Project Report

TASK ORDER NAME: GA_Central_2019_B19
TASK ORDER NUMBER: 140G0219F0277
CONTRACT NUMBER: G16PC00042
ATLANTIC PROJECT NUMBER: 19064
BLOCK NUMBER: Block 3

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SECTION 1: PROJECT OVERVIEW AND PURPOSE

1.1 Aerial LiDAR Project

1.1.1 Project Overview

USGS task order 140G0219F0277 required Winter 2019/Spring 2020 LiDAR surveys to be collected over 20,320 square miles covering part or all of 60 counties in Georgia and 6 counties in Alabama in support of the USGS 3DEP Program. 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 1.3. The Block 03 area encompasses approximately 2,391 square miles.

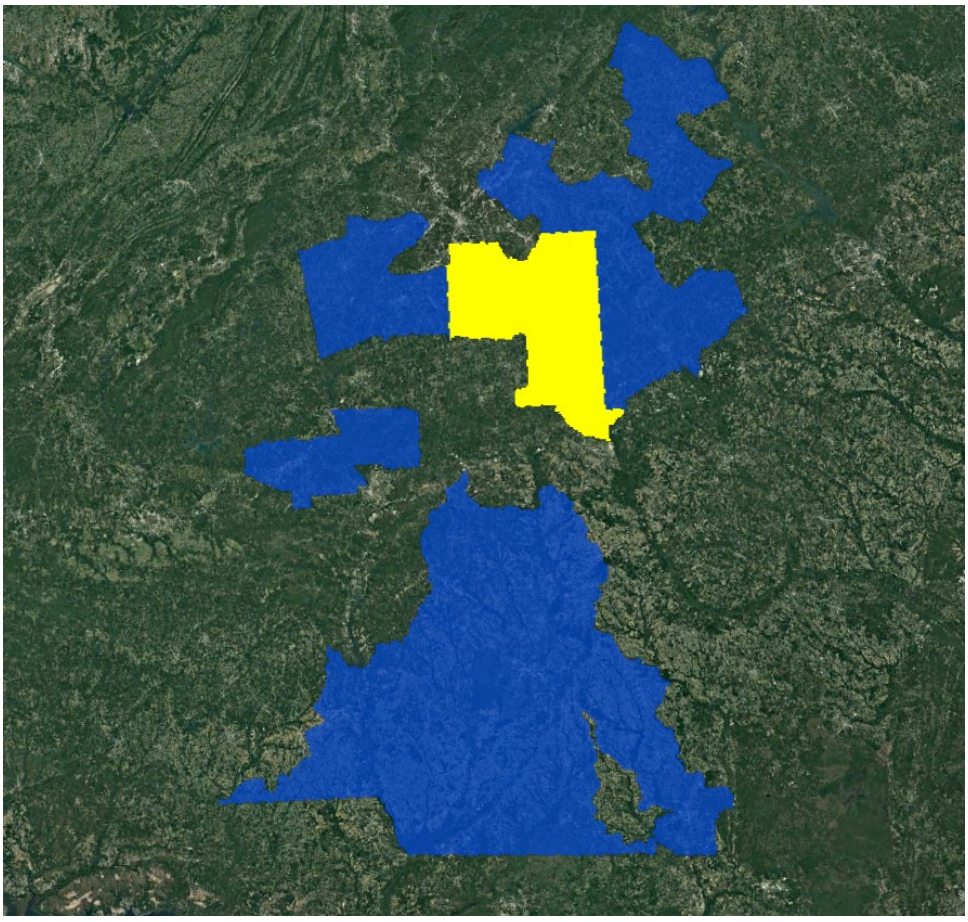

Figure 1: Aerial LiDAR Project Overview – Defined Project Area (DPA) in Yellow and Associated Areas of Interest (AOIs) in Blue

1.1.2 Project Purpose

Aerial lidar was collected to support the mapping efforts of individual counties in the State of Georgia and Alabama and the USGS 3DEP program.

1.1.3 Contract Deliverables

Item	Specification/Format
Classified Point Cloud	LAS v 1.4, tiled delivery
Bare Earth Surface	Raster DEM, 1m cell size, hydro flattened, GeoTIFF format
Breaklines	Hydro breaklines to BPA limit, .gdb format
Intensity Imagery	1m cell size, 8-bit, 256 gray scale, GeoTIFF format
Delivery Diagram	.gdb format
Metadata	Per product, FGDC compliant, .xml format
Project Report	Field work procedures, QC procedures and results, overall accuracy, .pdf format

Table 1: Aerial LiDAR Contract Deliverables

SECTION 2: FIELD OPERATIONS

2.1 Aerial LiDAR Project – Aerial Acquisition

2.1.1 Aircraft and Sensor Information

Atlantic operated a PACDV (N750DV) outfitted with an Optech Galaxy Prime LiDAR system during the collection of the project area. The specifications of this system are presented in the following table:

Parameter	Specification
Model	Galaxy Prime
Manufacturer	Optech
Performance Envelope	150 – 4700 m AGL, nominal
Absolute Horizontal Accuracy	1/10,000 x altitude
Absolute Elevation Accuracy	< 0.03 – 0.20 m RMSE from 150 – 4700 m AGL
Topographic Laser	1064-nm near-infrared
Laser Classification	Class IV
Pulse Repetition Frequency (Effective)	Programmable, 50 – 1000 kHz
Beam Divergence	0.25 mrad (1/e)
Laser Range Precision	< 0.008 m
Minimum Target Separation Distance	< 0.7 m (discrete)
Range Capture	Up to 8 range measurements, including last
Intensity Capture	Up to 8 intensity measurements, including last (12-bit)
Scan Angle (Fov)	10 – 60°
Swath Width	10 – 115% of altitude AGL
Scan Frequency	0 – 120 Hz advertised (0 – 240 scan lines/sec)
Scan Product	2000 maximum
Roll Compensation	±5° minimum
Data Storage	Internal solid-state drive (SSD)
Power Requirements	28 V; 300 W
Dimensions and Weight	Sensor: 0.34 x 0.34 x 0.25 m, 27 kg PDU: 0.42 x 0.33 x 0.10 m, 6.5 kg
Operation Temperature	0 to +35°C

Table 2: System Specifications – Galaxy Prime

2.1.2 Sensor Acquisition Information

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

Parameter	Specification
System	Optech Galaxy Prime
Nominal Pulse Spacing (m)	0.64

Parameter	Specification
Nominal Pulse Density (pls/m²)	2.44
Nominal Flight Height (AGL meters)	2000
Nominal Flight Speed (kts)	150
Pass Heading (°)	W-E
Sensor Scan Angle (°)	45
Scan Frequency (Hz)	60
Pulse Rate of Scanner (kHz)	350
Line Spacing (m)	1325.48
Pulse Width of Scanner (m)	1664
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	6
Beam Divergence (mrad)	0.25
Nominal Swath Width (m)	1657
Nominal Swath Overlap (%)	20
Scan Pattern	TRIANGLE

Table 3: Aerial LiDAR Sensor Acquisition Parameters

2.1.3 Flight Plan Execution

Atlantic acquired 126 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 12 flight missions conducted between December 18, 2019 and February 2, 2020. 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.

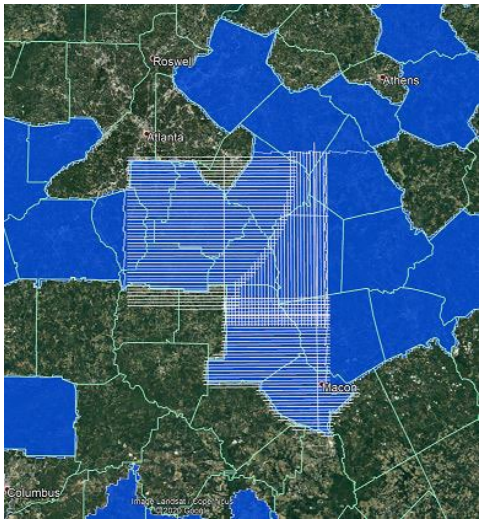

Figure 2: Orientation of Executed Flight-lines and LiDAR DPA

2.1.4 GNSS Reference Stations

Twenty-nine (29) 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
AL60	CORS	AL60	N32°24'40.94502"	W86°16'13.97620"	44.676
AL62	CORS	AL62	N32°08'53.36427"	W85°41'12.37920"	140.811
AL76	CORS	AL76	N31°52'29.95916"	W85°13'32.48368"	100.108
ALA1	CORS	ALA1	N32°35'55.88602"	W85°30'14.13658"	184.083
ALCN	CORS	ALCN	N34°09'46.97942"	W85°39'31.04961"	164.905
ALHC	CORS	ALHC	N33°31'25.44554"	W85°38'05.50165"	256.548
ALLA	CORS	ALLA	N32°55'02.66210"	W85°24'01.80632"	237.158
ALTA	CORS	ALTA	N33°25'24.59581"	W86°07'16.31626"	148.57
FRKN	CORS	FRKN	N35°11'30.71115"	W83°23'41.77452"	619.542
GAAY	CORS	GAAY	N31°39'40.91991"	W84°16'29.65337"	55.889
GABN	CORS	GABN	N34°08'07.10673"	W83°46'38.52707"	277.224
GABY	CORS	GABY	N31°22'39.31821"	W84°56'06.69095"	63.548
GACC	CORS	GACC	N33°32'44.73013"	W82°08'01.72592"	98.491
GACR	CORS	GACR	N32°22'51.45800"	W83°20'46.43062"	97.796
GAFO	CORS	GAFO	N33°02'06.87622"	W83°56'14.39651"	194.518
GAMO	CORS	GAMO	N31°08'37.61920"	W83°42'50.80405"	62.983
GAMV	CORS	GAMV	N33°05'56.63961"	W83°14'47.49484"	91.079
GANO	CORS	GANO	N33°55'57.28318"	W84°08'59.31401"	282.933
GANW	CORS	GANW	N33°18'20.82420"	W84°46'02.50964"	259.991
GATF	CORS	GATF	N31°27'06.88711"	W83°30'32.85608"	96.077
GAVA	CORS	GAVA	N30°50'35.11375"	W83°16'18.44500"	45.412
GAWA	CORS	GAWA	N33°52'21.24039"	W83°25'31.59152"	198.659
GAWI	CORS	GAWI	N33°59'31.13934"	W83°43'06.14438"	278.292
NCMU	CORS	NCMU	N35°04'06.80197"	W83°57'59.38966"	474.779
P804	CORS	P804	N32°57'47.83569"	W84°13'32.72125"	216.362
P806	CORS	P806	N32°57'47.92265"	W84°13'33.05744"	215.87
TALH	CORS	TALH	N30°23'47.50413"	W84°21'21.06139"	-7.292
ZJX1	CORS	ZJX1	N30°41'55.89381"	W81°54'29.46897"	1.722
ZTL4	CORS	ZTL4	N33°22'46.87805"	W84°17'48.21669"	260.682

Table 4: GNSS Reference Stations

2.2 Aerial LiDAR Project – Ground Acquisition

2.2.1 Ground Control Survey

A total of 98 ground survey points were collected in support of this project, including 29 LiDAR Control Points (LCP), 41 Non-vegetated Vertical Accuracy (NVA) and 28 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 and 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
LCP21	1112000.948	1248314.174	217.204
LCP22	1133595.951	1251562.853	241.065
LCP25	1137401.527	1240431.1	211.376
LCP26	1119982.904	1241586.583	200.371
LCP27	1128215.813	1229504.776	235.312
LCP39	1138716.429	1206719.958	169.49
LCP42	1141353.831	1175672.196	180.575
LCP43	1139468.302	1189553.512	160.42
LCP44	1141610.864	1202434.48	176.312
LCP45	1128626.619	1196728.432	157.84
LCP46	1129451.417	1216011.552	218.946
LCP47	1117517.701	1212654.045	188.592
LCP48	1129964.042	1170312.813	168.125
LCP49	1130925.066	1159055.317	123.101
LCP50	1141970.229	1156909.301	111.11
LCP52	1113506.578	1196091.409	194.648
LCP53	1101894.335	1199174.465	204.143
LCP54	1104414.009	1226271.912	216.222
LCP55	1087145.586	1230856.339	231.911

ID	Easting	Northing	Elevation
LCP56	1077388.509	1225328.152	271.938
LCP57	1076912.961	1211841.476	248.945
LCP58	1089892.263	1208667.47	235.578
LCP59	1086303.774	1195513.867	250.791
LCP64	1068104.312	1230183.77	268.985
LCP73	1067333.311	1219429.943	266.131
LCP74	1065759.962	1203983.972	258.161
LCP77	1147472.288	1184582.193	185.824
LCP78	1136001.604	1198373.166	189.153
LCP81	1147848.19	1154056.315	114.5

Table 51: LiDAR Control Point Coordinates

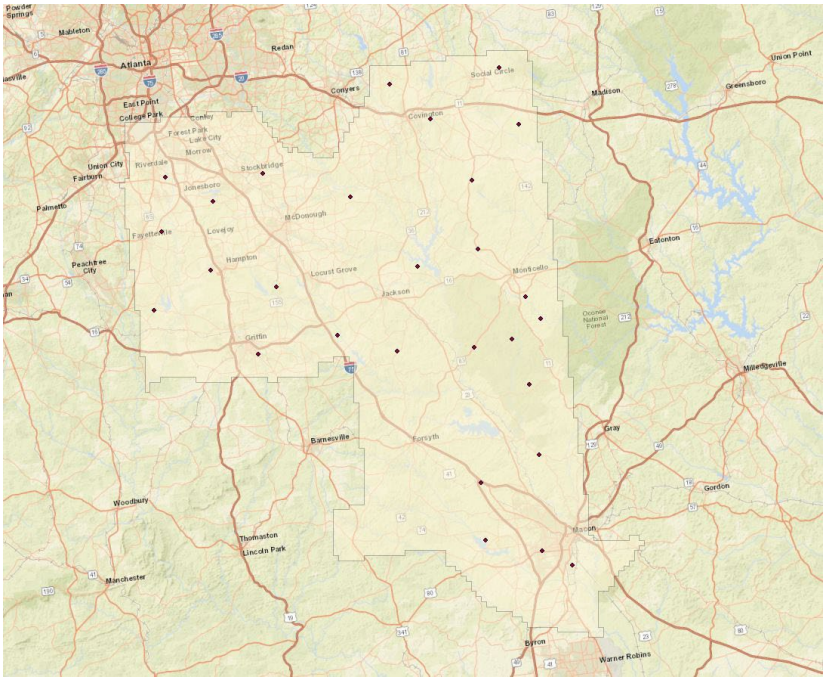

Figure 3: LiDAR Control Point Distribution

ID	Easting	Northing	Elevation
BE19	1112826.061	1238064.687	189.868
BE27	1142435.614	1220036.414	179.431
BE28	1100648.134	1219493.782	231.452
BE29	1080486.407	1232205.016	257.976
BE39	1080772.118	1199153.724	280.278

ID	Easting	Northing	Elevation
BE40	1108856.103	1203341.574	212.687
BE41	1131669.899	1202542.049	195.963
BE43	1114544.578	1180966.659	198.272
BE44	1147491.165	1174485.571	142.052
BE45	1155028.871	1158742.551	120.577
BE46	1105205.587	1159028.967	223.251
BE47	1140317.099	1183535.787	154.451
BE48	1125784.045	1164797.511	154.042
BE49	1079796.015	1217430.484	298.313
OT16	1129272.068	1236266.584	219.833
OT18	1121732.425	1216352.7	208.455
OT22	1140561.238	1148605.771	156.015
OT23	1116038.537	1169247.313	198.546
OT24	1091250.107	1203691.784	248.785
OT32	1068286.14	1226405.181	259.297
OT33	1070465.906	1208224.721	244.042
OT38	1121299.995	1193403.096	167.688
OT39	1110160.121	1227429.919	195.458
OT40	1091761.069	1223814.771	218.89
OT45	1065963.462	1235141.353	269.781
UR17	1118507.499	1247948.982	250.428
UR18	1137320.392	1246233.119	216.033
UR21	1118896.506	1226848.993	203.647
UR22	1109087.698	1211018.944	218.025
UR23	1120304.263	1204261.299	178.248
UR24	1135710.345	1211698.742	202.71
UR26	1146638.477	1195106.422	148.964
UR27	1130367.287	1188080.276	147.787
UR28	1120512.922	1176567.48	185.785
UR29	1135816.02	1164315.326	157.339
UR30	1134498.022	1179247.309	113.812
UR37	1146932.159	1160899.031	131.011
UR38	1094905.109	1213795.986	266.161
UR39	1097121.364	1227930.717	226.577
UR40	1072424.291	1217772.603	271.08
UR41	1069010.642	1198072.814	239.658

Table 62: Non-Vegetated Vertical Accuracy (NVA) Point Coordinates

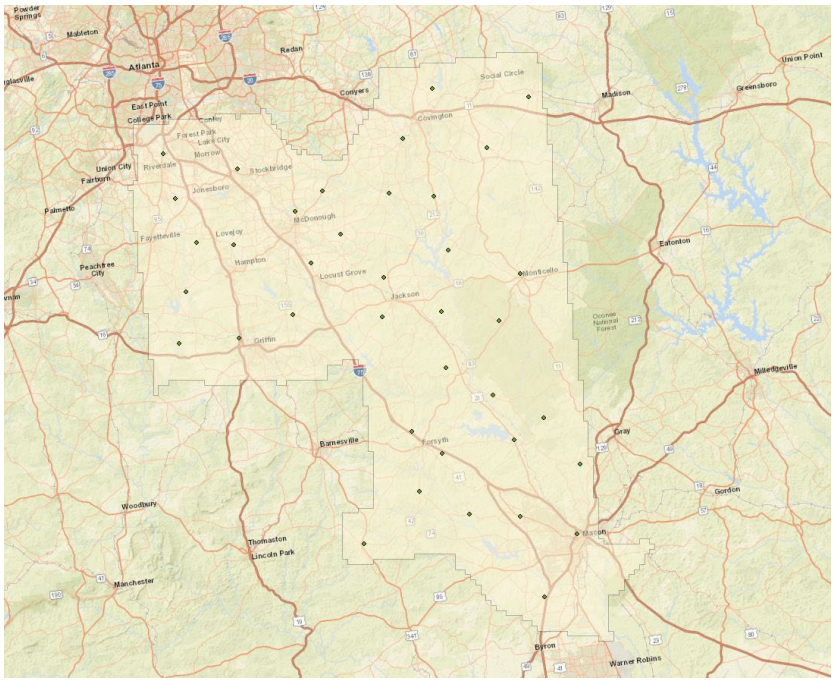

Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

ID	Easting	Northing	Elevation
BR11	1127787.12	1243151.304	228.324
BR12	1112516.062	1218474.348	203.357
BR13	1116311.835	1203102.882	198.245
BR20	1144687.006	1166141.677	103.704
BR21	1147631.78	1147285.804	110.026
BR22	1113642.407	1162851.841	190.664
BR23	1092992.022	1197890.422	240.494
BR24	1085528.616	1216495.145	276.115
BR25	1072681.511	1236533.072	293.376
BR26	1063276.208	1210624.065	260.422
HG10	1106682.472	1234502.541	234.221
HG13	1144346.328	1212020.035	172.126
HG20	1125396.317	1186389.763	157.861
HG21	1111844.315	1173341.957	187.102
HG22	1101183.644	1210189.148	223.433
HG23	1075220.818	1202568.857	241.178
HG24	1083603.223	1222564.835	259.046
HG33	1128393.587	1205850.818	143.581
TR11	1125137.76	1251567.205	231.672

ID	Easting	Northing	Elevation
TR13	1118939.23	1234901.784	204.051
TR16	1133074.47	1220257.812	209.165
TR21	1133508.488	1153572.21	136.045
TR22	1135206.794	1172048.98	164.962
TR23	1111405.086	1189076.053	175.756
TR24	1082981.872	1207417.264	253.289
TR25	1098795.568	1204856.838	198.364
TR33	1084022.115	1237337.598	259.455
TR34	1136479.457	1232691.835	225.724

Table 7: Vegetated Vertical Accuracy (VVA) Point Coordinates

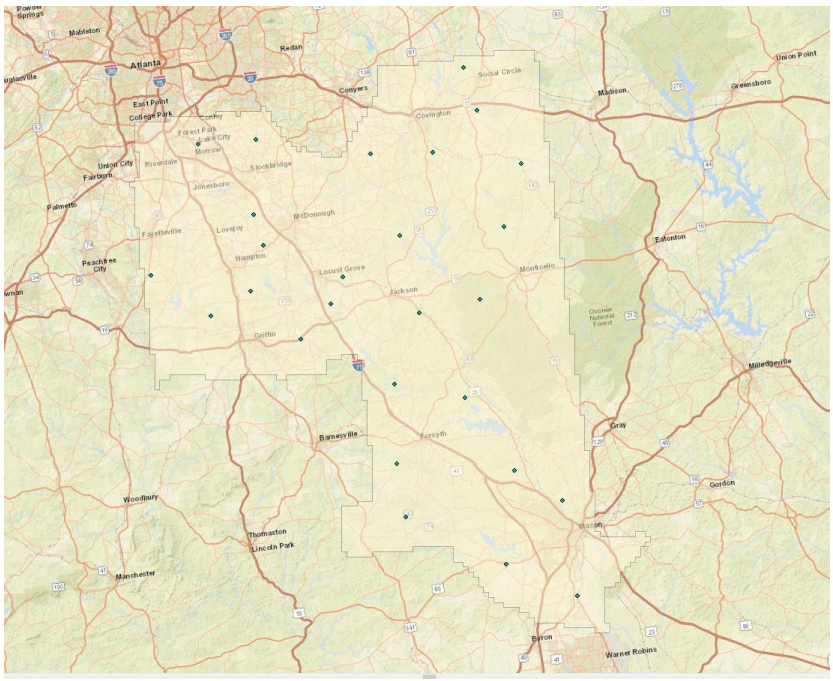

Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

SECTION 3: DATA PRODUCTION

3.1 Aerial LiDAR Project – Calibration/Classification

3.1.1 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.

3.1.2 Coordinate Reference System

Parameter	Specification
Horizontal Datum	Albers Equal Area
Coordinate System	NAD83 2011
Vertical Datum	NAVD88
Geoid Model	12B
EPSG Code	6350
Units of Reference	Meter

Table 3: Coordinate Reference System

3.1.3 LiDAR Point Cloud Statistics

Category	Value
Total Points (Nominal)	25,789,861,463
Nominal Pulse Spacing (M)	0.5094
Nominal Pulse Density (PLS/M^2)	3.8535
Total Points (Aggregate)	25,789,861,463
Aggregate Pulse Spacing (M)	0.5346
Aggregate Pulse Density (PLS/M^2)	3.4994

Table 4: LiDAR Point Cloud Statistics

3.1.4 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.

3.1.5 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 performed 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.

3.1.6 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 class 9 (Water).

Code	Description
1	Processed but unclassified
2	Bare-earth ground
3	Low Vegetation (0.5 – 5 feet)
4	Medium Vegetation (5 – 20 feet)
5	High Vegetation (>20 feet)
6	Buildings
7	Low Noise
9	Water
17	Bridge Decks
18	High Noise
20	Ignored Ground (breakline proximity)
21	Snow (where reliable identifiable)
22	Temporal Exclusion (typically non-favored data in intertidal zones)

Table 5: LiDAR Point Classification Codes and Descriptions

3.1.7 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 1.0-meter cell size. Intensity images were cut to match the tile index and its corresponding tile names and delivered in GeoTIFF format.

3.1.8 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.

3.1.9 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 GeoTIFF format.

SECTION 4: ACCURACY ASSESSMENT

4.1 Aerial LiDAR Project – Vertical Accuracy Assessment

4.1.1 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 6: 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).

4.1.2 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	Points (#)	RMSEz	Confidence Level (95%)	Percentile (95th)
NVA (Point Cloud)	40	0.0689	0.1350	0.0787
NVA (DEM)	40	0.0688	0.1349	0.0954
VVA (Point Cloud)	27	0.1023	0.2006	0.1630
VVA (DEM)	27	0.1065	0.2088	0.0876

Table 7: NVA/VVA Accuracies

SECTION 5: CERTIFICATION STATEMENTS

5.1 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.

James C. Cannon, ASPRS Certified Photogrammetrist #R1594CP

SECTION 6: CONTROL POINT ASSESSMENTS

6.1 Aerial LiDAR Project

6.1.1 Point Cloud Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Point Type
BE19	1112826.0610	1238064.6870	189.8680	189.9020	0.0340	NVA
BE27	1142435.6140	1220036.4140	179.4310	179.3590	-0.0720	NVA
BE28	1100648.1340	1219493.7820	231.4520	231.5060	0.0540	NVA
BE29	1080486.4070	1232205.0160	257.9760	258.0180	0.0420	NVA
BE39	1080772.1180	1199153.7240	280.2780	280.3340	0.0560	NVA
BE40	1108856.1030	1203341.5740	212.6870	212.7440	0.0570	NVA
BE41	1131669.8990	1202542.0490	195.9630	195.9890	0.0260	NVA
BE43	1114544.5780	1180966.6590	198.2720	198.3170	0.0450	NVA
BE44	1147491.1650	1174485.5710	142.0520	142.0430	-0.0090	NVA
BE45	1155028.8710	1158742.5510	120.5770	120.4890	-0.0880	NVA
BE46	1105205.5870	1159028.9670	223.2510	223.1720	-0.0790	NVA
BE47	1140317.0990	1183535.7870	154.4510	154.4880	0.0370	NVA
BE48	1125784.0450	1164797.5110	154.0420	153.9780	-0.0640	NVA
BE49	1079796.0150	1217430.4840	298.3130	298.3890	0.0760	NVA
BR11	1127787.1200	1243151.3040	228.3240	228.4870	0.1630	VVA
BR12	1112516.0620	1218474.3480	203.3570	203.4620	0.1050	VVA
BR13	1116311.8350	1203102.8820	198.2450	198.3080	0.0630	VVA
BR20	1144687.0060	1166141.6770	103.7040	103.6750	-0.0290	VVA
BR21	1147631.7800	1147285.8040	110.0260	110.1020	0.0760	VVA
BR22	1113642.4070	1162851.8410	190.6640	190.6330	-0.0310	VVA
BR23	1092992.0220	1197890.4220	240.4940	240.5930	0.0990	VVA
BR24	1085528.6160	1216495.1450	276.1150	276.1780	0.0630	VVA
BR25	1072681.5110	1236533.0720	293.3760	293.4900	0.1140	VVA
BR26	1063276.2080	1210624.0650	260.4220	260.7140	0.2920	VVA
HG10	1106682.4720	1234502.5410	234.2210	234.3040	0.0830	VVA
HG20	1125396.3170	1186389.7630	157.8610	157.8810	0.0200	VVA
HG21	1111844.3150	1173341.9570	187.1020	187.1310	0.0290	VVA
HG22	1101183.6440	1210189.1480	223.4330	223.5960	0.1630	VVA
HG23	1075220.8180	1202568.8570	241.1780	241.2950	0.1170	VVA
HG24	1083603.2230	1222564.8350	259.0460	259.1140	0.0680	VVA
HG33	1128393.5870	1205850.8180	143.5810	143.7420	0.1610	VVA
OT16	1129272.0680	1236266.5840	219.8330	219.8450	0.0120	NVA
OT18	1121732.4250	1216352.7000	208.4550	208.5010	0.0460	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Point Type
OT22	1140561.2380	1148605.7710	156.0150	155.9760	-0.0390	NVA
OT23	1116038.5370	1169247.3130	198.5460	198.5700	0.0240	NVA
OT24	1091250.1070	1203691.7840	248.7850	248.8420	0.0570	NVA
OT32	1068286.1400	1226405.1810	259.2970	259.3440	0.0470	NVA
OT33	1070465.9060	1208224.7210	244.0420	244.1040	0.0620	NVA
OT38	1121299.9950	1193403.0960	167.6880	167.7250	0.0370	NVA
OT39	1110160.1210	1227429.9190	195.4580	195.5310	0.0730	NVA
OT40	1091761.0690	1223814.7710	218.8900	218.9640	0.0740	NVA
OT45	1065963.4620	1235141.3530	269.7810	269.8390	0.0580	NVA
TR11	1125137.7600	1251567.2050	231.6720	231.6560	-0.0160	VVA
TR13	1118939.2300	1234901.7840	204.0510	204.1130	0.0620	VVA
TR16	1133074.4700	1220257.8120	209.1650	209.2210	0.0560	VVA
TR21	1133508.4880	1153572.2100	136.0450	135.9830	-0.0620	VVA
TR22	1135206.7940	1172048.9800	164.9620	164.9130	-0.0490	VVA
TR23	1111405.0860	1189076.0530	175.7560	175.7930	0.0370	VVA
TR24	1082981.8720	1207417.2640	253.2890	253.3400	0.0510	VVA
TR25	1098795.5680	1204856.8380	198.3640	198.4800	0.1160	VVA
TR33	1084022.1150	1237337.5980	259.4550	259.5520	0.0970	VVA
TR34	1136479.4570	1232691.8350	225.7240	225.7720	0.0480	VVA
UR17	1118507.4990	1247948.9820	250.4280	250.4540	0.0260	NVA
UR18	1137320.3920	1246233.1190	216.0330	216.2520	0.2190	NVA
UR21	1118896.5060	1226848.9930	203.6470	203.7120	0.0650	NVA
UR22	1109087.6980	1211018.9440	218.0250	218.1030	0.0780	NVA
UR23	1120304.2630	1204261.2990	178.2480	178.2870	0.0390	NVA
UR24	1135710.3450	1211698.7420	202.7100	202.7570	0.0470	NVA
UR27	1130367.2870	1188080.2760	147.7870	147.7850	-0.0020	NVA
UR28	1120512.9220	1176567.4800	185.7850	185.8210	0.0360	NVA
UR29	1135816.0200	1164315.3260	157.3390	157.2120	-0.1270	NVA
UR30	1134498.0220	1179247.3090	113.8120	113.8210	0.0090	NVA
UR37	1146932.1590	1160899.0310	131.0110	130.8700	-0.1410	NVA
UR38	1094905.1090	1213795.9860	266.1610	266.2520	0.0910	NVA
UR39	1097121.3640	1227930.7170	226.5770	226.6020	0.0250	NVA
UR40	1072424.2910	1217772.6030	271.0800	271.1200	0.0400	NVA
UR41	1069010.6420	1198072.8140	239.6580	239.7250	0.0670	NVA

Table 138: Point Cloud Check Point Assessment

6.1.2 Digital Elevation Model (DEM) Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
BE19	1112826.0610	1238064.6870	189.8680	189.8810	-0.0130	NVA
BE27	1142435.6140	1220036.4140	179.4310	179.3440	0.0870	NVA
BE28	1100648.1340	1219493.7820	231.4520	231.4800	-0.0280	NVA
BE29	1080486.4070	1232205.0160	257.9760	258.0250	-0.0490	NVA
BE39	1080772.1180	1199153.7240	280.2780	280.3410	-0.0630	NVA
BE40	1108856.1030	1203341.5740	212.6870	212.7280	-0.0410	NVA
BE41	1131669.8990	1202542.0490	195.9630	195.9950	-0.0320	NVA
BE43	1114544.5780	1180966.6590	198.2720	198.3000	-0.0280	NVA
BE44	1147491.1650	1174485.5710	142.0520	141.9690	0.0830	NVA
BE45	1155028.8710	1158742.5510	120.5770	120.4900	0.0870	NVA
BE46	1105205.5870	1159028.9670	223.2510	223.1580	0.0930	NVA
BE47	1140317.0990	1183535.7870	154.4510	154.4590	-0.0080	NVA
BE48	1125784.0450	1164797.5110	154.0420	153.9790	0.0630	NVA
BE49	1079796.0150	1217430.4840	298.3130	298.3850	-0.0720	NVA
OT16	1129272.0680	1236266.5840	219.8330	219.8460	-0.0130	NVA
OT18	1121732.4250	1216352.7000	208.4550	208.4780	-0.0230	NVA
OT22	1140561.2380	1148605.7710	156.0150	155.9640	0.0510	NVA
OT23	1116038.5370	1169247.3130	198.5460	198.5490	-0.0030	NVA
OT24	1091250.1070	1203691.7840	248.7850	248.8230	-0.0380	NVA
OT32	1068286.1400	1226405.1810	259.2970	259.3070	-0.0100	NVA
OT33	1070465.9060	1208224.7210	244.0420	244.0960	-0.0540	NVA
OT38	1121299.9950	1193403.0960	167.6880	167.6850	0.0030	NVA
OT39	1110160.1210	1227429.9190	195.4580	195.5360	-0.0780	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
OT40	1091761.0690	1223814.7710	218.8900	218.9610	-0.0710	NVA
OT45	1065963.4620	1235141.3530	269.7810	269.8320	-0.0510	NVA
UR17	1118507.4990	1247948.9820	250.4280	250.4530	-0.0250	NVA
UR18	1137320.3920	1246233.1190	216.0330	216.2600	-0.2270	NVA
UR21	1118896.5060	1226848.9930	203.6470	203.6940	-0.0470	NVA
UR22	1109087.6980	1211018.9440	218.0250	218.0840	-0.0590	NVA
UR23	1120304.2630	1204261.2990	178.2480	178.2720	-0.0240	NVA
UR24	1135710.3450	1211698.7420	202.7100	202.7460	-0.0360	NVA
UR27	1130367.2870	1188080.2760	147.7870	147.7800	0.0070	NVA
UR28	1120512.9220	1176567.4800	185.7850	185.7860	-0.0010	NVA
UR29	1135816.0200	1164315.3260	157.3390	157.1990	0.1400	NVA
UR30	1134498.0220	1179247.3090	113.8120	113.8010	0.0110	NVA
UR37	1146932.1590	1160899.0310	131.0110	130.8530	0.1580	NVA
UR38	1094905.1090	1213795.9860	266.1610	266.2450	-0.0840	NVA
UR39	1097121.3640	1227930.7170	226.5770	226.5960	-0.0190	NVA
UR40	1072424.2910	1217772.6030	271.0800	271.1080	-0.0280	NVA
UR41	1069010.6420	1198072.8140	239.6580	239.7250	-0.0670	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
BR11	1127787.1200	1243151.3040	228.3240	228.4980	-0.1740	VVA
BR12	1112516.0620	1218474.3480	203.3570	203.4660	-0.1090	VVA
BR13	1116311.8350	1203102.8820	198.2450	198.2160	0.0290	VVA
BR20	1144687.0060	1166141.6770	103.7040	103.5940	0.1100	VVA
BR21	1147631.7800	1147285.8040	110.0260	110.0850	-0.0590	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
BR22	1113642.4070	1162851.8410	190.6640	190.5890	0.0750	VVA
BR23	1092992.0220	1197890.4220	240.4940	240.5660	-0.0720	VVA
BR24	1085528.6160	1216495.1450	276.1150	276.1650	-0.0500	VVA
BR25	1072681.5110	1236533.0720	293.3760	293.4480	-0.0720	VVA
BR26	1063276.2080	1210624.0650	260.4220	260.7930	-0.3710	VVA
HG10	1106682.4720	1234502.5410	234.2210	234.2970	-0.0760	VVA
HG20	1125396.3170	1186389.7630	157.8610	157.8680	-0.0070	VVA
HG21	1111844.3150	1173341.9570	187.1020	187.1310	-0.0290	VVA
HG22	1101183.6440	1210189.1480	223.4330	223.5950	-0.1620	VVA
HG23	1075220.8180	1202568.8570	241.1780	241.2970	-0.1190	VVA
HG24	1083603.2230	1222564.8350	259.0460	259.1150	-0.0690	VVA
HG33	1128393.5870	1205850.8180	143.5810	143.6810	-0.1000	VVA
TR11	1125137.7600	1251567.2050	231.6720	231.6540	0.0180	VVA
TR13	1118939.2300	1234901.7840	204.0510	204.0430	0.0080	VVA
TR16	1133074.4700	1220257.8120	209.1650	209.2090	-0.0440	VVA
TR21	1133508.4880	1153572.2100	136.0450	135.9520	0.0930	VVA
TR22	1135206.7940	1172048.9800	164.9620	164.9050	0.0570	VVA
TR23	1111405.0860	1189076.0530	175.7560	175.7580	-0.0020	VVA
TR24	1082981.8720	1207417.2640	253.2890	253.3450	-0.0560	VVA
TR25	1098795.5680	1204856.8380	198.3640	198.4640	-0.1000	VVA
TR33	1084022.1150	1237337.5980	259.4550	259.4940	-0.0390	VVA
TR34	1136479.4570	1232691.8350	225.7240	225.7570	-0.0330	VVA

Table 14: DEM Check Point Assessment