Aftermath of Tropical Storms Irene and Lee — September 17, 2011
Development of a Seamless Topographic / Bathymetric Digital Terrain Model for Tampa Bay, Florida

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Abstract
This applications paper presents the methods used to create a seamless topobathy digital terrain model (DTM) at 50-foot resolution intended to support hurricane storm surge modeling in Tampa Bay, Florida. Lidar, bathymetry, and various breakline data were integrated using the Terrain Data Set structure in ArcGIS®. The use of the Terrain Data Set structure allowed for embedding large data sets (such as lidar points) and archiving them after DTM creation while maintaining topographic analysis capabilities. The bathymetric data, native to Mean Sea Level (MSL), were converted to North American Vertical Datum of 1988 (NAVD88) using an inverse distance weighted average offset from the three nearest NOAA tidal bench mark stations; the results of this conversion were within ±1 centimeters of those produced by NOAA VDatum software in a quality control test area. This methodology can therefore be used in coastal regions of other countries.

Introduction and Background
Airborne Light Detection and Ranging (lidar) is rapidly becoming the industry standard for acquisition of topographic data due to its ability to cover large areas accurately and efficiently. It provides the user with an accurate, relatively easy to process and analyze, and cost effective means of describing the topography of large areas; this is especially useful in many engineering and environmental applications (Cobry et al., 2003; Ritchie, 1996). The scientific, engineering and mapping communities have directed significant resources to developing innovative ways to capture, process, and utilize lidar data.

One of the most promising uses of lidar data is its application in constructing Digital Elevation Models (DEMs). These models such as the National Elevation Dataset (Gesch et al., 2002) provide an accurate means of representing the topography over regional scale sections of the Earth’s surface. This type of source data is necessary for many engineering and mapping applications, including the generation of nationwide land cover datasets such as the National Land Cover Dataset (NLCD) (Homer et al., 2007). DEMs are also useful in pre/post catastrophe analysis and various forms of water resources modeling due in part to readily available data for all of the coastal United States (Gesch et al., 2002) and the ability to process the data using GIS (Garcbrecht and Martz, 2000). In particular, DEMs derived from lidar data are typically resolved enough to capture overland flow characteristics with a high degree of spatial accuracy (Poppena et al., 2009).

In this paper, lidar is used in conjunction with hydrographic survey data to produce a seamless model of the topographic and bathymetric surface associated with the project area (Tampa Bay, Florida; see Figure 1). Similar studies have been carried out by Gesch and Wilson (2001) in Tampa Bay, Feyen et al. (2006) in North Carolina, and Barnard and Hoover (2009) in Southern California.

Before proceeding, it is necessary to define the following terms. These definitions are based on those presented by Maune (2007); however, they are specifically tailored to clarify the material presented herein.

- Digital Elevation Model (DEM) - A digital representation of the terrain consisting of regularly spaced (gridded) elevation data. While it is common for the term DEM to apply to bare-earth representations of terrain, it is used here as the umbrella term for all gridded elevation models;
- Digital Surface Model (DSM) - A gridded first or top surface representation of the terrain. This includes all man-made features (buildings, elevated transportation elements, monuments, etc.) lying on the bare earth; and
- Digital Terrain Model (DTM) - A gridded representation of the bare topographic surface of the Earth. All man-made structural features that are not considered part of the bare-earth surface are removed to expose the underlying terrain. DTM s typically incorporate not only point data, but also other elements such as breaklines and polygon masks in order to generate highly accurate depictions of the terrain.

According to the above definitions, this paper seeks to produce a DTM of the study area with special consideration...
given to hydraulically significant features (i.e., barriers and conveyances). This will be accomplished by integrating lidar, bathymetric, and breakline data. It should be noted that the lidar data is delivered as “bare earth” points; it is customary to receive data in this format from the vendor who often uses a combination of proprietary, automatic algorithms such as adaptive lidar vegetation point removal (Raber et al., 2002) and manual editing to filter out non-ground points (Hodgson et al., 2005). Breakline data describe significant linear changes in the terrain surface, such as a riverbank or shoreline. They are used to enforce the location (horizontal and vertical) of these features during interpolation, resulting in more accurate depictions of the terrain (Maune, 2007). The final DTM will be a raster product with 50-foot resolution.

In general, bathymetry or sounding data is referenced to a tidal datum such as Mean Sea Level (MSL), Mean Low Water (MLW) or Mean Lower Low Water (MLLW). For this study, all points (bathymetric and topographic) must be referenced to the North American Vertical Datum of 1988 (NAVD88) per project specifications. The process for obtaining bathymetric data and transforming it to comply with the project’s vertical datum requirement are described herein. The general outline of the procedure used to achieve the end product is: create a bathymetric DTM using hydrographic survey data, create a topographic DTM using lidar and various breakline data, and finally create a seamless topobathymetric DTM of the entire project area. The resulting DTM will be used in a model that simulates hurricane storm surge inundation in the project area. This is a popular and well-suited application of high-resolution DTMs (NOAA, 2007) and an accurate DTM that incorporates topographic and bathymetric data is essential for inundation modeling (Gonzalez et al., 2005).

Data Acquisition and Processing

The bathymetry data for the project area were obtained from the DVD-ROM entitled Geophysical Data System (GEODAS) for Gridded Bathymetric Data, NGDC Coastal Relief Model, Volumes 01 through 08, Version 4.1.20 prepared by the National Geophysical Data Center (NGDC). This DVD contains software entitled GEODAS Reader that lets the user specify an area using latitude and longitude and extract bathymetric data. This data is horizontally referenced to the North American Datum of 1983 (NAD83), and the water depths are in meters relative to Mean Sea Level (MSL). Please note that the NGDC data set contains both bathymetric and topographic data; for the purposes of this case study, only “sea cells” were extracted at 6 arc-second resolution. Furthermore, it is also important to note that the NGDC data described above is derived from many independent hydrographic surveys dating back to the 1950’s. The raw data from these hydrographic surveys reference different tidal datums such as MLW and MLLW. The use of the NGDC-processed data sets simplifies the datum adjustment process for presented herein; however, the user could apply the presented methodology to each individual hydrographic survey, provided care was taken to identify the datums and make the appropriate adjustments.

Recall that the ultimate goal of the study is to produce a seamless topobathymetric DTM. In order to accomplish this, all topographic and hydrographic survey data must be referenced to a common datum (NOAA, 2007), in this case NAVD88. Therefore, all bathymetry data must be transformed from MSL to NAVD88. This transformation is nontrivial because MSL varies spatially along the coastline. Fortunately, a software tool called VDatum (Gesch and Wilson, 2001; Myers, 2005) is being developed jointly by NOAA’s National Geodetic Survey (NGS), Office of Coast Survey (OCS) and Center for Operational Oceanographic Products and Services (CO-OPS). This process is made significantly more efficient and accurate in the coastal regions through the use of this software tool (Gesch and Wilson, 2001) and the authors acknowledge that VDatum is the best available method for transforming between tidal and orthometric vertical datums. However, this software is currently limited by its geographical coverage; in this case, it can only be used inside Tampa Bay itself leaving a significant portion of the project area untransformed. Therefore, in order to maintain consistency, VDatum will not be used to transform any of the points in this study.

With VDatum’s coverage only extending to part of the study area, an interim method of transforming bathymetric data from MSL to NAVD88 based on NOAA’s Tidal Benchmark Station (TBS) information was adopted from the existing “Interpolation” method of datum conversion (NOAA, 2007). Tidal Benchmark Stations are NOAA-maintained water level stations that have one or more orthometric datums surveyed in at their location. These stations allow for an offset calculation between an orthometric datum and the local tidal datums (MSL, MLLW, etc.). Information derived from the TBSs located inside the study area provides the foundation for transforming the bathymetric data.

Tidal Benchmark Station Data

First, a database containing all tidal benchmark stations maintained by NOAA CO-OPS was obtained. The database contains an entry for each tidal benchmark station and fields listing the station’s ID, Latitude, Longitude, and elevations of vertical datums (both tidal and orthometric). Please note that the raw elevations listed in the database are not referenced to any standard vertical datum; they are referenced to a local benchmark established at the station. This fact is not critical to the subject process because the differences (offsets) between tidal and orthometric data (in particular, MSL and NAVD88) are the critical values. With consideration to ease of data import/export and processing, extraneous fields in the database were deleted and a field containing the offset between MSL and NAVD88 (in meters) was created. This modified database was then imported into ArcGIS® using Tools > Add XY Data. Please note that at this point, no ArcToolbox operations can be performed on this data due to its format within ArcGIS®; the user must export the data to a shapefile in order to generate an ObjectID field, thereby enabling it for geoprocessing.

Prior to use, the data was pre-processed to simplify the datum conversion. The TBS points were first clipped

Figure 1. Location of Study Area.
geographically using a 50-mile buffer around the study area boundary. The 50-mile buffer was employed to provide proper adjustment availability to bathymetry points near the northern and southern extents of the study area. Next, all stations without an elevation value (referenced to the local station benchmark) for NAVD88 were deleted because they could not generate raw offsets between MSL and NAVD88 (i.e., without further processing/calculations). This process resulted in 115 tidal benchmark stations for the project area.

However, further refinement of the TBS data was required in order to remove abnormal and inconsequential data. The primary function of this step was to avoid unrealistic offset values introduced by errors in the TBS data. Stations with abnormally large or small offset values relative to nearby stations were removed from the data set in order to avoid unrealistic offset values. More specifically, a station was removed if its offset value was larger than three times (on an absolute value basis) the value at either of the nearest two stations within 5 kilometers. Three stations were removed for this reason. Furthermore, stations that were located significantly upriver (inland) with no nearby offshore bathymetry points were also removed from the data set. Nine stations were removed for this reason. Due to the relatively small geographic region and the limited number of potential removals, all candidates were individually inspected to confirm that their removal was reasonable.

After the above-referenced pre-processing, there were 103 Tidal Benchmark Stations remaining as shown in Figure 2. The last remaining task is to populate the MSL to NAVD88 offset field using the Field Calculator function in ArcGIS® using the following equation (recall that elevations of NAVD88 and MSL are referenced to a local benchmark established at the tidal benchmark station):

\[
(Elevation \text{ of NAVD88}) - (Elevation \text{ of MSL}) = \text{Offset} \quad (1)
\]

Refer to Figure 3 for a graphical description of this calculation. Table 1 contains some examples of TBS offset values.

![Figure 2. Location of Tidal Benchmark Stations.](image)

Adjustment of Bathymetry Points

The next step in the process was to apply this offset to the raw bathymetry points in order to transform them from MSL to NAVD88. The dataset obtained from the NGDC was in the form of a space delimited *.xyz file. This data was converted to a Feature Class in ArcGIS® initial download of bathymetry data contained approximately 2.4 million points. The Point Feature Class was then clipped to the boundary of the study; the clipped bathymetry contained approximately 1.5 million points. The XY coordinates were then added to each point in the clipped shapefile in order to continue the datum transformation process.

To summarize the process thus far, we have a point shapefile that contains all bathymetric data points and lists each point’s horizontal position (latitude and longitude) and its elevation in meters. We also have a shapefile containing the tidal benchmark stations listing their horizontal position and datum offsets. Before proceeding, we must project these data into a Cartesian system to enable the subsequent calculations. In this case, the project specifications require the use of State Plane coordinates, in particular Florida State Plane West (NAD83), units of feet.

In order to further reduce the potential for errors generated by incorrect TBS data, a three point nearest neighbor interpolation scheme is applied. The offset applied to each bathymetry point is constructed by using a weighted average of the offsets associated with the three geographically nearest TBSs according to the following formula (Shepard, 1968):

\[
O_{avg} = \frac{\sum_{n=1}^{3} o_n / d_n}{\sum_{n=1}^{3} 1 / d_n} \quad (2)
\]
where \( a_{avg} \) is the weighted average offset, \( a_0 \) is the offset associated with station \( n \), and \( d_i \) is the distance to station \( n \) raised to an exponent \( x \). The selection of the exponent \( x \) has been the subject of past research in two-dimensional interpolation of irregularly spaced points. Shepard (1968) recommends an exponent of two for the interpolation associated with general surface mapping (i.e., Inverse Distance Squared Weighting or Reciprocal Distance Squared Weighting). However, in this portion of the methodology, the objective is to reduce the possibility of a single erroneous station dominating the calculation of the offset. As the value of the exponent increases, the relative weight of the closest station is magnified. Therefore, for the purposes of this research, an exponent of one is deemed appropriate.

To generate the values used in Equation 2, a table is constructed using the freely available ArcGIS® Extension known as Hawth’s Tools (www.spatial ecology.com/htools/tooldesc.php). In particular, the Distances Between Points (Between Layers) function was used to generate a table consisting of each bathymetry point’s ID number, and the ID number and distances of the three (3) closest tidal benchmark stations. The bathymetry points were chosen as the source layer, the tidal benchmark stations were chosen as the target point layer, and “Nearest neighbors” with three closest points selected as the Analysis Option. This extension builds a table consisting of each bathymetry point, its three (3) nearest tidal benchmark stations, and the horizontal distances to those stations.

Table Views of the bathymetry points and the nearest tidal benchmark stations are created in ArcGIS® and named Bathymetry Table and Nearest TBM Table, respectively. These Table Views are joined yielding a new Table View called the Bathymetry-Nearest TBM Table that lists each bathymetry point, its horizontal and vertical position, and its nearest tidal benchmark stations.

Next, a Table View of the Tidal Benchmark Stations is created, named TBM Stations Table, and joined to the Bathymetry-Nearest TBM Table yielding a new Table View containing each bathymetry point, its horizontal and vertical position, nearest tidal benchmark stations (along with their distances from the point), and their associated offsets. An inverse distance weighted average offset for each bathymetry point is then calculated using Equation 2 above and applied by recalculating the POINT_Z attribute. We now have a file that can be used to construct the Bathymetric DEM.

**Incorporation of Topographic Data**

The major source of topographic data for the project is bare earth lidar and breakline products supplied by Woolpert, Inc. as part of the Florida Division of Emergency Management Coastal Lidar Project. In order to fill in areas in parts of Hillsborough, Hernando, Citrus, Manatee, Pasco, and Sarasota counties that are inside of the study area but outside of Woolpert’s coverage area, the project team utilized lidar and breakline data from the Southwest Florida Water Management District (SWFWMD). Finally, the remaining gaps in the data for the study area were filled using the Florida Fish and Wildlife Conservation Commission (commonly referred to as the FWC) 5 meter resolution DEM. According to the metadata, the FWC DEM was generated from tagged vector contours produced by the Florida Department of Environmental Protection (FDEP) and over 90,000 surface control points. Please refer to Figure 4 for a geographical depiction of data sources.

**Generation of the DTM**

In order to create the topographic DTM, the authors employed a framework within the ArcGIS® 9.2 environment utilizing an Esri data structure known as a Terrain Data Set (TDS). A TDS is a multi-resolution, Triangular Irregular Network (TIN) based surface constructed from raw data (lidar, sonar, photogrammetric sources, etc.) and stored as a feature in a geodatabase. A TDS resides inside feature datasets within personal, file and Spatial Database Engine (SDE) geodatabases. The other feature classes in the feature

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**Table 1. Tidal Benchmark Offset Examples**

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Station Name</th>
<th>*Elevation of NAVD88 (m)</th>
<th>*Elevation of MSL (m)</th>
<th>Offset Value (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8725362</td>
<td>TARPON BAY</td>
<td>1.534</td>
<td>1.350</td>
<td>0.184</td>
</tr>
<tr>
<td>8725809</td>
<td>MANASOTA</td>
<td>1.252</td>
<td>1.106</td>
<td>0.146</td>
</tr>
<tr>
<td>8726247</td>
<td>BRADENTON, MANATEE RIVER</td>
<td>0.907</td>
<td>0.900</td>
<td>0.007</td>
</tr>
<tr>
<td>8726724</td>
<td>CLEARWATER BEACH, GULF OF MEXICO</td>
<td>1.064</td>
<td>0.970</td>
<td>0.094</td>
</tr>
<tr>
<td>8727520</td>
<td>CEDAR KEY, GULF OF MEXICO</td>
<td>1.237</td>
<td>1.171</td>
<td>0.066</td>
</tr>
</tbody>
</table>

* Elevations of NAVD88 and MSL are referenced to a local station datum.
<table>
<thead>
<tr>
<th>Feature Class</th>
<th>Surface Feature Type (SFType)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIDAR POINTS</td>
<td>Mass point (contains elevations at points or vertices of lines or polygons)</td>
</tr>
<tr>
<td>HYDROGRAPHIC FEATURES</td>
<td>Hard Breakline (places TIN triangle edges on line and interprets as distinct break in slope)</td>
</tr>
<tr>
<td>ROADS</td>
<td>Hard Breakline</td>
</tr>
<tr>
<td>ISLANDS</td>
<td>Hard Fill Value (uses only points in polygon to interpolate elevations for polygon cells)</td>
</tr>
<tr>
<td>SOFT FEATURES</td>
<td>Soft Breakline (places triangle edges along line and interprets the terrain as smooth across line)</td>
</tr>
<tr>
<td>WATER BODIES</td>
<td>Hard Replace Polygon (areas of constant height)</td>
</tr>
<tr>
<td>COASTAL SHORELINE</td>
<td>Hard Breakline</td>
</tr>
<tr>
<td>PROJECT AREA</td>
<td>Soft Clip Polygon (define and prevent interpolation across polygon boundaries)</td>
</tr>
</tbody>
</table>

A dataset can either participate (i.e., be used but not stored in the TDS) or be embedded in the TDS, allowing the source data to be archived after the creation of the TDS. This is especially efficient for working with lidar data as digital file sizes are routinely one terabyte (TB) or more for county scale projects. In fact, the processed bare earth lidar data for a 5,000-foot square geographic area can contain approximately 1.1 million points (Coggin, 2008). Another advantage of a TDS is that it gives the user the ability to store and manage vector-based terrain information in the geodatabase. At this point, it is important to acknowledge the size limits for TDSs: two gigabytes (GB) in a personal geodatabase (FGDB), one TB in a file geodatabase (FCDM), and unlimited in an ArcSDE geodatabase.

The workflow for creating the topographic DTM is summarized as follows:

1. Create an FGDB and a feature dataset;
2. Convert LAS (lidar) data to a multipoint feature class using ArcGIS® 3D Analyst Tools (Note that some of the project lidar data was delivered in ASCII 3D format. These data were imported using the ASCII 3D to Feature Class conversion tool);
3. Import the multipoint feature class into the feature dataset along with any other relevant project feature classes such as breaklines and the project area boundary;
4. Build the TDS using the terrain parameters shown in Table 2;
5. Extract a Raster DTM (resolution = 50-feet, per project specifications) from the TDS.

Please note that the lidar data points for water bodies (Class 9 in the LAS system) required separate extraction and processing. Since the type of airborne lidar used in this project cannot accurately depict submerged topography, other means of representing the subsurface terrain of inland water bodies was needed. The project guidelines specified that in the absence of subsurface topographic data for inland water bodies, a depth of 1-foot should be specified. The project team applied this guideline by extracting all Class 9 LAS points separately and then adding the XYZ coordinates to the point attribute table. A new field was added to the attribute table and calculated to be POINT.Z - 1, effectively creating a 1-foot deep water body.

A few narrow gaps were discovered at the edges of the different topographic lidar data sets. These were very minor in nature and were treated by edge matching and a low pass filter in ArcGIS®. This served to eliminate the significance of the anomalous edges between lidar data sets.

Using the data and methodology described above, a land-only terrain surface for the Tampa Bay study area was generated. From this surface, a 50-foot resolution raster DTM was extracted.

The bathymetric DTM was created in a similar manner using the Terrain Dataset technique in ArcGIS® 9.2. Using this method, a terrain surface was first created from the bathymetric “mass points” and a raster DEM was then extracted from the terrain surface. Please note that both the shoreline (NOAA Medium Resolution Shoreline, Gulf of Mexico) and study boundary were triangulated as hard clips. The use of the coastline as well as other significant breaklines is an acceptable method to constrain the DTM (Jezek et al., 1999). Table 2 contains a list of the terrain parameters. As described above, a TDS was created and a 50-foot resolution raster DTM was extracted from this surface.

In order to produce the seamless topobathy DTM, the topographic and bathymetric Terrain Data Sets were merged. There was some overlap between the bathymetric and topographic data, but the NOAA medium-resolution shoreline used in this project was employed to clip the bathymetric data. There was a slight elevation disparity at the shoreline (hard breakline) that was treated by rubber sheeting and low pass filtering in ArcGIS® to reduce the significance of the anomalous edges. Once the topobathy TDS was complete and issues at the shoreline were resolved as described above, and the seamless topobathy DTM was extracted.

**Results**

The results of this study are the DTM raster products to be used in the hurricane storm surge modeling. Figure 5 depicts the topographic DTM and captures the prominent riverine features of the area including the Manatee, Little Manatee, Alafia, and Hillsborough Rivers. These are all large enough to be considered in the hurricane storm surge model therefore it is essential that they are described by the DTM.

![Figure 5. Topographic DTM.](image-url)
Figure 6 depicts the bathymetric DTM. Although Figure 6 covers a much larger area than Figure 5, the navigational channels within Tampa Bay and continental shelf are both easily recognized.

Figure 7 depicts the seamless topobathy DTM and it is evident that all of the prominent terrain features present in the topographic and bathymetric DTMs remain. This is a key advantage in using seamless topobathy DTMs in hurricane storm surge modeling. It allows for accurate inundation simulations, and also allows the modeler to study the effects of varying the initial water level as a parameter in the model independent of a horizontally predefined coastline boundary (Feyen et al., 2006).

For the area inside Tampa Bay, the results of the method of bathymetric adjustment presented herein compare favorably to those generated by VDatum. The area covered by VDatum contained a subset of the data consisting of 62,558 points. The average difference in applied offset was 0.061 meters with a range of 0.019 meters to 0.276 meters. The standard deviation was 0.026 meters. A difference plot of the applied offset values is shown in Figure 8. As shown, the differences between the two (2) methods are lower in offshore areas and higher in the estuarine areas as well as areas around the barrier islands (i.e., areas with more complex hydrodynamics).
Discussion
The method for generating digital terrain models, including the bathymetric adjustment, presented herein does have some limitations. As described above, the method requires significant manual processing of the data to ensure its applicability and accuracy. While this is typically the case for any DTM construction, especially those involving data from multiple sources, the additional step of adjusting the bathymetry adds some complexity to the process. However, the authors made efforts to present the method in an algorithmic manner so it (or parts of it) can be scripted in any number of computer programming languages. Related to the previous description, the time required to complete the method can be significant, and it is primarily a function of the number of points being used (either from geographically large or dense data sets). Other aspects that influence time are user skill and computing resources.

In addition to the time and labor based limitations, the method as presented has two (2) inherent geographical limitations: First, tidal benchmark stations located on narrow peninsulas, barrier islands, and inshore areas can lead to inaccuracies. In some instances, one of the nearest tidal benchmark stations to a bathymetry point will lie on the opposite side of a significant land barrier, as shown in Figure 9. This can lead to the application of an erroneous offset value because the tidal hydrodynamics at the southern most tidal benchmark station are drastically different than the other two (considered representative of the conditions at the bathymetry point), leading to different elevations of MSL [for example]. The use of multiple (in this case, three) tidal benchmark station offset values in the weighted average will reduce this effect overall.

Also, if the erroneous tidal benchmark station(s) are close to the bathymetry point relative to the others, its effect will not be artificially magnified due to the selection of the exponent in the IMW formulation. Another means for preventing errors of this nature is the incorporation of barrier methods to the interpolation (Raber and Tullis, 2007) by preventing the selection of a tidal benchmark station located on the opposite side of a “barrier” (in this case, a land mass).

Similarly, areas with sparse tidal benchmark station coverage present the same error. In this case, the tidal benchmark station(s) may be a substantial distance from the bathymetry point being adjusted and therefore not applicable on a tidal datum basis. This effect can be minimized by possibly selecting fewer tidal benchmark stations to include in the average or imposing maximum distance criteria to the selection of the stations, thereby focusing on only those stations close to the bathymetry point.
Conclusions

While other coastal modeling studies such as Feyen et al. (2006) have integrated lidar and bathymetric data, presented herein is a novel approach to generating coastal Digital Terrain Models (DTMs) using the Terrain Data Set structure in ArcGIS®. This approach is desirable primarily due to its ability to embed the points in the Terrain Data Set, thereby allowing the large point files to be compressed and archived at an alternate and/or offline storage site. This allows the user to generate end products with varying characteristics such as resolution and interpolation method without having to deal with cumbersome point files. These end products are usable in a variety of engineering and mapping applications; in particular, they are used effectively as a source of topographic data for hydrologic, hydraulic, and coastal inundation models. Also presented herein is a method for adjusting bathymetric data from a tidal datum to an orthometric datum. This particular method is useful in two (2) primary capacities: first, it can be used in areas that have yet to be covered by NOAA’s VDatum product. This includes areas outside of the United States, provided there are accurately surveyed tidal stations in the region. Second, the method can be used to verify the results of a VDatum conversion to ensure that the results are reasonable.

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