S.C Department of Natural Resources

LiDAR Campaign (Lee County, SC) Report of Survey

2011

EXECUTIVE SUMMARY

S.C. Department of Natural Resources contracted with Sanborn to provide LiDAR mapping services for Lee 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 411 square miles between February 21st 2010 and March 25th 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.

Three airborne GPS (Global Positioning System) base stations were used in the Lee County project. NGS points with PID's of AE3535, AJ7022, and AJ7047 were used as monuments for the GPS base station placement. These three 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.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 Lee County.

1.3 Project Location

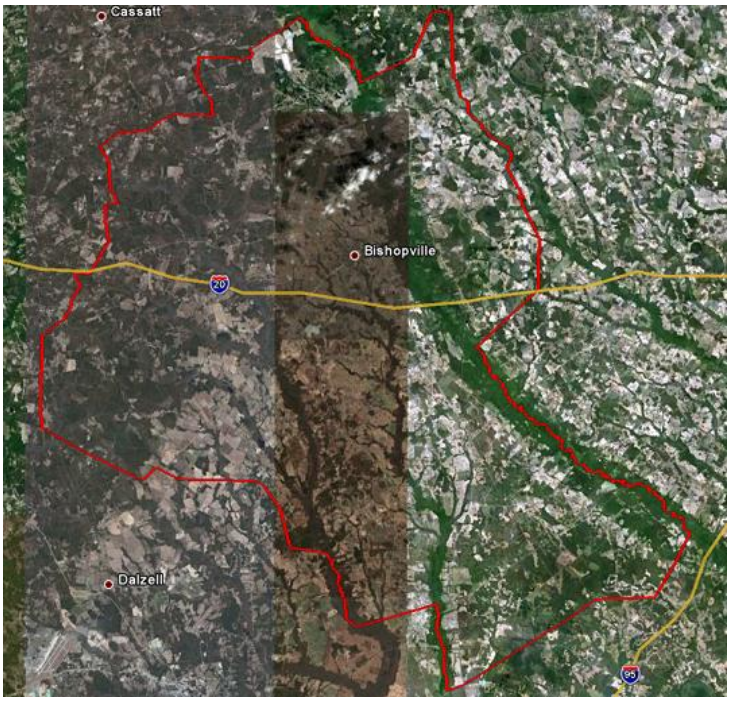

Figure 1: Area of Collection

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	≤ ±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/m2 (includes swath overlap; e.g., with 30% sidelap, ≥ 2 pulse/m2 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	≤ 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 scale, 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 proceedures using TerraSolid products are applied; inlcuding TerraScan and TerraMatch. Utilizing these two tools, Sanborn is able to correct each intiviual raw data strip to precisely match the two overlapping swaths. In return, the RMSE of the enitre project is substantually lower, resulting in a more accurate dataset. TerraMatch samples the data perpenicular to the flight pattern to assess and correct for roll errors, pitch errors, and heading errors.

Throughout the Lee 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.

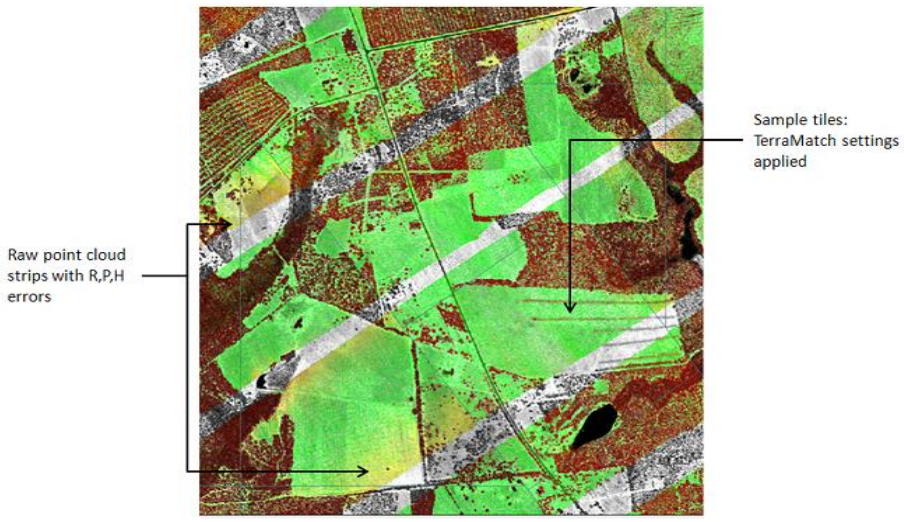

Figure 2: TerraMatch Tiling Sample

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 Lee county campaign. Although Sanborn and Keystone 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 Lee 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 between 1500 to 1700 meters above ground level (AGL) for the Leica system on a mission to mission basis.

Table 2: LiDAR Acquisition Parameters

Average Altitude	1500-1700 Meters AGL
Airspeed	~120 to ~140 knots
Scan Frequency	26.5-34 Hertz
Scan Width Half Angle	20 Degrees
Pulse Rate	70,000 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/ Keystone)	Start Time	End Time	Altitude (m)	Airspeed (Knots)	Scan Angle	Scan Rate	Pulse Rate	PDOP (Ave)
052b	Feb 21	Leica ALS50-S	20:07	00:33	1500	140	40˚	36	70000	2.0
056a	Feb 25	Leica ALS50-S	15:44	20:26	1500	140	40˚	36	70000	2.5
057b	Feb 26	Leica ALS50-S	18:31	22:34	1500	140	40˚	36	70000	2.1
078a	Mar 19	Leica ALS50-S	13:58	16:29	1500	140	40˚	36	70000	1.6
078b	Mar 19	Leica ALS50-S	17:20	22:05	1500	140	40˚	36	70000	1.8
084a	Mar 25	Leica ALS50-S	14:46	18:11	1500	140	40˚	36	70000	0.7
084b	Mar 25	Leica ALS50-S	19:07	21:44	1500	140	40˚	36	70000	0.8
077a	Mar 18	Leica ALS50-K	23:44	01:28	1700	120	40˚	26.5	70000	2.1
078a	Mar 19	Leica ALS50-K	05:04	09:38	1700	120	40˚	26.5	70000	2.7
078b	Mar 19	Leica ALS50-K	11:34	14:01	1700	120	40˚	26.5	70000	2.7

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 with in 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	15 cm RMSE

4.0 GEODETIC AUTHENTICATION

4.1 Final LiDAR Verification

The LiDAR data was evaluated using a collection of 24 NGS benchmarks; see figure 3 for diagram. For Lee County, the standard deviation is 0.353 feet and the root mean squared is 0.357 feet. The LiDAR data was compared to each of these benchmarks yielding much better result than was required for the project. Table 5 indicates the results for Lee County and each point including the overall results as it compares to the LiDAR data set.

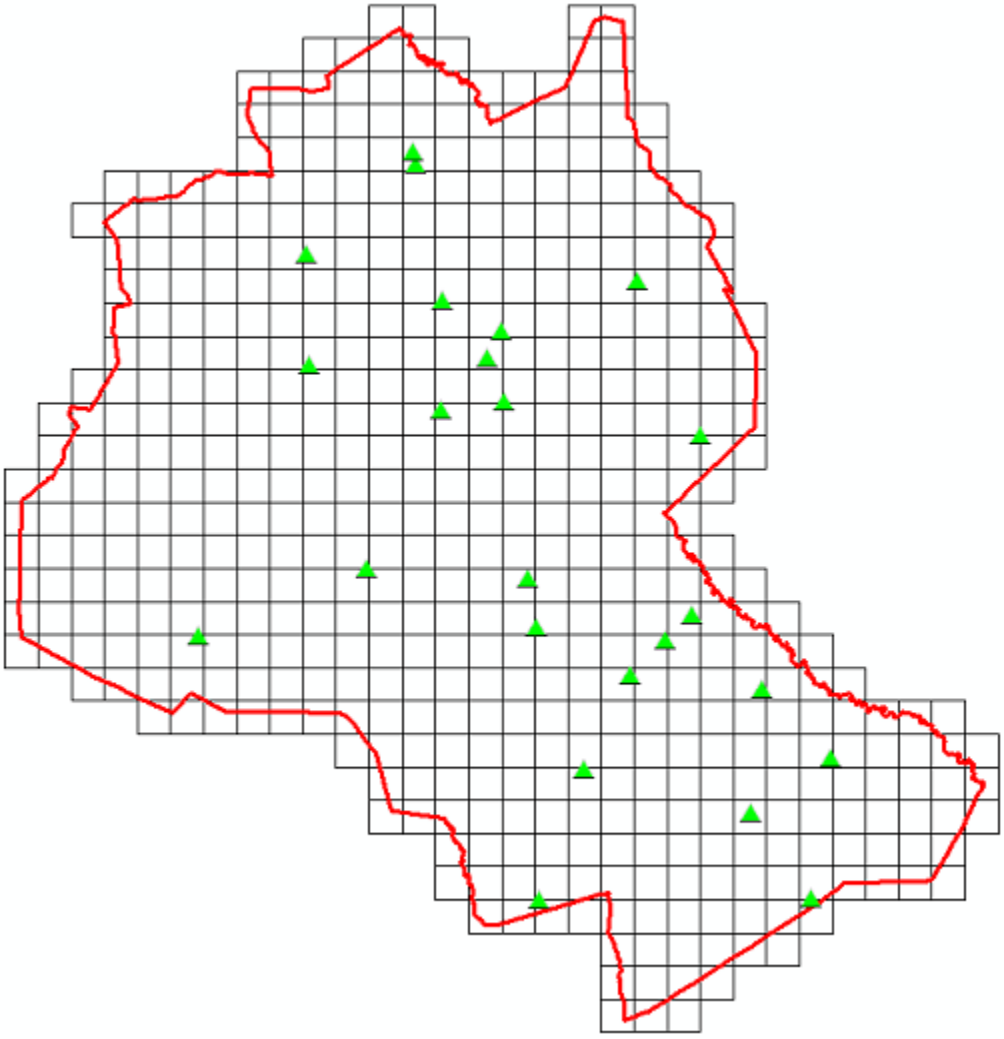

Figure 3: Lee Survey Checkpoint Diagram

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

Name	Vegetation Class	Easting	Northing	Known Z	Laser Z	Dz
EC3118	Bare Earth	2249640.860	823823.240	169.810	170.120	+0.310
EC3086	Bare Earth	2254941.860	829240.810	174.040	174.610	+0.570
EC3085	Bare Earth	2258953.900	833061.690	167.960	168.810	+0.850
EC3101	Bare Earth	2230037.900	875838.980	207.910	207.510	-0.400
AF7833	Bare Earth	2209766.060	839998.450	208.000	208.570	+0.570
EC1449	Bare Earth	2267706.740	803187.510	156.900	157.060	+0.160
EC1464	Bare Earth	2227932.630	871768.680	223.470	223.620	+0.150
EC1443	Bare Earth	2269558.850	821824.900	161.400	161.900	+0.500
AF7835	Bare Earth	2201176.510	870712.630	253.000	253.340	+0.340
EC3122	Bare Earth	2242498.710	809771.220	160.350	160.240	-0.110
EC2476	Bare Earth	2235908.130	789899.960	146.000	145.940	-0.060
AF7838	Bare Earth	2200762.130	887437.700	351.000	350.840	-0.160
EC2183	Bare Earth	2217175.440	900926.860	244.360	244.450	+0.090
EC1492	Bare Earth	2216689.620	902818.980	251.970	252.240	+0.270
EC1448	Bare Earth	2279829.250	811400.810	153.800	153.700	-0.100
AF7850	Bare Earth	2250619.170	883385.150	208.000	208.140	+0.140
EC1493	Bare Earth	2221113.570	880460.490	324.390	324.280	-0.110
EC1460	Bare Earth	2235381.170	831187.050	182.400	182.560	+0.160
AF7864	Bare Earth	2221071.710	863884.560	225.000	224.430	-0.570
AF7867	Bare Earth	2260091.470	860146.010	214.300	214.300	+0.000
AF7868	Bare Earth	2230536.820	865157.400	205.000	205.330	+0.330
EC2483	Bare Earth	2276913.540	790133.130	141.200	140.700	-0.500
EC1463	Bare Earth	2234102.570	838535.000	182.400	182.510	+0.110
EC1470	Bare Earth	2184422.060	829861.080	369.100	368.730	-0.370

Average dz	+0.090
Minimum dz	-0.570
Maximum dz	+0.850
Average Magnitude	0.289
Root Mean Square	**0.357**
Std deviation	0.353

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.