Case Studies in the Limitations of Static Vertical Flood Datums

Adventures in Datum Forensics

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6.1 Vertical and Horizontal Control

All FIS Reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum used for newly created or revised FIS Reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD29). With the completion of the North American Vertical Datum of 1988 (NAVD88), many FIS Reports and FIRMs are now prepared using NAVD88 as the referenced vertical datum.

Flood elevations shown in this FIS Report and on the FIRMs are referenced to NAVD88. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. For information regarding conversion between NGVD29 and NAVD88 or other datum conversion, visit the National Geodetic Survey website at www.ngs.noaa.gov.

Temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the archived project documentation associated with the FIS Report and the FIRMs for this community. Interested individuals may contact FEMA to access these data.

To obtain current elevation, description, and/or location information for benchmarks in the area, please visit the NGS website at www.ngs.noaa.gov.

The datum conversion locations and values that were calculated for Flood County are provided in Table 20.

<table>
<thead>
<tr>
<th>Quadrangle Name</th>
<th>Quadrangle Corner</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Conversion from NGVD29 to NAVD88 (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Forest</td>
<td>SE</td>
<td>44.500</td>
<td>-83.625</td>
<td>-0.628</td>
</tr>
<tr>
<td>Flood Lake</td>
<td>SE</td>
<td>44.500</td>
<td>-83.500</td>
<td>-0.655</td>
</tr>
<tr>
<td>Flood Point</td>
<td>SE</td>
<td>44.500</td>
<td>-83.875</td>
<td>-0.658</td>
</tr>
<tr>
<td>Flood Pond</td>
<td>SE</td>
<td>44.500</td>
<td>-83.750</td>
<td>-0.534</td>
</tr>
<tr>
<td>Flood SE</td>
<td>SE</td>
<td>44.250</td>
<td>-83.750</td>
<td>-0.647</td>
</tr>
<tr>
<td>Flood SW</td>
<td>SW</td>
<td>44.250</td>
<td>-83.625</td>
<td>-0.662</td>
</tr>
<tr>
<td>Floodland</td>
<td>SE</td>
<td>44.250</td>
<td>-83.500</td>
<td>-0.705</td>
</tr>
<tr>
<td>Metropolis SE</td>
<td>SE</td>
<td>44.375</td>
<td>-83.875</td>
<td>-0.554</td>
</tr>
<tr>
<td>Metropolis SW</td>
<td>SW</td>
<td>44.500</td>
<td>-83.375</td>
<td>-0.722</td>
</tr>
</tbody>
</table>

The projection used in the preparation of this map is State Plane Zone (FIPS Zone 3801). The horizontal datum was NAD 83, GRS 80 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, NOS
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242
(301) 713-4172 (fax)

To obtain current elevation, description, and/or location information for bench marks shown on this map, please contact the Information Services Branch of the National Geodetic Survey at (301) 713-3242 or visit its website at http://www.ngs.noaa.gov.

A countywide conversion factor could not be generated for Flood County because the maximum variance from average exceeds 0.25 feet. Calculations for the vertical offsets on a stream by stream basis are depicted in Table 21.

<table>
<thead>
<tr>
<th>Flooding Source</th>
<th>Average Vertical Datum Conversion Factor (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flower Creek</td>
<td>-0.584</td>
</tr>
<tr>
<td>Inundation River</td>
<td>-0.631</td>
</tr>
<tr>
<td>Little Creek</td>
<td>-0.545</td>
</tr>
<tr>
<td>North Fork Inundation River</td>
<td>-0.627</td>
</tr>
<tr>
<td>Petal Creek</td>
<td>-0.513</td>
</tr>
</tbody>
</table>
The National Spatial Reference System (NSRS)

A **common** and **consistent** geospatial framework to meet the economic, social, and environmental positioning needs of our Nation.

Foundational elements include:

- Latitude • Longitude • Elevation • Gravity • Shoreline Position + changes over time

Reliable FIRMs require data from disparate sources and dates be consistently aligned
Modernization of the National Spatial Reference System

NAPGD 2022
NGS Defines and Provides Access to NAVD88 Heights
NGS will Provide Access to NAPGD 2022 Heights
ILLUSTRATIVE

CASE STUDIES (ALASKA TO TEXAS)
CASE FILE: JUNEAU, AK

9452210 Juneau, Alaska
-13.14 +/- 0.35 mm/yr

Linear Mean Sea Level Trend
Upper 95% Confidence Interval
Lower 95% Confidence Interval
Monthly mean sea level with the average seasonal cycle removed
CASE FILE: JUNEAU, AK

CORS AB50
PBO Station MENDENHALLAK2005
Juneau, Alaska
Operated by: UNAVCO

Feel the Rebound! ~ 2 cm/year uplift
*** When and how you access or transform to NAVD88 matters ***
CASE FILE: CORDOVA, AK

2010 Population: 2,239
Prior FIS: 1979-2015
New FIS Effective: 12/16/2015

Graph showing sea level trend over time with a linear mean sea level trend and confidence intervals.
Fred obtains an Elevation Certificate in Cordova in 1994:

18.1’ MLLW

BFE in 1979 FIS/FIRM: “18 feet relative to MLLW”
(illustration not to scale)
Fred obtains an Elevation Certificate in Cordova in 1994:

18.1’ MLLW

A decade later (2004), his next door neighbor Susan hires a surveyor to get an Elevation Certificate:

17.9’ MLLW

BFE in 1979 FIS/FIRM: “18 feet relative to MLLW”

Local MLLW in 2004 (1983-2001 NTDE)

Fred

Susan

(Figure showing BFE and elevation of houses)

Fred

Susan

(Figure showing BFE and elevation of houses)

(BFE in 1979 FIS/FIRM: “18 feet relative to MLLW”)

(illustration not to scale)
Fred obtains an Elevation Certificate in Cordova in 1994: 
18.1’ MLLW (1960-78 tidal epoch)  
← Above BFE 

A decade later (2004), his next door neighbor Susan hires a surveyor to get an Elevation Certificate: 
17.9’ MLLW (1983-2001 tidal epoch)  
← Below BFE?
Vertical and Horizontal Control

All FIS Reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. For Cordova, the vertical datum used in the effective FIS Report and FIRMs was the Mean Lower Low Water (MLLW). With the completion of the NAVD88, the FIS Report and FIRMs are now prepared using NAVD88 as the referenced vertical datum.

Flood elevations shown in this FIS Report and on the FIRMs are referenced to NAVD88. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. The datum conversion factor from MLLW to NAVD88, as obtained from the National Oceanic and Atmospheric Administration (NOAA), is -2.10 feet.

\[ \text{NAVD88} = \text{MLLW} - 2.10 \]

Temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the archived project documentation associated with the FIS Report and the FIRMs for this community. Interested individuals may contact FEMA to access these data.

To obtain current elevation, description, and/or location information for benchmarks in the area, please contact information services Branch of the NGS at (301) 713-3242, or visit their website at www.ngs.noaa.gov.

The datum conversion locations and values that were calculated for the City of Cordova are provided in Table 20.

Can this equation be used to update all Cordova MLLW Elevation Certificates to NAVD88?
CASE FILE: HOUSTON, TX

Hurricane Harvey
August 2017
Following Tropical Storm Allison (June 2001), Harris County Flood Control District and FEMA initiated the Tropical Storm Allison Recovery Project.
Subsidence in Harris County, documented by multiple measurement techniques, can be as high as 7 cm/year.

See:
USGS Scientific Investigations Report 2012–5211
Harris-Galveston Coastal Subsidence District/NGS, 2014

WDVW
~1.5 cm/year
(2001-2017)
Practical Guidance on DOCUMENTATION OF DATUMS (METADATA)
Use Complete Nomenclature

NAD83

NAVD88

MLLW
Use Complete Nomenclature

NAD83(2011) epoch 2010.00

H. Datum
Realization/Adjustment
Reference Epoch

NAVD88 (GRS80, Geoid12B)

V. Datum
Reference Ellipsoid
Geoid Model

MLLW (9452210; 1960-78 #2128)

Tidal Datum
NOAA Tide Station
National Tidal Datum Epoch & Published Sheet Number
CASE FILE: METADATA

SECTION I

FIA MAP EFFECTIVE DATE
Feb 4, 1981

BASE FLOOD ELEVATION AT THE BUILDING SITE
26.0

ELEVATION CERTIFICATION

ZONES A, A1-30, A-99, AH: I certify that the building at the property location described above has the lowest floor (including basement) at an elevation of 26.4 feet, NGVD (mean sea level) and the average grade at the building site is at an elevation of 25.8 feet, NGVD.

KEY TO MAP

500-Year Flood Boundary
100-Year Flood Boundary
Zone Designations* With Date of Identification
e.g., 12/2/74
100-Year Flood Boundary
500-Year Flood Boundary
Base Flood Elevation Line With Elevation In Feet**
Base Flood Elevation In Feet Where Uniform Within Zone**
Elevation Reference Mark
River Mile

**Referenced to Mean Lower Low Water
**Section B & C – FIRM Information**

<table>
<thead>
<tr>
<th>B1. NFIP Community Name &amp; Community Number</th>
<th>B2. County Name</th>
<th>B3. State</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B4. Map/Panel Number</td>
<td>B5. Suffix</td>
<td>B6. FIRM Index Date</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9:**

- [ ] FIS Profile
- [ ] FIRM
- [ ] Community Determined
- [ ] Other/Source:  

**B11. Indicate elevation datum used for BFE in Item B9:**

- [ ] NGVD 1929
- [ ] NAVD 1988
- [ ] Other/Source:  

**B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)?**

- [ ] Yes
- [ ] No

**C1. Building elevations are based on:**

- [ ] Construction Drawings
- [ ] Building Under Construction
- [ ] Finished Construction

*A new Elevation Certificate will be required when construction of the building is complete.*


Complete items C2.a–h below according to the building diagram specified in item A7. In Puerto Rico only, enter meters.

**Benchmark Utilized:**

**Vertical Datum:**

**Indicate elevation datum used for the elevations in items a) through h) below:**

- [ ] NGVD 1929
- [ ] NAVD 1988
- [ ] Other/Source:  

**Datum used for building elevations must be the same as that used for the BFE:**

Check the measurement used.
• Extra care in combining data (lidar and ground survey) to a **common datum in the FIS**
• Extra language in FIS to clearly indicate the NTDE/Datum used (**good metadata**)
• Extra support for ECs and LOMAs/SOMAs
• **Conversion table** for distribution to FPAs and surveyors
• Development of job-aids and training materials for use in **training** classes targeted to FPMs and surveyors in areas where tidal datums are used as BFE datum
### STARR II

Juneau Time-dependent Datum Conversion Table

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MLLW 1941-1959 (5/9/1960)</td>
<td></td>
<td>0.96</td>
<td>1.19</td>
<td>1.59</td>
<td>1.71</td>
<td>1.91</td>
<td>2.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLLW 1960-1978 (4/27/1989)</td>
<td>-0.96</td>
<td></td>
<td>0.22</td>
<td>0.62</td>
<td>0.76</td>
<td>0.94</td>
<td>1.18</td>
<td></td>
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</tr>
<tr>
<td>MLLW 1960-1978 (11/2/1993)</td>
<td>-1.19</td>
<td>-0.22</td>
<td></td>
<td>0.40</td>
<td>0.51</td>
<td>0.73</td>
<td>0.94</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MLLW 1960-1978 (11/2/1999)</td>
<td>-1.60</td>
<td>-0.62</td>
<td>-0.40</td>
<td></td>
<td>0.11</td>
<td>0.32</td>
<td>0.56</td>
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<tr>
<td>MLLW 1983-2001 (4/21/2003)</td>
<td>-1.70</td>
<td>-0.73</td>
<td>-0.51</td>
<td>-0.11</td>
<td></td>
<td>0.21</td>
<td>0.45</td>
<td></td>
<td></td>
<td>-3.09</td>
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<tr>
<td>MLLW 2002-2006 (11/6/2007)</td>
<td>-1.91</td>
<td>-0.94</td>
<td>-0.72</td>
<td>-0.32</td>
<td>-0.21</td>
<td></td>
<td>0.24</td>
<td></td>
<td></td>
<td>-3.30</td>
</tr>
<tr>
<td>MLLW 2007-2011 (5/2/2014)</td>
<td>-2.15</td>
<td>-1.18</td>
<td>-0.96</td>
<td>-0.56</td>
<td>-0.45</td>
<td>-0.24</td>
<td></td>
<td></td>
<td></td>
<td>-3.54</td>
</tr>
</tbody>
</table>
The NSRS of Tomorrow (2022)

The North American-Pacific Geopotential Datum of 2022 (NAPGD2022):

- Time-dependent and geocentric
- Defined by relationships to a global/international ideal frame
- Primarily accessed via GPS technology and a newly refined semi-dynamic geoid model

Benefits:
- UAS/UAV support
- Improved subsidence/uptilt monitoring
- Improved tidal/geodetic ties
- International alignment
- NSRS access in remote areas
- Remove nationwide tilt
- Support monitoring
Additional

TRAINING AND RESOURCES
Online Resources from ngs.noaa.gov

Vertical Datums
A vertical datum is a surface of zero elevation that those heights be in a consistent zero elevation surface and methods of many different types of vertical datums and geodetic datums.

Tidal datums are determined by examples of these are Mean Sea Level (MHHW).
Mean Sea Level (MSL) is a tidal datum derived by Oceanographic Products and Services (NTDE) based on data collected at the tide station at which it was prepared, including LMSL at other tide stations.

Geodetic datums are predominantly leveling, determining the height of a point above a geoid.

In the United States and its territories, NOAA’s National Geodetic Survey (NGS) responsibilities include defining and providing access to and the maintenance of geodetic vertical datums. These datums are part of the overall National Spatial Reference System (NSRS). Currently five vertical datums are in use: Mean Sea Level, Mean Higher High Water, Mean Higher High Water, Mean Lower Low Water, and Mean Lower Low Water.
What can you do?

• Ensure **consistency** in your datums
• Understand presence of residual risk in highly dynamic areas
• Lead by example and exercise **best metadata practices**

• Be aware and help spread the word about upcoming **NSRS modernization**:
  – Proactively ask agencies, surveyors, and engineers about what preparations they are taking to learn about and prepare for the upcoming changes

• **Reach out** to NGS for support as needed
Thank You

Special thanks to:

Mike Michalski, CO-OPS Datums Lead
Boris Kanazir, NGS Geodesist
Christine Gallagher, Communications Chief
NOAA/FEMA Coordination

Cooperative Pilot Study (2011):
- National Geodetic Survey,
- North Carolina Floodplain Mapping Program,
- North Carolina Geodetic Survey, and
- Federal Emergency Management Agency

Key Outcomes:
- Recommendation of FEMA implementation plan to account for coordinate and height shifts.
- Improved relative positional accuracies and greater understanding of height uncertainties will enhance quality of flood mapping.
Educational Videos & Online Tutorials

Videos are ~3-5 minutes

Vertical Datums Tutorial is ~1 hour