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Project Report
Colusa Subreach Baseline Assessment & Dead Man's Reach Topographic Mapping

Contract #2285-H

terrapoint

Report Presented to:

The Nature Conservancy
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Table of Contents

1. Project Overview

Project Summary:

Baseline Assessment Topographic Mapping was carried out by Terrapoint on behalf of The Nature Conservancy in order to characterize both the elevation of the Sacramento River and the elevation of the surrounding floodplain lands. The difference between the two (relative elevation) is a surrogate for flood frequency that can be used to characterize inundation patterns. A high-resolution DEM was produced in order for Conservancy staff to assist in the development in watershed mapping, modeling products and restoration planning. Terrapoint met and exceeded accuracy specifications for the project.

Field Crew:

The Terrapoint field crew consisted of Mike Perdue, field project manager and Aubrey Tuttle, LiDAR operator. The Exact Air Inc. aircraft crew consisted of Jean-Phillippe Rioux, pilot and Francis Giguire, pilot.

Post Processing Crew:

Aubrey Tuttle completed the processing of GPS data. David Lavoie carried out data validation and calibration. Vegetation removal and final product generation were completed by the Ottawa processing team: Claude Vickers, Alan Dodson, Andrew Magnan and others.

Project Area and Location:

The project site covered approximately 93.2 square kilometers between Princeton and Colusa on the Sacramento River, as well as a smaller area of 3.6 square kilometers at the U.S. Fish and Wildlife Service Sacramento River NWR, Dead Man's Reach Unit.

Project Type:

The purpose of this project is to provide a high quality DEM and relative elevation model of the site for The Nature Conservancy.

Approximate Duration of Project:

The field data collection took place on February 16 and 22, 2006. The control network and check point surveys were completed between on February 17 and 21, 2006.

Calibration, vegetation removal and product generation took place from March 15 to April 10, 2006.

Number of Flights:

Two flights were required to cover the project area with 64 flight lines.

Coordinate System(s) Used:

All horizontal coordinate data were collected and referenced to NAD83 (1998) and NAVD88 and delivered in UTM Zone 10. GEOID03 for CONUS was applied to the vertical component of all deliverables.

Survey Measurement Units Used/Delivered:

All surveys were conducted and products delivered in Meters.

Processing Software Used:

The following software was used to reduce the GPS kinematic data, compute the 3-D laser points, classify and edit laser points, produce shaded relief images and transform the ellipsoidal heights to orthometric.

- ArcView
- Flykin
- Microstation
- TerraScan
- TerraModeler
- Terrapoint Proprietary LiDAR processing software

Capsule Review of Ground Control Survey(s) and Adjustment(s):

Terrapoint's field crew acquired and adjusted the ground control survey information. Terrapoint collected all of their LiDAR data referenced to NGS monuments DH3662 and KS1942. Kinematic GPS check points were acquired as discrete x, y, z points were collected as part of the ground truthing activities. A summary of all control coordinates is given in Table 1.

Table 1: Control and Base Coordinates

Name	Latitude			Longitude			Ellipsoidal Elevations (meters)
DH3662	39	39	34.81824	-122	01	36.97506	17.119
KS1942	39	36	58.45438	-121	40	55.09759	35.168
228501	39	29	42.94470	-121	36	57.32580	30.838
228502	39	13	55.98923	-121	59	46.83332	-7.304
CHO1	39	25	57.48425	-121	39	53.81145	17.069

Cautionary Tales

Gridded data, such as the bare earth, first surface, and relative elevation grid were produced at one meter postings. This gridded data should not be resampled to a finer grid size or extrapolated, as this will skew the data.

River-edge data in the gridded products will sometimes contain irregular triangles that affect the shape and elevation of the shoreline in localized areas. This occurs due to the lack of LiDAR returns on the water surface (water is a poor reflector). When using LiDAR data to map shorelines Terrapoint recommends using the bare earth ASCII points for these questionable areas.

The elevation value of certain returns over water at nadir are higher than off-nadir returns in the same area. The vast difference in return strength between a return at nadir and a return at an angle can cause the system to slightly misinterpret the range value. This effect is not common and its magnitude is typically regarded as insignificant.

2. Health and Safety

Following Terrapoint's safety procedures, the field crew conducted a safety meeting upon arrival at the project site.

3. Equipment Used

Aircraft Type:

A Navajo twin-engine aircraft (C-FQQB) was used for this project. The aircraft was based out of Oroville Municipal Airport. The Navajo was typically flown at an altitude of 3500 feet AGL (above ground level) for the duration of the survey.

Sensors Used:

The Airborne LiDAR survey was conducted using Terrapoint's 40 kHz ALTMS (Airborne Laser Terrain Mapping System), flying at an optimum height of 3500 ft AGL at 140 knots. The system consists of a 36-degree full angle laser, a NovAtel DL-4 GPS receiver and a Honeywell H764 IMU unit. The nominal flight line spacing was 1070 feet, providing overlap of 75% between flight lines.

GPS Type(s):

Two Sokkia GSR2600 dual frequency GPS receivers were used to support the airborne operations on this project.

4. Accuracy

The following list itemizes the accuracy attainable over the project area, as a function of terrain type and vegetation cover. Note that the accuracy quoted is the accuracy of the attainable DEM, once it is processed and edited to this stage. All data accuracies quoted relate to post processed GPS/IMU/LiDAR solutions.

Accuracy is as follows, quoted at the 95% confidence level (2 sigma),

1. Absolute Vertical Accuracy:
   +/- 10-15 centimeters on Hard Surfaces (roads and buildings)
   +/- 15-25 centimeters on Soft/Vegetated Surfaces (flat to rolling terrain)

2. Absolute Horizontal Accuracy:
   +/- 40 – 60 centimeters on all.

3. Contour Accuracy:
   1 ft Contour National Map Accuracy Standard (NMAS)

To verify that the accuracy criteria were being achieved, kinematic checkpoints were compared with a triangulated surface generated from the bald earth LiDAR points. This independently-collected GPS data is used to compare and validate the airborne LiDAR survey, and is the most efficient method of performing a statistically significant check on the entire project area. Although kinematic profiling is not as precise in an absolute sense as (for example) terrestrial observations (such as spirit leveling) or RTK-GPS, it is able to adequately identify gross errors and trends more easily and more comprehensively throughout the project.

A comparison of LiDAR data with 1306 kinematic checkpoints collected inside the project site along roadways yielded the results given in Table 2 (values in meters).

Table 2: Kinematic Point Comparison (all units meters)	
Average difference in elevation	-0.033
Minimum difference in elevation	-0.270
Maximum difference in elevation	+0.130
Average magnitude	0.050
Root mean square	0.063
Std deviation	0.053

As shown above, the accuracy specifications for the project were met and exceeded. The full listing of the kinematic / LiDAR comparison can be found in digitally on the accompanying CD (Ground_Truth_Report.txt).

5. LiDAR Quality Control

Quality control of the data was ongoing throughout the process. Following data acquisition, preliminary GPS processing was conducted in the field to ensure completeness and integrity.

The GPS and inertial data were processed in tandem to achieve the best positional result. Once the position and attitude of the aircraft were known at each epoch (1-second intervals), these data were integrated with the laser ranges to provide a position for each data point on the ground. The data were then processed using the proprietary laser processing software suite to produce coordinates.

Each flight involved setting up two base stations to collect data. Utilizing two base stations ensures GPS data collection in the event that the main base station fails. For all flights the GPS data were of high quality. This minimized the absolute error for the aircraft position.

The primary quality control tool for the laser ranges is the percentage of returns that are received back at the laser after it has emitted a signal. The acceptable range for returns, typically between 90% and 95% was met for this project. Lower percentages are normal over water and other poor reflectivity surfaces.

Terrapoint also utilizes a proprietary software package that performs a fully automated analysis of the quality of the LIDAR data using overlapping flight lines. Our flight lines overlap 75% on either side and thus 100% of points can be checked for overlap consistency. The overlap analysis attempts to minimize the differences in overlap areas by fine-tuning the calibration parameters of the LiDAR system.

6. Point Generation

The points are generated as Terrascan binary Format using Terrapoint's proprietary Laser Postprocessor Software. This software combines the Raw Laser file and GPS/IMU information to generate a point cloud for each individual flight.

All the point cloud files encompassing the project area were then divided into quarter quad tiles. The referencing system of these tiles is based upon the project boundary minimum and maximums. This process is carried out in Terrascan.

The bald earth is subsequently extracted from the raw LiDAR points using Terrascan in a Microstation environment. The automated vegetation removal process takes place by building an iterative surface model. This surface model is generated using three main parameters: Building size, Iteration angle and Iteration distance.

The initial model is based upon low points selected by a roaming window and are assumed to be ground points. The size of this roaming window is determined by the building size parameter. These low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the Iteration angle and distance constraints (fig. 1). This process is repeated until no additional points are added within an iteration.

There is also a maximum terrain angle constraint that determines the maximum terrain angle allowed within the model.

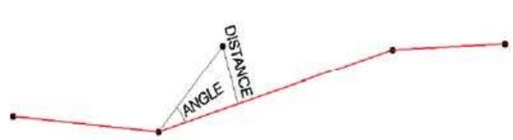

Figure 1: Terrascan iteration methodology.

(Image Source: Terrascan User's Guide, www.terrasolid.fi)

7. Classification Quality Control

Once the data setup has taken place the manual quality control of the surface occurs. This process consists of visually examining the LiDAR points within Terrascan and correcting errors that occurred during the automated process. These corrections include verifying that all non ground elements, such as vegetation and buildings are removed from the ground model and that all small terrain undulations such as road beds, dikes, rock cuts and hill tops are present within the model.

This process is done with the help of hillshades, contours, profiles and cross-sections. To correct misclassifications, a full suite of Terrascan and custom in-house data tools are used.

8. Relative Elevation Map Generation

The relative elevation model was created using the following methodology:

A three dimensional river centerline was collected for the main channel of the Sacramento River for the Southern Levee area. The elevation component was extracted from the water LiDAR point returns.

To extend the river elevation over the entire project, the aforementioned river centerline was offset outwards 3750 m due east and west. The extreme Southern part of the river centerline was also offset 3750 m due south.

Using Terramodeler and Terrascan, a model was created using the river centerline and offset centerlines as hard breakline elements. The XYZ node values of the breaklines were used to create an ESRI TIN surface and subsequently converted to an ESRI GRID that was used as the river elevation model in the calculation.

The relative elevation value was calculated by subtracting the river elevation model ESRI GRID from the LiDAR Bare Earth ESRI GRID Model.

9. Deliverables

Below is a list of the deliverables for this project. All LiDAR Data Products were delivered on DVD–ROM.

First Surface Data

- ASCII LiDAR returns, format X, Y, Z, Intensity, GPS_Time. Data tiled using USGS quarter-quad 25ths.
- Gridded data at 1-Meter postings in ArcView grid

format.

Intermediate Surface Data

- ASCII LiDAR returns, format X, Y, Z, Intensity, GPS_Time. Data tiled using USGS quarter-quad 25ths.

Bare Earth Surface Data

- ASCII LiDAR returns, format X, Y, Z, Intensity, GPS_Time. Data tiled using USGS quarter-quad 25ths.
- Gridded data at 1-Meter postings in ArcView grid format.

Relative Elevation Data

- Gridded data at 1-Meter postings in ArcView grid format.

10. Flightline Map

Red trajectory indicates flight 47a (February 16), blue trajectory indicates flight 53a (February 22). These files in digital form are contained on the accompanying CD.