Airborne Topographic LiDAR Report

St. Louis River AOC 2016 LiDAR Project Report: Located in Douglas County, WI

Task Order No. 19

July 12, 2016

Prime contractor: Ayres Associates Inc
Airborne LiDAR Acquisition Completed by Quantum Spatial, Inc.

AYRES ASSOCIATES quantum SPATIAL

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1. Summary / Scope

1.1. Summary

This report contains a summary of the St. Louis River Area of Concern (AOC) 2015-16 LiDAR acquisition task order, issued by Ayres Associates under their Task Order 19 dated September 21, 2015. The task order yielded a project area covering approximately 308 total square miles over Douglas County, Wisconsin. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic LiDAR was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned LiDAR Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
≥ 2 pts / m^2	2,100 m	40.0°	7.93%	≤ 9.25 cm

1.3. Coverage

The LiDAR project boundary covers approximately 308 square miles and partially covers Douglas County, Wisconsin. LiDAR extents are shown in Figure 1 on the following page. A buffer of 100 meters was created for the area.

1.4. Duration

LiDAR data was acquired from October 17, 2015 to October 19, 2015 in five total lifts. See "Section: 2.5. Time Period" for more details.

1.5. Issues

There were no issues to report with this project.

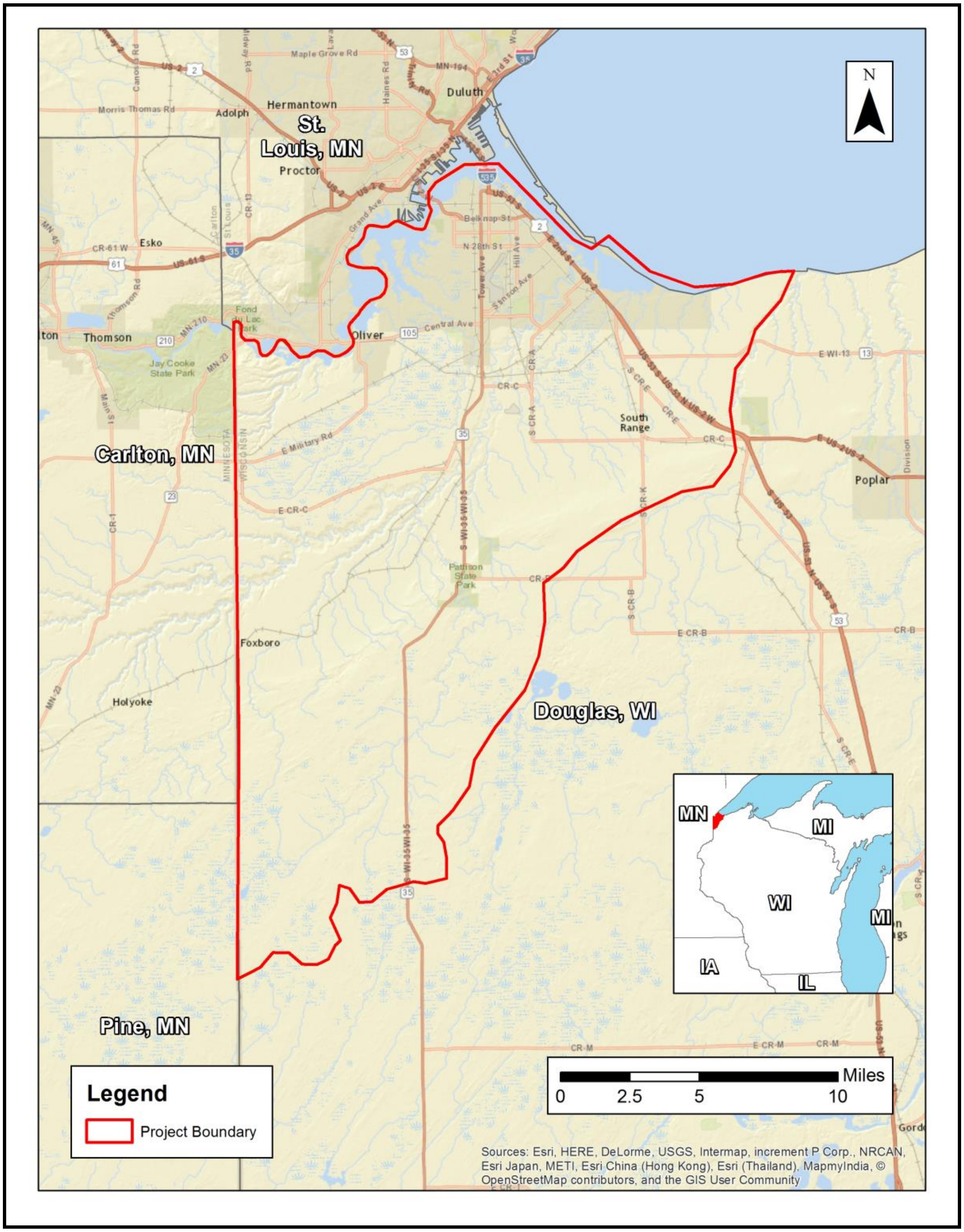
1.6. Deliverables

The following products were produced and delivered:

- Flight plans in digital format
- As-flown flight lines in Esri shapefile format
- Flight logs and notes
- Flight Quality Control Report
- WISCORS and supplemental base station data and OPUS reports
- LiDAR point cloud data, tiled, in LAS 1.4 format
- LiDAR point cloud data, in raw swaths, in LAS 1.4 format
- SBET/ABGPS/IMU materials and documentation
- Trajectories in .TRJ format
- All Flight mission parameters appropriate for inclusion in FGDC/USGS compliant metadata

All geospatial deliverables were produced in NAD83 (2011) UTM Zone 15, meters; NAVD88 (Geoid 12A), meters. All tiled deliverables have a tile size of 1,500 meters x 1,500 meters.

Figure 1. Project Boundary



2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using Optech MissionNAV planning software. The entire target area was comprised of 42 planned flight lines measuring approximately 1,439.72 total flight line kilometers (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized an Optech Orion H300 LiDAR sensor (Figure 3), serial number 324 during the project. These systems are capable of collecting data at a maximum frequency of 300 kHz, which affords elevation data collection of up to 300,000 points per second. These systems utilize a Multi-Pulse in the Air option (MPIA). These sensors are also equipped with the ability to measure up to 5 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd, 4th, and last returns. The intensity of the first four returns is also captured during aerial acquisition.

A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specifications in Table 2.

Figure 2. Planned Flight Lines

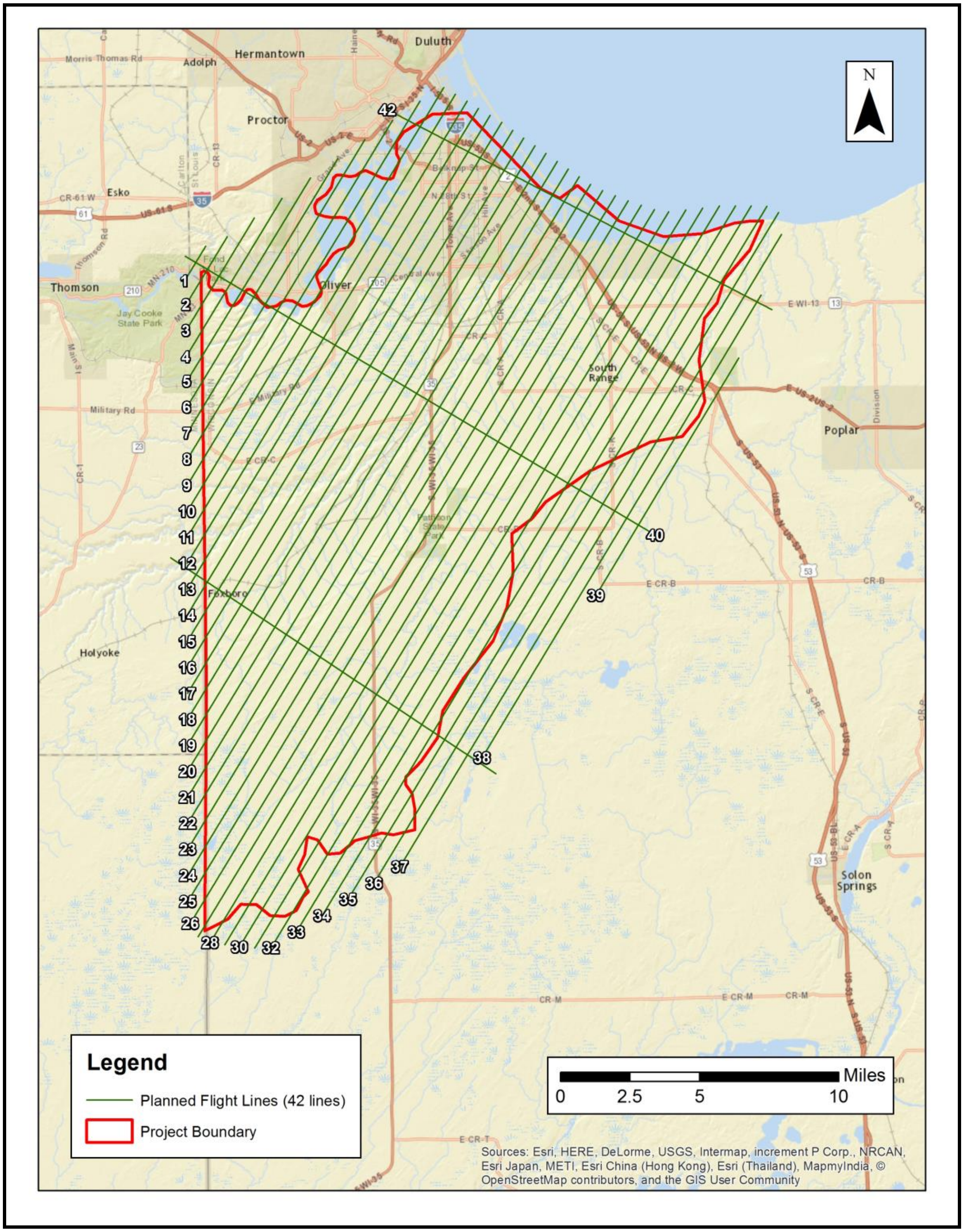
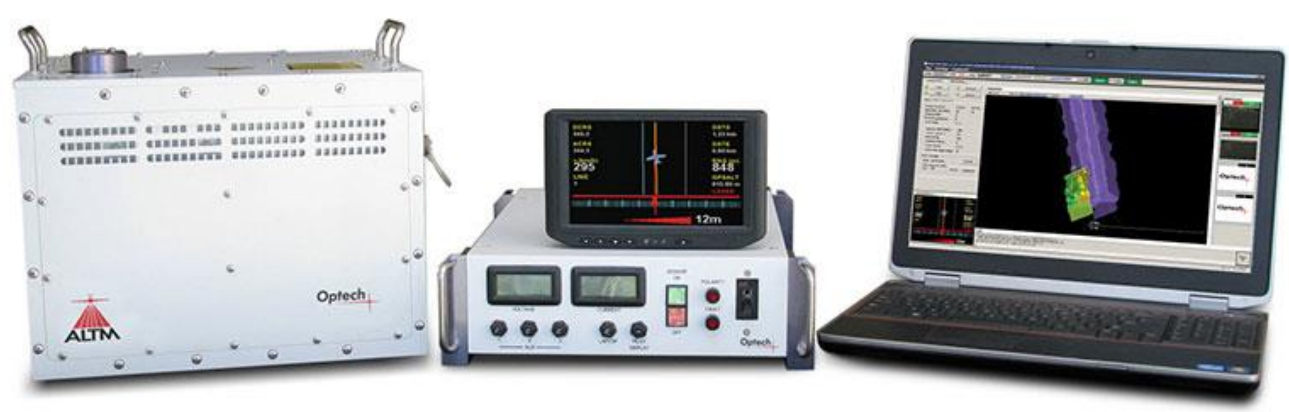


Table 2. LiDAR System Specifications

		SN324
Terrain and Aircraft Scanner	Flying Height	1,650 m
	Recommended Ground Speed	140 kts
Scanner	Field of View	38°
	Scan Rate Setting Used	52 Hz
Laser	Laser Pulse Rate Used	225 kHz
	Multi Pulse in Air Mode	Enabled
Coverage	Full Swath Width	1,136.28 m
Point Spacing and Density	Average Point Density	2.26 pts / m^2

Figure 3. Optech Orion H300 LiDAR Sensor



2.3. Aircraft

All flights for the project were accomplished through the use of a customized Cessna 206 Stationair (piston-single), Tail Number N7266Z. This aircraft provided an ideal, stable aerial base for LiDAR and orthoimagery acquisition. This aerial platform has relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Optech LiDAR system. Some of Quantum Spatial's operating aircraft can be seen in Figure 4 below.

Figure 4. Some of Quantum Spatial's Planes

2.4. Base Station Information

GPS base stations were utilized during all phases of flight (Table 3). The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations are depicted in Figure 5. Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A.

Table 3. Base Station Locations

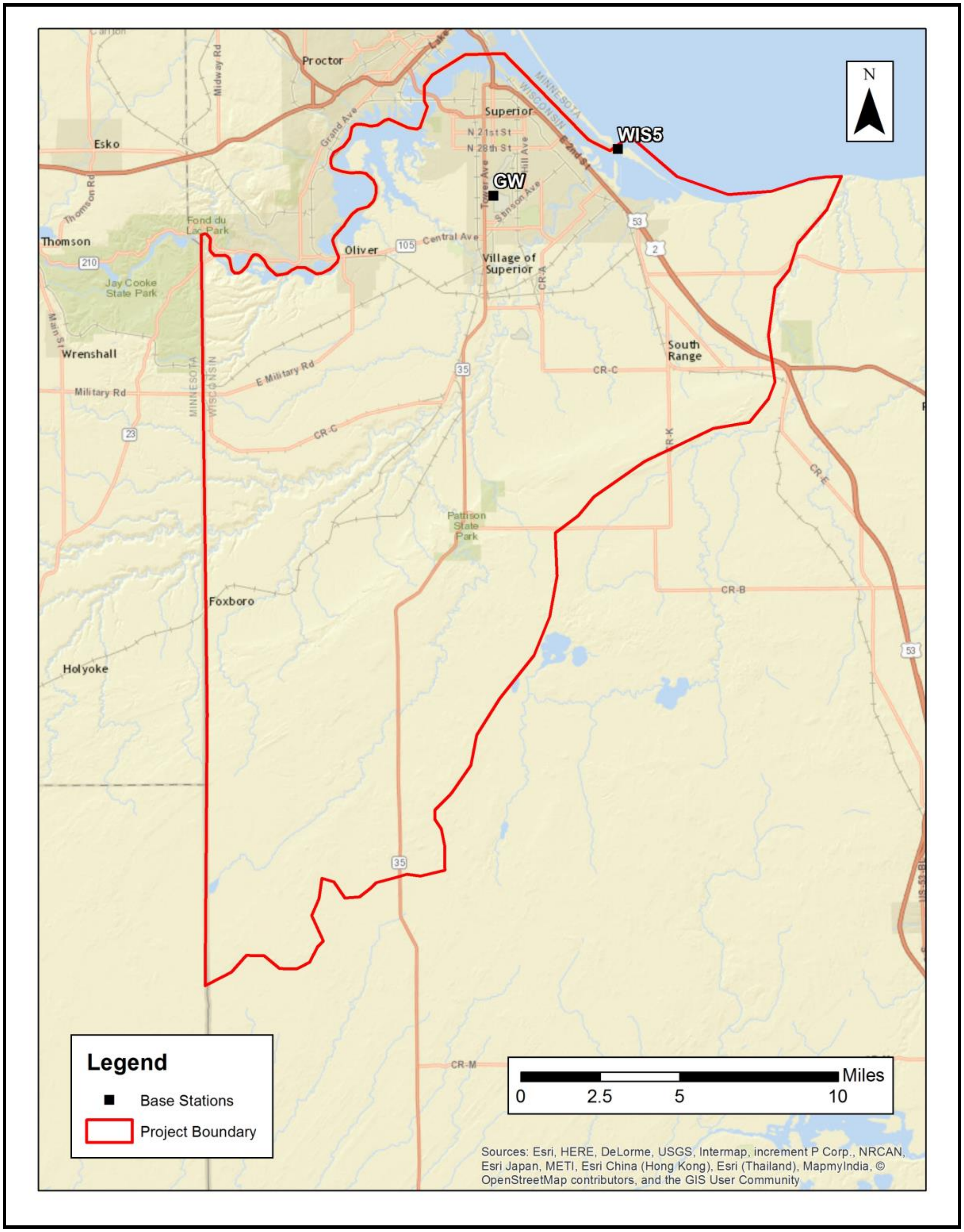
Base Station	Latitude	Longitude	Ellipsoid Height (m)
GW	46° 41' 4.25826"	92° 5' 54.10949"	177.108
WIS5	46° 42' 18.17202"	92° 0' 54.73297"	160.282

2.5. Time Period

Project specific flights were conducted over three days. Five sorties, or aircraft lifts were completed. Accomplished sorties are listed below.

- Oct 17, 2016-A (N7266Z, SN324)
- Oct 18, 2016-A (N7266Z, SN324)
- Oct 18, 2016-B (N7266Z, SN324)
- Oct 19, 2016-A (N7266Z, SN324)
- Oct 19, 2016-B (N7266Z, SN324)

Figure 5. Base Station Locations



3. Processing Summary

3.1. Flight Logs

Flight logs were completed by LIDAR sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

3.2. LiDAR Processing

Applanix + POSPac Mobile Mapping Suite software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the LiDAR sensor during all flights. POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a “Smoothed Best Estimate Trajectory (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the LiDAR missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory. All relevant graphs produced in the POSPac processing environment for each sortie during the project mobilization are available in Appendix A.

The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Laser point data are imported into TerraScan and a manual calibration is performed to assess the system offsets for pitch, roll, heading and scale. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above-ground features are removed from the data set. Point clouds were created using the Optech DashMap Post Processor software. GeoCue distributive processing software was used in the creation of some files needed in downstream processing, as well as in the tiling of the dataset into more manageable file sizes. TerraScan and TerraModeler software packages were then used for the automated data classification, manual cleanup, and bare earth generation. Project specific macros were developed to classify the ground and remove side overlap between parallel flight lines.

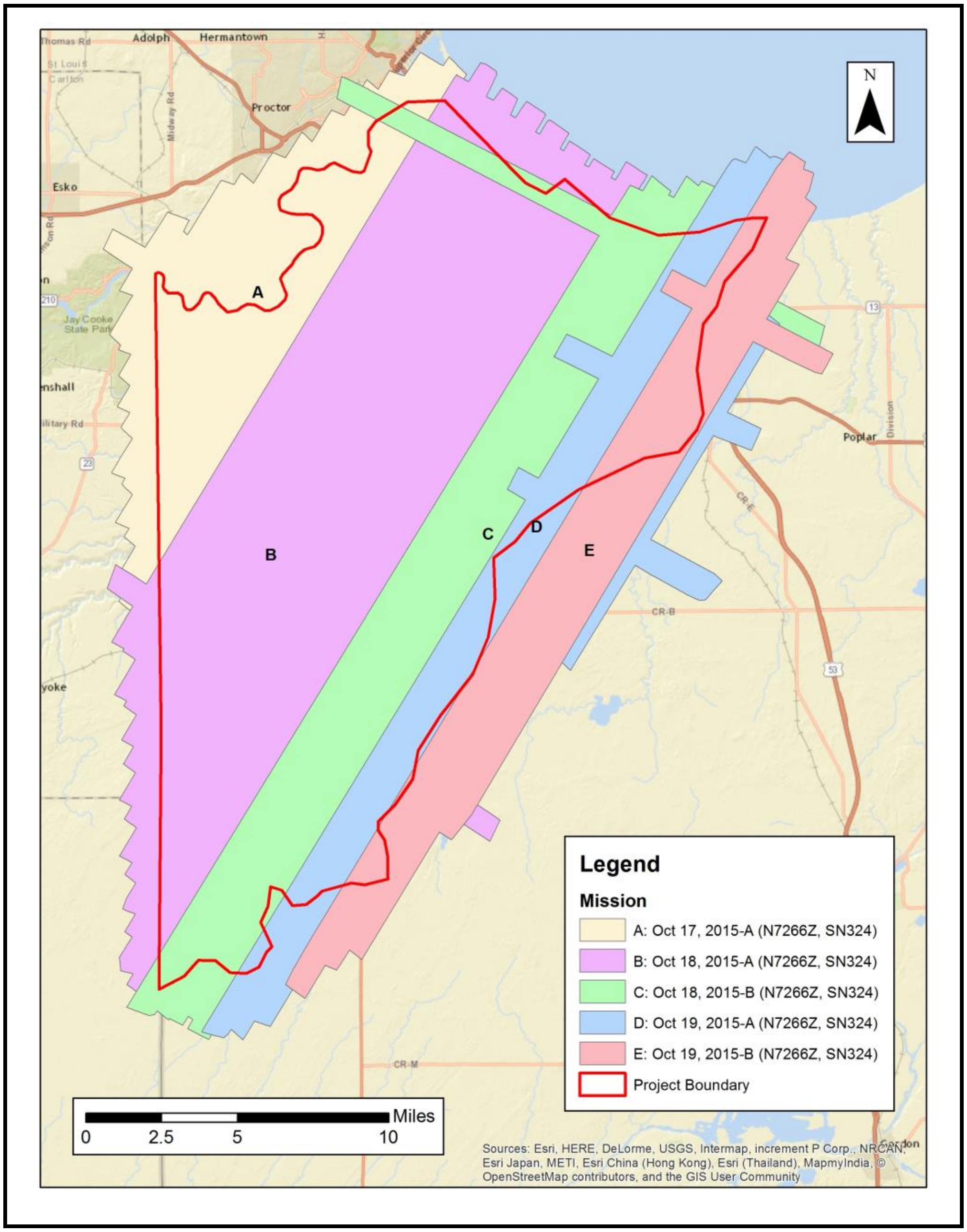
All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the dataset. GeoCue was used to create the deliverable industry-standard LAS files for the All Point Cloud Data.

4. Processing Summary

4.1. Flight Logs

Coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 6.

Figure 6. Flight Line Swath LAS File Coverage



5. Ground Control Point Collection

5.1. Point Collection

Quantum Spatial utilized 29 ground control (calibration) points as an independent test of the accuracy of this project. In this document, horizontal coordinates for ground control points are reported in NAD83 (2011) UTM Zone 15, meters; NAVD88 (Geoid 12A), meters.

5.2. Calibration Point Testing

TerraScan was used to perform a quality assurance check for each of the LiDAR bare earth calibration points. Note that these results of the surface calibration are not an independent assessment of the accuracy of these project deliverables, but the statistical results do provide additional feedback as to the overall quality of the elevation surface. See Figure 7 and Table 4.

Figure 7. Calibration Control Point Locations

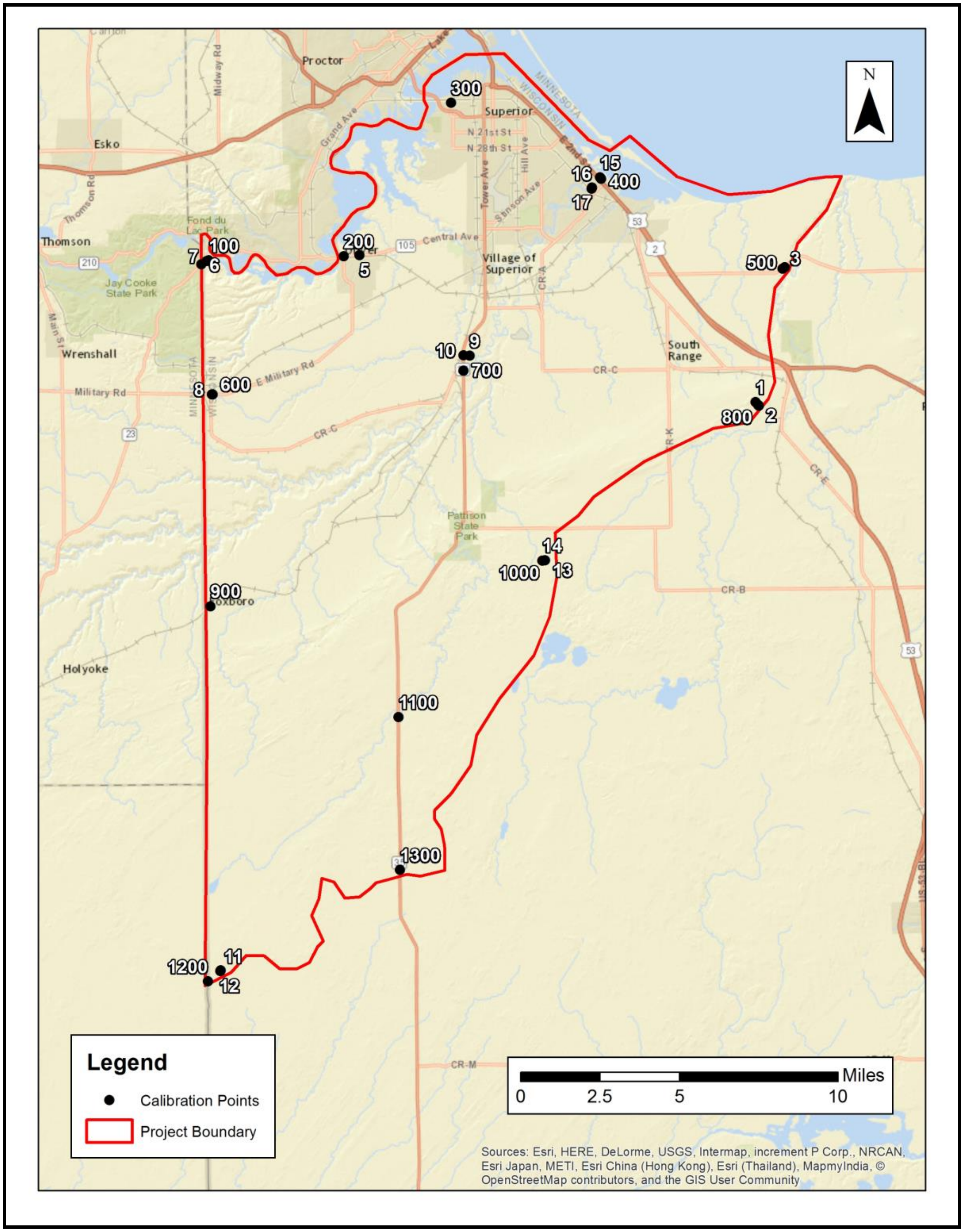


Table 4 Calibration Control Report

Number	Easting	Northing	Known Z	Laser Z	Dz
14	571445.098	5152020.418	349.406	349.580	+0.174
3	583630.634	5166818.645	221.302	221.410	+0.108
9	567754.284	5162398.803	210.449	210.490	+0.041
10	567442.014	5162414.419	211.301	211.340	+0.039
100	554514.397	5167234.693	189.591	189.620	+0.029
500	583734.342	5166875.205	221.254	221.270	+0.016
13	571569.501	5152026.136	349.189	349.200	+0.011
15	574355.807	5171440.003	192.591	192.600	+0.009
1200	554481.918	5130695.576	389.232	389.240	+0.008
1000	571577.005	5152034.272	349.123	349.130	+0.007
7	554411.946	5167196.474	190.156	190.160	+0.004
6	554135.044	5167038.198	194.490	194.490	+0.000
1300	564213.462	5136342.007	389.331	389.330	-0.001
900	554594.123	5149703.720	282.356	282.350	-0.006
200	561371.406	5167441.676	197.782	197.770	-0.012
400	574420.835	5171361.675	193.045	193.030	-0.015
11	555124.457	5131246.210	390.046	390.030	-0.016
1100	564137.207	5144080.658	357.868	357.850	-0.018
1	582257.073	5160052.133	322.259	322.240	-0.019
700	567432.882	5161645.824	211.771	211.750	-0.021
2	582418.300	5159870.955	318.905	318.880	-0.025
12	555099.573	5131207.726	389.714	389.680	-0.034
5	562165.890	5167493.818	199.976	199.940	-0.036
600	554717.759	5160434.208	266.665	266.620	-0.045
16	573944.813	5170874.308	194.269	194.220	-0.049
17	573951.553	5170913.181	194.109	194.060	-0.049

800	582379.811	5159908.922	319.667	319.610	-0.057
300	566807.903	5175213.832	192.430	192.360	-0.070
8	554683.888	5160430.814	266.754	266.680	-0.074

Average Dz	-0.003 m
Minimum Dz	-0.074 m
Maximum Dz	+0.174 m
Root Mean Square	0.050 m
Standard Deviation	0.051 m