Datums and Tides

Mean Low Tide versus Mean Lower Low Water

And the winner is.........!
Measuring Water Depths

• Boats, Airborne LIDAR, Satellites, AUV’s/ROV’s – Differences?

• Sensor Positioning
  1. GPS
  2. Laser

• Sensor motion
  1. Roll
  2. Pitch
  3. Heave
Airborne LIDAR Data
Variations in Water Surface Elevations

- Tides
- Waves
- Standing Waves (Seiches)
- Meteorological (wind, low/high pressure, storms)
- Earthquake (Tsunamis)
- Flow (Rivers, & Lakes/Reservoirs)
- Large Vessel Motion
- Climate Change/Tectonics
Why Do We Care?

• Accuracy of Result

• Repeatability of Result

• Comparison with Other (land) Data

• Relationship to Sea Level
## Corps Error Budget Tables

<table>
<thead>
<tr>
<th>Error Budget Source</th>
<th>Inland Navigation</th>
<th>Turning Basin</th>
<th>Coastal Entrance</th>
<th>Coastal Offshore</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min river slope</td>
<td>2 ft tide range</td>
<td>4-ft tide range</td>
<td>8-ft tide range</td>
</tr>
<tr>
<td></td>
<td>Staff gage &lt; 0.5 mile</td>
<td>Gage &lt; 1 mile</td>
<td>Gage &lt; 2 mile</td>
<td>Gage &gt; 5 mile</td>
</tr>
<tr>
<td></td>
<td>12-ft project</td>
<td>26-ft project</td>
<td>43-ft project</td>
<td>43-ft project</td>
</tr>
<tr>
<td></td>
<td>&lt;26-ft boat</td>
<td>&lt;26-ft boat</td>
<td>&lt;26-ft boat</td>
<td>65-ft boat</td>
</tr>
<tr>
<td></td>
<td>No H-P-R</td>
<td>No H-P-R</td>
<td>No H-P-R</td>
<td>H-P-R corn</td>
</tr>
<tr>
<td>Measurement system accuracy</td>
<td>0.05</td>
<td>0.05</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Velocity calibration accuracy</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.15</td>
</tr>
<tr>
<td>Sounder resolution</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Draft/index accuracy</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Tide/stage correction accuracy</td>
<td>0.1</td>
<td>0.15</td>
<td>0.25</td>
<td>0.5</td>
</tr>
<tr>
<td>Platform stability error</td>
<td>0.05</td>
<td>0.2</td>
<td>0.3</td>
<td>0.25</td>
</tr>
<tr>
<td>Vessel velocity error</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.15</td>
</tr>
<tr>
<td>Bottom reflectivity/sensitivity</td>
<td>0.05</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>RMS (95%)</strong></td>
<td>± 0.37 ft</td>
<td>± 0.66 ft</td>
<td>± 0.90 ft</td>
<td>± 1.32 ft</td>
</tr>
<tr>
<td><strong>Allowed per Table 3-1</strong></td>
<td>± 0.5 ft</td>
<td>± 1.0 ft</td>
<td>± 1.0 ft</td>
<td>± 2.0 ft</td>
</tr>
</tbody>
</table>
What is a seiche?

A seiche is a standing wave oscillating in a body of water.

This animation shows a standing wave (black) depicted as a sum of two propagating waves traveling in opposite directions (blue and red). Similar in motion to a seesaw, a seiche is a standing wave in which the largest vertical oscillations are at each end of a body of water with very small oscillations at the "node," or center point, of the wave. Standing waves can form in any enclosed or semi-enclosed body of water, from a massive lake to a small coffee cup.
Mississippi River

Av. Gradient = 0.5 feet per river mile
Figure 21. Relative sea level change at several locations in the U.S.
**Tides**

**Common Terms**

**Tide**: The alternating rise and fall of water levels with respect to land

**Tidal Current**: Horizontal motion resulting from rise & fall of water levels

**Tide Range**: difference in height between highest high & lowest low

**Tidal Period**: Time between successive lows or highs (Average ~12.4hs)

**Tidal Frequency**: How often 1 tidal period occurs per day (Average ~1.9 cycles per day)

**Mean Sea Level**: Average height of sea surface
Tide Generating Forces
Summary of Tide Generating Forces

**Astronomical Forces:**

- Gravitational pull of Moon creates bulge directly beneath Moon
- Centrifugal forces due to the Earth-Moon’s rotation creates second bulge opposite of Moon.
- Variations in the positions of the Moon & Sun relative to the Earth produce monthly variations in tides.
- Variations in the path of the Moon about the Sun produce decadal (18.6 yr) variations in tides
- Variations in the distance of the Earth/Moon from the Sun/Earth due to their elliptical orbits produce annual/monthly variations in tides.
- Variations in the declination of the Moon produces daily variations in the tides.

**Tides:**

- Deterministic; predictable
- With enough water level data, the tides can be predicted indefinitely for that location
Water Depths to Elevations

Datums (Vertical)

Terrestrial

- NGVD29
- NAVD88
- Mean Low Tide

Sea Level

- Mean Sea Level
- Mean Low Tide
- Mean High Tide

Plant
The following slide is taken directly from the NOAA/TCOON web sites pages that gives the official relationships for the various Sea Level Datums (Mean Sea Level and it’s various statistical offsets) and the Land (Terrestrial) Datums (NAVD88 and Mean Low Tide) for the Rainbow Bridge on the Neches River Channel. This location has been chosen because it is one of the (currently) few NOAA tide gauge sites for which data is available in real time on the internet, and has published the relationship between the Sea and Terrestrial datums.

One thing should be borne in mind. Mean Sea Level changes both by location around the coastline of the U.S. and over long periods of time. The relationships at the Rainbow Bridge do NOT hold true anywhere else - although the differences MAY be minor.
The relationships shown here are given reference to an arbitrary "station datum". Following slides have changed this to make things relative to Mean Low Low Water via high level math (addition and subtraction!!)

NAVD 88 elevation updated 5/2013, stated accuracy is 0.028m (about 1 inch). These datums are marked preliminary until the 2013 levels are run.
TIDAL/TERRESTRIAL DATUMS
Rainbow Bridge,
Port Arthur, Texas

Source: TCOON Web Site http://www.cbi.tamu.edu/TCOON/
US Army Corps of Engineers

Note that the original definition of Mean Low Tide was a variable offset from NGVD29 depending on location. (For this project area 0 ft. NGVD29 = +0.78 ft MLT) CRA has applied the known offset from NGVD29 to the newer NAVD88 datum for the work area (0 ft NGVD29 = +0.05 ft NAVD88) to define the relationship 0 feet NAVD 88 = +0.73 feet MLT. There is some uncertainty as to whether the Corps of Engineers is applying the original offset values to the new NAVD88 datum or is making the adjustment from NGVD29 as has been done here.

The following is an extract from the TCOON Datums data page for their tide gauge at the Rainbow Bridge. Note that they use an arbitrary "Station Datum" so that all measurements are positive. The differences between NAVD88 and the various tidal datums have been used for the drawing above.

July 20th 2013
Confused? Let's Try an Example!

Today
Suppose your dock/channel is at its design depth of 42 feet mean low tide and suppose the water level is at mean sea level (in between high and low tide) and you happen to be close to the Rainbow Bridge on the Neches River Channel.

But how do you know what the water level is?
Read a tide staff set to the mean low tide datum by a hydrographic surveyor -- or the Corps of Engineers.

Not got one? Too difficult?
Next slide.

You actually have 43.03 feet of water at the dock or in the channel!!
At high tide you have even more!
At low tide you have less.
At low tide and with a blue norther wind you could have less than 42 feet of water!!!!

* The actual depth of a dock or channel is determined by some sort of survey, typically a depth sounding survey using an automated data acquisition system.
TODAY

Look up the NOAA Tide Gauge on the Web
Assume it says that the current tide level is +1.5 feet Mean Low Low Water

TOMORROW- ish!

The NEW number for the design depth of the dock/channel is -42.5 feet
(Its JUST a number change!!)

Look up the NOAA Tide Gauge on the Web
(or look at your NEW tide staff at the dock or on the channel)
Again assume it says that the current tide level is +1.5 feet Mean Low Low Water

You now have 44 feet of water at the Dock or in the Channel!! (Actually 43.95 feet but that's close enough!)

You now have 44.0 feet of water at the Dock or in the Channel!!

NO DIFFERENCE!!!!
Datum Change - MLT to MLLW

- USACE - Chris Frabotta’s Presentation
  New Tide Staffs and Gauges – more of them!

- CRA’s Plans
  New, simple recording tide gauges at client docks. Measures water elevation from known point by bouncing sound waves off the surface and averaging over a selected interval and uploading result via Iridium satellite to CRA or client web site. Equipment/Installation cost ~ $2,000 plus $50/month data fee.
The following are provided for reference purposes - if you are feeling bold.
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HAT</strong></td>
<td>Highest Astronomical Tide is the elevation of the highest predicted astronomical tide expected to occur at a specific tide station over the National Tidal Datum Epoch.</td>
</tr>
<tr>
<td><strong>MHWH</strong> Mean Higher High Water</td>
<td>The average of the higher high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.</td>
</tr>
<tr>
<td><strong>MHW</strong> Mean High Water</td>
<td>The average of all the high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.</td>
</tr>
<tr>
<td><strong>DML</strong> Diurnal Tide Level</td>
<td>The arithmetic mean of mean higher high water and mean lower low water.</td>
</tr>
<tr>
<td><strong>MTL</strong> Mean Tide Level</td>
<td>The arithmetic mean of mean high water and mean low water.</td>
</tr>
<tr>
<td><strong>MSL</strong> Mean Sea Level</td>
<td>The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch. Shorter series are specified in the name; e.g. monthly mean sea level and yearly mean sea level.</td>
</tr>
<tr>
<td><strong>MLW</strong> Mean Low Water</td>
<td>The average of all the low water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.</td>
</tr>
<tr>
<td><strong>MLLW</strong> Mean Lower Low Water</td>
<td>The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.</td>
</tr>
<tr>
<td><strong>LAT</strong> Lowest Astronomical Tide</td>
<td>The elevation of the lowest astronomical predicted tide expected to occur at a specific tide station over the National Tidal Datum Epoch.</td>
</tr>
<tr>
<td><strong>GT</strong> Great Diurnal Range</td>
<td>The difference in height between mean high water and mean low water.</td>
</tr>
<tr>
<td><strong>MN</strong> Mean Range of Tide</td>
<td>The difference in height between mean high water and mean low water.</td>
</tr>
<tr>
<td><strong>DHQ</strong> Mean Diurnal High Water Inequality</td>
<td>The difference in height of the two high waters of each tidal day for a mixed or semidiurnal tide.</td>
</tr>
<tr>
<td><strong>DLQ</strong> Mean Diurnal Low Water Inequality</td>
<td>The difference in height of the two low waters of each tidal day for a mixed or semidiurnal tide.</td>
</tr>
<tr>
<td><strong>HWI</strong> Greenwich High Water Interval</td>
<td>The average interval (in hours) between the moon's transit over the Greenwich meridian and the following high water at a location.</td>
</tr>
<tr>
<td><strong>LWI</strong> Greenwich Low Water Interval</td>
<td>The average interval (in hours) between the moon's transit over the Greenwich meridian and the following low water at a location.</td>
</tr>
<tr>
<td><strong>Station Datum</strong></td>
<td>A fixed base elevation at a tide station to which all water level measurements are referred. The datum is unique to each station and is established at a lower elevation than the water is ever expected to reach. It is referenced to the primary bench mark at the station and is held constant regardless of changes to the water level gauge or tide staff. The datum of tabulation is most often at the zero of the first tide staff installed.</td>
</tr>
<tr>
<td><strong>National Tidal Datum Epoch</strong></td>
<td>The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years. Tidal datums in certain regions with anomalous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch.</td>
</tr>
</tbody>
</table>
What are NGVD 29 and NAVD 88?
"The National Geodetic Vertical Datum of 1929: The name, after May 10, 1973, of (the) Sea Level Datum of 1929." (Geodetic Glossary, pp. 57)

"Sea Level Datum of 1929: A vertical control datum established for vertical control in the United States by the general adjustment of 1929."

"Mean sea level was held fixed at the sites of 26 tide gauges, 21 in the U.S.A. and 5 in Canada. 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 involved, constituting 246 closed circuits and 25 circuits at sea level."

"The datum (was) not mean sea level, the geoid, or any other equipotential surface. Therefore it was renamed, in 1973, the National Geodetic Vertical Datum on 1929." (Geodetic Glossary, pp. 56)

The North American Vertical Datum of 1988 (NAVD 88) is the vertical control datum established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-U.S. leveling observations. It held fixed the height of the primary tidal bench mark, referenced to the new International Great Lakes Datum of 1985 local mean sea level height value, at Father Point/Rimouski, Quebec, Canada. Additional tidal bench mark elevations were not used due to the demonstrated variations in sea surface topography, i.e., the fact that mean sea level is not the same equipotential surface at all tidal bench marks.
Links

http://tidesandcurrents.noaa.gov/datum_options.html

http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf

http://www.ngs.noaa.gov/datums/vertical/VerticalDatums.shtml

http://www.cbi.tamucc.edu/cbi/data

http://tidesandcurrents.noaa.gov/