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Saint Paul Island Harbor

Multibeam/Singlebam Bathymetry, Mobile/Static LiDAR, and Control Survey

Saint Paul Harbor, Saint Paul Island, Alaska

SUMMARY REPORT

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Survey Period –September 27th through October 16th , 2022

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1. EXECUTIVE SUMMARY

Between September 27th through October 16th, 2022, eTrac Inc. completed a Hydrographic, Topographic, & Control Survey of the St. Paul Harbor, located on St. Paul Island, Alaska. Services included high resolution Multibeam Bathymetry, Singlebeam Bathymetry, Mobile & Static Terrestrial LiDAR, RTK Topography, Differential Leveling, and traditional land survey methods to verify horizontal and update vertical control.

Horizontal control for eleven (11) project benchmarks around St. Paul Harbor were verified by RTK techniques. Differential Leveling was performed at the NOAA Tidal Station to verify MLLW and on nine (9) Local Project Control Points to update vertical control. Vertical Control for two (2) project benchmarks were verified via RTK techniques.

Multibeam depths within the survey area ranged from -42ft to -1ft MLLW, while Terrestrial LiDAR and Topo ranged from -1ft to +38ft MLLW within the St. Paul Harbor survey limits.

Five (5) Navigation Aids were located during the survey; Navigation Aid 27830, Navigation Aid 27831, Navigation Aid 27832, Navigation Aid 27833, and Navigation Aid 27834 are in good condition.

Ten objects greater than 2ft in any one dimension above project depth were located within the St. Paul survey limits that were flagged as Obstructions to Navigation. Two additional objects that do not pose a Navigation hazard but are of significant size and location were located within the survey area and labeled as Objects of Interest. Dimensions and images for both Obstructions to Navigation and Objects of Interest are located within this report.

Further information regarding each stage of survey, methodology, and results can be found below throughout this document.

2. ABBREVIATIONS

°	Degree(s)
°F	Degree(s) Fahrenheit
3D	Three Dimensional
CMR(+)	Compact Measurement Record
CORS	Continuously Operating Reference Station
Ft	Feet
GLONASS	Global Navigation Satellite System (Russia's version of GPS)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
Hz	Hertz
IHO	International Hydrographic Organization
LiDAR	Light Detection and Ranging
MBES	Multibeam Echosounder System
MTL	Mobile Terrestrial Lidar
MLLW	Mean Lower Low Water
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic Atmospheric Administration
OPUS	Online Positioning User Service
POSMV	Position and Orientation System for Marine Vessels
PPK	Post Processed Kinematic
QA	Quality Assurance
QC	Quality Control
QPS	Quality Positioning Systems
RTK	Real Time Kinematic
SBET	Smoothed Best Estimate of Trajectory
SV	Sound Velocity
USM	Universal Sonar Mount

3. INTRODUCTION

eTrac Inc. (eTrac), acting as a private contractor for the U.S. Army Corps of Engineers (USACE), performed a Hydrographic, Topographic, and Control Survey of St. Paul Harbor located on St. Paul Island, Alaska. eTrac performed this Project Condition Survey (PCS) as part of Contract No. W911KB-18-D-0014. The project location is shown below in Figure 1 and the proposed survey area, supplied by the USACE, is shown below in Figure 2.

Figure 1 Project Location

Figure 2 St. Paul Harbor Survey Area

a. Objectives

Objectives associated with the St. Paul Harbor survey are outlined below:

- Complete a full-coverage Bathymetric Multibeam Survey and Split Line spacing Singlebeam Survey within the provided survey limits for St. Paul Harbor
- Complete a mobile & static Terrestrial LiDAR Survey of the harbor shoreline and breakwaters
- Verify Horizontal Control through a series of three (3) 180-sec RTK observations
- Update Vertical Control derived from differential leveling
- Complete a RTK Topographic Survey of the harbor to supplement the mobile Terrestrial LiDAR Survey
- Locate all dock corners, utilities, and buildings near and within the survey limits
- Identify and report on any object or significant feature (greater than 2ft in any one dimension & shoaler than Project Depth) within survey limits as well as objects of interest (larger objects below project depth or fall just outside the dredge and survey limits)
- Publish an OPUS solution of NOAA Tidal Station benchmark for *RBD1 1994*

b. Mobilization

All Multibeam was completed onboard a local Vessel of Opportunity (VOOP) (Figure 3). The VOOP was an open aluminum monohull vessel that was acquired and mobilized on St. Paul Island, AK. A positioning and motion detection system was installed on the vessel with a long antenna base allowing for maximum heading accuracy and better results in areas with low GNSS coverage. The VOOP had all offsets measured to ensure that measurements to and from the positioning equipment are accurate to less than 3cm.

Figure 3 VOOP Vessel

A POS MV WaveMaster V5 was used to position the vessel during survey operations. An R2Sonic 2020 Multibeam EchoSounder (MBES) was mobilized on the vessel using the side mounted Universal Sonar Mount (USM). The mount positions the system with 100% repeatability and was specifically designed with a break-away block system that protects the sonar from damage while working in shallow water, areas with large obstructions, or waters with strong currents.

An ocean kayak (Figure 4) was used to acquire all shallow water Singlebeam data within the lagoon and also supplement Multibeam data not able to be collected in shallow areas within the survey limits. A CV-100 Singlebeam Echosounder was mounted on a rover rod with a Trimble R8 Model 3 GNSS Receiver at the top. Offsets were measured to position the system on board the kayak accurately.

Figure 4 VOOP Kayak

c. Geodesy

All data within St. Paul Harbor was collected in reference to NAD83 (CORS) 2003.00, State Plane, Alaska Zone 9, U.S. Survey ft. Local project control is based on holding *RBD1 1994*.

The vertical datum for the project is Mean Lower Low Water (MLLW), U.S. Survey Feet, based on the NOAA/NOS tidal benchmark *9464212, VILLAGE COVE, ST. PAUL ISLAND, ALASKA* published 06/17/2019. This tidal datum is based on the 1983-2001 tidal epoch and is referenced by holding NOAA/NOS tidal benchmark *RBD1 1994* as 28.330'.

Prior to, and post data collection, Real Time Kinematic (RTK) observations of a second benchmark were acquired in order to verify the base setup.

4. VERTICAL CONTROL SURVEY

a. Methods & Procedures

A Vertical Control Survey was performed on October 8th and 10th, 2022. First, differential leveling was performed to verify MLLW at NOAA Tidal Station *9464212, VILLAGE COVE, ST. PAUL ISLAND, ALASKA*. MLLW at NOAA/NOS Tidal Benchmark *RBD1 1994* was verified by connecting it to *946 4212 N, 946 4212 P, SP-3 2001,* and *946 4212 T.* Second, differential leveling was performed between the NOAA Tidal Station and nine (9) other benchmarks located around St. Paul Harbor. Figure 5 below shows an overview of the Local Project control while Figure 6 shows the NOAA Tidal Benchmarks for St. Paul.

Figure 5 Overview of benchmarks at St. Paul Harbor

Figure 6 Overview of NOAA benchmarks

b. Results

MLLW was verified through differential leveling at the NOAA Tidal Station, connecting the Primary Benchmark *RBD1 1994* with four other benchmarks, *946 4212 N, 946 4212 P, SP-3 2001,* and *946 4212 T,* based on the same tidal station. All leveling meets or exceeds Secord Order, Class 1 criteria. The results of the NOAA benchmark leveling effort can be seen below in Table 1.

Table 1 MLLW Verification

Primary Vertical Control Verification - NOAA Station *"9464212, VILLAGE COVE, ST. PAUL ISLAND, ALASKA"*			
Name	**Published Elevation, ft (NOAA 06/17/2019)**	**Leveled Elevation, ft (eTrac Oct. 2022)**	**Δ (ft)**
RBD1 1994	28.330	N/A	N/A
4212 N 2002	10.604	10.565	0.039
4212 P 2002	12.277	12.257	0.020
SP-3 2001	15.213	15.187	0.026
4212 T 2008	12.224	12.198	0.026
RBD1 1994 was held as fixed for differential leveling.			

a. QC & Calibration

Before beginning differential leveling at St. Paul Harbor, a collimation test was performed. At the end of each level loop, loop closures and the difference (Δ) between published elevations and leveled elevations are calculated. Calculated closures and elevation differences can be found in Table 2 below.

Table 2 Field Leveling QC Results

Field Leveling Loop Closures and Accuracies – St. Paul Harbor		
Level Loop	**Name**	**Δ Published to Leveled (ft)**
Level Loop 2 Tbal: 3.855ft, Misclosure: -0.001ft	*SP-3 2001*	0.027
Level Loop 3 Tbal: -1.926ft, Misclosure: -0.001ft	*DUMP 1995*	0.005
Level Loop 4 Tbal: -0.857ft, Misclosure: 0.003ft	*945 4212 N 2022* *945 4212 P 2022* *945 4212 T 2022*	0.039 0.020 0.026
Level Loop 6 Tbal: -3.717ft, Misclosure: 0.003ft	*VILLAGE HILL RESET*	0.001
Level Loop 7 Tbal: 0.957ft, Misclosure: 0.001ft	*ST-1 1992*	-0.006
Level Loop 8 Tbal: 0.064ft, Misclosure: -0.002ft	*RBD3 1994*	-0.002
Level Loop 9 Tbal: -0.182ft, Misclosure: -0.003ft	*RBD4 1994*	0.000
Level Loop 10 Tbal: 1.979ft, Misclosure: 0.002ft	*ST-3 1992* *FOXY*	0.001 -0.009
RBD1 1994 was held as fixed for the differential leveling SP-2 1979 & ST-4 1992 with coordinate precision of 0.1' were measured by RTK GNSS		

5. HORIZONTAL CONTROL SURVEY

a. Methods & Procedures

A Horizontal Control Survey was performed on September 27th and October 5th and 6th, 2022 in order to verify control. To verify horizontal control three (3) 180-second RTK observations were performed on eleven (11) Local Control Points by holding *RBD1 1994*.

The Table 3 below lists final USACE coordinates:

Table 3 RTK Verification for St. Paul Harbor

Benchmark	USACE Provided Coordinates		eTrac RTK Observations		Difference	
	Northing	Easting	Northing	Easting	Δ N	Δ E
**RBD1 1994*	1,141,043.70	1,583,846.28	N/A		N/A	N/A
DUMP 1995	1,141,545.24	1,583,907.14	1,141,545.29	1,583,907.14	-0.05	0.00
FOXY	1,142,611.23	1,583,160.44	1,142,611.25	1,583,160.42	-0.02	0.02
RBD3 1994	1,141,658.26	1,583,526.92	1,141,658.27	1,583,526.91	-0.01	0.01
RBD4 1994	1,142,082.16	1,583,364.40	1,142,082.17	1,583,364.35	-0.01	0.05
SP-2 1979	1,142,158.06	1,585,194.13	1,142,158.07	1,585,194.16	-0.01	-0.03
SP-3 2001	1,141,172.88	1,584,526.18	1,141,172.91	1,584,526.15	-0.03	0.03
ST-1 1992	1,141,370.57	1,583,680.59	1,141,370.56	1,583,680.57	0.01	0.02
ST-3 1992	1,142,616.08	1,583,159.92	1,142,616.14	1,583,159.88	-0.06	0.04
ST-4 1992	1,142,668.99	1,584,684.10	1,142,669.06	1,584,684.11	-0.07	-0.01
VILLAGE HILL RESET	1,140,727.24	1,584,338.92	1,140,727.21	1,584,338.93	0.03	-0.01
**RBD1 1994* coordinates held for RTK base						

b. Results

Table 4 below lists the final USACE coordinates:

Table 4 Final Control for Saint Paul Harbor

Benchmark	eTrac Final Control		
	Northing	Easting	Elevation
**RBD1 1994*	1,141,043.70	1,583,846.28	28.33
DUMP 1995	1,141,545.24	1,583,907.14	11.31
FOXY	1,142,611.23	1,583,160.44	27.87
RBD3 1994	1,141,658.26	1,583,526.92	36.72
RBD4 1994	1,142,082.16	1,583,364.40	35.16
SP-2 1979	1,142,158.06	1,585,194.13	12.7*
SP-3 2001	1,141,172.88	1,584,526.18	15.21
ST-1 1992	1,141,370.57	1,583,680.59	33.17
ST-3 1992	1,142,616.08	1,583,159.92	27.97
ST-4 1992	1,142,668.99	1,584,684.10	16.8*
VILLAGE HILL RESET	1,140,727.24	1,584,338.92	94.67

6. TOPOGRAPHIC SURVEY

a. Methods & Procedures

An RTK Topographic Survey was conducted September 29th through October 16th, 2022. Data collection encompassed a full survey of the area including planimetrics and utilities while also supplementing the Multibeam, Singlebeam, and LiDAR datasets. An overview of the topographic survey data collected can be seen in Figures 7 and 8. For this survey, topographic data was additionally collected in order to compliment Singlebeam data with the lagoon area of the survey limits. Further images regarding the lagoon can be found within the Hydrographic Survey section.

Figure 7 Overview of Topographic data collected within survey limits

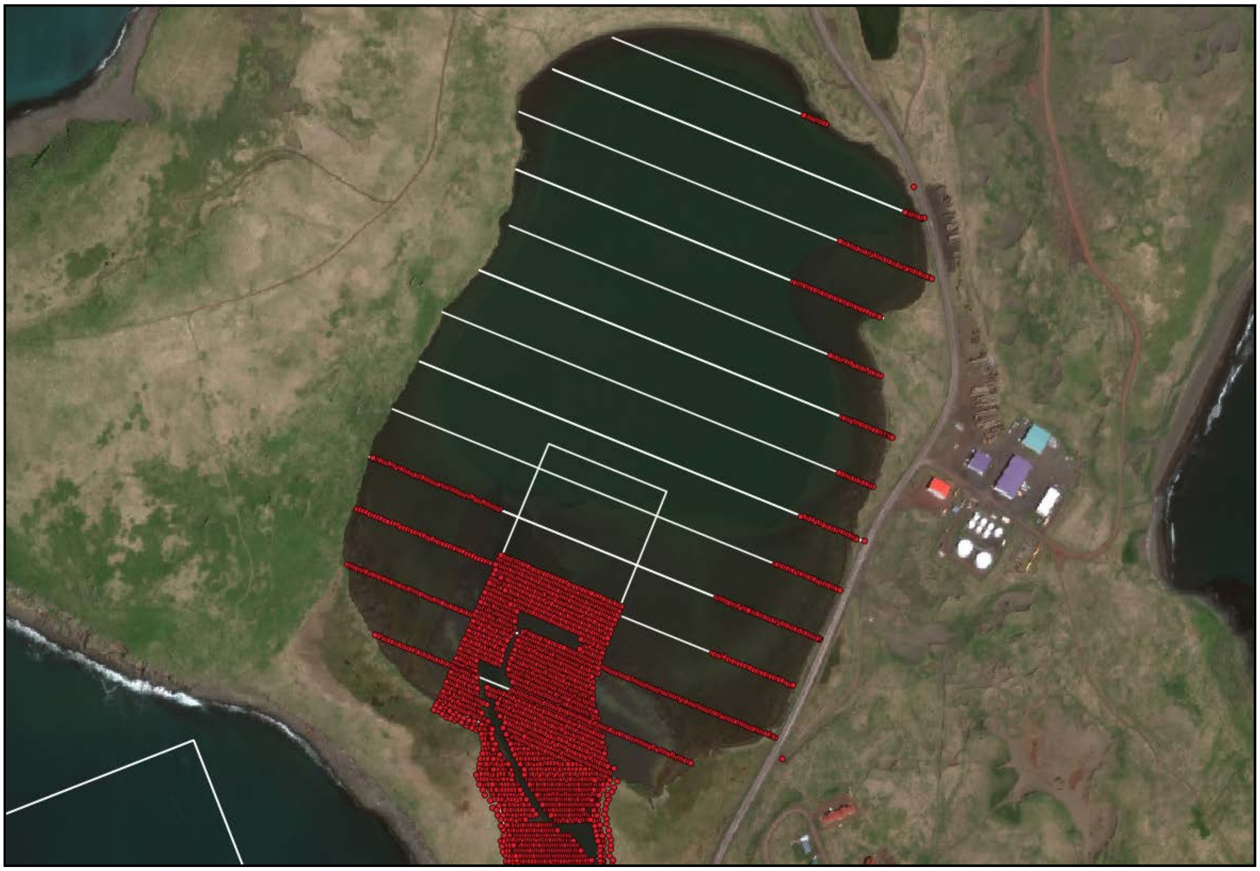

Figure 8 Overview of Topo Data Collected on Lagoon Cross Sections

b. QC

Prior to data collection, the GNSS rover being used conducts a check-in observation on a project benchmark; after data collection a check-out observation is taken on the same benchmark. The horizontal and vertical differences between these two observations and the published coordinates serve as a QC to verify the base setup during acquisition. Reference Table 5 below for the check-in and check-out observations taken before and after the topographic survey.

Table 5 RTK Check-In/Check-Out Observations From Topo Survey

Date	Obs. Type	ΔN (ft)	ΔE (ft)	ΔZ (ft)
9/29/2022	Check-in	0.01	-0.04	-0.01
9/29/2022	Check-out	0.05	-0.02	0.00
9/30/2022	Check-in	0.01	0.02	-0.02
9/30/2022	Check-out	0.00	0.00	-0.03
10/2/2022	Check-in	0.01	-0.04	0.01
10/2/2022	Check-out	0.02	-0.03	0.00
10/3/2022	Check-in	0.02	0.00	0.00
10/3/2022	Check-out	-0.01	-0.03	0.02
10/4/2022	Check-in	0.00	-0.02	-0.01
10/4/2022	Check-out	-0.01	-0.04	-0.01
10/6/2022	Check-in	-0.03	-0.03	-0.02
10/6/2022	Check-out	0.03	-0.02	0.01
10/7/2022	Check-in	-0.01	-0.04	-0.01
10/7/2022	Check-out	-0.03	-0.01	-0.02
10/9/2022	Check-in	0.02	-0.02	-0.01
10/9/2022	Check-out	0.00	-0.02	-0.02
10/11/2022	Check-in	-0.01	-0.02	0.01
10/11/2022	Check-out	0.01	0.00	0.00
10/12/2022	Check-in	-0.02	-0.03	-0.04
10/12/2022	Check-out	0.03	-0.03	-0.01
10/14/2022	Check-in	-0.02	0.00	0.01
10/14/2022	Check-out	-0.03	-0.07	-0.03
10/15/2022	Check-in	-0.03	-0.05	-0.05
10/15/2022	Check-out	-0.02	-0.05	0.00
10/16/2022	Check-in	-0.01	-0.06	-0.01
10/16/2022	Check-out	-0.03	-0.03	-0.04

7. TERRESTRIAL LIDAR SURVEY

a. Methods & Procedures

A mobile & static Terrestrial LiDAR Survey was conducted October 3rd, 5th, and 6th, 2022. Mobile LiDAR data was acquired in QINSy software and vessel positioning data was logged in POSView software. Prior to acquisition, a bore sight calibration was conducted to account of errors that could propagate into the data upon installation. LiDAR data was focused on areas where acquisition by multibeam was not possible. Data was collected strategically based on tides to minimize the gap between multibeam and LiDAR surveys while vessel speed and attitude were kept at minimum to reduce errors that are associated with motion. To achieve an overlap between MBES data, LiDAR was collected during the lowest tide during the duration of the project St. Paul Harbor. An overview of the St. Paul Harbor Scan data can be seen below in Figure 9.

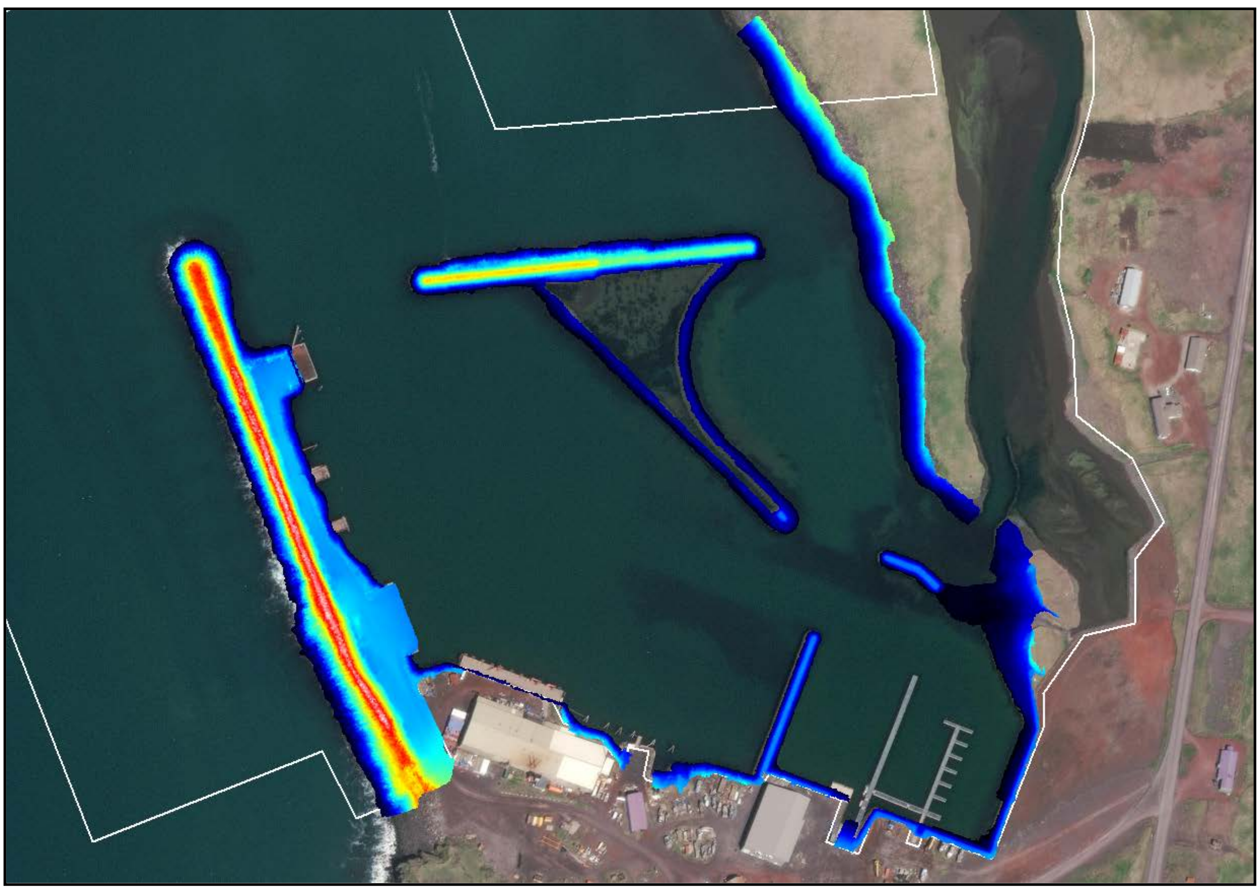

Figure 9 Overview of LiDAR Data in St. Paul Harbor

b. Data Processing & Calibration

All LiDAR data was processed in QINSy and RiScan Pro. A post-processed trajectory solution was computed using Applanix PosPac, which supplied a Post-Processed Kinematic (PPK) solution using the full 200 Hz update rate from the IMU. After initial application of the PPK trajectory, a bore-sight calibration was performed utilizing specific pairs of lines collected during calibration operations. An example of a pre- and post-calibration can be seen below in Figure 10 and Figure 11.

A bore-sight calibration quantifies and adjusts for misalignment angles between a scanner and the IMU. During the survey, specific planned lines were run along fixed objects such as piers, buildings, navigation aids, or flag poles. Based on various vessel and scanner orientations, each of the three misalignment angles (roll, pitch, and yaw) can be isolated and corrected in post processing.

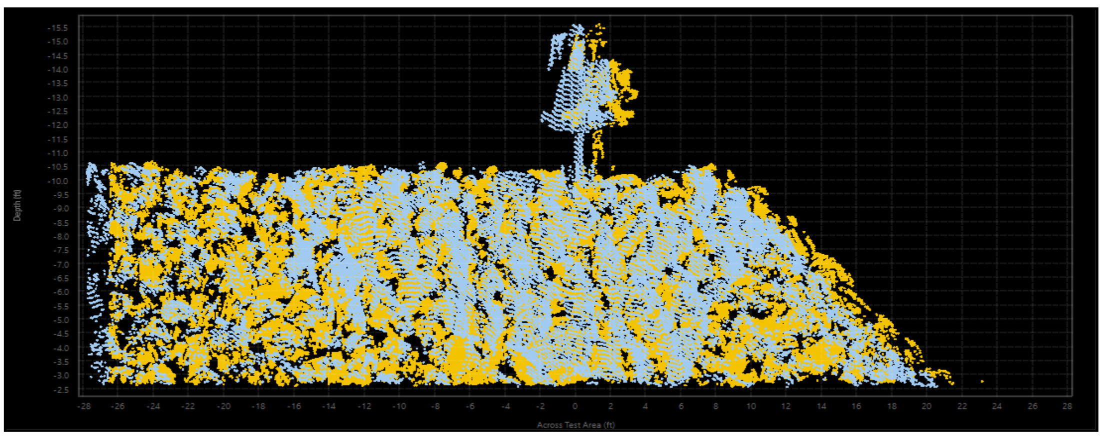

Figure 10 Example Pre-Boresight Calibration

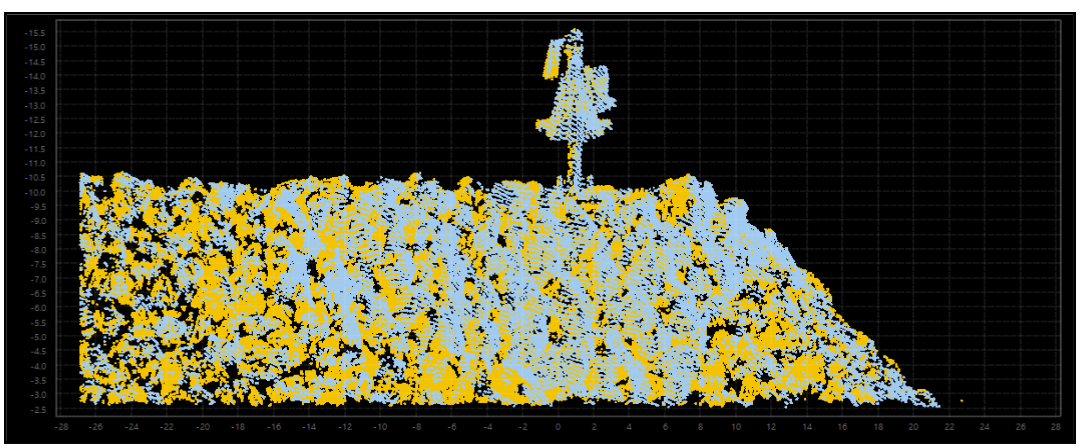

Figure 11 Example Post-Boresight Calibration

LiDAR data was analyzed in a 3D point cloud environment, which shows the full sounding dataset; this gives the processor the ability to fully analyze features and environments. Geological features and manmade objects are better quantified and understood by analyzing the dataset in a 3D environment. Figure 12 shows a 3D view of the end of a breakwater.

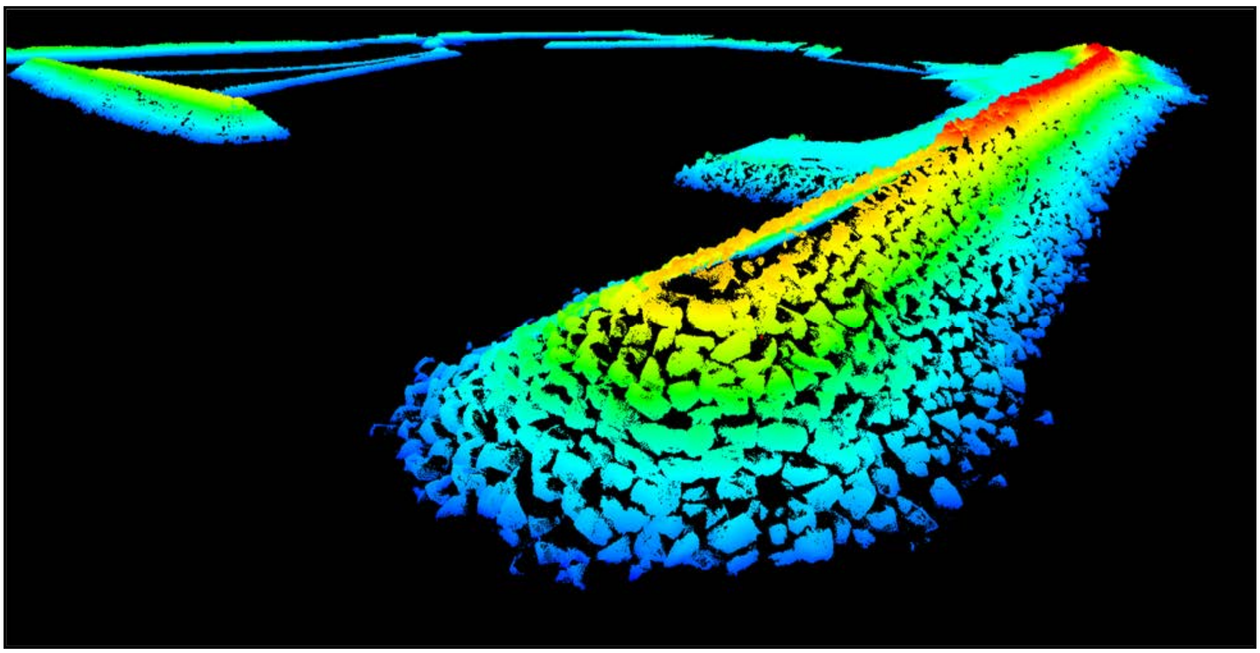

Figure 12 3D Point Cloud of LiDAR Data

i. QC and Calibration

RTK Observations of a reference point on the scanner mounting plate were performed prior to acquisition to verify the offsets on each axis. The measured values from the RTK rover were compared to the values computed in real-time by the data collection software QINSy.

8. HYDROGRAPHIC SURVEY

a. Methods & Procedures

Multibeam data was acquired September 30th through October 9th, 2022. Singlebeam data was acquired October 12th, 15th, and 16th, 2022. All multibeam data and positioning of the vessel data was acquired in QINSy software. Vessel positioning data was logged in POSView software. Sound velocity casts were collected to account for change throughout the water column at varying depths; casts were geospatially dispersed throughout the area to account for potential influencing environmental factors. Sound velocity was also measured and monitored at the sonar head to account for rapid changes and aid in beam forming for precise depth measurements. To compliment an overlap with mobile terrestrial LiDAR data, MBES data was collected during the highest tide during the duration of the project and scan data was collected during the lowest tide in St. Paul. An overview of the data can be seen below in Figure 13.

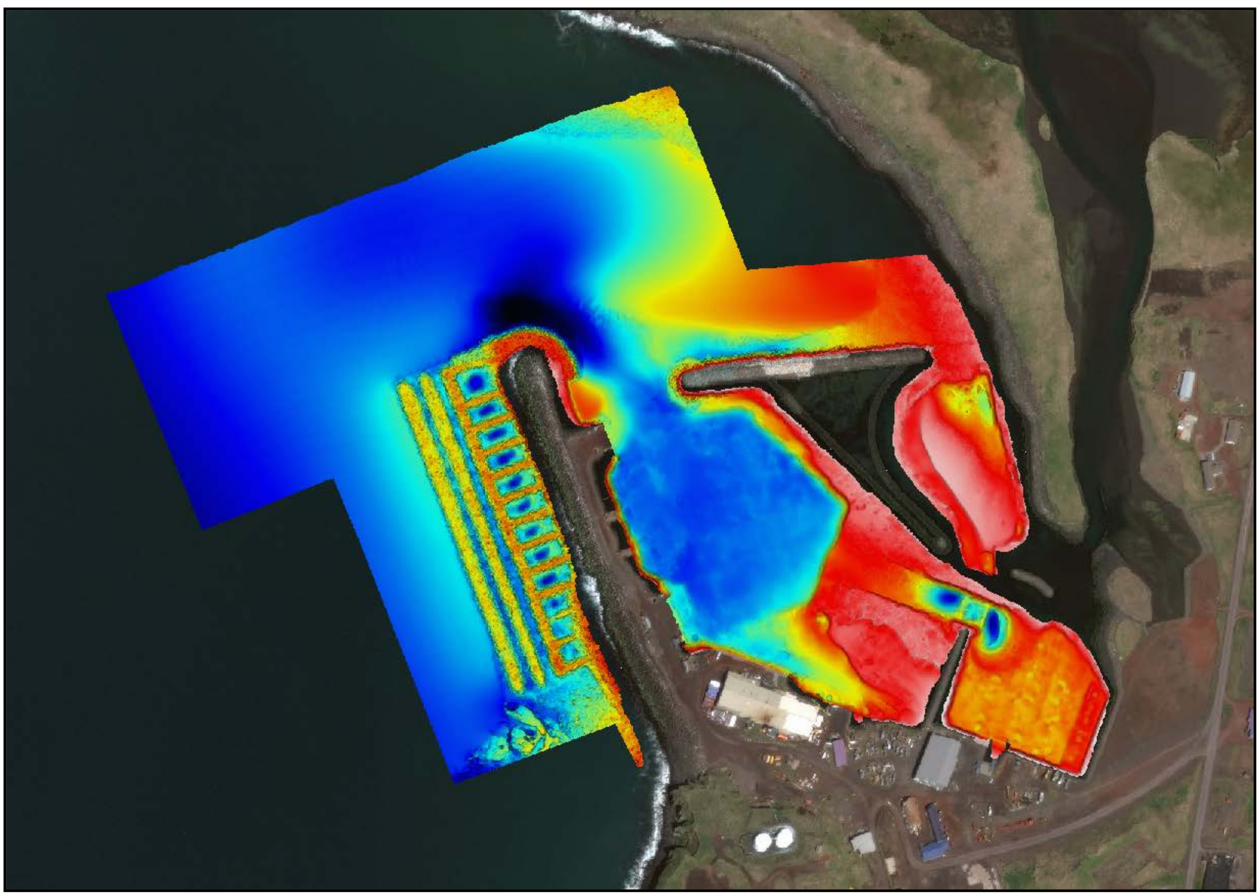

Figure 13 Overview of MBES Data in St. Paul Harbor

Singlebeam and topographic data was collected within the lagoon survey area. Within the lagoon, Singlebeam data was collected along 250ft transects. An overview of the Singlebeam can be seen below in Figure 14.

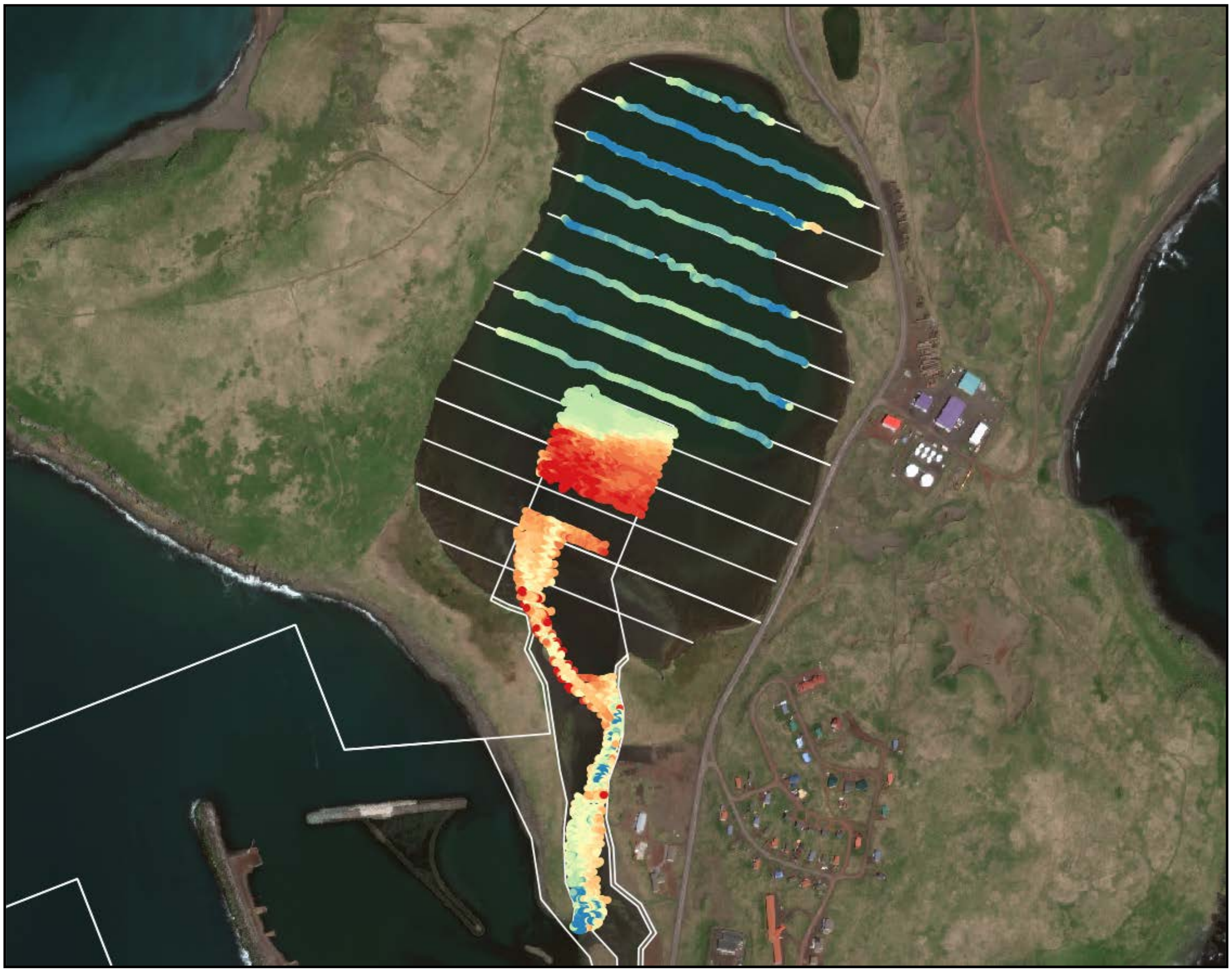

Figure 14 Overview of SBES Collection

b. Data Processing & Calibration

i. Patch Test

A patch test calibration quantifies and adjusts for misalignment angles between the multibeam sonar and the IMU. During the survey, specific planned lines were run to account for Roll, Pitch, and Yaw misalignment values.

Based on this patch test, each of the three misalignment angles can be isolated and corrected in post processing. An example of a pre and post patch test calibration can be seen below in Figure 15 and Figure 16.

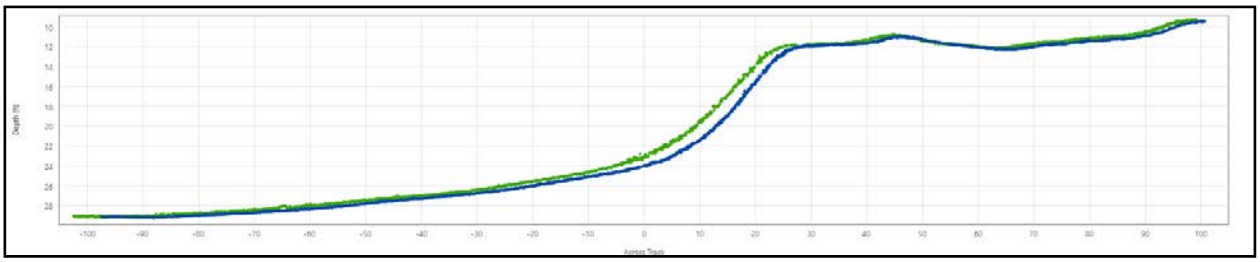

Figure 15 Example Pre-Patch Test Pitch Calibration

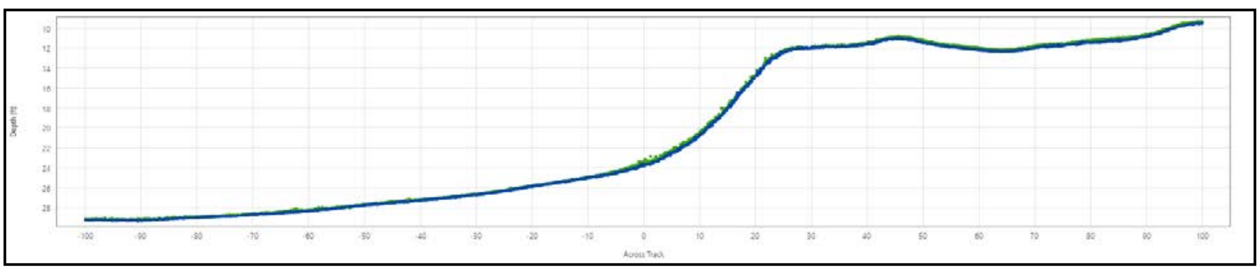

Figure 16 Example Post-Patch Test Pitch Calibration

ii. Vessel Position Data

Position data was post-processed in Applanix POSPac MMS Inertial processing software using both the vessel data file and receiver file (RINEX). This allowed for the creation of a more accurate and robust Smoothed Best Estimate of Trajectory (SBET) solution which was applied to both the Multibeam and LiDAR data for positioning corrections and horizontal and vertical control throughout the duration of the surveys. Prior to applying corrections, the SBET was analyzed for errors as seen below in Figure 17. After the data was analyzed for errors, the full motion and position solution of the SBET was applied to the MBES data to maximize overall accuracy.

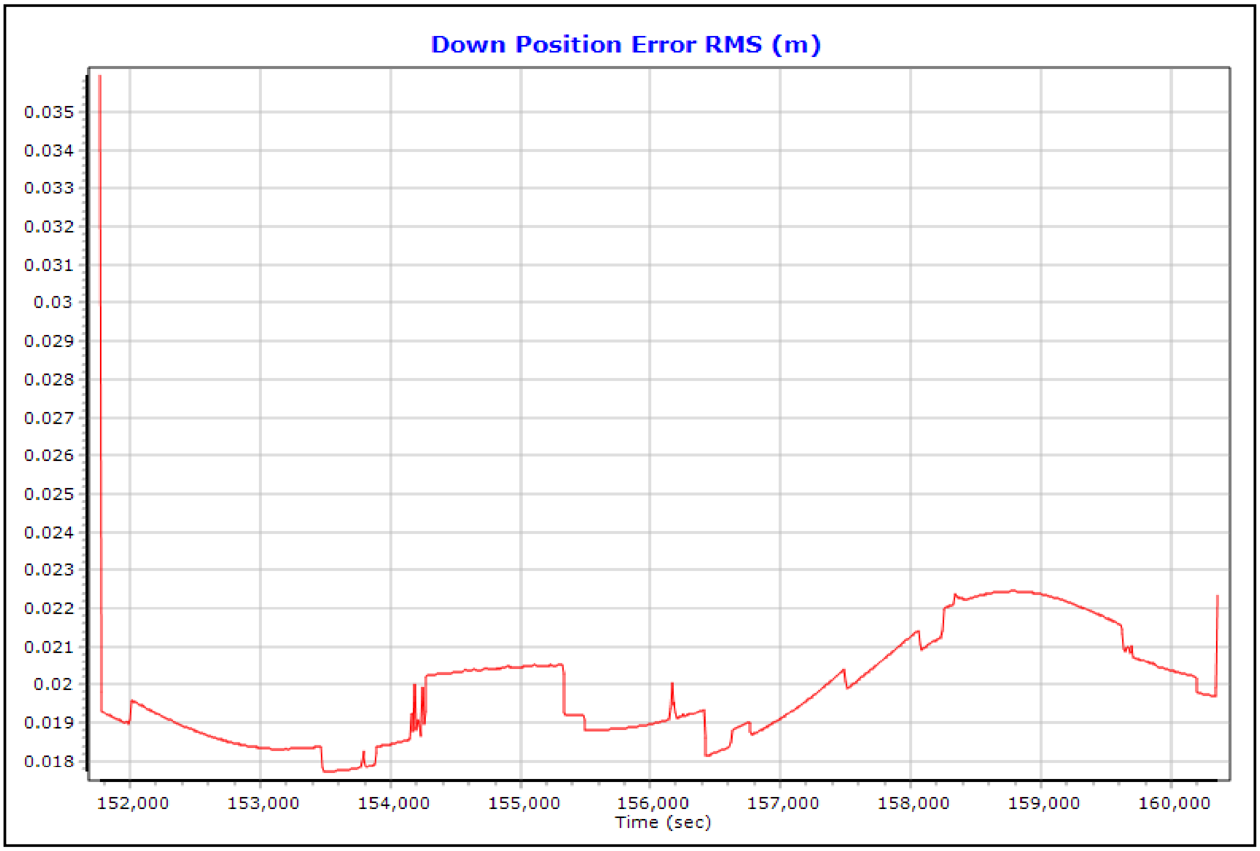

Figure 17 Example of Down Position Error for the Multibeam/LiDAR Surveys

iii. Multibeam Bathymetry Data

All MBES bathymetry data was processed in Qimera. The position SBET was applied to the data and then data was cleaned of spurious soundings caused by noise in the water column. Sound velocity casts were QC'ed against each other to check for outlier data and then applied in post processing as nearest in distance in time to assure each sounding is corrected by the appropriate cast.

Multibeam data was analyzed in both a 3D point cloud, which visualizes the full dataset, as well in 2D which is down sampled as a gridded dataset. Cleaning and analyzing data in point cloud and gridded data set gives the ability to fully analyze features and environments from different perspectives. The gridded dataset gives a representation of the general trend in bathymetry whereas depths, geological features, and objects can be better visualized by looking at the data in a 3D environment. Figure 18 shows a 3D view from the software used to view the bathymetry surface to look for geological features and objects. Figures 20 through 24 give an overview of each dredge area and the areas that are shoaler than project depth in bright green. Figures 25 through 29 are profiles of different areas within the survey area.

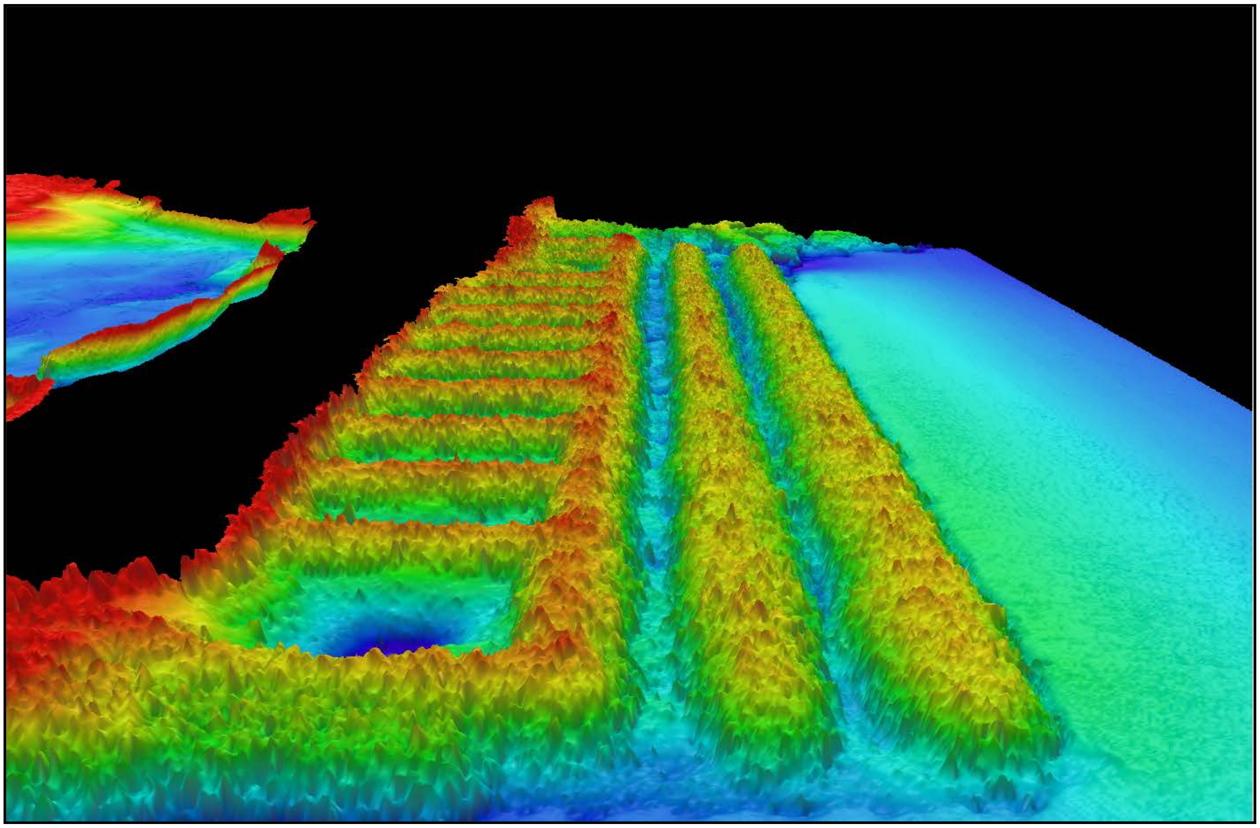

Figure 18 Typical Bathymetry gridded surface in 3D environment (vertical exaggeration x6)

Data was gridded at the highest resolution that the data coverage allowed. The resulting grid cell size was 1.5ft x 1.5ft. The point cloud data allows for a better understanding of object definition by viewing in 3D. A view of the point cloud data can be seen below in Figure 19.

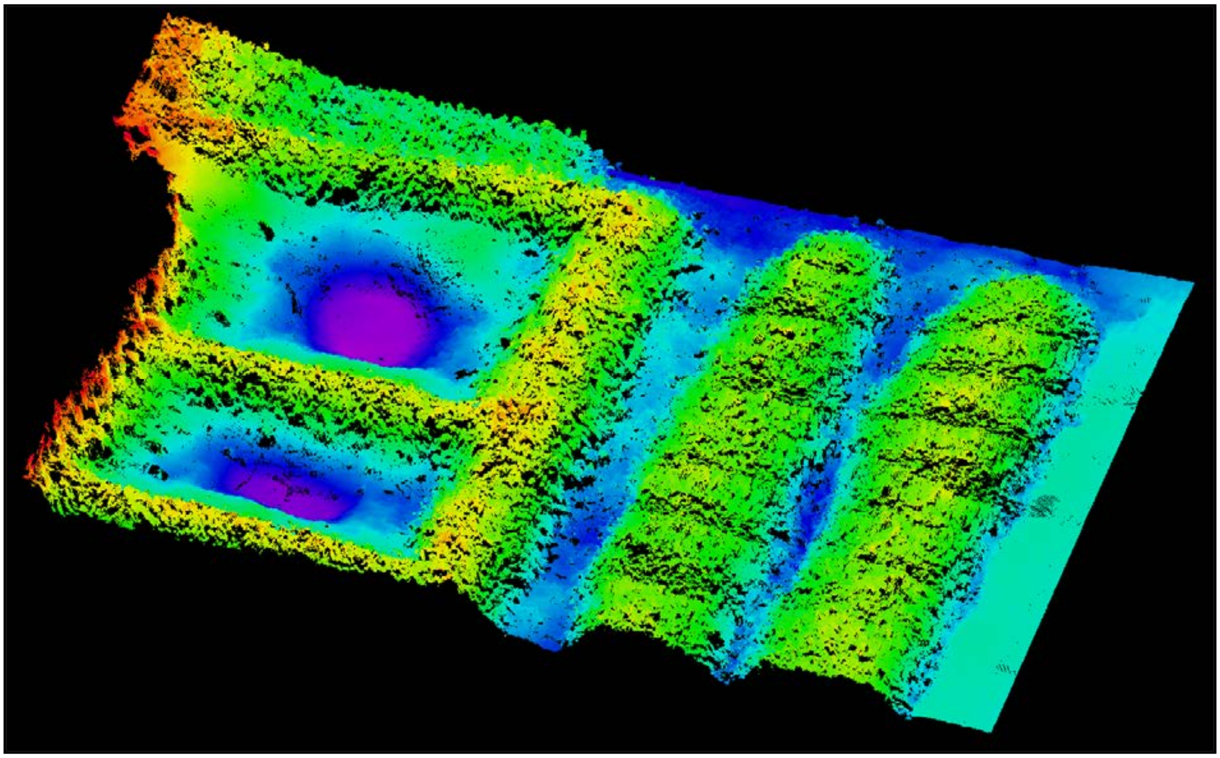

Figure 19 Point cloud of MBES data (vertical exaggeration x5)

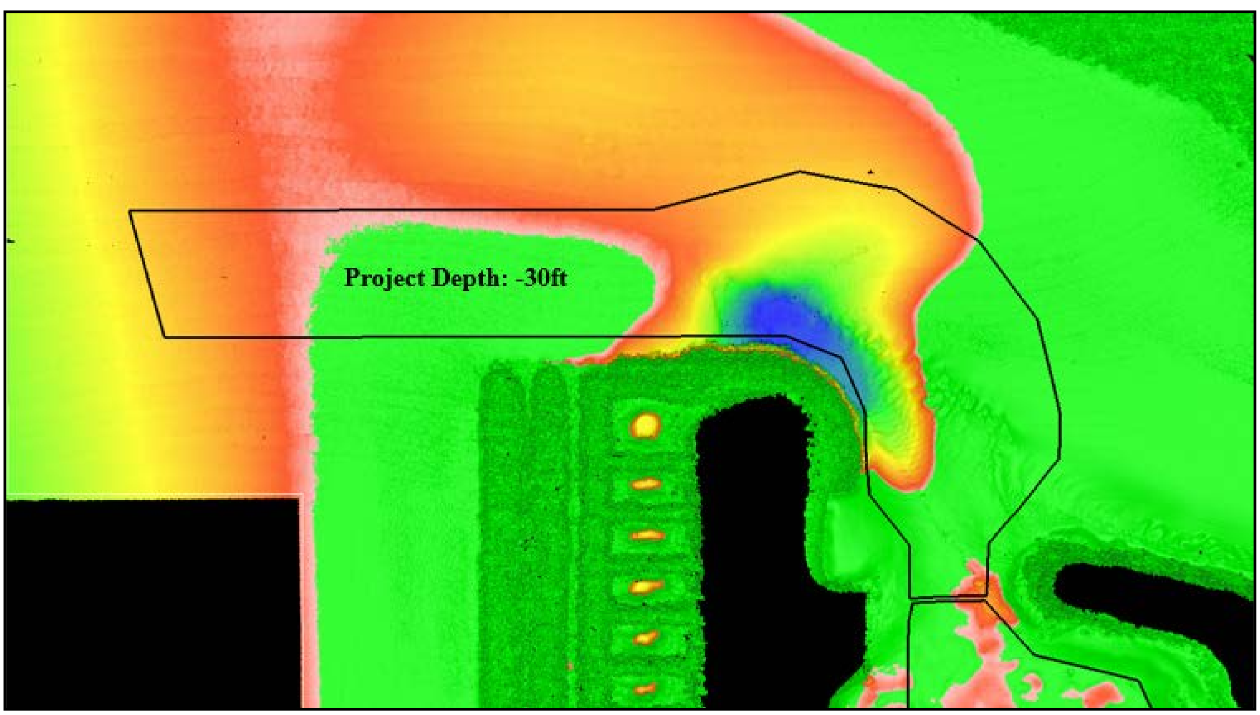

Figure 20 Project Depth of -30ft MLLW colored green within St. Paul Harbor Entrance

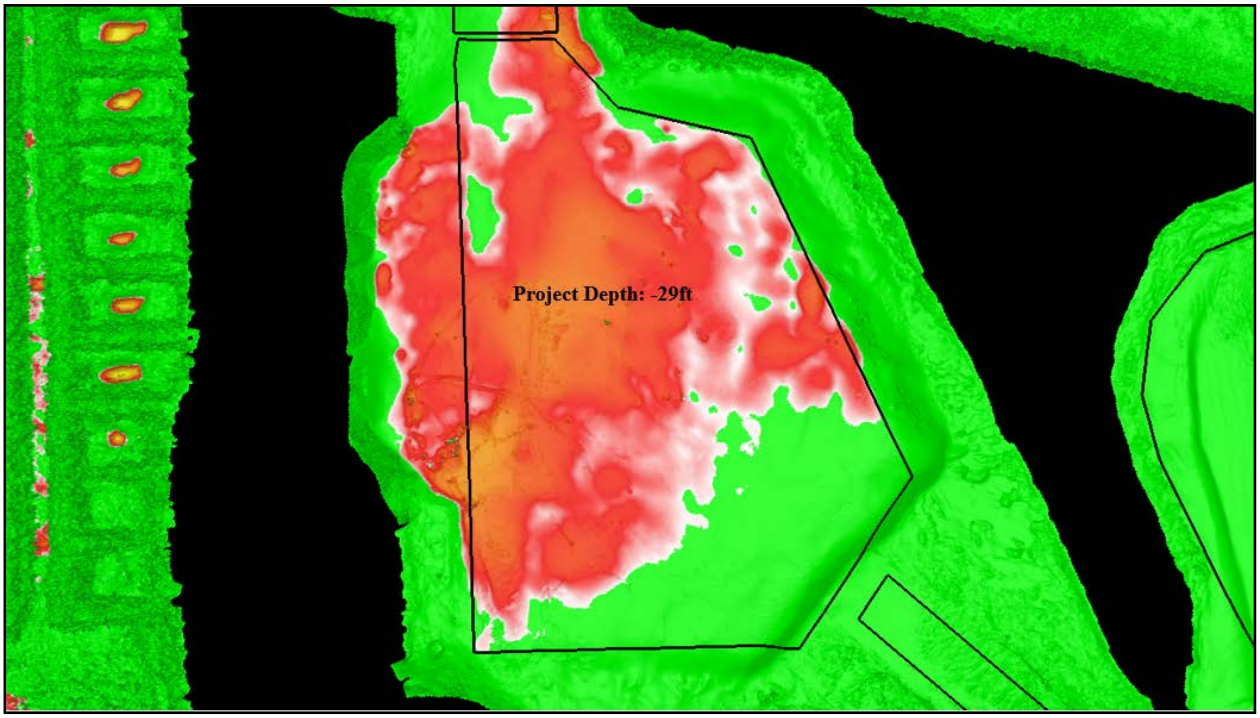

Figure 21 Project Depth of -29ft MLLW colored green within St. Paul Harbor

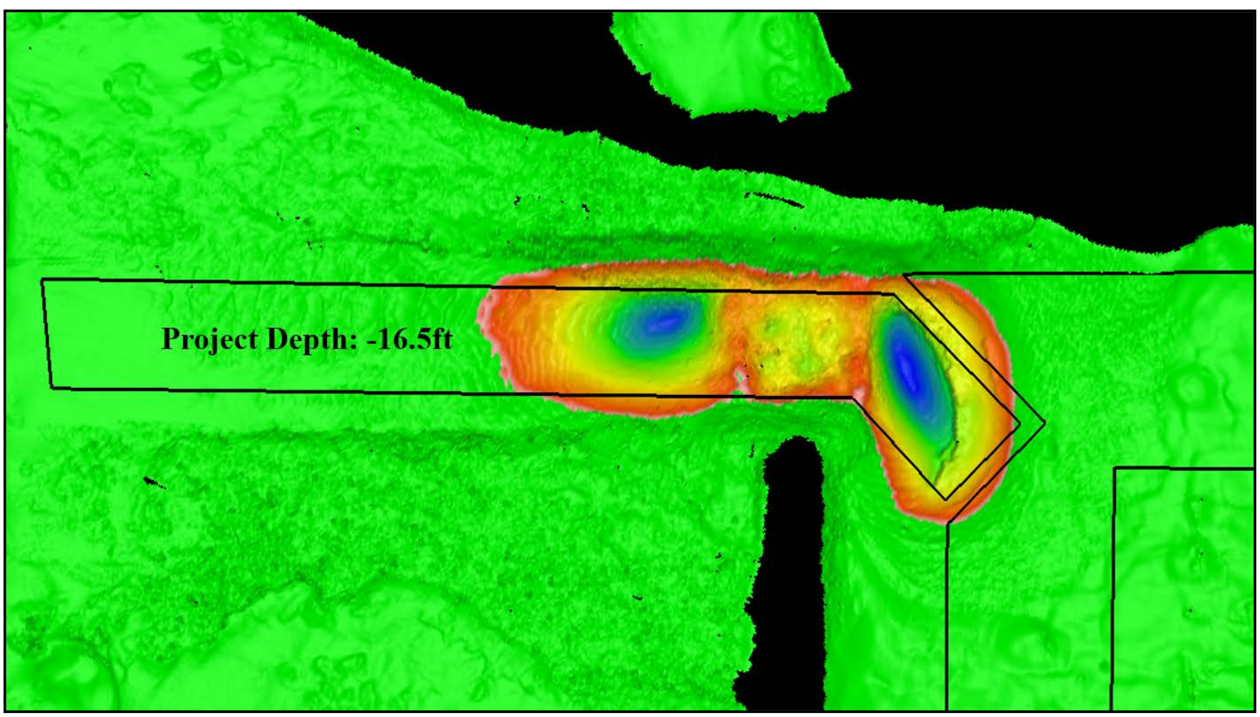

Figure 22 Project Depth of -16.5 MLLW colored green within St. Paul Harbor

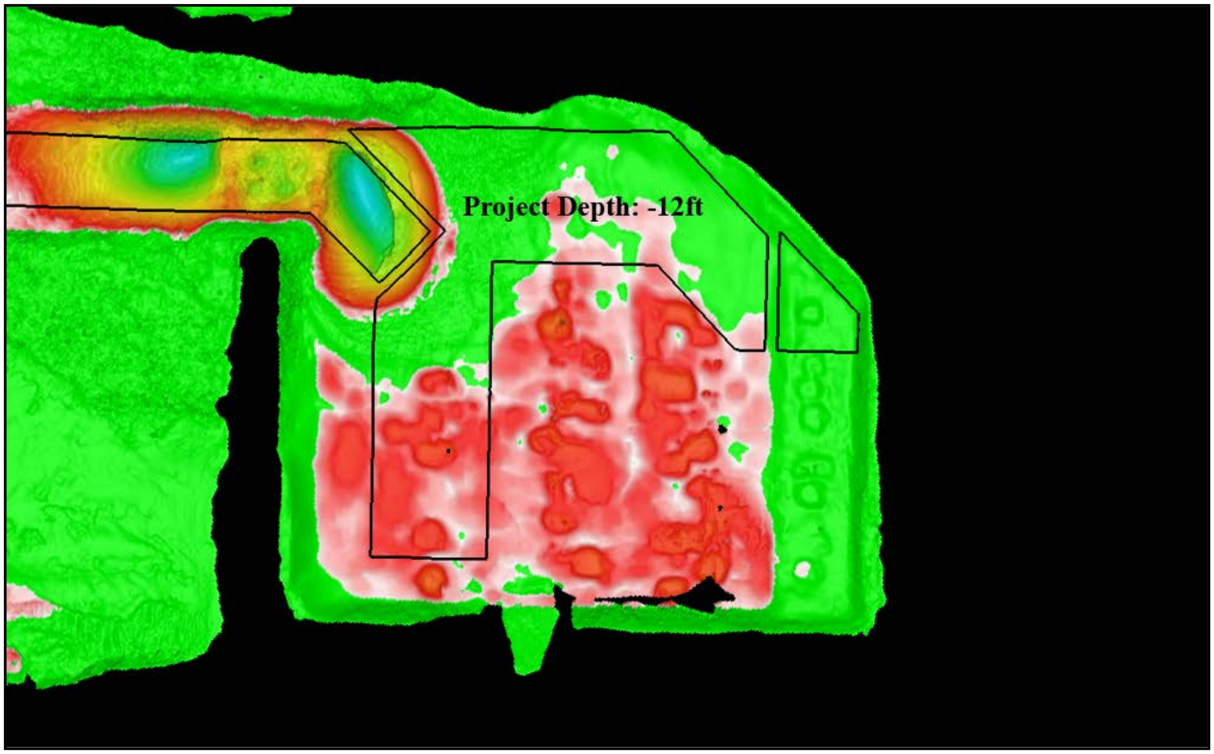

Figure 23 Project Depth of -12ft MLLW colored green within St. Paul Harbor

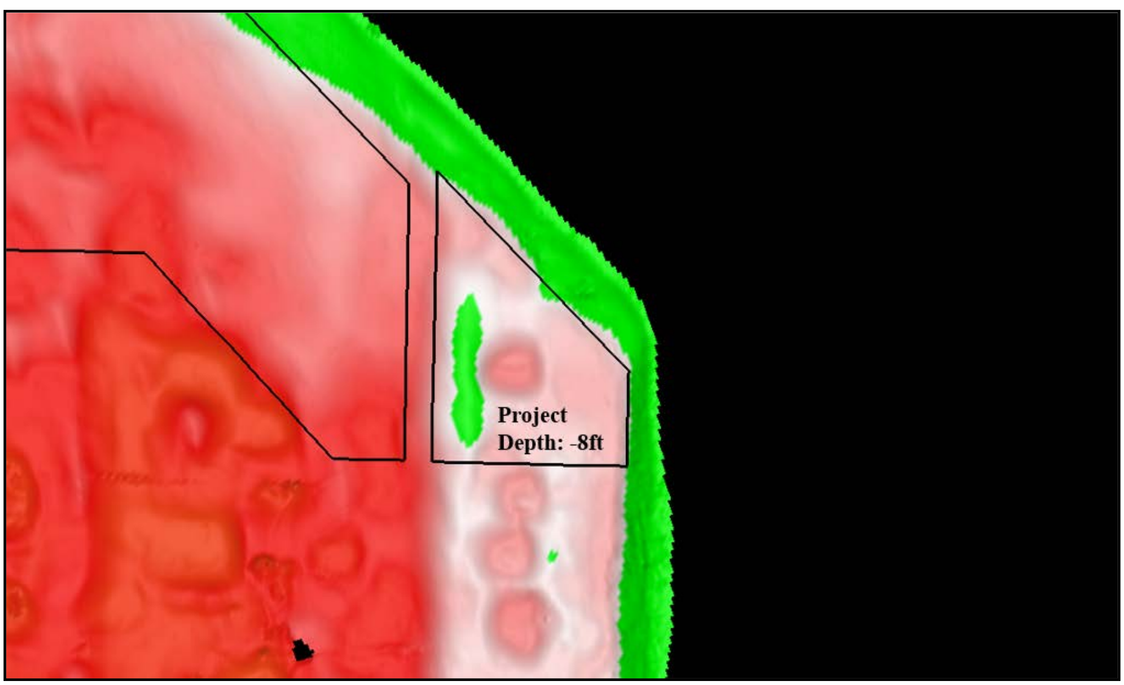

Figure 24 Project Depth of -8ft MLLW colored green within St. Paul Harbor Entrance

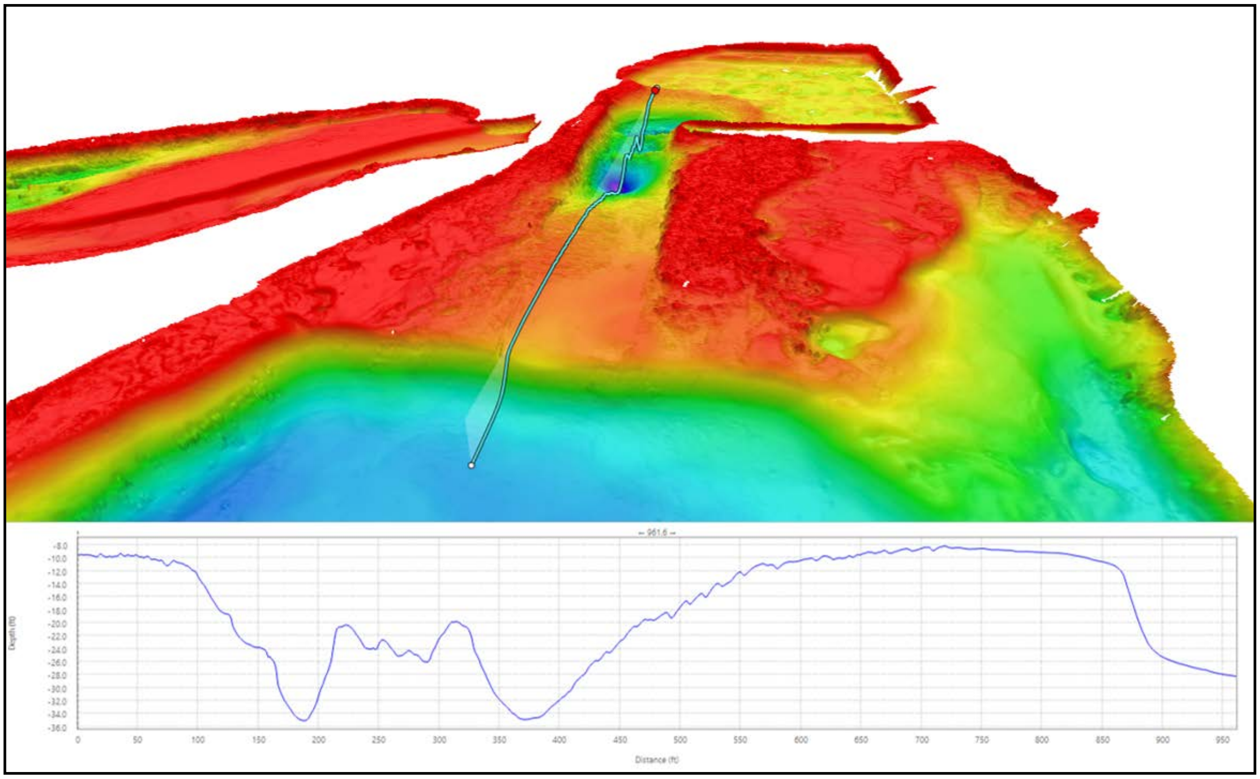

Figure 25 Cross Section from NW to SE of St. Paul Harbor Small Entrance Channel

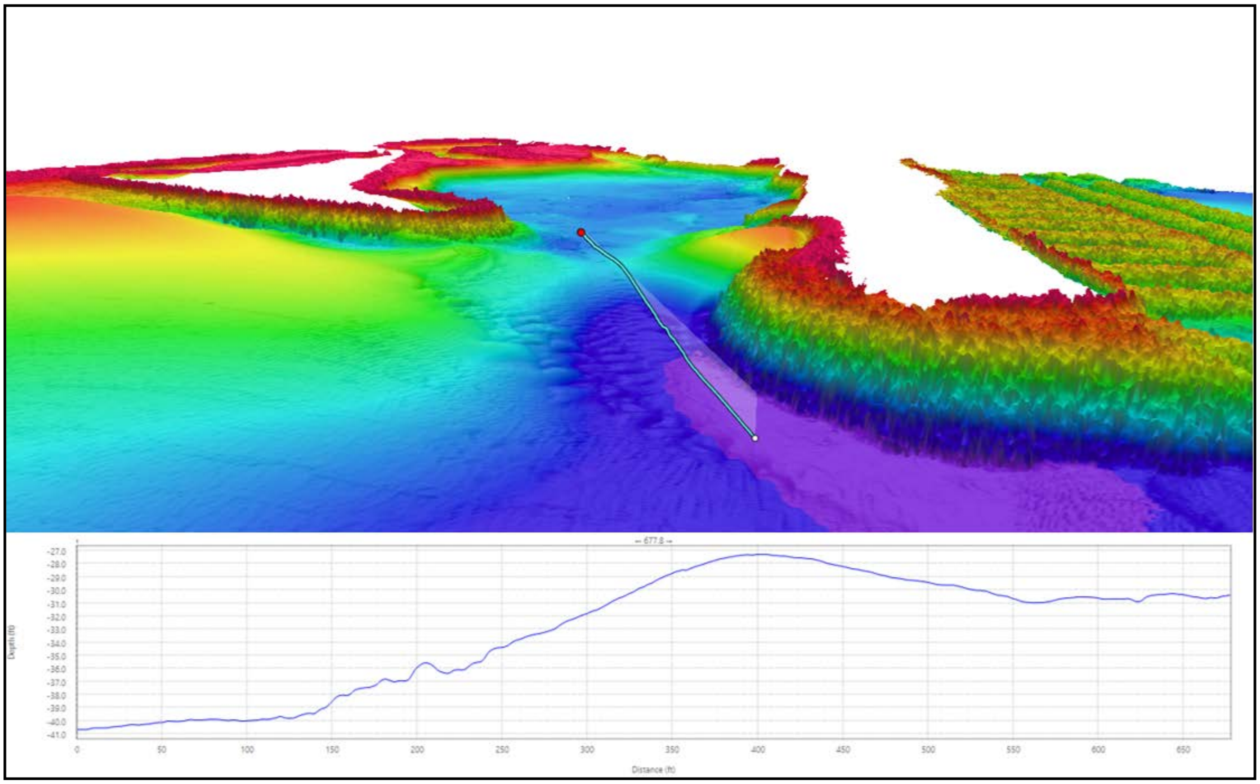

Figure 26 Cross Section from NW to SE of St. Paul Harbor Large Entrance Channel

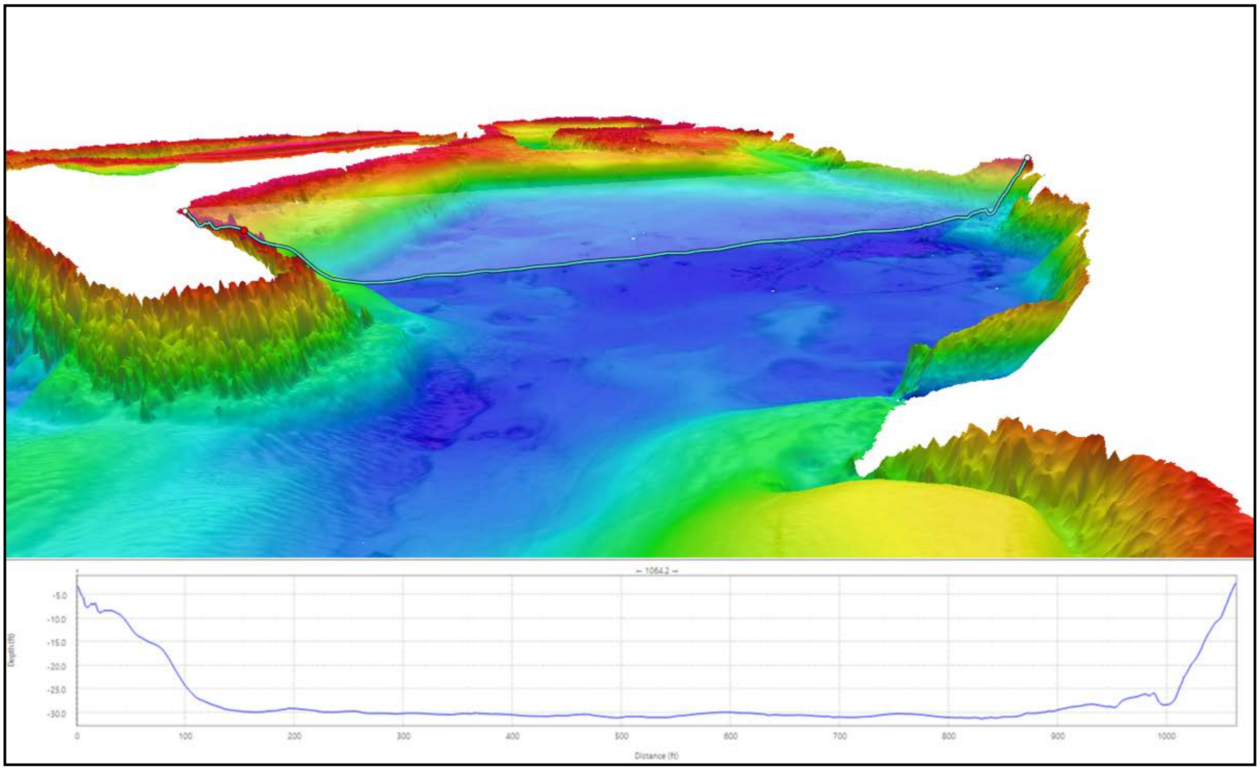

Figure 27 Cross Section from NE to SW of St. Paul Harbor Maneuvering Area

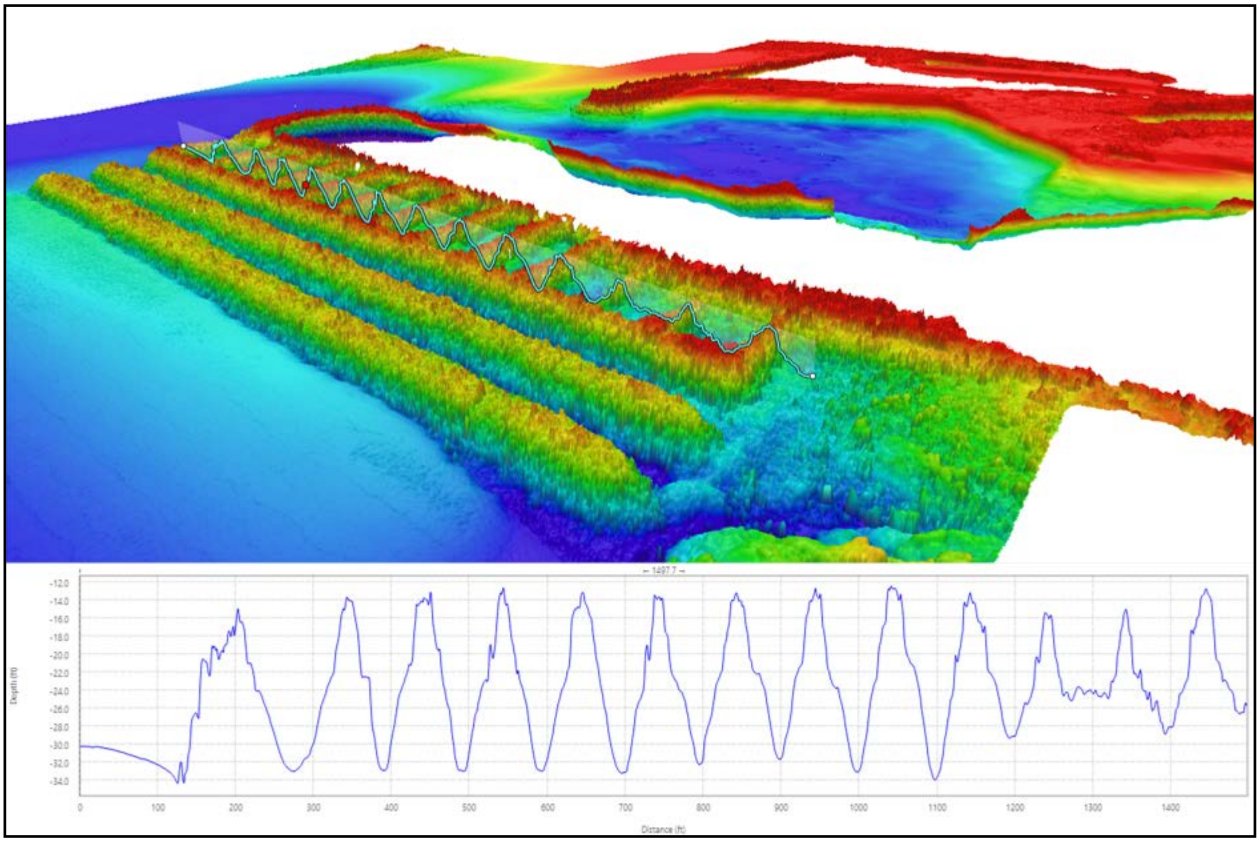

Figure 28 Cross Section from N to S of St. Paul Harbor Submerged Breakwater

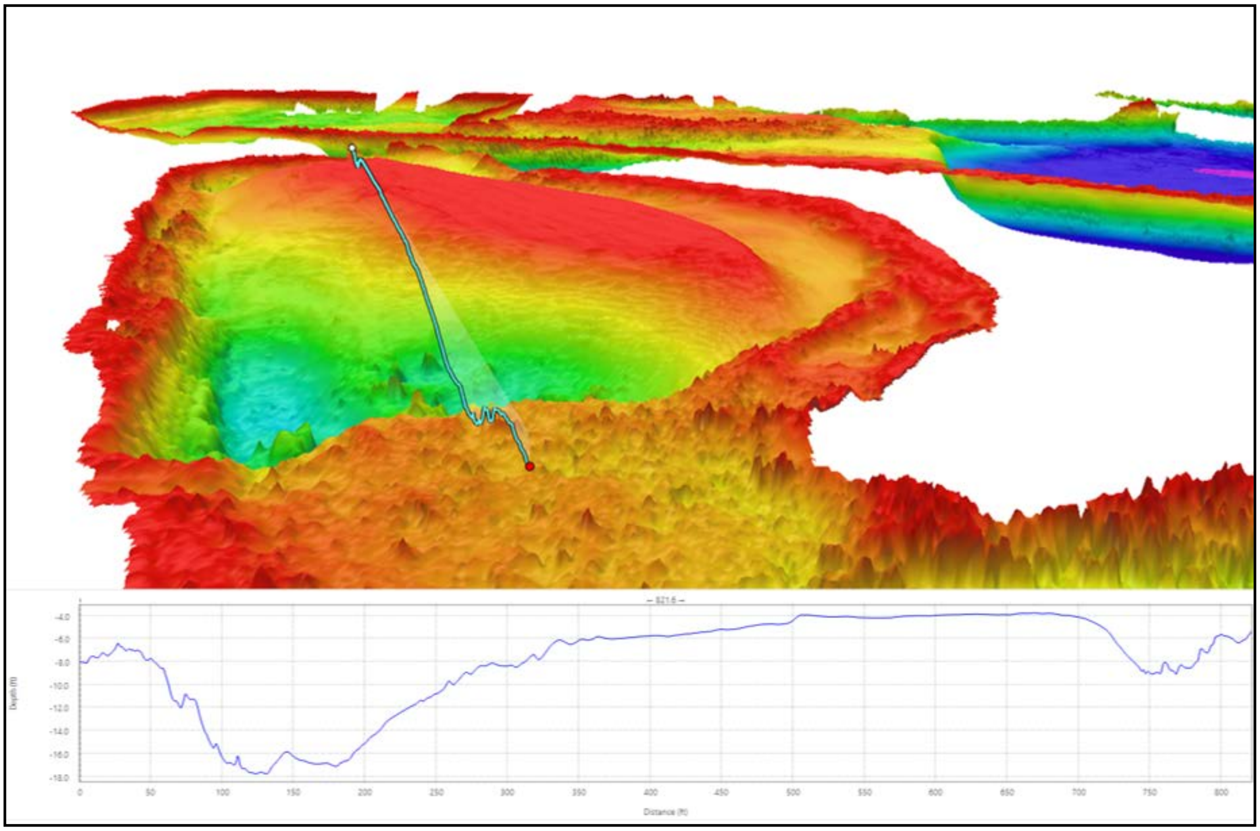

Figure 29 Cross Section from N to S of St. Paul Harbor Sediment Area

iv. QC and Calibration

RTK Observations of the MBES acoustic center, vessel reference point, and waterline were performed prior to acquisition. The measured values from the RTK rover were compared to the values computed in real-time by the data collection software QINSy.

A calibration patch test was conducted prior to survey operations to eradicate any heave, pitch, or roll artifacts in the data derived from installation alignment angles. Separate line pairs for roll, pitch, and yaw were collected and alignment values were calculated and applied prior to MBES data collection.

Real-time standard deviation plots for overlapping survey data were created and monitored throughout the survey. Collecting Multibeam data with an active standard deviation layer ensures all erroneous data or objects of interest stand up due to a high standard deviation value.

Comparisons were made between the Multibeam data, LiDAR data, and topographic data. The overlap between all three surveys serves as a QC to quantify and verify that blunders do not exist within each data set. An overview of all three datasets can be seen below in Figure 30 and Figure 31; the red data represents LIDAR data while the yellow is RTK topo, and the blue is a Multibeam shoal grid.

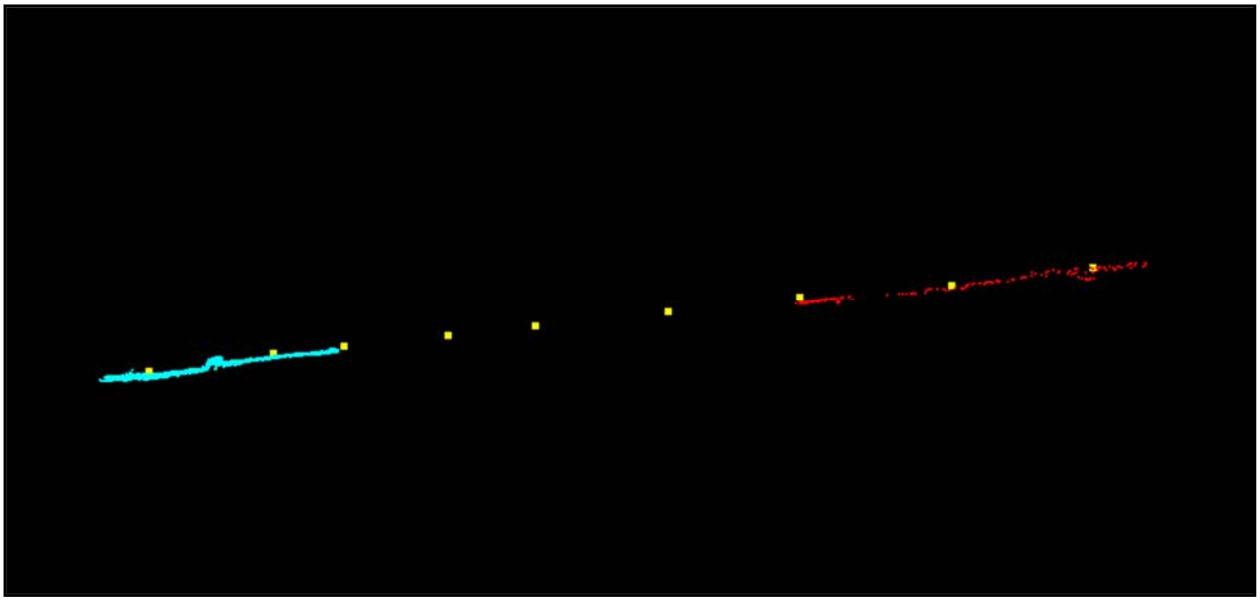

Figure 30 Overview of RTK Topo (Yellow), LiDAR (Red) and MBES (Blue)

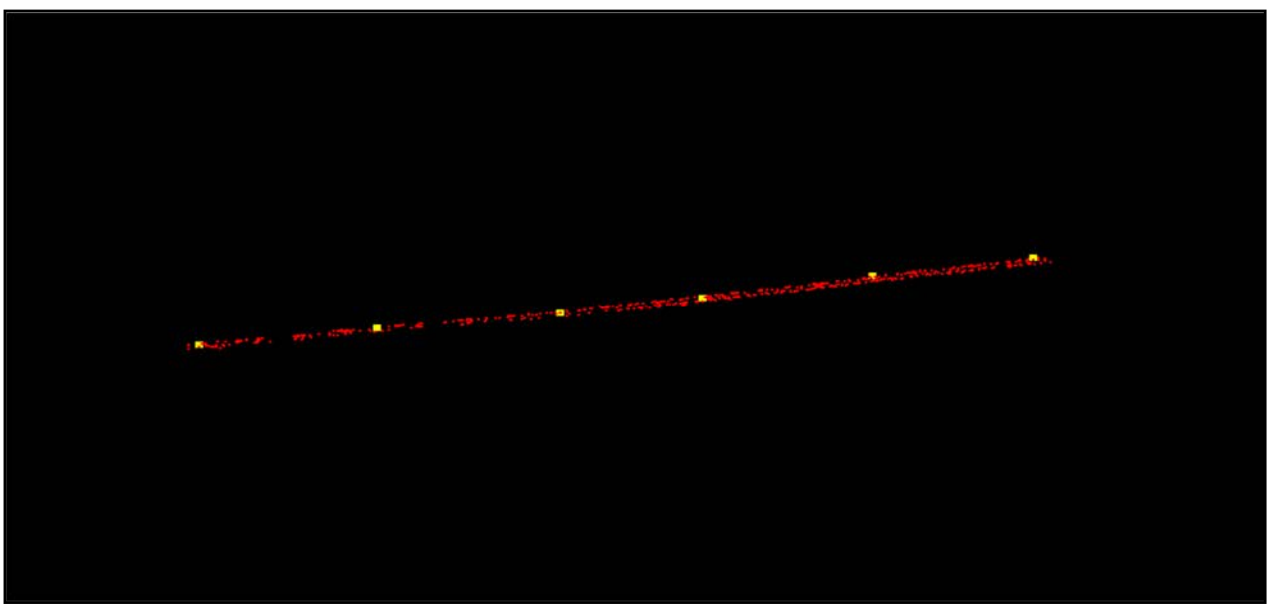

Figure 31 Overview of LiDAR (Red) and RTK Topographic Data (Yellow)

v. Dataset Comparison

Comparisons were made between the MBES and LiDAR datasets collected October 2022 and the dataset collected August 2020. Figure 32 shows an overall difference grid between the two data sets and accompanying profile views can be seen in Figure 33 though Figure 35.

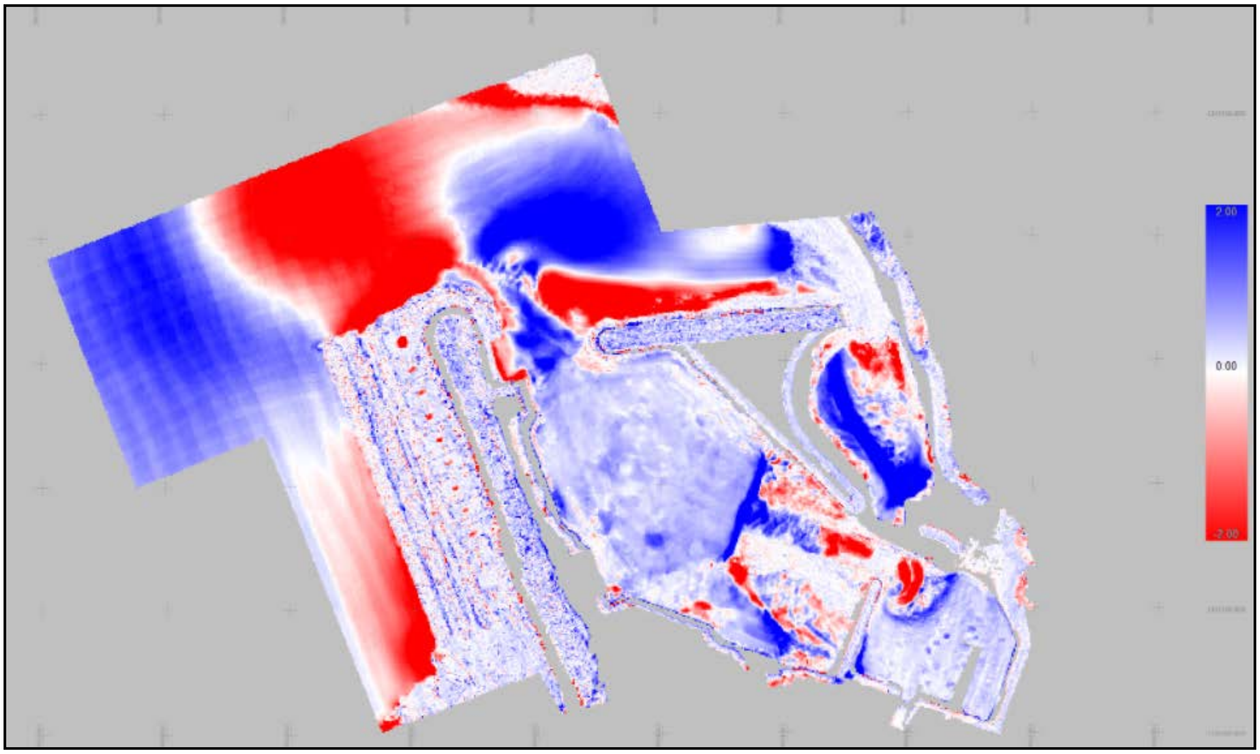

Figure 32 MBES Surface Differences October 2022 vs August 2020

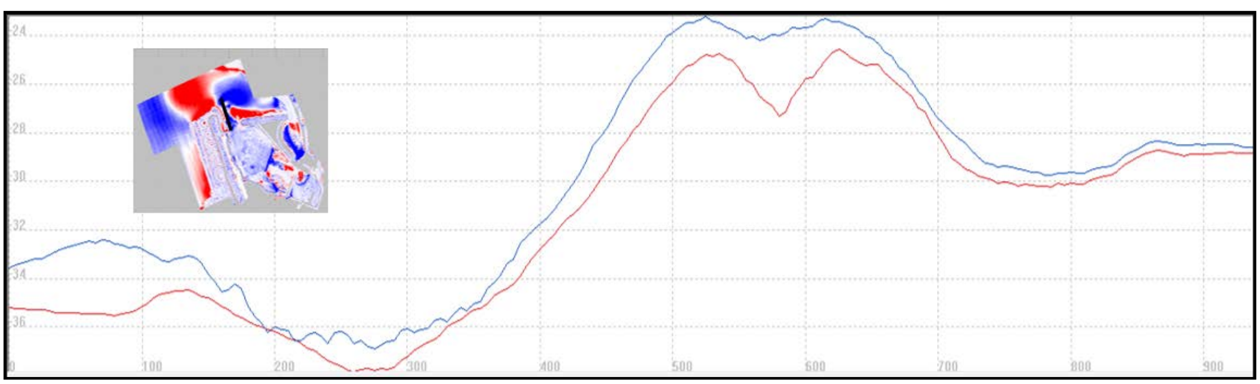

Figure 33 Profile of October 2022 (Blue) vs August 2020 (Red)

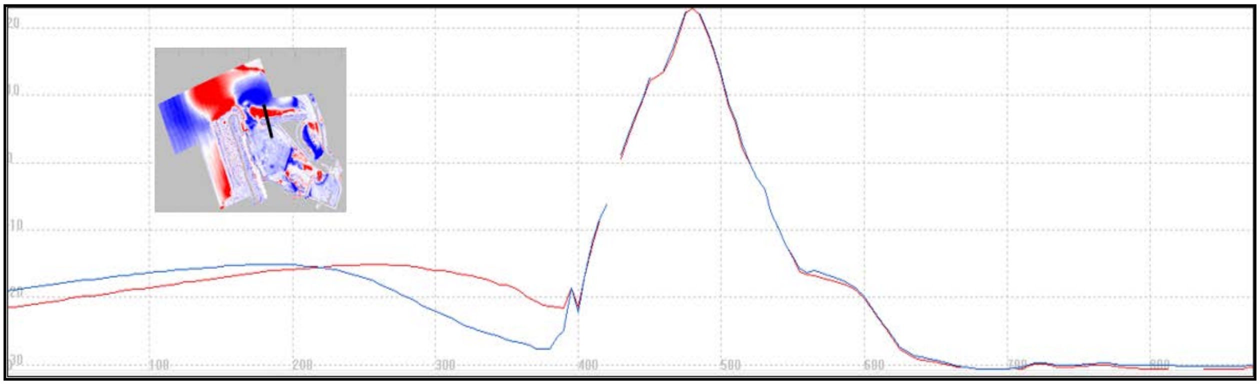

Figure 34 Profile of October 2022 (Blue) vs August 2020 (Red)

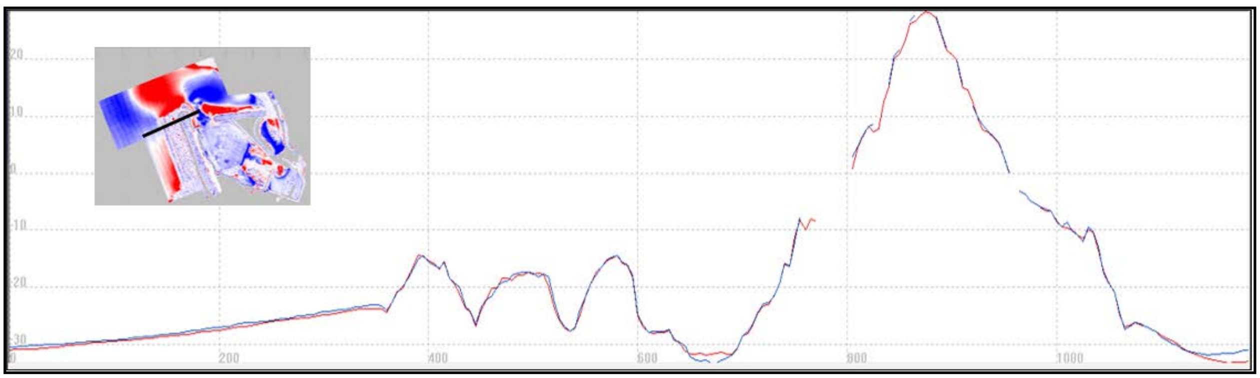

Figure 35 Profile of October 2022 (Blue) vs August 2020 (Red)

9. OBSTRUCTIONS & OBJECTS OF INTEREST

In St. Paul Harbor, ten (10) Obstructions to Navigation were located in the MBES data. The horizontal position, size, and shoalest depth of these objects was determined using the MBES data. Figure 36 shows an overview of the Objects and Obstructions within the survey area. Information on these objects, along with selected images, can be found below.

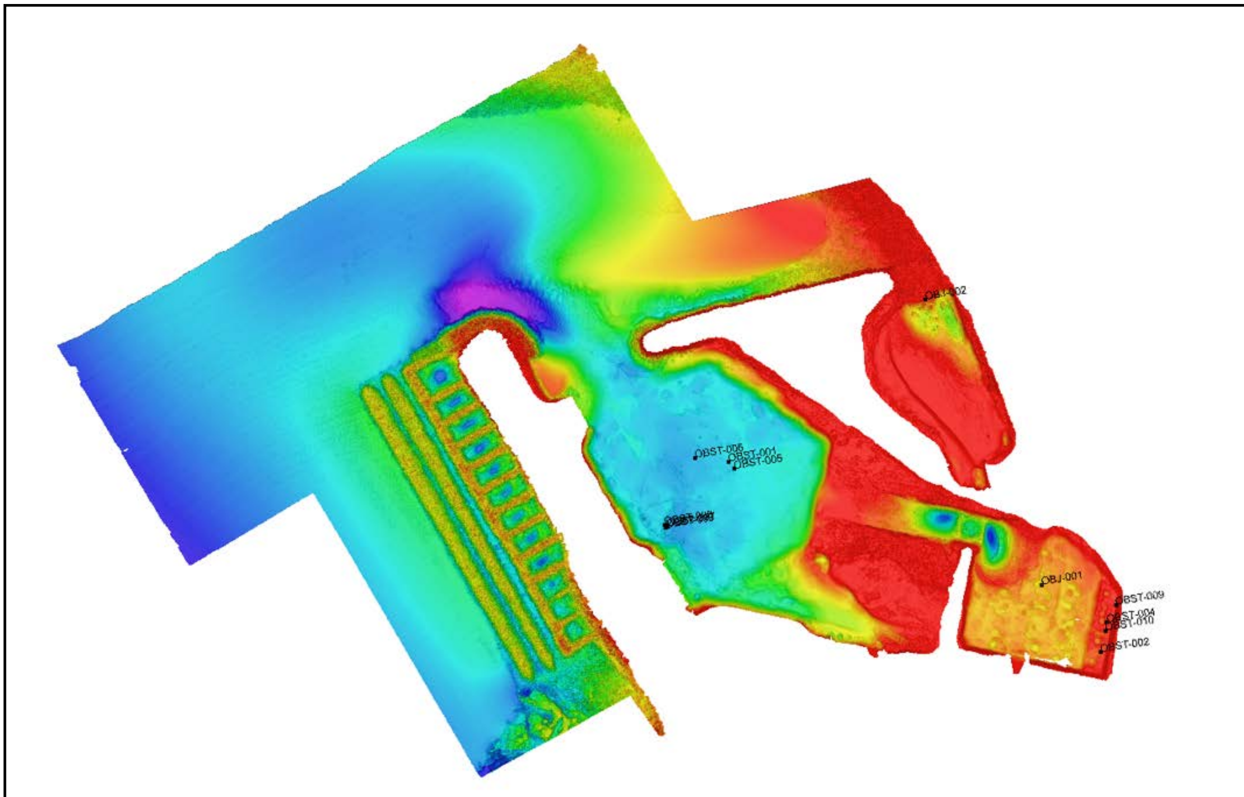

Figure 36 Location of Obstructions and Objects to Navigation within St. Paul Harbor

i. Obstructions to Navigation

The Obstruction to Navigation geodatabase detailing location along with depths and dimensions can be found below in Table 6.

Table 6 St. Paul Harbor Obstructions to Navigation

St. Paul Harbor-Obstructions to Navigation				
Easting (ft)	**Northing (ft)**	**Shoalest Depth (MLLW, ft)**	**Dimensions (ft)**	**OBJ ID**
1,584,011	1,142,083	-28.0	5x5x1	OBST-001
1,585,311	1,141,146	-8.7	2x5x2	OBST-002
1,583,732	1,141,866	-26.7	5x4x3	OBST-003
1,585,352	1,141,255	-7.5	2x4x2	OBST-004
1,584,028	1,142,052	-28.6	7x5x2	OBST-005
1,583,885	1,142,116	-27.9	5x7x3	OBST-006
1,583,738	1,141,870	-28.3	4x3x3	OBST-007
1,583,729	1,141,879	-27.8	18x4x3	OBST-008
1,585,395	1,141,316	-7.7	4x4x2	OBST-009
1,585,341	1,141,225	-8.5	5x4x1	OBST-010

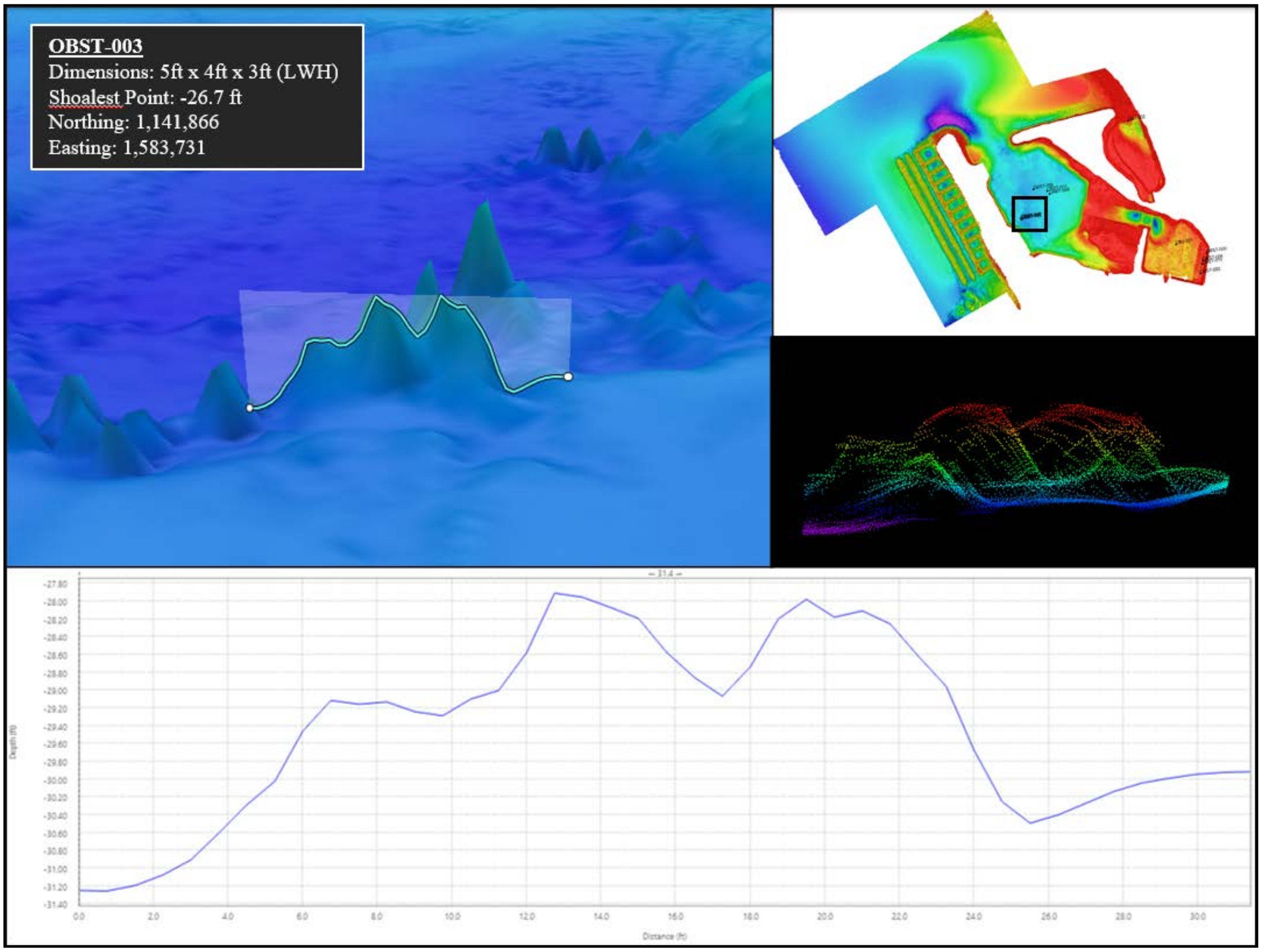

Figure 37 OBST-003: 3D, Profile, Point Cloud, and Overview

In Figure 37 above, OBST-003 is noted in detail. A 3D view, profile of bathymetry, point cloud view, and overview of object location can be seen. The obstruction has dimensions of 5ft x 4ft x 3ft and is located in the Maneuvering Area of St. Paul Harbor. With a shoalest depth of -26.7ft MLLW, it is considered an Obstruction to Navigation given its size, span, and location within the harbor.

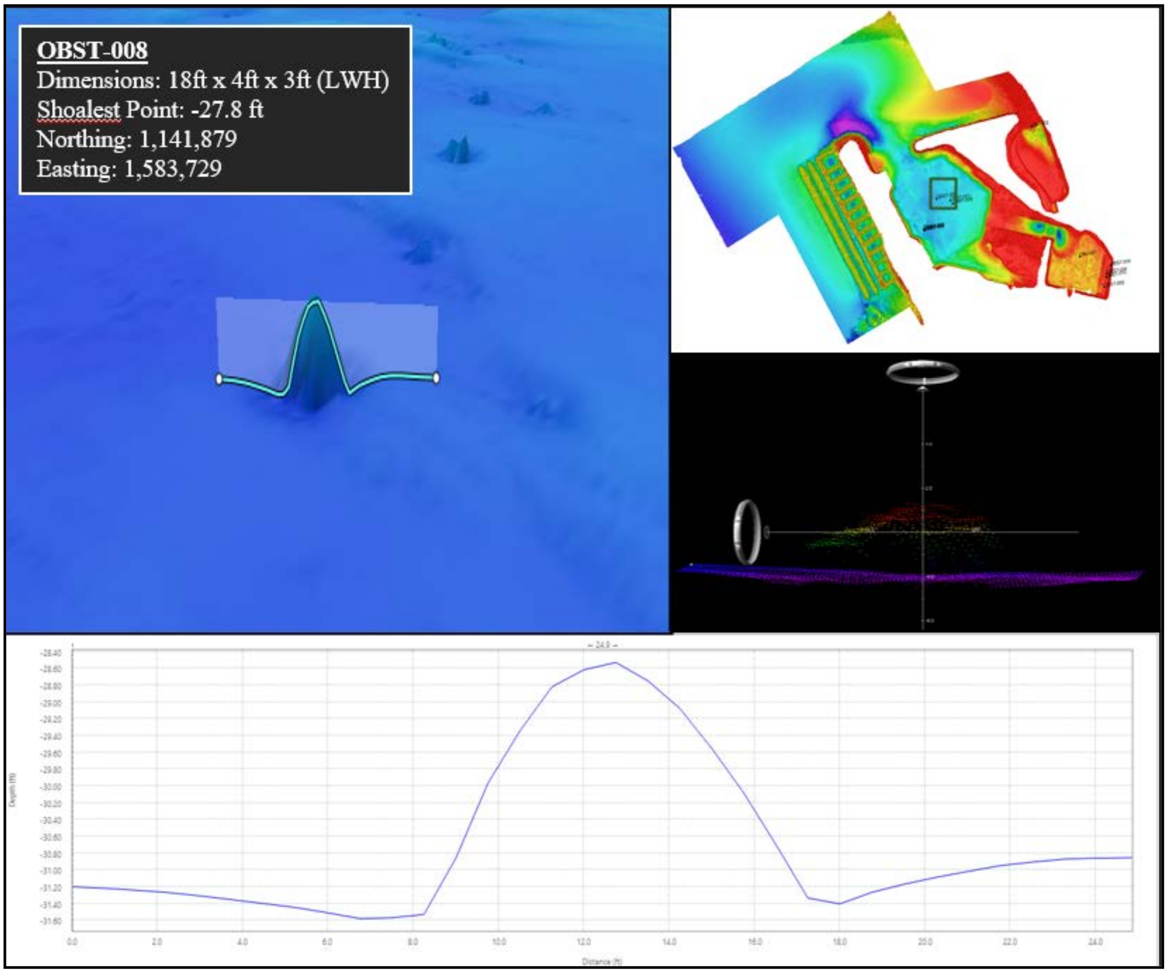

Figure 38 OBST-008: 3D, Profile, Point Cloud, and Overview

In Figure 38 above, OBST-008 is noted in detail. A 3D view, profile of bathymetry, point cloud view, and overview of object location can be seen. The obstructions has dimensions of 18ft x 4ft x 3ft and is located in the Maneuvering Area of St. Paul Harbor. With a shoalest depth of -27.8ft MLLW, it is considered an Obstruction to Navigation given its size and location.

ii. Objects of Interest

In St. Paul Harbor, two (2) Objects of Interest were located in the MBES data. The horizontal position, size, and shoalest depth of these objects was determined using the MBES data. Information on these objects, along with selected images, can be found below.

The Objects of Interest geodatabase detailing location along with depths and dimensions can be found below in Table 7.

Table 7 St. Paul Harbor Objects of Interest

St. Paul Harbor-Objects of Interest				
Easting (ft)	**Northing (ft)**	**Shoalest Depth (MLLW, ft)**	**Dimensions (ft)**	**OBJ ID**
1,585,130	1,141,434	-12.6	2x2x3	OBJ-001
1,584,852	1,142,584	-7.4	26x3x3	OBJ-002

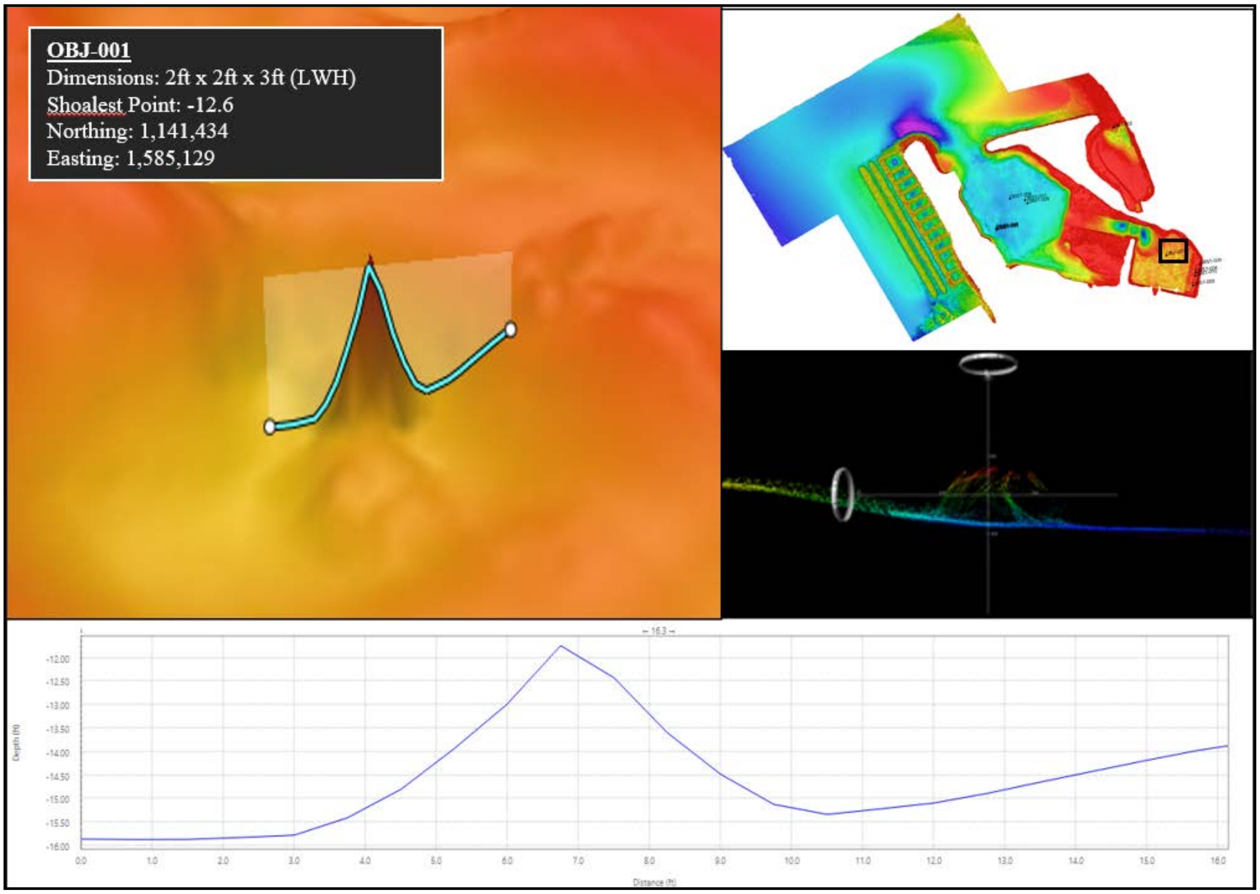

Figure 39 OBJ-001: 3D, Profile, Point Cloud, and Overview

In Figure 39 above, OBJ-001 is noted in detail. A 3D view, profile of bathymetry, point cloud view, and overview of object location can be seen. This is believed to be a large piece of debris with dimensions 2ft x 2ft x 3ft located in the Small Boat Harbor of St. Paul Harbor. With a shoalest depth of -12.6ft MLLW, it is considered an Object of Interest given its size and location within the harbor.

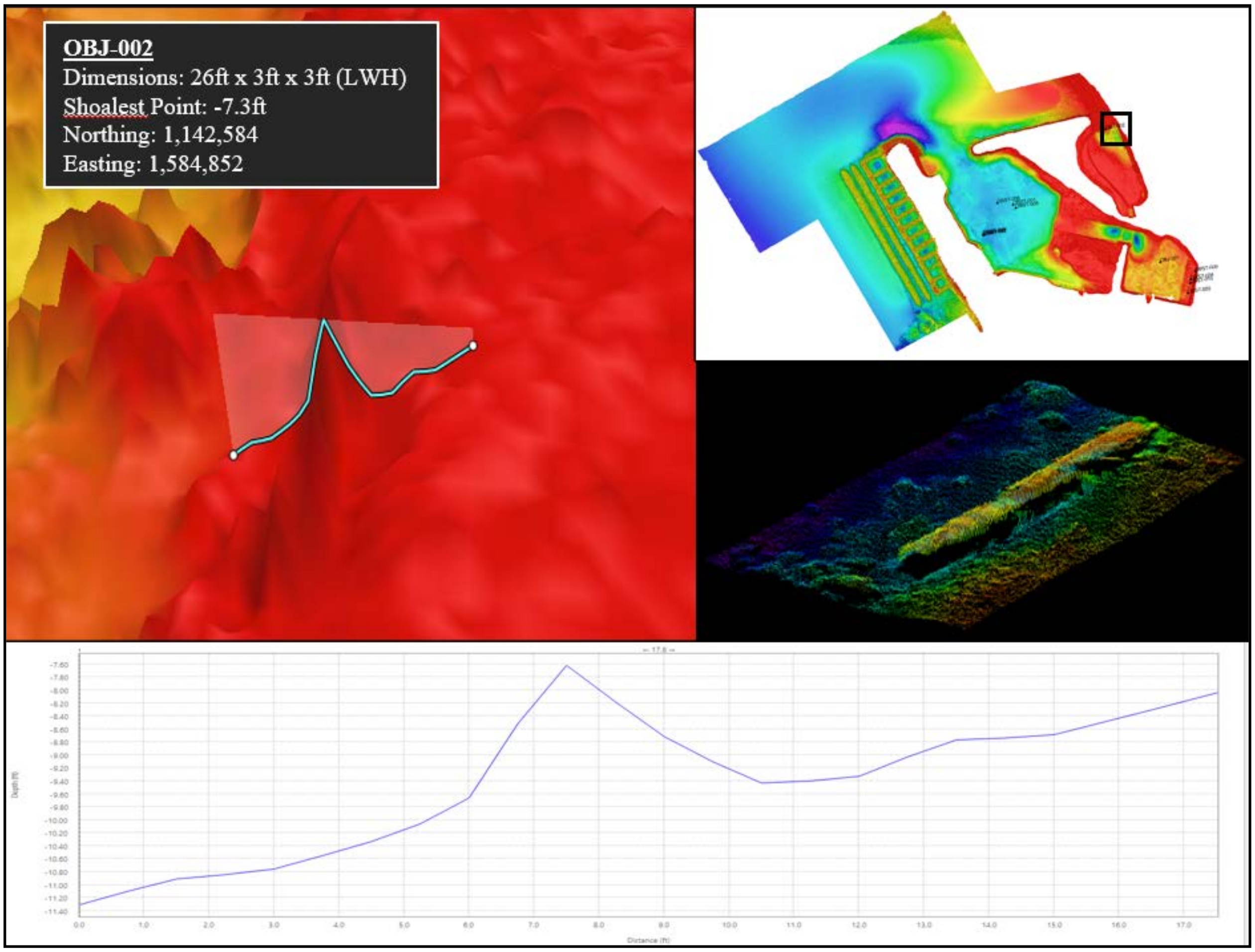

Figure 40 OBJ-002: 3D, Profile, Point Cloud, and Overview

In Figure 40 above, OBJ-002 is noted in detail. A 3D view, profile of bathymetry, point cloud view, and overview of object location can be seen. This is believed to be fishing debris with dimensions 26ft x 3ft x 3ft located in the Sediment Basin of St. Paul Harbor on the east side. With a shoalest depth of –7.3ft MLLW, it is considered an Object of Interest given its size and location.

10. NAVIGATION AIDS

Five (5) Navigation Aids were located within the St. Paul Harbor survey area. All Navigation Aids were located within the LiDAR dataset. All Navigation Aids were found in good condition. Images of the Navigation aids are in Figures 41 through 45. Additional Photos of all Navigation Aids can be found in Deliverables; 545_Navigation Aids.

Figure 41 Navigation Aid 27830 as seen from the breakwater

Figure 42 Navigation Aid 27831 as seen from a boat

Figure 43 Navigation Aid 27832 as seen from a boat

Figure 44 Navigation Aid 27834 as seen from a boat

Figure 45 Navigation Aid 27833 as seen from a boat

11. NAVD88 ELEVATION TIE

a. Methods & Procedures

Two (2) NOAA benchmark was observed for an extended period of time in order to process through OPUS to obtain NAV88 elevations to compute the shift to MLLW.

b. Results

The following benchmarks were observed with Trimble R8 Model 3 receivers for extended periods to produce OPUS solutions:

946 4242 RBD 1 (9 hours and 34 minutes)
946 4212 TERRA SP3 (9 hours and 3 minutes)

Table 8 *946 4212 TERRA SP3* OPUS Information

PID	Designation	Observation Date	Firm	Geoid Model	NAVD88 (ft)	Current to Previous (ft)
BBCN02	*946 4212 TERRA SP3*	8/30/2006	JOA	GEOID12B	15.931	N/A
BBCN02	*946 4212 TERRA SP3*	08/14/2020	eTrac	GEOID12B	15.859	-0.072
BBCN02	*946 4212 TERRA SP3*	10/05/2022	eTrac	GEOID12B	15.804	-0.055

Table 9 *RBD 1 1994* OPUS Information

PID	Designation	Observation Date	Firm	Geoid Model	NAVD88 (ft)	Current to Previous(ft)
BBGM90	*RBD 1 1994*	7/21/2019	eTrac	GEOID12B	28.986	N/A
BBGM90	*RBD 1 1994*	08/14/2020	eTrac	GEOID12B	28.910	-0.076
BBGM90	*RBD 1 1994*	09/27/2022	eTrac	GEOID12B	28.924	+0.014

12. HYPACK METADATA

Table 10 Hypack Metadata File

Metadata File Date	October 27, 2022
Survey Date	September 27 – October 16, 2022
Purpose	Project Condition Survey
Project Name	St. Paul Harbor
Area of Coverage	Survey Limits defined by USACE
Type of Survey	Hydrographic, Topographic, and Control
Access Constraints	None
Progress	Complete
Team Leader	Jensen Haebler
Survey Manager	Adam Taylor
Project Manager	Adam Taylor
Data Contact Person	Jensen Haebler
Organization	eTrac Inc
Address	617 S. Knik-Goose Bay Rd., Suite C
City	Wasilla
State	Alaska
Postal Code	99654
Metadata File Author	Cody Gibson
Organization	eTrac Inc
Telephone	(907) 373-3660
Address	617 S. Knik-Goose Bay Rd., Suite C
City	Wasilla
State	Alaska
Postal Code	99654
QA Person	Japeth Rupp
QA Date	October 27, 2022
Projected Coordinate System	Alaska State Plane Coordinate System
Datum Name	NAD 83 (CORS) Epoch 2003.00
Horizontal Zone	Alaska Zone 9
Projected Coordinate Units	U.S. Survey Feet
Implied Horizontal Accuracy	0.1 ft
Vertical Reference Datum	Mean Lower Low Water (MLLW)

Additional Deliverables

1) CAD FILES
- XML 12x12 Shoal Surface, 3x3 Mean Surface, and a 12ft Sort
- eTransmit Zip: 010169-VH03.zip & 010169-VH04.zip
- CAD Plot in PDF: 010169-VH03.pdf & 010169-VH04.pdf
- DWG: 010169-VH03.dwg & 010169-VH04.dwg

2) Final Control Table Spreadsheet
- 010169_ST PAUL_FINAL CONTROL_20221026.xlsx

3) Field Photos

4) U-SMART Forms (11 Benchmarks)

5) Land Survey Files
- Raw Data
- Point Files
  - 0.1x0.1x0.02 ft
  - 0.5x.5x0.1 ft
  - 3x3x0.2 ft
  - 12x12x1 ft
  - 12x12x2 ft
  - 12x12x4 ft
  - Topo Utilities PNEZD
  - Topo GS

6) MBES Survey Files
- ASCI XYZ for MBES Data: Mean value and Shoal-biased
  - 3x3 ft
  - 12x12 ft
  - 24x24 ft
- ASCI XYZ for Singlebeam Data include 3ft, 12ft and 24ft sort files

7) Horizontal & Vertical Control Data
- Receiver Files & Job files from Controller
- TBC Project

DISCLAIMER