W00628

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

DESCRIPTIVE REPORT

Type of Survey:	Basic Hydrographic Survey
Registry Number:	W00628

LOCALITY

State(s):	California
General Locality:	Port of Long Beach
Sub-locality:	Outer Harbor Western Anchorage & Main Channel

2020

CHIEF OF PARTY
Jonathan L. Dasler

LIBRARY & ARCHIVES

Date:

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

REGISTRY NUMBER:

HYDROGRAPHIC TITLE SHEET

W00628

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:	**Port of Long Beach**
Sub-Locality:	**Outer Harbor Western Anchorage & Main Channel**
Scale:	**5000**
Dates of Survey:	**07/15/2020 to 07/21/2020**
Instructions Dated:	**N/A**
Project Number:	**ESD-PHB-22**
Field Unit:	**David Evans and Associates, Inc.**
Chief of Party:	**Jonathan L. Dasler**
Soundings by:	**Teledyne RESON SeaBat T50-P (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

April 27, 2022

MEMORANDUM FOR: Pacific Hydrographic Branch

FROM: Report prepared by PHB on behalf of field unit
Jason Creech
Nautical Charting Program Manager, David Evans and Associates, Inc.

SUBJECT: Submission of Survey W00628

The purpose of this hydrographic survey was to support the Port of Long Beach (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), Category Zone of Confidence A1 (CATZOC A1) standards.

50cm and 1m grids were created for data archival and charting purposes, as well as a final feature file.

All soundings were reduced to Mean Lower Low Water using VDatum. 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.

All survey systems and methods utilized during this survey were as described in the Port of Long Beach Harbor Sounding Program Hydrographic Survey Report .

All data were reviewed for DTONs and none were identified in this survey.

David Evans & Associates, Inc. acquired the data outlined in this report. Additional documentation from the data provider may be attached to this report.

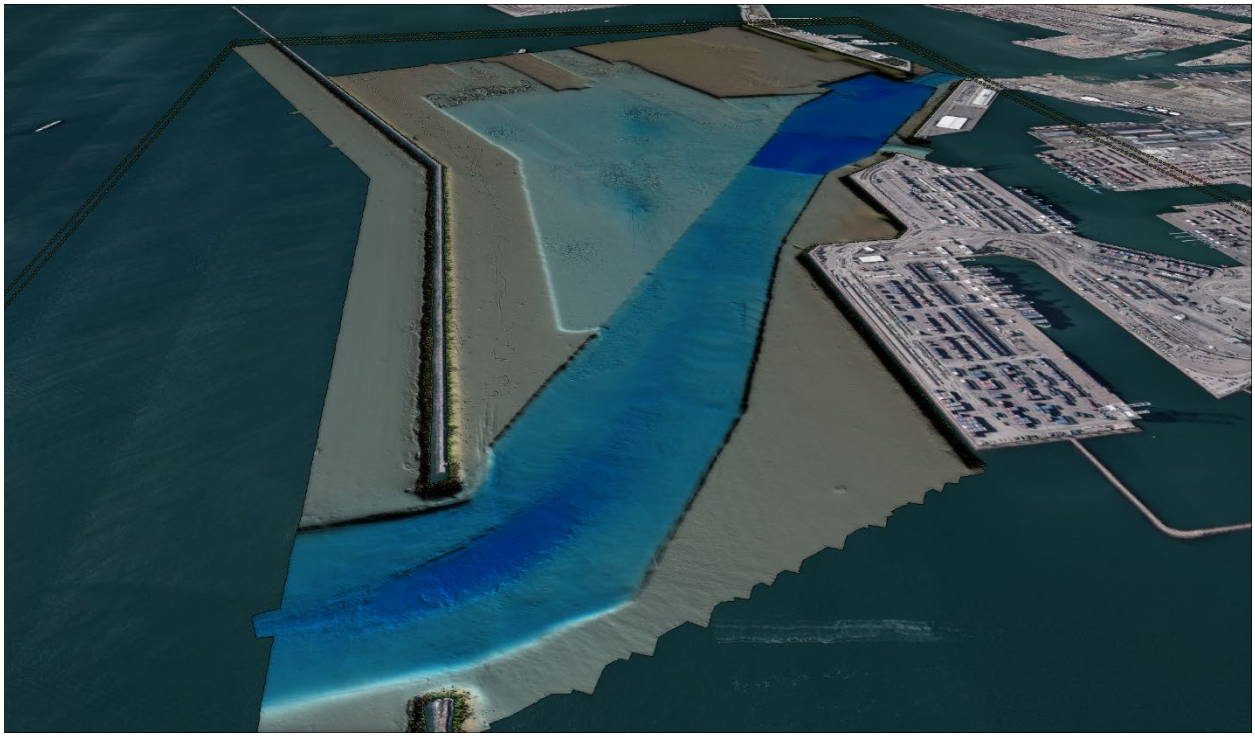
Although some holidays exist in this survey, they predominately occur in dynamic, rocky breakwaters. Two (2) insignificant holidays also occur in flat, homogeneic areas of the seafloor, but do not pose a threat to navigation.

This survey does meet charting specifications and is adequate to supersede prior data. The entire dataset qualifies for a CATZOC A1 categorization for accuracy which should supersede currently charted data; especially in the breakwater entrance which is presently CATZOC B.

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

Outer Harbor Western Anchorage (Area 5) & Main Channel (Area 6)

April 2022



Prepared by:

David Evans and Associates, Inc.
Marine Services Division
2801 SE Columbia Way, Suite 130
Vancouver, WA 98661

Owner:

Port of Long Beach
415 W. Ocean Blvd.
Long Beach, CA 90802

Port of Long Beach
Harbor Sounding Program
Hydrographic Survey Report
NOAA ESD Submission
Outer Harbor Western Anchorage (Area 5) & Main Channel (Area 6)

April 2022

Prepared by:

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

Reviewed by:

Jonathan L. Dasler, P.E., P.L.S.
NSPS-THSOA Certified Hydrographer, #107
David Evans and Associates, Inc.
Senior Vice President/Director of Marine Services

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Acronyms and Abbreviations

AML	Applied Microsystems Oceanographics
CATZOC A1	Categorized Zone of Confidence rating A1
CLBRTN	City of Long Beach Real-Time Reference Network
DEA	David Evans and Associates, Inc.
ENC	Electronic Navigational Charts
ESD	External Source Data
GMT	Greenwich Mean Time
GNSS	Global Navigation Satellite System
Hz	Hertz
HIPS	Hydrographic Information Processing System
HSSD	Hydrographic Surveys Specifications and Deliverables
HVF	HIPS Vessel File
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
kHz	kilohertz
MCU	Maximum Cumulative Uncertainty
MLLW	Mean Lower Low Water, Epoch 1983-2001
NAD83(2007)	North American Datum of 1983, 2007 realization
NCEI	National Centers for Environmental Information
NMEA	National Marine Electronics Association
NTRIP	Networked Transport of RTCM via Internet Protocol
NOAA	National Oceanic and Atmospheric Administration
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
RMS	Root Mean Square
RTCM	Radio Technical Commission for Maritime Services
RTK	Real-Time Kinematic
SBET	Smoothed Best Estimate of Trajectory
S/V	Survey Vessel
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
UTC	Coordinated Universal Time
VR	Variable Resolution
ZDA	Global Positioning System Timing Message

1.0 INTRODUCTION

Between July 15 and July 22, 2020, David Evans and Associates, Inc. (DEA), Marine Services Division, conducted a high-resolution hydrographic survey using Object Detection multibeam coverage in portions of San Pedro Bay. The purpose of this hydrographic survey was to support the Port of Long Beach (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), Category Zone of Confidence A1 (CATZOC A1) standards.

Specifically, this effort included the following:

- Portions of San Pedro Bay, Outer Harbor, Western Anchorage (Figure 1, Area 5)
- Portions of the Main Channel (Figure 1, Area 6)
- The Middle Breakwater area, outside of San Pedro Bay, including Long Beach Channel

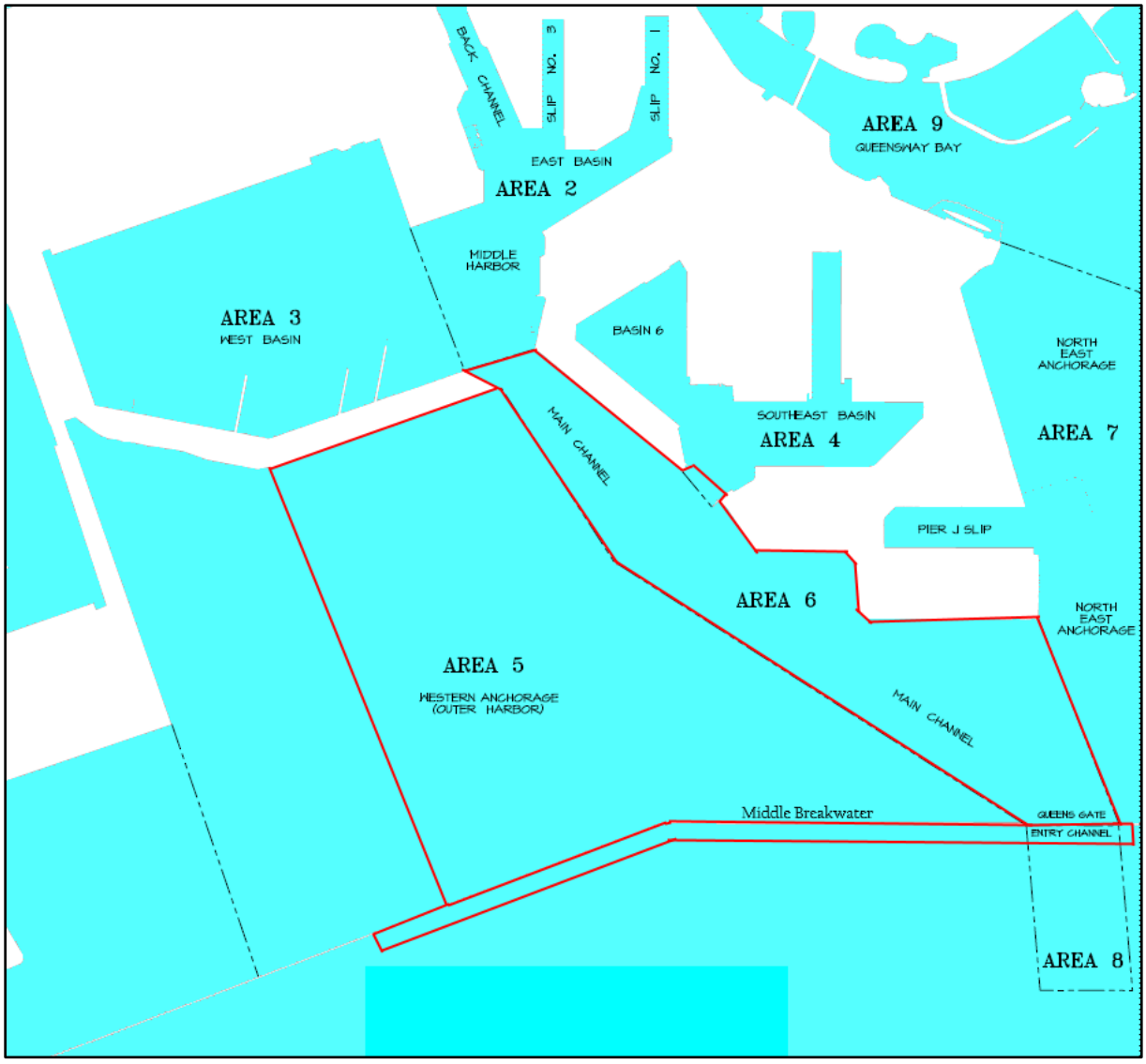


Figure 1. Port of Long Beach Hydrographic Survey Index Map with survey areas in red.

DEA submitted a report of survey, map products, and a series of digital deliverables to the Port of Long Beach on August 31, 2021.

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 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. A template for this table was provided by NOAA's ESD team in advance of this submission.

This report and data submission is intended to provide a framework to facilitate the submission and review of future Port of Long Beach surveys through the ESD process. Key elements of the ESD review process, including coverage, feature detection, and uncertainties, are discussed in the report and summarized in Appendix A.

This survey was performed under the direction of a California Licensed Surveyor and National Society of Professional Surveyors - The Hydrographic Society of America (NSPS-THSOA) Certified Hydrographer.

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 10 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 survey area is in Long Beach Harbor including San Pedro Bay and Long Beach Channel. The area was surveyed with an approximate line spacing of 100 feet to obtain completeness of data coverage and quality. Figure 2 illustrates the overall data coverage overlaid on the NOAA raster navigation chart, soundings in feet, with the significant overlap achieved beyond the boundaries of the individual areas.

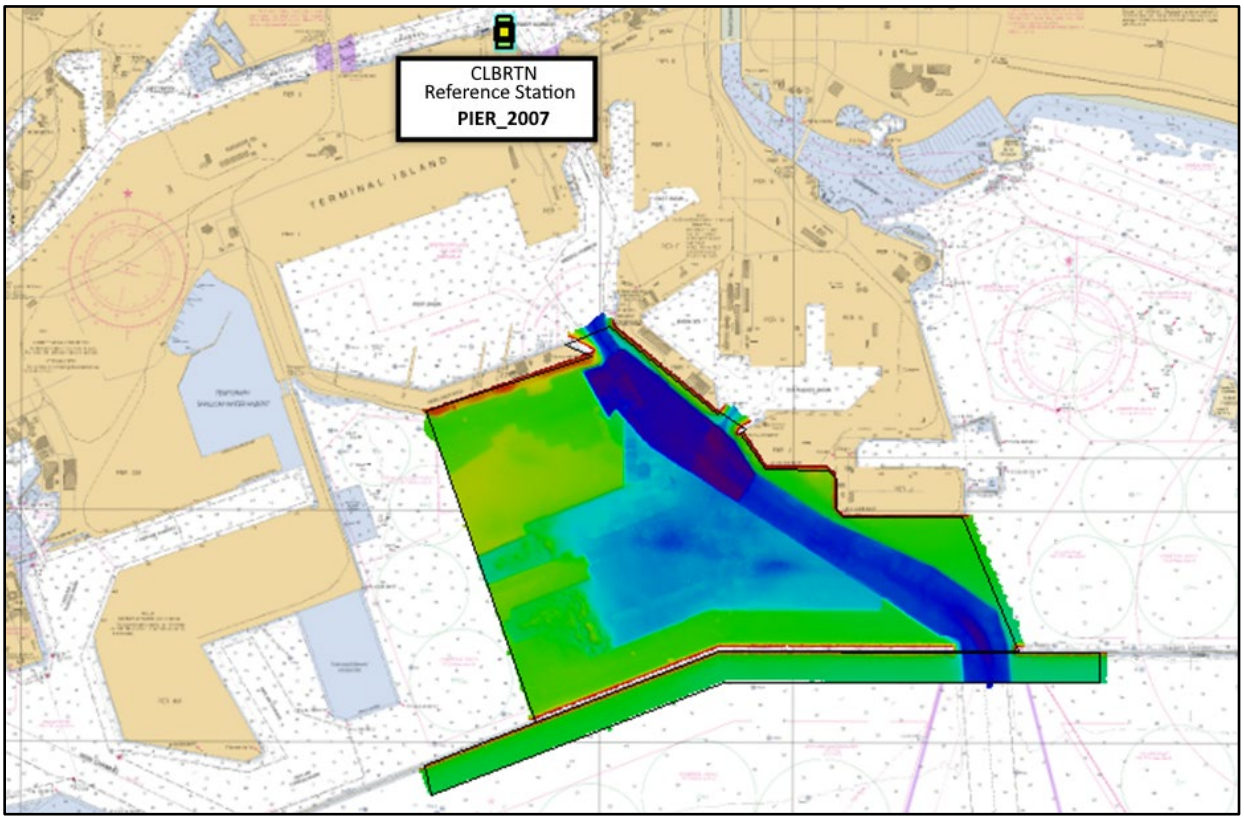


Figure 2. Overview of survey area with multibeam hillshade imagery of coverage

The survey exceeded the Special Order Hydrographic Survey specification as defined by the International Hydrographic Organization (IHO), March 2020, IHO Standards for Hydrographic Surveys, Special Publication No. 44, 6th Edition and U.S. Army Corps of Engineers EM 1110-2-1003, Hydrographic Surveying, in accordance with requirements for "Navigation & Dredging Support Surveys over a Soft Bottom".

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 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 1 includes final coordinates and elevations for the CLBRTN reference station used to control hydrographic surveys.

Table 1. CLBRTN Hydrographic Survey Control

Designation	Use	NAD83(2007)		
		Latitude	Longitude	Ellipsoid Height
PIER_2007	RTK GNSS Reference Station	N 33 46 04.95699	W 118 13 30.11817	-29.547 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 POLB 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 match Tidal Bench Mark 941 0660 Tidal 8), which is the primary bench mark for NOAA water level station 9410660 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 Vessel and Equipment

3.3.1 Broughton

The vessel used for this survey is the survey vessel (S/V) *William R Broughton* (Figure 3). The S/V *Broughton* is DEA's 24-foot custom Duckworth Offshore with twin outboard 115 horsepower engines. All of DEA's vessels are compliant with United States Coast Guard (USCG) and United States Army Corps of Engineers (USACE) regulations and pass annual marine survey inspections.

The vessel was equipped with an integrated navigation and data acquisition system, a custom mount for the dual Teledyne Reson SeaBat T50P multibeam sonar heads, with a sonar mounted to the port and starboard sides of the vessel and is ideal for jetty mapping and working in both rough and shallow waters. The dual head sonar configuration was able to accomplish the shallow water area coverage requirement to be processed without any data gaps between the survey lines. The survey vessel equipment consisted of an Applanix POS/MV (Position and Orientation System for Marine Vessels) combined inertial and RTK-GNSS, Trimble SPS855 RTK-GNSS receiver, Intuicom cellular modem, Hypack MAX version 2020, two data acquisition computers and AML Smart-X, SV+ and AML V2 SVP&T (Sound velocity, Pressure, and Temperature) sensors.

Figure 3: Multibeam Survey Vessel William R. Broughton

The hydrographic survey crew consisted of a lead hydrographer, and vessel operator from DEA. The crew have conducted several multibeam surveys on similar projects and have previously had extensive training in hydrographic survey operations. The vessel operator is licensed by the USCG. Both the operator and lead hydrographer hold current boater safety cards issued by the states of Washington and/or Oregon. All DEA field personnel have current First Aid and CPR training certifications. Weekly safety meetings were conducted for the duration of the project.

3.3.2 Multibeam Echosounder System

The multibeam hydrographic survey equipment consisted of dual Teledyne Reson SeaBat T50P multibeam bathymetric sonars, Applanix POS/MV combined inertial and GNSS positioning and motion reference system, a secondary Trimble SPS855 GNSS rover receiver, HYPACK/HYSWEEP navigation and acquisition software and an AML Oceanographic Smart•X sound speed profiler configured to take sound speed profiles while underway.

The T50P sonar is a multi-frequency multibeam sonar, capable of operating at frequencies between 200 to 400 kHz and has an integrated AML MicroX with an SV exchange sound speed sensor at each sonar head. The dual head sonars were deployed over the port and starboard sides of the vessel with custom mounts and were operated at 350 kHz, with each sonar producing a 120-degree combined swath of 512 equal angle overlapping beams, with each beam using a 0.5-degree across-track angle and 1.0-degree along-track angle.

The Applanix POS/MV motion reference sensor was utilized to measure and record vessel heading (yaw), heave (vertical movement from seas), pitch and roll. By utilizing vessel speed over ground and heading data provided by GNSS, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV data were used to derive sonar beam orientation and position individual soundings.

The navigation and survey acquisition system was a personal computer running HYPACK/HYSWEEP version 2020 software. HYPACK/HYSWEEP software was used for multibeam and sensor data acquisition and allowed the swath bathymetric data to be displayed as a painted color image on the navigation screen. This real-time display gave the hydrographer immediate indications of data quality and coverage.

Beam average back scatter and multibeam side scan data were logged in HYPACK HSX format during acquisition. Time series backscatter was not acquired.

3.3.3 Position, Heading and Motion Reference Systems

The S/V *Broughton* was outfitted with a POS/MV 320 version 5 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), dual frequency (L1/L2) GNSS antennas, and a data processor. A secondary GNSS receiver consisted of a Trimble SPS855 receiver that was positioned over the vessel reference point to be used for vertical control of the survey. The POS/MV primary GNSS receiver and the Trimble SPS851 receiver were provided RTK GNSS correctors received from the GNSS Station “CLBRTN”, which is a POLB Virtual Reference Service.

The Reson processors and HYPACK acquisition computers were 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 320 V5 integrated dual frequency RTK GNSS and inertial reference system was used for the motion sensor for this survey. The POS/MV 320 is a 6-degree of freedom motion unit, with a stated accuracy of 0.05 meters or 5 percent for heave, 0.02 degrees for roll and pitch and

heading. Real-time displays of the vessel motion accuracy were monitored throughout the survey with the MV-POSView controller program. If any of the vessel motion accuracy degraded to greater than 0.05 degrees root mean square (RMS), survey operations would be suspended until the inertial unit was able to regain the higher degree of accuracy.

3.3.4 Sound Speed Measurements

An AML Micro SV sound speed sensor mounted on the Reson T50-P sonar head was input into the Reson FP4 processor and sound speeds from the sensor were used in real-time during acquisition for beam forming on the T50-R's flat array. An AML Oceanographic Smart•X was used to measure the speed of sound of the water column and the depth at which the SSP was measured. Casts were taken during survey operations over both a temporal and spatial distribution to track sound speed profile changes due to tidal exchanges over the survey area.

4.0 EQUIPMENT CALIBRATION

4.1 Patch Test

Multibeam patch tests were conducted to measure alignment offsets between the IMU sensor and the Reson T50-R sonar transducers, and to determine time delays between the time-tagged sensor data. Patch tests consisted of a series of lines run in a specific pattern. 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 the same direction over the same area as the pitch tests. All lines were run at approximately 3 knots to 6 knots. Patch tests were run in the vicinity of the survey site. Patch test average values applied in CARIS software are listed in Table 2. All values were input and applied to all bathymetric data in the HIPS Vessel File (HVF).

Table 2. Broughton Reson T50-R Patch Test Values

Sonar Head	Start Date and Time (UTC)	End Date and Time (UTC)	Latency (seconds)	Pitch (Degrees)	Roll (Degrees)	Yaw (Degrees)
1 (Starboard)	July 16, 2020 01:02	July 16, 2020 01:20	0.000	-1.550	-0.617	-1.950
2 (Port)			0.000	-0.950	1.300	-2.250

4.2 Position and Vertical Check

A horizontal position check and vertical check was conducted on NOS tidal benchmark 9441 0660 Tidal 8, which is the primary benchmark for NOS water level station 9441 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 2-meter survey pole and data was logged in Hypack software while receiving RTK corrections from the CLBRTN. The position was compared to NAD83 (2007) California Zone 5 coordinates in U.S. Feet that was acquired by Psomas in October 2016 (Table 3.) and the vertical check was compared to the NOS MLLW published value of 13.76 Feet MLLW.

Table 3. Psomas Position on 9441 0660 Tidal 8

California Geodetic Coordinates of 1983					CCS 83, Zone 5 Coordinates		NAD83	
	Deg.	Min.	Seconds		Meters	US Survey Feet	Epoch:	2007.00
Latitude:	33	43	11.44146	Northing:	524,421.403	1,720,539.22	FGDC Acc.:	1.0 cm
Longitude:	118	16	22.21728	Easting:	1,974,709.401	6,478,692.42	Survey by:	Psomas
Ellipsoid Height (m):			-31.730		Combined Factor:	1.0000877	Adj.:	Oct 2016

The horizontal positioned obtained from 790 observed RTK GNSS samples yielded an average position North -0.01 feet and East -0.01 feet, with a standard deviation of North 0.01 feet and East 0.02 feet relative to the Psomas position in Table 3. This is well within the positioning requirements for the survey. The RTK GNSS vertical check resulted in a MLLW elevation 0.08 feet lower than the NOAA published MLLW elevation with a standard deviation of 0.02 feet over 790 samples. This is well within the expected vertical accuracy.

In addition, a vessel tide float was conducted near the NOS water level station 9441 0660, Port of Los Angeles, and compared to 6-minute preliminary MLLW data logged by the station. A Hypack line was logged for 20 minutes, and data was compared to the NOAA 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 0.06 feet lower than the NOAA observed water level with a standard deviation of 0.01 feet.

4.3 Bar Check

A bar check was performed prior to the onset of survey operations and again at the commencement of survey operations. This was done to confirm the draft of the multibeam transducer on the S/V *Broughton*. 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.

Bar checks were conducted at Long Beach Shoreline Marina, approximately 2.5 nautical miles to the north east of the survey area. The bar depth was assessed at 2.0 meters below the water surface.

The difference between the bar depth and corrected multibeam depth was within 1.5 centimeters (0.05 feet) on average with a maximum deviation of 2.5 centimeters (0.08 feet). 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 Multibeam Data Processing

Post-processing of multibeam data was conducted utilizing CARIS Hydrographic Information Processing System (HIPS) versions 11.3.5 and 11.3.8. 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 drop-outs for horizontal positioning and to extract ellipsoidally-referenced GPS heights. The CLBRTN reference station PIER (2007) was used for POSPAC processing SBET files. SBETs were applied in CARIS by loading the SBET files in HIPS per day. The 'Compute GPS Tides' process in CARIS HIPS is the primary means by which bathymetric data is reduced to chart datum.

CARIS HIPS references all multibeam 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 a surface that represents the difference between the NAD83 (2007) ellipsoid and MLLW for the survey area. The separation model used during data processing has been included with the digital deliverables in CARIS CSAR format.

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

Upon import, filters were applied for quality, rejecting beams assigned quality flags of '0' or '1', and swath width was adjusted to remove erroneous data. These data were flagged as rejected and were reaccepted during follow-on evaluation if necessary. 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 ASCII file for mapping obstructions and capturing least depths.

For the purposes of submission through the NOAA ESD process, sounding data were reprocessed after delivery to the Port of Long Beach. During the reprocessing effort, sounding Total Propagated Uncertainty (TPU) was computed using CARIS HIPS and new grids were generated using the CUBE gridding technique. Surfaces were generated following NOAA Object Detection grid resolution requirements defined in the 2021 Hydrographic Surveys Specifications and Deliverables (HSSD) and using the 2020 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 4.

Table 4. Submitted Surfaces

Surface Name	Surface Type	Resolution (m)	Depth Range (m)
Area_5_Area_6_MB_50cm _MLLW.csar	CARIS Raster Surface (CUBE)	0.5	0.975 – 28.492
Area_5_Area_6_MB_50cm _MLLW_Final.csar	Finalized CARIS Raster Surface (CUBE)	0.5	0.975 – 20.000
Area_5_Area_6_MB_1m _MLLW.csar	CARIS Raster Surface (CUBE)	1	1.034 – 28.485
Area_5_Area_6_MB_1m _MLLW_Final.csar	Finalized CARIS Raster Surface (CUBE)	1	18.000 – 28.485

5.2 Cross-Line Sonar Beam Analysis

The multibeam sonar recorded 512 beams for each sonar ping covering a swath 60 degrees to either side of nadir (vertical below the sonar). The swath width was filtered to 55 degrees to each side of nadir and a crossline analysis was conducted to prove each of the sonar beams within the 110-degree swath met accuracy requirements for the survey. The analysis involved running survey lines that cross orthogonal to the primary survey line pattern and comparing the soundings from individual sonar beams in the cross-line data to a finalized 3-foot grid from the main scheme lines. Requirements called for surveys to meet USACE Hydrographic Survey Manual (EM111-2-1003). The USACE requirement for maintenance dredging in water depths 15 feet to 75 feet, 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 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

Figure 4 depicts the results of this cross-line beam analysis to document all beams used in the 100-degree swath (55 degrees per side) meet both USACE requirements and IHO Special Order modified requirements. All beams exceeded 95% of soundings passing.

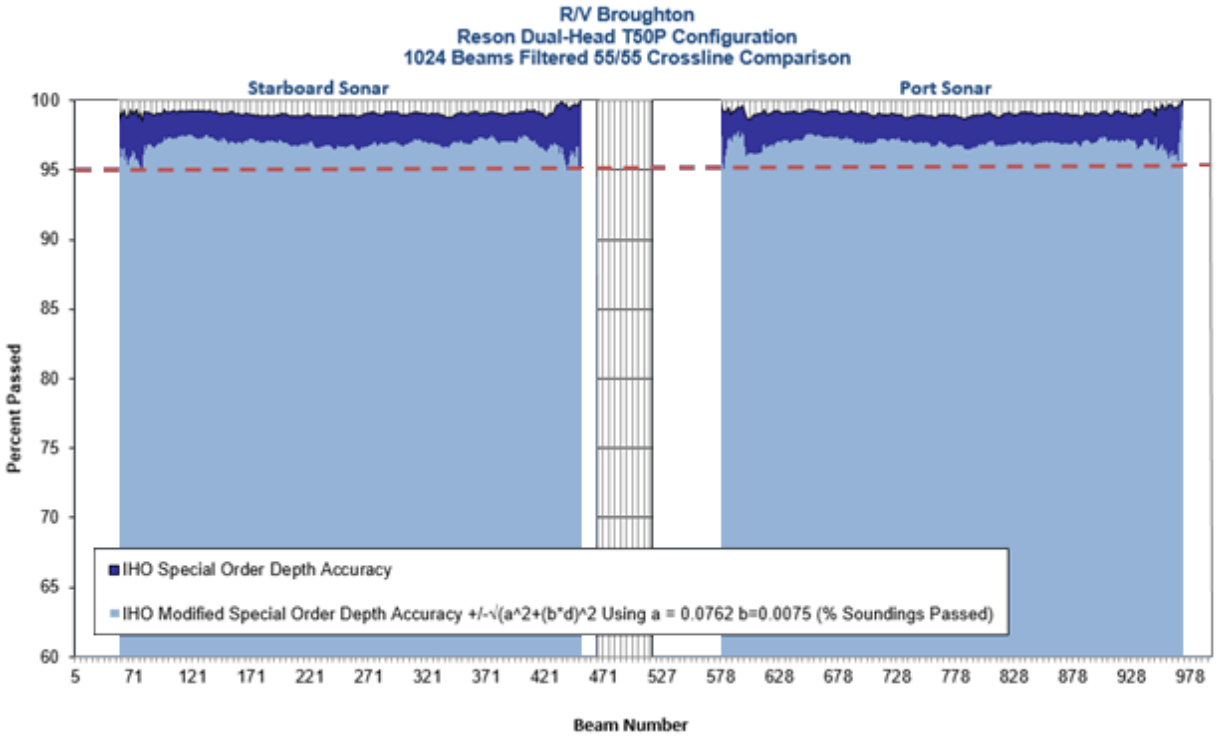
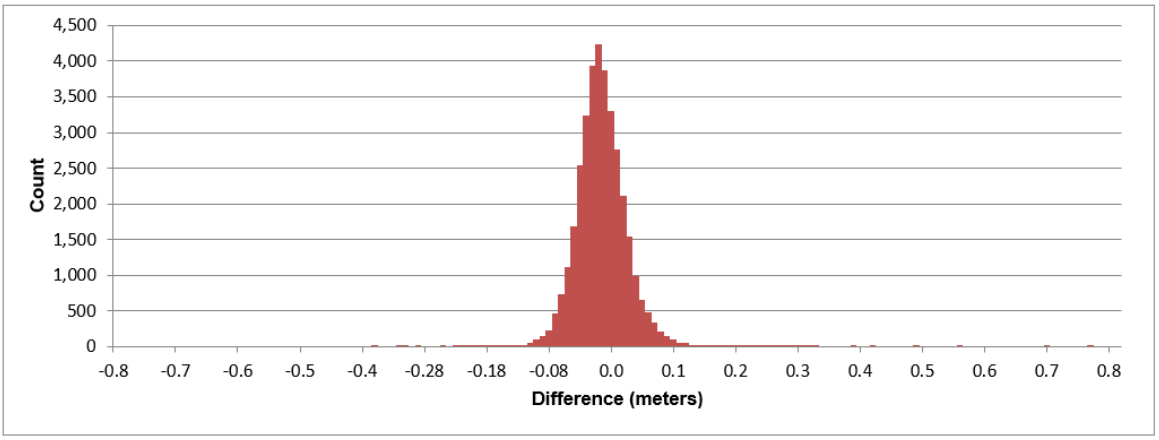


Figure 4. Histogram of Cross-Line Beam Analysis

5.3 Cross-Line Difference Analysis

To assess the precision of the survey, cross-line data was gridded at a 3-foot resolution, consistent with the resolution grid from the main survey lines. A difference analysis was conducted between the surfaces to evaluate the precision of the survey met project requirements. The USACE typical repeatability (precision) requirement for maintenance dredging in water depths 15-75 feet, depth range for most of this survey, is 0.3 feet. Figure 5 presents the full results of the analysis and documents that the survey exceeds USACE requirements for repeatability, or mean difference, of 0.01 m (0.03 feet vs. required 0.3 feet) and standard deviation at a 95% confidence level at 0.04 m (+/- 0.13 feet vs. required +/- 0.8 feet) for the full range of survey depths. The larger minimum and maximum values are on steeper slopes of the survey area and a result of comparing grid notes at a 3-foot resolution on a slope.



Mean:	0.01 m	Standard Deviation:	0.04 m
Minimum:	-0.40 m	Bin size:	0.01 m
Maximum:	0.79 m	Number of Nodes:	35,412

Figure 5. Histogram of Cross-Line versus Main Line gridded data difference

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 5 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 5. TPU Parameters

Parameter	Uncertainty
SVP Measured	0.5 m/s
SVP Surface	0.025 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 6 and 7. The mean grid uncertainty for depths reported for the 50-centimeter surface is 0.16 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.

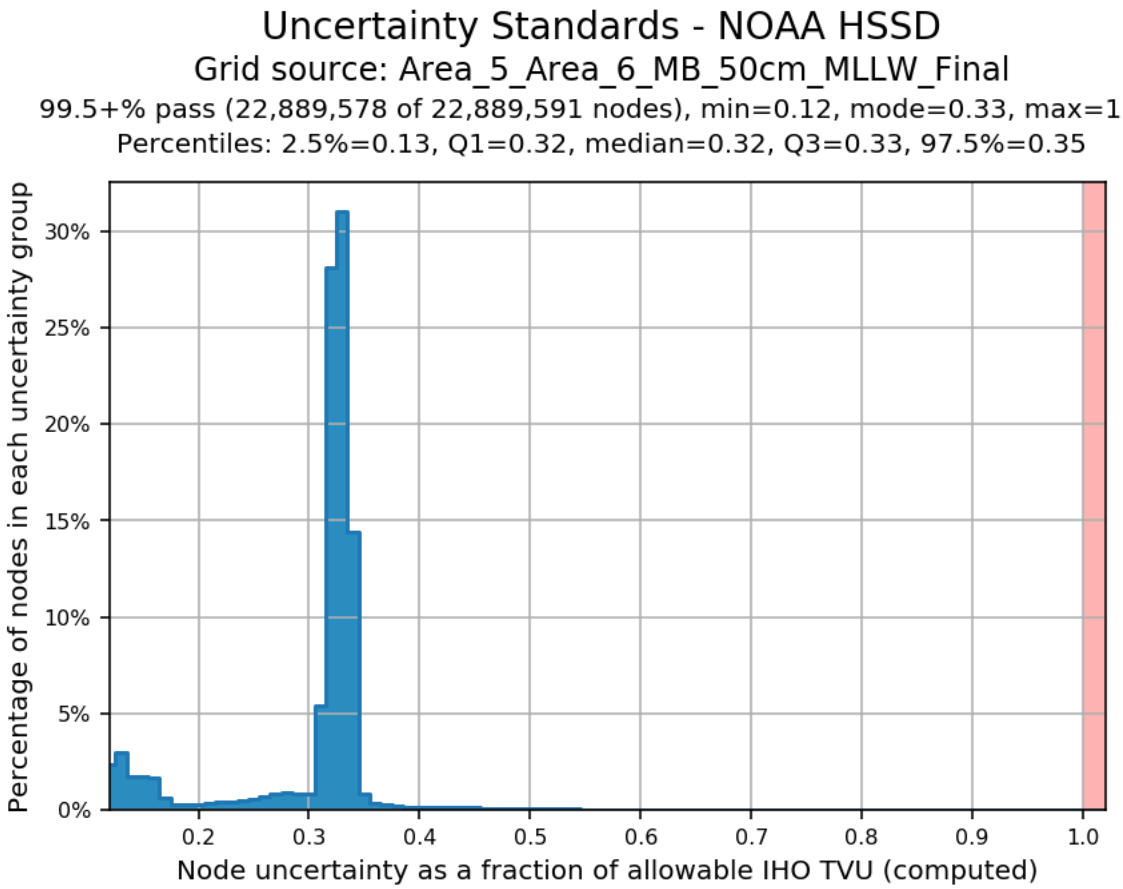


Figure 6. Node TVU Statistics – 50 centimeters, Finalized

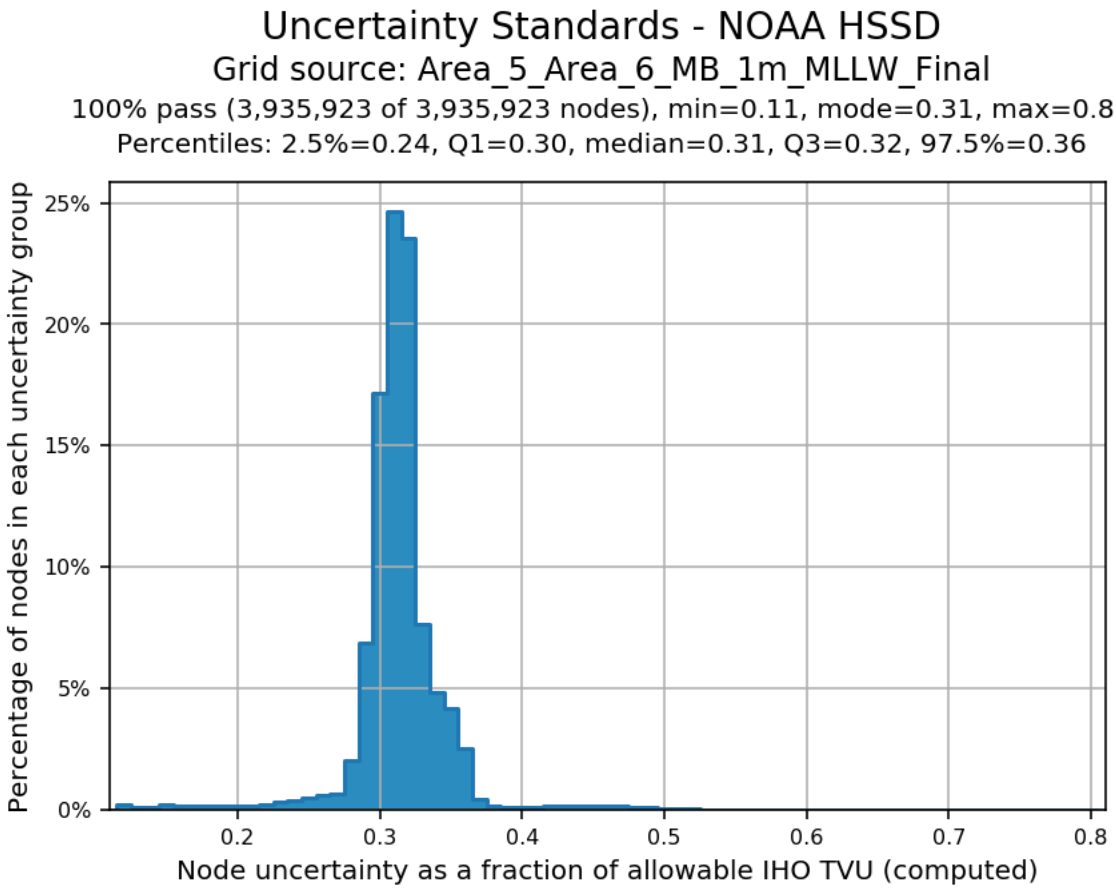


Figure 7. Node TVU Statistics – 1 meter, Finalized

5.5 Junctions

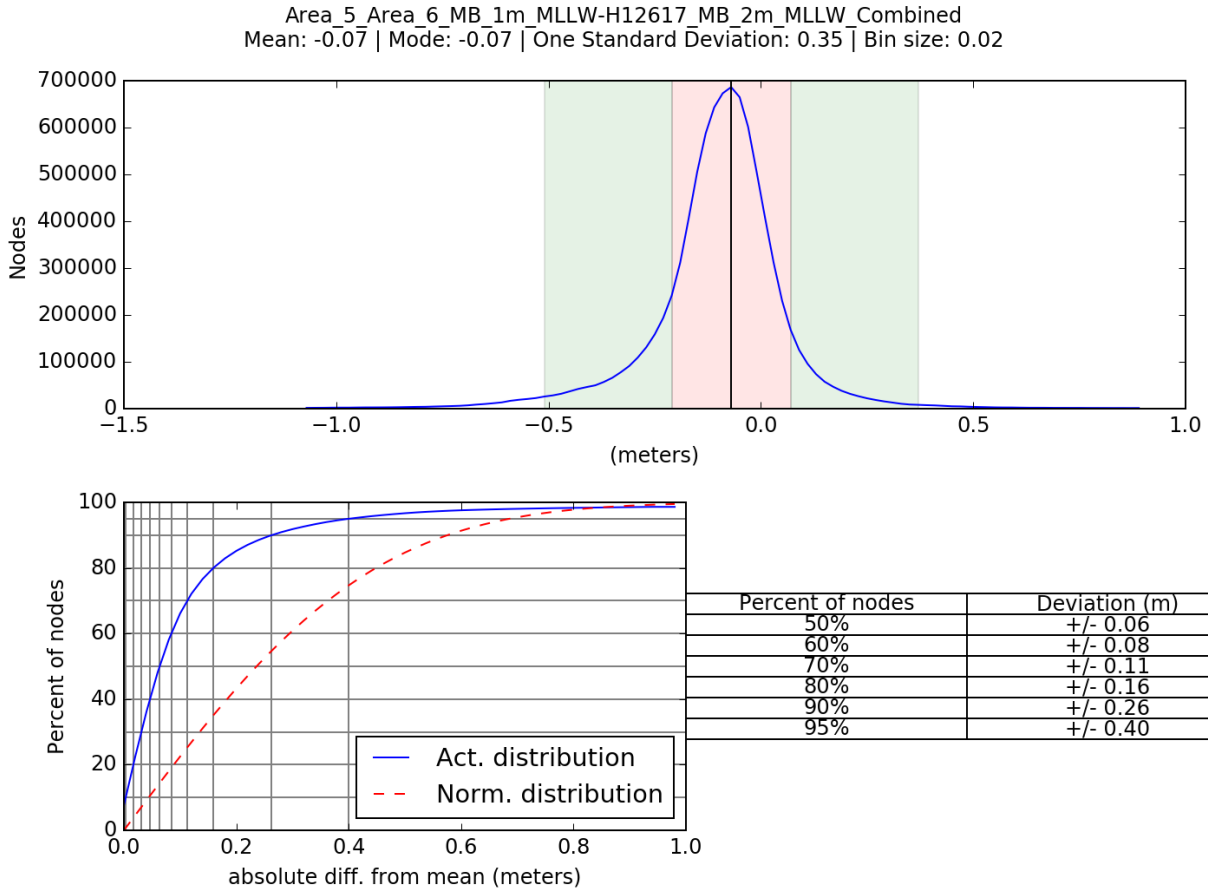
The survey junctions with NOAA prior surveys H12617 (performed in 2013) and H13197 (performed in 2018). A junction comparison was performed by computing a difference surface between a 1-meter resolution bathymetric surface of the recent and prior surveys. Bathymetric Attributes Grids for the prior surveys 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 6. The NOAA Pydro Gridded Surface Comparison Tool was used to perform this analysis.

Table 6. Junction Surveys

Registry Number	Year	Field Unit	Resolution
H12617	2013	NOAA Ship *Fairweather*	2 meters
H13197	2018	NOAA Ship *Rainier*	VR (2 meters)

H12617

The mean difference between the POLB survey and H12617 survey depths is 7 centimeters (POLB survey deeper than H12617), shown in Figure 8.

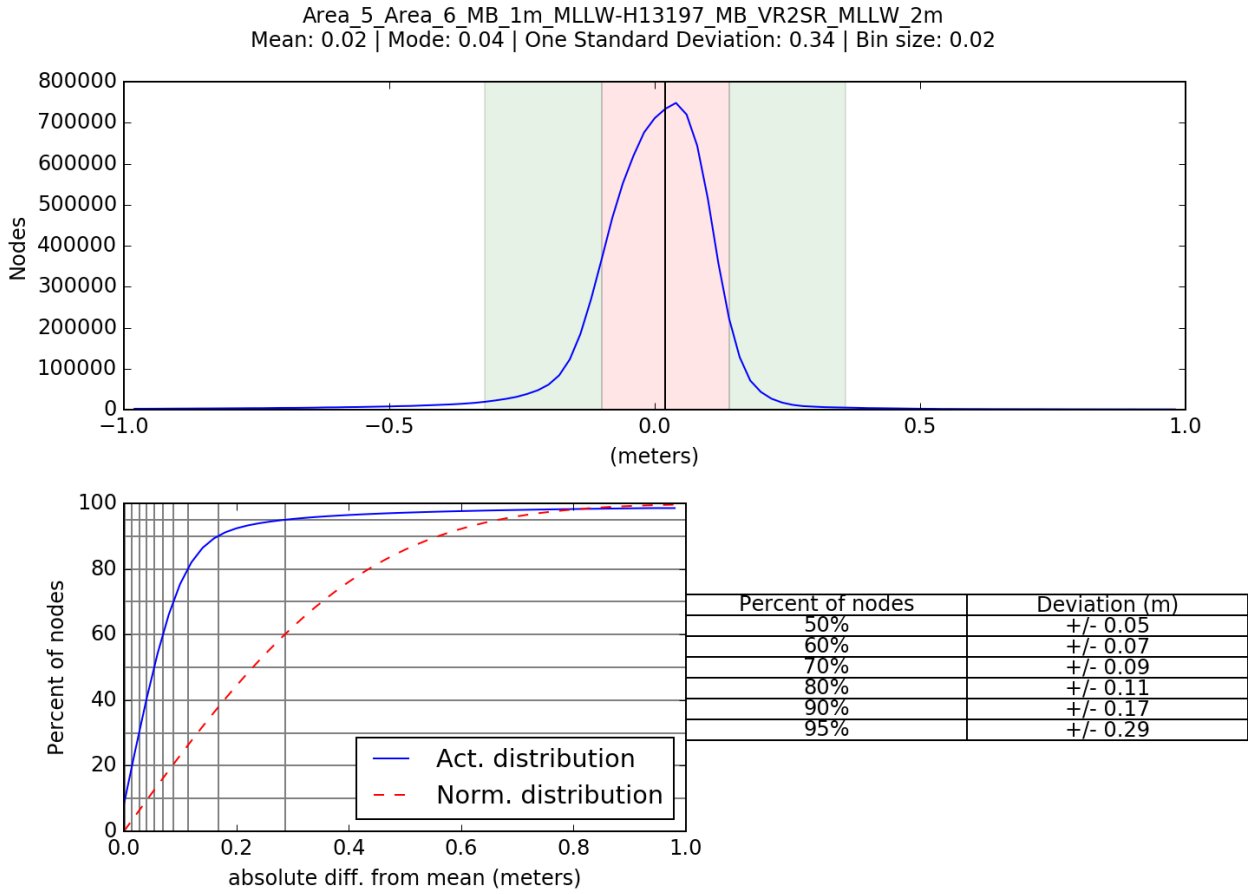


Percent of nodes	Deviation (m)
50%	+/- 0.06
60%	+/- 0.08
70%	+/- 0.11
80%	+/- 0.16
90%	+/- 0.26
95%	+/- 0.40

Figure 8. Distribution summary plot of differences between DEA survey and NOAA survey H12617

H13197

The mean difference between the POLB survey and H13197 survey depths is 2 centimeters (POLB survey shoaler than H13197), shown in Figure 9.



Percent of nodes	Deviation (m)
50%	+/- 0.05
60%	+/- 0.07
70%	+/- 0.09
80%	+/- 0.11
90%	+/- 0.17
95%	+/- 0.29

Figure 9. 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 10 and 11.

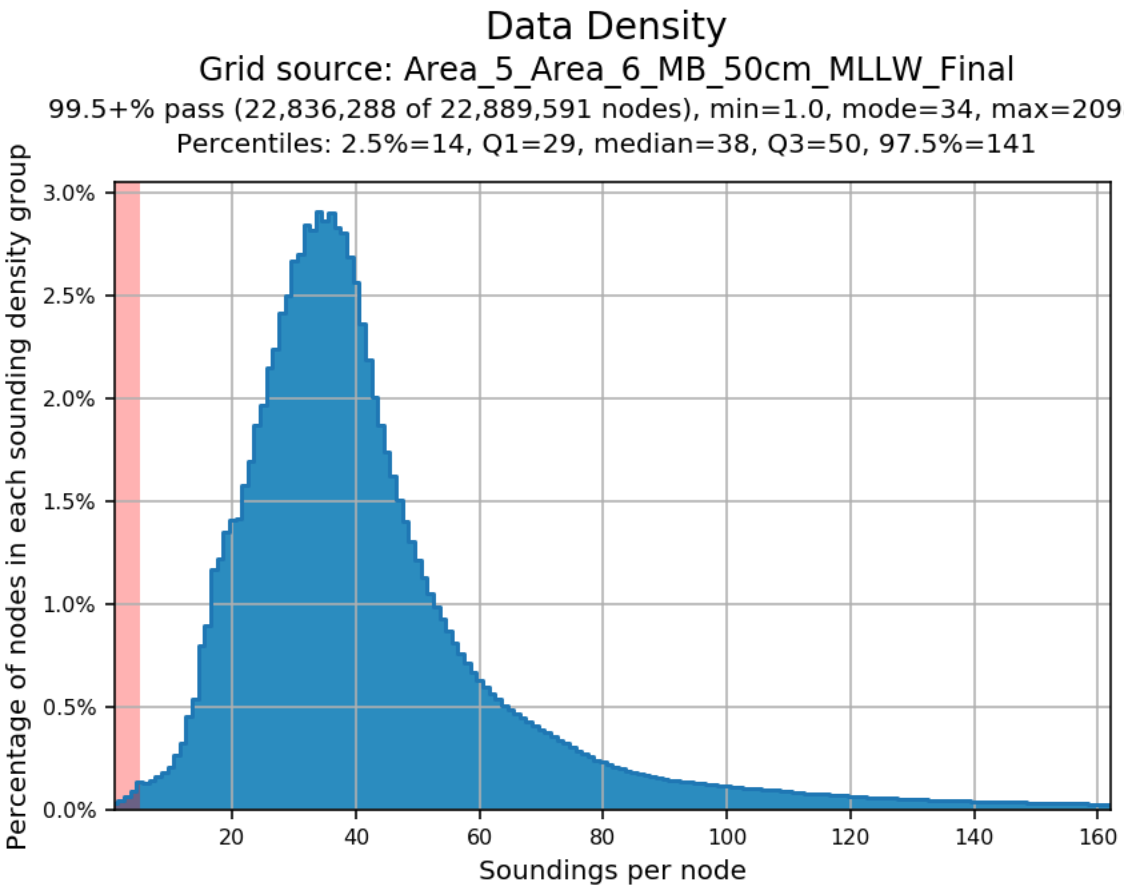


Figure 10: Node density statistics – 50cm finalized

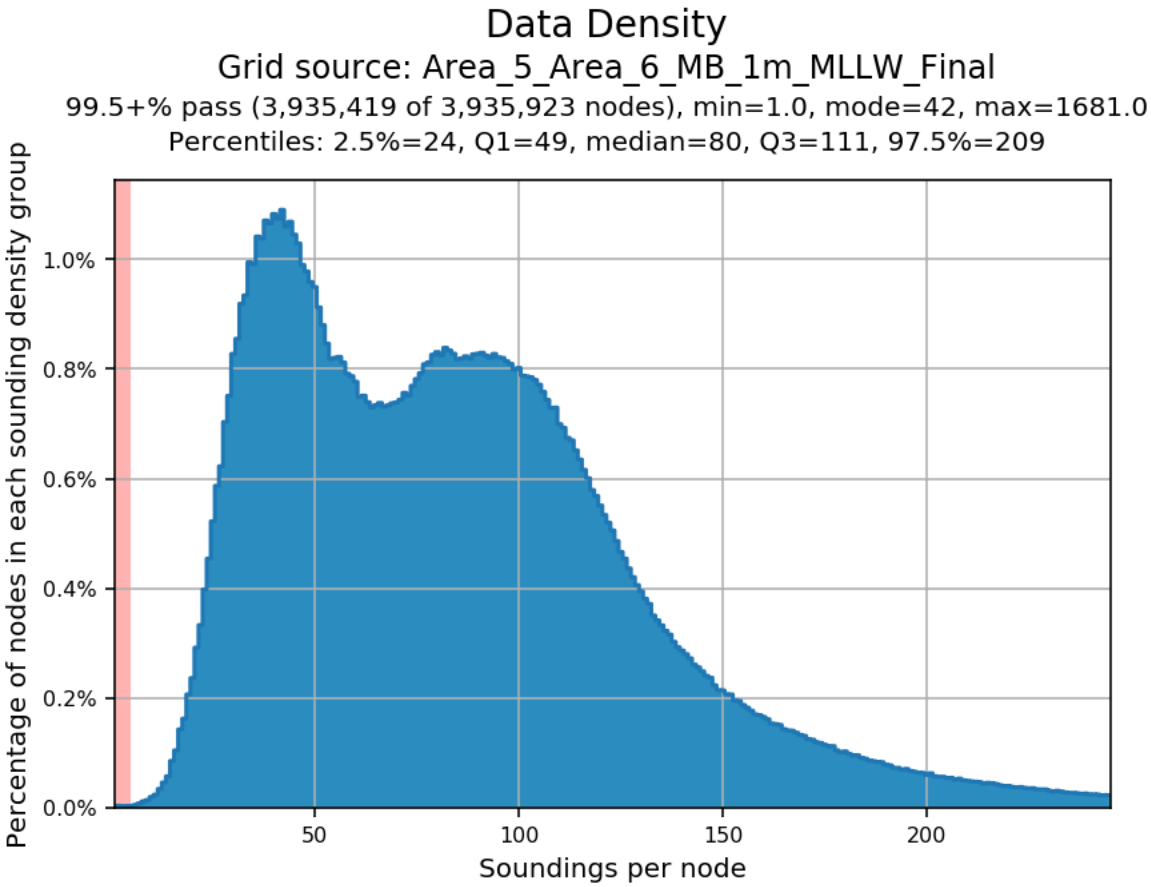


Figure 11: Node density statistics - 1m finalized

5.7 Backscatter

Beam average backscatter was logged during acquisition but was not processed.

5.8 Features

Multibeam data were reviewed to determine the presence of features meeting the height threshold for Object Detection Coverage set in the HSSD (2021). HIPS designated sounded were used to denote the lease depth of all submerged features present in the survey data. These lease 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 (2021). 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.

Several charted shoreline construction features were added to the S-57 Feature File for reference only and were not addressed. These features have descrp = Not Addressed.

5.9 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 7. A graphic showing the magnitudes of the differences between the survey and charts is show in Figures 12 through 17.

Table 7. ENCs used during the chart comparison

ENC	Scale	Edition	Update Application Date	Issue Date
US6LGBCC	5000	4	07/17/2021	07/1/2021
US6LGBCD	5000	6	09/02/2021	09/02/2021

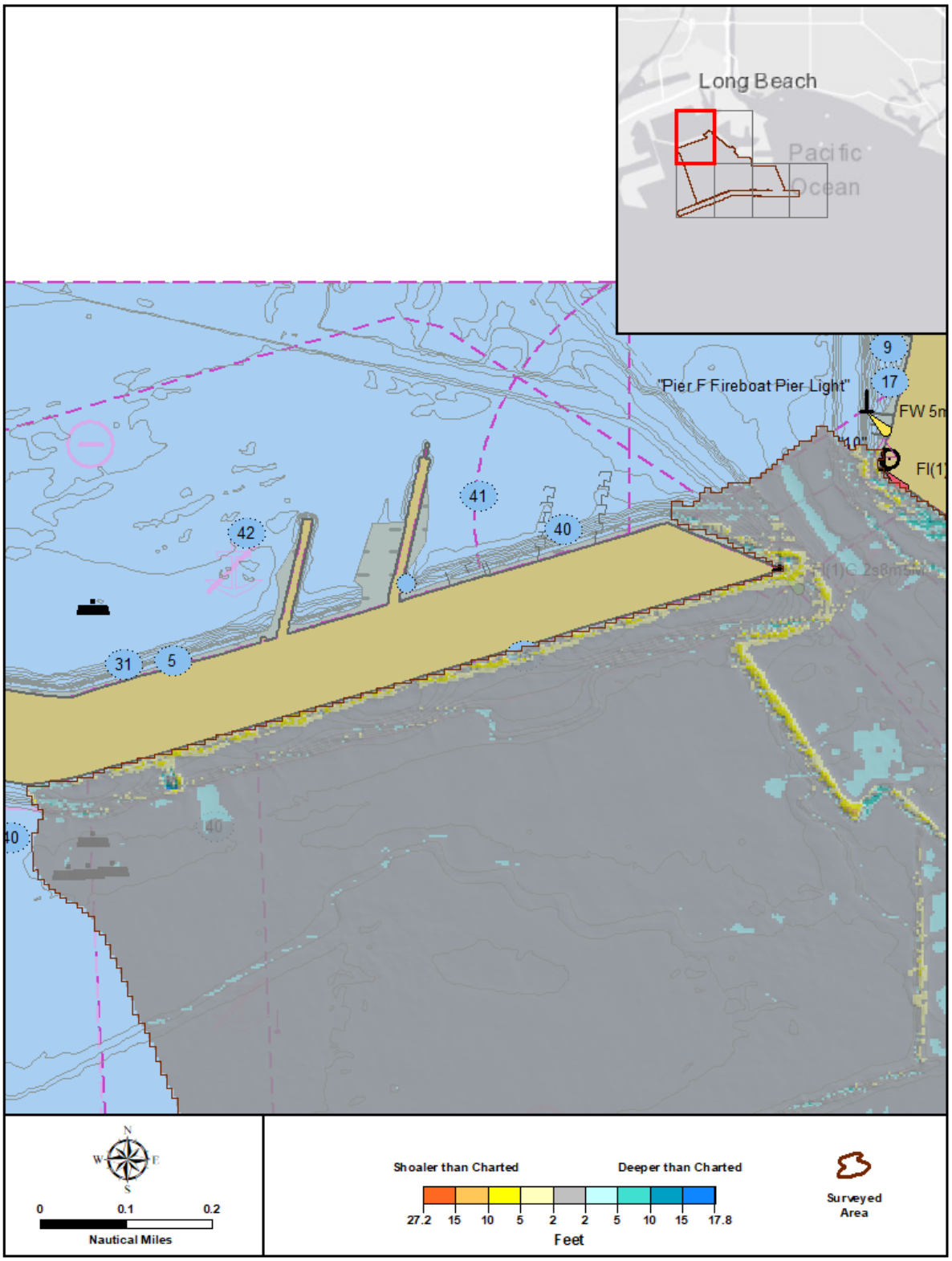


Figure 12: Depth Difference Between POLB Survey and Band 6 ENCs, Area 1 of 6

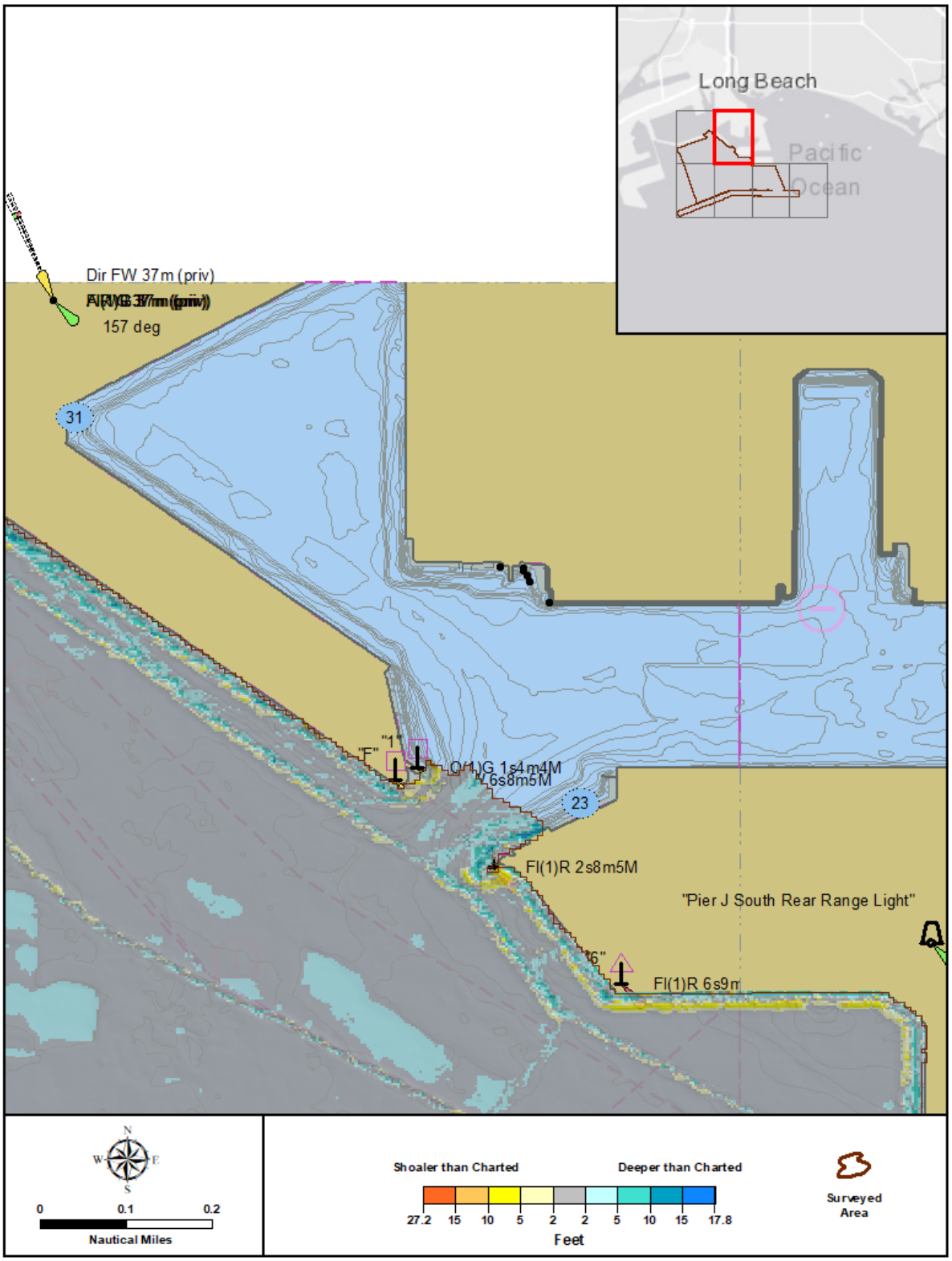


Figure 13: Depth Difference Between POLB Survey and Band 6 ENCs, Area 2 of 6

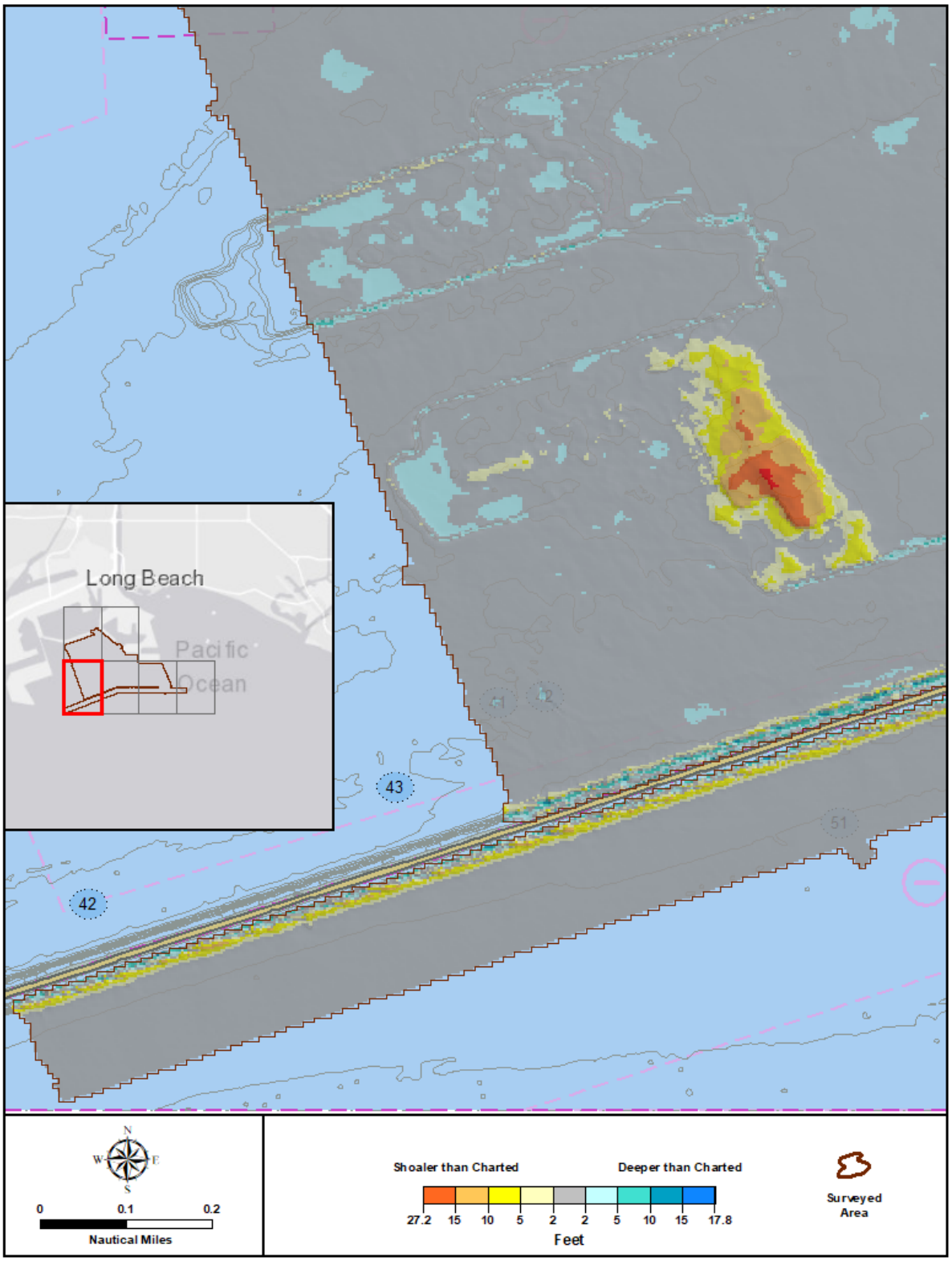


Figure 14: Depth Difference Between POLB Survey and Band 6 ENCs, Area 3 of 6

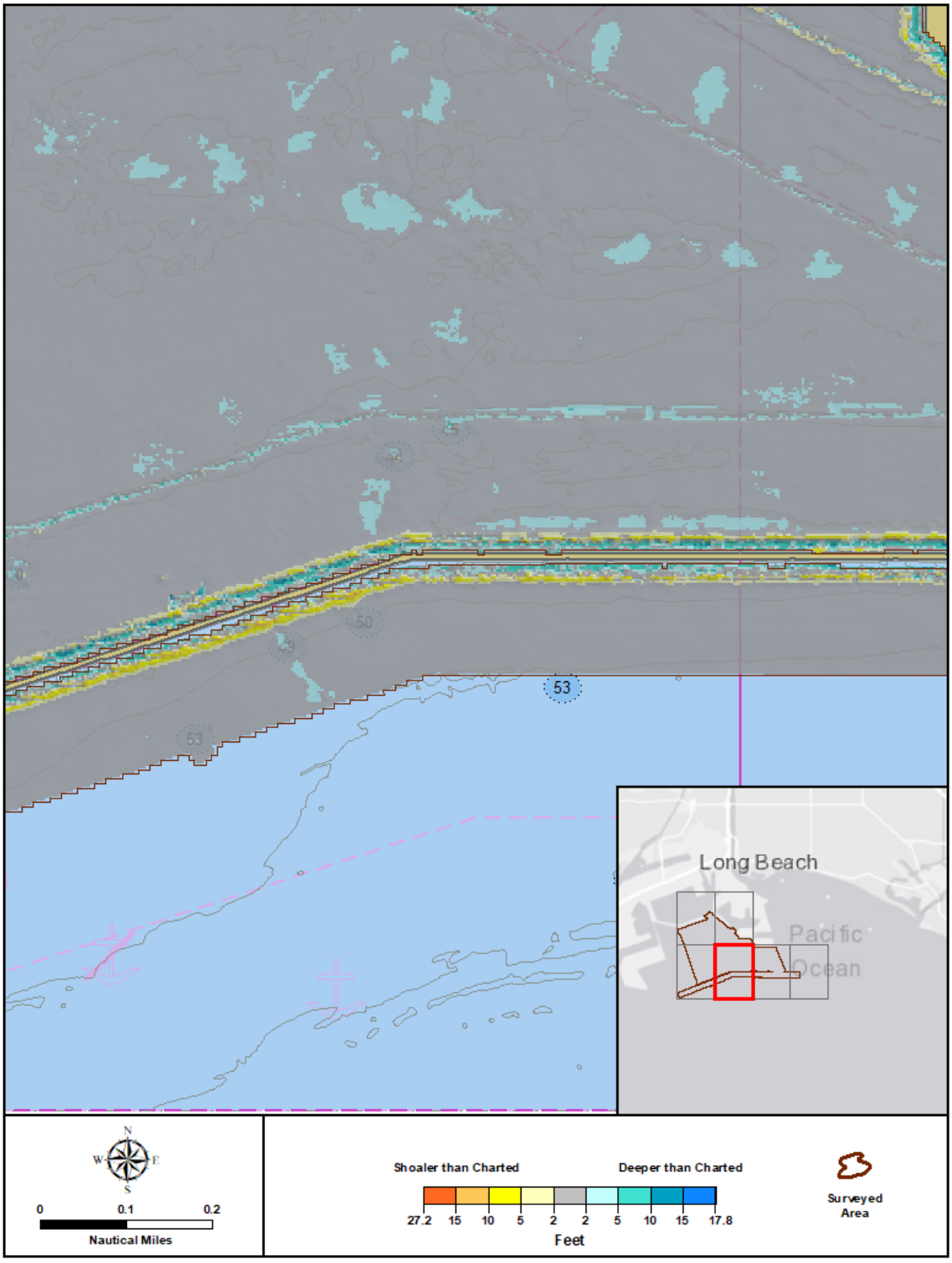


Figure 15: Depth Difference Between POLB Survey and Band 6 ENCs, Area 4 of 6

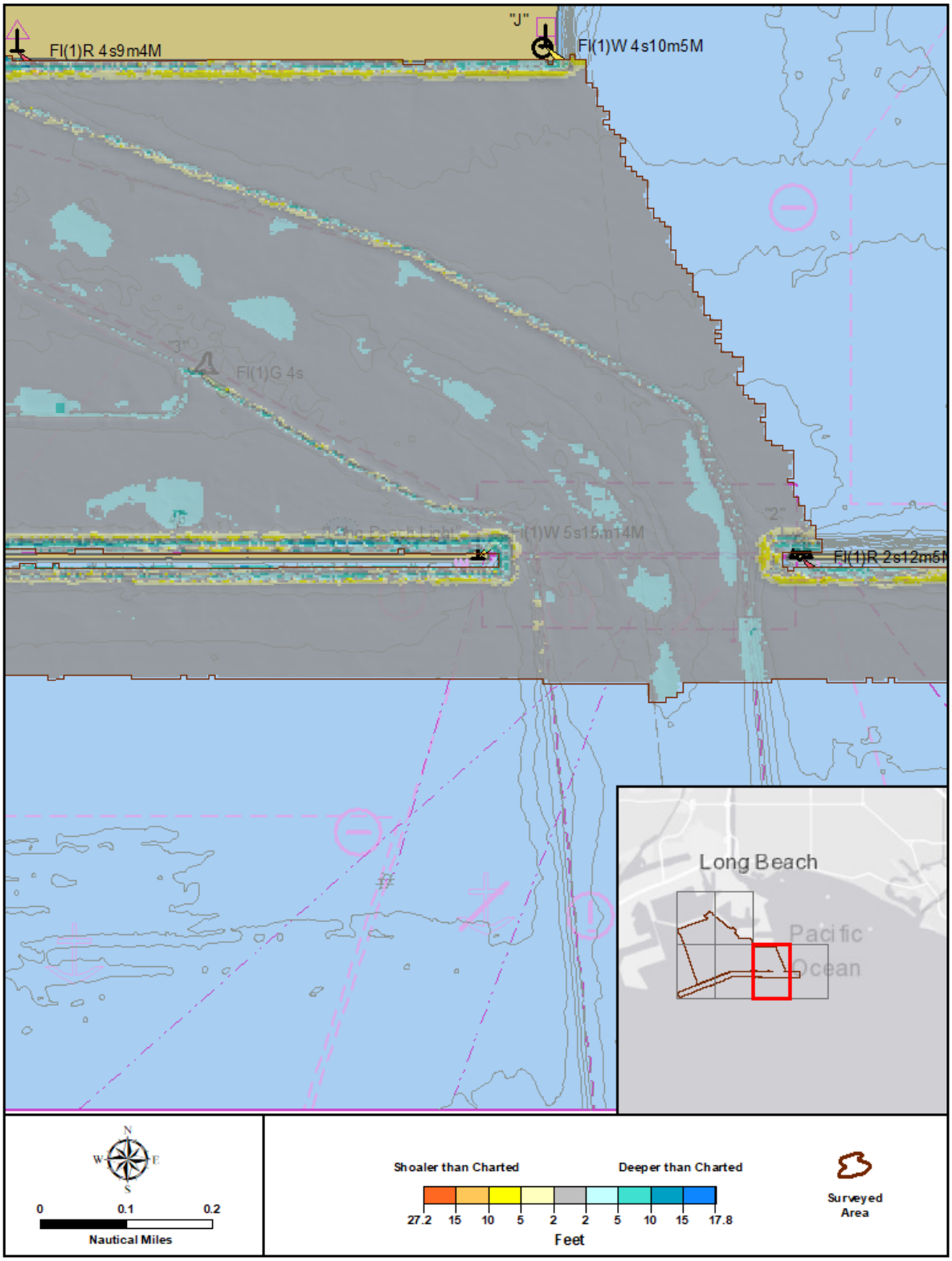


Figure 16: Depth Difference Between POLB Survey and Band 6 ENCs, Area 5 of 6

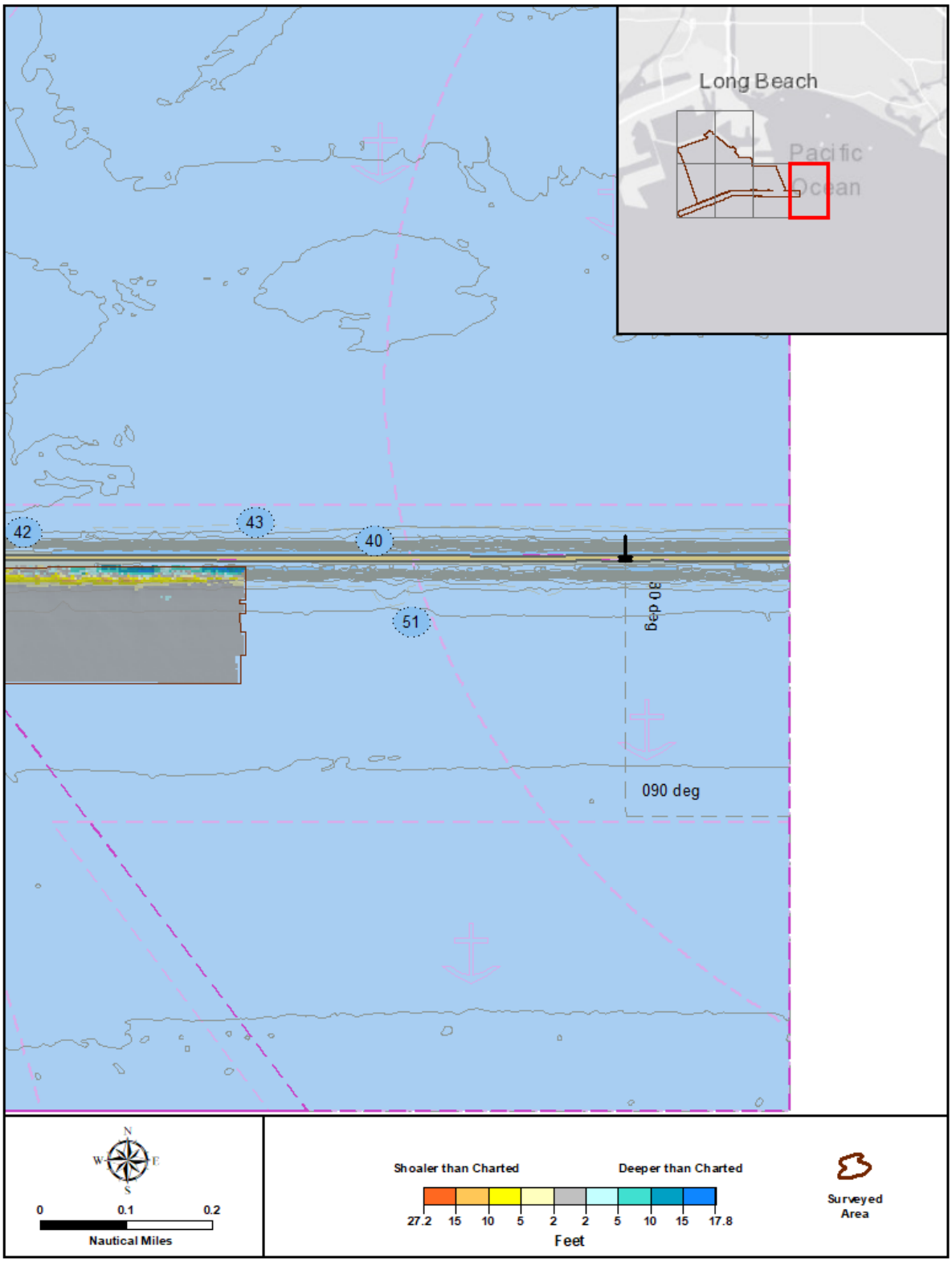


Figure 17: Depth Difference Between POLB Survey and Band 6 ENCs, Area 6 of 6

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 (2021). 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

APPENDIX A
Project Metadata

NOAA External Source Data Summary Information

ISO 19115 Metadata Term (not ISO)	Definition
Title	Port of Long Beach, San Pedro Bay
Responsible Party	Port of Long Beach
Contact Info	Kimberley A. Holtz, Survey Division Director, Port of Long Beach
Phone	562-283-7271
Electronic Mail Address	kim.holtz@polb.com
Online Resource	https://polb.com/
Legal Constraint: License	Data permission form (Data_Permissions_POLB_20220329.pdf) included with the survey submittal.

Quality of Bathymetric Data			
ISO 19115 Metadata Term (not ISO)	Definition	Format	
Acquisition Start Date Time	20200715	YYYYMMDD	Required
Acquisition End Date Time	20200722	YYYYMMDD	Required
Vertical Coordinate Reference System	Mean Lower Low Water (MLLW)	String	Required
Vertical Unit of Measure	Meters	String	Required
Positional Accuracy Vertical	0.16	Float	Vital
Horizontal Coordinate Reference System	PROJCS["NAD83(2011) / UTM zone 11N", GEOGCS["NAD83(2011)", DATUM["NAD83 (National Spatial Reference System 2011)", SPHEROID["GRS 1980",6378137,298.2572221010041, AUTHORITY["EPSG","7019"]], AUTHORITY["EPSG","1116"]], PRIMEM["Greenwich",0, AUTHORITY["EPSG","8901"]], UNIT["degree (supplier to define representation)",0.0174532925199433,	OGC WKT	Required

	AUTHORITY["EPSG","9122"]], AUTHORITY["EPSG","6318"]], PROJECTION["Transverse_Mercator", AUTHORITY["EPSG","16011"]], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-117], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["metre",1, AUTHORITY["EPSG","9001"]], AUTHORITY["EPSG","6340"]]		
Positional Accuracy Horizontal	0.10	Float	Vital
(Full Bathymetric Coverage Achieved)	True	True / False	Vital
(Full seafloor Coverage Achieved)	True	True / False	Vital
(Resolution)	0.5, 1.0	Float	Vital
(Significant Features Detected)	True	True / False	Vital
(Least Depth of Detected Features Measured)	True	True / False	Vital
(Size of Features Detected)	1.0	Float	Vital

Survey Equipment and Process Steps			
ISO 19115 Metadata Term (not ISO)	Definition	Format	
(Multibeam Sensor)	Reson SeaBat T50P	String	Required
(Vertical Beam Sensor)	N/A	String	Required
(Side Scan Sensor)	N/A	String	Required
(Lidar Sensor)	N/A	String	Required
(Interferometric Sensor)	N/A	String	Required

(Attitude and Positioning Equipment)	Applanix POS/MV 320 version 5	String	Conditional
(Sound Velocity Sensors)	AML Micro SV (surface sound speed), AML Oceanographic Smart X (sound speed profiles)	String	Conditional
(Sound Velocity Processing)	Sound velocity profiles were used to correct slant range measurements and to compensate for any ray path bending. These were applied in CARIS using the closest in distance and time algorithm.	String	Conditional
(Vertical Datum Processing)	ERS methods using post processed kinematic (PPK) SBET and custom VDatum based separation file. Soundings reduced to MLLW in CARIS HIPS.	String	Conditional
(Processing Software)	CARIS HIPS (version 11.3.5 and 11.3.8)	String	Conditional