

Prince of Wales Island 2017 QL1 LiDAR Project Report



USGS Contract # G16PC00016
Task Order # G17PD00553

Submitted: April 27, 2018

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Contents

| | |
|--|----|
| 1. Summary / Scope | 1 |
| 1.1. Summary..... | 1 |
| 1.2. Scope..... | 1 |
| 1.3. Coverage..... | 1 |
| 1.4. Duration..... | 1 |
| 1.5. Issues | 1 |
| 1.6. Deliverables | 2 |
| 2. Planning / Equipment | 4 |
| 2.1. Flight Planning | 4 |
| 2.2. LiDAR Sensor | 4 |
| 2.3. Aircraft..... | 7 |
| 2.4. Base Station Information..... | 8 |
| 2.5. Time Period | 10 |
| 3. Processing Summary | 11 |
| 3.1. Flight Logs..... | 11 |
| 3.2. LiDAR Processing..... | 12 |
| 3.3. LAS Classification Scheme | 13 |
| 3.4. Classified LAS Processing | 13 |
| 3.5. Hydro-Flattened Breakline Creation | 14 |
| 3.6. Hydro-Flattened Raster DEM Creation..... | 14 |
| 3.7. Intensity Image Creation | 14 |
| 3.8. Digital Surface Model Creation | 15 |
| 3.9. Shaded Relief Raster Creation..... | 15 |
| 3.10. Topographic Contour Creation | 15 |
| 3.11. Automated Building Polygon Creation | 15 |
| 4. Project Coverage Verification | 16 |
| 5. Ground Control and Check Point Collection | 18 |
| 5.1. Calibration Control Point Testing..... | 18 |
| 5.2. Point Cloud Testing | 18 |
| 5.3. Digital Elevation Model (DEM) Testing..... | 19 |

List of Figures

| | |
|--|----|
| Figure 1. LiDAR Project Boundary | 3 |
| Figure 2. Planned LiDAR Flight Lines | 5 |
| Figure 3. The Leica ALS80 and Riegl Q1560 and VQ1560i LiDAR Sensors..... | 6 |
| Figure 4. Some of Quantum Spatial's Planes..... | 7 |
| Figure 5. Base Station Locations | 9 |
| Figure 6. Flightline Swath LAS File Coverage | 17 |
| Figure 7. Calibration Control Point Locations..... | 20 |
| Figure 8. QC Checkpoint Locations - Raw NVA | 21 |
| Figure 9. QC Checkpoint Locations - NVA | 22 |
| Figure 10. QC Checkpoint Locations - VVA..... | 23 |

List of Tables

| | |
|--|---|
| Table 1. Originally Planned LiDAR Specifications | 1 |
| Table 2. LiDAR System Specifications | 6 |
| Table 3. Base Station Locations | 8 |

List of Appendices

Appendix A: GPS / IMU Processing Statistics, Flight Logs, and Base Station Logs

1. Summary / Scope

1.1. Summary

This report contains a summary of the Prince of Wales Island 2017 QL1 LiDAR acquisition task order, issued by USGS National Geospatial Technical Operations Center (NGTOC) under their Geospatial Products and Services Contract (GPSC v.3) on May 11, 2017. The task order yielded a project area covering 2,055.6 square miles (5,322 square kilometers), inclusive of a required 100-meter buffer, over most of Prince of Wales Island in the Prince of Wales-Hyder Census Area in Alaska’s Southeastern Panhandle. The intent of this document is only to provide specific validation information for the data acquisition/collection work 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

| Sensor | Average Point Density | Flight Altitude (AGL) | Field of View | Minimum Side Overlap | RMSEz |
|---------|--------------------------|-----------------------|---------------|----------------------|---------|
| ALS80 | 8.5 pts / m ² | 1700 m | 36° | 66% | ≤ 10 cm |
| VQ1560i | 8.5 pts / m ² | 1500 m | 58.5° | 60% | ≤ 10 cm |

1.3. Coverage

The LiDAR project boundary covers 2,055.6 square miles inclusive of the required buffer and encompasses the majority of Prince of Wales Island in Southeastern Alaska. A buffer of 100 meters was created to meet task order specifications. LiDAR extents are shown in Figure 1.

1.4. Duration

LiDAR data was acquired from May 26, 2017 to October 2, 2017 in 30 total lifts. See “Section: 2.6. Time Period” for more details.

1.5. Issues

There were no issues to report for this project.

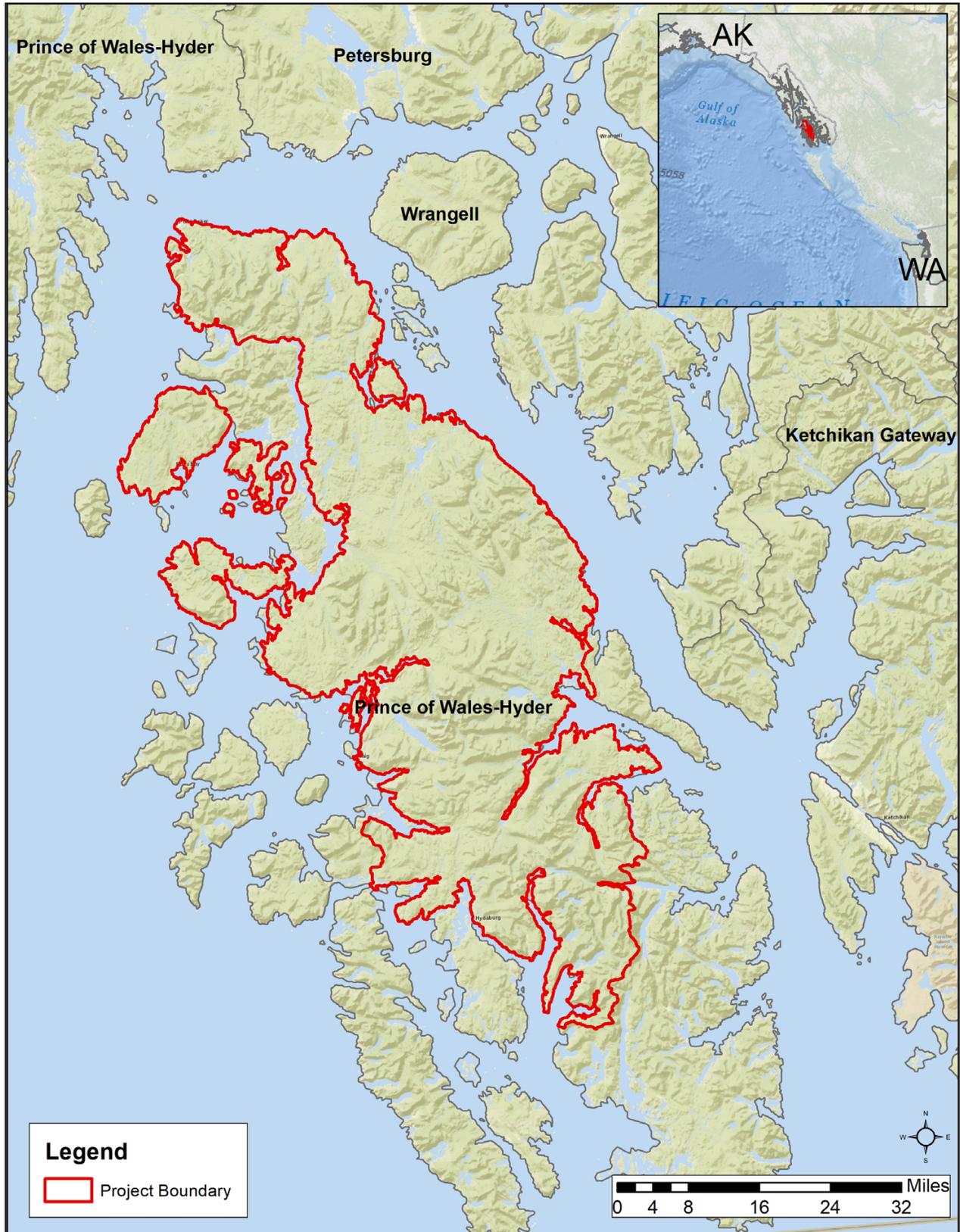
1.6. Deliverables

The following products were produced and delivered:

- Raw LiDAR point cloud data swaths in .LAS 1.4 format
- Classified LiDAR point cloud data tiles in .LAS 1.4 format
- 0.5-meter bare earth digital elevation model (DEM) tiles in ERDAS .IMG format
- Continuous hydro-flattened and bridge breaklines in Esri file geodatabase format
- 0.5-meter intensity imagery tiles in GeoTIFF format
- Optional 0.5-meter digital surface model (DSM) tiles in GeoTIFF format
- Optional 0.5-meter shaded relief raster tiles and mosaic in GeoTIFF format
- 1-foot contour tiles in Esri file geodatabase format
- Automated building polygons for AOI in untiled Esri file geodatabase format
- Projects extents geodatabase as a georeferenced digital spatial representation of the extents of each delivered dataset
- Calibration and QC checkpoints in Esri shapefile format
- Processing boundary in Esri shapefile format
- Tile index in Esri shapefile format
- Project-, deliverable-, and lift-level metadata in .XML format
- FOCUS, FOCUS on Accuracy, and FOCUS on Deliverables reports in .PDF format
- GPS/IMU statistics and flight logs in .PDF format
- Survey report in .PDF format

All geospatial deliverables were produced with a horizontal datum/projection of NAD83 (2011 Epoch 2010.00), UTM Zone 8, meters and a vertical datum/projection of NAVD88 (GEOID12B), meters. Tiled deliverables have a tile size of 1,000 meters x 1,000 meters (classified LAS tiles) or 2,000 meters x 2,000 meters (all other tiles). Tile names are derived from the US National Grid conventions.

Figure 1. Base Station Locations



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 Leica MissionPro and FMS Planner planning software. The entire target area was comprised of 908 planned flight lines measuring approximately 9169 total flight line miles (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized a Leica ALS80 LiDAR sensor (Figure 3), serial number 8146, a Riegl Q1560 LiDAR sensor (Figure 3), and a Riegl VQ1560i (Figure 3), serial number S222738, serial number S2220754.

The Leica ALS 80 system is capable of collecting data at a maximum frequency of 1,000 kHz. The system utilizes a Multi-Pulse in the Air option (MPIA). The sensor is also equipped with the ability to measure up to 6 returns per outgoing pulse from the laser. The intensity of the returns is also captured during aerial acquisition.

The Riegl VQ1560i system has a laser pulse repetition rate of up to 2 MHz resulting in more than 1.3 million measurements per second. The system utilizes a Multi-Pulse in the Air option (MPIA). The sensor is also equipped with the ability to measure up to an unlimited number of targets per pulse from the laser.

The Riegl Q1560 system is capable of collecting data at a maximum pulse repetition rate of 800 kHz, affording an effective rate of 532,000 measurements on the ground. The sensor's multiple time around processing software automatically resolves range ambiguities and handles more than 10 simultaneous pulses in the air.

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

Figure 2. Planned LiDAR Flight Lines

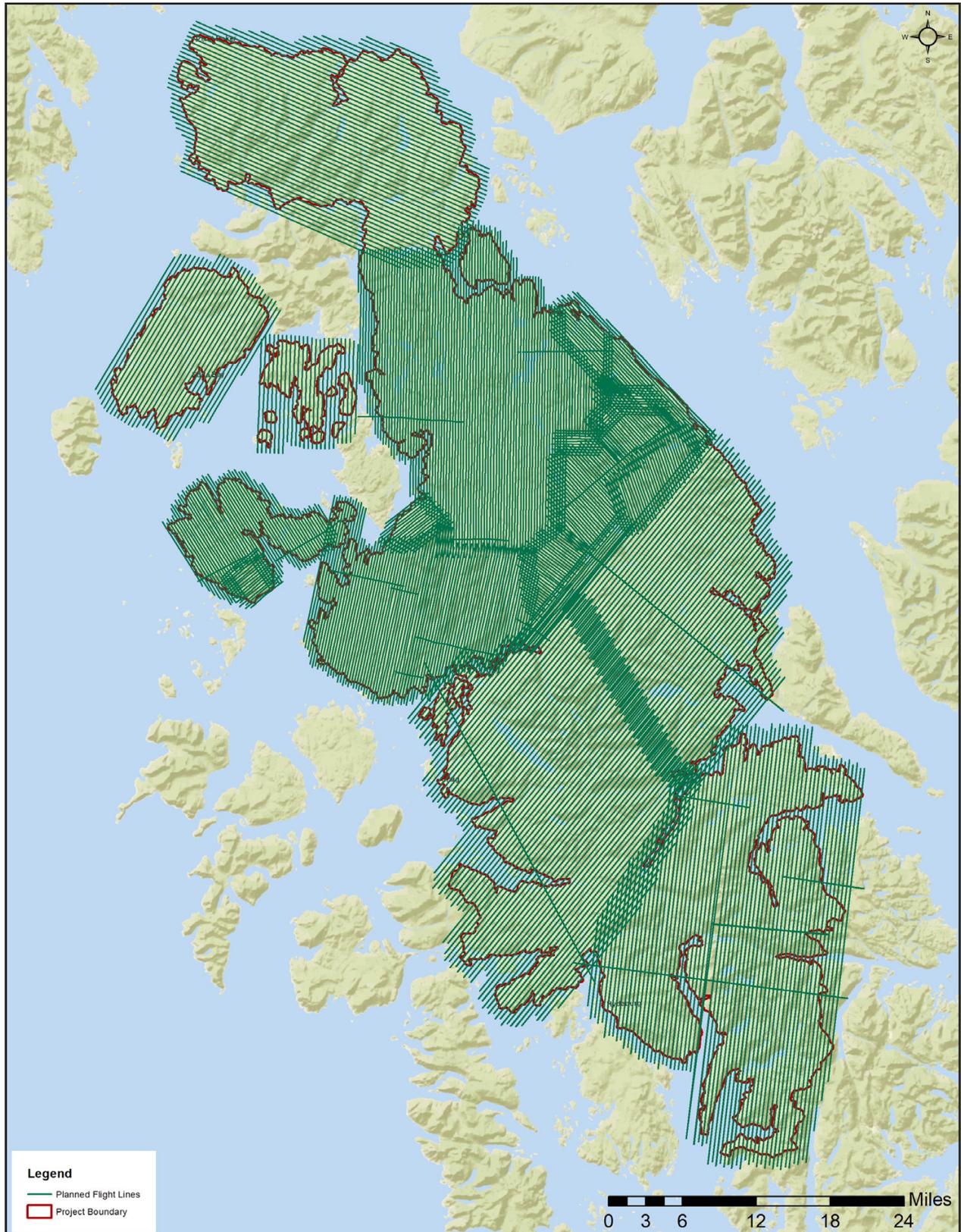
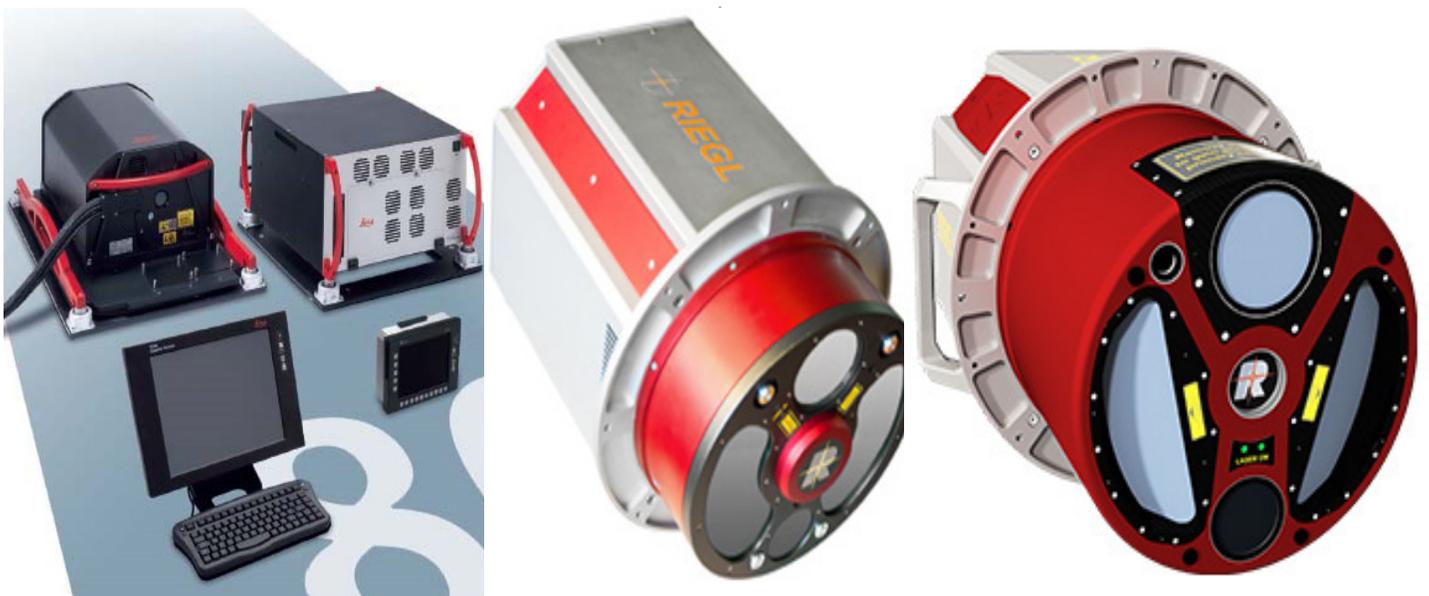


Table 2. LiDAR System Specifications

| | | Leica ALS80 | Riegl Q1560 | Riegl VQ1560i |
|------------------------------|--------------------------------|------------------------|------------------------|------------------------|
| Terrain and Aircraft Scanner | Flying Height | 1700 m | 1300 m | 2000 m |
| | Recommended Ground Speed (kts) | 120 kts | 160 kts | 160 kts |
| Scanner | Field of View | 36° | 60° | 60° |
| | Scan Rate Setting Used | 49 Hz | 191 Hz | 225 Hz |
| Laser | Laser Pulse Rate Used | 315 kHz | 800 kHz | 1000 kHz |
| | Multi Pulse in Air Mode | Enabled | Enabled | Enabled |
| Coverage | Full Swath Width (m) | 360 m | 550 m | 550 m |
| Point Spacing and Density | Average Point Spacing | 0.35 m | 0.35 m | 0.35 m |
| | Average Point Density | 8.5 pts/m ² | 8.5 pts/m ² | 8.5 pts/m ² |

Figure 3. The Leica ALS80 (Left), Riegl Q1560 (Middle), and Riegl VQ1560i (Right) LiDAR Sensors


2.3. Aircraft

All flights for the project were accomplished through the use of customized planes. Plane type and tail numbers are listed below.

LiDAR Collection Planes

- Piper Navajo Twin-Piston, Tail Numbers: C-FFRY, N44RL
- Cessna Caravan Single-Engine, Tail Numbers: N208NR, N604MD

These aircraft provided an ideal, stable aerial base for LiDAR and orthoimagery acquisition. These aerial platforms 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 Leica and Riegl LiDAR systems. Some of Quantum Spatial's operating aircraft can be seen in Figure 4 below.

Figure 4. Some of Quantum Spatial's Planes



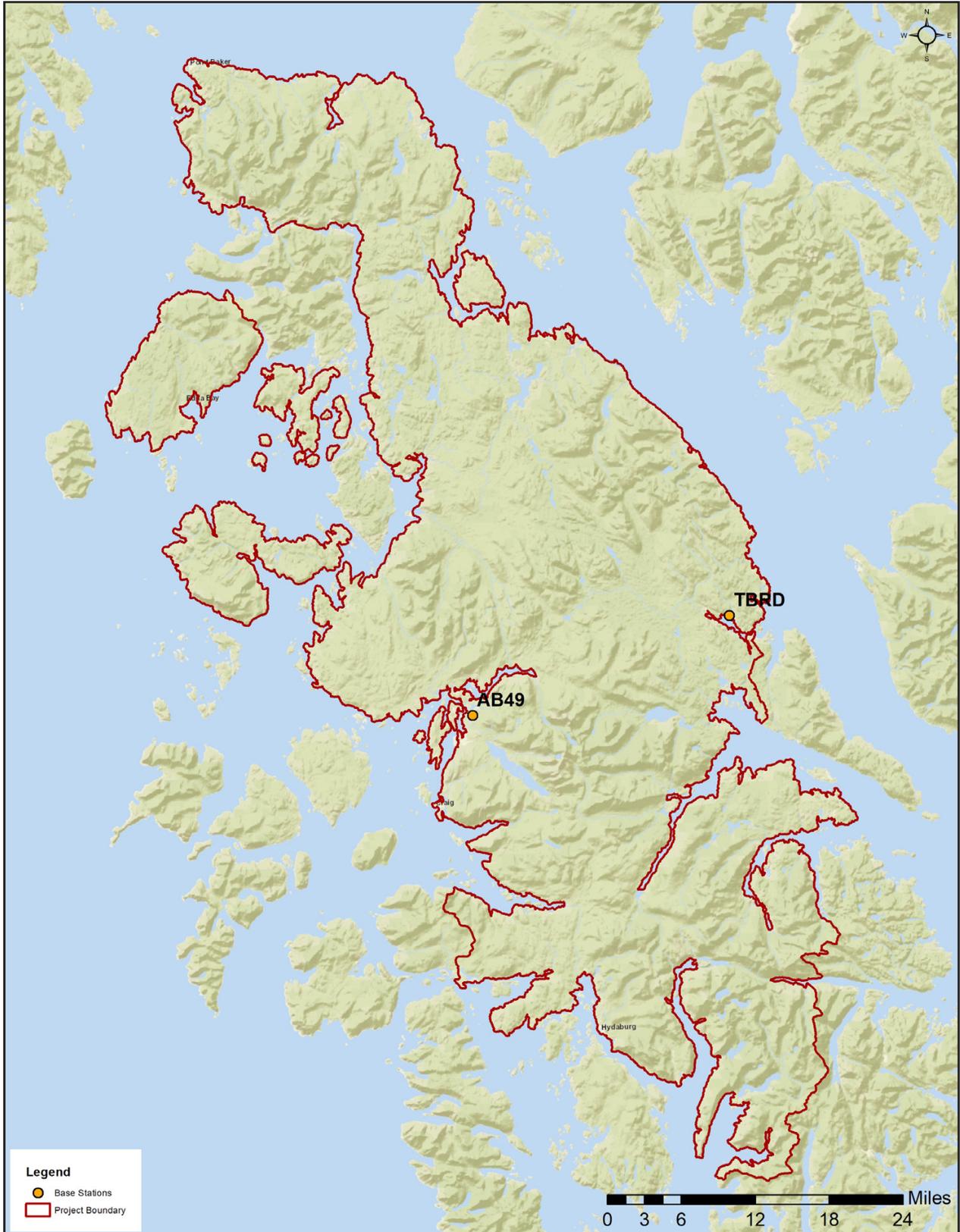
2.4. Base Station Information

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 | Longitude | Latitude | Ellipsoid Height (m) |
|--------------|--------------------|-------------------|----------------------|
| AB49 | 133° 4' 6.47087" | 55° 34' 48.35591" | 17.485 |
| TBRD | 132° 31' 45.73369" | 55° 41' 15.62257" | 36.823 |

Figure 5. Base Station Locations



2.5. Time Period

Project specific flights were conducted over several months. 30 sorties, or aircraft lifts were completed. Accomplished sorties are listed below.

- May 26, 2017-A (N208NR, SN8146)
- May 27, 2017-A (N208NR, SN8146)
- May 27, 2017-B (N208NR, SN8146)
- August 1, 2017-A (N604MD, SN8146)
- August 1, 2017-B (N604MD, SN8146)
- August 2, 2017-A (N604MD, SN8146)
- August 4, 2017-A (N604MD, SN8146)
- August 4, 2017-B (N604MD, SN8146)
- August 4, 2017-A (C-FFRY, SN2220754)
- August 5, 2017-A (N604MD, SN8146)
- August 5, 2017-B (N604MD, SN8146)
- August 5, 2017-C (N604MD, SN8146)
- August 5, 2017-A (C-FFRY, SN2220754)
- August 7, 2017-A (C-FFRY, SN2220754)
- August 8, 2017-A (N604MD, SN8146)
- August 8, 2017-B (N604MD, SN8146)
- August 8, 2017-A (C-FFRY, SN2220754)
- August 9, 2017-A (N604MD, SN8146)
- August 9, 2017-B (N604MD, SN8146)
- August 9, 2017-A (C-FFRY, SN2220754)
- August 10, 2017-A (N604MD, SN8146)
- Sept. 3, 2017-A (N604MD, SN8146)
- Sept. 3, 2017-B (N604MD, SN8146)
- Sept. 3, 2017-A (N44RL, SN2222738)
- Sept. 5, 2017-A (N604MD, SN8146)
- Sept. 6, 2017-A (N604MD, SN8146)
- Sept. 13, 2017-B (C-FFRY, SN2220754)
- Sept. 14, 2017-A (C-FFRY, SN2220754)
- Oct. 1, 2017-A (N44RL, SN2221238)
- Oct. 2, 2017-A (N44RL, SN2222738)

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). All available project specific flight logs for sorties are located in Appendix A.

3.2. LiDAR Processing

Inertial Explorer/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. Inertial Explorer/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 Inertial Explorer/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 these data are 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 Leica CloudPro software and Riegl RiPROCESS 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 were manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the bare earth dataset. GeoCue was used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. In-house software was then used to perform final statistical analysis of the classes in the LAS files.

3.3. LAS Classification Scheme

The classification classes are determined by the USGS Version 1.2 specifications and are an industry standard for the classification of LIDAR point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

- Class 1 – Processed, but Unclassified – These points would be the catch all for points that do not fit any of the other deliverable classes. This would cover features such as vegetation, cars, etc.
- Class 2 – Bare-Earth Ground – This is the bare earth surface
- Class 3 – Vegetation (Low) – This is 0.5-2 meters above the ground
- Class 4 – Vegetation (Medium) – This is 2-6 meters above the ground
- Class 5 – Vegetation (High) – This is more than 6 meters above the ground
- Class 6 – Man-Made Structures – Points falling on buildings, structures inside of water bodies, docks, and piers.
- Class 7 – Low Noise – Low points, manually identified below the surface that could be noise points in point cloud.
- Class 9 – Water – Points found inside of inland lake/ponds
- Class 10 – Ignored Ground – Points found to be close to breakline features. Points are moved to this class from the Class 2 dataset. This class is ignored during the DEM creation process in order to provide smooth transition between the ground surface and hydro-flattened surface.
- Class 17 – Bridge Decks – Points falling on bridge decks.
- Class 18 – High Noise – High points, manually identified above the surface that could be noise points in point cloud.

3.4. Classified LAS Processing

The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare-earth surface is finalized; it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) LiDAR data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 3 feet was also used around each hydro-flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 10). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

All overlap data were processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes by USGS. The overlap data were identified using the Overlap Flag, per LAS 1.4 specifications.

All data were manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper is used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for all point cloud data. Quantum Spatial proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.5. Hydro-Flattened Breakline Creation

Class 2 LiDAR was used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of Inland Streams and Rivers with a 75 foot nominal width and Inland Ponds and Lakes of 2 acres or greater surface area.

Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, Inland Streams and Rivers, and Inland Stream and River Islands using TerraModeler functionality.

Elevation values were assigned to all Inland streams and rivers using Quantum Spatial proprietary software.

All ground (ASPRS Class 2) LiDAR data inside of the collected inland breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 3 feet was also used around each hydro-flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

The breakline files were then translated to Esri file geodatabase format using Esri conversion tools.

3.6. Hydro-Flattened Raster DEM Creation

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 0.5-meter Raster DEM. Using automated scripting routines within ArcMap, an ERDAS Imagine .IMG file was created for each tile. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

3.7. Intensity Image Creation

GeoCue software was used to create the deliverable Intensity Images. All overlap classes (ASPRS class 17/18/25) were ignored during this process. This helps to ensure a more aesthetically pleasing image. The GeoCue software was then used to verify full project coverage as well. GeoTIFF files were then provided as the deliverable for this dataset requirement.

3.8. Digital Surface Model Creation

After the USGS issued final acceptance of classified .LAS and DEM files, digital surface models (DSMs) were developed. These comprised 0.5-meter first return grids, tiled to match the other tiled deliverables. DSM tiles were delivered in 32-bit floating point GeoTIFF rasters.

3.9. Shaded Relief Raster Creation

After the USGS issued final acceptance of classified .LAS and DEM files, tiled and mosaiced shaded relief rasters were generated from the bare-earth DEMs using first returns from the canopy top. Individual rasters used the same tiling and resolution as the bare-earth DEMs. A single mosaic of all shaded relief rasters was also generated. All rasters were delivered in 32-bit floating point GeoTIFF rasters.

3.10. Topographic Contour Creation

After the USGS issued final acceptance of classified .LAS and DEM files, 1-foot topographic contours in file geodatabase format were generated automatically from the hydro-flattened surface. These contours consisted of intermediate and auto-labeled index contours and did not include depressions, hidden contours, or spot elevations.

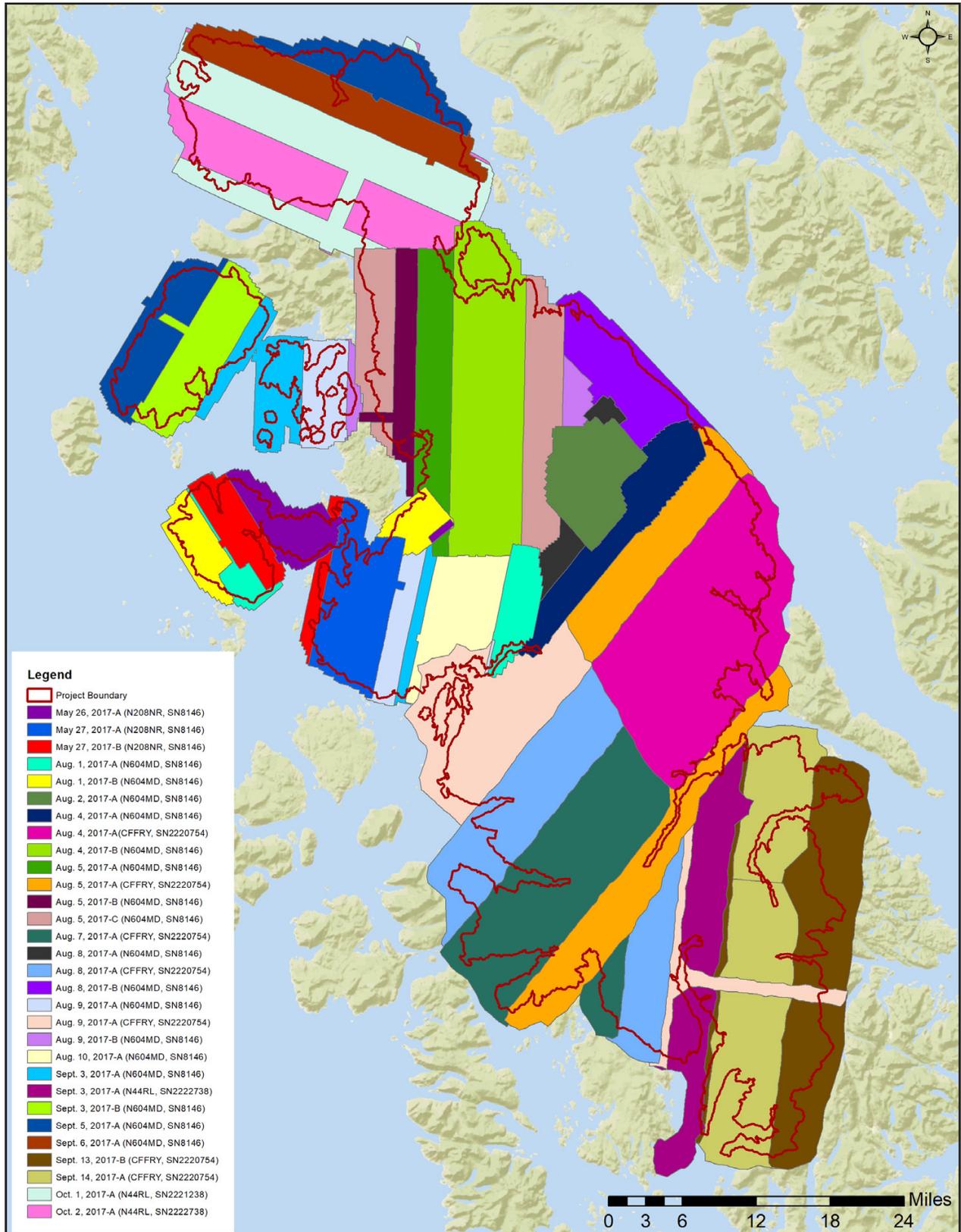
3.11. Automated Building Polygon Creation

After the USGS issued final acceptance of classified .LAS and DEM files, automated building polygons were generated from PolygonZ with default attribution and delivered as a file geodatabase.

4. Project Coverage Verification

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. Flightline Swath LAS File Coverage



5. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of 79 ground control (calibration) points along with 127 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 206 points) as an independent test of the accuracy of this project.

A combination of precise GPS surveying methods, including static and RTK observations were used to establish the 3D position of ground calibration points and QA points for the point classes above. GPS was not an appropriate methodology for surveying in the forested areas during the leaf-on conditions for the actual field survey (which was accomplished after the LiDAR acquisition). Therefore the 3D positions for the forested points were acquired using a GPS-derived offset point located out in the open near the forested area, and using precise offset surveying techniques to derive the 3D position of the forested point from the open control point. The explicit goal for these surveys was to develop 3D positions that were three times greater than the accuracy requirement for the elevation surface. In this case of the blind QA points the goal was a positional accuracy of 5 cm in terms of the RMSE.

The required accuracy testing was performed on the LiDAR dataset (both the LiDAR point cloud and derived DEMs) according to the USGS LiDAR Base Specification Version 1.2 (2014). In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in UTM 8.

5.1. Calibration Control Point Testing

Figure 7 shows the location of each bare earth calibration point for the project area. 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.

5.2. Point Cloud Testing

The project specifications require that only Non-Vegetated Vertical Accuracy (NVA) be computed for raw LiDAR point cloud swath files. The required accuracy (ACCz) is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the “bare earth” and “urban” land cover classes. The NVA was tested with 74 checkpoints located in bare earth and urban (non-vegetated) areas. These checkpoints were not used in the calibration or post processing of the LiDAR point cloud data. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See survey report for additional survey methodologies.

Elevations from the unclassified LiDAR surface were measured for the x,y location of each checkpoint. Elevations interpolated from the LiDAR surface were then compared to the elevation values of the surveyed control points. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National

Digital Elevation Program (NDEP)/ASRPS Guidelines. See Figure 9.

5.3. Digital Elevation Model (DEM) Testing

The project specifications require the accuracy (ACCz) of the derived DEM be calculated and reported in two ways:

1. The required NVA is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the “bare earth” and “urban” land cover classes. This is a required accuracy. The NVA was tested with 74 checkpoints located in bare earth and urban (non-vegetated) areas. See Figure 9.

2. Vegetated Vertical Accuracy (VVA): VVA shall be reported for “forested areas,” “brushlands/low trees” and “tall weeds/crops” land cover classes. The target VVA is: 29.4 cm at the 95th percentile, derived according to ASPRS Guidelines, Vertical Accuracy Reporting for LiDAR Data, i.e., based on the 95th percentile error in all vegetated land cover classes combined. This is a target accuracy. The VVA was tested with 53 checkpoints located in forested areas and brushlands/low trees (vegetated) areas. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See Figure 10.

See survey report for additional survey methodologies. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASRPS Guidelines.

A brief summary of results are listed below. For more information, see the FOCUS on Accuracy Report.

| Category | Target | Measured | Point Count |
|----------|---------|----------|-------------|
| Raw NVA | 0.196 m | 0.107 m | 74 |
| NVA | 0.196 m | 0.106 m | 74 |
| VVA | 0.294 m | 0.288 m | 53 |

Figure 7. Calibration Control Point Locations

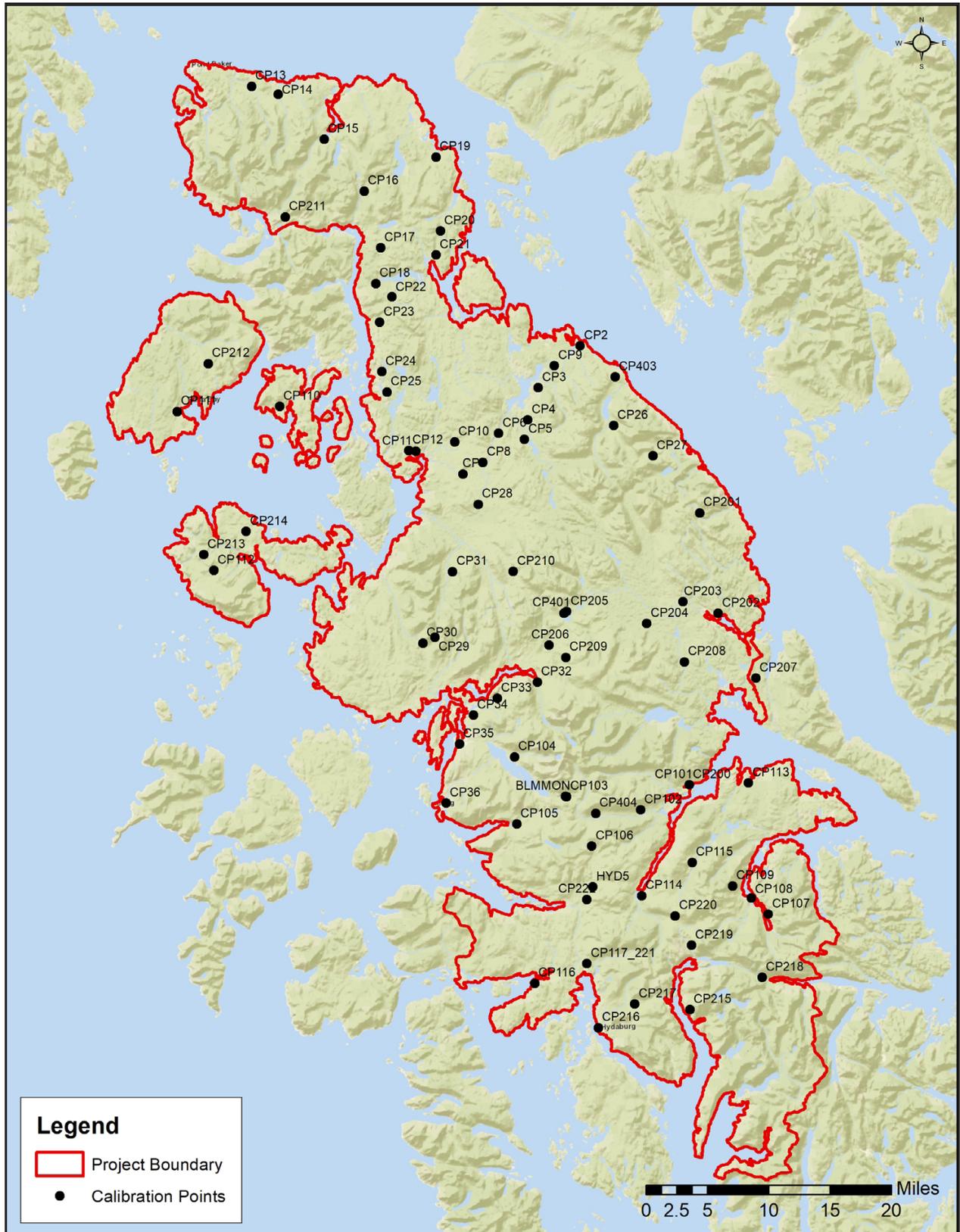


Figure 8. QC Checkpoint Locations - Raw NVA

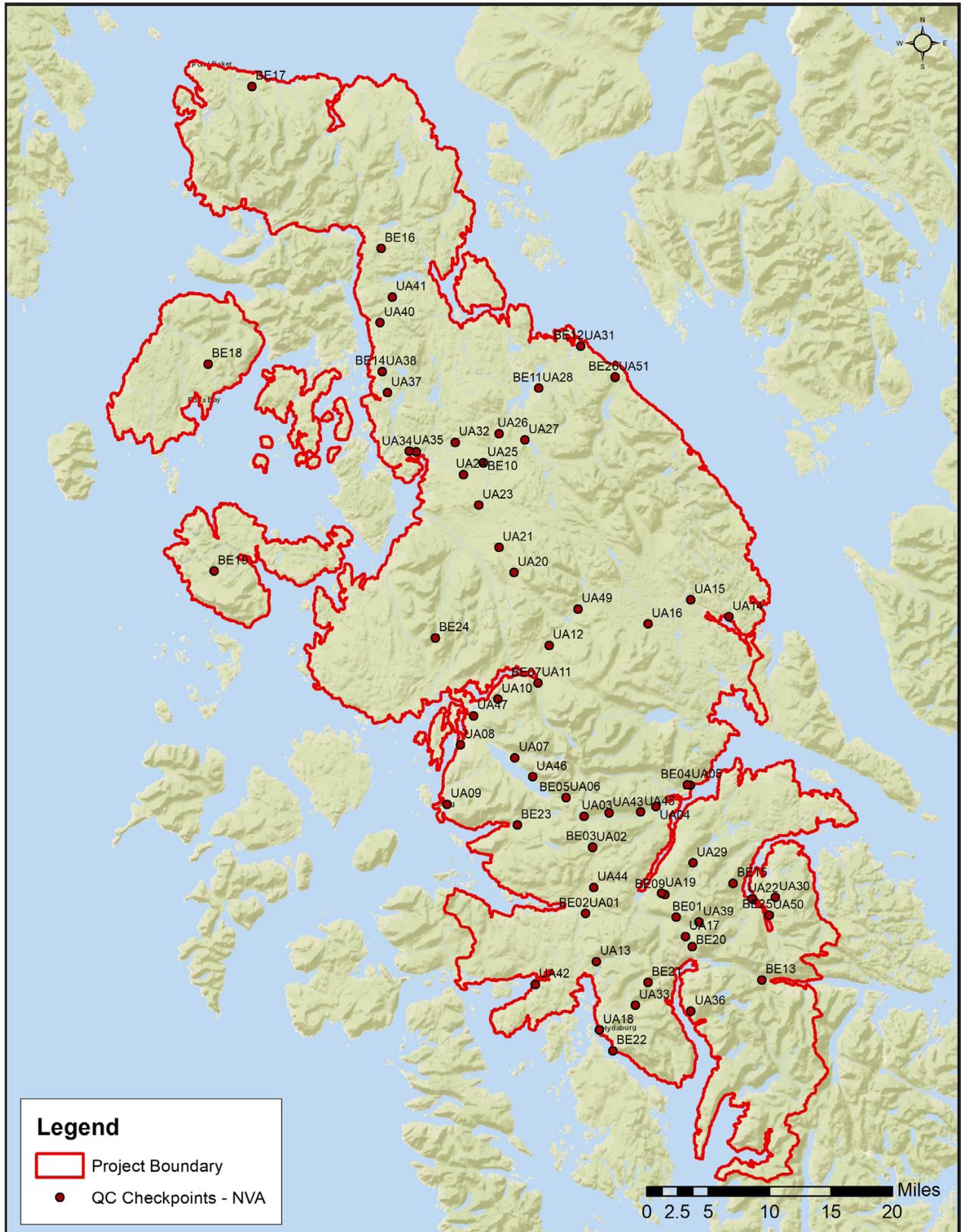


Figure 9. QC Checkpoint Locations - NVA

