Georgia Counties 2016 QL2 LiDAR
Interim Project Report - Early 2016 Dataset

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Georgia Counties 2016 QL2 LiDAR acquisition task order, issued by USGS National Geospatial Technical Operations Center under their Geospatial Product and Services Contract on March 2, 2016. The task order yielded a project area covering approximately 6,851 square miles over southwestern and eastern Georgia. 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

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 6,851 square miles and encompasses several full and partial counties throughout Georgia, listed below:

West Zone

- Brooks
- Calhoun
- Colquitt
- Grady
- Lamar
- Lee
- Marion
- Meriwether
- Mitchell
- Pike
- Schley
- Spalding
- Sumter
- Talbot
- Thomas
- Upson
- Worth

East Zone

- Burke
- Jenkins

Project extents are shown in Figure 1 and Figure 2 on the following page.

1.4. Duration

LiDAR data was acquired from February 28, 2016 to March 18, 2016 in thirty total lifts. See "Section: 2.5. Time Period" for more details.

1.5. Issues

Acquisition was delayed due to leaf-out conditions. This report provides details on the data acquired from February 28, 2016 to March 18, 2016. A final version of this report will be sent once the remaining data is acquired.

1.6. Deliverables

The following products were produced and delivered:

- Raw LiDAR Point Cloud data, swaths, in LAS 1.4 format
- Classified Point cloud data, tiled, in LAS 1.4 format
- 2-foot hydro-flattened bare earth raster DEM, in ERDAS .IMG format
- 2-foot intensity images, tiled, in GeoTIFF format
- Building footprints, in Esri file geodatabase format
- Hydro-flattened breaklines, in Esri file geodatabase formats
- Processing boundary, in Esri shapefile format
- Tile index, in Esri shapefile format
- Calibration points, in Esri shapefile format
- QC Checkpoints, in Esri shapefile format
- Accuracy assessment, in Excel .XLS format
- Project-, deliverable-, and lift-level metadata, in .XML format

All geospatial deliverables were produced in NAD83 (2011) State Plane Georgia East or West Zone (depending on the location of the AOI with respect to the zone), US survey feet; NAVD88 (Geoid 12B), US survey feet. All tiled deliverables have a tile size of 5,000 ft x 5,000 feet. Tile names correspond to the Georgia State Index.

Figure 1. Project Boundary - West AOI

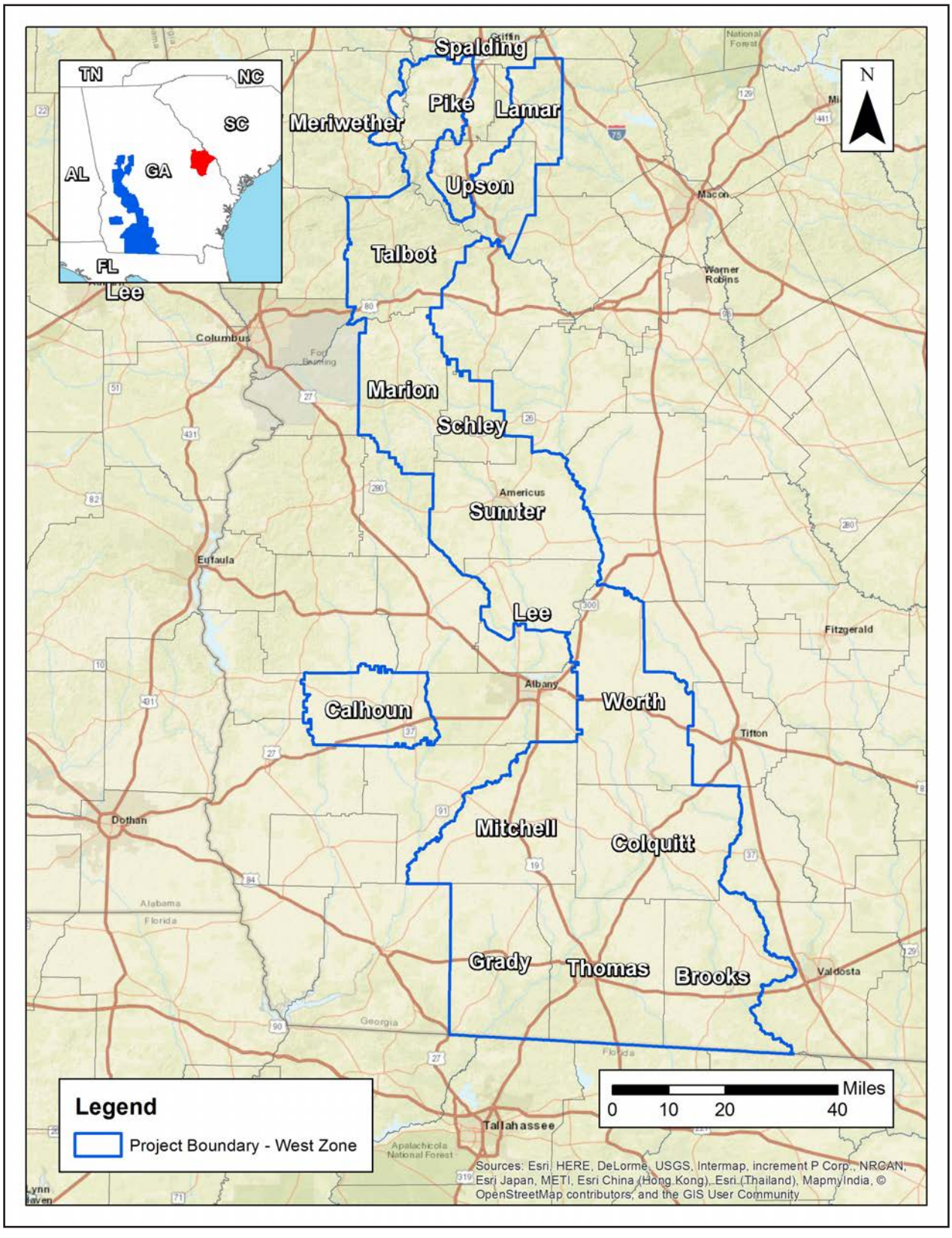
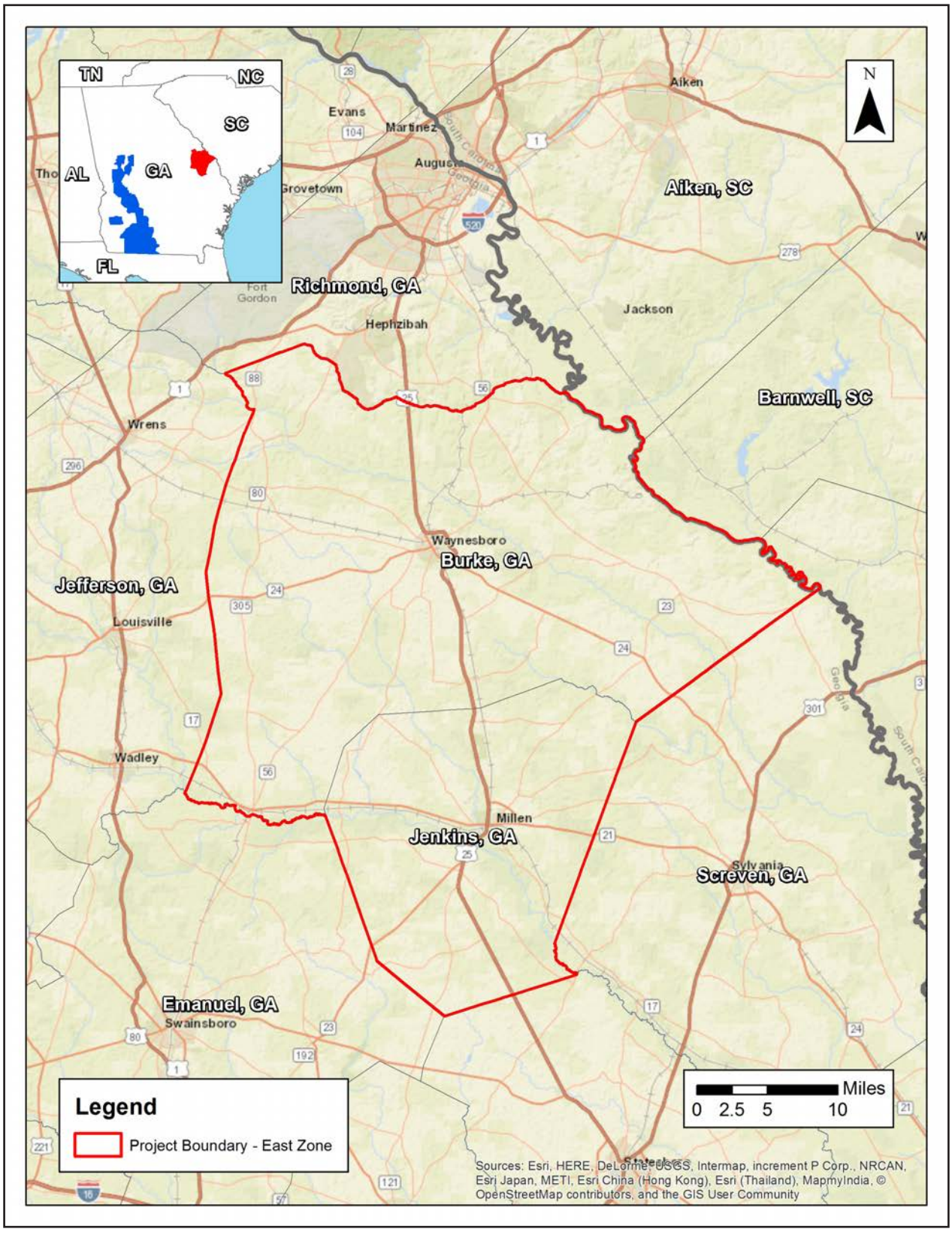


Figure 2. Project Boundary - East AOI



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 436 planned flight lines measuring approximately 13,205.40 total flight line miles (Figure 3 and Figure 4).

2.2. LiDAR Sensor

Quantum Spatial utilized a Optech Orion H300 LiDAR sensor (Figure 5), serial numbers 324 and 309, during the project. These systems are capable of collecting data at a maximum frequency of 167 kHz, which affords elevation data collection of up to 167,000 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 3. Planned Flight Lines - West Zone

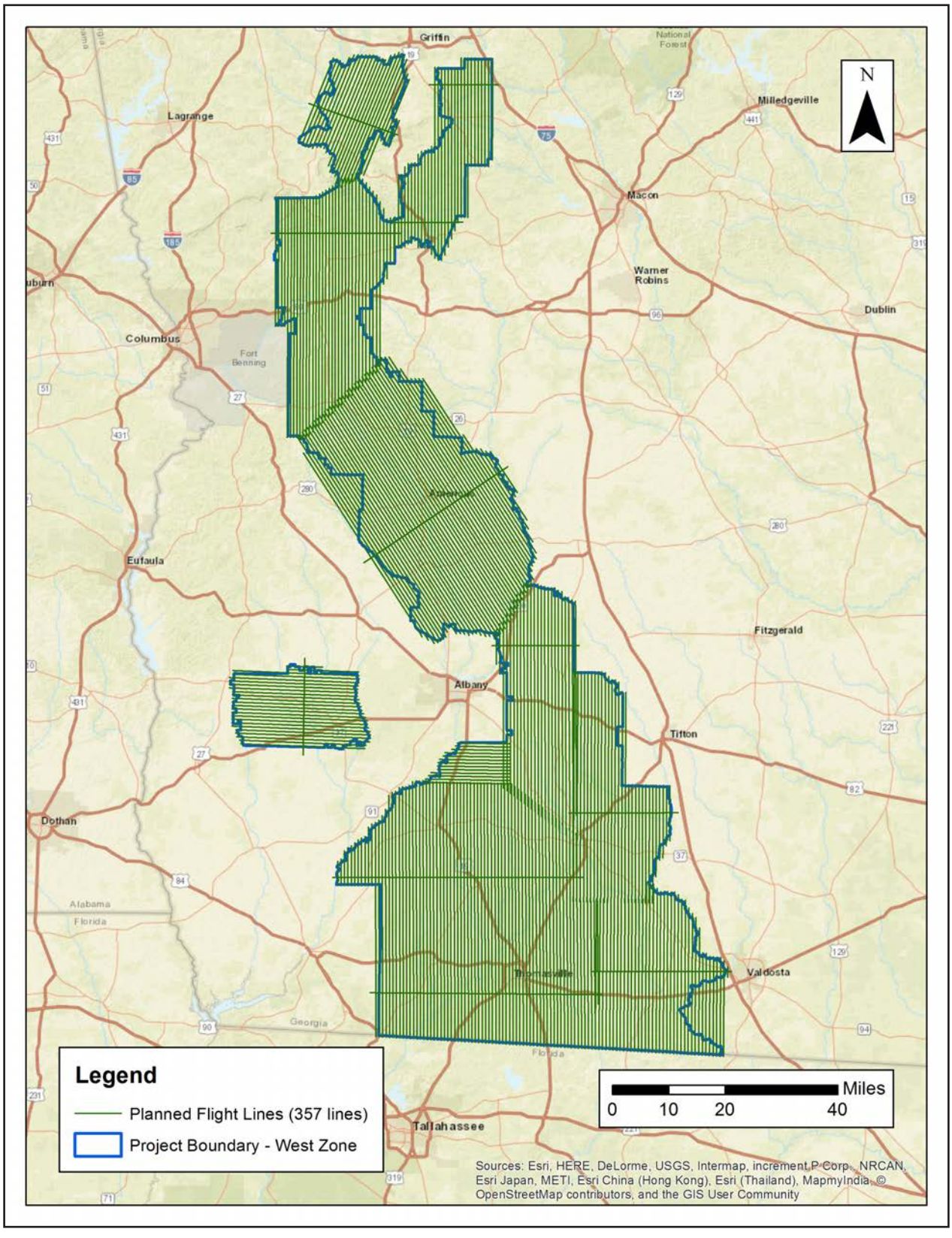


Figure 4. Planned Flight Lines - East Zone

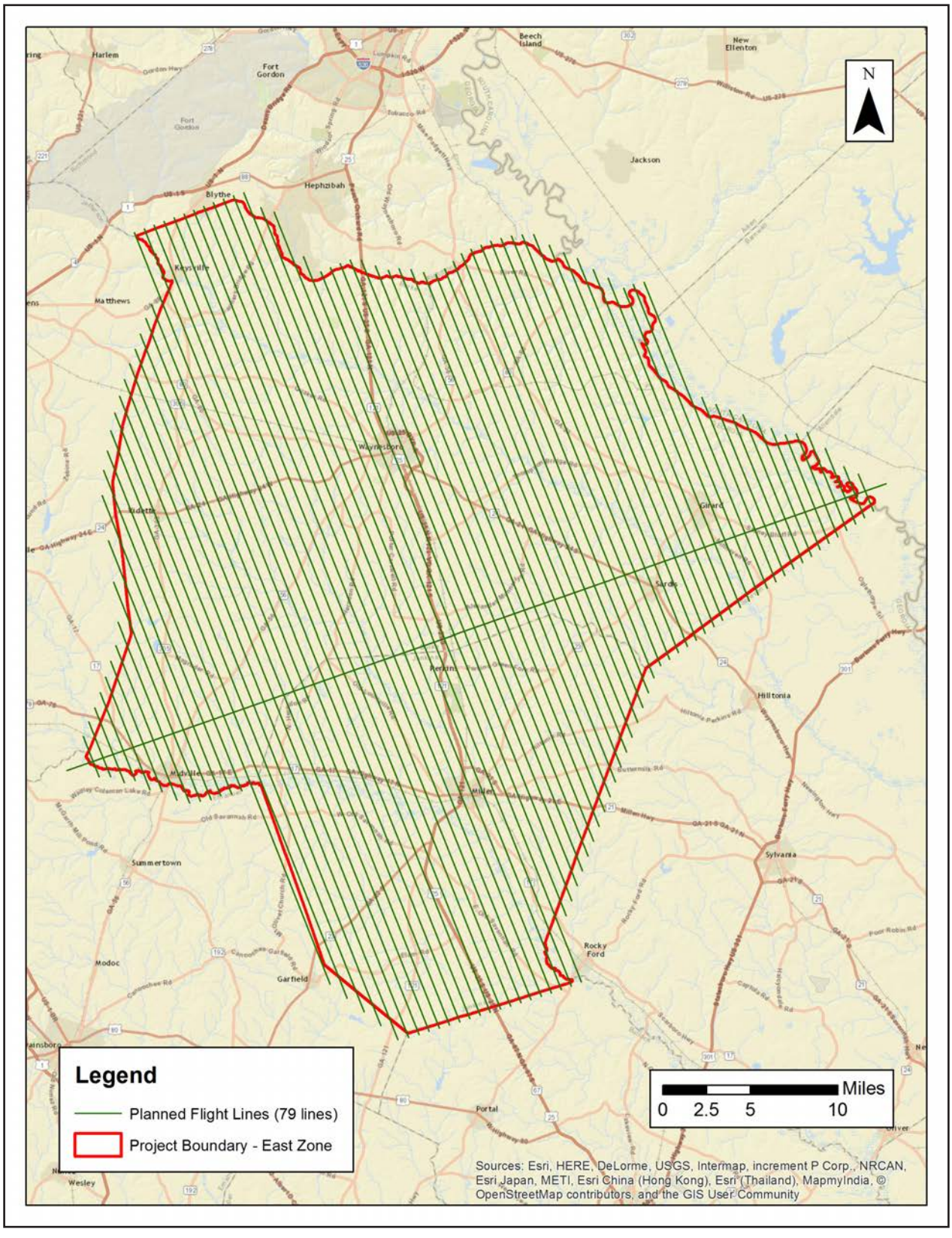


Table 2. Sensor Specifications

Terrain and Aircraft Scanner	Flying Height	1,700 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	1,170.17 m
Point Spacing and Density	Maximum Point Spacing Along Track	0.6580 m
	Maximum Point Spacing Along Track	0.6925 m
	Average Point Density	2.19 pts / m^2

Figure 5. Optech Orion LiDAR Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of a customized Cessna 402 (twin-piston), tail numbers N246MP and N2JJ. 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 Optech LiDAR systems. Some of the operating aircraft can be seen in Figure 6 below.

Figure 6. 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 7 and Figure 8. 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)
GATF	31° 27′ 6.86542″	83° 30′ 32.83055″	97.522
BD2674	30° 53′ 55.71421″	83° 52′ 29.29101″	47.473
0844	31° 25′ 43.03009″	83° 29′ 34.5141″	80.039
8339, DF2787	33° 2′ 28.9748″	82° 0′ 10.83182″	61.104
GAAE	33° 25′ 38.05128″	82° 4′ 4.04375″	125.771
GAWY	33° 5′ 59.42168″	82° 7′ 58.71653″	74.867

Figure 7. Base Station Locations - West AOI

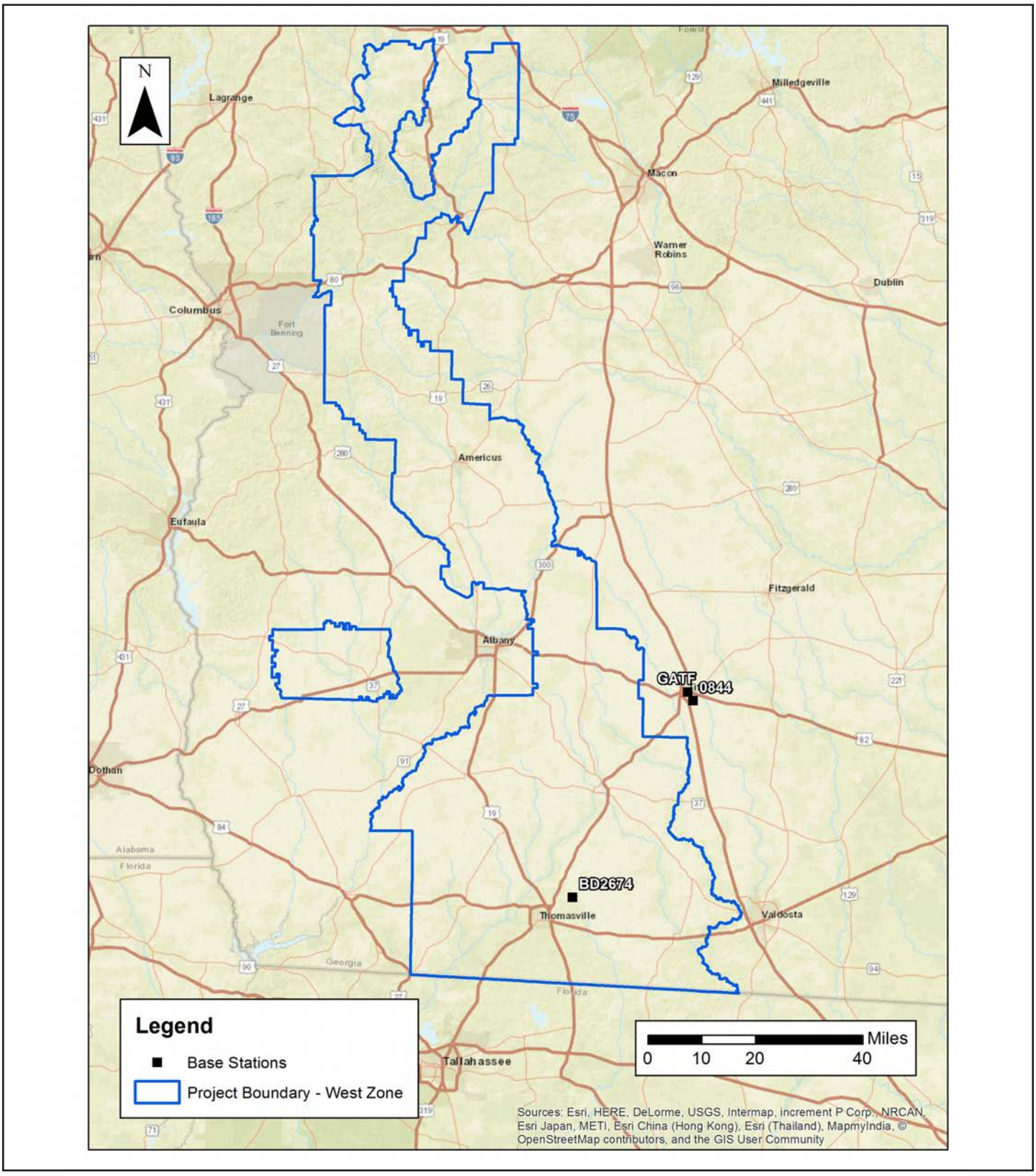
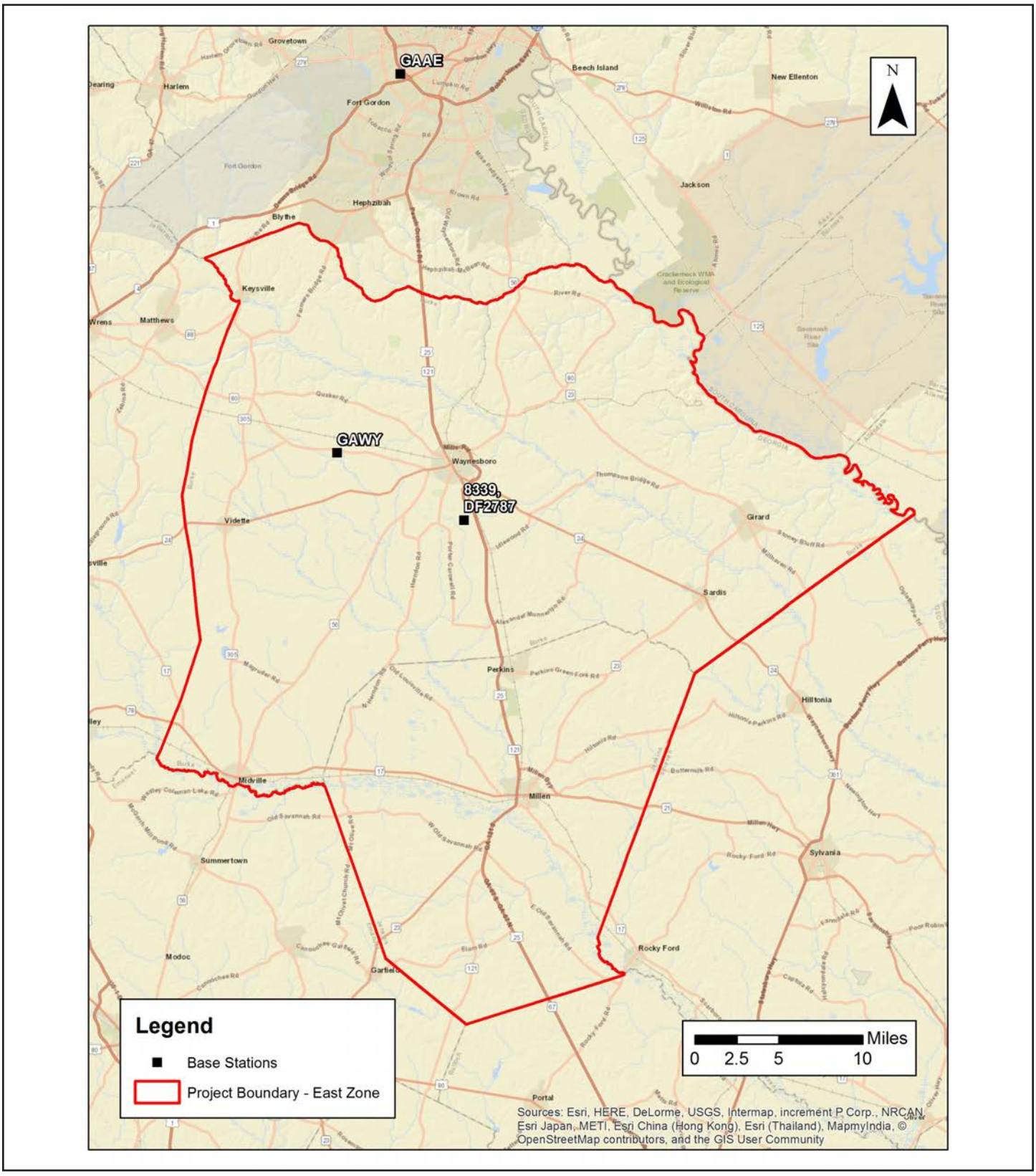


Figure 8. Base Station Locations - East AOI



2.5. Time Period

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

West AOI

- Feb 28, 2016-A (N246MP, SN324)
- Feb 29, 2016-A (N246MP, SN324)
- Mar 2, 2016-A (N246MP, SN324)
- Mar 3, 2016-A (N246MP, SN324)
- Mar 6, 2016-A (N246MP, SN324)
- Mar 7, 2016-A (N246MP, SN324)
- Mar 8, 2016-A (N246MP, SN324)
- Mar 11, 2016-A (N246MP, SN324)
- Mar 12, 2016-A (N2JJ, SN309)
- Mar 12, 2016-A (N246MP, SN324)
- Mar 12, 2016-B (N246MP, SN324)
- Mar 14, 2016-A (N2JJ, SN309)
- Mar 14, 2016-A (N246MP, SN324)
- Mar 14, 2016-B (N246MP, SN324)
- Mar 15, 2016-A (N2JJ, SN309)
- Mar 15, 2016-A (N246MP, SN324)
- Mar 15, 2016-B (N2JJ, SN309)
- Mar 15, 2016-B (N246MP, SN324)
- Mar 16, 2016-A (N246MP, SN324)
- Mar 18, 2016-A (N2JJ, SN309)

East AOI

- Mar 2, 2016-A (N2JJ, SN309)
- Mar 2, 2016-B (N2JJ, SN309)
- Mar 2, 2016-C (N2JJ, SN309)
- Mar 3, 2016-A (N2JJ, SN309)
- Mar 5, 2016-A (N2JJ, SN309)
- Mar 6, 2016-A (N2JJ, SN309)
- Mar 7, 2016-A (N2JJ, SN309)
- Mar 8, 2016-A (N2JJ, SN309)
- Mar 9, 2016-A (N2JJ, SN309)
- Mar 10, 2016-A (N2JJ, SN309)

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 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 6 – Buildings – Points occurring on building roofs.
- Class 7 – Low Noise – Low points, manually identified 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 – 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 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 Overlap Default and 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 was 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 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 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 2-foot Raster DEM. Using proprietary software and 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 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 were then provided as the deliverable for this dataset requirement.

3.8 Building Footprint Creation

Polygons were generated with an automated routine that utilized the Class 6 (Buildings) LiDAR data 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.

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 9 and Figure 10.

Figure 9. Flightline Swath LAS File Coverage - West AOI

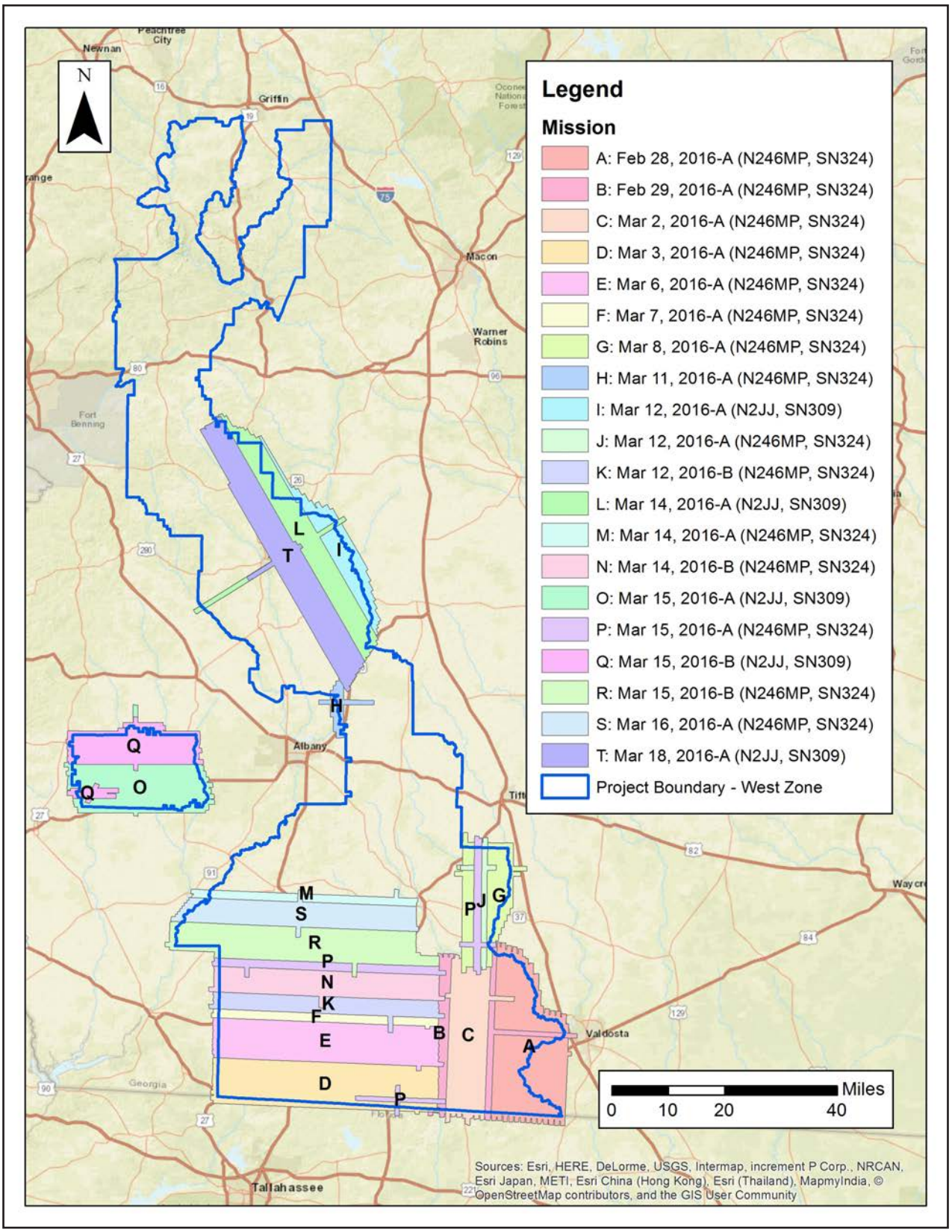
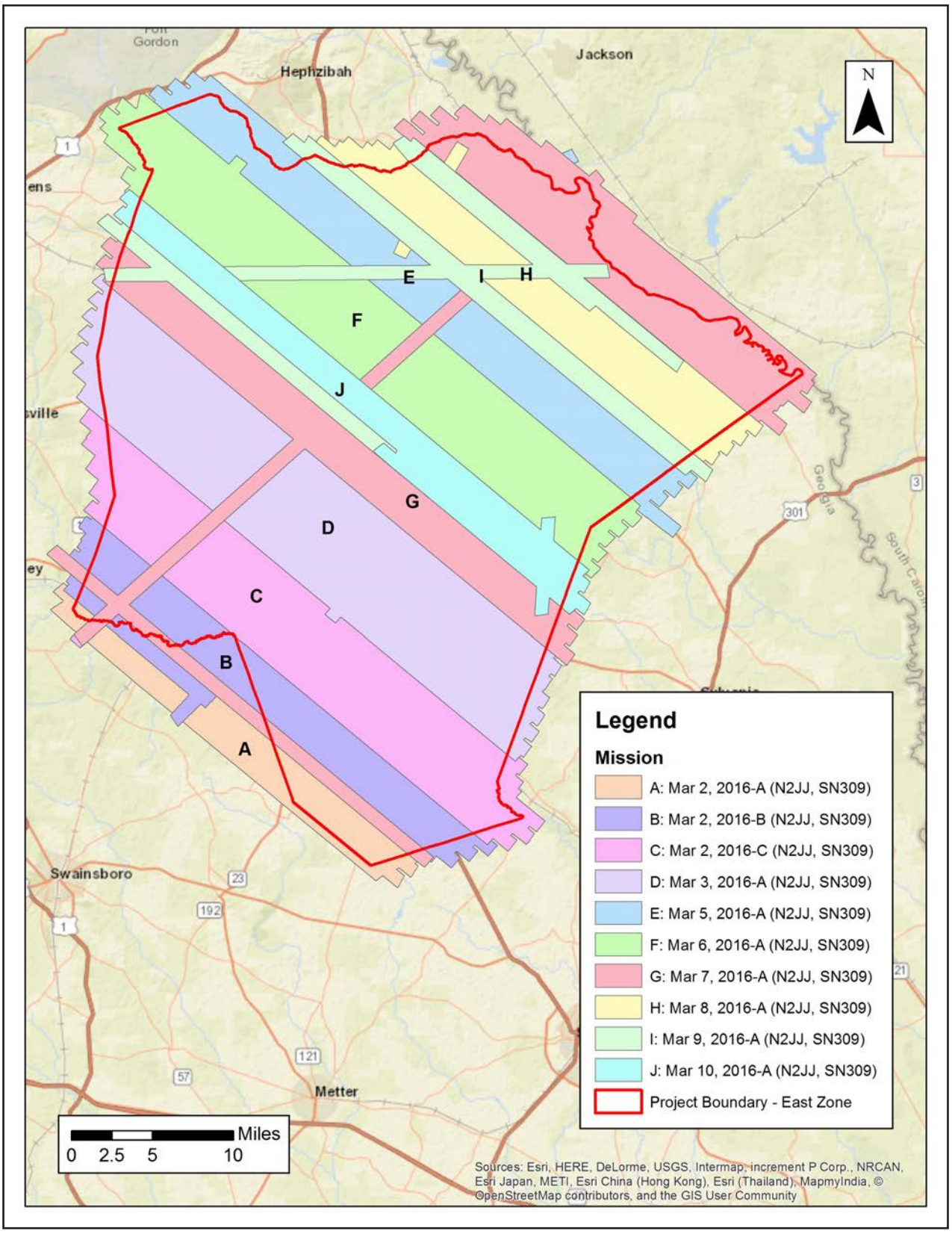


Figure 10. Flightline Swath LAS File Coverage - East AOI



5. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of 172 ground control (calibration) points along with 254 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 426 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 B.

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). In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in NAD83 (2011) State Plane Georgia West and East Zones, US survey feet; NAVD88 (GEOID12B), US survey feet.

5.1. Calibration Control Point Testing

Figure 11 through Figure 13 show the location of each bare earth calibration point for the project area. Table 4 through Table 6 depicts the Control Report for the LiDAR bare earth calibration points, as computed in TerraScan as a quality assurance check. 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 5 checkpoints in the GA West - Small AOI, 22 checkpoints in the GA West Spring 2016 AOI, and 40 checkpoints in the GA East AOI, all 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 14 through Figure 16 and Table 7 through Table 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 5 checkpoints in the GA West Small AOI, 21 checkpoints in the GA West Spring 2016 AOI, and 41 checkpoints in the GA East AOI, all located in bare earth and urban (non-vegetated) areas. See Figure 17 through Figure 19 and Table 10 through Table 12.

2. Vegetated Vertical Accuracy (VVA): VVA shall be reported for "forested", "shrubs", 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 6 checkpoints in the GA West Small AOI, 20 checkpoints in the GA West Spring 2016 AOI, and 17 checkpoints in the GA East AOI, all located in forested, shrubs, and tall weeds (vegetated) areas. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See Figure 20 through Figure 22 and Table 13 through Table 15.

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) 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.

Figure 11. Calibration Control Point Locations - GA West Small AOI

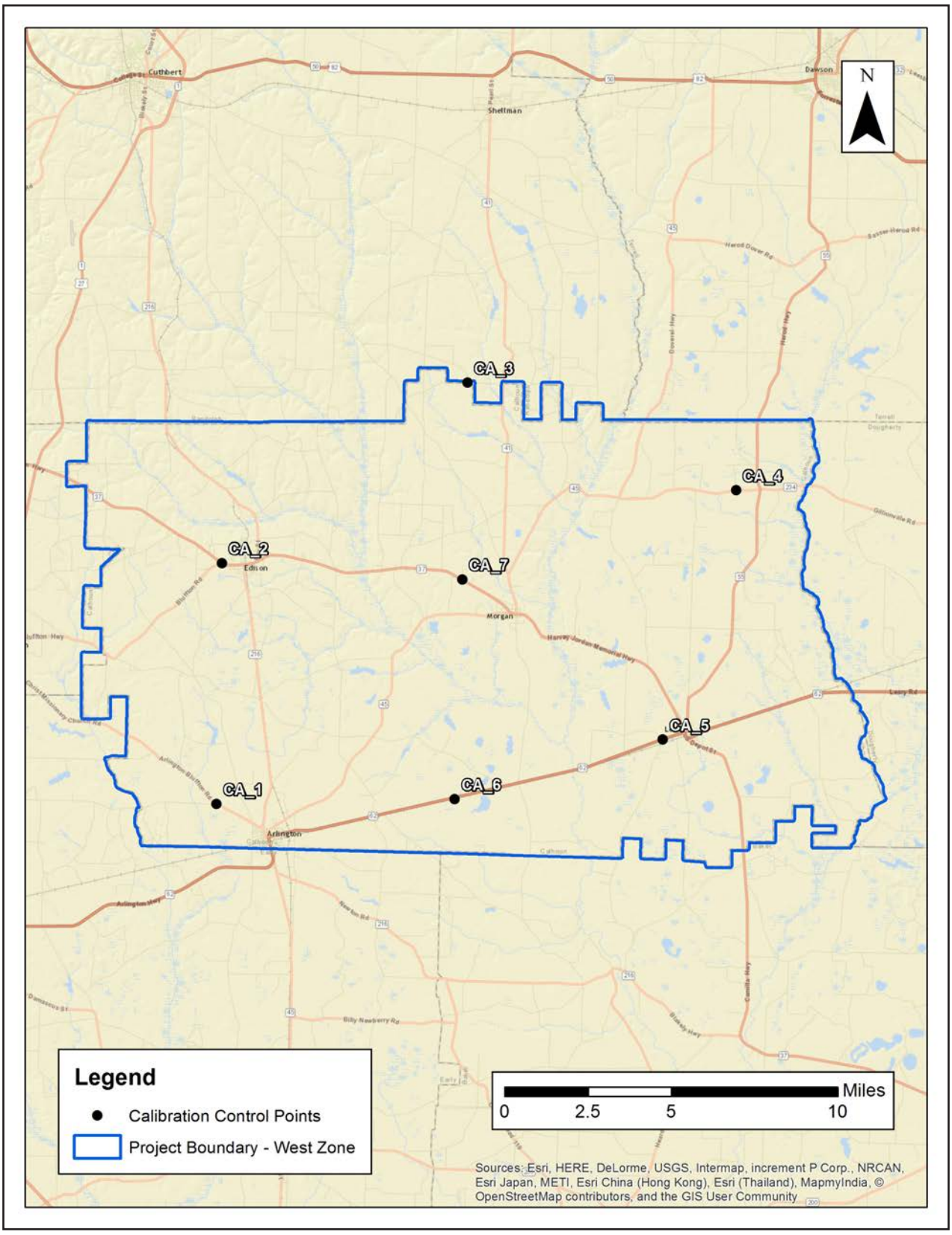


Table 4. Calibration Control Point Report - GA West Small AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
CA_1	2114139.020	529298.800	238.20	238.11	-0.09
CA_2	2114992.000	567387.240	307.85	307.80	-0.05
CA_3	2153939.720	596003.270	310.62	310.81	0.19
CA_4	2196507.150	578952.480	241.20	241.17	-0.03
CA_5	2184895.340	539488.950	213.04	212.76	-0.28
CA_6	2151907.380	530044.480	220.90	220.93	0.03
CA_7	2153120.220	564820.080	270.26	270.52	0.26
	Average Dz	0.000 ft			
	Minimum Dz	-0.280 ft			
	Maximum Dz	0.260 ft			
	Root Mean Square	0.167 ft			
	Std. Deviation	0.180 ft			

Figure 12. Calibration Control Point Locations - GA West Large AOI (Early 2016)

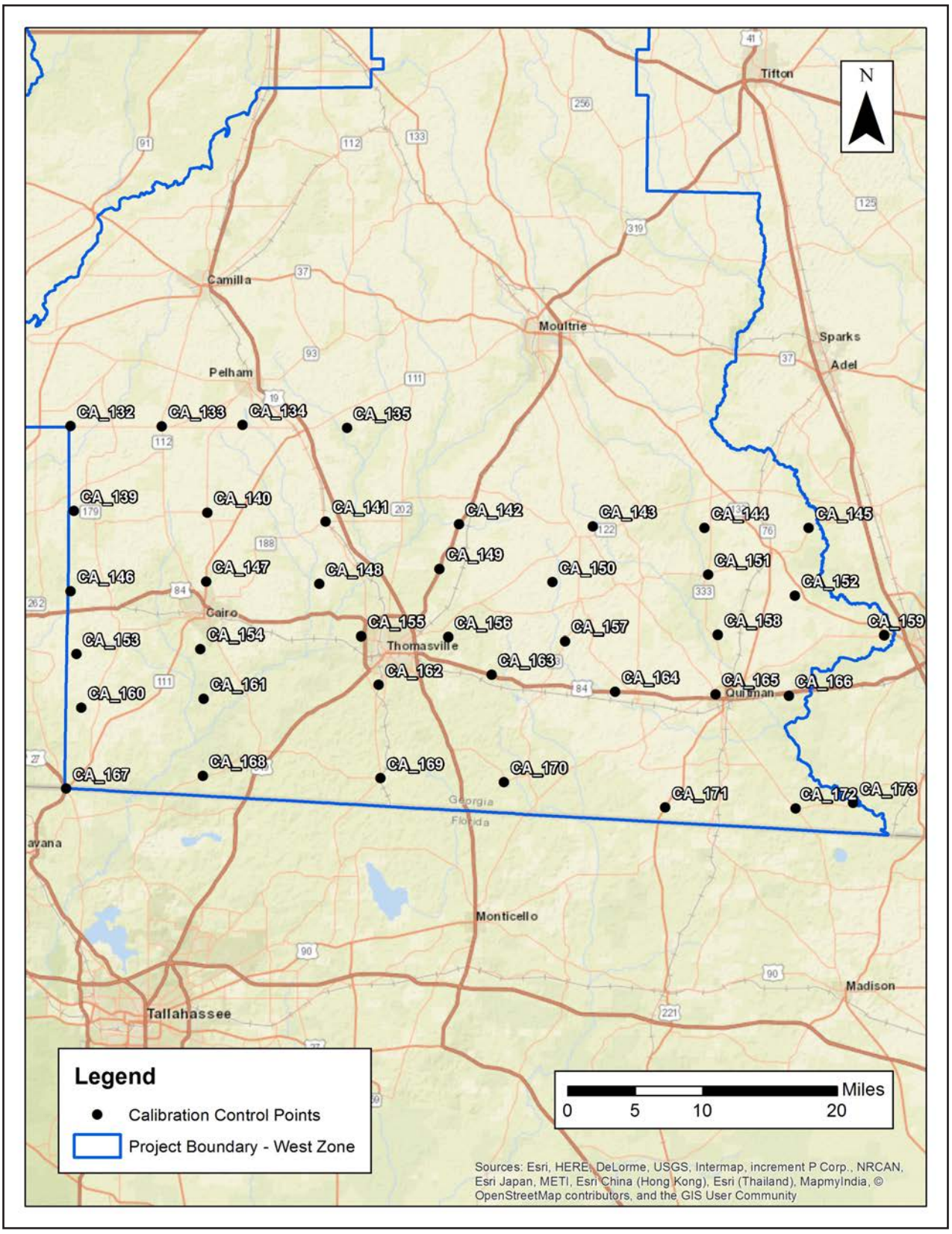


Table 5. Calibration Control Point Report - GA West Large AOI (Early 2016)

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
CA_132	2231318.64	392500.16	142.09	141.81	-0.28
CA_133	2267028.87	392444.51	181.41	181.23	-0.18
CA_134	2298695.60	392973.70	347.91	347.74	-0.17
CA_135	2339577.31	391770.66	280.67	280.61	-0.06
CA_139	2232630.82	359252.73	169.62	169.70	0.08
CA_140	2284845.98	358574.35	334.09	334.21	0.12
CA_141	2331203.41	355118.58	269.67	269.67	0.00
CA_142	2383410.95	354050.01	201.26	201.26	0.00
CA_143	2435937.51	353205.25	239.52	239.47	-0.05
CA_144	2479603.46	352569.65	162.59	162.66	0.07
CA_145	2520442.70	352541.59	152.03	152.08	0.05
CA_146	2231291.13	327838.55	311.78	311.92	0.14
CA_147	2284366.26	331594.61	262.37	262.20	-0.17
CA_148	2328678.48	330619.70	216.67	216.63	-0.04
CA_149	2375834.96	336506.98	214.97	214.73	-0.24
CA_150	2420008.61	331390.09	221.90	221.92	0.02
CA_151	2481020.11	334244.35	193.32	193.19	-0.13
CA_152	2515087.83	326057.45	222.57	222.64	0.07
CA_153	2233565.39	303304.83	292.01	291.98	-0.03
CA_154	2282137.23	305324.26	242.42	242.41	-0.01
CA_155	2345191.00	310244.53	257.80	257.97	0.17
CA_156	2379227.58	309885.93	218.80	218.76	-0.04
CA_157	2424940.81	308312.85	220.81	220.60	-0.21
CA_158	2484875.62	310759.55	191.19	191.33	0.14
CA_159	2550096.35	310597.09	144.26	144.45	0.19
CA_160	2235529.11	282370.74	275.82	275.95	0.13
CA_161	2283434.92	285864.81	216.37	216.48	0.11
CA_162	2351970.09	291255.14	237.79	237.64	-0.15
CA_163	2396183.57	295282.21	153.40	153.18	-0.22
CA_164	2444649.92	288589.54	186.50	186.69	0.19
CA_165	2483899.98	287586.78	208.19	208.29	0.10
CA_166	2512691.75	286968.29	188.23	188.08	-0.15

Number	Easting	Northing	Known Z	Laser Z	Dz
CA_167	2229587.76	250595.47	275.24	275.50	0.26
CA_168	2283055.21	255629.24	206.51	206.52	0.01
CA_169	2352637.11	254679.00	177.43	177.32	-0.11
CA_170	2401093.17	253148.98	187.26	187.51	0.25
CA_171	2464212.91	243176.63	134.41	134.40	-0.01
CA_172	2515291.37	242870.21	204.53	204.55	0.02
CA_173	2537919.01	244932.24	96.94	96.86	-0.08

Average Dz	-0.010 ft
Minimum Dz	-0.280 ft
Maximum Dz	0.260 ft
Root Mean Square	0.139 ft
Std. Deviation	0.141 ft

Figure 13. Calibration Control Point Locations - GA East AOI

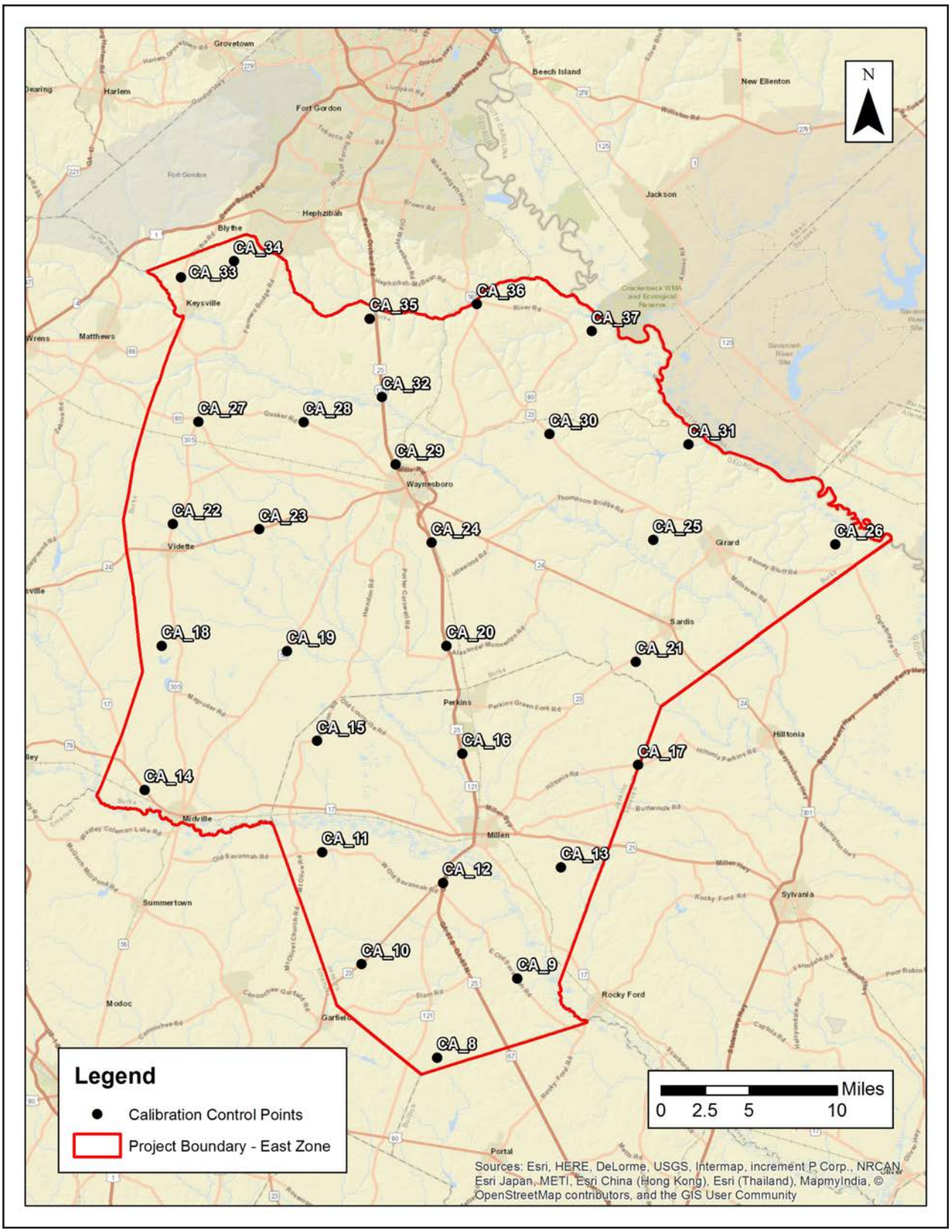


Table 6. Calibration Control Point Report - GA East AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
CA_8	711746.640	952893.990	312.67	312.87	0.20
CA_9	735751.360	976684.490	205.94	205.92	-0.02
CA_10	689119.680	980973.430	264.39	264.37	-0.02
CA_11	677380.010	1014563.880	169.42	169.01	-0.41
CA_12	713585.860	1005330.570	170.77	170.93	0.16
CA_13	748859.880	1010024.610	232.42	232.44	0.02
CA_14	624094.930	1033228.900	249.42	249.42	0.00
CA_15	675782.320	1047988.570	232.99	232.85	-0.14
CA_16	719359.570	1044123.140	211.82	211.84	0.02
CA_17	771990.550	1040742.000	283.93	284.00	0.07
CA_18	629193.420	1076370.540	321.21	321.41	0.20
CA_19	666806.370	1074822.070	233.20	233.23	0.03
CA_20	714584.050	1076370.900	268.27	268.33	0.06
CA_21	771396.350	1071661.990	222.39	222.46	0.07
CA_22	632552.990	1112831.990	335.69	335.61	-0.08
CA_23	658447.900	1111309.320	331.59	331.36	-0.23
CA_24	710093.380	1107311.690	313.45	313.47	0.02
CA_25	776565.780	1108089.470	205.02	205.00	-0.02
CA_26	831072.590	1106719.360	191.63	191.76	0.13
CA_27	640201.890	1143528.350	403.40	403.57	0.17
CA_28	671823.700	1143431.880	294.24	294.18	-0.06
CA_29	699359.720	1130711.910	284.55	284.38	-0.17
CA_30	745427.090	1139874.240	275.30	275.53	0.23
CA_31	787078.270	1136732.550	99.83	99.81	-0.02
CA_32	695281.490	1150988.350	207.69	207.69	0.00
CA_33	635033.290	1186841.880	441.26	441.26	0.00
CA_34	650926.680	1191703.610	411.83	411.77	-0.06
CA_35	691621.510	1174451.580	291.20	291.01	-0.19
CA_36	723702.400	1178851.680	135.64	135.57	-0.07
CA_37	758127.910	1170747.270	234.30	234.43	0.13

Average Dz	0.000 ft
Minimum Dz	-0.410 ft
Maximum Dz	0.230 ft
Root Mean Square	0.137 ft
Std. Deviation	0.139 ft

Figure 14. QC Checkpoint Locations - Raw NVA - GA West Small AOI

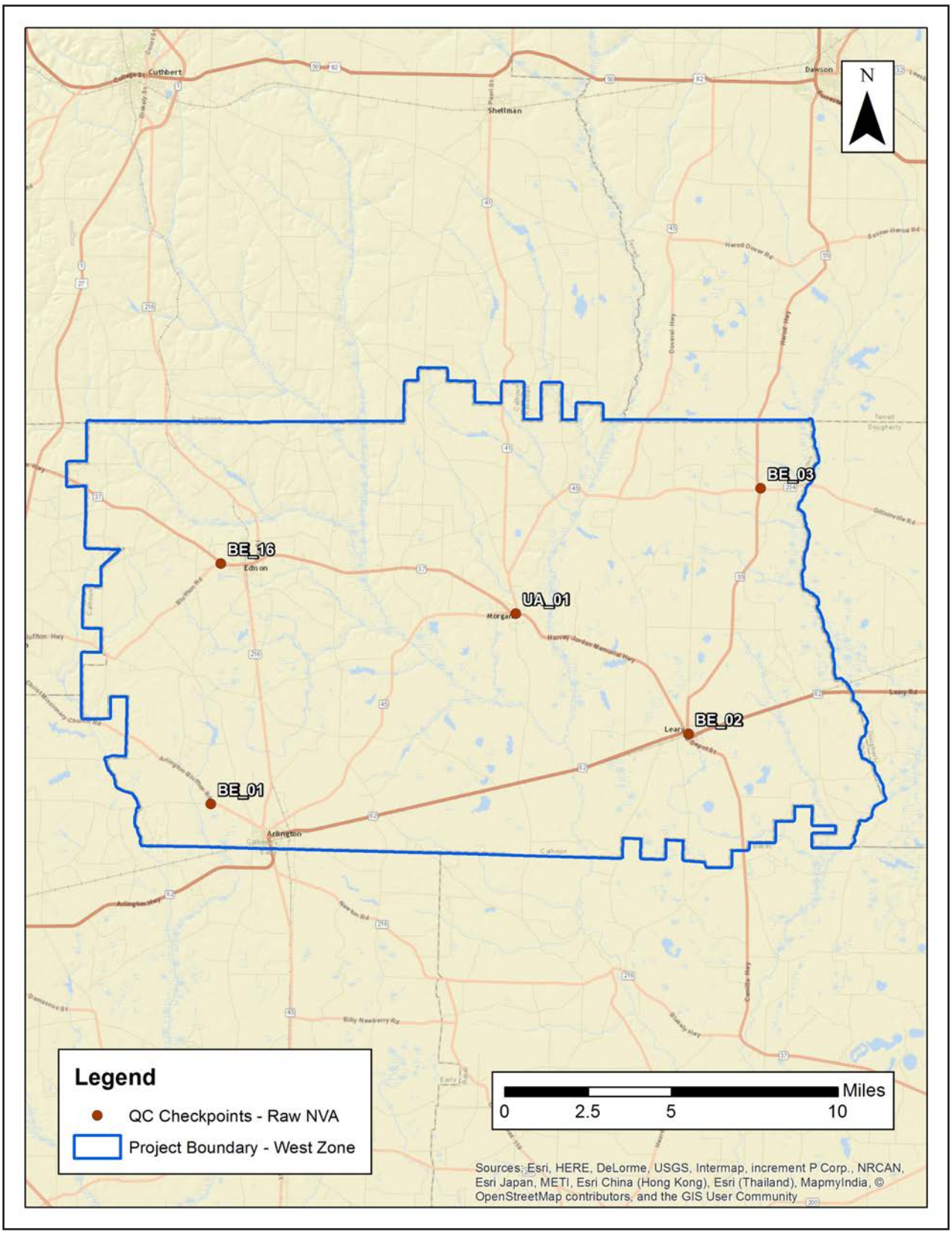


Table 7. QC Checkpoint Report - Raw NVA - GA West Small AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_01	2113232.470	529270.650	232.18	232.07	-0.11
BE_02	2189023.350	540374.420	201.69	201.59	-0.10
BE_03	2200396.300	579281.980	232.85	232.85	0.00
BE_16	2114839.510	567346.390	302.78	302.77	-0.01
UA_01	2161618.110	559369.860	244.32	244.17	-0.15

Average Dz	-0.070 ft
Minimum Dz	-0.150 ft
Maximum Dz	0.000 ft
Root Mean Square	0.095 ft
95% Confidence Level	0.185 ft

Figure 15. QC Checkpoint Locations - Raw NVA - GA West Large AOI (Early 2016)

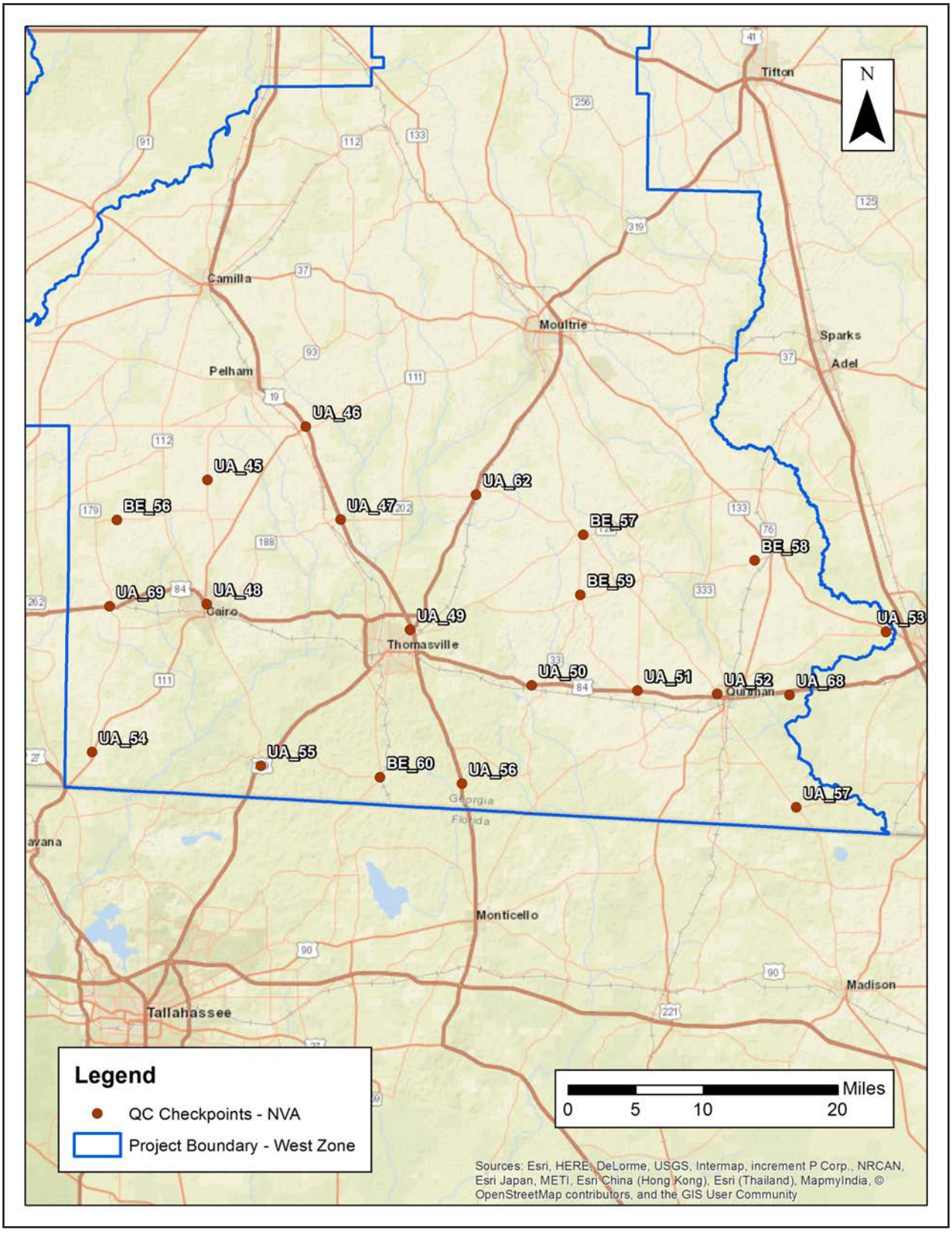


Table 8. QC Checkpoint Report - Raw NVA - GA West Large AOI (Early 2016)

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_56	2249483.030	355197.340	284.52	284.60	0.08
BE_57	2431950.820	349403.630	249.56	249.52	-0.04
BE_58	2499104.840	339347.140	239.76	239.76	0.00
BE_59	2430861.280	325946.010	262.11	262.19	0.08
BE_60	2352454.460	254595.860	183.28	183.18	-0.10
BE_61	2471460.060	259550.900	137.80	137.96	0.16
UA_45	2284793.850	370859.060	316.99	316.89	-0.10
UA_46	2323291.980	391783.740	304.59	304.60	0.01
UA_47	2336951.950	355307.370	237.32	237.44	0.12
UA_48	2284592.520	322296.010	260.99	260.68	-0.31
UA_49	2364208.210	312219.430	284.97	284.82	-0.15
UA_50	2411855.460	290657.640	182.94	182.92	-0.02
UA_51	2453238.380	288614.310	197.52	197.46	-0.06
UA_52	2484468.470	287234.690	200.09	200.07	-0.02
UA_53	2550422.430	311566.280	142.55	142.78	0.23
UA_54	2239637.610	264436.180	263.45	263.46	0.01
UA_55	2305758.110	259025.260	266.91	266.93	0.02
UA_56	2384518.480	252097.290	188.75	188.79	0.04
UA_57	2515352.990	242740.490	203.78	203.71	-0.07
UA_62	2389971.550	365056.410	227.84	227.82	-0.02
UA_68	2512738.260	286873.890	188.52	188.39	-0.13
UA_69	2246444.220	321431.520	288.83	288.59	-0.24

Average Dz	-0.020 ft
Minimum Dz	-0.310 ft
Maximum Dz	0.230 ft
Root Mean Square	0.123 ft
95% Confidence Level	0.241 ft

Figure 16. QC Checkpoint Locations - Raw NVA - GA East AOI

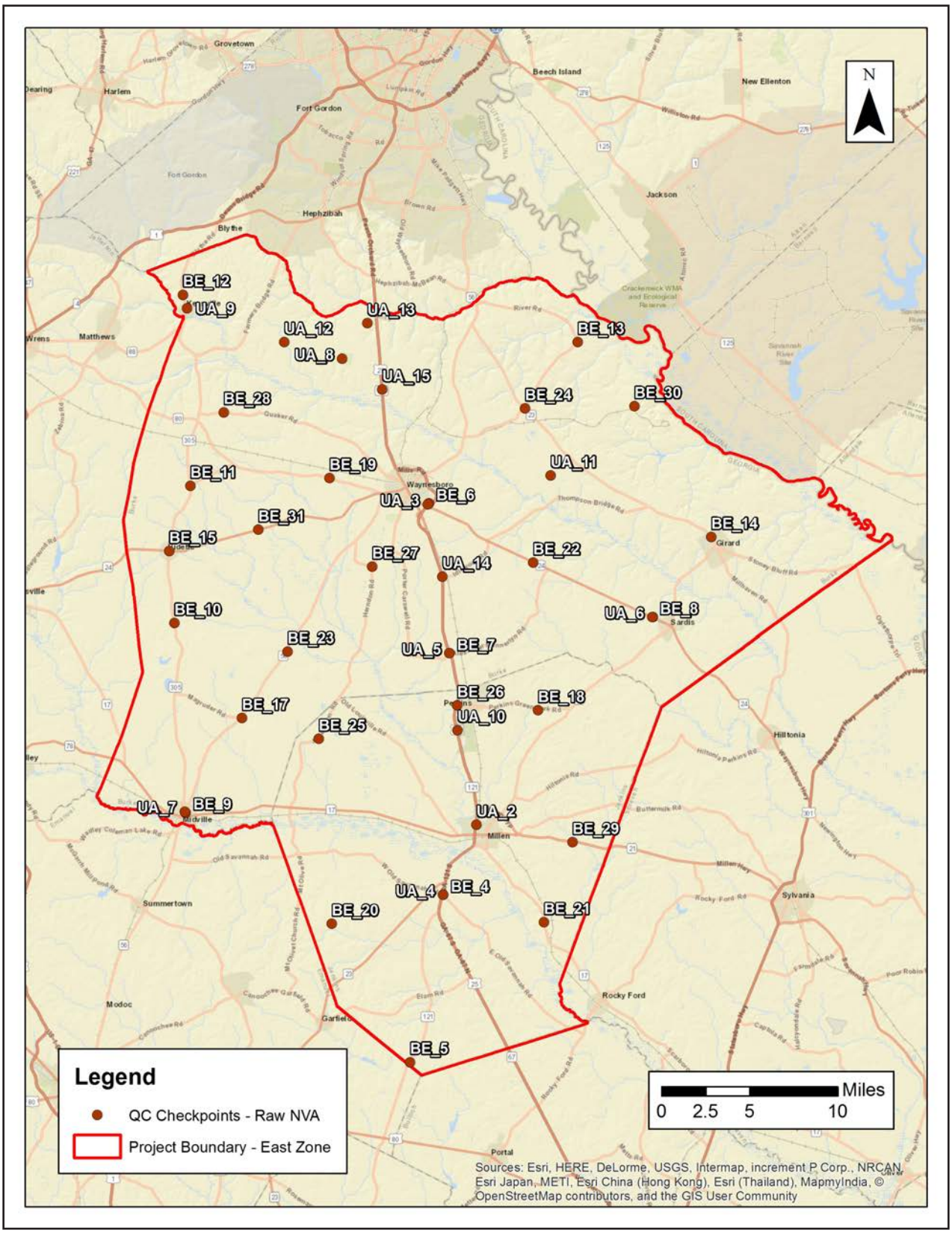


Table 9. QC Checkpoint Report - Raw NVA - GA East AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_4	713466.840	1001931.080	198.38	198.45	0.07
BE_5	703620.640	951799.000	341.85	341.90	0.05
BE_6	709196.250	1119152.010	282.73	282.49	-0.24
BE_7	715352.560	1074366.440	244.51	244.69	0.18
BE_8	776182.970	1085031.350	214.39	214.29	-0.10
BE_9	636335.330	1026554.810	212.55	212.62	0.07
BE_10	633012.290	1083283.390	341.29	341.13	-0.16
BE_11	637793.730	1124390.090	392.01	392.22	0.21
BE_12	635605.140	1181685.730	390.94	390.90	-0.04
BE_13	753751.010	1167507.150	227.04	227.10	0.06
BE_14	793820.850	1109031.400	232.85	232.89	0.04
BE_15	631413.930	1104815.040	349.48	349.39	-0.09
BE_17	653200.250	1054988.620	253.73	253.75	0.02
BE_18	741909.110	1057292.300	250.50	250.49	-0.01
BE_19	679446.760	1126761.220	337.79	337.72	-0.07
BE_20	680177.540	993257.150	264.24	264.27	0.03
BE_21	743641.500	993766.030	224.78	224.70	-0.08
BE_22	740437.890	1101392.400	307.37	307.40	0.03
BE_23	666870.520	1074826.200	233.13	233.12	-0.01
BE_24	737975.240	1147610.250	285.58	285.42	-0.16
BE_25	676289.470	1048702.840	233.06	slope	*
BE_26	717674.100	1058715.610	235.04	235.31	0.27
BE_27	692226.670	1100206.110	292.28	292.37	0.09
BE_28	647779.540	1146449.440	367.65	367.68	0.03
BE_29	752247.400	1017762.290	243.01	243.10	0.09
BE_30	770767.570	1148267.400	303.66	303.78	0.12
BE_31	658129.670	1111283.100	329.19	329.15	-0.04
UA_2	723433.700	1022984.350	174.38	174.36	-0.02
UA_3	708956.670	1118863.140	280.37	280.06	-0.31
UA_4	713447.790	1001940.120	199.04	199.11	0.07
UA_5	715401.740	1074375.000	245.10	245.28	0.18
UA_6	776153.670	1085052.670	214.59	214.56	-0.03

Number	Easting	Northing	Known Z	Laser Z	Dz
UA_7	636135.170	1026905.490	213.04	213.19	0.15
UA_8	683231.180	1162546.160	314.87	314.80	-0.07
UA_9	636823.820	1177602.400	280.97	281.03	0.06
UA_10	717810.070	1051331.300	221.35	221.49	0.14
UA_11	745631.730	1127527.040	256.62	256.66	0.04
UA_12	665862.260	1167520.380	306.55	306.40	-0.15
UA_13	690782.820	1173162.860	244.80	244.72	-0.08
UA_14	713199.640	1097147.830	289.84	289.94	0.10
UA_15	695285.400	1153255.370	236.41	236.33	-0.08

Average Dz	0.010 ft
Minimum Dz	-0.310 ft
Maximum Dz	0.270 ft
Root Mean Square	0.120 ft
95% Confidence Level	0.235 ft

Figure 17. QC Checkpoint Locations - NVA - GA West Small AOI

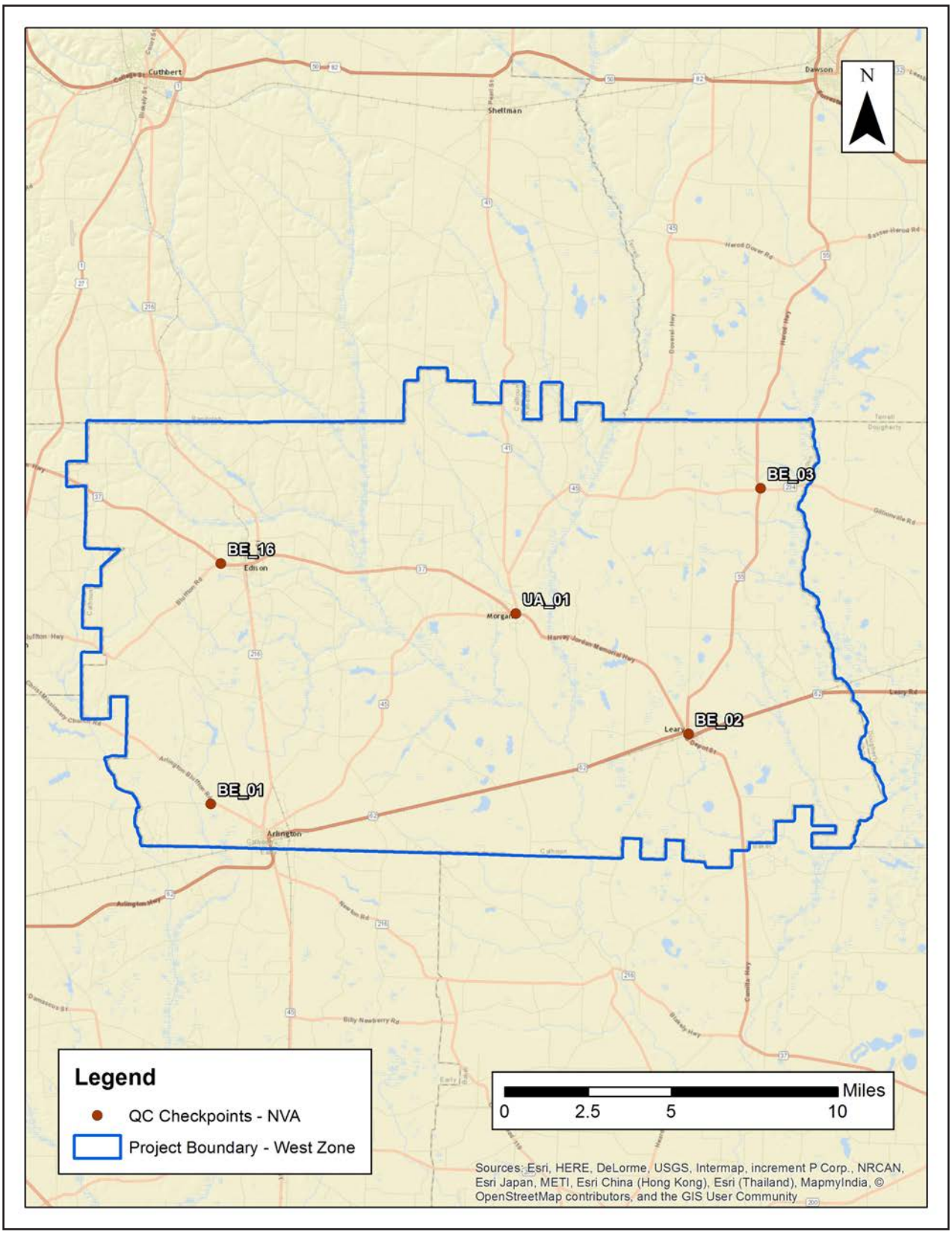


Table 10. QC Checkpoint Report - NVA - GA West Small AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_01	2113232.47	529270.65	232.18	232.07	-0.11
BE_02	2189023.35	540374.42	201.69	201.58	-0.11
BE_03	2200396.30	579281.98	232.85	232.85	0.00
BE_16	2114839.51	567346.39	302.78	302.77	-0.01
UA_01	2161618.11	559369.86	244.32	244.17	-0.15

Average Dz	-0.070 ft
Minimum Dz	-0.147 ft
Maximum Dz	0.004 ft
Root Mean Square	0.096 ft
95% Confidence Level	0.188 ft

Figure 18. QC Checkpoint Locations - NVA - GA West Large AOI (Early 2016)

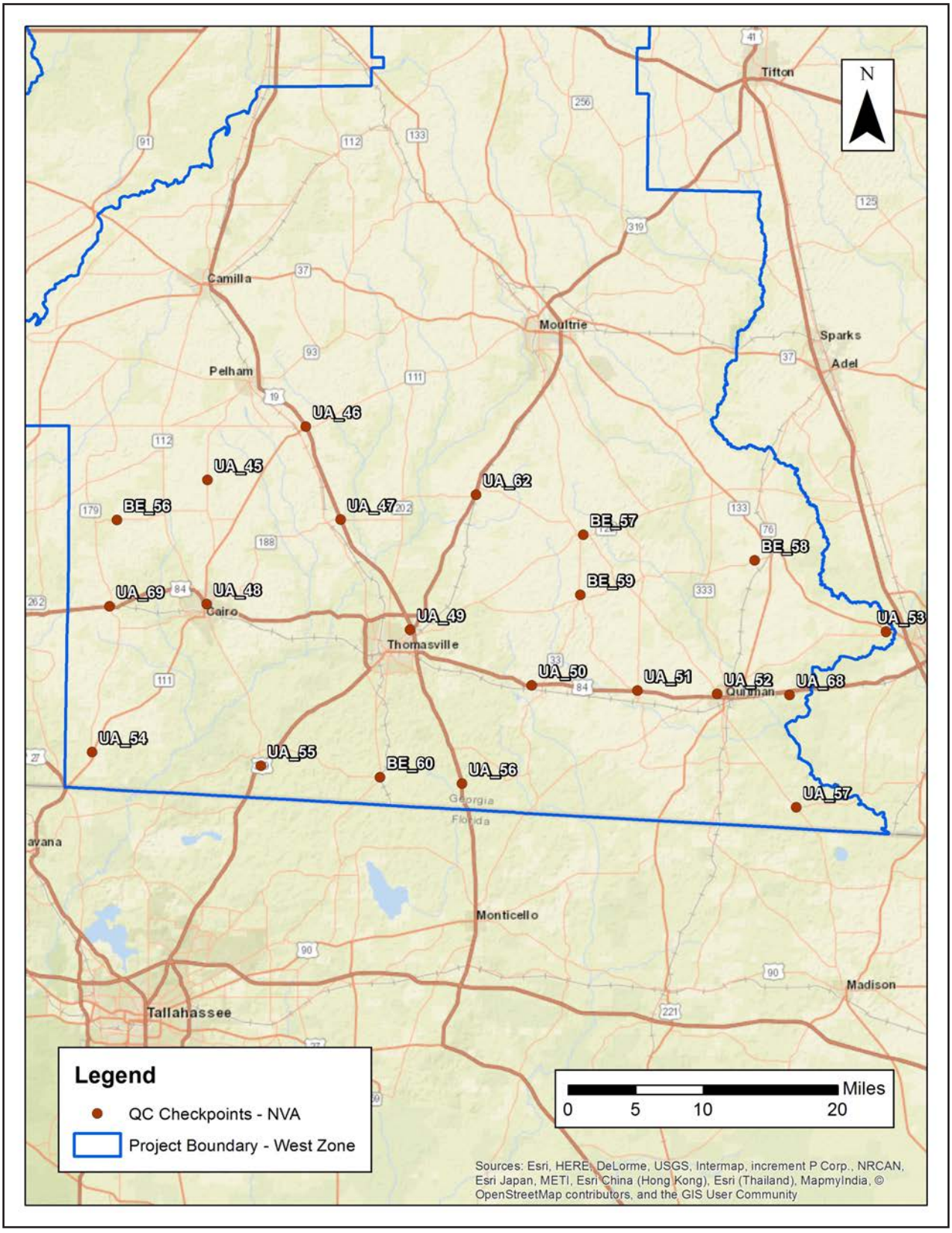


Table 11. QC Checkpoint Report - NVA - GA West Large AOI (Early 2016)

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_56	2249483.03	355197.34	284.52	284.59	0.07
BE_57	2431950.82	349403.63	249.56	249.53	-0.03
BE_58	2499104.84	339347.14	239.76	239.72	-0.04
BE_59	2430861.28	325946.01	262.11	262.19	0.08
BE_60	2352454.46	254595.86	183.28	183.13	-0.15
UA_45	2284793.85	370859.06	316.99	316.91	-0.08
UA_46	2323291.98	391783.74	304.59	304.60	0.01
UA_47	2336951.95	355307.37	237.32	237.43	0.11
UA_48	2284592.52	322296.01	260.99	260.66	-0.33
UA_49	2364208.21	312219.43	284.97	284.76	-0.21
UA_50	2411855.46	290657.64	182.94	182.94	0.00
UA_51	2453238.38	288614.31	197.52	197.46	-0.06
UA_52	2484468.47	287234.69	200.09	200.08	-0.01
UA_53	2550422.43	311566.28	142.55	142.82	0.27
UA_54	2239637.61	264436.18	263.45	263.46	0.01
UA_55	2305758.11	259025.26	266.91	266.96	0.05
UA_56	2384518.48	252097.29	188.75	188.83	0.08
UA_57	2515352.99	242740.49	203.78	203.71	-0.07
UA_62	2389971.55	365056.41	227.84	227.80	-0.04
UA_68	2512738.26	286873.89	188.52	188.43	-0.09
UA_69	2246444.22	321431.52	288.83	288.60	-0.24

Average Dz	-0.030 ft
Minimum Dz	-0.332 ft
Maximum Dz	0.266 ft
Root Mean Square	0.132 ft
95% Confidence Level	0.258 ft

Figure 19. QC Checkpoint Locations - NVA - GA East AOI

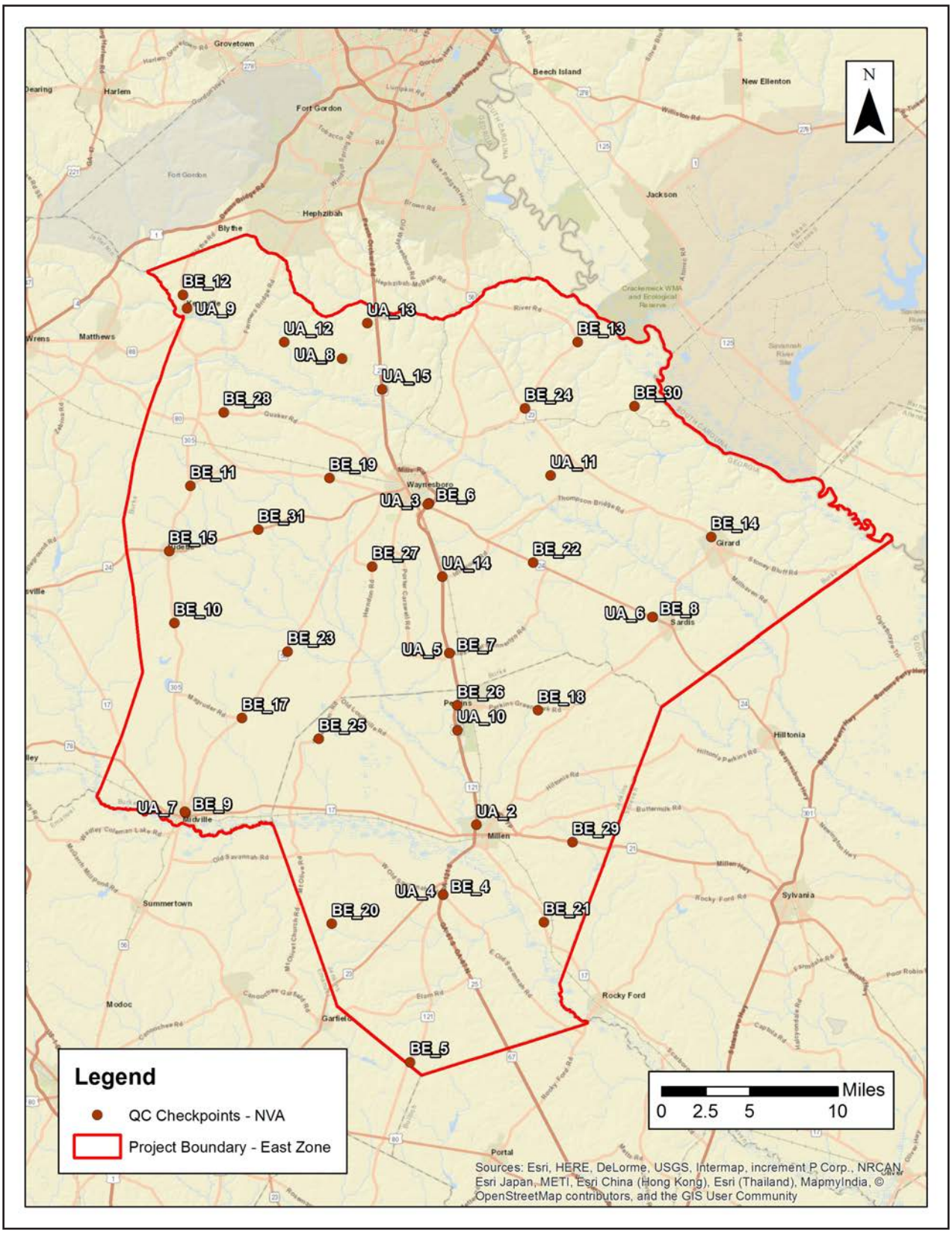


Table 12. QC Checkpoint Report - NVA - GA East AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE_4	713466.84	1001931.08	198.38	198.46	0.08
BE_5	703620.64	951799.00	341.85	341.85	0.00
BE_6	709196.25	1119152.01	282.73	282.50	-0.23
BE_7	715352.56	1074366.44	244.51	244.71	0.21
BE_8	776182.97	1085031.35	214.39	214.29	-0.10
BE_9	636335.33	1026554.81	212.55	212.62	0.07
BE_10	633012.29	1083283.39	341.29	341.14	-0.15
BE_11	637793.73	1124390.09	392.01	392.22	0.21
BE_12	635605.14	1181685.73	390.94	390.92	-0.02
BE_13	753751.01	1167507.15	227.04	227.10	0.06
BE_14	793820.85	1109031.40	232.85	232.89	0.04
BE_15	631413.93	1104815.04	349.48	349.40	-0.08
BE_17	653200.25	1054988.62	253.73	253.75	0.02
BE_18	741909.11	1057292.30	250.50	250.50	0.00
BE_19	679446.76	1126761.22	337.79	337.72	-0.07
BE_20	680177.54	993257.15	264.24	264.26	0.02
BE_21	743641.50	993766.03	224.78	224.69	-0.09
BE_22	740437.89	1101392.40	307.37	307.40	0.03
BE_23	666870.52	1074826.20	233.13	233.13	-0.01
BE_24	737975.24	1147610.25	285.58	285.42	-0.16
BE_25	676289.47	1048702.84	233.06	232.82	-0.24
BE_26	717674.10	1058715.61	235.04	235.35	0.31
BE_27	692226.67	1100206.11	292.28	292.39	0.11
BE_28	647779.54	1146449.44	367.65	367.68	0.03
BE_29	752247.40	1017762.29	243.01	243.10	0.09
BE_30	770767.57	1148267.40	303.66	303.79	0.13
BE_31	658129.67	1111283.10	329.19	329.13	-0.06
UA_2	723433.70	1022984.35	174.38	174.32	-0.06
UA_3	708956.67	1118863.14	280.37	280.17	-0.21
UA_4	713447.79	1001940.12	199.04	199.10	0.06
UA_5	715401.74	1074375.00	245.10	245.36	0.26
UA_6	776153.67	1085052.67	214.59	214.56	-0.03

Number	Easting	Northing	Known Z	Laser Z	Dz
UA_7	636135.17	1026905.49	213.04	213.17	0.13
UA_8	683231.18	1162546.16	314.87	314.85	-0.02
UA_9	636823.82	1177602.40	280.97	280.99	0.02
UA_10	717810.07	1051331.30	221.35	221.48	0.13
UA_11	745631.73	1127527.04	256.62	256.66	0.04
UA_12	665862.26	1167520.38	306.55	306.42	-0.13
UA_13	690782.82	1173162.86	244.80	244.72	-0.08
UA_14	713199.64	1097147.83	289.84	289.93	0.09
UA_15	695285.40	1153255.37	236.41	236.35	-0.06

Average Dz	0.020 ft
Minimum Dz	-0.240 ft
Maximum Dz	0.307 ft
Root Mean Square	0.122 ft
95% Confidence Level	0.239 ft

Figure 20. QC Checkpoint Locations - VVA - GA West Small AOI

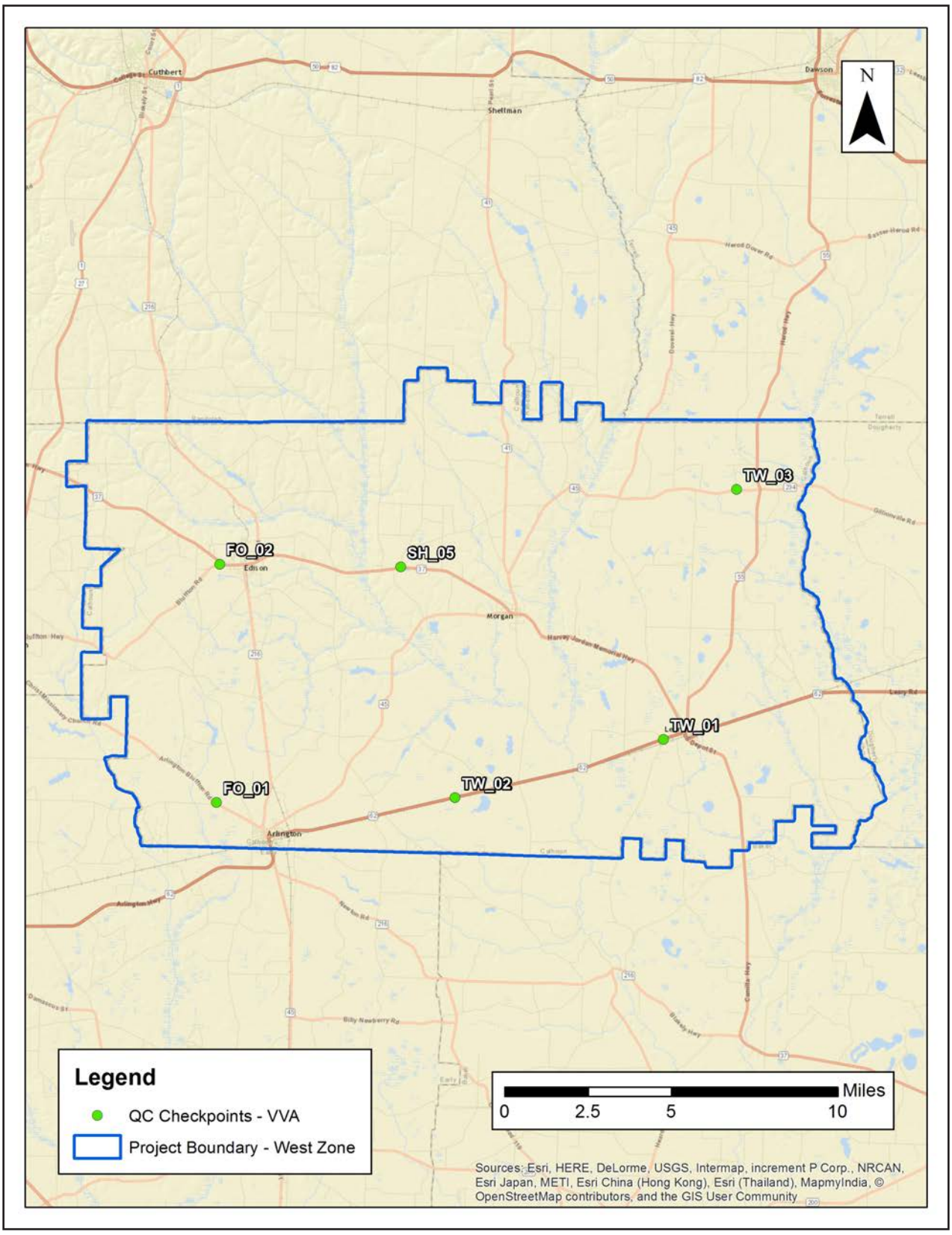


Table 13. QC Checkpoint Report - VVA - GA West Small AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
FO_01	2114149.02	529484.96	238.59	238.59	-0.01
FO_02	2114632.59	567233.20	300.69	300.76	0.07
SH_05	2143382.39	566775.06	283.29	283.43	0.14
TW_01	2184978.32	539501.55	211.95	211.92	-0.03
TW_02	2151937.17	530243.31	220.19	220.34	0.15
TW_03	2196569.24	579068.54	239.22	239.34	0.12
	Average Dz	0.090 ft			
	Minimum Dz	-0.026 ft			
	Maximum Dz	0.154 ft			
	Root Mean Square	0.102 ft			
	95th Percentile	0.151 ft			

Figure 21. QC Checkpoint Locations - VVA - GA West Large AOI (Early 2016)

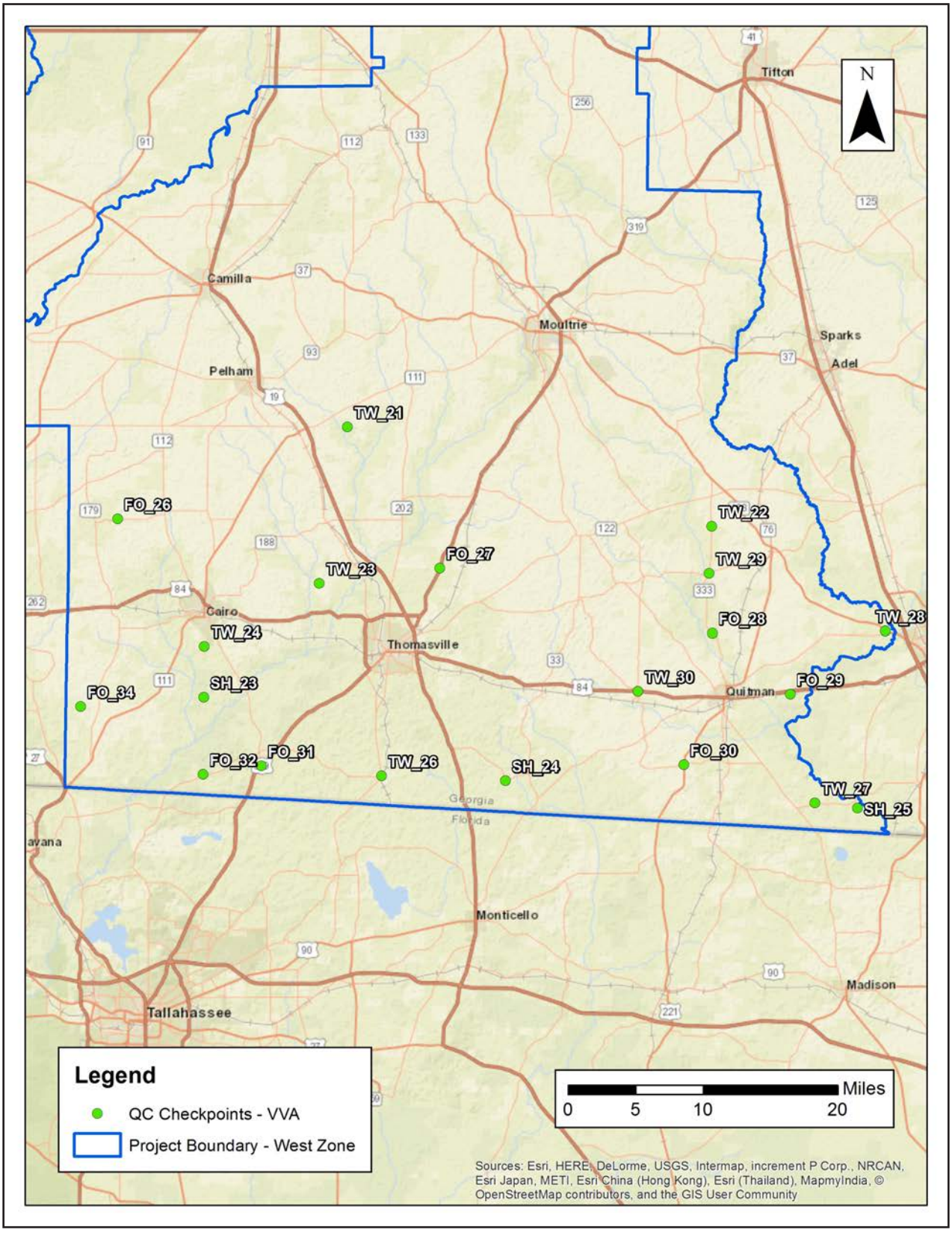


Table 14. QC Checkpoint Report - VVA - West Large AOI (Early 2016)

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
FO_26	2249652.58	355646.22	260.35	260.42	0.07
FO_27	2375729.85	336322.56	203.77	203.72	-0.05
FO_28	2482460.59	310986.67	186.09	186.09	-0.01
FO_29	2512956.88	287123.12	183.83	183.78	-0.05
FO_30	2471265.73	259461.13	135.90	136.32	0.42
FO_31	2305922.27	259036.90	264.64	264.66	0.02
FO_32	2283178.91	255779.89	210.23	210.37	0.14
FO_34	2235174.97	282366.50	269.20	269.56	0.36
SH_23	2283444.97	285952.82	217.86	218.32	0.46
SH_24	2401515.11	253241.36	189.82	190.03	0.21
SH_25	2539294.86	242526.06	92.16	92.51	0.35
TW_21	2339562.86	391710.52	281.92	281.68	-0.24
TW_22	2482164.42	352788.81	209.89	210.26	0.37
TW_23	2328613.36	330418.87	217.69	217.83	0.14
TW_24	2283616.19	305768.87	205.16	205.34	0.18
TW_26	2352909.62	255214.02	172.68	172.80	0.12
TW_27	2522545.34	244481.74	206.47	206.68	0.21
TW_28	2550180.12	311783.37	143.26	143.45	0.19
TW_29	2481219.33	334257.44	199.28	199.36	0.08
TW_30	2453255.94	288278.45	195.06	195.19	0.13

Average Dz	0.140 ft
Minimum Dz	-0.237 ft
Maximum Dz	0.456 ft
Root Mean Square	0.231 ft
95th Percentile	0.389 ft

Figure 22. QC Checkpoint Locations - VVA - GA East AOI

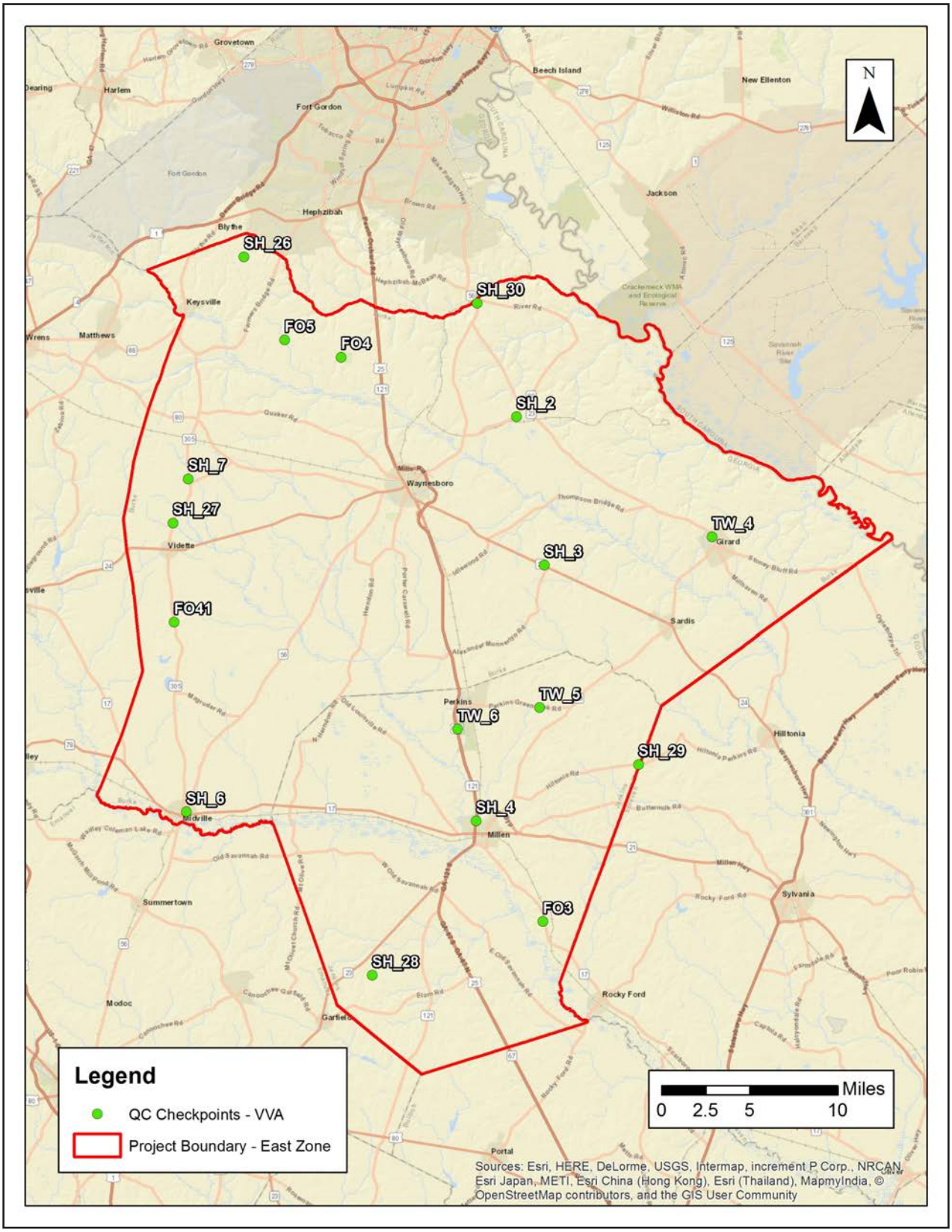


Table 15. QC Checkpoint Report - VVA - GA East AOI

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
FO3	743294.45	993609.72	218.12	218.19	0.07
FO4	682951.20	1162559.71	313.45	313.48	0.03
FO5	666032.38	1167728.53	306.37	306.20	-0.17
FO41	632855.44	1083139.93	348.67	348.39	-0.28
SH_2	735486.20	1144758.26	308.82	309.12	0.30
SH_3	743741.84	1100258.95	285.86	286.28	0.42
SH_4	723345.07	1023801.19	171.36	171.48	0.12
SH_6	636596.24	1026496.74	210.58	210.32	-0.26
SH_7	637167.75	1126132.42	371.79	372.28	0.49
SH_26	653848.35	1192667.13	431.06	431.26	0.20
SH_27	632558.85	1112896.38	334.38	334.41	0.03
SH_28	692208.56	977506.70	250.23	250.30	0.07
SH_29	771993.93	1040685.81	285.78	286.06	0.28
SH_30	723683.78	1178798.11	134.88	135.20	0.32
TW_4	793964.64	1108753.88	226.76	226.87	0.11
TW_5	742368.49	1057741.55	248.16	248.36	0.20
TW_6	717765.37	1051291.01	220.86	221.11	0.25

Average Dz	0.130 ft
Minimum Dz	-0.275 ft
Maximum Dz	0.490 ft
Root Mean Square	0.248 ft
95th Percentile	0.309