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Daily and quasi-weekly beach profile changes at Monterey, California

Koehr, James E.

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CHANGES AT MONTEREY, CALIFORNIA

JAMES E. KOEHR
JOHN D. ROHRBOUGH

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* * * * *

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AT

MONTEREY, CALIFORNIA

by

James E. Koehr

Lieutenant, United States Naval Reserve

and

John D. Rohrbough

Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

United States Naval Postgraduate School
Monterey, California

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This work is accepted as fulfilling

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from the

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ABSTRACT

Sand heights measured on two beach profiles, supplemented by wave
and tide data, were collected on daily and quasi-weekly bases for Del Monte
Beach between July 12, 1963, and March 31, 1964. This beach, composed of
fine quartz sand, is located in a sheltered indentation where long, low
swell predominates.

Analysis of the data revealed a dynamic beach characterized by constant
daily changes in the lower, active zone. No clear-cut seasonal variation
in cut and fill was evident, but large cycles of cut and fill having dura-
tions of ten to twenty days occurred irregularly throughout the period.
Daily sand-level changes were attributed to constantly changing wave
conditions.

It was concluded that further research on sand beaches should include
wave and sand-level observations taken on a daily basis.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. Introduction

Review of the literature on beaches and coasts has revealed a lack of information on the nature of short-duration beach changes. With a view to investigating this area, the authors undertook a beach-profile study on Del Monte Beach at the southern end of Monterey Bay, California. The study was restricted to the intertidal and exposed portion of the beach above the lowest tides. Sand-level changes along two profiles, each consisting of a series of metal pipes driven into the sand, were measured from July 1963 through March 1964 on a quasi-weekly and daily basis. Supporting wave and tide data were available for most of this period. Study of the relation of waves and tides to sand-level changes has revealed the importance of short-term wave variations in causing beach changes, and the need for further study of beach profiles in the field on a daily basis.

2. Description of the Area

    a. Southern Monterey Bay

    The two profiles studied in this report are located at the extreme
southern end of a long, crescent-shaped sand beach which forms the inner
shoreline of Monterey Bay. Approximately 1500 yards to the west of the
southernmost profile, the sand beach ends against the rocky shoreline of
the Monterey Peninsula. To the north, the beach extends the full length
of Monterey Bay, with seasonal interruptions at the mouths of the Salinas
and Pajaro Rivers and a permanent interruption at the entrance to Moss
Landing Harbor adjacent to the head of the Monterey Submarine Canyon. In
the vicinity of Santa Cruz, a transition to rocky shoreline occurs and
continues northward. A map of Monterey Bay is shown in Figure 1 and a
detailed map of Del Monte Beach in Figure 2.

    South of Moss Landing in southern Monterey Bay, sand dunes up to 130
feet in height back the beach except at the Salinas River mouth. The dunes,
related geomorphologically to the present shoreline and of evident Recent
age, are not actively growing, and along most of the coast they have been
eroded to form seacliffs of loose sand. As the southern end of the bay is
approached, the dunes decrease in size and disappear completely in the vicinity
of the southernmost profile.

    b. Waves and the Nearshore Circulation

    The Monterey Peninsula provides an excellent shelter to the beach
under study from the predominant onshore winds in the bay. Visual obser-
vations on windy days commonly reveal white caps in the bay in the vicinity
of Seaside and northward toward the middle and north parts of the bay, but
none at the extreme southern end. Galliher [2] noted this sheltering effect
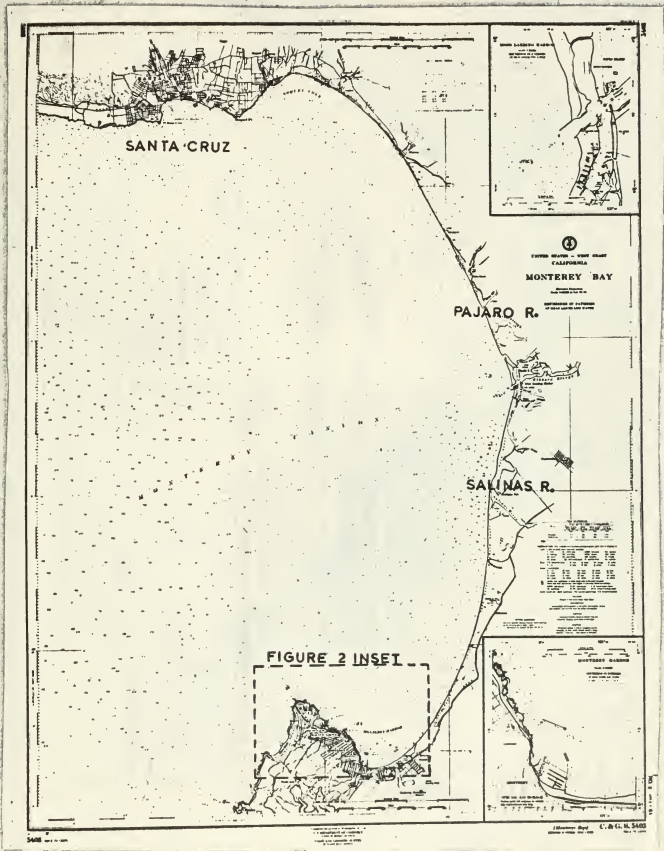in relation to dune deposits. He stated that "the high hills in the center

2

SANTA CRUZ

PAJARO R.

SALINAS R.

FIGURE 2 INSET

Figure 1

3

Figure 2

of the Peninsula serve to deflect the wind and decrease its carrying strength a short distance from the shoreline. This, combined with the interference to dune migration by trees...hinders the development of dunes." Therefore, except for comparatively uncommon northerly winds, wind waves are screened out and swell predominates on the beach area studied.

The sheltering effect of the Peninsula leads to marked wave refraction in the extreme southern end of the bay in which the breaker crests nearly parallel the shoreline. This observation is supported by refraction diagrams, visual observations, and aerial photography. Accordingly, long-shore currents may be presumed minimal and littoral drift negligible. Independent evidence of negligible littoral drift includes the fact that no sand has accumulated on either side of a steel bulkhead constructed along-side Monterey Wharf No. 2, and that apparently no sand is being lost to dunes or offshore with time. Therefore, it may be concluded that there is no net littoral drift and that all sand movement on the beach under study is evidently onshore-offshore.

A second effect of refraction is the reduction in size of the waves arriving at Del Monte Beach. Due to extreme divergence, wave heights and steepnesses are greatly reduced from their deep-water dimensions. This is confirmed from both wave recorder data and visual observations. In addition, a wave-height gradient is almost always evident along Del Monte Beach, the breaker height decreasing from north to south. As the shelter of the Peninsula is approached, decreasing wind and increasing refraction progressively lower the wave heights and filter out wind waves. For the uncommon case of wind waves from a northerly direction, a fetch limitation of 25 miles ordinarily keeps wind-wave heights low.

c. Tides

The tides of Monterey Bay, like those on the entire Pacific coast, are mixed and characterized by one cycle of greater range and one of lesser range each day. The greatest range of spring tides occurs near the solstices and the least near the equinoxes. According to the Tide Tables [10], which refer the Monterey tide to San Francisco, the tidal data for Monterey Bay, relative to Mean Lower Low Water, are as follows:

Extreme High Water	6.7 feet
Mean Higher High Water	5.3 feet
Mean Tide Level	2.8 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-1.8 feet
Mean Tide Range	5.3 feet
Extreme Tide Range	8.5 feet

Tidal data used in this paper were collected from a standard gage maintained by the U. S. Naval Postgraduate School on Wharf No. 2 at Monterey. Examination of the seven months of wave data analysed for this study show that wave heights were lower than the tide range for most of this period. This appears to be characteristic of long-term conditions on Del Monte Beach. Thus tidal cycles possibly may be expected to influence this beach to a greater than usual degree.

d. Beach Material

Del Monte Beach has an average slope of 1:12 and, based on visual examination with a 16-power hand lens, is dominantly composed on quartz and feldspar with small amounts of biotite and calcareous shell material. Grain-size distribution of the sand in Southern Monterey Bay progressively decreases from north to south. On Del Monte Beach the sand is fine with an average

median diameter of approximately 0.23 mm. and the sorting is very good with a Trask coefficient of approximately 1.15 [3]. No measurements of beach permeability were made; however, it is assumed that the permeability is compartively low due to the fine sand texture.

The sand is derived primarily from marine erosion of the Quaternary coastal dune deposits to the north of Del Monte Beach [9], although the rate of supply must be very slow on the basis of the wave and littoral drift considerations discussed above. There are no obvious sinks of sand in the southern end of the bay and it is probable that losses are due to attrition of grain size and to transport offshore during unusual storms. A very minor sand source is probably provided by the Salinas River. Short-term gains and losses of sand on Del Monte Beach appear to be derived almost entirely from exchange with the offshore zone.

3. Field Observations and Data Reduction

a. The Field Equipment

The basic equipment utilized for the collection of field data included: two profiles of pipes driven into the beach for measuring sand-level changes, a Snodgrass Mark IX wave recorder, and a Ballauf standard recording tide gage. The sand-level change data were supplemented by visual observations of general beach conditions such as the occurrences of cusps and scarps.

b. The Profiles

The beach profiles, labeled A and B, consisted of two sets of eleven steel pipes of two inch O. D. driven into the sand at two locations 1800 feet apart on Del Monte Beach, as shown in Figure 2. The pipes on Profile B and the nature of the local beach are shown in the photograph in Figure 3.

In each profile the pipes (referred to as poles) were located twelve feet apart on a straight line perpendicular to the shoreline and ran from the back of the beach to Extreme Low Water. On the average, the sand elevations at Poles A-4 and B-3 (measured from the seaward end of each profile) were approximately at the same elevation during the survey. The elevations of the pipes were surveyed by the Office of the City Engineer of Seaside, California, and were referred to a common arbitrary datum.

The sand level at each pipe was obtained relative to the top of the pipe using a T-shaped rule calibrated to hundredths of a foot. These values were then referred to the arbitrary datum by applying them to the surveyed elevation of each pole. Readings were always made within 1/2 hour of a low tide when the lowermost poles were most accessible. Scour depressions at the base of the poles were of such small magnitude that they presented no inaccuracies in the observations.

For the period July 12 to January 25 sand levels were recorded on a

PROFILE B
FIGURE 3

9
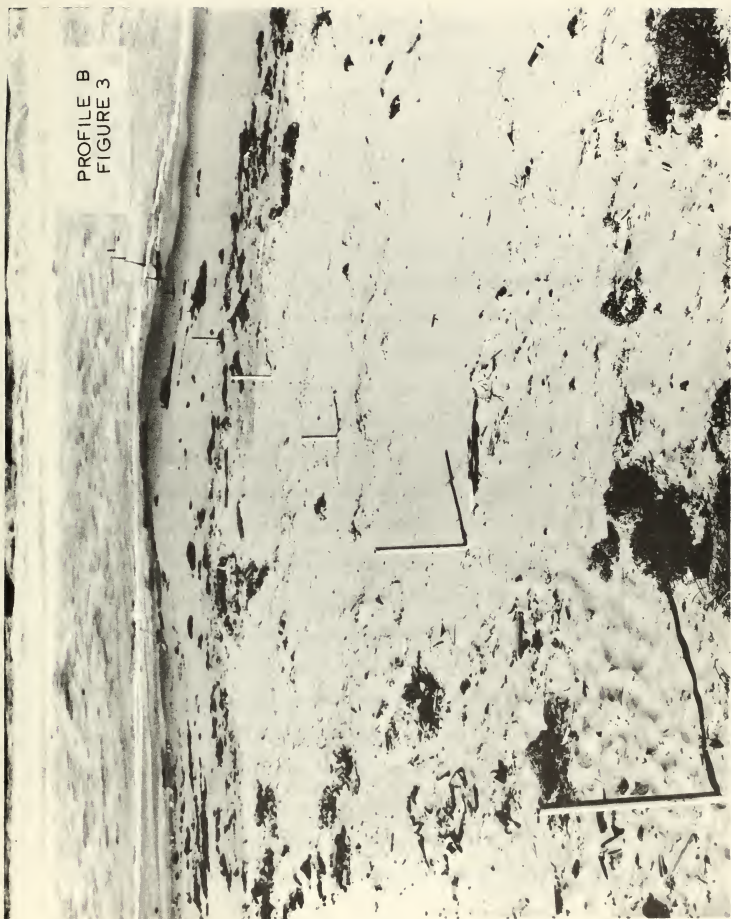
quasi-weekly basis, and from January 26 to March 31 on a daily basis. The daily readings were taken at intervals of roughly 25 hours because the time of low tide, when the readings were ordinarily made, advances about one hour each day. The use of permanently fixed pipes made reading on a daily basis both quick and accurate.

The data for Profiles A and B are graphed on Plate I.

c. Reduction of the Wave Data

The pressure head for the wave recorder is mounted on a tripod three feet above the bottom in a depth of 26 feet below MLLW and is located between Profiles A and B, as noted in Figure 2. A relay system allows a continuous trace to be recorded at the Naval Postgraduate School. The wave recorder provided a continuous trace of the waves from July 11 to November 5, 1963, when an underwater cable failure occurred. For the period thereafter wave data are in the form of visual observations of breakers made at irregular intervals. Each day while the recorder was functioning the waves were recorded at fast speed for two twenty-minute intervals at 8 AM and 4 PM for the purpose of analysis. The remainder of each day's record was traced at slow speed in order to provide general information on the wave height variation during the periods between fast traces.

The analysis of each fast trace was carried out by hand as follows: The average apparent period was obtained by counting the trace crossings over the zero-level line (representing the still-water level), halving the count, and dividing the result into the duration of the trace in seconds.

The significant wave height near the bottom at the sensor depth, H_p, was calculated by first obtaining the average amplitude of the one-tenth highest waves, $A_{1/10}$, from the trace; doubling that to obtain $H_{1/10}$; and

10

then applying the statistical formulas given by Pierson, Neumann, and James [4, p. 11], as follows:

$$H_{1/10} = 3.60 \sqrt{E}$$

$$H_p = 2.83 \sqrt{E}$$

$$\therefore H_p = 0.79 \; H_{1/10}.$$

These wave heights, computed for the sensor depth, were then corrected to obtain the true height at the surface. Since the pressure response decreases exponentially with depth below the water surface, the sensor wave-height values had to be proportionately increased. Wiegel [11] presents the following formulas for the pressure response factor, K, by which the sensor wave height should be multiplied to obtain the associated surface wave height:

For the pressure head not on the bottom

$$K = \frac{\cosh \left[2\pi \frac{d}{L} \left(1 - \frac{z}{d} \right) \right]}{\cosh \left(2\pi \frac{d}{L} \right)} \tag{1}$$

where d is water depth, L is wave length in depth d, and z is pressure-head depth (positive downward). When the water level stands at MLLW, d = 26 feet and z = 23 feet;

For the pressure head on the bottom (z = d)

$$K = \frac{1}{\cosh \left(2\pi \frac{d}{L} \right)} \tag{2}$$

Wiegel gives complete tables for K computed using (2).

With the aim of simplifying computation of the pressure response factor for each wave-height value, sample calculations were made for each combination of the shortest and longest wave period observed (7 and 18 seconds),

11

and the approximate lowest and highest tide for this area (MLLW and MHHW),
using the two equations. The calculations demonstrated that the values
obtained by using the simpler formula, which assumes the pressure head
to be at the bottom, never differed by more than four percent for a given
combination of extreme periods and water depths from the values obtained
using the other formula, and were negligible for the bulk of the data.
Thus to allow the use of Wiegel's tables, and thereby greatly reduce the
computational procedure, the pressure head was assumed to be located on
the bottom; and its depth was assumed constant at the mean tide depth of
25 feet, thereby neglecting the tidal variation in depth of the sensor.

To obtain K from Wiegel's tables, the relative depth d/L_o was obtained
for each wave trace using $d = 25$ feet and $L_o = 5.12T^2$, where L_o is the
deep-water wave length and T is the average apparent period obtained from
analysis of the wave trace. The corrected surface value of the significant
wave height, H_s, was then obtained from the relationship: $H_s = \dfrac{H_p}{K}$.

The final step in the wave-data reduction was to calculate the unre-
fracted deep-water wave height, H_o', and the initial wave steepness,
H_o'/L_o, in order to compare the changes with time of these wave properties
on a uniform basis, i.e., in deep water and independent of wave refraction.
The values of the actual deep-water wave height, H_o, were not calculated,
since they could not be calculated easily with no deep-water wave-direction
data readily available.

The pressure head is in a sufficiently large depth relative to the
dimensions of the waves that were recorded nearly all of the time that
the waves were described more closely by the Airy Wave Theory than by the
Solitary Wave Theory. Accordingly the Airy Theory relationship [1]:

$$\frac{H_s}{H_o'} = \sqrt{\frac{1}{2n}} \frac{C_o}{C_s} \tag{3}$$

12

was used to obtain H_o', where n is the ratio of group velocity to wave speed in a depth of 25 feet, and C_s and C_o are the wave speeds in a depth of 25 feet and in deep water, respectively. The values of H_o' for given values of d/L_o are tabulated directly in Wiegel's tables. The initial steepness H_o'/L_o is then obtained by simple division.

It is recognized that evaluation of both H and T by the procedures described above assume that an existing wave spectrum can be replaced by a simple sinusoidal wave train, and that the computation of H_s from H_p alone can be in error by as much as 25% [8, p. 77]. However, all values are in the proper direction and of the proper order of magnitude, and further, all distortions are relative. In addition, since swell waves greatly dominated throughout the survey period, the errors introduced are smaller than if waves having broader energy spectra prevailed. For these reasons, the resulting values of H_o', T, and H_o'/L_o are considered to be reasonably representative.

Graphical presentations of H_o', T, and H_o'/L_o for the period from July 11 to November 5, 1963, are shown on Plate I.

Visual observations of breaking waves made from the beach were the source of wave data for the period February 3 to March 31, 1964. Using a graduated wave pole and stop watch, measurements of the breaker period, T, and breaker height, H_b, were obtained at intervals of one to three days. Since the heights were in the breaker zone the Solitary Wave Theory was applied to obtain H_o' according to the following relationship:

$$\frac{H_b}{H_o'} = \frac{1}{3.3 \sqrt[3]{H_o'/L_o}} \quad . \tag{4}$$

Inman's graph of (4) was used to extract H_o' directly [7, p. 70]. The initial steepness, H_o'/L_o, was obtained as before.

13

No wave data were collected from November 5, 1963, to February 3, 1964, in anticipation of repair of the wave gage, which unfortunately was not completed during the remainder of the study.

d. Reduction of the Tide Data

The tide gage, situated on Monterey Wharf No. 2, provided uninterrupted data throughout the duration of the study. The tidal parameter considered by the writers to be the most likely to show a correlation with height changes in the beach profiles was the daily extreme tide range, measured from Higher High Water (HHW) to Lower Low Water (LLW). Accordingly, the highest and lowest tide heights for each day, obtained from analysis of the tide records, were graphed and are plotted on Plate I as an envelope of HHW and LLW. The tide heights plotted are relative to an arbitrary datum. Because observed rather than predicted tide heights were used, the curves are somewhat irregular. The fortnightly spring and neap tidal cycles are readily apparent in the envelope.

4. Observed Beach Profile Data

The nature of the beach profile changes illustrated in Plate I will
be described first, and then the effects of waves and tides on the profiles
will be considered in the sections that follow. The profile data are pre-
sented in the form of time-series plots of the sand height at each pole.
This method of presentation allows accurate measurement of daily and quasi-
weekly sand-level changes and readily lends itself to quantitative analysis.
Its disadvantages include the facts that the profile plot is not continuous
across the beach and that the existence of certain beach features such as
scarps are not apparent in the plot.

The daily data from January 25 to March 31 for Profile A will be
considered first. These observations represent the winter period when
wave variability is ordinarily greatest.

Notable beach features observed at Profile A included scarps, cusps,
and a low-tide terrace. There was never a clear-cut berm at Profile A,
and escarpments were only infrequently present and were of short duration
during cutting periods. Beach cusps for this period were commonly present;
however, the authors made no attempt to correlate the presence of beach
cusps with profile changes. A low-tide terrace was often noticed during
periods of minus tides. Rill marks were occasionally seen on the lower
part of the beach during low tide, and backwash marks were commonly evident
due to the presence of dark minerals in the sands.

The magnitude of the sand changes at Profile A during the period of
daily observations is shown in Figure 4 in the form of an envelope of the
highest and lowest sand-height readings for each pole. This plot shows
a similar maximum change from Poles A-1 through A-7. Examination of Plate
I further shows that the profile generally oscillated uniformly along its

15

EXTREMES OF POLE HEIGHT
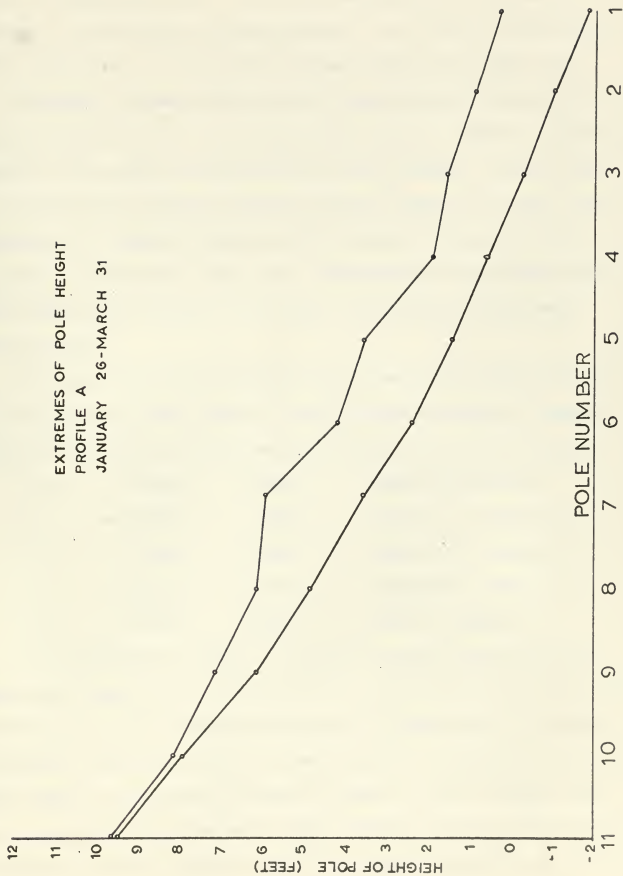PROFILE A
JANUARY 26-MARCH 31

POLE NUMBER

Figure 4

16

length between these extremes. According to Figure 4 the average beach slope is approximately 1:10. For quartz sand having the median grain diameter of that found on the beach studied, i.e., 0.23 mm. as previously noted, Shepard [7, p. 171] gives an average beach slope of about 1:20.

Throughout the period the sand level along the major portion of the profile essentially rose or fell with major filling or cutting. The lower portion of the profile displayed the most active changes. The sand level at the upper poles generally reflected the main trends at the lower poles, although at the highest poles the profile changed rarely and only when reached by large waves at high tide. Superimposed on these larger cycles were constant daily changes on the lower, active portion of the beach swept by waves.

The major cycles of cut and fill for the period are listed below for one representative pole, Pole A-4, which was selected because it appears indicative of activity on the lower, more active portion of the profile:

fill	1.83 feet	10 days	January 28-February 7
cut	2.01 feet	9 days	February 7 - February 16
fill	1.71 feet	12 days	February 16 - February 28
cut	1.62 feet	8 days	February 28 - March 7
fill	1.71 feet	24 days	March 7 - March 31.

From examination of Plate I, it can be seen that these major cycles were quite symmetrical, particularly in the lower part of the profile where rates of cut and fill were about the same. The upper part of the profile displayed a tendency for sudden cut and slow fill, as evidenced by Pole A-8. With regard to this cyclical transport of sand, it can be concluded that, since sand movement is dominantly onshore-offshore, the main pivotal point between cut and fill along the profile is seaward of the end of the profile.

The observations of Profile A revealed a dynamic beach characterized by constant daily change in the active portion that is washed regularly by waves. Again using Pole A-4 as representative, a histogram of daily rates of change in intervals of tenths of a foot was plotted and is shown in Figure 5. This figure reveals that daily changes in sand level were less than ± 0.1 feet during 40 percent of the days during this period. The maximum daily change rates were approximately 0.6 feet for fill and 1.6 feet for cut. The frequency of sand-level changes greater than ± 0.1 feet was about the same during periods of cut and fill. Thus it may be concluded that daily rates of cut and fill were approximately equal, and that rapid cut and slow fill was not observed as a characteristic pattern although this appears to be common on the exposed beaches of the Pacific coast.

In order to determine whether the beach cut or filled along the entire profile over a given 24-hour period, a pivot-point diagram was prepared from Plate I and is shown in Figure 6. Each pivot-point is marked by an X. A pivot point is defined as a point on the profile above which the beach cut and below which it filled, or vice versa, from one day to the next. Study of this figure revealed that pivot points occurred on about half the days during this period. The condition of cutting on the lower part and filling on the upper occurred about twice as often as building on the lower and cutting on the upper part of the beach. Pivot points were noted to occur at all levels on the beach, and they showed no general relationship to the major cycles.

Profile B for the period of daily data displayed characteristics generally similar to those at Profile A. However the slope at B was a more gentle 1:12, which reflects a slightly finer grain size than at A. Berms and escarpments along Profile B were somewhat more frequent and definitely more pronounced.

18
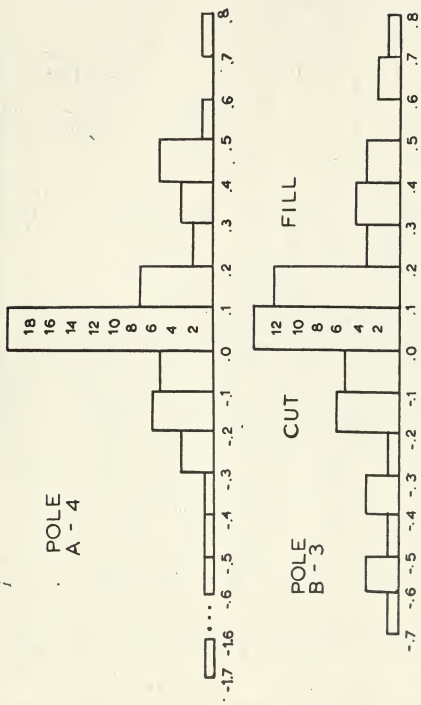
HISTOGRAM OF SAND CHANGES

DAILY DATA JANUARY 26 TO MARCH 31

HORIZONTAL - TENTHS OF FEET

VERTICAL - NUMBER OF DAYS

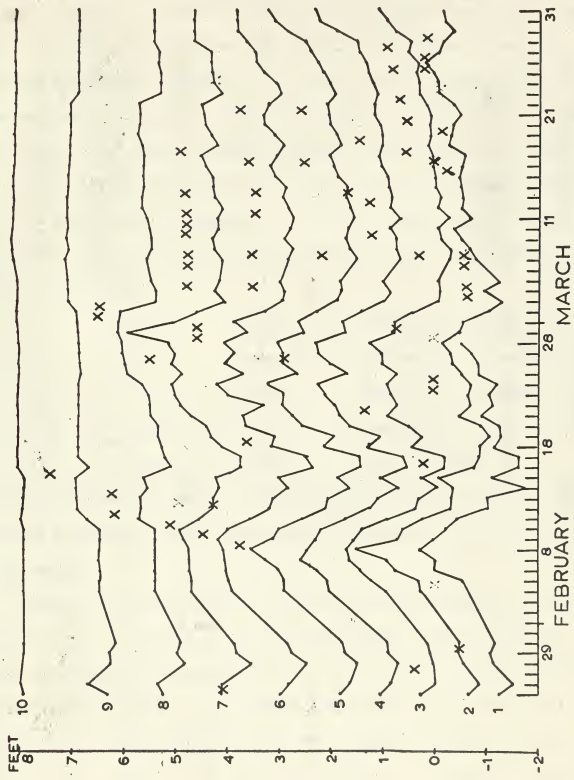Figure 5

19

PROFILE A PIVOT POINTS (FROM PLATE I)

Figure 6

20

The envelope of extreme sand level is shown in Figure 7. It reveals a steady decrease in the extreme range with increasing distance from the water, in contrast to the more uniform extreme range for the first seven poles at Profile A. The Figure also reveals that extreme changes at Profile B were a little greater in the lower portion of the profile than those observed at Profile A. This was surprising in view of the fact that beach slope, grain size, and breaker heights are all smaller at B than at A.

Major cycles of cut and fill at Profile B closely paralleled those at Profile A but were not as regular or clear-cut. Using Pole B-3 as representative of the entire profile and comparable to A-4, the major cycles of cut and fill were:

fill	2.50 feet	16 days	January 25 - February 10
cut	2.17 feet	6 days	February 10 - February 16
fill	1.23 feet	12 days	February 16 - February 28
cut	2.13 feet	10 days	February 28 - March 9
fill	1.55 feet	22 days	March 9 - March 31

Comparison of these values to the corresponding values at Pole A-4 showed a greater magnitude for the major cut and fill cycles at Profile B, contrary to expectation.

Daily rates of sand change at Pole B-3 were also similar to those observed at A-4. A histogram of the daily change, plotted in Figure 5, shows that changes of less than ±0.1 feet occurred about 30% of the time, and that periods of fill occurred more frequently than periods of cut. The extreme daily rates of beach erosion and building were about the same, as was the case at Pole A-4. A pivot-point analysis for Profile B, shown in Figure 8, produced results similar to those for Profile A.

EXTREMES OF POLE HEIGHT
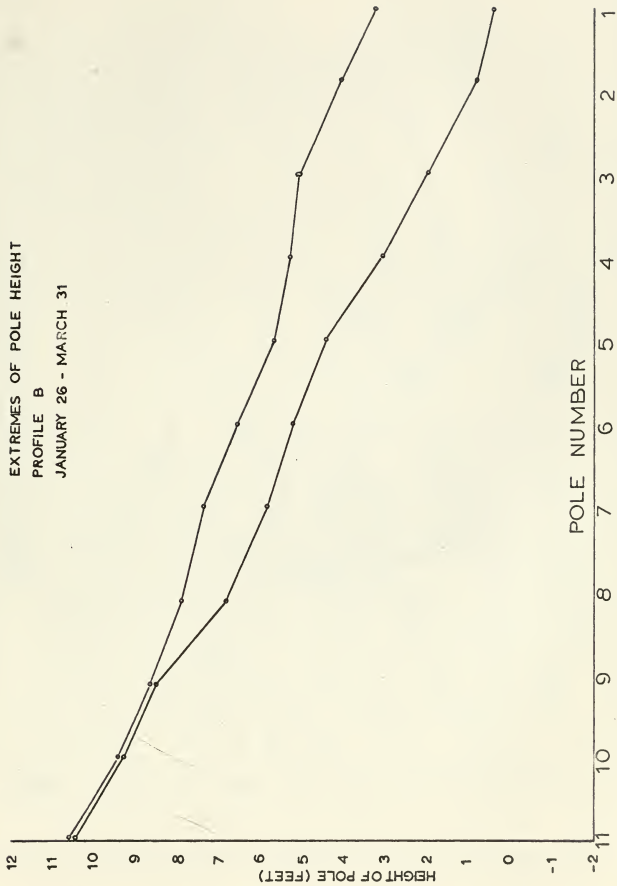PROFILE B
JANUARY 26 - MARCH 31

POLE NUMBER

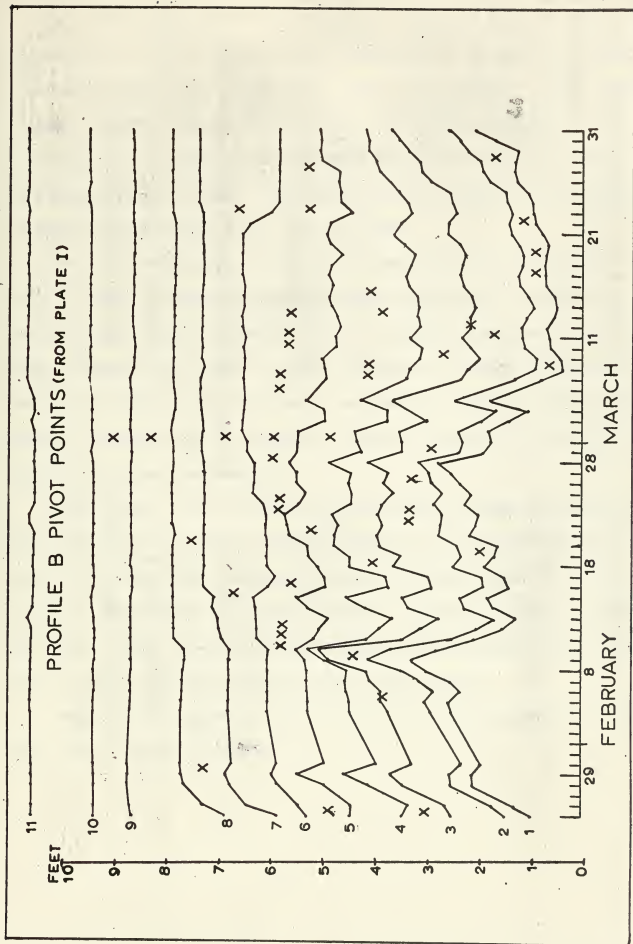HEIGHT OF POLE (FEET)

Figure 7

22

Figure 8

As a final comparison, the net change in the sand level at each of the eleven poles on both profiles from the beginning to the end of the daily observation period were obtained from Plate I and averaged. These profile averages revealed almost equal net builds of 0.65 feet at Profile A and 0.63 feet at B. Converting the average build of 0.65 feet to the amount of sand moved gave a fill of approximately 78 cubic feet per foot length of beach between Poles 1 and 11 for the period.

The quasi-weekly data, covering the summer and autumn period of July 12, 1963, to January 25, 1964 displayed characteristics similar to the daily winter data at both profiles. The general shape and slope of the beach throughout the period was nearly the same as previously described for the daily data. The envelopes of extreme sand height for each profile, shown in Figures 9 and 10, displayed a gradual decrease in range with increasing distance from the water.

Major cycles of cut and fill were not evident through the summer and fall until the first autumn storm on October 12. From that date until the start of the daily data, periodic cutting and filling seemed to occur on a four or five-week cycle at both profiles. Comparison between the autumn and winter cycles revealed equivalent magnitudes of change in both seasons but the cycles were more frequent in the winter period.

Compared with the daily data, the quasi-weekly data appeared too gross for further detailed analysis.
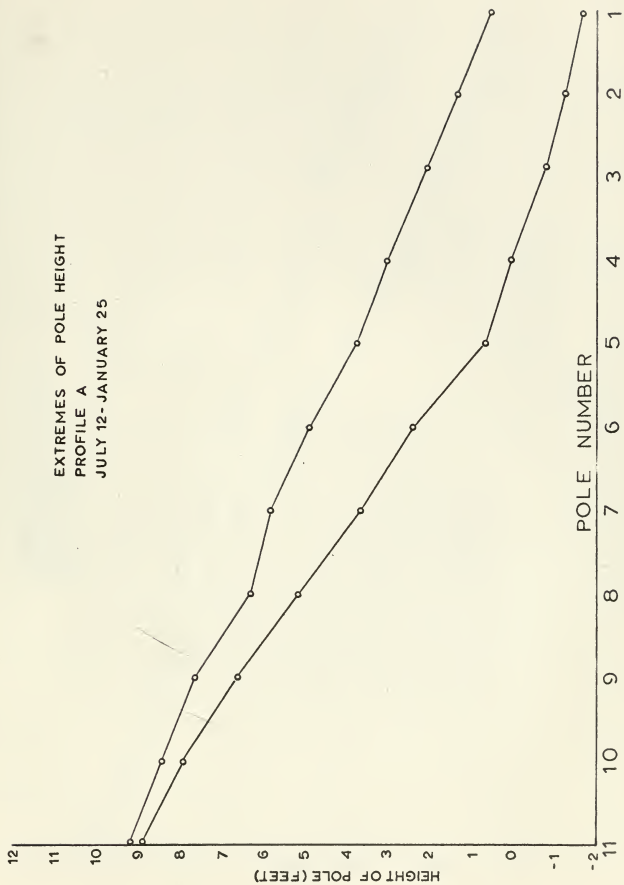
EXTREMES OF POLE HEIGHT
PROFILE A
JULY 12- JANUARY 25

POLE NUMBER

HEIGHT OF POLE (FEET)

Figure 9

25

EXTREMES OF POLE HEIGHT
PROFILE B
JULY 12 - JANUARY 25

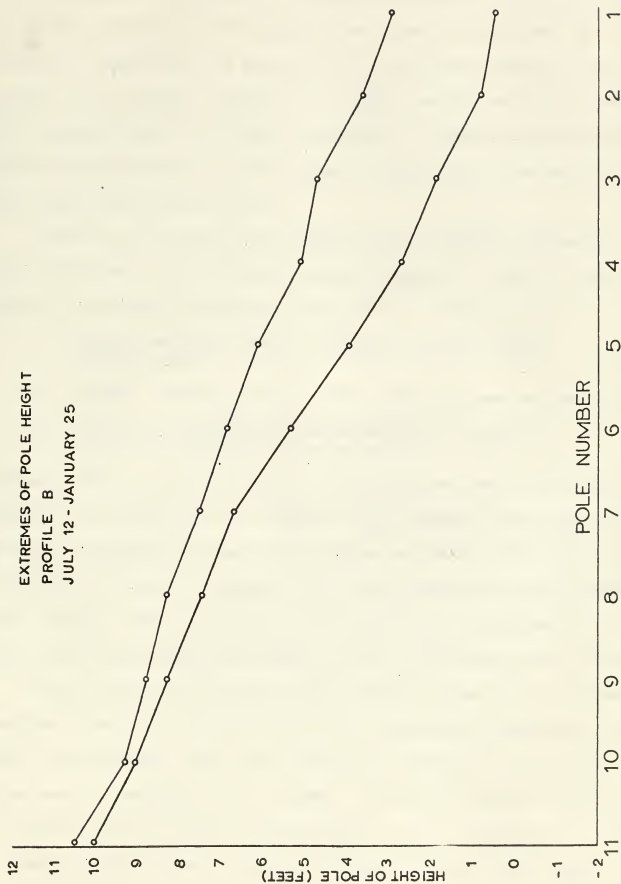HEIGHT OF POLE (FEET)

POLE NUMBER

Figure 10

5. Wave Effects on the Beach Profile

An analysis of the effect of varying wave conditions on the beach profile was attempted by both subjective and objective approaches. Accepting the significant wave parameters, H_o' (unrefracted deep-water wave height), H_o'/L_o (initial steepness), and T (wave period), as those parameters which determine sand-level changes, comparisons of these were made with the short and long-term beach profile changes as represented by the daily and quasi-weekly sand-level variations.

Inspection of the wave data plotted in Plate I required elimination of the visual wave data collected during the January 25 - March 31 period, except as very general indicators of wave action. This was due to:

(1) sparsity of the data (only 31 readings were made during a 67-day period);

(2) somewhat doubtful accuracy of the visual wave observations; and

(3) the general inadequacy of the visual data in providing a continuous record of the wave variability.

The unsuitability of the wave data for this period was particularly unfortunate in view of the fact that excellent daily sand-level data were collected. Therefore correlations between wave conditions and beach profiles were restricted to the July 12 - November 5 period when twice-daily gage recordings were obtained. However, the lack of daily sand-level observations for the latter period handicapped the analysis, but some relationships were obtained.

Visual analysis of the various wave parameters versus sand-level changes was first attempted. From the literature it is generally accepted that short-period, high-steepness waves cause cutting; and long-period low-steepness waves result in building [7, p. 177-182]. At certain intervals in Plate I, for example from late August through November, visual comparison of the wave steepness and sand elevation appears to confirm an inverse relationship

27

between these factors; but exceptions occurred when the opposite situation
was true, such as in early July. Therefore, no clear-cut relation between
wave parameters and profile changes is evident, except for the lower portion
of Profile B.

Although no consistent relationship was found, the fact that sand levels
and wave conditions both underwent constant daily changes is proof in itself
of the influence of changing wave conditions on the beach profile. The
profile data in Plate I reveals sizable sand-level changes; and yet, as
previously discussed, wind-wave activity and littoral drift on Del Monte
Beach appear to be of minor importance with regard to sand transfer. It
thus appears that the relatively low swell heights and steepnesses observed
were sufficient to cause the changes noted.

Because of the failure of subjective examination to reveal any consistent
influence of waves on the beach profiles, several objective comparisons were
attempted, with the most pertinent presented below.

In Figure 11 is plotted H_o'/L_o, averaged over the dates between quasi-
weekly sand readings, versus the change in sand level between the readings
for representative Poles A-4 and B-3. The scatter shows almost complete
randomness, although there is a very slight tendency toward positive changes
with decreasing initial steepness, and vice versa. Since the scatter was
so poor using one representative pole, it was decided to average the sand-
level change for an entire profile between observations.

Figure 12 shows the same H_o'/L_o average versus the average of the
changes for Poles A-3 to A-11. This figure demonstrates marked randomness
also. At this point it seemed evident that the average longer term H_o'/L_o
considerations were not the primary cause of the observed sand-level changes.
Therefore, it was decided to test short-term (1 and 3 day) wave parameters
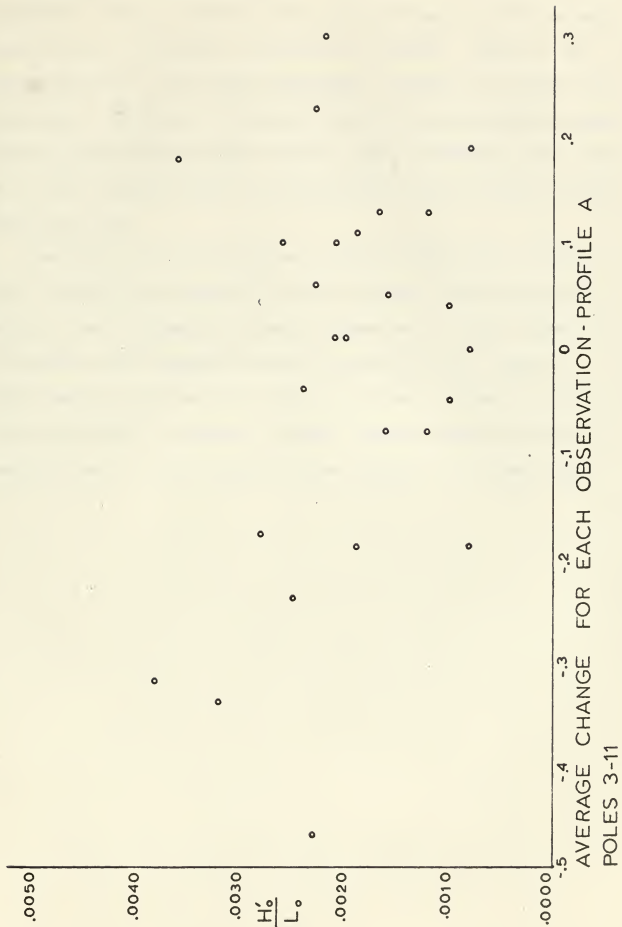against sand-level changes.

Figure 11

29

Figure 12

30

Figures 13 and 14 were the result of this attempt. The actual sand elevations at Poles A-4 and B-3 versus H_o'/L_o averaged over both one and three days prior to the sand observations were plotted. Figure 13 for Pole A-4 shows only a very weak relationship, but Figure 14 for Pole B-3 demonstrates a fairly good correlation, high sand levels being associated with low initial wave steepness, and vice versa. It should be noted that the B-3 data started on August 20 and therefore covered a shorter period than the A-4 data.

Examination of the scattergrams, particularly Figure 14, indicates that an initial wave steepness of 0.0020 represents a possible critical value such that when greater steepnesses prevailed, the beach tended to cut and when lower steepnesses occurred the beach filled. Empirical studies based on wave-tank observations [5, 6] have revealed a critical value of the initial steepness of 0.0250, a figure larger by an order of magnitude than all of the steepness values recorded at Del Monte Beach.
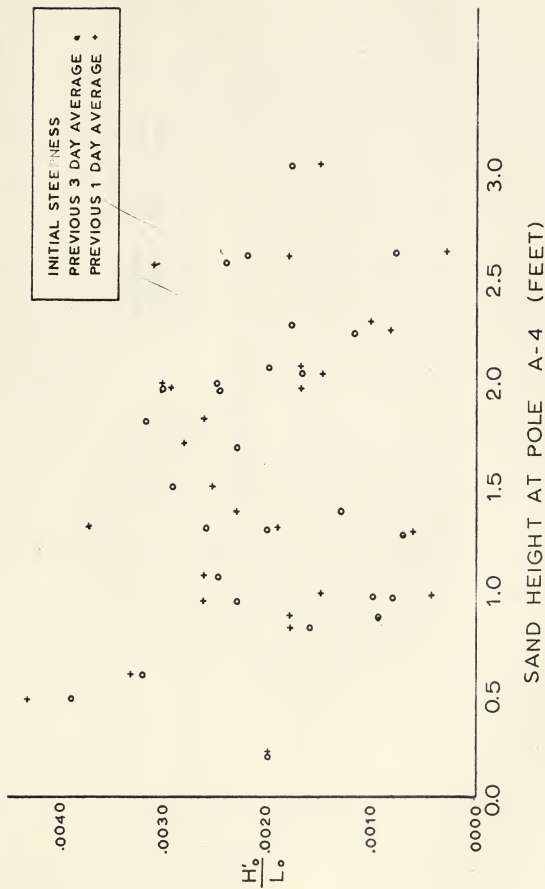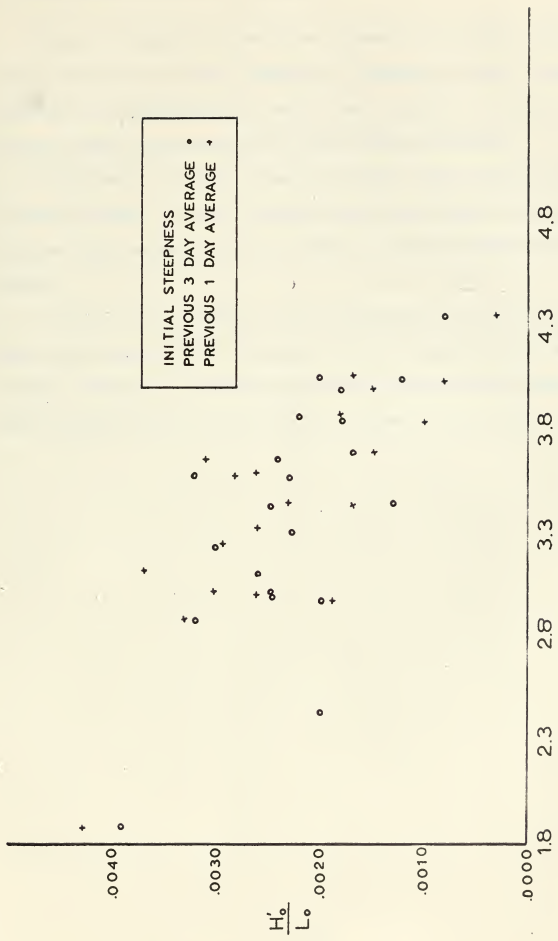
Figure 13

INITIAL STEEPNESS
PREVIOUS 3 DAY AVERAGE
PREVIOUS 1 DAY AVERAGE

$\dfrac{H'_o}{L_o}$

SAND HEIGHT AT POLE A-4 (FEET)

.0040
.0030
.0020
.0010
.0000

0.0   0.5   1.0   1.5   2.0   2.5   3.0

32

INITIAL STEEPNESS

PREVIOUS 3 DAY AVERAGE •
PREVIOUS 1 DAY AVERAGE +

SAND HEIGHT AT POLE B-3. (FEET)

$\dfrac{H_o'}{L_o}$

Figure 14

33

6. Tide Effects on the Beach Profile

A visual comparison of sand-level changes and the daily extreme range of the tides for the entire data period revealed no evident correlation. Examination was particularly directed toward finding a correlation between the tide stages and cutting and filling along the profiles.

The attempt to relate cut and fill cycles to the tide range cycle proved fruitless. For short periods the profiles suffered erosion as the tide range increased, but the reverse of this occurrence was just as common.

Because of the unusually low wave conditions that prevailed throughout most of the period, tidal influences could be expected to have been most evident. However, no relationship was found between tidal stages and sand-level changes on Del Monte Beach for the period of this study.

7. Conclusions

Study of the sand changes on Del Monte Beach revealed a dynamic beach characterized by constant daily changes in the lower active zone ordinarily covered by waves. No clear-cut seasonal variation in cut and fill was evident during the period of study, as has been found by Shepard and others on the exposed beaches of the California Coast. Large cycles of cut and fill having durations of 10 to 20 days occurred irregularly throughout the period, but more frequently in winter. It is concluded that these short-term beach changes were the direct result of changing wave conditions. No clear-cut influence of the tide was found.

Because of the sensitivity of this beach - and possibly all sand beaches - to changing wave conditions, profile measurements on natural beaches should be made at time intervals comparable to or less than the time intervals involved in the changing wave conditions on the beach under study. Therefore, in view of the wave regimes in the major oceans, suitable observation intervals seem to be on the order of one day or less on open coasts.

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PLATE 1

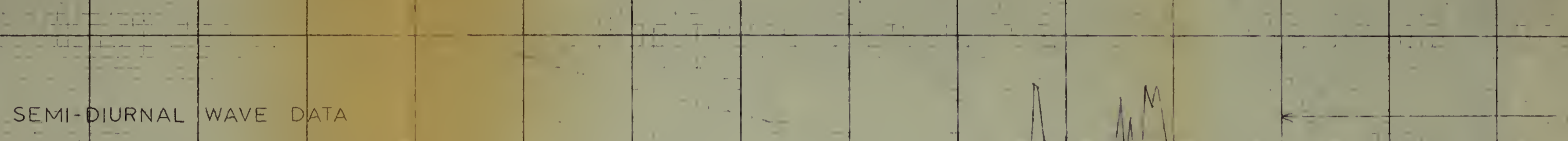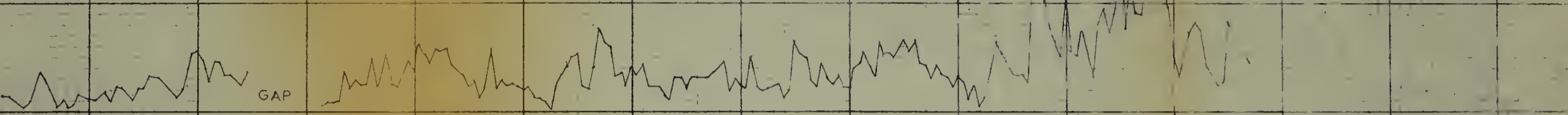TIDAL
RANGE
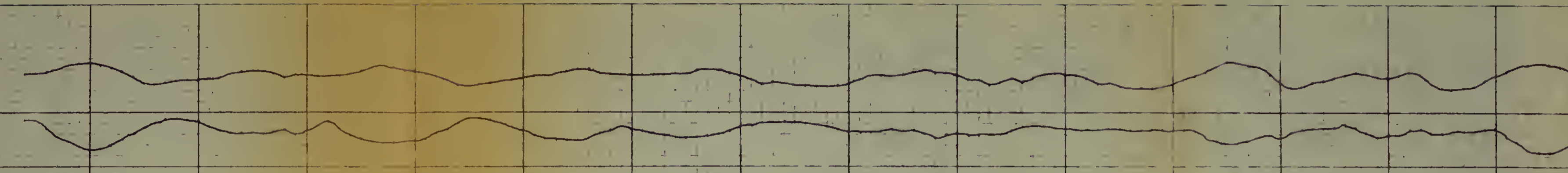
H'₀   SEMI-DIURNAL WAVE DATA

WAVE
PERIOD
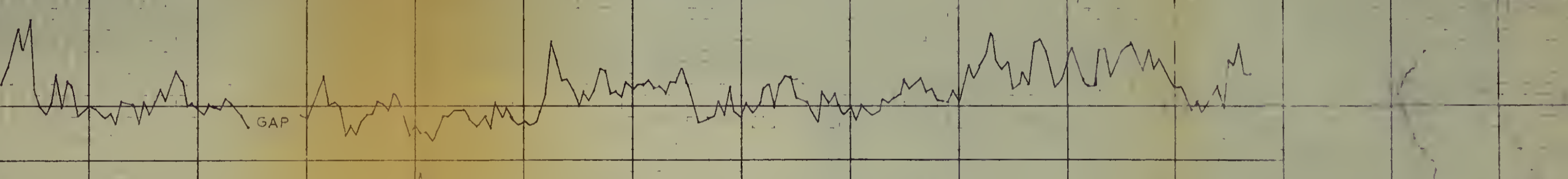
$\dfrac{H'_o}{L_o}$

PROFILE B

PLATE 1

PROFILE B

PROFILE A

FEET
10

POLE 11

POLE 10

POLE 9

POLE 8

POLE 7

POLE 6

POLE 5

POLE 4

POLE 3

POLE 2

POLE 1

10   20   30 1   9   19   29 1   8   18   28 1   8   18   28 1   7   17   27   1
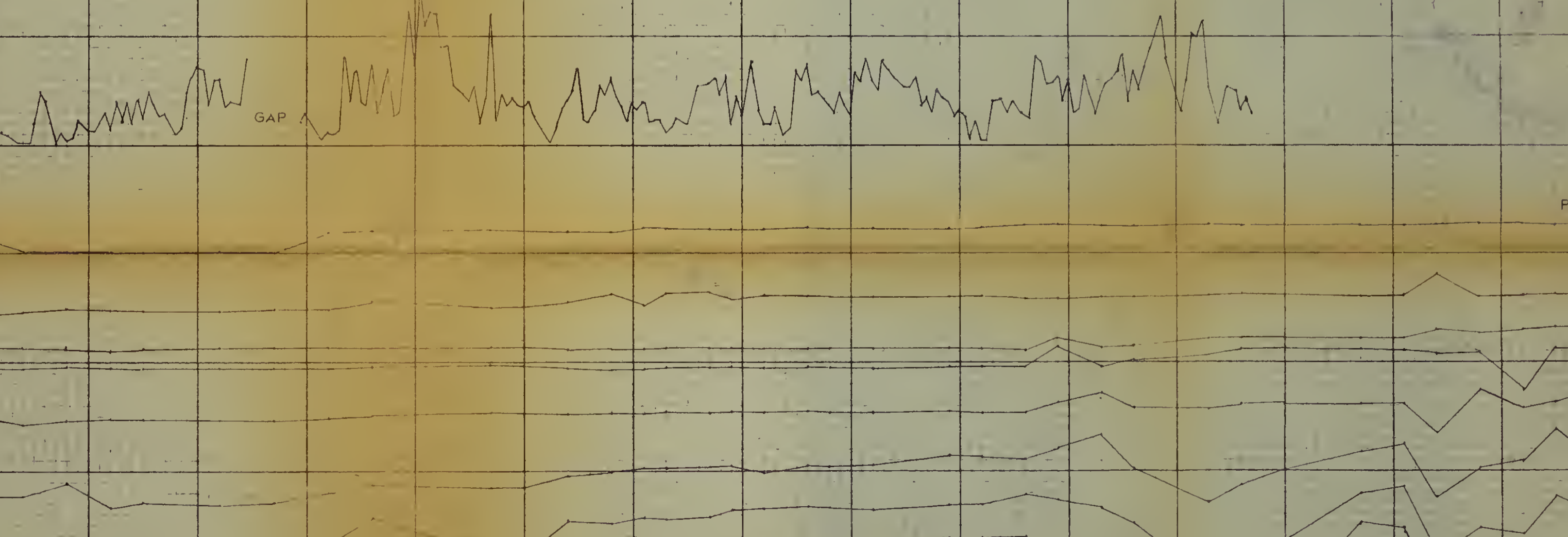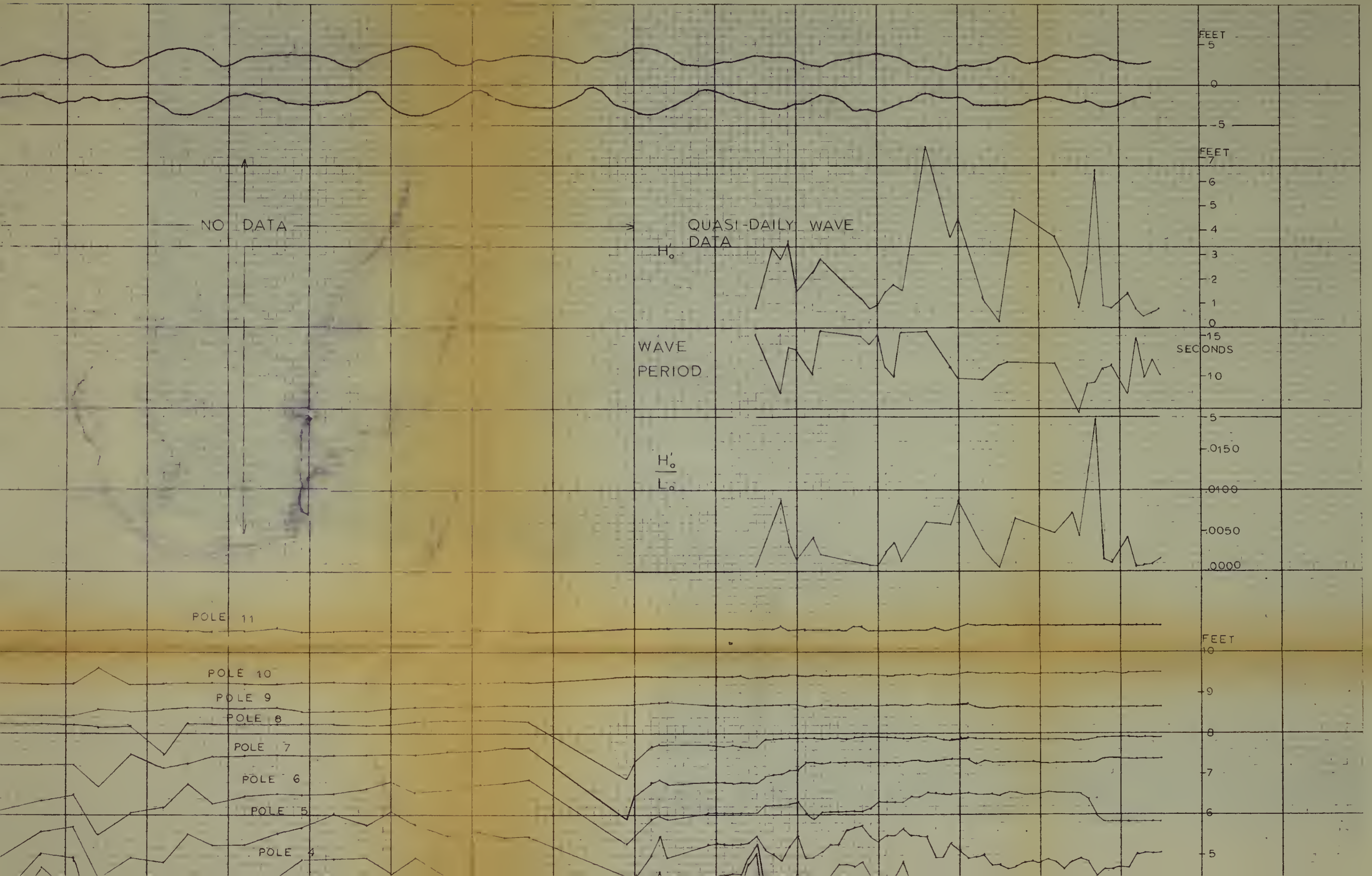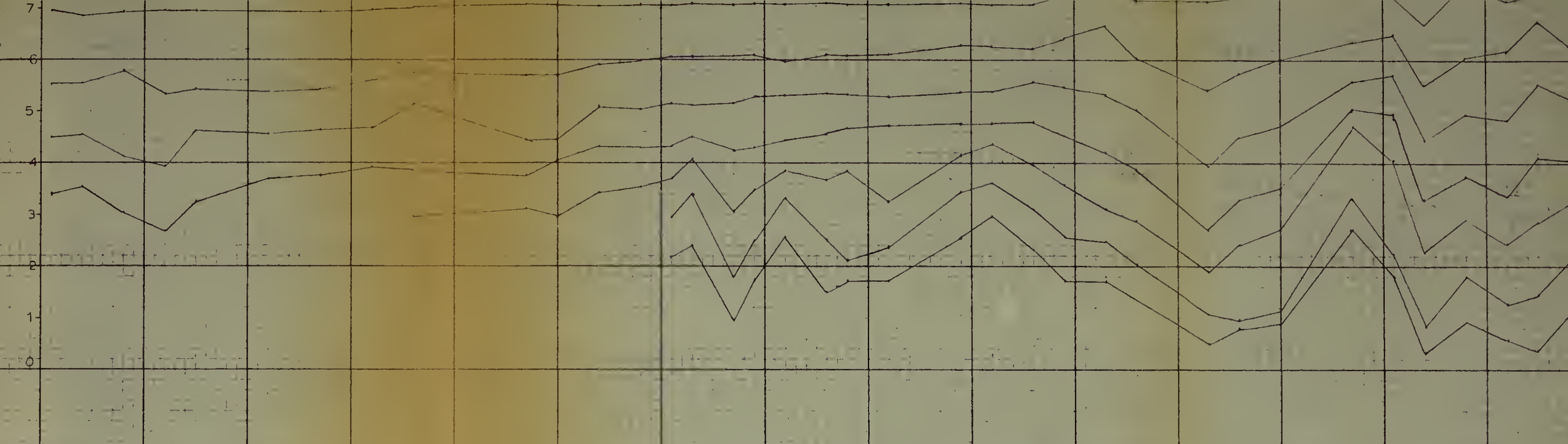
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POLE 6
POLE 5
POLE 4
POLE 3
POLE 2
POLE 1

←—QUASI-WEEKLY SAND DATA—|—DAILY SAND DATA—→

FEET

7   17   27   1   7   1   16   26   1   5   15   25   1   6   16   26   31

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