Trends in U.S. Tidal Datum Statistics and Tide Range

Reinhard E. Flick
California Department of Boating and Waterways

Joseph F. Murray
Scripps Institution of Oceanography

Lesley C. Ewing
California Coastal Commission

Yearly tidal datum statistics and tide ranges for the NOAA/NOS long-term stations in the U.S. tide gauge network were compiled to display their trends. The standard set of tidal datum statistics include: Highest Water, Mean Higher High Water (MHHW), Mean High Water (MHW), Mean Sea Level (MSL), Mean Tide Level (MTL), Mean Low Water (MLW), Mean Lower Low Water (MLLW), and Lowest Water. The statistics were calculated from monthly data published on the NOAA/NOS Internet web site. This study has been facilitated by the Internet, which has made U.S. water level data much more widely and easily available. Nevertheless, simple, comprehensive overviews of the trends revealed by these measurements, other than those for mean sea level (MSL), have been lacking.

The study was designed to address a simple question: Is the mean high tide rising as fast as mean sea level? Initial examination of the tide gauge records at San Francisco, CA showed that MHHW and MHW actually rose about 16% faster than MSL. MSL has increased by 0.720 feet per century since 1900. The faster rate of high tide rise can be attributed to the fact that the tide range is increasing. This tide range trend is due to the fact that the semidiurnal tide constituents are growing. Although the diurnal constituents are decreasing, this is not occurring fast enough to cancel the growth of the twice-per-day components. All open-coast stations on the West Coast show an increase in tide range over the available record.

The time series of the various U.S. tidal datum statistics were found to be highly variable, and different from one another. Of those U.S. stations with significant trends in tide range, 38 showed an upward trend, and 24 showed a downward trend. Some geographical patterns in tide range trends were also evident, especially on the Atlantic and Pacific coasts. Further, the 18.6 year lunar node cycle represents the largest component of the variability in the tidal datum statistics and tide ranges at many stations, and was quantified at each site.

This analysis focused on the observed trends in tide range, and on the trends in high water, especially relative to MSL, subjects of interest to coastal engineers. Several stations showed rates of increase of MHW that were about twice those of MSL. Interesting cases of secular change in tide regime were also revealed. At Galveston, TX for example, the diurnal inequality seems to have decreased. At Anchorage, AK the tide range has increased, but the low tides tended downward much faster than the high tides tended upward (both absolutely, and relative to MSL), leading to a falling MTL, even as MSL increased.

Few studies have been published that analyze changes in tide range, and none could be found for U.S. coasts. Bowen (1972) reviewed previous work and examined long-term trends in the Thames River. The study suggests that the observed increase in tide range in the upper Thames estuary was caused mainly by bank raising and river channelization. Amin (1983), also in a study of the Thames estuary, found that the diurnal tidal constituents were unchanged between 1929 and 1979, but that the semidiurnal constituents increased. Cartwright (1972) analyzed sea level observations made between 1711 and 1936 at Brest, France and found a 1% per century decrease in semidiurnal tidal amplitude. This study could not determine whether the changes were oceanic, or were due to local coastal modifications, but does suggest that any influences of harbor development at Brest is probably insignificant.

This analysis suggests that any studies concerned with present or future water levels should take into account tidal datum statistics beyond MSL. For example, coastal flooding and storm damage studies should consider trends and fluctuations in high water levels, since it is the peak values that cause flooding and determine the design of coastal structures. For habitat restoration planning, mean low water and tide range changes should be considered. Finally, new research proposes that cyclical changes in tide potential may modulate earth's climate on short and long time scales (Keeling and Whorf, 1997, 2000). Summaries of actual tide range measurements should be important to verify this mechanism.