Chapter 16

QUASI-WEEKLY AND DAILY PROFILE CHANGES ON A DISTINCTIVE SAND BEACH

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INTRODUCTION

Casual observations over a period of years of a long sand beach in the southern end of Monterey Bay, California, suggested that the sand elevation, while varying noticeably from one time to another, does not display the well-defined seasonal alternation between build-up in the summer and erosion in the winter that is now widely recognized on the exposed beaches of California. Accordingly, a program was established to measure the beach-profile changes by means of serial observations and to attempt to relate the changes to wave, tide, and beach conditions prevailing during the observation period. The results of the study, covering nine months, are presented herein.

In the course of the study it became evident that quite special conditions of sand, waves, and water circulation exist in the extreme southern end of Monterey Bay which make this small area a natural laboratory where beach profile changes as well as other nearshore phenomena may be investigated under quite simply defined conditions in nature. The characteristics of tnis beach will be described in some detail, partly because they are distinctive and therefore of more than usual interest, and partly because they are essential to understanding the causes of the profile changes observed.

CHARACTERISTICS OF THE BEACH STUDIED

Monterey Bay is a broad open indentation about 40 km. in width on the central California coast (Figure 1). Its entire inner shoreline, extending approximately between the cities of Santa Cruz on the north and Monterey on the south, is a long sand beach which is continuous except in the middle of the bay where the well-known Monterey Submarine Canyon heads within the entrance of Moss Landing Harbor. The two segments appear to be independent with regard to sand sources and littoral drift because of the barrier offered by the canyon. The beach marks the terminus of the alluvial plain of the Salinas River and is backed along most of its length by coastal dunes of Recent age which are largely inactive. Rocky headlands flank the beach on either end of the bay.

The beach profiles studied are located very near the southern end of the bay on what is known locally as Del Monte Beach (Figure 2). The

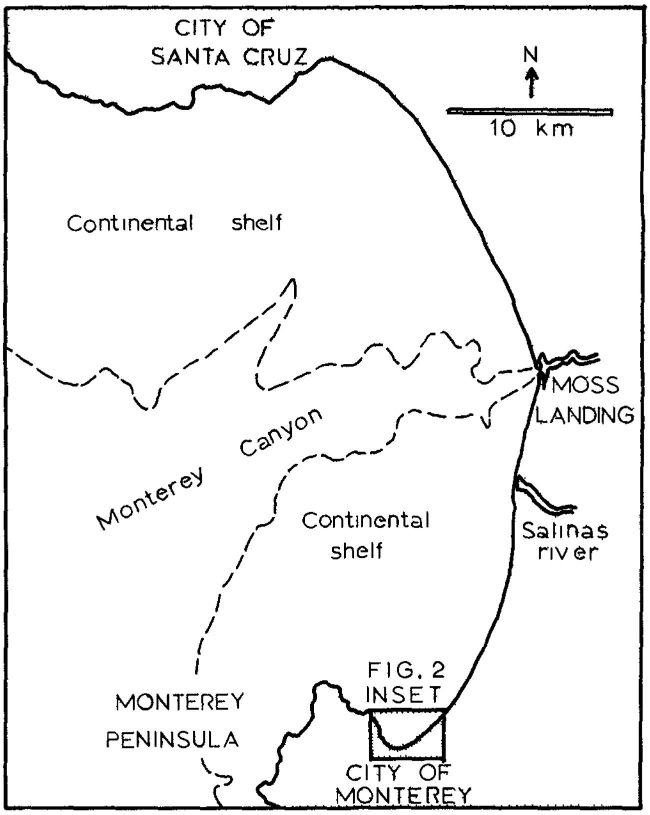

FIG 1 --MAP OF MONTEREY BAY

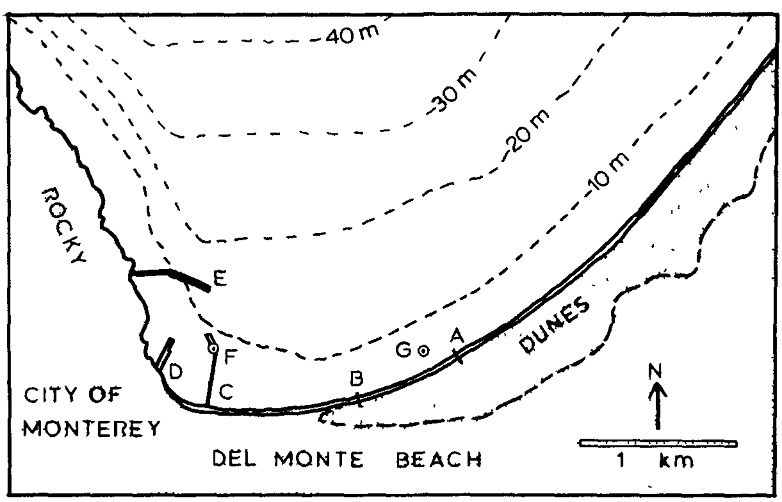

FIG 2 --MAP OF DEL MONTE BEACH A IS PROFILE A, B, IS PROFILE B, C IS A SOLID BULKHEAD, D IS END OF DEL MONTE BEACH, E IS A PERMEABLE BREAKWATER, F IS TIDE GAGE, G IS WAVE GAGE sand on Del Monte Beach is quartzitic, of fine to medium texture, and very well sorted. A definite gradient in both grain size and beach slope occurs along the beach, with the finest sand and flattest slope occurring at the south end of the beach (Figure 3).

The beach profile, basically very simple, usually displays a fairly uniform gradient from the back of the beach, through the intertidal zone, and into the surf zone. The profile ordinarily lacks a well-defined berm and offshore bar, but a narrow sand flat is sometimes present at the lowest tide level.

The predominant wave type on Del Monte Beach is swell a very large percentage of the time. The extreme southern corner of Monterey Bay, because of its recessed location, is so sheltered from the open ocean that both sea and swell entering the bay from all directions experience extreme refraction in travelling across the broad smooth shelf offshore, and are accordingly reduced to swell of moderate or low steepness upon arrival on Del Monte Beach. With regard to wind waves generated locally within the bay, large waves can arrive only from northerly directions but the frequency of northerly winds is very low. Afternoon sea breezes from westerly directions often generate a white-capped sea to the north of Del Monte Beach but the latter usually enjoys the shelter of the Monterey Peninsula and the sea is typically low or calm.

Associated with the dominance of swell are low breaker heights, which seldom exceed one meter and are usually much less. Due to the marked refraction effects, a noticeable decrease in the breaker height toward the south can nearly always be observed along Del Monte Beach. In view of the wave-height gradient a decision was made to establish two beach profiles, separated by 670 m., in order to study the influence of the gradient on the profile.

Breaker heights, seldom in excess of one meter as mentioned, are superimposed on an astronomical tide of the mixed type having a diurnal range averaging about two meters. Meteorological tides are negligible, the largest noted during the observation period having an amplitude of about 15 cm. according to a study of anomalous water levels at Monterey Harbor by O'Connor (1964). Thus, gravity waves are superimposed on nearly periodic water-level variations, which undoubtedly simplifies the relationship between waves and beach-profile changes.

The significant periods of the wave trains observed on Del Monte Beach vary widely between about 5 and 20 sec., like those measured on the exposed beaches of the Pacific Coast. No wave spectra have been measured, but visual observations indicate that the spectrum is characteristically narrow, even when wind waves enter the bay from the open ocean. Differential refraction of the spectrum probably accounts for the latter situation.

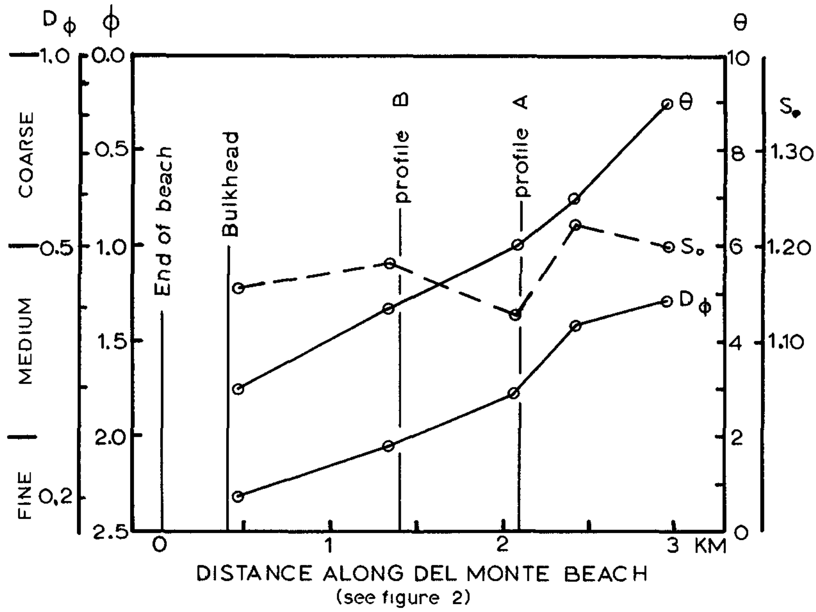

FIG. 3 --DISTRIBUTION OF GRAIN DIAMETER, D_ϕ (IN MM AND PHI UNITS), SAND SORTING S_O (IN TRASK COEFF), AND BEACH SLOPE θ (IN DEG) ALONG DEL MONTE BEACH (DATA FROM McFADDEN, 1964

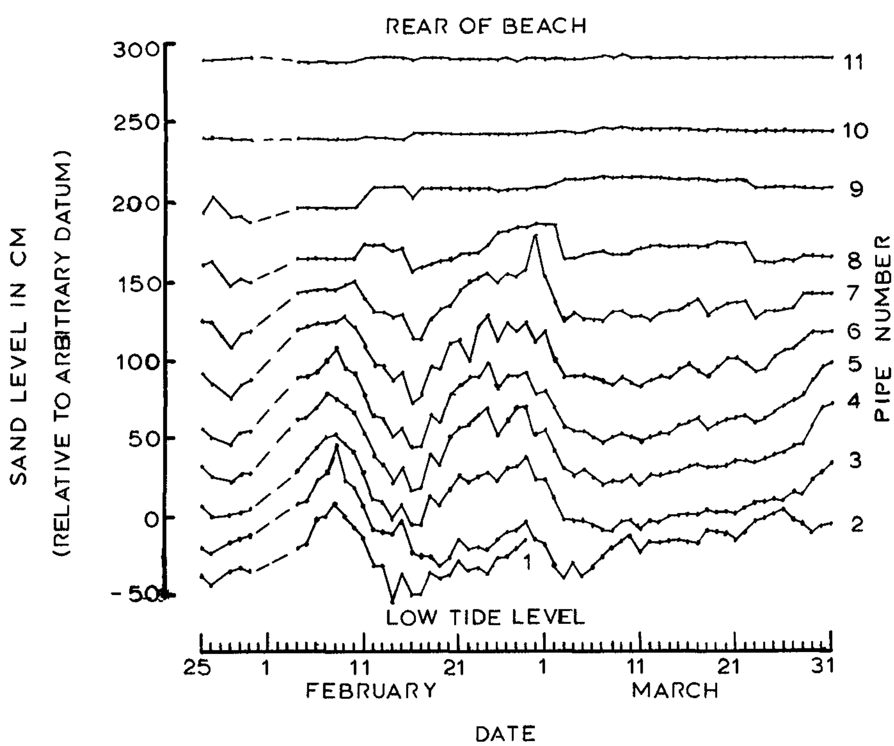

FIG 4 --DAILY SAND LEVEL VARIATION ON PROFILE A

The usual occurrence of low to negligible breaker angles is another consequence of the intense refraction in the southern end of the bay. The accelerating curvature of Del Monte Beach that can be readily seen in Figure 2 undoubtedly owes its adjustment largely to this effect. The beach has remained very nearly fixed in position since the earliest hydrographic survey in 1851 according to comparisons of successive hydrographic surveys by the U. S. Army, Corps of Engineers (1958).

Net littoral drift along Del Monte Beach is very small or non-existent, as indicated by a variety of both direct and indirect evidence. Such evidence includes the absence of any significant net sand accumulation against the solid bulkhead shown in Figure 2 since its construction two years ago, obvious differences that exist between the mineralogical composition and texture of the sand on Del Monte Beach and that on nearby pocket beaches along the rocky shoreline of Monterey Peninsula, occurrence of the gradient in sand texture along Del Monte Beach which would not be expected to persist in the presence of any significant littoral drift, absence of any significant sink for the beach sand (the coastal dunes to the north represent a large potential source), dominance of swell of small breaker height and angle which must produce generally negligible longshore currents, and the common occurrence of subdued cusps on Del Monte Beach which would not ordinarily be expected in the presence of significant longshore currents.

The absence of significant littoral drift indicates that only onshore-offshore transport of sand grains appears to be ordinarily involved in the beach profile changes. In addition, it indicates a long residence time for the sand on Del Monte Beach.

Neither coastal nor tidal currents are known to flow along Del Monte Beach according to local observers. The circulation of water seaward of the surf zone appears to be controlled almost entirely by the wind, as indicated in field observations made by Stevenson (1964). Water circulation within the surf zone on Del Monte Beach has been described by Brennan and Meaux (1964) from field measurements.

BEACH PROFILE MEASUREMENT AND OBSERVATIONS

The two profiles established on Del Monte Beach each consist of a series of 5 cm. pipes driven into the sand at intervals of 3,7 m. (12 feet) along a line perpendicular to the beach. The profiles, each 37 m. in length, extend from the landward limit of the beach, marked by fixed dunes, to the approximate lowest tide level. They are designated A and B.

During the conduct of a survey, the sand elevations against the pipes are measured relative to the tops of the pipes the heights of which are referred to a common datum. This method of profile measurement permits one man to take readings accurately in a matter of minutes, and to make subsequent profile surveys at precisely the same locations as often as desired.

The sequence of profile measurements collected over a period of time represents a time series at each fixed location which is directly amenable to statistical analysis and is in a form convenient for correlation with waves and other related time-dependent factors. An example of the profile data graphed in the form of a time series at each pipe is shown in Figure 4.

The profile observations to be described herein were made over the period from July 1963 to March 1964, inclusive. The profiles were measured quasi-weekly from July 1963 through January 1964, but a detailed study of continuously recorded wave data for that period showed the quasi-weekly interval to be inadequate for the purpose of relating observed beach changes to the varying wave conditions, and in February and March 1964 the beach profiles were measured daily near the time of low tide. The quasi-weekly profile data are not plotted herein but may be found in Koehr and Rohrbough (1964). The daily observations at Profile A only are presented herein (Figure 4).

During the nine months of observations Profiles A and B experienced an extreme range in sand height of about 100 cm. at the low-tide and mid-tide levels, diminishing to zero at the back of the beach where waves did not reach. The sand-level variations on both profiles were fairly similar in major trend and magnitude and were essentially synchronous, but they often differed considerably in their minor variations. The general similarity in the magnitude of the major fluctuations at the two profiles is interesting in view of the prominant gradient in wave height and other factors that occur between the profiles.

The most pronounced features evident in the data are large cycles of fill and cut, fairly symmetrical in time, averaging about 60 cm. on the lower part of the beach and commonly covering an interval averaging about 20 days. The entire active portion of the beach tended to rise and fall during each cycle. The cycles occurred at irregular intervals throughout the observational period but appeared to be more frequent in autumn and winter. Their cause has not been ascertained. Examples of two prominant cycles may be seen in Figure 4.

Superimposed on the large cycles and on the less active periods between them are continual day-to-day changes in the sand level. During the two-month period of daily observations, these changes exceeded 3 cm. per day about two-thirds of the time on the more active lower part of the beach, and ranged up to 20 cm. per day. The frequency distributions of the daily rates of change were similar for cut and fill.

During approximately half the period the sand level rose or fell in common at all points along the profile from one day to the next, whereas during the remainder of the period differential cutting and filling on different parts of the profile occurred. Filling on the upper part of the beach and cutting on the lower part occurred more frequently than the reverse situation. An example of the former case may be seen in Figure 4 for the one-day interval of January 25 to 26. The pivotal point in the profile occurred at Pipe 7.

No seasonal alternation between build-up in the summer and erosion in the winter, such as has been commonly observed on the exposed beaches of the California coast, is evident in the nine months of data.

CAUSITIVE FACTORS INFLUENCING THE PROFILE

Factors that were investigated in searching for causes of the observed profile changes were the waves, tides, and beach saturation.

Waves were recorded during the first four months of the study using a pressure sensor located in an average depth of 7.5 m. a short distance seaward of the two profiles (Figure 2). Fast traces were made twice daily and were analysed for the wave characteristics. A summary of the analysed records shows that the wave period ranged widely between 7 and 18 sec., with the most frequent period being 10.8 sec. The maximum significant wave height at the sensor location was 2.0 m., but the height was less than 1.0 m. in 93% of the records analysed. The initial wave steepness (unrefracted), H'_o/T^2, ranged between 0.001 and 0.034, and averaged about 0.010. Graphs of the wave parameters plotted with time (Koehr and Rohrbough, 1964) display continual daily fluctuations superimposed on longer undulations.

Comparison of the quasi-weekly beach profiles with the semi-diurnal wave data for the four-month period suggests that the sand level rises during periods of generally diminishing initial wave steepness, and falls during periods of increasing steepness, but the relationship is by no means clear-cut. In view of the daily variability of the wave data, the profile sampling interval was much too coarse, even with respect to the major beach cycles, to indicate any more than a very general relationship.

During the period of daily profile observations that followed, when reaction of the sand level to the wave parameters could have been studied more satisfactorily, the wave gage was unfortunately out of operation (visual observations proved to be inadequate). However, the constant change in the profiles from day to day indicate a sensitive reaction of the beach to very subtle changes in the character of the incident waves.

With regard to tidal influences on the profiles, both the quasi-weekly and daily sand elevations were examined for evidence of a possible fortnightly tidal cycle that might be expected in response to spring and neap tide ranges, such as is mentioned by Shepard (1963). Although conditions on Del Monte Beach seemed favorable for detection of such a cycle in view of the fact that the tide range exceeded the breaker height nearly all of the time, no such cycle was evident. It appears that the effects of variable wave run-up on the beach overshadowed any spring-neap tide effect.

It is of interest to mention here that Strahler (1964), using a profile sampling interval of a half hour on a beach on the New Jersey coast, found a semi-diurnal cycle of cut and fill that is associated with the semi-diurnal tide. The cycle was superimposed on what he termed an equilibrium profile. A cycle of this frequency cannot be detected in our own daily data because of our choice of sampling interval. However, the effect of the daily tides evidences itself indirectly in that the lowest portion of the profile which is covered with water at all tide stages displays a greater degree of daily variation in sand level than the higher parts of the profile which are wetted fewer hours of the day.

Saturation of the beach, which was not measured, was considered as a factor in altering the beach profile through deposition and erosion of sand accompanying the seepage of water into and out of the beach face with changing water levels. It may be presumed that the water table in Del Monte Beach is determined momentarily by the tide, which undoubtedly produces a semi-diurnal fluctuation in the water table (but not one of longer period because of the high permeability of sand), by the superimposed wave run-up, and possibly by heavy rainfall and ground-water discharge from the dune field behind the beach. The effects of the water table on changing the beach profile are undoubtedly complex, and have been accounted for by the authors only indirectly in terms of the wave and tide parameters that were measured and the beach profiles that resulted.

The weather during the nine-month period consisted of dry periods punctuated by a half-dozen storms, during two of which the rainfall exceeded 2.5 cm. in 24 hours. No effects of heavy rainfall were detected in the beach profiles, either immediately following the rainfall or over a longer period of time due to possible ground-water drainage from the dune field behind the beach.

SUMMARY AND CONCLUSIONS

Del Monte Beach, because of its sheltered location in Monterey Bay, California, provides a natural laboratory for the study of beach profile change and other nearshore phenomena by virtue of the relative simplicity of the natural conditions that prevail there.

Extreme wave refraction results in a prevalence of swell of low height and breaker angle, but having a wide range of period. Coastal currents, tidal currents, and meteorological tides are negligible. There is no significant net littoral drift, accordingly, changes in the beach profile appear to involve only onshore-offshore transport of sand grains.

A breaker-height gradient occurs along the beach, so that two beach profiles were established. Gradients also occur along the beach in sand texture, beach slope, and beach curvature.

The two profiles, restricted to the intertidal zone, were measured quasi-weekly and then daily over a period of nine months. The changes in sand level at both were quite similar in magnitude in spite of the wave height gradient along the beach.

Large time-symmetrical cycles of cut and fill commonly averaging about 60 cm. at the low-tide level and covering an interval of roughly 20 days occurred irregularly throughout the period. Superimposed on these were day to day variations in sand elevation ranging up to about 20 cm. Differential cutting and filling on different parts of the profile from one day to the next commonly occured. The low-tide portion of the profiles varied most sensitively with time.

No clear-cut seasonal cycle and no fortnightly spring-neap tidal cycle was detected in the data. The concurrent nature of the daily variations of both sand level and waves recorded immediately off the beach leave no doubt that changing wave conditions were the primary cause of the changes observed in Del Monte Beach, even though no clear-cut relationship between the two factors was apparent.

The authors conclude that further observations should be carried out on Del Monte Beach and on other beaches in order to further elucidate the character of sand changes on natural beaches and determine their causes. The additional conclusion is reached that because of the sensitivity of this beach, and probably all sand beaches, to changing wave conditions, profile measurements should be made at time intervals comparable to or less than the time intervals characteristic of the changing wave conditions, if the measurements are to be used to examine the causes of profile changes. In view of the broad wave regimes occurring in the world oceans, an acceptable observation interval seems to be on the order of one day or less on open coasts.

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