LiDAR Quality Assurance (QA) Report
Berkeley County, SC
South Carolina DNR LiDAR
May 27, 2010

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 Berkeley County, South Carolina produced by Sanborn Map Company for the South Carolina Department of Natural Resources (SC DNR). The project area consists of 1,585 tiles of LiDAR data in LAS format which covers approximately 1,228 square miles. Each tile contains LAS point cloud data classified according to a modified ASPRS classification scheme. The final deliverables also include LiDAR intensity images in GeoTiff format and an ESRI Geodatabase containing hydro breaklines and a GeoTerrain.

The LiDAR data and derived products were processed through Dewberry's comprehensive quantitative/qualitative review. This multipart analysis determines the degree to which the data met expectations for completeness, accuracy, and conformity to specific project requirements for each data product.

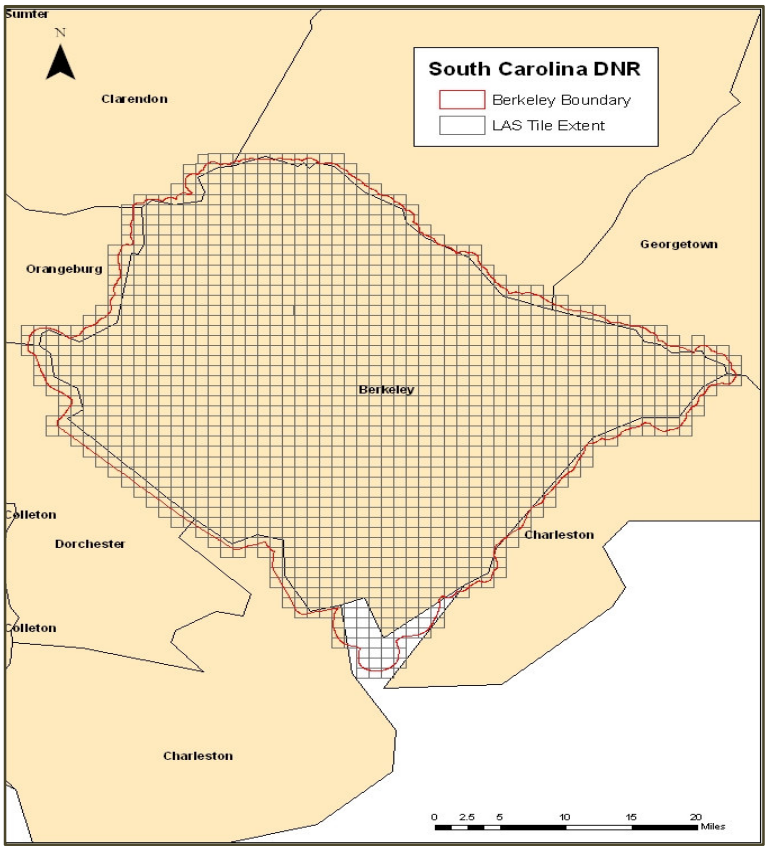


Figure 1: Berkeley County, South Carolina with tile grid overlaid.

Table 1 illustrates the accuracy assessment per the FEMA/NSSDA $RMSE_Z$ method and the NDEP/ASPRS Fundamental Vertical Accuracy (FVA) method which both indicates the data exceeds project specifications.

Table 1: Vertical accuracy assessment summary (FEMA/NSSDA methodology) – The data meets required accuracies.

Criterion	Checkpoints Used	**Accuracy Specification**	Results Achieved
RMSEz (FEMA/NSSDA)	166	**0.61 ft**	0.32 ft
FVA (NDEP/ASPRS)	51	**1.195 ft**	0.54 ft

Introduction

Dewberry's role in this project is to provide validation; of the completeness of LiDAR LAS masspoints, quantitative vertical accuracy assessment and reporting, and a qualitative review of the derived bare earth surface, breaklines and intensity images. 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 is reviewed on project, tile, and per point levels 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.

Completeness of Deliverables

Dewberry received 1,585 LiDAR files for Berkeley County. The LiDAR were delivered in tiles that adhere to the project boundary and the specified 5000 ft x 5000 ft tile schema. Each LAS file was verified to be projected according to the project specifications in (Horizontal) NAD 1983 State Plane South Carolina International Feet and (Vertical) NAVD 88 Geoid 03 Feet. All of the formatting and projection information were found to meet projection specification including the LAS format, unit and coordinate system information:

- LAS version 1.2
- Point data format 1
- Projection set in header
    - NAD 1983 State Plane South Carolina International Feet
    - Horizontal Unit: Linear Feet o NAVD88 – Geoid03
    - Vertical Unit: Feet

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
- GPS time

The classes required by SC DNR are:

- Class 1 (Unclassified)
- Class 2 (Bare Earth)
- Class 7 (Noise)
- Class 8 (Model Key Points)
- Class 9 (Water as defined by hydro enforcement)
- Class 10 (Points removed from bridges and box culverts)

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 LAS header information and then reading the actual point data 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 1.2 million. The statistical mean in Berkeley County is approximately 6 million. All tiles are within the anticipated size range except for those located within Lakes Moultrie and Marion, which are expected to have fewer points. The minimum and maximum elevations for class 2 were also evaluated.

Quantitative Vertical Accuracy Assessment

Vertical Accuracy Assessment

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 values 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

Vertical Accuracy Assessment Methodologies

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 (NSSDA). 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 ($RMSE_Z$ 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 ($RMSE_Z$ x 1.9600) in open terrain where there is no reason for LiDAR errors to depart from a normal error distribution.

Vertical Accuracy Ground Truth Information

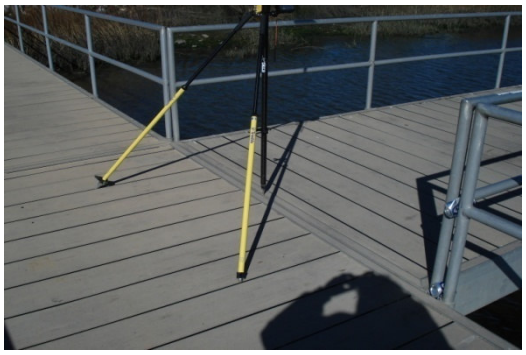
Typically for this type of data collection, a ground truth survey is conducted following the FEMA Guidelines and Specifications for Flood Hazard Mapping Partners Appendix A: Guidance for Aerial Mapping and Surveying which is based on the NSSDA specifications. This methodology utilizes a minimum of 20 points for each of the predominant land cover types (i.e. open terrain, weeds/crops, high grass, urban, etc.) for a minimum of three land cover classes.

There were 183 survey checkpoints delivered for Berkeley County. These points were split into five land cover types: Open Terrain, Brush, High Grass, Woods, and Urban. After an initial review of the survey photos, 17 checkpoints were discarded because they were located either on a bridge, on a slope or in the highly vegetated forest. While the majority of the forest points in Berkeley County yielded adequate elevations, three points were found to have elevations far outside of the expected range and were removed from the RMSE equation. It is Dewberry's experience that using GPS in the forest does not yield good results and should be avoided.

The discarded checkpoints are shown below in Figure 2.

U_8-11-09 – Survey photo – On the bridge

U_8-08-07 – Survey photo– On the bridge



U_8-10-12 – Survey photo-– On the bridge

U_8-07-11 – Survey photo– On the bridge

U_8-09-04 – Survey photo– On the bridge

U_8-11-01 – Survey photo– On the bridge

U_8-09-09 – Survey photo– On the bridge

U_8-11-01a – Survey photo– On the bridge

U_8-04-12 – Survey photo– On the elevated

U_8-02-14 – Survey photo-On the slope

surface

U_8-03-08 – Survey photo- On the slope

U_8-07-12 – Survey photo-In the forest. Delta Z between LiDAR and GPS is about 20ft.

W_8-05-05 – Survey photo- In the forest. Delta Z between LiDAR and GPS is about 10 ft.

W_8-07-02 – Survey photo- In the forest. Delta Z between LiDAR and GPS is about 6 ft.

U-8-04-16. Survey photo– On the bridge

U_8-4-08. Survey photo– On the bridge

Figure 2: Discarded Berkeley checkpoints

After 17 checkpoints were discarded, the checkpoints were classified into 5 land cover categories as follows:

- Open Terrain - 51
- Urban Terrain - 47
- Forest - 23
- High Grass - 23
- Brush - 22

The following figure identifies the checkpoints based on their land cover types and shows their spatial distribution. As seen from the image, the distribution on the provided checkpoints is not evenly dispersed, but instead is clustered in several areas of the county.

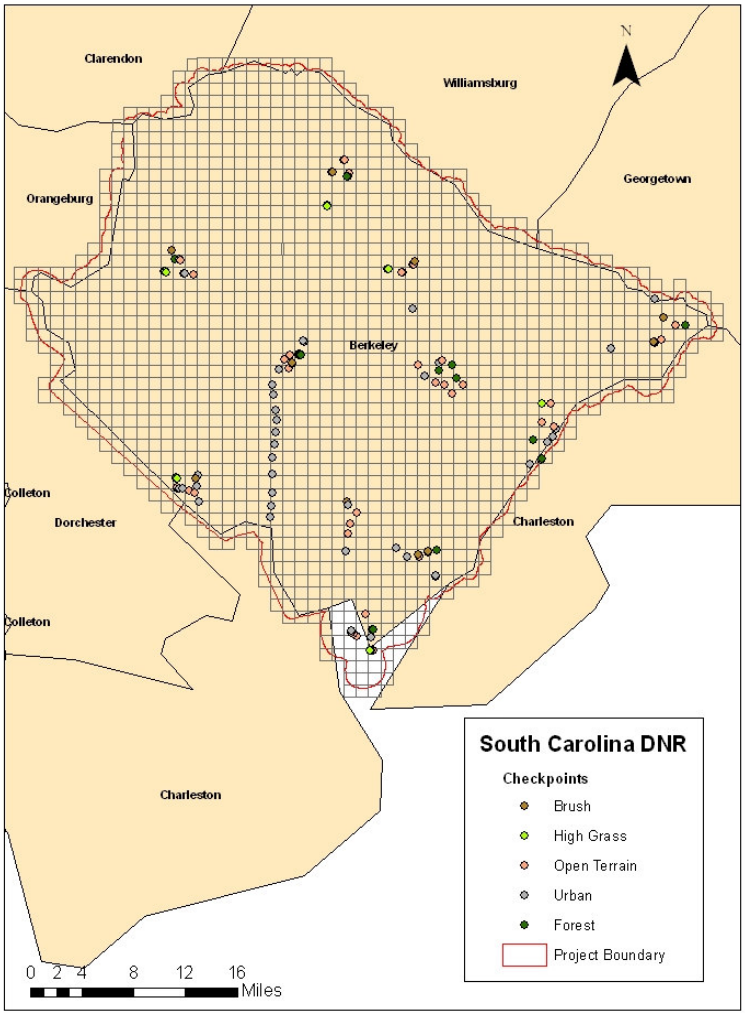


Figure 3: Map displays spatial location of 166 checkpoints.

Vertical Accuracy Assessment Results

The following tables and graph outline the vertical accuracy and the statistics of the associated errors as computed by the different methods. Table 2 shows the results for the Berkeley County dataset calculated with the FEMA/NSSDA methodology.

Table 2: RMSE method for testing vertical accuracy

100 % of Totals	**RMSE Spec = 0.61 ft**	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated	**0.32**	-0.02	-0.06	0.66	0.32	166	-0.80	1.07
Open Terrain	**0.28**	-0.07	-0.11	0.55	0.27	51	-0.61	0.57
Brush	**0.40**	0.16	0.10	0.08	0.37	22	-0.80	1.03
High Grass	**0.33**	008	0.15	-0.70	0.32	23	-0.71	0.55
Forest	**0.40**	0.09	0.08	1.04	0.40	23	-0.43	1.07
Urban	**0.27**	-0.15	-0.16	0.23	0.23	47	-0.80	0.55

The following graph displays the delta Z values of each checkpoint when compared to the LiDAR ground models.

Figure 4 illustrates the distribution of the elevation differences between the LiDAR data and the surveyed checkpoints. Delta Z values show that the majority of the checkpoints are pretty close to the LiDAR, but there are a few outliers that are above and below LiDAR within 1 ft range.

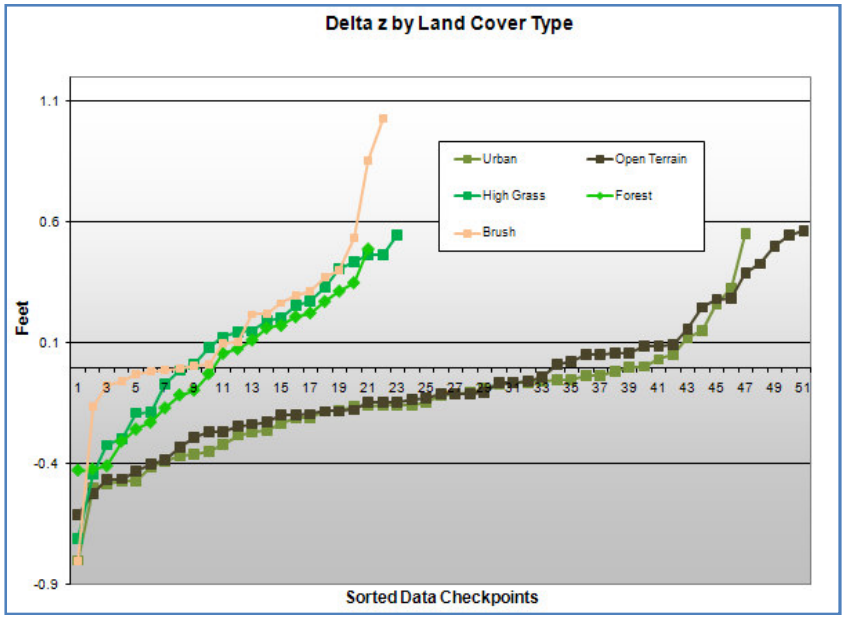


Figure 4 – Displays the differences in elevations between checkpoints and the LiDAR data sorted by land cover type and from the lowest to highest.

Utilizing the FEMA/NSSDA method the data meets the accuracy required for this project.

Table 3 contains the vertical accuracy results when using the NDEP/ASPRS methodology. Please refer back to the Vertical Accuracy Assessment Methodologies section for a complete description.

Table 3: Final statistics for Berkeley County using NDEP/ASPRS processes: Fundamental, Consolidated, and Vertical Accuracies.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) **Spec=1.195 ft**	CVA — Consolidated Vertical Accuracy (95th Percentile) **Spec=1.195 ft**	SVA — Supplemental Vertical Accuracy (95th Percentile) **Target=1.195 ft**
Consolidated	166		0.56	
Open Terrain	51	0.54		0.53
Brush	22			0.85
High Grass	23			0.54
Forest	23			1.00
Urban	47			0.49

The bullet points list the vertical accuracy at the 95% confidence level which equals the RMSEz x 1.9600. The consolidated value must be equal or less than 0.363 m, where as the other categories can exceed this value but the overall (consolidated) must be less that the stated amount.

- **Tested 0.54 ft fundamental vertical accuracy at 95% confidence level in Open Terrain using RMSEz x 1.9600 NDEP/ASPRS methodologies)**
- **Tested 0.56 ft consolidated vertical accuracy at 95% confidence level in all land cover categories (NDEP/ASPRS methodology)**
- **Tested 0.53 ft supplemental vertical accuracy at 95th percentile in Open Terrain category (NDEP/ASPRS methodology)**
- **Tested 0.85 ft supplemental vertical accuracy at 95th percentile in Brush category (NDEP/ASPRS methodology)**
- **Tested 0.54 ft supplemental vertical accuracy at 95th percentile in High Grass category (NDEP/ASPRS methodology)**
- **Tested 1.00 ft supplemental vertical accuracy at 95th percentile in Forest category (NDEP/ASPRS methodology)**
- **Tested 0.49 ft supplemental vertical accuracy at 95th percentile in Urban category (NDEP/ASPRS methodology)**

Utilizing the FEMA/NSSDA method the data meets the accuracy required for this project.

Given the good results and the high number of checkpoints used, the dataset meets accuracy requirements. Compared with the 0.61 foot specification for vertical accuracy, equivalent to 2-foot contours, the dataset is within the acceptance criteria and passes by all methods of accuracy assessment.