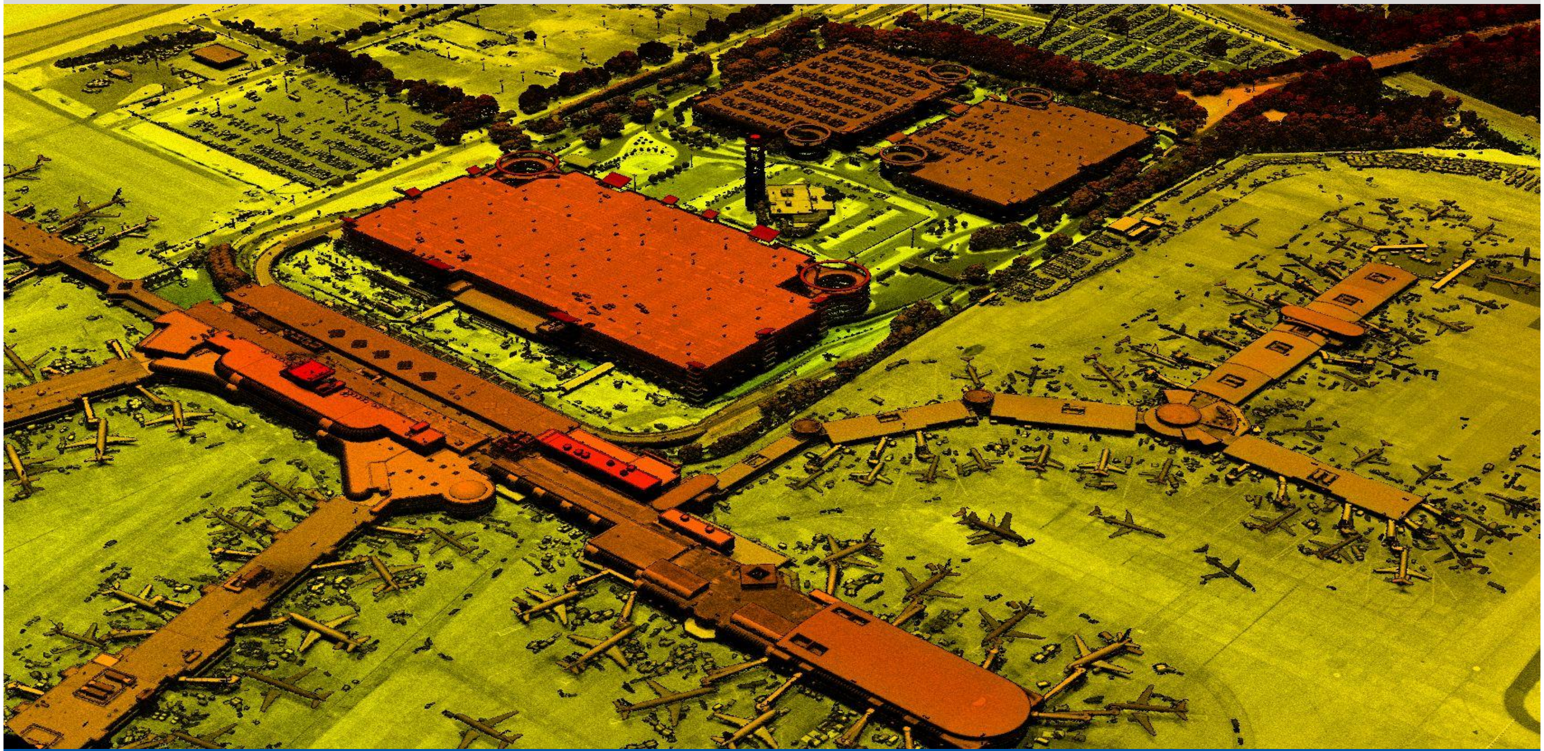
North Carolina Floodplain Mapping Program

286-000030 ESP

POST PROCESSING REPORT

Delivery Order 35
Phase 5 LiDAR Processing



February 21, 2019

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1.0 – Overview

This Post-Processing Report provides a comprehensive accounting of the Geiger-Mode Aerial LiDAR processing for Phase 5 of the North Carolina Floodplain Mapping Program, 286-000030 ESP, Delivery Order 35 (DO35). The purpose of this project was to update existing LiDAR data from the previous program, originally collected between 2000 and 2007, with more accurate and clearly defined LiDAR data utilizing the latest in sensor technology. To that end, the State of North Carolina, Department of Public Safety, Division of Emergency Management, Risk Management (NCEM) issued DO35 to ESP Associates, Inc. (ESP) to perform LiDAR data calibration and processing and survey support for the Phase 5 area the Mountain region of North Carolina. The task order area encompassed ~8,916.40 square miles.

Deliverables under DO35 included the following:

- Report of Survey – covering surveyed control in support of data calibration
- Report of Calibration
- Post-Processing Report
- Quality Control Plan and report (incorporated into the Post-Processing Report)
- Classified LiDAR in LAS 1.4 format
- Hydro-flattened Digital Elevation Models (DEMs) at 3.125, 10, and 20 ft. grids as GeoTIFF rasters
- High detail road and bridge polygons in ESRI geodatabase (GDB) format
- Intensity images in 8-bit, GeoTIFF format with a 5 ft. raster cell size
- Metadata, FGDC-compliant, project level by product

LiDAR data for the project and the validation site was collected by a single aerial vendor on the ESP team under DO30, between February 10, 2017 and April 10, 2017 using Geiger-mode Avalanche Photodiode (GmAPD) sensors. A Post Acquisition and a Survey Report was submitted for the data collection and ground support efforts under DO30.

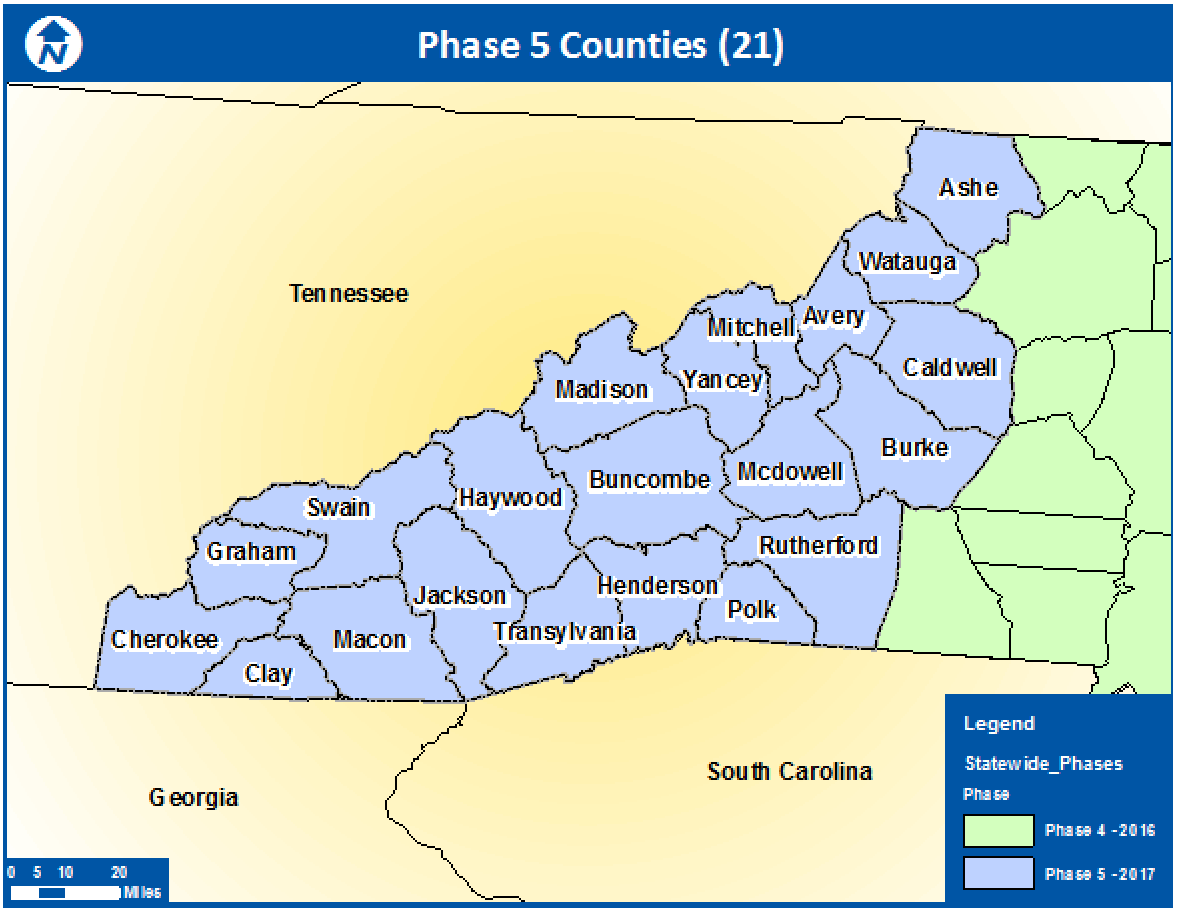
The project design was developed to ensure that the acquired LiDAR data met or exceeded the requirements for the current USGS Quality Level 1 (QL1) and State LiDAR Specifications with an aggregate nominal pulse density (ANPD) of >30 points per square meter (PPSM) for the collected density with a deliverable of 8 PPSM at an aggregate nominal post spacing (ANPS) of <0.35 meters. The project design supported an RMSE of 9.25 cm or better (USGS specifications of 10 cm were modified to State-required 9.25 cm) for Non-Vegetated Vertical Accuracy (NVA). Target Vegetated Vertical Accuracy (VVA) for this project was 30 cm or better at the 95th percentile, derived according to the American Society for Photogrammetry and Remote Sensing (ASPRS) Guidelines, Vertical Accuracy Reporting for Lidar Data, i.e., based on the 95th percentile error in all vegetated land cover classes combined.

Figure 1 depicts the North Carolina Counties for Phase 5 as approved by the NCEM for this Delivery Order. The baseline data (8ppsm) for delivery encompassed the entire area shown in Figure 1, plus a 100-meter buffer outside of the tile layout covering the project area. Data was delivered in full tiles.

Table 1: Counties included with this delivery order (21)

2017 North Carolina LiDAR Collection						
Ashe	Burke	Clay	Henderson	Madison	Polk	Transylvania
Avery	Caldwell	Graham	Jackson	McDowell	Rutherford	Watauga
Buncombe	Cherokee	Haywood	Macon	Mitchell	Swain	Yancey

Figure 1: 2017 Phase 5 LiDAR project area map



In areas bordering Phase 4 counties, a single line of overlap tiles between the two phases was processed and delivered again, utilizing the newer Phase 5 data. All processing and deliveries were conducted by county. Tiles overlapping county boundaries were not delivered twice. County tile layouts were developed utilizing the tile centroids where they intersected the county boundaries. A tile delivered with the Watauga County delivery, for instance, was not redelivered with the adjoining Caldwell County delivery. Figure 2 depicts the project tiling scheme. Figure 3 shows the intersection of the 100-meter buffer with the tile scheme and the selection of full tiles for delivery.

Figure 2: LiDAR tile scheme map

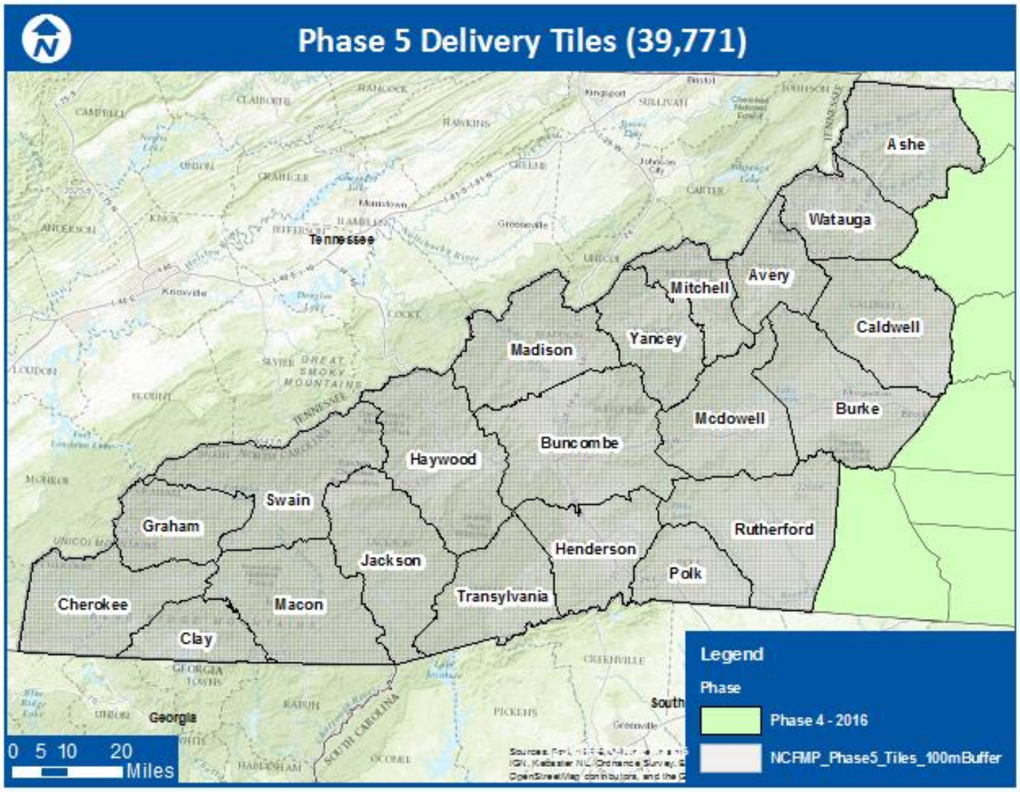
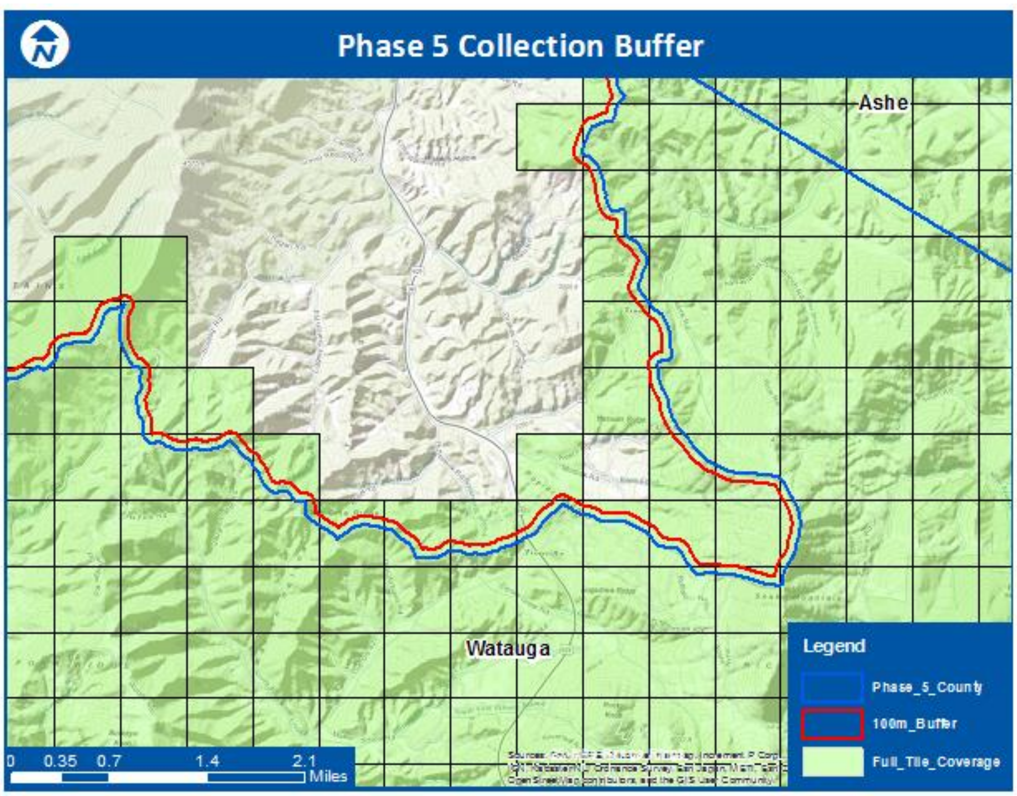


Figure 3: LiDAR tile scheme and 100-meter buffer

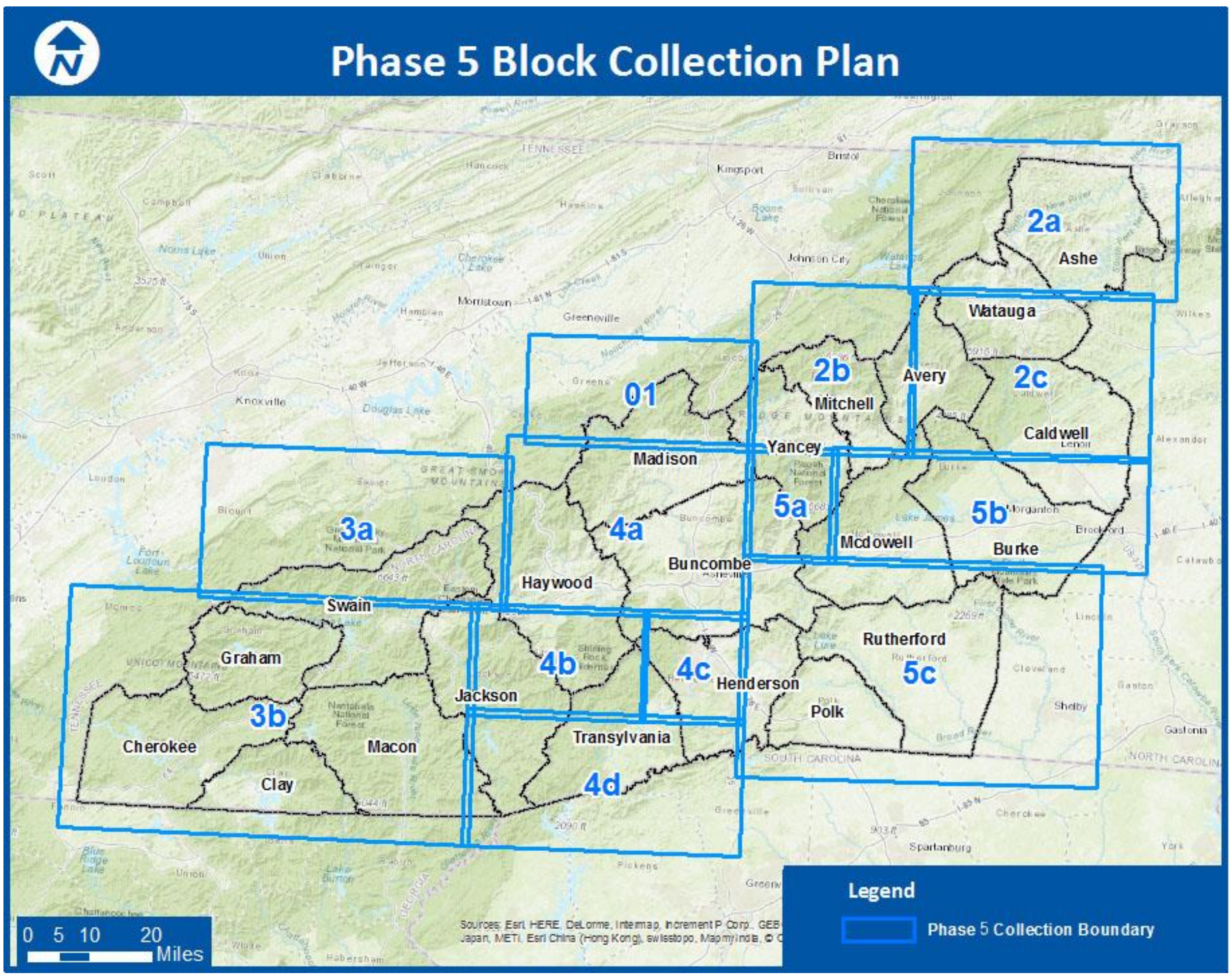


1.1– Processing Layouts

Several boundary layouts were used during the processing phase:

1. All data was collected and processed to the project boundary described in the previous section. A delivery of full 2,500 ft. X 2,500 ft. tiles was required (no partial tiles)
2. LiDAR data calibration was organized using the same block configuration as the data collection phase (shown in Figure 2)
3. Once the calibration of each LiDAR block was complete, the data was tiled using the statewide 2,500 ft. X 2,500 ft. tiling scheme. All remaining processes described were conducted on a tile by tile basis with the exception of road polygon collection (collected by county) and any automated processes on batches of tiles
4. Tiled deliverables were submitted by processing block (Figure 4)

Figure 4: LiDAR block layout (13 acquisition/calibration blocks)



2.0 – Data Processing

Data processing by the ESP Team began for each county area once the calibration for the relevant block was verified. Quality control checks and processes for the calibration phase are described in ESP's DO35 report of Calibration for Delivery Order No. 35 located within the Quality Control section. This signed and sealed document is included in Appendix A of this report. The Survey Report for this project is included in Appendix B of this report.

Once verified, the data was tiled out and then worked on by county. Each step in the process underwent internal QA/QC prior to either moving on to the next phase or to delivery.

2.1 – Data Tiling

Once the data calibration for each block was approved, the LiDAR data was tiled from flight lines into 2,500 ft. X 2,500 ft. tiles using an automated process and to the NC State Plane Coordinate System tile layout.

The tiled data was inspected to ensure that the automated process did not produce any partial or corrupt tiles. Once checked, the tiles were grouped by county and released into production per the project schedule.

2.2 – Classification of the LiDAR Point Cloud

Classification of the all-return LiDAR point cloud occurred in multiple steps to ensure proper classification to the project LiDAR classification schema and to ensure that the various LiDAR-derived deliverables matched each other. This division of steps was necessary to ensure that the project classification accuracy specification was met. The base ASPRS LiDAR classification schema was modified to the project requirements as outlined in table 2:

Table 2: Project classification schema

Class	Description	Class	Description
Class 1	Processed, Unclassified	**Class 7**	Noise (low)
Class 2	Bare Ground	**Class 9**	Water (breakline areas)
Class 3	Low Vegetation (0.5 – 3 ft.)	**Class 10**	Breakline Proximity
Class 4	Medium Vegetation (3 – 10 ft.)	**Class 11**	Noise (high)
Class 5	High Vegetation (10 – 220 ft.)	**Class 13**	Roads
Class 6	Buildings ($\geq$ 800 square ft.)	**Class 14**	Bridges

The steps during which the LiDAR points were classified are described below:

- ***Preliminary automated classification:*** Preliminary automated filtering macros produced an initial filter for the following classifications: Class 1 – Unclassified, Class 2 – Bare-Earth Ground, Class 3 – Low Vegetation, Class 4 – Medium Vegetation, Class 5 – High Vegetation, Class 6 – Building, Class 7 – Low Point (noise), and Class 11 – High Point (noise). Due to the density of points in Geiger, the client recommended all class 7 & 11 remain in class 1 – Unclassified. The automated filter searched and located class 7 & 11, but was then reclassified to class 1 as the final step.
- ***QA/QC of initial automated classification:*** A thorough QA/QC of Class 1 – Unclassified, Class 2 (bare-earth), Class 3 – Low Vegetation, Class 4 – Medium Vegetation, Class 5 – High Vegetation, Class 6 – Buildings, and Class 14- Bridge was necessary to fix any automated errors, i.e. ground classification errors, decks in ground class, decks in building class, building points in vegetation,

vegetation points in building class, and bridges in ground classification. During QA/QC, technicians reviewed each tile thoroughly for any gross errors caused by the software.

- ***Manual classifications:*** Once the automated filters were run and the results checked, the technicians manually classified Class 14 – Bridges. Automated filters have a much lower chance of success with this feature and the manual editing process ensured that this classification was accurate.
- ***Road classification:*** Road surface classification (Class 13) was accomplished using an automated classification routine constrained to the Edge of Pavement (EOP) polygons heads-up digitized for this purpose. The polygons were delivered along with the LAS files.
- ***Water features:*** Once the LiDAR tiles were mostly classified, technicians collected the hydro-flattening breaklines using the process described in Section 2.3 of this report. Class 9 (Water) was then automatically classified using the completed hydro-flattening line work along with a 1 foot buffer, reclassifying ground points that are directly on or immediately next to the lines to Class 10 (Proximity). This method ensured that the hydro-flattening line work and the water classification matched in all areas of the project.
- ***Final QA/QC of classification:*** a final QA/QC of the classified, all-return points cloud tiles was conducted once all classifications were complete. During this review, the technicians completed any additional manual edits necessary to correct any remaining classification issues that required a visual QC to identify. This included a comprehensive manual edit of classifications to ensure accuracy. Ancillary data in the form of a bridge location file and road centerlines provided by the State were also used to check that all locations were included in the classification if valid.

In summary, the steps at which the various classifications occurred are outlined in Table 3:

Table 3: Correlation between classifications and process used

Classifications	Process	Comments
Classes 1, 2, 3, 4, 5, 6, 7, 11	Preliminary automated filter	Fully automated
Classes 2, 3, 4, 5, and 6	Interim automated filter	Fully automated/manual edits and QC
Class 14	Manual classification	Manual interaction
Class 9	Classification using line work	Fully automated
Class 10	Classification using line work	Fully automated
Class 13	Classification using line work	Fully automated

For the vegetation, road, building, water, and bridge classifications the following criteria and guidelines were used in agreement with the project stakeholders:

- Vegetation classifications used the following inputs for the automated filtering:
  - Low vegetation: 0.5 – 3 ft.
  - Medium vegetation: 3 – 10 ft.
  - High vegetation: 10 – 220 ft.
- The road classification followed these guidelines:
  - Only state-maintained roads were classified
  - A state-provided road layer was used as a reference for road location
  - The latest available aerial images were used to identify new roads or roads not yet in the state file or to assist in identifying the Edge of Pavement (EOP)
  - Roads were classified EOP to EOP with islands and medians retained in Class 2 – bare ground, where applicable

- Not included were private drives, commercial roads or parking lots
- The building classification followed these guidelines:
  - Building classification was provided "as is" with only an automated solution and minimal manual interaction
  - Only structures $\geq$ 800 sq. ft. were included
  - Gross errors in building classification were corrected
- Water classification was conducted only on water bodies meeting the following criteria:
  - Ponds or lakes $\geq$ 2 acres
  - Streams or rivers wider than or equal to 100 ft.
  - Islands retained as Class 2 – bare ground only for islands $\geq$ 1 acre
  - Piers, decks, and boathouses were left in Class 1 - unclassified or in the vegetation classes and were not required to be edited as long as they were not in Class 2 – bare ground or in Class 6 – building
- The bridge classification followed these guidelines:
  - A bridge point file provided by the state was used to check locations
  - Where possible, pedestrian and road bridges not in the state file were classified
  - Vehicles and other non-bridge items on bridge decks were not included

Due to the varied land cover types located within the project, manual editing was required to achieve the level of classification accuracy required by the specifications. This was especially true for checking ground (Class 2), the vegetation classes (Classes 3-5), and the building classification (Class 6) where they overlapped (such as overhanging branches). Though there have been some improvements in automated filtering macros in software such as Terrascan, automation will not accommodate every possible scenario encountered within the project area.

The following issues on this project were checked for and manually corrected once the automated filters were run. This manual interaction occurred during the visual review of each tile:

- **Over-aggressive filtering** was corrected in areas where the automated filter had trouble retaining subtle ground features such as berms, banks, and ditches. This usually occurred in areas obscured by vegetation.
- Conversely, **under-aggressive** filtering was corrected where the filters left above-ground points in the ground classification. This also occurred mostly in areas obscured by vegetation or in urbanized areas where man-made features may have remained in the ground class.
- **Buildings and vegetation** required manual interaction during this project, especially in areas where the two features were adjacent. Even with advanced filtering, automation may become confused by vegetation that is touching or is in close proximity to building rooflines. A building filter may also "see" what appears to be a planar feature in dense forest/vegetation and classify these points as building. Technicians corrected these issues by manually by drawing profiles such as the one below and reclassifying the erroneous points to the proper classification.

The final step in the classification process was to finalize the LAS files by automatically populating the LAS headers with the following information:

- System identification – source sensor type or types and sensor serial number(s) for each tile
- Generating software – software used for final classification and manual editing
- Data projection included in a WKT VLR

The completed, deliverable product for this phase met the following specifications:

Table 4: Specifications met for this deliverable

Description	Comments	Referenced Standard
Naming convention	Files are readable, correctly named	NC LiDAR Standard, Sections 1.05 and 5.04.2
Project system	LAS in NC SPCS NAD83(2011), NAVD88, Geoid 12B	Request for Delivery Order, DO 35
Classification	No classifications in unused bins, variable length records present, min/max x, y, z ranges appropriate	Contractual, and Section 5.03.3 of the NC LiDAR Standard
Data Coverage	Data clipped correctly to tiles, project area and 100 m buffer covered	Contractual
Voids	Data does not exceed 4*Nominal Pulse Spacing (NPS) except where caused by water bodies, low reflectivity, or is filled in by another swath/lift	NC LiDAR Standard Section 5.01.4
Format	LAS are in version 1.4 format	Contractual
Density	Aggregate Nominal pulse spacing (ANPS) is 0.35 meter or better	Contractual

Vertical accuracy specifications for this project's classified LiDAR ground points met the following project criteria and were independently verified by the state:

- NVA Statement: "Compiled to meet ≤ 18.13 cm Fundamental Vertical Accuracy at the 95 percent confidence level in open terrain using $RMSE_z$ * 1.9600."
- VVA Statement: "Compiled to meet 30 cm Vegetated Vertical Accuracy at 95th percentile in open and vegetated terrain."

2.3 – Hydro-flattening Breaklines

Once a completed and verified bare-earth classification was available for an area, technicians began developing the hydro-flattening breaklines.

All streams/rivers and ponds/lakes visible in the LiDAR DEM were collected provided that they met the following minimum specifications:

- Streams/rivers that are ≥ 100 ft. in width
- Natural or man-made water impoundments (lakes, ponds, etc.) ≥ 2 acres
- Island polygons were collected for permanent island features ≥ 1 acre

Breakline collection was conducted using tools which allowed the technicians to select specific line types such as river banks and islands as well as polygon types such as lakes and ponds. The interface gave the technicians the flexibility to show object vertices as they collected the line work, constrain the line work to a fixed elevation, and/or to use min/max/mean methods of determining elevations. Using a profile view the technicians were also able to choose an elevation based on their interpretation of the river bank.

Figure 5: Water body prior to hydro-flattening breakline capture

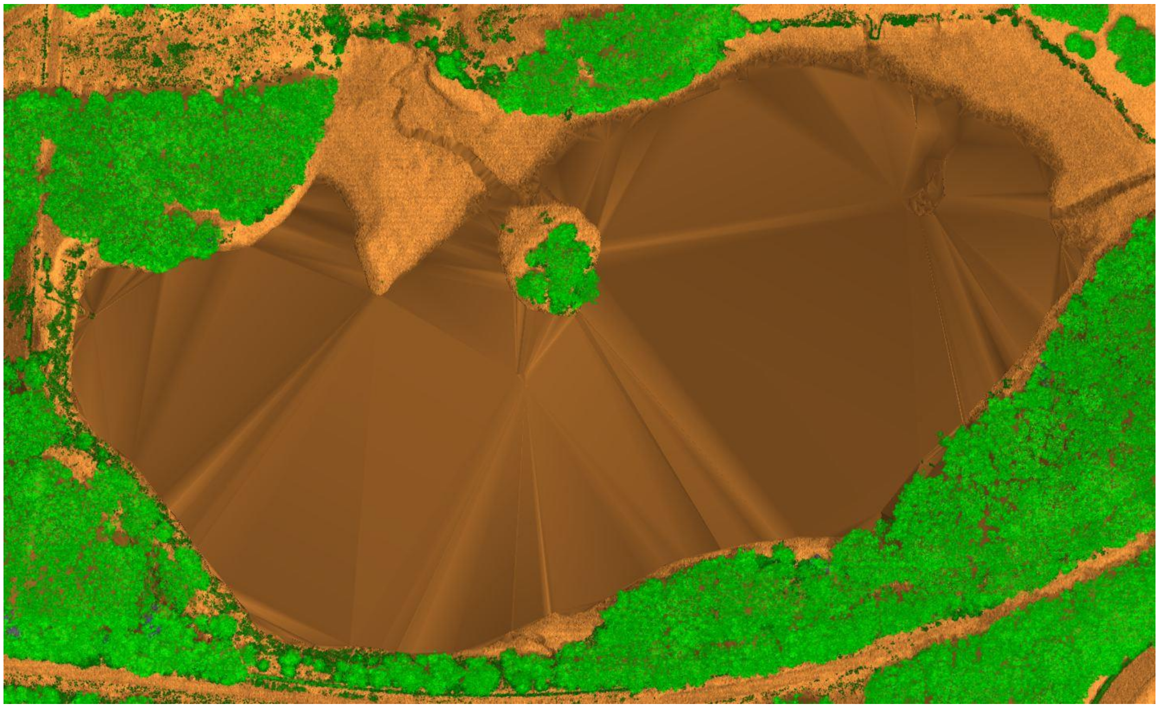
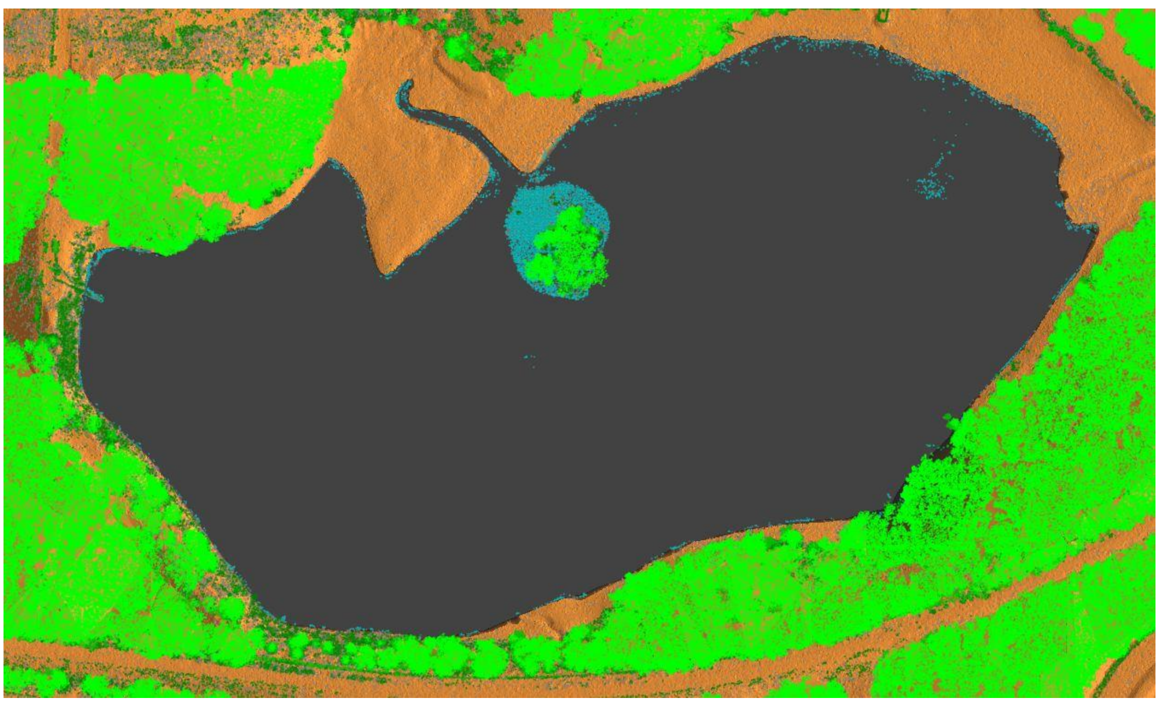


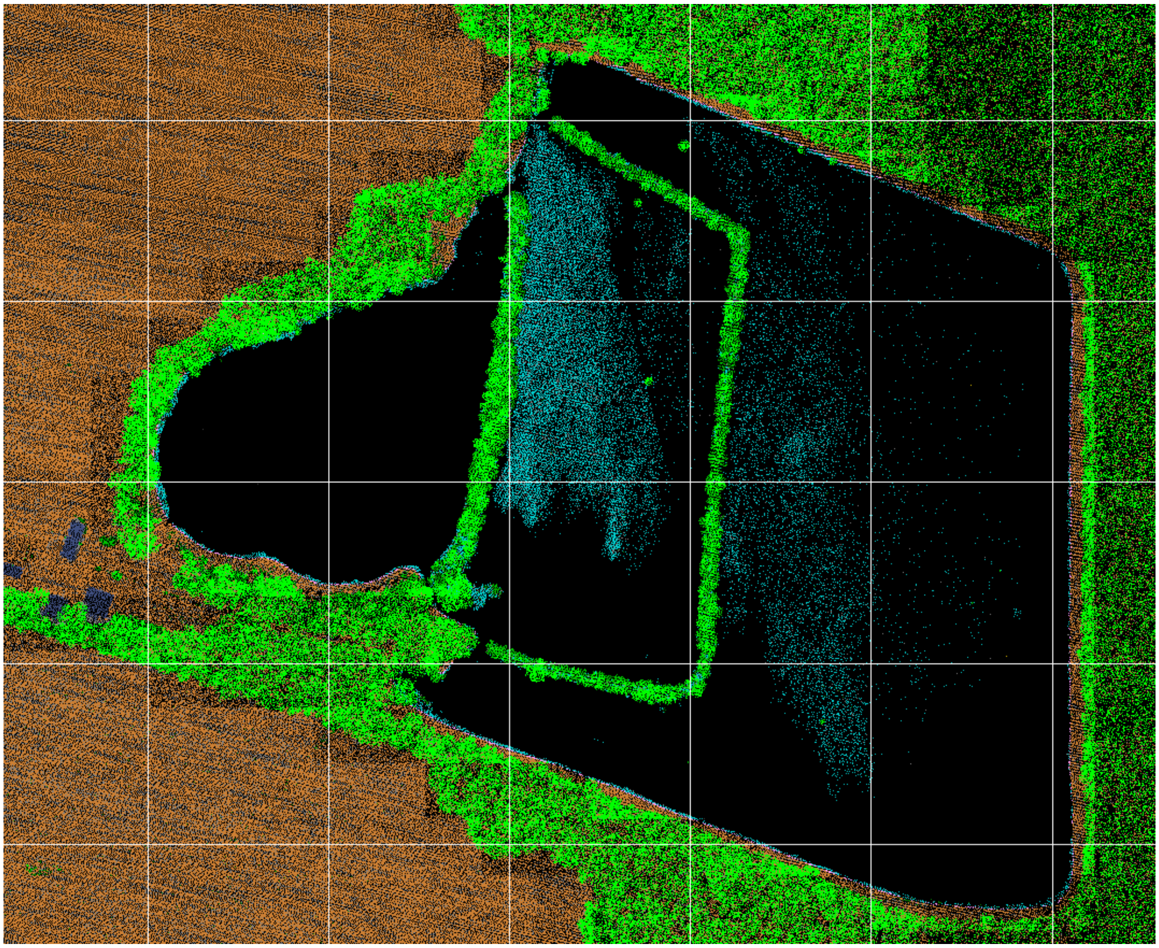
Figure 6: Water body hydro-flattened using hydro breakline



Pond and lake features were collected at one elevation representing the mean elevation of the feature where it met the bank around the edges. To ensure that only one elevation value was present on the pond/lake polygon, the technicians were able to lock the elevation value in as they were drawing.

For Quality Control, technicians used a tool specifically designed to assist them in determining if an island or pond feature met the minimum collection criteria. By utilizing this tool, the technicians were able to apply a grid sized to the minimum unit required allowing quick identification of features that should be collected. Figure 5 depicts a 1-acre grid overlaid on LIDAR data during the hydro breakline collection process.

Figure 7 Overlay of 1-acre minimum map unit

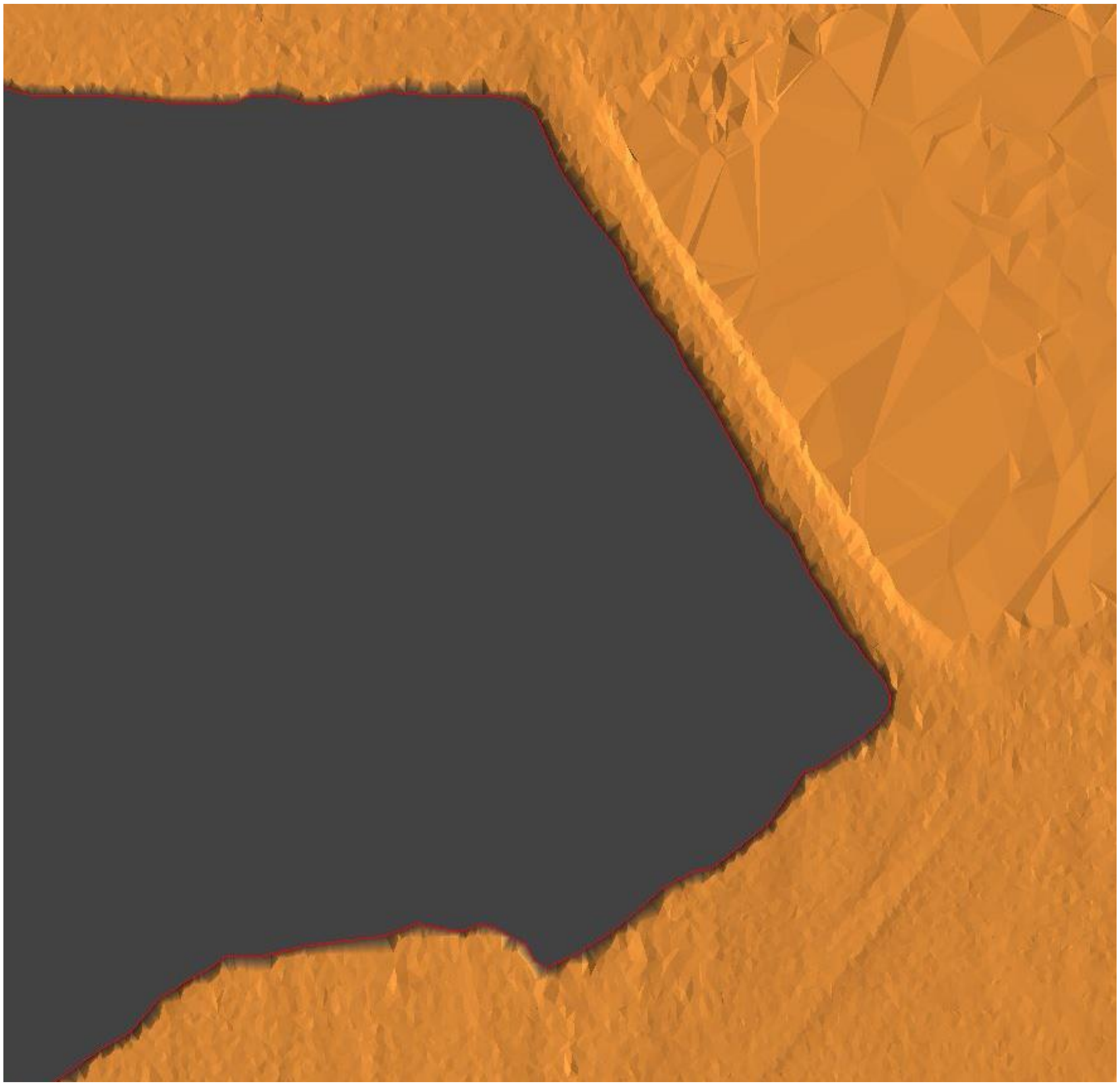


Rivers and streams were initially collected in 2D to ensure that the line work lined up in the x and y with the edges of river banks. The technicians then set a starting elevation at the head of the water feature and an ending elevation at the end of the water feature by drawing profiles at the edges of the banks to ensure that a proper starting and ending elevation is determined. The bank lines were then buffered, reclassifying ground points that are directly on or immediately next to the lines to Class 10 – Breakline Proximity. This prevented the line work from following the minute up and down elevation changes from point to point that is inherent to all LiDAR data. While these minute elevation variations in LiDAR would be within the acceptable vertical accuracy threshold of the project, they may still adversely affect the ability of the line work to "flow" downhill properly.

Once the line work was buffered, the technicians revisited the entire length of each water feature, drawing profiles and inspecting the elevations to ensure that they matched the LiDAR ground class. Using the hydro feature collection tool, the technicians were able to view the elevations of all vertices to check that they presented gradient downhill values (enforced monotonically) and to ensure that the features were flat from bank to bank. Note that this project did not contain any coastal or inter-coastal shorelines as it was fully contained, inland from the NC coastline.

As a final QA/QC check of the hydro-flattening breaklines, the technicians were able to visualize a TIN surface on-the-fly that incorporated the ground surface and the line work, so they could ensure that the surface was properly hydro-flattened. Figure 5 depicts an example of what the technician sees while using this QA/QC method.

Figure 8 Example of on-the-fly TIN generation incorporating hydro-flattening line work



The completed, deliverable product for this phase met the following specifications:

Table 5: Specifications met for this deliverable

Description	Comments	Referenced Standard
Inland Ponds and Lakes	• Collected if ≥ 2 acres • Polygons collected flat and level • Water surface collected at or below the immediately surrounding terrain. • Long impoundments such as reservoirs and inlets, whose water surface elevations drop when moving downstream, treated as rivers.	USGS LiDAR Base Specification Version 1.3
Inland Streams and Rivers	• Collected if ≥ 100 feet in width • Flat and level bank-to-bank • Water surface collected at or below the immediately surrounding terrain. • Stream channels break at road crossings (culvert locations). • Streams and rivers continuous at bridge locations.	USGS LiDAR Base Specification Version 1.3
Format	• ESRI Geodatabase by tile and county	Request for Delivery Order, DO 35

2.4 – Hydro-enforced DEMs

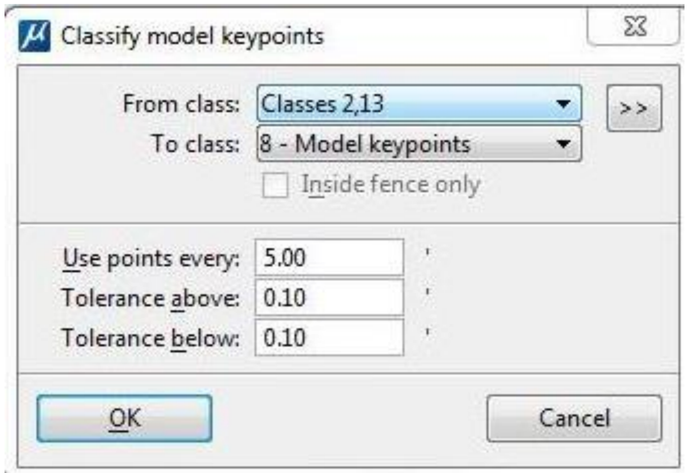
Hydro-enforced DEMs were delivered for this project in the form of GeoTIFFs set as a 32-bit floating grid. The GeoTIFFs were created by tile, by county using Classes 2 (Ground) and 13 (Roads) at resolutions of 3.125, 10, and 20 ft. pixels.

QA/QC for this deliverable was conducted by verifying that only Class 2 (bare ground) and Class 13 (road) were included in the DEMs, and that the Geo displayed properly. A final check ensured that the full extent of the terrain generated matched the tile layout of the delivered LAS and hydro-breakline data.

2.5– Terrain Geodatabases – Model Keypoints

ESRI terrain datasets were delivered for this project and were created for each county. The terrains were stored in individual File Geodatabase format in Arc version 10.4.1. The classified LiDAR bare earth points from the Class 2 (bare ground) and Class 13 (road) classifications first went through an automated process to determine model keypoints. Due to the high density of QL1 data a full bare earth model can be represented in a terrain as model keypoints, producing a much more manageable sized File Geodatabase. The model keypoint process using the parameters in Terrascan depicted in Figure 9:

Figure 9: Terrascan parameters for generating model keypoints



The model keypoint generation process classified the points needed to create an accurate triangulated surface model, using points every 5 ft. derived from the high-density source Geiger LiDAR. The tolerance of the maximum allowed elevation difference between the keypoint model and a TIN surface of the original Class 2 (ground) and Class 13 (roads) was set at ± 0.10 ft.

The model keypoint classifications were converted to multipoint features prior to being loaded. These multipoint features were stored as Surface Feature Type (SFType) “mass points” and were individually embedded into the Terrain dataset. A dissolve of the production tiles was conducted where the centroid of each tile that is in or closest to, a county was used for the county boundaries as SFType “hard clip”. Any breaklines developed as part of the project were included within the Terrain and contained the appropriate SFType assigned based on the type of input feature. The Pyramid Type was set to the Z Tolerance setting with the Pyramid Levels of 0, 0.5, 1, 2, 4, 8, 16, 32, 64, and 128 ft.

QA/QC for this deliverable was conducted by verifying that only Classes 2 (bare ground) and 13 (road) were included in the terrain datasets and that each pyramid level was calculated. A final check ensured that the full extent of the terrain generated matched the tile layout of the delivered LAS and hydro-breakline data.

2.6 – LiDAR Intensity Images

LiDAR intensity images were produced for all LiDAR tiles once the LiDAR data was accepted and approved by the state. LiDAR intensity images were produced using all point classifications and returns, with the exception of Class 7 and Class 11 (noise classes). The intensity images were developed in grayscale, 8-bit format using the same tiling scheme as the other LiDAR data deliverables. A 5 ft. raster cell size was used for the product. The 8-bit format used was an unsigned 8-bit depth with 256 available bins. QA/QC of the LiDAR intensity images was conducted via a visual review using ESRI ArcMap to ensure completeness of the files and reasonable tone and contrast quality across the data.

Every attempt was made to achieve homogeneity across the project area in image appearance. There will, however, be some variance in the appearance, especially over water bodies and other features where the reflected signal is either absorbed or reflected to a degree greater than normal.

Figure 10: Intensity image example

2.7 – Data Delivery Process

Once a deliverable was ready, the data was transferred to external hard drives and checked directly on the drive for the following potential issues:

- Corrupt files
- Completeness of the deliverable area
- Inclusion of ancillary files such as tile layouts

QA/QC of each LAS dataset also included a semi-automated review of LAS file information including (but not limited to):

- Inclusion of system identification (sensor(s) used) and generating software
- Correct global encoding present
- Projection information present
- No classifications outside of the project classification scheme present

2.8 – Metadata

Project metadata was generated using XML metadata editors in ESRI ArcCatalog. Project and deliverable-level metadata were generated containing comprehensive abstracts and process steps. QA/QC on the metadata was conducted via a visual inspection of the content and automated error checking using the USGS Geospatial Metadata Validation Service.

3.0 – Lessons Learned

This section of the post-processing report addresses the lessons learned during the processing phase of the project to provide insight into what issues were encountered, how they were dealt with, and what measures were taken to prevent future issues. Compared to the prior, Phase 4 project significantly less issues were encountered due to the maturation of both the Geiger hardware and software processes.

3.1 – Process for Road Polygon Collection

The process used for high detail road polygon collection during this project was dependent upon project schedule; while the LiDAR data was being calibrated, initial road polygons were collected and then later adjusted as the LiDAR became available in a given area. While this allowed work to continue in parallel to the LiDAR calibration task, the nature of the land cover in this project area (heavy, overhanging tree cover) adversely impacted the placement of the road polygons when only using the imagery for initial placement. This resulted in numerous road adjustments and significantly increased the chance of an erroneous polygon making it through the quality control process.

For future projects of this nature, areas similar in land cover to the Phase 5 area will need to be collected only when the LiDAR is available in order to ensure that the initial road polygons are of sufficient quality prior to finalizing the product.

4.0 – Certifications

Project Post-Processing Report prepared by:

Harold Rempel, CP, CMS LiDAR, GISP

American Society for Photogrammetry and Remote Sensing
HAROLD REMPEL
CERTIFIED
PHOTOGRAMMETRIST
(ASPRS) No. R1418
Exp. 2/21/2019

2/21/19

This is to certify that the items in this delivery including: 1) Classified LiDAR Point Cloud in LAS version 1.4 format, 2) Hydro-Flatting Breakline Files in ESRI personal .GDB format, 3) Hydro-enforced DEMs as ESRI terrain datasets in individual file .GDB format, 4) Metadata to FGDC standards for the point cloud, and 5) LiDAR Intensity Images in GeoTIFF format, meet project specific standards as defined in Delivery Order No. 35 *LiDAR Processing and Associated Products for Phase 5 Counties* and the *NC LiDAR Standard, Sections 1.05, 5.01.4, 5.03.3, and 5.04.2.*

ESP Associates, Inc. (ESP) used calibrated LiDAR data provided by Harris Corporation, under the oversight of ESP's NCPLS, which has a stated Non-Vegetated Vertical Accuracy (NVA) of ≤ 18.13 cm at the 95-percent confidence level (9.25 cm RMSEz) to produce these products. Vegetated Vertical Accuracy (VVA) was 30 cm or better at the 95th percentile, derived according to the American Society for Photogrammetry and Remote Sensing (ASPRS) Guidelines, Vertical Accuracy Reporting for Lidar Data, i.e., based on the 95th percentile error in all vegetated land cover classes combined. Appendix A of this report contains ESP's Report of Calibration dated January 18, 2018 which includes the original certification of the calibration. LiDAR data for this project was collected by a single aerial vendor on the ESP team under DO30, between February 10, 2017 and April 10, 2017 using Geiger-mode Avalanche Photodiode (GmAPD) sensors. A Post Acquisition and a Survey Report was submitted for the data collection and ground support efforts under DO30. Coordinates and elevations of all delivery items are in US Survey Feet and based on NAD83 (2011) and NAVD88 (GEOID12B) respectively. The work processes and deliverables detailed in this report were performed using sound and accepted surveying practices.

This certification covers 19 of the 21 counties, omitting Cherokee and Clay Counties. Cherokee and Clay will be certified via an addendum once NCEM has completed independent verification tasks.

Daniel B. Hill, PLS
North Carolina L-4137

NORTH CAROLINA
PROFESSIONAL
SEAL
L-4137
LAND SURVEYOR
DANIEL B. HILL

2/21/19

Post-Processing Report

Appendixes

Appendix A – Report of Calibration

A signed and sealed calibration report entitled: “DO35_Report of Calibration” is provided as a digital attachment to this report.

Appendix B – Survey Report

A signed and sealed survey report entitled "DO35_Survey_Report_112917" is provided as a digital attachment to this report. Accompanying this attachment are digital files comprised of:

- Phase5_ALL_GCPs.zip - file containing ESRI Shapefiles of ground control points within Phase 5 as well as recovered points in overlapping areas with Phase 5
- Phase5_Calibration_Points.zip – file containing calibration points by calibration block in shapefile and Excel formats as well as field photos of the points
- Phase5_Independent Checkpoints.zip – file containing a shapefile and Excel sheet of the internal, independent checkpoints used by ESP along with the associated field photos

Appendix C – Independent LiDAR Quality Control Reports

Independent LiDAR quality reports by county have been provided by the North Carolina Geodetic Survey (NCGS) and are posted on the NCGS website.