# Airborne LiDAR and Multi-Spectral Imagery

## Flathead Basin, MT


Russell Faux, Principal
Watershed Sciences, Inc.
517 SW 2nd Street, Suite 400
Corvallis, OR 97333
541-752-1204


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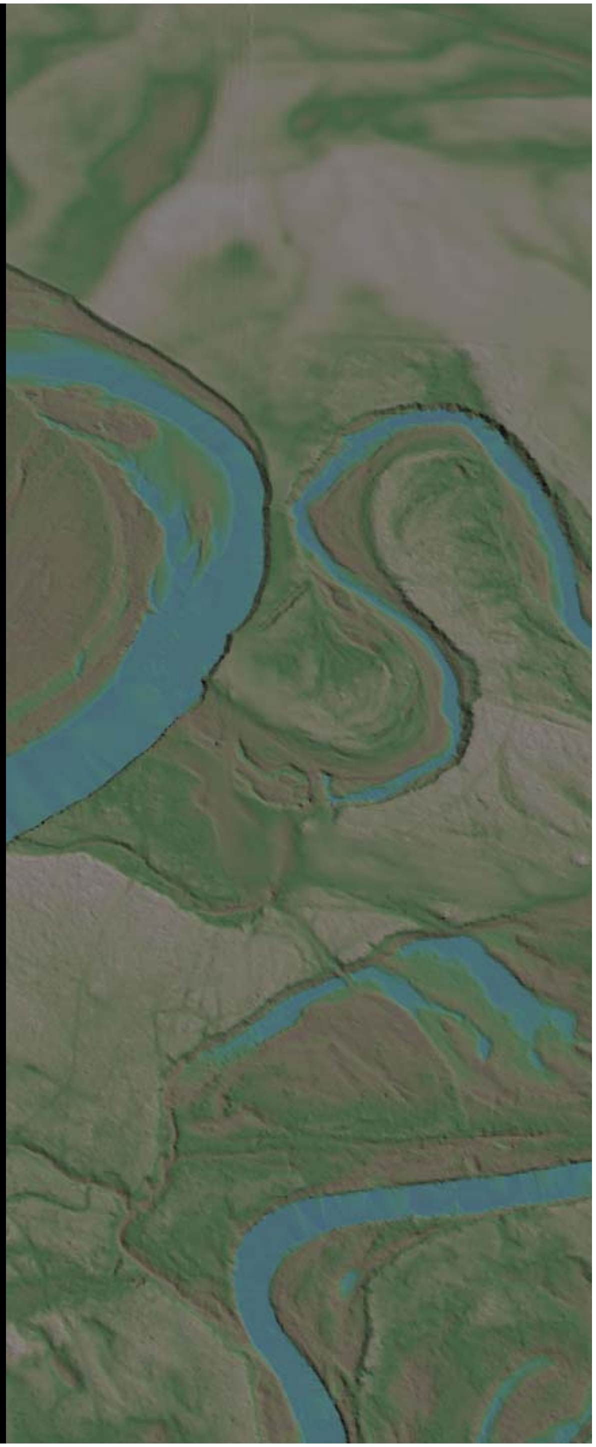
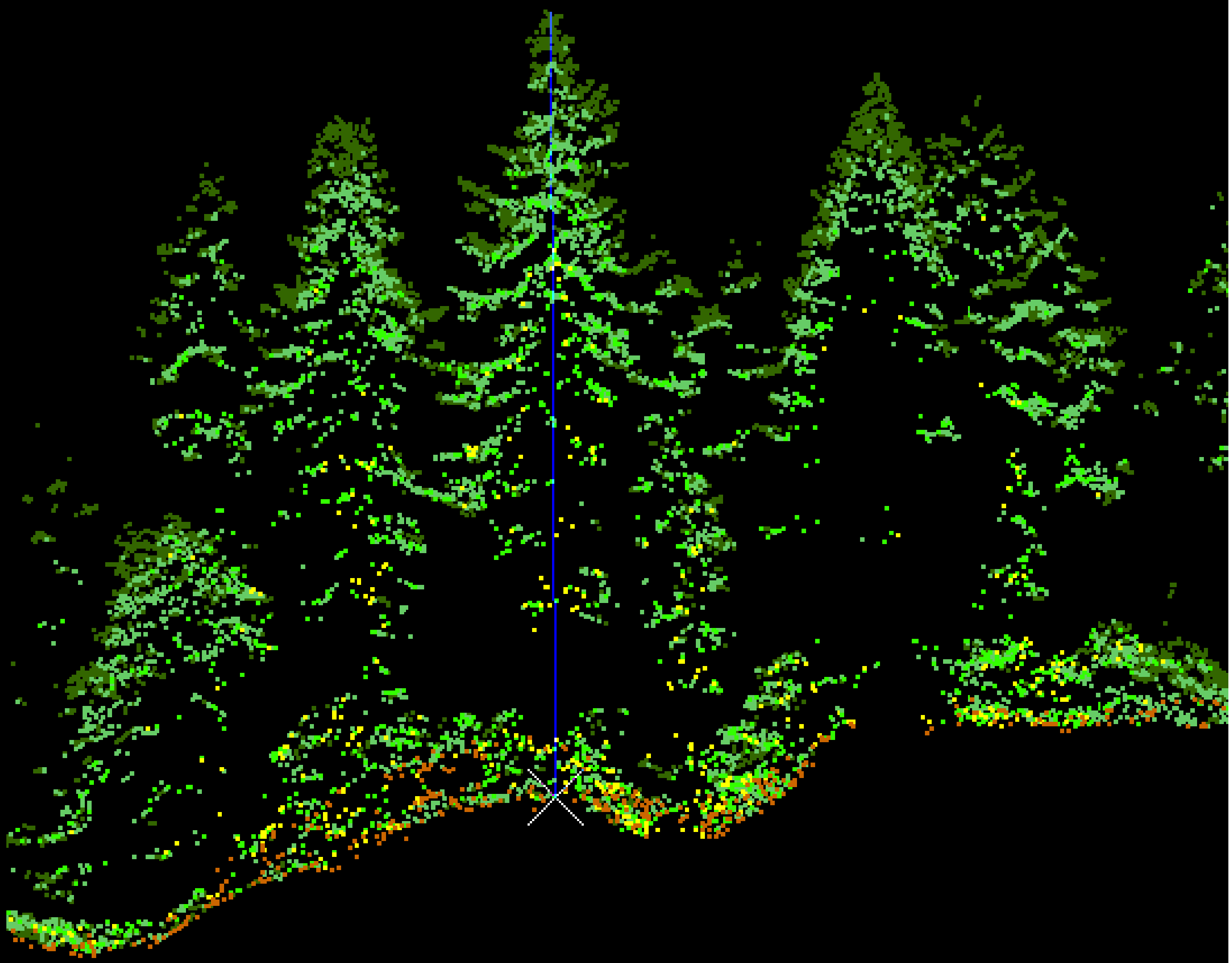
# Presentation Overview

1: Basic LiDAR Concepts
2: Flathead Basin Project
3: LiDAR Applications



# Part 1: Light Detection and Ranging (LiDAR)

**In its most basic form, LiDAR Data are just points**



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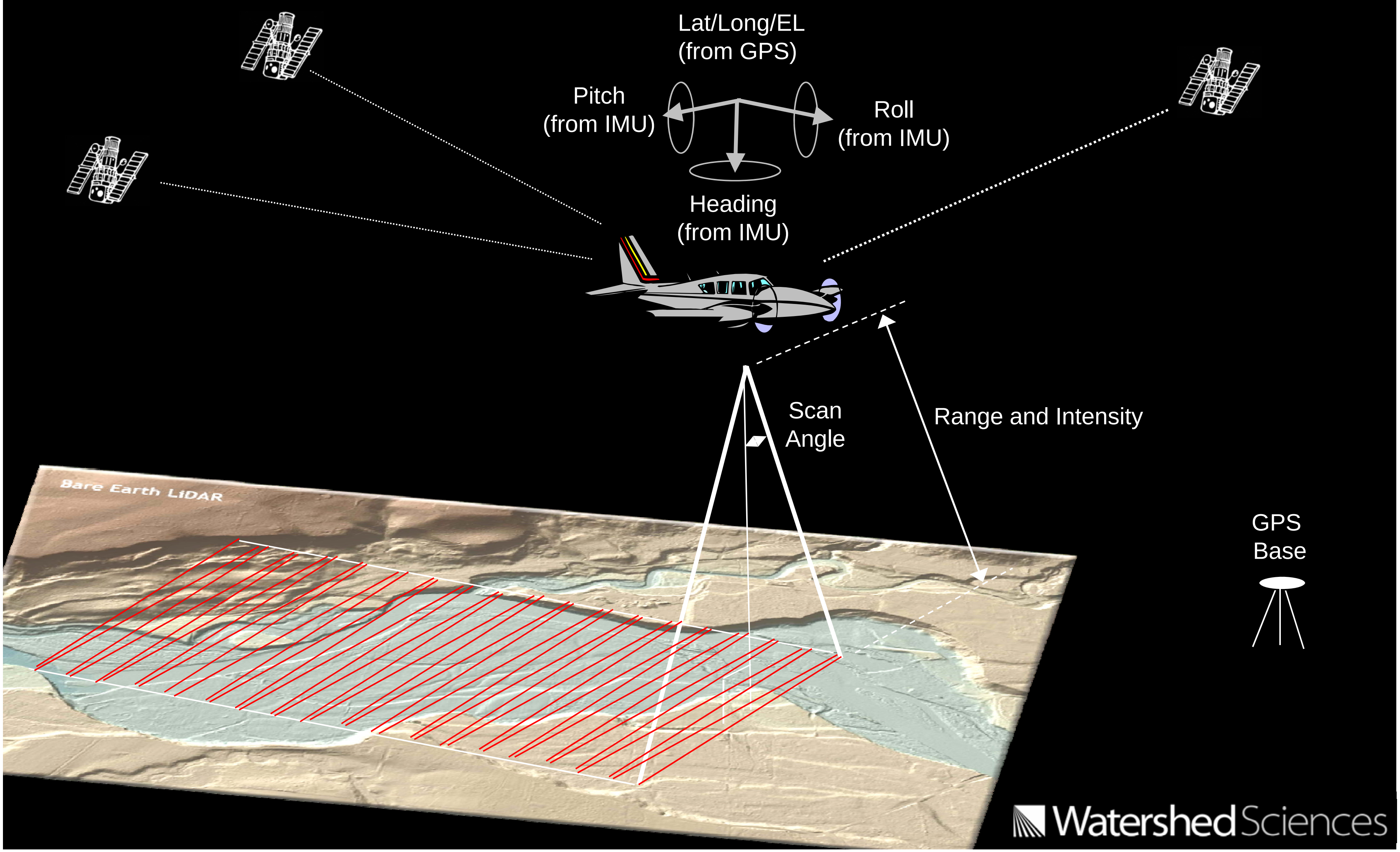
# Airborne LIDAR systems employ technologies that include…



# LiDAR Systems/Hardware

**Airborne Platforms**

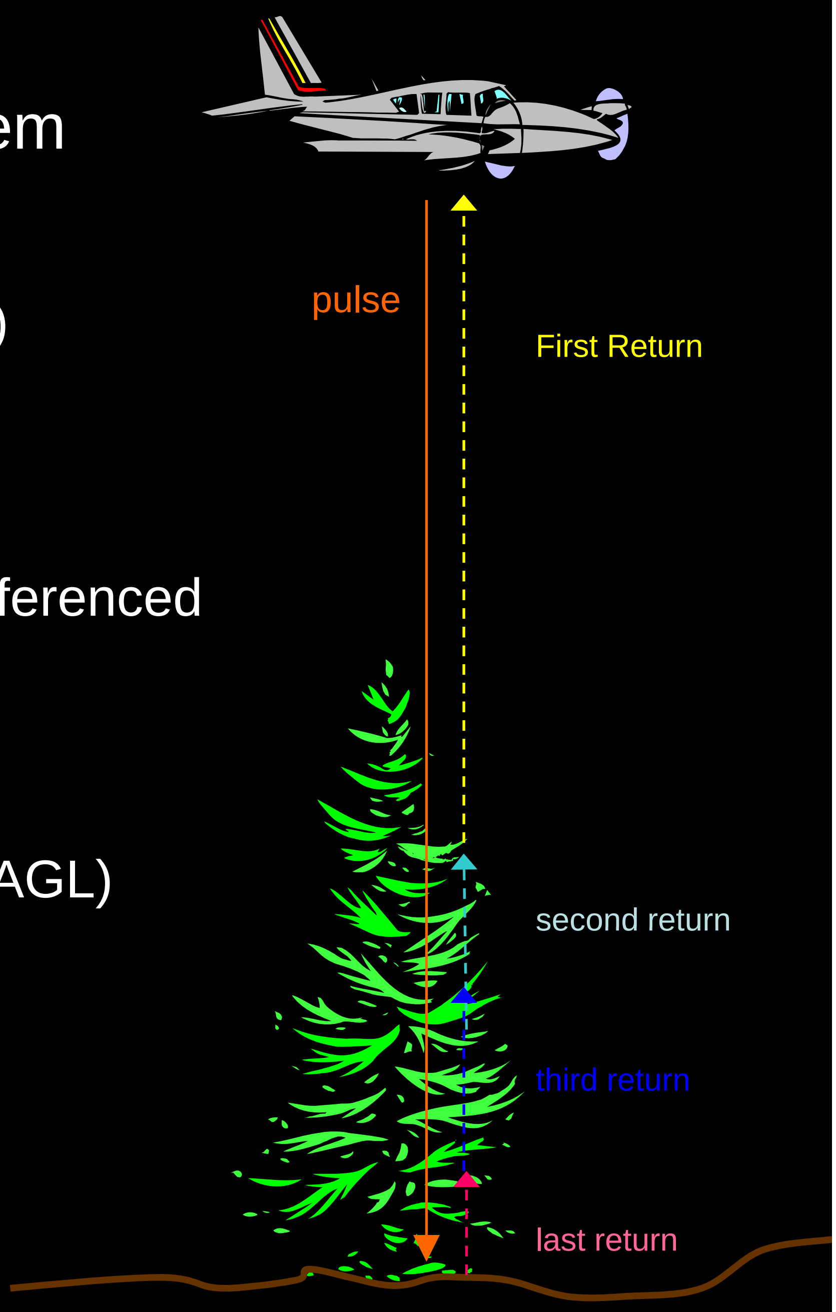

**Airborne LiDAR Systems**

**Ground GPS Systems**

# Airborne LiDAR Concepts

## small footprint, discrete return system

- Up to 200,000 pulses per Sec (200 KHz)
- Up to 4 returns per pulse
- Each LiDAR return is individually geo-referenced
- Records intensity of backscatter
- Sub-meter footprint (~22 cm @ 1000 m AGL)

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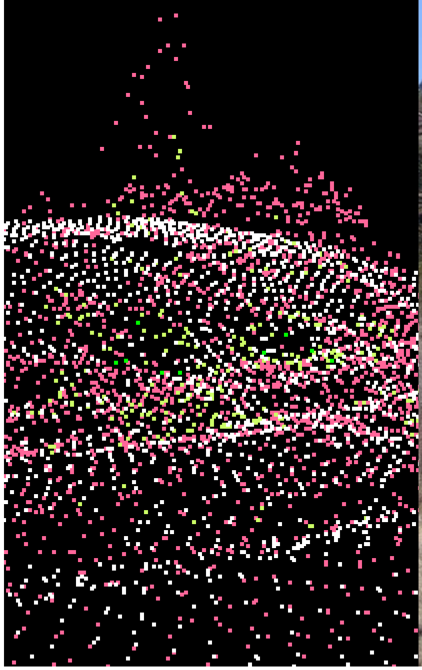
# In its most basic form, LiDAR Data are just points

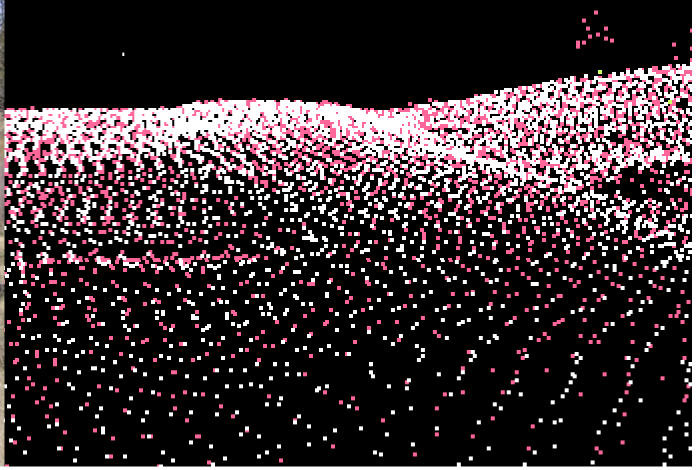
*Ponderosa Pine and Juniper*



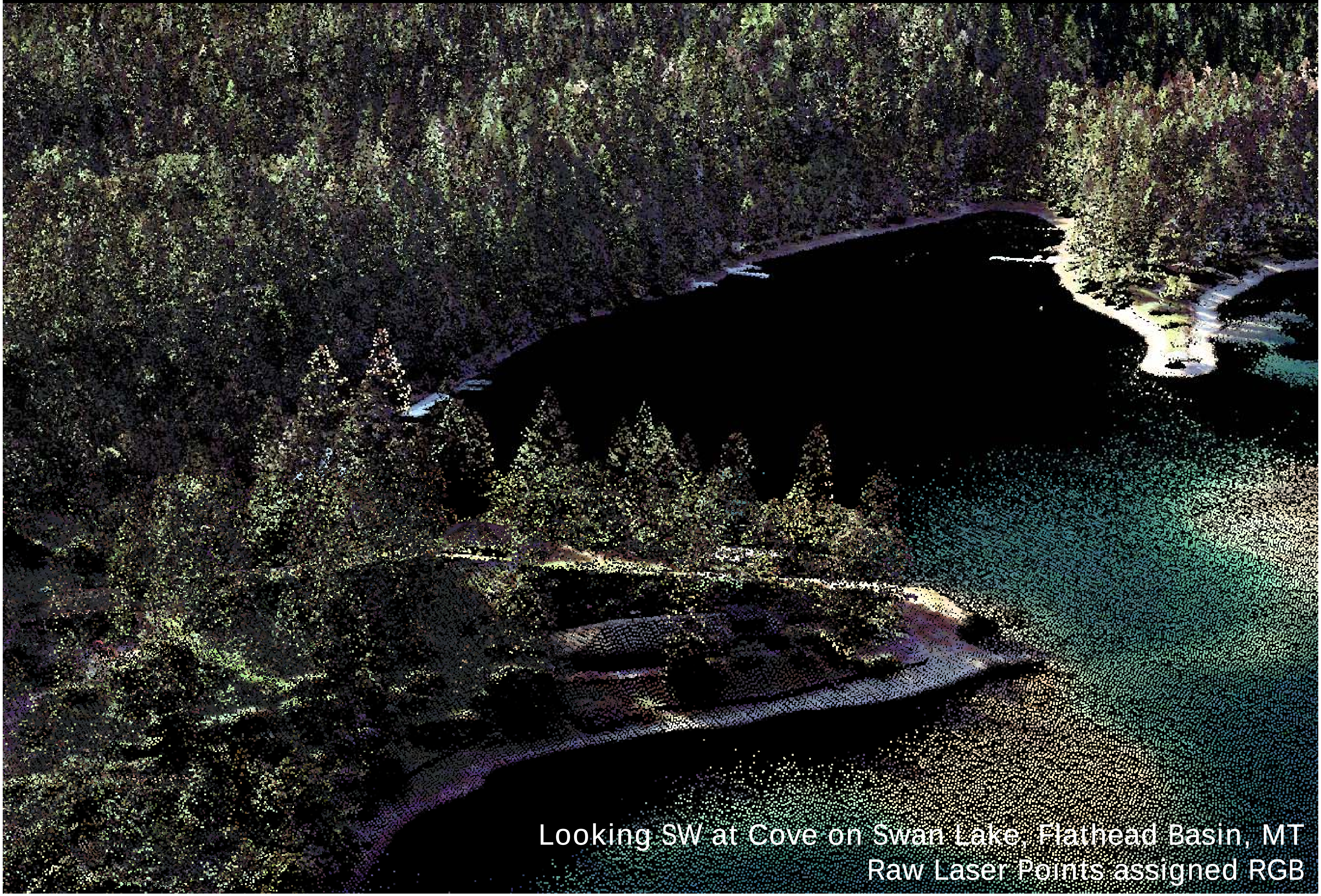
Multiple Laser Returns
are Apparent

*First Return*
*Second Return*
*Third Return*
*Fourth Return*
*Ground Points*

Penetration

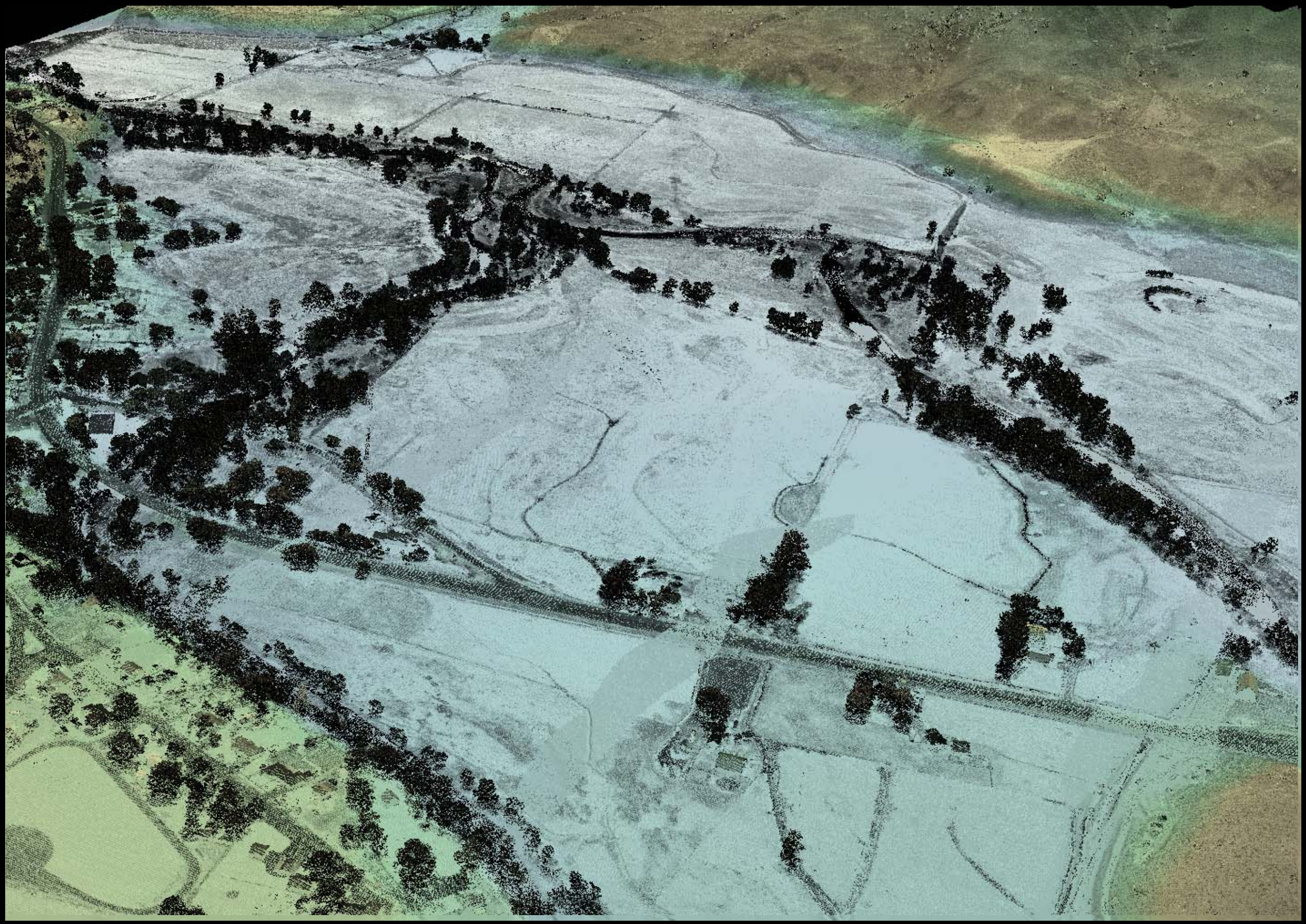


**LiDAR data are better when there are a lot of points…**



# Going from Points to Surfaces… Modeling Data

- Data clouds are massive
- TINs from data clouds
- GRIDs from TINs (Interpolated Surface)
- GRIDS are smaller and easier to work with



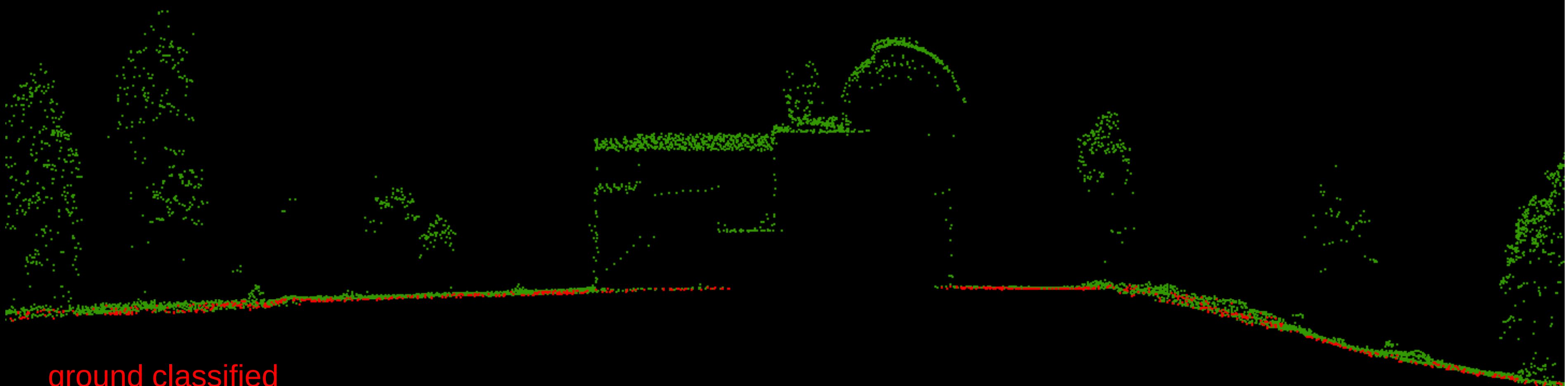
**All Returns**
**Colored by Intensity**

Dayville, OR

# Classifying Ground Returns

## LiDAR Returns 2-meter x-section

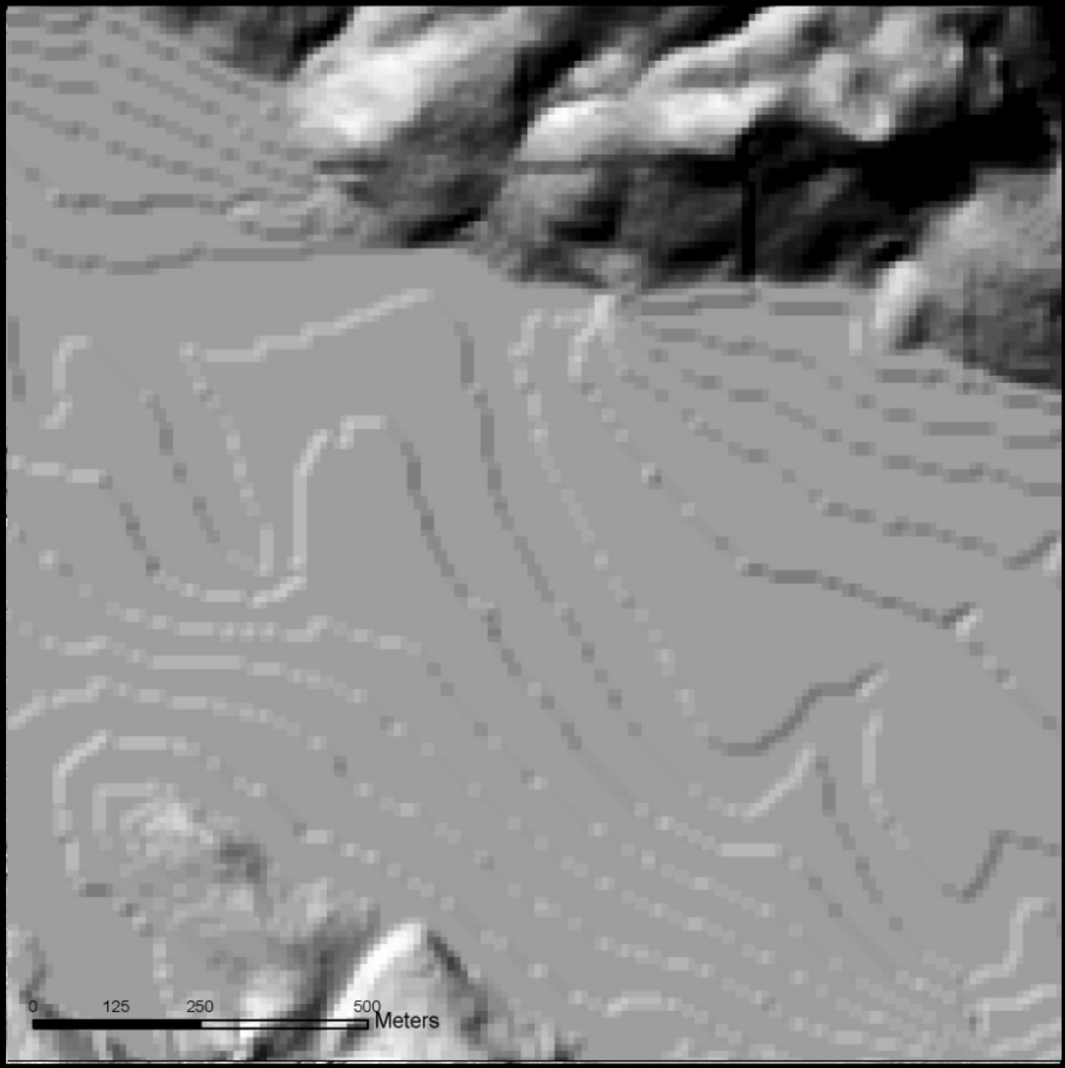
default



ground classified


Going from Points to Surfaces… Modeling Data (1 meter resolution)
Looking Upstream of Black Canyon Creek Confluence

# 10-Meter DEM versus 1-meter DEM

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# Data Accuracy…

- Relative: A measure of system calibration computed as the divergence between points from different flight lines
- Absolute: Compare known real-time kinematic (RTK) ground survey points to closest ground-classified laser point.
- Classification: A measure of accuracy of the resulting digital terrain model considering ground point classification and ground hit density.

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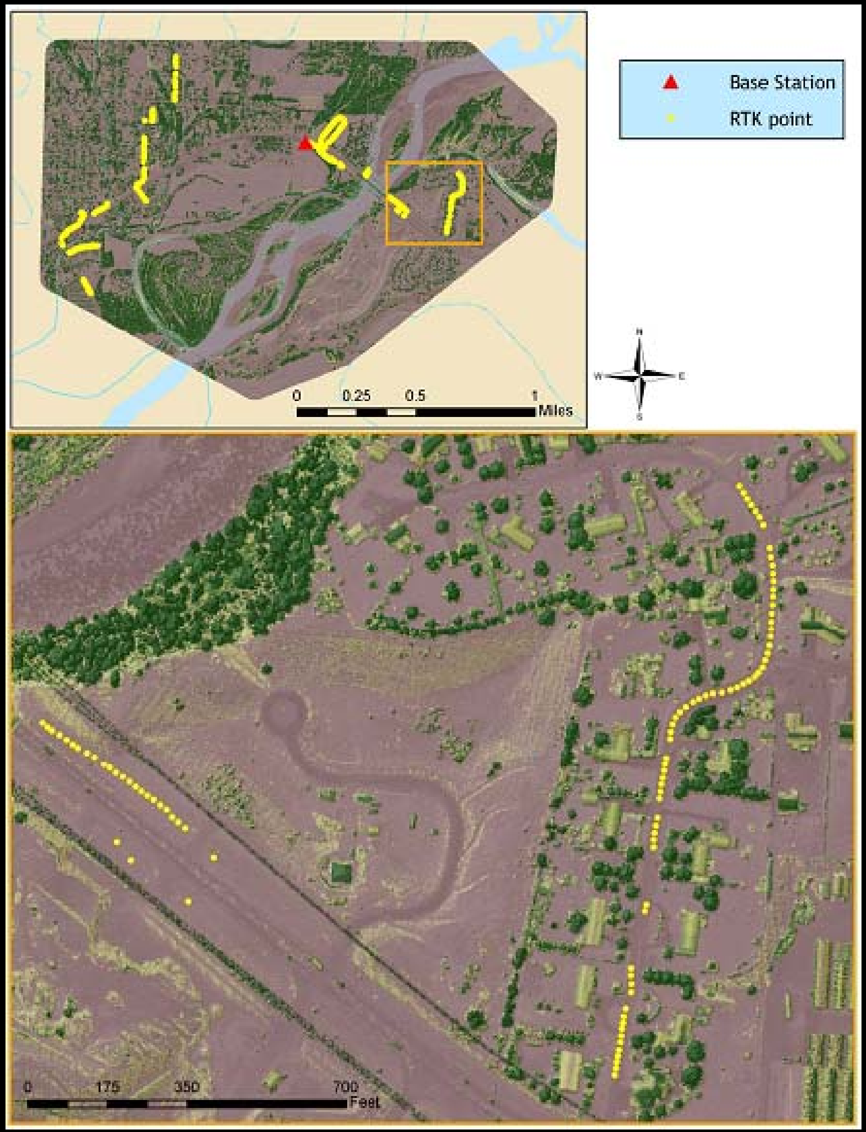
# Assessing Absolute Accuracy:

Measured as the deviation between ground survey and laser point data

- Assessed on open, hard surfaces
- Measured across multiple flight lines
- Statistical robustness of assessment (sample size & distribution)

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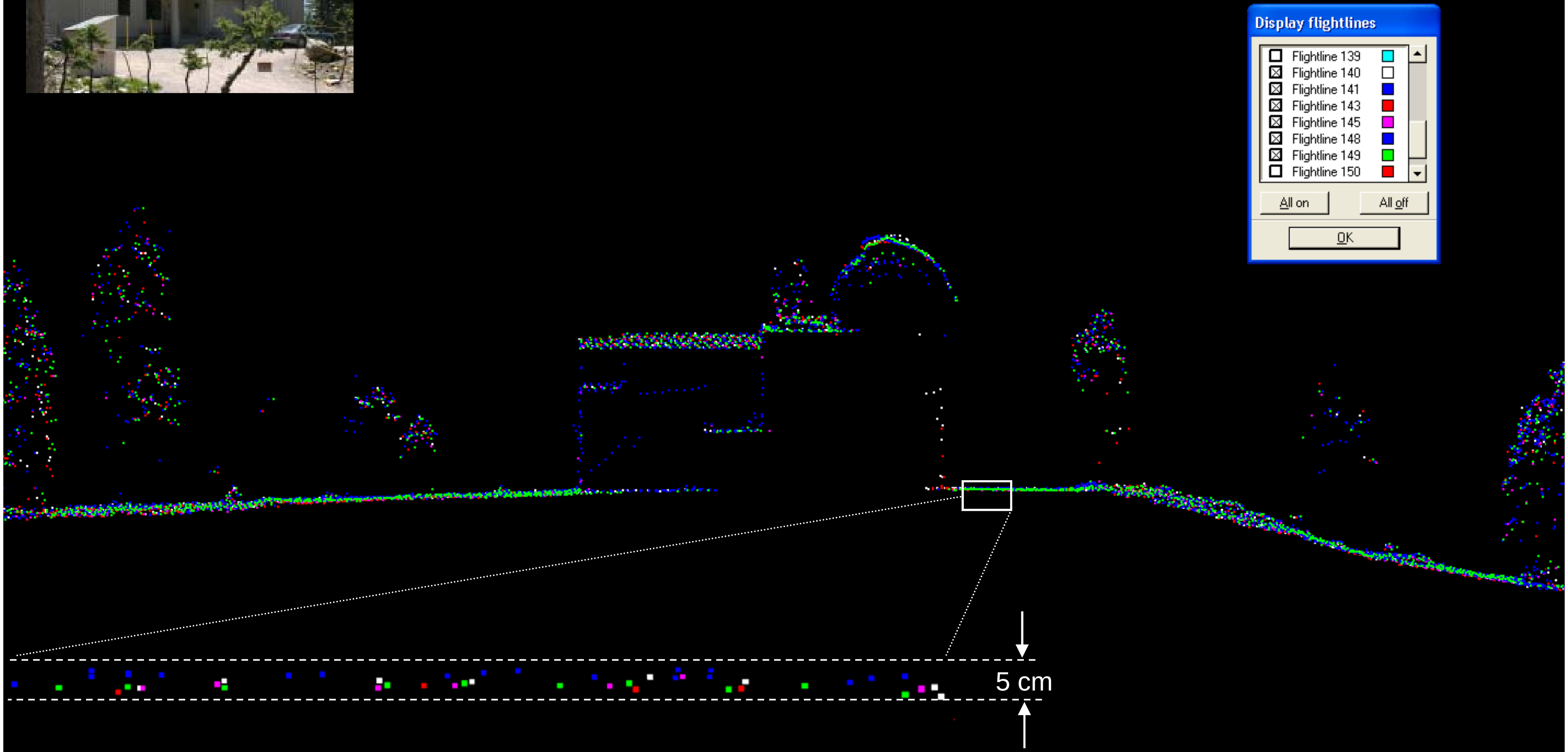
# Relative Accuracy Example

- A measure of system calibration
- Measured as the divergence of points from different flight lines

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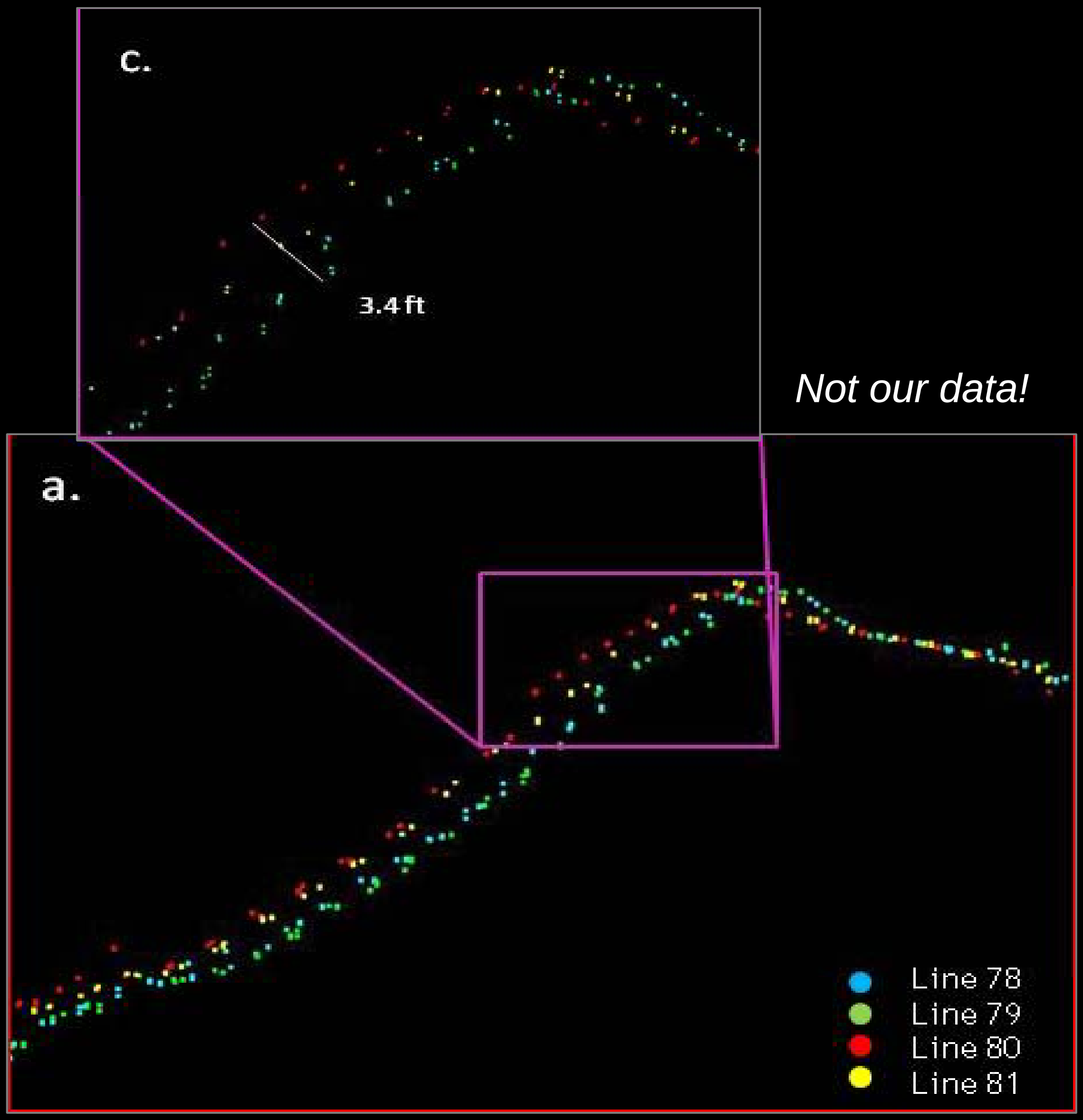
# **Relative Accuracy:** Another Example




*Not our data!*

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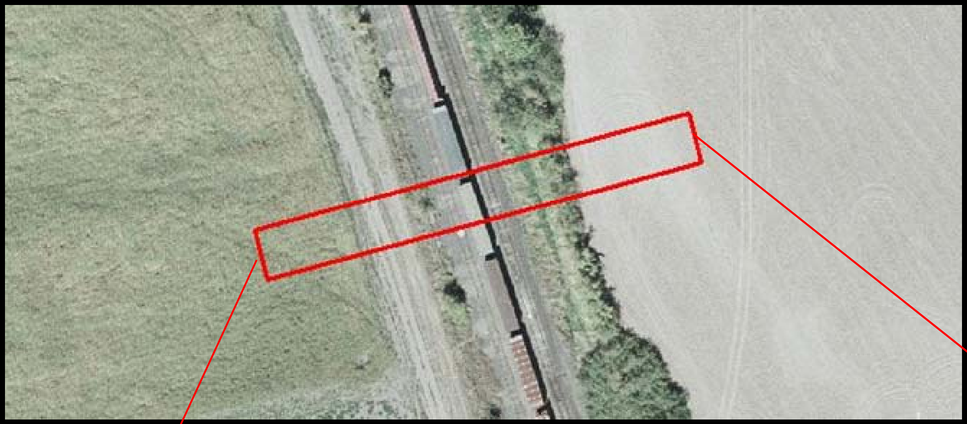
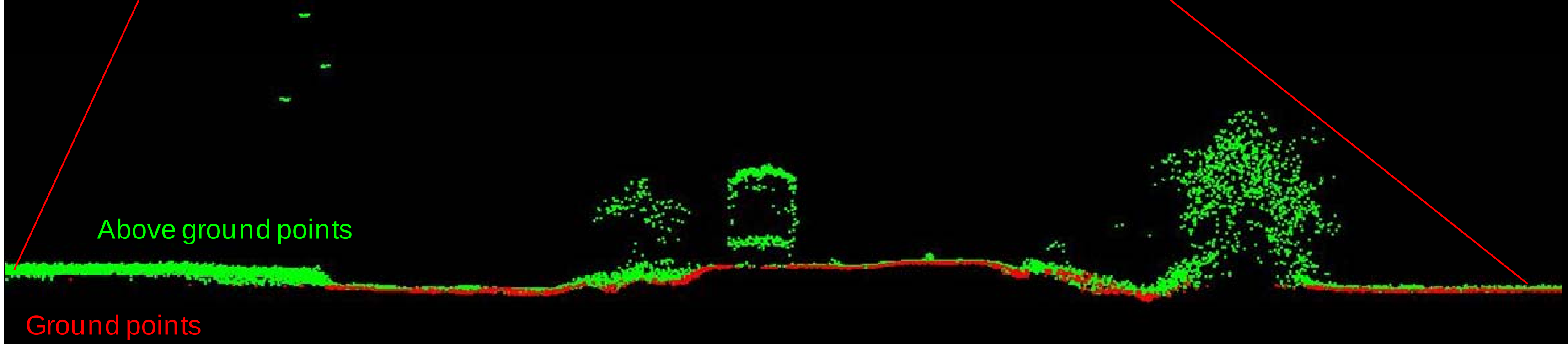
# Classification Accuracy

- Vegetation
- Bare Earth
- Water
- Buildings





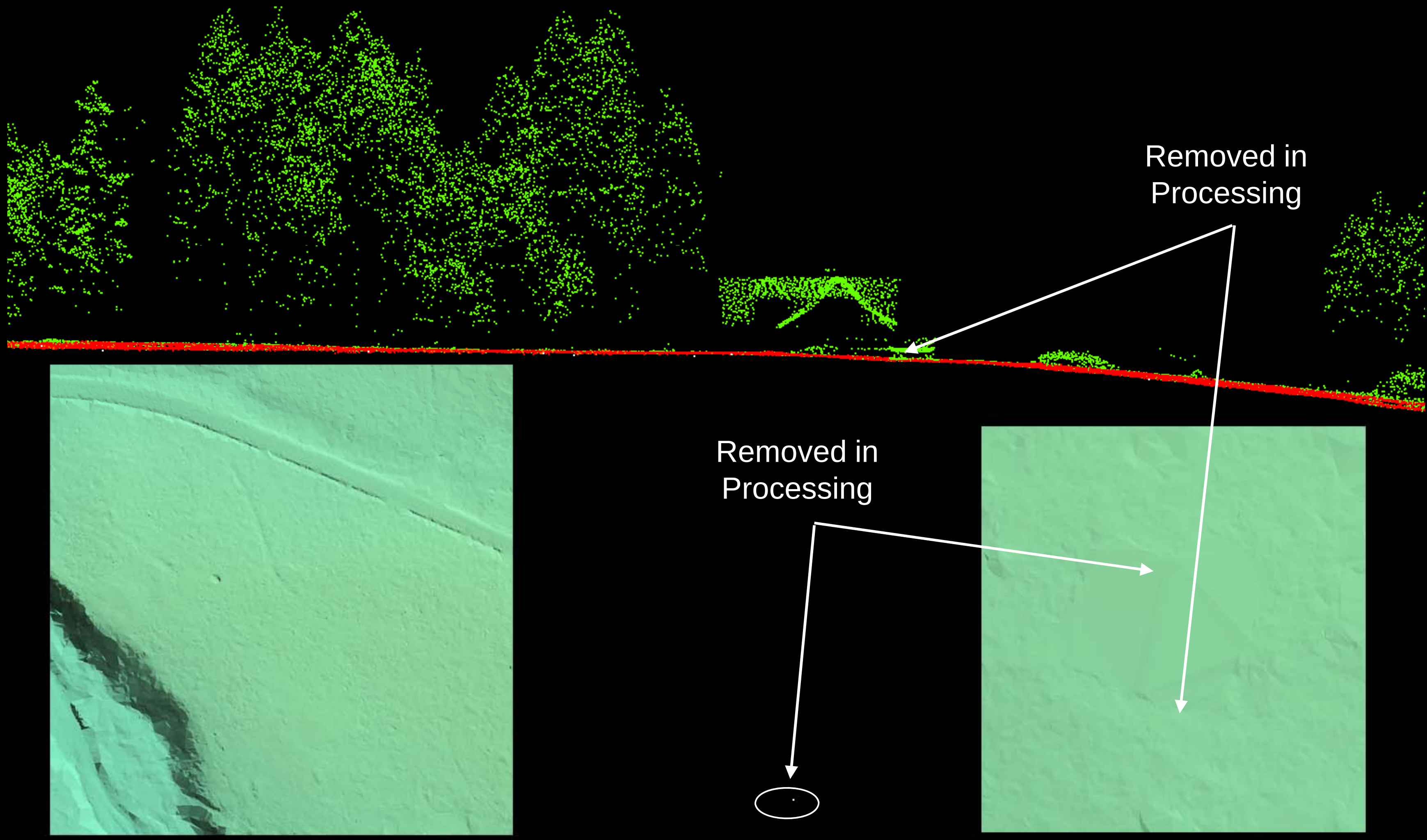

- Visual QA/QC Checks on DTM
  - Anomalies in the terrain model
  - Comparison to air photos
- Comparison with ground check points
- Delineation of Areas of Low Confidence

# Classification Accuracy Assessment

- Visual QA/QC Checks on DTM
  - Anomalies in the terrain model
  - Comparison to air photos
- Comparison with ground check points
  - FEMA: 20 distributed checkpoints on prevailing land cover types.
  - Independent of other check points.
- Delineation of Areas of Low Confidence
  - Ground return density versus slope.

# Classification Accuracy Assessment

*QA/QC Inspection*



# Part 2: Flathead Basin

Data Acquisition (303,040 acres)

<u>Airborne LiDAR (Sept 22-29, 2009)</u>

8 pulses/m$^2$ – Swan Lake

4 pulses/m$^2$ - Remaining Areas

<u>4-band Multispectral Imagery (Sept 23-25, 2009)</u>

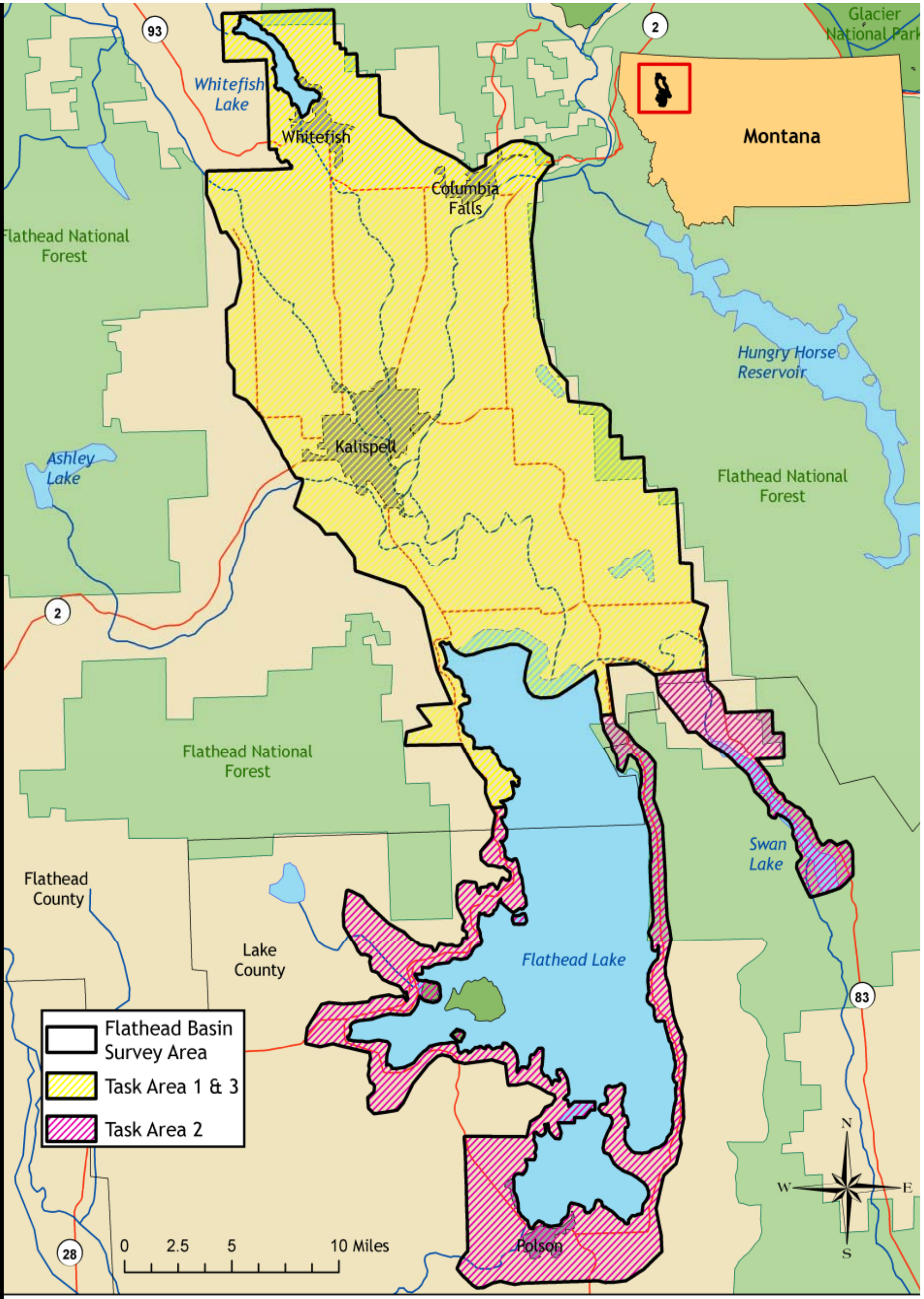
1- ft GSD

<u>Ground Control Survey</u>

Control Monuments

Land Cover Check Points

Pre-marks for Imagery

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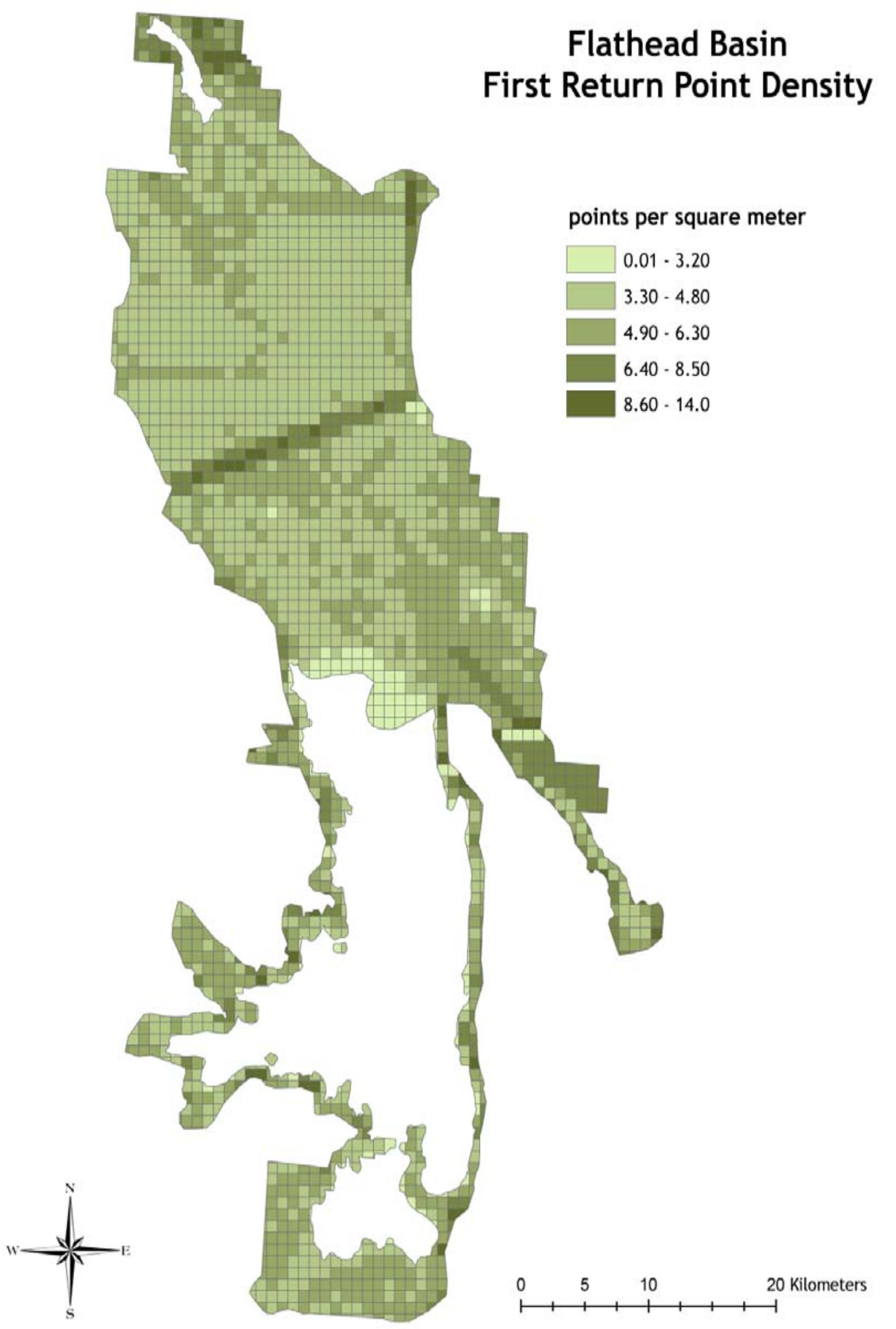
# Flathead Basin Project

Achieved Pulse Densities

Ground Point Density = 1.55/m$^2$ (0.14/ft$^2$)
First Return Density = 4.93/m$^2$ (0.46/ft$^2$)

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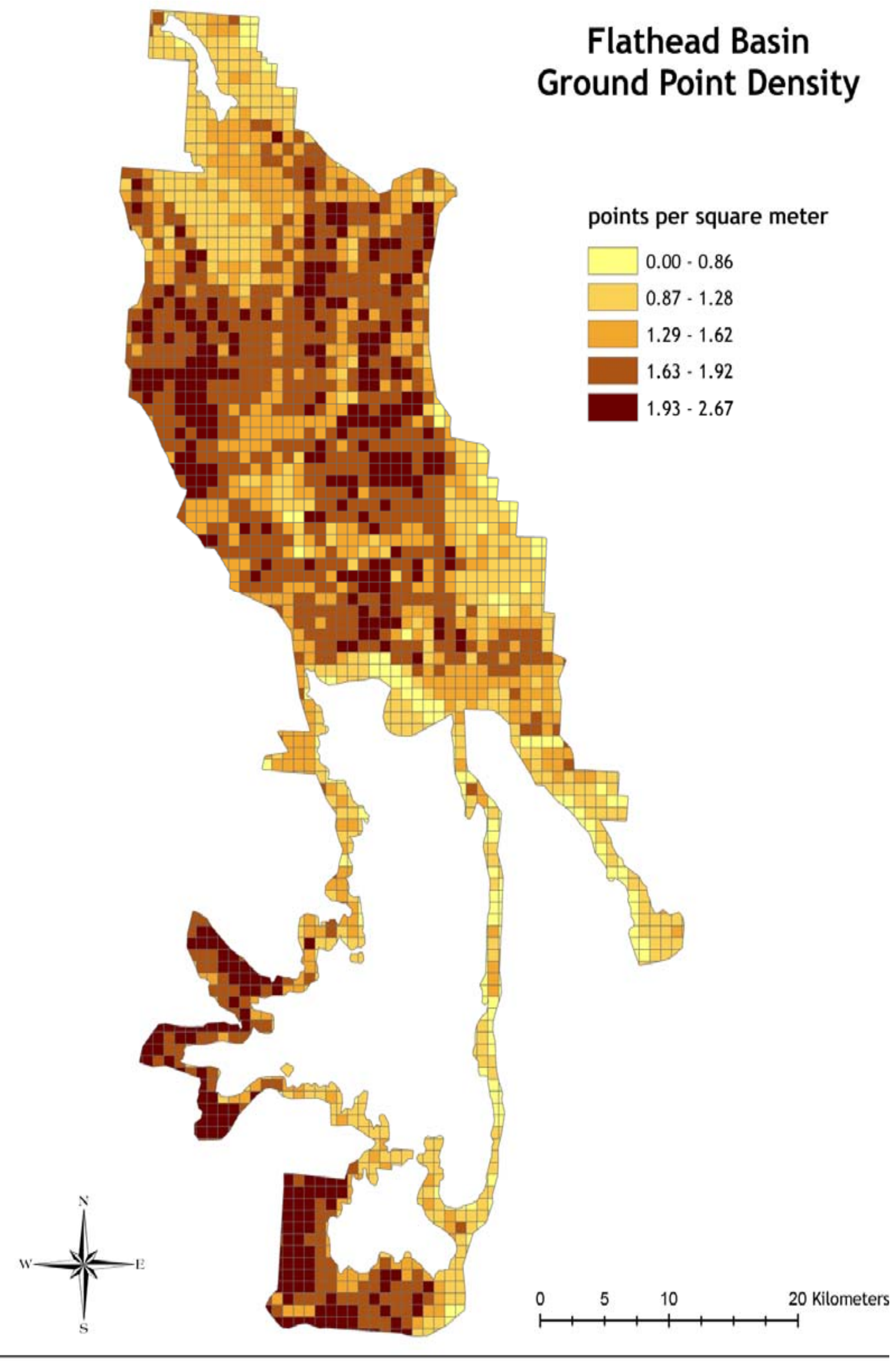


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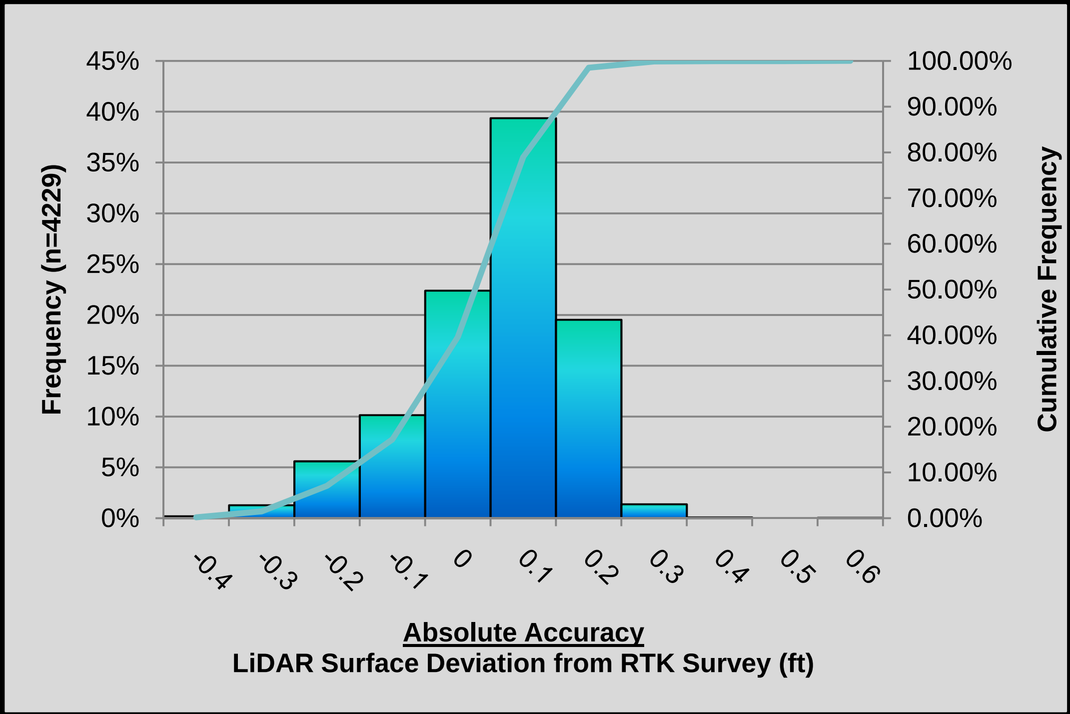
# Flathead Basin Project

## Assessed Accuracies

| Surface Type | Sample Size | RMSE |
|---|---|---|
| Hard-surface (WSI) | 4229 | 0.118 ft (0.036 m) |
| Asphalt (RDG) | 168 | 0.141 ft (0.043 m) |
| Cattails (RDG) | 27 | 1.037 ft (0.316 m) |
| Concrete (RDG) | 42 | 0.226 ft (0.069 m) |
| Cultivated Field (RDG) | 92 | 0.164 ft (0.050 m) |
| Drain Rock (RDG) | 28 | 0.178 ft (0.054 m) |
| Grass (RDG) | 49 | 0.282 ft (0.086 m) |
| Grass, Lawn (RDG) | 109 | 0.161 ft (0.049 m) |
| Gravel (RDG) | 174 | 0.178 ft (0.054 m) |
| Natural Field (RDG) | 110 | 0.392 ft (0.120 m) |
| Packed Dirt (RDG) | 57 | 0.204 ft (0.062 m) |
| Shrubs (RDG) | 22 | 0.570 ft (0.174 m) |



# Flathead Basin Project: Data Deliverables

| | |
|---|---|
| **Point Data:** | • All Returns (Las v. 1.2 format)<br>• Ground Classified Returns (Las v. 1.2 format) |
| **Vector Data:** | • AOI boundary and tiling area, (ESRI Geodatabase )<br>• 2 ft. contours, (ESRI Geodatabase)<br>• Breaklines (ESRI Geodatabase)<br>• DEM Tiling Index, (ESRI Geodatabase)<br>• Orthoimagery Tiling Index, (ESRI Geodatabase)<br>• Orthoimagery Flight Exposures (ESRI Geodatabase)<br>• *Updated Roads Layer (ESRI geodatabase)* |
| **Raster Data:** | • Elevation Models<br>- Bare earth DEM, 3-ft, ESRI Grid<br>- Bare earth DEM with breaklines enforced, 6-ft, ESRI Grid<br>• Digital Orthophotos<br>- Compressed mosaic (MrSid, 1-ft res)<br>- Compressed tiles (MrSid, 1-ft res)<br>- Uncompressed tiles (GeoTIFF, 1-ft res)<br>- Compressed near infrared tiles (MrSid, 1-ft res)<br>- Compressed near infrared mosaic (MrSid, 1-ft res)<br>- Uncompressed near infrared tiles (GeoTIFF , 1-ft res)<br>• Raw 4-Band Imagery (Tiff format) |

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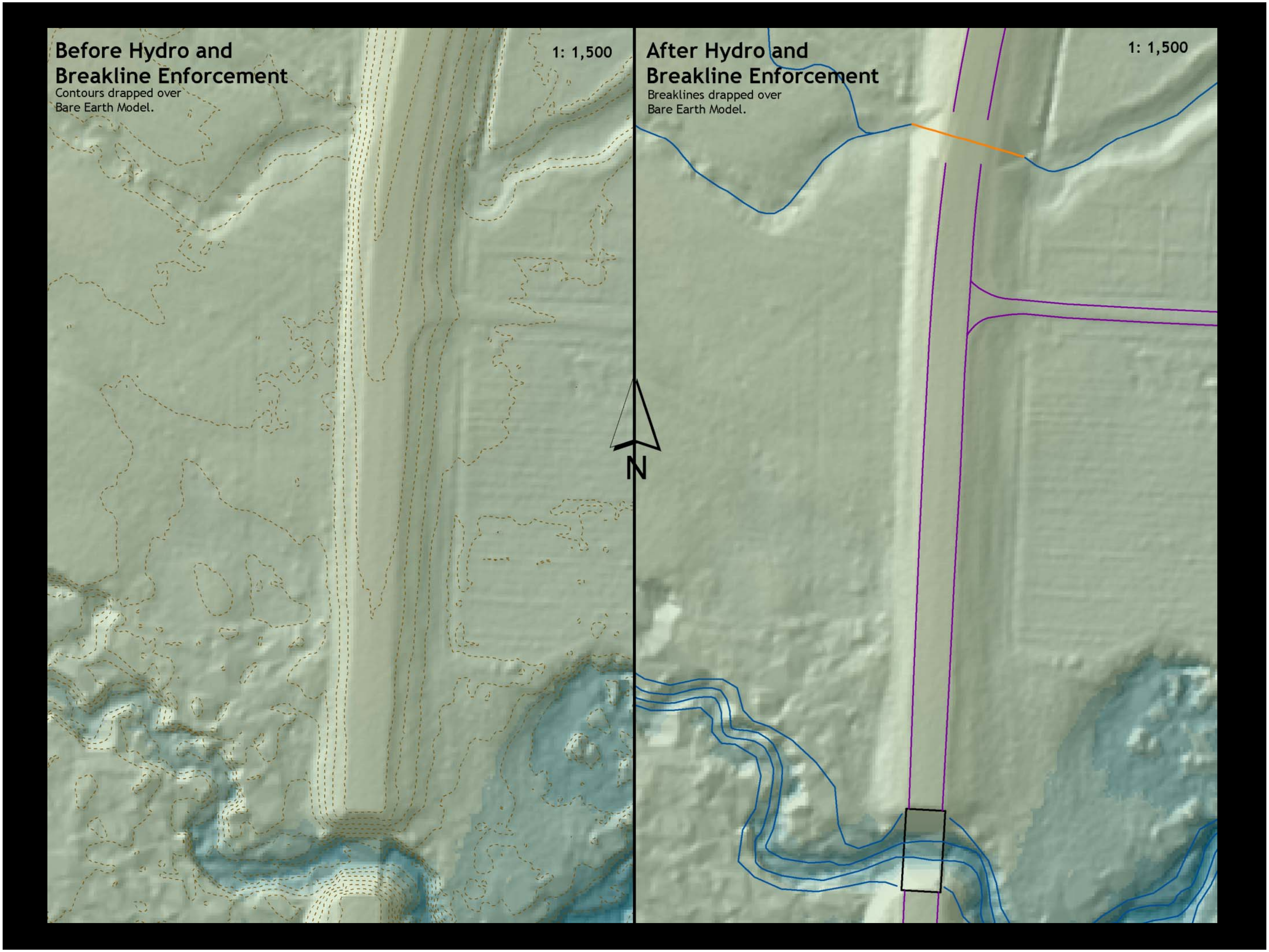
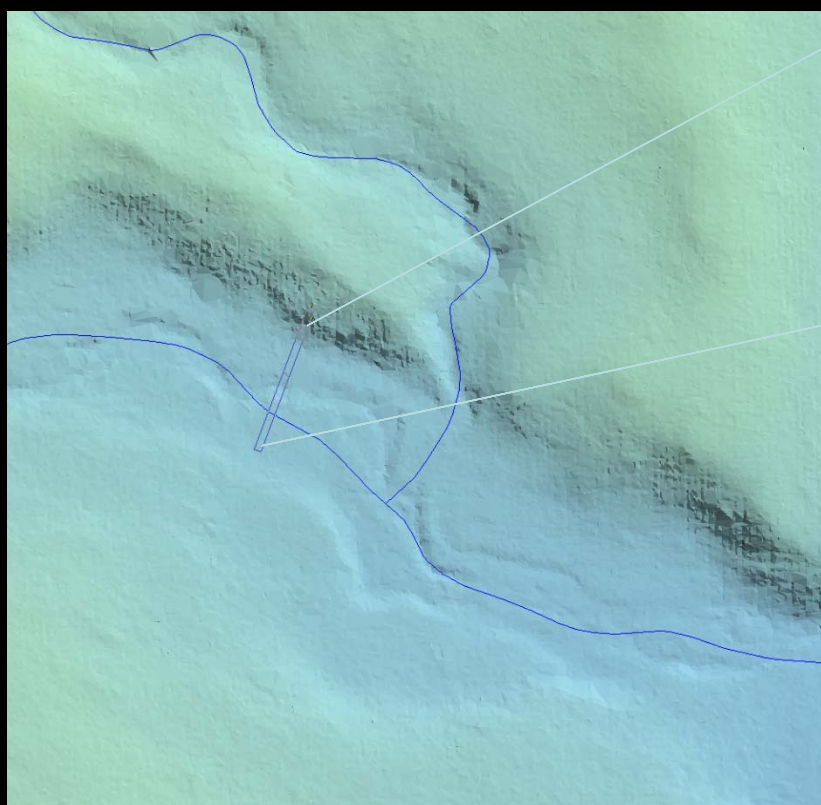
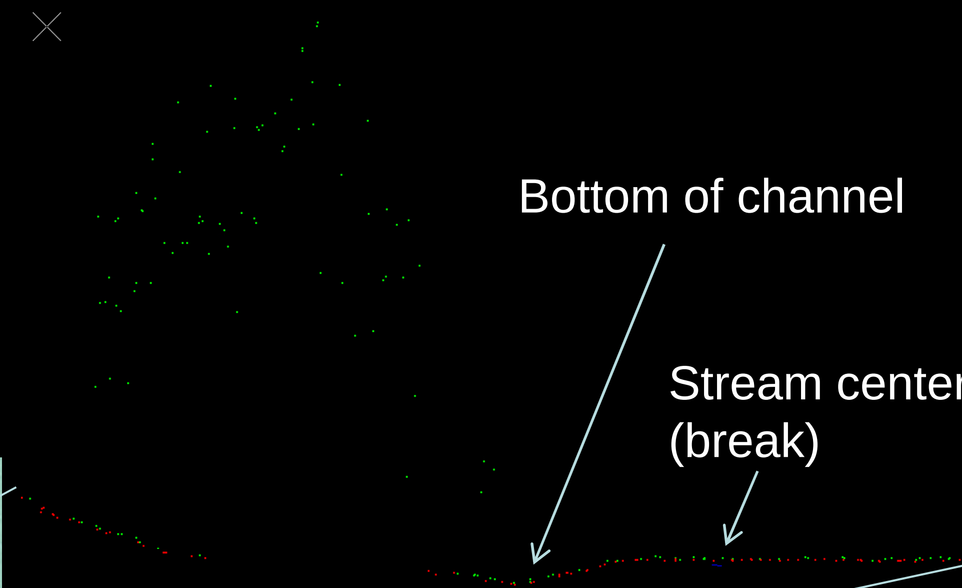

Before Hydro and Breakline Enforcement
Contours draped over Bare Earth Model.
1: 1,500
After Hydro and Breakline Enforcement
Breaklines draped over Bare Earth Model.
1: 1,500
N

# Breaklines collected for the Flathead study area

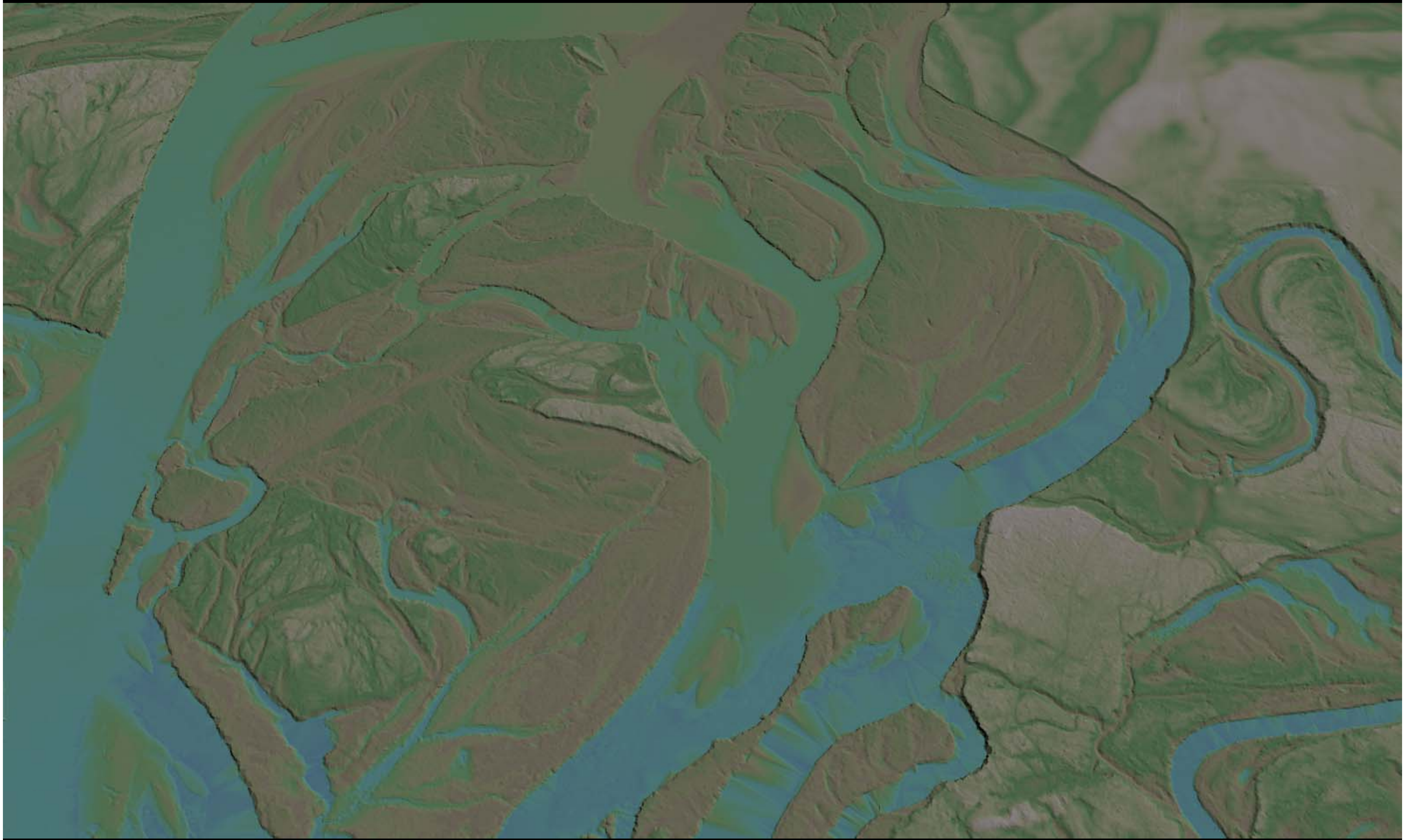
| **Feature** | **Implementation** |
| --- | --- |
| Hydro Break Earthen | Aid ground classificaton |
| Hydro Canal | Aid ground classificaton |
| Hydro Dam Concrete | Aid ground classificaton |
| Hydro Dam Earthen | Aid ground classificaton |
| Hydro Ditch Bottom | Aid ground classificaton |
| Hydro Ditch Top | Aid ground classificaton |
| Hydro Stream Bank Top | Aid ground classificaton |
| Hydro Stream Interm | Soft Breakline |
| Hydro Stream Perennial | Soft Breakline |
| Hydro Stream Disappear PNT | Provided as feature |
| Hydro Waterbody | Soft Breakline |
| Trans Airport Runway | Hard Breakline |
| Trans Airport Taxiway | Hard Breakline |
| Trans Road Paved Edge | Hard Breakline |
| Trans Road Unpaved Edge | Hard Breakline |
| Trans Road Private Paved Edge | Hard Breakline |
| Trans Road Private Unpaved Edge | Hard Breakline |
| Breakline Misc | Aid ground classificaton |

# Breakline Implementation



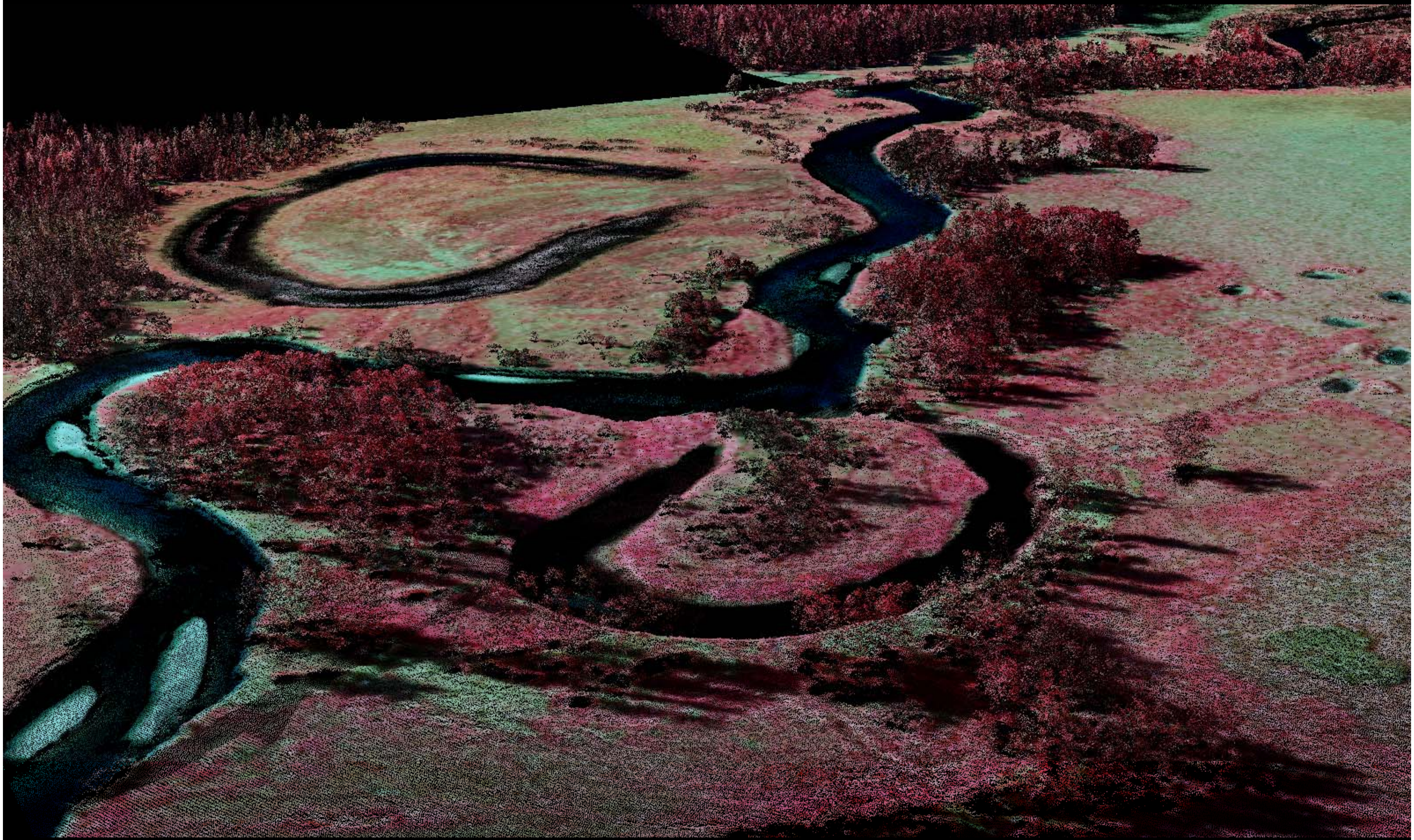


# Flathead Basin LiDAR



Flathead River east of Kalispell, MT;  1-meter Bare Earth DEM

# Flathead Basin Remote Sensing



Looking Northwest at Swan River ; Point Cloud Assigned NIR

Flathead Basin Remote Sensing – Fly Thru

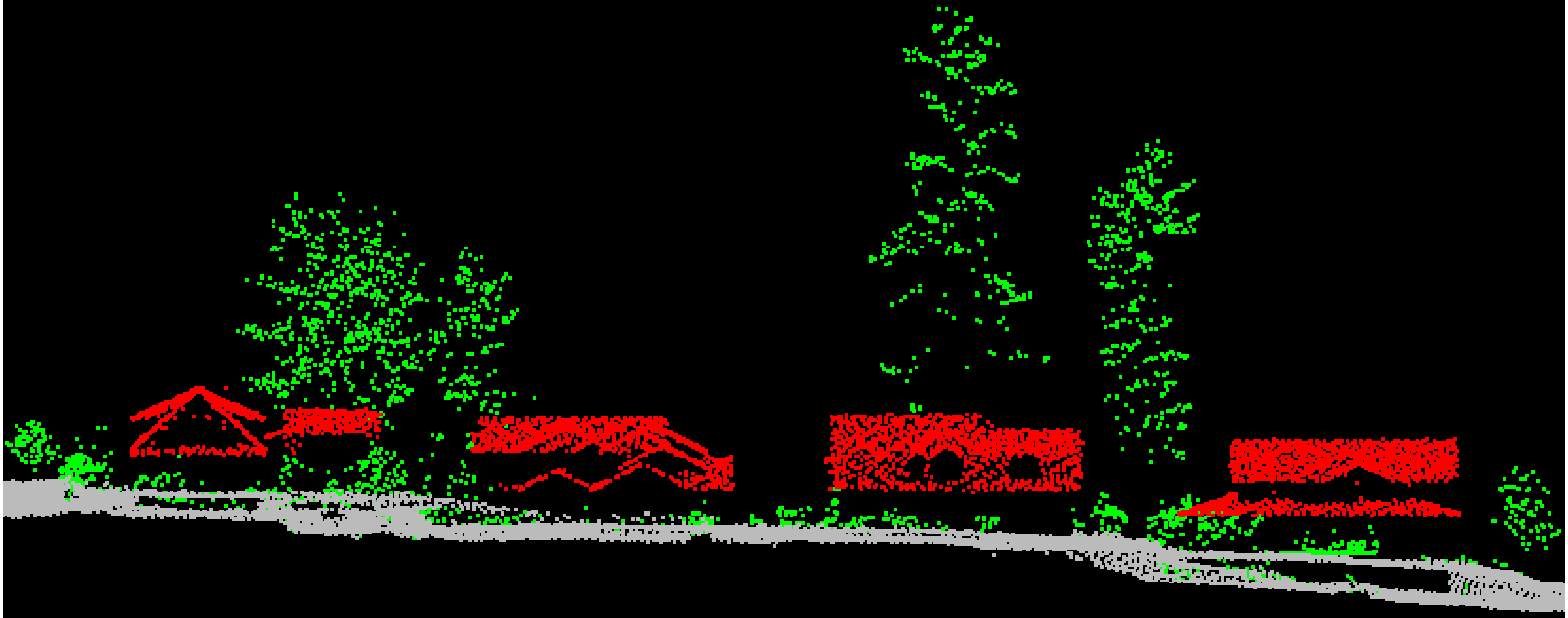
# Flathead Basin Remote Sensing

Looking West Southwest at the town of Polson, MT; Point Cloud Assigned RGB

# Flathead Basin Remote Sensing

Looking Southeast at the City of Whitefish, MT; Point Cloud Assigned RGB

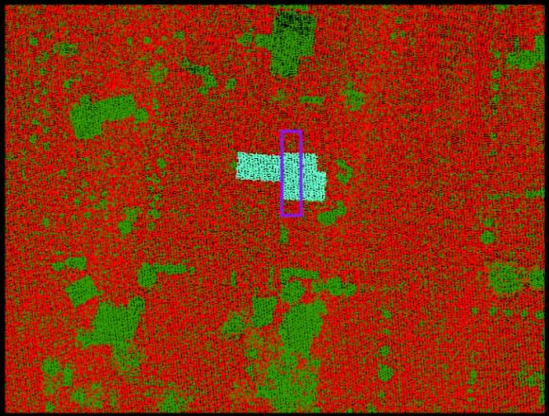
# Part 3: LiDAR Applications



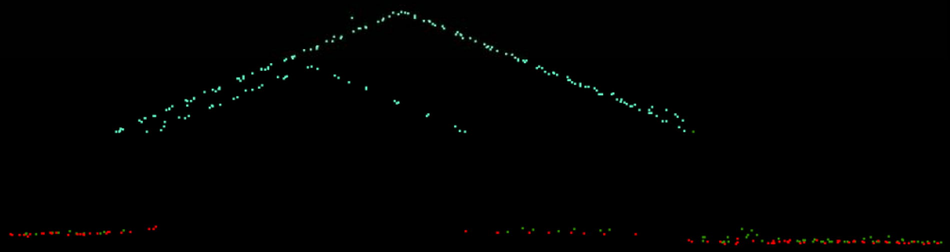
Resulting data classifications are ground, buildings and vegetation.

# Classification of Buildings/Structures

A



B



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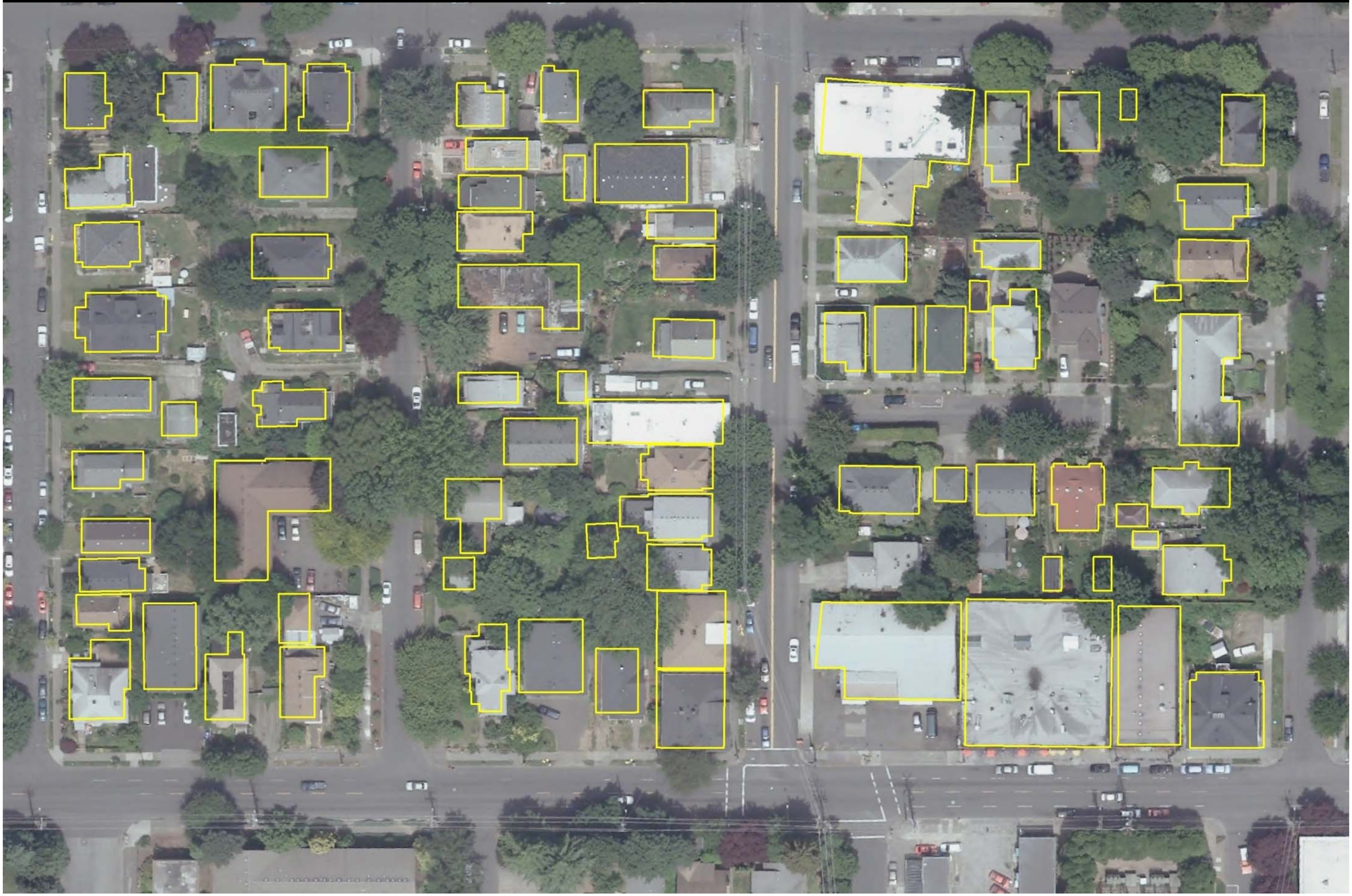
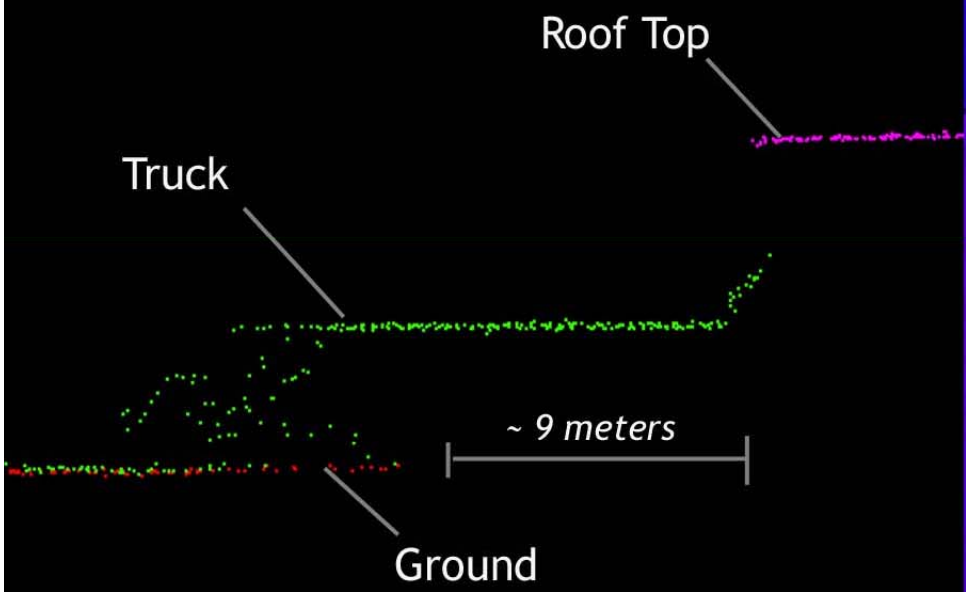
Flathead Basin Remote Sensing

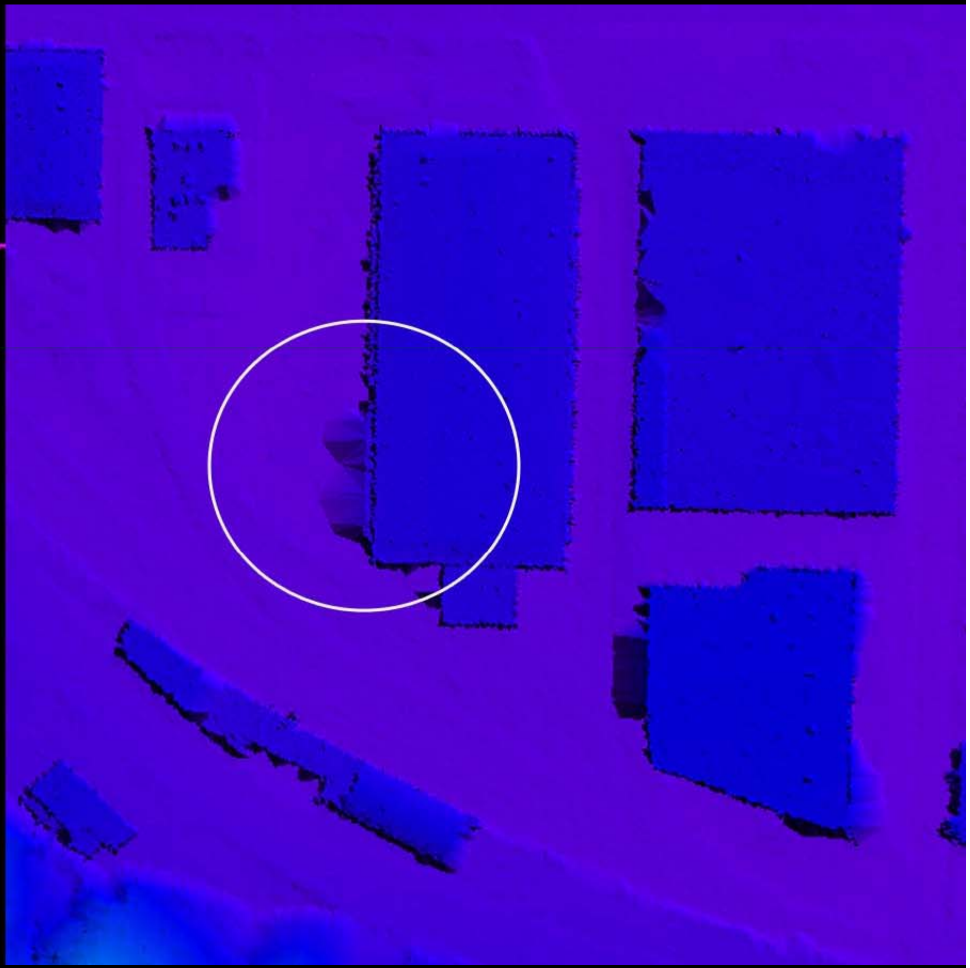
# Removal of Buildings/Structures

# Removal of Buildings/Structures



# Building Extraction: Challenges

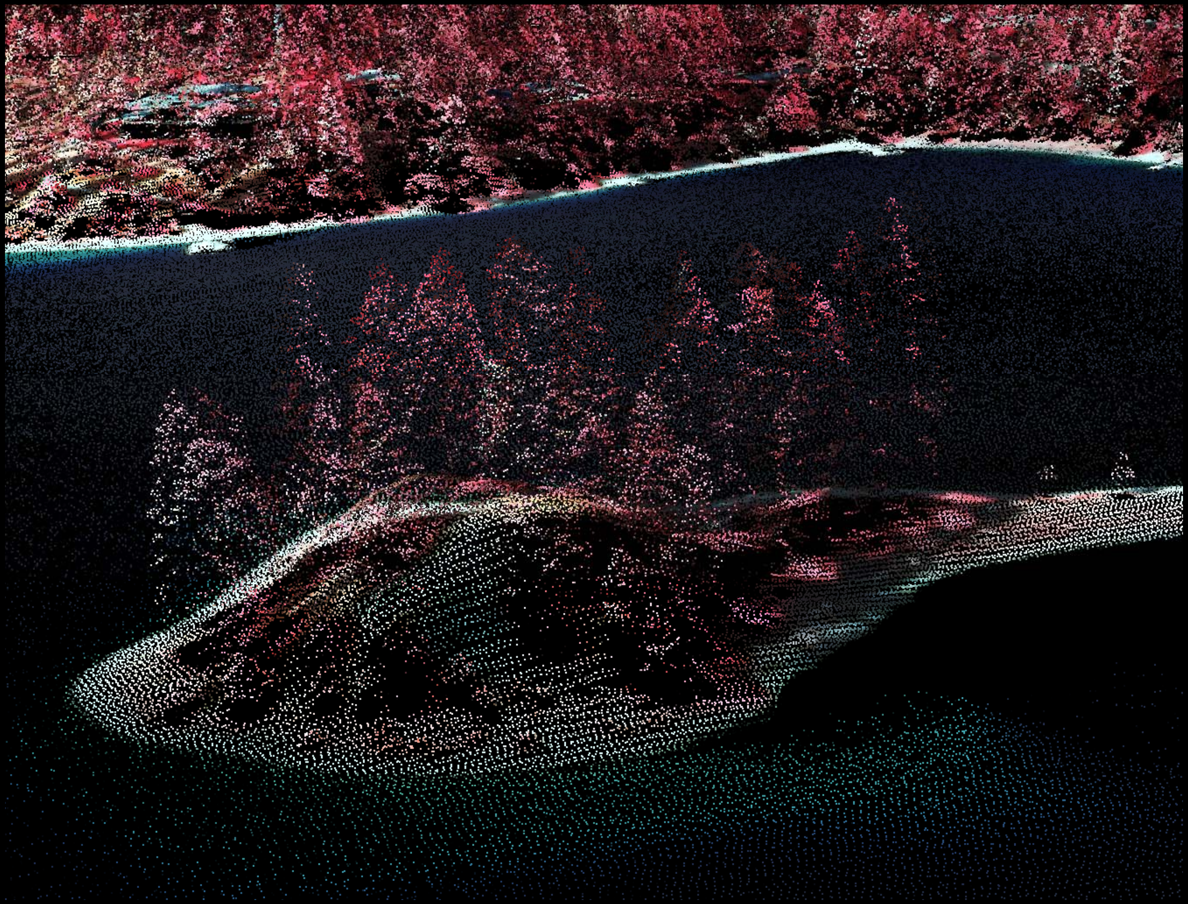


- Industrial areas often have semi-trucks and trains.
- Care must be taken to not classify trucks as buildings.

# Vegetation Characterization

LiDAR point cloud provides the basis for deriving vegetation metrics to characterize structure at the stand or tree approximate scale.



Swan Lake; Flathead Basin

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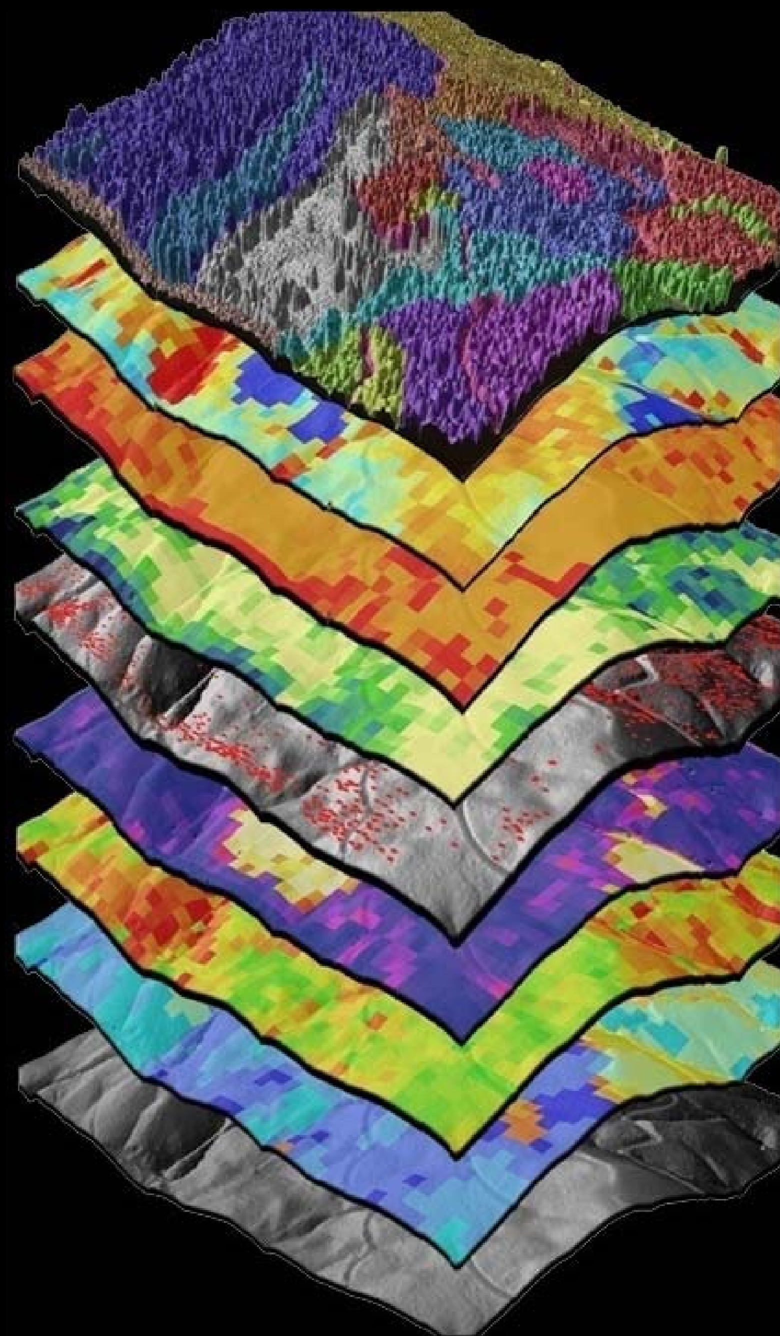
# Automated Data Strata Sampling

WSI LiDAR Feature Extraction Tool: In-house tool developed to generate vegetation metrics and other feature classifications. Capable of generating over 114 metrics/data strata.

# Common Vegetation Metrics:

**PCA selection of data strata can vary depending on the land cover and analysis objectives.**

- **<u>Vegetation Height (P90):</u> Height at which 90% of LiDAR returns fall below.**
- **<u>Stem Density:</u>** # of local maxima per cell. Relative measure of density between forest stands.
- **<u>Standard Deviation of Height:</u> Std deviation of local maxima per cell.**
- **<u>Canopy Cover:</u> % total returns over returns above a specified threshold.**
- **<u>Canopy Height Model:</u> Point elevations normalize to ground elevations.**
- **<u>LiDAR Intensities:</u> Normalized 1$^{st}$ return intensities.**



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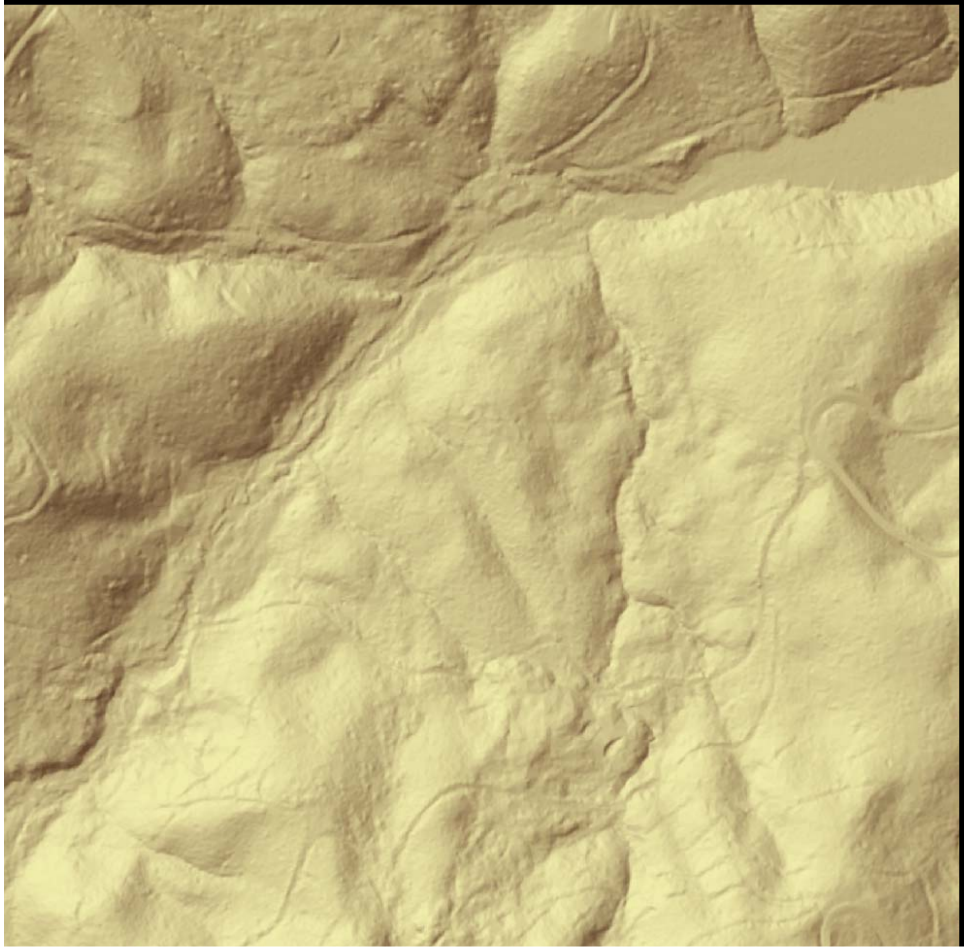
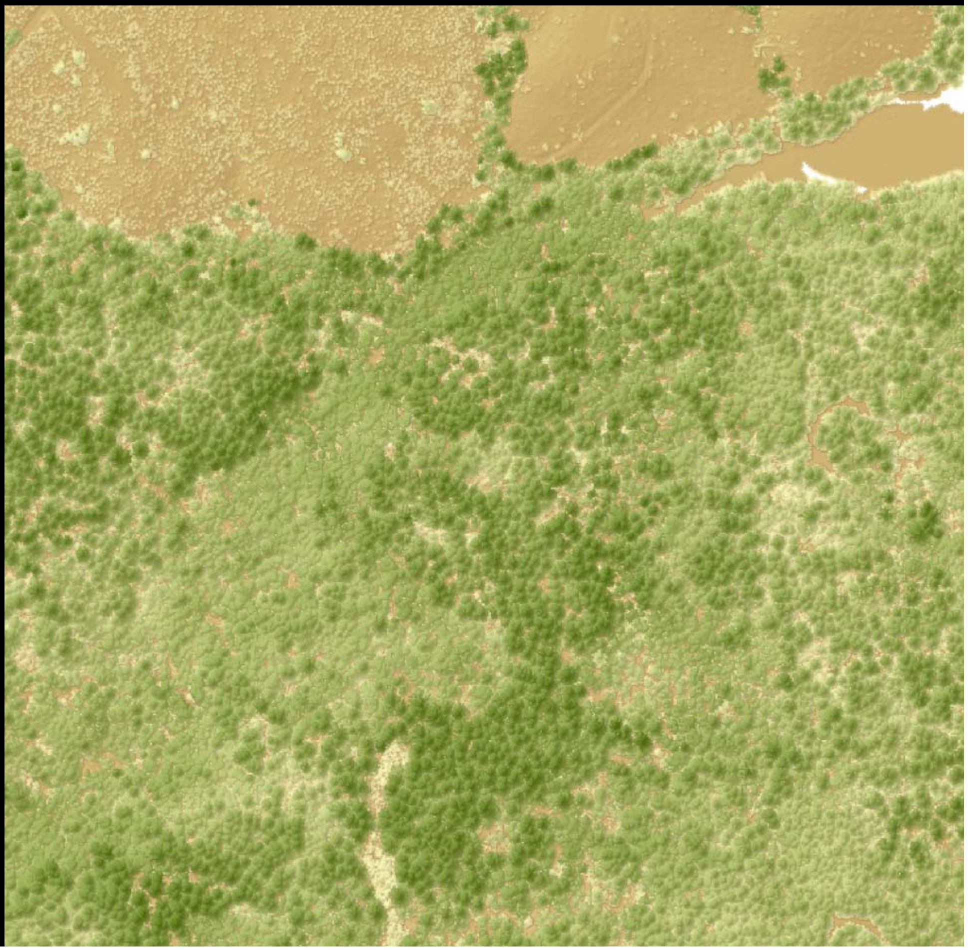
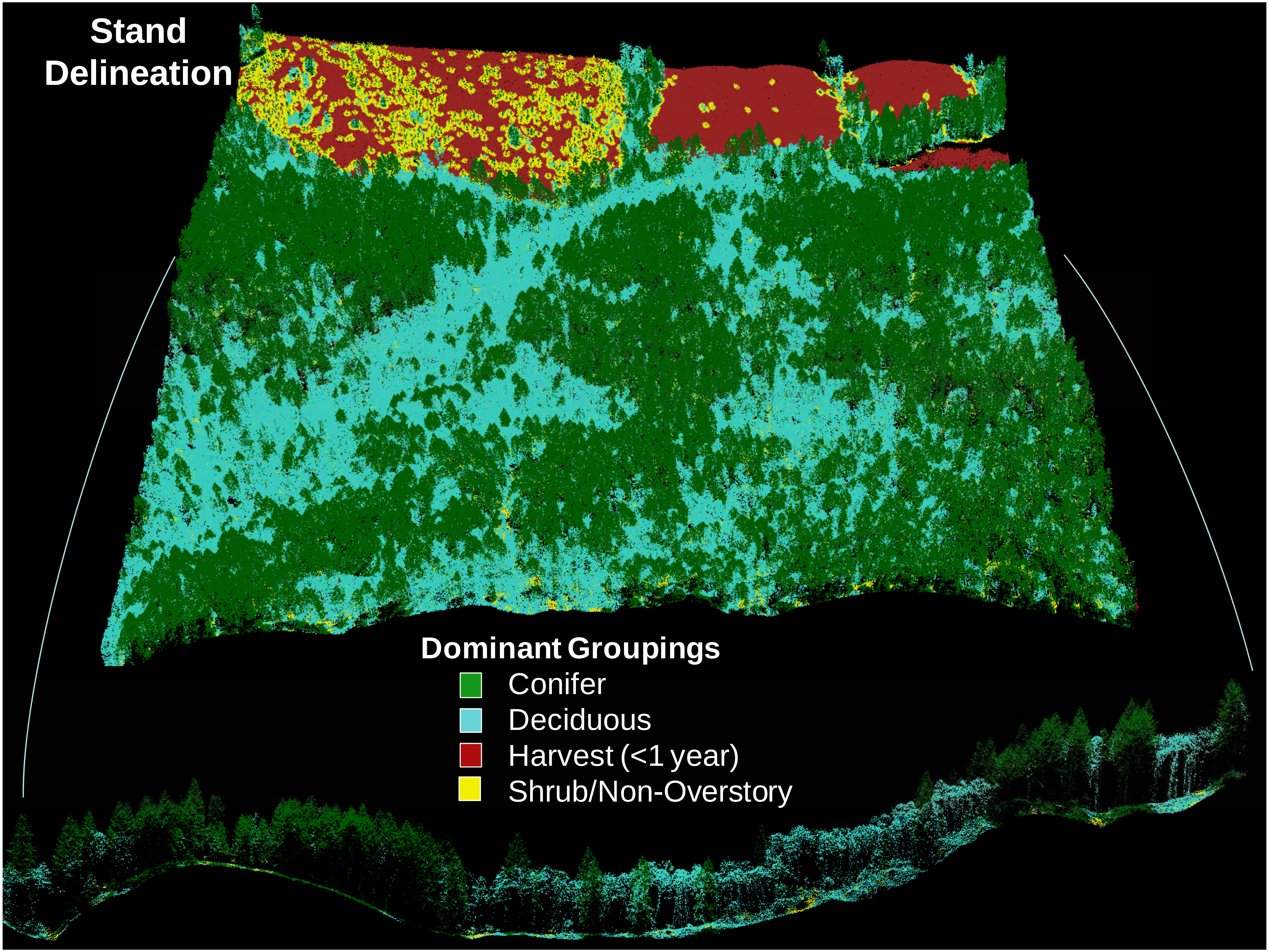
# Stand Delineation

Bare Earth



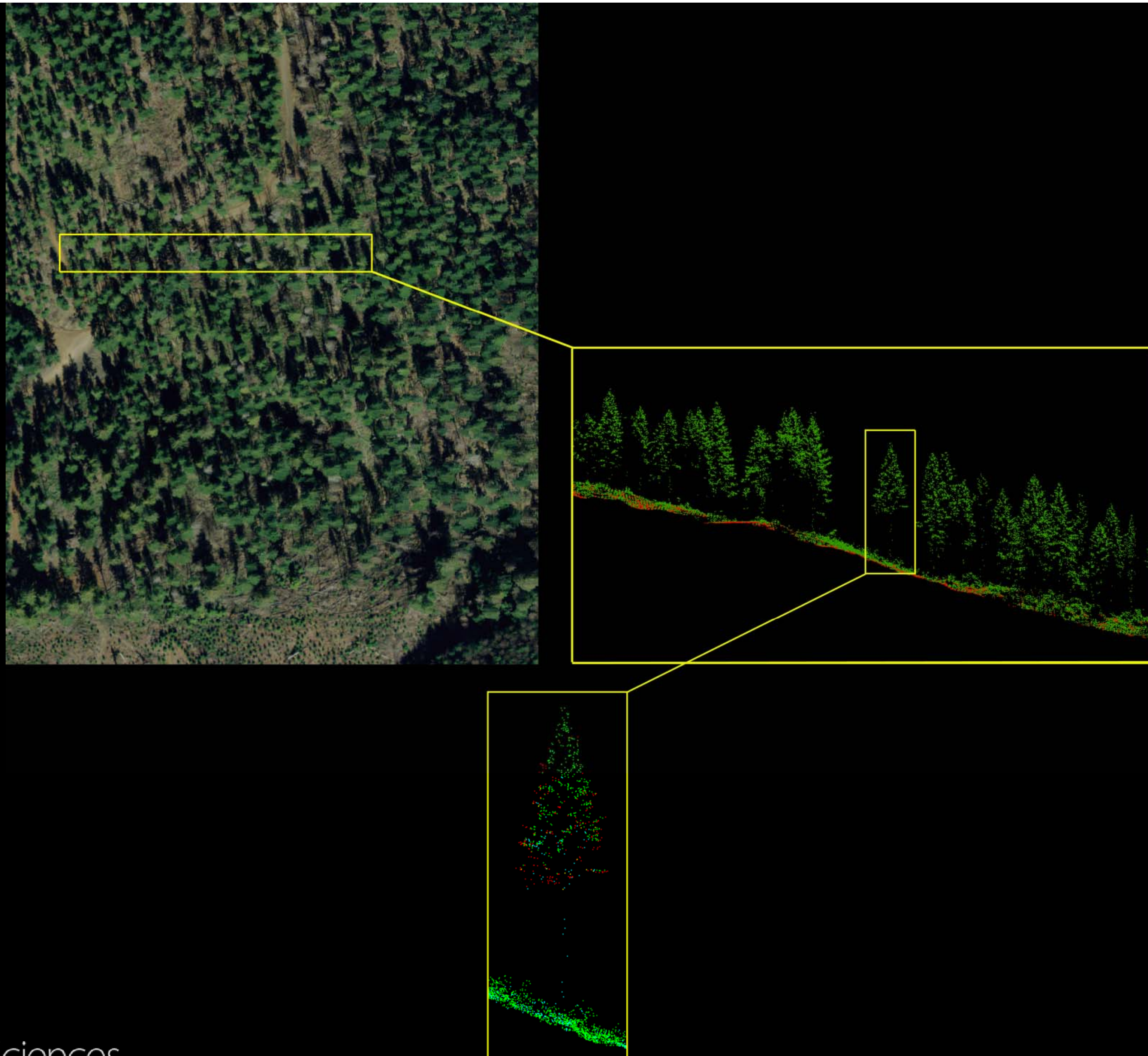
Highest Hit




Stand
Delineation
Dominant Groupings
Conifer
Deciduous
Harvest (<1 year)
Shrub/Non-Overstory

# Tree Level Segmentation

## Vegetation Height Clusters



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# Individual Tree Metrics: Height

Individual tree height is a critical in variable in forest biomass, carbon stocks, and growth and site productivity.

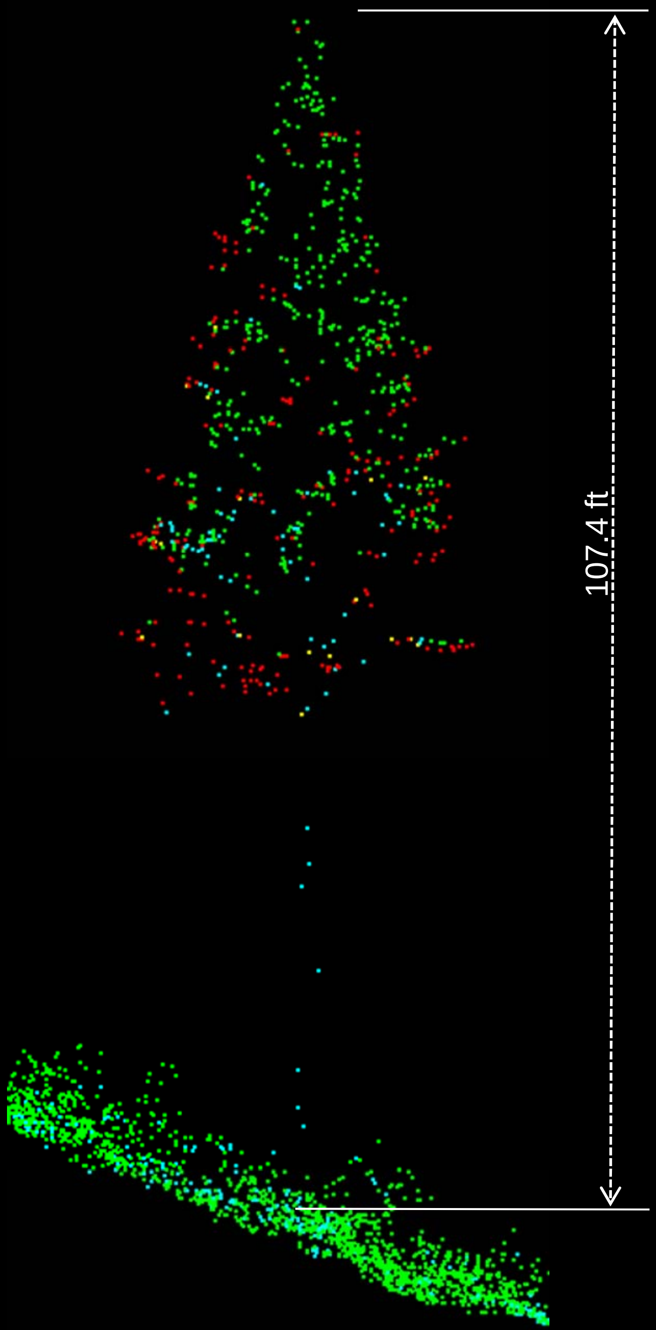
DBH is not measured directly, but highly correlated w/ LiDAR derived tree height and crown width

Individual Height Accuracies (Anderson et. al.):

LiDAR @ 6 pulses/sq m:

| | |
|---|---|
| *Ponderosa Pine:* | *-0.43 ±0.13 m* |
| *Douglas Fir:* | *-1.05 ±0.41 m* |
| *Field Techniques:* | *-0.27 ±0.27 m* |

Digital Terrain Accuracy Directly Impacts on Individual Tree Height Measurements.



# Tree Level Segmentation

Conifers have Distinguishable Crowns

Multiple-Methods for Segmentation:

- Inverse Canopy Height Model
- Physical Similarity Delineations
- Object Oriented/Rules Based

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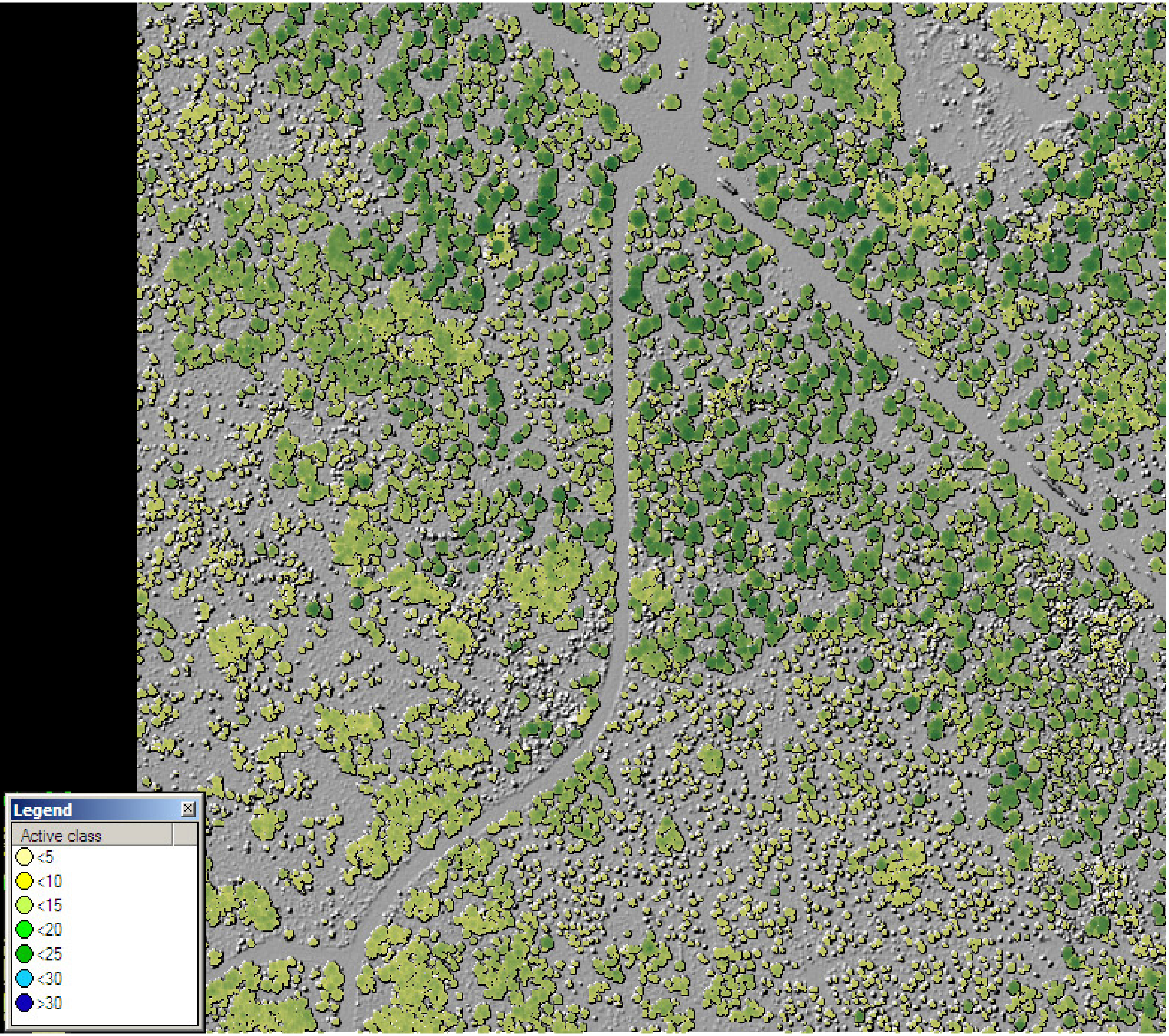
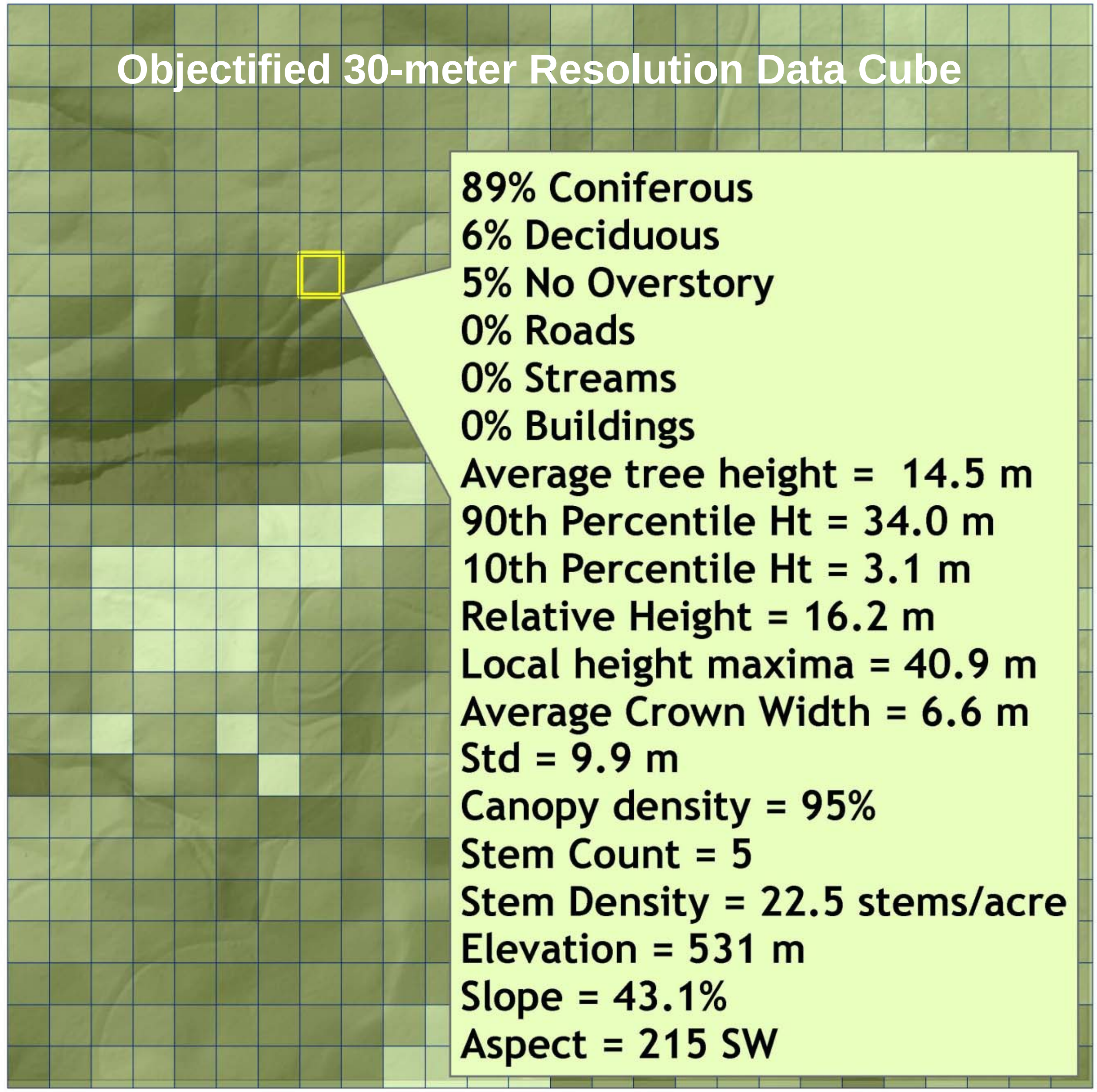
# Tree Cluster Level Classification

## Physical Similarity Delineations



# Ongoing Developments: Stand Level Classification

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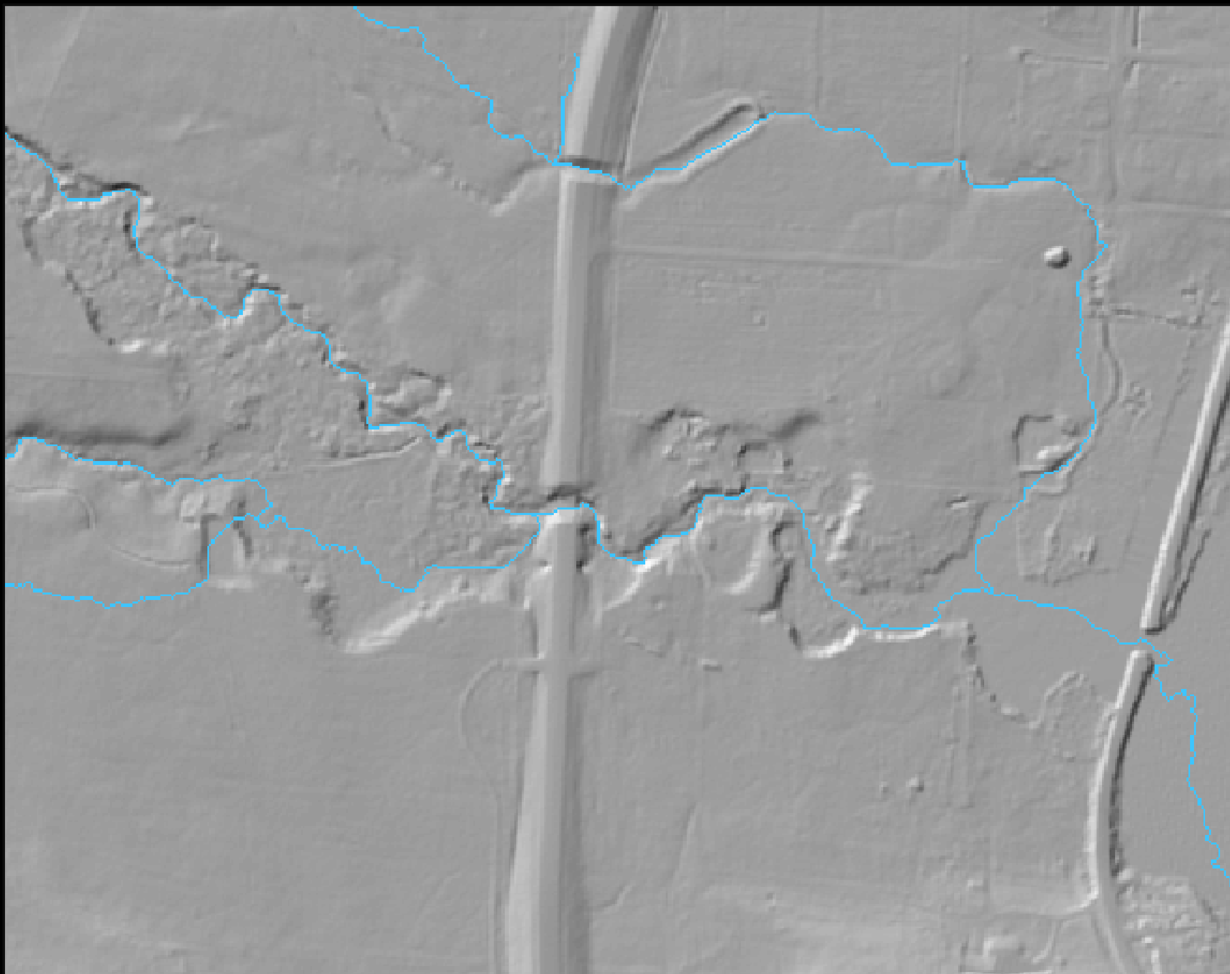
# Stream/Wetland Delineation



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# Other Common Applications

- Landslide Detection and Mapping
- Flood Hazard Mapping
- Volume Calculation/Change Detection

*Mount St. Helens Dome Growth over 20 Day Period - 2004*

*September 24* *September 30* *October 14*

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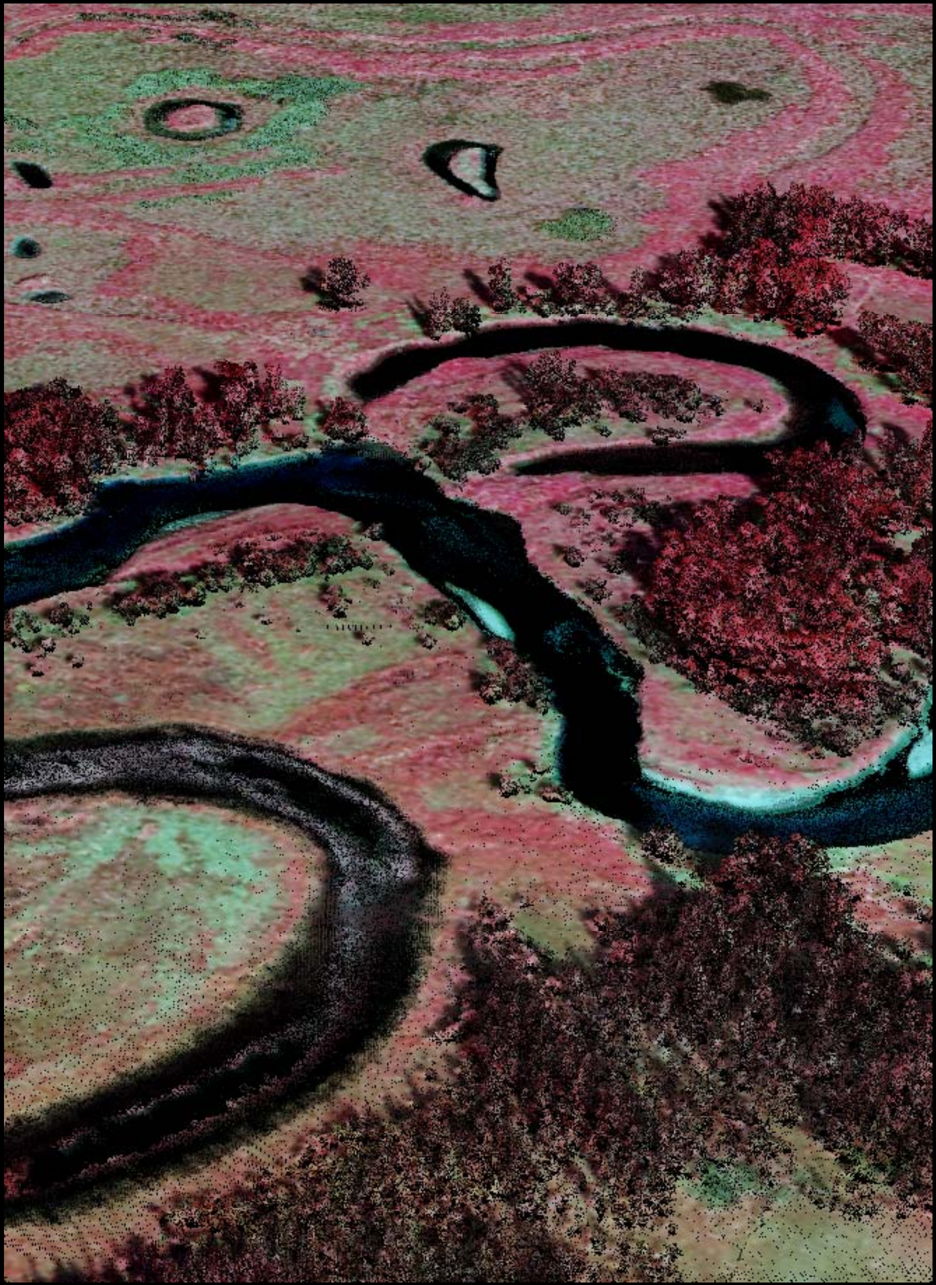
## Thank you

Montana DNRC

Lake and Kalispell Counties

Polson, Kalispell, Whitefish

Project Team:
River Design Group
3Di West



## Contact Information

Russ Faux
541-752-1204
faux@watershedsciences.com

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