Pike and Scott Counties, IL
2015 LiDAR Project Report

USGS Contract # G10PC0026
Requisition # 0040242353
Task Order # G15PD01036

Submitted: July 27, 2016

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Pike and Scott Counties, IL 2015 LiDAR acquisition task order, issued by USGS National Geospatial Technical Operations Center (NGTOC) under their Geospatial Product and Services Contract on September 9, 2015. The task order yielded a project area covering approximately 1,100 square miles over Pike and Scott Counties, Illinois. The intent of this document is only to provide specific validation information for the data acquisition/ collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic LiDAR was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned LiDAR Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
≥ 4 pts / m^2	1,875 m	37°	30%	≤ 10 cm

1.3. Coverage

The LiDAR project boundary covers approximately 1,100 square miles and encompasses the entirety of Pike and Scott Counties in western Illinois. A 100-meter buffer was created for the area to meet task order specifications. LiDAR extents are shown in Figure 1 on the following page.

1.4. Duration

LiDAR data was acquired from November 22, 2015 to December 3, 2015 in ten total lifts. See "Section: 2.5. Time Period" for more details.

1.5. Issues

There were no issues to report with this project.

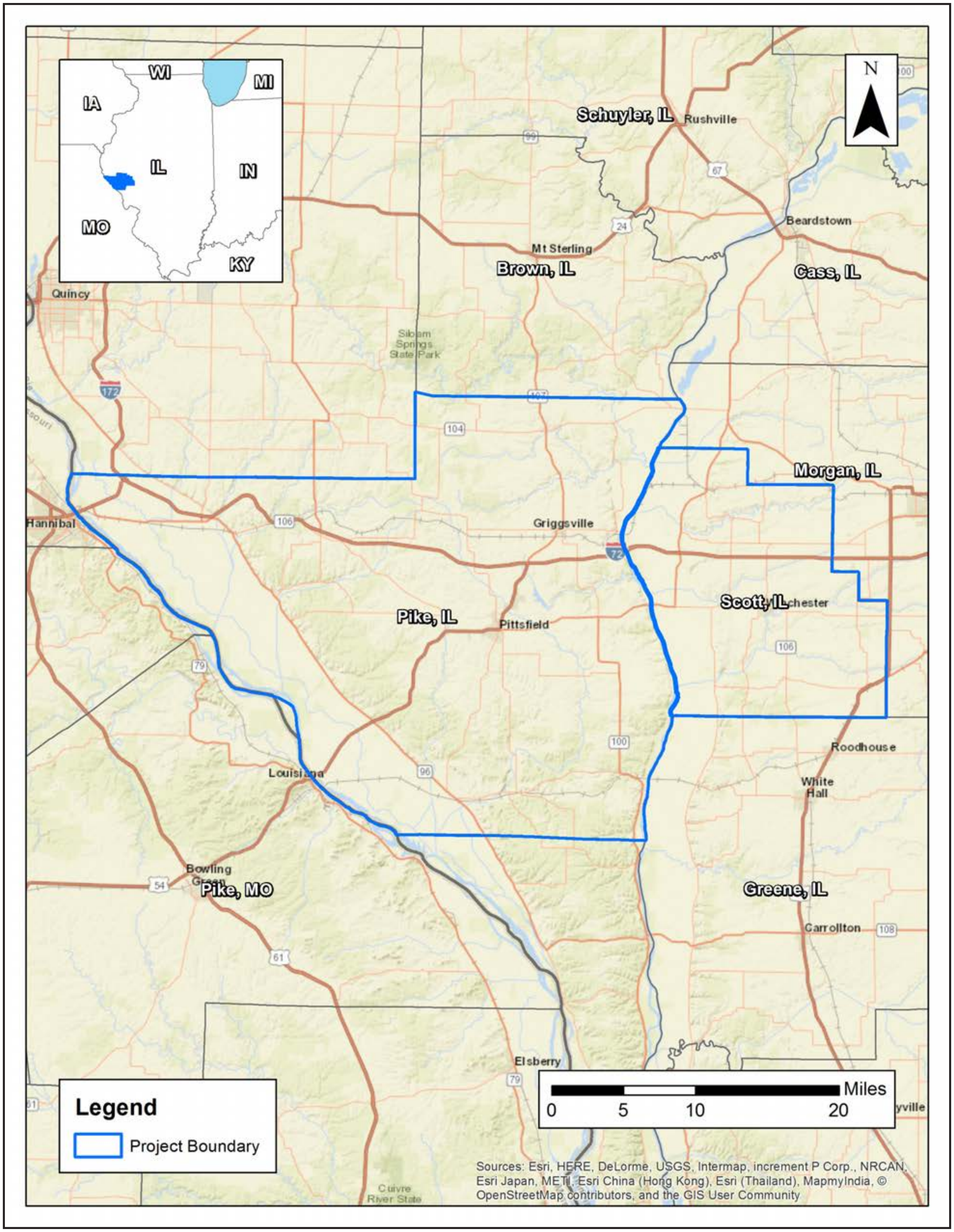
1.6. Deliverables

The following products were produced and delivered:

- Raw point cloud data, swaths, in LAS 1.4 format
- Classified LiDAR data, tiled, in LAS 1.4 format
- 2-foot hydro-flattened bare-earth raster DEM, tiled, in ERDAS .IMG format
- Hydro-flattened breaklines in Esri shapefile format
- 2-foot intensity images, in GeoTIFF format
- 2-foot hydro-flattened bare-earth raster DEM , mosaicked, in Esri Grid format
- Processing boundary, in Esri shapefile format
- Tile index in Esri shapefile format
- Calibration control and QC checkpoints, in Esri shapefile format
- Accuracy Assessment, in .XLS format
- Project-, deliverable-, and lift-level metadata in .XML format

All spatial deliverables were delivered in NAD83 (2011), State Plane Illinois West, US survey feet; NAVD88 (Geoid 12B), US survey feet. Tiled deliverables have a size of 2,000 feet x 2,000 feet and follow the US National Grid naming conventions.

Figure 1. Project Boundary



2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using Optech MissionNAV planning software. The entire target area was comprised of 75 planned flight lines measuring approximately 2,387.75 total flight line miles (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized two Optech Orion H300 LiDAR sensors (Figure 3), serial numbers 324 and 329, 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 2. Planned LiDAR Flight Lines

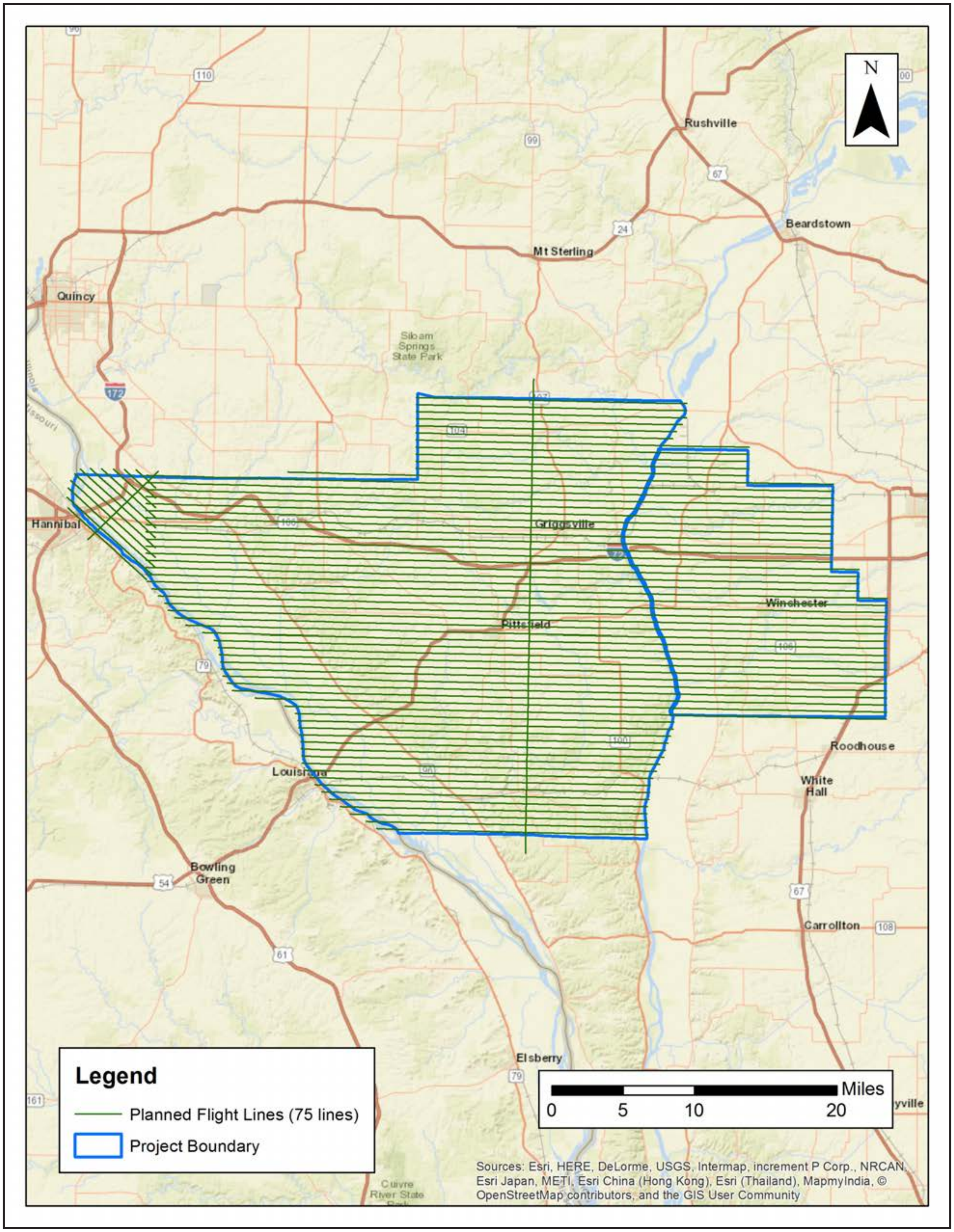


Table 2. Lidar System Specifications

Terrain and Aircraft Scanner	Flying Height	1,400 m
	Recommended Ground Speed	130 kts
Scanner	Field of View	29°
	Scan Rate Setting Used	68.0 Hz
Laser	Laser Pulse Rate Used	275 kHz
	Multi Pulse in Air Mode	Enabled
Coverage	Full Swath Width	724.13 m
	Line Spacing	800 m
Point Spacing and Density	Maximum Point Spacing Along Track	0.4917 m
	Maximum Point Spacing Along Track	0.4814 m
	Average Point Density	4.22 pts / m^2

Figure 3. Optech Orion H300 LiDAR Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of the customized planes listed below:

- Piper Navajo (twin-piston), Tail Number N73TM
- Partenavie P68-C (fixed wing multi-engine), Tail Number N300LF

These aircraft provided an ideal, stable aerial base for LiDAR acquisition. They have relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Optech LiDAR system.

Figure 4. Some of Quantum Spatial's Planes

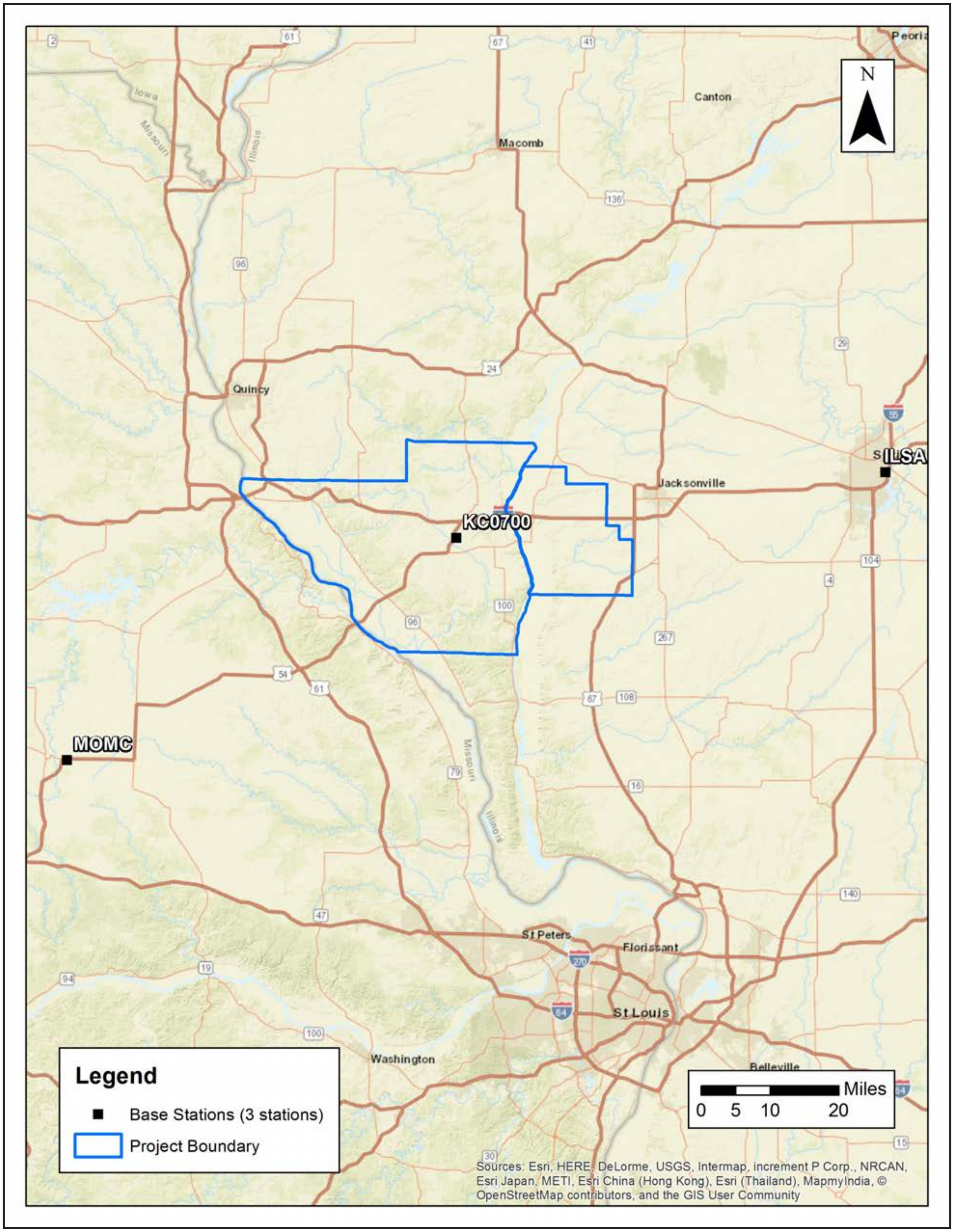
2.4. Base Station Information

GPS base stations were utilized during all phases of flight (Table 3). The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations are depicted in Figure 5. Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A.

Table 3. Base Station Locations

Base Station	Latitude	Longitude	Ellipsoid Height (m)
KC0700	39° 38′ 22.59808″	90° 46′ 47.95911″	180.712
ILSA	39° 46′ 43.0602″	89° 36′ 37.08186″	154.03
MOMC	39° 9′ 42.50085″	91° 49′ 45.93338″	217.988

Figure 5. Base Station Locations



2.5. Time Period

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

- Nov 22, 2015-A (N73TM, SN324)
- Nov 22, 2015-A (N300LF, SN329)
- Nov 23, 2015-A (N73TM, SN324)
- Nov 23, 2015-A (N300LF, SN329)
- Nov 23, 2015-B (N73TM, SN324)
- Nov 23, 2015-B (N300LF, SN329)
- Nov 24, 2015-A (N73TM, SN324)
- Nov 24, 2015-A (N300LF, SN329)
- Nov 24, 2015-B (N73TM, SN324)
- Dec 3, 2015-A (N300LF, SN329)

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 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 – Points above ground (0 - 5 feet)
- Class 4 – Medium Vegetation – Points above ground (5 - 20 feet)
- Class 5 – High Vegetation – Points above ground (> 20 feet)
- Class 6 – Man-made structures – Points falling on buildings, structures inside of water bodies, docks, piers.
- 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 bridge decks were classified to Class 17.

Upon completion of the bare earth clean-up, automated classification was completed on the dataset to complete final requested classification of the dataset. These classes include: Class 3 – Low vegetation (any default points found within 0.5 – 5' of the final bare earth surface); Class 4 – Medium vegetation (any default points found within 5 – 20' of the final bare earth surface); Class 5 – High vegetation (any default points found above 20' of the final bare earth surface); Class 6 – Man-made features (any default points that meet the criteria for a building, structure inside of a water feature, etc.)

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 was 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 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 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 shapefile format using Esri conversion tools.

3.6. Hydro-Flattened Bare-Earth Raster DEM Creation

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

3.7. Intensity Image Creation

GeoCue software was used to create the deliverable Intensity Images with a 2-foot cell size. 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.

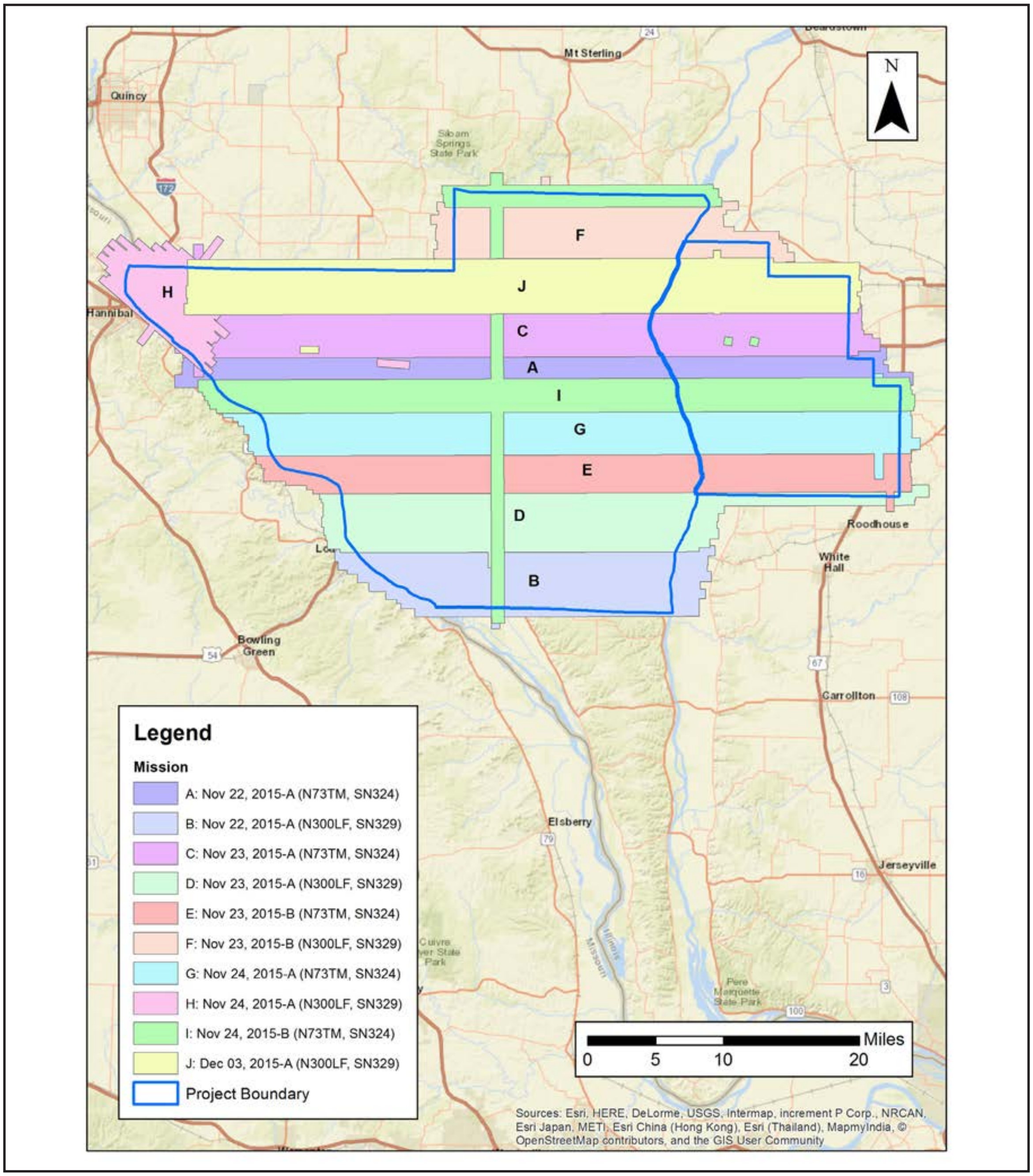
3.8. Hydro-Flattened Bare-Earth Raster Mosaic Creation

After final surface acceptance, a mosaic of the 2-foot bare-earth raster DEM files was created using automated scripting routines within ArcMap, an Esri Grid format mosaic was created. The surface was reviewed for completeness to ensure all tiles were included in the mosaic.

4. Project Coverage Verification

Coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 6.

Figure 6. Flightline Swath LAS File Coverage



5. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of 42 ground control (calibration) points along with 105 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 147 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.

In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in NAD83 (2011) State Plane Illinois West, US survey feet; NAVD88 (Geoid 12B), US survey feet.

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. Calibration Control Point Testing

Figure 7 shows the location of each bare earth calibration point for the project area. Table 4 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

Raw Nonvegetated Vertical Accuracy (Raw NVA): The tested Raw NVA for the dataset was found to be 0.039 m (0.126 ft) in terms of the $RMSE_z$. The resulting NVA stated as the 95% confidence level ($RMSE_z \times 1.96$) is 0.076 m (0.248 ft). This dataset meets the required NVA of ≤ 0.196 m (0.643 ft) 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 8 and Table 5.

5.3. Digital Elevation Model (DEM) Testing

The tested Non-Vegetated Vertical Accuracy (NVA) for the dataset captured from the DEM using bi-linear interpolation to derive the DEM elevations was found to be 0.039 m (0.128 ft) in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.077 m (0.252 ft). This dataset meets the required NVA of ≤ 0.196 m (0.643 ft) at the 95% confidence level (based on NSSDA). See Figure 9 and Table 6.

The tested Vegetated Vertical Accuracy (VVA) for the dataset captured from the DEM using bi-linear interpolation for all classes (including the bare earth class) was found to be 0.144 m (0.474 ft), which is stated in terms of the 95th percentile error. Therefore the data meets the required VVA of ≤ 0.294 m (0.965 ft). This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories. See Figure 10 and Table 7.

Figure 7. Calibration Control Point Locations

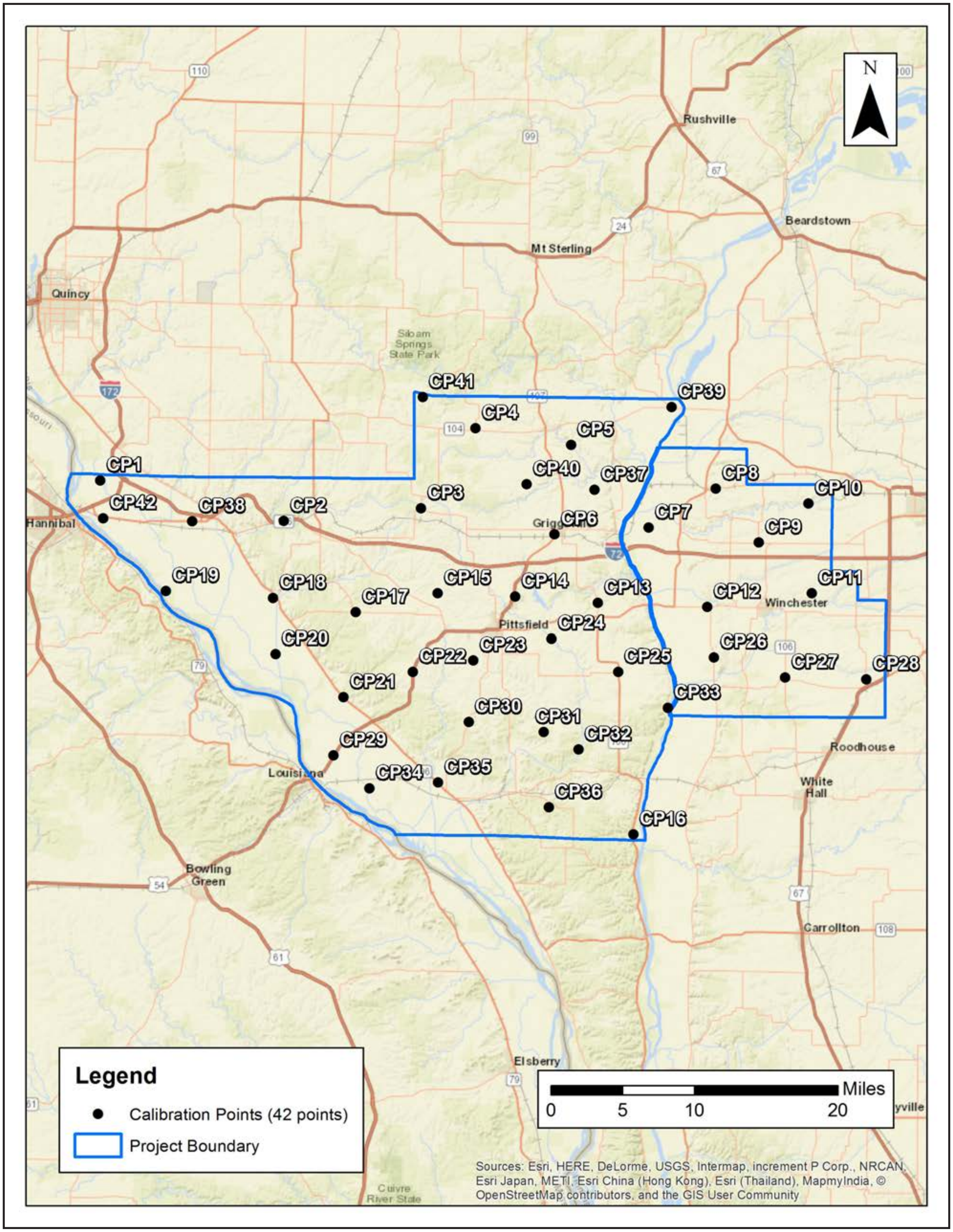


Table 4. Calibration Control Point Report

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
CP1	1970094.82	1125871.25	462.54	462.62	0.08
CP2	2037660.67	1111069.62	560.17	560.10	-0.07
CP3	2088092.15	1115684.10	870.95	870.94	-0.01
CP4	2108204.62	1145113.27	646.31	646.45	0.14
CP5	2143268.99	1139056.31	471.75	471.73	-0.02
CP6	2137186.78	1106150.08	683.30	683.48	0.18
CP7	2171841.77	1108586.08	429.91	430.13	0.22
CP8	2196532.46	1122980.16	492.35	492.22	-0.13
CP9	2212343.59	1103084.98	577.09	577.09	0.00
CP10	2230648.37	1117507.10	566.86	566.80	-0.06
CP11	2231842.02	1084463.94	584.93	584.86	-0.07
CP12	2193430.45	1079438.41	449.18	449.43	0.25
CP13	2153167.35	1080942.77	634.49	634.61	0.12
CP14	2122706.96	1083253.94	704.15	704.33	0.18
CP15	2094239.66	1084483.79	805.15	805.25	0.10
CP16	2166189.27	995995.72	438.61	438.47	-0.14
CP17	2064137.51	1077446.32	737.02	736.90	-0.12
CP18	2033647.85	1082730.97	468.12	468.22	0.10
CP19	1994302.07	1085253.13	463.53	463.54	0.01
CP20	2034578.55	1062214.63	454.39	454.72	0.33
CP21	2059576.81	1046435.75	482.21	482.31	0.10
CP22	2085117.32	1055729.59	797.97	797.92	-0.05
CP23	2107365.52	1059906.85	769.27	769.29	0.02
CP24	2136124.91	1067868.64	666.10	666.21	0.11
CP25	2160602.84	1055672.31	670.20	670.16	-0.04
CP26	2195872.72	1060943.25	495.44	495.58	0.14
CP27	2222009.56	1053644.12	632.98	632.90	-0.08
CP28	2251923.01	1052984.23	690.41	690.60	0.19
CP29	2055941.54	1025032.58	447.51	447.41	-0.10
CP30	2105642.30	1037234.05	711.59	711.44	-0.15
CP31	2133274.68	1033631.66	712.34	712.22	-0.12
CP32	2146020.54	1027182.52	533.91	533.59	-0.32

Number	Easting	Northing	Known Z	Laser Z	Dz
CP33	2178889.14	1042471.48	431.77	431.91	0.14
CP34	2069126.93	1012836.27	446.89	446.65	-0.24
CP35	2094372.80	1014976.17	455.77	455.86	0.09
CP36	2135079.91	1005958.52	555.29	555.04	-0.25
CP37	2151919.51	1122469.68	586.36	586.35	-0.01
CP38	2004006.25	1110972.66	468.23	468.11	-0.12
CP39	2180335.65	1152913.89	431.10	431.01	-0.09
CP40	2127024.71	1124495.98	594.58	594.58	0.00
CP41	2088720.84	1156628.06	753.49	753.43	-0.06
CP42	1971200.38	1111941.28	460.24	460.28	0.04

Average Dz	0.01 ft
Minimum Dz	-0.320 ft
Maximum Dz	0.330 ft
Root Mean Square	0.140 ft
Std. Deviation	0.142 ft

Figure 8. QC Checkpoint Locations - Raw NVA

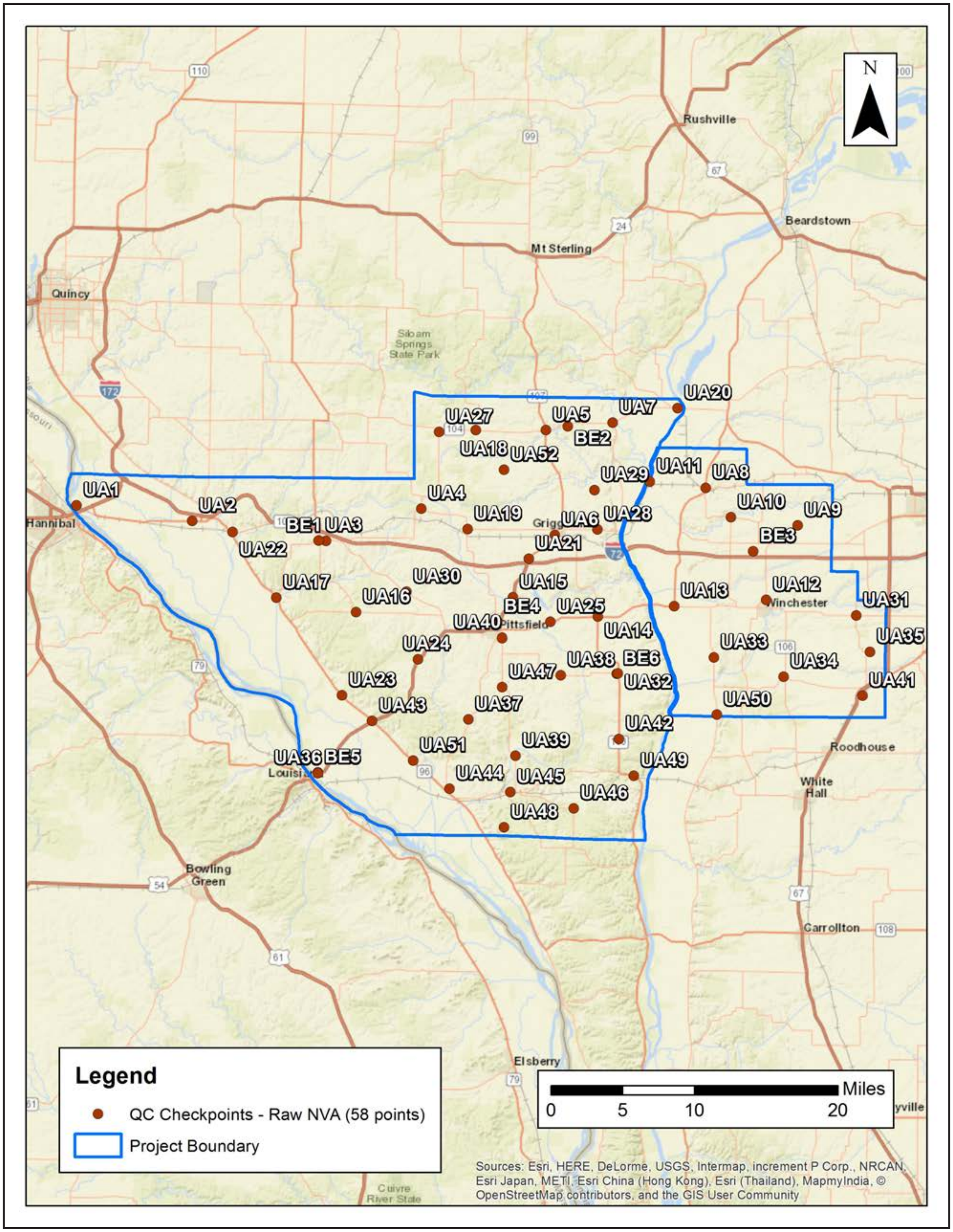


Table 5. QC Checkpoint Report - Raw NVA

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE1	2053231.53	1103622.71	746.62	746.7	0.08
BE2	2142068.02	1145792.59	569.19	569.22	0.03
BE3	2210351.61	1099812.75	561.79	561.76	-0.03
BE4	2116148.23	1073965.91	703.22	703.2	-0.02
BE5	2050194.79	1018721.78	462.04	461.92	-0.12
BE6	2160123.17	1055000.78	651.05	650.99	-0.06
UA1	1961430.31	1116716.93	475.83	475.86	0.03
UA2	2003967.19	1111011.11	468.28	468.1	-0.18
UA3	2050415.66	1103765.89	728.41	728.31	-0.1
UA4	2088189.03	1115587.98	872.39	872.27	-0.12
UA5	2134013.88	1144515.54	497.12	497.27	0.15
UA6	2137330.56	1105909.28	685.45	685.51	0.06
UA7	2158561.36	1147183.02	483.53	483.44	-0.09
UA8	2192848.32	1123215.95	469.95	469.87	-0.08
UA9	2226692.08	1109465.26	595.14	595.31	0.17
UA10	2202049.09	1112462.93	494.87	494.8	-0.07
UA11	2172304.6	1125565.57	436.61	436.59	-0.02
UA12	2215045.85	1082036.18	552.47	552.55	0.08
UA13	2181221.95	1079645.13	432.93	433.03	0.1
UA14	2153113.98	1075842.54	639.31	639.5	0.19
UA15	2121930.13	1082934.61	676.21	676.35	0.14
UA16	2064169.93	1077490.14	737.78	737.66	-0.12
UA17	2034846.62	1082789.12	475.77	475.74	-0.03
UA18	2108245.66	1144427.19	634.66	634.66	0
UA19	2105225.9	1108093.37	785.62	785.64	0.02
UA20	2182473.24	1152536.97	429.51	429.48	-0.03
UA21	2127720.97	1097112.46	686.83	686.62	-0.21
UA22	2018772.73	1106969.16	482	481.97	-0.03
UA23	2059048.52	1047037.93	488.06	488.05	-0.01
UA24	2087042.67	1060333.64	787.02	786.98	-0.04
UA25	2135722.12	1073889.22	623.58	623.61	0.03
UA26	2133884.86	1135386.03	592.35	592.28	-0.07

Number	Easting	Northing	Known Z	Laser Z	Dz
UA27	2094761.01	1143837.45	754.96	754.89	-0.07
UA28	2152963.94	1107967.73	639.4	639.39	-0.01
UA29	2151972.43	1122427.01	587.04	586.85	-0.19
UA30	2082746.03	1084961.66	681.61	681.63	0.02
UA31	2248210.56	1076290.16	615.34	615.28	-0.06
UA32	2160554.18	1055172.48	653.34	653.16	-0.18
UA33	2195837.47	1060977.19	495.11	495.37	0.26
UA34	2221455.66	1053933.27	629.64	629.55	-0.09
UA35	2253196.17	1063095.09	655.01	655.06	0.05
UA36	2050182.11	1018422.4	461.89	461.73	-0.16
UA37	2105593.86	1038189.65	719.25	719.12	-0.13
UA38	2139544	1054420.36	692.48	692.41	-0.07
UA39	2122887.8	1024816.65	516.51	516.32	-0.19
UA40	2117991.54	1068127.29	724.15	724.14	-0.01
UA41	2250465.76	1046944.94	681.95	681.86	-0.09
UA42	2160936	1030960.15	652.51	652.28	-0.23
UA43	2070145.7	1037631.71	485.91	485.89	-0.02
UA44	2098528.41	1012689.86	544.73	544.44	-0.29
UA45	2120928.36	1011450.74	482.73	482.46	-0.27
UA46	2144225.35	1005466.75	682.58	682.33	-0.25
UA47	2118012.62	1050039.9	669.73	669.64	-0.09
UA48	2118646.19	998580.52	738.76	738.49	-0.27
UA49	2166386.54	1017447.25	441.07	441	-0.07
UA50	2196901.72	1039998.87	463.09	463.03	-0.06
UA51	2085280.58	1023032.61	505.07	505.08	0.01
UA52	2118683.03	1129848.48	620.25	620.12	-0.13

Average Dz	-0.05 ft
Minimum Dz	-0.290 ft
Maximum Dz	0.260 ft
Root Mean Square	0.126 ft
95% Confidence Level	0.248 ft

Figure 9. QC Checkpoint Locations - NVA

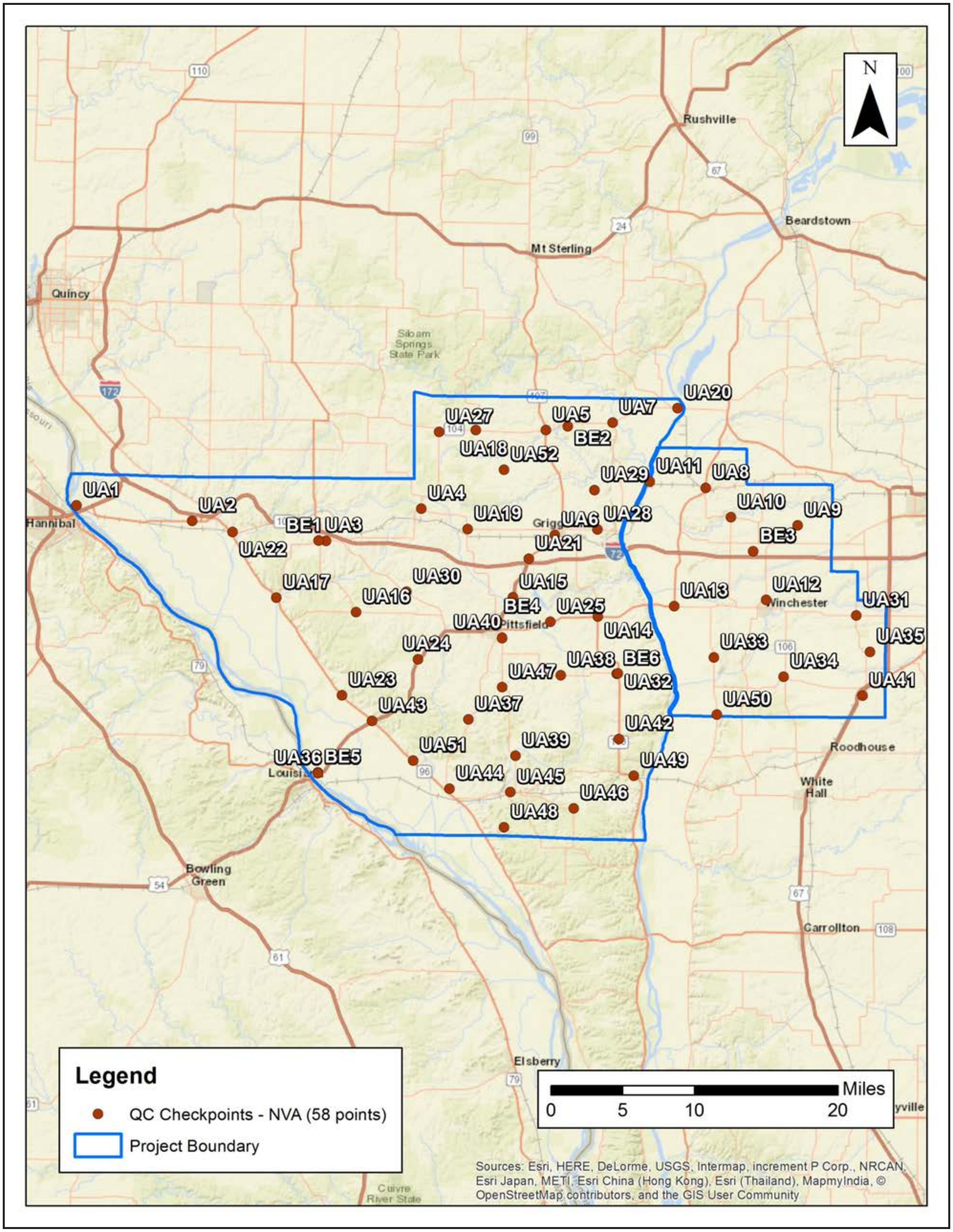


Table 6. QC Checkpoint Report - NVA

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE1	2053231.53	1103622.71	746.62	746.7	0.08
BE2	2142068.02	1145792.59	569.19	569.29	0.1
BE3	2210351.61	1099812.75	561.79	561.75	-0.04
BE4	2116148.23	1073965.91	703.22	703.2	-0.02
BE5	2050194.79	1018721.78	462.04	461.93	-0.11
BE6	2160123.17	1055000.78	651.05	650.99	-0.06
UA1	1961430.31	1116716.93	475.83	475.84	0.01
UA2	2003967.19	1111011.11	468.28	468.09	-0.19
UA3	2050415.66	1103765.89	728.41	728.3	-0.11
UA4	2088189.03	1115587.98	872.39	872.26	-0.13
UA5	2134013.88	1144515.54	497.12	497.13	0.01
UA6	2137330.56	1105909.28	685.45	685.57	0.12
UA7	2158561.36	1147183.02	483.53	483.48	-0.05
UA8	2192848.32	1123215.95	469.95	469.88	-0.07
UA9	2226692.08	1109465.26	595.14	595.27	0.13
UA10	2202049.09	1112462.93	494.87	494.74	-0.13
UA11	2172304.6	1125565.57	436.61	436.58	-0.03
UA12	2215045.85	1082036.18	552.47	552.58	0.11
UA13	2181221.95	1079645.13	432.93	433.02	0.09
UA14	2153113.98	1075842.54	639.31	639.48	0.17
UA15	2121930.13	1082934.61	676.21	676.34	0.13
UA16	2064169.93	1077490.14	737.78	737.65	-0.13
UA17	2034846.62	1082789.12	475.77	475.74	-0.03
UA18	2108245.66	1144427.19	634.66	634.65	-0.01
UA19	2105225.9	1108093.37	785.62	785.67	0.05
UA20	2182473.24	1152536.97	429.51	429.47	-0.04
UA21	2127720.97	1097112.46	686.83	686.61	-0.22
UA22	2018772.73	1106969.16	482	481.94	-0.06
UA23	2059048.52	1047037.93	488.06	488.09	0.03
UA24	2087042.67	1060333.64	787.02	786.99	-0.03
UA25	2135722.12	1073889.22	623.58	623.54	-0.04
UA26	2133884.86	1135386.03	592.35	592.27	-0.08

Number	Easting	Northing	Known Z	Laser Z	Dz
UA27	2094761.01	1143837.45	754.96	754.89	-0.07
UA28	2152963.94	1107967.73	639.4	639.41	0.01
UA29	2151972.43	1122427.01	587.04	586.86	-0.18
UA30	2082746.03	1084961.66	681.61	681.63	0.02
UA31	2248210.56	1076290.16	615.34	615.3	-0.04
UA32	2160554.18	1055172.48	653.34	653.16	-0.18
UA33	2195837.47	1060977.19	495.11	495.37	0.26
UA34	2221455.66	1053933.27	629.64	629.56	-0.08
UA35	2253196.17	1063095.09	655.01	655.06	0.05
UA36	2050182.11	1018422.4	461.89	461.7	-0.19
UA37	2105593.86	1038189.65	719.25	719.12	-0.13
UA38	2139544	1054420.36	692.48	692.42	-0.06
UA39	2122887.8	1024816.65	516.51	516.3	-0.21
UA40	2117991.54	1068127.29	724.15	724.12	-0.03
UA41	2250465.76	1046944.94	681.95	681.85	-0.1
UA42	2160936	1030960.15	652.51	652.25	-0.26
UA43	2070145.7	1037631.71	485.91	485.87	-0.04
UA44	2098528.41	1012689.86	544.73	544.47	-0.26
UA45	2120928.36	1011450.74	482.73	482.47	-0.26
UA46	2144225.35	1005466.75	682.58	682.32	-0.26
UA47	2118012.62	1050039.9	669.73	669.62	-0.11
UA48	2118646.19	998580.52	738.76	738.48	-0.28
UA49	2166386.54	1017447.25	441.07	441	-0.07
UA50	2196901.72	1039998.87	463.09	463.02	-0.07
UA51	2085280.58	1023032.61	505.07	505.03	-0.04
UA52	2118683.03	1129848.48	620.25	620.12	-0.13

Average Dz	-0.06 ft
Minimum Dz	-0.280 ft
Maximum Dz	0.260 ft
Root Mean Square	0.128 ft
95% Confidence Level	0.252 ft

Figure 10. QC Checkpoint Locations - VVA

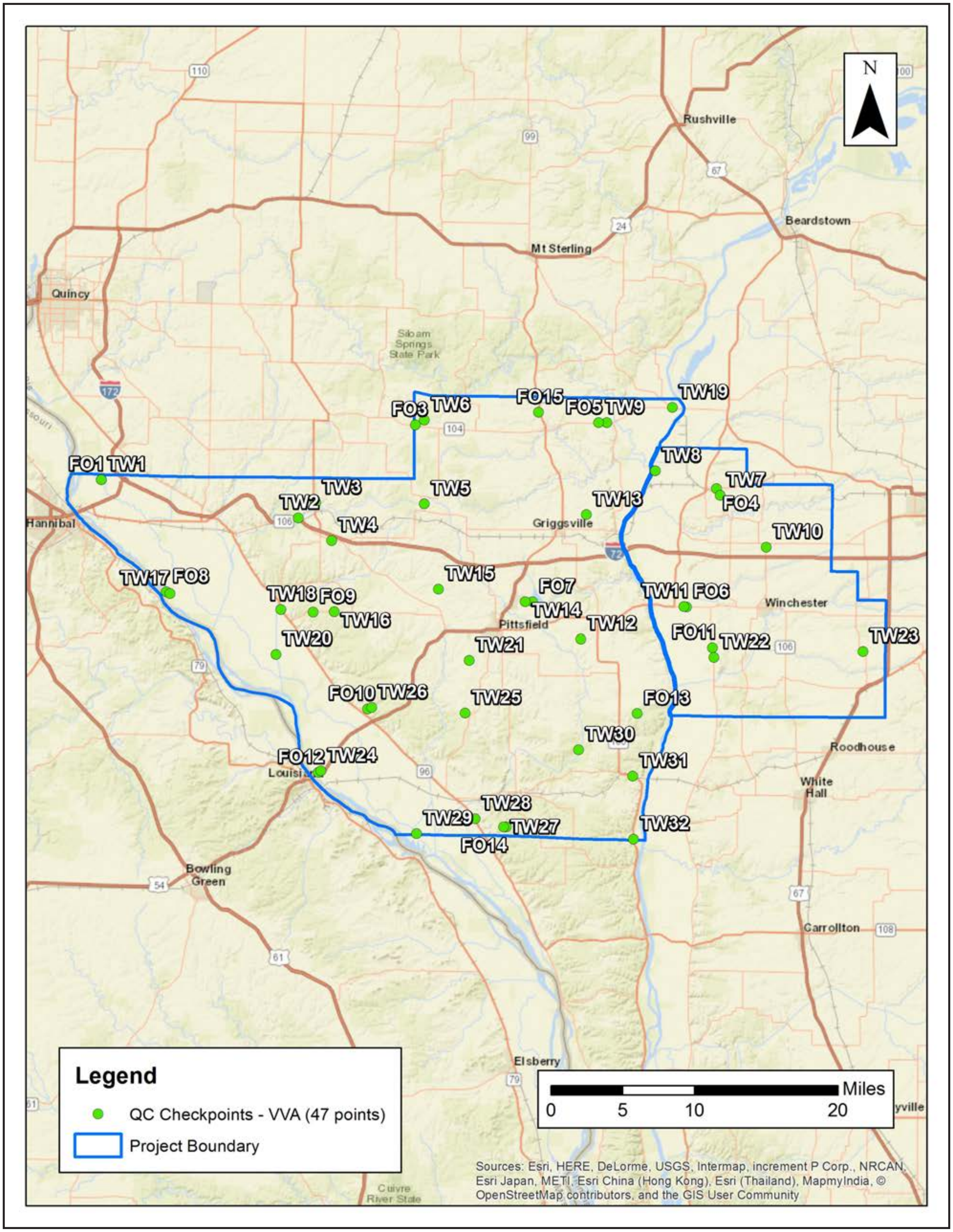


Table 7. QC Checkpoint Report - VVA

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
FO1	1970515.03	1126201.43	455.14	455	-0.14
FO2	2049174.06	1117610.62	567.69	567.69	0
FO3	2086059.74	1146313.36	645.03	644.99	-0.04
FO4	2196723.97	1122889.99	479.81	479.88	0.07
FO5	2156374.86	1147161.94	575.07	575.04	-0.03
FO6	2185721.74	1079407.5	433.2	433.39	0.19
FO7	2129167.35	1081264.85	620.55	620.56	0.01
FO8	1994411.33	1084970.59	463.38	463.78	0.4
FO9	2048397.6	1077559.29	716.64	716.33	-0.31
FO10	2068386.44	1042087.15	503.67	503.71	0.04
FO11	2195268.2	1064530.84	461.5	461.54	0.04
FO12	2050361.86	1018752.66	455.18	455.14	-0.04
FO13	2167607.29	1040389.74	691.1	691.03	-0.07
FO14	2119435.77	998662.58	742.86	742.64	-0.22
FO15	2131299.88	1150996.11	531.06	531.2	0.14
TW1	1970460.35	1126190.7	458.49	458.54	0.05
TW2	2043009.9	1112122.01	551.41	551.58	0.17
TW3	2049346.99	1117667.37	569.56	569.68	0.12
TW4	2055243.71	1103789.09	725.16	725.93	0.77
TW5	2089280.07	1117370.93	827	827.3	0.3
TW6	2089276.7	1148212.4	755.56	755.69	0.13
TW7	2198094.79	1120461.68	502.25	502.38	0.13
TW8	2174259.74	1129507.41	438.77	438.98	0.21
TW9	2153396.08	1147178.58	587.56	587.64	0.08
TW10	2215077.87	1101306.9	558.88	559.06	0.18
TW11	2184777.19	1079595.65	429.38	429.56	0.18
TW12	2146815.18	1067622.15	681.49	681.74	0.25
TW13	2148953.32	1113431.98	617.04	617.28	0.24
TW14	2126477.41	1081338.83	674.09	674.33	0.24
TW15	2094517.53	1085998.14	795.26	795.68	0.42
TW16	2056211.31	1077648.6	759.54	759.58	0.04
TW17	1995786.96	1084337.24	458.25	458.36	0.11

Number	Easting	Northing	Known Z	Laser Z	Dz
TW18	2036579.99	1078416.46	474.8	475.28	0.48
TW19	2180561.13	1152742.4	426.4	426.65	0.25
TW20	2034788.23	1062137.34	458.02	458.48	0.46
TW21	2105822.1	1059965.03	741.47	741.71	0.24
TW22	2195780.33	1061030.44	490.78	491.23	0.45
TW23	2250630.14	1063165.57	651.76	651.72	-0.04
TW24	2051233.77	1019201.79	450.03	450.03	0
TW25	2104337.88	1040576.29	697.6	698.27	0.67
TW26	2069883.63	1042523.08	514.56	514.86	0.3
TW27	2118551.19	998659.42	744.43	744.36	-0.07
TW28	2108003.53	1001730.66	480.2	480.48	0.28
TW29	2086433.1	996190.91	445.17	445.12	-0.05
TW30	2146051.04	1027008.49	533.92	534.09	0.17
TW31	2165950.56	1017388.43	440.55	440.47	-0.08
TW32	2166213.35	994149.9	448.61	448.7	0.09

Average Dz	0.14 ft
Minimum Dz	-0.310 ft
Maximum Dz	0.770 ft
Root Mean Square	0.256 ft
95th Percentile	0.474 ft