Title: SOP # 3.2.3.3. C13 Guidelines and Requirements for Datum Updates and Field Work For the VDatum Project

Purpose:

The purpose of this document is describe the processes and procedures necessary to compile a list of water level stations requiring datum updates and to specificy subsequent field work required for filling in gaps in information needed for datum transformation in the NOS VDatum tool.

Background:

VDatum is a software tool developed by the National Ocean Service (NOS) for transforming bathymetric/topographic data among 28 tidal, orthometric and ellipsoidal vertical datums. The ability to properly reference data to multiple vertical datums is critical to a variety of applications in the coastal zone, and it also serves to extend the capabilities of emerging technologies in providing state-of-the art products.

A National VDatum complement NOS work in developing a national bathymetric database, a National Spatial Reference System (NSRS), and a national tidal datum reference system, which can be combined with the topographic data in providing seamless data products across the land-water interface. Together, these products will also enable a consistent, accurate national shoreline to be defined relative to tidal and geodetic datums. Some other applications that benefit from VDatum include inundation modeling (storm surge, tsunami, and sea level rise impacts), ecosystem modeling, and coastal zone management. VDatum also enhances the capabilities of technologies such as kinematic GPS (K-GPS) for vertical referencing of hydrographic survey depths, use of topographic and bathymetric LIDAR for determining mean lower low water (MLLW) and mean high water (MHW) shorelines, and development of digital elevation models (DEMs).

The vertical datums incorporated into VDatum are selected so as to accommodate the wide variety of bathymetric and topographic data sources that could potentially be used as input to the transformation software. Vertical datums can be classified as tidal datums (tidally-derived surface), orthometric datums, or 3D ellipsoidal datums. Examples of the types of data that are referenced to these categories of datums include bathymetry that is usually referenced to a tidal datum, topographic data that is often surveyed relative to an orthometric datum such as the North American Vertical Datum of 1988 (NAVD88), and LIDAR data that is referenced to an ellipsoidal datum.

The Center for Operational Oceanographic Products and Services (CO-OPS) of the National Ocean Service (NOS) operates and maintains a network of 200 long-term National Water Level Observation Network (NWLON) stations as part of the National Water Level Program (NWLP) for the United States coast and in the Great Lakes. In addition, CO-OPS installs and

operates short-term water level stations in support of a variety of programs including hydrographic and photogrammetry surveys, marine boundary determination, habitat restoration, dredging, climate change, and long-term sea level rise studies.

The water level data collected is vertically referenced to a local network of benchmarks at each station. At each NWLON station, a local network of ten bench marks exists; whereas for each subordinate station, a local network of five bench marks exists. Many of these benchmarks are a part of the NSRS and can be used to reference tidal and geodetic relationships which are published on CO-OPS benchmark sheets. Use of static GPS observations to obtain ellipsoidal elevation relationships are now specified in CO-OPS Project Instructions to CO-OPS field teams and are also specified in the NOS Specifiations and Deliverables for both NOS and NOS contractor field parties.

Use in VDatum:

CO-OPS tidal datums, corresponding NAVD88 elevations, and corresponding GPS ellipsoidal elevations on bench marks are utilized in the VDatum transformation tool (see draft VDatum Program SOP). Tidal datums generated from a hydrodynamic model (ADCIRC) are compared with CO-OPS tidal datums and datum fields are corrected with the Tidal Constituent And Residual Interpolation (TCARI) spatial interpolation to ensure agreement at the location of tide stations (Hess et al. 2005). Using information from CO-OPS tide station locations and datums, VDatum generates a gridded Topography of the Sea Surface (TSS), which is defined as the elevation of North American Vertical Datum of 1988 (NAVD88) to Local Mean Sea Level (LMSL) (Hess et al. 2005). Information on the relationship between the ellipsoid and MLLW and MHW will be used for future VDatum applications to kinematic GPS hydrpgrahic and shoreline surveying. Computed harmonic constants from tide stations in the CO-OPS database are used to evaluate and calibrate the numerical hydrodynamic modles used in VDatum.

Therefore, an assessment of CO-OPS active and historic tide stations' spatial distribution, tidal datums, their relationship to the NAVD88, and availability of harmonic constants is necessary to support the VDatum program. Additional information such as tidal - ellipsoidal relationships, the distribution of Continuously Operating Reference Stations (CORS), and availability of third party water level data sources is also needed. The four general requirements for water level station information, datums, and analyses are:

A) The datum models require data points distributed throughout the model grid to compare the modeled datum elevations relative to LMSL with the observed values. The distribution should provide the desired geospatial coverage and coverage of changes in range of tide.

(B) The VDatum transformation tool requires source data points throughout the model grid to compare the modeled relationship of NAVD88 to the tidal datums.

(C) The VDatum transformation tool requires source data points through out the model grid to compare the modeled relationship of the GPS ellipsoid to NAVD88 and LMSL and the tidal datums.

(D) The VDatum tool requires source data points throughout the model grid to compare the modeled amplitudes and phases of the major harmonic constants with those from the observations.

VDatum Assessments:

CO-OPS tidal stations for VDatum efforts are classified into the following five categories.

(1) NWLON station with at least one bench mark with NAVD 88 elevation
(2) NWLON station with no connection to NAVD 88 elevation
(3) Historical subordinate station with at least one bench mark with NAVD 88 elevation
(4) Historical subordinate station with no connection to NAVD 88 elevation
(5) New subordinate tide stations needed in the VDatum gap area
(6) Locations needed for new harmonic constants

Based upon the four requirements listed above, CO-OPS shall complete a comprehensive VDatum assessment that will include a VDatum Station list for each area of interest (each state). The created VDatum station list shall identify the selected stations based upon the six types of station categories, along with station number, name, latitude, longitude, epoch for published sheet, if applicable, status and values of tidal datums, geodetic datums, and ellipsoid heights.

As a starting point, CO-OPS will starts with a list of stations where datums are available for 1983-2001 epoch for each state, this list for each state will be identified as **83-01 Datums List**. Based upon the criteria (see below) for selection for VDatum Station list, CO-OPS will create a list for each state, this list will be identified as **VDatum Station List** for each state. Where the information about the geodetic datums and/or GPS datums (ellipsoid heights) is not available, then CO-OPS will create a list of stations where additional information (such as geodetic NAVD 88 elevations or GPS ellipsoid heights) is needed. This list will be identified as the **VDatum Work List** for each state. CO-OPS will provide the VDatum work list to the appropriate field parties.

CO-OPS will use as a guideline criteria of 0.2 foot per mile change of tidal range along with the other appropriate criteria such as the spatial distribution of stations, accuracy and time frame of the information, to select the locations for the VDatum Station list.

VDatum Assessment Objectives:

The objectives of creating the VDatum Work List is that (a) field parties will be able to collect GPS observations on the existing or new bench mark at each tide station, (2) obtain ellipsoid height for the occupied bench mark through OPUS (3) obtain NAVD 88 elevation for the

occupied bench mark through the NGS geodetic model, or through levels if a Geodetic Bench Mark (GBM) (on a NGS level line) is located within 2 miles of the tide station.

Once the geodetic elevation and ellipsoid height for occupied bench mark has been forwarded to CO-OPS, CO-OPS will include that information on the VDatum Station List and CO-OPS will provide the VDatum Station List consisting of tidal, geodetic, and GPS datums to OCS CSDL for developing the gridded TSS.

The total error budget and accuracies of the various components of the VDatum project should be considered for the project design. The tidal datums are accurate within 9 mm, the ellipsoid heights obtained with 4 hour GPS observations are accurate to 2 cm, the level connection to GBM, if available, is accurate to mm, and accuracy of the TSS is dependent upon the accuracies of the involved components, probably cm or more.

Specifications for Recovery and Installation of Bench Marks, Levels, and GPS Observations:

CO-OPS' "Specifications and Deliverables for the Installation, Operation, and Removal of Water Level Stations, Updated March 2008, shall be the reference specifications for the installation of bench marks, levels, GPS data collection for the VDatum projects.

For each existing or historical station on the VDatum Work List for area of interest (each state), CO-OPS shall create a digital folder listing (a) bench mark stamping and designations (if available) of all bench marks available at the tide station (b) bench mark descriptions (c) To reach the tide station statement (d) bench mark sketch. CO-OPS shall make available the folder to the appropriate field party (NGS, CO-OPS, contractor, etc.)

Based upon the VDatum Work List and information provided by CO-OPS, the field party will try to recover existing bench marks at each tide station. CO-OPS bench marks descriptions will identify which mark is primary, if not, CO-OPS will provide that information.

NGS has defined the following monumentation quality codes, also called the stability codes, for various bench mark settings.

Stability code A – monuments of the most reliable nature which may be expected to hold their elevations very well; e.g. Class A rod marks, or marks installed on large boulders/rock outcrop.

Stability code B – monuments which probably hold their elevations well; e.g. Class B rod marks, or marks installed on large concrete footings/foundations.

Stability code C – monuments which may hold their elevations but which are commonly subject to surface ground movements; e.g. pavement or concrete monuments.

Stability code D – movements of questionable or unknown reliability.

The station bench mark selected for GPS observations shall be of stability code A, B, or C. GPS observations on the primary bench mark (PBM) are preferred if the PBM is either stability code A or B or C, and is also suitable for satellite observations. Stability code D bench marks shall not be used for GPS observations. These are modified requirements for VDatum projects than as specified in the Specifications.

Collect at least minimum of 4 hours of GPS data on suitable existing or new tidal mark. In some rare cases, for historical tide stations, none of the existing bench marks may be found suitable for GPS observations; in that case installation of a new mark that has 360 degree horizontal clearance around the mark and 10 degrees and above horizon clearance for satellites availability may be necessary. In those situations, the new installed mark shall be connected to PBM and other bench marks in the local network, so that geodetic and GPS datums could be referenced to the historic tidal datums. If a new bench mark is required to be installed for GPS, then it must be connected to the PBM during the same site visit when the GPS observations are performed. If leveling equipment is not available at the time the GPS bench mark is set, GPS observations should be deferred until the bench mark is connected to the PBM.

Refer to the Specifications for the required GPS documentation necessary for OPUS solution and blue-booking. Data submission requirements for GPS project consists of project reports, station (bench mark) description or recovery notes, observation log sheets, station visibility diagrams, photographs or rubbings of station marks, raw GPS data, Rinex GPS data, and other information as pertinent.

Field Party shall connect the existing or new installed tidal mark to the existing Geodetic Bench Mark (GBM) of a NGS level line if the NGS level line is available within 2 miles of the tide station location, using at a minimum NGS 3rd order levels. NGS 2nd order Class I levels are preferred and electronic digital levels are also preferred over the optical leveling equipment since the electronic levels can be blue-booked. Where possible, the field party shall perform the valid level tie to two nearby GBM that are listed in NGS database and are within two miles of the tide station. Refer to the Specifications for additional information.

Geodetic elevation obtained through the leveling operations by connecting a tidal bench mark to a GBM is desirable if the NGS level line is available within 2 miles of a tide station location. If the GBM is not available within 2 miles of a tide station, then the only way geodetic height can be derived is through the NGS geodetic model. The 2 mile distance criterion has been set based upon the resources available and accuracies necessary for the geodetic elevations.

Submission of Required Documentation:

The field party will provide the following documentation to CO-OPS

(1) Bench mark descriptions of recovered and newly installed mark including verification of position (latitude and longitude) of each mark with a handheld GPS receiver unit.

(2) Level records (raw levels) including level equipment information (electronic files) and field notes of precise leveling, if applicable (i.e. GBM within 2 miles of a tide station, or a new tidal mark installed)

(3) Level abstract (electronic file for optical and barcode levels), if applicable (i.e. GBM within 2 miles of a tide station, or a new tidal mark installed)

(4) Large-scale bench mark location sketch of the station site showing the relative location of the bench marks, and major reference objects found in the bench mark descriptions. The bench mark sketch shall include an arrow indicating north direction, a title block, and latitude and longitude (derived from handheld GPS) of the gauge (JPEG and PDF format).

(5) Digital photographs of bench mark disk faces, setting, and bench mark locations from two different (perpendicular) cardinal directions (JPEG and PDF format)

(6) GPS Project report, GPS observations in raw and RINEX format, GPS observations log sheets, antenna height measurements, visibility diagrams, OPUS results, as required GPS documentation, if applicable, (all in various electronic format).

(7) Derived NAVD 88 elevation of the bench mark from NGS geodetic model or through level connection to a GBM, if available within 2 miles.

(8) Ellipsoid heights of the bench marks(s) through NGS OPUS software.

Submit all the required documentation as listed above to CO-OPS within 60 days of GPS observations.

SUMMARY

CO-OPS will perform comprehensive VDatum Assessments for each VDatum project area determined by the NOS VDatum Program Team. CO-OPS will deliver a VDatum Assessment document to that team that includes an assessment of gaps information, and overall VDatum station List and a VDatum work list specifying requirments for further field work necessary to fill the gaps.

CO-OPS will update datums to the latest tidal datum epochs and perform updated harmonic analyses for selected historical subordinate stations if digital data are readily available on the CO-OPS Database management System (DMS). CO-OPS will process the submitted field work data and analyze the information and provide the appropriate products to CSDL for generating the gridded Topography of the Sea Surface (TSS) and for ingesting GPS observation data into the NGS OPUS system.

CO-OPS will consider requirements for new tide stations required to fill critical VDatum gaps as part of the routine annual Reliable Operating System (ROS) cycle in order to properly resource implementation.