

Lidar Mapping Report

Acquisition, Processing, and Delivery of Airborne Lidar Elevation Data for the NE Sandhills Lidar 2016 D17 Project



USGS CONTRACT: G16PC00029

CONTRACTOR: Merrick-Surdex JV

TASK ORDER NUMBER: G17PD00008

TASK NAME: NE Sandhills LiDAR 2016 D17, Contract G16PC00029

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Submitted to:



Submitted by:



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Project Summary

Merrick-Surdex Joint Venture, LLP (“Merrick-Surdex JV”) was awarded the NE_Sandhills LiDAR 2016_D17 (USGS Task Order Number G17PD00008) project by the United State Geological Survey (USGS) to provide a high-resolution data set of lidar for partial counties in Nebraska totaling 18,110 square miles. The counties included are Arthur, Blaine, Boone, Brown, Cherry, Custer, Garfield, Grant, Greeley, Hooker, Howard, Keith, Lincoln, Logan, Loup, McPherson, Rock, Sheridan, Sherman, Thomas, Valley and Wheeler. This project will support the Nebraska USDA-NRCS in generating digital elevation models and contours for use in dam safety assessments, engineering design and design reviews, conservation planning, research, delivery, floodplain mapping, and hydrologic modeling.

Unless otherwise stated, the lidar mapping requirements and deliverables meet the Quality Level Two (QL2) standards as outlined in the USGS-NGP Lidar Base Specifications, Techniques and Methods 11–B4, Version 1.2, November 2014 (TM11-B4) (<http://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf>). QL2 lidar specifications suggest a point density of greater than or equal to two points per square meter (≥ 2 ppsm) Aggregate Nominal Pulse Density (ANPD), and point spacing of less than or equal to seven-tenths of a meter (≤ 0.71 m) Aggregate Nominal Pulse Spacing (ANPS).

The vertical accuracy requirements of the lidar data meets or exceeds the following:

Absolute Vertical Accuracy

- ≤ 10 cm RMSEz
- ≤ 19.6 cm Non-vegetated Vertical Accuracy (NVA) at the 95% confidence level
- ≤ 29.4 cm Vegetated Vertical Accuracy (VVA) at the 95% percentile

Relative Vertical Accuracy

- ≤ 6 cm Smooth surface repeatability
- ≤ 8 cm Swath overlap difference, RMSDz
- ± 16 cm Swath overlap difference, maximum

Project Spatial Reference

- Projection – Universal Transverse Mercator (UTM), Zones 13N (Sheridan County) and 14N
- Horizontal Datum - North American Datum of 1983 (NAD 83), National Adjustment of 2011 (NA2011) (epoch 2010.00)
- Vertical Datum – North American Vertical Datum of 1988 (NAVD 88); GEOID 12B
- Units – Meters
- EPSG Codes - UTM Zone 13 = EPSG 6342, UTM Zone 14 = EPSG 6343

CONTACT INFORMATION

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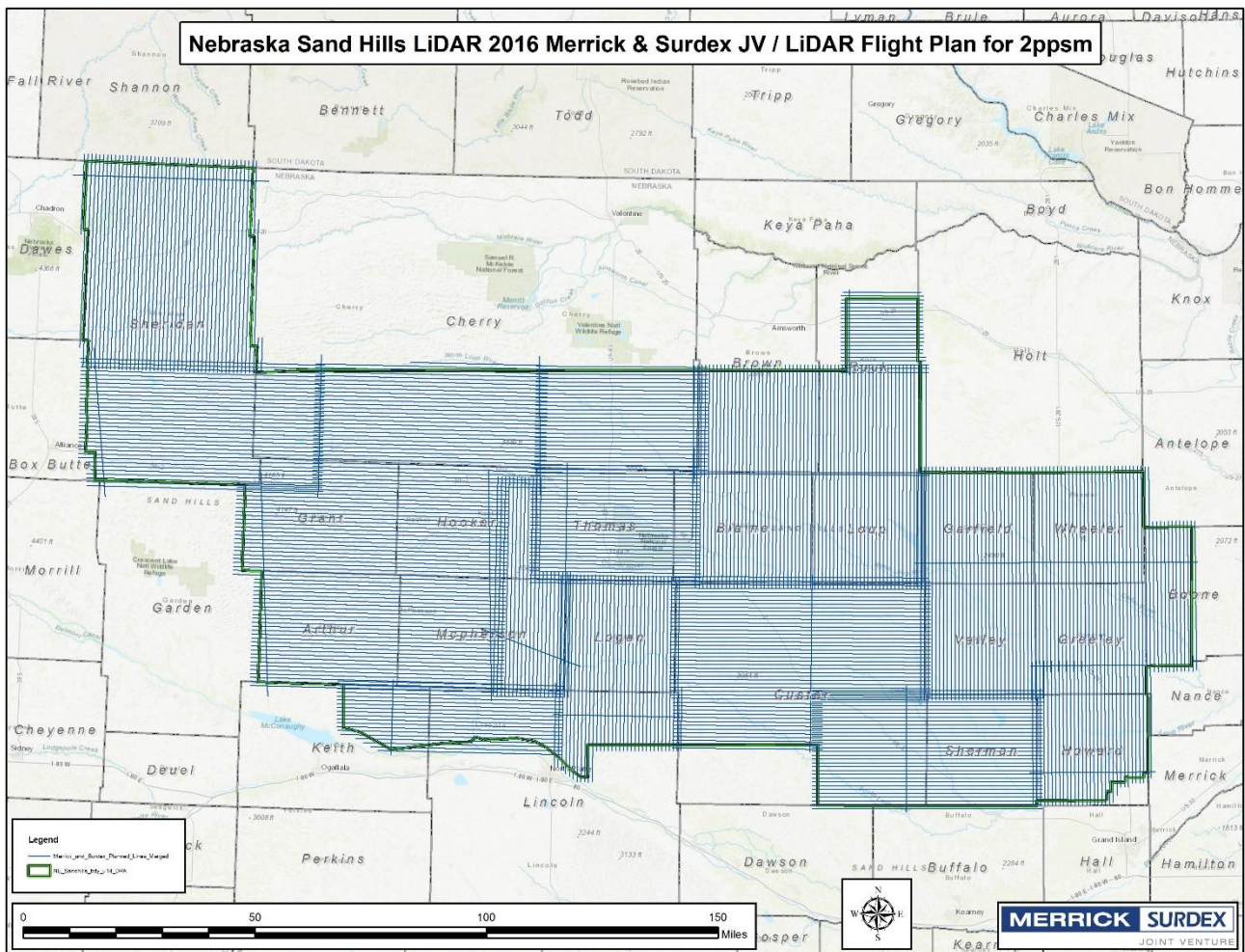
Doug.jacoby@merrick.com

The contents of this report summarize the methods used to calibrate and classify the lidar data as well as the results of these methods for the project NE_Sandhills LiDAR 2016_D17 (USGS NE Sandhills).

Lidar Flight Information

The acquisition area for the NE Sandhills project is delineated by the fully dissolved extent of the client-approved Esri shapefiles (*Nebraska2016*). The Merrick-Surdex JV acquired the QL2 lidar point cloud utilizing Optech Galaxy lidar sensors. The Galaxy is a high performance 550 kHz lidar sensor capable of collecting large areas efficiently.

Merrick-Surdex JV planned an acquisition area of approximately 18,110 square miles to include a one hundred-meter (100m) buffer per TM11-B4. See below illustration of the proposed lidar flight plan.

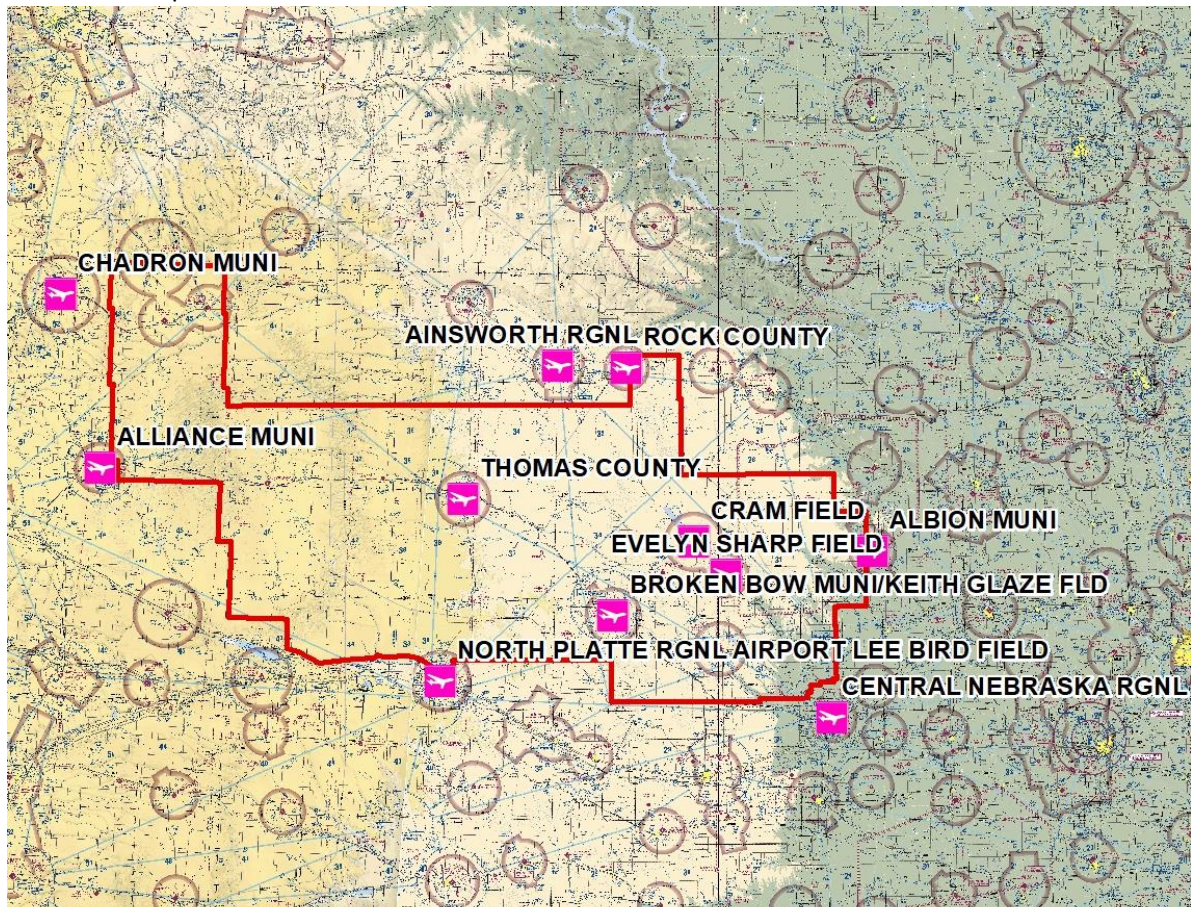


Airports of Operation

Multiple airports were used for the collection of this project. See below for a list of the airports used as well as an image of the project area with airports displayed.

- North Platte Regional Airport Lee Bird Field – North Platte, Nebraska
 - FAA Identifier: LBF
 - Lat/Long: 41-07-34.4000N / 100-41-01.2000W
 - Elevation: 2777.1 ft. / 846.5 m (surveyed)
 - From City: 3 miles E of NORTH PLATTE, NE
 - Zip Code: 69101
- Thomas County Airport – Thedford, Nebraska
 - FAA Identifier: TIF
 - Lat/Long: 41-57-45.7500N / 100-34-13.1000W
 - Elevation: 2925 ft. / 891.5 m (surveyed)
 - From City: 1 mile S of THEDFORD, NE
 - Zip Code: 69166
- Broken Bow Municipal Airport/Keith Glaze Field– Broken Bow, Nebraska
 - FAA Identifier: BBW
 - Lat/Long: 41-26-11.2000N / 099-38-31.8000W
 - Elevation: 2546.3 ft. / 776.1 m (surveyed)
 - From City: 2 miles N of BROKEN BOW, NE
 - Zip Code: 68822
- Evelyn Sharp Field Airport– Ord, Nebraska
 - FAA Identifier: ODX
 - Lat/Long: 41-37-25.3000N / 098-57-06.7000W
 - Elevation: 2070 ft. / 630.9 m (surveyed)
 - From City: 2 miles NW of ORD, NE
 - Zip Code: 68862
- Rock County Airport– Bassett, Nebraska
 - FAA Identifier: RBE
 - Lat/Long: 42-34-16.1000N / 099-34-10.3000W
 - Elevation: 2349.3 ft. / 716.1 m (surveyed)
 - From City: 2 miles SW of BASSETT, NE
 - Zip Code: 68714
- Albion Municipal Airport– Albion, Nebraska
 - FAA Identifier: BVN
 - Lat/Long: 41-43-42.8770N / 098-03-20.7350W
 - Elevation: 1806.2 ft. / 550.5 m (surveyed)
 - From City: 3 miles NW of ALBION, NE
 - Zip Code: 68620
- Cram Field Airport– Burwell, Nebraska
 - FAA Identifier: BUB
 - Lat/Long: 41-46-39.2758N / 099-09-00.7627W
 - Elevation: 2183.3 ft. / 665.5 m (surveyed)
 - From City: 1 mile SW of BURWELL, NE
 - Zip Code: 68823
- Ainsworth Regional Airport– Ainsworth, Nebraska

- FAA Identifier: ANW
- Lat/Long: 42-34-45.2000N / 099-59-34.7000W
- Elevation: 2588.7 ft. / 789.0 m (surveyed)
- From City: 6 miles NW of AINSWORTH, NE
- Zip Code: 69214
- Central Nebraska Regional Airport– Grand Island, Nebraska
 - FAA Identifier: GRI
 - Lat/Long: 40-58-03.1530N / 098-18-34.7000W
 - Elevation: 1847.1 ft. / 563 m (estimated)
 - From City: 3 miles NE of GRAND ISLAND, NE
 - Zip Code: 68801
- Chadron Municipal Airport– Chadron, Nebraska
 - FAA Identifier: CDR
 - Lat/Long: 42-50-15.2077N / 103-05-43.4469W
 - Elevation: 3297.8 ft. / 1005.2 m (surveyed)
 - From City: 4 miles W of CHADRON, NE
 - Zip Code: 69337
- Alliance Municipal Airport– Alliance, Nebraska
 - FAA Identifier: AIA
 - Lat/Long: 42-03-11.6000N / 102-48-13.5000W
 - Elevation: 3930.6 ft. / 1198.0 m (surveyed)
 - From City: 3 miles SE of ALLIANCE, NE
 - Zip Code: 69301



Aerial Mission(s) Duration / Time

The project was collected using three lidar fixed wing aircraft using three different Optech Galaxy lidar sensors. Lidar data collection for the project was accomplished between December 20, 2016 and June 8, 2017. Each mission represents a lift of the aircraft and system from the ground, collects data, and lands again. Multiple lifts within a day are represented by Mission A, B, C, D, E. The table below relates each mission to the date collected, the sensor and serial number used, the start/end time and the actual average MSL in meters. The time is shown in Global Positioning System (GPS) seconds of the week.

Mission(s)	Date	Sensor S/N	Start Time GPS sec.	End Time GPS sec.	Actual Avg. MSL (m)
161220A	December 20, 2016	5060382	229117	240607	3001.67
161220B	December 20, 2016	5060382	248706	259491	2984.60
161221A	December 21, 2016	5060382	317154	321835	2960.83
161221A	December 21, 2016	314	314551	323454	2659.69
161221B	December 21, 2016	5060382	333897	345715	2862.38
161222A	December 22, 2016	5060382	399329	411936	2883.10
161222B	December 22, 2016	5060382	417625	428638	2904.13
161222B	December 22, 2016	314	403496	414450	2677.06
161222C	December 22, 2016	314	424927	435813	2675.23
161223A	December 23, 2016	5060382	499811	512470	2829.15
161223C	December 23, 2016	314	506203	517973	2685.90
161224A	December 24, 2016	5060382	569475	576722	2767.58
161224A	December 24, 2016	314	525379	529317	2693.52
161224C	December 24, 2016	314	572058	577021	2813.00
161226B	December 26, 2016	5060382	167384	175256	2788.01
161226C	December 26, 2016	314	167070	174678	2818.18
161227C	December 27, 2016	5060382	250401	259583	2784.04
161227D	December 27, 2016	314	254920	259318	2895.30
161228A	December 28, 2016	5060382	317150	319822	2786.48
161229A	December 29, 2016	5060382	400208	407625	2809.65
161229B	December 29, 2016	5060382	415230	419908	2826.72
161230A	December 30, 2016	5060382	487371	500735	2667.91
161230B	December 30, 2016	5060382	507637	517224	2682.85
161231A	December 31, 2016	5060382	576273	586949	2688.95
161231B	December 31, 2016	5060382	595297	1323	2688.03
170118C	January 18, 2017	5060382	345400	349665	2879.75
170120C	January 20, 2017	5060382	515021	516998	2877.01
170121D	January 21, 2017	5060382	576153	580335	2880.36
170122D	January 22, 2017	5060382	57822	65187	2890.72
170122E	January 22, 2017	5060382	72001	80715	2886.46
170123C	January 23, 2017	5060382	148046	149134	2808.43
170213C	February 13, 2017	5060382	144004	151223	2573.43
170213D	February 13, 2017	5060382	151404	157486	2587.45
170213E	February 13, 2017	5060382	166443	175438	2599.64
170214B	February 14, 2017	5060382	230942	238634	2610.92
170215A	February 15, 2017	5060380	317219	330771	3035.88

170216A	February 16, 2017	5060380	400294	419505	3050.69
170217A	February 17, 2017	5060380	486070	498394	3092.31
170221A	February 21, 2017	5060380	226580	241182	3105.76
170416C	April 16, 2017	5060382	68964	86584	2712.11
170423B	April 23, 2017	5060382	50991	63351	2690.17
170423D	April 23, 2017	5060382	76057	93718	2711.20
170426C	April 26, 2017	314	344164	347420	3008.38
170427A	April 27, 2017	5060382	392485	398019	2696.87
170502B	May 2, 2017	5060382	228525	232565	2598.42
170502B	May 2, 2017	314	226714	232292	2581.35
170503A	May 3, 2017	314	303672	305175	2600.86
170504A	May 4, 2017	5060382	394396	405615	2621.28
170504D	May 4, 2017	5060382	420483	435846	2646.58
170504A	May 4, 2017	314	389203	399508	2593.85
170504B	May 4, 2017	314	405916	420860	2627.68
170504C	May 4, 2017	314	427089	438044	2657.25
170505A	May 5, 2017	5060380	514274	523958	3004.59
170505A	May 5, 2017	5060382	481661	486922	2656.94
170505C	May 5, 2017	5060382	500363	515626	2761.49
170505A	May 5, 2017	314	484843	488843	2677.67
170505B	May 5, 2017	314	500473	505676	2772.77
170505D	May 5, 2017	314	514620	518451	2785.26
170506A	May 6, 2017	5060380	574408	592107	3078.18
170506C	May 6, 2017	314	569516	584544	2752.65
170506D	May 6, 2017	314	593565	3708	2726.13
170507A	May 7, 2017	5060380	55928	73295	3100.32
170507A	May 7, 2017	314	11002	16835	2727.96
170508A	May 8, 2017	5060380	137723	154622	3019.05
170509A	May 9, 2017	5060380	227309	237977	2369.90
170509A	May 9, 2017	314	176389	177155	2823.97
170511B	May 11, 2017	314	406827	423433	2805.99
170511C	May 11, 2017	314	432695	445861	2822.75
170512A	May 12, 2017	5060380	484079	498286	3082.51
170512A	May 12, 2017	5060356	484340	506259	3104.53
170512B	May 12, 2017	5060356	509754	525660	3111.39
170513A	May 13, 2017	5060380	576650	588957	3230.52
170513A	May 13, 2017	5060356	566233	588205	3156.84
170513B	May 13, 2017	5060356	592554	604605	3133.89
170514A	May 14, 2017	5060380	59403	64906	3227.42
170514A	May 14, 2017	5060356	51338	71439	2930.90
170514B	May 14, 2017	5060356	73127	80920	2938.49
170516A	May 16, 2017	5060380	221863	228831	3232.88
170522A	May 22, 2017	5060380	135113	140078	3241.98

170524A	May 24, 2017	5060380	303463	322143	3244.31
170524B	May 24, 2017	5060380	325553	336573	3231.67
170525A	May 25, 2017	5060382	350994	361020	2726.44
170526A	May 26, 2017	5060380	477635	489566	3027.82
170526B	May 26, 2017	5060382	489112	504928	2631.03
170528A	May 28, 2017	5060380	45986	63615	3048.82
170528B	May 28, 2017	5060382	56509	67285	2741.37
170529A	May 29, 2017	5060380	132559	149780	3030.67
170529B	May 29, 2017	5060382	139539	148194	2716.07
170530A	May 30, 2017	5060380	217908	237565	3025.68
170530D	May 30, 2017	5060382	244358	248215	2806.60
170601A	June 1, 2017	5060382	400575	408945	2804.16
170602A	June 2, 2017	5060382	447913	451767	2797.76
170608A	June 8, 2017	5060380	396489	402488	3184.35

GNSS / IMU Data

A five-minute INS initialization is conducted on the ground, with the aircraft engines running, prior to flight, to establish fine-alignment of the INS. GPS ambiguities are resolved by flying within ten kilometers of the base stations. During the data collection, the operator recorded information on log sheets which includes weather conditions, lidar operation parameters, and flight line statistics. Near the end of the mission, GPS ambiguities were again resolved by flying within ten kilometers of the base stations to aid in post-processing. Data is sent back to the main office for preliminary processing to check overall quality of GPS / INS data and to ensure sufficient overlap between flight lines. Any problematic data may be re-flown immediately as required.

The airborne GPS data was post-processed using Applanix POSPac Mobile Mapping Suite version 8.x. A fixed-bias carrier phase solution was computed in both the forward and reverse chronological directions. Whenever practical, lidar acquisition was limited to periods when the PDOP (Positional Dilution Of Precision) was less than 4.0. PDOP indicates satellite geometry relating to position. Generally, PDOP's of 4.0 or less result in a good quality solution, however PDOP's between 4.0 and 5.0 can still yield good results most of the time. PDOP's over 6.0 are of questionable results and PDOP's of over 7.0 usually result in a poor solution. Usually as the number of satellites increase the PDOP decreases. Other quality control checks used for the GPS include analyzing the combined separation of the forward and reverse GPS processing from one base station and the results of the combined separation when processed from two different base stations. An analysis of the number of satellites, present during the flight and data collection times, is also performed.

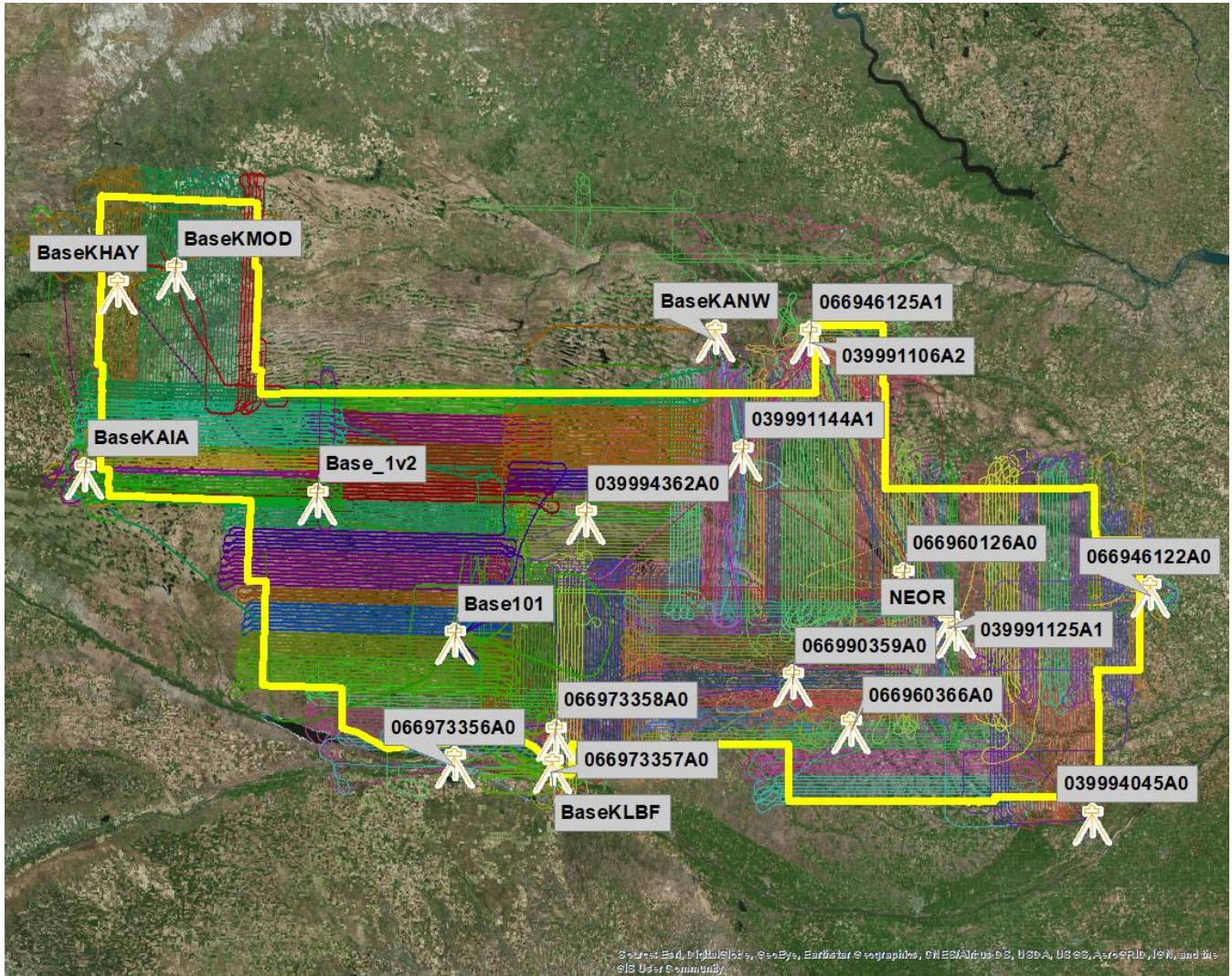
The GPS trajectory was combined with the raw IMU data and post-processed using POSPac Mobile Mapping Suite version 8.x. The Smoothed Best Estimated Trajectory (SBET) and refined attitude data are then utilized in the LMS Post Processor to compute the laser point-positions – the trajectory is combined with the attitude data and laser range measurements to produce the 3-dimensional coordinates of the mass points. Up to four return values are produced within the Optech lidar Mapping Suite (LMS) processor software for each pulse which ensures the greatest chance of ground returns in a heavily forested area.

GPS Controls

Ground GNSS Base Stations were set up to control the lidar airborne flight lines. In addition, CORS (Continually Operating Reference Stations) are at times used to further enhance the airborne solution. The ground GNSS Base Stations coordinates were obtained from NGS (National Geodetic Survey) Online Positioning User Service (OPUS) solutions. CORS coordinates were obtained from NGS datasheets. See the following table and map for ground GNSS Base Station information and locations:

Point ID	Latitude (NAD83 – 2011)	Longitude (NAD83 – 2011)	Ellipsoid Height (m)
BaseKLBF	N41°08'01.00902"	W100°41'47.63455"	824.254
Base101	N41°33'14.48412"	W101°08'12.88085"	984.921
BaseKHAY	N42°40'51.89156"	W102°41'46.80500"	1146.569
BaseKAIA	N42°03'43.66753"	W102°48'29.96597"	1178.817
BaseKMOD	N42°44'12.89572"	W102°26'29.71730"	1123.913
BaseKANW	N42°34'40.29142"	W100°00'01.92684"	764.550
Base_1v2	N42°00'22.50918"	W101°46'09.65388"	1113.506
039994045A0	N40°58'20.5454"	W98°19'08.48203"	538.3257
066973357A0	N41°08'00.43361"	W100°41'47.74877"	826.085
066973356A0	N41°08'36.0776"	W101°07'36.09091"	884.5364
066973358A0	N41°14'27.8941"	W100°41'07.42014"	886.2263
066960366A0	N41°16'30.5817"	W99°22'49.55711"	677.6095
066990359A0	N41°25'58.8364"	W99°38'14.40507"	748.5306
NEOR	N41°35'42.806"	W98°55'00.88864"	605.915
039991125A1	N41°37'20.774"	W98°56'57.76334"	605.364
066946122A0	N41°43'39.34654"	W98°03'14.04137"	521.6728
066960126A0	N41°46'31.39224"	W99°08'53.34356"	642.5976
039994362A0	N41°57'49.16664"	W100°34'06.1088"	866.5168
039991144A1	N42°10'58.13918"	W99°52'17.53564"	751.8497
039991106A2	N42°34'28.41919"	W99°34'23.12803"	693.059
066946125A1	N42°34'32.44711"	W99°34'16.92734"	692.6956

GNSS Base Station Map – missions color coded



Lidar Calibration – see appendix 1 for a more detailed workflow description

Merrick-Surdex JV takes great care to ensure all lidar acquisition missions are carried out in a manner conducive to post-processing an accurate data set. This begins in the flight-planning stage with attention to GPS baseline distances and GPS satellite constellation geometry and outages. Proper AGPS surveying techniques are always followed including pre- and post-mission static initializations. In-air IMU alignments (figure-eights) are performed both before and after on-site collection to ensure proper calibration of the IMU accelerometers and gyros.

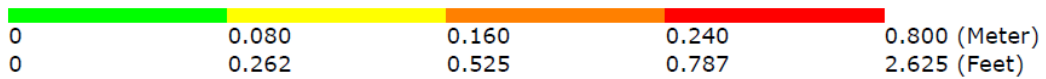
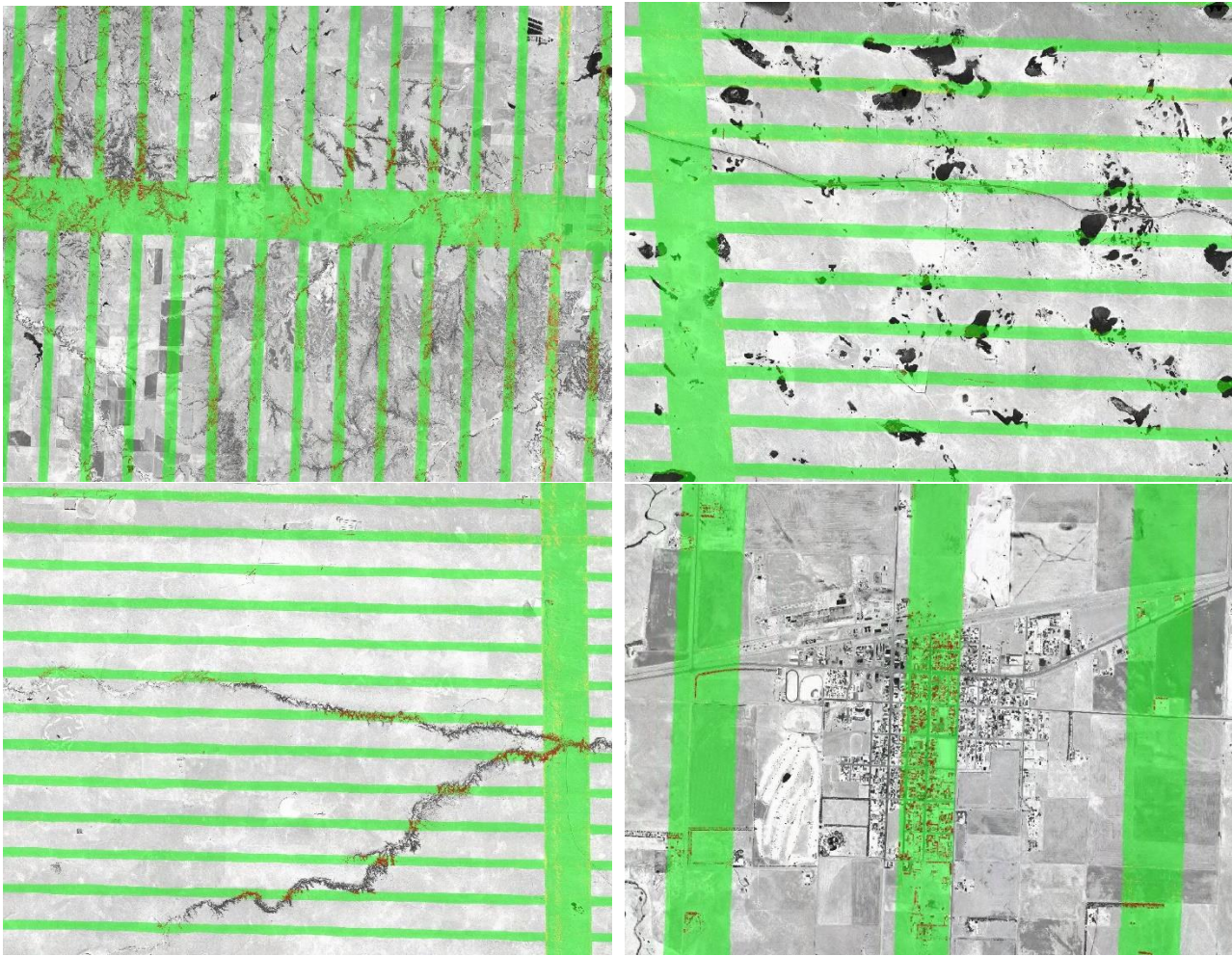
A minimum of one cross-flight is planned throughout the project area across all flightlines and over roadways where possible. The cross-flight provides a common control surface used to remove any vertical discrepancies in the lidar data between flightlines. The cross-flight is critical to ensure flightline ties across the project area. The areas of overlap between flightlines are used to boresight (calibrate) the lidar point cloud to achieve proper flightline to flightline alignment in all three axes. This includes adjustment of both IMU and scanner-related

variables such as roll, pitch, heading, timing interval (range), and torsion. Each lidar mission flown is accompanied by a hands-on boresight in the office.

After boresighting is complete a detailed statistical report is generated to check relative and absolute accuracies before filtering of lidar begins.

Relative Accuracy – flight line to flight line

The project representative flight line separation raster examples (below) depict the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on relative distance. This color thematic rendering is modulated by intensity to show land cover features.



Unfiltered lidar Control Point Report

The following tables illustrate the results of the lidar data compared to the lidar control points post-calibration. The listing is sorted by the Z Error column showing, in ascending order, the vertical difference between the lidar points and the 138 surveyed ground points used for lidar calibration.

All ground control surveys performed by CompassData, Inc.

Project Data Unit: Meter

Vertical Accuracy Class tested: 10.0-cm

Elevation Calculation Method: Interpolated from TIN

LiDAR Classifications Included: 0-255

Check Points in Report: 138

Check Points with LiDAR Coverage: 138

Check Points (NVA): 138

Check Points (VVA): 0

Average Vertical Error Reported: 0.002 Meter

Maximum (highest) Vertical Error Reported: 0.248 Meter

Median Vertical Error Reported: 0.001 Meter

Minimum (lowest) Vertical Error Reported: -0.113 Meter

Standard deviation of Vertical Error: 0.048 Meter

Skewness of Vertical Error: 0.982

Kurtosis of Vertical Error: 4.772

Non-vegetated Vertical Accuracy (NVA) RMSE(z): 4.754cm PASS

Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 9.317cm PASS

FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 9.317cm

Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 4.791cm PASS

Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 9.390cm PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10.0-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 4.754cm, equating to +/- 9.317cm at the 95% confidence level.

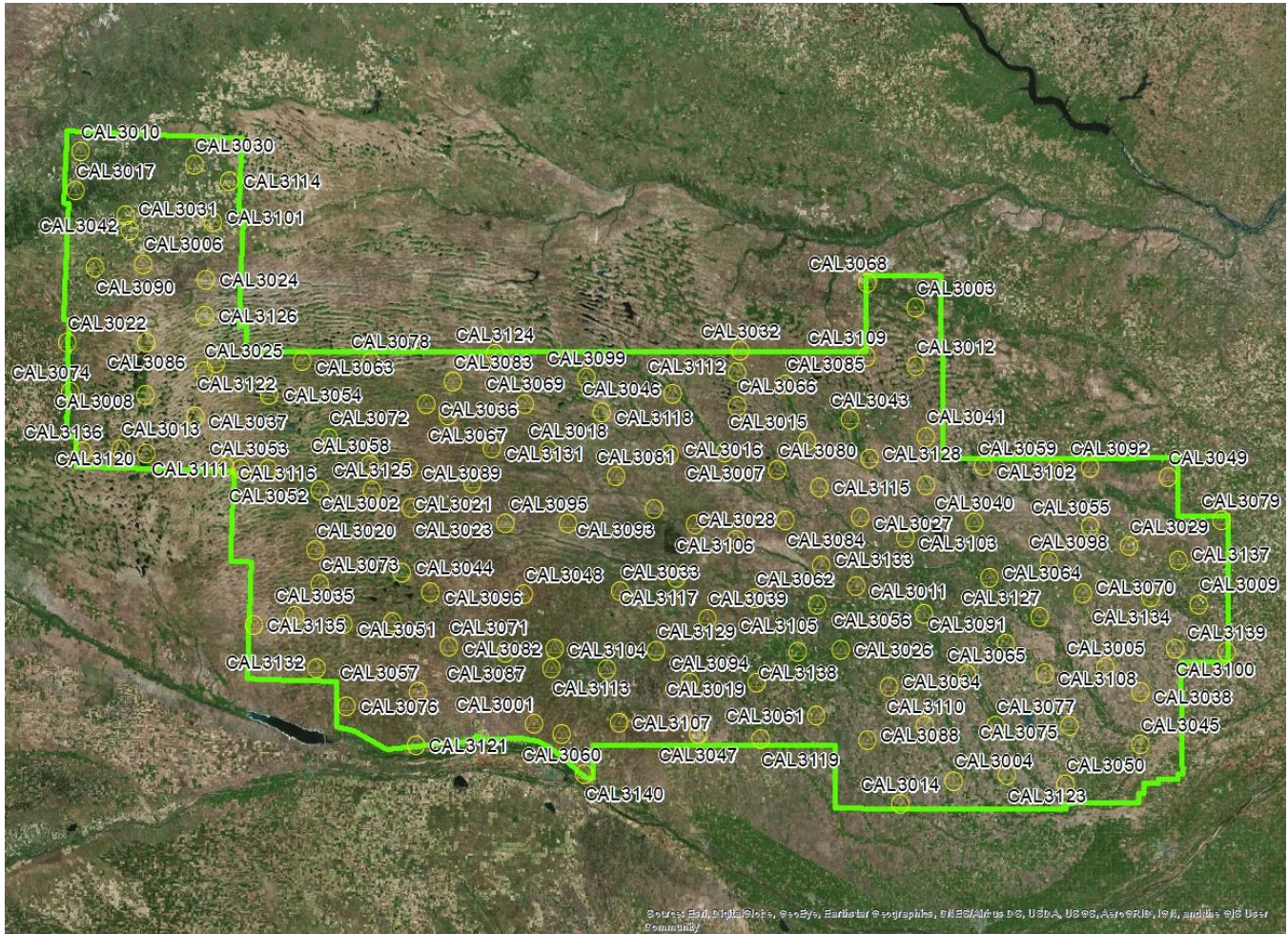
Check Point Id	Check Point X	Check Point Y	Coverage	Check Point Z	Z from lidar	Z Error
CAL3009	565393.833	4611560.652	Yes	589.004	589.252	0.248
CAL3029	542430.179	4630746.892	Yes	645.747	645.887	0.14
CAL3128	456585.428	4659533.083	Yes	740.29	740.405	0.115
CAL3022	191131.03	4697850.91	Yes	1165.958	1166.073	0.115
CAL3102	494182.987	4657185.991	Yes	701.076	701.153	0.077
CAL3021	325014.647	4651448.813	Yes	1005.874	1005.949	0.075
CAL3044	301704.488	4621794.469	Yes	1064.6	1064.673	0.073
CAL3074	192082.95	4681697.67	Yes	1199.541	1199.611	0.07
CAL3137	558511.365	4626112.774	Yes	646.698	646.768	0.07
CAL3134	549420.239	4613943.072	Yes	597.731	597.8	0.069
CAL3023	335864.888	4638049.386	Yes	973.011	973.078	0.067
CAL3059	518148.437	4656361.265	Yes	668.478	668.537	0.059
CAL3116	243199.02	4656738.01	Yes	1189.606	1189.664	0.058
CAL3076	283354.893	4577842.383	Yes	1039.872	1039.927	0.055
CAL3046	391345.276	4680820.205	Yes	850.304	850.358	0.054
CAL3016	390451.854	4660938.58	Yes	832.452	832.498	0.046
CAL3129	385921.689	4596169.899	Yes	857.819	857.865	0.046

CAL3015	435702.15	4665467.963	Yes	762.643	762.689	0.046
CAL3002	304915.056	4643344.905	Yes	1058.184	1058.229	0.045
CAL3005	534668.172	4590607.244	Yes	640.081	640.119	0.038
CAL3017	193740.23	4748205.05	Yes	1087.208	1087.245	0.037
CAL3041	475266.335	4666848.462	Yes	754.5	754.537	0.037
CAL3084	428571.531	4639389.935	Yes	777.651	777.688	0.037
CAL3052	274624.883	4649215.659	Yes	1128.652	1128.689	0.037
CAL3118	367910.835	4674962.044	Yes	890.022	890.057	0.035
CAL3133	440433.263	4624415.168	Yes	817.613	817.647	0.034
CAL3011	451958.003	4617621.633	Yes	790.336	790.368	0.032
CAL3047	399768.447	4568645.812	Yes	934.365	934.396	0.031
CAL3056	474337.835	4608327.961	Yes	699.817	699.847	0.03
CAL3131	331630.021	4663156.828	Yes	992.57	992.6	0.03
CAL3063	268722.766	4691855.737	Yes	1152.474	1152.503	0.029
CAL3127	512711.245	4607274.994	Yes	631.194	631.223	0.029
CAL3051	282524.269	4605022.961	Yes	1101.9	1101.927	0.027
CAL3101	239341.5	4737655.6	Yes	1102.167	1102.193	0.026
CAL3100	557533.523	4596666.305	Yes	623.237	623.263	0.026
CAL3040	490944.305	4638620.134	Yes	753.462	753.486	0.024
CAL3025	236083.06	4688602.57	Yes	1200.654	1200.677	0.023
CAL3117	392737.057	4620320.755	Yes	855.775	855.798	0.023
CAL3092	529378.195	4656374.535	Yes	645.78	645.801	0.021
CAL3105	439125.505	4611250.2	Yes	788.403	788.424	0.021
CAL3088	455637.071	4566681.28	Yes	781.433	781.452	0.019
CAL3018	350256.63	4662364.746	Yes	935.417	935.436	0.019
CAL3097	475129.19	4650611.348	Yes	717.408	717.426	0.018
CAL3136	196013.12	4661811.92	Yes	1191.111	1191.129	0.018
CAL3075	522798.151	4571328.925	Yes	627.006	627.024	0.018
CAL3093	385154.975	4642811.958	Yes	838.859	838.877	0.018
CAL3048	342231.774	4614757.732	Yes	989.911	989.929	0.018
CAL3085	428560.072	4684187.756	Yes	820.445	820.462	0.017
CAL3096	311325.585	4615600.144	Yes	1048.034	1048.05	0.016
CAL3140	361992.182	4555441.027	Yes	854.196	854.211	0.015
CAL3123	501914.854	4555059.146	Yes	688.81	688.825	0.015
CAL3103	468351.262	4633510.732	Yes	736.233	736.248	0.015
CAL3073	274452.856	4618232.72	Yes	1116.004	1116.018	0.014
CAL3068	455785.351	4717490.26	Yes	704.628	704.642	0.014
CAL3058	291155.181	4657437.013	Yes	1094.279	1094.29	0.011
CAL3057	307234.672	4582622.512	Yes	1005.757	1005.768	0.011
CAL3119	420396.354	4566791.853	Yes	820.107	820.117	0.01
CAL3121	306473.333	4564999.727	Yes	959.87	959.878	0.008
CAL3027	453480.067	4640254.987	Yes	743.01	743.018	0.008
CAL3026	446977.452	4596410.954	Yes	812.783	812.791	0.008
CAL3095	356660.856	4638288.478	Yes	933.725	933.731	0.006

CAL3010	195338.32	4760940.93	Yes	1045.199	1045.204	0.005
CAL3120	217322.51	4661358.44	Yes	1187.456	1187.461	0.005
CAL3089	304163.903	4656707.475	Yes	1055.57	1055.575	0.005
CAL3067	317027.125	4673985.732	Yes	1030.252	1030.256	0.004
CAL3014	466550.164	4545609.147	Yes	688.627	688.631	0.004
CAL3082	352159.954	4596765.558	Yes	962.427	962.43	0.003
CAL3007	408751.122	4661467.433	Yes	803.82	803.823	0.003
CAL3081	372499.589	4653827.544	Yes	889.355	889.356	0.001
CAL3135	252940.073	4604713.303	Yes	1145.477	1145.478	0.001
CAL3019	419211.592	4585514.335	Yes	863.753	863.753	0
CAL3066	412690.666	4677074.835	Yes	820.214	820.214	0
CAL3053	257557.917	4656328.471	Yes	1173.716	1173.715	-0.001
CAL3008	216945.1	4680559.65	Yes	1179.241	1179.239	-0.002
CAL3042	211921.37	4734811.19	Yes	1140.163	1140.161	-0.002
CAL3049	555084.569	4653440.277	Yes	611.964	611.962	-0.002
CAL3125	291976.869	4649243.412	Yes	1090.639	1090.636	-0.003
CAL3054	258066.224	4680795.307	Yes	1163.66	1163.657	-0.003
CAL3037	233448.08	4673582.17	Yes	1194.041	1194.037	-0.004
CAL3113	351428.171	4590444.447	Yes	966.562	966.557	-0.005
CAL3115	439909.503	4650090.908	Yes	760.777	760.771	-0.006
CAL3062	418331.785	4613492.215	Yes	839.006	838.998	-0.008
CAL3124	332705.84	4694062.121	Yes	958.662	958.653	-0.009
CAL3034	462946.55	4584282.988	Yes	742.04	742.03	-0.01
CAL3004	484285.377	4553166.742	Yes	670.072	670.061	-0.011
CAL3080	425969.342	4655849.908	Yes	782.912	782.901	-0.011
CAL3033	374130.008	4615833.947	Yes	901.682	901.671	-0.011
CAL3138	432573.519	4595735.89	Yes	803.149	803.136	-0.013
CAL3031	210474.43	4740173.67	Yes	1179.335	1179.322	-0.013
CAL3036	309741.259	4677700.212	Yes	1044.228	1044.214	-0.014
CAL3111	248575.61	4656165.88	Yes	1189.925	1189.911	-0.014
CAL3003	471851.404	4709353.58	Yes	695.073	695.058	-0.015
CAL3050	521286.886	4552050.007	Yes	629.333	629.316	-0.017
CAL3104	369729.897	4590059.613	Yes	930.726	930.708	-0.018
CAL3001	345334.64	4572074.217	Yes	912.308	912.289	-0.019
CAL3061	438929.436	4574663.255	Yes	786.414	786.395	-0.019
CAL3078	291373.14	4691659.277	Yes	1080.516	1080.494	-0.022
CAL3132	273705.499	4590507.589	Yes	1086.356	1086.334	-0.022
CAL3077	498083.207	4571350.029	Yes	642.758	642.736	-0.022
CAL3106	398667.162	4637841.552	Yes	816.356	816.333	-0.023
CAL3087	336098.764	4595298.036	Yes	986.765	986.741	-0.024
CAL3035	266469.829	4607836.666	Yes	1120.441	1120.417	-0.024
CAL3072	277519.51	4666549.819	Yes	1121.842	1121.817	-0.025
CAL3065	488720.642	4588158.738	Yes	664.737	664.711	-0.026
CAL3038	546113.387	4582656.036	Yes	598.158	598.131	-0.027

CAL3028	412505.216	4632904.406	Yes	800.846	800.818	-0.028
CAL3083	318669.603	4685027.127	Yes	1026.337	1026.309	-0.028
CAL3108	514409.791	4588732.877	Yes	634.394	634.366	-0.028
CAL3107	373535.231	4572300.553	Yes	910.535	910.503	-0.032
CAL3086	217155.83	4697959.96	Yes	1170.152	1170.12	-0.032
CAL3099	362857.333	4686375.363	Yes	885.356	885.323	-0.033
CAL3114	244847.79	4751196.27	Yes	1100.972	1100.937	-0.035
CAL3045	546062.233	4565142.696	Yes	549.442	549.406	-0.036
CAL3130	298682.012	4605672.127	Yes	1067.674	1067.637	-0.037
CAL3043	450109.285	4672394.626	Yes	763.119	763.082	-0.037
CAL3070	527032.127	4615279.819	Yes	657.396	657.359	-0.037
CAL3020	273061.768	4629428.585	Yes	1124.889	1124.851	-0.038
CAL3013	208670	4662794.23	Yes	1181.44	1181.401	-0.039
CAL3060	354666.345	4568648.032	Yes	912.744	912.705	-0.039
CAL3112	412597.97	4688269.782	Yes	827.024	826.982	-0.042
CAL3091	501530.501	4598588.09	Yes	653.919	653.876	-0.043
CAL3098	515941.876	4625687.917	Yes	653.381	653.336	-0.045
CAL3094	397005.893	4585608.92	Yes	847.717	847.672	-0.045
CAL3071	317382.249	4597495.803	Yes	1006.82	1006.774	-0.046
CAL3110	474857.713	4571273.355	Yes	715.82	715.772	-0.048
CAL3055	529487.956	4637047.384	Yes	651.789	651.741	-0.048
CAL3064	496280.367	4620200.679	Yes	652.406	652.352	-0.054
CAL3069	342318.108	4677727.024	Yes	961.705	961.648	-0.057
CAL3039	402872.364	4606785.471	Yes	854.073	854.016	-0.057
CAL3109	455486.078	4693131.597	Yes	757.521	757.46	-0.061
CAL3006	216327.65	4723864.3	Yes	1150.466	1150.401	-0.065
CAL3032	413736.333	4695164.063	Yes	830.028	829.96	-0.068
CAL3012	471901.365	4690047.411	Yes	726.086	725.995	-0.091
CAL3126	236684.1	4706841.38	Yes	1178.936	1178.843	-0.093
CAL3090	200152.44	4722819.57	Yes	1148.929	1148.833	-0.096
CAL3030	232998.2	4756687.81	Yes	1172.202	1172.096	-0.106
CAL3024	237012.86	4718811.46	Yes	1151.652	1151.543	-0.109
CAL3122	240453.39	4691002.94	Yes	1189.603	1189.49	-0.113

Lidar Control Point Layout



Lidar Filtering and Classification

The lidar filtering process encompasses a series of automated and manual steps to classify the boresighted point cloud data set. Each project represents unique characteristics in terms of cultural features (urbanized vs. rural areas), terrain type and vegetation coverage. These characteristics are thoroughly evaluated at the onset of the project to ensure that the appropriate automated filters are applied and that subsequent manual filtering yields correctly classified data. Data is most often classified by ground and “unclassified”, but specific project applications can include a wide variety of classifications including but not limited to buildings, vegetation, power lines, etc. MARS® software is used for the auto-filtering, manual filtering and QC of the classified data.

Merrick-Surdex JV used the American Society for Photogrammetry and Remote Sensing’s (ASPRS) LAS Specification Version 1.4 – R13, 15 July 2013, Point Data Record Format 6 for this project and classified the lidar point cloud in accordance with the following classification classes and bitflags. Classes highlighted in **GREEN** represent project specific requirements.

- **Class 1 = Unclassified**
- **Class 2 = Bare-earth Ground**
- Class 3 = Low Vegetation
- Class 4 = Medium Vegetation

- Class 5 = High Vegetation
- Class 6 = Buildings
- Class 7 = Low point (noise)
- Class 8 = Model Key Points
- Class 9 = Water
- Class 10 = Ignored ground (near a breakline)
- Class 17 = Bridge decks
- Class 18 = High noise
- Bitflags
 - Overlap: Any part of a swath that also is covered by any part of any other swath.
 - Withheld: Within the LAS file specification, a single bit flag indicating that the associated lidar point is geometrically anomalous or unreliable and should be ignored for all normal processes.

Merrick-Surdex JV has developed several customized automated filters that are applied to the lidar data set based on project specifications, terrain, and vegetation characteristics. A filtering macro, which may contain one or more filtering algorithms, is executed to derive LAS files separated into the different classification groups as defined in the ASPRS classification table. The macros are tested in several portions of the project area to verify the appropriateness of the filters. Often, there is a combination of several filter macros that optimize the filtering based on the unique characteristics of the project. Automatic filtering generally yields a ground surface that is 85-90% valid, so additional editing (hand-filtering) is required to produce a more robust ground surface.

Lidar data is next taken into a graphic environment using MARS® to manually re-classify (or hand-filter) “noise” and other features that may remain in the ground classification after auto filter. A cross-section of the post auto-filtered surface is viewed to assist in the reclassification of non-ground data artifacts. The following is an example of re-classification of the non-ground points (elevated features) that need to be excluded from the true ground surface. Certain features such as berms, hilltops, cliffs and other features may have been aggressively auto-filtered and points will need to be re-classified into the ground classification. Data in the profile view displays non-ground (Unclassified, class 1) in grey and ground in brown/tan (Class 2). In figure 1, a small building was not auto-filtered and needs to be manually re-classified. Note that figure 2 has the building points reclassified to unclassified from the true ground surface.

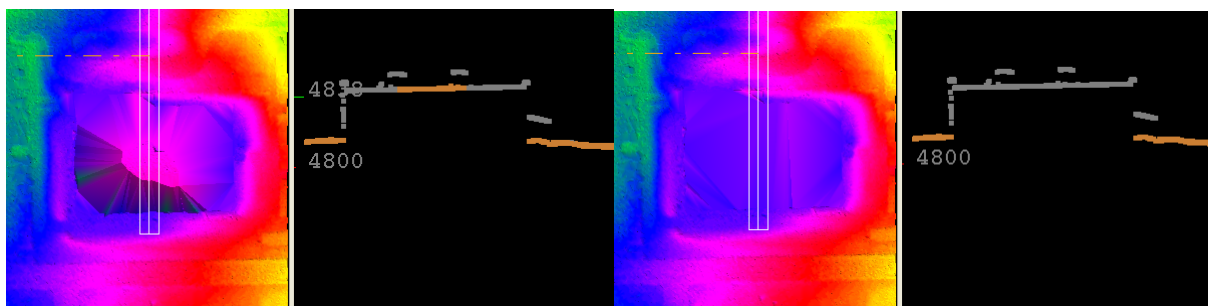


Figure 1

Figure 2

A combination of automated and semi-automated routines to classify buildings and vegetation. We expect that the classified buildings will meet a filtering criterion in the range of 90-95%.

At this point, individual lidar points from the original point cloud have now been parsed into separate classifications.

After the hand-filtering has been completed and quality checked, a Check Point Report is generated to validate that the accuracy of the ground surface is within the defined accuracy specifications. Each surveyed ground

check point is compared to the lidar surface by interpolating an elevation from a Triangulated Irregular Network (TIN) of the surface. The MARS® derived report provides an in-depth statistical report, including an RMSE of the vertical errors; a primary component in most accuracy standards and a statistically valid assessment of the overall accuracy of the ground surface.

The below lidar check point report provides statistics for 319 NVA and 226 VVA ground survey points used to validate the final filtered lidar surface. Three of the planned 322 NVA points were not included in the final vertical accuracy assessment due to access issues in the area resulting in the points being outside the Defined Project Area (DPA) boundary - point numbers 1013, 1188 and 1239.

All ground control surveys performed by CompassData, Inc.

Project Data Unit: Meter
 Vertical Accuracy Class tested: 10.0-cm
 Elevation Calculation Method: Interpolated from TIN
 LIDAR Classifications Included: 2/0 Ground (All)/0W

Check Points in Report: 545
 Check Points with LiDAR Coverage: 545
 Check Points (NVA): 319
 Check Points (VVA): 226
 Average Vertical Error Reported: 0.011 Meter
 Maximum (highest) Vertical Error Reported: 0.325 Meter
 Median Vertical Error Reported: 0.006 Meter
 Minimum (lowest) Vertical Error Reported: -0.111 Meter
 Standard deviation of Vertical Error: 0.055 Meter
 Skewness of Vertical Error: 1.288
 Kurtosis of Vertical Error: 4.318
 Non-vegetated Vertical Accuracy (NVA) RMSE(z): 5.620cm PASS
 Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 11.015cm PASS
 Vegetated Vertical Accuracy (VVA) at the 95th Percentile +/-: 16.750cm PASS
 FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 11.015cm
 Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 5.601cm PASS
 Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 10.978cm PASS
 Vegetated Vertical Accuracy (VVA) at the 95th Percentile +/- (DEM): 16.780cm PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10.0-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 5.620cm, equating to +/- 11.015cm at the 95% confidence level. Actual VVA accuracy was found to be +/- 16.750cm at the 95th percentile.

Check Point Id	Check Point X	Check Point Y	Coverage	Check Point Z	Z from Lidar	Z Error	NVA or VVA
NVA1050	300473.186	4580046.729	Yes	1031.56	1031.516	-0.044	NVA
NVA1143	306339.67	4569053.587	Yes	973.595	973.624	0.029	NVA
NVA1286	297210.152	4564491.495	Yes	969.376	969.379	0.003	NVA
NVA1288	283379.711	4585461.065	Yes	1070.927	1070.854	-0.073	NVA
NVA1290	280941.375	4571483.557	Yes	1000.257	1000.27	0.013	NVA
NVA1035	327181.671	4578273.082	Yes	944.921	944.954	0.033	NVA
NVA1040	359365.634	4559781.52	Yes	884.014	884.049	0.035	NVA
NVA1082	362913.749	4572573.914	Yes	910.911	910.945	0.034	NVA
NVA1110	375546.196	4567326.563	Yes	895.923	895.947	0.024	NVA
NVA1113	372576.967	4578754.161	Yes	919.072	919.03	-0.042	NVA
NVA1118	342859.093	4583624.575	Yes	952.822	952.804	-0.018	NVA
NVA1146	345237.936	4572950.039	Yes	915.088	915.109	0.021	NVA
NVA1149	395019.149	4571955.352	Yes	897.198	897.258	0.06	NVA

NVA1189	383785.365	4578678.201	Yes	890.405	890.413	0.008	NVA
NVA1193	322544.687	4567391.936	Yes	921.123	921.141	0.018	NVA
NVA1196	329063.652	4570175.443	Yes	936.047	936.062	0.015	NVA
NVA1207	356684.456	4583858.577	Yes	950.649	950.692	0.043	NVA
NVA1229	318078.73	4579422.082	Yes	971.195	971.186	-0.009	NVA
NVA1255	360390.974	4568430.517	Yes	907.873	907.92	0.047	NVA
NVA1006	283360.613	4608066.603	Yes	1097.024	1096.995	-0.029	NVA
NVA1038	298198.24	4611369.558	Yes	1073.067	1073.026	-0.041	NVA
NVA1043	274142.507	4623832.467	Yes	1122.516	1122.469	-0.047	NVA
NVA1062	265338.651	4597647.838	Yes	1109.545	1109.472	-0.073	NVA
NVA1064	258316.52	4617111.735	Yes	1145.141	1145.119	-0.022	NVA
NVA1122	283617.76	4614591.711	Yes	1101.915	1101.863	-0.052	NVA
NVA1180	274803.427	4605370.517	Yes	1111.816	1111.776	-0.04	NVA
NVA1186	273491.553	4601379.434	Yes	1107.039	1106.98	-0.059	NVA
NVA1222	252097.508	4594294.857	Yes	1114.717	1114.648	-0.069	NVA
NVA1237a	297614.511	4593100.928	Yes	1047.58	1047.588	0.008	NVA
NVA1254	275590.319	4615002.548	Yes	1123.706	1123.652	-0.054	NVA
NVA1256	274745.211	4590489.461	Yes	1078.746	1078.705	-0.041	NVA
NVA1307	272433.706	4587769.554	Yes	1077.788	1077.722	-0.066	NVA
NVA1318	291928.447	4607663.384	Yes	1078.4	1078.363	-0.037	NVA
NVA1014	270852.964	4653696.93	Yes	1137.652	1137.691	0.039	NVA
NVA1029	274764.312	4647461.208	Yes	1125.85	1125.87	0.02	NVA
NVA1033	272271.248	4659505.03	Yes	1134.271	1134.312	0.041	NVA
NVA1076	292982.669	4642849.325	Yes	1091.159	1091.145	-0.014	NVA
NVA1078	298119.891	4661659.622	Yes	1073.492	1073.46	-0.032	NVA
NVA1092	287128.949	4656469.339	Yes	1104.388	1104.39	0.002	NVA
NVA1115	256710.611	4641279.268	Yes	1157.762	1157.834	0.072	NVA
NVA1121	281700.06	4631182.141	Yes	1108.481	1108.472	-0.009	NVA
NVA1205	293666.164	4624747.543	Yes	1094.207	1094.155	-0.052	NVA
NVA1206	257575.427	4656249.881	Yes	1178.506	1178.526	0.02	NVA
NVA1283	270838.178	4632975.481	Yes	1128.194	1128.212	0.018	NVA
NVA1301	258416.049	4663802.902	Yes	1166.012	1166.047	0.035	NVA
NVA1310	245155.973	4632225.422	Yes	1159.433	1159.609	0.176	NVA
NVA1322	246137.914	4644787.584	Yes	1173.712	1173.865	0.153	NVA
NVA1077	346270.262	4655184.944	Yes	940.078	940.097	0.019	NVA
NVA1104	330945.624	4656321.934	Yes	977.618	977.663	0.045	NVA
NVA1130	316815.623	4651047.468	Yes	1039.012	1039.091	0.079	NVA
NVA1137	345522.618	4648170.63	Yes	960.155	960.155	0	NVA
NVA1166	327275.32	4623617.198	Yes	1027.592	1027.564	-0.028	NVA
NVA1190	330533.55	4651581.175	Yes	998.732	998.8	0.068	NVA
NVA1201	329905.43	4644215.428	Yes	996.103	996.138	0.035	NVA
NVA1208	335741.849	4623319.193	Yes	1014.492	1014.419	-0.073	NVA

NVA1211	309826.308	4656494.866	Yes	1039.761	1039.796	0.035	NVA
NVA1217	314582.98	4633357.587	Yes	1036.684	1036.704	0.02	NVA
NVA1240	319421.715	4643535.189	Yes	1017.14	1017.222	0.082	NVA
NVA1269	335735.754	4638208.881	Yes	974.188	974.202	0.014	NVA
NVA1294	305344.232	4643411.1	Yes	1056.04	1056.102	0.062	NVA
NVA1304	330960.493	4632964.743	Yes	1007.778	1007.777	-0.001	NVA
NVA1005	375687.563	4608047.117	Yes	913.191	913.176	-0.015	NVA
NVA1055	392802.295	4621669.515	Yes	852.516	852.592	0.076	NVA
NVA1126	367136.119	4622121.483	Yes	921.405	921.443	0.038	NVA
NVA1154	390661.644	4594526.766	Yes	860.399	860.4	0.001	NVA
NVA1173	374622.76	4593196.064	Yes	881.881	881.893	0.012	NVA
NVA1200	388218.134	4586479.431	Yes	933.866	933.855	-0.011	NVA
NVA1212	361729.223	4592603.729	Yes	907.862	907.894	0.032	NVA
NVA1225	369736.432	4589909.819	Yes	934.036	934.016	-0.02	NVA
NVA1292	389294.493	4611961.644	Yes	880.209	880.192	-0.017	NVA
NVA1317	370950.055	4612977.188	Yes	909.177	909.21	0.033	NVA
NVA1009	311829.571	4614898.29	Yes	1045.251	1045.21	-0.041	NVA
NVA1067	347438.516	4614535.078	Yes	963.212	963.165	-0.047	NVA
NVA1093	336738.959	4618088.158	Yes	1023.96	1023.936	-0.024	NVA
NVA1094	336719.701	4602007.603	Yes	994.726	994.706	-0.02	NVA
NVA1159	344368.487	4589257.382	Yes	958.712	958.635	-0.077	NVA
NVA1165	316969.527	4602570.91	Yes	1021.616	1021.567	-0.049	NVA
NVA1192	336453.279	4608421.889	Yes	1013.135	1013.098	-0.037	NVA
NVA1194	308689.031	4592530.061	Yes	1023.887	1023.881	-0.006	NVA
NVA1223	357349.283	4610310.286	Yes	938.836	938.845	0.009	NVA
NVA1237b	326703.049	4602071.846	Yes	1002.388	1002.36	-0.028	NVA
NVA1252	348173.299	4597698.901	Yes	973.58	973.473	-0.107	NVA
NVA1257	340994.621	4600067.492	Yes	996.982	996.978	-0.004	NVA
NVA1282	306064.074	4589044.478	Yes	1025.753	1025.749	-0.004	NVA
NVA1287	350477.879	4592823.382	Yes	972.815	972.816	0.001	NVA
NVA1314	307372.589	4602985.9	Yes	1038.745	1038.732	-0.013	NVA
NVA1004	456528.052	4672388.702	Yes	772.89	772.96	0.07	NVA
NVA1007	473348.115	4715850.003	Yes	679.097	679.085	-0.012	NVA
NVA1041	455650.469	4698162.651	Yes	750.696	750.712	0.016	NVA
NVA1071	479073.866	4683638.951	Yes	724.798	724.77	-0.028	NVA
NVA1088	460564.563	4683610.862	Yes	758.262	758.251	-0.011	NVA
NVA1117	456536.233	4666749.325	Yes	756.941	757.042	0.101	NVA
NVA1133	476335.231	4690082.931	Yes	718.257	718.247	-0.01	NVA
NVA1136	471795.688	4698215.635	Yes	715.194	715.13	-0.064	NVA
NVA1181	478375.715	4659547.472	Yes	739.969	739.953	-0.016	NVA
NVA1246	458954.091	4707793.281	Yes	721.766	721.768	0.002	NVA
NVA1274	475764.914	4668497.686	Yes	753.713	753.673	-0.04	NVA

NVA1016	428647.89	4642553.802	Yes	762.979	763.008	0.029	NVA
NVA1028	412490.997	4623542.887	Yes	832.946	833.005	0.059	NVA
NVA1090	409684.659	4657448.028	Yes	796.652	796.674	0.022	NVA
NVA1099	395886.95	4657364.185	Yes	823.875	823.858	-0.017	NVA
NVA1106	428862.286	4653180.925	Yes	776.476	776.533	0.057	NVA
NVA1120	441461.841	4639710.808	Yes	748.91	748.956	0.046	NVA
NVA1185	441511.282	4646124.285	Yes	749.119	749.132	0.013	NVA
NVA1198	437116.31	4622247.123	Yes	762.822	762.831	0.009	NVA
NVA1226	439917.663	4648100.611	Yes	757.148	757.178	0.03	NVA
NVA1253	421119.177	4629316.333	Yes	783.756	783.759	0.003	NVA
NVA1261	414637.663	4644290.092	Yes	800.061	800.036	-0.025	NVA
NVA1277	401483.217	4652602.272	Yes	817.012	816.993	-0.019	NVA
NVA1302	408395.764	4631942.195	Yes	799.852	799.786	-0.066	NVA
NVA1309	403859.084	4641908.274	Yes	842.441	842.442	0.001	NVA
NVA1045	568742.074	4593289.567	Yes	556.4	556.725	0.325	NVA
NVA1123	560577.628	4611636.249	Yes	585.494	585.493	-0.001	NVA
NVA1147	571101.347	4600788.535	Yes	540.232	540.378	0.146	NVA
NVA1152	569618.227	4635123.859	Yes	585.19	585.424	0.234	NVA
NVA1157	565453.046	4622962.332	Yes	638.461	638.677	0.216	NVA
NVA1174	559954.924	4637412.058	Yes	587.406	587.422	0.016	NVA
NVA1020	405897.864	4664693.609	Yes	813.085	813.002	-0.083	NVA
NVA1047	442372.585	4687594.149	Yes	784.963	784.918	-0.045	NVA
NVA1056	428225.906	4687398.065	Yes	824.94	824.959	0.019	NVA
NVA1132	412567.859	4684959.313	Yes	825.497	825.477	-0.02	NVA
NVA1195	435362.874	4674861.046	Yes	789.147	789.178	0.031	NVA
NVA1209	427767.996	4693664.796	Yes	809.022	809.039	0.017	NVA
NVA1241	428761.636	4664372.478	Yes	792.866	792.829	-0.037	NVA
NVA1249	428068.583	4676542.756	Yes	796.74	796.768	0.028	NVA
NVA1299	445154.896	4659971.82	Yes	744.307	744.315	0.008	NVA
NVA1311	442139.405	4670432.963	Yes	772.752	772.767	0.015	NVA
NVA1015	373908.55	4687531.48	Yes	877.142	877.123	-0.019	NVA
NVA1023	341562.535	4684210.052	Yes	951.857	951.865	0.008	NVA
NVA1024	297076.717	4692848.508	Yes	1058.161	1058.171	0.01	NVA
NVA1025	365999.982	4683424.99	Yes	878.967	878.994	0.027	NVA
NVA1027	264452.807	4693268.234	Yes	1181.49	1181.514	0.024	NVA
NVA1037	317115.262	4676208.901	Yes	1029.491	1029.513	0.022	NVA
NVA1039	372819.522	4663826.929	Yes	922.542	922.528	-0.014	NVA
NVA1065	259901.534	4668757.912	Yes	1162.336	1162.277	-0.059	NVA
NVA1068	368060.713	4673638.559	Yes	891.366	891.41	0.044	NVA
NVA1074	377422.515	4674413.378	Yes	870.62	870.661	0.041	NVA
NVA1095	253925.428	4692075.981	Yes	1168.042	1168.088	0.046	NVA
NVA1101	387689.014	4682636.036	Yes	858.118	858.167	0.049	NVA

NVA1116	275949.45	4678436.45	Yes	1135.598	1135.602	0.004	NVA
NVA1127	308020.701	4678510.817	Yes	1044.615	1044.585	-0.03	NVA
NVA1135	331640.425	4673092.343	Yes	997.077	997.077	0	NVA
NVA1141	386586.645	4668391.749	Yes	838.341	838.416	0.075	NVA
NVA1151	333021.656	4688321.418	Yes	972.568	972.61	0.042	NVA
NVA1169	317241.008	4671493.166	Yes	1031.436	1031.44	0.004	NVA
NVA1177	373325.498	4683352.982	Yes	863.055	863.073	0.018	NVA
NVA1191	257962.775	4678982.09	Yes	1158.743	1158.691	-0.052	NVA
NVA1203	291703.336	4684754.102	Yes	1092.56	1092.489	-0.071	NVA
NVA1215	378244.063	4665357.143	Yes	872.474	872.47	-0.004	NVA
NVA1216	290655.793	4667229.602	Yes	1096.038	1095.989	-0.049	NVA
NVA1218	315962.618	4691890.536	Yes	1016.506	1016.435	-0.071	NVA
NVA1235	274965.58	4666133.66	Yes	1122.568	1122.656	0.088	NVA
NVA1236	398393.513	4675008.715	Yes	833.913	834.006	0.093	NVA
NVA1243	350643.728	4674057.699	Yes	939.867	939.911	0.044	NVA
NVA1248	331913.739	4668268.872	Yes	1002.287	1002.26	-0.027	NVA
NVA1250	275375.047	4688839.406	Yes	1131.827	1131.873	0.046	NVA
NVA1258	291826.343	4675945.889	Yes	1114.089	1114.038	-0.051	NVA
NVA1276	318647.363	4685045.061	Yes	1026.02	1025.985	-0.035	NVA
NVA1316	373120.044	4694345.816	Yes	885.76	885.765	0.005	NVA
NVA1008	414904.742	4600652.011	Yes	843.872	843.897	0.025	NVA
NVA1012	446650.409	4582309.908	Yes	765.076	765.084	0.008	NVA
NVA1017	465256.212	4569762.208	Yes	729.823	729.808	-0.015	NVA
NVA1019	454943.94	4591563.332	Yes	759.442	759.457	0.015	NVA
NVA1031	436101.676	4570778.946	Yes	796.078	796.11	0.032	NVA
NVA1048	454632.497	4563274.332	Yes	755.627	755.633	0.006	NVA
NVA1052	468393.932	4580936.336	Yes	711.307	711.287	-0.02	NVA
NVA1057	396632.165	4577806.14	Yes	914.956	914.958	0.002	NVA
NVA1061	400037.482	4607022.186	Yes	856.164	856.204	0.04	NVA
NVA1073	404219.349	4621412.421	Yes	854.664	854.705	0.041	NVA
NVA1084	476451.471	4569598.317	Yes	710.595	710.533	-0.062	NVA
NVA1085	458341.62	4617978.16	Yes	773.656	773.638	-0.018	NVA
NVA1087a	471094.59	4558479.761	Yes	718.198	718.245	0.047	NVA
NVA1091	419252.779	4617221.853	Yes	832.749	832.729	-0.02	NVA
NVA1105	457753.471	4555243	Yes	745.535	745.526	-0.009	NVA
NVA1119	454027.984	4605083.513	Yes	761.27	761.277	0.007	NVA
NVA1128	454878.704	4572936.466	Yes	772.109	772.095	-0.014	NVA
NVA1131	451426.419	4549619.979	Yes	740.58	740.557	-0.023	NVA
NVA1139	443101.767	4607655.055	Yes	780.595	780.558	-0.037	NVA
NVA1145	411372.209	4592648.904	Yes	924.038	924.028	-0.01	NVA
NVA1150	424562.074	4595822.353	Yes	845.848	845.83	-0.018	NVA
NVA1172	444112.777	4598815.166	Yes	795.66	795.638	-0.022	NVA

NVA1175	430840.133	4587653.743	Yes	846.166	846.173	0.007	NVA
NVA1178	428763.303	4611807.608	Yes	814.919	814.94	0.021	NVA
NVA1179	467942.084	4610171.86	Yes	708.932	708.845	-0.087	NVA
NVA1187	405075.21	4584936.775	Yes	815.211	815.175	-0.036	NVA
NVA1231	480737.031	4605041.017	Yes	719.42	719.475	0.055	NVA
NVA1233	459987.597	4584070.761	Yes	765.252	765.271	0.019	NVA
NVA1238	400279.451	4595959.119	Yes	924.899	924.94	0.041	NVA
NVA1245	409305.085	4568583.417	Yes	910.206	910.203	-0.003	NVA
NVA1280	425565.187	4566890.766	Yes	797.1	797.115	0.015	NVA
NVA1295	470923.619	4588975.279	Yes	737.675	737.674	-0.001	NVA
NVA1298	417350.574	4582930.988	Yes	832.052	832.055	0.003	NVA
NVA1300	432704.965	4603718.583	Yes	787.83	787.877	0.047	NVA
NVA1107	510278.026	4625783.222	Yes	675.138	675.138	0	NVA
NVA1124	509599.226	4647375.39	Yes	667.162	667.219	0.057	NVA
NVA1142	500789.863	4627400.612	Yes	717.948	717.927	-0.021	NVA
NVA1148	512387.773	4642874.194	Yes	659.342	659.345	0.003	NVA
NVA1156	492775.359	4639454.355	Yes	718.769	718.809	0.04	NVA
NVA1176	494187.204	4656292.937	Yes	702.427	702.487	0.06	NVA
NVA1221	482103.38	4633548.344	Yes	703.962	704.022	0.06	NVA
NVA1224	492676.416	4646249.361	Yes	719.785	719.813	0.028	NVA
NVA1264	518150.677	4657920.975	Yes	665.679	665.721	0.042	NVA
NVA1272	491220.559	4629818.767	Yes	717.098	717.093	-0.005	NVA
NVA1315	506214.081	4634903.45	Yes	671.929	671.885	-0.044	NVA
NVA1034	547942.675	4595508.832	Yes	592.15	592.246	0.096	NVA
NVA1042	548061.665	4616376.58	Yes	578.511	578.701	0.19	NVA
NVA1051	538252.019	4607480.281	Yes	653.786	653.784	-0.002	NVA
NVA1069	538358.971	4599768.263	Yes	612.542	612.575	0.033	NVA
NVA1083	557101.779	4598752.466	Yes	610.507	610.572	0.065	NVA
NVA1097	525576.386	4596960.154	Yes	622.588	622.654	0.066	NVA
NVA1155	533645.6	4587366.115	Yes	616.803	616.828	0.025	NVA
NVA1184	527892.765	4619588.425	Yes	635.422	635.427	0.005	NVA
NVA1228	544706.2	4607476.994	Yes	628.879	628.968	0.089	NVA
NVA1260	531873.32	4608825.934	Yes	656.759	656.791	0.032	NVA
NVA1278	542769.099	4587438.982	Yes	605.281	605.337	0.056	NVA
NVA1319	557654.298	4582708.089	Yes	615.425	615.447	0.022	NVA
NVA1032	547710.408	4573824.374	Yes	595.233	595.2	-0.033	NVA
NVA1053	527523.189	4560052.172	Yes	617.839	617.82	-0.019	NVA
NVA1144	537165.741	4560091.816	Yes	599.012	598.989	-0.023	NVA
NVA1161	545795.972	4563581.957	Yes	547.995	547.965	-0.03	NVA
NVA1182	526021.959	4574569.791	Yes	634.357	634.442	0.085	NVA
NVA1199	544920.164	4550578.317	Yes	574.082	574.082	0	NVA
NVA1230	533552.998	4548479.293	Yes	605.509	605.429	-0.08	NVA

NVA1251	557686.363	4563452.226	Yes	556.313	556.275	-0.038	NVA
NVA1262	537218.192	4574054.03	Yes	563.966	563.959	-0.007	NVA
NVA1018	467794.516	4624342.012	Yes	694.75	694.746	-0.004	NVA
NVA1044	473381.034	4640044.13	Yes	689.088	689.062	-0.026	NVA
NVA1066	464006.657	4657511.337	Yes	736.755	736.74	-0.015	NVA
NVA1072	476880.016	4623534.181	Yes	681.498	681.483	-0.015	NVA
NVA1171	449751.797	4623230.815	Yes	796.359	796.381	0.022	NVA
NVA1213	467972.035	4643373.65	Yes	700.757	700.75	-0.007	NVA
NVA1220	457447.065	4658234.73	Yes	735.689	735.741	0.052	NVA
NVA1232	453390.212	4631761.14	Yes	733.17	733.173	0.003	NVA
NVA1313	464743.793	4648260.471	Yes	708.759	708.791	0.032	NVA
NVA1026	486065.173	4568892.884	Yes	689.087	689.143	0.056	NVA
NVA1030	497253.607	4574529.959	Yes	640.582	640.639	0.057	NVA
NVA1046	506711.313	4548793.302	Yes	639.471	639.497	0.026	NVA
NVA1058	485557.508	4577732.514	Yes	714.913	714.845	-0.068	NVA
NVA1070	514722.766	4558939.332	Yes	658.861	658.885	0.024	NVA
NVA1109	511727.892	4579384.732	Yes	649.73	649.756	0.026	NVA
NVA1111	493991.351	4556074.32	Yes	676.616	676.622	0.006	NVA
NVA1163	508233.421	4561748.75	Yes	643.587	643.62	0.033	NVA
NVA1259	514780.231	4568132.264	Yes	653.834	653.856	0.022	NVA
NVA1271	485902.756	4556809.906	Yes	663.284	663.301	0.017	NVA
NVA1291	493813.414	4545550.128	Yes	644.747	644.699	-0.048	NVA
NVA1003	372539.2	4629235.037	Yes	892.144	892.125	-0.019	NVA
NVA1036	358681.43	4638203.245	Yes	933.402	933.419	0.017	NVA
NVA1054	348646.257	4631554.494	Yes	956.988	956.979	-0.009	NVA
NVA1075	354623.883	4652521.917	Yes	921.995	922.005	0.01	NVA
NVA1087b	370801.794	4634953.899	Yes	904.364	904.355	-0.009	NVA
NVA1098	379930.729	4646603.779	Yes	849	849.05	0.05	NVA
NVA1167	393773.988	4649867.159	Yes	854.478	854.547	0.069	NVA
NVA1197	362880.374	4624124.015	Yes	927.858	927.861	0.003	NVA
NVA1210	388961.242	4641690.115	Yes	832.021	832.029	0.008	NVA
NVA1263	375339.671	4657366.871	Yes	893.872	893.851	-0.021	NVA
NVA2001	364113.953	4648369.246	Yes	879.529	879.532	0.003	NVA
NVA1021	509535.237	4609049.598	Yes	637.151	637.17	0.019	NVA
NVA1125	493384.115	4584739.306	Yes	669.102	669.072	-0.03	NVA
NVA1138	518382.717	4590582.967	Yes	614.259	614.248	-0.011	NVA
NVA1202	483993.775	4618678.249	Yes	759.642	759.653	0.011	NVA
NVA1227	501836.586	4606626.619	Yes	646.551	646.504	-0.047	NVA
NVA1242	495397.886	4618416.477	Yes	644.942	644.912	-0.03	NVA
NVA1275	483908.581	4585782.096	Yes	678.043	678.009	-0.034	NVA
NVA1279	503151.021	4593784.631	Yes	644.511	644.437	-0.074	NVA
NVA1284	515823.177	4619454.192	Yes	667.689	667.684	-0.005	NVA

NVA1285	487127.248	4595376.688	Yes	702.934	702.882	-0.052	NVA
NVA1308	511136.356	4600231.779	Yes	638.488	638.448	-0.04	NVA
NVA1059	539052.404	4622685.323	Yes	608.336	608.369	0.033	NVA
NVA1063	542250.594	4654901.755	Yes	616.579	616.676	0.097	NVA
NVA1102	552129.965	4624457.002	Yes	647.001	647.011	0.01	NVA
NVA1108	526168.219	4648280.306	Yes	657.228	657.226	-0.002	NVA
NVA1168	555067.533	4654684.624	Yes	610.532	610.534	0.002	NVA
NVA1170	537482.465	4637261.185	Yes	659.331	659.311	-0.02	NVA
NVA1214	545499.646	4630774.827	Yes	662.733	662.85	0.117	NVA
NVA1270	522811.038	4630344.156	Yes	628.044	627.986	-0.058	NVA
NVA1293	547577.034	4643688.957	Yes	611.453	611.545	0.092	NVA
NVA1002	218090.2835	4752309.793	Yes	1099.759	1099.791	0.032	NVA
NVA1010	236132.228	4686386.59	Yes	1223.863	1223.905	0.042	NVA
NVA1011	206567.1992	4722585.039	Yes	1151.808	1151.697	-0.111	NVA
NVA1022	218324.3666	4680163.866	Yes	1192.311	1192.346	0.035	NVA
NVA1049	200303.0077	4707520.436	Yes	1144.678	1144.737	0.059	NVA
NVA1060	237166.1737	4759742.755	Yes	1118.094	1118.107	0.013	NVA
NVA1079	217216.0146	4678248.182	Yes	1182.116	1182.299	0.183	NVA
NVA1080	216273.8116	4723865.199	Yes	1149.932	1149.868	-0.064	NVA
NVA1081	238572.0552	4754898.657	Yes	1141.75	1141.772	0.022	NVA
NVA1086	210288.9461	4757214.916	Yes	1075.639	1075.647	0.008	NVA
NVA1096	234264.5896	4731663.566	Yes	1100.692	1100.626	-0.066	NVA
NVA1100	211922.0551	4734865.268	Yes	1140.209	1140.233	0.024	NVA
NVA1103	241826.1947	4710703.724	Yes	1160.545	1160.485	-0.06	NVA
NVA1112	210860.3344	4662878.238	Yes	1184.761	1184.838	0.077	NVA
NVA1114	201473.3776	4761001.494	Yes	1091.273	1091.335	0.062	NVA
NVA1129	237123.5328	4723243.366	Yes	1116.798	1116.757	-0.041	NVA
NVA1134	192622.7062	4718233.148	Yes	1194.763	1194.72	-0.043	NVA
NVA1140	218375.4736	4715759.24	Yes	1145.579	1145.471	-0.108	NVA
NVA1153	236341.8392	4696089.114	Yes	1184.57	1184.674	0.104	NVA
NVA1158	202451.1633	4697286.466	Yes	1188.577	1188.654	0.077	NVA
NVA1160	196525.7668	4732578.374	Yes	1171.247	1171.302	0.055	NVA
NVA1162	217300.5376	4691083.119	Yes	1176.619	1176.62	0.001	NVA
NVA1164	229271.4699	4726742.855	Yes	1112.913	1112.865	-0.048	NVA
NVA1183	230111.909	4746881.054	Yes	1109.247	1109.335	0.088	NVA
NVA1204	222155.1573	4662052.49	Yes	1187.913	1188	0.087	NVA
NVA1219	239358.1432	4737621.196	Yes	1104.533	1104.635	0.102	NVA
NVA1234	246356.7846	4748921.433	Yes	1094.648	1094.697	0.049	NVA
NVA1244	247232.4361	4683341.696	Yes	1187.637	1187.706	0.069	NVA
NVA1247	200091.4793	4663666.513	Yes	1187.076	1187.211	0.135	NVA
NVA1265	216684.4504	4700874.18	Yes	1164.996	1164.916	-0.08	NVA
NVA1266	208943.4982	4695137.587	Yes	1177.118	1177.161	0.043	NVA

NVA1267	215442.028	4743781.791	Yes	1167.847	1167.824	-0.023	NVA
NVA1268	226931.2042	4759356.246	Yes	1188.437	1188.418	-0.019	NVA
NVA1281	193874.7365	4681891.43	Yes	1194.015	1194.13	0.115	NVA
NVA1289	243956.9831	4731152.9	Yes	1086.646	1086.654	0.008	NVA
NVA1296	241204.2721	4685681.901	Yes	1198.383	1198.379	-0.004	NVA
NVA1297	236740.4853	4710246.512	Yes	1168.844	1168.809	-0.035	NVA
NVA1303	195317.3751	4745362.844	Yes	1129.974	1130.012	0.038	NVA
NVA1305	193819.5486	4726112.427	Yes	1174.117	1174.088	-0.029	NVA
NVA1306	233661.6779	4659506.121	Yes	1194.488	1194.627	0.139	NVA
NVA1312	225000.6449	4741356.256	Yes	1149.039	1149.041	0.002	NVA
NVA1320	242272.3231	4657277.402	Yes	1191.694	1191.843	0.149	NVA
NVA1321	218057.286	4666890.63	Yes	1188.338	1188.461	0.123	NVA
VVA2105	565497.927	4622997.807	Yes	636.98	637.287	0.307	VVA
VVA2102	569662.509	4635131.252	Yes	583.543	583.843	0.3	VVA
VVA2154	544667.703	4607478.119	Yes	628.161	628.43	0.269	VVA
VVA2193	425578.417	4566852.77	Yes	793.51	793.778	0.268	VVA
VVA2099	571940.174	4605632.848	Yes	593.276	593.518	0.242	VVA
VVA2029	567205.834	4593367.071	Yes	572.252	572.485	0.233	VVA
VVA_alt_3	456557.478	4666770.517	Yes	755.338	755.554	0.216	VVA
VVA2133	388233.976	4586446.215	Yes	931.141	931.334	0.193	VVA
VVA2068	552151.79	4624475.816	Yes	645.445	645.632	0.187	VVA
VVA2040	400045.485	4607070.663	Yes	855.413	855.599	0.186	VVA
VVA2204	547615.887	4643665.971	Yes	611.495	611.661	0.166	VVA
VVA2170	200109.91	4663649.61	Yes	1184.454	1184.609	0.155	VVA
VVA2172	275369.05	4688833.021	Yes	1131.196	1131.341	0.145	VVA
VVA2126	383757.032	4578694.702	Yes	889.645	889.784	0.139	VVA
VVA2027	359396.083	4559769.815	Yes	885.115	885.246	0.131	VVA
VVA2003	456664.855	4672366.077	Yes	775.696	775.822	0.126	VVA
VVA2150	357382.928	4610341.966	Yes	937.6	937.722	0.122	VVA
VVA2206	470913.754	4589015.869	Yes	738.6	738.72	0.12	VVA
VVA2181	518134.597	4657957.03	Yes	664.839	664.953	0.114	VVA
VVA2064	525542.667	4596946.975	Yes	624.222	624.33	0.108	VVA
VVA2037	348641.53	4631518.085	Yes	955.945	956.052	0.107	VVA
VVA2104	390640.317	4594499.602	Yes	861.005	861.111	0.106	VVA
VVA2221	557675.941	4582754.549	Yes	621.627	621.73	0.103	VVA
VVA2143	361708.547	4592608.327	Yes	908.297	908.398	0.101	VVA
VVA2053	557089.454	4598765.87	Yes	609.494	609.594	0.1	VVA
VVA2028	455637.415	4698109.767	Yes	749.311	749.411	0.1	VVA
VVA2078	256679.971	4641299.87	Yes	1157.424	1157.523	0.099	VVA
VVA2198	297243.758	4564412.233	Yes	968.578	968.677	0.099	VVA
VVA2070	329909.144	4656397.407	Yes	979.382	979.478	0.096	VVA
VVA2039	539206.861	4622782.045	Yes	607.928	608.023	0.095	VVA

VVA2020	274741.103	4647446.541	Yes	1125.249	1125.344	0.095	VVA
VVA2074	375564.459	4567329.765	Yes	897.361	897.453	0.092	VVA
VVA2173	557711.935	4563472.892	Yes	555.373	555.465	0.092	VVA
VVA2077	195349.63	4761005.17	Yes	1046.01	1046.102	0.092	VVA
VVA2097	411423.242	4592664.133	Yes	922.541	922.632	0.091	VVA
VVA2141	427814.271	4693685.866	Yes	807.971	808.062	0.091	VVA
VVA2197	487365.962	4595353.796	Yes	707.176	707.267	0.091	VVA
VVA2033	200313.4	4707343.99	Yes	1143.906	1143.995	0.089	VVA
VVA2112	555111.776	4654725.849	Yes	612.273	612.361	0.088	VVA
VVA2161	398419.266	4675002.957	Yes	833.487	833.574	0.087	VVA
VVA2178	531907.345	4608777.528	Yes	655.989	656.076	0.087	VVA
VVA2153	500046.118	4606654.306	Yes	670.504	670.591	0.087	VVA
VVA2042	529289.775	4657989.182	Yes	639.634	639.72	0.086	VVA
VVA2056	370822.478	4634939.855	Yes	903.766	903.849	0.083	VVA
VVA2194	193071.64	4681654.8	Yes	1200.696	1200.779	0.083	VVA
VVA2021	497217.384	4574551.718	Yes	640.435	640.518	0.083	VVA
VVA2130	368839.894	4620806.69	Yes	907.112	907.194	0.082	VVA
VVA2119	494221.378	4656253.56	Yes	700.427	700.507	0.08	VVA
VVA2215	245148.491	4632154.392	Yes	1160.822	1160.902	0.08	VVA
VVA2175	421167.026	4629337.947	Yes	781.936	782.015	0.079	VVA
VVA2209	445169.23	4660078.951	Yes	745.039	745.117	0.078	VVA
VVA2114	537574.763	4637314.118	Yes	654.946	655.024	0.078	VVA
VVA2024	327169.666	4578297.969	Yes	946.64	946.718	0.078	VVA
VVA2046	479103.648	4683579.538	Yes	724.844	724.921	0.077	VVA
VVA2124	230091.13	4746878	Yes	1109.186	1109.263	0.077	VVA
VVA2220	370910.747	4612986.599	Yes	908.189	908.265	0.076	VVA
VVA2089	412515.063	4684952.737	Yes	823.893	823.969	0.076	VVA
VVA2174	352135.817	4596804.616	Yes	960.537	960.612	0.075	VVA
VVA2139	360901.204	4583741.732	Yes	938.118	938.193	0.075	VVA
VVA2013	428616.441	4642587.48	Yes	762.06	762.133	0.073	VVA
VVA2073	511698.171	4579368.279	Yes	647.626	647.697	0.071	VVA
VVA2157	480776.872	4605072.083	Yes	717.233	717.304	0.071	VVA
VVA2185	201903.45	4663656.48	Yes	1184.545	1184.616	0.071	VVA
VVA2101	332983.856	4688333.599	Yes	970.766	970.836	0.07	VVA
VVA2061	287182.873	4656475.873	Yes	1102.768	1102.838	0.07	VVA
VVA2117	559968.819	4637357.109	Yes	587.151	587.221	0.07	VVA
VVA2147	457385.279	4658227.615	Yes	734.228	734.296	0.068	VVA
VVA2223	246152.658	4644768.811	Yes	1174.052	1174.119	0.067	VVA
VVA2067	387719.109	4682635.106	Yes	856.512	856.578	0.066	VVA
VVA2084	560523.206	4611591.331	Yes	586.401	586.466	0.065	VVA
VVA2071	428916.322	4653112.591	Yes	775.664	775.729	0.065	VVA
VVA2123	526045.766	4574583.042	Yes	633.33	633.395	0.065	VVA

VVA2106	196519.73	4732556.2	Yes	1169.97	1170.035	0.065	VVA
VVA2051	346247.898	4655153.3	Yes	939.563	939.625	0.062	VVA
VVA2085	509620.958	4647395.96	Yes	667.242	667.304	0.062	VVA
VVA2148	482079.468	4633554.313	Yes	703.767	703.828	0.061	VVA
VVA2032	454627.121	4563246.149	Yes	756.971	757.03	0.059	VVA
VVA2201	280921.638	4571460.333	Yes	999.698	999.757	0.059	VVA
VVA2047	404158.293	4621418.19	Yes	856.157	856.215	0.058	VVA
VVA2195	270813.362	4632942.759	Yes	1126.847	1126.905	0.058	VVA
VVA2131	437147.642	4622283.464	Yes	762.533	762.59	0.057	VVA
VVA2217	464767.733	4648214.324	Yes	707.381	707.438	0.057	VVA
VVA2092	471816.657	4698222.277	Yes	714.249	714.305	0.056	VVA
VVA2100	395038.35	4571978.05	Yes	898.192	898.248	0.056	VVA
VVA2082	441484.517	4639587.852	Yes	751.145	751.201	0.056	VVA
VVA2111	393811.905	4649816.036	Yes	851.551	851.606	0.055	VVA
VVA2171	428072.963	4676607.34	Yes	797.672	797.726	0.054	VVA
VVA2222	242296.05	4657247.12	Yes	1190.597	1190.651	0.054	VVA
VVA2015	467813.692	4624308.016	Yes	693.707	693.76	0.053	VVA
VVA2048	377415.807	4674471.532	Yes	867.954	868.007	0.053	VVA
VVA2006	473421.756	4715856.54	Yes	678.639	678.691	0.052	VVA
VVA2145	314578.523	4633307.25	Yes	1035.027	1035.079	0.052	VVA
VVA2098	345218.107	4572963.126	Yes	914.426	914.477	0.051	VVA
VVA2116	374577.274	4593201.696	Yes	881.592	881.641	0.049	VVA
VVA2138	257637.533	4656241.759	Yes	1178.304	1178.351	0.047	VVA
VVA2152	439973.578	4648123.22	Yes	757.047	757.093	0.046	VVA
VVA2134	483979.617	4618628.932	Yes	762.914	762.958	0.044	VVA
VVA2093	518358.047	4589325.017	Yes	636.075	636.119	0.044	VVA
VVA2031	442382.766	4687527.019	Yes	783.562	783.605	0.043	VVA
VVA2203	389293.24	4611980.262	Yes	880.844	880.887	0.043	VVA
VVA2096	306332.992	4569163.07	Yes	975.604	975.646	0.042	VVA
VVA2189	297632.635	4593077.127	Yes	1048.257	1048.298	0.041	VVA
VVA2004	375705.1	4608064.622	Yes	912.385	912.426	0.041	VVA
VVA2086	493423.488	4584700.529	Yes	669.191	669.232	0.041	VVA
VVA2091	331714.66	4673067.563	Yes	992.935	992.976	0.041	VVA
VVA2191	542763.136	4587460.341	Yes	603.518	603.557	0.039	VVA
VVA2014	465220.811	4569688.935	Yes	724.075	724.114	0.039	VVA
VVA2129	308673.192	4592506.015	Yes	1023.951	1023.989	0.038	VVA
VVA2103	236394.87	4696102.97	Yes	1184.312	1184.349	0.037	VVA
VVA2018	297127.635	4692866.832	Yes	1057.751	1057.787	0.036	VVA
VVA2205	305420.068	4643330.074	Yes	1055.156	1055.192	0.036	VVA
VVA2066	395911.717	4656300.998	Yes	826.442	826.477	0.035	VVA
VVA2090	192632.82	4718245.03	Yes	1194.231	1194.265	0.034	VVA
VVA2183	208958.27	4695160.91	Yes	1177.114	1177.148	0.034	VVA

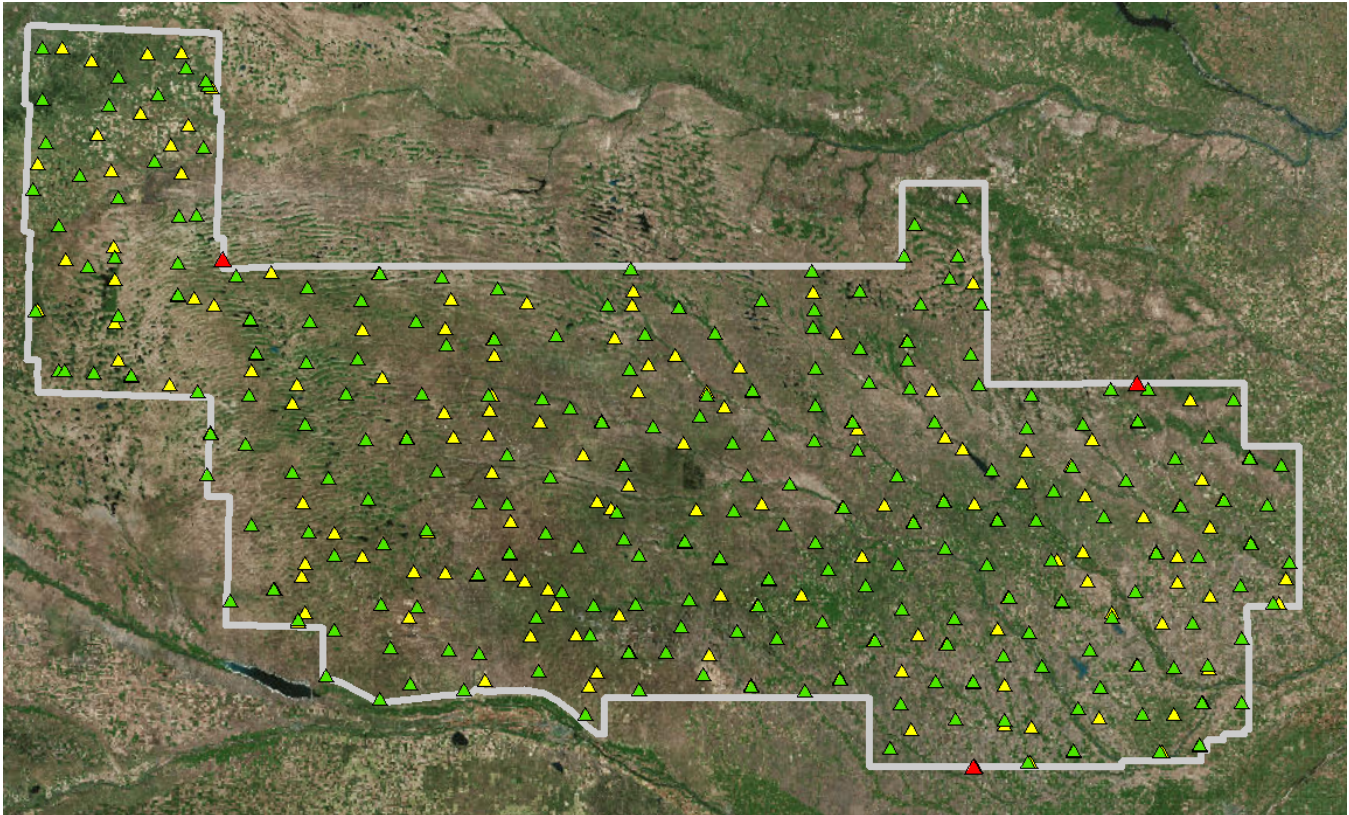
VVA2075	210836.38	4662892.95	Yes	1184.568	1184.601	0.033	VVA
VVA2007	414872.678	4600677.869	Yes	843.583	843.616	0.033	VVA
VVA2108	508221.679	4561716.637	Yes	641.325	641.355	0.03	VVA
VVA2118	430824.763	4587677.301	Yes	845.759	845.789	0.03	VVA
VVA2016	454918.593	4591545.768	Yes	759.615	759.644	0.029	VVA
VVA2132	544964.176	4550604.196	Yes	574.605	574.633	0.028	VVA
VVA2054	476368.891	4569678.684	Yes	714.898	714.926	0.028	VVA
VVA2155	318094.255	4579412.584	Yes	970.983	971.011	0.028	VVA
VVA2062	253939.557	4692071.677	Yes	1167.656	1167.683	0.027	VVA
VVA2083	281676.49	4631163.744	Yes	1110.401	1110.427	0.026	VVA
VVA2160	274956.788	4666085.598	Yes	1125.036	1125.062	0.026	VVA
VVA2169	458922.416	4707812.389	Yes	721.887	721.911	0.024	VVA
VVA2136	222123.79	4662069.39	Yes	1187.454	1187.477	0.023	VVA
VVA2060	419236.385	4617190.371	Yes	830.899	830.921	0.022	VVA
VVA2092_alt	469443.403	4691659.09	Yes	733.756	733.777	0.021	VVA
VVA2005	283402.971	4608073.992	Yes	1096.057	1096.078	0.021	VVA
VVA2019	366055.101	4683402.368	Yes	877.614	877.634	0.02	VVA
VVA2142	309799.069	4656436.117	Yes	1042.375	1042.395	0.02	VVA
VVA2163	477005.821	4544039.464	Yes	698.814	698.834	0.02	VVA
VVA2049	354692.804	4652508.528	Yes	919.2	919.22	0.02	VVA
VVA2167	258003.661	4679002.393	Yes	1158.878	1158.898	0.02	VVA
VVA2177	514746.691	4568056.325	Yes	649.04	649.058	0.018	VVA
VVA2190	475740.796	4668544.185	Yes	754.651	754.668	0.017	VVA
VVA2034	300452.663	4580084.959	Yes	1030.647	1030.663	0.016	VVA
VVA2088	451430.691	4549591.715	Yes	737.937	737.953	0.016	VVA
VVA2030	506731.021	4548818.115	Yes	639.44	639.455	0.015	VVA
VVA2210	432719.659	4603721.184	Yes	787.836	787.85	0.014	VVA
VVA2087	308058.01	4678439.442	Yes	1045.858	1045.87	0.012	VVA
VVA2057	460610.409	4683660.592	Yes	757.11	757.122	0.012	VVA
VVA2001	364341.936	4648287.546	Yes	877.116	877.128	0.012	VVA
VVA2017	218326.68	4680174.44	Yes	1191.98	1191.992	0.012	VVA
VVA2023	547324.285	4574589.682	Yes	597.643	597.653	0.01	VVA
VVA2022	436230.85	4570642.201	Yes	797.469	797.479	0.01	VVA
VVA2035	468583.172	4581130.023	Yes	712.884	712.893	0.009	VVA
VVA2188	485978.613	4558009.475	Yes	679.436	679.445	0.009	VVA
VVA2122	478399.784	4659506.399	Yes	739.431	739.438	0.007	VVA
VVA2159	245366.58	4749779.15	Yes	1091.28	1091.287	0.007	VVA
VVA2043	258316.919	4617135.49	Yes	1145.394	1145.401	0.007	VVA
VVA2196	515862.671	4619437.885	Yes	667.367	667.372	0.005	VVA
VVA2184	215469.65	4743776.63	Yes	1166.997	1167.002	0.005	VVA
VVA2180	537190.803	4574102.103	Yes	564.384	564.388	0.004	VVA
VVA2011	446684.755	4582284.792	Yes	763.632	763.636	0.004	VVA

VVA9001	244858.57	4751133.96	Yes	1100.089	1100.093	0.004	VVA
VVA2072	526172.389	4648315.821	Yes	657.897	657.9	0.003	VVA
VVA2182	217142.29	4697981.89	Yes	1168.548	1168.551	0.003	VVA
VVA2080	344359.088	4589318.141	Yes	956.972	956.974	0.002	VVA
VVA2208	417343.096	4582903.316	Yes	830.971	830.973	0.002	VVA
VVA2095	500674.881	4627376.403	Yes	719.51	719.512	0.002	VVA
VVA2219	373088.091	4694354.146	Yes	885.985	885.987	0.002	VVA
VVA2065	379960.461	4646643.09	Yes	848.475	848.476	0.001	VVA
VVA2115	444172.715	4598821.107	Yes	796.043	796.044	0.001	VVA
VVA2009	236105.79	4686405.77	Yes	1222.359	1222.36	0.001	VVA
VVA2045	347476.963	4614523.226	Yes	963.057	963.058	0.001	VVA
VVA2055	458366.314	4617833.594	Yes	777.67	777.67	0	VVA
VVA2146	315971.301	4691938.413	Yes	1016.602	1016.602	0	VVA
VVA2079	275969.434	4678415.745	Yes	1134.583	1134.58	-0.003	VVA
VVA2166	350664.752	4674103.985	Yes	940.971	940.968	-0.003	VVA
VVA2127	336442.435	4608459.896	Yes	1012.675	1012.671	-0.004	VVA
VVA2059	409735.373	4657519.813	Yes	796.249	796.245	-0.004	VVA
VVA2137	293698.798	4624754.373	Yes	1094.338	1094.333	-0.005	VVA
VVA2128	322557.943	4567172.509	Yes	922.974	922.969	-0.005	VVA
VVA2008	311284.481	4615576.1	Yes	1046.526	1046.52	-0.006	VVA
VVA2113	317214.666	4671487.482	Yes	1031.406	1031.396	-0.01	VVA
VVA2165	495389.735	4618436.647	Yes	643.98	643.969	-0.011	VVA
VVA2069	241849.01	4710669.45	Yes	1161.132	1161.119	-0.013	VVA
VVA_alt1	428507.745	4682070.332	Yes	819.569	819.555	-0.014	VVA
VVA2050	292961.195	4642822.824	Yes	1089.596	1089.582	-0.014	VVA
VVA2044	259918.603	4668784.436	Yes	1160.455	1160.441	-0.014	VVA
VVA2058	471065.764	4558451.322	Yes	716.826	716.812	-0.014	VVA
VVA2036	527545.503	4560075.266	Yes	617.675	617.661	-0.014	VVA
VVA2151	492725.864	4646259.175	Yes	718.33	718.315	-0.015	VVA
VVA2211	408387.663	4631912.549	Yes	798.906	798.89	-0.016	VVA
VVA2168	409281.853	4568548.651	Yes	909.894	909.878	-0.016	VVA
VVA2107	545780.764	4563616.223	Yes	547.079	547.062	-0.017	VVA
VVA2038	485547.898	4577708.96	Yes	716.03	716.013	-0.017	VVA
VVA2121	467971.079	4610148.28	Yes	708.394	708.377	-0.017	VVA
VVA2158	453359.409	4631922.865	Yes	727.909	727.892	-0.017	VVA
VVA2212	195281.3	4745393.59	Yes	1126.613	1126.595	-0.018	VVA
VVA2120	428729.099	4611831.908	Yes	814.413	814.393	-0.02	VVA
VVA2076	372505.328	4578717.293	Yes	918.085	918.065	-0.02	VVA
VVA2164	428726.927	4664382.866	Yes	790.165	790.144	-0.021	VVA
VVA2213	272452.967	4588387.005	Yes	1078.539	1078.517	-0.022	VVA
VVA2216	442084.552	4670464.555	Yes	778.161	778.139	-0.022	VVA
VVA2125	405050.235	4584901.158	Yes	811.183	811.16	-0.023	VVA

VVA2214	403842.945	4641945.994	Yes	844.519	844.496	-0.023	VVA
VVA2026	372782.482	4663840.151	Yes	922.13	922.105	-0.025	VVA
VVA2187	522808.878	4630326.339	Yes	627.854	627.829	-0.025	VVA
VVA2218	506304.28	4634841.97	Yes	671.492	671.467	-0.025	VVA
VVA2025	298217.824	4611387.162	Yes	1072.246	1072.22	-0.026	VVA
VVA2081	454051.948	4605079.338	Yes	760.254	760.228	-0.026	VVA
VVA2200	243991.39	4731108.31	Yes	1087.127	1087.1	-0.027	VVA
VVA2202	492903.129	4545583.026	Yes	649.692	649.664	-0.028	VVA
VVA2149	252110.45	4594306.588	Yes	1115.013	1114.984	-0.029	VVA
VVA2162	326747.248	4602322.665	Yes	1003.429	1003.398	-0.031	VVA
VVA2207	236745.17	4710144.3	Yes	1166.641	1166.607	-0.034	VVA
VVA2110	327297.562	4623604.576	Yes	1027.476	1027.441	-0.035	VVA
VVA2186	335719.079	4638191.026	Yes	974.152	974.115	-0.037	VVA
VVA2052	238612.23	4754881.82	Yes	1141.284	1141.247	-0.037	VVA
VVA2002	218097.19	4752347.35	Yes	1099.885	1099.846	-0.039	VVA
VVA2156	533048.683	4548499.208	Yes	603.72	603.68	-0.04	VVA
VVA2179	414665.826	4644284.132	Yes	799.646	799.602	-0.044	VVA
VVA2041	265310.037	4597636.776	Yes	1108.8	1108.752	-0.048	VVA
VVA2176	275574.08	4614975.327	Yes	1118.168	1118.116	-0.052	VVA
VVA2140	335716.072	4623264.703	Yes	1013.8	1013.747	-0.053	VVA
VVA2135	291759.622	4684775.033	Yes	1096.486	1096.428	-0.058	VVA
VVA2010	206579.63	4722606.38	Yes	1151.173	1151.113	-0.06	VVA
VVA2199	283397.251	4585466.749	Yes	1071.356	1071.295	-0.061	VVA
VVA2012	526183.791	4659634.487	Yes	636.952	636.888	-0.064	VVA
VVA2144	290646.929	4667258.129	Yes	1096.177	1096.106	-0.071	VVA
VVA2192	503179.603	4594223.108	Yes	642.744	642.669	-0.075	VVA
VVA2094	218385.85	4715724.92	Yes	1145.924	1145.844	-0.08	VVA
VVA2109	229209.54	4726744.84	Yes	1113.465	1113.367	-0.098	VVA

Lidar Check Point Layout

- Yellow = NVA
- Green = VVA
- Outside DPA



Hydro-flattening Breakline Collection

Hydro-flattening breaklines are captured per the USGS National Geospatial Program Lidar Base Specification Version 1.2. Final hydro-flattened breaklines features are appropriately turned into polygons (flat elevations) and polylines (decreasing by elevation) and are used to reclassify ground points in water to Water (Class 9). The lidar points around the breaklines are reclassified to Ignored Ground (Class 10) based on predetermined buffer.

Linear hydrographic features

To collect hydrographic features, Merrick-Surdex JV uses a methodology that directly interacts with the lidar bare-earth data to collect drainage breaklines. To determine the alignment of a drainageway, the technician first views the area as a TIN of bare-earth points using a color ramp to depict varying elevations. In areas of extremely flat terrain, the technician may need to determine the direction of flow based on measuring lidar bare-earth points at each end of the drain. The operator will then use the color ramped TIN to digitize the drainage in 2D with the elevation being attributed directly from the bare-earth LAS data. MARS® software has the capability of “flipping” views between the elevation TIN, Intensity and imagery, as necessary, to further assist in the determination of the drainage. All drainage breaklines are collected in a downhill direction. For each point collected, the software uses a five-foot (5’) search radius to identify the lowest point within that proximity.

Within each radius, if a bare-earth point is not found that is lower than the previous point, the elevation for subsequent point remains the same as the previous point. This forces the drain to always flow in a downhill direction. Waterbodies that are embedded along a drainageway are validated to ensure consistency with the downhill direction of flow.

This methodology may differ from those of other vendors in that Merrick-Surdex JV relies on the bare-earth data to attribute breakline elevations. As a result of our methodology, there is no mismatch between lidar bare-earth data and breaklines that might otherwise be collected in stereo 3D as a separate process. This is particularly important in densely vegetated areas where breaklines collected in 3D from imagery will most likely not match (either horizontally or vertically), the more reliable lidar bare-earth data.

Merrick-Surdex JV has the capability of “draping” 2D breaklines to a bare-earth elevation model to attribute the “z” as opposed to the forced downhill attribution methodology described above. However, the problem with this process is the “pooling” effect or depressions along the drainageway caused by a lack of consistent penetration in densely vegetated areas.

Criteria of linear hydrographic breaklines are as follows:

- Linear hydrographic features (e.g., visible streams, rivers, shorelines, canals, etc.) greater than one hundred feet (100’) wide will be captured as a double-lined polygon
 - linear hydrographic features must be flat and level bank-to-bank (perpendicular to the apparent flow centerline) with gradient following the immediately surrounding terrain
 - water surface edge must be at or just below the immediately surrounding terrain
 - streams should break at road crossings (e.g., culverts), and streams and rivers should not break at bridges

Waterbodies

Waterbodies are digitized from the color ramped TIN, similar to the process described above. The elevation attribute is determined as the technician collects the hydro feature by using the lowest bare-earth point within the polygon.

Criteria of waterbody breaklines are as follows:

- Waterbodies (e.g., lakes, ponds, reservoirs) greater than two (2) acres in size are surrounded by a water breakline (i.e., closed polygon)
 - waterbodies must be flat and level with a single elevation for every bank vertex
 - water surface edge must be at or just below the immediately surrounding terrain
 - long impoundments, such as reservoirs or inlets, whose water surface elevations drop when moving downstream should be treated as rivers

Color cycles provide a clear indication of where breaklines are to be collected, especially hydrographic breaklines. Figure 3 demonstrates no breaklines, where Figure 4 is breakline enforced displayed using color cycles within the MARS® software environment.

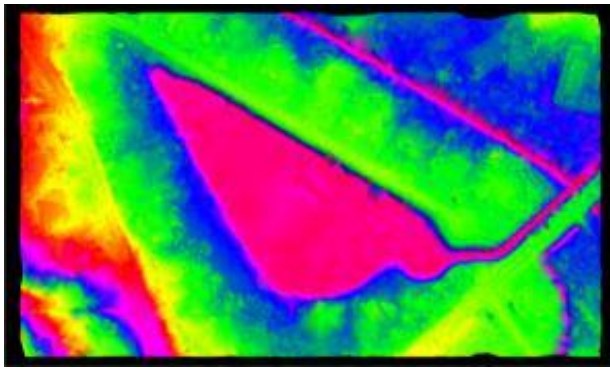


Figure 3

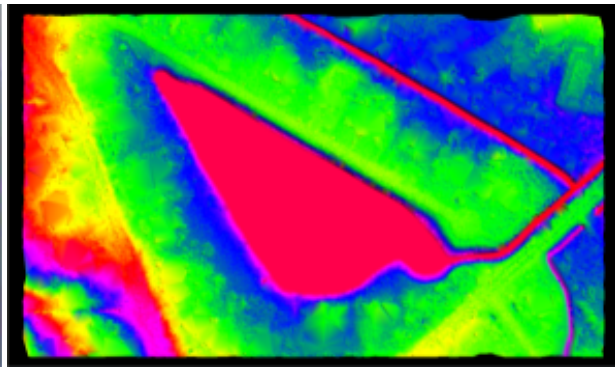


Figure 4

Bare-Earth Surface (DEM)

Merrick-Surdex JV exports the hydro-flattening breakline enforced Class 2 (ground) lidar points to a one-meter (1m) cell size, 32-bit format using MARS®, the DEMs are exported to the project tiling scheme. Projection information is applied that reflects the project requirements.

Intensity Images

Merrick-Surdex JV exports all lidar points to a one-meter (1m) cell size 16-bit client desired format using MARS®, the intensity images are exported to the project tiling scheme and / or project-wide boundary. Projection information is applied that reflects the project requirements.

Contour Generation

Quarter meter Contours are generated using MARS® proprietary software at the desired contour interval. Topology QC checks are completed to ensure topography is logical and complete. Additional QC checks for dangles and appropriate attribution are also verified to comply with project requirements before delivery to the client.

List of Deliverables

- Minimum standards as outlined in **TM11-B4 / Exhibit 1**
- Raw lidar point cloud
 - Fully compliant ASPRS LAS 1.4, point record format 6
 - Calibrated
 - By swath
 - Intensity values normalized (rescaled) to 16-bit
 - FGDC-compliant metadata
- Classified lidar point cloud
 - Fully compliant ASPRS LAS 1.4, point record format 6
 - By tile
 - Intensity values normalized (rescaled) to 16-bit
 - FGDC-compliant metadata
- Bare-earth DEM
 - 1m cell size 32-bit floating point raster in ERDAS IMG format
 - Bare-earth (hydro-flattened)

- Culverts will not be removed from the DEMs
 - Bridges will be removed from the DEMs
 - By tile and by county
 - FGDC-compliant metadata
- First Return Digital Surface Model (DSM)
 - 1m cell size 32-bit floating point raster in ERDAS IMG format
 - By tile and by county
 - FGDC-compliant metadata
- Hillshades
 - 1m cell size floating point raster in ERDAS IMG format
 - By county
 - FGDC-compliant metadata
- Hydro-flattened breaklines
 - Project-wide Esri feature class(es) for insertion into file geodatabase
 - FGDC-compliant metadata
- Intensity Images
 - 1m cell size 16-bit floating point raster in ERDAS IMG format
 - By tile and by county
 - FGDC-compliant metadata
- Two-foot (2') contours
 - Esri feature class(es) for insertion into file geodatabase
 - By county
 - FGDC-compliant metadata
- Control
 - Survey report
 - Esri shapefile format
 - FGDC-compliant metadata
- FGDC-compliant metadata (project level)
- Detailed lidar Mapping / Project Report

County-wide deliverables for Sheridan County will all be referenced to UTM Zone 13 North.

County-wide deliverables for Arthur, Blaine, Boone, Brown, Cherry, Custer, Garfield, Grant, Greeley, Hooker, Howard, Keith, Lincoln, Logan, Loup, McPherson, Rock, Sherman, Thomas, Valley and Wheeler Counties will all be referenced to UTM Zone 14 North.

Appendix 1

Following is a more detailed lidar calibration workflow description.

LIDAR CALIBRATION AND BLOCK LAS OUTPUT

Note: All figures represented on the following pages are for general illustration purposes, and are not examples derived from the project.

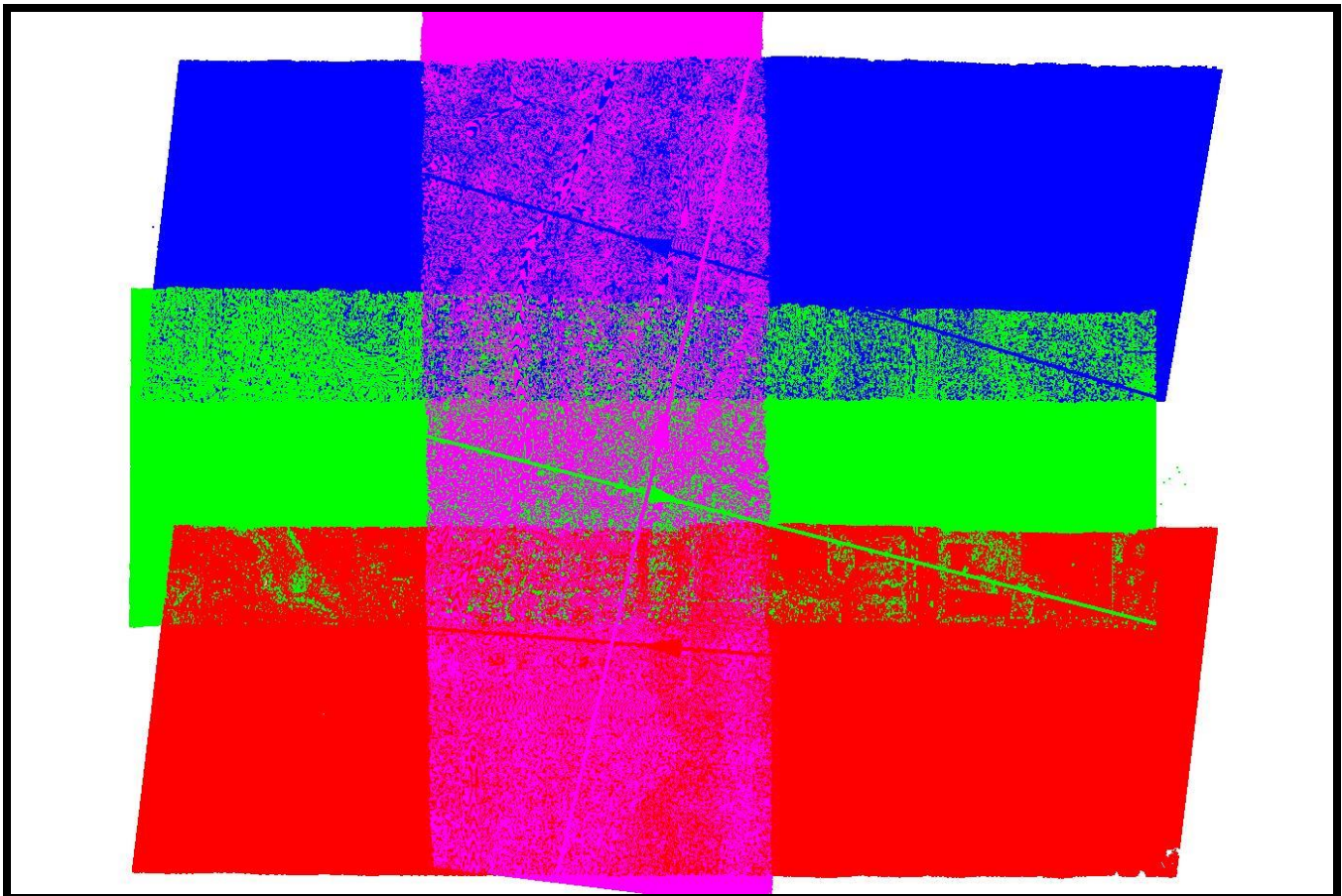
Initial Processing

Lidar data is output as LAS point data using Optech's Lidar Mapping Suite (LMS). LMS matches ground and roof planes plus roof lines to self-calibrate and correct system biases. These biases occur within the hardware of the laser scanning systems, within the Inertial Measurement Unit (IMU) and because of environmental conditions which affect the refraction of light. The systemic biases that are corrected for include scale, roll, pitch, and heading.

In addition to the self-calibration mode LMS runs a "production" mode which applies the self-calibration parameters and then analyzes each individual flight line and applies small adjustments to each line to tie overlapping lidar points even more tightly together.

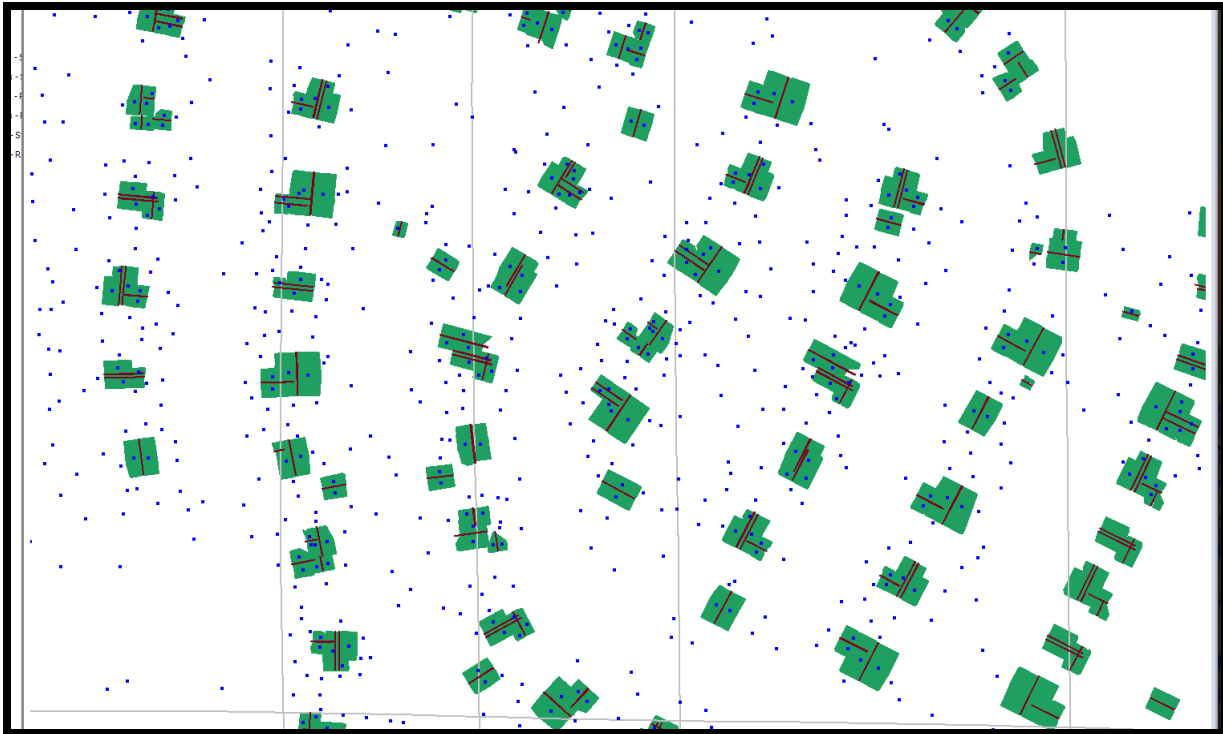
Boresight Self-Calibration Processing Procedures

An LMS boresight calibration is performed on an as-needed basis to correct scale, roll, pitch and heading biases. A minimum of three overlapping flights are flown in opposing directions with one cross flight.



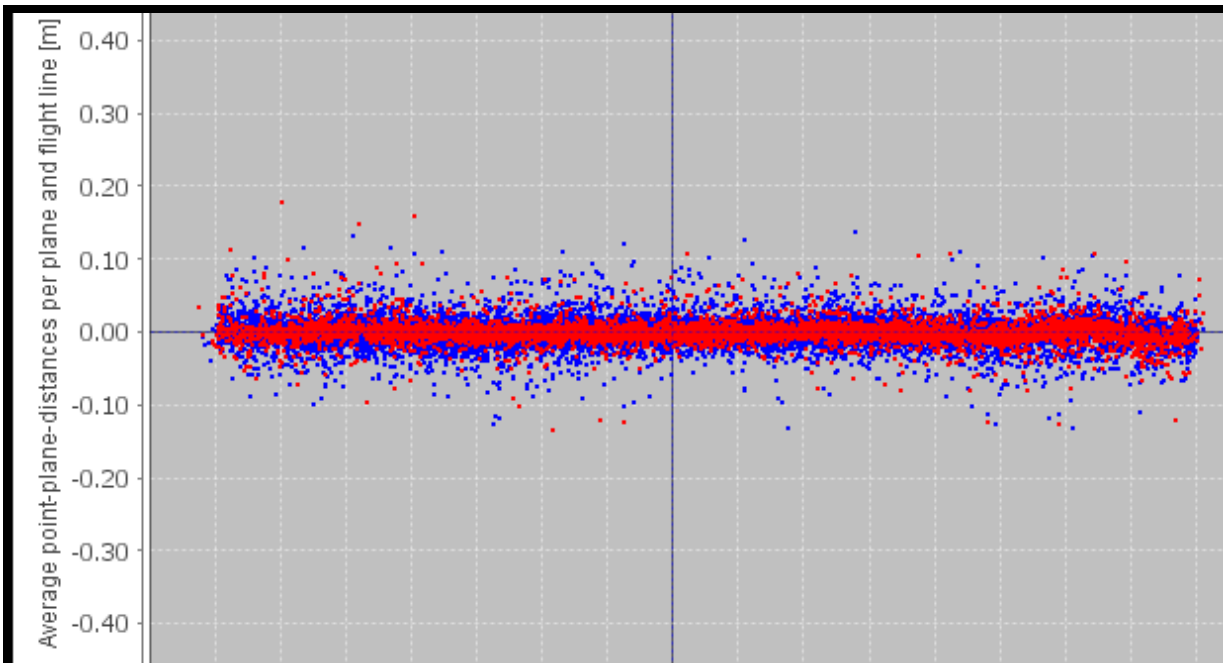
The Boresighting module frees scan angle scale, scan angle lag, XYZ boresight corrections and elevation position corrections while locking scan angle offset and XY position corrections.

The picked calibration site will have a good distribution of buildings for the self-calibration software to match ground planes, roof planes and roof lines.

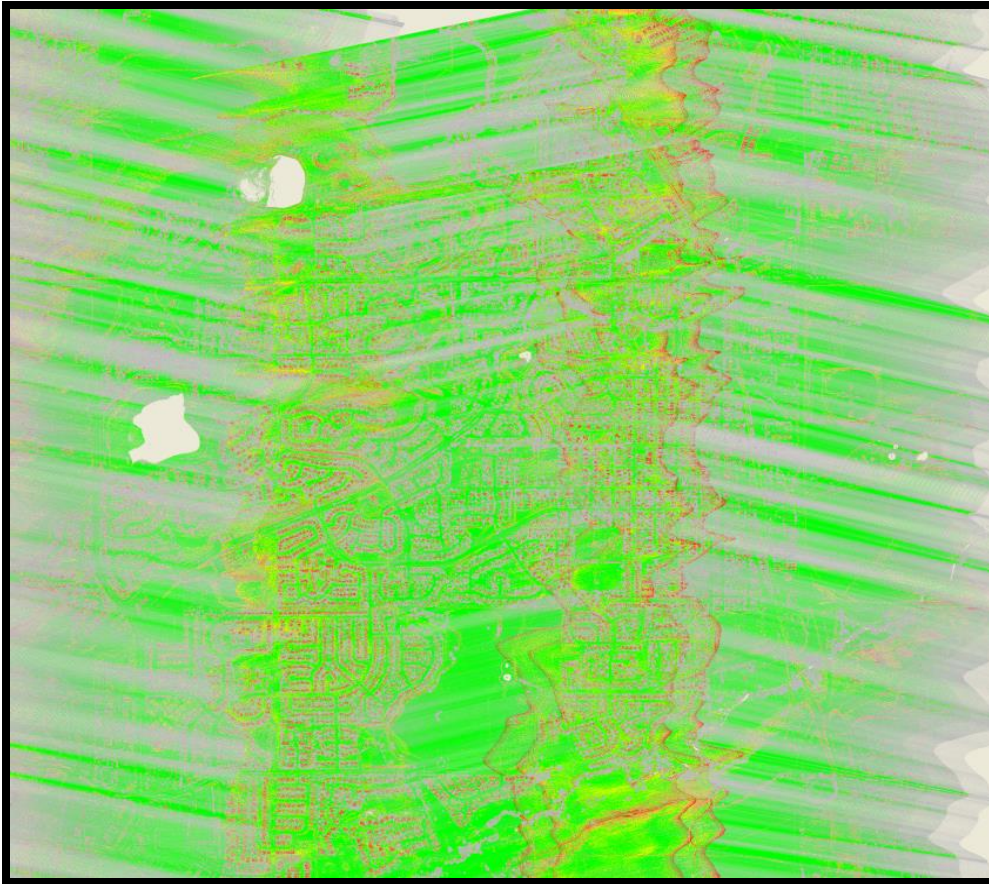


At the conclusion of the self-calibration run the data is quality checked with LMS plots

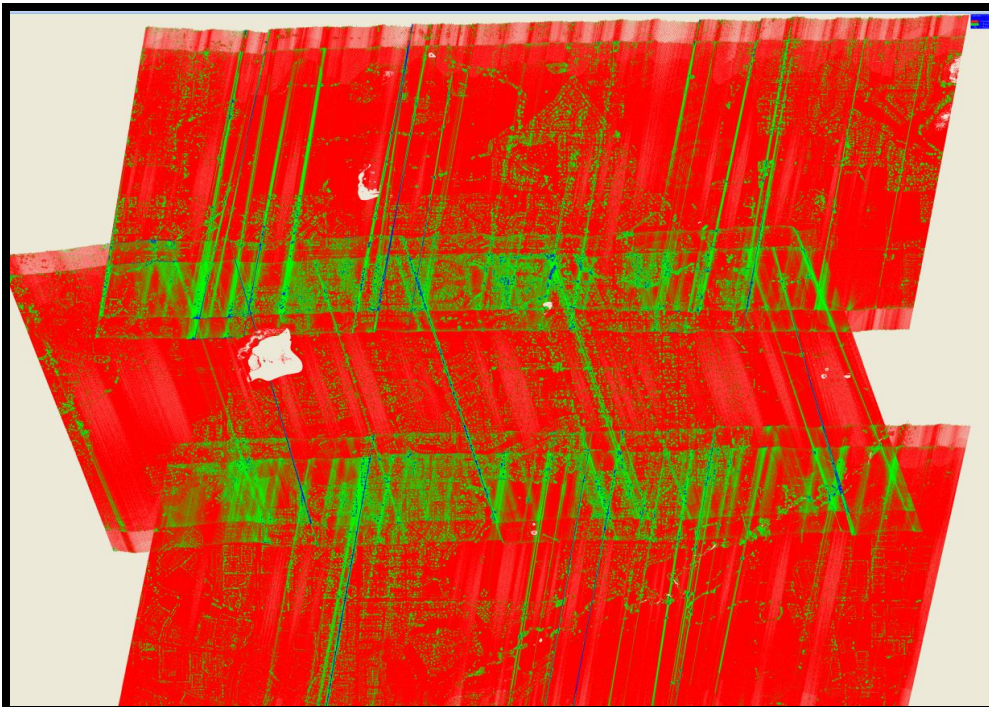
Plot of plane vertical distances from datum plane.



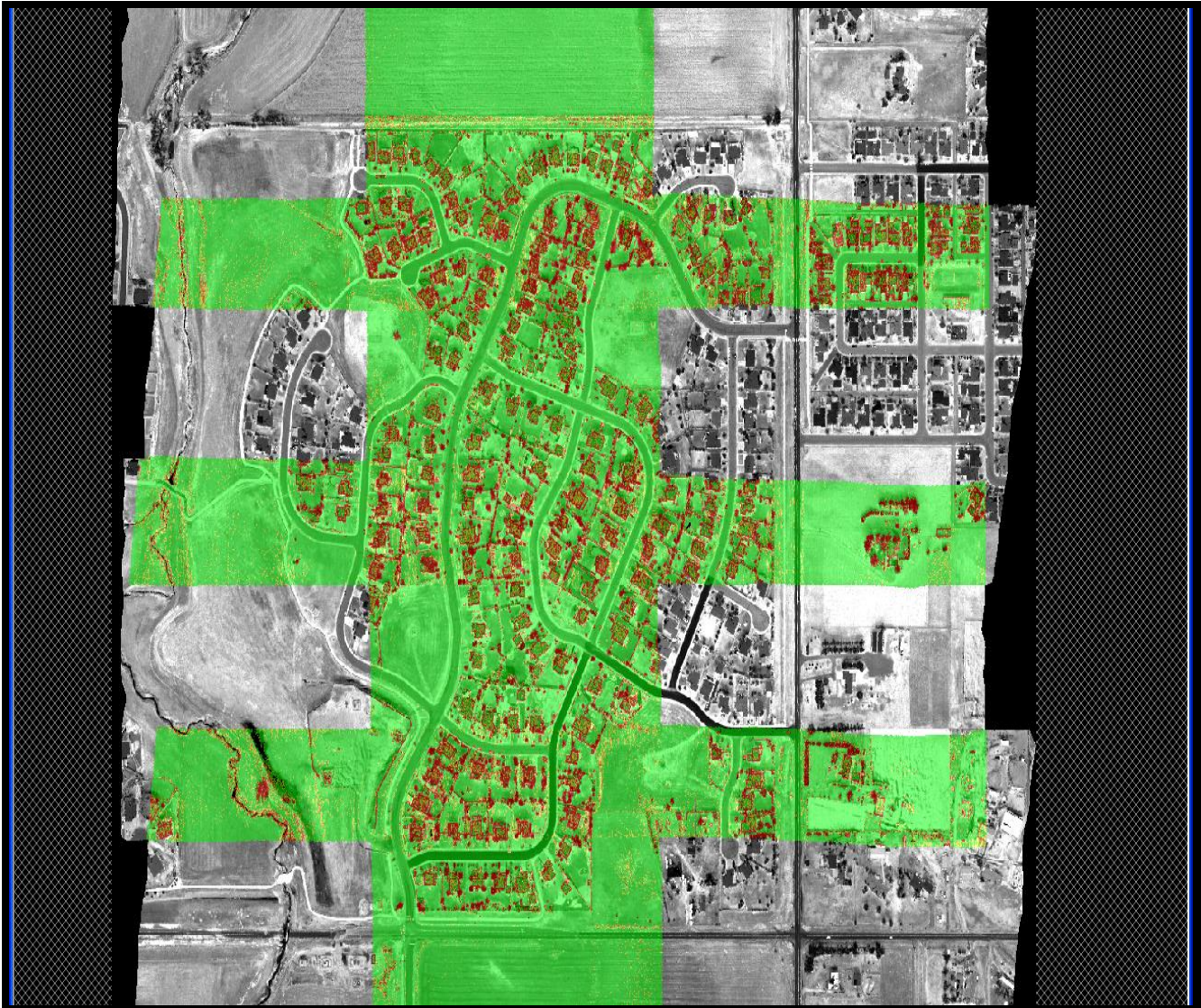
Plot of height differenced between flight lines. (Green=less than 5cm).



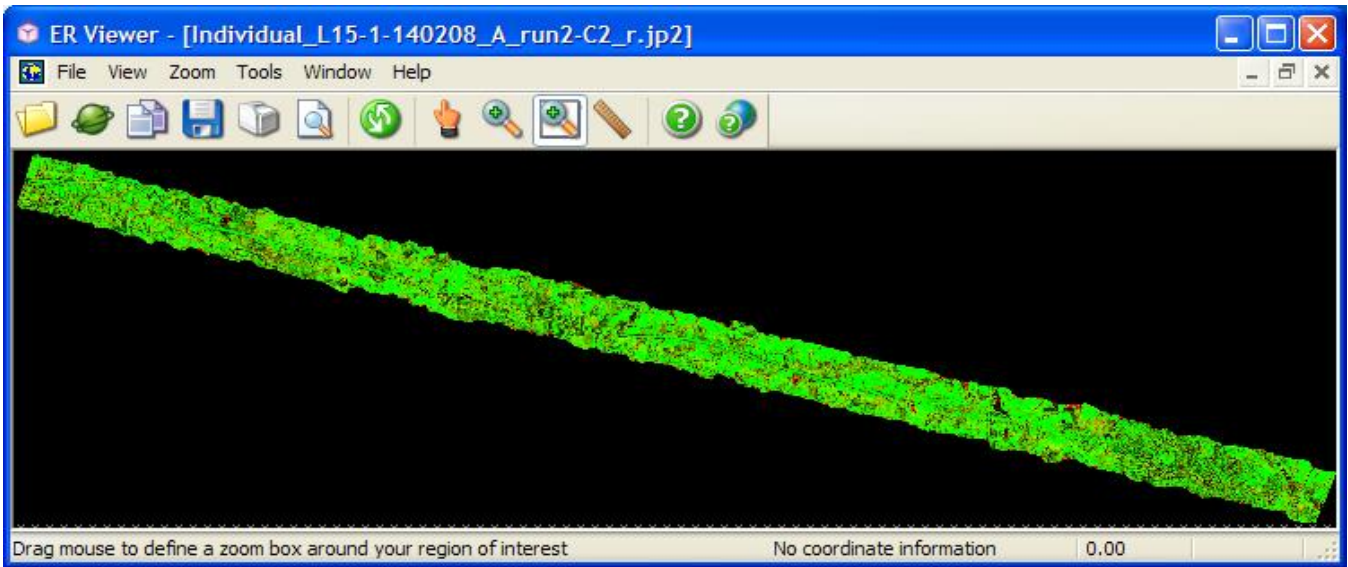
Plot of point densities. (Red=5-9 points per cell, green 10+ points per cell).



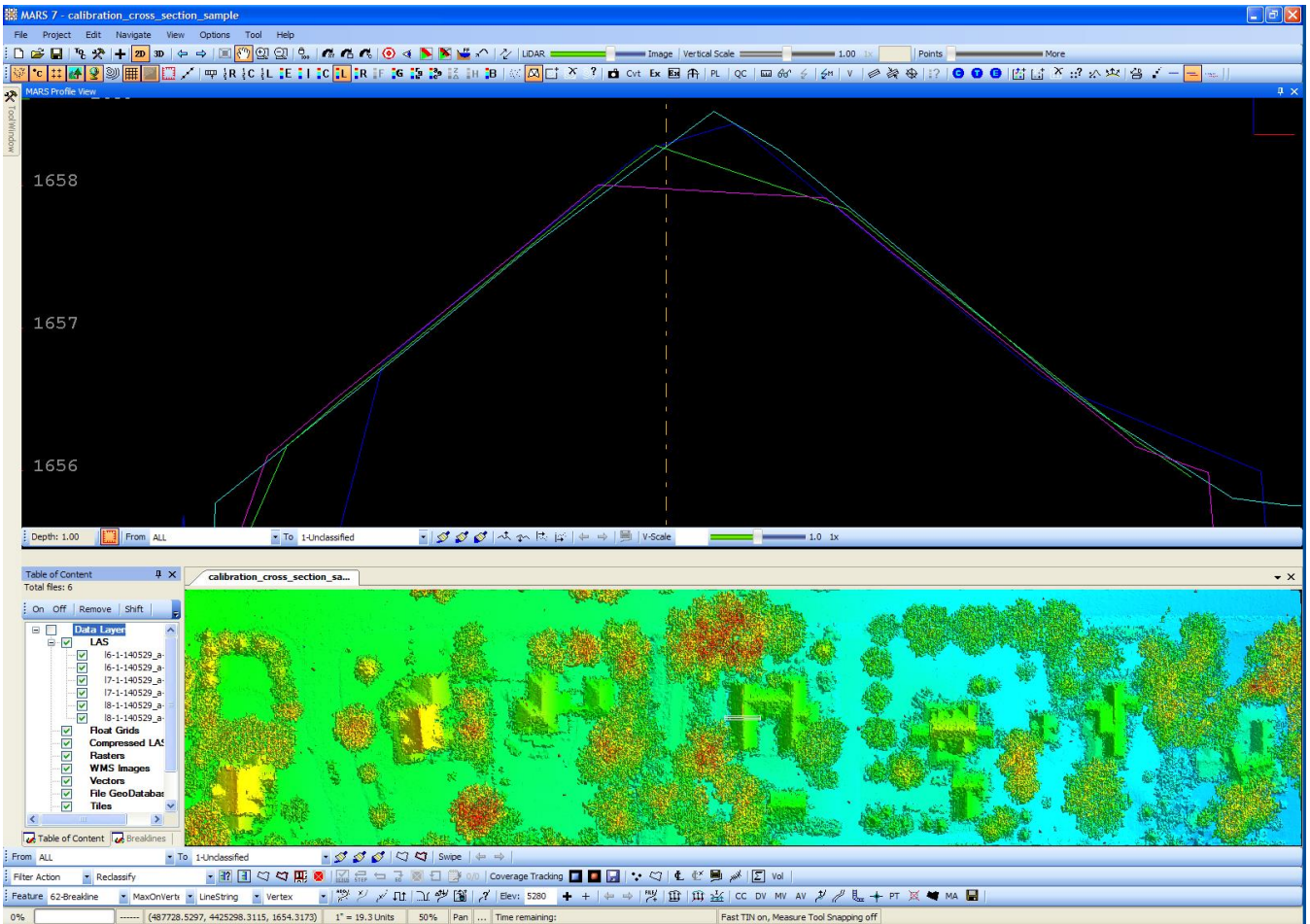
A Flight Line Separation Raster image is generated in Merrick Advanced Remote Sensing Software (MARS®), in this example ground returns from multiple flight lines that are fitting within 3 centimeters are colored green.



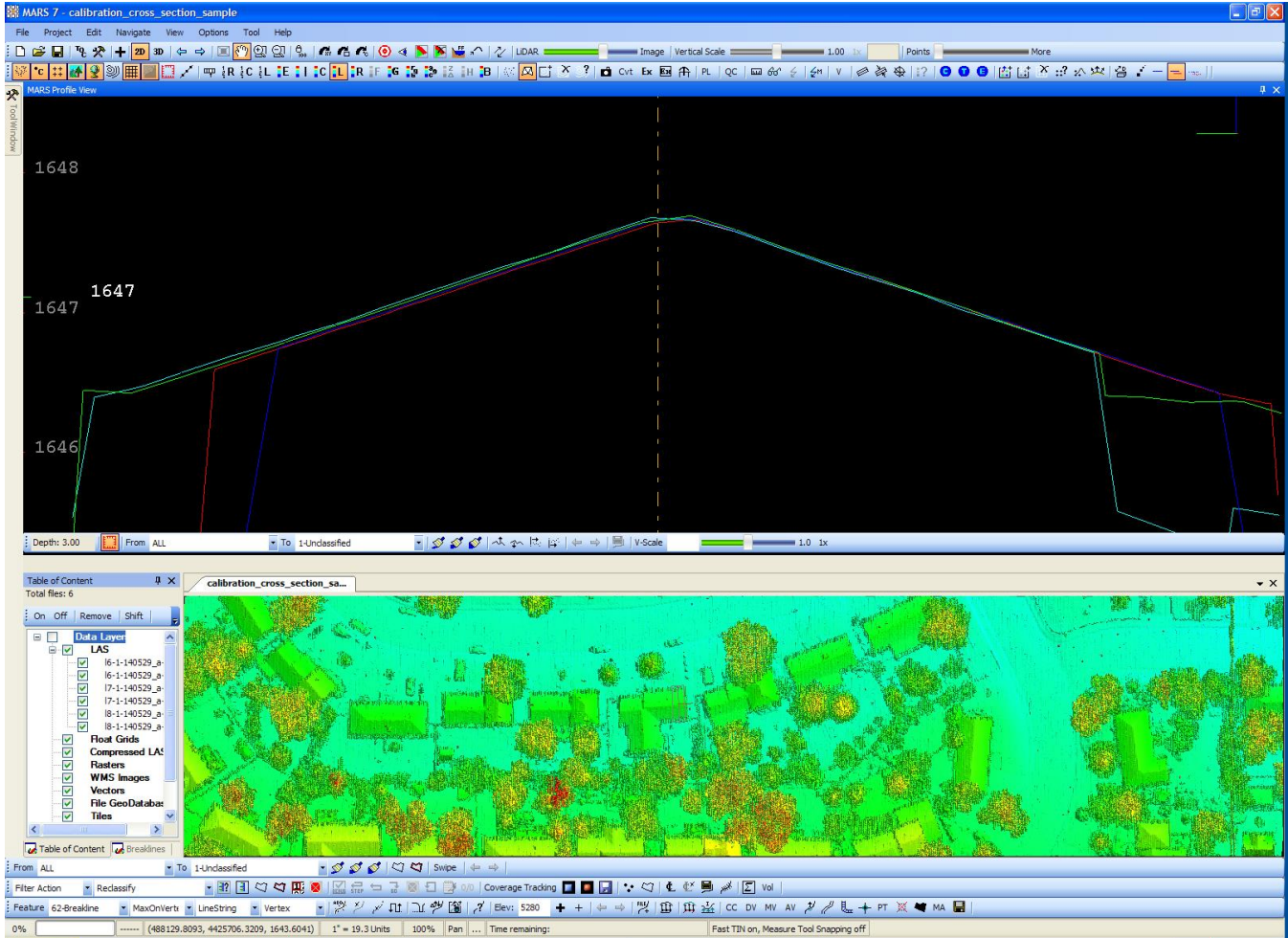
MARS® tests for internal relative vertical accuracy using inbound and outbound scan values. Again, Green is showing inbound and outbound scan data fitting to 3 centimeters.



Building cross sections are checked for good alignment. Pitch and heading are checked on roof planes parallel to the flight direction.



Roll and scale are checked on roof planes perpendicular to the flight direction.

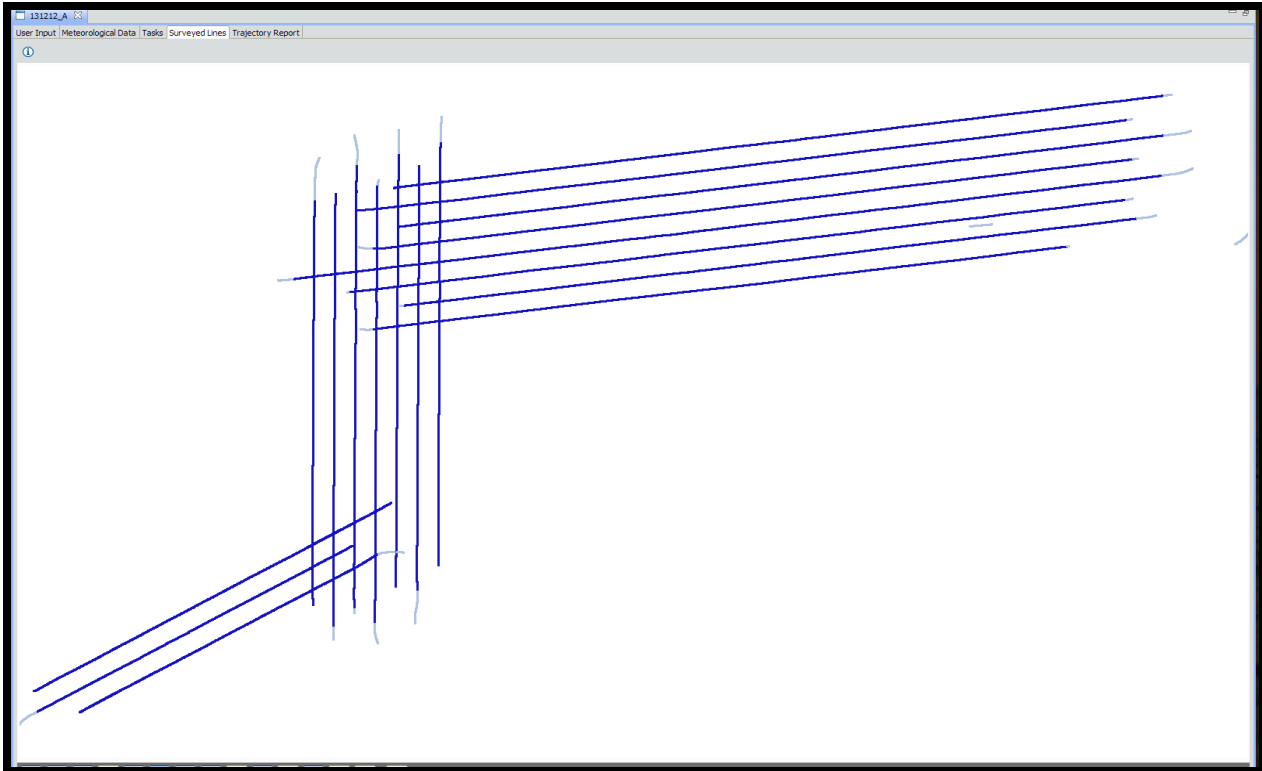


The LMS program outputs a "LCP" file with all the correction parameters. The calibration process may be run several times until the boresight adjustments are acceptable. When the boresight solution is acceptable the LCP file adjustments are saved and also applied to subsequent projects. Each new project is again analyzed and when the adjustment biases show too much drift a new boresight calibration is run. The LCP file may hold calibration tolerances for several projects.

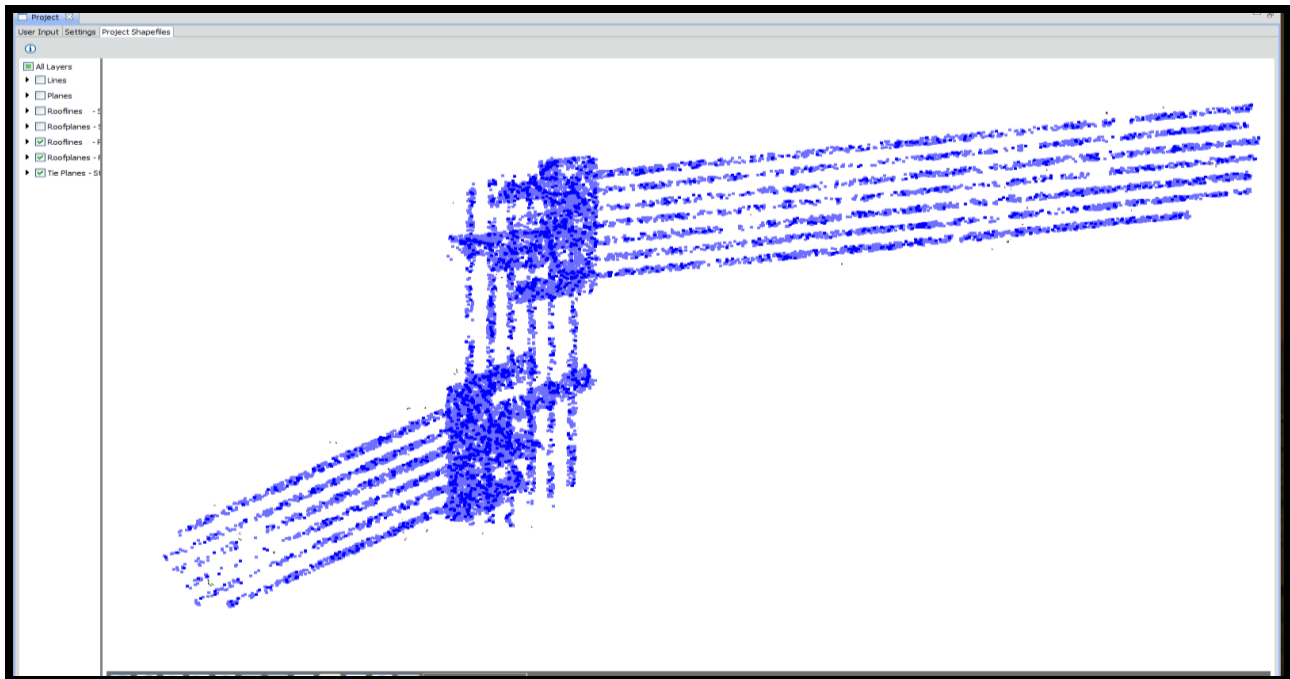
Block LAS Production Processing Procedures

The LMS production mode is run on each flight line to further tie the final lidar LAS flight line files tightly together. Production settings allow scan angle scale, scan angle lag to float and allows elevation to move slightly during flight line to flight line comparison thus further tying flight lines together. A cross flight with locked elevation data is used for controlling flight line elevations.

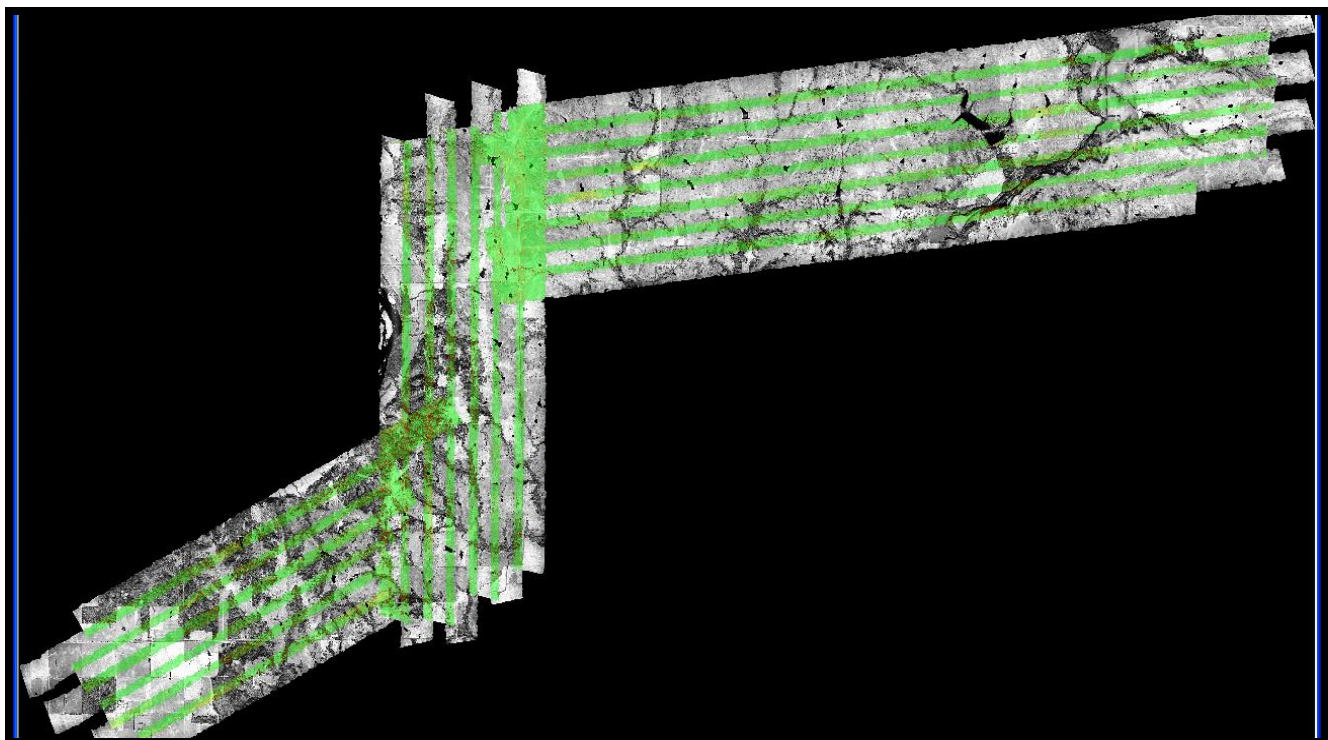
A block of data is selected to process with LMS production settings. Data collected during turns at the ends of flight lines is deselected (light blue lines).



As in self-calibration the LMS production program analyses ground, roof planes and rooflines. One cross flight is locked in elevation and all other lines are adjusted to it. Unlike the calibration site the distribution of roof planes is usually much less dense. Here matched ground tie planes are blue.

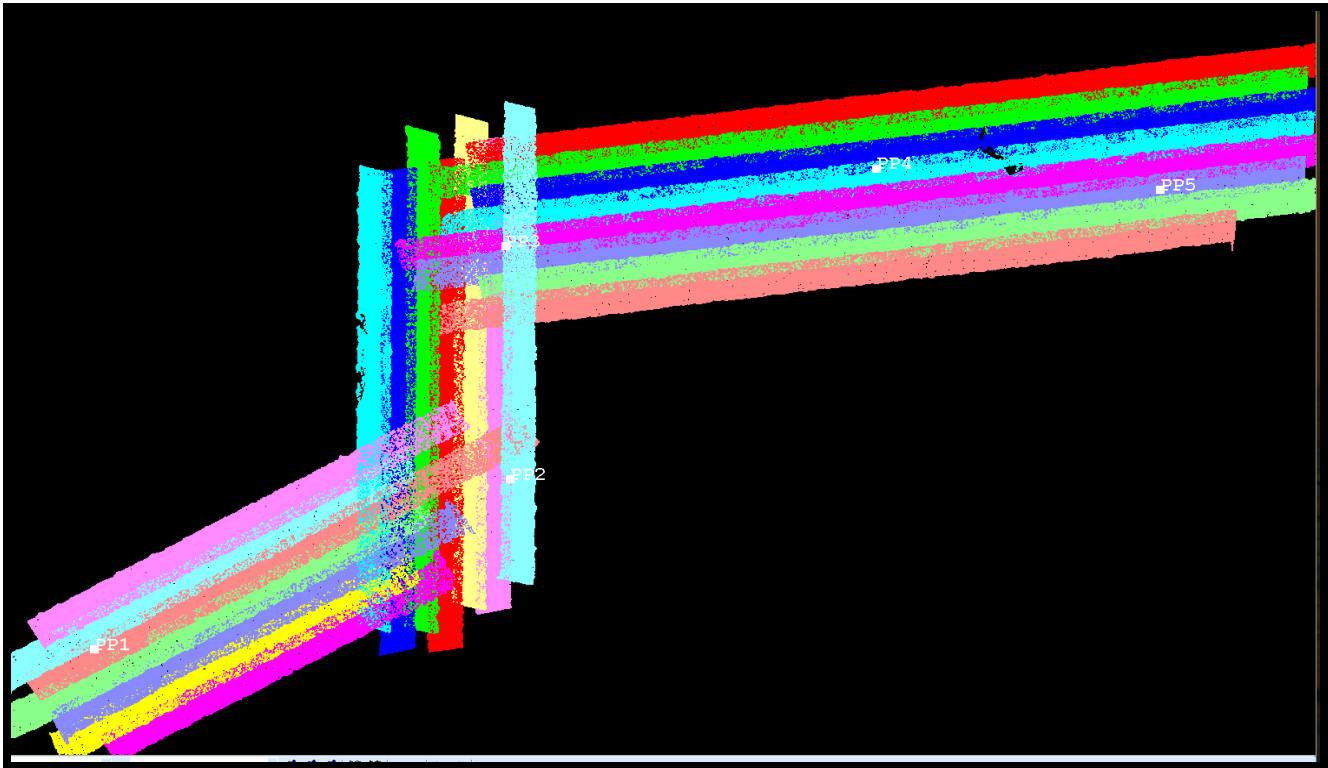


The same quality control outputs used to check self-calibrations are available to analyze the production run. Output plots are again available in LMS and cross sections plus a Flight Line Separation Raster are generated in MARS® to check coverage and quality.



Correcting the Final Elevation

After all the lines are tied together a ground control network is imported into MARS®. The ground control network may be pre-existing or collected by a licensed surveyor.



The next step is to match the ground control elevations to the lidar data set. A control report is run and the data set is shifted slightly to zero out the average elevation error and points checked for quality.

The final step before boresighted, leveled LAS files are ready for filtering is to run the MARS® QC Module on the block data. The Boresighted lidar QC Report outputs individual reports on Point Density, Nominal Pulse Spacing, Data Voids, Spatial Distribution, Scan Angles, Control Report, Flight Line Separation, Flight Line Overlap, Buffered Boundary, LAS Formats, Datums and Coordinates.

These reports are checked with the required specifications in the Project Management Plan.