memo

Date: November 11, 2009

To: Jeremy Freimund, Lummi Water Resources Manager

From: Jim Johannessen, Licensed Engineering Geologist, CGS

Re: **Lummi Bay and Nooksack River Delta Tidal Station Data - Revised**

This memo describes the most appropriate water level stations (tidal stations) for the Lummi Indian Reservation. In particular the stations that pertain to the Lummi Bay and separately for the Nooksack River Delta area are described. In addition, this memo describes the appropriate factor to convert elevations based on a tidal datum to elevations based on the National Geodetic Vertical Datum (NVGD).

Lummi Bay Area Tidal Stations

The Lummi Bay area (at the Lummi River or Red River Delta) is located immediately east of Sandy Point. The nearest long-term tidal station to Lummi Bay is the Cherry Point station, maintained by the National Ocean Service (NOS, within NOAA) (NOAA Station ID: 9449424) and is recommended as the best tidal station to use for Lummi Bay. This station has data for the entire "current tidal epoch" of water level recording, January 1983 to December 2001. This is the most recent 18.5-year period (tidal epoch) that is used for computing tides, due to the variation in the orbits of the earth and moon. The station was first established in 1973, and therefore has a very long record for Northern Puget Sound. The Cherry Point station is the primary station for the entire US Georgia Strait area. It is based on a considerable time series record, one that spans over one 18-year tidal epoch. This is a time period that includes significant variations in the orbit of the earth and moon, and provides a much reliable data record. The Cherry Point station uses the Seattle station as its Control Station, which has one of the longest records in the Northwest. The tidal station is located approximately 5.5 miles from the central shore of the Lummi River Delta.

Dr. Curtis Ebbesmeyer is a partner at Evans-Hamilton Inc. in Seattle and one of the leading experts on the physical oceanography of the greater Puget Sound. When Dr. Ebbesmeyer was asked what was the most appropriate tidal station for use at the Sandy Point area in the mid-1990s, he stated that Cherry Point was the most appropriate station. This was because of the long data record at Cherry Point and the fact that the Cherry Point station has had a higher level of scrutiny since it is a reference station for a broad area of the southern Strait of Georgia.

Aside form the quantity and quality of the water level time series data that each station is based on, the physical oceanographic setting is the most important factor affecting the validity of using a particular station over another. Tidal streams are strongly influenced by the physical shape of water basins as well as their natural periods. Tidal streams are directed, focused, and exaggerated by a major constriction, land mass, and/or confluence as tidal waters flood and ebb. In the area around Sandy Point, there is a major confluence of straits and passages, including Rosario Strait, Boundary Pass, Hale Pass, and the largest, the Strait of Georgia. The physical oceanographic nature of this area causes the level of Mean High Water (MHW) and Mean Higher High Water (MHHW) to increase to higher levels between the San Juan Islands (and Bellingham Bay) towards the north. This is due to:

1. The western Whatcom County mainland, starting at Sandy Point and continuing northward, acts as a constriction to flood tide water, relative to Lummi Island locations further south.

2. The tidal stream input from Boundary Pass and President Channel around the north side of the San Juan archipelago converges northward flood water in Rosario Strait near Sandy Point which causes mean high and mean higher high water levels to increase.

The current benchmark sheet published by NOAA is dated 4/21/2003, and can be found at http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9449424%20Cherry%20Point,%20WA&type=Bench%20Mark%20Data%20Sheets#DatumsPage

Lummi Bay-Datum Conversion

Several different conversions have been used for Mean Lower Low Water (MLLW) to NGVD29 for the Cherry Point station. Pacific Surveying and Engineering (PSE) performed work for the Lummi Nation during 1996 using the MLLW datum. PSE inferred a conversion to NGVD29 of 5.02 ft, but did not use this number as it was outside of the scope of their work (that is MLLW + 5.02 = NGVD29). This conversion factor was since rounded to +5.0 ft by Lummi Nation staff. The PSE conversion was based on tie in to a 3rd order survey monument that was based on poorly-document data (monument "1 AG 10") located at the corner of Slater and Elder Roads. This number should not be considered highly reliable due to the low level of accuracy associated with a 3rd order monument in a telephone pole that dated back to 1978. Rich Carter, who oversaw the original 1996 work for PSE stated that the American Geodetic Survey monuments like the Slater Road one can be off by up to 0.5 ft vertically in this area. He also expressed that the age of the monument and telephone pole is problematic. This conversion was also for the "superceded tidal epoch" and is therefore not quite current.

A different conversion from NGVD29 to MLLW was noted as "inferred" in the work by PSE with undocumented methods of +5.25 ft. The exact method for this conversion cannot be determined at this time, and has not been used to our knowledge.

For general reference only, a MLLW to NGVD29 datum conversion factor was used by Phillip Williams and Associates for Birch Bay (NOT for the Lummi Bay area) of 4.95 that was based on Pittman (2000).

Amid the uncertainly of all of the above-discussed conversions, the best result can be obtained by using the datum conversion program supported by NOAA, "Vdatum". This program was checked to several surrounding published benchmarks with NGVD and MLLW elevations, and checked perfectly. The value given for the Lummi Bay delta shore was also compared to surrounding values and found to fit the regional pattern better than the above-discussed tie-in numbers. However, it must be cautioned that models such as Vdatum do have inherent problems and are not as reliable as surveying using 1st order monuments.

For the central shore of the Lummi River Delta (at N 48.79 degrees, W 122.675 degrees) using Vdatum, the conversion from MLLW to NGVD29 at this location is -4.732 ft (this number, appropriately rounded to 4.73, is subtracted from the MLLW value to get NGVD29). The conversion from MLLW to NAVD88 is -0.792 ft (this number, appropriately rounded to 0.79, is subtracted from the MLLW value to get NAVD88).

The extent of the area that the above-mentioned conversion number applies to is the Point Whitehorn area down to Portage Point on the south end of the Lummi Peninsula. For an exact line, the line

separating Hale Passage from Portage Bay, as first defined for a boundary between different marine water quality zones by Washington State (longitude 122 degrees 39' 00" W).

Nooksack River Delta Area Stations

The Nooksack River Delta is located in northern Bellingham Bay. The only good candidate tidal station for the location is the Bellingham Bay station (Station ID: 9449211), which is also a long-term station, first installed in the area in 1934. This station is in the Georgia Pacific industrial area in the northeast portion of the bay, and is 4.5 miles from the central shore of the delta. This station is located in a similar location of Bellingham Bay and is free of any large water flow constrictions, as is the delta area. It is therefore recommended that the Bellingham tidal station is the most accurate and appropriate station to use for reference to tidal levels at the Nooksack River Delta area.

Nooksack River Delta Area Conversion

The published benchmark sheet (http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9449211%20Bellingham,%20WA&type=Bench%20Mark%20Data%20Sheets) lists the conversion from MLLW to NAVD88 at the station location as +0.147 m. This number is added to the MLLW value to get NAVD88, which is equivalent to +0.482 ft. However, this is for the station location and a slightly different value would be expected for the Nooksack River Delta. Using the datum conversion program supported by NOAA, Vdatum, for the central shore of the delta (at N 48.7687 degrees, W 122.575 degrees), the conversion from MLLW to NGVD29 at this location is -4.49 ft (this number is subtracted from the MLLW value to get NGVD29). The conversion from MLLW to NAVD88 is -0.559 ft (this number, appropriately rounded to 0.56 ft, is subtracted from the MLLW value to get NAVD88).

The extent of the area that the above-mentioned conversion number applies to is Bellingham Bay west to Portage Point on the south end of the Lummi Peninsula. For an exact line, the line separating Hale Passage from Portage Bay, as first defined for a boundary between different marine water quality zones by Washington State (longitude 122 degrees 39' 00" W).

References

Pacific Surveying and Engineering, 1996. Sandy Point mapping project for the Lummi Nation and Coastal Geologic Services, Bellingham WA.

Pittman, P., 2000. Benchmark elevations at Sandy Point, Ferndale, Washington, Whatcom County Public Works Department memorandum to surveyors, May 11.

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