Humboldt Bay Sea Level Rise DEM Development Report

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1 OVERVIEW

In February 2013, Northern Hydrology and Engineering (NHE) contracted Pacific Watershed Associates (PWA) to develop a seamless topographic/bathymetric digital elevation model (DEM) to support the hydrodynamic modeling and inundation mapping components of the Humboldt Bay Sea Level Rise Adaptation Planning (HBSLRAP) project. Although a number of different terrain data sets existed for the Humboldt Bay region, including a recently acquired high resolution bare-earth Lidar DEM (California State Coastal Conservancy 2012), none provided the continuous coverage of subtidal, intertidal, and terrestrial areas required to support hydrodynamic and inundation modeling associated with sea level rise. To complete this task, PWA acquired and evaluated several bathymetry data sets covering the Humboldt Bay region, established common horizontal and vertical datums, prioritized input data sets according to accuracy, spatial resolution, and date of development, and mosaicked these data sets with the bare-earth lidar DEM to generate a continuous bathymetric and topographic surface model of Humboldt Bay and the surrounding coastal communities.

2 DATA ACQUISITION AND EVALUATION

Several data sets were acquired and evaluated for inclusion in the Humboldt Bay project DEM. To begin with, the 2009-2011 California Coastal Conservancy Coastal Lidar Project hydro-flattened, bare earth DEM was evaluated for intertidal, shoreline and adjacent terrestrial coverage and accuracy. This lidar data set provides the Humboldt Bay region with 1-meter resolution topographic data spanning the intertidal zone up to and in some cases, beyond the 10 meter elevation contour. Development of this data set helped to address what had been a significant data gap in terms of providing high-resolution topographic data for coastal areas of Humboldt County. Although this data set provided seamless coverage of both the intertidal portions of Humboldt Bay and the surrounding terrestrial landscape, subtidal areas that were submerged at the time of data acquisition lacked depth data due to the limited ability of lidar to penetrate turbid estuarine water. For subtidal portions of Humboldt Bay subject to recurrent maintenance dredging, several partially-overlapping surveys conducted during the last 10 years by the U.S. Army Corps of Engineers (USACE), the National Ocean Service (NOS), and the Seafloor Mapping Lab (SFML) at California State University Monterey Bay provided contemporary/recent bathymetry data for inclusion in the project DEM. For subtidal areas of Humboldt Bay not subject to ongoing dredging, historic soundings included in the National Oceanic and Atmospheric Administration (NOAA) electronic navigational chart of Humboldt Bay were used to supplement bathymetry. Table 1 below lists the sources of topographic and bathymetric data used to generate the Humboldt Bay project DEM.

Table 1. Topographic, bathymetric, and shoreline datasets used to develop the Humboldt Bay project DEM.

Source	Year	Type	Resolution/Scale	Horizontal Datum	Vertical Datum
CA SCC/NOAA CSC	2009-2011	Bare-Earth Lidar	1 meter grid	NAD83 UTM Zone 10	NAVD88
USACE	2013	Hydrographic survey	N/A	NAD83 California zone 1 ft	MLLW
NOS/NOAA	2008	Multibeam sonar	1:10,000	NAD83	MLLW
SFML	2005	Multibeam sonar	1 meter grid	WGS84 UTM Zone 10N	NAVD88
OCS/NOAA	1900-1989	ENC 18622 extracted soundings	1:25,000	WGS84	MLLW
NOAA/CSC	2009	Humboldt Bay CA Habitat: classified imagery	1:24,000	NAD83 UTM Zone 10N	MLLW
CA SCC	2013	Humboldt Bay CA Shoreline Inventory	1:2,400	NAD83 UTM Zone 10N	N/A

3 DATA PRIORITIZATION AND PROCESSING

The coastal lidar DEM was determined to be the highest priority data set for terrestrial and intertidal areas above mean lower low water (MLLW) based on spatial resolution, vertical accuracy, and broad coverage of the majority of the project/study area including most of the resources of concern to the HBSLRAP project. For subtidal areas, partially overlapping SFML, NOS and USACE hydrographic survey data depicting bathymetry within the dredged, navigational channel reaches of Humboldt Bay were evaluated and prioritized on the basis of spatial resolution and extent. Remaining subtidal portions of Humboldt Bay slough channels not maintained by active dredging, and not readily navigable by most contemporary hydrographic survey platforms, lacked recent bathymetric data. For these areas, historic sounding data extracted from a NOAA raster navigational chart were used to generate bathymetry for the project DEM.

All processing associated with development of the Humboldt Bay project DEM was done using ArcGIS 10.1 software (ESRI, Redlands, CA). To achieve full coverage of intertidal and terrestrial portions of the project area, the California Coastal Conservancy Lidar DEM was downloaded as two adjacent tiles that were then mosaicked to a new raster and projected to WGS84 UTM Zone 10 North. Shoreline data developed as a major component of the Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment Project (Laird et al. 2013) was converted to a polygon and additional shoreline segments along the north and south jetties were digitized to enclose the bay portion of the model. To define the geographic extent of Humboldt Bay where supplemental bathymetry data would be used to generate the subtidal surface of the project DEM, the *Unknown Benthic Habitat* feature class extracted from the 2009 Humboldt Bay CA Habitat shapefile, was used to delineate MLLW (Schlosser and Eicher 2009) and serve as an analysis mask for further processing.

SFML multibeam sonar data were assigned the highest priority of the partially overlapping, supplemental bathymetry data sources for subtidal areas due to the high spatial resolution of the data and broad coverage of the upper reaches of major channels in both North and South Bay. NOS multibeam sonar data were assigned the second highest priority, because although it provided high resolution bathymetry of navigational channel sideslopes beyond the extent of the SFML or USACE data, it lacked continuous bottom coverage within the channels. USACE hydrographic survey data were given the lowest priority of the three recently acquired bathymetry data sets due to the lower spatial resolution of the data; however, this data set provided more extensive coverage of navigational channel centerlines as well as portions of the inner harbor adjacent to Woodley Island that the other data sets lacked.

USACE and NOS hydrographic data were projected to WGS84 UTM Zone 10 North and converted from a vertical datum of MLLW to NAVD88 using correction data from the North Spit tide gage. Inverse distance weighted (IDW) interpolation was then used to generate a surface from the USACE x,y,z point data. USACE and NOS data were combined with SFML data using the mosaic to new raster tool. For upper channel sloughs and tributaries, historic soundings provided in the NOAA nautical chart of Humboldt Bay were used to generate a bathymetric surface. Since the nautical chart sounding data were extremely sparse in coverage and not readily suitable for direct surface interpolation, a triangulated irregular network (TIN) was created as an intermediate processing step to generate more realistic channel morphology. To develop the TIN, the subtidal extent polygon generated from the *Unknown Benthic Habitats* feature class was corrected to NAVD88 and used as a hard breakline. Sounding data from the nautical chart representing channel centerline depths were also corrected to NAVD88 and used to digitize hard breaklines representing channel thalwegs. To complete the TIN surface, the subtidal extent polygon was used to softclip the triangulation extent. The TIN was converted to a raster grid and mosaicked with the lower channel bathymetry, with priority given to the surface generated by the more recent bathymetry datasets. The combined bathymetry was merged with the coastal lidar DEM using the mosaic to new raster tool to generate a seamless topographic/bathymetric DEM of the project area. Modified shoreline data (Laird et al. 2013) was then used to divide the project DEM into terrestrial/upland and tidally influenced subcomponents for the purpose of hydrodynamic modeling. Figure 1 illustrates the coverage of input topographic and bathymetric data contributing to the Humboldt Bay project DEM.

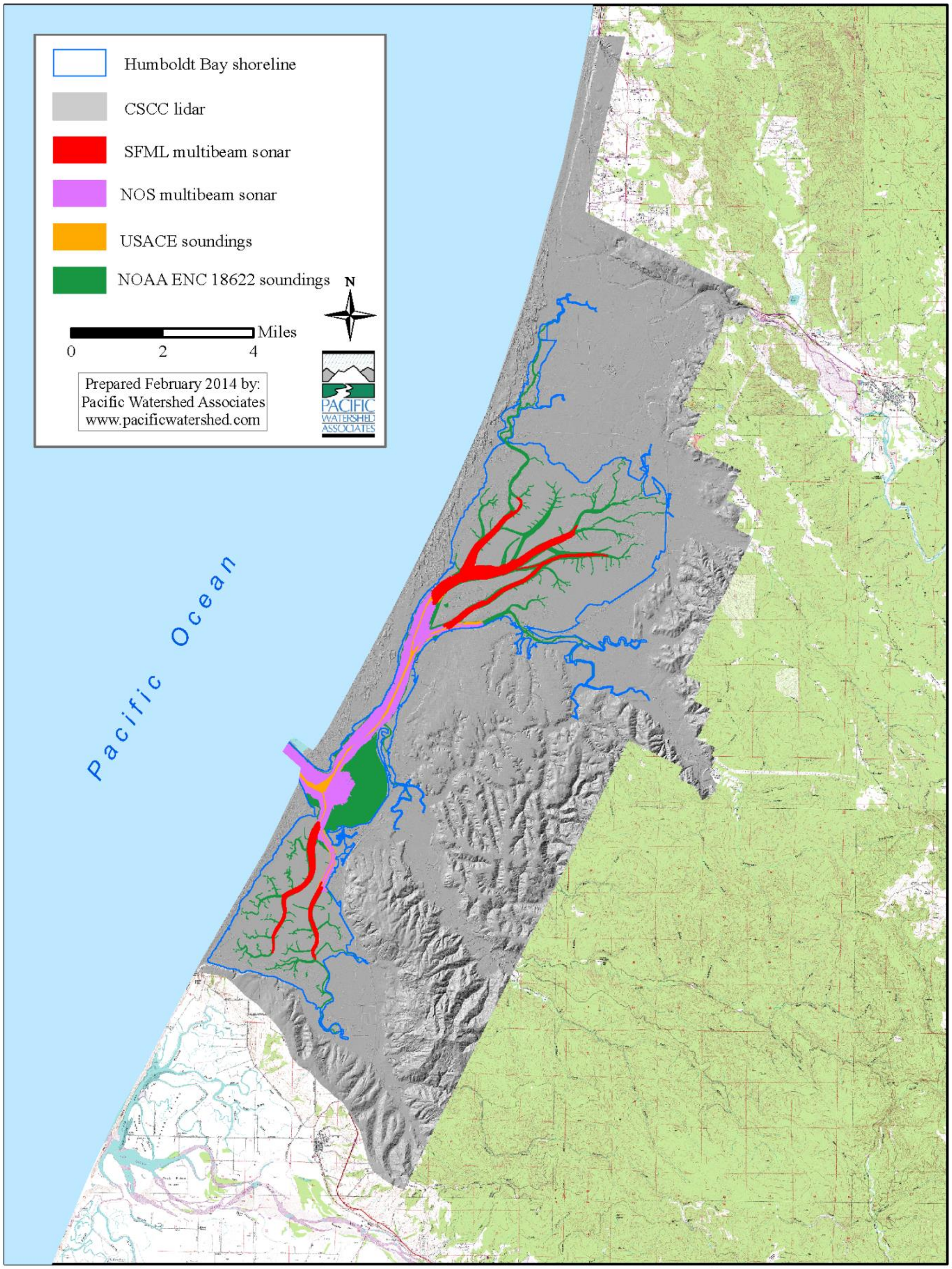

Figure 1. Topographic and bathymetric data sources contributing to the Humboldt Bay project DEM.

4 DISCUSSION

The accuracy of the elevation and bathymetry data used to develop the project DEM, varied according to the type and age of the input data. Recently developed Lidar-based coastal elevation data covering the majority of the project area was reported as having a vertical accuracy of 18 cm for at least 95% of positions where survey grade GPS data were available for comparison (California State Coastal Conservancy 2012). For bathymetric datasets, vertical accuracy was somewhat more difficult to quantify due to the combined effects of depth dependent and independent (tide level and vessel motion) factors, as well as less consistent vertical accuracy standards. Multibeam sonar survey data provided by SFML were reported to have a heave (vessel vertical position) accuracy of 10 cm prior to tidal correction (SFML 2005). NOS multibeam sonar data were reported to have a total positional accuracy of 1 meter (Moore et al. 2008) following vessel motion and tidal correction and USACE hydrographic sounding data were reported as having a precision of 0.1 feet prior to tidal correction, with an unknown heave accuracy (USACE 2013). For historic bathymetric sounding data collected between 1900-1990 (inset sections B4 and B5, chart 18622; NOAA 2010) that was utilized to supplement coverage of tidal slough and bay tributary channels, positional accuracy is unknown, however; comparison of channel alignment and morphology derived from recent imagery data (NOAA 2009) and historic soundings suggest that both vertical and horizontal positional uncertainty of the historic sounding data may be on the order of several meters in some locations.

5 CONCLUSIONS AND RECOMMENDATIONS

The Humboldt Bay project DEM represents the best continuous bathymetric/topographic surface model of the Humboldt Bay area developed to date in terms of both overall accuracy and precision. The DEM was compiled from the best data available in the public domain at the time the study was conducted. The recent acquisition of high-resolution lidar topographic data covering the majority of the study area made it possible for the first time, to conduct a vulnerability assessment for the Humboldt Bay community.

While this project DEM provides a sound foundation for inundation and hydrodynamic modeling simulations, it is not intended to be used for other purposes, including as an aid to navigation. To improve upon this DEM for future modeling applications, the following actions are recommended. Modern, high-resolution bathymetry of sloughs and bay tributaries should be acquired to improve our understanding of the subtidal estuarine extent of Humboldt Bay. Additionally, post-processing of lidar data for low-elevation intertidal areas partially submerged at the time of data acquisition could be improved by evaluating and correcting the vertical offset observed between adjacent flight lines, particularly in areas of South Humboldt Bay.

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