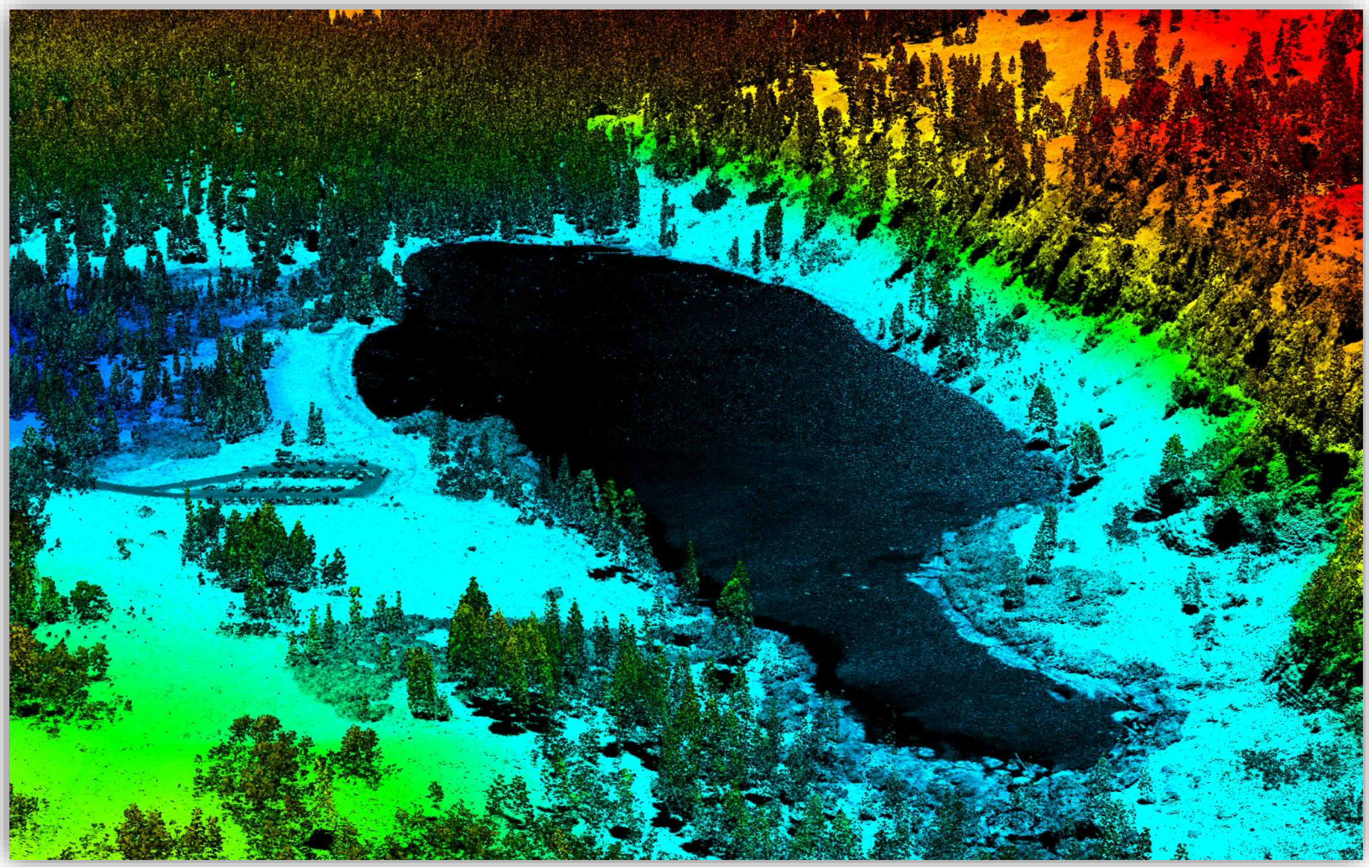
# TECHNICAL PROJECT REPORT

## LOGAN RIVER WATERSHED AERIAL LIDAR

CACHE COUNTY, UT AND FRANKLIN COUNTY, ID

**August 12-13, 2020**

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# Technical Project Report
## Logan River Watershed Aerial LiDAR

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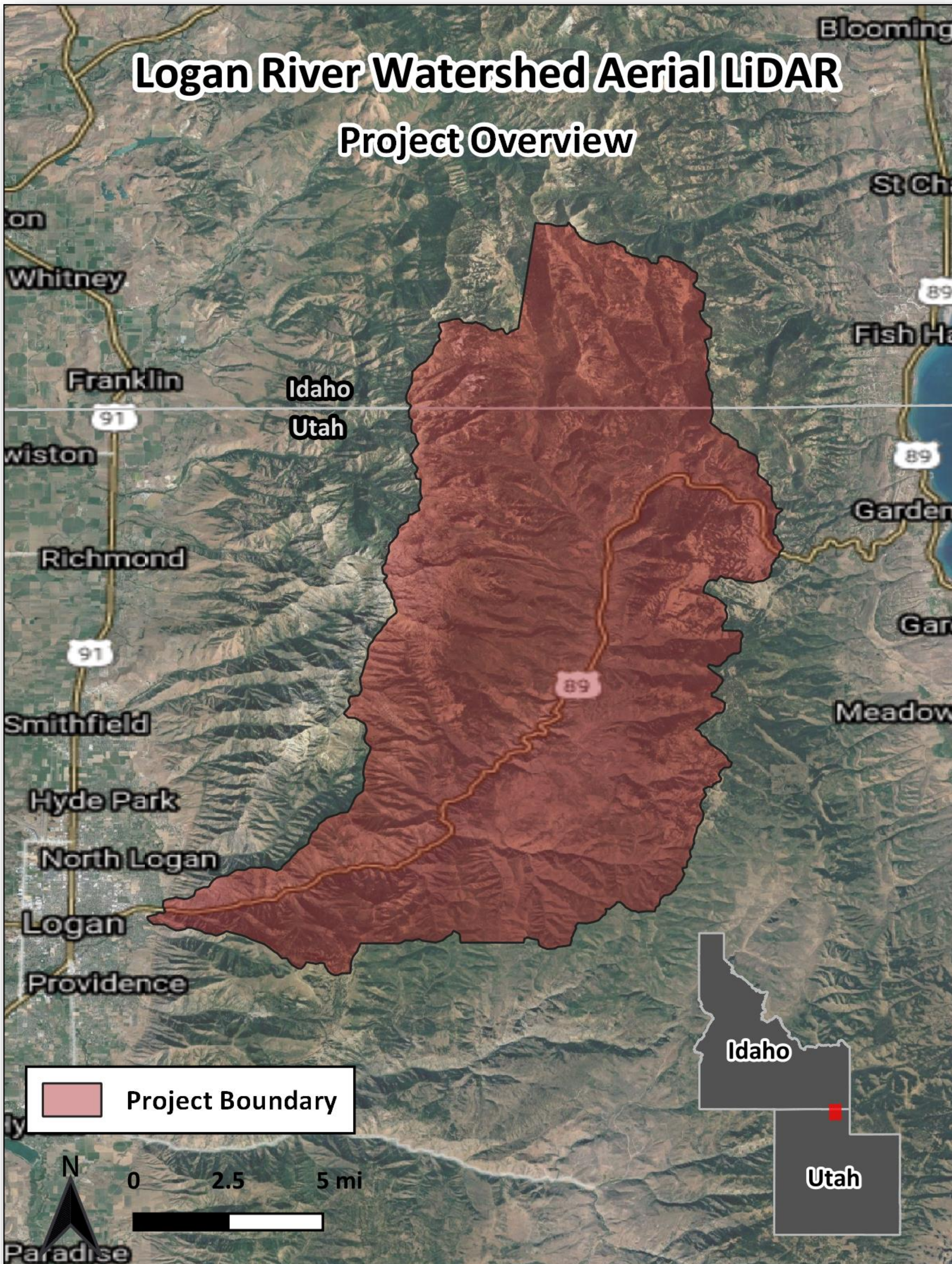
## 1. Overview

Aero-Graphics was contracted to perform aerial LiDAR scanning over the Logan River Watershed in Cache County, UT and Franklin County, ID. The project area covers approximately 216 square miles. This report describes the planning, acquisition, and processing of the LiDAR dataset as well as other deliverables.

***Exhibit 1**: Logan River Watershed project boundary*



# 2. Acquisition

## 2.1 Airborne Acquisition – Equipment and Methodology

LiDAR acquisition for the Logan River Watershed project was performed with an Optech Galaxy Prime LiDAR sensor. Aero-Graphics flew at an approximate altitude of 5,167 ft above ground level (AGL) and made appropriate adjustments to compensate for topographic relief. LiDAR acquisition was planned with 30% side overlap and an average point density of 8.13 points per square meter over 50 flightlines. The settings used for collection consisted of a pulse rate frequency (PRF) of 550 kHz, a scan frequency of 76.9 Hz, and a scan angle of +/- 16° from the nadir position (full scan angle 32°).

***Exhibit 2:*** *Summary of flight parameters*

| Altitude (ft AGL) | Sidelap (%) | Speed (kts) | PRF (kHz) | Scan Freq (Hz) | Scan Angle ° (full) |
|---|---|---|---|---|---|
| **5,167** | **30** | **120** | **550** | **76.9** | **32** |

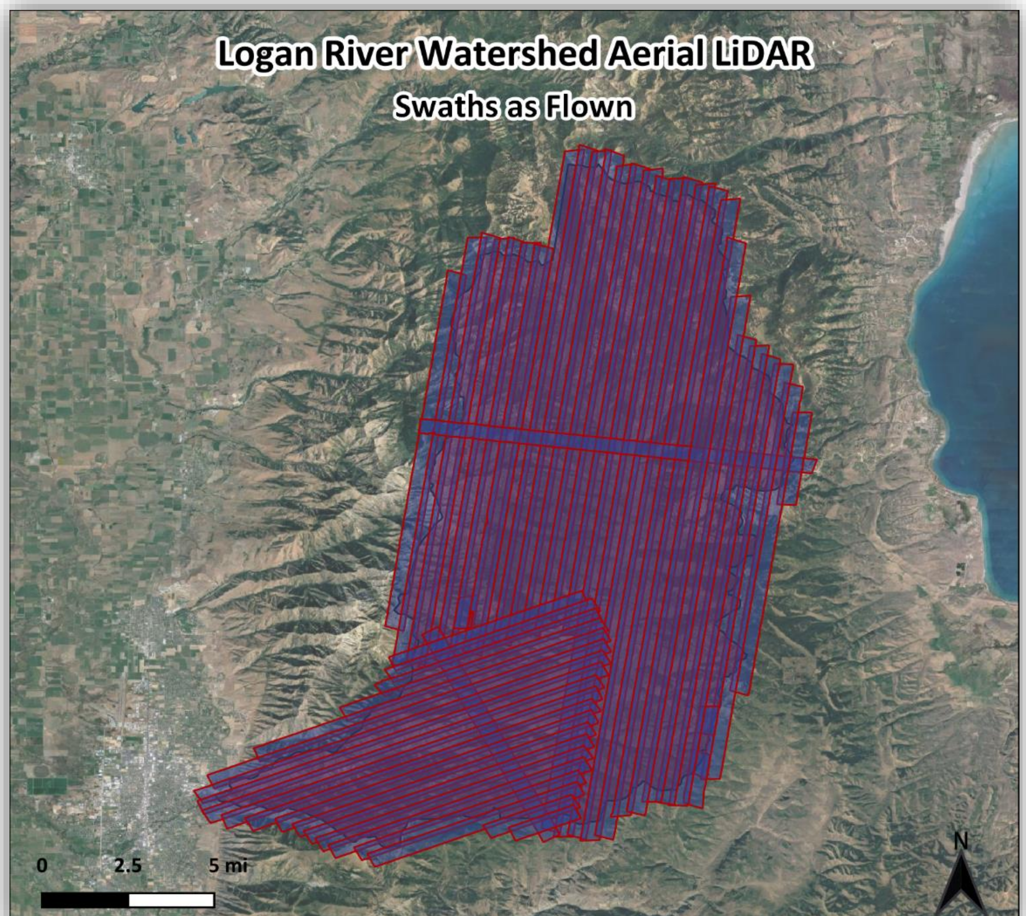
| Average Point Density p/m$^2$ | Post spacing Cross Track (m) | Post Spacing Down Track (m) | Swath Width (m) | # Flightlines |
|---|---|---|---|---|
| **8.13** | **0.31** | **0.40** | **903** | **50** |

The Optech Galaxy Prime is one of the most efficient and accurate sensors available in the industry. This sensor features SwathTRAK technology, which dynamically adjusts the scan FOV in real time during data acquisition. It also features a 1MHz effective pulse rate, providing on the-ground point density and efficiency formerly reserved for dual-beam sensors. Up to 8 returns per pulse are possible for increased vertical resolution of complex targets without the need for full waveform recording and processing. Industry-leading data precision and accuracy (<5cm RMSEz) results in the highest-quality datasets possible.

***Exhibit 3:*** *The acquisition platform for the Logan River Watershed project was a turbocharged Cessna 206. Our 206 has been customized for LiDAR and other airborne sensors with an upgraded power system and avionics. The stability of this platform is ideal for efficient LiDAR collection at high and low altitudes and a variety of airspeeds.*


Aero-Graphics utilizes Optech's Airborne Mission Manager (AMM) software to plan flight lines and sensor settings. AMM allows the aerial department to simulate the effects of different sensors, mounts, and settings, ensuring the flight plan will meet the needs of the project while being as efficient as possible. To compliment the flight planning process, the Galaxy Prime LiDAR sensor is equipped with FMS Nav, the latest data collection and navigation software release from Optech. The use of FMS Nav helps ensure an accurate and consistent acquisition mission with real-time quality assurance while still airborne. The system operator can monitor the point density and swath during the mission to confirm adequate coverage within the area of interest, as shown in **Exhibit 4**.

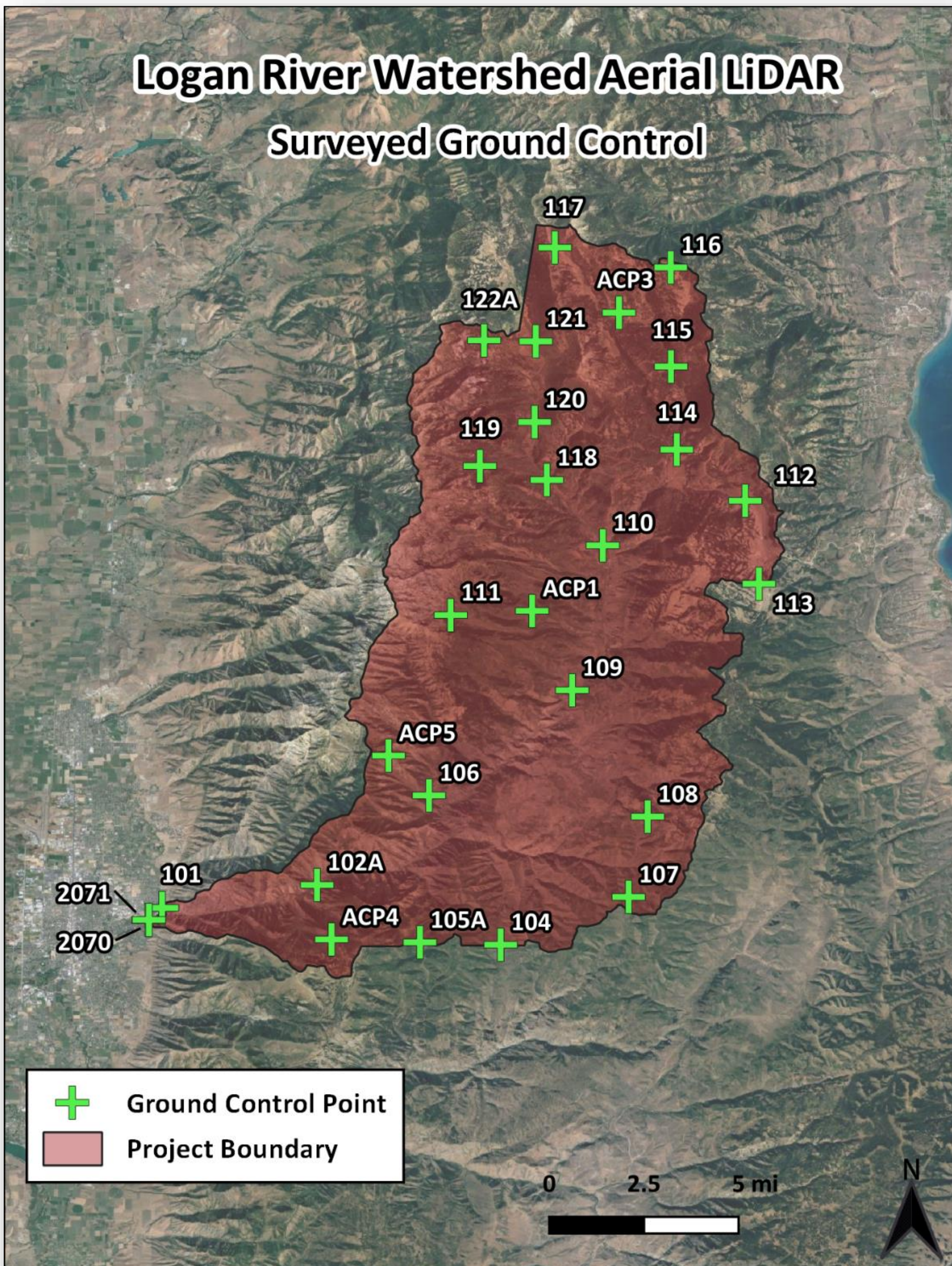
***Exhibit 4:*** *Swath data for the Logan River Watershed project was recorded and viewed real-time by the sensor operator.*



## 2.2 Ground Control

Aero-Graphics utilized statically-collected survey data collected at strategic points throughout the project area to ensure that the LiDAR data maintained its true geographic integrity. Ground control coordinates can be found in Appendix A. A summary of LiDAR calibration control vertical accuracy can be found in section 5.2 as well as a more detailed report in Appendix B.

***Exhibit 5:*** *Static ground control for the Logan River Watershed project*



## 3. LiDAR Processing Workflow

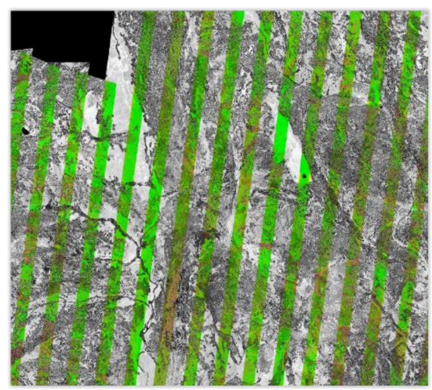
a. **Absolute Sensor Calibration.** Our absolute sensor calibration adjusted for the difference in roll, pitch, heading, and scale between the raw laser point cloud from the sensor and surveyed control points on the ground.

b. **Kinematic Air Point Processing.** Differentially corrected the 1/5-second airborne GPS positions with ground base station; combined and refined the GPS positions with 1/200-second IMU (roll-pitch-yaw) data through development of a smoothed best estimate of trajectory (SBET).

c. **Raw LiDAR Point Processing (Calibration).** Combined SBET with raw LiDAR range data; solved real-world position for each laser point; produced point cloud data by flight strip in ASPRS v1.4 .LAS format; output in local coordinate system.

d. **Relative Calibration.** Performed relative calibration by correcting for roll, pitch, heading, and scale discrepancies between adjacent flightlines; tested resulting relative accuracy. Results presented in Section 5.1.

   a. Generated a **Dz Ortho Raster** which identifies clustering of larger residuals, differences in measured elevations, between overlapping flightlines. These errors are usually caused by topographic relief or environmental factors and require manual adjustments to correct. In most cases multiple iterations of the Dz Ortho Raster are created to aid in fine tuning relative calibration parameters.



e. **Vertical Accuracy Assessment.** Performed comparative tests that showed Z-differences between each static survey point and the laser point surface. Results presented in Section 5.2.

f. **Tiling & Long/Short Filtering.** Cut data into project-specified tiles and filtered out grossly long and short returns.

g. **Classification & QA/QC.** Ran classification algorithms on points in each tile; separated into bare earth and unclassified points; revisited areas not completely classified automatically and manually corrected them.

# 4. Results

## 4.1 Relative Calibration Accuracy Results

*Between-swath relative accuracy* is defined as the elevation difference in overlapping areas between a given set of two adjacent flightlines. The statistics are based on the comparison of the flightlines and points listed below.

**Logan River Watershed project area: (52 flightlines, > 4.5 billion points)**

- Between-swath relative accuracy **average** of 0.1312 foot

## 4.2 Calibration Control Vertical Accuracy

Vertical absolute accuracy reports were generated as a quality assurance check. The location of each control point is displayed in the Surveyed Ground Control map in **Exhibit 5**. Detailed results for each point are included in **Appendix B**.

***Exhibit 6:*** *Calibration control vertical accuracy results summary*

| Calibration Control Accuracy$_z$: Logan River Watershed Project Area | |
|---|---|
| Average Error = +0.018 ft | RMSE = 0.106 ft |
| Minimum Error = -0.142 ft | σ = 0.107 ft |
| Maximum Error = +0.201 ft | Average Magnitude = 0.090 ft |
| Survey Sample Size: n = 27 | |

## 4.3 Data Density

The goal for this project was to achieve a minimum LiDAR point density of **8.0** points per square meter. First return density is the best representation of the quality of the acquisition because the density of first returns is independent of vegetation and other random factors that could increase the overall point density. The acquisition mission achieved an actual average of **8.4** points per square meter for first returns. The following two exhibits show the density of first return points

***Exhibit 7:*** *Laser point density of first returns by tile, points per square meter*

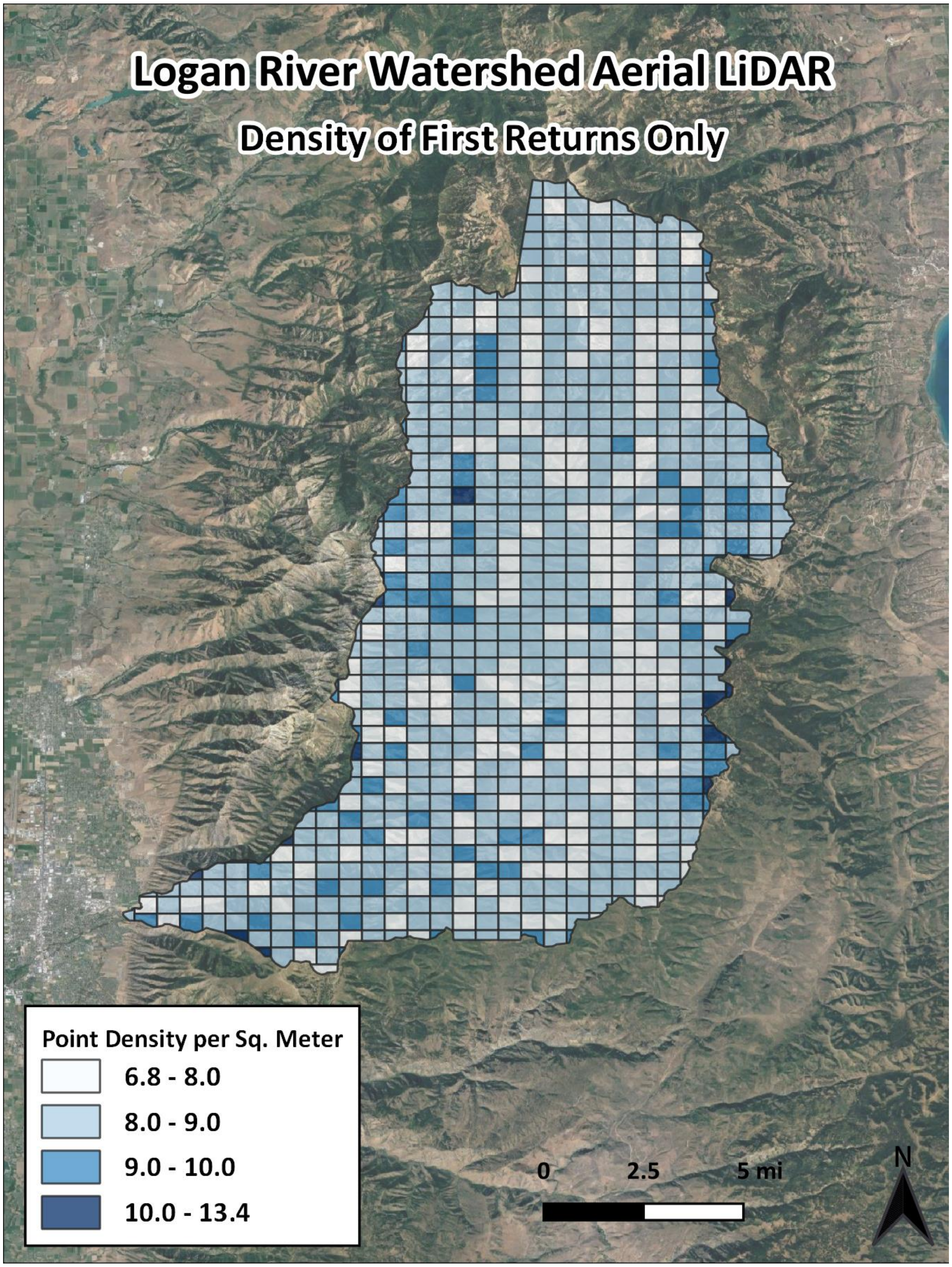
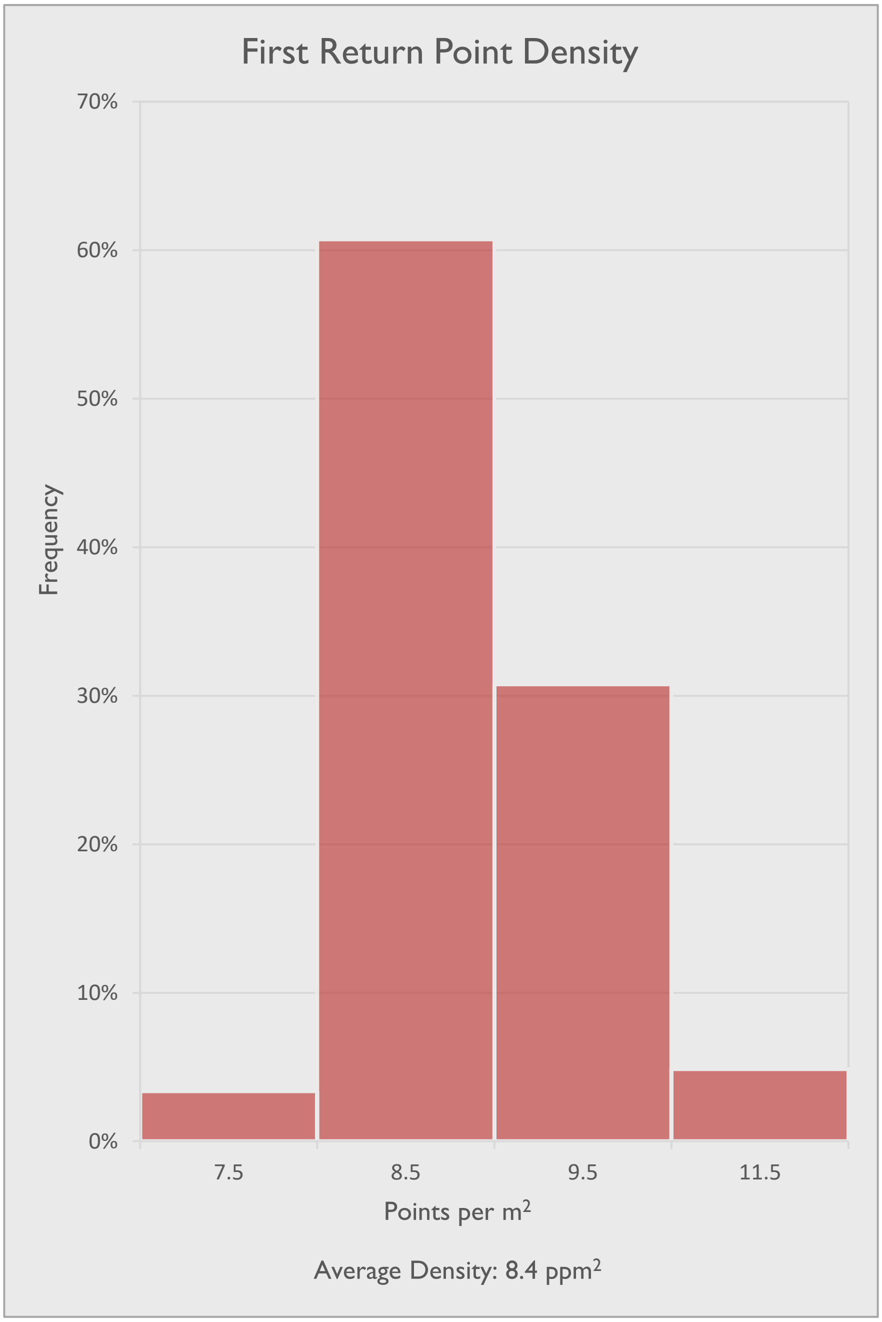


***Exhibit 8:*** *Logan River Watershed Project* ***– First returns*** *Laser Point Density by Frequency, points/m²*.
*Demonstrates the percentage of project tiles with points in a given density range*



## 5. Projection, Datum, Units

| | | |
|---|---|---|
| Projection: | | State Plane Utah North Zone |
| Datum | Vertical: | NAVD88 (minus .063’) |
| | Horizontal: | NAD83 (CORS96) |
| Units: | | US Feet |

## 6. Deliverables

| | |
|---|---|
| LiDAR Data: | • Unclassified and bare-earth classified LiDAR data furnished in LAS v1.4 format |
| Vector Data: | • Bare-earth and first-return DEMs at 1.5 ft resolution in GeoTIFF format |
| Report of Survey: | • Technical Project Report including methodology, accuracy, and results in PDF format |

## Appendix A – Ground Control Coordinates

| Survey Point | Logan River Watershed Aerial Survey | | |
|---|---|---|---|
| | Easting | Northing | Elevation (ft) |
| 101 | 1561642.428 | 3795581.955 | 4838.607 |
| 102A | 1583209.931 | 3799785.843 | 5058.100 |
| 104 | 1608737.425 | 3788631.865 | 6736.650 |
| 105A | 1597513.433 | 3789102.086 | 7682.852 |
| 106 | 1598817.933 | 3816388.097 | 5652.119 |
| 107 | 1626557.447 | 3797496.069 | 7299.173 |
| 108 | 1629215.176 | 3812411.190 | 7397.798 |
| 109 | 1618732.239 | 3835898.668 | 6036.607 |
| 110 | 1623013.357 | 3862802.840 | 6655.498 |
| 111 | 1601882.886 | 3849879.834 | 8054.305 |
| 112 | 1642762.808 | 3871088.671 | 7596.048 |
| 113 | 1644674.754 | 3855657.837 | 7820.307 |
| 114 | 1633279.131 | 3880593.760 | 7155.541 |
| 115 | 1632480.272 | 3896033.757 | 7791.386 |
| 116 | 1632452.848 | 3914437.209 | 8334.745 |
| 117 | 1616414.551 | 3918133.504 | 8513.598 |
| 118 | 1615259.549 | 3874956.088 | 7166.102 |
| 119 | 1605979.769 | 3877565.664 | 8105.510 |
| 120 | 1613572.410 | 3885723.616 | 7519.616 |
| 121 | 1613758.996 | 3900712.399 | 8084.348 |
| 122A | 1606593.442 | 3900902.515 | 8444.482 |
| ACP1 | 1613198.691 | 3850645.687 | 7761.238 |
| ACP3 | 1625296.154 | 3906035.401 | 8524.760 |
| ACP4 | 1585212.049 | 3789662.794 | 8217.334 |
| ACP5 | 1593196.575 | 3823786.680 | 8514.439 |
| 2070 | 1559699.175 | 3793350.189 | 4636.602 |
| 2071 | 1559803.496 | 3793369.218 | 4640.899 |

## Appendix B – Calibration Control Accuracy Report

| Logan River Watershed Project Area | | | |
|---|---|---|---|
| **Survey Point** | **Known Z (ft)** | **Laser Z (ft)** | **Dz (ft)** |
| 101 | 4838.607 | 4838.760 | 0.153 |
| 102A | 5058.100 | 5058.280 | 0.180 |
| 104 | 6736.650 | 6736.740 | 0.090 |
| 105A | 7682.852 | 7682.710 | -0.142 |
| 106 | 5652.119 | 5652.110 | -0.009 |
| 107 | 7299.173 | 7299.090 | -0.083 |
| 108 | 7397.798 | 7397.680 | -0.118 |
| 109 | 6036.607 | 6036.570 | -0.037 |
| 110 | 6655.498 | 6655.690 | 0.192 |
| 111 | 8054.305 | 8054.260 | -0.045 |
| 112 | 7596.048 | 7596.010 | -0.038 |
| 113 | 7820.307 | 7820.400 | 0.093 |
| 114 | 7155.541 | 7155.480 | -0.061 |
| 115 | 7791.386 | 7791.320 | -0.066 |
| 116 | 8334.745 | 8334.770 | 0.025 |
| 117 | 8513.598 | 8513.570 | -0.028 |
| 118 | 7166.102 | 7166.080 | -0.022 |
| 119 | 8105.510 | 8105.560 | 0.050 |
| 120 | 7519.616 | 7519.730 | 0.114 |
| 121 | 8084.348 | 8084.250 | -0.098 |
| 122A | 8444.482 | 8444.590 | 0.108 |
| ACP1 | 7761.238 | 7761.160 | -0.078 |
| ACP3 | 8524.760 | 8524.810 | 0.050 |
| ACP4 | 8217.334 | 8217.310 | -0.024 |
| ACP5 | 8514.439 | 8514.320 | -0.119 |
| 2070 | 4636.602 | 4636.800 | 0.198 |
| 2071 | 4640.899 | 4641.100 | 0.201 |

| | |
|---|---|
| **Average Dz (ft)** | **+0.018** |
| **Minimum Dz (ft)** | **-0.142** |
| **Maximum Dz (ft)** | **+0.201** |
| **Average Magnitude (ft)** | **0.090** |
| **RMS (ft)** | **0.106** |
| **Std. Deviation (ft)** | **0.107** |