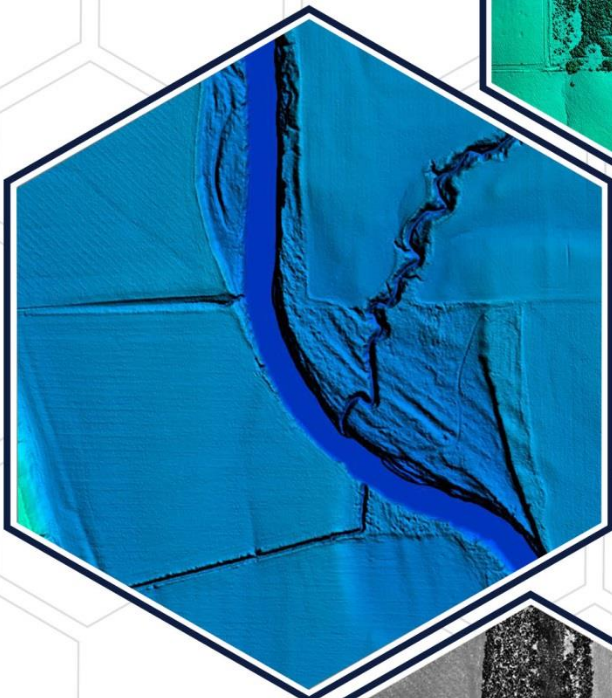

Final Survey Report

Light Detection and Ranging (LiDAR)
Contract Number 39891
Kansas Department of Agriculture South AOI

6531 SE Forbes Suite B
Topeka, Kansas
May 2016

Table of Contents

Section 1: Executive Summary

1.1 Introduction

In support of the *2016 Kansas Department of Agriculture South AOI Light Detection and Ranging (LiDAR)* project, a geodetic control survey was required to provide geographic coordinates for the aerial LiDAR, and, quality assurance and quality control (QA/QC) verification. The importance of this survey was twofold; to ensure a homogenous project meeting the United States Geological Survey (USGS) version 1.2 November 2014 standards for LiDAR Base Specification and to "tie" the mapping to the existing National Geodetic Survey (NGS) framework. This allows for repeatable accuracies for current and future surveying and mapping needs.

A primary control survey was established using three (3) existing (NGS) control monuments. To ensure the validity and the "fit" of the three NGS control stations within a network environment, a GNSS static survey was performed. Two observations sessions of 3 hours were performed on two (2) consecutive days. These three control monument were used as the central control for the base stations and the subsequent radial surveys that were derived from them.

To control the LiDAR acquisition, twenty-five (25) Ground Calibration Points (GCP) were strategically positioned throughout the project area of interest (AOI) and survey locations were derived by performing a Global Navigation Satellite System (GNSS) survey. In addition to the 25 Ground Calibration Points, 146 checkpoints were surveyed to be used for LiDAR vertical assessment. The checkpoints were distributed throughout the AOI representing a good sample of different types of land cover classes. Checkpoints surveyed were classified into two (2) ground cover sample groups being Nonvegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA).

The GNSS surveyed for all checkpoints were performed to meet the (USGS) version 1.2 November 2014 standards for LiDAR Base Specification which equates to having the digital elevation model RMSE equal to or less than 10.0 cm. (0.33 ft.); an accuracy equal to or less than of 19.6 cm. (0.64 ft.) at the 95% confidence level for NVA checkpoints; and an accuracy equal to or less than 29.4 cm. (0.96 ft.) at the 95% confidence level for VVA checkpoints. Typically surveys should be at least three times as accurate as the final product being tested. Based on primary control survey network design, local network accuracies, and survey techniques, accuracies are within 3 cm.

All GCP's and Checkpoints meet and exceed the required accuracy, and were established utilizing the UTM, Zone 14 (NAD83), 2007 Epoch of 2002.00, (HARN) horizontally, and NAVD88 utilizing Geoid 12B. The following sections within this report contain the methodology and results with additional supporting documentation in a separate document - *15164_Survey_Report_2016_Kansas_LiDAR_South-AOI_Appendix.pdf.*

Section 2: Survey Standards and Equipment

2.1 Introduction

Several different survey methods and procedures were used in the development of this survey. The survey consisted of the following step:

1. NGS control monument reconnaissance and condition evaluation
2. GNSS survey of all NGS control monuments
   2.a Minimum collection of 3 hours sessions on 2 consecutive days
3. Evaluate the integrity of the NGS control monuments
4. Identify locations for GCP's and Checkpoints for adequate positioning.
5. GNSS survey of GCP's and Checkpoints.
6. Review the quality of GCP and checkpoint computed coordinates through data processing.

2.2 Applicable Standards

The accuracy standard for the survey was United States Geological Survey (USGS) version 1.2 November 2014 standards for LiDAR Base Specification of Quality Level 2 (QL2). Quality Level 2 ensures that point cloud and derivative products are suitable for the 3D Elevation Program (3DEP) and the National Elevation Dataset (NED).

Table 1 – USGS Vertical Accuracy for digital elevation models (QL2)

Nonvegetated (NVA) RMSE	Nonvegetated (NVA) 95% Confidence Level	Vegetated (VVA) 95% Confidence Level
≤ 10.0 cm.	≤ 19.6 cm.	≤ 29.4 cm.

2.3 Datum and Coordinate Systems

All monumented survey control coordinates are reported in UTM, Zone 14 North American Datum 1983 (NAD83), 2007 Epoch of 2002.00 High Accuracy Reference Network (HARN) horizontally, and the North American Vertical Datum of 1988 (NAVD88) utilizing Geoid 12B vertically.

2.4 Survey Equipment

The following survey equipment was utilized to collect the survey coordinates:

- Leica SR530 GPS System SN 30192 (Dual Frequency)
- Leica SR530 GPS System SN 136534 (Dual Frequency)
- Leica SR530 GPS System SN 136512 (Dual Frequency)
- Leica SR530 GPS System SN 136496 (Dual Frequency)
- Topcon HiPer V GPS System SN 1132-10002 (Dual Frequency)
- Topcon HiPer V GPS System SN 1132-10002 (Dual Frequency)

Section 3: Survey Methodology and Processing Results

A survey crew mobilized to the South Kansas AOI to perform the survey between January 21st and May 3th, 2015.

3.1 Primary Control Network Survey

A primary control network was performed to check the integrity of three (3) existing NGS monuments as illustrated in Figure 1. Final values from the primary control network will be used as central control for ground calibration points and checkpoints to control LiDAR acquisition.

The survey crew recovered NGS Monuments ***2K3A***, ***HQG A***, and ***WILBUR*** to be used as primary control. Each GNSS observation consisted of; setting the receiver on a fixed height tripod or a fixed 2 meter rod which mitigates antenna height errors, the collection of dual frequency GNSS data with Global Positioning System (GPS) Leica w/ Leica AT502 antenna receivers and Topcon HiPer V (GPS) receivers both configured to log data at 1 Hz, and at 10 degrees mask for a minimum of 3 hour observations on two (2) consecutive days, and post-processing data using GrafNet 8.60.2105 with their respective GPS antenna type and antenna height reading. Table 2 list the NGS Control station and the associated designation assigned in the data collection.

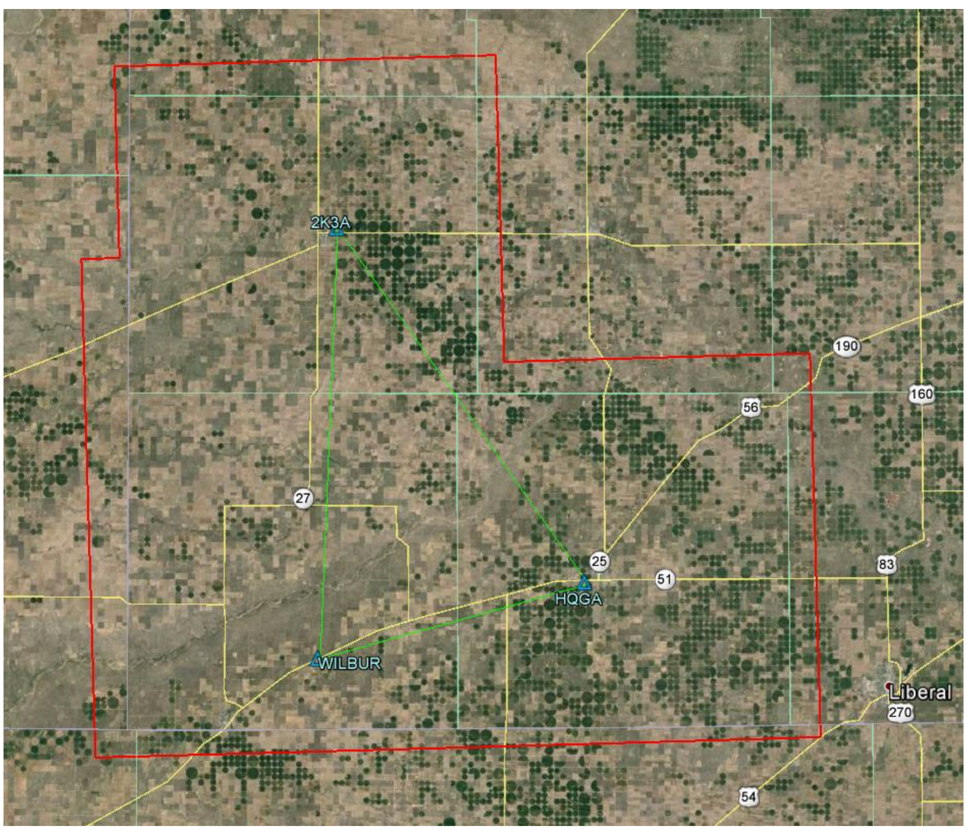

Figure 1 - NGS Control Monuments in Primary Network Survey

Table 2 -List of NGS Survey Control PID and associated Designation

NGS PID	Designation	Method
HH0691	2K3 A	Used Published Coordinate
HH0685	HQG A	GNSS Static
HH0797	WILBUR	GNSS Static

The NGS monument datasheets can be found in a separate document - *15164_Survey_Report_2016_Kansas_LiDAR_South-AOI_Appendix.pdf.*

Observations for each session was processed using GrafNet 8.60.2105 with their respective GPS antenna type, and antenna height reading, and two (2) adjustments were made during network's development.

A minimally constrained network adjustment were performed, holding National Geodetic Survey (NGS) Monument **(*PID: HH0691 Designation: 2K3 A*)** as a horizontal and vertical control point. During this adjustment, baselines were analyzed and evaluated against other redundant baselines to see if it should remain or be rejected. The purpose of the minimally constrained adjustment is to check the integrity of vector measurements against the NGS control points and to compare the computed values versus the published values.

Minimally constrained adjustment for horizontal and vertical shows that NGS Monuments **(*PID: HH0797 Designation: WILBUR* *and* *PID: HH0685 Designation: HQG A)*** are within acceptable limits within the minimally constrained adjustment. Table 3 list the NGS Control station and Minimally Constrained root-mean-square RMS Residuals.

After full evaluation of the minimally constrained adjustment, the network was constrained for a final network adjustment, holding **(*PID: HH0691 Designation: 2K3 A*)** as a horizontal and vertical control point and applying the scale factor. Point residuals for NGS Monument **(*PID: HH0797 Designation: WILBUR* *and* *PID: HH0685 Designation: HQG A)*** were reviewed based on the distance between each point and are found to be within acceptable limits.

Table 3 -List of NGS Survey Control and Minimally Constrained RMS

NGS PID	Designation	Eastern Residual	Northern Residual	Height Residual
HH0797	WILBUR	-0.046 m	0.041 m	-0.054 m
HH0685	HQG A	0.035 m	-0.001 m	0.070 m

The final coordinates derived from the adjusted network can be located in Table 4 and also the network adjustment reports can be found in a separate document - *15164_Survey_Report_2016_Kansas_LiDAR _South-AOI_Appendix.pdf.*

3.2 Real Time Kinematic GNSS Radial Survey

A Real Time Kinematic GNSS Radial Survey was performed utilizing Topcon's Magnet Relay for GIS cloud-based solutions software to collect data on thirty-one (31) checkpoints being nineteen (19) NVA and twelve (12) VVA. This survey was controlled by using the final NGS control monument values from the primary control survey for each GNSS session. Topcon's Magnet Relay solutions provided high-accuracy real-time corrections via cellular collection at the GNSS base Global Positioning System (GPS) receiver.

Each GNSS observation consisted of the following:

1. Setting a Topcon GPS HiPer V base receiver on a fixed height tripod over the primary NGS control monument for session control.
2. Collect dual frequency base GNSS data at base receiver and receive real-time corrections from Topcon's Magnet Relay solutions. Base GPS receiver was configured to log data at 1 Hz, and at a 10 degree mask for the duration of the session.
3. Setting a Topcon GPS HiPer V rover receiver on a fixed 2 meter rod for checkpoint collection.
4. Collect dual frequency rover GNSS data on each checkpoint using the radial line survey method. GPS receiver was configured to log data at 1 Hz, and at a 10 degree mask for a minimum of 10 second observations.

The advantages of using Real-Time Kinematic (RTK) first and foremost is the accuracy (typically +/- 10mm (0.03 ft.) + 1ppm RMS). Other advantages include; not requiring additional time duration for individual static occupation for each point, and the ability to tie all points collected into the established network for final coordinates.

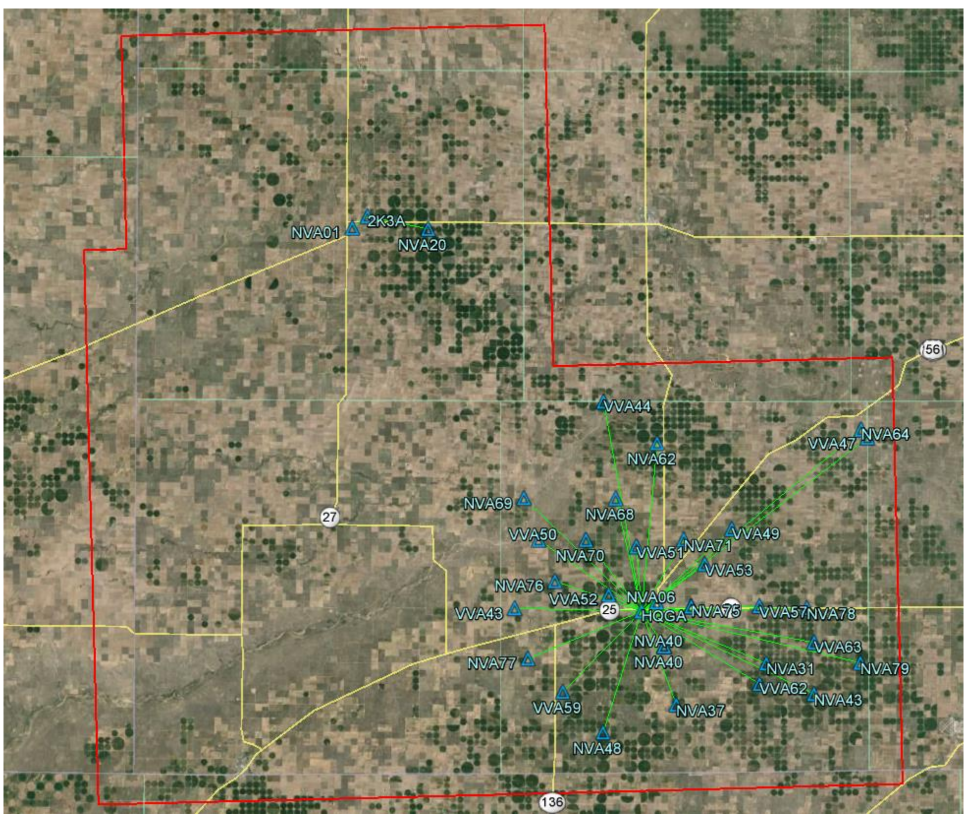

Figure 2 – Real Time Kinematic GNSS Radial Survey Points

3.3 Static GNSS Radial Survey

Using the three primary network control points as base station locations, static GNSS radial baselines were surveyed to collect three-dimensional positions on twenty-five (25) Ground Calibration Points (GCP). These calibration points strategically positioned throughout the project AOI are used to control the LiDAR.

An additional 115 checkpoints, consisting of sixty-two (62) NVA and fifty-three (53) VVA points, distributed throughout the AOI representing a good sample of different types of land cover classes were surveyed to validate the LiDAR accuracy. See Figure 3)

Each GNSS observation consisted of the following:

1. Setting Topcon GPS HiPer V base receiver or on a fixed height tripod over the primary NGS control monument for session control.
2. Collect dual frequency base GNSS data at base receiver. Base GPS receiver was configured to log data at 1 Hz, and at a 10 degree mask for the duration of the session.
3. Setting a Topcon GPS HiPer V rover receiver on a fixed 2 meter rod for GCP and checkpoint collection.
4. Collect dual frequency rover GNSS data on each checkpoint using the radial line survey method. GPS receiver was configured to log data at 1 Hz, and at a 10 degree mask for a minimum of 30 minute observations.
5. All observations were post-processing data using GrafNet 8.60.2105 with their respective GPS antenna type and antenna height reading.

The advantages of using Static GNSS Radial is that the accuracy (typically +/- 10mm (0.03 ft.) + 1ppm RMS) is equal to the accuracies obtained from Real-Time Kinematic (RTK) and the ability to tie all points collected into the established network for final coordinates. The only disadvantage is the increased occupation time for each point.

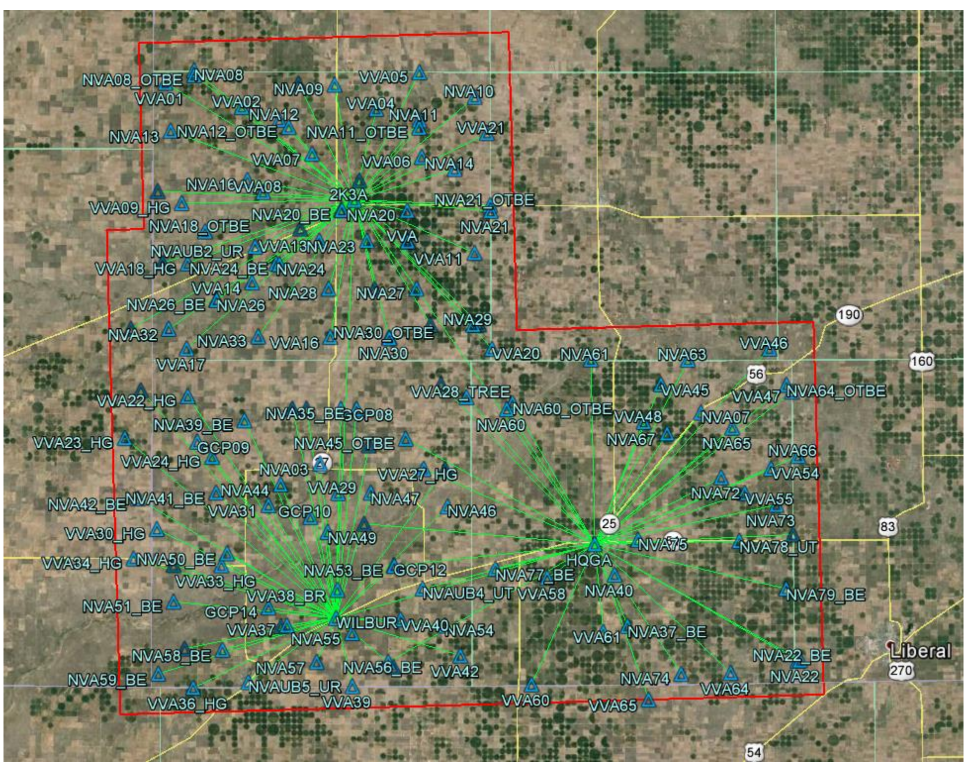

Figure 3 – Ground Calibration Point and Checkpoint Static GNSS Radial Survey

3.4 Final Ground Control Coordinates

Table 4 lists the final coordinates derived from the primary control network survey, Ground Calibration Point and Checkpoint Network Survey, and Real Time Kinematic (RTK) GNSS Survey.

Table 4 - Final Coordinates to be used for the LiDAR solution.

Point ID	Easting	Northing	Height	Class	Field Designation
0001	237397.830	4181095.885	1073.065	OPEN TERRAIN	NVA08
0002	237396.416	4180454.430	1073.856	OPEN TERRAIN	NVA08_X
0003	256326.655	4178616.996	1003.670	OPEN TERRAIN	NVA09
0004	275205.704	4176425.833	976.657	OPEN TERRAIN	NVA10
0005	267646.038	4173507.394	980.884	OPEN TERRAIN	NVA11
0006	267595.293	4172523.330	974.442	OPEN TERRAIN	NVA11_X
0007	248733.925	4174117.369	1036.700	OPEN TERRAIN	NVA12
0008	234007.235	4173101.712	1093.305	OPEN TERRAIN	NVA13
0009	272235.945	4166831.086	957.159	OPEN TERRAIN	NVA14
0010	259331.896	4165661.266	1009.945	OPEN TERRAIN	NVA15
0011	244207.787	4166156.564	1070.607	OPEN TERRAIN	NVA16
0012	232057.740	4165011.330	1119.139	OPEN TERRAIN	NVA17
0013	238308.047	4159433.650	1076.132	OPEN TERRAIN	NVA18
0014	251176.674	4159459.847	1043.119	OPEN TERRAIN	NVA19
0015	265664.587	4161425.062	991.139	OPEN TERRAIN	NVA20
0016	256860.380	4161760.039	1017.528	OPEN TERRAIN	NVA20_X
0017	276931.853	4161062.325	955.009	OPEN TERRAIN	NVA21
0018	276882.603	4161825.562	956.588	OPEN TERRAIN	NVA21_X
0019	316942.889	4099676.136	903.299	OPEN TERRAIN	NVA22
0020	316614.780	4099629.034	902.423	OPEN TERRAIN	NVA22_X
0021	260130.345	4157535.197	1005.846	OPEN TERRAIN	NVA23
0022	247811.972	4154857.320	1053.831	OPEN TERRAIN	NVA24
0023	232432.863	4155360.815	1095.234	OPEN TERRAIN	NVA25
0024	239616.158	4150265.152	1082.741	OPEN TERRAIN	NVA26
0025	239616.484	4150168.383	1082.555	OPEN TERRAIN	NVA26_X
0026	254778.386	4151266.462	1025.204	OPEN TERRAIN	NVA28
0027	274153.100	4145865.782	965.062	OPEN TERRAIN	NVA29
0028	274930.295	4145891.579	964.122	OPEN TERRAIN	NVA29_X
0029	262751.294	4144522.296	999.508	OPEN TERRAIN	NVA30
0030	262786.413	4144397.206	999.695	OPEN TERRAIN	NVA30_X
0031	304261.637	4109553.111	927.162	OPEN TERRAIN	NVA31
0032	233024.856	4146509.243	1106.382	OPEN TERRAIN	NVA32
0033	245096.404	4145133.730	1060.112	OPEN TERRAIN	NVA33
0034	269582.000	4138031.376	982.252	OPEN TERRAIN	NVA34
0035	293499.196	4105002.439	951.559	OPEN TERRAIN	NVA37

Point ID	Easting	Northing	Height	Class	Field Designation
0036	293810.063	4104961.243	950.598	OPEN TERRAIN	NVA37_X
0037	229045.147	4138397.506	1123.634	OPEN TERRAIN	NVA38
0038	242915.510	4133946.222	1065.542	OPEN TERRAIN	NVA39
0039	238834.369	4124375.524	1079.845	OPEN TERRAIN	NVA41
0040	228237.640	4123890.691	1122.952	OPEN TERRAIN	NVA42
0041	309794.717	4105822.572	917.881	OPEN TERRAIN	NVA43
0042	247573.369	4125221.676	1060.667	OPEN TERRAIN	NVA44
0043	264612.949	4130874.934	997.571	OPEN TERRAIN	NVA45
0044	269998.517	4121639.710	991.445	OPEN TERRAIN	NVA46
0045	259699.784	4123774.045	1027.051	OPEN TERRAIN	NVA47
0046	253736.716	4118679.745	1051.316	OPEN TERRAIN	NVA49
0047	240072.051	4116203.863	1084.649	OPEN TERRAIN	NVA50
0048	232650.178	4109906.829	1090.288	OPEN TERRAIN	NVA51
0049	247081.291	4106247.182	1065.294	OPEN TERRAIN	NVA52
0050	262594.662	4113872.050	1013.823	OPEN TERRAIN	NVA53
0051	269184.715	4105686.941	1020.756	OPEN TERRAIN	NVA54
0052	256627.250	4105044.067	1040.984	OPEN TERRAIN	NVA55
0053	262114.952	4100333.924	1034.832	OPEN TERRAIN	NVA56
0054	261404.268	4101018.784	1041.184	OPEN TERRAIN	NVA56_X
0055	239083.149	4103276.024	1083.298	OPEN TERRAIN	NVA58
0056	230301.246	4100307.038	1100.685	OPEN TERRAIN	NVA59
0057	278347.109	4134448.012	970.403	OPEN TERRAIN	NVA60
0058	279123.311	4135268.523	968.798	OPEN TERRAIN	NVA60_X
0059	289853.791	4140770.948	917.186	OPEN TERRAIN	NVA61
0060	292023.707	4135679.668	946.602	OPEN TERRAIN	NVA62
0061	302951.230	4140370.869	915.147	OPEN TERRAIN	NVA63
0062	316131.110	4136646.861	899.290	OPEN TERRAIN	NVA64
0063	316130.762	4136636.962	899.088	OPEN TERRAIN	NVA64_X
0064	308665.992	4131112.846	922.722	OPEN TERRAIN	NVA65
0065	317441.262	4127067.594	903.810	OPEN TERRAIN	NVA66
0066	286975.601	4129319.595	960.794	OPEN TERRAIN	NVA68
0067	276153.587	4129642.007	975.368	OPEN TERRAIN	NVA69
0068	283346.686	4124573.825	972.907	OPEN TERRAIN	NVA70
0069	294871.402	4124302.427	950.112	OPEN TERRAIN	NVA71
0070	306977.892	4124510.705	924.722	OPEN TERRAIN	NVA72
0071	300831.962	4098315.505	930.684	OPEN TERRAIN	NVA74
0072	295557.338	4116440.402	938.624	OPEN TERRAIN	NVA75
0073	279566.591	4119840.937	972.349	OPEN TERRAIN	NVA76
0074	276197.084	4113110.544	985.108	OPEN TERRAIN	NVA77_X
0075	309195.258	4115925.898	912.070	OPEN TERRAIN	NVA78

Point ID	Easting	Northing	Height	Class	Field Designation
0076	315362.419	4109340.708	905.163	OPEN TERRAIN	NVA79
0077	315315.252	4109335.059	905.580	OPEN TERRAIN	NVA79_X
0078	256734.336	4161778.090	1017.357	OPEN TERRAIN	NVA01
0079	238428.607	4129179.950	1088.033	URBAN	VVA24
0080	266315.101	4110742.996	1010.317	URBAN	NVA04
0081	242424.747	4098856.212	1098.333	URBAN	NVA05
0082	291478.431	4117029.960	948.230	URBAN	NVA06
0083	284791.616	4101973.062	969.785	URBAN	NVA48
0084	233960.207	4103577.143	1078.533	BRUSH	VVA35
0085	263250.102	4106695.534	1023.073	BRUSH	VVA40
0086	316848.862	4135689.381	897.185	BRUSH	VVA41
0087	274739.245	4116779.860	982.414	BRUSH	VVA43
0088	285838.330	4140681.043	938.864	BRUSH	VVA44
0089	313978.153	4141561.914	882.751	BRUSH	VVA46
0090	316848.862	4135689.382	897.185	BRUSH	VVA47
0091	289266.583	4123635.505	960.172	BRUSH	VVA51
0092	297280.183	4121373.345	941.522	BRUSH	VVA53
0093	310084.048	4122303.318	922.142	BRUSH	VVA55
0094	280165.730	4106855.522	999.660	BRUSH	VVA59
0095	309943.943	4111876.932	913.500	BRUSH	VVA63
0096	233457.320	4179552.117	1093.926	CROPS	VVA01
0097	243719.101	4175986.153	1053.290	CROPS	VVA02
0098	251453.704	4178909.329	1023.353	CROPS	VVA03
0099	261891.017	4175191.156	991.246	CROPS	VVA04
0100	267828.263	4179934.453	1007.822	CROPS	VVA05
0101	267825.182	4168569.763	977.163	CROPS	VVA06
0102	253042.169	4169430.987	1024.084	CROPS	VVA07
0103	246289.812	4164491.916	1053.841	CROPS	VVA08
0104	235262.372	4163318.079	1105.024	CROPS	VVA09
0105	274594.472	4155503.220	968.401	CROPS	VVA11
0106	260995.611	4151045.043	1006.982	CROPS	VVA12
0107	253696.222	4157723.632	1030.902	CROPS	VVA13
0108	244467.022	4152403.950	1064.503	CROPS	VVA14
0109	254810.247	4144797.217	1025.863	CROPS	VVA16
0110	235402.424	4143808.701	1096.901	CROPS	VVA17
0111	235845.221	4155209.273	1092.247	CROPS	VVA18
0112	227918.668	4146677.290	1125.745	CROPS	VVA19
0113	276575.870	4142570.610	966.523	CROPS	VVA20
0114	276712.496	4171526.060	956.903	CROPS	VVA21
0115	235368.472	4137417.057	1095.584	CROPS	VVA22

Point ID	Easting	Northing	Height	Class	Field Designation
0116	226704.766	4132032.323	1128.868	CROPS	VVA23
0117	251353.656	4135273.002	1036.617	CROPS	VVA25
0118	259613.596	4130120.240	1016.752	CROPS	VVA26
0119	266923.077	4126746.298	1007.455	CROPS	VVA27
0120	230673.298	4119711.964	1117.027	CROPS	VVA30
0121	245846.205	4122510.133	1060.092	CROPS	VVA31
0122	258688.679	4119640.434	1037.984	CROPS	VVA32
0123	239259.762	4114615.244	1088.692	CROPS	VVA33
0124	227412.093	4115850.148	1132.144	CROPS	VVA34
0125	234969.238	4098301.476	1109.249	CROPS	VVA36
0126	254838.569	4110888.534	1030.794	CROPS	VVA38
0127	256472.352	4097915.807	1056.798	CROPS	VVA39
0128	271160.818	4101633.456	1010.616	CROPS	VVA42
0129	299204.308	4137190.507	928.517	CROPS	VVA45
0130	296754.136	4132209.495	941.205	CROPS	VVA48
0131	300563.271	4125390.665	937.608	CROPS	VVA49
0132	277767.480	4124721.428	978.261	CROPS	VVA50
0133	285867.753	4118088.652	959.169	CROPS	VVA52
0134	313724.709	4125461.144	912.062	CROPS	VVA54
0135	316467.328	4116556.713	895.180	CROPS	VVA56
0136	303600.309	4116280.623	923.062	CROPS	VVA57
0137	283166.540	4111708.167	976.388	CROPS	VVA58
0138	280633.020	4097498.759	983.158	CROPS	VVA60
0139	290483.698	4104238.344	957.382	CROPS	VVA61
0140	303385.045	4107173.721	930.837	CROPS	VVA62
0141	307529.783	4098259.270	915.892	CROPS	VVA64
0142	296356.367	4095006.718	940.806	CROPS	VVA65
0143	252970.245	4127878.805	1035.521	TREE	NVA03
0144	272973.990	4136195.581	982.054	TREE	VVA28
0145	255289.765	4123848.799	1036.440	TREE	VVA29
0146	247873.750	4106300.161	1061.512	TREE	VVA37
0147	258563.218	4163071.254	987.453	NGS Mon	2K3A
0148	289673.634	4116038.256	928.045	NGS Mon	HQGA
0149	254529.207	4107110.077	1025.581	NGS Mon	WILBUR

Section 4: Accuracy

4.1 Summary of Survey Accuracies

The accuracy of this survey can be defined multiple ways due to the methods for how the control points, ground calibration points, and checkpoints were derived. In most cases the accuracy is defined as either a network accuracy which consists of the standard deviations based on a series of statistical analysis. Table 5 summarizes the estimated accuracies.

Table 5 - Survey and Coordinate Accuracies

Method	Estimated Accuracy
Ground Control Network	0.014 m (0.045 ft) horizontally, 0.022 m (0.071 ft) vertically
GCP and Checkpoint Network Survey	0.030 m (0.098 ft) horizontally, 0.030 m (0.098 ft) vertically
Real Time Kinematic GNSS Survey	0.030 m (0.098 ft) horizontally, 0.030 m (0.098 ft) vertically

With all three methods, the accuracy far surpasses the United States Geological Survey (USGS) version 1.2 November 2014 standards for LiDAR Base Specification standard and the results can be found in the LiDAR report previously submitted.

Section 5: Custody Transference Assurance

5.1 Intentionally Left Blank Page

A blank page has been intentionally inserted at the end of this report to serve as a page check when custody is transferred. The blank page is marked “This page intentionally left blank” to verify that every page of this document is accounted for.

This page intentionally left blank.