atlantic

Project Report

USDA-FS Region-6, Gifford Pinchot et al National Forests
2017 Leaf-On Airborne LiDAR Data Acquisition
Sol. No. AG-05G2-S-17-0019
Atlantic Project No. 17042
Willamette National Forest – Manatash Taneum AOI

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SECTION I: PROJECT OVERVIEW & PURPOSE

1. Aerial LiDAR Project

a. Project Overview

The United States Forest Service, Region 6, (USFS) required leaf-on airborne LiDAR surveys to be collected over of national forestry in Oregon and Washington State. The following areas were requested to be covered: Gifford Pinchot National Forest (GIP) in Vancouver, Washington; Okanogan-Wenatchee National Forest (OKA) in Wenatchee, Washington; Malheur National Forest (MAL) in John Day, Oregon; Deschutes National Forest (DES) in Bend, Oregon, Willamette National Forest (WIL) in Eugene, Oregon, Umpqua National Forest (UMP) in Douglas, Lane, and Jackson Counties, Oregon. The following report applies to the Manatash Taneum AOI, which encompasses sixty one (61) square miles of the Okanogan-Wenatchee National Forest in Washington.

Aerial LiDAR data for this task order was planned, acquired, processed and produced at an aggregate nominal pulse spacing (ANPS) of 0.35 meters and aggregate nominal pulse density of 8 pulses per square meter.

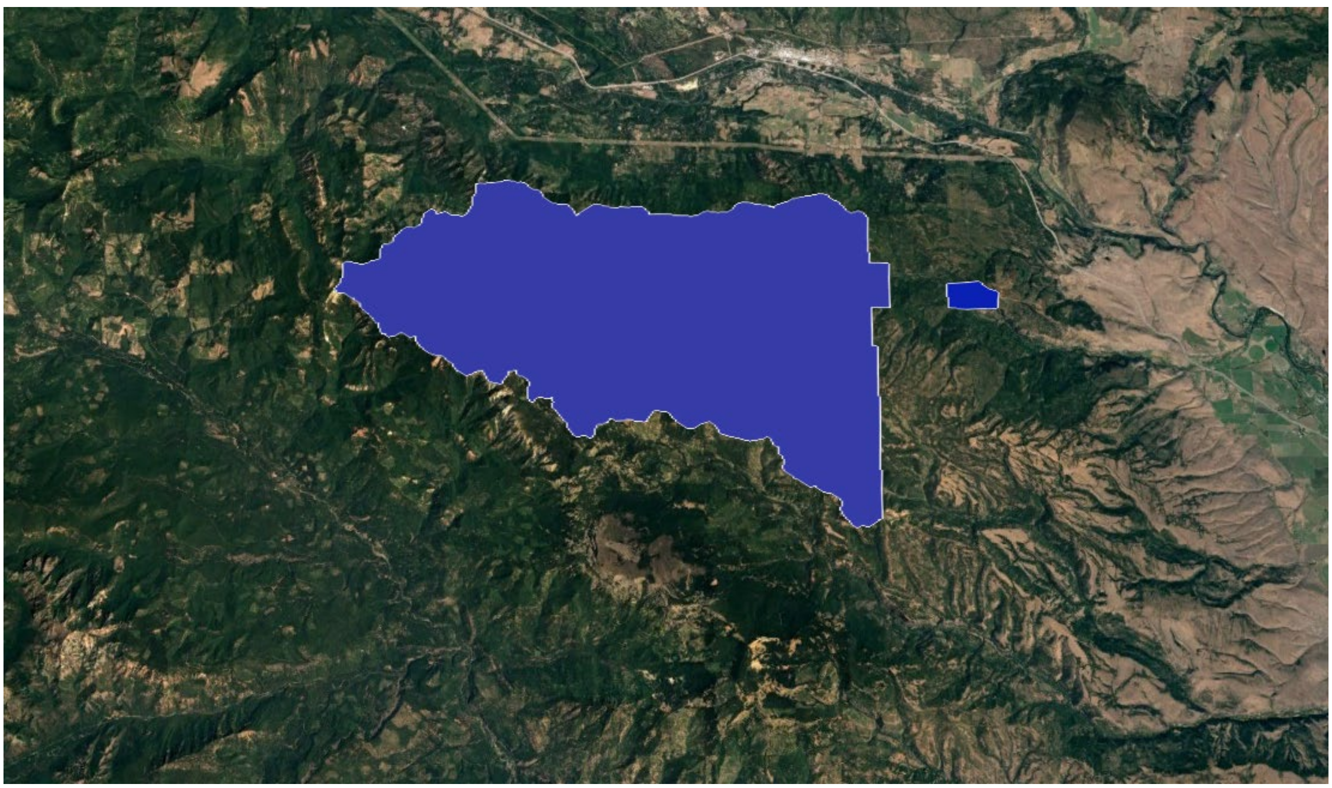

Figure 1: Aerial LiDAR Project Overview – Defined Project Area (DPA) and Associated Areas of Interest (AOIs)

b. Project Purpose

The primary goals of this project are to provide high accuracy Light Detection and Ranging (LiDAR) data to enhance project planning and implementation; identify areas for the implementation of forest restoration treatments designed to restore forest structure in young-growth stands; and to provide engineering and resource specialists more information for on-the-ground project planning. In addition, these data will be used by researchers and scientists to characterize vegetation type and structure as it currently exists on the landscape and to provide a detailed, accurate, and precise benchmark for future change detection work. The data products specified herein may also be used for vegetation mapping, road identification and mapping, hydrologic feature delineation, and landcover characterization applications including a canopy height model, understory vegetation prediction, and other stand metrics.

c. Client Contact Information

Client Contact Information	
Name of Contact	Mark Riley
Organization	Forest Service R6 Data Resources Management
Position	Remote Sensing Program Lead
Telephone	503.808.2989
E-Mail Address	markriley@fs.fed.us
Mailing Address	1220 SW 3rd Ave
City	Portland
State or Province	Oregon
Postal Code	97204

Table 1: Aerial LiDAR Client Contact Information

d. Contract Deliverables

Item	Specification/Format
Report	PDF
Metadata	FGDC Content Standards for Digital Geospatial Metadata (FGDC-STD-001-1998)
Aircraft Trajectories	ArcGIS shapefile
All-Return Point Cloud	LAS 1.2 in LAZ format
Bare Earth Elevation Model (Digital Terrain Model, DTM)	ERDAS .img format
Intensity Image	ERDAS .img
Supporting Shapefiles	ArcGIS shapefile
GPS Report	PDF
Quality Analysis/Quality Control	PDF

Table 2: Aerial LiDAR Contract Deliverables

SECTION II: FIELD OPERATIONS

1. Aerial Acquisition

a. Aircraft & Sensor Information

Atlantic operated a Leica ALS70-HP LiDAR system on a Cessna (N732JE) during Oct 14, 2017 for the project area. The specifications of this LiDAR 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

Table 3: 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)	0.35
Nominal Pulse Density (pls/m²)	8
Nominal Flight Height (AGL meters)	2400
Nominal Flight Speed (kts)	110
Pass Heading (°)	Varies
Sensor Scan Angle (°)	24
Scan Frequency (Hz)	40.5
Pulse Rate of Scanner (kHz)	239,800

Parameter	Specification
Line Spacing (m)	400
Pulse Duration of Scanner (ns)	4
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	1
Beam Divergence (mrad)	0.15
Nominal Swath Width (m)	933
Nominal Swath Overlap (%)	52
Scan Pattern	Triangle

Table 4: Aerial LiDAR Sensor Acquisition Parameters

c. Flight Plan Execution 1

Atlantic acquired 57 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 4 flight missions conducted between October 14, 2017 and May 8, 2019. 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.

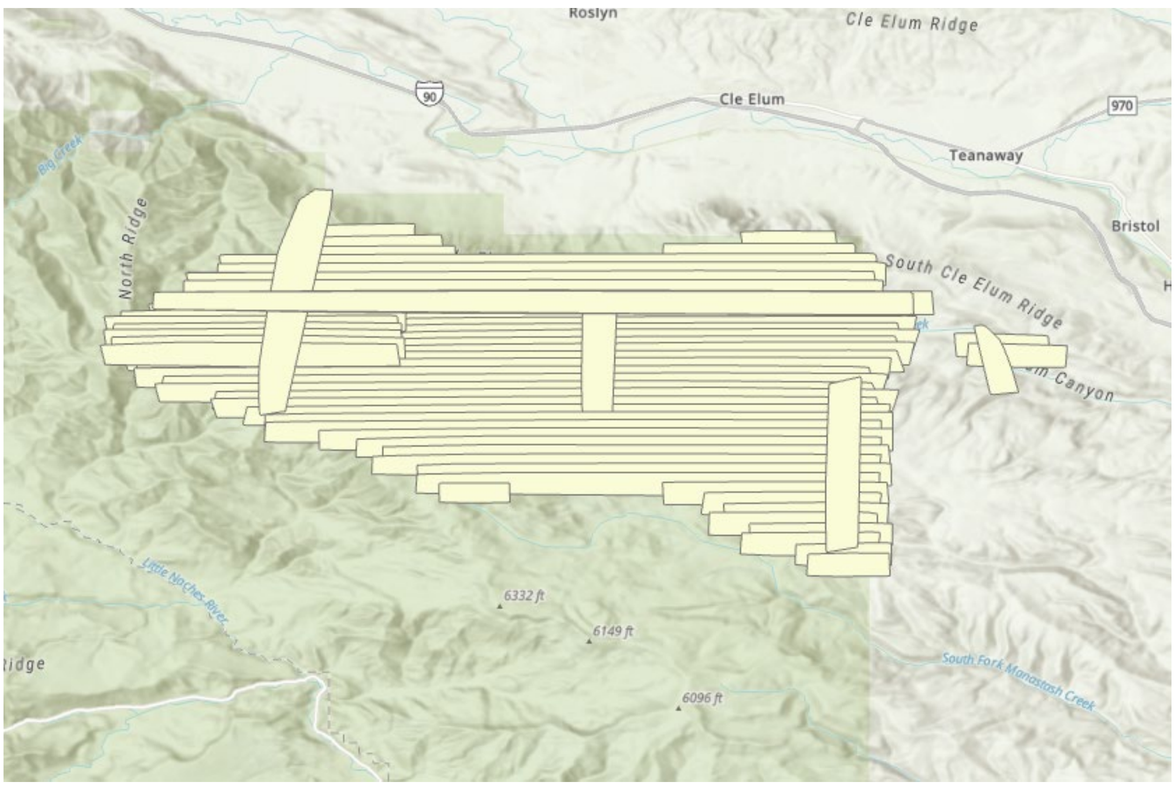

Figure 2: Orientation of Executed Flight-lines and LiDAR DPA

d. GNSS Reference Stations

Five (5) Continuously Operating Reference Stations (CORS) were used to control the LiDAR acquisition for the defined project area. The coordinates provided in the table below are in the specified coordinate reference system for the project, as detailed in Section III-1-b.

Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
HAHD	CORS	HAHD	47°17'26.86780"	121°47'17.03836"	854.303
LINH	CORS	LINH	47°00'01.19124"	120°32'18.54528"	472.723
P449	CORS	P449	46°15'35.24858"	119°37'51.59548"	208.417
P450	CORS	P450	45°57'12.00241"	119°32'39.10698"	163.659
SC00	CORS	SC00	46°57'03.31247"	120°43'28.53448"	1178.794

2. Ground Acquisition

a. Ground Control Survey

A total of 11 Non-vegetated Vertical Accuracy (NVA) points were collected in support of this project.

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:

Point ID	Observed (X)	Observed (Y)	Observed (Z)	Report Point Type
GCP07	536132.0280	1448759.3200	716.3770	NVA
GCP09	535154.2330	1449608.4770	735.2450	NVA
GCP31	515305.9170	1451918.9880	1499.5250	NVA
GCP32	517522.8030	1449506.5770	1497.7220	NVA
GCP33	519493.2600	1447728.5060	1480.3470	NVA
GCP34	516646.7010	1450985.7760	1225.6350	NVA
GCP35	529208.8490	1443952.4660	1368.6990	NVA
GCP36	529320.3700	1447207.1010	1405.6520	NVA
GCP38	521605.6470	1452928.5770	1409.1300	NVA
GCP39	527395.6840	1451145.6910	1055.5430	NVA
GCP40	524734.0810	1448495.5920	1063.2700	NVA

Table 5: Non-Vegetated Vertical Accuracy (NVA) Point Coordinates

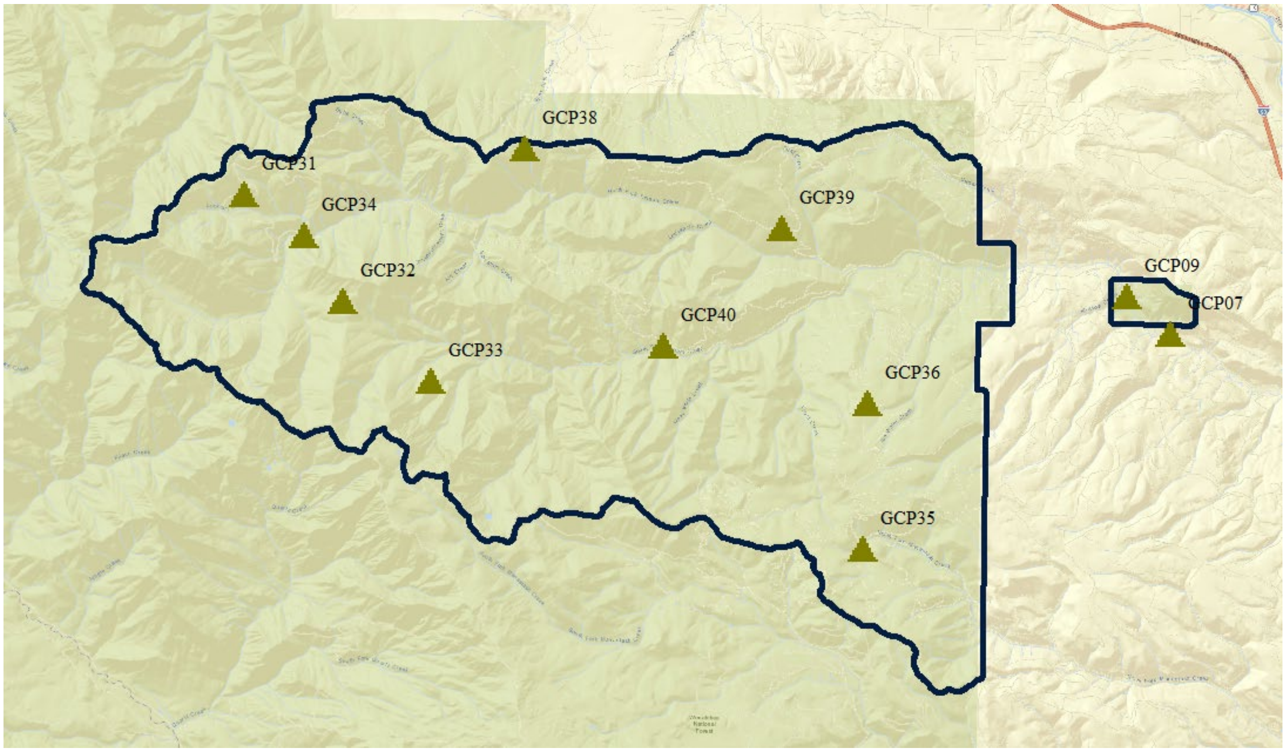

Figure 3: Non-Vegetated Vertical Accuracy (NVA) Point Distribution Data Production

SECTION III: DATA PRODUCTION

1. 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

Projection: NAD 1983 Oregon Washington Albers
Horizontal Datum: NAD83
Vertical Datum: NAVD88
Spheroid: GRS1980
Horizontal Units: Meter
Vertical Units: Meter

c. LiDAR Point Cloud Statistics

Category	Value
Total Points	2,188,642,667
Nominal Pulse Spacing (m)	0.2907
Nominal Pulse Density (pls/m²)	11.8374
Aggregate Total Points	2,246,672,626
Aggregate Nominal Pulse Spacing (m)	0.3010
Aggregate Nominal Pulse Density (pls/m²)	11.0350

Table 6: 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 raster's (maximum elevation – minimum elevation) at a cell size equal to 2 x ANPS, rounded to the next integer.

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 raster's (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.

Code	Description
1	Processed, Unclassified
2	Ground
7	Low Point (Noise)
18	High Point (Noise)

Table 7: 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 1.0-meter cell size. Intensity images were cut to match the tile index and its corresponding tile names and delivered in .tif format.

h. Bare Earth Elevation Model – Digital Terrain Model (DTM)

Bare earth Digital Elevation Models (DTMs) were derived using the bare earth (ground) LiDAR points. All DEMs were created with a grid spacing of 1.0-meter. DTMs for this project were cut to match the tile index and its corresponding tile names and delivered in .img format.

SECTION IV: ACCURACY ASSESSMENT

1. 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 8: 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	Points (#)	RMSEz	Confidence Level (95%)	Percentile (95th)
NVA (Point Cloud)	10	0.0887	0.1738	0.0193
NVA (DEM)	10	0.0828	0.1623	0.1706

Table 9: NVA/VVA Accuracies

SECTION V: CERTIFICATION STATEMENT

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

American Society for Photogrammetry and Remote Sensing
BRIAN MAYFIELD
CERTIFIED
PHOTOGRAMMETRIST
(ASPRS) NO. R1276
Exp. 11/2/2020

SECTION VI: CONTROL POINT ASSESSMENTS

1. Point Cloud Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	Report Point Type
GCP09	535154.2330	1449608.4770	735.2450	NVA
GCP31	515305.9170	1451918.9880	1499.5250	NVA
GCP32	517522.8030	1449506.5770	1497.7220	NVA
GCP33	519493.2600	1447728.5060	1480.3470	NVA
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GCP38	521605.6470	1452928.5780	1409.1300	NVA
GCP39	527395.6840	1451145.6910	1055.5430	NVA
GCP40	524734.0810	1448495.5920	1063.2700	NVA

Table 10: Point Cloud Check Point Assessment

2. Digital Elevation Model (DEM) Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
GCP09	535154.2330	1449608.4770	735.2450	735.0730	0.1720	NVA
GCP31	515305.9170	1451918.9880	1499.5250	1499.5320	-0.0070	NVA
GCP32	517522.8030	1449506.5770	1497.7220	1497.7140	0.0080	NVA
GCP33	519493.2600	1447728.5060	1480.3470	1480.1780	0.1690	NVA
GCP34	516646.7010	1450985.7760	1225.6350	1225.6150	0.0200	NVA
GCP35	529208.8490	1443952.4660	1368.6990	1368.6410	0.0580	NVA
GCP36	529320.3700	1447207.1010	1405.6520	1405.6160	0.0360	NVA
GCP38	521605.6470	1452928.5770	1409.1300	1409.1150	0.0150	NVA
GCP39	527395.6840	1451145.6910	1055.5430	1055.4740	0.0690	NVA
GCP40	524734.0810	1448495.5920	1063.2700	1063.2530	0.0170	NVA

Table 11: DEM Check Point Assessment