LiDAR Quality Assurance (QA) Report
2010 South Carolina Consortium Project
Saluda County
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Submitted to:
South Carolina Department of Natural Resources

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Executive Summary

The following LiDAR quality assurance report documents Dewberry's review of LiDAR data and derived products for Saluda County, South Carolina. This is the first review of the Saluda data. The data was flown by Sanborn for the 2010 SC LiDAR Consortium Project. The figure below shows Saluda County and the adjoining South Carolina counties (Figure 1).

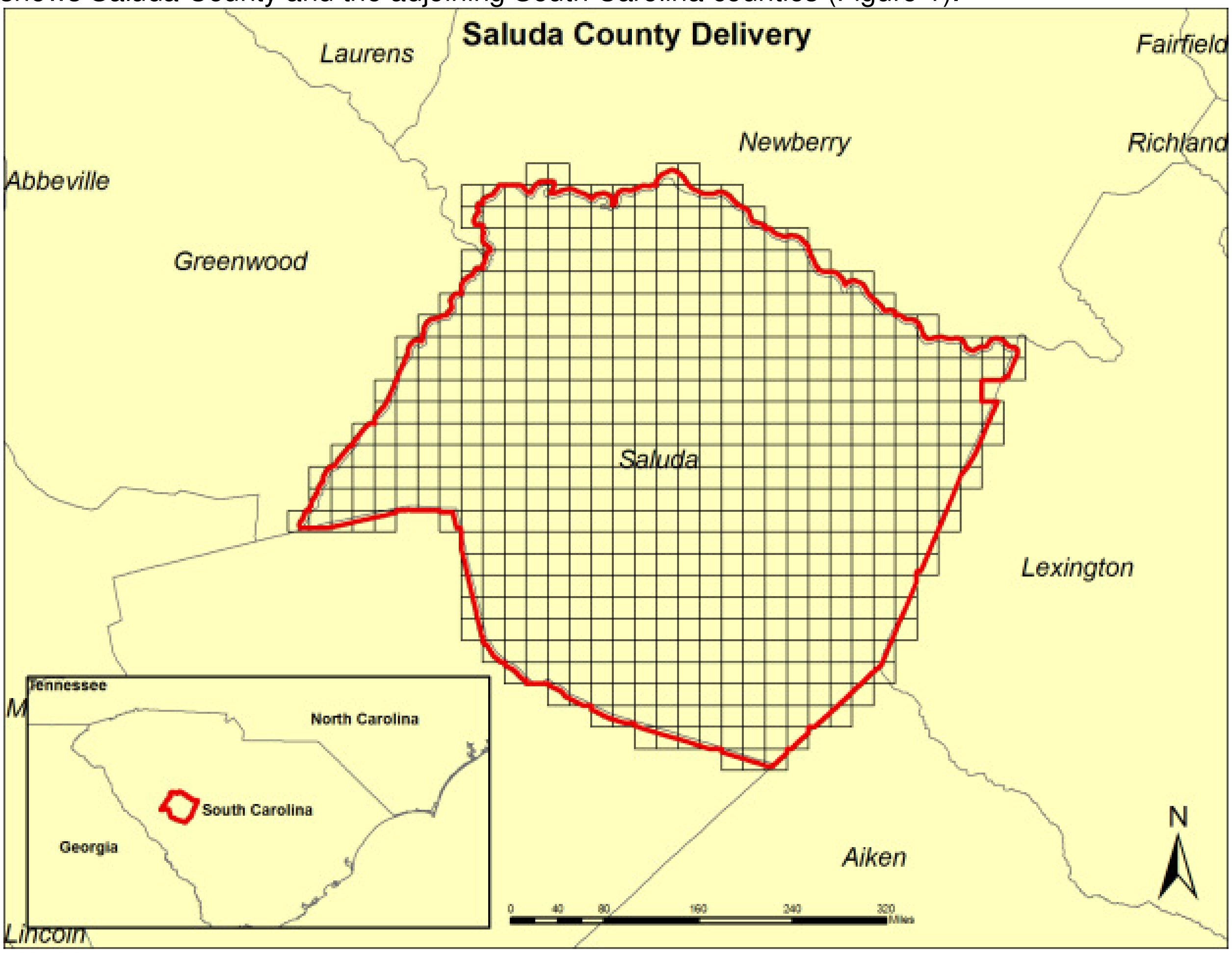

Figure 1: Location of Saluda County overlaid by delivered LAS grid.

Saluda County is approximately 460 square miles which amounts to 575 LAS tiles (5000' x 5000'). The delivered LAS files provide full coverage to the extent of the county as illustrated in the figure above. Each tile contains LAS point cloud data classified according to the ASPRS classification scheme. The second delivery of LAS has been correctly tiled into the South Carolina statewide tiling scheme in order to match the project requirements.

The final deliverables also include an ESRI Geodatabase containing hydrographic breaklines and terrain, a DEM in Arc GRID format, and individual intensity images per tile. The intensity images and the tile grid delivered with the geodatabase continue to have the older false tile names.

Deliverables Summary for Saluda County

Deliverable	Dewberry Recommendation
All-Return LAS Point Cloud Data	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Breakline Geodatabase	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Bare Earth DEMs	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Intensity Images	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
LAS Metadata	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
Breakline Metadata	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject
DEM Metadata	☑ Accept ☐ Accept with Comments ☐ Return for Corrections ☐ Reject

Overview

The goal of the South Carolina LiDAR Consortium Project is to provide high accuracy elevation datasets of multiple deliverable products including LiDAR; hydro-enforced digital elevation models (DEMs), intensity images, and 3D breaklines for several counties within the state of South Carolina. The project area spans nine counties. However, this delivery consists of approximately 460 square miles or 575 5000' by 5000' tiles. This data will be used to support the State's program to develop a high resolution elevation database that can be used to update flood hazard data and maps, support hydrologic and watershed investigations, support telecommunications, law enforcement and emergency management activities as well as provide data for climate change and sea level rise research for the State.

Dewberry's role is to provide Quality Assurance (QA) of the LiDAR data and supplemental deliverables provided by Sanborn that includes completeness checks, vertical accuracy testing, and a qualitative review of the bare earth surface. Each product is reviewed independently and against the other products to verify the degree to which the data meets expectations.

LiDAR Analysis

The LiDAR data are reviewed on project, tile, and point level to determine the relative accuracy, proper classification and conformity to project requirements. This review begins with a computational analysis of the points for completeness and to determine point data format, projection, classification scheme, number of returns per pulse, and intensity values of the points.

All the data were delivered in the proper tile size with the proper point cloud format, multiple returns per pulse and an intensity value for each point.

LiDAR Completeness Review

Dewberry received 575 LiDAR tiles for Saluda County. The LiDAR was delivered in LAS format 1.2.

Each record includes the following fields (among others):

- X, Y, Z coordinates
- Flight line data
- Intensity value
- Return number
- Number of returns
- Scan direction
- Edge of flight line
- Scan angle
- Classification
- GPSI time

The LiDAR data has been classified to contain the appropriate classes:

Required Classes
- ❑ Class 1 (Unclassified)
- ❑ Class 2 (Bare Earth)
- ❑ Class 7 (Noise)
- ❑ Class 8 (Model Key Points)
- ❑ Class 9 (Water)
- ❑ Class 10 (Points removed from Bridges and Culverts)
- ❑ Class 11 (Ignored Ground)

LiDAR Quantitative Review

One of the first steps in assessing the quality of the LiDAR is a vertical accuracy analysis of the ground models in comparison to surveyed checkpoints. South Carolina Geodetic Survey provided 97 checkpoints for the county area. Two checkpoints were removed from the RMSE calculations as they were located outside of the county boundary.

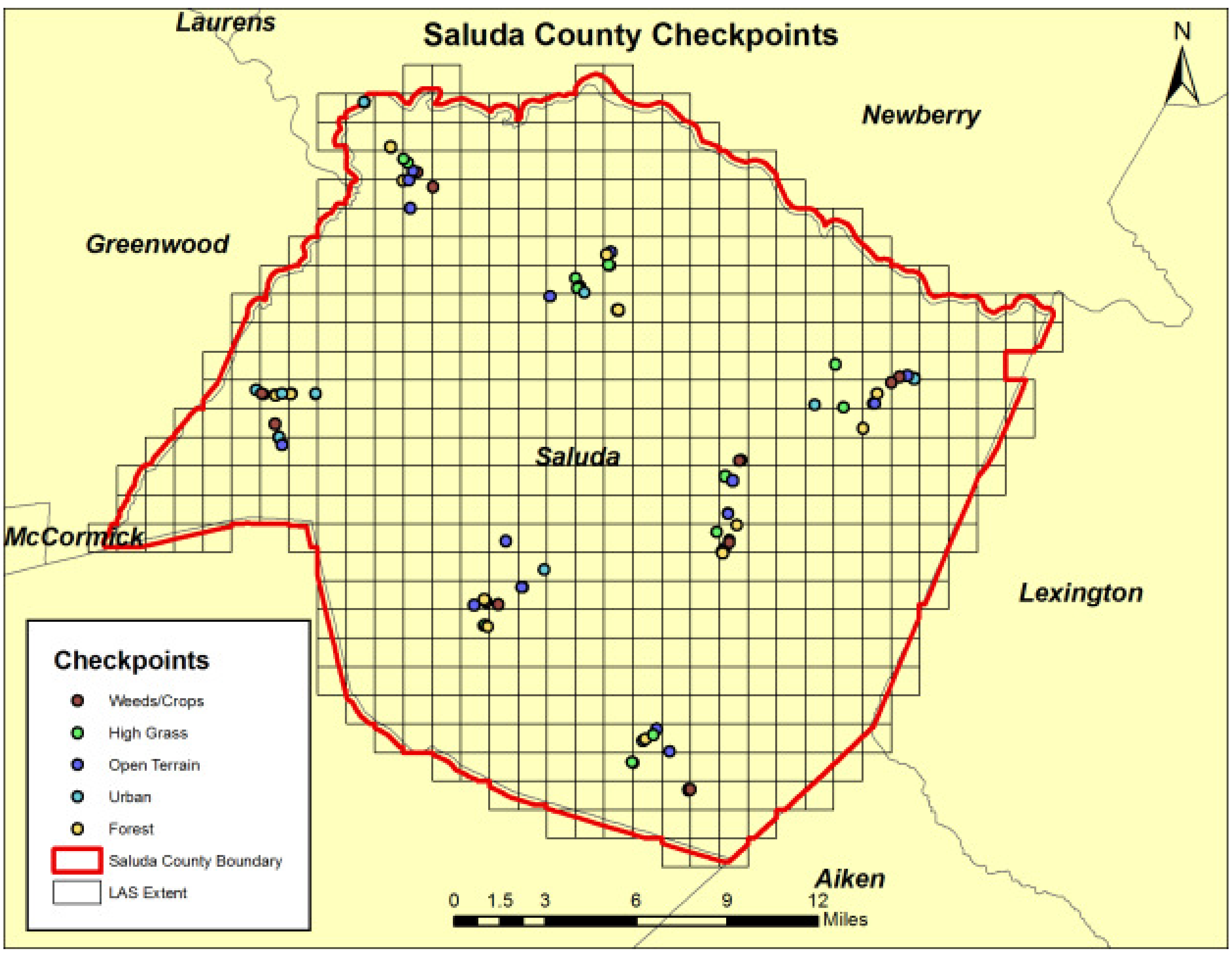

Figure 2: Checkpoints distribution for the current delivery for Saluda County, SC.

The vertical accuracy assessment compares the measured survey checkpoint elevations with those of the TIN as generated from the bare-earth LiDAR. The X/Y locations of the survey checkpoints are overlaid on the TIN and the interpolated Z values of the LiDAR are recorded. These interpolated Z values are then compared with the survey checkpoint Z values and this difference represents the amount of error between the measurements. Once all the Z values are recorded, the Root Mean Square Error (RMSE) is calculated and the vertical accuracy scores are interpolated from the RMSE value. The RMSE equals the square root of the average of the set of squared differences between the dataset coordinate values and the coordinate values from the survey checkpoints.

The first method of evaluating vertical accuracy uses the FEMA specification which follows the methodology set forth by the National Standard for Spatial Data Accuracy. The accuracy is reported at the 95% confidence level using the Root Mean Square Error (RMSE) which is valid when errors follow a normal distribution. By this method, vertical accuracy at the 95% confidence level equals $RMSE_Z$ 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 same (RMSEZ x 1.9600) method in open terrain only; an alternative method 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.

The Fundamental Vertical Accuracy (FVA) is calculated in the same way when implementing FEMA/NSSDA and NDEP/ASPRS methodologies; both methods utilize the 95% confidence level (RMSEZ x 1.9600) in open terrain where there is no reason for LiDAR errors to depart from a normal error distribution.

Table 1 outlines the calculated RMSEz and associated statistics while Table 2 outlines vertical accuracy and the statistics of the associated errors as computed by the different methods.

100 % of Totals	**$RMSE_Z$ (ft) Spec=0.6 ft**	**Mean (ft)**	**Median (ft)**	**Skew**	**Std Dev (ft)**	**# of Points**	**Min (ft)**	**Max (ft)**
Consolidated	0.39	0.22	0.19	0.11	0.32	97	-0.69	1.11
Open Terrain	0.31	0.12	0.14	0.08	0.26	29	-0.69	0.58
Weeds/Crops	0.61	0.55	0.53	0.08	0.26	14	0.18	0.93
Forest	0.30	0.25	0.27	-0.35	0.17	16	-0.08	0.50
Urban	0.22	-0.03	-0.05	0.25	0.22	23	-0.39	0.46
High Grass	0.52	0.16	0.13	0.26	0.26	15	0.11	1.11

Table 1: The table shows the calculated RMSEz values for CVA and FVA as well as associated statistics of the errors for Saluda.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy ($RMSE_Z$ x 1.9600) Spec=1.20 ft	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=1.20 ft	SVA — Supplemental Vertical Accuracy (95th Percentile) Spec=1.20 ft
Consolidated	97		0.78	
Open Terrain	29	0.60		0.57
Weeds/Crops	14			0.93
Forest	16			0.48
Urban	23			0.39
High Grass	15			0.88

Table 2: The table shows the calculated $Accuracy_z$ of the FVA using FEMA/NSSDA guidelines (RMSEz x 1.9600) and the $Accuracy_z$ of the CVA using NDEP/ASPRS guidelines (95^{th} percentile) for Saluda.

Point Count/Elevation Analysis

To verify the content of the data and validate the data integrity, a statistical analysis was performed on each tile. This process allows Dewberry to review 100% of the data at a macro level to identify any gross outliers. The statistical analysis consists of first extracting the header information and then reading the actual records and computing the number of points, minimum, maximum, and mean elevation for each class. Minimum and maximum for other relevant variables are also evaluated.

Each tile was queried to extract the number of LiDAR points. With a nominal point spacing of 1.4 meters, the expected total number of points per tile should be approximately 3.15 million. The mean number of points per tile in Saluda is approximately 5.6 million. The minimum and maximum elevations for class 2 were also evaluated using statistics and no major anomalies were identified.

LiDAR Qualitative Review

The goal of Dewberry's qualitative review is to assess the continuity and the level of cleanliness of the bare earth product. Each LiDAR tile is expected to meet the following acceptance criteria:

- The point density is homogenous and sufficient to meet the user's needs;
- The ground points have been correctly classified (no man-made structures or vegetation remains, no gaps except over water bodies);
- The ground surface model exhibits a correct definition (no aggressive classification, no over-smoothing, no inconsistency in the post-processing);
- No obvious anomalies due to sensor malfunction or systematic processing artifacts are present (data voids, spikes, divots, ridges between flight lines or tiles, cornrows, etc);
- Residual artifacts <5%

Dewberry analysts performed a visual inspection of 100% of the bare earth data digital terrain model (DTM) at the macro and micro level. The DTMs are built by first creating a fishnet grid of the LiDAR masspoints with a grid distance of 3x the full point cloud resolution. Then a triangulated irregular network is built based on this gridded DTM and displayed as a 3D surface. A shaded relief effect was applied which enhances 3D rendering. The software used for visualization allows the user to navigate, zoom and rotate models and to display elevation information with an adaptive color coding in order to better identify anomalies.