LiDAR Remote Sensing Data Collection: South Fork John Day River, Oregon

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Oregon State University
Department of Fisheries and Wildlife
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Submitted by:

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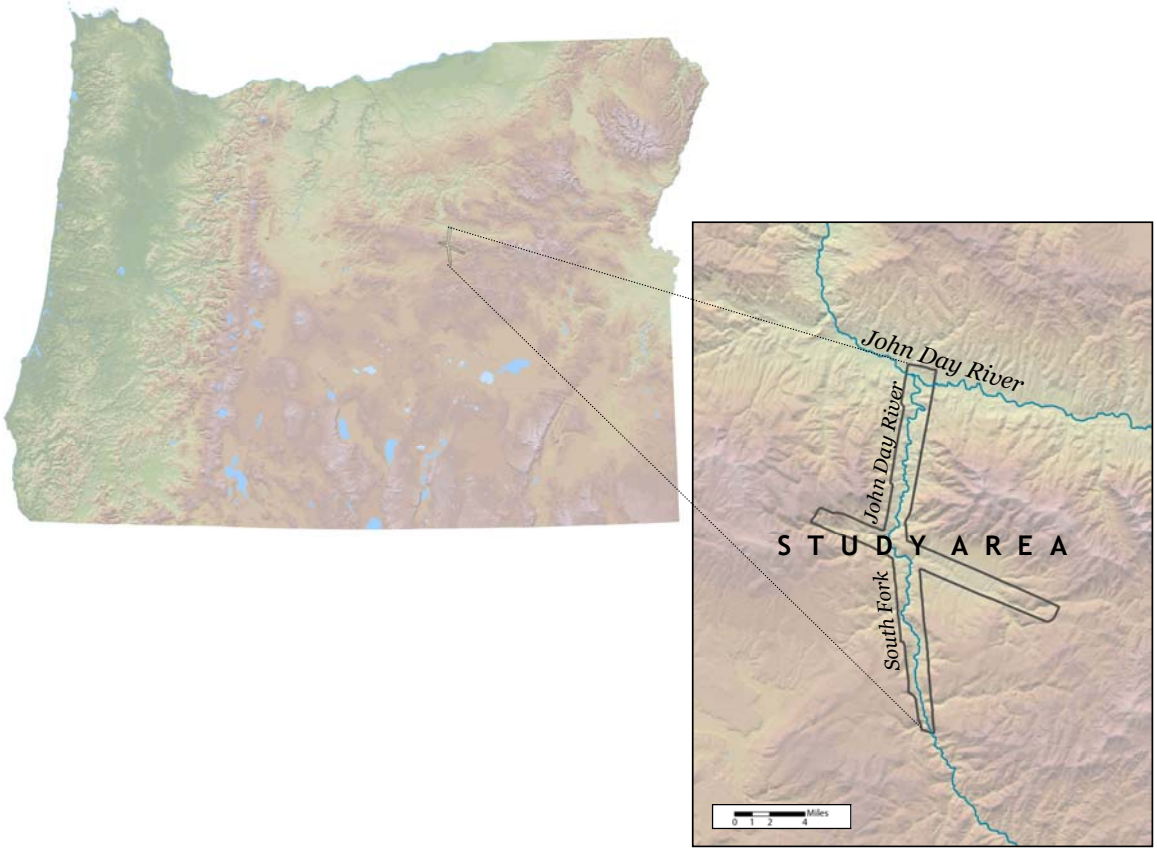
Overview

Watershed Sciences, Inc. (WS) collected Light Detection and Ranging (LiDAR) data for the John Day Basin Research Monitoring and Evaluation Pilot Project on March 11, 2005. This work was funded by and conducted in cooperation with:

- Oregon State University, Dept. of Fisheries and Wildlife
- U.S. Bureau of Reclamation, Pacific Northwest Regional Office
- NOAA Fisheries, Northwest Fisheries Science Center
- Oregon Department of Environmental Quality

The LiDAR survey area encompasses the South Fork John Day River from ~.75 miles above Sunflower Creek in the south to the confluence with the John Day River in the north, extending west ~4.5 miles up Black Canyon Creek, and extending east up Murderers Creek ~ 8.6 miles, resulting in a total area of 31,048 acres.

Figure 1. Full extent of Study Area covering 31,048 acres.



A total of 516,282,572 laser points were collected over the study area using an Optech ALTM 3100 LiDAR system set to acquire points at an average spacing of less than 0.50 meters (>4 points per square meter). The system also recorded individual return intensities (per laser return) that are used to create combined elevation models that display both elevation and surface reflectivity.

Trimble 5700 ground GPS units were deployed and used to process kinematic solutions to the onboard GPS and inertial measurement unit (IMU) using PosPAC v4.1. Points were computed per flight line using the REALM Survey Suite v3.5. Microstation V8 and TerraScan were used to import the points into processing bins, remove pits and birds, and compute the bare earth model. TerraModeler was then used to create TINs and output ARCINFO ASCII lattice models, which were then imported into ArcMap to render one-meter mosaics of first and ground models. QT Modeler was used to create 0.25 meter models of the LiDAR data; these models share the same boundaries as the processing bins (see figure 6).

Laser point absolute accuracy is largely a function of internal consistency and laser noise:

- **Absolute Accuracy**: This is the comparison of laser points to real time kinematic (RTK) ground level survey data. A total of 175 RTK GPS measurements were compared to ground laser points collected for comparison with the LiDAR point data. The deviation RMSE and standard deviation are both 0.025 meters, with a median (50th percentile) absolute deviation of 0.02 meters and a 95th percentile of 0.04 meters.

- **Internal Consistency**: Internal consistency refers to the ability to place a laser point in the same location over multiple flight lines, GPS conditions and aircraft attitudes. The data were analyzed for internal consistency between opposing and orthogonal flight lines and passed divergence test requirements of less than 0.15 meters per any one overlapping flight line. Testing was done at Ashland Airport.

- **Laser Noise**: For any given target, laser noise is the breadth of the data cloud per laser return (i.e., last, first, etc.). Lower intensity surfaces (roads, rooftops, still/calm water) will experience higher laser noise. The laser noise range for this mission varies between .04 - .07 meters, per testing performed at the Ashland Airport.

Technical Approach

Data Collection

Our LiDAR system is mounted in the belly of a Cessna Caravan 208 (Figure 3). Quality control (QC) flights were performed based on manufacturer's specifications prior to the survey. The QC flight was conducted at the Ashland Airport using known surveyed control points. The positional accuracy of the LiDAR (x, y, z) returns are checked against these known locations to verify the calibration and to report base accuracy.

The Optech 3100 system was set to a 71kHz laser repetition rate and flown at 1,100 meters above ground level (AGL), capturing a 30° scan width (15° from NADIR). These settings yielded points with an average density of greater than 4.1 points per square meter. The entire area was surveyed with opposing flight line overlap of 50% to reduce laser shadowing and increase surface laser painting. While the system allows up to four range measurements per pulse, only the first and last returns were processed in the output. The data stream from the IMU was stored independently during the flight, and was differentially corrected and integrated with LiDAR pulse data during post processing. Throughout the survey, a DGPS Trimble 5700 base station recorded fast static (1 Hz) data to minimize kinematic solution baselines and increase GPS data accuracy (Table 1).

Figure 2. The Cessna Caravan 208 - A removable composite cargo pod provides housing for GPS equipment and the LiDAR system and other remote sensing sensors.

Flight Parameters

System:	Optech 3100
Flight AGL (m):	1,100 m
Flight Speed:	105 knots
Scan Width:	30° (15° from NADIR)
Scan Pulse Repetition Frequency (PRF):	71,000 pulses per second (71kHz)

A total of 175 quality control real-time kinematic (RTK) GPS data points were collected using a Trimble 5700 ground based DGPS station. These data points were acquired in a plot adjacent to the main study area because of radio communications limitations experienced in the study area. Data collected were then compared to the processed LiDAR data to ensure accuracies across the project area.

Table 1. Base Station Surveyed Coordinates and Calculated Errors

Point ID	***NAD83/96 (HARN)***					
	Latitude (North)	***Error (m)***	***Longitude (West)***	***Error (m)***	***Ellipsoid Height (m)***	***Error (m)***
John Day 1	44°11'46.80888"	.022	119°33'35.16745"	.014	1441.196	.017

The following factors should be borne in mind when considering the accuracy of this dataset:

- RTK points were collected ~250 meters above the valley bottom.
- RTK points were collected along a landing strip and a road (see figure 4 (B)).
- Additional ground survey points distributed throughout the study area would more accurately capture spatial variability and accuracy.
- If more data become available, the accuracy statistics can be recalculated.

Data Gaps: While there may be the appearance of data gaps in the GRIDs and surface models, these are limited to areas under large buildings or over very still/calm water surfaces (ponds, pools, etc.) where the bare ground model required greater than 25 meters to build a triangle. In these cases, the models display no data.

Data Processing

Laser point return coordinates were computed using the REALM software suite based on independent data from the LiDAR system (pulse time, scan angle), IMU (aircraft attitude), and aircraft position (differentially corrected and optimized using the multiple DGPS base stations data). The inertial measurement data were used to calculate the kinematic corrections for the aircraft trajectories using PosPAC v4.2. Flight lines and LiDAR data were reviewed to insure complete coverage of the study area and positional accuracy of the laser points.

TerraScan Processing

To facilitate laser point processing, bins (polygons) are created to divide the data set into manageable sizes. The entire study area was divided into 174 individual bins (including the test plot) of approximately 1 km^2 each (see Figure 6, below). Laser point returns (first and last) are assigned an associated (x, y, z) coordinate, along with unique intensity values. The raw LiDAR points were filtered for noise, pits and birds by screening for absolute elevation limits, isolated points and height above ground.

The TerraScan software suite is designed specifically for developing a standard bare earth model to remove buildings, vegetation, and other features. The high point density and multiple returns result in uncomplicated identification of vegetated and obscured areas using first and last returns. The processing sequence begins by removing all points that are not "near" the earth based on evaluation of the multi-return layers. The resulting bare earth (ground) model is visually inspected and additional ground modeling is performed in site specific areas (over a 50 meter radius) to improve ground detail. This was only done in areas with known ground modeling deficiencies, such as: bedrock outcrops, cliffs, deeply incised stream banks, and dense vegetation.

Figure 6. Processing Bins – 174 Total Bins (including test plot); approximately 1 km^2

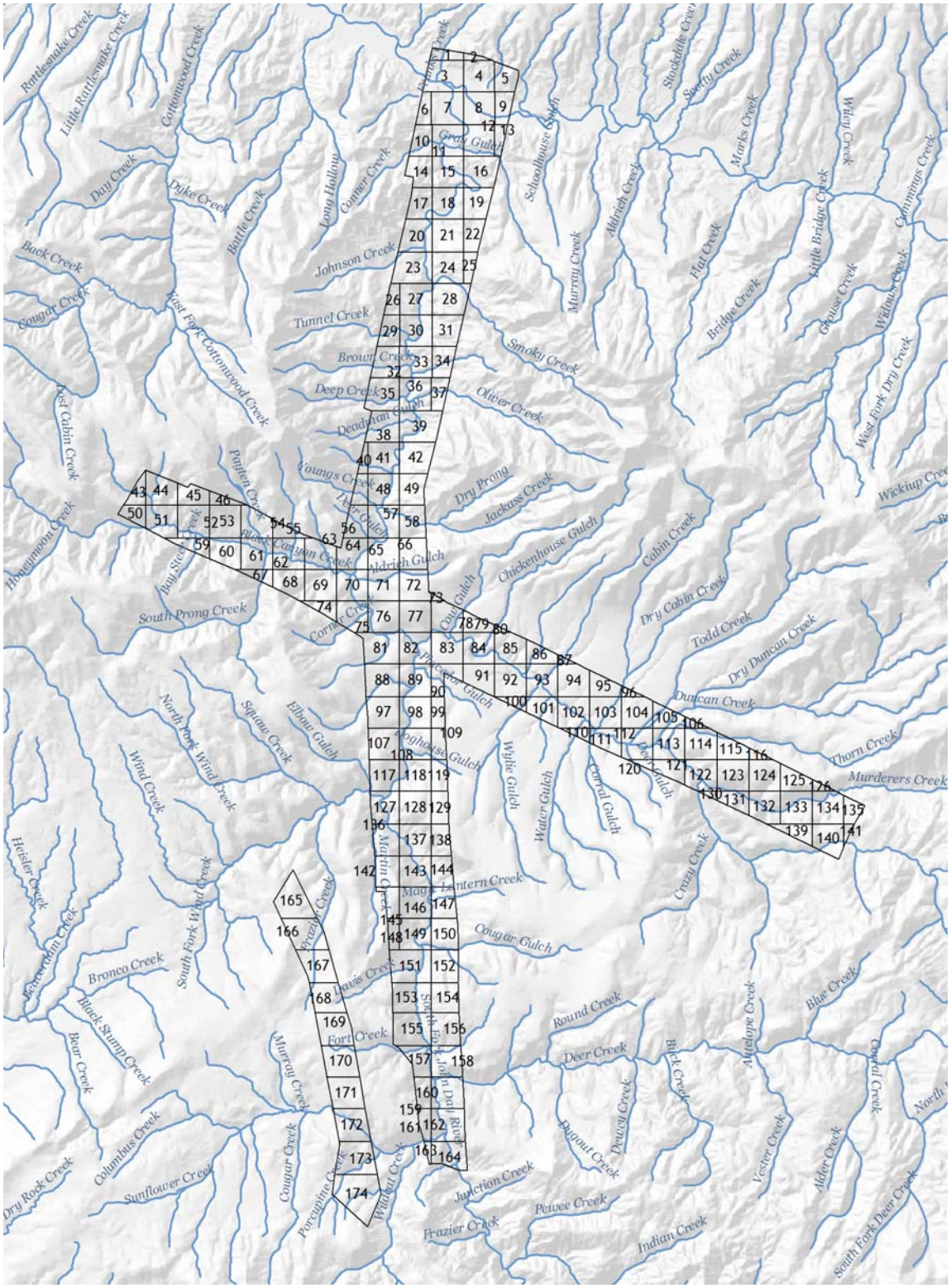
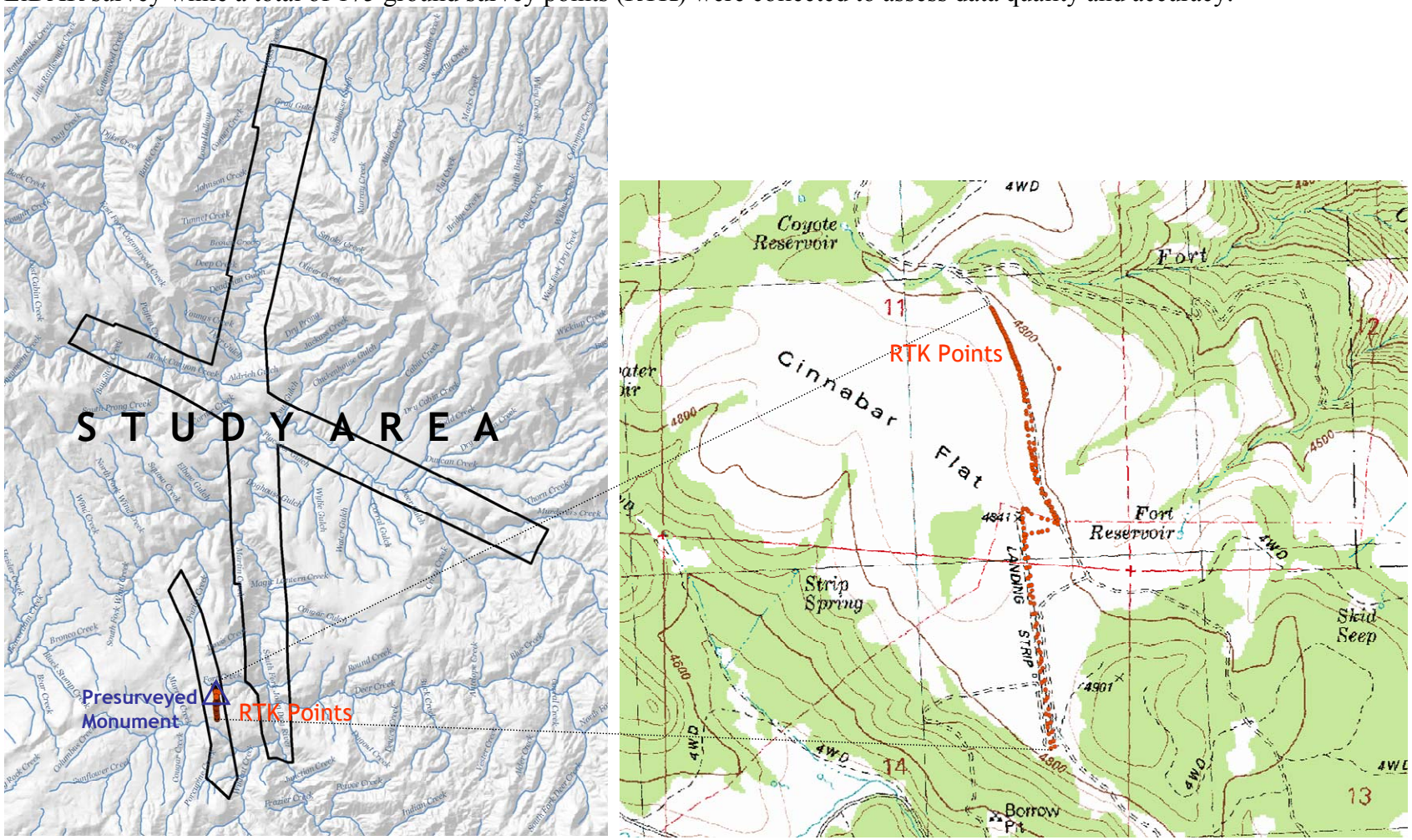


Figure 3. GPS Monuments and Gound Survey Points. A pre-surveyed monument was used to survey fast static (1 Hz) data during the LiDAR survey while a total of 175 ground survey points (RTK) were collected to assess data quality and accuracy.



Description of Processing Steps:

Units: Meters
Projection: UTM Zone 11, Nad83, NAVD88, Geoid03

1. Import point data into 174 bins
2. Perform relative accuracy testing.
3. Remove False LiDAR Points: False high and low points were removed by establishing thresholds for point removal that are above and below the known terrain elevations.
4. Calculate bare ground model from last return points, with the maximum building size of 100 m^2 and maximum terrain angle of 88°. The challenge is to remove buildings and vegetation, but leave rock outcrops and cliffs.

   Important: Water points are left in the bare earth model because it is unclear which points are water and which are mud flat, river bed, rocks, etc.

5. Manual removal of bridges and highway spans.
6. Generate TINs within all bins (including points 100 m outside) and export ASCII lattice files for first return and ground points (figure 7).

No weeding or superfluous point removal was performed. The intent of a LiDAR survey is to accurately place points on targets, not remove points. If laser noise is low and internally consistent, aside from pits and birds, it assumed that the remaining laser returns are from targets within the survey area.

Statement of Accuracy

Table 2. **Absolute Accuracy** – Divergence between laser points and RTK survey points.

Standard Deviation:	0.025 m	5th Percentile:	0.001 m
RMSE:	0.025 m	25th Percentile:	0.01 m
n:	175	50th Percentile:	0.018 m
Minimum Δz:	-0.061	75th Percentile:	0.0295 m
Maximum Δz:	0.060	95th Percentile:	0.0443 m
Average Magnitude:	0.003 m		

Figure 8. Point Divergence Statistics: Deviation and Absolute Deviation from Laser Points.

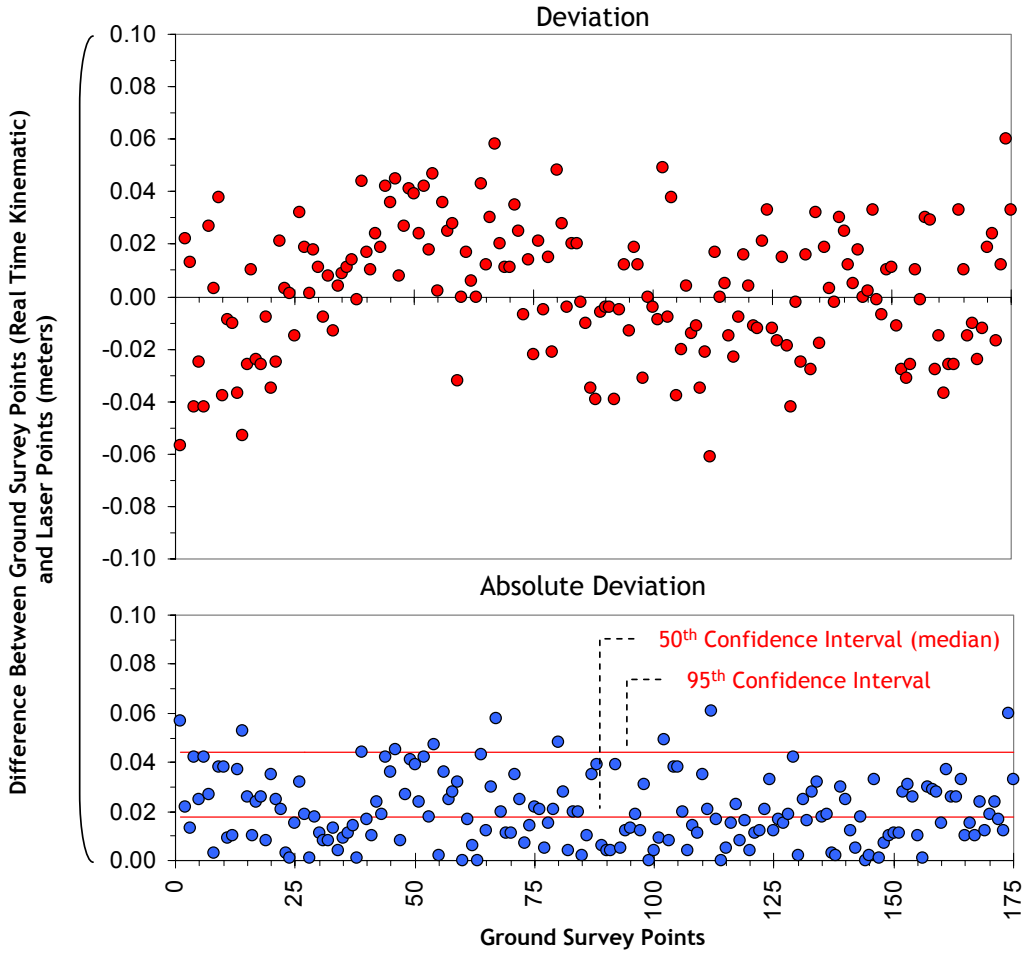


Table 3. LiDAR accuracy is a combination of several sources of error which are cumulative. Some error sources that are biased and act in a patterned displacement can be resolved in post processing.

Type of Error	Source	Post Processing Solution	Effect
GPS (Static/Kinematic)	Long Base Lines	None	
	Poor Satellite Constellation	None	
	Poor Antenna Visibility	Reduce Visibility Mask	Slight
Internal Consistency	Poor System Calibration	Recalibration IMU and sensor offsets/settings	Large
	Inaccurate System	None	
Laser Noise	Poor Laser Timing	None	
	Poor Laser Reception	None	

Quality Assurance and Control

Quality assurance and control is built into the overall methodology. The data collection was monitored using the diagnostic features of the system during the flight. The precise navigation system and 30% side over-lap during acquisition is designed to eliminate missing coverage and ensure laser painting of multiple sides of surfaces. The quality of the GPS signal (or PDOP) is recorded throughout the flight and only PDOP values less than 3.0 are accepted.

Deliverables

DVD1:
ESRI 1-meter GRIDs
- Bare Earth
- First Returns

Presentation
Report

DVD2:
ASCII Points, 001-174

DVD3:
QT Reader
QT Models, All Points 001-100

DVD4:
QT Models, All Points 101-174

DVD5:
QT Models, Bare Earth 001-050

DVD6:
QT Models, Bare Earth 051-100

DVD7:
QT Models, Bare Earth 101-150

DVD8:
QT Models, Bare Earth 151-174

Selected Images

Displayed on following pages

Figure 4. Laser Returns – Multiple Returns shown with Classified Ground Points, in relation to a true-color ground photo (taken near the mouth of Deer Creek).

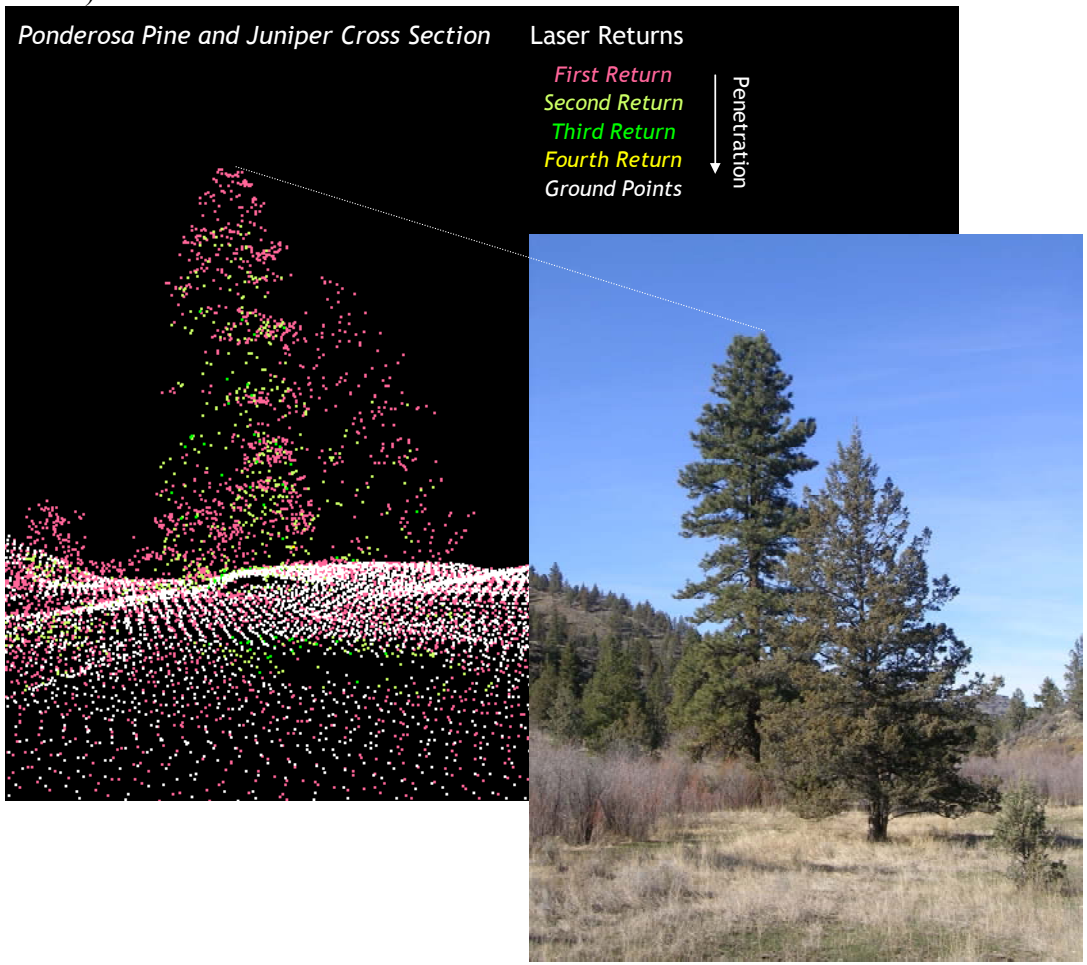


Figure 5. Points Converted into Surface Models: Bare Ground Image shown with true-color ground image (taken downstream of Tunnel Creek, on the east side of South Fork Rd).

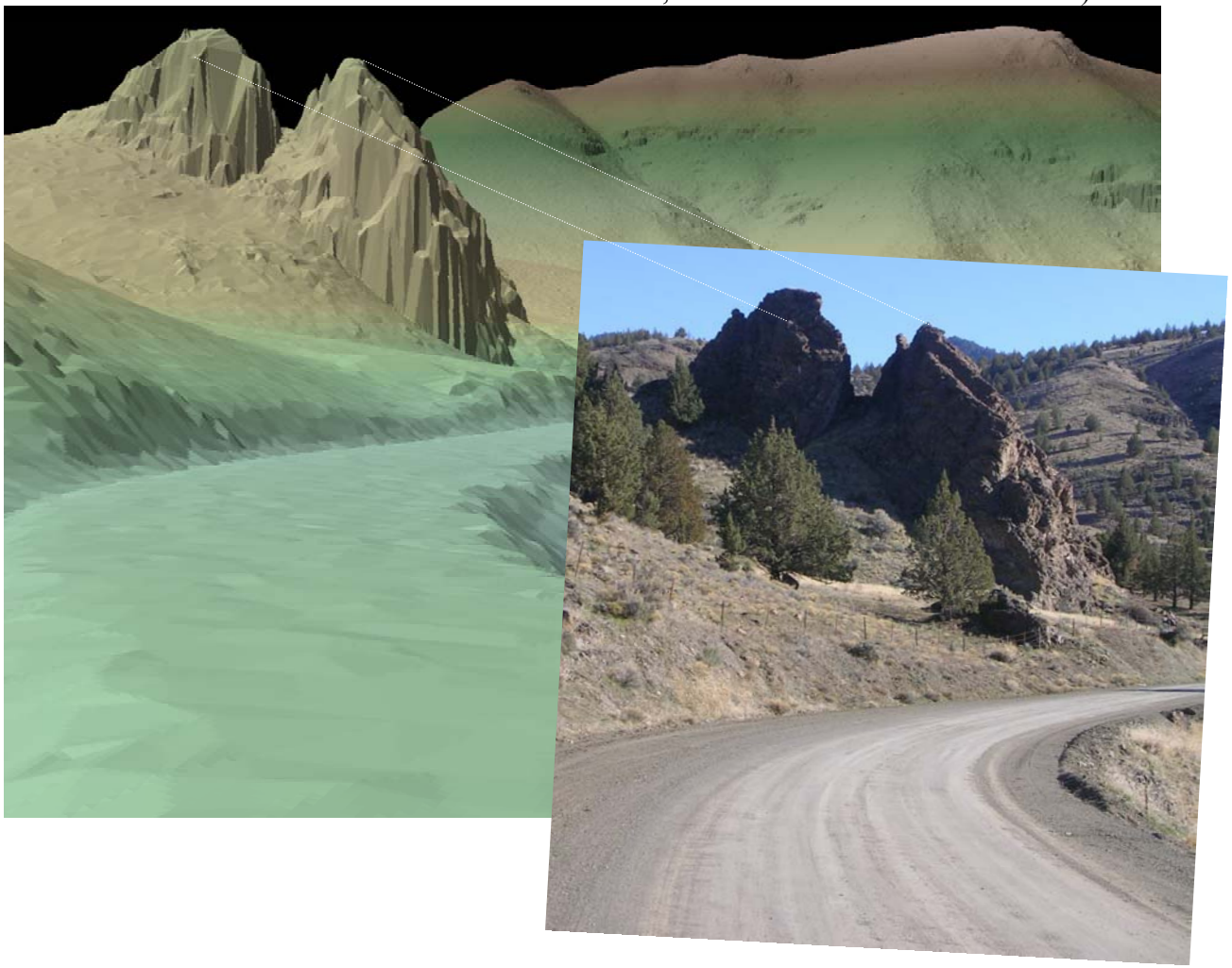


Figure 6. Points Converted into Surface Models: Bare Ground Image shown with true-color ground image (Looking Upstream of Black Canyon Creek Confluence).

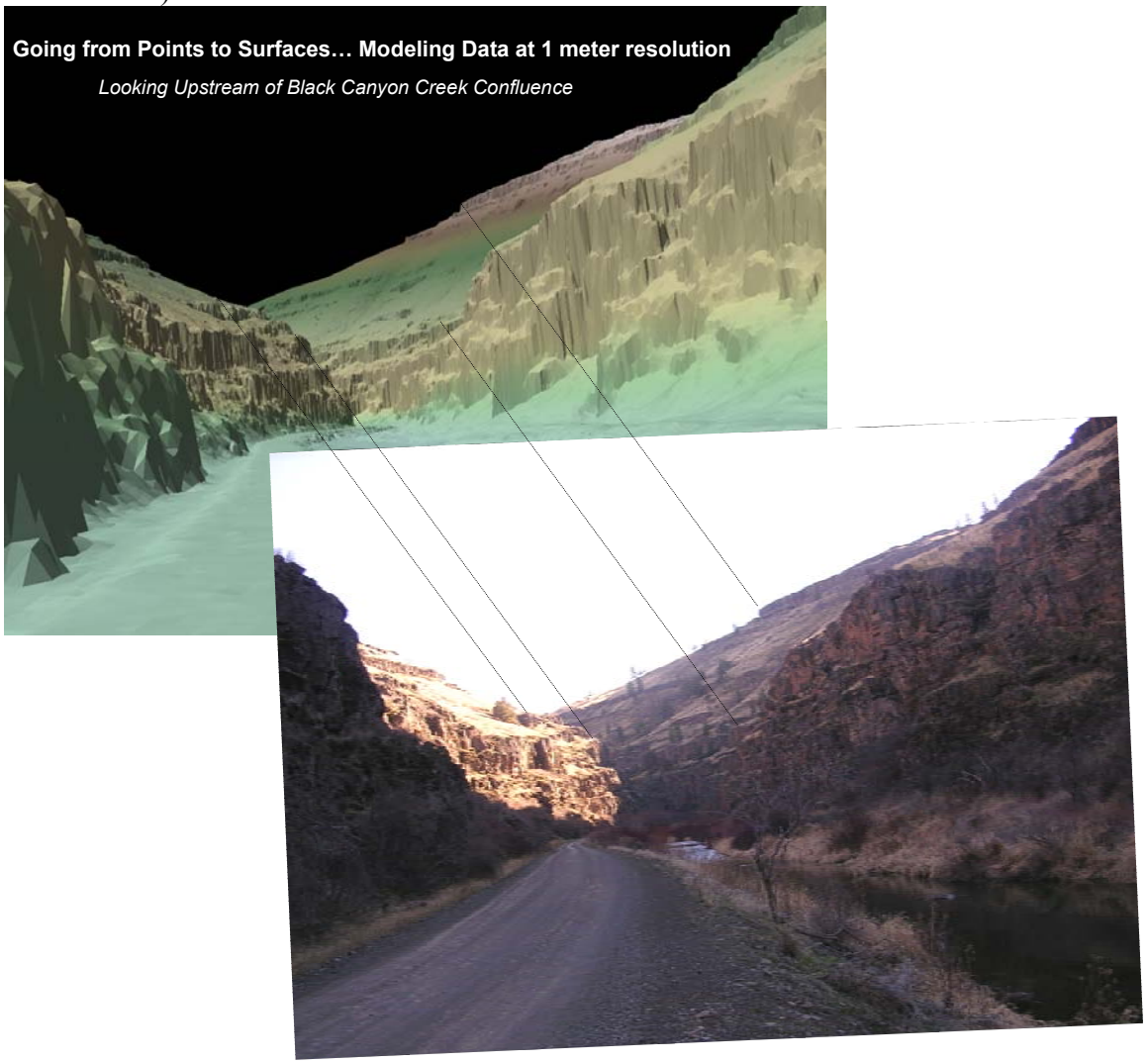


Figure 7. First Return Points and Bare Ground Surfaces (Near Dayville)

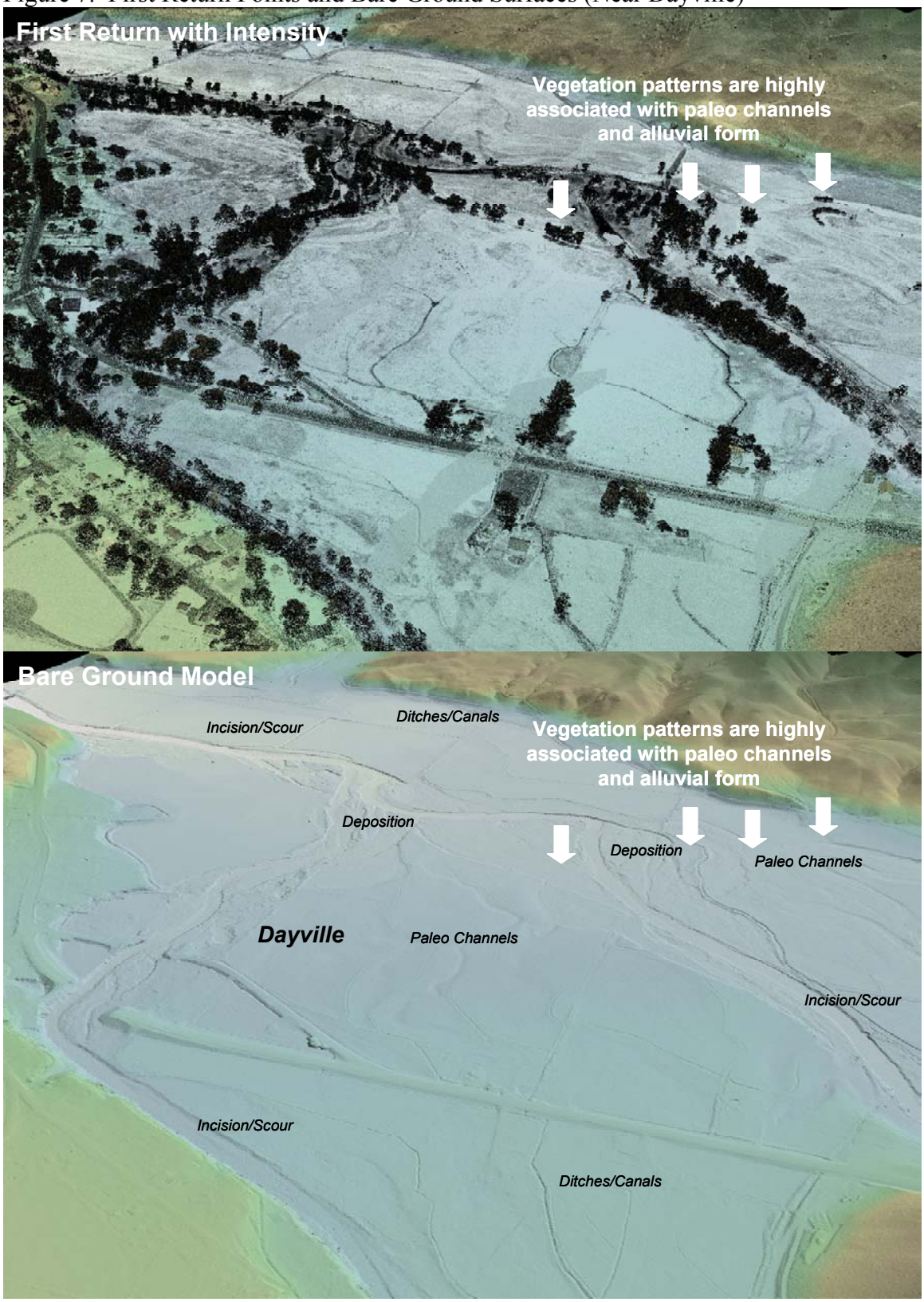


Figure 8. First Return Points and Bare Ground Surfaces (Upstream from Dayville)

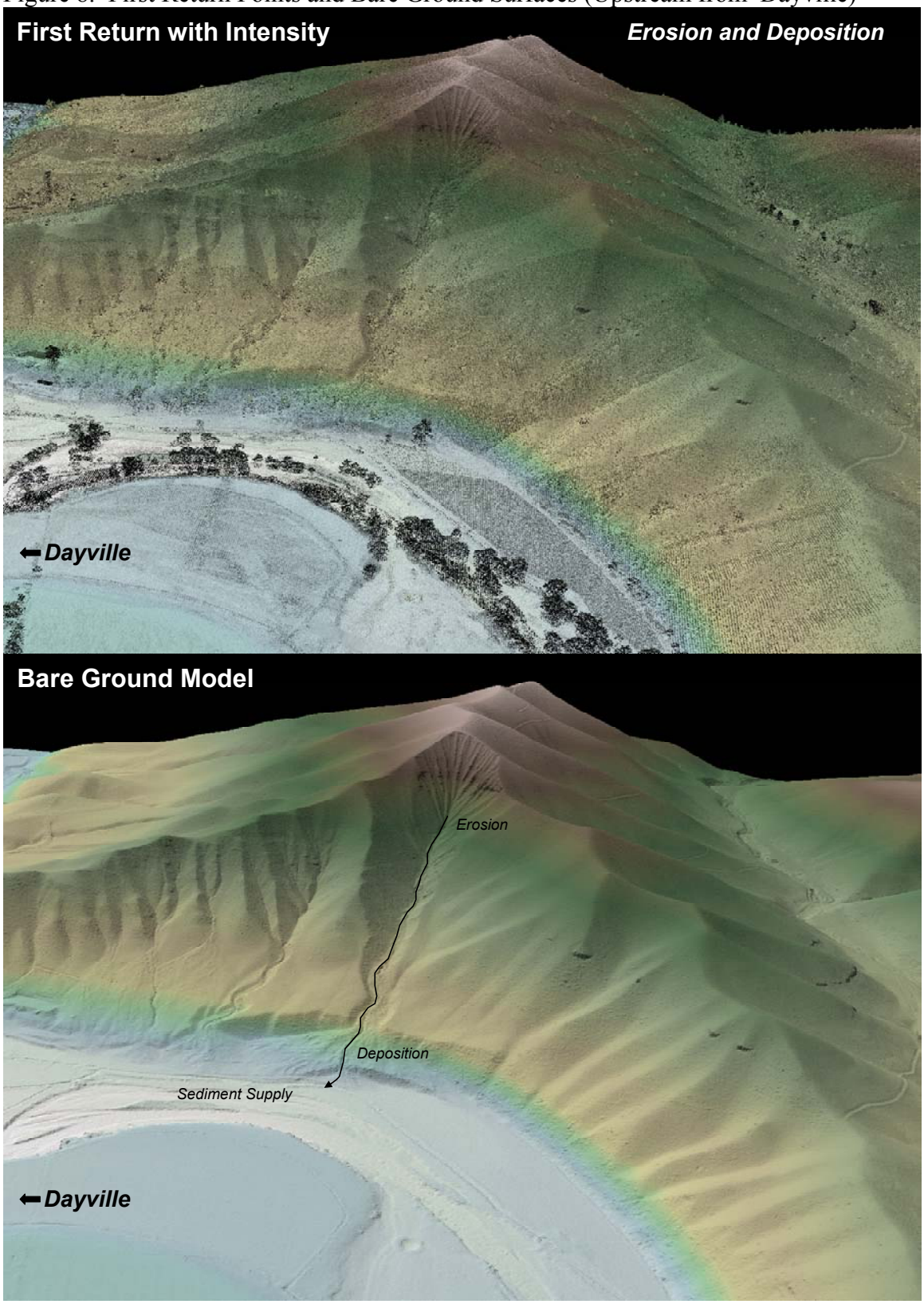


Figure 9. First Return Points and Bare Ground Surfaces (Near Smokey Creek)

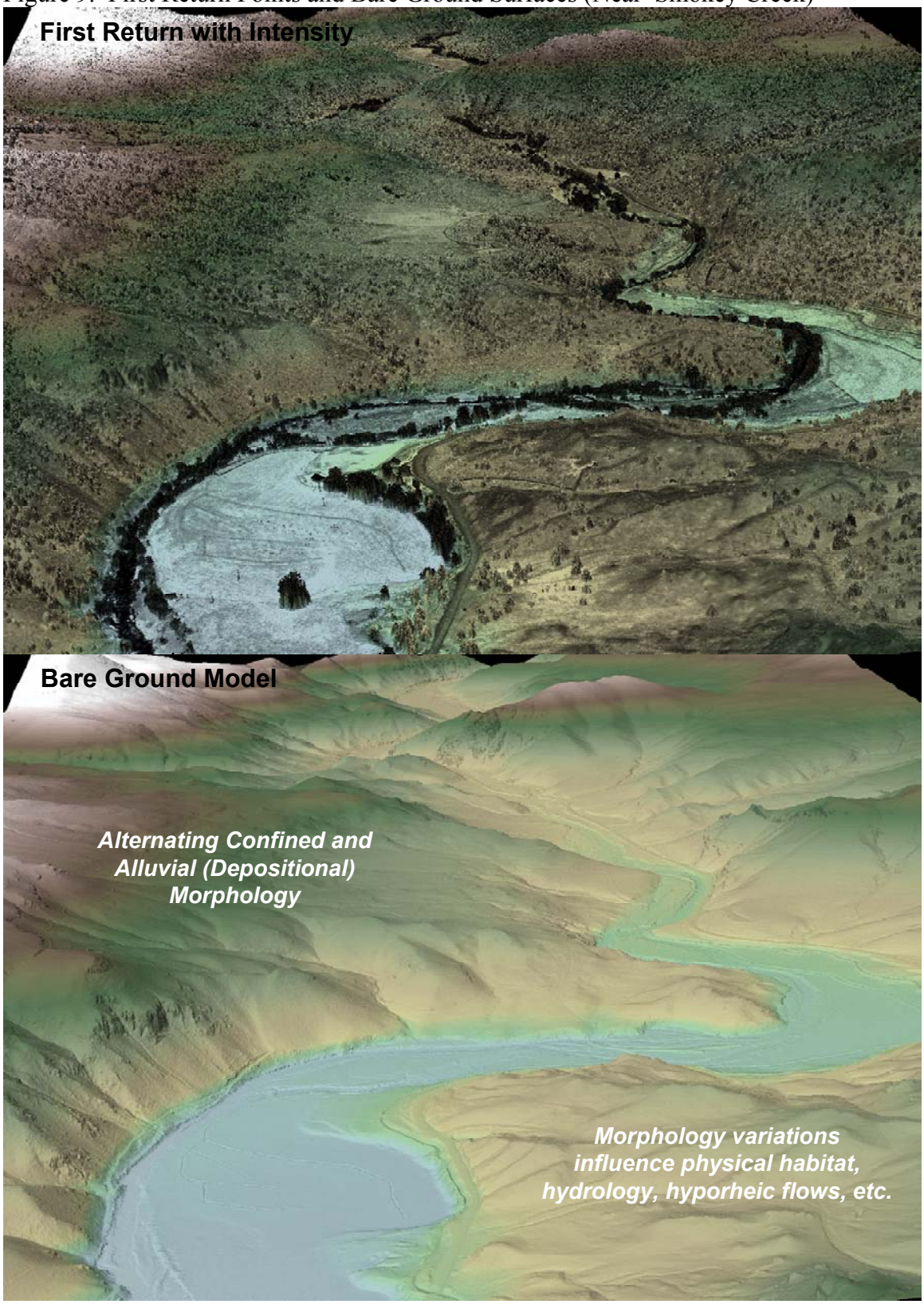


Figure 10. First Return Points and Bare Ground Surfaces (Looking at Smokey Creek)

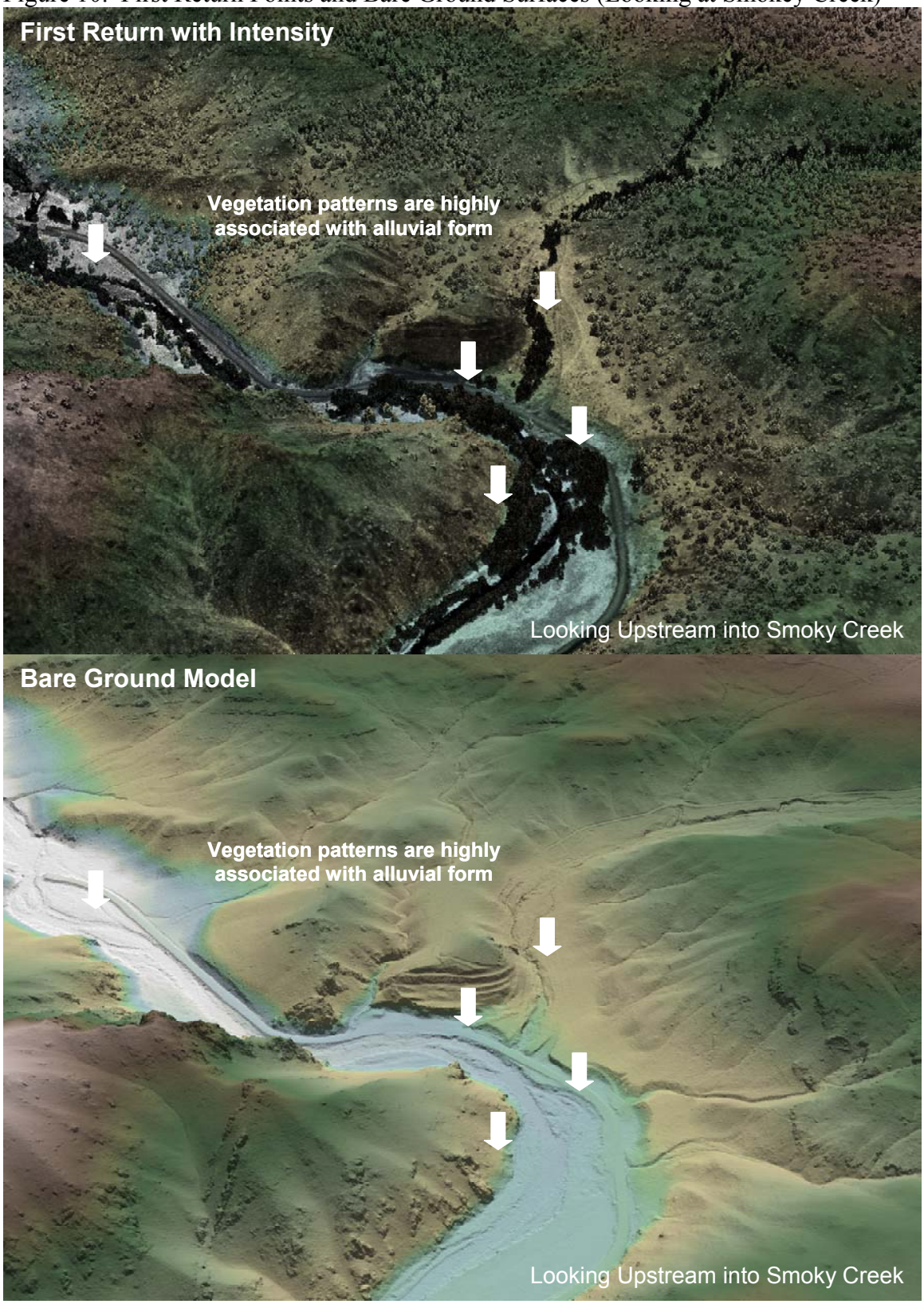
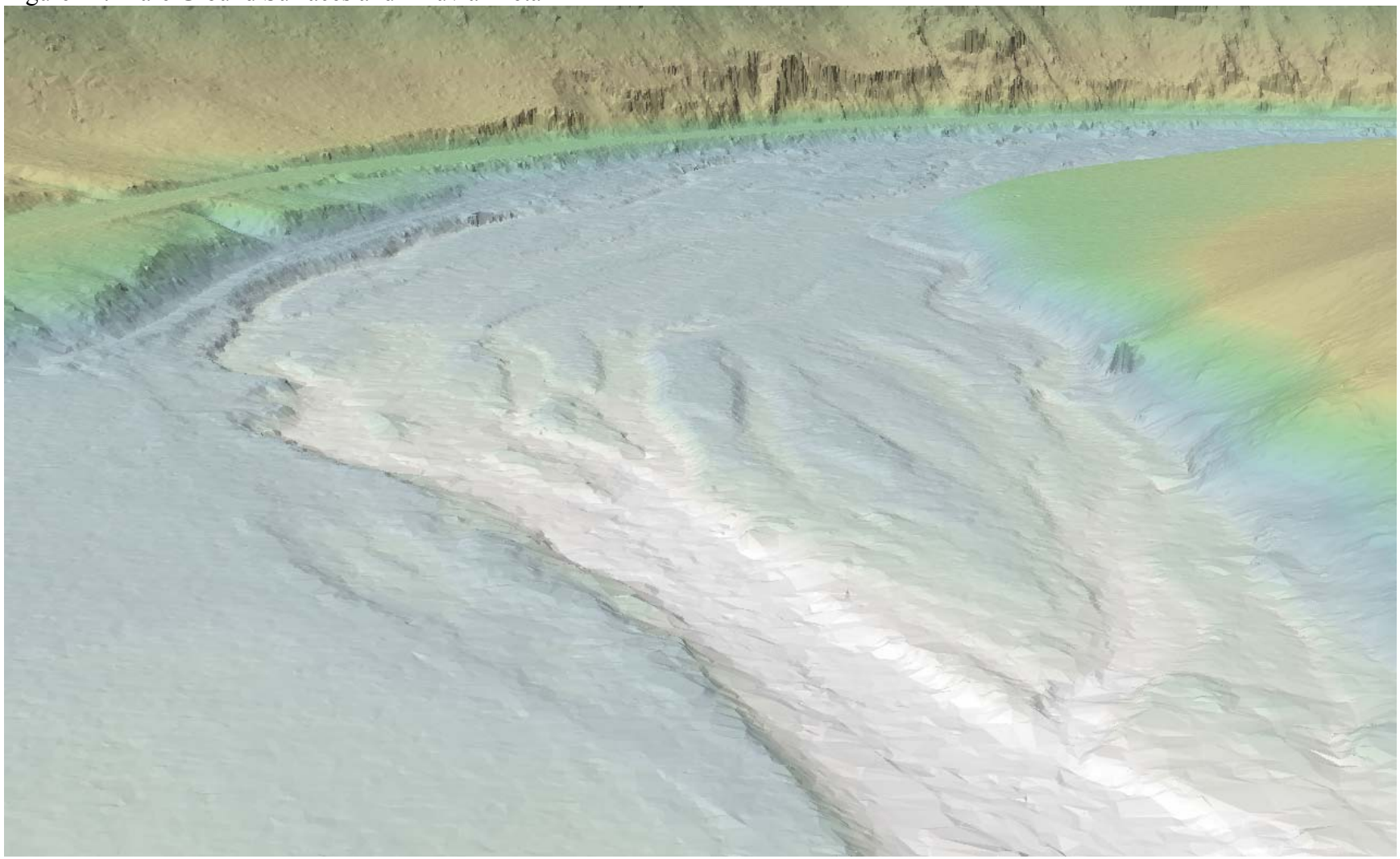


Figure 11. Bare Ground Surfaces and Alluvial Detail



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