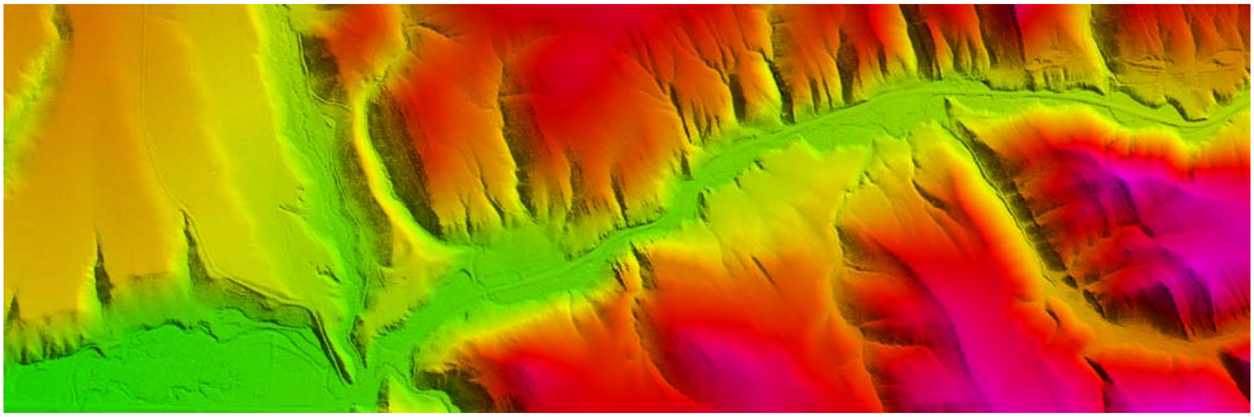
LIDAR DATA ACQUISITION AND PROCESSING
Deep Creek Area
Townsend, MT



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1. Overview

MT LiDAR, LLC acquired LiDAR data of the Deep Creek drainage and surrounding area near Townsend, MT on April 8-9, 2014. The requested survey area was expanded to include a 100 meter buffer to ensure complete coverage to the survey area boundary. The total area mapped was approximately 12,000 acres.

2. LiDAR Acquisition

MT LiDAR utilized a MD500 NOTAR helicopter with Leica ALS 50 II Corridor Mapper to collect the data for this project. A helicopter is less effected by up and down drafts than a fixed wing aircraft. The NOTAR (no tail rotor) system has less vibration than a helicopter with a tail rotor. Because the GPS is mounted at the rear of the cockpit on the tail boom, this makes a huge difference in the quality of the GPS. The helicopter is able to fly lower (300 – 800m AGL) and slower than a conventional fixed wing aircraft, allowing for better coverage of the laser pulse on the ground and increased penetration through vegetation to the ground. The LiDAR mapper records up to four returns per pulse with a maximum pulse rate of 150,000 pulses per second. Some surfaces return fewer pulses, therefore the overall point density will vary based on terrain, vegetation and water bodies.

The project area was flown at heights between 272-700 meters above ground level at a planned speed of 80 knots. The sensor scan angle was ±35°, ±17.5° from nadir, yielding an average of 6.5 points per square meter. Opposing flight lines were flown with a side-lap of 50% (100% overlap) to reduce shadowing and ensure complete coverage, providing an average overall point density of 10+ points per square meter.

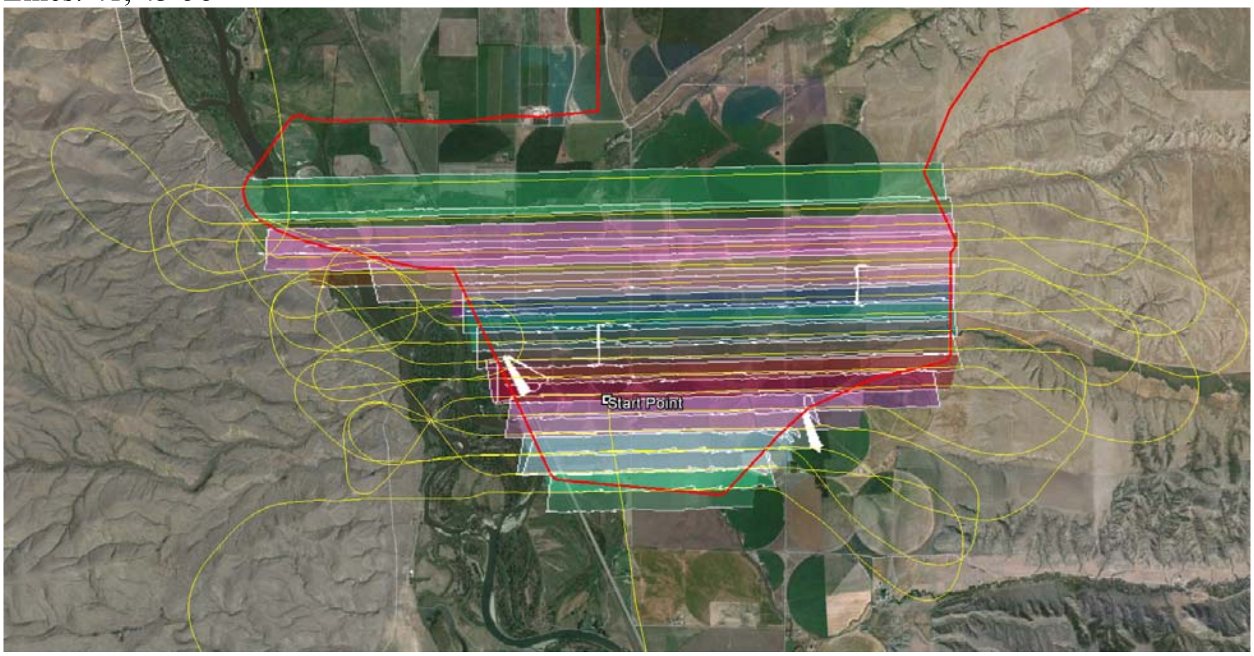
Two Leica GPS 1200 receivers were placed on ground control previously set by WWC Engineering operating at 2hz for the duration of the acquisition flight to accurately solve for laser point position, positional coordinates of the airborne sensor and attitude of the aircraft. The two control points were located at the Northwest end of the project area to allow for shorter GPS baselines between the helicopter mounted GPS and the ground GPS station to improve residuals. Flight line lengths were minimized to keep the IMU (inertial measurement unit) in the LiDAR system active by requiring more turns. The IMU records the pitch/roll/heading of the helicopter while in flight. WWC provided the survey control coordinates used to process the data.

Flight Lines and Aircraft Trajectories

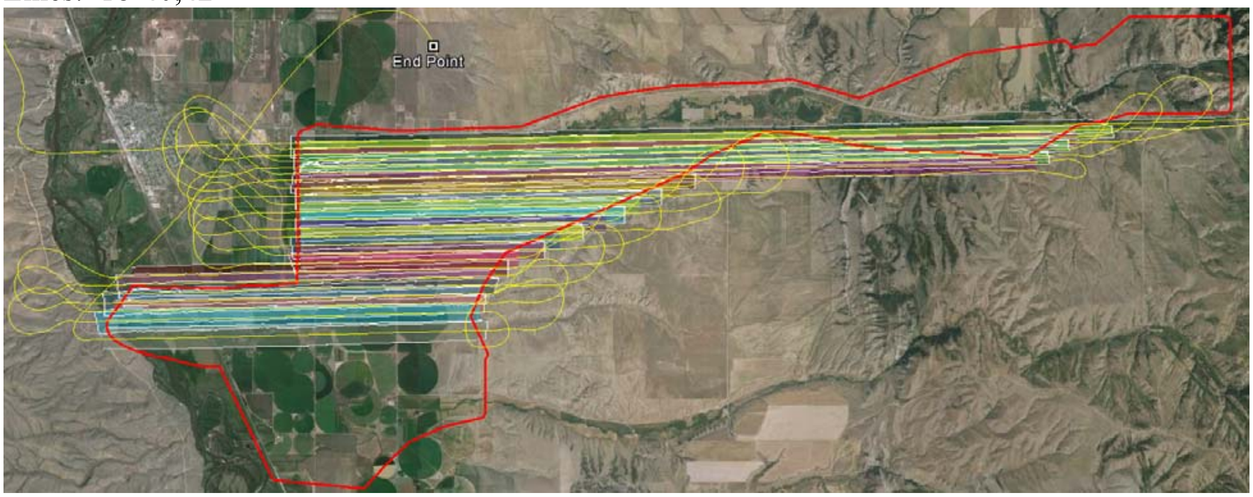
Fifty-eight flight lines were flown in alternating directions across the project area. Seven or more satellites were utilized with an average PDOP of 1.8 throughout the duration of the flights. The minimum number of satellites observed during active collection was 7.

The acquisition was divided into three flights/lifts with the trajectories shown below.
Flight 1
April 8th 2014
Lines: 1-17

Flight 2
April 8th 2014
Lines: 41, 43-58



Flight 3
April 9th 2014
Lines: 18-40,42



3. LiDAR Data Processing

1. GPS Post Processing

   The static ground GPS data collected over surveyed monuments with known coordinates were used to correct the kinematic aircraft GPS position data to obtain an accurate GPS solution and aircraft position. The aircraft position was corrected using the GPS solution and IMU data to adjust the attitude of the aircraft. The results of the post-processing confirmed the number of satellites used was ≥ 7 with an average PDOP of 1.8.

2. Laser Point Processing

   Using the solution file created in the GPS post-processing and the calibration flight data for the sensor, the raw laser data was processed to generate corrected x,y,z values for the raw laser data. This data was exported into LAS v. 1.2 files, retaining up to four point returns with x,y,z coordintates, echo (return number) and the raw intensity values for each pulse.

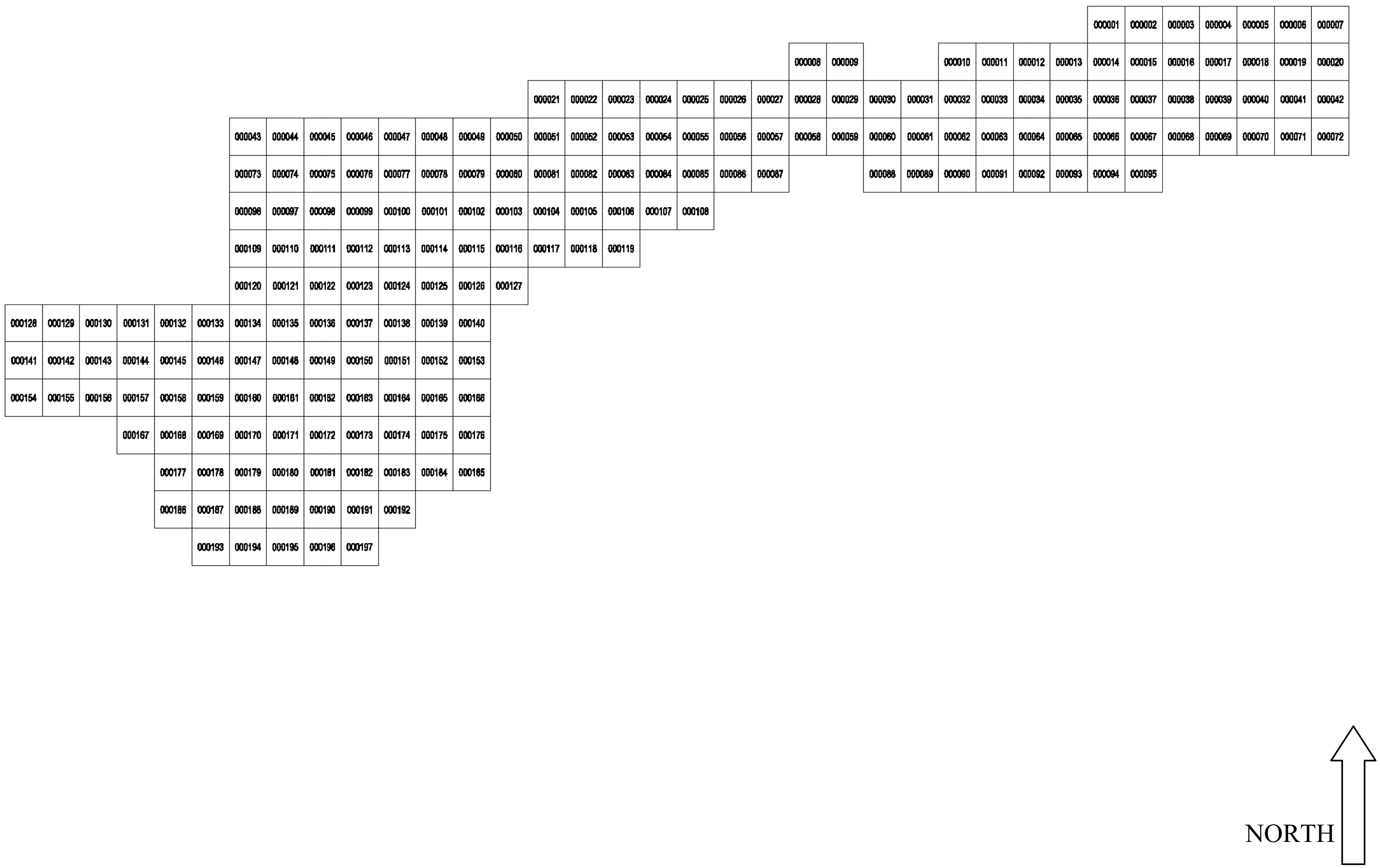
   The LAS files were too large to commence subsequent processing so a tile scheme (fig. 3.1) was created to divide the dataset into manageable sizes. The resulting point files were projected into:
   Horizontal: UTM, NAD83, Zone 12N International Feet
   Vertical: NAVD88, GEOID12A, International Feet

   The LiDAR points were filtered to eliminate noise and high and low points and classified to ground. During the ground classification process, software was used to classify near-ground points by taking out all points that were not near the earth based on geometric constraints used to evaluate multi-return points. The resulting bare earth (ground) model was visually inspected and additional ground point modeling was performed in areas as necessary to improve ground detail. The manual editing typically occurs in areas with known ground model deficiencies such as rock outcrops, cliffs, stream banks, dense vegetation and near buildings. Any points found were manually reclassified to the default class, or noise class as appropriate.

3. Results

   The resulting ground surface was used to generate the required deliverables. Reports were generated to test the accuracy of the ground surface using static control points and RTK ground truthing points, both provided by WWC.

Figure 3-1: Tile Scheme



4. Ground Control Point Locations

WWC provided a series of GPS derived ground check points to validate the dataset. The approximate locations of the control points are displayed below in figure 4-1.

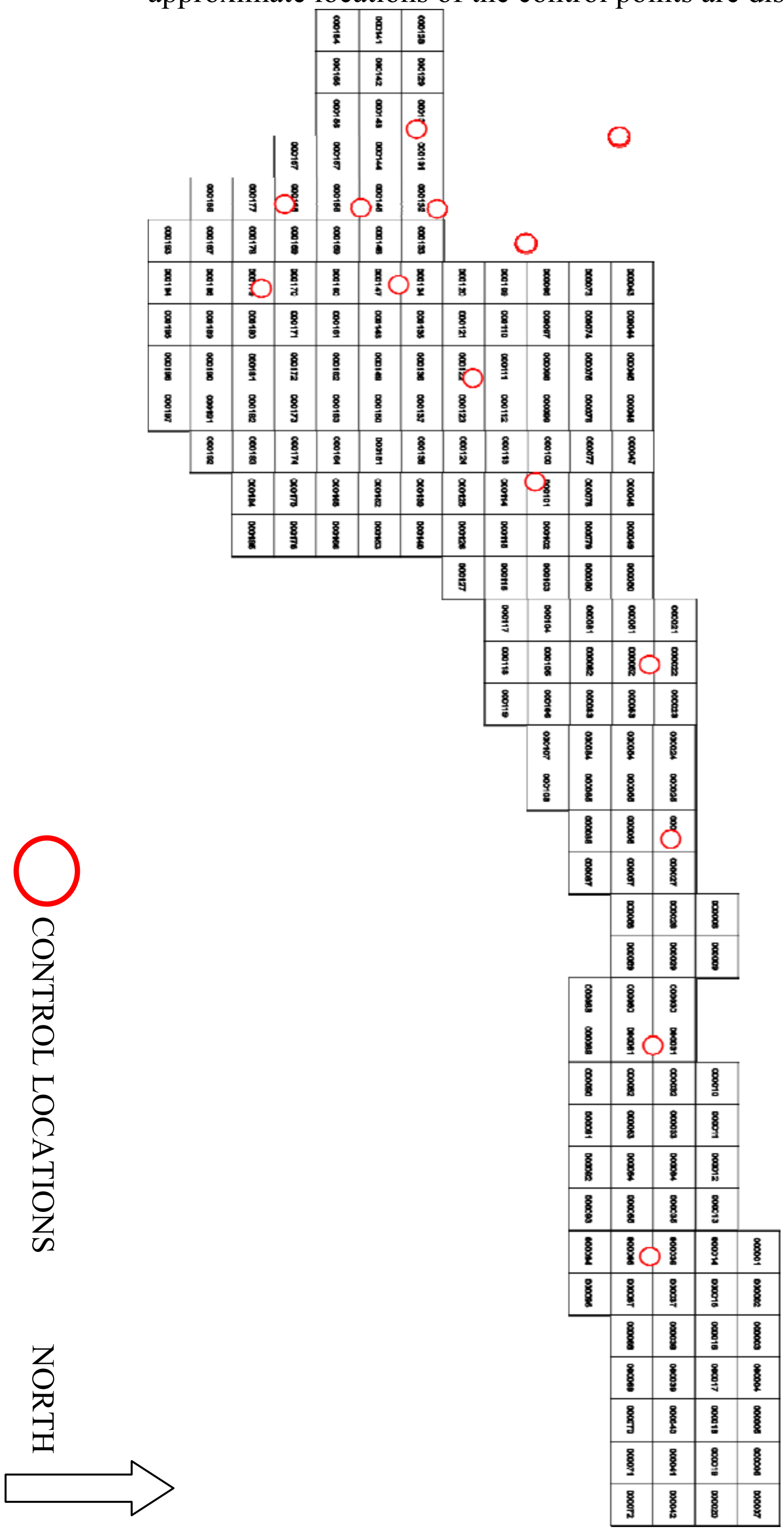


Figure 4-1: Control Locations

5. Accuracy Assessments

In order to verify the quality of the final ground surface, data from the ground survey conducted in the area was compared to the LiDAR ground surface. WWC provided 313 static and real-time kinematic (RTK) GPS measurements inside the project boundary. The check points were distributed among multiple flight swaths. To assess the absolute accuracy, the coordinates of the GPS recorded ground points were compared to the closest laser ground points.

The following control report was generated comparing all control points and check points within the project area.

Minimum dz	-0.270’
Maximum dz	0.613’
Average magnitude	0.101’
RMSE(z)	0.127’
Std deviation	0.127’

Tested .249’ fundamental vertical accuracy at 95 percent confidence level in open terrain using RMSE(z) x 1.9600.

No ground check points were removed from the above report. Some points appear to have been recorded near breaks which contribute to the RMSE and elevation discrepancies. Check points on bridges were not used as the bridges have been removed from the ground class.

A complete list of all control points used and the Z value differences has been included with the dataset in Excel format.

Deliverables, File Formats, File Naming Schemes

1. Point Files
    a. All Points:
        i. All_Points_block#.las (LAS v. 1.2)
        ii. All_Points_block#.xyz (XYZ)
    b. Ground Classifed Bare:
        i. Earth Points – Ground_block#.las (LAS v. 1.2)
        ii. Earth Points – Ground_block#.xyz (XYZ)
    c. Model Key Points
        i. 1.0ft – Ground_Keys_1.0ft_block#.las (LAS v. 1.2)
        ii. 1.0ft – Ground_Keys_1.0ft_block#.xyz (XYZ)
2. Key Points DTM files in Microstation format (LandXML 1.2)
    a. Deep_Creek_Tin01-10.xml (surfaces that generated the 1 foot contours)
3. Drawing File – Deep_Creek_LiDAR.dgn
    a. AOI Boundary with buffer
    b. LiDAR Tile Scheme
    c. LandXML Tile Scheme
    d. 1 foot interval contours
4. Final Data Report – Final Report.pdf (PDF)
5. Control Report in Excel Format of the Vertical Accuracy

All data is delivered in the following coordinate system:

Horizontal: UTM, NAD83, Zone 12N International Feet
Vertical: NAVD88, GEOID12A, International Feet

LAS Files use the following classification:
Code 1: Processed but unclassified
Code 2: Bare Earth
Code 7: Noise (low or high or manually identified)
Code 8: Keypoints (only used for 1.0ft Ground Key points files)
Code 9: Water