

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

HORIZONTAL & VERTICAL CONTROL REPORT

Type of Survey: Navigable Area
Project Number: OPR-B342-KR-24
Time Frame: June – September 2024

LOCALITY

State(s): Connecticut, New York

General Locality: Long Island Sound

2024

CHIEF OF PARTY

John R. Bean

LIBRARY & ARCHIVES

Date:

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A. TIME BASIS

Coordinated Universal Time (UTC) was used to annotate the tide records and all other data obtained for this project.

B. VERTICAL CONTROL

All soundings are referenced to Mean Lower Low Water (MLLW) using Ellipsoidally Referenced Survey (ERS) methods per the Project Instructions.

B.1 ERS Water Level Source Data

Inertially Aided Post Processed Kinematic (IAPPK) ellipsoid heights were computed using POSPac MMS, Applanix SmartBase (ASB) processing. The ellipsoid heights in the resulting Smoothed Best Estimate Trajectory (SBET) data were used as the basis for the development of ERS Water Level.

ASB processing was organized into POSPac projects by vessel and day. Figure 1 illustrates the locations of Continuously Operating Reference Stations (CORS) stations and OSI's locally installed base station, OSCT, which all contributed to ASB processing. The total number of stations occasionally varied from one POSPac project to the next (i.e. vessel-day) based on CORS data availability and solution quality. The table inset in Figure 1 shows the POSPac IAPPK project count for each station. The final coordinates of OSCT were determined using the NGS' Online Positioning User Service (OPUS).

ERS water levels ("GPS Vertical Adjustments") were derived from SBET altitude. SBET altitude corrected for heave, dynamic draft, and static draft were reviewed graphically in MATLAB and compared to the local NOAA tide gauge water levels. When apparent invalid altitude was present in the daily SBET, additional CORS stations were added to the ASB network. For any remaining daily SBETs with invalid altitude data, NOAA's POSPacAutoQC application was used to interpolate through and replace the invalid data.

B.2 VDatum Separation Model (SEP)

A VDatum Separation Model (SEP) was provided by NOAA with the original project files and described in the Project Instructions (Table 1).

Table 1

<i>Ellipsoid Referenced Survey via VDATUM</i>				
This project has a requirement to acquire survey data vertically referenced to the ellipsoid. Separation models for referencing data to MLLW will be provided with the project and updated by the COR as needed.				
<i>MLLW VDATUM Model</i>				
VDatum Version	Geoid	Area	Area Version	Separation Uncertainty
v4.1.2	2011	New York/Connecticut/Rhode Island	RICTbis34_8301	7.90569 centimeters

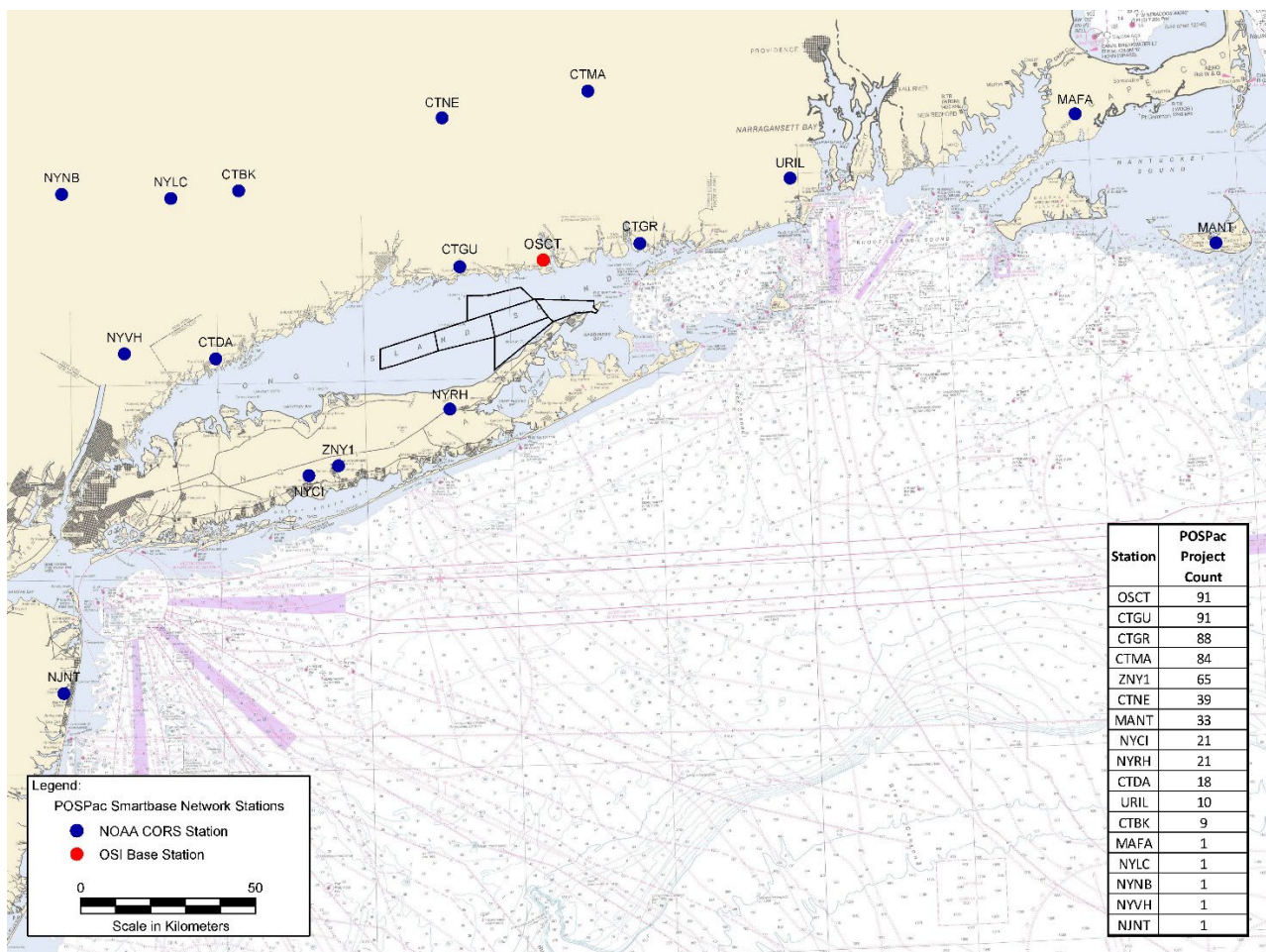


Figure 1. Local NOAA CORS and “OSCT” in relation to the project site with corresponding station POSPac project counts.

B.3 ERS SBET Altitude Smoothing

ASB derived ERS SBET altitudes were smoothed prior to inclusion in the data reduction process.

I. ERS SBET Altitude Smoothing Steps:

- 1) Create and export final SBETs
- 2) Interpolate invalid altitude spikes with POSPacAutoQC
- 3) Smooth resultant SBETs using MATLAB
 - Convert SBET altitude to an isolated NAVD88 tide by removing the following components of the SBET altitude:
 - Static draft based on time
 - Dynamic draft based on speed
 - Delayed heave based on time
 - SEP based on position
 - Smooth NAVD88 tide with a 4th order Butterworth low-pass filter
 - Export smoothed SBETs after re-applying the above components
- 4) Import smoothed SBETs in CARIS HIPS
- 5) Run CARIS HIPS “Compute GPS Tides” with the NOAA-provided SEP to create tide correctors.

II. ERS Smoothed Tide Curve QA/QC:

Graphical analysis was the primary QA/QC tool used during the development phase of the ERS smoothing routine described above. MATLAB graphs were generated for all conversion and correction steps to identify erroneous source data or MATLAB program code.

III. Choice of Smoothing Parameters:

Combined SBETs were smoothed with a 4th order Butterworth low-pass filter using MATLAB’s “filtfilt” function, which runs the filter in forward and reverse, resulting in a zero-lag solution.

OSI has demonstrated the effectiveness of this smoothing method on select prior NOAA contract surveys since 2018.

To determine the best smoothing parameter settings for this survey site, the final SBETs were smoothed and applied to the soundings using each of the following smoothing methods:

- 0.5, 1, 2, 3, 4-hour low pass filters

Statistical comparisons were made of crossline and main scheme difference data generated by CARIS HIPS. Standard deviation surfaces at intersections were reviewed, and the smoothed ERS SBET altitude was compared to local NOAA tide gauges and evaluated for trends and general agreement.

As a result of this iterative comparative analysis, a 4th order Butterworth low pass filter with the following settings were selected to smooth ERS tides:

- 1-hour cutoff frequency: *RV North Cove, RV South Cove, and RV West Cove II*

B.4 Final Application of ERS Water Levels

For the final application of ERS water levels, the final processed SBET ellipsoid record was imported to CARIS. The CARIS “Compute GPS Vertical Adjustment” function was used in conjunction with the NOAA-provided SEP to apply MLLW correctors to the soundings:

OPR-B342-KR-24_100m_NAD83_2011-MLLW_geoid18.csar

Qualitative and quantitative crossline analysis, as well as junction analysis, indicated that the final ERS correctors applied to reduce soundings to MLLW were adequate for the purpose. The results of crossline and junction analysis are presented in the Descriptive Report (DR) for each survey.

B.5 GNSS Base Station “OSCT”

To supplement IAPPK SBET processing, OSI installed a temporary GNSS base station on the roof of Ocean Survey’s home office in Old Saybrook, CT (Figure 2). The installed station was designated “OSCT” [Ocean Surveys Connecticut] and consisted of a Trimble NetR9 GNSS receiver equipped with a Zephyr 3 Geodetic antenna (Model: TRM115000.00 None). OSCT also supplied real-time RTCM RTK correctors to the nearshore survey vessels (when in cell service range) via a cellular based NTRIP stream. Real-time correctors provided precise horizontal positioning and allowed for real-time water level monitoring, which aided the survey vessels in mapping the Navigable Area Limit Line (NALL).



Figure 2. Ortho imagery and setup images of OSI’s user-installed base station “OSCT” on the roof of Ocean Survey’s home office in Old Saybrook, CT.

The configuration of the NetR9 was based on UNAVCO standard configuration settings for this device. The NetR9 was configured to record GNSS observables continuously throughout the period of the survey and parse data observables into daily files for each 24-hour period. Data were delivered to OSI’s home office processing center via regular automated FTP and e-mail “pushes.” Pushes were transmitted over a network connection that was established on site for this purpose. Data were also saved to the receiver’s internal storage as a backup.

The HSSD (2022) requires that: “*The integrity of the geodetic tie of non-NOAA CORS installations to the NSRS shall be verified at least once per week while the site is utilized for survey operations.*”

Verification may be achieved by repeated OPUS sessions to demonstrate that the difference between adopted and check positions are within the error budget allotted per THU (Section 3.2)." OSI submitted all individual days of dual frequency GNSS observables (Rinex files) from OSCT to OPUS. Data were submitted with an ARP height of 0m. OSI used OPUS Projects (<https://www.ngs.noaa.gov/OPUS-Projects/OpusProjects.shtml>) for OPUS solution management, quality control, and to compute the final network-adjusted coordinates, which were then incorporated into ASB processing (Table 2). Processing steps and parameter selection were in accordance with the NGS-provided OPUS Projects Managers Training (required to obtain access to OPUS projects).

Table 2
OPUS Projects Network Adjusted Positions of OSCT

Time period	Latitude (NAD83-2011)	Longitude (NAD83-2011)	Ellipsoid Height (GRS80)
DN 171 - 271	41° 18' 01.42990" N	72° 22' 53.57596" W	-9.285 m

Figure 3 shows a summary of the residuals for each of the daily OPUS solutions for both projects, and the improved residuals obtained with OPUS Projects session processing. The residuals are relative to the final network-adjusted position computed by OPUS Projects using all the solutions. The error bars on each point indicate the 1-sigma peak-to-peak root mean square (RMS) error estimate of the 3D position components, namely east, north, and ellipsoid height. The apparent offset in the mean position of the daily residuals and the final network-adjusted positions are due to plate velocities as handled in OPUS Projects for the time span of the project. All processing was done in ITRF 2014; however, final network-adjusted coordinates are also provided by OPUS Projects in NAD 83 (2011) @ 2010.00 (i.e. Table 2).

MARK Processing Results Plots

Scale Uncertainties by: 1.0x (68.3%)

Show: Preferences Network Session OPUS RTK Other GNSS Published

The "zero" point coordinates, N41:18:01.465500493068249, W072:22:53.59818, -10.530 m el. height, are the mean of all network adjustments.

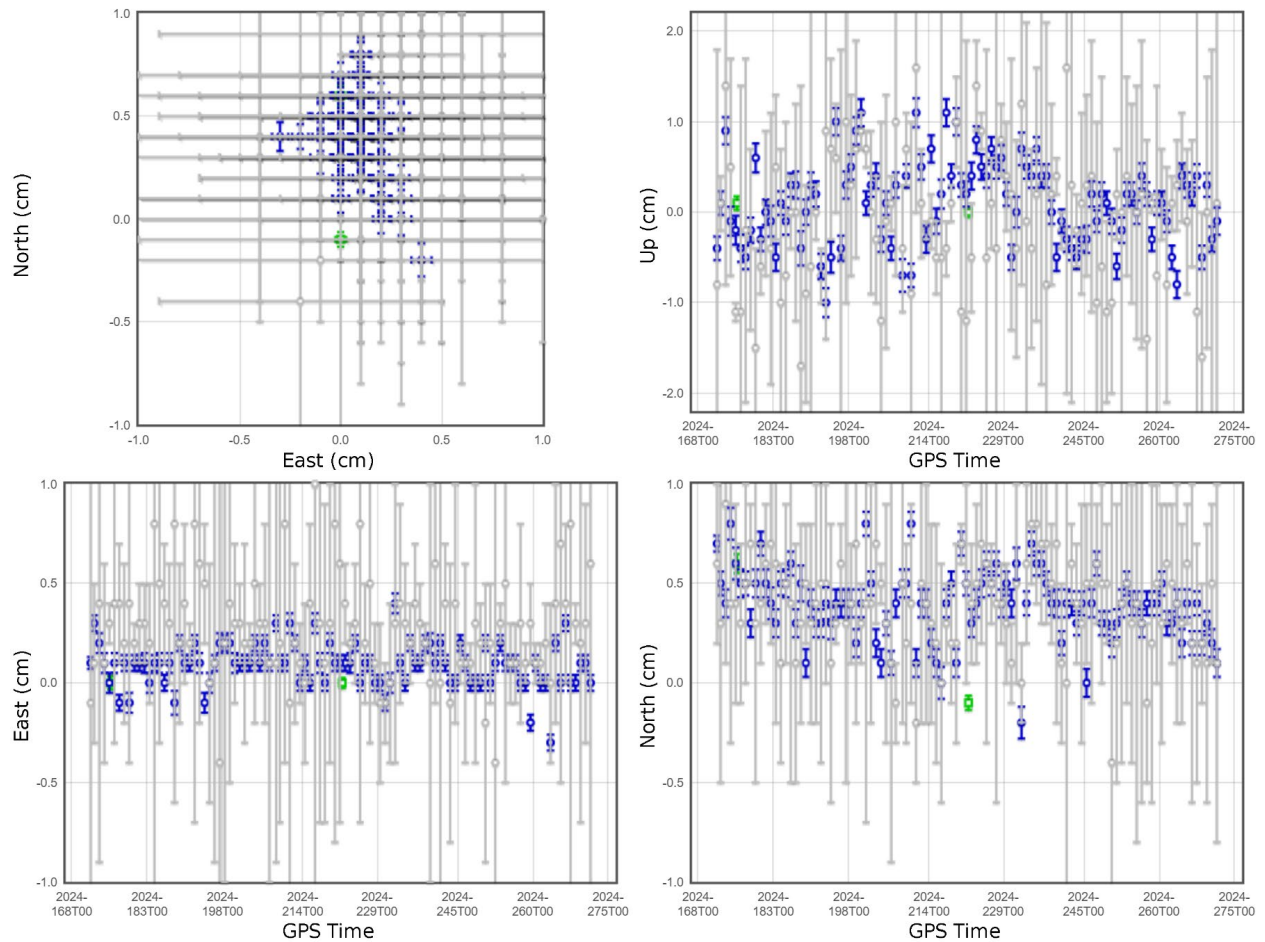


Figure 3. OPUS project coordinate residuals for GNSS observables at OSCT. OPUS solutions are in grey, improved OPUS Project session solutions are in blue. Error bars represent 1-sigma. Residuals are relative to the final network-adjusted and velocity corrected position (green) from OPUS Projects.

Individual OSCT OPUS Project results (OPUS solutions, sessions, and final network adjustment) are included in the HVCR digital deliverables.

C. HORIZONTAL CONTROL

C.1 Horizontal Datum

The horizontal datum for this project is the North American Datum of 1983 (NAD83). Horizontal coordinates are referenced to Latitude/Longitude and Universal Transverse Mercator (UTM) Zone 18N, in meters.

C.2 Horizontal Control

During the survey, the POSMV on the *RV North Cove* and *RV South Cove* received RTCM RTK correctors from “OSCT” base station via a cellular NTRIP stream, while the *RV West Cove II* was configured to receive SBAS (FAA WAAS) correctors for real-time positioning. Real-time vessel navigation was replaced during post processing with ASB-derived SBET positioning and attitude. Final SBET positioning is referenced to NAD83 (2011).

Positioning system confidence checks for each vessel were accomplished at the start of survey and periodically thereafter. In practice, the distance between the vessel’s reference point (RP) and the dockside horizontal control point as computed by the navigation system was compared to the tape-measured distance between the vessel RP and the horizontal control point.

Temporary navigation confidence check points were installed near each vessel’s dock. “Harbor One 2020 - MLLW” was installed near OSI’s home base of Old Saybrook, CT prior to beginning the survey (Figure 4). The temporary point was established in UTM Zone 18, meters using a single OPUS observation with a duration of approximately 4 hours. One other temporary point was established in Noank, CT prior to *RV West Cove II*’s transit to the survey site (Figure 5).

Temporary points were established using a rover system, either a Trimble R8 or Trimble R10 GNSS interfaced with a TSC3 data collector. The rover systems, programmed to receive real-time RTCM RTK corrections from the base station “OSCT”, were verified by occupying nearby NGS survey disks. The X,Y coordinates for both temporary navigation confidence check points are presented in Table 3. The OPUS report for the installation of the temporary navigation confidence check point “WC24” in Noank, CT for the *RV West Cove II* calibrations is included in the HVCR digital deliverables.

In all cases, dockside navigation system accuracy checks demonstrated accuracy that was substantially better than 1.0 meter.

Table 3
Temporary Navigation Confidence Check Points

Designation	Easting UTM 18N, NAD83 (meters)	Northing UTM 18N, NAD83 (meters)	Locale	For Survey Vessel
Harbor One 2020 - MLLW	721,994.20	4,573,420.06	Old Saybrook, CT	<i>RV North Cove</i> <i>RV South Cove</i> <i>RV West Cove II</i>
WC24	751,747.33	4,578,830.61	Noank, CT	<i>RV West Cove II</i>

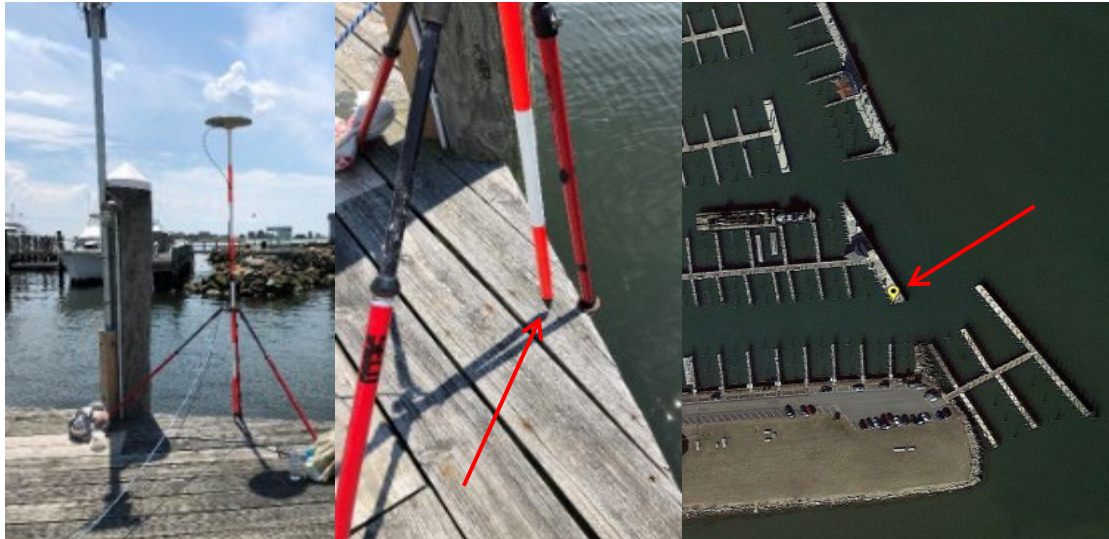


Figure 4. “Harbor One 2020-MLLW” is a PK Nail in a dock at Harbor One Marina in Old Saybrook, CT.

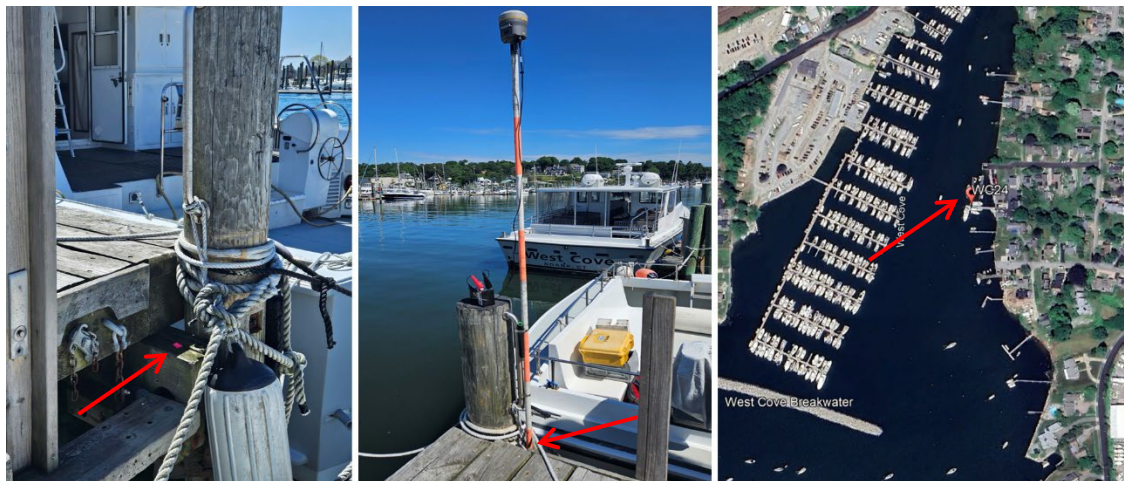


Figure 5. “WC24” is a pink backed PK nail in pier decking at the end of the fixed dock at *RV West Cove II*'s home port inside of West Cove in Noank, CT.

Navigation system confidence checks for each vessel are included below in Table 4 through Table 6.

Table 4
***RV North Cove* Tabulation of Navigation System Confidence Checks**

Date	Time UTC	Nav. Check-point	DGNSS Corr. Source	Observed Easting UTM 18N, NAD83 (meters)	Observed Northing UTM 18N, NAD83 (meters)	Calculated Distance TP to Nav. Checkpoint (meters)	Tape Measure TP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
6/21/2024 (DN 173)	15:05	Harbor One 2020 - MLLW	RTCM	721,994.20	4,573,420.06	8.75	8.75	0.00

Table 5
***RV South Cove* Tabulation of Navigation System Confidence Checks**

Date	Time UTC	Nav. Checkpoint	DGNSS Corr. Source	Observed Easting UTM 18N, NAD83 (meters)	Observed Northing UTM 18N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
06/19/2024 (DN 171)	17:20	Harbor One 2020 - MLLW	RTCM	721,997.92	4,573,426.99	7.87	7.97	0.1
6/20/2024 (DN 172)	14:00	Harbor One 2020 - MLLW	RTCM	721,994.20	4,573,420.06	8.07	8.12	0.05

Table 6
***RV West Cove II* Tabulation of Navigation System Confidence Checks**

Date	Time UTC	Nav. Checkpoint	DGNSS Corr. Source	Observed Easting UTM 18N, NAD83 (meters)	Observed Northing UTM 18N, NAD83 (meters)	Calculated Distance RP to Nav. Checkpoint (meters)	Tape Measure RP to Nav. Checkpoint (meters)	Difference Calculated vs. Tape Measured (meters)
7/5/2024 (DN 187)	18:13	WC24	RTCM	751,747.33	4,578,830.61	6.24	6.20	0.04
7/8/2024 (DN 190)	17:08	WC24	WAAS	751,747.33	4,578,830.61	6.57	6.59	0.02

D. APPROVAL SHEET

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys H13926, H13927, H13928, H13929, H13930, and H13931 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Approver Name	Approver Title	Approval Date	Signature
John R. Bean	Chief of Party	12/5/2024	
David T. Somers	Data Processing Manager	12/5/2024	