3. GENERAL TIDAL DATUM COMPUTATION PROCEDURES

3.1 Datum Computation Procedures Overview

A vertical datum is termed a tidal datum when it is defined by a certain phase of the tide. Tidal datums are local datums and should not be extended into areas which have differing hydrographic characteristics without substantiating measurements. In order that they may be recovered when needed, such datums are referenced to fixed points known as bench marks.

1. Make Observations - Tidal datums are computed from continuous water level observations over specified lengths of time. Observations are made at specific locations called tide stations. Each tide station consists of a water level gauge or sensor(s), a data collection platform or data logger and data transmission system, and a set of tidal bench marks established in the vicinity of the tide station. NOS collects water level data at 6-minute intervals.

2. Tabulate the Tide - Once the 6-minute interval data are quality controlled and any small gaps filled, the data are processed by tabulating the high and low tides and hourly heights for each day. Tidal parameters from these daily tabulations of the tide are then reduced to mean values, typically on a calendar month basis for longer period records or over a few days or weeks for shorter-term records.

3. Compute Tidal Datums - First reduction tidal datums are determined directly by averaging values of the tidal parameters over a 19-year NDTE. Equivalent NDTE tidal datums are computed from tide stations operating for shorter time periods through comparison of simultaneous data between the short-term station and a long term station.

4. Compute Bench Mark Elevations - Once the tidal datums are computed from the tabulations, the elevations are referenced to the bench marks established on the land using the elevation differences established by differential leveling between the tide gauge sensor “zero” and the bench marks during the station operation. The bench mark elevations and descriptions are disseminated by NOS through a station specific published bench mark sheet. Connections between tidal datum elevations and geodetic elevations are obtained after leveling between tidal bench marks and geodetic network bench marks. Traditionally, this has been accomplished using differential leveling, however GPS surveying techniques can also be used (NGS, 1997).

A primary determination of any tidal datum is based directly on the average of observations over a 19 year period. For example, a primary determination of Mean High Water is based directly on the average of the high waters over a 19 year period. Tidal datums must be specified with regard to the NTDE. Although many tidal datums are discussed in this report, the principal tidal datums include Mean Higher High Water (MHHW), Mean High Water (MHW), Mean Sea Level (MSL), Mean Low Water (MLW), and Mean Lower Low Water (MLLW) (Marmer, 1951 and NOS, 2000).

MHHW is defined as the arithmetic mean of the higher high water heights of the tide observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). Only the higher high water of each pair of high waters of a tidal day is included in the mean (Figure 1). For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of a 19-year value (Marmer, 1951).

MHW is defined as the arithmetic mean of all of the high water heights observed over a specific 19-year Metonic cycle (the NTDE). For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of a 19-year value.

MSL is defined as the arithmetic mean of hourly heights observed over a specific 19-year Metonic cycle (the NTDE). Shorter series are specified in the name, like monthly mean sea level or yearly mean sea level (e.g., Marmer, 1951; Hicks, 1985).

MLW is defined as the arithmetic mean of all of the low water heights observed over a specific 19-year Metonic cycle (the NTDE). For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of a 19-year value.

MLLW is defined as the arithmetic mean of the lower low water heights of the tide observed over a specific 19-year Metonic cycle (the NTDE). Only the lower low water of each pair of low waters of a tidal day is included in the mean. For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of a 19-year value.

In addition, the Mean Tide Level (MTL), Diurnal Tide Level (DTL), Mean Range (Mn), Diurnal High Water Inequality (DHQ), Diurnal Low Water Inequality (DLQ), and Great Diurnal Range (Gt) are defined as follows:

MTL is a tidal datum equivalent to the average of MHW and MLW.

DTL is a tidal datum equivalent to the average of MHHW and MLLW.

Mn is the difference in elevation between MHW and the MLW.

DHQ is the difference in elevation between MHHW and MHW.

DLQ is the difference in elevation between MLW and MLLW.

Gt is the difference in elevation between MHHW and MLLW.

3.2 Other Vertical Datums and Their Relationship to Tidal Datums

In addition to tidal datums, other vertical datums are determined and employed for various applications. Examples are fixed datums of the National Geodetic Reference System, or the National Geodetic Vertical Datum (NGVD 1929) (previously referred to as the Sea Level Datum of 1929), or the North American Vertical Datum of 1988 (NAVD 88). NGVD 1929 is a fixed datum adopted as a standard geodetic reference for heights and was derived from a general adjustment of the first order leveling nets of the US and Canada, in which MSL was held fixed as observed at 26 stations in the US and Canada. Numerous adjustments have been made to these leveling networks since originally established in 1929. The North American Vertical Datum of 1988 (NAVD 88) involved a simultaneous least-squares, minimum constraint adjustment of the Canadian-Mexican-US leveling observations. Local MSL was held fixed at Father Point/Rimouski, Quebec, Canada, as the single constraint. The North American Vertical Datum of 1988 (NAVD 88) and International Great Lakes Datum of 1985 (IGLD 85) are both based upon this simultaneous, least-squares, minimum constraint adjustment of Canada, Mexico, and U.S. leveling observations. These fixed geodetic datums (e.g., NGVD 1929 and NAVD 88) do not reflect the changes in sea level and because they represent a "best" fit over a broad area, their relationship to local mean sea level differs from one location to another. MSL is a tidal datum often confused with NGVD 1929 and they are not equivalent. NGVD 1929 was replaced by NAVD 88 and the National Geodetic Survey no longer supports the NGVD 1929 system.

Figure 12 shows the datums related to Station Datum (STND) at San Francisco Bay, CA. The elevation of the primary bench mark (PBM 180 1936), is 5.794 m above STND. The Highest Water Level (HWL) recorded at San Francisco is 4.462 m above station datum, and the Lowest Water Level (LWL) is 0.945 m . HWL and LWL are not tidal datums, but are the extreme values of the maximum and minimum water levels recorded at the station. For San Francisco Bay, the value of NGVD 29 is below Mean Sea Level (MSL), and NAVD88 is lower still. MSL pertains to local mean sea level and should not be confused with NAVD 88, the ellipsoid or the superseded NGVD 29. Figures 13a and 13b show why the direct transfer of tidal datum relationships through NAVD 88, NGVD 29 or the ellipsoidal differences, even within the same bay, estuary or river, may not be accurate. The graph illustrates that tidal datums are local datums relative to the land and great care must be taken to extrapolate tidal datum differences and relationships to geodetic datums. In some instances, linear interpolation can be used to estimate datum relationships between two known points along a stretch of shoreline that is not very complicated in a topographic and bathymetric sense.

When in doubt of the relationship of a tidal datum to a geodetic datum, establishment of a tide station and connection to geodetic datum using differential levels or GPS is recommended for most applications. NOS establishes geodetic connections at the NWLON stations through differential levels between tidal bench marks and geodetic bench marks. Use of GPS survey equipment to occupy tidal bench marks is the emerging state-of-the-art method for making the connections. See the NOS Web-sites at www.tidesandcurrents.noaa.gov and www.ngs.noaa.gov for further information on geodetic and tidal datum elevations on bench marks.

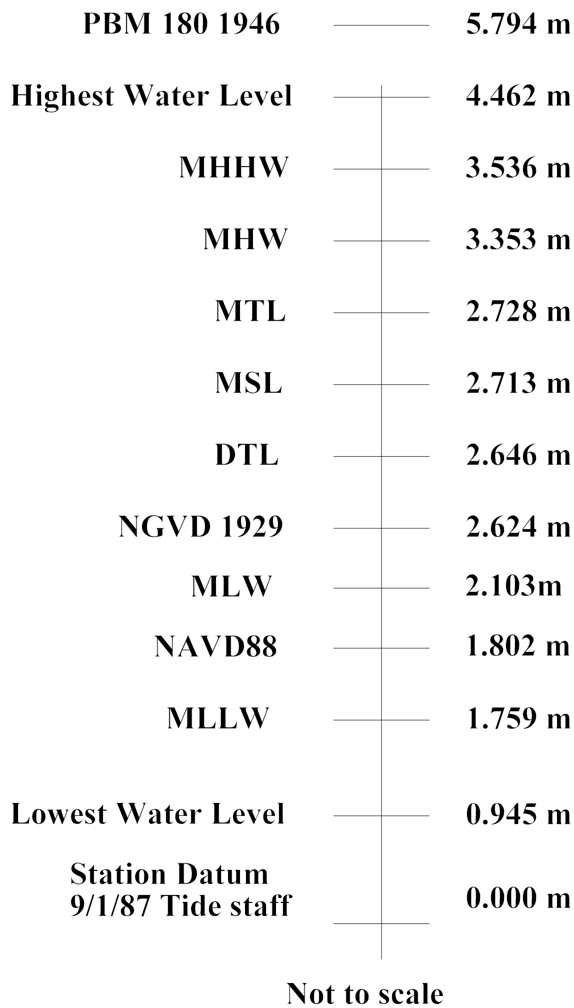

Figure 12. A tidal datum stick diagram for San Francisco, CA showing the relationships of the various tidal and geodetic datums.

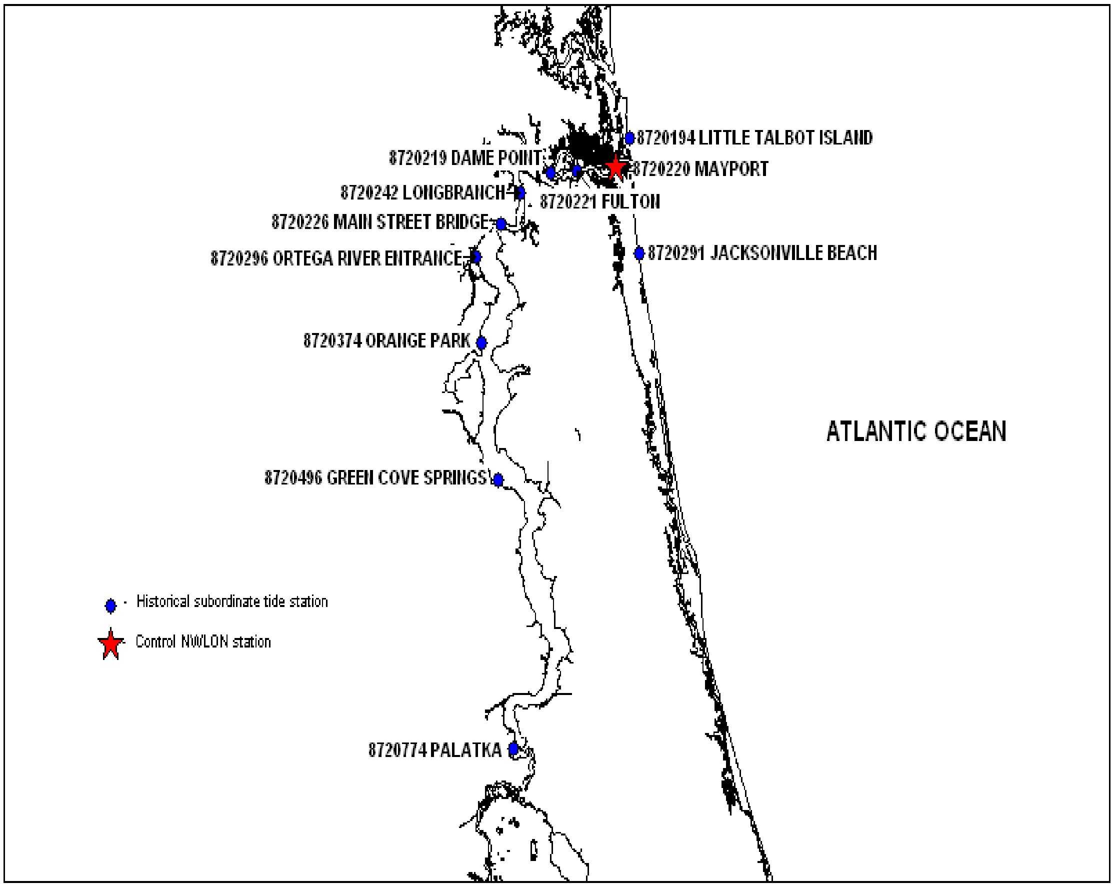

Figure 13a. Locations of stations plotted in Figure 13b.

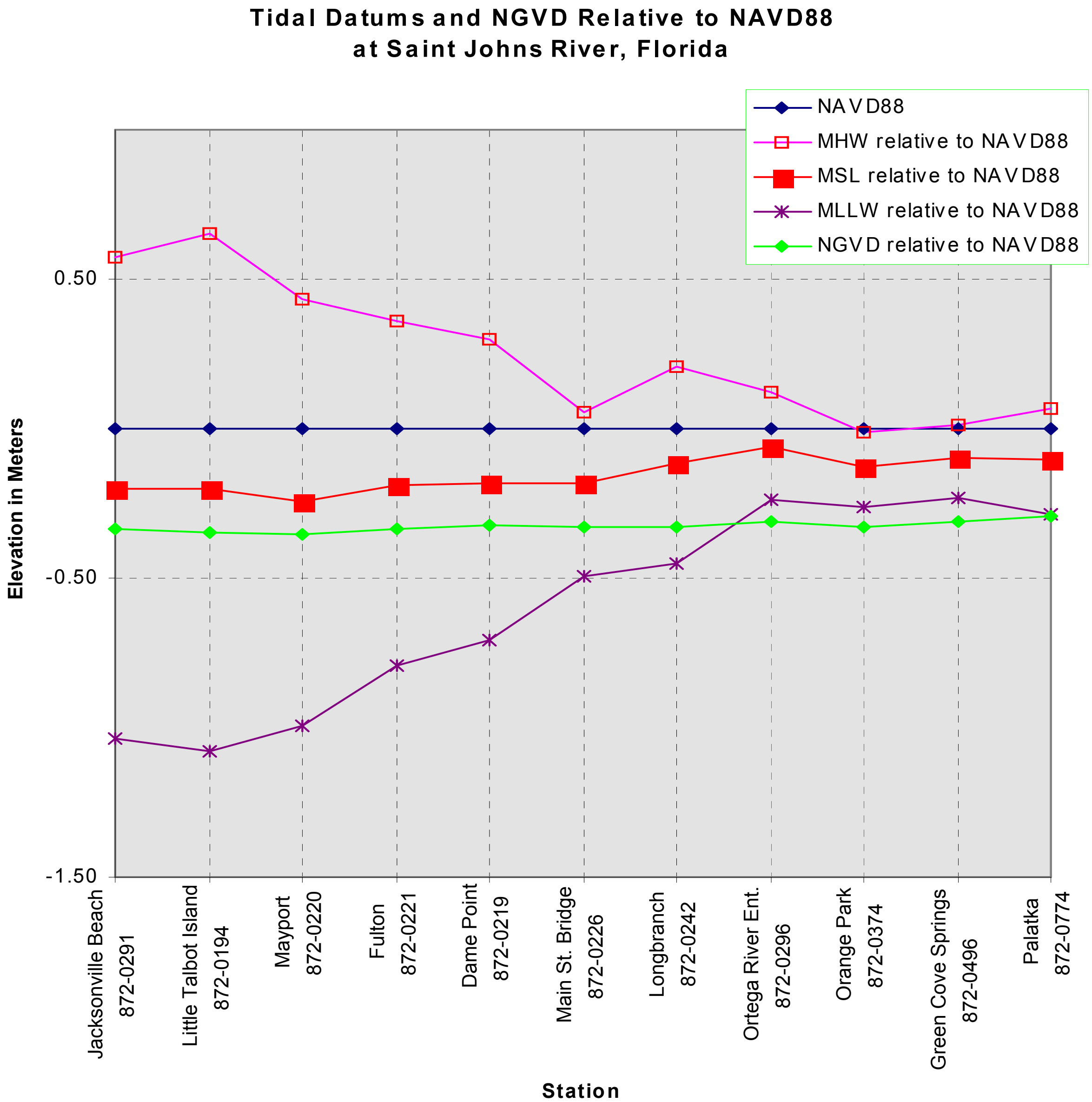

Figure 13b. The relationship of the geodetic datums to tidal datums in the St. John's River, FL. The perspective is going upstream from left to right. The graph was constructed by assigning NAVD88 to a relative zero value at each site, and adjusting the other datums accordingly.