Eastern Vermont
2014 LiDAR Project Report

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1. Summary / Scope

1.1. Summary

This report contains a summary of the East Varmont 2014 LiDAR and Orthoimagery acquisition task order, issued by USGS National Geospatial Technical Operations Center (NGTOC), under their Geospatial Product and Services Contract (GPSC) ordered on September 13, 2014. The task order yielded a project area covering 2,533 square miles over northeastern Vermont. The intent of this document is to only provide specific validation information for the LiDAR 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
2.12 pts / m^2	1,400 m	38.0°	31.43%	9.25 cm or better

1.3. Coverage

The LiDAR project boundary covers 2,533 square miles and encompasses a total of 5 project areas in northeastern Vermont. LiDAR extents are shown in Figure 1 on the following page. A buffer of 100 meters was created for the area to meet task order specifications.

1.4. Duration

LiDAR data was acquired from November 8, 2014 to November 4, 2015 in twenty-six total lifts. See “Section: 2.5. Time Period” for more details.

1.5. Issues

Issues were due to acquisition of data over multiple years.

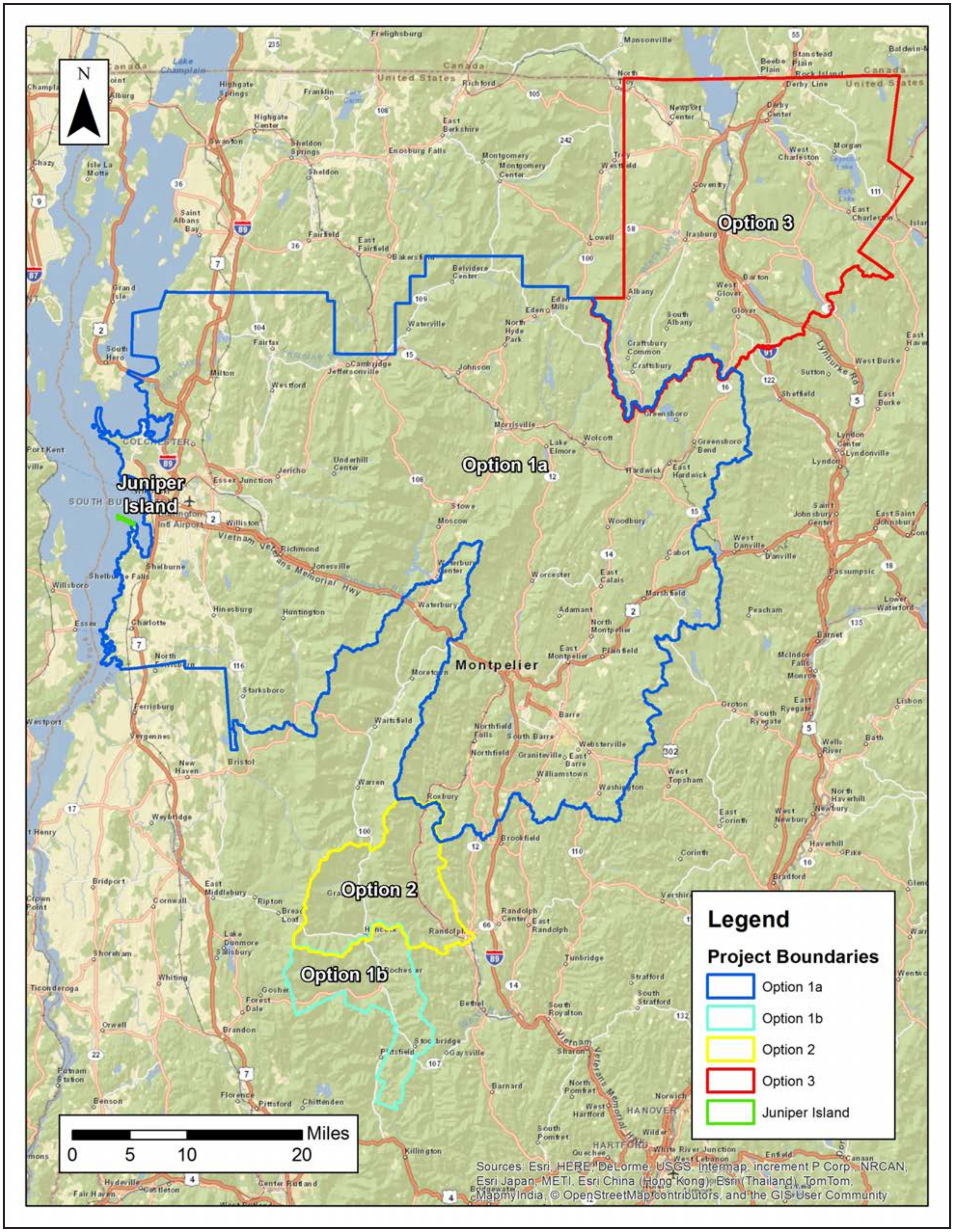
1.6. Deliverables

The following products were produced and delivered:

- Raw LiDAR point cloud data in LAS 1.2 format
- Classified LiDAR point cloud data in LAS 1.2 format
- 0.7-meter hydro-flattened raster DEM in ERDAS .IMG format
- 0.7-meter hydro-enforced raster DEM in Esri Grid format
- Ground control and calibraiton points in Esri Shapefile format
- Intensity images in GeoTIFF format
- 0.5-meter contours in Esri Shapefile format
- Combination hydro-flattened and hydro-enforced breaklies in Esri shapefile format
- QA/QC Reports
- Tile layouts in Esri Shapefile format
- Processing boundary in Esri Shapefile format
- Flightline swaths in Esri Shapefile format
- Project-, deliverable-, and lift-level metdata in XML format

All geospatial products were produced in NAD83 State Plane Vermont Zone, meters; NAVD88 (Geoid 12A), meters. All tiled deliverables have a tile size of 1,400 meters x 1,400 meters. Tile names are derived from the US National Grid.

Figure 1. LiDAR 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 name or area project using Leica MissionPro planning software. The entire target area was comprised of 424 planned flight lines measuring approximately total 9,612.33 flight line miles (Figure 2).

2.2. LiDAR Sensor

Leica ALS 70 LiDAR sensors (Figure 3), serial numbers 7123, 7121, 7225, and 7108, during the project. The system is capable of collecting data at a maximum frequency of 500 kHz, which affords elevation data collection of up to 500,000 points 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 4 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd and last returns. The intensity of the 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 LiDAR Flight Lines

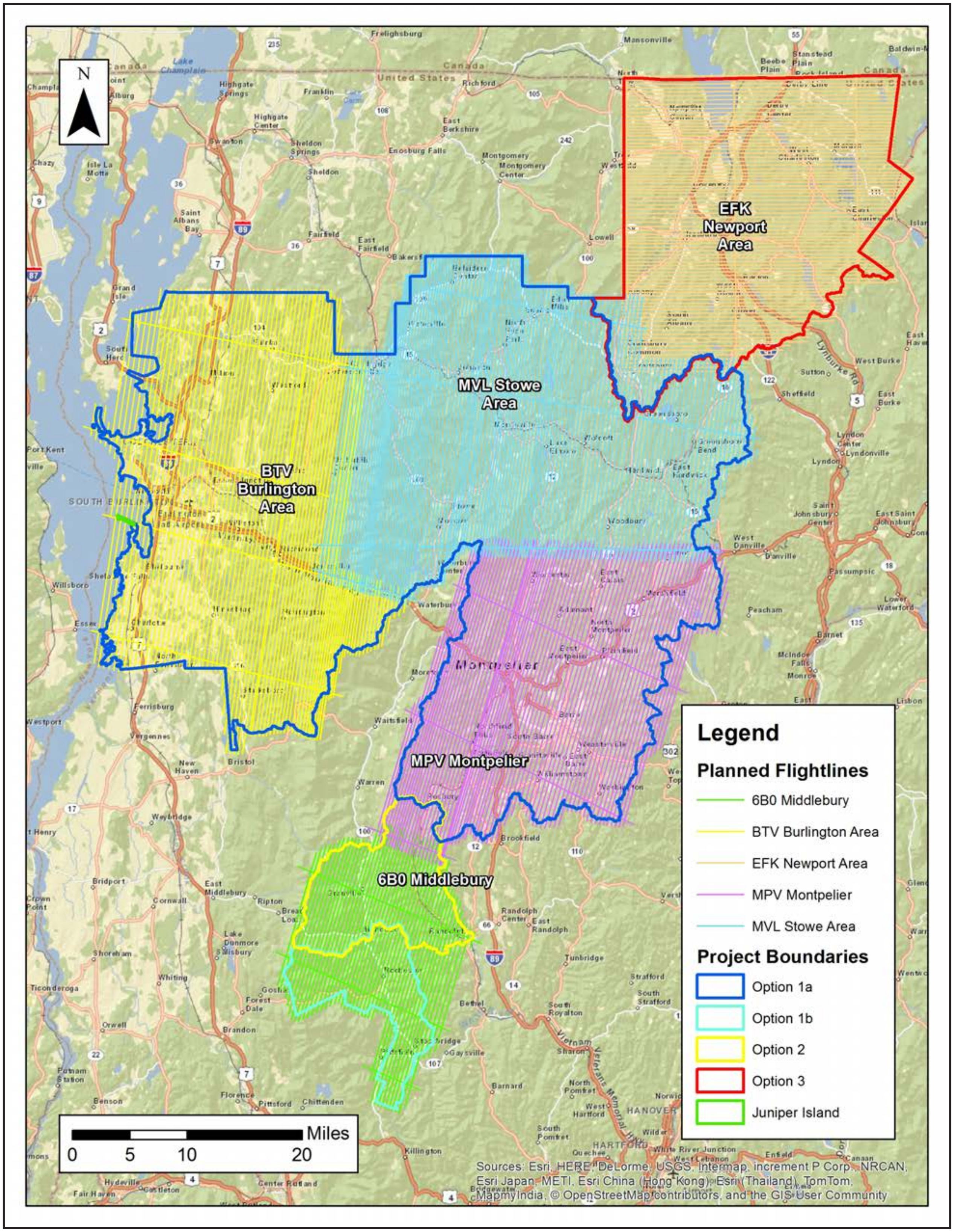


Table 2. Lidar System Specifications

Terrain and Aircraft Scanner	Flying Height	373 - 1,402 m
	Recommended Ground Speed	120 kts
Scanner	Field of View	38.0
	Scan Rate Setting Used	31.8 Hz
Laser	Laser Pulse Rate Used	194.6 kHz
	Multi Pulse in Air Mode	Disabled
Coverage	Full Swath Width	965.4 m
	Line Spacing	176.09 m
Point Spacing and Density	Maximum Point Spacing Across Track	0.97 m
	Maximum Point Spacing Along Track	0.97 m
	Average Point Density	3.27 pts / m^2

Figure 3. Leica ALS 70 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
- Partenavia P-68 (twin-piston), Tail Number: N775MW
- Piper Navajo (twin-piston), Tail Number: N1872H
- Cessna 310 (twin-piston), Tail Number: N1107Q

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 LiDAR system.

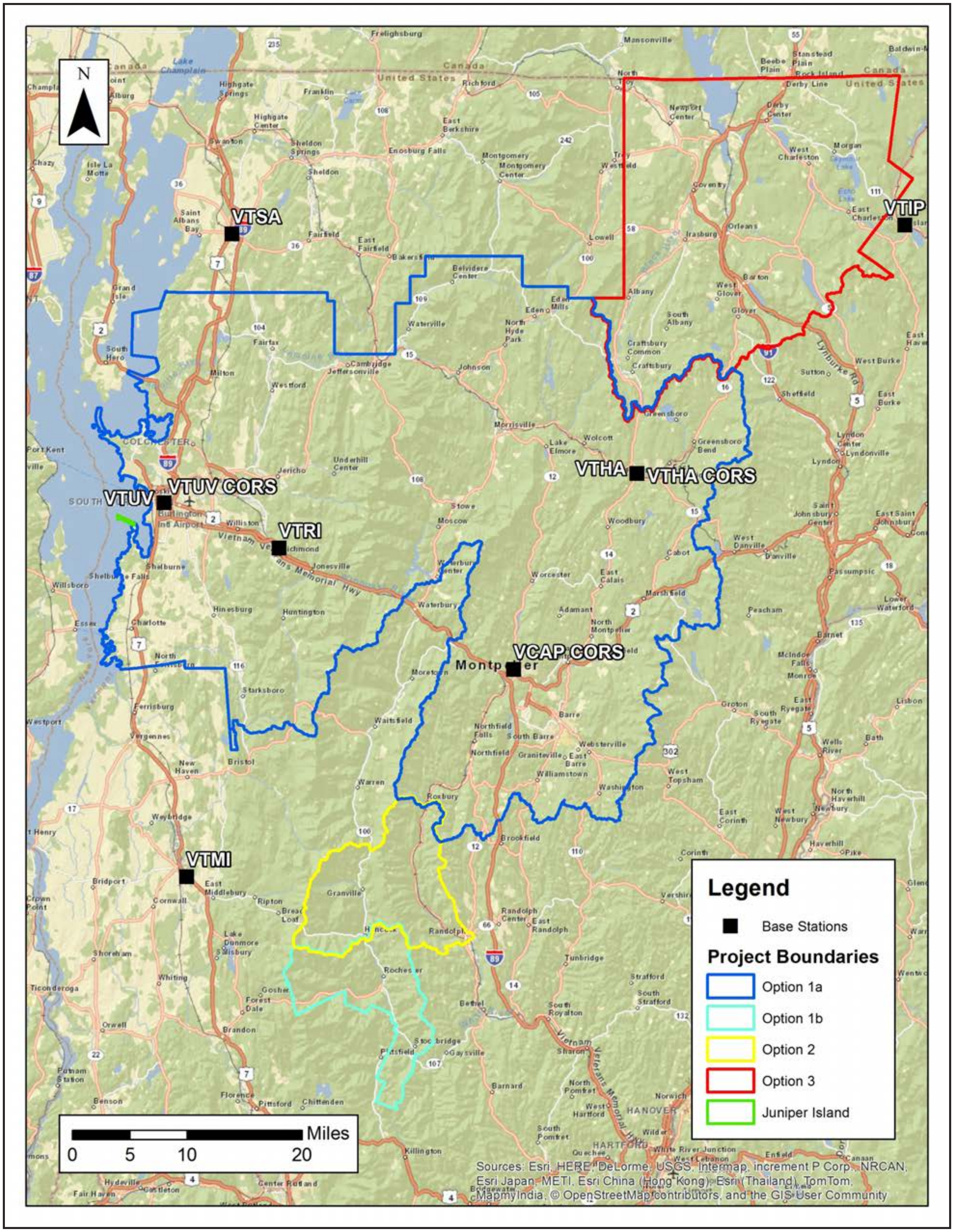
2.4. Base Station Information

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 4. Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A and B.

Table 3. Base Station Locations

Base Station	Latitude	Longitude	Ellipsoid Height (m)
OHAS	41° 55′ 30.22143″	80° 33′ 03.84434″	181.594
VCAP CORS	44° 15′ 43.14289″	72° 34′ 56.57401″	159.464
VTHA	44° 30′ 30.69556″	72° 21′ 57.16354″	256.821
VTHA CORS	44° 30′ 30.73228″	72° 21′ 57.18269″	255.754
VTIP	44° 49′ 12.18043″	71° 53′ 25.83872″	341.732
VTMI	43° 59′ 55.02507″	73° 09′ 09.38024″	96.027
VTRI	44° 24′ 47.72636″	72° 59′ 41.37328″	112.262
VTSA	44° 48′ 32.64649″	73° 04′ 54.28896″	177.578
VTUV	44° 28′ 09.21279″	73° 11′ 52.37575″	112.41
VTUV CORS	44° 28′ 09.24915″	73° 11′ 52.39587″	111.335

Figure 4. Base Station Locations



2.5. Time Period

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

- Nov 8, 2014-A (SN7123)
- Nov 8, 2014-B (SN7255)
- Nov 9, 2014-A (SN7123)
- Nov 9, 2014-B (SN7255)
- Nov 11, 2014-A (SN7123)
- Nov 11, 2014-A (SN7255)
- Nov 11, 2014-B (SN7123)
- Nov 11, 2014-B (SN7255)
- Nov 18, 2014-A (SN7255)
- May 8, 2015-A (SN7121)
- May 8, 2015-A (SN7123)
- May 8, 2015-A (SN7225)
- May 8, 2015-B (SN7121)
- May 8, 2015-B (SN7123)
- May 8, 2015-B (SN7225)
- May 8, 2015-C (SN7121)
- May 9, 2015-A (SN7121)
- Oct 24, 2015-A (SN7108)
- Oct 24, 2015-B (SN7108)
- Oct 26, 2015-A (SN7108)
- Oct 27, 2015-B (SN7108)
- Oct 28, 2015-A (SN7108)
- Oct 31, 2015-A (SN7108)
- Oct 31, 2015-B (SN7108)
- Nov 4, 2015-A (SN7108)
- Nov 4, 2015-B (SN7108)

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 and B.

3.2. LiDAR Processing

Intertial Explorer 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. Intertial Explorer 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 Intertial Explorer 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 Intertial Explorer processing environment for each sortie during the project mobilization are available in Appendix A and B.

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 Leica ALS 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 were 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 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 1.0 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 7 – Noise – Low or high points, manually identified above or below the surface that could be noise points in point cloud.
- Class 9 – In-land 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 – Overlap Default (Unclassified) – Points found in the overlap between flight lines. These points are created through automated processing methods and not cleaned up during processing.
- Class 18 – Overlap Bare-earth ground – Points found in the overlap between flight lines. These points are created through automated processing, matching the specifications determined during the automated process, that are close to the Class 2 dataset (when analyzed using height from ground analysis)
- Class 25 – Overlap Water – Points found in the overlap between flight lines that are located inside hydro features. These points are created through automated processing methods and not cleaned up during processing.

3.4. Classified LAS Processing

The bare earth surface was 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 0.7 meters 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 classified to Class 17 (Overlap Default) and Class 18 (Overlap Ground). These classes were created through automated processes only and were not verified for classification accuracy. Due to software limitations within TerraScan, these classes were used to trip the withheld bit within various software packages. These processes were reviewed and accepted by USGS through numerous conference calls and pilot study areas.

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 both the All Point Cloud Data and the Bare Earth. 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 / Hydro-Enforced 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 30 meter nominal width and Inland Ponds and Lakes of 8,000 sq. meters or greater surface area.

Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, 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 0.7 meter was also used around each hydro flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

Hydro enforcement was also a requirement of this task order. This was accomplished by connecting any collected hydro feature that met the collection parameters. Any ground (ASPRS Class 2) LiDAR data inside of this collected feature was then moved to Class 13. A mutually agreed upon class between USGS and Quantum Spatial.

The breakline files were then translated to Esri Shapefile 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 0.7 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.

Class 2 LiDAR in conjunction with the hydro breaklines and any collected enforcement lines were used to create a 0.7 meter Hydro Enforcement Raster DEM. Using automated scripting routines within ArcMap, an hydro-flattened DEMs were produced in ERDAS Imagine .IMG format.

Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

3.7. Hydro-Enforced Raster DEM Creation

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 0.7 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.

Class 2 LiDAR in conjunction with the hydro breaklines and any collected enforcement lines were used to create a 0.7 meter Hydro Enforcement Raster DEM. Using automated scripting routines within ArcMap, hydro-enforced DEMs were produced in Esri Grid format. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

3.8. 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. GeoTIFFs and world files were then provided as the deliverable for this dataset requirement.

3.9. Contour Creation

Using automated scripting routines within Terramodeler, 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 0.5-meter contour dataset in Esri shapefile format.

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 5 through Figure 7.

Figure 5. Coverage - Option 1a and Juniper Island

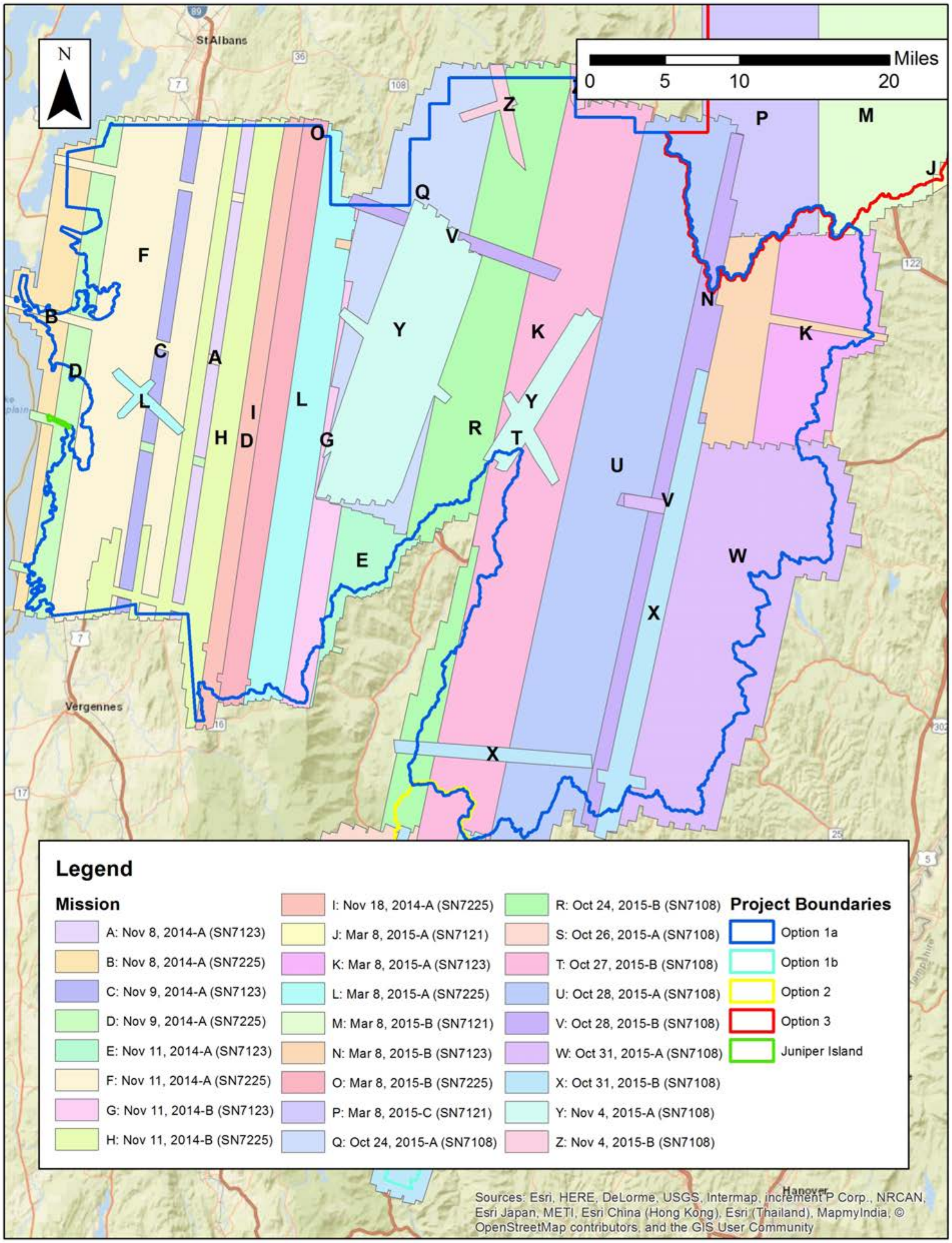


Figure 6. Coverage - Option 1b and 2

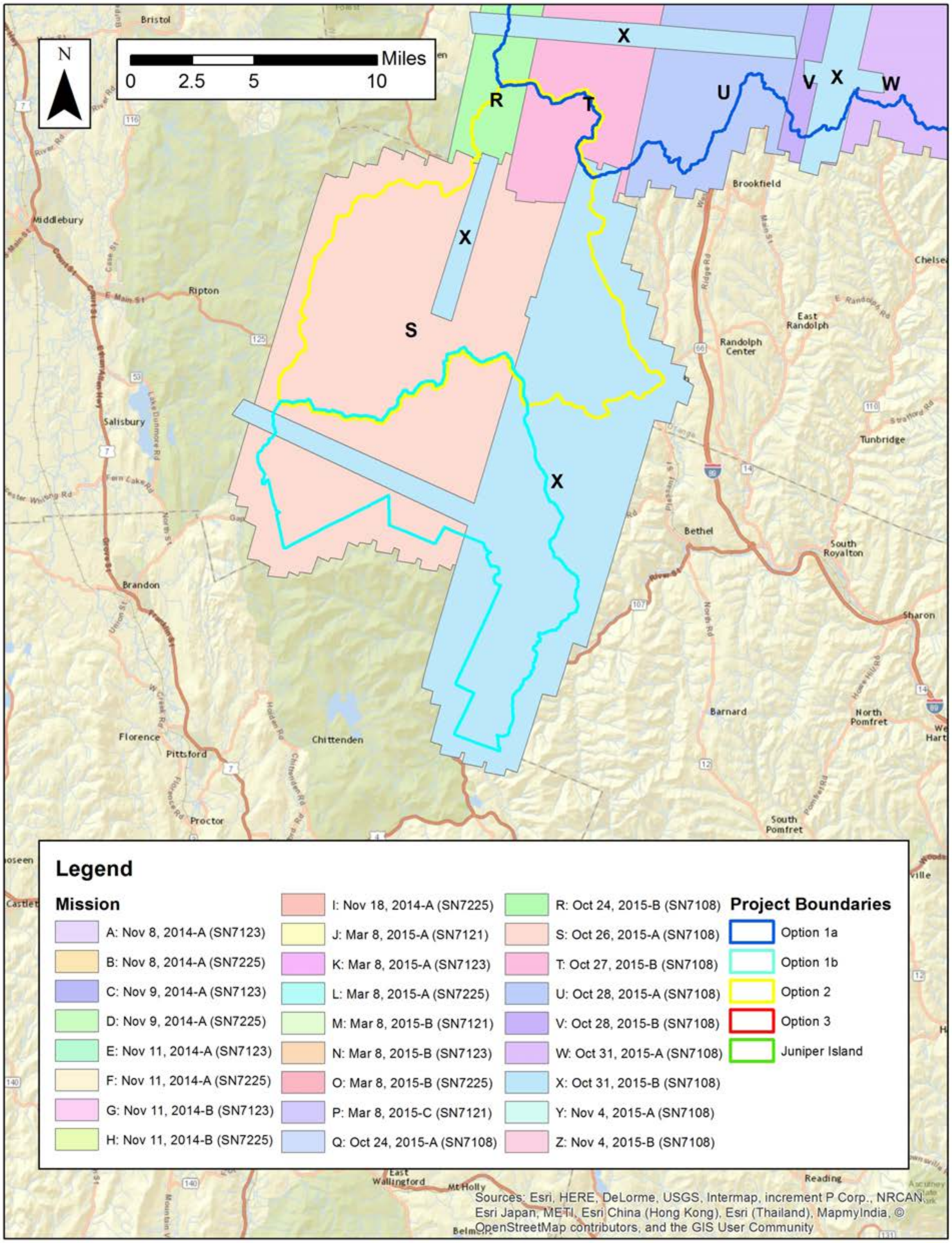
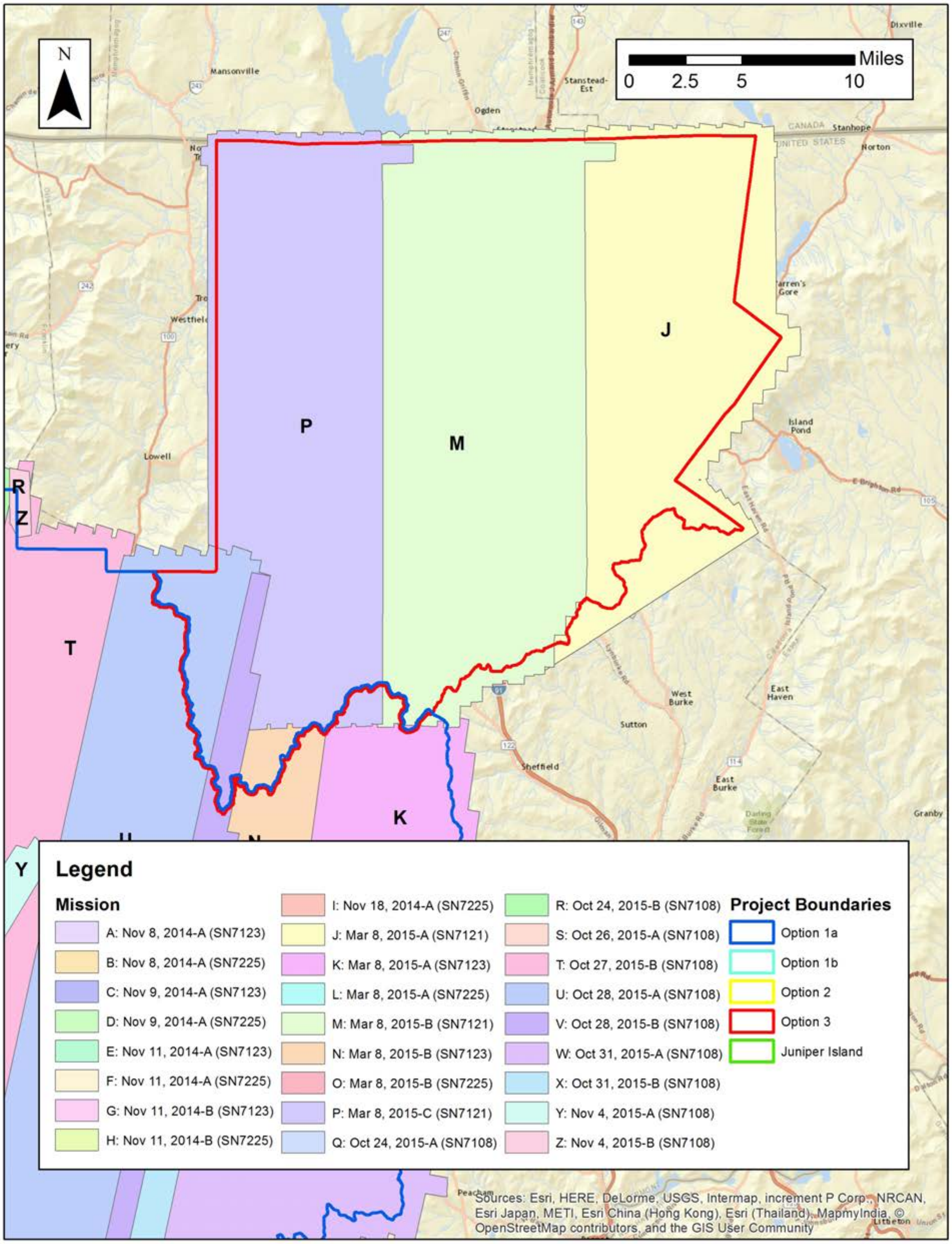


Figure 7. Coverage - Option 3



5. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of # ground control (calibration) points along with # blind QA points in Vegetated and Non-Vegetated land cover classifications (total of # 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 C.

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 1.0. In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in .

5.1. Calibration Control Point Testing

Figure 8 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

Raw Fundamental Vertical Accuracy (Raw NVA): The tested Raw FVA for the dataset was found to be 0.078 meters in terms of the RMSEz. The resulting FVA stated as the 95% confidence level (RMSEz x 1.96) is 0.153 meters. This dataset meets the required FVA of 0.1813 meters at the 95% confidence level (according to the National Standard for Spatial Database Accuracy (NSSDA)), based on TINs derived from the final calibrated and controlled LiDAR swath data. See Figure 9 and Table 4.

5.3. Digital Elevation Model (DEM) Testing

Fundamental Vertical Accuracy (FVA)

The tested FVA for the dataset captured from the DEM using bi-linear interpolation to derive the DEM elevations was found to be 0.080 meters in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.157 meters. This dataset meets the required FVA of 0.1813 meters at the 95% confidence level (based on NSSDA). See Figure 9 and Table 5.

Supplemental Vertical Accuracy (SVA)

The tested SVA accuracies for the dataset for each of the land cover classes other than open ground are summarized below. These results are stated in terms of the 95th percentile error (based on ASPRS guidelines) for each of the land cover classes other than open ground.

The following land cover classes were tested and the resulting 95th percentile error values are listed below:

- Forested, Fully Covered by Trees: 0.171 meters (Figure 10, Table 6)
- Tall Weeds: 0.339 meters (Figure 11, Table 7)

SVA was calculated to be 0.266 meters. These values meet the target value of 0.269 m. See Table 8.

Consolidated Vertical Accuracy (CVA)

The tested CVA for the dataset captured from the DEM using bi-linear interpolation for all classes (including the bare earth class) was found to be 0.230 meters, which is stated in terms of the 95th percentile error. Therefore the data meets the required CVA of 0.269 meters. This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories. See Table 9.

5.4. Notes

Points TW08 and TW14 were removed from the Tall Weeds, SVA, and CVA calculations. For more information, please see the Tall Weeds QAQC Point Issues document in Appendix D.

Figure 8. Calibration Control Point Locations

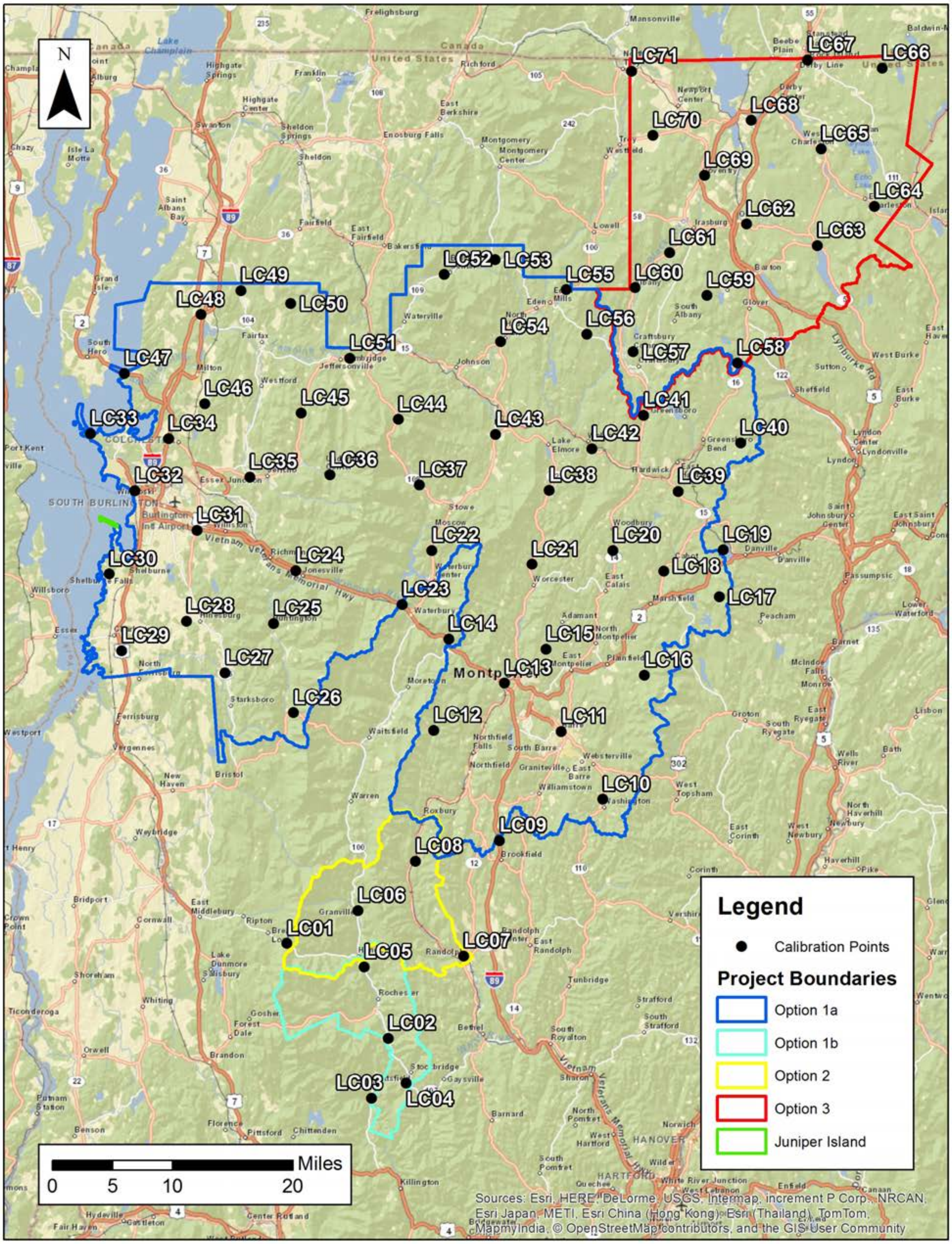


Figure 9. QC Checkpoint Locations - Bare Earth

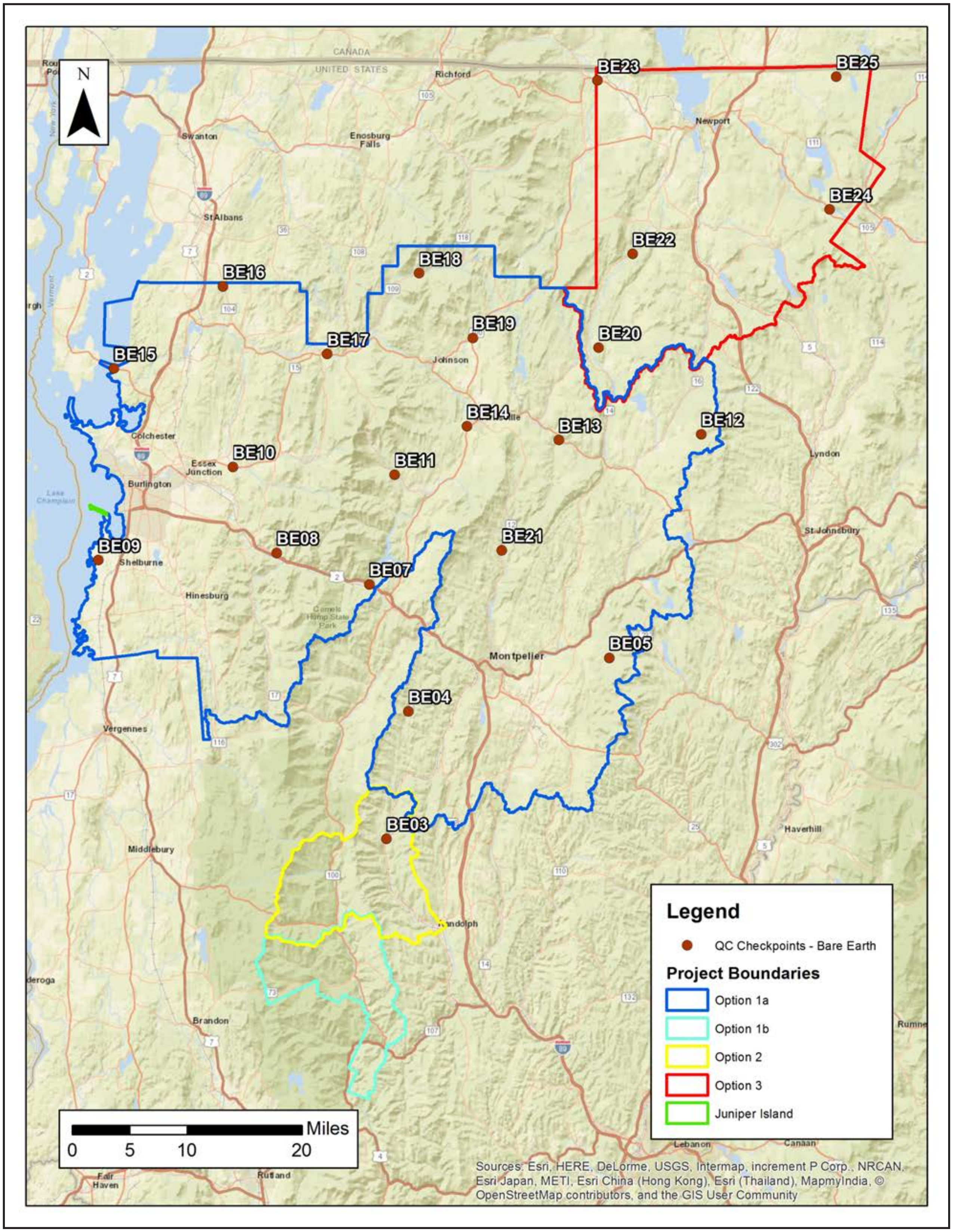


Table 4. QC Checkpoint Report - Raw FVA

Units = meters

Number	Easting	Northing	Known Z	Laser Z	Dz
BE03	479506.291	170566.636	265.639	265.88	0.24
BE04	482573.480	188449.507	435.773	435.77	0.00
BE05	510728.284	195936.344	436.162	436.22	0.06
BE07	477129.464	206178.949	137.147	137.36	0.21
BE08	464130.39	210595.11	97.08	97.02	-0.06
BE09	439099.12	209566.25	68.49	68.53	0.04
BE10	457975.19	222653.43	153.76	153.73	-0.03
BE11	480650.642	221549.400	264.115	264.16	0.05
BE12	523632.398	227227.244	532.852	532.85	0.00
BE13	503701.988	226416.106	245.836	245.86	0.02
BE14	490765.708	228351.373	198.426	198.42	-0.01
BE15	441315.92	236432.62	30.80	30.75	-0.05
BE16	456613.38	247955.02	188.26	188.23	-0.03
BE17	471196.313	238481.738	146.514	146.56	0.05
BE18	484068.985	249794.514	257.966	257.96	-0.01
BE19	491601.970	240743.949	263.025	262.93	-0.09
BE20	509239.711	239346.004	378.996	378.99	-0.01
BE21	495652.864	210944.363	247.864	247.87	0.01
BE22	514041.10	252493.95	263.29	263.32	0.03
BE23	509092.06	276828.38	185.34	185.36	0.02
BE24	541605.82	258742.64	354.07	354.05	-0.02
BE25	542575.73	277352.58	419.00	418.96	-0.04
	Average Dz	0.02 m			
	Minimum Dz	-0.095 m			
	Maximum Dz	0.241 m			
	Root Mean Square	0.078 m			
	95% Confidence Level	0.153 m			

Table 5. QC Checkpoint Report - FVA

Units = meters

Number	Easting	Northing	Known Z	Laser Z	Dz
BE03	479506.29	170566.64	265.64	265.87	0.23
BE04	482573.48	188449.51	435.77	435.77	0.00
BE05	510728.28	195936.34	436.16	436.21	0.05
BE07	477129.46	206178.95	137.15	137.37	0.22
BE08	464130.39	210595.11	97.08	97.04	-0.04
BE09	439099.12	209566.25	68.49	68.54	0.05
BE10	457975.19	222653.43	153.76	153.74	-0.02
BE11	480650.64	221549.40	264.12	264.16	0.05
BE12	523632.40	227227.24	532.85	532.85	0.00
BE13	503701.99	226416.11	245.84	245.87	0.03
BE14	490765.71	228351.37	198.43	198.43	0.00
BE15	441315.92	236432.62	30.80	30.75	-0.05
BE16	456613.38	247955.02	188.26	188.23	-0.03
BE17	471196.31	238481.74	146.51	146.55	0.04
BE18	484068.99	249794.51	257.97	257.96	-0.01
BE19	491601.97	240743.95	263.03	262.89	-0.14
BE20	509239.71	239346.00	379.00	379.01	0.01
BE21	495652.86	210944.36	247.86	247.87	0.00
BE22	514041.10	252493.95	263.29	263.32	0.03
BE23	509092.06	276828.38	185.34	185.38	0.04
BE24	541605.82	258742.64	354.07	354.08	0.00
BE25	542575.73	277352.58	419.00	418.97	-0.03
Average Dz		0.02 m			
Minimum Dz		-0.138 m			
Maximum Dz		0.235 m			
Root Mean Square		0.080 m			
95% Confidence Level		0.157 m			

Figure 10. QC Checkpoint Locations - Forested

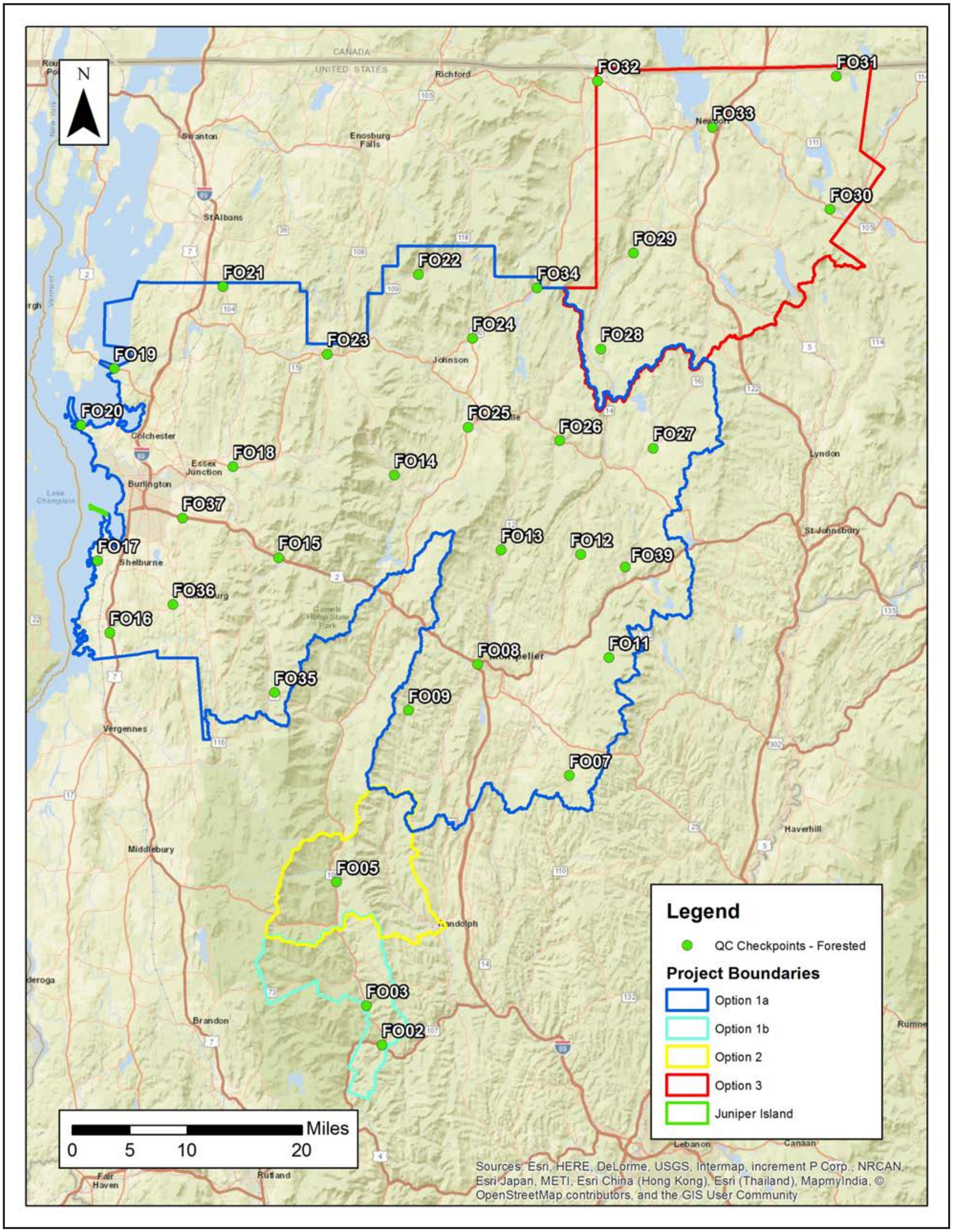


Figure 11. QC Checkpoint Locations - Tall Weeds

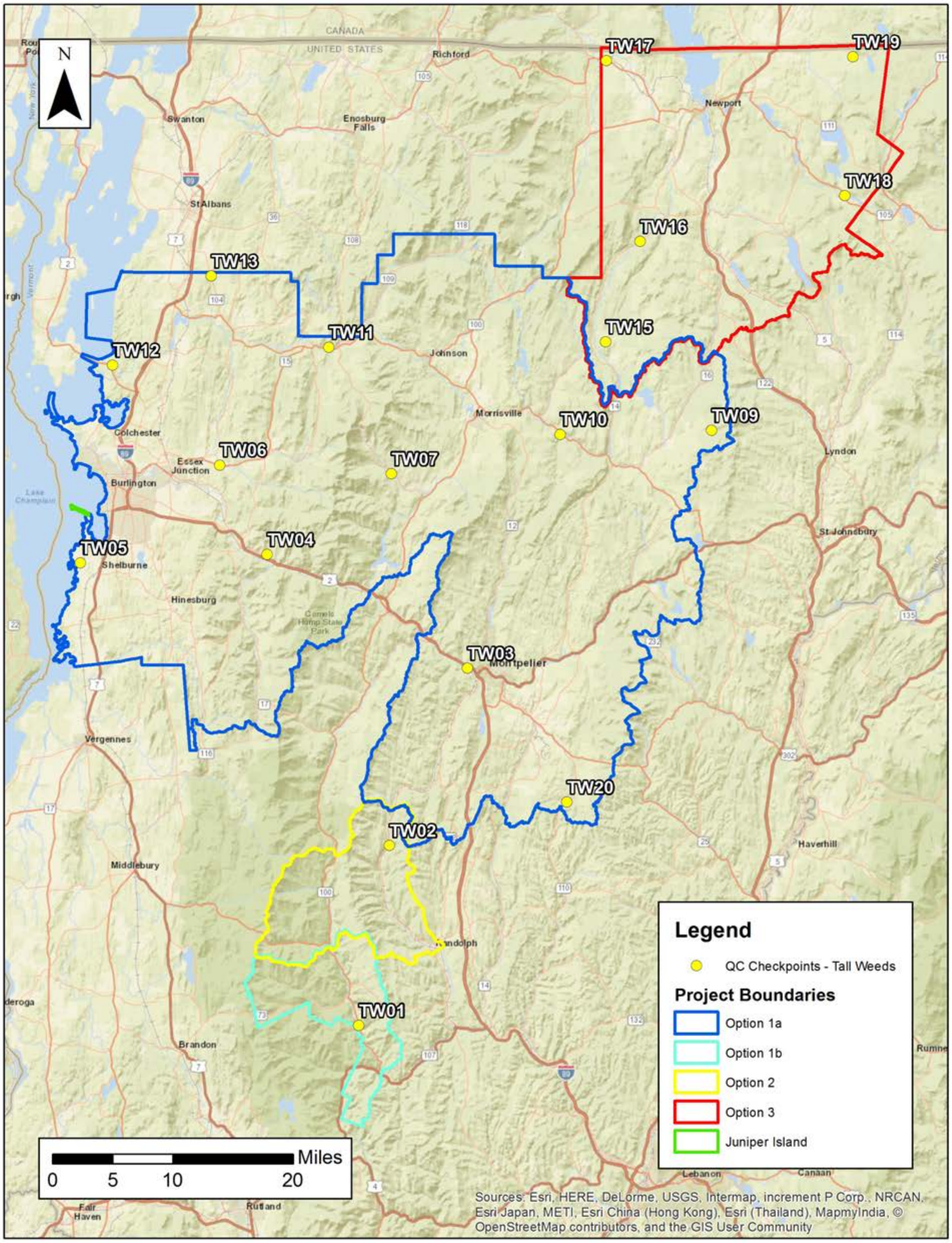


Table 6. QC Checkpoint Report - Forested

Units = meters

Number	Easting	Northing	Known Z	Laser Z	Dz
FO02	478884.83	141648.57	240.23	240.30	0.07
FO03	476710.99	147152.49	261.02	261.09	0.07
FO05	472518.50	164524.57	299.62	299.56	-0.06
FO07	505141.63	179428.86	391.31	391.39	0.08
FO08	492315.36	195006.05	158.93	159.06	0.13
FO09	482578.49	188559.18	430.64	430.65	0.01
FO11	510718.62	195960.11	434.89	434.90	0.01
FO12	506754.87	210342.34	286.92	287.01	0.09
FO13	495573.36	210992.41	248.29	248.39	0.10
FO14	480598.80	221484.37	262.00	262.23	0.22
FO15	464396.99	209913.80	95.54	95.53	-0.02
FO16	440743.20	199393.72	79.07	79.19	0.13
FO17	439019.80	209504.11	63.68	63.71	0.04
FO18	458006.94	222663.48	153.09	153.04	-0.06
FO19	441335.33	236464.75	29.40	29.45	0.05
FO20	436686.96	228503.62	34.98	35.08	0.10
FO21	456602.87	247941.26	186.17	186.30	0.13
FO22	483973.48	249627.74	265.13	265.31	0.19
FO23	471186.21	238444.75	146.84	146.90	0.06
FO24	491583.12	240655.84	258.75	258.79	0.04
FO25	490961.61	228201.21	209.99	210.02	0.03
FO26	503790.54	226325.79	245.00	245.00	0.00
FO27	516864.48	225244.75	352.34	352.37	0.04
FO28	509544.12	239177.17	371.35	371.40	0.05
FO29	514136.04	252647.18	268.59	268.73	0.14
FO30	541660.05	258737.98	352.53	352.62	0.08
FO31	542586.07	277397.93	415.09	415.24	0.16
FO32	509096.59	276764.51	176.23	176.31	0.08
FO33	525189.64	270234.97	275.46	275.56	0.10
FO34	500623.48	247760.11	379.97	379.96	-0.02
FO35	463834.98	191078.86	456.11	456.13	0.03
FO36	449575.22	203338.36	106.75	106.82	0.07

Number	Easting	Northing	Known Z	Laser Z	Dz
FO37	450929.94	215442.52	144.28	144.19	-0.09
FO39	513007.49	208583.78	275.56	275.63	0.07
	Average Dz	0.06 m			
	Minimum Dz	-0.090 m			
	Maximum Dz	0.224 m			
	Root Mean Square	0.091 m			
	95th Percentile	0.171 m			

Table 7. QC Checkpoint Report - Tall Weeds

Units = meters

Number	Easting	Northing	Known Z	Laser Z	Dz
TW01	476469.09	147632.68	239.21	239.33	0.12
TW02	480538.51	171724.03	274.29	274.49	0.20
TW03	491019.41	195481.58	155.24	155.34	0.11
TW04	464184.09	210672.53	97.03	96.99	-0.04
TW05	439194.56	209546.26	72.80	72.90	0.11
TW06	457811.61	222654.25	153.64	153.66	0.02
TW07	480820.11	221464.78	262.88	263.19	0.31
TW09	523671.59	227284.43	533.09	533.19	0.10
TW10	503398.05	226759.97	210.18	210.27	0.09
TW11	472459.36	238434.52	135.82	136.15	0.33
TW12	443490.50	236034.58	35.54	35.64	0.11
TW13	456695.59	247970.92	191.00	191.21	0.21
TW15	509509.01	239166.44	371.87	371.97	0.10
TW16	514123.74	252620.71	267.93	268.06	0.13
TW17	509597.08	276846.95	197.40	197.51	0.11
TW18	541525.15	258757.02	351.97	352.20	0.23
TW19	542598.96	277350.05	417.83	418.03	0.20
TW20	504315.69	177546.54	465.85	466.24	0.39
	Average Dz	0.16 m			
	Minimum Dz	-0.041 m			
	Maximum Dz	0.389 m			
	Root Mean Square	0.189 m			
	95th Percentile	0.339 m			

Points TW08 and TW14 were removed from the calculation.

Table 8. QC Checkpoint Report - SVA

Units = meters

Number	Easting	Northing	Known Z	Laser Z	Dz
FO02	478884.83	141648.57	240.23	240.30	0.07
FO03	476710.99	147152.49	261.02	261.09	0.07
FO05	472518.50	164524.57	299.62	299.56	-0.06
FO07	505141.63	179428.86	391.31	391.39	0.08
FO08	492315.36	195006.05	158.93	159.06	0.13
FO09	482578.49	188559.18	430.64	430.65	0.01
FO11	510718.62	195960.11	434.89	434.90	0.01
FO12	506754.87	210342.34	286.92	287.01	0.09
FO13	495573.36	210992.41	248.29	248.39	0.10
FO14	480598.80	221484.37	262.00	262.23	0.22
FO15	464396.99	209913.80	95.54	95.53	-0.02
FO16	440743.20	199393.72	79.07	79.19	0.13
FO17	439019.80	209504.11	63.68	63.71	0.04
FO18	458006.94	222663.48	153.09	153.04	-0.06
FO19	441335.33	236464.75	29.40	29.45	0.05
FO20	436686.96	228503.62	34.98	35.08	0.10
FO21	456602.87	247941.26	186.17	186.30	0.13
FO22	483973.48	249627.74	265.13	265.31	0.19
FO23	471186.21	238444.75	146.84	146.90	0.06
FO24	491583.12	240655.84	258.75	258.79	0.04
FO25	490961.61	228201.21	209.99	210.02	0.03
FO26	503790.54	226325.79	245.00	245.00	0.00
FO27	516864.48	225244.75	352.34	352.37	0.04
FO28	509544.12	239177.17	371.35	371.40	0.05
FO29	514136.04	252647.18	268.59	268.73	0.14
FO30	541660.05	258737.98	352.53	352.62	0.08
FO31	542586.07	277397.93	415.09	415.24	0.16
FO32	509096.59	276764.51	176.23	176.31	0.08
FO33	525189.64	270234.97	275.46	275.56	0.10
FO34	500623.48	247760.11	379.97	379.96	-0.02
FO35	463834.98	191078.86	456.11	456.13	0.03
FO36	449575.22	203338.36	106.75	106.82	0.07

Number	Easting	Northing	Known Z	Laser Z	Dz
FO37	450929.94	215442.52	144.28	144.19	-0.09
FO39	513007.49	208583.78	275.56	275.63	0.07
TW01	476469.09	147632.68	239.21	239.33	0.12
TW02	480538.51	171724.03	274.29	274.49	0.20
TW03	491019.41	195481.58	155.24	155.34	0.11
TW04	464184.09	210672.53	97.03	96.99	-0.04
TW05	439194.56	209546.26	72.80	72.90	0.11
TW06	457811.61	222654.25	153.64	153.66	0.02
TW07	480820.11	221464.78	262.88	263.19	0.31
TW09	523671.59	227284.43	533.09	533.19	0.10
TW10	503398.05	226759.97	210.18	210.27	0.09
TW11	472459.36	238434.52	135.82	136.15	0.33
TW12	443490.50	236034.58	35.54	35.64	0.11
TW13	456695.59	247970.92	191.00	191.21	0.21
TW15	509509.01	239166.44	371.87	371.97	0.10
TW16	514123.74	252620.71	267.93	268.06	0.13
TW17	509597.08	276846.95	197.40	197.51	0.11
TW18	541525.15	258757.02	351.97	352.20	0.23
TW19	542598.96	277350.05	417.83	418.03	0.20
TW20	504315.69	177546.54	465.85	466.24	0.39
Average Dz		0.09 m			
Minimum Dz		-0.090 m			
Maximum Dz		0.389 m			
Root Mean Square		0.134 m			
95th Percentile		0.266 m			

Points TW08 and TW14 were removed from the calculation.

Table 9. QC Checkpoint Report - CVA

Units = meters

Number	Easting	Northing	Known Z	Laser Z	Dz
BE03	479506.29	170566.64	265.64	265.87	0.23
BE04	482573.48	188449.51	435.77	435.77	0.00
BE05	510728.28	195936.34	436.16	436.21	0.05
BE07	477129.46	206178.95	137.15	137.37	0.22
BE08	464130.39	210595.11	97.08	97.04	-0.04
BE09	439099.12	209566.25	68.49	68.54	0.05
BE10	457975.19	222653.43	153.76	153.74	-0.02
BE11	480650.64	221549.40	264.12	264.16	0.05
BE12	523632.40	227227.24	532.85	532.85	0.00
BE13	503701.99	226416.11	245.84	245.87	0.03
BE14	490765.71	228351.37	198.43	198.43	0.00
BE15	441315.92	236432.62	30.80	30.75	-0.05
BE16	456613.38	247955.02	188.26	188.23	-0.03
BE17	471196.31	238481.74	146.51	146.55	0.04
BE18	484068.99	249794.51	257.97	257.96	-0.01
BE19	491601.97	240743.95	263.03	262.89	-0.14
BE20	509239.71	239346.00	379.00	379.01	0.01
BE21	495652.86	210944.36	247.86	247.87	0.00
BE22	514041.10	252493.95	263.29	263.32	0.03
BE23	509092.06	276828.38	185.34	185.38	0.04
BE24	541605.82	258742.64	354.07	354.08	0.00
BE25	542575.73	277352.58	419.00	418.97	-0.03
TW01	476469.09	147632.68	239.21	239.33	0.12
TW02	480538.51	171724.03	274.29	274.49	0.20
TW03	491019.41	195481.58	155.24	155.34	0.11
TW04	464184.09	210672.53	97.03	96.99	-0.04
TW05	439194.56	209546.26	72.80	72.90	0.11
TW06	457811.61	222654.25	153.64	153.66	0.02
TW07	480820.11	221464.78	262.88	263.19	0.31
TW09	523671.59	227284.43	533.09	533.19	0.10
TW10	503398.05	226759.97	210.18	210.27	0.09
TW11	472459.36	238434.52	135.82	136.15	0.33

Number	Easting	Northing	Known Z	Laser Z	Dz
TW12	443490.50	236034.58	35.54	35.64	0.11
TW13	456695.59	247970.92	191.00	191.21	0.21
TW15	509509.01	239166.44	371.87	371.97	0.10
TW16	514123.74	252620.71	267.93	268.06	0.13
TW17	509597.08	276846.95	197.40	197.51	0.11
TW18	541525.15	258757.02	351.97	352.20	0.23
TW19	542598.96	277350.05	417.83	418.03	0.20
TW20	504315.69	177546.54	465.85	466.24	0.39
FO02	478884.83	141648.57	240.23	240.30	0.07
FO03	476710.99	147152.49	261.02	261.09	0.07
FO05	472518.50	164524.57	299.62	299.56	-0.06
FO07	505141.63	179428.86	391.31	391.39	0.08
FO08	492315.36	195006.05	158.93	159.06	0.13
FO09	482578.49	188559.18	430.64	430.65	0.01
FO11	510718.62	195960.11	434.89	434.90	0.01
FO12	506754.87	210342.34	286.92	287.01	0.09
FO13	495573.36	210992.41	248.29	248.39	0.10
FO14	480598.80	221484.37	262.00	262.23	0.22
FO15	464396.99	209913.80	95.54	95.53	-0.02
FO16	440743.20	199393.72	79.07	79.19	0.13
FO17	439019.80	209504.11	63.68	63.71	0.04
FO18	458006.94	222663.48	153.09	153.04	-0.06
FO19	441335.33	236464.75	29.40	29.45	0.05
FO20	436686.96	228503.62	34.98	35.08	0.10
FO21	456602.87	247941.26	186.17	186.30	0.13
FO22	483973.48	249627.74	265.13	265.31	0.19
FO23	471186.21	238444.75	146.84	146.90	0.06
FO24	491583.12	240655.84	258.75	258.79	0.04
FO25	490961.61	228201.21	209.99	210.02	0.03
FO26	503790.54	226325.79	245.00	245.00	0.00
FO27	516864.48	225244.75	352.34	352.37	0.04
FO28	509544.12	239177.17	371.35	371.40	0.05
FO29	514136.04	252647.18	268.59	268.73	0.14
FO30	541660.05	258737.98	352.53	352.62	0.08
FO31	542586.07	277397.93	415.09	415.24	0.16

Number	Easting	Northing	Known Z	Laser Z	Dz
FO32	509096.59	276764.51	176.23	176.31	0.08
FO33	525189.64	270234.97	275.46	275.56	0.10
FO34	500623.48	247760.11	379.97	379.96	-0.02
FO35	463834.98	191078.86	456.11	456.13	0.03
FO36	449575.22	203338.36	106.75	106.82	0.07
FO37	450929.94	215442.52	144.28	144.19	-0.09
FO39	513007.49	208583.78	275.56	275.63	0.07
	Average Dz	0.07 m			
	Minimum Dz	-0.138 m			
	Maximum Dz	0.389 m			
	Root Mean Square	0.144 m			
	95th Percentile	0.230 m			

Points TW08 and TW14 were removed from the calculation.