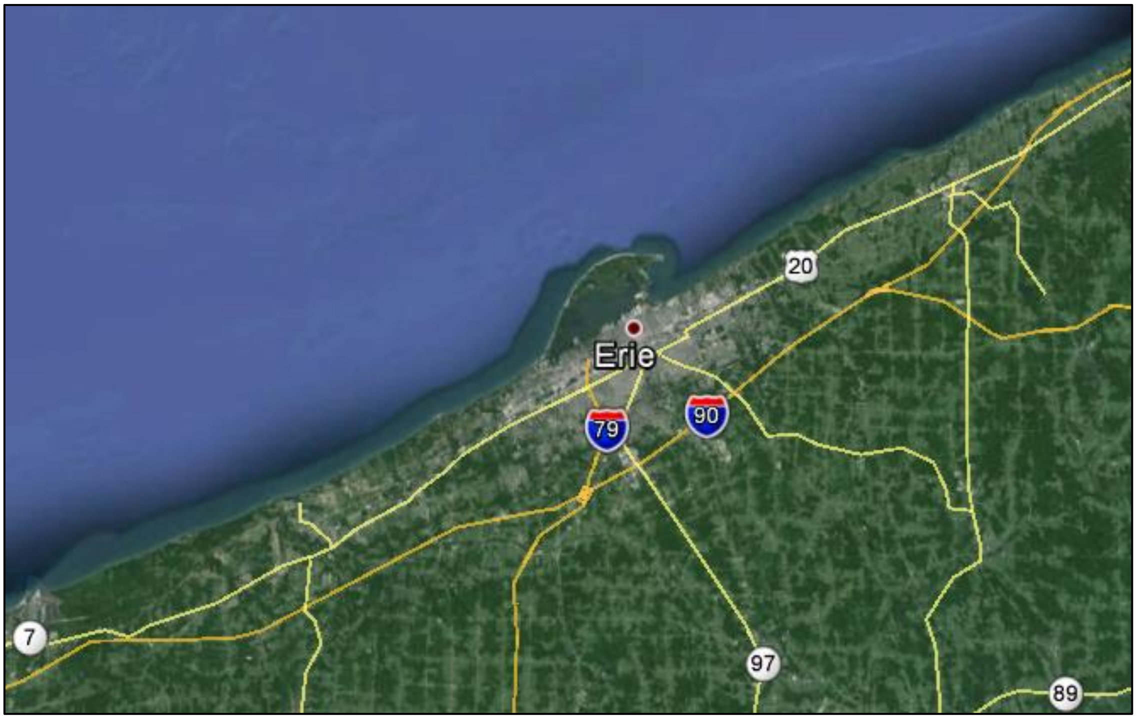
WOOLPERT



Lake Erie Watershed 2015 Ortho/ LiDAR/Hydro Project

Pennsylvania State University

November 2015

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Section 1: Overview

Project Name: Lake Erie Watershed 2015 Ortho/ LiDAR/Hydro Project

Woolpert Project: # 75294

This report contains a comprehensive outline of Lake Erie Watershed 2015 Ortho/ LiDAR/Hydro Processing task order. This task order requires lidar data to be acquired over approximately 512 square miles of the Lake Erie Shoreline, Pennsylvania. 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	7,070 ft/ 2,155 m
Average Ground Speed:	150 knots / 173 mph
Field of View (full)	40 degrees
Pulse Rate	272 kHz
Scan Rate	41.0 Hz
Side Lap	25%

The lidar data was processed and projected in NAD 83 (HARN) Pennsylvania State Plane North in units of Survey Feet. The vertical datum used for the task order was referenced to NAVD 1988, GEOID09, in units of Survey Feet.

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 three (3) 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, Lake Erie Watershed 2015, PA Lidar

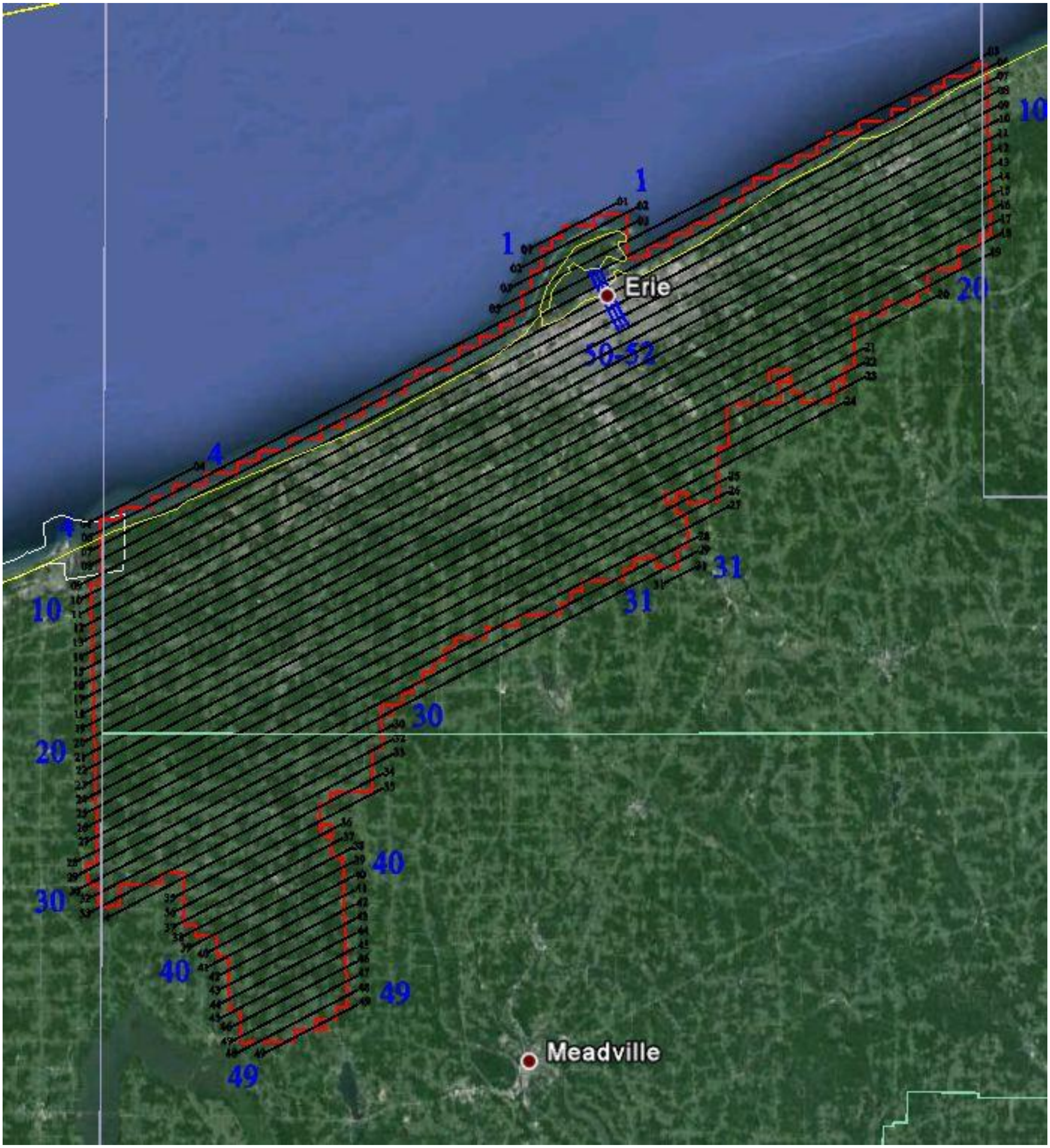


Table 2.2: Airborne Lidar Acquisition Flight Summary			
Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = EDT) Wheels Up/ Wheels Down
April 29, 2015 – Sensor ALS-7177	1-20	14:17 – 22:34	10:17 AM – 06:34 PM
May 1, 2015 – Sensor ALS-7177	21-52	17:45 – 21:00	9:46 AM - 05:49 PM
May 7, 2015 – Sensor ALS-7177	22, 29-30, 32-34, 36-39, 49	12:15 – 16:40	10:08 AM – 2:34 PM

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)
OHAS_CORS	41° 55' 30.22147"	-80°33' 03.84436"	181.660

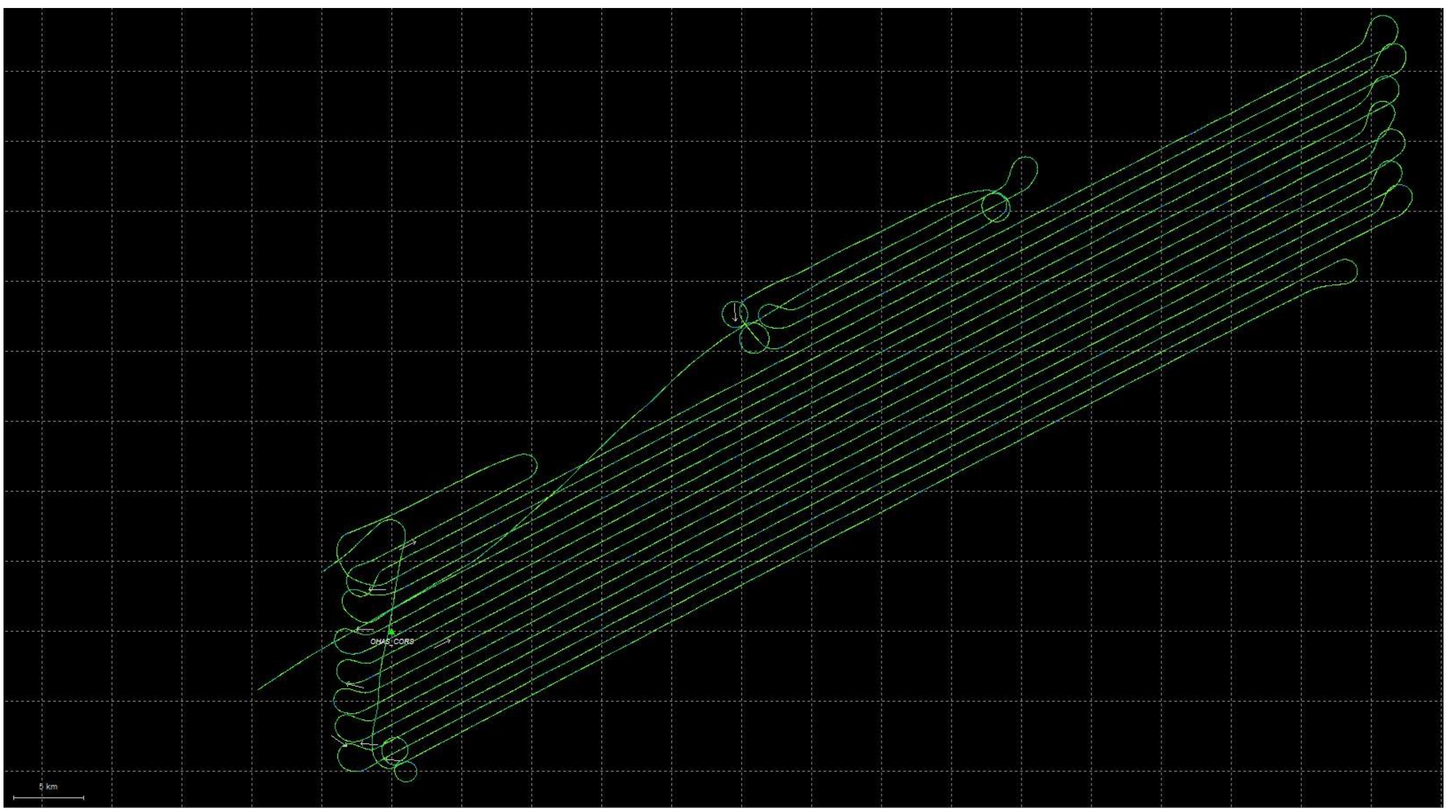
Data Processing

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, Day11915_SH7177

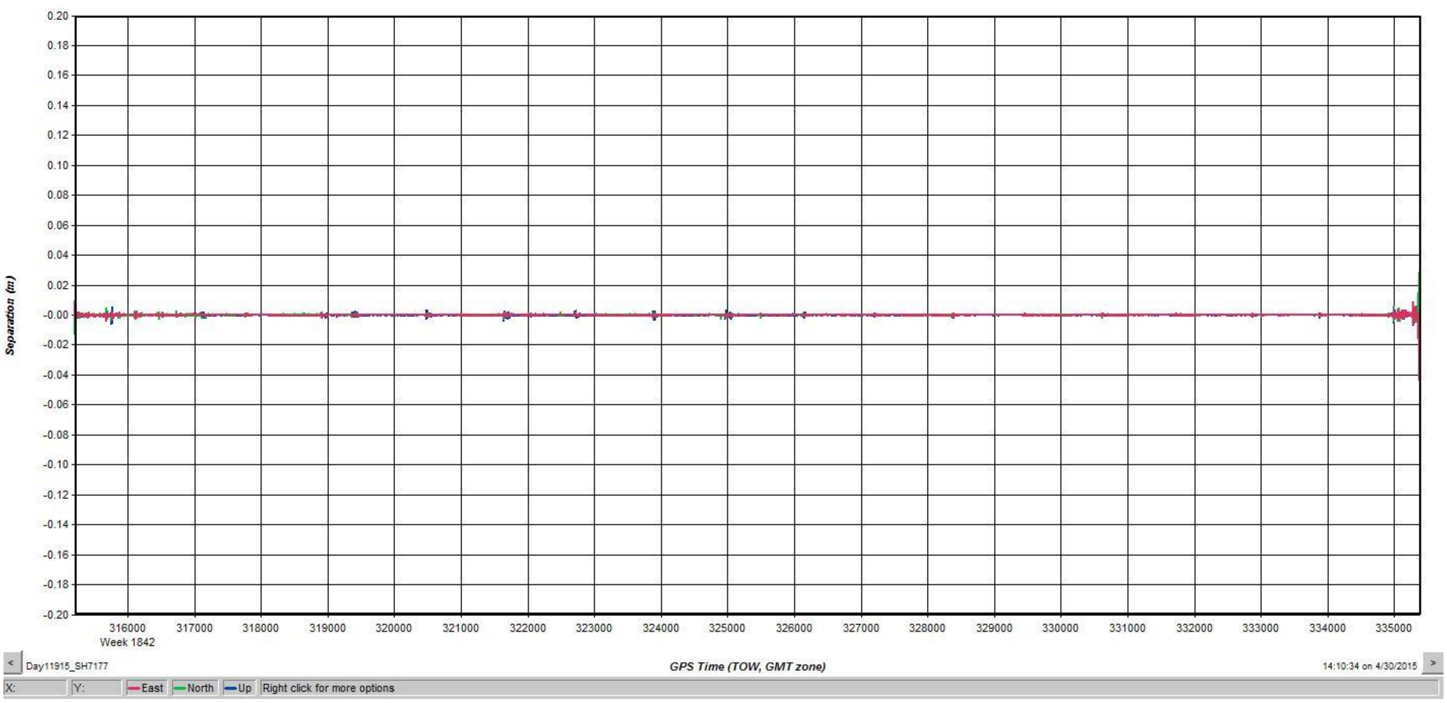


Combination Separation

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, Day11915_SH7177

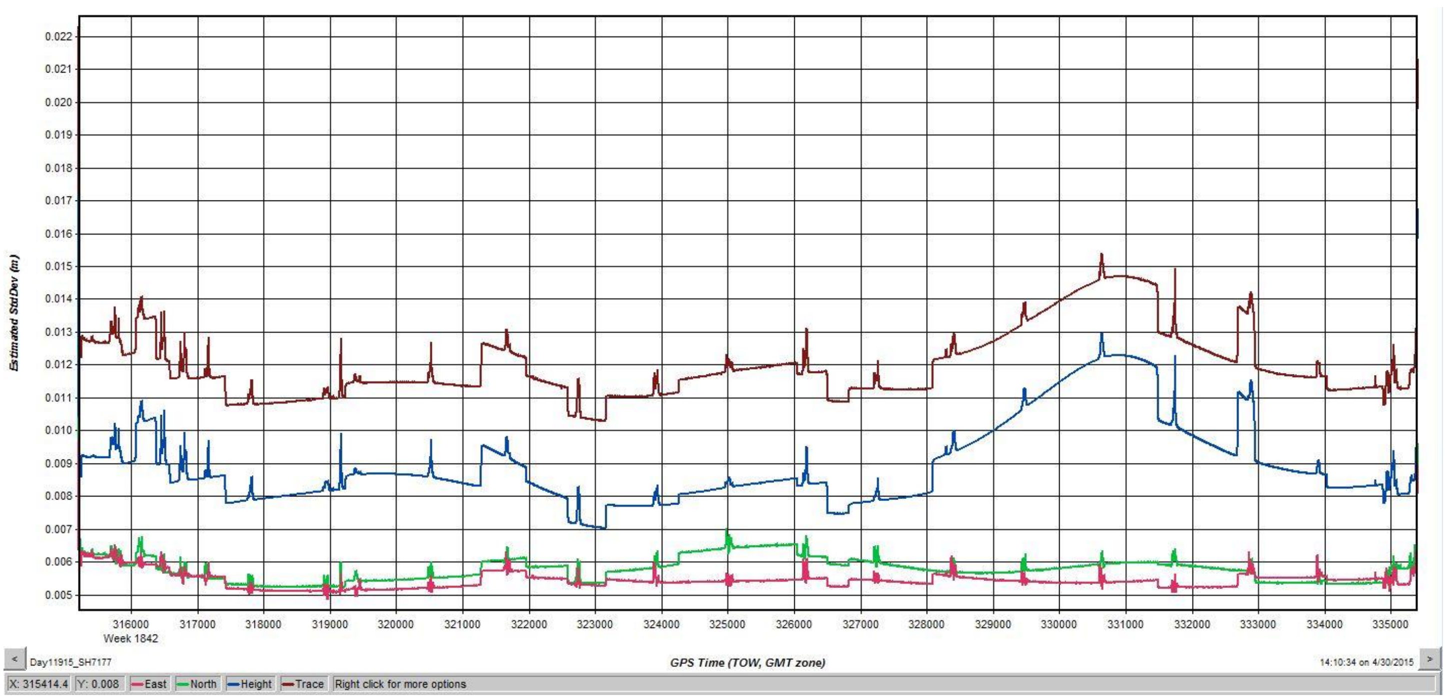


Estimated Positional Accuracy

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, Day11915_SH7177

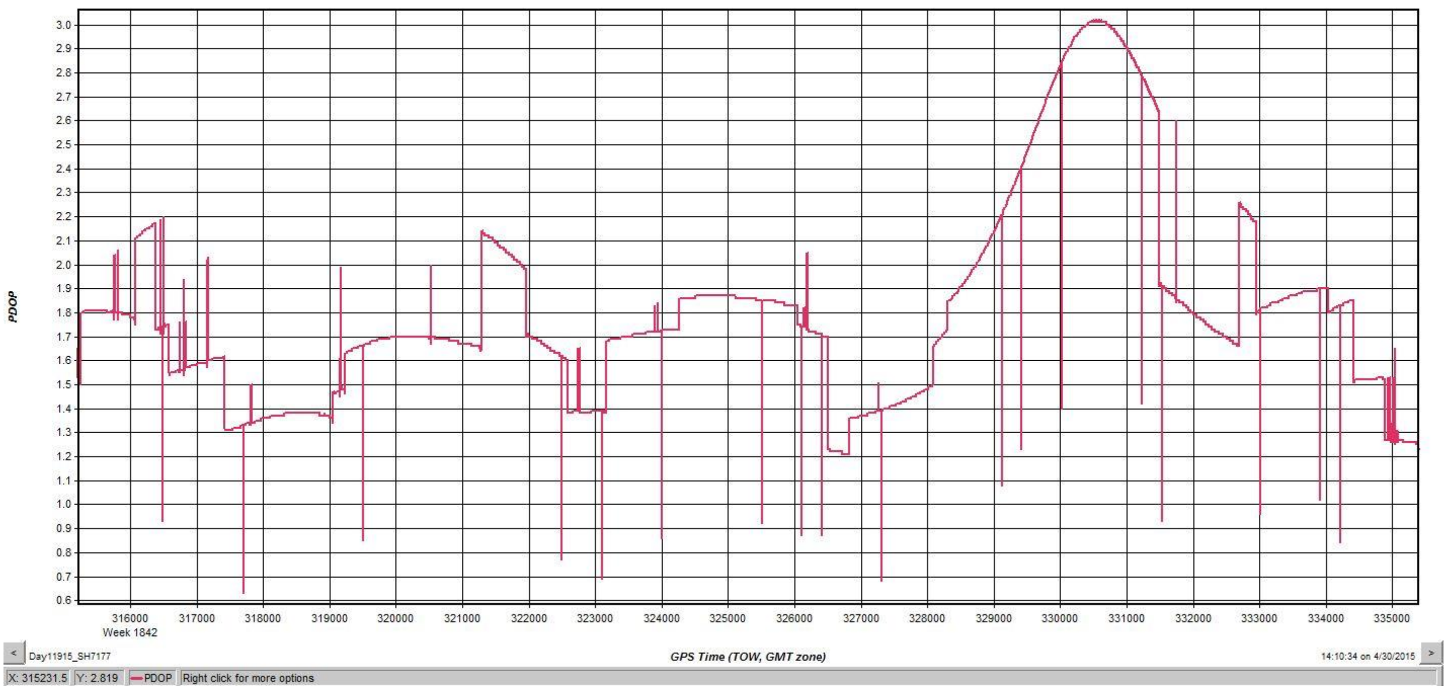


PDOP

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, Day11915_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 points (Class 1), Ground points (Class 2), Low vegetation (Class 3), Medium vegetation (Class 4), High vegetation (Class 5), Building (Class 6), Noise (Class 7), Water (Class 9), Ignored Ground (Class 10), Bridge deck (Class 13), Overlap Default (Class 17), Overlap Ground (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 NAD 83 (HARN) Pennsylvania State Plane North. The vertical datum used for the task order was referenced to NAVD 1988, GEOID09. Coordinate positions were specified in units of Survey Feet.

Section 4: Hydrologic Flattening

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

Lake Erie Watershed 2015 LiDAR (PA) 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 2-acre or greater and streams at a minimum size of 30 meters (100 feet) nominal width, were compiled to meet task order requirements. **Figure 4.1** illustrates an example of 30 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30 meters (100 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

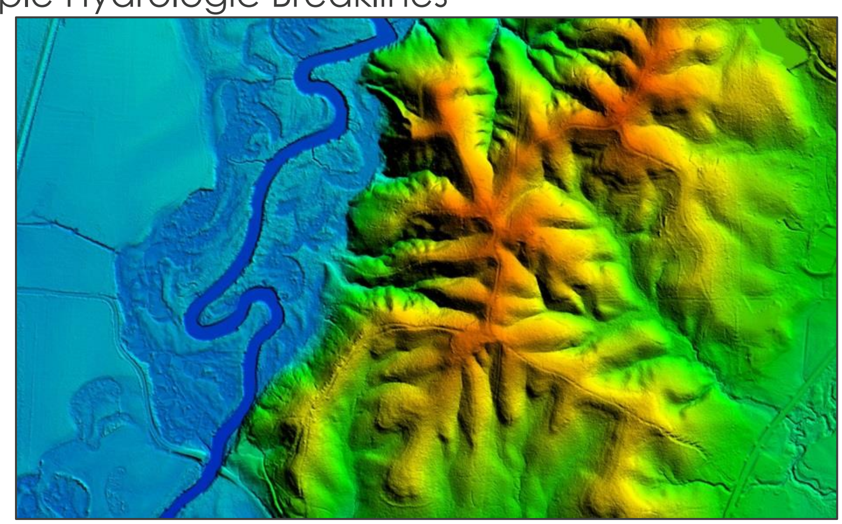


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

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.

Table 5.1: Overall Vertical Accuracy Statistics,		
Average error	+0.215	US Survey Foot
Minimum error	-0.228	US Survey Foot
Maximum error	+0.833	US Survey Foot
Average magnitude	0.238	US Survey Foot
Root mean square	0.303	US Survey Foot
Standard deviation	0.216	US Survey Foot

Table 5.2: Raw Swath Quality Check Point Analysis NVA

Point ID	Easting (US Survey Foot)	Northing (US Survey Foot)	TIN Elevation (US Survey Foot)	Dz (US Survey Foot)
2001	1252169	555651.4	1233.5	0.372
2002	1215600	592333.3	1133.63	0.023
2003	1218619	667143.2	640.02	0.101
2004	1336120	735954.8	576.73	0.346
2005	1423657	771660.6	606.32	0.833
2006	1416873	739927.1	1290.89	0.296
2007	1346799	668494.8	1239.23	-0.053
2008	1260195	638256.5	981.01	0.061
2009	1250916	611935.2	907.65	0.049
2010	1290536	686016.2	835.86	-0.104
2011	1220169	623803.5	973.99	-0.02
2012	1384205	703732.2	1389.51	0.405
2013	1378341	749967.5	667.35	0.288
2014	1331684	696178.5	1090.08	0.481
2015	1300714	656340.5	1272.01	0.128
2016	1270470	678695.1	771.56	0.008
2017	1241716	651848.8	870.7	0.096
2018	1314366	690075.7	947.36	0.371
2019	1352363	723529.2	773.7	0.151
2020	1388467	741131.2	840.46	0.249
2021	1253056	590593.1	936.3	-0.228
2022	1318417	666895.6	1125.19	0.292
2023	1283230	633414.3	1207.5	0.072

2024	1316375	716706	659.08	0.269
2025	1271770	660321	937.6	0.104
2026	1329115	723343.6	580.65	0.213
2027	1237183	639522.3	907.83	0.1
2028	1232163	594321.9	1152.49	0.095
2029	1364227	698950.2	1357.58	0.41
2030	1395214	722493.6	1453.4	0.528
2031	1405881	762915	597.87	0.218
2032	1374521	723998.8	1082.29	0.617
2033	1248052	677001.4	715.21	0.074
2034	1341827	713028.1	869.73	0.385
2035	1216596	647541.6	833.12	0.297

VERTICAL ACCURACY CONCLUSIONS

Raw LAS Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.593 U.S. survey feet non-vegetated 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 Non-Vegetated Vertical Accuracy (NVA) Tested 0.566 U.S. survey feet non-vegetated 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.

NVA/VVA ASSESMENT

Table 5.3: Non-Vegetated Vertical Accuracy Quality Check Point Analysis NVA

Point ID	Easting (US Survey Foot)	Northing (US Survey Foot)	DEM Elevation (US Survey Foot)	Dz (US Survey Foot)
2001	1252168.528	1233.415	1233.128	0.287
2002	1215600.172	1133.595	1133.607	-0.012
2003	1218619.368	639.983	639.919	0.064
2004	1336120.212	576.652	576.384	0.268
2005	1423657.278	606.302	605.487	0.815
2006	1416873.155	1290.865	1290.594	0.271
2007	1346798.924	1239.125	1239.283	-0.158
2008	1260195.295	980.994	980.949	0.045
2009	1250915.516	907.604	907.601	0.003
2010	1290535.599	835.823	835.964	-0.141
2011	1220168.791	973.894	974.01	-0.116
2012	1384204.895	1389.476	1389.105	0.371
2013	1378340.692	667.323	667.062	0.261
2014	1331684.426	1089.974	1089.599	0.375
2015	1300713.851	1271.875	1271.882	-0.007

2016	1270470.298	771.613	771.552	0.061
2017	1241715.695	870.603	870.604	-0.001
2018	1314366.114	947.364	946.989	0.375
2019	1352363.04	773.803	773.549	0.254
2020	1388466.51	840.363	840.211	0.152
2021	1253055.586	936.234	936.528	-0.294
2022	1318417.246	1125.165	1124.898	0.267
2023	1283229.57	1207.525	1207.428	0.097
2024	1316375.145	659.043	658.811	0.232
2025	1271770.03	937.544	937.496	0.048
2026	1329114.535	580.712	580.437	0.275
2027	1237183.468	907.804	907.73	0.074
2028	1232163.078	1152.365	1152.395	-0.030
2029	1364226.774	1357.545	1357.17	0.375
2030	1395213.752	1453.406	1452.872	0.534
2031	1405880.693	597.982	597.652	0.330
2032	1374520.592	1082.454	1081.673	0.781
2033	1248052.409	715.073	715.136	-0.063
2034	1341827.168	869.603	869.345	0.258
2035	1216595.757	833.103	832.823	0.280

VERTICAL ACCURACY CONCLUSIONS

Bare-Earth DEM Non-Vegetated Vertical Accuracy (NVA) Tested 0.586 U.S. survey feet non-vegetated 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.

Table 5.4: Vegetated Vertical Accuracy Quality Check Point Analysis VVA

Point ID	Easting (US Survey Foot)	Northing (US Survey Foot)	DEM Elevation (US Survey Foot)	Dz (US Survey Foot)
3001	1252206.262	1233.545	1232.979	0.566
3002	1215502.92	1133.715	1133.448	0.267
3003	1218721.799	640.143	640.035	0.108
3004	1336728.026	577.922	577.554	0.368
3005	1423622.567	606.092	605.585	0.507
3006	1416837.715	1288.525	1287.929	0.596
3007	1346878.808	1240.745	1240.296	0.449
3008	1260389.7	979.914	979.604	0.310
3009	1250828.456	904.294	903.449	0.845
3010	1291648.723	869.243	869.163	0.080
3011	1220838.104	972.944	972.808	0.136
3012	1384199.69	1389.726	1389.223	0.503

3013	1378321.17	667.473	667.207	0.266
3014	1331646.4	1089.594	1089.123	0.471
3015	1300696.566	1271.385	1271.366	0.019
3016	1270000.803	765.913	765.917	-0.004
3017	1241695.586	872.103	872.049	0.054
3018	1314279.544	945.374	944.908	0.466
3019	1352358.561	775.703	775.273	0.430
3020	1388506.579	838.453	838.149	0.304
3021	1253026.793	933.904	933.75	0.154
3022	1318399.247	1124.845	1124.843	0.002
3023	1283305.829	1206.815	1206.44	0.375
3024	1316438.269	658.873	658.37	0.503
3025	1271739.538	935.994	936.095	-0.101
3026	1378952.039	1132.205	1131.571	0.634
3027	1403212.336	1406.276	1405.758	0.518
3028	1219118.122	905.484	905.113	0.371
3029	1232127.899	1151.065	1151.051	0.014
3030	1298112.525	664.813	664.641	0.172
3001	1252206.262	1233.545	1232.979	0.566

VERTICAL ACCURACY CONCLUSIONS

Vegetated Vertical Accuracy (VVA) Tested 0.616 U.S. survey feet vegetated vertical accuracy at the 95th percentile in the vegetated vertical accuracy class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM.
Vegetated Vertical Accuracy Errors at the 95th percentile include:
Point 3009, Easting 1250828.456, Northing 611877.97, Z-Error 0.845 U.S. survey feet
Point 3026, Easting 1378952.039, Northing 725784.617, Z-Error 0.634 U.S. survey feet

Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		November 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
	4/29/2015	119	75294	2	Erie, PA 0.7m Lidar

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
Other	N475RC	13.1	10:17:18	14:17:18	CORS
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
GEBHART	ALS-7177	21.3	6:34:00	22:34:00	OHAS

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	KDAY
Calm	10	Clear	0	11	5	29.90	na	Arriving	KDAY

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	41	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi	x	B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode			Pre-Trigger Dist.
150	Kts	6500	Ft	7070	Ft	Yes		No	x	n/a	@	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 x No
1	NE	15:45:51	15:47:29	7:43:45	17		1.1	Low returns when over Bayfront
2	SW	15:50:45	15:53:00	0:00:00	18		1	
3	NE	15:55:54	15:58:07	0:00:00	19		1	
5	NE	16:06:46	16:15:15	0:00:00	16		1.3	
6	SW	16:18:08	16:34:15	0:00:00	17		1.3	
4	NE	16:36:56	16:38:48	0:00:00	17		1.3	
7	NE	16:44:28	17:00:20	0:00:00	16		1.3	
8	SW	17:03:28	17:19:41	0:00:00	17		1.1	
9	NE	17:22:07	17:37:40	0:00:00	18		1.1	
10	SW	17:40:31	17:57:12	0:00:00	17		1.2	
11	NE	17:59:45	18:15:33	0:00:00	17		1.2	
12	SW	18:18:20	18:34:46	0:00:00	18		1	
13	NE	18:37:13	18:52:40	0:00:00	19		1.1	
14	SW	18:55:35	19:11:52	0:00:00	17		1.3	
15	NE	19:14:27	19:29:49	0:00:00	18		1.1	
16	SW	19:32:36	19:49:09	0:00:00	18		1.2	
17	NE	19:51:43	20:07:19	0:00:00	18		1.2	
18	SW	20:10:26	20:26:45	0:00:00	19		1.1	
19	NE	20:29:14	20:44:16	0:00:00	19		1	
20	SW	20:46:26	21:01:37	0:00:00	18		1	
				0:00:00				
				0:00:00				
				0:00:00				
				0:00:00				
				0:00:00				
				0:00:00				
				0:00:00				
				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 #
Operator: Todd	

FLI4.9-02 10/16/12 R 07

Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	5/1/2015	121	75197	3	erie,pa

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
SMITH	N475RC	21.3	9:46:00	13:46:00	
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
GEBHART	ALS-7177	29.4	5:49:00	11:45:36	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	day
350/13	10			11	6	3007		Arriving	day

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	41	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi	x	B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.
150	Kts	6500	Ft	7070	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 x No
40	w	15:24:00	15:27:00		17	0.6	1	
41	e	15:30:00	15:33:00		17	0.6	1.1	
42	w	15:35:00	15:38:00		16	0.6	1.2	
43	e	15:41:00	15:43:00		17	0.6	1.2	
44	w	15:46:00	15:49:00		17	0.6	1.1	
45	e	15:52:00	15:54:00		18	0.6	1	
46	w	15:57:00	16:00:00		17	0.6	1.1	clds 3-6
47	e	16:03:00	16:05:00		16	0.6	1.2	
48	w	16:08:00	16:10:00		16	0.6	1.3	
49	e	16:13:00	16:15:00		16	0.6	1.3	clds 3,2
46	w	16:18:00	16:20:00		16	0.6	1.3	reflt
39	e	16:24:00	16:27:00		16	0.6	1.3	clds
38	w	16:30:00	16:33:00		19	0.6	1	clds
37	e	16:36:00	16:39:00		19	0.6	1	clds
36	w	16:42:00	16:45:00		19	0.6	1.1	clds
35	e	16:49:00	16:53:00		17	0.6	1.2	clds
34	w	16:56:00	17:01:00		16	0.6	1.3	clds
33	e	17:04:00	17:10:00		17	0.6	1.2	clds
32	w	17:13:00	17:19:00		19	0.6	1.1	clds
30	e	17:22:00	17:28:00		19	0.6	1.1	clds
31	e	17:33:00	17:34:00		18	0.6	1.2	clds
29	w	17:37:00	17:47:00		18	0.6	1.2	clds
28	e	17:51:00	18:03:00		17	0.6	1.3	clds
27	w	18:06:00	18:17:00		17	0.6	1.2	
26	e	18:20:00	18:32:00		19	0.6	1.1	
25	w	18:35:00	18:46:00		19	0.6	1.1	
24	e	18:49:00	19:04:00		18	0.6	1.1	
23	w	19:07:00	19:19:00		19	0.6	1.1	clds
22	e	19:22:00	19:36:00		18	0.6	1.1	clds
21	w	19:39:00	19:53:00		18	0.6	1.2	
50	n	20:07:00	20:08:00		16	0.6	1.2	
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission Yes x No

Additional Comments:	Drive #

Woolpert

Leica LIDAR

MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name

Operator	Aircraft	HOBBS Start			
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	day
								Arriving	day

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	41	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi	x	B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	7070	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 x No
51	s	20:11:00	20:12:00		16	0.6	1.2	
52	n	20:16:00	20:17:00		16	0.6	1.2	
74	w	20:40:00	20:41:00		16	0.6	1.2	lake erie reflt
				0:00:00				
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission Yes x No

Additional Comments:

Drive #

Woolpert

Leica LIDAR

MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
5/7/2015	127	75197	3	erie,pa

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
SMITH	N475RC	32.8	10:08:00	14:08:00	

Pilot	Sensor Type	HOBBS END	Local End Time	Zulu End Time	PID
GEBHART	ALS-7177	37.2	2:34:00	18:34:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	day
120/6	10			22	16	3015		Arriving	day

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	41	272	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi	x	B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.
150	Kts	6500	Ft	7070	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 X No
49	w	15:36:00	15:37:00		16	0.7	1.2	
39	e	15:41:00	15:44:00		16	0.7	1.3	
38	w	15:47:00	15:50:00		16	0.7	1.3	
37	e	15:53:00	15:56:00		17	0.7	1.3	
36	w	15:59:00	16:02:00		17	0.7	1.3	
34	e	16:05:00	16:10:00		17	0.7	1.3	
33	w	16:13:00	16:18:00		19	0.7	1.1	
32	e	16:21:00	16:26:00		17	0.7	1.4	
30	w	16:29:00	16:35:00		16	0.7	1.3	
29	e	16:37:00	16:48:00		17	0.7	1.3	
22	w	16:54:00	17:08:00		19	0.7	1.1	

↑ Times entered are Zulu / GMT ↑		Page	1	Verify S-Turns After Mission	Yes	x	No

Additional Comments:	Drive #

Section 7: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.2 classified point cloud
- LAS v1.2 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