Perspective
Volume 5

COASTAL SYSTEMS INTERNATIONAL

Figure 1: Datum Dilemma

Tidal Datums

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Tidal Datums impact coastal engineering, dredging, navigation and law. Whether you are a captain of a ship or a waterfront property owner, the depth of the water is of concern. However, if you are driving through the Eisenhower Tunnel in Colorado on Interstate 70 through the Continental Divide at elevation 11,112 feet above mean sea level, the mean sea level reference is generally not a concern. A few feet difference at this elevation is not likely to cause any problems, but a few feet difference on the coast could mean the grounding of a ship. The question is, what is mean sea level, and if tidal datums vary along the coast, then does the elevation of Eisenhower Tunnel vary? Also, what is the difference between MLW and MLLW, and how does NGVD or NAVD relate to these datums? These are common questions and sources of confusion along the coast, and this perspective will provide an overview of tidal datums.

Geodetic Datum

It is important to understand a geodetic datum before addressing tidal datums. These datums are easier to understand vertical references, since they are constant throughout the United States. A geodetic datum is a fixed reference adopted as a standard geodetic datum for heights. The National Geodetic Vertical Datum (NGVD) was derived from land surveys from a general adjustment of the first order level nets in the U.S. and Canada. Essentially, surveyors ran levels from coast-to-coast as mean sea level was held fixed at the sites of 26 tide gauges. The datum is defined by the observed heights of mean sea level at the 26 tide gauges and by the set of elevations of all bench marks resulting from the adjustment. A total of 106,724 km of leveling was completed. The National Ocean Service (NOS) lists the difference between tidal datums and NGVD for every tidal datum along the coast. The relationship between the geodetic datum and the local mean sea level is not consistent at locations along the coasts. The elevation of

Eisenhower Tunnel is referenced to NGVD, and not mean sea level. Although NGVD 29 closely resembles the mean sea level of 1929, since measurements were made concurrently at 26 locations in 1929.

NGVD has recently been superceded by the North American Vertical Datum (NAVD) 88, which was derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. The National Geodetic Survey (NGS) is a good source of information on the conversion from NGVD to NAVD. This transition process will take some time as many construction plans, FEMA flood maps, topographic surveys, dredging projects, etc. still reference NGVD.

The Tide

The rise and fall of the tides along the coast is a complex process, and the range of the tide influences the establishment of a tidal datum. If the water levels along the coast did not change, there would be no need for tidal datums. To help understand the need for establishment of tidal datum, it is important to have a basic understanding of tidal hydraulics. By definition from the National Oceanic and Atmospheric Administration (NOAA), the tide is the periodic rise and fall of the water resulting from gravitational interactions between the sun, moon and earth. Most areas in the Atlantic coastal United States are subject to semi-diurnal tides that have a period (or cycle) of approximately one-half of a tidal day, or to be exact 12 hours, 25 minutes. The tide is actually a wave; the wave period is the difference from the wave crest to crest or trough to trough. For tides, the crest is essentially "high tide" and the trough is "low tide." There are two high and two low tides in a 24-hour day. There are two other types of tides, diurnal and mixed, which are observed in some parts of the gulf coast of the United States. **Figure 2** illustrates a semidiurnal tide.

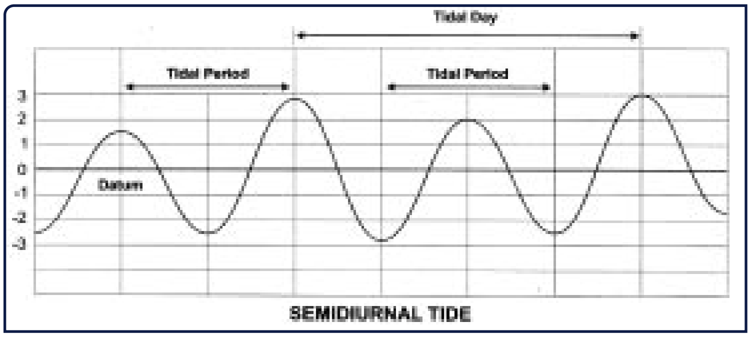

Figure 2: Basic Tide Figure (Courtesy NOS)

Figure 3 and Table 1 illustrate typical tidal ranges along the Atlantic and Gulf Coasts of the United States. Note that the tide ranges vary greatly, with selected mean tidal ranges in **Table 1**.

LOCATION	TIDE RANGE (ft)
Miami, Florida:	2.32’
Seattle, Washington:	7.66 ‘
New York:, New York	4.53’

Table 1: Tide Ranges

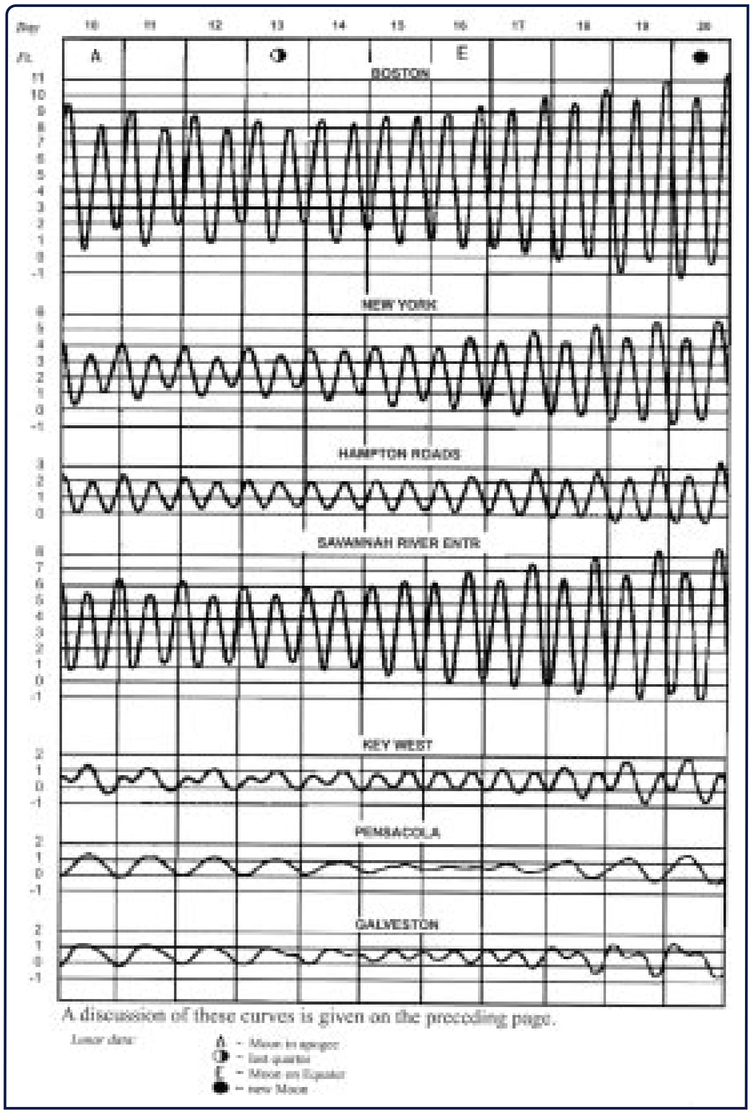

Figure 3: Tide Figures (Courtesy NOS)

The best source of information on tides and water level observations is the NOS Center for Operational and Oceanographic Products and Services available online at www.TidesandCurrents.noaa.gov/.

Tidal Datum

Based on the variability of the tides discussed in the above paragraphs, how does the NOS establish a tidal datum when the vertical plane of reference moves up and down relative to a fixed geodetic datum such as NAVD 88? A tidal datum is simply the plane that defines the intersection between the ocean and the land, and it is referenced to an average fixed height of the water level during the tidal cycle. The datum is determined from water level measurements obtained along the coast including estuaries and rivers influenced by the tide. The NOS, which is a branch of the NOAA, is responsible for establishing tidal datums and monitoring water levels in the United States. It is important to remember that tidal datum are local datums, and they vary from location to location along the coasts.

The NOS has conducted water level observations to establish these tidal datums. All water level observations are referenced to a specific 19-year metonic cycle, or the National Tidal Datum Epoch. The epoch is used for tidal datum determinations, and the 19-year metonic cycle is used to obtain the arithmetic mean of tidal height observations so that all tidal datum determinations throughout the United States will have a common reference. The current National Tidal Datum Epoch is 1983-2001, which recently superceded the previous 1960-1978 epoch.

These water level observations are averaged to provide the following datum:

- Mean Low Water (MLW): The arithmetic mean of the low water heights observed over a specific 19-year Metonic cycle.

- Mean Lower Low Water (MLLW):The arithmetic mean of lower low water heights of a mixed or semi-diurnal tide observed over a specific 19-year Metonic cycle. Only the lowest low water of each pair of low waters of a tidal day is included in the mean. MLLW is the nauticalchart datum for navigation in the United States.

Similarly, the definitions for Mean High Water (MHW) and Mean Higher High Water (MHHW) are based on averages for the respective high water heights. A typical tide station sheet as published by the NOS is listed in **Table 2**: Tidal datum at Virginia Key, Biscayne Bay, Florida. (Station 8723214).

LENGTH OF SERIES:	8 YEARS
TIME PERIOD:	01/1994 - 12/2001
TIDAL EPOCH:	1983 - 2001
CONTROL TIDE STATION:	8724580 KEY WEST
HIGHEST OBSERVED WATER LEVEL (11/15/1994)	= 1.263 (4.14’)
MEAN HIGHER HIGH WATER (MHHW)	= 0.684 (2.24’)
MEAN HIGH WATER (MHW)	= 0.662 (2.17’)
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	= 0.608 (1.99’)
MEAN TIDE LEVEL (MTL)	= 0.349 (1.15’)
MEAN LOW WATER (MLW)	= 0.036 (0.12’)
MEAN LOWER LOW WATER (MLLW)	= 0.000 (0.00’)
LOWEST OBSERVED WATER LEVEL (03/29/1994)	= -0.393 (-1.29’)
ELEVATIONS OF TIDAL DATUM REFERRED TO MEAN LOWER LOW WATER (MLLW), IN METERS	

Table 2: Typical Tide Station Sheet

Note the difference between MLW and MLLW in **Table 2** is only 0.12 feet in the Miami, Florida area. This difference in Seattle, Washington is 1.48 feet!

The NOS relies on a network of control tide stations for these 19-year metonic cycle observations. These primary stations are supplemented by secondary and tertiary stations to provide adequate tidal datum coverage along the coasts. Secondary stations operate for at least one year, but less than 19 years. Tertiary stations operate less than one year but more than one month. The NOS mathematically adjusts the measurements at a tertiary or secondary station to establish tidal datum for a particular area since it is not practical to observe tides for 19 years at each location. In the State of Florida, there are over 300 separate tidal datums. The Virginia Key tidal datum in **Table 2** is based on 8 years of observations, and therefore it is a secondary tide station referenced to a control station in Key West.

Hydrographic Surveys & Datums

Conventional topographic land surveys and maps typically reference a geodetic datum. Coastal shoreline areas and waterfront properties are areas where land and hydrographic surveys often overlap. The use of proper datums can be confusing. Some regulatory agencies require surveys referenced to the geodetic datum, however, tidal datum references are required to understand navigation and the depth of water at a potential marina site, for example. Hydrographic surveys are conducted to map the sub-surface topography. Surveys are conducted for applications such as shipping channels and for dredging. For all surveys (land and hydrographic) conducted in tidal areas, a diagram of datum plane is a helpful tool that graphically illustrates the differences between the datum, and ALWAYS references a geodetic datum. The relationship between NAVD 88 and the tidal datum (usually MLLW) should be shown on the survey map as illustrated in **Figure 4.**

Dredging & Tidal Datums

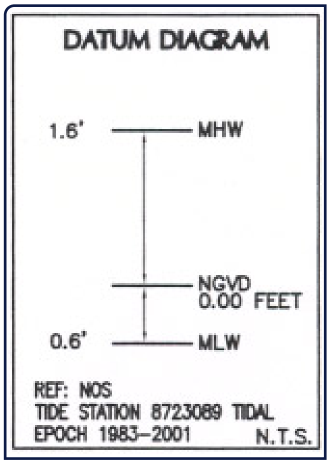

Figure 4: Diagram of Datum Plane

Specific tidal datums are sometimes developed for dredging and navigation projects. The NOS tidal datum may not provide adequate coverage for a dredging project along a navigation channel in a tidally-influenced bay or river. The U.S Army Corps of Engineers will establish gauging stations to determine site-specific tidal datums for use in a dredging construction project. **Figure 5** illustrates the reduction in tidal variation and gauging adjustments made by the Corps of Engineers for the dredging of the Miami River.

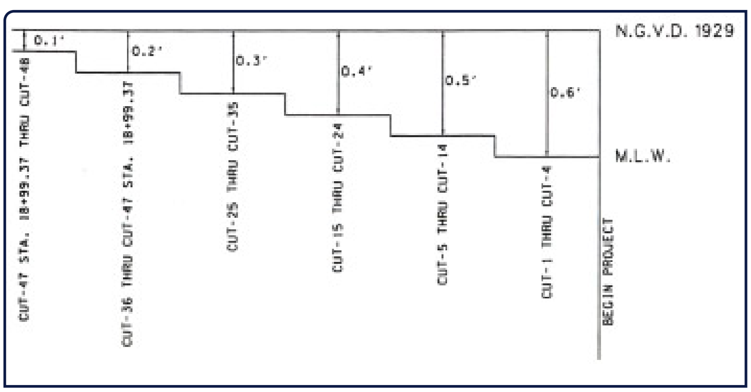

Figure 5: Vertical Datum Diagram for Dredging Project

At the mouth of the Miami River (closest to the ocean), the tide difference between MLW and NGVD is 0.6 feet, and at the upstream end of the proposed navigation project, the tide difference is only 0.1 feet. The nearest NOS published tidal bench mark is in Biscayne Bay, which necessitated the establishment of a project-specific tidal datum relationship for the dredging project. If the tidal datum at the mouth of the river was used for the dredging of the entire project, an excessive amount of dredging would have been conducted to provide adequate navigation depths for vessels.

Tidal Datums As Legal Boundaries

Tidal datums are referenced as legal shoreline boundaries in many states. For example, a boundary survey for a piece of property may reference the mean high water (MHW) line or MLW line as the property boundary between an upland piece of property and state sovereign land. The Florida Department of Environmental Protection (DEP) Bureau of Surveying and Mapping is presently developing an interactive web-based map which will allow the user to obtain mean high water (MHW) datum over the internet. A qualified, registered land surveyor must be retained to establish water boundaries, and the discussion of legal water boundaries is beyond the scope of this perspective. For more information on the methods and procedures for MHW surveys in the State of Florida, please visit:

http://data.labins.org/2003/SurveyData/WaterBoundary/MHW_Procedures/index.cfm

References

Tidal Datums and Their Applications, NOAA Special Publication NOS CO-OPS 1

The National Tidal Datum Convention of 1980, NOS.

NOS Center for Operational and Oceanographic Products and Services, www.TidesandCurrents.noaa.gov

National Geodetic Survey, www.ngs.noaa.gov

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