H12688

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

DESCRIPTIVE REPORT

Type of Survey:	Navigable Area
Registry Number:	H12688

LOCALITY

State(s):	Alaska
General Locality:	North Coast of Kodiak Island
Sub-locality:	Kizhuyak Bay

2015

CHIEF OF PARTY
Edward J. Van Den Ameele, CDR/NOAA

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Date:

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

REGISTRY NUMBER:

HYDROGRAPHIC TITLE SHEET

H12688

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):	**Alaska**
General Locality:	**North Coast of Kodiak Island**
Sub-Locality:	**Kizhuyak Bay**
Scale:	**40000**
Dates of Survey:	**09/23/2015 to 09/30/2015**
Instructions Dated:	**09/09/2015**
Project Number:	**OPR-P136-RA-15**
Field Unit:	**NOAA Ship *Rainier***
Chief of Party:	**Edward J. Van Den Ameele, CDR/NOAA**
Soundings by:	**Multibeam Echo Sounder**
Imagery by:	**Multibeam Echo Sounder Backscatter**
Verification by:	**Pacific Hydrographic Branch**
Soundings Acquired in:	**meters at Mean Lower Low Water**

Remarks:

The purpose of this survey is to provide contemporary surveys to update National Ocean Service (NOS) nautical charts. All separates are filed with the hydrographic data. Any revisions to the Descriptive Report (DR) generated during office processing are shown in bold, red italic text. The processing branch maintains the DR as a field unit product, therefore, all information and recommendations within the body of the DR are considered preliminary unless otherwise noted. The final disposition of surveyed features is represented in the OCS nautical chart update products. All pertinent records for this survey, including the DR, are archived at the National Centers for Environmental Information (NCEI) and can be retrieved via http://www.ncei.noaa.gov/.

Table of Contents

List of Tables

List of Figures

Descriptive Report to Accompany Survey H12688

Project: OPR-P136-RA-15

Locality: North Coast of Kodiak Island

Sublocality: Kizhuyak Bay

Scale: 1:40000

September 2015 - September 2015

NOAA Ship *Rainier*

Chief of Party: Edward J. Van Den Ameele, CDR/NOAA

A. Area Surveyed

This survey is referred to as "Kizhuyak Bay" (priority 1) within the Project Instructions. The area covers approximately seven square nautical miles of the southern half of Kizhuyak Bay on the north coast of Kodiak Island, Alaska (Figure 1).

A.1 Survey Limits

Data were acquired within the following survey limits:

Northwest Limit	Southeast Limit
57° 30' 0" N 152° 33' 0" W	57° 26' 24" N 152° 30' 0" W

Table 1: Survey Limits

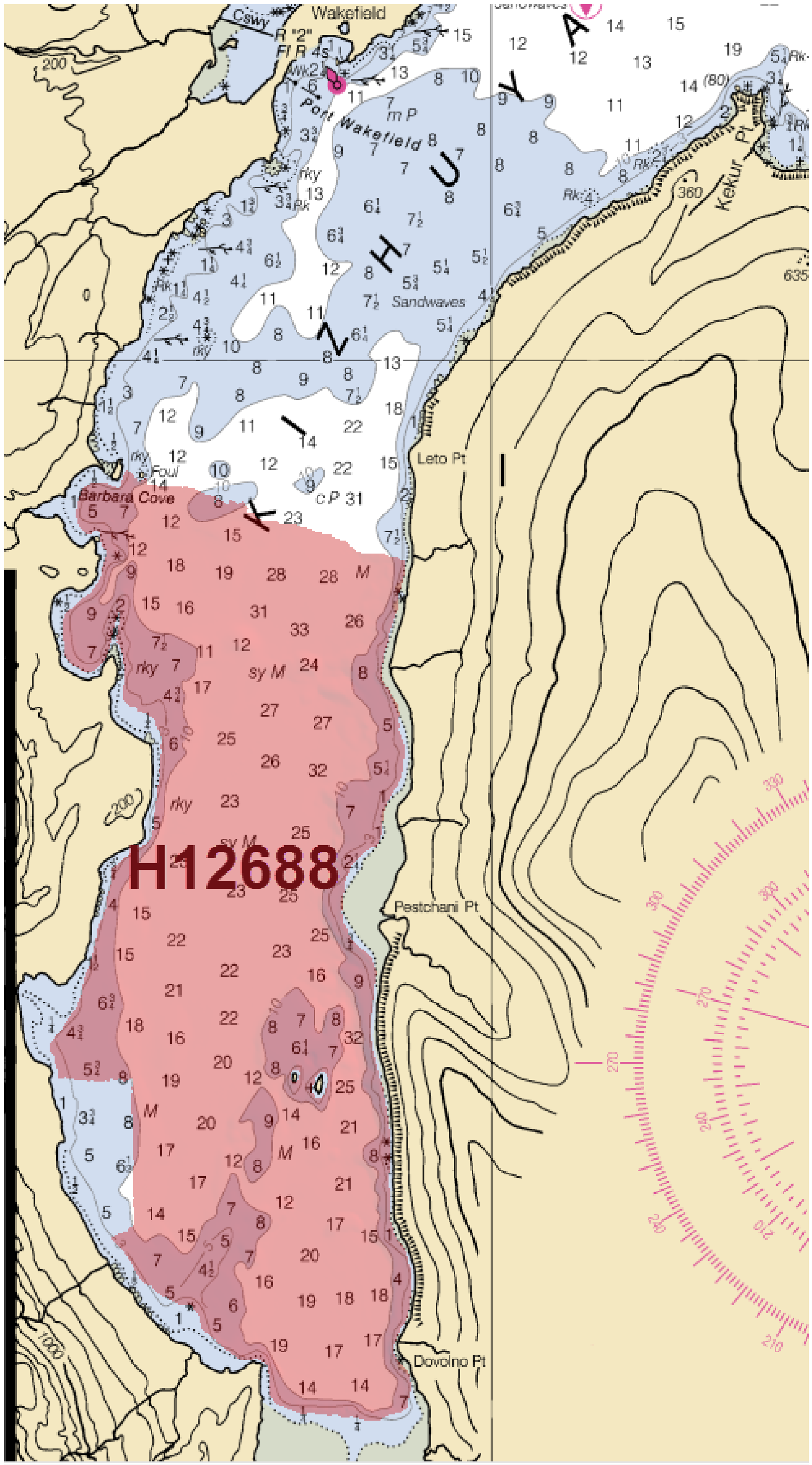

Figure 1: Overlay of H12688 acquired survey coverage on Chart 16594.

Deteriorating weather conditions necessitated an earlier than planned departure from the project area resulting in a deviation from the assigned sheet limits (Figure 2). A small area along the western shoreline of Kizhuyak Bay was not surveyed as assigned.

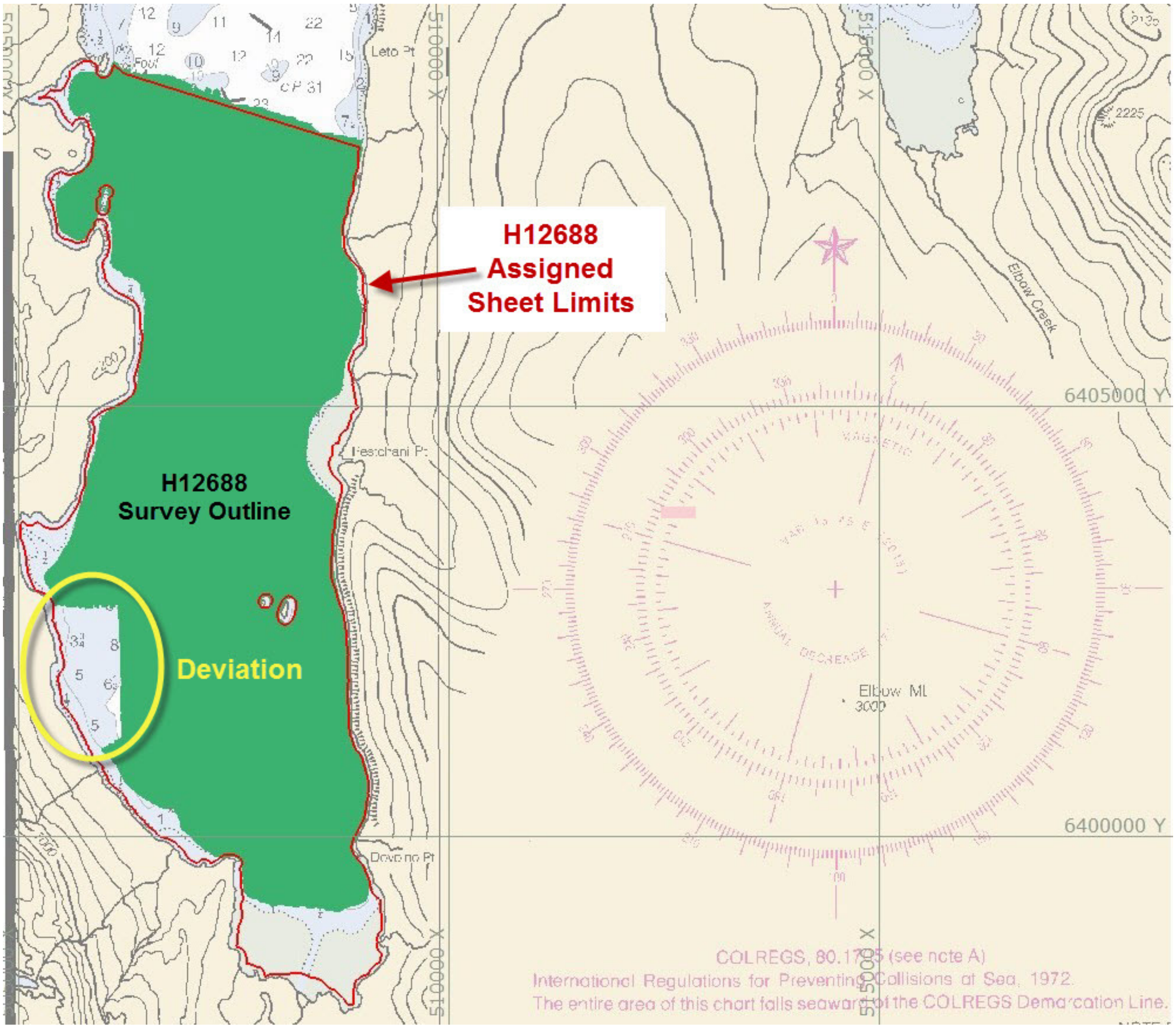

Figure 2: H12688 deviation from assigned sheet limits.

A.2 Survey Purpose

The purpose of this project is to provide contemporary data to update National Ocean Service (NOS) nautical charting products, which will support Kodiak's large fishing fleet and increasing levels of passenger vessel traffic.

A.3 Survey Quality

The entire survey is adequate to supersede previous data.

Survey H12688 met data quality standards as outlined in NOS Hydrographic Surveys Specifications and Deliverables (HSSD) May 2015, including the 5 soundings per node density requirement. In order to extract statistics of the density achieved, the density layer of each finalized surface was queried within Caris then examined in Excel. Overall, the required data density was achieved in 99.96% of nodes (Figure 3). The finalized CSAR surface IHO compliance tool within Pydro was used to analyze H12688 MBES data; the results showed that an average of 99.98% of H12688 nodes met HSSD object detection requirements (Figures 4-6).

Resolution	Depth range	Number of nodes	Fewer than five soundings per node	Percent of nodes with greater than five soundings per node
1m	0 - 20m	6,404,624	3,258	99.95%
2m	18 - 40m	2,796,823	222	99.99%
4m	36 - 80m	668,024	19	100.00%
	TOTAL:	9,869,471	3,499	99.96%

Figure 3: Summary table showing the percentage of nodes satisfying the 5 soundings density requirement, subdivided by depth range.

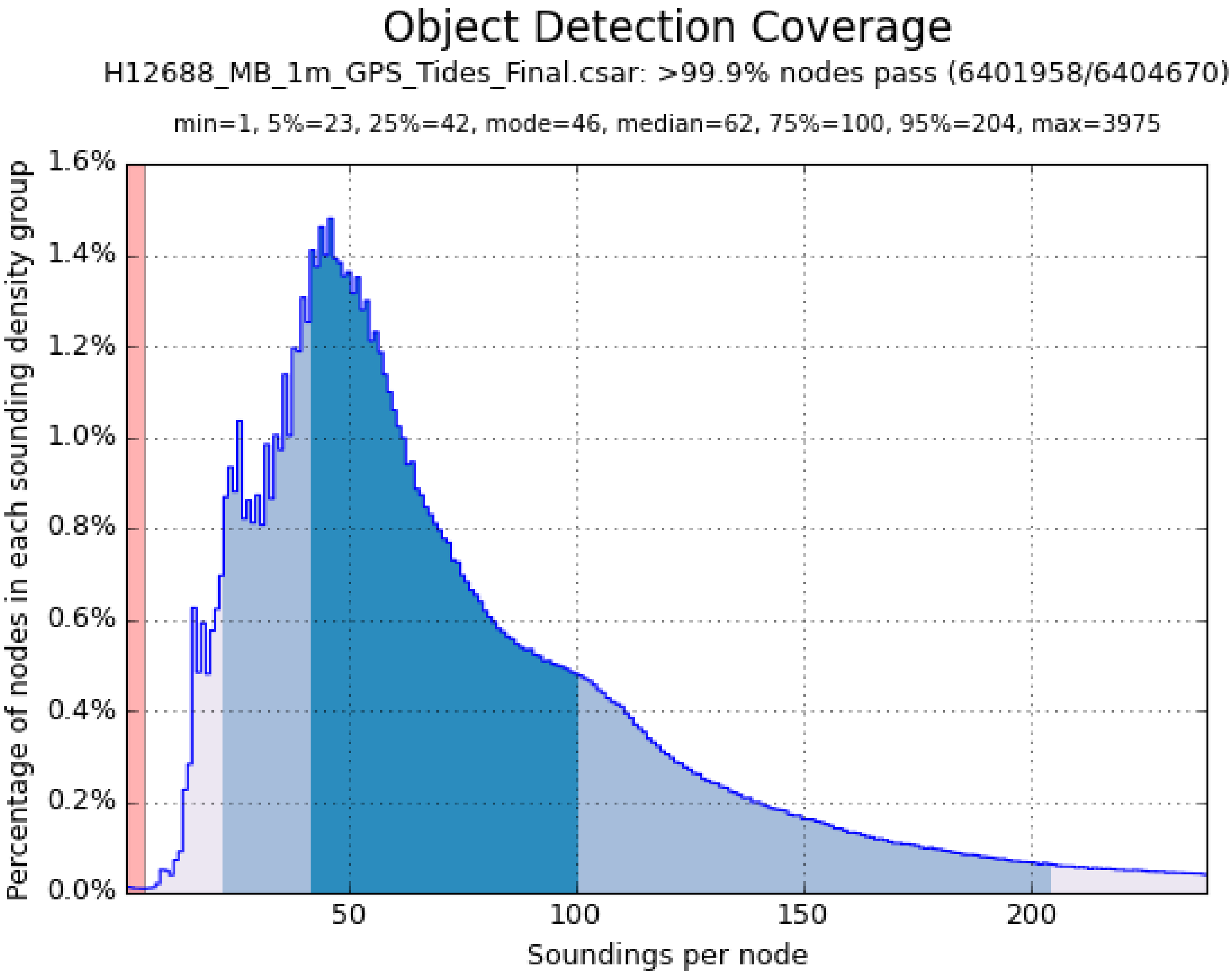

Figure 4: Pydro derived histogram plot showing HSSD object detection compliance of H12688 1-meter resolution MBES data.

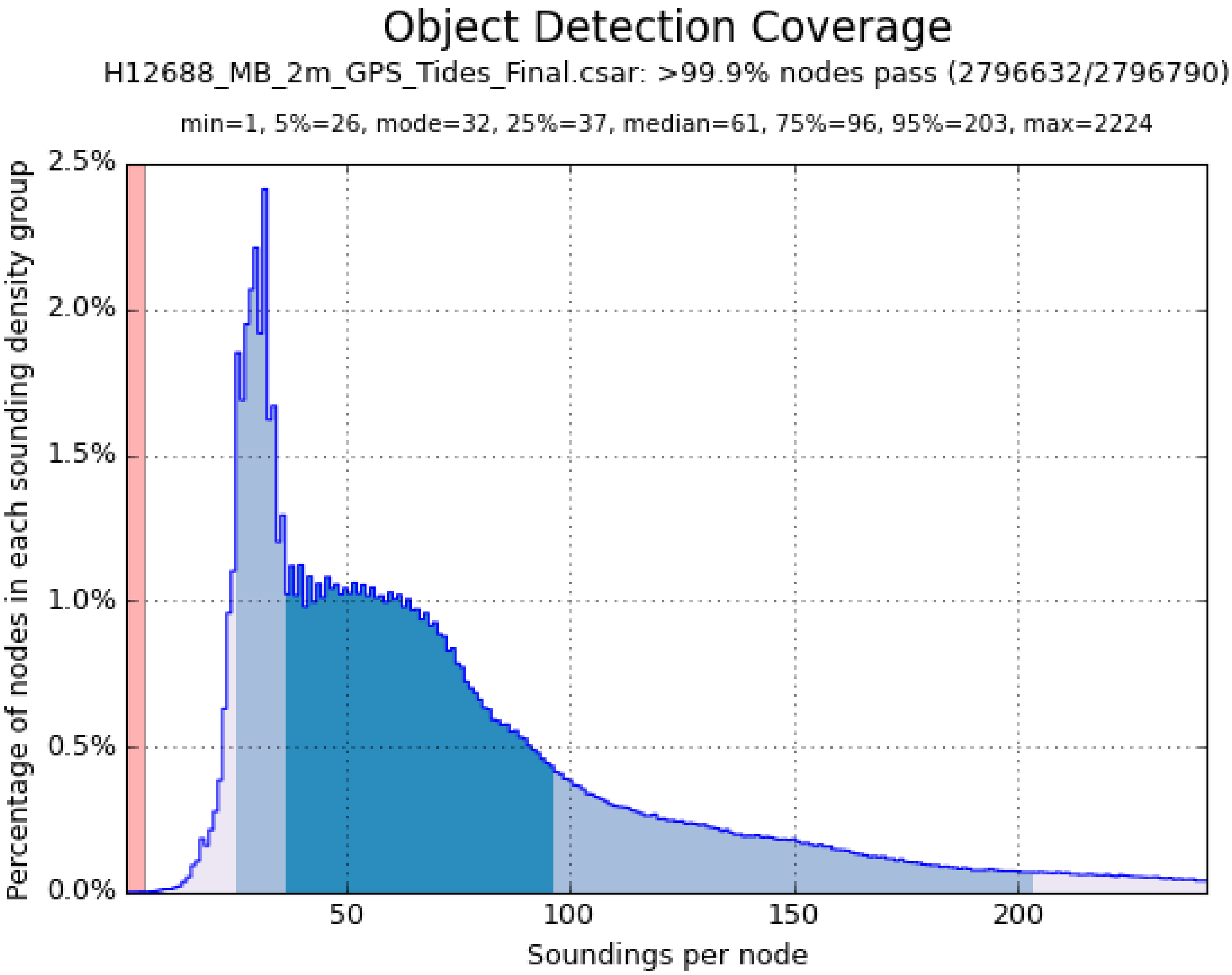

Figure 5: Pydro derived histogram plot showing HSSD object detection compliance of H12688 2-meter resolution MBES data.

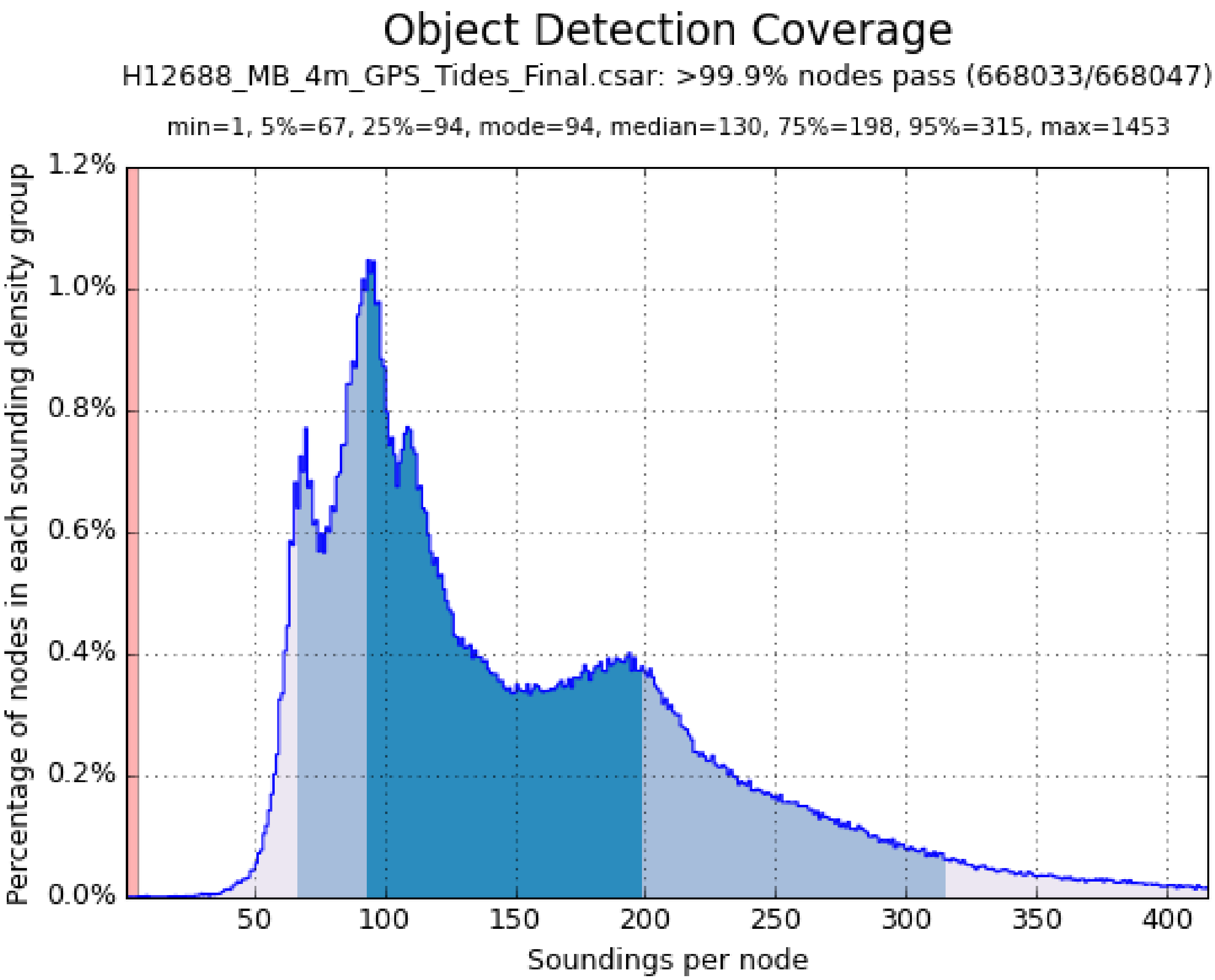

Figure 6: Pydro derived histogram plot showing HSSD object detection compliance of H12688 4-meter resolution MBES data.

A.4 Survey Coverage

The following table lists the coverage requirements for this survey as assigned in the project instructions:

Water Depth	Coverage Required
Inshore limit to 8 meters water depth	100m spaced Set Line Spacing, Single Beam Echosounder (SBES), or Multibeam Echosounder (MBES) with concurrent backscatter
Greater than 8 meters water depth	MBES with concurrent Backscatter

Complete multibeam echosounder coverage was achieved within the assigned survey area except where noted. Eight holidays measuring approximately 3 by 20 meters are located near the northeast shoreline of the survey (Figure 7). The holidays were examined to ensure that no navigationally significant features were evident in the surrounding data.

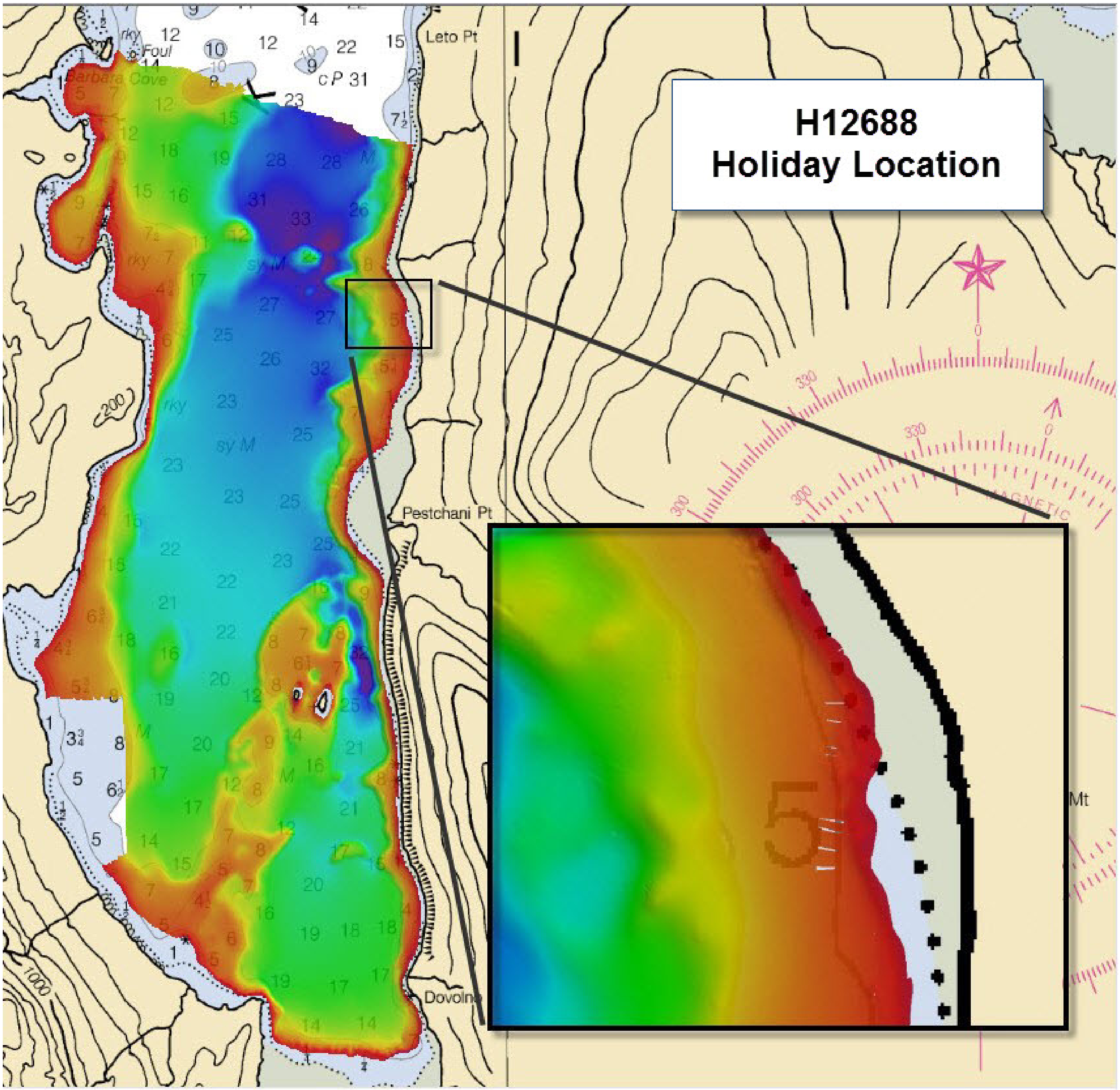

Figure 7: H12688 complete coverage holidays.

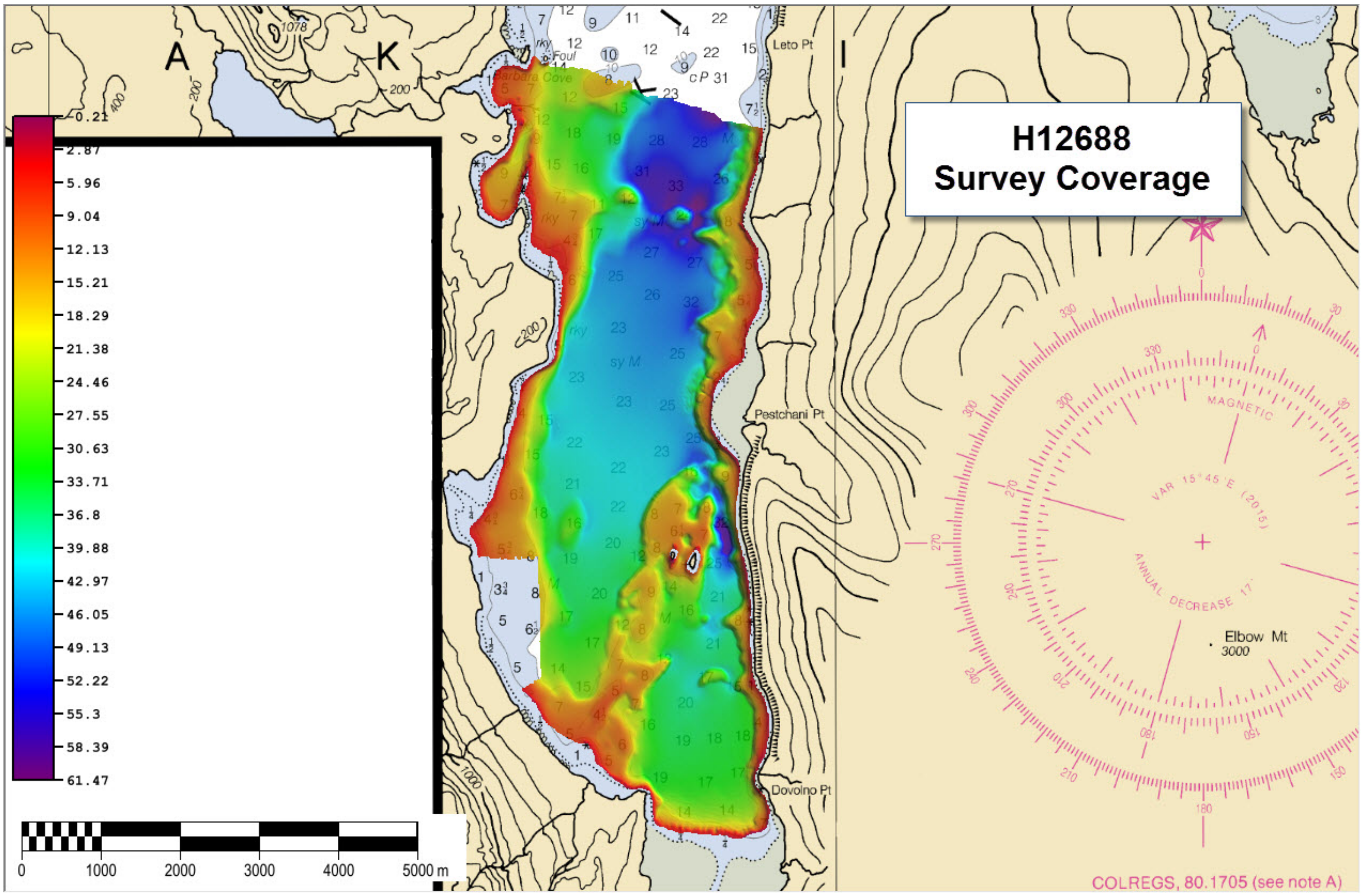

Figure 8: H12668 survey coverage (Chart 16594).

A.5 Survey Statistics

The following table lists the mainscheme and crossline acquisition mileage for this survey:

	HULL ID	*2801*	*2802*	*2803*	*2804*	*Total*
LNM	SBES Mainscheme	0	0	0	0	0
	MBES Mainscheme	24.42	71.41	37.04	74.92	207.79
	Lidar Mainscheme	0	0	0	0	0
	SSS Mainscheme	0	0	0	0	0
	SBES/SSS Mainscheme	0	0	0	0	0
	MBES/SSS Mainscheme	0	0	0	0	0
	SBES/MBES Crosslines	2.38	0	0	11.17	13.55
	Lidar Crosslines	0	0	0	0	0
Number of Bottom Samples						1
Number Maritime Boundary Points Investigated						0
Number of DPs						0
Number of Items Investigated by Dive Ops						0
Total SNM						7.37

Table 2: Hydrographic Survey Statistics

The following table lists the specific dates of data acquisition for this survey:

Survey Dates	Day of the Year
09/23/2015	266
09/24/2015	267

Survey Dates	Day of the Year
09/29/2015	272
09/30/2015	273

Table 3: Dates of Hydrography

B. Data Acquisition and Processing

B.1 Equipment and Vessels

Refer to the Data Acquisition and Processing Report (DAPR) for a complete description of data acquisition and processing systems, survey vessels, quality control procedures and data processing methods. Additional information to supplement sounding and survey data, and any deviations from the DAPR are discussed in the following sections.

B.1.1 Vessels

The following vessels were used for data acquisition during this survey:

Hull ID	***2801***	***2802***	***2803***	***2804***
LOA	8.8 meters	8.8 meters	8.8 meters	8.8 meters
Draft	1.1 meters	1.1 meters	1.1 meters	1.1 meters

Table 4: Vessels Used

B.1.2 Equipment

The following major systems were used for data acquisition during this survey:

Manufacturer	Model	Type
Applanix	POS M/V v4	Positioning and Attitude System
Reson	SeaBat 7125 SV2	MBES
Reson	SeaBat 7125-B	MBES
Reson	SVP71	Sound Speed System
Sea-Bird Electronics	SBE 19plus SEACAT Profiler	Conductivity, Temperature, and Depth Sensor

Table 5: Major Systems Used

B.2 Quality Control

B.2.1 Crosslines

Crosslines acquired for this survey totaled 6.52% of mainscheme acquisition.

Multibeam crosslines were acquired by Rainier launches 2801 and 2804. A 2-meter CUBE surface was created using only H12688 mainscheme lines, and a second 2-meter surface was created using only crosslines. A 2-meter difference surface was then generated in Caris from which statistics were derived. The difference surface was compared to the HSSD allowable total vertical uncertainty (TVU) standards. The results showed that 99.98% of depth differences between H12688 mainscheme and crossline data met HSSD TVU standards (Figure 10).

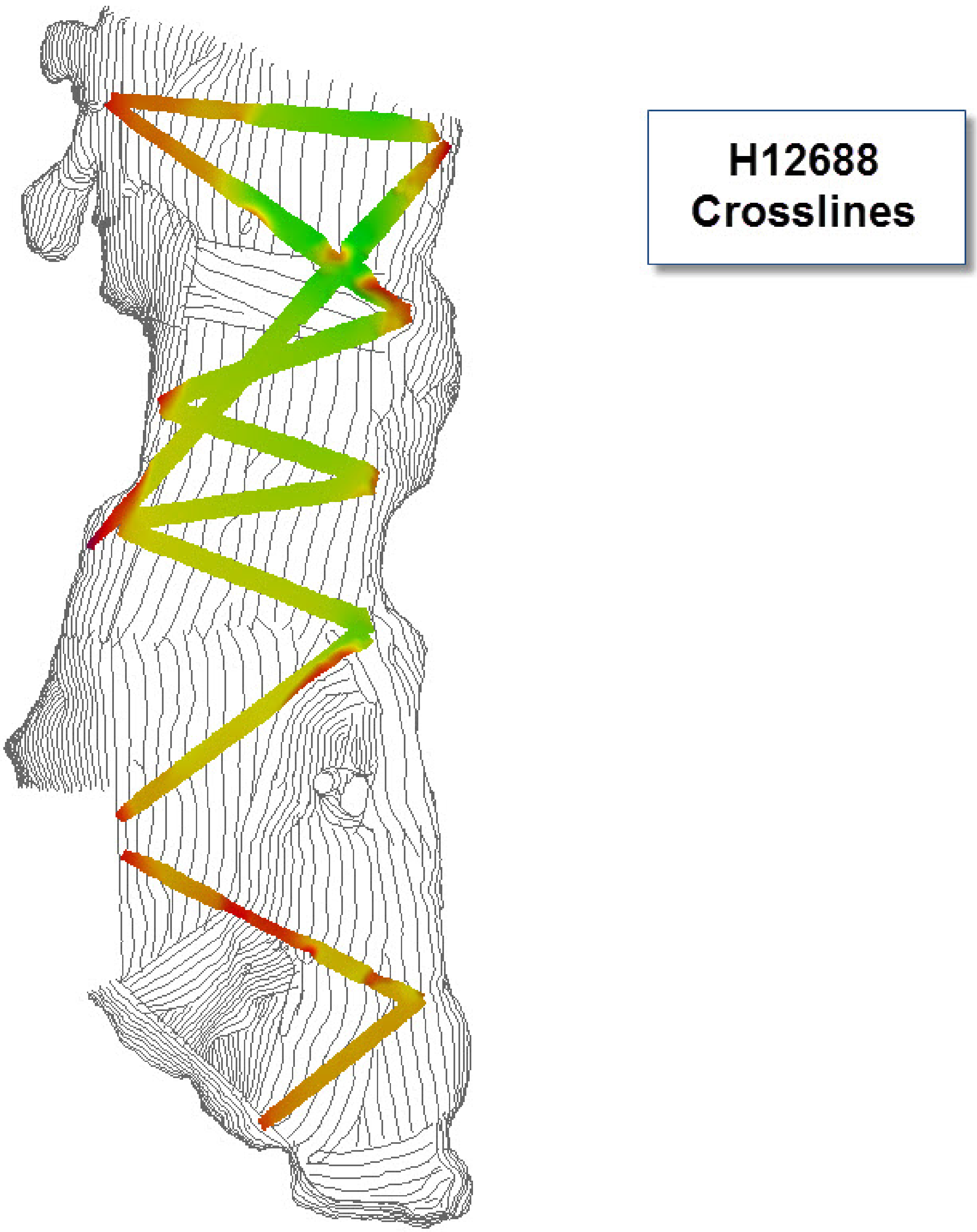

Figure 9: H12688 crosslines (mainscheme lines shown in gray).

Depth range	IHO Order	Number of nodes	Nodes satisfying HSSD	Percent nodes satisfying HSSD accuracy
Less than 100m	Order 1	956,535	956,356	99.98%

Figure 10: Summary table indicating percentage of difference surface nodes between H12688 mainscheme and crossline data that met HSSD allowable TVU standards.

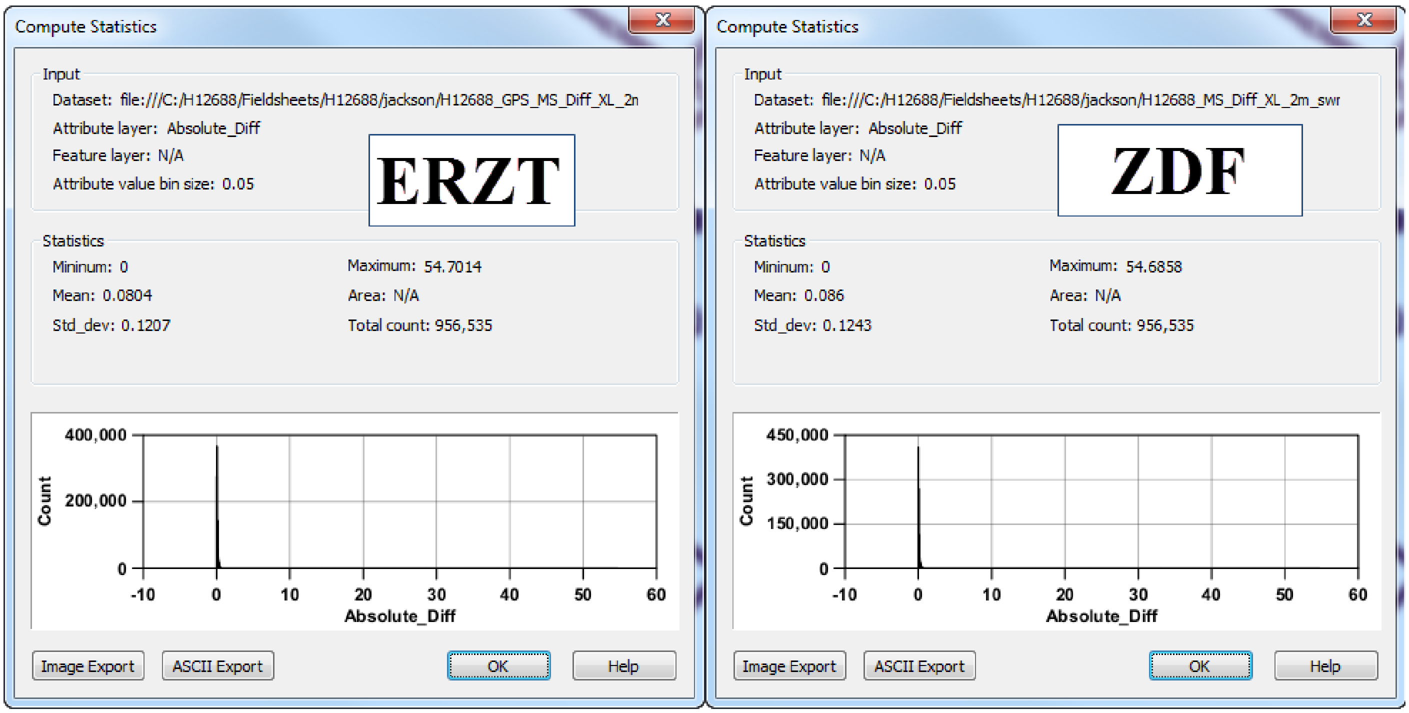

Figure 11: H12688 mainscheme to crossline comparison statistics using ERZT (left) and ZDF (right) methods.

B.2.2 Uncertainty

The following survey specific parameters were used for this survey:

Measured	Zoning	Method
0.020456 meters	0 meters	ERZT

Table 6: Survey Specific Tide TPU Values

Hull ID	Measured - CTD	Measured - MVP	Surface
2801, 2802, 2803, 2804	3 meters/second		0.15 meters/second

Table 7: Survey Specific Sound Speed TPU Values

Total Propagated Uncertainty (TPU) values for survey H12688 were derived from a combination of fixed values for equipment and vessel characteristics, as well as field assigned values for sound speed uncertainties. Tidal uncertainties were provided by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS). The Zoned Tides were not directly used in reducing the soundings to MLLW. Therefore, no tidal uncertainty values were entered into the tide value section of the Caris compute TPU function related to ZDF; however, a measured tide uncertainty value of 0.020456 meters was entered to account for ERZT processing methods. See the OPR-P136-RA-15 ERZT memo included in Supplemental Correspondence for further information.

In addition to the usual a priori estimates of uncertainty, some real-time and post processed uncertainty sources were also incorporated into the depth estimates of this survey. Real-time uncertainties from Reson MBES sonars were recorded and applied during post processing. Applanix TrueHeave (POS) files, which record estimates of heave uncertainty, were also applied during post processing. Finally, the post processed uncertainties associated with vessel roll, pitch, yaw and navigation, were applied in Caris HIPS using SBET / RMS files generated using POSPac software.

Uncertainty values of submitted finalized grids were calculated in Caris using the "Greater of the Two" of uncertainty and standard deviation (scaled to 95%). The finalized CSAR IHO compliance tool within Pydro was used to analyze H12688 MBES data. The results showed that 99.99% of H12688 nodes across all depth ranges, met HSSD TVU uncertainty requirements (Figures 12-14).

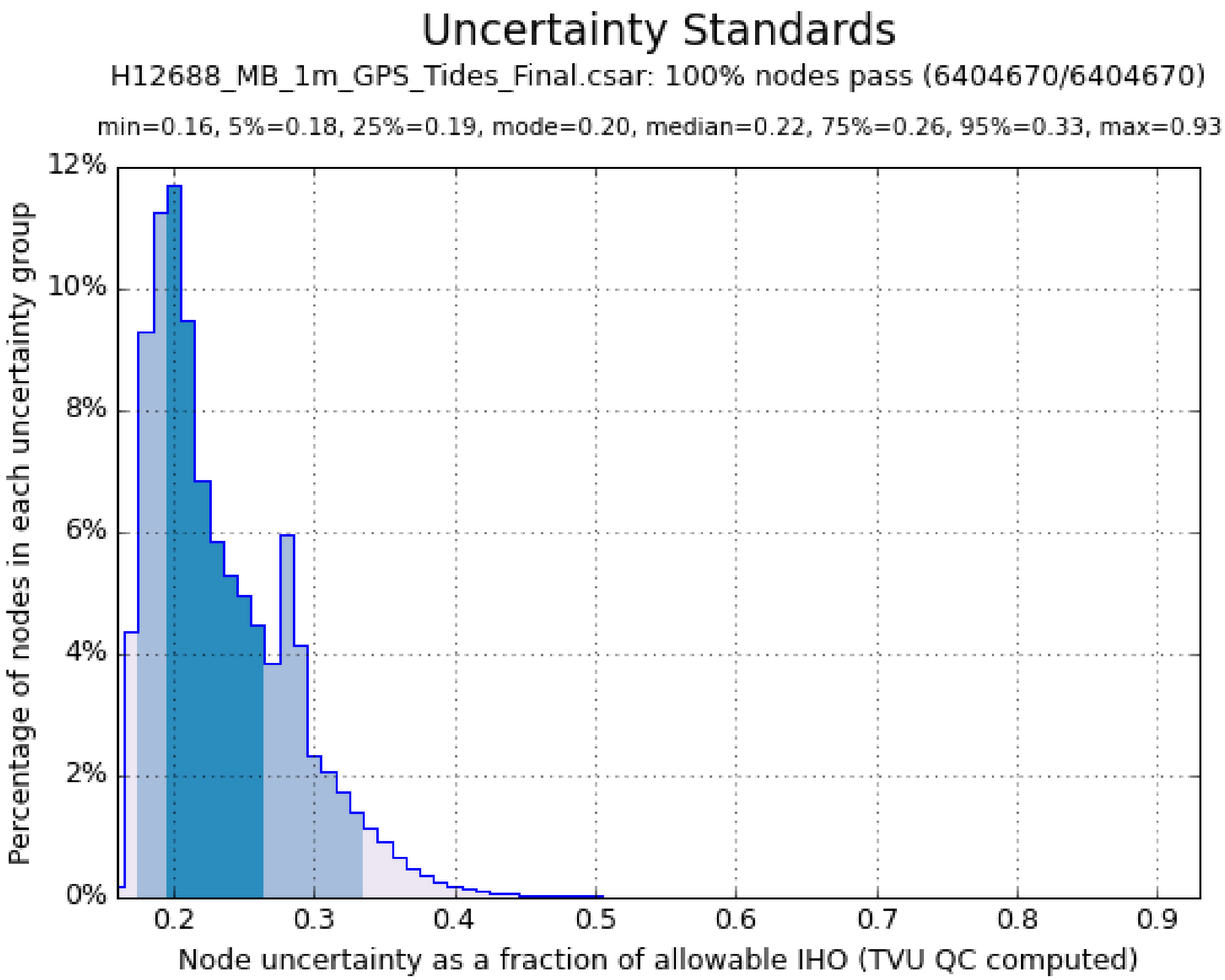

Figure 12: Pydro histogram plot showing HSSD uncertainty compliance of H12688 1-meter resolution grid.

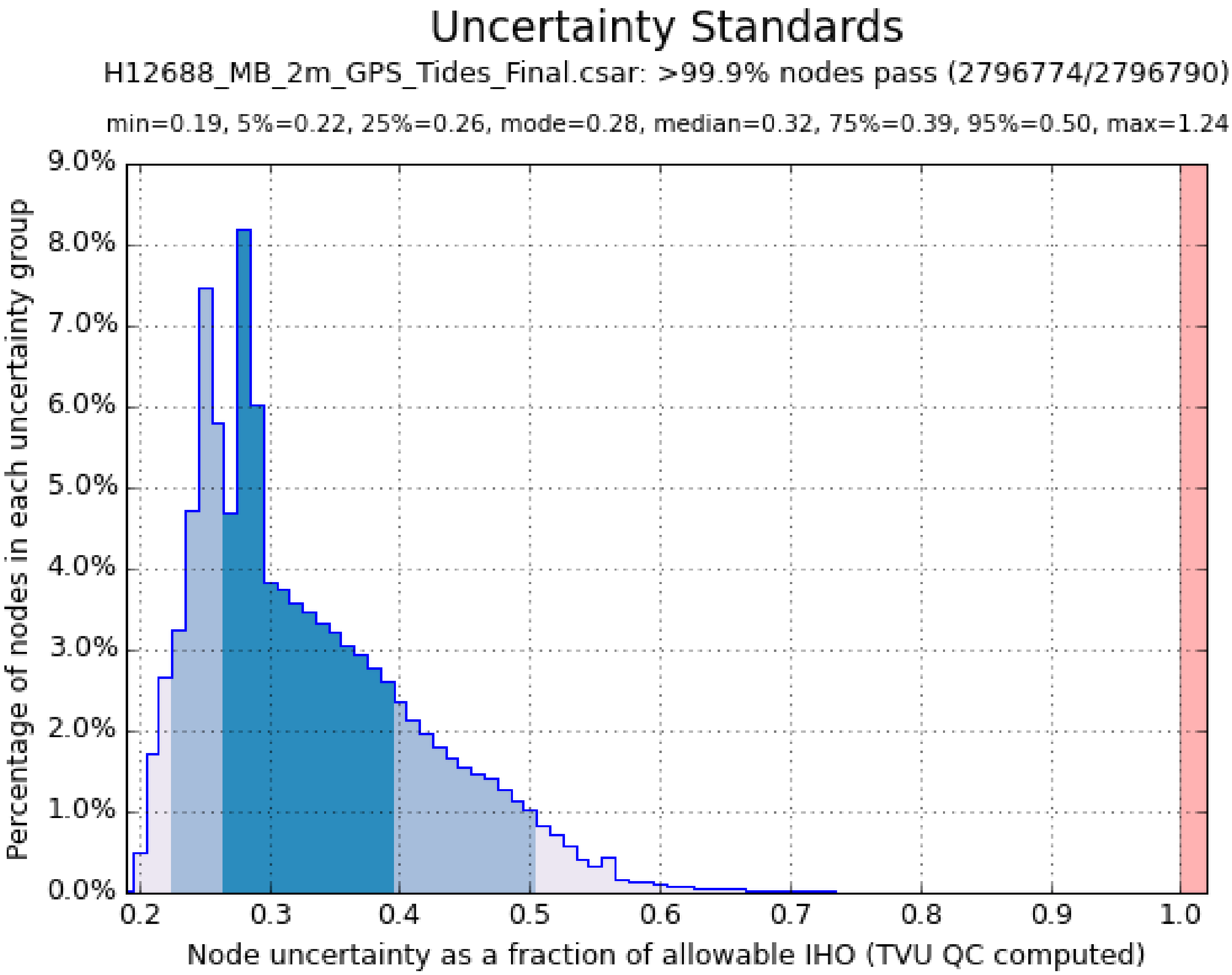

Figure 13: Pydro histogram plot showing HSSD uncertainty compliance of H12688 2-meter resolution grid.

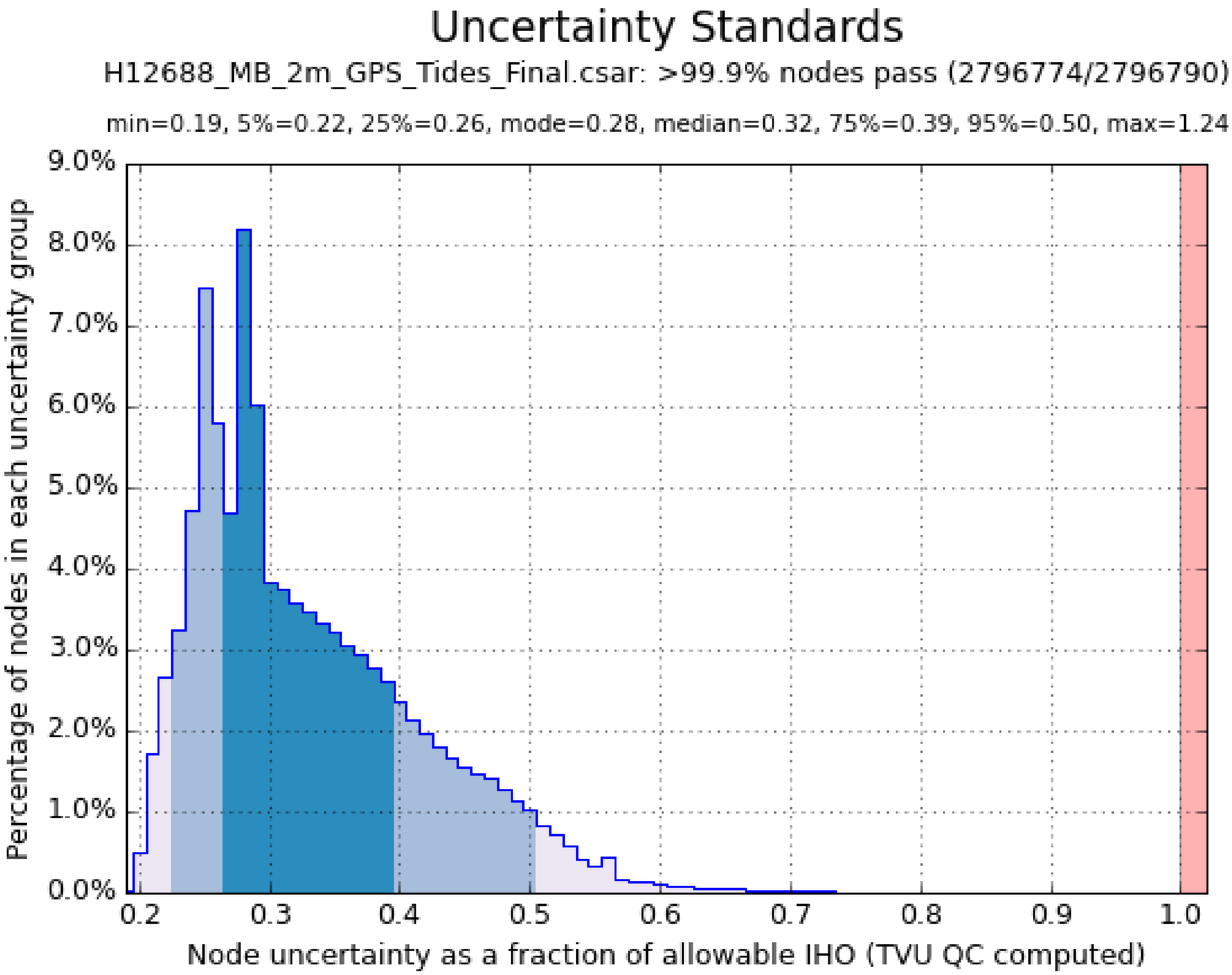

Figure 14: Pydro histogram plot showing HSSD uncertainty compliance of H12688 4-meter resolution grid.

B.2.3 Junctions

A junction comparison was conducted between H12688 and 2012 Rainier survey H12512.

The following junctions were made with this survey:

Registry Number	Scale	Year	Field Unit	Relative Location
H12512	1:40000	2012	NOAA Ship RAINIER	N

Table 8: Junctioning Surveys

H12512

The overlap with survey H12512 encompassed approximately 0.32 square nautical miles along the northern boundary of H12688. A comparison was made using a difference surface derived from the H12688_MB_GPS_Tides_4m_Combined CUBE surface and the H12512_MB_MLLW_8m_Combined CUBE surface. Analysis of the difference surface indicated that H12688 is an average of 0.1 meter shoaler than H12512 with a standard deviation of 0.3 meters. The difference surface was compared to the allowable TVU standards specified in the HSSD. 94.00% of the depth differences between H12668 and H12512 were within the allowable uncertainties. This difference is likely due to the dynamic nature of the bottom in the overlapping area. Horizontal differences between WGS84 and NAD83 could contribute to these disagreements.

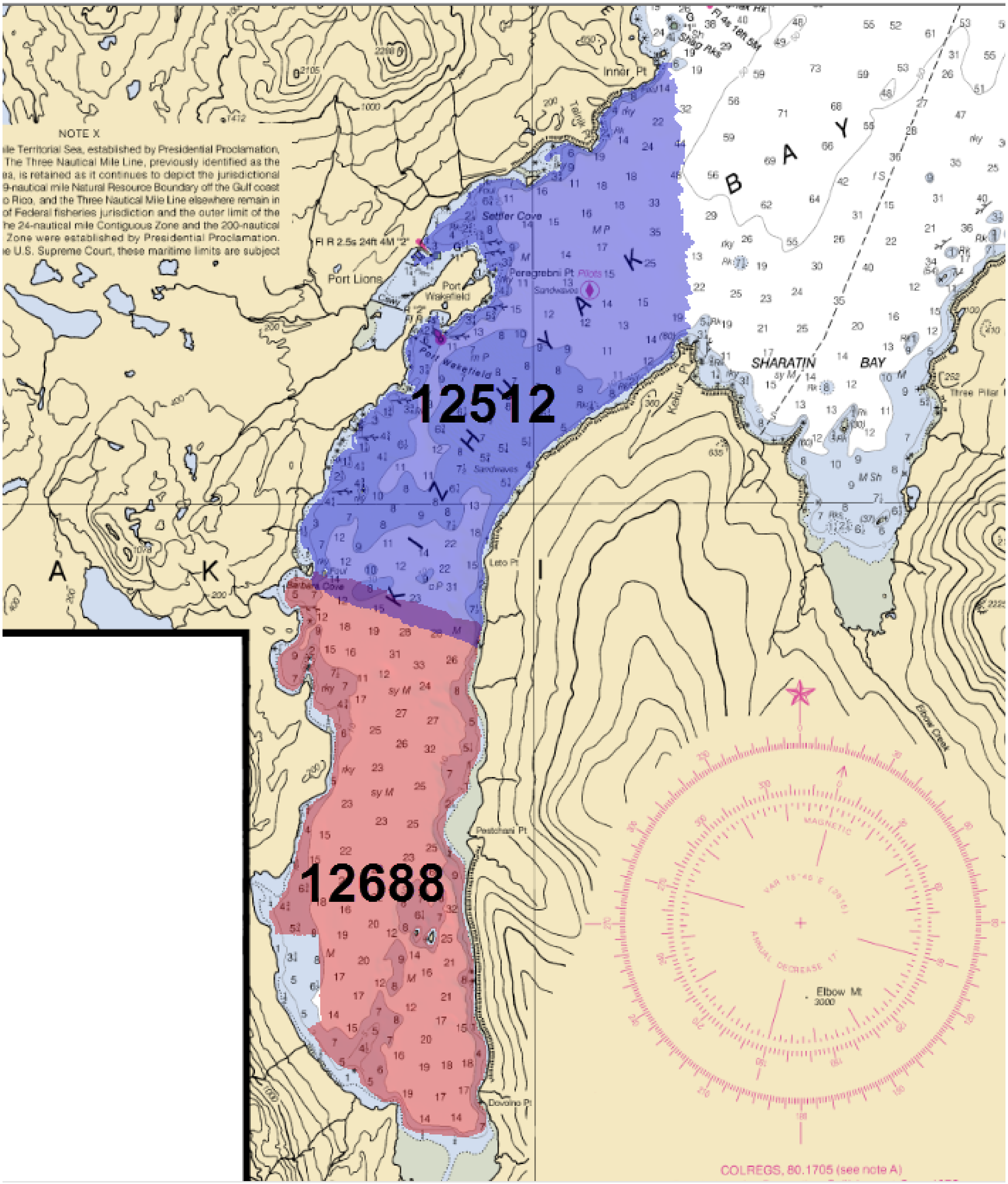

Figure 15: H12688 Junction Overview

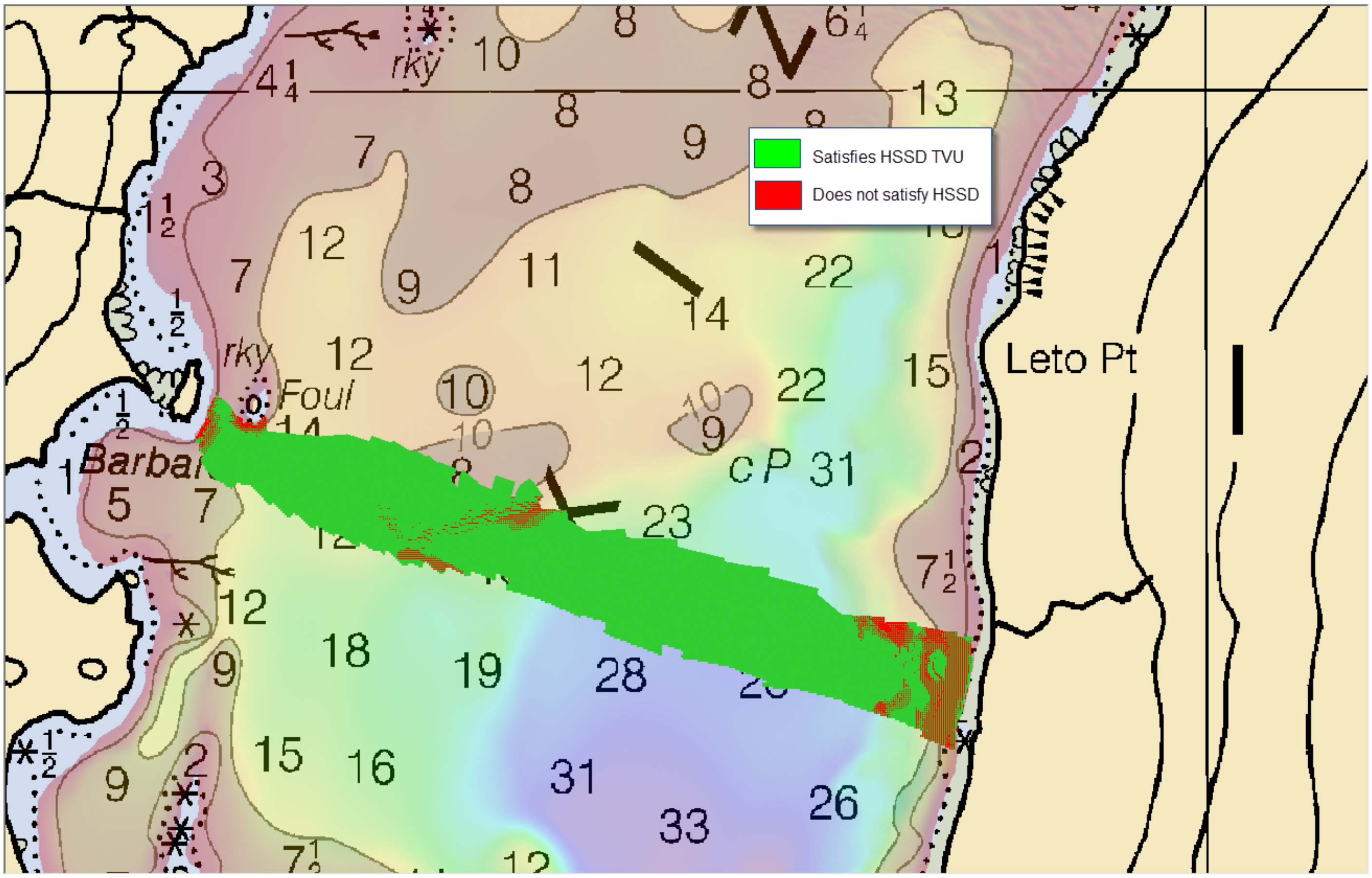

Figure 16: H12688 Junction Agreement

Since both surveys were processed in NAD83, a difference in horizontal datum would not cause the disagreements noted in the junction area.

B.2.4 Sonar QC Checks

Sonar system quality control checks were conducted as detailed in the quality control section of the DAPR.

B.2.5 Equipment Effectiveness

There were no conditions or deficiencies that affected equipment operational effectiveness.

B.2.6 Factors Affecting Soundings

There were no other factors that affected corrections to soundings.

B.2.7 Sound Speed Methods

Sound Speed Cast Frequency: For survey H12688, 29 sound speed profiles were acquired using SBE 19plus CTD probes at discrete locations within the survey area at least once every four hours, when significant changes in surface sound speed were observed, or when surveying in a new area. All casts were concatenated into a master file and applied to survey data using the "Nearest in distance within time (4 hours)" profile selection method.

B.2.8 Coverage Equipment and Methods

All equipment and survey methods were used as detailed in the DAPR.

B.3 Echo Sounding Corrections

B.3.1 Corrections to Echo Soundings

All data reduction procedures conform to those detailed in the DAPR.

B.3.2 Calibrations

All sounding systems were calibrated as detailed in the DAPR.

B.4 Backscatter

Backscatter data, logged as .7k files, were acquired but not formally processed by Rainier personnel. Sample backscatter lines were reviewed on Rainier for quality control purposes. The data was submitted directly to the National Centers for Environmental Information (NCEI).

B.5 Data Processing

B.5.1 Primary Data Processing Software

The following software program was the primary program used for bathymetric data processing:

Manufacturer	Name	Version
Caris	HIPS and SIPS	9.0.19

Table 9: Primary bathymetric data processing software

The following Feature Object Catalog was used: NOAA Profile V_5_3_3.

B.5.2 Surfaces

The following surfaces and/or BAGs were submitted to the Processing Branch:

Surface Name	Surface Type	Resolution	Depth Range	Surface Parameter	Purpose
H12688_MB_1m_GPS_Tides	CUBE	1 meters	-0.3 meters - 61.5 meters	NOAA_1m	Complete MBES
H12688_MB_2m_GPS_Tides	CUBE	2 meters	-0.3 meters - 61.5 meters	NOAA_2m	Complete MBES
H12688_MB_4m_GPS_Tides	CUBE	4 meters	-0.3 meters - 61.5 meters	NOAA_4m	Complete MBES
H12688_MB_1m_GPS_Tides_Final	CUBE	1 meters	-1 meters - 20 meters	NOAA_1m	Complete MBES
H12688_MB_2m_GPS_Tides_Final	CUBE	2 meters	18 meters - 40 meters	NOAA_2m	Complete MBES
H12688_MB_4m_GPS_Tides_Final	CUBE	4 meters	36 meters - 61.5 meters	NOAA_4m	Complete MBES

Table 10: Submitted Surfaces

All Caris CUBE surfaces were created with lines reduced to MLLW via ERZT methods. 1 sounding was designated in accordance with HSSD requirements.

C. Vertical and Horizontal Control

Additional information discussing the vertical or horizontal control for this survey can be found in the accompanying HVCR.

C.1 Vertical Control

The vertical datum for this project is Mean Lower Low Water.

Standard Vertical Control Methods Used:

ERZT

The following National Water Level Observation Network (NWLON) stations served as datum control for this survey:

Station Name	Station ID
Kodiak Island	945-7292

Table 11: NWLON Tide Stations

File Name	Status
9457292.tid	Final Approved

Table 12: Water Level Files (.tid)

File Name	Status
P136RA2015_Rev2_CORP.zdf	Final

Table 13: Tide Correctors (.zdf or .tc)

A request for final approved tides was sent to N/OPS1 on 11/27/2015. The final tide note was received on 12/10/2015.

See attached Tide Note dated December 10, 2015.

Non-Standard Vertical Control Methods Used:

Ellipsoid to Chart Datum Separation File:

H12688_WGS84_MLLW_SEP_1000m

Ellipsoidally Referenced Zoned Tides (ERZT) methods were used to transform between the ellipsoid and water level data. A 1000-meter resolution separation model between the ellipsoid and MLLW was computed using the real-time position measurements observed during the survey relative to the water line and the loaded zoned tide file (ZDF). "GPS tides" were then computed using the above separation model and the corrected GPS-height-to-water level data (SBET). For additional information see the OPR-P136-RA-15 ERZT memo submitted separately.

See attached ERZT Capability Memo dated July 12, 2016.

C.2 Horizontal Control

The horizontal datum for this project is North American Datum of 1983 (NAD83).

The projection used for this project is Univeral Transverse Mercator (UTM) Zone 5 North.

The following PPK methods were used for horizontal control:

Smart Base

The following CORS Stations were used for horizontal control:

HVCR Site ID	Base Station ID
AC02	AKHIOKCORP AK2005
AC34	OLDHARBOR_AK2006
AC38	QUARTZ_CRK AK2005
AC39	SHUYAKISSP AK2006
AC67	PILLARMTN_AK2006
KOD6	KODIAK 6

Table 14: CORS Base Stations

The following DGPS Stations were used for horizontal control:

DGPS Stations
Kodiak, AK (313 kHz)

Table 15: USCG DGPS Stations

D. Results and Recommendations

D.1 Chart Comparison

Chart comparisons were performed using a Caris sounding layer and a contour layer based on the 4m combined surface. The contours and soundings were overlaid on the charts and compared for general agreement and to identify areas of significant change.

D.1.1 Raster Charts

The following are the largest scale raster charts, which cover the survey area:

Chart	Scale	Edition	Edition Date	LNM Date	NM Date
16594	1:78900	14	01/2015	11/17/2015	11/21/2015

Table 16: Largest Scale Raster Charts

16594

The comparison of soundings from Chart 16594 and H12688 showed general agreement within 1 fathom. The exceptions were noted and varied from 4 to 7 fathoms in difference (Figure 17).

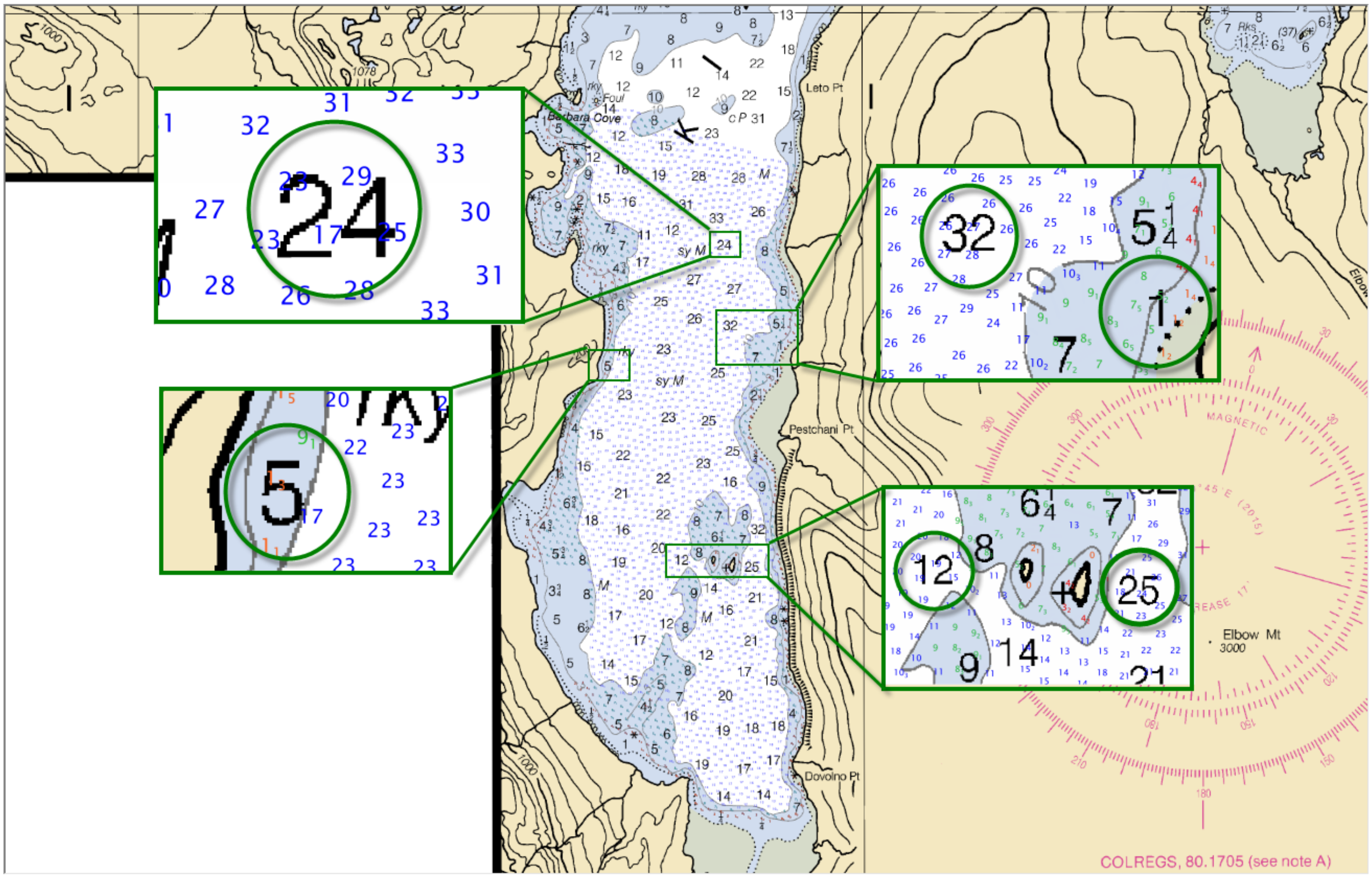

Figure 17: 16594 with sounding and depth differences highlighted.

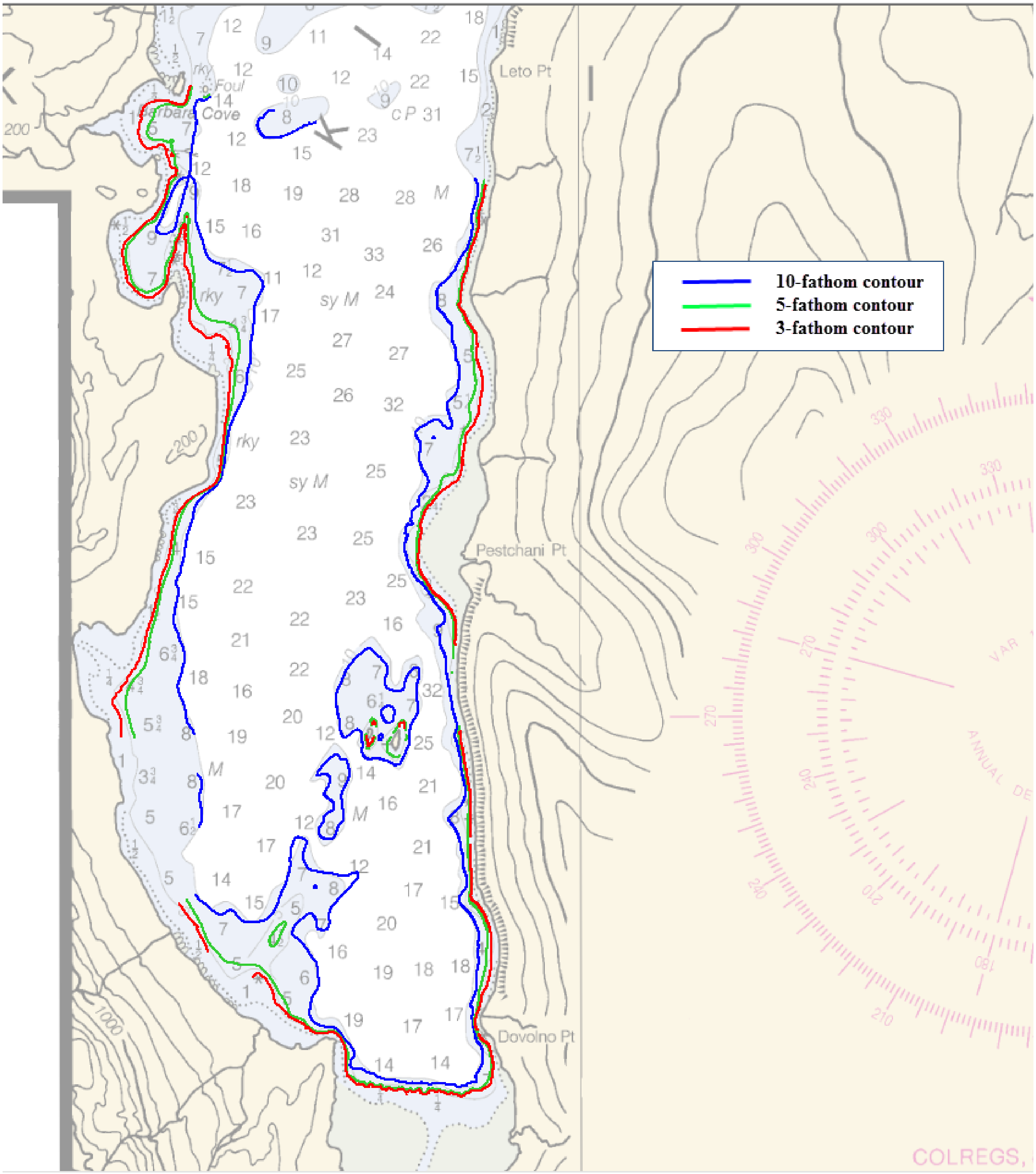

Figure 18: 16594 overlayed with H12688 contours.

D.1.2 Electronic Navigational Charts

The following are the largest scale ENCs, which cover the survey area:

ENC	Scale	Edition	Update Application Date	Issue Date	Preliminary?
US4AK5PM	1:78900	5	11/06/2015	11/06/2015	NO

Table 17: Largest Scale ENCs

US4AK5PM

ENC US4AK5PM coincides with raster 16594 with the exception of the 29-fathom depth in the northwestern corner of the surveyed area (Figure 19).

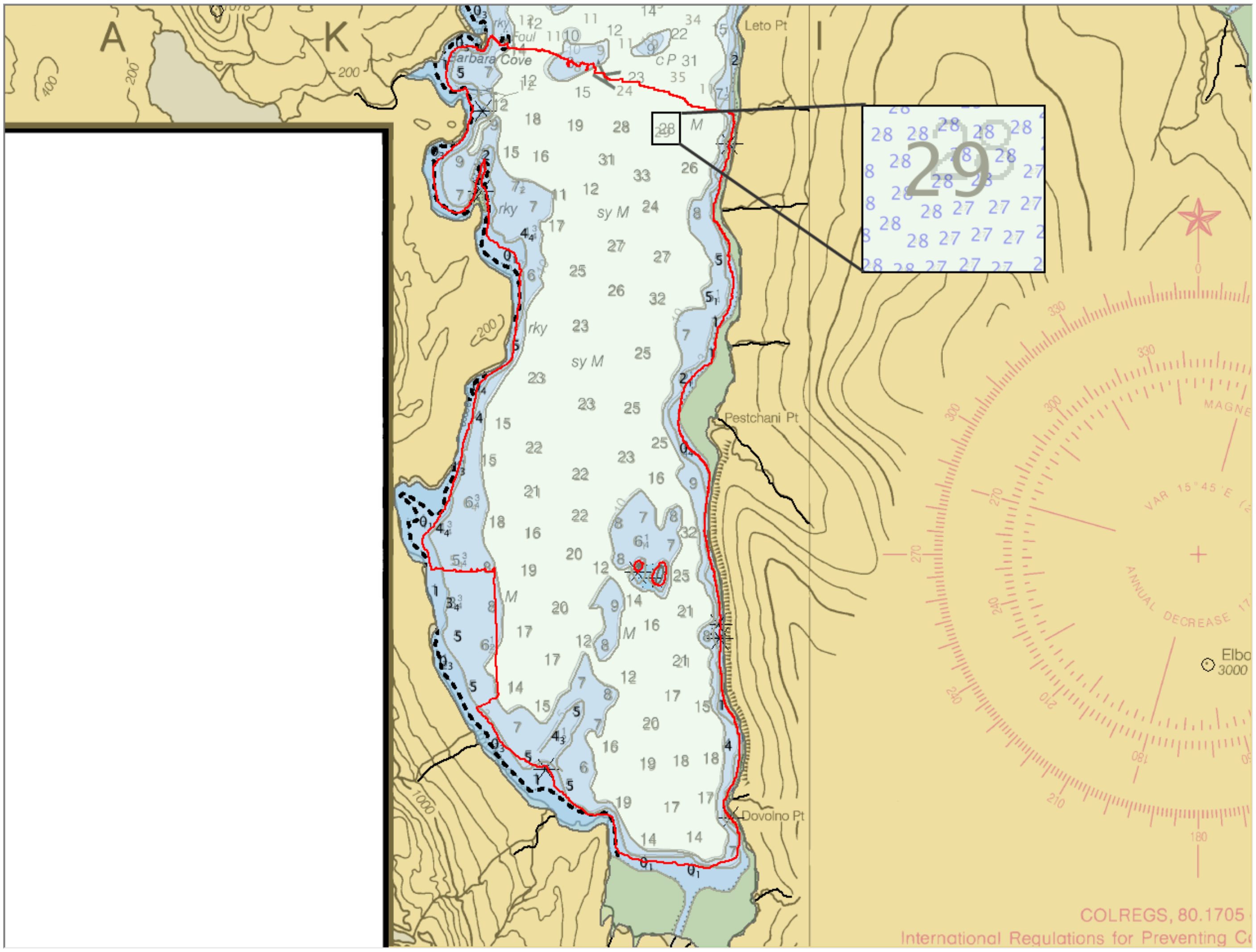

Figure 19: US4AK5PM overlaid on 16594 with soundings.

D.1.3 Maritime Boundary Points

No Maritime Boundary Points were assigned for this survey.

D.1.4 Charted Features

No charted features that contain the label PA, ED, PD or Rep exist for this survey.

D.1.5 Uncharted Features

Several new features were found during shoreline verification. The new features were addressed as required with S-57 attribution and recorded in the H12688 Final Feature File.

D.1.6 Dangers to Navigation

No Danger to Navigation Reports were submitted for this survey.

D.1.7 Shoal and Hazardous Features

All shoal and hazardous features were investigated in accordance with the Project Instructions and the HSSD, and are addressed in the Final Feature File submitted with this report.

D.1.8 Channels

No channels exist for this survey. There are no designated anchorages, precautionary areas, safety fairways, traffic separation schemes, pilot boarding areas, or channel and range lines within the survey limits.

D.1.9 Bottom Samples

One bottom sample was acquired for this survey, and is detailed in the Final Features File accompanying this report. The assigned bottom samples for this survey were not acquired due to an earlier than planned departure resulting from deteriorating weather conditions.

The Final Feature File is not appended to this report.

D.2 Additional Results

D.2.1 Shoreline

Shoreline verification was conducted near predicted mean lower low water in accordance with applicable sections of the FPM and HSSD. There were 47 features for this survey. All assigned features were addressed as required with S-57 attribution and recorded in the H12688 Final Feature File to best represent the features as chart scale.

There were 48 features submitted for this survey.

D.2.2 Prior Surveys

Prior survey comparisons exist for this survey, but were not investigated.

D.2.3 Aids to Navigation

No Aids to navigation (ATONs) exist for this survey.

D.2.4 Overhead Features

No overhead features exist for this survey.

D.2.5 Submarine Features

No submarine features exist for this survey.

D.2.6 Ferry Routes and Terminals

No ferry routes or terminals exist for this survey.

D.2.7 Platforms

No platforms exist for this survey.

D.2.8 Significant Features

No significant features exist for this survey.

D.2.9 Construction and Dredging

No present or planned construction or dredging exist within the survey limits.

D.2.10 New Survey Recommendation

It is recommended that the area between the sheet limits and the area surveyed be investigated.

Section D.2.10 refers to the area described in Section A.1 of this report, which was not surveyed due to deteriorating weather conditions.

D.2.11 Inset Recommendation

No new insets are recommended for this area.

E. Approval Sheet

As Chief of Party, field operations for this hydrographic survey were conducted under my direct supervision, with frequent personal checks of progress and adequacy. I have reviewed the attached survey data and reports.

All field sheets, this Descriptive Report, and all accompanying records and data are approved. All records are forwarded for final review and processing to the Processing Branch.

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys and Specifications Deliverables Manual, Field Procedures Manual, Letter Instructions, and all HSD Technical Directives. These data are adequate to supersede charted data in their common areas. This survey is complete and no additional work is required with the exception of deficiencies noted in the Descriptive Report.

Approver Name	Approver Title	Approval Date	Signature
Edward J. Van Den Ameele, CDR/NOAA	Commanding Officer, NOAA Ship Rainier	05/06/2016	
Steven Loy, LT/NOAA	Field Operations Officer, NOAA Ship Rainier	05/06/2016	Digitally signed by Steven Loy DN: cn=Steven Loy, o=NOAA, ou=NOAA RAINIER, email=ops.rainier@noaa.gov, c=US Date: 2016.05.11 07:20:06 -07'00'
James B. Jacobson	Chief Survey Technician, NOAA Ship Rainier	05/06/2016	James Jacobson I have reviewed this document 2016.05.10 07:32:06 -08'00'
Samuel W. McKay, ENS/NOAA	Junior Officer, NOAA Ship Rainier	05/06/2016	

F. Table of Acronyms

Acronym	Definition
AHB	Atlantic Hydrographic Branch
AST	Assistant Survey Technician
ATON	Aid to Navigation
AWOIS	Automated Wreck and Obstruction Information System
BAG	Bathymetric Attributed Grid
BASE	Bathymetry Associated with Statistical Error
CO	Commanding Officer
CO-OPS	Center for Operational Products and Services
CORS	Continually Operating Reference Staiton
CTD	Conductivity Temperature Depth
CEF	Chart Evaluation File
CSF	Composite Source File
CST	Chief Survey Technician
CUBE	Combined Uncertainty and Bathymetry Estimator
DAPR	Data Acquisition and Processing Report
DGPS	Differential Global Positioning System
DP	Detached Position
DR	Descriptive Report
DTON	Danger to Navigation
ENC	Electronic Navigational Chart
ERS	Ellipsoidal Referenced Survey
ERZT	Ellipsoidally Referenced Zoned Tides
FFF	Final Feature File
FOO	Field Operations Officer
FPM	Field Procedures Manual
GAMS	GPS Azimuth Measurement Subsystem
GC	Geographic Cell
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HSD	Hydrographic Surveys Division
HSSD	Hydrographic Survey Specifications and Deliverables

Acronym	Definition
HSTP	Hydrographic Systems Technology Programs
HSX	Hypack Hysweep File Format
HTD	Hydrographic Surveys Technical Directive
HVCR	Horizontal and Vertical Control Report
HVF	HIPS Vessel File
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
ITRF	International Terrestrial Reference Frame
LNM	Local Notice to Mariners
LNM	Linear Nautical Miles
MCD	Marine Chart Division
MHW	Mean High Water
MLLW	Mean Lower Low Water
NAD 83	North American Datum of 1983
NAIP	National Agriculture and Imagery Program
NALL	Navigable Area Limit Line
NM	Notice to Mariners
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NRT	Navigation Response Team
NSD	Navigation Services Division
OCS	Office of Coast Survey
OMAO	Office of Marine and Aviation Operations (NOAA)
OPS	Operations Branch
MBES	Multibeam Echosounder
NWLON	National Water Level Observation Network
PDBS	Phase Differencing Bathymetric Sonar
PHB	Pacific Hydrographic Branch
POS/MV	Position and Orientation System for Marine Vessels
PPK	Post Processed Kinematic
PPP	Precise Point Positioning
PPS	Pulse per second

Acronym	Definition
PRF	Project Reference File
PS	Physical Scientist
PST	Physical Science Technician
RNC	Raster Navigational Chart
RTK	Real Time Kinematic
SBES	Singlebeam Echosounder
SBET	Smooth Best Estimate and Trajectory
SNM	Square Nautical Miles
SSS	Side Scan Sonar
ST	Survey Technician
SVP	Sound Velocity Profiler
TCARI	Tidal Constituent And Residual Interpolation
TPE	Total Propagated Error
TPU	Topside Processing Unit
USACE	United States Army Corps of Engineers
USCG	United Stated Coast Guard
UTM	Universal Transverse Mercator
XO	Executive Officer
ZDA	Global Positiong System timing message
ZDF	Zone Definition File

UNITED STATES DEPARMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Silver Spring, Maryland 20910

TIDE NOTE FOR HYDROGRAPHIC SURVEY

DATE : December 10, 2015

HYDROGRAPHIC BRANCH: Pacific
HYDROGRAPHIC PROJECT: OPR-P136-RA-2015
HYDROGRAPHIC SHEET: H12688

LOCALITY: Kizhuyak Bay, Kodiak Island, AK
TIME PERIOD: September 23-30, 2015

TIDE STATION USED: 9457292 Kodiak, AK
Lat. 57° 43.8'N Long. 152° 30.8' W
PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000
HEIGHT OF HIGH WATER ABOVE PLANE OF REFERENCE: 2.40m

REMARKS: RECOMMENDED ZONING

Preliminary zoning for this project was provided under project P136-RA-2015. Preliminary zoning is accepted as the final zoning for Registry No. H12688 for the time period of September 23-30, 2015.

Please use the zoning file P136RA2015_Rev2_CORP submitted with the project instructions for OPR-P136-RA-2015. Zones SWA274 and SWA274A are the applicable zones for H12688.

Refer to attachments for zoning information.

Note 1: Provided time series data are tabulated in metric units (meters), relative to MLLW and on Greenwich Mean Time on the 1983-2001 National Tidal Datum Epoch (NTDE).

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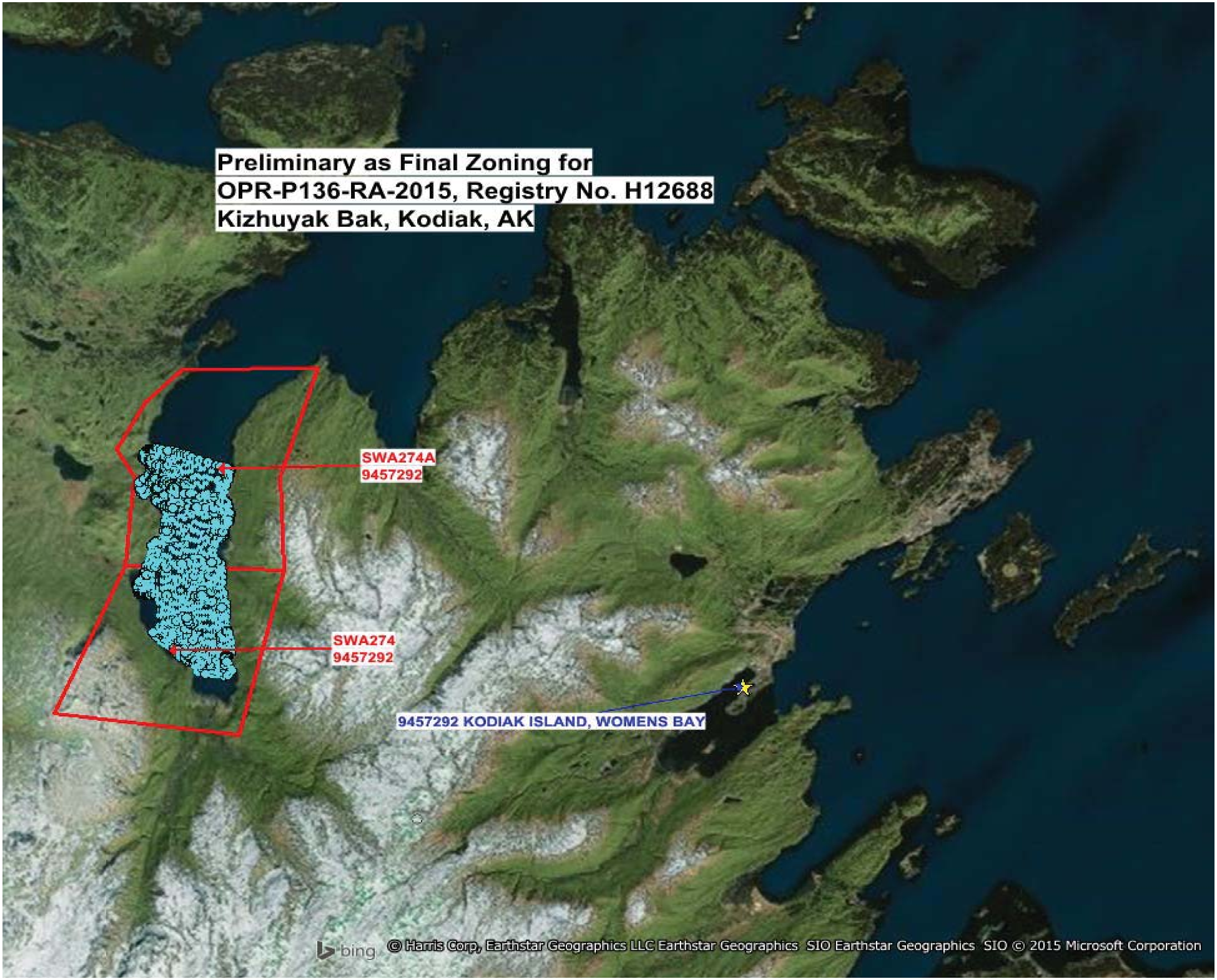
Date: 2015.12.10 14:02:35 -05'00'

CHIEF, PRODUCTS AND SERVICES BRANCH


Preliminary as Final Zoning for
OPR-P136-RA-2015, Registry No. H12688
Kizhuyak Bak, Kodiak, AK
SWA274A
9457292
SWA274
9457292
9457292 KODIAK ISLAND, WOMENS BAY
bing
© Harris Corp, Earthstar Geographics LLC Earthstar Geographics SIO Earthstar Geographics SIO © 2015 Microsoft Corporation

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Marine and Aviation Operations
NOAA Ship *Rainier* (S-221)
2002 SE Marine Science Dr, Newport, OR 97365

July 12, 2016

MEMORANDUM FOR: Lieutenant Commander Michael Gonsalves, NOAA
Chief, Operations Branch
Hydrographic Surveys Division

FROM: Commander Edward J. Van Den Ameele, NOAA
Commanding Officer

SUBJECT: OPR-P136-RA-15 ERS / ERZT Capability Memo

NOAA Ship *Rainier* conducted an evaluation of reducing sounding data to chart datum through comparison between methods using ellipsoidally-referenced zoned tides (ERZT) and the traditional methods with zoned discrete tides (ZDF) in order to produce ellipsoidally-referenced surveys (ERS) per the OPR-P136-RA-15 Project Instructions (PI). Results indicate that the differences between the two methods are within acceptable limits and both are valid methods for reducing sounding data to chart datum. Procedures, results, and recommendations are in the attached report.

It is recommended that surveys H12688, H12691 and H12692 be reduced to Mean Lower-Low Water (MLLW) using ERZT, as detailed in the attached report.

It is understood that upon review of this report, a determination will be made for the final vertical transformation technique to be used to create the final deliverables.

Attachment:
H12688, H12691, H12692 ERZT Report

H12688, H12691, H12692 ERZT Report

1.0 Introduction

This document describes the methods and results of the vertical datum analysis component of the vertical control requirements of the Hydrographic Survey Project Instructions for OPR-P136-RA-15 North Coast of Kodiak Island. This report specifically addresses surveys H12688, H12691 and H12692.

The Project Instructions required *Rainier* to recommend the final vertical transformation technique after comparing crossline data. The recommendations and supporting data included in this report are intended for use by the Hydrographic Surveys Division (HSD) to support the final decision on the use of ellipsoidally-referenced zoned tides (ERZT) methods to reduce hydrographic data to chart datum using the field-generated separation model in lieu of reduction using measured water levels and the Zoned Discrete Tides methodology for the OPR-P136-RA-15 surveys.

The basis of this analysis is a comparison of the results of using both ZDF and ERZT bathymetry for vertical control for each survey, and a comparison of different ERZT separation models (SEP).

2.0 Procedure

The ERZT evaluation was conducted with a standard operating procedure (SOP) provided by HSD as a primary reference. Though the SOP was utilized as an initial reference, *Rainier* did not find that it adequately addressed all issues required for utilization. *Rainier* addressed this through development of our own SOPs, and numerous emails, phone calls, and decisions as hydrographers. The general procedure is outlined below.

Survey data for H12688, H12691 and H12692 were reduced to Mean Lower Low Water (MLLW) using the final approved ZDF grid and water levels to produce the traditional surfaces and time series data. Survey data were also reduced to MLLW using a field-created ERZT SEP applied to the data with GPS tides and then merged. ERZT SEPs were first created at a fine resolution (100m) to use in analysis and troubleshooting of vertical positioning, primarily in the case of Smoothed Best Estimate of Trajectories (SBET) data.

SBETs were generated using a PPK SmartBase method as outlined in OPR-P136-RA-15 HVCR. In error, *Rainier* SBETs for this project were produced in WGS84 rather than NAD83. Due to the significant effort required to re-export and re-apply all SBETs, the decision was made in consultation with HSD and Hydrographic Systems Technology Branch (HSTB) to keep data in WGS84. The ZDF method did not utilize the vertical component of the SBET data in the process of reducing to MLLW; thus, the incorrect datum, WGS84 instead of NAD83, only affected the horizontal component of positioning when using ZDF to reduce to MLLW. This error introduced a bias into the horizontal positioning; the total difference between NAD83 and WGS84 within the survey area was within allowable horizontal position uncertainties.

Once all SBETs were resolved, or a consistent ERZT SEP model could be generated with a majority of the SBETs being correct, a coarser ERZT SEP was generated (1000m) for sounding reduction in application of GPS Tides. ERZT SEP models were also compared to an estimated separation surface (ESEP) provided by HSTB based on Geoid12B, the ZDF model amplitudes, and a model of sea-surface topography. These ESEPs provided by HSTB were used as an additional means of evaluation and troubleshooting and were not used to reduce final data to MLLW.

ERZT uncertainty was calculated using a standard error estimator, wherein the mean of the ERZT standard deviation layer was divided by the square root of an estimated number of survey lines in a given node. This value was then applied when computing Total Propagated Uncertainty (TPU).

Crossline difference surfaces (main-scheme versus crossline data) and statistics were generated for each method of reduction to MLLW and compared against one another.

ERZT SEPs generated by *Rainier* were also compared to the HSTB-created ESEPs as a means of comparison and troubleshooting. Difference surfaces and statistics of these two SEPs were also evaluated.

3.0 Results

This report will answer two questions:

• What are the quantitative and qualitative differences between the two reduction methods?

• Which method of reduction to MLLW is appropriate for this specific survey?

3.1 ERZT Model

The ERZT model separation surfaces were generated by RA using the ERZT SOP (Figures 1-3). These models provide the separation between the WGS84 ellipsoid and MLLW datums. The slope of the separation model was examined for errors and inconsistencies that could produce vertical offsets in reduced data. See Table 1 for a list of ERZT Models generated, and Figures 1-3 for images of each SEP model.

Sheet	Resolution	Separation Model File Name
H12688	1000m	H12688_WGS84_MLLW_SEP_1000m.csar
H12691	1000m	H12691_WGS84_MLLW_SEP_1000m.csar
H12692	1000m	H12692_WGS84_MLLW_SEP_1000m.csar

Table 1. Separation models submitted

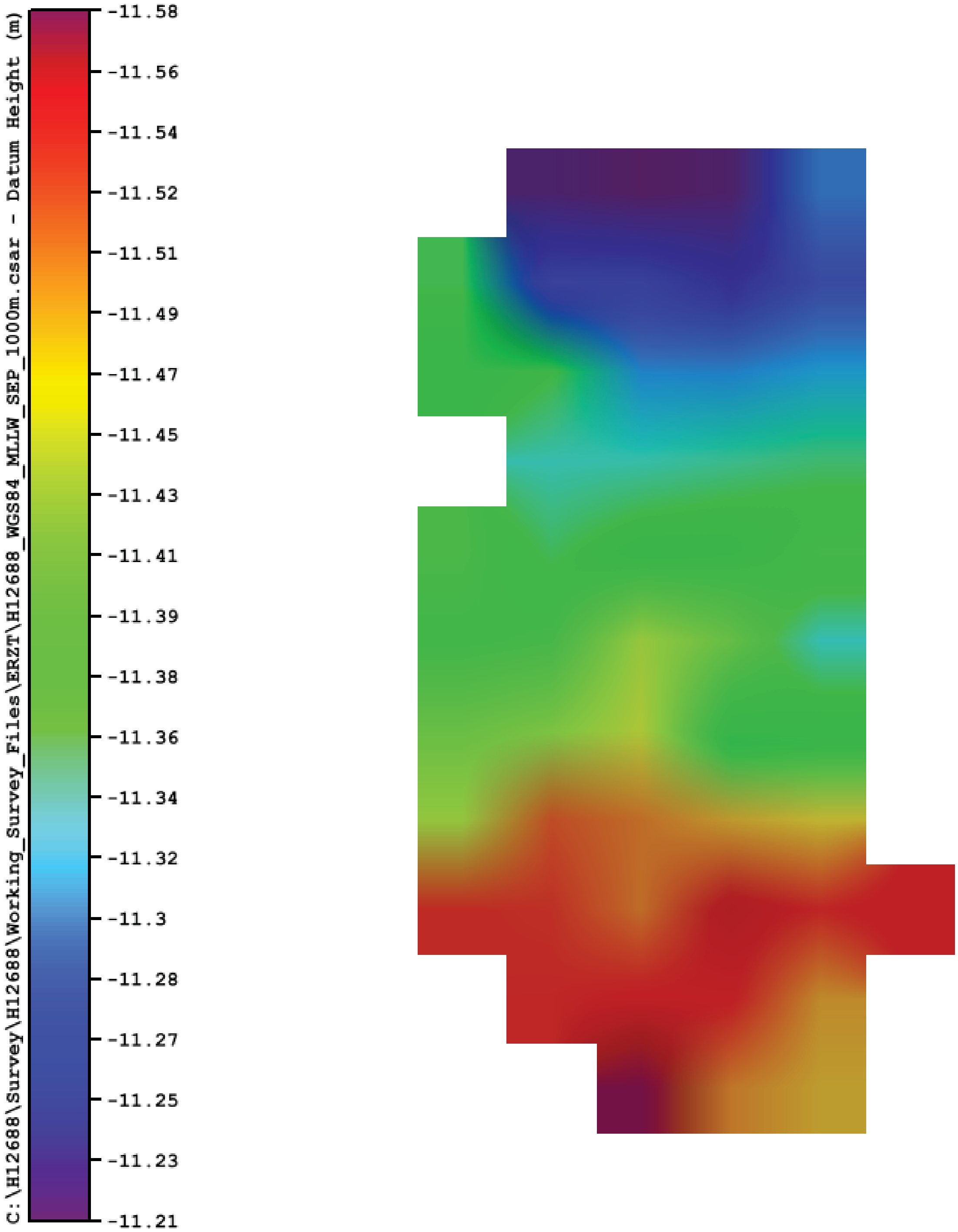


Figure 1. Image of H12688_WGS84_MLLW_SEP_1000m.csar ERZT SEP with 1000m resolution.

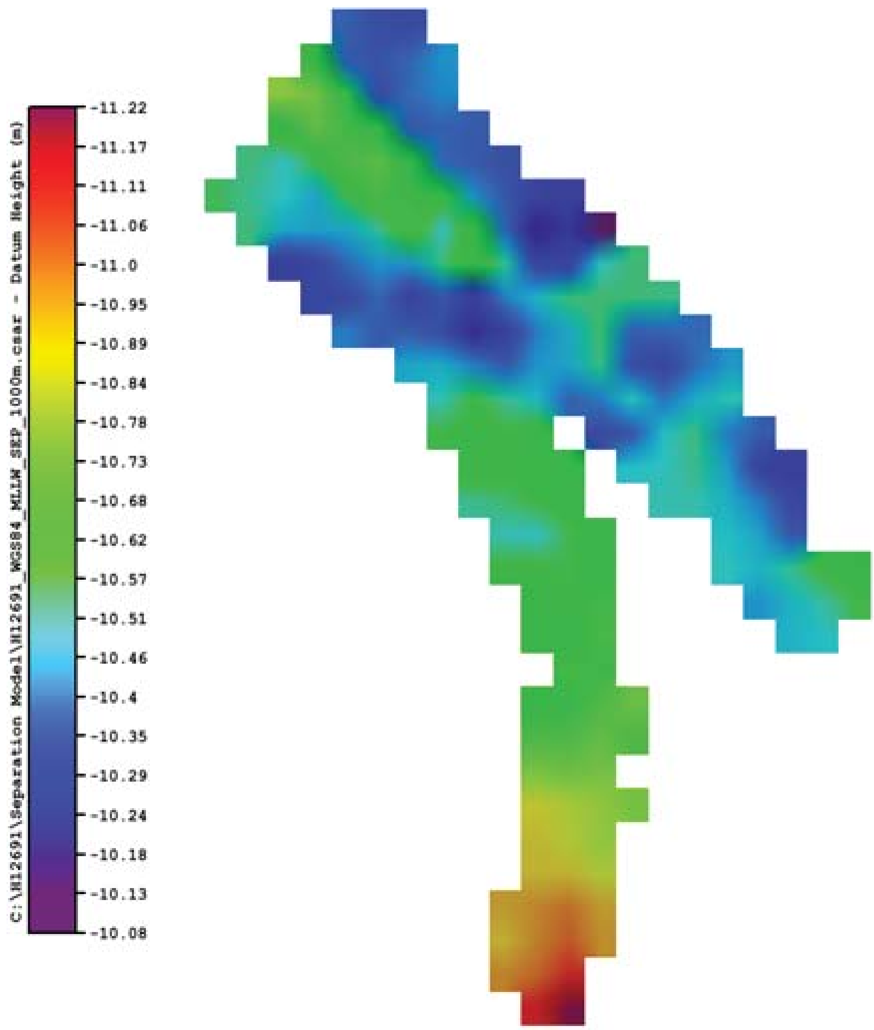


Figure 2. Image of H12691_WGS84_MLLW_SEP_1000m.csar ERZT SEP with 1000m resolution.

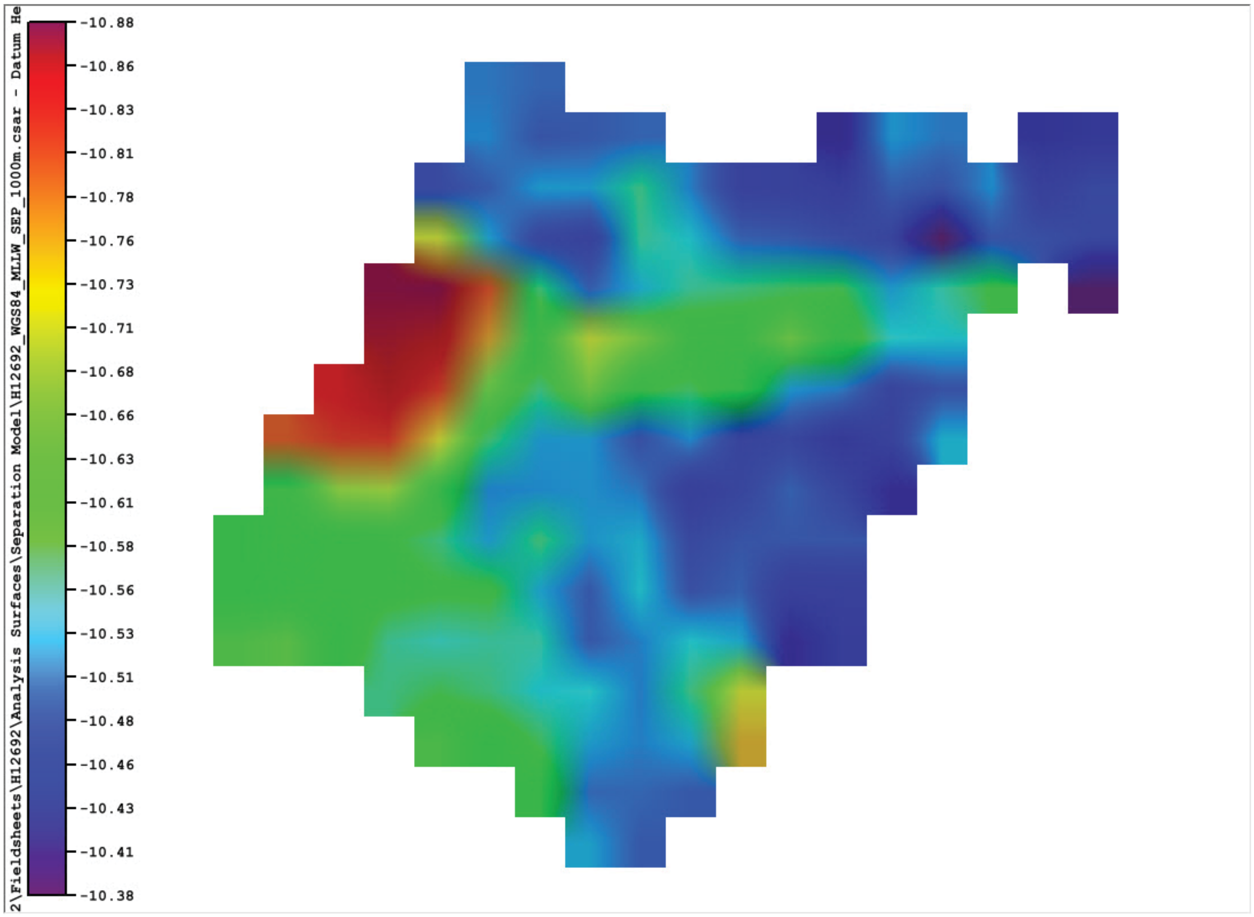


Figure 3. Image of H12692_WGS84_MLLW_SEP_1000m.csar ERZT SEP with 1000m resolution.

The separation surfaces are free of gaps and anomalies within the H12688, H12691 and H12692 survey areas. Variability (as seen in Figures 1-3) in the ERZT separation surface is due to variation in the SBETs, tide model, sea surface topography, heave, dynamic and static draft. More gradual trends represent the variation of the SEP over large distances.

Examining the SEP alone within the limits of H12688, H12691 and H12692 there are no anomalous spikes or discontinuities, suggesting the overall vertical positioning and use of the model as a means of sounding reduction are both reasonable.

3.2. Quantitative Analysis

	ZDF XL - MS Difference		ERZT XL - MS Difference		ESEP- ERZT (WGS84) Difference		ZDF MLLW - ERZT MLLW Difference	
Sheet	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
H12688	0.086	0.124	0.0804	0.1207	-0.2009	0.0717	0.0004	0.0339
H12691	0.028	0.416	-0.044	0.401	0.22	0.162	-0.018	0.191
H12692	-0.004	0.580	0.051	0.4758	0.2609	0.089	0.007	0.200

Table 2. Results of difference surface analysis

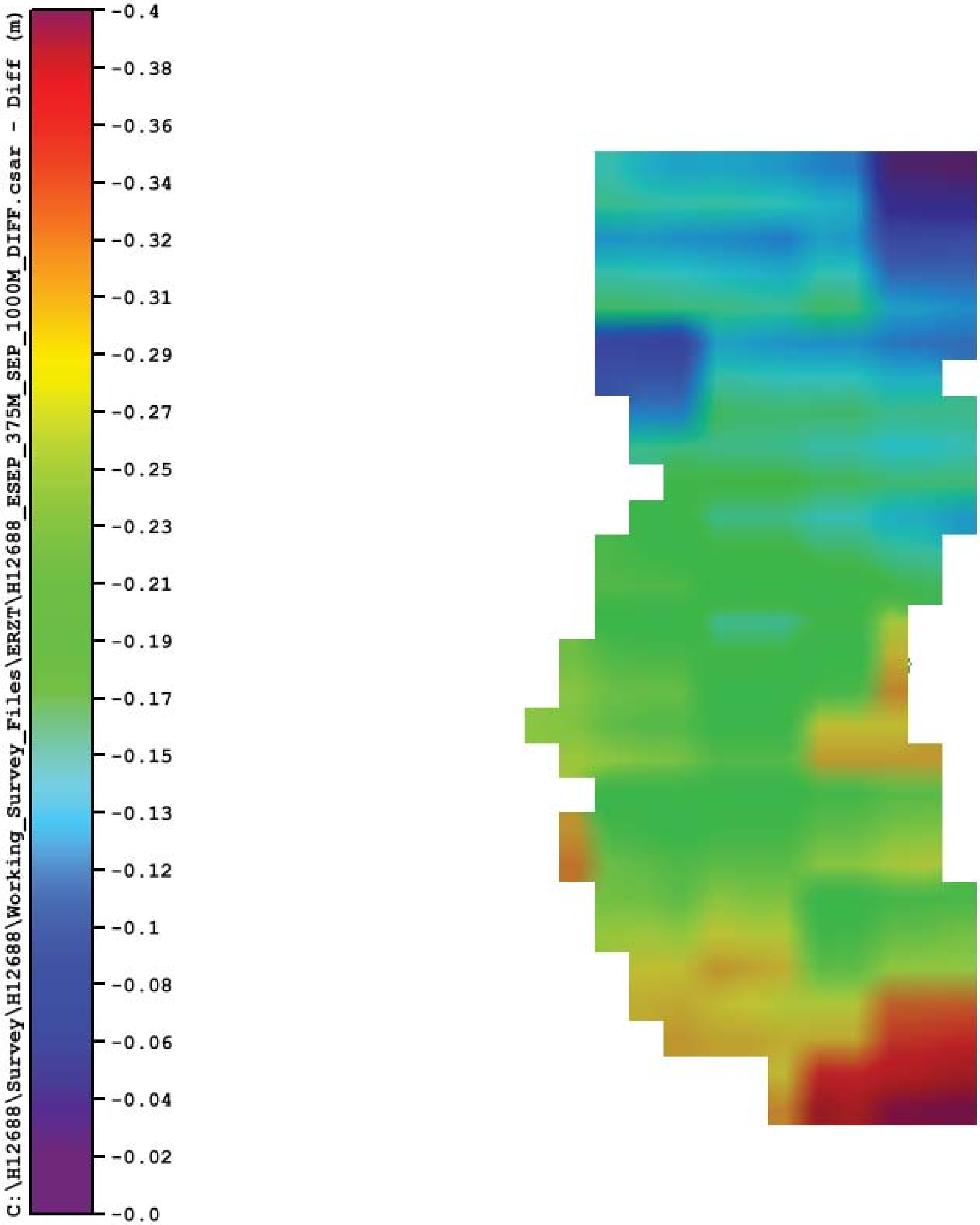


Figure 4. Image of ESEP - ERZT SEP difference surface 1000m resolution

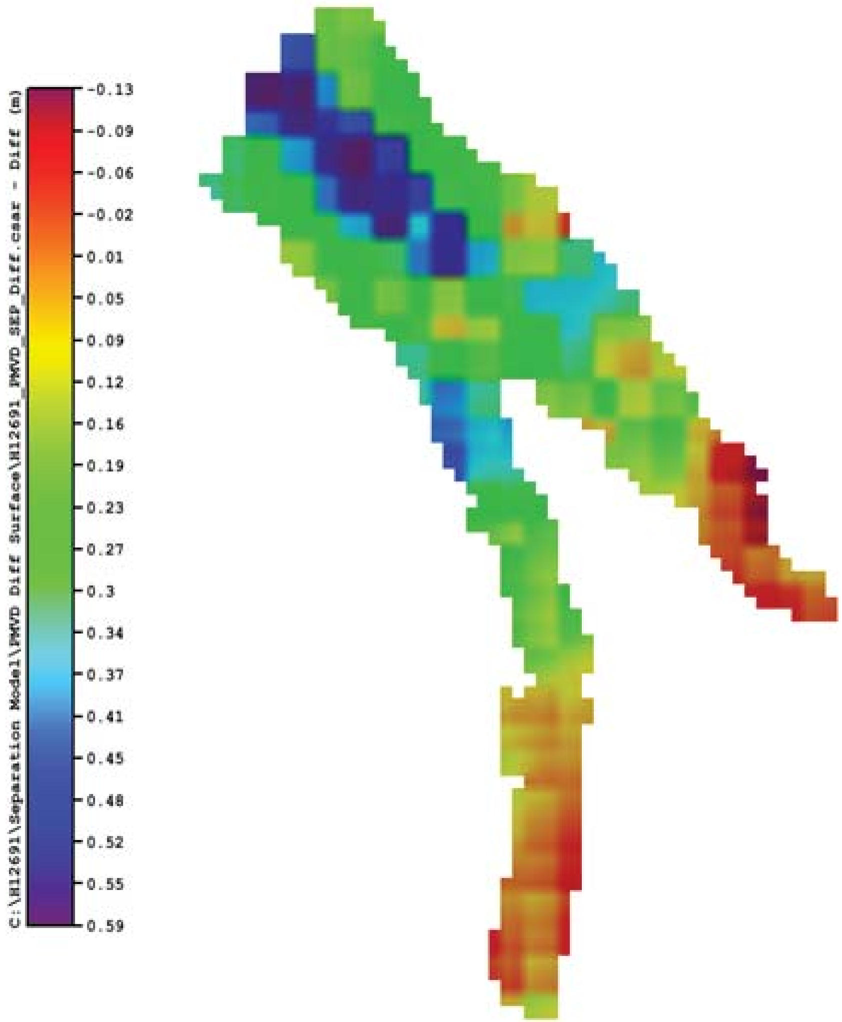


Figure 5. Image of H12691 ESEP - ERZT SEP difference surface 1000m resolution

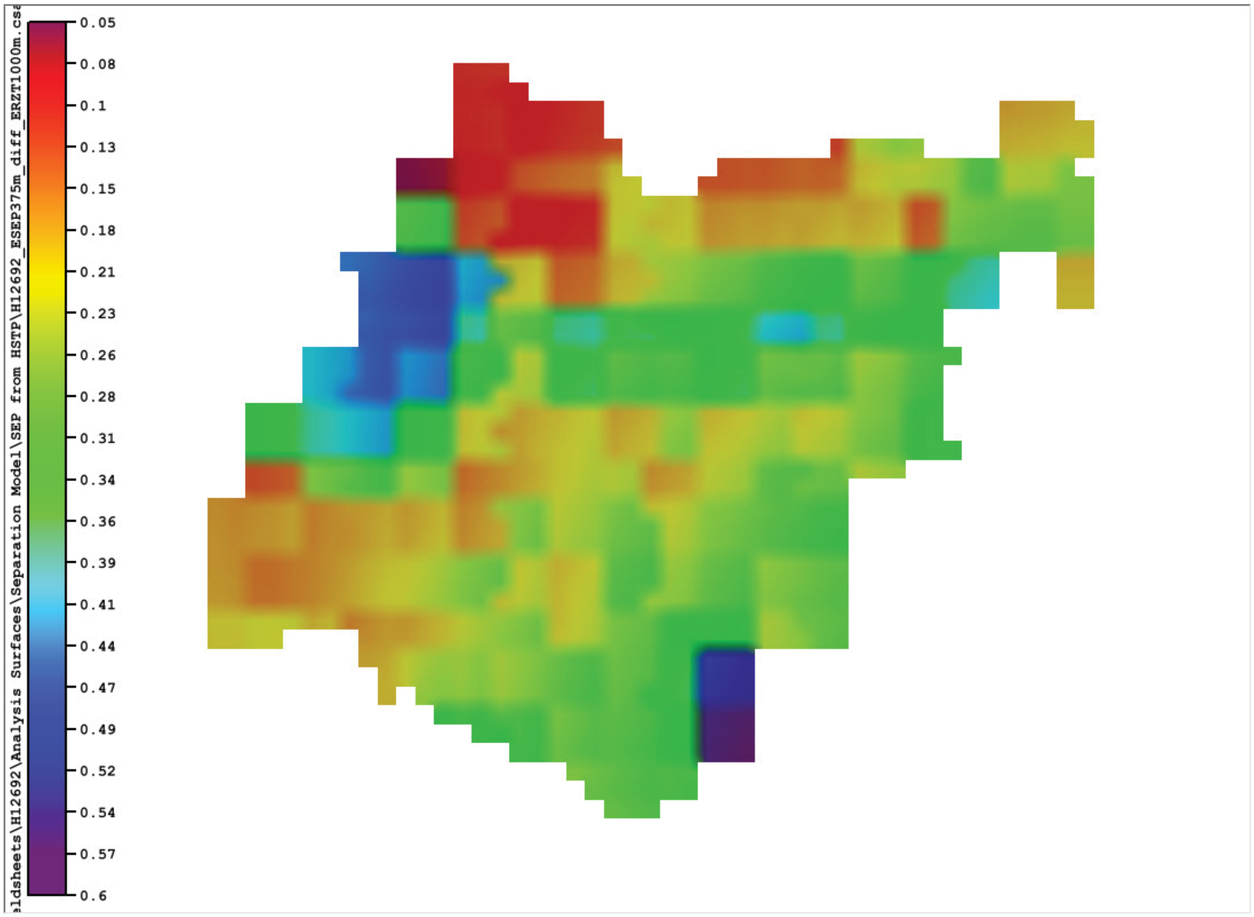


Figure 6. Image of H12692 ESEP - ERZT SEP difference surface 1000m resolution

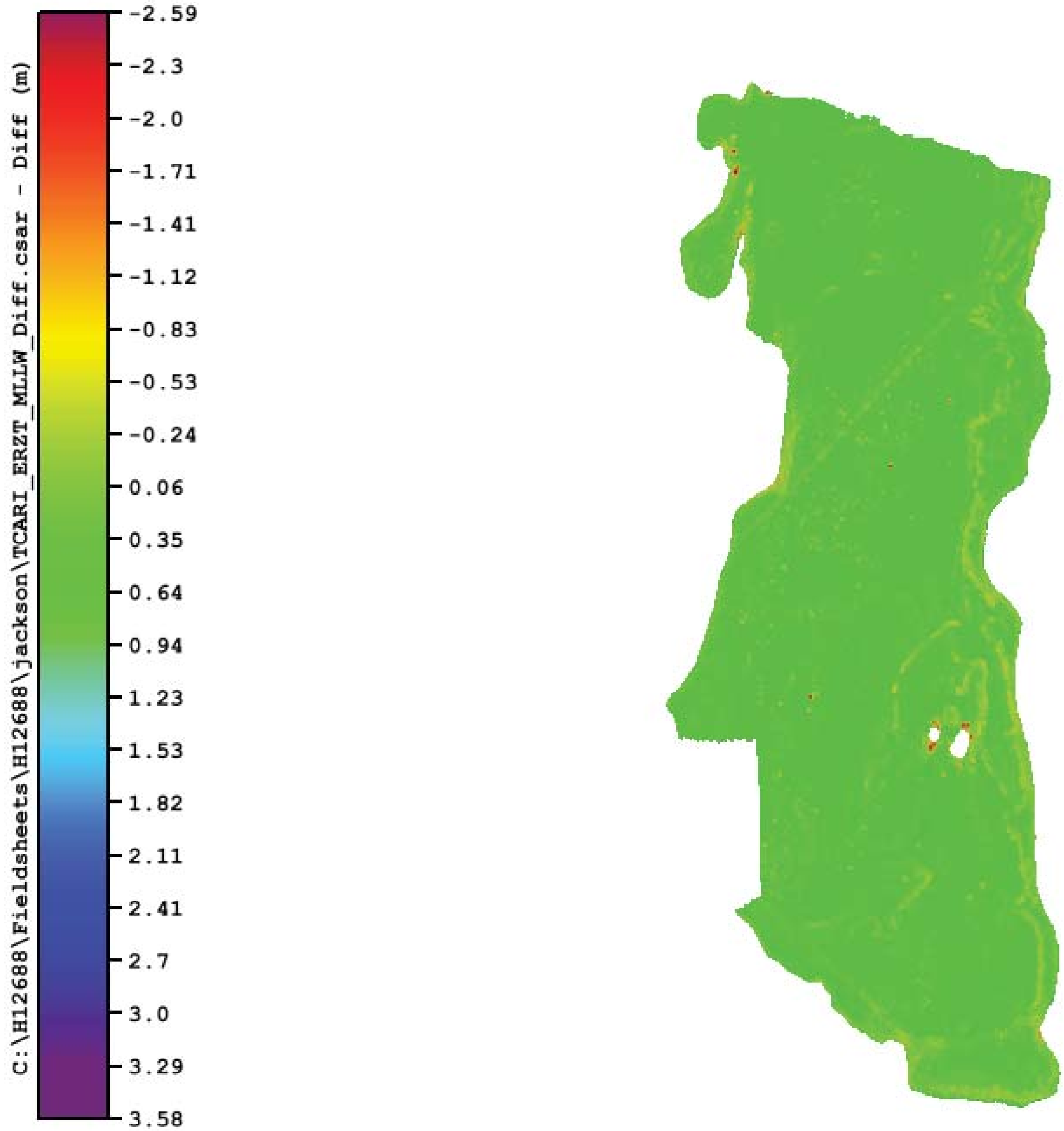


Figure 7. Image of H12688 ERZT MLLW - ZDF MLLW difference surface

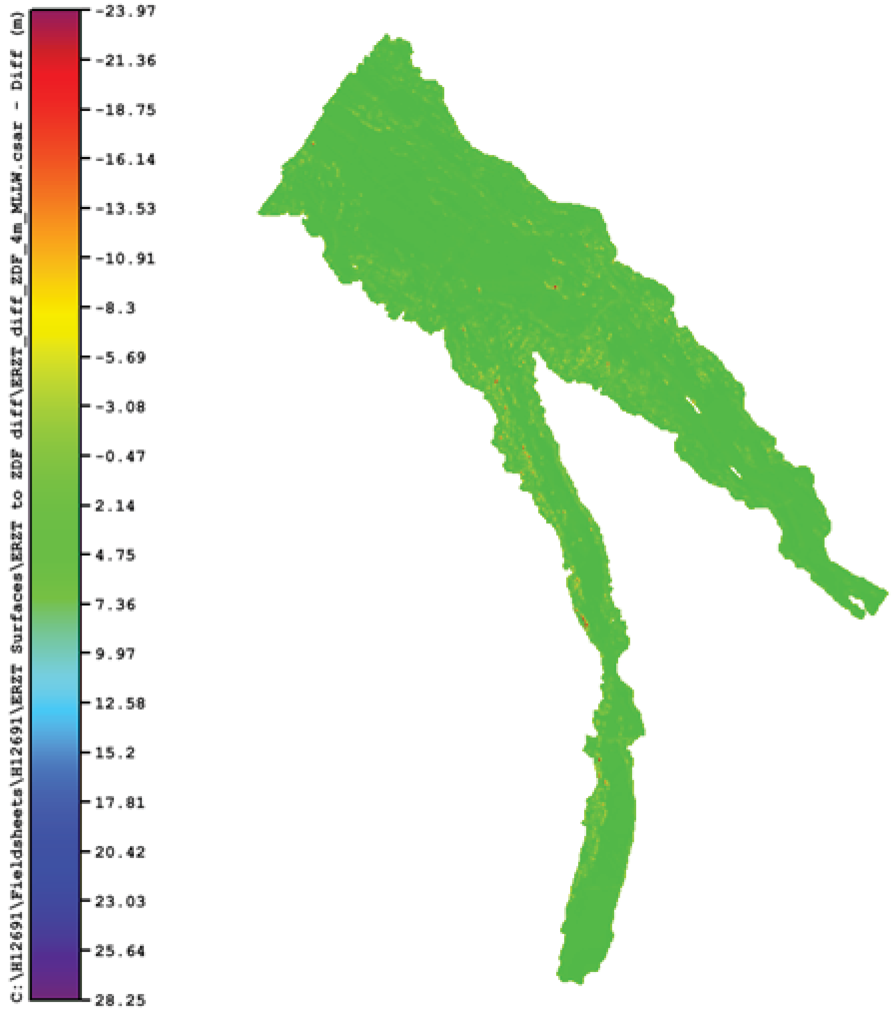


Figure 8. Image of H12691 ERZT MLLW - ZDF MLLW difference surface

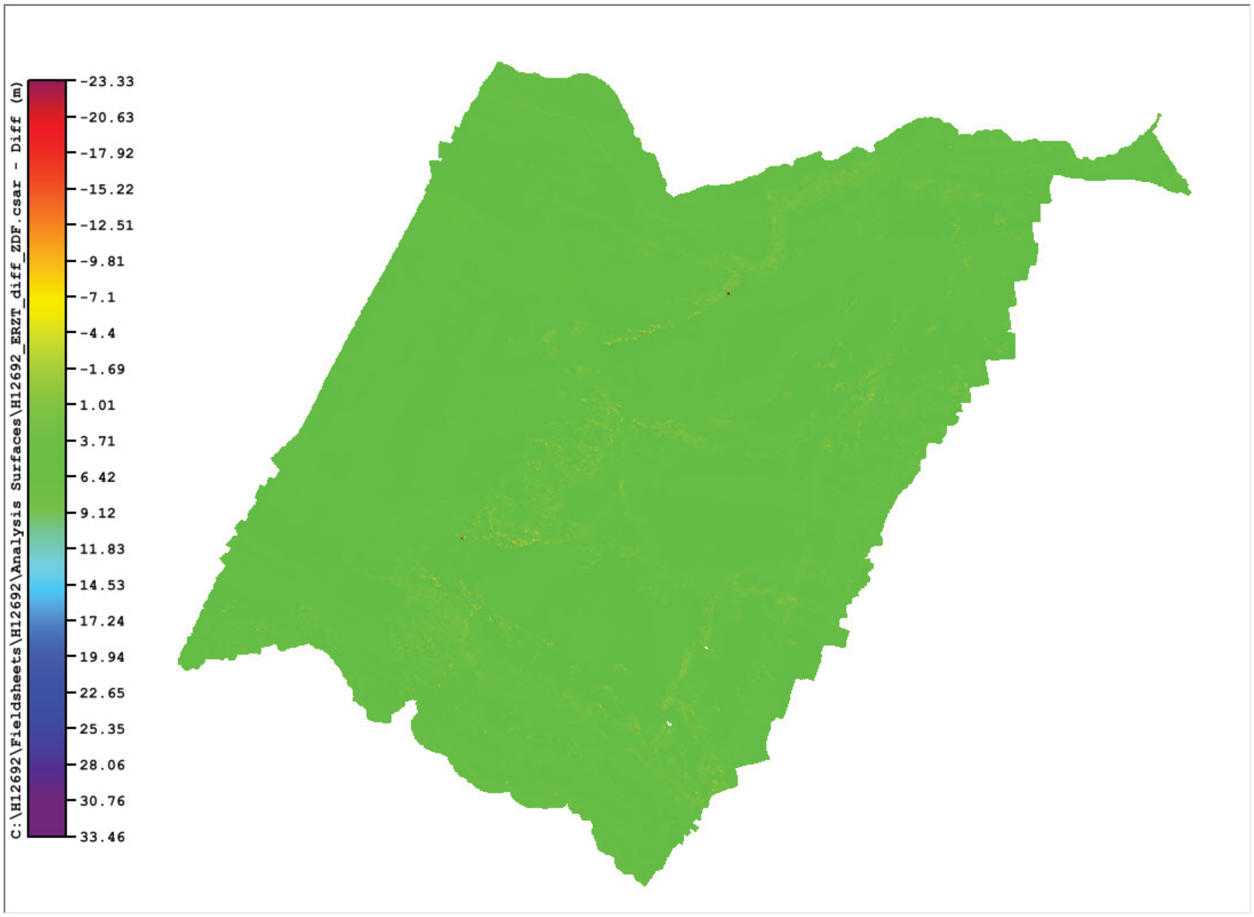


Figure 9. Image of H12692 ERZT MLLW - ZDF MLLW difference surface

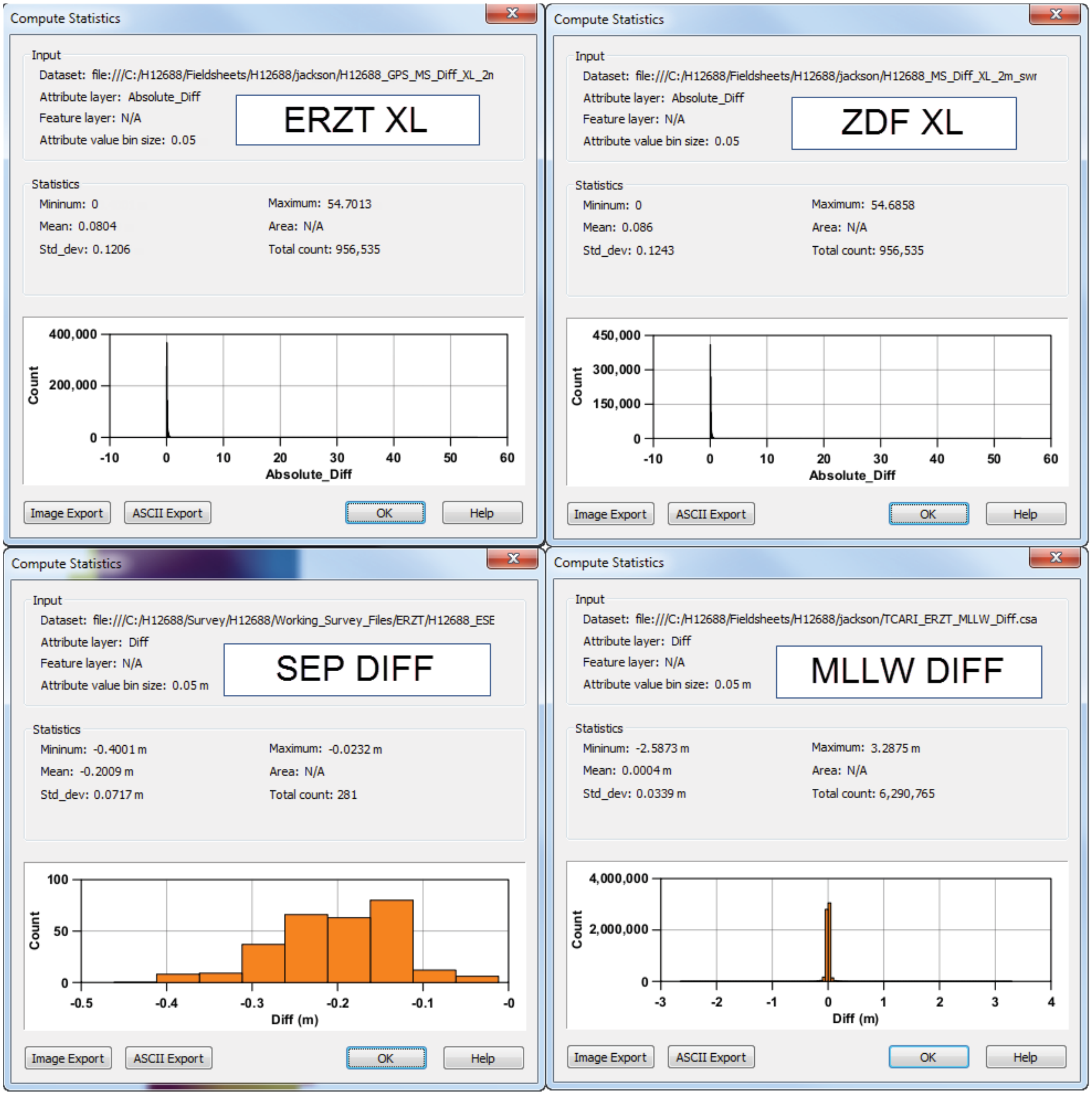


Figure 10. H12688 Histograms of crossline to mainscheme differences using ERZT and ZDF, ESEP model to ERZT difference, and ESEP model to MLLW difference

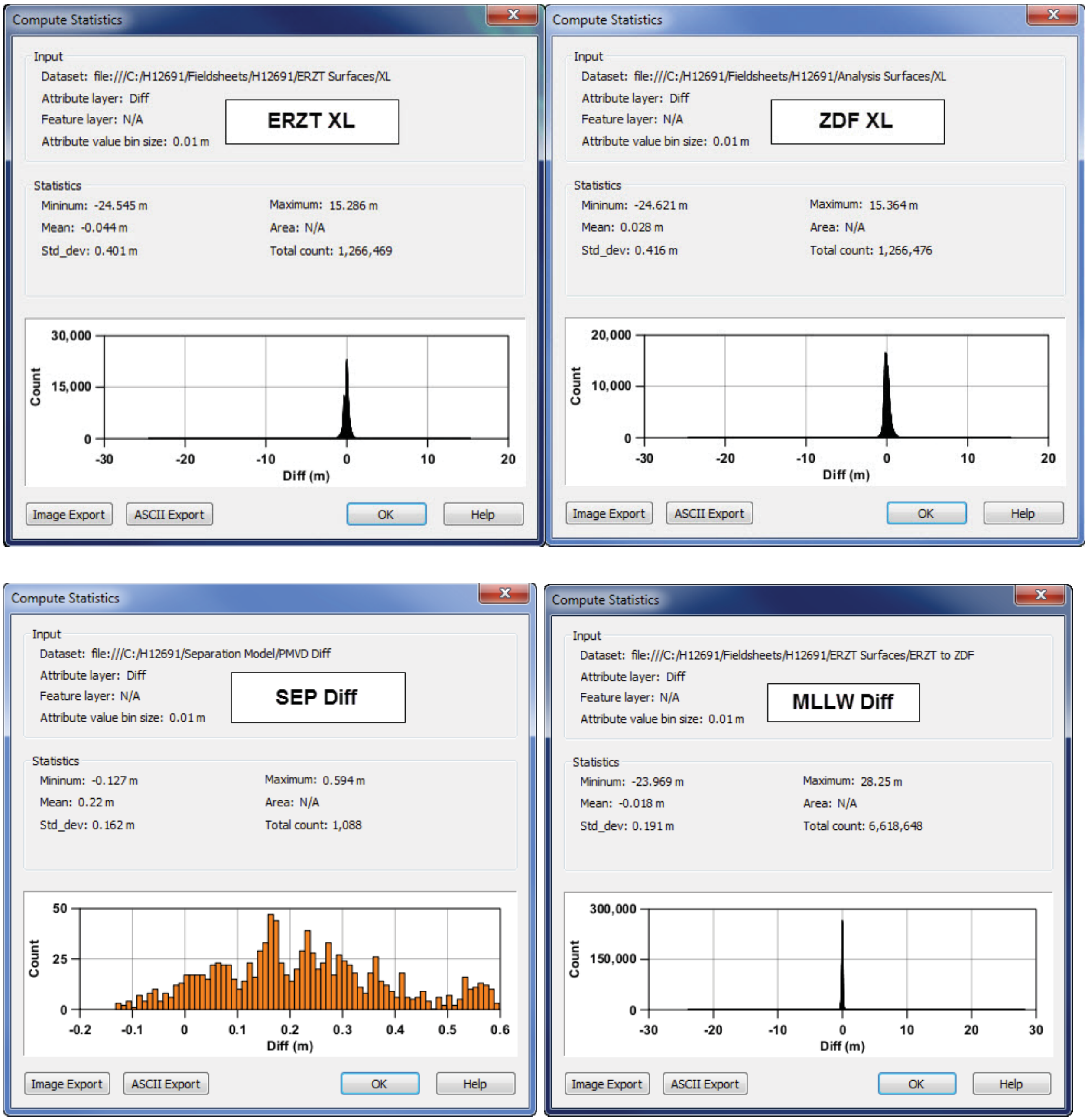


Figure 11. H12691 Histograms of crossline to mainscheme differences using ERZT and ZDF, ESEP model to ERZT difference, and ESEP model to MLLW difference

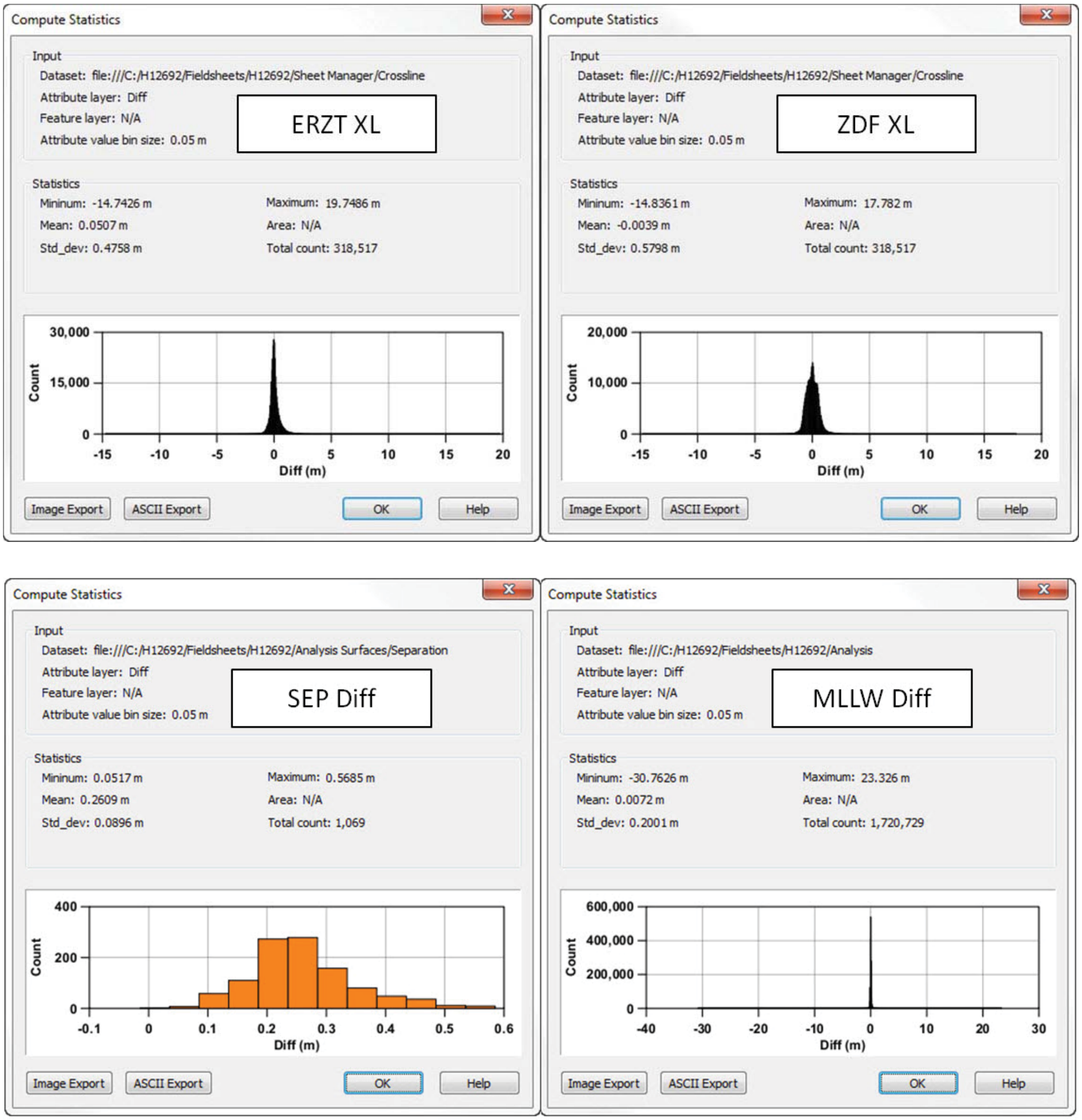


Figure 12. H12692 Histograms of crossline to mainscheme differences using ERZT and ZDF, ESEP model to ERZT difference, and ESEP model to MLLW difference

For surveys H12688,H12691, and H12692, the ERZT-reduced data show a comparable or smaller mean difference and smaller standard deviation in the crossline depth analysis than tidally-reduced data using ZDF. This result suggests for these surveys, ERZT is an acceptable and more consistent method of sounding reduction.

A difference surface of ESEP minus ERZT were created to examine the variation between field vessel derived separation models as compared to those created using datum differences at tide stations.

The two realizations of MLLW were differenced, and show zero mean difference, and a small standard deviation, suggesting that both realizations of bathymetry data are equivalent, and that both methods of reduction are unbiased relative to each other.

4.0 Interpolation and Uncertainty

For surveys H12688, H12691 and H12692 no SBETs required interpolation.

The following shows the uncertainty value determination for H12688, H12691 and H12692:

Sheet	Surface	Mean of Std_Dev child layer (Mean)	Estimated lines per cell (N)	Resultant 1 sigma uncertainty (Mean/Sqrt(N))
H12688	H12688_WGS84_MLLW_SEP_1000m.csar	0.0636	9.667	0.020456
H12691	H12691_WGS84_MLLW_SEP_1000m.csar	0.1000	8.16	0.035003
H12692	H12692_WGS84_MLLW_SEP_1000m.csar	0.0747	4.4848	0.035274

Table 4. Uncertainty determination.

Post-processed position solutions were consistently accurate for the entirety of H12688, H12691 and H12692 following SBET correction.

For H12691, one line which creates two ERS holidays exists for a reduced to MLLW via ERZT as compared to the tidally reduced data. The *Delayed Heave* time extents did not entirely cover the line, therefore, SBET corrections could not be applied.This line was not used for ERZT derived MLLW surface creation, but was examined for significance in subset mode when reduced via ZDF. The line is included as part of the submittal for reference. Also for H12691, some errors in processing had been found after the creation of the 1000-meter separation model. For one small group of lines, only a TID file had been applied for the tidal correction. For another small group of lines, an incorrect NAD83 SBET had been applied. Both of these line sets were investigated with the created 1000-meter separation model and compared to the provided ESEP and were found to be in good agreement with the surrounding data.

For H12688, H12691 and H12692, had there been ERS holidays or lines that could not be adjusted with interpolation in AutoQC the ZDF-reduced data still remains adequate for chart applications.

For H12688, H12691 and H12692, a given number of lines per cell (N) were used as a reasonable value for the number of lines in a given node of the separation model. For the SEP model created for this survey, any given SEP cell at 1000m resolution could have had tens of survey lines or as few as one inside its bounds. With minimal guidance or tools, hydrographers calculated a value they felt best represented the average for a given sheet. Use of a larger or smaller reasonable value changes the final SEP model uncertainty by up to centimeters.

5.0 Results and Recommendations

For H12688, H12691 and H12692 it is recommended that soundings be reduced to MLLW through use of the ERZT method. Quantitative analysis of crosslines for this survey demonstrates ERZT as a more precise reduction method compared to ZDF. Qualitatively, hydrographers involved in the production of the survey believe the ERZT reduced data to be a potential improvement as compared to the ZDF reduction, due to the greater accuracy, precision, and significant potential for faster data analysis and submission. During the course of the survey, ERZT methods were helpful in resolving issues that would have been problematic for a tidally reduced survey, such as incorrectly applied tides and SBETs not applying correctly, giving greater value to the ERZT methods.

For future ERZT and ERS surveys, the following recommendations should be considered:

1. Procedures and workflows should be fully tested and documented prior to delivery to the *Rainier*. The ERZT SOP as provided from HSD did not provide any detail on how to determine uncertainty. Numerous references to VDatum were also in the SOP, though no VDatum model exists for Alaska during the time of survey. The SOP focused on crosslines, though for *Rainier* the occasional need to interpolate would require analysis of all lines. Crosslines alone without Vdatum or another reference SEP might not be fully representative of the ERS specific conditions of an area. To best troubleshoot SBETs, a comparison is required to discover any bias. Without this comparison, a bias would be difficult to quickly troubleshoot.
2. NOAA HSSD and Project Instructions should be updated to specify the vertical and horizontal datums of all positions and separation models.
3. Best practices and tools to determine ERZT uncertainty should be explored. Determination of applied SEP model resolution should be evaluated further, likely in consideration of the tide model resolution in areas where ERZT could be applied. Geographic information system type tools could be used to better count and determine uncertainty for a grid allowing for standardized procedures and results.
4. *Rainier* ERS SOPs and data submission for items related to vertical reduction of soundings should be independently evaluated by OCS staff for consistency and to minimize errors. *Rainier* SBETs have been processed and exported in a WGS84 datum for some time, though most NOAA specifications require NAD83.
5. Due to staffing challenges on *Rainier*, only a few crewmembers aboard are familiar with software used in the processing and troubleshooting of these SBETs. *Rainier* personnel need additional training on ERS and ERZT theory, as well as hands on training on how to use associated equipment and software most effectively to ensure *Rainier* capability of ERS.
6. . *Rainier* should update and improve their quality control procedures and have procedures reviewed by outside unit experts.
7. Original SBETs were typically generated and applied within 2 weeks upon receipt of base station data for the Kodiak project, though due to equipment limitations of radio range and data throughput, base station downloads were infrequent. Low internet bandwith also limited ability for the ship to download required clock and ephemeris data in a consistent and timely

manner. Full use of ERZT methods and troubleshooting occurred months after completion of the project.

8. *Rainier* only has 2 POSPAC MMS keys, limiting the amount of data that can be processed concurrently. Increasing the number of projects to be processed simultaneously would be advantageous given the possibility for *Rainier* to have 5 different POSMV units operating simultaneously.
9. *Rainier*, HSD and HSTB should attempt to resolve SBETs using ERZT methods sooner, and investigate methods to improve data throughput and processing time.
10. Implementation of decimeter or centimeter level real time corrections (SBAS, RTK, RTG, etc) should be further investigated for potential to minimize post processing efforts while ensuring high precision and accurate vertical positioning.
11. With proper control of vessel positioning, ERZT methodology could offer significant possibilities to reduce overall survey submission time, particularly in areas with well established tidal control. Reduced dependency upon tertiary tide stations and/or concurrent hydrographic data collection adds additional time for data acquisition, and greater operational flexibility. Data could conceivably be reduced and submitted without having or waiting for receipt of final tides packages from CO-OPS, minimizing field unit waiting and burden. Continue efforts on implementing full ERS/ERZT methods.
12. Analysis of ERZT SEP models allows sheet managers and other processors to evaluate vertical positioning quality in a visual manner, allowing for "directed editing" techniques to be applied to problem troubleshooting. These visual and surface based approaches are often more approachable for many users than detailed inspection of PPK graphs, and determination if errors also overlap with sonar data collection. This could significantly alter SBET processing workflows by reducing total QC performed and only focusing on problematic data.
13. The following published resources were useful as references in this effort and should be disseminated more widely.
    a. Measuring the Water Level Datum Relative to the Ellipsoid During Hydrographic Survey, Rice and Riley, 2011. http://ushydro.thsoa.org/hy11/0427A_08.pdf - This describes ERZT theory.
    b. Ellipsoidally Referenced Surveying for Hydrography, Mills and Dodd, 2014 https://www.fig.net/resources/publications/figpub/pub62/Figpub62.pdf - A good general resource for ERS topics.
    c. INVESTIGATION OF THRESHOLD CROSSING HEIGHT VARIATIONS FOR WIDE AREA AUGMENTATION SYSTEM (WAAS) LOCALIZER PERFORMANCE WITH VERTICAL GUIDANCE (LPV) APPROACH PROCEDURES, Johnson and DiBenedetto, 2007. https://www.faa.gov/air_traffic/flight_info/avn/flightinspection/onlineinformation/pdf/06-27_Official_Final_Report_Body.pdf - Describes datum differences and application to aviation for WGS84 and NAD83.

APPROVAL PAGE

H12688

Data meet or exceed current specifications as certified by the OCS survey acceptance review process. Descriptive Report and survey data except where noted are adequate to supersede prior surveys and nautical charts in the common area.

The following products will be sent to NCEI for archive
- H12688_DR.pdf
- Collection of depth varied resolution BAGS
- Processed survey data and records
- H12688_GeoImage.pdf

The survey evaluation and verification has been conducted according current OCS Specifications.

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DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=OTHER, cn=HOLMBERG.PETER.SCOTT.1365886101
Date: 2017.02.28 10:35:54 -08'00'

Approved:______________________________

Peter Holmberg
Cartographic Team Lead, Pacific Hydrographic Branch

The survey has been approved for dissemination and usage of updating NOAA's suite of nautical charts.

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Date: 2017.02.28 13:33:54 -08'00'

Approved:______________________________

CDR Benjamin K. Evans, NOAA
Chief, Pacific Hydrographic Branch