

Brazos Basin-TX_Red River FEMA R6 Lidar 2016_D17

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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 Brazos portion the Texas Red River FEMA Region 6 Project Area.

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 15,254 tiles were produced for the project encompassing an area of approximately 12,660 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 D. 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 acquired ground control points for use in lidar calibration and processing. Please see Appendix A to view the separate Checkpoint Survey Report and Appendix B to view the separate Ground Control Survey Report that was created for this portion of the project.

Leading Edge Geomatics Ltd. completed lidar data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Brazos Basin, TX, which includes the counties of Archer, Baylor, Bell, Bosque, Brown, Callahan, Coleman, Comanche, Coryell, Dickens, Eastland, Erath, Fisher, Hamilton, Jack, Jones, King, Knox, Lampasass, McLennan, Mills, Palo Pinto, Runnels, Shackelford, Stephens, Stonewall, Taylor, Throckmorton, and Young.

DATE OF SURVEY

The lidar aerial acquisition was conducted between November 17, 2016 and May 28, 2018.

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 (NAD 83 CORS2011)

Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)

Coordinate System: UTM Zone 14N.

Units: Horizontal units are in meters; Vertical units are in meters.

Geoid Model: GEOID 12b. (Geoid 12B was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the Brazos Basin Texas FEMA R6 Lidar Project, the tested $RMSE_z$ of the classified lidar data for checkpoints in non-vegetated terrain equaled **9.6 cm** compared with the 10 cm specification;

and the NVA of the classified lidar data computed using $RMSE_z \times 1.9600$ was equal to **18.8 cm**, compared with the 19.6 cm specification.

For the Brazos Basin Texas FEMA R6 Lidar Project, the tested VVA of the classified lidar data computed using the 95th percentile was equal to **21.6 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

PROJECT TILING FOOTPRINT

Fifteen thousand two hundred fifty-four (15,254) 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).

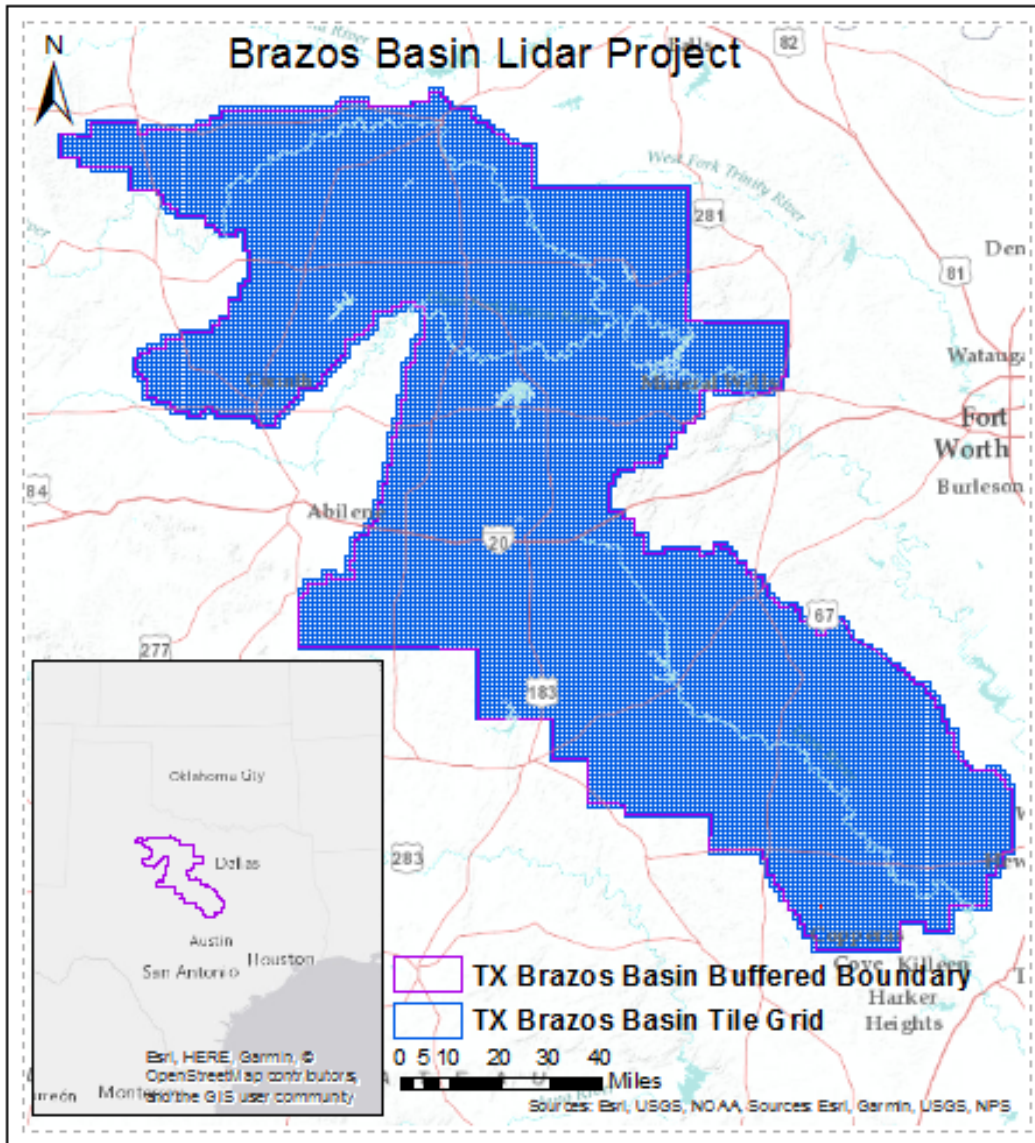


Figure 1 - Project Map

Lidar Acquisition Report

Dewberry elected to subcontract the lidar acquisition and calibration activities to Leading Edge Geomatics Ltd (LEG). LEG was responsible for providing lidar acquisition, calibration and delivery of lidar data files to Dewberry.

Dewberry received final calibrated swath data from LEG on June 28, 2018 and July 5, 2018.

LIDAR ACQUISITION DETAILS

Leading Edge Geomatics planned a total 1497 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 13 areas based on 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. LEG also completed calibrations in Abilene, Texas.

LIDAR SYSTEM PARAMETERS

Leading Edge Geomatics operated two different models of laser on three different aircraft for this project. Two Cessna 170 aircraft (UNB and CAU) were used to fly the Riegl VQ780i lasers, while a Cessna 206 aircraft (RBV) was used to fly the Riegl Q1560.

Error! Reference source not found. shows the parameters of the two laser types.

Item	Parameter	
	Riegl 780	Riegl 1560
System	Riegl 780	Riegl 1560
Altitude (AGL meters)	1800	1600
Approx. Flight Speed (knots)	100	100
Scanner Pulse Rate (kHz)	280	350 x2
Scan Frequency (hz)	68	80
Pulse Duration of the Scanner (nanoseconds)	5	5
Pulse Width of the Scanner (m)	1.5	1.5
Swath width (m)	1996	1737
Central Wavelength of the Sensor Laser (nanometers)	1064	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes	Yes
Beam Divergence (milliradians)	0.25	0.25
Nominal Swath Width on the Ground (m)	1996	1737
Swath Overlap (%)	55	55
Total Sensor Scan Angle (degree)	60	57
Computed Down Track spacing (m) per beam	0.76	0.64
Computed Cross Track Spacing (m) per beam	0.76	0.64
Nominal Pulse Spacing (single swath), (m)	0.76	0.65
Nominal Pulse Density (single swath) (ppsm), (m)	1.746	2.4
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.536	0.45
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	3.48	4.8
Maximum Number of Returns per Pulse	Infinite	infinite

Table 1: Leading Edge Geomatics 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 flightlines.

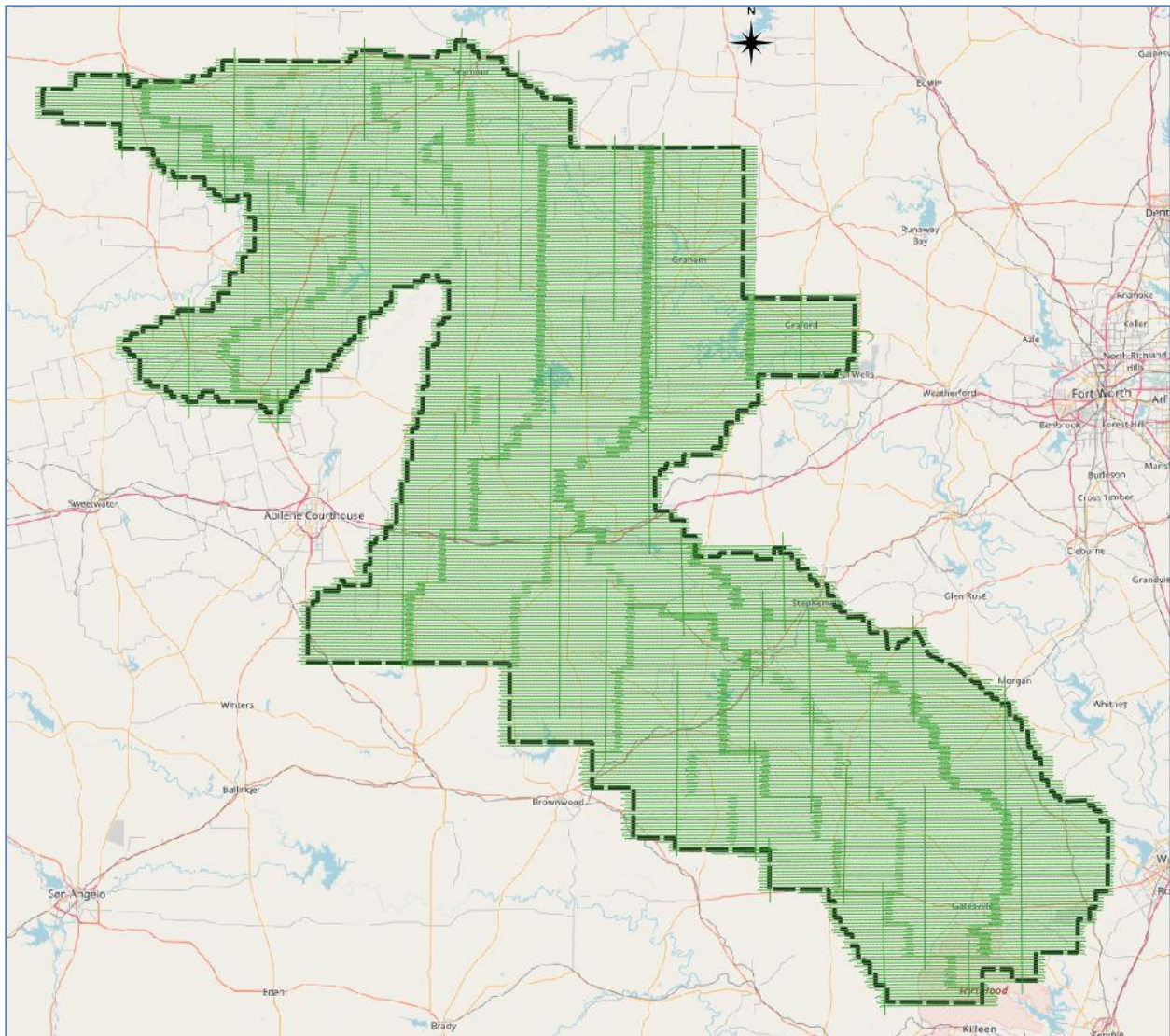


Figure 2: Trajectories as flown by Leading Edge Geomatics

LIDAR CONTROL

Fifty one newly established base stations were used to control the lidar acquisition for the Brazos 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(2011) UTM 14		Orthometric Ht (NAVD88 Geoid12B, m)
	Easting (m)	Northing (m)	
TXL1	190388.959	3760381.579	1097.294
TXLA	224201.123	3628668.263	916.881
TXLU	236008.38	3714265.465	981.962
TXP1	278112.915	3674044.481	794.009
TXSC	309742.205	3524640.151	705.146
TXSO	235167.975	3559536.86	827.621

TXAB	428907.489	3596471.995	517.742
TXDC	629630.611	3678337.292	284.002
TXVE	473891.145	3776929.895	381.315
TXLL	530769.299	3400115.222	330.823
TXWA	679301.044	3495178.214	129.803
TXEA	517968.856	3585096.407	437.122
TXWE	610207.796	3625170.500	367.238
TXB3	467966.121	3446221.408	528.160
TXWF	545740.072	3746068.975	309.029
TXRL	361054.481	3530339.368	575.111
TXBI	408323.244	3514322.651	527.115
TXGL	541040.811	3482012.666	486.678
TXMN	626518.813	3531249.629	239.374
TXBT	645162.43	3434213.167	205.387
TXMT	330763.13	3764965.314	736.441
TXBU	578067.544	3402230.831	463.906
TXMW	580246.215	3629901.997	276.821
TXHI	676686.058	3540767.305	182.112
TXC2	693841.742	3417675.630	124.302
TXHM	584649.048	3507473.253	373.072
TXC3	460049.662	3519432.171	525.275
TXJA	579638.371	3673209.638	355.232
TXOL	523288.647	3690783.088	361.432
TXST	577052.582	3566510.036	405.639
TXKE	657681.376	3587086.557	256.677
TXSY	476023.643	3718105.456	396.850
TXTA	649126.32	3382337.407	175.122
TXPD	380920.201	3764269.715	562.114
TXTH	484348.058	3671139.666	402.113
SGI1	3288161.295	582433.699	251.571
ZFW1	680981.651	3634168.431	183.68
LCSM	680793.217	3321201.486	100.363
SMSW	368500.694	3593903.131	666.369
TXAL	431347.485	3590964.245	531.259
TXCo	501608.621	3584580.209	503.35
TXEY	505198.405	3511971.148	434.602
TXS8	363194.537	3482044.908	585.743
TXSD	320860.58	3620723.776	712.850
TXSI	311908.785	3524061.73	705.396
LEG01	329240.841	3722493.178	789.402
LEG02	405070.454	3737174.031	510.668
LEG04	540716.318	3664401.212	337.769
LEG05	431775.404	3671507.112	489.894
LEG-HASKELL2	432973.563	3672799.339	489.936

Table 2 – Base stations used to control lidar acquisition

AIRBORNE GPS KINEMATIC

Airborne GPS data was processed using the POSPac kinematic On-The-Fly (OTF) software suite using Appianix Smartbase processing. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4.

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

GPS processing reports for each mission were delivered with the data for each flight. Please see the separate document, Appendix D, for this information.

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 either Riegl's RiProcess application or command-line versions of Riegl lidar processing software. System calibration was conducted prior to the aircraft departing for the project and the initial calibration values are used to position the point cloud. If a calibration error greater than specification is observed within the mission, the roll, pitch and yaw 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.

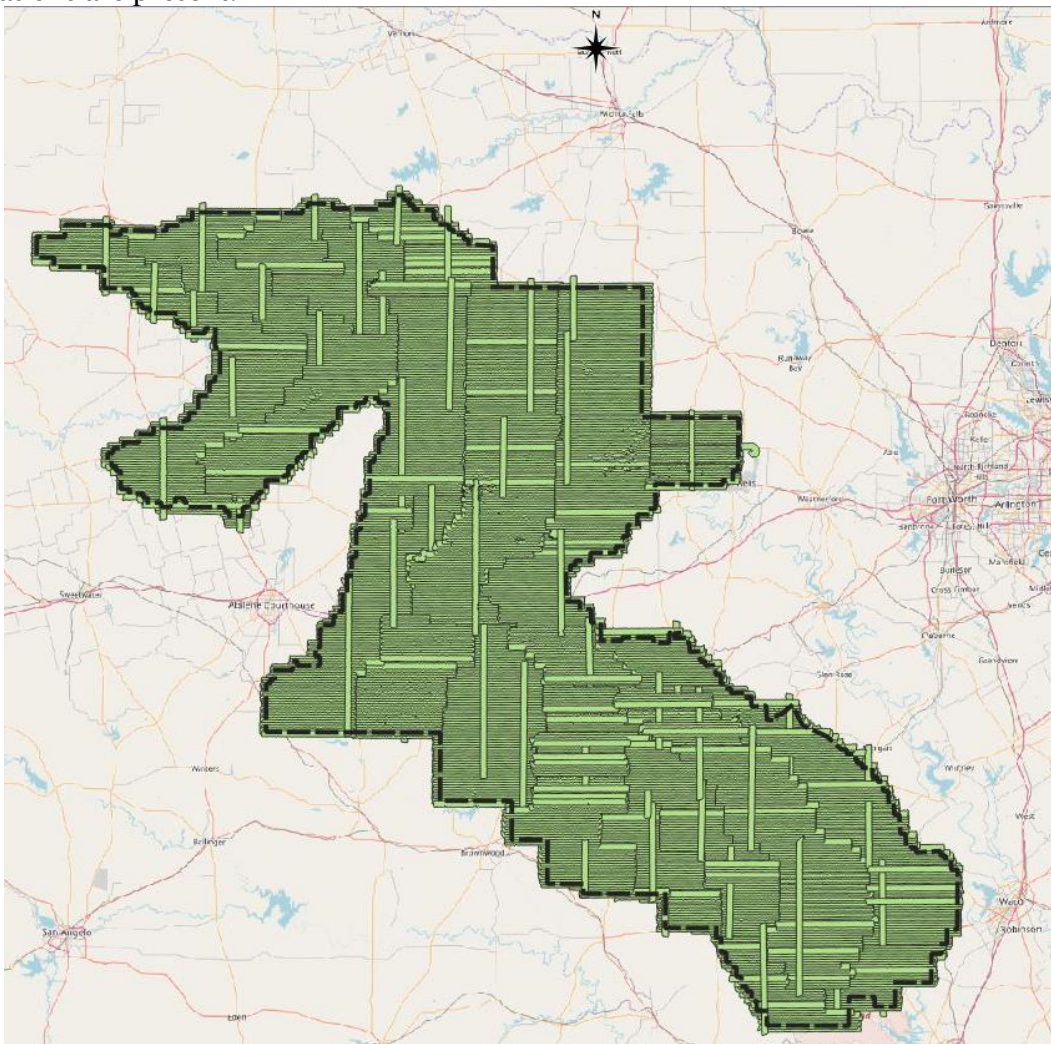


Figure 3 – Lidar swath output showing complete coverage.

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 ≤ 6 cm and ≤ 8 cm RMSDz within swath overlap.

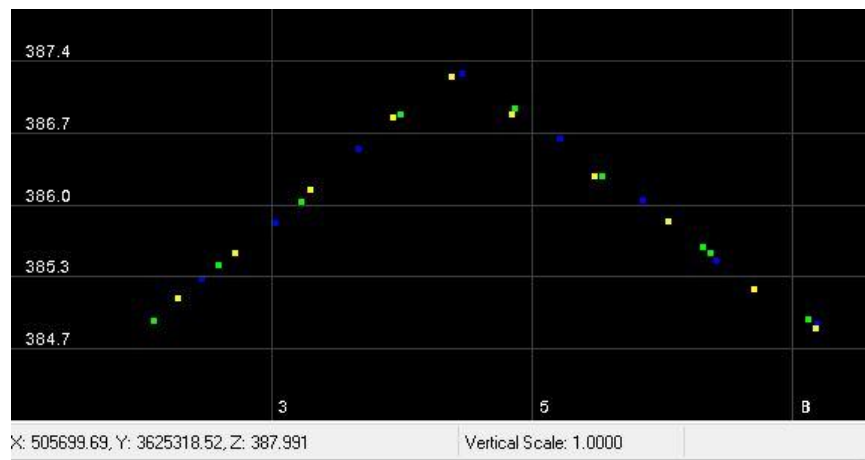


Figure 4 – Profile view cross section of multiple swaths.

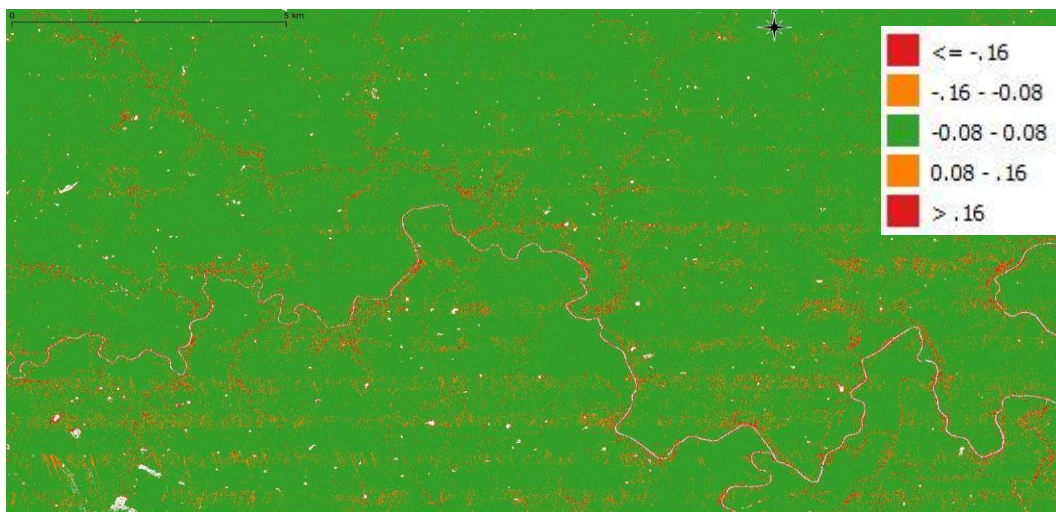


Figure 5 – QC block colored by separation to ensure accuracy at swath edges (16cm max range).

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 RMSE_z) or better in open, non-vegetated terrain) when compared to static GPS checkpoints. Below is a summary for the test:

The calibrated Brazos dataset was tested to 0.138 m (0.453 ft) vertical accuracy at 95% confidence level based on consolidated RMSE_z (0.0706m x 1.9600) when compared to 1,162 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.

Avg	0.0481
RMS	0.0706
NSSDA	0.1383

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 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 two hundred nineteen 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 $RMSE_z (10 \text{ cm}) \times 1.96$. The dataset for the Brazos Basin Lidar Project 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 $RMSE_z = 9.8 \text{ cm}$, equating to $\pm 19.1 \text{ cm}$ at 95% confidence level. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	# of Points	$RMSE_z$ NVA Spec=0.10 m	NVA – Non-vegetated Vertical Accuracy ($RMSE_z \times 1.9600$) Spec=0.196 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
Non-Vegetated Terrain	219	0.098	0.191	0.084	0.083	0.154	0.050	-0.050	0.301	0.960

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

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 $RMSD_z$ 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 Brazos Basin lidar project are shown in the figure below; this project meets inter-swath relative accuracy specifications.

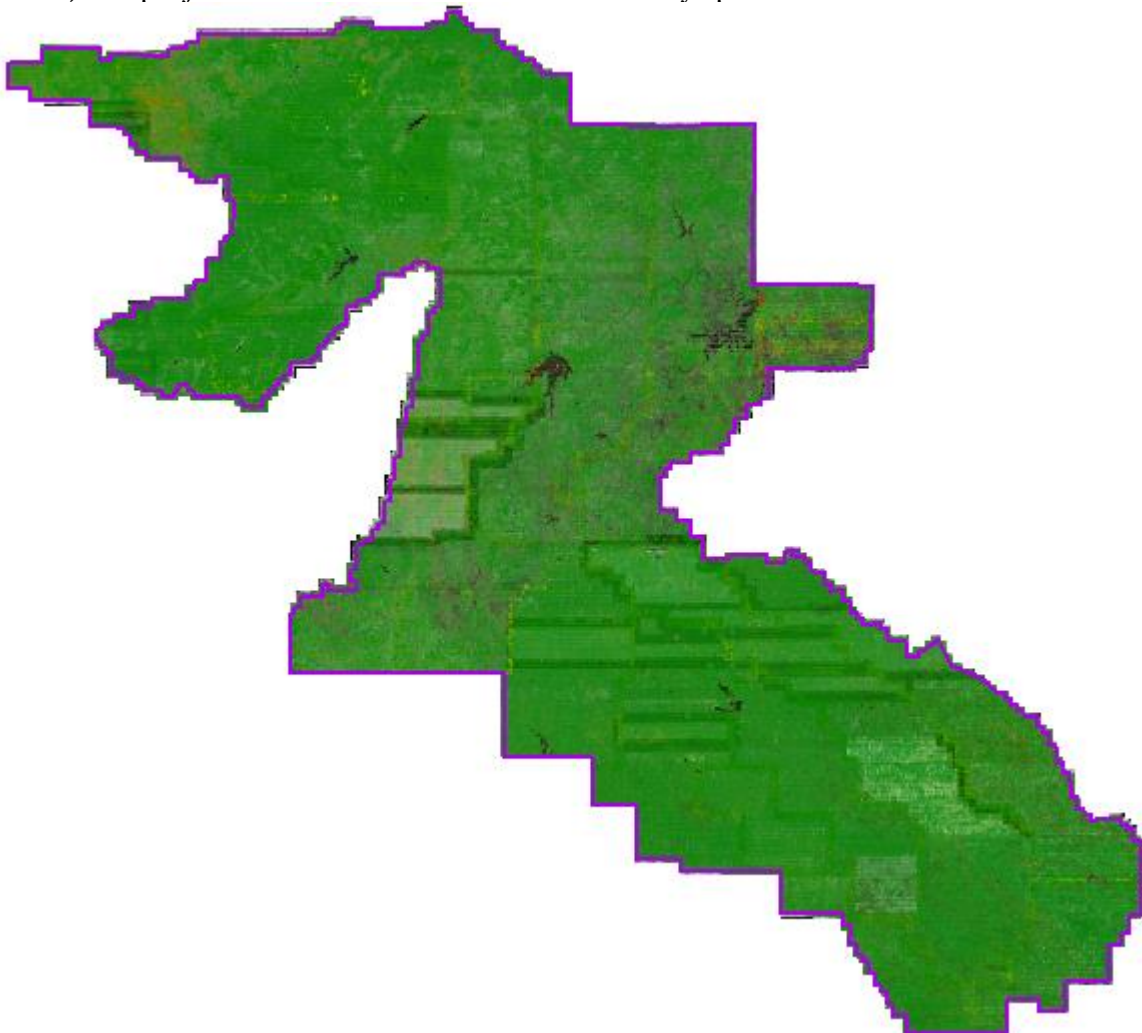


Figure 6– Single return DZ Orthos for the Brazos Basin Lidar Project. Inter-swath relative accuracy passes specifications.

There were calibration issues identified in the majority of the 2017 acquisition and it was determined to be too extensive to fix in house. The data was sent back to the acquisition provider for recalibration.

Dewberry also worked closely with the acquisition provider to understand where the calibration issues stemmed from and ensure they did not happen again on this project.

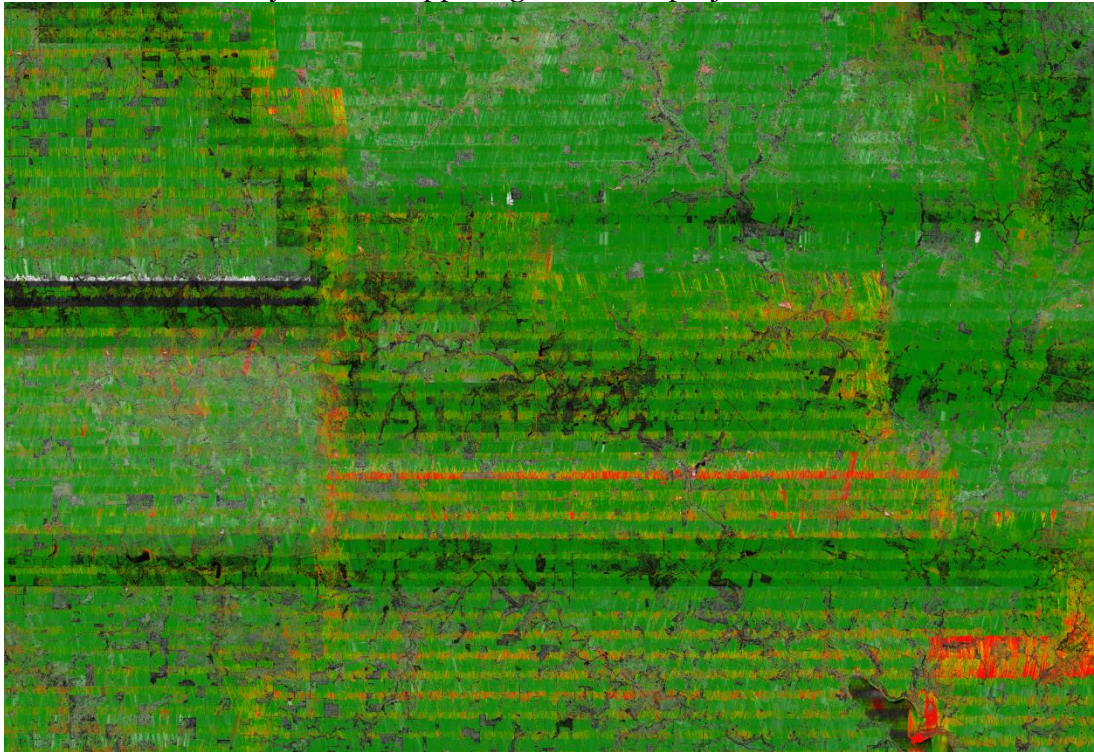


Figure 7 - DZ orthos created from the original full point cloud. Some red pixels are expected along embankments, sloped terrain, and in vegetated land cover. However, the red areas here are clear indications that the data were not calibrated properly and required corrections by the lidar provider.

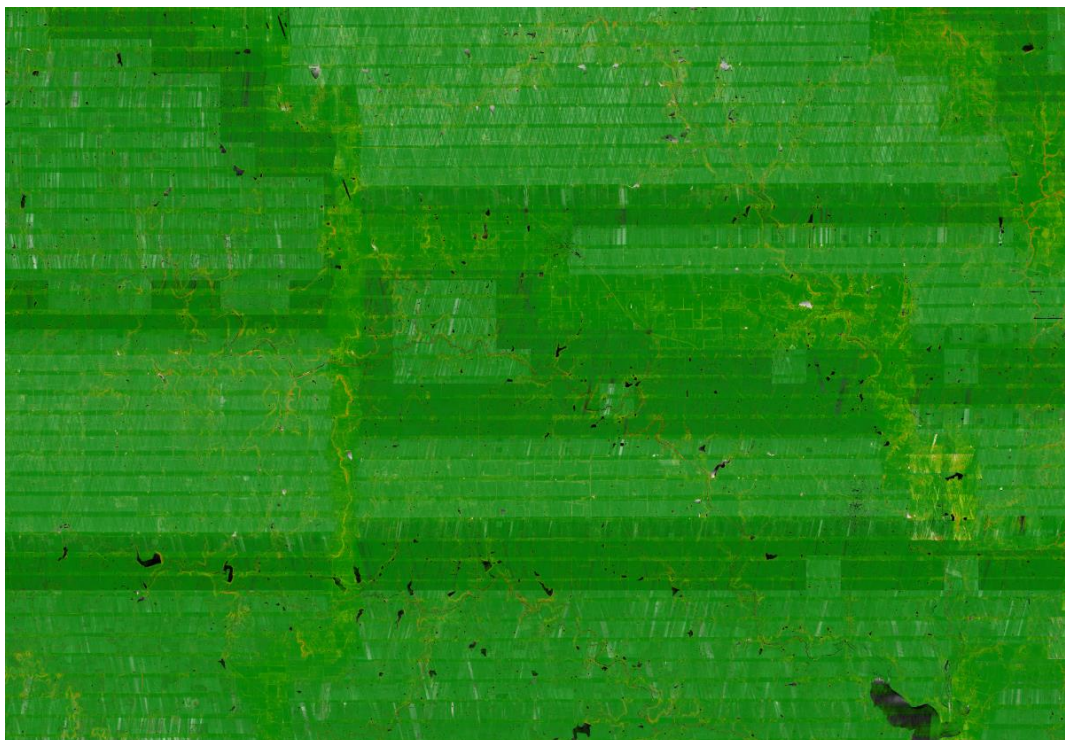


Figure 8 - DZ orthos created from the final full point cloud. All areas are colored green, verifying that the relative accuracy of data are within specifications and that the calibration of the data is acceptable.

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 Brazos Basin lidar project; this project meets intra-swath relative accuracy specifications.

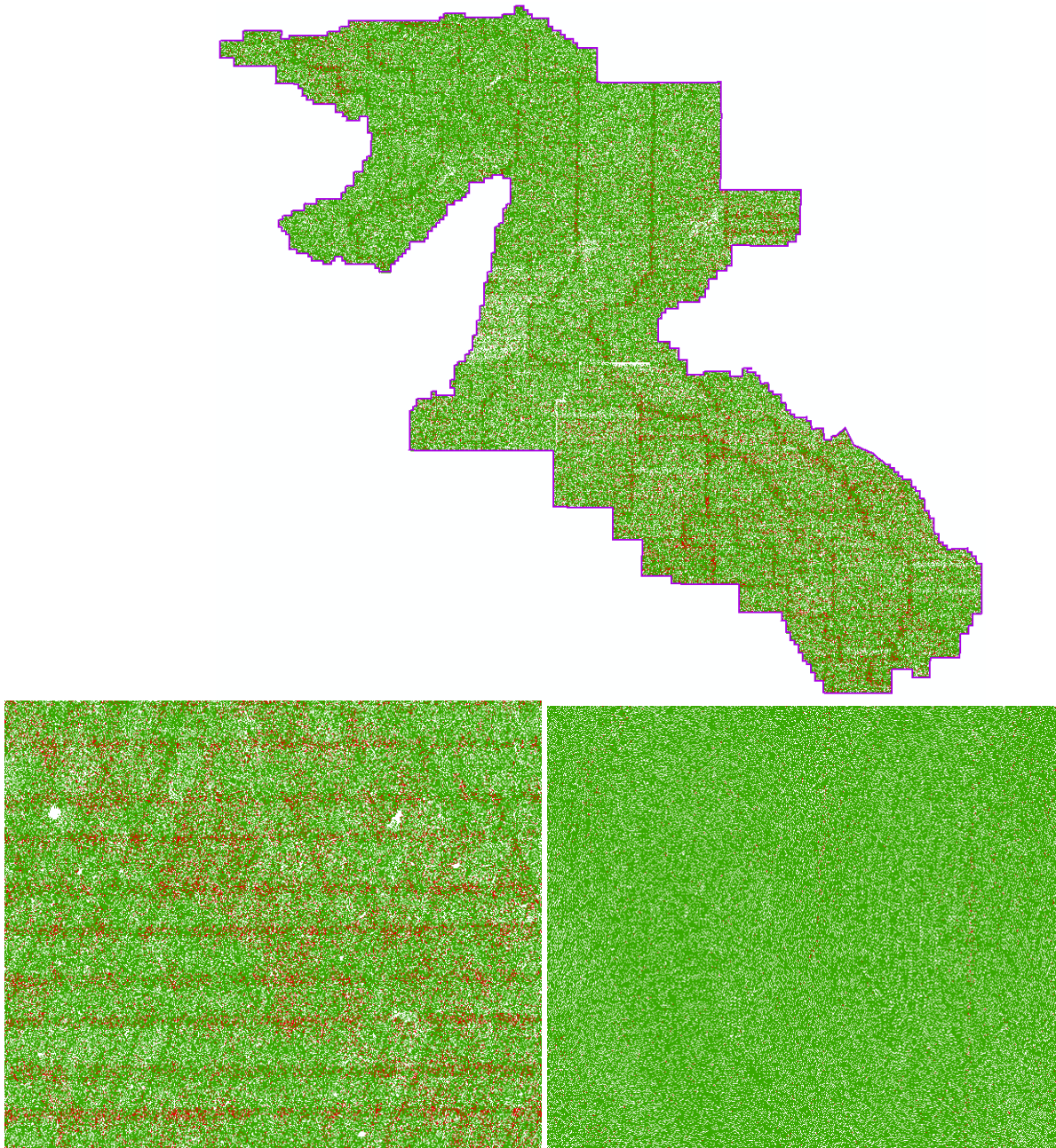


Figure 9—Intra-swath relative accuracy. The top image shows the full project area; areas where the maximum difference is ≤ 6 cm per pixel within each swath are colored green and areas exceeding 6 cm are

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 (and some between swath overlap) is colored red because it exceeds 6 cm maximum difference, as expected, due to actual slope/terrain change (or between swath differences which are allowable up to 8 cm RMSDz). 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 Brazos Basin; no horizontal alignment issues were identified.

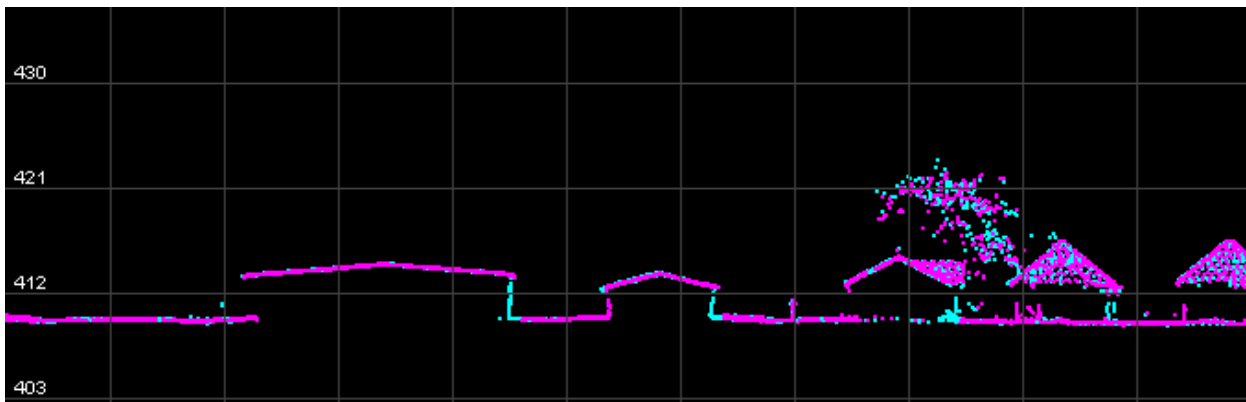


Figure 10– Horizontal Alignment. Two separate flight lines differentiated by color (Teal/Purple) are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

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 0.45 meters or an ANPD of 4.79 points per square meter which satisfies the project requirements. A visual review of a 1-square meter density grid (figure below) shows that there are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-square meter cells contain at least 2 points per square meter (green areas) and when density is viewed/analyzed by representative 1-square kilometer areas (to account for the irregular spacing of lidar point clouds), density passes with no issues.

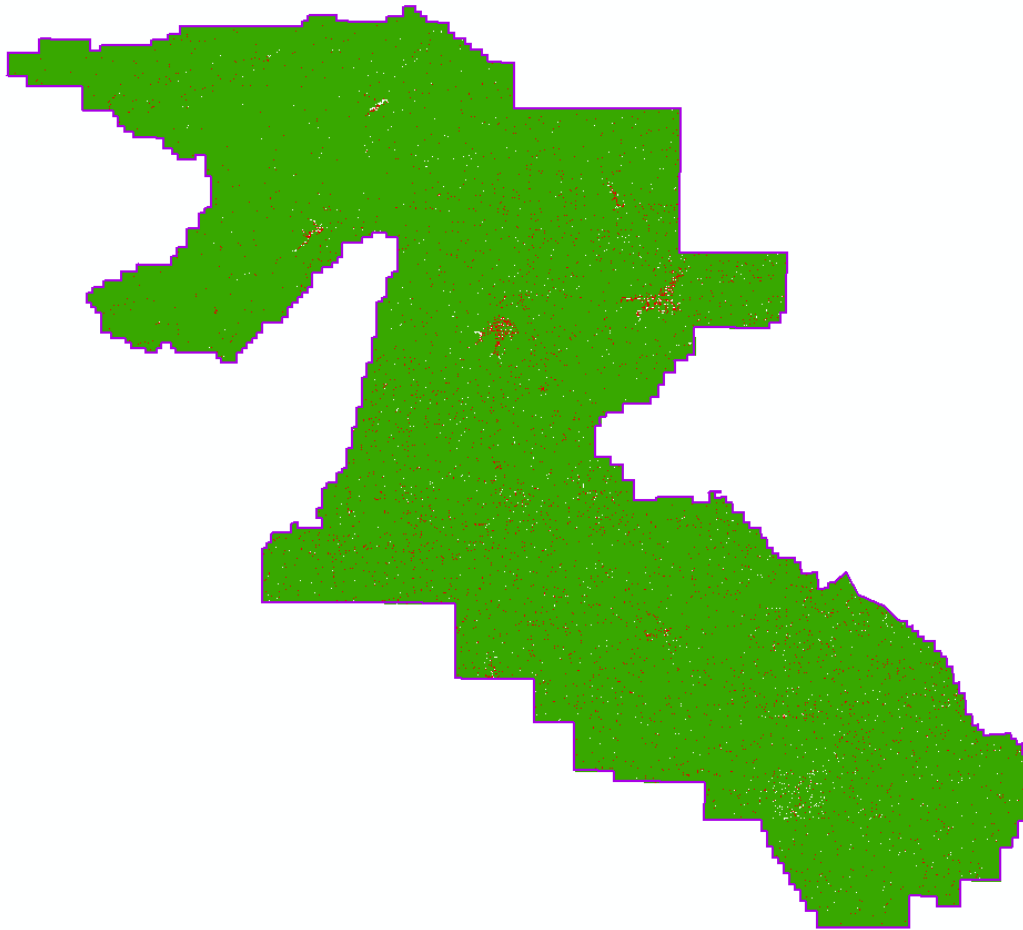


Figure 11– 1-square meter density grid. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

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. ArcGIS tools are 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.

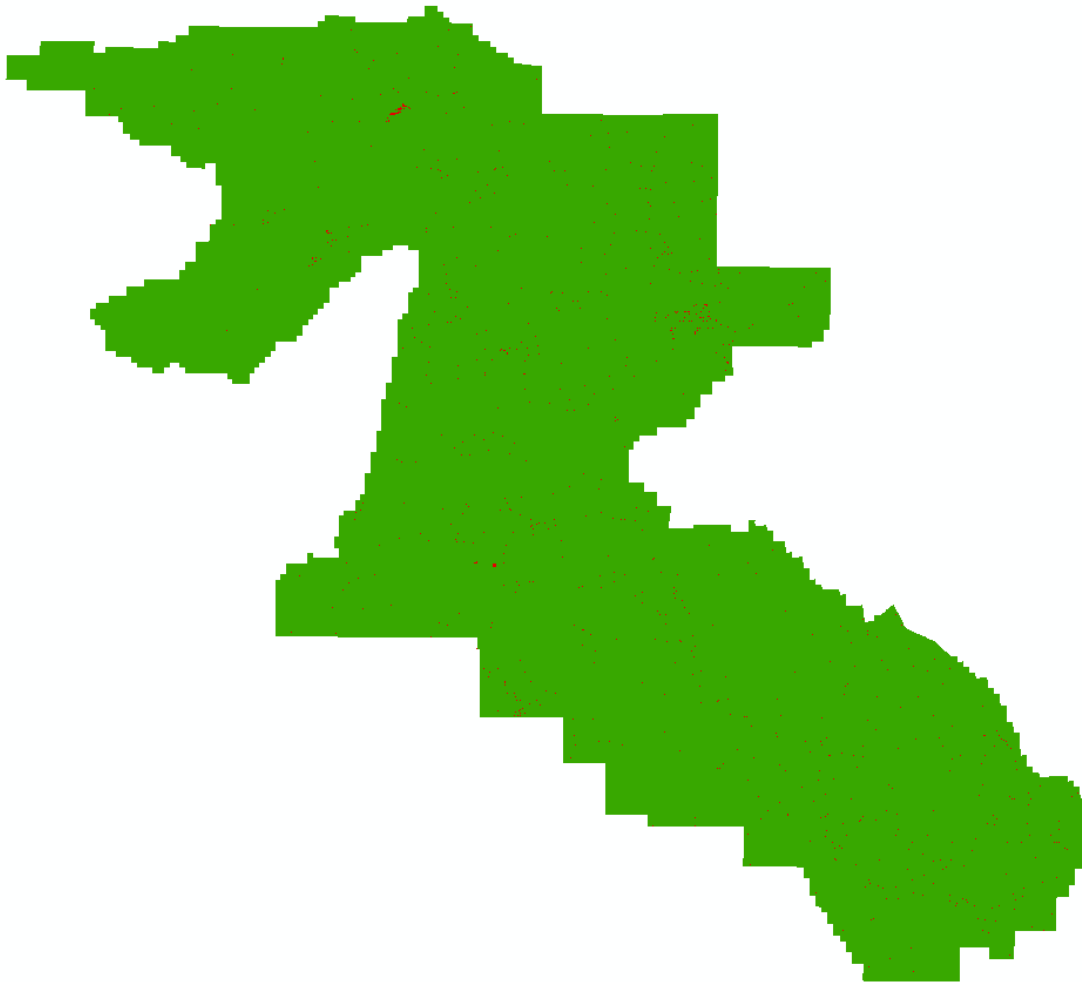


Figure 12– Spatial Distribution. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, 99.6% of cells contain at least one lidar point.

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.

Synthetic Points

These LAS files contain synthetic points. These points were generated by the Riegl processing software to fill Multiple Time Around (MTA) zones, which are a physical phenomenon that exists in any time of flight lidar system which has multiple pulses in air and wishes to record all of them seamlessly without range gate limitations. The MTA zones only exist in narrow bands of ranges and typically are dependent on flight planning parameters and project area topography.

Riegl offers a synthetic point solution that fills these voids with interpolated points using information from neighboring returns. Due to the typical linear interpolation of DEM processing, the use of these points have little to no effect on DEM generation or visualization.

Dewberry has maintained the synthetic point flag for these points in the lidar point cloud. Their existence has also been documented in the final metadata for this project. Please see the separate document delivered with these data, titled “180530_Riegl_MTA_Synthetic_Points.pdf” for a more in-depth explanation of the synthetic points.

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 Brazos Basin Lidar Project.

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 Brazos Basin lidar project.

Intensity Variation

In the Brazos dataset there are several intensity discrepancies due to the use of multiple sensors on this project. Due to the large size of this project it was necessary to deploy several scanners to complete acquisition in a timely manner. With any lidar system, there can be a unique dynamic range of intensities between systems of the same model line. In addition this deployment included using two different Riegl sensors (VQ-780i & VQ-1560i). Due to the differing nature between these sensor lines there can be some cases where the intensity ranges do not match. In some areas of the project there may be dark or light edges between these datasets.

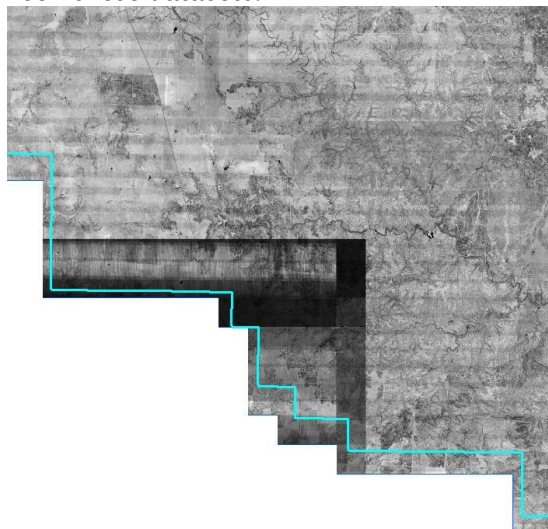


Figure 13 – Area showing intensity discrepancies due to the use of multiple sensors.

Another intensity related discrepancy identified in the Brazos dataset is in the statistical distribution of values. Most of the swaths have a full 16 bit range (0-65535). However after examining the tiled intensity statistics it was realized that the distribution of these swath's intensities were uneven. In the majority of cases the high intensity points represented a low number of noise points, while the majority of returns are in a lower dynamic range. The end result is that some tiles that contained noise points show a full 16 bit intensity range, while some tiles that do not contain these high intensity noise points have a much lower intensity maximum.

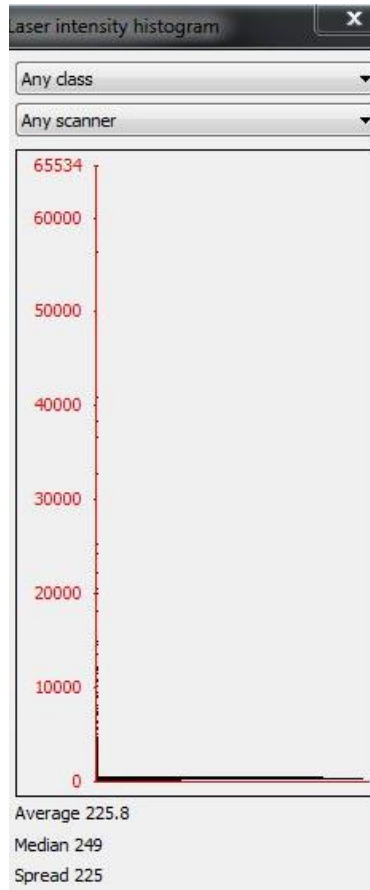


Figure 14 – Swath 170320_140212 intensity histogram displaying normal 16-bit stretch (0-65535) with the majority of returns in a lower dynamic range.

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.

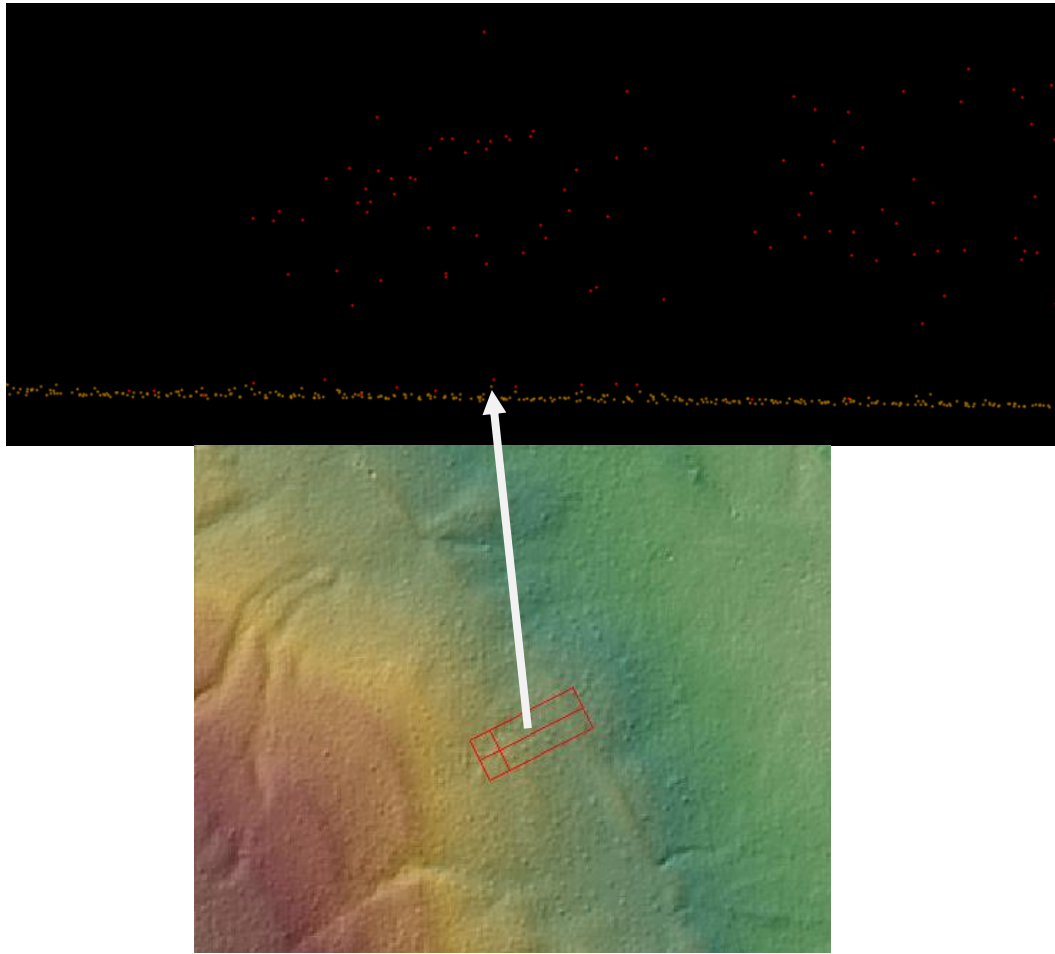


Figure 15 – Tile number 14SNA730685. Profile with points colored by class (class 1=red, class 2=orange) is shown in the top view and a TIN of the surface is shown in the bottom view. The arrow identifies low vegetation points. A limited number of these small features are still classified as ground but 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.

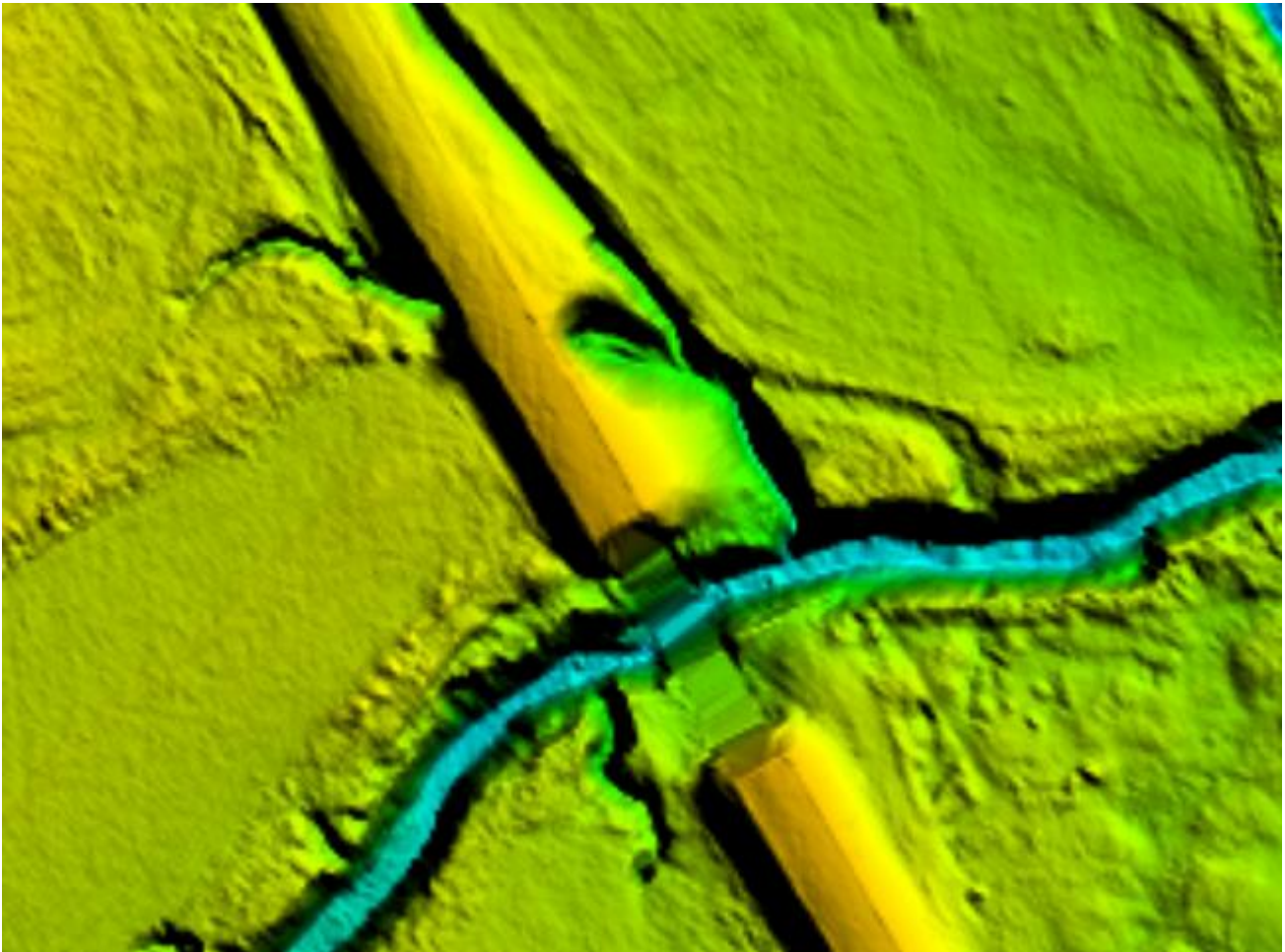
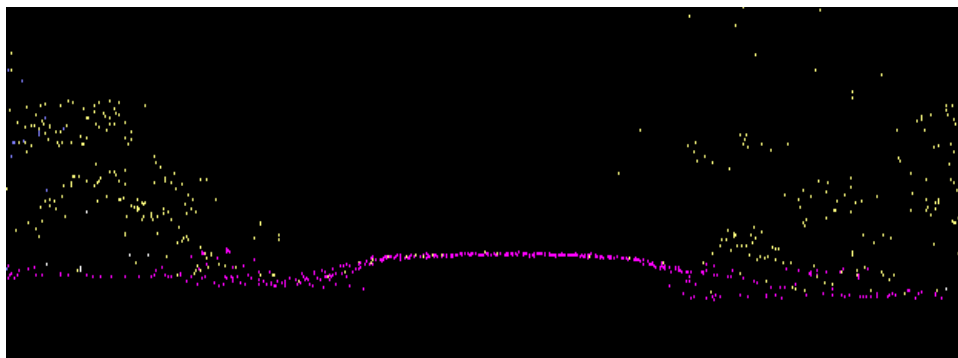


Figure 16 – Tile number 14SNA730670. The DEM shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated.

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.



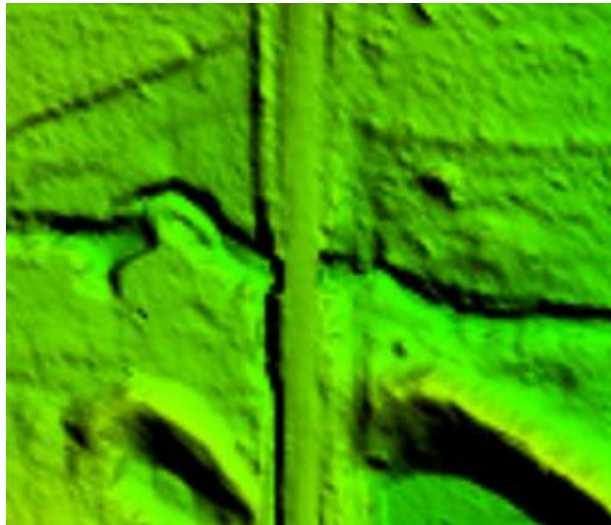


Figure 17– Tile number 14SNA055760 DEM is shown. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

In Ground Structures

In ground structures exist within the project area. These types of structures occur mainly on military bases and in facilities designed for munitions testing and storage. These features are correctly included in the ground classification.

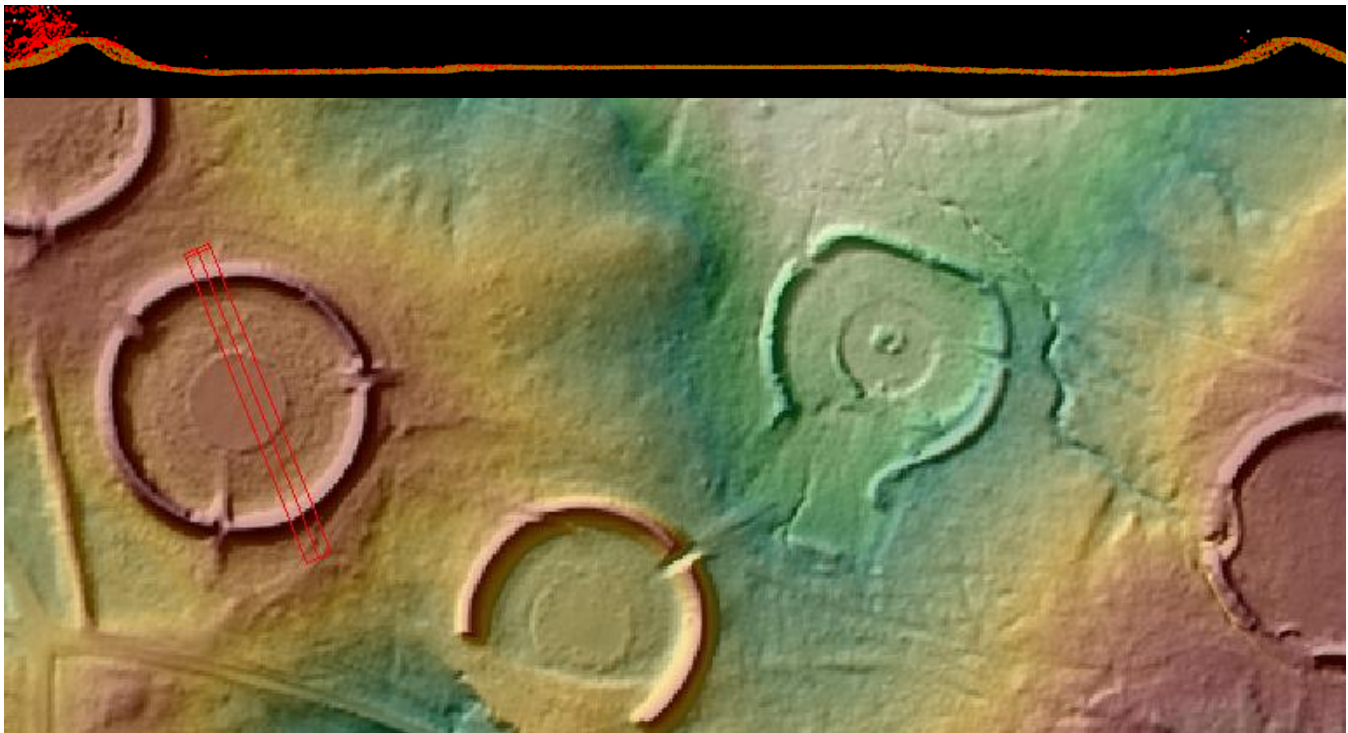


Figure 18 – Tile 14SNA430595. Profile with the points colored by class (class 1=red, class 2=orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Dirt Mounds

Irregularities in the natural ground exist and may be misinterpreted as artifacts that should be removed. Small hills and dirt mounds are present throughout the project area. These features are correctly included in the ground.

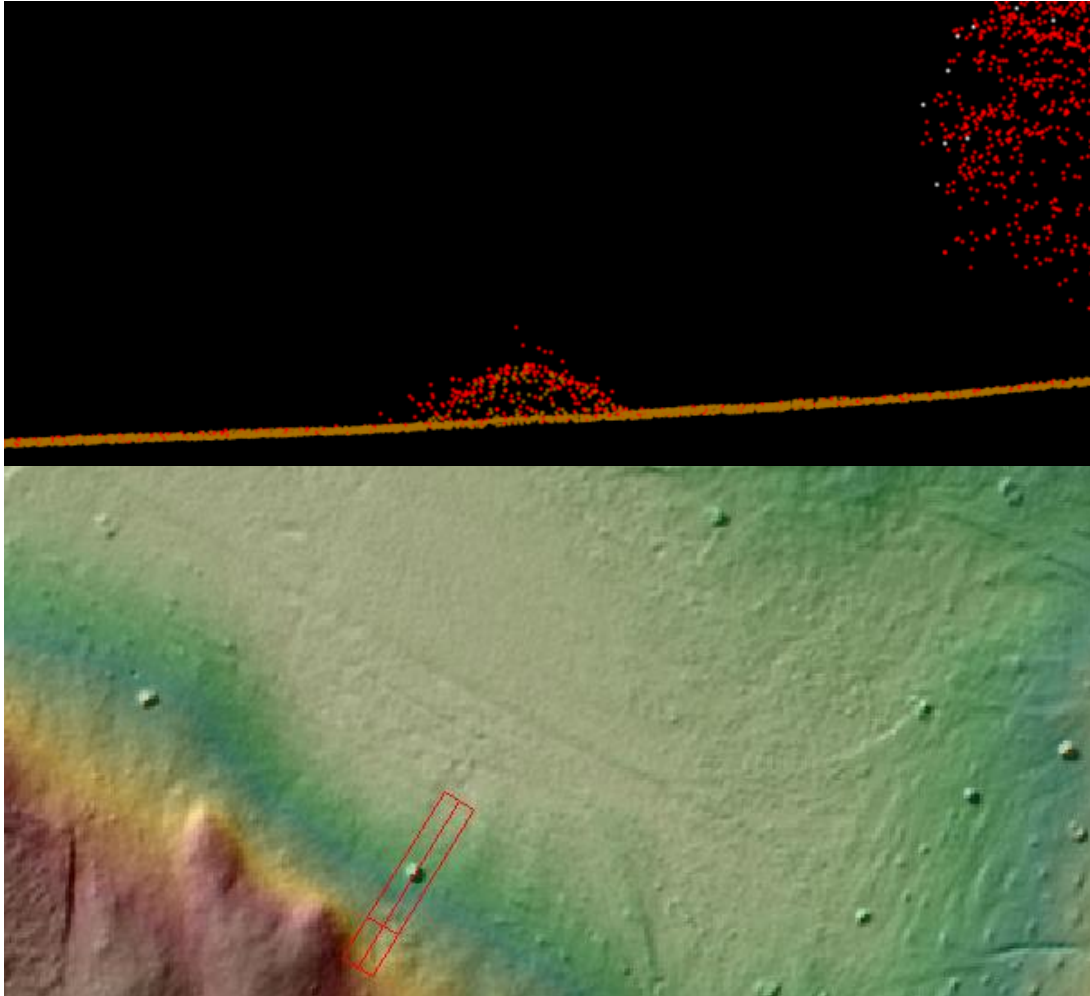


Figure 19 - Tile 14SNA430610. Profile with the points colored by class (class 1=red, class 2=orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Elevation Change Within Breaklines

While water bodies are flattened in the final DEMs, other features such as linear hydrographic features can have significant changes in elevation within a small distance. In linear hydrographic features, this is often due to the presence of a structure that affects flow such as a dam or spillway. Dewberry has reviewed the DEMs to ensure that changes in elevation are shown from bank to bank. These changes are often shown as steps to reduce the presence of artifacts while ensuring consistent downhill flow. An example is shown below.

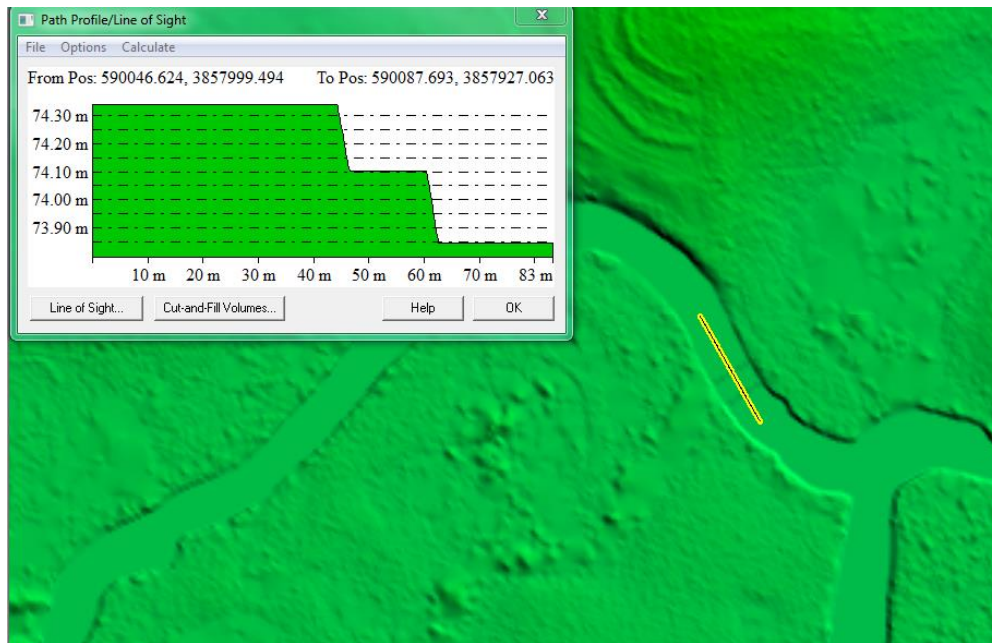
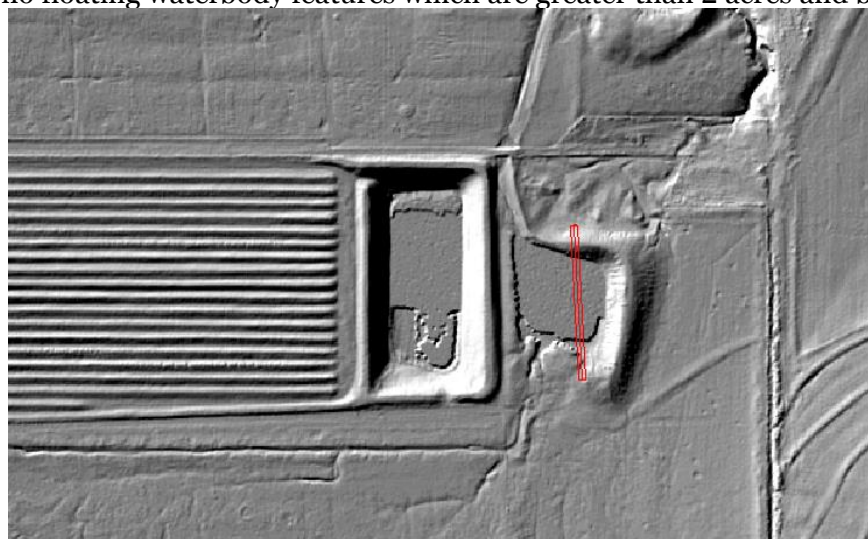


Figure 20 – Tile number 14RMA950310. Elevation change has been stair stepped. The steps are flat from bank to bank and flow consistently downhill.

Floating Non-Breaklined Waterbodies

There are some waterbodies which are smaller than 2 acres that appear to be floating. This phenomenon is most evident in areas of temporal change where water levels between overlapping flight lines differ. But this phenomenon can also occur within a single flight line on small waterbodies surrounded by marshy, saturated soils where the water has a higher reflectivity of the lidar pulse compared to the much lower reflectivity and even partial absorption of the lidar pulse in the marshy, saturated soils. When breaklined, waterbody elevations can be set to match or be slightly below the surrounding terrain. As these features are smaller than 2 acres and are not breaklined, these “floating” features are present in the DEM due to the temporal differences and lidar characteristics outlined above. There are no floating waterbody features which are greater than 2 acres and breaklined.



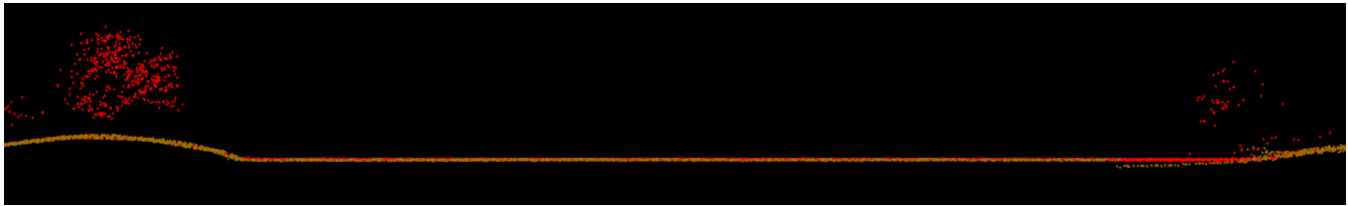


Figure 21 – Tile number 15SWU895565. Temporal difference in pond water surface causing the appearance of floating points. This will only be visible in ponds that are below the 2 acres breakline specification.

Flight line Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flight line ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible ridge that is within tolerance is shown below.

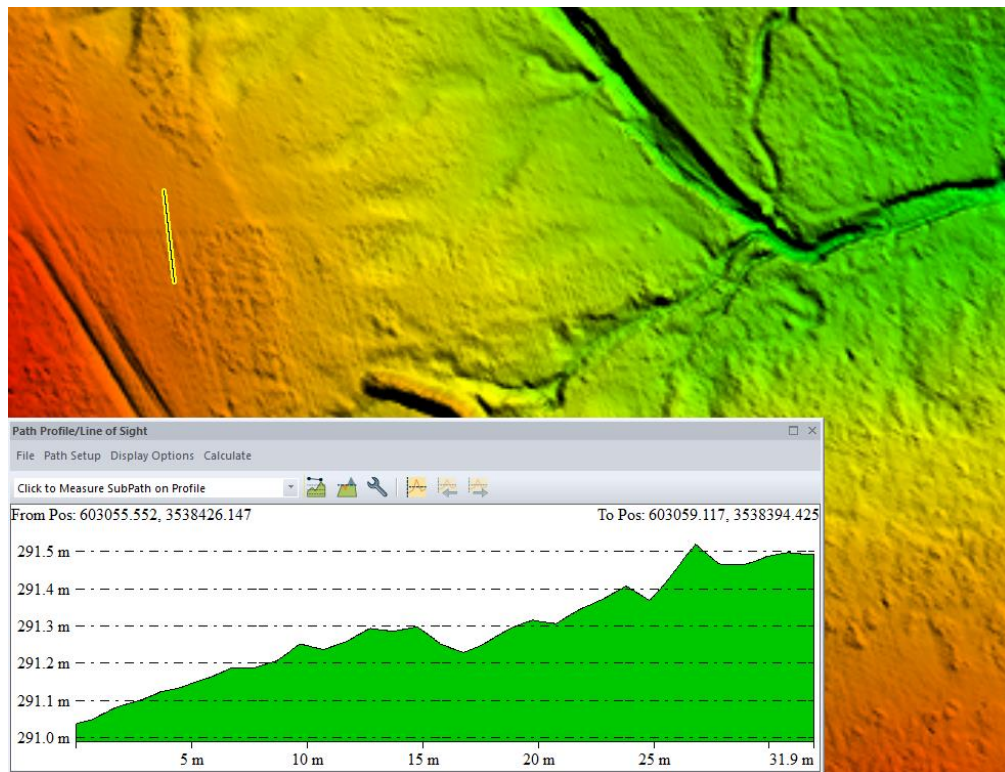


Figure 22– Tile number 14RPA030370. The flight line ridge is less than 8 cm. Overall, the Brazos Basin lidar data meets the project specifications for 8 cm RMSDz relative accuracy.

Corn Rowing

The term corn rowing refers to the presence of large or higher than normal elevation changes from one point to the next (adjacent or near) point in a single swath or flight line. The varying elevations from points to nearby points in the same swath results in a ground surface model that has higher and lower ground, often appearing in rows, hence the term corn rowing. Corn rowing can appear worse in areas of overlap where corn rowing issues from each individual swath are combined in one area.

Additionally, corn rowing can be worse at edges of flight lines acquired with lidar sensors whose mirror uses back and forth scan patterns as the geometry of points at the outer edge of each scan will include additional error compared to points scanned at nadir due to inherent errors in the lidar system.

Regardless of location, corn rowing results from poor point to point relative accuracy, which is also

known as intra-swath or within swath relative accuracy and smooth surface repeatability. When identifying allowable thresholds for corn rowing, the within swath relative accuracy or smooth surface repeatability maximum threshold is the value that must be used. Some corn rowing is visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of visible corn rowing that is within tolerance is shown below.

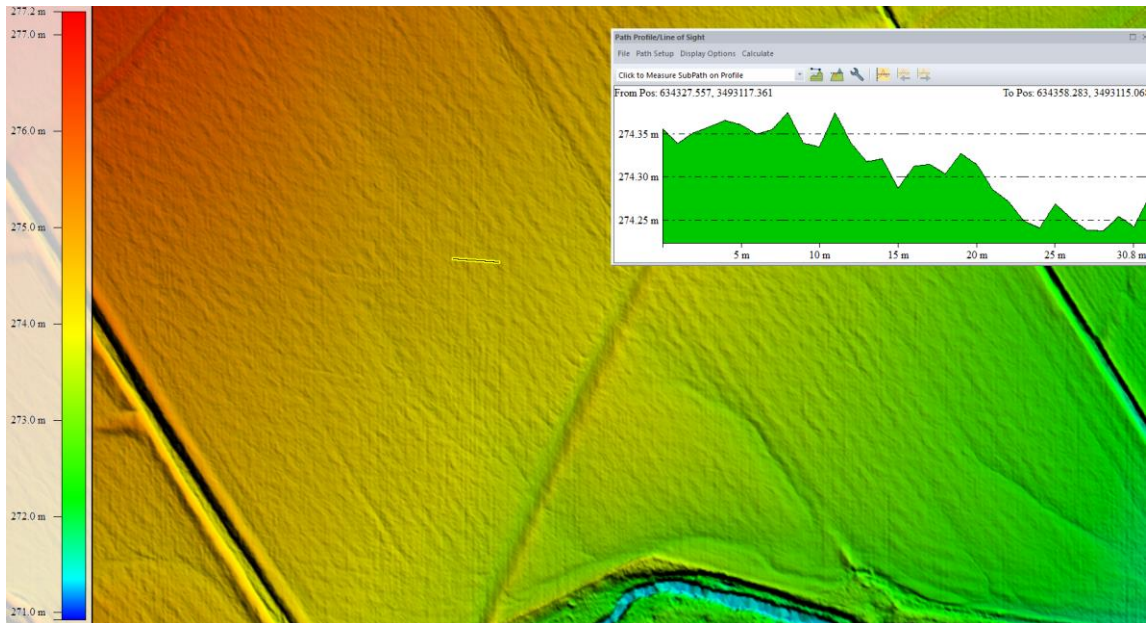


Figure 23– Tile number 14RPV330920. The corn rowing is less than 6 cm. Overall, the Brazos Basin lidar data meets the project specifications for 6 cm within swath relative accuracy.

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 14, meters and NAVD88 (Geoid 12B), 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

Note: These LAS files contain synthetic points. These points were generated by the Riegl processing software to fill Multiple Time Around (MTA) zones. Dewberry has maintained the synthetic point flag for these points in the lidar point cloud.

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, three hundred seventy (370) 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 14N		NAVD88 (Geoid 12B)
	Easting X (m)	Northing Y (m)	Elevation (m)
NVA-293	598552.492	3455488.427	315.473
NVA-294	604304.773	3459609.568	287.198
NVA-295	625203.329	3463982.058	300.789
NVA-296	631250.778	3461168.656	287.763
NVA-297	634591.578	3468358.186	217.675
NVA-298	641879.105	3476976.343	258.071
NVA-299	650727.888	3481224.650	218.194
NVA-300	655439.118	3491699.194	193.387
NVA-301	654473.076	3497983.355	196.052
NVA-302	646826.731	3494234.498	221.065
NVA-303	637318.673	3484777.527	277.672
NVA-304	626917.196	3480283.768	301.492
NVA-305	617165.958	3478683.718	260.792
NVA-306	606474.463	3473574.143	320.977
NVA-307	594772.189	3467052.026	286.421
NVA-308	586705.232	3470768.506	369.870
NVA-309	596462.621	3478408.039	327.297
NVA-310	617721.380	3485667.270	277.503
NVA-311	633354.631	3491205.183	295.923
NVA-312	637491.284	3499470.853	272.551
NVA-313	644701.462	3503615.268	182.967
NVA-314	637310.602	3511593.795	192.367
NVA-315	629172.292	3504878.593	296.462
NVA-316	621212.493	3496262.706	331.675
NVA-317	609991.110	3494714.443	297.994
NVA-318	603781.274	3487747.004	279.991
NVA-319	588915.315	3482496.083	353.848
NVA-320	579030.643	3480398.963	415.763
NVA-321	589617.459	3489734.710	359.319
NVA-322	600877.559	3494577.576	316.772
NVA-323	608975.708	3503258.624	362.249
NVA-324	616162.209	3510594.604	278.334

NVA-325	624523.322	3516147.049	276.943
NVA-326	630847.141	3521755.244	221.907
NVA-327	628039.675	3532618.698	239.393
NVA-328	615034.243	3521251.521	283.412
NVA-329	610827.140	3515510.227	301.464
NVA-330	596899.056	3512159.049	320.377
NVA-331	597042.608	3501536.526	308.052
NVA-332	585850.364	3498860.354	383.452
NVA-333	579756.614	3491316.043	370.823
NVA-334	574781.728	3488003.000	463.347
NVA-335	569687.640	3494078.690	432.489
NVA-336	581374.404	3507785.115	377.771
NVA-337	597801.297	3523733.062	376.450
NVA-338	607460.259	3530251.499	343.573
NVA-339	619564.172	3540607.432	265.570
NVA-340	606070.332	3538533.641	281.224
NVA-341	594927.384	3530778.788	356.172
NVA-342	583713.538	3523009.561	358.707
NVA-343	576356.403	3516101.883	365.390
NVA-344	569884.709	3507856.728	403.907
NVA-345	558316.019	3503996.540	454.248
NVA-346	544841.112	3499103.934	494.458
NVA-347	530376.907	3505785.835	495.244
NVA-348	544767.280	3513864.950	404.523
NVA-349	556253.525	3523487.319	364.446
NVA-350	570364.170	3527155.376	366.361
NVA-351	580432.210	3538279.747	352.192
NVA-352	596753.606	3539000.977	338.258
NVA-353	596416.802	3550030.308	363.246
NVA-354	574909.059	3547230.930	364.741
NVA-355	563793.293	3539944.931	407.066
NVA-356	553812.392	3539127.831	369.245
NVA-357	537378.394	3528015.284	418.158
NVA-358	529566.762	3519196.905	525.905
NVA-359	519299.794	3519389.315	491.383
NVA-360	494227.823	3528259.197	473.639
NVA-361	507670.379	3529151.293	493.230
NVA-362	523722.974	3532286.635	468.640
NVA-363	530429.809	3536492.398	413.103
NVA-364	541305.182	3541706.921	366.338
NVA-365	556937.424	3545228.695	407.988
NVA-366	562775.815	3549037.972	453.126
NVA-367	581550.470	3555937.680	382.681
NVA-368	568417.652	3559991.616	420.239
NVA-369	571743.536	3570901.886	399.052
NVA-370	556649.715	3558392.277	438.651
NVA-371	540932.578	3552700.896	400.834
NVA-372	533793.599	3548030.397	408.902
NVA-373	521305.239	3542630.172	435.695

NVA-374	507437.301	3536452.116	515.146
NVA-375	494600.092	3540461.227	461.132
NVA-376	503362.791	3552029.205	503.777
NVA-377	522441.210	3553726.224	453.445
NVA-378	543045.623	3563990.578	405.313
NVA-379	564502.519	3574587.508	444.544
NVA-380	553244.782	3573427.287	458.913
NVA-381	542512.430	3570718.982	416.731
NVA-382	530974.931	3564562.077	445.173
NVA-383	493712.893	3559118.446	540.185
NVA-384	484386.562	3554734.680	529.482
NVA-385	460136.067	3552749.008	544.686
NVA-386	443961.670	3552986.642	607.543
NVA-387	434211.009	3556535.229	602.550
NVA-388	461900.427	3565463.567	566.332
NVA-389	481708.028	3568168.784	550.307
NVA-390	503929.231	3570458.687	493.990
NVA-391	516113.470	3570466.686	487.824
NVA-392	528544.528	3583525.506	442.336
NVA-393	528600.790	3589488.586	447.853
NVA-394	517108.748	3585349.858	436.271
NVA-395	500274.049	3582622.340	510.425
NVA-396	482294.287	3581767.571	492.106
NVA-397	462845.321	3584232.287	523.568
NVA-398	452250.224	3578373.178	585.814
NVA-399	457271.032	3589873.534	597.489
NVA-400	479547.305	3591473.760	440.837
NVA-401	493171.683	3592062.195	470.857
NVA-402	502711.894	3591960.027	441.845
NVA-403	519680.124	3596716.053	485.974
NVA-404	524467.626	3604171.979	481.106
NVA-405	510028.353	3602913.720	427.056
NVA-406	494616.984	3601691.896	422.824
NVA-407	484586.736	3600846.130	415.932
NVA-408	466000.791	3598545.211	514.519
NVA-409	464376.185	3611393.764	466.278
NVA-410	480823.053	3607306.512	422.149
NVA-411	503847.577	3605666.775	399.290
NVA-412	515939.324	3609656.586	397.881
NVA-413	530432.620	3610438.431	432.163
NVA-414	540181.577	3612387.030	406.559
NVA-415	546311.968	3623944.490	369.234
NVA-416	531010.253	3620088.463	382.120
NVA-417	522494.130	3620514.208	387.024
NVA-418	509116.327	3621363.674	366.212
NVA-419	491406.933	3615426.425	417.089
NVA-420	475830.468	3615010.473	431.519
NVA-421	471726.472	3621315.078	436.323
NVA-422	467327.354	3627155.827	492.680

NVA-423	485029.683	3629868.132	408.834
NVA-424	502953.000	3630409.874	364.500
NVA-425	517804.139	3630438.012	397.478
NVA-426	539130.903	3634074.332	372.299
NVA-427	553570.133	3633475.190	362.029
NVA-428	577275.896	3634351.716	270.332
NVA-429	578329.535	3644861.699	324.815
NVA-430	570121.827	3644490.072	295.983
NVA-431	558251.701	3643426.943	337.628
NVA-432	538735.266	3644605.632	370.595
NVA-433	525852.940	3639703.680	356.891
NVA-434	508341.319	3636320.761	350.062
NVA-435	492013.319	3639120.525	357.548
NVA-436	477804.998	3640466.253	381.709
NVA-437	470218.928	3649542.897	425.761
NVA-438	494851.409	3654028.728	390.433
NVA-439	508443.629	3648832.174	364.881
NVA-440	521227.497	3647145.071	323.823
NVA-441	530953.731	3651854.130	316.196
NVA-442	547239.279	3653613.668	320.245
NVA-443	547108.204	3666234.413	345.467
NVA-444	540443.494	3664413.058	335.866
NVA-445	522500.760	3660806.804	344.447
NVA-446	508859.390	3661585.350	378.087
NVA-447	492763.266	3661944.454	394.779
NVA-448	478179.960	3664929.622	436.001
NVA-449	466787.500	3671458.424	511.457
NVA-450	476626.654	3673060.752	433.193
NVA-451	483471.993	3671092.570	401.106
NVA-452	500459.484	3671667.651	376.830
NVA-453	512367.291	3671540.211	350.591
NVA-454	524151.989	3672849.970	349.220
NVA-455	540122.860	3675451.384	358.002
NVA-456	545639.471	3680521.090	395.303
NVA-457	551368.369	3691215.022	338.843
NVA-458	535662.002	3687750.412	377.247
NVA-459	522567.061	3691498.419	360.217
NVA-460	516104.275	3684611.963	369.539
NVA-461	495339.648	3684234.291	375.907
NVA-462	481492.326	3683378.862	411.217
NVA-463	477932.018	3700890.497	394.639
NVA-464	496359.786	3696513.416	371.288
NVA-465	500365.380	3704657.079	395.689
NVA-466	484830.040	3710602.051	412.558
NVA-467	475734.286	3715839.126	392.042
NVA-468	468318.313	3705662.983	414.198
NVA-469	462318.860	3693480.485	414.627
NVA-470	462886.066	3682949.064	458.005
NVA-471	453972.836	3671597.985	442.538

NVA-472	455206.070	3659839.961	481.976
NVA-473	443344.814	3656083.449	436.003
NVA-474	441582.819	3652833.562	451.097
NVA-475	433351.705	3636654.097	469.867
NVA-476	415751.444	3624092.141	529.743
NVA-477	404770.991	3624047.754	547.727
NVA-478	410758.848	3636756.010	505.546
NVA-479	424072.051	3645495.305	491.706
NVA-480	427971.401	3655430.027	453.910
NVA-481	444113.042	3671072.449	441.943
NVA-482	446805.857	3681628.884	438.588
NVA-483	451870.250	3695124.715	443.097
NVA-484	451274.030	3703191.244	442.729
NVA-485	464955.860	3718803.201	417.563
NVA-486	438268.103	3717953.408	458.711
NVA-487	437057.652	3687871.668	462.743
NVA-488	430598.707	3668998.891	483.782
NVA-490	411106.937	3646547.829	505.193
NVA-491	394539.054	3637773.142	523.660
NVA-492	388649.480	3635753.369	537.675
NVA-493	416484.347	3670094.380	515.352
NVA-494	428498.741	3680529.600	478.673
NVA-495	421798.092	3693677.469	479.834
NVA-496	425162.439	3705597.626	434.092
NVA-497	426751.450	3716326.215	452.633
NVA-498	414282.784	3716294.941	485.945
NVA-499	411598.003	3706002.954	484.565
NVA-500	408138.384	3690999.381	461.890
NVA-501	411132.774	3685178.069	487.195
NVA-502	388199.998	3688625.612	542.496
NVA-503	383290.280	3695251.973	541.138
NVA-504	398788.625	3712733.566	527.841
NVA-505	381551.494	3702420.089	529.893
NVA-506	379322.001	3708944.650	532.935
NVA-507	376019.558	3702245.185	583.598
NVA-508	369652.352	3704798.228	594.597
NVA-509	362961.485	3712283.572	607.719
NVA-510	382827.691	3706345.958	549.367
NVA-511	402896.152	3705878.276	522.267
NVA-512	402112.171	3699763.758	503.018
VVA-203	598286.690	3458177.027	299.780
VVA-204	606939.686	3463938.499	273.227
VVA-205	626765.494	3463403.807	296.988
VVA-206	632848.919	3466943.403	223.689
VVA-207	638102.573	3474027.804	206.981
VVA-208	655928.459	3487638.459	169.412
VVA-209	651751.011	3499528.672	200.408
VVA-210	647854.646	3506390.314	196.718
VVA-211	637993.695	3497674.950	254.226

VVA-212	625103.401	3485380.682	259.971
VVA-213	616642.536	3475692.268	261.307
VVA-214	603416.276	3472096.038	263.297
VVA-215	589086.545	3471244.114	333.200
VVA-216	592618.767	3478432.728	366.146
VVA-217	605816.060	3485270.833	269.185
VVA-218	616721.374	3492599.422	343.603
VVA-219	625450.672	3505349.307	297.149
VVA-220	634213.207	3515957.612	226.614
VVA-221	629379.246	3526281.778	228.295
VVA-222	617118.427	3518536.366	271.801
VVA-223	607368.214	3501540.314	298.844
VVA-224	595110.095	3497898.275	341.807
VVA-225	570649.108	3485605.797	409.190
VVA-226	564071.040	3496564.687	434.830
VVA-227	575613.042	3501684.804	389.691
VVA-228	587322.020	3512528.112	347.744
VVA-229	596642.979	3506611.318	276.826
VVA-230	598863.736	3520453.716	345.726
VVA-231	610179.336	3526482.207	356.674
VVA-232	621990.187	3534502.628	252.732
VVA-233	612590.479	3541892.785	274.658
VVA-234	599285.543	3530671.595	320.382
VVA-235	587519.933	3522682.178	363.576
VVA-236	573881.414	3522039.845	338.985
VVA-237	561040.011	3513862.000	434.214
VVA-238	545569.970	3507476.380	465.357
VVA-239	530642.784	3501441.887	458.111
VVA-240	523856.231	3513090.195	484.612
VVA-241	538379.689	3518238.768	454.834
VVA-242	561170.910	3527907.262	341.579
VVA-243	570196.482	3536740.613	401.679
VVA-244	586237.387	3545930.153	351.455
VVA-245	600481.808	3542730.615	302.626
VVA-246	598657.898	3553242.470	381.291
VVA-247	585789.261	3555006.269	392.656
VVA-248	573825.042	3556922.260	396.587
VVA-249	566277.049	3548155.494	437.836
VVA-250	553096.775	3542676.777	382.768
VVA-251	544207.638	3530654.990	384.666
VVA-252	531576.222	3529456.642	471.268
VVA-253	516803.905	3524456.324	535.166
VVA-254	499566.297	3530795.571	463.309
VVA-255	493976.210	3544769.691	480.918
VVA-256	517976.392	3539075.909	476.162
VVA-257	533531.367	3545273.873	390.324
VVA-258	553227.672	3562386.325	400.717
VVA-259	567186.943	3567142.193	410.164
VVA-260	539522.738	3561417.251	404.711

VVA-261	526048.815	3551743.714	418.278
VVA-262	507828.743	3551450.987	477.146
VVA-263	436307.521	3561520.531	622.825
VVA-264	460087.562	3559380.553	530.394
VVA-265	481797.837	3561202.774	545.795
VVA-266	498799.023	3561147.232	506.469
VVA-267	514661.479	3566206.327	471.748
VVA-268	534118.125	3572845.068	393.894
VVA-269	551184.342	3575069.866	446.047
VVA-270	524464.245	3584378.164	461.428
VVA-271	504751.894	3577705.244	480.594
VVA-272	488125.120	3574388.359	539.889
VVA-273	472108.821	3573340.034	506.327
VVA-274	450966.152	3568507.958	591.996
VVA-275	457011.431	3581873.084	586.684
VVA-276	480595.111	3585597.291	464.485
VVA-277	494641.062	3587162.462	499.632
VVA-278	510601.178	3591897.764	454.055
VVA-279	529382.820	3604222.281	463.980
VVA-280	535703.763	3610521.412	436.653
VVA-281	513760.661	3607314.520	401.415
VVA-282	495343.713	3598561.187	427.791
VVA-283	484036.471	3598734.358	423.418
VVA-284	475928.742	3590319.310	432.760
VVA-285	470042.470	3601591.674	440.113
VVA-286	475938.922	3608011.237	411.950
VVA-287	494727.872	3611600.941	384.282
VVA-288	515293.398	3613961.531	399.188
VVA-289	544738.146	3621025.090	381.490
VVA-290	528766.587	3625645.587	382.071
VVA-291	502853.225	3621325.380	386.409
VVA-292	481862.866	3617754.689	397.876
VVA-293	466150.734	3613674.877	473.284
VVA-294	475133.382	3630767.418	413.419
VVA-295	489474.267	3633209.930	393.880
VVA-296	511803.308	3635059.650	352.189
VVA-297	531824.952	3636396.219	327.650
VVA-298	562377.224	3636049.412	293.825
VVA-299	580153.992	3639314.309	307.108
VVA-300	565844.470	3647705.975	339.597
VVA-301	540858.508	3650555.698	325.536
VVA-302	515957.110	3648293.833	375.088
VVA-303	504361.633	3652885.336	364.505
VVA-304	491320.582	3649494.360	380.778
VVA-305	481785.366	3645145.262	379.619
VVA-306	467702.614	3669832.063	518.498
VVA-307	484668.257	3668164.657	409.634
VVA-308	499773.633	3663713.703	389.741
VVA-309	519109.403	3669792.162	345.101

VVA-310	533925.648	3664861.970	328.544
VVA-311	550097.017	3676365.570	383.290
VVA-312	542879.524	3685700.922	356.819
VVA-313	528501.562	3682369.372	339.596
VVA-314	516085.382	3680171.260	348.063
VVA-315	495156.757	3676263.604	377.961
VVA-316	478237.112	3677948.757	410.640
VVA-317	481055.389	3690970.629	415.184
VVA-318	489852.664	3687485.382	394.969
VVA-319	506987.864	3689451.214	363.178
VVA-320	521850.364	3686338.598	357.090
VVA-321	514999.964	3693826.840	390.049
VVA-322	540252.349	3693852.873	366.311
VVA-323	498520.168	3700738.126	392.127
VVA-324	484835.914	3708991.579	393.261
VVA-325	466029.069	3710330.992	430.448
VVA-326	457515.019	3702741.312	424.502
VVA-327	456887.045	3687025.840	422.920
VVA-328	450264.486	3670072.055	438.450
VVA-329	445151.450	3650730.228	447.697
VVA-330	431014.919	3643890.038	478.198
VVA-331	421887.118	3631284.240	487.495
VVA-332	403434.416	3628428.783	565.556
VVA-333	383426.042	3633918.450	565.110
VVA-334	401322.460	3645006.247	524.337
VVA-335	414517.032	3654072.826	478.773
VVA-336	421875.343	3662271.512	484.405
VVA-337	440028.199	3661843.642	444.380
VVA-338	428280.262	3676313.910	488.039
VVA-339	442091.009	3692727.153	450.810
VVA-340	449847.677	3714634.992	410.849
VVA-341	438296.043	3712989.199	417.188
VVA-342	432593.911	3698230.084	467.812
VVA-343	417301.323	3680391.234	497.412
VVA-344	412647.597	3691468.835	484.402
VVA-345	409790.723	3699740.912	439.288
VVA-346	420638.109	3716283.441	470.421
VVA-347	402089.290	3710378.288	509.882
VVA-348	408087.576	3683781.815	468.148
VVA-349	382105.039	3700014.044	519.025
VVA-350	373393.882	3703281.314	583.939
VVA-351	365587.524	3711625.455	597.166
VVA-352	402947.596	3704215.201	502.014
VVA-353	366975.722	3709354.760	591.608

Table 4: USGS FEMA VI – Brazos Basin lidar surveyed accuracy checkpoints

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

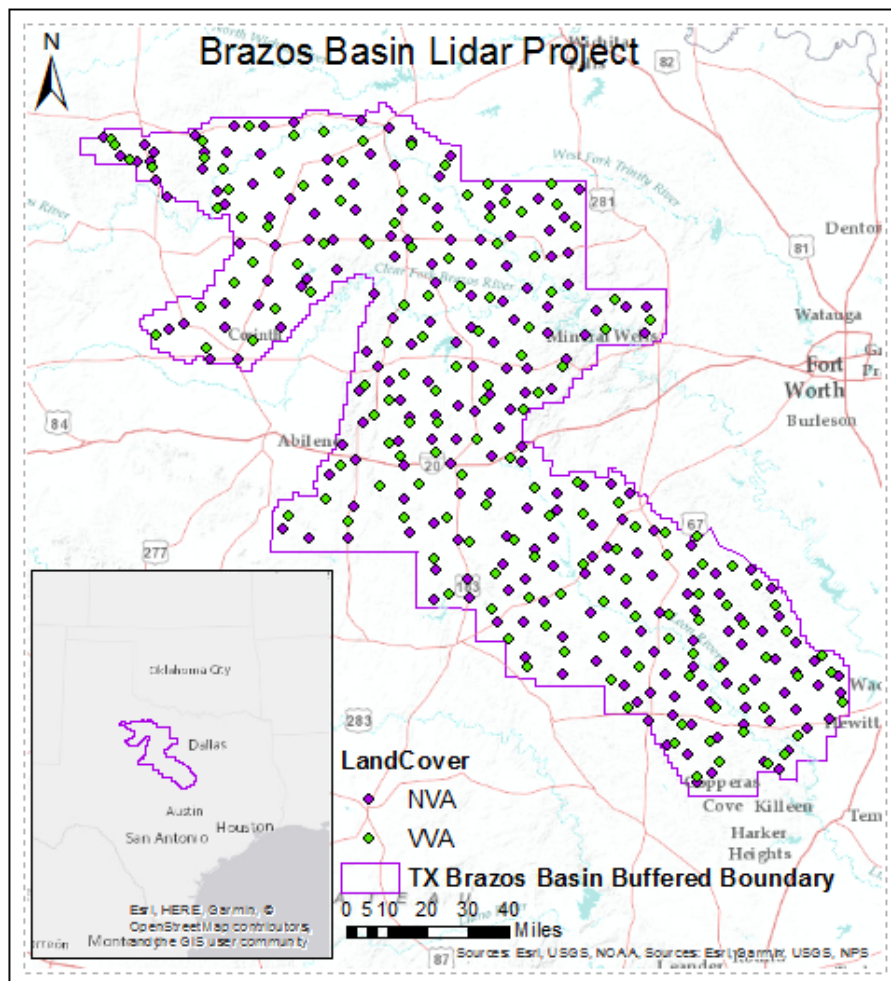


Figure 24 – Location of QA/QC Checkpoints

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 Brazos Basin lidar project, 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 95th percentile error for all checkpoints in all vegetated land cover categories combined. The Brazos Basin Lidar Project VVA standard is 29.4 cm based on the 95th percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95th 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 5.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using $RMSE_z \times 1.9600$	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 5 – 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 ($RMSE_z \times 1.9600$) Spec=19.6 cm	VVA – Vegetated Vertical Accuracy (95 th Percentile) Spec=29.4 cm
NVA	219	18.8	
VVA	151		21.6

Table 6 – Tested NVA and VVA

This lidar dataset 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 $RMSE_z = 9.6$ cm, equating to +/- 18.8 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 21.6 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 +35 cm.

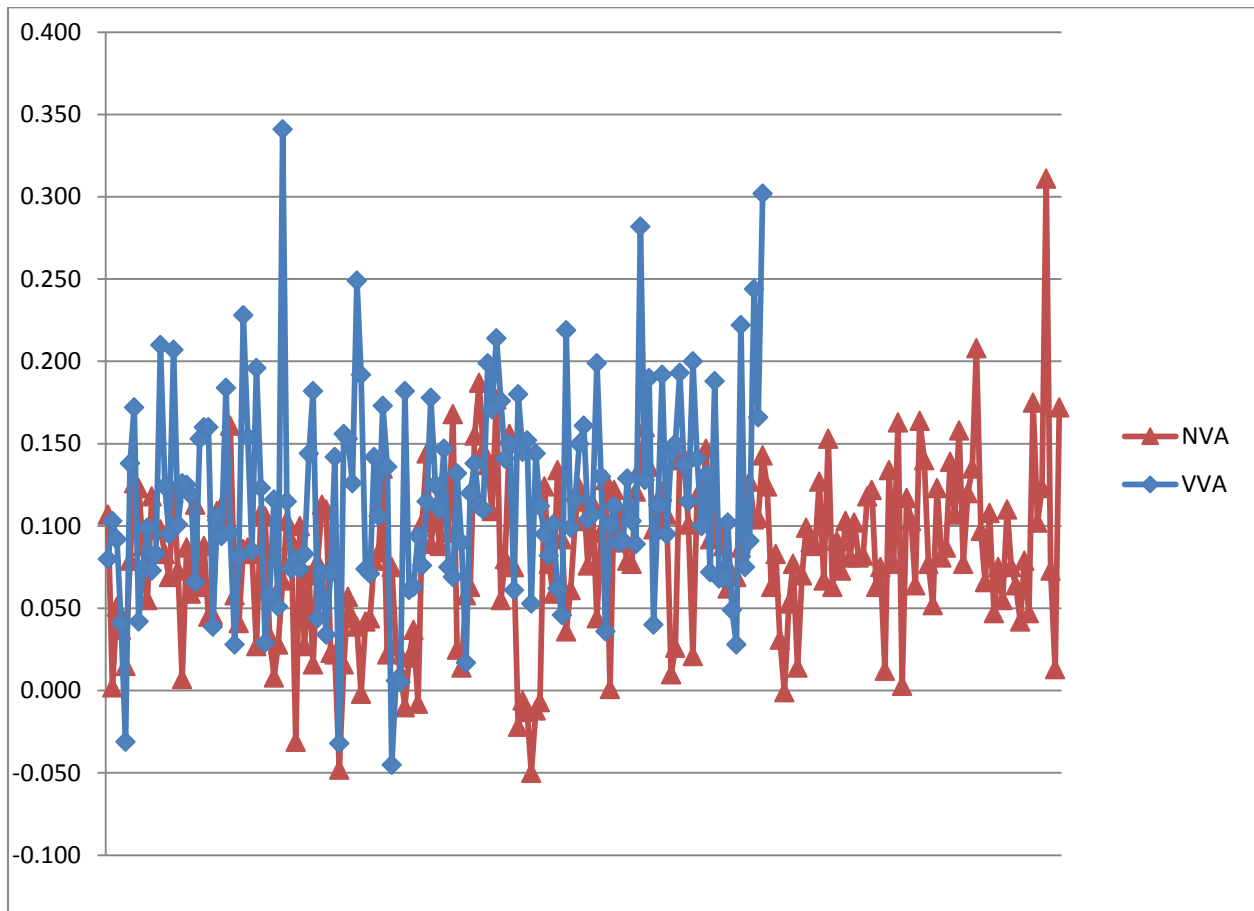


Figure 25 – Magnitude of elevation discrepancies per land cover category

Table 7 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) UTM Zone 14		NAVD88 (Geoid 12B)	Lidar Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
VVA-234	599285.543	3530671.595	320.382	320.610	0.228	0.228
VVA-243	570196.482	3536740.613	401.679	402.020	0.341	0.341
VVA-260	539522.738	3561417.251	404.711	404.960	0.249	0.249
VVA-308	499773.633	3663713.703	389.741	389.960	0.219	0.219
VVA-325	466029.069	3710330.992	430.448	430.730	0.282	0.282
VVA-348	408087.576	3683781.815	468.148	468.370	0.222	0.222
VVA-351	365587.524	3711625.455	597.166	597.410	0.244	0.244
VVA-353	366975.722	3709354.760	591.608	591.910	0.302	0.302

Table 7 – 5% Outliers

Table 8 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) Spec=0.100 m NVA	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	219	0.096	0.082	0.084	0.183	0.050	1.487	-0.050	0.311
VVA	151	N/A	0.117	0.112	0.461	0.062	1.107	-0.045	0.341

Table 8 – 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 -0.05 meters and a high of +0.34 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 +0.025 meters to +0.175 meters.

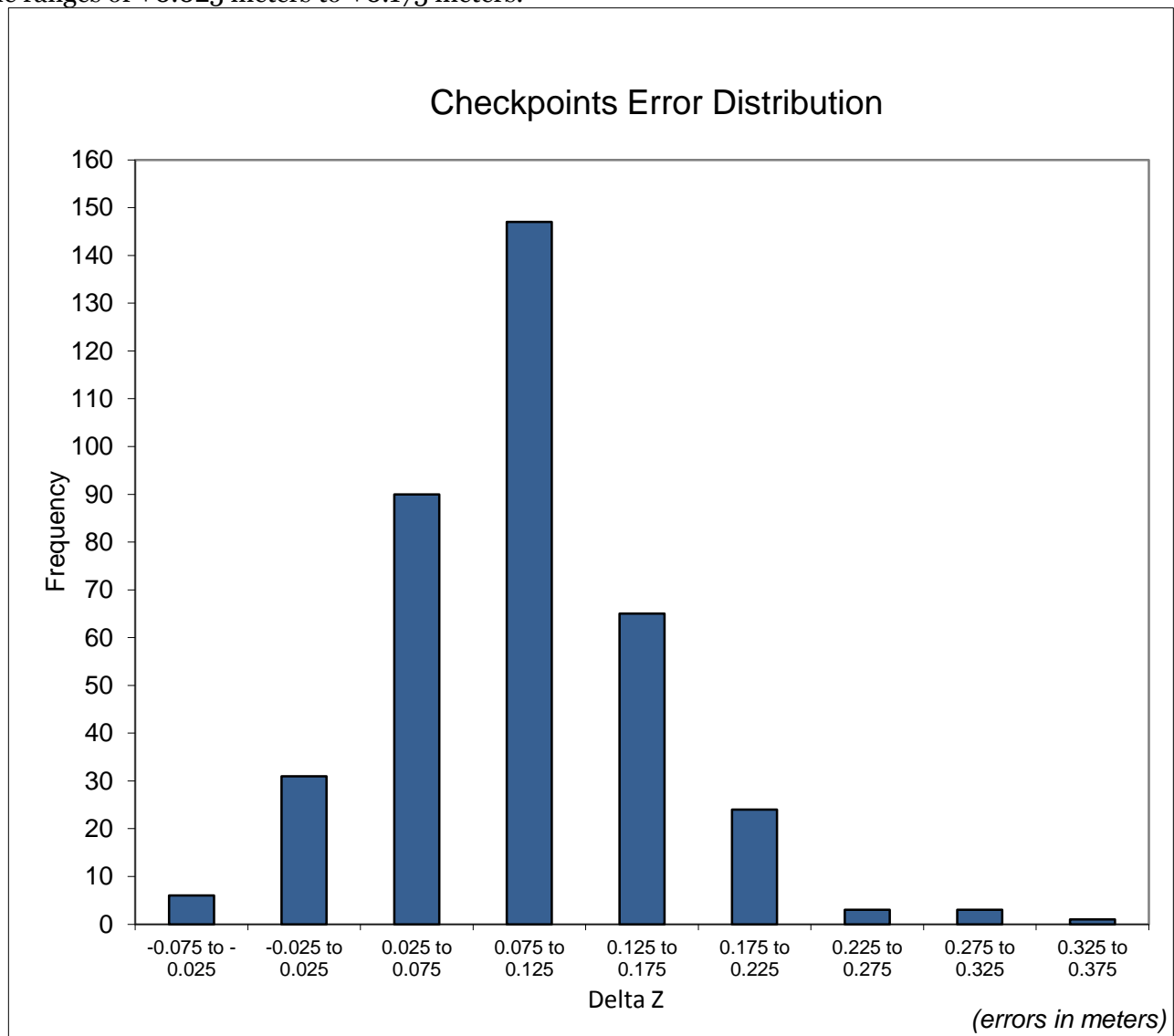


Figure 26 – Histogram of Elevation Discrepancies with errors in meters

Based on the vertical accuracy testing conducted by Dewberry, the lidar dataset for the Brazos Basin Lidar Project satisfies the project’s pre-defined vertical accuracy criteria.

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

Sixty-three 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 ACCURACY_r) is computed by the formula $RMSE_r * 1.7308$ or $RMSE_{xy} * 2.448$.

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
63	35.8	36.4	51.0	88.4

Table 9-Tested horizontal accuracy at the 95% confidence level

This data set was produced to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 41 cm RMSE_x/RMSE_y Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 1 meter at a 95% confidence level. Sixty-three (63) checkpoints were photo-identifiable to produce a statistically significant tested horizontal accuracy value. Using this set of photo-

identifiable checkpoints, positional accuracy of this dataset was found to be RMSE_x = 35.8 cm and RMSE_y = 36.4 cm which equates to +/- 88.4 cm at 95% confidence level.

Breakline Production & Qualitative Assessment Report

BREAKLINE PRODUCTION METHODOLOGY

Dewberry used a combination of lidargrammetry and automated techniques to collect breaklines for this project. The delineation of lakes and ponds, or other water bodies at a constant elevation, was achieved using eCognition software. Dewberry produced full point cloud intensity imagery, bare earth ground models, density models, and slope models. These files were ingested into eCognition, segmented into polygons, and training samples were created to identify water. eCognition used the training samples and defined parameters to identify water segments throughout the project area. Water segments were then reviewed for completeness. Segments identified as lakes and ponds were merged and smoothed. 3D elevations were then applied to the breakline features. Lidargrammetry was used to monotonically collect streams and rivers, or features that have gradient 3D elevations. Dewberry used GeoCue software to develop lidar stereo models of the project area so the lidar derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using lidargrammetry procedures with lidar intensity imagery, Dewberry used the stereo models to stereo-compile the streams and rivers in accordance with the project's Data Dictionary.

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.

Elevation Data Processing-Breaklines

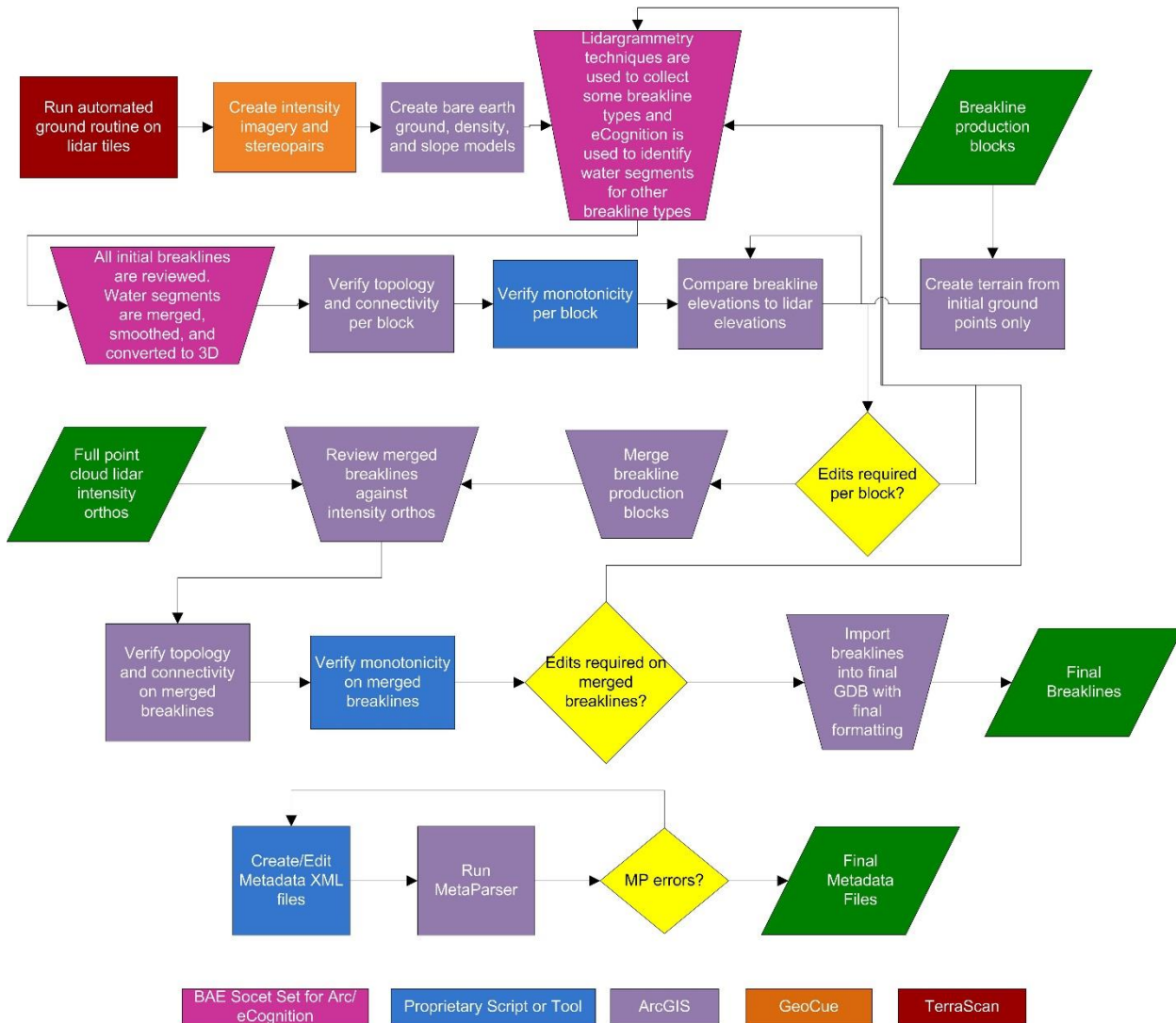


Figure 27-Breakline QA/QC workflow

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 <i>slightly</i> 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 10-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(2011), 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 14, 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	<p>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.</p>	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>Every effort should be made to avoid breaking a stream or river into segments.</p> <p>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.</p> <p>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.</p>

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	<p>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.</p> <p>“Donuts” will exist where there are islands within a closed water body feature.</p>	<p>Water bodies shall be captured as closed polygons with the water feature to the right. <u>The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body.</u></p> <p>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.</p> <p>An Island within a Closed Water Body Feature that is 1 acre in size or greater will also have a “donut polygon” compiled.</p> <p>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.</p>

Beneath Bridge Breaklines

Feature Dataset: BREAKLINES

Feature Type: Polyline

Contains Z Values: Yes

XY Resolution: Accept Default Setting

XY Tolerance: 0.003

Feature Class: Bridge_Breaklines

Contains M Values: No

Annotation Subclass: None

Z Resolution: Accept Default Setting

Z Tolerance: 0.001

Description

This polyline feature class is used to enforce terrain beneath bridge decks where ground data may not have been acquired. Enforcing the terrain beneath bridge decks prevents bridge saddles.

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

Feature Definition

Description	Definition	Capture Rules
Bridge Breaklines	Bridge Breaklines should be used where necessary to enforce terrain beneath bridge decks and to prevent bridge saddles in the bare earth DEMs.	<p>Bridge breaklines should be collected beneath bridges where bridge saddles exist or are likely to exist in the bare earth DEMs.</p> <p>Bridge breaklines should be collected perpendicular to the bridge deck so that the endpoints are on either side of the bridge deck. Typically two bridge breaklines are collected per bridge deck, one at either end of the bridge deck to enforce the terrain under the full bridge deck.</p> <p>The endpoints of the bridge breaklines will match the elevation of the ground at their xy position to enforce the ground/bare earth elevations beneath the bridge deck and prevent bridge saddles from forming.</p>

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 28-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 colored 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.

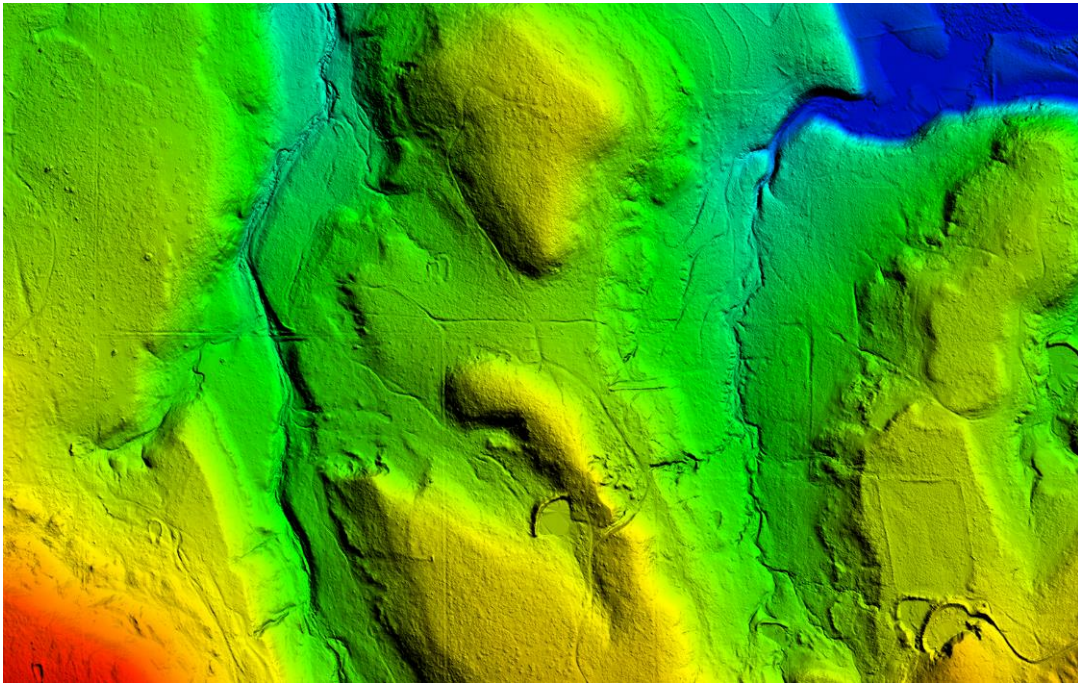


Figure 29-Tile 14RMA935295. The bare earth DEM is shown

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.

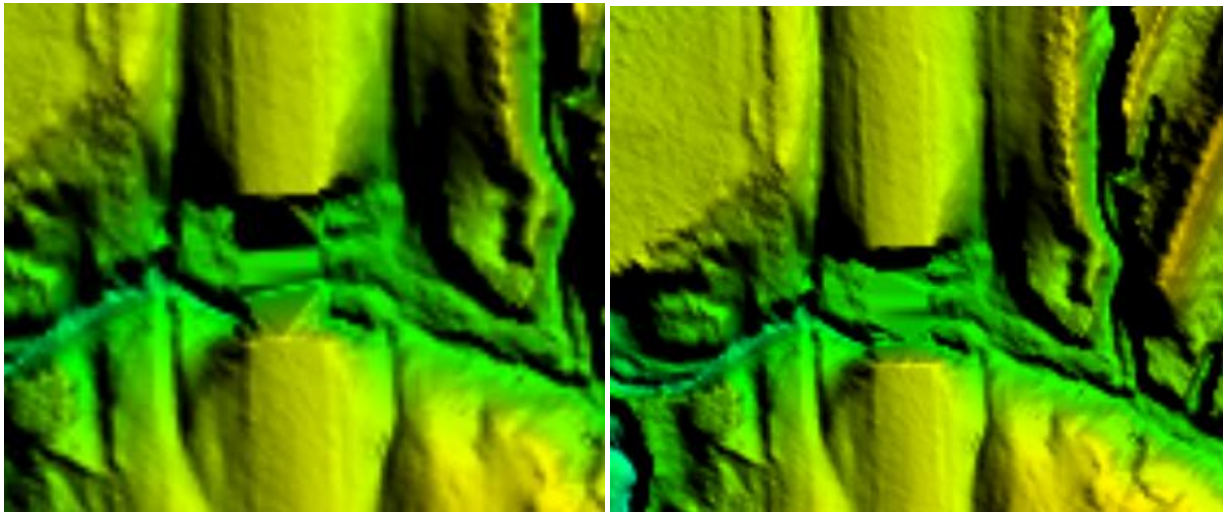


Figure 30- Tile 14RNA070310. The DEM on the left shows a bridge saddle artifact while the DEM on the right shows the same location after bridge breaklines have been enforced.

DEM VERTICAL ACCURACY RESULTS

The same 370 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 11 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=0.196 m	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.294 m
NVA	219	0.186	
VVA	151		0.221

Table 11 – 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 RMSE_z Vertical Accuracy Class. Actual NVA accuracy was found to be RMSE_z =9.5 cm, equating to +/- 18.6 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 22.1 cm at the 95th percentile.

Table 12 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83 (2011) UTM Zone 14N		NAVD88 (Geoid 12B)		DeltaZ	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Z-Survey (m)	Z-LiDAR (m)		

VVA-234	599285.543	3530671.595	320.382	320.609	0.227	0.227
VVA-243	570196.482	3536740.613	401.679	402.008	0.329	0.329
VVA-260	539522.738	3561417.251	404.711	404.965	0.254	0.254
VVA-293	466150.734	3613674.877	473.284	473.507	0.223	0.223
VVA-325	466029.069	3710330.992	430.448	430.759	0.311	0.311
VVA-348	408087.576	3683781.815	468.148	468.385	0.237	0.237
VVA-351	365587.524	3711625.455	597.166	597.415	0.249	0.249
VVA-353	366975.722	3709354.760	591.608	591.917	0.309	0.309

Table 12 – 5% Outliers

Table 13 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) Spec=0.100 m NVA	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	219	0.095	0.081	0.082	0.124	0.049	1.401	-0.051	0.303
VVA	151	N/A	0.120	0.111	0.540	0.062	1.043	-0.042	0.329

Table 13 – Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Brazos Basin 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	DEM should be hydro-flattened or hydro-enforced as required by project specifications
Pass	DEM 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 14-A subset of the high-level steps from Dewberry’s bare earth DEM Production and QA/QC checklist performed for this project.

Appendix A: Checkpoint Survey Report

Check Point Survey Report

“Texas Brazos Basin FEMA Region 6 LiDAR”
USGS Contract: G16PC00020
Task Order Number: G17PC00014

Prepared for:
United States Geological Survey (USGS)



Prepared By:

Dewberry Consultants LLC

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Lanham, Maryland, 20706

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INTRODUCTION

1.1 Project Summary

Dewberry Consultants LLC is under contract to the United States Geological Survey to provide 370 Check Points in the State of Texas. Under the above referenced USGS Task Order, Dewberry is tasked to complete the quality assurance of LiDAR products. As part of this work Dewberry staff will complete Check Point surveys that will be used to evaluate vertical and horizontal accuracy. The ground survey was conducted January 26 thru February 15, 2017.

Existing NGS Control Points were located and surveyed to check the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 of this Report.

As an internal QA/QC procedure and to verify that the Check Points meet the 95% confidence level approximately 50% of the points were re-observed and are shown in Section 5 of this report.

Final horizontal coordinates are referenced to UTM, Zone 14, NAD83 (2011) in meters. Final Vertical elevations are referenced to NAVD88 in meters using Geoid model 2012B (Geoid12B).

1.2 Points of Contact

Questions regarding the technical aspects of this report should be addressed to:

Dewberry Consultants LLC

Gary D. Simpson, L.S.
Senior Associate

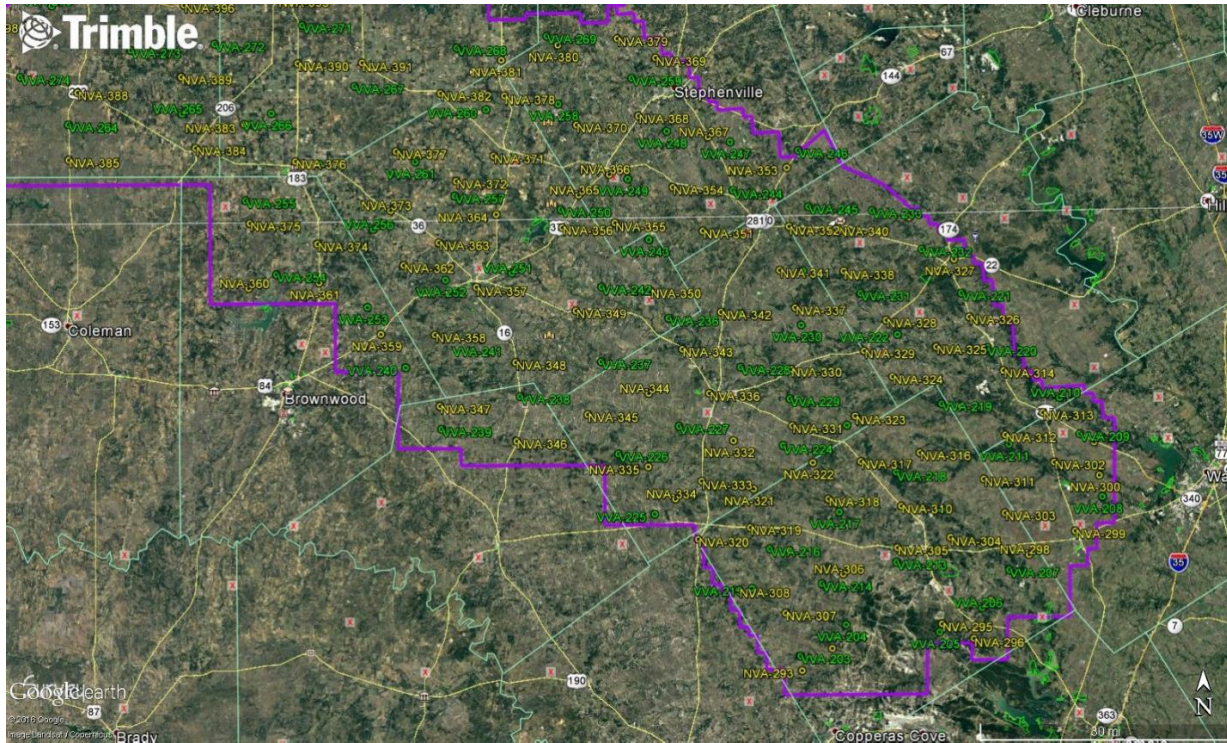
10003 Derekwood Lane

Suite 204

Lanham, Maryland 20706

(301) 364-1855 direct

(301) 731-0188 fax



PROJECT DETAILS

2.1 Survey Equipment

In performing the GPS observations Trimble R-10 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC3 Data Collector to collect GPS raw data were used to perform the field surveys.

2.2 Survey Point Detail

The 370 LiDAR Check Points were well distributed throughout the project area.

A sketch was made for each location and a nail was set at the point where possible or at an identifiable point. The Check Point locations are detailed on the “Check Point Documentation Report” sheets attached to this report.

2.3 Network Design

The GPS survey performed by Dewberry Consultants LLC office located in Lanham, MD was tied to a Real Time Network operated by TXDOT RTN. The network is a series of “real-time” continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

2.4 Field Survey Procedures and Analysis

Dewberry field surveyors used Trimble R-10 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location.

All locations were occupied once with approximately 50% of the locations being re-observed. All re-observations matched the initially derived station positions within the allowable tolerance of $\pm 5\text{cm}$ or within the 95% confidence level. Each occupation which utilized the VRS network was occupied for approximately three (3) minutes in duration and measured to 180 epochs.

Each occupation which utilized OPUS (if used) was occupied between 20 and 30 minutes.

Field GPS observations are detailed on the “Check Point Documentation Reports” submitted as part of this report.

Thirteen (13) existing NGS monument listed in the NSRS database were located as an additional QA/QC method to check the horizontal and vertical accuracy of the VRS network as well as being the primary project control monuments designated as DF8276, AB2830, CA0068, CT0756, AB2790, DP0535, BZ1355, AB2839, DO0946, CT0338,

CT1194, CA0021 and ct0955. The results are as follows:

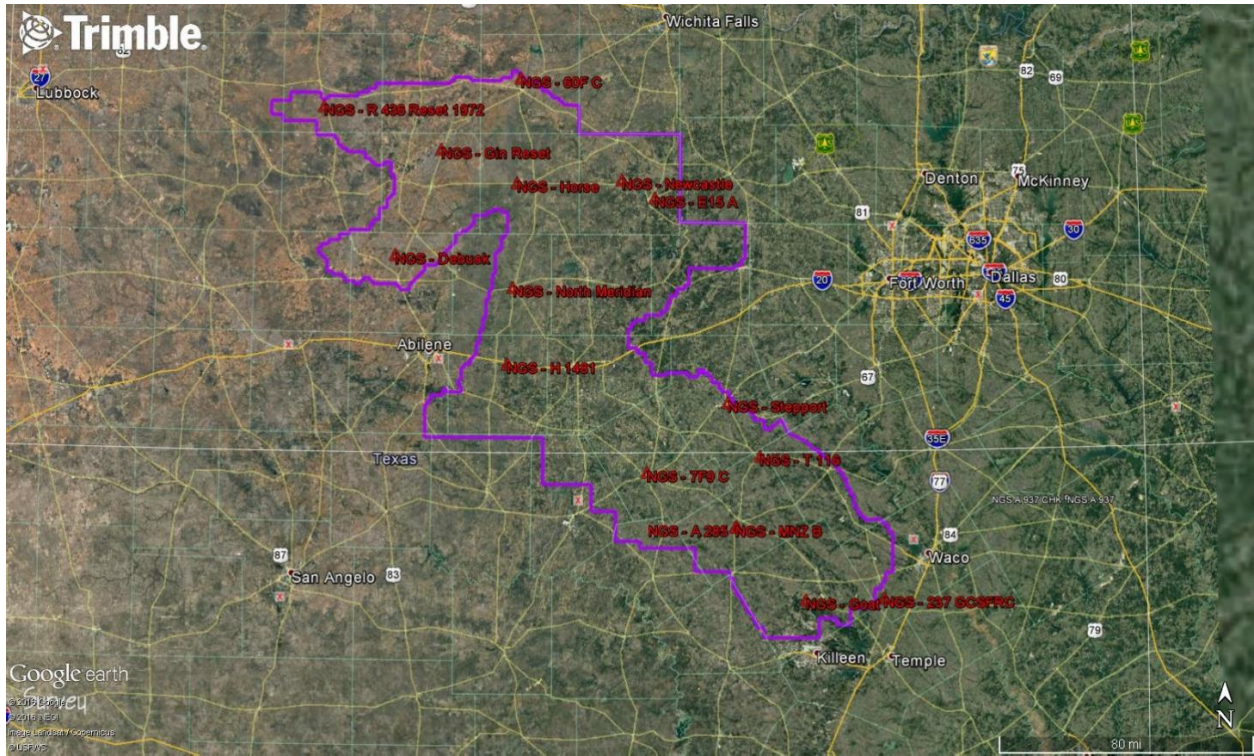
PT. #	Observed Values			Data Sheet Values			ΔX	ΔY	ΔZ
	NORTHING	EASTING	ELEVS.	NORTHING	EASTING	ELEVS.			
7F9 C	3531135.353	537841.786	419.003	3531135.350	537841.778	418.980	0.003	0.008	0.023
60F C**	3722415.077	475810.859	407.977	3722415.077	475810.863	N/A	0.000	-0.004	N/A
A 285	3504725.069	581960.401	379.833	3504725.061	581960.387	379.852	0.008	0.014	-0.019
DE BUSK	3636619.191	414578.370	495.759	3636619.179	414578.326	495.709	0.012	0.044	0.050
E15 A	3664109.726	541471.148	337.419	3664109.729	541471.138	337.390	-0.003	0.010	0.029
KINGSTONE RESET	3695942.390	383133.190	539.857	3695942.374	383133.217	539.900	0.016	-0.027	-0.043
GOAT**	3469120.796	615725.911	341.201	3469120.783	615725.852	N/A	0.013	0.059	N/A
MNZ B**	3504567.949	581109.467	394.365	3504567.933	581109.460	N/A	0.016	0.007	N/A
NEWCASTLE	3672834.582	525352.176	362.567	3672834.578	525352.174	362.600	0.004	0.002	-0.033
NORTH MERIDIAN*	3620640.313	472176.503	430.550	N/A	N/A	430.568	N/A	N/A	-0.018
STEPPORT**	3564945.278	577215.900	401.796	3564945.275	577215.891	N/A	0.003	0.009	N/A
T 116*	3539058.229	593016.898	331.512	N/A	N/A	331.521	N/A	N/A	-0.009
H1481	3583559.298	469475.090	474.529	3583559.333	469475.078	474.500	-0.035	0.012	0.029

(*) Indicates a vertical NGS Mark (**)

Indicates a horizontal NGS Mark

The above results indicate that the VRS network is providing positional values within the 5cm parameters for this survey.

NGS Monuments



2.5 Adjustment

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS).

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the TxDOT RTN system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 Data Processing Procedures

After field data is collected the information is downloaded from the data collectors into the office software. The Software program used is called TBC or Trimble Business Center.

Downloaded data is run through the TBC program to obtain the following reports; points report, point comparison report and a point detail report. The reports are reviewed for point accuracy and precision.

After review of the point data an “ASCII” or “txt” file which is the industry standard is created. Point files are loaded into our CADD program (Carlson Survey 2014) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). The data can now be imported into the final product.

FINAL COORDINATES

UTM Zone 14, NAD83 (2011), NAVD88			
POINT ID	NORTHING (m)	EASTING (m)	ELEV. (m)
NVA			
NVA-293	3455488.427	598552.492	315.473
NVA-294	3459609.568	604304.773	287.198
NVA-295	3463982.058	625203.329	300.789
NVA-296	3461168.656	631250.778	287.763
NVA-297	3468358.186	634591.578	217.675
NVA-298	3476976.343	641879.105	258.071
NVA-299	3481224.650	650727.888	218.194
NVA-300	3491699.194	655439.118	193.387
NVA-301	3497983.355	654473.076	196.052
NVA-302	3494234.498	646826.731	221.065
NVA-303	3484777.527	637318.673	277.672
NVA-304	3480283.768	626917.196	301.492
NVA-305	3478683.718	617165.958	260.792
NVA-306	3473574.143	606474.463	320.977
NVA-307	3467052.026	594772.189	286.421
NVA-308	3470768.506	586705.232	369.870
NVA-309	3478408.039	596462.621	327.297
NVA-310	3485667.270	617721.380	277.503
NVA-311	3491205.183	633354.631	295.923
NVA-312	3499470.853	637491.284	272.551
NVA-313	3503615.268	644701.462	182.967
NVA-314	3511593.795	637310.602	192.367
NVA-315	3504878.593	629172.292	296.462
NVA-316	3496262.706	621212.493	331.675
NVA-317	3494714.443	609991.110	297.994
NVA-318	3487747.004	603781.274	279.991
NVA-319	3482496.083	588915.315	353.848
NVA-320	3480398.963	579030.643	415.763
NVA-321	3489734.710	589617.459	359.319
NVA-322	3494577.576	600877.559	316.772
NVA-323	3503258.624	608975.708	362.249
NVA-324	3510594.604	616162.209	278.334
NVA-325	3516147.049	624523.322	276.943

NVA-326	3521755.244	630847.141	221.907
NVA-327	3532618.698	628039.675	239.393
NVA-328	3521251.521	615034.243	283.412
NVA-329	3515510.227	610827.140	301.464
NVA-330	3512159.049	596899.056	320.377
NVA-331	3501536.526	597042.608	308.052
NVA-332	3498860.354	585850.364	383.452
NVA-333	3491316.043	579756.614	370.823
NVA-334	3488003.000	574781.728	463.347
NVA-335	3494078.690	569687.640	432.489
NVA-336	3507785.115	581374.404	377.771
NVA-337	3523733.062	597801.297	376.450
NVA-338	3530251.499	607460.259	343.573
NVA-339	3540607.432	619564.172	265.570
NVA-340	3538533.641	606070.332	281.224
NVA-341	3530778.788	594927.384	356.172
NVA-342	3523009.561	583713.538	358.707
NVA-343	3516101.883	576356.403	365.390
NVA-344	3507856.728	569884.709	403.907
NVA-345	3503996.540	558316.019	454.248
NVA-346	3499103.934	544841.112	494.458
NVA-347	3505785.835	530376.907	495.244
NVA-348	3513864.950	544767.280	404.523
NVA-349	3523487.319	556253.525	364.446
NVA-350	3527155.376	570364.170	366.361
NVA-351	3538279.747	580432.210	352.192
NVA-352	3539000.977	596753.606	338.258
NVA-353	3550030.308	596416.802	363.246
NVA-354	3547230.930	574909.059	364.741
NVA-355	3539944.931	563793.293	407.066
NVA-356	3539127.831	553812.392	369.245
NVA-357	3528015.284	537378.394	418.158
NVA-358	3519196.905	529566.762	525.905
NVA-359	3519389.315	519299.794	491.383
NVA-360	3528259.197	494227.823	473.639
NVA-361	3529151.293	507670.379	493.230
NVA-362	3532286.635	523722.974	468.640
NVA-363	3536492.398	530429.809	413.103
NVA-364	3541706.921	541305.182	366.338

NVA-365	3545228.695	556937.424	407.988
NVA-366	3549037.972	562775.815	453.126
NVA-367	3555937.680	581550.470	382.681
NVA-368	3559991.616	568417.652	420.239
NVA-369	3570901.886	571743.536	399.052
NVA-370	3558392.277	556649.715	438.651
NVA-371	3552700.896	540932.578	400.834
NVA-372	3548030.397	533793.599	408.902
NVA-373	3542630.172	521305.239	435.695
NVA-374	3536452.116	507437.301	515.146
NVA-375	3540461.227	494600.092	461.132
NVA-376	3552029.205	503362.791	503.777
NVA-377	3553726.224	522441.210	453.445
NVA-378	3563990.578	543045.623	405.313
NVA-379	3574587.508	564502.519	444.544
NVA-380	3573427.287	553244.782	458.913
NVA-381	3570718.982	542512.430	416.731
NVA-382	3564562.077	530974.931	445.173
NVA-383	3559118.446	493712.893	540.185
NVA-384	3554734.680	484386.562	529.482
NVA-385	3552749.008	460136.067	544.686
NVA-386	3552986.642	443961.670	607.543
NVA-387	3556535.229	434211.009	602.550
NVA-388	3565463.567	461900.427	566.332
NVA-389	3568168.784	481708.028	550.307
NVA-390	3570458.687	503929.231	493.990
NVA-391	3570466.686	516113.470	487.824
NVA-392	3583525.506	528544.528	442.336
NVA-393	3589488.586	528600.790	447.853
NVA-394	3585349.858	517108.748	436.271
NVA-395	3582622.340	500274.049	510.425
NVA-396	3581767.571	482294.287	492.106
NVA-397	3584232.287	462845.321	523.568
NVA-398	3578373.178	452250.224	585.814
NVA-399	3589873.534	457271.032	597.489
NVA-400	3591473.760	479547.305	440.837
NVA-401	3592062.195	493171.683	470.857
NVA-402	3591960.027	502711.894	441.845
NVA-403	3596716.053	519680.124	485.974

NVA-404	3604171.979	524467.626	481.106
NVA-405	3602913.720	510028.353	427.056
NVA-406	3601691.896	494616.984	422.824
NVA-407	3600846.130	484586.736	415.932
NVA-408	3598545.211	466000.791	514.519
NVA-409	3611393.764	464376.185	466.278
NVA-410	3607306.512	480823.053	422.149
NVA-411	3605666.775	503847.577	399.290
NVA-412	3609656.586	515939.324	397.881
NVA-413	3610438.431	530432.620	432.163
NVA-414	3612387.030	540181.577	406.559
NVA-415	3623944.490	546311.968	369.234
NVA-416	3620088.463	531010.253	382.120
NVA-417	3620514.208	522494.130	387.024
NVA-418	3621363.674	509116.327	366.212
NVA-419	3615426.425	491406.933	417.089
NVA-420	3615010.473	475830.468	431.519
NVA-421	3621315.078	471726.472	436.323
NVA-422	3627155.827	467327.354	492.680
NVA-423	3629868.132	485029.683	408.834
NVA-424	3630409.874	502953.000	364.500
NVA-425	3630438.012	517804.139	397.478
NVA-426	3634074.332	539130.903	372.299
NVA-427	3633475.190	553570.133	362.029
NVA-428	3634351.716	577275.896	270.332
NVA-429	3644861.699	578329.535	324.815
NVA-430	3644490.072	570121.827	295.983
NVA-431	3643426.943	558251.701	337.628
NVA-432	3644605.632	538735.266	370.595
NVA-433	3639703.680	525852.940	356.891
NVA-434	3636320.761	508341.319	350.062
NVA-435	3639120.525	492013.319	357.548
NVA-436	3640466.253	477804.998	381.709
NVA-437	3649542.897	470218.928	425.761
NVA-438	3654028.728	494851.409	390.433
NVA-439	3648832.174	508443.629	364.881
NVA-440	3647145.071	521227.497	323.823
NVA-441	3651854.130	530953.731	316.196
NVA-442	3653613.668	547239.279	320.245

NVA-443	3666234.413	547108.204	345.467
NVA-444	3664413.058	540443.494	335.866
NVA-445	3660806.804	522500.760	344.447
NVA-446	3661585.350	508859.390	378.087
NVA-447	3661944.454	492763.266	394.779
NVA-448	3664929.622	478179.960	436.001
NVA-449	3671458.424	466787.500	511.457
NVA-450	3673060.752	476626.654	433.193
NVA-451	3671092.570	483471.993	401.106
NVA-452	3671667.651	500459.484	376.830
NVA-453	3671540.211	512367.291	350.591
NVA-454	3672849.970	524151.989	349.220
NVA-455	3675451.384	540122.860	358.002
NVA-456	3680521.090	545639.471	395.303
NVA-457	3691215.022	551368.369	338.843
NVA-458	3687750.412	535662.002	377.247
NVA-459	3691498.419	522567.061	360.217
NVA-460	3684611.963	516104.275	369.539
NVA-461	3684234.291	495339.648	375.907
NVA-462	3683378.862	481492.326	411.217
NVA-463	3700890.497	477932.018	394.639
NVA-464	3696513.416	496359.786	371.288
NVA-465	3704657.079	500365.380	395.689
NVA-466	3710602.051	484830.040	412.558
NVA-467	3715839.126	475734.286	392.042
NVA-468	3705662.983	468318.313	414.198
NVA-469	3693480.485	462318.860	414.627
NVA-470	3682949.064	462886.066	458.005
NVA-471	3671597.985	453972.836	442.538
NVA-472	3659839.961	455206.070	481.976
NVA-473	3656083.449	443344.814	436.003
NVA-474	3652833.562	441582.819	451.097
NVA-475	3636654.097	433351.705	469.867
NVA-476	3624092.141	415751.444	529.743
NVA-477	3624047.754	404770.991	547.727
NVA-478	3636756.010	410758.848	505.546
NVA-479	3645495.305	424072.051	491.706
NVA-480	3655430.027	427971.401	453.910
NVA-481	3671072.449	444113.042	441.943

NVA-482	3681628.884	446805.857	438.588
NVA-483	3695124.715	451870.250	443.097
NVA-484	3703191.244	451274.030	442.729
NVA-485	3718803.201	464955.860	417.563
NVA-486	3717953.408	438268.103	458.711
NVA-487	3687871.668	437057.652	462.743
NVA-488	3668998.891	430598.707	483.782
NVA-490	3646547.829	411106.937	505.193
NVA-491	3637773.142	394539.054	523.660
NVA-492	3635753.369	388649.480	537.675
NVA-493	3670094.380	416484.347	515.352
NVA-494	3680529.600	428498.741	478.673
NVA-495	3693677.469	421798.092	479.834
NVA-496	3705597.626	425162.439	434.092
NVA-497	3716326.215	426751.450	452.633
NVA-498	3716294.941	414282.784	485.945
NVA-499	3706002.954	411598.003	484.565
NVA-500	3690999.381	408138.384	461.890
NVA-501	3685178.069	411132.774	487.195
NVA-502	3688625.612	388199.998	542.496
NVA-503	3695251.973	383290.280	541.138
NVA-504	3712733.566	398788.625	527.841
NVA-505	3702420.089	381551.494	529.893
NVA-506	3708944.650	379322.001	532.935
NVA-507	3702245.185	376019.558	583.598
NVA-508	3704798.228	369652.352	594.597
NVA-509	3712283.572	362961.485	607.719
NVA-510	3706345.958	382827.691	549.367
NVA-511	3705878.276	402896.152	522.267
NVA-512	3699763.758	402112.171	503.018
VVA			
VVA-203	3458177.027	598286.690	299.780
VVA-204	3463938.499	606939.686	273.227
VVA-205	3463403.807	626765.494	296.988
VVA-206	3466943.403	632848.919	223.689
VVA-207	3474027.804	638102.573	206.981
VVA-208	3487638.459	655928.459	169.412
VVA-209	3499528.672	651751.011	200.408
VVA-210	3506390.314	647854.646	196.718

VVA-211	3497674.950	637993.695	254.226
VVA-212	3485380.682	625103.401	259.971
VVA-213	3475692.268	616642.536	261.307
VVA-214	3472096.038	603416.276	263.297
VVA-215	3471244.114	589086.545	333.200
VVA-216	3478432.728	592618.767	366.146
VVA-217	3485270.833	605816.060	269.185
VVA-218	3492599.422	616721.374	343.603
VVA-219	3505349.307	625450.672	297.149
VVA-220	3515957.612	634213.207	226.614
VVA-221	3526281.778	629379.246	228.295
VVA-222	3518536.366	617118.427	271.801
VVA-223	3501540.314	607368.214	298.844
VVA-224	3497898.275	595110.095	341.807
VVA-225	3485605.797	570649.108	409.190
VVA-226	3496564.687	564071.040	434.830
VVA-227	3501684.804	575613.042	389.691
VVA-228	3512528.112	587322.020	347.744
VVA-229	3506611.318	596642.979	276.826
VVA-230	3520453.716	598863.736	345.726
VVA-231	3526482.207	610179.336	356.674
VVA-232	3534502.628	621990.187	252.732
VVA-233	3541892.785	612590.479	274.658
VVA-234	3530671.595	599285.543	320.382
VVA-235	3522682.178	587519.933	363.576
VVA-236	3522039.845	573881.414	338.985
VVA-237	3513862.000	561040.011	434.214
VVA-238	3507476.380	545569.970	465.357
VVA-239	3501441.887	530642.784	458.111
VVA-240	3513090.195	523856.231	484.612
VVA-241	3518238.768	538379.689	454.834
VVA-242	3527907.262	561170.910	341.579
VVA-243	3536740.613	570196.482	401.679
VVA-244	3545930.153	586237.387	351.455
VVA-245	3542730.615	600481.808	302.626
VVA-246	3553242.470	598657.898	381.291
VVA-247	3555006.269	585789.261	392.656
VVA-248	3556922.260	573825.042	396.587
VVA-249	3548155.494	566277.049	437.836

VVA-250	3542676.777	553096.775	382.768
VVA-251	3530654.990	544207.638	384.666
VVA-252	3529456.642	531576.222	471.268
VVA-253	3524456.324	516803.905	535.166
VVA-254	3530795.571	499566.297	463.309
VVA-255	3544769.691	493976.210	480.918
VVA-256	3539075.909	517976.392	476.162
VVA-257	3545273.873	533531.367	390.324
VVA-258	3562386.325	553227.672	400.717
VVA-259	3567142.193	567186.943	410.164
VVA-260	3561417.251	539522.738	404.711
VVA-261	3551743.714	526048.815	418.278
VVA-262	3551450.987	507828.743	477.146
VVA-263	3561520.531	436307.521	622.825
VVA-264	3559380.553	460087.562	530.394
VVA-265	3561202.774	481797.837	545.795
VVA-266	3561147.232	498799.023	506.469
VVA-267	3566206.327	514661.479	471.748
VVA-268	3572845.068	534118.125	393.894
VVA-269	3575069.866	551184.342	446.047
VVA-270	3584378.164	524464.245	461.428
VVA-271	3577705.244	504751.894	480.594
VVA-272	3574388.359	488125.120	539.889
VVA-273	3573340.034	472108.821	506.327
VVA-274	3568507.958	450966.152	591.996
VVA-275	3581873.084	457011.431	586.684
VVA-276	3585597.291	480595.111	464.485
VVA-277	3587162.462	494641.062	499.632
VVA-278	3591897.764	510601.178	454.055
VVA-279	3604222.281	529382.820	463.980
VVA-280	3610521.412	535703.763	436.653
VVA-281	3607314.520	513760.661	401.415
VVA-282	3598561.187	495343.713	427.791
VVA-283	3598734.358	484036.471	423.418
VVA-284	3590319.310	475928.742	432.760
VVA-285	3601591.674	470042.470	440.113
VVA-286	3608011.237	475938.922	411.950
VVA-287	3611600.941	494727.872	384.282
VVA-288	3613961.531	515293.398	399.188

VVA-289	3621025.090	544738.146	381.490
VVA-290	3625645.587	528766.587	382.071
VVA-291	3621325.380	502853.225	386.409
VVA-292	3617754.689	481862.866	397.876
VVA-293	3613674.877	466150.734	473.284
VVA-294	3630767.418	475133.382	413.419
VVA-295	3633209.930	489474.267	393.880
VVA-296	3635059.650	511803.308	352.189
VVA-297	3636396.219	531824.952	327.650
VVA-298	3636049.412	562377.224	293.825
VVA-299	3639314.309	580153.992	307.108
VVA-300	3647705.975	565844.470	339.597
VVA-301	3650555.698	540858.508	325.536
VVA-302	3648293.833	515957.110	375.088
VVA-303	3652885.336	504361.633	364.505
VVA-304	3649494.360	491320.582	380.778
VVA-305	3645145.262	481785.366	379.619
VVA-306	3669832.063	467702.614	518.498
VVA-307	3668164.657	484668.257	409.634
VVA-308	3663713.703	499773.633	389.741
VVA-309	3669792.162	519109.403	345.101
VVA-310	3664861.970	533925.648	328.544
VVA-311	3676365.570	550097.017	383.290
VVA-312	3685700.922	542879.524	356.819
VVA-313	3682369.372	528501.562	339.596
VVA-314	3680171.260	516085.382	348.063
VVA-315	3676263.604	495156.757	377.961
VVA-316	3677948.757	478237.112	410.640
VVA-317	3690970.629	481055.389	415.184
VVA-318	3687485.382	489852.664	394.969
VVA-319	3689451.214	506987.864	363.178
VVA-320	3686338.598	521850.364	357.090
VVA-321	3693826.840	514999.964	390.049
VVA-322	3693852.873	540252.349	366.311
VVA-323	3700738.126	498520.168	392.127
VVA-324	3708991.579	484835.914	393.261
VVA-325	3710330.992	466029.069	430.448
VVA-326	3702741.312	457515.019	424.502
VVA-327	3687025.840	456887.045	422.920

VVA-328	3670072.055	450264.486	438.450
VVA-329	3650730.228	445151.450	447.697
VVA-330	3643890.038	431014.919	478.198
VVA-331	3631284.240	421887.118	487.495
VVA-332	3628428.783	403434.416	565.556
VVA-333	3633918.450	383426.042	565.110
VVA-334	3645006.247	401322.460	524.337
VVA-335	3654072.826	414517.032	478.773
VVA-336	3662271.512	421875.343	484.405
VVA-337	3661843.642	440028.199	444.380
VVA-338	3676313.910	428280.262	488.039
VVA-339	3692727.153	442091.009	450.810
VVA-340	3714634.992	449847.677	410.849
VVA-341	3712989.199	438296.043	417.188
VVA-342	3698230.084	432593.911	467.812
VVA-343	3680391.234	417301.323	497.412
VVA-344	3691468.835	412647.597	484.402
VVA-345	3699740.912	409790.723	439.288
VVA-346	3716283.441	420638.109	470.421
VVA-347	3710378.288	402089.290	509.882
VVA-348	3683781.815	408087.576	468.148
VVA-349	3700014.044	382105.039	519.025
VVA-350	3703281.314	373393.882	583.939
VVA-351	3711625.455	365587.524	597.166
VVA-352	3704215.201	402947.596	502.014
VVA-353	3709354.760	366975.722	591.608

3. GPS OBSERVATIONS

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY (AST)	RE-OBSERV. DATE	RE-OBSERV. TIME
NVA					
NVA-293	2/6/2017	37	12:52	2/8/2017	11:18
NVA-294	2/6/2017	37	12:09	2/8/2017	11:01
NVA-295	2/6/2017	37	11:49	N/A	N/A
NVA-296	2/6/2017	37	11:05	N/A	N/A
NVA-297	2/6/2017	37	12:38	N/A	N/A
NVA-298	2/6/2017	37	13:22	N/A	N/A
NVA-299	2/6/2017	37	16:18	2/7/2017	10:19
NVA-300	2/6/2017	37	18:02	2/7/2017	10:56
NVA-301	2/7/2017	38	11:51	2/8/2017	9:29
NVA-302	2/6/2017	37	15:56	2/7/2017	11:12
NVA-303	2/6/2017	37	13:57	2/8/2017	12:10
NVA-304	2/6/2017	37	9:20	2/7/2017	9:39
NVA-305	2/4/2017	35	16:44	2/7/2017	18:02
NVA-306	2/6/2017	37	15:52	2/8/2017	12:45
NVA-307	2/6/2017	37	14:44	2/8/2017	12:14
NVA-308	2/6/2017	37	15:34	N/A	N/A
NVA-309	2/6/2017	37	16:48	N/A	N/A
NVA-310	2/7/2017	38	11:01	N/A	N/A
NVA-311	2/6/2017	37	14:38	2/8/2017	11:56
NVA-312	2/6/2017	37	15:04	2/8/2017	13:10
NVA-313	2/7/2017	38	12:58	2/8/2017	10:00
NVA-314	2/7/2017	38	13:32	2/7/2017	18:17
NVA-315	2/8/2017	39	10:32	N/A	N/A
NVA-316	2/8/2017	39	11:00	N/A	N/A
NVA-317	2/7/2017	38	11:47	2/8/2017	14:48
NVA-318	2/7/2017	38	17:24	2/8/2017	13:57
NVA-319	2/7/2017	38	16:35	2/8/2017	17:27
NVA-320	2/7/2017	38	16:17	2/8/2017	17:43
NVA-321	2/7/2017	38	15:20	N/A	N/A
NVA-322	2/7/2017	38	13:20	2/8/2017	14:27
NVA-323	2/10/2017	41	16:21	N/A	N/A
NVA-324	2/10/2017	41	16:50	N/A	N/A
NVA-325	2/7/2017	38	17:32	N/A	N/A
NVA-326	2/7/2017	38	14:08	2/8/2017	13:42

NVA-327	2/7/2017	38	15:06	2/8/2017	14:24
NVA-328	2/7/2017	38	16:51	N/A	N/A
NVA-329	2/10/2017	41	17:05	2/11/2017	17:25
NVA-330	2/10/2017	41	17:25	2/11/2017	17:09
NVA-331	2/7/2017	38	12:17	2/8/2017	16:06
NVA-332	2/7/2017	38	14:55	N/A	N/A
NVA-333	2/7/2017	38	15:45	2/8/2017	17:02
NVA-334	2/9/2017	40	17:41	N/A	N/A
NVA-335	2/9/2017	40	17:15	N/A	N/A
NVA-336	2/7/2017	38	14:09	2/8/2017	16:42
NVA-337	2/14/2017	45	14:11	N/A	N/A
NVA-338	2/14/2017	45	13:40	N/A	N/A
NVA-339	2/8/2017	39	15:00	N/A	N/A
NVA-340	2/8/2017	39	16:04	N/A	N/A
NVA-341	2/14/2017	45	12:40	N/A	N/A
NVA-342	2/14/2017	45	15:04	N/A	N/A
NVA-343	2/9/2017	40	16:03	2/11/2017	16:24
NVA-344	2/10/2017	41	12:14	N/A	N/A
NVA-345	2/10/2017	41	12:49	N/A	N/A
NVA-346	2/9/2017	40	11:19	2/10/2017	10:15
NVA-347	2/9/2017	40	9:47	N/A	N/A
NVA-348	2/9/2017	40	12:34	2/10/2017	10:54
NVA-349	2/9/2017	40	15:10	2/11/2017	14:10
NVA-350	2/11/2017	42	15:42	N/A	N/A
NVA-351	2/14/2017	45	15:37	N/A	N/A
NVA-352	2/8/2017	39	16:18	N/A	N/A
NVA-353	2/8/2017	39	11:28	N/A	N/A
NVA-354	2/14/2017	45	17:26	N/A	N/A
NVA-355	2/14/2017	45	16:52	N/A	N/A
NVA-356	2/13/2017	44	13:45	2/15/2017	11:56
NVA-357	2/9/2017	40	14:09	2/15/2017	12:26
NVA-358	2/9/2017	40	13:36	N/A	N/A
NVA-359	2/11/2017	42	11:23	N/A	N/A
NVA-360	2/11/2017	42	9:32	2/12/2017	9:37
NVA-361	2/11/2017	42	10:20	N/A	N/A
NVA-362	2/13/2017	44	11:44	N/A	N/A
NVA-363	2/13/2017	44	11:10	N/A	N/A
NVA-364	2/13/2017	44	12:45	N/A	N/A
NVA-365	2/13/2017	44	14:34	2/15/2017	11:06

NVA-366	2/13/2017	44	15:15	2/15/2017	10:30
NVA-367	2/14/2017	45	10:11	N/A	N/A
NVA-368	2/13/2017	44	18:08	2/15/2017	9:56
NVA-369	2/4/2017	35	17:23	N/A	N/A
NVA-370	2/13/2017	44	16:30	N/A	N/A
NVA-371	2/2/2017	33	17:20	1/4/2017	14:30
NVA-372	2/12/2017	43	16:47	2/15/2017	13:38
NVA-373	2/12/2017	43	17:42	2/15/2017	14:05
NVA-374	2/14/2017	45	18:34	2/13/2017	10:09
NVA-375	2/12/2017	43	10:11	N/A	N/A
NVA-376	2/12/2017	43	11:52	N/A	N/A
NVA-377	2/12/2017	43	16:08	2/15/2017	15:07
NVA-378	2/2/2017	33	14:39	2/4/2017	14:47
NVA-379	2/4/2017	35	16:52	N/A	N/A
NVA-380	2/4/2017	35	15:55	N/A	N/A
NVA-381	2/2/2017	33	14:21	2/4/2017	15:11
NVA-382	2/2/2017	33	16:34	2/4/2017	13:28
NVA-383	2/12/2017	43	13:35	N/A	N/A
NVA-384	2/3/2017	34	13:58	2/12/2017	14:12
NVA-385	2/3/2017	34	16:45	2/4/2017	10:51
NVA-386	2/3/2017	34	15:47	2/4/2017	10:26
NVA-387	2/3/2017	34	14:42	N/A	N/A
NVA-388	2/3/2017	34	12:31	2/4/2017	11:21
NVA-389	2/4/2017	35	13:14	2/15/2017	17:09
NVA-390	2/4/2017	35	11:52	N/A	N/A
NVA-391	2/4/2017	35	12:29	N/A	N/A
NVA-392	2/1/2017	32	11:21	2/2/2017	12:25
NVA-393	2/1/2017	32	11:37	2/2/2017	12:38
NVA-394	2/1/2017	32	10:38	2/2/2017	11:10
NVA-395	2/1/2017	32	9:37	2/2/2017	10:20
NVA-396	2/2/2017	33	9:42	2/4/2017	10:20
NVA-397	2/1/2017	32	11:24	2/2/2017	9:55
NVA-398	2/3/2017	34	11:05	N/A	N/A
NVA-399	2/1/2017	32	10:53	N/A	N/A
NVA-400	2/1/2017	32	18:14	2/2/2017	11:20
NVA-401	2/1/2017	32	16:03	N/A	N/A
NVA-402	2/1/2017	32	16:45	N/A	N/A
NVA-403	2/1/2017	32	12:32	N/A	N/A
NVA-404	1/31/2017	31	15:07	N/A	N/A

NVA-405	1/31/2017	31	15:37	N/A	N/A
NVA-406	2/1/2017	32	15:17	N/A	N/A
NVA-407	1/31/2017	31	15:50	2/1/2017	17:17
NVA-408	2/1/2017	32	12:04	2/2/2017	12:56
NVA-409	2/1/2017	32	13:52	N/A	N/A
NVA-410	1/31/2017	31	15:32	2/1/2017	17:03
NVA-411	2/1/2017	32	14:56	N/A	N/A
NVA-412	1/31/2017	31	13:00	2/1/2017	13:59
NVA-413	1/31/2017	31	13:30	2/1/2017	13:34
NVA-414	1/31/2017	31	14:24	N/A	N/A
NVA-415	1/29/2017	29	10:52	1/30/2017	9:51
NVA-416	1/29/2017	29	12:08	1/30/2017	10:59
NVA-417	1/29/2017	29	16:36	1/30/2017	16:36
NVA-418	1/29/2017	29	15:36	1/30/2017	15:40
NVA-419	2/1/2017	32	15:40	N/A	N/A
NVA-420	1/31/2017	31	14:31	2/1/2017	16:09
NVA-421	1/31/2017	31	12:59	N/A	N/A
NVA-422	2/2/2017	33	14:30	N/A	N/A
NVA-423	2/2/2017	33	15:28	N/A	N/A
NVA-424	1/31/2017	31	12:01	N/A	N/A
NVA-425	1/29/2017	29	14:46	1/30/2017	12:10
NVA-426	1/29/2017	29	13:17	N/A	N/A
NVA-427	1/29/2017	29	10:30	N/A	N/A
NVA-428	1/26/2017	26	13:29	1/27/2017	9:46
NVA-429	1/26/2017	26	15:03	1/27/2017	10:06
NVA-430	1/26/2017	26	15:25	1/27/2017	10:44
NVA-431	1/29/2017	29	9:43	N/A	N/A
NVA-432	1/27/2017	27	14:58	N/A	N/A
NVA-433	1/29/2017	29	14:10	1/30/2017	12:37
NVA-434	1/30/2017	30	14:28	N/A	N/A
NVA-435	2/10/2017	41	11:49	N/A	N/A
NVA-436	2/2/2017	33	16:39	N/A	N/A
NVA-437	2/2/2017	33	17:57	N/A	N/A
NVA-438	2/10/2017	41	10:41	N/A	N/A
NVA-439	2/10/2017	41	12:22	N/A	N/A
NVA-440	1/30/2017	30	13:25	N/A	N/A
NVA-441	1/27/2017	27	14:02	1/30/2017	12:58
NVA-442	1/26/2017	26	17:23	1/27/2017	11:41
NVA-443	1/27/2017	27	12:41	N/A	N/A

NVA-444	1/27/2017	27	13:30	N/A	N/A
NVA-445	2/9/2017	40	9:27	2/10/2017	8:39
NVA-446	2/10/2017	41	9:01	N/A	N/A
NVA-447	2/9/2017	40	17:52	2/10/2017	10:00
NVA-448	2/9/2017	40	17:09	2/10/2017	14:23
NVA-449	2/9/2017	40	14:57	2/10/2017	17:12
NVA-450	2/9/2017	40	16:02	2/10/2017	16:20
NVA-451	2/9/2017	40	16:34	2/10/2017	14:57
NVA-452	2/9/2017	40	10:27	2/11/2017	9:49
NVA-453	2/9/2017	40	9:55	2/11/2017	9:20
NVA-454	2/8/2017	39	14:07	2/11/2017	11:34
NVA-455	2/11/2017	42	8:48	N/A	N/A
NVA-456	2/9/2017	40	18:36	2/11/2017	9:05
NVA-457	2/8/2017	39	17:05	N/A	N/A
NVA-458	2/8/2017	39	15:53	N/A	N/A
NVA-459	2/9/2017	40	9:18	2/9/2017	9:18
NVA-460	2/9/2017	40	8:47	2/11/2017	12:08
NVA-461	2/9/2017	40	11:06	2/11/2017	12:56
NVA-462	2/9/2017	40	12:27	2/10/2017	15:40
NVA-463	2/9/2017	40	12:54	2/11/2017	13:53
NVA-464	2/9/2017	40	16:33	2/12/2017	11:11
NVA-465	2/9/2017	40	16:03	2/11/2017	10:15
NVA-466	2/9/2017	40	14:50	N/A	N/A
NVA-467	2/9/2017	40	13:28	2/11/2017	14:14
NVA-468	2/10/2017	41	18:36	2/11/2017	15:29
NVA-469	2/10/2017	41	16:53	N/A	N/A
NVA-470	2/9/2017	40	13:46	N/A	N/A
NVA-471	2/9/2017	40	14:28	2/10/2017	18:28
NVA-472	2/11/2017	42	18:39	N/A	N/A
NVA-473	2/11/2017	42	15:41	N/A	N/A
NVA-474	2/11/2017	42	15:27	N/A	N/A
NVA-475	2/11/2017	42	16:09	N/A	N/A
NVA-476	2/13/2017	44	9:28	N/A	N/A
NVA-477	2/13/2017	44	10:57	N/A	N/A
NVA-478	2/12/2017	43	12:55	N/A	N/A
NVA-479	2/11/2017	42	15:23	2/12/2017	11:46
NVA-480	2/12/2017	43	11:16	N/A	N/A
NVA-481	2/10/2017	41	17:46	N/A	N/A
NVA-482	2/11/2017	42	11:20	N/A	N/A

NVA-483	2/10/2017	41	15:50	N/A	N/A
NVA-484	2/10/2017	41	15:30	2/11/2017	16:28
NVA-485	2/10/2017	41	8:42	N/A	N/A
NVA-486	2/10/2017	41	9:33	2/12/2017	12:43
NVA-487	2/10/2017	41	13:07	2/11/2017	17:30
NVA-488	2/12/2017	43	10:42	N/A	N/A
NVA-489	2/14/2017	45	14:52	N/A	N/A
NVA-490	2/12/2017	43	13:27	N/A	N/A
NVA-491	2/12/2017	43	14:43	2/13/2017	12:44
NVA-492	2/12/2017	43	15:54	N/A	N/A
NVA-493	2/11/2017	42	13:28	N/A	N/A
NVA-494	2/11/2017	42	12:02	N/A	N/A
NVA-495	2/10/2017	41	11:57	N/A	N/A
NVA-496	2/10/2017	41	10:58	N/A	N/A
NVA-497	2/10/2017	41	10:28	2/12/2017	13:41
NVA-498	2/12/2017	43	14:20	N/A	N/A
NVA-499	2/12/2017	43	16:00	2/13/2017	17:50
NVA-500	2/12/2017	43	15:40	2/14/2017	16:12
NVA-501	2/13/2017	44	9:57	2/14/2017	16:53
NVA-502	2/13/2017	44	13:46	2/14/2017	11:07
NVA-503	2/13/2017	44	13:51	2/14/2017	13:51
NVA-504	2/12/2017	43	15:00	2/13/2017	15:07
NVA-505	2/13/2017	44	13:10	2/14/2017	12:15
NVA-506	2/13/2017	44	11:47	N/A	N/A
NVA-507	2/13/2017	44	14:44	2/14/2017	12:31
NVA-508	2/13/2017	44	15:16	2/14/2017	13:15
NVA-509	2/13/2017	44	16:32	N/A	N/A
NVA-510	2/13/2017	44	12:27	N/A	N/A
NVA-511	2/13/2017	44	15:55	N/A	N/A
NVA-512	2/13/2017	44	16:33	N/A	N/A
VVA					
VVA-203	2/6/2017	37	12:35	2/8/2017	11:31
VVA-204	2/6/2017	37	11:33	N/A	N/A
VVA-205	2/6/2017	37	12:03	N/A	N/A
VVA-206	2/6/2017	37	12:26	N/A	N/A
VVA-207	2/6/2017	37	13:03	N/A	N/A
VVA-208	2/6/2017	37	17:46	2/7/2017	10:44
VVA-209	2/7/2017	38	11:39	2/8/2017	9:39
VVA-210	2/7/2017	38	12:40	N/A	N/A

VVA-211	2/6/2017	37	15:19	2/8/2017	13:00
VVA-212	2/7/2017	38	10:35	N/A	N/A
VVA-213	2/4/2017	35	17:00	2/8/2017	13:17
VVA-214	2/6/2017	37	17:38	2/8/2017	12:31
VVA-215	2/6/2017	37	15:11	N/A	N/A
VVA-216	2/6/2017	37	16:29	N/A	N/A
VVA-217	2/7/2017	38	15:06	2/8/2017	13:42
VVA-218	2/7/2017	38	11:26	2/8/2017	15:06
VVA-219	2/8/2017	39	10:51	N/A	N/A
VVA-220	2/7/2017	38	13:49	2/7/2017	18:03
VVA-221	2/7/2017	38	14:23	2/8/2017	13:52
VVA-222	2/7/2017	38	17:12	N/A	N/A
VVA-223	2/10/2017	41	16:03	N/A	N/A
VVA-224	2/7/2017	38	12:42	2/8/2017	15:53
VVA-225	2/9/2017	40	18:03	N/A	N/A
VVA-226	2/10/2017	41	13:22	N/A	N/A
VVA-227	2/9/2017	40	16:38	2/10/2017	14:41
VVA-228	2/11/2017	42	16:45	N/A	N/A
VVA-229	2/10/2017	41	15:20	N/A	N/A
VVA-230	2/11/2017	42	17:48	2/11/2017	17:52
VVA-231	2/7/2017	38	16:14	N/A	N/A
VVA-232	2/7/2017	38	15:31	2/8/2017	14:38
VVA-233	2/8/2017	39	15:36	N/A	N/A
VVA-234	2/14/2017	45	13:12	2/14/2017	13:16
VVA-235	2/14/2017	45	14:45	N/A	N/A
VVA-236	2/9/2017	40	15:44	2/11/2017	16:08
VVA-237	2/10/2017	41	11:38	N/A	N/A
VVA-238	2/9/2017	40	11:58	2/10/2017	10:48
VVA-239	2/9/2017	40	10:04	2/10/2017	9:40
VVA-240	2/9/2017	40	9:20	N/A	N/A
VVA-241	2/9/2017	40	12:56	N/A	N/A
VVA-242	2/11/2017	42	14:33	2/11/2017	14:37
VVA-243	2/14/2017	45	16:12	N/A	N/A
VVA-244	2/14/2017	45	12:12	2/14/2017	12:16
VVA-245	2/8/2017	39	17:18	N/A	N/A
VVA-246	2/14/2017	45	11:02	2/14/2017	11:06
VVA-247	2/14/2017	45	10:30	N/A	N/A

VVA-248	2/13/2017	44	18:39	N/A	N/A
VVA-249	2/13/2017	44	15:33	2/15/2017	10:44
VVA-250	2/13/2017	44	14:10	2/15/2017	11:34
VVA-251	2/11/2017	42	13:13	N/A	N/A
VVA-252	2/11/2017	42	11:54	2/13/2017	12:07
VVA-253	2/11/2017	42	11:05	N/A	N/A
VVA-254	2/11/2017	42	9:57	2/11/2017	10:04
VVA-255	2/12/2017	43	11:06	N/A	N/A
VVA-256	2/13/2017	44	10:44	N/A	N/A
VVA-257	2/12/2017	43	17:01	2/15/2017	13:21
VVA-258	2/13/2017	44	17:21	2/13/2017	17:25
VVA-259	2/13/2017	44	17:50	2/13/2017	17:54
VVA-260	2/7/2017	38	15:57	N/A	N/A
VVA-261	2/12/2017	43	16:26	2/15/2017	14:29
VVA-262	2/12/2017	43	12:13	N/A	N/A
VVA-263	2/3/2017	34	14:19	N/A	N/A
VVA-264	2/3/2017	34	17:22	2/4/2017	11:08
VVA-265	2/12/2017	43	14:33	N/A	N/A
VVA-266	2/12/2017	43	13:17	2/15/2017	16:06
VVA-267	2/2/2017	33	17:26	2/4/2017	12:45
VVA-268	2/2/2017	33	13:50	N/A	N/A
VVA-269	2/4/2017	35	15:36	N/A	N/A
VVA-270	2/1/2017	32	10:59	2/2/2017	12:11
VVA-271	2/1/2017	32	10:02	2/2/2017	10:35
VVA-272	2/4/2017	35	11:14	N/A	N/A
VVA-273	2/4/2017	35	12:41	N/A	N/A
VVA-274	2/3/2017	34	13:08	2/4/2017	11:49
VVA-275	2/3/2017	34	10:21	N/A	N/A
VVA-276	2/2/2017	33	11:01	2/2/2017	11:05
VVA-277	2/1/2017	32	16:20	N/A	N/A
VVA-278	2/1/2017	32	17:28	N/A	N/A
VVA-279	1/31/2017	31	14:29	2/1/2017	13:00
VVA-280	1/31/2017	31	13:51	N/A	N/A
VVA-281	1/31/2017	31	12:41	2/1/2017	14:12
VVA-282	2/1/2017	32	15:31	N/A	N/A
VVA-283	2/1/2017	32	17:30	N/A	N/A
VVA-284	2/2/2017	33	11:37	N/A	N/A

VVA-285	2/1/2017	32	12:53	2/2/2017	13:33
VVA-286	1/31/2017	31	15:12	2/1/2017	16:40
VVA-287	1/31/2017	31	16:04	N/A	N/A
VVA-288	1/29/2017	29	16:02	1/30/2017	16:00
VVA-289	1/29/2017	29	11:16	1/30/2017	10:11
VVA-290	1/29/2017	29	12:46	1/30/2017	11:40
VVA-291	1/31/2017	31	11:12	N/A	N/A
VVA-292	2/1/2017	32	15:18	2/1/2017	15:22
VVA-293	2/1/2017	32	14:12	N/A	N/A
VVA-294	2/2/2017	33	15:02	2/2/2017	15:06
VVA-295	2/2/2017	33	15:47	N/A	N/A
VVA-296	1/30/2017	30	16:36	N/A	N/A
VVA-297	1/27/2017	27	16:19	1/29/2017	13:41
VVA-298	1/29/2017	29	17:48	N/A	N/A
VVA-299	1/26/2017	26	14:09	N/A	N/A
VVA-300	1/26/2017	26	15:51	1/27/2017	11:00
VVA-301	1/27/2017	27	15:34	N/A	N/A
VVA-302	1/30/2017	30	13:43	N/A	N/A
VVA-303	2/10/2017	41	12:38	2/10/2017	12:41
VVA-304	2/10/2017	41	11:17	N/A	N/A
VVA-305	2/2/2017	33	17:02	N/A	N/A
VVA-306	2/9/2017	40	15:16	2/10/2017	16:59
VVA-307	2/9/2017	40	16:50	2/10/2017	14:44
VVA-308	2/10/2017	41	9:38	2/10/2017	13:48
VVA-309	2/9/2017	40	7:57	2/11/2017	18:37
VVA-310	2/8/2017	39	13:40	N/A	N/A
VVA-311	2/11/2017	42	8:23	2/8/2017	12:56
VVA-312	2/9/2017	40	18:20	N/A	N/A
VVA-313	2/8/2017	39	11:58	2/11/2017	10:51
VVA-314	2/9/2017	40	8:30	2/11/2017	11:54
VVA-315	2/9/2017	40	11:07	N/A	N/A
VVA-316	2/9/2017	40	11:45	2/10/2017	15:24
VVA-317	2/9/2017	40	12:37	2/11/2017	13:25
VVA-318	2/9/2017	40	11:28	N/A	N/A
VVA-319	2/9/2017	40	10:14	2/8/2017	16:27
VVA-320	2/9/2017	40	9:03	2/11/2017	10:33
VVA-321	2/9/2017	40	9:57	2/9/2017	17:14

VVA-322	2/8/2017	39	16:15	2/11/2017	10:06
VVA-323	2/9/2017	40	16:17	2/12/2017	22:57
VVA-324	2/9/2017	40	15:19	2/12/2017	11:37
VVA-325	2/10/2017	41	18:15	2/11/2017	15:14
VVA-326	2/10/2017	41	17:40	2/11/2017	16:05
VVA-327	2/10/2017	41	16:28	N/A	N/A
VVA-328	2/10/2017	41	18:00	2/11/2017	10:30
VVA-329	2/11/2017	42	17:05	N/A	N/A
VVA-330	2/11/2017	42	15:43	2/11/2017	15:46
VVA-331	2/13/2017	44	9:54	N/A	N/A
VVA-332	2/13/2017	44	10:37	N/A	N/A
VVA-333	2/13/2017	44	12:02	2/14/2017	12:35
VVA-334	2/13/2017	44	13:46	N/A	N/A
VVA-335	2/11/2017	42	14:44	N/A	N/A
VVA-336	2/11/2017	42	13:46	2/11/2017	13:49
VVA-337	2/11/2017	42	18:06	N/A	N/A
VVA-338	2/11/2017	42	12:28	N/A	N/A
VVA-339	2/10/2017	41	13:30	2/11/2017	17:01
VVA-340	2/10/2017	41	15:12	N/A	N/A
VVA-341	2/10/2017	41	9:49	2/12/2017	13:09
VVA-342	2/10/2017	41	11:30	N/A	N/A
VVA-343	2/11/2017	42	12:51	N/A	N/A
VVA-344	2/13/2017	44	10:25	2/14/2017	16:25
VVA-345	2/12/2017	43	16:54	2/14/2017	15:14
VVA-346	2/12/2017	43	13:57	N/A	N/A
VVA-347	2/12/2017	43	15:18	2/13/2017	15:19
VVA-348	2/13/2017	44	9:39	N/A	N/A
VVA-349	2/13/2017	44	13:21	2/14/2017	12:01
VVA-350	2/13/2017	44	15:00	2/13/2017	15:00
VVA-351	2/13/2017	44	16:15	N/A	N/A
VVA-352	2/13/2017	44	16:15	2/13/2017	16:18
VVA-353	2/13/2017	44	16:10	N/A	N/A

4. POINT COMPARISON

Point ID	Point CK	Delta North (m)	Delta East (m)	Vertical Difference (m)
NVA				
NVA-293	NVA-293CK	0.018	0.018	-0.030
NVA-294	NVA-294CK	-0.014	0.000	-0.012
NVA-299	NVA-299CK	0.026	0.036	-0.006
NVA-300	NVA-300CK	0.004	0.016	-0.030
NVA-301	NVA-301CK	0.011	-0.011	-0.018
NVA-302	NVA-302CK	0.007	0.008	0.010
NVA-303	NVA-303CK	-0.006	0.040	-0.021
NVA-304	NVA-304CK	-0.006	-0.002	-0.010
NVA-305	NVA-305CK	0.001	0.003	0.006
NVA-306	NVA-306CK	0.002	-0.001	0.002
NVA-307	NVA-307CK	-0.002	0.000	0.010
NVA-311	NVA-311CK	-0.005	0.031	-0.026
NVA-312	NVA-312CK	-0.012	0.006	-0.007
NVA-313	NVA-313CK	0.034	-0.004	0.023
NVA-314	NVA-314CK	0.000	-0.008	0.006
NVA-317	NVA-317CK	0.008	0.004	-0.008
NVA-318	NVA-318CK	0.000	0.004	-0.023
NVA-319	NVA-319CK	-0.005	-0.002	0.009
NVA-320	NVA-320CK	0.018	0.004	0.018
NVA-322	NVA-322CK	-0.006	-0.010	-0.001
NVA-326	NVA-326CK	-0.006	0.001	-0.018
NVA-327	NVA-327CK	-0.017	0.013	-0.027
NVA-329	NVA-329CK	0.002	0.011	-0.006
NVA-330	NVA-330CK	0.002	-0.004	0.025
NVA-331	NVA-331CK	0.000	0.010	0.014
NVA-333	NVA-333CK	-0.010	-0.006	-0.006
NVA-335	NVA-335CK	0.005	-0.002	0.014
NVA-336	NVA-336CK	-0.001	0.001	-0.010
NVA-343	NVA-343CK	-0.005	-0.002	0.025
NVA-346	NVA-346CK	0.005	0.002	-0.001
NVA-348	NVA-348CK	0.007	0.000	-0.016
NVA-349	NVA-349CK	0.011	0.005	0.032
NVA-356	NVA-356CK	0.014	-0.002	-0.014
NVA-357	NVA-357CK	-0.003	-0.009	0.006
NVA-360	NVA-360CK	0.009	-0.005	-0.018
NVA-365	NVA-365CK	0.009	-0.006	-0.007

NVA-366	NVA-366CK	0.008	0.006	-0.024
NVA-368	NVA-368CK	0.004	-0.013	0.000
NVA-371	NVA-371CK	0.007	0.001	0.002
NVA-372	NVA-372CK	-0.007	-0.012	-0.017
NVA-373	NVA-373CK	0.001	0.007	0.003
NVA-374	NVA-374CK	0.002	0.003	-0.002
NVA-377	NVA-377CK	0.006	0.000	0.012
NVA-378	NVA-378CK	0.013	-0.030	-0.010
NVA-381	NVA-381CK	-0.009	-0.002	0.011
NVA-382	NVA-382CK	-0.007	-0.003	0.008
NVA-384	NVA-384CK	0.000	0.008	-0.005
NVA-385	NVA-385CK	-0.007	0.006	0.005
NVA-386	NVA-386CK	-0.009	0.001	0.016
NVA-388	NVA-388CK	-0.018	0.006	0.009
NVA-389	NVA-389CK	0.004	0.002	-0.009
NVA-392	NVA-392CK	0.004	-0.010	-0.002
NVA-393	NVA-393CK	-0.008	-0.012	0.004
NVA-394	NVA-394CK	-0.011	0.016	0.002
NVA-395	NVA-395CK	0.002	-0.011	0.003
NVA-396	NVA-396CK	0.019	0.007	-0.017
NVA-397	NVA-397CK	0.001	0.006	-0.010
NVA-400	NVA-400CK	0.014	0.008	0.016
NVA-407	NVA-407CK	-0.015	0.007	-0.002
NVA-408	NVA-408CK	-0.014	-0.007	0.031
NVA-410	NVA-410CK	0.005	0.001	-0.009
NVA-412	NVA-412CK	-0.003	0.000	0.002
NVA-413	NVA-413CK	0.022	0.023	0.008
NVA-415	NVA-415CK	-0.006	0.007	0.014
NVA-416	NVA-416CK	0.000	0.002	-0.006
NVA-417	NVA-417CK	-0.001	-0.008	-0.018
NVA-418	NVA-418CK	-0.010	0.002	-0.003
NVA-420	NVA-420CK	-0.002	0.000	0.017
NVA-425	NVA-425CK	0.004	0.003	0.002
NVA-428	NVA-428CK	0.001	-0.005	0.006
NVA-429	NVA-429CK	0.015	-0.002	0.044
NVA-430	NVA-430CK	-0.004	0.000	-0.022
NVA-433	NVA-433CK	-0.011	0.009	-0.003
NVA-441	NVA-441CK	-0.010	0.002	-0.037
NVA-442	NVA-442CK	-0.008	0.003	0.004
NVA-445	NVA-445CK	-0.009	-0.007	-0.004
NVA-447	NVA-447CK	0.001	-0.026	-0.007

NVA-448	NVA-448CK	0.003	-0.014	0.001
NVA-449	NVA-449CK	0.005	-0.027	-0.012
NVA-450	NVA-450CK	-0.009	-0.027	0.007
NVA-451	NVA-451CK	0.010	-0.008	-0.003
NVA-452	NVA-452CK	-0.009	-0.008	0.012
NVA-453	NVA-453CK	-0.004	0.004	-0.017
NVA-454	NVA-454CK	0.018	-0.004	0.017
NVA-456	NVA-456CK	-0.002	0.003	0.014
NVA-459	NVA-459CK	-0.002	0.005	0.005
NVA-460	NVA-460CK	-0.002	0.003	-0.003
NVA-461	NVA-461CK	0.005	0.001	0.003
NVA-462	NVA-462CK	-0.002	-0.022	-0.002
NVA-463	NVA-463CK	-0.011	-0.007	0.012
NVA-464	NVA-464CK	-0.003	-0.010	0.003
NVA-465	NVA-465CK	0.023	-0.026	0.013
NVA-467	NVA-467CK	-0.009	-0.020	-0.016
NVA-468	NVA-468CK	-0.005	-0.002	-0.031
NVA-471	NVA-471CK	-0.006	-0.005	0.022
NVA-479	NVA-479CK	-0.011	0.006	0.015
NVA-484	NVA-484CK	0.013	-0.010	-0.037
NVA-486	NVA-486CK	0.000	-0.005	-0.017
NVA-487	NVA-487CK	-0.017	-0.005	-0.011
NVA-491	NVA-491CK	0.005	0.014	0.021
NVA-497	NVA-497CK	0.000	-0.016	-0.011
NVA-499	NVA-499CK	-0.023	0.009	-0.014
NVA-500	NVA-500CK	-0.013	0.020	0.007
NVA-501	NVA-501CK	-0.006	-0.008	-0.004
NVA-502	NVA-502CK	-0.002	-0.028	0.020
NVA-503	NVA-503CK	-0.019	0.032	0.005
NVA-504	NVA-504CK	-0.001	-0.004	0.004
NVA-505	NVA-505CK	0.013	-0.023	0.032
NVA-507	NVA-507CK	-0.020	0.000	0.018
NVA-508	NVA-508CK	0.016	0.018	-0.017
VVA				
VVA-203	VVA-203CK	0.025	0.025	-0.019
VVA-208	VVA-208CK	0.013	-0.009	-0.024
VVA-209	VVA-209CK	0.018	-0.003	0.008
VVA-211	VVA-211CK	-0.016	0.002	-0.018
VVA-213	VVA-213CK	0.005	-0.001	0.007
VVA-214	VVA-214CK	-0.014	0.008	-0.006
VVA-217	VVA-217CK	-0.002	0.005	0.014

VVA-218	VVA-218CK	-0.003	0.000	-0.034
VVA-220	VVA-220CK	0.005	0.007	0.029
VVA-221	VVA-221CK	-0.006	-0.008	0.001
VVA-224	VVA-224CK	0.002	-0.004	-0.008
VVA-227	VVA-227CK	0.004	0.003	0.002
VVA-230	VVA-230CK	0.005	0.002	-0.004
VVA-232	VVA-232CK	0.002	0.006	-0.037
VVA-234	VVA-234CK	-0.007	-0.005	-0.021
VVA-236	VVA-236CK	-0.011	-0.002	-0.016
VVA-238	VVA-238CK	0.006	-0.002	0.000
VVA-239	VVA-239CK	-0.001	0.001	0.035
VVA-242	VVA-242CK	-0.005	0.004	0.018
VVA-244	VVA-244CK	0.004	-0.008	-0.009
VVA-246	VVA-246CK	-0.003	0.002	0.010
VVA-249	VVA-249CK	0.004	0.006	0.019
VVA-250	VVA-250CK	0.008	0.011	-0.018
VVA-252	VVA-252CK	0.004	0.000	-0.012
VVA-254	VVA-254CK	-0.003	0.004	0.005
VVA-257	VVA-257CK	0.010	0.002	0.013
VVA-260	VVA-260CK	0.020	-0.002	-0.028
VVA-261	VVA-261CK	-0.013	-0.013	0.038
VVA-264	VVA-264CK	0.000	-0.003	0.022
VVA-266	VVA-266CK	-0.007	-0.018	-0.008
VVA-267	VVA-267CK	-0.001	0.005	-0.011
VVA-270	VVA-270CK	-0.019	-0.011	0.009
VVA-271	VVA-271CK	-0.006	0.000	-0.007
VVA-274	VVA-274CK	0.011	-0.002	-0.033
VVA-276	VVA-276CK	0.000	-0.003	0.004
VVA-279	VVA-279CK	0.001	-0.004	-0.027
VVA-281	VVA-281CK	-0.005	0.008	0.006
VVA-285	VVA-285CK	-0.006	-0.011	0.045
VVA-286	VVA-286CK	0.002	0.028	0.016
VVA-288	VVA-288CK	0.004	-0.002	-0.001
VVA-289	VVA-289CK	-0.034	0.021	0.010
VVA-290	VVA-290CK	0.000	-0.008	0.006
VVA-292	VVA-292CK	-0.005	0.001	0.003
VVA-294	VVA-294CK	-0.008	0.005	-0.016
VVA-297	VVA-297CK	0.005	-0.034	-0.036
VVA-300	VVA-300CK	-0.029	-0.024	0.029
VVA-303	VVA-303CK	0.018	0.018	-0.027

VVA-306	VVA-306CK	-0.007	-0.001	0.003
VVA-307	VVA-307CK	0.006	0.001	-0.013
VVA-308	VVA-308CK	-0.001	-0.002	-0.017
VVA-309	VVA-309CK	-0.011	0.000	0.010
VVA-311	VVA-311CK	0.006	-0.001	-0.020
VVA-313	VVA-313CK	0.009	0.002	0.023
VVA-314	VVA-314CK	0.015	0.000	0.006
VVA-316	VVA-316CK	-0.009	-0.004	-0.006
VVA-317	VVA-317CK	0.007	-0.003	-0.009
VVA-319	VVA-319CK	0.001	0.011	0.014
VVA-320	VVA-320CK	-0.016	-0.006	-0.003
VVA-321	VVA-321CK	-0.006	0.011	0.001
VVA-322	VVA-322CK	-0.091	0.082	0.020
VVA-323	VVA-323CK	-0.010	-0.014	0.018
VVA-324	VVA-324CK	-0.017	0.003	-0.001
VVA-325	VVA-325CK	-0.005	-0.001	-0.031
VVA-326	VVA-326CK	0.003	-0.006	-0.023
VVA-328	VVA-328CK	-0.017	0.003	-0.069
VVA-330	VVA-330CK	-0.005	-0.003	0.016
VVA-333	VVA-333CK	-0.009	0.008	0.005
VVA-336	VVA-336CK	0.004	-0.001	0.025
VVA-339	VVA-339CK	-0.006	-0.008	-0.076
VVA-341	VVA-341CK	0.015	-0.006	-0.056
VVA-344	VVA-344CK	-0.010	0.005	-0.013
VVA-345	VVA-345CK	-0.022	0.024	-0.013
VVA-347	VVA-347CK	-0.035	-0.002	0.038
VVA-349	VVA-349CK	-0.001	-0.001	-0.013
VVA-350	VVA-350CK	-0.007	0.049	0.051
VVA-352	VVA-352CK	-0.002	-0.005	-0.004

Appendix B: Ground Control Survey Report

Ground Control Point Survey Report

“Texas Brazos Basin FEMA Region 6 LiDAR”
USGS Contract: G16PC00020
Task Order Number: G17PC00014

Prepared for:
United States Geological Survey (USGS)



Prepared By:
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INTRODUCTION

1.1 Project Summary

Dewberry Consultants LLC is under contract to the United States Geological Survey to provide 201 Ground Control Points in the State of Texas. Under the above referenced USGS Task Order, Dewberry is tasked to complete the quality assurance of LiDAR products. As part of this work Dewberry staff will complete Ground Control Point surveys that will be used to evaluate vertical and horizontal accuracy. The ground survey was conducted January 26 thru February 15, 2017.

Existing NGS Control Points were located and surveyed to check the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 of this Report.

As an internal QA/QC procedure and to verify that the Ground Control Points meet the 95% confidence level approximately 50% of the points were re-observed and are shown in Section 5 of this report.

Final horizontal coordinates are referenced to UTM, Zone 14, NAD83 (2011) in meters. Final Vertical elevations are referenced to NAVD88 in meters using Geoid model 2012B (Geoid12B).

1.2 Points of Contact

Questions regarding the technical aspects of this report should be addressed to:

Dewberry Consultants LLC

Gary D. Simpson, L.S.
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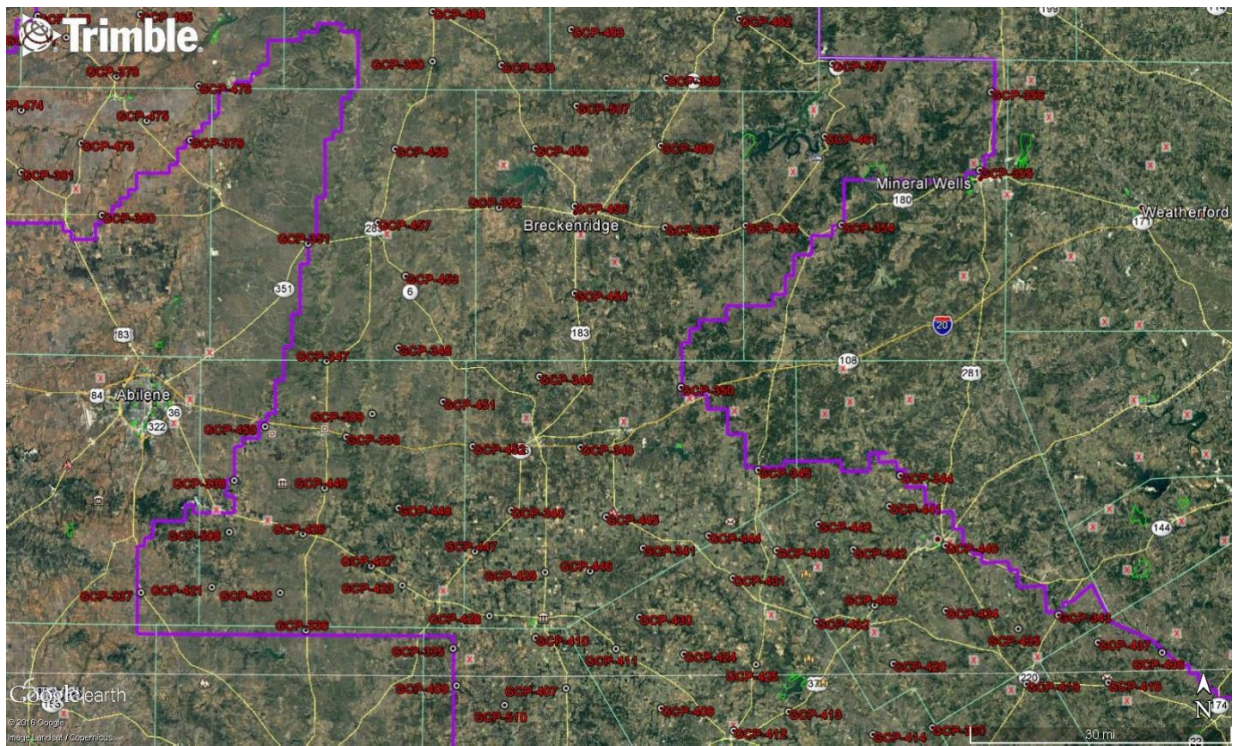
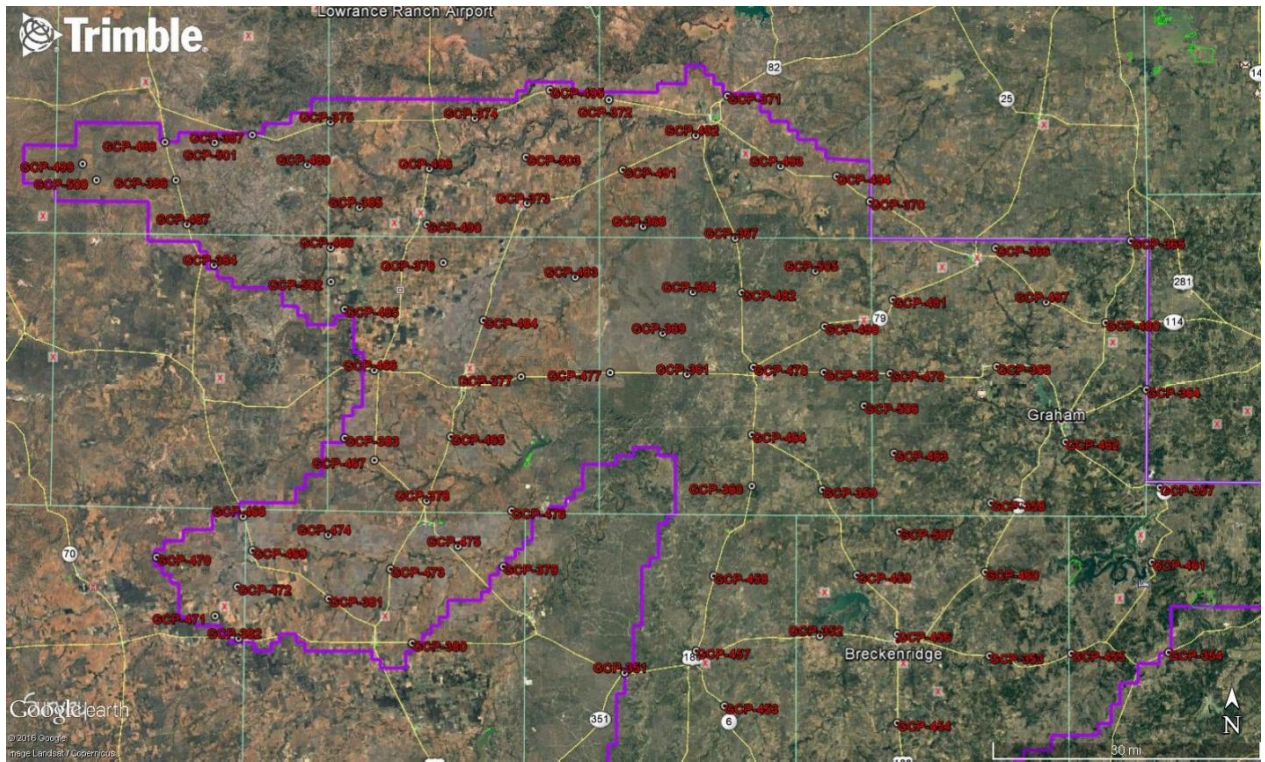
Suite 204

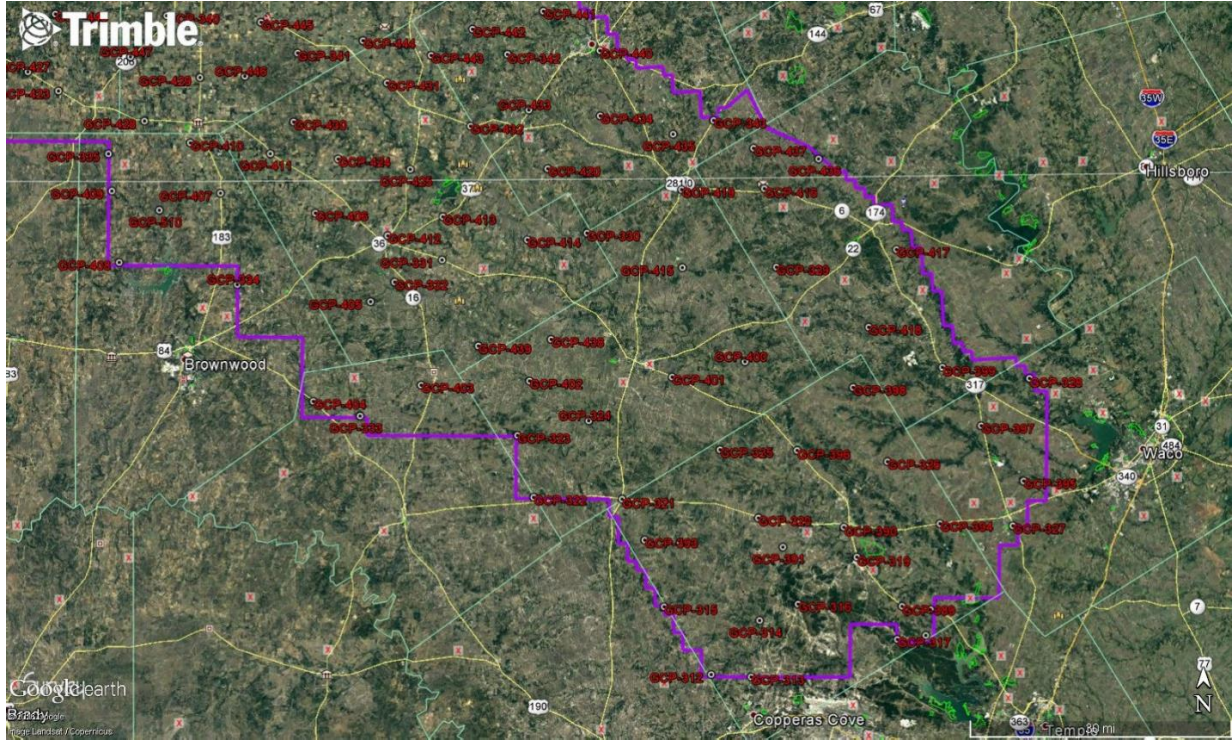
Lanham, Maryland 20706

(301) 364-1855 direct

(301) 731-0188 fax

1.3 Project Area





PROJECT DETAILS

2.1 Survey Equipment

In performing the GPS observations Trimble R-10 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC3 Data Collector to collect GPS raw data were used to perform the field surveys.

2.2 Survey Point Detail

The 201 Ground Control Points were well distributed throughout the project area.

A sketch was made for each location and a nail was set at the point where possible or at an identifiable point. The Ground Control Point locations are detailed on the “Check Point Documentation Report” sheets attached to this report.

2.3 Network Design

The GPS survey performed by Dewberry Consultants LLC office located in Lanham, MD was tied to a Real Time Network operated by TXDOT RTN. The network is a series of “real-time” continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

2.4 Field Survey Procedures and Analysis

Dewberry field surveyors used Trimble R-10 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location.

All locations were occupied once with approximately 50% of the locations being re-observed. All re-observations matched the initially derived station positions within the allowable tolerance of $\pm 5\text{cm}$ or within the 95% confidence level. Each occupation which utilized the VRS network was occupied for approximately three (3) minutes in duration and measured to 180 epochs.

Each occupation which utilized OPUS (if used) was occupied between 20 and 30 minutes.

Field GPS observations are detailed on the “Control Point Documentation Reports” submitted as part of this report.

Thirteen (13) existing NGS monument listed in the NSRS database were located as an additional QA/QC method to check the horizontal and vertical accuracy of the VRS network as well as being the primary project control monuments designated as DF8276, AB2830, CA0068, CT0756, AB2790, DP0535, BZ1355, AB2839, DO0946, CT0338,

CT1194, CA0021 and CT0955. The results are as follows:

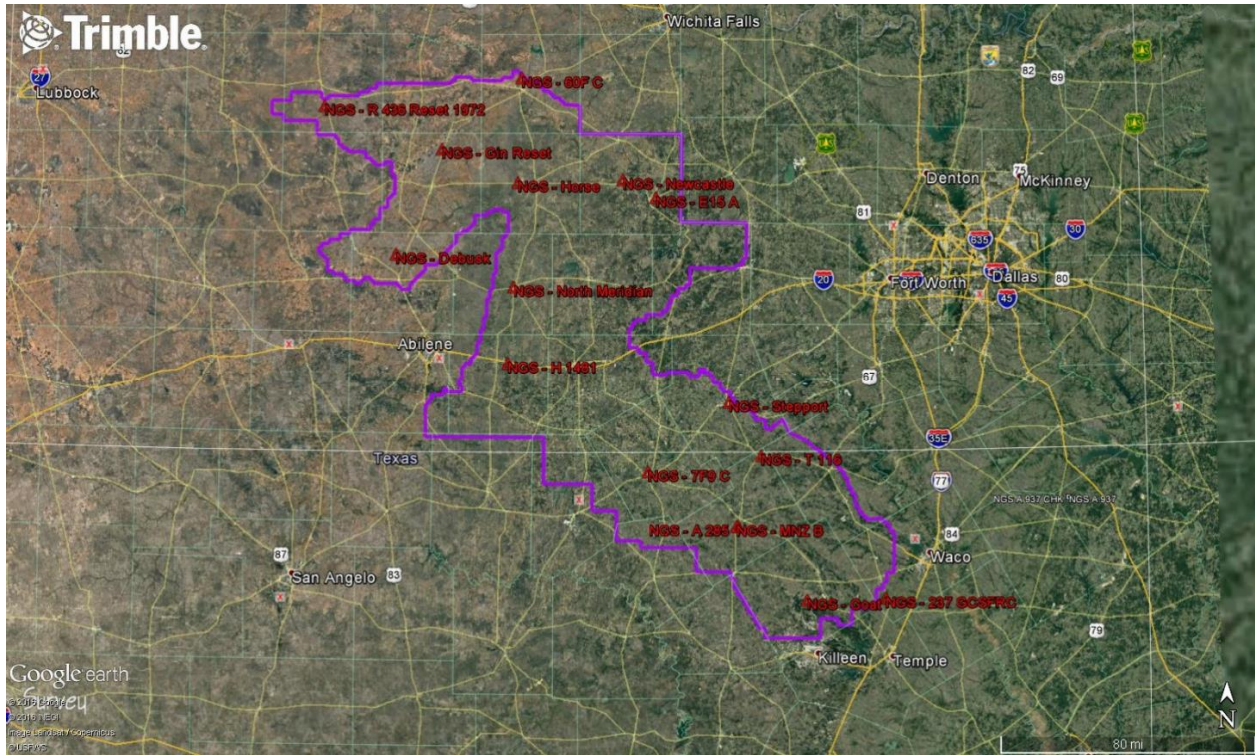
PT. #	Observed Values			Data Sheet Values			ΔX	ΔY	ΔZ
	NORTHING	EASTING	ELEVS.	NORTHING	EASTING	ELEVS.			
7F9 C	3531135.353	537841.786	419.003	3531135.350	537841.778	418.980	0.003	0.008	0.023
60F C**	3722415.077	475810.859	407.977	3722415.077	475810.863	N/A	0.000	-0.004	N/A
A 285	3504725.069	581960.401	379.833	3504725.061	581960.387	379.852	0.008	0.014	-0.019
DE BUSK	3636619.191	414578.370	495.759	3636619.179	414578.326	495.709	0.012	0.044	0.050
E15 A	3664109.726	541471.148	337.419	3664109.729	541471.138	337.390	-0.003	0.010	0.029
KINGSTONE RESET	3695942.390	383133.190	539.857	3695942.374	383133.217	539.900	0.016	-0.027	-0.043
GOAT**	3469120.796	615725.911	341.201	3469120.783	615725.852	N/A	0.013	0.059	N/A
MNZ B**	3504567.949	581109.467	394.365	3504567.933	581109.460	N/A	0.016	0.007	N/A
NEWCASTLE	3672834.582	525352.176	362.567	3672834.578	525352.174	362.600	0.004	0.002	-0.033
NORTH MERIDIAN*	3620640.313	472176.503	430.550	N/A	N/A	430.568	N/A	N/A	-0.018
STEPPORT**	3564945.278	577215.900	401.796	3564945.275	577215.891	N/A	0.003	0.009	N/A
T 116*	3539058.229	593016.898	331.512	N/A	N/A	331.521	N/A	N/A	-0.009
H1481	3583559.298	469475.090	474.529	3583559.333	469475.078	474.500	-0.035	0.012	0.029

(*) Indicates a vertical NGS Mark (**)

Indicates a horizontal NGS Mark

The above results indicate that the VRS network is providing positional values within the 5cm parameters for this survey.

NGS Monuments



2.5 Adjustment

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS).

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the TXDOT RTN system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 Data Processing Procedures

After field data is collected the information is downloaded from the data collectors into the office software. The Software program used is called Trimble Business Center.

Downloaded data is run through the TBC program to obtain the following reports; points report, point comparison report and a point detail report. The reports are reviewed for point accuracy and precision.

After review of the point data an “ASCII” or “txt” file which is the industry standard is created. Point files are loaded into our CADD program (Carlson Survey 2014) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). The data can now be imported into the final product.

3. FINAL COORDINATES/ELEVATIONS

UTM Zone 14, NAD83 (2011), NAVD88			
POINT ID	NORTHING (m)	EASTING (m)	ELEV. (m)
GC P			
GCP-312	3451326.621	596969.848	330.839
GCP-313	3450871.190	604232.923	317.532
GCP-314	3461074.207	605808.869	247.070
GCP-315	3463617.909	588380.099	370.203
GCP-316	3464045.889	612801.189	350.473
GCP-317	3457599.020	630973.582	224.679
GCP-318	3462998.017	637033.276	249.822
GCP-319	3472524.945	623564.073	222.646
GCP-320	3479647.595	605559.226	306.524
GCP-321	3483079.114	580730.885	375.695
GCP-322	3483411.692	564628.589	444.241
GCP-323	3494585.579	561692.642	487.918
GCP-324	3497252.096	574654.664	402.355
GCP-325	3491996.007	598573.195	321.333
GCP-326	3489810.388	629110.915	311.527
GCP-327	3478146.994	652084.319	214.562
GCP-328	3504858.787	655157.114	193.165
GCP-329	3525110.317	608844.864	343.700
GCP-330	3531139.873	574350.376	392.602
GCP-331	3526289.618	547960.334	376.241
GCP-332	3522286.664	539326.053	435.949
GCP-333	3498106.505	533035.520	477.878
GCP-334	3521868.294	510517.321	448.655
GCP-335	3545611.644	486917.341	488.956
GCP-336	3548886.562	460102.640	530.231
GCP-337	3555650.018	429932.587	581.310
GCP-338	3575944.993	447074.602	611.571
GCP-339	3583920.594	467551.235	481.914
GCP-340	3570621.376	497551.819	520.807
GCP-341	3563765.956	521565.239	438.293
GCP-342	3563434.495	559863.035	473.963
GCP-343	3551504.842	597444.067	383.399
GCP-344	3576819.545	568454.797	424.599

GCP-345	3577829.681	542535.118	424.872
GCP-346	3581991.886	510209.983	467.984
GCP-347	3597518.142	463924.445	500.407
GCP-348	3599993.355	477056.587	459.829
GCP-349	3594729.527	502708.669	431.770
GCP-350	3592764.470	528450.835	476.398
GCP-351	3618784.379	460560.896	577.504
GCP-352	3625250.971	495354.117	381.985
GCP-353	3621663.137	525574.403	380.254
GCP-354	3622126.997	557737.320	346.884
GCP-355	3632057.152	583052.608	284.027
GCP-356	3646224.748	585188.122	344.120
GCP-357	3651393.334	556121.361	357.667
GCP-358	3648745.764	525700.795	318.915
GCP-359	3651161.327	495743.810	390.643
GCP-360	3651742.020	483193.364	426.370
GCP-361	3671476.718	471697.207	478.168
GCP-362	3671820.796	496035.598	371.475
GCP-363	3672826.144	526840.287	361.578
GCP-364	3668720.347	553671.347	356.756
GCP-365	3695033.484	550964.938	313.133
GCP-366	3693778.998	526698.979	377.118
GCP-367	3695483.631	480270.998	435.982
GCP-368	3697610.498	463892.590	412.560
GCP-369	3678575.402	467472.830	462.161
GCP-370	3701987.691	504282.453	390.449
GCP-371	3720672.306	478909.516	408.483
GCP-372	3719970.612	457812.836	428.888
GCP-373	3701690.981	443259.611	451.735
GCP-374	3716708.347	433924.873	463.150
GCP-375	3716094.382	408167.607	492.776
GCP-376	3691208.861	428340.662	472.388
GCP-377	3671078.670	442101.043	445.278
GCP-378	3649165.079	425366.284	468.793
GCP-379	3637547.284	439003.397	469.218
GCP-380	3624002.335	422766.530	520.644
GCP-381	3631854.425	407894.269	522.051
GCP-382	3624795.323	391773.012	577.950
GCP-383	3660240.640	410769.209	498.262

GCP-384	3690954.964	387454.132	538.211
GCP-385	3700987.352	413406.169	458.168
GCP-386	3705883.203	380624.456	547.510
GCP-387	3713857.458	394260.375	568.230
GCP-388	3458322.808	636171.449	218.760
GCP-389	3463622.234	631818.411	285.370
GCP-390	3477994.821	621232.794	251.621
GCP-391	3474366.584	610049.645	293.113
GCP-392	3475283.323	591282.915	360.954
GCP-393	3475692.869	584838.320	390.054
GCP-394	3478569.967	638694.127	268.910
GCP-395	3486249.431	654077.190	194.820
GCP-396	3491872.131	612616.281	292.216
GCP-397	3496297.335	646279.911	234.530
GCP-398	3503224.933	622849.314	318.508
GCP-399	3506860.626	639195.932	194.418
GCP-400	3507891.783	603130.684	328.576
GCP-401	3505123.854	589851.581	339.137
GCP-402	3504410.830	563898.300	404.535
GCP-403	3503689.888	544176.011	482.710
GCP-404	3500760.264	524469.235	440.498
GCP-405	3518753.736	534948.555	478.609
GCP-406	3534769.127	524862.190	435.281
GCP-407	3538444.867	507513.934	501.517
GCP-408	3525897.860	488939.785	453.225
GCP-409	3538845.906	487562.873	466.996
GCP-410	3547543.281	501965.730	499.585
GCP-411	3545533.078	516611.923	467.113
GCP-412	3530694.336	538042.440	417.480
GCP-413	3534118.063	548124.876	365.832
GCP-414	3529932.623	563500.673	371.019
GCP-415	3524905.509	591731.397	367.236
GCP-416	3539185.366	606684.358	276.752
GCP-417	3528185.588	630784.843	220.040
GCP-418	3514136.558	625735.094	263.057
GCP-419	3538970.858	591599.243	311.257
GCP-420	3542778.198	567214.385	438.048
GCP-421	3556652.008	442942.194	624.230
GCP-422	3555705.194	455406.512	563.313

GCP-423	3557032.814	477711.767	555.590
GCP-424	3544563.821	528982.896	409.586
GCP-425	3542684.464	542164.284	381.038
GCP-426	3566306.218	459595.477	542.435
GCP-427	3560533.790	472058.964	579.524
GCP-428	3551515.979	493557.291	511.588
GCP-429	3559385.500	503700.818	476.770
GCP-430	3551282.232	520855.989	443.583
GCP-431	3558325.218	537913.934	426.238
GCP-432	3550471.262	553146.974	409.415
GCP-433	3553356.086	563770.960	428.979
GCP-434	3552326.184	576767.377	369.353
GCP-435	3549014.294	590056.963	354.100
GCP-436	3544564.314	616593.089	286.520
GCP-437	3546466.519	604699.105	329.832
GCP-438	3511931.348	567817.563	395.896
GCP-439	3510752.927	554576.137	416.629
GCP-440	3564140.063	576735.711	397.196
GCP-441	3571264.084	566418.652	449.335
GCP-442	3568021.872	553497.608	441.534
GCP-443	3563320.587	545924.012	400.341
GCP-444	3566005.301	533487.616	423.934
GCP-445	3569360.274	514749.970	485.562
GCP-446	3559594.098	511918.082	460.017
GCP-447	3563179.015	490950.076	535.057
GCP-448	3571095.743	476976.697	561.693
GCP-449	3574601.594	463579.370	546.885
GCP-450	3585728.617	452727.184	608.928
GCP-451	3590192.081	485157.098	479.279
GCP-452	3582129.243	490553.593	495.061
GCP-453	3612884.286	478313.581	407.977
GCP-454	3609775.895	509122.138	412.284
GCP-455	3622037.825	540249.460	396.536
GCP-456	3625548.020	509107.366	371.683
GCP-457	3622617.407	473286.320	441.419
GCP-458	3635873.657	476411.800	419.515
GCP-459	3635992.194	501931.264	360.483
GCP-460	3636466.699	524830.156	344.615
GCP-461	3638153.695	554720.188	331.477

GCP-462	3659461.484	539178.444	317.723
GCP-463	3657528.299	508493.755	375.248
GCP-464	3660752.776	483246.176	427.905
GCP-465	3660464.750	429668.990	466.348
GCP-466	3672216.976	416072.220	514.360
GCP-467	3656328.795	416066.247	479.427
GCP-468	3646381.462	392638.788	535.949
GCP-469	3640354.488	394335.460	525.901
GCP-470	3639150.617	377167.198	594.537
GCP-471	3628759.885	387598.834	565.645
GCP-472	3633934.653	391570.792	542.911
GCP-473	3637079.918	418933.894	491.044
GCP-474	3643105.510	407823.601	510.849
GCP-475	3641099.275	430933.539	475.523
GCP-476	3647410.787	440478.341	459.462
GCP-477	3671787.215	458005.953	464.487
GCP-478	3672730.319	483482.329	415.914
GCP-479	3671622.643	507791.479	349.432
GCP-480	3680590.826	546366.462	396.518
GCP-481	3684649.999	508326.076	370.384
GCP-482	3685915.045	481401.409	421.091
GCP-483	3688635.936	451803.315	432.151
GCP-484	3681025.928	435454.795	472.999
GCP-485	3683000.395	410764.134	484.639
GCP-486	3693881.458	408238.328	458.690
GCP-487	3698056.448	382606.399	526.236
GCP-488	3712609.547	378631.512	542.159
GCP-489	3708523.868	404113.498	526.496
GCP-490	3697971.106	425423.802	468.758
GCP-491	3707597.244	460269.064	429.712
GCP-492	3713648.331	473253.645	412.670
GCP-493	3708226.731	488351.455	394.155
GCP-494	3706433.674	498344.285	394.009
GCP-495	3721713.557	447336.438	445.512
GCP-496	3707819.276	425841.133	429.148
GCP-497	3684221.916	535715.886	366.304
GCP-498	3679932.113	496155.984	359.466
GCP-499	3708908.055	363875.797	593.375
GCP-500	3705902.794	366394.596	590.595

GCP-501	3712481.003	387506.349	553.825
GCP-502	3687841.260	408311.152	469.556
GCP-503	3709816.703	443060.666	432.787
GCP-504	3685984.437	472740.072	450.353
GCP-505	3689700.548	494537.911	374.798
GCP-506	3665926.280	503200.299	364.850
GCP-507	3643669.670	509489.482	358.064
GCP-508	3566632.622	446139.987	606.061
GCP-509	3587991.412	472240.144	453.631
GCP-510	3535356.134	496322.251	473.504
GCP-511	3711541.186	361197.347	605.060
GCP-512	3695047.577	399685.720	465.927

4. GPS OBSERVATIONS

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY (AST)	RE-OBSERV. DATE	RE-OBSERV. TIME
GCP-312	2/6/2017	37	13:12	N/A	N/A
GCP-313	2/6/2017	37	13:44	N/A	N/A
GCP-314	2/6/2017	37	11:48	2/8/2017	10:52
GCP-315	2/6/2017	37	14:19	2/8/2017	11:54
GCP-316	2/6/2017	37	11:00	2/8/2017	10:15
GCP-317	2/6/2017	37	11:23	N/A	N/A
GCP-318	2/6/2017	37	10:36	N/A	N/A
GCP-319	2/6/2017	37	10:01	2/8/2017	9:43
GCP-320	2/4/2017	35	16:13	2/7/2017	17:46
GCP-321	2/7/2017	38	16:02	2/8/2017	17:15
GCP-322	2/9/2017	40	18:26	N/A	N/A
GCP-323	2/10/2017	41	13:36	N/A	N/A
GCP-324	2/9/2017	40	16:58	2/10/2017	14:15
GCP-325	2/7/2017	38	13:00	2/8/2017	14:14
GCP-326	2/6/2017	37	14:21	2/8/2017	11:45
GCP-327	2/6/2017	37	16:33	2/7/2017	10:06
GCP-328	2/7/2017	38	12:19	N/A	N/A
GCP-329	2/7/2017	38	16:29	N/A	N/A
GCP-330	2/11/2017	42	15:08	N/A	N/A
GCP-331	2/9/2017	40	14:54	2/11/2017	13:56
GCP-332	2/9/2017	40	14:23	N/A	N/A
GCP-333	2/9/2017	40	10:51	2/10/2017	9:55
GCP-334	2/11/2017	42	10:47	N/A	N/A
GCP-335	2/12/2017	43	10:50	N/A	N/A
GCP-336	2/3/2017	34	14:24	N/A	N/A
GCP-337	2/3/2017	34	14:57	2/4/2017	9:39
GCP-338	2/3/2017	34	11:24	2/3/2017	11:28
GCP-339	2/2/2017	33	10:11	N/A	N/A
GCP-340	2/4/2017	35	11:39	N/A	N/A
GCP-341	2/2/2017	33	17:00	2/4/2017	13:08
GCP-342	2/13/2017	44	16:55	N/A	N/A
GCP-343	2/14/2017	45	11:16	N/A	N/A
GCP-344	2/4/2017	35	17:09	N/A	N/A
GCP-345	2/2/2017	33	13:23	N/A	N/A

GCP-346	2/1/2017	32	10:19	2/2/2017	10:53
GCP-347	2/1/2017	32	11:49	2/2/2017	12:37
GCP-348	2/1/2017	32	12:27	2/2/2017	0.65
GCP-349	2/1/2017	32	16:58	N/A	N/A
GCP-350	2/1/2017	32	12:12	2/2/2017	12:52
GCP-351	1/31/2017	31	14:06	N/A	N/A
GCP-352	1/31/2017	31	11:34	N/A	N/A
GCP-353	1/29/2017	29	12:26	1/30/2017	11:19
GCP-354	1/29/2017	29	17:11	1/30/2017	9:30
GCP-355	1/26/2017	26	12:59	1/27/2017	9:08
GCP-356	1/26/2017	26	14:37	1/27/2017	10:23
GCP-357	1/26/2017	26	17:44	1/27/2017	11:27
GCP-358	1/27/2017	27	14:22	1/30/2017	13:10
GCP-359	2/10/2017	41	10:59	N/A	N/A
GCP-360	2/2/2017	33	17:22	N/A	N/A
GCP-361	2/9/2017	40	15:34	2/10/2017	16:45
GCP-362	2/9/2017	40	10:42	2/11/2017	10:00
GCP-363	2/8/2017	39	14:55	2/11/2017	11:10
GCP-364	1/27/2017	27	12:59	N/A	N/A
GCP-365	2/8/2017	39	16:45	2/11/2017	9:43
GCP-366	2/9/2017	40	7:36	2/9/2017	17:46
GCP-367	2/9/2017	40	12:21	2/11/2017	13:45
GCP-368	2/10/2017	41	15:14	N/A	N/A
GCP-369	2/9/2017	40	14:02	N/A	N/A
GCP-370	2/9/2017	40	16:54	2/12/2017	10:04
GCP-371	2/9/2017	40	13:44	N/A	N/A
GCP-372	2/10/2017	41	8:57	2/12/2017	12:09
GCP-373	2/16/2017	47	13:50	2/11/2017	16:42
GCP-374	2/10/2017	41	10:05	2/12/2017	12:55
GCP-375	2/12/2017	43	14:35	N/A	N/A
GCP-376	2/10/2017	41	12:19	N/A	N/A
GCP-377	2/10/2017	41	17:35	2/11/2017	10:56
GCP-378	2/11/2017	42	15:07	2/12/2017	11:28
GCP-379	2/11/2017	42	16:25	N/A	N/A
GCP-380	2/13/2017	44	9:10	N/A	N/A
GCP-381	2/13/2017	44	10:16	N/A	N/A
GCP-382	2/12/2017	43	18:25	2/13/2017	11:14
GCP-383	2/11/2017	42	14:05	N/A	N/A
GCP-384	2/13/2017	44	14:07	2/14/2017	11:18

GCP-385	2/12/2017	43	16:31	2/14/2017	15:00
GCP-386	2/13/2017	44	12:38	N/A	N/A
GCP-387	2/13/2017	44	10:57	N/A	N/A
GCP-388	2/6/2017	37	10:16	N/A	N/A
GCP-389	2/6/2017	37	10:51	N/A	N/A
GCP-390	2/4/2017	35	17:23	2/5/2017	9:40
GCP-391	2/6/2017	37	18:05	2/8/2017	13:00
GCP-392	2/6/2017	37	16:13	N/A	N/A
GCP-393	2/6/2017	37	15:55	N/A	N/A
GCP-394	2/6/2017	37	13:41	2/8/2017	12:25
GCP-395	2/6/2017	37	17:32	2/7/2017	10:35
GCP-396	2/8/2017	39	15:27	N/A	N/A
GCP-397	2/6/2017	37	15:44	2/7/2017	11:22
GCP-398	2/8/2017	39	11:04	N/A	N/A
GCP-399	2/7/2017	38	13:17	N/A	N/A
GCP-400	2/10/2017	41	15:42	N/A	N/A
GCP-401	2/7/2017	38	13:50	2/8/2017	16:20
GCP-402	2/10/2017	41	12:28	N/A	N/A
GCP-403	2/9/2017	40	11:33	2/10/2017	10:27
GCP-404	2/9/2017	40	10:28	2/10/2017	9:22
GCP-405	2/9/2017	40	13:11	N/A	N/A
GCP-406	2/13/2017	44	11:29	N/A	N/A
GCP-407	2/12/2017	43	18:21	2/13/2017	10:22
GCP-408	2/11/2017	42	9:10	2/12/2017	9:21
GCP-409	2/12/2017	43	10:30	N/A	N/A
GCP-410	2/12/2017	43	11:35	N/A	N/A
GCP-411	2/12/2017	43	17:54	2/15/2017	14:16
GCP-412	2/11/2017	42	12:17	2/13/2017	12:28
GCP-413	2/11/2017	42	13:32	2/13/2017	13:26
GCP-414	2/11/2017	42	14:48	N/A	N/A
GCP-415	2/14/2017	45	14:28	N/A	N/A
GCP-416	2/8/2017	39	15:53	N/A	N/A
GCP-417	2/7/2017	38	14:44	2/8/2017	14:11
GCP-418	2/7/2017	38	17:44	N/A	N/A
GCP-419	2/8/2017	39	16:55	N/A	N/A
GCP-420	2/14/2017	45	16:33	N/A	N/A
GCP-421	2/3/2017	34	15:22	2/4/2017	10:11
GCP-422	2/3/2017	34	17:02	N/A	N/A
GCP-423	2/12/2017	43	14:58	N/A	N/A

GCP-424	2/12/2017	43	17:15	2/15/2017	13:48
GCP-425	2/13/2017	44	12:57	2/15/2017	12:59
GCP-426	2/3/2017	34	12:46	2/4/2017	11:32
GCP-427	2/12/2017	43	15:15	N/A	N/A
GCP-428	2/4/2017	35	14:18	N/A	N/A
GCP-429	2/12/2017	43	12:58	2/15/2017	15:51
GCP-430	2/15/2017	46	14:35	N/A	N/A
GCP-431	2/2/2017	33	15:38	2/4/2017	14:14
GCP-432	2/13/2017	44	14:55	N/A	N/A
GCP-433	2/13/2017	44	15:57	2/15/2017	10:12
GCP-434	2/14/2017	45	17:40	N/A	N/A
GCP-435	2/14/2017	45	11:55	N/A	N/A
GCP-436	2/8/2017	39	15:23	N/A	N/A
GCP-437	2/8/2017	39	17:38	N/A	N/A
GCP-438	2/10/2017	41	11:53	N/A	N/A
GCP-439	2/10/2017	41	11:14	N/A	N/A
GCP-440	2/14/2017	45	9:25	2/15/2017	9:32
GCP-441	2/4/2017	35	16:36	N/A	N/A
GCP-442	2/4/2017	35	16:17	N/A	N/A
GCP-443	2/2/2017	33	14:59	2/4/2017	14:57
GCP-444	2/2/2017	33	16:18	2/4/2017	13:40
GCP-445	2/4/2017	35	12:15	N/A	N/A
GCP-446	2/12/2017	43	12:36	N/A	N/A
GCP-447	2/4/2017	35	13:36	2/15/2017	16:45
GCP-448	2/4/2017	35	12:57	2/15/2017	17:22
GCP-449	2/2/2017	33	12:14	2/4/2017	12:09
GCP-450	2/1/2017	32	10:30	2/2/2017	9:37
GCP-451	2/1/2017	32	17:54	N/A	N/A
GCP-452	2/2/2017	33	10:05	2/4/2017	10:36
GCP-453	1/31/2017	31	14:46	2/1/2017	16:21
GCP-454	1/31/2017	31	12:05	2/1/2017	12:29
GCP-455	1/29/2017	29	11:43	1/30/2017	10:41
GCP-456	1/29/2017	29	15:13	1/30/2017	15:25
GCP-457	1/31/2017	31	12:40	N/A	N/A
GCP-458	2/2/2017	33	16:21	2/2/2017	16:25
GCP-459	1/30/2017	30	14:58	N/A	N/A
GCP-460	1/29/2017	29	14:27	1/30/2017	12:25
GCP-461	1/29/2017	29	10:09	N/A	N/A
GCP-462	1/26/2017	26	15:03	1/27/2017	12:01

GCP-463	2/10/2017	41	12:57	N/A	N/A
GCP-464	2/9/2017	40	15:27	2/10/2017	10:20
GCP-465	2/12/2017	43	11:01	N/A	N/A
GCP-466	2/11/2017	42	13:12	2/14/2017	15:33
GCP-467	2/11/2017	42	14:27	N/A	N/A
GCP-468	2/12/2017	43	14:02	2/13/2017	13:11
GCP-469	2/12/2017	43	14:16	N/A	N/A
GCP-470	2/13/2017	44	12:17	N/A	N/A
GCP-471	2/12/2017	43	18:09	2/13/2017	11:27
GCP-472	2/12/2017	43	15:41	2/13/2017	11:38
GCP-473	2/12/2017	43	12:04	N/A	N/A
GCP-474	2/12/2017	43	11:12	N/A	N/A
GCP-475	2/11/2017	42	15:55	2/11/2017	15:58
GCP-476	2/11/2017	42	16:43	N/A	N/A
GCP-477	2/9/2017	40	14:40	2/10/2017	18:17
GCP-478	2/9/2017	40	16:20	2/10/2017	15:06
GCP-479	2/9/2017	40	10:12	2/11/2017	9:33
GCP-480	2/9/2017	40	18:50	N/A	N/A
GCP-481	2/9/2017	40	10:30	N/A	N/A
GCP-482	2/9/2017	40	12:40	2/10/2017	15:50
GCP-483	2/10/2017	41	16:08	N/A	N/A
GCP-484	2/11/2017	42	11:37	2/14/2017	16:33
GCP-485	2/13/2017	44	9:20	N/A	N/A
GCP-486	2/12/2017	43	17:26	2/14/2017	16:00
GCP-487	2/13/2017	44	13:37	2/14/2017	11:51
GCP-488	2/13/2017	44	12:01	N/A	N/A
GCP-489	2/12/2017	43	15:35	2/13/2017	15:30
GCP-490	2/10/2017	41	11:15	N/A	N/A
GCP-491	2/10/2017	41	17:57	2/11/2017	15:48
GCP-492	2/9/2017	40	13:15	2/11/2017	15:00
GCP-493	2/9/2017	40	15:35	N/A	N/A
GCP-494	2/9/2017	40	15:52	2/12/2017	10:39
GCP-495	2/10/2017	41	9:14	1/12/2017	12:29
GCP-496	2/10/2017	41	10:46	N/A	N/A
GCP-497	2/8/2017	39	15:37	2/9/2017	18:02
GCP-498	2/9/2017	40	10:52	2/11/2017	12:42
GCP-499	2/13/2017	44	16:02	N/A	N/A
GCP-500	2/13/2017	44	15:31	2/14/2017	13:22
GCP-501	2/13/2017	44	11:16	N/A	N/A

GCP-502	2/13/2017	44	10:10	2/14/2017	16:44
GCP-503	2/10/2017	41	14:34	N/A	N/A
GCP-504	2/9/2017	40	13:02	N/A	N/A
GCP-505	2/9/2017	40	11:47	N/A	N/A
GCP-506	2/10/2017	41	9:20	2/10/2017	13:31
GCP-507	1/30/2017	30	14:07	N/A	N/A
GCP-508	2/3/2017	34	13:25	N/A	N/A
GCP-509	2/2/2017	33	11:58	2/2/2017	12:02
GCP-510	2/12/2017	43	9:54	N/A	N/A
GCP-511	2/13/2017	44	16:50	2/13/2017	16:53
GCP-512	2/13/2017	44	17:15	N/A	N/A

5. POINT COMPARISON

Point ID	Point CK	Delta North (M)	Delta East (M)	Vertical Difference (M)
GCP-314	GCP-314CK	-0.006	0.000	0.002
GCP-315	GCP-315CK	0.022	0.016	0.008
GCP-316	GCP-316CK	-0.002	-0.005	-0.013
GCP-319	GCP-319CK	-0.005	0.013	-0.003
GCP-320	GCP-320CK	0.007	-0.007	-0.015
GCP-321	GCP-321CK	0.000	0.009	0.013
GCP-324	GCP-324CK	-0.006	-0.005	0.017
GCP-325	GCP-325CK	-0.009	0.011	-0.005
GCP-326	GCP-326CK	0.011	0.023	-0.016
GCP-327	GCP-327CK	-0.011	0.013	0.001
GCP-331	GCP-331CK	-0.004	-0.001	-0.007
GCP-333	GCP-333CK	0.002	-0.003	-0.008
GCP-337	GCP-337CK	0.005	-0.002	0.032
GCP-338	GCP-339CK	-0.004	0.004	0.002
GCP-341	GCP-341CK	-0.007	-0.003	0.009
GCP-346	GCP-346CK	0.005	0.001	0.000
GCP-347	GCP-347CK	-0.014	-0.005	0.026
GCP-348	GCP-348CK	0.002	0.007	0.012
GCP-350	GCP-350CK	0.012	-0.002	-0.001
GCP-353	GCP-353CK	-0.019	0.044	-0.010
GCP-354	GCP-354CK	-0.008	-0.006	0.040
GCP-355	GCP-353CK	0.001	0.006	0.014
GCP-356	GCP-354CK	0.005	0.019	0.010
GCP-357	GCP-353CK	0.006	-0.002	0.006
GCP-358	GCP-354CK	0.007	-0.005	-0.043
GCP-361	GCP-361CK	-0.001	0.003	0.002
GCP-362	GCP-362CK	0.001	0.013	-0.006
GCP-363	GCP-363CK	-0.007	0.008	-0.006
GCP-365	GCP-365CK	-0.007	-0.001	0.003
GCP-366	GCP-366CK	0.000	0.002	-0.006
GCP-367	GCP-367CK	0.010	0.015	0.008
GCP-370	GCP-370CK	-0.006	-0.005	-0.006
GCP-372	GCP-372CK	-0.026	-0.021	-0.007
GCP-373	GCP-373CK	0.008	0.002	-0.034
GCP-374	GCP-374CK	-0.002	-0.016	0.004
GCP-377	GCP-377CK	0.013	0.011	-0.038

GCP-378	GCP-378CK	-0.008	0.043	0.021
GCP-382	GCP-382CK	0.033	-0.016	-0.037
GCP-384	GCP-384CK	-0.017	0.023	0.039
GCP-385	GCP-385CK	-0.021	-0.004	-0.044
GCP-390	GCP-390CK	-0.001	-0.007	0.013
GCP-391	GCP-391CK	0.002	0.010	-0.021
GCP-394	GCP-394CK	-0.021	0.022	-0.041
GCP-395	GCP-395CK	0.000	0.014	-0.023
GCP-397	GCP-397CK	0.008	0.011	-0.009
GCP-401	GCP-401CK	0.005	-0.004	-0.004
GCP-403	GCP-403CK	-0.001	0.003	-0.005
GCP-404	GCP-404CK	-0.005	-0.013	0.034
GCP-407	GCP-407CK	0.004	-0.010	0.025
GCP-408	GCP-408CK	0.003	0.000	0.025
GCP-411	GCP-411CK	0.005	0.002	0.004
GCP-412	GCP-412CK	-0.001	0.004	-0.006
GCP-413	GCP-413CK	-0.003	0.004	0.000
GCP-417	GCP-417CK	0.019	-0.009	0.027
GCP-421	GCP-421CK	0.000	0.001	-0.010
GCP-424	GCP-424CK	0.005	0.001	0.026
GCP-425	GCP-425CK	0.006	0.005	0.022
GCP-426	GCP-426CK	-0.011	0.000	0.024
GCP-429	GCP-429CK	0.001	-0.007	-0.019
GCP-431	GCP-431CK	-0.005	0.007	-0.013
GCP-433	GCP-433CK	-0.004	-0.004	0.009
GCP-440	GCP-440CK	-0.003	0.000	-0.007
GCP-443	GCP-443CK	-0.015	-0.002	-0.044
GCP-444	GCP-444CK	-0.003	-0.003	-0.009
GCP-447	GCP-447CK	-0.003	-0.004	0.022
GCP-448	GCP-448CK	-0.013	-0.012	-0.017
GCP-449	GCP-449CK	-0.001	0.006	-0.023
GCP-450	GCP-450CK	-0.003	-0.001	0.015
GCP-452	GCP-452CK	-0.016	-0.020	0.002
GCP-453	GCP-453CK	0.003	-0.004	0.006
GCP-454	GCP-454CK	-0.020	-0.010	-0.016
GCP-455	GCP-455CK	-0.004	0.005	0.013
GCP-456	GCP-456CK	-0.001	0.004	0.003
GCP-458	GCP-458CK	-0.001	0.009	-0.008
GCP-460	GCP-460CK	-0.001	0.007	-0.011
GCP-462	GCP-462CK	0.001	0.004	0.008
GCP-464	GCP-464CK	0.008	0.008	0.012

GCP-466	GCP-466CK	0.006	0.005	0.009
GCP-468	GCP-468CK	0.044	-0.008	0.006
GCP-471	GCP-471CK	0.035	0.003	0.022
GCP-472	GCP-472CK	-0.007	-0.005	0.035
GCP-475	GCP-475CK	-0.004	-0.007	-0.011
GCP-477	GCP-477CK	0.014	-0.024	0.019
GCP-478	GCP-478CK	-0.006	-0.006	0.001
GCP-479	GCP-479CK	-0.003	0.021	0.031
GCP-482	GCP-482CK	-0.003	-0.01	-0.016
GCP-484	GCP-484CK	0.007	0.002	0.009
GCP-486	GCP-486CK	-0.007	0.009	-0.001
GCP-487	GCP-487CK	-0.001	0.022	-0.039
GCP-489	GCP-489CK	-0.009	0.010	0.032
GCP-491	GCP-491CK	0.023	-0.004	-0.025
GCP-492	GCP-492CK	0.010	-0.006	-0.018
GCP-494	GCP-494CK	-0.015	-0.008	0.030
GCP-495	GCP-495CK	-0.003	-0.021	-0.041
GCP-497	GCP-497CK	0.003	-0.003	0.005
GCP-498	GCP-498CK	0.002	-0.005	0.022
GCP-500	GCP-500CK	-0.024	0.004	0.005
GCP-502	GCP-502CK	-0.020	0.002	-0.052
GCP-506	GCP-506CK	0.006	0.000	-0.005
GCP-509	GCP-509CK	0.000	0.001	-0.008
GCP-511	GCP-511CK	-0.002	0.001	0.010

Appendix C: Complete List of Delivered Tiles

14RNV940500	14RNV985530	14RNV970560	14RPV165575	14RPV360590
14RNV955500	14RPV000530	14RNV985560	14RPV180575	14RPV375590
14RNV970500	14RPV015530	14RPV000560	14RPV195575	14RNV880605
14RNV985500	14RPV030530	14RPV015560	14RPV210575	14RNV895605
14RNV000500	14RPV045530	14RPV030560	14RPV300575	14RNV910605
14RPV015500	14RPV060530	14RPV045560	14RPV315575	14RNV925605
14RPV030500	14RPV075530	14RPV060560	14RPV330575	14RNV940605
14RPV045500	14RPV090530	14RPV075560	14RPV345575	14RNV955605
14RPV060500	14RPV105530	14RPV090560	14RPV360575	14RNV970605
14RPV075500	14RPV120530	14RPV105560	14RPV375575	14RNV985605
14RPV090500	14RPV135530	14RPV120560	14RNV895590	14RPV000605
14RPV105500	14RPV150530	14RPV135560	14RNV910590	14RPV015605
14RPV120500	14RPV165530	14RPV150560	14RNV925590	14RPV030605
14RPV135500	14RPV180530	14RPV165560	14RNV940590	14RPV045605
14RPV150500	14RPV195530	14RPV180560	14RNV955590	14RPV060605
14RPV165500	14RPV210530	14RPV195560	14RNV970590	14RPV075605
14RPV180500	14RNV910545	14RPV210560	14RNV985590	14RPV090605
14RPV195500	14RNV925545	14RPV300560	14RPV000590	14RPV105605
14RPV210500	14RNV940545	14RPV315560	14RPV015590	14RPV120605
14RNV940515	14RNV955545	14RPV330560	14RPV030590	14RPV135605
14RNV955515	14RNV970545	14RPV345560	14RPV045590	14RPV150605
14RNV970515	14RNV985545	14RPV360560	14RPV060590	14RPV165605
14RNV985515	14RPV000545	14RPV375560	14RPV075590	14RPV180605
14RNV000515	14RPV015545	14RNV895575	14RPV090590	14RPV195605
14RPV015515	14RPV030545	14RNV910575	14RPV105590	14RPV210605
14RPV030515	14RPV045545	14RNV925575	14RPV120590	14RPV225605
14RPV045515	14RPV060545	14RNV940575	14RPV135590	14RPV240605
14RPV060515	14RPV075545	14RNV955575	14RPV150590	14RPV255605
14RPV075515	14RPV090545	14RNV970575	14RPV165590	14RPV270605
14RPV090515	14RPV105545	14RNV985575	14RPV180590	14RPV285605
14RPV105515	14RPV120545	14RPV000575	14RPV195590	14RPV300605
14RPV120515	14RPV135545	14RPV015575	14RPV210590	14RPV315605
14RPV135515	14RPV150545	14RPV030575	14RPV225590	14RPV330605
14RPV150515	14RPV165545	14RPV045575	14RPV240590	14RPV345605
14RPV165515	14RPV180545	14RPV060575	14RPV255590	14RPV360605
14RPV180515	14RPV195545	14RPV075575	14RPV270590	14RPV375605
14RPV195515	14RPV210545	14RPV090575	14RPV285590	14RNV880620
14RPV210515	14RNV910560	14RPV105575	14RPV300590	14RNV895620
14RNV940530	14RNV925560	14RPV120575	14RPV315590	14RNV910620
14RNV955530	14RNV940560	14RPV135575	14RPV330590	14RNV925620
14RNV970530	14RNV955560	14RPV150575	14RPV345590	14RNV940620

14RNV955620	14RPV060635	14RPV045650	14RPV000665	14RNV955680
14RNV970620	14RPV075635	14RPV060650	14RPV015665	14RNV970680
14RNV985620	14RPV090635	14RPV075650	14RPV030665	14RNV985680
14RPV000620	14RPV105635	14RPV090650	14RPV045665	14RPV000680
14RPV015620	14RPV120635	14RPV105650	14RPV060665	14RPV015680
14RPV030620	14RPV135635	14RPV120650	14RPV075665	14RPV030680
14RPV045620	14RPV150635	14RPV135650	14RPV090665	14RPV045680
14RPV060620	14RPV165635	14RPV150650	14RPV105665	14RPV060680
14RPV075620	14RPV180635	14RPV165650	14RPV120665	14RPV075680
14RPV090620	14RPV195635	14RPV180650	14RPV135665	14RPV090680
14RPV105620	14RPV210635	14RPV195650	14RPV150665	14RPV105680
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14SLC600110	14SMC230110	14SMC860110	14SMC140125	14SMC770125
14SLC615110	14SMC245110	14SMC875110	14SMC155125	14SMC785125
14SLC630110	14SMC260110	14SMC890110	14SMC170125	14SMC800125
14SLC645110	14SMC275110	14SMC905110	14SMC185125	14SMC815125
14SLC660110	14SMC290110	14SMC920110	14SMC200125	14SMC830125
14SLC675110	14SMC305110	14SMC935110	14SMC215125	14SMC845125
14SLC690110	14SMC320110	14SMC950110	14SMC230125	14SMC860125
14SLC705110	14SMC335110	14SLC615125	14SMC245125	14SMC875125
14SLC720110	14SMC350110	14SLC630125	14SMC260125	14SMC890125
14SLC735110	14SMC365110	14SLC645125	14SMC275125	14SMC905125
14SLC750110	14SMC380110	14SLC660125	14SMC290125	14SMC920125
14SLC765110	14SMC395110	14SLC675125	14SMC305125	14SMC935125
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14SLC810110	14SMC440110	14SLC720125	14SMC350125	14SLC645140
14SLC825110	14SMC455110	14SLC735125	14SMC365125	14SLC660140
14SLC840110	14SMC470110	14SLC750125	14SMC380125	14SLC675140
14SLC855110	14SMC485110	14SLC765125	14SMC395125	14SLC690140
14SLC870110	14SMC500110	14SLC780125	14SMC410125	14SLC705140
14SLC885110	14SMC515110	14SLC795125	14SMC425125	14SLC720140
14SLC900110	14SMC530110	14SLC810125	14SMC440125	14SLC735140
14SLC915110	14SMC545110	14SLC825125	14SMC455125	14SLC750140
14SLC930110	14SMC560110	14SLC840125	14SMC470125	14SLC765140

14SLC795140	14SMC425140	14SLC750155	14SMC560155	14SMC290170
14SLC810140	14SMC440140	14SLC765155	14SMC575155	14SMC305170
14SLC825140	14SMC455140	14SLC960155	14SMC590155	14SMC320170
14SLC840140	14SMC470140	14SLC975155	14SMC605155	14SMC335170
14SLC855140	14SMC485140	14SLC990155	14SMC620155	14SMC350170
14SLC870140	14SMC500140	14SMC005155	14SMC635155	14SMC365170
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14SLC900140	14SMC530140	14SMC035155	14SMC665155	14SMC395170
14SLC915140	14SMC545140	14SMC050155	14SMC680155	14SMC410170
14SLC930140	14SMC560140	14SMC065155	14SMC695155	14SMC425170
14SLC945140	14SMC575140	14SMC080155	14SMC710155	14SMC440170
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14SLC990140	14SMC620140	14SMC125155	14SMC755155	14SMC485170
14SMC005140	14SMC635140	14SMC140155	14SMC770155	14SMC500170
14SMC020140	14SMC650140	14SMC155155	14SMC785155	14SMC515170
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14SMC050140	14SMC680140	14SMC185155	14SMC815155	14SMC545170
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14SMC155140	14SMC785140	14SMC290155	14SMC020170	14SMC650170
14SMC170140	14SMC800140	14SMC305155	14SMC035170	14SMC665170
14SMC185140	14SMC815140	14SMC320155	14SMC050170	14SMC680170
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14SMC215140	14SMC845140	14SMC350155	14SMC080170	14SMC710170
14SMC230140	14SMC860140	14SMC365155	14SMC095170	14SMC725170
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14SMC395140	14SLC720155	14SMC530155	14SMC260170	14SMC050185
14SMC410140	14SLC735155	14SMC545155	14SMC275170	14SMC065185

14SMC080185	14SMC665185	14SMC425200	14SMC695215
14SMC095185	14SMC680185	14SMC440200	14SMC710215
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14SMC170185	14SMC755185	14SMC515200	14SMC425230
14SMC185185	14SMC770185	14SMC530200	14SMC440230
14SMC200185	14SMC785185	14SMC545200	14SMC455230
14SMC215185	14SMC800185	14SMC560200	14SMC470230
14SMC230185	14SMC815185	14SMC575200	14SMC485230
14SMC245185	14SMC830185	14SMC590200	14SMC500230
14SMC260185	14SMC845185	14SMC605200	14SMC710230
14SMC275185	14SMC035200	14SMC620200	14SMC725230
14SMC290185	14SMC050200	14SMC635200	14SMC740230
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14SMC335185	14SMC095200	14SMC680200	14SMC725245
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14SMC380185	14SMC140200	14SMC725200	14SMC725260
14SMC395185	14SMC155200	14SMC740200	14SMC740260
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14SMC470185	14SMC230200	14SMC815200	
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14SMC500185	14SMC260200	14SMC845200	
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14SMC650185	14SMC410200	14SMC680215	

Appendix D: GPS Processing

Attached as separate document due to file size.