WOOLPERT

TN 3 County QL2 Lidar

USGS/ Rolla, MO

June 2016

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Section 1: Overview

Project Name: TN 3 County QL2 Lidar

Project: # 75367

This report contains a comprehensive outline of the TN 3 County QL2 Lidar Processing task order for the United States Geological Survey (USGS). This task is issued under USGS Contract No. G10PC00057, Task Order No. G15PD00231. This task order requires lidar data to be acquired over approximately 2,084 square miles. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.7 meter. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

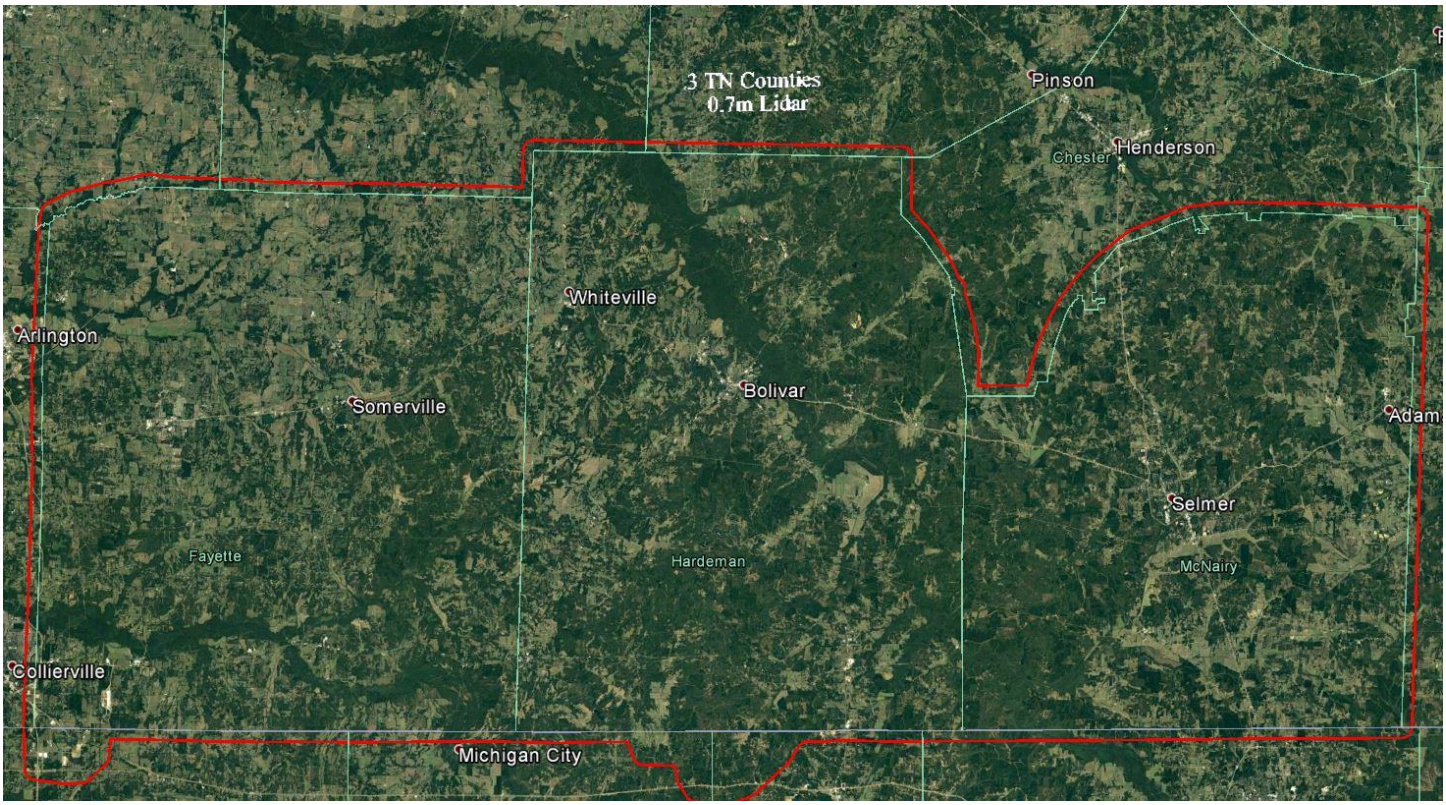
The data was collected using a Leica ALS80 1000 kHz Multiple Pulses in Air (MPiA) lidar sensor.

The ALS80 sensor collects up to an unlimited, as well as intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial lidar was collected at the following sensor specifications:

Table 1.1: ALS80 Specifications	
Post Spacing	2.3ft / 0.7 m
AGL (Above Ground Level) average flying height	4,593 ft / 1,400 m
MSL (Mean Sea Level) average flying height	varies
Average Ground Speed:	150 knots / 173 mph
Field of View (full)	45 degrees
Pulse Rate	143.8 kHz
Scan Rate	64.27 Hz
Side Lap	30%

TN 3 County QL2 Lidar was processed and projected in UTM Zone 16N, NAD83(2011). The vertical datum used for the task order was referenced to NAVD88, GEOID12B in units of meters.

Figure 1.1: Lidar Task Order AOI



Section 2: Acquisition

The existing lidar data was acquired on board Digital Aerial Services (DAS) Cessna aircraft with a Leica ALS80HP 1000 kHz Multiple Pulses in Air (MPiA) Lidar Sensor System.

The ALS80HP lidar system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC80 Operation Controller aboard the aircraft.

The ALS80 1,000 kHz Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Table 2.1: ALS 80 Lidar System Specifications	
Operating Altitude	100 – 7,620 meters
Scan Angle	0 to 72° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	1000 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	6 - 19 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 43 cm (one standard deviation)
Number of Returns per Pulse	unlimited
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (~0.15 mrad @ 1/e)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 72 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium

Prior to mobilizing to the project site, flight crews coordinated with the necessary Air Traffic Control personnel to ensure airspace access.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

The lidar data was collected in nine (9) separate missions, flown as close together as the weather permitted, to ensure consistent ground conditions across the project area.

An initial quality control process was performed immediately on the lidar data to review the data coverage, airborne GPS data, and trajectory solution. Any gaps found in the lidar data were relayed to the flight crew, and the area was re-flown.

Figure 2.1: Lidar Flight Layout, TN 3 County Lidar

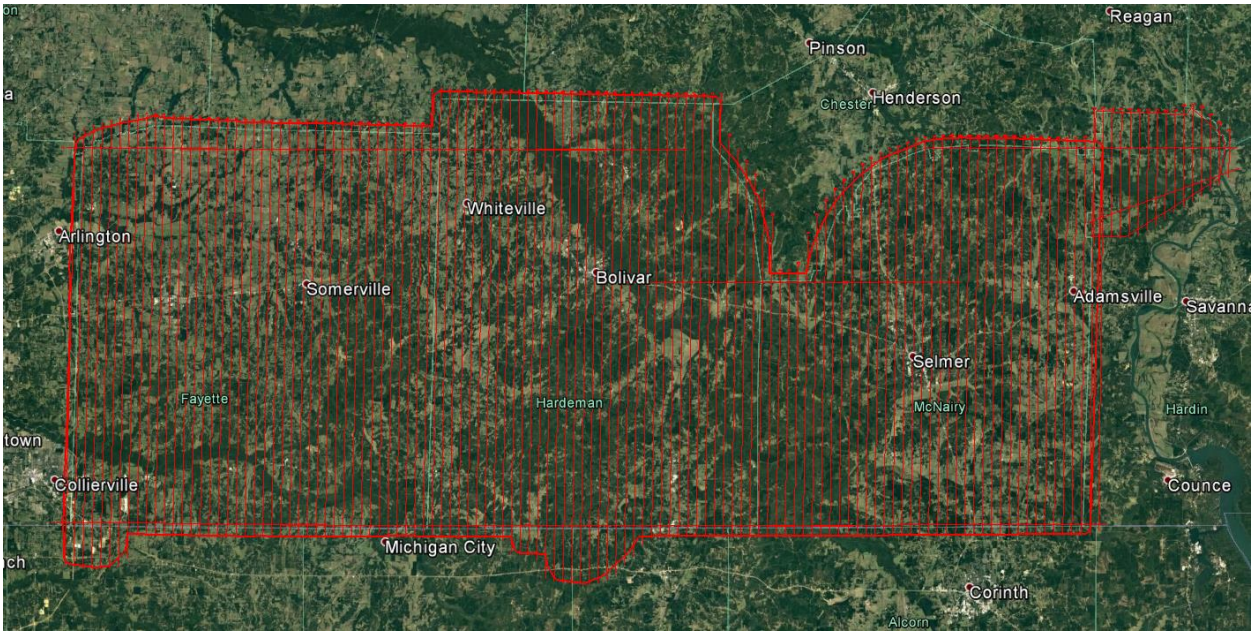


Table 2.2: Airborne Lidar Acquisition Flight Summary Woolpert

Date of Mission	Lines Flown	Mission Time (UTC) Collect Start/ Collect End	Mission Time (Local = EDT) Collect Start/ Collect End
December 17, 2015 A	68-83	15:37 - 19:48	10:37AM – 2:48PM
December 17, 2015 B	84-99	21:38 - 01:58	04:38 PM – 08:58 PM
December 18, 2015	100-112	22:52 – 2:31	05:52 PM – 09:31 PM
December 19, 2015 A	113-131	15:20 – 18:40	10:20 AM – 01:40 PM
December 19, 2015 B	55-67	21:32 – 01:27	04:32 PM – 08:27 PM
December 20, 2015	41, 43-54	15:33 – 19:36	10:33AM – 02:48 PM
January 05, 2016 A	15-28,	18:09 – 21:55	01:09 PM – 04:55 PM
January 05, 2016 B	1-14	23:21 – 03:17	06:21 PM – 10:17 PM
January 06, 2016	29-40, 42	17:50 – 21:13	12:50 PM – 04:13 PM

Section 3: Lidar Data Processing

Applications and Work Flow Overview

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
   Software: POSPac Software v. 5.3, IPAS Pro v.1.35.
2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift.
   Software: ALS Post Processing Software v.2.75 build #25, Proprietary Software, TerraMatch v. 16.01., Leica Lidar Survey Studio (LSS)
3. Imported processed LAS point cloud data into the task order tiles. Resulting data were classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control.
   Software: TerraScan v.16.01.
4. The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts from the ground class.
   Software: TerraScan v.16.01.

Global Navigation Satellite System (GNSS) – Inertial Measurement Unit (IMU) Trajectory Processing

Equipment

Flight navigation during the lidar data acquisition mission is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and/or heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

The aircraft are all configured with a NovAtel Millennium 12-channel, L1/L2 dual frequency Global Navigation Satellite System (GNSS) receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with a Litton LN200 series Inertial Measurement Unit (IMU) operating at 200 Hz. CORS stations were utilized for each mission. The CORS stations utilized during the Lidar acquisition missions are listed below:

Table 3.1: GNSS Base Station Woolpert

Station (Name)	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
TN43 CORS	35°13'42.85127"	88°36'14.10607"	122.415
TN44 CORS	35°38'25.50230"	88°55'08.62785"	92.404
MSBV CORS	34°39'56.46136"	88°33'51.48410"	129.975
TN46 CORS	35°13'16.56358"	88°19'06.05172"	117.806

TN45 CORS	35°17'57.37250"	89°39'34.60012"	64.175
ZME1 CORS	35°04'02.59576"	89°57'19.30103"	69.857
MSEV CORS	31°35'42.08167"	89°12'13.27473"	53.831

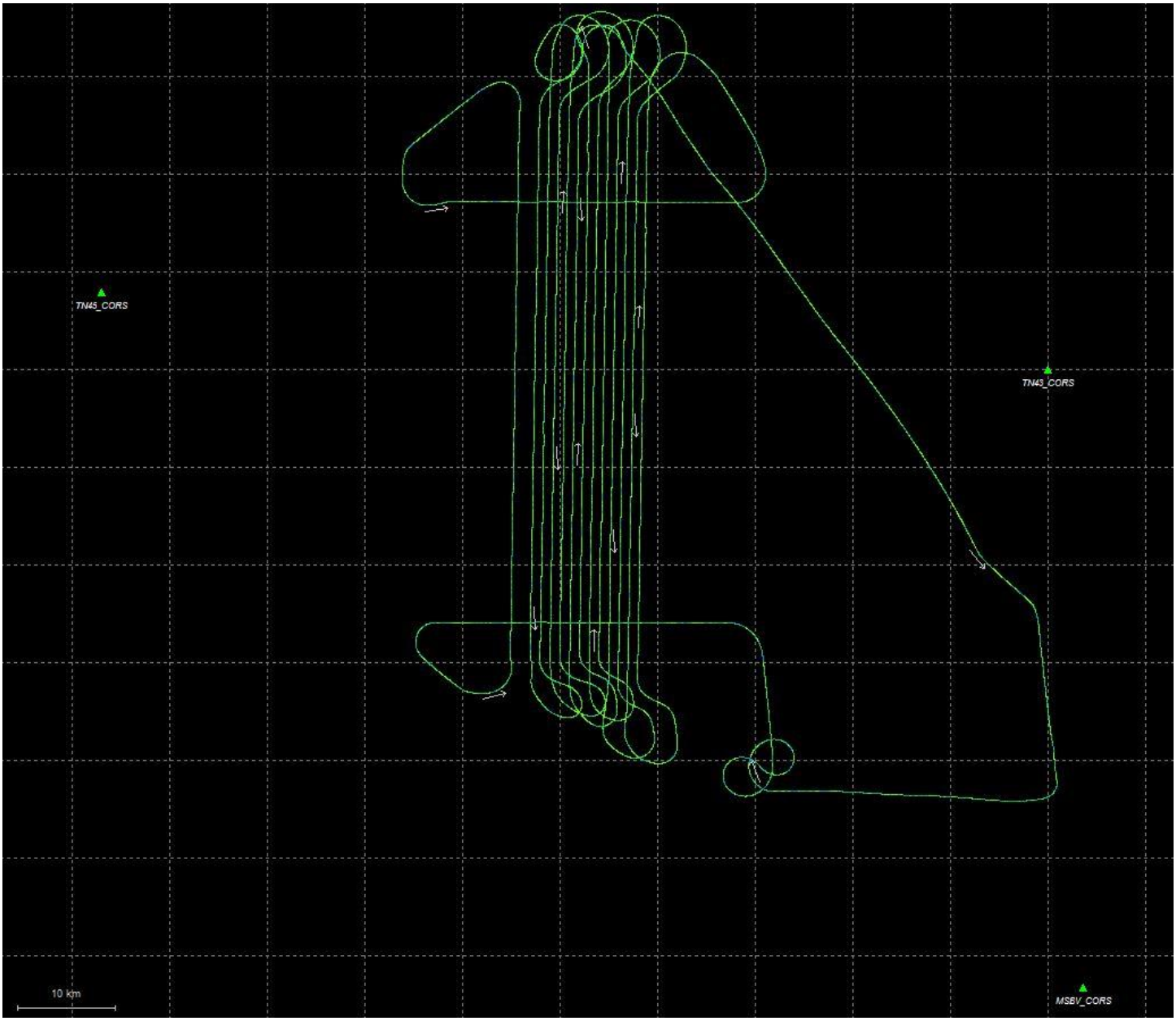
Data Processing

All airborne GNSS and IMU data was post-processed and quality controlled using Applanix MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

Trajectory Quality

The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

Figure 3.1: Trajectory, Day035415



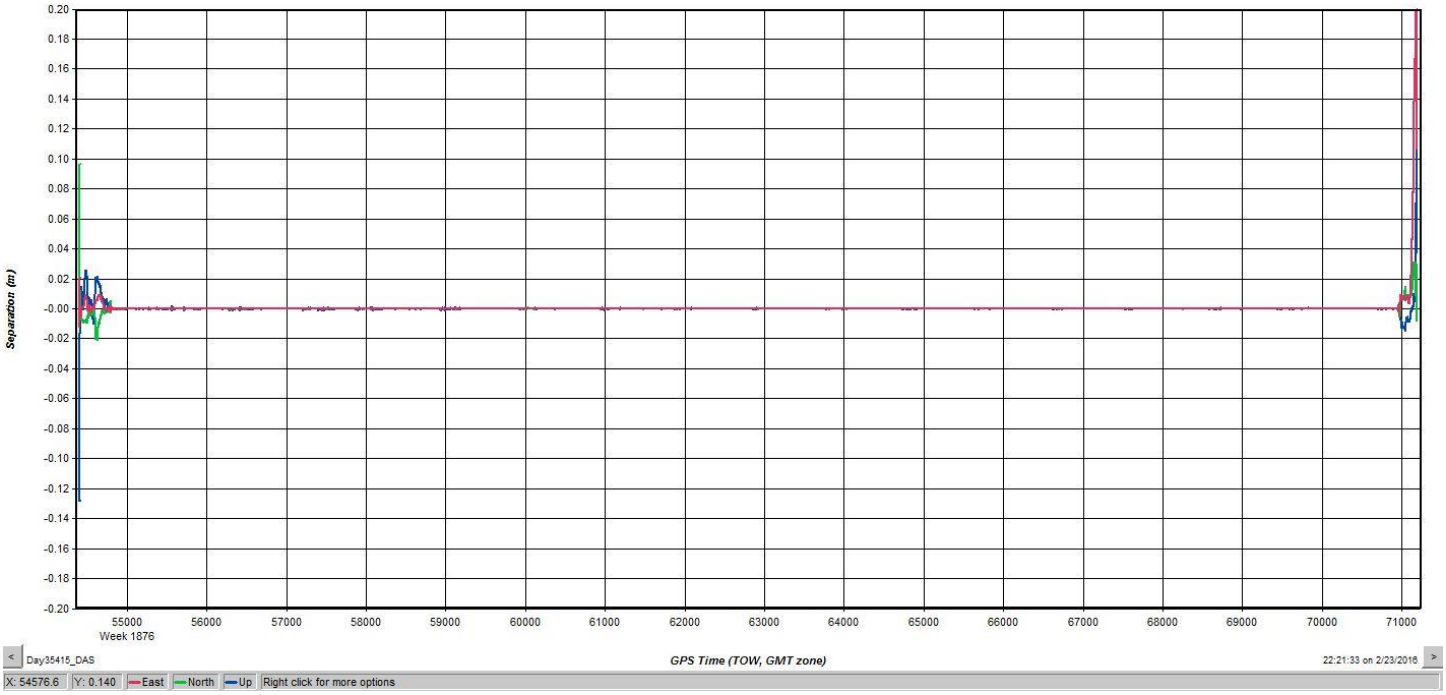
Combination Separation

The Combined Separation is a measure of the difference between the forward run and the backward run solution of the trajectory.

The Kalman filter is processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate reliable solution is achieved.

Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we achieve results below this threshold.

Figure 3.2: Combined Separation, Day035415

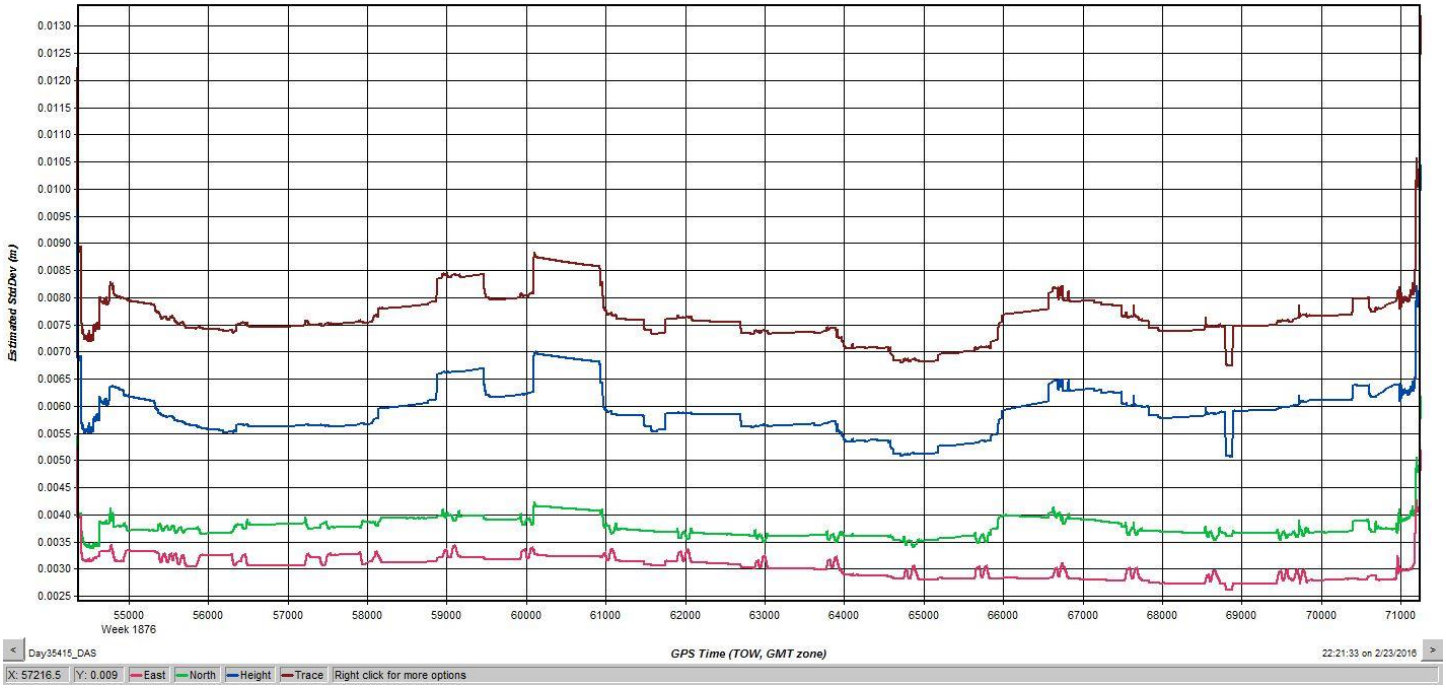


Estimated Positional Accuracy

The Estimated Positional Accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

Woolpert's goal is to maintain an Estimated Positional Accuracy of less than ten (10) centimeters, often achieving results well below this threshold.

Figure 3.3: Estimated Positional Accuracy, Day035415

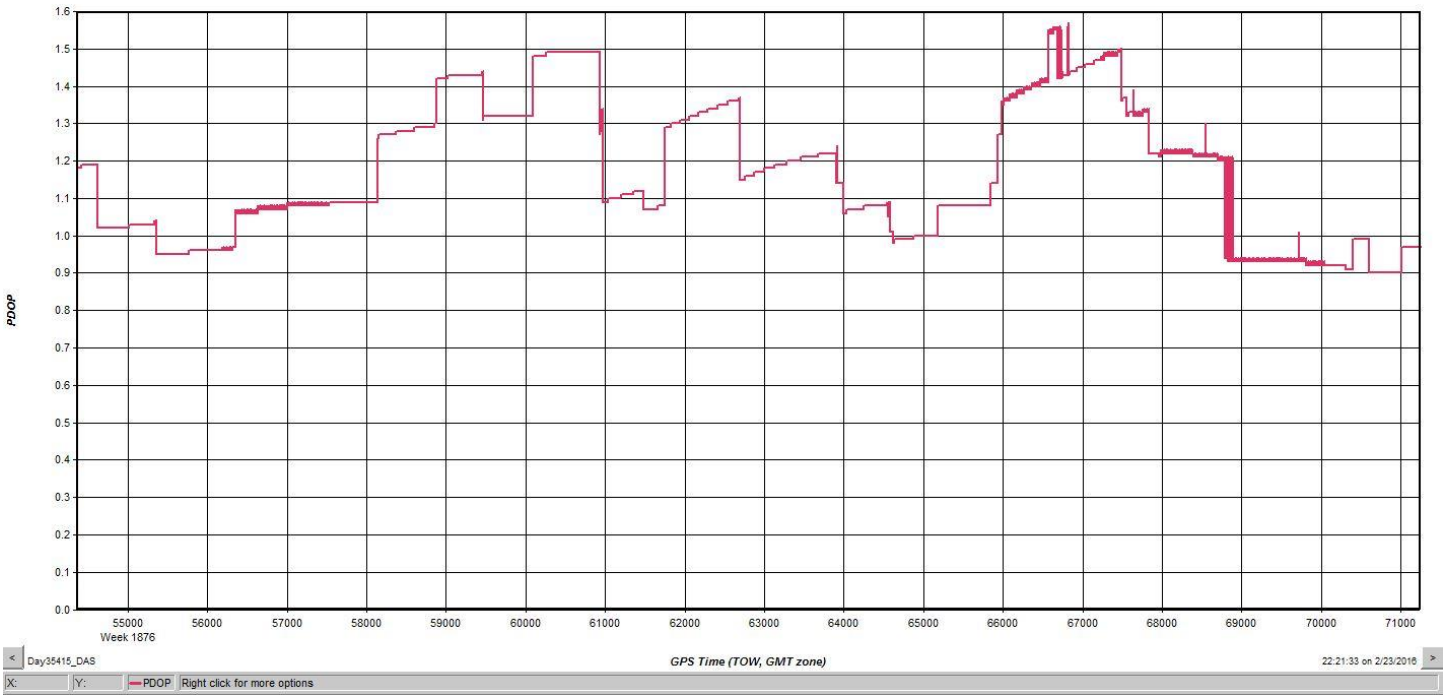


PDOP

The PDOP measures the precision of the GPS solution in regards to the geometry of the satellites acquired and used for the solution.

Woolpert's goal is to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.

Figure 3.4: PDOP, Day035415



Lidar Data Processing

When the sensor calibration, data acquisition, and GPS processing phases were complete, the formal data reduction processes by Woolpert lidar specialists included:

- Processed individual flight lines to derive a raw “Point Cloud” LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.
- Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet client specified classes.
- Once all project data was imported and classified, survey ground control data was imported and calculated for an accuracy assessment. As a QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparisons against the TIN and the DEM using surveyed ground control of higher accuracy. The lidar is adjusted accordingly to meet or exceed the vertical accuracy requirements.
- The lidar tiles were reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the task order requirements. A portion of this requires a manual step to ensure anomalies have been removed from the ground class.
- The lidar LAS files are classified into the Default (Class 1), Ground (Class 2), Low Noise (Class 7), Water (Class 9), Ignored Ground (Class 10), Bridge Decks (Class 17) and High Noise (Class 18) classifications.
- FGDC Compliant metadata was developed for the task order in .xml format for the final data products.
- The horizontal datum used was referenced to UTM Zone 16N NAD83(2011). The vertical datum used for the task order was referenced to NAVD88, GEOID12B in units of meters.

Section 4: Hydrologic Flattening

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

TN 3 County QL2 Lidar processing task order required the compilation of breaklines defining water bodies and rivers. The breaklines were used to perform the hydrologic flattening of water bodies, and gradient hydrologic flattening of double line streams and rivers. Lakes, reservoirs and ponds, at a minimum size of 2-acre or greater, were compiled as closed polygons. The closed water bodies were collected at a constant elevation. Rivers and streams, at a nominal minimum width of 30 meters (100 feet), were compiled in the direction of flow with both sides of the stream maintaining an equal gradient elevation.

LIDAR DATA REVIEW AND PROCESSING

Woolpert utilized the following steps to hydrologically flatten the water bodies and for gradient hydrologic flattening of the double line streams within the existing lidar data.

1. Woolpert used the newly acquired lidar data to manually draw the hydrologic features in a 2D environment using the lidar intensity and bare earth surface. Open Source imagery was used as reference when necessary.
2. Woolpert utilizes an integrated software approach to combine the lidar data and 2D breaklines. This process “drapes” the 2D breaklines onto the 3D lidar surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D lidar surface and assigned a constant elevation at or just below ground elevation.
3. The lakes, reservoirs and ponds, at a minimum size of 2-acre or greater and streams at a minimum size of 30 meters (100 feet) nominal width, were compiled to meet task order requirements. **Figure 4.1** illustrates an example of 30 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30 meters (100 feet), were draped with both sides of the stream maintaining an equal gradient elevation.
4. All ground points were reclassified from inside the hydrologic feature polygons to water, class nine (9).
5. All ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class ten (10).
6. The lidar ground points and hydrologic feature breaklines were used to generate a new digital elevation model (DEM).

Figure 4.1: Example Hydrologic Breaklines

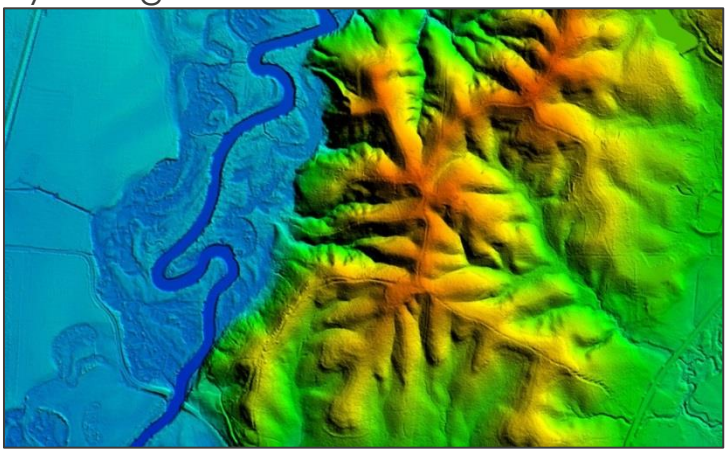


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the “tinning” across the lake surface.

Figure 4.3 reflects a DEM generated from lidar with breaklines compiled to define the hydrologic features. This figure illustrates the results of adding the breaklines to hydrologically flatten the DEM data. Note the smooth appearance of the lake surface in the DEM.

Figure 4.2

Figure 4.3

Terrascan was used to add the hydrologic breakline vertices and export the lattice models. The hydrologically flattened DEM data was provided to USGS in ERDAS .IMG format.

The hydrologic breaklines compiled as part of the flattening process were provided to the USGS as an ESRI Shapefile The breaklines defining the water bodies greater than 2-acre and for the gradient flattening of all rivers and streams at a nominal minimum width of 30 meters (100 feet) were provided as a Polygon-Z feature class.

DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v16, by reviewing the grids and hydrologic breakline features. Additionally, ESRI software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

Edits and corrections were addressed individually by tile. If a water body breakline needed to be adjusted to improve the flattening of the DEM data, the area was cross referenced by tile number, corrected accordingly, a new DEM file was regenerated and reviewed.

Section 5: ACCURACY ASSESSMENT

Accuracy Assessment

This section contains accuracy assessments for TN 3 County QL2 Lidar. The vertical accuracy statistics were calculated by comparison of the lidar bare earth points to the ground surveyed QA/QC points. Data deliverables were delivered in NAD1983(2011) UTM16, NAVD88 Geoid12B meters.

Table 5.1: Overall Vertical Accuracy Statistics		
Average error	0.007	meter
Minimum error	-0.130	meter
Maximum error	0.410	meter
Average magnitude	0.051	meter
Root mean square	0.077	meter
Standard deviation	0.0077	meter

Table 5.2: Raw Swath Quality Check Point Analysis NVA

Point ID	Easting (meter)	Northing (meter)	TIN Elevation (meter)	Dz (meter)
2001_GPS	268293.050	3921622.080	95.350	-0.03
2001_GPS_A	267649.060	3921429.120	96.670	-0.06
2002_GPS	304153.280	3915460.870	151.080	-0.03
2003_GPS	329836.020	3922916.750	147.330	0.02
2004_GPS	336073.510	3912289.860	141.580	0
2005_GPS	339634.120	3902364.460	142.250	-0.01
2006_GPS	351089.370	3908259.530	147.750	0.03
2007_GPS	375899.920	3916899.150	129.580	-0.04
2008_GPS	362233.820	3913582.610	178.450	-0.05
2009_GPS	373197.670	3900137.140	158.950	0.08
2009_GPS_A	373132.250	3900136.510	159.480	0.41
2010_GPS	356775.950	3889949.070	147.890	0.02
2010_GPS_A	356766.350	3889974.990	149.940	-0.02
2011_GPS	359531.800	3903417.900	186.750	0.04
2011_GPS_A	359491.520	3903421.810	185.660	-0.04
2012_GPS	370130.740	3884976.050	183.100	-0.03
2013_GPS	374722.060	3872823.220	140.200	0.04
2014_GPS	360045.890	3880537.720	132.690	0.01
2014_GPS_A	360023.680	3880516.260	132.590	0.02
2015_GPS	349236.350	3876414.490	124.190	0
2016_GPS	330784.820	3889203.010	134.600	-0.05
2017_GPS	316981.140	3868569.670	207.740	-0.05
2017_GPS_A	316826.190	3869582.470	204.050	-0.03

2018_GPS	321861.410	3907414.240	108.940	-0.03
2019_GPS	333397.140	3899695.240	116.060	0.09
2019_GPS_A	333392.510	3899613.870	113.880	0.07
2020_GPS_A	346065.970	3887490.180	129.960	0.03
2021_GPS	335730.850	3880472.960	119.090	-0.08
2021_GPS_A	335665.090	3880475.560	119.360	-0.07
2022_GPS	319854.540	3880544.720	146.440	0
2022_GPS_A	319863.930	3880580.970	147.220	-0.03
2023_GPS	300164.640	3879987.810	171.340	-0.05
2023_GPS_A	300193.490	3879950.960	172.720	-0.04
2024_GPS	312167.420	3895975.090	146.260	-0.02
2024_GPS_A	312224.270	3895970.540	147.240	-0.07
2025_GPS	295240.620	3906551.710	136.620	0
2026_GPS	288437.330	3894544.900	150.380	-0.03
2027_GPS	281899.400	3912344.610	113.380	-0.04
2027_GPS_A	281924.020	3912399.820	112.490	-0.02
2028_GPS	262240.930	3912247.470	86.310	-0.04
2029_GPS	274233.790	3902558.960	123.710	-0.05
2030_GPS	259438.100	3900156.910	89.650	0
2030_GPS_A	259489.050	3900101.690	90.140	-0.02
2031_GPS	274090.630	3910578.950	95.610	0.02
2031_GPTS_A	274083.840	3910545.930	96.310	-0.06
2032_GPS	270920.090	3897544.580	117.450	0
2033_GPS	304364.850	3888865.060	173.050	-0.12
2034_GPS	260866.570	3871012.300	124.260	0.04
2034_GPS_A	260886.210	3870973.240	124.840	-0.03
2035_GPS	277203.020	3875712.300	137.460	-0.13
2036_GPS	283226.260	3888349.630	150.270	-0.01
2036_GPS_A	283183.190	3888321.720	149.430	0.01
2037_GPS	263735.500	3893045.530	120.310	-0.02
2037_GPS_A	263746.910	3893033.030	120.340	-0.02
2038_GPS	259067.320	3887207.370	89.790	0.07
2039_GPS	260797.090	3881419.920	107.650	0.05
2039_GPS_A	260784.680	3881390.540	108.300	0.08
2040_GPS	280625.840	3882435.300	104.900	0.19
2040_GPS_A	280681.570	3882412.240	104.890	-0.06
2041_GPS	269362.030	3880131.400	105.420	0
2041_GPS_A	269298.900	3880117.900	104.960	0
2042_GPS	274550.880	3893147.360	128.060	0
2042_GPS_A	274573.880	3893216.670	125.290	0
2043_GPS	273699.790	3886432.810	129.880	-0.08
2043_GPS_A	273607.720	3886452.520	128.050	-0.09
2044_GPS	289329.700	3881747.970	134.550	0.09
2045_GPS	298004.210	3888089.550	166.670	-0.02
2045_GPS_A	297961.460	3888087.230	167.070	-0.05
2046_GPS	300818.640	3899531.660	164.750	0.04
2047_GPS	280985.450	3918956.220	109.560	-0.11

2048_GPS	290348.190	3915017.600	120.540	0.03
2049_GPS	308010.210	3922868.180	120.470	0.04
2049_GPS_A	307934.800	3922872.810	120.400	0.01
2050_GPS	322508.290	3913623.710	120.260	-0.05
2050_GPS_A	322570.870	3913609.130	118.660	-0.05
2051_GPS	311111.200	3915043.800	132.000	0.06
2052_GPS	321484.600	3920058.380	149.070	0.05
2053_GPS	304961.590	3910672.020	150.250	0.1
2053_GPS_A	304992.590	3910631.340	150.540	0.07
2054_GPS	315780.440	3906017.340	136.550	0.09
2055_GPS	330346.850	3908451.390	118.450	0.06
2056_GPS	342201.280	3892064.370	137.160	0
2057_GPS	315451.760	3887758.770	170.470	0.02
2057_GPS_A	315509.390	3887737.070	169.910	0.03
2058_GPS	309542.890	3880448.560	171.940	-0.05
2058_GPS_A	309550.160	3880398.520	172.060	-0.01
2059_GPS	286304.760	3902472.270	119.830	0.29
2059_GPS_A	286312.770	3902506.860	118.340	-0.13
2060_GPS	296202.450	3874724.360	140.520	-0.06
2060_GPS_A	296258.090	3874792.060	141.810	-0.06
2061_GPS	311057.930	3873908.670	196.130	-0.03
2061_GPS_A	310979.520	3873904.080	196.330	-0.01
2062_GPS	327379.710	3879789.160	131.210	0
2062_GPS_A	327373.080	3879705.630	131.750	-0.03
2063_GPS	328016.970	3901756.690	158.140	0.14
2063_GPS_A	328209.660	3901464.670	152.180	0.11
2064_GPS	320939.580	3900841.050	115.150	0.25
2064_GPS_A	320647.890	3901245.610	127.460	0.09
2065_GPS	340507.420	3875805.010	149.720	-0.06
2066_GPS	345198.270	3883213.790	167.100	-0.12
2067_GPS	352691.080	3894464.600	156.260	0.02
2068_GPS	352788.910	3901336.640	149.030	0.02
2068_GPS_A	352716.680	3901569.200	147.050	0.02
2069_GPS	367615.320	3908296.500	166.310	0.03
2069_GPS_A	367609.800	3908233.930	165.340	0.03
2070_GPS	366279.730	3896264.270	155.530	0
2071_GPS	370173.560	3891521.420	145.210	0
2072_GPS	361403.780	3875291.320	153.670	-0.01
2072_GPS_A	361405.230	3875374.760	152.570	0
2073_GPS	357374.340	3887885.340	138.880	-0.02
2073_GPS_A	357367.660	3887928.060	138.320	0
2074_GPS	369363.990	3880284.080	189.830	0
2075_GPS	319001.580	3903304.960	134.750	0.08
2075_GPS_A	318974.490	3903288.420	134.130	0.07
2076_GPS	354219.220	3913963.040	144.790	0.05
2077_GPS	335978.550	3897352.060	137.670	-0.08
2078_GPS	325246.850	3889104.460	143.030	0.13

2078_GPS_A	325191.380	3889041.560	144.910	0.05

VERTICAL ACCURACY CONCLUSIONS

Raw Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.150 Meters Non vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using all points.

LAS Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.150 Meters Non vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using ground points.

Table 5.3: Non-Vegetated Vertical Accuracy Quality Check Point Analysis NVA

Point ID	Easting (meter)	Northing (meter)	DEM Elevation (meter)	Dz (meter)
2001_GPS	268293.050	3921622.080	95.350	0.03
2001_GPS_A	267649.060	3921429.120	96.690	0.04
2002_GPS	304153.280	3915460.870	151.080	0.03
2003_GPS	329836.020	3922916.750	147.340	-0.03
2004_GPS	336073.510	3912289.860	141.550	0.03
2005_GPS	339634.120	3902364.460	142.230	0.03
2006_GPS	351089.370	3908259.530	147.750	-0.03
2007_GPS	375899.920	3916899.150	129.600	0.02
2008_GPS	362233.820	3913582.610	178.430	0.07
2009_GPS	373197.670	3900137.140	158.960	-0.09
2009_GPS_A	373132.250	3900136.510	159.480	-0.41
2010_GPS	356775.950	3889949.070	147.880	-0.01
2010_GPS_A	356766.350	3889974.990	149.920	0.04
2011_GPS	359531.800	3903417.900	186.770	-0.06
2011_GPS_A	359491.520	3903421.810	185.650	0.05
2012_GPS	370130.740	3884976.050	183.100	0.03
2013_GPS	374722.060	3872823.220	140.200	-0.04
2014_GPS	360045.890	3880537.720	132.700	-0.02
2014_GPS_A	360023.680	3880516.260	132.570	0
2015_GPS	349236.350	3876414.490	124.190	0
2016_GPS	330784.820	3889203.010	134.600	0.05
2017_GPS	316981.140	3868569.670	207.730	0.06
2017_GPS_A	316826.190	3869582.470	204.050	0.03
2018_GPS	321861.410	3907414.240	108.940	0.03
2019_GPS	333397.140	3899695.240	116.030	-0.06
2019_GPS_A	333392.510	3899613.870	113.890	-0.08
2020_GPS_A	346065.970	3887490.180	129.910	0.02
2021_GPS	335730.850	3880472.960	119.100	0.07

2021_GPS_A	335665.090	3880475.560	119.370	0.06
2022_GPS	319854.540	3880544.720	146.440	0
2022_GPS_A	319863.930	3880580.970	147.210	0.04
2023_GPS	300164.640	3879987.810	171.330	0.06
2023_GPS_A	300193.490	3879950.960	172.730	0.03
2024_GPS	312167.420	3895975.090	146.220	0.06
2024_GPS_A	312224.270	3895970.540	147.250	0.06
2025_GPS	295240.620	3906551.710	136.620	0
2026_GPS	288437.330	3894544.900	150.380	0.03
2027_GPS	281899.400	3912344.610	113.380	0.04
2027_GPS_A	281924.020	3912399.820	112.490	0.02
2028_GPS	262240.930	3912247.470	86.320	0.03
2029_GPS	274233.790	3902558.960	123.720	0.04
2030_GPS	259438.100	3900156.910	89.650	0
2030_GPS_A	259489.050	3900101.690	90.150	0.01
2031_GPS	274090.630	3910578.950	95.610	-0.02
2031_GPTS_A	274083.840	3910545.930	96.300	0.07
2032_GPS	270920.090	3897544.580	117.440	0.01
2033_GPS	304364.850	3888865.060	173.010	0.16
2034_GPS	260866.570	3871012.300	124.240	-0.02
2034_GPS_A	260886.210	3870973.240	124.840	0.03
2035_GPS	277203.020	3875712.300	137.450	0.14
2036_GPS	283226.260	3888349.630	150.260	0.02
2036_GPS_A	283183.190	3888321.720	149.430	-0.01
2037_GPS	263735.500	3893045.530	120.310	0.02
2037_GPS_A	263746.910	3893033.030	120.350	0.01
2038_GPS	259067.320	3887207.370	89.790	-0.07
2039_GPS	260797.090	3881419.920	107.670	-0.07
2039_GPS_A	260784.680	3881390.540	108.300	-0.08
2040_GPS	280625.840	3882435.300	104.890	-0.18
2040_GPS_A	280681.570	3882412.240	104.870	0.08
2041_GPS	269362.030	3880131.400	105.430	-0.01
2041_GPS_A	269298.900	3880117.900	104.960	0
2042_GPS	274550.880	3893147.360	128.080	-0.02
2042_GPS_A	274573.880	3893216.670	125.300	-0.01
2043_GPS	273699.790	3886432.810	129.880	0.08
2043_GPS_A	273607.720	3886452.520	128.060	0.08
2044_GPS	289329.700	3881747.970	134.540	-0.08
2045_GPS	298004.210	3888089.550	166.670	0.02
2045_GPS_A	297961.460	3888087.230	167.080	0.04
2046_GPS	300818.640	3899531.660	164.750	-0.04
2047_GPS	280985.450	3918956.220	109.560	0.11
2048_GPS	290348.190	3915017.600	120.530	-0.02
2049_GPS	308010.210	3922868.180	120.470	-0.04
2049_GPS_A	307934.800	3922872.810	120.420	-0.03
2050_GPS	322508.290	3913623.710	120.250	0.06
2050_GPS_A	322570.870	3913609.130	118.690	0.02

2051_GPS	311111.200	3915043.800	132.000	-0.06
2052_GPS	321484.600	3920058.380	149.070	-0.05
2053_GPS	304961.590	3910672.020	150.230	-0.08
2053_GPS_A	304992.590	3910631.340	150.540	-0.07
2054_GPS	315780.440	3906017.340	136.560	-0.1
2055_GPS	330346.850	3908451.390	118.450	-0.06
2056_GPS	342201.280	3892064.370	137.150	0.01
2057_GPS	315451.760	3887758.770	170.450	0
2057_GPS_A	315509.390	3887737.070	169.910	-0.03
2058_GPS	309542.890	3880448.560	171.940	0.05
2058_GPS_A	309550.160	3880398.520	172.050	0.02
2059_GPS	286304.760	3902472.270	119.820	-0.28
2059_GPS_A	286312.770	3902506.860	118.350	0.12
2060_GPS	296202.450	3874724.360	140.530	0.05
2060_GPS_A	296258.090	3874792.060	141.800	0.07
2061_GPS	311057.930	3873908.670	196.120	0.04
2061_GPS_A	310979.520	3873904.080	196.300	0.04
2062_GPS	327379.710	3879789.160	131.220	-0.01
2062_GPS_A	327373.080	3879705.630	131.750	0.03
2063_GPS	328016.970	3901756.690	158.130	-0.13
2063_GPS_A	328209.660	3901464.670	152.180	-0.11
2064_GPS	320939.580	3900841.050	115.150	-0.25
2064_GPS_A	320647.890	3901245.610	127.450	-0.08
2065_GPS	340507.420	3875805.010	149.720	0.06
2066_GPS	345198.270	3883213.790	167.100	0.12
2067_GPS	352691.080	3894464.600	156.270	-0.03
2068_GPS	352788.910	3901336.640	149.030	-0.02
2068_GPS_A	352716.680	3901569.200	147.050	-0.02
2069_GPS	367615.320	3908296.500	166.320	-0.04
2069_GPS_A	367609.800	3908233.930	165.340	-0.03
2070_GPS	366279.730	3896264.270	155.540	-0.01
2071_GPS	370173.560	3891521.420	145.210	0
2072_GPS	361403.780	3875291.320	153.680	0
2072_GPS_A	361405.230	3875374.760	152.580	-0.01
2073_GPS	357374.340	3887885.340	138.870	0.03
2073_GPS_A	357367.660	3887928.060	138.320	0
2074_GPS	369363.990	3880284.080	189.830	0
2075_GPS	319001.580	3903304.960	134.760	-0.09
2075_GPS_A	318974.490	3903288.420	134.130	-0.07
2076_GPS	354219.220	3913963.040	144.790	-0.05
2077_GPS	335978.550	3897352.060	137.670	0.08
2078_GPS	325246.850	3889104.460	143.020	-0.12
2078_GPS_A	325191.380	3889041.560	144.910	-0.05

VERTICAL ACCURACY CONCLUSIONS

Bare-Earth DEM Non-Vegetated Vertical Accuracy (NVA) Tested 0.150 Meters Non-Vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM.

Table 5.4: Vegetated Vertical Accuracy Quality Check Point Analysis VVA

Point ID	Easting (meter)	Northing (meter)	DEM Elevation (meter)	Dz (meter)
3001_GPS	267664.290	3921396.140	95.110	-0.050
3001_GPS_A	268289.090	3921667.460	96.510	0.020
3002_GPS	304126.230	3915436.320	150.970	-0.020
3003_GPS	329805.970	3922916.590	147.800	-0.050
3004_GPS	339675.590	3902367.610	140.060	0.000
3005_GPS	339636.410	3902330.630	143.780	-0.030
3006_GPS	351104.580	3908248.880	147.710	-0.070
3007_GPS	375875.740	3916908.660	130.090	-0.010
3008_GPS	362262.740	3913580.200	176.080	-0.040
3009_GPS	280672.610	3882393.700	104.450	0.010
3009_GPS_A	280576.880	3882449.400	104.310	-0.040
3010_GPS	356757.970	3889989.790	149.960	-0.040
3010_GPS_A	356828.880	3889846.310	146.840	-0.040
3011_GPS	359558.590	3903413.650	188.030	-0.050
3011_GPS_A	359533.250	3903390.370	186.580	-0.060
3012_GPS	370153.660	3884961.070	182.760	0.020
3013_GPS	374693.870	3872785.750	139.340	-0.030
3013_GPS_A	374747.900	3872845.990	140.350	-0.030
3014_GPS	360013.800	3880547.470	132.690	-0.140
3014_GPS_A	360070.440	3880532.350	132.670	-0.070
3015_GPS	349214.900	3876424.600	123.670	-0.020
3015_GPS_A	349193.970	3876387.040	123.410	-0.040
3016_GPS	330771.920	3889230.880	132.670	0.010
3017_GPS	316968.830	3868542.170	209.650	-0.010
3017_GPS_A	316795.930	3869611.020	204.250	-0.050
3018_GPS	321864.290	3907436.870	108.040	0.040
3019_GPS	333398.430	3899599.580	113.260	-0.100
3020_GPS	346140.780	3887503.060	129.880	-0.050
3020_GPS_A	346100.220	3887558.510	127.780	-0.120
3021_GPS	269339.790	3880095.990	105.640	-0.090
3021_GPS_A	269367.380	3880152.820	105.230	-0.040
3022_GPS	319859.570	3880596.040	147.500	-0.070
3023_GPS	274589.230	3893205.660	125.780	-0.050
3023_GPS_A	274528.300	3893163.190	129.050	-0.030
3023_GPS_B	274524.400	3893175.120	128.880	-0.030

3024_GPS	312227.920	3895950.540	148.680	0.000
3024_GPS_A	312116.850	3895985.360	147.840	-0.150
3025_GPS	295215.890	3906539.970	137.370	-0.170
3026_GPS	288434.920	3894519.450	150.070	-0.100
3027_GPS	281905.270	3912322.190	113.690	-0.020
3028_GPS	262262.040	3912246.370	86.110	-0.030
3029_GPS	274241.400	3902510.970	123.230	-0.020
3030_GPS	259523.700	3900131.130	90.360	-0.110
3030_GPS_A	259389.450	3900144.700	89.650	-0.060
3031_GPS	274099.750	3910557.930	96.400	-0.190
3031_GPS_A	274056.960	3910560.320	95.700	-0.060
3032_GPS	273638.370	3886451.310	128.210	-0.340
3032_GPS_A	273717.050	3886430.240	129.940	-0.060
3033_GPS	304387.680	3888888.780	173.140	-0.170
3034_GPS	260900.890	3871061.920	124.800	-0.020
3034_GPS_A	260845.450	3871007.980	123.860	-0.070
3035_GPS	277212.930	3875690.280	137.230	0.090
3035_GPS_A	277239.250	3875735.830	136.100	0.130
3036_GPS	283245.620	3888358.130	149.890	-0.140
3036_GPS_A	283192.480	3888298.450	149.350	-0.040
3037_GPS	263719.930	3893050.760	120.230	-0.030
3038_GPS	259126.030	3888124.180	101.150	-0.130
3039_GPS	289305.770	3881784.080	133.860	-0.350
3039_GPS_A	289284.350	3881737.110	134.320	-0.160
3040_GPS	280934.880	3918915.160	110.110	-0.070
3041_GPS	290346.270	3914990.670	120.130	-0.090
3042_GPS	308024.160	3922892.240	121.870	-0.100
3042_GPS_A	307940.890	3922895.350	120.850	-0.090
3043_GPS	311113.880	3915065.130	130.480	0.020
3044_GPS	321513.490	3920065.140	150.070	-0.010
3044_GPS_A	321472.960	3920034.850	147.410	0.040
3045_GPS	304964.330	3910688.600	150.230	-0.110
3045_GPS_A	305014.720	3910660.190	149.800	-0.050
3046_GPS	315804.450	3906033.080	134.270	-0.120
3047_GPS	330339.670	3908489.960	119.850	-0.180
3047_GPS_A	330333.080	3908427.440	117.630	-0.040
3048_GPS	342186.030	3892090.140	135.160	-0.080
3049_GPS	315493.890	3887775.650	170.020	-0.010
3050_GPS	296161.030	3874729.490	139.210	-0.090
3050_GPS_A	296189.150	3874703.440	140.480	-0.030
3051_GPS	310933.230	3873886.180	196.590	-0.010
3051_GPS_A	311012.030	3873928.410	196.400	-0.030
3052_GPS	327369.480	3879767.220	131.380	-0.030
3052_GPS_A	327381.620	3879660.010	130.440	-0.020
3053_GPS	328029.490	3901777.660	157.710	-0.090
3053_GPS_A	328192.320	3901471.870	151.900	-0.230
3054_GPS	320919.730	3900830.250	115.110	-0.290

3054_GPS_A	320617.800	3901264.570	127.240	-0.200
3055_GPS	340525.310	3875836.000	148.180	-0.080
3056_GPS	345212.960	3883190.620	167.090	-0.080
3057_GPS	352784.180	3901315.670	148.660	-0.060
3057_GPS_A	352715.290	3901583.940	146.800	-0.130
3058_GPS	367651.580	3908339.180	167.600	-0.160
3058_GPS_A	367582.280	3908216.700	164.700	-0.050
3059_GPS	361380.090	3875367.250	152.230	-0.010
3059_GPS_A	361392.110	3875260.130	153.120	-0.050
3060_GPS	357343.070	3887946.840	138.080	-0.030
3061_GPS	320782.560	3880797.610	163.330	-0.120
3062_GPS	290414.670	3915067.440	119.050	-0.030
3063_GPS	304360.030	3888850.370	173.160	-0.140
3070_GPS	366251.720	3896238.910	156.430	-0.060
3071_GPS	370183.410	3891495.330	144.650	0.000

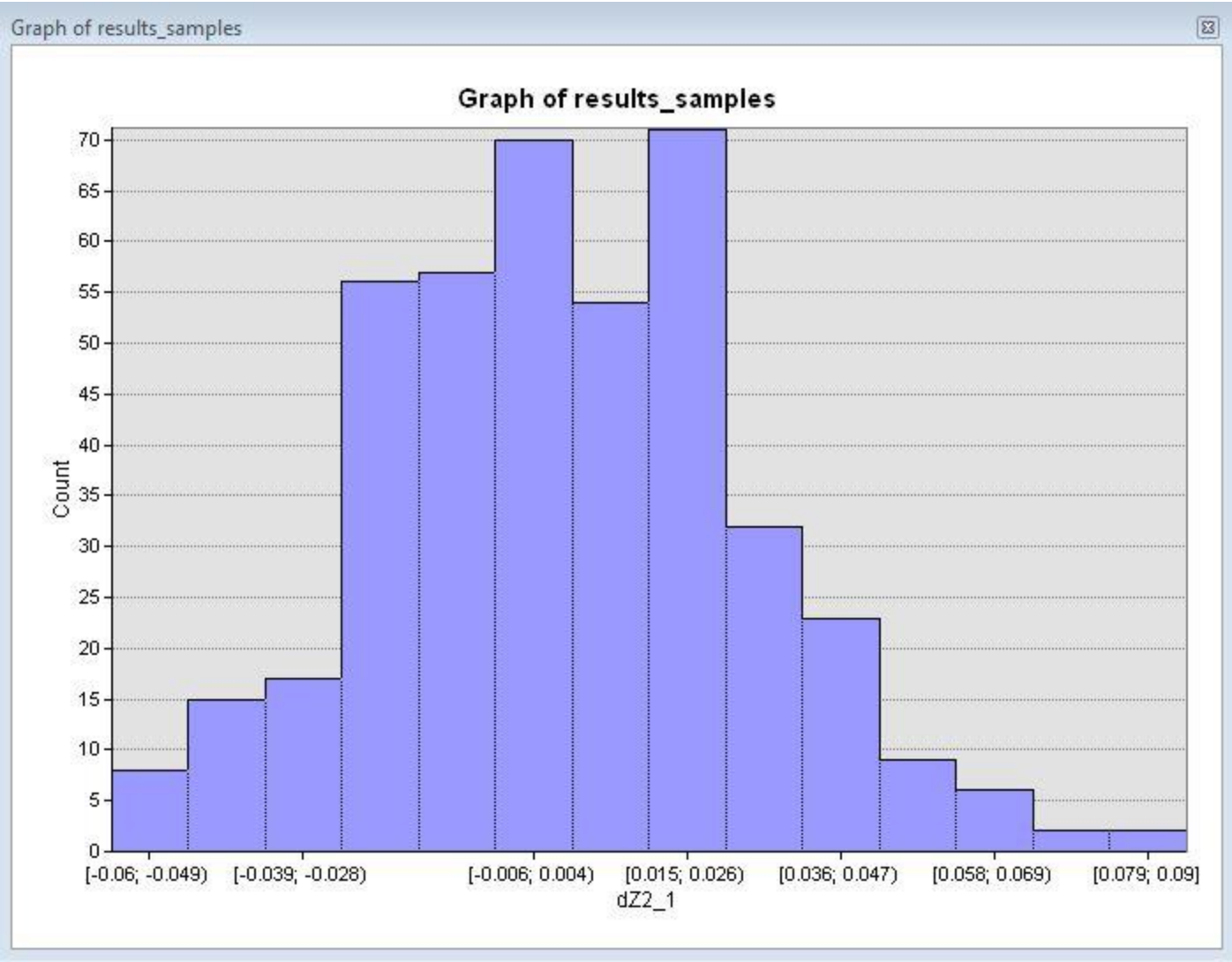
VERTICAL ACCURACY CONCLUSIONS

Vegetated Vertical Accuracy (VVA) Tested 0.192 Meters at the 95th percentile reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. VVA Errors larger than 95th percentile include:
Point 3032GPS, Easting 273638.370, Northing 3886451.310, Z-Error 0.340 meters
Point 3039GPS, Easting 289305.770, Northing 3881784.080, Z-Error 0.350 meters
Point 3053GPS_A, Easting 328192.320, Northing 3879660.010, Z-Error 0.230 meters
Point 3054GPS, Easting 320919.730, Northing 3900830.250, Z-Error 0.290 meters
Point 3054GPS_A, Easting 320617.800, Northing 3901264.570, Z-Error 0.200 meters

RELATIVE ACCURACY ASSESSMENT AND CONCLUSION

Relative accuracy also known as "between swath" accuracy was tested through a series of well distributed flight line overlap locations. The relative accuracy for the TN 3 County QL2 Lidar tested at 0.090 meters RMSDz.

Figure 5.1: Relative Accuracy Histogram, TN 3 County QL2 Lidar



Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		June 2016

Section 6: Flight Logs

Flight logs for the project are shown on the following pages:

ALS80 LiDAR Flight Log														
Project		TN3CountyQL2			ALS80	SN 8235							Sensor Operator/s	
											-		Bertin Evina-Ze	
Date/Julian:		12/17/2015			Mem Drive MM70			TAR AIRSPD (KNTS)				Base PID:	Pilot/s	
Hobbs End		2925.9			1-808654A			155				TEMP	MWAZ	
Hobbs ST		2921.1		LIFT				TAR ALT AGL (ft):		Flight Plan(s):		Base Height:	Aircraft	Airport Idnt:
Flight Time		4.8		A				6,300		TN_ALS80		1.500	421C 13RF	CRX(Corinth, MS)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A									744				
	1	69	151217_153730	15:37	15:48	6,300	0	156	739	15	1.3	0.7	
	2	70	151217_155325	15:53	16:04		180	157	735	15	1.2	0.7	
	3	71	151217_160845	16:08	16:19		0	155	730	15	1.2	0.7	
	4	72	151217_162401	16:24	16:34		180	157	725	14	1.2	0.8	
	5	73	151217_163935	16:39	16:50		0	155	720	13	1.5	0.9	
	6	74	151217_165512	16:55	17:05		180	156	715	14	1.3	0.8	
	7	75	151217_171038	17:10	17:20		0	155	710	15	1.2	0.8	
	8	76	151217_172540	17:25	17:34		180	157	706	15	1.3	0.8	
	9	77	151217_173932	17:39	17:48		0	156	702	16	1.3	0.7	
	10	78	151217_175353	17:53	18:02		180	155	697	17	1.1	0.6	
	11	79	151217_180723	18:07	18:15		0	155	693	17	1.2	0.6	
	12	80	151217_182036	18:20	18:28		180	156	690	17	1.2	0.6	
	13	81	151217_183316	18:33	18:39		0	155	687	18	1.1	0.6	
	14	82	151217_184433	18:44	18:50		180	155	684	19	1.0	0.6	
	15	X04	151217_185712	18:57	19:03		270	155	681	17	1.3	0.6	X-STRIP
	16	68	151217_191303	19:13	19:23		0	156	676	18	1.2	0.6	
	17	X02	151217_193126	19:31	19:36		90	160	673	18	1.2	0.6	X-STRIP
	18	83	151217_194144	19:41	19:48		180	158	670	18	1.2	0.6	

ALS80 LiDAR Flight Log													
Project	TN3CountyQL2			ALS80	SN 8235							Sensor Operator/s	
										-		Bertin Evina-Ze	
Date/Julian:	12/17/2015			Disk Drive MM70			TAR AIRSPD (KNTS)				Base PID:	Pilot/s	
Hobbs End	2930.7			1-808654A			155				TEMP	MWAZ	
Hobbs ST	2925.9		LIFT				TAR ALT AGL (ft):		Flight Plan(s):		Base Height:	Aircraft	Airport Idnt:
Flight Time	4.8		B				6,300		TN_ALS80		1.500	421C 13RF	CRX(Corinth, MS)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
B									670				
	1	84	151217_213849	21:38	21:46	6,300	0	155	666	18	1.2	0.7	
	2	85	151217_215217	21:52	22:00		180	156	663	17	1.3	0.7	
	3	86	151217_220533	22:05	22:13		0	156	659	16	1.3	0.7	
	4	87	151217_221846	22:18	22:27		180	154	655	17	1.1	0.6	
	5	88	151217_223323	22:33	22:42		0	158	651	17	1.2	0.7	
	6	89	151217_224800	22:48	22:56		180	156	647	18	1.0	0.6	
	7	90	151217_230255	23:03	23:12		0	158	643	15	1.4	0.7	
	8	91	151217_231739	23:18	23:26		180	156	639	17	1.1	0.6	
	9	92	151217_233225	23:32	23:41		0	156	634	15	1.3	0.7	
	10	93	151217_234641	23:46	23:55		180	155	630	16	1.3	0.7	
	11	94	151218_000128	24:01	24:10		0	155	626	16	1.1	0.7	
	12	95	151218_001606	24:16	24:25		180	156	622	16	1.1	0.7	
	13	96	151218_003010	24:30	24:39		0	154	617	16	1.0	0.7	
	14	97	151218_004417	24:44	24:53		180	154	613	13	1.3	0.8	
	15	X04	151218_010237	1:02	1:06		270	154	611	14	1.2	0.8	X-STRIP
	16	98	151218_011539	1:16	1:25		0	155	607	15	1.2	0.7	
	17	X02	151218_013319	1:33	1:37		270	158	605	15	1.2	0.7	X-STRIP
	18	99	151218_014730	1:47	1:58		180	155	601	16	1.2	0.7	

ALS80 LiDAR Flight Log														
Project	TN3CountyQL2			ALS80	SN 8235								Sensor Operator/s	
											-		Bertin Evina-Ze	
Date/Julian:	12/18/2015			Disk Drive MM70			TAR AIRSPD (KNTS)					Base PID:	Pilot/s	
Hobbs End	2930.7			1-808654A			155					TEMP	Mike Millard	
Hobbs ST	2925.9		LIFT				TAR ALT AGL (ft):		Flight Plan(s):			Base Height:	Aircraft	Airport Idnt:
Flight Time	4.8		B				6,400		TN_ALS80			1.500	421C 13RF	CRX(Corinth, MS)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
B									600				
	1	100	151218_225226	22:52	23:02	6,400	0	150	595	18	1.1	0.6	
	2	101	151218_230820	23:08	23:17		180	156	591	17	1.2	0.7	
	3	102	151218_232328	23:23	23:33		0	154	587	16	1.3	0.7	
	4	103	151218_233843	23:38	23:48		180	155	582	16	1.3	0.7	
	5	104	151218_235358	23:54	24:03		0	154	578	17	1.1	0.6	
	6	105	151219_000839	24:08	24:18		180	158	573	17	1.1	0.6	
	7	106	151219_002559	24:26	24:35		0	152	569	18	1.0	0.6	
	8	107	151219_004155	24:41	24:51		180	155	564	14	1.3	0.8	
	9	108	151219_005741	24:57	1:07		0	155	560	15	1.2	0.7	
	10	109	151219_011232	1:12	1:22		180	158	556	16	1.2	0.7	
	11	110	151219_012838	1:28	1:38		0	154	551	16	1.2	0.7	
	12	X01	151219_014321	1:43	1:47		180	151	550	17	1.2	0.6	X-STRIP
	13	111	151219_015417	1:54	2:03		0	155	545	16	1.3	0.7	
	14	X04	151219_021000	2:10	2:13		270	153	544	17	1.3	0.7	X-STRIP
	15	112	151219_022136	2:21	2:31		0	155	539	19	1.1	0.6	

ALS80 LiDAR Flight Log													
Project	TN3CountyQL2			ALS80	SN 8235								Sensor Operator/s
										-			Bertin Evina-Ze
Date/Julian:	12/19/2015			Disk Drive MM70			TAR AIRSPD (KNTS)				Base PID:		Pilot/s
Hobbs End	2939.0			1-808654A			155				TEMP		MWAZ
Hobbs ST	2935.0		LIFT				TAR ALT AGL (ft):		Flight Plan(s):		Base Height:	Aircraft	Airport Idnt:
Flight Time	4.0		A				6,350		TN_ALS80		1.500	421C 13RF	CRX(Corinth, MS)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A									539				
	1	X04	151219_152023	15:20	15:22	6,350	90	156	538	17	1.3	0.7	X-STRIP
	2	113	151219_152756	15:27	15:37		0	155	534	16	1.3	0.7	
	3	114	151219_154219	15:42	15:52		180	156	529	16	1.2	0.7	
	4	115	151219_155633	15:56	16:06		0	155	525	16	1.2	0.7	
	5	116	151219_161024	16:10	16:20		180	158	521	15	1.2	0.8	
	6	117	151219_162546	16:25	16:35		0	155	516	15	1.2	0.8	
	7	X01	151219_164114	16:41	16:45		90	155	514	15	1.0	0.8	X-STRIP
	8	X03	151219_165133	16:51	16:55		250	153	512	16	1.1	0.7	X-STRIP
	9	118	151219_165940	16:59	17:02		0	157	511	16	1.1	0.7	
	10	119	151219_170744	17:07	17:11		180	154	509	16	1.1	0.7	
	11	120	151219_171536	17:15	17:18		0	155	508	16	1.2	0.7	
	12	121	151219_172340	17:23	17:27		180	157	507	17	1.2	0.7	
	13	122	151219_173151	17:31	17:34		0	154	505	18	1.1	0.6	
	14	123	151219_173928	17:39	17:42		180	157	504	18	1.1	0.6	
	15	124	151219_174738	17:47	17:50		0	154	502	19	1.1	0.6	
	16	125	151219_175538	17:55	17:58		180	157	501	19	1.1	0.6	
	17	126	151219_180239	18:02	18:05		0	157	500	19	1.1	0.6	
	18	127	151219_181011	18:10	18:12		180	156	499	19	1.1	0.6	
	19	128	151219_181800	18:18	18:20		0	154	498	19	1.1	0.6	
	20	129	151219_182518	18:25	18:27		180	157	497	21	1.1	0.6	
	21	130	151219_183241	18:32	18:32		0	154	496	21	1.0	0.6	
	22	131	151219_183901	18:39	18:40		180	155	496	20	1.0	0.6	

ALS80 LiDAR Flight Log														
Project	TN3CountyQL2			ALS80	SN 8235								Sensor Operator/s	
											-		Bertin Evina-Ze	
Date/Julian:	12/19/2015			Disk Drive MM70			TAR AIRSPD (KNTS)					Base PID:	Pilot/s	
Hobbs End	2943.6			1-808654A			155					TEMP	Mike Millard	
Hobbs ST	2939.0		LIFT				TAR ALT AGL (ft):		Flight Plan(s):			Base Height:	Aircraft	Airport Idnt:
Flight Time	4.6		A				6,300		TN_ALS80			1.500	421C 13RF	CRX(Corinth, MS)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A									495				
	1	67	151219_213244	21:32	21:43	6,300	0	156	490	17	1.1	0.7	
	2	66	151219_214858	21:49	21:59		180	154	485	16	1.3	0.7	
	3	65	151219_220532	22:05	22:16		0	157	480	16	1.1	0.6	
	4	64	151219_222148	22:21	22:33		180	157	475	16	1.1	0.6	
	5	63	151219_223817	22:38	22:49		0	155	470	15	1.1	0.6	
	6	62	151219_225533	22:55	23:07		180	157	465	15	1.2	0.7	
	7	61	151219_231217	23:12	23:24		0	158	460	15	1.1	0.6	
	8	60	151219_232840	23:28	23:40		180	156	455	16	1.3	0.7	
	9	59	151219_234449	23:44	23:56		0	155	450	16	1.2	0.7	
	10	58	151220_000137	24:01	24:13		180	153	445	16	1.1	0.6	
	11	X04	151220_002018	24:20	24:23		270	154	440	16	1.0	0.6	X-STRIP
	12	57	151220_002912	24:29	24:41		0	154	435	17	1.2	0.7	
	13	X01	151220_004858	24:49	24:52		270	158	433	18	1.2	0.7	X-STRIP
	14	56	151220_005904	24:59	1:10		180	156	428	18	1.2	0.7	
	15	55	151220_011538	1:15	1:27		0	156	422	19	1.2	0.7	

ALS80 LiDAR Flight Log														
Project	TN3CountyQL2			ALS80	SN 8235								Sensor Operator/s	
											-		Bertin Evina-Ze	
Date/Julian:	12/20/2015			Disk Drive MM70			TAR AIRSPD (KNTS)					Base PID:	Pilot/s	
Hobbs End	2948.0			1-808654A			155					TEMP	MWAZ	
Hobbs ST	2943.6		LIFT				TAR ALT AGL (ft):		Flight Plan(s):			Base Height:	Aircraft	Airport Idnt:
Flight Time	4.4		A				6,300		TN_ALS80			1.500	421C 13RF	CRX(Corinth, MS)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A									422				
	1	X04	151220_153304	15:33	15:37	6,300	270	157	420	17	1.3	0.7	X-STRIP
	2	41	151220_154152	15:41	15:52		0	156	415	16	1.2	0.7	
	3	X01	151220_155900	15:59	16:04		90	156	412	16	1.1	0.7	X-STRIP
	4	54	151220_161029	16:10	16:22		180	152	407	16	1.2	0.8	
	5	53	151220_162709	16:27	16:38		0	156	402	15	1.4	0.8	
	6	52	151220_164347	16:43	16:55		180	154	397	15	1.1	0.7	
	7	51	151220_165959	17:00	17:10		0	158	392	15	1.1	0.7	
	8	50	151220_171619	17:16	17:27		180	152	387	16	1.2	0.7	
	9	49	151220_173129	17:31	177:42		0	157	382	18	1.1	0.6	
	10	48	151220_174738	17:47	17:58		180	156	377	19	1.1	0.6	
	11	47	151220_180257	18:03	18:13		0	157	372	19	1.1	0.6	
	12	46	151220_181846	18:18	18:30		180	153	367	21	1.0	0.5	
	13	45	151220_183405	18:34	18:44		0	155	362	20	1.0	0.6	
	14	44	151220_185032	18:50	19:01		180	152	357	18	1.3	0.6	
	15	43	151220_190557	19:05	19:36		0	157	352	18	1.3	0.6	
	16												

ALS80 LiDAR Flight Log													
Project	TN3CountyQL2			ALS80	SN 8235							Sensor Operator/s	
										-		Bertin Evina-Ze	
Date/Julian:	1/5/2016			Disk Drive MM70			TAR AIRSPD (KNTS)				Base PID:	Pilot/s	
Hobbs End	2964.1			1-808654A			155				FE2752	MWAZ	
Hobbs ST	2959.6		LIFT				TAR ALT AGL (ft):		Flight Plan(s):		Base Height:	Aircraft	Airport Idnt:
Flight Time	4.5		A				6,300		TN_ALS80		1.500	421C 13RF	M08 (Bolivar, TN)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A									392				
	1	28	160105_180908	18:09	18:19	6,300	180	156	348	18	1.3	0.7	
	2	27	160105_182406	18:24	18:34		0	157	344	19	1.2	0.6	
	3	26	160105_183846	18:38	18:48		180	156	338	20	1.1	0.6	
	4	25	160105_185347	18:53	19:03		0	158	334	20	1.1	0.6	
	5	24	160105_190826	19:08	19:18		180	156	330	20	1.0	0.6	
	6	23	160105_192249	19:22	19:32		0	156	326	19	1.0	0.6	
	7	22	160105_193736	19:37	19:48		180	155	322	21	1.0	0.5	
	8	21	160105_195210	19:52	20:02		0	157	318	20	1.0	0.6	
	9	20	160105_201025	20:11	20:20		180	154	314	19	1.1	0.6	
	10	19	160105_202440	20:24	20:34		0	157	310	18	1.2	0.6	
	11	X01	160105_204121	20:41	20:46		270	155	306	18	1.2	0.7	X-STRIP
	12	18	160105_205115	20:51	21:01		180	156	302	17	1.2	0.7	
	13	X04	160105_210758	21:08	21:11		90	156	300	17	1.1	0.7	X-STRIP
	14	17	160105_211537	21:15	21:25		0	155	296	19	1.0	0.6	
	15	16	160105_213021	21:30	21:40		180	157	292	18	1.0	0.6	
	16	15	160105_214529	21:45	21:55		0	155	287	16	1.3	0.7	

ALS80 LiDAR Flight Log													
Project	TN3CountyQL2			ALS80	SN 8235							Sensor Operator/s	
										-		Bertin Evina-Ze	
Date/Julian:	1/5/2016			Disk Drive MM70			TAR AIRSPD (KNTS)				Base PID:	Pilot/s	
Hobbs End	2964.1			1-808654A			155				FE2752	Mike Millard	
Hobbs ST	2959.6		LIFT				TAR ALT AGL (ft):		Flight Plan(s):		Base Height:	Aircraft	Airport Idnt:
Flight Time	4.5		B				6,300		TN_ALS80		1.500	421C 13RF	M08 (Bolivar, TN)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
B									287				
	1	X01	160105_232101	23:21	23:24	6,300	270	157	285	16	1.2	0.7	X-STRIP
	2	1	160105_233017	23:30	23:40		180	155	281	15	1.2	0.7	
	3	2	160105_234532	23:46	23:56		0	156	277	15	1.2	0.7	
	4	3	160106_000131	24:01	24:12		180	159	273	16	1.2	0.6	
	5	4	160106_001658	24:17	24:27		0	155	269	17	1.1	0.6	
	6	5	160106_003250	24:32	24:43		180	160	265	17	1.2	0.7	
	7	6	160106_004841	24:49	24:59		0	156	261	18	1.3	0.6	
	8	7	160106_010529	1:05	1:16		180	143	257	17	1.1	0.6	
	9	8	160106_012134	1:21	1:32		0	156	253	19	1.2	0.6	
	10	9	160106_013810	1:33	1:45		180	158	249	16	1.1	0.6	
	11	10	160106_015330	1:53	2:03		0	156	245	16	1.4	0.6	
	12	11	160106_020908	2:09	2:19		180	160	241	16	1.4	0.6	
	13	12	160106_022406	2:24	2:34		0	157	237	16	1.4	0.6	
	14	13	160106_024012	2:40	2:50		180	152	233	18	1.2	0.6	
	15	X04	160106_025728	2:57	3:01		90	155	229	16	1.3	0.7	X-STRIP
	16	14	160106_030708	3:07	3:17		0	156	225	16	1.3	0.7	

ALS80 LiDAR Flight Log

Project	TN3CountyQL2			ALS80	SN 8235							Sensor Operator/s	
										-		Bertin Evina-Ze	
Date/Julian:	1/6/2016			Disk Drive MM70			TAR AIRSPD (KNTS)				Base PID:	Pilot/s	
Hobbs End	2968.7			1-808654A			155				FE2752	MWAZ	
Hobbs ST	2964.1		LIFT				TAR ALT AGL (ft):		Flight Plan(s):		Base Height:	Aircraft	Airport Idnt:
Flight Time	4.6		A				6,300		TN_ALS80		1.500	421C 13RF	M08 (Bolivar, TN)

Lift		Flight Line	Mission Line	UTC time: B:	UTC time: E:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A									219				
	1	X01	160106_175005	17:50	17:53	6,300	270	156	217	19	1.2	0.6	X-STRIP
	2	29	160106_175849	17:58	18:08		180	157	213	19	1.2	0.6	
	3	30	160106_181255	18:13	18:23		0	156	209	19	1.2	0.6	
	4	31	160106_182718	18:27	18:37		180	157	205	19	1.2	0.6	
	5	32	160106_184152	18:42	18:51		0	156	200	19	1.1	0.6	
	6	33	160106_185642	18:56	19:06		180	157	195	18	1.1	0.6	
	7	34	160106_191105	19:11	19:21		0	155	190	20	0.9	0.6	
	8	35	160106_192610	19:26	19:36		180	155	186	19	1.0	0.7	
	9	36	160106_194021	19:40	19:50		0	155	181	18	1.1	0.5	
	10	37	160106_195509	19:55	20:05		180	158	177	17	1.1	0.6	
	11	38	160106_200930	20:09	20:19		0	155	172	16	1.0	0.7	
	12	39	160106_202446	20:24	20:34		180	155	167	17	1.2	0.7	
	13	40	160106_203918	20:39	20:49		0	155	162	17	1.3	0.8	
	14	42	160106_205306	20:53	21:04		180	156	157	18	1.1	0.7	
	15	X04	160106_210841	21:08	21:13		270	158	158	16	1.1	0.7	X-STRIP

Section 7: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.4 classified point cloud
- LAS v1.4 raw unclassified point cloud flight line strips.
- Hydro Breaklines as ESRI shapefile
- Bridge Breaklines as ESRI shapefile
- Digital Elevation Model in ESRI Grid format
- 8-bit gray-scale intensity images in .TIF format
- Tile layout and data extent provided as ESRI shapefile
- Control Points provided as ESRI shapefile
- FGDC compliant metadata per product in XML format
- Lidar processing report in pdf format
- Survey report in pdf format