SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

FINAL DATA REPORT

FOR THE SOUTH PEACE LiDAR SURVEY

PREPARED BY:

3001 INTERNATIONAL, INC.

Acquisition

The South Peace LiDAR Survey project area consists of approximately 1,801 square miles located in Hardy, Desoto, and Charlotte Counties. The project was planned and executed to produce a LiDAR point cloud of a density sufficient to support a maximum final post spacing of 6 feet for unobscured areas. To accomplish this task, 3001 inc. acquired 445 flight lines between February 11, 2005 and April 14, 2005. The ABGPS, inertial measurement unit (IMU), and raw scans were collected during the LiDAR aerial survey. The ABGPS monitors the xyz position of the sensor and the IMU monitors the orientation. During the aerial survey laser pulses reflected from features on the ground surface are detected by the receiver optics and collected by the data logger. GPS locations are based on data collected by receivers on the aircraft and base stations on the ground. The ground base stations are placed no more than 35 km radius from the flight survey area.

Post-Processing

The data posting is a function of flight altitude, airspeed, scan angle, scan rate, laser pulse rates, and terrain relief. The afore mentioned parameters were taken into consideration at the time of flight planning. Many parameters are considered in order to achieve the maximum possible Global Positioning System (GPS) positioning accuracy, such as the separation between the airborne and base station GPS receivers, satellite geometry as reflected by the Position Dilution of Precision (PDOP), signal multipath, and many other factors.

The post-flight data processing software maximizes detection probability while minimizing false alarms. It corrects for several unavoidable, but predictable, biases from the environment as well as removing effects inherent to the hardware configuration.

Monitoring the data during collection is only part of the process done to assure proper operation of equipment and ultimately, data quality. However, all subsystems may indicate correct operating parameters (precision), but that does not mean that together they are providing correct solutions (accuracy). In order to validate the collection process, calibration tests are performed. These procedures allow the operator to know if the subsystems have been set up properly and if there are any inherent biases in the instrumentation. Bore-sight configurations are flown before each mission to ensure the sensor is functioning properly and within specifications. After acquisition, each mission is calibrated separately before editing and filtering. Prior to the calibration process, the GPS base stations, which are correlated to National Geodetic Surveys' (NGS) Continuously Operating Reference System (CORS) network stations, are processed in conjunction with the airborne GPS raw observables to determine the aircrafts positions. The processed GPS positions are combined with the inertial data (IMU) using the Applanix POSPacTM in a closed loop fashion (forward and backward solution with Kalman filter option) to compute the Smoothed Best Estimate of Trajectory (SBET) parameters, namely position, velocity, and attitude.

The ABGPS, IMU, and raw scans are integrated using proprietary software developed by the Leica Geosystems and delivered with the Leica ALS50 System. The resultant file is in a LAS binary file format. LAS is a binary file format that maintains information specific to the LiDAR data (return#, intensity value, xyz, etc.). The resultant points are produced in the State Plane Florida West coordinate system, with units in feet and referenced to the NAD83 horizontal datum and NAVD88 vertical datum.

During the planning phase of this project, the airport/job site was chosen as the calibration test site. On a mission basis, the LiDAR was flown over this test area in two opposing directions and with additional parallel flights flown with a 30% overlap. The airborne results in each direction are then compared with results of the other flight directions. The attitude misalignment parameters derived from the calibration (bore sighting), and the modeled "windup" values were used in the post-processing software (MFCCP) to resolve the systematic errors in the data. Once the calibration parameters and modeled "windup" value are acceptable, all mission data are processed.

Accuracy Assessment

The accuracy assessment compared ground truth checkpoints against LIDAR points from the edited data set, which were within 3 feet horizontally from the ground truth points. Note that the edited LIDAR points are simply a subset of the raw LIDAR points. The points that fell above the ground surface on vegetation canopies, buildings, or other obstructions were removed from the data set. Comparisons were also made between the survey points and the LIDAR derived terrain surface. This comparison provides an additional verification of the LIDAR data against the survey data.

The survey data was collected in accordance with the *FEMA FLOOD HAZARD MAPPING PROGRAM, GUIDELINES AND SPECIFICATIONS FOR FLOOD HAZARD MAPPING PARTNERS, APPENDIX A*.

Ground truth data was collected for each of the following land cover categories:

1. Bare-earth and low grass
2. Brush lands and low trees
3. Forested areas fully covered by trees
4. Urban areas

The accuracy assessment was performed using a standard method to compute the root mean square error (RMSE) based on a comparison of ground control points (GCP) and filtered LiDAR data points. Filtered LiDAR data has had vegetation and cultural features removed and by analysis represent bare-earth elevations. The RMSE figure was used to compute the vertical National Standard for Spatial Data Accuracy (NSSDA). Ground control was established by 3001, Inc. A spatial proximity analysis was used to select edited LiDAR data points contiguous to the relevant GCPs. A search radius decision rule is applied with consideration of terrain complexity, cumulative error, and adequate sample size. Cumulative error results from the errors inherent in the various sources of horizontal measurement. These sources include the airborne GPS, GCPs, and the uncertainty of the accuracy of the LiDAR data points. This accuracy is achieved prior to the sub-sampling that occurs through integration with the inertial measurement unit (IMU) positions that are recorded. The horizontal accuracy of the GCPs is estimated to be in the range of approximately 1 to 1.6 inches. Finally, sample size was considered. The specification for the National Standard for Spatial Data Accuracy is a minimum of 20 points to conduct a statistically significant accuracy evaluation (Minnesota Planning, 1999, Positional Accuracy Handbook, Minnesota Planning Land Management Information Center, St. Paul, Minnesota., p.3). Most statistical texts indicate that a minimum of 30 sample points provide a reasonable Approximation of a normal distribution. The intent of the NSSDA is to reflect the geographic area of interest and the distribution of error in the data set (Federal Geographic Data Committee, 1998, Geospatial National Standard for Spatial Data Accuracy, Federal Geographic Data Committee Secretariat, Reston, Virginia, p.3-4). Additional steps were taken to ensure the vertical accuracy of the LiDAR data including: Step 1: Precision Bore sighting (Check Edge-matching) Step 2: Compare the LiDAR data to the Field Survey (Field survey is to FEMA specifications and more stringent internal specifications) Step 3: Automated Filtering Step 4: Manual Editing (Quality Control) Step 5: 3-D digitizing and Photogrammetric Compilation of hydrographic breaklines

The unedited data are classified to facilitate the application of the appropriate feature extraction filters. Combinations of proprietary filters are applied as appropriate for the production of bare earth digital terrain models (DTMs). Interactive editing methods are used in areas where it is inappropriate or impossible to use the feature extraction filters, based upon the design criteria and/or limitations of the relevant filters. These same feature extraction filters are used to produce elevation height surfaces.

Filtered and edited data are subjected to rigorous QA/QC according to the 3001 Inc. Quality Control Plan and procedures. Very briefly, a series of quantitative and visual procedures are employed to validate the accuracy and consistency of the filtered and edited data. Survey control points were established by 3001, Inc. and GPS-derived ground control points (GCPs) points in various areas of dominant and prescribed land cover. These points are coded according to land cover, surface material, and ground control suitability. A suitable number of points are selected for calculation of a statistically significant accuracy assessment as per the requirements of the National Standard for Spatial Data Accuracy. A spatial proximity analysis is used to select edited LiDAR data points within a specified distance of the relevant GCPs. A search radius decision rule is applied with consideration of terrain complexity, cumulative error, and adequate sample size. Accuracy validation and evaluation is accomplished using proprietary software to apply relevant statistical routines for calculation of Root Mean Square Error (RMSE) and the National Standard for Spatial Data Accuracy (NSSDA) according to Federal Geographic Data Committee (FGDC) specifications.

The LiDAR mass points were delivered in American Society for Photogrammetry and Remote Sensing LAS 1.0 format. The header file for each dataset is complete as define by the LAS 1.0 specification. In addition, the following fields are included: Flight Date Julian, Year, and Class. The LAS files do not include overlap. The data was classified as follows: Class 1 = Unclassified. This class includes vegetation, buildings, noise etc. Class 2 = Ground Class 3 = Water. The datasets were delivered in the Districts standard 5000' by 5000' tiling scheme. The tiles are contiguous and do not overlap. The tiles are suitable for seamless topographic data mosaics that include no "no data" areas. The names of the tiles are left padded with zeros as required to achieve a five-character length and all files utilize the LAS file extension.

During processing, the District found that there was a consistent bias between the LiDAR data that had been provided and the Districts survey data. 3001 investigated the issue and found that during processing a constant value was applied to the entire data set through an automated process. To correct this issue, 3001 performed an accuracy assessment of the entire data set to check the extent of the error. The results showed that the error was introduced to the entire dataset. 3001 removed the bias and submitted the data to the District for evaluation. The District verified the vertical accuracy and accepted the dataset.

Reworks

On November 18, 2008, the District notified 3001 of the following issues within the South Peace data set:

- A 1.2' vertical shift along the Polk / Hardy County Border
- Ridges in the dataset
- Breakline files that stopped (for no apparent reason) along the Peace River.

After further investigation, the district reported that the vertical shift continued east and south along the Carter Creek project. To quantify the extent of the shift, the district performed surveys at different points throughout the data set. The survey data was provided to 3001 for further analysis and to be used as the base for further processing.

3001's initial investigation focused on the breakline issues. During acquisition, there was a significant rain event in Southwest Florida. According to the gage at the USGS 02295637, Peace River at Zolfo Springs Florida, the gage height went from approximately 14.3 feet to 17.3 feet between February 28, 2005 and March 2, 2005. Then between March 2, 2005 and March 4, 2005 the height of the gage declined to about 15.1 feet. The changes in the channel are evident in the breaklines. In some areas of the Peace River LiDAR Survey there are sudden changes in the size of the channel as well as the elevation of the breaklines. Due to the inconsistencies in the channel, 3001 created obscured polygons around the affected channels. After analyzing the data for breaklines that stopped (for no apparent reason), 3001 determined that the breaklines did not stop, they were supplemented with obscured polygons, as requested during the initial processing, due to the flooding that occurred during acquisition. The obscured polygons do not have elevations and are not in the hydro-breakline dataset;

therefore, users that do not load the all of the breakline data sets cannot accurately assess the data.

The features that were identified as ridges were parallel to the flight lines and located on bodies of water. 3001 analyzed these areas and concluded that as small pond and streams were scanned, an increase in intensity created artificial features resembling ridges (berms) on the surface of water bodies. To aid in data modeling, breaklines were created for these areas and the water (berms) were reclassed.

As requested, 3001 reprocessed the area in question to make the Peace River South LiDAR data match the newly acquired survey data and adjacent Polk County and Carter Creek LiDAR data. This reprocessing was accomplished by:

1. Calculating elevation differences for natural features that were common in adjacent data sets on the north (Polk LiDAR) and east (Carter Creek LiDAR) edges of the area to be adjusted.

2. Calculating elevation difference between the South Peace LiDAR data and field survey data collected by the District for interior areas of the area to be adjusted.

3. Unaffected areas to the west and south of the area to be adjusted were held constant and the remainder of the data was adjusted to best fit the border and interior points described in steps (1) and (2).

To adjust the data, 3001 applied rigorous mathematical computations using 9-parameter Affine Transformation (proprietary software package). The transformation parameters were derived using common point coordinates (pass points) of the identified natural features and the ground control points.

Though the exact cause or causes of the issues within the South Peace data are not clear, a variable vertical bias may have been applied to the data set during processing.