University of Illinois

Lidar 2020 - Data Acquisition (U20067) and Processing (U20125) of 5 Counties in Wabash and Embarras Basin Lidar Mapping Report

Contractor: Merrick & Company

Client Point-of-Contact (POC):

Sheena K. Beaverson
Program Manager, Illinois Height Modernization
Illinois State Geological Survey
Prairie Research Institute
University of Illinois at Urbana-Champaign
Champaign, Illinois 61820
Ph: (217) 244-9306

Merrick Project Manager:

Name: Doug Jacoby, CMS, GISP
Address: 5970 Greenwood Plaza Blvd.
Greenwood Village, CO 80111
Office: (303) 353-3903
E-mail: doug.jacoby@merrick.com

Prepared For:

Illinois State Geological Survey
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Submitted By:

MERRICK®

Table of Contents

Glossary of Terms

Term	Description
AGL	Above Ground Level
AGPS	Airborne Global Positioning System
AGNSS	Airborne Global Navigation Satellite System
ANPD	Aggregate Nominal Pulse Density
ANPS	Aggregate Nominal Pulse Spacing
ASPRS	American Society of Photogrammetry and Remote Sensing
AT	Aerial Triangulation
CD	Compact Disk
CMS	Certified Mapping Scientist
CORS	Continuous Operating Reference Station
CP	Certified Photogrammetrist
CVA	Consolidated Vertical Accuracy
DACS™	Digital Airborne Camera System
DEM	Digital Elevation Model
DFIRM	Digital Flood Insurance Rate Maps
DSM	Digital Surface Model
DTM	Digital Terrain Model
DVD	Digital Versatile Disk / Digital Video Disk
DXF	Data Exchange Format / Drawing Interchange
FIRM	Flood Insurance Rate Maps
FEMA	Federal Emergency Management
FGDC	Federal Geographic Data Committee
FVA	Fundamental Vertical Accuracy
FY	Fiscal Year
GIS	Geographic Information System
GISP	Geographic Information System Professional
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSD	Ground Sample Distance
HARN	High Accuracy Reference Network
HDD	Hard Drive Disk
HPGN	High Precision Geodetic Network
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
LAS	(or .las) – industry accepted LIDAR data exchange file format
LB	License Business
LS	Land Surveyor
LiDAR	(or Lidar) Light Detection And Ranging
MARS®	Merrick Advanced Remote Sensing
Merrick	Merrick & Company
MSL	Mean Sea Level
NAD	North American Datum
NDEP	National Digital Elevation Program
NGP	National Geospatial Program
NGS	National Geodetic Survey
NMAS	National Map Accuracy Standards
No.	Number

NPS	Nominal Point Spacing
NSRS	National Spatial Reference System
NSSDA	National Standard for Spatial Data
NVA	Non-vegetated Vertical Accuracy
OPUS	Online Positioning User Service
PDOP	Positional Dilution Of Precision
PLS	Professional Land Surveyor
PLSS	Public Land Survey System
ppsm	Points (or pulses) per square meter
PSM	Professional Surveyor and Mapper
QL1	Quality Level One
QL2	Quality Level Two
RLS	Registered Land Surveyor
RGB	Red, Green, Blue (i.e., three-band image)
RGBNIR	Red, Green, Blue, Near Infra-Red (i.e., four-band image)
RMSE	Root Mean Square Error
SBET	Smoothed Best Estimated Trajectory
SHA	Secured Hash Standard
SPCS	State Plane Coordinate System
SVA	Supplemental Vertical Accuracy
TIN	Triangular Irregular Network
USGS	United State Geological Survey
VVA	Vegetated Vertical Accuracy
XML	eXtensible Markup Language

Project Summary

The University of Illinois at Urbana-Champaign ("UIUC") awarded Merrick & Company ("Merrick") the projects **U20067: LiDAR 2020-Data Acquisition of 5 Counties in Wabash & Embarras Basin** and **U20125: LiDAR 2020-Data Processing of 5 Counties in Wabash & Embarras Basin (IL_8County_2020_A20)**. This Professional Services award supports the Illinois Height Modernization Program ("ILHMP"), which is managed by the Illinois State Geological Survey ("ISGS"). The required Professional Services included the acquisition and processing of high fidelity lidar data for Clark, Coles, Cumberland, Douglas and Edgar counties located in the Wabash and Embarras Basin within the state of Illinois. The original project area was comprised of approximately 2,505 square miles. Acquisition services include LiDAR acquisition; ground control survey; LiDAR post-processing, LiDAR calibration, and; QA/QC reporting. In addition to the acquisition efforts, LiDAR classification; hydro-flattening; QA/QC, and; development of derivative deliverable products (including metadata) will be prepared for two (2) Pilot Project locations identified prior to the completion of the LiDAR acquisition.

The lidar data requirements and deliverables meet Quality Level Two (QL2) standards for final deliverables as outlined in the USGS-NGP Lidar Base Specifications, Version 2.1, October 2019 (https://www.usgs.gov/media/files/lidar-base-specification-version-21). QL2 lidar specifications suggest a pulse density of greater than or equal to two pulses per square meter (≥2ppsm) Aggregate Nominal Pulse Density (ANPD), and pulse spacing of less than or equal to seventy-one centimeters (≤0.71m) Aggregate Nominal Pulse Spacing (ANPS). For this project, the point density specification was modified to produce an Aggregate Nominal Point Density (ANPD) of greater than or equal to four points per square meter (≥4ppsm), or less than or equal to five-tenths of a meter (≤0.50m) Aggregate Nominal Point Spacing (ANPS).

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

Absolute Vertical Accuracy

- ≤10cm RMSEz
- ≤19.6cm Non-vegetated Vertical Accuracy (NVA) at the 95% confidence level
- ≤30.0cm Vegetated Vertical Accuracy (VVA) at the 95% percentile

Project Spatial Reference

- Horizontal Datum – North American Datum of 1983 (NAD 83)
- Epoch – National Adjustment of 2011 (NA2011) (epoch 2010.00)
- Geoid – GEOID 12B
- Vertical Datum – North American Vertical Datum of 1988 (NAVD 88)
- Projection – Illinois State Plane Coordinate System, East Zone (FIPSZONE: 1201)
- Units – U.S. Survey Foot

CONTACT INFORMATION

Questions regarding this report should be addressed to:

Doug Jacoby, CMS, GISP
Program Manager
Merrick & Company
5970 Greenwood Plaza Blvd.
Greenwood Village, CO 80111
T: +1 303-353-3903
Doug.jacoby@merrick.com

Project Report

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 U20067/U20125.

Lidar Flight Information

The acquisition area for the U20067/U20125 project was originally defined by the following description:

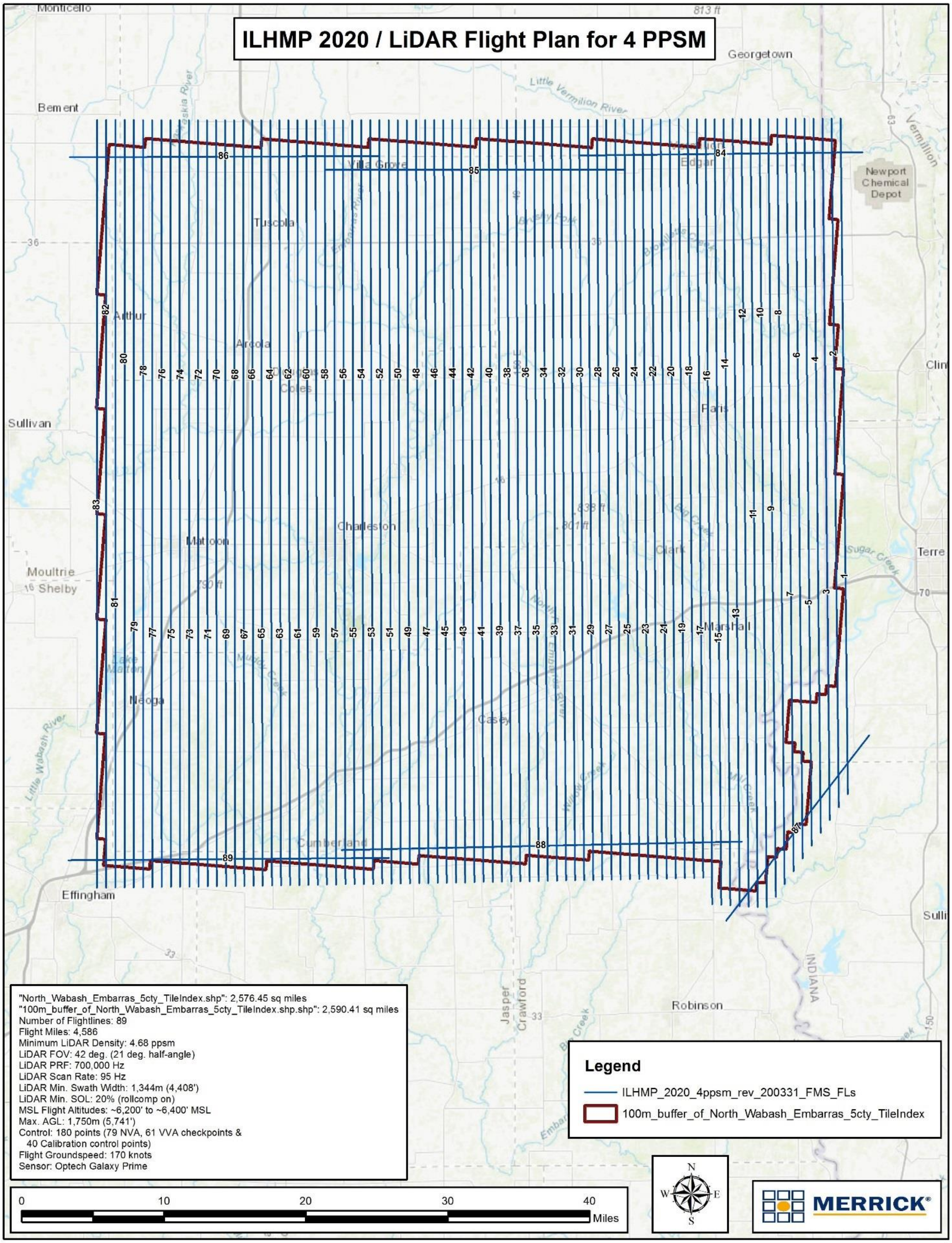
- UIUC / ISGS project boundary
- Full extent of the client-provided Esri shapefile *Wabash_Embarras_North_TileIndex*
- Approximately 2,505.02 square miles
- 17,459 tiles formatted as 2,000' x 2,000'

As a result of supplemental funding from the USGS 3DEP program, the project area was revised / expanded as follows:

- USGS 3DEP project boundary
- Full extent of the Esri shapefile *USGS_Albers_1KM_N*
- Approximately 2,576.45 square miles
- 18,288 tiles formatted as 2,000' x 2,000'
- USGS Project Information
    - Work Package Name: IL_8County_2020_A20
    - Work package ID: 192235
    - PTS URL: https://pts2.er.usgs.gov/PTS/package/192235

Merrick acquired the lidar point cloud utilizing an Optech Galaxy PRIME lidar sensor. The Galaxy PRIME is a high performance (1,000 kHz / 1 MHz) lidar sensor capable of collecting large areas efficiently.

Merrick planned an acquisition area to include a proper flight line orientation and numbers for accurate sensor calibration. See below illustration of the proposed lidar flight plan.


ILHMP 2020 / LiDAR Flight Plan for 4 PPSM
"North_Wabash_Embarras_5cty_TileIndex.shp": 2,576.45 sq miles
"100m_buffer_of_North_Wabash_Embarras_5cty_TileIndex.shp.shp": 2,590.41 sq miles
Number of Flightlines: 89
Flight Miles: 4,586
Minimum LiDAR Density: 4.68 ppsm
LiDAR FOV: 42 deg. (21 deg. half-angle)
LiDAR PRF: 700,000 Hz
LiDAR Scan Rate: 95 Hz
LiDAR Min. Swath Width: 1,344m (4,408')
LiDAR Min. SOL: 20% (rollcomp on)
MSL Flight Altitudes: ~6,200' to ~6,400' MSL
Max. AGL: 1,750m (5,741')
Control: 180 points (79 NVA, 61 VVA checkpoints & 40 Calibration control points)
Flight Groundspeed: 170 knots
Sensor: Optech Galaxy Prime
Legend
ILHMP_2020_4ppsm_rev_200331_FMS_FLs
100m_buffer_of_North_Wabash_Embarras_5cty_TileIndex
0 10 20 30 40 Miles
Tuscola
Arthur
Arcola
Charleston
Mattoon
Neoga
Casey
Cumberland
Effingham
Paris
Clark
Marshall
Edgar
Villa Grove
Georgetown
Bement
Sullivan
Moultrie
Shelby
Robinson
Jasper
Crawford
Newport Chemical Depot
INDIANA
MERRICK

Aerial Mission(s) Duration / Time

Merrick's lidar acquisition was collected using a fixed wing aircraft and an Optech Galaxy PRIME lidar sensor. Data collection for the project was accomplished between April 8, 2020 and May 3, 2020. 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, and D. 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 GNSS seconds of the week.

Mission(s)	Date	Sensor S/N	Actual Avg. MSL (ft)
200408_A	April 8, 2020	5060385	6316
200410_A	April 10, 2020	5060385	6332
200410_B	April 10, 2020	5060385	6348
200418_A	April 18, 2020	5060385	6283
200419_A	April 19, 2020	5060385	6266
200420_A	April 20, 2020	5060385	6332
200421_A	April 21, 2020	5060385	6299
200422_A	April 22, 2020	5060385	6266
200502_A	May 2, 2020	5060385	6201
200503_A	May 3, 2020	5060385	6217
200503_B	May 3, 2020	5060385	6316

GNSS / IMU Data

The airborne GNSS 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 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 GNSS include analyzing the combined separation of the forward and reverse GNSS 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 GNSS trajectory was combined with the raw IMU data and post-processed using POSPac Mobile Mapping Suite version 8.x. The 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 LMS processor software for each pulse which ensures the greatest chance of ground returns in a heavily forested area.

GNSS Controls

Virtual Ground GNSS Base Station(s) were used to control the lidar airborne flight lines. Trimble CenterPoint™ RTX™ correction service is a high-accuracy, satellite-delivered global positioning service. This technology provides high-accuracy GNSS positioning without the use of traditional reference station-based differential RTK infrastructure and delivers very high cm level accuracy. In addition, CORS (Continually Operating Reference Stations) are at times used to further enhance the airborne solution.

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

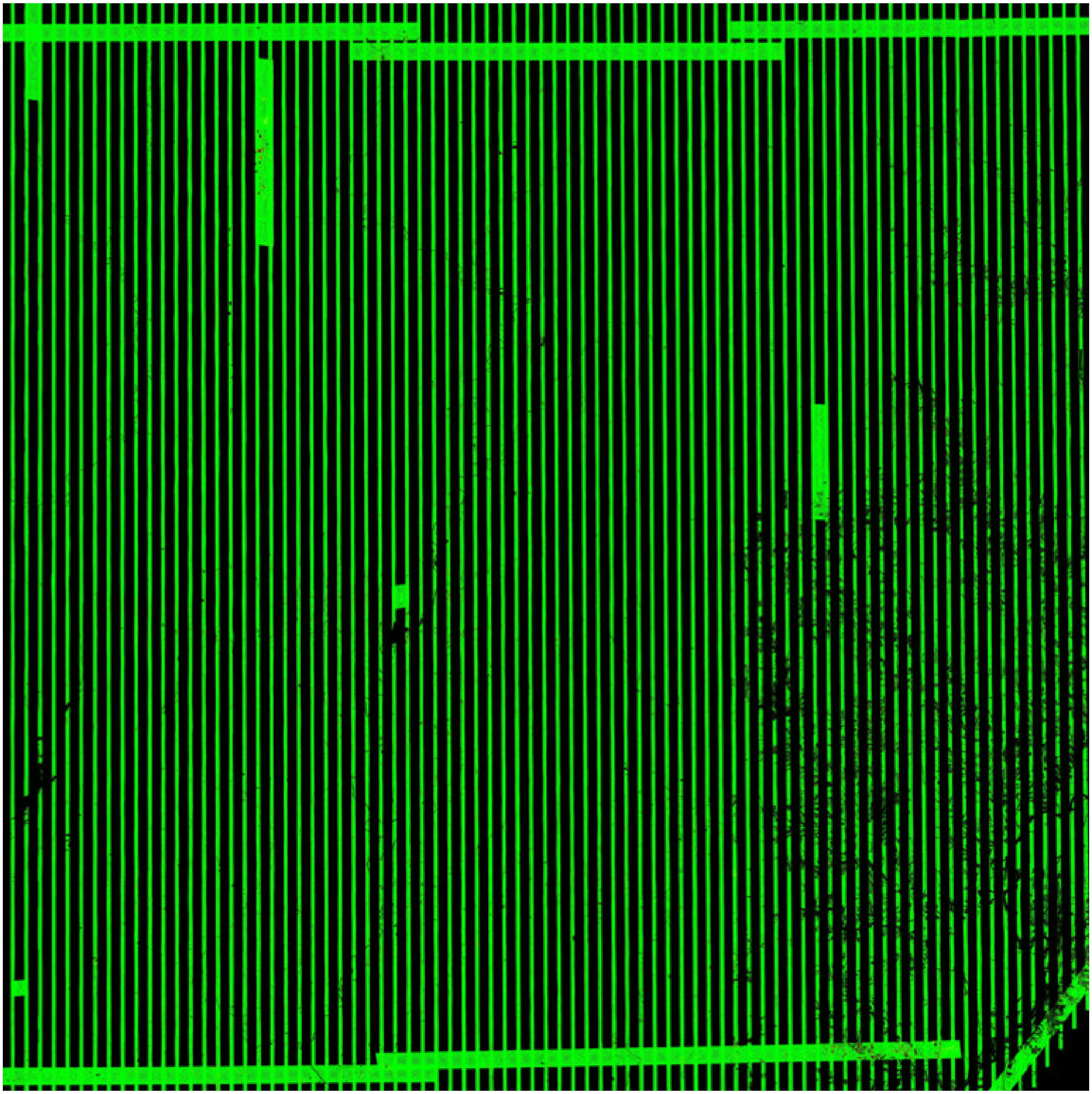
Merrick takes great care to ensure all lidar acquisition missions are carried out in a manner conducive to post-processing an accurate data set. This begins in the flight-planning stage with attention to GNSS baseline distances and GNSS satellite constellation geometry and outages. Proper AGNSS surveying 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.

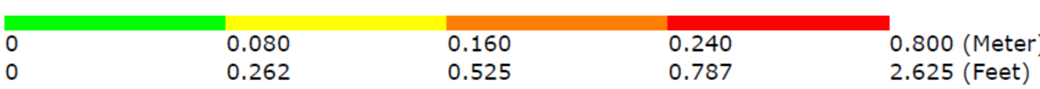
A minimum of one cross-flight is planned for each mission and over roadways where possible. Cross-flight lines provides a common control surface used to remove any vertical discrepancies in the lidar data between flight lines. Cross-flight lines are critical to ensure flight line ties across the project area. The areas of overlap between flight lines are used to boresight (calibrate) the lidar point cloud to achieve proper flight line to flight line alignment in all three axes. This includes adjustment of both IMU and scanner-related variables such as roll, pitch, heading, 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.




0
0.080
0.160
0.240
0.800 (Meter)
0
0.262
0.525
0.787
2.625 (Feet)

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 forty-four (44) surveyed ground points used for lidar calibration.

Project Data Unit: U.S. Survey Foot
Vertical Accuracy Class tested: 10.0-cm
Elevation Calculation Method: Interpolated from TIN
LiDAR Classifications Included: 0-4, 6-118, 120-255

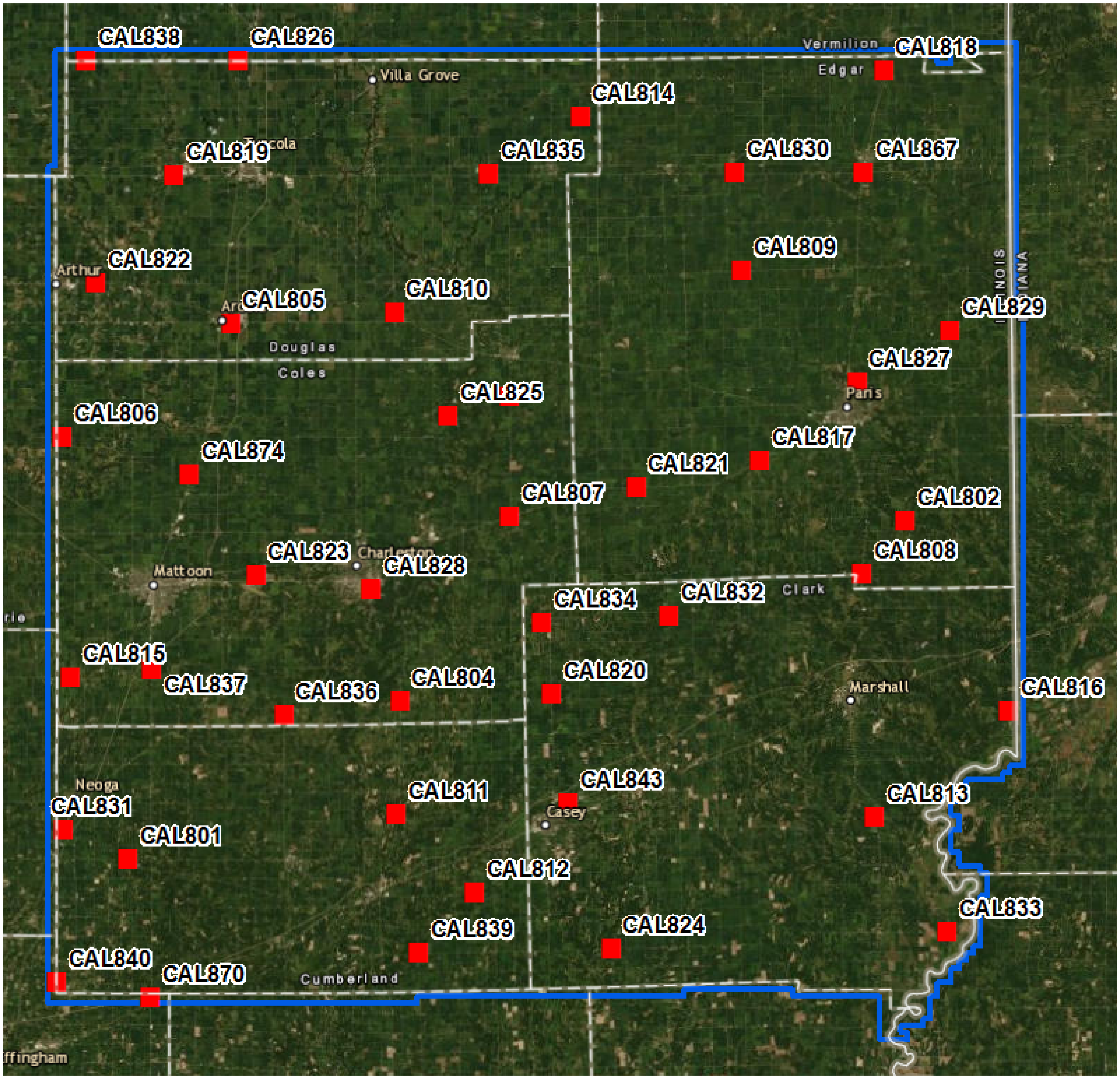
Check Points in Report: 44
Check Points with LiDAR Coverage: 44
Check Points (NVA): 44
Check Points (VVA): 0
Average Vertical Error Reported: 0.000 U.S. Survey Foot
Maximum (highest) Vertical Error Reported: 0.34 U.S. Survey Foot
Median Vertical Error Reported: 0.007 U.S. Survey Foot
Minimum (lowest) Vertical Error Reported: -0.279 U.S. Survey Foot
Standard deviation of Vertical Error: 0.123 U.S. Survey Foot
Skewness of Vertical Error: 0.345
Kurtosis of Vertical Error: 0.139
Non-vegetated Vertical Accuracy (NVA) RMSE(z): 3.714cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 7.280cm PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 7.280cm
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 3.981cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 7.803cm 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 = 3.714cm, equating to +/- 7.280cm at the 95% confidence level.

Checkpoint Id	Checkpoint X	Checkpoint Y	Coverage	Checkpoint Z	Z from lidar	Z Error
CAL833	1191883	928951.8	Yes	449.297	449.637	0.34
CAL824	1098766	924224.4	Yes	530.925	531.178	0.253
CAL817	1139793	1059306	Yes	712.102	712.277	0.175
CAL874	982080.6	1055265	Yes	670.511	670.67	0.159
CAL802	1180081	1042547	Yes	721.755	721.898	0.143
CAL867	1168643	1139021	Yes	643.157	643.288	0.131
CAL821	1105693	1052021	Yes	729.139	729.261	0.122
CAL813	1171779	960649.4	Yes	549.767	549.87	0.103
CAL830	1132908	1138860	Yes	660.4905	660.586	0.096
CAL816	1208903	990072.6	Yes	465.122	465.217	0.095
CAL809	1134892	1111890	Yes	669.9763	670.064	0.088
CAL832	1114654	1016235	Yes	673.475	673.558	0.083
CAL836	1008223	988953.4	Yes	707.591	707.672	0.081
CAL831	947266	957046.1	Yes	657.042	657.114	0.072
CAL808	1168125	1027962	Yes	630.97	631.038	0.068
CAL827	1166798	1080903	Yes	670.9655	671.011	0.045
CAL828	1032315	1023480	Yes	705.32	705.355	0.035
CAL838	953417.9	1169907	Yes	683.574	683.602	0.028
CAL806	946979.5	1065762	Yes	669.877	669.904	0.027

CAL840	945268.5	914814.6	Yes	624.906	624.926	0.02
CAL804	1040320	992602.2	Yes	682.509	682.528	0.019
CAL829	1192381	1095396	Yes	645.2855	645.292	0.007
CAL839	1045440	923112.1	Yes	593.359	593.365	0.006
CAL811	1039196	961261.4	Yes	553.758	553.736	-0.022
CAL822	956267	1108407	Yes	653.7965	653.768	-0.029
CAL801	964981.6	949006.3	Yes	643.501	643.469	-0.032
CAL814	1090191	1154406	Yes	652.0935	652.05	-0.043
CAL834	1079731	1014466	Yes	745.423	745.357	-0.066
CAL826	995631.3	1169984	Yes	685.9425	685.873	-0.069
CAL837	971630.9	1001549	Yes	741.932	741.851	-0.081
CAL815	949130.9	999124	Yes	692.373	692.292	-0.081
CAL807	1070600	1043710	Yes	693.126	693.042	-0.084
CAL803	1070774	1077057	Yes	661.3675	661.282	-0.085
CAL818	1174168	1167037	Yes	671.6255	671.523	-0.102
CAL810	1038810	1100165	Yes	645.349	645.242	-0.107
CAL870	971316.1	910580.7	Yes	601.155	601.045	-0.11
CAL819	977756.2	1138057	Yes	670.267	670.152	-0.115
CAL835	1064787	1138362	Yes	643.0165	642.887	-0.13
CAL823	1000537	1027619	Yes	703.982	703.848	-0.134
CAL812	1060974	939562.4	Yes	615.248	615.107	-0.141
CAL825	1053632	1071448	Yes	662.4105	662.256	-0.154
CAL805	993559.3	1097195	Yes	677.182	677.026	-0.156
CAL820	1082293	994639.6	Yes	671.056	670.879	-0.177
CAL843	1086961	964650.2	Yes	639.703	639.424	-0.279

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 used the ASPRS LAS Specification Version 1.4 – R15 (revised 09 July 2019), Point Data Record Format 6 for this project and classified the lidar point cloud in accordance with the following classification classes and bitflags. The following outlines project specific requirements.

- Class 1 = Unclassified
- Class 2 = Bare-earth Ground
- Class 3 = Low Vegetation [0.5-5 feet]
- Class 4 = Medium Vegetation [5-20 feet]
- Class 5 = High Vegetation [>20 feet]
- Class 6 = Buildings
- Class 7 = Low point (noise)
- Class 9 = Water
- Class 17 = Bridge decks
- Class 18 = High noise
- Class 20 = Ignored ground (near a breakline)

- 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.
    - Model Key Points: Created from ground (class = 2) points using a five foot horizontal and a 0.2 foot vertical variance.

Merrick 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.

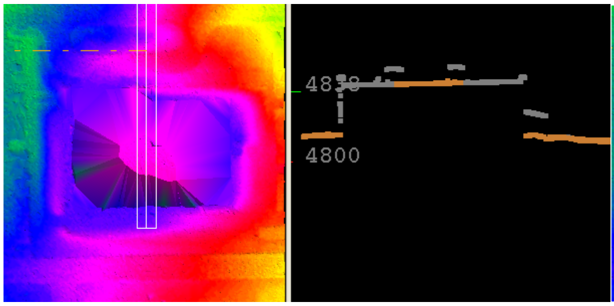


Figure 1

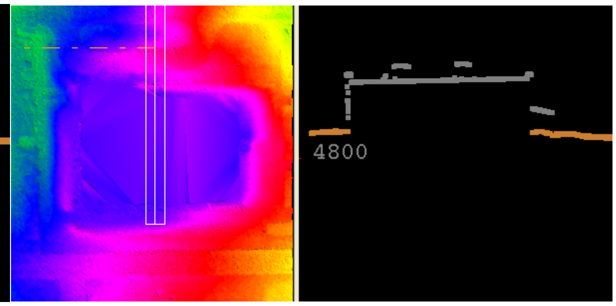


Figure 2

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.

Filtered Lidar Checkpoint Report

After hand-filtering has been completed and quality checked, a Checkpoint Report is generated to validate that the vertical accuracy of the ground surface is within the defined accuracy specifications. Each surveyed ground checkpoint 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 reports provide statistics for 140 ground survey checkpoints (79 NVA, 61 VVA) used to validate the final filtered lidar surface.

Units: Meter (/US Survey Feet)

Vertical Accuracy Class tested: 10-cm

Check Points in defined project area (DPA):	140
Check Points with Lidar Coverage	140
Check Points with Lidar Coverage (NVA)	79
Check Points with Lidar Coverage (VVA)	61
Average Z Error (NVA)	0.006/0.018
Maximum Z Error (NVA)	0.112/0.367
Median Z Error (NVA)	0.011/0.035
Minimum Z Error (NVA)	-0.085/-0.279
Standard deviation of Vertical Error (NVA)	0.046/0.151
Skewness of Vertical Error (NVA)	0.051
Kurtosis of Vertical Error (NVA)	-0.445
Non-vegetated Vertical Accuracy (NVA) RMSE(z) [1]	0.046/0.151 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- [1]	0.090/0.297 PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-	0.090/0.297
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM) [2]	0.046/0.151 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level (DEM) +/- [2]	0.090/0.090 PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile (TIN) +/- [1]	0.123/0.402 PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile (DEM) +/- [2]	0.128/0.420 PASS

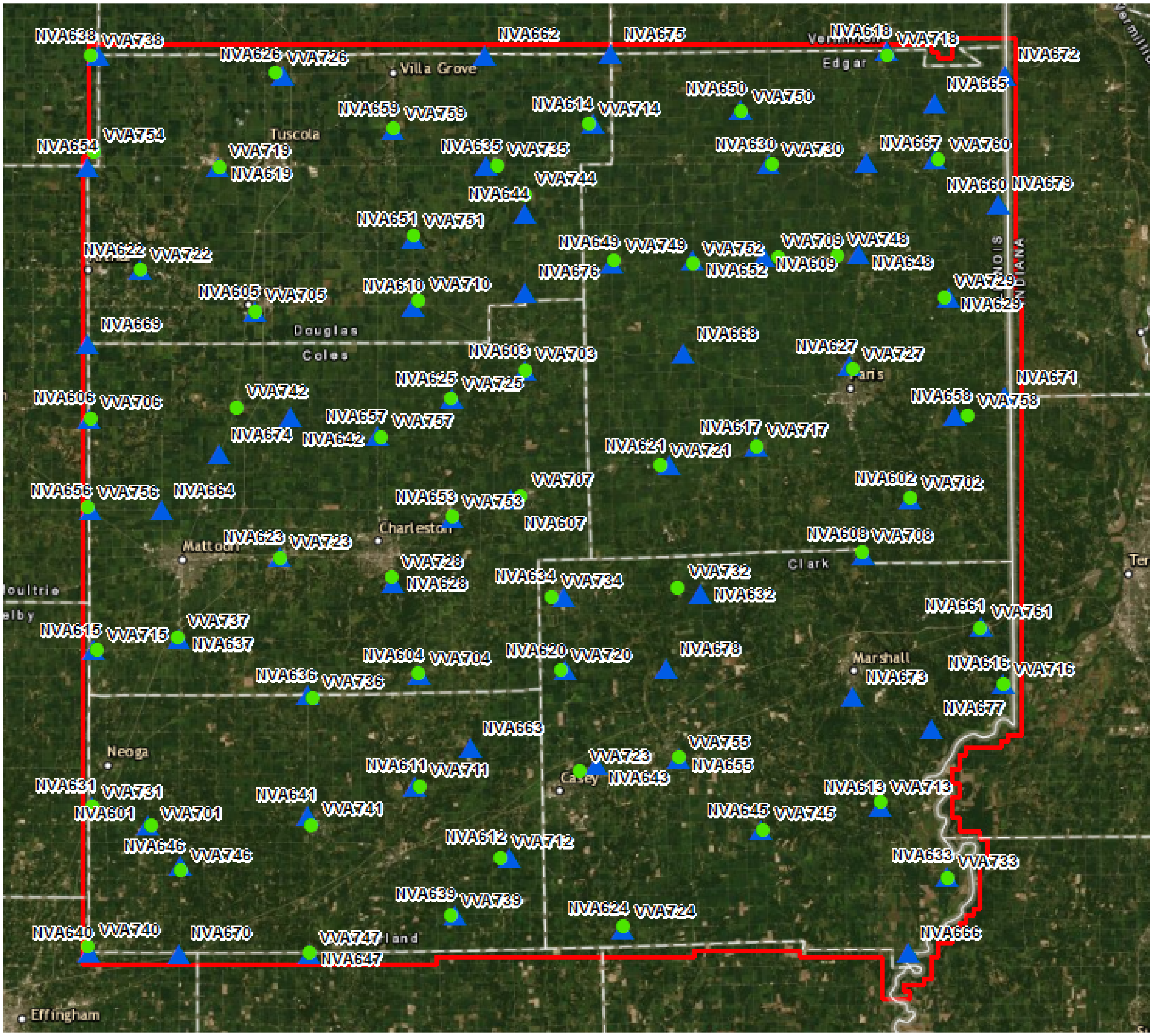
This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 4.6cm, equating to +/- 9.0cm at the 95% confidence level. Actual VVA accuracy was found to be +/- 12.8cm at the 95th percentile.

[1] This value is calculated from TIN-based testing of the lidar point cloud data.

[2] This value is calculated from RAM-based grid testing of the lidar data. The grid cells are sized according to the Quality Level selected, and are defined in the USGS NGP Lidar Base Specification Version 2.1 (Table 6).

Lidar Check Point Layout

NVA
VVA



Hydro-flattening Breakline Collection

Hydro- flattening breaklines are captured per the USGS National Geospatial Program Lidar Base Specification Version 2.1. 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 20) based on predetermined buffer.

Linear hydrographic features

To collect hydrographic features, Merrick 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 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 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 one (1) 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.

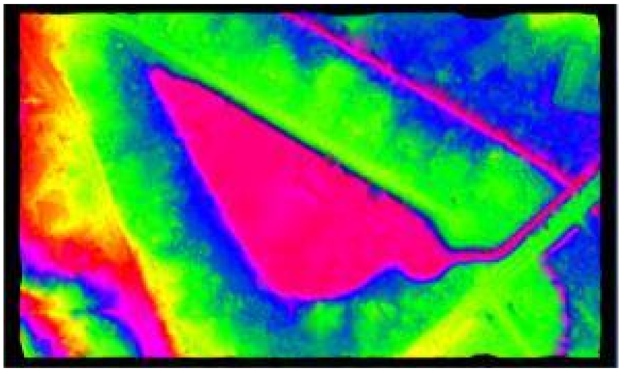
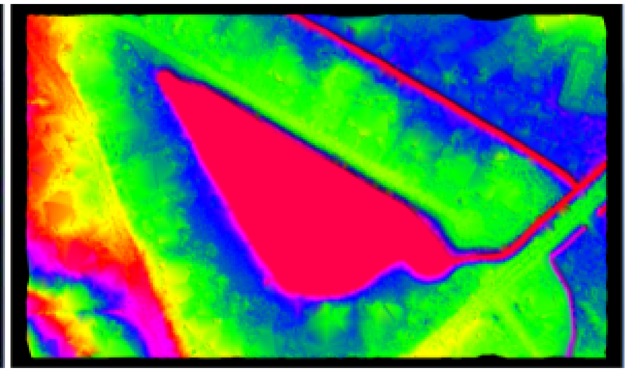



Figure 3 **Figure 4**

List of Deliverables

- Classified LiDAR point cloud
  - Fully compliant ASPRS LAS 1.4-R15, point record format 6
  - By tile
  - Intensity values normalized (rescaled) to 16-bit
- Hydro-flattened breaklines
  - Project-wide Esri feature class(es) for insertion into file geodatabase
    - PolylineZ – double-sided streams and rivers
    - PolygonZ – waterbodies
- Bare-earth Digital Elevation Model (DEM)
  - Two-foot (2’) cell size 32-bit DEM in Cloud Optimized GeoTIFF format
  - Bare-earth (hydro-flattened)
    - Culverts will not be removed from the DEMs
    - Bridges will be removed from the DEMs
  - By tile
- Intensity Images
  - 2’ cell size 8-bit 256-color gray scale in Cloud Optimized GeoTIFF format
  - By tile
- FGDC-compliant metadata in XML format
  - Breaklines
  - Classified_LAS
  - DEM
  - Intensity
  - Project
- Esri shapefiles
  - DPA
  - NVA, VVA lidar checkpoints
  - Calibration control
  - 2,000’ x 2,000’ formatted tiles
- FlightIndex.gdb (this replaces the Swath shapefile)
- MARS® QC folder
  - PDF QC reports
  - Miscellaneous files
- Swath Separation Image (SSI)
- Lidar and Mapping Report
  - Acquisition
  - Processing

- Accuracy assessment

- Ground Control Survey Report
  - Collection
  - Processing
  - Coordinate listing (all points)
  - Photos (all points)
  - Shapefiles of coordinates (all points)

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.

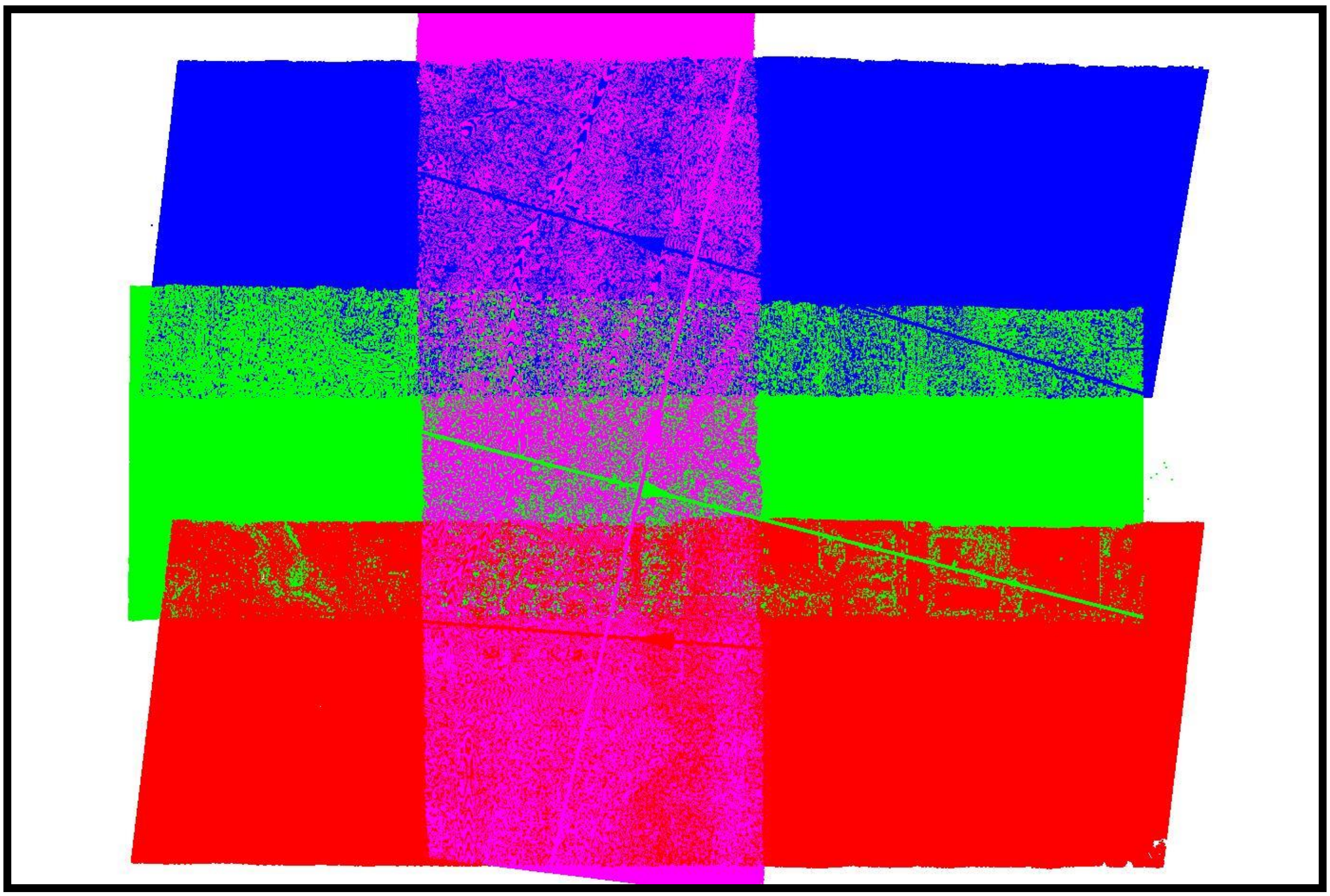
Initial Processing

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.

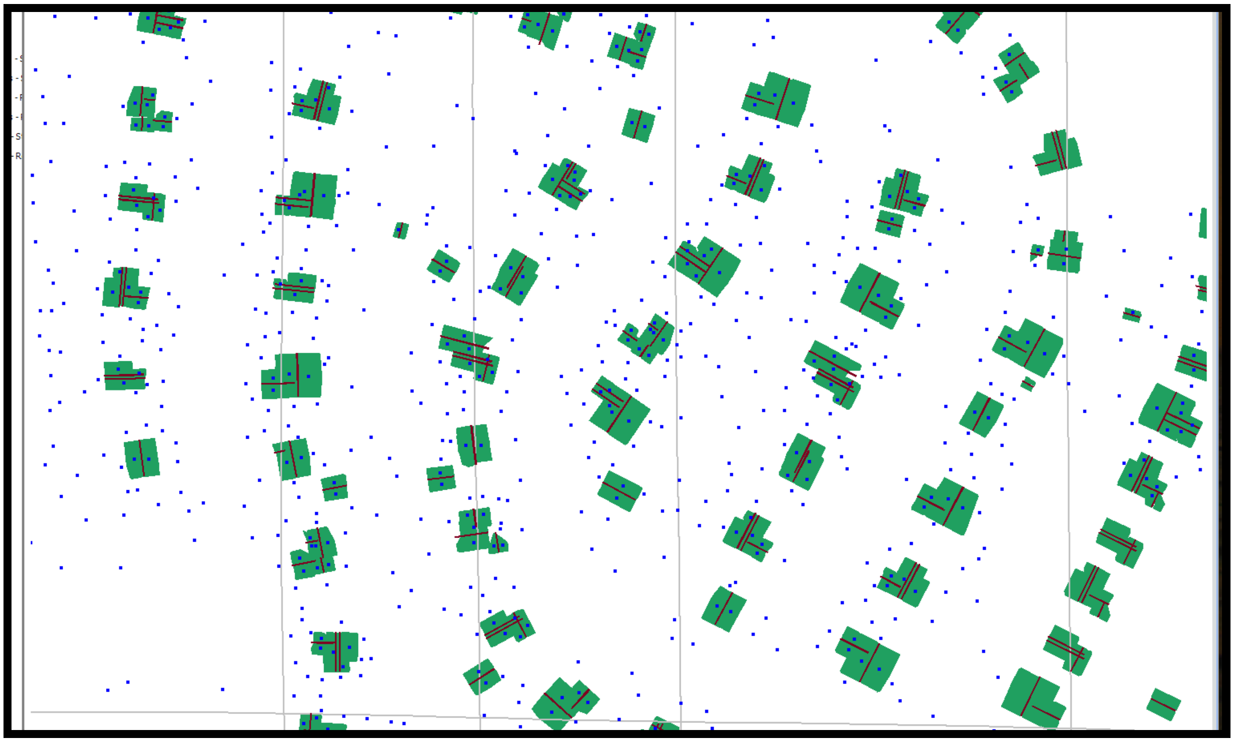
Boresight Self-Calibration Processing Procedures

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.



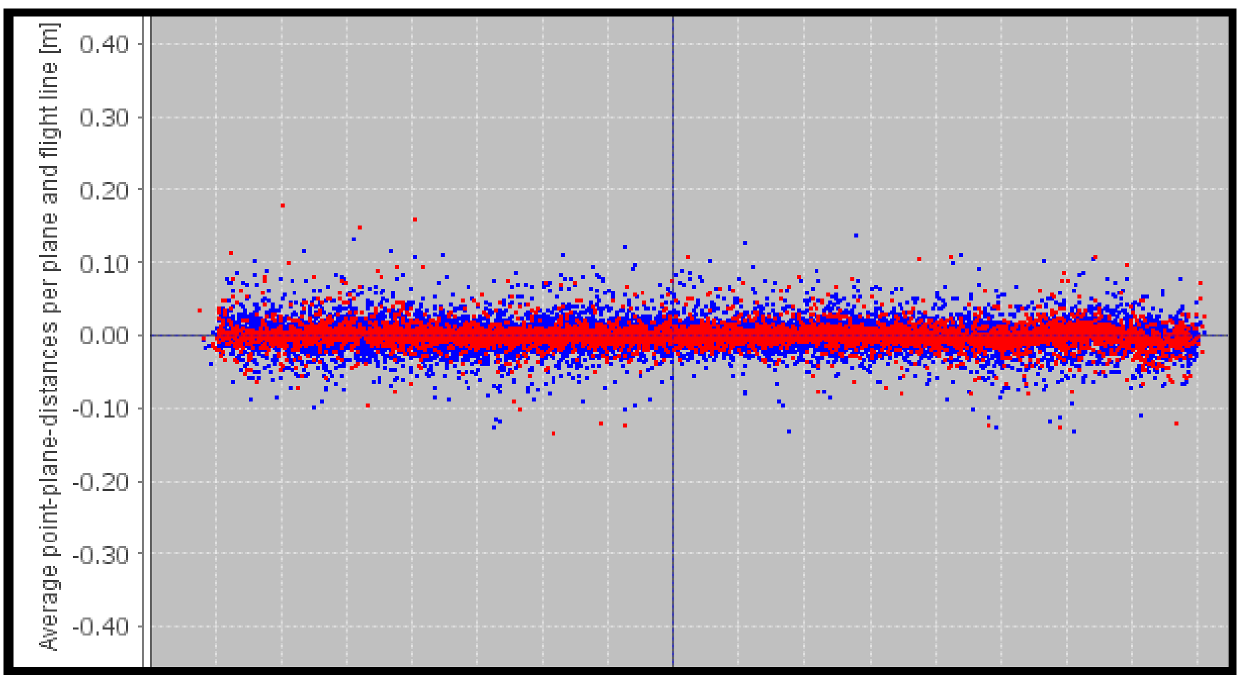
The Boresighting module frees scan angle scale, scan angle lag, XYZ boresight corrections and elevation position corrections while locking scan angle offset and XY position corrections.

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.

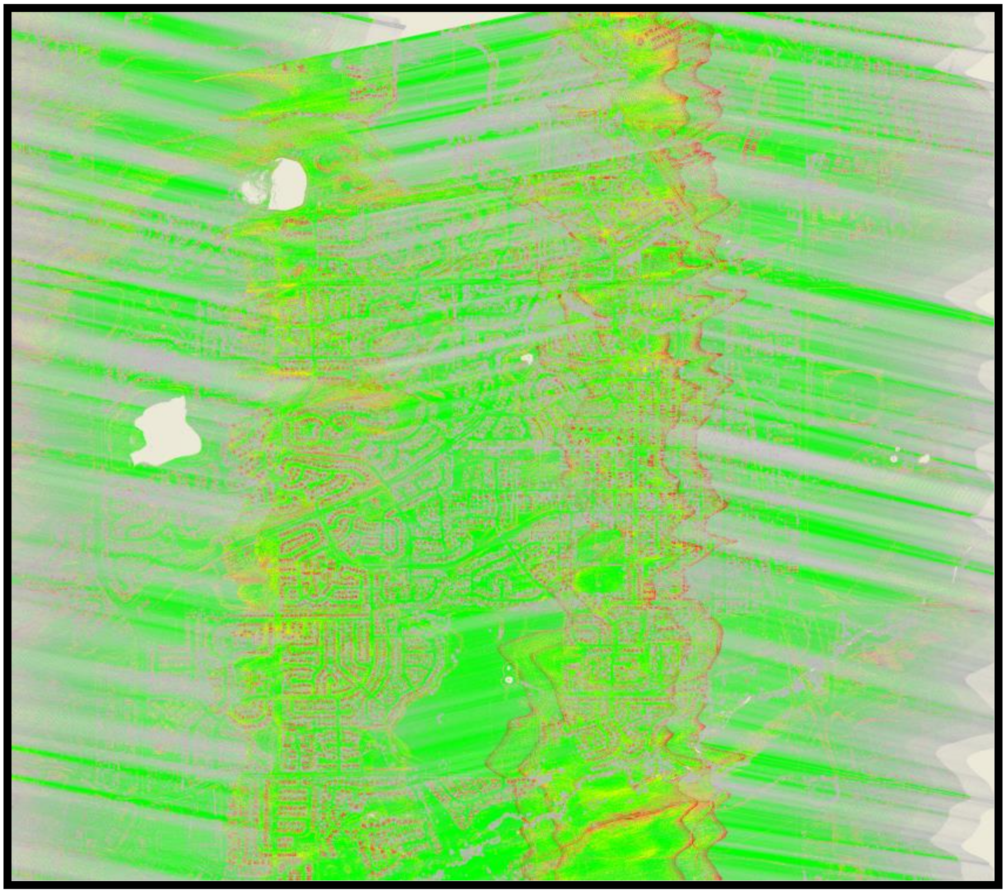


At the conclusion of the self-calibration run the data is quality checked with LMS plots

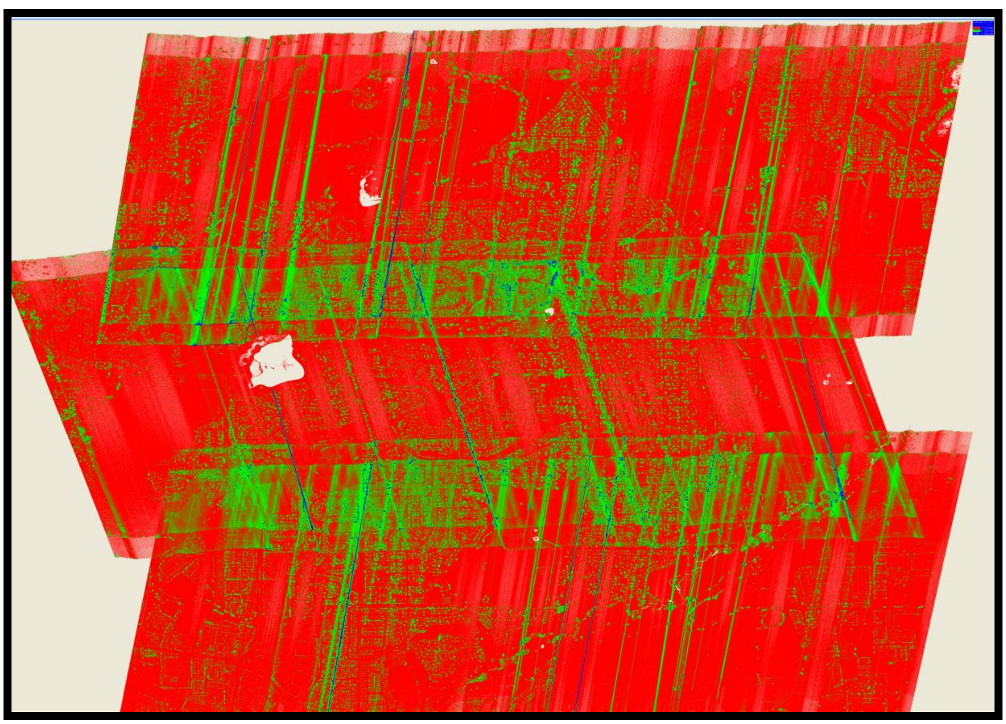
Plot of plane vertical distances from datum plane.



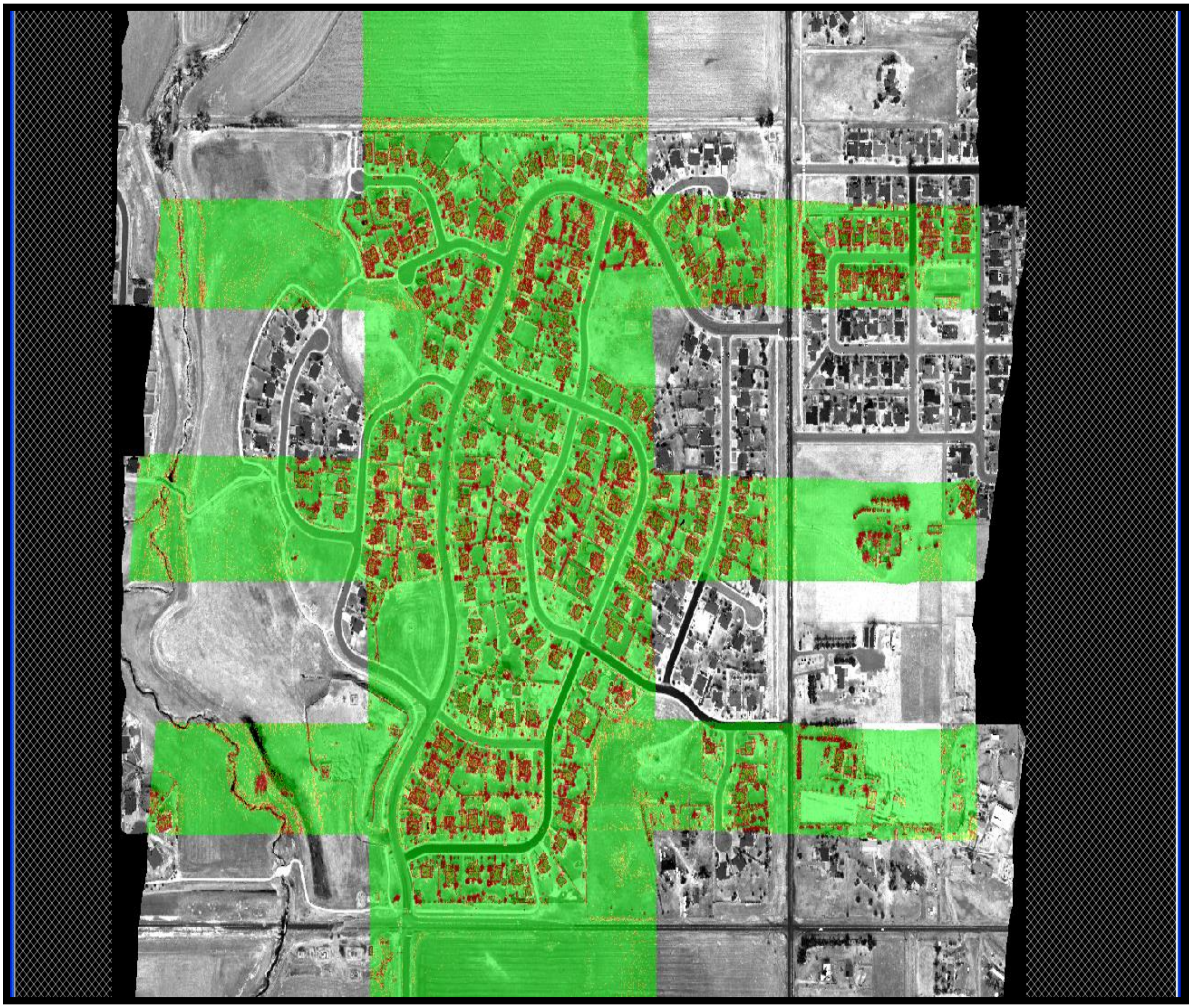
Plot of height differenced between flight lines. (Green=less than 5cm).



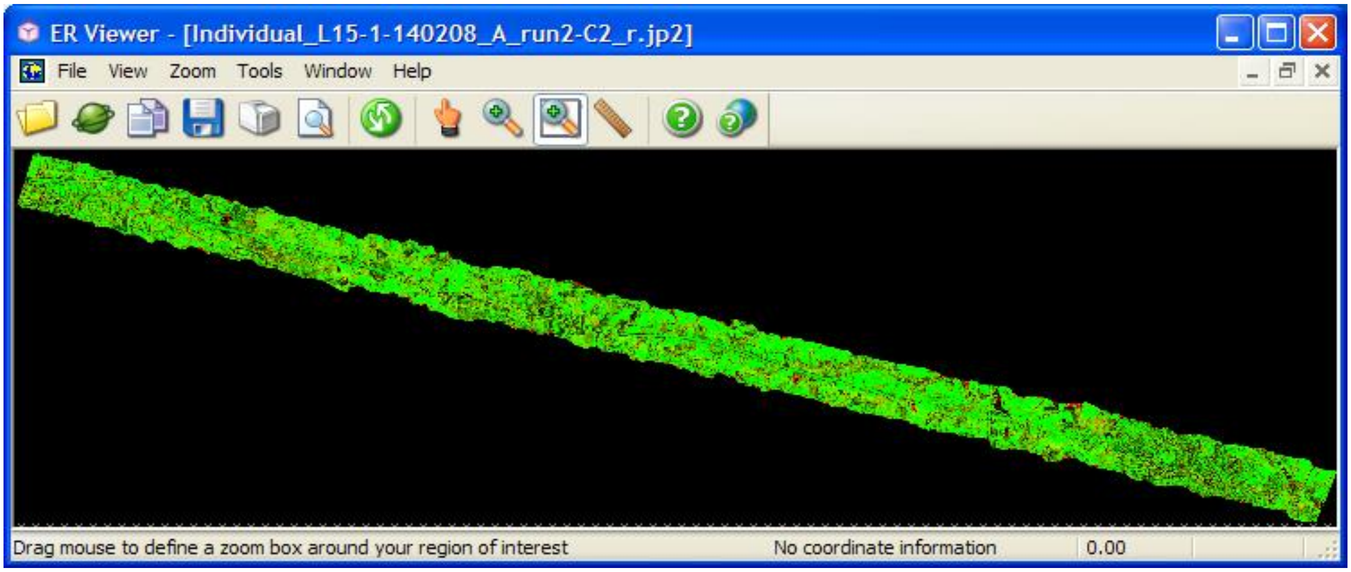
Plot of point densities. (Red=5-9 points per cell, green 10+ points per cell).



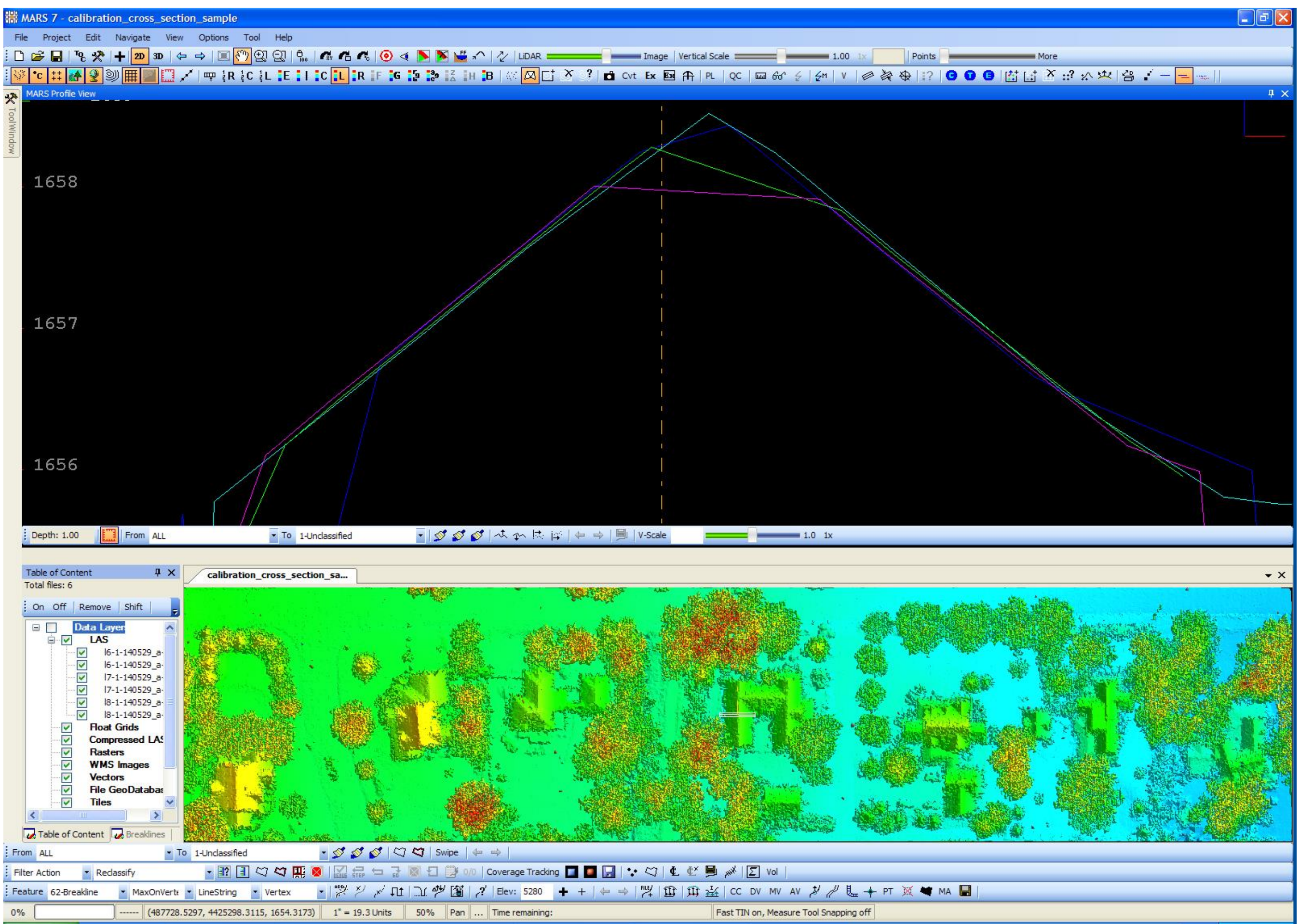
A Flight Line Separation Raster image is generated in Merrick Advanced Remote Sensing Software (MARS®), in this example ground returns from multiple flight lines that are fitting within 3 centimeters are colored green.



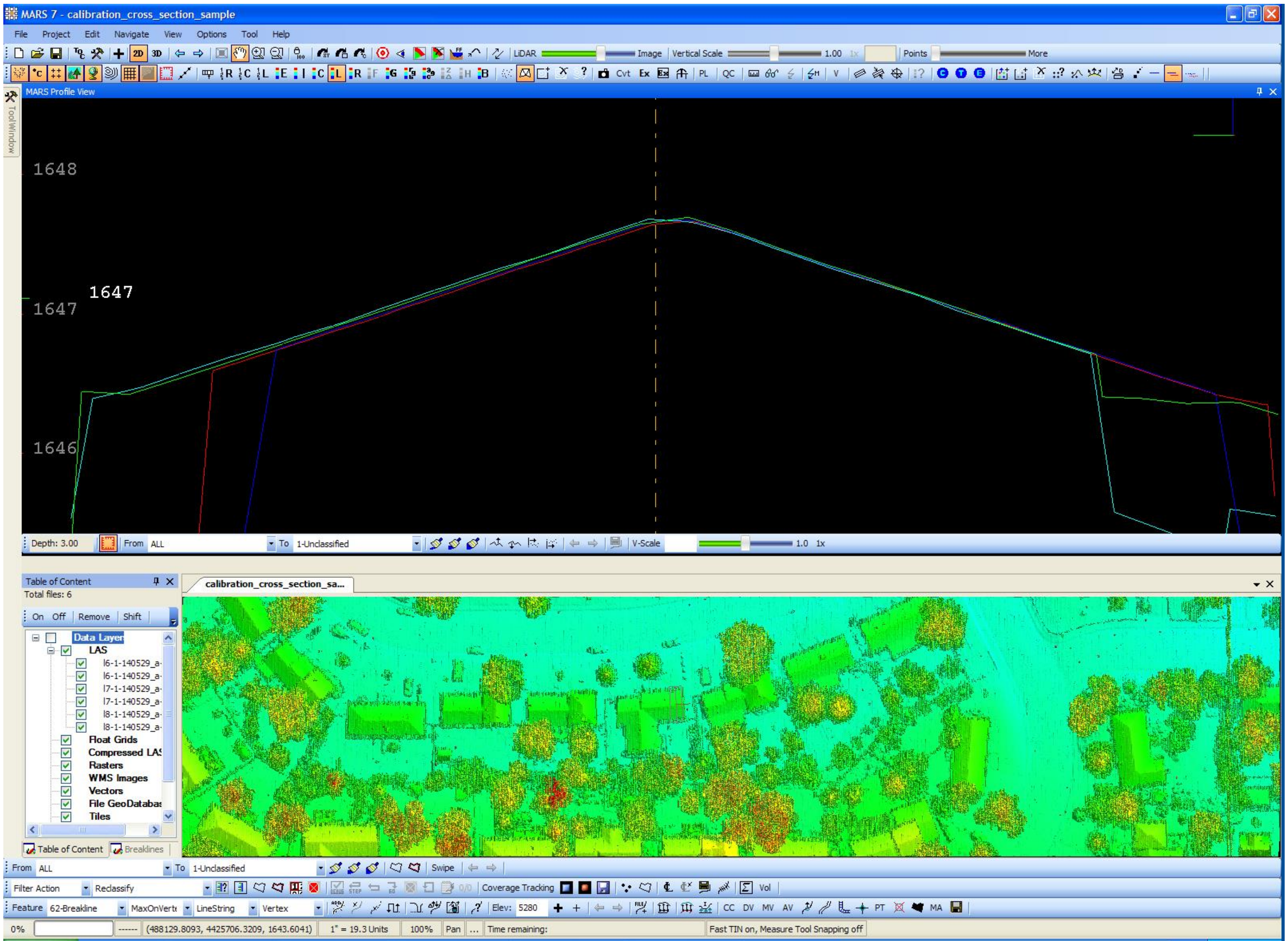
MARS® tests for internal relative vertical accuracy using inbound and outbound scan values. Again, Green is showing inbound and outbound scan data fitting to 3 centimeters.



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.

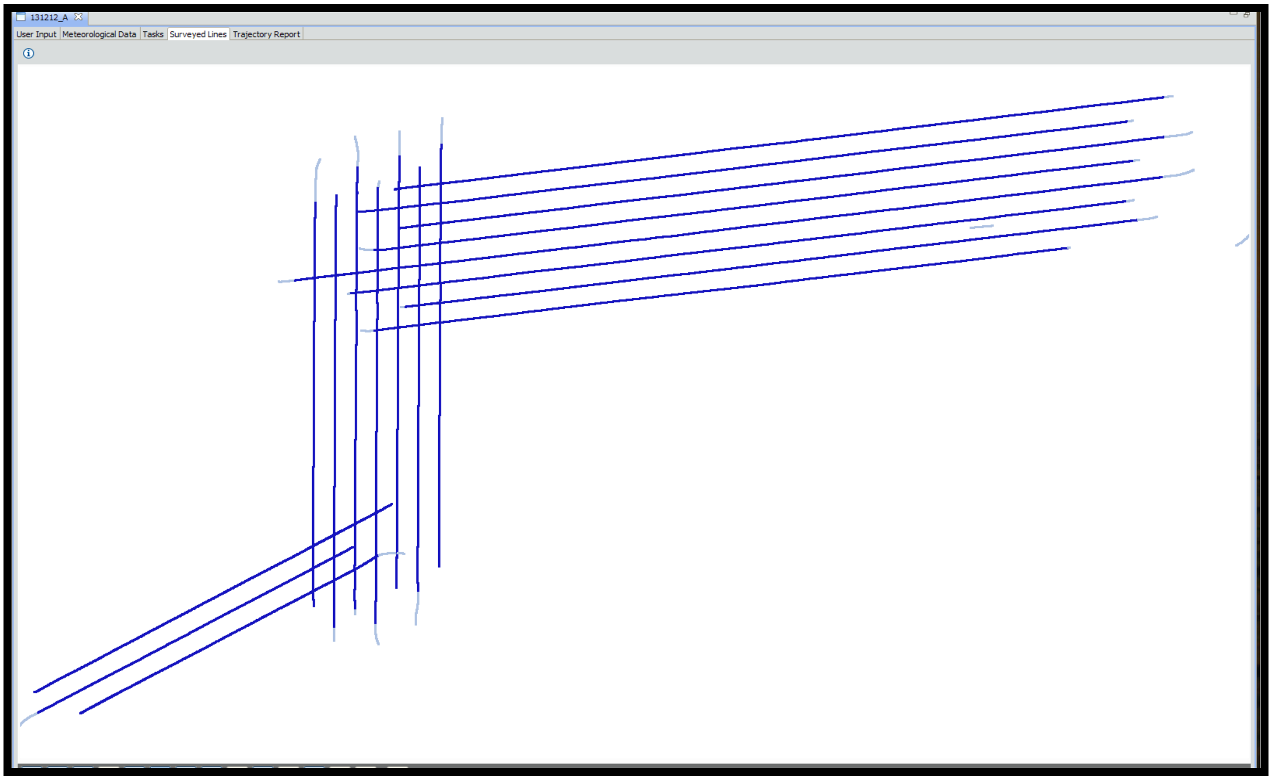


The LMS program outputs a "LCP" file with all the correction parameters. The calibration process may be run several times until the boresight adjustments are acceptable. When the boresight solution is acceptable the LCP file adjustments are saved and also applied to subsequent projects. Each new project 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.

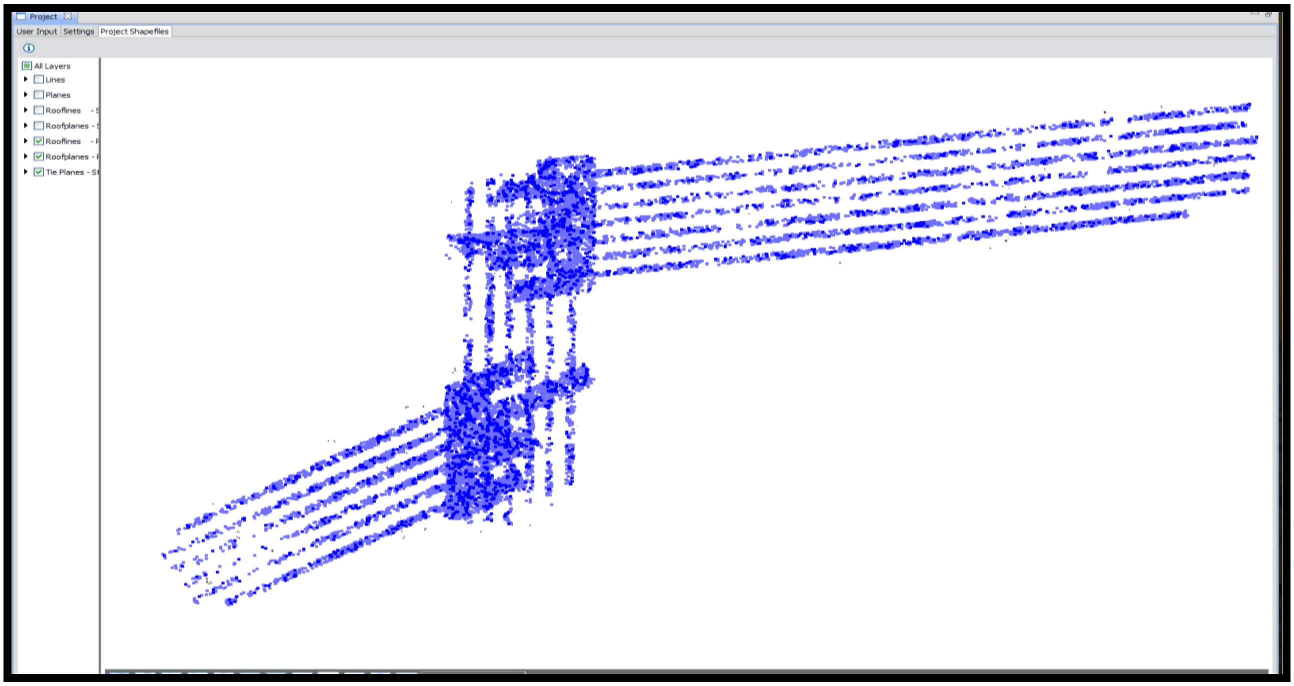
Block LAS Production Processing Procedures

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.

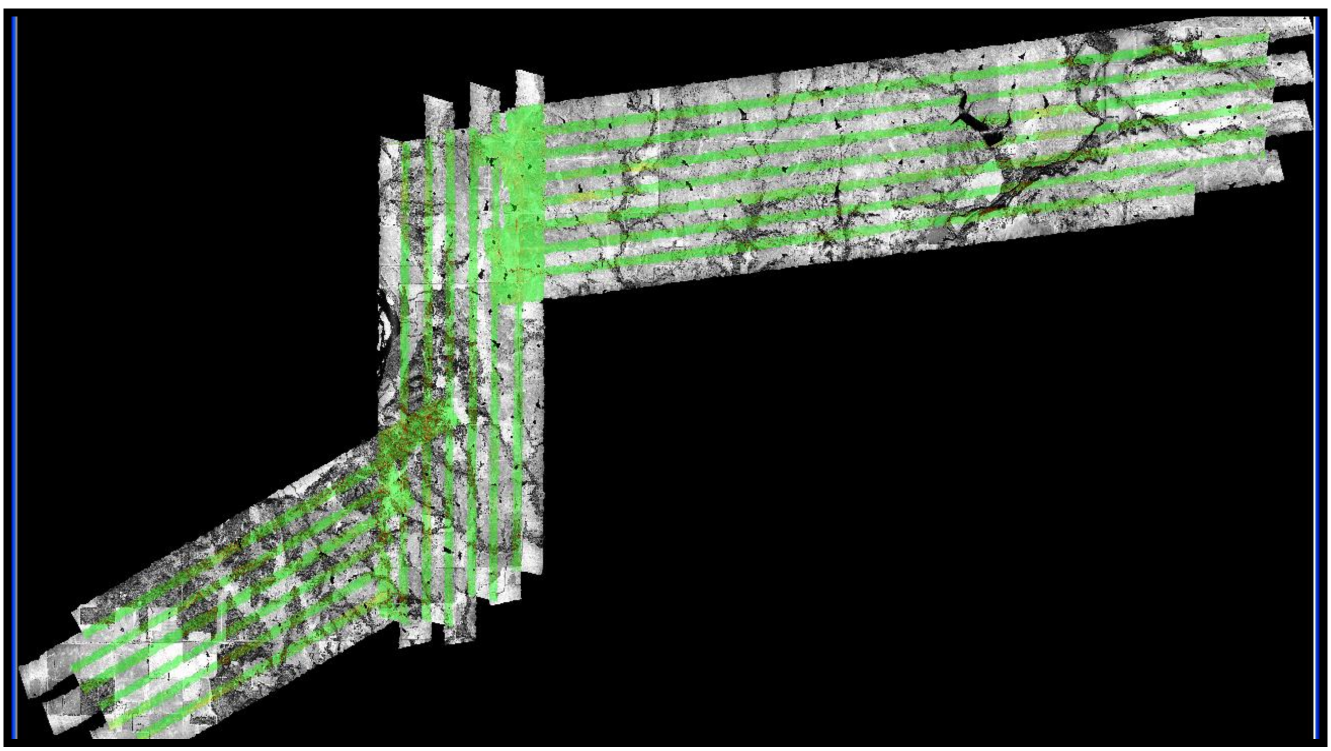
A block of data is selected to process with LMS production settings. Data collected during turns at the ends of flight lines is deselected (light blue lines).



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.

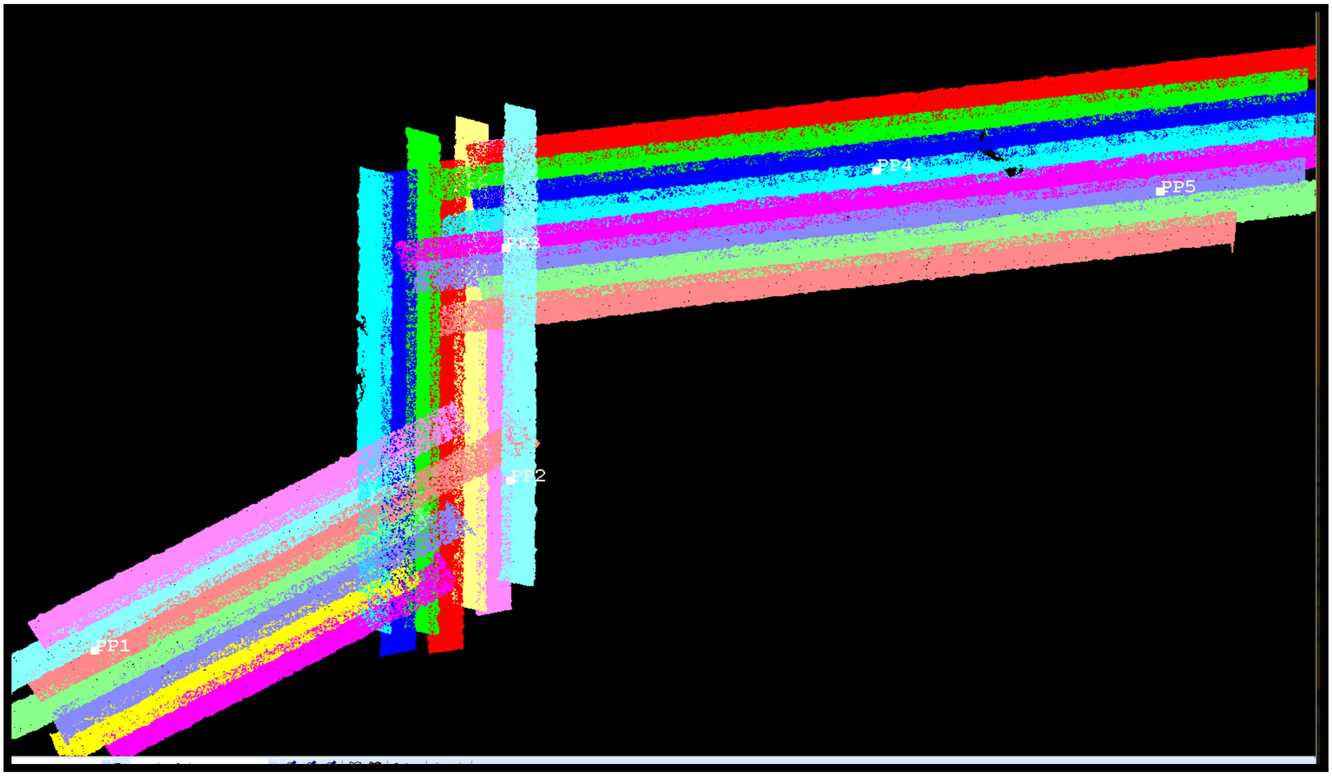


The same quality control outputs used to check self-calibrations are available to analyze the production run. Output plots are again available in LMS and cross sections plus a Flight Line Separation Raster are generated in MARS® to check coverage and quality.



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.

Appendix 2

Survey Report.

JUNEAU
ASSOCIATES, INC., P.C.
ENGINEERING & LAND SURVEYING

VOSB

2100 State Street
P.O. Box 1325
Granite City, IL 62040
618-877-1400 • F.618-452-5541

100 N. Research Dr.
Edwardsville, IL 62025
618-659-0900 • F.618-659-0941

555 West Central Rd., Suite 101
Hoffman Estates, IL 60192
847-991-2004 • F.618-452-5541

330 N. Fourth Street, Suite 200
St. Louis, MO 63102
314-241-4444 • F.314-909-1331

Survey Report

1. Introduction

1.1 *Project Summary*

Juneau Associates, Inc., P.C. is under contract with Merrick & Company to provide 140 checkpoints and 40 calibration points in Clark, Coles, Cumberland, Douglas, and Edgar Counties in Illinois. The ground survey was conducted January 27 through February 14, 2020.

Existing NGS monuments were located and surveyed to check the accuracy of RTK/GPS survey equipment with the results shown in section 2.4 of this report.

Final horizontal coordinates of points located in stated counties are referenced to US State Plane 1983, NAD 1983/ NA2011, Illinois East 1201. Final vertical elevations are referenced to NAVD 88 using Geoid12b model as requested. All final units are in U.S. survey feet.

1.2 *Points of Contact*

Questions regarding technical aspects of this survey report should be made to:

Juneau Associates, Inc., P.C.

Jeremy Dressel, P.L.S.

2100 State St Granite City, Illinois

(618) 844-1400

2. Project Details

2.1 *Survey Equipment*

The GPS observations were performed using Trimble R-8 & R-10 GNSS receiver/antenna attached to a Trimble carbon fiber fixed tip GPS pole. A Trimble TSC3 data collector was used to store GPS raw data.

2.2 *Survey Field Note Information*

The 180 total points observed were well distributed throughout the project. Field notes were kept recording the internal point number used, the NVA, VVA, CAL code, and the time, date, and current weather for each observation of said checkpoints and calibration points.

2.3 *Network Design*

The GPS survey was performed using a RTK (Real-Time Kinematic) system managed by Trimble called VRS Now. VRS Now provides instant access to real-time kinematic (RTK) corrections using a network of fixed continuously operating reference stations. This system allows field crews to utilize a mobile hot spot via a cellular device which connects the data collector to the VRS Now network server, which then connects to the fixed reference stations to give the GPS readings corrections to selected coordinate system.

2.4 *Field Survey Procedure and Analysis*

Juneau Associates field survey crews used a Trimble R-8 & R-10 GNSS receivers to collect data that was then corrected to the designated coordinate system by the process discussed in section 2.3

Calibration and NVA locations were occupied twice for three minutes, 180 EPOCS. VVA locations were occupied once for three minutes, 180 EPOCS, and again for one minute, 60 EPOCS. These observations specific time and current weather conditions were recorded in the field notes.

Seven existing NGS monuments with known horizonal and vertical coordinates were located to check the accuracy of the VRS network used to complete this project. DE8982, KB0450, KA1307, KS1453, and DE8937 were utilized. The “As Surveyed” vs. “Published” coordinate results are as follows on next page:

	As Surveyed (ft)			Published (ft)			Residual Errors		
NGS PT. ID	Northing (ft)	Easting (ft)	Elevation (ft)	Northing (ft)	Easting (ft)	Elev (ft)	Delta N	Delta E	Delta Elev
DE8982	1138166.055	944028.000	663.859	1138166.130	944027.940	663.740	-0.075	0.060	0.119
KB0450	898106.176	944181.583	603.990	898106.270	944181.530	603.740	-0.094	0.052	0.250
KA1307	897642.155	1173391.772	454.948	897642.200	1173391.790	455.050	-0.045	-0.018	-0.102
KA1453	1165282.440	1122055.951	719.908	1165282.470	1122055.980	719.930	-0.030	-0.029	-0.022
DE8937	1070296.118	1158867.421	739.120	1070296.160	1158867.410	739.100	-0.042	0.011	0.020
Number of check points							5	5	5
Mean Error							-0.0572833	0.015316667	0.05295
Standard deviation							0.0262227	0.040262179	0.135710906
RMSE(ft)							0.061899	0.03913355	0.13242984
RMSEr (ft)							0.073232		
RMSEr (cm)							2.23211		
Horizontal Accuracy (ACCr) at 95% Confidence Level (cm)							5.4642054		
Horizontal Accuracy (ACCr) at 95% Confidence Level (ft)							0.1792718		
Vertical Accuracy (ACCz) at 95% Confidence Level (cm)									7.790370735

Above indicates that the accuracies would meet the 2.5cm horizontal and 5cm vertical accuracy class of the ASPRS Positional Accuracy Standards.

2.5 *Data Processing Procedures*

After the Survey crew collects the field data, the information is uploaded from the data collectors to a FTP site, and then downloaded into the office software. The program used for this project is called Trimble Business Center (TBC).

Data is imported into this program to obtain the following reports; Point list reports and Point Derivation Report. This is completed to check the accuracy and precision of each individual report, as well as confirm that the proper coordinate systems were used while observing points in the field. After careful review, the points shot are exported out of TBC into a .csv file for the final product.

3. FINAL COORDINATES

POINT #	NORTHING (FT)	EASTING (FT)	ELEV. (FT)
CALIBRATION POINTS			
CAL801	949,006.30	964,981.60	643.50
CAL802	1,042,546.99	1,180,081.48	721.76
CAL803	1,077,057.42	1,070,773.85	661.37
CAL804	992,602.18	1,040,319.69	682.51
CAL805	1,097,194.69	993,559.31	677.18
CAL806	1,065,762.20	946,979.49	669.88
CAL807	1,043,710.21	1,070,600.21	693.13
CAL808	1,027,962.39	1,168,125.45	630.97
CAL809	1,111,889.75	1,134,891.65	669.98
CAL810	1,100,165.19	1,038,809.62	645.35
CAL811	961,261.40	1,039,196.03	553.76
CAL812	939,562.39	1,060,974.29	615.25
CAL813	960,649.45	1,171,778.92	549.77
CAL814	1,154,405.69	1,090,191.32	652.09
CAL815	999,123.96	949,130.89	692.37
CAL816	990,072.61	1,208,903.38	465.12
CAL817	1,059,305.66	1,139,793.18	712.10
CAL818	1,167,037.11	1,174,168.28	671.63
CAL819	1,138,056.61	977,756.17	670.27
CAL820	994,639.62	1,082,292.59	671.06
CAL821	1,052,021.50	1,105,693.36	729.14
CAL822	1,108,407.44	956,267.03	653.80
CAL823	1,027,619.30	1,000,537.37	703.98
CAL824	924,224.42	1,098,766.27	530.93
CAL825	1,071,448.02	1,053,631.58	662.41
CAL826	1,169,983.86	995,631.29	685.94
CAL827	1,080,903.27	1,166,798.46	670.97
CAL828	1,023,480.02	1,032,315.13	705.32
CAL829	1,095,396.39	1,192,380.69	645.29

POINT #	NORTHING (FT)	EASTING (FT)	ELEV. (FT)
CAL830	1,138,859.70	1,132,907.78	660.49
CAL831	957,046.05	947,265.97	657.04
CAL832	1,016,234.61	1,114,654.35	673.48
CAL833	928,951.80	1,191,883.46	449.30
CAL834	1,014,465.75	1,079,730.99	745.42
CAL835	1,138,362.48	1,064,787.38	643.02
CAL836	988,953.40	1,008,222.69	707.59
CAL837	1,001,549.25	971,630.87	741.93
CAL838	1,169,906.65	953,417.92	683.57
CAL839	923,112.07	1,045,439.74	593.36
CAL840	914,814.64	945,268.51	624.91
CAL843	964,650.15	1,086,961.31	639.70
CAL867	1,139,021.12	1,168,642.99	643.16
CAL870	910,580.75	971,316.10	601.16
CAL874	1,055,264.67	982,080.63	670.51
NVA CHECK POINTS			
NVA601	949,032.19	962,325.71	650.45
NVA602	1,042,574.23	1,181,412.80	688.75
NVA603	1,079,529.19	1,070,704.34	661.59
NVA604	992,149.70	1,040,312.17	678.10
NVA605	1,096,299.19	993,024.10	677.18
NVA606	1,065,780.19	945,287.24	669.06
NVA607	1,042,604.94	1,066,825.63	682.01
NVA608	1,026,667.48	1,168,138.86	629.84
NVA609	1,111,948.04	1,139,292.07	671.90
NVA610	1,097,911.50	1,038,817.23	649.77
NVA611	960,177.60	1,039,251.31	547.98
NVA612	939,636.01	1,066,412.82	620.21
NVA613	954,058.91	1,172,790.08	537.68
NVA614	1,150,421.33	1,090,230.56	645.50
NVA615	999,170.10	946,881.15	670.24
NVA616	989,533.78	1,208,019.86	462.79
NVA617	1,057,697.70	1,137,229.49	720.07
NVA618	1,171,250.92	1,174,704.85	679.09
NVA619	1,138,063.33	982,617.17	693.37
NVA620	993,311.48	1,082,328.80	665.42
NVA621	1,052,305.46	1,112,251.47	734.58
NVA622	1,108,373.60	960,288.05	655.48
NVA623	1,025,904.76	1,000,487.36	701.84
NVA624	919,061.76	1,099,041.28	576.99
NVA625	1,071,436.36	1,049,632.47	662.42
NVA626	1,164,390.65	1,000,989.97	696.15
NVA627	1,080,782.31	1,164,123.00	671.60
NVA628	1,018,396.33	1,032,814.50	683.16
NVA629	1,100,677.81	1,192,287.19	631.04
NVA630	1,138,826.67	1,140,924.72	661.11

POINT #	NORTHING (FT)	EASTING (FT)	ELEV. (FT)
NVA631	954,408.30	946,328.06	649.94
NVA632	1,015,254.04	1,121,315.10	682.72
NVA633	934,242.33	1,191,790.12	451.14
NVA634	1,014,470.29	1,082,007.16	729.57
NVA635	1,138,350.61	1,059,486.08	641.91
NVA636	986,180.91	1,008,238.63	687.37
NVA637	1,002,634.88	971,386.37	752.01
NVA638	1,169,890.15	948,116.75	672.66
NVA639	923,195.62	1,050,723.63	603.23
NVA640	912,178.04	945,273.18	599.63
NVA641	951,687.63	1,008,418.87	597.48
NVA642	1,066,107.72	1,003,240.87	663.46
NVA643	966,132.46	1,091,095.56	640.09
NVA644	1,124,564.92	1,070,623.78	650.85
NVA645	947,522.98	1,138,287.95	585.29
NVA646	937,120.88	971,637.07	623.67
NVA647	912,108.31	1,008,583.82	584.52
NVA648	1,112,951.32	1,166,664.55	643.90
NVA649	1,110,428.65	1,095,848.07	662.61
NVA650	1,154,673.44	1,132,871.19	669.20
NVA651	1,117,343.30	1,038,822.44	636.67
NVA652	1,111,102.30	1,118,953.66	669.57
NVA653	1,037,237.57	1,049,826.57	669.25
NVA654	1,138,042.72	944,960.17	665.18
NVA655	968,157.69	1,115,019.76	616.64
NVA656	1,039,349.16	945,956.13	660.66
NVA657	1,060,619.49	1,028,283.83	675.87
NVA658	1,066,480.60	1,194,257.43	672.22
NVA659	1,148,778.07	1,032,950.65	651.32
NVA660	1,140,298.70	1,188,638.73	626.92
NVA661	1,006,170.23	1,201,934.29	576.48
NVA662	1,170,250.20	1,059,280.88	667.05
NVA663	971,047.42	1,054,986.32	616.36
NVA664	1,039,305.63	966,335.51	687.85
NVA665	1,156,114.87	1,188,254.84	640.49
NVA666	912,348.90	1,180,685.37	448.51
NVA667	1,139,171.74	1,169,000.90	643.11
NVA668	1,084,394.20	1,116,181.72	675.59
NVA669	1,087,019.07	945,186.15	664.90
NVA670	912,011.70	971,209.84	587.05
NVA671	1,071,893.53	1,208,390.23	627.03
NVA672	1,164,453.55	1,208,654.59	622.24
NVA673	985,732.00	1,164,992.03	649.75
NVA674	1,055,267.70	982,739.30	672.36
NVA675	1,170,362.26	1,095,361.25	701.98
NVA676	1,101,960.98	1,070,761.19	658.00

POINT #	NORTHING (FT)	EASTING (FT)	ELEV. (FT)
NVA677	976,639.10	1,187,474.79	540.06
NVA678	993,921.02	1,111,436.91	641.11
NVA679	1,127,347.06	1,206,932.89	618.37
VVA CHECK POINTS			
VVA701	949,063.48	963,224.14	644.83
VVA702	1,042,835.69	1,181,486.88	676.13
VVA703	1,079,592.89	1,070,692.51	660.23
VVA704	992,597.80	1,040,117.34	668.14
VVA705	1,096,653.30	993,121.94	677.38
VVA706	1,065,825.23	945,755.90	668.00
VVA707	1,043,587.38	1,069,519.73	691.95
VVA708	1,027,534.95	1,167,561.58	633.57
VVA709	1,112,184.71	1,143,416.93	664.48
VVA710	1,099,618.64	1,040,185.44	646.55
VVA711	960,171.19	1,040,377.16	578.81
VVA712	939,699.60	1,063,719.53	612.12
VVA713	955,430.98	1,172,618.78	537.01
VVA714	1,150,354.18	1,088,985.31	643.04
VVA715	999,220.38	947,537.98	670.19
VVA716	989,462.97	1,208,118.60	459.56
VVA717	1,057,803.36	1,137,159.79	724.25
VVA718	1,170,279.92	1,174,465.80	673.76
VVA719	1,138,155.44	982,949.20	692.67
VVA720	993,369.61	1,081,057.24	654.87
VVA721	1,052,328.78	1,109,580.79	724.88
VVA722	1,108,385.17	960,030.48	652.43
VVA723	1,025,751.42	1,000,104.55	698.69
VVA724	919,909.48	1,098,909.41	578.55
VVA725	1,071,391.31	1,049,497.74	660.40
VVA726	1,164,936.43	999,108.80	687.15
VVA727	1,079,950.18	1,164,733.18	675.65
VVA728	1,020,096.87	1,032,196.10	683.89
VVA729	1,100,702.60	1,190,997.83	632.13
VVA730	1,138,803.97	1,141,441.50	661.33
VVA731	954,117.16	946,143.13	649.61
VVA732	1,017,248.73	1,114,604.38	668.34
VVA733	933,929.21	1,192,083.66	457.21
VVA734	1,014,546.12	1,078,138.38	764.87
VVA735	1,138,456.72	1,062,651.12	641.69
VVA736	985,662.75	1,009,588.33	689.02
VVA737	1,002,934.50	970,721.36	751.54
VVA738	1,169,938.89	946,067.27	669.83
VVA739	923,048.32	1,049,398.53	600.54
VVA740	914,169.76	945,202.41	617.87
VVA741	949,078.15	1,009,398.99	600.31
VVA742	1,069,038.06	987,764.00	660.90

POINT #	NORTHING (FT)	EASTING (FT)	ELEV. (FT)
VVA723	964,425.70	1,086,401.08	639.26
VVA744	1,129,951.67	1,070,538.48	635.47
VVA745	947,585.34	1,139,167.89	583.04
VVA746	935,823.28	971,546.06	620.37
VVA747	912,282.97	1,008,641.16	583.53
VVA748	1,112,553.14	1,160,246.49	657.54
VVA749	1,111,054.92	1,096,337.68	662.19
VVA750	1,153,960.58	1,132,820.62	666.71
VVA751	1,118,158.34	1,038,453.89	635.96
VVA752	1,110,285.49	1,118,888.16	667.01
VVA753	1,037,526.87	1,049,756.96	671.25
VVA754	1,142,607.49	946,612.04	665.10
VVA755	968,343.07	1,114,882.35	615.93
VVA756	1,040,200.41	944,828.33	655.36
VVA757	1,060,455.58	1,029,407.71	678.86
VVA758	1,066,551.85	1,197,707.90	661.10
VVA759	1,148,951.47	1,032,983.83	660.33
VVA760	1,140,175.16	1,189,446.27	616.88
VVA761	1,005,666.57	1,201,525.64	560.30