Dewberry & Davis LLC
1000 N. Ashley Drive, Suite 801
Tampa, FL 33602-3718
813.225.1325
813.225.1385 fax
www.dewberry.com

FEMA Region 6 - Archer and Jack Counties, TX QL2 LiDAR Project

Report Produced for U.S. Geological Survey

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SUBMITTED BY:

Dewberry
1000 North Ashley Drive Suite 801
Tampa, FL 33602
813.225.1325

SUBMITTED TO:
U.S. Geological Survey
1400 Independence Road
Rolla, MO 65401
573.308.3810

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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 USGS Acher and Jack Counties TX LiDAR Project Area.

The LiDAR data were processed to a bare-earth digital terrain model (DTM). 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 2252 tiles were produced for the project encompassing an area of approximately 1671 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 verified the GPS base station coordinates used during LiDAR data acquisition to ensure that the base station coordinates were accurate. Please see Appendix A to view the separate Survey Report that was created for this portion of the project.

Precision Aerial Reconnaissance (PAR) completed LiDAR data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Texas counties of Archer and Jack.

DATE OF SURVEY

The LiDAR aerial acquisition was conducted from January 04, 2015 to March 12, 2015.

DATUM REFERENCE

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) (2011)
Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)
Coordinate System: UTM Zone 14
Units: Horizontal units are in meters, Vertical units are in meters.
Geiod Model: Geoid12a (Geoid 12a was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the Archer and Jack Counties TX LiDAR Project, the tested $RMSE_z$ of the classified LiDAR data for checkpoints in open terrain equaled **0.054 m** compared with the 0.0925 m specification; and the FVA of the classified LiDAR data computed using $RMSE_z$ x 1.9600 was equal to **0.106 m**, compared with the 0.181 m specification.

For the Archer and Jack Counties TX LiDAR Project, the tested CVA of the classified LiDAR data computed using the 95^{th} percentile was equal to **0.108 m,** compared with the 0.363 m 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. Raw Point Cloud Data (Swaths)
2. Classified Point Cloud Data (Tiled)
3. Bare Earth Surface (Raster DEM – IMG Format)
4. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
5. Breakline Data (File GDB)
6. Independent Survey Checkpoint Data (Report, Photos, & Points)
7. Calibration Points
8. Metadata
9. Project Report (Acquisition, Processing, QC)
10. Project Extents, Including a shapefile derived from the LiDAR Deliverable

PROJECT TILING FOOTPRINT

Two thousand two hundred and fifty two (2252) tiles were delivered for the project. Each tile's extent is 1,500 meters by 1,500 meters (see Appendix B for a complete listing of delivered tiles).

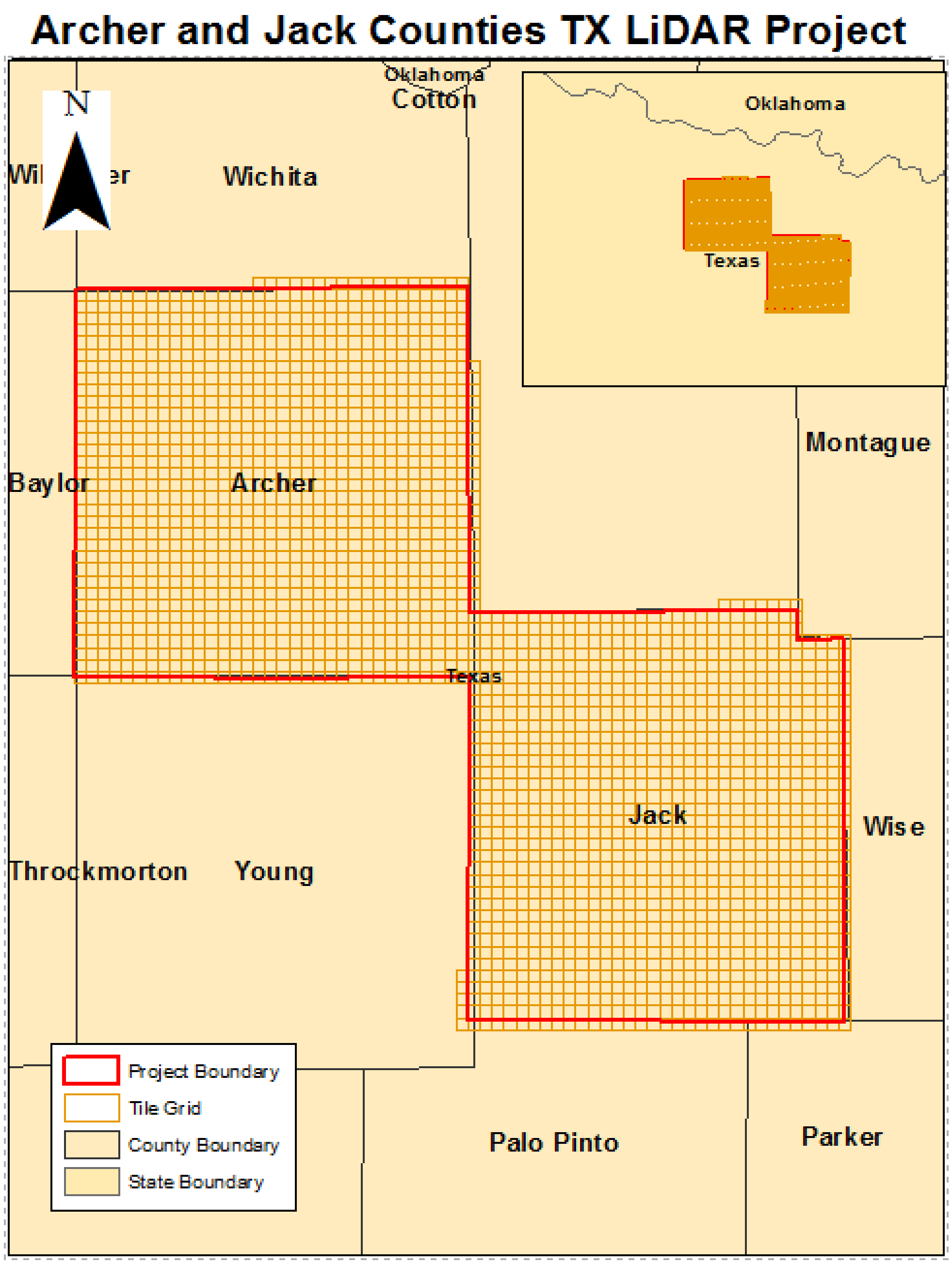


Figure 1 - Project Map

LiDAR Acquisition Report

Precision Aerial Reconnaissance (PAR) provided high accuracy, calibrated multiple return LiDAR for roughly 1671 square miles around Archer and Jack Counties TX area. Data was collected and delivered in compliance with the "U.S. Geological Survey National Geospatial Program Base LiDAR Specifications, Version 1.0"

LIDAR ACQUISITION DETAILS

LIDAR acquisition began on January 04, 2015 (julian day 04) and was completed on January 16, 2015 (julian day 16). Reflights were captured on March 11, 2015 (julian day 70) and March 12, 2015 (Julian day 71). A total of 77 survey missions were flown for Jack County and 74 survey missions were flown for Archer County. PAR utilized a Leica ALS 70-CM for the acquisition. The flight plan was flown as planned with no modifications. There were no unusual occurrences during the acquisition and the sensor performed within specifications.

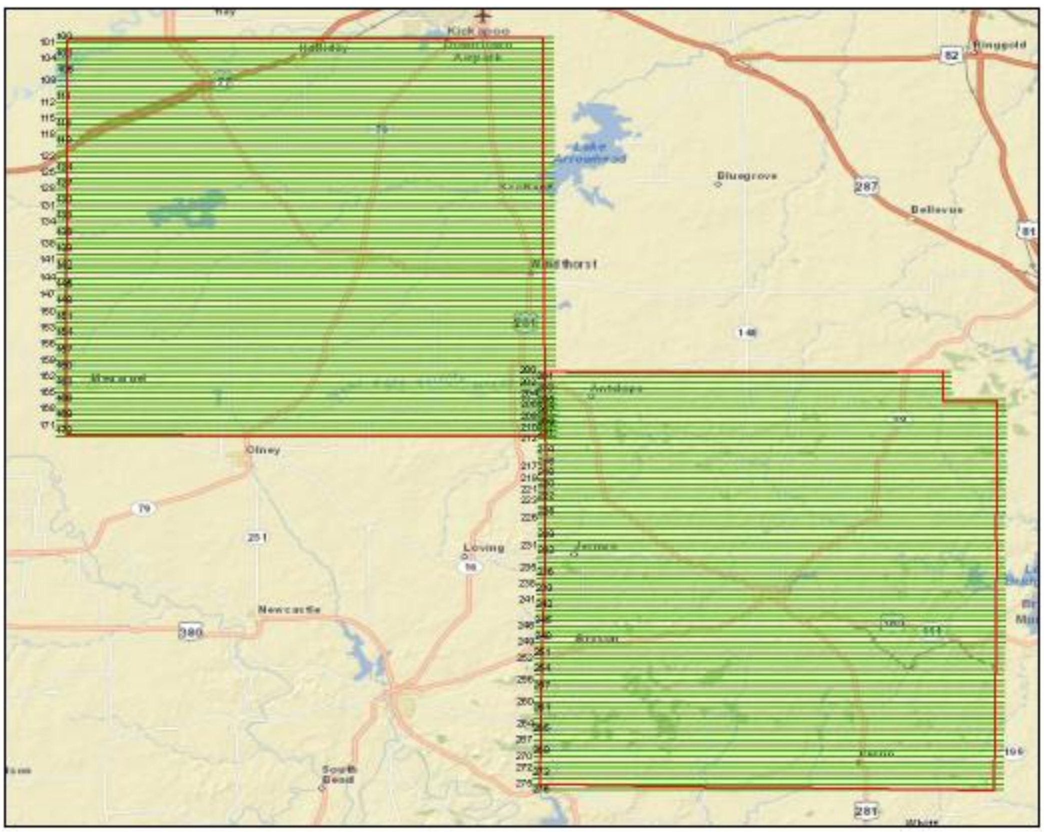


Figure 2 - Flight Layout

Laser Firing Rate: 371.2
Altitude (mtr. AGL):1450
Swath Overlap (%): 30
Approx. Ground Speed (kts): 115
Scan Rate (Hz): 48.7
Computed Swath Width (mtr): 1061

Line Spacing (mtr): 670

LIDAR CONTROL

Two points set by PAR were used to control the LiDAR acquisition for the Archer and Jack Counties TX 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	Easting (m)	Northing (m)	Ellipsoid Ht (m)
21Fnail	579609.850	3677159.065	313.856
T39nail	535531.471	3715892.213	322.491

Table 1 – Base Stations used to control LiDAR acquisition

AIRBORN GPS KINEMATIC

Airborne GPS data was processed using the Novatel's Inertial Explorer software. Flights were flown with a minimum of 6 satellites in view (10° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 40km.

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

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

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 Leica's Cloud Pro. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the LiDAR unit is reviewed for completeness, acceptable density and errors or corrupted values. In addition, all GPS data, aircraft trajectory, mission information, and ground control files are reviewed. On a project level, a supplementary coverage check is carried out to ensure data voids unreported by Field Operations are not present.

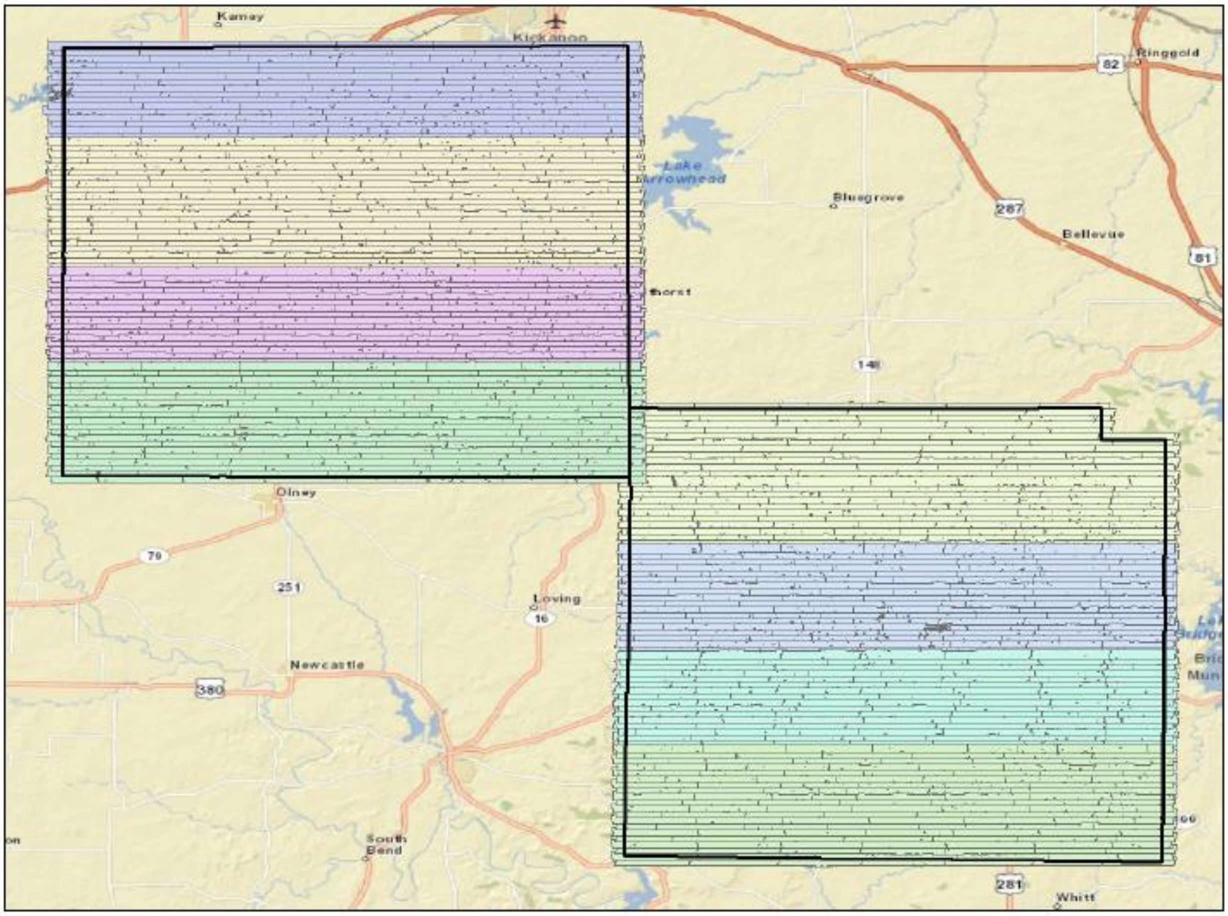


Figure 3 – LiDAR Swath output showing complete coverage.

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 scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 5 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:

Relative accuracy <= 6 cm RMSEZ within individual swaths and <=8 cm RMSEZ or within swath overlap (between adjacent swaths).

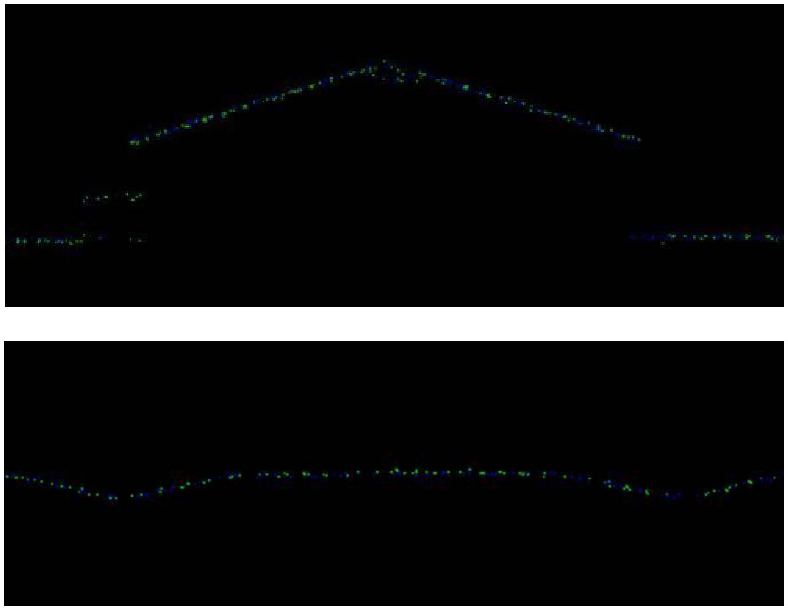


Figure 4 – Profile views showing correct roll and pitch adjustments.

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

PRELIMINARY VERTICAL ACCURACY ASSESSMENT

A preliminary RMSEz error check was performed by PAR in the raw LiDAR dataset against GPS static and kinematic data and compared to RMSEz project specifications. The LiDAR data was examined in open, flat areas away from breaks. LiDAR ground points for each flight line generated by an automatic classification routine are used.

The calibrated LiDAR dataset was tested to 0.06m vertical accuracy at 95% confidence level based on consolidated RMSEz (0.030m x 1.9600) when compared to 2 GPS static check points (GPS base stations).

Number	Easting(m)	Northing(m)	Known Z(m)	Laser Z(m)	Dz
21Fnail	579609.850	3677159.065	313.825	313.856	+0.031
T39nail	535331.471	3715892.213	322.491	322.520	+0.029

Average dz +0.030
Minimum dz +0.029
Maximum dz +0.031
Average magnitude 0.030
Root mean square 0.030
Std deviation 0.001

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

FINAL SWATH VERTICAL ACCURACY ASSESSMENT

Once Dewberry received the calibrated swath data from Precision Aerial Reconnaissance, Dewberry tested the vertical accuracy of the open terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the twenty-one open terrain independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in open terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in open 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. Project specifications require a FVA of 0.181 m based on the $RMSE_z$ (0.0925 m) x 1.96. The dataset for the Archer and Jack Counties TX LiDAR Project satisfies this criteria. The raw LiDAR swath data tested 0.090 m vertical accuracy at 95% confidence level in open terrain, based on $RMSE_z$ (0.046 m) x 1.9600. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	$RMSE_z$ (m) Open Terrain Spec=0.0925	FVA – Fundamental Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.181m	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Open Terrain	0.046	0.090	0.00	0.004	-0.117	0.047	21	-0.088	0.082

Table 2: FVA at 95% Confidence Level for Raw Swaths

LiDAR Processing & Qualitative Assessment

DATA CLASSIFICATION AND EDITING

LiDAR mass points were produced to LAS 1.2 specifications, including the following LAS classification codes:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, or 10, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Noise, low and high points
- Class 9 = Water, points located within collected breaklines
- Class 10 = Ignored Ground due to breakline proximity.

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 outliers in the dataset to class 7. 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.

The following fields within the LAS files are populated to the following precision: GPS Time (0.000001 second precision), Easting (0.003 meter precision), Northing (0.003 meter precision), Elevation (0.003 meter precision), Intensity (integer value - 16 bit dynamic range), Number of Returns (integer - range of 1-4), Return number (integer range of 1-4), Scan Direction Flag (integer - range 0-1), Classification (integer), Scan Angle Rank (integer), Edge of flight line (integer, range 0-1), User bit field (integer - flight line information encoded). The LAS file also contains a Variable length record in the file header that defines the projection, datums, and units.

Once the initial ground routine has been performed on the data, Dewberry creates Delta Z (DZ) orthos to check the relative accuracy of the LiDAR data. These orthos compare the elevations of LiDAR points from overlapping flight lines on a 1 meter pixel cell size basis. If the elevations of points within each pixel are within 8 cm of each other, the pixel is colored green. If the elevations of points within each pixel are between 8 cm and 12 cm of each other, the pixel is colored yellow, and if the elevations of points within each pixel are greater than 12 cm in difference, the pixel is colored red. Pixels that do not contain points from overlapping flight lines are colored according to their intensity values. DZ orthos can be created using the full point cloud or ground only points and are used to review and verify the calibration of the data is acceptable. Some areas are expected to show sections or portions of red, including terrain variations, slope changes, and vegetated areas or buildings if the full point cloud is used. However, 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. The DZ orthos for Archer and Jack Counties showed that the data was calibrated correctly with no issues that would affect its usability. The figure below shows an example of the DZ orthos.

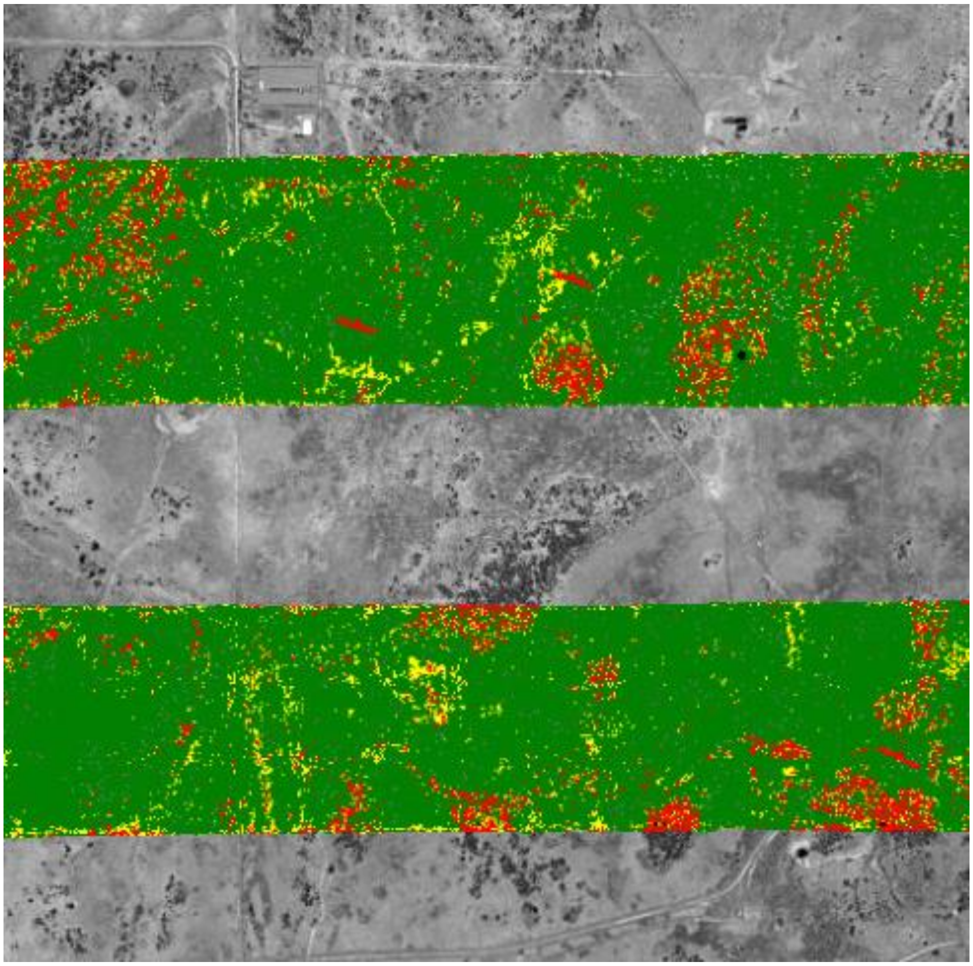


Figure 5 - DZ orthos created from the full point cloud. Some red pixels are visible along embankments, sloped terrain, and in vegetated land cover, as expected. Open, flat areas are green indicating the calibration and relative accuracy of the data is acceptable.

Once the calibration and relative accuracy of the data was confirmed, Dewberry utilized a variety of software suites for data processing. The LAS dataset was imported into GeoCue task management software for processing in Terrascan. Each tile was 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. 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. The final classification routine applied to the dataset selects ground points within a specified distance of the water breaklines and classifies them as class 10, ignored ground due to breakline proximity.

QUALITATIVE ASSESSMENT

Dewberry's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology to assess the quality of the data for a bare-earth digital terrain model (DTM). This process looks for anomalies in the data and also identifies areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model.

Within this review of the LiDAR data, two fundamental questions were addressed:

- Did the LiDAR system perform to specifications?
- Did the vegetation removal process yield desirable results for the intended bare-earth terrain product?

Mapping standards today address the quality of data by quantitative methods. If the data are tested and found to be within the desired accuracy standard, then the data set is typically accepted. Now with the proliferation of LiDAR, new issues arise due to the vast amount of data. Unlike photogrammetrically-derived DEMs where point spacing can be eight meters or more, LiDAR nominal point spacing for this project is 1 point per 0.7 square meters. The end result is that millions of elevation points are measured to a level of accuracy previously unseen for traditional elevation mapping technologies and vegetated areas are measured that would be nearly impossible to survey by other means. The downside is that with millions of points, the dataset is statistically bound to have some errors both in the measurement process and in the artifact removal process.

As previously stated, the quantitative analysis addresses the quality of the data based on absolute accuracy. This accuracy is directly tied to the comparison of the discreet measurement of the survey checkpoints and 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 with DZ orthos. Once the absolute and relative accuracy has been ascertained, the next stage is to address the cleanliness of the data for a bare-earth DTM.

By using survey checkpoints to compare the data, the absolute accuracy is verified, but this also allows us to understand if the artifact removal process was performed correctly. To reiterate the quantitative approach, if the LiDAR sensor operated correctly over open terrain areas, then it most likely operated correctly over the vegetated areas. This does not mean that the entire bare-earth was measured; only that the elevations surveyed are most likely accurate (including elevations of treetops, rooftops, etc.). In the event that the LiDAR pulse filtered through the vegetation and was able to measure the true surface (as well as measurements on the surrounding vegetation) then the level of accuracy of the vegetation removal process can be tested as a by-product.

To fully address the data for overall accuracy and quality, the level of cleanliness (or removal of above-ground artifacts) is paramount. Since there are currently no effective automated testing procedures to measure cleanliness, Dewberry employs a combination of statistical and visualization processes. 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. By creating multiple images and using overlay techniques, not only can potential errors be found, but Dewberry can also find where the data meets and exceeds expectations. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

ANALYSIS

Dewberry utilizes GeoCue software as the primary geospatial process management system. GeoCue is a three tier, multi-user architecture that uses .NET technology from Microsoft. .NET technology provides the real-time notification system that updates users with real-time project status, regardless of who makes changes to project entities. GeoCue uses database technology for sorting project metadata. Dewberry uses Microsoft SQL Server as the database of choice. Specific analysis is conducted in Terrascan and QT Modeler environments.

Following the completion of LiDAR point classification, the Dewberry qualitative assessment process flow for the Archer and Jack Counties TX LiDAR project incorporated the following reviews:

1. *Format:* The LAS files are verified to meet project specifications. The LAS files for the Archer and Jack Counties TX LiDAR project conform to the specifications outlined below.

- Format, Echos, Intensity
  - LAS format 1.2
  - Point data record format 1
  - Multiple returns (echos) per pulse
  - Intensity values populated for each point
- ASPRS classification scheme
  - Class 1 – unclassified
  - Class 2 – Bare-earth ground
  - Class 7 – Noise
  - Class 9 – Water
  - Class 10 – Ignored Ground due to breakline proximity
- Projection
  - Datum – North American Datum 1983
  - Projected Coordinate System – UTM Zone 14
  - Linear Units – Meters
  - Vertical Datum – North American Vertical Datum 1988, Geoid 12a
  - Vertical Units - Meters
- LAS header information:
  - Class (Integer)
  - Adjusted GPS Time (0.0001 seconds)
  - Easting (0.003 meters)
  - Northing (0.003 meters)
  - Elevation (0.003 meters)
  - Echo Number (Integer 1 to 4)
  - Echo (Integer 1 to 4)
  - Intensity (16 bit integer)
  - Flight Line (Integer)
  - Scan Angle (Integer degree)

2. *Data density, data voids:* The LAS files are used to produce Digital Elevation Models using the commercial software package "QT Modeler" 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. For the Archer and Jack Counties TX LiDAR project it is stipulated that the minimum post spacing in un-obscured areas should be 1 point per 0.7 square meters.

    a. 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. These are considered to be acceptable voids. No unacceptable voids are present in the Archer and Jack Counties TX LiDAR project.

3. *Bare earth quality:* Dewberry reviewed the cleanliness of the bare earth to ensure the ground has correct definition, meets the project requirements, there is correct classification of points, and there are less than 5% residual artifacts.

    a. *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.

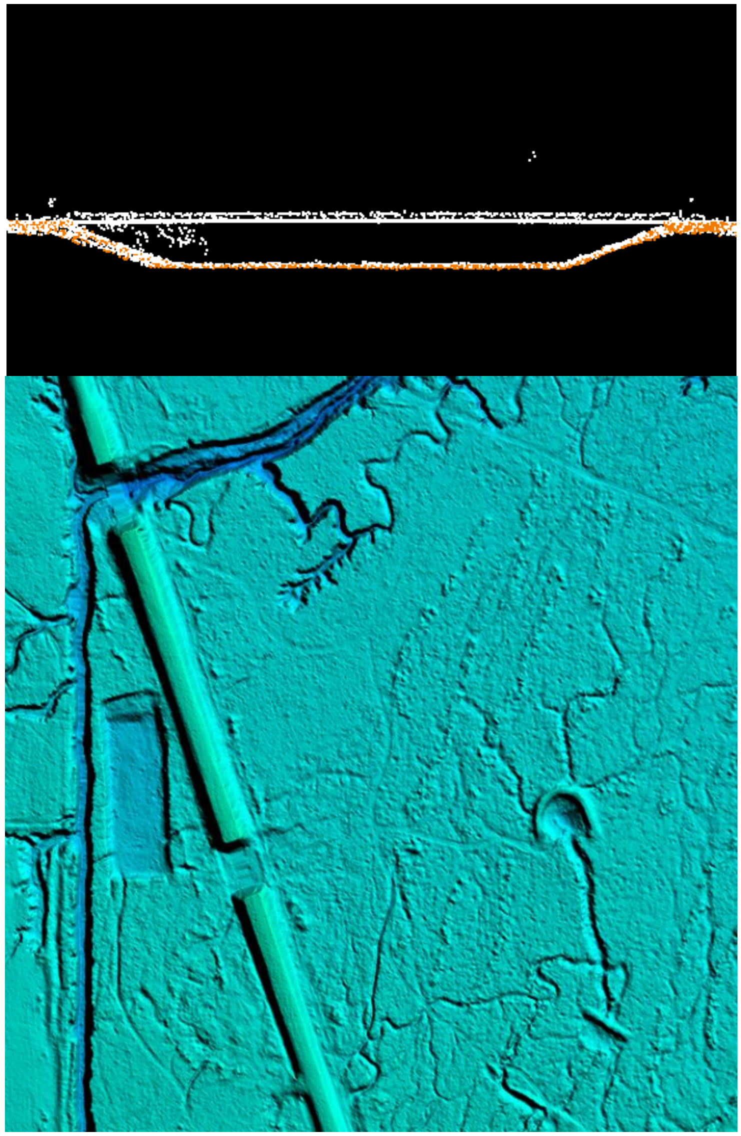


Figure 6 – Tile number 14SNB760825. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the LiDAR points of this particular feature colored by class. All bridge points have been removed from ground (orange) and are unclassified (white).

b. *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.

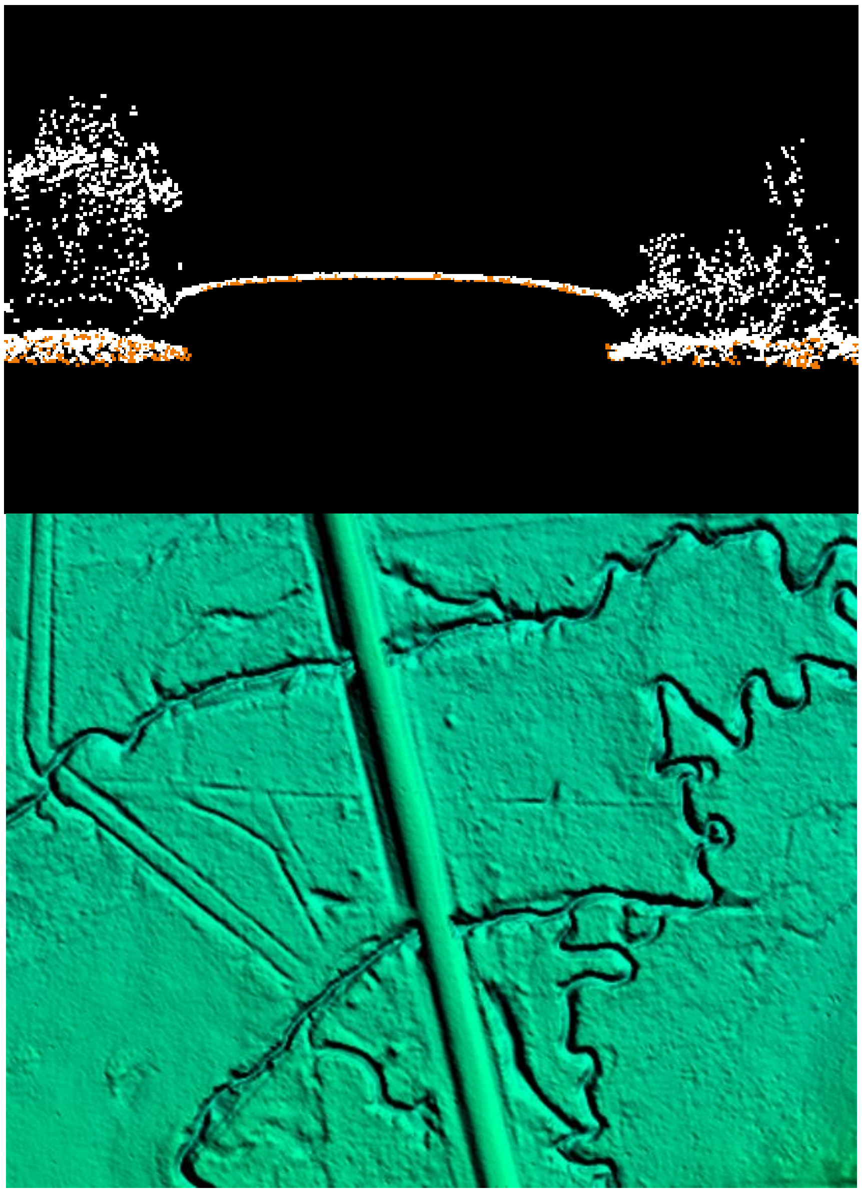


Figure 7– Tile number 15SXU150490. Profile with points colored by class (class 1=white, class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 1.

c. *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.

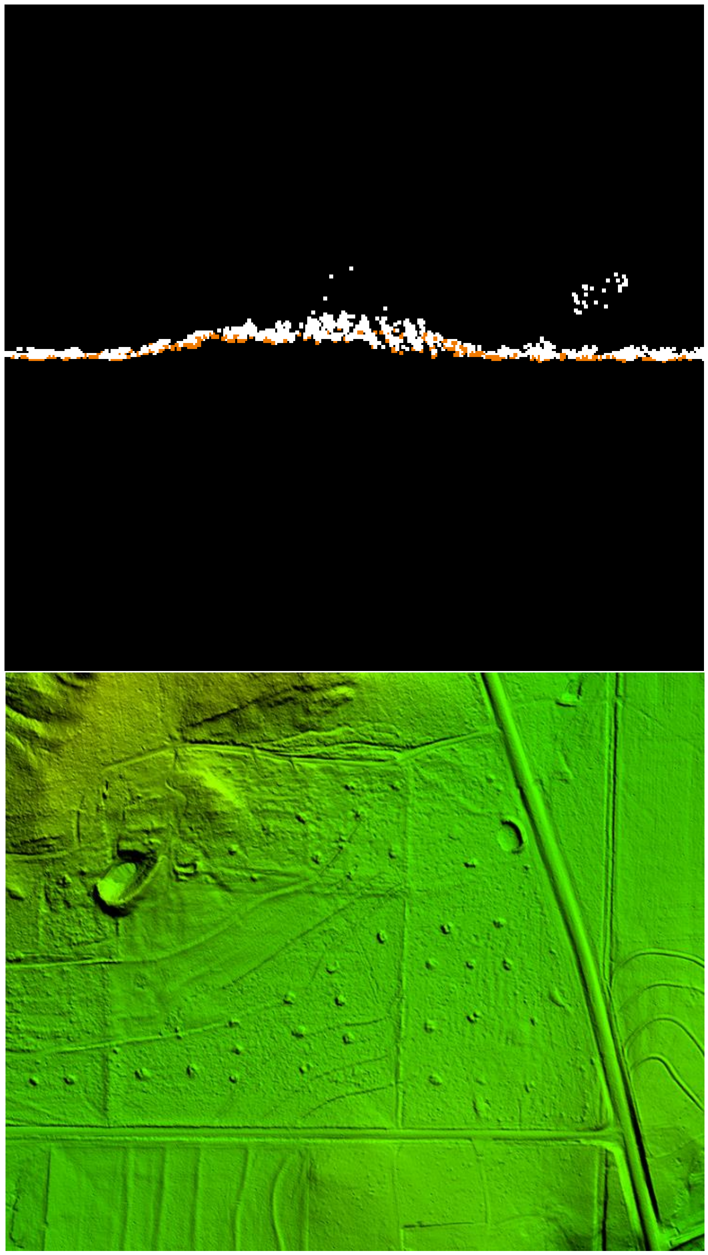


Figure 8 - Tile 14SNB760810. Profile with the points colored by class (class 1=white, class 2=orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

d. *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.

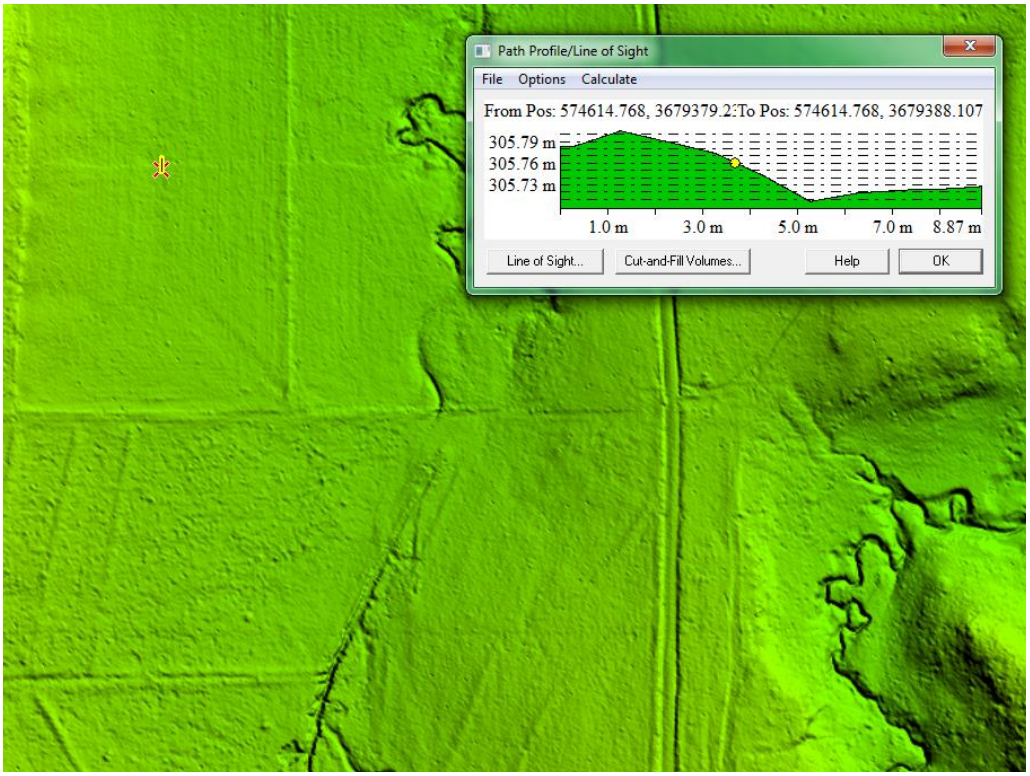


Figure 9– Tile number 14SNB745780. The flight line ridge is less than 8 cm. Overall, the Archer and Jack Counties TX LiDAR data meets the project specifications for 8 cm RMSEz relative accuracy.

Survey Vertical Accuracy Checkpoints

All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table. A total of one hundred and five (105) checkpoints were surveyed for the Archer and Jack Counties TX LiDAR Project.

Point ID	NAD83(2011) UTM Zone 14		NAVD88
	Easting X (m)	Northing Y (m)	Elevation (m)
OT-1	509250.293	3741333.014	320.086
OT-2	523709.961	3739964.981	326.251
OT-3	543163.47	3741469.43	308.646
OT-4	514631.529	3728526.744	356.516

OT-5	536319.163	3728411.377	298.546
OT-6	550815.23	3721818.047	300.369
OT-7	518273.208	3715792.265	331.864
OT-8	531634.468	3708365.373	327.737
OT-9	550384.913	3701529.345	306.691
OT-10	525232.042	3697501.213	373.035
OT-11	507144.666	3701841.976	384.759
OT-12	558559.263	3690725.992	331.456
OT-13	574224.922	3693778.308	286.655
OT-14	585984.436	3702331.226	317.387
OT-15	597256.306	3686507.759	315.448
OT-16	570419.744	3679314.473	319.772
OT-17	558690.164	3669840.457	376.148
OT-18	581356.236	3666195.668	370.894
OT-19	596583.285	3660704.458	353.719
OT-20	574234.644	3658695.697	327.75
OT-21	554424.162	3658448.376	335.708
UT-1	544150.349	3743697.233	302.209
UT-2	527885.343	3741683.935	322.045
UT-3	518749.266	3738061.082	339.404
UT-4	505373.48	3730780.075	369.807
UT-5	523629.888	3727451.941	305.851
UT-6	534807.892	3717486.384	324.436
UT-7	549043.058	3724138.407	297.81
UT-8	552068.979	3715070.148	324.403
UT-9	551382.38	3704673.529	336.865
UT-10	529092.662	3700489.409	352.821
UT-11	507777.674	3700555.839	398.49
UT-12	558584.45	3697624.323	302.741
UT-13	574652.445	3700661.112	313.913
UT-14	590899.34	3702463.076	322.617
UT-15	593410.435	3686839.454	300.784
UT-16	578537.463	3675783.482	330.121
UT-17	557920.001	3680707.799	357.567
UT-18	557489.807	3669360.3	381.724
UT-19	596753.506	3670566.596	280.709
UT-20	586910.395	3655336.119	319.689
UT-21	569651.239	3654405.31	304.1
BLT-1	562037.359	3656584.66	368.523
BLT-2	581046.989	3658871.613	344.628
BLT-3	594018.125	3665924.209	301.74
BLT-4	572307.067	3663464.814	363.011
BLT-5	557996.403	3674078.739	408.154
BLT-6	571453.78	3674477.126	349.851
BLT-7	582341.302	3679168.64	310.662
BLT-8	600257.623	3680559.297	264.99
BLT-9	597706.491	3689411.576	301.319
BLT-10	578282.145	3687318.9	284.378
BLT-11	564153.48	3691558.468	298.534
BLT-12	585622.979	3698861.84	324.677
BLT-13	535871.57	3697317.096	337.987
BLT-14	521766.673	3710933.217	340.109
BLT-15	507191.321	3708245.88	355.344

BLT-16	539817.88	3707919.841	324.218
BLT-17	535967.987	3722054.279	294.584
BLT-18	516040.639	3726806.647	351.05
BLT-19	545001.89	3735014.219	290.443
BLT-20	528992.614	3737142.015	310.291
BLT-21	515043.884	3743606.966	318.879
FO-1	594529.218	3654620.477	385.02
FO-2	585935.136	3662534.429	363.912
FO-3	565207.468	3660324.634	432.061
FO-4	555381.06	3667254.989	362.97
FO-5	570642.907	3669767.133	374.011
FO-6	594043.609	3674083.042	290.063
FO-7	584863.516	3683227.351	282.701
FO-8	562427.949	3676981.431	351.726
FO-9	575283.928	3687981.032	298.082
FO-10	590175.621	3696656.24	362.653
FO-11	579145.831	3699351.528	295.309
FO-12	562203.451	3700957.419	307.466
FO-13	550928.35	3696103.762	307.954
FO-14	521146.357	3701411.415	344.032
FO-15	512619.614	3697727.477	380.677
FO-16	507501.603	3714491.07	349.059
FO-17	546063.042	3715933.33	309.828
FO-18	509587.18	3732331.468	343.765
FO-19	528413.631	3732087.452	315.53
FO-20	541506.557	3736666.246	301.766
FO-21	519770.315	3740991.448	318.169
GWC-1	550054.712	3740557.431	296.551
GWC-2	534649.93	3737849.26	315.093
GWC-3	514789.233	3735658.885	342.223
GWC-4	517096.945	3730149.593	348.691
GWC-5	547119.692	3728297.38	293.267
GWC-6	514160.706	3714709.359	343.819
GWC-7	524079.68	3720479.28	330.986
GWC-8	536016.645	3713969.72	318.354
GWC-9	546092.705	3711893.024	312.313
GWC-10	542290.216	3701903.9	321.732
GWC-11	526076.501	3706263.649	327.508
GWC-12	513287.342	3703299.325	399.538
GWC-13	556234.176	3700657.924	312.07
GWC-14	568202.108	3700365.664	295.577
GWC-15	583459.301	3692610.305	320.747
GWC-16	589336.767	3680511.622	277.144
GWC-17	558325.956	3684420.266	334.123
GWC-18	565761.591	3669336.187	373.573
GWC-19	584521.224	3668619.624	355.81
GWC-20	578161.477	3658760.527	353.069
GWC-21	558150.101	3664653.328	366.118

Table 3: Archer and Jack Counties TX LiDAR surveyed accuracy checkpoints

LiDAR Vertical Accuracy Statistics & Analysis

BACKGROUND

Dewberry tests and reviews project data both quantitatively (for accuracy) and qualitatively (for usability).

For quantitative assessment (i.e. vertical accuracy assessment), one hundred and five (105) check points were surveyed for the project and are located within bare earth/open terrain, urban, tall weeds/crops, brush lands/tress, and forested/fully grown land cover categories. The checkpoints were surveyed for the project using RTK survey methods. 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.

VERTICAL ACCURACY TEST PROCEDURES

FVA (Fundamental Vertical Accuracy) is determined with check points located only in the open terrain (grass, dirt, sand, and/or rocks) land cover category, 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 FVA 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 Archer and Jack Counties TX LiDAR project, vertical accuracy must be 0.181 meters or less based on an $RMSE_z$ of 0.0925 meters x 1.9600.

CVA (Consolidated Vertical Accuracy) is determined with all checkpoints in all land cover categories combined where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. CVA at the 95% confidence level equals the 95^{th} percentile error for all checkpoints in all land cover categories combined. The Archer and Jack Counties TX LiDAR Project CVA standard is 0.363 meters based on the 95^{th} percentile. The CVA is accompanied by a listing of the 5% outliers that are larger than the 95^{th} percentile used to compute the CVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from CVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas CVA assumes LiDAR errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

SVA (Supplemental Vertical Accuracy) is determined for each land cover category other than open terrain. SVA at the 95% confidence level equals the 95^{th} percentile error for all checkpoints in each land cover category. The Archer and Jack Counties TX LiDAR Project SVA target is 0.363 meters based on the 95^{th} percentile. Target specifications are given for SVA's as one individual land cover category may exceed this target value as long as the overall CVA is within specified tolerances. Again, $Accuracy_z$ differs from SVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas SVA 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 4.

Quantitative Criteria	Measure of Acceptability
Fundamental Vertical Accuracy (FVA) in open terrain only using $RMSE_z$ *1.9600	0.181 meters (based on $RMSE_z$ (0.0925 meters) * 1.9600)
Consolidated Vertical Accuracy (CVA) in all land cover categories combined at the 95% confidence level	0.363 meters (based on combined 95th percentile)
Supplemental Vertical Accuracy (SVA) in each land cover category separately at the 95% confidence level	0.363 meters (based on 95th percentile for each land cover category)

Table 4 — Acceptance Criteria

VERTICAL ACCURACY TESTING STEPS

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 FVA, CVA, and SVA values.
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

The figure below shows the location of the QA/QC checkpoints within the project area.

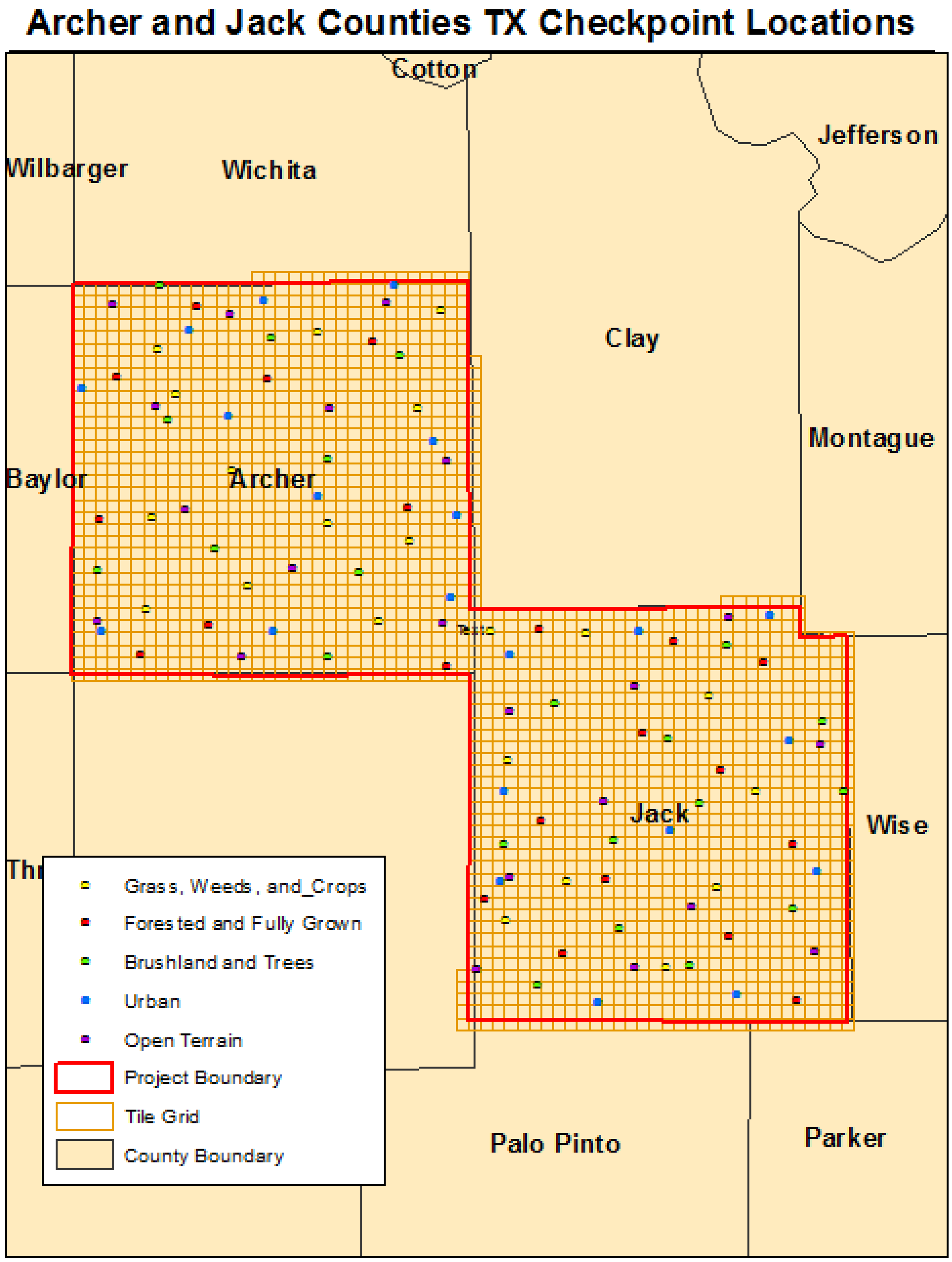


Figure 10 – Location of QA/QC Checkpoints

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	FVA — Fundamental Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.181 m	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=0.363 m	SVA — Supplemental Vertical Accuracy (95th Percentile) Target=0.363 m
Consolidated	105		0.108	
Bare Earth-Open Terrain	21	0.106		
Urban	21			0.077
Tall Weeds and Crops	21			0.090
Brush Lands and Trees	21			0.106
Forested and Fully Grown	21			0.139

Table 5 — FVA, CVA, and SVA Vertical Accuracy at 95% Confidence Level

The $RMSE_z$ for checkpoints in open terrain only tested 0.054 meters, within the target criteria of 0.0925 meters. Compared with the 0.181 meters specification, the FVA tested 0.106 meters at the 95% confidence level based on $RMSE_z$ x 1.9600.

Compared with the 0.363 meters specification, CVA for all checkpoints in all land cover categories combined tested 0.108 meters based on the 95th percentile.

Compared with the target 0.363 meters specification, SVA for checkpoints in the urban land cover category tested 0.077 meters based on the 95th percentile, checkpoints in the tall weeds and crops land cover category tested 0.090 meters based on the 95th percentile, checkpoints in the forested and fully grown land cover category tested 0.139 meters based on the 95th percentile, and checkpoints in the brush and small trees land cover category tested 0.106 meters based on 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 +/- 0.10 meters of the checkpoints elevations, but there were some outliers where LiDAR and checkpoint elevations differed by up to +0.148 meters.

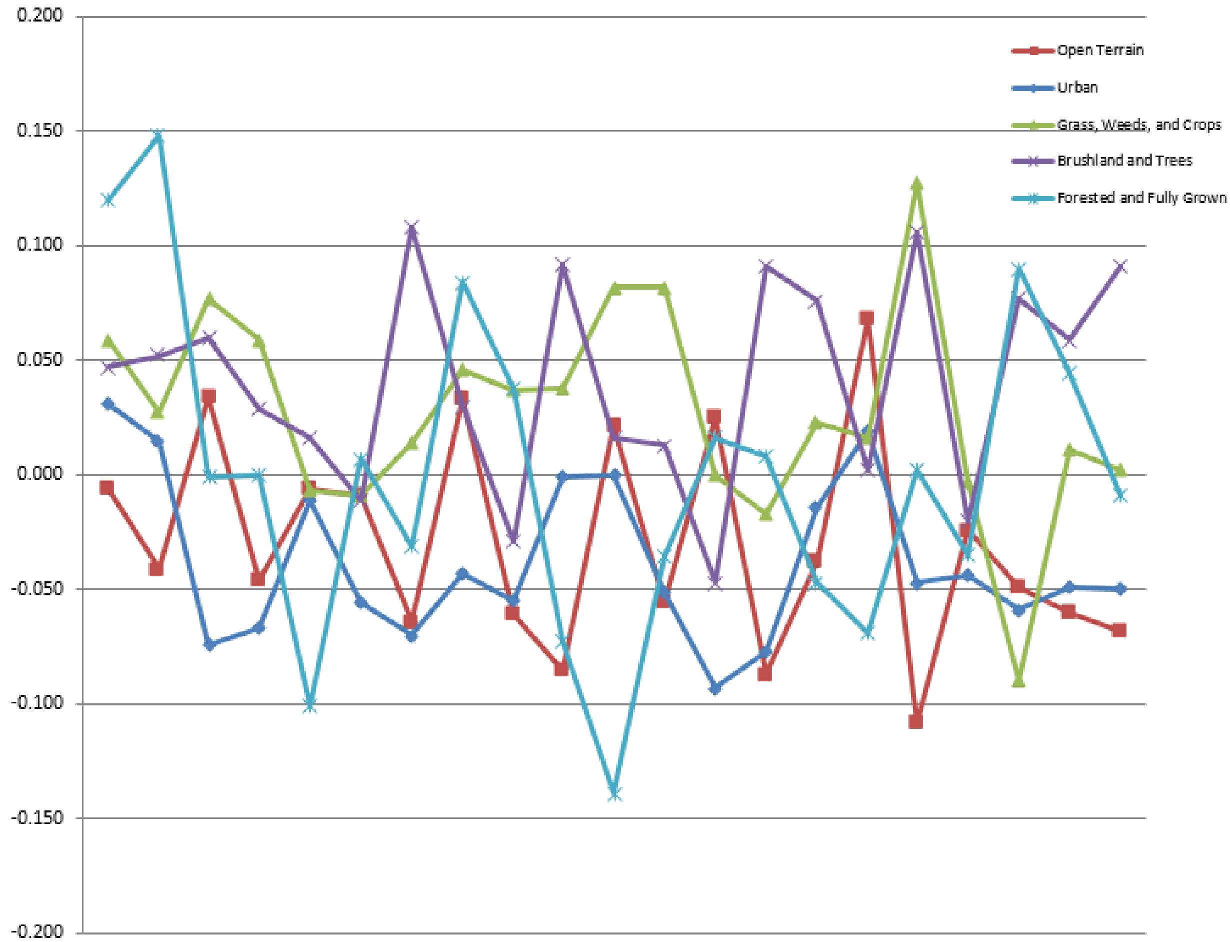


Figure 11 – Magnitude of elevation discrepancies per land cover category

Table 6 lists the 5% outliers that are larger than the 95th percentile.

Point ID	NAD83(2011) UTM Zone 14		NAVD88	LiDAR Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
FO-1	594529.218	3654620.477	385.020	385.140	0.120	0.120
FO-2	585935.136	3662534.429	363.912	364.060	0.148	0.148
FO-11	579145.831	3699351.528	295.309	295.170	-0.139	0.139
GWC-17	558325.956	3684420.266	334.123	334.250	0.127	0.127

Table 6 — 5% Outliers

Table 7 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) Open Terrain Spec=0.0925 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
Consolidated	105		0.000	0.000	0.206	0.058	-0.139	0.148
Open Terrain	21	0.054	-0.030	-0.041	0.420	0.046	-0.108	0.068
Urban	21		-0.038	-0.049	0.574	0.035	-0.093	0.031
Tall Weeds and Crops	21		0.027	0.023	-0.202	0.046	-0.090	0.127
Brush Lands and Trees	21		0.041	0.047	-0.241	0.046	-0.047	0.108
Forested and Fully Grown	21		0.001	0.000	0.240	0.071	-0.139	0.148

Table 7 — 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 -0.139 meters and a high of +0.148 meters, the histogram shows that the majority of the discrepancies are skewed on the negative side. The vast majority of points are within the ranges of -0.05 meters to +0.05 meters.

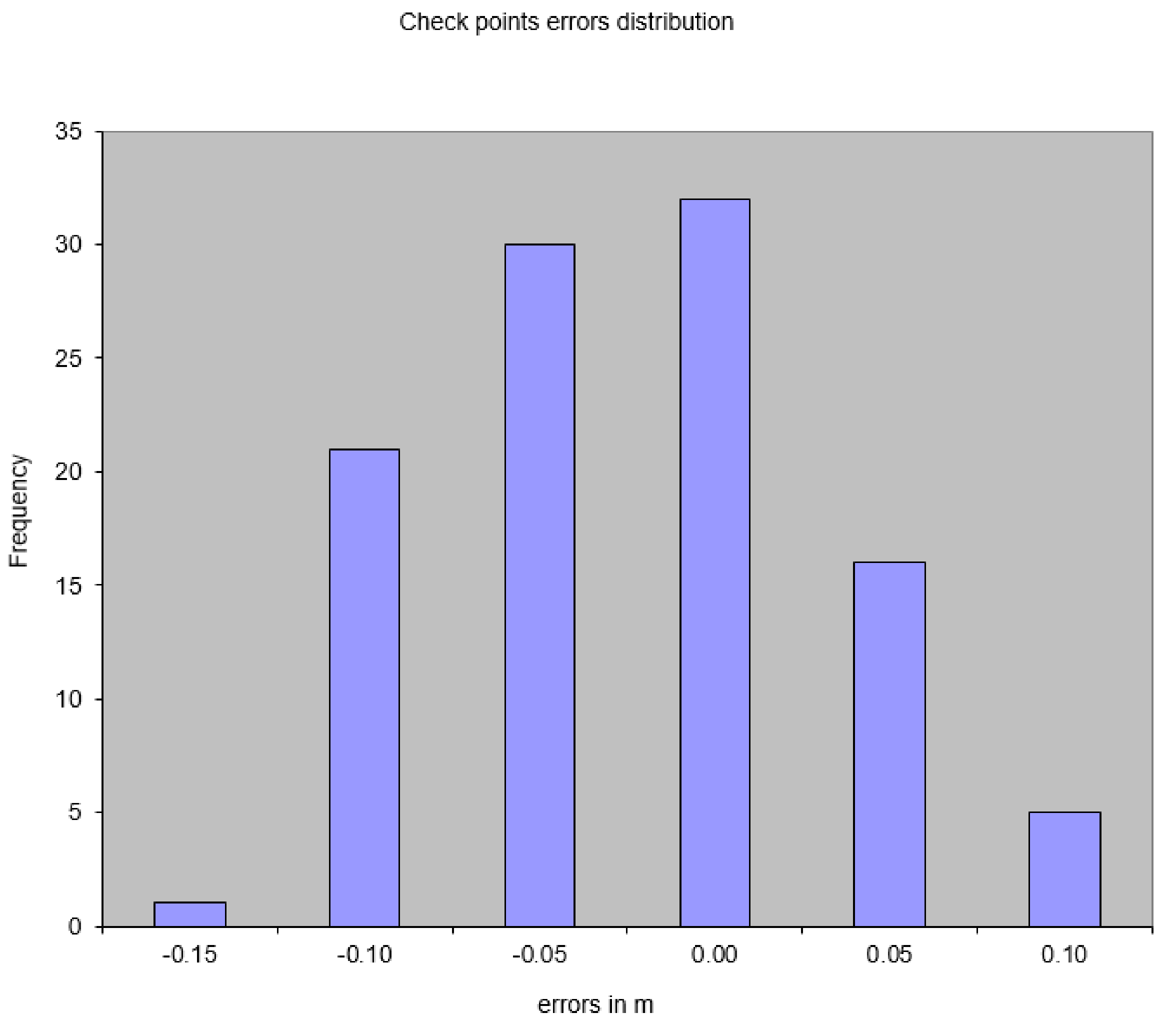


Figure 12 – Histogram of Elevation Discrepancies with errors in meters

Based on the vertical accuracy testing conducted by Dewberry, the LiDAR dataset for the Archer and Jack Counties TX LiDAR Project satisfies the project's pre-defined vertical accuracy criteria.

Breakline Production & Qualitative Assessment Report

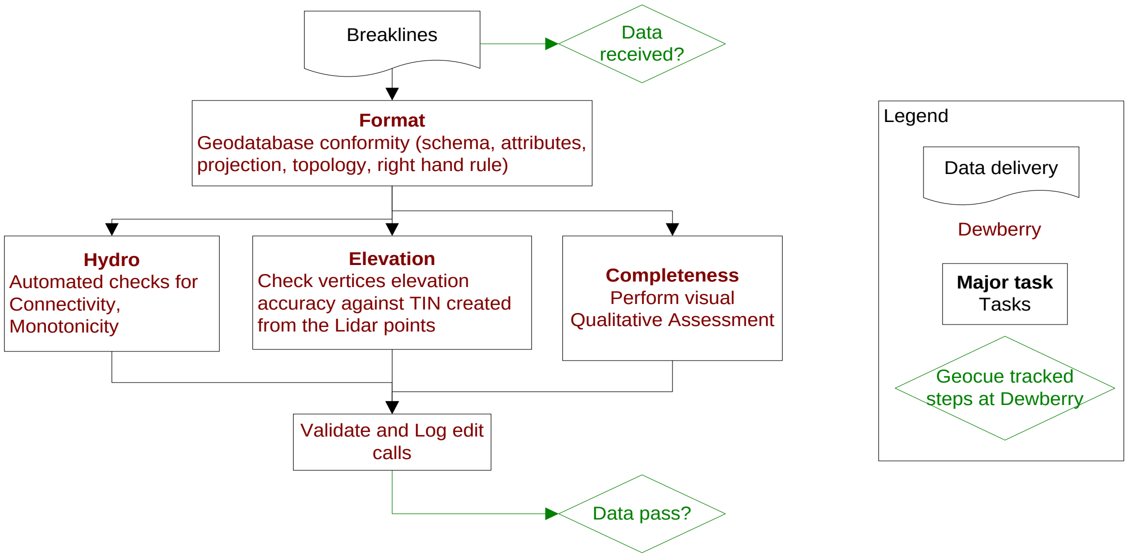
BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop LiDAR stereo models of the Archer and Jack Counties TX LiDAR 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 developed by Dewberry to stereo-compile the two types of hard breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are reviewed in stereo and the lowest elevation is applied to the entire waterbody.

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.



BREAKLINE TOPOLOGY RULES

Automated checks are applied on hydro features to validate the 3D connectivity of the feature and the monotonicity of the hydrographic breaklines. Dewberry's major concern was that the hydrographic breaklines have a continuous flow downhill and that breaklines do not undulate. Error points are generated at each vertex not complying with the tested rules and these potential edit calls are then visually validated during the visual evaluation of the data. This step also helped validate that breakline vertices did not have excessive minimum or maximum elevations and that elevations are consistent with adjacent vertex elevations.

The next step is to compare the elevation of the breakline vertices against the 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.

Dewberry's final check for the breaklines was to perform a full qualitative analysis. Dewberry compared the breaklines against LiDAR intensity images to ensure breaklines were captured in the required locations. The quality control steps taken by Dewberry are outlined in the QA Checklist below.

BREAKLINE QA/QC CHECKLIST

Project Number/Description: TO G14PD01083 Archer and Jack Counties TX LiDAR

Date:_______08/14/2015_____

Overview

☒ All Feature Classes are present in GDB

☒ All features have been loaded into the geodatabase correctly. Ensure feature classes with subtypes are domained correctly.

☒ The breakline topology inside of the geodatabase has been validated. See Data Dictionary for specific rules

☒ Projection/coordinate system of GDB is accurate with project specifications

Perform Completeness check on breaklines using either intensity or ortho imagery

☒ Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency (See Data Dictionary for specific collection rules). Features should be collected consistently across tile bounds within a dataset as well as be collected consistently between datasets.

☒ Check to make sure breaklines are compiled to correct tile grid boundary and there is full coverage without overlap

☒ Check to make sure breaklines are correctly edge-matched to adjoining datasets if applicable. Ensure breaklines from one dataset join breaklines from another dataset that are coded the same and all connecting vertices between the two datasets match in X,Y, and Z (elevation). There should be no breaklines abruptly ending at dataset boundaries and no discrepancies of Z-elevation in overlapping vertices between datasets.

Compare Breakline Z elevations to LiDAR elevations

☒ Using a terrain created from LiDAR ground points and water points, drape breaklines on terrain to compare Z values. Breakline elevations should be at or below the elevations of the immediately surrounding terrain. This should be performed before other breakline checks are completed.

Perform automated data checks using ESRI's Data Reviewer
The following data checks are performed utilizing ESRI's Data Reviewer extension. These checks allow automated validation of 100% of the data. Error records can either be written to a table for future correction, or browsed for immediate correction. Data Reviewer checks should always be performed on the full dataset.

☒ Perform "adjacent vertex elevation change check" on the Inland Ponds feature class (Elevation Difference Tolerance=.001 meters). This check will return Waterbodies whose vertices are not all identical. This tool is found under "Z Value Checks."

☒ Perform "unnecessary polygon boundaries check" on Inland Ponds and Lakes, Tidal Waters, and Islands (if delivered as a separate feature class) feature classes. This tool is found under "Topology Checks."

☒ Perform "different Z-Value at intersection check" (Inland Streams and Rivers to Inland Streams and Rivers), (Ponds and Lakes to Ponds and Lakes), (Tidal Waters to Tidal Waters), (Streams and Rivers to Ponds and Lakes), (Streams and Rivers to Tidal Waters), (Ponds and Lakes to Tidal Waters), (Island to Inland Ponds and Lakes), (Island to Tidal Waters), (Island to Island),and (Islands to Inland Streams and Rivers) (Elevation Difference Tolerance= .01 meters Minimum, 600 meters Maximum, Touches). This tool is found under "Z Value Checks." Please note that polygon feature classes will need to be converted to lines for this check.

☒ Perform "duplicate geometry check" on (Inland Streams and Rivers to Inland Streams and Rivers), (Inland Ponds and Lakes to Inland Ponds and Lakes), (Tidal Waters to Tidal Waters), (Islands to Islands-if delivered as a separate shapefile), (Inland Streams and Rivers to Inland Ponds and Lakes), (Inland Streams and Rivers to Tidal Waters), (Inland Ponds and Lakes to Tidal Waters), (Islands to Tidal Waters), and (Islands to Inland Ponds and Lakes). Attributes do not need to be checked during this tool. This tool is found under "Duplicate Geometry Checks."

☒ Perform "geometry on geometry check" (Inland Streams and Rivers to Inland Ponds and Lakes), (Inland Streams and Rivers to Tidal Waters), (Inland Ponds and Lakes to Tidal Waters), (Inland Streams and Rivers to Inland Streams and Rivers), (Inland Ponds and Lakes to Inland Ponds and Lakes), (Tidal waters to Tidal waters), (Islands to Tidal Waters), and (Islands to Inland Ponds and Lakes), (Islands to Islands). Spatial relationship is crosses, attributes do not need to be checked. This tool is found under "Feature on Feature Checks." Please note that "crosses" only works with line feature classes and not polygons. If the inputs are polygons, they will need to be converted to a line prior to running this tool.

☒ Perform "geometry on geometry check (Tidal Waters to Islands), and (Inland Ponds and Lakes to Islands), (Inland Streams and Rivers to Islands). Spatial relationship is contains, attributes do not need to be checked. This tool is found under "Feature on Feature Checks."

☒ Perform "geometry on geometry check" (Inland Streams and Rivers to Inland Ponds and Lakes), (Inland Streams and Rivers to Tidal Waters), (Inland Ponds and Lakes to Tidal Waters), (Inland Streams and Rivers to Inland Streams and Rivers), (Inland Ponds and Lakes to Inland Ponds and Lakes), (Tidal waters to Tidal waters), (Islands to Tidal Waters), and (Islands to Inland Ponds and Lakes), (Islands to Islands). Spatial relationship is intersect, attributes do not need to be checked. This tool is found under "Feature on Feature Checks." Please note that false positives may be returned with this tool but that this tool may identify issues not found with "crosses."

☒ Perform "polygon overlap/gap is sliver check" on (Tidal Waters to Tidal Waters), (Island to Island), (Island to Inland Ponds and Lakes) and (Inland Ponds and Lakes to Inland Ponds and Lakes), (Inland Ponds and Lakes to Tidal Waters). Maximum Polygon Area is not required. This tool is found under "Feature on Feature Checks."

Perform Dewberry Proprietary Tool Checks

☒ Perform monotonicity check on (Inland Streams and Rivers) and (Tidal Waters to Tidal Waters if they are not a constant elevation) using "A3_checkMonotonicityStreamLines." This tool looks at line direction as well as elevation. Features in the output shapefile attributed with a "d" are correct monotonically, but were compiled from low elevation to high elevation. These features are ok and can be ignored. Features in the output shapefile attributed with an "m" are not correct monotonically and need elevations to be corrected. Input features for this tool need to be in a geodatabase and must be a line. If features are a polygon they will need to be converted to a line feature. Z tolerance is 0.01 meters.

☒ Perform connectivity check between (Inland Streams and Rivers to Inland Streams and Rivers), (Ponds and Lakes to Ponds and Lakes), (Tidal Waters to Tidal Waters), (Streams and Rivers to Ponds and Lakes), (Streams and Rivers to Tidal Waters), (Ponds and Lakes to Tidal Waters), (Island to Inland Ponds and Lakes), (Island to Tidal Waters), (Island to Island),and (Islands to Inland Streams and Rivers) using the tool "07_CheckConnectivityForHydro." The input for this tool needs to be in a geodatabase. The output is a shapefile showing the location of overlapping vertices from the polygon features and polyline features that are at different Z-elevation.

Metadata

☒ Each XML file (1 per feature class) is error free as determined by the USGS MP tool

☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc. Content should be consistent across all feature classes.

Completion Comments: **Complete – Approved**

Data Dictionary

HORIZONTAL AND VERTICAL DATUM

The horizontal datum shall be North American Datum of 1983, Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Meters. Geoid12a 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	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity. Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 1 acre. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

INLAND PONDS AND LAKES

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

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

Description

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

Table Definition

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

Feature Definition

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

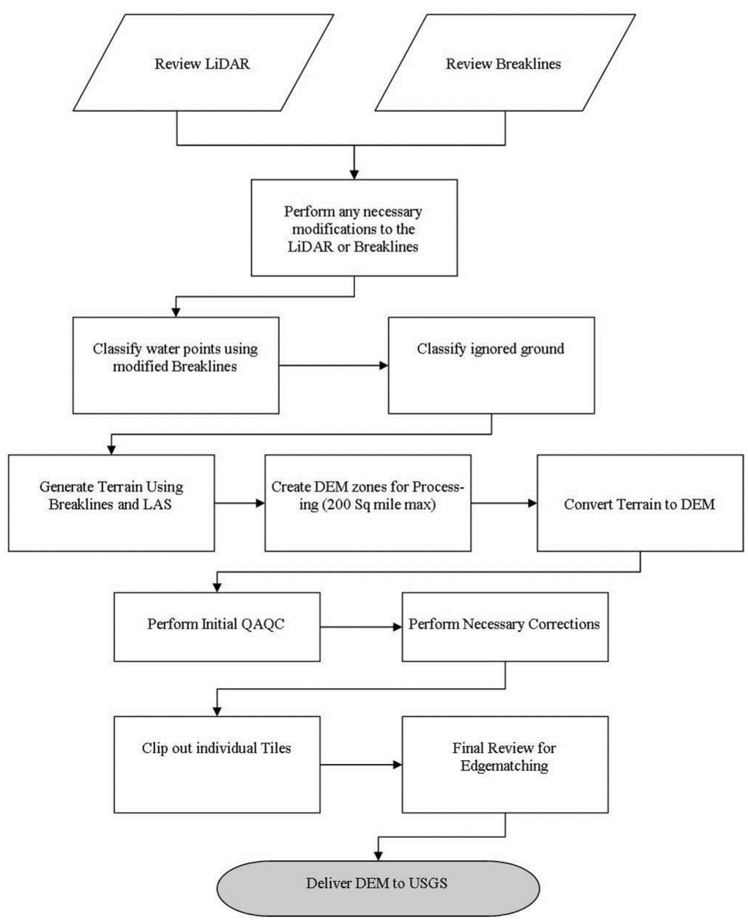
		will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

Dewberry utilized ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software is used to generate the products and the QC is performed in both ArcGIS and Global Mapper.

Dewberry Hydro-Flattening Workflow



1. <u>Classify Water Points</u>: LAS point falling within hydrographic breaklines shall be classified to ASPRS class 9 using TerraScan. Breaklines must be prepared correctly prior to performing this task.

2. Classify Ignored Ground Points: Classify points in close proximity to the breaklines from Ground to class 10 (Ignored Ground). Close proximity will be defined as no more than 1x the nominal point spacing on the landward side of the breakline.
3. Terrain Processing: A Terrain will be generated using the Breaklines and LAS data that has been imported into Arc as a Multipoint File.
4. Create DEM Zones for Processing: Create DEM Zones that are buffered around the edges. Zones should be created in a logical manner to minimize the number of zones without creating zones too large for processing. Dewberry will make zones no larger than 200 square miles (taking into account that a DEM will fill in the entire extent not just where LiDAR is present). Once the first zone is created it must be verified against the tile grid to ensure that the cells line up perfectly with the tile grid edge.
5. Convert Terrain to Raster: Convert Terrain to raster using the DEM Zones created in step 4. In the environmental properties set the extents of the raster to the buffered Zone. For each subsequent zone, the first DEM will be utilized as the snap raster to ensure that zones consistently snap to one another.
6. Perform Initial QAQC on Zones: During the initial QA process anomalies will be identified and corrective polygons will be created.
7. Correct Issues on Zones: Dewberry will perform corrections on zones following Dewberry's correction process.
8. Extract Individual Tiles: Dewberry will extract individual tiles from the zones utilizing a Dewberry proprietary tool.
9. Final QA: Final QA will be performed on the dataset to ensure that tile boundaries are seamless.

DEM QUALITATIVE ASSESSMENT

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

The image below shows an example of a bare earth DEM.

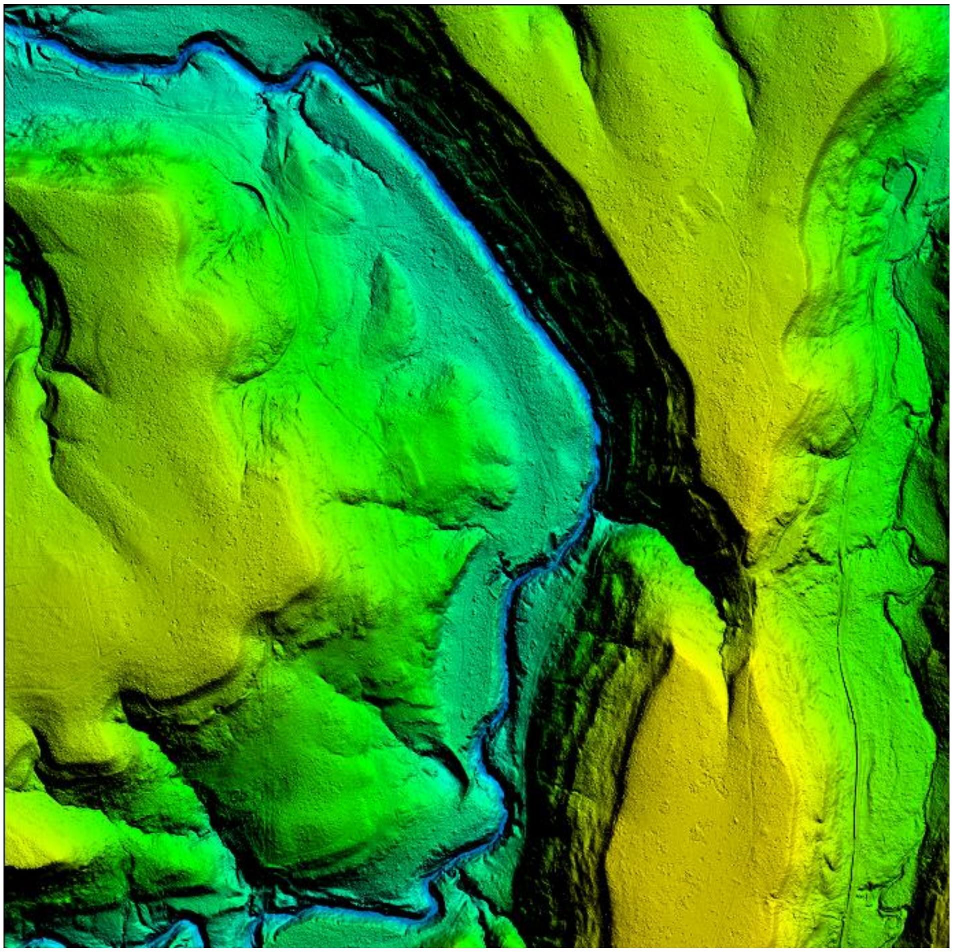


Figure 13 - Tile 14SNB910780. Bare earth DEM example.

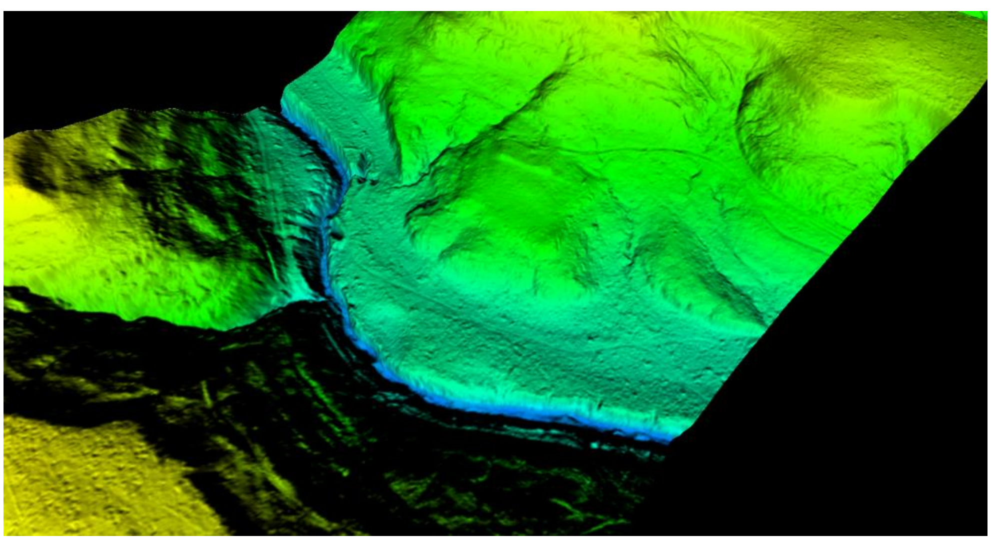


Figure 14-Tile 14SNB910780. 3D Profile view of the bare earth DEM

When some bridges are removed from the ground surface, the distance from bridge abutment to bridge abutment is small enough that the DEM interpolates acress 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.

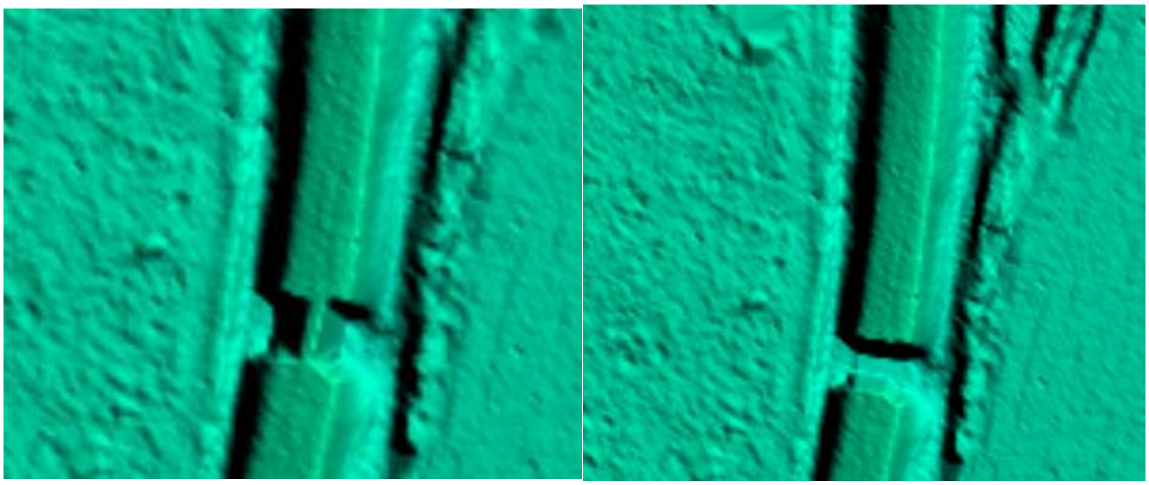


Figure 15-Tile 14SNC355245. The DEM on the left shows a bridge saddle artifact while the DEM on the right shows the same location after bridge breaklines have been enforced.

DEM VERTICAL ACCURACY RESULTS

The same 105 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.

Table 8 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	FVA — Fundamental Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.181 m	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=0.363 m	SVA — Supplemental Vertical Accuracy (95th Percentile) Target=0.363 m
Consolidated	105		0.106	
Bare Earth-Open Terrain	21	0.108		
Urban	21			0.074
Tall Weeds and Crops	21			0.100
Brush Lands and Trees	21			0.106
Forested and Fully Grown	21			0.136

Table 8 — FVA, CVA, and SVA Vertical Accuracy at 95% Confidence Level

The $RMSE_z$ for checkpoints in open terrain only tested 0.055 meters, within the target criteria of 0.0925 meters. Compared with the 0.181 meters specification, the FVA tested 0.108 meters at the 95% confidence level based on $RMSE_z$ x 1.9600.

Compared with the 0.363 meters specification, CVA for all checkpoints in all land cover categories combined tested 0.106 meters based on the 95th percentile.

Compared with the target 0.363 meters specification, SVA for checkpoints in the tall weeds and crops land cover category tested 0.100 meters based on the 95th percentile, checkpoints in the forested and fully grown land cover category tested 0.136 meters based on the 95th percentile, checkpoints in the brush and small trees land cover category tested 0.106 meters based on the 95th percentile, and checkpoints in the urban land cover category tested 0.074 meters based on the 95th percentile.

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

Point ID	NAD83 (2011) UTM Zone 14		NAVD88	DEM Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
FO-1	594529.218	3654620.477	385.020	385.142	0.122	0.122
FO-2	585935.136	3662534.429	363.912	364.061	0.149	0.149
FO-5	570642.907	3669767.133	374.011	373.904	-0.107	0.107
FO-11	579145.831	3699351.528	295.309	295.173	-0.136	0.136
GWC-17	558325.956	3684420.266	334.123	334.248	0.125	0.125

Table 9 — 5% Outliers

Table 10 provides overall descriptive statistics.

100 % of Totals	$RMSE_z$ (m) Open Terrain Spec=0.0925m	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated		0.001	0.002	0.187	0.059	105	-0.136	0.149
Open Terrain	0.055	-0.030	-0.045	0.353	0.047	21	-0.105	0.070
Urban		-0.038	-0.051	0.809	0.034	21	-0.086	0.038
Tall Weeds and Crops		0.031	0.039	-0.401	0.047	21	-0.091	0.125
Brush Lands and Trees		0.038	0.030	-0.481	0.052	21	-0.085	0.106
Forested and Fully Grown		0.004	0.005	0.153	0.072	21	-0.136	0.149

Table 10 — Overall Descriptive Statistics

DEM QA/QC CHECKLIST

Project Number/Description: TO G14PD01083 Archer and Jack Counties TX LiDAR
Date:______08/14/2015_____
Overview

☒ Correct number of files is delivered and all files are in ERDAS IMG format
☒ Verify Raster Extents
☒ Verify Projection/Coordinate System

Review

☒ Manually review bare-earth DEMs in Arc with a hillshade to check for issues with the hydro-flattening process or any general anomalies that may be present. Specifically, water should be flowing downhill, water features should NOT be floating above surrounding terrain and bridges should NOT be present in bare-earth DEM. Hydrologic breaklines should be overlaid during review of DEMs.

☒ DEM cell size is 1 meter

☒ Perform all necessary corrections in Arc using Dewberry's proprietary correction workflow.

☒ Review all corrections in Global Mapper

☒ Perform final overview on tiled data in Global Mapper to ensure seamless product.

Metadata

☒ Project level DEM metadata XML file is error free as determined by the USGS MP tool

☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc.

Completion Comments: Complete – Approved

Appendix A: Survey Report

1. INTRODUCTION

1.3 *Project Summary*

Dewberry Consultants, LLC is under contract to the USGS to provide 105 Check Points for USGS in the State of Texas. Under the above referenced USGS Task Order, Dewberry is tasked to complete the quality assurance of high resolution LiDAR-derived elevation products.

As part of this work Dewberry staff will complete checkpoint surveys that will be used to evaluate vertical accuracy on the bare-earth terrain derived from the LiDAR.

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.

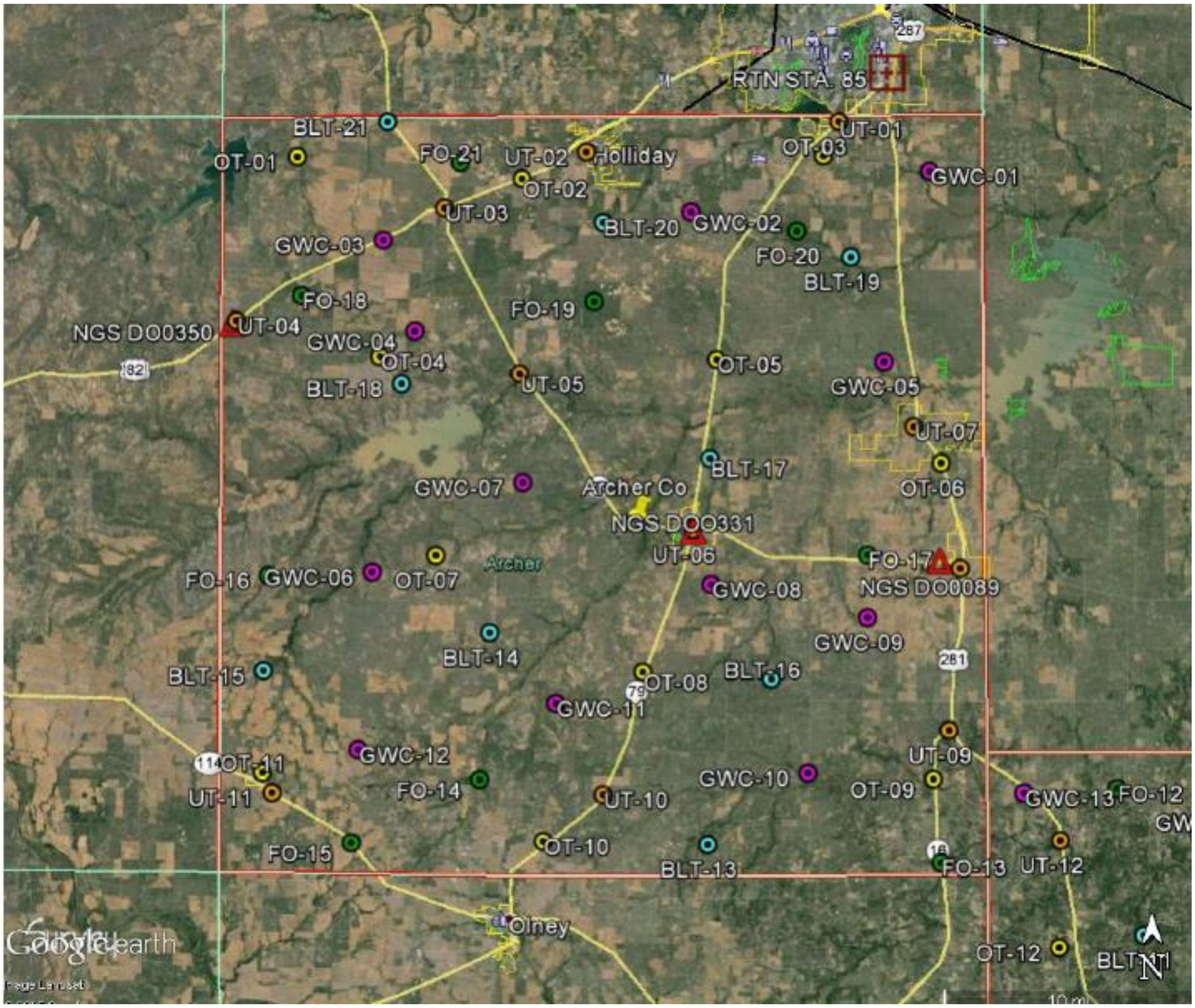
As an internal QA/QC procedure and to verify that the LiDAR Check Points meet the 95% confidence level approximately 50% of the points were re-observed and are shown in Section 5 of this report.

Final horizontal coordinates are referenced to UTM Zone 14, NAD83 in meters. Final Vertical elevations are referenced to NAVD88 in meters using Geoid model 2012A (Geoid12A).

1.2 *Points of Contact*

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

Dewberry Consultants LLC
Gary Simpson, L.S.
Senior Associate
10003 Derekwood Lane
Suite 204
Lanham, Maryland 20706
(301) 364-1855 direct
(301) 731-0188 fax


RTN STA. 85
BLT-21
UT-01
OT-03
OT-01
FO-21
UT-02
Holliday
GWC-01
OT-02
UT-03
BLT-20
GWC-02
GWC-03
FO-20
BLT-19
FO-18
FO-19
NGS DO0350
UT-04
GWC-04
OT-04
OT-05
BLT-18
UT-05
GWC-05
UT-07
BLT-17
OT-06
GWC-07
Archer Co
NGS DO0331
UT-06
FO-17
FO-16
GWC-06
OT-07
Archer
GWC-08
NGS DO0089
GWC-09
BLT-14
BLT-15
OT-08
BLT-16
GWC-11
UT-09
GWC-12
OT-11
GWC-10
OT-09
GWC-13
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OT-10
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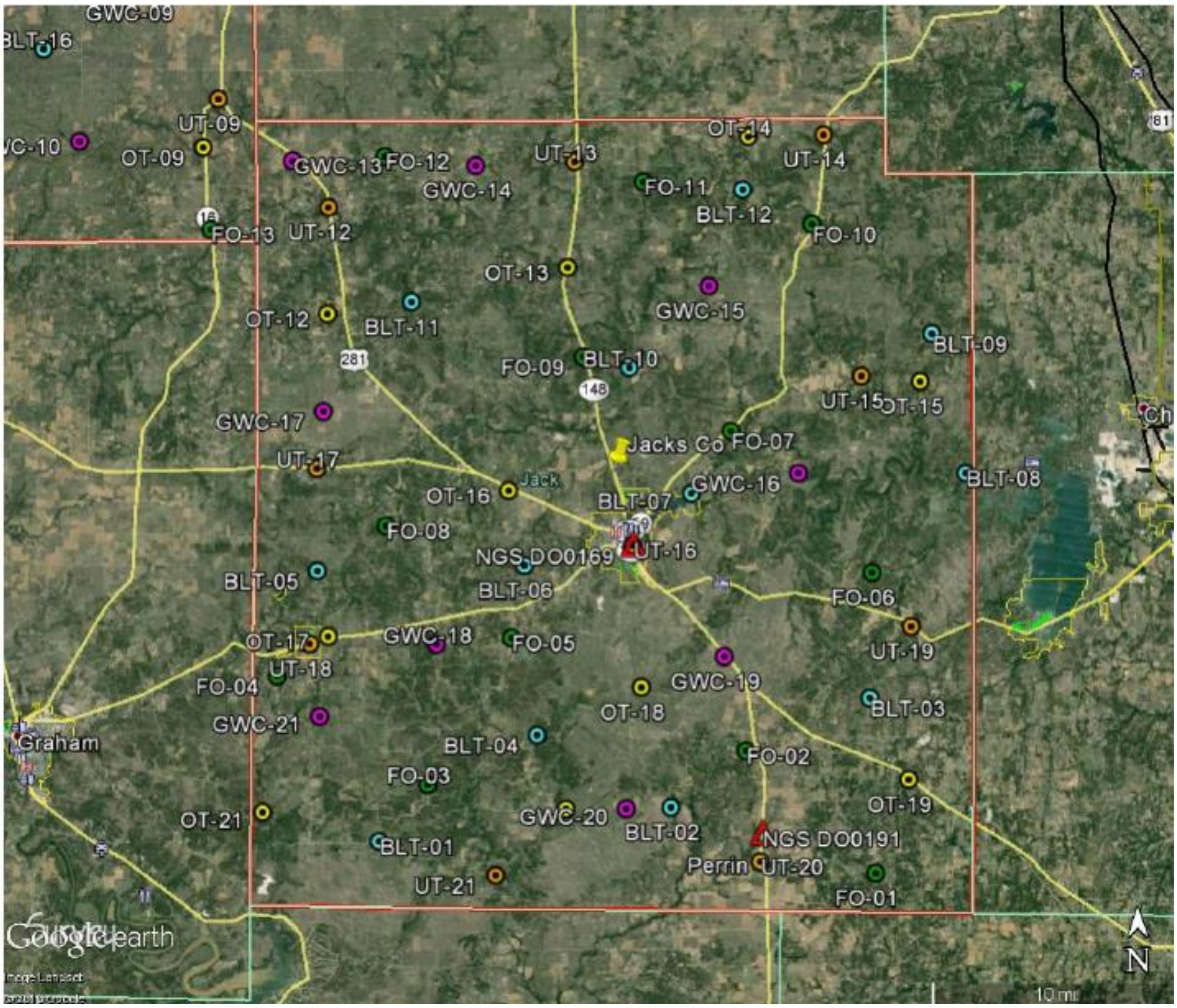
UT-12
Olney
OT-12
Google earth



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 105 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 LiDAR Check Point locations are detailed on the "Ground Control

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 (RTN) managed by Western Data Systems. 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 reobserved. All re-observations matched the initially derived station positions within the allowable tolerance of ± 5cm 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 18 and 20 minutes.

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

Three (3) existing NGS monument listed in the NSRS database were located as an additional QA/QC method to check the accuracy of the VRS network as well as being the primary project control monuments designated as PID DO0115, DO0169 and DO0418. The results are as follows:

	As Surveyed (M)			Published (M)			Differences (M)		
NGS PT. ID	Northing(M)	Easting(M)	Elev.(M)	Northing(M)	Easting(M)	Elev.(M)	Δ N	Δ E	Δ Elev.
DO 0814	3733775.470	509178.179	358.551	3733775.431	509178.137	358.5	0.039	0.042	0.051
DO 0115	3705079.450	551412.427	339.344	3705079.496	551412.381	339.298	0.046	0.046	0.046
JACKSBORO	3675761.525	578522.250	329.996	3675761.570	578522.208	329.987	0.045	0.042	0.009

The above results indicate that the VRS network is providing positional values within the

5cm parameters for this survey.

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 GPSNet 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.

3. *FINAL COORDINATES*

POINT #	NORTHING (M)	EASTING (M)	ELEV. (M)
BRUSH & LOW TREES POINTS			
BLT-1	3656584.660	562037.359	368.523
BLT-2	3658871.613	581046.989	344.628
BLT-3	3665924.209	594018.125	301.740
BLT-4	3663464.814	572307.067	363.011
BLT-5	3674078.739	557996.403	408.154
BLT-6	3674477.126	571453.780	349.851
BLT-7	3679168.640	582341.302	310.662
BLT-8	3680559.297	600257.623	264.990
BLT-9	3689411.576	597706.491	301.319
BLT-10	3687318.900	578282.145	284.378
BLT-11	3691558.468	564153.480	298.534

BLT-12	**3698861.840**	**585622.979**	**324.677**
BLT-13	**3697317.096**	**535871.570**	**337.987**
BLT-14	**3710933.217**	**521766.673**	**340.109**
BLT-15	**3708245.880**	**507191.321**	**355.344**
BLT-16	**3707919.841**	**539817.880**	**324.218**
BLT-17	**3722054.279**	**535967.987**	**294.584**
BLT-18	**3726806.647**	**516040.639**	**351.050**
BLT-19	**3735014.219**	**545001.890**	**290.443**
BLT-20	**3737142.015**	**528992.614**	**310.291**
BLT-21	**3743606.966**	**515043.884**	**318.879**
FOREST POINTS			
FO-1	**3654620.477**	**594529.218**	**385.020**
FO-2	**3662534.429**	**585935.136**	**363.912**
FO-3	**3660324.634**	**565207.468**	**432.061**
FO-4	**3667254.989**	**555381.060**	**362.970**
FO-5	**3669767.133**	**570642.907**	**374.011**
FO-6	**3674083.042**	**594043.609**	**290.063**
FO-7	**3683227.351**	**584863.516**	**282.701**
FO-8	**3676981.431**	**562427.949**	**351.726**
FO-9	**3687981.032**	**575283.928**	**298.082**
FO-10	**3696656.240**	**590175.621**	**362.653**
FO-11	**3699351.528**	**579145.831**	**295.309**
FO-12	**3700957.419**	**562203.451**	**307.466**

FO-13	**3696103.762**	**550928.350**	**307.954**
FO-14	**3701411.415**	**521146.357**	**344.032**
FO-15	**3697727.477**	**512619.614**	**380.677**
FO-16	**3714491.070**	**507501.603**	**349.059**
FO-17	**3715933.330**	**546063.042**	**309.828**
FO-18	**3732331.468**	**509587.180**	**343.765**
FO-19	**3732087.452**	**528413.631**	**315.530**
FO-20	**3736666.246**	**541506.557**	**301.766**
FO-21	**3740991.448**	**519770.315**	**318.169**
GRASS, WEEDS & CROPS POINTS			
GWC-1	**3740557.431**	**550054.712**	**296.551**
GWC-2	**3737849.260**	**534649.930**	**315.093**
GWC-3	**3735658.885**	**514789.233**	**342.223**
GWC-4	**3730149.593**	**517096.945**	**348.691**
GWC-5	**3728297.380**	**547119.692**	**293.267**
GWC-6	**3714709.359**	**514160.706**	**343.819**
GWC-7	**3720479.280**	**524079.680**	**330.986**
GWC-8	**3713969.720**	**536016.645**	**318.354**
GWC-9	**3711893.024**	**546092.705**	**312.313**
GWC-10	**3701903.900**	**542290.216**	**321.732**
GWC-11	**3706263.649**	**526076.501**	**327.508**
GWC-12	**3703299.325**	**513287.342**	**399.538**
GWC-13	**3700657.924**	**556234.176**	**312.070**
GWC-14	**3700365.664**	**568202.108**	**295.577**
GWC-15	**3692610.305**	**583459.301**	**320.747**
GWC-16	**3680511.622**	**589336.767**	**277.144**
GWC-17	**3684420.266**	**558325.956**	**334.123**
GWC-18	**3669336.187**	**565761.591**	**373.573**
GWC-19	**3668619.624**	**584521.224**	**355.810**
GWC-20	**3658760.527**	**578161.477**	**353.069**
GWC-21	**3664653.328**	**558150.101**	**366.118**
OPEN TERRAIN POINTS			
OT-1	**3741333.014**	**509250.293**	**320.086**
OT-2	**3739964.981**	**523709.961**	**326.251**
OT-3	**3741469.430**	**543163.470**	**308.646**
OT-4	**3728526.744**	**514631.529**	**356.516**
OT-5	**3728411.377**	**536319.163**	**298.546**

OT-6	**3721818.047**	**550815.230**	**300.369**
OT-7	**3715792.265**	**518273.208**	**331.864**
OT-8	**3708365.373**	**531634.468**	**327.737**
OT-9	**3701529.345**	**550384.913**	**306.691**
OT-10	**3697501.213**	**525232.042**	**373.035**
OT-11	**3701841.976**	**507144.666**	**384.759**
OT-12	**3690725.992**	**558559.263**	**331.456**
OT-13	**3693778.308**	**574224.922**	**286.655**
OT-14	**3702331.226**	**585984.436**	**317.387**
OT-15	**3686507.759**	**597256.306**	**315.448**
OT-16	**3679314.473**	**570419.744**	**319.772**
OT-17	**3669840.457**	**558690.164**	**376.148**
OT-18	**3666195.668**	**581356.236**	**370.894**
OT-19	**3660704.458**	**596583.285**	**353.719**
OT-20	**3658695.697**	**574234.644**	**327.750**
OT-21	**3658448.376**	**554424.162**	**335.708**
URBAN TERRAIN POINTS			
UT-1	**3743697.233**	**544150.349**	**302.209**
UT-2	**3741683.935**	**527885.343**	**322.045**
UT-3	**3738061.082**	**518749.266**	**339.404**
UT-4	**3730780.075**	**505373.480**	**369.807**
UT-5	**3727451.941**	**523629.888**	**305.851**
UT-6	**3717486.384**	**534807.892**	**324.436**
UT-7	**3724138.407**	**549043.058**	**297.810**
UT-8	**3715070.148**	**552068.979**	**324.403**
UT-9	**3704673.529**	**551382.380**	**336.865**
UT-10	**3700489.409**	**529092.662**	**352.821**
UT-11	**3700555.839**	**507777.674**	**398.490**
UT-12	**3697624.323**	**558584.450**	**302.741**
UT-13	**3700661.112**	**574652.445**	**313.913**
UT-14	**3702463.076**	**590899.340**	**322.617**
UT-15	**3686839.454**	**593410.435**	**300.784**
UT-16	**3675783.482**	**578537.463**	**330.121**
UT-17	**3680707.799**	**557920.001**	**357.567**
UT-18	**3669360.3**	**557489.807**	**381.724**
UT-19	**3670566.596**	**596753.506**	**280.709**
UT-20	**3655336.119**	**586910.395**	**319.689**

UT-21	3654405.31	569651.239	304.100

4. *GPS OBSERVATIONS*

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY	RE-OBSERV. DATE	RE-OBSERV. TIME
BLT-1	1/8/2015	8	9:22	N/A	N/A
BLT-2	1/7/2015	7	16:01	1/8/2015	7:06
BLT-3	1/7/2015	7	11:30	1/7/2015	19:44
BLT-4	1/7/2015	7	16:55	1/8/2015	7:29
BLT-5	1/8/2015	8	14:08	1/9/2015	5:49
BLT-6	1/7/2015	7	14:22	N/A	N/A
BLT-7	1/9/2015	9	7:51	N/A	NLA
BLT-8	1/9/2015	9	11:07	N/A	N/A
BLT-9	1/9/2015	9	10:15	N/A	N/A
BLT-10	1/9/2015	9	12:58	N/A	N/A
BLT-11	1/8/2015	8	15:42	1/10/2015	6:34
BLT-12	1/9/2015	9	16:27	N/A	N/A
BLT-13	1/10/2015	10	16:55	1/11/2015	6:39
BLT-14	1/11/2015	11	11:34	N/A	N/A
BLT-15	1/11/2015	11	9:55	N/A	N/A
BLT-16	1/10/2015	10	16:08	1/11/2015	18:44
BLT-17	1/10/2015	10	13:56	1/11/2015	19:26
BLT-18	1/11/2015	11	14:35	N/A	N/A
BLT-19	1/10/2015	10	11:41	N/A	N/A
BLT-20	1/12/2015	12	12:31	N/A	N/A
BLT-21	1/12/2015	12	9:24	N/A	N/A
FO-1	1/7/2015	7	8:59	1/7/2015	18:10
FO-2	1/7/2015	7	10:24	1/7/2015	18:53
FO-3	1/8/2015	8	9:55	1/8/2015	17:53
FO-4	1/8/2015	8	11:04	N/A	N/A
FO-5	1/7/2015	7	14:51	N/A	N/A
FO-6	1/7/2015	7	12:25	1/7/2015	20:30
FO-7	1/9/2015	9	8:23	N/A	N/A
FO-8	1/8/2015	8	13:32	1/9/2015	6:19
FO-9	1/9/2015	9	12:28	N/A	N/A
FO-10	1/9/2015	9	15:53	1/12/2015	16:47
FO-11	1/9/2015	9	14:33	N/A	N/A
FO-12	1/8/2015	8	16:34	N/A	N/A
FO-13	1/10/2015	10	8:05	N/A	N/A
FO-14	1/11/2015	11	12:47	N/A	N/A
FO-15	1/11/2015	11	8:32	N/A	N/A
FO-16	1/11/2015	11	11:23	N/A	N/A
FO-17	1/10/2015	10	14:24	1/12/2015	14:44
FO-18	1/11/2015	11	16:36	N/A	N/A
FO-19	1/12/2015	12	12:02	N/A	N/A
FO-20	1/10/2015	10	11:59	1/12/2015	6:31

FO-21	**1/12/2015**	**12**	**10:02**	**N/A**	**N/A**
GWC-1	**1/10/2015**	**10**	**13:02**	**1/12/2015**	**5:31**
GWC-2	**1/12/2015**	**12**	**12:54**	**N/A**	**N/A**
GWC-3	**1/12/2015**	**12**	**8:57**	**N/A**	**N/A**
GWC-4	**1/11/2015**	**11**	**14:56**	**N/A**	**N/A**
GWC-5	**1/10/2015**	**10**	**11:17**	**1/12/2015**	**13:23**
GWC-6	**1/11/2015**	**11**	**10:45**	**N/A**	**N/A**
GWC-7	**1/11/2015**	**11**	**13:30**	**N/A**	**N/A**
GWC-8	**1/10/2015**	**10**	**15:20**	**1/11/2015**	**17:59**
GWC-9	**1/10/2015**	**10**	**9:21**	**1/11/2015**	**18:18**
GWC-10	**1/10/2015**	**10**	**16:31**	**1/11/2015**	**7:11**
GWC-11	**1/11/2015**	**11**	**12:19**	**N/A**	**N/A**
GWC-12	**1/11/2015**	**11**	**9:12**	**N/A**	**N/A**
GWC-13	**1/8/2015**	**8**	**17:03**	**1/9/2015**	**18:20**
GWC-14	**1/9/2015**	**9**	**17:49**	**1/12/2015**	**17:49**
GWC-15	**1/9/2015**	**9**	**16:52**	**1/12/2015**	**16:24**
GWC-16	**1/12/2015**	**12**	**15:07**	**N/A**	**N/A**
GWC-17	**1/8/2015**	**8**	**14:53**	**1/10/2015**	**7:01**
GWC-18	**1/8/2015**	**8**	**12:18**	**N/A**	**N/A**
GWC-19	**1/7/2015**	**7**	**15:47**	**1/8/2015**	**5:46**
GWC-20	**1/7/2015**	**7**	**17:40**	**1/8/2015**	**6:28**
GWC-21	**1/8/2015**	**8**	**10:29**	**1/8/2014**	**18:21**
OT-1	**1/12/2015**	**12**	**10:38**	**N/A**	**N/A**
OT-2	**1/12/2015**	**12**	**8:22**	**N/A**	**N/A**
OT-3	**1/10/2015**	**10**	**12:20**	**1/12/2015**	**5:49**
OT-4	**1/11/2015**	**11**	**15:15**	**N/A**	**N/A**
OT-5	**1/10/2015**	**10**	**13:32**	**1/12/2015**	**6:58**
OT-6	**1/10/2015**	**10**	**10:38**	**1/12/2015**	**14:06**
OT-7	**1/11/2015**	**11**	**11:05**	**N/A**	**N/A**
OT-8	**1/10/2015**	**10**	**15:44**	**1/11/2015**	**7:31**
OT-9	**1/10/2015**	**10**	**8:39**	**1/10/2015**	**18:39**
OT-10	**1/10/2015**	**10**	**17:26**	**1/11/2015**	**5:49**
OT-11	**1/11/2015**	**11**	**9:34**	**N/A**	**N/A**
OT-12	**1/8/2015**	**8**	**15:14**	**1/10/2015**	**6:10**
OT-13	**1/9/2015**	**9**	**13:42**	**1/9/2015**	**19:18**
OT-14	**1/9/2015**	**9**	**15:05**	**N/A**	**N/A**
OT-15	**1/9/2015**	**9**	**9:07**	**1/12/2015**	**15:53**
OT-16	**1/8/2015**	**8**	**12:52**	**1/9/2015**	**6:49**
OT-17	**1/8/2015**	**8**	**11:45**	**1/9/2015**	**5:19**
OT-18	**1/7/2015**	**7**	**16:12**	**1/8/2015**	**6:02**
OT-19	**1/7/2015**	**7**	**10:58**	**1/7/2015**	**19:20**
OT-20	**1/7/2015**	**7**	**17:21**	**1/8/2015**	**6:49**
OT-21	**1/8/2015**	**8**	**16:01**	**N/A**	**N/A**
UT-1	**1/10/2015**	**10**	**12:37**	**1/12/2015**	**6:11**
UT-2	**1/12/2015**	**12**	**7:55**	**N/A**	**N/A**
UT-3	**1/11/2015**	**11**	**17:06**	**N/A**	**N/A**
UT-4	**1/11/2015**	**11**	**15:50**	**N/A**	**N/A**
UT-5	**1/11/2015**	**11**	**14:12**	**N/A**	**N/A**

UT-6	1/10/2015	10	14:50	N/A	N/A
UT-7	1/10/2015	10	10:58	1/12/2015	13:48
UT-8	1/10/2015	10	9:46	N/A	N/A
UT-9	1/10/2015	10	8:56	1/10/2015	19:01
UT-10	1/10/2015	10	17:50	1/11/2015	6:15
UT-11	1/11/2015	11	8:51	N/A	N/A
UT-12	1/8/2015	8	16:07	1/10/2015	5:40
UT-13	1/9/2015	9	14:02	1/9/2015	18:47
UT-14	1/9/2015	9	15:36	1/12/2015	17:19
UT-15	1/9/2015	9	8:47	1/12/2015	15:28
UT-16	1/7/2015	7	13:06	1/8/2015	5:21
UT-17	1/8/2015	8	14:32	1/10/2015	7:23
UT-18	1/8/2015	8	11:28	1/8/2015	18:43
UT-19	1/7/2015	7	11:56	1/7/2015	20:09
UT-20	1/7/2015	7	9:43	1/7/2015	18:33
UT-21	1/8/2015	8	7:50	1/8/2015	19:23

5. *POINT COMPARISON*

POINT ID	POINT CK	DELTA NORTH (M)	DELTA EAST (M)	VERT. DIFF (M)
BLT-2	BLT-2CK	0.003	0.002	0.004
BLT-3	BLT-3CK	0.002	0.003	0.001
BLT-4	BLT-4CK	0.007	0.004	0.007
BLT-5	BLT-5CK	0.001	0.008	0.016
BLT-11	BLT-11CK	0.002	0.010	0.006
BLT-13	BLT-13CK	0.004	0.003	0.012
BLT-16	BLT-16CK	0.006	0.001	0.018
BLT-17	BLT-17CK	0.001	0.002	0.004
FO-1	FO-1CK	0.012	0.004	0.003
FO-2	FO-2CK	0.001	0.012	0.006
FO-3	FO-3CK	0.009	0.008	0.007
FO-6	FO-6CK	0.004	0.001	0.021
FO-8	FO-8CK	0.002	0.011	0.018
FO-10	FO-10CK	0.000	0.003	0.004
FO-17	FO-17CK	0.004	0.001	0.002
FO-20	FO-20CK	0.007	0.002	0.016
GWC-1	GWC-1CK	0.000	0.002	0.004
GWC-5	GWC-5CK	0.011	0.001	0.007
GWC-8	GWC-8CK	0.006	0.004	0.024
GWC-9	GWC-9CK	0.005	0.003	0.012
GWC-10	GWC-10CK	0.005	0.004	0.005
GWC-13	GWC-13CK	0.002	0.001	0.018

GWC-14	**GWC-14CK**	**0.003**	**0.015**	**0.001**
GWC-15	**GWC-15CK**	**0.002**	**0.000**	**0.008**
GWC-17	**GWC-17CK**	**0.003**	**0.007**	**0.006**
GWC-19	**GWC-19CK**	**0.009**	**0.005**	**0.002**
GWC-20	**GWC-20CK**	**0.003**	**0.003**	**0.001**
GWC-21	**GWC-21CK**	**0.002**	**0.002**	**0.001**
OT-3	**OT-3CK**	**0.005**	**0.002**	**0.011**
OT-5	**OT-5CK**	**0.001**	**0.003**	**0.018**
OT-6	**OT-6CK**	**0.001**	**0.001**	**0.017**
OT-8	**OT-8CK**	**0.000**	**0.002**	**0.004**
OT-9	**OT-9CK**	**0.001**	**0.004**	**0.012**
OT-10	**OT-10CK**	**0.001**	**0.003**	**0.014**
OT-12	**OT-12CK**	**0.002**	**0.006**	**0.010**
OT-13	**OT-13CK**	**0.005**	**0.009**	**0.002**
OT-15	**OT-15CK**	**0.003**	**0.009**	**0.003**
OT-16	**OT-16CK**	**0.005**	**0.005**	**0.007**
OT-17	**OT-17CK**	**0.006**	**0.007**	**0.019**
OT-18	**OT-18CK**	**0.001**	**0.004**	**0.005**
OT-19	**OT-19CK**	**0.007**	**0.005**	**0.005**
OT-20	**OT-20CK**	**0.006**	**0.005**	**0.006**
UT-1	**UT-1CK**	**0.004**	**0.001**	**0.003**
UT-7	**UT-7CK**	**0.003**	**0.002**	**0.005**
UT-9	**UT-9CK**	**0.008**	**0.018**	**0.010**
UT-10	**UT-10CK**	**0.001**	**0.001**	**0.008**
UT-12	**UT-12CK**	**0.002**	**0.002**	**0.004**
UT-13	**UT-13CK**	**0.005**	**0.003**	**0.007**
UT-14	**UT-14CK**	**0.000**	**0.004**	**0.003**
UT-15	**UT-15CK**	**0.003**	**0.000**	**0.008**
UT-16	**UT-16CK**	**0.002**	**0.005**	**0.010**
UT-17	**UT-17CK**	**0.000**	**0.004**	**0.001**
UT-18	**UT-18CK**	**0.004**	**0.002**	**0.001**
UT-19	**UT-19CK**	**0.010**	**0.002**	**0.001**
UT-20	**UT-20CK**	**0.002**	**0.000**	**0.003**
UT-21	**UT-21CK**	**0.010**	**0.006**	**0.012**

Appendix B: Complete List of Delivered Tiles

14SNB520510	14SNC205275	14SNC190110	14SPB000975	14SNB700855	14SNB835675
14SNB535510	14SNC220275	14SNC205110	14SNB040990	14SNB715855	14SNB850675
14SNB550510	14SNC235275	14SNC220110	14SNB055990	14SNB730855	14SNB865675
14SNB565510	14SNC250275	14SNC235110	14SNB070990	14SNB745855	14SNB880675
14SNB580510	14SNC265275	14SNC250110	14SNB085990	14SNB760855	14SNB895675
14SNB595510	14SNC280275	14SNC265110	14SNB100990	14SNB775855	14SNB910675
14SNB610510	14SNC295275	14SNC280110	14SNB115990	14SNB790855	14SNB925675
14SNB625510	14SNC310275	14SNC295110	14SNB130990	14SNB805855	14SNB940675
14SNB640510	14SNC325275	14SNC310110	14SNB145990	14SNB820855	14SNB955675
14SNB655510	14SNC340275	14SNC325110	14SNB160990	14SNB835855	14SNB970675
14SNB670510	14SNC355275	14SNC340110	14SNB175990	14SNB850855	14SNB985675
14SNB685510	14SNC370275	14SNC355110	14SNB190990	14SNB865855	14SPB000675
14SNB700510	14SNC385275	14SNC370110	14SNB205990	14SNB880855	14SNB535690
14SNB715510	14SNC400275	14SNC385110	14SNB220990	14SNB895855	14SNB550690
14SNB730510	14SNC415275	14SNC400110	14SNB235990	14SNB910855	14SNB565690
14SNB745510	14SNC430275	14SNC415110	14SNB250990	14SNB925855	14SNB580690
14SNB760510	14SNC445275	14SNC430110	14SNB265990	14SNB940855	14SNB595690
14SNB775510	14SNC460275	14SNC445110	14SNB280990	14SNB955855	14SNB610690
14SNB790510	14SNC475275	14SNC460110	14SNB295990	14SNB970855	14SNB625690
14SNB805510	14SNC490275	14SNC475110	14SNB310990	14SNB985855	14SNB640690
14SNB820510	14SNC505275	14SNC490110	14SNB325990	14SPB000855	14SNB655690
14SNB835510	14SNC520275	14SNC505110	14SNB340990	14SNB535870	14SNB670690
14SNB850510	14SNC535275	14SNC520110	14SNB355990	14SNB550870	14SNB685690
14SNB865510	14SNC040290	14SNC535110	14SNB370990	14SNB565870	14SNB700690
14SNB880510	14SNC055290	14SNC040125	14SNB385990	14SNB580870	14SNB715690
14SNB895510	14SNC070290	14SNC055125	14SNB400990	14SNB595870	14SNB730690
14SNB910510	14SNC085290	14SNC070125	14SNB415990	14SNB610870	14SNB745690
14SNB925510	14SNC100290	14SNC085125	14SNB430990	14SNB625870	14SNB760690
14SNB940510	14SNC115290	14SNC100125	14SNB445990	14SNB640870	14SNB775690
14SNB955510	14SNC130290	14SNC115125	14SNB460990	14SNB655870	14SNB790690
14SNB970510	14SNC145290	14SNC130125	14SNB475990	14SNB670870	14SNB805690
14SNB985510	14SNC160290	14SNC145125	14SNB490990	14SNB685870	14SNB820690
14SPB000510	14SNC175290	14SNC160125	14SNB505990	14SNB700870	14SNB835690
14SNB520525	14SNC190290	14SNC175125	14SNB520990	14SNB715870	14SNB850690
14SNB535525	14SNC205290	14SNC190125	14SNB535990	14SNB730870	14SNB865690
14SNB550525	14SNC220290	14SNC205125	14SNB550990	14SNB745870	14SNB880690
14SNB565525	14SNC235290	14SNC220125	14SNB565990	14SNB760870	14SNB895690
14SNB580525	14SNC250290	14SNC235125	14SNB580990	14SNB775870	14SNB910690
14SNB595525	14SNC265290	14SNC250125	14SNB595990	14SNB790870	14SNB925690
14SNB610525	14SNC280290	14SNC265125	14SNB610990	14SNB805870	14SNB940690
14SNB625525	14SNC295290	14SNC280125	14SNB625990	14SNB820870	14SNB955690

14SNB640525	14SNC310290	14SNC295125	14SNB640990	14SNB835870	14SNB970690
14SNB655525	14SNC325290	14SNC310125	14SNB655990	14SNB850870	14SNB985690
14SNB670525	14SNC340290	14SNC325125	14SNB670990	14SNB865870	14SPB000690
14SNB685525	14SNC355290	14SNC340125	14SNB685990	14SNB880870	14SNB535705
14SNB700525	14SNC370290	14SNC355125	14SNB700990	14SNB895870	14SNB550705
14SNB715525	14SNC385290	14SNC370125	14SNB715990	14SNB910870	14SNB565705
14SNB730525	14SNC400290	14SNC385125	14SNB730990	14SNB925870	14SNB580705
14SNB745525	14SNC415290	14SNC400125	14SNB745990	14SNB940870	14SNB595705
14SNB760525	14SNC430290	14SNC415125	14SNB760990	14SNB955870	14SNB610705
14SNB775525	14SNC445290	14SNC430125	14SNB775990	14SNB970870	14SNB625705
14SNB790525	14SNC460290	14SNC445125	14SNB790990	14SNB985870	14SNB640705
14SNB805525	14SNC475290	14SNC460125	14SNB805990	14SPB000870	14SNB655705
14SNB820525	14SNC490290	14SNC475125	14SNB820990	14SNB535885	14SNB670705
14SNB835525	14SNC505290	14SNC490125	14SNB835990	14SNB550885	14SNB685705
14SNB850525	14SNC520290	14SNC505125	14SNB850990	14SNB565885	14SNB700705
14SNB865525	14SNC535290	14SNC520125	14SNB865990	14SNB580885	14SNB715705
14SNB880525	14SNC040305	14SNC535125	14SNB880990	14SNB595885	14SNB730705
14SNB895525	14SNC055305	14SNC040140	14SNB895990	14SNB610885	14SNB745705
14SNB910525	14SNC070305	14SNC055140	14SNB910990	14SNB625885	14SNB760705
14SNB925525	14SNC085305	14SNC070140	14SNB925990	14SNB640885	14SNB775705
14SNB940525	14SNC100305	14SNC085140	14SNB940990	14SNB655885	14SNB790705
14SNB955525	14SNC115305	14SNC100140	14SNB955990	14SNB670885	14SNB805705
14SNB970525	14SNC130305	14SNC115140	14SNB970990	14SNB685885	14SNB820705
14SNB985525	14SNC145305	14SNC130140	14SNB985990	14SNB700885	14SNB835705
14SPB000525	14SNC160305	14SNC145140	14SPB000990	14SNB715885	14SNB850705
14SNB520540	14SNC175305	14SNC160140	14SNC040005	14SNB730885	14SNB865705
14SNB535540	14SNC190305	14SNC175140	14SNC055005	14SNB745885	14SNB880705
14SNB550540	14SNC205305	14SNC190140	14SNC070005	14SNB760885	14SNB895705
14SNB565540	14SNC220305	14SNC205140	14SNC085005	14SNB775885	14SNB910705
14SNB580540	14SNC235305	14SNC220140	14SNC100005	14SNB790885	14SNB925705
14SNB595540	14SNC250305	14SNC235140	14SNC115005	14SNB805885	14SNB940705
14SNB610540	14SNC265305	14SNC250140	14SNC130005	14SNB820885	14SNB955705
14SNB625540	14SNC280305	14SNC265140	14SNC145005	14SNB835885	14SNB970705
14SNB640540	14SNC295305	14SNC280140	14SNC160005	14SNB850885	14SNB985705
14SNB655540	14SNC310305	14SNC295140	14SNC175005	14SNB865885	14SPB000705
14SNB670540	14SNC325305	14SNC310140	14SNC190005	14SNB880885	14SNB535720
14SNB685540	14SNC340305	14SNC325140	14SNC205005	14SNB895885	14SNB550720
14SNB700540	14SNC355305	14SNC340140	14SNC220005	14SNB910885	14SNB565720
14SNB715540	14SNC370305	14SNC355140	14SNC235005	14SNB925885	14SNB580720
14SNB730540	14SNC385305	14SNC370140	14SNC250005	14SNB940885	14SNB595720
14SNB745540	14SNC400305	14SNC385140	14SNC265005	14SNB955885	14SNB610720
14SNB760540	14SNC415305	14SNC400140	14SNC280005	14SNB970885	14SNB625720

14SNB775540	14SNC430305	14SNC415140	14SNC295005	14SNB985885	14SNB640720
14SNB790540	14SNC445305	14SNC430140	14SNC310005	14SPB000885	14SNB655720
14SNB805540	14SNC460305	14SNC445140	14SNC325005	14SNB535900	14SNB670720
14SNB820540	14SNC475305	14SNC460140	14SNC340005	14SNB550900	14SNB685720
14SNB835540	14SNC490305	14SNC475140	14SNC355005	14SNB565900	14SNB700720
14SNB850540	14SNC505305	14SNC490140	14SNC370005	14SNB580900	14SNB715720
14SNB865540	14SNC520305	14SNC505140	14SNC385005	14SNB595900	14SNB730720
14SNB880540	14SNC535305	14SNC520140	14SNC400005	14SNB610900	14SNB745720
14SNB895540	14SNC040320	14SNC535140	14SNC415005	14SNB625900	14SNB760720
14SNB910540	14SNC055320	14SNC040155	14SNC430005	14SNB640900	14SNB775720
14SNB925540	14SNC070320	14SNC055155	14SNC445005	14SNB655900	14SNB790720
14SNB940540	14SNC085320	14SNC070155	14SNC460005	14SNB670900	14SNB805720
14SNB955540	14SNC100320	14SNC085155	14SNC475005	14SNB685900	14SNB820720
14SNB970540	14SNC115320	14SNC100155	14SNC490005	14SNB700900	14SNB835720
14SNB985540	14SNC130320	14SNC115155	14SNC505005	14SNB715900	14SNB850720
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14SNB625645	14SNC160410	14SNC085245	14SNC070080	14SNB835960	14SPB000810
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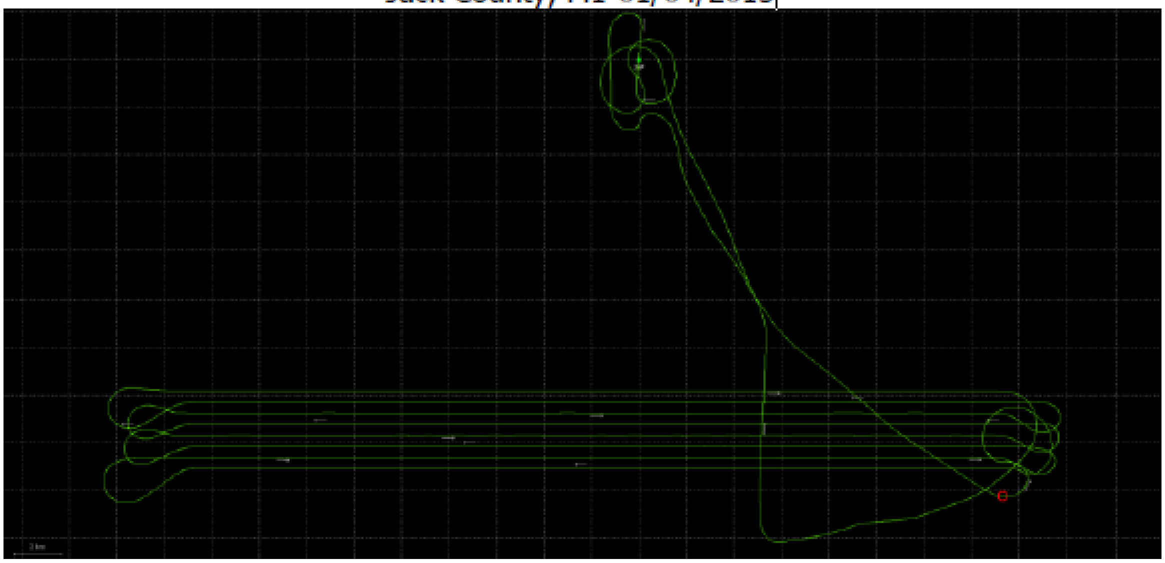
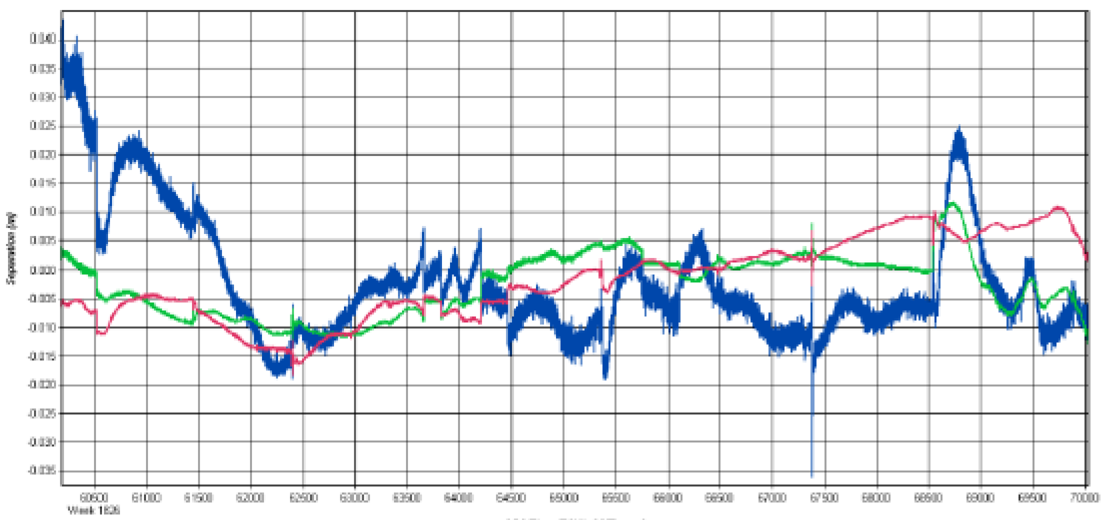
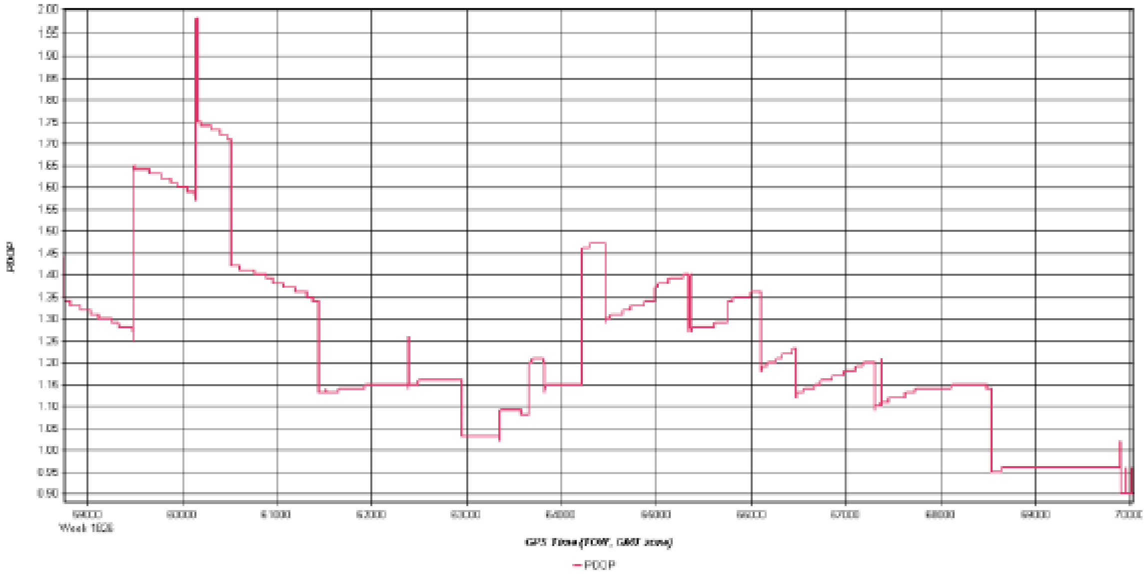
Appendix C: GPS Processing Reports for Each Mission

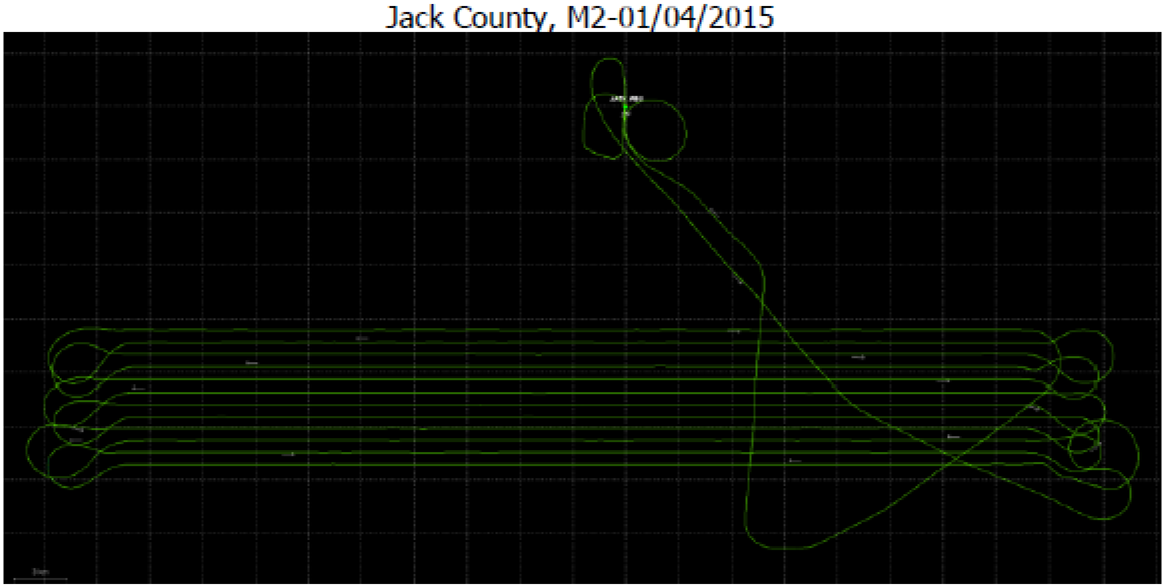
Jack County, M1-01/04/2015

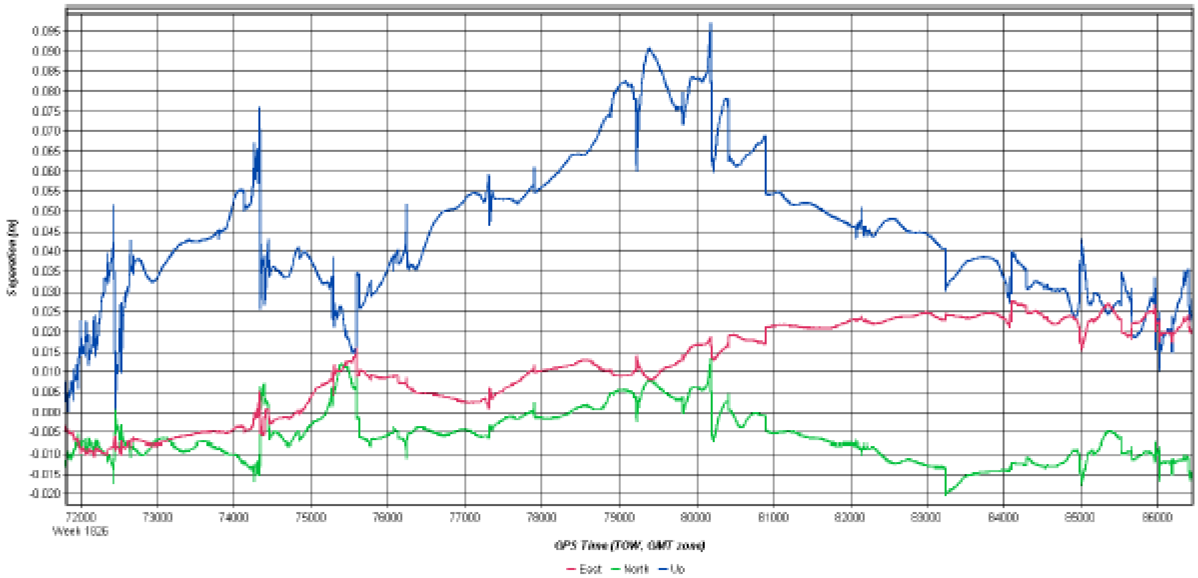


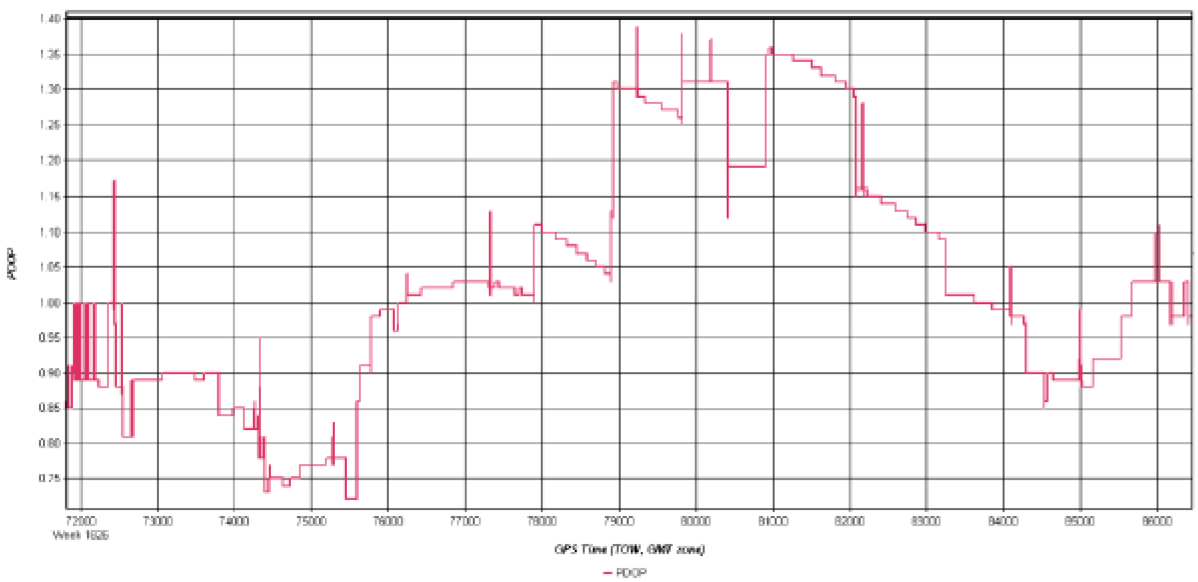




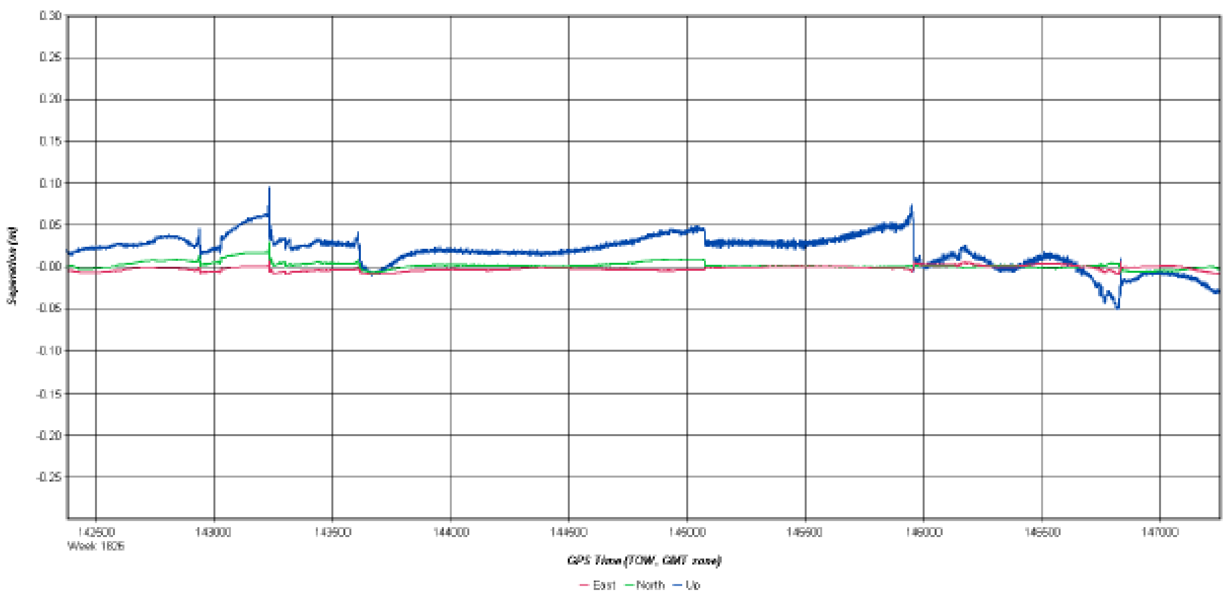
Jack County, M2-01/04/2015

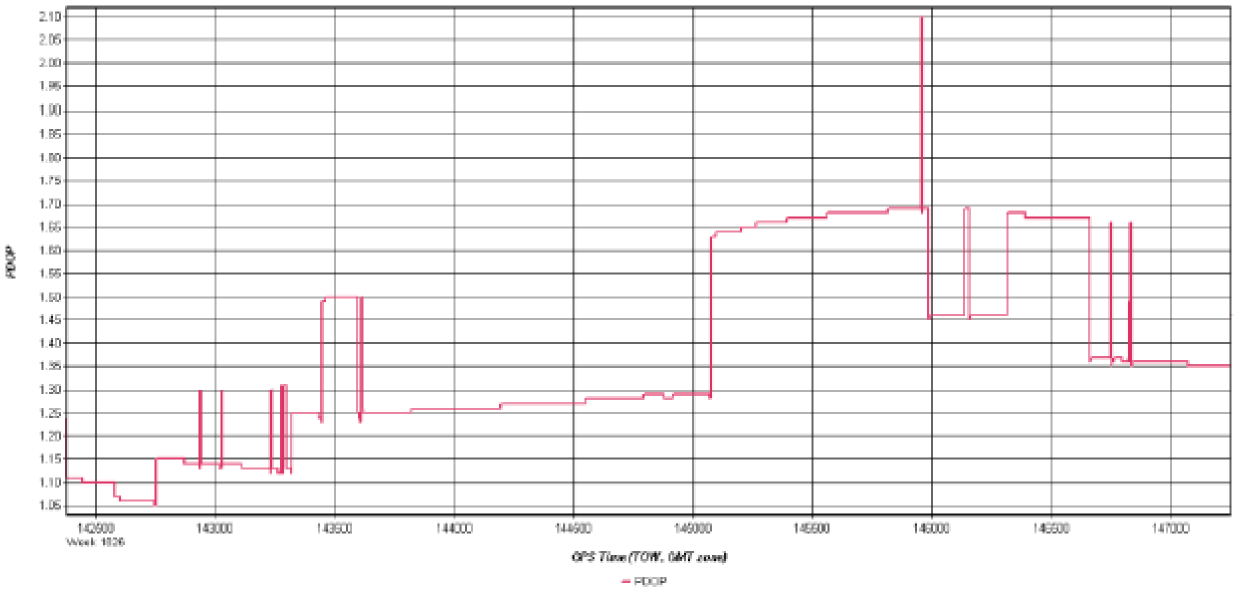



Separation (m)
GPS Time (TOW, GMT zone)
Week 1826
East
North
Up

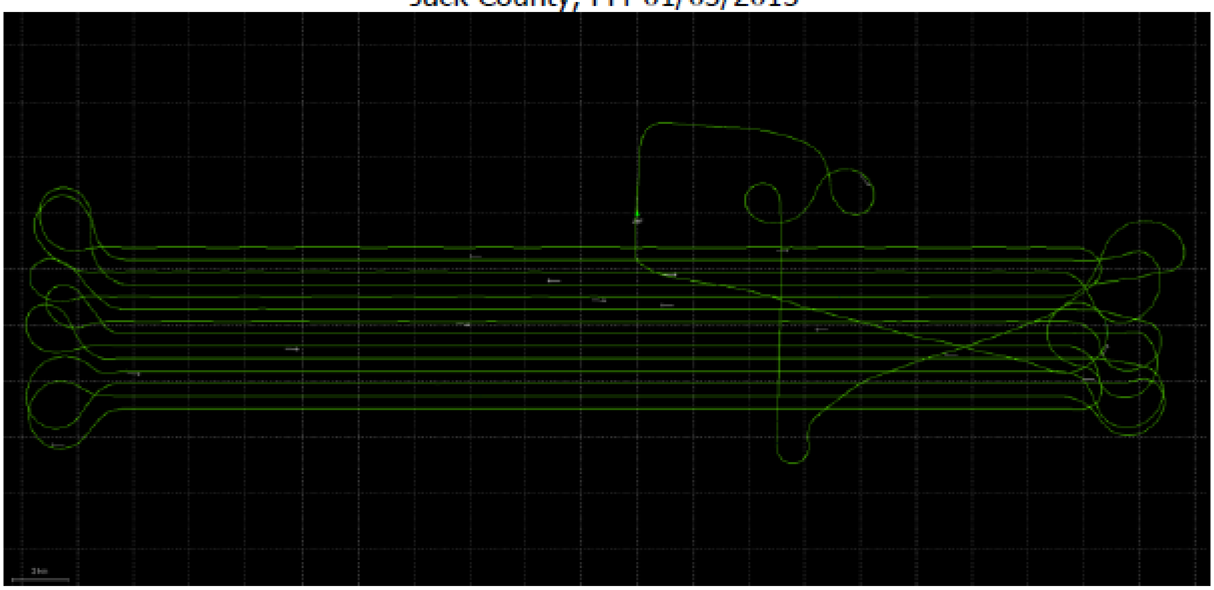

PDOP
GPS Time (TOW, GMT zone)
Week 1826
PDOP

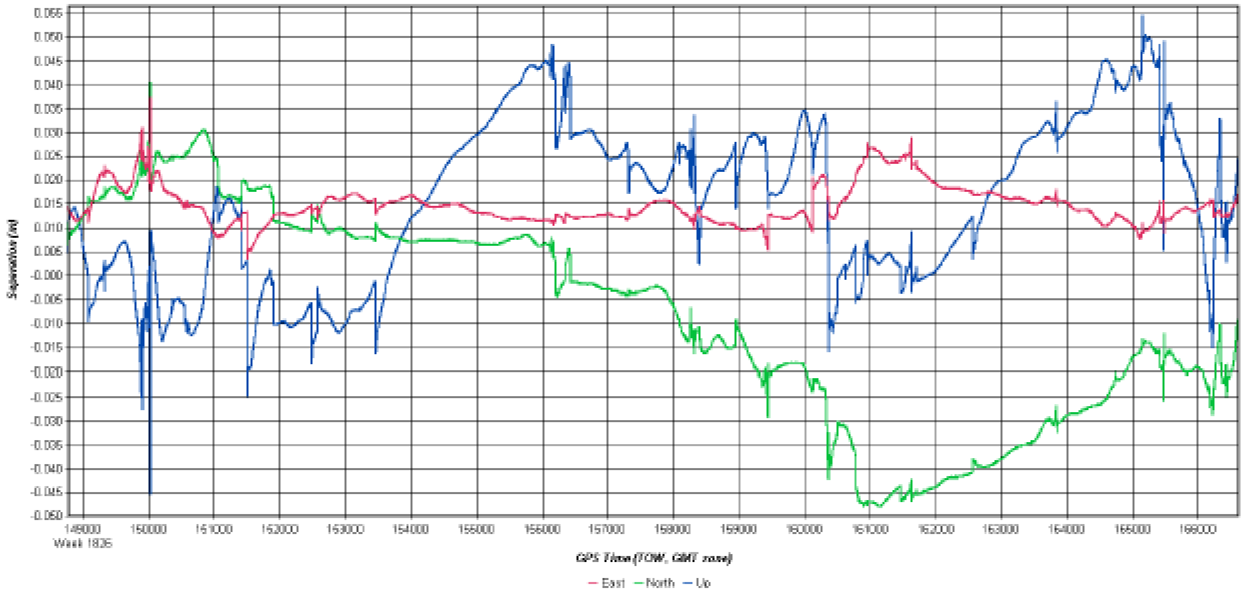
Jack County, M3-01/05/2015

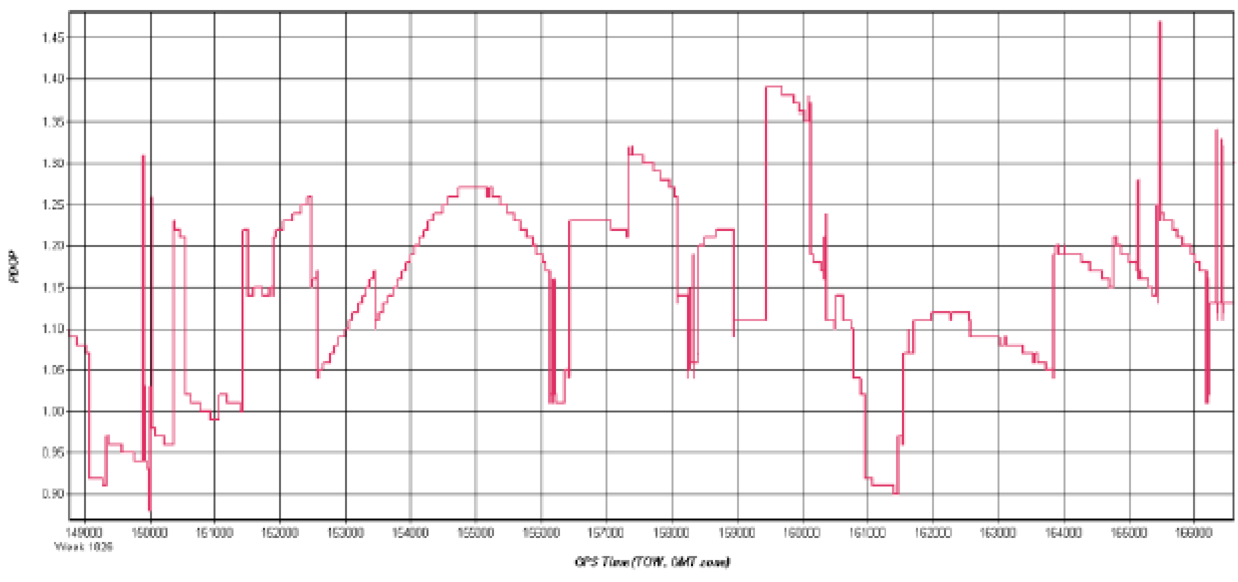




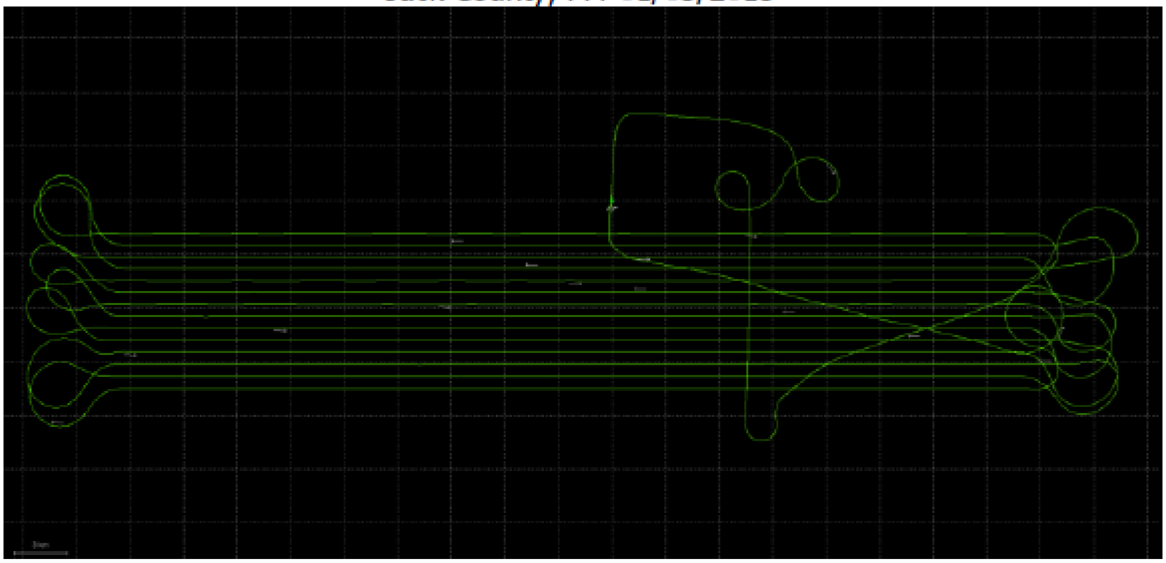
Jack County, M4-01/05/2015

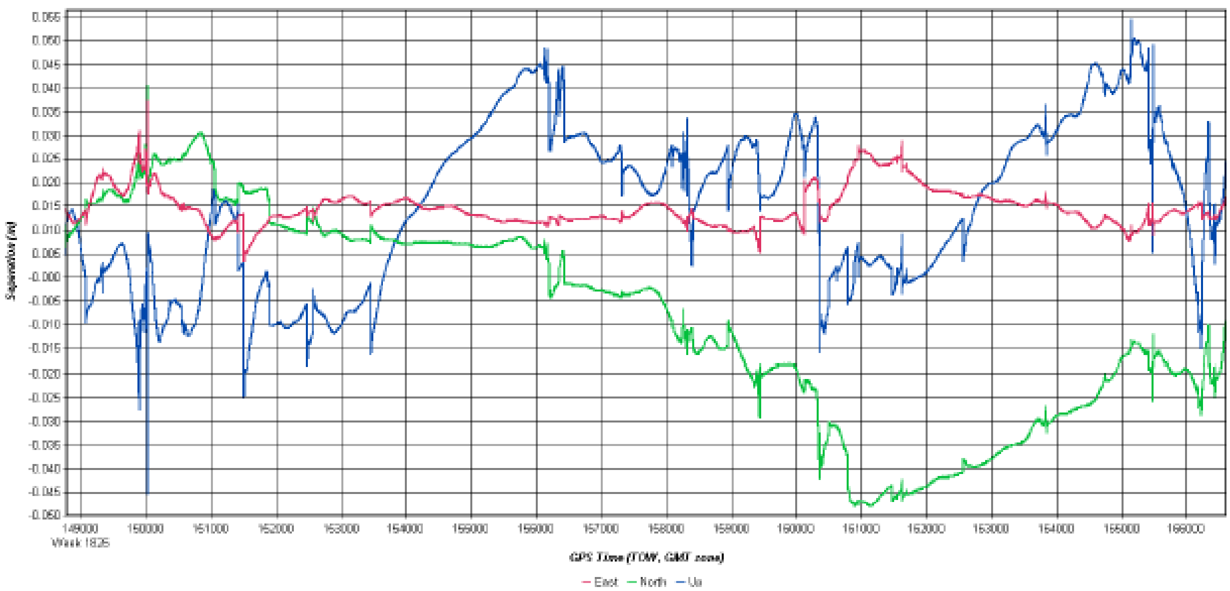


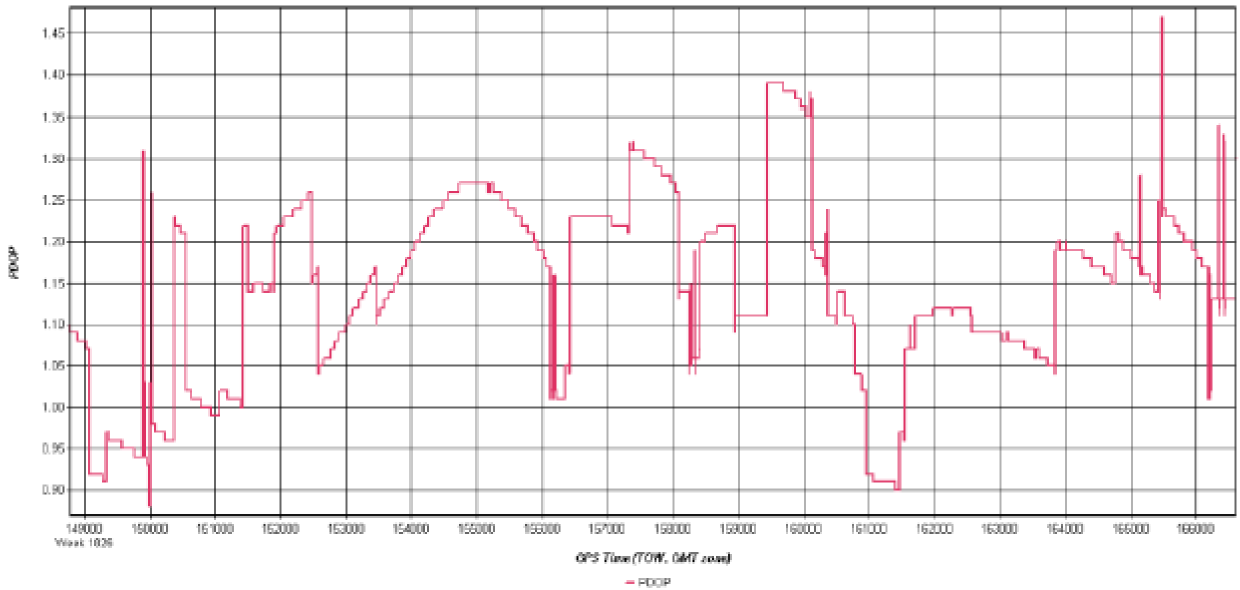

Separation (m)
GPS Time (TOW, GMT zone)
Week 1826
East
North
Up


PDOP
GPS Time (TOW, GMT zone)
Week 1826
PDOP

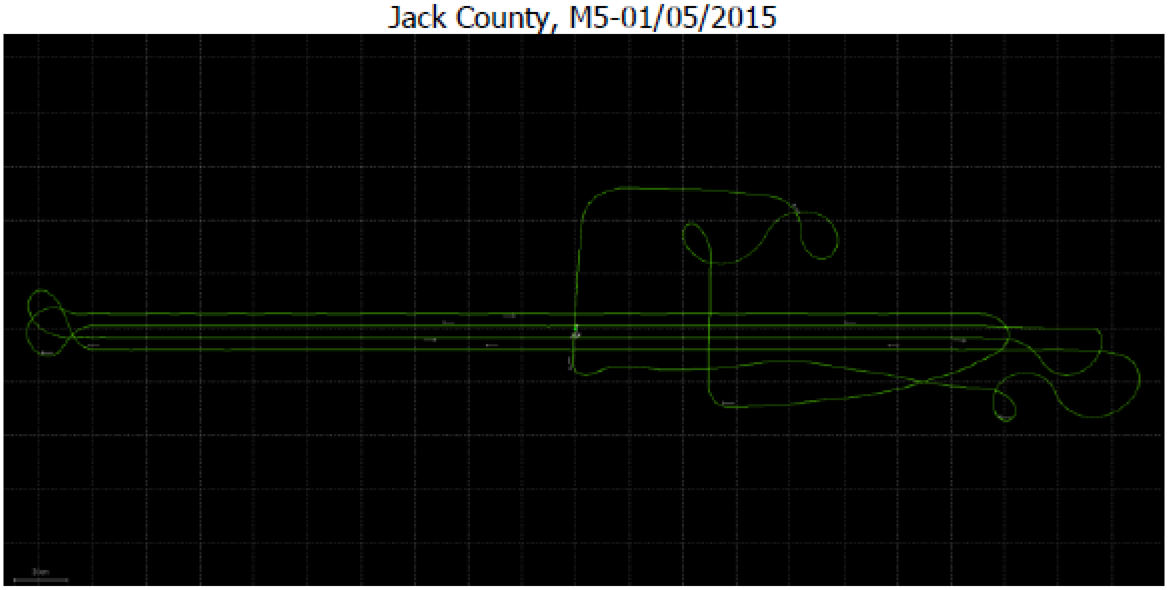
Jack County, M4-01/05/2015

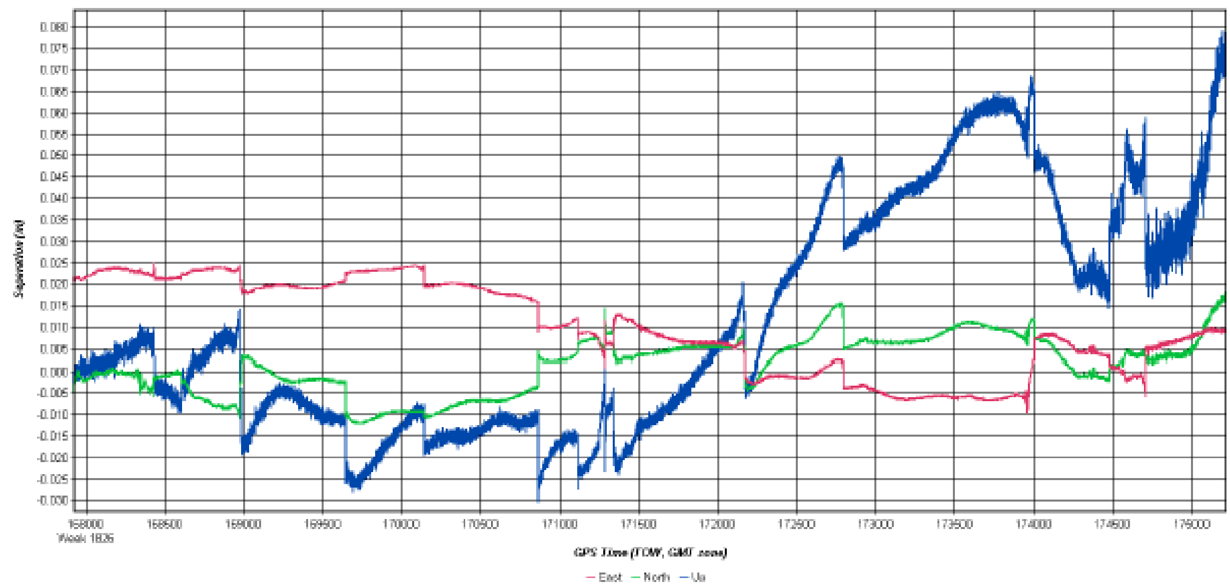






Jack County, M5-01/05/2015




Separation (m)
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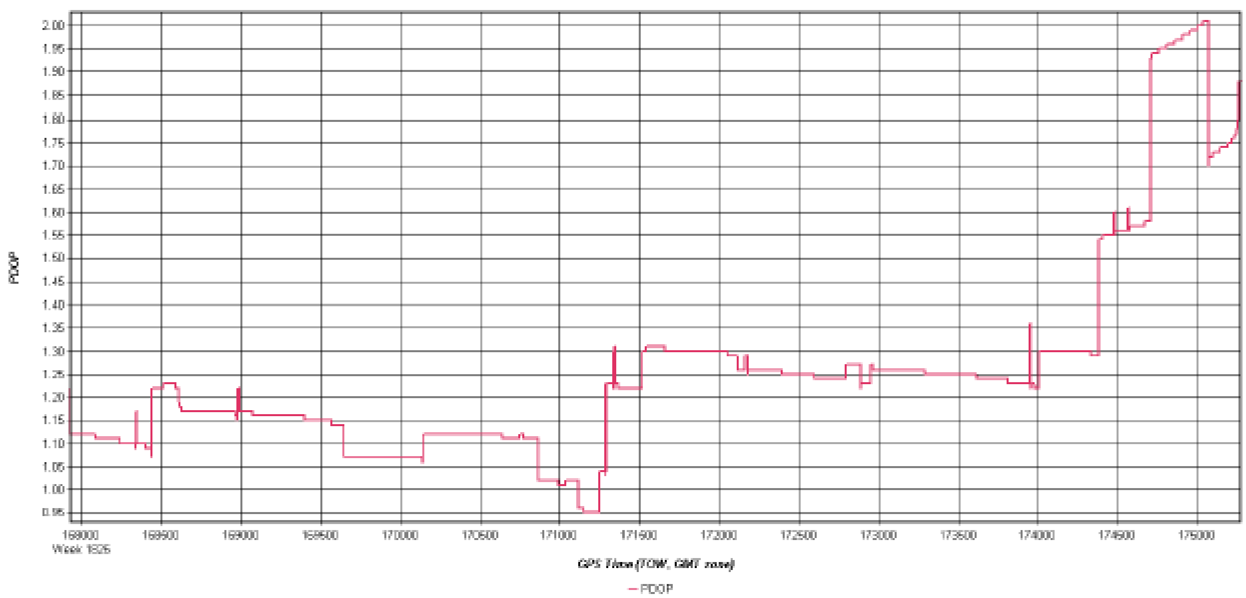
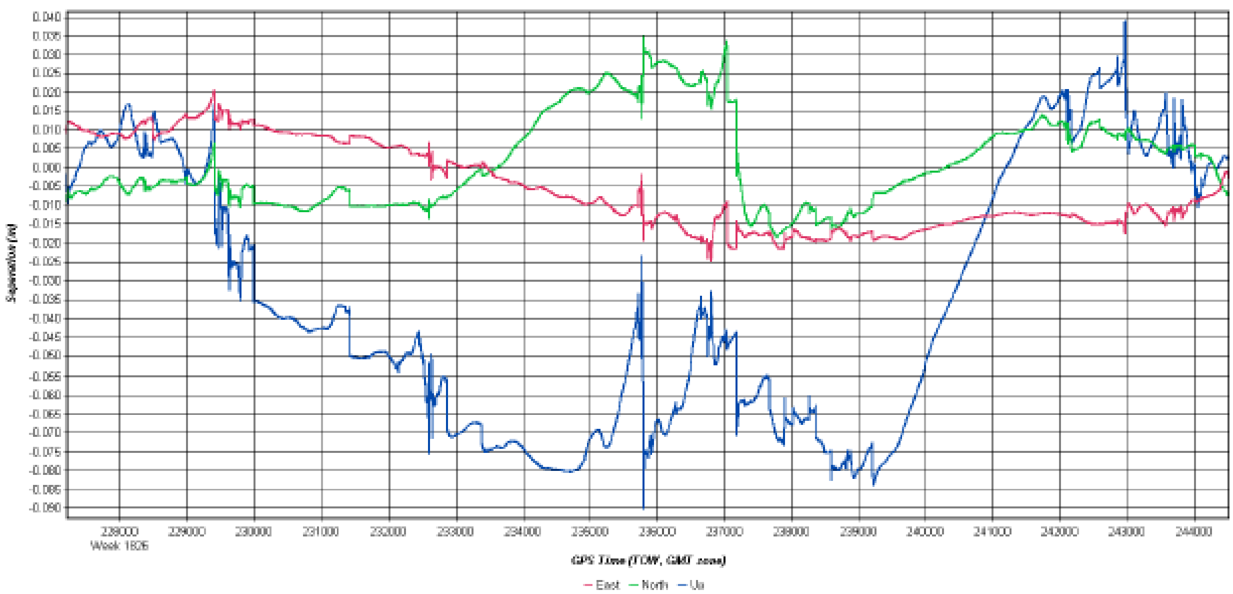
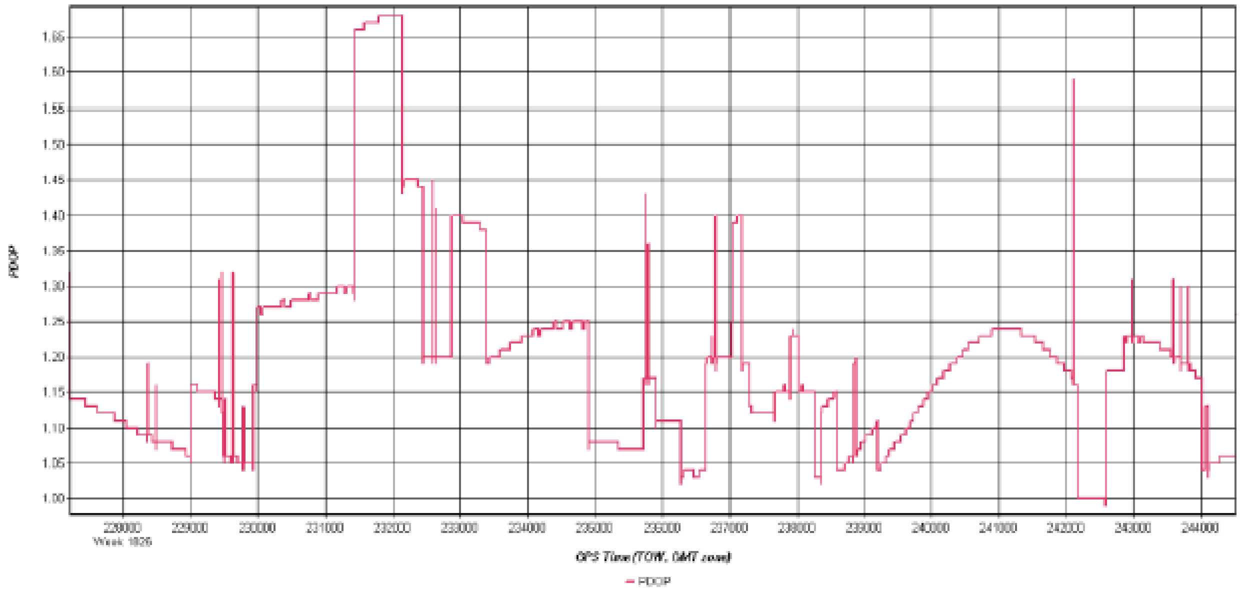
0.070
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
168000
Week 1826
168500
169000
169500
170000
170500
171000
171500
172000
172500
173000
173500
174000
174500
175000
GPS Time (TOW, GMT zone)
East
North
Up

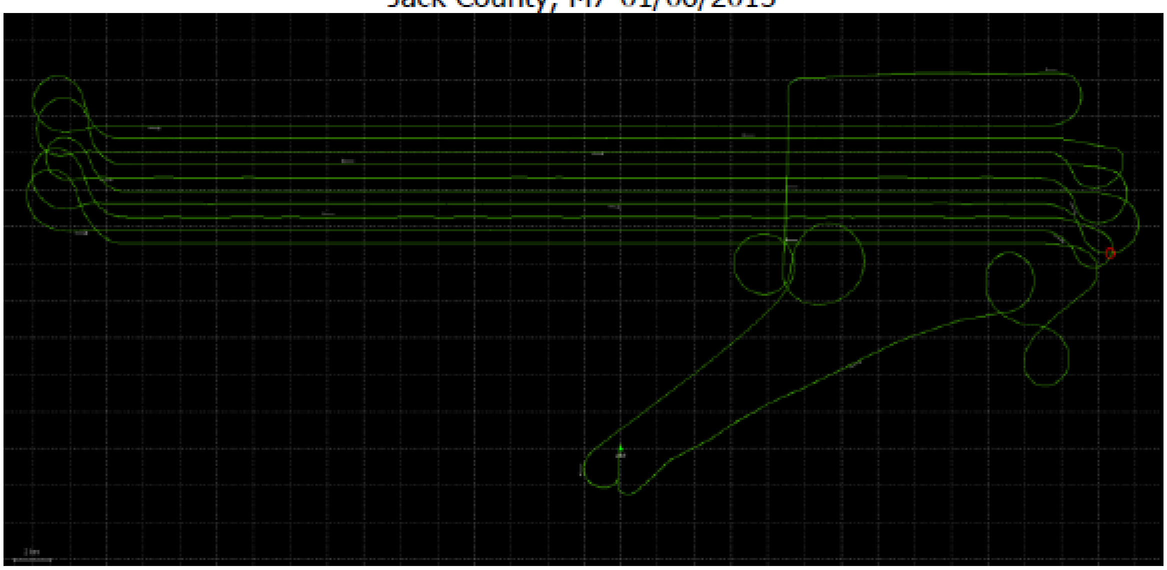

PDOP
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
168000
Week 1826
168500
169000
169500
170000
170500
171000
171500
172000
172500
173000
173500
174000
174500
175000
GPS Time (TOW, GMT zone)
PDOP

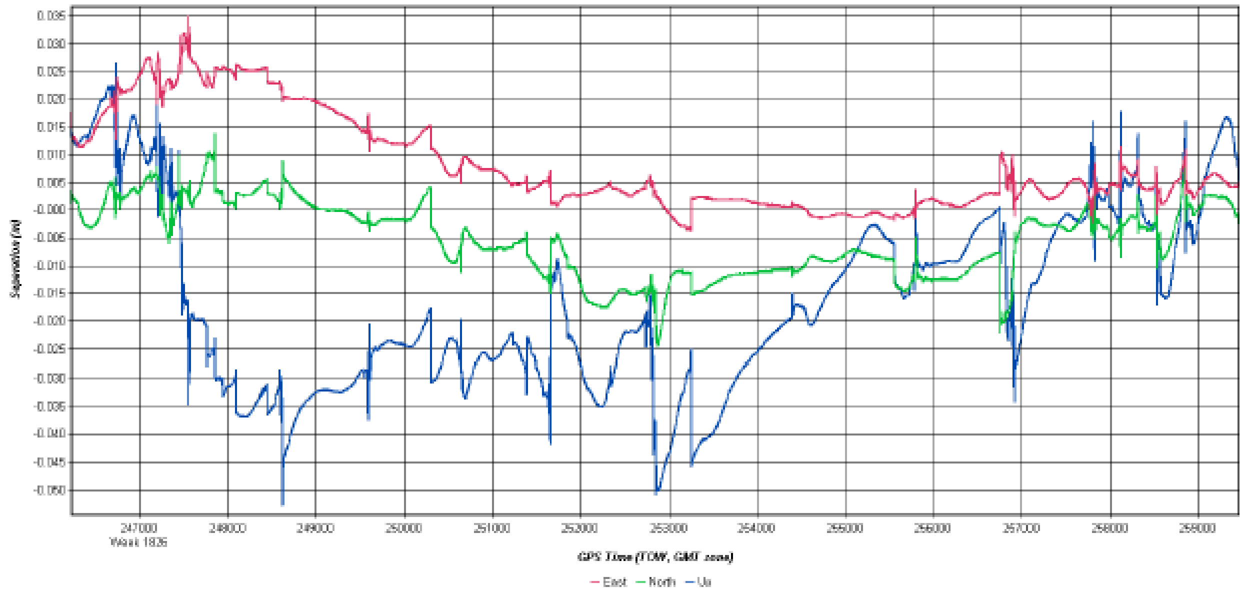
Jack County, M6-01/06/2015

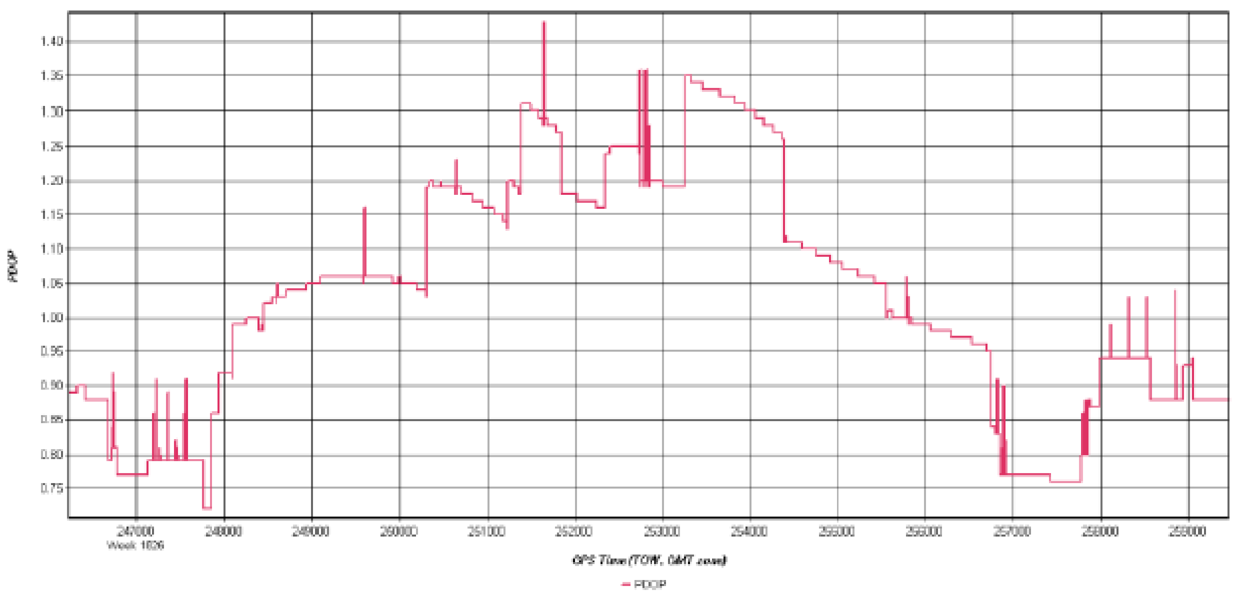




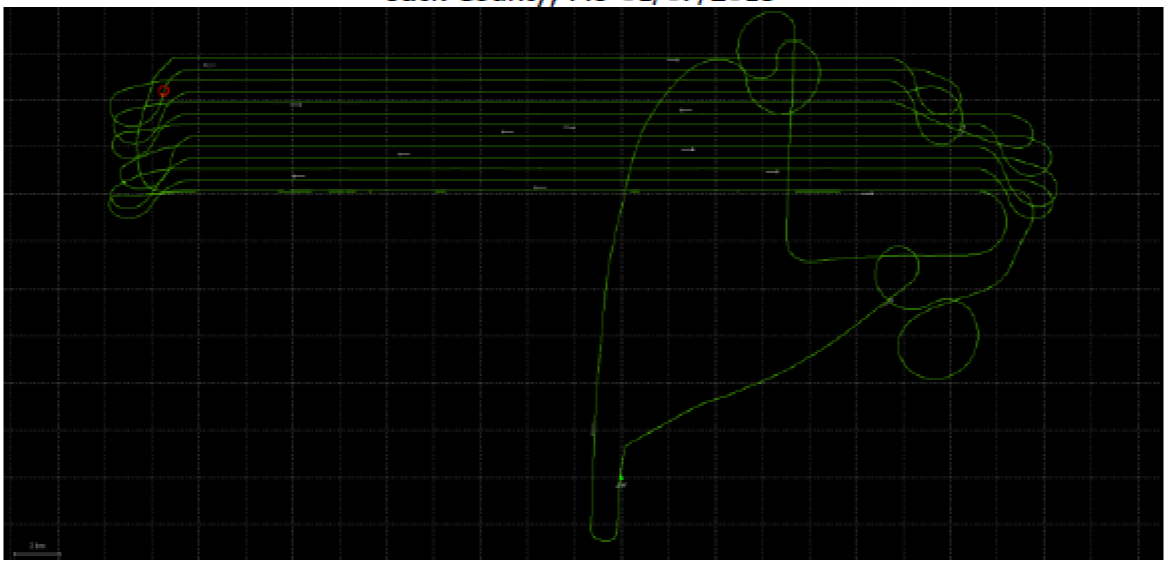
Jack County, M7-01/06/2015

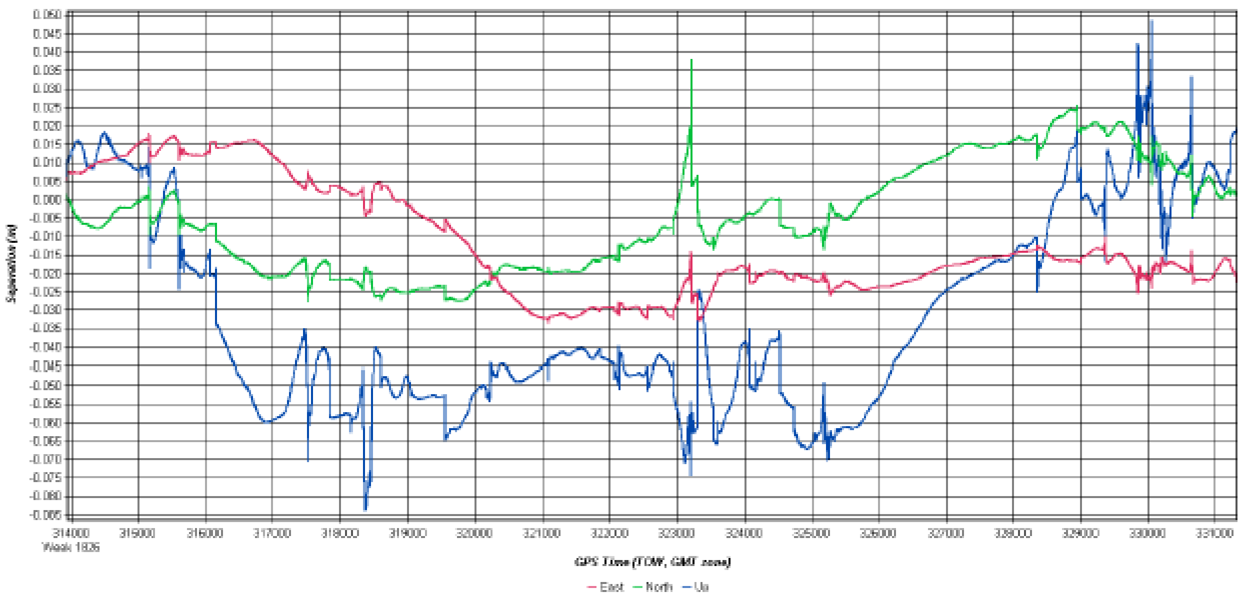


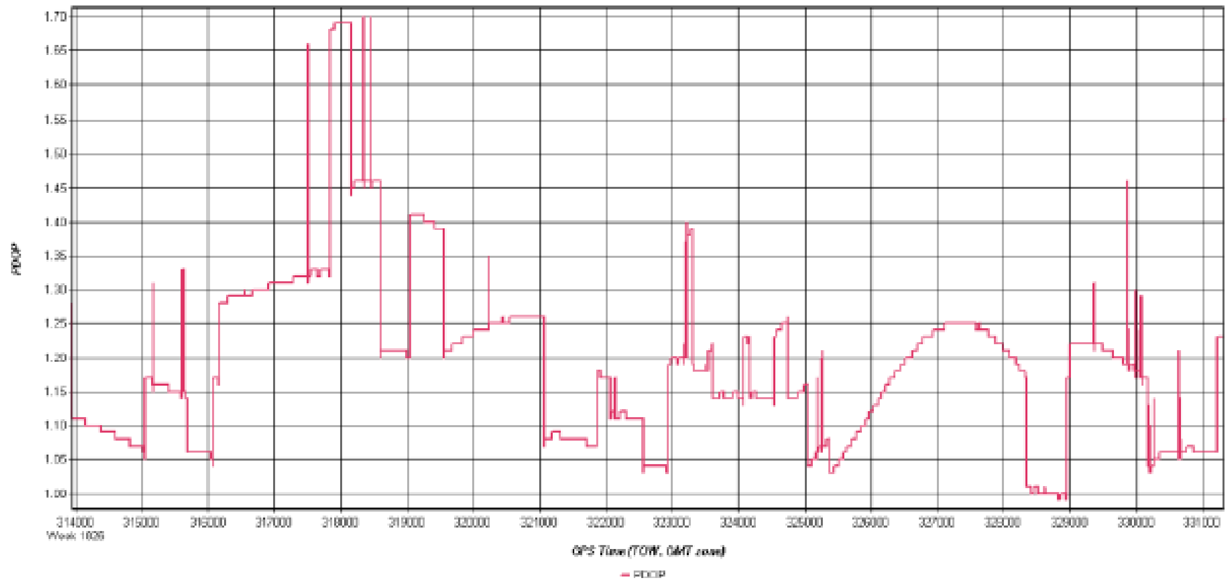

Separation (m)
GPS Time (TOW, GMT zone)
Week 1826
East
North
Up


PDOP
GPS Time (TOW, GMT zone)
Week 1826
PDOP

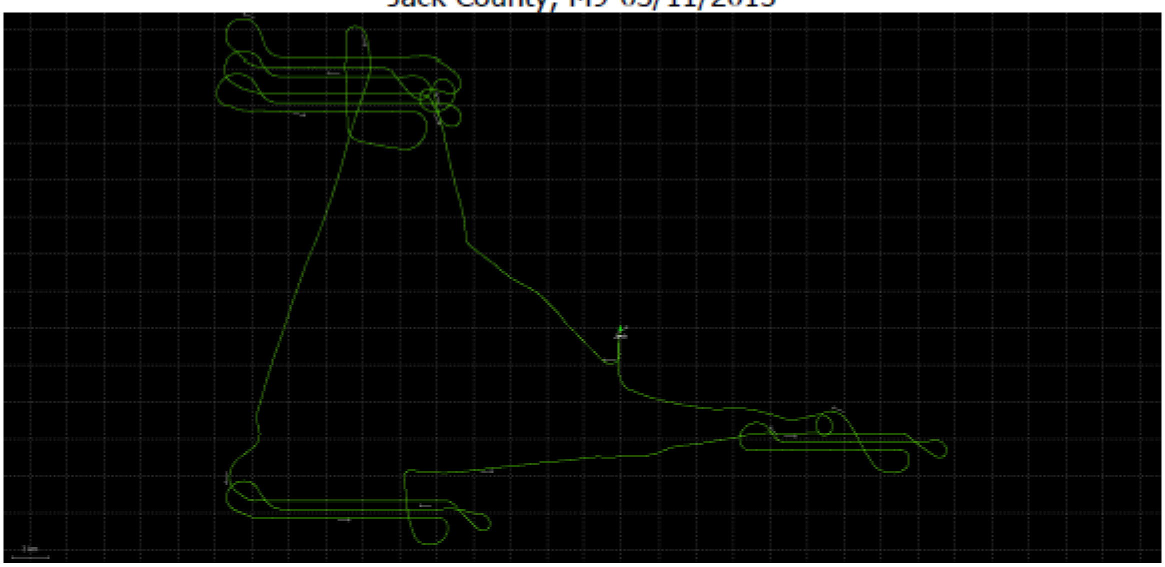
Jack County, M8-01/07/2015

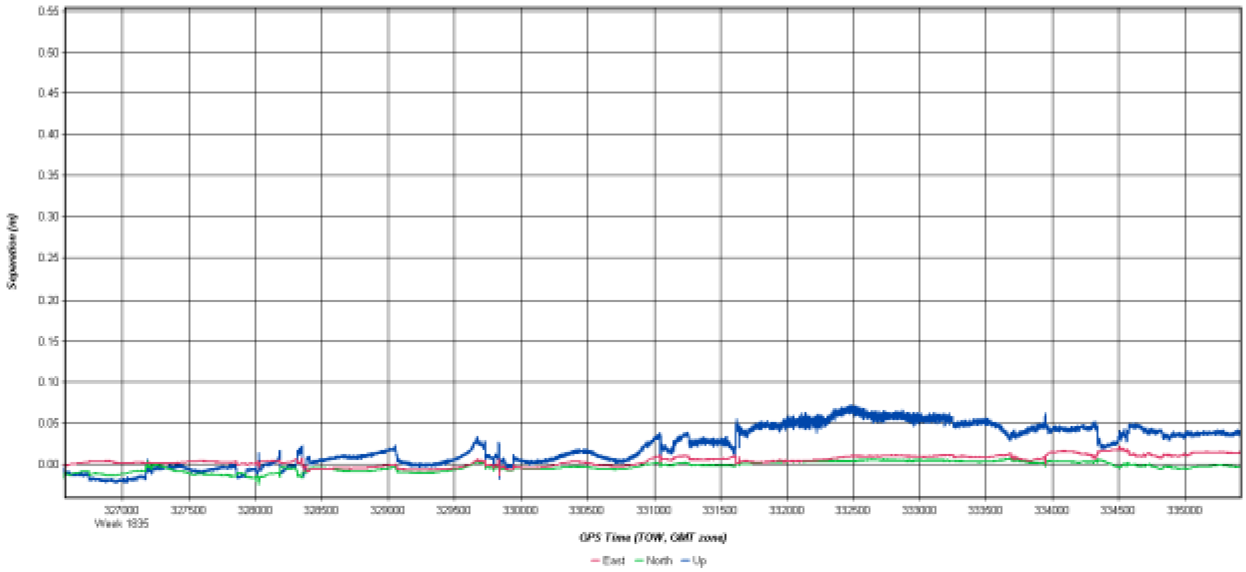


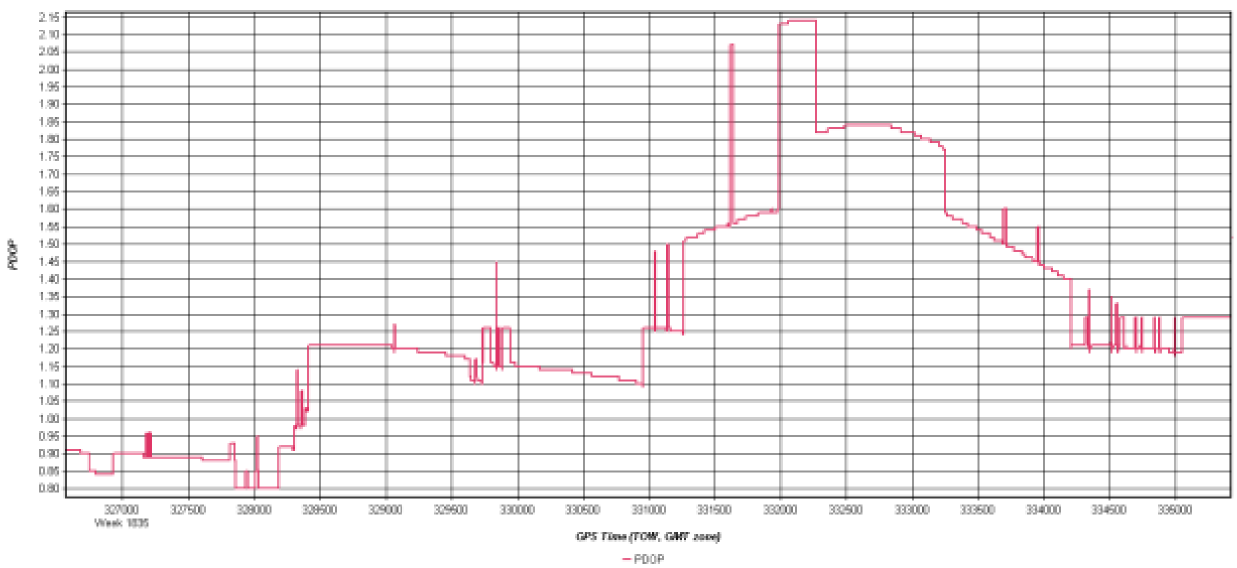




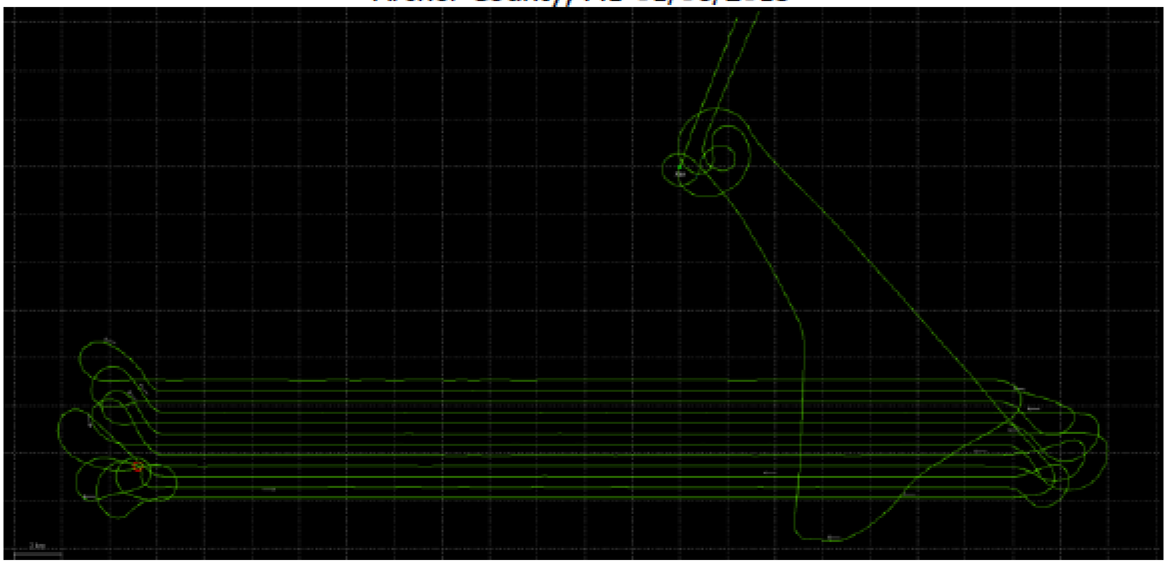
Jack County, M9-03/11/2015

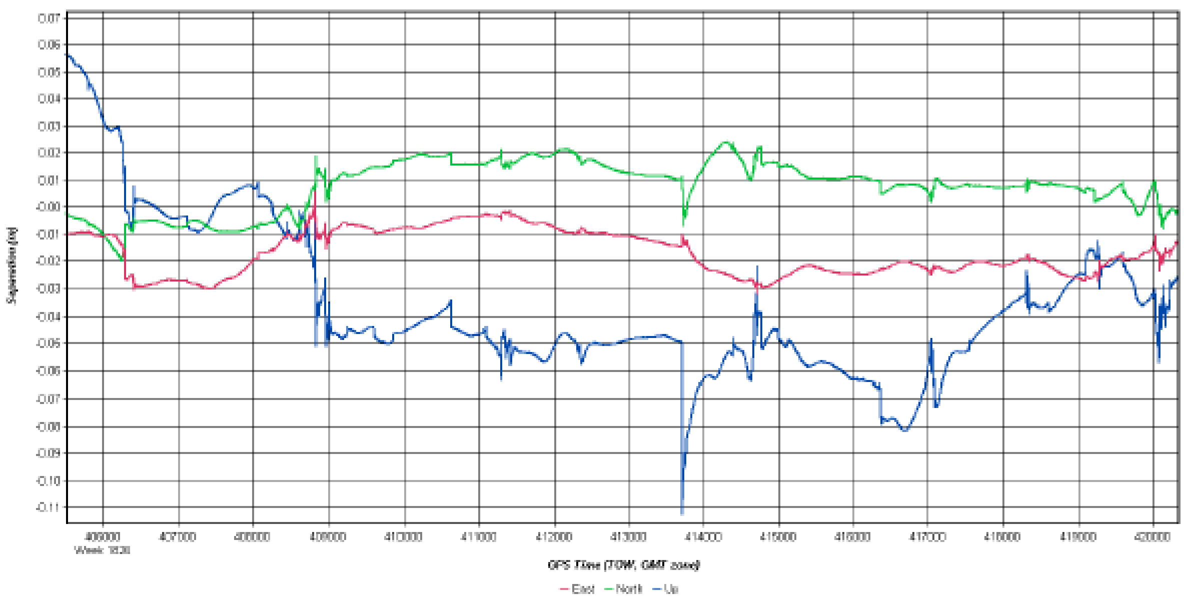


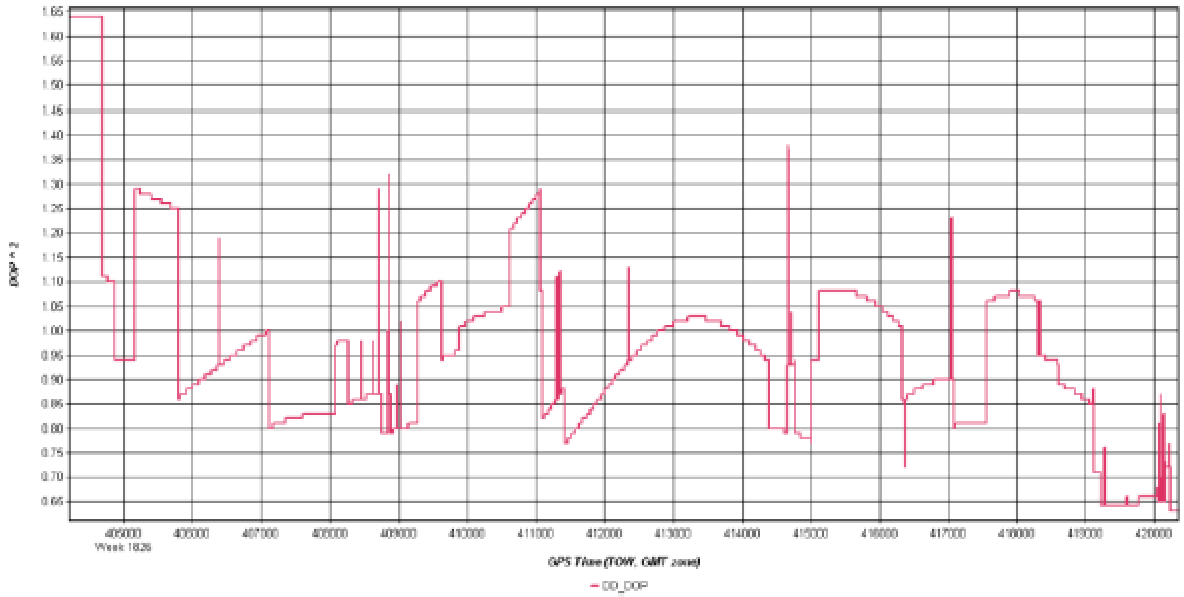

Separation (m)
GPS Time (TOW, GMT zone)
Week 1835
East
North
Up


PDOP
GPS Time (TOW, GMT zone)
Week 1835
PDOP

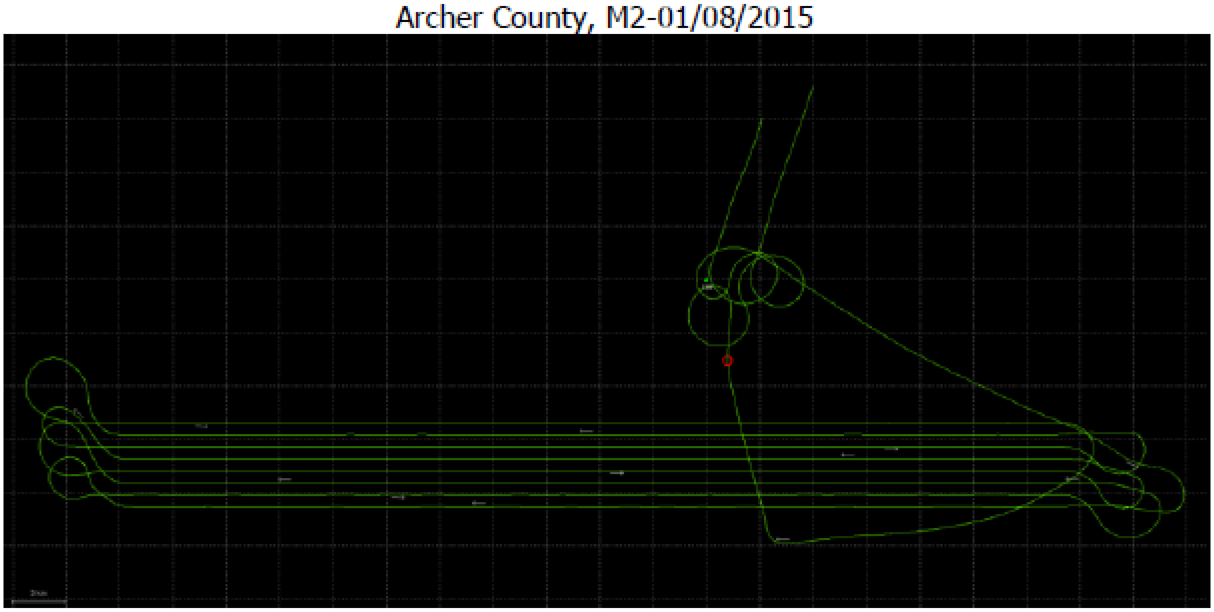
Archer County, M1-01/08/2015

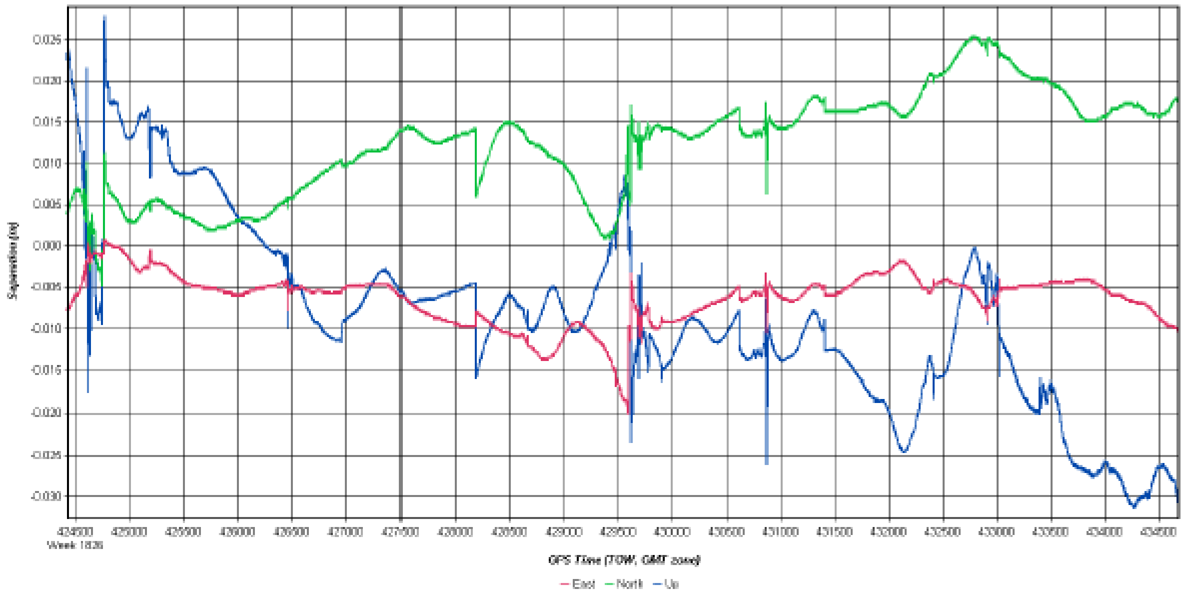


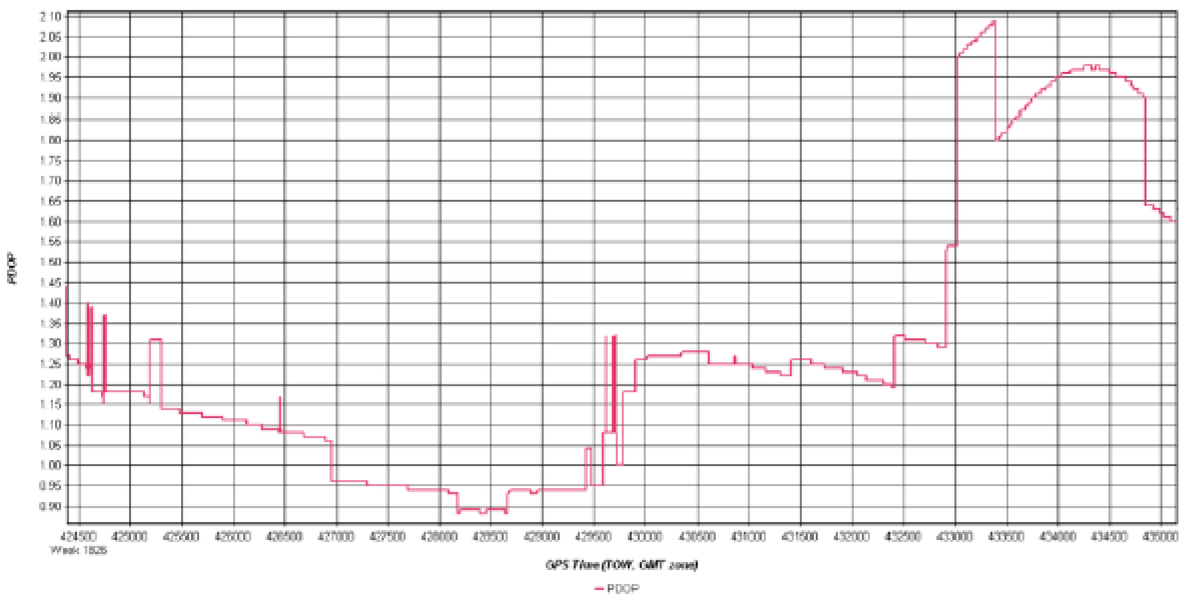




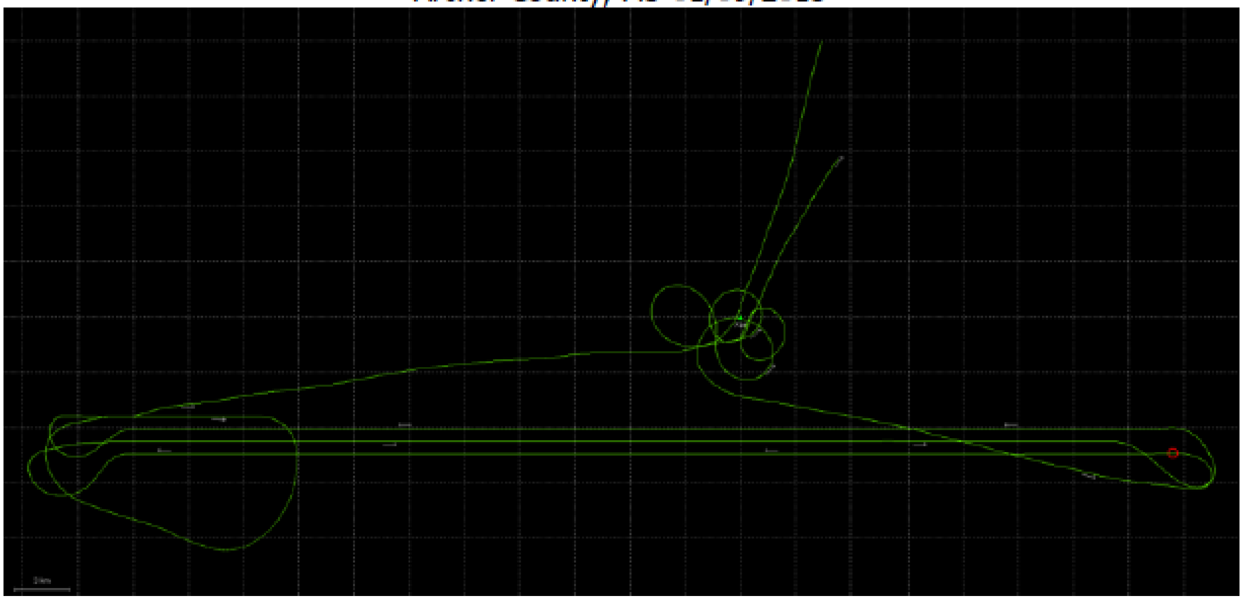
Archer County, M2-01/08/2015

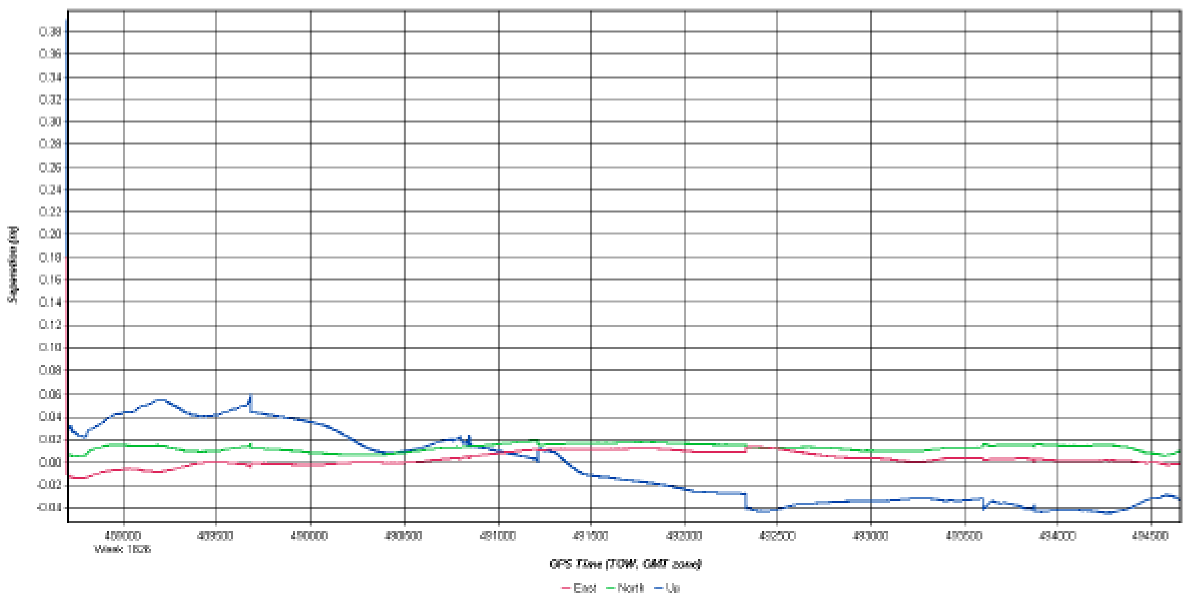


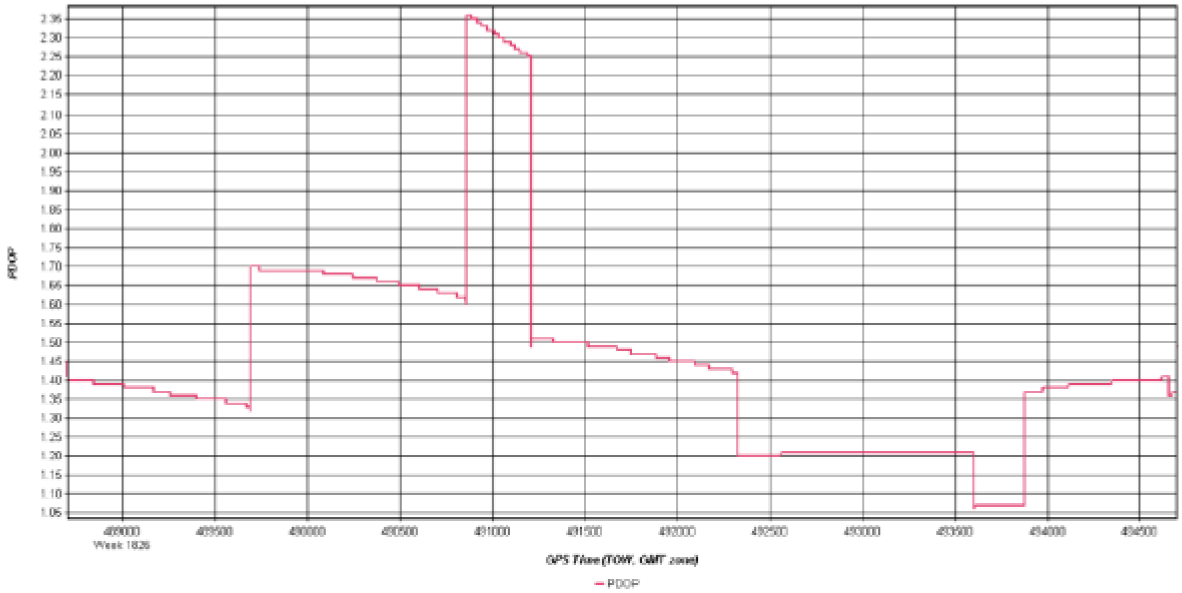

Separation (m)
Week 1826
GPS Time (TOW, GMT zone)
East
North
Up


PDOP
Week 1826
GPS Time (TOW, GMT zone)
PDOP

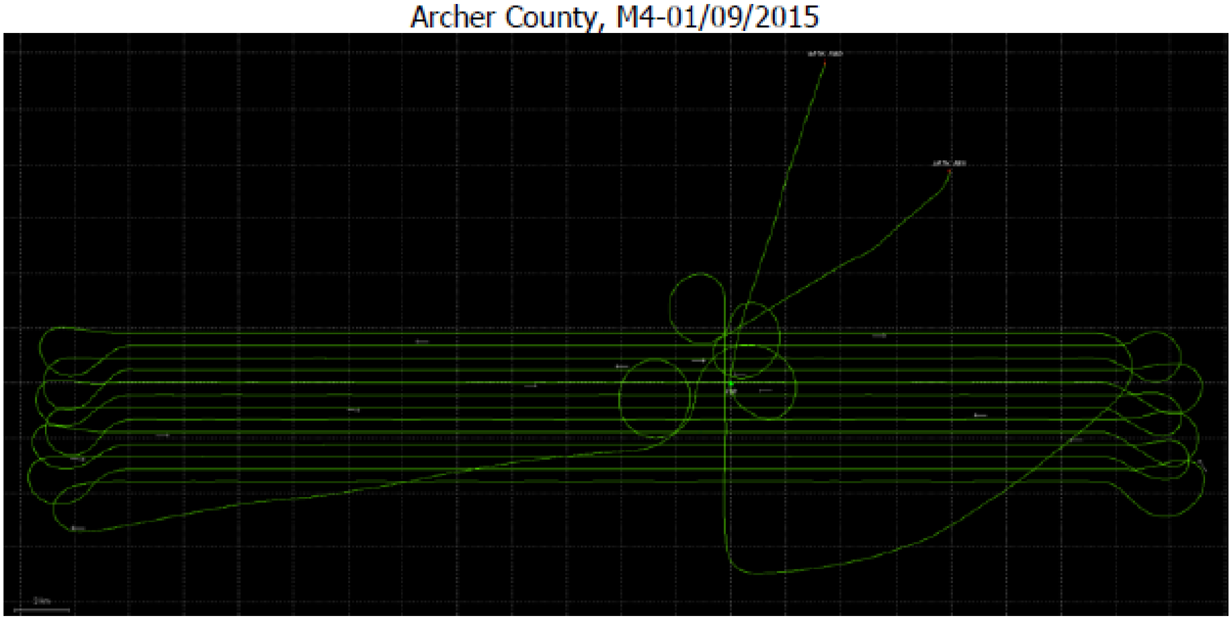
Archer County, M3-01/09/2015

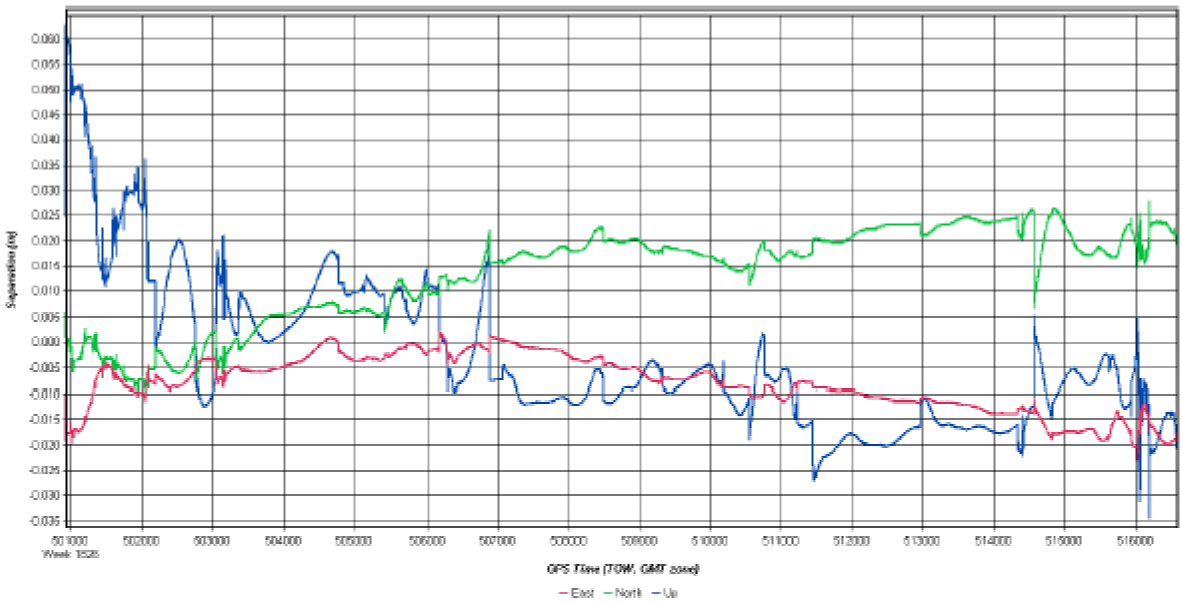


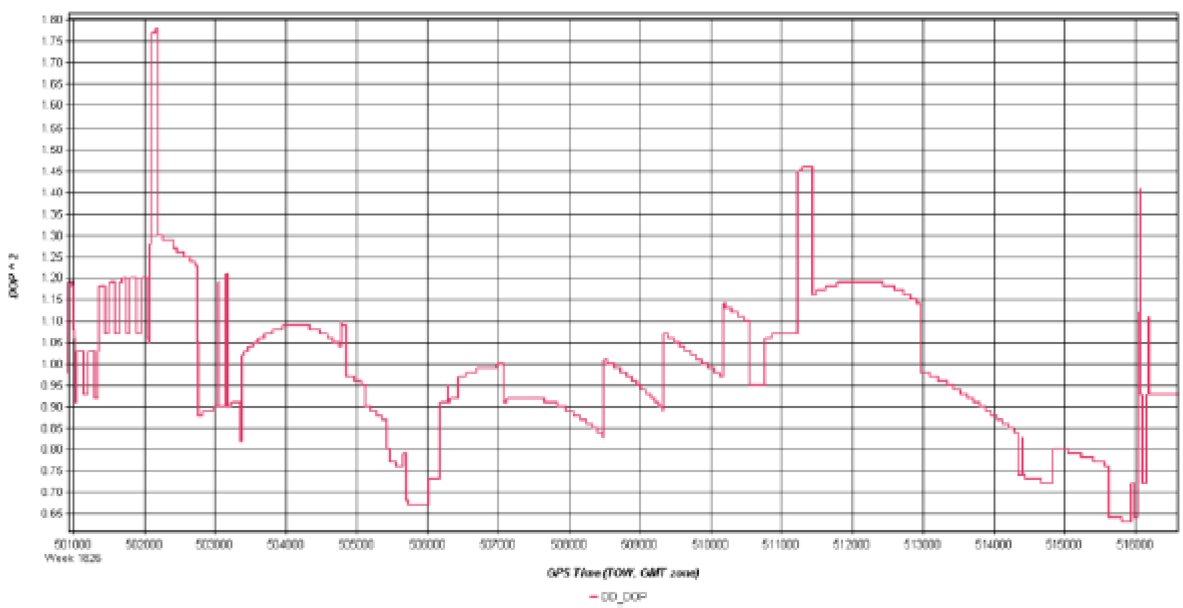




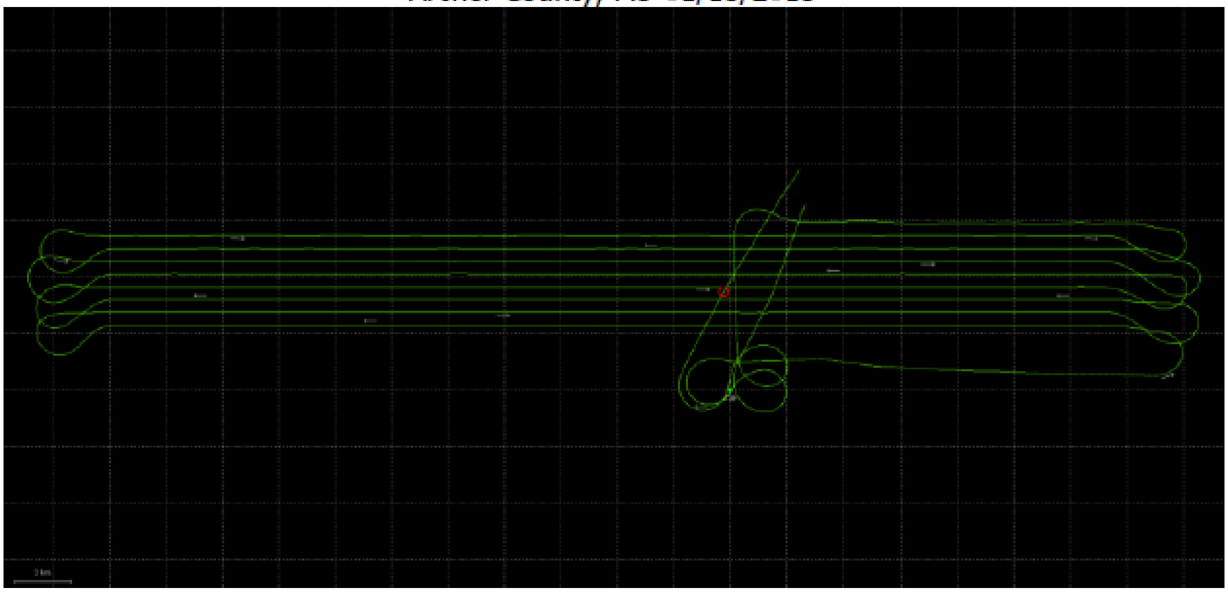
Archer County, M4-01/09/2015

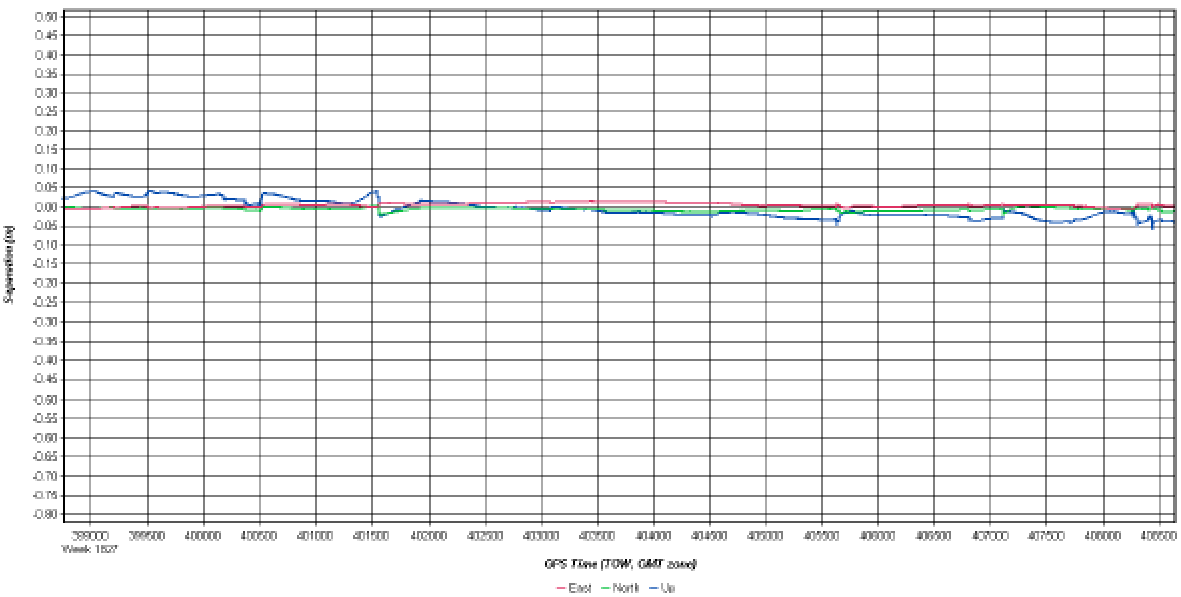


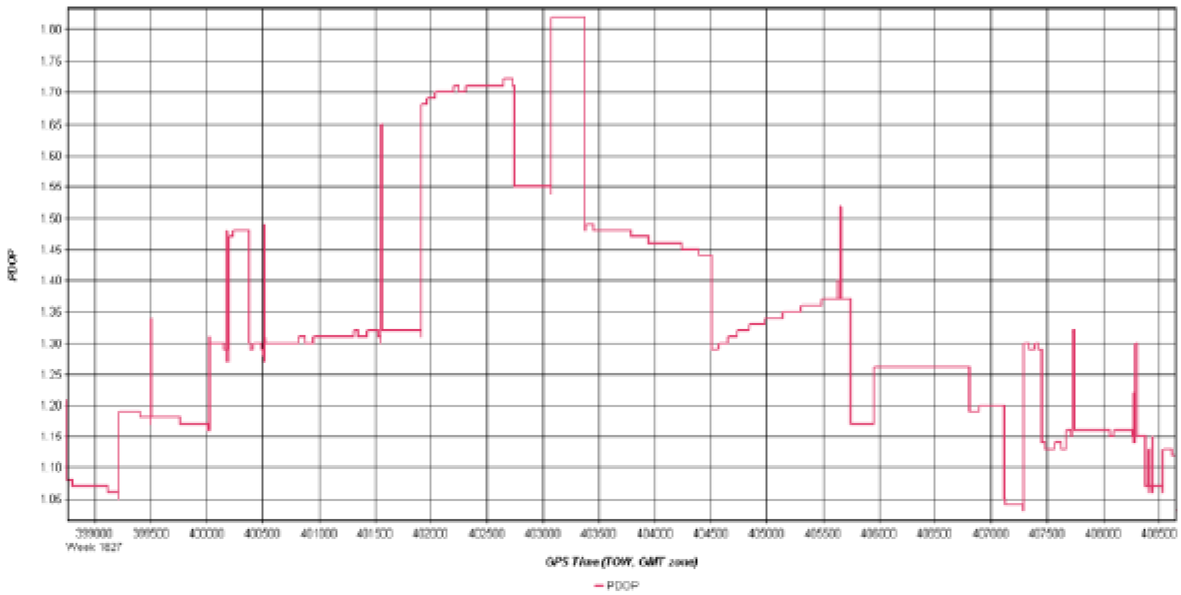

Separation (m)
GPS Time (TOW, GMT zone)
East
North
Up


DOP ^ 2
GPS Time (TOW, GMT zone)
DD_DOP

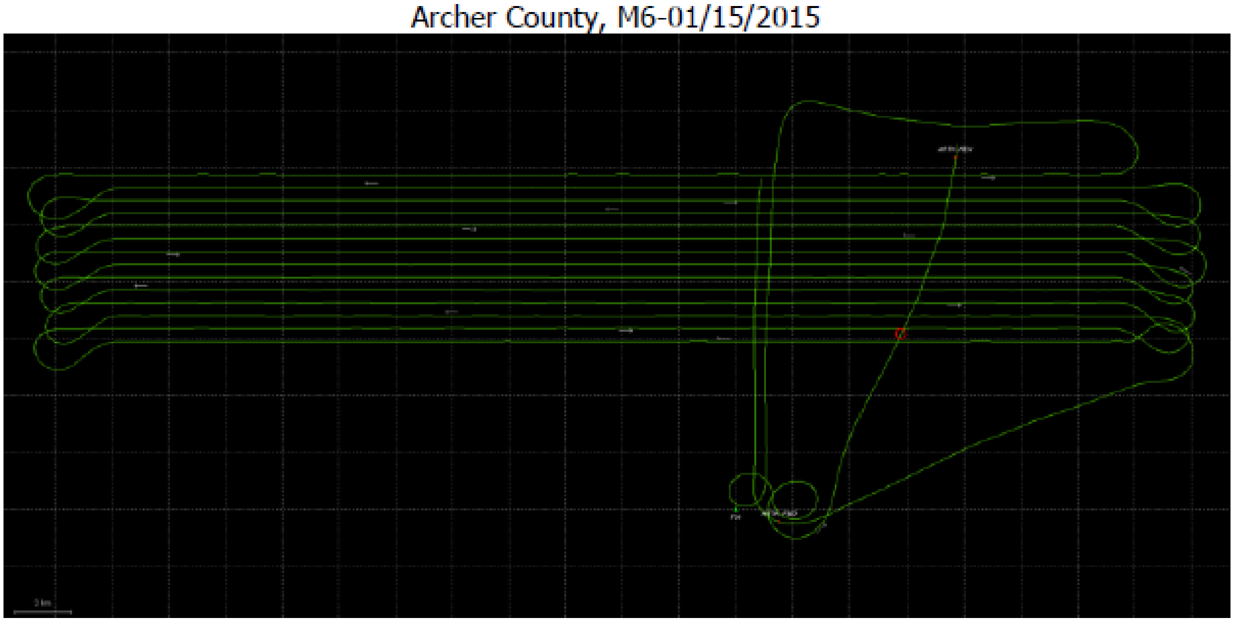
Archer County, M5-01/15/2015

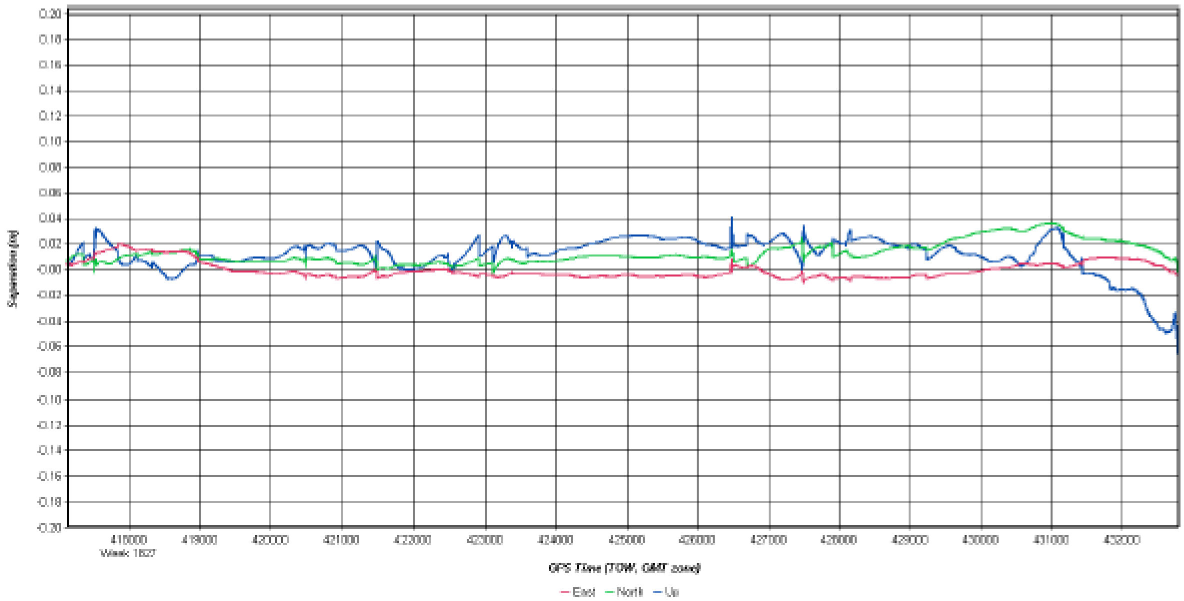


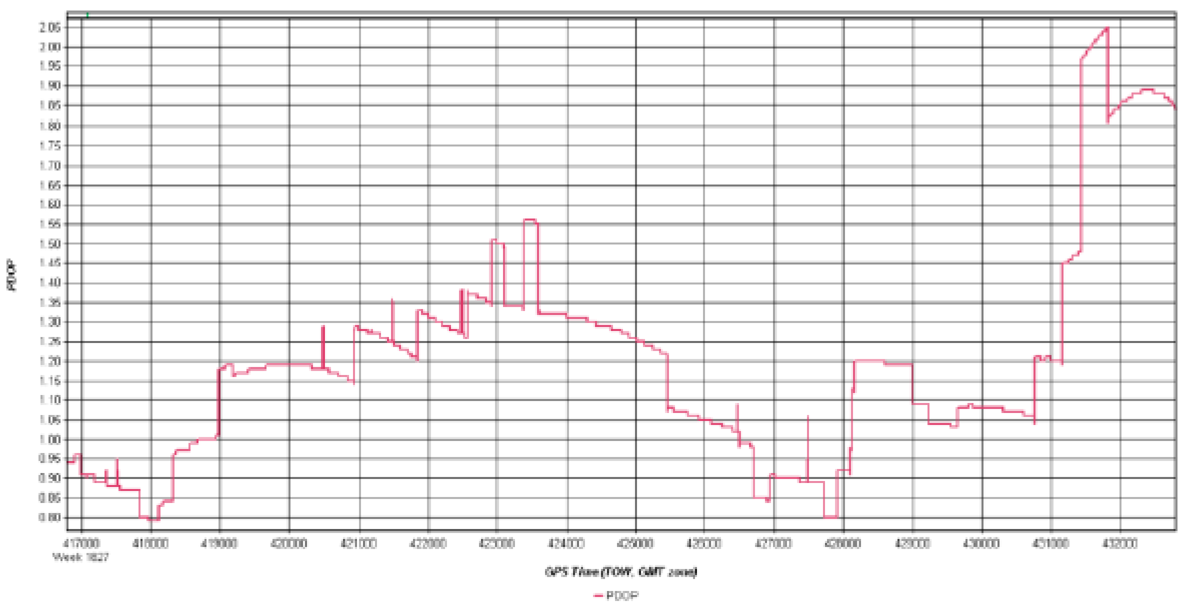




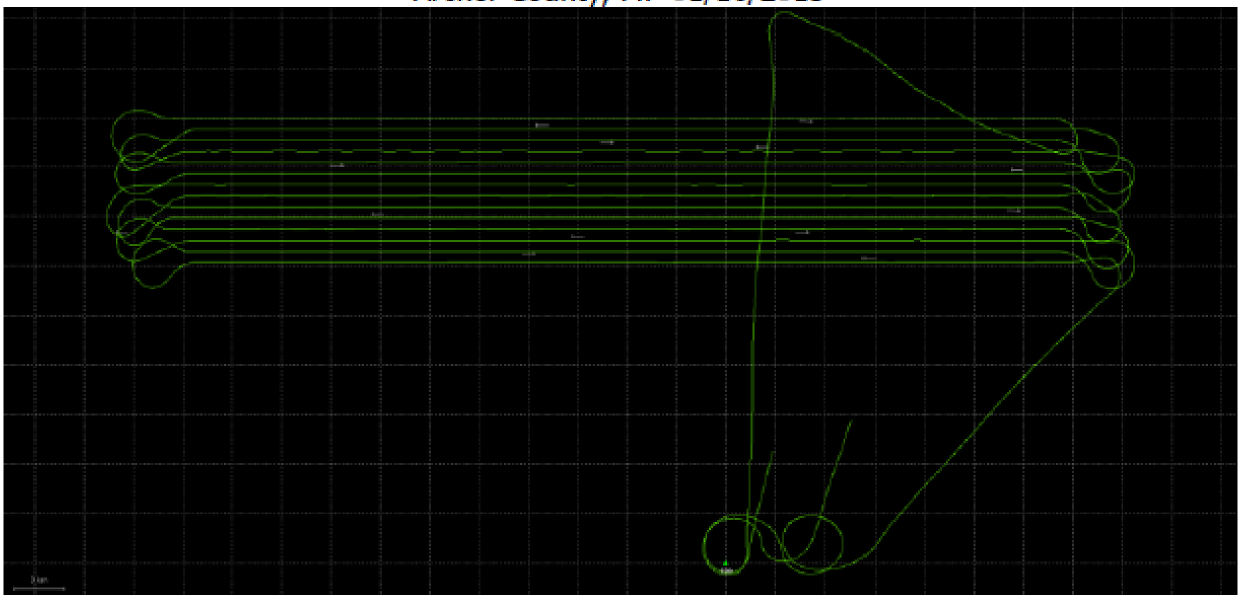
Archer County, M6-01/15/2015

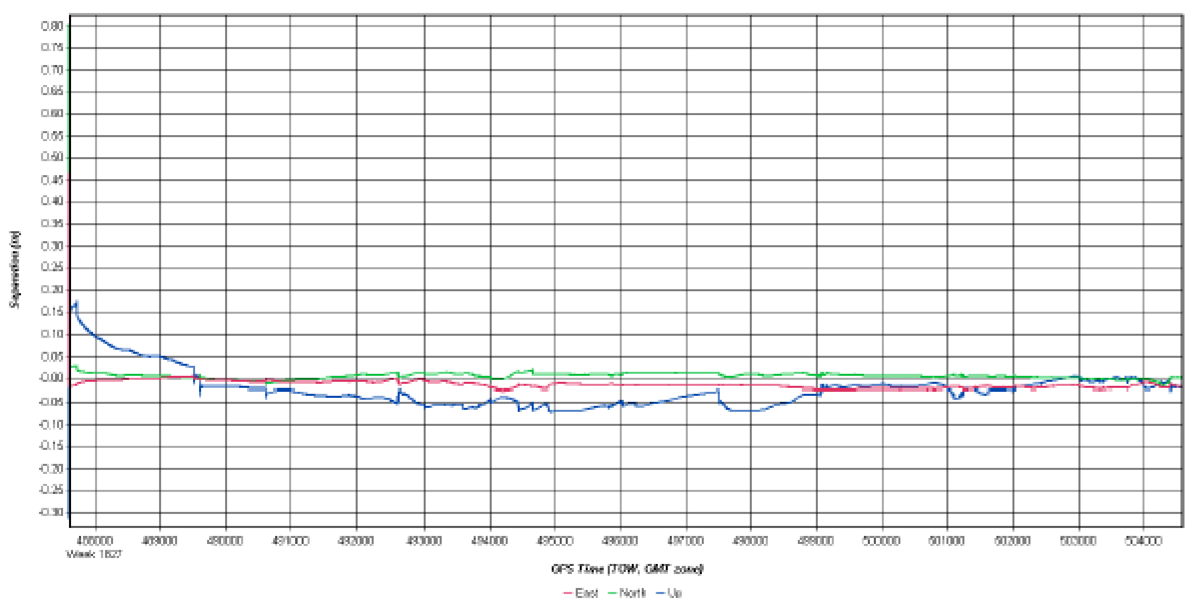


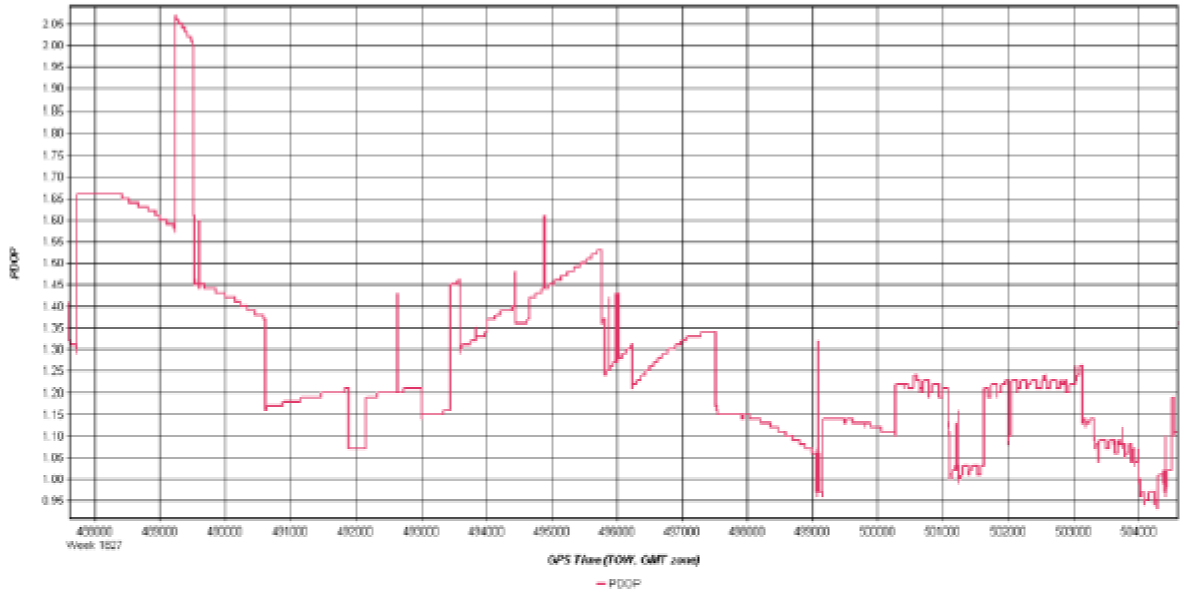

Separation (m)
Week 1827
GPS Time (TOW, GMT zone)
East
North
Up


PDOP
Week 1827
GPS Time (TOW, GMT zone)
PDOP

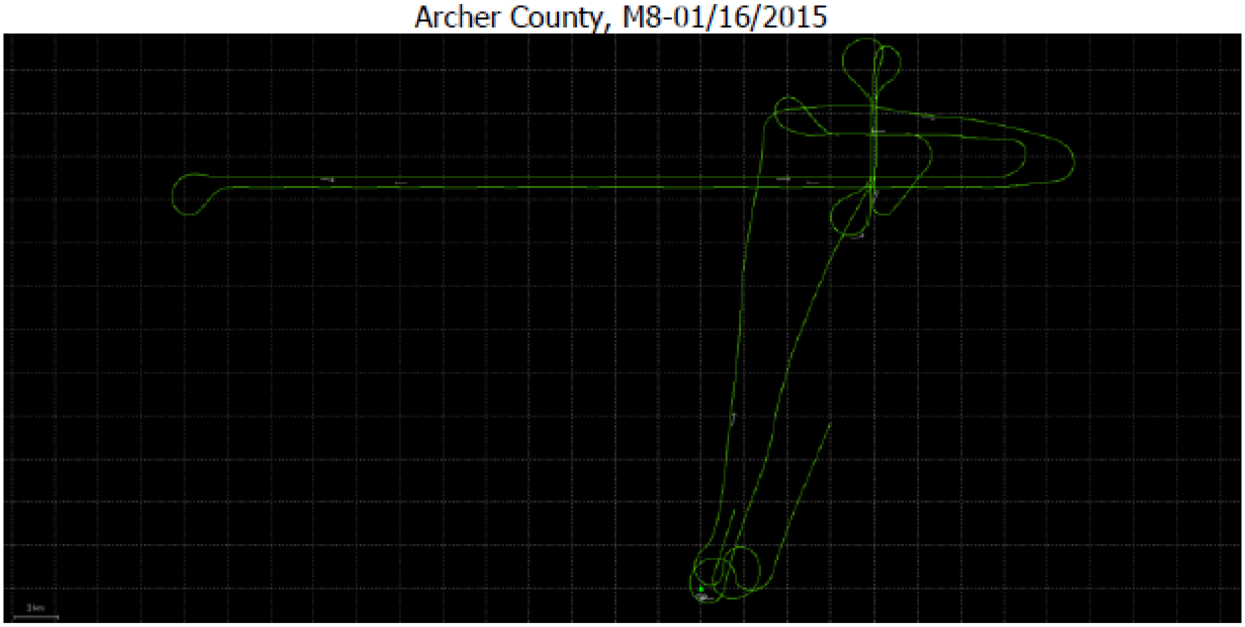
Archer County, M7-01/16/2015

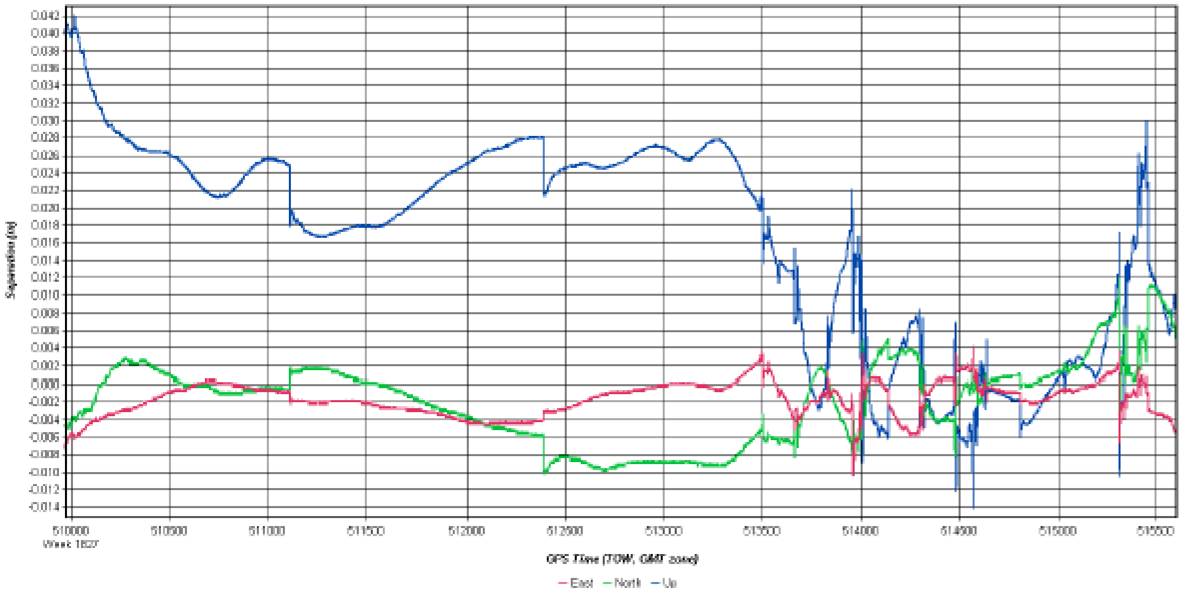


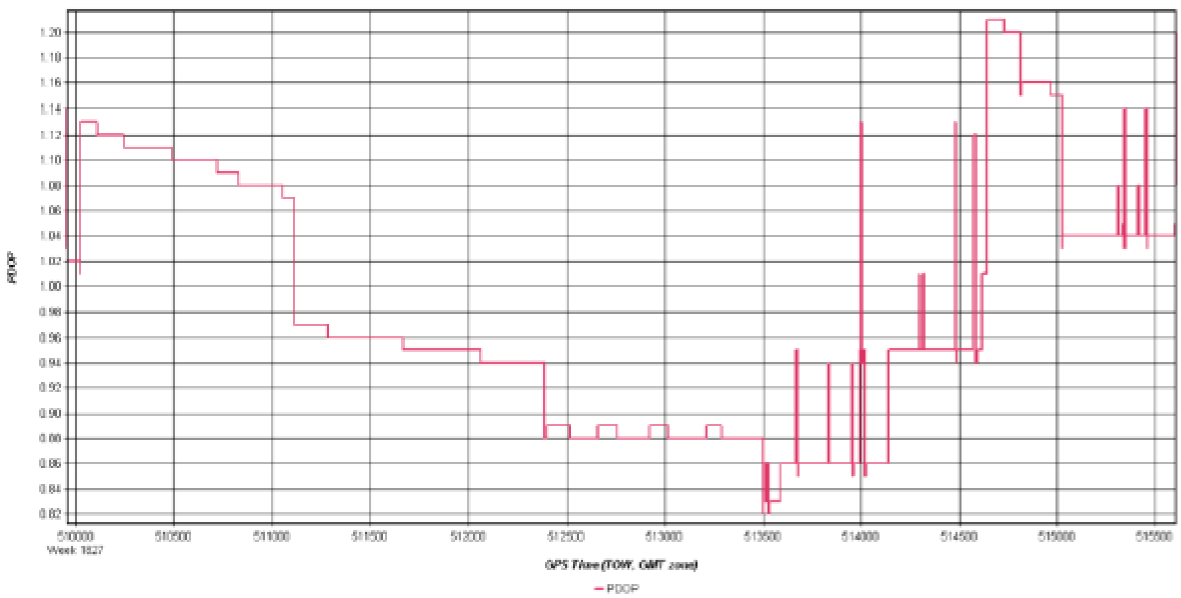




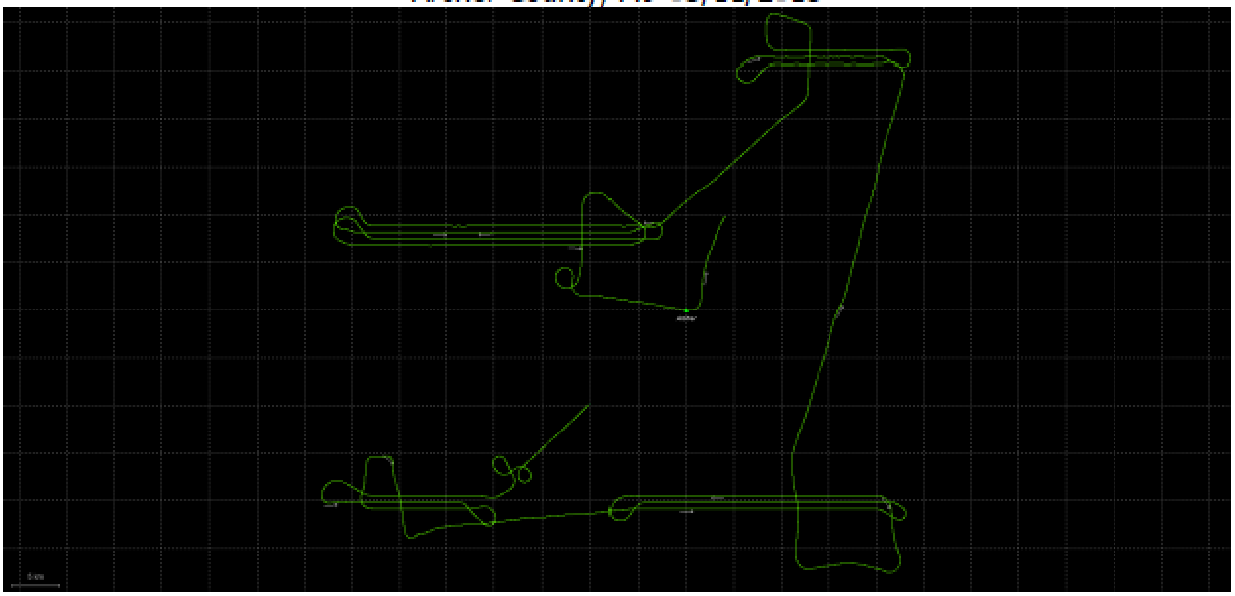
Archer County, M8-01/16/2015

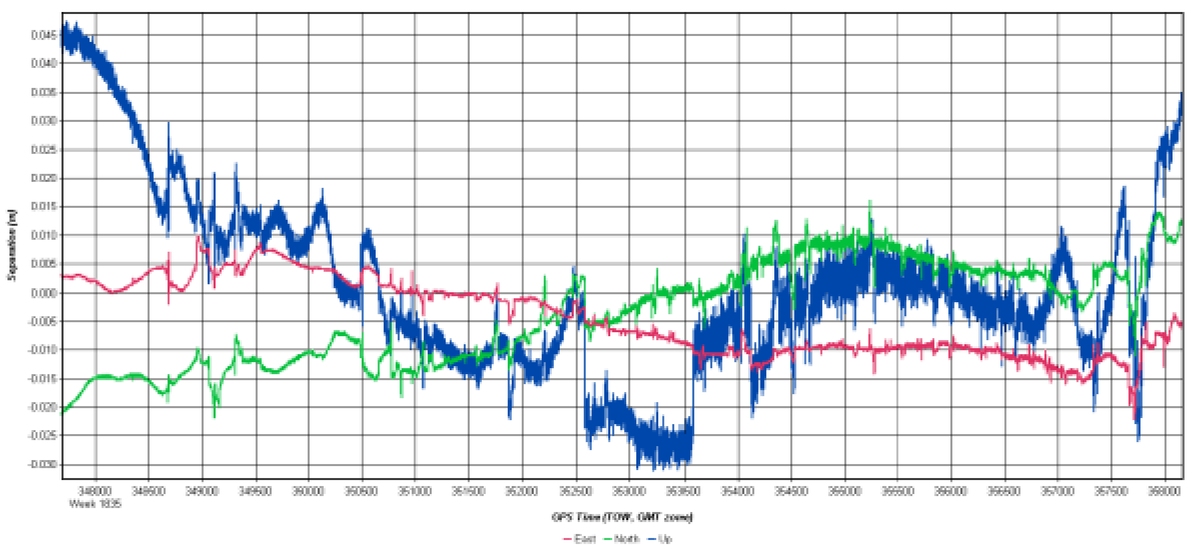


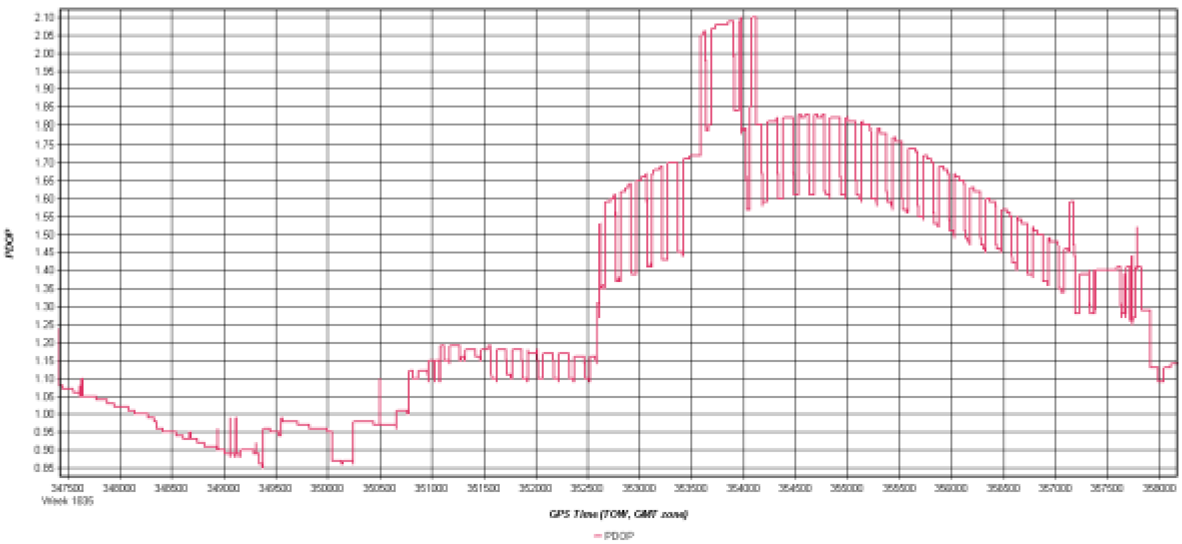

Separation (m)
GPS Time (TOW, GMT zone)
Week 1827
East
North
Up


PDOP
GPS Time (TOW, GMT zone)
Week 1827

Archer County, M9-03/11/2015






PDOP
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1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
347500
Week 1835
348000
348500
349000
349500
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351500
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357000
357500
358000
GPS Time (TOW, GMT zone)
PDOP