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GEOSPATIAL SERVICES

TECHNICAL PROJECT REPORT

LANES CREEK AERIAL SURVEY

Caribou, ID

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Technical Project Report

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1. Overview

1.1 Project Area

Aero-Graphics was contracted to perform aerial LiDAR scanning and imagery acquisition over the Lanes Creek project area in Caribou, ID. The project area covers approximately 25.5 square miles. This report describes the planning, acquisition, and processing of the LiDAR dataset as well as other deliverables.

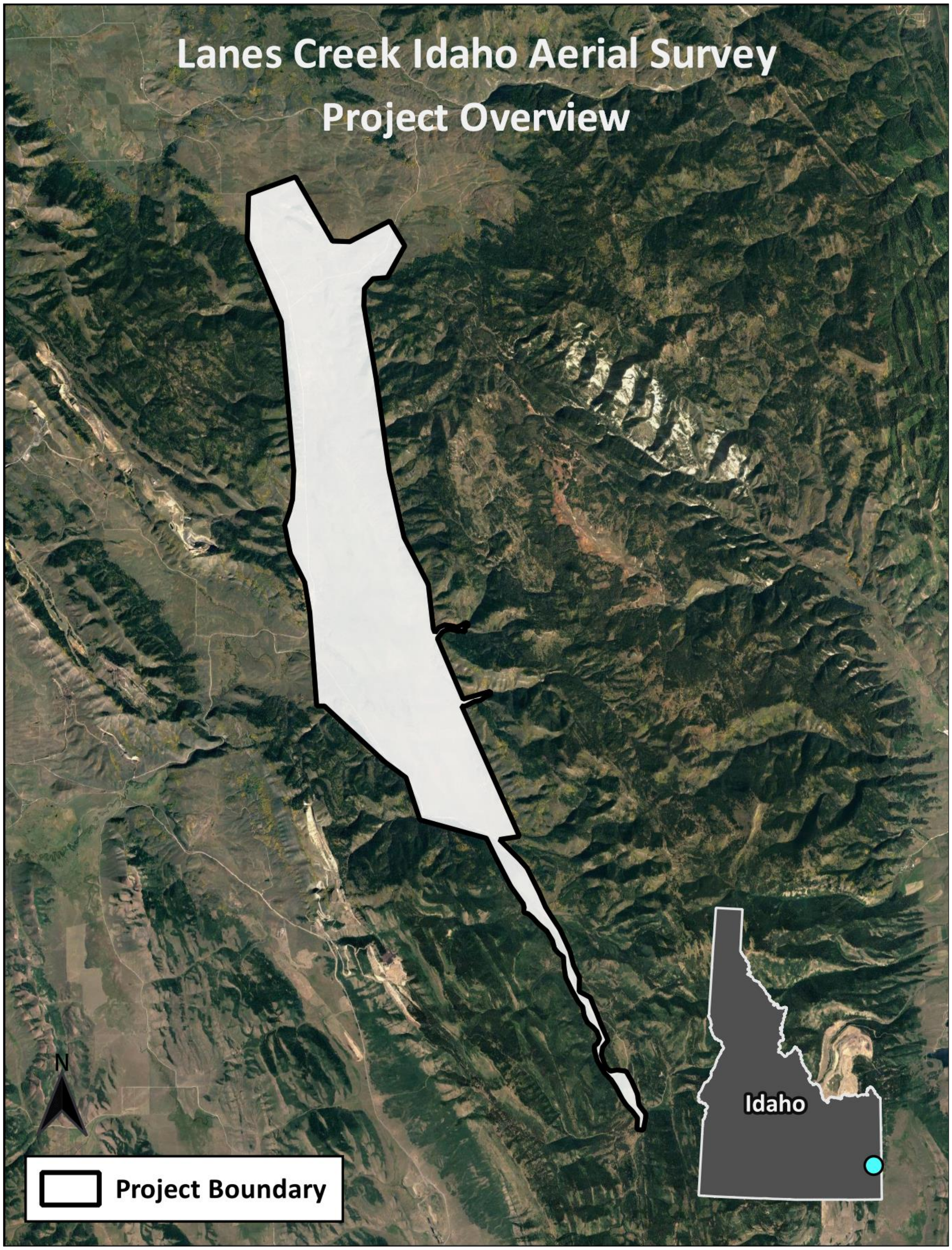
1.2 Project Deliverables

LiDAR Data	▪ Classified LiDAR data in LAS v1.4 format
Raster Data	▪ Orthorectified color imagery with 0.5' pixel size in TIFF and SID formats ▪ DEM surface data in TIFF format with a 1.5' cell size
Vector Data	• One-foot contours, planimetric vector data, and DTM surface in DWG format
Report of Survey	▪ Technical Project Report and Metadata including methodology, accuracy, and results

1.3 Projection, Datum, Units

Projection		State Plane Idaho East
Datum	Vertical	NAVD88 (GEOID18)
	Horizontal	NAD83
Units		U.S. Feet

<u>Exhibit 1:</u> Lanes Creek project boundary



2. Acquisition

2.1 Flight Planning

Aero-Graphics created a unique flight plan for this project using Optech's Airborne Mission Manager (AMM) flight planning software. AMM simulates flight plans based on the project area's terrain, as well as the sensor's model, mount, and settings. These features helped ensure that this project's specifications were met in the most efficient way possible. A summary of this project's flight parameters and sensor settings are outlined in **Exhibit 2**.

Exhibit 2: Summary of planned flight parameters and sensor settings

Planned Specifications		
Aircraft		Cessna 206
Altitude (ft above ground level)		5,171
Speed (kts)		145
LiDAR Sensor		Optech Galaxy T2000
PRF (kHz)		600
Scan frequency (Hz)		94
Laser power		Medium
Scan Angle	Full	32°
	From nadir	± 16°
Planned Average Point Density (p/m²)		13.76
Post Spacing at Nadir	Cross Track (m)	0.27
	Down Track (m)	0.27
Swath Width (m)		891
Sidelap (%)		60
No. of Flightlines		24
Aerial Camera		PhaseOne iXU-RS 1000
No. of Images		658
Ground Sampling Distance	cm	14.5
	in	5.7

2.2 Data Acquisition

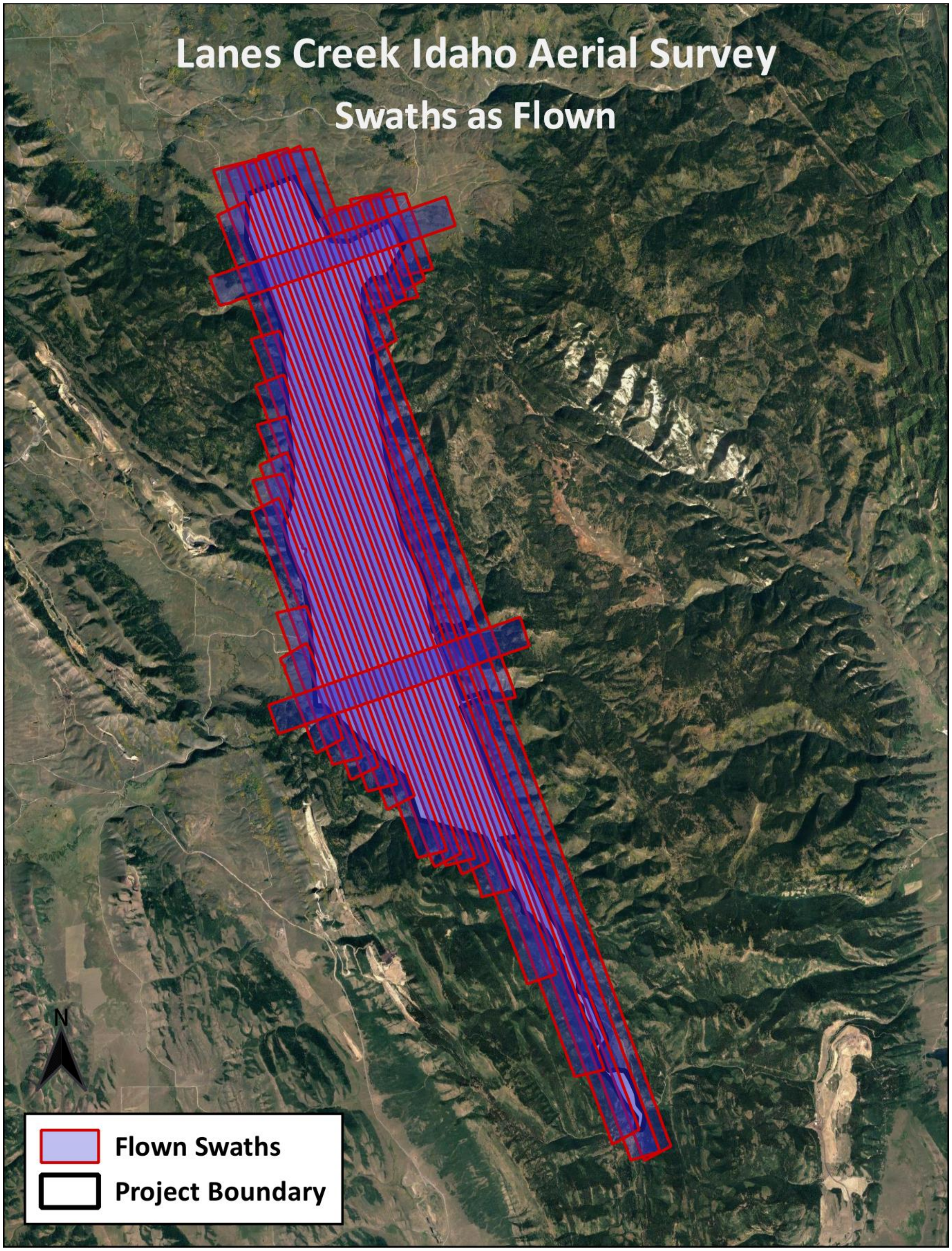
Aero-Graphics acquired LiDAR data and aerial imagery on July 4 and 11, 2023 with a turbocharged Cessna 206 (**Exhibit 3**). The stability of this platform is ideal for efficient data collection at high and low altitudes and at a variety of airspeeds. Additionally, our Cessna 206 has been customized to house a variety of airborne sensors, and the power system and avionics have been upgraded specifically to meet aerial survey needs.

Exhibit 3: A Cessna 206 was the acquisition platform for this project

The Optech Galaxy T2000 was selected for this project on account of its high accuracy and efficiency (**Exhibit 4**). This sensor uses SwathTrak technology, which dynamically adjusts the scan field of view in real time to maintain a constant swath width over a variety of terrains. It also features up to 8 returns per pulse, which increases the vertical resolution of complex terrains. The sensor is complemented with the use of FMS Nav, which allowed the system operator to monitor the point density and swath attributes of this project in real time, ensuring quality data and full coverage, as shown in **Exhibit 5**. More information about point density can be found in Section 6.5.

Exhibit 4: The Optech Galaxy T2000 was used for data acquisition

Exhibit 5: **Swath data for the Lanes Creek project was recorded and viewed real-time by the sensor operator.**

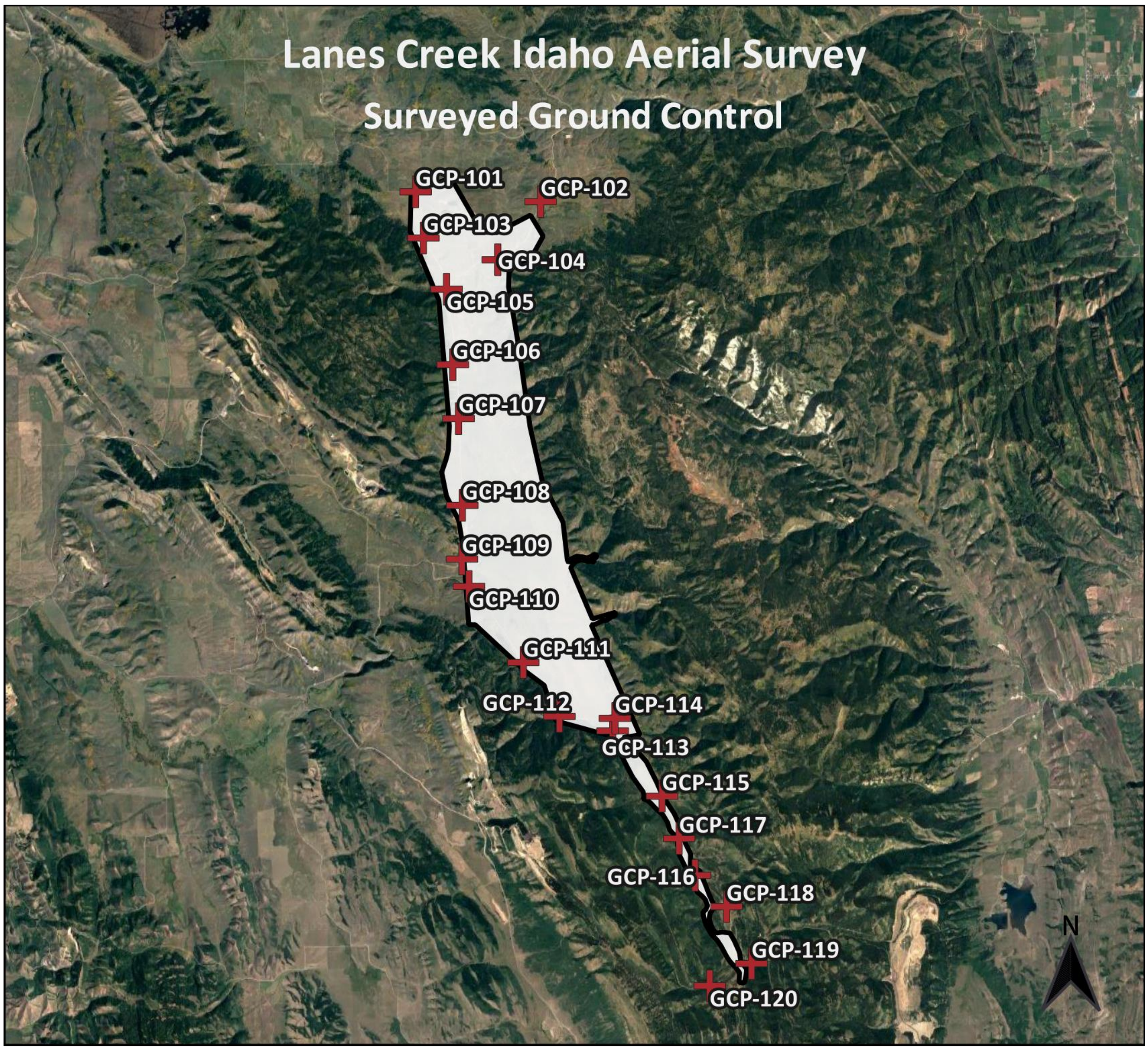


***LiDAR returns decrease over bodies of water, affecting the swath width**

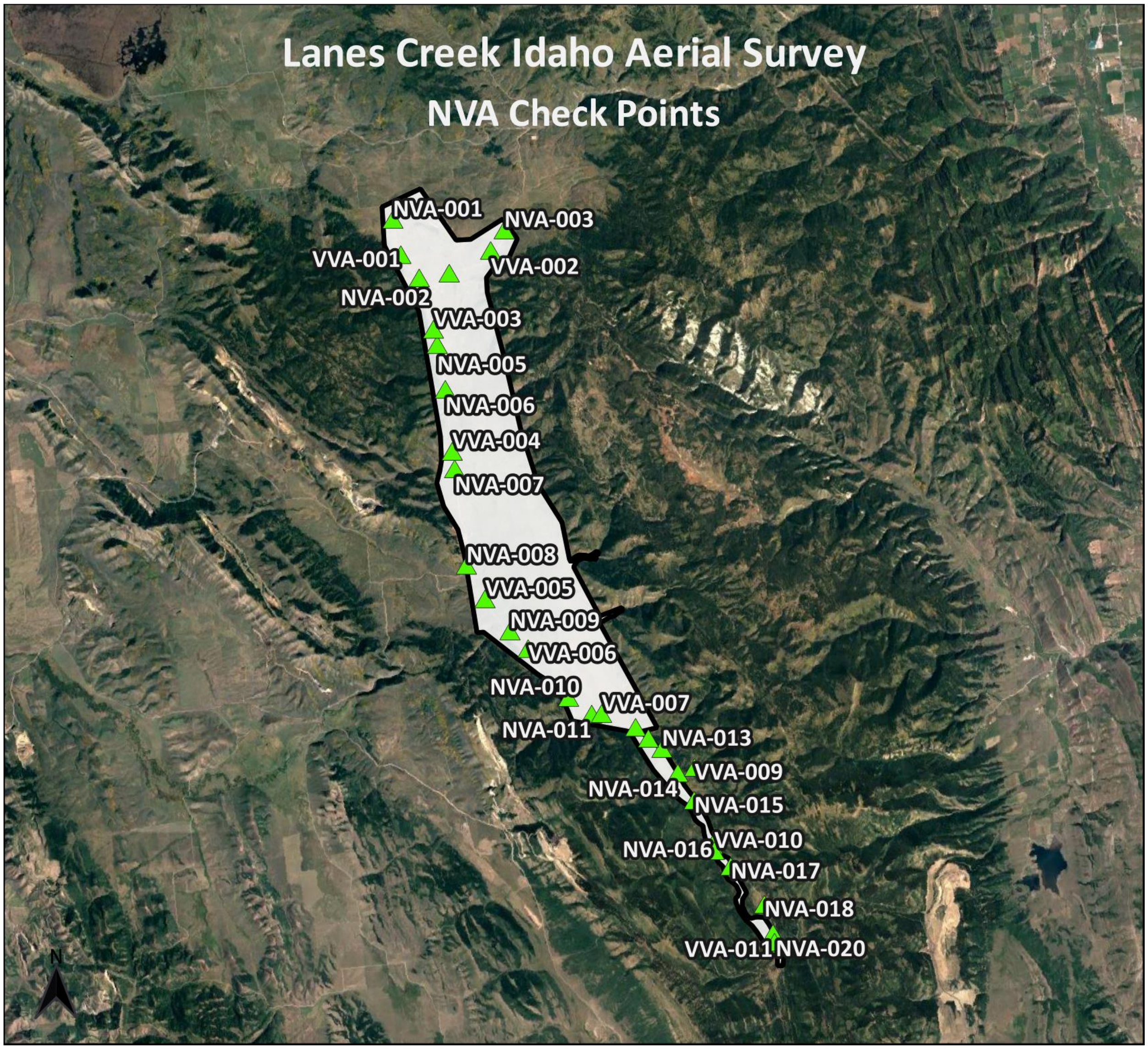
2.3 GROUND CONTROL

Aero-Graphics utilized statically-collected survey data gathered at strategic points throughout the project area to ensure the LiDAR and imagery data maintained their true geographic integrity (**Exhibit 6**). Ground control coordinates can be found in Appendix A. A summary of LiDAR calibration control vertical accuracy can be found in Section 6.2, as well as a more detailed report in Appendix B.

Exhibit 6: Static ground control for the Lanes Creek project



<u>Exhibit 7:</u> Non-Vegetated Check Points for the Lanes Creek project



3. LiDAR Processing Workflow

1. **Kinematic Air Point Processing** The airborne GPS positions (collected at 1-second intervals) were post-processed using Applanix's POSPac MMS GNSS Inertial software (PP-RTX). A smoothed best estimate of trajectory (SBET) was developed by combining the corrected GPS positions with 1/200-second inertial measurement unit (IMU) data, which tracked the plane's roll, pitch, and yaw throughout the flight.

2. **Raw LiDAR Point Processing (Calibration)** The SBET and LiDAR range data were combined to solve for the real-world positions of each laser point. Point cloud data was produced by flight strip in ASPRS v1.4 LAS format. Flight strips were output in the project's coordinate system.

3. **Absolute Sensor Calibration** The raw laser point cloud was adjusted for differences in roll, pitch, heading, and scale through a comparison to the surveyed ground control points.

4. **Relative Calibration** The raw laser point cloud was adjusted for differences in comparison to the surveyed ground control. These results are presented in Section 6.1.
    a. A **Dz Ortho Raster** was generated as part of this process (**Exhibit 8**). This raster identifies clusters of large residuals and 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.

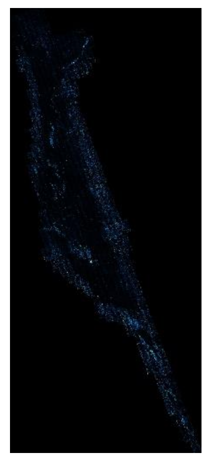


Exhibit 8: The dz ortho raster generated for the Lanes Creek project

5. **Vertical Accuracy Assessment** Height differences between each static survey point and the laser point surface were identified through comparative tests. Results are presented in Section 6.2.

6. **Tiling & Long/Short Filtering** Data was clipped to match the project-specified tiles. Extremely long and short returns were also filtered out as outliers.

7. **Classification & QA/QC** Classification algorithms were run on all points within each tile to separate the cloud into bare earth and unclassified points. Areas that were not completely classified by the algorithms were manually corrected.

4. Imagery Processing Workflow

1. **Acquisition QA/QC and Image Processing** Following acquisition, the images were reviewed for flight and environmental issues such as excessive off-nadir plane rotation and cloud shadows. Photo centers were ingested into a spatial database and project-wide acquisition was reviewed for completeness. Any failed images were flagged for reflight. The raw images were then processed to standard TIFF format for further processing.

2. **Aerotriangulation** Trimble-Inpho's Match-AT software was used to perform digital aerotriangulation. During this process, tie points and ground control points were identified in each stereo pair. These points were processed with the exterior orientation parameters of each image (roll, pitch, yaw, and latitude, longitude, altitude) to complete the final bundle adjustment and minimize error throughout the image block. Quality control was performed on the image block using Inpho DTMaster by reviewing each control and tie point in stereo for proper positioning, with no points floating or digging. All parallax was cleared before the data moved to the next stage.

3. **Orthorectification** A bare-earth gridded surface was generated for orthorectification in TerraSolid's TerraScan software. Horizontal positioning was checked for proper tolerances by reviewing the relative positioning between images as well as the positioning relative to higher order control.

4. **Radiometric Balancing and Mosaicking** To compensate for visual effects within individual images, subtle radiometric adjustments were made on the orthorectified imagery in Inpho's OrthoVista software. Next, a block-wide contrast and color balance was performed to achieve a uniform appearance across the project. Individual orthophotos were combined into a seamless, geometrically-perfect orthomosaic. After this, the project was tiled according to project requirements, and a tile index was created.

5. **Final QC and Delivery Prep** Compression, reprojection into the project coordinate system, metadata, and other project specifications were completed as needed. A final review for completeness was performed in preparation for data delivery to the client.

5. Map Production Workflow

1. **Contour Generation and Editing** Contours were generated from key points within the model, which were derived from bare-earth LiDAR data and supplemental breaklines. Index contours were generated every fifth contour. A 5-inch coordinate grid was included. Contours in areas obscured by dense vegetation or other elements in the landscape were dashed to indicate questionable accuracy.

2. **Topo QC and Editing** Planimetry data was reviewed in stereo to ensure all required features were collected. Once all features were collected, batch processes were run on the data to remove duplicate features, make small positional adjustments, and flag features for manual editing. Final contours were automatically generated after the final edits were completed.

6. Results

6.1 Relative Calibration Accuracy Results

Inter-swath relative accuracy is defined as the elevation difference in the overlapping area of parallel swaths. The statistics below are based on the elevation differences calculated between swaths.

Lanes Creek project area: (24 flightlines, > 3.3 billion points)

- Inter-swath relative accuracy **average** of 0.12 ft

6.2 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 6**. Detailed results for each point are included in **Appendix B**.

Exhibit 10: Calibration control vertical accuracy results summary

Calibration Control $Accuracy_z$: Lanes Creek Project Area	
Average Error = +0.02 ft	Average Magnitude = 0.09 ft
Minimum Error = -0.14 ft	RMSE = 0.11 ft
Maximum Error = +0.21 ft	σ = 0.11 ft
Survey Sample Size: n = 20	

6.3 Point Cloud Testing

The project specifications require that only Non-Vegetated Vertical Accuracy (NVA) be computed for raw LiDAR point cloud swath files. NVA is defined as the elevation difference between the LiDAR surface and ground surveyed static points collected in open terrain (bare soil, sand, rocks, and short grass) as well as urban terrain (asphalt and concrete surfaces). The NVA for this project was tested with 18 check points. These check points were not used in the calibration or post-processing of the LiDAR point cloud data. Elevations from the unclassified LiDAR surface were measured for the xy location of each check point. Elevations interpolated from the LiDAR surface were then compared to the elevation values of the surveyed control points.

The bare-earth LiDAR dataset was designed to meet or exceed ASPRS Positional Accuracy Standards at the 9 cm vertical accuracy class. Absolute accuracy for non-vegetated areas (NVA) must be accurate within 9.0 cm (0.29 ft) RMSEz and 17.6 cm (0.58 ft) at the 95% confidence level. The tested NVA for this dataset was found to be accurate within 0.10 US Survey Feet (3.1 cm) in terms of the RMSEz. The resulting NVA stated at the 95% confidence level (RMSEz x 1.96) is 0.20 US Survey Feet (6.2 cm). Therefore, this dataset meets the required NVA of 0.58 US Survey Feet at the 95% confidence level as defined by the National Standards for Spatial Data Accuracy (NSSDA).

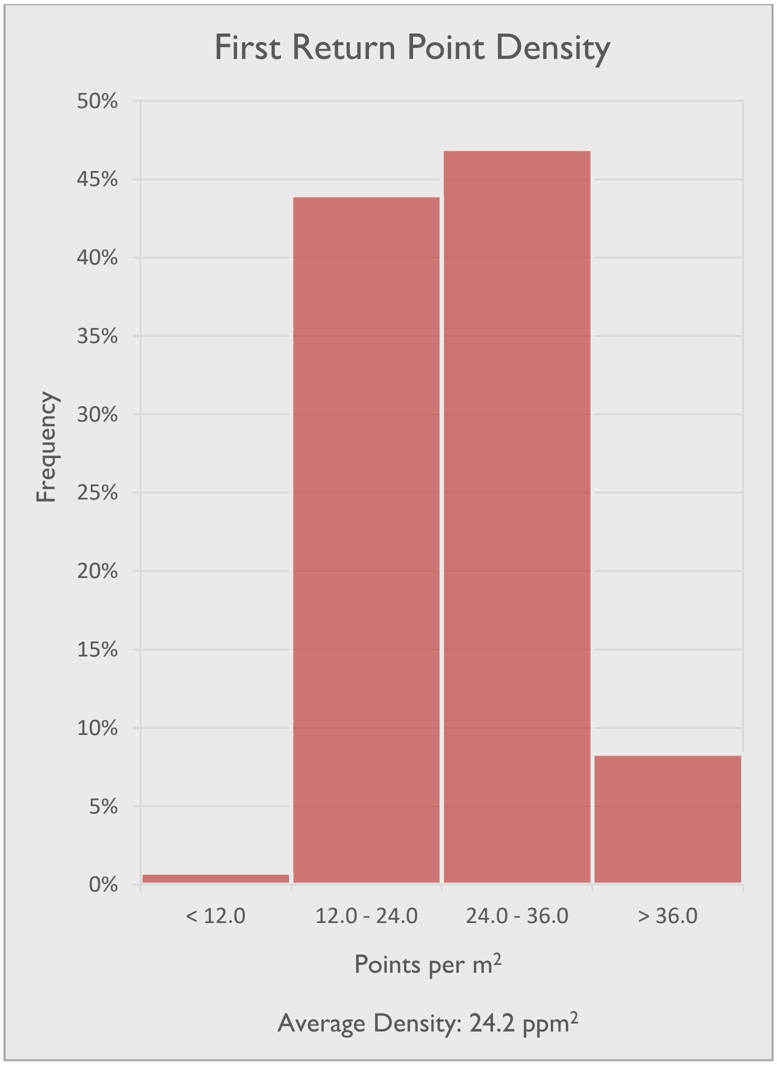
6.5 Orthophoto Accuracy

Horizontal accuracy of the orthophoto is dependent upon the quality of the ground control, aerotriangulation solution, and the resulting ortho surface creation. Each bundle-adjusted AT solution is checked visually with the stereo imagery to ensure the surveyed control point falls directly on the center of the target and within a specified vertical tolerance (one-quarter the equivalent contour interval). If these tolerances are met, horizontal accuracy is usually acceptable. Aero-Graphics utilized the project's survey grade control throughout the block to verify the integrity of each stereomodel. The orthorectified imagery was designed to meet ASPRS Accuracy Standards for the 15cm horizontal accuracy class.

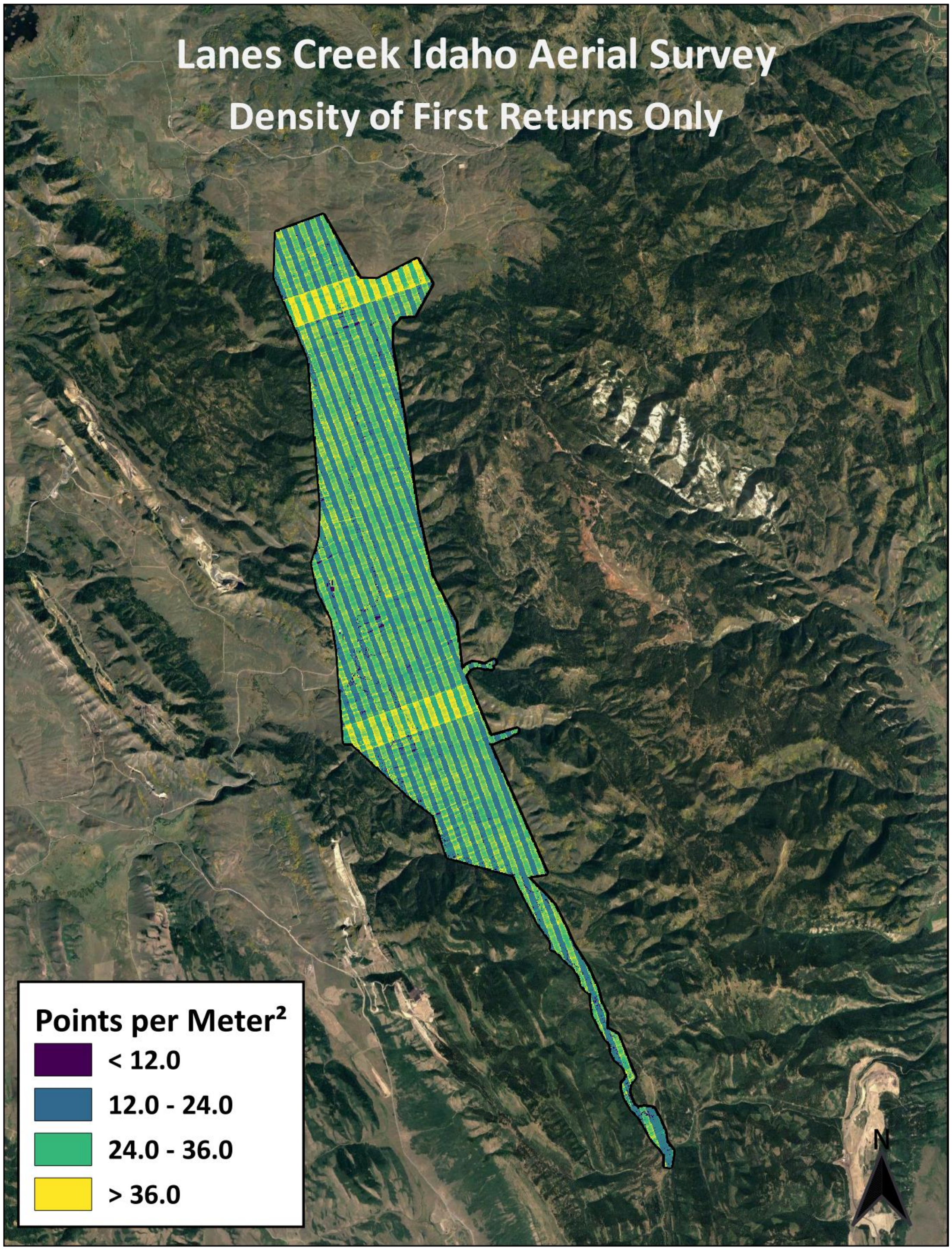
6.6 Data Density

The goal for this project was to achieve a minimum LiDAR point density of **12.0** 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 **24.2** points per square meter for first returns. The following two exhibits show the density of first return points. Please note that loss of point density over water is to be expected.

<u>Exhibit 11:</u> Lanes Creek Project– First returns laser point density by frequency, points/m². This figure displays the percentage of points in a given density range



<u>Exhibit 12:</u> Laser Point Density of First Returns, points/m²



APPENDIX A – GROUND CONTROL COORDINATES

Survey Point	Lanes Creek Aerial Survey		
	Easting	Northing	Elevation (ft)
GCP-101	878276.226	468003.104	6685.76
GCP-102	892878.947	466853.198	6712.86
GCP-103	879186.220	462604.784	6706.03
GCP-104	887872.719	460072.796	6642.14
GCP-105	881888.815	456631.800	6654.16
GCP-106	882624.017	447826.429	6635.87
GCP-107	883290.975	441529.585	6588.66
GCP-108	883729.135	431398.330	6446.85
GCP-109	883688.026	425131.644	6562.08
GCP-110	884498.809	421936.343	6426.14
GCP-111	890850.671	413062.156	6538.18
GCP-112	895072.535	406761.790	6606.89
GCP-113	901286.254	405083.944	6585.80
GCP-114	901554.379	406544.661	6589.88
GCP-115	907054.070	397459.364	6689.24
GCP-116	910909.387	388223.966	6759.25
GCP-117	909045.585	392512.318	6722.92
GCP-118	914587.761	384570.982	6881.16
GCP-119	917509.353	377920.314	6925.31
GCP-120	912620.565	375322.256	7054.45
NVA-001	878860.706	466006.705	6688.46
NVA-002	881331.438	458940.216	6659.10
NVA-003	891711.131	463641.031	6669.49
NVA-004	884870.680	459181.359	6577.97
NVA-005	882740.733	451002.595	6592.26
NVA-006	883230.170	445729.836	6600.13
NVA-007	883516.742	436398.763	6476.04
NVA-008	883897.618	425065.353	6556.04
NVA-009	888304.852	416983.833	6493.85
NVA-010	894436.906	408668.301	6561.19
NVA-011	896965.853	406503.986	6596.25
NVA-012	901934.333	404522.450	6593.90
NVA-013	904788.017	401781.114	6624.40
NVA-014	906390.053	398782.553	6676.77
NVA-015	908006.298	395424.181	6697.51
NVA-016	909675.239	390075.970	6737.39
NVA-017	911592.412	387393.539	6782.42

NVA-018	915108.890	382647.125	6879.32
NVA-019	916063.502	378759.674	6889.81
NVA-020	916024.860	377923.184	6893.14
VVA-001	879428.323	461824.442	6740.11
VVA-002	889920.145	461398.959	6646.94
VVA-003	882463.152	452816.817	6589.07
VVA-004	883401.401	438445.927	6502.97
VVA-005	885720.666	420969.175	6458.55
VVA-006	890234.540	414759.131	6479.31
VVA-007	898112.955	406463.274	6578.54
VVA-008	903312.860	403108.527	6622.59
VVA-009	908390.579	399267.758	6791.95
VVA-010	909830.493	389378.855	6744.14
VVA-011	915828.564	379189.272	6882.51
VVA-012	915914.614	378144.645	6891.68

APPENDIX B – CALIBRATION CONTROL ACCURACY REPORT

Lanes Creek Aerial Survey			
Survey Point	**Known Z (ft)**	**Laser Z (ft)**	**Dz (ft)**
GCP-101	6685.76	6685.73	-0.03
GCP-103	6706.03	6705.89	-0.14
GCP-104	6642.14	6642.08	-0.06
GCP-105	6654.16	6654.14	-0.02
GCP-106	6635.87	6635.80	-0.07
GCP-107	6588.66	6588.62	-0.04
GCP-108	6446.85	6446.89	0.04
GCP-109	6562.08	6562.17	0.09
GCP-110	6426.14	6426.08	-0.06
GCP-111	6538.18	6538.26	0.08
GCP-112	6606.89	6606.86	-0.03
GCP-113	6585.80	6585.74	-0.06
GCP-114	6589.88	6589.79	-0.09
GCP-115	6689.24	6689.18	-0.06
GCP-116	6759.25	6759.45	0.20
GCP-117	6722.92	6723.12	0.20
GCP-118	6881.16	6881.37	0.21
GCP-119	6925.31	6925.46	0.15

Average Dz (ft)	+0.02
Minimum Dz (ft)	-0.14
Maximum Dz (ft)	+0.21
Average Magnitude (ft)	0.09
RMS (ft)	0.11
Std. Deviation (ft)	0.11