioned above in which only a qualitative measurement has been made.

DESCRIPTION OF TABLES

The basic data on the samples collected for the present study are presented in Table 1. In some places the sand was distinctly stratified and two samples, an upper and a lower sample were taken. The lower samples are given first in the table and parentheses are placed around the median of the upper sample. Table 2 gives the mean grain size along the different north-south lines. The number of samples represented by each mean is given in order to indicate the general reliability of the mean. The table also shows the mean grain size of the entire population at each sampling time. This mean is based on all the samples collected, including those not represented on the main north-south lines. At sampling time A in August, 1955 several lines of samples were taken in addition to the standard lines. The general means thus do not represent the mean of the individual means presented in the lines above. The standard deviation, sigma, of the sample and the standard deviation of the mean of all the samples are also included in the table so that readers can more readily appraise the general variability of grain size and the significznce of the difference in means between samples. Data for March, 1954 and May, 1955 are also included in Table 2.

Table 3 gives the significance of the difference between means for the different sampling intervals. These are calculated according to the "t" formula described above. The data are presented in terms of percent, that is 100 times the parameter indicating the probability that the means are drawn from the same population. Thus the first figure of 0.29 percent for times X and A indicates that the chances are 100/0.29 or 340 to 1 against the means being drawn from the same population. The large difference between these means indicates a considerable significance. The significance between the means for times C in November, 1955 and B in October is 10.10, which indicates the chances are 100/10.1 or 10 to 1 that the difference is not random but is real. Thus the probability is only moderate that the difference is real.

The data are rearranged in Table 4 to show the average grain size for the different elevation zones. The previous work on this beach indicates that the lower part of the foreshore is coarser than the upper. A similar study of the data was made in the present investigation. The means presented at the base of the table are taken from Table 2 and are given in order to help readers appraise the significance of differences between means.

Table 5 shows the significance of the difference between the averages for the different elevation zones. This table is constructed in the same way as Table 3.

Table 6 presents means of the coefficient of sorting for the different north-south lines for each interval of sampling. The general mean and the standard deviation are included for benefit of those who wish to ascertain the significance of the difference between means. Table 7 gives the same thing for the elevation zones. No tables for significance of means are given, as the means are so close to one another that few significant differences are indicated.

Table 8 presents comparative data on cusps. It gives first the number of cusps along the stretch of beach studied, followed by data on the position and change in position of the cusps. For purpose of identification the cusps are designated from left to right or west to east on the beach by letters (Figures 3 to 10), beginning with A on the left. The position of different series of cusps is recorded with respect to distance from three east to west lines, namely, lines 200 west, 0 west, and 200 east. The position of the cusps at the individual times is shown for the nearest cusp to the west and east of the designated lines, respectively. The changes in position of these cusps is thus indicated by the difference in distance from the reference line between successive intervals of sampling. Below the data indicating position of cusps normal to the beach, additional data are presented showing the position parallel to the beach. The average distance of the cusps north of the 0-north line is shown, as well as the maximum interval between the most seaward and the most landward cusps. Thus, in August 1955, the average position of cusps is 46 feet north of the zero north line and the maximum distance any cusp is seaward of another cusp is 59 feet. The data thus give information on the general shift in position of the beach at the area occupied. Cusp position is taken at the spit or horn of the cusp at the edge of the berm. Data are also presented on the average interval between cusps, and the maximum and minimum interval. Likewise information is given on the height and variation in height of the cusps.

Table 8 also shows the grain size distribution of different parts of the cusps. Four categories of samples in two groups were taken. The first group considers the samples on north-south lines passing through the cusps, and the other group considers samples taken on lines passing midway between the cusps in the indentations or bays. Each group includes two series of samples, those within 50 feet of the top of the cusp on the down or beach side and those within 50 feet on the upper or berm side. Similar suites were taken on the lines between the cusps. The dividing line for the latter series is the elevation of the cusp point itself. The samples on the beach or "lower bay" side are within a horizontal distance of 50 feet of the elevation of the crest of the cusp and those on the up or "upper bay" side are the same distance on the berm side of the cusp elevation.

Table 1

Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series A - August 26, 1955

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} Phi units	D_{90} Phi units
328W	94N	1.03	1.19	0.000	340	700
328W	64N	1.24	1.21	0.012	320	840
328W	48N	0.48	1.13	-0.006	420	1100
328W	0N	0.72	1.20	0.028	510	1150
260W	0N	0.74	1.15	0.017	415	810
257W	0N	0.48	1.04	-0.009	570	830
256W	120N	-0.78	1.45	0.006	860	3640
256W	96N	-0.22	1.13	-0.006	800	1430
256W	64N)	.87	1.48	.042	327	1340
256W	64N)	(- .26)	1.14	- .002	620	1580
256W	48N	.95	1.24	.002	325	1050
256W	32N	.97	1.31	.007	320	780
256W	21N	.95	1.31	.020	340	790
256W	16N	1.11	1.24	.024	360	720
256W	4N	.95	1.22	-.017	380	710
256W	1N	.65	1.14	.003	520	820
256W	0N	.87	1.14	.023	510	660
256W	4S	.78	1.22	-.013	460	690
256W	16S	.42	1.13	-.009	390	970
256W	32S	-.03	1.41	.004	580	1900
256W	64S	.14	1.23	-.005	620	1400
256W	72S	.54	1.11	-.002	470	820
256W	88S	.88	1.10	-.006	355	700
255W	0N	.54	1.08	.000	560	800
252W	0N	.84	1.24	.016	400	960
201W	65N	-.33	1.17	.031	780	1850
201W	51N	.67	1.31	-.040	390	1170
201W	36N	.67	1.33	-.065	390	800
201W	0N	.87	1.32	-.017	330	920
140W	Bottom 55N	-.26	1.20	.021	850	1900
140W	Top 55N	1.13	1.17	.002	385	670
140W	33N	1.09	1.20	.020	410	590
140W	0N	1.03	1.33	.050	380	780
68W	48N	-2.56	1.77	-.046	3000	--
68W	0N	.43	1.31	.047	420	1330
65W	0N	.52	1.52	.026	350	1580
64W	85N	-.46	1.18	.006	1100	2000
64W	64N	-.04	1.29	-.045	510	1400
64W	64N	(.14)	1.20	.039	800	1700
64W	32N	.92	1.48	-.003	275	1100
64W	16N	.92	1.35	-.027	310	780
64W	4N	.58	1.51	.026	340	1300
64W	1N	.57	1.31	-.042	350	1300
64W	0N	.67	1.30	.005	370	940
64W	1S	.52	1.30	-.006	380	1220
64W	4S	.60	1.41	-.004	420	1300
64W	16S	.34	1.39	.009	330	1350
64W	32S	.52	1.24	.003	440	980
64W	64S	.40	1.26	-.022	375	790
64W	Sea.St.	-.14	1.32	-.031	620	1600
63W	0N	.55	1.31	-.019	390	1310
60W	0N	.76	1.31	.031	340	1130
44W	55N	-3.33	1.36	.013	5800	10000
16W	0N	1.15	1.11	-.010	275	600
4W	0N	.90	1.35	-.007	270	1000
1W	0N	.82	1.34	-.018	370	875
0W	91N	-.60	1.24	.007	1030	2250
0W	64N	.43	1.44	.042	390	2000
0W	64N	(.67)	1.25	-.004	380	1150
0W	48N	.82	1.48	.047	340	1370
0W	32N	.72	1.51	.017	520	785
0W	16N	.95	1.31	-.042	300	740
0W	4N	1.42	1.24	.020	275	580
0W	1N	.72	1.40	-.028	320	1090
0W	0N	.90	1.26	.004	310	840
0W	1S	.84	1.25	-.014	370	860
0W	4S	.83	1.42	.029	285	1080
0W	16S	1.09	1.18	-.004	250	660
0W	32S	1.33	1.11	.011	360	580
0W	94S	.78	1.[illegible]	-.001	390	1020

Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series A - August 26, 1955

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} Phi units	D_{90}
ON	Sea.St.	-.68	1.31	.013	1100	2700
1E	ON	.67	1.26	-.052	380	820
4E	ON	.86	1.31	-.008	270	920
16E	ON	1.00	1.14	.020	350	720
16E	ON	(.84)	1.13	.019	515	920
64E	105N	.54	1.27	.002	1000	2330
64E	80N	.40	1.30	.013	460	1260
64E	64N	.48	1.25	.002	395	910
64E	64N	(-.41)	1.26	.018	690	2450
64E	48N	.97	1.28	.001	335	790
64E	32N	.65	1.31	-.019	360	1120
64E	16N	.42	1.34	.031	410	1290
64E	ON	-.47	1.54	-.053	420	2200
64E	Sea.St.	-.70	1.19	.007	450	2200
128E	86N	.17	1.30	.002	570	2000
128E	Lower 55N	1.06	1.22	-.027	320	570
128E	55N	(-3.13)	1.26	-.013	5500	15000
128E	38N	1.09	1.31	.057	370	760
128E	ON	.97	1.09	.000	375	680
194E	75N	.97	1.28	-.044	300	850
194E	38N	.50	1.22	-.031	415	890
194E	21N	-.14	1.34	-.046	590	1570
194E	ON	.92	1.26	.008	340	820
256E	128N	.42	1.32	.031	505	1310
256E	96N	1.14	1.30	.060	355	720
256E	80N	1.37	1.26	.026	295	560
256E	64N	1.09	1.28	.047	370	740
256E	48N	1.42	1.23	.019	280	630
256E	32N	1.22	1.29	.029	380	670
256E	23N	.66	1.18	-.010	420	810
256E	23N	(.56)	1.16	.017	390	1160
256E	ON	.51	1.12	-.013	425	800
256E	Sea.St.	1.29	1.29	.024	290	730
352E	104N	1.25	1.38	.028	280	780
352E	87N	1.06	1.16	.023	320	700
352E	71N	.96	1.27	-.021	320	770
352E	34N	.32	1.38	-.009	420	1300
252E	ON	1.06	1.17	.030	260	880
		Series B - October 8, 1955				
256W	64N	.80	1.31	-.023	335	825
256W	32N	.97	1.25	-.010	325	810
256W	16N	.83	1.31	.013	355	1020
256W	4N	.92	1.30	.002	330	910
256W	1N	.65	1.30	-.004	350	1250
256W	ON	.72	1.22	.015	350	1060
256W	1S	.74	1.25	.037	310	800
256W	4S	.52	1.37	.030	380	1250
256W	16S	.74	1.25	-.048	325	1050
256W	32S	-.80	1.26	.014	600	2650
256W	64S	.69	1.29	.046	320	1030
256W	64S	(.32)	1.26	-.006	540	1150
64W	96N	.25	1.41	.040	510	1250
64W	64N	1.06	1.20	.033	380	700
64W	32N	1.06	1.32	.092	290	1160
64W	16N	1.09	1.29	.002	310	920
64W	4N	1.12	1.18	.052	375	740
64W	OS	1.05	1.28	.003	315	880
64W	4S	1.03	1.32	-.002	300	910
64W	16S	.69	1.28	.005	370	1200
64W	32S	.18	1.30	-.024	500	1400
64W	63N	1.05	1.08	.068	395	800
1W	ON	.60	1.44	.024	370	1350
ON	120N	.97	1.15	.004	365	900
ON	96N	.93	1.26	.014	340	980
ON	64N	1.00	1.12	-.015	335	760
ON	32N	(-.14)	1.23	.025	510	1700
ON	32N	1.03	1.04	.012	440	640
ON	16N	.98	1.19	.007	380	680
ON	4N	.72	1.26	-.030	420	910
ON	4N	(.56)	1.34	.083	370	870
ON	1N	.50	1.44	.007	410	1380
ON	ON	.74	1.12	.029	430	1700
ON	1S	.76	1.36	.052	430	2700
ON	4S	.95	1.47	.010	390	1380

Table 1 - Continued

Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series B - October 8, 1955

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10}	D_{90}
					Phi Units	
0W	16S	.69	1.42	.040	445	1035
0W	32S	.50	1.57	.049	450	2030
0W	52S	.96	1.47	.057	270	1220
1E	0N	.77	1.22	-.017	425	980
58E	47N	1.24	1.22	-.022	300	630
64E	64N	1.11	1.18	.011	370	890
64E	32N	1.03	1.25	-.038	290	920
64E	16N	1.11	1.08	.009	340	695
64E	4N	1.03	1.02	-.003	340	545
64E	0N	.87	1.08	-.019	415	670
64E	0N	(1.15)	1.03	.010	340	545
64E	4S	1.60	1.04	.004	290	495
64E	16S	1.15	1.10	.013	405	600
64E	32S	1.00	1.04	-.009	350	650
64E	64S	.95	1.32	.062	375	1030
256E	96N	1.03	1.48	.072	380	1140
256E	64N	.97	1.12	.007	405	960
256E	32N	1.06	1.23	.018	310	705
256E	16N	.93	1.08	-.013	302	640
256E	8N	1.12	1.15	-.016	285	570
256E	4N	1.24	1.22	-.003	850	625
256E	4S	1.06	1.19	.001	330	730
256E	8S	.93	1.23	.029	350	990
256E	16S	1.00	1.35	.034	315	1150
256E	32S	.69	1.27	.012	355	1100
256E	64S	1.00	1.28	.012	310	740
		Series C - November 12, 1955				
256W	114N	.25	1.22	-.003	510	1250
256W	64N	.56	1.24	.001	420	1010
256W	32N	.60	1.27	.011	435	1150
256W	16N	.84	1.34	.023	350	1100
256W	4N	.60	1.31	.008	390	1120
256W	0N	.74	1.26	.014	385	1050
256W	4S	.69	1.35	.006	370	1000
256W	16S	.30	1.36	-.019	415	1340
256W	32S	.17	1.48	-.005	385	1700
256W	64S	.32	1.25	.015	530	1280
64W	120N	.23	1.15	.002	880	1800
64W	96N	.12	1.28	-.022	520	1350
64W	64N	.67	1.28	.018	390	1000
64W	32N	.52	1.10	.037	540	1030
64W	16N	.43	1.32	.001	560	980
64W	4N	.87	1.32	.004	420	980
64W	0N	.76	1.39	.041	360	1090
64W	4S	1.00	1.24	-.014	325	800
64W	16S	.95	1.18	.011	445	810
64W	32S	.56	1.41	.022	410	1200
64W	64S	.67	1.23	-.001	405	1030
0W	94N	.06	1.36	-.022	500	1550
0W	64N	.62	1.24	.002	435	1020
0W	32N	.78	1.17	.028	430	910
0W	16N	.64	1.30	.006	350	980
0W	4N	.60	1.29	.002	420	1230
0W	1N	.50	1.33	-.002	440	1100
0W	0N	.56	1.31	.016	405	1100
0W	1S	.69	1.27	.012	380	968
0W	4S	.48	1.33	-.008	408	1230
0W	16S	.54	1.39	.024	390	1430
0W	32S	.36	1.44	-.023	408	1430
0W	64S	.78	1.28	.009	360	1020
0W	90S	.84	1.38	-.001	300	2030
1E	0N	.56	1.29	.002	420	1150
4E	0N	.65	1.26	.003	410	1000
64E	148N	.03	1.33	.001	620	1450
64E	100N	.75	1.25	.003	380	990
64E	64N	.92	1.27	.004	360	900
64E	32N	1.03	1.26	-.011	330	790

Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series C - November 12, 1955

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} Phi Units	D_{90} Phi Units
64E	16N	1.09	1.19	.004	340	720
64E	4N	.93	1.29	.030	370	1010
64E	0N	.90	1.32	.004	330	940
64E	4S	1.05	1.23	-.004	320	800
64E	16S	1.15	1.26	.006	310	780
64E	32S	1.29	1.21	.004	290	640
64E	64S	.57	1.36	-.010	350	1100
64E	86S	1.09	1.31	.003	295	810
256E	190N	.58	1.37	.018	400	1100
256E	150N	.60	1.30	.021	410	1180
256E	96N	.89	1.23	.000	360	870
256E	64N	1.12	1.10	.004	290	640
256E	32N	.95	1.26	.008	320	840
256E	16N	1.25	1.23	.022	310	720
256E	4N	1.09	1.28	-.008	220	760
256E	0N	1.25	1.20	.007	290	640
256E	4S	1.03	1.27	.027	310	810
256E	16S	.89	1.34	.002	325	1020
256E	32S	.84	1.57	.050	315	1400
256E	64S	1.03	1.26	-.007	320	800

Series D - December 28, 1955

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} Phi Units	D_{90} Phi Units
256W	64N	.78	1.24	.011	370	900
256W	32N	.72	1.41	-.032	320	1150
256W	16N	.95	1.27	.012	326	810
256W	16N	(.78)	1.27	.021	380	980
256W	4N	.42	1.29	-.010	470	1160
256W	0N	.58	1.28	.022	340	1230
256W	4S	.50	1.27	.000	480	1100
256W	4S	(.60)	1.20	.023	410	1020
256W	16S	.69	1.26	.012	400	1080
256W	48S	.72	1.24	-.020	360	930
256W	64S	.89	1.20	.002	375	810
64W	144N	1.49	1.24	.019	265	570
64W	128N	.62	1.34	.015	360	1200
64W	96N	.68	1.21	-.014	380	940
64W	64N	.67	1.26	.010	410	1060
64W	32N	.89	1.18	.065	515	930
64W	16N	.62	1.30	.009	390	1120
64W	4N	.25	1.31	.008	410	1250
64W	0N	.50	1.31	.000	450	1140
64W	4S	.22	1.31	-.023	510	1350
64W	16S	.60	1.29	.024	510	1050
64W	32S	.92	1.27	.005	330	940
64W	48S	.89	1.24	-.026	270	950
46W	55N	.72	1.31	.006	360	1070
46W	25N	.96	1.22	-.014	320	760
16W	0N	.77	1.30	.011	365	1070
0W	192N	-.04	1.66	-.001	400	3050
0W	144N	-.31	1.25	-.009	710	2050
0W	144N	(1.29)	1.34	.000	260	730
0W	64N	.93	1.26	.030	300	930
0W	32N	.84	1.35	.046	380	1020
0W	16N	.76	1.19	-.022	390	860
0W	4N	.07	1.37	-.061	440	1360
0W	1N	.02	1.46	-.056	350	1490
0W	0N	-.36	1.22	-.012	590	1940
0W	1S	.36	1.41	-.027	440	1280
0W	4S	.30	1.33	.016	425	1450
0W	16S	.84	1.36	-.001	325	1020
0W	32S	.18	1.36	-.036	400	1480
0W	92S	1.03	1.40	-.024	202	900
1E	0N	.02	1.38	-.031	480	1450
16E	0N	.87	1.30	.017	350	1030
64E	192N	.32	2.06	.002	290	2900
64E	144N	.56	1.41	-.002	320	1180
64E	96N	1.06	1.14	-.012	320	870
64E	64N	1.00	1.20	-.006	320	780
64E	32N	.97	1.24	-.007	320	740
64E	16N	1.00	1.18	-.008	320	710
64E	4N	.87	1.20	-.018	310	780
64E	0N	.97	1.25	-.011	330	740

Table 1 - Continued

Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series D - December 28, 1955

Location	Median (phi units)	So	$Log_{10}Sk$	D_{10} Phi Units	D_{90} Phi Units
64E 4S	1.06	1.23	.000	275	760
64E 4S	(1.09)	1.25	.004	320	760
64E 16S	.97	1.28	.001	320	820
64E 32S	.92	1.23	.010	385	860
64E 64S	.54	1.50	.019	350	1400
143E 100N	.76	1.13	-.030	400	1000
143E 80N	.93	1.29	.018	460	890
212E 16S	.74	1.40	.050	370	1450
216E 96N	.97	1.45	-.114	270	900
256E 192N	.27	1.21	-.010	505	1300
256E 144N	.60	1.47	-.036	260	930
256E 112N	1.06	1.29	-.013	300	790
256E 64N	1.06	1.17	-.048	285	570
256E 64N	(1.03)	1.32	-.025	310	780
256E 32N	.78	1.26	.011	365	960
256E 16N	.73	1.34	.036	400	1160
256E 4N	.85	1.16	-.016	360	820
256E 0N	0.00	1.16	-.024	660	1520
256E 0N	(.45)	1.30	-.002	470	1130
256E 4S	.56	1.26	.009	410	1180
256E 32S	.60	1.39	.015	360	1200
256E 64S	.93	1.28	-.014	320	910
419E 155N	.78	1.29	-.004	370	1090
419E 135N	.40	1.25	-.005	500	1130
419E 84N	.98	1.20	-.007	350	780

Series E - February 11, 1956

Location	Median (phi units)	So	$Log_{10}Sk$	D_{10} Phi Units	D_{90} Phi Units
256W 210N	.09	1.10	-.002	745	1170
256W 168N	.21	1.26	-.007	525	1300
256W 126N	.63	1.31	-.002	392	1000
256W 96N	.77	1.33	.011	363	1050
256W 64N	.57	1.32	.000	400	1130
256W 32N	.57	1.25	.008	455	1185
256W 16N	.60	1.26	.006	430	1045
256W 4N	.47	1.25	.003	480	1160
256W 4N	.47	1.25	.003	480	1160
256W 0N	.60	1.26	.014	450	1120
256W 4S	.09	1.35	-.032	475	1500
256W 16S	.65	1.26	.010	415	1060
256W 32S	.51	1.46	-.028	335	1220
256W 64S	.71	1.33	.011	370	1100
64W 170N	.06	1.24	.004	530	1500
64W 126N	.63	1.24	.005	430	1035
64W 96N	.58	1.37	.002	380	1260
64W 64N	.65	1.28	-.052	370	910
64W 32N	.51	1.24	-.005	453	1040
64W 16N	.08	1.39	-.012	493	1670
64W 4N	.17	1.40	-.059	250	1520
64W 0N	.45	1.37	-.002	430	1270
64W 4S	.59	1.25	.015	460	1100
64W 16S	.46	1.29	-.001	495	1280
64W 32S	.24	1.30	-.003	520	1395
64W 64S	.45	1.41	.030	420	1170
1W 0N	-.08	1.88	.076	465	4400
0W 126N	.12	1.13	-.008	640	1230
0W 64N	.41	1.25	.006	500	1220
0W 32N	.01	1.35	-.046	585	1440
0W 16N	0.00	1.30	-.024	545	1500
0W 4N	-.37	1.34	.089	785	2300
0W 1N	-.36	1.52	.014	600	3200
0W 0N	0.00	1.75	.057	510	3700
0W 1S	.21	1.78	.057	433	4200
0W 2S	.65	1.68	.090	380	3150
0W 4S	.87	1.34	.040	367	1400
0W 16S	.67	1.26	-.001	425	910
0W 32S	.46	1.23	.007	500	1135
0W 64S	.79	1.20	.014	407	920
0W 89S	1.00	1.27	-.010	295	860
1E 0N	.13	1.44	-.047	525	2560
64E 126N	-.02	1.29	-.007	605	1640
64E 96N	.25	1.22	-.021	525	1200
64E 64N	.51	1.34	-.001	390	1260

Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series E - February 11, 1956

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} phi units	D_{90} phi units
64E	32N	.98	1.21	.039	383	1340
64E	16N	0.00	1.11	.001	640	1300
64E	4N	0.00	1.34	-.014	523	1600
64E	0N	-.02	1.28	.013	580	1720
64E	4S	.13	1.36	.002	520	1600
64E	16S	-.20	1.32	.040	765	2900
64E	32S	1.16	1.21	-.008	308	690
64E	64S	1.08	1.25	-.011	283	705
256E	116N	-.05	1.16	.000	750	1460
256E	96N	.84	1.25	.002	376	895
256E	64N	.40	1.22	.008	535	1090
256E	16N	.47	1.22	.009	520	1095
256E	4N	-.03	1.31	-.002	590	2025
256E	0N	.02	1.29	.002	535	1480
256E	4S	.50	1.28	.007	345	1195
256E	16S	.34	1.35	-.006	440	1380
256E	32S	.52	1.31	.013	390	1290
256E	32S	(.48)	1.26	-.006	440	1120
256E	64S	.56	1.29	.000	440	1120

Series F - March 24, 1956

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} phi units	D_{90} phi units
256W	196N	-.59	1.30	.012	910	2510
256W	126N	.50	1.37	.013	420	1340
256W	96N	.46	1.24	-.004	500	1100
256W	64N	.25	1.25	-.013	488	1300
256W	48N	.78	1.38	-.001	375	1000
256W	32N	.84	1.23	-.004	372	830
256W	16N	.78	1.25	.011	400	920
256W	4N	.90	1.27	.005	355	845
256W	1N	.66	1.28	-.005	390	1000
256W	0N	.69	1.28	.001	348	960
256W	1S	.55	1.31	-.020	425	1070
256W	4S	.61	1.37	.003	385	1130
256W	16S	.58	1.28	.002	413	1090
256W	32S	.85	1.27	-.001	355	895
256W	48S	.85	1.26	.004	365	925
256W	64S	.88	1.28	.003	365	890
64W	130N	.35	1.33	-.006	455	1260
64W	96N	.43	1.35	-.001	410	1285
64W	64N	.48	1.32	-.020	400	1110
64W	48N	.76	1.25	.012	380	950
64W	32N	.64	1.38	.004	375	1130
64W	16N	.58	1.26	.012	435	1110
64W	4N	.93	1.25	.004	365	850
64W	1N	.81	1.26	-.004	375	905
64W	0N	.83	1.24	.007	368	860
64W	4S	.76	1.22	.011	395	980
64W	16S	.92	1.22	.001	355	835
64W	32S	.58	1.31	.012	366	1170
64W	48S	.93	1.30	.014	355	925
64W	64S	.60	1.29	.003	385	1060
1W	0N	.60	1.29	-.011	410	1000
0W	140N	-.23	1.29	.004	680	2000
0W	96N	.28	1.28	-.013	510	1235
0W	64N	.41	1.30	.001	505	1290
0W	16N	.80	1.28	.009	370	935
0W	4N	.62	1.24	.003	430	1010
0W	1N	.52	1.30	-.021	400	1180
0W	0N	.64	1.22	.014	450	1000
0W	1S	.75	1.26	.003	348	845
0W	4S	.60	1.22	-.009	440	970
0W	16S	.41	1.31	.003	465	1240
0W	32S	.29	1.25	.002	550	1320
0W	32S	(.25)	1.32	-.003	500	1380
0W	48S	.61	1.37	.005	375	1190
0W	64S	1.11	1.21	.013	330	750
0W	84S	1.05	1.21	.000	295	720
1E	0N	.58	1.20	.003	425	980
48E	0N	-.08	1.35	-.015	575	1950
64E	126N	.38	1.39	-.019	390	1380
64E	96N	.43	1.14	-.011	365	1205

Table 1 - Continued
Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series F - March 24, 1956

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10}	D_{90} phi units
64E	64N	.11	1.32	-.009	565	1550
64E	32N	.21	1.31	-.012	510	1400
64E	16N	.27	1.28	-.008	430	1340
64E	4N	.46	1.26	.014	515	1180
64E	1N	.46	1.28	.007	485	1060
64E	0N	.26	1.36	-.007	480	1400
64E	1S	.40	1.29	-.001	455	1180
64E	4S	.33	1.28	-.007	520	1280
64E	16S	.21	1.29	-.007	510	1380
64E	32S	.67	1.42	.001	345	1370
64E	48S	1.00	1.28	.001	325	830
64E	64S	1.00	1.25	.015	335	810
256E	128N	.57	1.31	-.003	383	1135
256E	96N	.35	1.41	-.003	310	1030
256E	64N	.43	1.30	.015	495	1350
256E	48N	.29	1.28	-.007	460	1240
256E	32N	.46	1.29	-.007	420	1120
256E	16N	.34	1.28	.003	525	1280
256E	4N	-.02	1.31	-.023	575	1500
256E	1N	-.15	1.29	-.026	576	1580
256E	0N	-.14	1.32	-.026	590	1610
256E	0N	(-.35)	1.14	-.006	890	1620
256E	1S	.03	1.34	-.027	540	1500
256E	4S	-.18	1.14	.006	760	1580
256E	16S	-.14	1.40	-.040	490	1650
256E	32S	.61	1.35	.011	390	1200
256E	48S	.92	1.31	-.006	355	885
256E	64S	1.00	1.22	-.004	375	765

Series G - May 4, 1956

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10}	D_{90} phi units
256W	128N	.27	1.23	.005	595	1245
256W	96N	-.20	1.26	.006	730	1900
256W	64N	.76	1.18	.017	430	900
256W	32N	.59	1.23	.002	435	1080
256W	16N	.76	1.21	-.003	400	890
256W	0N	.50	1.25	-.002	435	1095
256W	4S	.62	1.26	-.009	415	1050
256W	16S	.64	1.28	.009	405	1100
256W	32S	.57	1.32	.021	420	1240
256W	64S	.85	1.27	.002	350	875
64W	160N	.79	1.12	-.009	410	765
64W	128N	.40	1.30	-.017	425	1180
64W	96N	0.00	1.24	-.022	560	1470
64W	64N	.93	1.23	-.003	355	800
64W	32N	.73	1.22	.003	395	1000
64W	16N	.70	1.30	.022	405	1075
64W	4N	.69	1.30	.008	355	1000
64W	4N	(.64)	1.31	.007	400	1075
64W	0N	.88	1.23	.014	400	900
64W	4S	.85	1.27	.001	347	915
64W	16S	.88	1.22	.003	360	865
64W	32S	.85	1.29	.013	357	945
64W	64S	.68	1.19	.008	432	940
0W	180N	-.13	1.21	-.003	715	1630
0W	128N	.56	1.25	.015	510	1100
0W	96N	-.49	1.15	.002	1090	1900
0W	64N	.91	1.22	-.003	338	820
0W	32N	.86	1.20	-.005	356	826
0W	16N	.33	1.31	.003	525	1380
0W	4N	.71	1.28	.009	338	1000
0W	1N	.75	1.27	.011	385	1000
0W	0N	.81	1.27	.001	370	865
0W	1S	.76	1.22	.000	368	885
0W	4S	.69	1.26	.004	385	970
0W	16S	.76	1.31	.004	369	985
0W	32S	.48	1.39	-.012	370	1220
0W	64S	.95	1.35	.015	320	1000
0W	96S	1.15	1.26	-.018	252	675
64E	160N	-.03	1.23	-.017	580	1510
64E	128N	.43	1.26	.006	505	1190

Table 1 - Continued
Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series G - May 4, 1956

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} phi units	D_{90} phi units
64E	96N	.38	1.30	.016	505	1380
64E	64N	.65	1.20	.006	415	965
64E	32N	.83	1.25	.002	370	885
64E	16N	.80	1.31	.005	370	940
64E	4N	.77	1.27	.017	374	1000
64E	0N	.37	1.30	-.017	435	1175
64E	4S	.37	1.32	-.010	435	1185
64E	16S	.44	1.41	.026	485	1280
64E	32S	.47	1.34	.012	420	1290
64E	64S	.88	1.18	-.006	370	780
200E	75N	-3.08	1.18	-.001	5430	11000
256E	128N	.10	1.36	-.005	500	1600
256E	96N	.78	1.32	.019	345	1070
256E	64N	.89	1.34	.003	333	1600
256E	32N	.41	1.29	.011	505	1230
256E	16N	.60	1.30	.012	430	1075
256E	4N	.76	1.27	.001	367	925
256E	0N	.56	1.30	.001	420	1055
256E	4S	.48	1.31	-.001	440	1115
256E	16S	.45	1.51	-.024	500	1110
256E	32S	.13	1.32	-.005	500	1460
256E	64S	.73	1.16	.022	395	1060
256E	96S	1.03	1.24	-.010	294	735

Series H - June 18, 1956

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} phi units	D_{90} phi units
256W	64N	.83	1.17	-.002	395	820
256W	32N	.05	1.36	.010	520	1790
256W	16N	.89	1.30	.005	330	1000
256W	8N	.75	1.32	.008	370	1050
256W	4N	.80	1.27	-.014	355	930
256W	1N	.80	1.25	.008	375	920
256W	0S	.73	1.29	.009	355	1000
256W	1S	.71	1.25	.006	395	1000
256W	4S	.78	1.25	-.005	355	890
256W	8S	.48	1.33	-.002	416	1320
256W	16S	.67	1.29	.010	380	1100
256W	32S	.69	1.31	.006	390	1200
256W	64S	.55	1.36	-.005	392	1270
256W	90S	.98	1.22	-.015	312	740
64W	82N	.84	1.10	.009	420	795
64W	64N	1.14	1.18	.001	313	660
64W	32N	.98	1.36	-.003	275	915
64W	16N	.82	1.26	-.006	345	880
64W	8N	.40	1.39	-.015	365	1460
64W	4N	.38	1.49	-.006	356	1600
64W	1N	.35	1.36	-.014	425	1365
64W	0N	.75	1.26	-.007	360	930
64W	1S	.87	1.26	-.017	350	850
64W	4S	.87	1.28	.005	340	935
64W	8S	.98	1.27	.013	340	865
64W	16S	.71	1.29	.007	400	1055
64W	32S	.87	1.26	-.002	342	905
64W	64S	.95	1.20	-.009	343	760
64W	76S	.90	1.23	.008	362	856
0W	110N	.63	1.19	.000	430	880
0W	82N	.95	1.12	.007	400	690
0W	64N	1.24	1.16	.005	300	620
0W	32N	.95	1.35	-.001	264	910
0W	16N	.48	1.27	-.008	430	1120
0W	8N	.57	1.29	.007	420	1130
0W	4N	.74	1.26	.006	390	970
0W	1N	.73	1.24	-.004	390	980
0W	0N	.80	1.25	.006	380	920
0W	1S	.67	1.29	-.002	380	1070
0W	2S	.68	1.28	.010	400	1060
0W	4S	.58	1.27	.002	425	1035
0W	8S	.78	1.29	-.001	345	1100
0W	16S	.51	1.31	-.011	415	1100
0W	32S	.35	1.31	-.014	425	1250
0W	82S	1.15	1.23	-.010	287	680

Table 1 - Continued
Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series H - June 18, 1956

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} phi units	D_{90} phi units
64E	88N	1.06	1.22	-.016	325	635
64E	64N	.76	1.24	-.009	338	890
64E	32N	-.07	1.26	-.004	630	1660
64E	16N	.81	1.21	-.003	383	960
64E	8N	.84	1.33	-.002	370	940
64E	4N	.77	1.24	-.008	379	930
64E	1N	.74	1.22	.009	415	960
64E	0N	.50	1.33	-.009	400	1220
64E	1S	.44	1.29	-.009	440	1155
64E	4S	.42	1.24	-.010	480	1100
64E	8S	.46	1.22	-.006	423	1300
64E	16S	0.00	1.32	-.030	540	1545
64E	32S	.22	1.43	-.008	430	1660
64E	64S	.95	1.24	-.014	313	780
64E	82S	.64	1.22	-.003	435	910
256E	96N	1.19	1.27	.009	283	715
256E	64N	1.09	1.26	-.003	288	745
256E	48N	.80	1.20	.002	386	860
256E	32N	.72	1.33	.003	322	1090
256E	16N	.95	1.26	.027	362	900
256E	8N	.60	1.24	.014	425	1040
256E	4N	.50	1.28	.013	455	1275
256E	1N	.56	1.32	-.010	396	1095
256E	0N	.44	1.30	.011	460	1300
256E	1S	.57	1.30	.014	420	1200
256E	4S	.09	1.33	.004	515	1640
256E	8S	.10	1.29	-.027	485	1400
256E	16S	-.48	1.20	-.001	880	2040
256E	32S	.60	1.34	.053	390	1200
256E	64S	.96	1.29	-.004	280	880
256E	82S	.97	1.27	-.004	317	835

Series Y - May 31, 1955

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} phi units	D_{90} phi units
256W	48N	.28	1.22	-.009	530	1195
256W	32N	.53	1.20	-.004	480	1065
256W	16N	.71	1.11	.007	440	875
256W	4N	.50	1.24	.007	470	1085
256W	1N	.37	1.29	-.008	480	1305
256W	0N	.50	1.26	.002	460	1105
256W	1S	.49	1.27	.016	480	1085
256W	4S	.47	1.25	-.001	480	1100
256W	16S	.60	1.13	.003	510	1295
256W	32S	-.03	1.21	-.003	645	1050
256W	64S	.27	1.21	-.006	545	1185
256W	96S	1.17	1.19	-.006	340	580
160W	0N	.91	1.21	.012	380	800
160W	32S	.27	1.22	-.016	660	1200
90W	32N	.06	1.21	-.003	660	1390
90W	0N	.67	1.26	.009	430	950
90W	32S	.35	1.27	-.004	510	1175
16W	0N	.88	1.17	-.006	380	720
4W	0N	1.06	1.24	.008	340	765
1W	0N	.94	1.19	-.006	355	715
0W	48N	.45	1.22	-.003	520	1035
0W	32N	.23	1.21	.004	575	1245
0W	16N	.62	1.33	.012	410	1140
0W	1N	.99	1.23	-.013	340	740
0W	0N	1.03	1.22	-.013	340	690
0W	1S	.93	1.20	.013	355	710
0W	4S	.94	1.22	.002	370	740
0W	16S	.69	1.21	.000	415	930
0W	32S	.72	1.17	-.003	430	920
0W	64S	.80	1.18	-.008	400	780
0W	96S	.67	1.28	-.020	365	1070
1E	0N	.90	1.12	.006	365	710
4E	0N	.94	1.18	.004	370	755
16E	0N	.73	1.28	.012	415	980
110E	0N	.69	1.20	.012	430	930

Table 1 - Continued
Basic parameters of Point Reyes sediments
(For explanation of parameters see end of Table 1)

Series Y - May 31, 1955

Location		Median (phi units)	So	$Log_{10}Sk$	D_{10} phi units	D_{90} phi units
110E	32S	.71	1.14	-.005	430	870
190E	ON	.92	1.18	-.005	370	700
	32S	.77	1.15	-.003	430	785
256E	48N	.48	1.27	-.005	460	1085
	32N	.77	1.19	-.001	410	805
	16N	.67	1.26	.008	410	980
	4N	.75	1.24	.004	430	895
	1N	.73	1.17	-.002	450	785
	ON	.77	1.10	-.008	450	750
	1S	.73	1.14	-.002	440	800
	4S	.76	1.17	.005	430	905
	16S	.73	1.13	-.011	430	795
	32S	.66	1.10	.006	550	785
	64S	.78	1.41	.018	345	1340
	96S	.56	1.45	-.004	345	1240

Explanation

Location is the coordinate of the sample with reference to the 0 North 0 West point, in feet North (N) or South (S) and West (W) or East (E).

Md is the median grain diameter D50 of the sample, expressed in phi-units (if ϕ is the diameter in phi-units and M is the diameter in millimeters, then $\phi = -\log_2 M$).

So is the sorting coefficient of the sample (for grain size in microns $So = \sqrt{D_{75}/D_{25}}$).

$Log_{10}Sk$ is the logarithm of the skewness of the sample (for grain size in microns $\log_{10} Sk = \log_{10} \sqrt{(D_{25} \times D_{75})/(D_{50})^2}$).

D_{10} and D_{90} are the 10 and 90 percentiles, respectively, of the size-distribution of the particles in the samples, expressed in microns.

Numbers in parentheses refer to the upper of two samples taken at the same locality.

Table 2

Average grain size along North-South lines in phi units

		X Mar. 1954	Y May 1955	A Aug. 1955	B Oct. 1955	C Nov. 1955	D Dec. 1955	E Feb. 1956	F Mar. 1956	G May 1956	H June 1956
256W	Md	.71	.49	.52	.59	.51	.69	.50	.60	.54	.69
	N	8	12	17	12	10	11	14	16	10	14
64W	Md	.49		.42	.86	.62	.70	.41	.69	.69	.79
	N	6		14	10	11	12	12	14	13	15
OW	Md	.38	.73	.60	.74	.59	.42	.32	.53	.61	.74
	N	12	11	15	16	13	14	14	15	15	16
64E	Md	.51		.09	.10	.90	.87	.35	.44	.53	.57
	N	5		9	10	12	13	11	14	12	15
256E	Md	.61	.70	.97	1.00	.96	.69	.37	.28	.58	.60
	N	8	12	10	11	12	13	11	16	12	16
Mean ϕ		.46	.66	.62(1)	.84	.75	.68	.38	.50	.58	.68
Mean μ		730	635	655	560	595	625	770	710	670	625
σ		.38	.27	.52	.30	.30	.35	.34	.33	.30	.31
$\sigma/\sqrt{N_T}$		.056	.038	.051	.039	.039	.041	.043	.038	.038	.036
N_T		46	50	105	61	60	75	64	78	63	76

Explanation

Md - Mean median diameter in phi units
N - Number of samples represented by mean diameter
Mean ϕ - Mean median diameter in phi units of all samples on beach
Mean μ Same median diameter in microns
σ - Standard deviation of individual samples on beach
$\sigma/\sqrt{N_T}$ - Standard deviation of mean ϕ in phi units
N_T - Total number of samples on beach

(1) Excludes three coarse samples. If these three samples are included mean is 0.52 phi units, σ is 0.83 phi units and $\sigma/\sqrt{N_T}$ is .080 phi units

Table 3

Significance of means of entire area

	X Mar. 1954	Y May 1955	A Aug. 1955	B Oct. 1955	C Nov. 1955	D Dec. 1955	E Feb. 1956	F Mar. 1956	G May 1956	H June 1956
Y	0.29									
A	4.55	52.87								
B	0.00	0.08	0.06							
C	0.00	9.49	4.24	10.10						
D	0.15	71.88	35.76	0.47	2.14					
E	25.85	0.00	0.03	0.00	0.00	0.00				
F	54.85	0.23	5.74	0.00	0.00	0.12	3.66			
G	7.35	13.10	52.87	0.00	0.16	7.35	0.05	11.41		
H	0.53	76.42	42.95	1.83	30.30	100.00	0.00	9.30	12.36	
Md	.46	.66	.62	.84	.75	.68	.38	.50	.58	.68
N_T	46	50	105	61	60	75	64	78	63	76
$\sigma/\sqrt{N_T}$	.056	.038	.051	.039	.039	.041	.043	.038	.038	.036

See Table 2 for explanation of Md, N_T and $\sigma/\sqrt{N_T}$
The significance in per cent is the percentage probability that the difference in mean median diameter could have arisen from purely random causes. A figure of less than 5 per cent indicates that the difference is real and not due to vagaries of sampling. A figure of 0.00 means that the chances are more than 20,000 to 1 that the difference is real.

Table 4

Average grain size of elevation zones

Zone feet		A Aug. 1955	B Oct. 1955	C Nov. 1955	D Dec. 1955	E Feb. 1956	F Mar. 1956	G May 1956	H June 1956	Mean	σ
3-6	Md	-.25	--	.27	.76	.17	.26	.38	.96	.29	.56
	N	7	--	4	4	6	4	2	4	31	
6-9	Md	.50	.80	.43	.61	.36	.32	.45	1.08	.53	.46
	N	.19	4	5	2	3	6	5	4	48	
9-12	Md	.94	1.04	.77	.87	.49	.45	.38	.71	.77	.33
	N	27	5	4	5	3	4	7	5	60	
12-15	Md	.65	1.00	.84	.94	.34	.47	.59	.73	.66	.35
	N	26	6	10	5	11	6	7	4	75	
15-18	Md	.71	.85	.74	.68	.28	.47	.62	.57	.62	.33
	N	14	40	28	4	20	42	26	47	251	
18-21	Md	.34	.75	.45	.71	.57	.86	.77	.77	.70	.24
	N	2	4	2	10	13	13	9	6	57	
21 +	Md	.23	1.00	.89	.74	.73	.83	.93	.93	.79	.37
	N	3	1	4	2	2	2	4	6	23	
Mean		.62	.84	.75	.68	.38	.50	.58	.65	.63	
	$\sigma/\sqrt{N_T}$	.051	.039	.039	.043	.043	.038	.038	.036		
	N_T	105	61	60	75	64	78	63	76		

Md - Mean median diameter in phi units
N_T - Number of samples averaged
Md, $\sigma/\sqrt{N_T}$ and N_T are from Table 2
Mean and σ in rows represent the entire population of the samples represented in the row. They are based on the individual samples

Table 5

Significance of means of elevation zones

	Elevation zone						
	3-6	6-9	9-12	12-15	15-18	18-21	21
	Per cent						
6-9	4.66						
9-12	0.00	0.23					
12-15	0.07	9.30	5.88				
15-18	0.13	19.36	0.14	37.35			
18-21	0.01	2.09	18.68	43.54	3.24		
21 +	0.01	1.11	81.81	13.89	3.49	28.46	
	Phi units						
Mean	.29	.53	.77	.66	.62	.70	.79
σ	.56	.46	.33	.35	.33	.24	.37
$\sigma/\sqrt{N}$	.100	.066	.043	.040	.021	.032	.077
N	31	48	60	75	251	57	23

See Table 3 for explanation

The data are based on the population of each zone for all 8 times of occupation - A to H, inclusive.

Table 6

Sorting of North-South lines

		X Mar. 1955	Y May 1955	A Aug. 1955	B Oct. 1955	C Nov. 1955	D Dec. 1955	E Feb. 1956	F Mar. 1956	G May 1956	H June 1956	Mean(1)
256W	Ms	1.40	1.22	1.24	1.28	1.31	1.24	1.29	1.29	1.24	1.28	1.28
	N	9	12	17	12	10	11	14	16	10	14	
64W	Ms	1.33		1.33	1.26	1.26	1.27	1.32	1.28	1.25	1.28	1.29
	N	6		14	10	11	12	12	14	13	15	
OW	Ms	1.32	1.22	1.33	1.30	1.31	1.36	1.39	1.27	1.26	1.26	1.30
	N	12	11	15	16	13	14	14	15	15	16	
64E	Ms	1.29		1.30	1.11	1.19	1.32	1.27	1.30	1.28	1.27	1.26
	N	5		9	10	12	13	11	14	12	15	
256E	Ms	1.26	1.26	1.24	1.15	1.28	1.28	1.27	1.29	1.31	1.28	1.26
	N	8	8	10	11	12	13	11	16	12	16	
Mean(2)		1.32	1.21	1.28	1.25	1.27	1.30	1.32	1.29	1.27	1.27	
σ		.05	.07	.12	.12	.08	.13	.14	.06	.06	.06	
$\sigma/\sqrt{N_T}$		.004	.009	.011	.016	.011	.015	.018	.006	.008	.007	
N_T		46	50	108	61	60	75	64	78	63	76	

Ms - Means sorting of all samples on line
N - Number of samples
σ - Standard deviation of all samples on beach
N_T - Total number of samples on beach
(1) - Mean of means
(2) - Mean of all samples on beach

Table 7

Sorting of elevation zones

Elev. zone	A Aug. 1955	B Oct. 1955	C Nov. 1955	D Dec. 1955	E Feb. 1956	F Mar. 1956	G May 1956	H June 1956	Mean(1)
3-6 Ms	1.27	--	1.26	1.30	1.19	1.33	1.18	1.18	1.25
N	7	--	4	4	6	4	2	5	7
6-9 Ms	1.30	1.33	1.29	1.41	1.24	1.31	1.30	1.21	1.30
N	22	4	5	2	3	6	5	4	8
9-12 Ms	1.29	1.19	1.26	1.23	1.31	1.28	1.24	1.30	1.26
N	26	5	4	5	3	2	7	5	8
12-15 Ms	1.30	1.22	1.22	1.26	1.27	1.31	1.23	1.29	1.26
N	27	6	10	4	12	8	7	4	8
15-18 Ms	1.19	1.25	1.32	1.29	1.41	1.28	1.30	1.27	1.29
N	14	40	29	39	24	42	28	47	8
18-21 Ms	1.17	1.24	1.29	1.25	1.29	1.27	1.26	1.28	1.26
N	2	4	4	9	13	13	8	6	8
21+ Ms	1.24	1.28	1.31	1.39	1.34	1.25	1.24	1.23	1.29
N	3	1	3	3	2	2	4	5	8
Mean(2)	1.28	1.25	1.27	1.30	1.32	1.29	1.27	1.27	
N_T	108	61	60	75	64	78	63	76	
$\sigma/\sqrt{N}_T$	.011	.016	.011	.015	.018	.006	.008	.007	

Ms - Mean sorting of elevation zone
N - Number of samples in elevation zone
N_T - Total number samples on beach
$\sigma/\sqrt{N_T}$ - Standard deviation of mean sorting of samples
(1) - Mean of means
(2) - Mean of all samples on beach

Table 8

Characteristic features of cusps

Dates

	A Aug. 1955	B Oct. 1955	C Nov. 1955	D Dec. 1955	E Feb. 1956	F Mar. 1956	G May 1956	H June 1956	Ave
No. of cusps	6	4	4	5	5	6	5	4	5
Position of cusps - east and west									
200 west(1)									
west cusp	13'	62'	58'	52'	85'	100'	80'	80'	--
east cusp	127'	180'	180'	150'	120'	75'	67'	136'	--
0 west									
west cusp	63'	20'	20'	50'	60'	35'	133'	64'	--
east cusp	75'	110'	172'	145'	103'	45'	55'	113'	--
200 east									
west cusp	60'	0'	28'	55'	18'	85'	93'	87'	--
east cusp	48'	110'	112'	103'	45'	50'	70'	103'	--
Position of cusps - north and south									
mean	36N	42N	64N	72N	58N	48N	73N	29N	53N
max. diff.(2)	59'	52'	94'	103'	100'	35'	65'	13'	68'
Interval between cusps									
mean	135'	205'	195'	140'	135'	115'	165'	198'	161'
maximum	150'	250'	240'	215'	210'	180'	190'	230'	208'
minimum	110'	190'	140'	125'	60'	75'	150'	175'	123'
Elevation of cusps									
mean	13'	16'	14'	16'	14'	15'	14'	16'	15'
maximum	14'	16'	16'	18'	15'	16'	16'	17'	16'
minimum	12'	15'	12'	15'	13'	13'	13'	16'	14'
Characteristic features of cusps									
Mean median grain size in phi units									
cusp slope(3)	.77	.93	.58	.76	.56	.44	.37	.66	.67
cusp crest	.50	.59	.63	.56	.42	.47	.75	.46	.52
lower bay	.99	1.06	.73	1.02	.39	.57	.86	.78	.86
upper bay	.79	1.08	.77	.91	.16	.71	.68	.67	.75
mean median(4)	.62	.84	.75	.68	.38	.50	.58	.68	.63
Mean coefficient of sorting									
cusp slope	1.33	1.23	1.23	1.27	1.29	1.33	1.25	1.26	1.29
cusp crest	1.33	1.29	1.31	1.25	1.21	1.29	1.28	1.27	1.29
lower bay	1.27	1.19	1.27	1.30	1.28	1.29	1.27	1.30	1.27
upper bay	1.17	1.17	1.25	1.26	1.26	1.26	1.28	1.29	1.24
mean sorting(3)	1.28	1.25	1.27	1.30	1.32	1.29	1.27	1.27	1.28

Explanation

Distances and elevations are given in feet

(1) "200 West, West cusp 13" for August 1955 means that the first cusp west of of line 200 west is 13 feet west of that line; and "200 West 127 east" means that the first cusp east of line 200 West is 127 feet east of that line.

(2) "Maximum difference" represents distance measured in feet in seaward direction.

(3) "Cusp slope" represents samples within 50 feet of point of the cusp on seaward or down side.

"Cusp crest", represents samples on the berm within 50 feet of the edge of the cusp.

"Lower bay" samples are samples from the bay or swale between cusps taken within a horizontal distance of 50 feet of the elevation of the cusp point; Upper bay samples are within 50 feet of the cusps elevation in the landward side.

(4) Mean median and sorting represent means for the entire beach, not for the group of samples representing the particular parts of cusps.

(5) The averages in the last column are of two types. One represents the mean of the 8 means representing the individual times the beach was occupied. The other, which is restricted to the last two categories giving median grain size and sorting for different parts of the cusps represents the entire suite of samples in each category for all the 8 times the beach was occupied. Such means do not represent the mean of the means except in the last line for each group, where means representing the entire samples on the beach are averaged.

DESCRIPTION OF FIGURES

Figure 1 shows the general location of Point Reyes, 35 miles northwest of San Francisco. The beach is exposed to the full force of the waves from the open Pacific Ocean. Figure 2 gives the general features of Point Reyes Beach. The part of the beach studied in the present investigation is situated at Station A, 3 miles northeast of Point Reyes. Station B, investigated in the previous work has not been occupied in the present study. The beach extends in a nearly straight line between the headland of Point Reyes on the south and the high land extending southeastward from Tomales Bluff. The land back of Station A rises to a height of about 250 feet. The cliff at Point Reyes and the highlands west of Tomales Bay attain a maximum elevation of more than 500 feet. The bedrock of the area west of Tomales Bay consists of quartz diorite below, overlain by conglomeratic sandstones and chert of Miocene age and this in turn by dune sand of Pleistocene and Recent age. In the area adjacent to Station A, Pleistocene dune sand is exposed in the cliffs behind the beach. In places this old dune sand is eroded during winter storms. The San Andreas fault passes northwesterly through Tomales Bay and separates areas underlain by Franciscan rocks of Mesozoic age on the east from the quartz diorite and other rocks on the west.

Figures 3 to 10 show the beach configuration for the 8 times the beach was occupied between August, 1955 and June, 1956. The cusps are lettered alphabetically from left to right. The position of the outer edge of the berm is indicated by a dashed line.

Profiles of the beach are shown in Figures 11 to 14. Profiles are given for three of the five lines of samples, namely, 256-W, O-W, and 256 E. On Figures 11 the profile at time X, for March, 1954 is included in order to show the change in beach after the beach was occupied in the previous study. Beach characteristics for time X are shown in each of the two previous publications on Point Reyes Beach,(1) and (2). In Figures 11 to 14, three profiles are combined together for purposes of comparison and three series of profiles are shown on each figure. In order to indicate the differences in elevation between successive periods of occupation of the beach, the last profile of the series shown above is repeated in the series given below. Thus the first series in Figure 11 shows times X, A and B; and the second series indicate times B, C,and D.

Figure 15 shows average median diameter by elevation zones. In preparing this table all the samples for each elevation zone shown in Table 3 have been averaged for each time the beach was occupied. These averages are represented by dots placed at the midpoint of each elevation zone. Three series, each containing three graphs are shown in Figure 15. These correspond to the 8 suites of samples, A to H inclusive, and the average of all samples in series A to H. The average is not the average of the 8 averages for the suites A to H but is a composite mean of all the samples collected in suites A to H.

The areal variation of grain size in August 1955 is shown in Figure 16. The beach was occupied more fully at this time than at any other time. The figure is presented as an example giving the general variation in grain size over the beach at a typical time. As the statistical studies show that the areal variation is similar each time the beach was occupied little is gained by showing maps of the areal variation at the other times. Maps were prepared, but they show the same general variability and trends.

Figure 17 shows the sorting by elevation zones. The chart was prepared in the same manner as Figure 15 and is based on data presented in Table 7. The general relationship of sorting to median grain diameters is represented in Figure 18. This figure represents all the samples collected during times A to H inclusive.

Figures 19 to 26 present maps showing the cut and fill between successive times of occupation of the beach. On these figures "cut" means erosion or scour between successive times of occupation of the beach. Fill represents deposition. Thus Figure 19 shows the amount of cut and fill between August 1955 and March 1954, which was the time of the previous occupation of the beach. The contours on Figures 19 to 26 were prepared by superimposing one beach contour chart upon another and marking difference in elevations where contour lines cross one another on the two charts. Contours are then drawn upon the basis of difference in elevation on the two charts. To give some idea of the configuration of the beach, 5-foot contour lines on the beach surface are shown for the later of the two charts used in preparing the cut and fill chart. Thus in Figure 19 the heavy contour lines show the position of the 5-foot contour in August 1955, which time was the later of the two times used in preparing the cut and fill map shown in Figure 19.

Figure 27 shows the relationship between cusp interval and average grain size on the beach for the 8 times the beach was occupied in the present study.

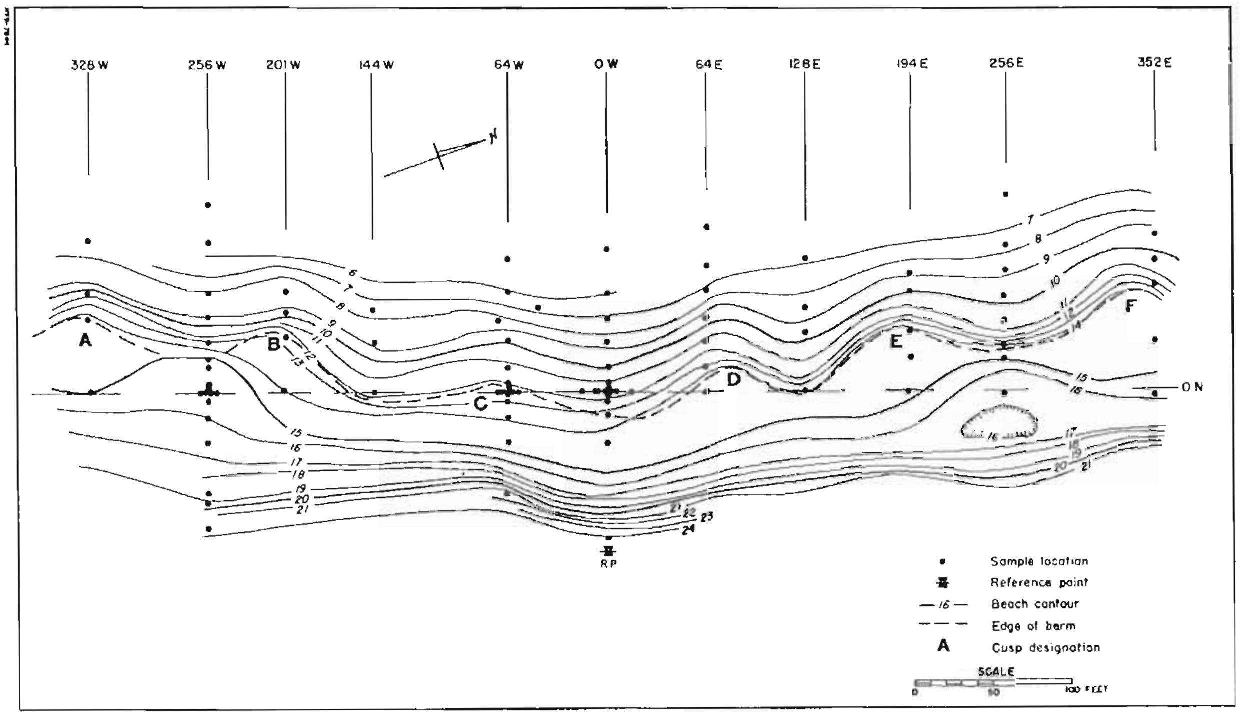

FIGURE 3. SAMPLE LOCATIONS, PT. REYES BEACH—SERIES A—AUGUST 26, 1955

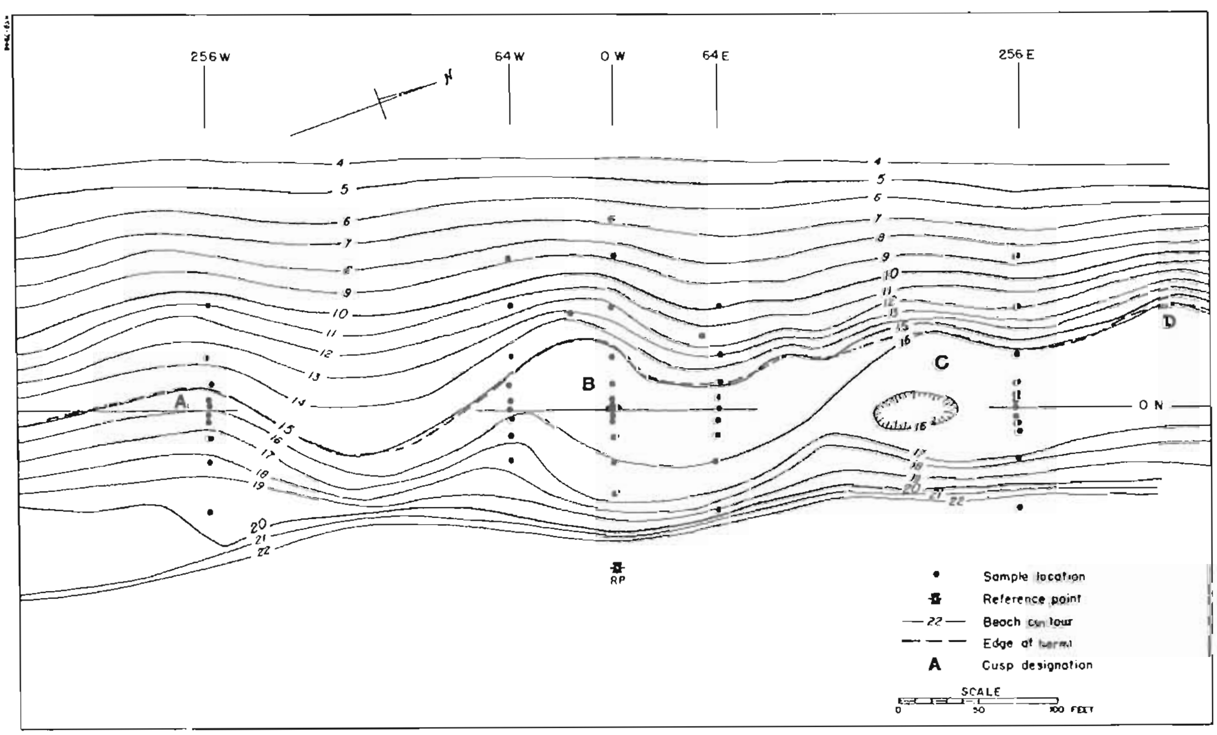

FIGURE 4. SAMPLE LOCATIONS, PT. REYES BEACH—SERIES B—OCTOBER 8, 1955

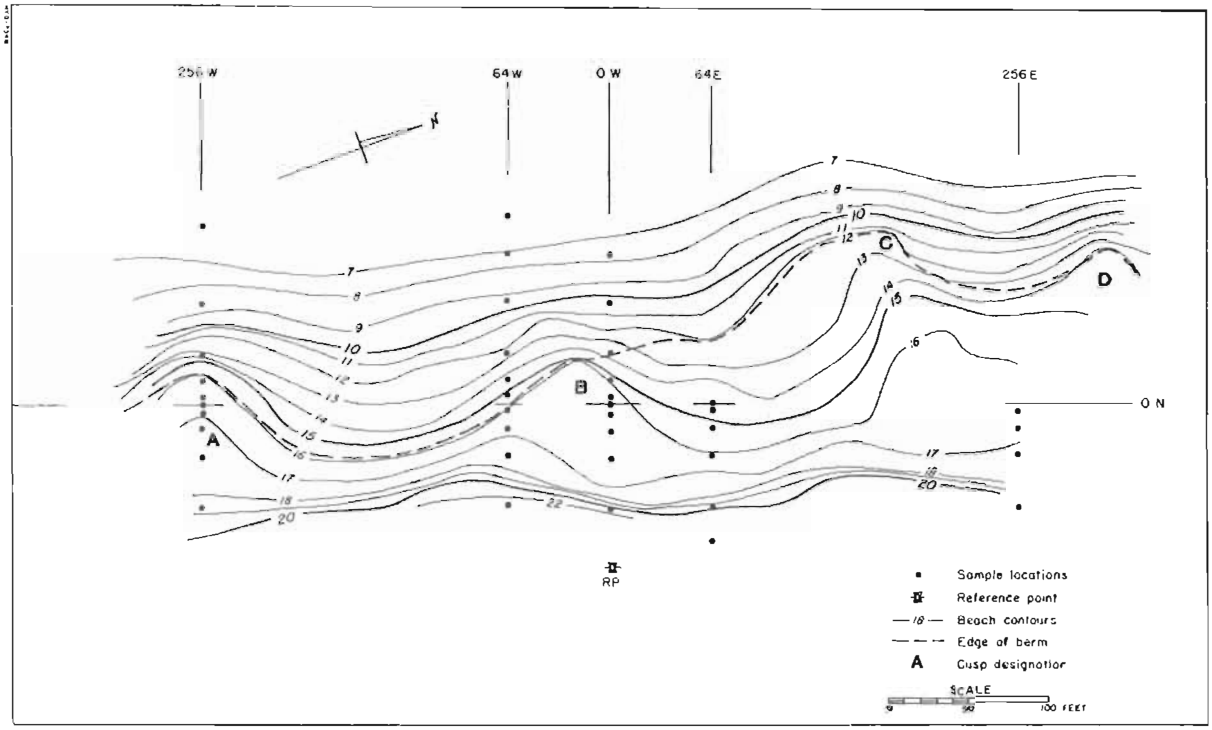

FIGURE 5. SAMPLE LOCATIONS, PT. REYES BEACH-SERIES C-NOVEMBER 12, 1955

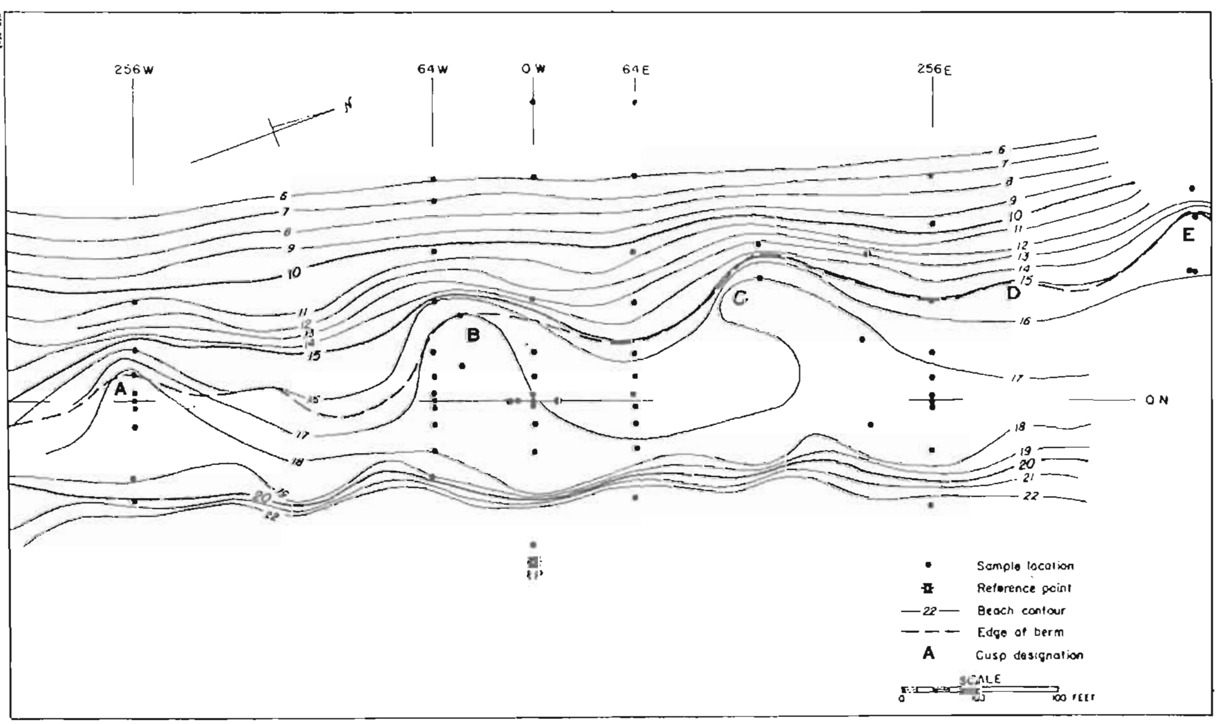

FIGURE 6. SAMPLE LOCATIONS, PT. REYES BEACH-SERIES D-DECEMBER 28, 1955

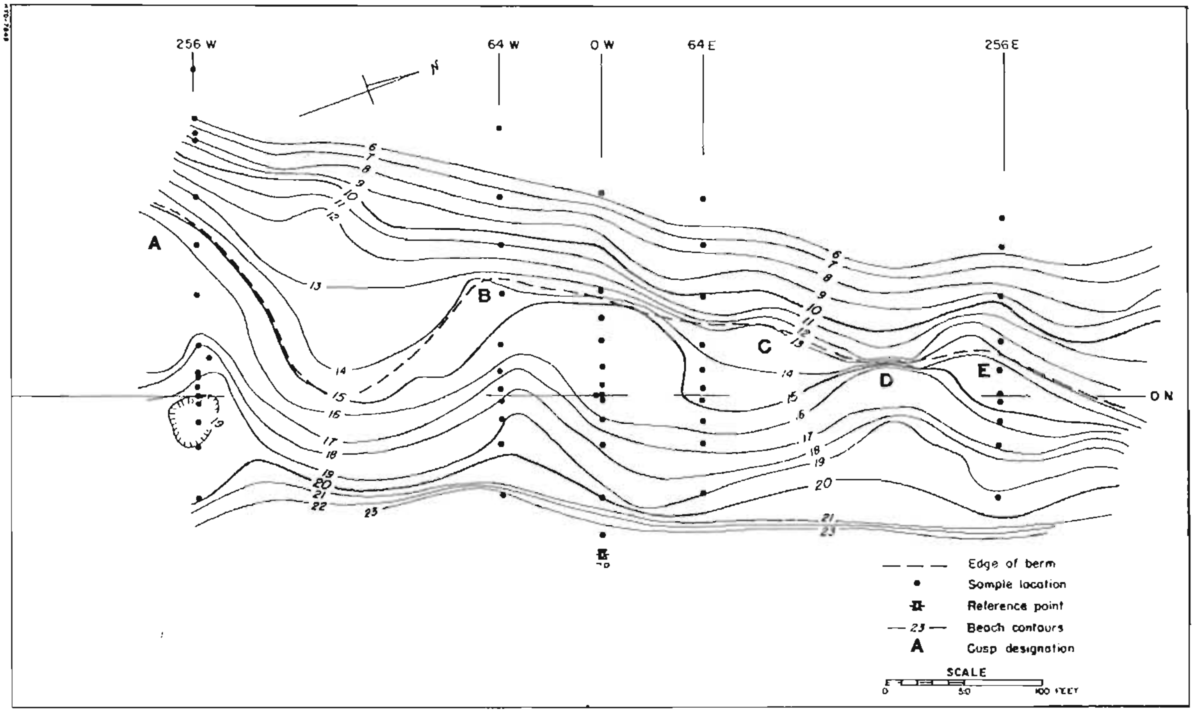

FIGURE 7. SAMPLE LOCATIONS, PT. REYES BEACH-SERIES E-FEBRUARY 11, 1956

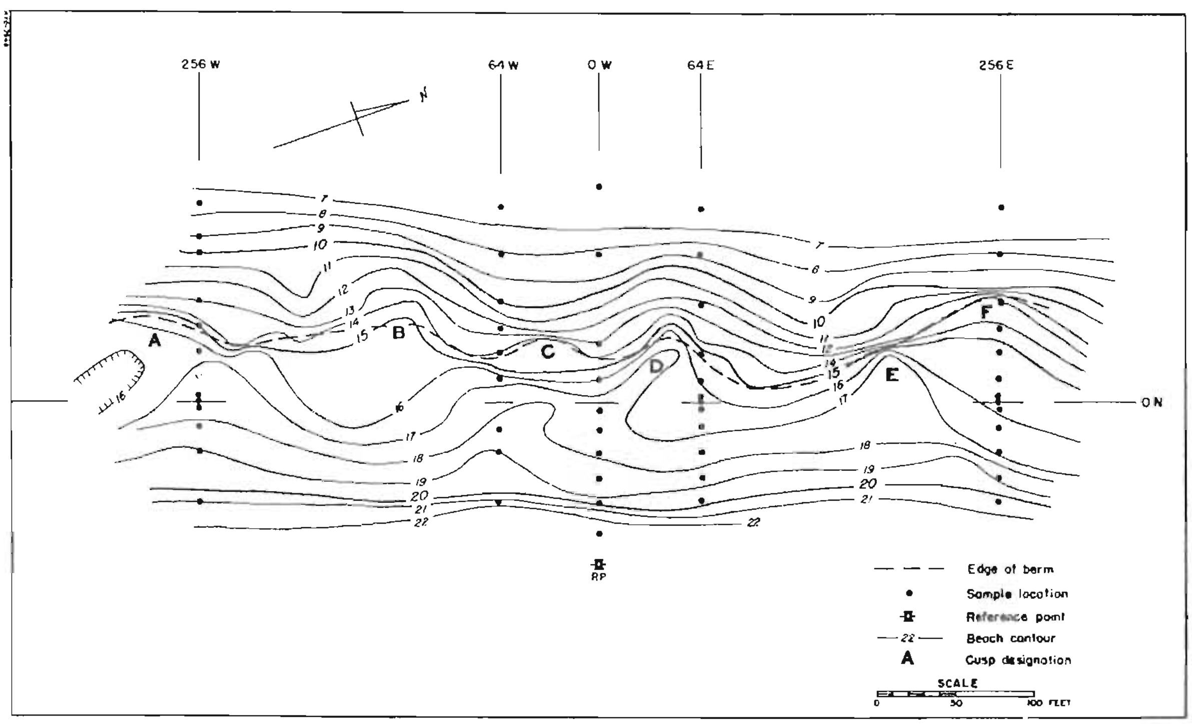

FIGURE 8. SAMPLE LOCATIONS, PT. REYES BEACH-SERIES F - MARCH 24, 1956

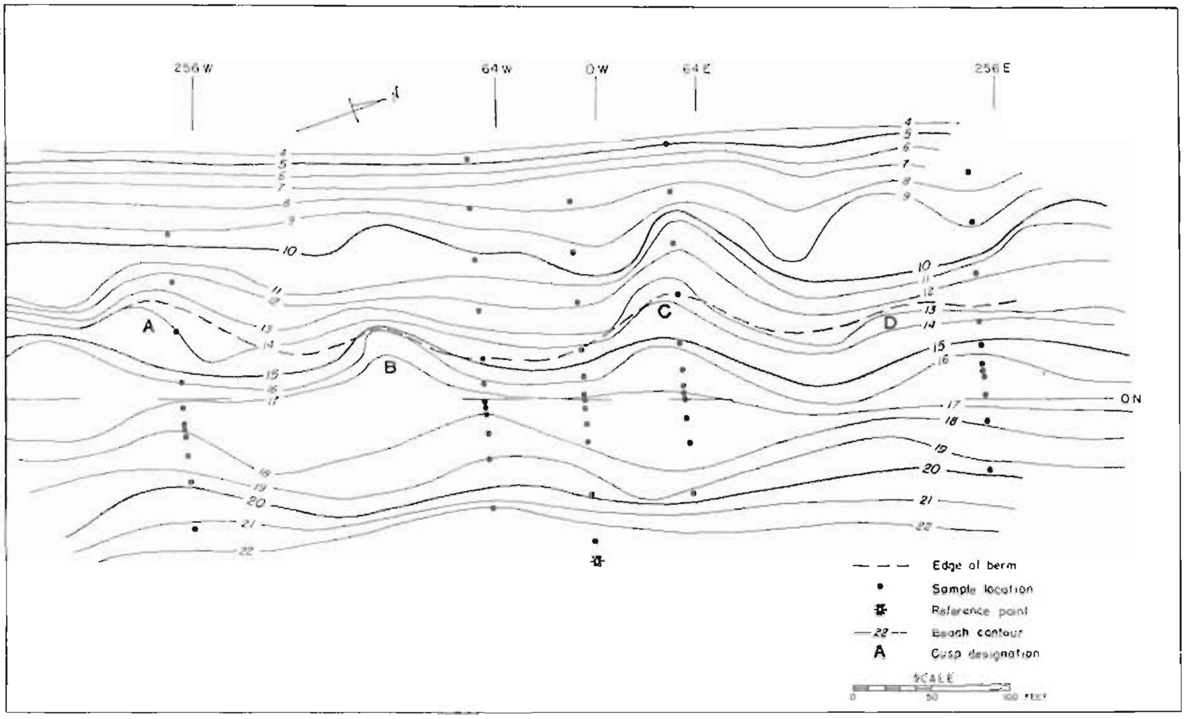

FIGURE 9. SAMPLE LOCATIONS, PT. REYES BEACH-SERIES G-MAY 4, 1956

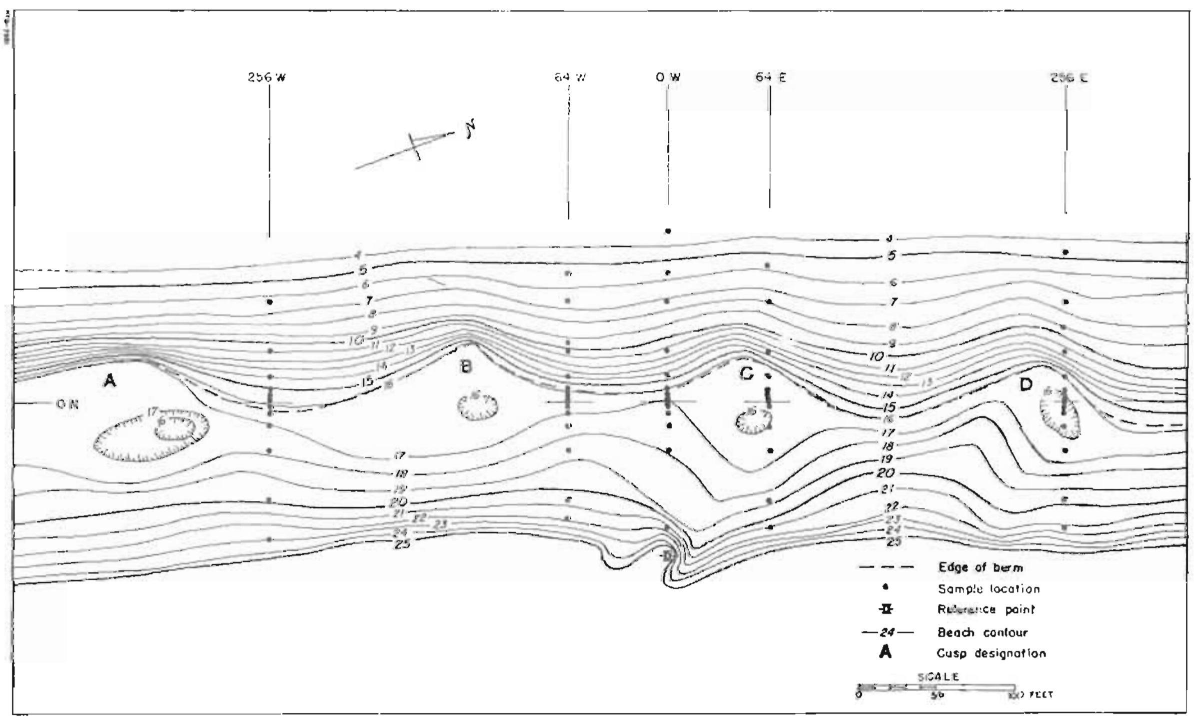

FIGURE 10. SAMPLE LOCATATIONS, PT. REYES BEACH-SERIES H-JUNE 18, 1956

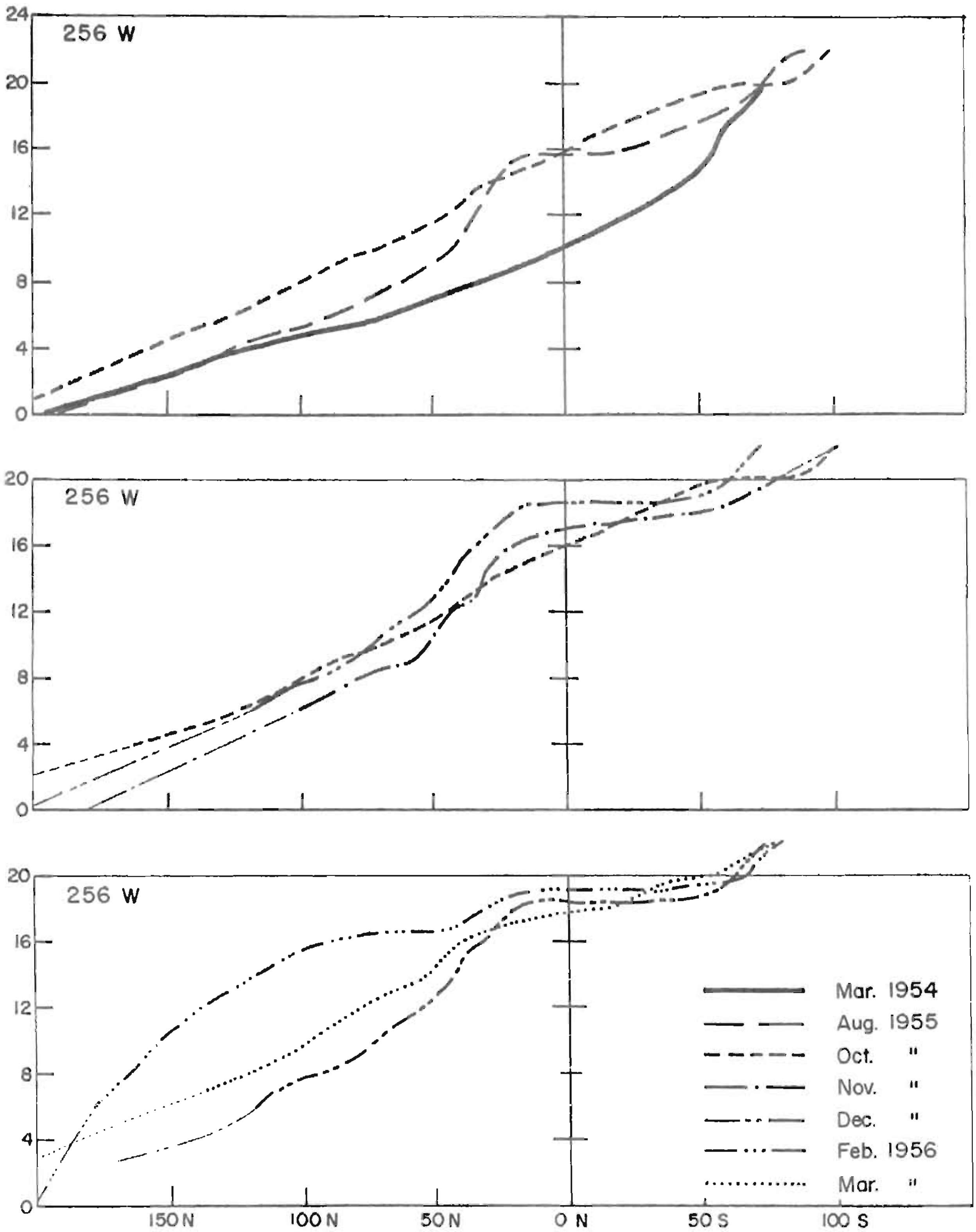

FIGURE 11. BEACH PROFILES, LINE 256 W (MARCH 1954–MARCH 1956)

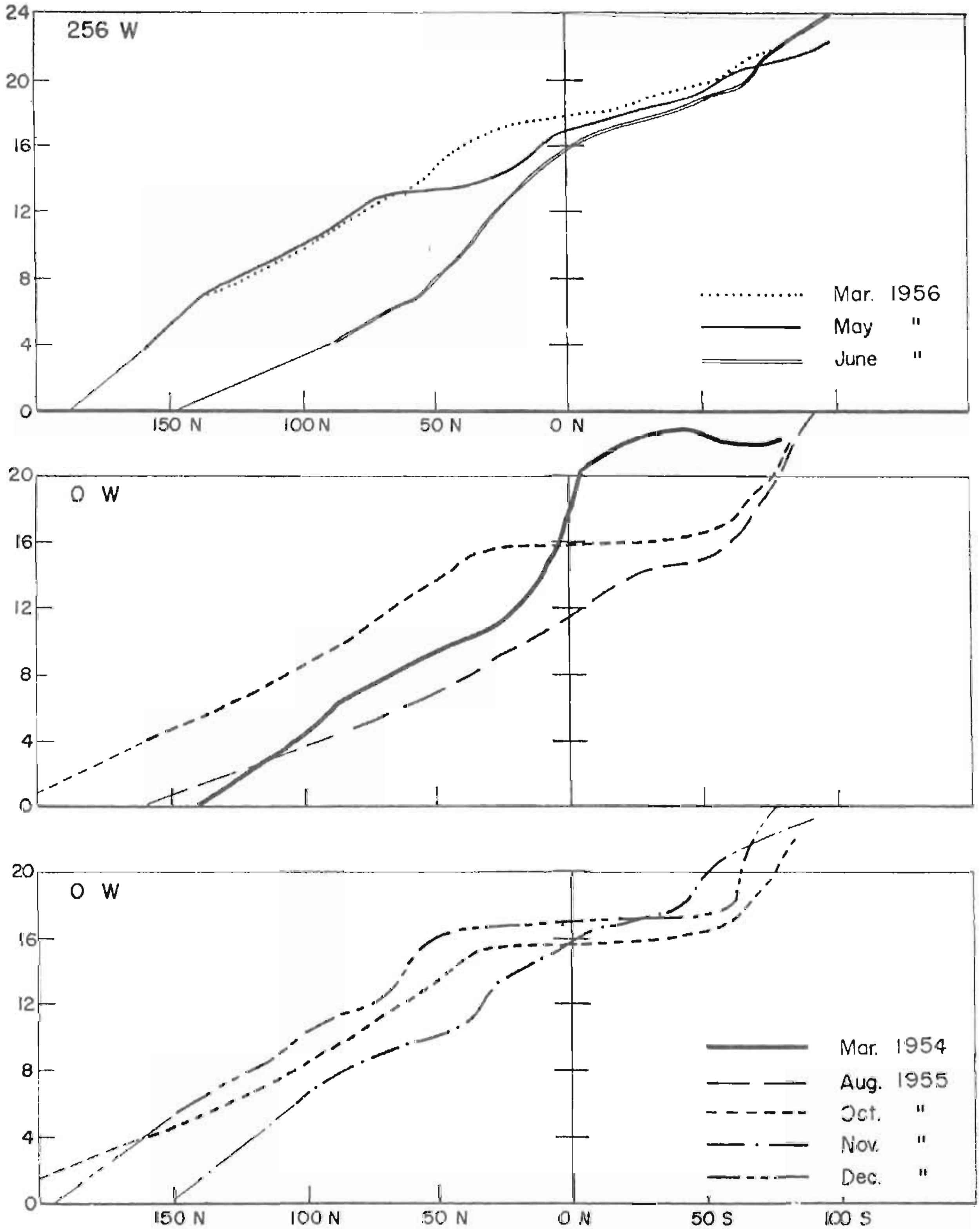

FIGURE 12 BEACH PROFILES, LINE 256 W (MARCH 1956-JUNE 1956)
LINE OW (MARCH 1954-DECEMBER 1955)

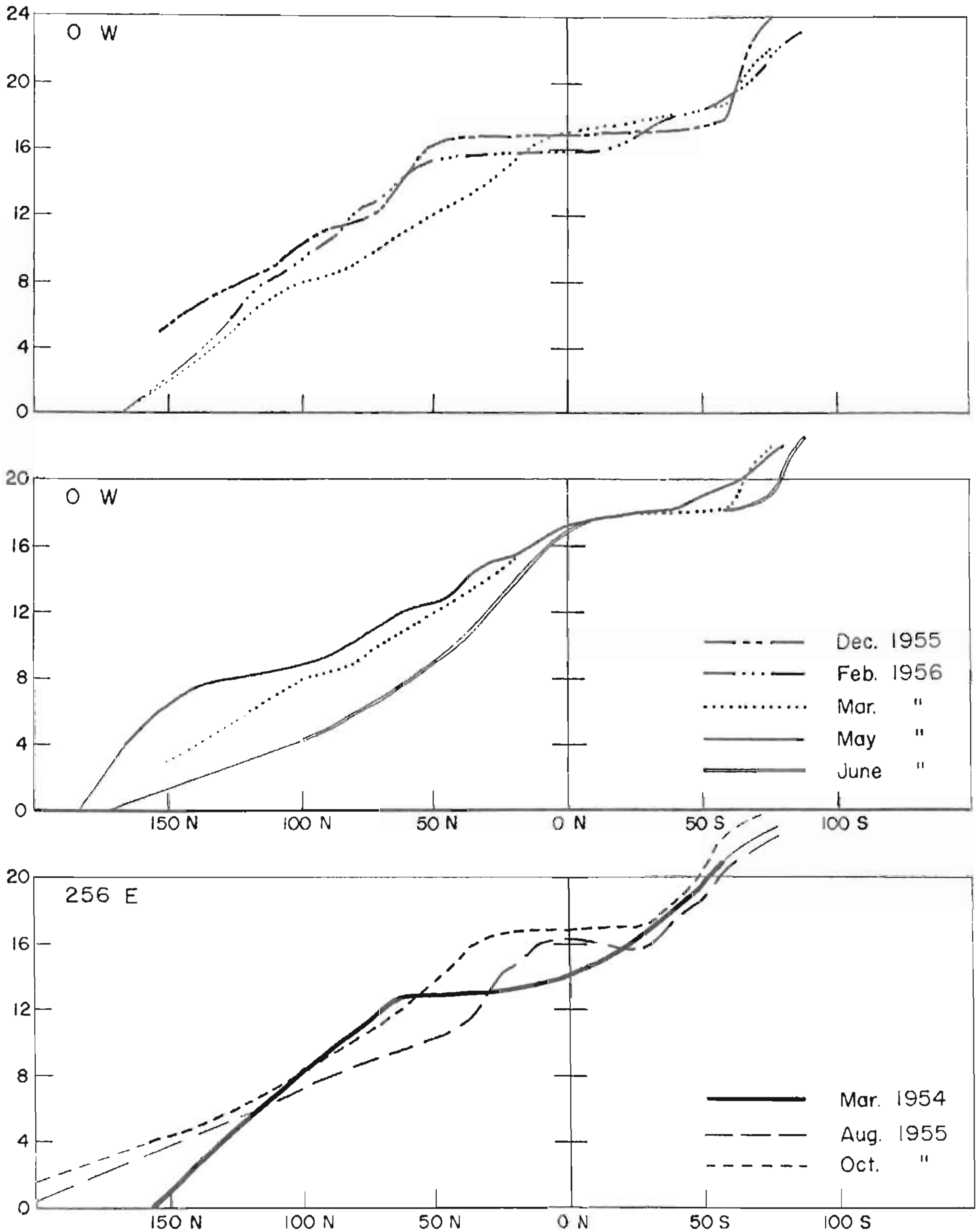

FIGURE 13. BEACH PROFILES, LINE OW (DECEMBER 1955-JUNE 1956)
LINE 256 E (MARCH 1954-OCTOBER 1955)

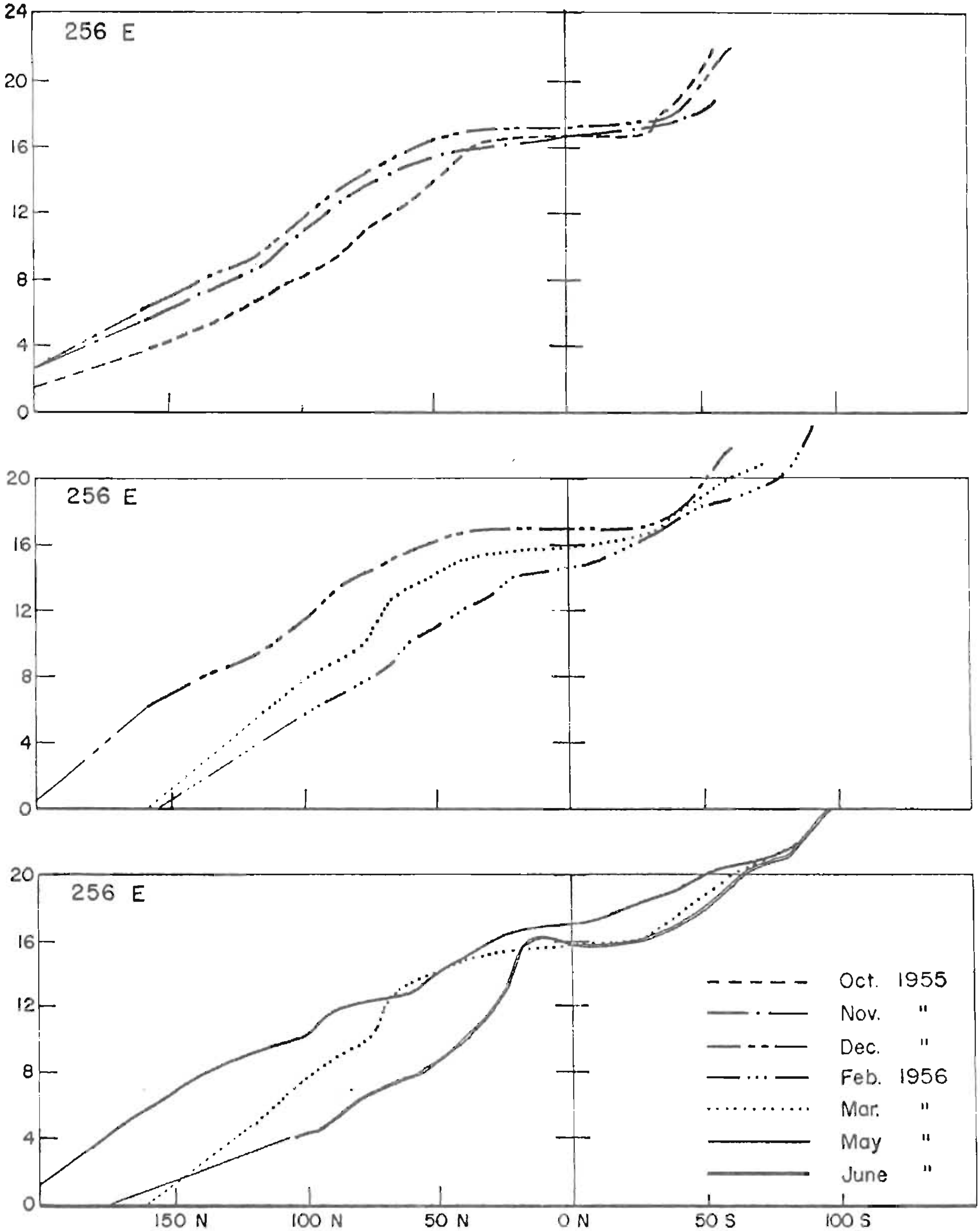

FIGURE 14. BEACH PROFILES, LINE 256 E (OCTOBER 1955-JUNE 1956)

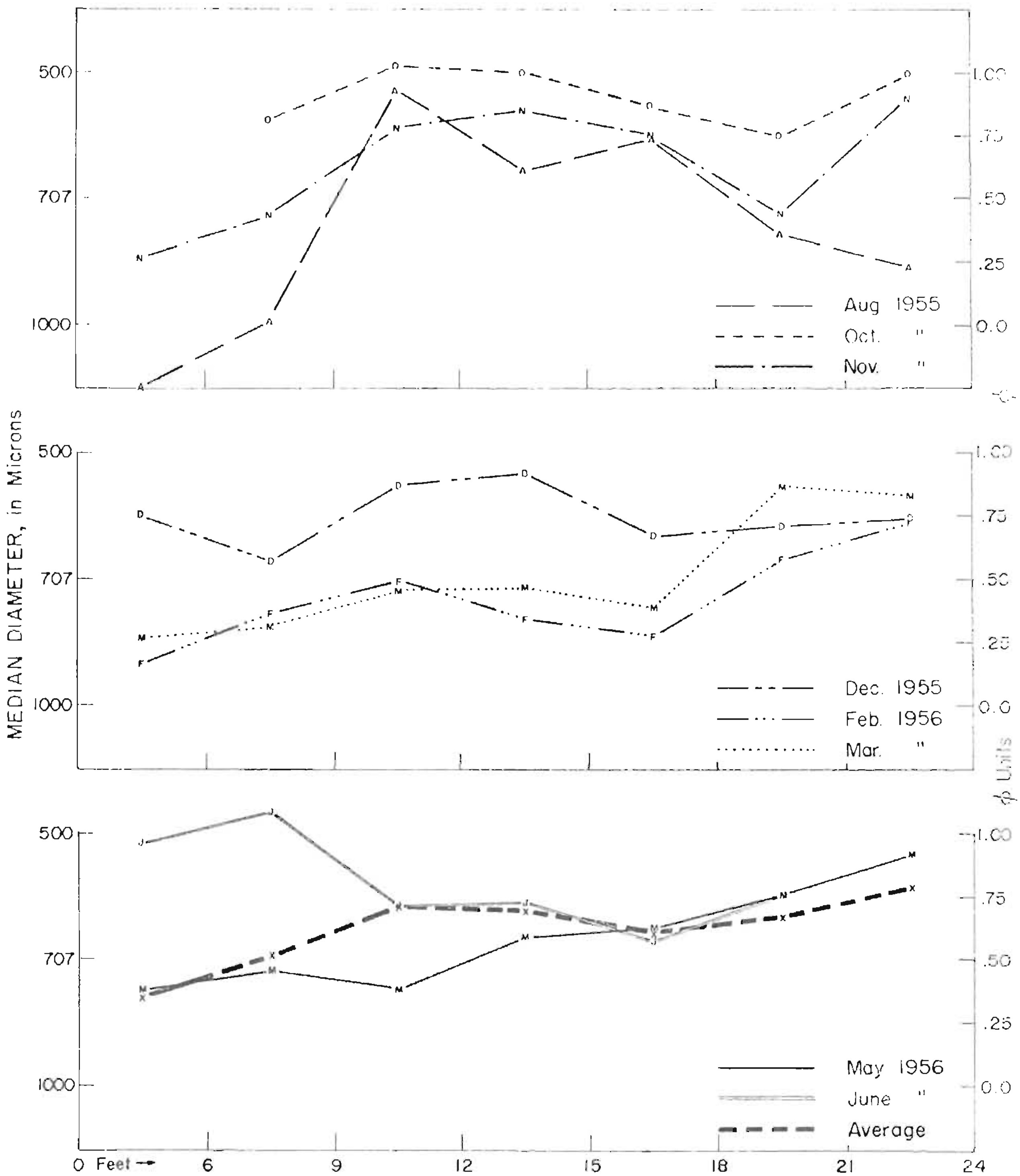

FIGURE 15. MEDIAN DIAMETER BY ELEVATION ZONES

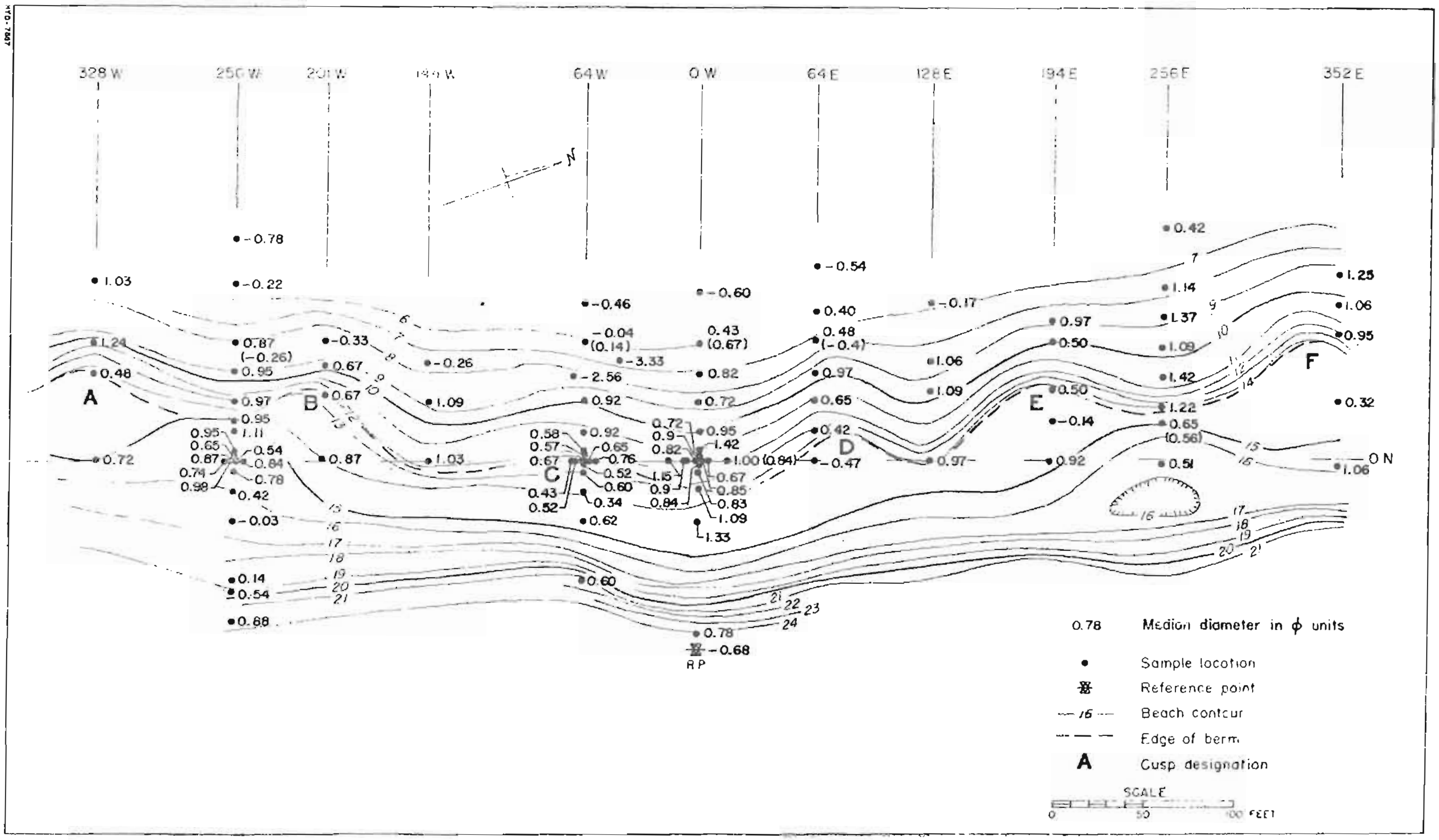

FIGURE 16. AREAL VARIATION IN MEDIAN DIAMETER

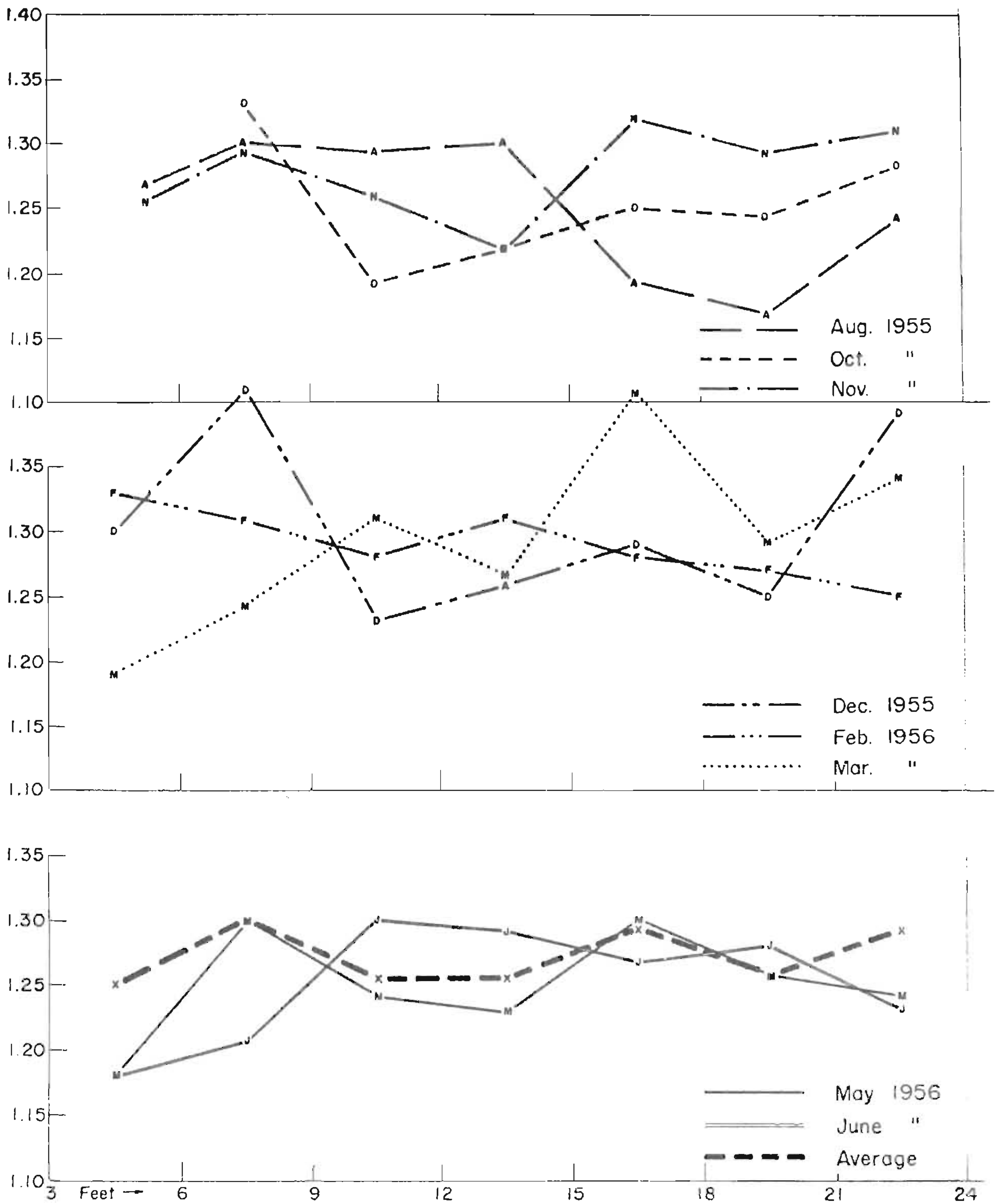

FIGURE 17. SORTING BY ELEVATION ZONES

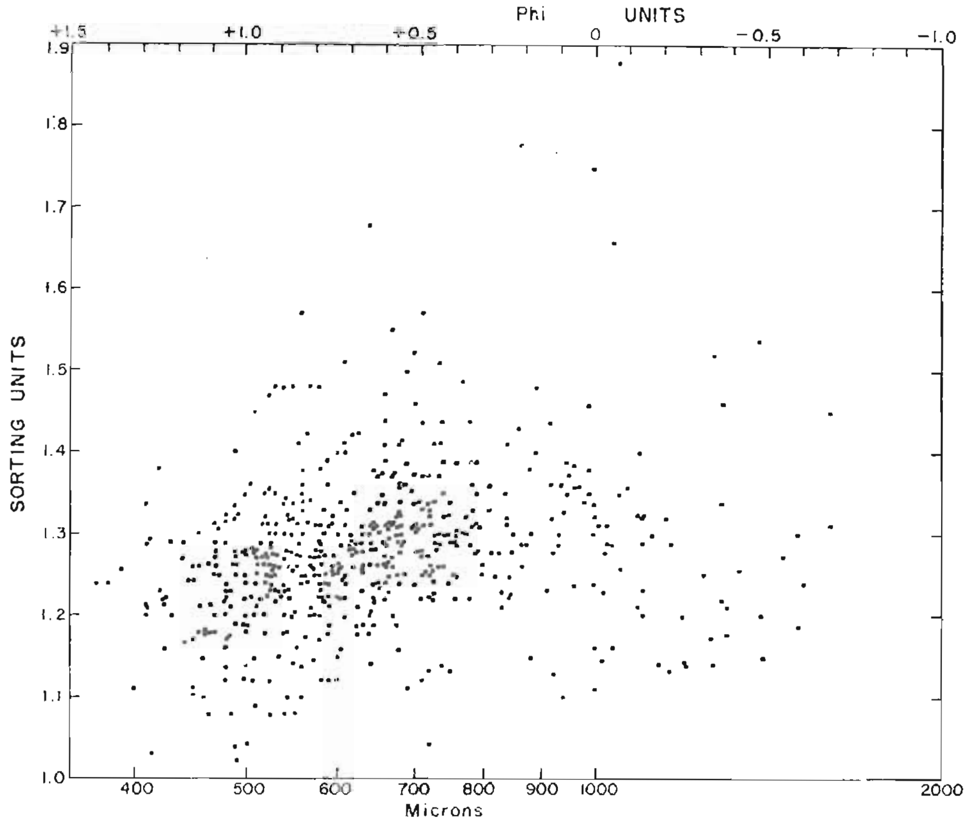

FIGURE 18. RELATION OF SORTING TO MEDIAN DIAMETER

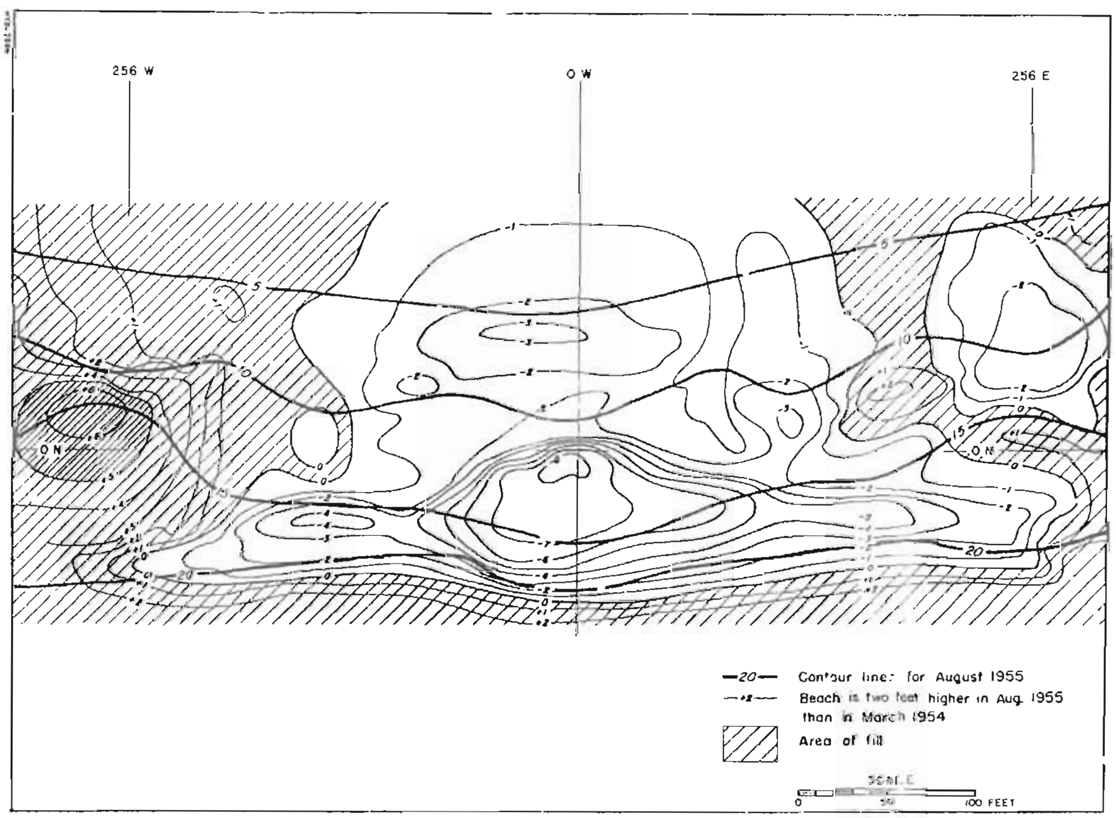

FIGURE 19. CUT AND FILL BETWEEN MARCH 1954 AND AUGUST 1955

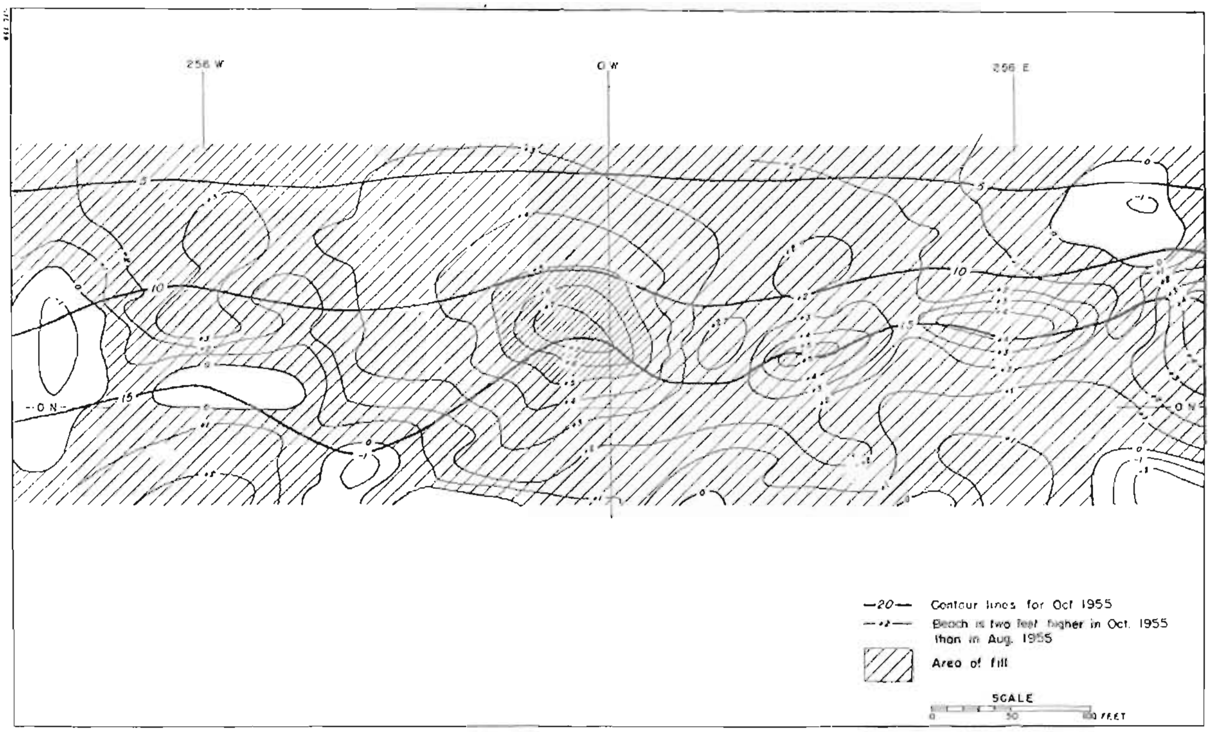

FIGURE 20. CUT AND FILL BETWEEN AUGUST 1955 AND OCTOBER 1955

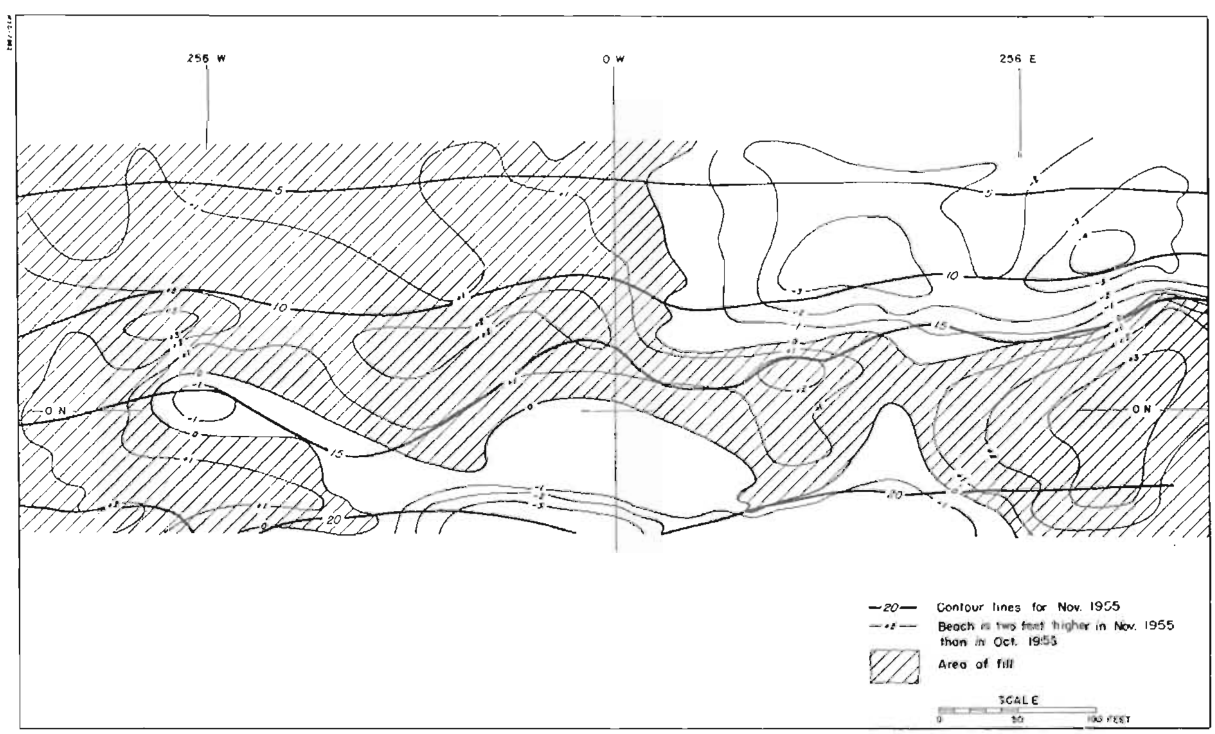

FIGURE 21. CUT AND FILL BETWEEN OCTOBER 1955 AND NOVEMBER 1955

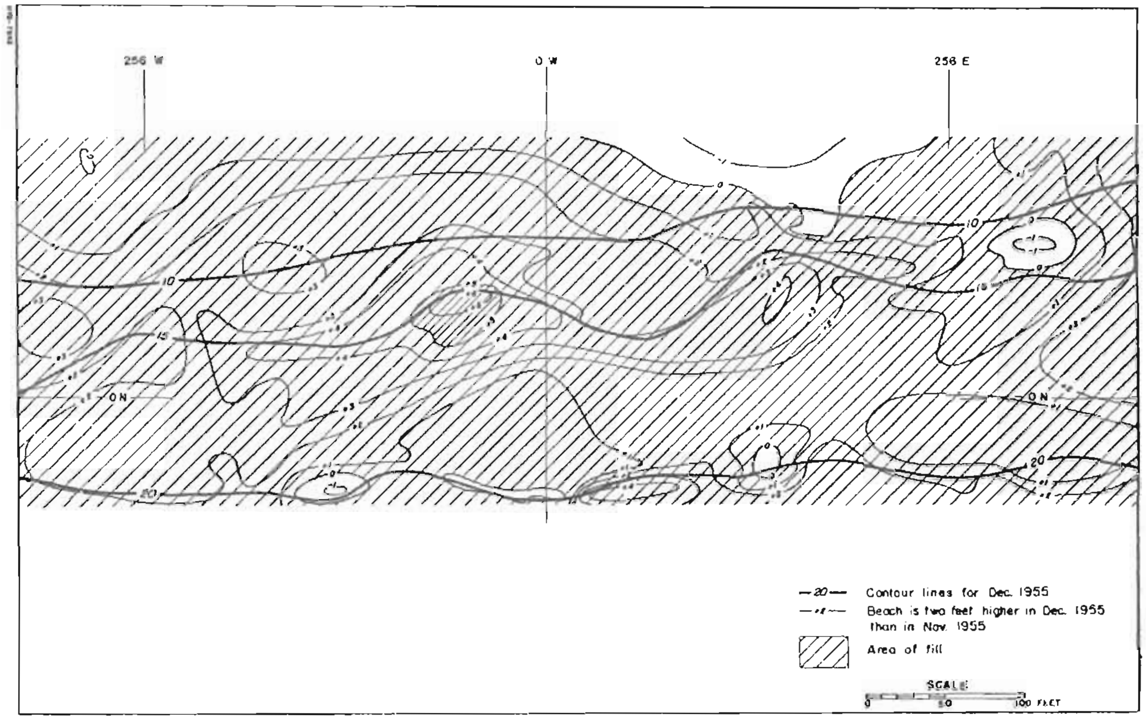

FIGURE 22. CUT AND FILL BETWEEN NOVEMBER 1955 AND DECEMBER 1955

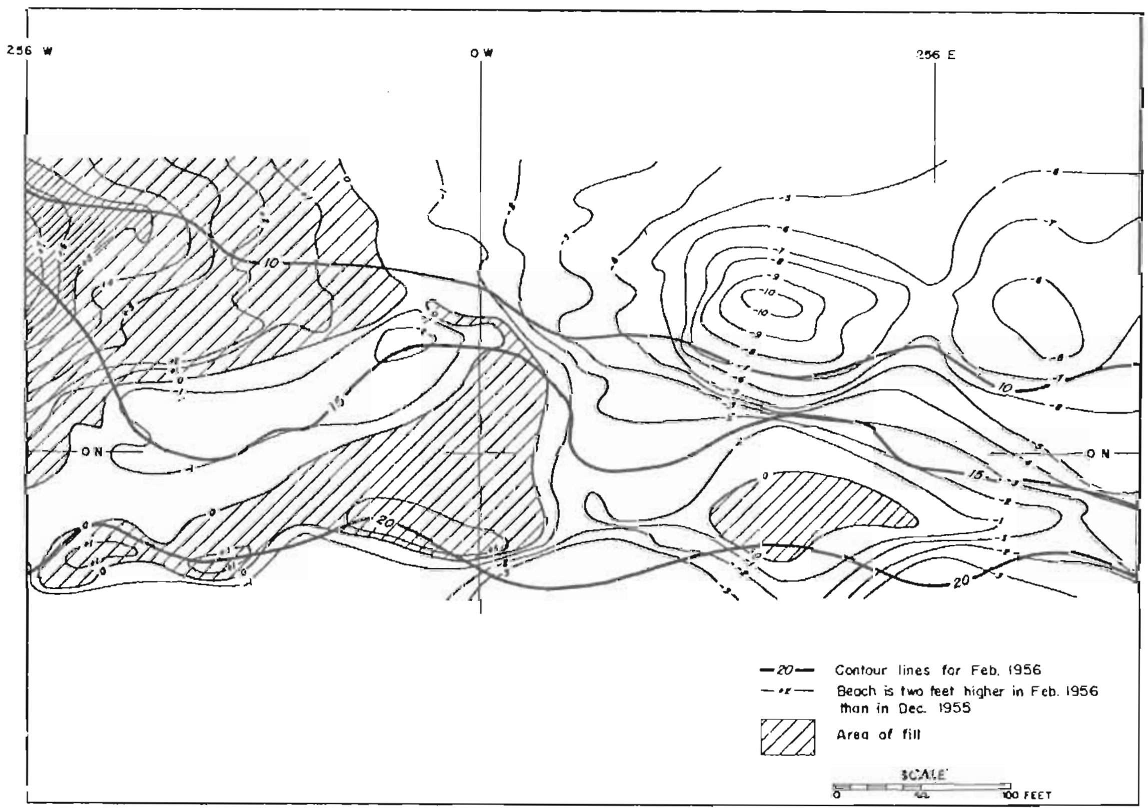

FIGURE 23. CUT AND FILL BETWEEN DECEMBER 1955 AND FEBRUARY 1956

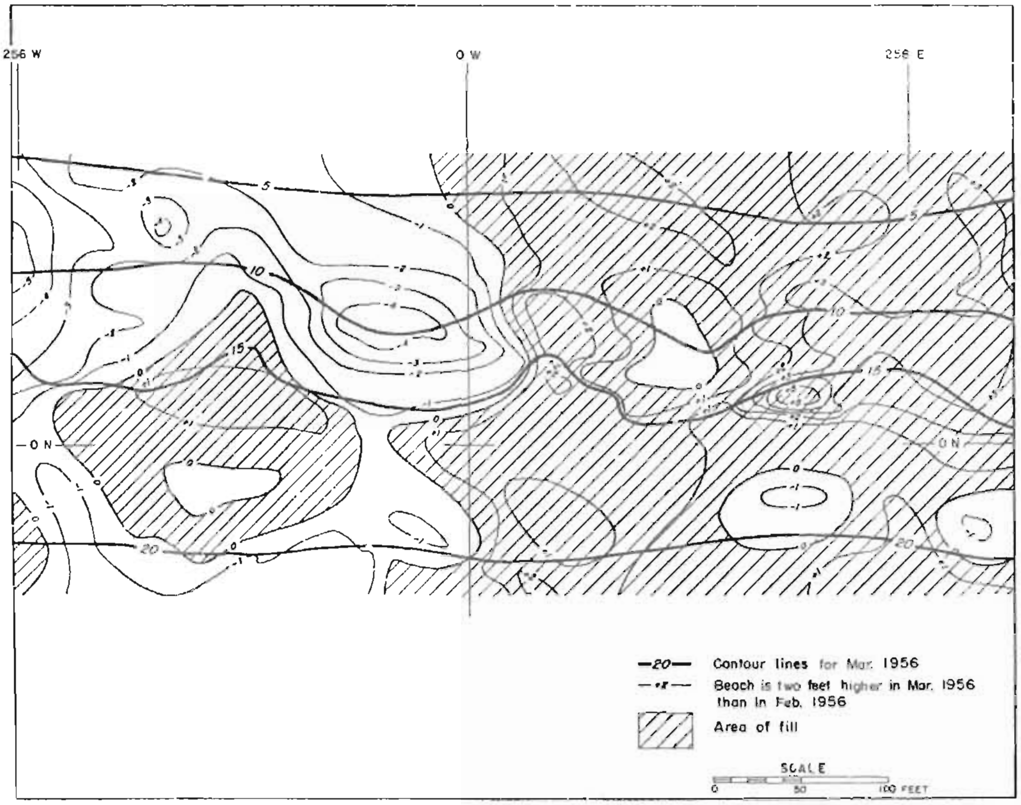

FIGURE 24. CUT AND FILL BETWEEN FEBRUARY 1956 AND MARCH 1956

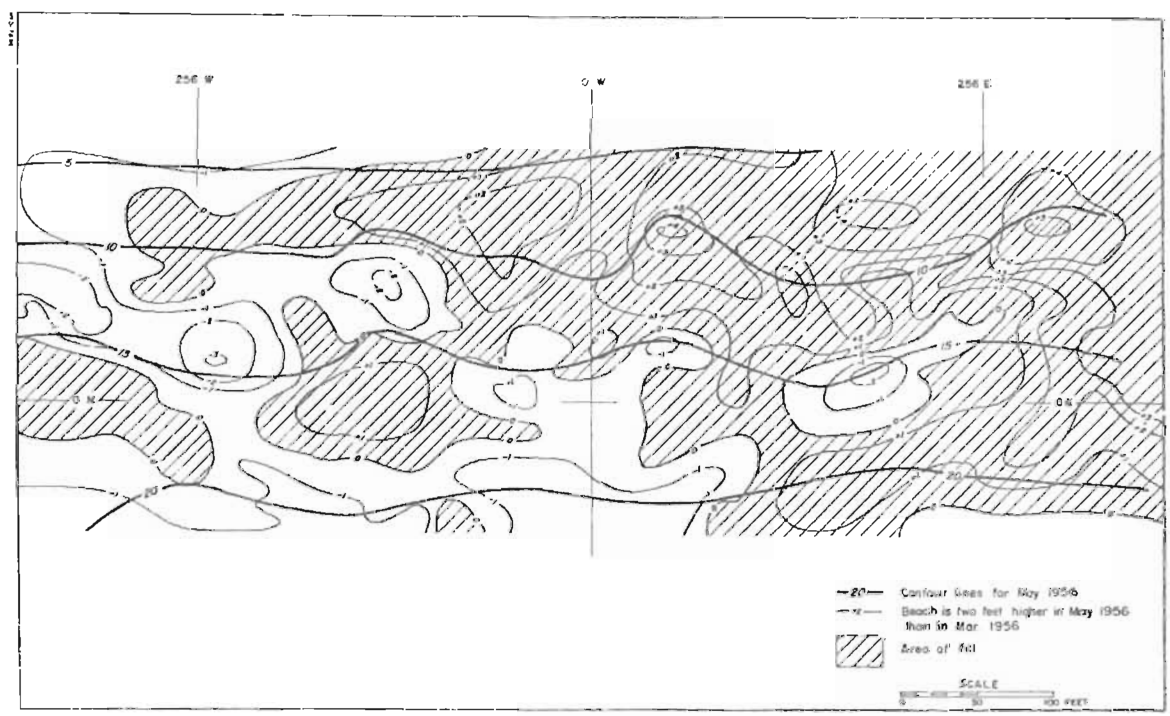

FIGURE 25. CUT AND FILL BETWEEN MARCH 1956 AND MAY 1956

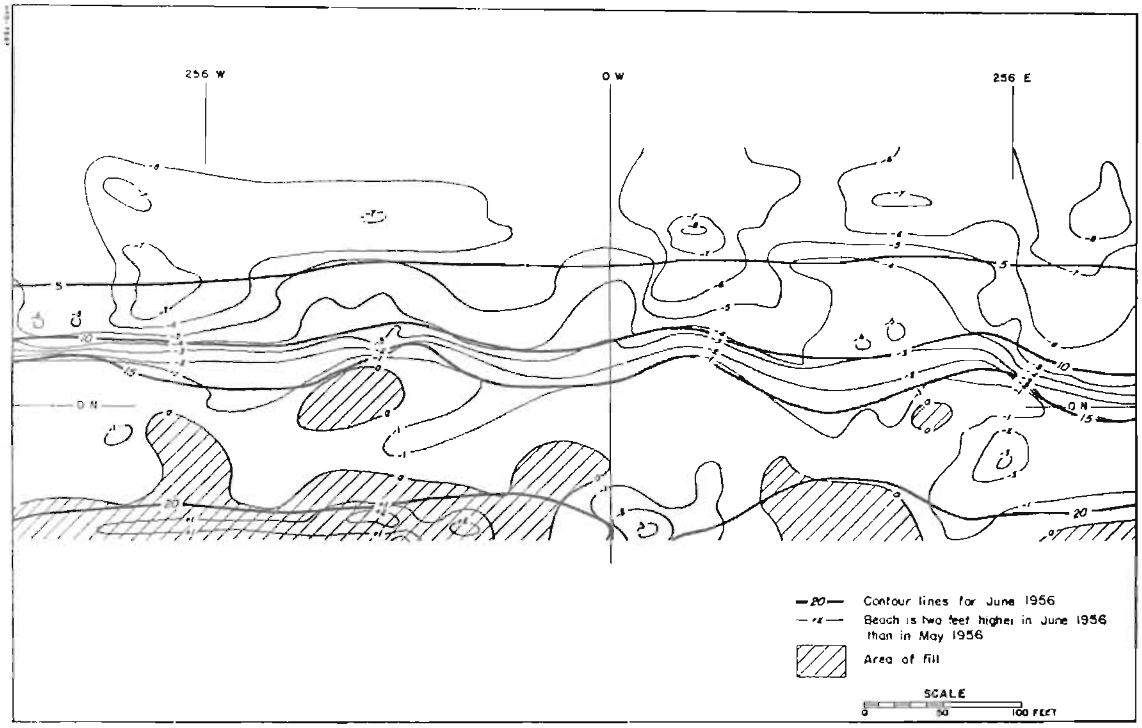

FIGURE 26. CUT AND FILL BETWEEN MAY 1956 AND JUNE 1956

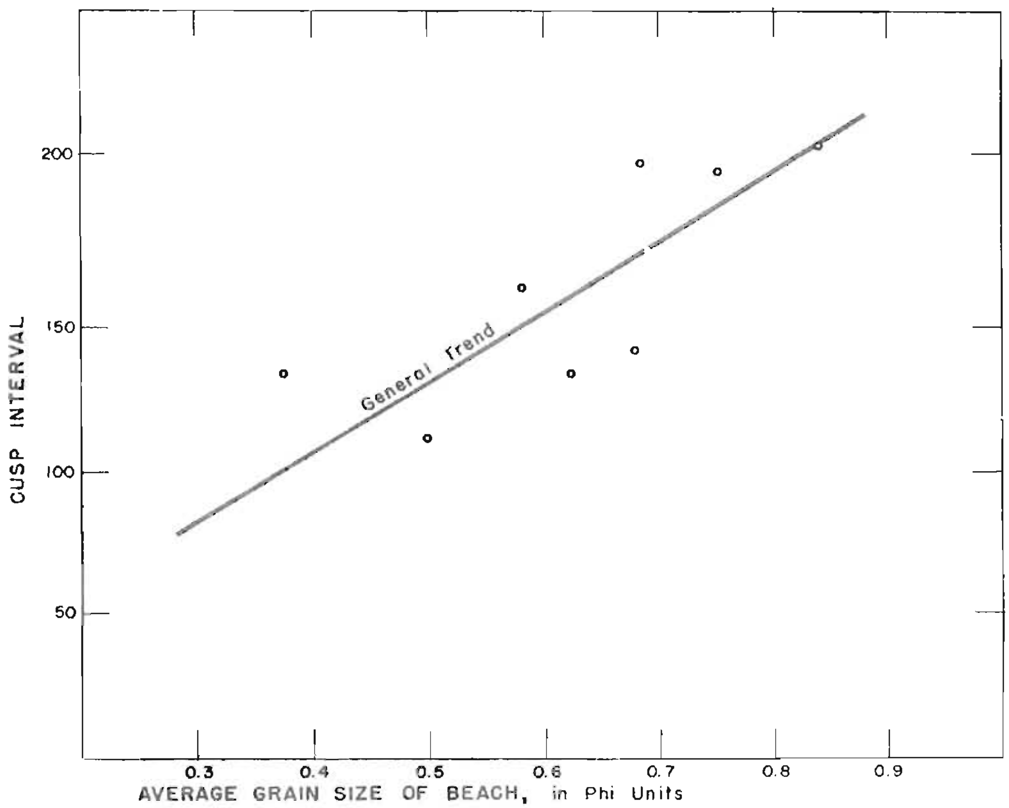

FIGURE 27. RELATION OF CUSP INTERVAL TO GRAIN SIZE

CHARACTER OF SEDIMENTS

Grain Size Variation.

The general variation in grain size is shown in Table 2. The areal variation at a typical time is given in Figure 16, which gives the areal variation of the median diameter with respect to beach contours in August, 1955. The mean grain size ranges from 0.38 phi units in February 1956 to 0.84 phi units in October, 1955. The mean diameter shows a progressive change throughout the season. It is 0.38 in February, the minimum; 0.50 in March; 0.58 in May; 0.68 in June; 0.62 in August; 0.84 in October, the maximum; and 0.68 in December. Table 2 shows that the median is 0.62 in August 1955. This figure of 0.62 excludes three very coarse samples, two of which have phi diameters of more than minus 3, (See Figure 16). If these three samples, (Samples 68W, 48N; 44W, 55N; and 128E, 55N) are included the average median is 0.52. These three coarse samples were specially selected to show how coarse the beach can get. In part they represent places where returning water flowed in a stream and sorted the pebbles. In other places they seem to show the effect of wave wash. As shown by the two samples at 128E, 55N they are underlain by normal beach sand. The sediments in these three places were round, flat pebbles; the median diameter of the coarsest samples was 8.8 millimeters or one-third inch.

The extreme mean medians of 0.84 and 0.38 phi units correspond to 560 and 770 microns, respectively. Similar variations were noted in the previous study(1) where the medians for October, 1953 and March, 1954 were 0.90 and 0.48 respectively.

The standard deviation of the samples at the individual sampling times ranged mostly between 0.30 and 0.35 phi units. The extremes were 0.27 in May, 1955 and 0.52 in August, 1955. The large figure for August represents a highly variable condition and is even larger, 0.83 phi units, if the three coarse samples are included. In the previous work between June 1953 and March 1954 the standard deviation had a similar range. The extremes were 0.29 in June, 1952 and 0.41 in February 1954. In November, 1954 a group of 11 samples had a standard deviation of 0.15; but as shown in the previous report(1) the standard deviation of a small group of samples tends to be lower than a large group. A standard deviation, 0.30 to 0.35 phi units, indicates that 68 percent of the samples on the beach are within ratios of 5/4 and 4/5 of the mean median diameter; that is, the median diameter is within 20 to 25 percent of the mean value for 68 percent of the samples and more than that for the other 32 percent.

A part of the variation in grain size is caused by lamination of the samples. The samples are taken by scooping up material from the upper two inches of the sand. At times, the lower layers of sand are finer or coarser than the upper layers at time of sampling. In a few instances, upper and lower samples were taken. In such samples, the upper layer was first scooped off, and then the lower sample was taken. Such samples are indicated by appropriate notes in Table 1. No attempt has been made to study such lamination in the present investigation, other than to report obviously different sizes in the different layers as indicated in Table 1.

The pattern of variation in grain size in August 1955, is shown by Figure 16. The areal variation of the beach was greater at this time than at any other time the beach was occupied. The figure shows the generally coarse sediments of the beach.

The differences in grain size from one time of occupation to another are indicated by Table 3. This table shows the significance of the difference between mean grain size of the entire beach at different times, expressed in percent. A figure of 5 percent means that the chances are 100/5 or 20 to 1 that the difference is real and not anomalous. The data in the table show that between successive occupations of the beach the differences between mean grain size range from a moderate to an extremely great distinctive difference. That is the beach is continually changing its character. Only between May and August 1955, where the significance in percent is 52.9 does the difference seem indistinctive, though significances of around 10 percent are noted for three other times, October-November 1955, March-May 1956, and May-June 1956. Certain months are noticeably different from all other months. October, when the grain size is small and February when it is coarse, show very little affinity with other months.

The coarser grain size in the lower foreshore is better indicated by the data presented in Tables 4 and 5 and in Figure 15. In Table 4 the median diameters of the samples are averaged for each three-foot zone for each time of sampling. Table 5 shows the significance of the differences between mean grain diameter of the sands in the different elevation zones. Figure 15 presents graphically the means shown in Table 4. It is obvious from these data that the sediments in the zone of 3 to 6-foot elevation are coarser than those in other zones. The sediments in the 6 to 9-foot zone similarly are coarser than those in the 9 to 12-foot zone; however, above the 9 to 12-foot zone no distinctive differences are indicated. This distinction in grain size is clearly portrayed by the data in Table 5. The significance of difference between the 3 to 6-foot and the 6 to 9-foot zone is 4.7 percent and between the 6 to 9 and 9 to 12-foot zones it is 0.2 percent. The significance of differences between other successive zones is much less. The relationship for the lower zones is brought out in another way. In 6 out of 7 of the suites of sediments taken between August, 1955 and June 1956, the mean phi diameter of the 3 to 6-foot zone is lower than in the 6 to 9-foot zone, and in 6 out of 8 suites the mean phi diameter of the 6 to 9-foot zone is lower than in the 9 to 12-foot zone. A similar relationship was found in the previous study(1). However, in that investigation the sediments on the berm were observed to be slightly coarser than those on the upper foreshore. No such difference is indicated by the data in the present study.

Sorting

The coefficients of sorting of the different suites of samples are summarized in Tables 6 and 7 and Figures 17 and 18. The average sorting ranges mainly between 1.27 and 1.30 with extremes of 1.31 in February 1956 and 1.21 in May 1955. The general average for this beach is 1.28. In the previous series for the period, June 1953 to November 1954, the sorting ranged between 1.23 and 1.33, with an average of slightly less than 1.29. The coefficient of sorting in the recent series is a little higher in December and March than at other times, but the differences are hardly enough to be distinctive. A similar relationship was observed in the previous samples[1].

The standard deviation of the samples ranges between 0.06 and 0.14 phi units. The maximum deviation was observed in the winter months. The range in standard deviation in the present series of samples is similar to that of the earlier series[1].

The sorting of the samples as arranged by individual elevation zones shows no distinctive differences except for the sediments in the 3 to 6-foot zone, in which the sorting seems better than in higher zones. The general overall average of the sediments in this zone is 1.25 compared with 1.30 in the 6 to 9-foot zone and 1.27 for the higher zones.

As shown by Inman[4] sorting is crudely related to grain size. Marine and beach sediments tend to be best sorted for grain diameters between 150 and 200 microns. For greater and smaller grain size the sorting is poorer; that is, the coefficient of sorting is larger. This relationship was found in the previous study[1] of Point Reyes Beach. In the report describing the results of that work a table showing the coefficient of correlation between sorting and grain size was presented. A similar relationship has been found in the present study, the results of which are shown graphically in Figure 18. Though the scatter is high a generally increasing degree of sorting is shown for increasingly smaller grain size.

Skewness

The sediments in the present suites of samples are so evenly skewed that no distinctive differences are indicated. Perhaps more detailed analyses, using screens with closer ratios between successive sieves, might give more reliable measures of skewness than the sieves used in the present invesgigation. However, the weight accumulation curves give such consistent results that the conclusion is reached that the sediments on this beach are evenly skewed.

CONFIGURATION OF BEACH

The configuration of the beach is shown by Figures 3 to 10. Profiles of the beach slopes are given in Figures 11 to 14 and the characteristic features of the cusps are presented in Table 8. The beach has a variable outline, characterized by cusps. These cusps are more or less crescentic in shape. Most of them have fairly sharp pointed flat-topped promontories at their extremeties and more or less gently sloping swales or bays in the indentations of the shore line between cusps. The top or crest of the cusp forms a part of the berm, and is nearly level. Swales between the cusps gradually merge into the berm. The interval between cusps ranges from 60 to 250 feet. The average is 161 feet. The interval varies roughly with the season, being large in the summer and fall and small in the winter and spring. The maximum average interval is 205 feet in October and the smallest is 115 feet in March. Thus the long intervals tend to be associated with fine sediments and short intervals with coarse sediments. This relationship is subject to exceptions because the interval between cusps is small in August.

The relationship between cusp interval and grain size is more clearly brought out by Figure 27. On this figure the average cusp interval is plotted against average grain size of the beach for each of the 8 times it was occupied in the present series. The data indicate a general trend from a large interval with fine sediments to a short interval with coarse sediments. Whether such a trend is real or anomalous can hardly be established with 8 times of occupation. The general relationship cannot be as straight as indicated, because extrapolation of the graph to zero phi units, or one millimeter, indicates a cusp interval of zero feet.

The elevation of the crest or point of the cusps varies mainly between 14 and 16 feet. Extremes are 12 and 17 feet. The elevation changes from time of one beach occupation to another. No seasonal trend in height is indicated. The position of the front of the cusps with respect to the zero-line parallel to the beach likewise changes from one time of occupation to another. The total range in average position of the cusps parallel to shore is 44 feet, from 29 North to 73 North. This maximum range in position took place between successive occupations of the beach in May and June 1956. No seasonal trend is indicated by the data. The beach may be out or in during summer or winter.

The large swales or indentations of 1500 to 3000 feet in lineal extent along the beach and up to 200 feet at right angles to the beach, noted in the previous survey(1) were not observed during the current series of occupations. In the former study the cusps had approximately the same interval as in the current series, but they were superimposed upon the larger indentations of the coastline. In the current series the general coastline was more irregular. The large indentations were associated with rip tides. Evidently the rip tides vary in magnitude and extent from one period of time to another, as they were not so evident during the cur rent series of occupation as in the preceding series.

In an effort to determine the pattern of migration of the cusps a series of measurements showing position of the cusps with respect to arbitrary reference lines at right angles to the beach are shown in the first part of Table 8. Three reference lines are given, 200 West, 0 West and 200 East. The distance of the nearest cusps to both east and west of these reference lines is shown in the table.

The data presented on Figures 3 to 14 and in Table 8, do not indicate whether the cusps have moved up or down the beach. The maximum lateral change in position of cusp points from one time of occupation to another is about 60 feet, which is something less than one-half interval between cusps. This is a significant change in position, but whether it is one-half cycle to the east or west, or more than one cycle in either direction is not indicated by the data.

At intervals during the visits to the beach, cusps were in the active process of being eroded. At one time, May 1956, three levels of cusps were observed at elevations of 10, 14 and 17 feet. The ones at 10 feet appeared to be in the process of formation. At another time, a series of small cusps with a short interval of spacing were noted at an elevation of about 8 feet. When the beach was occupied in August 1956, no cusps were present and the existing berm was being actively eroded by waves washing over a new berm at an elevation of 10 to 12 feet. A scarp, 5 feet in height lay at the rear of the new berm where the old berm was being eroded. That the cusps can form at a rapid rate is shown by the rapid rate of fill noted during the preceding August, when in the course of 4 hours as the tide came in, 8 inches of fill were deposited on the middle foreshore in one place. Stakes placed in the beach were used as means of measurement. The maximum fill observed was 12 inches from 2 p.m. in the afternoon to 9 a.m. the next day.

The slope of the beach at Point Reyes beach is steep. On the swales or bays between cusps the slope is commonly 4 to 8 degrees and on the upper part of the foreshore on the cusp points the slope is 6 to 15 degrees. At times the slopes immediately below the crest are high; 17 to 20 degrees have been noted frequently and on the day just mentioned when the cusps were being eroded, the slope was greater than 45 degrees, or 100 percent, on the scarp at the rear of the lower berm.

The grain size seems to vary with position on the cusps, but the sorting does not. In making a study of grain size variation on the cusps, the cusps were divided into four parts. Two of them were on the promontories or projections of the cusps on the boundary between one cusp point and the other; and two were in the swales or bays between the cusps. Each category was further divided into two groups, one for samples within 50 feet seaward of the elevation of the crest of the cusp and the other within 50 feet landward of this elevation. The summaries thus made are presented in the lower part of Table 8. The data indicate that the grain size in the lower part of the bays between cusps is distincly more fine grained than the general average for the beach and for the samples on the points of the cusps. The general average median diameter in the lower part of the swale is 0.86 phi unit compared with 0.63 for the overall average for the beach and 0.52 for the crest of the berm and 0.67 phi unit for the cusp slope. This general trend seems to hold for most of the times the beach was occupied. It perhaps is associated with the lower slope of the bays compared with the cusps and thus with slower velocity of return water. The relationship also may be anomalous, owing to the small number of times the beach has been sampled, though the probable errors of the means as indicated by the standard deviation suggest the differences are moderately distinctive. The upper part of the foreshore in the bays above the elevation of the berm crest is slightly coarser than the sediments below, which suggests that the results are anomalous, because if the grain size is controlled by velocity of return water it should be lower on the upper part of the beach than on the lower part. All that can be interpreted at present is the suggestion that the sediments in the swales are finer than on the cusp points.

No general differences came out of the sorting study of the cusps. The only trend suggested by the data on sorting is a crude relationship between coefficient of sorting and cusp interval. The better the sorting, that is, the lower the coefficient of sorting, the greater is the interval between cusps. As the scatter of the points, when the data are plotted, is high, the relationship may be more apparent than real. However, it is in line with the relationship between grain size and sorting mentioned above (Figure 18). The fine-grained sediments in the present suite of samples are better sorted than the coarse-grained sediments and the finer sediments have a greater cusp interval than the coarse sediments (Figure 27).

CUT AND FILL

Point Reyes Beach cuts and fills at a remarkable rate. This feature is shown by Figures 11 to 14 which show beach profiles for each time the beach was occupied; and by Figures 19 to 26 which show the cut and fill over the beach at each time it was surveyed. Similar profiles and cut and fill maps were presented in the previous report on this beach[(2)].

Figures 19 to 26 show that the maximum amount of cut in any one interval between occupations is 10 feet between December and February (times D and E, Figure 23), and the minimum 1 foot, between August and October and between November and December (Figures 20 and 22). The maximum fill is 7 feet, between August and October and between December and February (Figures 20 and 23), and the least is 2 feet between May and

June (Figure 26). These figures are for the maximum and minimum cut and fill shown upon the area mapped. The shaded portion on the maps indicates the area which was filled. The maximum time of fill was between August and October and November and December, when 90 percent of the map area was filled. The maximum times of cutting were between December and February and between May and June (Figures 23 and 26) when more than 70 percent of the area was cut.

The cut and fill represents two processes; one, removal and formation of cusps which cause the local areas of large cut and fill, and the other, general accretion over the beach. The period from August to December was largely a period of fill and the time between December and June was largely cut, though a large amount of fill took place between March and May. The fill is thus mainly associated with the time that fine deposits are forming in the beach and the cut with the period when coarse sediments are being deposited. As the waves are generally high in winter and low in summer, wave energy thus may be a contributing factor in determining whether the beach cuts or fills.

Figures 11 to 14 give a picture of the horizontal and vertical cut and fill between successive occupations of the beach. For example, along line 256 West the zero contour shifted a maximum of 100 feet in the course of the investigations, and the maximum shift between any two successive occupations is 65 feet. Along the 14-foot contour the maximum shift for the entire time is 160 feet and the greatest shift between successive times of investigations is 70 feet. At the 20-foot contour the shifts are less as this contour marks the crest of the storm berm. The beach at the 20-foot mark, however, is subject to erosion, particularly during the winter months.

Figures 11 to 14 also give information on the average slope of the beach. At the seaward end of the profiles the slopes range mainly from 4 to 8 percent. Slopes of 6 to 15 percent are commonly found between the 10 and 15-foot elevation. The steeper slopes are on the point of cusps.

CONCLUDING REMARKS

Point Reyes Beach is a highly variable beach. It erodes in the winter and builds up in the summer. At times of erosion relatively coarse sediments are deposited and, with times of fill, relatively fine sediments are laid down, though the beach almost always consists of coarse sand, that is, with median diameter between 500 and 1000 microns. At times finer and coarser sand than this size is found. The configuration of the beach is irregular, and is characterized by cusps which shift position both laterally and perpendicularly to the shore line along the beach, some times at a rapid rate. The wave pattern on the beach invariably is irregular. At times each succeeding wave brings in sand of different grain size. At other times the pebbles at the edge of the swash mark are several millimeters in diameter. These pebbles are round and flat and consist mainly of Franciscan chert and greenstone in varying degrees of metasomatic metamorphism.

The configuration and grain size distribution of the sand upon the beach undoubtedly is a result of the wave pattern, but the wave pattern in turn is influenced by the shape of the beach, because the beach configuration determines the pattern of downrush of water which in turn affects the uprush pattern. The bars offshore, which probably are irregular in outline give the waves a complicated pattern and varying velocity distribution, which in turn affects the grain size and the processes of erosion and deposition. The water offshore generally is too rough to attempt studies of the bottom with a boat or DUKW. Furthermore to understand the processes of erosion and deposition of the beach, one would have to make daily observations on the beach. The shortest interval between visits in the present study has been 6 weeks, and in this time invariably the beach had changed greatly in configuration and moderately in grain size. Further study of this beach at closer intervals is needed.

REFERENCES

1. Trask, Parker D., and Charles A. Johnson, "Sand Variation at Point Reyes Beach", Beach Erosion Board Technical Memorandum No. 65, 1955

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APPENDIX A

CUT AND FILL ON POINT REYES BEACH, CALIFORNIA*
(June 1953 - March 1954)

by

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ABSTRACT

The beach at Point Reyes, 35 miles northwest of San Francisco, California, cuts and fills in an irregular manner, as indicated by contour maps of the beach made at different seasons of the year. Maps of this beach have been made at two stations, 5 miles apart, at three seasons of the year; one in June 1953 at the end of the winter season, one in October 1953 at the end of the summer season, and one in February and March 1954 in the middle of the winter season. In the intervals between sampling, the beach was locally cut and filled as much as 6 feet. Point Reyes Beach is a long straight beach between two headlands exposed to the full force of the waves of the north Pacific. It is characterized by cusps 60 to 200 feet apart, averaging 125 feet. The cusps are superimposed on large embayments or undulations of the beach which seem to be associated with rip tides. The embayments are 1500 to 3000 feet apart and extend up to 200 feet inward from the protuberances that separate them from one another. The pattern of cut and fill on Point Reyes beach is irregular and is associated with the migration or destruction of the cusps and embayments as they change position in the course of time. The beach in general does not prograde or retreat from season to season; just the individual parts of the beach change position, and in so doing the beach locally cuts and fills. The cause of the migration of the large embayments seemingly is change in position of the rip tides. The cause of movement of the cusps is not apparent. The variation in grain size with cut and fill was also investigated, but no relationship was found.

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*Originally prepared September 1955, this report has been added as an appendix to afford ready reference from the body of the main report. As this report was prepared a year earlier than the main report, conflicts in qualitative statements between the two reports may occur; no effort has been made to revise or bring this appendix up to date. The report was prepared at the Waves Research Laboratory of the Institute of Engineering Research at the University of California in Berkeley in pursuance of contract DA-49-055-eng-8 with the Beach Erosion Board.

INTRODUCTION

Point Reyes beach, 35 miles northwest of San Francisco, California, is a variable beach. The grain size on this beach changes greatly within a short distance for given times, and from time to time at given places. The average median diameter during different times of the year ranges between 600 and 750 microns. Variations of 150 to 250 microns from these averages are of common occurrence. The beach also cuts and fills extensively from one season to another. This cut and fill is more of a lateral phenomenon along the course of the beach than an advance and recession of the general shore line, as happens on numerous other beaches. The beach is exposed to the ocean for a distance of 2500 miles offshore. The waves thus beat upon it with full force. The beach is remarkably straight over a distance of 10 miles between two headlands.

In connection with a study of grain size variation on this beach*, data were obtained which permitted the making of charts and statistical studies of the cut and fill at two stations, 5 miles apart along the beach. These stations were occupied at three times during the year, June and October 1953 and February or March 1954 and are designated as Station A and Station B. Station A is three miles northeast of the headland of Point Reyes; Station B is 5.2 miles northeast of Station A. The graphs and statistical compilations of these studies form the basis for the present paper.

The paper on grain size variation to which reference has just been made contains tables and figures that show the location of the samples and summarize the results of the mechanical analyses that were made. The median diameter and sorting of these samples are also presented in Figures 9-20** of the present report. These figures also show the profile of the beach along the lines from which samples were obtained. The primary purpose of the investigation was to determine the grain size variation among samples taken according to a rectangular grid at Station A and B. In the sampling program, samples were taken on 5 lines normal to the shore - namely, along a centerline and on lines east and west on either side of the centerline. Samples were taken on these lines at regular intervals of 16, 32, 64, 96 and 128 feet, and at a few other positions as well. As the samples were taken at equal distances from a zero line parallel to the beach, profiles parallel to the beach can also be drawn. Two such profiles are shown in Figure 21.**

*Trask, Parker D, and Charles A. Johnson. Sand Variation on Point Reyes Beach, California, Beach Erosion Board Tech. Memo. No. 65, 1955.

**Figs. 9-21 of present report are same as Figs. 9-21 of previous report published as Tech. Memo. No. 65 of Beach Erosion Board; Figs. 10-21 are not reprinted in this appendix.

The samples are numbered according to coordinates from a zero point. Thus, sample 256W 16S represents a sample on the line 256 feet west of the zero point at a position 16 feet south of the zero line parallel to the beach. The mechanical analyses of the samples were made by Gerald Grabe, using standard procedure. The sieves differed in size by geometric ratio. The samples were sieved in a rotap for 10 minutes.

METHODS OF STUDY

The general geographic setting of Point Reyes Beach is indicated on Figures 1 and 2*. Detailed analysis of the cut and fill is shown on Figures 3 to 8. A typical chart showing beach contours and the sample grid is presented on Figure 9. A summary of the statistical compilations is given in Tables 1 and 2. The grid lines for February 1954 shown in Figure 9, are at an angle of about 15 degrees to the lines for June and October. The beach slopes, as shown on Figures 9-21**, are based on the beach contours shown in Figures 3-9 of the report on grain size variation just cited. The lines of cut and fill shown on Figures 3-8 in the present report are also based on the beach contour lines presented on Figures 3-9 of the grain-size report. The contour lines on these charts are based on surveys made with transit and tape. The contours were drawn in the office after the data were taken.

In preparing the contour lines showing cut and fill upon the beach between periods of sampling, the procedure was to superimpose the beach contour charts for the individual times of sampling and mark off difference elevations where the contour lines cross one another. Cut and fill contours were then drawn upon the basis of the difference elevations. Lines of fill during the interval between the two times of sampling are indicated as positive, and lines of cut as negative. Areas of fill are marked by hash-lines. Heavy contours show topography of the beach at the later of the two time intervals.

In preparing the data for Table 1, showing average cut and fill between intervals, the area between individual lines of cut and fill (i.e., between the cut and fill isopleths) was computed by planimeter for each foot difference in cut or fill. These unit areas of cut and fill were then averaged. In view of the fact that the sampling and survey points occupied at the time the beach was studied were not designed for studies of cut and fill, some of the lines showing equal cut and fill are based on relatively few data.

A statistical study of the average median grain diameter of samples between the individual cut and fill lines is presented in Table 2. The averages presented in this table are based on 1 to 10 samples. Averages

* See Figures 1 & 2 of main text; not reprinted in this Appendix.

** Figures 10-21 not printed; see Technical Memorandum No. 65 of the Beach Erosion Board.

based on 1 or 2 samples are indicated by asterisk. The probable error of the averages thus is large, particularly in consideration of the inherent variability in grain size.

In making planimeter studies of cut and fill, the same area on the beach is covered for each time interval. This area forms the central part of the general map area covered on the charts. Owing to insufficient control, the exterior parts of the map area were not used. The areas for which planimeter control was made for Stations A and B are shown on the charts for June for each area (Figs. 3 and 6). In compiling statistics on variation in grain size between cut and fill contour lines over the entire map area were used. Thus the data in Table 2 represents a larger area than those in Table 1, which were restricted to the area blocked out on Figure 3 and 6 for planimeter studies.

RESULTS

Station A. The pattern of cut and fill varied at each station. At some times the areas of cut and fill were normal to the beach, at others parallel, and at still others in a transverse or circular direction. In the interval between June and October at Station A the lines of equal cut and fill tend to be normal to the shore. That is, the cut and fill isopleths exhibit a trend at right angles to the coast for part of their course. The period between June and October, at Station A was a period of general fill for this part of the beach. The average fill as indicated in Table 1 is 1.78 feet. The maximum fill was 6 feet on the upper part of the berm in the central part of the area. Two areas were cut, one with a center 80 feet seaward from the point of maximum fill, where the beach was cut 2 feet, and the other about 100 feet east of this place where the beach likewise was cut 2 feet. Between these two areas of cut was an area of fill, the maximum being 2 feet. The cut and fill pattern at Station A between June and October 1953 thus is irregular. The rate of change in cut and fill, that is, $\Delta T/\Delta S$, where ΔT is the difference in elevation between successive time intervals, and ΔS is the horizontal distance on the beach, is large. In one place this slope line ($\Delta T/\Delta S$) is 8 feet in 80 feet, or 10 percent.

The main causes of the differences in cut and fill between June and October are the disappearance and change in position of the cusps at that season, and a seaward advance of the shore of 30 or 40 feet. The alternation of areas of cut and fill parallel to shore is the manifestation of loss of cusps between June and October. North of the area of planimeter control, that is, in the area of the lower foreshore, the average fill is 2 or 3 feet in response to the advance of the shore seaward.

The main change between October and March, as shown on Figure 4, is the erosion of the west part of the chart area, where a maximum of 6 feet of cut is recorded. The east half of the map area is essentially fill, though one area of cut of 2 feet is shown in the central part. On the whole the area neither gained nor lost sediment, as the average difference in elevation between March and October is only 0.16 feet of fill.

The lines of equal cut and fill are more perpendicular than parallel to the coast line, though the pattern is somewhat irregular. The data presented in Figure 4 suggest that Station A was opposite one of the large indentations or areas of erosion, believed to be caused by rip currents, in which the beach is cut back toward the cliffs. A comparison of the beach contours for March and October shows the erosion of the west part of the map area and the development of cusps in the east part.

The cut and fill between June 1953 and March 1954 shown in Figure 5 forms a complex pattern. The beach, both in March and in June, had cusps, but the cusps were not at the same position at successive times. Also, in March the west part of the beach had been cut back toward the cliffs. The result was 5 feet of cut on the west side of the map area and a general area of fill in the east part, amounting to as much as 5 feet at the east edge. The shore line was in much the same general position in March as in June. Many of the cut and fill isopleths trend normal to the beach for considerable distance. The beach area showed a net gain of 1.54 feet of fill between June 1953 and March 1954.

Station B. The pattern of cut and fill at Station B, 5 miles north of Station A, is different than at A. The cut and fill isopleths for the period of June to October 1953 trend parallel to the coast line, as shown on Figure 6. The area of the foreshore in general has eroded 1 to 2 feet except at the east end, where it has been filled to a maximum of 5 feet. Slight changes in the berm of 1 or 2 feet are also observed. In general the area has been neither filled nor cut. The average difference in the area of planimeter control, according to Table 1, is 0.16 feet of fill. Comparison of contours of the beach surface between June and October shows the development of prominent cusps in the east part of the map area in October, which accounts for the 5 feet of fill. In general, Area B changed relatively little between October and June.

At Station B between October 1953 and February 1954, as shown by Figure 7, the east half of the area was extensively cut and the west was filled. Both the cut and fill attained a maximum of 6 feet. The beaches as a whole, however, changed relatively little, as the general change in the map area studied is a cut of only 0.13 feet (Table 1). The variation in amount of cut and fill is associated with shift in position of cusps. A tongue of erosion runs westward across the outer part of the berm more or less parallel to the shore line. Inspection of beach contours for the two periods suggests that in October the map area was on the east edge of one of the large embayments of the coastline, which caused the beach contour lines to be bent inward toward the west, whereas in February 1954 the map area was on the west edge of one of the embayments and the beach contour lines trended inward toward the east.

Between February 1954 and June 1953 the map area shows little gain or loss of sediment. The average is 0.03 feet of fill. As shown by Figure 8, the east half of the map area has lost sediment and the west side has gained sediment, though irregularities exist in this pattern. The maximum gain on the west is 5 feet and loss on the east is 4 feet. The effect of shifting cusps is indicated by circular patches. The net loss on the east is presumably influenced by the large embayment that had developed in that area in February 1954.

Cut and fill along profiles. Profiles normal to the beach along the east-west lines of the sampling grid are presented in Figure 10 to 20*. Three lines are shown on each figure. For Figures 10 to 19* the lines for June, October and February or March are given. For Figure 20*, which shows the beach at Station B for February 1954, the profiles are presented in two halves. One half shows profiles for the grid lines 0-W, 64W, and 256W, and the other for the lines 0-W, 64E, and 256E. Figure 21* presents profiles for Stations A and B along the 0-N line through the zero point parallel to the shore. The figures also contain data on median diameter and sorting. The median is given both in microns and in phi units. In Table 2 which presents data on the relation of grain size to cut and fill, the median diameters are presented in phi units. Corresponding grain diameters in microns are readily determined by consulting the scales on the two sides of Figures 10 to 21*.

At Station A, as shown by Figure 10*, the foreshore on grid line 256W at the west end of the map area is in essentially the same position for June and October, but is pushed back in March. At the zero point (0-W, 0-N) the cut between October and March is more than 5 feet. The general decrease in grain size up the foreshore is well shown in this figure. The sorting is approximately 1.25, which is the general average for Station A. The irregularity in grain size distribution of the different samples is well shown by this figure.

Along line 64W, Station A (Figure 11*), little change is noted between June and March. On the profile for October the upper part of the foreshore near the berm is very steep and the back end of the berm 64 feet south of the zero line is also steep. The zero west line at Station A shows considerable change in the crest of the berm between all three time intervals (Figure 12*). The grain size and sorting are rather irregular from sample to sample. Similar relations are shown for line 64E (Figure 13*). The 256E line (Figure 14*) shows continual fill between June and March. The sediments along the different profiles are irregular in grain size.

An essential characteristic of all profiles at Station A is the uniform slope of the foreshore from season to season. At Station B similar relationships prevail. Along line 256W, Station B, (Figure 15*) the fill between October 1953 and March 1954 is rather pronounced. This

*Not printed; see Tech. Memo No. 65 of the Beach Erosion Board.

fill seemingly is associated with the change in flank of one of the embayments presumed to be associated with rip tides. The grain size variation is more regular along this profile than on some of the other profiles. Along line 256W the grain size decreases up the foreshore and then increases on the berm, as is the general habit for Point Reyes beach. The sorting tends to become poorer shoreward, which likewise seems to be a characteristic of this beach. The profile along line 64W at Station B is essentially the same for all three seasons, but the grain size distribution varies greatly from place to place. The zero west line (0-W), Figure 17*, shows the fill associated with the development of a cusp during February. The berm exhibits relatively little change. The median diameter of the sand on this profile during February and June is highly irregular, but not in October, when it varies at a regular rate from coarse on the lower foreshore through fine on the upper foreshore, to coarse again on the berm.

The 64E profile (Figure 18*) varies relatively little in shape from season to season, but the grain size variation is great. Station 256E (Figure 19*) shows considerable fill in October, during the period when the west part of the map area was being extensively eroded. The sediments on this profile also are variable.

Figure 20* indicates how the beach slope changes from profile to profile from west to east across the beach at Station B in February 1954. It should be recalled that the grid lines on this section are at an angle of 15 degrees to the grid lines of Figure 10 to 19*.

Profiles parallel to the beach are shown in Figure 21*. The line of the profile is the zero north line, which passes through the upper part of the foreshore near the berm. Station A is shown in the upper part of the figure and Station B in the lower part. The figure shows very clearly the change in position of the cusps from season to season. In comparing this figure with Figures 10 to 20*, one should note that the vertical scale is greater in Figure 21* than in the other figures. The variations in elevation between cusps thus are accentuated.

Grain size variation. A statistical study of grain size variation is presented in Table 2. This table shows the average median diameter for each interval of one foot difference in cut or fill between the periods October and June, February or March and October, and February or March and June. The individual averages are based on 1 to 10 samples. The averages thus have a fairly high probable error, particularly in consideration of the variability in grain size. No general relationship is indicated by the variation in grain size with the amount of cut and fill. On theoretical grounds one would not expect to find much variation. The samples represent the upper two inches of sediment. Thus, considering that the fill between intervals of sampling commonly amounts to several feet, and assuming that grain size variation might be related to

*Not printed; see Tech. Memo. No. 65 of the Beach Erosion Board.

the same processes that cause the cut and fill, in order for a relationship between grain size and fill to be apparent, the grain size distribution throughout the entire column of sediment that has been eroded or deposited must be known. Furthermore, the variations in cut and fill represent the total variation during the four or five months between sampling intervals. Actually the beach may have been cut or filled in an irregular manner during that interval of time. Thus the final end product can hardly be expected to exhibit any relationship to details of the processes of cut and fill, granted that such a relationship might exist. Furthermore, the average grain size for the whole population of samples taken at each station at each time interval is included in Table 2 to show the general grain size distribution of the area under consideration. It should be pointed out that the area that forms the basis for the statistical compilation in Table 2 is the entire part of the general area sampled. Thus considering the variability in grain size distribution on the beach, the respective averages shown in Table 2 do not necessarily agree with the general average for the entire station.

A few interesting relations come out of the data in Table 2, but owing to the vagaries of sediment variation on this beach the relationships presumably are more apparent than real. At Station A the sediments in the area of cut during the period of October to March are generally more fine grained than those in the areas of fill during the same period. The average median diameter of the samples for March in areas of cut of 1 to 7 feet is 0.84 phi units compared with 0.52 for the area of fill from 0 to 6 feet (560 microns compared with 700 microns). The reverse trend is noted for the sediments in the same zones for October at the beginning of the period of cut and fill. It might thus be interpreted that the processes leading to erosion of the sediments might also lead to the deposition of fine materials. That is, at the beginning of the period of erosion the sediments are coarse and at the end they are fine, and vice versa for the areas of fill. No such difference between areas of cut and fill is noted for the other time intervals for which data are available. The question merits further study, but if it is investigated core samples should be taken and the beach should be occupied at shorter intervals. In passing, the comment might be made that in areas of cut the sediments exposed at the surface might represent material deposited sometime previously and only recently exposed by erosion. Thus the grain size would have little connection with the conditions of sedimentation prevailing at the time of survey.

In this connection it should be pointed out that the average median diameter of the sediments in the areas of fill between March and June shown in Table 2, column 3, is about 1.0 phi unit, or 500 microns, compared with 0.52 phi unit or 700 microns for the areas of fill between March and October. This relationship is the reverse of the one just described, which suggests that perhaps the relationship is anomalous.

Another matter that should be considered is the grain size variation with respect to position on the beach. As shown in Figures 10 to 20* the median diameter in general decreases upward on the foreshore to the edge of the berm, where it begins to increase in size again. Thus for any given interval of time the conditions of sedimentation prevailing at that interval of time should vary in a more or less orderly fashion across the beach. Granting the same general conditions of deposition at a later time, but with different configuration of the beach or a different location of the cusps, then at given points in space the grain size will, or may, be different, depending upon the wave pattern and the position of the beach surface at the particular time. If at the same time the general conditions of sedimentation change so that the general grain size is larger or smaller over the entire area, the grain size distribution on the beach becomes further complicated. All in all, the relation of grain size distribution to beach morphology is a complicated subject. It warrants further investigation.

CONCLUSIONS

The main result that arises from this work is the presentation in a somewhat detailed way of the cut and fill on a highly variable beach. The grain size distribution varies greatly within a short distance at any given place. It also varies with position on the beach. The shape of the beach is irregular and generally contains cusps 60 to 200 feet apart. These cusps migrate or are destroyed in a manner not yet understood. The variations in beach shape presented in this paper indicate very clearly that the cusps do change their position. The cusps are superimposed upon much larger undulations of the beach line, 1500 to 3000 feet in length and up to 200 feet in width. These large undulations also change their position. The beach itself as a whole, however, does not seem to change its position. The water line on the average appears to be at about the same place throughout the year, in contrast with other beaches which build out and retreat with the season. This generalization that the Point Reyes beach in gross is constant, is not supported by sufficient data to be substantiated; rather, it is a concept that comes out of the work done to date.

The present report is a by-product of an investigation carried out for another purpose. Specific lines of attack were not planned. The data that are presented thus are those that arose in the course of other work. In the future a special study should be made of the variations in the shape of the beach, particularly with the object of endeavoring to determine the cause of the variations. To achieve this purpose a detailed sampling program should be undertaken. The beach should also be sampled at shorter intervals than in the past, and with better topographic control. Such a program should throw light upon the regimen of Point Reyes beach.

* Not printed; See Tech. Memo. No. 65 of the Beach Erosion Board.

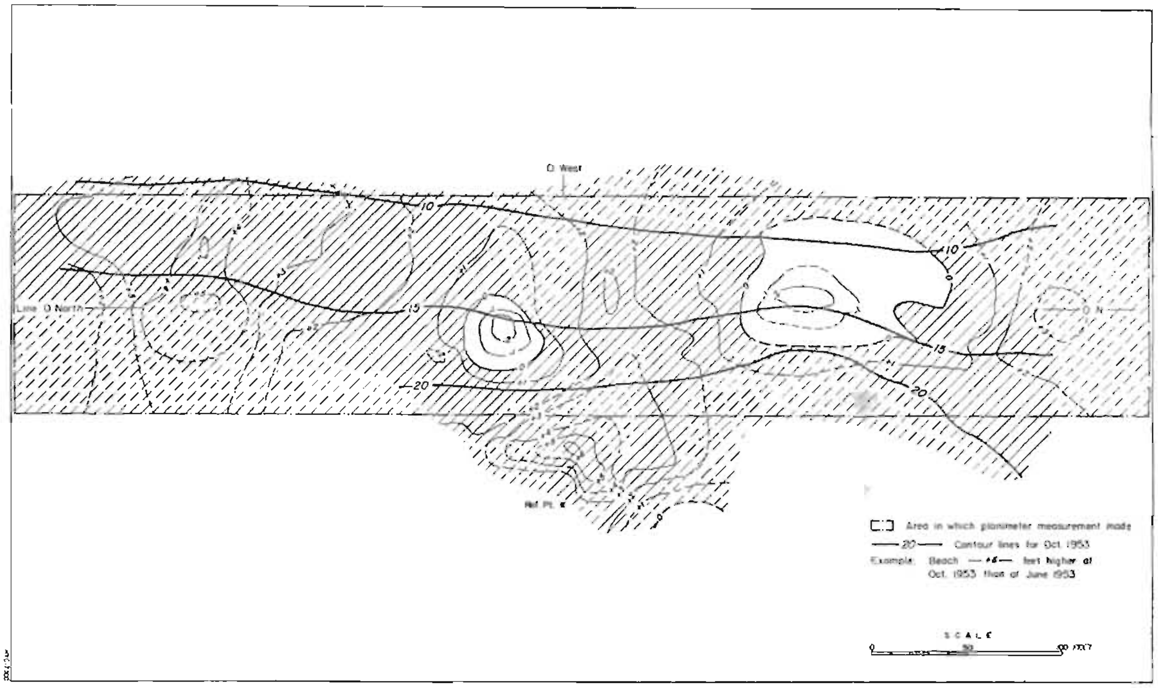

FIGURE 3. CUT AND FILL BETWEEN OCTOBER 1953 AND JUNE 1953 AT STATION A (COAST GUARD STATION)
APPENDIX A

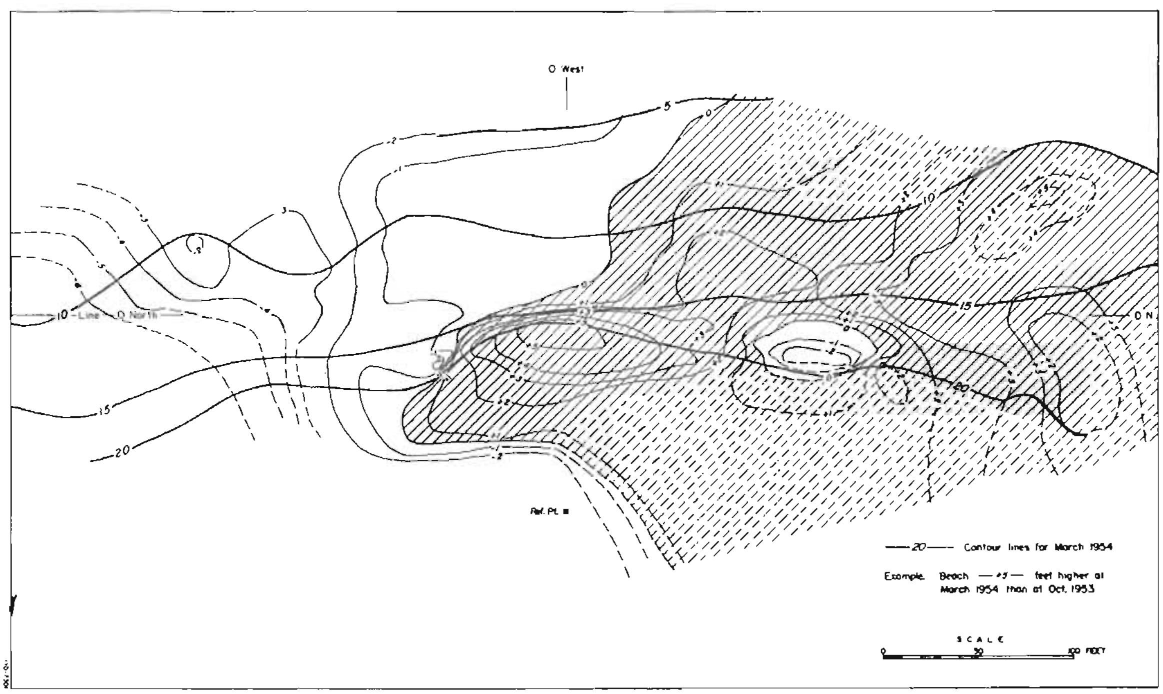

FIGURE 4. CUT AND FILL BETWEEN MARCH 1954 AND OCTOBER 1953 AT STATION A (COAST GUARD STATION)
APPENDIX A

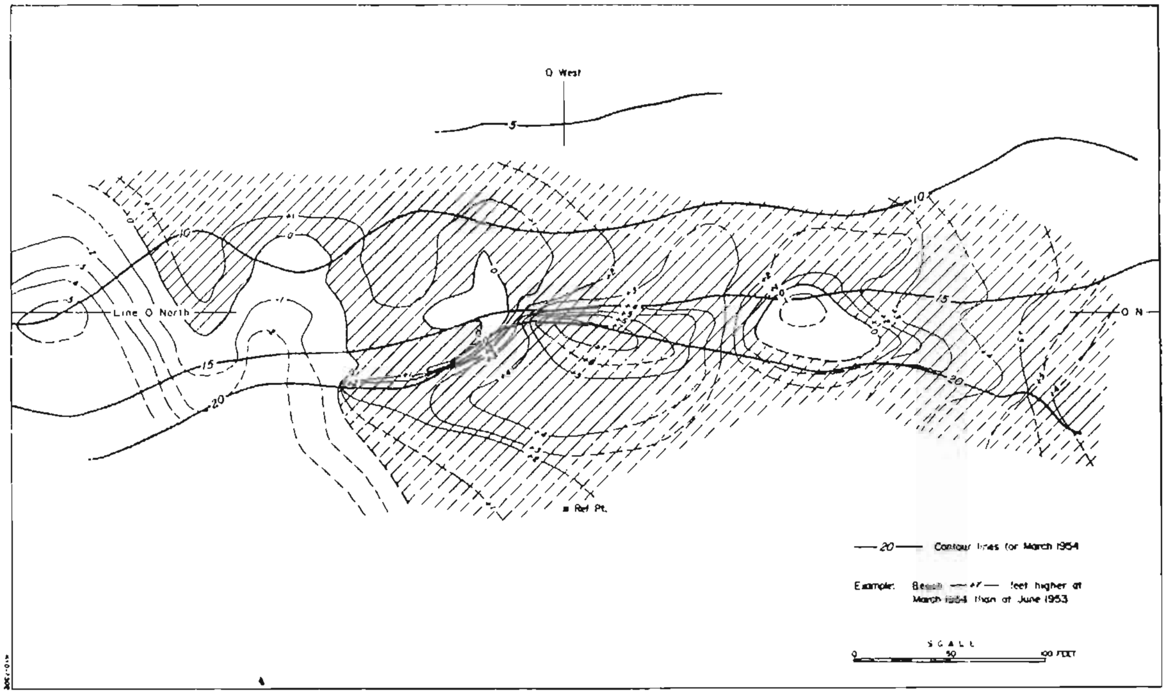

FIGURE 5. CUT AND FILL BETWEEN MARCH 1954 AND JUNE 1953 AT STATION A (COAST GUARD STATION)
APPENDIX A

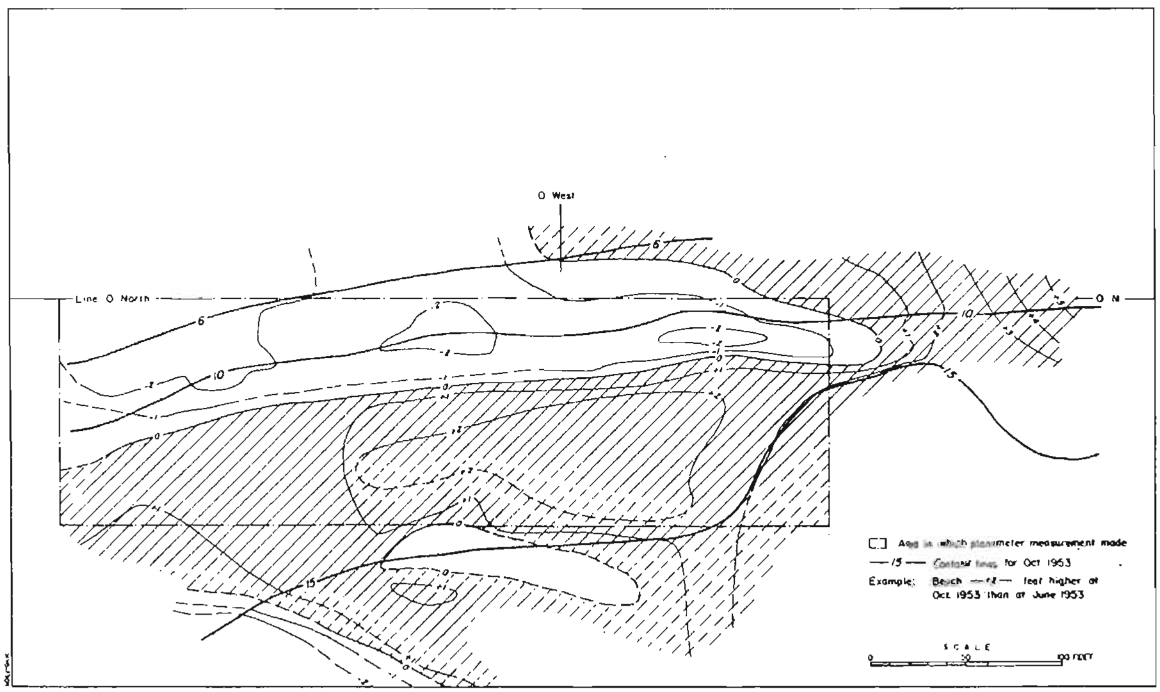

FIGURE 6. CUT AND FILL BETWEEN OCTOBER 1953 AND JUNE 1953 AT STATION B (ABBOTTS LAGOON)
APPENDIX A

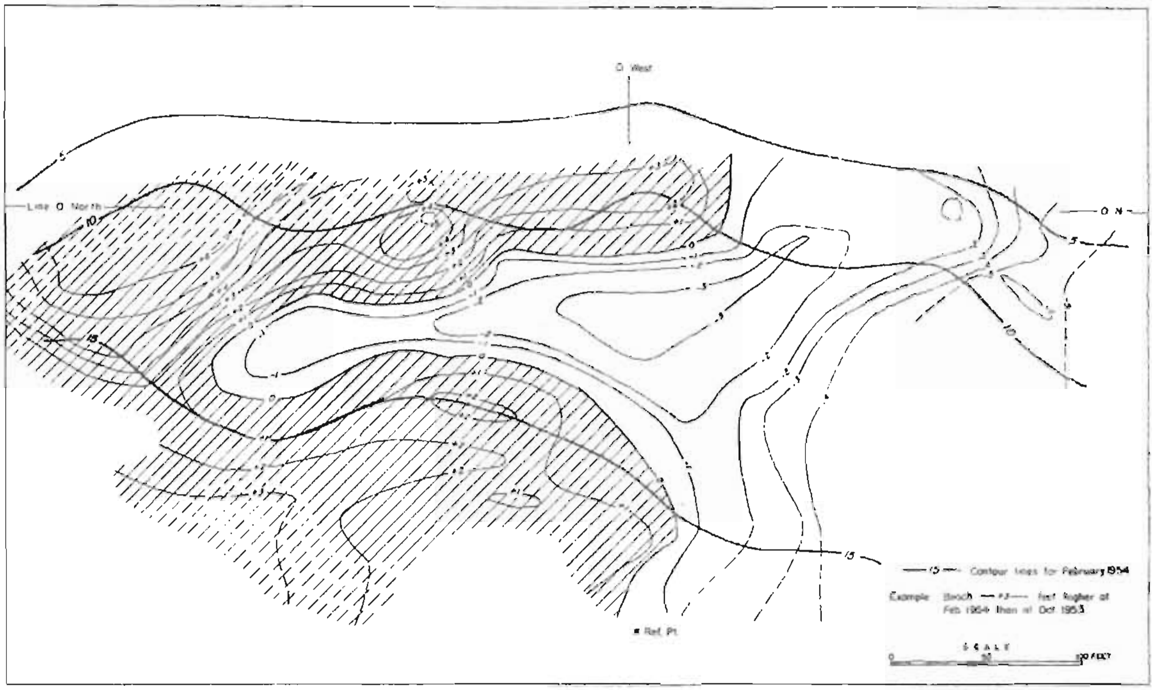

FIGURE 7. CUT AND FILL BETWEEN FEBRUARY 1954 AND OCTOBER 1953 AT STATION B (ABBOTTS LAGOON)
APPENDIX A

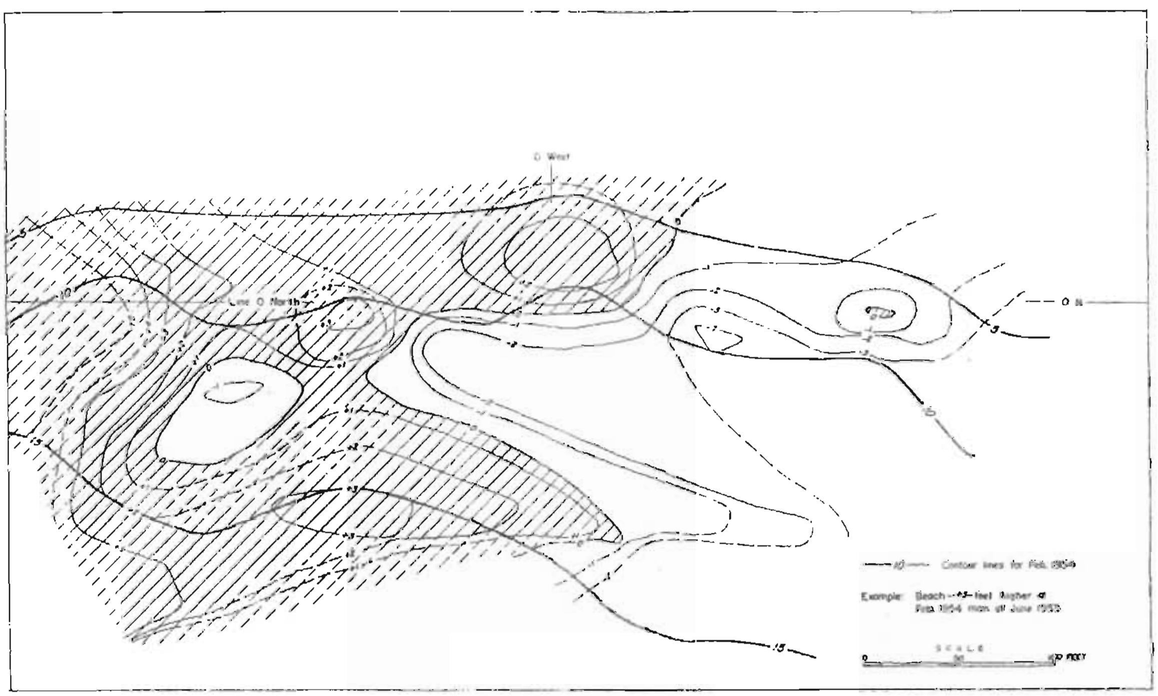

FIGURE 8. CUT AND FILL BETWEEN FEBRUARY 1954 AND JUNE 1953 AT STATION B (ABBOTTS LAGOON)
APPENDIX A

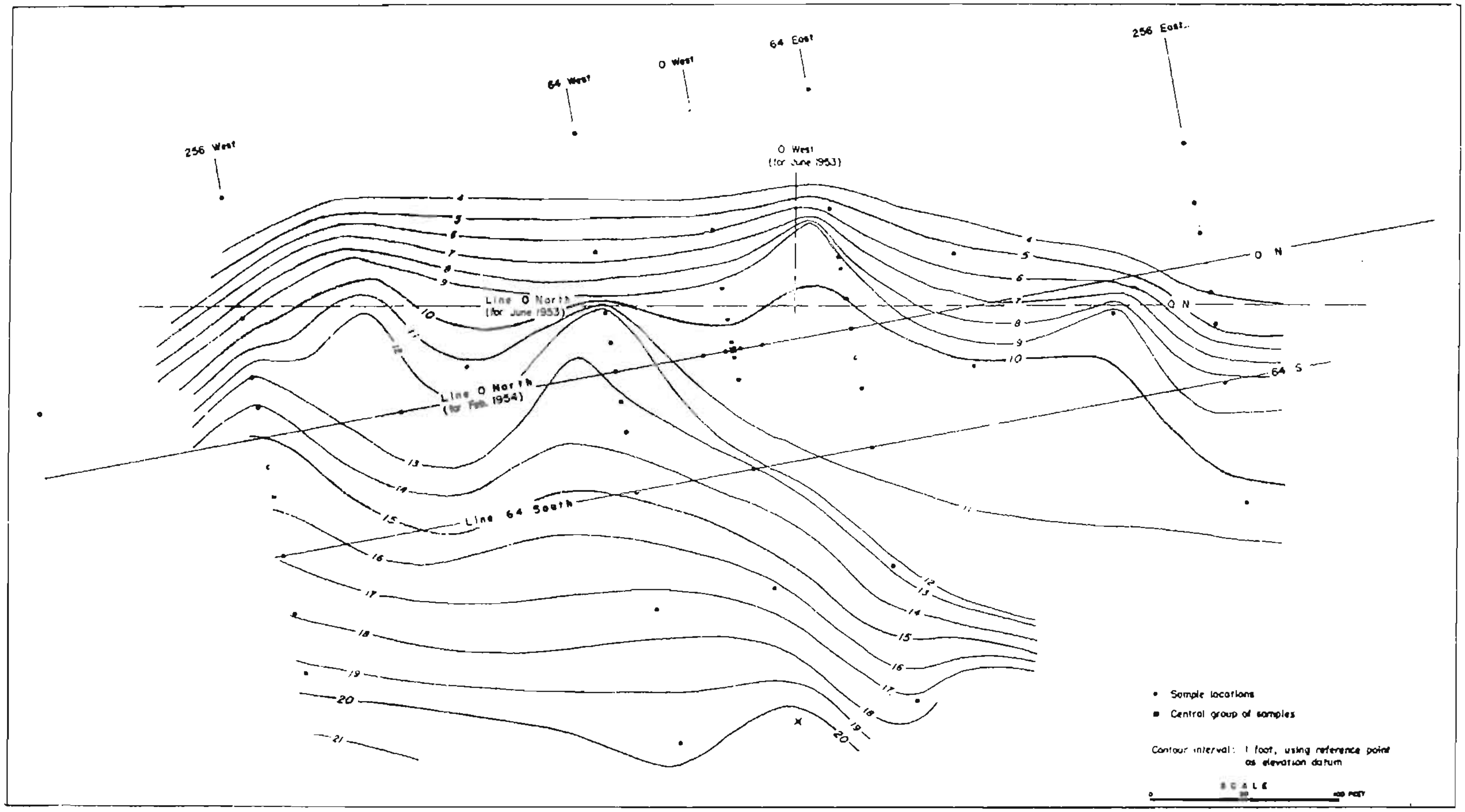

FIGURE 9. SAMPLE LOCATIONS, STATION B (ABBOTTS LAGOON)—FEBRUARY 1954
APPENDIX A

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