W00660

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

DESCRIPTIVE REPORT

Type of Survey:	Navigable Area
Registry Number:	W00660

LOCALITY

State(s):	California
General Locality:	Long Beach
Sub-locality:	Vicinity of Terminal Island

2021

CHIEF OF PARTY
John M. Staly, CH

LIBRARY & ARCHIVES

Date:

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTRY NUMBER:

HYDROGRAPHIC TITLE SHEET

W00660

INSTRUCTIONS: The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

State(s):	**California**
General Locality:	**Long Beach**
Sub-Locality:	**Vicinity of Terminal Island**
Scale:	**25000**
Dates of Survey:	**08/11/2021 to 08/20/2021**
Instructions Dated:	**N/A**
Project Number:	**ESD-PHB-22**
Field Unit:	**David Evans and Associates, Inc.**
Chief of Party:	**John M. Staly, CH**
Soundings by:	**Teledyne RESON SeaBat T50-R (MBES)**
Imagery by:	**N/A**
Verification by:	**Pacific Hydrographic Branch**
Soundings Acquired in:	**meters at Mean Lower Low Water**

Remarks:

Any revisions to the Descriptive Report (DR) applied during office processing are shown in red italic text. The DR is maintained as a field unit product, therefore all information and recommendations within this report are considered preliminary unless otherwise noted. The final disposition of survey data is represented in the NOAA nautical chart products. All pertinent records for this survey are archived at the National Centers for Environmental Information (NCEI) and can be retrieved via https://www.ncei.noaa.gov/. Products created during office processing were generated in NAD83 UTM 11N, MLLW. All references to other horizontal or vertical datums in this report are applicable to the processed hydrographic data provided by the field unit.

DESCRIPTIVE REPORT MEMO

December 29, 2022

MEMORANDUM FOR: Pacific Hydrographic Branch

FROM: Report prepared by PHB on behalf of field unit
John M. Staly, CH
Project Manager, David Evans and Associates, Inc.

SUBJECT: Submission of Survey W00660

The purpose of this hydrographic survey is to support the POLB Harbor Sounding Program and update bathymetric maps with current data that is suitable for nautical charting updates to meet the National Oceanic and Atmospheric Administration (NOAA), Office of Coast Survey (OCS), Categorized Zone of Confidence A1 (CATZOC A1) standards.

Please see the attached report for products that were created for this survey.

The vertical datum for this project is Mean Lower Low Water. The horizontal datum for this project is North American Datum of 1983 (NAD 83). The projection used for this project is Universal Transverse Mercator (UTM) Zone 11.

Please see the attached report for more information about the data acquisition and processing that occurred for survey W00660.

Two Dangers to Navigation were reported and registered by NDB.

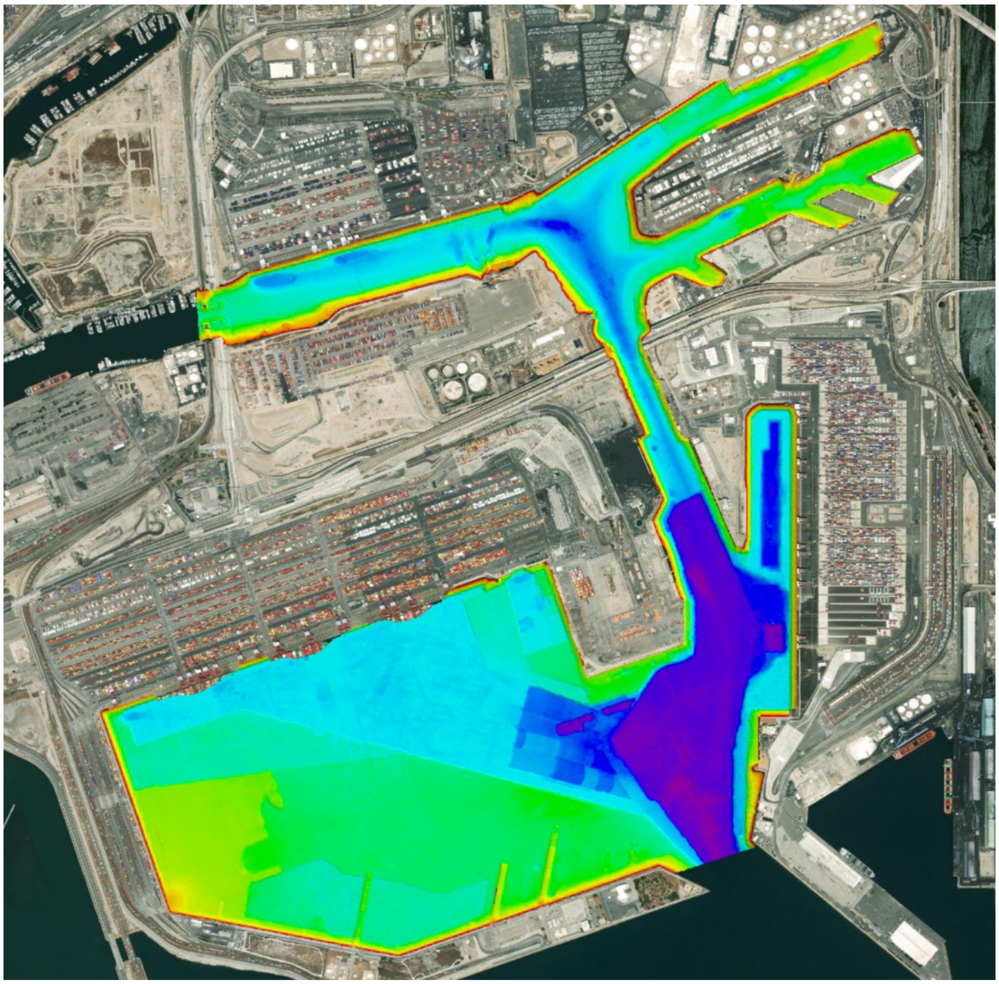
Data was provided by David Evans and Associates, Inc. on behalf of the Port of Long Beach. acquired the data outlined in this report. Additional documentation from the data provider may be attached to this report.

This survey does meet charting specifications and is adequate to supersede prior data.

Port of Long Beach
Harbor Sounding Program
W00660 - Hydrographic Survey Report
NOAA ESD Submission

Inner Harbor (Area 1), Middle Harbor (Area 2), West Basin (Area 3), Long Beach Pilot Operating Area (Area 8)

August 2021



Prepared by:

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Marine Services Division
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Owner:

Port of Long Beach
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Port of Long Beach
Harbor Sounding Program

W00660 - Hydrographic Survey Report
NOAA ESD Submission

Inner Harbor (Area 1), Middle Harbor (Area 2), West Basin (Area 3), Long Beach Pilot Operating Area (Area 8)

August 2021

Prepared by:

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NSPS-THSOA Certified Hydrographer, #322
David Evans and Associates, Inc.
Project Manager

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NSPS-THSOA Certified Hydrographer, #107
David Evans and Associates, Inc.
Senior Vice President, Director of Marine Services

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ACRONYMS AND ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
CATZOC A1	Categorized Zone of Confidence rating A1
CLBRTN	City of Long Beach Real-Time Reference Network
DEA	David Evans and Associates, Inc.
DtoN	Danger to Navigation
ENCs	Electronic Navigational Charts
GMT	Greenwich Mean Time
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HVF	HIPS Vessel File
Hz	Hertz
IHO	International Hydrographic Organization
kHz	kilohertz
kW	kilowatt
MHW	Mean High Water
MLLW	Mean Lower Low Water, Epoch 1983-2001
NAD83(2007)	North American Datum of 1983, 2007 realization
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NTRIP	Networked Transport of RTCM via Internet Protocol
Obst	Obstruction
OCS	Office of Coast Survey
PDT	Pacific Daylight Time
POLB	Port of Long Beach
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse Per Second
Rk	Rock
RTCM	Radio Technical Commission for Maritime Services
RTK	Real-Time Kinematic
SBET	Smoothed Best Estimate of Trajectory
S/V	Survey Vessel
TVU	Total Vertical Uncertainty
USACE	United States Army Corps of Engineers
UTC	Coordinated Universal Time
Wk	Wreck
ZDA	Global Positioning System Timing Message

1.0 INTRODUCTION

Between August 11, 2021, and August 20, 2021, David Evans and Associates, Inc. (DEA), Marine Services Division, conducted a high-resolution hydrographic survey using Object Detection multibeam coverage in the Port of Long Beach (POLB) (Figure 1). The purpose of this hydrographic survey is to support the POLB Harbor Sounding Program and update bathymetric maps with current data that is suitable for nautical charting updates to meet the National Oceanic and Atmospheric Administration (NOAA), Office of Coast Survey (OCS), Categorized Zone of Confidence A1 (CATZOC A1) standards.

Specifically, this effort included the following:

- Portion of Los Cerritos Channel, Channel 2, Channel 3, Inner Harbor (Figure 1, Area 1)
- Back Channel, Middle Harbor, Pier E (Figure 1, Area 2)
- West Basin (Figure 1, Area 3)
- Portion of the Long Beach Pilot Operating Area (Figure 1, Area 8)

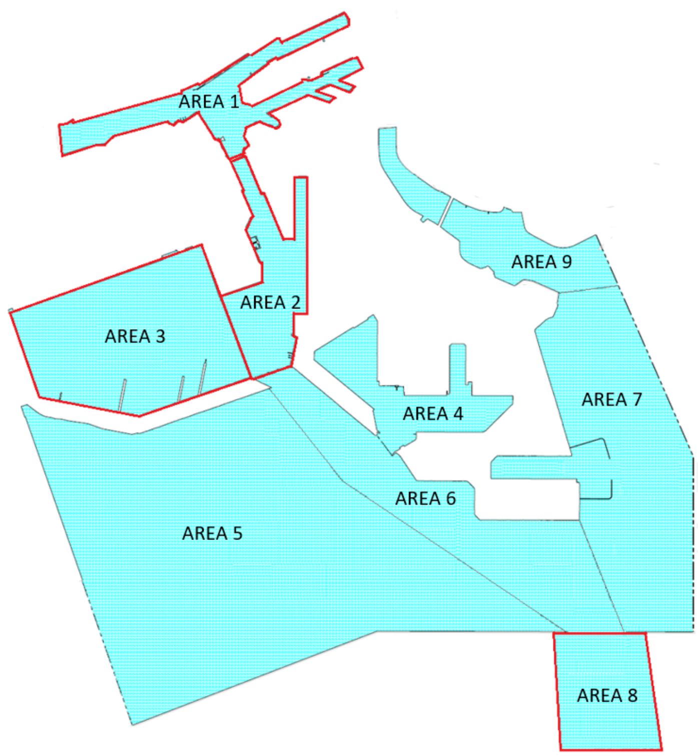


Figure 1. Port of Long Beach Hydrographic Survey Index Map with survey areas in red

DEA submitted a report of survey, map products, and a series of digital deliverables to the Port of Long Beach on October 28, 2022.

This report, which was written specifically to support the External Source Data (ESD) submission to NOAA OCS, describes data acquisition, processing, and quality control methodology, as well as summarizes the project's horizontal and vertical control. A list of deliverables included with the ESD submission is included in Section 6.0 Deliverables of this report. A table listing project metadata required for the ESD submission process is included in Appendix A. Data acquisition, processing and reporting for this survey closely follows methods used for prior ESD survey W00628, which was performed by David Evans and Associates, Inc. for the Port of Long Beach. Survey W00628 was accepted by the NOAA processing branch and assessed to support CATZOC A1 requirements for coverage, quality, uncertainty, and feature detection.

Surveys were performed under the direction of a California-licensed Professional Land Surveyor and National Society of Professional Surveyors - The Hydrographic Society of America (NSPS-THSOA) Certified Hydrographer.

Dates of Hydrography for the survey are included in Table 1.

Table 1. W00660 Dates of Hydrography

Survey Dates	Day of the Year
8/11/2021	223
8/12/2021	224
8/13/2021	225
8/14/2021	226
8/15/2021	227
8/16/2021	228
8/17/2021	229
8/18/2021	230
8/19/2021	231
8/20/2021	232

2.0 HORIZONTAL AND VERTICAL DATUMS

The horizontal datum for this survey is the California State Plane Zone 5, NAD83, 2007 realization (NAD83 (2007)), which is the datum used by Port of Long Beach. The vertical datum is Mean Lower Low Water, Epoch 1983-2001 (MLLW). The horizontal and vertical units are in U.S. Survey Feet.

For the purposes of the NOAA ESD submission, the coordinate reference system (CRS) for the CARIS HIPS project and derivative products has been changed to NAD83 (2011), UTM Zone 11 North. The transformation was necessary to overcome a known bug in HIPS which prevents the incorporation of designated soundings into finalized surfaces which use a CRS with horizonal units in feet.

All time tagging in HYPACK software and in the hydrographic survey logs are Coordinated Universal Time (UTC), which is a time standard equivalent to Greenwich Mean Time (GMT), which is seven hours ahead of Pacific Daylight Time (PDT).

3.0 BATHYMETRIC SURVEYS

3.1 Survey Area and Coverage

The full survey area included Areas 1, 2, 3, and 8. Figure 2 shows the overall data coverage overlaid on the NOAA raster navigation chart, soundings in feet, with significant overlap achieved beyond the boundaries of the individual areas. There are some coverage gaps at Terminal T, Berths T132 through T138, and Pier 15, where ships were at berth during the entire survey period. Occasional small object detection holidays exist along the edges of the survey area or along the tops of break waters.

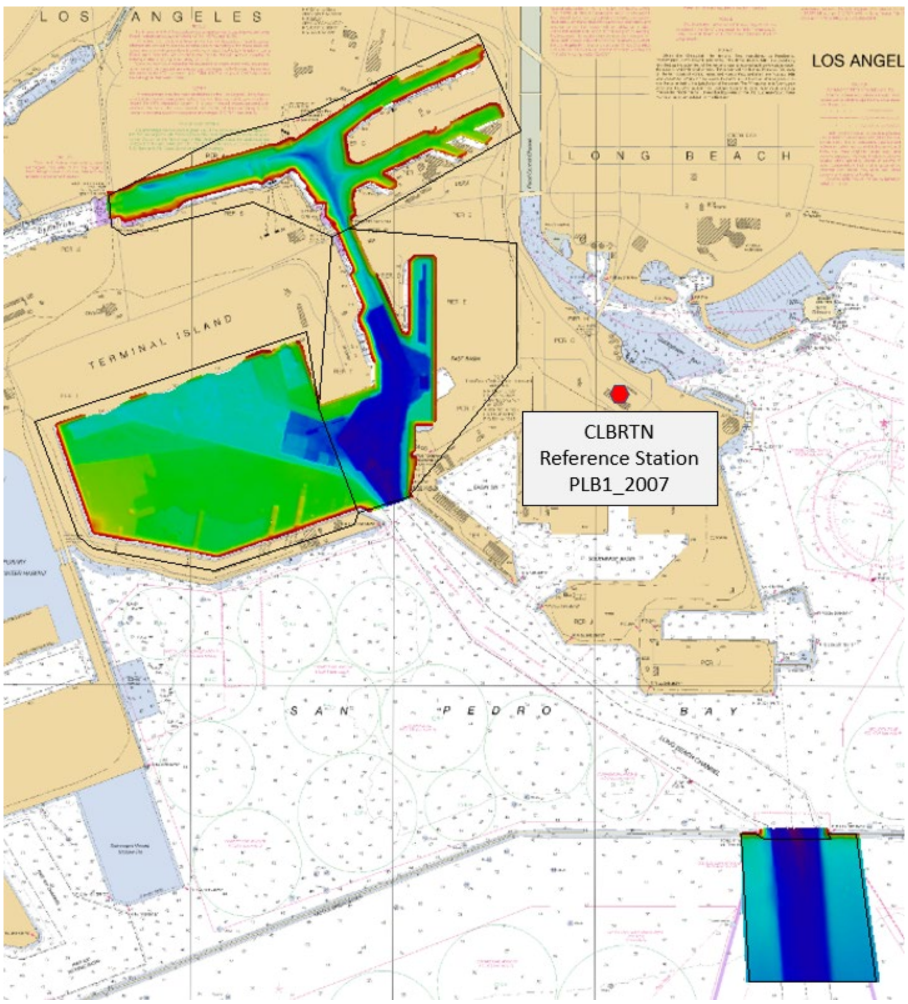


Figure 2. Overview of survey area with multibeam hillshade imagery of coverage

The survey exceeded the Special-Order Hydrographic Survey specification as defined by the International Hydrographic Organization (IHO), September 2020, IHO Standards for Hydrographic Surveys, Special Publication No. 44, Edition 6.0.0, and NOAA CATZOC A1 requirements for multibeam bathymetric surveys.

3.2 Control

Control for the survey was provided by the City of Long Beach Real-Time Reference Network (CLBRTN), which provided Real-Time Kinematic (RTK) corrections to the survey vessel via Networked Transport of Radio Technical Commission for Maritime Services (RTCM) via Internet Protocol (NTRIP). This provided the survey vessel global navigation satellite system (GNSS) correctors for precise horizontal and vertical positioning relative to NAD83(2007) geographic positions and ellipsoid heights. Archived observables from the CLBRTN were also used for post-processing corrections during cellular outages. Table 2 includes final coordinates and elevations for the CLBRTN reference station used to control hydrographic surveys.

Table 2. CLBRTN Hydrographic Survey Control

Designation	Use	NAD83(2007)		
		Latitude	Longitude	Ellipsoid Height
PLB1_2007	GNSS Reference Station	N 33 45 11.99087	W 118 11 52.54022	-20.614 meters

HYPACK software was used to project NAD83(2007) geographic positions to California Zone 5 coordinates in U.S. Feet. A custom separation model that was compiled for the Port of Long Beach by DEA was used to reduce ellipsoid heights to MLLW. The model was compiled from NOAA's VDatum model, adjusted to fill gaps in the grid and vertically adjust NAD83(2007) ellipsoid heights to match MLLW published values for Tidal Benchmark 941 0660 Tidal 8, which is the primary benchmark for the NOAA, National Ocean Service (NOS) water level station 941 0660 at Port of Los Angeles. DEA established the vertical adjustment relative to corrections from the CLBRTN NAD83(2007) during previous multiple RTK and static GNSS observations on 941 0660 Tidal 8.

3.3 Survey Vessel and Equipment

3.3.1 Survey Vessel

The vessel used for the multibeam hydrographic and laser scan survey was DEA's customized 27-foot aluminum-hulled survey vessel (S/V) *Seahawk* (Figure 3), powered by twin 200-HP outboard engines. The Seahawk is a North River offshore vessel customized by DEA for safe and efficient hydrographic survey operations. The vessel is equipped with port and starboard sonar mounts, 7.5 kW generator, GNSS and inertial positioning and motion reference system, mounts for a mobile laser scanner, equipment rack with hydrographer workstation, and twin Garmin multifunction displays for radar, chart plotter, and sonar.

Figure 3: Multibeam Survey Vessel *Seahawk*

3.3.2 Data Acquisition System

All multibeam bathymetry and laser scan data were acquired in HYPACK HYSWEEP. Data from each survey sensor was date- and time-stamped and logged in individual survey line files in HSX file format. The software also displayed real-time coverage and other quality control information (position quality, individual sonar beam quality, etc.).

All time-tagging of bathymetric data in HYPACK software and in the hydrographic survey logs are Coordinated Universal Time (UTC), which is a time standard equivalent to Greenwich Mean Time (GMT), which is seven hours ahead of Pacific Daylight Time (PDT).

3.3.3 Multibeam Echosounder System

The multibeam echosounder consisted of a single Teledyne RESON SeaBat T50R. The system utilized a single sonar head mounted on a port custom side-mount strut. The sonar was operated at 400 kilohertz (kHz) with 512 beams. Range adjustments were made during acquisition as dictated by changes in water depth.

3.3.4 Laser Scanning System

Vessel laser data was acquired using a Carlson Merlin laser scanner. The laser data was time-stamped to UTC times using the internal Global Positioning System (GPS) mounted on the laser scanner. This system was used to map the three existing bridge heights and transmission lines that span the Cerritos Channel. Processed laser scan point cloud data were used to digitize the outline of an uncharted fireboat dock which has been included in the feature file and to verify the position of some charted shoreline construction features. Raw and processed laser scan data were not included with the ESD submission but are available upon request.

3.3.5 Position, Heading, and Motion Reference Systems

Position, heading, and vessel attitude were acquired with an Applanix Position and Orientation System for Marine Vessels (POS/MV) with GNSS and inertial reference system, which was used to measure attitude, heading, heave, and position. The system was comprised of an Inertial Motion Unit (IMU), multi-frequency GNSS antennas, and a data processor. A secondary Trimble SPS855 GNSS receiver was installed over the vessel reference point to be used for vertical control for the survey.

The RESON sonar processor was provided a Pulse Per Second (PPS) and National Marine Electronics Association (NMEA) Global Positioning System Timing Message (ZDA) to achieve precise synchronization of sonar measurements with position and attitude data from the POS/MV.

The POS/MV integrated multi-frequency RTK-GNSS, and inertial reference system, were used as the motion sensor for this survey. The POS/MV is a 6-degree-of-freedom motion unit, with a stated accuracy of 0.02 meters, or 2% for TrueHeave, and 0.02 degrees for roll, pitch, and heading. Real-time displays of the vessel motion accuracy were monitored throughout the survey with the MV-POSView controller program.

3.3.6 Sound Speed Measurements

An AML Oceanographic Micro X housing (SN:010992) with SV-Xchange sound velocity sensor (SN:209142) mounted on the Teledyne RESON T50 sonar head was input into the RESON processor, and sound speeds from the sensor were used in real-time during acquisition. A Sea-Bird SBE 19plus conductivity, pressure, and depth sensor (SN:4962) and AML Oceanographic Smart X Profiler (SN: 134877) with sound velocity (SN:206832), pressure (SN304506), and temperature (SN:404148) Xchange sensors were used as the sound speed profilers during multibeam operations, with casts taken to the full depth of the project.

3.3.7 Vertical Measurements

All bathymetric data was time-tagged and recorded relative to the vessel reference point. Using a fixed vertical reference for both the sonar and GNSS systems, as opposed to using the water surface and making water surface observations, provides improved vertical accuracy as it considers dynamic changes in draft and local water surface variations in the vicinity of the survey. The sonar fixed draft was used to reference the soundings to the project vertical datum. Vertical reference point measurements, which approximately represent the water surface elevation, were obtained using each navigation system: the Applanix POS/MV and the Trimble SPS-855 RTK-GNSS receiver. RTK correctors were applied to the shipboard GNSS for logging of approximate water surface elevations at a rate of five hertz (Hz).

4.0 EQUIPMENT CALIBRATION

4.1 Patch Test

Patch tests were conducted to measure alignment offsets between the IMU sensor and the Teledyne RESON T50 sonar array and the Merlin laser scanner. In addition, these tests were used to confirm no time delays were present between the time-tagged sensor data. Patch tests consisted of a series of lines run in a specific pattern. A precise timing latency test was performed by running multiple lines in the same direction at differing speeds over a known feature on the seafloor.

Roll alignment was determined by evaluating reciprocal lines run over a flat bottom. The pitch tests consisted of a set of reciprocal lines located on a steep slope. The yaw error was determined by running parallel lines in opposite directions over the same area as the pitch tests. All lines were run at approximately 3 to 6 knots. Patch tests were run in the vicinity of the survey site. Patch test average values applied in CARIS HIPS software are listed in Table 3. All values were input and applied to all bathymetric data in the HIPS Vessel File (HVF).

Table 3. Patch Test Values

Date	Time	Sensor	Latency (seconds)	Pitch (degrees)	Roll (degrees)	Yaw (degrees)
8/11/2021	00:00	RESON T50	0.000	-0.825	-0.800	-1.100
8/12/2021	02:00	RESON T50	0.000	-0.700	-0.800	-1.260
8/13/2021	02:00	RESON T50	0.000	-0.767	-0.800	-1.025
8/14/2021	02:00	RESON T50	0.000	-0.750	-0.800	-1.250
8/16/2021	02:00	RESON T50	0.000	-0.667	-0.820	-1.263
8/17/2021	02:00	RESON T50	0.000	-0.933	-0.783	-0.888
8/18/2021	02:00	RESON T50	0.000	-0.723	-0.800	-1.100
8/19/2021	02:00	RESON T50	0.000	-0.790	-0.803	-1.050
8/20/2021	02:00	RESON T50	0.000	-0.800	-0.810	-0.900
8/19/2021	00:00	Merlin Laser	0.000	-14.920	0.510	0.690
8/20/2021	00:00	Merlin Laser	0.000	-14.920	0.510	0.690
8/20/2021	16:50	Merlin Laser	0.000	0.300	0.400	0.780

4.2 Position and Vertical Check

A horizontal position check and vertical check was conducted on NOS tidal benchmark 941 0660 Tidal 8, which is the primary benchmark for NOS water level station 941 0660, Port of Los Angeles. To conduct this check, the survey vessel pulled alongside the pier and the GNSS antenna from the Trimble SPS855 secondary positioning system was positioned on the monument with a 5.71-foot adjustable survey pole and data was logged in HYPACK software while receiving RTK-GNSS corrections from the CLBRTN CMR_X_2007 mount point. The position was compared to NAD83(2007) California Zone 5 coordinates in U.S. Feet that was acquired by Psomas in October 2016 (Table 4), and the vertical check was compared to the NOS published value of 13.76 feet MLLW.

Table 4. Psomas Position on 941 0660 Tidal 8

California Geodetic Coordinates of 1983			
	Deg.	Min.	Seconds
Latitude:	33	43	11.44146
Longitude:	118	16	22.21728
Ellipsoid Height (m):			-31.730

CCS 83, Zone 5 Coordinates		
	Meters	US Survey Feet
Northing:	524,421.403	1,720,539.22
Easting:	1,974,709.401	6,478,692.42
Combined Factor:	1.0000877	

NAD83	
Epoch:	2007.00
FGDC Acc.:	1.0 cm
Survey by:	Psomas
Adj.:	Oct 2016

The horizontal position obtained from 43 observed RTK-GNSS samples yielded an average position error North -0.02 feet (-0.06 cm) and East 0.06 feet (1.8 cm), with a standard deviation of North 0.01 feet and East 0.01 feet relative to the Psomas position in Table 4. This is well within the positioning requirements for the survey. The RTK-GNSS vertical check resulted in a MLLW elevation 0.10 feet (3 cm) lower than the NOS published MLLW elevation with a standard deviation of 0.01 feet (0.3 cm) over 43 samples. This is well within the expected vertical accuracy.

In addition, a vessel tide float was conducted near the NOS water level station 941 0660, Port of Los Angeles, and compared to 6-minute verified MLLW data logged by the station. A HYPACK line was logged for 15 minutes, and data was compared to the NOS water level observation at the even 6-minute interval using a 3-minute average centered on the 6-minute observation. The comparison resulted in an average water level observation 0.05 feet (1.5 cm) higher than the NOS observed water level with a standard deviation of 0.09 feet (2.7 cm).

4.3 Bar Check

A bar check was performed during survey operations. This was done to confirm the draft of the multibeam transducer on the *Seahawk*. The bar check was accomplished by lowering a bar on a marked chain below the sonar head to a known distance from the water surface, reading port and starboard drafts for an average draft, acquiring a sound speed cast, and logging multibeam on the bar.

The bar check was conducted within Area 2 and bar depth was assessed at 6 feet below the water surface. The difference between the bar depth and corrected multibeam depth was within 0.10 feet (3 cm) on average with a standard deviation of 0.06 feet (1.8 cm). During survey operations, dynamic draft and any changes in static draft due to vessel loading are accounted for using RTK-GNSS heights and a fixed distance from the GNSS antenna phase center to the acoustic reference point of the sonar.

4.4 Sound Speed Sensor Calibration

DEA submits sound speed sensors for factory calibration annually per NOAA specifications. In addition, a comparison is made to other sensors periodically during the survey to validate that the sensors are operating within design parameters.

5.0 DATA PROCESSING AND ANALYSIS

5.1 Data Processing

Post-processing of multibeam and vessel-based laser data was conducted utilizing HIPS versions 11.3.17 to 11.3.23, 11.4.4 and 11.4.14. Patch test data were analyzed, and alignment corrections were applied during processing. Smoothed Best Estimate of Trajectory (SBET) files were calculated using Applanix POSPAC for post-processing of combined inertial-GNSS data sets to account for any RTK dropouts for horizontal positioning and to extract ellipsoidally referenced GPS heights. The CLBRTN reference station PLB1 (2007) was used for POSPAC processing SBET files. SBETs were applied in HIPS by loading by day. The “Georeference - Compute GPS Tides” process in HIPS is the primary means by which bathymetric data is reduced to chart datum.

HIPS references all data to an ellipsoid height of the waterline obtained by RTK-GNSS and then applies the separation model to the ellipsoid-referenced data to achieve soundings relative to chart datum (MLLW). The separation model is an XYZ surface that represents the difference between the ellipsoid, NAD83(2007), and MLLW for a given geographic area. The XYZ separation model used for this workflow was a CARIS CSAR file and represents the difference between NAD83(2007) and MLLW at a given location.

Sound velocity profiles were used to correct multibeam slant range measurements and to compensate for any ray path bending. These were applied in CARIS using the closest in distance and time algorithm.

Processing began by verifying attitude (heave, pitch, roll, and heading) and navigation data, which were reviewed and accepted. Using the CARIS subset editor, sounding data were reviewed for quality and data flyers. Sounding data, including sonar beams reflecting from sediment in the water column, returns from aquatic life, or noise due to aeration in the water column, were carefully reviewed before being flagged as rejected. Soundings on significant features were designated and exported as an independent American Standard Code for Information Interchange (ASCII) file for mapping obstructions and capturing least depths.

For the purposes of submission through the NOAA ESD pipeline, data were reprocessed to incorporate sounding Total Propagated Uncertainty (TPU) and the creation of bathymetric surfaces using the CUBE gridding technique. Surfaces were generated following NOAA Object Detection grid resolution requirements defined in the 2022 Hydrographic Surveys Specifications and Deliverables (HSSD) and using the 2022 NOAA CUBE parameters file. Finalized CUBE grids were generated using the “greater of the two” option for the final uncertainty value and appropriate depth thresholds for Object Detection surfaces.

Object Detection Coverage surfaces submitted with this survey are listed in Table 5.

Table 5. Submitted Surfaces

Surface Name	Surface Type	Resolution (m)	Depth Range (m)
W00660_MB_50cm_MLLW.csar	CARIS Raster Surface (CUBE)	0.5	-0.691 – 26.723
W00660_MB_50cm _MLLW_Final.csar	Finalized CARIS Raster Surface (CUBE)	0.5	-0.691 – 20.000
W00660_MB_1m _MLLW.csar	CARIS Raster Surface (CUBE)	1	-0.682 – 26.692
W00660_MB_1m _MLLW_Final.csar	Finalized CARIS Raster Surface (CUBE)	1	18.008 – 26.749

5.2 Multibeam Crossline Sonar Beam Analysis

The multibeam sonar recorded 512 beams for each sonar ping covering a 120-degree swath, 60 degrees to either side of nadir (vertical below the sonar). The swath width was filtered to 60 degrees per side for Areas 1, 2 and 3, and 45 degrees per side for Area 8 to each side of nadir, and a crossline analysis was conducted to prove each of the sonar beams within the swath met accuracy requirements for the survey. The analysis involved running survey lines that crossed orthogonal to the primary survey line pattern and comparing the soundings from individual sonar beams in the crossline data to a 1-foot grid from the main scheme lines. The U.S. Army Corps of Engineers (USACE) requirement for maintenance dredging in water depths 15 feet to 75 feet, approximate depth range for this survey, is +/- 0.8 feet at a 95% confidence level. The analysis was also conducted using the IHO Special Order depth accuracy standards, which was modified from a 0.25-meter (0.82-foot) minimum accuracy to a 0.0762-meter (0.25-foot) minimum accuracy. This standard also uses a factor to increase the allowable inaccuracy based on depth. The IHO-modified Special Order allowable total vertical uncertainty (TVU) formula is listed below:

$$+-\sqrt{a^2+(b*d)^2}$$

Where:

a = 0.25 feet or 0.0762 meters (IHO Special Order calls for a= 0.25 meters)
b = 0.0075 (IHO Special Order depth factor)
d = water depth in feet

Figures 4 and 5 depict the results of this crossline beam analysis to document all beams used in the 120- and 90-degree swaths (60 and 45 degrees per side) meet both USACE requirements and IHO Special Order modified requirements. All beams exceeded 95% of soundings passing.

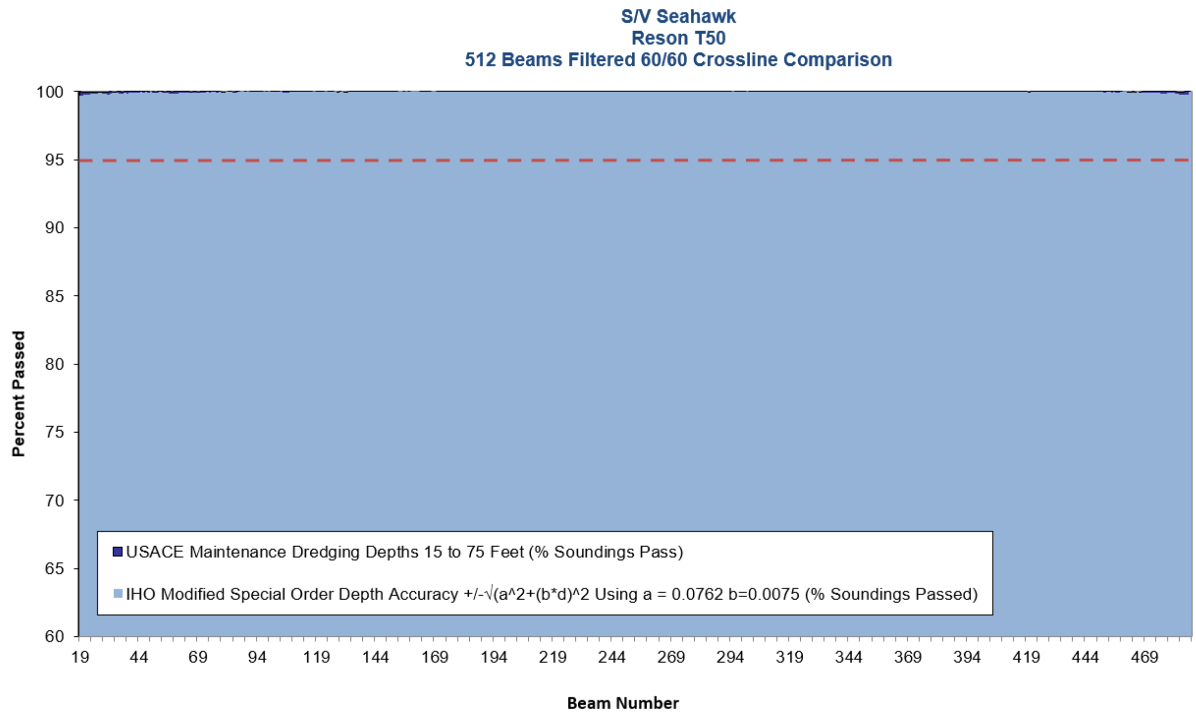


Figure 4. Histogram of crossline beam analysis Areas 1, 2, and 3

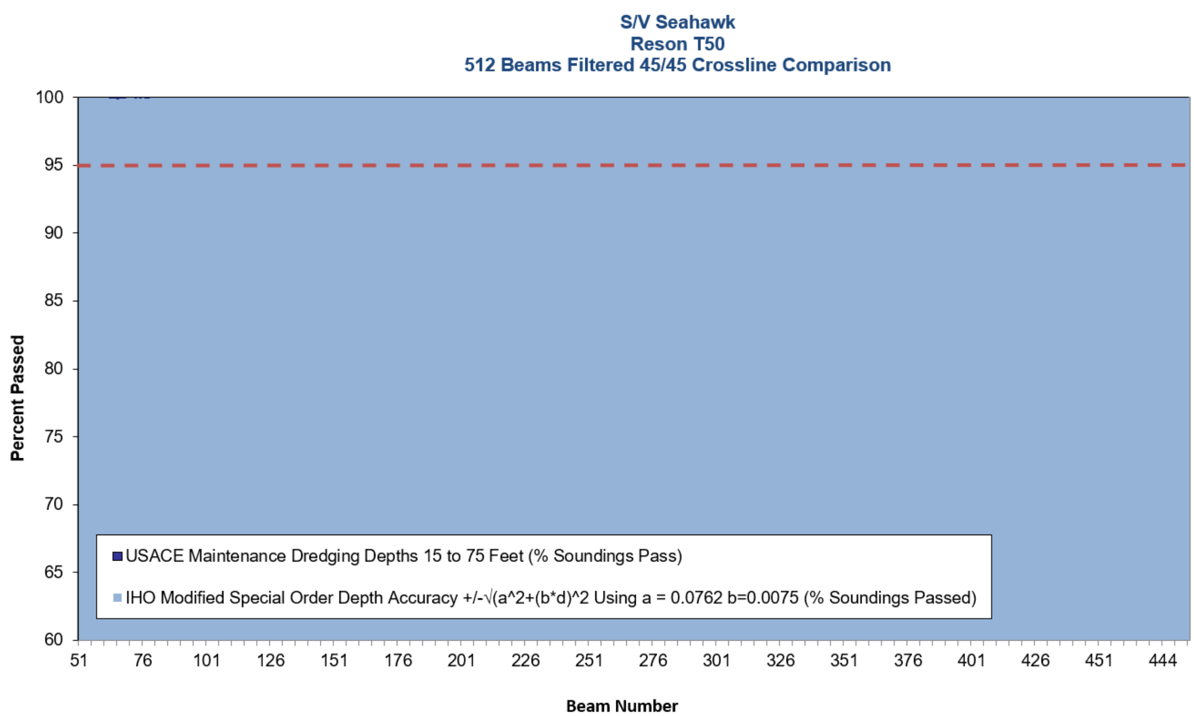
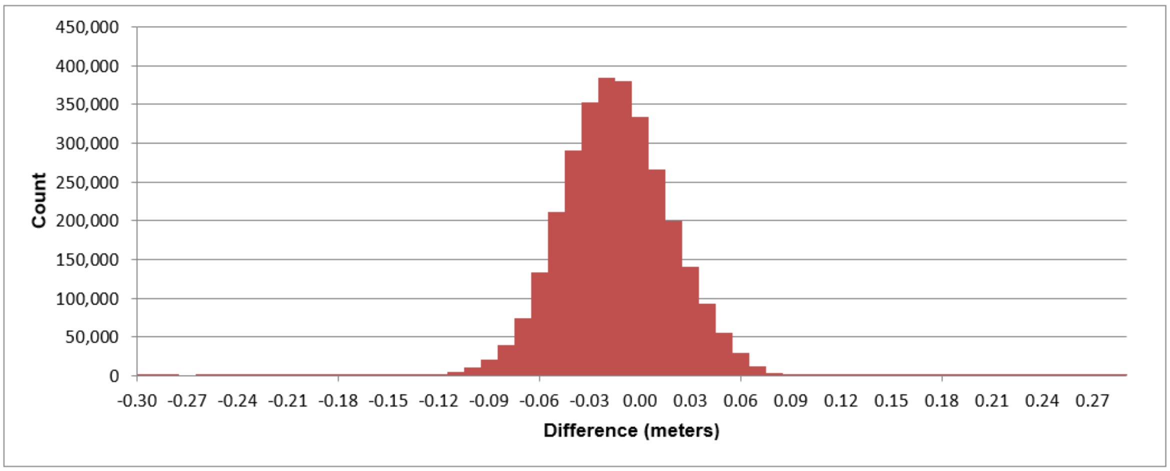


Figure 5. Histogram of crossline beam analysis Area 8

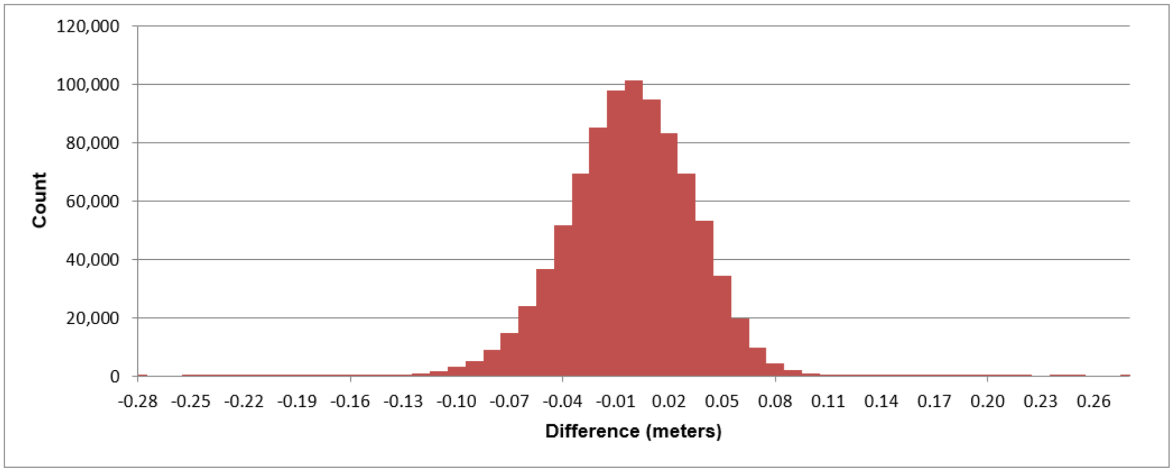
5.3 Multibeam Crossline Difference Analysis

To assess the precision of the survey, crossline data was gridded at a 1-foot resolution, consistent with the resolution grid from the main survey lines. A difference analysis was conducted between the surfaces to evaluate whether the precision of the survey met project requirements. The USACE typical repeatability (precision) requirement for maintenance dredging in water depths 15 to 75 feet, depth range for most of this survey, is 0.3 feet. Figures 6 and 7 present the full results of the analysis and document that the survey exceeds USACE requirements for repeatability, or mean difference, of 0.01 meters (0.03 feet vs. required 0.3 feet) and standard deviation at a 95% confidence level at 0.04 meters (+/- 0.13 feet vs. required +/- 0.8 feet) for the full range of survey depths. The larger minimum and maximum values are a result of comparing grid nodes at 1-foot resolution on slopes and features within the survey area.



Mean:	-0.01 m	Standard Deviation:	0.03 m
Minimum:	-0.3 m	Bin size:	0.01 m
Maximum:	0.29 m	Number of Nodes:	3,046,825

Figure 6. Histogram of crossline versus main line gridded data difference Areas 1, 2, and 3



Mean:	0 m	Standard Deviation:	0.04 m
Minimum:	-0.28 m	Bin size:	0.01 m
Maximum:	0.28 m	Number of Nodes:	876,421

Figure 7. Histogram of crossline versus main line gridded data difference Area 8

5.4 Uncertainty

Sounding TPU was computed specifically for the NOAA ESD submission. The HIPS vessel file was modified to include accurate values for parameters used in the computation process. Table 6 includes values for additional parameters used during TPU computation not stored in the HVF. The value used for Tide Measured uncertainty represents the uncertainty of the GNSS ellipsoid height measurements. The value used for Tide Zoning represents the published maximum cumulative uncertainty (MCU) for the regional VDatum grid covering the survey area.

Table 6. TPU Parameters

Parameter	Uncertainty
SVP Measured	0.5 m/s
SVP Surface	0.03 m/s
Tide Measured	0.03 m
Tide Zoning	0.081

The NOAA Pydro QC Tools was used to evaluate uncertainty values in the finalized CUBE surfaces generated from the survey data. Results from this analysis are presented in Figures 8 and 9. The mean grid uncertainty for depths reported for the 50-centimeter surface is 0.17 meters. This value is representative of the general depth uncertainty for the entire survey and has been included in the Positional Accuracy Vertical field in Appendix A. The best estimate for horizontal position accuracy for the survey reported in Appendix A is 0.1 meters.

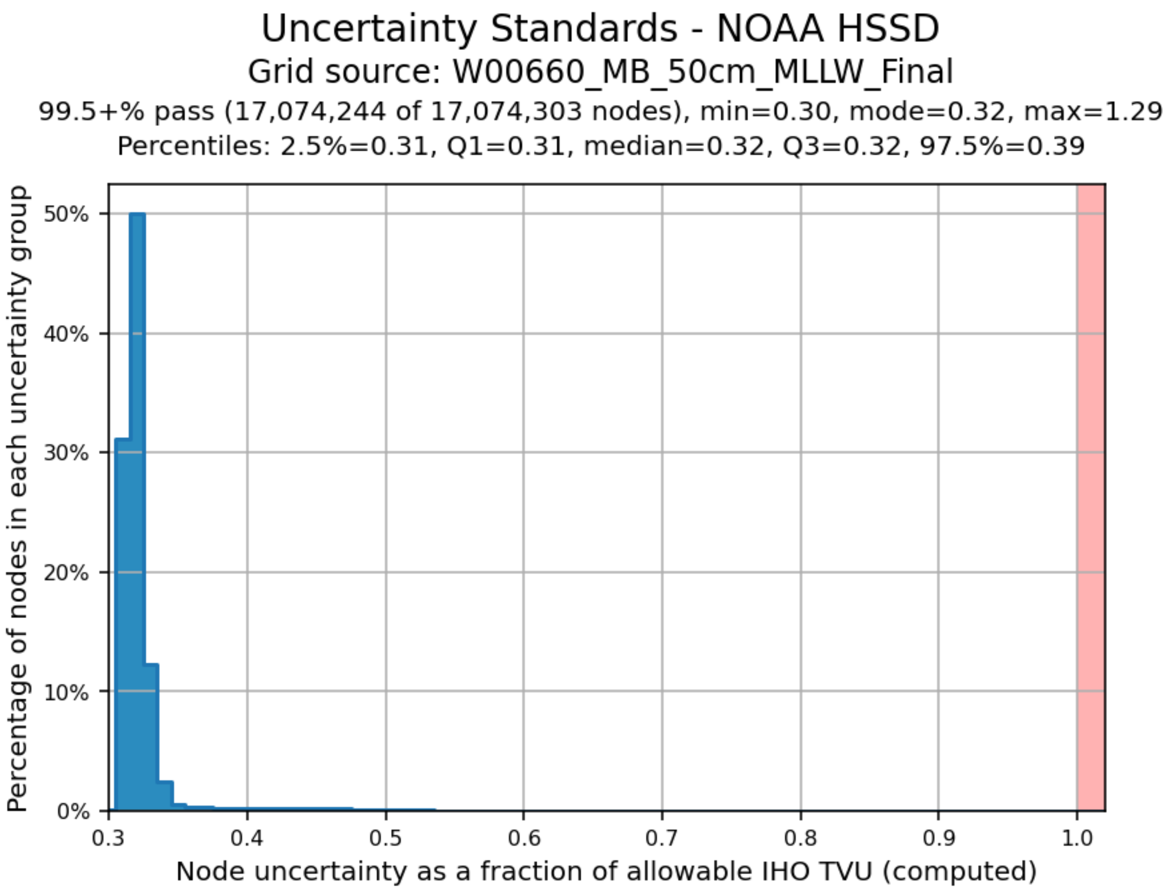


Figure 8. Node TVU Statistics – 50 centimeters, Finalized

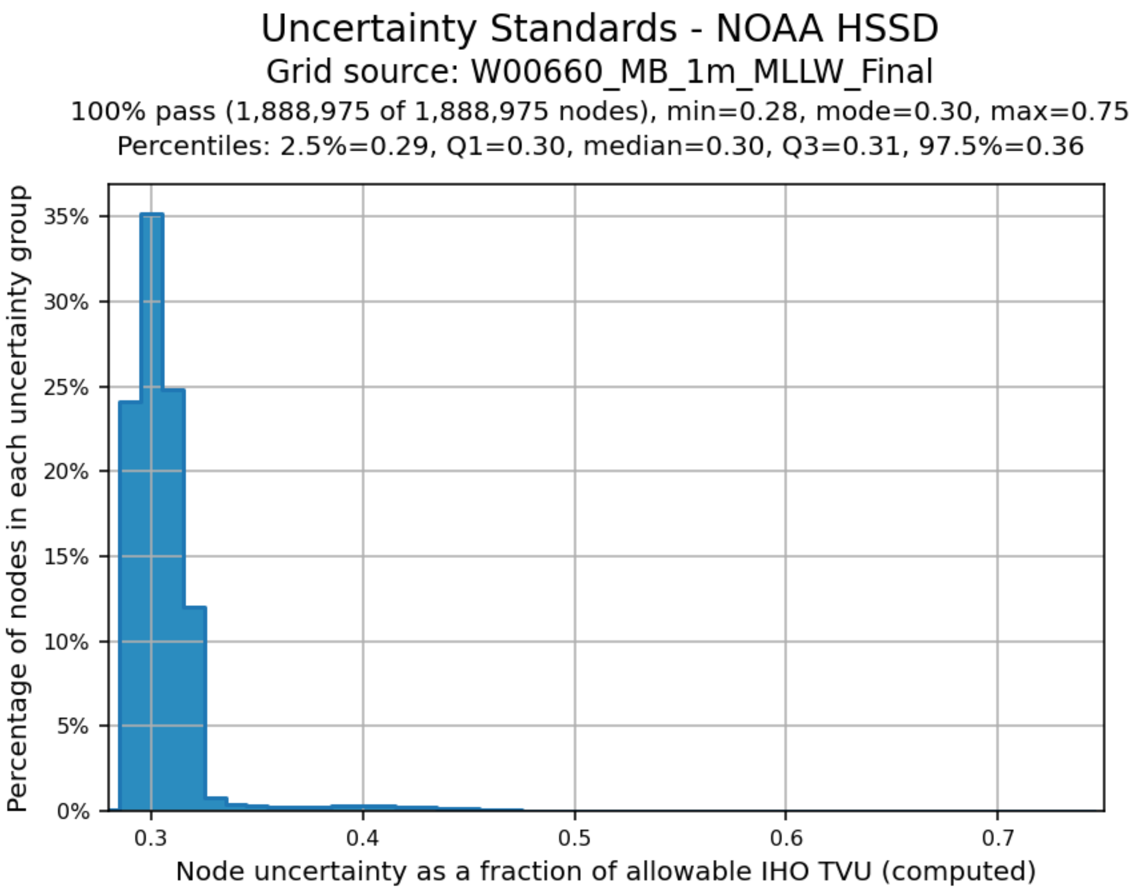


Figure 9. Node TVU Statistics – 1 meter, Finalized

5.5 Junctions

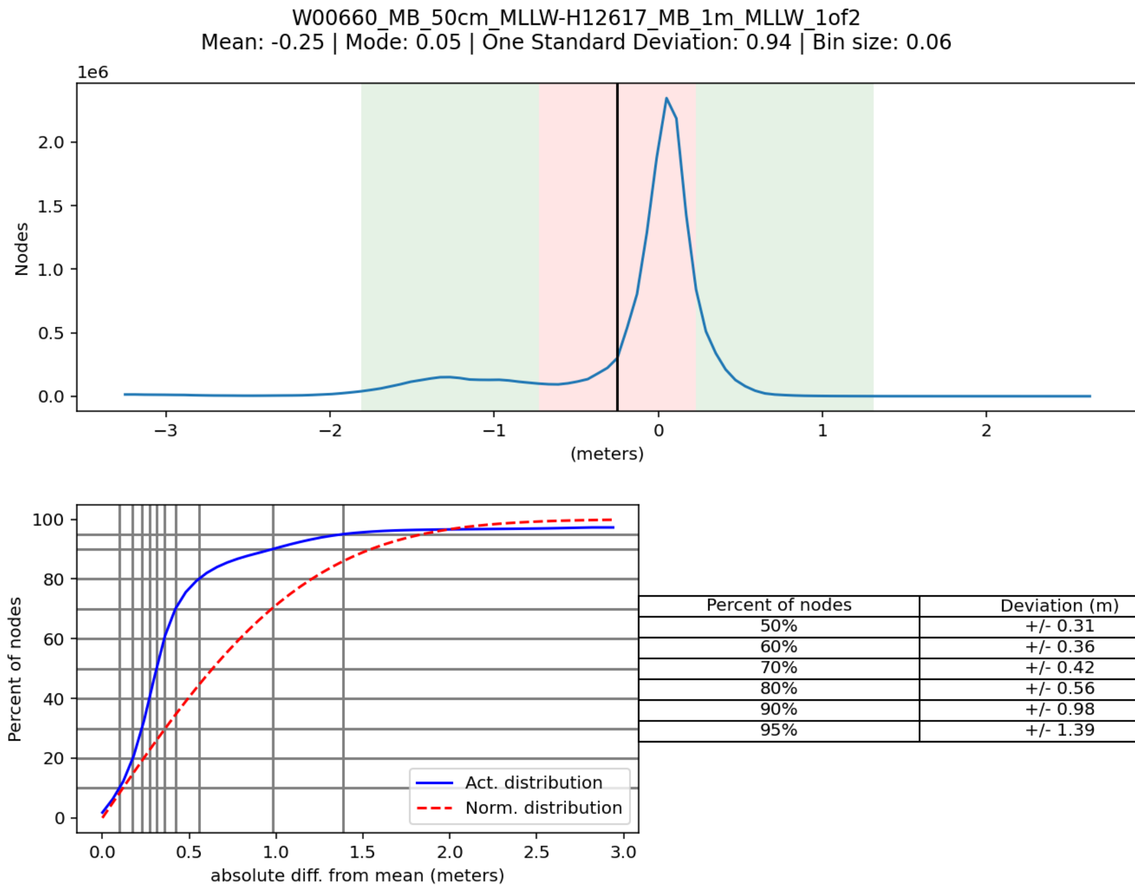
The survey junctions with NOAA prior surveys H12617 (performed in 2013) and H13197 (performed in 2018) and a previous POLB Harbor Sounding Program (performed in 2020), which has been assigned NOAA registry number W00628. A junction comparison was performed by computing a difference surface between bathymetric surfaces from the recent and prior surveys. Bathymetric Attributes Grids for the prior NOAA surveys were downloaded from NOAA's National Centers for Environmental Information (NCEI) website. The H13197 Variable Resolution (VR) surface was converted to a 2-meter single resolution surface prior to differencing as shown in Table 7. The NOAA Pydro Gridded Surface Comparison Tool was used to perform this analysis. The registry number W00628 was not applied to the 2020 POLB survey until after it was submitted through the ESD process. Surfaces from this survey used Area_5_Area_6_MB in the file naming scheme.

Table 7. Junction Surveys

Registry Number	Year	Field Unit	Resolution
H12617	2013	NOAA Ship *Fairweather*	1 meter
H13197	2018	NOAA Ship *Rainier*	VR (1 meter)
W00628	2020	David Evans and Associates, Inc.	0.5 meter

<u>H12617</u>

The mean difference between the POLB survey and H12617 survey depths is 25 centimeters (POLB survey deeper than H12617), shown in Figure 10.

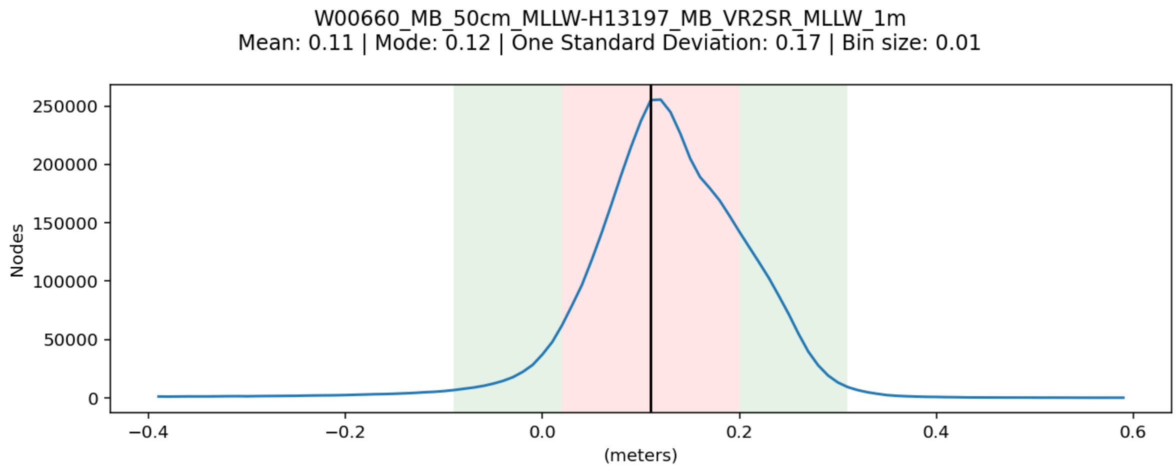


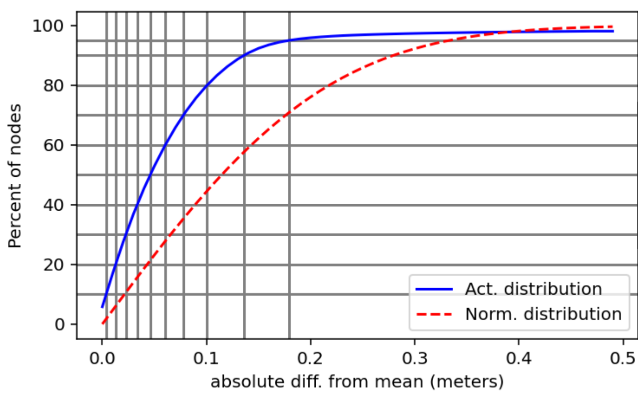
Percent of nodes	Deviation (m)
50%	+/- 0.31
60%	+/- 0.36
70%	+/- 0.42
80%	+/- 0.56
90%	+/- 0.98
95%	+/- 1.39

Figure 10. Distribution summary plot of differences between DEA survey and NOAA survey H12617

<u>H13197</u>

The mean difference between the POLB survey and H13197 survey depths is 11 centimeters (POLB survey shoaler than H13197), shown in Figure 11.



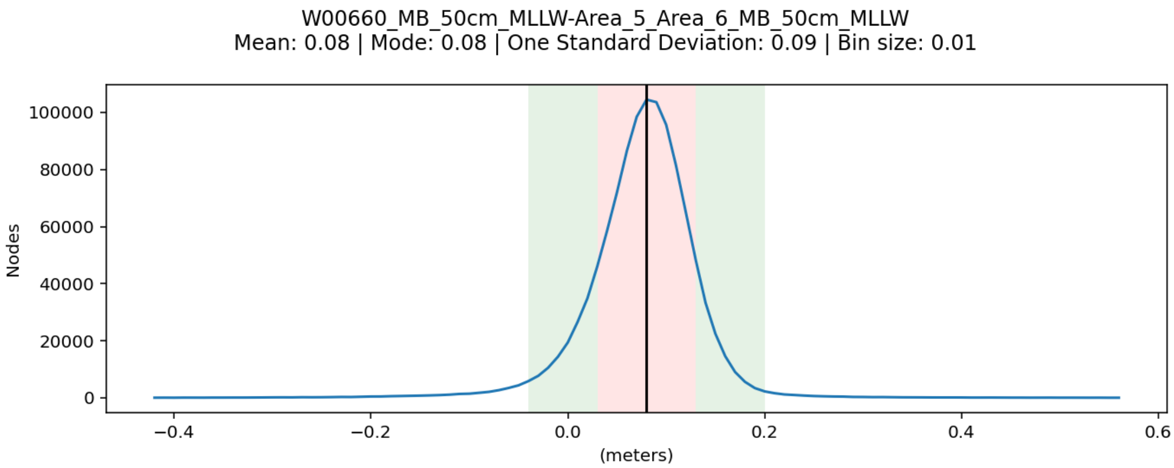


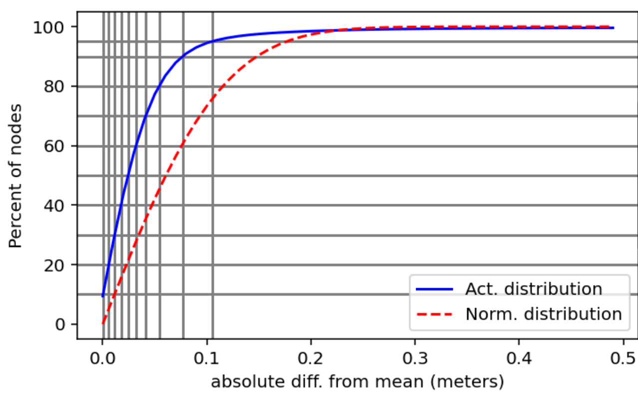
Percent of nodes	Deviation (m)
50%	+/- 0.05
60%	+/- 0.06
70%	+/- 0.08
80%	+/- 0.10
90%	+/- 0.14
95%	+/- 0.18

Figure 11. Distribution summary plot of differences between DEA survey and NOAA survey H13197

<u>W00628</u>

The mean difference between the POLB survey and W00628 survey depths is 8 centimeters (POLB survey shoaler than W00628), shown in Figure 12.





Percent of nodes	Deviation (m)
50%	+/- 0.02
60%	+/- 0.03
70%	+/- 0.04
80%	+/- 0.05
90%	+/- 0.08
95%	+/- 0.10

Figure 12. Distribution summary plot of differences between DEA survey and NOAA survey H13197

5.6 Density

Sounding density was analyzed using the NOAA requirement that 95% of all grid nodes are populated using at least five soundings. Each submitted surface was analyzed using NOAA Pydro QC Tools and found to meet density requirements. Individual surface results are presented in Figures 13 and 14.

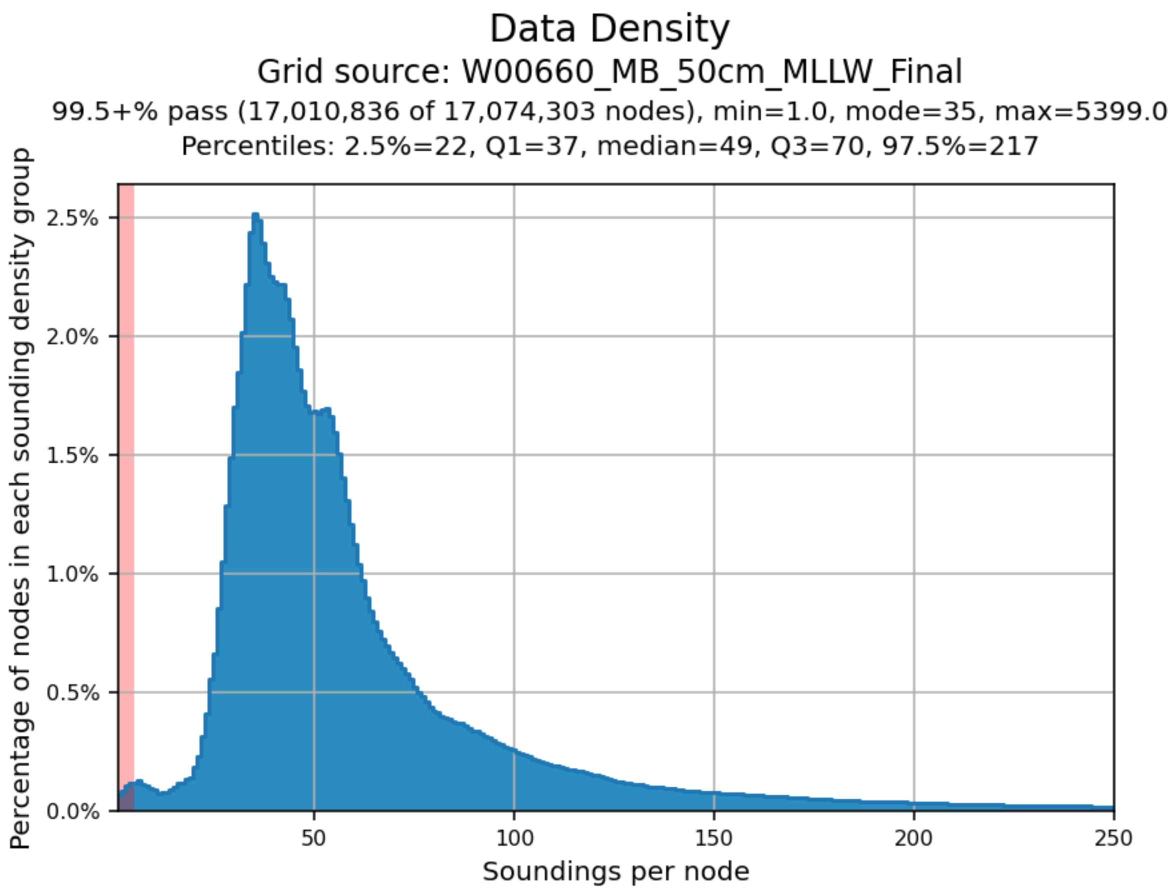


Figure 13: Node density statistics – 50 centimeters, finalized

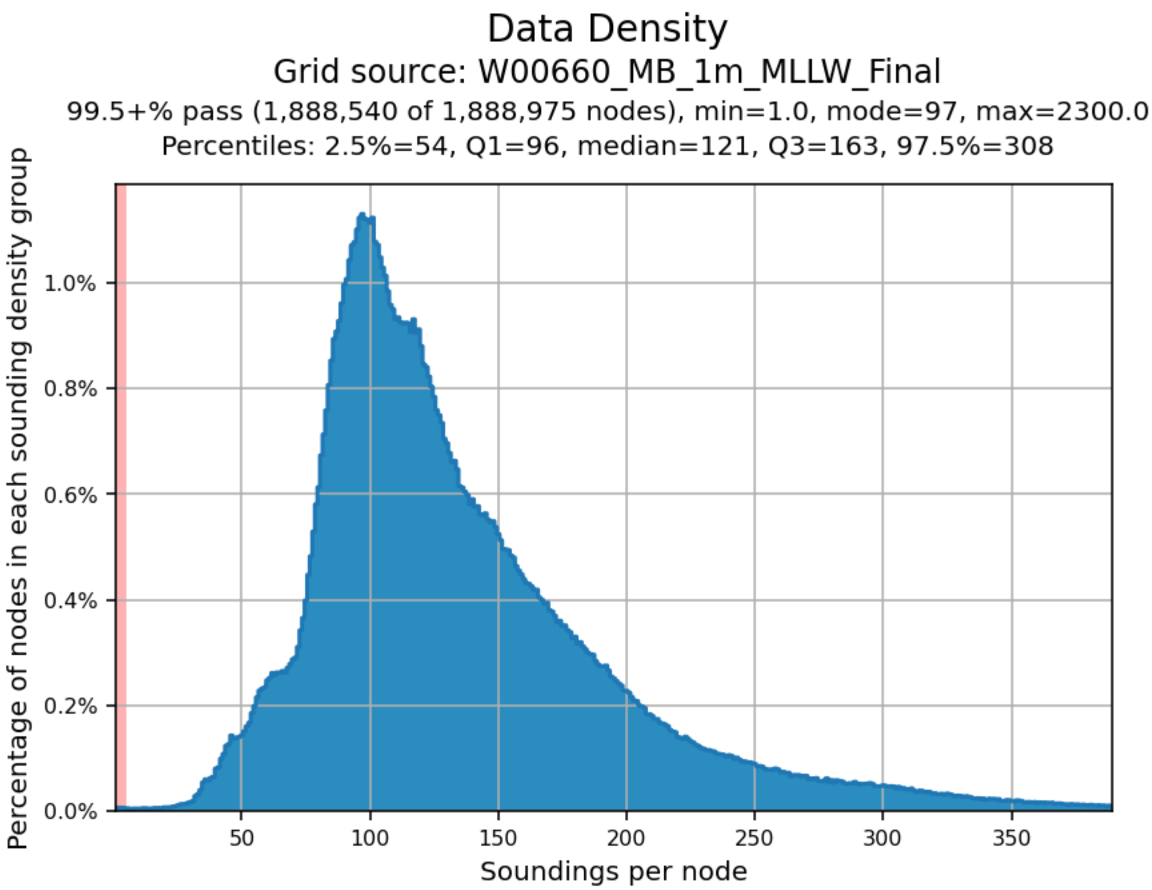


Figure 14: Node density statistics – 1 meter, finalized

5.7 Backscatter

Time series backscatter was logged in HYPACK 7k format during acquisition but was not processed. HYPACK 7k files have been included with the Raw data deliverables.

5.8 Vessel-Based Laser Analysis

Vessel-based laser data was reviewed in CARIS HIPS subset editor. An ellipsoid to Mean High Water (MHW) surface was extracted using NOAA Pydro software to determine the separation between MLLW and MHW in the survey area. At locations of low clearance, the MLLW to MHW separation value was applied to determine the final MHW elevation for the Long Beach International Gateway Bridge, Gerald Desmond Bridge (removed since this survey), Schuyler F. Heim Bridge, and Transmission Lines (Table 8). Figures 15 through 18 show the Vessel-Based Lidar with multibeam data and the span height above MHW. The lowest value for each structure is shown in bold font. Coordinates included in Table 8 are relative to California State Plane Zone 5, NAD83, 2007 realization (NAD83 (2007)). All values shown in Table 8 and Figures 15 through 18 are U.S. Survey Feet.

Table 8. Bridge and Transmission Line Heights Above MHW and MLLW

Structure	Easting	Northing	Height (MHW)	Height (MLLW)
Long Beach International Gateway Bridge (low steel)	6494288.3	1736803.9	205.2	209.5
Long Beach International Gateway Bridge N Center Channel Light	6494386.6	1736952.5	205.4	209.7
Long Beach International Gateway Bridge N East Light	6494523.7	1737014.6	205.0	209.3
Long Beach International Gateway Bridge N West Light	**6494250.6**	**1736890.2**	**204.9**	**209.2**
Long Beach International Gateway Bridge S Center Channel Light	6494452.8	1736808.7	205.4	209.7
Long Beach International Gateway Bridge S East Light	6494589.4	1736870.5	205.1	209.4
Long Beach International Gateway Bridge S West Light	6494316.1	1736746.9	205.0	209.3
Gerald Desmond Bridge Center Channel Light	6494496.8	1736709.9	154.5	158.8
Gerald Desmond Bridge East Light	**6494599.9**	**1736846.8**	**154.4**	**158.7**
Gerald Desmond Bridge West Light	6494326.0	1736722.1	155.0	159.3
Schuyler F. Heim Bridge	6488817.4	1737256.7	48.3	52.6
Schuyler F. Heim Bridge Navigation Light	**6488796.2**	**1737335.5**	**46.2**	**50.5**
Cerritos Channel Transmission Lines	**6492800.7**	**1738717.6**	**291.7**	**296.3**

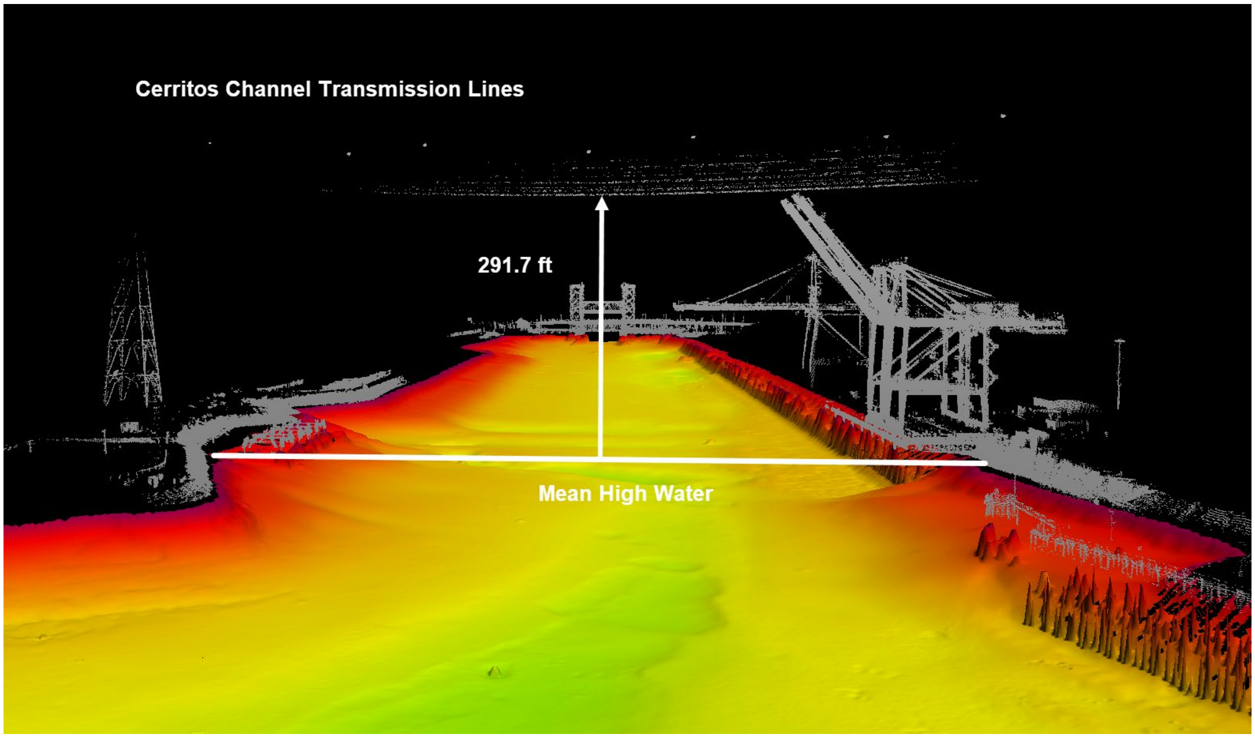


Figure 15. Transmission lines height above MHW determined from vessel-based laser data

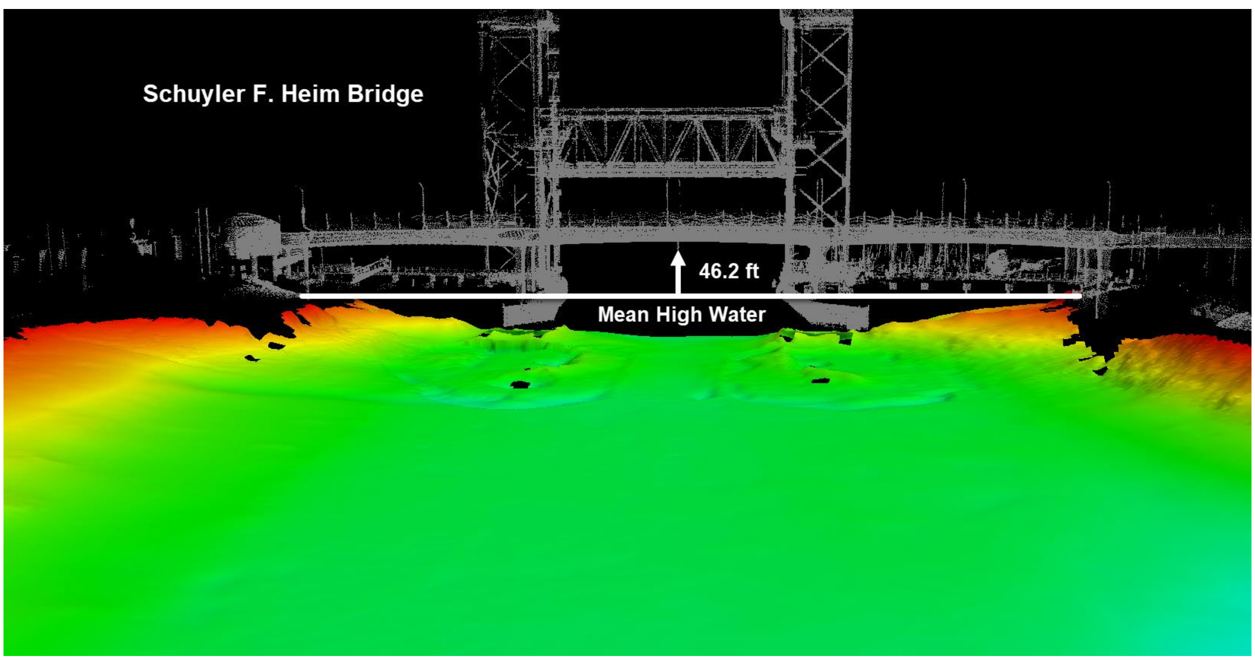


Figure 16. Schuyler F. Heim Bridge height above MHW determined from vessel-based laser data

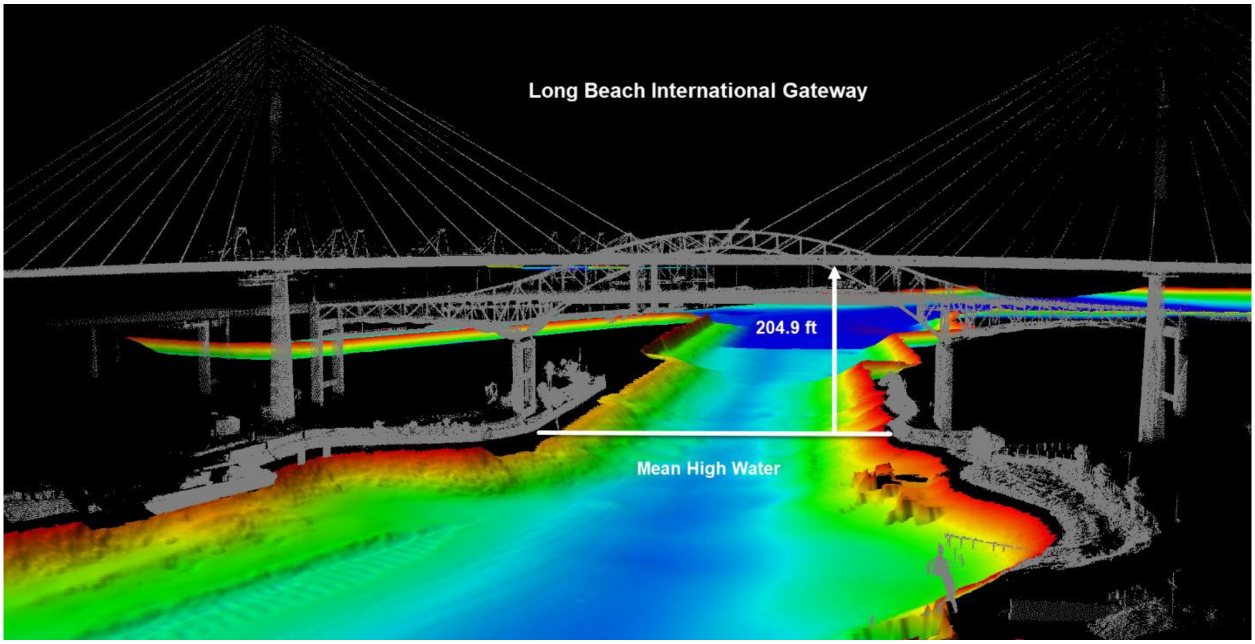


Figure 17. Long Beach International Gateway Bridge height above MHW determined from vessel-based laser data

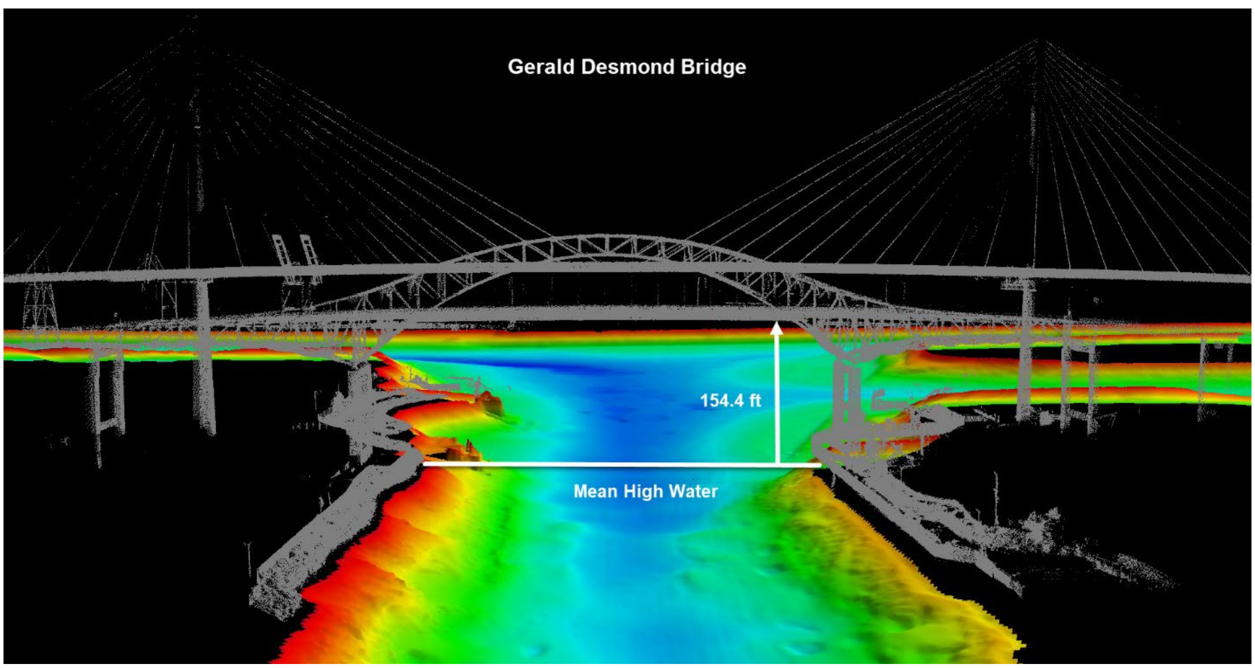


Figure 18. Gerald Desmond Bridge height above MHW determined from vessel-based laser data

5.9 Features

Multibeam data were reviewed to determine the presence of features meeting the height threshold for Object Detection Coverage set in the HSSD (2022). HIPS designated sounded were used to denote the least depth of all submerged features present in the survey data. These least depths were integrated into bathymetric surfaces during the surface finalization process.

An S-57 feature file was created for the survey following the standard practice for a Final Feature File set in the HSSD (2022). In lieu of a standard CSF, a subset of charted features such as obstructions, wrecks, underwater rocks and shoreline construction features were selected from the ENCs and copied to the S-57 Feature File. These charted features were then addressed where applicable.

Charted obstructions and underwater rocks were addressed using the attribute descrp as either Delete (where a charted feature was disproved using 100% MBES) or Delete/New (where position/depth has been updated) or Delete/New and a geometry change (where depth has been updated and the feature has been changed from point to area). Where an unsurveyed obstruction was identified from the MBES data, descrp = New was used.

A Danger to Navigation (DtoN) report was submitted to the Pacific Hydrographic Branch (PHB) on October 27, 2022 reporting a hazardous uncharted obstruction. This obstruction is included in the survey's feature file.

5.10 Chart Comparison

A chart comparison was performed by comparing survey depths to a digital surface generated from the Band 6 electronic navigational charts (ENCs) covering the survey area. The results of the comparison are detailed below. The ENCs used during the chart comparison are listed in Table 9. A graphic showing the magnitudes of the differences between the survey and charts is shown in Figures 19 through 22.

Table 9. ENCs used during the chart comparison

ENC	Scale	Edition	Update Application Date	Issue Date
US6LGBCB	5000	5	08/12/2022	08/12/2022
US6LGBCC	5000	5	08/16/2022	08/16/2022
US6LGBCD	5000	7	08/16/2022	08/16/2022
US6LGBDB	5000	5	08/24/2022	08/24/2022
US6LGBDC	5000	7	08/11/2022	08/31/2022

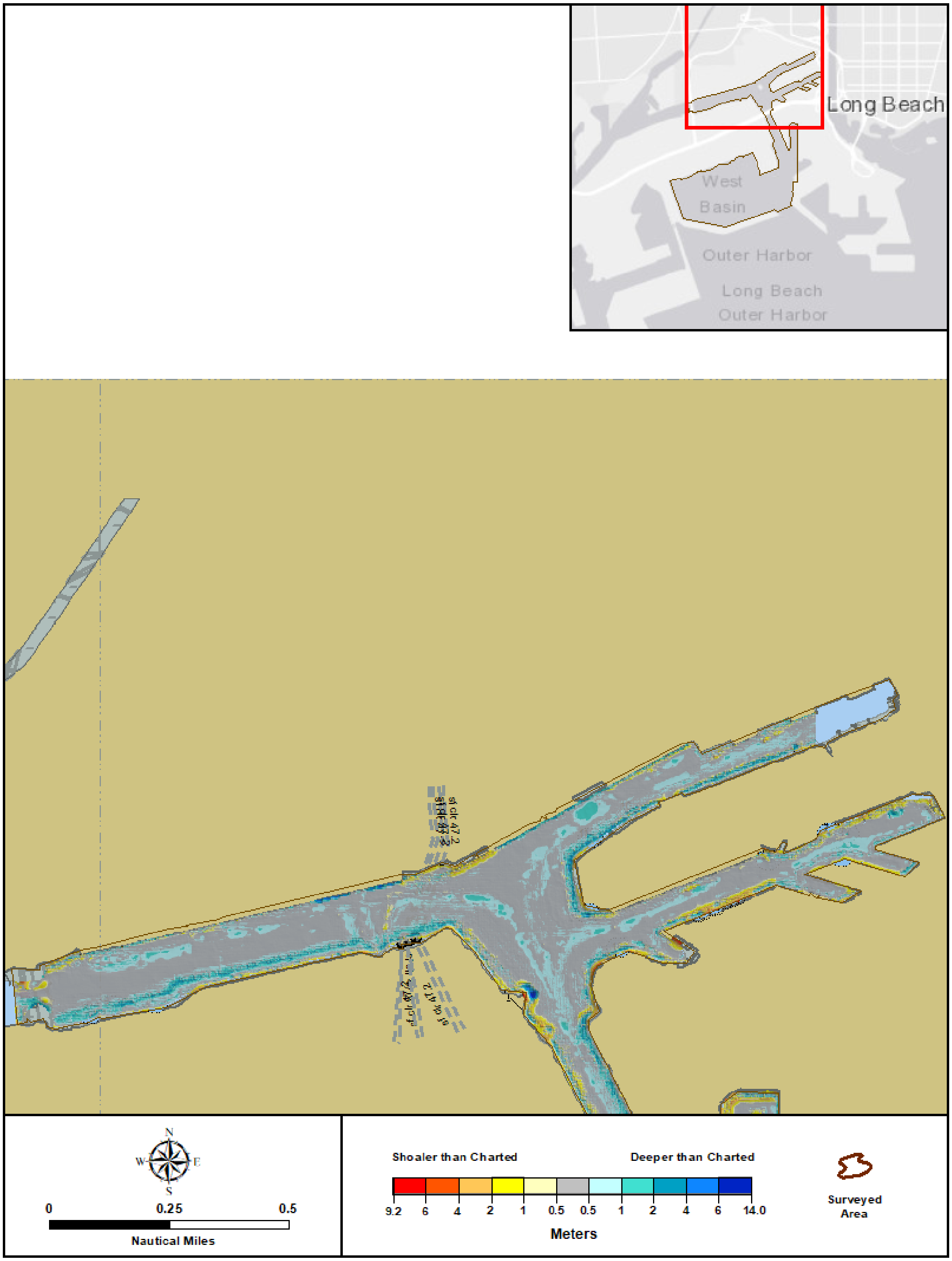


Figure 19. Depth Difference Between POLB Survey and Band 6 ENCs, Area 1 of 4

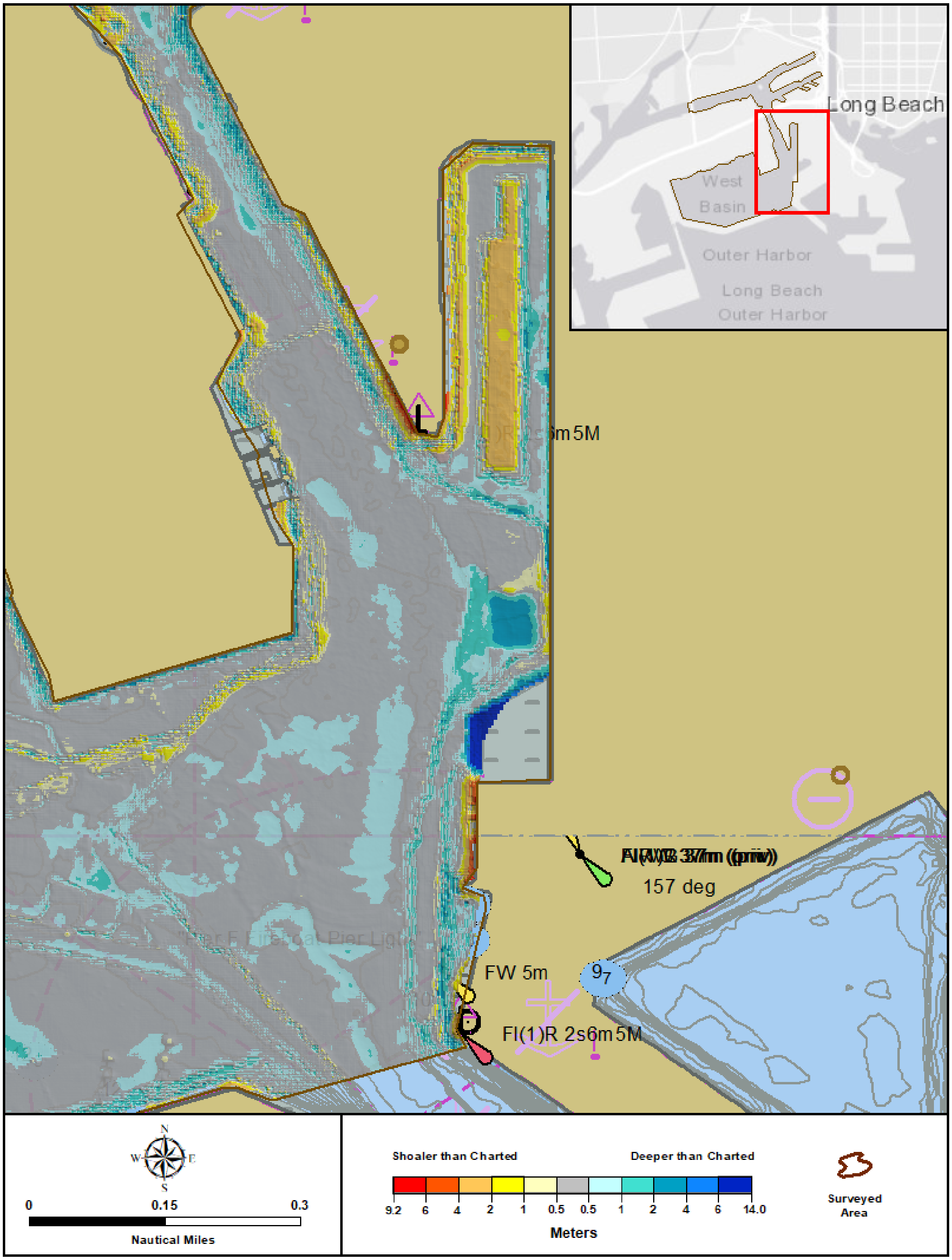


Figure 20. Depth Difference Between POLB Survey and Band 6 ENCs, Area 2 of 4

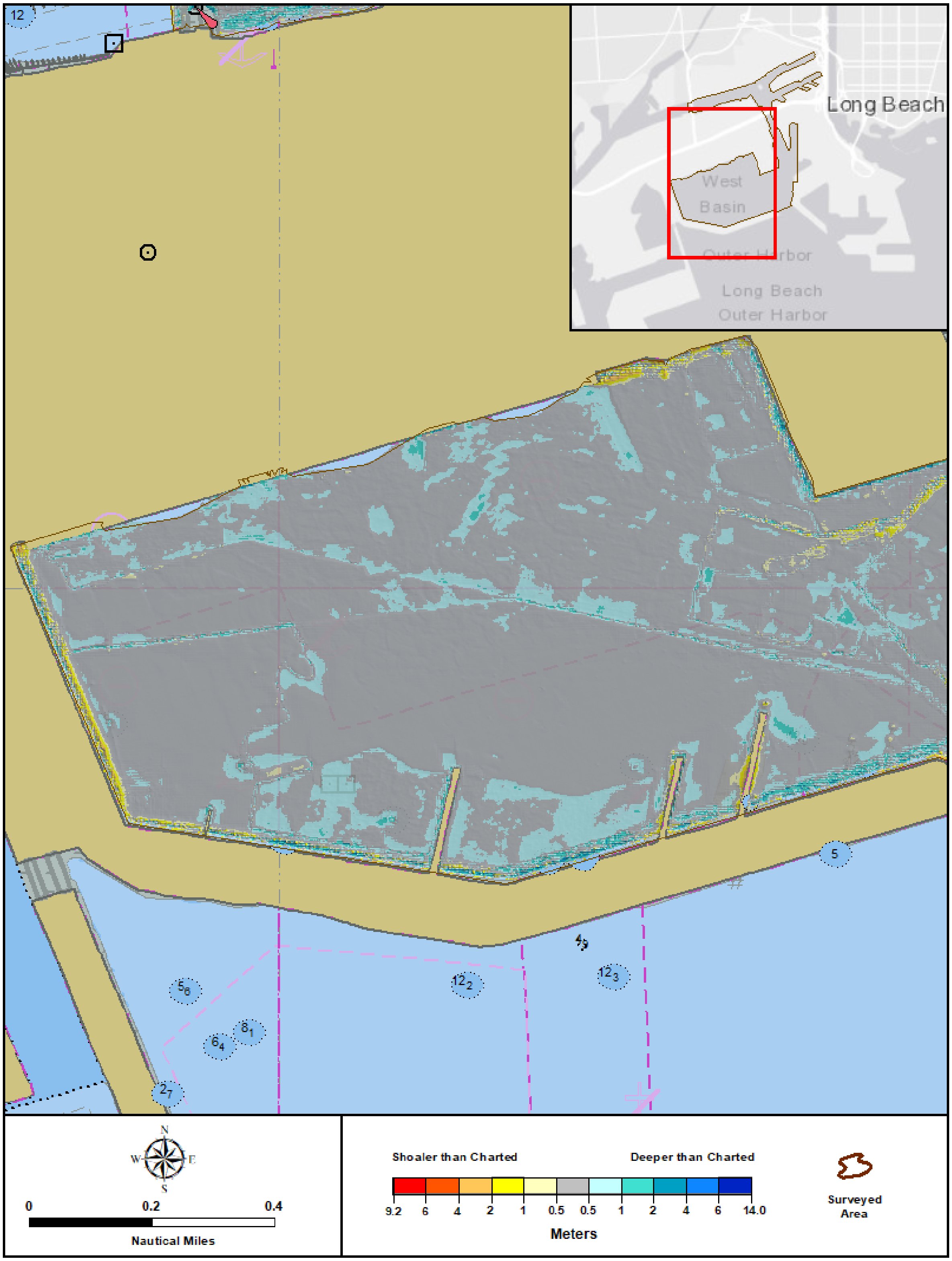


Figure 21. Depth Difference Between POLB Survey and Band 6 ENCs, Area 3 of 4

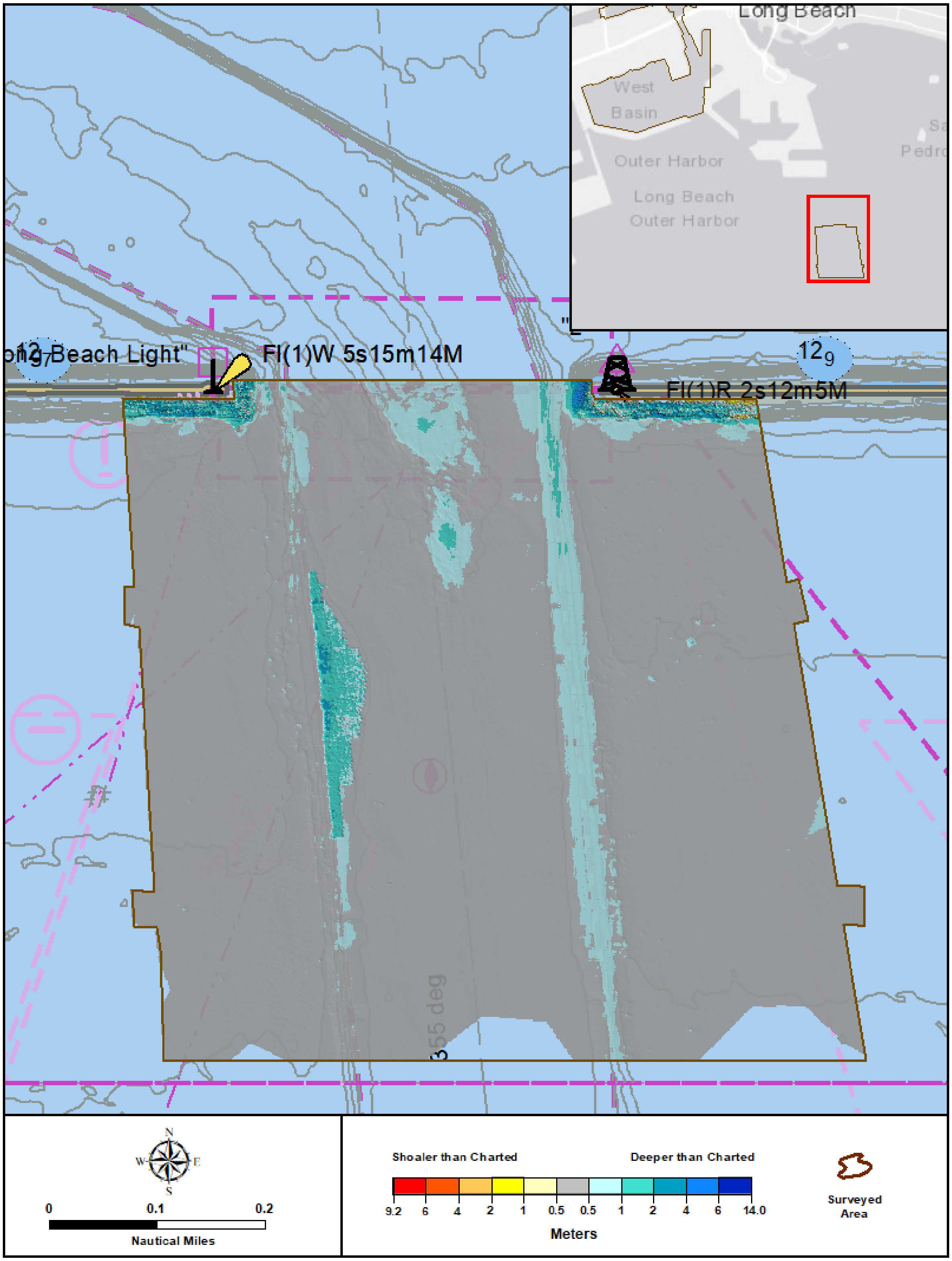


Figure 22. Depth Difference Between POLB Survey and Band 6 ENCs, Area 4 of 4

6.0 DELIVERABLES

Deliverables were submitted to the NOAA EDS team on a USB drive with a directory structure following Appendix I: Data Directory Structure of the HSSD (2022). Digital deliverables included the following:

1. Raw Data
2. Processed Data in CARIS HIPS format
3. Object Detection Coverage Bathymetric Surfaces
4. Feature File
5. Project report
6. Processed SBET