Hertford County, Chowan River Basin

The LIDAR accuracy assessment for Hertford County was performed in accordance with section 1.5 of the *Guidelines for Digital Elevation Data*, Version 0.3, published by the National Digital Elevation Program (NDEP), see www.ndep.gov. The NDEP specifies the mandatory determination of Fundamental Vertical Accuracy and the optional determination of Supplemental Vertical Accuracy and/or Consolidated Vertical Accuracy. Consistent also with Appendix A, Aerial Mapping and Surveying, of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, the North Carolina Floodplain Mapping Program (NCFMP) established mandatory acceptance standards for Fundamental and Consolidated Vertical Accuracy, utilizing five land cover categories listed in Table 1 below.

Fundamental Vertical Accuracy (FVA) is determined with check points located only in open terrain (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 errors are expected to follow a normal error distribution. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600, as specified in Appendix 3-A of the National Standard for Spatial Data Accuracy (NSSDA), FGDC-STD-007.3-1998, see www.fgdc.gov/standards/status/sub1_3.html. For the current Phase II of the North Carolina Floodplain Mapping Program (NCFMP), the FVA standard is 1.19 ft at the 95% confidence level, equivalent to the accuracy expected from 2 ft. contours.

Consolidated Vertical Accuracy (CVA) is determined with all checkpoints in all land cover categories combined where there is a possibility that the LIDAR sensor and post-processing may not have mapped the bare-earth ground surface and where errors may not follow a normal error distribution. CVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all land cover categories combined. The CVA is accompanied by a listing of the 5% of the outliers that are larger than the 95th percentile. For Phase II of the NCFMP, the CVA standard is 1.61 ft at the 95% confidence level.

Supplemental Vertical Accuracy (SVA) is determined separately for each individual land cover category, recognizing that the LIDAR sensor and post-processing may not have mapped the bare-earth ground surface and where errors may not follow a normal error distribution. For each land cover category, the SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in that particular land cover category. For Phase II of the NCFMP, there is no SVA standard; nevertheless, the SVA target is 1.61 ft. SVA statistics are calculated individually for open terrain, weeds and crops, scrub, forests, and built-up areas in order to facilitate the analysis of the data based on each of these land cover categories that exist within the county watersheds.

The primary QA/QC steps were as follows:

1. Watershed Concepts' LIDAR subcontractor (EarthData International) acquired the raw LIDAR data in early 2003 and performed post-processing to derive the bare-earth digital terrain model (DTM). EarthData also performed in-house QA/QC of its data.

2. An independent field survey contractor (CGGL Group) surveyed "ground truth" county checkpoints in accordance with guidance received from the North Carolina Geodetic Survey (NCGS). See Figure 1 for the location of these QA/QC checkpoints for each land cover category.
3. NCGS provided the horizontal coordinates only for each checkpoint to Watershed Concepts which interpolated the bare-earth LIDAR DTM to provide the z-value for each of these checkpoint coordinates.
4. NCGS computed the associated z-value differences between the interpolated z-value from the LIDAR data and the ground truth survey checkpoints and computed the FVA and CVA. NCGS' Excel workbook, with FVA and CVA calculations, was submitted to Dewberry on September 15, 2003.
5. All data was reviewed by Dewberry and further analyzed to assess the quantitative quality of the data. The review process re-examined the various accuracy parameters as defined by NDEP guidelines. Also the overall descriptive statistics of each dataset were computed to assess any trends or anomalies. The following tables, graphs and figures illustrate the data quality utilizing 100% of the checkpoints as per the vertical accuracy tests endorsed by the NCFMP.

Figure 1 shows the location of the QA/QC checkpoints within the county, symbolized to reflect the five land cover categories used.

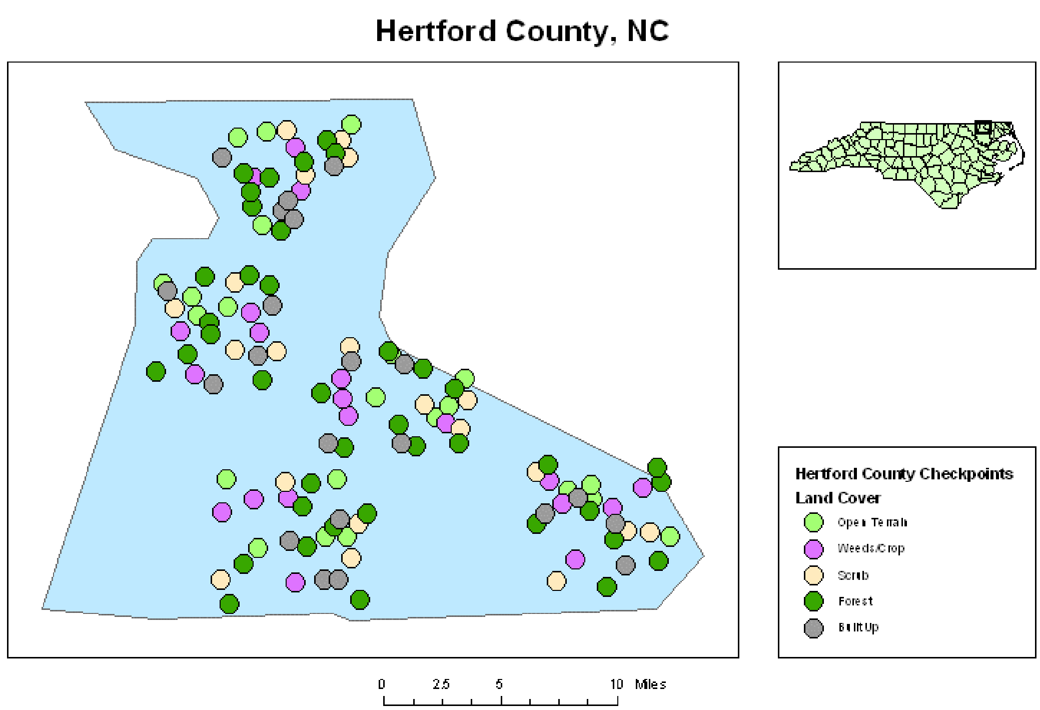

Figure 1

Table 1 summarizes the vertical accuracy by fundamental, consolidated and supplemental methods:

Table 1: Vertical Accuracy at 95% Confidence Level				
Land cover category	**# of Points**	**Fundamental Vertical Accuracy Spec = 1.19 (ft)**	**Consolidated Vertical Accuracy Spec = 1.61 (ft)**	**Supplemental Vertical Accuracy (No specification, but target = 1.61 ft)**
Total	124		**1.11**	
Open Terrain	23	**1.04**		0.93
Weeds/Crops	20			0.88
Scrub	20			0.96
Forest	40			1.75
Built Up	21			1.03

The LIDAR data of Hertford County (Chowan Basin) meets the specifications as per the following vertical accuracy tests.

Compared with the 1.19 ft (36.3 cm) FVA specification, Fundamental Vertical Accuracy tested 1.04 feet (31.7 cm) at the 95% confidence level in open terrain only, based on RMSE x 1.9600. The NSSDA specifies that vertical accuracy at the 95% confidence level equals RMSE x 1.9600, but this method is valid only when errors follow a normal error distribution, as in open terrain.*

Compared with the 1.61 ft (49.0 cm) CVA specification, Consolidated Vertical Accuracy tested 1.11 feet (33.7 cm) at the 95% confidence level in open terrain, weeds and crops, scrub, forests, and built-up areas combined, based on the 95th Percentile. NDEP guidelines specify that vertical accuracy at the 95% confidence level equals the 95th percentile when errors do not follow a normal error distribution, as in vegetated areas. Table 2 lists the 5% outliers larger than the 95th percentile (1.11 ft):

Table 2: 5% Outliers larger than 95th percentile		
Land cover category	**Elev. Diff (ft)**	The errors in **bold** are the only errors larger than the CVA standard (1.61 ft) which permits up to 5% of the checkpoints, normally 6 of 120, to be larger than 1.61 ft.
Scrub	1.30	
Forest	**-2.81**	
Forest	**-1.89**	
Forest	**-1.74**	
Forest	-1.47	
Forest	-1.32	
Built Up	-1.11	

* The checkpoint errors in open terrain do not represent a normal error distribution as all checkpoints have negative errors. However, all checkpoint errors in open terrain are equal to or less than 1.04 ft and would pass all the normal acceptance tests for 2' contour interval equivalency. Furthermore, the alternative SVA in open terrain is 0.93 ft at the

95% confidence level which would greatly exceed the FVA specification of 1.19 ft in open terrain. The entire Hertford County dataset displays a systematic bias of approximately 6" as the vast majority of errors are negative. Either the LIDAR dataset is systematically too low or the surveyed checkpoints are systematically too high. The simplest possible explanation is if there is a systematic bias between a first GPS base station, used to control the LIDAR aircraft's airborne GPS, and a second GPS base station, used to control the QC checkpoint surveys. NCGS should investigate this and other potential sources of systematic errors as it is desirable to identify and correct any systematic errors in the LIDAR data, if they exist. Nevertheless, even with the systematic bias, the CVA (1.11 ft) easily passes the CVA specification (1.61 ft), causing Dewberry to conclude that the LIDAR dataset is acceptable for its intended purpose, even if a small systematic bias remains.

Figure 2 illustrates the Supplemental Vertical Accuracy by specific land cover category.

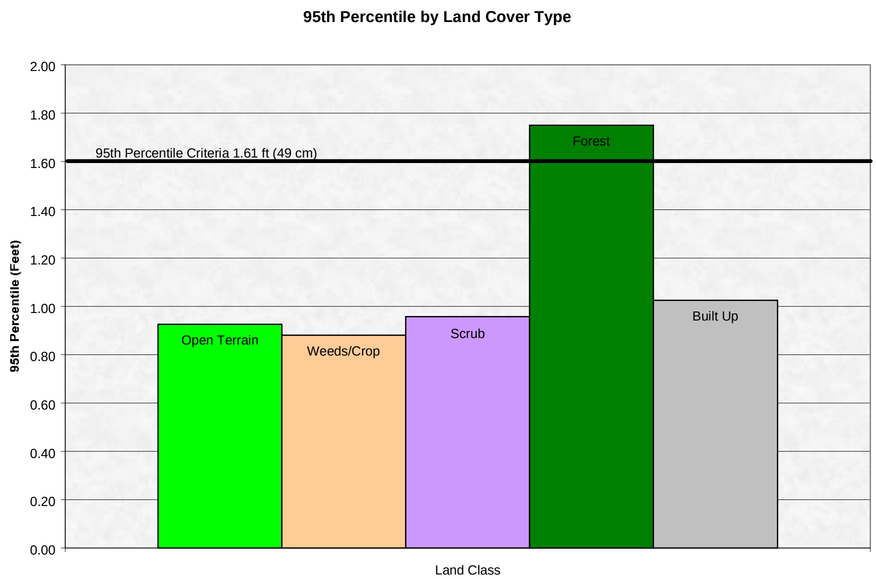

Figure 2

Figure 3 illustrates the magnitude of the differences between the checkpoints and LIDAR data by specific land cover category and sorted from lowest to highest.

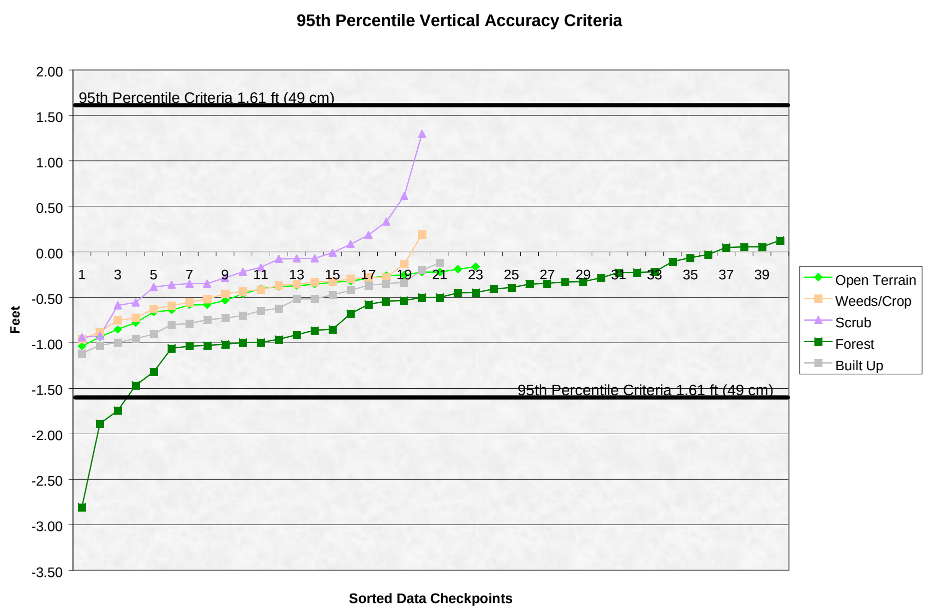

Figure 3

Figure 4 illustrates the RMSE of each land cover category.

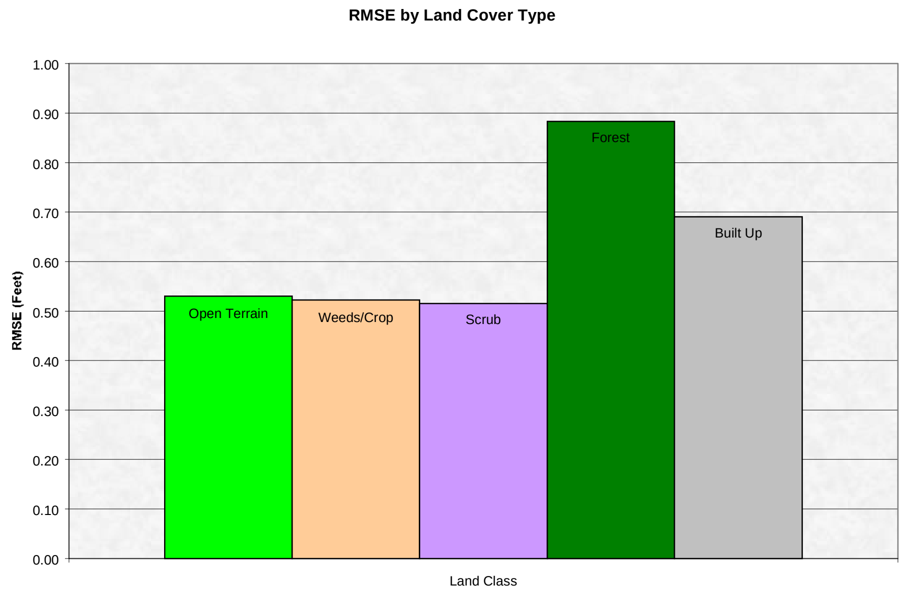

Figure 4

Table 3 illustrates the overall statistics for the checkpoint data.

Table 3: Overall Descriptive Statistics

Land cover category	RMSE (feet)	Mean (feet)	Median (feet)	Skew	Std Dev (feet)	# of Points	Min (feet)	Max (feet)
Consolidated	0.69	-0.50	-0.43	-0.81	0.47	124	-2.81	1.30
Open Terrain	0.53	-0.47	-0.38	-0.85	0.25	23	-1.04	-0.16
Weeds/Crops	0.52	-0.45	-0.42	0.21	0.26	20	-0.96	0.19
Scrub	0.51	-0.14	-0.19	1.07	0.51	20	-0.94	1.30
Forest	0.88	-0.65	-0.50	-1.46	0.60	40	-2.81	0.13
Built Up	0.69	-0.63	-0.65	0.06	0.28	21	-1.11	-0.12

Figure 5 illustrates a histogram of the associated delta errors (discrepancies) between the data checkpoints and the interpolated TIN values. The frequency shows the number of discrepancies within each band of elevation differences.

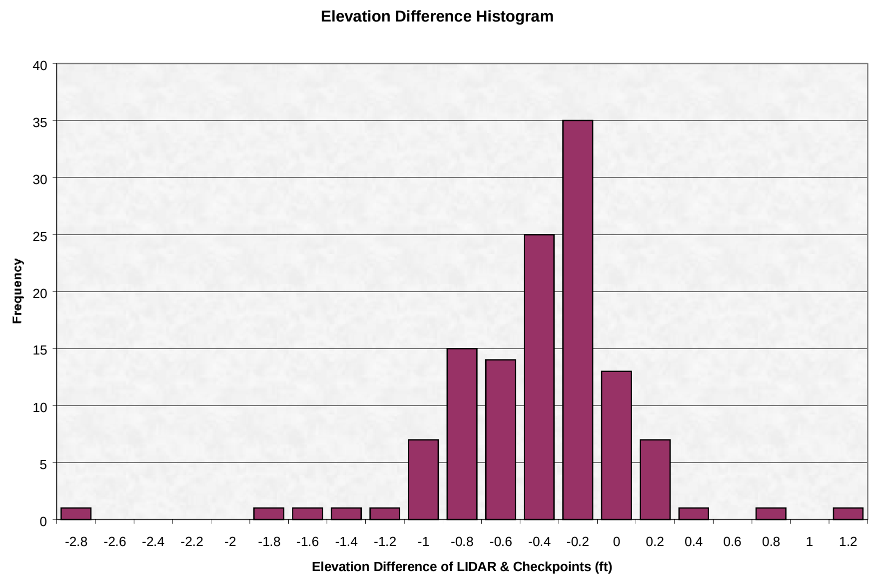

Figure 5

Based on the vertical accuracy testing methodology and the number of checkpoints, the data is of good quality.

Although not tested independently because LIDAR DTM points are not clearly defined points on the ground, the LIDAR provider was required to perform daily calibration checks to ensure that the horizontal (radial) accuracy was equal to or better than 5.68 ft at the 95% confidence level, equivalent to a radial RMSE ($RMSE_r$) of 3.28 ft (1 meter).

Function	Responsible Organization
LIDAR Data Collection and Processing	EarthData International
QA/QC Surveys	CGGL Group
TIN Interpolation	Watershed Concepts
Initial LIDAR Accuracy Assessments	North Carolina Geodetic Survey
Final LIDAR Accuracy Assessments and Report	Dewberry & Davis

Users are encouraged to review the associated metadata for additional details of the county's LIDAR dataset.