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Virginia– FEMA R3 South West Lidar - 2016

Report Produced for U.S. Geological Survey

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Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (lidar) technology for the Virginia FEMA R3 SW Lidar 2016 Project. This task order contains two separate AOIs totaling 8615 square miles. This report details the Virginia Southeast portion of the project. Please see the project report titled “West Virginia Northeast” for detail pertaining to that section of the project.

The lidar data were processed and classified according to project specifications. Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. Data was formatted according to tiles with each tile covering an area of 1500m by 1500m. A total of 7,349 tiles were produced for the project encompassing an area of approximately 6,070 sq. miles.

THE PROJECT TEAM

Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LAS classification, all lidar products, breakline production, Digital Elevation Model (DEM) production, and quality assurance.

Dewberry's Gary Simpson completed ground surveying for the project and delivered surveyed checkpoints. His task was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the lidar-derived surface model. He also surveyed ground control points for use in lidar calibration and processing. Please see Appendices A and B to view the separate Survey Reports that were created for this portion of the project.

Leading Edge Geomatics (LEG) completed lidar data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Virginia counties of Bland, Buchanan, Craig, Dickenson, Giles, Grayson, Lee, Russell, Scott, Smyth, Tazewell, Washington, Wise, and Wythe, as well as including the cities of Bristol, Galax, and Norton in Virginia and the city of Bluefield in West Virginia.

DATE OF SURVEY

The lidar aerial acquisition was conducted from November 3, 2016 to April 17, 2017.

COORDINATE REFERENCE SYSTEM

Data produced for the project were delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011))
Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)
Coordinate System: UTM Zone 17
Units: Horizontal units are in meters, Vertical units are in meters.
Geiod Model: Geoid12B (Geoid 12B was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the Virginia South West AOI, the tested $RMSE_z$ of the classified lidar data for checkpoints in non-vegetated terrain equaled **6.2 cm** compared with the 10 cm specification; and the NVA of the classified lidar data computed using $RMSE_z$ x 1.9600 was equal to **12.2 cm**, compared with the 19.6 cm specification.

For the Virginia South West AOI, the tested VVA of the classified lidar data computed using the 95^{th} percentile was equal to **20.8 cm,** compared with the 29.4 cm specification.

Additional accuracy information and statistics for the classified lidar data, raw swath data, and bare earth DEM data are found in the following sections of this report.

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. Classified Point Cloud Data (Tiled)
2. Bare Earth Surface (Raster DEM – IMG Format)
3. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
4. Breakline Data (File GDB)
5. Independent Survey Checkpoint Data (Report, Photos, & Points)
6. Calibration Points
7. Metadata
8. Project Report (Acquisition, Processing, QC)
9. Project Extents, Including a shapefile derived from the lidar deliverable
10. Contours (1-foot automated contours in File GDB)

PROJECT TILING FOOTPRINT

Seven thousand three hundred forty nine (7349) tiles were delivered for the project. Each tile's extent is 1,500 meters by 1,500 meters (see Appendix C for a complete listing of delivered tiles).

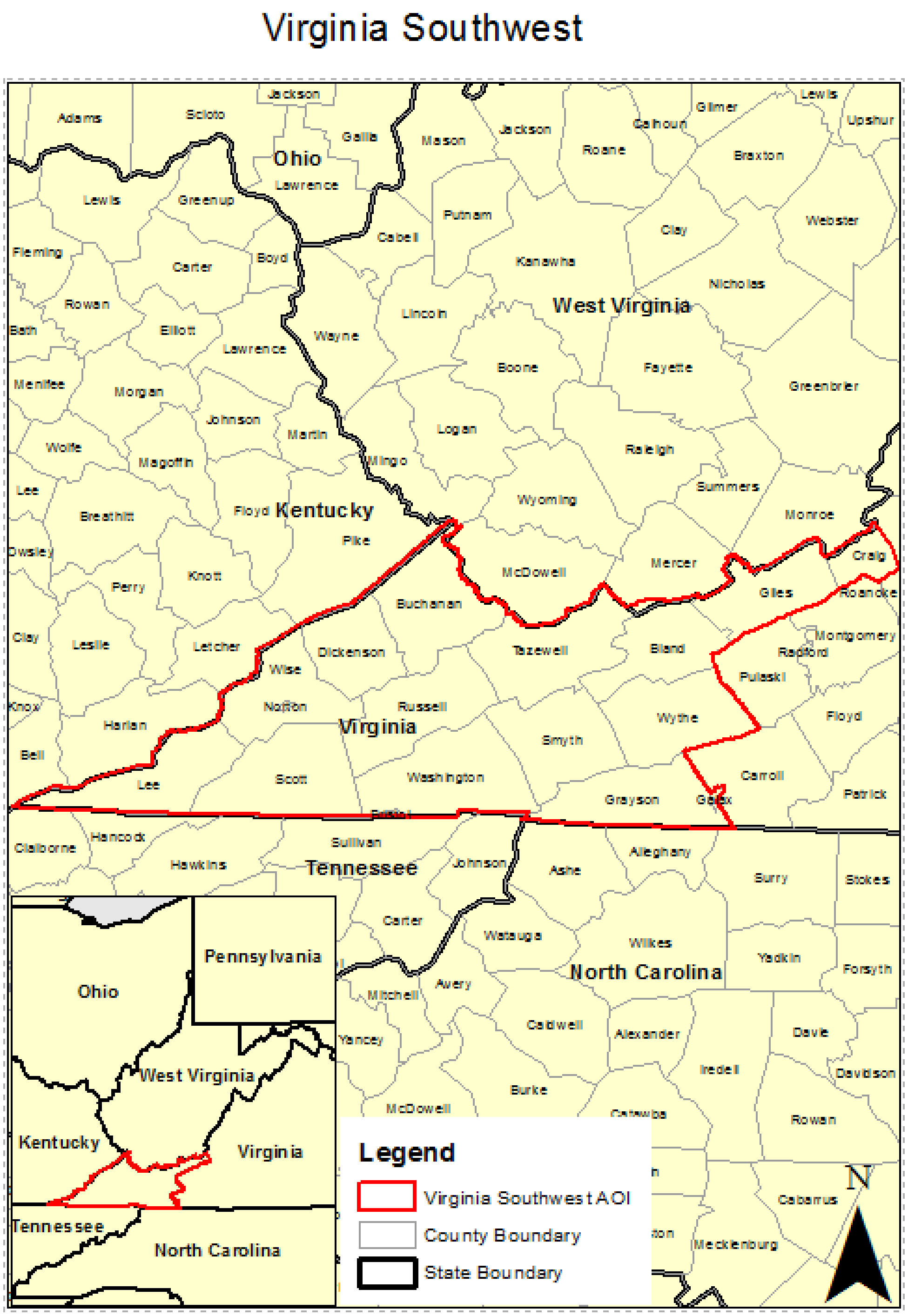


Figure 1 –

Figure 1 - Project Map

Lidar Acquisition Report

Dewberry elected to subcontract the LiDAR Acquisition and Calibration activities for the Virginia South West portion of the FEMA R3 SW LiDAR project to Leading Edge Geomatics (LEG). Leading Edge Geomatics was responsible for providing LiDAR acquisition, calibration and delivery of LiDAR data files to Dewberry.

Dewberry received calibrated swath data in several deliveries from LEG between March 7, 2017 and August 28, 2017.

LIDAR ACQUISITION DETAILS

Leading Edge Geomatics planned a total of 1399 passes to complete the entire project area. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. Due to large changes in terrain height, the project area was broken down into three areas based of height above sea level. This was required to maintain the project accuracy specification. In order to reduce any margin for error in the flight plan, Leading Edge Geomatics followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Track Air flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- LiDAR coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas had been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Leading Edge Geomatics will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Leading Edge Geomatics monitored weather and atmospheric conditions and conducted LiDAR missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, snow, rain, fog, smoke, mist and low clouds. LiDAR systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Leading Edge Geomatics accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Leading Edge Geomatics closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Leading Edge Geomatics LiDAR sensors are calibrated at a designated site located in downtown Fredericton, New Brunswick and are periodically checked and adjusted to minimize corrections at project sites. Both systems were calibrated before departing for the project area.

LIDAR SYSTEM PARAMETERS

Leading Edge Geomatics operated two Cennsa 172 (C-FMNB, C-FCAU) and a Piper Navajo (C-GKCN). Each of the Cessna's carried a Riegl 680i scanner and the Navajo carried a Riegl 780. Table 1 illustrates Leading Edge Geomatics system parameters for LiDAR acquisition on this project.

Item	Parameter
System	Riegl 780/680i
Altitude (AGL meters)	1800
Approx. Flight Speed (knots)	100
Scanner Pulse Rate (kHz)	280
Scan Frequency (hz)	68
Pulse Duration of the Scanner (nanoseconds)	5
Pulse Width of the Scanner (m)	1.5
Swath width (m)	1996
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	yes
Beam Divergence (milliradians)	0.25
Nominal Swath Width on the Ground (m)	1996
Swath Overlap (%)	55
Total Sensor Scan Angle (degree)	60
Computed Down Track spacing (m) per beam	0.76
Computed Cross Track Spacing (m) per beam	0.76
Nominal Pulse Spacing (single swath), (m)	0.76
Nominal Pulse Density (single swath) (ppsm), (m)	1.746
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.536
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	3.48
Maximum Number of Returns per Pulse	infinite

Table 1: Leading Edge Geomatics (LEG) lidar system parameters

ACQUISITION STATUS REPORT AND FLIGHTLINES

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. LiDAR acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. LiDAR missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather, water conditions and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 2 shows the combined trajectory of the flight lines.

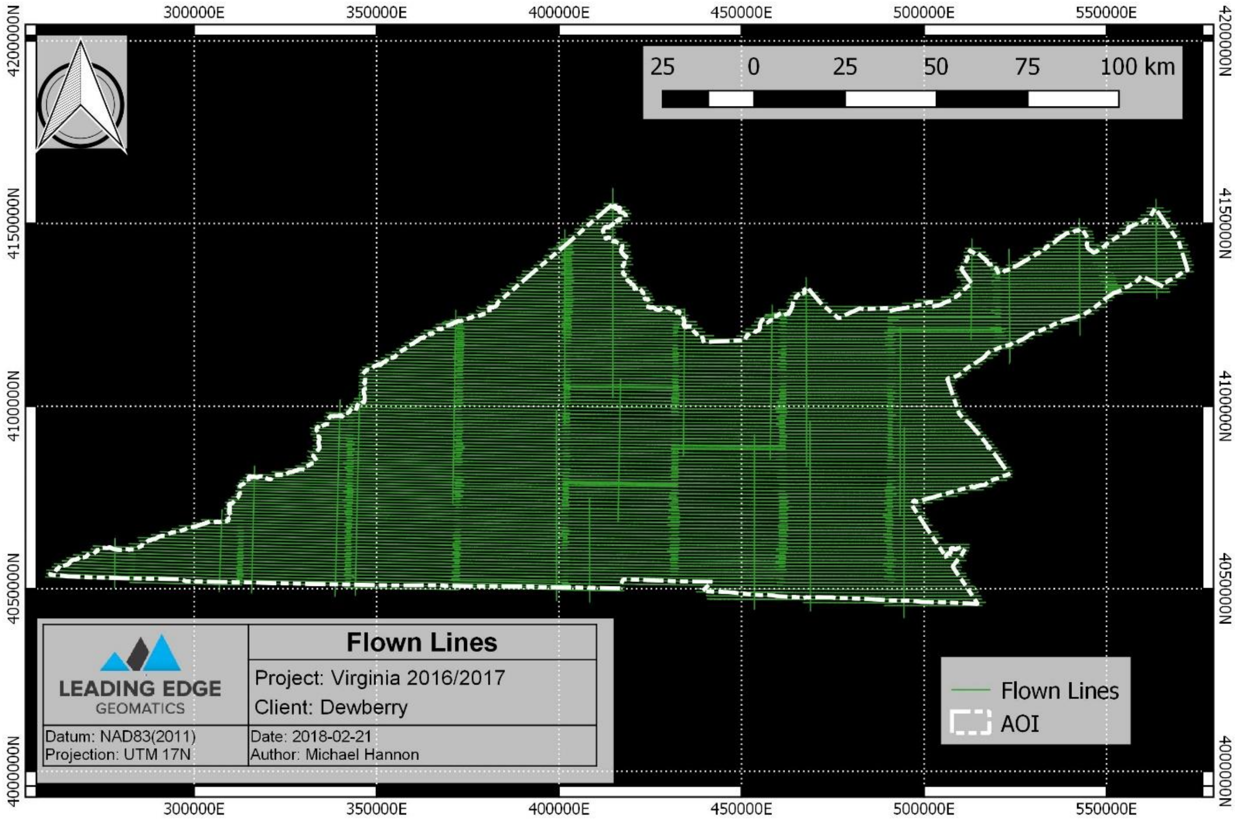


Figure 2: Trajectories as flown by Leading Edge Geomatics (LEG)

LIDAR CONTROL

Twenty -Seven existing NGS monuments and nine newly established base stations were used to control the lidar acquisition for the Southwest Virginia Portion of the lidar project area. The coordinates of all used base stations are provided in the table below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Name	NAD83 UTM 17		Ellipsoid Ht (NAD83, m)
	Easting X (m)	Northing Y (m)	
ASUB	4007913.76	438712.9	957.907
DOBS	4031171.95	525106.73	340.708
KYTK	4115239.07	254924.94	245.058
KYTL	4149604.85	364245.28	186.977
LOYH	4129769.66	648492.6	205.829
LOYP	4209942.97	673914.79	393.433
LOYU	4112970.37	550334.05	601.292
LS04	4135662.55	592316.72	325.522
NCNW	4002420.29	488077.63	270.426
NCSR	4039164.81	489727.4	839.991

NCWC	4025533.46	573117.44	276.386
NCWJ	4027650.17	457097.05	934.802
TN11	4024963.18	375045.99	449.262
TN12	4013884.53	294562.08	337.185
TN14	4033523.46	225132.5	329.582
TN18	4025170.74	394283.85	445.954
TN1B	4038452.37	337701.98	329.259
TNJC	4027617.03	373097.38	441.07
VAAB	4060937.24	408508.45	607.24
VABG	4080314.17	343079.94	575.3
VARY	4094983.21	598814.96	339.848
VAWE	4093569.85	359383.39	726.546
VAWY	4089339.37	492476.82	674.259
WVAT	4142412.73	493994.11	705.98
WVBF	4124381.7	478808.11	780.667
WVLE	4186254.18	550885.02	656.568
WVOH	4205629.8	488396.18	597.551

Table 2 – Base stations used to control lidar acquisition

AIRBORN GPS KINEMATIC

Airborne GPS data was processed using the PosPac kinematic On-The-Fly (OTF) software suite. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 40 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix E.

GENERATION AND CALIBRATION OF LASER POINTS (RAW DATA)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Optech's Dashmap, initially with default values from Optech or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

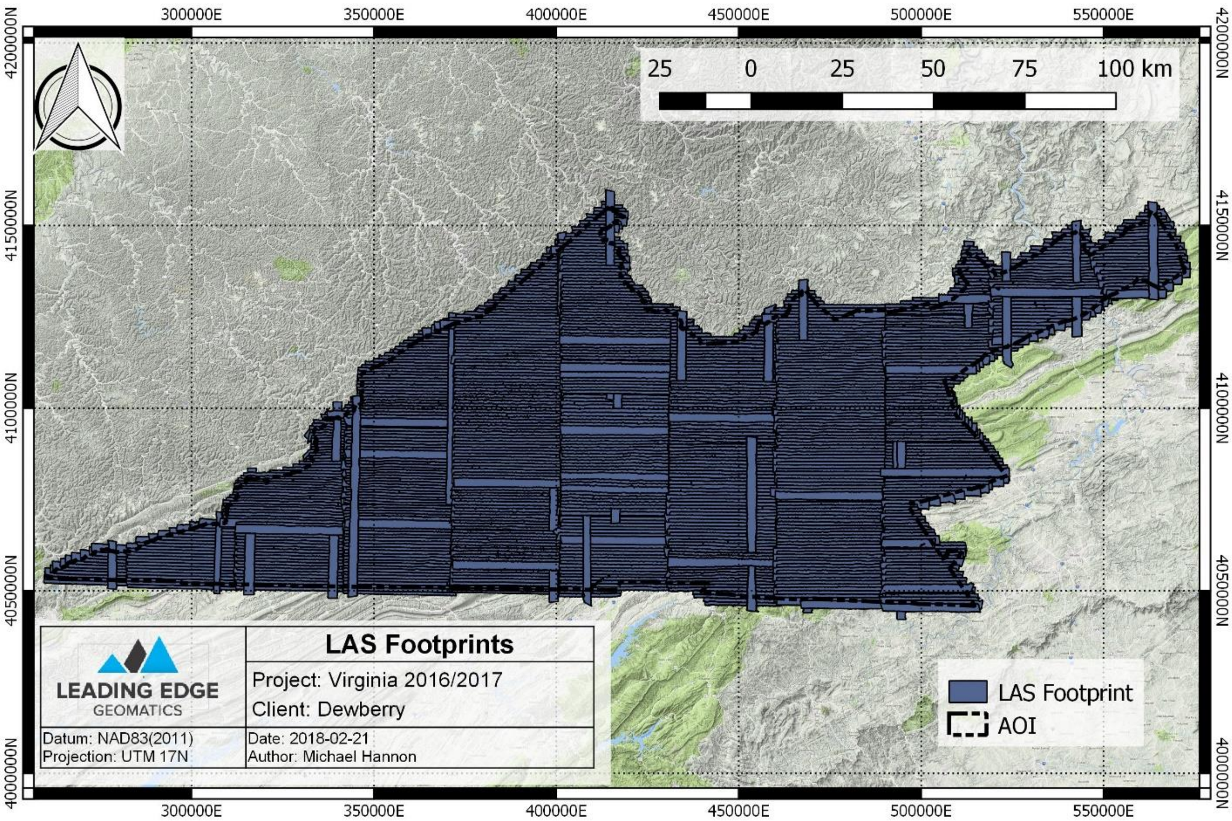


Figure 3 – Lidar swath output showing complete coverage.

BORESIGHT AND RELATIVE ACCURACY

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the LiDAR unit or GPS. Roll, pitch and yaw are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Absolute Vertical Accuracy <=10 cm RMSEZ in non-vegetated open areas.
Absolute Horizontal Accuracy = 0.6m RMSE
Relative Swath Accuracy ≤ 6cm and ≤ 8cm RMSDz within swath overlap.

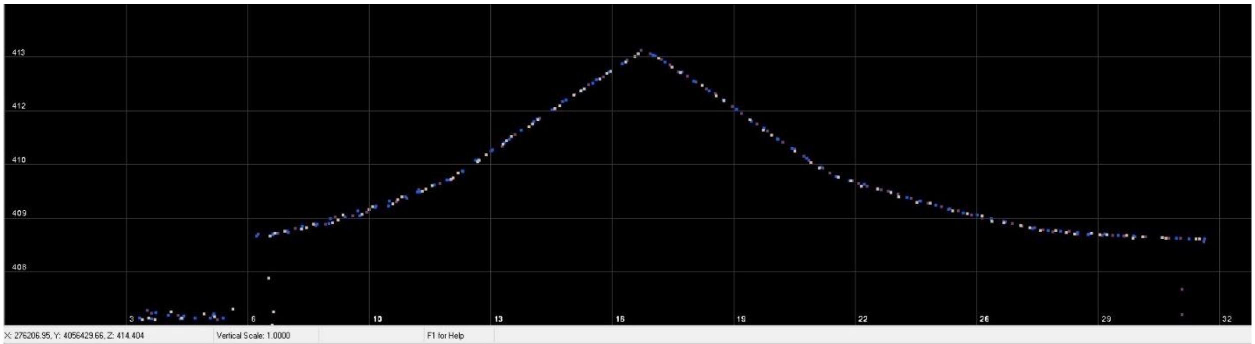


Figure 4 – Profile view cross section of multiple swaths.

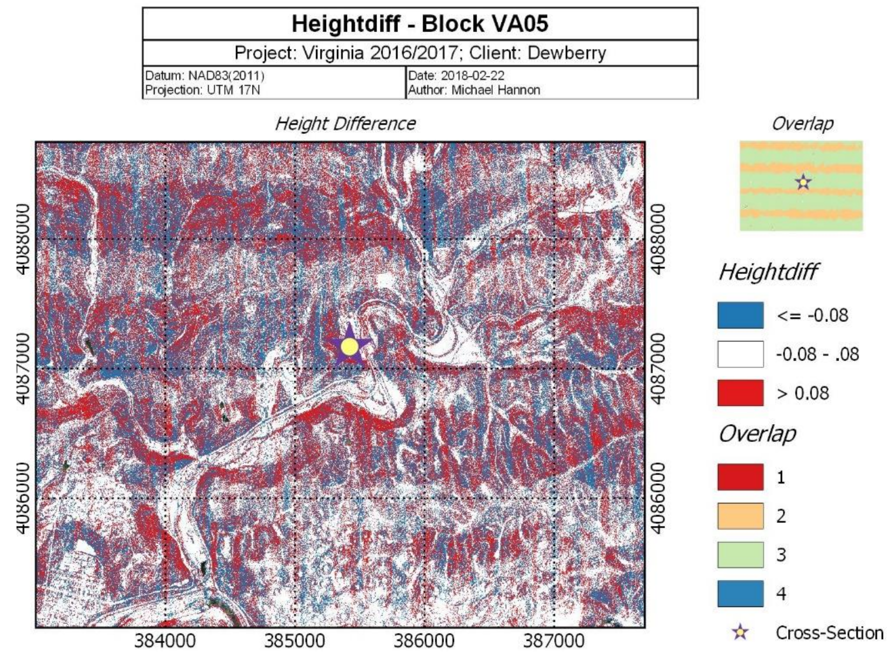


Figure 5 – QC block colored by separation to ensure accuracy at swath edges (8cm range).

A different set of QC blocks are generated for final review after all transformations have been applied.

PRELIMINARY VERTICAL ACCURACY ASSESSMENT

A preliminary $RMSE_z$ error check is performed by Leading Edge Geomatics at this stage of the project life cycle in the raw LiDAR dataset against GPS static data and compared to $RMSE_z$ project specifications. The LiDAR data is examined in open, flat areas away from breaks. Ground control points were collected by Real-Time Kinematic (RTK) survey and compared against the LiDAR ground points and statistics are generated.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met project accuracy requirements (vertical accuracy <=10 cm RMSEz) or better in open, non-vegetated terrain) when compared to static GPS checkpoints. Below is a summary for the test:

The calibrated Virginia dataset was tested to 0.0968 m (0.318 ft) vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.0494 x 1.9600) when compared to 732 independently collected RTK check points.

The following are the final statistics for the GPS static checkpoints used by Leading Edge Geomatics to internally verify vertical accuracy.

Average dz	0.0384 m
Root mean square	0.0494 m
Std deviation	0.0494 m

Overall the calibrated LiDAR data products collected by Leading Edge Geomatics meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Leading Edge Geomatics quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

Lidar Processing & Qualitative Assessment

INITIAL PROCESSING

Once Dewberry receives the calibrated swath data from the acquisition provider, Dewberry performs several validations on the dataset prior to starting full-scale production on the project. These validations include vertical accuracy of the swath data, inter-swath (between swath) relative accuracy validation, intra-swath (within a single swath) relative accuracy validation, verification of horizontal alignment between swaths, and confirmation of point density and spatial distribution. This initial assessment allows Dewberry to determine if the data are suitable for full-scale production. Addressing issues at this stage allows the data to be corrected while imposing the least disruption possible on the overall production workflow and overall schedule.

Final Swath Vertical Accuracy Assessment

Once Dewberry received the calibrated swath data from LEG, Dewberry tested the vertical accuracy of the non-vegetated terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the 115 non-vegetated (open terrain and urban) independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the lidar point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete lidar point. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project. Project specifications require a NVA of 19.6 cm based on the $RMSE_z$ (10 cm) x 1.96. The dataset for the Virginia Southwest AOI satisfies this criteria. This raw lidar swath data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 6.4 cm, equating to +/- 12.5 cm at 95% confidence level. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	# of Points	$RMSE_z$ NVA	NVA –Non-vegetated Vertical	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis

		Spec=0.10 m	Accuracy ($RMSE_z$ x 1.9600) Spec=0.196 m							
Non-Vegetated Terrain	115	0.064	0.125	0.007	0.007	0.005	0.063	-0.179	0.202	0.448

Table 3: NVA at 95% Confidence Level for Raw Swaths

One checkpoint (NVA-136) was removed from the raw swath vertical accuracy testing due to its location underneath parked vehicle. Only non-vegetated terrain checkpoints are used to test the raw swath data because the raw swath data has not been classified to remove vegetation, structures, and other above ground features from the ground classification. While NVA-136 is located in open terrain, the car is modeled by the lidar point cloud. These high points caused erroneous high values during the swath vertical accuracy testing so this point was removed from the final calculations. Once the data underwent the classification process, the vehicle was removed from the final ground classification and this point could be used in the final vertical accuracy testing for the fully classified lidar data. Table 4, below, provides the coordinates for this checkpoint and the vertical accuracy results from the raw swath data. Table 5, below, provides the usable vertical accuracy results of this checkpoint from the fully classified lidar. The differences in the tables show how above ground features can cause erroneous vertical accuracy results in the raw swath data. Figure 4, below, shows a 3D model of the lidar point cloud and the location of the checkpoint beneath a power line.

Point ID	NAD83 UTM 17N		NAVD88 (Geoid 12B)	Lidar Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
NVA-136	409807.916	4061488.872	642.649	643.409	0.760	0.760

Table 4: Checkpoint removed from raw swath vertical accuracy testing

Point ID	NAD83 State Plane VA		NAVD88 (Geoid 12A)	Lidar Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
NVA-136	409807.916	4061488.872	642.649	642.684	0.035	0.035

Table 5: Final tested vertical accuracy for NVA- 136 post ground classification

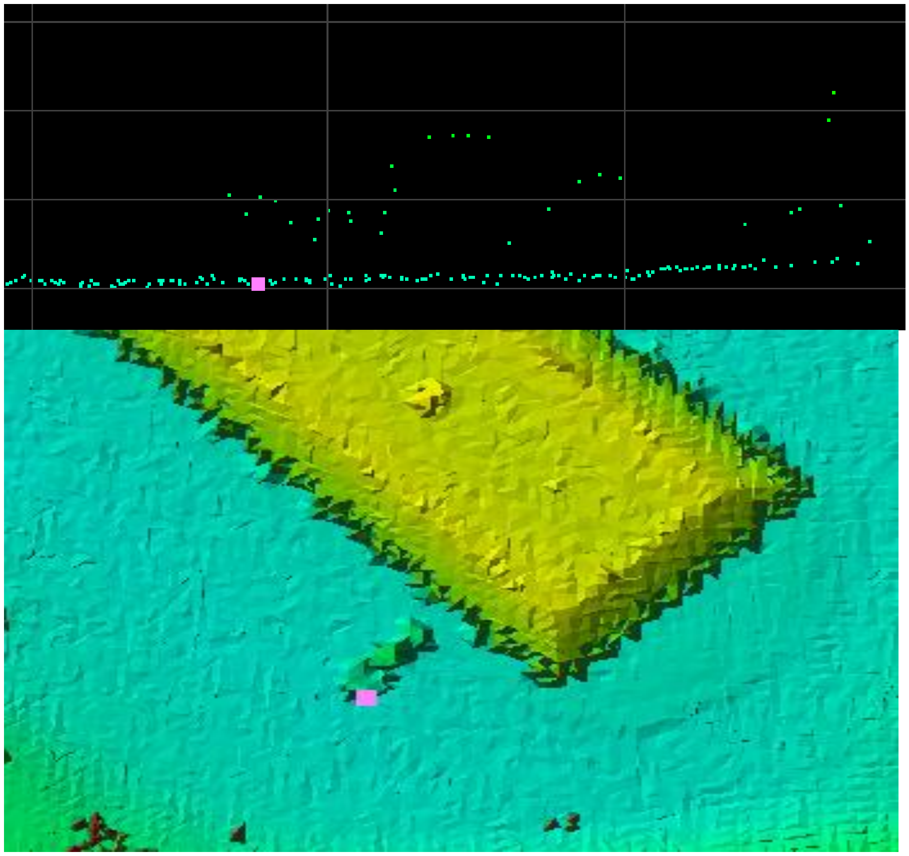


Figure 6 – NVA- 136, shown as the Pink Square, is located underneath a vehicle. This point was removed from raw swath vertical accuracy testing because above ground features, including vehicles, have not been separated from the ground classification yet.

Inter-Swath (Between Swath) Relative Accuracy

Dewberry verified inter-swath or between swath relative accuracy of the dataset by creating Delta-Z (DZ) orthos. According to the SOW, USGS Lidar Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet inter-swath relative accuracy of 8 cm RMSDz or less with maximum differences less than 16 cm. These measurements are to be taken in non-vegetated and flat open terrain using single or only returns from all classes. Measurements are calculated in the DZ orthos on 1-meter pixels or cell sizes. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm to 16 cm are colored yellow, and areas in the dataset where overlapping flight lines have elevation differences in each pixel greater than 16 cm are colored red. Pixels that do not contain points from overlapping flight lines are colored according to their intensity values. Areas of vegetation and steep slopes (slopes with 16 cm or more of valid elevation change across 1 linear meter) are expected to appear yellow or red in the DZ orthos. If the project area is heavily vegetated, Dewberry may also create DZ Orthos from the initial ground classification only, while keeping all other parameters consistent. This allows Dewberry to review the ground classification relative accuracy beneath vegetation and to ensure flight line ridges or other issues do not exist in the final classified data.

Flat, open areas are expected to be green in the DZ orthos. Large or continuous sections of yellow or red pixels can indicate the data was not calibrated correctly or that there were issues during acquisition that could affect the usability of the data, especially when these yellow/red sections follow the flight lines and not the terrain or areas of vegetation. The DZ orthos for the Southwest Virginia AOI are shown in the figure below; this project meets inter-swath relative accuracy specifications.

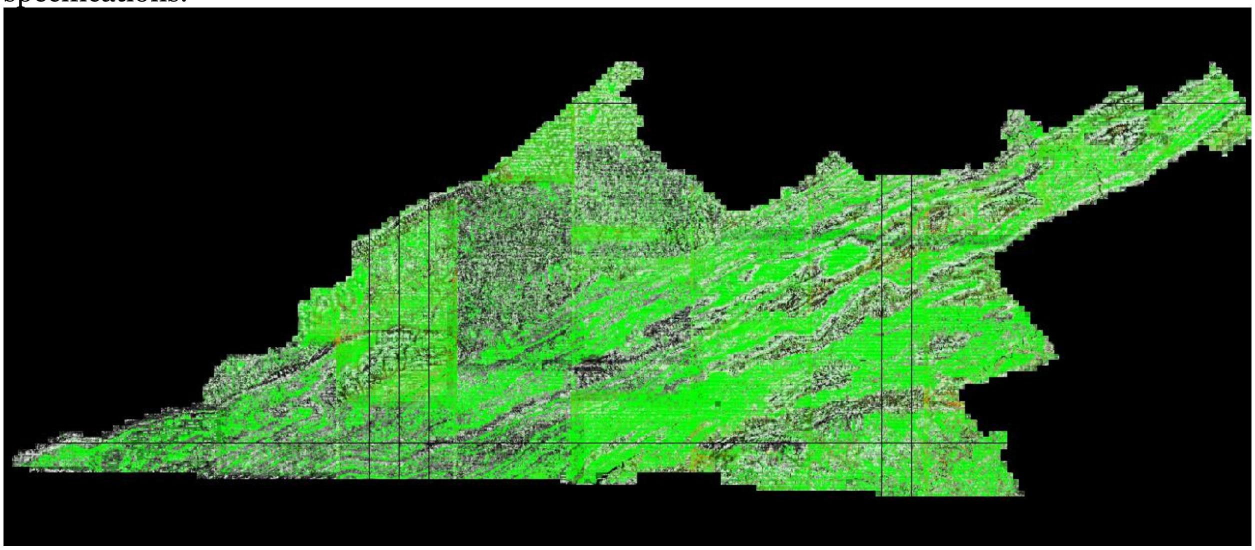
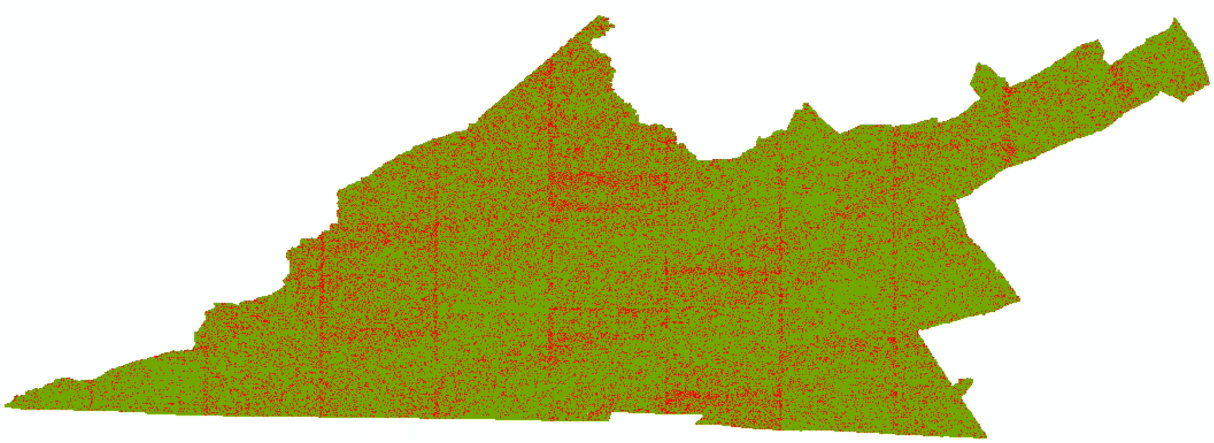


Figure 7– Single return DZ Orthos for the Virginia Southwest AOL. Inter-swath relative accuracy passes specifications.

Intra-Swath (Within a Single Swath) Relative Accuracy

Dewberry verifies the intra-swath or within swath relative accuracy by using Quick Terrain Modeler (QTM) scripting and visual reviews. QTM scripting is used to calculate the maximum difference of all points within each 1-meter pixel/cell size of each swath. Dewberry analysts then identify planar surfaces acceptable for repeatability testing and analysts review the QTM results in those areas. According to the SOW, USGS Lidar Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet intra-swath relative accuracy of 6 cm maximum difference or less. The image below shows two examples of the intra-swath relative accuracy of the Virginia AOI; this project meets intra-swath relative accuracy specifications.



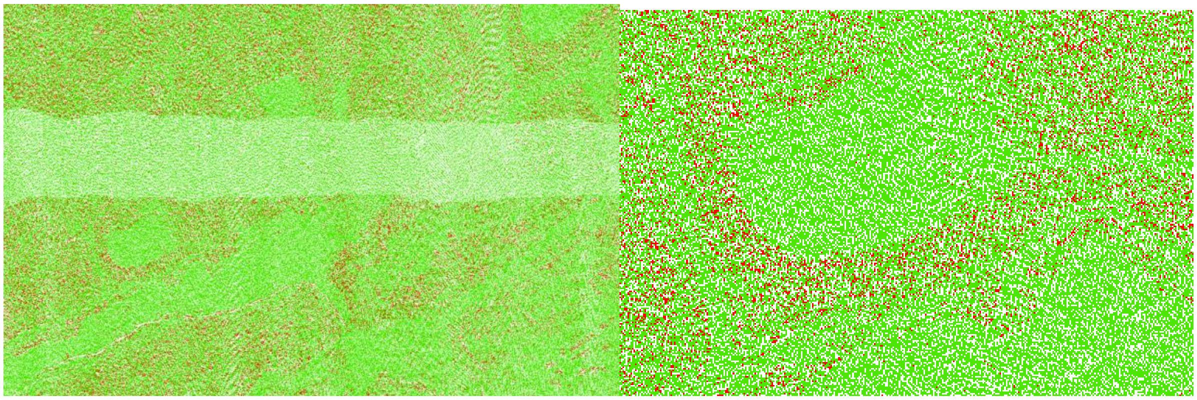


Figure 8–Intra-swath relative accuracy. The top image shows the full project area; areas where the maximum difference is ≤6 cm per pixel within each swath are colored green and areas exceeding 6 cm are colored red. The left image shows a large portion of the dataset; flat, open areas are colored green as they are within 6 cm whereas sloped terrain is colored red because it exceeds 6 cm maximum difference, as expected, due to actual slope/terrain change. The right image is a close-up of a flat area. With the exception of few trees (shown in red as the elevation/height difference in vegetated areas will exceed 6 cm) this open flat area is acceptable for repeatability testing. Intra-swath relative accuracy passes specifications.

Horizontal Alignment

To ensure horizontal alignment between adjacent or overlapping flight lines, Dewberry uses QTM scripting and visual reviews. QTM scripting is used to create files similar to DZ orthos for each swath but this process highlights planar surfaces, such as roof tops. In particular, horizontal shifts or misalignments between swaths on roof tops and other elevated planar surfaces are highlighted. Visual reviews of these features, including additional profile verifications, are used to confirm the results of this process. The image below shows an example of the horizontal alignment between swaths for the Southwest Virginia AOI; no horizontal alignment issues were identified.

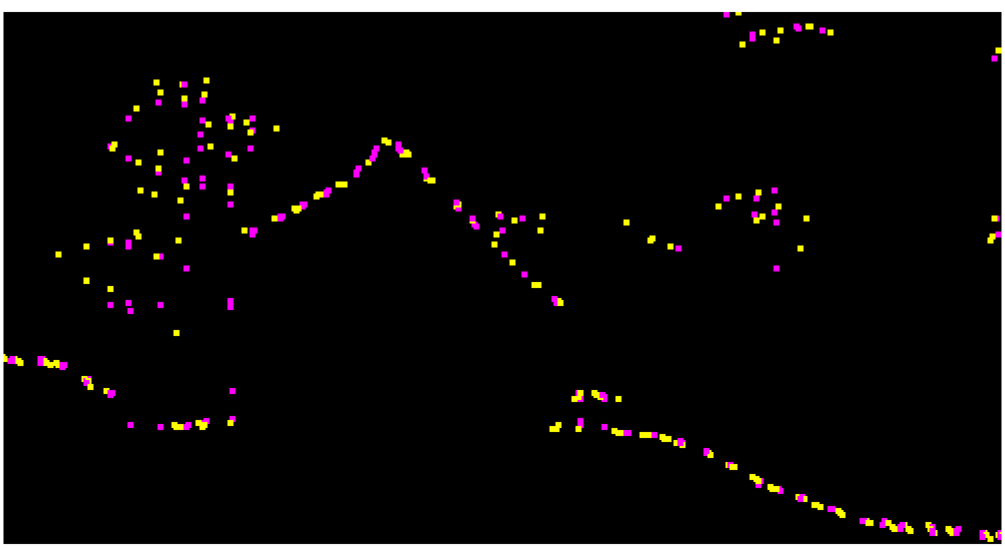


Figure 9– Horizontal Alignment. Two separate flight lines differentiated by color (Purple/Yellow) are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

Point Density and Spatial Distribution

The required Aggregate Nominal Point Spacing (ANPS) for this project is no greater than 0.71 meters, which equates to an Aggregate Nominal Point Density (ANPD) of 2 points per square meter or greater. Density calculations were performed using first return data only located in the geometrically usable center portion (typically ~90%) of each swath. By utilizing statistics, the project area was determined to have an ANPS of 0.4 meters or an ANPD of 2.1 points per square meter which satisfies the project requirements.

Figure 10– Green represent pixels that contain the required number of points.

The spatial distribution of points must be uniform and free of clustering. This specification is tested by creating a grid with cell sizes equal to the design NPS*2. QTM scripting is then used to calculate the number of first return points of each swath within each grid cell. At least 90% of the cells must contain 1 lidar point, excluding acceptable void areas such as water or low NIR reflectivity features, i.e. some asphalt and roof composition materials. This project passes spatial distribution requirements, as shown in the image below.

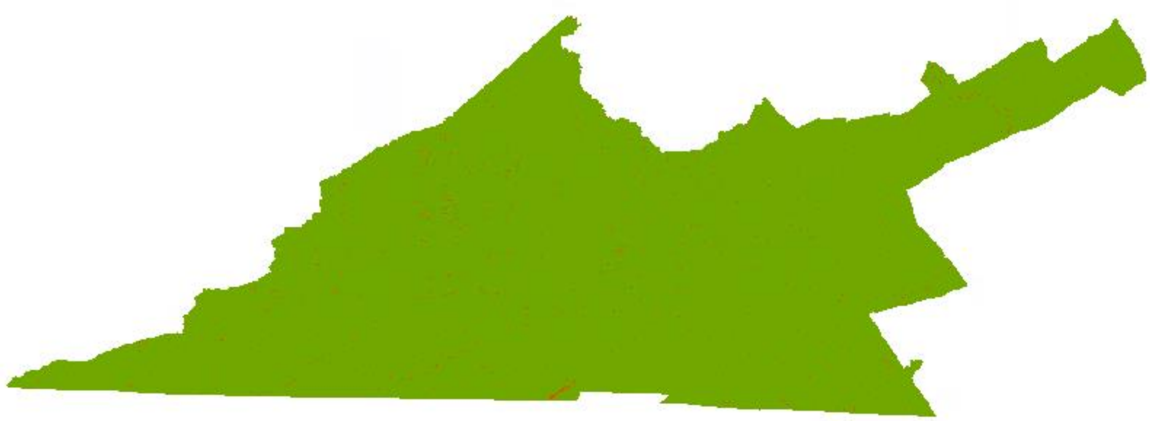


Figure 11– Spatial Distribution. All tiles containing at least one lidar point are colored green.

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data was confirmed, Dewberry utilized a variety of software suites for data processing. The data was processed using GeoCue and TerraScan software. The initial step is the setup of the GeoCue project, which is done by importing a project defined tile boundary index encompassing the entire project area. The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. Points along flight line edges that are geometrically unusable are identified as withheld and classified to a separate class so that they will not be used in the initial ground algorithm. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model.

This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

Each tile was then imported into Terrascan and a surface model was created to examine the ground classification. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, and bridges that were present following the initial processing conducted by Dewberry. Dewberry analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. Bridge decks are classified to class 17 using bridge breaklines compiled by Dewberry. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled by Dewberry to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, points that are within 1x NPS or less of the hydrographic features are moved to class 10, an ignored ground due to breakline proximity. Overage points are then identified in Terrascan and GeoCue is used to set the overlap bit for the overage points and the withheld bit is set on the withheld points previously identified in Terrascan before the ground classification routine was performed.

The lidar tiles were classified to the following classification schema:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, 10, 17, or 18, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Low Noise
- Class 9 = Water, points located within collected breaklines

- Class 10 = Ignored Ground due to breakline proximity
- Class 17 = Bridge Decks
- Class 18 = High Noise

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, all headers, appropriate point data records, and variable length records, including spatial reference information, are updated in GeoCue software and then verified using proprietary Dewberry tools.

Lidar Qualitative Assessment

Dewberry's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as lidar orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models as well as reviewing the actual point cloud data. This process looks for anomalies in the data, areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model, and other classification errors. This report will present representative examples where the lidar and post processing had issues as well as examples of where the lidar performed well.

VISUAL REVIEW

The following sections describe common types of issues identified in lidar data and the results of the visual review for the Southwest Virginia AOI.

Data Voids

The LAS files are used to produce density grids using the commercial software package QT Modeler (QTM) which creates a 3-dimensional data model derived from Class 2 (ground) points in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas. Acceptable voids (areas with no lidar returns in the LAS files) that are present in the majority of lidar projects include voids caused by bodies of water. No unacceptable voids are present in the Virginia Southwest AOI.

Artifacts

Artifacts are caused by the misclassification of ground points and usually represent vegetation and/or man-made structures. The artifacts identified are usually low lying structures, such as porches or low vegetation used as landscaping in neighborhoods and other developed areas. These low lying features are extremely difficult for the automated algorithms to detect as non-ground and must be removed manually. The vast majority of these features have been removed but a small number of these features are still in the ground classification. The limited numbers of features remaining in the ground are usually 0.3 meters or less above the actual ground surface, and should not negatively impact the usability of the dataset.

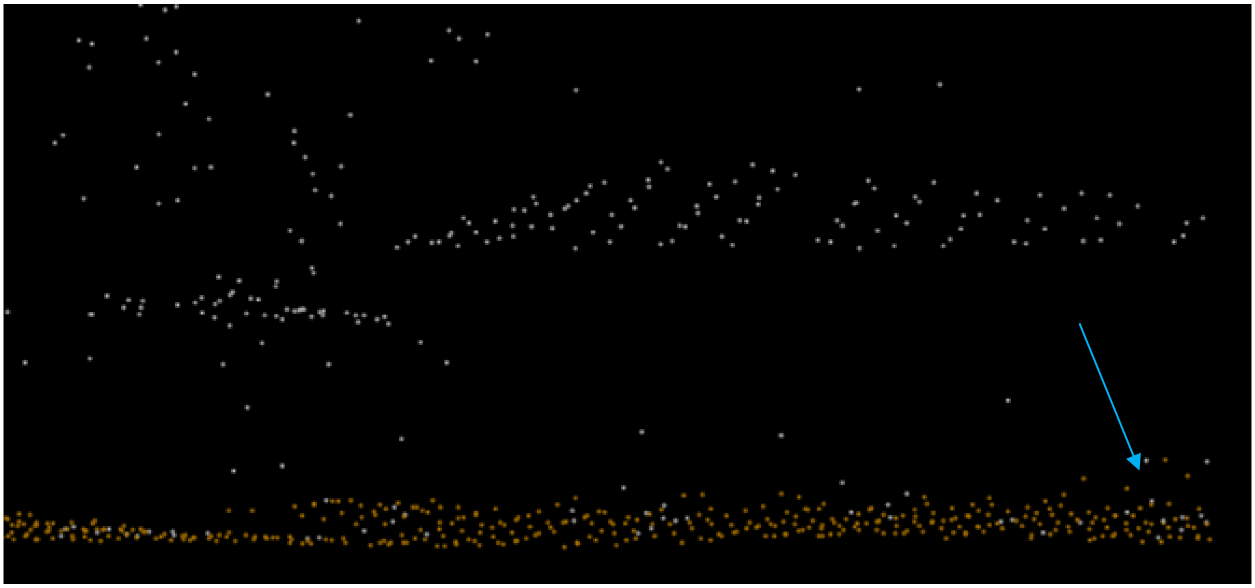
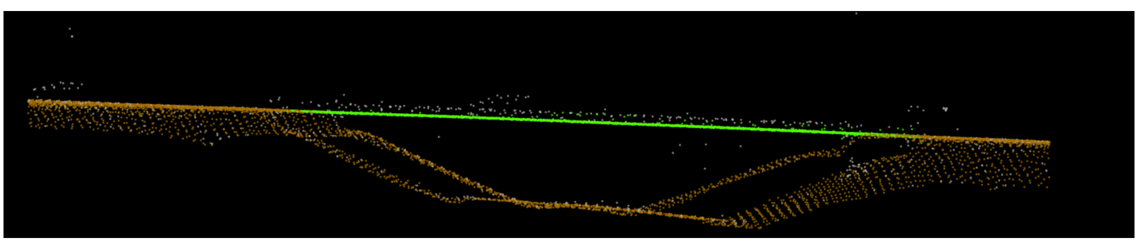


Figure 12 – Tile number AY144. Profile with points colored by class (class 1=grey, class 2=orange. The arrow identifies low vegetation points. A limited number of these small features are still classified as ground but do not impact the usability of the dataset.

Bridge Removal Artifacts

The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to continue the surface beneath the bridge where no lidar data was acquired. Locations where bridges were removed will generally contain less detail in the bare-earth surface because these areas are interpolated.



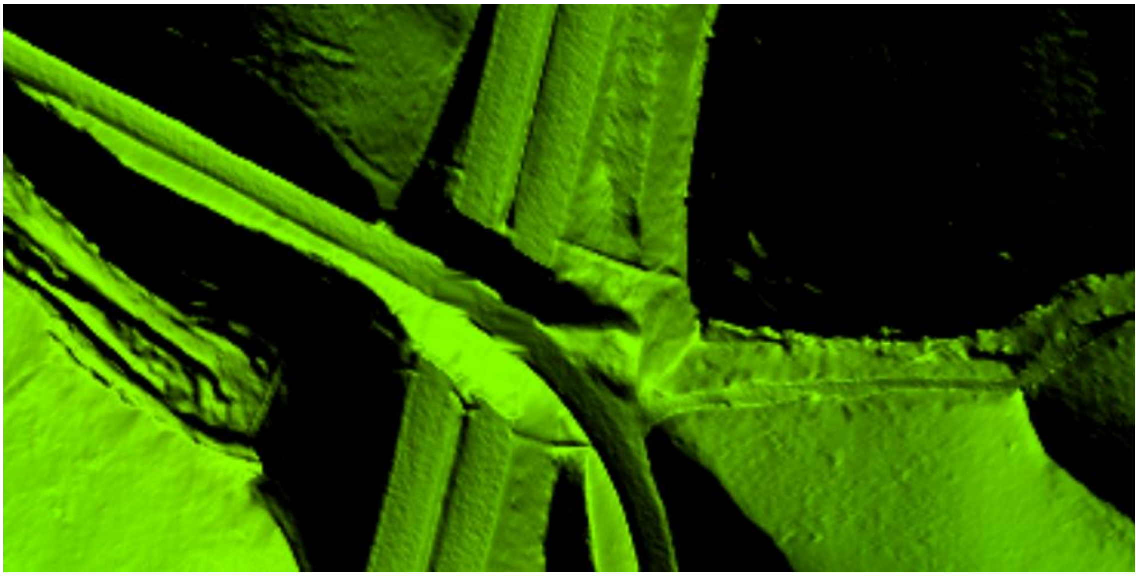


Figure 13 – Tile number AP153. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the lidar points of this particular feature colored by class. All bridge points have been removed from ground (orange) and are classified to bridge deck (green).

Culverts and Bridges

Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, Dewberry erred on assuming they would be culverts especially if they are on secondary or tertiary roads. Below is an example of a culvert that has been left in the ground surface.

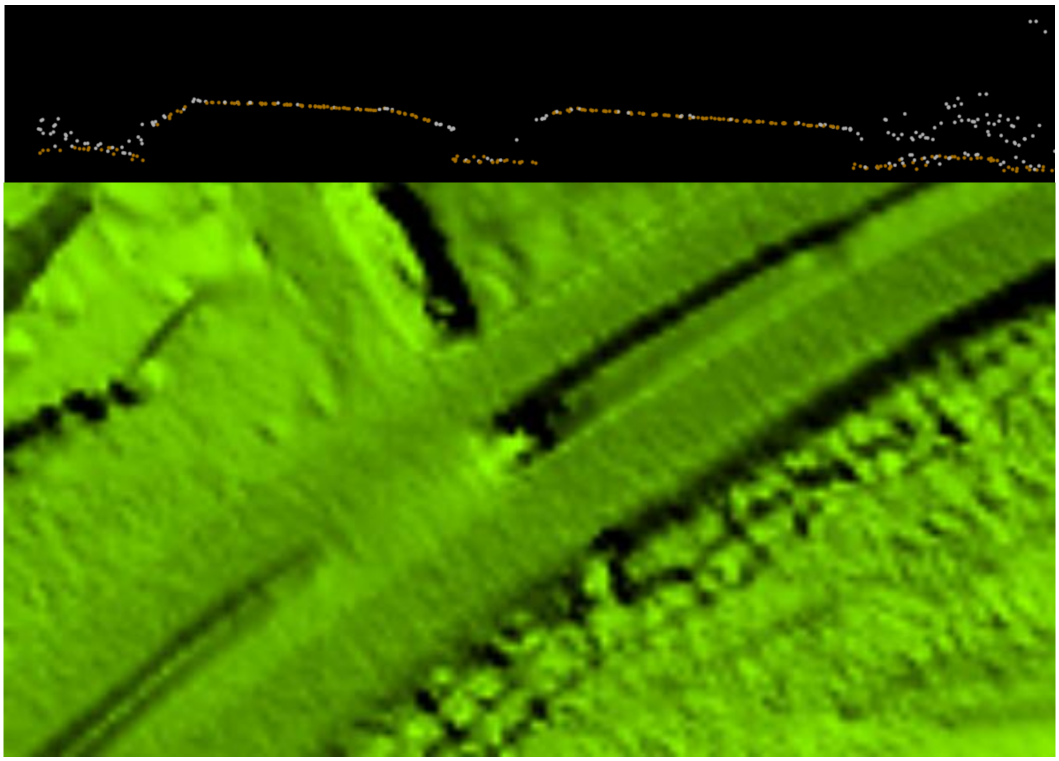


Figure 14– Tile number AW138. Profile with points colored by class (class 1=grey, class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

FORMATTING

After the final QA/QC is performed and all corrections have been applied to the dataset, all lidar files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using Dewberry proprietary tools. The table below lists some of the main lidar header fields that are updated and verified.

Classified Lidar Formatting		
Parameter	**Requirement**	**Pass/Fail**
LAS Version	1.4	Pass
Point Data Format	Format 6	Pass
Coordinate Reference System	NAD83 (2011) UTM Zone 17, meters and NAVD88 (Geoid 12A), meters in WKT Format	Pass
Global Encoder Bit	Should be set to 17 for Adjusted GPS Time	Pass
Time Stamp	Adjusted GPS Time (unique timestamps)	Pass
System ID	Should be set to the processing system/software and is set to NIIRS10 for GeoCue software	Pass
Multiple Returns	The sensor shall be able to collect multiple returns per pulse and the return numbers are recorded	Pass
Intensity	16 bit intensity values are recorded for each pulse	Pass
Classification	Required Classes include: Class 1: Unclassified Class 2: Ground Class 7: Low Noise Class 9: Water Class 10: Ignored Ground Class 17: Bridge Decks Class 18: High Noise	Pass
Overlap and Withheld Points	Overlap (Overage) and Withheld points are set to the Overlap and Withheld bits	Pass
Scan Angle	Recorded for each pulse	Pass
XYZ Coordinates	Unique Easting, Northing, and Elevation coordinates are recorded for each pulse	Pass

Derivative Lidar Products

USGS required a derivative lidar product to be created.

CONTOURS

One-foot contours have been created for the full project area. The contour attributes include labeling as either Index or Intermediate and an elevation value. The contours are also 3D, storing the elevation value within its internal geometry. Some smoothing has been applied to the contours to enhance their aesthetic quality. No contours have been reviewed or edited for correct topology and correct behavior, including correct hydrographic crossings per SOW specifications. Due to the large number of contours present and their file size, the contours have been tiled to the project tiles. Keeping all contours in one large contour file rendered the contours un-usable. The contour tiles are all located within one file GDB and are named according to the final project tile grid.

Lidar Positional Accuracy

BACKGROUND

Dewberry quantitatively tested the dataset by testing the vertical accuracy of the lidar. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest lidar points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the lidar data is actually tested. However there is an increased level of confidence with lidar data due to the relative accuracy. This relative accuracy in turn is based on how well one lidar point "fits" in comparison to the next contiguous lidar measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Dewberry also tests the horizontal accuracy of lidar datasets when checkpoints are photo-identifiable in the intensity imagery. Photo-identifiable checkpoints in intensity imagery typically include checkpoints located at the ends of paint stripes on concrete or asphalt surfaces or checkpoints located at 90 degree corners of different reflectivity, e.g. a sidewalk corner adjoining a grass surface. The XY coordinates of checkpoints, as defined in the intensity imagery, are compared to surveyed XY coordinates for each photo-identifiable checkpoint. These differences are used to compute the tested horizontal accuracy of the lidar. As not all projects contain photo-identifiable checkpoints, the horizontal accuracy of the lidar cannot always be tested.

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment, one hundred ninety nine (199) check points were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, and forested/fully grown land cover categories. Please see appendix A to view the survey report which details and validates how the survey was completed for this project.

Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the “dispersed method” of placement.

All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table.

Point ID	NAD83 (2011) UTM Zone 17		NAVD88 (Geoid 12B)
	Easting X (m)	Northing Y (m)	Elevation (m)
NVA-065	568717.177	4138058.716	457.226
NVA-066	562962.158	4148854.224	568.663
NVA-067	555367.920	4137304.653	748.514
NVA-068	542874.069	4143629.396	818.402
NVA-069	542873.221	4129041.525	575.861
NVA-070	529434.256	4136880.719	541.363
NVA-071	533709.789	4126876.067	521.828
NVA-072	523334.083	4131521.874	543.432
NVA-073	513141.441	4136765.222	509.032
NVA-074	512990.630	4128640.921	491.673
NVA-075	519408.396	4121462.002	736.688
NVA-076	510250.062	4114172.240	638.351
NVA-077	504111.690	4120160.338	682.190
NVA-078	490189.021	4121832.992	616.962
NVA-079	501639.443	4114941.019	645.946
NVA-080	501164.063	4102174.524	685.450
NVA-081	505132.986	4088823.665	632.624
NVA-082	512417.839	4078252.321	622.880
NVA-083	497680.937	4081373.274	707.431
NVA-084	493821.618	4090276.589	720.067
NVA-085	489895.984	4106402.651	760.412
NVA-086	486533.924	4111625.760	668.457
NVA-087	475031.795	4108336.315	961.623
NVA-088	478724.134	4124321.204	772.937
NVA-089	470187.202	4119626.269	758.660
NVA-090	469669.561	4128755.382	707.737
NVA-091	455906.039	4109829.525	739.582
NVA-092	470176.404	4105127.099	942.595
NVA-093	474587.088	4100420.550	829.465
NVA-094	475420.541	4083323.266	776.120
NVA-095	484409.390	4074420.727	702.023
NVA-096	485236.222	4065026.025	796.176
NVA-097	507092.570	4056662.830	718.010
NVA-098	486526.771	4052895.357	821.126
NVA-099	475459.117	4064197.372	932.763
NVA-100	474503.616	4077278.068	800.089
NVA-101	469717.797	4083372.373	758.354
NVA-102	452532.448	4096419.559	643.187
NVA-103	451198.671	4103596.823	841.419
NVA-104	444634.235	4115921.626	521.352
NVA-105	430481.116	4116886.165	910.264

NVA-106	418863.744	4122168.128	479.602
NVA-107	410841.482	4129907.039	404.940
NVA-108	409841.557	4141956.475	295.313
NVA-109	416444.738	4114544.692	499.363
NVA-110	428818.366	4105628.752	591.358
NVA-111	441638.568	4095988.958	715.281
NVA-112	429524.183	4096113.726	689.402
NVA-113	443232.591	4083680.008	625.496
NVA-114	462082.029	4080169.221	700.502
NVA-115	438884.876	4073057.560	624.088
NVA-116	462826.449	4069903.363	791.573
NVA-117	452191.398	4066769.065	748.936
NVA-118	460254.078	4062150.360	939.957
NVA-119	469843.728	4049412.805	763.730
NVA-120	463752.483	4056325.448	857.732
NVA-121	451930.758	4050418.168	969.122
NVA-122	443944.817	4050657.181	1090.464
NVA-123	436499.908	4062376.609	696.735
NVA-124	430339.350	4070672.909	664.573
NVA-125	431730.525	4081446.947	520.226
NVA-126	413238.216	4087924.129	684.256
NVA-127	407024.358	4102817.777	634.655
NVA-128	399439.052	4114042.378	572.580
NVA-129	397657.525	4120928.700	654.829
NVA-130	394458.038	4134889.886	282.676
NVA-131	380795.110	4121969.337	378.348
NVA-132	385436.799	4105591.146	478.286
NVA-133	395114.556	4091191.331	473.598
NVA-134	403214.801	4084282.433	631.874
NVA-135	408919.890	4072117.409	459.663
NVA-136	409807.916	4061488.872	642.649
NVA-137	429331.129	4053630.932	599.277
NVA-138	399188.495	4054984.005	560.752
NVA-139	391545.571	4050745.521	523.602
NVA-140	393210.231	4073905.064	634.847
NVA-141	380894.327	4074083.045	669.020
NVA-142	383111.890	4085022.299	452.876
NVA-143	368879.192	4089332.368	606.412
NVA-144	384751.214	4097070.145	545.681
NVA-145	363233.028	4096255.318	774.164
NVA-146	377009.463	4102406.850	737.299
NVA-147	376378.800	4111085.867	659.471
NVA-148	369126.019	4119602.558	556.619
NVA-149	364198.182	4113245.210	467.278
NVA-150	367542.635	4105290.032	459.195
NVA-151	358077.446	4110144.323	482.472
NVA-152	351508.880	4103225.216	718.825

NVA-153	355181.889	4088904.570	649.481
NVA-154	364198.345	4081280.111	847.883
NVA-155	369323.886	4077164.363	412.552
NVA-156	376846.949	4063827.767	531.996
NVA-157	372897.362	4055911.905	401.734
NVA-158	367203.022	4061569.306	485.022
NVA-159	359015.362	4070783.449	386.478
NVA-160	350881.297	4078976.961	973.622
NVA-161	341267.483	4081693.295	448.021
NVA-162	341425.324	4091299.424	574.873
NVA-163	331006.254	4081553.102	644.971
NVA-164	340775.506	4075636.996	586.149
NVA-165	348788.593	4066602.492	466.339
NVA-166	359675.921	4056413.225	411.919
NVA-167	344479.680	4056439.996	410.062
NVA-168	339164.737	4066108.768	414.728
NVA-169	331385.325	4071630.521	457.401
NVA-170	318647.577	4078363.317	527.179
NVA-171	316861.867	4068891.524	434.473
NVA-172	329233.494	4065415.938	565.724
NVA-173	333058.613	4057125.263	372.976
NVA-174	317373.089	4055160.189	383.603
NVA-175	309981.018	4062076.597	437.183
NVA-176	307412.202	4054105.343	426.736
NVA-177	295379.546	4063137.755	433.421
NVA-178	291528.562	4057169.507	427.725
NVA-179	280309.880	4056685.962	419.628
NVA-180	265092.667	4053722.300	369.857
VVA-047	559722.582	4145196.383	535.466
VVA-048	562526.101	4139778.119	757.912
VVA-049	547561.065	4138416.566	620.999
VVA-050	533863.502	4135901.310	1265.326
VVA-051	546050.066	4133799.811	701.632
VVA-052	528766.225	4122026.598	579.295
VVA-053	513618.984	4140680.248	453.721
VVA-054	515717.498	4117185.122	597.731
VVA-055	506617.632	4125877.015	523.123
VVA-056	506564.424	4114319.702	631.437
VVA-057	489361.285	4120885.347	620.818
VVA-058	467313.082	4127246.521	769.508
VVA-059	474755.974	4118862.825	1103.243
VVA-060	485064.145	4108551.118	952.839
VVA-061	503890.297	4096370.620	679.881
VVA-062	483068.790	4096035.863	713.778
VVA-063	490183.019	4080664.506	812.320
VVA-064	510881.080	4086140.571	642.634
VVA-065	501853.721	4049571.930	763.605

VVA-066	484818.997	4061124.979	815.913
VVA-067	472350.459	4072074.545	812.797
VVA-068	465169.154	4090992.417	809.788
VVA-069	465611.797	4098419.714	721.218
VVA-070	456175.314	4121148.017	657.252
VVA-071	448613.911	4116354.663	704.733
VVA-072	437396.857	4115134.246	689.928
VVA-073	428162.477	4122212.941	803.257
VVA-074	413555.206	4131832.810	511.454
VVA-075	406311.279	4145029.345	280.220
VVA-076	402179.108	4135702.732	397.679
VVA-077	422176.273	4114001.186	831.570
VVA-078	437445.421	4108008.835	639.441
VVA-079	435347.070	4089336.491	1224.106
VVA-080	448575.316	4089741.627	593.395
VVA-081	466399.994	4079863.692	812.672
VVA-082	437990.797	4078620.462	722.178
VVA-083	455110.555	4067420.910	781.847
VVA-084	471691.039	4060107.408	862.972
VVA-085	458798.697	4052386.347	972.077
VVA-086	438318.545	4056831.477	925.678
VVA-087	427744.113	4077130.672	608.511
VVA-088	419110.733	4091631.002	723.175
VVA-089	410195.307	4100037.688	666.585
VVA-090	404285.020	4115509.421	450.448
VVA-091	390682.009	4127089.424	635.545
VVA-092	377204.271	4122077.661	534.848
VVA-093	390687.933	4109586.643	406.776
VVA-094	402490.703	4092756.688	475.169
VVA-095	414175.500	4076306.477	523.468
VVA-096	420777.039	4058226.561	574.556
VVA-097	408479.202	4051134.642	534.205
VVA-098	397854.470	4068152.071	438.218
VVA-099	392650.368	4084436.088	542.875
VVA-100	377864.543	4100478.650	500.829
VVA-101	373278.527	4115108.464	535.241
VVA-102	356287.066	4113426.923	629.649
VVA-103	362287.555	4102358.735	495.363
VVA-104	369624.258	4095685.828	797.243
VVA-105	378719.774	4091104.613	857.703
VVA-106	373343.985	4083220.198	585.846
VVA-107	383838.465	4070872.097	540.918
VVA-108	386639.000	4064277.116	423.854
VVA-109	390801.451	4055089.543	616.383
VVA-110	374066.176	4051673.347	493.282
VVA-111	371065.067	4065352.449	602.410
VVA-112	364929.278	4076947.154	436.772

VVA-113	354588.996	4086712.841	968.501
VVA-114	346254.781	4097526.676	653.673
VVA-115	350531.856	4106855.071	505.494
VVA-116	336762.438	4092098.582	599.090
VVA-117	347875.019	4080791.564	503.674
VVA-118	354448.511	4064645.276	460.088
VVA-119	348748.204	4056114.960	491.610
VVA-120	339553.642	4067855.477	429.186
VVA-122	316401.019	4075174.568	466.998
VVA-123	323065.397	4065644.052	477.637
VVA-124	325628.985	4056086.160	445.872
VVA-125	315079.079	4055662.729	431.951
VVA-126	306408.004	4067054.799	486.725
VVA-127	298953.317	4063315.896	500.715
VVA-128	295682.925	4054509.531	404.660
VVA-129	282638.475	4054483.093	467.836
VVA-130	271750.810	4057340.982	444.156

Table 6:Virginia South West AOI surveyed accuracy checkpoints

The figure below shows the location of the QA/QC checkpoints used to test the positional accuracy of the dataset.

Virginia Southwest - Checkpoint Locations

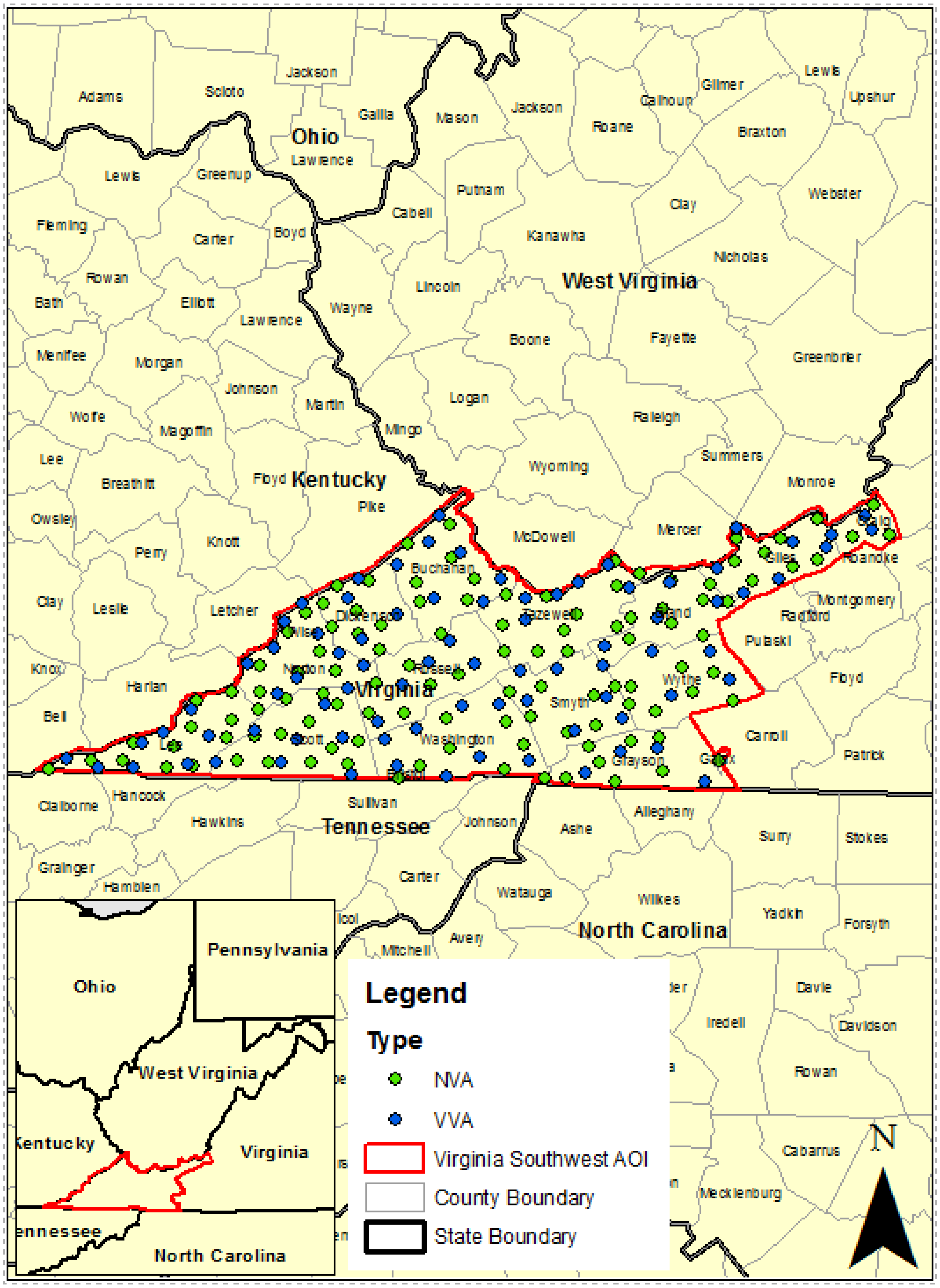


Figure 15 – Location of QA/QC Checkpoints

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the lidar sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated lidar sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600. For the Virginia Southwest AOI, vertical accuracy must be 19.6 cm or less based on an $RMSE_z$ of 10 cm x 1.9600.

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95^{th} percentile error for all checkpoints in all vegetated land cover categories combined. The Virginia Southwest AOI VVA standard is 29.4 cm based on the 95^{th} percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95^{th} percentile used to compute the VVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from VVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas VVA assumes lidar errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in Table 7.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using $RMSE_z$ *1.9600	19.6 cm (based on $RMSE_z$ (10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	29.4 cm (based on combined 95^{th} percentile)

Table 7 — Acceptance Criteria

The primary QA/QC vertical accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, Dewberry interpolated the bare-earth lidar DTM to provide the z-value for every checkpoint.
3. Dewberry then computed the associated z-value differences between the interpolated z-value from the lidar data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.
4. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

VERTICAL ACCURACY RESULTS

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified lidar LAS files.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	116	0.122	
VVA	83		0.208

Table 8 – Tested NVA and VVA

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =5 cm, equating to +/- 10 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 13 cm at the 95th percentile.

The figure below illustrates the magnitude of the differences between the QA/QC checkpoints and lidar data. This shows that the majority of lidar elevations were within +/- 20 cm of the checkpoints elevations, but there were some outliers where lidar and checkpoint elevations differed by up to +70 cm.

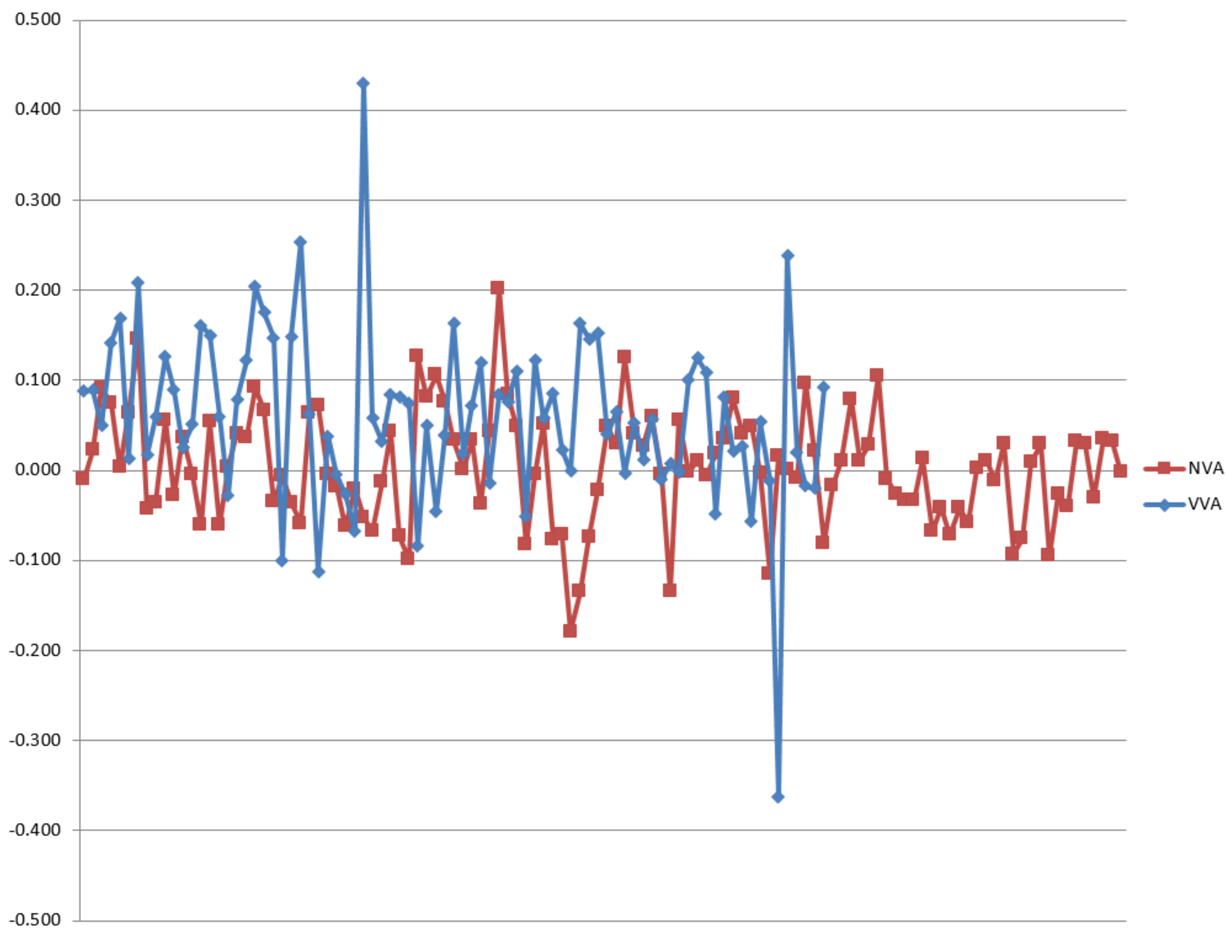


Figure 16 – Magnitude of elevation discrepancies per land cover category

Table 9 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83 UTM Zone 15		NAVD88 (Geoid 12A)	Lidar Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
VVA-126	306408.004	4067054.799	486.725	486.964	0.239	0.239
VVA-071	448613.911	4116354.663	704.733	704.987	0.254	0.254
VVA-125	315079.079	4055662.729	431.951	431.588	-0.363	0.363
VVA-078	437445.421	4108008.835	639.441	639.871	0.430	0.430

Table 9 – 5% Outliers

Table 10 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	116	0.062	0.004	0.002	0.005	0.062	0.518	-0.179	0.202
VVA	83	N/A	0.060	0.058	-0.261	0.098	5.259	-0.363	0.430

Table 10 – Overall Descriptive Statistics

The figure below illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the lidar triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.36 meters and a high of +0.43 meters, the histogram shows that the majority of the discrepancies are skewed on the positive side. The vast majority of points are within the ranges of -0.05 meters to +0.05 meters.

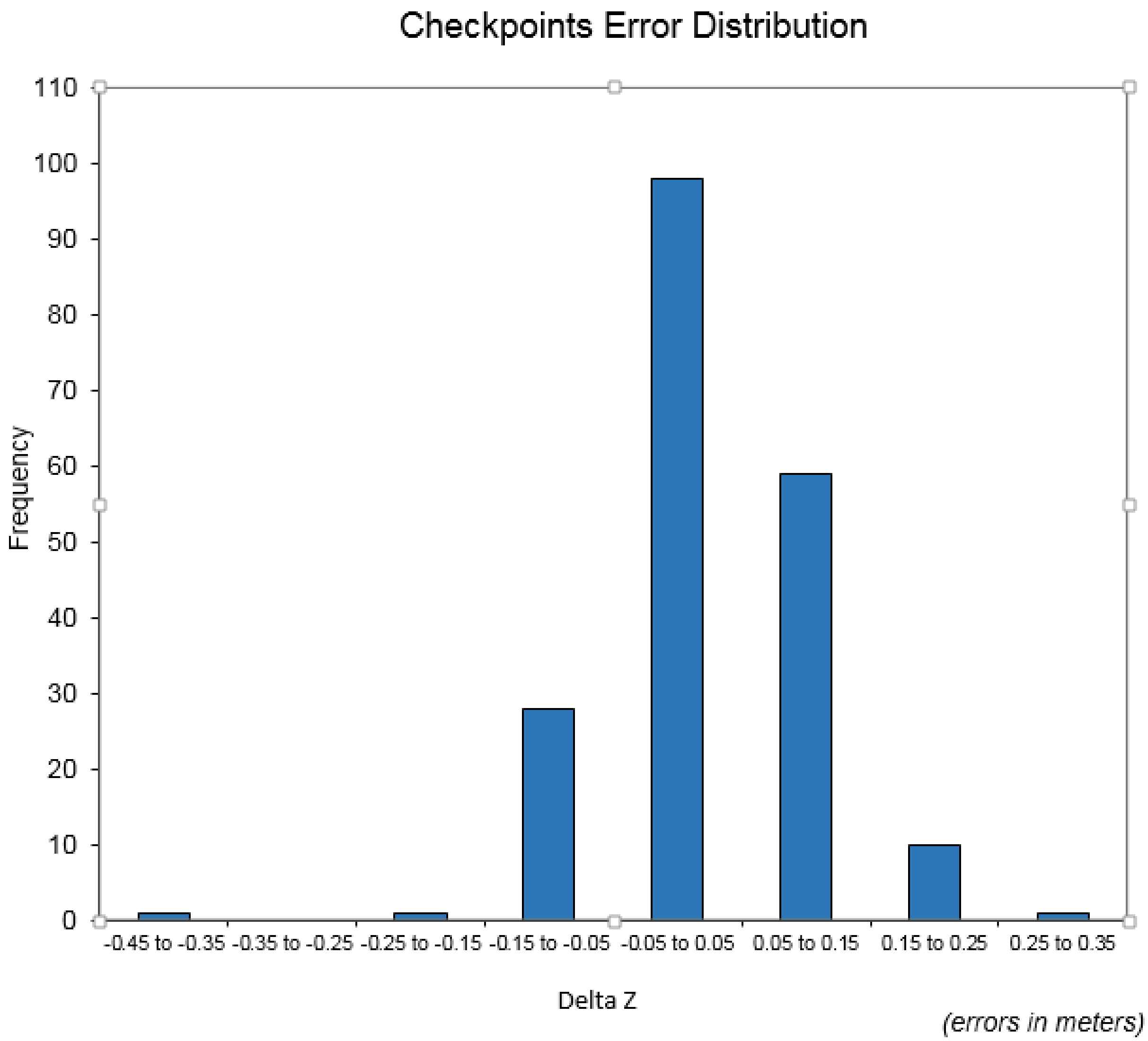


Figure 17 – Histogram of Elevation Discrepancies with errors in meters

Based on the vertical accuracy testing conducted by Dewberry, the lidar dataset for the Virginia Southwest AOI satisfies the project's pre-defined vertical accuracy criteria.

A separate vertical accuracy report has been attached as Appendix D with this project that reports the vertical accuracy results for the combined project vertical accuracies that include both the West Virginia Northeast and Virginia Southwest AOIs.

HORIZONTAL ACCURACY TEST PROCEDURES

Horizontal accuracy testing requires well-defined checkpoints that can be identified in the dataset. Elevation datasets, including lidar datasets, do not always contain well-defined checkpoints suitable for horizontal accuracy assessment. However, the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) recommends at least half of the NVA vertical check points should be located at the ends of paint stripes or other point features visible on the lidar intensity image, allowing them to double as horizontal check points.

Dewberry reviews all NVA checkpoints to determine which, if any, of these checkpoints are located on photo-identifiable features in the intensity imagery. This subset of checkpoints are then used for horizontal accuracy testing.

The primary QA/QC horizontal accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications and tried to locate half of the NVA checkpoints on features photo-identifiable in the intensity imagery.
2. Next, Dewberry identified the well-defined features in the intensity imagery.
3. Dewberry then computed the associated xy-value differences between the coordinates of the well-defined feature in the lidar intensity imagery and the ground truth survey checkpoints.
4. The data were analyzed by Dewberry to assess the accuracy of the data. Horizontal accuracy was assessed using NSSDA methodology where horizontal accuracy is calculated at the 95% confidence level. This report provides the results of the horizontal accuracy testing.

HORIZONTAL ACCURACY RESULTS

Thirty Eight (38) checkpoints were determined to be photo-identifiable in the intensity imagery and were used to test the horizontal accuracy of the lidar dataset.

Using NSSDA methodology (endorsed by the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)), horizontal accuracy at the 95% confidence level (called ACCURACYr) is computed by the formula RMSEr * 1.7308 or RMSExy * 2.448.

No horizontal accuracy requirements or thresholds were provided for this project. However, lidar datasets are generally calibrated by methods designed to ensure a horizontal accuracy of 1 meter or less at the 95% confidence level.

# of Points	$RMSE_x$ (Target=41 cm)	$RMSE_y$ (Target=41 cm)	$RMSE_r$ (Target=58 cm)	$ACCURACY_r$ ($RMSE_r$ x 1.7308) Target=100 cm
38	0.237	0.208	0.316	0.546

Table 11-Tested horizontal accuracy at the 95% confidence level

This data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 41 cm RMSEx/RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 1 meter at a 95% confidence level. Using this small sample set of photo-identifiable checkpoints, positional accuracy of this dataset was found to be RMSEx = 23.7cm and RMSEy = 20.8cm which equates to +/- 54.6 cm at 95% confidence level.

Breakline Production & Qualitative Assessment Report

BREAKLINE PRODUCTION METHODOLOGY

The breaklines were collected by using intensity imagery and bare earth models within Arcmap and LP360 software. After 2D digitization for horizontal placement in Arcmap, LP360 was used to conflate the 2D breaklines into 3D using the input bare earth models. Lakes and ponds were assigned a single lowest elevation for each entire feature and monotonicity is enforced on streams and rivers while maintaining elevations below the surrounding terrain."

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are at a constant elevation where the lowest elevation of the water body has been applied to the entire water body.

BREAKLINE QUALITATIVE ASSESSMENT

Dewberry completed breakline qualitative assessments according to a defined workflow. The following workflow diagram represents the steps taken by Dewberry to provide a thorough qualitative assessment of the breakline data.

Completeness and horizontal placement is verified through visual reviews against lidar intensity imagery. Automated checks are applied on all breakline features to validate topology, including the 3D connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

The next step is to compare the elevation of the breakline vertices against the ground elevation extracted from the ESRI Terrain built from the lidar ground points, keeping in mind that a discrepancy is expected because of the hydro-enforcement applied to the breaklines and because of the interpolated imagery used to acquire the breaklines. A given tolerance is used to validate if the elevations differ too much from the lidar.

After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

BREAKLINE CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Use lidar-derived data, which may include intensity imagery, stereo pairs, bare earth ground models, density models, slope models, and terrains, to collect breaklines according to project specifications.
Pass	In areas of heavy vegetation or where the exact shoreline is hard to delineate, it is better to err on placing the breakline *slightly* inside or seaward of the shoreline (breakline can be inside shoreline by 1x-2x NPS).
Pass	After each producer finishes breakline collection for a block, each producer must perform a completeness check, breakline variance check, and all automated checks on their block before calling that block complete and ready for the final merge and QC

Pass	After breaklines are completed for production blocks, all production blocks should be merged together and completeness and automated checks should be performed on the final, merged GDB. Ensure correct snapping-horizontal (x,y) and vertical (z)-between all production blocks.
Pass	Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency. Features should be collected consistently across tile bounds. Check that the horizontal placement of breaklines is correct. Breaklines should be compared to full point cloud intensity imagery and terrains
Pass	Breaklines are correctly edge-matched to adjoining datasets in completion, coding, and horizontal placement.
Pass	Using a terrain created from lidar ground (all ground including 2, 8, and 10) and water points (class 9), compare breakline Z values to interpolated lidar elevations.
Pass	Perform all Topology and Data Integrity Checks
Pass	Perform hydro-flattening and hydro-enforcement checks including monotonicity and flatness from bank to bank on linear hydrographic features and flatness of water bodies. Tidal waters should preserve as much ground as possible and can include variations or be non-monotonic.

Table 12-A subset of the high-level steps from Dewberry's Production and QA/QC checklist performed for this project.

DATA DICTIONARY

The following data dictionary was used for this project.

Horizontal and Vertical Datum

The horizontal datum shall be North American Datum of 1983, Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Meters. Geoid12B shall be used to convert ellipsoidal heights to orthometric heights.

Coordinate System and Projection

All data shall be projected to UTM Zone 17, Horizontal Units in Meters and Vertical Units in Meters.

Inland Streams and Rivers

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: STREAMS_AND_RIVERS
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict linear hydrographic features with a width greater than 100 feet.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software

SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity. Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 1 acre. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

Inland Ponds and Lakes

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: PONDS_AND_LAKES
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict closed water body features that are at a constant elevation.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. “Donuts” will exist where there are islands within a closed water body feature.	Water bodies shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature that is 1 acre in size or greater will also have a “donut polygon” compiled. These instructions are only for docks or piers that follow the coastline or water’s edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water’s edge beneath

		the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

Dewberry utilized ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software is used to generate the products and the QC is performed in both ArcGIS and Global Mapper. The figure below shows the entire process necessary for bare earth DEM production, starting from the lidar swath processing.

The final bare-earth lidar points are used to create a terrain. The final 3D breaklines collected for the project are also enforced in the terrain. The terrain is then converted to raster format using linear interpolation. For most projects, a single terrain/DEM can be created for the whole project. For very large projects, multiple terrains/DEMs may be created. The DEM(s) is reviewed for any issues requiring corrections, including remaining lidar mis-classifications, erroneous breakline elevations, poor hydro-flattening or hydro-enforcement, and processing artifacts. After corrections are applied, the DEM(s) is then split into individual tiles following the project tiling scheme. The tiles are verified for final formatting and then loaded into Global Mapper to ensure no missing or corrupt tiles and to ensure seamlessness across tile boundaries.

Figure 18-DEM Production Workflow

DEM QUALITATIVE ASSESSMENT

Dewberry performed a comprehensive qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Dewberry has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. To perform this review Dewberry creates HillShade models and overlays a partially transparent colorized elevation model to review for these issues. All corrections are completed using Dewberry's proprietary correction workflow. Upon completion of the corrections, the DEM data is loaded into Global Mapper for its second review and to verify corrections. Once the DEMs are tiled out, the final tiles are again loaded into Global Mapper to ensure coverage, extents, and that the final tiles are seamless.

The images below show an example of a bare earth DEM.

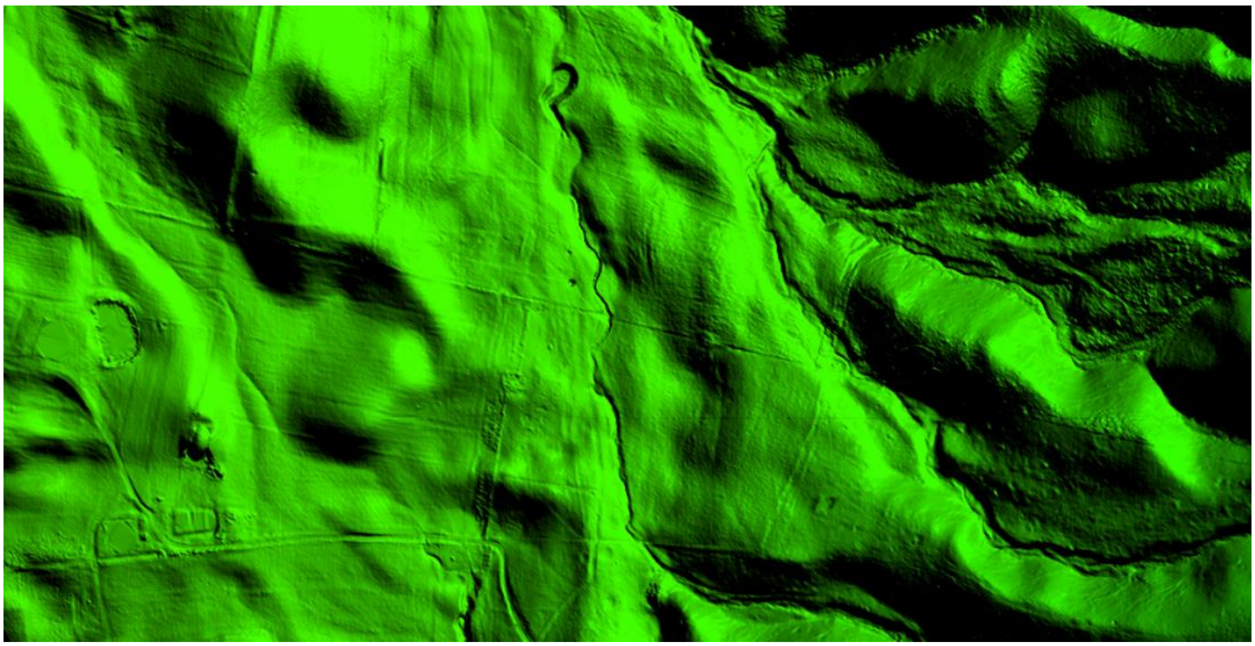


Figure 19-Tile AO144. The bare earth DEM

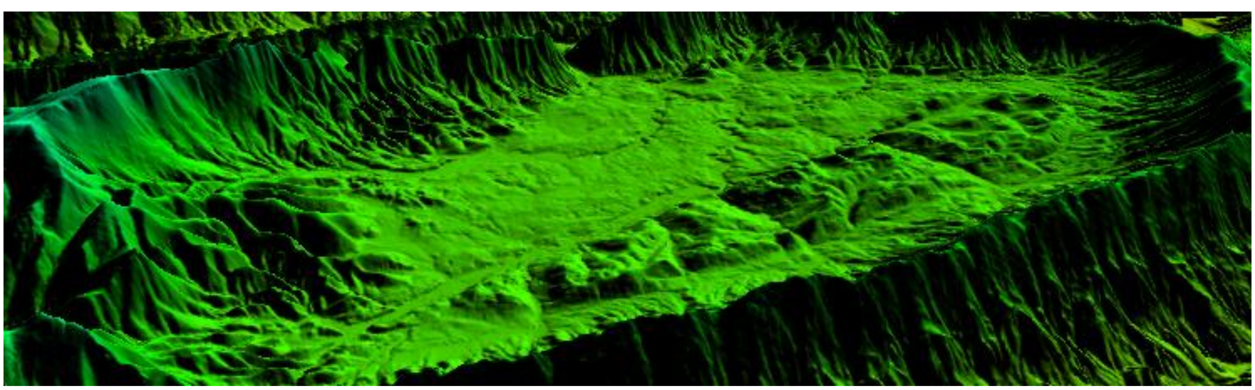


Figure 20- 60 Tile area, Burke's Garden, VA; 3D Profile view of the bare earth DEM

When some bridges are removed from the ground surface, the distance from bridge abutment to bridge abutment is small enough that the DEM interpolates across the entire bridge opening, forming 'bridge saddles.' Dewberry collected 3D bridge breaklines in locations where bridge saddles were present and enforced these breaklines in the final DEM creation to help mitigate the bridge saddle artifacts. The image below on the left shows a bridge saddle while the image below on the right shows the same bridge after bridge breaklines have been enforced.

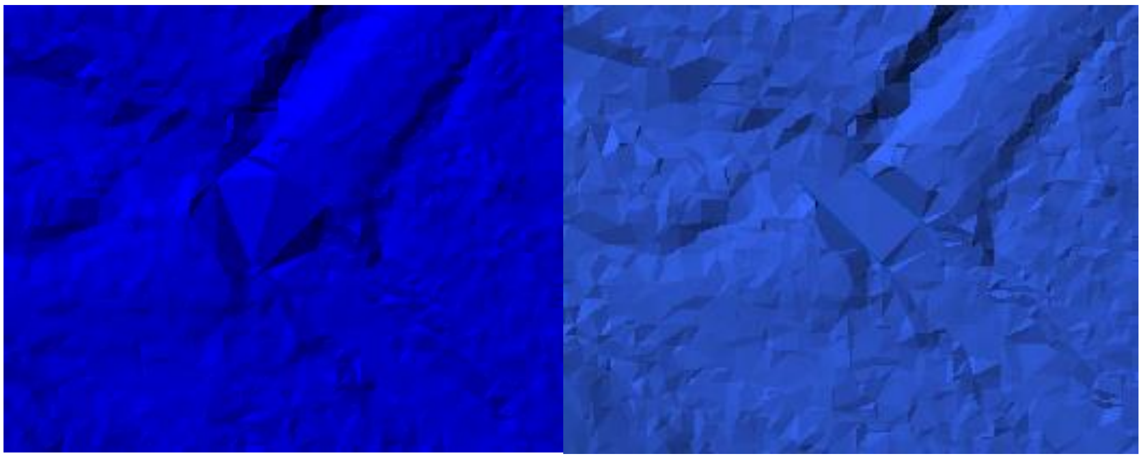


Figure 21-Tile U69. The TIN ground surface on the left shows a bridge saddle artifact while the TIN ground surface on the right shows the same location after bridge breaklines have been enforced.

DEM VERTICAL ACCURACY RESULTS

The same 199 checkpoints that were used to test the vertical accuracy of the lidar were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source lidar and final DEM deliverable. DEMs are created by averaging several lidar points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several lidar points together but may interpolate (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the surveyed elevations. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Table 13 summarizes the tested vertical accuracy results from a comparison of the surveyed checkpoints to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA — Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA — Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	116	0.118	
VVA	83		0.210

Table 13 — DEM tested NVA and VVA

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =6 cm, equating to +/- 11.8 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 21 cm at the 95th percentile.

Table 14 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83 UTM Zone 15		NAVD88 (Geoid 12A)	DEM Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
VVA-071	448613.911	4116354.663	704.733	704.972	0.239	0.239
VVA-126	306408.004	4067054.799	486.725	486.981	0.256	0.256
VVA-125	315079.079	4055662.729	431.951	431.618	-0.333	0.333
VVA-078	437445.421	4108008.835	639.441	639.863	0.422	0.422
VVA-071	448613.911	4116354.663	704.733	704.972	0.239	0.239

Table 14 — 5% Outliers

Table 15 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	116	0.060	0.003	0.002	0.115	0.061	0.956	-0.161	0.217
VVA	83	N/A	0.068	0.065	-0.258	0.099	3.863	-0.333	0.422

Table 15 — Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Virginia Southwest Lidar Project satisfies the project's pre-defined vertical accuracy criteria.

DEM CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's bare earth DEM Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Masspoints (LAS to multipoint) are created from ground points only (class 2 and class 8 if model key points created, but no class 10 ignored ground points or class 9 water points
Pass	Create a terrain for each production block using the final bare earth lidar points and final breaklines.
Pass	Convert terrains to rasters using project specifications for grid type, formatting, and cell size
Pass	Create hillshades for all DEMs
Pass	Manually review bare-earth DEMs in ArcMap with hillshades to check for issues
Pass	DEMs should be hydro-flattened or hydro-enforced as required by project specifications
Pass	DEMs should be seamless across tile boundaries

Pass	Water should be flowing downhill without excessive water artifacts present
Pass	Water features should NOT be floating above surrounding
Pass	Bridges should NOT be present in bare-earth DEMs.
Pass	Any remaining bridge saddles where below bridge breaklines were not used need to be fixed by adding below bridge breaklines and re-processing.
Pass	All qualitative issues present in the DEMs as a result of lidar processing and editing issues must be marked for corrections in the lidar These DEMs will need to be recreated after the lidar has been corrected.
Pass	Calculate DEM Vertical Accuracy including NVA, VVA, and other statistics
Pass	Split the DEMs into tiles according to the project tiling scheme
Pass	Verify all properties of the tiled DEMs, including coordinate reference system information, cell size, cell extents, and that compression has not been applied to the tiled DEMs
Pass	Load all tiled DEMs into Global Mapper to verify complete coverage to the (buffered) project boundary and that no tiles are corrupt.

Table 16-A subset of the high-level steps from Dewberry's bare earth DEM Production and QA/QC checklist performed for this project.

Appendix A and B: Survey Reports

The survey report is attached as a separate ancillary document.

Appendix C: Complete List of Delivered Tiles

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D157
D158

D159	E36	E78	E120	E162	F37
D160	E37	E79	E121	E163	F38
D161	E38	E80	E122	E164	F39
D162	E39	E81	E123	E165	F40
D163	E40	E82	E124	E166	F41
D164	E41	E83	E125	E167	F42
D165	E42	E84	E126	F1	F43
D166	E43	E85	E127	F2	F44
D167	E44	E86	E128	F3	F45
D168	E45	E87	E129	F4	F46
E4	E46	E88	E130	F5	F47
E5	E47	E89	E131	F6	F48
E6	E48	E90	E132	F7	F49
E7	E49	E91	E133	F8	F50
E8	E50	E92	E134	F9	F51
E9	E51	E93	E135	F10	F52
E10	E52	E94	E136	F11	F53
E11	E53	E95	E137	F12	F54
E12	E54	E96	E138	F13	F55
E13	E55	E97	E139	F14	F56
E14	E56	E98	E140	F15	F57
E15	E57	E99	E141	F16	F58
E16	E58	E100	E142	F17	F59
E17	E59	E101	E143	F18	F60
E18	E60	E102	E144	F19	F61
E19	E61	E103	E145	F20	F62
E20	E62	E104	E146	F21	F63
E21	E63	E105	E147	F22	F64
E22	E64	E106	E148	F23	F65
E23	E65	E107	E149	F24	F66
E24	E66	E108	E150	F25	F67
E25	E67	E109	E151	F26	F68
E26	E68	E110	E152	F27	F69
E27	E69	E111	E153	F28	F70
E28	E70	E112	E154	F29	F71
E29	E71	E113	E155	F30	F72
E30	E72	E114	E156	F31	F73
E31	E73	E115	E157	F32	F74
E32	E74	E116	E158	F33	F75
E33	E75	E117	E159	F34	F76
E34	E76	E118	E160	F35	F77
E35	E77	E119	E161	F36	F78

F79	F121	F163	G38	G80	G122
F80	F122	F164	G39	G81	G123
F81	F123	F165	G40	G82	G124
F82	F124	F166	G41	G83	G125
F83	F125	F167	G42	G84	G126
F84	F126	G1	G43	G85	G127
F85	F127	G2	G44	G86	G128
F86	F128	G3	G45	G87	G129
F87	F129	G4	G46	G88	G130
F88	F130	G5	G47	G89	G131
F89	F131	G6	G48	G90	G132
F90	F132	G7	G49	G91	G133
F91	F133	G8	G50	G92	G134
F92	F134	G9	G51	G93	G135
F93	F135	G10	G52	G94	G136
F94	F136	G11	G53	G95	G137
F95	F137	G12	G54	G96	G138
F96	F138	G13	G55	G97	G139
F97	F139	G14	G56	G98	G140
F98	F140	G15	G57	G99	G141
F99	F141	G16	G58	G100	G142
F100	F142	G17	G59	G101	G143
F101	F143	G18	G60	G102	G144
F102	F144	G19	G61	G103	G145
F103	F145	G20	G62	G104	G146
F104	F146	G21	G63	G105	G147
F105	F147	G22	G64	G106	G148
F106	F148	G23	G65	G107	G149
F107	F149	G24	G66	G108	G150
F108	F150	G25	G67	G109	G151
F109	F151	G26	G68	G110	G152
F110	F152	G27	G69	G111	G153
F111	F153	G28	G70	G112	G154
F112	F154	G29	G71	G113	G155
F113	F155	G30	G72	G114	G156
F114	F156	G31	G73	G115	G157
F115	F157	G32	G74	G116	G158
F116	F158	G33	G75	G117	G159
F117	F159	G34	G76	G118	G160
F118	F160	G35	G77	G119	G161
F119	F161	G36	G78	G120	G162
F120	F162	G37	G79	G121	G163

G164	H41	H83	H125	I5	I47
G165	H42	H84	H126	I6	I48
G166	H43	H85	H127	I7	I49
H2	H44	H86	H128	I8	I50
H3	H45	H87	H129	I9	I51
H4	H46	H88	H130	I10	I52
H5	H47	H89	H131	I11	I53
H6	H48	H90	H132	I12	I54
H7	H49	H91	H133	I13	I55
H8	H50	H92	H134	I14	I56
H9	H51	H93	H135	I15	I57
H10	H52	H94	H136	I16	I58
H11	H53	H95	H137	I17	I59
H12	H54	H96	H138	I18	I60
H13	H55	H97	H139	I19	I61
H14	H56	H98	H140	I20	I62
H15	H57	H99	H141	I21	I63
H16	H58	H100	H142	I22	I64
H17	H59	H101	H143	I23	I65
H18	H60	H102	H144	I24	I66
H19	H61	H103	H145	I25	I67
H20	H62	H104	H146	I26	I68
H21	H63	H105	H147	I27	I69
H22	H64	H106	H148	I28	I70
H23	H65	H107	H149	I29	I71
H24	H66	H108	H150	I30	I72
H25	H67	H109	H151	I31	I73
H26	H68	H110	H152	I32	I74
H27	H69	H111	H153	I33	I75
H28	H70	H112	H154	I34	I76
H29	H71	H113	H155	I35	I77
H30	H72	H114	H156	I36	I78
H31	H73	H115	H157	I37	I79
H32	H74	H116	H158	I38	I80
H33	H75	H117	H159	I39	I81
H34	H76	H118	H160	I40	I82
H35	H77	H119	H161	I41	I83
H36	H78	H120	H162	I42	I84
H37	H79	H121	H163	I43	I85
H38	H80	H122	H164	I44	I86
H39	H81	H123	H165	I45	I87
H40	H82	H124	H166	I46	I88

I89	I131	J12	J54	J96	J138
I90	I132	J13	J55	J97	J139
I91	I133	J14	J56	J98	J140
I92	I134	J15	J57	J99	J141
I93	I135	J16	J58	J100	J142
I94	I136	J17	J59	J101	J143
I95	I137	J18	J60	J102	J144
I96	I138	J19	J61	J103	J145
I97	I139	J20	J62	J104	J146
I98	I140	J21	J63	J105	J147
I99	I141	J22	J64	J106	J148
I100	I142	J23	J65	J107	J149
I101	I143	J24	J66	J108	J150
I102	I144	J25	J67	J109	J151
I103	I145	J26	J68	J110	J152
I104	I146	J27	J69	J111	J153
I105	I147	J28	J70	J112	J154
I106	I148	J29	J71	J113	J155
I107	I149	J30	J72	J114	J156
I108	I150	J31	J73	J115	J157
I109	I151	J32	J74	J116	J158
I110	I152	J33	J75	J117	J159
I111	I153	J34	J76	J118	J160
I112	I154	J35	J77	J119	J161
I113	I155	J36	J78	J120	J162
I114	I156	J37	J79	J121	J163
I115	I157	J38	J80	J122	J164
I116	I158	J39	J81	J123	J165
I117	I159	J40	J82	J124	J166
I118	I160	J41	J83	J125	J167
I119	I161	J42	J84	J126	K9
I120	I162	J43	J85	J127	K10
I121	I163	J44	J86	J128	K11
I122	I164	J45	J87	J129	K12
I123	I165	J46	J88	J130	K16
I124	I166	J47	J89	J131	K17
I125	I167	J48	J90	J132	K18
I126	J7	J49	J91	J133	K19
I127	J8	J50	J92	J134	K20
I128	J9	J51	J93	J135	K21
I129	J10	J52	J94	J136	K22
I130	J11	J53	J95	J137	K23

K24	K66	K108	K150	L43	L85
K25	K67	K109	K151	L44	L86
K26	K68	K110	K152	L45	L87
K27	K69	K111	K153	L46	L88
K28	K70	K112	K154	L47	L89
K29	K71	K113	K155	L48	L90
K30	K72	K114	K156	L49	L91
K31	K73	K115	K157	L50	L92
K32	K74	K116	K158	L51	L93
K33	K75	K117	K159	L52	L94
K34	K76	K118	K160	L53	L95
K35	K77	K119	K161	L54	L96
K36	K78	K120	K162	L55	L97
K37	K79	K121	K163	L56	L98
K38	K80	K122	K165	L57	L99
K39	K81	K123	K166	L58	L100
K40	K82	K124	K167	L59	L101
K41	K83	K125	L18	L60	L102
K42	K84	K126	L19	L61	L103
K43	K85	K127	L20	L62	L104
K44	K86	K128	L21	L63	L105
K45	K87	K129	L22	L64	L106
K46	K88	K130	L23	L65	L107
K47	K89	K131	L24	L66	L108
K48	K90	K132	L25	L67	L109
K49	K91	K133	L26	L68	L110
K50	K92	K134	L27	L69	L111
K51	K93	K135	L28	L70	L112
K52	K94	K136	L29	L71	L113
K53	K95	K137	L30	L72	L114
K54	K96	K138	L31	L73	L115
K55	K97	K139	L32	L74	L116
K56	K98	K140	L33	L75	L117
K57	K99	K141	L34	L76	L118
K58	K100	K142	L35	L77	L119
K59	K101	K143	L36	L78	L120
K60	K102	K144	L37	L79	L121
K61	K103	K145	L38	L80	L122
K62	K104	K146	L39	L81	L123
K63	K105	K147	L40	L82	L124
K64	K106	K148	L41	L83	L125
K65	K107	K149	L42	L84	L126

L127	M26	M68	M110	M152	N54
L128	M27	M69	M111	M153	N55
L129	M28	M70	M112	M154	N56
L130	M29	M71	M113	M155	N57
L131	M30	M72	M114	M156	N58
L132	M31	M73	M115	M157	N59
L133	M32	M74	M116	M158	N60
L134	M33	M75	M117	M159	N61
L135	M34	M76	M118	M160	N62
L136	M35	M77	M119	M161	N63
L137	M36	M78	M120	M162	N64
L138	M37	M79	M121	N23	N65
L139	M38	M80	M122	N24	N66
L140	M39	M81	M123	N25	N67
L141	M40	M82	M124	N26	N68
L142	M41	M83	M125	N27	N69
L143	M42	M84	M126	N28	N70
L144	M43	M85	M127	N29	N71
L145	M44	M86	M128	N30	N72
L146	M45	M87	M129	N31	N73
L147	M46	M88	M130	N32	N74
L148	M47	M89	M131	N33	N75
L149	M48	M90	M132	N34	N76
L150	M49	M91	M133	N35	N77
L151	M50	M92	M134	N36	N78
L152	M51	M93	M135	N37	N79
L153	M52	M94	M136	N38	N80
L154	M53	M95	M137	N39	N81
L155	M54	M96	M138	N40	N82
L156	M55	M97	M139	N41	N83
L157	M56	M98	M140	N42	N84
L158	M57	M99	M141	N43	N85
L159	M58	M100	M142	N44	N86
L160	M59	M101	M143	N45	N87
L161	M60	M102	M144	N46	N88
L162	M61	M103	M145	N47	N89
M20	M62	M104	M146	N48	N90
M21	M63	M105	M147	N49	N91
M22	M64	M106	M148	N50	N92
M23	M65	M107	M149	N51	N93
M24	M66	M108	M150	N52	N94
M25	M67	M109	M151	N53	N95

N96	N138	O44	O86	O128	P40
N97	N139	O45	O87	O129	P41
N98	N140	O46	O88	O130	P42
N99	N141	O47	O89	O131	P43
N100	N142	O48	O90	O132	P44
N101	N143	O49	O91	O133	P45
N102	N144	O50	O92	O134	P46
N103	N145	O51	O93	O135	P47
N104	N146	O52	O94	O136	P48
N105	N147	O53	O95	O137	P49
N106	N148	O54	O96	O138	P50
N107	N149	O55	O97	O139	P51
N108	N150	O56	O98	O140	P52
N109	N151	O57	O99	O141	P53
N110	N152	O58	O100	O142	P54
N111	N153	O59	O101	O143	P55
N112	N154	O60	O102	O144	P56
N113	N155	O61	O103	O145	P57
N114	N156	O62	O104	O146	P58
N115	N157	O63	O105	O147	P59
N116	N158	O64	O106	O148	P60
N117	N159	O65	O107	O149	P61
N118	N160	O66	O108	O150	P62
N119	N161	O67	O109	O151	P63
N120	O26	O68	O110	O152	P64
N121	O27	O69	O111	O153	P65
N122	O28	O70	O112	O154	P66
N123	O29	O71	O113	O155	P67
N124	O30	O72	O114	O156	P68
N125	O31	O73	O115	O157	P69
N126	O32	O74	O116	O158	P70
N127	O33	O75	O117	O159	P71
N128	O34	O76	O118	O160	P72
N129	O35	O77	O119	P31	P73
N130	O36	O78	O120	P32	P74
N131	O37	O79	O121	P33	P75
N132	O38	O80	O122	P34	P76
N133	O39	O81	O123	P35	P77
N134	O40	O82	O124	P36	P78
N135	O41	O83	O125	P37	P79
N136	O42	O84	O126	P38	P80
N137	O43	O85	O127	P39	P81

P82	P124	Q38	Q80	Q122	R37
P83	P125	Q39	Q81	Q123	R38
P84	P126	Q40	Q82	Q124	R39
P85	P127	Q41	Q83	Q125	R40
P86	P128	Q42	Q84	Q126	R41
P87	P129	Q43	Q85	Q127	R42
P88	P130	Q44	Q86	Q128	R43
P89	P131	Q45	Q87	Q129	R44
P90	P132	Q46	Q88	Q130	R45
P91	P133	Q47	Q89	Q131	R46
P92	P134	Q48	Q90	Q132	R47
P93	P135	Q49	Q91	Q133	R48
P94	P136	Q50	Q92	Q134	R49
P95	P137	Q51	Q93	Q135	R50
P96	P138	Q52	Q94	Q136	R51
P97	P139	Q53	Q95	Q137	R52
P98	P140	Q54	Q96	Q138	R53
P99	P141	Q55	Q97	Q139	R54
P100	P142	Q56	Q98	Q140	R55
P101	P143	Q57	Q99	Q141	R56
P102	P144	Q58	Q100	Q142	R57
P103	P145	Q59	Q101	Q143	R58
P104	P146	Q60	Q102	Q144	R59
P105	P147	Q61	Q103	Q145	R60
P106	P148	Q62	Q104	Q146	R61
P107	P149	Q63	Q105	Q147	R62
P108	P150	Q64	Q106	Q148	R63
P109	P151	Q65	Q107	Q149	R64
P110	P152	Q66	Q108	Q150	R65
P111	P153	Q67	Q109	Q151	R66
P112	P154	Q68	Q110	Q152	R67
P113	P155	Q69	Q111	Q153	R68
P114	P156	Q70	Q112	Q154	R69
P115	P157	Q71	Q113	Q155	R70
P116	P158	Q72	Q114	Q156	R71
P117	P159	Q73	Q115	Q157	R72
P118	P160	Q74	Q116	Q158	R73
P119	Q33	Q75	Q117	Q159	R74
P120	Q34	Q76	Q118	R33	R75
P121	Q35	Q77	Q119	R34	R76
P122	Q36	Q78	Q120	R35	R77
P123	Q37	Q79	Q121	R36	R78

R79	R121	S36	S78	S120	T35
R80	R122	S37	S79	S121	T36
R81	R123	S38	S80	S122	T37
R82	R124	S39	S81	S123	T38
R83	R125	S40	S82	S124	T39
R84	R126	S41	S83	S125	T40
R85	R127	S42	S84	S126	T41
R86	R128	S43	S85	S127	T42
R87	R129	S44	S86	S128	T43
R88	R130	S45	S87	S129	T44
R89	R131	S46	S88	S130	T45
R90	R132	S47	S89	S131	T46
R91	R133	S48	S90	S132	T47
R92	R134	S49	S91	S133	T48
R93	R135	S50	S92	S134	T49
R94	R136	S51	S93	S135	T50
R95	R137	S52	S94	S136	T51
R96	R138	S53	S95	S137	T52
R97	R139	S54	S96	S138	T53
R98	R140	S55	S97	S139	T54
R99	R141	S56	S98	S140	T55
R100	R142	S57	S99	S141	T56
R101	R143	S58	S100	S142	T57
R102	R144	S59	S101	S143	T58
R103	R145	S60	S102	S144	T59
R104	R146	S61	S103	S145	T60
R105	R147	S62	S104	S146	T61
R106	R148	S63	S105	S147	T62
R107	R149	S64	S106	S148	T63
R108	R150	S65	S107	S149	T64
R109	R151	S66	S108	S150	T65
R110	R152	S67	S109	S151	T66
R111	R153	S68	S110	S152	T67
R112	R154	S69	S111	S153	T68
R113	R155	S70	S112	S154	T69
R114	R156	S71	S113	S155	T70
R115	R157	S72	S114	S156	T71
R116	R158	S73	S115	S157	T72
R117	R159	S74	S116	S158	T73
R118	S33	S75	S117	S159	T74
R119	S34	S76	S118	S160	T75
R120	S35	S77	S119	T34	T76

T77	T119	T161	U73	U115	U157
T78	T120	T162	U74	U116	U158
T79	T121	T163	U75	U117	U159
T80	T122	T164	U76	U118	U160
T81	T123	U35	U77	U119	U161
T82	T124	U36	U78	U120	U162
T83	T125	U37	U79	U121	U163
T84	T126	U38	U80	U122	U164
T85	T127	U39	U81	U123	U165
T86	T128	U40	U82	U124	U166
T87	T129	U41	U83	U125	U167
T88	T130	U42	U84	U126	V35
T89	T131	U43	U85	U127	V36
T90	T132	U44	U86	U128	V37
T91	T133	U45	U87	U129	V38
T92	T134	U46	U88	U130	V39
T93	T135	U47	U89	U131	V40
T94	T136	U48	U90	U132	V41
T95	T137	U49	U91	U133	V42
T96	T138	U50	U92	U134	V43
T97	T139	U51	U93	U135	V44
T98	T140	U52	U94	U136	V45
T99	T141	U53	U95	U137	V46
T100	T142	U54	U96	U138	V47
T101	T143	U55	U97	U139	V48
T102	T144	U56	U98	U140	V49
T103	T145	U57	U99	U141	V50
T104	T146	U58	U100	U142	V51
T105	T147	U59	U101	U143	V52
T106	T148	U60	U102	U144	V53
T107	T149	U61	U103	U145	V54
T108	T150	U62	U104	U146	V55
T109	T151	U63	U105	U147	V56
T110	T152	U64	U106	U148	V57
T111	T153	U65	U107	U149	V58
T112	T154	U66	U108	U150	V59
T113	T155	U67	U109	U151	V60
T114	T156	U68	U110	U152	V61
T115	T157	U69	U111	U153	V62
T116	T158	U70	U112	U154	V63
T117	T159	U71	U113	U155	V64
T118	T160	U72	U114	U156	V65

V66	V108	V150	W55	W97	W139
V67	V109	V151	W56	W98	W140
V68	V110	V152	W57	W99	W141
V69	V111	V153	W58	W100	W142
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V72	V114	V156	W61	W103	W145
V73	V115	V157	W62	W104	W146
V74	V116	V158	W63	W105	W147
V75	V117	V159	W64	W106	W148
V76	V118	V160	W65	W107	W149
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V78	V120	V162	W67	W109	W151
V79	V121	V163	W68	W110	W152
V80	V122	V164	W69	W111	W153
V81	V123	V165	W70	W112	W154
V82	V124	V166	W71	W113	W155
V83	V125	V167	W72	W114	W156
V84	V126	V168	W73	W115	W157
V85	V127	V169	W74	W116	W158
V86	V128	V170	W75	W117	W159
V87	V129	V171	W76	W118	W160
V88	V130	V172	W77	W119	W161
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V90	V132	W37	W79	W121	W163
V91	V133	W38	W80	W122	W164
V92	V134	W39	W81	W123	W165
V93	V135	W40	W82	W124	W166
V94	V136	W41	W83	W125	W167
V95	V137	W42	W84	W126	W168
V96	V138	W43	W85	W127	W169
V97	V139	W44	W86	W128	W170
V98	V140	W45	W87	W129	W171
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V100	V142	W47	W89	W131	W173
V101	V143	W48	W90	W132	W174
V102	V144	W49	W91	W133	X37
V103	V145	W50	W92	W134	X38
V104	V146	W51	W93	W135	X39
V105	V147	W52	W94	W136	X40
V106	V148	W53	W95	W137	X41
V107	V149	W54	W96	W138	X42

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X70	X112	X154	Y63	Y105	Y147
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X72	X114	X156	Y65	Y107	Y149
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X76	X118	X160	Y69	Y111	Y153
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AO62	AO104	AO146	AP80	AP122	AP164
AO63	AO105	AO147	AP81	AP123	AP165
AO64	AO106	AO148	AP82	AP124	AP166
AO65	AO107	AO149	AP83	AP125	AP167
AO66	AO108	AO150	AP84	AP126	AQ58
AO67	AO109	AO151	AP85	AP127	AQ59
AO68	AO110	AO152	AP86	AP128	AQ60
AO69	AO111	AO153	AP87	AP129	AQ61
AO70	AO112	AO154	AP88	AP130	AQ62
AO71	AO113	AO155	AP89	AP131	AQ63
AO72	AO114	AO156	AP90	AP132	AQ64
AO73	AO115	AO157	AP91	AP133	AQ65

AQ66	AQ108	AQ150	AR82	AR124	AR166
AQ67	AQ109	AQ151	AR83	AR125	AR167
AQ68	AQ110	AQ152	AR84	AR126	AR168
AQ69	AQ111	AQ153	AR85	AR127	AR169
AQ70	AQ112	AQ154	AR86	AR128	AR170
AQ71	AQ113	AQ155	AR87	AR129	AS61
AQ72	AQ114	AQ156	AR88	AR130	AS62
AQ73	AQ115	AQ157	AR89	AR131	AS63
AQ74	AQ116	AQ158	AR90	AR132	AS64
AQ75	AQ117	AQ159	AR91	AR133	AS65
AQ76	AQ118	AQ160	AR92	AR134	AS66
AQ77	AQ119	AQ161	AR93	AR135	AS67
AQ78	AQ120	AQ162	AR94	AR136	AS68
AQ79	AQ121	AQ163	AR95	AR137	AS69
AQ80	AQ122	AQ164	AR96	AR138	AS70
AQ81	AQ123	AQ165	AR97	AR139	AS71
AQ82	AQ124	AQ166	AR98	AR140	AS72
AQ83	AQ125	AQ167	AR99	AR141	AS73
AQ84	AQ126	AQ168	AR100	AR142	AS74
AQ85	AQ127	AR59	AR101	AR143	AS75
AQ86	AQ128	AR60	AR102	AR144	AS76
AQ87	AQ129	AR61	AR103	AR145	AS77
AQ88	AQ130	AR62	AR104	AR146	AS78
AQ89	AQ131	AR63	AR105	AR147	AS79
AQ90	AQ132	AR64	AR106	AR148	AS80
AQ91	AQ133	AR65	AR107	AR149	AS81
AQ92	AQ134	AR66	AR108	AR150	AS82
AQ93	AQ135	AR67	AR109	AR151	AS83
AQ94	AQ136	AR68	AR110	AR152	AS84
AQ95	AQ137	AR69	AR111	AR153	AS85
AQ96	AQ138	AR70	AR112	AR154	AS86
AQ97	AQ139	AR71	AR113	AR155	AS87
AQ98	AQ140	AR72	AR114	AR156	AS88
AQ99	AQ141	AR73	AR115	AR157	AS89
AQ100	AQ142	AR74	AR116	AR158	AS90
AQ101	AQ143	AR75	AR117	AR159	AS91
AQ102	AQ144	AR76	AR118	AR160	AS92
AQ103	AQ145	AR77	AR119	AR161	AS93
AQ104	AQ146	AR78	AR120	AR162	AS94
AQ105	AQ147	AR79	AR121	AR163	AS95
AQ106	AQ148	AR80	AR122	AR164	AS96
AQ107	AQ149	AR81	AR123	AR165	AS97

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AU133	AU175	AV107	AV149	AW80	AW126
AU134	AV66	AV108	AV150	AW81	AW127
AU135	AV67	AV109	AV151	AW82	AW128
AU136	AV68	AV110	AV152	AW83	AW129
AU137	AV69	AV111	AV153	AW84	AW130
AU138	AV70	AV112	AV154	AW85	AW131
AU139	AV71	AV113	AV155	AW86	AW132
AU140	AV72	AV114	AV156	AW87	AW133
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AU144	AV76	AV118	AV160	AW91	AW137
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AU148	AV80	AV122	AV164	AW95	AW141
AU149	AV81	AV123	AV165	AW96	AW142
AU150	AV82	AV124	AV166	AW97	AW143
AU151	AV83	AV125	AV167	AW98	AW144
AU152	AV84	AV126	AV168	AW99	AW145
AU153	AV85	AV127	AV169	AW100	AW146
AU154	AV86	AV128	AV170	AW101	AW147
AU155	AV87	AV129	AV171	AW102	AW148
AU156	AV88	AV130	AV172	AW103	AW149
AU157	AV89	AV131	AV173	AW104	AW150
AU158	AV90	AV132	AV174	AW105	AW151
AU159	AV91	AV133	AV175	AW106	AW152
AU160	AV92	AV134	AV176	AW107	AW153
AU161	AV93	AV135	AV177	AW108	AW154
AU162	AV94	AV136	AW67	AW109	AW155
AU163	AV95	AV137	AW68	AW110	AW156
AU164	AV96	AV138	AW69	AW111	AW157
AU165	AV97	AV139	AW70	AW112	AW158
AU166	AV98	AV140	AW71	AW113	AW159
AU167	AV99	AV141	AW72	AW114	AW160
AU168	AV100	AV142	AW73	AW115	AW161
AU169	AV101	AV143	AW74	AW116	AW162
AU170	AV102	AV144	AW75	AW117	AW163
AU171	AV103	AV145	AW76	AW118	AW164
AU172	AV104	AV146	AW77	AW119	AW165
AU173	AV105	AV147	AW78	AW120	AW166

AW167	AX98	AX148	AY78	AY131	AY173
AW168	AX99	AX149	AY79	AY132	AY174
AW169	AX100	AX150	AY80	AY133	AY175
AW170	AX101	AX151	AY81	AY134	AY176
AW171	AX102	AX152	AY82	AY135	AY177
AW172	AX103	AX153	AY83	AY136	AY178
AW173	AX104	AX154	AY84	AY137	AY179
AW174	AX105	AX155	AY85	AY138	AY180
AW175	AX106	AX156	AY86	AY139	AY181
AW176	AX107	AX157	AY87	AY140	AY182
AW177	AX108	AX158	AY88	AY141	AY183
AW178	AX109	AX159	AY89	AY142	AY184
AW179	AX110	AX160	AY90	AY143	AZ74
AX69	AX111	AX161	AY91	AY144	AZ75
AX70	AX112	AX162	AY92	AY145	AZ76
AX71	AX113	AX163	AY93	AY146	AZ77
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AX76	AX118	AX168	AY98	AY151	AZ82
AX77	AX119	AX169	AY99	AY152	AZ83
AX78	AX128	AX170	AY100	AY153	AZ84
AX79	AX129	AX171	AY101	AY154	AZ85
AX80	AX130	AX172	AY102	AY155	AZ86
AX81	AX131	AX173	AY103	AY156	AZ87
AX82	AX132	AX174	AY104	AY157	AZ88
AX83	AX133	AX175	AY105	AY158	AZ89
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AX85	AX135	AX177	AY107	AY160	AZ91
AX86	AX136	AX178	AY108	AY161	AZ92
AX87	AX137	AX179	AY109	AY162	AZ93
AX88	AX138	AX180	AY110	AY163	AZ94
AX89	AX139	AX181	AY111	AY164	AZ95
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AX93	AX143	AY73	AY115	AY168	AZ99
AX94	AX144	AY74	AY116	AY169	AZ100
AX95	AX145	AY75	AY117	AY170	AZ101
AX96	AX146	AY76	AY118	AY171	AZ102
AX97	AX147	AY77	AY130	AY172	AZ103

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AZ105	AZ160	BA90	BA148	BA190	BB139
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AZ108	AZ163	BA93	BA151	BB82	BB142
AZ109	AZ164	BA94	BA152	BB83	BB143
AZ110	AZ165	BA95	BA153	BB84	BB146
AZ111	AZ166	BA96	BA154	BB85	BB147
AZ112	AZ167	BA97	BA155	BB86	BB148
AZ113	AZ168	BA98	BA156	BB87	BB149
AZ114	AZ169	BA99	BA157	BB88	BB150
AZ115	AZ170	BA100	BA158	BB89	BB151
AZ116	AZ171	BA101	BA159	BB90	BB152
AZ130	AZ172	BA102	BA160	BB91	BB153
AZ131	AZ173	BA103	BA161	BB92	BB154
AZ132	AZ174	BA104	BA162	BB93	BB155
AZ133	AZ175	BA105	BA163	BB94	BB156
AZ134	AZ176	BA106	BA164	BB95	BB157
AZ135	AZ177	BA107	BA165	BB96	BB158
AZ136	AZ178	BA108	BA166	BB97	BB159
AZ137	AZ179	BA109	BA167	BB98	BB160
AZ138	AZ180	BA110	BA168	BB99	BB161
AZ139	AZ181	BA111	BA169	BB100	BB162
AZ140	AZ182	BA112	BA170	BB101	BB163
AZ141	AZ183	BA113	BA171	BB102	BB164
AZ142	AZ184	BA114	BA172	BB103	BB165
AZ143	AZ185	BA115	BA173	BB104	BB166
AZ144	AZ186	BA116	BA174	BB105	BB167
AZ145	AZ187	BA133	BA175	BB106	BB168
AZ146	BA76	BA134	BA176	BB107	BB169
AZ147	BA77	BA135	BA177	BB108	BB170
AZ148	BA78	BA136	BA178	BB109	BB171
AZ149	BA79	BA137	BA179	BB110	BB172
AZ150	BA80	BA138	BA180	BB111	BB173
AZ151	BA81	BA139	BA181	BB112	BB174
AZ152	BA82	BA140	BA182	BB113	BB175
AZ153	BA83	BA141	BA183	BB114	BB176
AZ154	BA84	BA142	BA184	BB115	BB177
AZ155	BA85	BA143	BA185	BB134	BB178
AZ156	BA86	BA144	BA186	BB135	BB179
AZ157	BA87	BA145	BA187	BB136	BB180
AZ158	BA88	BA146	BA188	BB137	BB181

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BB183	BC136	BC192	BD169	BE99	BE193
BB184	BC137	BD82	BD170	BE100	BE194
BB185	BC138	BD83	BD171	BE101	BE195
BB186	BC139	BD84	BD172	BE102	BE196
BB187	BC140	BD85	BD173	BE103	BF85
BB188	BC141	BD86	BD174	BE104	BF86
BB189	BC142	BD87	BD175	BE105	BF87
BB190	BC157	BD88	BD176	BE106	BF88
BB191	BC158	BD89	BD177	BE107	BF89
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BC85	BC163	BD94	BD182	BE139	BF94
BC86	BC164	BD95	BD183	BE140	BF95
BC87	BC165	BD96	BD184	BE166	BF96
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BC96	BC174	BD105	BD193	BE175	BF105
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BC98	BC176	BD107	BE83	BE177	BF107
BC99	BC177	BD108	BE84	BE178	BF108
BC100	BC178	BD109	BE85	BE179	BF109
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BC102	BC180	BD136	BE87	BE181	BF139
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BC105	BC183	BD139	BE90	BE184	BF169
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BC107	BC185	BD141	BE92	BE186	BF171
BC108	BC186	BD161	BE93	BE187	BF172
BC109	BC187	BD164	BE94	BE188	BF173
BC110	BC188	BD165	BE95	BE189	BF174
BC111	BC189	BD166	BE96	BE190	BF175
BC112	BC190	BD167	BE97	BE191	BF176

BF177	BG106	BH91	BH194	BI177	BJ99
BF178	BG107	BH92	BH195	BI178	BJ100
BF179	BG168	BH93	BH196	BI179	BJ101
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BF181	BG170	BH95	BH198	BI181	BJ103
BF182	BG171	BH96	BH199	BI182	BJ104
BF183	BG172	BH97	BH200	BI183	BJ105
BF184	BG173	BH98	BH201	BI184	BJ167
BF185	BG174	BH99	BH202	BI185	BJ168
BF186	BG175	BH100	BH203	BI186	BJ169
BF187	BG176	BH101	BH204	BI187	BJ170
BF188	BG177	BH102	BH205	BI188	BJ171
BF189	BG178	BH103	BH206	BI189	BJ172
BF190	BG179	BH104	BH207	BI190	BJ173
BF191	BG180	BH105	BI88	BI191	BJ175
BF192	BG181	BH106	BI89	BI192	BJ176
BF193	BG182	BH168	BI90	BI193	BJ177
BF194	BG183	BH169	BI91	BI194	BJ178
BF195	BG184	BH170	BI92	BI195	BJ179
BF196	BG185	BH171	BI93	BI196	BJ180
BF197	BG186	BH172	BI94	BI197	BJ181
BF204	BG187	BH173	BI95	BI198	BJ182
BG86	BG188	BH174	BI96	BI199	BJ183
BG87	BG189	BH175	BI97	BI200	BJ184
BG88	BG190	BH176	BI98	BI201	BJ185
BG89	BG191	BH177	BI99	BI202	BJ186
BG90	BG192	BH178	BI100	BI203	BJ187
BG91	BG193	BH179	BI101	BI204	BJ188
BG92	BG194	BH180	BI102	BI205	BJ189
BG93	BG195	BH181	BI103	BI206	BJ190
BG94	BG196	BH182	BI104	BI207	BJ191
BG95	BG197	BH183	BI105	BI208	BJ192
BG96	BG198	BH184	BI167	BJ89	BJ193
BG97	BG199	BH185	BI168	BJ90	BJ194
BG98	BG202	BH186	BI169	BJ91	BJ195
BG99	BG203	BH187	BI170	BJ92	BJ196
BG100	BG204	BH188	BI171	BJ93	BJ197
BG101	BG205	BH189	BI172	BJ94	BJ198
BG102	BH87	BH190	BI173	BJ95	BJ199
BG103	BH88	BH191	BI174	BJ96	BJ200
BG104	BH89	BH192	BI175	BJ97	BJ201
BG105	BH90	BH193	BI176	BJ98	BJ202

BJ203	BK190	BL183	BM181	BN185	BO198
BJ204	BK191	BL184	BM182	BN186	BO199
BJ205	BK192	BL185	BM183	BN187	BO200
BJ206	BK193	BL186	BM184	BN188	BO201
BJ207	BK194	BL187	BM185	BN189	BO202
BJ208	BK195	BL188	BM186	BN190	BO203
BK90	BK196	BL189	BM187	BN193	BO204
BK91	BK197	BL190	BM188	BN194	BO205
BK92	BK198	BL191	BM189	BN195	BO206
BK93	BK199	BL192	BM190	BN196	BO207
BK94	BK200	BL193	BM191	BN197	BP96
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BK96	BK202	BL195	BM193	BN199	BP98
BK97	BK203	BL196	BM194	BN200	BP99
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BK101	BK207	BL200	BM198	BN204	BP185
BK102	BK208	BL201	BM199	BN205	BP186
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BK106	BL95	BL205	BM203	BO96	BP190
BK167	BL96	BL206	BM204	BO97	BP195
BK168	BL97	BL207	BM205	BO98	BP196
BK169	BL98	BL208	BM206	BO99	BP197
BK170	BL99	BM93	BM207	BO100	BP198
BK171	BL100	BM94	BN94	BO101	BP199
BK172	BL101	BM95	BN95	BO102	BP200
BK173	BL102	BM96	BN96	BO103	BP201
BK178	BL103	BM97	BN97	BO104	BP202
BK179	BL104	BM98	BN98	BO184	BP203
BK180	BL105	BM99	BN99	BO185	BP204
BK181	BL106	BM100	BN100	BO186	BP205
BK182	BL168	BM101	BN101	BO187	BP206
BK183	BL169	BM102	BN102	BO188	BQ98
BK184	BL170	BM103	BN103	BO189	BQ99
BK185	BL171	BM104	BN104	BO190	BQ100
BK186	BL179	BM105	BN105	BO194	BQ101
BK187	BL180	BM168	BN182	BO195	BQ102
BK188	BL181	BM169	BN183	BO196	BQ103
BK189	BL182	BM170	BN184	BO197	BQ188

BQ189	BQ204	BR198	BS100	BS202	BT106
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BQ199	BR100	BR201	BS103	BT101	BU102
BQ200	BR101	BR202	BS104	BT102	BU103
BQ201	BR102	BR203	BS105	BT103	BU104
BQ202	BR103	BR204	BS106	BT104	BU105
BQ203	BR104	BR205	BS201	BT105	BU202

Appendix D: Project Wide Vertical Accuracy Results

The GPS Processing reports have been attached as a separate ancillary file.

Appendix E: GPS Processing

The GPS Processing reports have been attached as a separate ancillary file.