Prince of Wales Phase II 2018 LiDAR Project Report

USGS Contract # G16PC00016
Task Order # 140G0218F0180

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Prepared by:

Quantum Spatial, Inc
523 Wellington Way, Suite 375
Lexington, KY 40503
859-277-8700

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Prince of Wales Phase II 2018 LiDAR acquisition task order, issued by the USGS under their Contract G16PC00016 on 23 April 2018 and modified on 4 June 2018. The task order yielded a project area covering 1198 square miles over the Alaska Panhandle. 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.

While collection is planned for the data to utilize the maximum FOV for each sensor, some lidar points may be found to have a scan angle that is outside planned ranges. This is due to the sensor being flown over mountainous terrain with abrupt changes in relief. These points are left in the LAS files, and automated macro classification is used to classify these points.

Table 1. Originally Planned LiDAR Specifications

Sensor	Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
VQ 1560i	8 pts / m^2	1300 m	58°	60%	≤ 10 cm

1.3. Coverage

The buffered project boundary covers 1198 square miles over the Alaska Panhandle. A buffer of 100 meters was created to meet task order specifications. Project extents are shown in Figure 1.

1.4. Duration

LiDAR data was acquired from 6 May 2018 to 18 September 2018 in 19 total lifts. See "Section: 2.5. Time Period" for more details.

1.5. Issues

There were no major issues to report for this project.

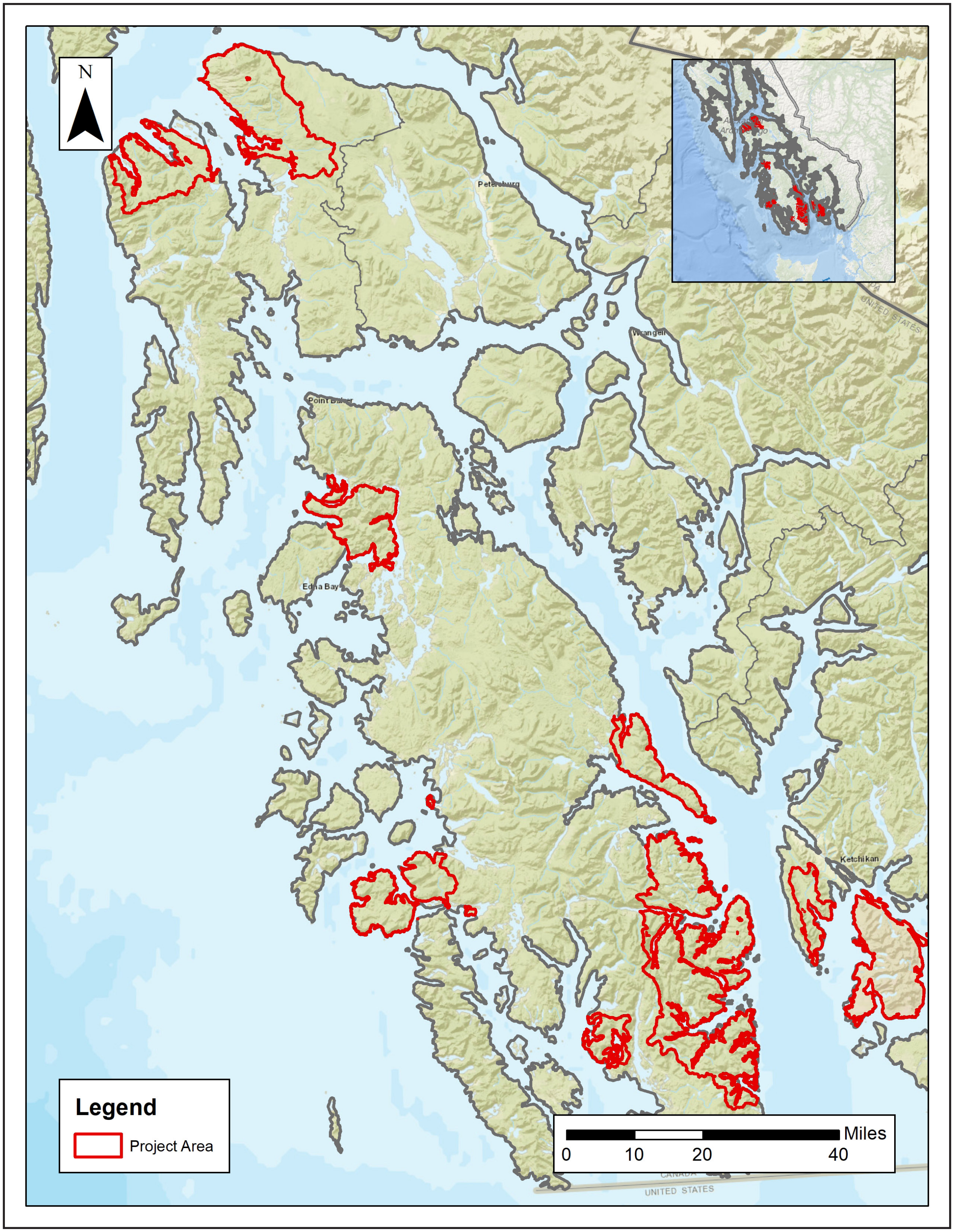
1.6. Deliverables

The following products were produced and delivered:

- Classified LiDAR point cloud data tiles in .LAS 1.4 format
- Continuous hydro-flattened breaklines in Esri file geodatabase format
- 0.5-meter hydro-flattened bare earth digital elevation model (DEM) tiles in GeoTIFF format
- 0.5-meter first return digital surface model (DSM) tiles in GeoTIFF format
- 0.5-meter shaded relief raster mosaic and tiles of the DEM and DSM in GeoTIFF format
- 0.5-meter intensity imagery tiles in GeoTIFF format
- 1-foot automated contour tiles in Esri file geodatabase format
- Automated building footprint polygons in Esri file geodatabase format
- Processing boundary in Esri shapefile format
- Tile index in Esri shapefile format
- QC checkpoints (NVA/VVA) in Esri shapefile format
- Survey report in .PDF format
- FOCUS report in .PDF format
- FOCUS on Deliverables report in .PDF format
- FOCUS on Accuracy report in .PDF format
- Project and deliverable metadata in .XML format

All geospatial deliverables were produced with a horizontal datum/projection of NAD83 (2011) UTM Zone 8, Meters and NAD83 (2011) Alaska State Plane, FIPS 5001, Meters, and a vertical datum/projection of NAVD88 GEOID 12B Meters. All tiled deliverables have a tile size of 2000 m x 2000 m for raster products and 1000 m x 1000 m for LAS files. Tile names are derived from the US National Grid.

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 Riegl RiPARAMETER planning software. The entire target area was comprised of 892 planned flight lines (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized Riegl VQ 1560i LiDAR sensors (Figure 3), serial numbers 0750, 1114, during the project.

The Riegl 1560i 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.

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

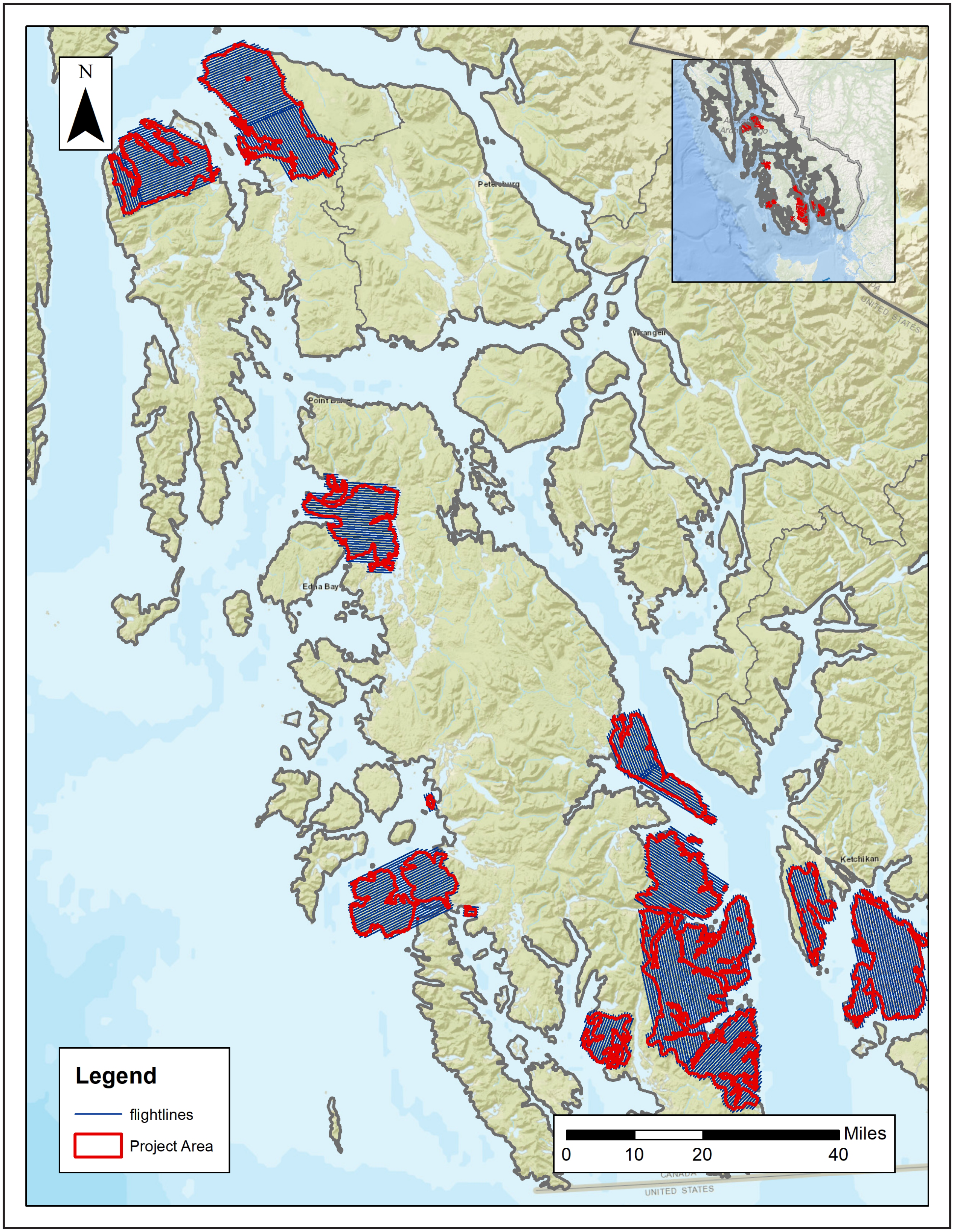


Table 2. LiDAR System Specifications

		VQ 1560i
Terrain and Aircraft Scanner	Flying Height	1300 m
	Recommended Ground Speed	150 kts
Scanner	Field of View	58°
	Scan Rate Setting Used	178 Hz
Laser	Laser Pulse Rate Used	800 kHz
	Multi Pulse in Air Mode	yes
Coverage	Full Swath Width	1441 m
	Line Spacing	576 m
Point Spacing and Density	Average Point Spacing	0.35 m
	Average Point Density	8 pts / m^2

Figure 3. Riegl VQ 1560i LiDAR Sensor

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-FFFC, C-FFSL

These aircraft provided an ideal, stable aerial base for LiDAR acquisition. These aerial platforms have relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds, proving ideal for collection of high-density, consistent data posting using state-of-the-art Riegl VQ 1560i 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. Time Period

Project specific flights were conducted between 6 May 2018 and 18 September 2018. 19 aircraft lifts were completed. Accomplished lifts are listed below.

- 05062018-A (SN0750, C-FFFC)
- 05072018-A (SN0750, C-FFFC)
- 05082018-A (SN0750, C-FFFC)
- 05152018-A (SN0750, C-FFFC)
- 05162018-A (SN0750, C-FFFC)
- 05172018-A (SN0750, C-FFFC)
- 05182018-A (SN0750, C-FFFC)
- 07032018-A (SN0750, C-FFFC)
- 07042018-A (SN0750, C-FFFC)
- 07212018-A (SN0750, C-FFFC)
- 07222018-A (SN0750, C-FFFC)
- 07252018-A (SN0750, C-FFFC)
- 07252018-B (SN0750, C-FFFC)
- 09132018-A (SN1114, C-FFSL)
- 09142018-A (SN1114, C-FFSL)
- 09152018-A (SN1114, C-FFSL)
- 09162018-A (SN1114, C-FFSL)
- 09172018-A (SN1114, C-FFSL)
- 09182018-A (SN1114, C-FFSL)

3. Processing Summary

3.1. Flight Logs

Flight logs are completed by LIDAR sensor technicians for most missions 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). When available, project specific flight logs for each sortie are available in the appendices. However, these records were not furnished for this project.

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 upon request.

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 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 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 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 – Low Vegetation (0.5 - 2 meters above ground)
- Class 4 – Medium Vegetation (2 - 6 meters above ground)
- Class 5 – High Vegetation (over 6 meters above 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.
- Class 21 – Snow

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

All data was 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's 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 Processing

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 100 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's 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.

Breaklines are reviewed against lidar intensity imagery to verify completeness of capture. All breaklines are then compared to TINs (triangular irregular networks) created from ground only points prior to water classification. The horizontal placement of breaklines is compared to terrain features and the breakline elevations are compared to lidar elevations to ensure all breaklines match the lidar within acceptable tolerances. Some deviation is expected between breakline and lidar elevations due to monotonicity, connectivity, and flattening rules that are enforced on the breaklines. Once completeness, horizontal placement, and vertical variance is reviewed, all breaklines are reviewed for topological consistency and data integrity using a combination of Esri Data Reviewer tools and proprietary tools.

3.6. Hydro-Flattened Raster DEM Processing

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, a GeoTIFF 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 Processing

GeoCue software was used to create the deliverable intensity images. All overlap classes 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. TIF/TWF files with a cell size of 0.5 meter were then provided as the deliverable for this dataset requirement.

3.8. Contour Processing

Using automated scripting routines within ArcMap, a terrain surface was created using the ground (ASPRS Class 2) LiDAR data as well as the hydro-flattened breaklines. This surface was then used to generate the final 1-foot contour dataset in Esri File Geodatabase format.

3.9. Building Footprint Processing

Polygons were generated with an automated routine that utilized the Class 6 (Buildings) building points as an input. The polygons were then simplified to remove any extraneous vertices. A height value is assigned using the highest Z value found in the Class 6 building points located inside a given building polygon. The final polygon features were produced in Esri File Geodatabase format.

3.10. First Return DSM Processing

First return LiDAR points in conjunction with the hydro-breaklines were used to create a 0.5-meter hydro-flattened raster DSM. Using automated scripting routines within ArcMap, a GeoTIFF 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.

Figure 5. 1K LiDAR Tile Layout

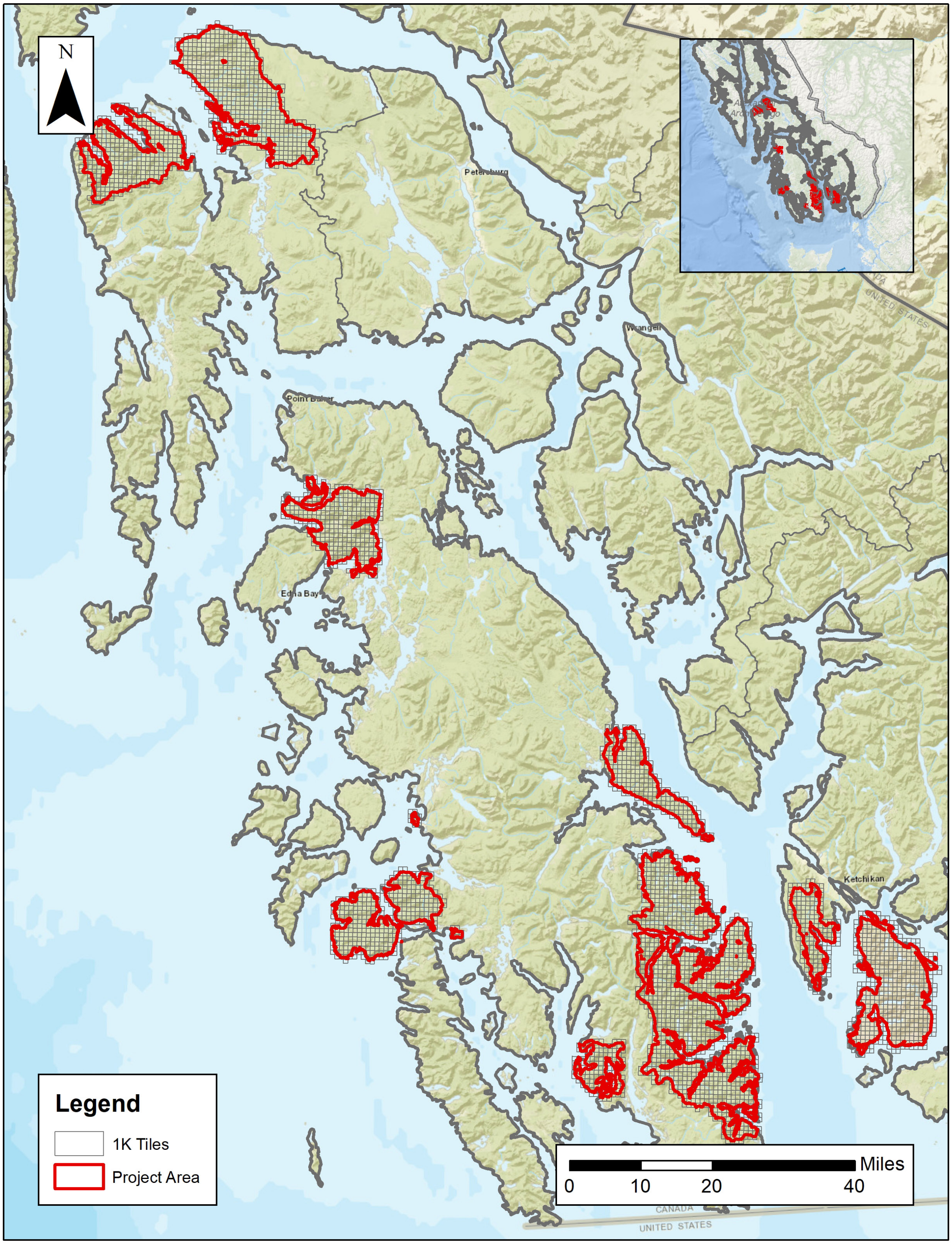
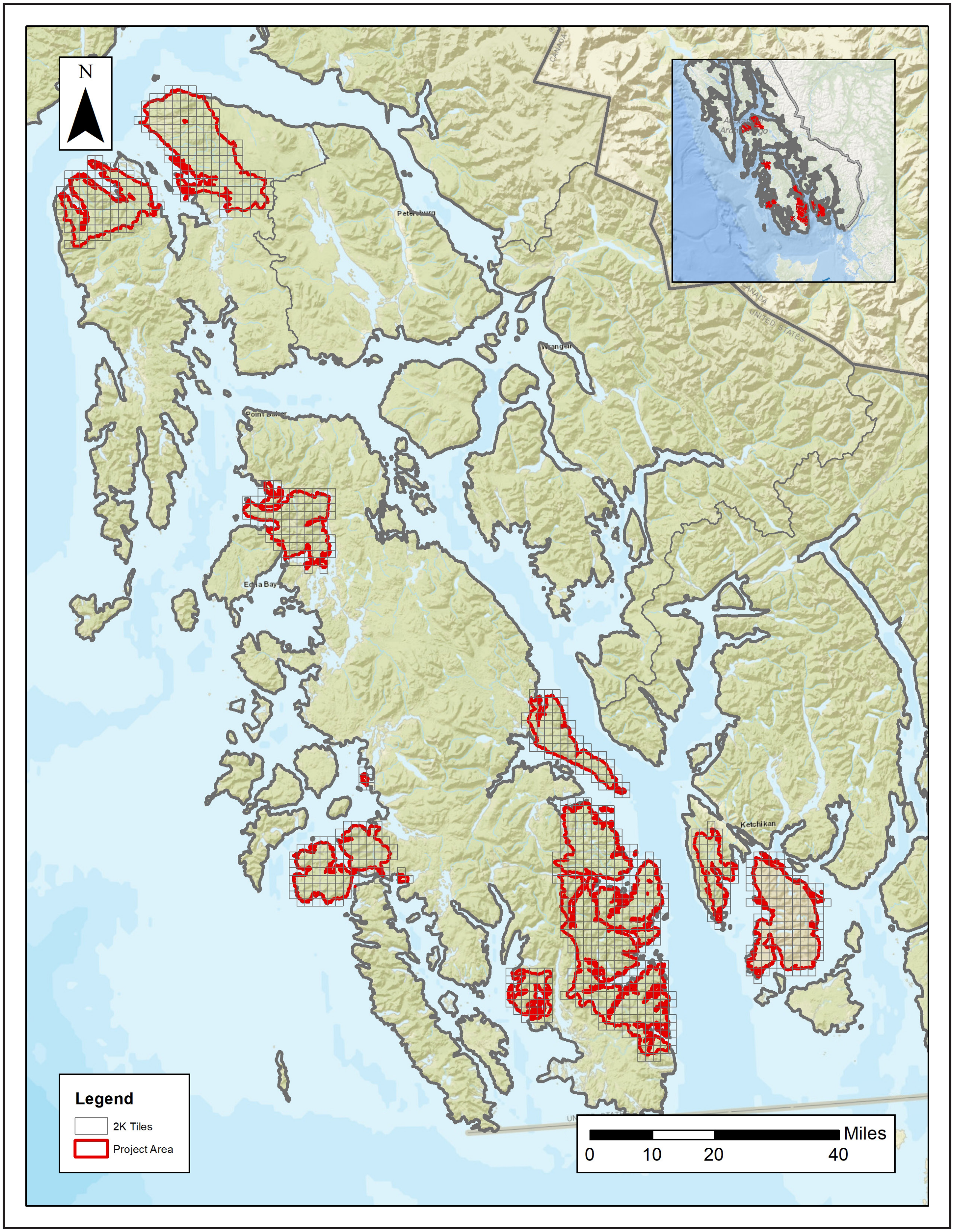


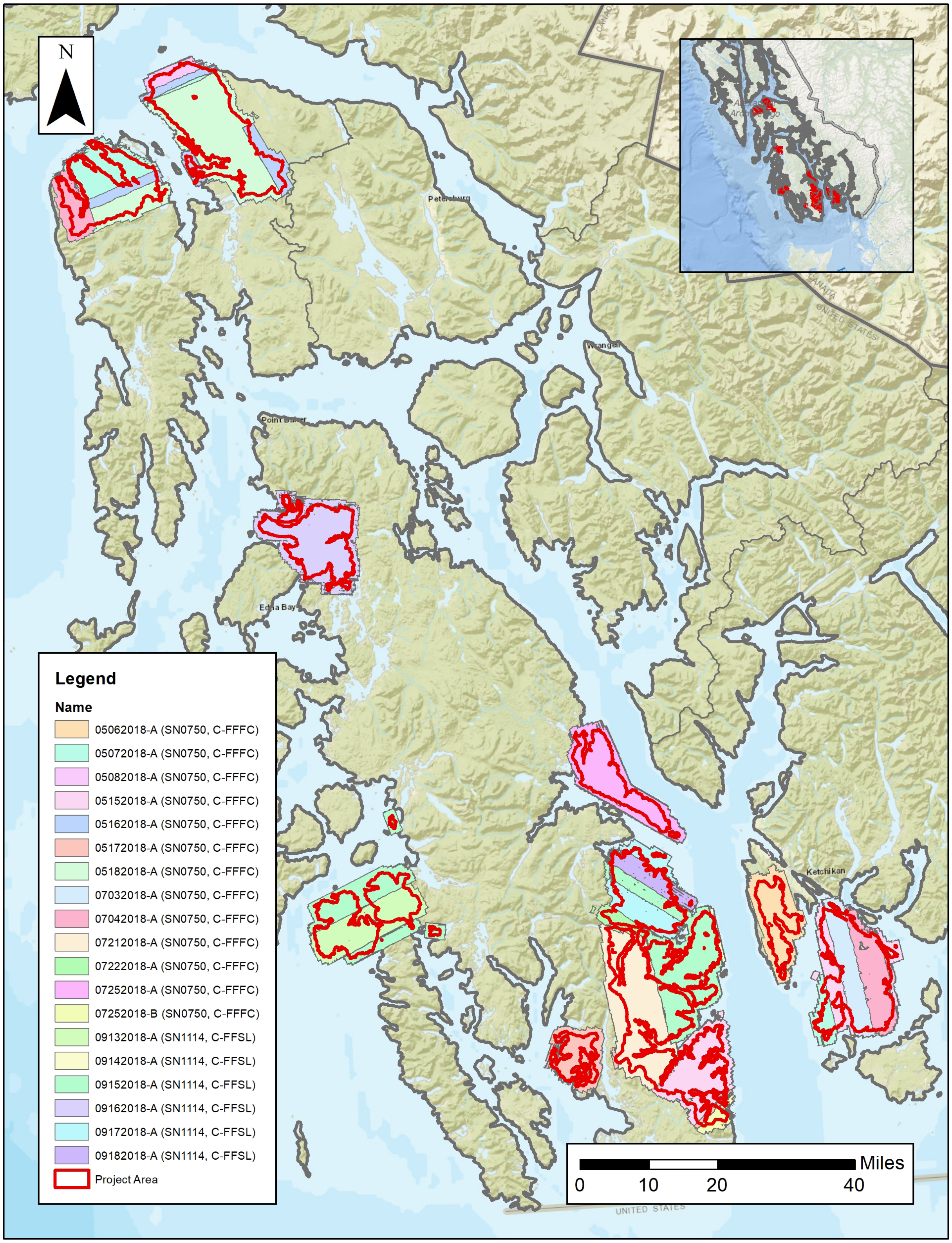
Figure 6. 2K LiDAR Tile Layout



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 7.

Figure 7. LiDAR Flightline Coverage



5. Ground Control and Check Point Collection

The Alaska Department of Natural Resources completed a field survey of 231 blind QA 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.

For more information, see the Survey Report in Appendix A.

The required accuracy testing was performed on the LiDAR dataset (both the LiDAR point cloud and derived DEM’s) according to the USGS LiDAR Base Specification Version 1.2 (2014).

5.1. 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 103 checkpoints located in bare earth and urban (non-vegetated) areas. These check points 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 check point. 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) x 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 8.

5.2. 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 103 checkpoints located in bare earth and urban (non-vegetated) areas. See Figure 8.

2. Vegetated Vertical Accuracy (VVA): VVA shall be reported for "shrubs," "forested," and "tall weeds" 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 128 checkpoints located in tall weeds, forests, and shrubs (vegetated) areas. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See Figure 9.

AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 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.

	Target	Measured	Point Count
Raw NVA	**0.1960**	**0.1620**	**103**
NVA	**0.1960**	**0.1522**	**103**
VVA	**0.2940**	**0.2805**	**128**

Figure 8. QC Checkpoint Locations - NVA

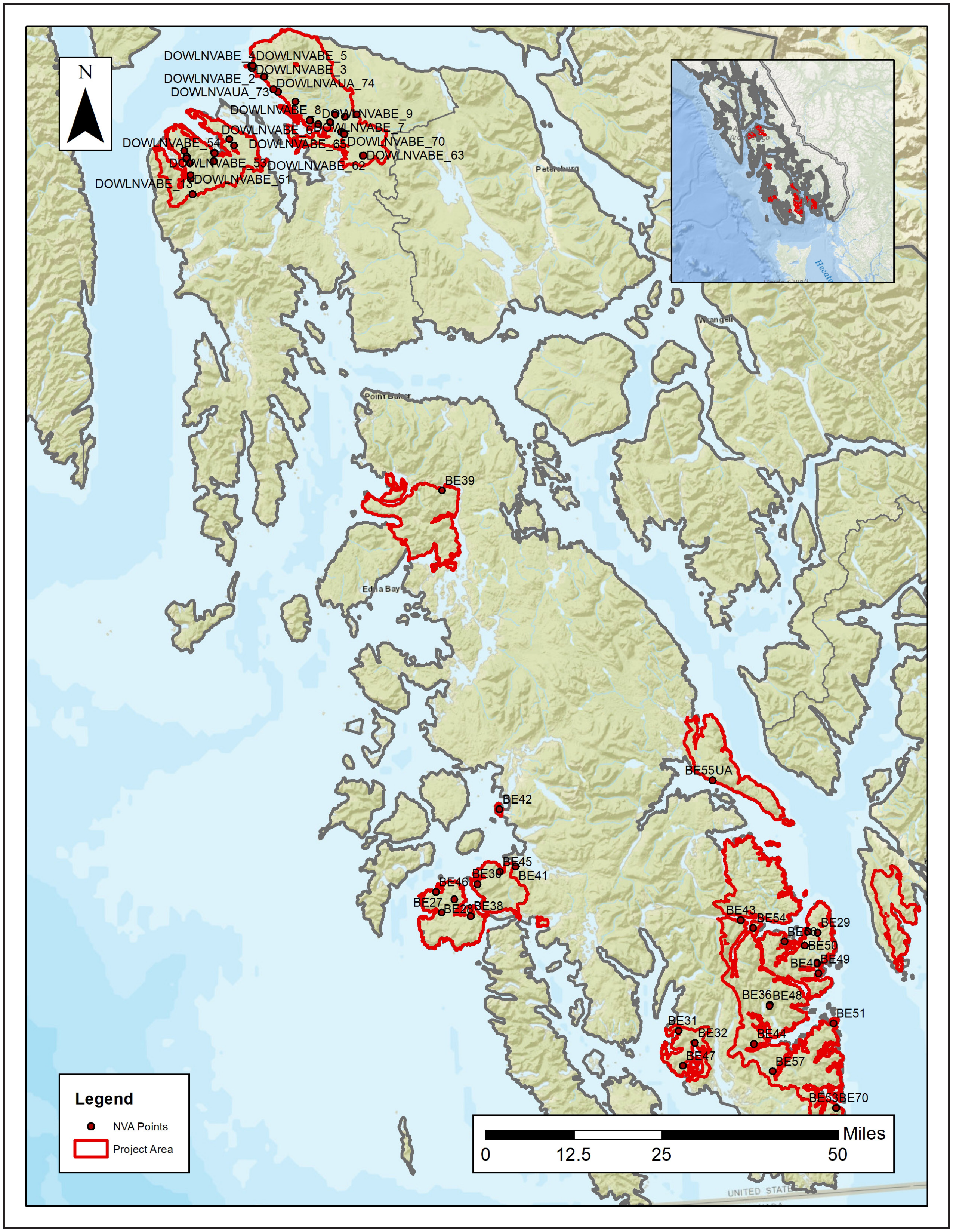


Figure 9. QC Checkpoint Locations - VVA