Site Characterization Multibeam Survey around the Stillwater Bridge in Old Town, Maine

At the request of VHB, Substructure recently completed a site characterization multibeam and sub-bottom profile survey around the Stillwater Avenue Bridge where it crosses the Stillwater River in Old Town, Maine (Figure 1). The following is a brief discussion of the methods employed during this survey. In addition, page-sized plots presenting the results of this survey are also provided.

1. Prior to the start of the survey, Substructure recovered the ME-DOT survey point 608 located along Stillwater Avenue north of the bridge and near the entrance drive into the Brookfield dam area. A Trimble R10 dual-frequency Global Navigation Satellite System (GNSS) receiver was set over this point to serve as a short-term base station and an R10 GNSS rover was used to set a temporary survey point on the Brookfield property between the boat ramp entrance and the dam area (Figure 2). The GNSS base receiver was moved to this new point and configured to log 1-second dual-frequency GNSS static data and to transmit real-time kinematic (RTK) differential GNSS (DGNSS) correctors to the survey vessel via a dedicated NTRIP caster network. This set-up provided cm-level horizontal and vertical accuracies on the survey vessel during most of the survey operations. During the survey, the NAD83 horizontal datum with a ME Central (ME-1812) state plane coordinate system (U.S. Survey Feet), and the NAVD88 vertical datum (U.S. Survey Feed) were used. The National Geodetic Survey (NGS) Geoid Model12B was used to transform the NAD83 GNSS ellipsoidal heights to NAVD88 orthometric heights. After completion of the survey operations, the static 1-second GNSS data logged at the base station were submitted to government-sponsored web-based processing services to compute a post-processed reference position for the base station.

2. Substructure conducted all survey operations aboard their small survey barge *Piper* on 8/26/2020 (Day 239) during a period of fair weather, strong northwesterly winds, and generally low flow conditions on the River. For the multibeam survey operations, standard equipment on *Piper* included an R2Sonic 2024 multibeam echosounder, an Applanix 320 POSMV vessel motion reference and navigation unit, a Valeport Mini sound velocity sensor (SVS) mounted near the multibeam array, a YSI Castaway conductivity-temperature-depth (CTD) speed of sound profiler, and QPS QINSy hydrographic data acquisition and processing software (Figure 3). For the sub-bottom profile operations, this same sensor and software suite was supplemented with an Innomar SES-2000 dual-frequency parametric sub-bottom profiler deployed on an over-the-bow fairing tightly integrated with the primary navigation system. Due to the hardness of the river bottom (primarily gravel and rock), the sub-bottom data did not provide any useful acoustic returns below the initial river bottom reflector.

3. During the acoustic survey operations, periodic water column speed of sound profiles were acquired with the Castaway and entered directly into the data acquisition package. The R2Sonic 2024 also included a near surface CTD sensor that provided a continuous speed of sound measurement near the multibeam sonar head. The near surface speed of sound readings compared well between the CTD sensor and the speed of sound profiler throughout the survey. In addition, the water-column was well mixed during the survey operations, and all of the speed of sound profiles showed negligible differences throughout the vertical range, with a slight rise in water temperatures and speed of sound noted throughout the day.

4. Initial processing of the multibeam data included confirming the base station reference information, reviewing the raw sensor and navigation data, reviewing and editing the RTK water-level data, reviewing and applying the speed of sound profile data, cleaning the raw acoustic data, and creation of preliminary gridded products to assess data coverage and conduct cross-check comparisons. All post-processing was conducted using QPS Qimera, Hypack, and SonarWiz software. In addition, the raw POSMV data were re-processed using the POSPac Mobile Mapping Suite (MMS) software to re-compute and reapply the complete navigation and elevation solution. Due to the overhead bridge obstruction and frequent disruption of satellite coverage, there were frequent short-term periods when the elevation solutions were degraded. After POSPac processing, horizontal Root Mean Square (RMS) values were consistently at or below 1 cm, while the vertical RMS values were consistently below 3 cm (Figure 4). The intermittent short term spikes in the elevation time-series due to the bridge obstruction were smoothed over through interpolation using the valid data. Static GNSS data were

recorded at the base station for around seven hours on the day of the survey and then submitted to both the NGS Online Positioning User Service (OPUS) and the Natural Resource Canada Precise Point Positioning (PPP) Service to check the original reference position and elevation derived from the initial RTK survey. The post-processed static GNSS reference results were used for POSPac post-processing, though the post-processed latitude, longitude, and ellipsoidal height agreed within 0.05 feet of the original RTK-derived reference values.

5. There were no unusual circumstances encountered during the multibeam and sub-bottom survey and the initial results covered most of the required areas around the bridge. Due to shallow depths and the presence of numerous rocks and boulders, it was not possible to acquire data around the immediate shoreline of the island between the bridges. In addition, the very hard rock and gravel river bottom also limited the effectiveness of the sub-bottom to reveal any acoustic horizons beneath the initial river bottom reflector (Figure 5). The extensive areas of overlapping bathymetric data agreed well throughout the survey area and the cross-check comparisons were also consistent. In addition, the smoothed GNSS-derived water-level data acquired on *Piper* were consistent with the periodic river-level observations that were made during the day. Processing of the multibeam data included final area-based editing focused on the standard deviation surfaces, creation of final gridded bathymetric datasets (e.g., 6-inch average and minimum grids), and development of hillshade surface models, selected elevation files, contour files, and overview data images (Figure 6). In addition, a GoogleEarth KMZ file was also created so that the various data layers could be viewed within the standard GoogleEarth interface (Figure 7).

Figure 1. GoogleEarth image showing the general location of the Stillwater Bridge survey area. The small boat launch on the Brookfield property adjacent to the bridge was used for launching and recovering the survey barge. A temporary survey control point was established on the Brookfield property for the local GNSS base station.

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Subject:        OPUS solution : 31222392.20O OP1598512088133

 FILE: 31222392.20O OP1598512088133

 2005   NOTE:  The IGS precise and IGS rapid orbits were not available
 2005   at processing time.  The IGS ultra-rapid orbit was/will be used to
 2005   process the data.
 2005
                              NGS OPUS SOLUTION REPORT
                              ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

      USER: trw@substructure.com                    DATE: August 27, 2020
RINEX FILE: 3122239o.20o                            TIME: 03:13:16 UTC


  SOFTWARE: page5  1801.18 master56.pl 160321      START: 2020/08/26  14:02:00
 EPHEMERIS: igu21203.eph [ultra-rapid]              STOP: 2020/08/26  20:59:00
  NAV FILE: brdc2390.20n                        OBS USED: 15927 / 17295    :  92%
  ANT NAME: TRMR10          NONE             # FIXED AMB:    104 /    120    :  87%
ARP HEIGHT: 1.8                              OVERALL RMS: 0.020(m)


 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)             ITRF2014 (EPOCH:2020.6522)

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         Y:     -4214916.991(m)   0.010(m)         -4214915.588(m)   0.010(m)
         Z:      4480489.234(m)   0.009(m)          4480489.279(m)   0.009(m)

       LAT:   44 54 45.82487      0.010(m)       44 54 45.86382      0.010(m)
     E LON:  291 18 59.09098      0.003(m)      291 18 59.07334      0.003(m)
     W LON:   68 41  0.90902      0.003(m)       68 41  0.92666      0.003(m)
    EL HGT:            5.545(m)   0.008(m)                4.403(m)   0.008(m)
 ORTHO HGT:           30.228(m)   0.058(m) [NAVD88 (Computed using GEOID18)]
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Figure 2. Overview of the DGNSS base station that was used to support the Stillwater Bridge site characterization survey. Left photo shows the R10 base GNSS receiver set-up over the MEDOT survey point 608 to obtain the initial RTK reference information for the temporary survey point on the Brookfield property. The right photo shows the base receiver in the background set-up over the temporary survey point that was used during the survey operations. The lower text box shows a portion of the OPUS computed results for the seven hours of 1-sec static GNSS data that were submitted for the temporary survey point.

Substructure's Survey Vessel Piper

Substructure's engineers and technicians designed and built **Piper** specifically to conduct inshore multibeam surveys capable of satisfying the International Hydrographic Organization's (IHO) Special Order standards. The design of Piper is optimized for portability and versatility in inshore and inland water bodies. The extremely shallow draft and durability (1/4" USCG marine aluminum plate) make this an idea vessel for all inshore surveying operations, sampling, laser scanning, and construction. The outboard options include standard outboard propeller, outboard jet, and electric outboard. While utilizing the outboard jet option, draft is just 14 inches.

***Piper** outfitted for combined multibeam and mobile laser scanning operations on a shallow inland river. Laser scanner is mounted on overhead canopy aft of POSMV antennas and multibeam sonar is mounted on port side.*

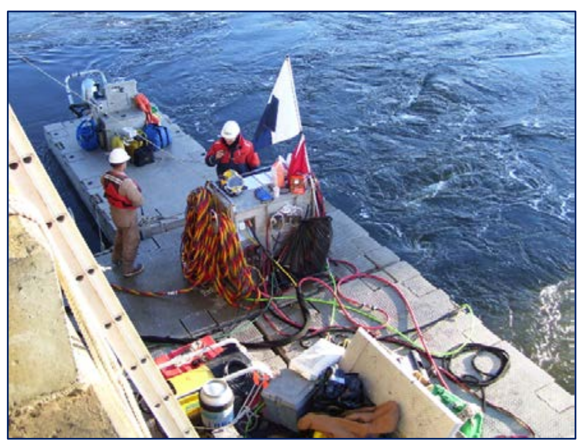
***Piper** on a large inland lake configured for multibeam survey operations during a period of inclement weather*

Piper Hydrographic Survey Package

- Designed and built around a system of Substructure-owned components for conducting surveys to International Hydrographic Organization's Special Order Standards.
- Dual- or single-head R2Sonic 2024 and Reson 8125 Multibeam Echosounders, Applanix POSMV 320 v5 Vessel Position and Orientation Unit, Odom Digibar Speed of Sound Profiler, YSI Castaway CTD, Seabird SBE 37SI CTD, Knudsen 3212 Chirp Sub-Bottom Profiler, and Hypack / Hysweep, QPS QINSy, and Caris HIPS/SIPS Data Acquisition and Processing Software Packages.
- Real-time Kinematic (RTK) differential GNSS (DGNSS) base stations (Trimble R10s) and multiple data link options for high-accuracy horizontal and vertical control.
- A-frame and davit attachments with a large working deck when operated in the multiple barge configuration that can support a variety of survey, diving, sampling, and instrument deployment and recovery operations.

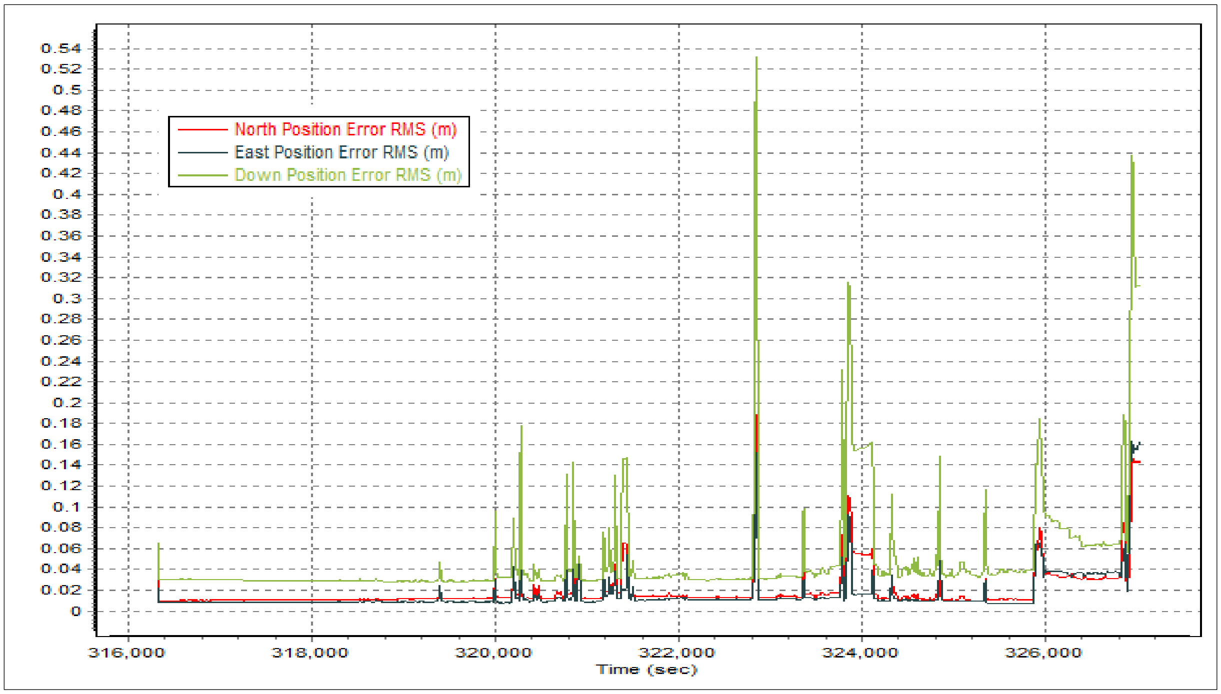
Piper Basic Vessel Information

- Fitted with asymmetric hydrodynamic fairing for superior acoustic multibeam sensor performance.
- Standardized mounts enable efficient installation of all Substructure sensors.
- AWWA-compliant version for work in drinking water reservoirs that uses electric propulsion and HP-gas generator.
- Rapid transportation via dedicated trailer.
- Rated lift points for efficient crane deployments that can be useful for hard to access areas like dam areas.
- Deployable in larger configuration of multiple barges providing extensive working deck space.
- Can be mobilized to remote locations via 20 foot shipping container. (up to 5 modules)
- Supports inspection class ROV operations.



***Piper** provides the main control as part of the multi-barge configuration that in this case was being used to support commercial diving operations for a mid-winter emergency cable repair.*

Figure 3. Overview of Substructure's Survey Barge *Piper* that was used for the Stillwater Bridge survey. Due to the low bridge clearance, the canopy was removed and the POSMV antennas were mounted near the deck.



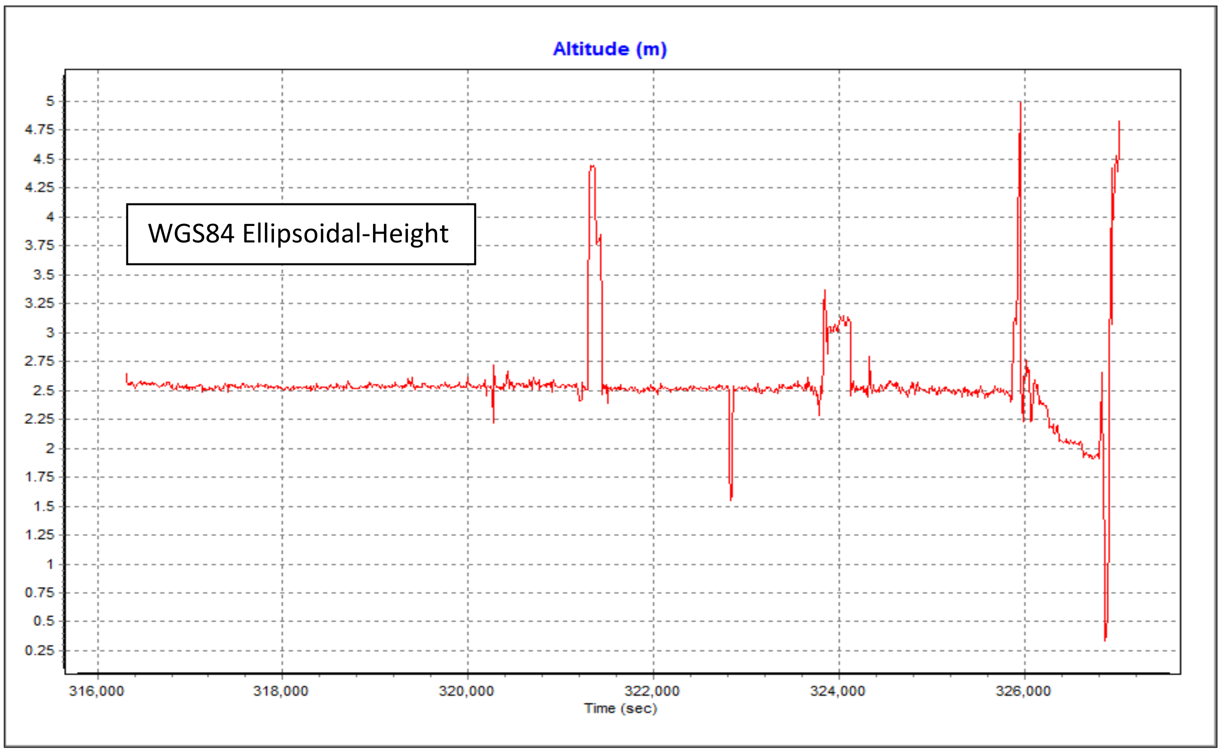


Figure 4. Overview of the POSPac MMS processing results for the survey period on 8/26/2020 (Day 239). The top panel shows that the post-processed horizontal Root Mean Square (RMS) values were consistently at or below 1 cm, while the vertical RMS values were consistently below 3 cm throughout the survey. The intermittent short term spikes in the RMS values were due to reduced satellite coverage while working around the bridge. The lower panel shows that the river water-level was consistent throughout the survey period, so that any short-term spikes in the elevation time-series due to the bridge obstruction could be smoothed over through interpolation using the valid data.

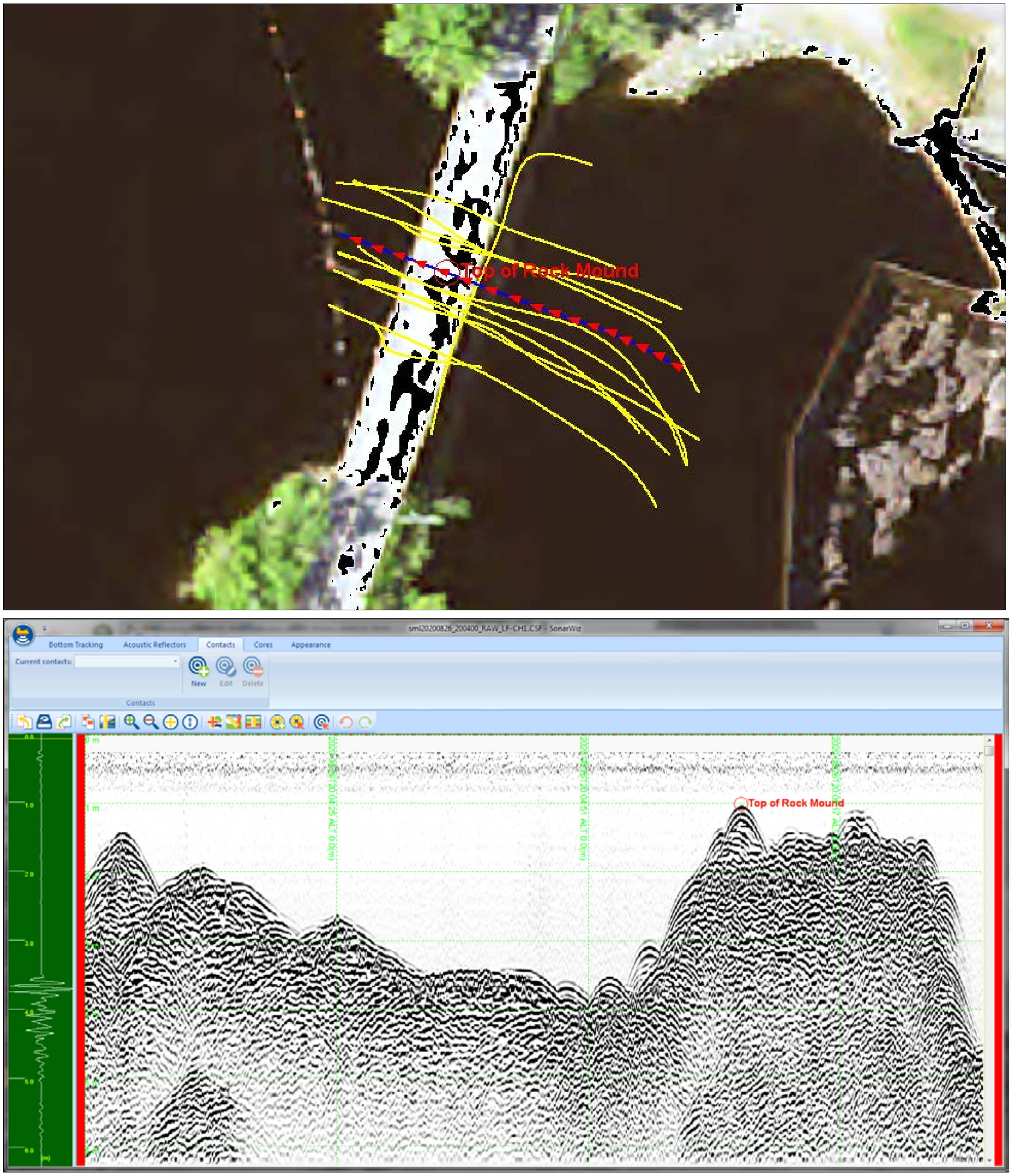


Figure 5. Sample SonarWiz view of one of the low frequency sub-bottom profile lines that were run between the piers of the northern bridge. These operations were conducted after the river barrier had been reinstalled, so navigation was restricted on the upstream side of the bridge. The top panel shows the trackplot for all of the sub-bottom profile lines that were run. The lower panel shows the low frequency (4 kHz) sonar trace for the highlighted line in the top panel. The high point of the rock mound located under the bridge has been identified on both the sonar trace and the trackplot. Because of the hardness of the river bottom, no acoustic horizons could be seen below the initial surface reflector.

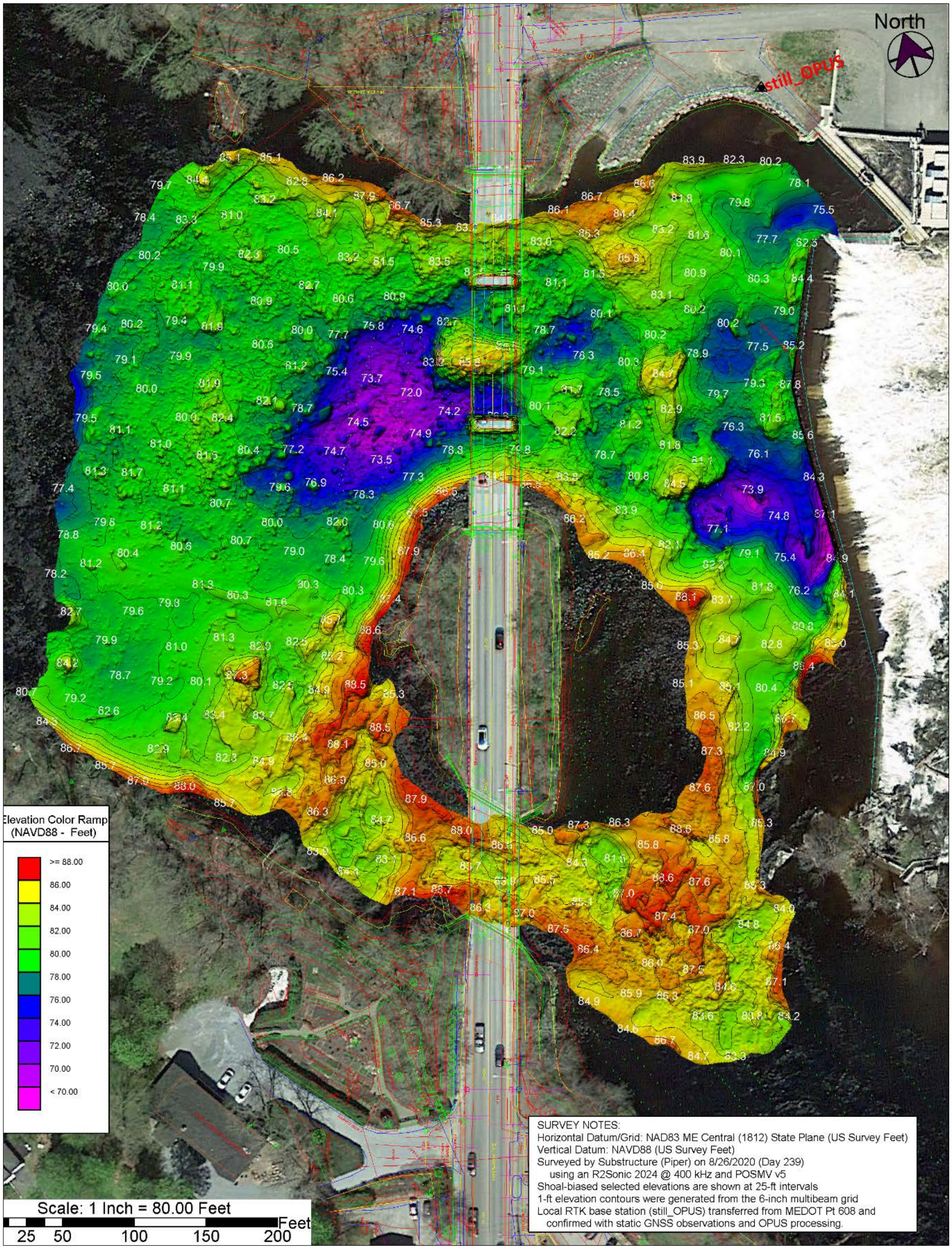


Figure 6. Page-sized survey drawing around the Stillwater Bridge showing hillshade bathymetric surface created from the 6-inch average multibeam grid and also temporary base station control point (still_OPUS). The background layers include 1ft elevation contours, shoal-biased selected elevations, GoogleEarth aerial imagery, and various bridge design CAD file layers. The geoTIF image file was exported at 300DPI to preserve resolution and enable zooming.

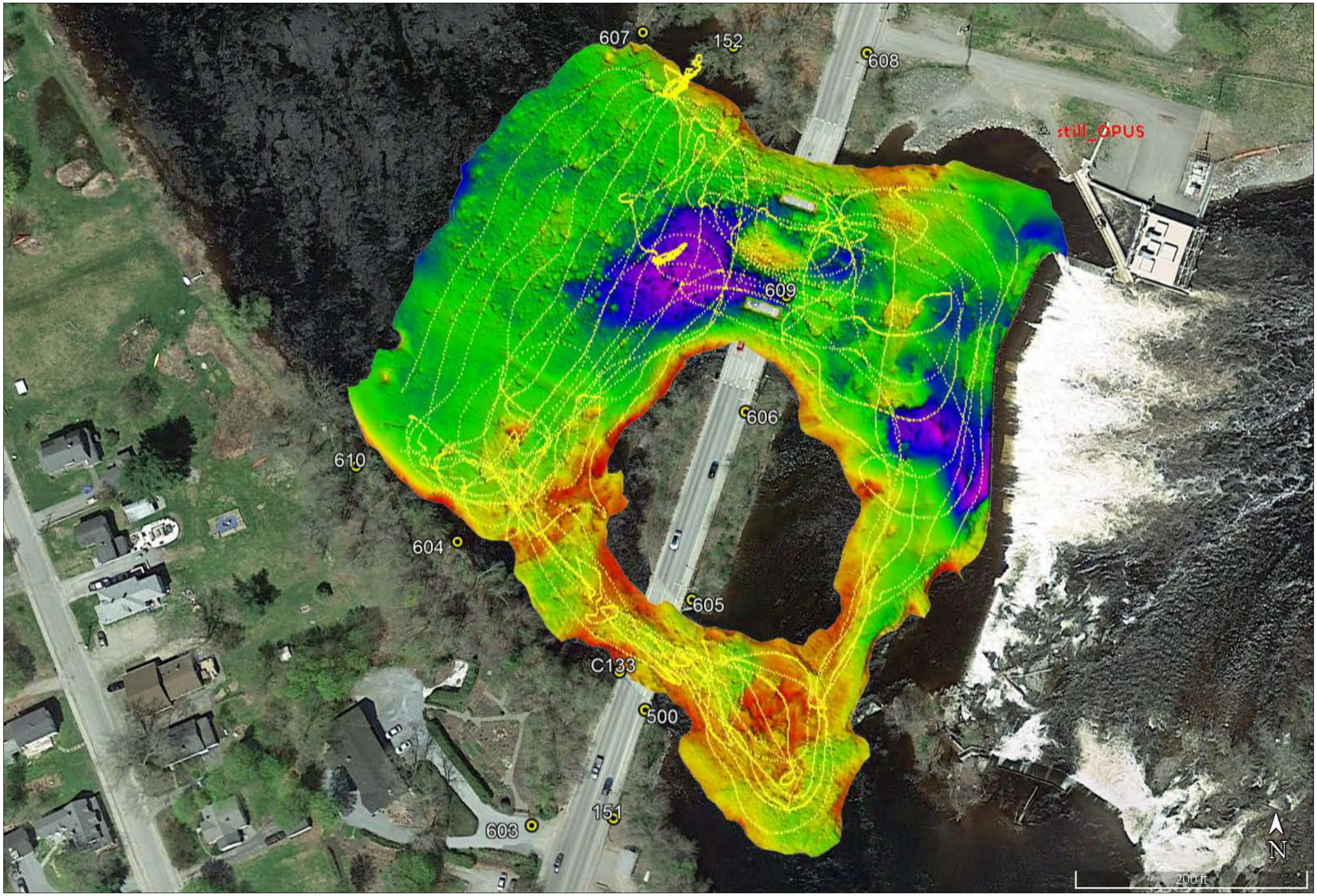


Figure 7. This 1080 resolution image was created in GoogleEarth using an exported KMZ file that included the 6-inch bathymetric hillshade surface, the track plot of the boat during the multibeam operations, the temporary base station control point (still_OPUS) on the Brookfield property, and the MEDOT control points in the area around the bridge.