Project Report

TASK ORDER NAME: 2018 Kansas QL2 LiDAR
CONTRACT ID: 00000000000000000000039891
EVENT ID: EVT0003259
ATLANTIC PROJECT NUMBER: 18006
PROJECT BLOCK NUMBER: Block 7A

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SECTION I: PROJECT OVERVIEW & PURPOSE

1. Aerial LiDAR Project

a. Project Overview

The State of Kansas Contract 00000000000000000000039891 required Leaf-off 2018 QL 2 LiDAR surveys to be collected over 54,663 square miles covering part or all of 86 counties in Kansas in support of the Kansas Department of Agriculture and Kansas Data Access and Support Center. Aerial LiDAR data for this task order was planned, acquired, processed and produced at an aggregate nominal pulse spacing (ANPS) of 0.71 meters and in compliance with USGS National Geospatial Program LiDAR Base Specification version 1.2. Project Block 7A encompasses part or all of 7 counties in Southern Kansas and covers approximately 2200.78 square miles.

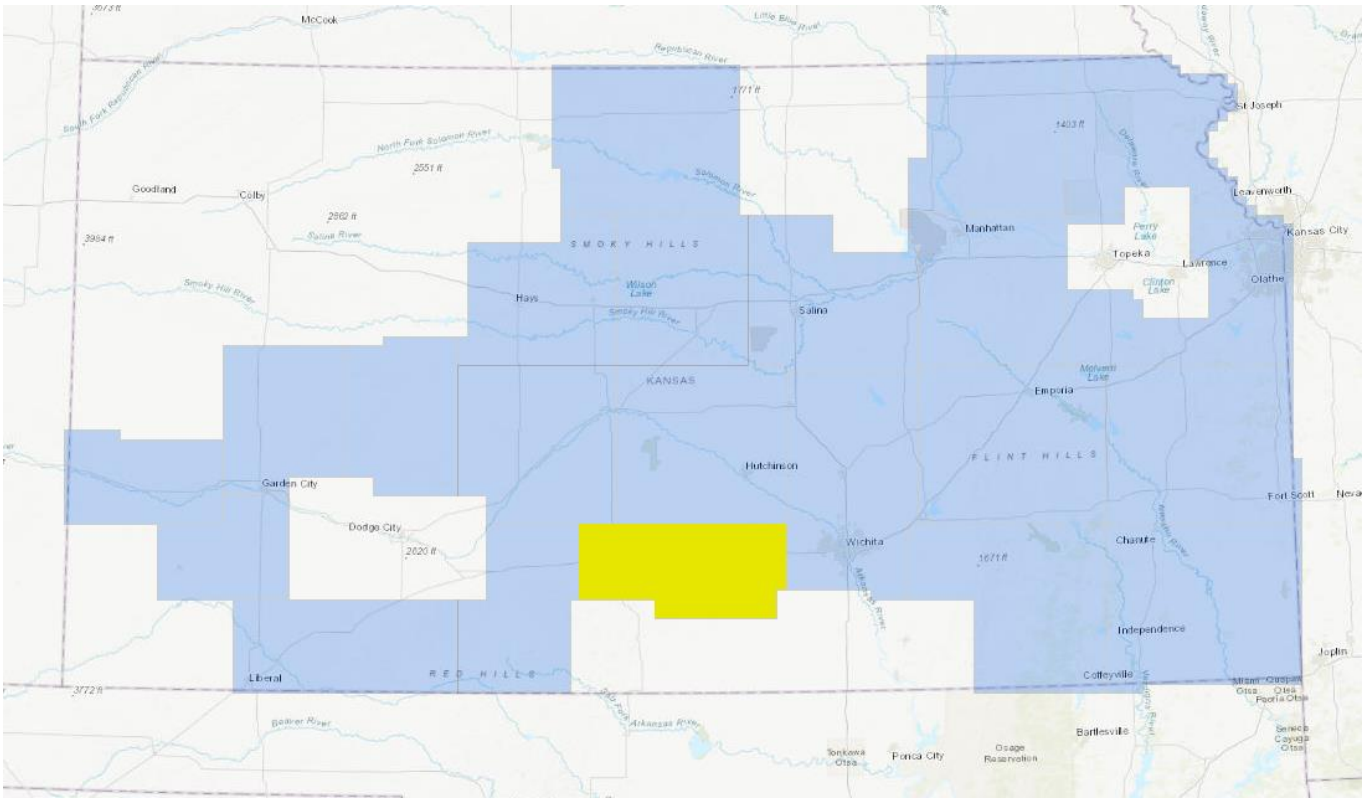


Figure 1: Aerial LiDAR Project Overview – Defined Project Area (DPA) and Associated Areas of Interest (AOIs)

b. Project Purpose

The State of Kansas, on behalf of the Kansas Department of Agriculture and Kansas Data Access and Support Center, has contracted with Atlantic for professional services related to the development of Light Detection and Ranging (LiDAR). Additional partners include the USDA Natural Resource Conservation Service, the U.S. Geological Survey, the Kansas GIS Policy Board, the Kansas Department of Transportation and the Kansas Water Office. These LiDAR elevation data will be used for conservation planning, design, research, floodplain mapping, wetlands identification, dam safety assessments, hydrologic modeling, and subsidence monitoring.

c. Client Contact Information

Client Contact Information	
Name of Contact	Tara Lanzrath, CFM
Organization	Kansas Department of Agriculture
Position	Floodplain Mapping Coordinator
Telephone	785-296-2513
E-Mail Address	Tara.Lanzrath@ks.gov
Mailing Address	6531 SE Forbes Ave., Suite B
City	Topeka
State or Province	Kansas
Postal Code	66619

Table 1: Aerial LiDAR Client Contact Information

d. Contract Deliverables

Item	Specification/Format
Metadata	FGDC compliant, xml format
Project Report	.pdf format
Raw Point Cloud	Swaths, LAS 1.4
Classified Point Cloud	LAS 1.4
Bare Earth DEM	ERDAS .IMG format, Hydroflattened
First Return DSM	ERDAS .IMG format
Hydro Polygon Breaklines	.gdb format
Intensity Imagery	ERDAS .IMG format

Table 2: Aerial LiDAR Contract Deliverables

SECTION II: FIELD OPERATIONS

1. Aerial LiDAR Project – Aerial Acquisition

a. Aircraft & Sensor Information

Atlantic operated a Cessna (N732JE) outfitted with a Leica ALS70-HP LiDAR system during the collection of the project area. The specifications of this system are presented in the following table:

Parameter	Specification
Model	ALS70-HP
Manufacturer	Leica
Platform	Fixed-Wing
Scan Pattern	Sine, Triangle, Raster
Maximum Scan Rate (Hz)	Sine: 200 Triangle: 158 Raster: 120
Field of View (°)	0 – 75 (Full Angle, User Adjustable)
Maximum Pulse Rate (kHz)	500
Maximum Flying Height (m AGL)	3500
Number of Returns	Unlimited
Number of Intensity Measurements	3 (First, Second, Third)
Roll Stabilization (Automatic Adaptive, °)	75 - Active FOV
Storage Media	Removable 500 GB SSD
Storage Capacity (Hours @ Max Pulse Rate)	6
Size (cm)	Scanner: 37 W x 68 L x 26 H Control Electronics: 45 W x 47 D x 36 H
Weight (kg)	Scanner: 43 Control Electronics: 45
Operation Temperature (°C)	0 – 40
Flight Management	FCMS
Power Consumption	927 @ 22.0 – 30.3 VDC

Table3: System Specifications – ALS70-HP

b. Sensor Acquisition Information

The following table illustrates project specific system parameters for LiDAR acquisition on this project:

Parameter	Specification
System	Leica ALS70-HP
Nominal Pulse Spacing (m)	0.71
Nominal Pulse Density (pls/m²)	2.2
Nominal Flight Height (AGL meters)	2000
Nominal Flight Speed (kts)	130
Pass Heading (°)	0
Sensor Scan Angle (°)	45
Scan Frequency (Hz)	33.9
Pulse Rate of Scanner (kHz)	256,400
Line Spacing (m)	1,171

Parameter	Specification
Pulse Duration of Scanner (ns)	4
Pulse Width of Scanner (m)	.35
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	2
Beam Divergence (mrad)	.15
Nominal Swath Width (m)	1,740
Nominal Swath Overlap (%)	20
Scan Pattern	TRIANGLE

Table 4: Aerial LiDAR Sensor Acquisition Parameters

c. Flight Plan Execution

Atlantic acquired 79 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 7 flight missions conducted between February 11, 2018 and April 29, 2018. Onboard differential Global Navigation Satellite System (GNSS) unit(s) recorded sample aircraft positions at 2 hertz (Hz) or more frequency. LiDAR data was only acquired when a minimum of six (6) satellites were in view.

Figure 2: Orientation of Executed Flight-lines and LiDAR DPA

d. GNSS Reference Stations

Eleven (11) Continuously Operating Reference Stations (CORS) were used to control the LiDAR acquisition for the defined project area. The coordinates provided in below are in NAD83 (2011), Geographic Coordinate System, Ellipsoid, Meters.

Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
ICT3	CORS	ICT3	37°45'09.33297"	97°12'58.42230	401.242m
ICT4	CORS	ICT4	37°37'08.57671"	97°37'57.00056"	392.172m
ICT5	CORS	ICT5	37°47'12.04062"	97°37'32.73360"	411.107m
KSPR	CORS	KSPR	37°41'26.44138"	98°44'27.53387"	573.45m
KSBK	CORS	KSBK	37°33'03.90852"	99°38'06.26885"	717.084m
KSCW	CORS	KSCW	37°16'24.87324"	99°19'39.34067"	624.848m
KSAY	CORS	KSAY	37°08'40.33068"	98°01'49.57453"	383.653m
KSKY	CORS	KSKY	37°54'40.30614"	99°24'21.76286"	641.963m
KSGB	CORS	KSGB	38°21'16.83108"	98°45'53.40654"	545.627m
KSHU	CORS	KSHU	38°01'52.62370"	97°54'08.45874"	440.099m
OKBF	CORS	OKBF	36°49'40.90146'	99°38'28.88423"	538.779m

Table 5: GNSS Reference Stations

2. Aerial LiDAR Project – Ground Acquisition

a. Ground Control Survey

A total of 72 ground survey points were collected in support of this project, including 19 LiDAR Control Points (LCP), 32 Non-vegetated Vertical Accuracy (NVA) and 21 Vegetated Vertical Accuracy (VVA).

Point cloud data accuracy was tested against a Triangulated Irregular Network (TIN) constructed from LiDAR points in clear and open areas. A clear and open area can be characterized with respect to topographic and ground cover variation such that a minimum of five (5) times the Nominal Pulse Spacing (NPS) exists with less than 1/3 of the RMSEZ deviation from a low-slope plane. Slopes that exceed ten (10) percent were avoided.

Each land cover type representing ten (10) percent or more of the total project area were tested and reported with a VVA. In land cover categories other than dense urban areas, the tested points did not have obstructions forty-five (45) degrees above the horizon to ensure a satisfactory TIN surface. The VVA value is provided as a target. It is understood that in areas of dense vegetation, swamps, or extremely difficult terrain, this value may be exceeded.

The NVA value is a requirement that must be met, regardless of any allowed "busts" in the VVA(s) for individual land cover types within the project. Checkpoints for each assessment (NVA & VVA) are required to be well-distributed throughout the land cover type, for the entire project area.

The following tables and figures outline the coordinate values and distribution of LCP, NVA and VVA points collected in support of this project:

ID	Easting	Northing	Elevation
LCP321	606210.033	4187082.513	455.845
LCP322	594831.41	4172026.541	448.235
LCP323	596362.922	4165699.367	431.984
LCP324	591670.856	4159295.112	469.519
LCP325	598946.951	4151226.583	451.276
LCP326	581289.478	4149311.527	462.226
LCP327	571165.951	4181298.778	500.931
LCP330	566924.722	4166995.726	478.873
LCP485	508595.759	4156757.143	626.714
LCP489	525478.462	4153610.773	585.306
LCP490	535955.422	4156893.632	564.632
LCP491	539097.479	4161139.446	559.994
LCP492	527622.785	4164847.925	552.055
LCP503	532516.214	4180857.97	580.136
LCP506	562158.14	4153861.914	517.347
LCP528	589405.33	4142953.445	425.579
LCP593	511666.019	4182225.826	612.006
LCP595	534013.414	4186386.102	571.254

ID	Easting	Northing	Elevation
LCP596	558547.915	4157577.762	520.247

Table 6: LiDAR Control Point Coordinates

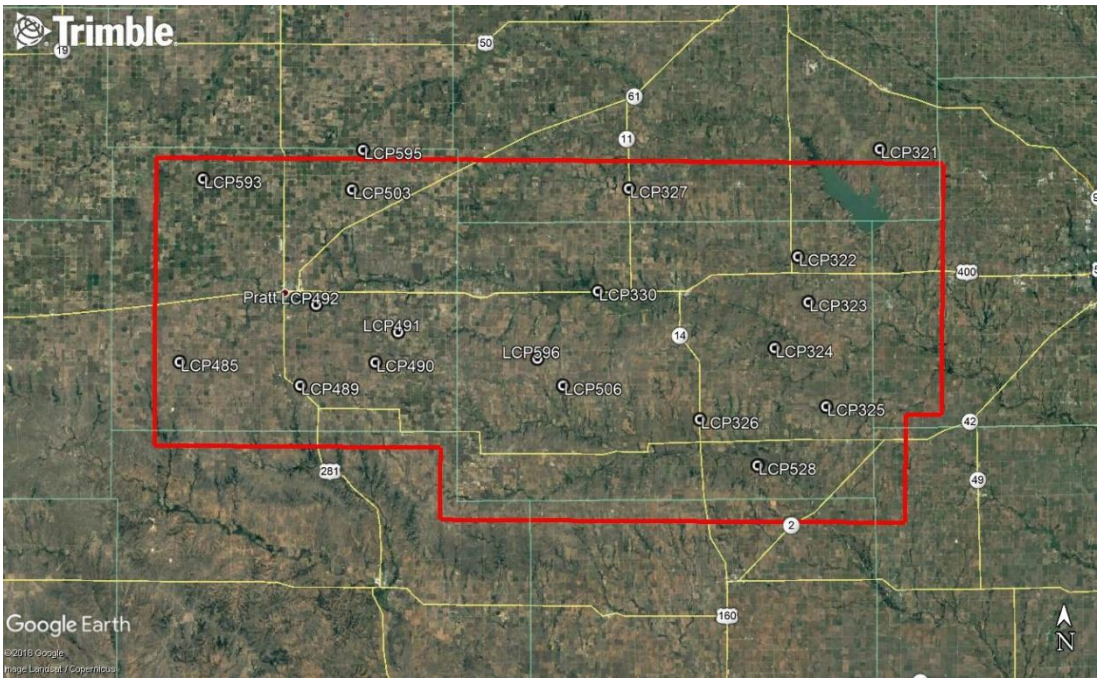


Figure 3: LiDAR Control Point Distribution

ID	Easting	Northing	Elevation
NVA423	513360.175	4175581.513	609.667
NVA429	508595.483	4156766.924	626.159
NVA431	539107.888	4161131.726	559.7
NVA432	581297.054	4149310.246	462.072
NVA433	591669.623	4159289.817	469.432
NVA434	525473.381	4153619.375	585.603
NVA435	594831.127	4172022.511	448.216
NVA436	562163.824	4153853.365	517.197
NVA437	532532.335	4180866.795	580.111
NVA438	571170.511	4181324.275	500.728
NVA624	506846.106	4174567.157	621.707
NVA630	571346.327	4173465.495	503.532
NVA631	554465.202	4156950.709	537.302
NVA632	560257.867	4143261.957	514.592
NVA633	544807.822	4174646.514	547.691
NVA634	539610.153	4152040.402	563.467
NVA635	584174.165	4175053.893	464.203
NVA636	581199.577	4156147.195	487.595

ID	Easting	Northing	Elevation
NVA637	581512.388	4139450.92	483.178
NVA638	599169.825	4138242.699	413.39
NVA822	511655.96	4182226.555	611.865
NVA831	578315.191	4166269.884	457.697
NVA832	585576.328	4182043.222	477.028
NVA833	550027.967	4166721.485	520.288
NVA834	523443.642	4175789.798	595.141
NVA835	551198.077	4143906.093	532.569
NVA836	601859.293	4146426.619	454.032
NVA837	550499.762	4184408.781	536.096
NVA838	574003.32	4144603.049	458.775
NVA862	578287.422	4160670.032	485.515
NVA891	508367.645	4166397.624	618.562
NVA896	554464.48	4156958.18	537.539

Table 7: Non-Vegetated Vertical Accuracy (NVA) Point Coordinates

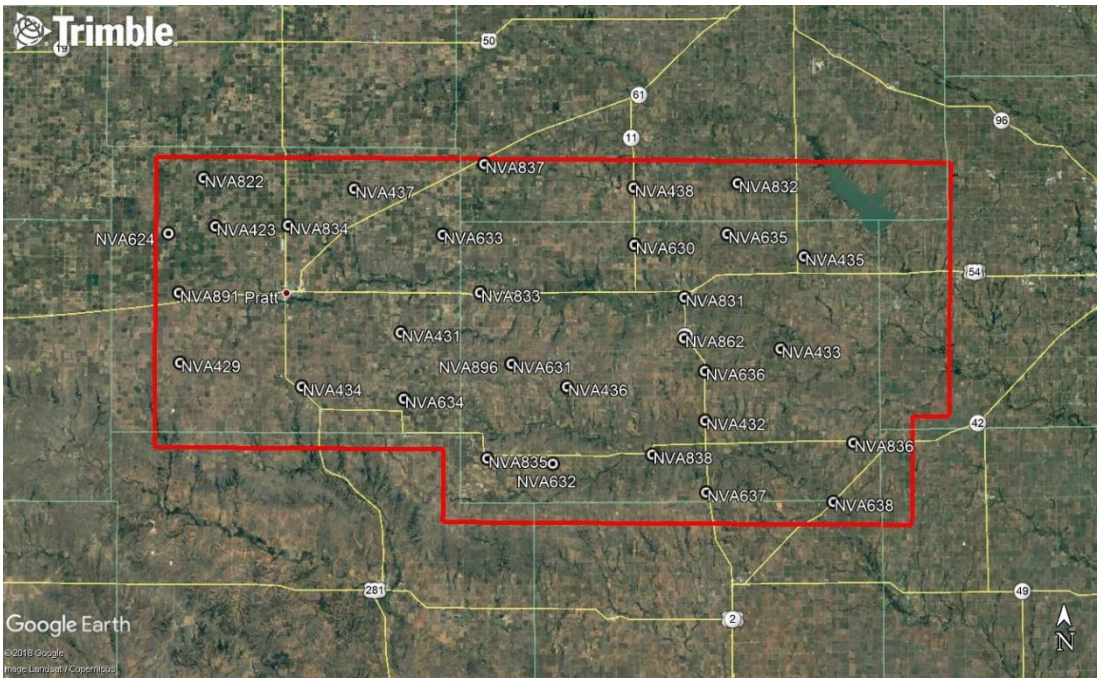


Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

ID	Easting	Northing	Elevation
VVA301	596382.884	4165699.025	431.654
VVA302	598966.078	4151227.612	451
VVA303	527621.588	4164827.308	551.926
VVA304	606208.687	4187097.111	455.658
VVA305	534021.941	4186371.282	571.279

ID	Easting	Northing	Elevation
VVA434	531488.635	4174607.375	565.538
VVA435	580112.487	4176585.733	482.048
VVA436	558541.507	4157576.384	520.198
VVA437	568920.424	4137008.804	515.151
VVA439	578295.718	4160680.123	485.636
VVA567	515065.905	4152665.405	608.343
VVA571	506333.034	4150297.285	605.72
VVA573	568800.623	4182894.52	485.314
VVA574	545109.205	4181110.437	555.618
VVA576	565519.228	4145918.081	485.03
VVA577	590741.481	4160331.974	445.227
VVA578	524706.043	4149167.207	556.731
VVA595	581533.723	4139460.171	482.696
VVA628	515067.158	4152653.016	608.321
VVA631	523448.467	4175794.954	594.971
VVA632	565508.182	4145915.077	485.084

Table 8: Vegetated Vertical Accuracy (VVA) Point Coordinates

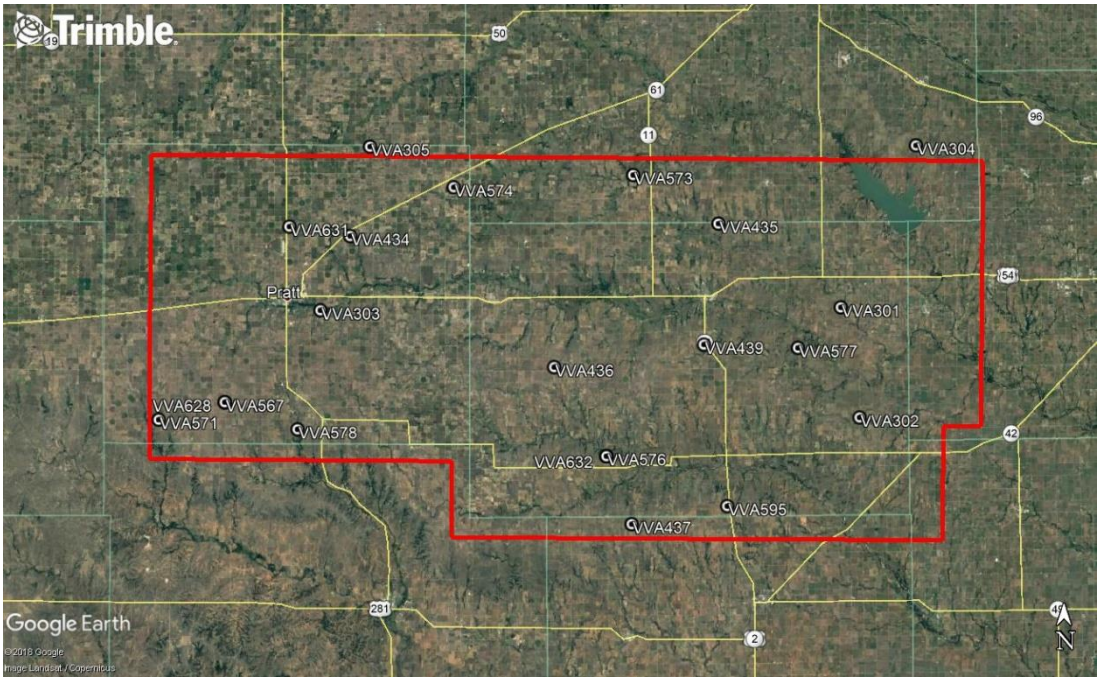


Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

SECTION III: DATA PRODUCTION

3. Aerial LiDAR Project – Calibration/Classification

a. LiDAR Point Cloud Generation

Atlantic used Leica software products to download the IPAS ABGNSS/IMU data and raw laser scan files from the airborne system. Waypoint Inertial Explorer is used to extract the raw IPAS ABGNSS/IMU data, which is further processed in combination with controlled base stations to provide the final Smoothed Best Estimate Trajectory (SBET) for each mission. The SBETs are combined with the raw laser scan files to export the LiDAR ASCII Standard (*.las) formatted swath point clouds.

b. Coordinate Reference System

Horizontal Datum: NAD83(ITRF96)
Coordinate System: UTM, 14N
Vertical Datum: NAVD88
Geoid Model: 12B
Units of Reference: Meter

c. LiDAR Point Cloud Statistics

Category	Value
Total Points	16,900,751,813
Nominal Pulse Spacing (m)	0.6470
Nominal Pulse Density (pls/m²)	2.3891
Nominal Pulse Spacing (ft)	2.1226
Nominal Pulse Density (pls/ft²)	0.2220
Aggregate Total Points	15,747,366,343
Aggregate Nominal Pulse Spacing (m)	0.5650
Aggregate Nominal Pulse Density (pls/m²)	3.1329
Aggregate Nominal Pulse Spacing (ft)	1.8536
Aggregate Nominal Pulse Density (pls/ft²)	0.2911

Table 9: LiDAR Point Cloud Statistics

d. Smooth Surface Repeatability (Interswath)

Departures from planarity of first returns within single swaths in non-vegetated areas were assessed at multiple locations with hard surface areas (parking lots or large rooftops) inside the project area. Each area was evaluated using signed difference rasters (maximum elevation – minimum elevation) at a cell size equal to 2 x ANPS, rounded to the next integer. The following figure depicts a sample of the assessment.

e. LiDAR Calibration

Using a combination of GeoCue, TerraScan and TerraMatch; overlapping swath point clouds are corrected for any orientation or linear deviations to obtain the best fit swath-to-swath calibration. Relative calibration was evaluated using advanced plane-matching analysis and parameter corrections derived. This process was repeated interactively until residual errors between overlapping swaths, across all project missions, was reduced to ≤2cm. A final analysis of the calibrated lidar is preformed using a TerraMatch tie line report for an overall statistical model of the project area. Individual control point assessments for this project can be found in Section VI of this report.

Upon completion of the data calibration, a complete set of elevation difference intensity rasters (dZ Orthos) are produced. A user-defined color ramp is applied depicting the offsets between overlapping swaths based on project specifications. The dZ orthos provide an opportunity to review the data calibration in a qualitative manner. Atlantic assigns green to all offset values that fall below the required RMSDz requirement of the project. A yellow color is assigned for offsets that fall between the RMSDz value and 1.5x of that value. Finally, red values are assigned to all values that fall beyond 1.5x of the RMSDz requirements of the project.

f. LiDAR Classification

Multiple automated filtering routines are applied to the calibrated LiDAR point cloud identifying and extracting bare-earth and above ground features. GeoCue, TerraScan, and TerraModeler software was used for the initial batch processing, visual inspection and any manual editing of the LiDAR point clouds. Atlantic utilized collected breakline data to preform classification for classes 9 (Water) and 10 (Ignored Ground).

Code	Description
1	Unclassified
2	Ground
7	Low point (noise)
9	Water
10	Ignored ground (breakline proximity)
`17	Bridge
18	High point (noise)

Table 10: LiDAR Point Classification Codes and Descriptions

g. LiDAR Intensity Imagery

LiDAR intensity imagery was created from the final calibrated and classified lidar point cloud. Intensity images were produced from all classified points and posted to a 0.5-meter cell size. Intensity images were cut to match the tile index and its corresponding tile names and delivered in .img format.

h. Hydro-line Collection/Conflation

Hydro breaklines were compiled using LiDAR intensity data and surface terrain models of the entire project area. After the collection, all delineated hydro features were validated for monotonicity and vertical variance. This procedure ensures that no points were floating above ground. Hydro-lines were then encoded into the LiDAR surface and used to hydro-enforce/flatten all significant water bodies. These final hydro-lines were then used in the production of bare Earth digital models to hydro flatten significant water bodies. This product was delivered as an ESRI geodatabase for the entire project area.

i. Bare-Earth Surface – Digital Elevation Model (DEM)

Bare earth Digital Elevation Models (DEMs) were derived using the hydro-lines and bare earth (ground) LiDAR points. All DEMs were created with a grid spacing of 1 meter. DEMs for this project were cut to match the tile index and its corresponding tile names and delivered in 32-bit floating point .img format.

j. Surface-Digital Elevation Model (DSM)

Surface digital elevation models (DSMs) were derived using all first return LiDAR points, excluding LiDAR points classified as high or low noise. All DSMs were created with a grid spacing of 1 meter. DSMs for this project were cut to match the tile index and its corresponding tile names and delivered in 32-bit floating point .img format.

SECTION IV: ACCURACY ASSESSMENT

1. Aerial LiDAR Project – Vertical Accuracy Assessment

a. Requirements

Per the table below, the Vertical Accuracy Assessment utilized the required parameters for Vertical Data Accuracy Class IV.

Vertical Data Accuracy Class	RMSEz in Non-Vegetated Terrain (cm)	Non-Vegetated Vertical Accuracy (NVA) at 95% Confidence Level (cm)	Vegetated Vertical Accuracy (VVA) at 95th Percentile (cm)
I	1.0	2.0	2.9
II	2.5	4.9	7.4
III	5.0	9.8	14.7
IV	10.0	19.6	29.4
V	12.5	24.5	36.8
VI	20.0	39.2	58.8
VII	33.3	65.3	98.0
VIII	66.7	130.7	196.0
IX	100.0	196.0	294.0
X	333.3	653.3	980.0

Table 11: Vertical Accuracy Standards, Source: ASPRS Positional Accuracy Standards for Digital Geospatial Data v1.0 (2014)

*The terms NVA and VVA are from the American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data v1.0 (2014). The term NVA refers to assessments in clear, open areas (which typically produce only single LiDAR returns); the term VVA refers to assessments in vegetated areas (typically characterized by multiple return LiDAR).

b. Results

An overall statistical assessment of the check points can be found in the following two tables (values provided in meters):

Broad Land Cover Type	# of Points	RMSEz	95% Confidence Level	95th Percentile
NVA of Point Cloud	32	0.0975	0.1912	0.1530
VVA of Point Cloud	21	0.1035	0.2029	0.1770
NVA of DEM	32	0.1022	0.2003	0.1596
VVA of DEM	19	0.0983	0.1926	0.1608

Table 12: NVA/VVA Accuracies

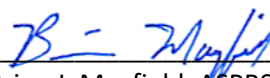
SECTION V: CERTIFICATION STATEMENTS

1. Aerial LiDAR Project

This accuracy assessment confirms that the data may be used for the intended applications stated in Section I of this document. This dataset may also be used as a topographic input for other applications, but the user should be aware that this LiDAR dataset was designed with a specific purpose and was not intended to meet specifications and/or requirements of users outside of the United States Geological Survey.

It should also be noted that LiDAR points do not represent a continuous surface model. LiDAR points are discrete measurements of the surface and any values derived within a triangle of three LiDAR points are interpolated. As such, the user should not use the resultant LiDAR dataset for vertical placement of a planimetric feature such as a headwall, building footprint or any other planimetric feature unless there is an associated LiDAR point that can be reasonably located on this structure.

Consideration should be given by the end user of this dataset to the fact that this LiDAR dataset was developed differently and separately than previous LiDAR datasets that may be available for this geographic location. It is likely that the data in this project was created using different geodetic control, a different Geoid, newer LiDAR technology and more up-to-date processing techniques. As such, any direct comparative analysis performed between this dataset and previous datasets could result in misleading or inaccurate results. Users are encouraged to proceed with caution while performing this type of comparative analysis and to completely understand the variables that make each of these datasets unique and not corollary.
It is encouraged that the user refers to the full FGDC Metadata and project reports for a complete understanding on the content of this dataset.
I, hereby, certify to the extent of my knowledge that the statements and statistics represented in this document are true and factual.



Brian J. Mayfield, ASPRS Certified Photogrammetrist #R1276

SECTION VI: CONTROL POINT ASSESSMENTS

1. Aerial LiDAR Project

a. Point Cloud Check Point Assessment

Point ID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
NVA433	591669.623	4159289.817	469.4320	469.4370	BARE EARTH	0.0050
NVA432	581297.054	4149310.246	462.0720	462.0580	BARE EARTH	(0.0140)
NVA631	554465.202	4156950.709	537.3020	537.2830	BARE EARTH	(0.0190)
NVA831	578315.191	4166269.884	457.6970	457.6780	BARE EARTH	(0.0190)
NVA637	581512.388	4139450.920	483.1780	483.1530	BARE EARTH	(0.0250)
NVA833	550027.967	4166721.485	520.2880	520.2630	BARE EARTH	(0.0250)
NVA638	599169.825	4138242.699	413.3900	413.4160	BARE EARTH	0.0260
NVA822	511655.960	4182226.555	611.8650	611.8910	BARE EARTH	0.0260
NVA630	571346.327	4173465.495	503.5320	503.5040	BARE EARTH	(0.0280)
NVA633	544807.822	4174646.514	547.6910	547.7320	BARE EARTH	0.0410
NVA837	550499.762	4184408.781	536.0960	536.0520	BARE EARTH	(0.0440)
NVA431	539107.888	4161131.726	559.7000	559.6460	BARE EARTH	(0.0540)
NVA832	585576.328	4182043.222	477.0280	476.9660	BARE EARTH	(0.0620)
NVA434	525473.381	4153619.375	585.6030	585.6750	BARE EARTH	0.0720
NVA436	562163.824	4153853.365	517.1970	517.1250	BARE EARTH	(0.0720)
NVA635	584174.165	4175053.893	464.2030	464.2760	BARE EARTH	0.0730
NVA423	513360.175	4175581.513	609.6670	609.7420	BARE EARTH	0.0750
NVA632	560257.867	4143261.957	514.5920	514.5160	BARE EARTH	(0.0760)
NVA636	581199.577	4156147.195	487.5950	487.5160	BARE EARTH	(0.0790)
NVA435	594831.127	4172022.511	448.2160	448.1320	BARE EARTH	(0.0840)
NVA862	578287.422	4160670.032	485.5150	485.4160	BARE EARTH	(0.0990)
NVA896	554464.480	4156958.180	537.5390	537.4320	BARE EARTH	(0.1070)
NVA634	539610.153	4152040.402	563.4670	563.3580	BARE EARTH	(0.1090)
NVA437	532532.335	4180866.795	580.1110	579.9970	BARE EARTH	(0.1140)
NVA891	508367.645	4166397.624	618.5620	618.6790	BARE EARTH	0.1170
NVA438	571170.511	4181324.275	500.7280	500.6070	BARE EARTH	(0.1210)
NVA835	551198.077	4143906.093	532.5690	532.4410	BARE EARTH	(0.1280)
NVA836	601859.293	4146426.619	454.0320	453.8730	BARE EARTH	(0.1590)
NVA838	574003.320	4144603.049	458.7750	458.6140	BARE EARTH	(0.1610)
NVA834	523443.642	4175789.798	595.1410	594.9710	BARE EARTH	(0.1700)
NVA624	506846.106	4174567.157	621.7070	621.9040	BARE EARTH	0.1970
NVA429	508595.483	4156766.924	626.1590	626.3580	BARE EARTH	0.1990
VVA436	558541.507	4157576.384	520.1980	520.1990	BRUSH	0.0010
VVA439	578295.718	4160680.123	485.6360	485.6350	BRUSH	(0.0010)
VVA302	598966.078	4151227.612	451.0000	451.0050	BRUSH	0.0050

Point ID	Easting	Northing	KnownZ	LaserZ	Description	DeltaZ
VVA437	568920.424	4137008.804	515.1510	515.1460	BRUSH	(0.0050)
VVA632	565508.182	4145915.077	485.0840	485.0670	BRUSH	(0.0170)
VVA573	568800.623	4182894.520	485.3140	485.2950	BRUSH	(0.0190)
VVA631	523448.467	4175794.954	594.9710	594.9940	BRUSH	0.0230
VVA434	531488.635	4174607.375	565.5380	565.5620	BRUSH	0.0240
VVA304	606208.687	4187097.111	455.6580	455.6320	BRUSH	(0.0260)
VVA576	565519.228	4145918.081	485.0300	485.0020	BRUSH	(0.0280)
VVA303	527621.588	4164827.308	551.9260	551.9600	BRUSH	0.0340
VVA595	581533.723	4139460.171	482.6960	482.6320	BRUSH	(0.0640)
VVA435	580112.487	4176585.733	482.0480	482.1260	BRUSH	0.0780
VVA301	596382.884	4165699.025	431.6540	431.7410	BRUSH	0.0870
VVA577	590741.481	4160331.974	445.2270	445.1080	BRUSH	(0.1190)
VVA628	515067.158	4152653.016	608.3210	608.4630	BRUSH	0.1420
VVA571	506333.034	4150297.285	605.7200	605.8940	BRUSH	0.1740
VVA578	524706.043	4149167.207	556.7310	556.9060	BRUSH	0.1750
VVA305	534021.941	4186371.282	571.2790	571.4560	BRUSH	0.1770
VVA567	515065.905	4152665.405	608.3430	608.5250	BRUSH	0.1820
VVA574	545109.205	4181110.437	555.6180	555.4100	BRUSH	(0.2080)

Table 13: Point Cloud Check Point Assessment

b. Digital Elevation Model (DEM) Check Point Assessment

Point ID	Easting	Northing	KnownZ	DEMZ	Description	DeltaZ
NVA423	513360.175	4175581.513	609.6670	609.7401	BARE EARTH	0.0731
NVA429	508595.483	4156766.924	626.1590	626.3511	BARE EARTH	0.1921
NVA431	539107.888	4161131.726	559.7000	559.6214	BARE EARTH	(0.0786)
NVA432	581297.054	4149310.246	462.0720	462.0567	BARE EARTH	(0.0153)
NVA433	591669.623	4159289.817	469.4320	469.4247	BARE EARTH	(0.0073)
NVA434	525473.381	4153619.375	585.6030	585.6706	BARE EARTH	0.0676
NVA435	594831.127	4172022.511	448.2160	448.1437	BARE EARTH	(0.0723)
NVA436	562163.824	4153853.365	517.1970	517.1327	BARE EARTH	(0.0643)
NVA437	532532.335	4180866.795	580.1110	579.9829	BARE EARTH	(0.1281)
NVA438	571170.511	4181324.275	500.7280	500.5981	BARE EARTH	(0.1299)
NVA624	506846.106	4174567.157	621.7070	621.9096	BARE EARTH	0.2026
NVA630	571346.327	4173465.495	503.5320	503.5085	BARE EARTH	(0.0235)
NVA631	554465.202	4156950.709	537.3020	537.2589	BARE EARTH	(0.0431)
NVA632	560257.867	4143261.957	514.5920	514.5243	BARE EARTH	(0.0677)
NVA633	544807.822	4174646.514	547.6910	547.7393	BARE EARTH	0.0483
NVA634	539610.153	4152040.402	563.4670	563.3516	BARE EARTH	(0.1154)
NVA635	584174.165	4175053.893	464.2030	464.2645	BARE EARTH	0.0615

Point ID	Easting	Northing	KnownZ	DEMZ	Description	DeltaZ
NVA636	581199.577	4156147.195	487.5950	487.4974	BARE EARTH	(0.0976)
NVA637	581512.388	4139450.920	483.1780	483.1360	BARE EARTH	(0.0420)
NVA638	599169.825	4138242.699	413.3900	413.3119	BARE EARTH	(0.0781)
NVA822	511655.960	4182226.555	611.8650	611.8717	BARE EARTH	0.0067
NVA831	578315.191	4166269.884	457.6970	457.6367	BARE EARTH	(0.0603)
NVA832	585576.328	4182043.222	477.0280	476.9286	BARE EARTH	(0.0994)
NVA833	550027.967	4166721.485	520.2880	520.2308	BARE EARTH	(0.0572)
NVA834	523443.642	4175789.798	595.1410	594.9860	BARE EARTH	(0.1550)
NVA835	551198.077	4143906.093	532.5690	532.4413	BARE EARTH	(0.1277)
NVA836	601859.293	4146426.619	454.0320	453.8644	BARE EARTH	(0.1676)
NVA837	550499.762	4184408.781	536.0960	536.0607	BARE EARTH	(0.0353)
NVA838	574003.320	4144603.049	458.7750	458.6139	BARE EARTH	(0.1611)
NVA862	578287.422	4160670.032	485.5150	485.4175	BARE EARTH	(0.0975)
NVA891	508367.645	4166397.624	618.5620	618.6951	BARE EARTH	0.1331
NVA896	554464.480	4156958.180	537.5390	537.4212	BARE EARTH	(0.1178)
VVA301	596382.884	4165699.025	431.6540	431.6944	BRUSH	0.0404
VVA302	598966.078	4151227.612	451.0000	451.0360	BRUSH	0.0360
VVA303	527621.588	4164827.308	551.9260	551.9445	BRUSH	0.0185
*VVA304	606208.687	4187097.111	455.6580	-	BRUSH	-
*VVA305	534021.941	4186371.282	571.2790	-	BRUSH	-
VVA434	531488.635	4174607.375	565.5380	565.5243	BRUSH	(0.0137)
VVA435	580112.487	4176585.733	482.0480	482.0746	BRUSH	0.0266
VVA436	558541.507	4157576.384	520.1980	520.1881	BRUSH	(0.0099)
VVA437	568920.424	4137008.804	515.1510	515.1326	BRUSH	(0.0184)
VVA439	578295.718	4160680.123	485.6360	485.6233	BRUSH	(0.0127)
VVA567	515065.905	4152665.405	608.3430	608.5057	BRUSH	0.1627
VVA571	506333.034	4150297.285	605.7200	605.8786	BRUSH	0.1586
VVA573	568800.623	4182894.520	485.3140	485.2908	BRUSH	(0.0232)
VVA574	545109.205	4181110.437	555.6180	555.4124	BRUSH	(0.2056)
VVA576	565519.228	4145918.081	485.0300	484.8910	BRUSH	(0.1390)
VVA577	590741.481	4160331.974	445.2270	445.1120	BRUSH	(0.1150)
VVA578	524706.043	4149167.207	556.7310	556.8768	BRUSH	0.1458
VVA595	581533.723	4139460.171	482.6960	482.6575	BRUSH	(0.0385)
VVA628	515067.158	4152653.016	608.3210	608.4816	BRUSH	0.1606
VVA631	523448.467	4175794.954	594.9710	594.9155	BRUSH	(0.0555)
VVA632	565508.182	4145915.077	485.0840	485.0919	BRUSH	0.0079

*Points VVA304 & VVA305 were outside the DEM delivery boundary.

Table 14: DEM Check Point Assessment