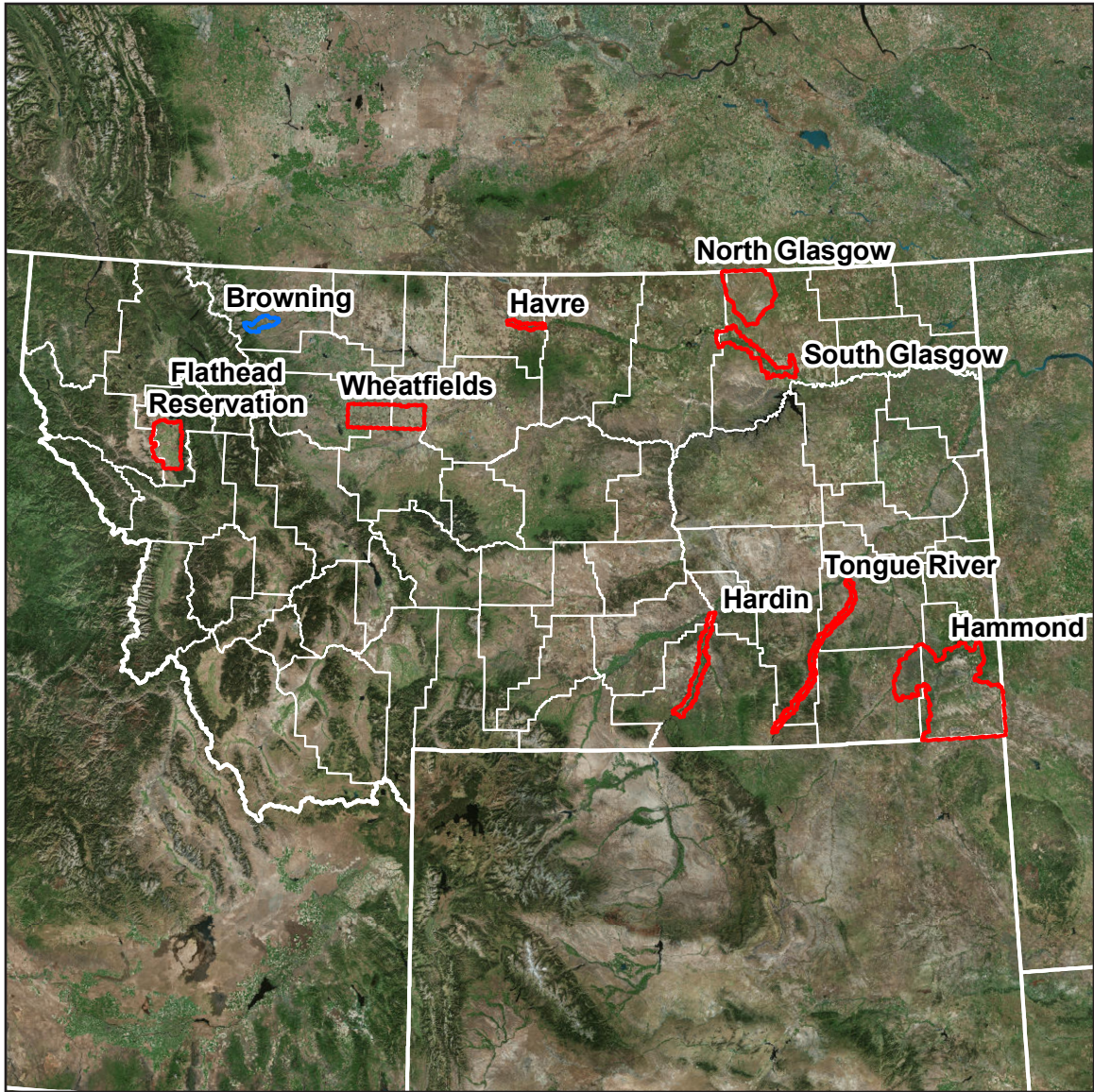


# MT NRCS MT 2018 D18

## Airborne Lidar Report

March 2019



Contract # G16PC00022  
Task Order # 140G0218F0148



Contractor Woolpert  
Project # 78608

# Table of Contents

1. Overview .....	1
About.....	1
Purpose.....	1
Specifications .....	1
Spatial Reference .....	2
Deliverables .....	3
2. Acquisition .....	5
Flight Planning .....	5
Lidar Sensor Information .....	6
GNSS and IMU Equipment.....	8
Timeline.....	8
Acquisition Quality Assurance .....	9
3. Processing .....	18
Processing Summary .....	18
GNSS-IMU Trajectory Processing .....	18
Geometric Calibration .....	19
Lidar Data Classification.....	19
Hydrologic Flattening .....	20
Digital Elevation Model .....	21
Intensity Imagery .....	21
Metadata.....	21
4. Accuracy Assessment .....	22
Results Summary .....	22
Raw Lidar Swath Testing .....	22
Digital Elevation Model Testing.....	22
Inter-Swath Testing .....	24
Intra-Swath Testing .....	24



# Table of Contents

## List of Figures

Figure 1-1. Project Area .....	4
Figure 2-1: Flown Flight Lines - Browning .....	10
Figure 2-2: Flown Flight Lines - Flathead Reservation .....	11
Figure 2-3: Flown Flight Lines - Hammond .....	12
Figure 2-4: Flown Flight Lines - Hardin.....	13
Figure 2-5: Flown Flight Lines - Havre.....	14
Figure 2-6: Flown Flight Lines - North/South Glasgow.....	15
Figure 2-7: Flown Flight Lines - Tongue River.....	16
Figure 2-8: Flown Flight Lines - Wheatfields.....	17

## List of Tables

Table 1-2. Deliverables .....	3
Table 2-1. Acquisition Requirements.....	5
Table 2-2. Optech Orion H300 Sensor Info .....	6
Table 2-3. Optech Galaxy PRIME Sensor Info .....	7
Table 2-4. GNSS Base Stations.....	8
Table 2-5. Acquisition Specifications.....	9
Table 4-1. Vertical Accuracy Summary.....	22
Table 4-2. VVA Errors .....	23

## Appendix Documents

Appendix 1: Flight Logs.....	A1-1
Appendix 2: Raw Swath NVA Checkpoint Results .....	A2-1
Appendix 3: DEM NVA Checkpoint Results.....	A3-1
Appendix 4: DEM VVA Checkpoint Results.....	A4-1

# 1. Overview

## About

This project contains a comprehensive outline of the 140G0218F0148 MT NRCS MT 2018 D18 task order issued by the United States Geological Survey's National Geospatial Technical Operations Center (USGS-NGTOC). This task order called for the acquisition and processing of QL1 and QL2 data over nine areas of interest covering approximately 5,235 square miles in Montana.

Data partially covers the following counties:

- Big Horn, Blaine, Carter, Cascade, Chouteau, Custer, Glacier, Hill, Lake, Phillips, Powder River, Rosebud, Sanders, Teton, Treasure, Valley, Yellowstone

## Purpose

The purpose of this project was to collect lidar data to be used for the following purposes: conservation planning, soil survey mapping, highly-erodible land determinations, wetland mapping and wetland determinations, engineering practice design, dam rehabilitation, easement monitoring, natural resource inventories, updates to the National Hydrography Dataset (NHD).

## Specifications

Data for this task order was acquired and produced to meet USGS Lidar Base Specification v1.3 standards and the American Society of Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0).



## Spatial Reference

Geospatial data products were produced using the following horizontal and vertical spatial data reference system.

Area of Interest		
<b>Horizontal</b>	<b>EPSG Code</b>	6514
	<b>Datum</b>	NAD83 (2011)
	<b>Projection</b>	State Plane Montana
	<b>Units</b>	

After QA and acceptance by USGS, a secondary dataset was produced using the following system.

Area of Interest		
<b>Horizontal</b>	<b>EPSG Code</b>	6350
	<b>Datum</b>	NAD83 (2011)
	<b>Projection</b>	Albers Equal Area
	<b>Units</b>	Meters
<b>Vertical</b>	<b>Datum</b>	NAVD88
	<b>Geoid</b>	GEOID12B
	<b>Units</b>	Meters
	<b>Height Type</b>	Orthometric Heights

## Deliverables

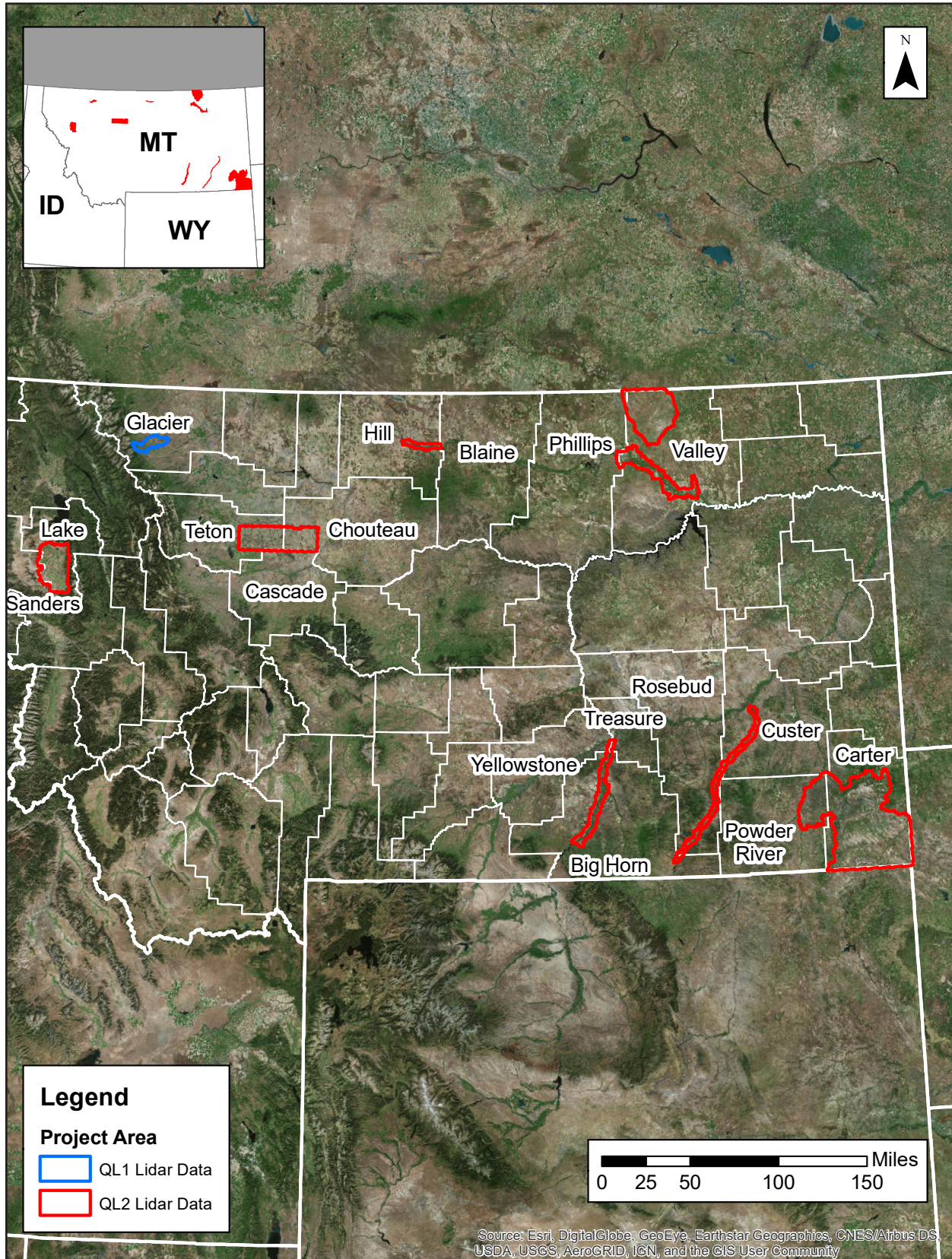
All data products produced as part of this task order are listed below. All tiled deliverables had a tile size of 1,000-meters x 1,000-meters. Tiles names are derived from the easting and northing locations of the lower left corner of the tile.

Table 1-2. Deliverables

<b>Lidar Data</b>	
Classified lidar point cloud data	Tiles in .las v1.4 format Classes <ul style="list-style-type: none"> <li>• 1 – Processed, not Classified</li> <li>• 2 – Ground</li> <li>• 7 – Noise</li> <li>• 9 – Water</li> <li>• 17 – Bridge Decks</li> <li>• 18 – High Noise</li> <li>• 20 – Ignored Ground</li> </ul>
Breaklines used for hydro-flattening	<ul style="list-style-type: none"> <li>• Lake and River features as feature classes in an Esri file geodatabase               <ul style="list-style-type: none"> <li>• Water bodies greater than 2 acres as polygon features</li> <li>• Rivers 30.5 meters / 100 feet and greater in width as polyline features</li> </ul> </li> <li>• Bridges used in DEM generation as point features in Esri shapefile format</li> </ul>
Hydro-flattened bare earth digital elevation model (DEM)	1-meter pixel size, 32-bit floating-point; no bridges or overpass structures GeoTIFF format
Intensity Imagery	1-meter pixel size, 8-bit gray-scale (linear rescaling from 16-bit intensity) GeoTIFF format
Flight Line Index	Polygon features in an Esri file geodatabase
<b>Control Data</b>	
Lidar calibration points	Esri shapefile format
Lidar NVA checkpoints	Esri shapefile format
Lidar VVA checkpoints	Esri shapefile format
<b>Other Data</b>	
Data Extent	Esri shapefile format
Delivery Diagram	Esri shapefile format
Tile Index	Esri shapefile format
<b>Metadata and Reports</b>	
Metadata	Deliverable-level FGDC CSDGM/USGS MetaParser Compliant metadata in .xml format
Lidar Project Report	Project report with flight logs in .pdf format
Survey Report	Survey report in .pdf format



Figure 1-1. Project Area



## 2. Acquisition

### Flight Planning

Aerial lidar data was collected using the specifications listed below.

Table 2-1. Acquisition Requirements

Specification	Target
Resolution	QL1 Data <ul style="list-style-type: none"> <li>• 8 points per square meter</li> <li>• 0.35-meter nominal point spacing</li> </ul> QL2 Data <ul style="list-style-type: none"> <li>• 2 points per square meter</li> <li>• 0.71-meter nominal point spacing</li> </ul>
Overlap	At contractor's discretion, but enough to ensure there are no data gaps between usable portions of the swath and nominal point density is achieved
Acquisition Window	At a period of annual minimal water level in the spring 2018 leaf-off window running March 1 – April 30, 2018
Acquisition Conditions	<ul style="list-style-type: none"> <li>• Cloud and fog-free between the aircraft and ground</li> <li>• Ground is snow free</li> <li>• Ground has no unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation</li> <li>• Preference of vegetation is leaf-off</li> </ul>
Data Voids	Not allowed except <ul style="list-style-type: none"> <li>• Where caused by water bodies</li> <li>• Where caused by areas of low near infra-red (NIR) reflectivity (i.e. asphalt or composition roofing)</li> <li>• Where caused by lidar shadowing from buildings or other features</li> <li>• Where appropriately filled-in by another swath</li> </ul>
Control	Airborne Global Positioning System (ABGPS) and Inertial Measurement Unit (IMU) data to be used along with differentially-corrected GPS ground control points



## Lidar Sensor Information

Aerial lidar data was acquired using the Optech Orion H300 and Optech Galaxy PRIME lidar sensor systems. A total of 400 flight lines were collected.

Table 2-2. Optech Orion H300 Sensor Info

Optech Orion H-300	
Operational envelope <sup>1, 2, 3, 4</sup>	150-4000 m AGL, nominal
Effective laser repetition rate	Programmable, 35-300 kHz
Laser wavelength	1064 nm
Elevation accuracy <sup>2, 3</sup>	<3-15 cm; 1 $\sigma$
Horizontal accuracy <sup>2, 3</sup>	1/7500 x altitude; 1 $\sigma$
Position and orientation system	POS AV™ AP50 (OEM)
Sensor range precision <sup>5</sup>	<8 mm, 1 $\sigma$
Scan width (FOV)	Programmable, 0-50 degrees
Scan frequency	Programmable, 0-90 Hz
Sensor scan product	1000 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, $\pm 30^\circ$ (FOV dependent)
Vertical target separation distance	<0.7 m
Multipulse	Yes
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Data storage	Internal solid state drive SSD (SATA II); Removable SSD (optional)
Image capture	Compatible with Optech CS-Series digital metric cameras
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Recorder (optional)
Gyro-stabilization	SOMAG GSM 3000 integration kit (optional)
Power requirements	28 V; 300 W; 12 A
Dimensions and weight	Sensor: 340 x 340 x 250 mm, 25 kg; PDU: 415 x 328 x 100 mm, 6.5 kg
Operating temperature	0 to +35°C
Relative humidity	0-95% non-condensing

1. Target reflectivity  $\geq 20\%$ .

2. Dependent on selected operational parameters using nominal FOV of up to  $50^\circ$  and Optech LMS Professional software suite in standard atmospheric conditions (i.e., 23 km visibility).

3. Angle of incidence  $\leq 25^\circ$ .

4. Target size  $\geq$  laser footprint.

5. Under Optech test conditions, 1 sigma.

Source: Optech Orion H300 Airborne Lidar Summary Specification Sheet

<http://info.teledyneoptech.com/acton/attachment/19958/f-02a8/1/-/-/-/ORION-H-Specsheet-140624-WEB.pdf>

Table 2-3. Optech Galaxy PRIME Sensor Info

<b>Optech Galaxy PRIME</b>	
<b>Sensor Performance</b>	
Performance envelope <sup>1, 2, 3, 4</sup>	150-6000 m AGL, nominal
Absolute horizontal accuracy <sup>2, 3</sup>	1/10,000 × altitude; 1 $\sigma$
Absolute elevation accuracy <sup>2, 3</sup>	< 0.03-0.25 m RMSE from 150-6000 m AGL
<b>Laser Configuration</b>	
Topographic laser	1064-nm near-infrared
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Pulse repetition frequency (effective)	Programmable, 50-1000 kHz
Beam divergence	0.25 mrad (1/e)
Laser range precision <sup>5</sup>	< 0.008 m, 1 $\sigma$
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)
<b>Sensor Configuration</b>	
Position and orientation system	POS AV™ AP60 (OEM); 220-channel dual frequency GNSS receiver; GNSS airborne antenna with Iridium filters; high-accuracy AIMU (Type 57); non-ITAR
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
Flight management system	Optech FMS (Airborne Mission Manager and Nav) with operator console
SwathTRAK™	Dynamic FOV for fixed-width data swaths in variable terrain
PulseTRAK™	Multipulse tracking algorithm with no density loss across PIA transition zones
Roll compensation	±5° minimum
Data storage	Removable SSD (primary); internal SSD (spare)
Power requirements	28 V; 400 W
Dimensions and weight	Sensor: 0.34 × 0.34 × 0.25 m, 27 kg PDU: 0.42 × 0.33 × 0.10 m, 6.5 kg
Operating temperature	0 to +35°C

1. Target reflectivity  $\geq 20\%$ ; 99% detection probability
2. Dependent on selected operational parameters; assumes nominal FOV of up to 40° in standard atmospheric conditions (i.e. 23-km visibility) and use of Optech LMS Professional software suite
3. Angle of incidence  $\leq 20^\circ$
4. Target size  $\geq$  laser footprint
5. Under Teledyne Optech test conditions, 1 sigma

Source: Optech Galaxy PRIME Airborne Lidar Terrain Mapper Specification Sheet  
<http://info.teledyneoptech.com/acton/attachment/19958/f-0278/1/-/-/-/Galaxy%20PRIME%20Brochure.pdf>

## GNSS and IMU Equipment

Prior to mobilizing to the project site, flight crews coordinated with the necessary air traffic control personnel to ensure airspace access. Crews were on-site, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

Flight navigation during acquisition was 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.

Base stations were set by acquisition staff and was used to support the aerial data acquisition. See the table below for stations operated during acquisition.

Table 2-4. GNSS Base Stations

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
H60705p_EIGW	N 48° 36' 03.72708"	W 113° 06' 30.69007"	1395.096
H60703o_EIGW	N 48° 32' 44.51410"	W 109° 45' 35.11591"	771.449
H60706n_EIGW	N 48° 12' 37.46830"	W 106° 37' 40.30745"	676.874
A1	N 47° 29' 10.81478"	W 114° 05' 50.88160"	906.745
A4	N 47° 47' 07.14815"	W 111° 15' 44.43160"	1058.809
A6	N 48° 49' 14.49660"	W 106° 55' 18.27347"	723.302
A9	N 45° 54' 48.05395"	W 107° 35' 28.94204"	844.495
A10	N 45° 27' 40.10407"	W 107° 43' 16.81729"	923.232
A11	N 46° 08' 16.76705"	W 105° 48' 15.45279"	771.748
A12	N 45° 45' 12.52128"	W 106° 18' 12.47598"	862.131
A13	N 45° 17' 38.18179"	W 106° 33' 34.44317"	956.321
A18	N 45° 23' 46.43891"	W 104° 58' 38.64389"	1012.842

## Timeline

Lidar data was collected from May 30, 2018 through December 14, 2018. Acquisition specifications are listed in the table below. An initial quality control process was immediately performed on to review the data coverage, airborne GPS data, and trajectory solution.

Table 2-5. Acquisition Specifications

Settings	QL1 Galaxy Prime	QL2 Orion H-300	QL2 Galaxy PRIME
Max. Number of Returns	8	4	8
Nominal Point Spacing	0.3 m	0.7 m	0.7 m
Nominal Point Density	9.97 ppsm	2.03 ppsm	2.29 ppsm
Flying Height Above Ground Level	1,500 m	1,800 m	2,500 m
Flight Speed	120 kts	110 kts	120 knots
Scan Angle	36°	29°	46°
Scan Rate Used	82 Hz	40.3	50 Hz
Pulse Rate Used	600 kHz	125 kHz	300 kHz
Multi-Pulse in Air	Enabled	Enabled	Enabled
Swath Width	975 m	931 m	2,122 m
Swath Overlap	20%	30%	20%

For more information, see the Flight Logs in Appendix 1.

## Acquisition Quality Assurance

Woolpert developed a quality assurance and validation plan to ensure the acquired lidar data meets the USGS Base Specification Version 1.3. For quality assurance purposes, the lidar data was processed immediately following acquisition to verify the coverage has appropriate density, distribution, and no unacceptable data voids. Accompanying GPS data was post processed using differential and Kalman filter algorithms to derive a best estimate of trajectory. The quality of the solution was verified to be consistent with the accuracy requirements of the task order. Any required re-flights were scheduled at the earliest opportunity.

The spatial distribution of the geometrically usable first return lidar points was reviewed for density requirements as well as regular and uniform point distribution - verifying the lidar data is spaced so that 90% of the cells in a 2\*NPS grid placed over the data contain at least one lidar point. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. Additionally, the data was reviewed for unacceptable data voids – verifying no area greater than or equal to  $(4 \times \text{ANPS})^2$  exhibited data coverage gaps.



Figure 2-1: Flown Flight Lines - Browning

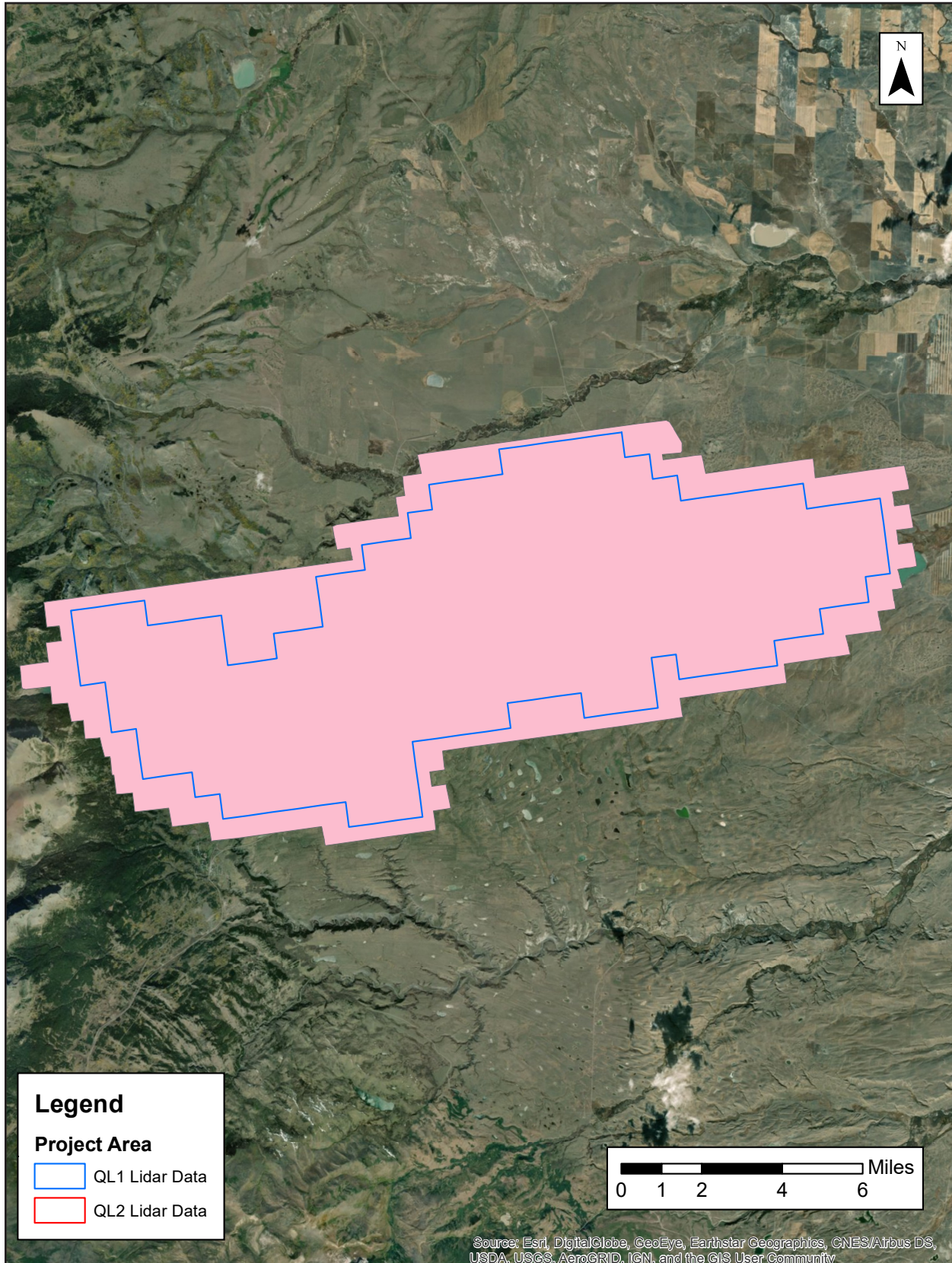




Figure 2-2: Flown Flight Lines - Flathead Reservation

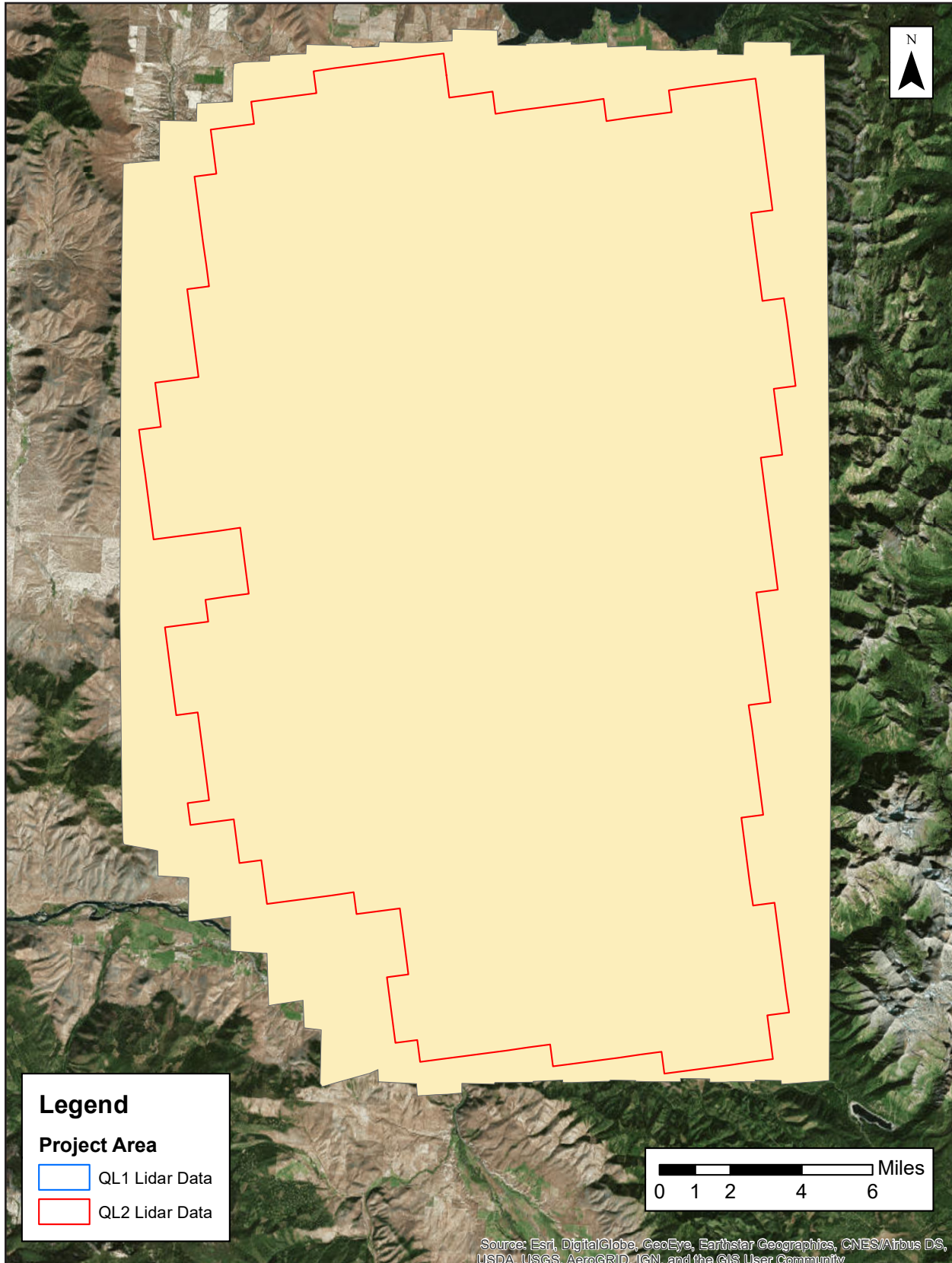


Figure 2-3: Flown Flight Lines - Hammond

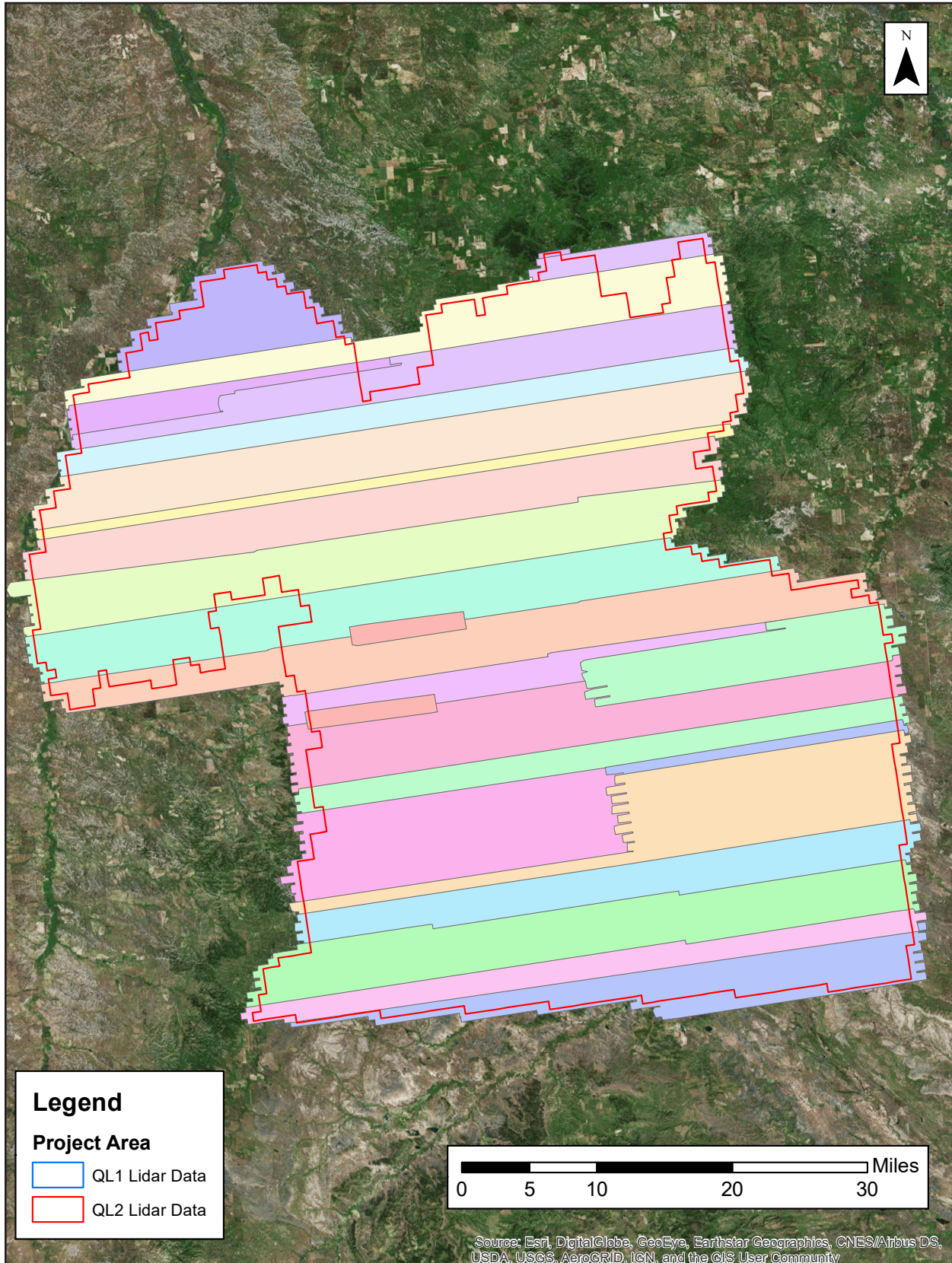




Figure 2-4: Flown Flight Lines - Hardin

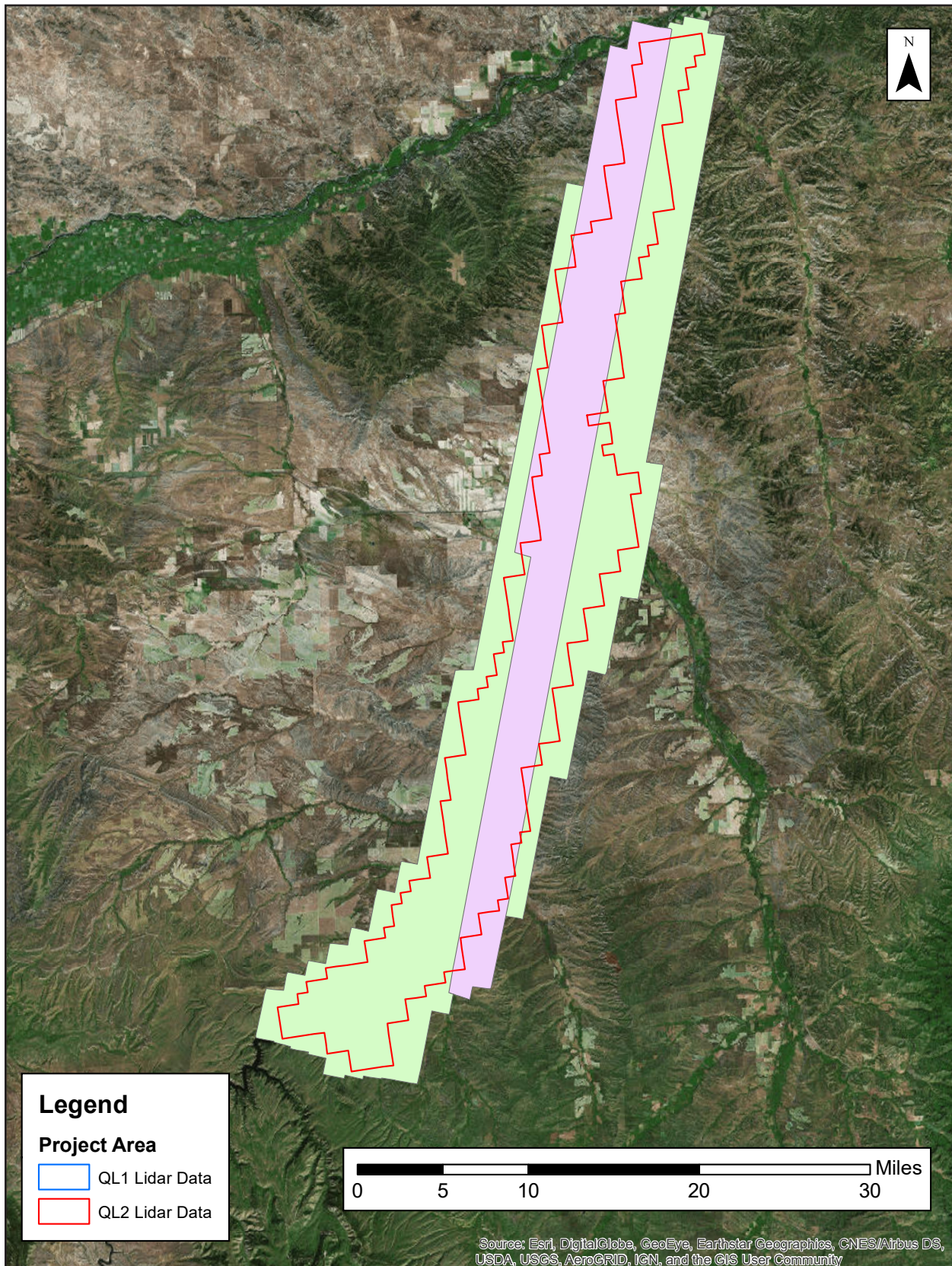




Figure 2-5: Flown Flight Lines - Havre

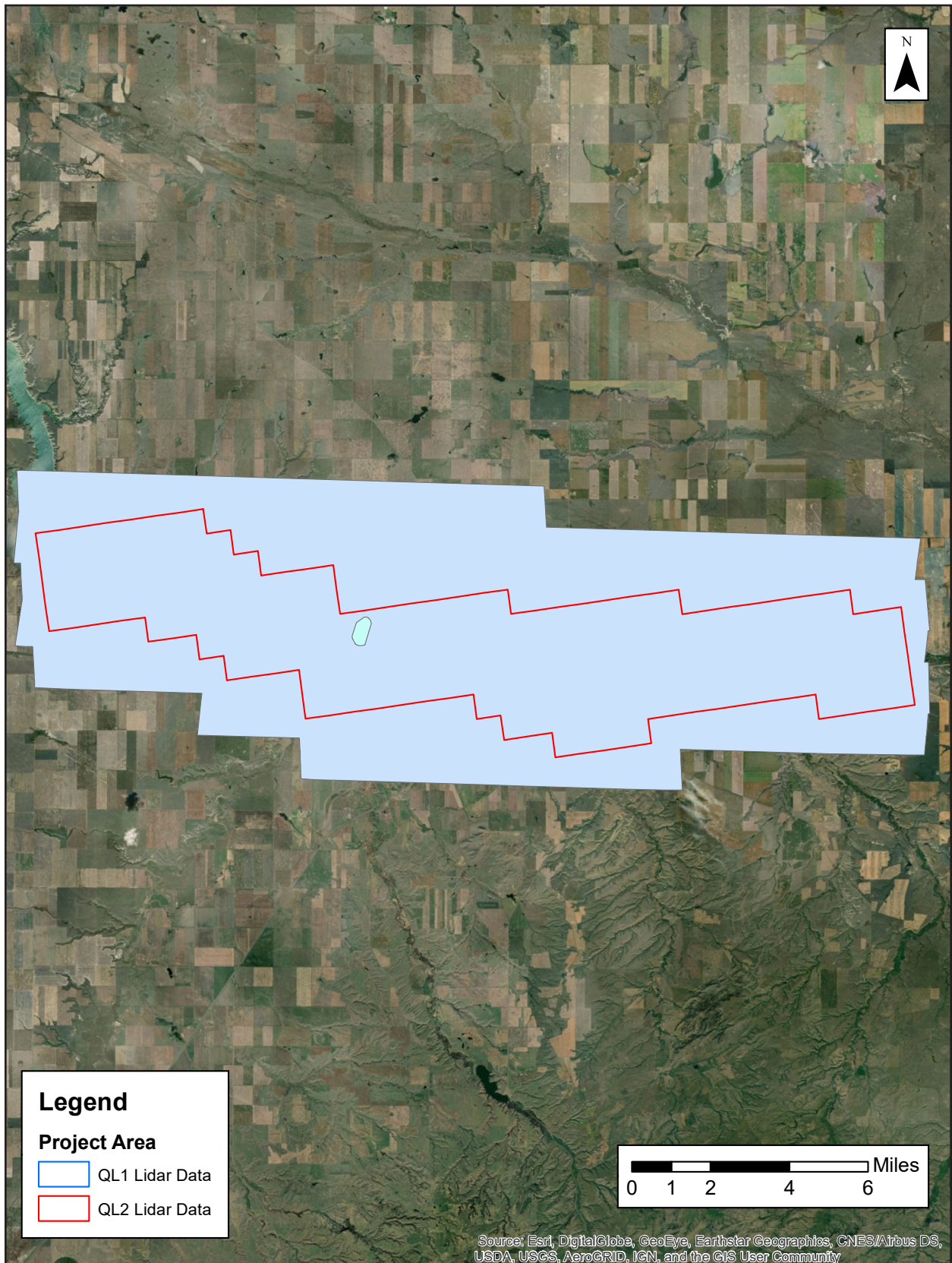




Figure 2-6: Flown Flight Lines - North/South Glasgow

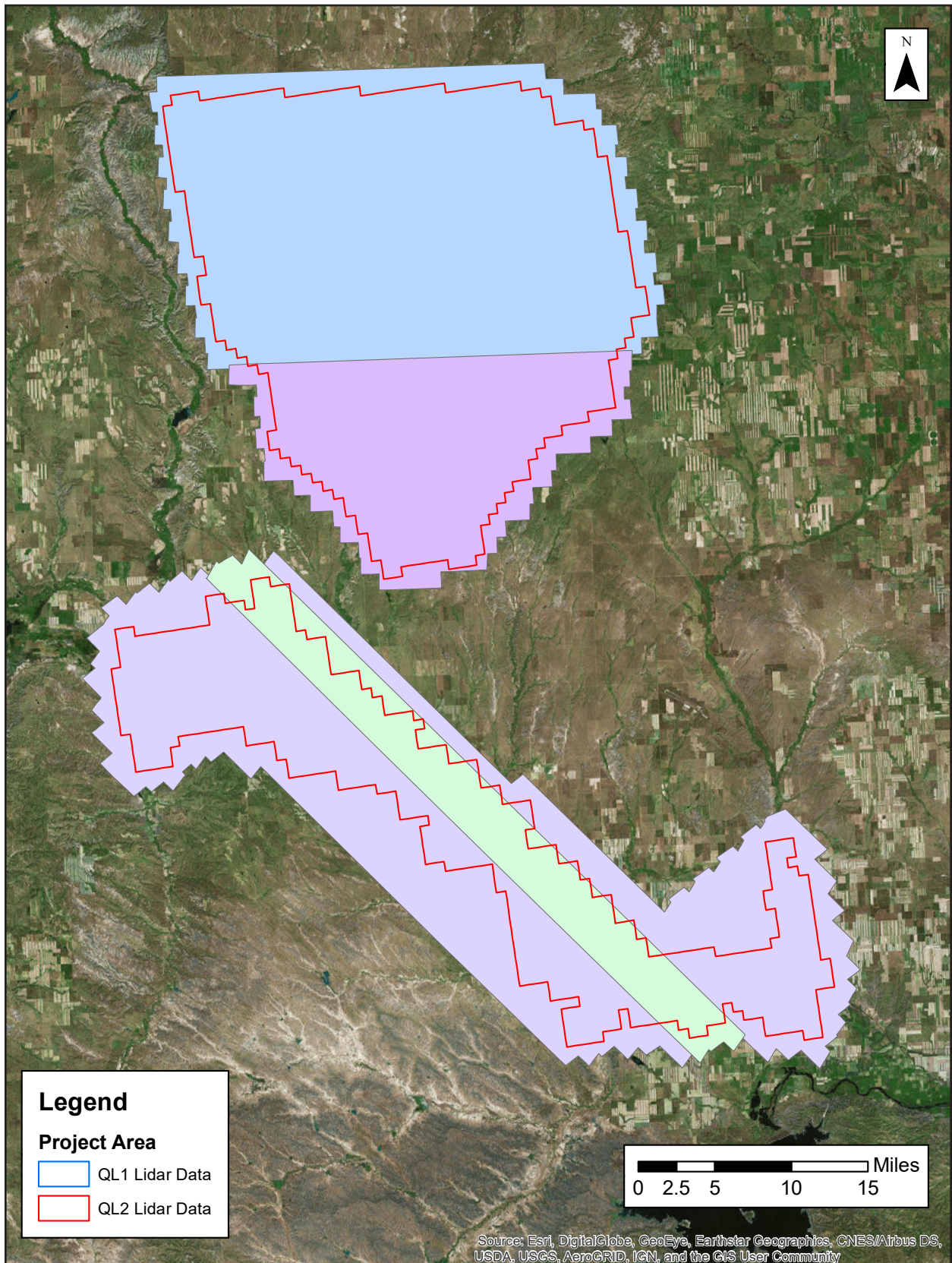




Figure 2-7: Flown Flight Lines - Tongue River

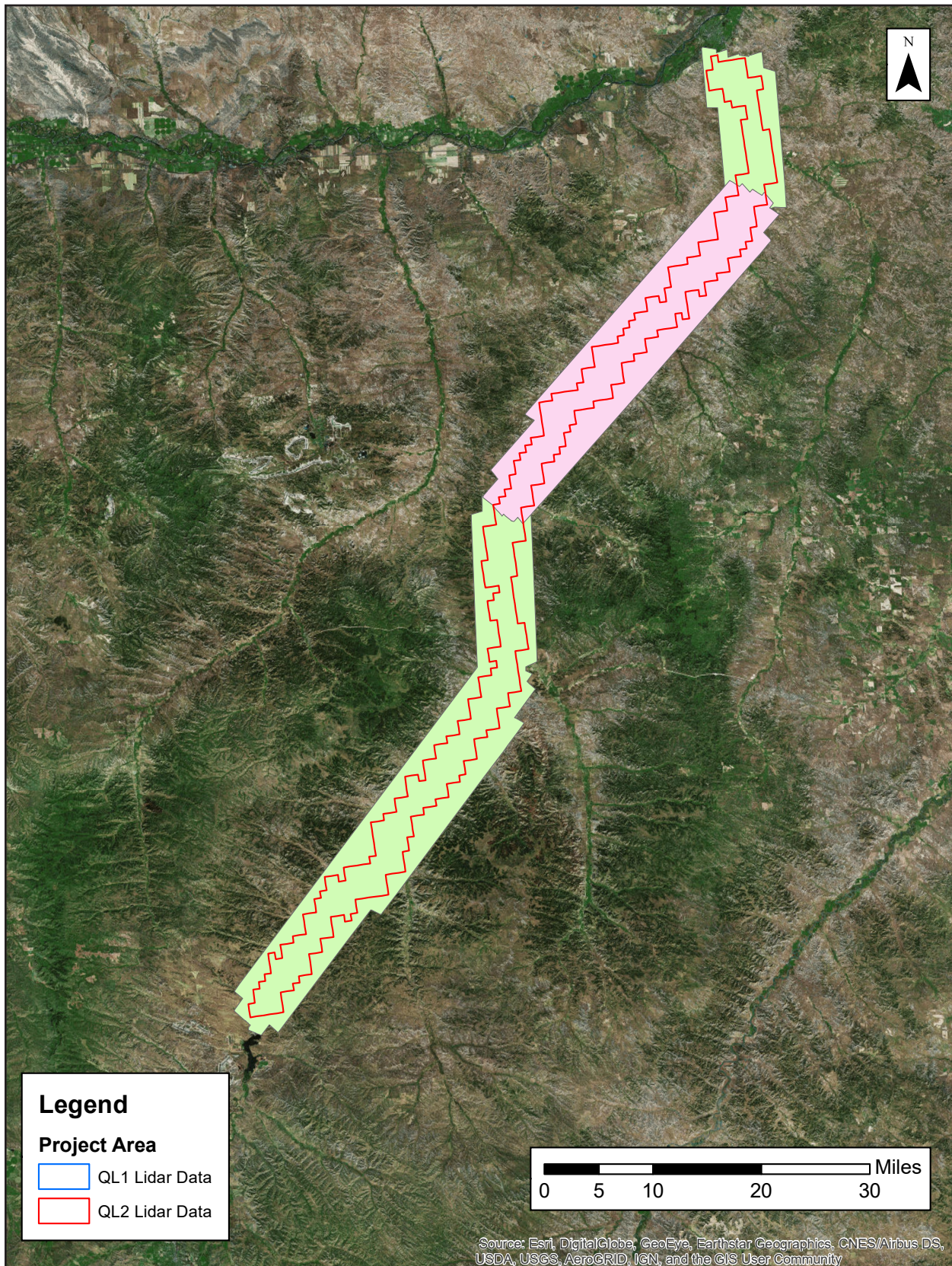
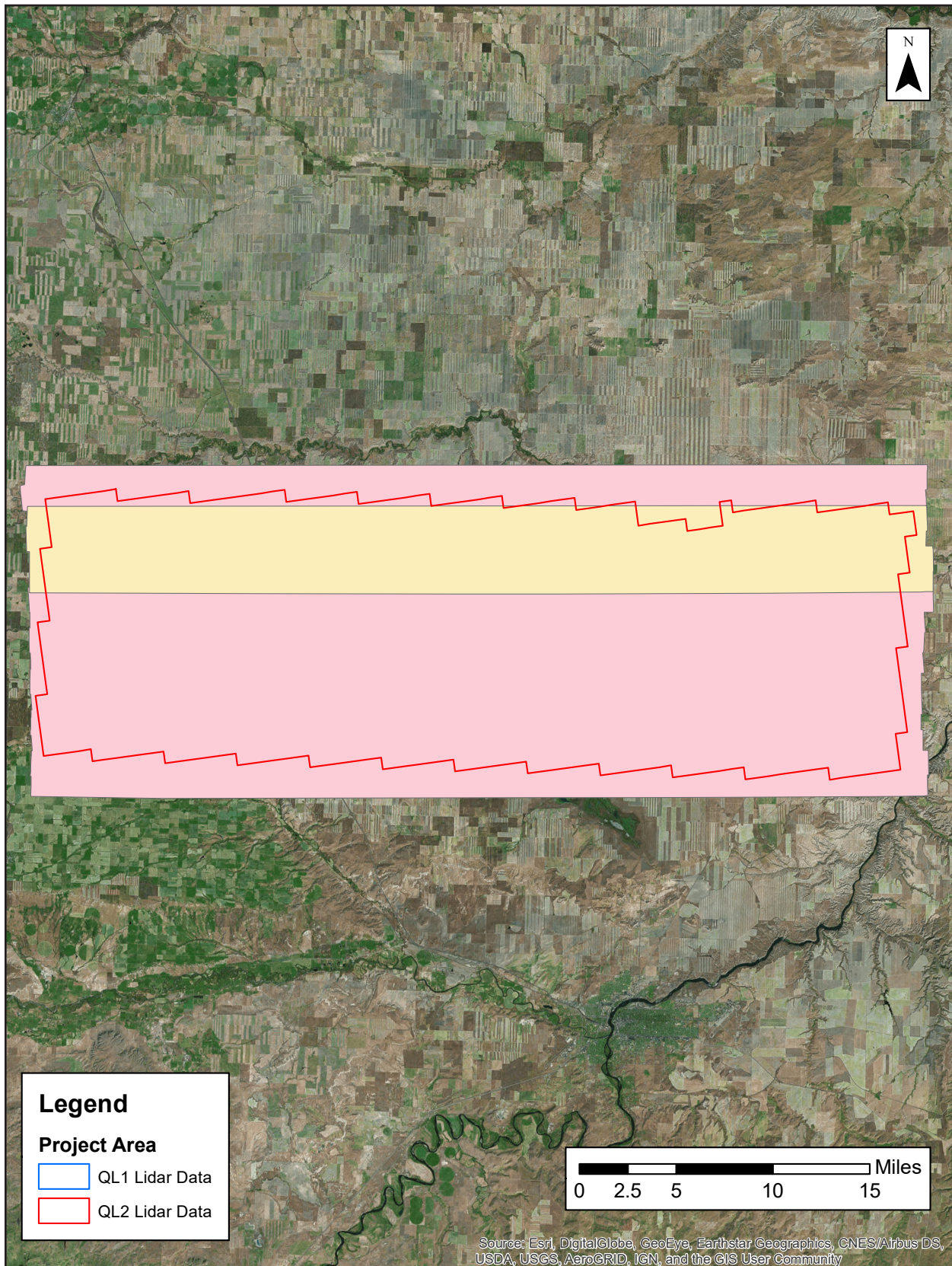




Figure 2-8: Flown Flight Lines - Wheatfields



# 3. Processing

## Processing Summary

Once the lidar data passed initial QC, the dataset was corrected for aircraft orientation and movement. This process used airborne inertial, orientation, and GPS data collected during acquisition along with ground-based GPS data. The data went through a geometric calibration that further corrected each laser point. This calibrated data set was used to create the LAS point cloud. The LAS point data was initially classified into “ground” and “non-ground”, then further refined using the classes specified in this task order. Breaklines were drawn to denote hydrological features. After the hydro-flattening process, the final deliverables products were created.

## GNSS-IMU Trajectory Processing

Kinematic corrections for the aircraft position were resolved using aircraft GPS and static ground GPS (1-Hz) for each geodetic control (base station) for three subsystems: inertial measurement unit (IMU), sensor orientation information, and airborne GPS data.

Post-processing of the IMU system data and aircraft position with attitude data was completed to compute an optimally accurate, blended navigation solution based on Kalman filtering technology, or the smoothed best estimate of trajectory (SBET).

**Software:** POSPac Software v. 5.3, IPAS Pro v.1.35., Novatel Inertial Explorer v8.60.6129

## Trajectory Quality

The GNSS trajectory and 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).

## Combination Separation

Combined separation is a measure of the difference between the forward-run and the backward-run solution of the trajectory. The Kalman filter was processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate and reliable solution is achieved.

The data for this task order was processed with a goal to maintain a combined separation difference of less than ten (10) centimeters.

## Estimated Positional Accuracy

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.

## PDOP

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



The data for this task order was processed with a goal 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.

## Geometric Calibration

After the initial phase was complete, a formal reduction process was performed on the data. Laser point position was calculated by associating the SBET position to each laser point return time, scan angle, intensity, etc. Raw laser point cloud data was created for the whole project area 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. Statistical reports were generated for comparison and used to make the necessary adjustments to remove any residual systematic error.

**Software:** Proprietary Software, TerraMatch v18, Leica CloudPro 1.2.4

## Lidar Data Classification

LAS data was 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 of higher accuracy.

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 the following client-specified classes:

- Class 1 – Default / Processed, but not Classified
- Class 2 – Bare Earth Ground
- Class 7 – Low Noise
- Class 9 – Water
- Class 17 – Bridge Decks
- Class 18 – High Noise
- Class 20 – Ignored Ground

Classified LAS files were evaluated through a series of manual QA/QC steps as well as a peer-based review to eliminate remaining artifacts from the ground class. This included a review of the DEM surface to remove artifacts and ensure topographic quality.

**Software:** Proprietary Software, TerraScan v18

## Hydrologic Flattening

The lidar task order required compilation of breaklines defining the following types of water body features:

Lakes, reservoirs, ponds	Minimum of 2-acres or greater Compiled as closed polygons, collected at a constant elevation
Rivers, streams	Nominal width of 30.5 meters / 100 feet Compiled in direction of flow, with both sides maintaining an equal elevation gradient
Bridge breaklines	Breaklines used to enforce a logical terrain surface below a bridge

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. The newly acquired lidar data was utilized to manually compile 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. An integrated software approach was applied 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. All classified ground points from inside the hydrologic feature polygons were reclassified to water, class nine (9).
4. All classified ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class twenty (20). The buffer distance was approximately the task order designed nominal pulse spacing distance.
5. Breaklines used for bridge removal during the hydrologic flattening were included with the hydrologic breakline geodatabase deliverable. The purpose of these breaklines is for a more aesthetically pleasing DEM appearance.
6. The lidar ground points and breaklines were used to generate a digital elevation model (DEM).
7. QA/QC for this task was performed by reviewing the hydrologically flattened DEM and hydrologic breakline features. Additionally, a combined approach utilizing commercial off the shelf software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

TerraScan was used to add the hydrologic breakline vertices and export the lattice models.

Breaklines defining the water bodies greater than 2-acres were provided as polygon features. Rivers and streams with a nominal minimum width of 30.5 meters (100 feet) were provided as polyline features. All lake and river breaklines compiled as part of the flattening process were provided in an Esri file geodatabase.

Breaklines used for bridge removal were provided as point features in Esri shapefile format.

**Software:** TerraScan v18, TerraModeler v18, Esri ArcMap v10.4, LP360 v2018.1.57.4

## Digital Elevation Model

TerraScan was used to add the hydrologic breakline vertices and export the lattice models. Class 2 (ground) lidar points in conjunction with the hydro breaklines and bridge breaklines were used to create a 1-meter hydro-flattened bare-earth raster DEM. Using automated scripting routines within ArcMap, an 32-bit floating point raster GeoTIFF file was created for each tile. Files were clipped to match the task order tiling scheme. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

## Intensity Imagery

Lidar intensity data derived from the acquired lidar data was linearly rescaled from 16-bit intensity and provided as a 1-meter pixel, 8-bit, 256 gray scale GeoTIFF format intensity images. Files were clipped to match the task order tiling scheme.

**Software:** TerraScan v18

## Metadata

FGDC CSDGM/USGS MetaParser-compliant metadata was produced in XML format. The metadata includes a complete description of the task order client information, contractor information, project purpose, lidar acquisition and ground survey collection parameters, lidar acquisition and ground survey collection dates, spatial reference system information, data processing including acquisition quality assurance procedures, GPS and base station processing, geometric calibration, lidar classification, hydrologic flattening, intensity imagery development, and final product development.

Other metadata deliverables included Esri shapefiles of the ground control and QA/QC points, delivery tile index, and delivery extent. A georeferenced, polygonal representation of the detailed extents of each acquired lidar swath was produced as a polygon feature class in an Esri file geodatabase.

## 4. Accuracy Assessment

### Results Summary

The tables below show a summary of all test results. The following sections describe the testing methods used.

**Software:** TerraScan v18, Esri ArcMap v10.4

Table 4-1. Vertical Accuracy Summary

Testing Categories	Target	Measured	Minimum Points	Points Used
<b>Raw Swath NVA</b> RMSEz 95% at Confidence Level	0.196 m	0.069 m	124	138
<b>DEM NVA</b> RMSEz at 95% Confidence Level	0.196 m	0.076 m	124	138
<b>DEM VVA</b> RMSEz at 95th Percentile	0.30 m	0.262 m	91	98

### Raw Lidar Swath Testing

This project required Non-Vegetated Vertical Accuracy (NVA) to be tested on the raw lidar point cloud swath data. The dataset was required to meet a target value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS).

The raw NVA was to be calculated with a minimum of 124 independent checkpoints that were not used in the calibration or post processing of the lidar point cloud data. Checkpoints were to be distributed throughout the project area and located in bare earth and urban (non-vegetated) land cover classes.

Testing was performed using TINs created from the final calibrated and controlled swath data. For each NVA checkpoint, an elevation value was derived from the TIN at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The raw NVA was tested using 138 checkpoints. These checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies. This dataset was tested to be 0.069 meters using an RMSEz of 0.035 meters x 1.9600.

For full checkpoint results, see the tables in Appendix 2.

### Digital Elevation Model Testing

This project required Non-Vegetated Accuracy (NVA) and Vegetated Vertical Accuracy (VVA) testing of the digital elevation model (DEM) dataset. The calculated NVA value was required to meet 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600. VVA was required to meet 29.4 cm at the 95th percentile error. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing



(ASPRS).

Testing was performed using the bare earth DEM created as part of this task order. For each checkpoint, an elevation value was derived from the DEM at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The NVA was to be calculated with a minimum of 124 independent checkpoints falling on bare earth and urban (non-vegetated) classes. VVA had a minimum of checkpoints requirement of 91 for the falling in brush/tall grass/weeds (vegetated) land cover classes. These points were not used in the calibration or post processing of the lidar point cloud data and distributed throughout the project area. Checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies.

The DEM NVA measured 0.076 meters using an RMSEz of 0.039 meters x 1.9600 using 138 checkpoints. VVA tested 0.262 meters at the 95th percentile using 98 checkpoints.

VVA errors larger than the 95th percentile are listed below. All values are in meters.

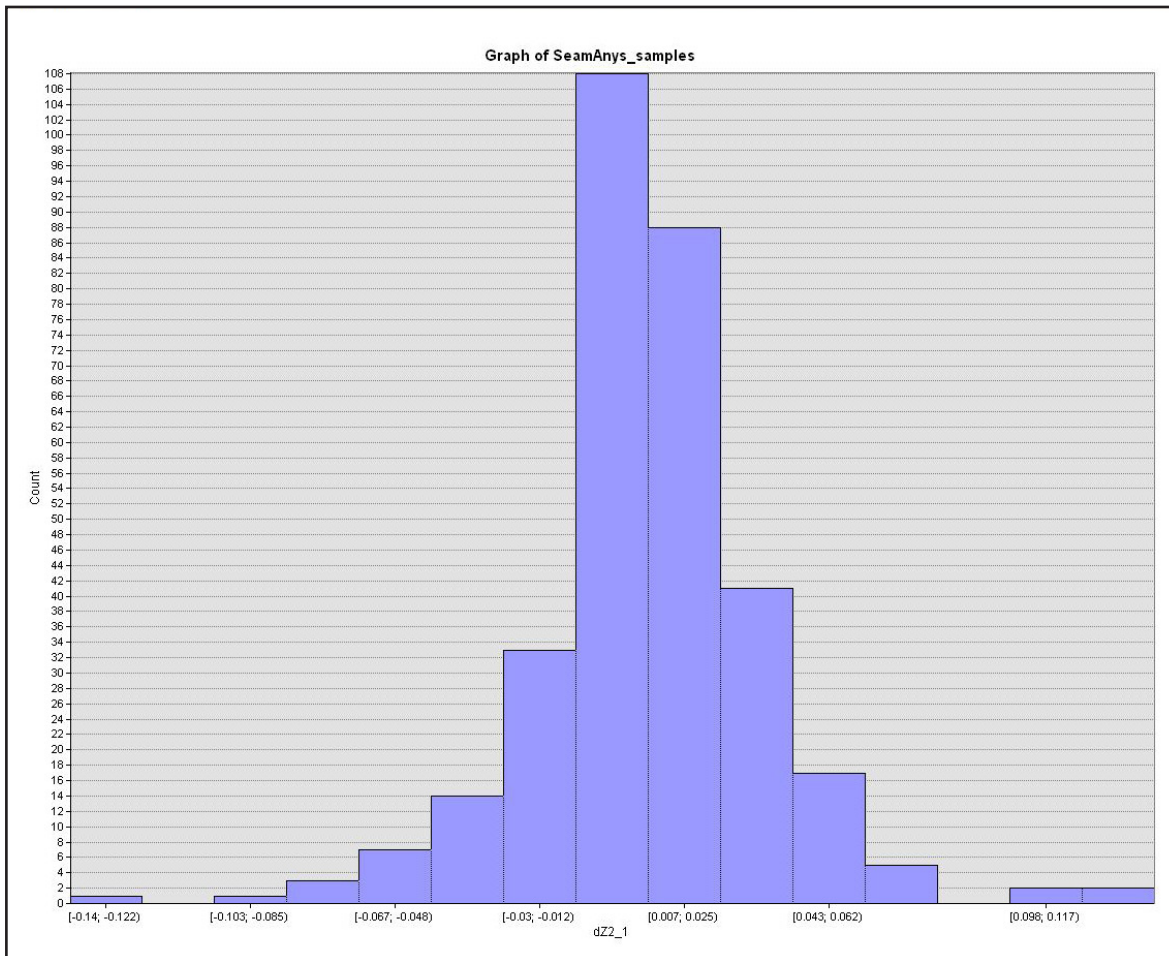
For full checkpoint results, see the tables in Appendix 3 and 4.

Table 4-2. VVA Errors

Point ID	Easting	Northing	Z-Error
3033	776427.09	505132.75	0.380
3053	747956.69	189861.67	0.310
3063	1000032.84	99647.71	0.340
3067	992454.12	151004.33	0.310

## Inter-Swath Testing

Inter-swath accuracy was tested against well-distributed flight line overlap locations. The relative accuracy for the lidar measured at 0.031 meters RMSE.



Values are in meters.

Approved By	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		March 2019

## Intra-Swath Testing

Intra-swath accuracy, also known as “within swath” accuracy, was tested against single swath first return data located in flat open areas. The intra-swath accuracy for the lidar measured at 0.021 meters RMSDz.

# Appendix 1: Flight Logs

## Browning

# Woolpert

<b>Optech Galaxy PRIME</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name					
		7/5/2018	186			Montana USGS LiDAR					
Operator		Aircraft		HOBS Start	Local Start Time	ZULU Start Time	Base				
Smith		N7269T		7970.5	11:07:12	17:07:12					
Pilot		Sensor Type		HOBS END	Local End Time	Zulu End Time	PID				
Hoddenbach		Galaxy PRIME		7977.8	13:58:03	19:58:03					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing			
								Arriving			
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values			
36		82		600	100	Gain - Course/Up	Single	A			
						Gain - Fine/Down	Multi	B			
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.	
112		Kts	4920	Ft	Ft	Yes	NO	@		NS	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓											
t		17:07:12	17:07:26	0:00:14		0.7	1.3	test			
x		17:14:12	17:18:05	0:03:52		0.7	1.3	crossline			
1		17:20:12	17:21:26	0:01:14		0.7	1.3				
2		17:22:38	17:25:24	0:02:47		0.7	1.3				
3		17:26:55	17:29:41	0:02:46		0.7	1.3				
4		17:31:19	17:34:55	0:03:36		0.7	1.3				
5		17:36:35	17:42:24	0:05:49		0.7	1.3				
x		17:44:17	17:47:49	0:03:32		0.7	1.3	crossline			
6		17:49:26	17:52:21	0:02:56		0.7	1.3				
7		17:54:11	17:56:55	0:02:45		0.7	1.3				
8		17:59:01	18:02:30	0:03:28		0.7	1.3				
9		18:04:39	18:09:39	0:05:00		0.7	1.3				
10		18:12:03	18:18:16	0:06:13		0.7	1.3				
11		18:22:41	18:31:32	0:08:51		0.7	1.3				
12		18:33:33	18:42:58	0:09:25		0.7	1.3				
13		18:44:36	18:53:26	0:08:50		0.7	1.3				
14		18:55:19	19:04:39	0:09:19		0.7	1.3				
15		19:06:16	19:15:05	0:08:50		0.7	1.3				
16		19:16:35	19:25:32	0:08:57		0.7	1.3				
17		19:27:08	19:28:00	0:00:52		0.7	1.3				
18		19:30:17	19:38:40	0:08:23		0.7	1.3				
19		19:40:40	19:48:40	0:08:01		0.7	1.3				
20		19:50:43	19:58:03	0:07:21		0.7	1.3				
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission		Yes	No
Additional Comments:										Drive #	



# Appendix 1: Flight Logs

## Flathead Reservation

# Woolpert

Optech Galaxy PRIME		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name			
		7/16/2018	197			Montana USGS LiDAR			
Operator		Aircraft		HOBSBS Start	Local Start Time	ZULU Start Time	Base		
Putnam		N7269T		8025.1	12:02:17	18:02:17			
Pilot		Sensor Type		HOBSBS END	Local End Time	Zulu End Time	PID		
McBeth		Galaxy PRIME		8035.0	18:32:00	0:32:00			
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	
								Arriving	
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values	
46		52		300	100	Gain - Course/Up	Single	A	
						Gain - Fine/Down	Multi	B	
Air Speed		AGL		MSL		Waveform Used		Waveform Mode	Pre-Trigger Dist.
112		Kts	8200	Ft	Ft	Yes	NO	@	NS
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	
↓ Times entered are Zulu / GMT ↓									
x		18:02:17	18:07:08	0:04:50		0.7	1.3	crossline	
1		18:11:45	18:24:35	0:12:49		0.7	1.3		
2		18:25:55	18:38:26	0:12:30		0.8	1.4		
3		18:39:11	18:52:01	0:12:50		0.7	1.3		
4		18:52:45	19:05:13	0:12:27		0.7	1.3		
5		19:05:55	19:18:47	0:12:52		0.7	1.3		
6		19:19:42	19:31:58	0:12:16		0.7	1.3		
7		19:32:46	19:45:44	0:12:58		0.8	1.3		
x		19:50:19	19:55:00	0:04:41		0.7	1.3	crossline	
t		20:57:49	20:58:03	0:00:14		0.7	1.3	test	
8		21:13:35	21:25:53	0:12:17		0.7	1.3		
9		21:26:58	21:39:38	0:12:40		0.7	1.3		
x		21:46:00	21:55:48	0:09:48		0.7	1.3	crossline	
10		21:58:17	22:06:48	0:08:31		0.7	1.3		
11		22:08:34	22:18:08	0:09:34		0.7	1.3		
12		22:19:35	22:29:38	0:10:02		0.7	1.3		
13		22:30:54	22:42:24	0:11:31		0.8	1.6		
14		22:44:56	22:56:39	0:11:44		0.7	1.3		
15		22:58:29	23:11:01	0:12:33		0.7	1.3		
16		23:12:45	23:25:38	0:12:53		0.7	1.3		
17		23:26:39	23:39:50	0:13:11		0.7	1.3		
18		23:41:34	23:54:36	0:13:01		0.7	1.3		
x		0:02:58	0:11:53	0:08:54		0.7	1.3	crossline	
19		0:18:57	0:32:00	0:13:03		0.7	1.3		
↑ Times entered are Zulu / GMT ↑									
				Page	1		Verify S-Turns After Mission		Yes <input type="checkbox"/> No <input type="checkbox"/>
Additional Comments:									Drive #

# Appendix 1: Flight Logs

## Hammond











# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name				
		6/3/2018	154			Montana USGS LiDAR				
Operator		Aircraft		HOBBSS Start	Local Start Time	ZULU Start Time	Base			
Putnam		N27DV		3956.7	9:17:20	15:17:20				
Pilot		Sensor Type		HOBBSS END	Local End Time	Zulu End Time	PID			
Allen		Orion H-300			13:29:05	19:29:05				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing		
								Arriving		
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values		
29		40.3		125	92	Gain - Course/Up	Single	A		
						Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL	Waveform Used		Waveform Mode	Pre-Trigger Dist.		
110	Kts	5900	Ft		Yes	No	@	NS	Ft	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓										
		15:17:20	15:25:57	0:08:37		0.6	1.2	crossline		
42		15:29:27	15:35:14	0:05:46		0.6	1.2			
43		15:38:13	15:44:18	0:06:04		0.6	1.2			
44		15:47:06	15:53:17	0:06:11		0.6	1.2			
45		15:55:50	16:02:18	0:06:28		0.6	1.2			
46		16:12:00	16:23:51	0:11:51		0.6	1.2			
47		16:33:16	16:44:50	0:11:34		0.6	1.2			
48		16:47:32	17:04:43	0:17:11		0.6	1.2			
49		17:06:53	17:24:26	0:17:33		0.6	1.2			
50		17:26:50	17:44:15	0:17:25		0.6	1.2			
51		17:46:06	18:03:29	0:17:22		0.6	1.2			
51		18:06:10	18:29:05	0:22:54		0.6	1.2			
53		18:31:35	18:53:52	0:22:18		0.6	1.2			
54		18:56:46	19:14:19	0:17:33		0.6	1.2			
x		19:16:26	19:18:25	0:01:59		0.6	1.2	crossline		
Test		19:18:40	19:18:43	0:00:03		0.6	1.2	test		
55		19:22:14	19:29:05	0:06:51		0.6	1.2			
↑ Times entered are Zulu / GMT ↑					Page	1		Verify S-Turns After Mission	Yes	No
Additional Comments:										Drive #

# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name				
		6/3/2018	154			Montana USGS LiDAR				
Operator		Aircraft		HOBSBS Start	Local Start Time	ZULU Start Time	Base			
Putnam		N27DV		3956.7	14:46:16	20:46:16				
Pilot		Sensor Type		HOBSBS END	Local End Time	Zulu End Time	PID			
Allen		Orion H-300		3966.2	17:12:47	23:12:47				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing		
								Arriving		
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode		Threshold Values	
29		40.3		125	92	Gain - Course/Up	Single	A		
						Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.
110		Kts	5900	Ft	Ft	Yes	No	@		NS
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓										
x		20:46:16	20:48:52	0:02:36		0.8	1.3	crossline		
56		20:57:55	21:20:42	0:22:46		0.8	1.3			
57		21:23:04	21:47:03	0:23:59		0.8	1.3			
58		21:49:29	22:13:00	0:23:30		0.8	1.3			
59		22:15:09	22:21:54	0:06:45		0.8	1.3			
x		22:24:17	22:26:02	0:01:45		0.8	1.3	crossline		
60		22:29:24	22:47:47	0:18:23		0.8	1.3			
61		22:49:37	23:12:47	0:23:10		0.8	1.3			
↑ Times entered are Zulu / GMT ↑										
				Page	1		Verify S-Turns After Mission		Yes	No
Additional Comments:										Drive #

# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name				
		6/4/2018	155			Montana USGS LiDAR				
Operator		Aircraft		HOBSBS Start	Local Start Time	ZULU Start Time	Base			
Putnam		N27DV		3966.2	9:09:25	15:09:25				
Pilot		Sensor Type		HOBSBS END	Local End Time	Zulu End Time	PID			
Allen		Orion H-300			13:59:17	19:59:17				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing		
								Arriving		
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode		Threshold Values	
29		40.3		125	92	Gain - Course/Up	Single	A		
						Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.
110		Kts	5900	Ft	Ft	Yes	NO	@		NS
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓										
x		15:09:25	15:12:54	0:03:28		0.6	1.1	crossline		
62		15:26:01	15:49:09	0:23:08		0.6	1.1			
63		15:51:42	16:15:42	0:24:00		0.6	1.1			
64		16:18:18	16:41:51	0:23:34		0.6	1.1			
65		16:44:20	17:08:50	0:24:30		0.6	1.1			
66		17:11:21	17:35:04	0:23:44		0.6	1.1			
67		17:37:55	18:02:46	0:24:52		0.6	1.1			
68		18:04:43	18:28:59	0:24:16		0.6	1.1			
69		18:31:18	18:56:07	0:24:49		0.6	1.1			
70		18:58:21	19:21:57	0:23:36		0.6	1.1			
71		19:24:04	19:30:10	0:06:06		0.6	1.1			
x		19:33:52	19:36:47	0:02:55		0.6	1.1	crossline		
72		19:39:57	19:59:17	0:19:20		0.6	1.1			
↑ Times entered are Zulu / GMT ↑										
Page					1		Verify S-Turns After Mission		Yes	No
Additional Comments:										Drive #





# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name						
		6/5/2018	156			Montana USGS LiDAR						
Operator		Aircraft		HOBSBS Start	Local Start Time	ZULU Start Time	Base					
Putnam		N27DV		3974.7	9:10:59	15:10:59						
Pilot		Sensor Type		HOBSBS END	Local End Time	Zulu End Time	PID					
Allen		Orion H-300		3980.8	13:32:04	19:32:04						
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing				
								Arriving				
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode		Threshold Values			
29		40.3		125	92	Gain - Course/Up	Single	A				
						Gain - Fine/Down	Multi	B				
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.		
110		Kts	5900	Ft	Ft	Yes	NO	@		NS		
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments				
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:				
↓ Times entered are Zulu / GMT ↓										Verify S-Turns Before Mission	Yes	No
76		15:10:59	15:33:26	0:22:27		0.6	1.2					
77		15:37:57	15:43:46	0:05:49		0.6	1.2					
x		15:47:03	15:50:08	0:03:05		0.6	1.2	crossline				
78		15:54:49	16:08:37	0:13:48		0.6	1.2					
x		16:12:09	16:15:26	0:03:17		0.6	1.2	crossline				
79		16:19:32	16:28:50	0:09:18		0.6	1.2					
80		16:32:10	16:54:50	0:22:40		0.6	1.2					
81		16:57:42	17:21:36	0:23:54		0.6	1.2					
82		17:24:40	17:46:53	0:22:13		0.6	1.2					
83		17:49:47	18:13:57	0:24:10		0.6	1.2					
84		18:17:13	18:40:17	0:23:04		0.6	1.2					
85		18:42:44	19:06:37	0:23:53		0.6	1.2					
86		19:09:00	19:32:04	0:23:03		0.6	1.2					
↑ Times entered are Zulu / GMT ↑										Verify S-Turns After Mission	Yes	No
Additional Comments:										Drive #		



# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name				
		6/8/2018	159			Montana USGS LiDAR				
Operator		Aircraft		HOBBSS Start	Local Start Time	ZULU Start Time	Base			
Putnam		N27DV		3986.9	9:22:32	15:22:32				
Pilot		Sensor Type		HOBBSS END	Local End Time	Zulu End Time	PID			
Allen		Orion H-300		3993.3	14:10:15	20:10:15				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing		
								Arriving		
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values		
29		40.3		125	92	Gain - Course/Up	Single	A		
						Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL	Waveform Used		Waveform Mode	Pre-Trigger Dist.		
110		Kts	5900	Ft	Yes	No	@	NS	Ft	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓										
99		15:22:32	15:44:11	0:21:39		0.7	1.2			
100		15:46:47	15:50:05	0:03:18		0.7	1.2			
x		15:52:15	15:56:37	0:04:22		0.7	1.2	crossline		
Test		16:00:23	16:00:50	0:00:26		0.7	1.2			
101		16:03:25	16:16:26	0:13:01		0.7	1.2			
x		16:19:08	16:23:08	0:04:00		0.7	1.2	crossline		
102		16:27:21	16:36:31	0:09:10		0.7	1.2			
103		16:39:06	17:01:37	0:22:31		0.7	1.2			
104		17:03:59	17:28:15	0:24:15		0.7	1.2			
105		17:30:35	17:53:27	0:22:51		0.7	1.2			
106		17:56:00	18:20:18	0:24:18		0.7	1.2			
107		18:22:44	18:45:49	0:23:04		0.7	1.2			
108		18:49:04	19:14:59	0:25:55		0.7	1.2			
109		19:17:47	19:42:46	0:24:59		0.7	1.2			
110		19:45:01	20:10:15	0:25:15		0.7	1.2			
↑ Times entered are Zulu / GMT ↑										
				Page	1		Verify S-Turns After Mission		Yes	No
Additional Comments:										Drive #



# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name			
		6/9/2018	160			Montana USGS LiDAR			
Operator		Aircraft		HOBBS Start	Local Start Time	ZULU Start Time	Base		
Putnam		N27DV		3993.3	9:05:54	15:05:54			
Pilot		Sensor Type		HOBBS END	Local End Time	Zulu End Time	PID		
Allen		Orion H-300		3999.5	13:52:39	19:52:39			
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	
								Arriving	
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values	
29		40.3		125	92	Gain - Course/Up	Single	A	
						Gain - Fine/Down	Multi	B	
Air Speed		AGL		MSL		Waveform Used		Waveform Mode	Pre-Trigger Dist.
110		Kts	5900	Ft	Ft	Yes	NO	@	NS
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	
↓ Times entered are Zulu / GMT ↓									
111		15:05:54	15:14:29	0:08:35		0.7	1.2		
x		15:16:44	15:19:58	0:03:14		0.7	1.2	crossline	
112		15:23:18	15:35:06	0:11:48		0.7	1.2		
x		15:37:56	15:41:59	0:04:03		0.7	1.2	crossline	
113		15:46:16	15:53:21	0:07:06		0.7	1.2		
114		15:55:57	16:21:09	0:25:11		0.7	1.2		
115		16:23:14	16:48:21	0:25:07		0.7	1.2		
116		16:52:04	17:19:34	0:27:30		0.7	1.2		
117		17:21:54	17:48:33	0:26:40		0.7	1.2		
118		17:51:06	18:18:17	0:27:11		0.7	1.2		
119		18:26:22	18:45:55	0:19:33		0.7	1.2		
120		18:47:51	19:08:08	0:20:17		0.7	1.2		
121		19:10:11	19:30:08	0:19:58		0.7	1.2		
122		19:31:52	19:52:39	0:20:48		0.7	1.2		
↑ Times entered are Zulu / GMT ↑									
				Page	1		Verify S-Turns After Mission		
								Yes	No
Additional Comments:									Drive #

# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name					
		6/23/2018	174			Montana USGS LiDAR					
Operator		Aircraft		HOBS Start	Local Start Time	ZULU Start Time	Base				
Guenther		N27DV		4012.4	9:05:46	15:05:46					
Pilot		Sensor Type		HOBS END	Local End Time	Zulu End Time	PID				
Vickernam		Orion H-300		4016.1	11:38:11	17:38:11					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing			
								Arriving			
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode		Threshold Values		
29		40.3		125	92	Gain - Course/Up	Single	A			
						Gain - Fine/Down	Multi	B			
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.	
110		Kts	5900	Ft	Ft	Yes	NO	@		NS	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓											
Test		15:05:46	15:06:00	0:00:14		0.7	1.3	test			
x		15:22:13	15:30:20	0:08:07		0.7	1.3	crossline			
123		15:34:21	15:44:16	0:09:55		0.7	1.3				
x		15:48:04	15:50:42	0:02:38		0.7	1.3	crossline			
124		15:56:26	16:03:41	0:07:15		0.7	1.3				
125		16:07:07	16:26:36	0:19:30		0.7	1.3				
126		16:30:30	16:40:33	0:10:04		0.7	1.3				
127		16:43:24	16:48:18	0:04:54		0.7	1.3				
128		16:55:11	17:08:19	0:13:09		0.7	1.3				
129		17:11:41	17:21:49	0:10:08		0.7	1.3				
Test		17:25:12	17:25:12	0:00:00		0.7	1.3	test			
130		17:25:53	17:38:11	0:12:18		0.7	1.3				
↑ Times entered are Zulu / GMT ↑											
				Page		1		Verify S-Turns After Mission		Yes	No
Additional Comments:										Drive #	

# Woolpert

Optech Orion H-300		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name					
		6/26/2018	177			Montana USGS LiDAR					
Operator		Aircraft		HOBBES Start	Local Start Time	ZULU Start Time		Base			
Guenther		N27DV		4016.1	7:51:56	13:51:56					
Pilot		Sensor Type		HOBBES END	Local End Time	Zulu End Time		PID			
Vickernam		Orion H-300		4022.2	12:39:20	18:39:20					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing			
								Arriving			
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
29		40.3		125	92	Gain - Course/Up		Single	A		
						Gain - Fine/Down		Multi	B		
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.	
110		Kts	5900	Ft	Ft	Yes	No	@		NS	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓											
Test		13:51:56	13:52:14	0:00:18		0.7	1.3	test			
x		14:08:32	14:15:23	0:06:51		0.7	1.3	crossline			
131		14:19:27	14:29:52	0:10:26		0.7	1.3				
132		14:33:25	14:45:44	0:12:19		0.7	1.3				
133		14:50:20	15:00:27	0:10:08		0.7	1.3				
134		15:04:15	15:17:02	0:12:48		0.7	1.3				
135		15:20:04	15:30:13	0:10:09		0.7	1.3				
136		15:33:36	15:46:39	0:13:03		0.7	1.3				
137		15:49:33	16:07:51	0:18:18		0.7	1.3				
138		16:10:34	16:31:18	0:20:44		0.7	1.3				
139		16:34:16	16:52:12	0:17:56		0.7	1.3				
140		16:55:22	17:15:49	0:20:27		0.7	1.3				
141		17:18:44	17:36:34	0:17:50		0.7	1.3				
142		17:40:20	17:59:49	0:19:29		0.7	1.3				
143		18:02:27	18:20:30	0:18:03		0.7	1.3				
144		18:22:30	18:31:48	0:09:19		0.7	1.3				
x		18:35:41	18:39:20	0:03:39		0.7	1.3	crossline			
↑ Times entered are Zulu / GMT ↑		Page				1		Verify S-Turns After Mission		Yes	No
Additional Comments:										Drive #	

# Woolpert

Optech Orion H-300	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name							
	6/27/2018	178			Montana USGS LiDAR							
Operator		Aircraft		HOBS Start	Local Start Time		ZULU Start Time	Base				
Guenther		N27DV		4022.2	10:07:59		17:07:59					
Pilot		Sensor Type		HOBS END	Local End Time		Zulu End Time	PID				
Vickernam		Orion H-300		4028.1	15:54:20		21:54:20					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing				
								Arriving				
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain	Mode	Threshold Values		
29		40.3		125		92		Gain - Course/Up	Single	A		
								Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.		
110		Kts	5900	Ft		Ft	Yes	No	@		NS	Ft
Line #	Dir.	Line Start Time		Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a				n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓												
Test		17:07:59		17:08:14	0:00:15		0.8	1.3	test			
x		17:32:30		17:38:06	0:05:36		0.8	1.3	crossline			
145		17:42:48		17:51:42	0:08:53		0.8	1.3				
146		17:54:43		18:04:54	0:10:10		0.8	1.3				
147		18:07:33		18:16:44	0:09:12		0.8	1.3				
148		18:20:04		18:30:22	0:10:18		0.8	1.3				
149		18:32:44		18:41:56	0:09:13		0.8	1.3				
150		18:44:52		18:55:18	0:10:27		0.8	1.3				
151		18:58:24		19:07:21	0:08:58		0.8	1.3				
152		19:10:35		19:20:42	0:10:07		0.8	1.3				
153		19:23:05		19:32:03	0:08:57		0.8	1.3				
154		19:35:27		19:39:11	0:03:44		0.8	1.3				
155		19:42:02		19:45:31	0:03:29		0.8	1.3				
x		19:49:23		19:54:20	0:04:57		0.8	1.3	crossline			
156		19:59:04		20:20:20	0:21:16		0.8	1.3				
x		20:22:59		20:25:26	0:02:27		0.8	1.3	crossline			
157		20:28:13		20:45:37	0:17:25		0.8	1.3				
158		20:48:28		21:09:56	0:21:29		0.8	1.3				
159		21:12:37		21:30:36	0:17:59		0.8	1.3				
160		21:33:19		21:54:20	0:21:01		0.8	1.3				
↑ Times entered are Zulu / GMT ↑												
					Page		1		Verify S-Turns After Mission	Yes	No	
Additional Comments:										Drive #		



# Woolpert

Optech Orion H-300	MM/DD/YEAR		Day of Year		Project #		Phase #		Project Name							
	6/28/2018		179						Montana USGS LiDAR							
Operator		Aircraft		HOBS Start		Local Start Time		ZULU Start Time		Base						
Guenther		N27DV		4028.1		10:52:49		16:52:49								
Pilot		Sensor Type		HOBS END		Local End Time		Zulu End Time		PID						
Vickernam		Orion H-300		4034.3		15:38:03		21:38:03								
Wind Dir/Speed	Visibility		Ceiling	Cloud Cover %		Temp	Dew Point		Pressure		Haze/Fire/Cloud	Departing				
												Arriving				
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain		Mode	Threshold Values					
29		40.3		125		92		Gain - Course/Up		Single	A					
								Gain - Fine/Down		Multi	B					
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.						
110	Kts	5900	Ft		Ft	Yes	NO	@		NS	Ft					
Line #	Dir.	Line Start Time		Line End Time		Time On Line	SV's	HDOP	PDOP	Line Notes/Comments						
Test	n/a					n/a	n/a	n/a	n/a	GPS Began Logging At:						
↓ Times entered are Zulu / GMT ↓												Verify S-Turns Before Mission	Yes	No		
x		16:52:49		16:55:55		0:03:06		0.7	1.3	crossline						
161		16:59:17		17:09:13		0:09:56		0.7	1.3							
x		17:12:57		17:16:38		0:03:40		0.7	1.3	crossline						
162		17:22:01		17:36:23		0:14:22		0.7	1.3							
163		17:39:01		17:49:05		0:10:04		0.7	1.3							
164		17:52:06		18:06:04		0:13:58		0.7	1.3							
165		18:08:58		18:18:54		0:09:56		0.7	1.3							
166		18:22:02		18:35:20		0:13:18		0.7	1.3							
167		18:38:08		18:48:16		0:10:08		0.7	1.3							
168		18:51:15		19:04:38		0:13:23		0.7	1.3							
169		19:07:13		19:17:24		0:10:11		0.7	1.3							
170		19:20:11		19:33:37		0:13:26		0.7	1.3							
171		19:36:22		19:47:03		0:10:41		0.7	1.3							
172		19:49:33		20:02:46		0:13:13		0.7	1.3							
173		20:05:25		20:16:28		0:11:03		0.7	1.3							
x		20:18:47		20:20:43		0:01:56		0.7	1.3	crossline						
174		20:24:14		20:36:40		0:12:26		0.7	1.3							
175		20:39:12		20:50:14		0:11:02		0.7	1.3							
176		20:52:39		21:05:14		0:12:34		0.7	1.3							
177		21:08:01		21:19:00		0:10:59		0.7	1.3							
178		21:21:25		21:34:05		0:12:40		0.7	1.3							
x		21:36:35		21:38:03		0:01:28		0.7	1.3	crossline						
↑ Times entered are Zulu / GMT ↑												Page	1	Verify S-Turns After Mission	Yes	No
Additional Comments:													Drive #			

# Woolpert

Optech Orion H-300	MM/DD/YEAR		Day of Year		Project #		Phase #		Project Name										
	7/1/2018		182						Montana USGS LiDAR										
Operator		Aircraft		HOBBS Start		Local Start Time		ZULU Start Time		Base									
Guenther		N27DV		4034.3		9:46:52		15:46:52											
Pilot		Sensor Type		HOBBS END		Local End Time		Zulu End Time		PID									
Vickernam		Orion H-300		4040.3		14:27:54		20:27:54											
Wind Dir/Speed	Visibility		Ceiling	Cloud Cover %	Temp	Dew Point	Pressure		Haze/Fire/Cloud		Departing								
											Arriving								
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain		Mode		Threshold Values							
29		40.3		125		92		Gain - Course/Up		Single		A							
								Gain - Fine/Down		Multi		B							
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.									
110		Kts	5900		Ft	Yes	NO	@		NS	Ft								
Line #	Dir.	Line Start Time		Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments										
Test	n/a				n/a	n/a	n/a	n/a	GPS Began Logging At:										
↓ Times entered are Zulu / GMT ↓												Verify S-Turns Before Mission		Yes	No				
Test		15:46:52		15:47:07	0:00:15		0.7	1.3	test										
x		15:50:39		15:57:10	0:06:31		0.7	1.3	crossline										
179		16:10:08		16:19:55	0:09:47		0.7	1.3											
x		16:22:23		16:28:20	0:05:57		0.7	1.3	crossline										
Test		16:30:30		16:30:57	0:00:27		0.7	1.3											
180		16:35:43		16:44:13	0:08:30		0.7	1.3											
181		16:47:38		16:58:56	0:11:18		0.7	1.3											
182		17:01:31		17:09:45	0:08:14		0.7	1.3											
183		17:12:50		17:18:33	0:05:43		0.7	1.3											
184		17:29:01		17:36:49	0:07:48		0.7	1.3											
185		17:39:56		17:49:51	0:09:55		0.7	1.3											
186		17:53:48		18:02:16	0:08:28		0.7	1.3											
187		18:05:17		18:15:55	0:10:38		0.7	1.3											
188		18:21:58		18:32:55	0:10:57		0.7	1.3											
189		18:36:09		18:53:33	0:17:24		0.8	1.4											
190		18:56:38		19:09:47	0:13:09		0.8	1.4											
191		19:12:51		19:33:27	0:20:36		0.8	1.4											
192		19:36:00		19:51:58	0:15:58		0.8	1.4											
193		19:54:54		20:18:54	0:23:59		0.8	1.4											
x		20:22:31		20:27:54	0:05:23		0.8	1.4	crossline										
↑ Times entered are Zulu / GMT ↑												Page		1		Verify S-Turns After Mission		Yes	No
Additional Comments:											Drive #								

# Woolpert

Optech Orion H-300	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name						
	7/2/2018	183			Montana USGS LiDAR						
Operator		Aircraft		HOBS Start	Local Start Time		ZULU Start Time	Base			
Guenther		N27DV		4040.3	8:47:11		14:47:11				
Pilot		Sensor Type		HOBS END	Local End Time		Zulu End Time	PID			
Vickernam		Orion H-300		4046.1	13:39:28		19:39:28				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing			
								Arriving			
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain	Mode	Threshold Values	
29		40.3		125		92		Gain - Course/Up	Single	A	
								Gain - Fine/Down	Multi	B	
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.	
110	Kts	5900	Ft		Ft	Yes	NO	@		NS	Ft
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓											
Test		14:47:11	14:47:36	0:00:24		0.7	1.3	test			
x		15:11:06	15:20:31	0:09:25		0.7	1.3	crossline			
194		15:23:34	15:31:54	0:08:20		0.7	1.3				
195		15:35:16	15:46:08	0:10:52		0.7	1.3				
196		15:48:23	15:57:08	0:08:45		0.7	1.3				
197		16:00:03	16:10:46	0:10:43		0.7	1.3				
198		16:13:02	16:21:24	0:08:21		0.7	1.3				
199		16:24:48	16:35:16	0:10:28		0.7	1.3				
200		16:37:43	16:46:07	0:08:24		0.7	1.3				
201		16:49:08	16:59:48	0:10:41		0.7	1.3				
202		17:02:13	17:10:24	0:08:11		0.7	1.3				
203		17:13:25	17:24:07	0:10:43		0.7	1.3				
204		17:26:27	17:34:40	0:08:13		0.7	1.3				
205		17:37:39	17:48:11	0:10:33		0.7	1.3				
206		17:50:41	17:58:47	0:08:05		0.7	1.3				
207		18:01:58	18:12:29	0:10:31		0.7	1.3				
208		18:14:55	18:23:07	0:08:12		0.7	1.3				
209		18:26:21	18:37:11	0:10:50		0.7	1.3				
x		18:49:51	18:52:09	0:02:18		0.7	1.3	crossline			
210		18:55:32	19:13:10	0:17:38		0.7	1.3				
211		19:16:24	19:39:28	0:23:04		0.7	1.3				
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission	Yes	No	
Additional Comments:										Drive #	

# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name					
		7/3/2018	184			Montana USGS LiDAR					
Operator		Aircraft		HOBS Start	Local Start Time	ZULU Start Time	Base				
Guenther		N27DV		4046.1	8:46:34	14:46:34					
Pilot		Sensor Type		HOBS END	Local End Time	Zulu End Time	PID				
Vickernam		Orion H-300		4051.1	12:41:45	18:41:45					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	Arriving		
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values			
29		40.3		125	92	Gain - Course/Up	Single	A			
						Gain - Fine/Down	Multi	B			
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.	
110		Kts	5900	Ft	Ft	Yes	NO	@		NS	Ft
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓											
Test		14:46:34	14:46:58	0:00:23		0.7	1.3	test			
x		15:18:48	15:22:53	0:04:05		0.7	1.3	crossline			
212		15:26:58	15:37:05	0:10:07		0.7	1.3				
x		15:40:00	15:45:24	0:05:25		0.7	1.3	crossline			
213		15:50:32	15:58:45	0:08:13		0.7	1.3				
214		16:01:59	16:27:45	0:25:47		0.7	1.3				
215		16:30:41	16:48:32	0:17:50		0.7	1.3				
216		16:51:21	17:17:05	0:25:45		0.7	1.3				
217		17:19:43	17:37:31	0:17:48		0.7	1.3				
218		17:40:38	18:07:08	0:26:29		0.7	1.3				
219		18:10:07	18:26:54	0:16:47		0.7	1.3				
220		18:30:14	18:41:45	0:11:31		0.7	1.3				
↑ Times entered are Zulu / GMT ↑											
				Page	1		Verify S-Turns After Mission				
Additional Comments:										Yes	No
										Drive #	



# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name				
		7/4/2018	187			Montana USGS LiDAR				
Operator		Aircraft		HOBBS Start	Local Start Time	ZULU Start Time	Base			
Guenther		N27DV		4051..1	8:50:18	14:50:18				
Pilot		Sensor Type		HOBBS END	Local End Time	Zulu End Time	PID			
Vickernam		Orion H-300		4057.0	13:46:19	19:46:19				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	Arriving	
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values		
29		40.3		125	92	Gain - Course/Up	Single	A		
						Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL	Waveform Used		Waveform Mode	Pre-Trigger Dist.		
110		Kts	5900	Ft	Ft	Yes	NO	@	NS	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓										
Test		14:50:18	14:50:43	0:00:25		0.7	1.3	test		
x		15:12:32	15:18:04	0:05:33		0.7	1.3	crossline		
221		15:22:47	15:38:22	0:15:35		0.7	1.3			
222		15:42:04	15:46:04	0:03:59		0.7	1.3	crossline		
x		15:52:48	15:56:52	0:04:03		0.7	1.3			
223		16:02:24	16:21:08	0:18:44		0.7	1.3			
224		16:24:25	16:48:06	0:23:41		0.7	1.3			
225		16:50:45	17:09:55	0:19:10		0.7	1.3			
226		17:12:35	17:35:29	0:22:54		0.7	1.3			
227		17:38:20	17:57:41	0:19:21		0.7	1.3			
228		18:00:47	18:23:04	0:22:17		0.7	1.3			
229		18:25:53	18:46:00	0:20:07		0.7	1.3			
230		18:49:07	19:11:18	0:22:11		0.7	1.3			
231		19:13:59	19:34:12	0:20:13		0.7	1.3			
232		19:37:02	19:46:19	0:09:17		0.7	1.3			
↑ Times entered are Zulu / GMT ↑										
				Page	1		Verify S-Turns After Mission		Yes	No
Additional Comments:									Drive #	

# Woolpert

<b>Optech Orion H-300</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name			
		7/6/2018	187			Montana USGS LiDAR			
Operator		Aircraft		HOBS Start	Local Start Time	ZULU Start Time	Base		
Guenther		N27DV		4057.0	9:02:21	15:02:21			
Pilot		Sensor Type		HOBS END	Local End Time	Zulu End Time	PID		
Vickernam		Orion H-300		4060.5	11:15:35	17:15:35			
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	Arriving
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values	
29		40.3		125	92	Gain - Course/Up	Single	A	
						Gain - Fine/Down	Multi	B	
Air Speed		AGL		MSL		Waveform Used		Waveform Mode	
110		Kts	5900	Ft	Ft	Yes	No	@ NS Ft	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	
↓ Times entered are Zulu / GMT ↓									
Test	1	15:02:21	15:02:43	0:00:22		0.7	1.3	test	
	x	15:28:32	15:31:37	0:03:06		0.7	1.3	crossline	
	233	15:36:19	15:51:30	0:15:11		0.7	1.3		
	234	15:54:10	16:14:24	0:20:14		0.7	1.3		
	235	16:17:17	16:40:46	0:23:29		0.7	1.3		
	236	16:43:33	16:45:18	0:01:46		0.7	1.3		
	x	16:50:13	16:51:59	0:01:45		0.7	1.3	crossline	
	237	16:56:26	17:15:35	0:19:09		0.7	1.3		
↑ Times entered are Zulu / GMT ↑									
Page						1		Verify S-Turns After Mission	
								Yes	No
Additional Comments:									Drive #



# Appendix 1: Flight Logs

## Hardin



# Woolpert

Optech Galaxy PRIME	MM/DD/YEAR		Day of Year		Project #		Phase #		Project Name				
	7/12/2018		193						Montana USGS LiDAR				
Operator		Aircraft		HOBBSS Start		Local Start Time		ZULU Start Time		Base			
Putnam		N7269T		8005.9		9:32:24		15:32:24					
Pilot		Sensor Type		HOBBSS END		Local End Time		Zulu End Time		PID			
McBeth		Galaxy PRIME		8011.3		14:14:13		20:14:13					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing					
								Arriving					
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain		Mode		Threshold Values	
46		52		300		100		Gain - Course/Up		Single		A	
								Gain - Fine/Down		Multi		B	
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.			
112		Kts	8200		Ft	Yes	NO	@		NS	Ft		
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments					
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:					
↓ Times entered are Zulu / GMT ↓													
t		15:32:24	15:32:40	0:00:16		0.7	1.3	test					
x		16:22:00	16:29:31	0:07:30		0.7	1.3	crossline					
1		16:31:48	16:33:25	0:01:37		0.7	1.3						
2		16:35:15	16:37:10	0:01:55		0.7	1.3						
3		16:38:22	16:40:52	0:02:31		0.7	1.3						
4		16:42:09	16:44:52	0:02:43		0.7	1.3						
5		16:46:28	16:50:11	0:03:43		0.7	1.3						
6		16:52:12	16:56:48	0:04:36		0.7	1.3						
7		16:58:35	17:04:20	0:05:45		0.7	1.3						
8		17:10:32	17:20:40	0:10:08		0.7	1.3						
9		17:22:17	17:45:40	0:23:23		0.7	1.3						
x		17:47:55	17:52:04	0:04:08		0.7	1.3	crossline					
10		17:57:46	18:01:27	0:03:41		0.7	1.3						
x		18:04:15	18:08:37	0:04:22		0.7	1.3	crossline					
11		18:14:59	18:31:17	0:16:17		0.9	1.7						
12		18:32:14	18:52:21	0:20:07		0.7	1.3						
13		18:56:52	19:18:47	0:21:55		0.7	1.3						
t		19:19:35	19:45:08	0:25:32		0.7	1.3	not used					
x		19:48:16	19:55:16	0:07:00		0.7	1.3	crossline					
14		20:01:20	20:14:13	0:12:53		0.7	1.3						
↑ Times entered are Zulu / GMT ↑													
Page						1		Verify S-Turns After Mission					
										Yes	No		
Additional Comments:											Drive #		



# Appendix 1: Flight Logs

## Havre

# Woolpert

<b>Optech Galaxy PRIME</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name				
		7/3/2018	184			Montana USGS LiDAR				
Operator		Aircraft		HOBBS Start	Local Start Time	ZULU Start Time	Base			
Smith		N7269T		7964.3	11:08:52	17:08:52				
Pilot		Sensor Type		HOBBS END	Local End Time	Zulu End Time	PID			
Hoddenbach		Galaxy PRIME		7968.3	12:35:41	18:35:41				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	Arriving	
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values		
46		45		300	100	Gain - Course/Up	Single	A		
						Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL		Waveform Used		Waveform Mode	Pre-Trigger Dist.	
112		Kts	8200	Ft	Ft	Yes	No	@	NS	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓										
t		17:08:52	17:09:09	0:00:16		0.7	1.3	test		
x		17:13:18	17:17:27	0:04:09		0.7	1.3	crossline		
1		17:20:15	17:27:04	0:06:50		0.7	1.3			
2		17:28:46	17:38:09	0:09:23		0.7	1.3			
3		17:40:30	17:52:04	0:11:34		0.7	1.3			
4		17:53:43	18:02:50	0:09:07		0.7	1.3			
5		18:05:02	18:17:02	0:11:59		0.7	1.3			
6		18:19:16	18:26:33	0:07:18		0.7	1.3			
7		18:30:58	18:35:41	0:04:43		0.7	1.3			
↑ Times entered are Zulu / GMT ↑										
				Page	1		Verify S-Turns After Mission		Yes	No
Additional Comments:									Drive #	





# Appendix 1: Flight Logs

## North Glasgow

# Woolpert

Optech Galaxy PRIME	MM/DD/YEAR		Day of Year		Project #		Phase #		Project Name			
	7/8/2018		189						Montana USGS LiDAR			
Operator		Aircraft		HOBBS Start		Local Start Time		ZULU Start Time		Base		
Smith		N7269T		7986.6		10:18:12		16:18:12				
Pilot		Sensor Type		HOBBS END		Local End Time		Zulu End Time		PID		
Hoddenbach		Galaxy PRIME		7996.7		15:14:34		21:14:34				
Wind Dir/Speed	Visibility		Ceiling	Cloud Cover %	Temp	Dew Point	Pressure		Haze/Fire/Cloud		Departing	
											Arriving	
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain		Mode		Threshold Values
46		50		300		100		Gain - Course/Up		Single		A
								Gain - Fine/Down		Multi		B
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.		
112		Kts	8200		Ft	Yes	NO	@		NS	Ft	
Line #	Dir.	Line Start Time		Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a				n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓												
t		16:18:12		16:18:33	0:00:22		0.6	1.2	test			
x		16:22:45		16:38:10	0:15:25		0.6	1.2	crossline			
1		16:43:31		16:58:08	0:14:36		0.6	1.2				
2		16:59:17		17:08:57	0:09:40		0.6	1.2				
3		17:11:02		17:27:14	0:16:12		0.6	1.2				
4		17:28:53		17:39:21	0:10:28		0.6	1.2				
5		17:41:12		17:57:38	0:16:26		0.6	1.2				
6		17:59:10		18:09:58	0:10:48		0.6	1.2				
7		18:12:56		18:29:16	0:16:20		0.6	1.2				
8		18:30:51		18:41:47	0:10:56		0.6	1.2				
9		18:43:18		18:59:41	0:16:23		0.6	1.2				
10		19:00:58		19:12:12	0:11:14		0.6	1.2				
11		19:14:19		19:30:28	0:16:09		0.6	1.2				
12		19:32:08		19:43:16	0:11:08		0.6	1.2				
13		19:45:05		20:01:31	0:16:26		0.6	1.2				
14		20:03:03		20:14:23	0:11:20		0.6	1.2				
15		20:16:53		20:32:56	0:16:03		0.6	1.2				
16		20:34:20		20:45:29	0:11:09		0.6	1.2				
17		20:47:15		21:02:07	0:14:52		0.6	1.2				
18		21:03:50		21:14:34	0:10:44		0.6	1.2				
↑ Times entered are Zulu / GMT ↑												
Page							1		Verify S-Turns After Mission		Yes	No
Additional Comments:											Drive #	

# Woolpert

Optech Galaxy PRIME	MM/DD/YEAR		Day of Year		Project #		Phase #		Project Name							
	7/8/2018		189						Montana USGS LiDAR							
Operator		Aircraft		HOBSBS Start		Local Start Time		ZULU Start Time		Base						
Smith		N7269T		7986.6		16:23:51		22:23:51								
Pilot		Sensor Type		HOBSBS END		Local End Time		Zulu End Time		PID						
Hoddenbach		Galaxy PRIME		7996.7		18:52:14		0:52:14								
Wind Dir/Speed	Visibility		Ceiling	Cloud Cover %	Temp	Dew Point	Pressure		Haze/Fire/Cloud		Departing					
											Arriving					
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain		Mode		Threshold Values				
46		50		300		100		Gain - Course/Up		Single		A				
								Gain - Fine/Down		Multi		B				
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.						
112		Kts	8200		Ft		Yes		NO	@		NS	Ft			
Line #	Dir.	Line Start Time		Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments							
Test	n/a				n/a	n/a	n/a	n/a	GPS Began Logging At:							
↓ Times entered are Zulu / GMT ↓												Verify S-Turns Before Mission	Yes	No		
t		22:23:51		22:24:03	0:00:12		0.7	1.3	test							
x		22:28:31		22:35:39	0:07:08		0.7	1.3	crossline							
19		22:42:26		22:53:31	0:11:05		0.7	1.3								
20		22:55:23		23:07:33	0:12:10		0.7	1.3								
21		23:09:19		23:18:44	0:09:25		0.7	1.3								
22		23:20:32		23:32:23	0:11:51		0.7	1.3								
23		23:34:06		23:43:11	0:09:05		0.7	1.3								
24		23:45:45		23:56:04	0:10:19		0.7	1.3								
25		23:57:33		0:04:59	0:07:26		0.7	1.3								
26		0:06:28		0:14:37	0:08:09		0.7	1.3								
27		0:16:37		0:22:31	0:05:54		0.7	1.3								
28		0:24:41		0:31:01	0:06:19		0.7	1.3								
29		0:32:29		0:36:57	0:04:29		0.7	1.3								
30		0:38:34		0:42:46	0:04:12		0.7	1.3								
31		0:44:28		0:47:46	0:03:18		0.7	1.3	part was used as line #33							
32		0:50:13		0:52:14	0:02:01		0.7	1.3								
33									see line #31							
↑ Times entered are Zulu / GMT ↑												Verify S-Turns After Mission	Yes	No		
Additional Comments:											Page		1		Drive #	

# Appendix 1: Flight Logs

## South Glasgow

# Woolpert

<b>Optech Galaxy PRIME</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name					
		7/6/2018	187			Montana USGS LiDAR					
Operator		Aircraft		HOBBS Start	Local Start Time	ZULU Start Time	Base				
Smith		N7269T		7977.8	10:07:06	16:07:06					
Pilot		Sensor Type		HOBBS END	Local End Time	Zulu End Time	PID				
Hoddenbach		Galaxy PRIME		7983.6	15:07:43	21:07:43					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing			
								Arriving			
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values			
46		49		300	100	Gain - Course/Up	Single	A			
						Gain - Fine/Down	Multi	B			
Air Speed		AGL		MSL		Waveform Used		Waveform Mode	Pre-Trigger Dist.		
112		Kts	8200	Ft	Ft	Yes	NO	@	NS		
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓											
t		16:07:06	16:07:18	0:00:11		0.7	1.3	test			
x		16:18:54	16:27:38	0:08:43		0.7	1.3	crossline			
1		16:29:55	16:31:55	0:02:00		0.7	1.3				
2		16:34:14	16:36:45	0:02:31		0.7	1.3				
3		16:39:17	16:43:19	0:04:02		0.7	1.3				
4		16:45:50	16:49:50	0:04:00		0.7	1.3				
5		16:51:59	16:57:43	0:05:44		0.7	1.3				
6		16:59:24	17:04:29	0:05:04		0.7	1.3				
7		17:06:29	17:12:50	0:06:21		0.7	1.3				
8		17:14:24	17:19:57	0:05:33		0.7	1.3				
9		17:21:43	17:28:16	0:06:33		0.7	1.3				
10		17:30:10	17:36:03	0:05:52		0.7	1.3				
11		17:42:38	17:54:02	0:11:24		0.7	1.3				
12		17:56:08	18:15:14	0:19:05		0.7	1.3				
x		18:18:23	18:27:31	0:09:08		0.7	1.3	crossline			
13		18:29:27	18:30:50	0:01:23		0.7	1.3				
14		18:34:50	18:37:14	0:02:24		0.7	1.3				
15		18:38:52	18:42:05	0:03:13		0.7	1.3				
16		18:44:19	18:48:07	0:03:48		0.7	1.3				
17		18:49:53	18:54:04	0:04:11		0.7	1.3				
18		18:55:52	19:00:40	0:04:48		0.7	1.3				
19		19:02:50	19:08:48	0:05:57		0.7	1.3				
20		19:10:26	19:28:02	0:17:36		0.7	1.3				
21		19:29:37	19:47:26	0:17:49		0.7	1.3				
22		19:49:04	20:06:39	0:17:35		0.7	1.3				
23		20:08:08	20:26:11	0:18:03		0.7	1.3				
24		20:27:52	20:46:09	0:18:17		0.7	1.3				
25		20:48:09	21:07:43	0:19:34		0.7	1.3				
↑ Times entered are Zulu / GMT ↑					Page		1		Verify S-Turns After Mission	Yes	No
Additional Comments:											
Drive #											





# Appendix 1: Flight Logs

## Tongue River

# Woolpert

Optech Galaxy PRIME		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name				
		7/11/2018	192			Montana USGS LiDAR				
Operator		Aircraft		HOBSBS Start	Local Start Time	ZULU Start Time	Base			
Putnam		N7269T		7996.7	10:32:17	16:32:17				
Pilot		Sensor Type		HOBSBS END	Local End Time	Zulu End Time	PID			
McBeth		Galaxy PRIME		8005.9	15:11:41	21:11:41				
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing		
								Arriving		
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode	Threshold Values		
46		52		300	100	Gain - Course/Up	Single	A		
						Gain - Fine/Down	Multi	B		
Air Speed		AGL		MSL	Waveform Used		Waveform Mode	Pre-Trigger Dist.		
112		Kts	8200	Ft	Ft	Yes	NO	@	NS	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓										
t		16:32:17	16:32:34	0:00:17		0.7	1.3	test		
1		17:01:05	17:23:09	0:22:04		0.7	1.3			
2		17:25:11	17:40:24	0:15:13		0.7	1.3			
3		17:42:09	18:05:14	0:23:05		0.7	1.3			
4		18:06:57	18:22:03	0:15:07		0.7	1.3			
5		18:23:47	18:45:37	0:21:51		0.7	1.3			
x		18:51:16	18:55:10	0:03:54		0.7	1.3	crossline		
6		18:59:08	19:07:43	0:08:34		0.7	1.3			
x		19:11:36	19:16:26	0:04:50		0.7	1.3	crossline		
x		19:19:25	19:22:04	0:02:39		0.7	1.3	crossline		
7		19:27:25	19:33:49	0:06:23		0.7	1.3			
8		19:35:11	19:43:23	0:08:12		0.7	1.3			
9		19:44:40	19:51:40	0:07:00		0.7	1.3			
10		19:53:17	20:01:41	0:08:24		0.7	1.3			
11		20:02:59	20:09:22	0:06:23		0.7	1.3			
12		20:23:44	20:29:42	0:05:58		0.7	1.3			
13		20:31:09	20:33:51	0:02:41		0.7	1.3			
x		20:36:33	20:39:49	0:03:15		0.7	1.3	crossline		
14		20:42:37	20:49:01	0:06:24		0.7	1.3			
15		20:50:04	20:56:13	0:06:09		0.7	1.3			
16		20:57:10	21:04:33	0:07:24		0.7	1.3			
17		21:05:31	21:11:41	0:06:10		0.7	1.3			
↑ Times entered are Zulu / GMT ↑										
				Page	1		Verify S-Turns After Mission		Yes	No
Additional Comments:									Drive #	

# Woolpert

<b>Optech Galaxy PRIME</b>		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name					
		7/11/2018	192			Montana USGS LiDAR					
Operator		Aircraft		HOBSBS Start	Local Start Time	ZULU Start Time	Base				
Putnam		N7269T		7996.7	16:29:40	22:29:40					
Pilot		Sensor Type		HOBSBS END	Local End Time	Zulu End Time	PID				
McBeth		Galaxy PRIME		8005.9	18:47:29	0:47:29					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing			
								Arriving			
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)	Laser Power %	Fixed Gain	Mode		Threshold Values		
46		52		300	100	Gain - Course/Up	Single	A			
						Gain - Fine/Down	Multi	B			
Air Speed		AGL		MSL	Waveform Used		Waveform Mode		Pre-Trigger Dist.		
112		Kts	8200	Ft	Ft	Yes	No	@	NS	Ft	
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments			
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:			
↓ Times entered are Zulu / GMT ↓											
t		22:29:40	22:30:02	0:00:23		0.7	1.3	test			
x		22:53:07	22:56:32	0:03:24		0.7	1.3	crossline			
18		23:01:05	23:19:39	0:18:34		0.7	1.3				
x		23:21:35	23:26:10	0:04:35		0.7	1.3	crossline			
19		23:28:39	23:39:33	0:10:55		0.7	1.3				
20		23:40:30	23:59:18	0:18:48		0.7	1.3				
21		0:01:00	0:14:59	0:13:59		0.7	1.3				
22		0:15:42	0:33:35	0:17:53		0.7	1.3				
23		0:34:10	0:47:29	0:13:19		0.7	1.3				
↑ Times entered are Zulu / GMT ↑											
Page						1		Verify S-Turns After Mission		Yes	No
Additional Comments:										Drive #	

# Appendix 1: Flight Logs

## Wheatfields



# Woolpert

Optech Galaxy PRIME		MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name							
		7/15/2018	196			Montana USGS LiDAR							
Operator		Aircraft		HOBBBS Start		Local Start Time		ZULU Start Time		Base			
Putnam		N7269T		8017.5		9:07:21		15:07:21					
Pilot		Sensor Type		HOBBBS END		Local End Time		Zulu End Time		PID			
McBeth		Galaxy PRIME		8025.1		16:27:44		22:27:44					
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing					
								Arriving					
Scan Angle (FOV)		Scan Frequency (Hz)		Pulse Rate (kHz)		Laser Power %		Fixed Gain		Mode			
46		52		300		100		Gain - Course/Up		Single			
								Gain - Fine/Down		Multi			
Air Speed		AGL		MSL		Waveform Used		Waveform Mode		Pre-Trigger Dist.			
112		Kts	8200	Ft		Ft	Yes		NO	@	NS		
Line #	Dir.	Line Start Time		Line End Time		Time On Line		SV's	HDOP	PDOP	Line Notes/Comments		
Test	n/a					n/a		n/a	n/a	n/a	GPS Began Logging At:		
↓ Times entered are Zulu / GMT ↓													
t		15:07:21		15:07:33		0:00:12			0.7	1.3	test		
1		15:26:44		15:48:49		0:22:04			0.7	1.3			
x		15:52:41		16:01:17		0:08:36			0.7	1.3	crossline		
2		16:05:57		16:24:13		0:18:16			0.7	1.3			
x		16:28:42		16:36:42		0:08:00			0.7	1.3	crossline		
3		16:41:45		17:03:13		0:21:28			0.7	1.3			
4		17:04:25		17:22:13		0:17:48			0.7	1.3			
5		17:24:00		17:45:53		0:21:53			0.7	1.3			
6		17:47:18		18:04:52		0:17:34			0.7	1.3			
7		18:05:59		18:27:54		0:21:55			0.7	1.3			
8		18:28:54		18:46:39		0:17:45			0.7	1.3			
9		18:48:21		19:09:44		0:21:22			0.7	1.3			
10		19:10:34		19:28:15		0:17:41			0.7	1.3			
11		21:26:14		21:49:26		0:23:12			0.7	1.3			
x		21:52:29		21:57:20		0:04:51			0.7	1.3	crossline		
12		22:01:33		22:19:20		0:17:47			0.7	1.3			
x		22:23:28		22:27:44		0:04:16			0.7	1.3	crossline		
↑ Times entered are Zulu / GMT ↑						Page		1		Verify S-Turns After Mission		Yes	No
Additional Comments:											Drive #		



# Appendix 2: Raw Swath NVA Checkpoint Results

Coordinate values are listed in the following spatial reference system:

**Horizontal:** NAD83 (2011) State Plane Montana, meters

**Vertical:** NAVD88 GEOID12B, meters

Summary	
Point Count	138
Average dZ	+0.000 m
Minimum dZ	-0.140 m
Maximum dZ	+0.100 m
Average Magnitude	0.026 m
Root Mean Square	0.035 m
Standard Deviation	0.036 m

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2001	340711.250	483351.050	1341.230	1341.230	+0.000
2002	340762.300	485303.680	1337.400	1337.400	+0.000
2003	349025.610	484193.930	1293.210	1293.240	+0.030
2004	333219.660	480949.270	1427.130	1427.120	-0.010
2005	326479.090	475305.870	1512.950	1512.940	-0.010
2006	587133.190	477799.370	759.040	759.090	+0.050
2007	587438.850	476185.170	767.530	767.520	-0.010
2008	566342.640	483082.900	786.580	786.570	-0.010
2009	583804.170	478807.510	795.450	795.480	+0.030
2010	599729.860	479134.260	751.280	751.220	-0.060
2011	746918.420	167164.540	885.370	885.370	+0.000
2012	746121.270	165903.370	888.650	888.650	+0.000
2013	722792.490	118966.670	1005.030	1005.030	+0.000
2014	727930.470	121887.440	968.380	968.390	+0.010
2015	746519.770	181778.280	867.550	867.590	+0.040
2016	751622.930	199819.290	885.540	885.510	-0.030
2017	739037.470	136188.730	938.040	938.010	-0.030
2018	814553.640	101968.280	1066.600	1066.690	+0.090
2019	818515.060	110526.010	1024.460	1024.500	+0.040

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2020	838986.650	132470.230	957.160	957.150	-0.010
2021	851774.070	154648.190	889.870	889.850	-0.020
2022	850174.780	174490.580	871.800	871.870	+0.070
2023	866646.330	198054.020	806.610	806.630	+0.020
2024	888723.600	225846.540	757.210	757.070	-0.140
2025	813714.010	442954.780	680.420	680.390	-0.030
2026	812371.170	443966.850	653.590	653.550	-0.040
2027	812825.100	441580.970	637.220	637.190	-0.030
2028	833823.680	436164.950	629.160	629.120	-0.040
2029	802327.180	449444.980	642.020	641.960	-0.060
2030	792033.170	459626.220	648.120	648.080	-0.040
2031	778421.020	463210.550	662.870	662.910	+0.040
2032	775269.790	474505.320	697.130	697.190	+0.060
2033	251935.240	350746.060	883.450	883.450	+0.000
2034	253032.130	351681.350	895.090	895.100	+0.010
2035	253247.470	382033.150	937.630	937.610	-0.020
2036	254430.790	372552.020	931.800	931.790	-0.010
2037	246666.400	389756.400	1005.470	1005.510	+0.040
2038	243940.070	384893.130	896.300	896.320	+0.020
2039	244389.740	370333.860	901.980	902.010	+0.030
2040	240787.370	364088.330	888.460	888.500	+0.040
2041	256897.680	364734.340	941.760	941.760	+0.000
2042	249184.470	356770.790	819.130	819.080	-0.050
2043	485662.140	388045.690	983.470	983.470	+0.000
2044	485675.340	393985.680	976.660	976.680	+0.020
2045	472886.370	396498.990	1034.210	1034.260	+0.050
2046	469571.680	391047.330	1091.690	1091.690	+0.000
2047	463392.360	399283.720	1055.510	1055.490	-0.020
2048	459942.140	388078.030	1133.240	1133.220	-0.020
2049	444391.880	401463.560	1095.090	1095.090	+0.000
2050	447310.050	393171.590	1172.680	1172.640	-0.040
2051	431445.700	401640.550	1140.950	1140.970	+0.020
2052	421047.110	402003.190	1149.840	1149.840	+0.000
2053	429541.480	390440.400	1132.870	1132.870	+0.000

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2054	419946.570	390694.620	1190.720	1190.690	-0.030
2055	455459.240	396242.030	1164.540	1164.540	+0.000
2056	482707.080	402100.990	938.910	938.820	-0.090
2057	813738.980	515253.860	897.510	897.540	+0.030
2058	786763.360	485842.080	699.420	699.460	+0.040
2059	786577.240	494661.530	763.570	763.570	+0.000
2060	786411.120	500245.530	811.110	811.110	+0.000
2061	789337.180	509573.410	741.210	741.230	+0.020
2062	788964.700	520735.100	790.910	790.920	+0.010
2063	787953.640	527846.980	780.030	779.950	-0.080
2064	809571.670	518177.310	847.590	847.640	+0.050
2065	804046.430	520172.790	807.320	807.330	+0.010
2066	799540.960	521590.500	797.870	797.880	+0.010
2067	798958.970	524568.580	791.560	791.530	-0.030
2068	781120.820	514226.790	802.700	802.730	+0.030
2069	780873.150	518060.110	811.150	811.150	+0.000
2070	778341.770	501945.200	755.360	755.410	+0.050
2071	789219.990	513607.310	747.950	747.970	+0.020
2072	788559.590	504506.750	809.740	809.770	+0.030
2073	1000942.280	96177.420	1052.630	1052.610	-0.020
2074	1003331.750	97273.070	1066.250	1066.250	+0.000
2075	1001261.410	104404.990	1040.010	1039.990	-0.020
2076	991362.380	105194.390	1081.090	1081.030	-0.060
2077	976179.730	111504.320	1101.560	1101.520	-0.040
2078	959760.580	118914.790	1132.320	1132.310	-0.010
2079	970308.550	113934.560	1113.090	1113.100	+0.010
2080	961814.760	124988.440	1105.060	1105.070	+0.010
2081	967495.710	130077.970	1077.490	1077.450	-0.040
2082	968189.200	131705.690	1074.840	1074.790	-0.050
2083	971315.180	133628.520	1060.740	1060.720	-0.020
2084	973429.040	135212.030	1059.340	1059.300	-0.040
2085	977811.430	137485.560	1042.170	1042.130	-0.040
2086	986456.800	153268.410	1070.990	1070.980	-0.010
2087	950768.800	154947.720	930.200	930.280	+0.080

Point ID	Easting	Northing	Known Z	Laser Z	dZ
2088	953633.430	158870.340	947.060	947.160	+0.100
2089	1023302.350	140330.920	981.760	981.750	-0.010
2090	981128.860	139555.750	1033.410	1033.370	-0.040
2091	985085.190	142314.750	1023.790	1023.750	-0.040
2092	989879.880	148043.140	1019.080	1019.040	-0.040
2093	991353.550	151410.310	1024.210	1024.160	-0.050
2094	982506.670	155745.020	1092.340	1092.330	-0.010
2095	1001400.870	152534.180	1068.650	1068.640	-0.010
2096	997757.350	158046.130	999.250	999.250	+0.000
2097	1002746.930	163575.540	1014.530	1014.580	+0.050
2098	1003919.400	167780.450	1028.130	1028.130	+0.000
2099	1003222.830	171761.700	993.410	993.440	+0.030
2100	999607.260	172530.840	974.460	974.470	+0.010
2101	980096.190	177599.970	1027.180	1027.200	+0.020
2102	980446.820	174068.010	1016.510	1016.510	+0.000
2103	975114.190	173367.590	1077.770	1077.790	+0.020
2104	973862.150	172606.200	1087.610	1087.640	+0.030
2105	970385.370	167980.950	1071.220	1071.200	-0.020
2106	968395.190	165044.530	1052.760	1052.730	-0.030
2107	999625.470	153288.780	1026.210	1026.230	+0.020
2108	944500.190	176316.840	871.710	871.710	+0.000
2109	942788.050	175796.540	864.840	864.850	+0.010
2110	942668.450	172267.070	899.310	899.300	-0.010
2111	940850.750	168902.550	880.550	880.550	+0.000
2112	939231.550	166129.910	948.300	948.300	+0.000
2113	936076.780	164996.490	913.520	913.540	+0.020
2114	933096.040	160525.150	932.820	932.880	+0.060
2115	930560.160	155703.020	902.460	902.520	+0.060
2116	929368.200	153528.060	915.400	915.430	+0.030
2117	928505.760	151258.410	935.710	935.760	+0.050
2118	927882.640	146110.470	948.880	948.910	+0.030
2119	926744.870	144332.350	926.510	926.480	-0.030
2120	929132.100	133530.140	934.400	934.460	+0.060
2121	932237.820	131815.240	957.890	957.900	+0.010



Point ID	Easting	Northing	Known Z	Laser Z	dZ
2122	930454.780	133035.170	951.880	951.890	+0.010
2123	1012336.530	116048.900	1069.810	1069.800	-0.010
2124	1013740.690	114332.320	1046.380	1046.370	-0.010
2125	1015242.380	112662.750	1076.400	1076.410	+0.010
2126	1016538.440	110769.050	1084.330	1084.290	-0.040
2127	1017218.800	109200.330	1117.160	1117.120	-0.040
2128	1018456.480	106832.160	1119.110	1119.100	-0.010
2129	1021407.470	105565.000	1093.490	1093.490	+0.000
2130	1024794.170	103954.810	1064.710	1064.670	-0.040
2131	949421.600	157483.390	929.680	929.670	-0.010
2132	340156.140	484402.390	1336.140	1336.150	+0.010
2133	341089.910	483886.250	1329.690	1329.700	+0.010
2134	584912.560	477254.740	801.260	801.260	+0.000
2136	798409.060	483017.170	897.760	897.750	-0.010
2140	802039.470	490507.770	917.440	917.480	+0.040
2141	801107.270	489236.760	894.660	894.620	-0.040
2142	800182.710	487527.830	869.440	869.460	+0.020

# Appendix 3: DEM NVA Checkpoint Results

Coordinate values are listed in the following spatial reference system:

**Horizontal:** NAD83 (2011) State Plane Montana, meters

**Vertical:** NAVD88 GEOID12B, meters

Summary	
Point Count	138
Root Mean Square Error	0.039 m
95% Confidence Level	0.076 m
Mean of Residuals	0.03 m
Standard Deviation	0.025 m

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2001	340711.250	483351.050	1341.230	1341.210	0.020
2002	340762.300	485303.680	1337.400	1337.380	0.020
2003	349025.610	484193.930	1293.210	1293.250	0.040
2004	333219.660	480949.270	1427.130	1427.120	0.010
2005	326479.090	475305.870	1512.950	1512.990	0.040
2006	587133.190	477799.370	759.040	759.060	0.020
2007	587438.850	476185.170	767.530	767.530	0.000
2008	566342.640	483082.900	786.580	786.570	0.010
2009	583804.170	478807.510	795.450	795.470	0.020
2010	599729.860	479134.260	751.280	751.210	0.070
2011	746918.420	167164.540	885.370	885.370	0.000
2012	746121.270	165903.370	888.650	888.650	0.000
2013	722792.490	118966.670	1005.030	1005.020	0.010
2014	727930.470	121887.440	968.380	968.390	0.010
2015	746519.770	181778.280	867.550	867.580	0.030
2016	751622.930	199819.290	885.540	885.520	0.020
2017	739037.470	136188.730	938.040	938.010	0.030
2018	814553.640	101968.280	1066.600	1066.670	0.070
2019	818515.060	110526.010	1024.460	1024.520	0.060
2020	838986.650	132470.230	957.160	957.140	0.020

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2021	851774.070	154648.190	889.870	889.850	0.020
2022	850174.780	174490.580	871.800	871.870	0.070
2023	866646.330	198054.020	806.610	806.630	0.020
2024	888723.600	225846.540	757.210	757.060	0.150
2025	813714.010	442954.780	680.420	680.380	0.040
2026	812371.170	443966.850	653.590	653.560	0.030
2027	812825.100	441580.970	637.220	637.200	0.020
2028	833823.680	436164.950	629.160	629.120	0.040
2029	802327.180	449444.980	642.020	641.970	0.050
2030	792033.170	459626.220	648.120	648.070	0.050
2031	778421.020	463210.550	662.870	662.930	0.060
2032	775269.790	474505.320	697.130	697.200	0.070
2033	251935.240	350746.060	883.450	883.420	0.030
2034	253032.130	351681.350	895.090	895.090	0.000
2035	253247.470	382033.150	937.630	937.610	0.020
2036	254430.790	372552.020	931.800	931.790	0.010
2037	246666.400	389756.400	1005.470	1005.500	0.030
2038	243940.070	384893.130	896.300	896.330	0.030
2039	244389.740	370333.860	901.980	902.020	0.040
2040	240787.370	364088.330	888.460	888.500	0.040
2041	256897.680	364734.340	941.760	941.760	0.000
2042	249184.470	356770.790	819.130	819.080	0.050
2043	485662.140	388045.690	983.470	983.450	0.020
2044	485675.340	393985.680	976.660	976.670	0.010
2045	472886.370	396498.990	1034.210	1034.260	0.050
2046	469571.680	391047.330	1091.690	1091.690	0.000
2047	463392.360	399283.720	1055.510	1055.500	0.010
2048	459942.140	388078.030	1133.240	1133.230	0.010
2049	444391.880	401463.560	1095.090	1095.100	0.010
2050	447310.050	393171.590	1172.680	1172.650	0.030
2051	431445.700	401640.550	1140.950	1140.970	0.020
2052	421047.110	402003.190	1149.840	1149.790	0.050
2053	429541.480	390440.400	1132.870	1132.860	0.010
2054	419946.570	390694.620	1190.720	1190.690	0.030

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2055	455459.240	396242.030	1164.540	1164.530	0.010
2056	482707.080	402100.990	938.910	938.800	0.110
2057	813738.980	515253.860	897.510	897.530	0.020
2058	786763.360	485842.080	699.420	699.450	0.030
2059	786577.240	494661.530	763.570	763.530	0.040
2060	786411.120	500245.530	811.110	811.100	0.010
2061	789337.180	509573.410	741.210	741.240	0.030
2062	788964.700	520735.100	790.910	790.920	0.010
2063	787953.640	527846.980	780.030	779.940	0.090
2064	809571.670	518177.310	847.590	847.640	0.050
2065	804046.430	520172.790	807.320	807.330	0.010
2066	799540.960	521590.500	797.870	797.860	0.010
2067	798958.970	524568.580	791.560	791.510	0.050
2068	781120.820	514226.790	802.700	802.750	0.050
2069	780873.150	518060.110	811.150	811.150	0.000
2070	778341.770	501945.200	755.360	755.410	0.050
2071	789219.990	513607.310	747.950	747.960	0.010
2072	788559.590	504506.750	809.740	809.750	0.010
2073	1000942.280	96177.420	1052.630	1052.620	0.010
2074	1003331.750	97273.070	1066.250	1066.250	0.000
2075	1001261.410	104404.990	1040.010	1040.010	0.000
2076	991362.380	105194.390	1081.090	1081.030	0.060
2077	976179.730	111504.320	1101.560	1101.530	0.030
2078	959760.580	118914.790	1132.320	1132.290	0.030
2079	970308.550	113934.560	1113.090	1113.090	0.000
2080	961814.760	124988.440	1105.060	1105.060	0.000
2081	967495.710	130077.970	1077.490	1077.450	0.040
2082	968189.200	131705.690	1074.840	1074.770	0.070
2083	971315.180	133628.520	1060.740	1060.740	0.000
2084	973429.040	135212.030	1059.340	1059.310	0.030
2085	977811.430	137485.560	1042.170	1042.130	0.040
2086	986456.800	153268.410	1070.990	1070.940	0.050
2087	950768.800	154947.720	930.200	930.280	0.080
2088	953633.430	158870.340	947.060	947.160	0.100

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2089	1023302.350	140330.920	981.760	981.760	0.000
2090	981128.860	139555.750	1033.410	1033.370	0.040
2091	985085.190	142314.750	1023.790	1023.780	0.010
2092	989879.880	148043.140	1019.080	1019.010	0.070
2093	991353.550	151410.310	1024.210	1024.170	0.040
2094	982506.670	155745.020	1092.340	1092.320	0.020
2095	1001400.870	152534.180	1068.650	1068.600	0.050
2096	997757.350	158046.130	999.250	999.250	0.000
2097	1002746.930	163575.540	1014.530	1014.590	0.060
2098	1003919.400	167780.450	1028.130	1028.120	0.010
2099	1003222.830	171761.700	993.410	993.420	0.010
2100	999607.260	172530.840	974.460	974.480	0.020
2101	980096.190	177599.970	1027.180	1027.230	0.050
2102	980446.820	174068.010	1016.510	1016.490	0.020
2103	975114.190	173367.590	1077.770	1077.810	0.040
2104	973862.150	172606.200	1087.610	1087.640	0.030
2105	970385.370	167980.950	1071.220	1071.200	0.020
2106	968395.190	165044.530	1052.760	1052.720	0.040
2107	999625.470	153288.780	1026.210	1026.230	0.020
2108	944500.190	176316.840	871.710	871.720	0.010
2109	942788.050	175796.540	864.840	864.850	0.010
2110	942668.450	172267.070	899.310	899.290	0.020
2111	940850.750	168902.550	880.550	880.550	0.000
2112	939231.550	166129.910	948.300	948.320	0.020
2113	936076.780	164996.490	913.520	913.540	0.020
2114	933096.040	160525.150	932.820	932.880	0.060
2115	930560.160	155703.020	902.460	902.520	0.060
2116	929368.200	153528.060	915.400	915.440	0.040
2117	928505.760	151258.410	935.710	935.760	0.050
2118	927882.640	146110.470	948.880	948.920	0.040
2119	926744.870	144332.350	926.510	926.490	0.020
2120	929132.100	133530.140	934.400	934.480	0.080
2121	932237.820	131815.240	957.890	957.880	0.010
2122	930454.780	133035.170	951.880	951.890	0.010

Point ID	Easting	Northing	Known Z	DEM Z	dZ
2123	1012336.530	116048.900	1069.810	1069.760	0.050
2124	1013740.690	114332.320	1046.380	1046.380	0.000
2125	1015242.380	112662.750	1076.400	1076.410	0.010
2126	1016538.440	110769.050	1084.330	1084.290	0.040
2127	1017218.800	109200.330	1117.160	1117.120	0.040
2128	1018456.480	106832.160	1119.110	1119.100	0.010
2129	1021407.470	105565.000	1093.490	1093.480	0.010
2130	1024794.170	103954.810	1064.710	1064.680	0.030
2131	949421.600	157483.390	929.680	929.680	0.000
2132	340156.140	484402.390	1336.140	1336.150	0.010
2133	341089.910	483886.250	1329.690	1329.710	0.020
2134	584912.560	477254.740	801.260	801.250	0.010
2136	798409.060	483017.170	897.760	897.740	0.020
2140	802039.470	490507.770	917.440	917.480	0.040
2141	801107.270	489236.760	894.660	894.610	0.050
2142	800182.710	487527.830	869.440	869.450	0.010



# Appendix 4: DEM VVA Checkpoint Results

Coordinate values are listed in the following spatial reference system:

**Horizontal:** NAD83 (2011) State Plane Montana, meters

**Vertical:** NAVD88 GEOID12B, meters

Summary	
Point Count	98
Root Mean Square Error	0.129 m
95th Percentile	0.262 m
Mean of Residuals	0.093 m
Standard Deviation	0.089 m

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3001	321385.01	479952.84	1625.58	1625.66	0.080
3002	323303.97	476282.43	1470.07	1470.25	0.180
3003	333717.12	484036.74	1411.26	1411.22	-0.040
3004	348997.52	484187.51	1292.62	1292.7	0.080
3005	341043.53	479983.16	1382.94	1383.02	0.080
3006	256841.37	363654.57	913.86	914.12	0.260
3007	253380.05	359483.91	836.24	836.32	0.080
3008	242002.34	364046.84	883.39	883.47	0.080
3009	245154.2	384833.35	908	908.06	0.060
3010	257925.84	384037.36	972.61	972.69	0.080
3011	248367.74	366869.49	898.37	898.43	0.060
3012	246701.63	377076.67	939.34	939.52	0.180
3013	252224.14	379161.87	923.27	923.37	0.100
3014	486652.95	387856.42	967.22	967.22	0.000
3015	432634.4	385436.95	1141.62	1141.57	-0.050
3016	458164.49	388120.85	1124.2	1124.25	0.050
3017	424725.19	386301.42	1138.57	1138.8	0.230
3019	436261.27	399797.63	1131.61	1131.6	-0.010
3020	446419.49	401276.34	1103.22	1103.3	0.080
3022	485726.69	400458.6	930.45	930.47	0.020

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3023	423071.4	401940.41	1149.72	1149.91	0.190
3024	472869.58	396578.67	1031.65	1031.87	0.220
3025	587510.83	478639.39	755.54	755.56	0.020
3026	584768.61	478918.43	757.27	757.4	0.130
3027	596609.59	479415.58	752.55	752.55	0.000
3028	566872.17	482393.9	804.53	804.59	0.060
3029	573959.79	482278.96	769.33	769.36	0.030
3030	579466.06	479224.01	766.05	766.1	0.050
3032	782816.25	502098.63	720.48	720.62	0.140
3033	776427.09	505132.75	758.58	758.96	0.380
3034	780872.43	519569.15	835.25	835.22	-0.030
3035	788113.81	523420.19	781.63	781.64	0.010
3036	787899.41	528879.87	776.87	776.94	0.070
3037	786786.03	484819.78	682.57	682.64	0.070
3038	789302.59	510210.48	737.98	737.99	0.010
3039	790473.92	517737.14	750.95	751.04	0.090
3040	798352.28	519420.09	838.53	838.54	0.010
3041	798976.92	524574.81	789.81	789.84	0.030
3042	813698.93	515297.26	895.57	895.59	0.020
3043	808588.71	447499.56	638.27	638.25	-0.020
3045	826548.18	439036.49	630.58	630.64	0.060
3046	798996.5	454468.32	643.8	643.78	-0.020
3047	791688.31	461740.94	646.89	646.89	0.000
3048	782017.66	466214.48	653.17	653.34	0.170
3049	771494.16	467834.81	657.23	657.36	0.130
3050	743536.45	157353.39	896.18	896.4	0.220
3051	737218.73	136697.87	927.18	927.37	0.190
3052	752312.82	202628.16	837.89	838.09	0.200
3053	747956.69	189861.67	863.45	863.76	0.310
3054	733965.02	126362.15	962.14	962.37	0.230
3055	854536.47	182021.33	839.63	839.88	0.250
3056	849536.98	154107.6	908.68	908.76	0.080
3057	887071.35	237537.09	735.65	735.68	0.030
3058	875508.8	205537.51	794.72	794.79	0.070

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3059	833468.54	125811.82	959.66	959.78	0.120
3060	974555.9	176001.95	1153.77	1153.74	-0.030
3061	973773.49	172539.68	1082.99	1083.06	0.070
3062	966750.87	160779.34	1084.26	1084.33	0.070
3063	1000032.84	99647.71	1042.32	1042.66	0.340
3064	997309.15	101634.98	1040.11	1040.21	0.100
3065	977630.42	137341.81	1038.74	1038.85	0.110
3066	981673	140005.22	1027.91	1028.13	0.220
3067	992454.12	151004.33	1002.28	1002.59	0.310
3068	995959.95	156778.01	992.1	992.13	0.030
3069	1005949.21	162422.69	1118.07	1118.21	0.140
3070	999297.65	172860.76	966.87	967.01	0.140
3071	943780.38	176252.26	857.04	857.24	0.200
3072	930731.44	155899.37	899.99	900.07	0.080
3073	935114.43	162826.94	970.59	970.61	0.020
3074	939587.98	166834.85	915.07	915.12	0.050
3075	942704.69	171076.46	897.69	897.71	0.020
3076	953959.25	177691.89	886.69	886.82	0.130
3077	948228.66	158437.98	912.22	912.35	0.130
3078	952459.62	150655.84	935.86	935.92	0.060
3079	930125.5	133255.54	950.94	950.99	0.050
3080	954572.42	147229.52	942.66	942.78	0.120
3081	950083.8	146266.8	993.79	993.93	0.140
3082	977624.38	134561.34	1052.2	1052.31	0.110
3083	1015407.2	111788.55	1103.43	1103.45	0.020
3084	1012138.21	121814.24	1009.35	1009.35	0.000
3086	927995.38	150017.25	915.61	915.72	0.110
3087	1004585.61	122134.22	1032.09	1032.13	0.040
3088	1000141.36	125097.86	1059.53	1059.63	0.100
3089	997793.4	126972.26	1078.7	1078.73	0.030
3090	994852.06	130024.32	1120.88	1121.03	0.150
3091	982339.71	139142.75	1027.29	1027.52	0.230
3092	987250.44	139399.87	1030.81	1030.85	0.040
3093	994150.69	144749.29	1027.44	1027.52	0.080

Point ID	Easting	Northing	Known Z	DEM Z	dZ
3094	985920.31	107337.25	1056.48	1056.51	0.030
3095	961372.59	118701.77	1136.36	1136.43	0.070
3096	1016455	124571.9	999.98	999.91	-0.070
3097	1015892.03	126163.89	996.52	996.5	-0.020
3098	1019048.42	131051.67	992.32	992.41	0.090
3099	1024113.23	143374.97	973.4	973.46	0.060
3100	998983.68	167451.44	991	991.21	0.210
3101	969122.12	166335.15	1059.03	1059.11	0.080
3102	953036.25	157796.64	975.21	975.26	0.050
3103	956042.84	179876.96	912.67	912.76	0.090