



S.C Department of Natural Resources

LiDAR Campaign (Saluda County, SC) Report of Survey

2011

EXECUTIVE SUMMARY

S.C. Department of Natural Resources contracted with Sanborn to provide LiDAR mapping services for Saluda County. Utilizing multi-return systems, Light Detection and Ranging (LiDAR) data in the form of 3-dimensional positions of a dense set of mass points was collected for approximately 460 square miles between February 20th 2010 and March 27th 2010. All systems consist of geodetic GPS positioning, orientation derived from high-end inertial sensors and high-accurate lasers. The sensor is attached to the aircraft's underside and emits rapid pulses of light that are used to determine distances between the plane and terrain below.

Specifically, the Leica ALS-50 system was used to collect data for the survey campaign. The LiDAR system is calibrated by conducting flight passes over a known ground surface before and after each LiDAR mission. During final data processing, the calibration parameters are inserted into post-processing software.

Four airborne GPS (Global Positioning System) base stations were used in the Saluda County project. NGS points with PID's AE3535, DE1757, DF3844, and DE3192, were used as monuments for the GPS base station placement. These four base stations were tied to each other to create a GPS survey network. The coordinates of these stations were checked against each other with the three dimensional GPS baseline created at the airborne support set up and determined to be within project specifications.

The acquired LiDAR data was processed to obtain first and last return point data. The last return data was further filtered to yield a LiDAR surface representing the bare earth.

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1.0 INTRODUCTION

This document contains the technical write-up of the LiDAR campaign, including standard specifications, system calibration techniques, field procedures, and the accuracy of the LiDAR data.

1.1 Contact Information

Questions regarding the technical aspects of this report should be addressed to:

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1.2 Purpose of the LiDAR Acquisition

As stated in the Statement of Work for Acquisition and Production of High Resolution Elevation data for the SCDNR 2010 project, this LiDAR operation was designed to create high resolution data sets that will establish an authoritative source for elevation information for Saluda County.

1.3 Project Location

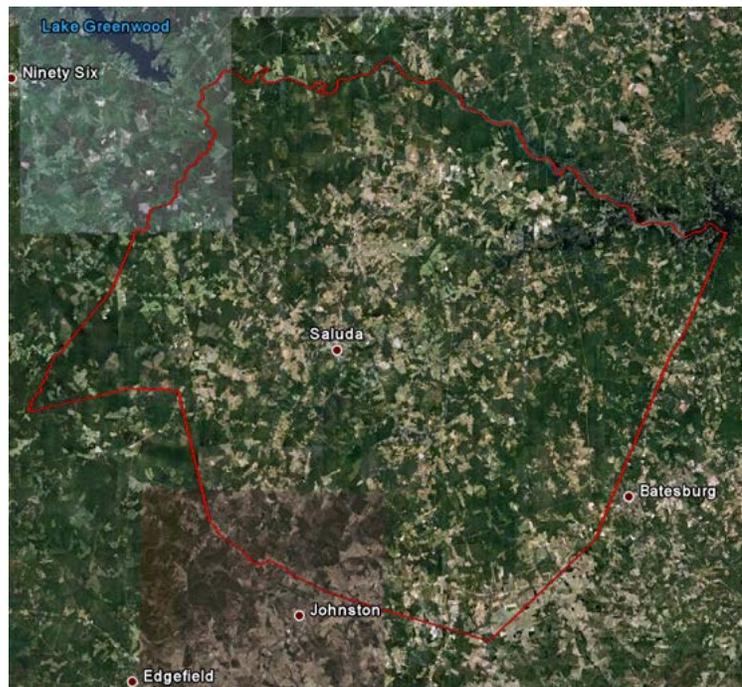


Figure 1: Area of Collection

1.4 Standard Specifications for LiDAR

Table 1: LiDAR Specifications

Data Acquisition		
Requirement	Description	
Returns per pulse	LiDAR sensor shall be capable of recording up to 3 (or more) returns per pulse, including 1st and last returns	
Scan angle	$\leq \pm 20$ degrees	*
Swath overlap	Nominal sidelap on adjoining swaths, i.e., survey shall be designed for 50% overlap coverage at planned aircraft height above ground	50%
Design pulse density (nominal)	Pulses/m ² (includes swath overlap; e.g., with 30% sidelap, ≥ 2 pulse/m ² in each swath)	≥ 1
GPS procedures	At least 2 GPS reference stations in operation during all missions, sampling positions at 1 Hz or higher frequently. Differential GPS baseline lengths shall not exceed 30 km. Differential GPS unit in aircraft shall sample position at 2 Hz or higher. LiDAR data shall only be acquired when GPS PDOP is ≤ 3.5 and at least 6 satellites are in view.	*
Data Collection Season	Target window for collection of LiDAR data ends Spring of 2010. This may be extended with approval by State program managers	*
Survey conditions	Leaf-off and no significant snow cover, as observed by state contract representatives.	*
Geographic Coverage and Continuity		
Coverage	No voids between swaths. No voids because of cloud cover or instrument failure.	
Swath overlap	$\leq 50\%$ no-overlap area per project.	

2.0 LIDAR CALIBRATION

2.1 Introduction

LiDAR calibrations are performed to determine and therefore eliminate systematic biases that occur within the hardware of the Leica ALS-50 system. Once the biases are determined they can be modeled out. The systematic biases are corrected for include heading, roll, and pitch.

The following procedures are intended to prevent operational errors in the field and office work, and are designed to detect inconsistencies. The emphasis is not only on the quality control (QC) aspects, but also on the documentation, i.e., on the quality assurance (QA).

2.2 Calibration Procedures

When Sanborn receives raw point cloud data from its subcontractors, calibration procedures using TerraSolid products are applied- including TerraScan and TerraMatch. Utilizing these two tools, Sanborn is able to correct each individual raw data strip to precisely match the two overlapping swaths. In return, the RMSE of the entire project is substantially lower, resulting in a more accurate dataset. TerraMatch samples the data perpendicular to the flight pattern to assess and correct for roll errors, pitch errors, and heading errors.

Throughout the Saluda County project, flight direction consisted of a southwest to northeast flight pattern. Rows of small sample tiles were placed perpendicular to the raw strips, and populated with the raw point cloud data. Once the population of the data is complete, a filter is applied to each sample tile. The filter classifies bare earth and building rooftops per flight line in order for TerraMatch to recognize the individual strips and their features, allowing the software to find corrections for roll, pitch, and heading throughout the project. Once the adjustments are calculated, the settings are applied to the final delivery tiles.

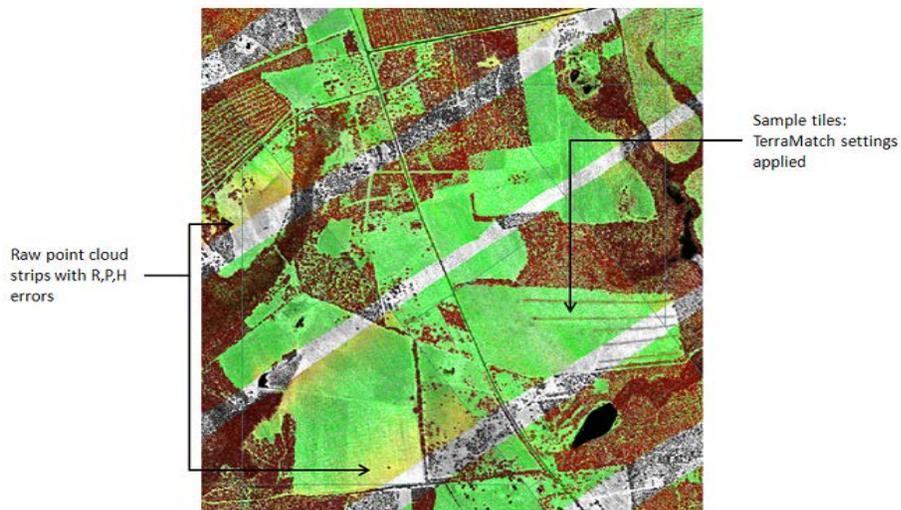


Figure 2: TerraMatch Tiling Sample

3.0 LIDAR FLIGHT AND SYSTEM REPORT

3.1 Introduction

This section addresses LiDAR system, flight reporting and data acquisition methodology used during the collection of the Saluda county campaign. Although Sanborn conducts all LiDAR with the same rigorous and strict procedures and processes, all LiDAR collections are unique.

3.2 Field Work Procedures

A minimum of two GPS base stations were set for the Saluda County project, which is within the project area or within the required baseline specifications of the project.

Pre-flight checks such as cleaning the sensor head glass are performed. A four minute INS initialization is conducted on the ground, with the engines running, prior to flight, to establish fine-alignment of the INS. GPS ambiguities are resolved by flying within ten kilometers of the base stations.

The flight missions were typically four or five hours in duration including runway calibration flights flown at the beginning and the end of each mission. During the data collection, the operator recorded information on log sheets which includes weather conditions, LiDAR operation parameters, and flight line statistics. Near the end of the mission GPS ambiguities are again resolved by flying within ten kilometers of the base stations, to aid in post-processing.

Table 2 shows the planned LiDAR acquisition parameters with a flying height of 1500 meters above ground level (AGL) for the Leica system on a mission to mission basis.

Table 2: LiDAR Acquisition Parameters

Average Altitude	1500 Meters AGL
Airspeed	~140 knots
Scan Frequency	36 Hertz
Scan Width Half Angle	20 Degrees
Pulse Rate	71,800 Hertz

Preliminary data processing was performed in the field immediately following the missions for quality control of GPS data and to ensure sufficient overlap between flight lines. Any problematic data could then be re-flown immediately as required. Final data processing was completed in the Colorado Springs office.

Table 3: Collection Dates, Times, Average Per Flight Collection Parameters and PDOP

Mission	Date	Sensor # (Sanborn 1,2)	Start Time	End Time	Altitude (m)	Airspeed (Knots)	Scan Angle	Scan Rate	Pulse Rate	PDOP (Ave)
051a	Feb 20	ALS50-S1	14:46	20:25	1500	140	40°	36	71800	1.7
052a	Feb 21	ALS50-S1	13:20	17:59	1500	140	40°	36	71800	2.1
075a	Mar 16	ALS50-S1	02:05	07:03	1500	140	40°	36	71800	1.9
075b	Mar 16	ALS50-S2	04:26	07:28	1500	140	40°	36	71800	1.9
077a	Mar 18	ALS50-S1	15:06	19:45	1500	140	40°	36	71800	2.2
086a	Mar 27	ALS50-S2	15:58	18:30	1500	140	40°	36	71800	1.6
086b	Mar 27	ALS50-S2	19:07	21:44	1500	140	40°	36	71800	1.7

3.3 Final LiDAR Processing

LiDAR filtering was accomplished using TerraSolid, TerraScan LiDAR processing and modeling software. The filtering process reclassifies all the data into classes within the LAS formatted file based scheme set using the LAS format 1.2 specifications or by the client. Once the data is classified, the entire data set is reviewed and manually edited for anomalies that are outside the required guidelines of the product specification or contract guidelines, whichever apply. Table 4 indicates the required product specifications.

The coordinate and datum transformations are then applied to the data set to reflect the required deliverable projection, coordinate and datum systems as provided in the contract.

The client required deliverables are then generated. At this time, a final QC process is undertaken to validate all deliverables for the project. Prior to release of data for delivery, Sanborn’s quality control/quality assurance department reviews the data and then releases it for delivery.

Table 4: Processing Accuracies and Requirements

Accuracy of LiDAR Data (H)	1m RMSE
Accuracy of LiDAR data in bare areas (Z)	15 cm RMSE

4.0 GEODETIC AUTHENTICATION

4.1 Final LiDAR Verification

The LiDAR data was evaluated using a collection of 14 NGS benchmarks; see figure 3 for diagram. For Saluda County, the standard deviation is 0.48 feet and the root mean squared is 0.46 feet. The LiDAR data was compared to each of these benchmarks yielding a better result than was required for the project. Table 5 indicates the results for Saluda County and each point including the overall results as it compares to the LiDAR data set.

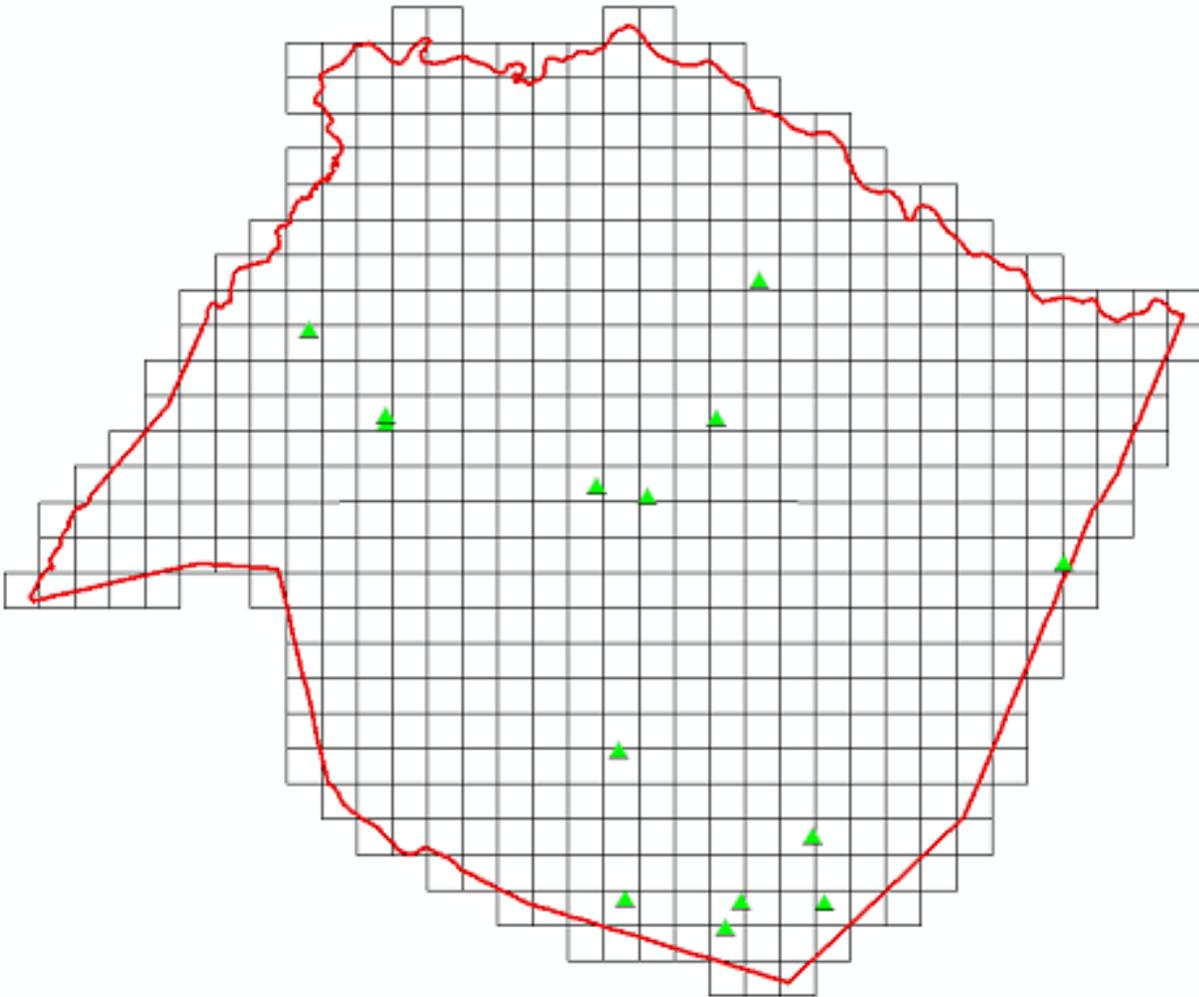


Figure 3: Saluda Survey Checkpoint Diagram

Table 5: LiDAR Accuracy Assessment based on the Checkpoint Survey (Feet)

Name	Vegetation Class	Easting	Northing	Known Z	Laser Z	Dz
DE1092	Bare Earth	1794673.480	733539.720	636.890	637.460	+0.570
DE2551	Bare Earth	1840440.430	781349.830	522.530	522.270	-0.260
DE1096	Bare Earth	1806462.310	733252.110	636.460	636.380	-0.080
DE1119	Bare Earth	1777277.870	754947.460	482.540	482.160	-0.380
DH4148	Bare Earth	1797288.400	821435.330	447.100	447.570	+0.470
DH4149	Bare Earth	1804752.220	742748.550	570.800	571.120	+0.320
DH3554	Bare Earth	1778227.170	733894.370	655.000	655.410	+0.410
EC3005	Bare Earth	1781418.610	790899.120	462.200	461.310	-0.890
DH4150	Bare Earth	1733326.500	814461.230	544.600	544.480	-0.120
EC3006	Bare Earth	1744207.480	802350.280	541.800	540.980	-0.820
EC3007	Bare Earth	1744274.530	801116.700	536.900	537.410	+0.510
EC3008	Bare Earth	1791069.720	801949.820	414.200	414.650	+0.450
AH5674	Bare Earth	1792500.550	729843.690	632.500	632.600	+0.100
DH4152	Bare Earth	1774168.850	792345.350	396.200	396.040	-0.160
Average dz		+0.009				
Minimum dz		-0.890				
Maximum dz		+0.570				
Average Magnitude		0.396				
Root Mean Square		0.464				
Std deviation		0.481				

5.0 COORDINATES AND DATUM

5.1 Introduction

The final adjustment was constrained to the published NAD83 geodetic coordinates (ϕ , λ) and NAVD88 elevations. The adjustment was cross-referenced to the GEOID03 model to enable the estimation of orthometric heights.

5.2 Horizontal Datum

The final horizontal coordinates are provided in State Plane HARN South Carolina FIPS 3900 on the North American Datum of 1983 (NAD83 adjustment of 1992) units of intl feet.

5.3 Vertical Datum

The final orthometric elevations were determined for all points in the network using Geoid03 model and are provided on the North American Vertical Datum of 1988 in units of survey feet.