WOOLPERT

USGS Animas, NM Lidar

USGS/ Rolla, MO

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Section 1: Overview

Project Name: Animas, NM Lidar Woolpert

Project: # 74753

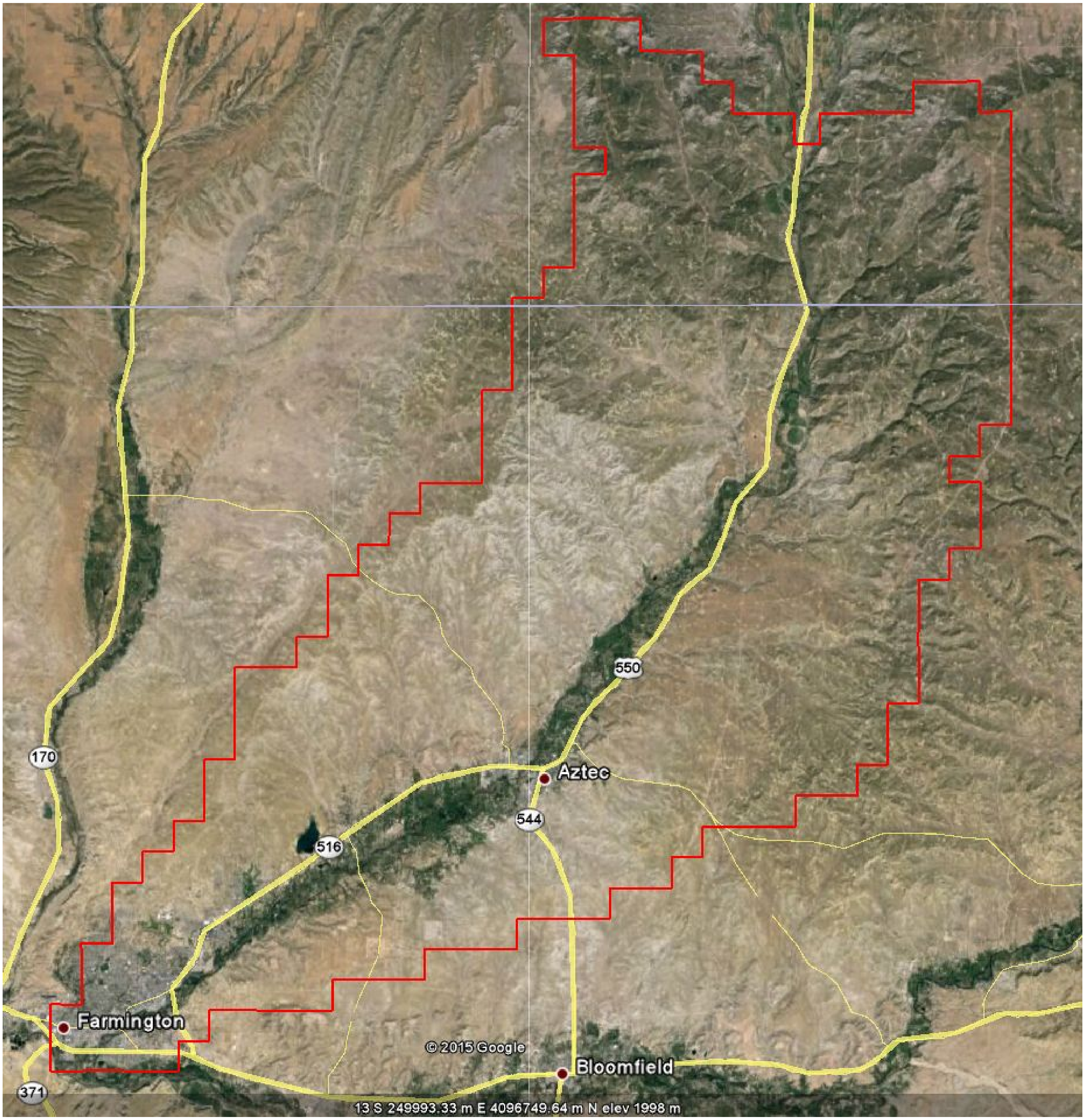
This report contains a comprehensive outline of the Animas, NM Lidar Processing task order for the United States Geological Survey (USGS). This task is issued under USGS Contract No. G10PC00057, Task Order No. G14PD01092. This task order requires lidar data to be acquired over approximately 559 square miles. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.7 meter. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

The data was collected using a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) lidar sensor. The ALS70 sensor collects up to four returns per pulse, as well as intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial lidar was collected at the following sensor specifications:

Table 1.1: ALS70 Specifications	
Post Spacing	2.3ft / 0.7 m
AGL (Above Ground Level) average flying height	6,500 ft / 1,981 m
MSL (Mean Sea Level) average flying height	varies
Average Ground Speed:	150 knots / 173 mph
Field of View (full)	40 degrees
Pulse Rate	272 kHz
Scan Rate	41.5 Hz
Side Lap	25%

The lidar data was processed and projected in UTM, Zone 12, North American Datum of 1983 (2011) and UTM, Zone 13, North American Datum of 1983 (2011) in units of meters. The vertical datum used for the task order was referenced to NAVD 1988, GEOID12A, in units of meters.

Figure 1.1: Lidar Task Order AOI



Section 2: Acquisition

The existing lidar data was acquired with a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) Lidar Sensor System, on board Woolpert Cessna aircraft. The ALS70 lidar system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC50 Operation Controller aboard the aircraft.

The ALS70 500 kHz Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Table 2.1: ALS Lidar System Specifications	
Operating Altitude	200 – 3,500 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	500 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	7 - 16 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 38 cm (one standard deviation)
Number of Returns per Pulse	7 (infinite)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (~0.15 mrad @ 1/e)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium

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

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

The lidar data was collected in four (4) separate missions, flown as close together as the weather permitted, to ensure consistent ground conditions across the project area.

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

Figure 2.1: Lidar Flight Layout, Animas, NM Lidar

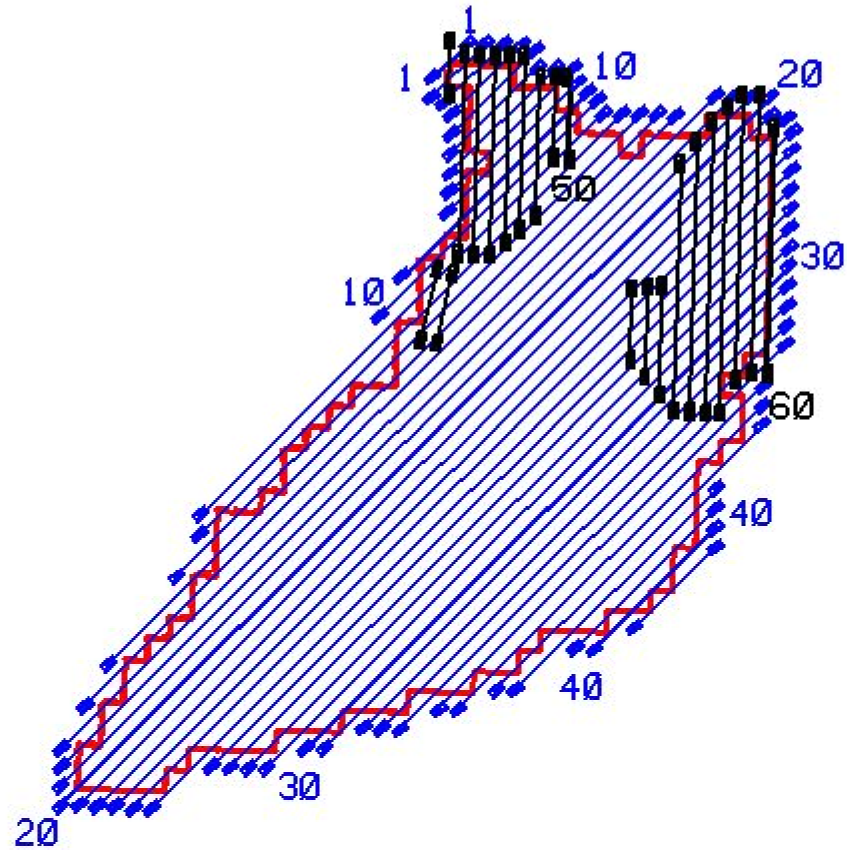


Table 2.2: Airborne Lidar Acquisition Flight Summary			
Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = EDT) Wheels Up/ Wheels Down
October 12, 2014 – Sensor ALS-7177	01-21	14:30 – 18:21	8:30AM – 12:21PM
October 13, 2014 – Sensor ALS-7177	19-51	14:35 – 20:06	08:35AM - 02:06PM
October 14, 2014 – Sensor ALS-7177	52-62	16:04 – 17:53	10:04AM – 11:53PM
October 15, 2014 – Sensor ALS-7177	21	15:35 – 16:25	09:35AM – 10:25PM

Section 3: Lidar Data Processing

Applications and Work Flow Overview

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
   Software: POSPac Software v. 5.3, IPAS Pro v.1.35.
2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift.
   Software: ALS Post Processing Software v.2.75 build #25, Proprietary Software, TerraMatch v. 15.01.
3. Imported processed LAS point cloud data into the task order tiles. Resulting data were classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control.
   Software: TerraScan v.15.01.
4. The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts from the ground class.
   Software: TerraScan v.15.01.

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

Equipment

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

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

All Woolpert aerial sensors are equipped with a Litton LN200 series Inertial Measurement Unit (IMU) operating at 200 Hz.

A base-station unit was mobilized for each acquisition mission where a CORS station was not utilized, and was operated by a member of the Woolpert acquisition team. Each base-station setup consisted of one Trimble 4000 – 5000 series dual frequency receiver, one Trimble Compact L1/L2 dual frequency antenna, one 2-meter fixed-height tripod, and essential battery power and cabling. Ground planes were used on the base-station antennas. Data was collected at 1 or 2 Hz.

The GNSS base station operated during the Lidar acquisition missions is listed below:

Table 3.1: GNSS Base Station

Station (Name)	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
KFMN_Arpt_Base	36° 44' 24.12008"	-108° 13' 10.25945"	1655.722

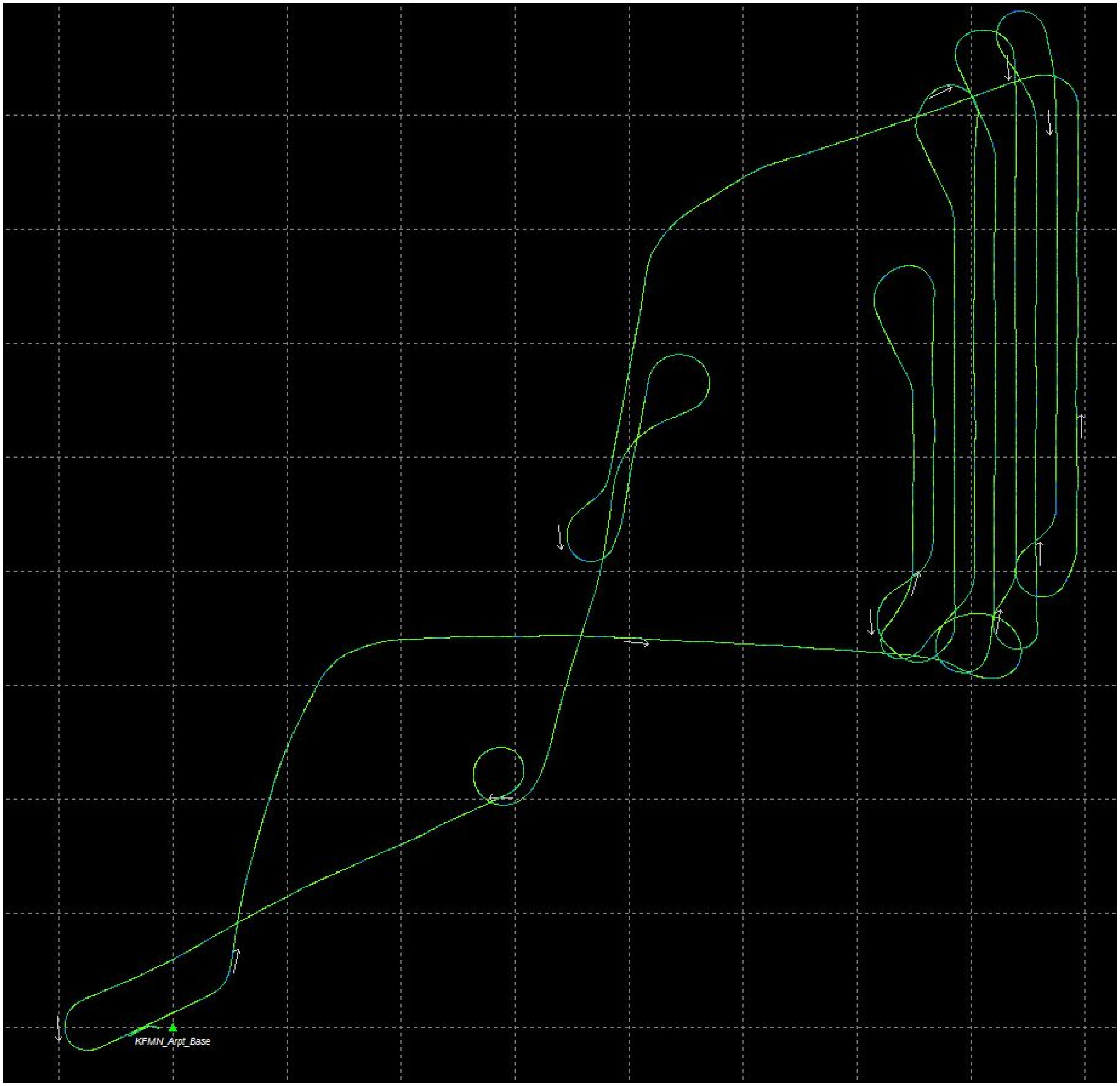
Data Processing

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

Trajectory Quality

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

Figure 3.1: Trajectory, Day28714_SH7177



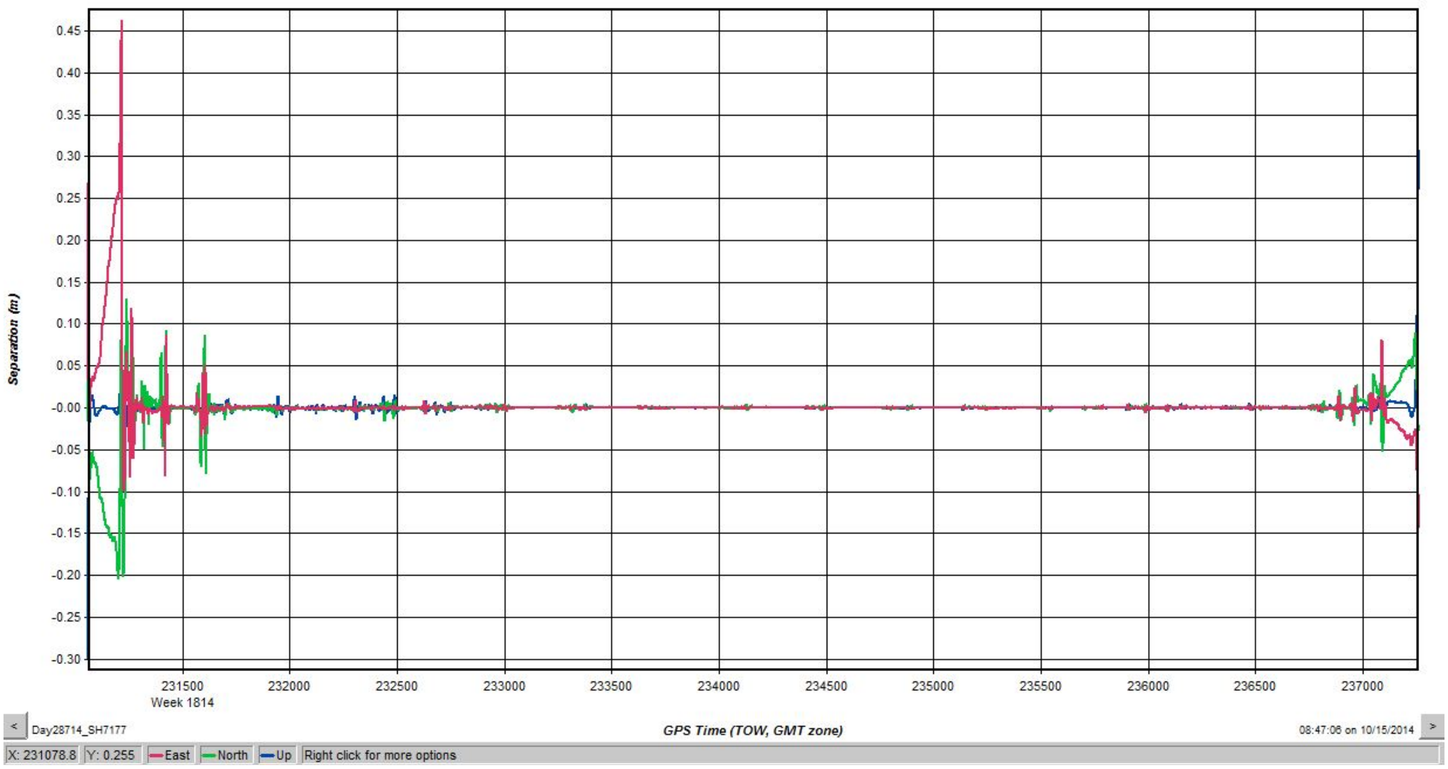
Combination Separation

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

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

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

Figure 3.2: Combined Separation, Day28714_SH7177

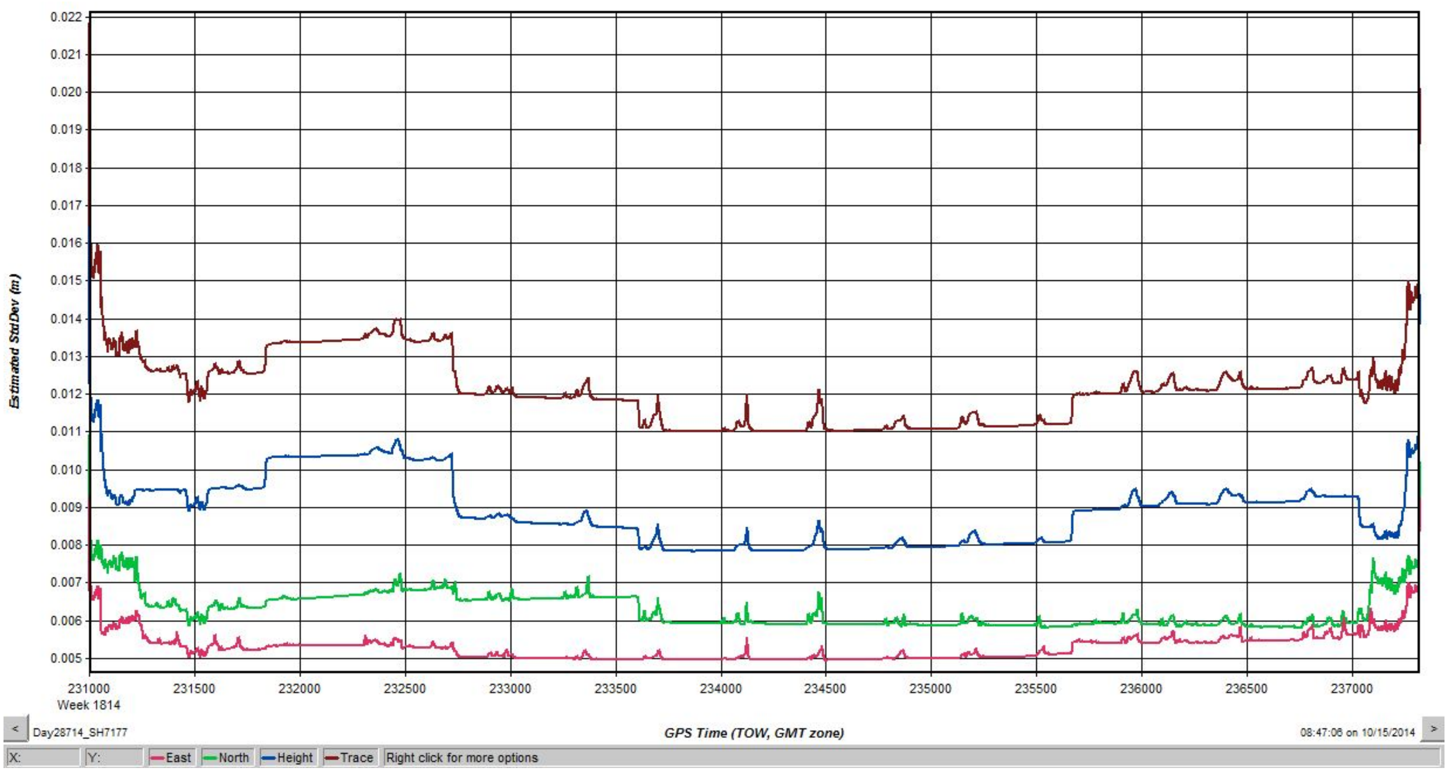


Estimated Positional Accuracy

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

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

Figure 3.3: Estimated Positional Accuracy, Day28714_SH7177

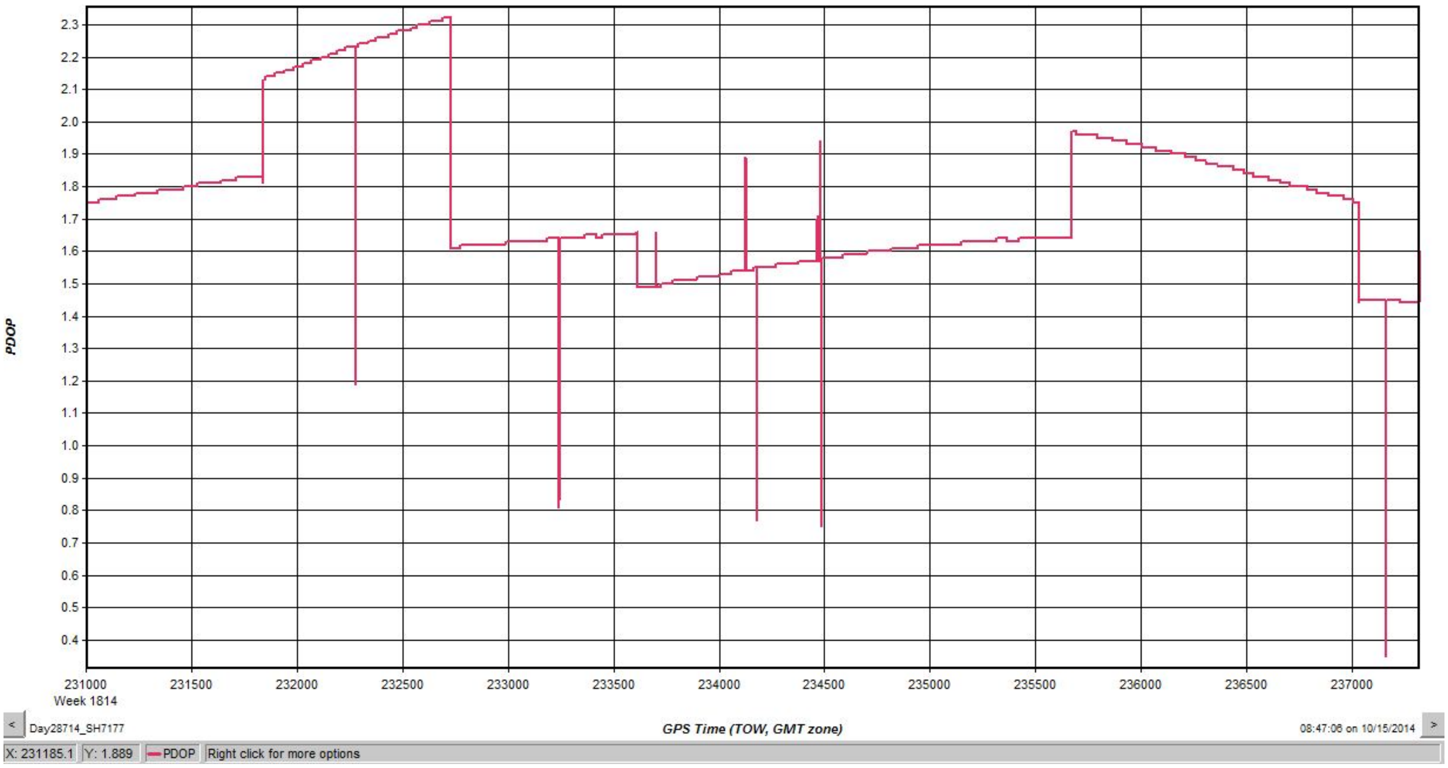


PDOP

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

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

Figure 3.4: PDOP, Day28714_SH7177



Lidar Data Processing

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

- Processed individual flight lines to derive a raw “Point Cloud” LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.
- Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet client specified classes.
- Once all project data was imported and classified, survey ground control data was imported and calculated for an accuracy assessment. As a QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparisons against the TIN and the DEM using surveyed ground control of higher accuracy. The lidar is adjusted accordingly to meet or exceed the vertical accuracy requirements.
- The lidar tiles were reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the task order requirements. A portion of this requires a manual step to ensure anomalies have been removed from the ground class.
- The lidar LAS files are classified into the Default (Class 1), Ground (Class 2), Low Noise (Class 7), Water (Class 9), Ignored Ground (Class 10), Bridge (Class 17) and High Noise (Class 18) classifications.
- FGDC Compliant metadata was developed for the task order in .xml format for the final data products.
- The horizontal datum used for the task order was referenced to UTM12N North American Datum of 1983 (2011) and UTM13N North American Datum of 1983 (2011). The vertical datum used for the task order was referenced to NAVD 1988, meters, GEOID12A. Coordinate positions were specified in units of meters.

Section 4: Hydrologic Flattening

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

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

LIDAR DATA REVIEW AND PROCESSING

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

1. Woolpert used the newly acquired lidar data to manually draw the hydrologic features in a 2D environment using the lidar intensity and bare earth surface. Open Source imagery was used as reference when necessary.
2. Woolpert utilizes an integrated software approach to combine the lidar data and 2D breaklines. This process “drapes” the 2D breaklines onto the 3D lidar surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D lidar surface and assigned a constant elevation at or just below ground elevation.
3. The lakes, reservoirs and ponds, at a minimum size of 1-acre or greater and streams at a minimum size of 15 meters (50 feet) nominal width, were compiled to meet task order requirements. **Figure 4.1** illustrates an example of 15 meters (50 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 15 meters (50 feet), were draped with both sides of the stream maintaining an equal gradient elevation.
4. All ground points were reclassified from inside the hydrologic feature polygons to water, class nine (9).
5. All ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class ten (10).
6. The lidar ground points and hydrologic feature breaklines were used to generate a new digital elevation model (DEM).

Figure 4.1: Example Hydrologic Breaklines

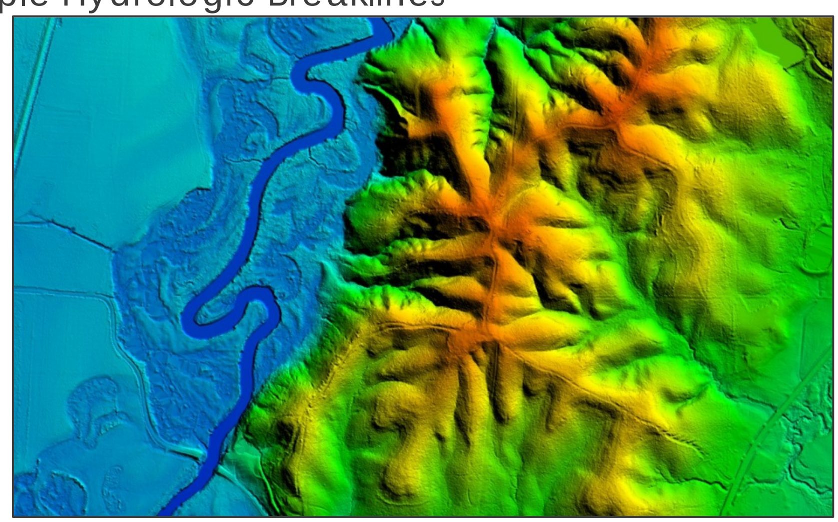


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

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

Figure 4.2

Figure 4.3

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

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

DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v15, by reviewing the grids and hydrologic breakline features. Additionally, ESRI software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

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

Section 5: ACCURACY ASSESSMENT

Accuracy Assessment

The vertical accuracy statistics were calculated by comparison of the lidar bare earth points to the ground surveyed QA/QC points. Animas, NM Lidar was processed and delivered in NAD1983(2011) UTM13, NAVD88 Geoid12A meters. A portion of the AOI falls into the UTM 12 zone. Data deliverables were reprojected and also delivered in NAD1983(2011) UTM12, NAVD88 Geoid12A meters. It should be noted that accuracy analysis was reported for the UTM13 data delivery

Table 5.1: Overall Vertical Accuracy Statistics,		
Average error	0.007	meter
Minimum error	-0.112	meter
Maximum error	0.133	meter
Average magnitude	0.068	meter
Root mean square	0.075	meter
Standard deviation	0.077	meter

Table 5.2: Raw Swath Quality Check Point Analysis FVA

Point ID	Easting (meter)	Northing (meter)	TIN Elevation (meter)	Dz (meter)
2001	234264.557	4110243.235	2065.660	-0.056
2002	238695.625	4108909.345	2050.410	-0.082
2003	243126.900	4106233.213	1872.720	-0.084
2004	250957.161	4105459.193	2225.290	0.034
2005	252695.250	4097952.744	2093.810	-0.074
2006	244152.540	4098493.666	1877.770	0.085
2007	235774.112	4098394.189	1942.600	-0.052
2008	233774.282	4093424.907	1881.680	-0.031
2009	242810.145	4090692.847	1814.800	0.099
2010	250491.423	4090433.803	2034.770	0.019
2011	244812.864	4083494.630	1910.970	0.133
2012	237632.951	4084455.563	1768.760	0.049
2013	226204.937	4087786.471	1917.470	-0.078
2014	221439.607	4083734.852	1833.300	-0.112
2015	224264.261	4080171.506	1750.370	-0.046
2016	229296.465	4084282.613	1809.900	0.020
2017	239920.565	4077651.531	1955.880	0.052
2018	234071.574	4074149.333	1800.130	0.051
2019	228876.816	4074767.594	1743.530	0.051
2020	222816.338	4071520.604	1762.050	0.105
2021	218235.231	4077120.605	1798.830	-0.061
2022	217055.172	4070155.687	1626.790	0.126

VERTICAL ACCURACY CONCLUSIONS

Raw LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.147 meters fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using all points.

LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.123 meters fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using ground points.

Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.127 meters fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM.

SUPPLEMENTAL VERTICAL ACCURACY ASSESSMENTS

Table 5.3: Sage/Steppe Quality Check Point Analysis SVA

Point ID	Easting (meter)	Northing (meter)	DEM Elevation (meter)	Dz (meter)
4001	234233.663	4110261.313	2062.440	-0.102
4002	238655.588	4108887.452	2048.670	-0.055
4003	243103.405	4106245.872	1874.330	0.109
4004	250946.913	4105480.451	2223.570	0.035
4005	252674.006	4097985.032	2096.280	-0.063
4006	244188.57	4098506.199	1876.140	0.096
4007	235735.888	4098424.601	1942.770	-0.035
4008	233716.485	4093582.464	1884.590	0.022
4009	242822.007	4090737.348	1815.160	0.098
4010A	250516.64	4090449.230	2035.090	-0.105
4011	244805.63	4083521.248	1909.510	0.068
4012	237604.205	4084441.506	1770.210	0.016
4013	226228.939	4087820.224	1919.020	-0.019
4014	221433.789	4083762.148	1832.410	-0.036
4015	224280.301	4080178.119	1749.910	-0.012
4016	229163.987	4084046.628	1825.960	-0.001
4017	239908.742	4077625.645	1954.600	0.062
4018	234075.021	4074188.203	1801.010	0.118
4019	228861.286	4074764.252	1742.710	0.061

4020	222833.379	4071522.888	1762.690	0.167
4021	218235.805	4077131.189	1798.400	-0.038
4022	217093.377	4070189.012	1627.040	0.219

VERTICAL ACCURACY CONCLUSIONS

Sage/Steppe Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.164 meters supplemental vertical accuracy at the 95th percentile in the Sage/Steppe supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Sage/Steppe Errors at the 95th percentile include:

- Point 4020, Easting 222833.379, Northing 4071522.888, Z-Error 0.167 meters
- Point 4022, Easting 217093.377, Northing 4070189.012, Z-Error 0.219 meters

Table 5.4: Brushlands and Trees Quality Check Point Analysis SVA

Point ID	Easting (meter)	Northing (meter)	DEM Elevation (meter)	Dz (meter)
5001	234234.186	4110188.322	2062.87	-0.156
5002	238724.586	4108894.048	2051.350	-0.040
5003	243091.639	4106208.238	1876.240	-0.042
5004	250978.083	4105461.470	2229.360	0.093
5005	252632.48	4097949.529	2100.820	0.069
5006	244178.579	4098462.871	1874.890	0.033
5007	235666.57	4098445.130	1944.120	-0.012
5008	233748.327	4093630.028	1885.330	0.022
5009	242832.321	4090712.244	1815.320	0.006
5010	250552.739	4090469.789	2037.010	0.060
5011	244791.205	4083498.880	1910.770	0.131
5012	237572.072	4084406.993	1772.060	0.145
5013	226250.015	4087849.109	1920.410	-0.001
5014	221461.562	4083761.098	1833.090	-0.042
5015	224239.632	4080191.616	1752.550	-0.037
5016	229192.978	4084033.436	1827.880	-0.011
5017	239882.314	4077599.695	1953.310	0.041
5018	234138.902	4074199.091	1806.280	0.005
5019	228850.095	4074720.614	1744.860	0.076
5020	222816.096	4071489.489	1763.130	0.161
5021	218232.128	4077172.043	1795.880	-0.076
5022	217099.348	4070163.133	1627.230	0.173

VERTICAL ACCURACY CONCLUSIONS

(SVA) Tested 0.160 meters supplemental vertical accuracy at the 95th percentile in the Brushlands and Trees supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Brushlands and Trees Errors larger than 95th percentile include:

- Point 5020, Easting 222816.096, Northing 4071489.489, Z-Error 0.161 meters
- Point 5022, Easting 217099.348, Northing 4070163.133, Z-Error 0.173 meters

CONSOLIDATED VERTICAL ACCURACY ASSESSMENT AND CONCLUSION

Consolidated Vertical Accuracy (CVA) Tested 0.159 meters consolidated vertical accuracy at the 95th percentile level; reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. CVA is based on the 95th percentile error in all land cover categories combined.

- Point 4020, Easting 222833.379, Northing 4071522.888, Z-Error 0.167 meters
- Point 4022, Easting 217093.377, Northing 4070189.012, Z-Error 0.219 meters
- Point 5020, Easting 222816.096, Northing 4071489.489, Z-Error 0.161 meters
- Point 5022, Easting 217099.348, Northing 4070163.133, Z-Error 0.173 meters

Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		August 2015

Section 6: Flight Logs

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

Woolpert

Leica LIDAR

MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
10/12/2014	285	74753	2	Animas, NM

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N7079F	3380.5	8:30:00	14:30:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
RADER	ALS-7177	3383.8	12:24:00	18:24:00	Farnport

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
030 6	10	Clear	0	6	4	29.9		Departing	KFMN
								Arriving	KFMN

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	41.5	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.	
150	Kts	6500	Ft	11,735	Ft	Yes		No	X	@	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:	14:46:45
		↕ Times entered are Zulu / GMT ↕						Verify S-Turns Before Mission Yes X No	
12	NE	15:08:12	15:15:20	6:40:52	19	0.6	1	FL 1-41 11,735 MSL	
11	SW	15:18:23	15:22:29	0:00:00	15	0.7	1.3	FL 42-62 13,000 MSL	
10	NE	15:24:40	15:28:00	0:00:00	13	0.7	1.3	Takeoff: 14:58	
9	SW	15:30:11	15:32:31	0:00:00	13	0.7	1.3		
8	NE	15:34:39	15:36:49	0:00:00	14	0.7	1.3		
7	SW	15:38:54	15:40:48	0:00:00	15	0.7	1.3	Min rangegate warning	
6	NE	15:42:51	15:44:24	0:00:00	16	0.7	1.3	Min rangegate warning	
5	SW	15:46:54	15:48:20	0:00:00	16	0.7	1.3	Min rangegate warning	
4	NE	15:50:24	15:51:39	0:00:00	16	0.7	1.3	Min rangegate warning	
3	SW	15:54:07	15:55:09	0:00:00	15	0.7	1.3	Min rangegate warning	
2	NE	15:57:27	15:58:25	0:00:00	15	0.7	1.3	Min rangegate warning	
1	SW	16:00:50	16:01:25	0:00:00	15	0.7	1.3	Min rangegate warning	
13	SW	16:00:07	16:14:24	0:00:00	15	0.7	1.3	Min rangegate warning	
14	NE	16:17;20	16:25:36	0:00:00	15	0.8	1.5	Min rangegate warning	
15	SW	16:28:19	16:38:05	0:00:00	15	0.8	1.5	Min rangegate warning	
16	NE	16:41:23	16:52:03	0:00:00	15	0.7	1.2	Min rangegate warning	
17	SW	16:55:21	17:07:07	0:00:00	16	0.7	1.2	Min rangegate warning	
18	NE	17:09:22	17:21:24	0:00:00	15	0.7	1.3	Min rangegate warning	
19	SW	17:24:06	17:36:36	0:00:00	16	0.7	1.2	Light Precip wpts 24-32	
20	NE	17:38:56	17:51:41	0:00:00	17	0.6	1.1	Snow wpts 44-39	
21	SW	17:54:45	18:07:44	0:00:00	17	0.6	1.1	Snow wpts 5-32	
				0:00:00					
				0:00:00				Base station knocked over from	
				0:00:00				41 mph winds	
				0:00:00					
				0:00:00				Landing 18:18z	
				0:00:00				Static 18:22:22 - 18:24:22	
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission Yes X No	

Additional Comments:	Drive #
	S/N:0096

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	10/13/2014	286	74753	2	Animas, NM

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N7079F	3383.8	8:35:00	14:35:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
RADER	ALS-7177		2:06:00	20:06:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
var 3	10	Clear	0	3	-3	3024		Departing	KFMN
								Arriving	KFMN

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	41.5	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	11,735	Ft	Yes		No	X	@ 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:	14:44;18
⇕ Times entered are Zulu / GMT ⇕								Verify S-Turns Before Mission	Yes X No
22	NW	15:18:11	15:20:16	6:57:38	18	0.9	1.2	FL 1-41 11,735 MSL	
23	SE	15:22:51	15:34:47	0:00:00	12	0.8	1.3	FL 42-62 13,000 MSL	
24	NW	15:37:41	15:49:41	0:00:00	14	0.7	1.1		
25	SE	15:52:10	16:03:34	0:00:00	15	0.7	1.3		
26	NW	16:06:04	16:16:29	0:00:00	14	0.7	1.4		
27	SE	16:18:58	16:28:54	0:00:00	15	0.7	1.4		
28	NW	16:31:25	16:41:14	0:00:00	16	0.7	1.3		
29	SE	16:43:42	16:52:58	0:00:00	15	0.7	1.3		
30	NW	16:55:33	17:04:12	0:00:00	15	0.7	1.3		
31	SE	17:06:17	17:14:31	0:00:00	16	0.7	1.3		
32	NW	17:16:46	17:24:30	0:00:00	16	0.7	1.3		
33	SE	17:27:00	17:34:11	0:00:00	17	0.6	1.1		
34	NW	17:36:38	17:43:35	0:00:00	17	0.6	1.1		
35	SE	17:45:57	17:51:43	0:00:00	17	0.6	1.1		
36	NW	17:53:52	17:59:20	0:00:00	17	0.6	1.2		
37	SE	18:01:46	18:06:30	0:00:00	16	0.6	1.4		
38	NW	18:08:48	18:12:28	0:00:00	15	0.7	1.4		
39	SE	18:14:56	18:17:25	0:00:00	15	0.7	1.3		
40	NW	18:20:13	18:22:27	0:00:00	16	0.7	1.3		
41	SE	18:24:55	18:26:17	0:00:00	16	0.7	1.3		
19	SE	18:32:32	18:35:02	0:00:00	16	0.7	1.3	wpts 23-33	
20	NW	18:39:20	18:41:18	0:00:00	16	0.7	1.3	wpts 45-38	
21	SE	18:51:25	18:58:21	0:00:00	16	0.7	1.3	wpts 1-33	
42	N	19:07:16	19:08:03	0:00:00	16	0.7	1.3		
43	S	19:10:27	19:13:01	0:00:00	16	0.7	1.3		
44	N	19:15:07	19:18:08	0:00:00	16	0.7	1.3		
45	S	19:20:49	19:23:17	0:00:00	16	0.7	1.3		
46	N	19:25:50	19:28:28	0:00:00	16	0.7	1.3		
47	S	19:30:49	19:33:10	0:00:00	16	0.7	1.3	Landing: 20:01	
48	N	19:35:34	19:27:37	0:00:00	16	0.7	1.3	Static: 20:04:14 - 20:06:14	
49	S	19:39:45	19:40:46	0:00:00	16	0.7	1.3	see page two for flightlines 50-51	
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission	Yes X No

Additional Comments:	Drive #
	00096

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	10/13/2014	286	74753	2	Animas, NM

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N7079F	3383.8	8:35:00	14:35:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
RADER	ALS-7177	3389.9	2:06:00	20:06:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	KFMN
VAR 3	10	Clear	0	3	-3	30.24		Arriving	KFMN

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	41.5	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.	
150	Kts	Varies	Ft	13000	Ft	Yes		No	x	@	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:	14:44:18
↕ Times entered are Zulu / GMT ↕								Verify S-Turns Before Mission	Yes [ ] No [ ]
50	N	19:43:12	19:44::22	15:37:04	15	0.7	1.1		
51	S	19:48:06	19:48:58	0:00:00	15	0.7	1.1		
				0:00:00				Landing: 200:01	
				0:00:00				Static: 20:04 14 - 20:06:14	
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
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↑ Times entered are Zulu / GMT ↑				Page		2		Verify S-Turns After Mission	Yes [ ] No [ ]

Additional Comments:	Drive #

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	10/4/2014	287	74753	2	Animas, NM

Operator	Aircraft	Hobbs Start	Local Start Time	Zulu Start Time	Base
GALAMBOS	N7079F	3383.8	10:04:00	16:04:00	WOOLPERT PIN
Pilot	**Sensor Type**	**Hobbs End**	**Local End Time**	**Zulu End Time**	**PID**
RADER	ALS-7177	3390.4	11:53:00	17:53:00	9:18

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
120 6	10	clear	0	6	-2	30.32		Departing	KFMN
								Arriving	KFMN

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	41.5	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	11,735	Ft	Yes		No	X	@ 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:	16:10:44
⇩ Times entered are Zulu / GMT ⇩								Verify S-Turns Before Mission	Yes x No
52	N	16:35:39	16:36:46	9:20:59	16	0.8	1.3	Takeoff 1620z	
53	S	16:39:48	16:41:11	0:00:00	16	0.8	1.3	FL 42-62 13,000 MSL	
54	N	16:43:58	16:47:10	0:00:00	15	0.7	1.4		
55	S	16:50:05	16:53:23	0:00:00	15	0.7	1.4		
56	N	16:56:00	16:59:48	0:00:00	15	0.7	1.4		
57	S	17:02:40	17:06:29	0:00:00	16	0.7	1.4		
58	N	17:08:55	17:12:37	0:00:00	16	0.7	1.4		
59	S	17:15:10	17:18:39	0:00:00	16	0.7	1.3		
60	N	17:21:00	17:24:16	0:00:00	15	0.7	1.5		
61	SW	17:30:33	17:31:26	0:00:00	17	0.6	1.1		
62	NE	17:33:32	17:34:26	0:00:00	17	0.6	1.1		
				0:00:00				Landing: 17:47:25	
				0:00:00				Static: 17:51:26	
				0:00:00					
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				0:00:00					
				0:00:00					
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↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission	Yes x No

Additional Comments:	Drive #
	96

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	10/15/2014	288	74753	2	Animas, NM

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
GALAMBOS	N7079F	3390.4	9:35:00	15:35:00	CORS
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
RADER	ALS-7177	3392.2	10:25:00	16:25:00	Durango

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	KFMN
110 11	10	Clear	0	7	-1	30.23		Arriving	KSRR

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	41.5	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.
150	Kts	6500	Ft	11,735	Ft	Yes		No	X	@	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:	15:43:44
		⇩ Times entered are Zulu / GMT ⇩						Verify S-Turns Before Mission	Yes x No
21	SW	16:08:45	16:16:12	0:00:00	15	0.7	1.4	FL 1-41 11,735 MSL	
				0:00:00				Takeoff: 15:53z	
				0:00:00				Landing: 11:46 (L) 1746z	
				0:00:00					
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Additional Comments:	Drive #
Client set Base Station	S/N:00099

Section 7: Final Deliverables

The final lidar deliverables are listed below.

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