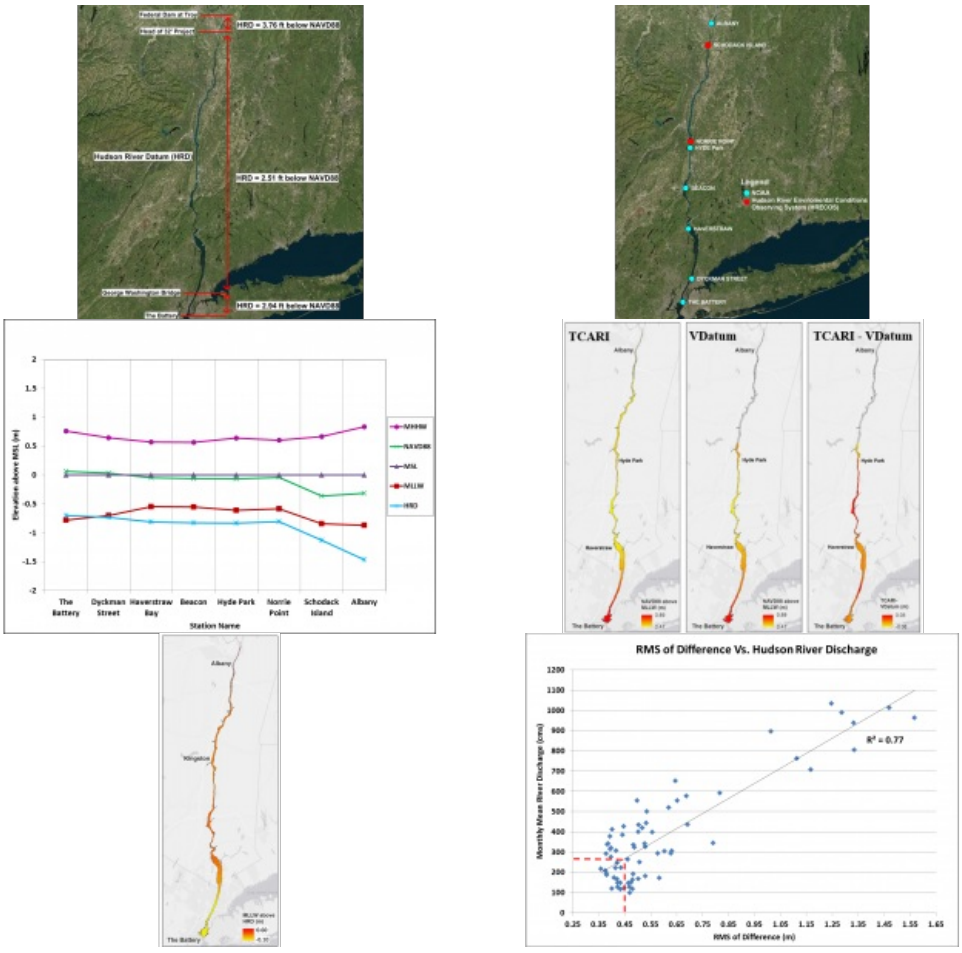
INTERPOLATION METHOD TO GENERATE THE SEPARATION SURFACE

Vertical Datums in the Hudson River



A fixed low water reference plane, Hudson River Datum (HRD), was adopted as chart datum for certain portions of the Hudson River to approximate mean low water when river levels are lowest. Due to river discharge, water levels in the river are influenced more by flow than by tides; therefore, tidal datums computed from river water levels might not be representative of low tide levels. Hydrographic surveyors can apply a GEOID model to reference the HRD using Ellipsoidally Referenced Survey (ERS) techniques. Projects not utilizing ERS require a Mean Lower Low Water (MLLW) – HRD separation surface to reduce the bathymetry data to the HRD. This article describes an interpolation method to generate the separation surface using a tool called Tidal Constituent and Residual Interpolation (TCARI).

The Current Definition of HRD

The HRD was adopted by the US Army Corps of Engineers (USACE), New York District in 1926 and was related to the mean sea level at the NOAA tide station at Sandy Hook, NJ (8531680) (Schureman, 1934). The definition of HRD has been modified several times and has since been updated to reference the North American Vertical Datum of 1988 (NAVD88) (USACE, 2015). NAVD88 provides a link between HRD and tidal datums at tide stations (Figure 1).

Figure 1: Current relationship between NAVD88 and HRD (USACE 2015).

Currently, the USACE relies on the NAVD88-MLLW to relate MLLW to HRD. Where it exists, this separation is obtained using National Oceanic and Atmospheric Administration's (NOAA) Vertical Datum Transformation tool (VDatum), which transforms geospatial data among a variety of tidal, orthometric and ellipsoidal vertical datums (Myers, 2005). The VDATUM model extends from the entrance to New York Harbour north to East Kingston, NY. For projects north of VDATUM coverage, discrete offsets relate NAVD88 to HRD and are associated with geographic locations along the river (Figure 1). The USACE relies on a HRD separation value of 2.55ft (0.78m) below NAVD88 north to the south of Albany downtown (USACE, 2016). The USACE uses a separation for HRD of 3.80ft (1.16m) below NAVD88 from south of Albany downtown to Federal Lock in Troy and 13.59ft (4.14m) below NAVD88 from Federal Dam in Troy to Waterford (USACE, 2016).

Figure 2: Water level stations used to generate the MLLW-HRD separation surface in the Hudson River.

Generating Mean Lower Low Water to HRD Separation Model

Tidal and geodetic datums from six NOAA water level stations and two Hudson River Environmental Conditions Observing System (HRECOS) stations were used to create a separation surface (Figure 2). Data from the HRECOS water level stations were used to supplement the geospatial coverage of datums from the NOAA water level stations. All NOAA stations have published tidal datums on the 1983 – 2001 NTDE and NAVD88 relationships with the exception of the water level station at Beacon, NY (8518934). Table 1 shows the tidal, geodetic and HRD values that were used to generate the separation surface.

Table 1: Tidal, geodetic and Hudson River Datum values referenced to MSL at stations along the Hudson River. The HRD values are calculated based on the offsets on the USACE dredging chart published in 1986 (Figure 2).

Station ID	Station Name	Length of Data Series	NAVD88 (m)	HRD (m)	MLLW (m)	NAVD88 – MLLW (m)	MLLW – HRD (m)
8518750	The Battery, NY	19 years	0.063	-0.702	-0.783	0.846	-0.081
8518902	Dyckman Street, NY	3 months	0.029	-0.736	-0.702	0.731	0.034
8518924	Haverstraw Bay, NY	3 months	-0.050	-0.815	-0.550	0.500	0.265
8518934	Beacon, NY	3 months	-0.066	-0.831	-0.553	0.487	0.278
8518951	Hyde Park, NY	3 months	-0.071	-0.836	-0.614	0.543	0.222
HRECOS	Norrie Point, NY	3 months	-0.042	-0.807	-0.584	0.542	0.223
HRECOS	Schodack Island, NY	3 months	-0.364	-1.129	-0.846	0.482	0.283
8518995	Albany, NY	5 years	-0.319	-1.465	-0.869	0.550	0.596

Tidal, geodetic and HRD values are referenced to MSL and shown in Figure 3. All tidal and geodetic datums are above HRD from The Battery, NY (8518750) up to Albany, NY (8518995). Tidal datum values above HRD are consistent with the original purpose of a conservative low water datum. Near the mouth of the river, where the influence of river discharge is minimal, HRD is very close to MLLW. Further north, HRD begins to diverge from MLLW due to increased influences from river discharge.

The separation surface was generated using the Tidal Constituent and Residual Interpolation (TCARI) tool, constrained by the observed datum values at the locations of the eight water level stations mentioned in Table 1. The interpolation scheme uses a 2D Laplace interpolation over a Delaunay triangulation grid constrained by boundary conditions (Hess et al., 2004).

Figure 3: Tidal, geodetic and HRD values at water level stations from The Battery, NY (8518750) north to Albany, NY (8518995).

Results

A NAVD88-MLLW datum separation surface was created based on the tidal, geodetic and HRD values shown in Table 1. To quality control the result, the interpolated separation surface is compared to the separation values from VDATUM in the areas covered by VDATUM - Figure 4 shows this comparison. The differences in the separation surface values between the TCARI and VDatum solutions range from -0.06m to 0.08m.

Using the NAVD88-MLLW surface and the NAVD88/HRD relationships shown in Figure 1, the same approach was used to create an MLLW-HRD separation surface. This new surface allows water level data collected at The Battery, NY (8518750) to be biased to HRD throughout the Hudson River (Figure 5).

Discussion and Conclusion

The difference in MLLW-HRD separation between VDatum and TCARI interpolation ranges from -0.06m to 0.08m (Figure 4). The published uncertainty for this VDATUM model is 0.19m (95% CI). With the maximum difference of 0.08m on top of the 0.19m VDatum uncertainty, the separation surface is still within the 0.45m IHO tide error tolerance and can be applied to hydrographic surveys. However, it should be noted that when applied to data, this difference would be realized as a bias, and not a random error.

Figure 4: TCARI generated (left), VDatum generated (middle) NAVD88-MLLW separation surfaces and the difference between TCARI and VDatum (right).

Improvements to both the TCARI and VDatum generated separation surfaces can be achieved by collecting and incorporating additional

tidal datum information along the Hudson River, specifically, between Hyde Park, NY and Albany, NY. The Hudson River VDatum model was created in 2010. Since that time, four short-term stations have been installed between The Battery, NY (8518750) and the northern end of the VDatum coverage: Dyckman Street, NY (8518902), Haverstraw Bay, NY (8518924), Beacon, NY (8518934) and Hyde Park, NY (8518951). Tidal datums from these stations will be incorporated in the updated VDatum model to improve the accuracy of datum transformation.

Water levels in the northern Hudson River near Albany, NY (8518995) are significantly affected by high river discharge. A comparison between water level data using The Battery as the control station and observed data at Albany indicates that the 2*Root Mean Square of the difference is less than 0.45m during periods of river discharge less than 280 cubic metres per second (cms). In order to use The Battery, NY (8518750) as tide control for hydrographic surveys in the northern Hudson River, it is strongly recommended that hydrographic surveys only be conducted when the river discharge is less than 280cms (Figure 6).

Figure 5: Figure 5. MLLW above HRD separation surface generated by TCARI.

If an Ellipsoidally Referenced Survey (ERS) is conducted in the Hudson River, then a Geoid model can provide the NAD83 ellipsoid to NAVD88 separation values for the area north of East Kingston, NY where a VDatum model is not available. The offset of 2.55ft (0.78m) below NAVD88 can be applied to the geoid separation in order to relate data to HRD.

Figure 6: Scatter plot of RMS of difference between zoned water levels using The Battery, NY (8518750) as control and observed data at Albany, NY (8518995) against river discharge.

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