Airborne Topographic LiDAR Report

Wisconsin Coastal Management 2015-16 LiDAR Project Report: Bayfield County (Northern Project)

July 9, 2016

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

AYRES ASSOCIATES quantum SPATIAL

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

1. Summary / Scope

1.1. Summary

This report contains a summary of the 2015-16 Wisconsin Coastal Management/3DEP LiDAR data collection for Bayfield County (Northern Project Area). The task orders (in conjunction with the Southern Project Area) yielded a project area covering approximately 1,681 total square miles over Bayfield 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	1,700 m	38°	30%	≤ 10 cm

1.3. Coverage

The LiDAR project boundary covers approximately 1,681 square miles, which includes the Northern Project Area (flown fall 2015) and the Southern Project Area (flown spring 2016). LiDAR extents for the Northern Project Area 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 22, 2015 to November 8, 2015 in sixteen total lifts. See “Section: 2.5. Time Period” for more details.

1.5. Issues

There were no issues to report with this project.

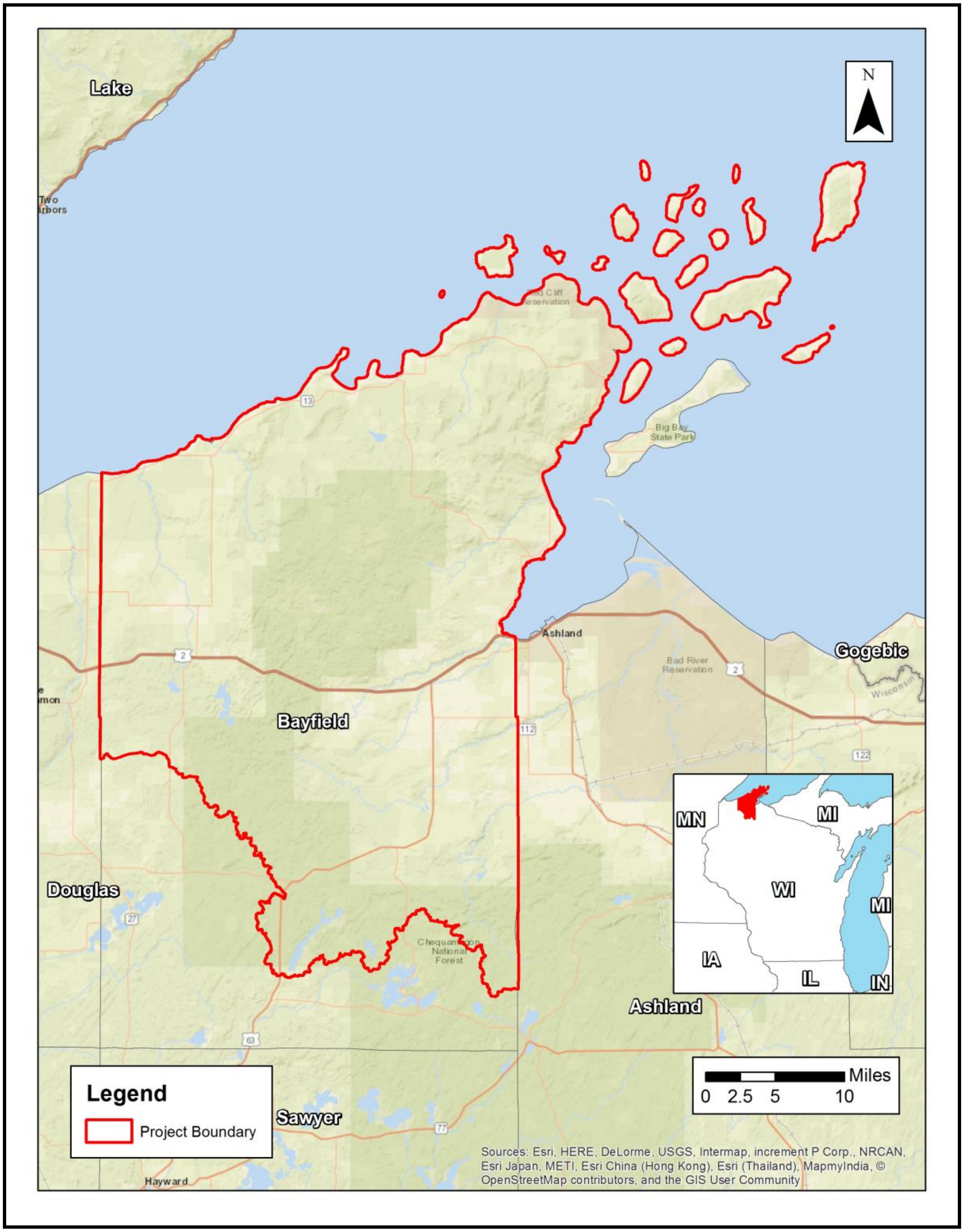
1.6. Deliverables

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) WISCRS Bayfield County, US survey feet; NAVD88 (Geoid 12A), US survey feet. All tiled deliverables have a tile size of 4,500 feet x 4,500 feet.

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 117 planned flight lines measuring approximately 5,861.54 total flight line kilometers (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized an Optech Orion H300 LiDAR sensor (Figure 3), serial numbers 324 and 329 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

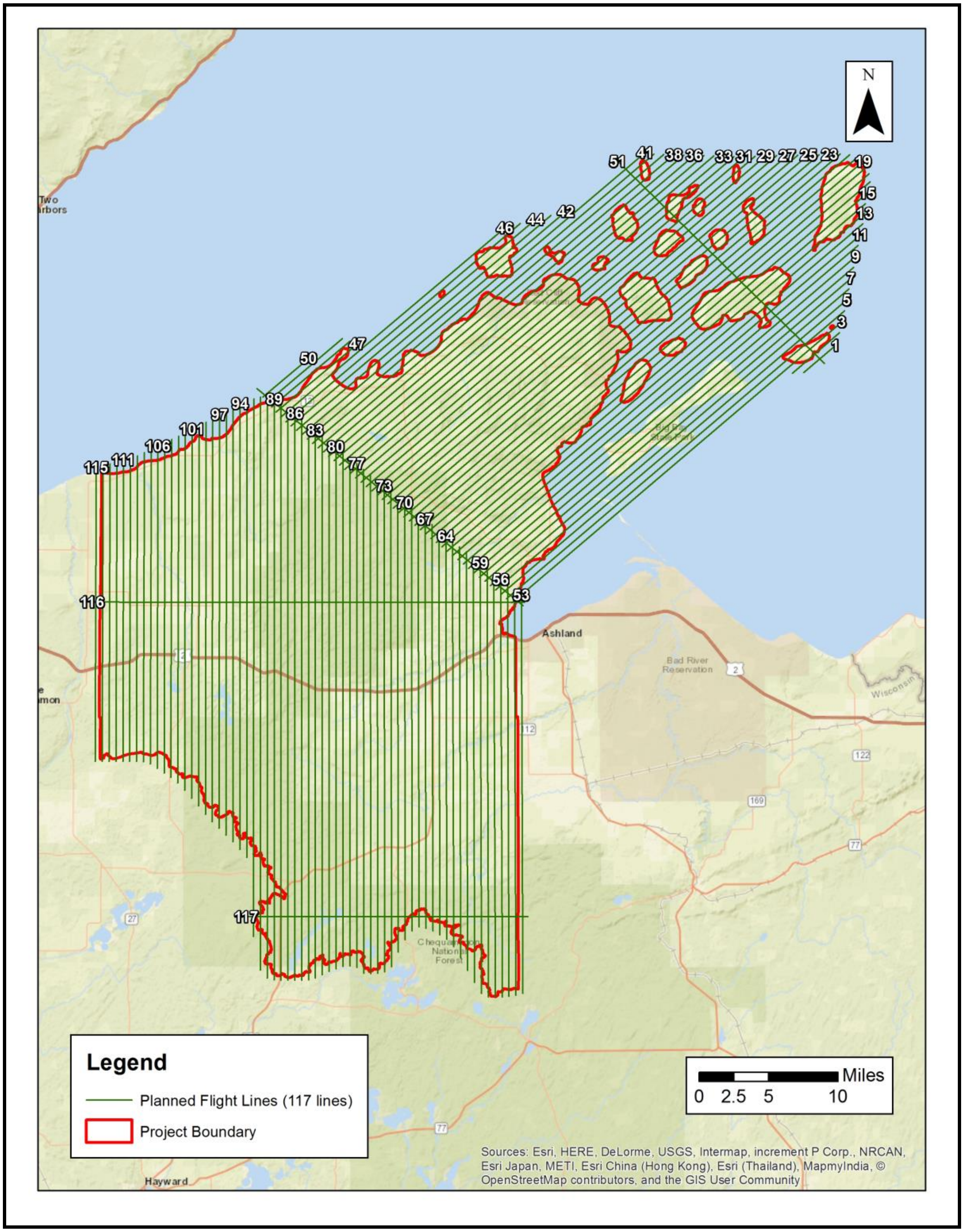


Table 2. LiDAR System Specifications

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	1,1136.28 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 the following customized aircraft:

- Cessna 206 Stationair (piston-single) , Tail Number N7266Z
- Piper Navajo (twin-piston), Tail Number N73TM
- Partenavia P68-C (multi-piston), Tail Number N300LF

These aircraft provided an ideal, stable aerial base for LiDAR and orthoimagery acquisition. These aerial platforms have 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

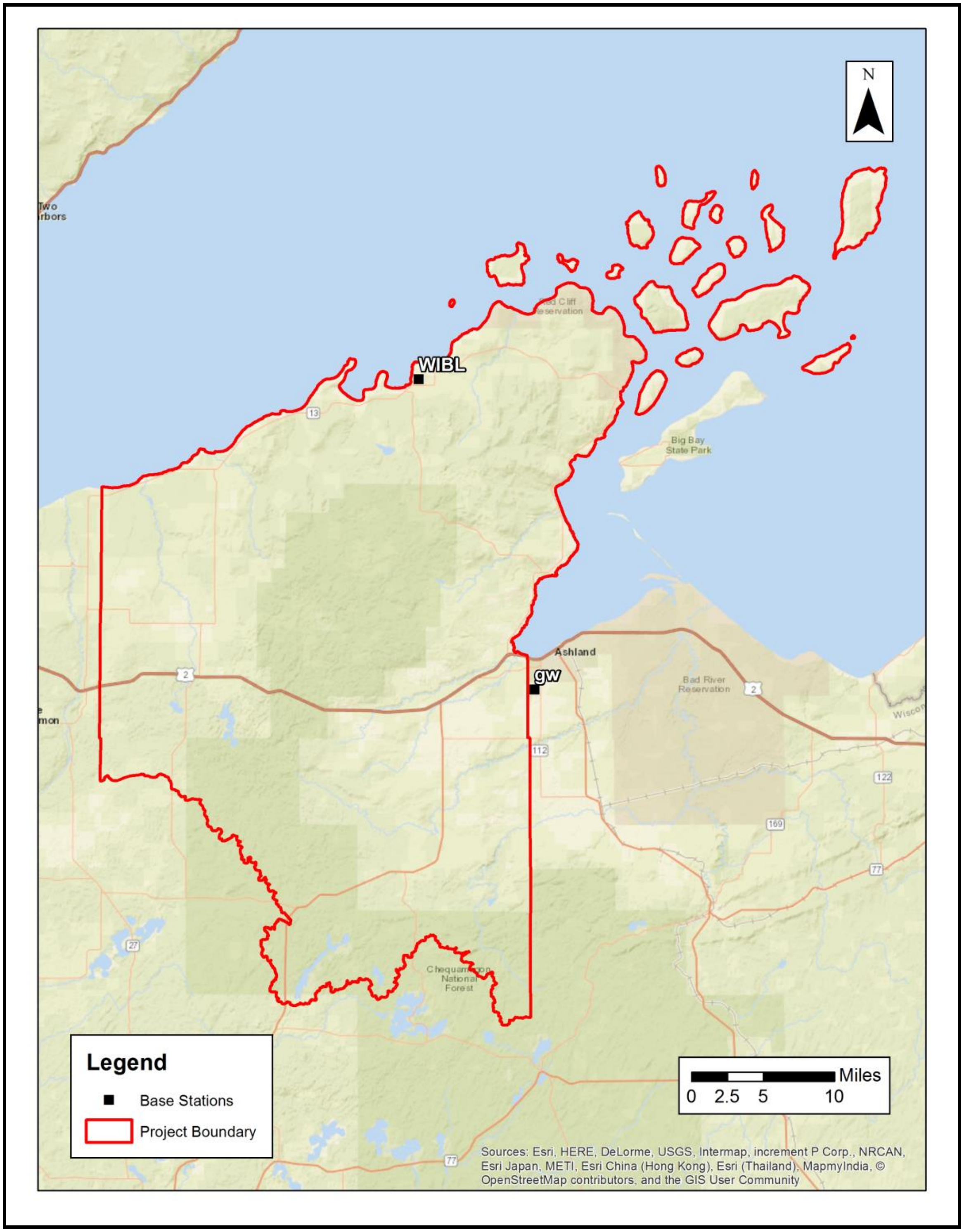
Base Station	Latitude	Longitude	Ellipsoid Height (m)
WIBL	46° 51' 58.80345"	91° 5' 8.72582"	201.71
gw	46° 33' 5.94204"	90° 54' 57.26501"	219.273

2.5. Time Period

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

- Oct 22, 2015-A (N300LF, SN329)
- Oct 22, 2015-A (N7266Z, SN324)
- Oct 22, 2015-B (N7266Z, SN324)
- Oct 25, 2015-A (N300LF, SN329)
- Oct 25, 2015-B (N300LF, SN329)
- Oct 25, 2015-B (N73TM, SN324)
- Oct 27, 2015-A (N300LF, SN329)
- Oct 27, 2015-A (N7266Z, SN324)
- Oct 27, 2015-B (N300LF, SN329)
- Nov 02, 2015-A (N300LF, SN329)
- Nov 02, 2015-A (N73TM, SN324)
- Nov 02, 2015-B (N73TM, SN324)
- Nov 03, 2015-A (N300LF, SN329)
- Nov 03, 2015-A (N73TM, SN324)
- Nov 07, 2015-A (N73TM, SN324)
- Nov 08, 2015-A (N73TM, 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.

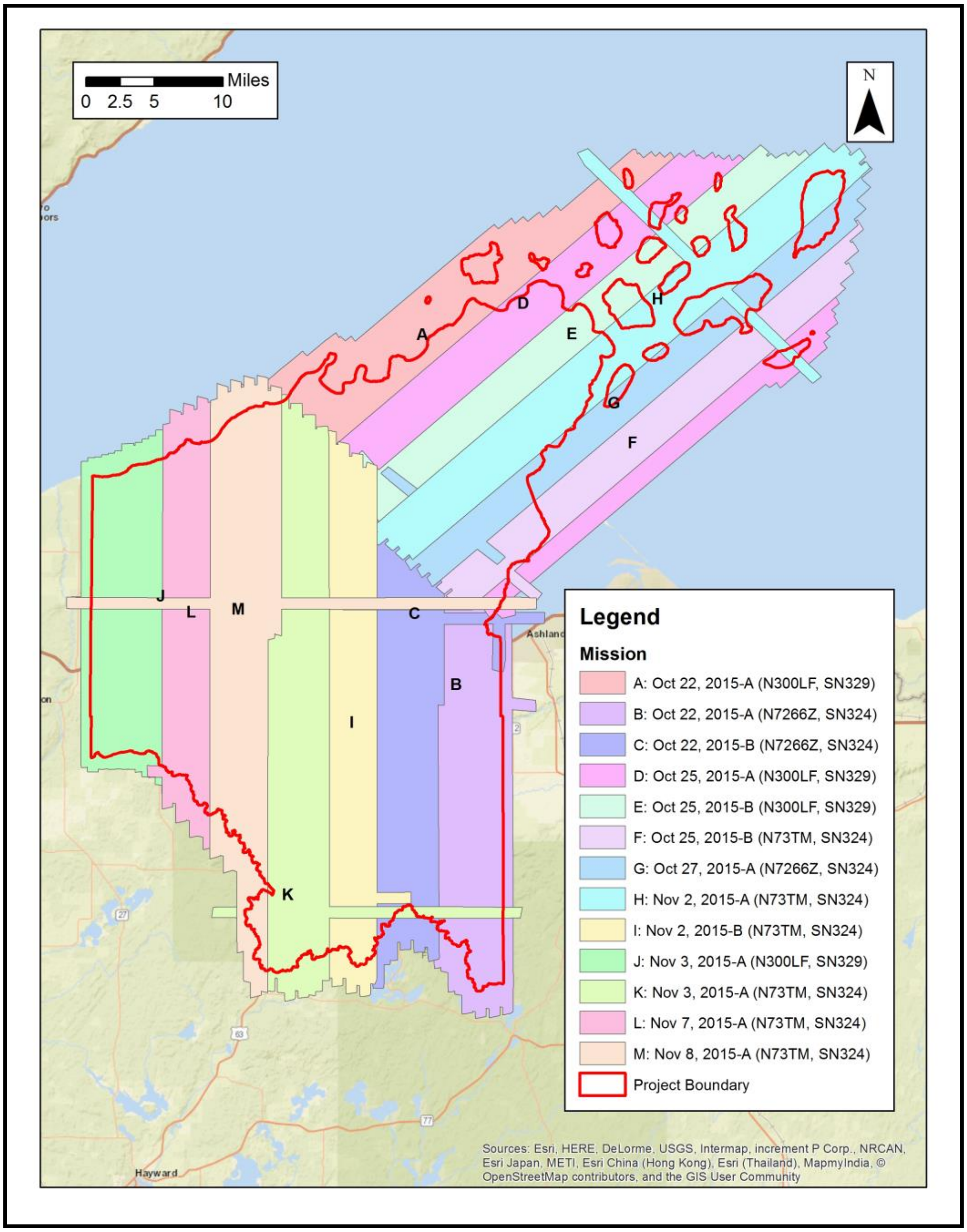
All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the dataset. GeoCue was used to create the deliverable industry-standard LAS files for the All Point Cloud Data.

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 38 total ground control (calibration) points as an independent test of the accuracy of this project. In the northern half of the area of interest, 10 points were used; 28 points were used in the southern half. In this document, horizontal coordinates for ground control points are reported NAD83_2011, WISCRS – Bayfield County, NAVD88 (Geoid 12A), survey feet.

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 - North

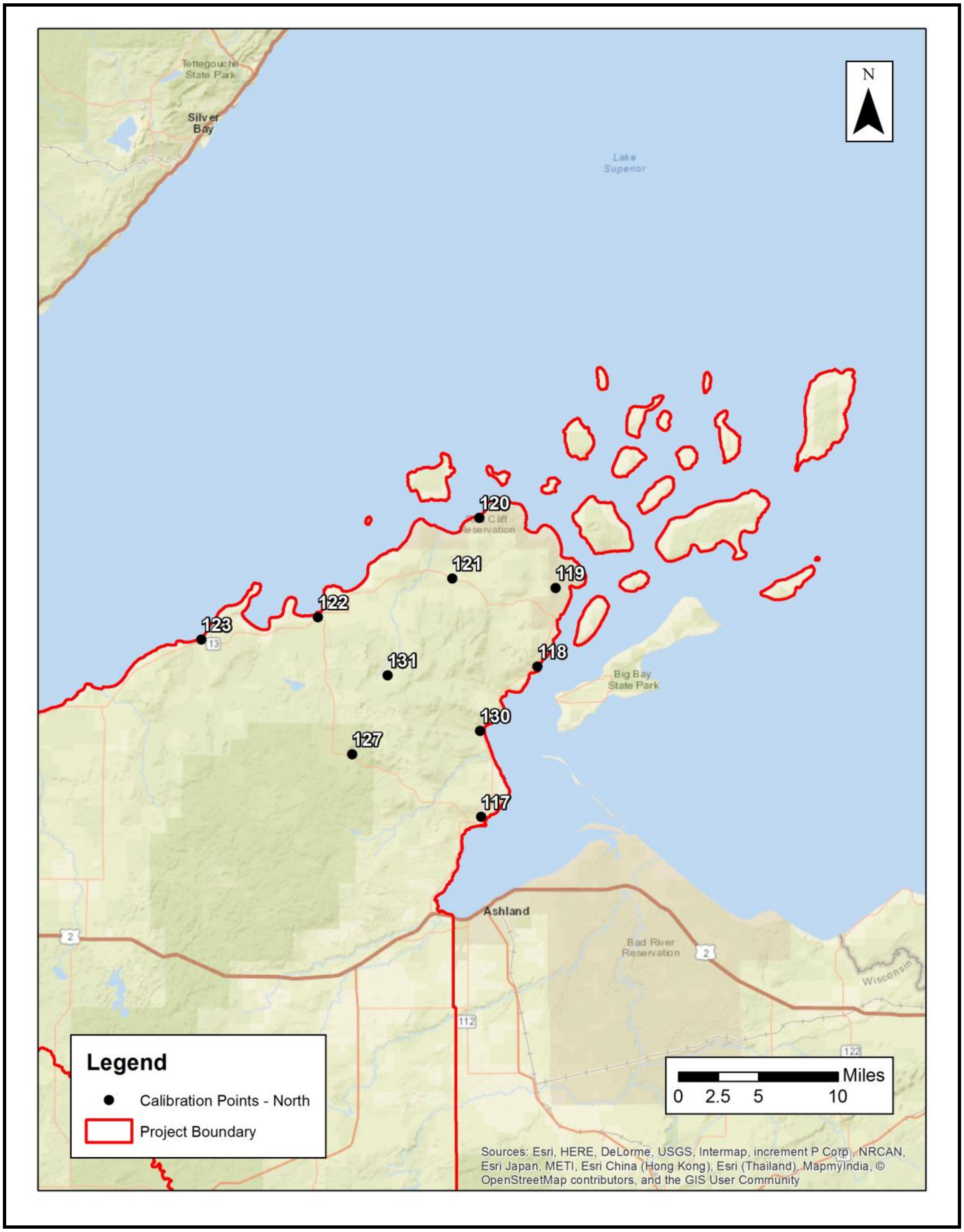


Figure 8. Calibration Control Point Locations - South

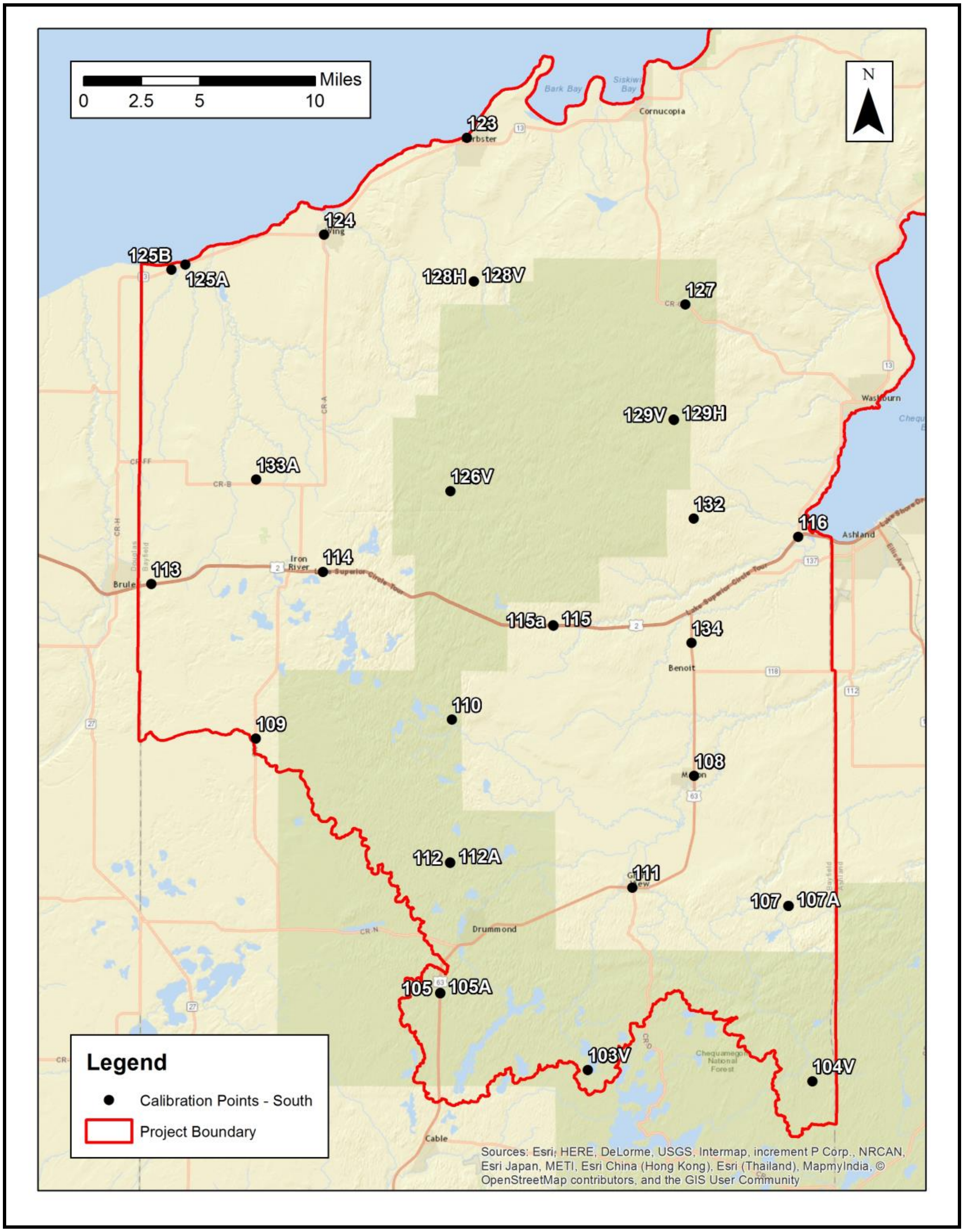


Table 4. Calibration Control Report

All units listed are US Survey Feet.

Number	Easting	Northing	Known Z	Laser Z	Dz
103V	751412.45	335537.71	1443.54	1443.37	-0.17
104V	802689.71	332939.72	1420.17	1420.23	+0.06
105	717725.72	353038.29	1469.59	1469.44	-0.15
105A	717731.57	353090.80	1469.96	1469.90	-0.06
107	797256.38	372932.02	1131.02	1131.09	+0.07
107A	797183.56	372887.03	1130.43	1130.66	+0.23
108	775657.96	402601.74	947.12	947.25	+0.13
109	675625.64	411087.50	1285.96	1286.02	+0.06
110	720446.79	415395.94	1026.70	1026.68	-0.02
111	761542.53	377107.40	1060.28	1060.20	-0.08
112	720022.82	382820.01	1291.13	1290.77	-0.36
112A	720026.20	382758.32	1289.67	1289.60	-0.07
113	651806.99	446297.80	1104.87	1104.89	+0.02
114	690981.79	449103.16	1134.72	1134.79	+0.07
115	743514.35	436881.01	981.18	981.44	+0.26
115a	743608.11	436869.25	981.79	982.05	+0.26
116	799450.53	457067.73	611.25	611.21	-0.04
117	816344.01	489414.98	668.34	668.59	+0.25
118	834987.72	539069.41	614.93	614.85	-0.08
119	840993.99	565034.48	720.54	720.70	+0.16
120	815717.29	588216.08	625.11	624.95	-0.16
121	806796.44	568160.20	840.93	840.76	-0.17
122	762391.80	555383.77	610.40	610.67	+0.27
123	723822.79	548069.33	608.76	608.80	+0.04
124	691285.63	525979.11	672.22	672.22	+0.00
125A	659608.62	519184.39	633.77	633.77	+0.00
125B	656418.53	517973.08	639.77	639.85	+0.08
126V	720054.78	467539.70	1264.03	1264.13	+0.10
127	773704.11	510087.93	1250.54	1250.47	-0.07
128H	725409.95	515369.13	1068.58	1068.29	-0.29
128V	725423.57	515363.15	1068.76	1068.79	+0.03
129H	771037.05	483814.85	1151.70	1151.57	-0.13
129V	771051.06	483762.53	1152.63	1152.49	-0.14
130	815963.73	517819.99	608.42	608.53	+0.11
131	785396.29	536171.36	958.61	958.22	-0.39
132	775547.39	461214.68	1050.55	1050.38	-0.17
133A	675716.08	470137.07	1008.79	1008.96	+0.17
134	775116.46	432927.75	868.90	868.95	+0.05
Average Dz	0.001				
Minimum Dz	-0.390				
Maximum Dz	0.270				
Root Mean Square	0.163				
Standard Deviation	0.170				