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FOUR COUNTY SC LIDAR QUALITY ASSURANCE

OCONEE COUNTY REVIEW

FOR

UNITED STATES GEOLOGIC SURVEY
AND
SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

USGS CONTRACT: G10PC00025
TASK ORDER G11PD01086

First review: November 15, 2011
Second review: February 21, 2012

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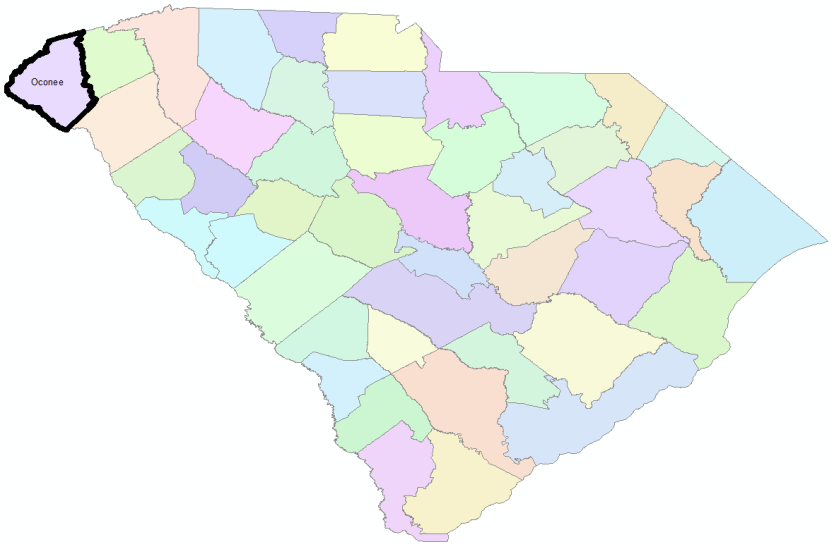
1) Executive Summary

USGS Contract Number	Production Contractor	Date Prepared	Delivery #	Aerometric, Inc. Recommendation
G10PC00025	Dewberry	Feb. 21, 2012	2	Pass

Table 1: Executive Summary Table

Aerometric, Inc. has reviewed the Oconee County portion of the Four County SC LiDAR Quality Assurance as outlined in the SC Acceptance Criteria. Oconee County comprises 674 square miles provided in 872 LAS files (5,000 i. ft x 5,000 i. ft.) as prepared by Dewberry in ASPRS LAS cloud data classification. Breaklines were also provided supplemental to the LAS in preparation of the overall county Digital Elevation Model (DEM). The location of Oconee County is as follows:



Figuree 1: Vicinity Map

In summary, AeroMetric's review finds that Dewberry collected and processed the data within general conformance with the SC Acceptance Criteria (Criteria). The Criteria served as a checklist for the review and the following narrative. The order of the Completeness/Usability Acceptance Criteria was modified for readability, but the status of each acceptance criteria is as follows:

CRITERIA	TESTED CHARACTERISTIC	STATUS
COMPLETENESS/USABILITY ACCEPTANCE CRITERIA		
5	USB external hard drives	PASS
4	Metadata	PASS
7	File name	PASS
6	File organization	PASS
9	Format of DEM	PASS
10	Format of LiDAR Processing Report	PASS
11	Format of Accuracy Report	PASS
12	Georeferencing	PASS
20	Conformance of tiles to index grid	PASS
13	Horizontal Units	PASS
14	Vertical Units	PASS
15	Horizontal Datum	PASS
17	Coordinate System	PASS
16	Vertical Datum	PASS
1	Flight lines	PASS
2	Acquisition Parameters	PASS
3	GPS Trajectories	PASS
8	Format of LiDAR Mass Points	PASS
18	Mass points	PASS
19	Elevation (DEM)	PASS

CRITERIA	TESTED CHARACTERISTIC	STATUS
VERTICAL AND HORIZONTAL ACCURACY ACCEPTANCE CRITERIA		
21	FEMA Ground Cover Category Accuracy Validation	PASS
22	NSSDA/FEMA Vertical Accuracy Validation	PASS
23	ASPRS/NDEP Vertical Accuracy Validation	PASS
24	NSSDA Horizontal Accuracy	PASS
LIDAR ACCEPTANCE CRITERIA		
25	Ground	PASS
26	Continuity	PASS
27	Inconsistent Post-Processing/Editing	PASS
28	Over-smoothing	PASS
29	Artifacts	PASS
BREAKLINE ACCEPTANCE CRITERIA		
30	Completeness	PASS
31	Monotonicity	PASS
32	Vertical Consistency	PASS
33	Topology	PASS

Table 2: Acceptance Status Summary Table
See Attachment A for Measure of Acceptability

2) Overview

Aerometric, Inc. has reviewed the Oconee County portion of the Four County SC LiDAR Quality Assurance as outlined in the SC Acceptance Criteria (Criteria). Automated checks and functionality of data has been evaluated for the entire project area, and manual/visual reviews were performed for 10% of the project area. This report was prepared to follow the Criteria's outline, which covers four categories – Completeness/Usability Acceptance Criteria, Vertical and Horizontal Accuracy Acceptance Criteria, LiDAR Acceptance Criteria, and Breakline Acceptance Criteria. These four criteria and their associated sub-categories are described in the following narrative.

3) Completeness/Usability Acceptance Criteria

This portion of the SC Acceptance Criteria (Criteria) focuses on the fundamental elements of the project deliverables provided by Dewberry. The order of the Criteria outline was modified for readability, and divided into three categories – data format, project location, and project data. These categories and their compliance are described as follows:

DATA FORMAT

The first check of the submittal was confirmed that the media was readable, all were files accessible, and no files were corrupted.

The project and tile (file) level metadata is also required to be provided in XML format that can be validated using Metadata Parser (mp) software. The metadata for bare-earth and breaklines also needs to be FGDC-compliant tile level, and the metadata for LAS (point cloud) is required to be project level. The metadata has been validated and found to be in general compliance.

The file naming convention appears to adhere to the South Carolina Geodetic Survey 1:200-scale index.

The DEM was provided for the full county in International Feet and in Arc Grid Format as required.

The Criteria also requires that the LiDAR Processing Report and the Accuracy Report are to be provided as a PDF, which were provided as the TriCounty_SC_Report.pdf.

PROJECT LOCATION

The project files are required to and do open in the correct location and conform to the master index grid. No gaps were found between the tiles at a 1:1 view. Tiles must also be and are complete except for boundary tiles.

In accordance with the Criteria, the horizontal and vertical units were provided to 3 decimal places and as feet. Additionally, the horizontal datum is the NAD 83 HARN, and project files are projected on the 3900 □ South Carolina State Plane Coordinate System. The vertical datum is the NAVD 88 processed with Geoid03 as required.

PROJECT DATA

The flightlines were flown with a sidelap of 45 to 50%. The collected data couldn't have holidays and needed to have periodic and local calibration checks. No holidays were noted in the review of 10% of the project area. The exhibits below show the extents of sidelap:

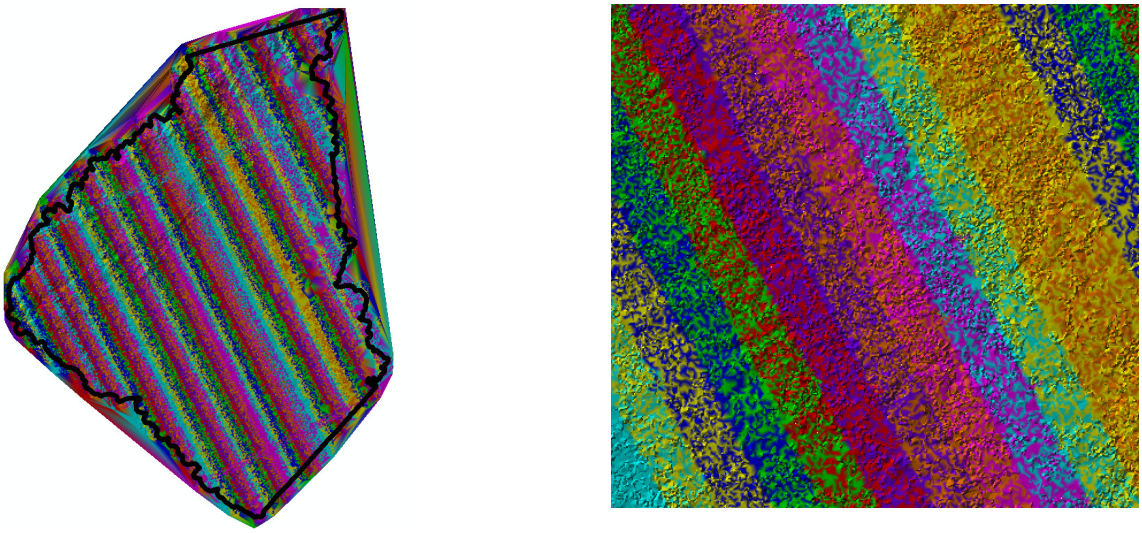


Figure 2: Overall project flightline exhibit (left) and enlarged view (right)

The Criteria also requires GPS baseline lengths to be less than 25 miles. The GPS baseline lengths are established by the distance between check points. Six check points were collected for the Oconee County data collection – the classification was not provided for two points, three are classified as bare earth, and five points are classified as bare earth. The figure below shows the location of said checkpoints in relation to Oconee County and the provided tiles.

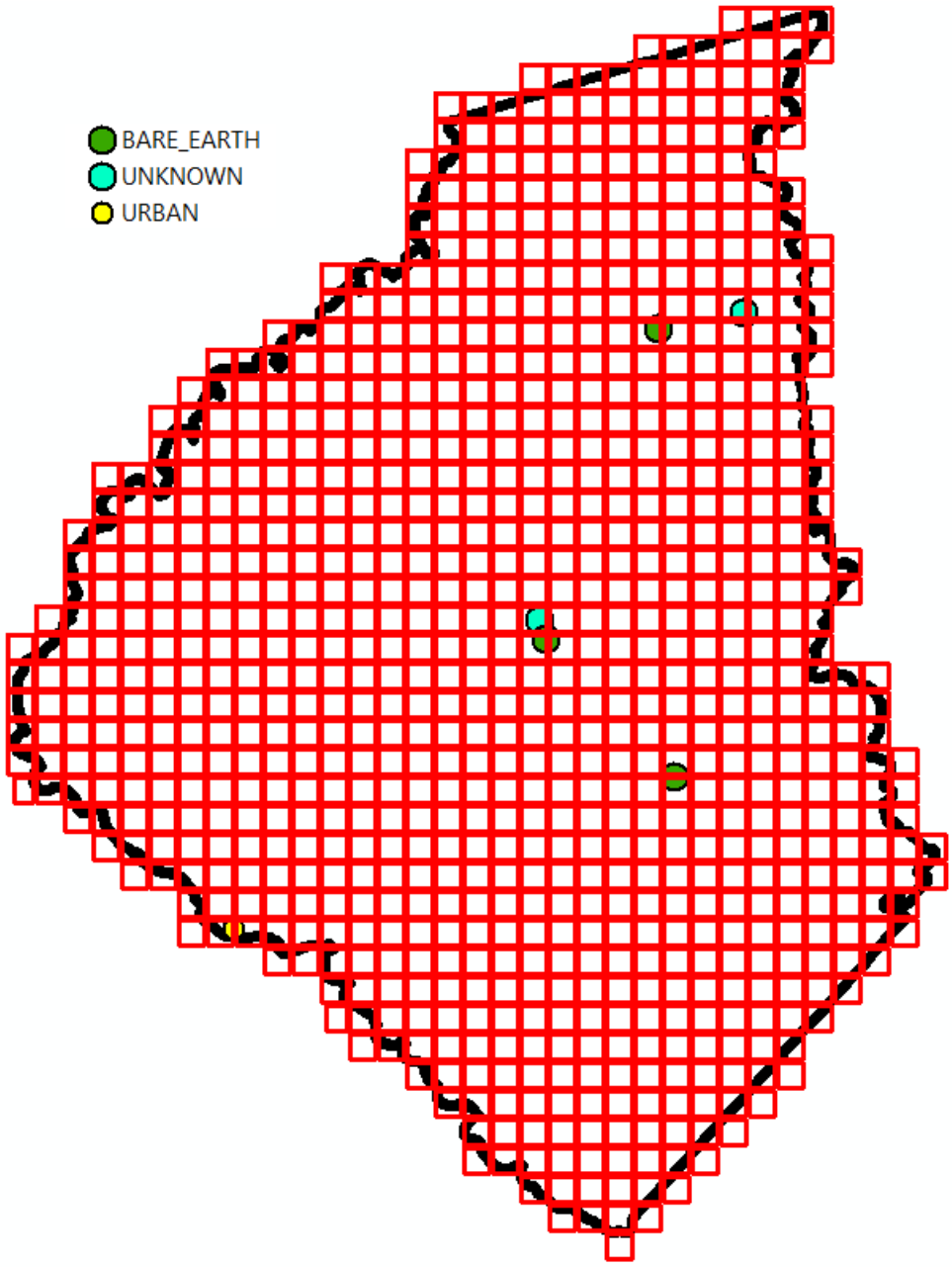


Figure 3: Oconee County Checkpoints

Additionally, the Criteria requires the GPS trajectories to be evaluated with foreward and reverse comparisons within 10-20 cm. The GPS solution chart below, as provided by Dewberry, shows forward and reverse comparisons within 3 - 7 cm as provided in the TriCounty_SC_Report.pdf.

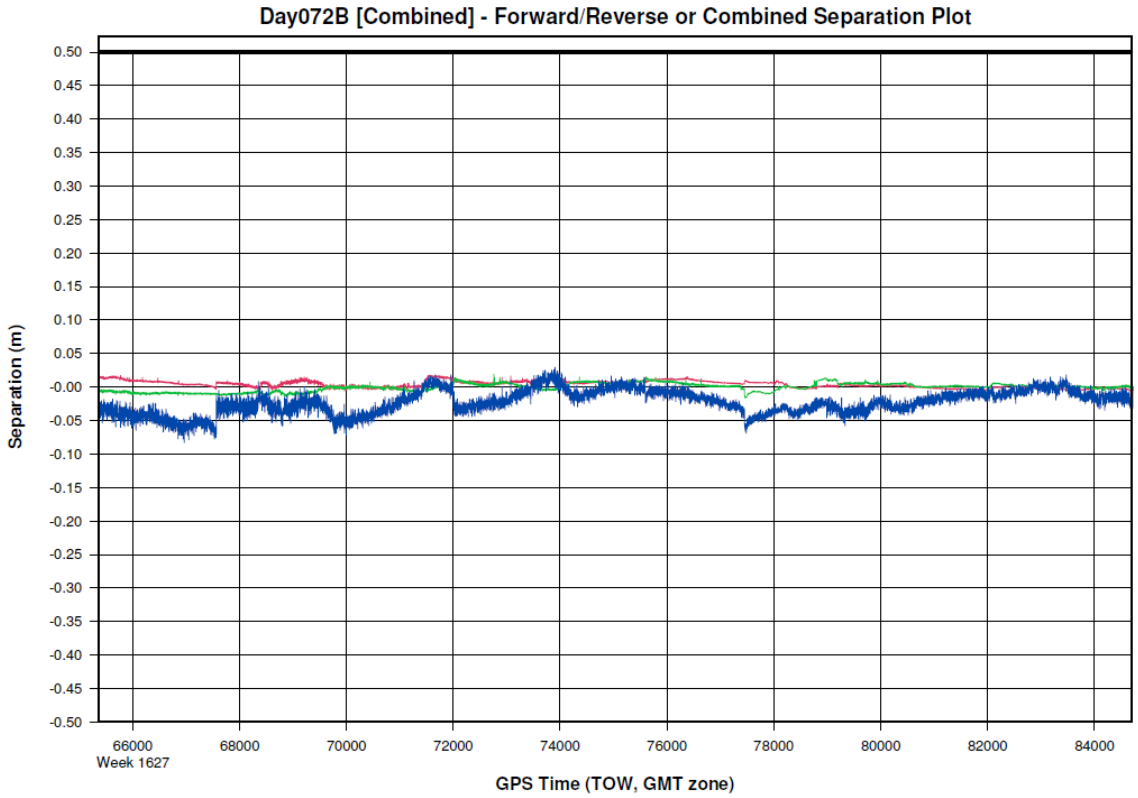


Figure 4: Forward vs. Reverse Post-Processed Solution – Lift 072B

The files were written one per 5000' x 5000' (Item 6). An automated routine was used to confirm that more than 90% of points have another point within 1.4 meters per USGS Standards (96% of all points have a point within 1.4 meter).

The mass points were provided as Point Data Format 1 with the LAS 1.2 classification codes:

Class 1 = Unclassified (Default, noise)
Class 2 = Ground
Class 7 = Noise
Class 8 = Model Key (thinned)
Class 9 = Hydro
Class 10 = Ignored Ground

The project points conform to the LAS 1.2 classification codes noted.

The DEM is required to have no null values and valid min/max stats. The breaklines must also match the elevations. The automated review of the DEM confirms that it has no null values. The minimum and maximum DEM elevations are 610.23 and 3,3454.99 respectively, and the minimum and maximum LAS are 609.99 and 3,671.61 respectively. These minimum appear to more reasonably match the elevations provided in the LAS ground surface, and the maximum LAS ground surface elevations are located outside of the project boundary, so a manual inspection confirmed the maximum elevation from the DEM is reasonable.

4) Vertical and Horizontal Accuracy Acceptance Criteria

As stated in the Criteria, the ground cover category accuracy validation is required, per Section A.8.6.2, Appendix A, to FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners," to acquire 20 check points for each of the following five categories:

1 – Bare earth, low grass
2 – High grass and crops
3 – Scrub/brush
4 – Forested
5 – Urban areas

Additionally, each ground cover category must be tested in accordance with USGS LiDAR Guidelines and Base Specifications - Version 13, requires that, for 2 ft contour accuracy:

$RMSE_z$ = 15.0 cm = 0.49 ft

One point under the Urban classification, A-201, was found to be 2.9 feet greater than ground surface, which appeared to be a result of the processing of ground surface. Without the processing of the ground surface, this point appeared to be within approximately 0.5' of the surface. This point was considered a statistical outlier for the purposes of this report. Neglecting said point, the results for each ground cover category are as follows:

Ground Classification	# of Points	RMSEz (ft) Open Terrain Max* = 0.49 ft	Mean	Median	Skew	Standard Deviation	Min	Max
--	--	(ft)	(ft)	(ft)	--	(ft)	(ft)	(ft)
1 - BARE EARTH	30	0.22	0.02	0.05	-1.19	0.22	-0.77	0.47
2 - BRUSH	22	0.28	-0.06	-0.06	-0.35	0.28	-0.79	0.56
3 - HIGH GRASS	22	0.24	-0.18	-0.18	-0.17	0.17	-0.50	0.10
4 - FORESTED	12	0.26	-0.08	-0.13	0.45	0.25	-0.39	0.36
5 - URBAN	21	0.21	0.14	0.16	-0.53	0.16	-0.24	0.39

*Maximum allowable per the SC Acceptance Criteria

Table 1: Ground Cover Category Accuracy Validation Table

As stated in the Criteria, the NSSDA/FEMA vertical accuracy validation must be tested in accordance with NSSDA and FEMA Vertical Accuracy Testing Guidelines, which states that, for 2 ft contour accuracy:

Accuracyz = 30.0 cm or 0.98 ft at 95% confidence level.

The vertical accuracy results are as follows:

Ground Classification	# of Points	FVA - Fundamental Vertical Accuracy 95th Percentile Max = 0.98 ft	SVA - Supplemental Vertical Accuracy 95th Percentile Max = 0.98 ft	CVA - Consolidated Vertical Accuracy 95th Percentile Max = 0.98 ft
--	--	(ft)	(ft)	(ft)
OPEN TERRAIN	51	±0.43		
HIGH GRASS/BRUSH	44		±0.43	
FORESTED	12		±0.50	
ALL	107			±0.72

*Maximum allowable per the SC Acceptance Criteria

Table 2: Vertical Accuracy Validation Table

The Criteria also states that the NSSDA horizontal accuracy requires breaklines to be compiled to meet RSMEz of 1 meter. The visual inspection of vertices in 10% of the project area found that waterbodies, single stream, connector, and stream banks were generally collected accordingly. These breaklines are recommended to "Pass."

5) LiDAR Acceptance Criteria

As stated in the Criteria, the Ground Points (Bare Earth) surface must be post-processed to remove 98% of structure points and 95% of vegetation points. The visual inspection of 10% of the project area confirms that 98% of the structure points and 95% of vegetation points have been removed. Additionally, the inspection review of 10% of the project area found that LiDAR mass points were generally allocated to the appropriate point classification.

The Criteria also states that there can be no data voids greater than two times post spacing (2.8 meters) and no vertical offsets greater than 20 cm between adjoining strips and/or tiles. USGS Standards require that 90% of all points meet two times post spacing, which was confirmed in Item 8 of the Acceptance Criteria. No vertical offsets of more than 20 cm were noted in the visual inspection of 10% of the project area.

There are to be no visible variations in TIN/DTM caused by differing processing techniques. Mild variations in the TIN/DTM were noticed in the visual inspection of 10% of the project area. These variations do not constitute aggressive removal of mass points and may not be caused by differing processing techniques. As a result, this item is recommended to "Pass."

The Criteria also requires that smoothing techniques shall not remove topographic features necessary to define drainage features, and 90% of artifacts must be removed with no spikes, holes, or blunders, and no cornrows or seamline mismatches greater than 20 cm. The visual

inspection of 10% of the project area confirms that the smoothing techniques did not remove topographic features necessary to define drainage features, and artifacts were removed accordingly.

6) Breakline Acceptance Criteria

The Criteria requires that breaklines must be collected for all streams larger than 40 feet in width, for waterbodies 1 acre in size or greater with a tributary drainage area one-half square mile or greater. Single line breaklines were required for streams with features less than 40-ft wide. Stream connector/centerlines were required to show flow between interconnecting rivers and streams at culverts and similar feature type locations. The visual inspection of hydro breaklines in 10% of the project area found that streams greater than forty-feet in width and waterbodies greater than one acre in size are generally collected. Single stream and connector breaklines were also collected in general conformance with the Criteria. This item is recommended to "Pass."

The Criteria also requires hydro-correction for downhill direction of stream flow. The visual inspection of hydro breaklines in 10% of the project area found that the stream breaklines generally conform to the Criteria. This item is recommended to "Pass."

As stated in the Criteria, vertical consistency of the breaklines shall meet the following criteria:

- Vertices should not have a 0 elevation
- Vertices should not have excessive min or max z-values when compared to adjacent vertices
- Vertical variance between breaklines & LiDAR DTM < 1 ft

The visual inspection of vertices in 10% of the project area found that waterbodies and stream banks were generally collected accordingly. Single stream and connector breaklines were also collected in general conformance with the Criteria. This item is recommended to "Pass."

As stated in the Criteria, breaklines should not intersect unless they are at the same elevation, except that bridges and overpasses may intersect hydrographic features. The visual inspection of 10% of the project area confirms that the breaklines were collected as noted.

7) Final Conclusions and Recommendations

All of the corrections and modifications recommended by Aerometric on behalf of the South Carolina Department of Natural Resources and US Geological Survey have been made to the LiDAR data for Oconee County. We recommend that the LiDAR data for Oconee County be accepted as final. Please note that the assessment of the LiDAR data and its derivative products are based on a combination on automated validation tools applied to 100% of the data and a manual analysis of approximately 10% of the land surface area for that county, which

Aerometric believes is sufficient in detecting the vast majority of significant errors. Minor errors may still remain. Any significant anomalies discovered by subsequent use of the data should be brought to the attention of SCDNR.

APPENDIX

ATTACHMENT A: MEASURE OF ACCEPTANCE

Criteria	Tested Characteristic	Measure of Acceptability
Completeness/Usability Acceptance Criteria		
1.	Flight lines	Flight lines flown as planned with 10% minimum sidelap between flight lines, flying height (≈8,300' AMT), PDOP ≤ 4; no holidays; periodic, local, calibration checks. Flight overlap is 45% to 50% in SC DNR spec
2.	Acquisition Parameters	GPS baseline lengths <25 miles; scan angles of ±18° from nadir; FOV 30°
3.	GPS Trajectories	Forward and reverse comparisons within 10-20 cm
4.	Metadata	Project and tile (file) level metadata in XML format that can be validated using Metadata Parser (mp) software. FGDC-compliant tile level metadata for bare-earth and breaklines; project level metadata for LAS (point cloud)
5.	USB external hard drives (Firewire) make/model coordinated with DEM	Media is readable, all files accessible, no files corrupted
6.	File organization	Files written one per 5000' x 5000'. DEM can be full county (International Foot)
7.	File name	Files named as agreed to by SCDNR **Files named according SCGS 1:200-scale index (see item 20 below)**
8.	Format of LiDAR Mass Points	LAS, nominal post spacing 1.4 meters
9.	Format of bare-earth DEM	ARC GRID Format, **10-foot grid spacing**
10.	Format of LiDAR Processing Report	PDF
11.	Format of Accuracy Report	PDF
12.	Georeferencing	Opens in correct location and conforms to the master index grid
13.	Horizontal Units	FT to 2 decimal places - **3 decimal places**
14.	Vertical Units	FT to 2 decimal places – **3 decimal places**
15.	Horizontal Datum	NAD 83 HARN
16.	Vertical Datum	NAVD 88, processed with Geoid03
17.	Coordinate System	3900 ≚ South Carolina State Plane Coordinate System
18.	Mass points	Point cloud with nominal post spacing of 1.4 m. LAS 1.2 classification codes: Class 1 = Unclassified (Default, noise) Class 9 = Hydro Class 2 = Ground Class 10 = Ignored Ground Class 7 = Noise Class 8 = Model Key (thinned)
19.	**Elevation**	For DEM: no null values, valid min/max stats, elevation matches breaklines
20.	**Conformance of tiles to index grid**	Tiles match index grid, no gaps between tiles at 1:1 view. Tiles must be complete except for boundary tiles.

ATTACHMENT A: MEASURE OF ACCEPTANCE (CONTINUED)

Criteria	Tested Characteristic	Measure of Acceptability
Vertical and Horizontal Accuracy Acceptance Criteria		
21.	FEMA Ground Cover Category Accuracy Validation	Tested in accordance with Section A.8.6.2, Appendix A, to FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners" for 5 categories: (1) bare-earth, low grass; (2) high grass & crops; (3) scrub/brush; (4) forested; (5) urban areas
22.	NSSDA/FEMA Vertical Accuracy Validation (assumes all errors follow a normal error distribution so that $Accuracy_z$ (vertical accuracy at 95% confidence level) = $RMSE_z$ x 1.9600	Tested in accordance with NSSDA and FEMA Vertical Accuracy Testing Guidelines (1) If equivalent to 2 ft contour accuracy: $RMSE_z$ = 18.5 cm = 0.61 ft; $Accuracy_z$ = 36.3 cm or 1.19 ft at 95% confidence level **RMSE = 15.0 cm (USGS v.13 spec).** (2) If equivalent to 4 ft contour accuracy: $RMSE_z$ = 37.0 cm = 1.22 ft; $Accuracy_z$ = 72.6 cm or 2.38 ft at 95% confidence level Must pass criteria in category 1 plus all categories combined.
23.	ASPRS/NDEP Vertical Accuracy Validation (assumes errors in categories 2, 3, 4 and 5 do not necessarily follow a normal error distribution). Errors larger than 95th percentile must be identified and analyzed.	Tested in accordance with ASPRS and NDEP LiDAR Testing Guidelines: (1) If equivalent to 2 ft contour accuracy: FVA = 36.3 cm or 1.19 ft in open terrain only based on $RMSE_z$ x 1.9600; CVA = 36.3 cm or 1.19 ft based on 95th percentile for all categories combined; SVA target for vegetated categories = 36.3 cm or 1.19 ft based on 95th percentile errors **CVA & SVA = 30.0 cm** (2) If equivalent to 4 ft contour accuracy: FVA = 72.6 cm or 2.38 ft in open terrain only based on $RMSE_z$ x 1.9600; CVA = 72.6 cm or 2.38 ft based on 95th percentile for all categories combined; SVA target for vegetated categories = 72.6 cm or 2.38 ft based on 95th percentile errors
24.	NSSDA Horizontal Accuracy	Compiled to meet $RMSE_r$ of 1 meter
LiDAR Acceptance Criteria		
25.	Ground Points (Bare Earth)	Post-processed to remove 98% of structures and 95% of vegetation
26.	Continuity	No data voids >2X post spacing. No vertical offsets > 20 cm between adjoining strips and/or tiles
27.	Inconsistent Post-Processing/Editing	No visible variations in TIN/DTM caused by differing processing techniques
28.	Over-smoothing	Smoothing techniques shall not remove topographic features necessary to define drainage features
29.	Artifacts	90% of artifacts removed; no spikes, holes, or blunders; no cornrows or seamline mismatches > 20 cm.
Breakline Acceptance Criteria		
30.	Completeness	Breaklines collected for all streams larger than 40 feet in width. Waterbodies 1 acre in size or greater. Single line streams for features less than 40 ft. Stream connector/centerlines should be used to show flow between interconnecting rivers and streams at culverts and similar feature type locations. See Work Plan for more collection information. **Drainage area ½ square mile or greater**
31.	Monotonicity	Hydro correction for downhill direction of stream flow is required
32.	Vertical Consistency	• Vertices should not have a 0 elevation • Vertices should not have excessive min or max z-values when compared to adjacent vertices • Vertical variance between breaklines & LiDAR DTM < 1 ft
33.	Topology	Breaklines should not intersect unless the same elevation; but bridges and overpasses may intersect hydrographic features