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Tide and Beach Fluctuations and the Mean High Water Line

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Abstract

This paper examines how tide elevation and beach width fluctuations in southern California influence the location of the Mean High Water Line (MHWL). Tide height changes on time scales ranging from daily to the lunar node cycle of 18.6 years duration are reviewed. Beach profile data from Del Mar, California measured between 1978 and 1996 are used to illustrate beach width changes. The conclusion is that the position of either a fluctuating or an average MHWL can be determined on a typical southern California beach, provided that sufficient profile data exists.

Introduction

The Mean High Water Line is defined as "the line on a chart or map which represents the intersection of land with the water surface at the elevation of mean high water" (Hicks, 1989). The MHWL has in the past been accepted as the common law boundary between the uplands, which can be held as private property, and the tidelands, and so also the submerged lands, both of which are held by the state in trust for the public. This definition was settled upon in 17th century England, adopted by the sovereign States after the Revolution, and subsequently by the United States (Shalowitz, 1962).

In recent years, confusion has arisen in the courts about whether the MHWL is or should be the boundary, and if so, how its location can be calculated (see other papers in this session). Notwithstanding this confusion, the MHWL remains an important concept that still has enormous practical consequences pending a clear definition of an alternative boundary.

Similarities and differences between tide elevation fluctuations and beach width changes are discussed below. While there are some similarities, the chief practical difference is that there are usually far less beach width data than there are water level data. Since beach changes are also less predictable than the tides, the lack of measurements represents the most serious drawback to any effort at rationalization of shoreline boundaries in terms of the MHWL.

Mean High Water and Mean High Water Line

Mean High Water (MHW) is a tidal datum. It is defined as the average height of all high water elevations observed over (or adjusted to) a specified 19-year tidal epoch (Hicks, 1989). The definition of the MHWL states that the water level datum represents an average (*mean* high water), but implies no averaging of the horizontal position of its intersection with the beach. If the beach changes width, as most open coast beaches do, this line moves with the beach.

Beach width is usually defined as the distance from a (fixed) back shore location to the intersection of the beach profile with a given elevation plane, and is therefore closely related to the definition of the MHWL itself. This means that the MHWL is an ambulatory boundary that changes with beach width, conceivably over very short time spans. This is less than ideal, especially for a public-private boundary. In some areas, the boundary has been determined and fixed, either by agreement or court decision. But, depending upon the local shoreline processes, this may not be an ideal, long-term solution either, although boundaries can and are occasionally re-litigated.

The definition of MHW is relatively clear and generally not disputed, at least on coasts where the tide dominates the water level fluctuations. In contrast, very little seems to be understood, determined or accepted about how to account for changes in the location of the MHWL resulting from beach width changes and the resulting uncertainty in property boundaries, or even if anything should be done to improve this situation. Even where beach width data are available, there are no specific, published methods to calculate an "average" MHWL on the basis of, for example, a mean high water beach width, much less an agreed upon standard that is in any way analogous to methods developed to compute tidal datum elevations.

Water Level Fluctuations

Ocean water level changes on the coast of California are mainly due to the tide, which has a mean range of about 5.5 ft, and an extreme range of about 9 ft. Strictly defined, tides are the periodic rise and fall of waters of the earth in response to the gravitational forces of the moon and the sun. Effects of wind and barometric pressure (storm surge) reach up to about 2 ft (Flick, 1991), excluding the influence of wave set-up and surf beat in shallow water. Seasonal changes in water level are about 0.5 ft (Reid and Mantyla, 1976). In addition, climate changes and geologic processes such as subsidence, tectonic uplift and earthquake related movements produce long-term changes in relative sea level. Tide gauges indicate that relative sea level in southern California has risen about 0.7 ft over the past century (USACOE, 1989).

Tide Fluctuations

Since the tide is the dominant portion of the sea level fluctuation on most open coasts, it is logical that water level datums be computed with consideration to the inherent astronomical time scales of tidal periodicities. This is true even though the datum computations use the total water level record, not just the part attributable to the tide. In order of increasing span, the periodicities of practical importance are: 2 cpd, 2 cpm, 2 cpy, 1 cpy, 1 cp 4.4 y and 1 cp 18.6 y (where cp stands for cycle per, and d, m and y stand for day, month and year, respectively).

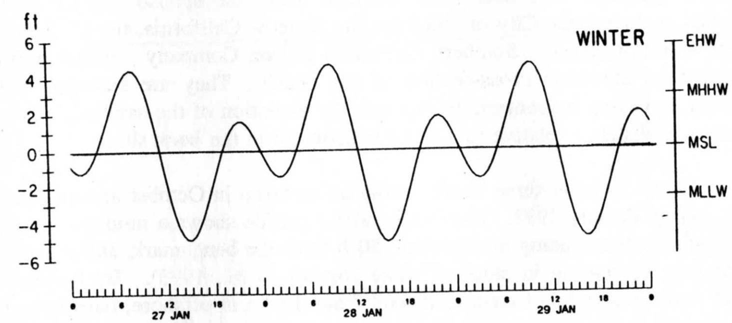

Figure 1
West-coast (San Diego) tide curve for time of peak tide range in winter.

In order to accommodate the 18.6 y lunar node cycle and the annual cycles, tidal datums are calculated over a 19-year period, the nearest whole number of years. To account for long-term sea level change, a specific 19-year period is chosen and periodically updated. This is the called the National Tidal Datum Epoch, and is currently set at 1960 - 1978 (Hicks, 1989).

Some of the important characteristics of west coast tide fluctuations are illustrated in Figure 1. The tide is mixed with nearly equal semi-daily and daily components (Zetler and Flick, 1985). The two high tides and two low tides each day are, respectively, unequal in amplitude. Monthly changes are dominated by the spring-neap cycle formed by the interference of semidiurnal constituents. This produces two periods of relatively high tides (spring) around full and new moon, and two of lower ranges (neap) around the times of half-moon (not shown). One spring tide range per month is usually higher than the other, because of changes in the moon's distance and declination. The declination dependence is called the tropic cycle and is caused by interference of diurnal constituents.

Longer period variations also occur. There is a 4.4 y cycle caused by the precession of the lunar perigee that results in higher peak monthly tides of about 0.5 ft, compared with years in between. This cycle crested in 1982-83, 1986-87, 1990-91, and 1995-96, and will peak again in 1999-2000, and periodically thereafter. The 18.6 y regression of the lunar node causes an 0.3 ft variation in peak tide heights with a maximum in 1986-87, a minimum in 1997, and so on (Zetler and Flick, 1985).

Beach Profile Changes

An 18-year long record, extending from 1978 to 1996 with gaps, of beach profile data from Del Mar, California has been accumulated at Scripps Institution of Oceanography. The data were collected under the sponsorship of various agencies, including the City of Del Mar, the State of California, the U. S. Army Corps of Engineers and Southern California Edison Company. Beach profiles represent an elevation cross-section of the beach. They are surveyed using standard surveying instruments to measure the elevation of the sand surface as a function of distance relative to a fixed benchmark in the back shore.

Figure 2 shows three beach profile traces taken in October and December 1982, and in January 1983. The October 1982 profile shows a moderately wide, flat beach berm extending up to about 150 ft from the benchmark, and a concave beach face decreasing in slope offshore (Inman, *et al.*, 1993). By December, winter storm waves had transported sand from the berm offshore, narrowing the beach width and generally flattening the beach profile. By late January 1983, the beach had been greatly reduced in width, with essentially all the sand being removed from the upper beach and moved offshore. Note that because of the concave shape of the profiles, the respective changes in beach width depend upon the elevation under consideration. At the elevation of MLLW (-2.56 ft below NGVD), the decrease in width (295 ft) between October and January was almost twice the loss (157 ft) at the elevation of MHW (2.07 ft above NGVD).

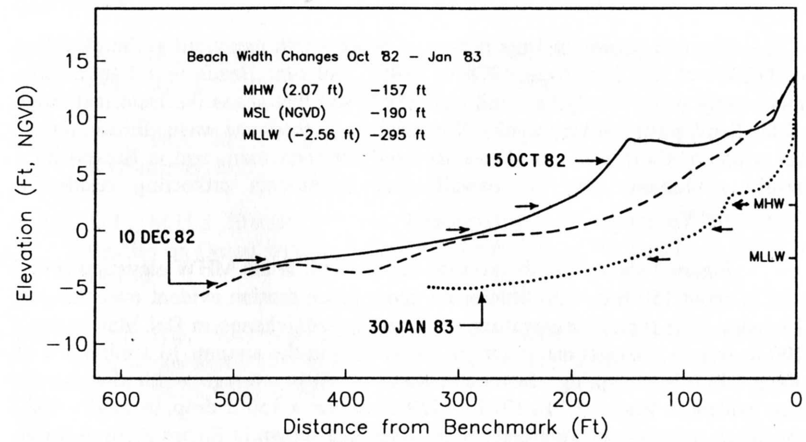

Figure 2
Beach profiles at Del Mar showing beach width decrease at elevations of MHW, MSL and MLLW during the severe winter of 1982-83.

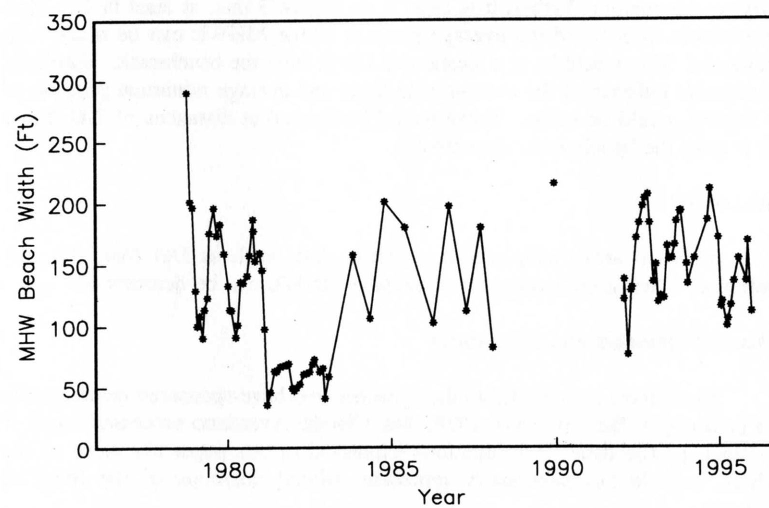

Figure 3
Time history of beach width at Del Mar, CA from 1978 to 1996.

Beach Width Changes

Figure 3 shows the time history of beach width measured at the elevation of NGVD at Del Mar from 1978 to 1996. Del Mar Beach is a 1-mile long, moderately wide, low-lying, sand and cobble spit that spans the historical range of the San Dieguito River mouth. The beach has a moderate wave climate, typical for southern California. It is heavily used for recreation, and is backed by a nearly continuous line of seawalls and revetments protecting residential development.

Figure 3 shows that the average beach width at the MHW elevation at Del Mar is about 150 feet, with little or no upper beach erosion evident over the past 18 years. The typical seasonal range of beach width change in Del Mar is about 100 ft, from a seasonal maximum of 200 ft wide in the autumn, to a minimum of about 100 ft in the spring. Several episodes of above average width changes are also evident in Figure 3. In 1978 - 1979 there was a 150 ft drop, in 1982 - 1983 the beach retreated as described above. The data shown in Figure 3 are useful to illustrate the changes in the location of the MHWL over time, and to explore various options for utilizing these data to determine an average MHWL.

The seasonal changes in beach width are analogous to the periodic fluctuations in tide range. Although Del Mar beach shows little or no sign of any trends in beach width, such trends would be present in areas of long-term beach erosion or accretion, and would be analogous to the observed rise in sea level. Carrying the analogy further, it is clear from Figure 3 that, at least in Del Mar, a reasonable estimate of the average position of the MHWL can be made with confidence. This would be at a location of 150 ft from the benchmark. Similarly, a reasonable estimate of the average maximum and average minimum position of the MHWL could be made. These would be located at distances of 200 ft and 100 ft from the benchmark, respectively.

Conclusion

In beach areas with adequate profile data, such as Del Mar, CA, the position of either a fluctuating or an average MHWL can be determined.

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