Dewberry®

PROJECT REPORT

For the

Berkeley, Clarke, Frederick, and Morgan County Acquisition and Classification for FEMA Region 3 FY 12 VA LiDAR

USGS Contract:

G12PD00040

Prepared for:

United States Geological Survey & Federal Emergency Management Agency

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Report Date: September 20, 2012

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1 *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 Morgan County, West Virginia. The FEMA Region 3 FY 12 LiDAR project area encompasses 12 counties: Berkeley (WV), Clarke (VA), Fairfax (VA), Fauquier (VA), Frederick (MD), Frederick (VA), Jefferson (WV), Loudoun (VA), Morgan (WV), Washington (MD), Allegany (MD), and St. Mary/Golden Beach (MD). The deliverables, as required in the task order, are classified point cloud data (LAS), raw swath cloud data, hydro-flattened bare-earth DEMs, breaklines, metadata, and reports. This deliverable serves as the pilot deliverable for the FEMA Region III VA task order. This report documents the development of the deliverable products, including the planning, acquisition, and processing of the LiDAR data as well as the derivation of LiDAR products.

Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LiDAR classification, breakline production, DEM development and quality assurance. Dewberry's staff performed the final post-processing of the LAS files for the project, produced the breaklines used to enhance the LiDAR-derived surface, generated the 1 meter DEMs, and performed quality assurance inspections on all subcontractor generated data and reports. Geodigital performed the LiDAR data acquisition including data calibration. Their reports can be found in the Appendices.

This report covers the Berkeley, Clarke, Frederick, and Morgan County deliverable.

2 *Project Tiling Footprint and Coordinate System*

The LiDAR delivery consists of one thousand one hundred and fifty four tiles (1,154) (Figure 1). Each tile's extent is 1500 meters by 1500 meters. This conforms to the Orthophotography and high-resolution elevation tile grid developed by the state of Virginia Geographic Information Network.

The projection information is:

Horizontal Datum: NAD83
Vertical Datum: NAVD88
Projection: UTM
Zone: 17N
Units (Horizontal & Vertical): Meters
Geoid: Geoid09

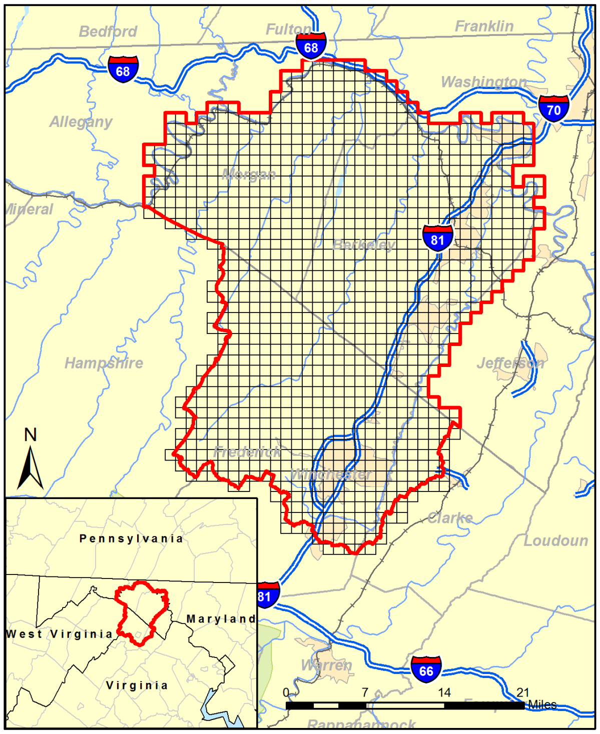


Figure 1 - Tile grid and project boundary of the Morgan, Berkeley, Frederick, and Clarke area.

3 LiDAR Acquisition, Calibration and Control Survey Report

The LiDAR acquisition was completed in thirty four flight missions between January 29th and April 26th, 2012. Geodigital provided a separate report documenting all of the steps in their acquisition process. That document can be found in Appendix A. Their report includes the LiDAR collection parameters, planned flight path maps, flight line trajectories, forward/reverse or combined separation plots, estimated position accuracy reports, and the flight log. Geodigital's Geodetic Control Survey Report (Appendix B) contains a thorough review of control used, including the final coordinates of the control, a map of the fully constrained control network, details of the constrained GPS network, new control station descriptions, and published control station descriptions. Geodigital's LiDAR Data Calibration Report (Appendix C) contains details of the LiDAR data processing and calibration as well as their vertical accuracy assessment (discussed below).

4 Vertical Accuracy Assessment

Geodigital verified internally prior to delivery to Dewberry that the LiDAR data met fundamental accuracy requirements (vertical accuracy NSSDA RMSEZ = 12.5cm, NSSDA AccuracyZ 95% = 24.5 cm) or better; in open, non-vegetated terrain) when compared to kinematic and static GPS checkpoints. Below is a summary for both tests:

The LiDAR dataset was tested to 0.1207m vertical accuracy at 95% confidence level based on consolidated RMSEz (0.04m x 1.960) when compared to 100 GPS static check points.

Dewberry further collected additional survey checkpoints and used those checkpoints to verify the accuracy of the LiDAR. Figure 2 shows the distribution of these check points throughout the dataset.

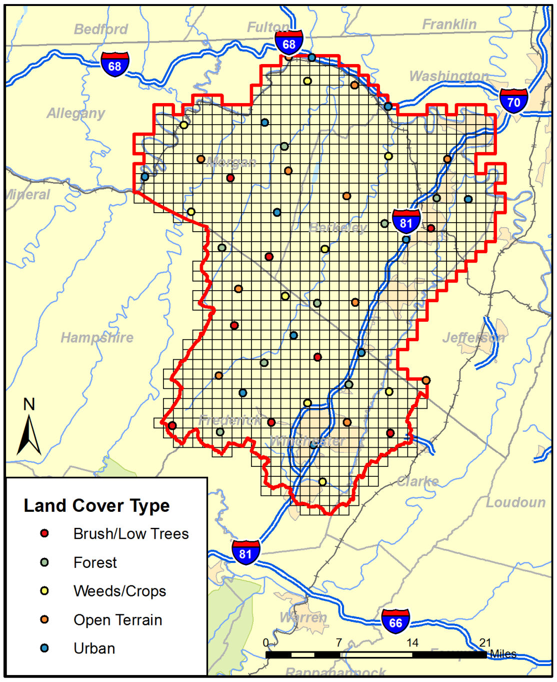


Figure 2 – Checkpoint Map shows that checkpoints are well distributed throughout project area.

Appendix A, Guidance for Aerial Mapping and Surveying, to FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners" requires a minimum of 60 test points -- 20 each in a minimum of three land cover categories representative of the floodplain. FEMA's Procedure Memorandum No. 61 – "Standards for Lidar and Other High Quality Digital Topography" -- specifies that the positional accuracy of LiDAR shall be in accordance with ASPRS/NDEP standards for accuracy testing as well as the USGS "Lidar Guidelines and Base Specifications, v13." All of these standards and guidelines require testing for Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy (SVA), and Consolidated Vertical Accuracy (CVA), using a minimum of 20 checkpoints each in a minimum of three land cover categories for a minimum total of 60 QA/QC checkpoints.

The tables below show the vertical accuracy statistics and results. FVA (Fundamental Vertical Accuracy) is determined with check points located only in the open terrain land cover category (grass, dirt, sand, and/or rocks) , 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 (RMSEz) of the checkpoints x 1.9600. The second method of testing vertical accuracy, endorsed by the National Digital Elevation Program (NDEP) and American Society for Photogrammetry and Remote Sensing (ASPRS) uses the 95th percentile to report vertical accuracy in each of the other land cover categories (defined as Supplemental Vertical Accuracy – SVA) and all land cover categories combined (defined as

Consolidated Vertical Accuracy – CVA). The 95th percentile method is used when vertical errors may not follow a normal error distribution, as in vegetated terrain.

For the FEMA Region 3 FY 12 LiDAR project, the scope of work required the vertical accuracy to be NSSDA $RMSE_Z$ = 12.5 cm (NSSDA $Accuracy_Z$ 95% = 24.5 cm) or better; in open, non-vegetated terrain checked against the raw, swath LAS, classified LAS, and DEMs. The CVA is required to be NSSDA $Accuracy_Z$ 95% = 24.5 cm in both the classified LAS and DEMs. The following contains tables that list the RMSE checks for classified LAS, raw-swath LAS, and the digital elevation models.

The RMSE values for the classified and Swath LAS reflect the calculations for the entire FEMA Region 3 FY 12 LiDAR project area. The RMSE values for the DEMs represent the current delivery and the counties in which the DEMs have been delivered.

Classified LiDAR – RMSE Checks

The $RMSE_Z$ is 0.10 meters in open terrain meets the project specifications of 0.125 meters. The fundamental vertical accuracy is 0.20 meters which meets the project specifications of 0.245. The consolidated vertical accuracy is 0.26 meters which meets project specifications of 0.363 meters. Additional details and the supplemental vertical accuracy can be found in the tables below.

Table 1 – Overall Descriptive Statistics for Checkpoints

100 % of Totals	$RMSE_Z$ (m) Spec = 0.125 m[1]	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated		0.10	0.09	1.75	0.43	202	-3.30	3.93
Open Terrain	0.10	0.06	0.07	-0.91	0.08	45	-0.19	0.21
Weeds/Crop		0.11	0.11	-0.56	0.09	41	-0.13	0.27
Forest		0.17	0.09	0.57	1.06	33	-3.30	3.93
Urban		0.04	0.05	-0.63	0.08	42	-0.15	0.17
Brush/Low Trees		0.13	0.12	0.08	0.08	41	-0.06	0.32

[1] Specification for Open Terrain points only.

Table 2 –FVA, SVA, and CVA values for the FEMA Region 3 FY 12 LiDAR project area – Classified LAS Checks.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec = 0.245 m	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec = 0.363 m	SVA — Supplemental Vertical Accuracy (95th Percentile) Target = 0.363 m
Consolidated	202		0.26	
Open Terrain	45	0.20		
Weeds/Crop	41			0.25
Forest	33			2.76
Urban	42			0.16
Brush/Low Trees	41			0.24

DEMs – RMSE Checks

The $RMSE_z$ values for this deliverable were combined with the values from the rest of the project area that have been completed thus far: including Allegany, Golden Beach, Berkeley, Frederick (VA), Clarke, Morgan, Washington, and Loudoun Counties. The $RMSE_Z$ is 0.10 meters in open terrain which meets the project specifications of 0.125 meters. The fundamental vertical accuracy is 0.20 meters which meets the project specifications of 0.245. The consolidated vertical accuracy is 0.30 meters which meets project specifications of 0.363 meters. Additional details and the supplemental vertical accuracy can be found in the tables below.

Table 3 – Overall Descriptive Statistics for Checkpoints

100 % of Totals	$RMSE_Z$ (m) Spec = 0.125 m[1]	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated		0.09	0.10	-4.59	0.18	109	-1.28	0.67
Open Terrain	0.10	0.08	0.07	-1.89	0.07	22	-0.17	0.17
Weeds/Crop		0.14	0.14	0.40	0.08	23	-0.02	0.33
Forest		0.03	0.13	-2.20	0.42	17	-1.28	0.67
Urban		0.07	0.05	-0.08	0.04	22	-0.04	0.15
Brush/Low Trees		0.14	0.13	0.08	0.08	25	-0.03	0.32

[1] Specification for Open Terrain points only.

Table 4 –FVA, SVA, and CVA values for the delivered DEMs – DEM Checks.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec = 0.245 m	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec = 0.363 m	SVA — Supplemental Vertical Accuracy (95th Percentile) Target = 0.363 m
Consolidated	109		0.30	
Open Terrain	22	0.20		0.17
Weeds/Crop	23			0.27
Forest	17			0.82
Urban	22			0.12
Brush/Low Trees	25			0.25

Raw LAS Swaths – RMSE Checks

The $RMSE_Z$ is 0.11 meters in open terrain which meets the project specifications of 0.125 meters. The fundamental vertical accuracy is 0.21 meters which meets the project specifications of 0.245 meters.

Table 5 – Overall Descriptive Statistics for Checkpoints

100 % of Totals	$RMSE_Z$ (ft) Spec=0.125m	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Open Terrain	0.11	0.07	0.08	-0.89	0.08	45	-0.19	0.21

Table 6 – FVA value for the REMA Region 3 FY 12 LiDAR project area – Raw LAS Checks.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEZ x 1.9600) Spec = 0.245 m
Open Terrain	45	0.21

As stated earlier, the DEM RMSE results are preliminary and will not be official until all areas are merged for testing of the total area with all project checkpoints.

5 *LiDAR Processing & Qualitative Assessment*

5.1 LiDAR Classification Methodology

The LiDAR is tiled into the 1500 m x 1500 m tiles named using the US National Grid tiling scheme. The data were processed using GeoCue and TerraScan software. The initial step was to setup the GeoCue project, which is done by importing the project defined tile boundary index. The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and divided into tiles. Once tiled, the laser points were tested to ensure calibration accuracy from flightline to flightline. This check was done by creating a set of deltaZ ortho images. This process measured the relative accuracy between flight lines, or how well one flight line fits an overlapping flight line vertically. No issues were found during this step.

After these checks, the data was classified using a proprietary routine in TerraScan. This routine classified out any obvious outliers from the dataset, following which the ground layer was extracted from the point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model. This surface model was generated using three main parameters: building size, iteration angle and iteration distance. The initial model was based on low points being selected by a "roaming window" with the assumption is that these are the ground points. The size of this roaming window was determined by the building size parameter. The low points were triangulated and the remaining points were evaluated and subsequently added to the model if they met the iteration angle and distance constraints. This process was repeated until no additional points were added within iterations. A second critical parameter was the maximum terrain angle constraint, which determined the maximum terrain angle allowed within the classification model.

Once the automated classification finished, each tile was imported into TerraScan and a surface model was created to examine the ground classification. Low lying buildings, porches, bridges, and small vegetation artifacts are often not caught during automated classification. These errors were inspected and edited during this step. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification, such as vegetation and buildings that are present following the initial processing. Dewberry analysts employed 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points were removed from the ground classification.

After the ground classification corrections were complete, the dataset was processed through a water classification routine that utilized the breaklines compiled by Dewberry to automatically classify hydro features. The water classification routine selects points within the breakline polygon and automatically classifies them as class 9, water. The water classification routine also buffers the breakline polygon by the nominal point spacing and classifies points within that buffered polygon to class 10, ignored ground for DEM production. The ground class for this data set is comprised of Class 2. Once the data classification was finalized, the LAS format 1.0 format points were converted to LAS 1.2 Point Data Record Format 1 and converted to the required ASPRS classification scheme.

- Class 1 = Unclassified, and used for all other features that do not fit into the Classes 2, 7, 9, or 10, including vegetation, buildings, etc.
- Class 2 = Ground
- Class 7 = Noise
- Class 9 = Water
- Class 10 = Ignored Ground due to breakline proximity.
- Class 11 = Withheld

The following fields within the LAS files are populated to the following precision:

- GPS Time (0.000001 second precision)
- Easting (0.01 meter precision)
- Northing (0.01 meter precision)
- Elevation (0.01 meter precision)
- Intensity (integer value - 12 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.

Following the completion of LiDAR point classification, the Dewberry qualitative assessment process flow for the project incorporated the following reviews:

1. Format: Using TerraScan, Dewberry verified that all points were classified into valid classes according to project specifications.
    a. LAS format 1.2, point data record format 1
    b. All points contain populated intensity values.
    c. All LAS files contain Variable Length Records with georeferencing information.
    d. All LiDAR points in the LAS files are classified in accordance with project specifications.

2. Spatial Reference Checks: The LAS files were imported into the GeoCue processing environment. As part of the Dewberry process workflow, the GeoCue import produced a minimum bounding polygon for each data file. This minimum bounding polygon was one of the tools used in conjunction with the statistical analysis to verify spatial reference integrity.
    a. No issues were identified with the spatial referencing of this dataset.

3. 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 ground points in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas.
    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.
    b. Dewberry identified no data voids within the dataset.

4. Bare earth quality: Dewberry assured the cleanliness of the bare earth during classification by removing all artifacts, including vegetation, buildings, bridges, and other features not valid for inclusion in the ground surface model.

5.2 LiDAR Processing Conclusion

Based on the procedures and quality assurance checks, the classification conforms to project specifications set by the scope of work. All issues found during the qualitative QC were fixed. The dataset conforms to project specifications for format and header values. The quality control steps taken by Dewberry to assure the classified LAS meet project specifications are detailed below.

5.3 Classified LiDAR QA\QC Checklist

Overview

☒ Correct number of files delivered and all files adhere to project format specifications

☒ LAS statistics are run to check for inconsistencies

☒ Dewberry quantitative review process is completed

☒ Dewberry qualitative review process is completed

☒ Create LAS extent geometry

Data Inventory and Coverage

☒ All tiles present and labeled according to the project tile grid

Dewberry Quantitative Review Process

☒ LAS statistics review:

    ☒ LAS format 1.2

    ☒ Point data record format 1

- ☒ Georeference information is populated and accurate
    - NAD_1983_UTM_Zone_17N
    - NAVD88 - Geoid09 (Meters)
- ☒ GPS time recorded as Adjusted GPS Time, with 0.01 precision
- ☒ Points have intensity values
- ☒ Files contain multiple returns (minimum First, Last, and one Intermediate)
- ☒ Scan angle < 40°

☒ Data meets Nominal Pulse Spacing requirement: <=0.5 meters

- ☒ Tested on single swath, first return data only;
- ☒ Tested on geometrically usable portion (90%) of swath

☒ Data passes Geometric Grid Data Density Test

- ☒ Tested on 1 meter grid
- ☒ Tested on first return data only
- ☒ At least 90% of grid cells contain at least 1 point

☒ Data tested for vertical accuracy

- ☒ Checkpoint inventory
- ☒ Vertical accuracy assessment. LiDAR compiled to meet requirements.

Completion Comments: Complete – Approved

6 Breakline Production

6.1 Breakline Production Methodology

Dewberry used GeoCue software to develop LiDAR stereo models of the project area so the LiDAR derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using LiDARgrammetry procedures with LiDAR intensity imagery, Dewberry stereo-compiled the five types of hard breaklines in accordance with the project's Data Dictionary. All drainage breaklines were monotonically enforced to show downhill flow. Water bodies were reviewed in stereo and the lowest elevation was applied to the entire waterbody.

6.2 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 (Figure 3).

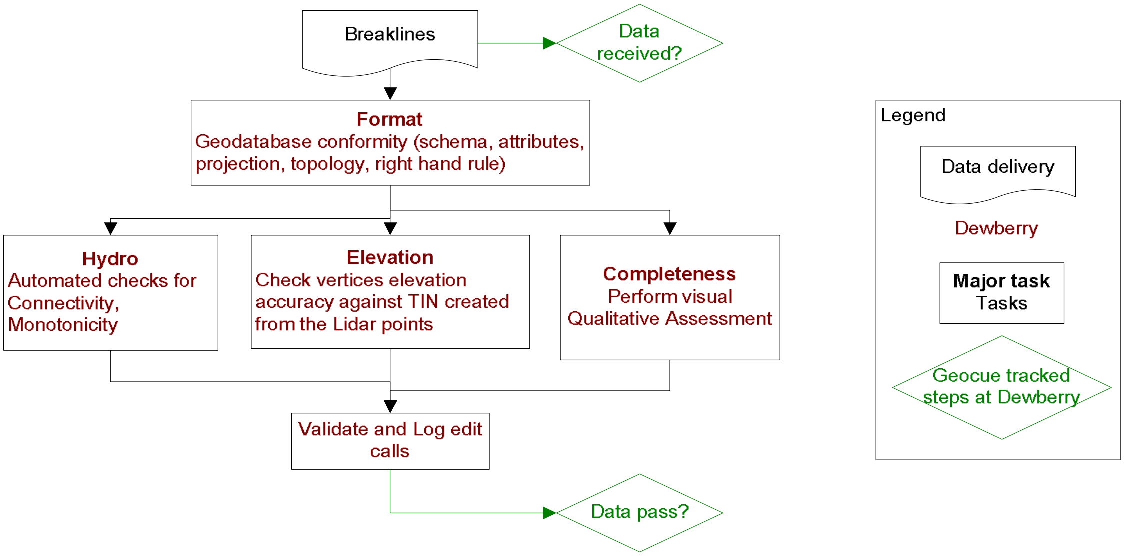


Figure 3 – Breakline Workflow

6.3 Breakline Topology Rules

Automated checks were 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 were generated at each vertex not complying with the tested rules and these potential edit calls were 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 were consistent with adjacent vertex elevations.

The next step was 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 was used to ensure that the elevations did not differ drastically 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.

6.4 Breakline QA/QC Checklist

Overview

☒ All Feature Classes are present in a geodatabase (GDB)

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

☒ The breakline topology inside of the GDB 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). NHD data will be used to help evaluate completeness of collected hydrographic features. 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 and GeoFIRM tools, drape breaklines on terrain to compare Z values. Breakline elevations should be at or below the elevations of the immediately surrounding terrain. Z value differences should generally be limited to within 1 FT. This should be performed before other breakline checks are completed.

Perform automated data checks using PLTS

The following data checks were performed utilizing ESRI's PLTS extension. These checks allowed automated validation of 100% of the data. Error records were either written to a table for future correction, or browsed for immediate correction. PLTS 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 feet). 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 waterbodies and Streams feature classes. This tool is found under "Topology Checks."

☒ Perform "duplicate geometry check". Attributes do not need to be checked during this tool. This tool is found under "Duplicate Geometry Checks."

☒ Perform "geometry on geometry check". Spatial relationship is contains, attributes do not need to be checked. This tool is found under "Feature on Feature Checks."

☒ Perform "polygon overlap/gap is sliver check". 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 features 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 errors 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. Z tolerance is .01 feet. Polygons need to be exported as lines for the monotonicity tool.

☒ Perform connectivity check between (tidal waters to inland streams), (tidal waters to inland ponds), (inland ponds to inland streams) 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. The unnecessary polygon boundary check must be run and all errors fixed prior to performing connectivity check. If there are exceptions to the polygon boundary rule then that feature class must be checked against itself, i.e. inland streams to inland streams.

Metadata

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

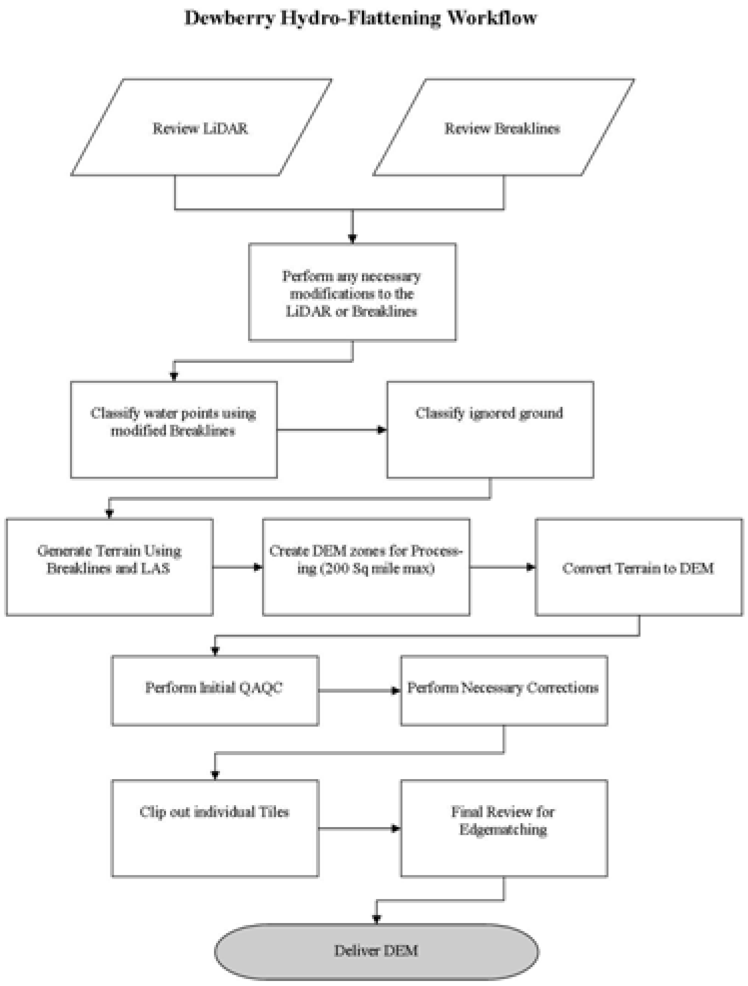
☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc. Content should be consistent across all feature classes.

Completion Comments: **Complete – Approved**

7 DEM Production & Qualitative Assessment

7.1 DEM Production Methodology

Dewberry used ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software was used to generate the products and the QC was performed in both ArcGIS and Global Mapper. The DEM workflow is shown in Figure 4 and described below.



Dewberry Hydro-Flattening Workflow

Figure 4 – Dewberry's DEM Workflow

1. Classify Water Points: 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 equal to the nominal point spacing on either side of the breakline. Breaklines will be buffered using this specification and the subsequent file will need to be prepared in the same manner as the water breaklines for classification. This process will be performed after the water points have been classified and only run on remaining ground points.
3. Terrain Processing: A Terrain will be generated using the Breaklines and LAS data that has been imported into ArcGIS as a Multipoint File. If the final DEMs are to be clipped to a project boundary that boundary will be used during the generation of the Terrain.
4. Create DEM Zones for Processing: Create DEM Zones that are buffered by 14m around the edges. Zones should be created in a logical manner to minimize the number of zones without creating zones to 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. Utilizing the natural neighbors interpolation method. 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: Corrections on zones will be performed following Dewberry's in-house correction process.
8. Extract Individual Tiles: Individual Tiles will be extracted from the zones utilizing the Dewberry created tool.
9. Final QA: Final QA will be performed on the dataset to ensure that tile boundaries are seamless.

7.2 DEM Qualitative Assessment

Dewberry performed a comprehensive qualitative assessment of the 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 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 scan for artifacts caused by the DEM generation process and to examine the hydro-flattened features. To perform this review, Dewberry created HillShade models and overlaid a partially transparent colorized elevation model. Upon completion of this review, the DEM data was loaded into Global Mapper to ensure that all files were readable and that no artifacts existed between tiles.

The quality control steps taken by Dewberry are outlined in the QA Checklist below.

7.3 DEM QA/QC Checklist

Overview

☒ Correct number of files is delivered and all files are in IMG Format

☒ All files are visually inspected to be free of artifacts and processing anomalies

☒ DEM extent geometry shapefile is created

Review

☒ All files are tiled with a 1 meter cell size

☒ Georeference information is populated and accurate

NAD_1983_UTM_Zone_17N

☒ Vertical accuracy is verified by comparing the LAS to the DEM

☒ Water Bodies, wide streams and rivers and other non-tidal water bodies as defined in Section III are hydro-flattened within the DEM

☒ Manually review bare-earth DEMs with a hillshade to check for processing issues or any general anomalies enforcement process or any general anomalies that may be present

Completion Comments: **Complete – Approved**

8 Conclusion

Dewberry was tasked by the client to collect LiDAR data and create derived LiDAR products for Berkeley, Clarke, Frederick, and Morgan County, WV. Geodigital was subcontracted to perform the LiDAR acquisition and calibration. Once Dewberry received the LiDAR data, initial QA/QC checks on the raw LAS swaths were performed. The LiDAR data were compiled to meet a vertical accuracy of 0.125 meters and, based on Geodigital's vertical accuracy tests and Dewberry's independently collected checkpoints, the data meets that criterion. The LiDAR data tested at 0.10 m vertical accuracy at 95% confidence level. Dewberry then classified the data according to project specifications and the classification was checked to ensure its accuracy. 3D breaklines were collected for the area. These breaklines and the LiDAR ground points were used to generate a DEM with hydro-flattened water bodies. Finally metadata were created for all deliverables. Based on the scope of work, all delivered products for the Berkeley, Clarke, Frederick, and Morgan County project conform to project specifications.