Northwest **Power** and
Conservation Council

December 7, 2021

MEMORANDUM

TO: **Fish and Wildlife Committee Members**

FROM: **Leslie Bach**

SUBJECT: **Remote sensing tools for habitat assessment, restoration planning, monitoring and evaluation.**

BACKGROUND:

Presenters: Brandon Overstreet, U.S. Geological Survey, George Fornes, Washington Department of Fish and Wildlife and Phil Roni, Cramer Fish Sciences

Summary: The panel presentation will describe new tools and technological advances in remote sensing applications for habitat work. Panelists will touch on a variety of tools including Light Detection and Ranging (LiDAR), Unoccupied Aerial Vehicles (UAVs, aka drones) and Multi-spectral satellite imagery. They will describe various applications of the tools to accomplish multiple phases of the habitat protection and restoration process.

Relevance: Protecting, enhancing and restoring habitat for fish and wildlife is a key component of the Columbia Basin Fish and Wildlife Program and is identified in multiple strategies. Implementation of habitat projects has developed and evolved over time. The Program recognizes and promotes an adaptive management approach to implementation, which provides a systematic process to develop, execute, learn and improve the strategies used to mitigate, protect and enhance for the impacts of the hydrosystem on the Basin's fish, wildlife and their habitat. The Council has long supported the development and testing of innovative approaches to implementing and testing the strategies in the Fish and Wildlife Program.

Background: Habitat protection and restoration involves a multi-step process to identify, design, implement and evaluate projects and actions. Historically the data and information utilized in these activities was collected and compiled through ground-based measurements. Often restoration sites are difficult to access, or cover significantly large areas, making ground-based measurements sometimes challenging and time-consuming. Recent advances in remote sensing technology and decreases in costs have expanded the set of tools available to restoration practitioners and managers in developing and implementing habitat projects. Remote sensing offers a rapidly growing suite of methods by which aquatic system assessment can be performed efficiently, at multiple spatial scales and in areas that may be difficult to access directly. These methods include a range of sensor types, mounted on a variety of platforms including satellite, airborne and ground-based systems.

A remote sensing approach to inform adaptive management: an example from the Willamette Basin

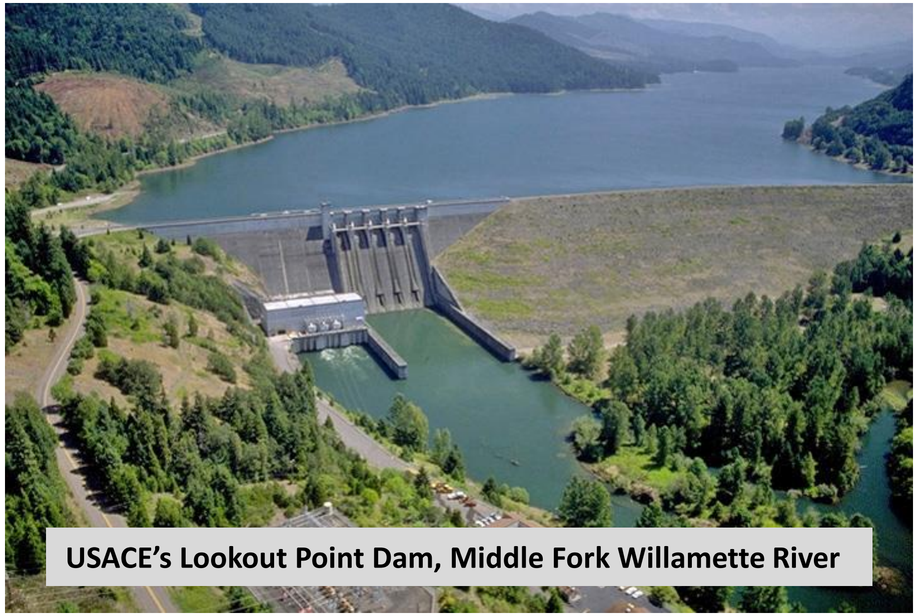
Brandon Overstreet, James White, and Rose Wallick

USGS Oregon Water Science Center

Northwest Power and Conservation Council Meeting

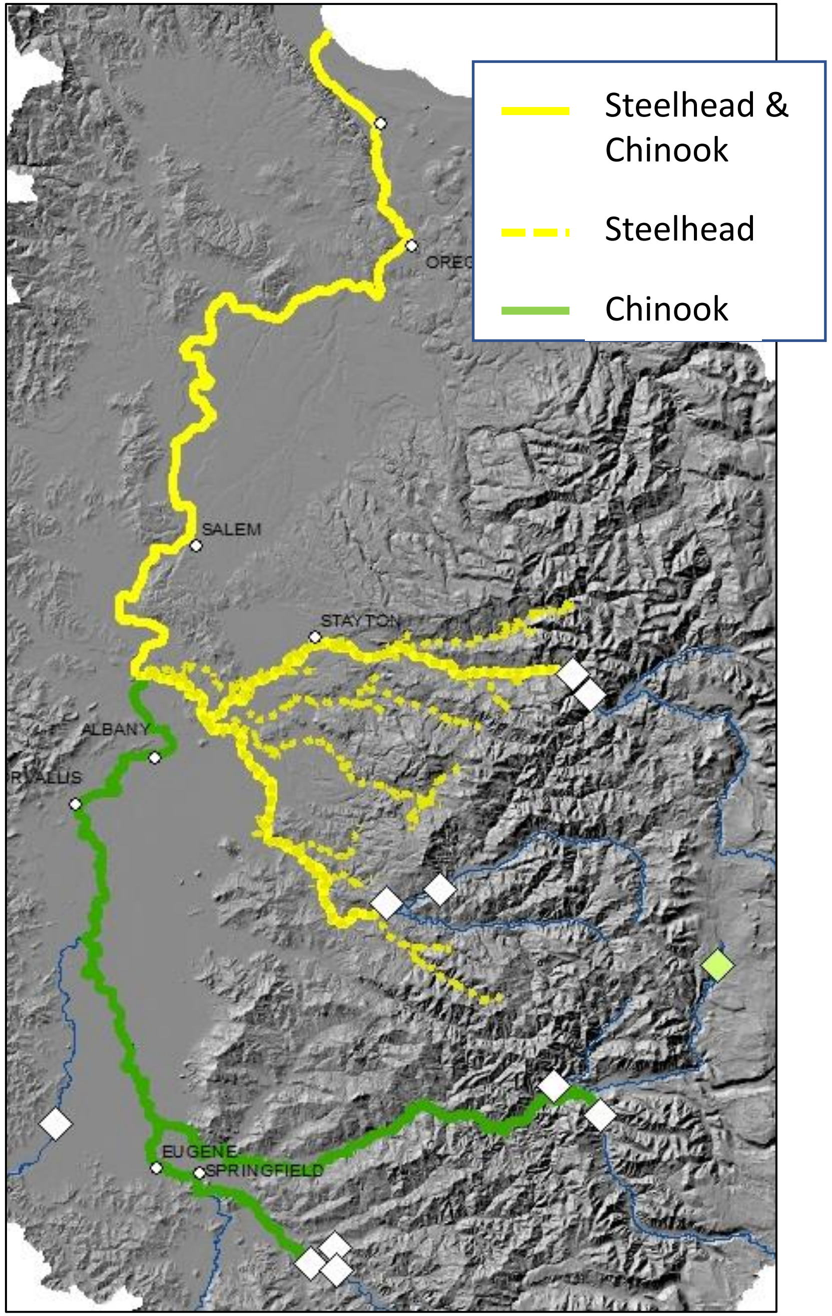
Informing adaptively managed flow and restoration programs in the Willamette basin often requires cost-effective remote sensing approaches

Figure from Warren and others, 2019



USACE's Lookout Point Dam, Middle Fork Willamette River

Willamette River near Eugene, confluence of Middle Fork and Coast Fork Willamette Rivers; April 8, 2019 flood



Photographs from USACE and R. Wallick (USGS); Map by R. Wallick (USGS) based on NOAA Critical Habitat maps.

Questions that motivate our Willamette Basin science

What are the geomorphic impacts dam operations that pass juvenile salmon but also release fine sediment?

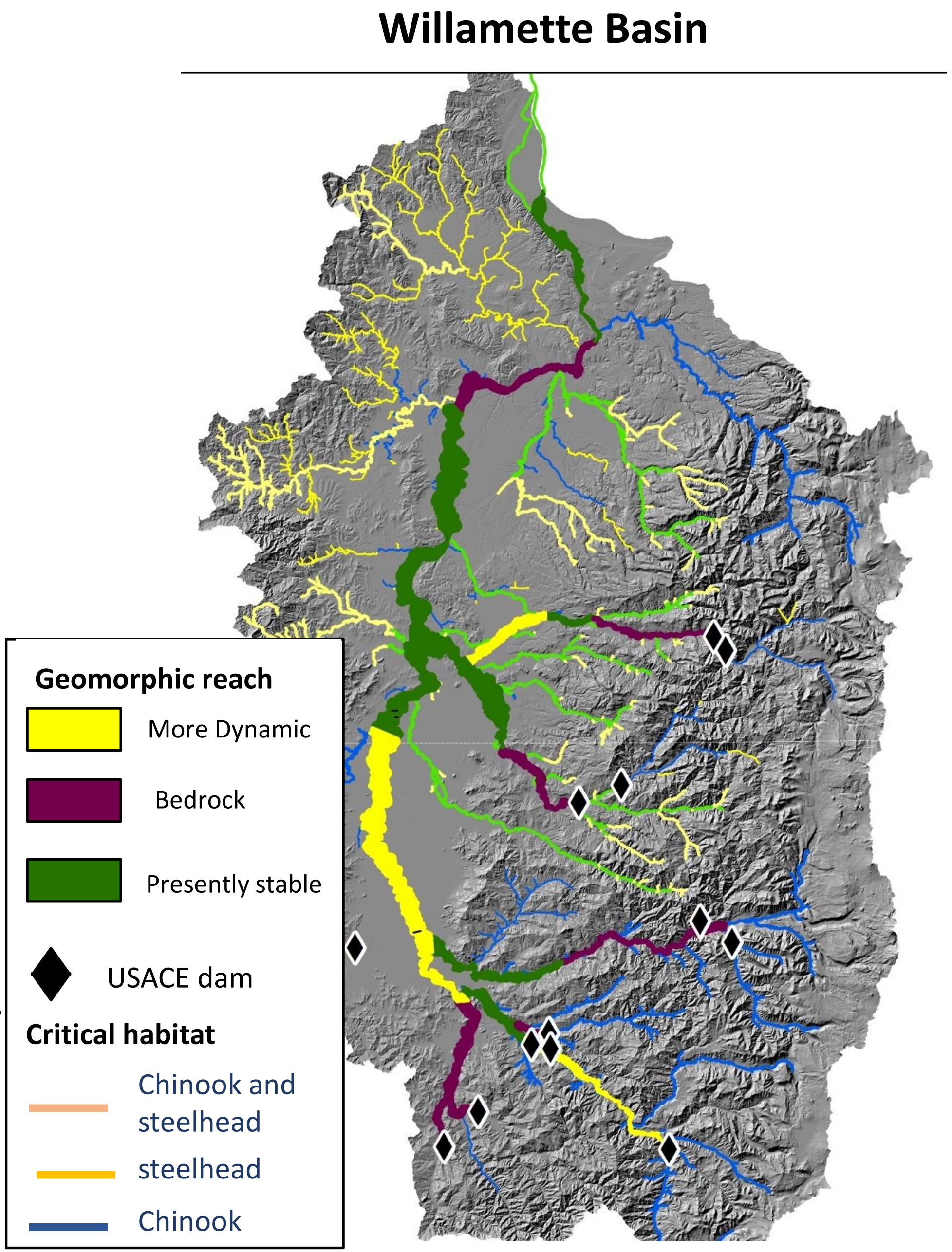
How does below-dam rearing habitat for ESA-listed salmon vary through the year and along the river network?

How effective are large-scale restoration projects at increasing below-dam rearing habitat and addressing habitat limitations?

How can we affordably track changes in bathymetry, habitats and hazards with publicly available imagery?

How much of the Willamette River system is lethal or sub-optimal for salmon, and what can be done to improve temperature conditions?

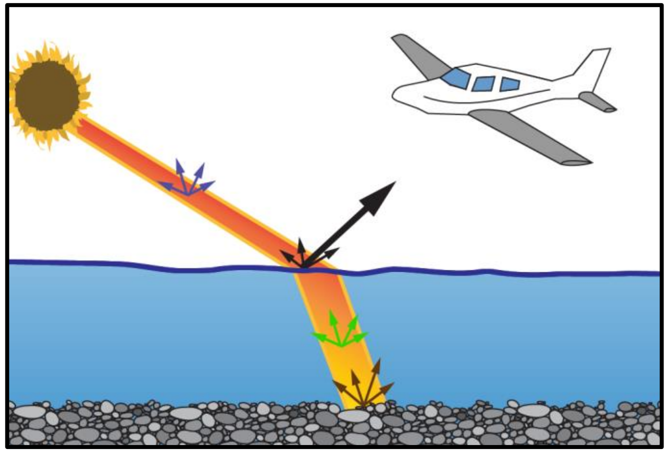
What are the implications of present-day patterns of habitat, temperature and non-native predatory fish and what can be done about it?



Provisional USGS mapping adapted from Wallick and others, 2013 and NOAA Critical Habitat Maps. Do not cite

Remote sensing technology

Passive Sensors



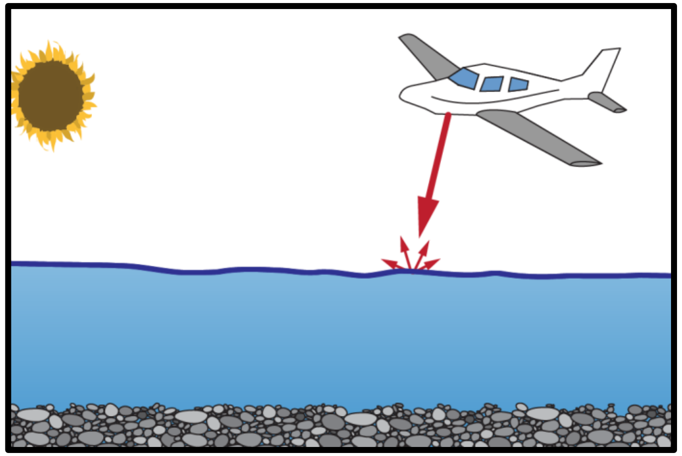
Examples

- Visible and near-infrared imagery
- Thermal imagery

River Attributes

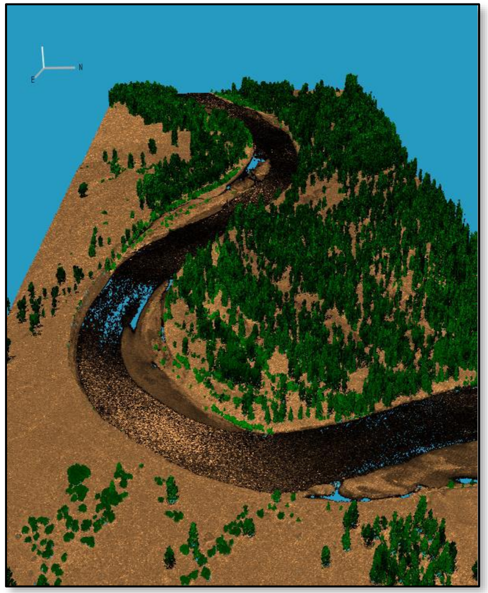
- Streamside veg/shading
- Inundation
- Water temp.
- Geomorphic features
- Bathymetry

Active Sensors



- Topographic LiDAR
- Bathymetric Lidar
- Radar
- Sonar

- Topography/swales and side channels
- Vegetation height
- Water surface elevation
- Bathymetry



Remote sensing data across river scales

Catchment

Landsat 8 satellite imagery,
9 spectral bands
100 foot pixel resolution
15 day repeat

Reach

NAIP aerial imagery,
4 spectral bands (R,G,B,NIR)
2 foot pixel resolution
Bi-annual collection

Hydraulic Unit

UAS aerial imagery,
3 Spectral Bands
1 inch pixel resolution

Management focused remote sensing

SCIENTIFIC QUESTION

↓

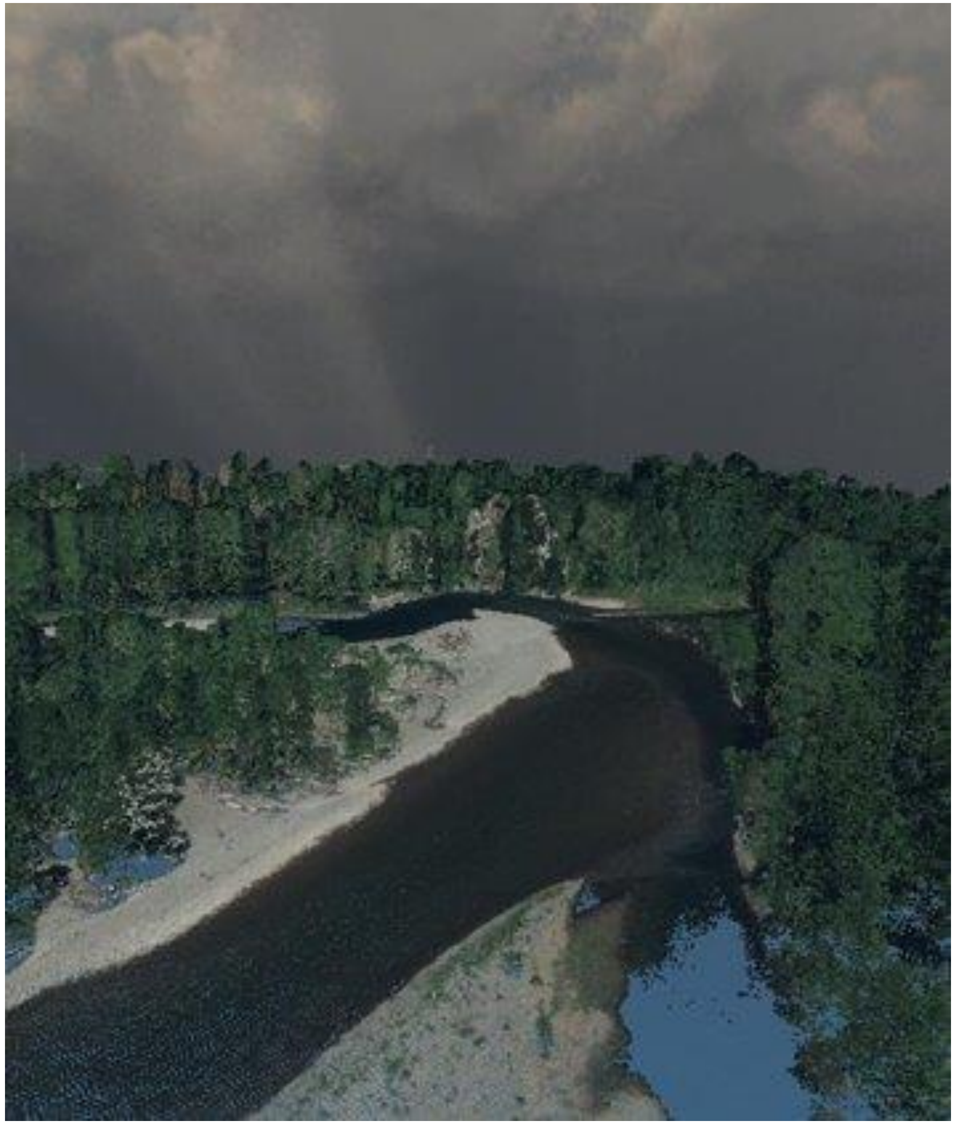
RIVER ATTRIBUTES *NEEDED*

↓

SCALE, FREQUENCY, AND RESOLUTION

↓

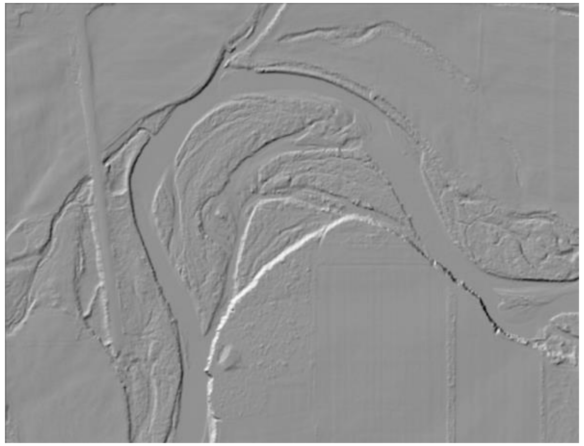
DATA/METHOD AVAILABILITY



Case study: Modeling salmon habitat in the Willamette River Watershed

SCIENTIFIC QUESTION	How does juvenile Chinook salmon rearing habitat vary with instream flow targets across river reaches
RIVER ATTRIBUTES *NEEDED*	River bathymetry and floodplain topography to support flow modeling
SCALE, FREQUENCY, AND RESOLUTION	River scale, high-resolution (1 – 2 meters)
DATA/METHOD AVAILABILITY	Lidar for floodplain topography, NAIP imagery for image-derived bathymetry

High resolution imagery. Source: USDA National Ag. Imagery Program



Topographic lidar. Source: Oregon Department of Geology and Mineral Industries

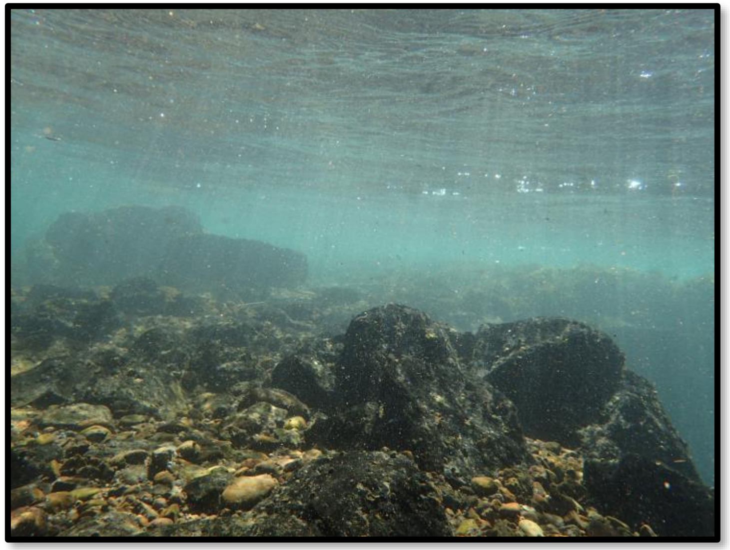
USGS

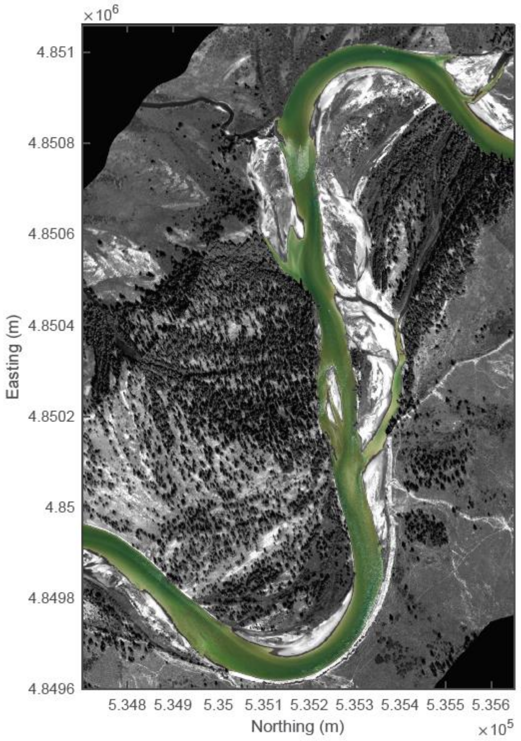
Mapping water depth from river imagery

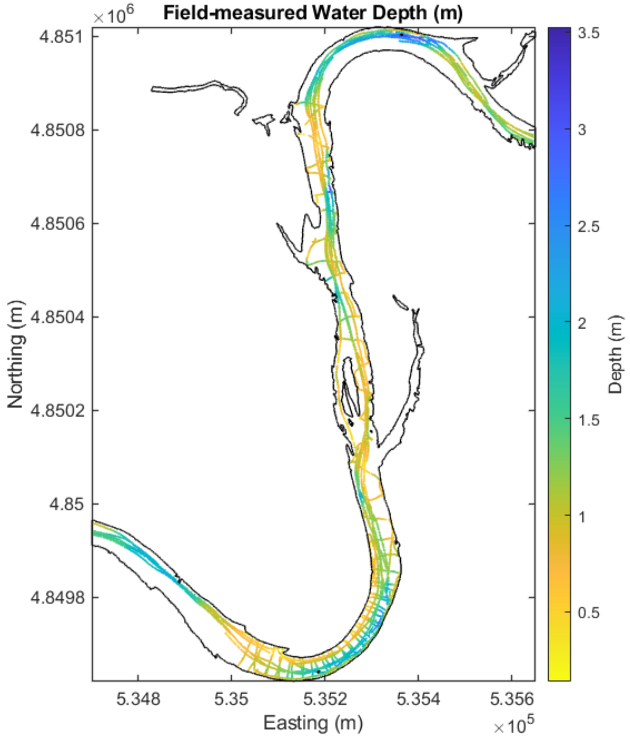
- Absorption of light in water provides a signature of water depth in river imagery.
- We can isolate the absorption of light in river imagery by taking the ratio of two image bands.

$$X = ln\left[\frac{R(\lambda_1)}{R(\lambda_2)}\right]$$

- Define equation that expresses water depth as a function of the band ratio calculated for each image pixel



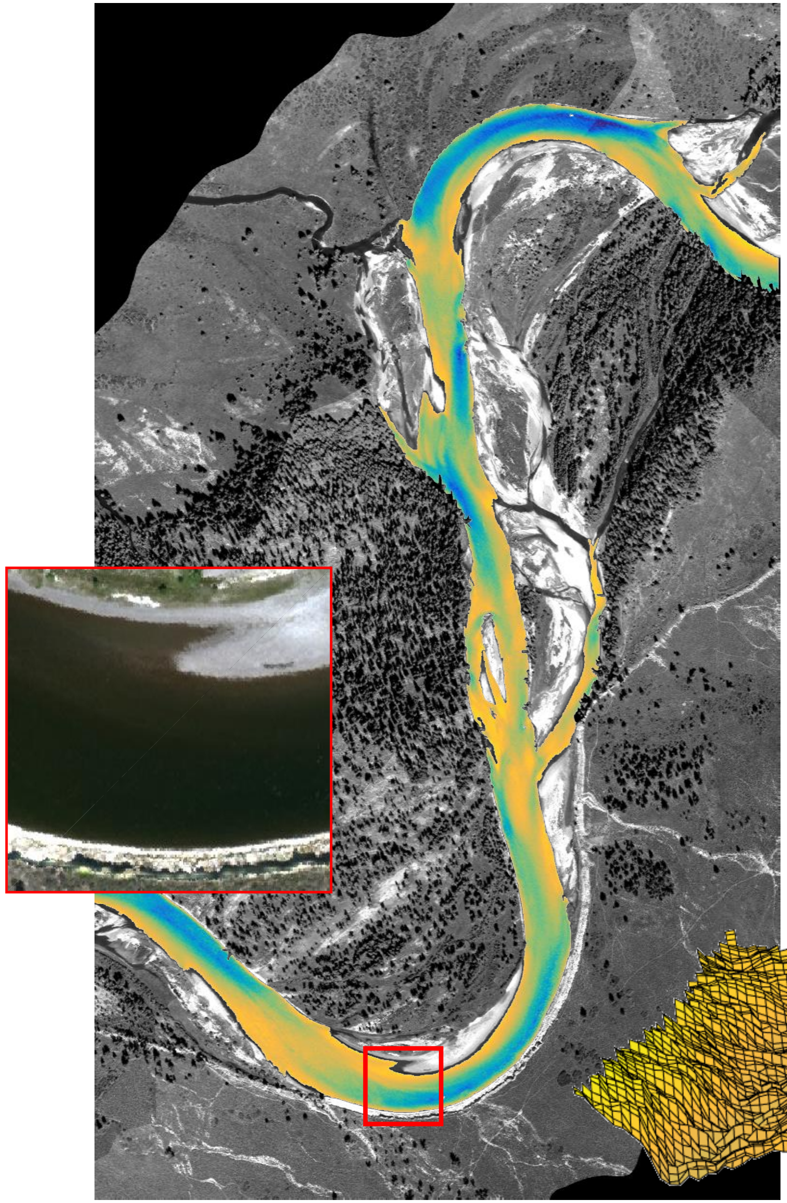


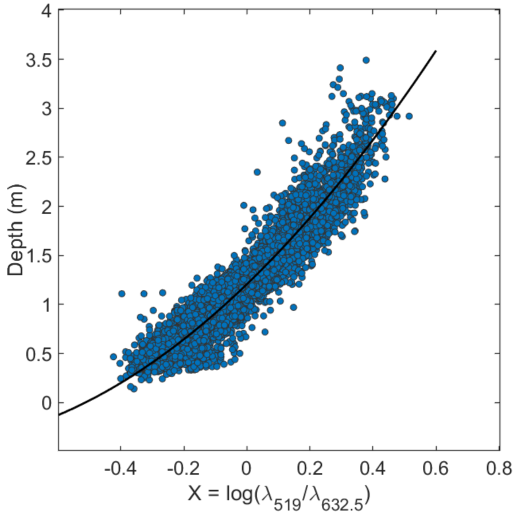


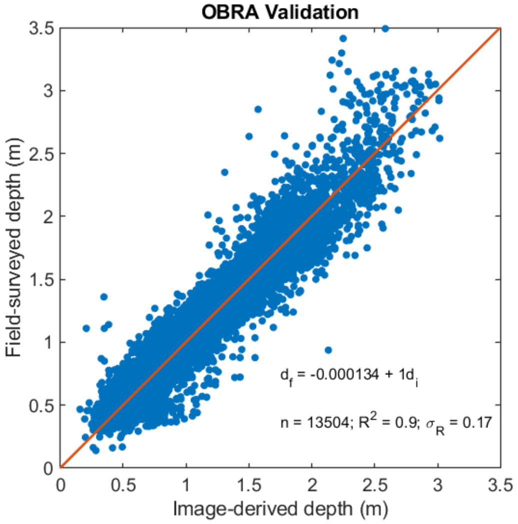
Figures from Overstreet, 2020

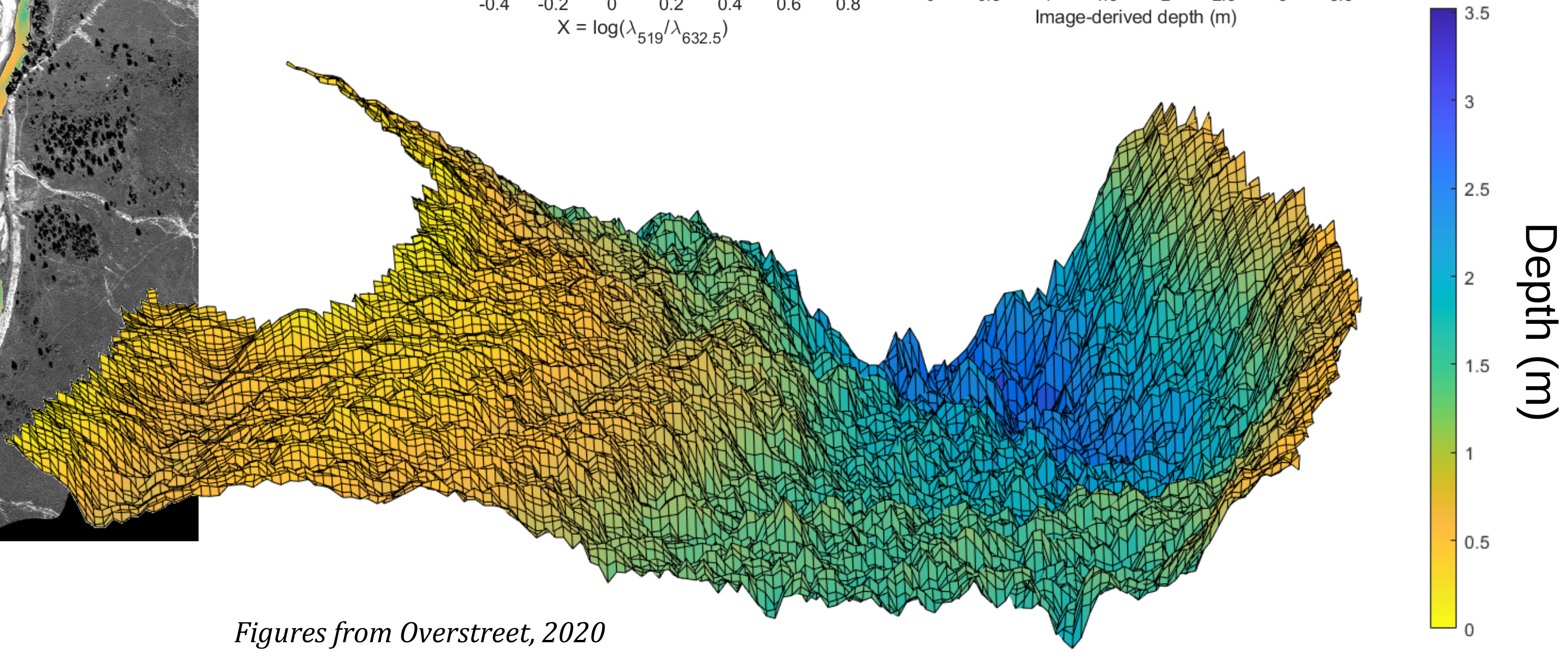
USGS

Image-derived depth map





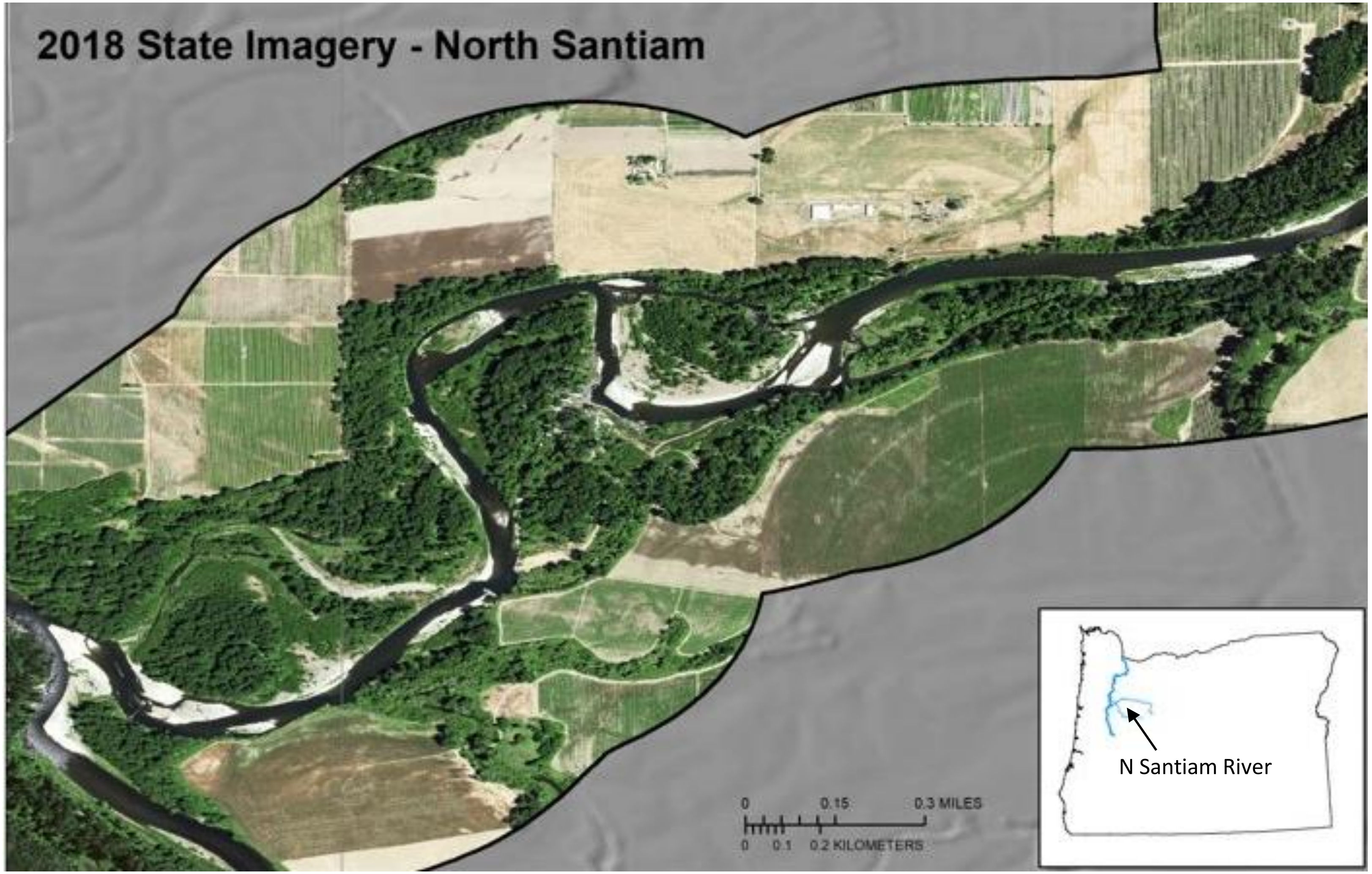


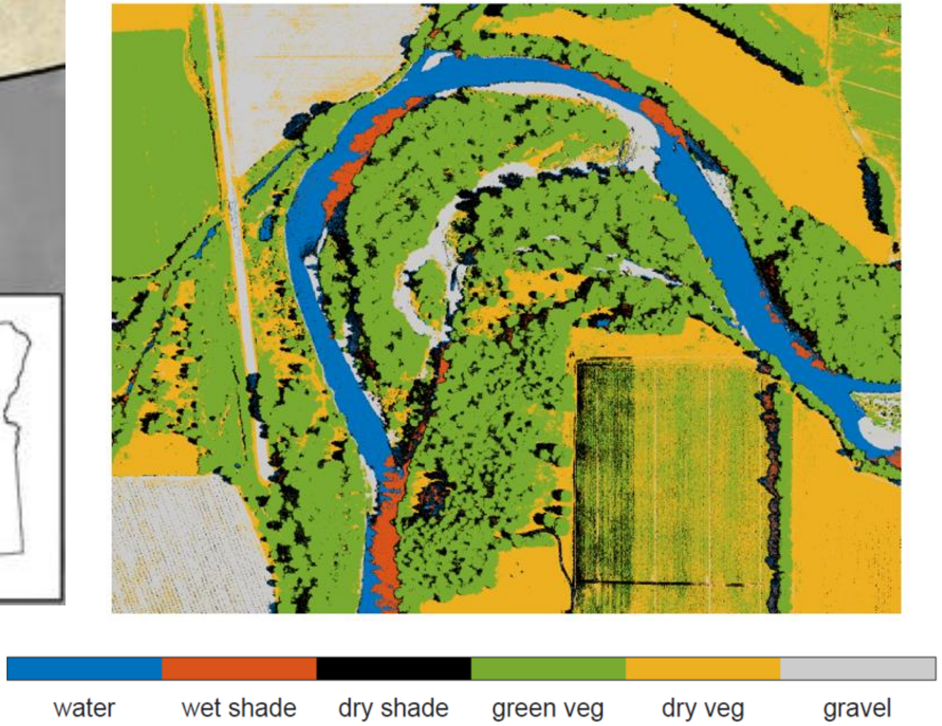


Figures from Overstreet, 2020

USGS

North Santiam River: River-scale image-based bathymetric mapping

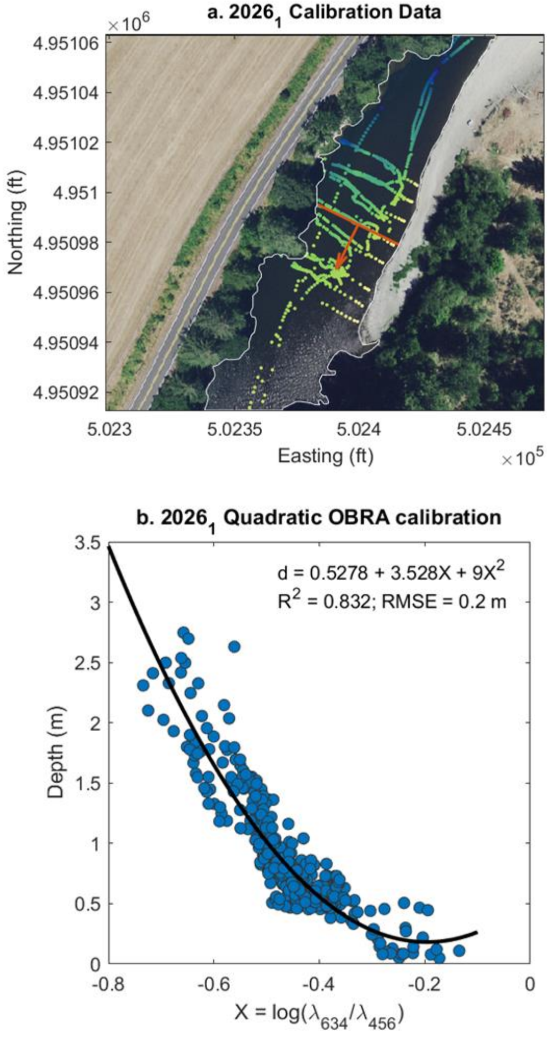


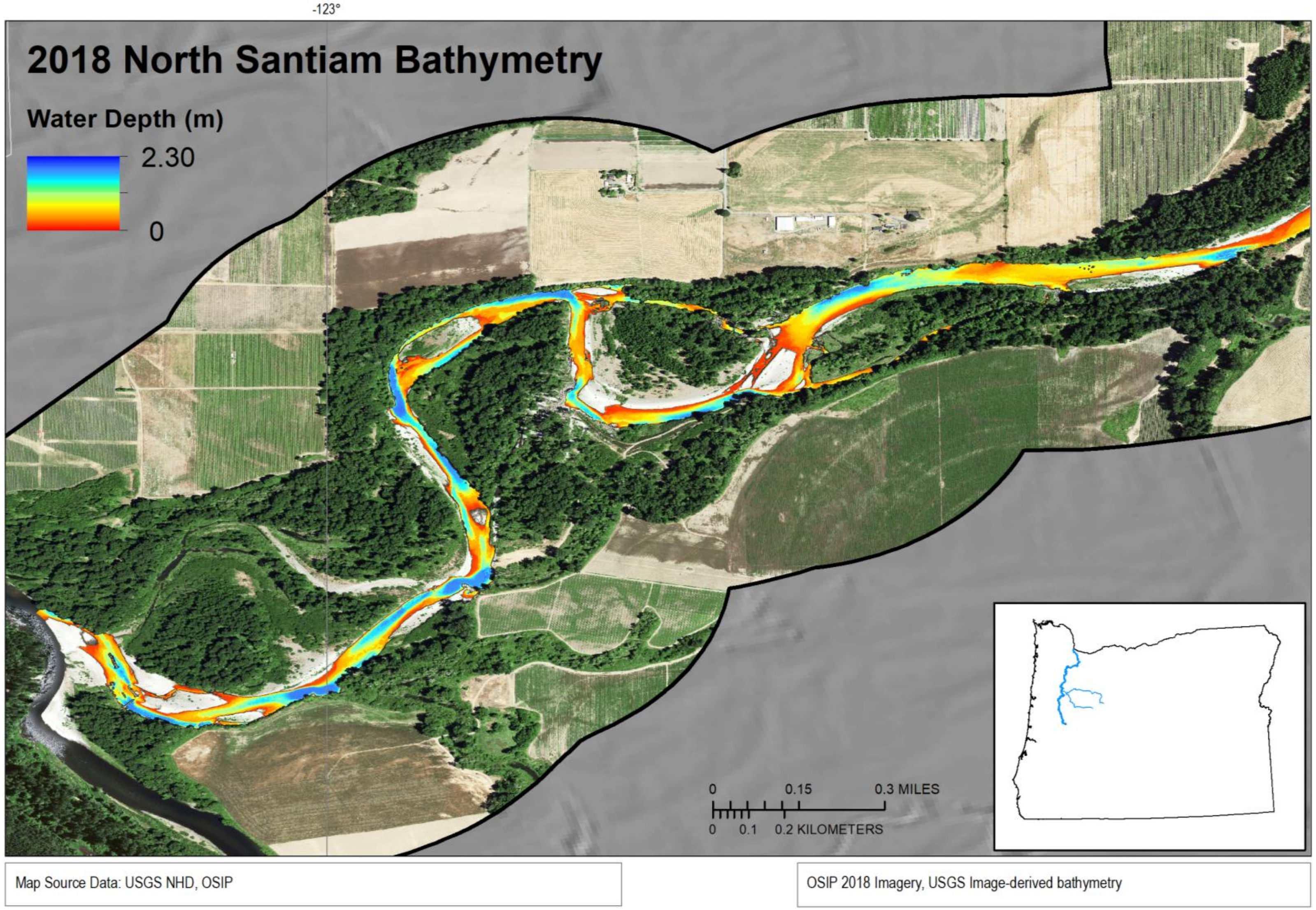


USGS

Provisional USGS data, do not cite

North Santiam River: River-scale image-based bathymetric mapping



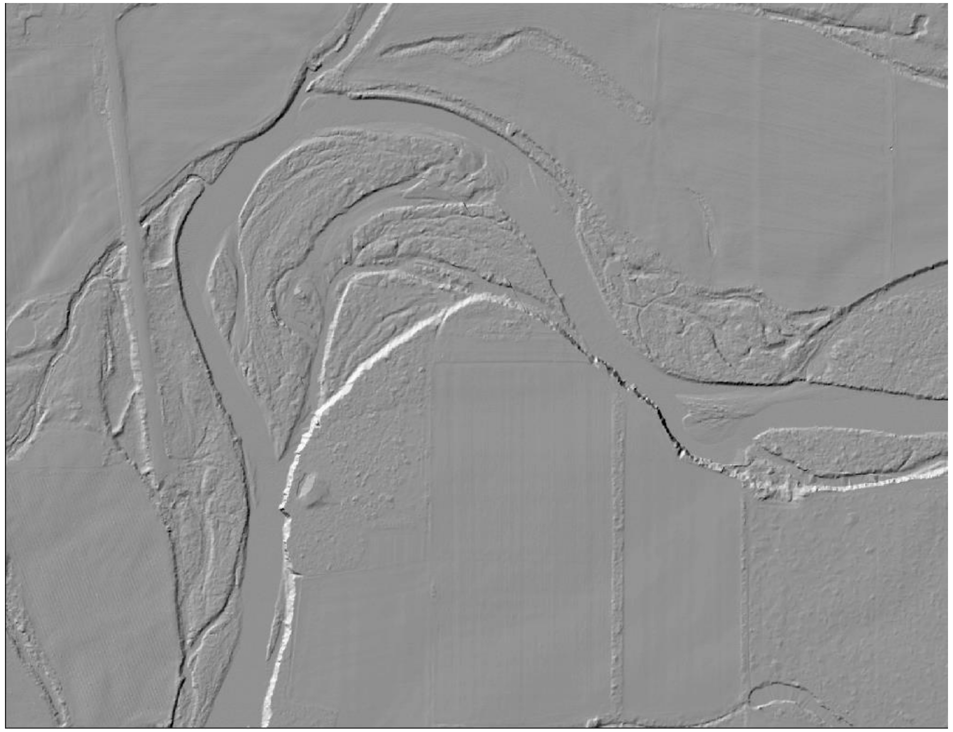


USGS

Provisional USGS data, do not cite

Modeling salmon habitat on the North Santiam River

Bathymetry



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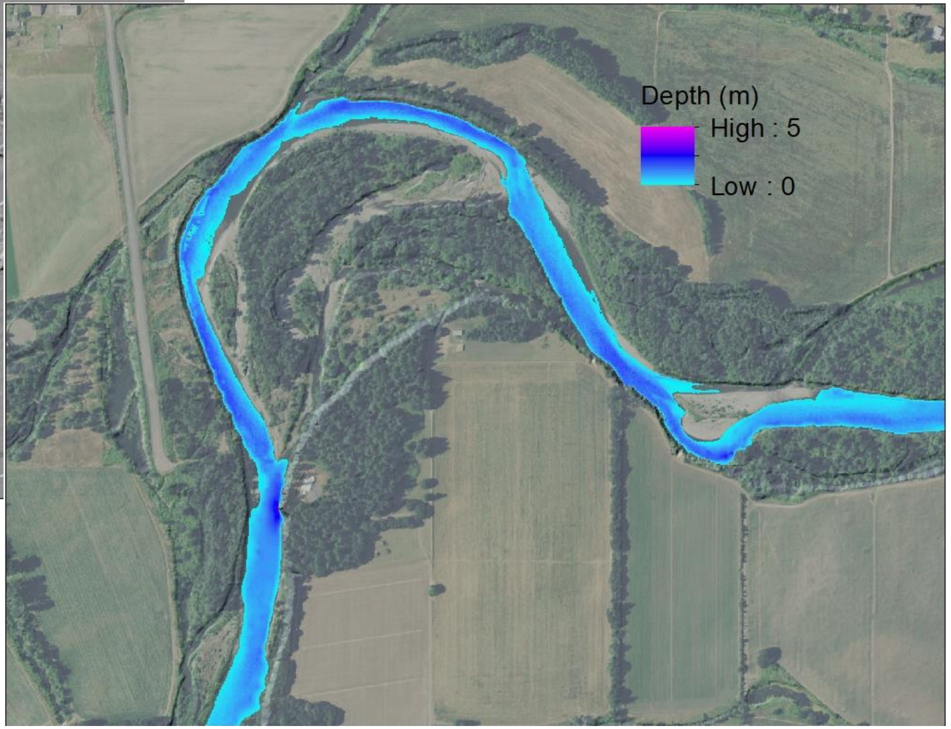
Modeling salmon habitat on the North Santiam River

Bathymetry

Depth



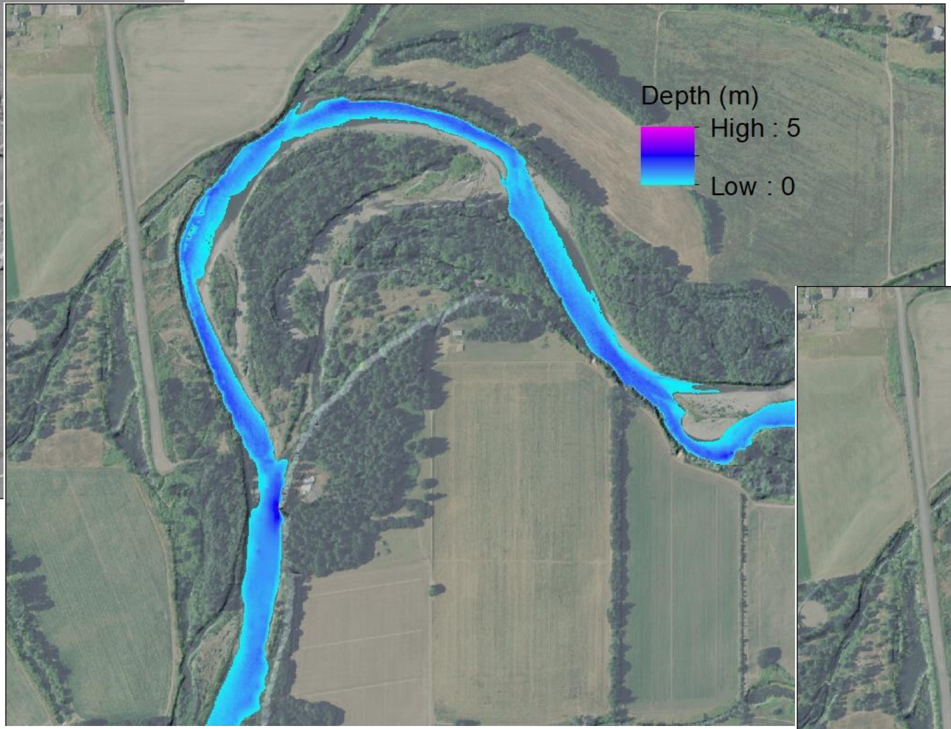
USGS

Provisional USGS data, do not cite

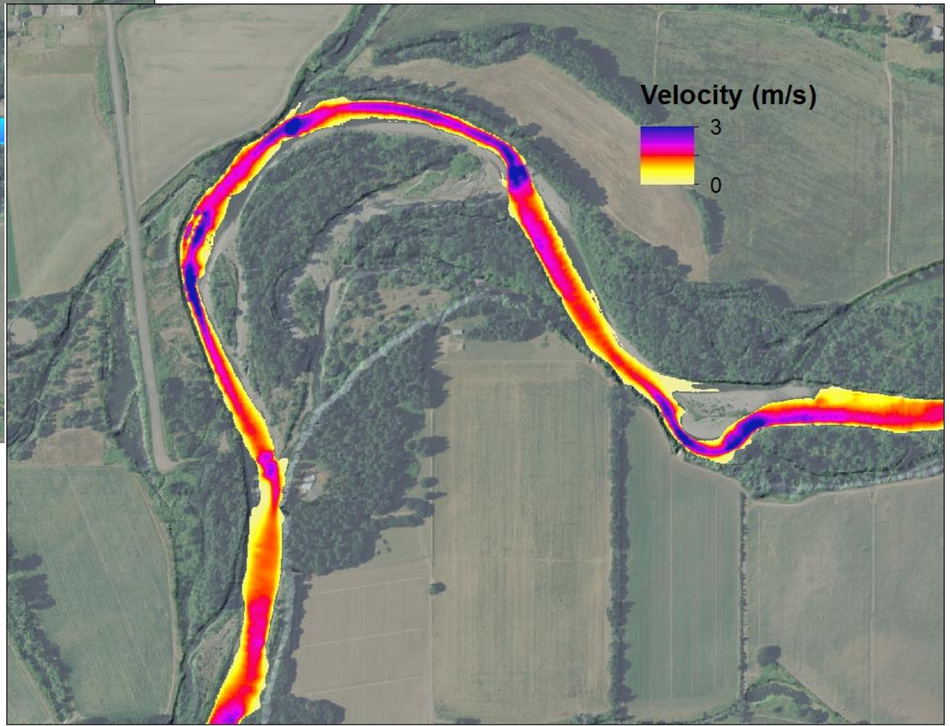
Modeling salmon habitat on the North Santiam River

Bathymetry

Depth



Velocity



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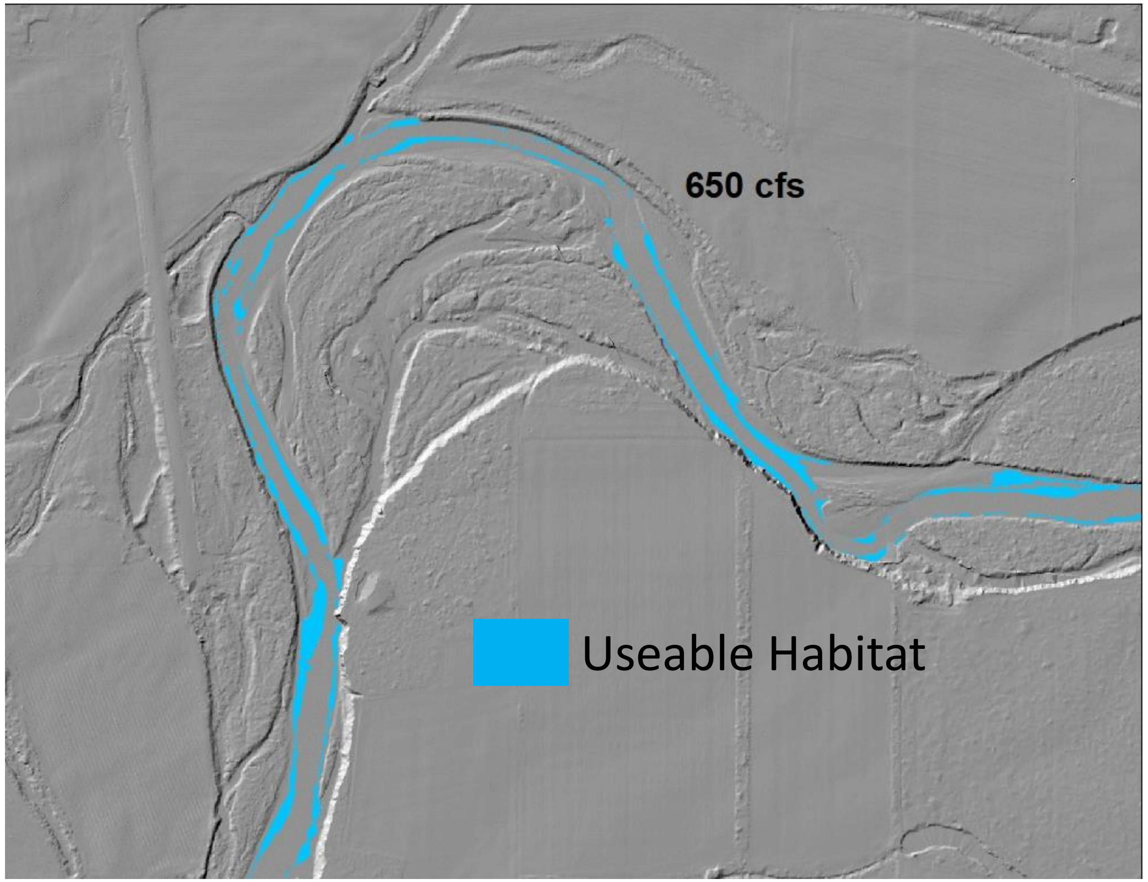
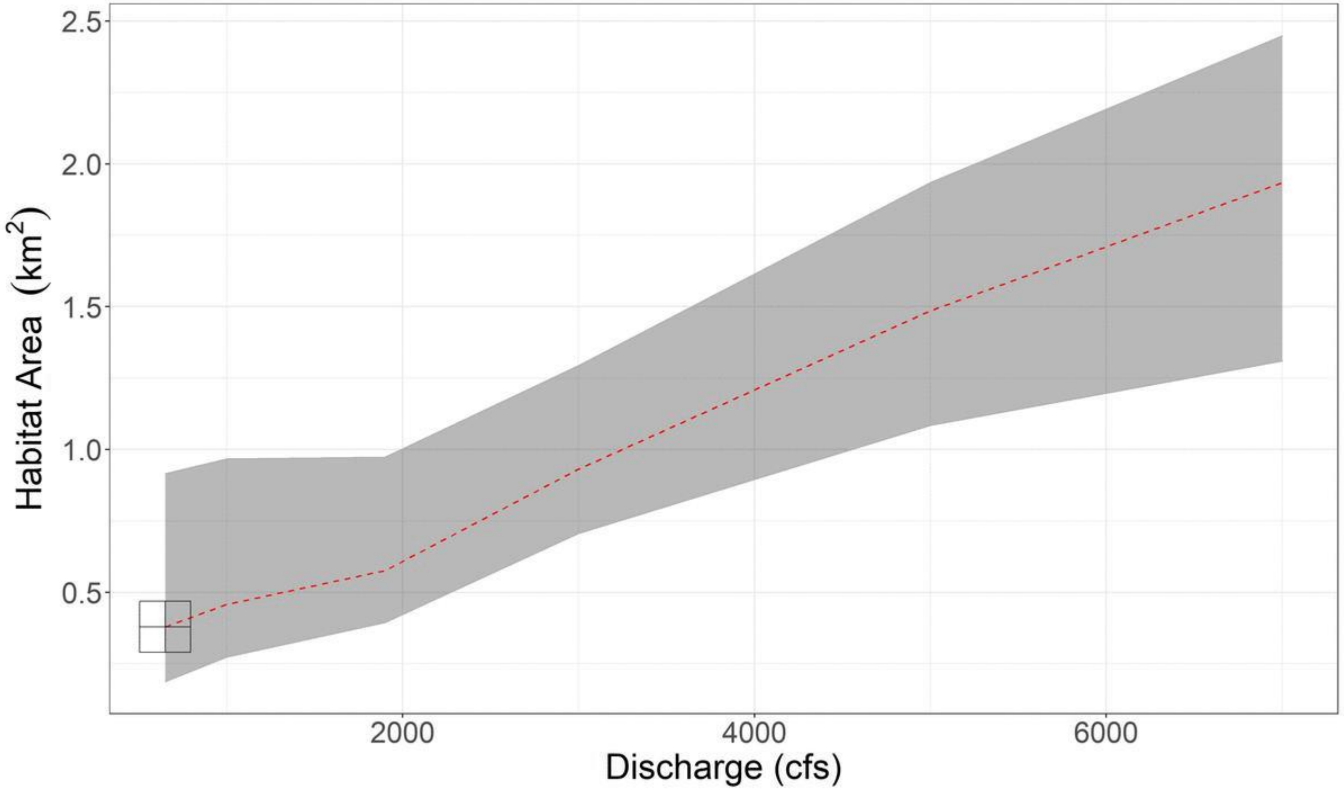
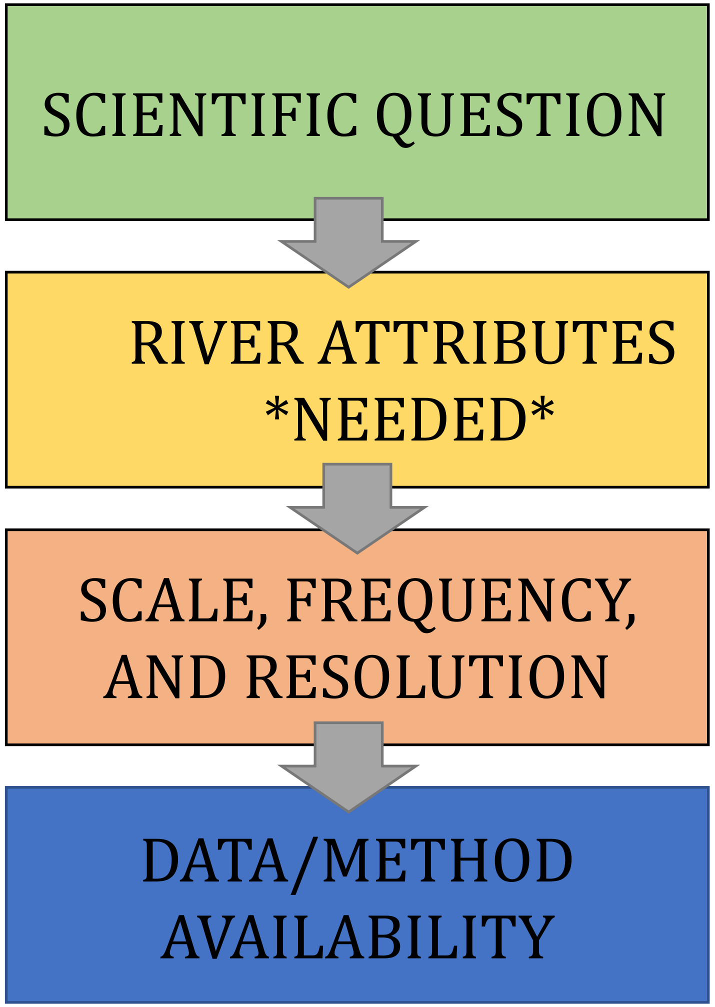
Habitat Modeling





Provisional USGS data, do not cite

Conclusions



- Remote sensing approaches need to be driven by management questions
- Remote sensing technology is rapidly evolving and widely available
- Remote sensing can provide a cost-effective basis for mapping river attributes at scales relevant to river management
- For remote sensing to be effective we need to stay focused on analysis, reporting and adaptive refinement

Figure from Warren and others, 2019

USGS

Brandon Overstreet
USGS Oregon Water Science Center
boverstreet@usgs.gov

WDFW Habitat Program Use of Small Unmanned Aircraft Systems

George Fornes

December 14, 2021

Washington Department of FISH AND WILDLIFE

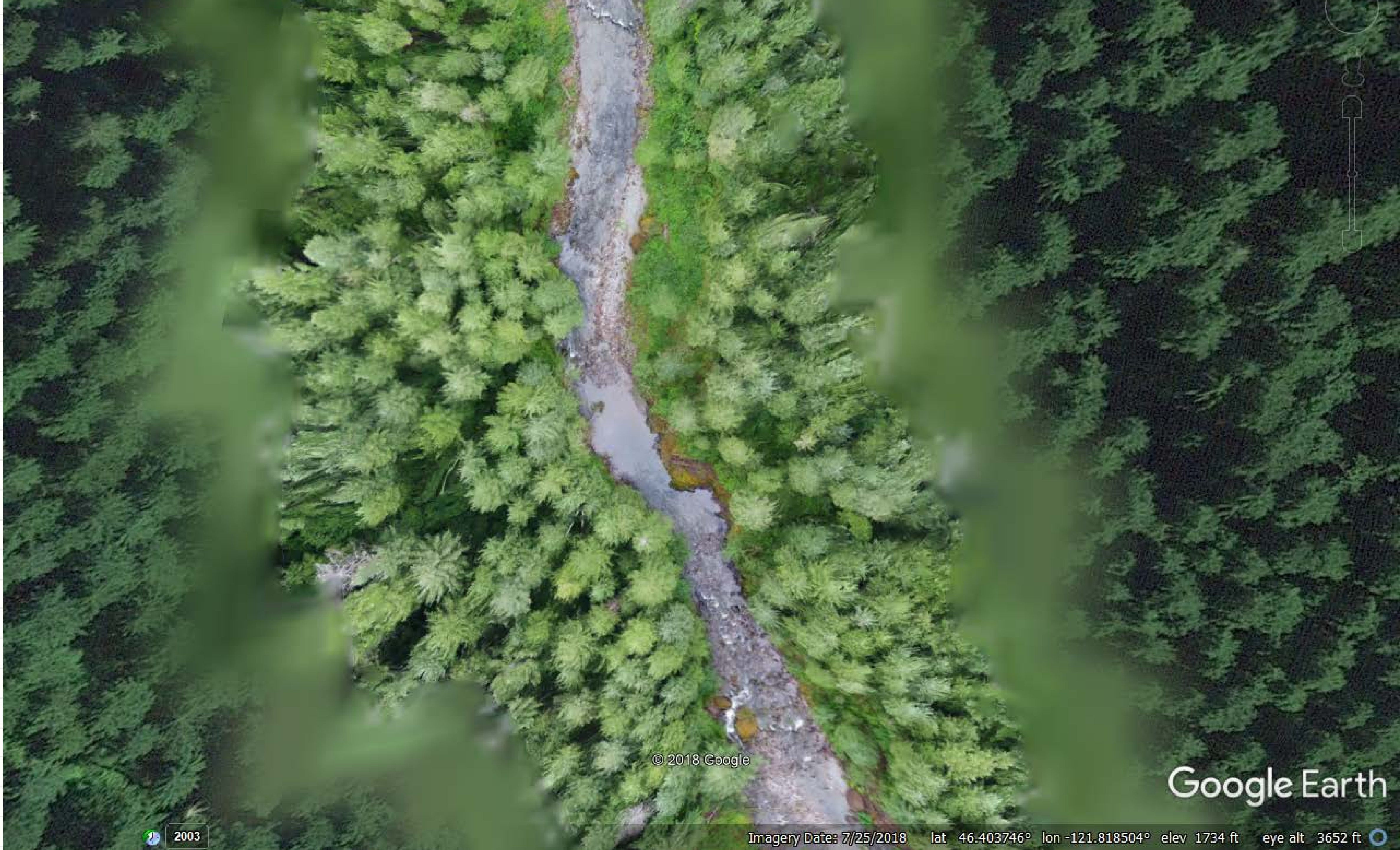
Overview

1. Yellowjacket Creek
2. Deer Creek
3. Chinook WLA
4. Automated Flight Planning
5. South Bachelor Island
6. Bonus – Enforcement Program

1. Yellowjacket Creek

- Spawning habitat surveys related to a permit application for mineral prospecting
- One crew hiked in
- Another crew flew


© 2018 Google
Google Earth
2003
Imagery Date: 7/25/2018 lat 46.403746° lon -121.818504° elev 1734 ft eye alt 3652 ft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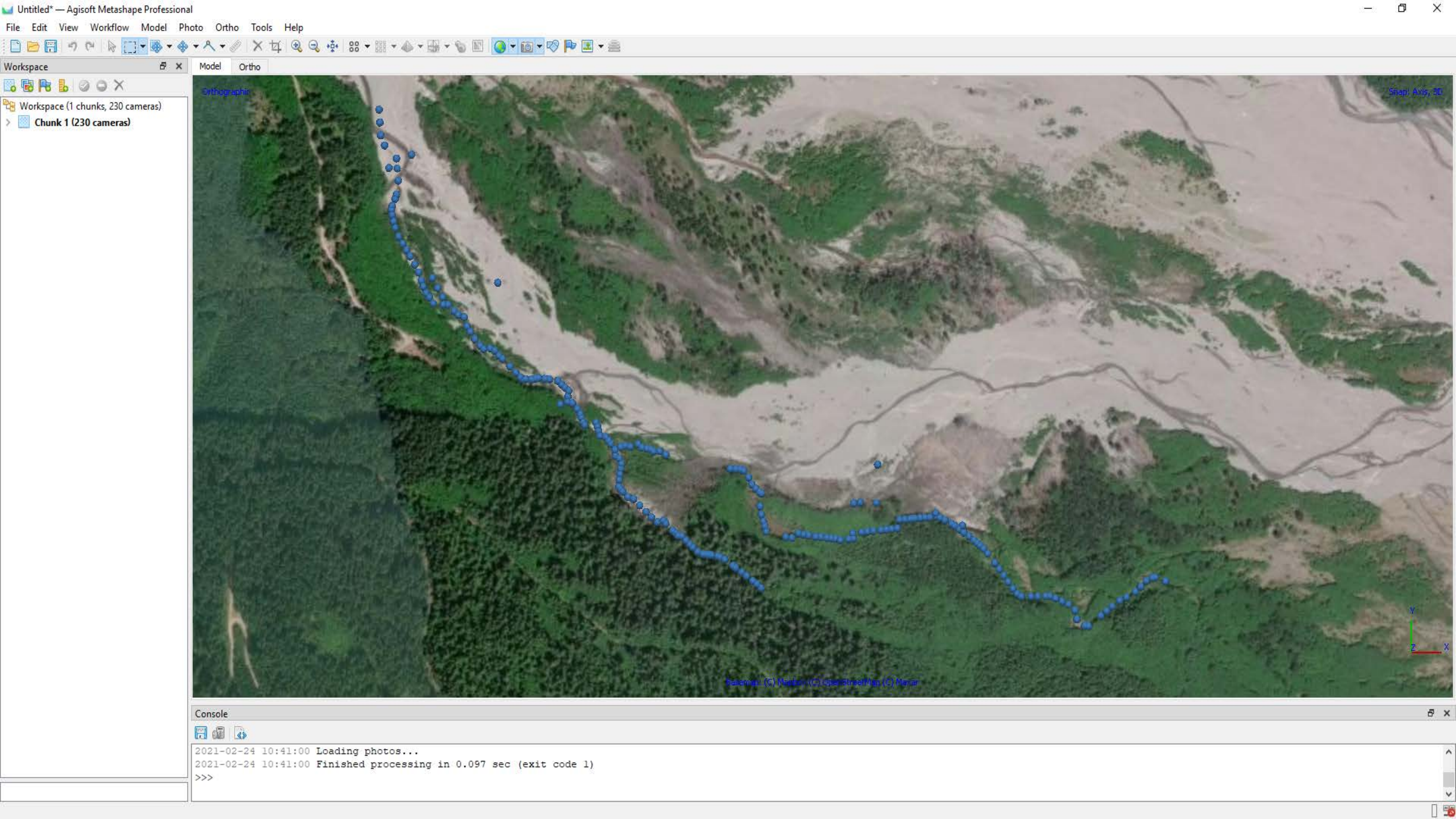
2. Deer Creek

- Flew 1/7/2021
- Salmon habitat surveys related to upcoming construction of a new fish release site
- NF Toutle River, upstream of SRS
- Vast improvement over readily available imagery (Google Earth)
- Examining connections between release site and potential spawning areas


505
Spirit Lake Hwy
504
© 2021 Google
Google Earth
Imagery Date: 7/25/2018 lat 46.272610° lon -122.404269° elev 3214 ft eye alt 24.85 mi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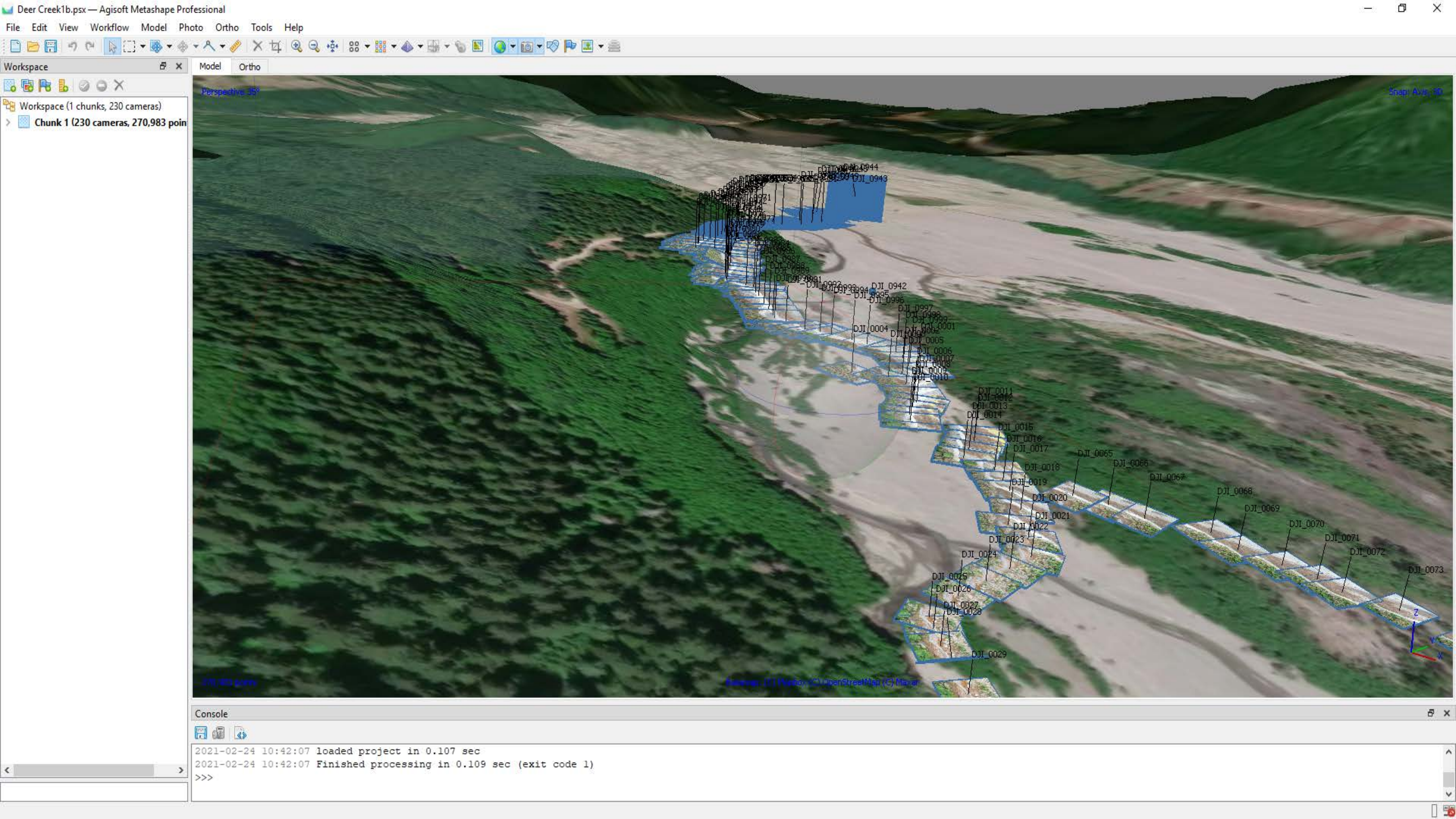
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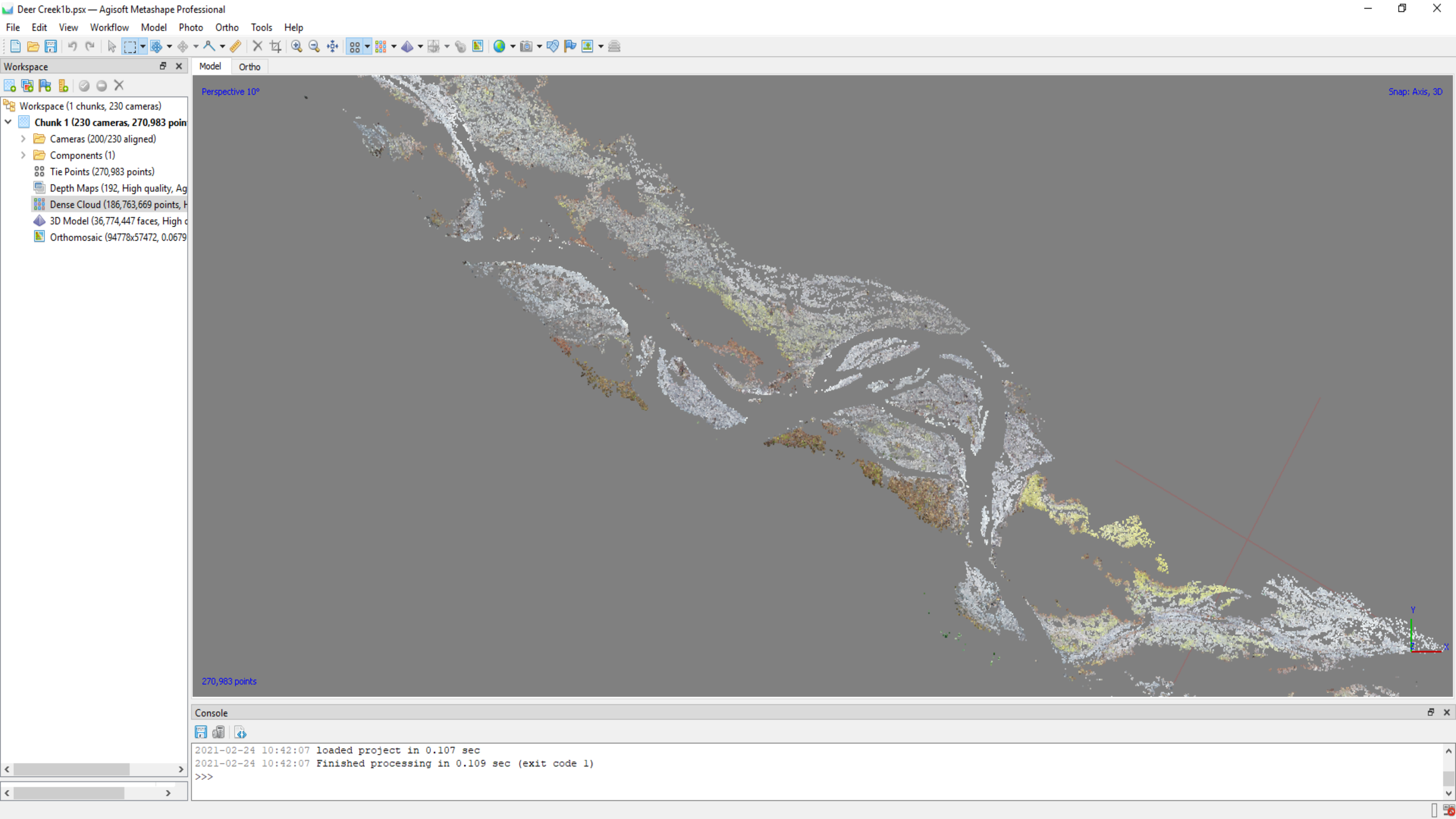
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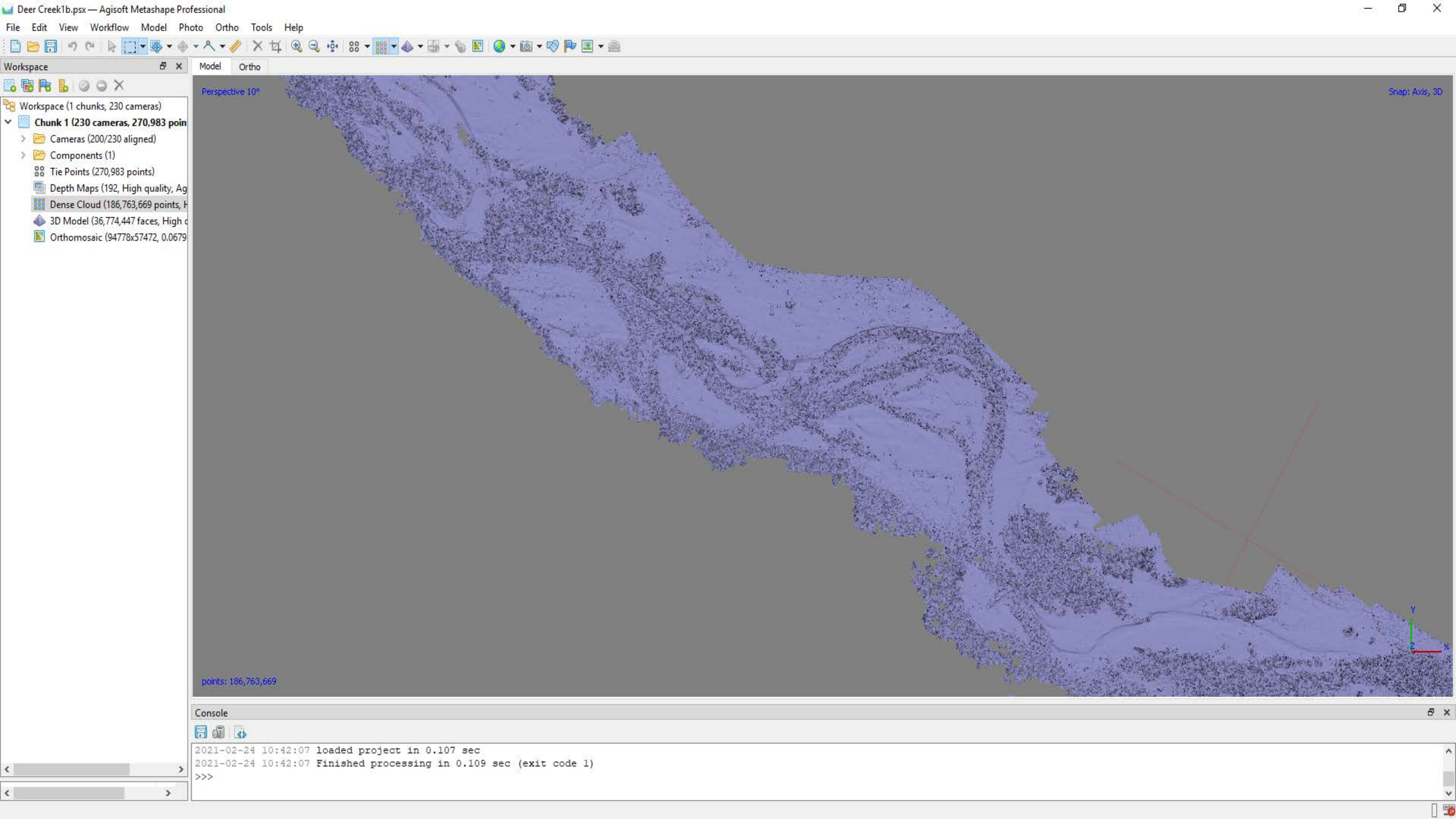
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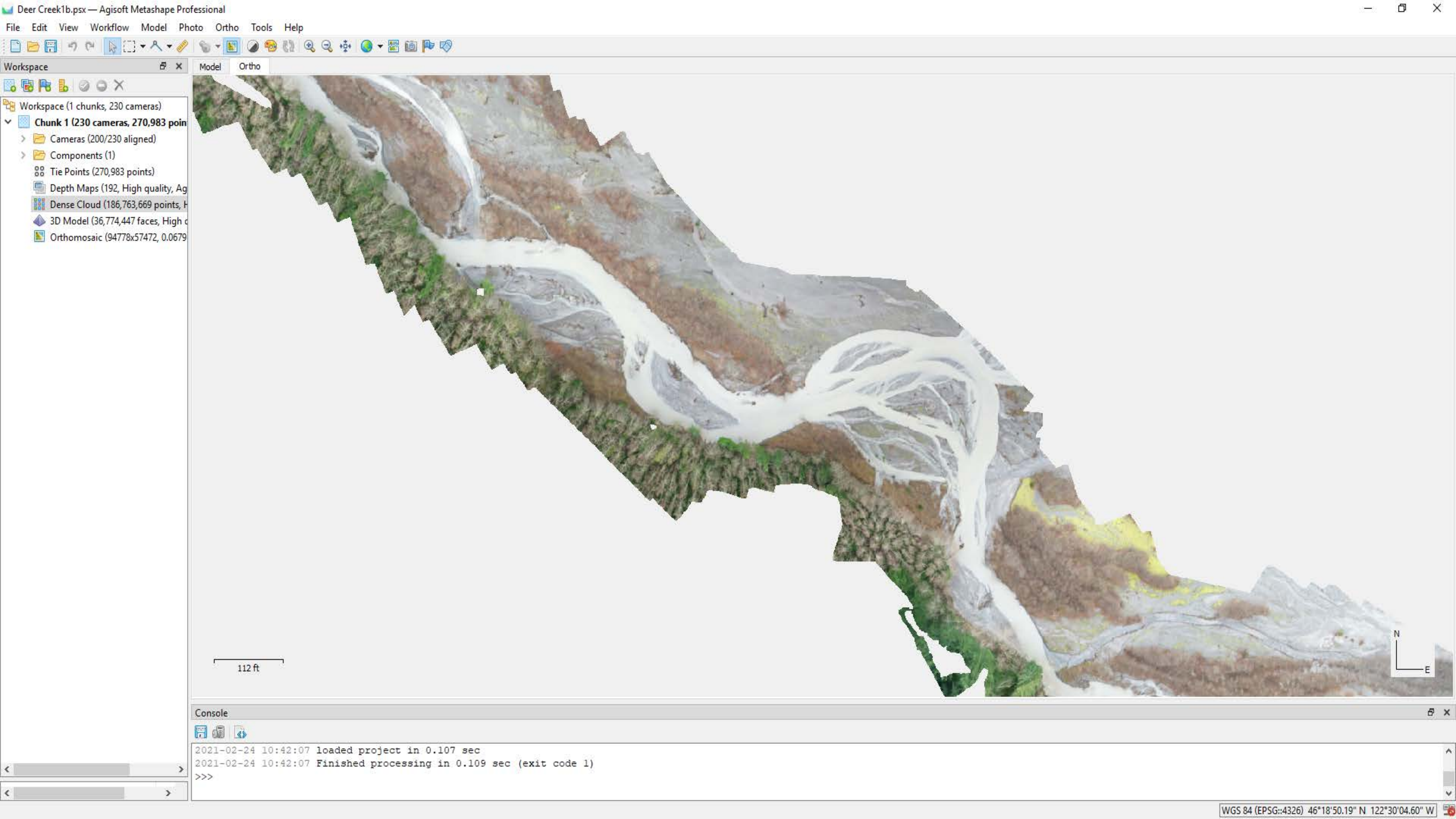

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Potential New Release Site
gle Earth


© 2020 Google
Google Earth


Google Earth


Potential New Release Site
gle Earth


© 2020 Google
Google Earth

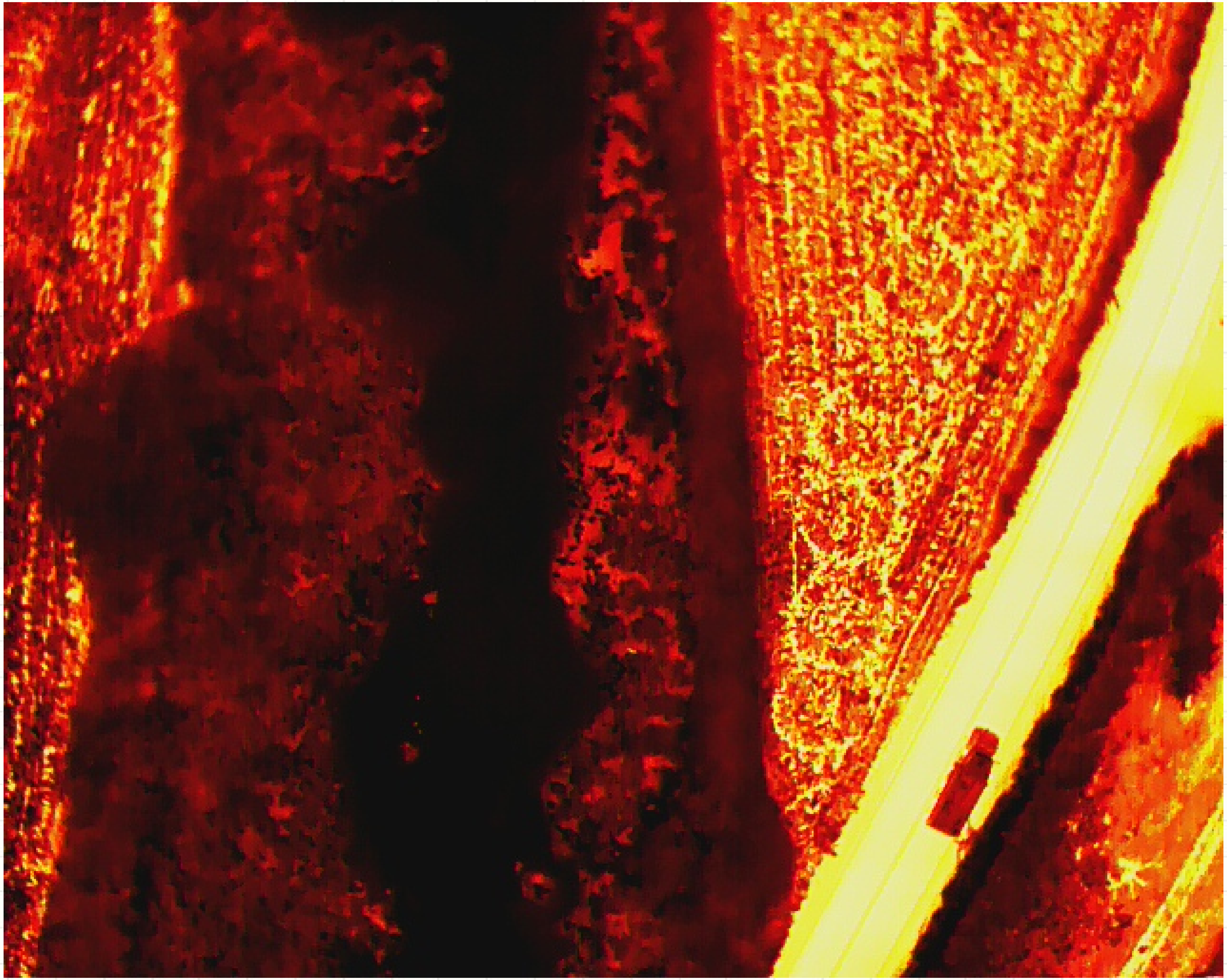

Google Earth

3. Chinook Wildlife Area

- Flew 9/14/2021
- Floodplain reconnection
- Assessing extents of mowed areas and inundation

9/14/2021

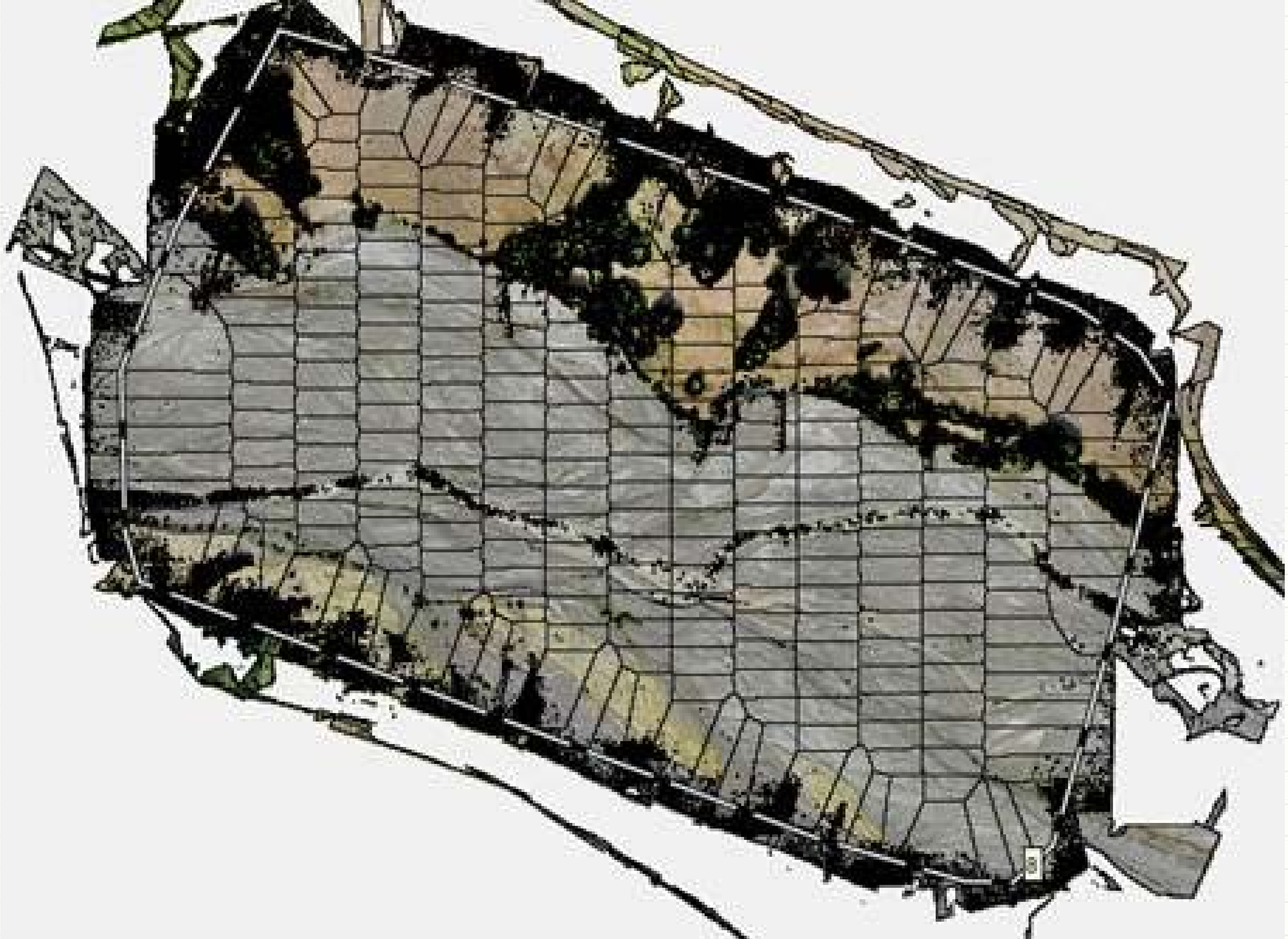
9/14/2021



9/14/2021

4. Automated Flight Planning

- Flew 9/20/2021
- Been around a while, but recently figured out how to install required software onto controller
- Tested at Mud Flow Unit of Mt. St. Helens Wildlife Area

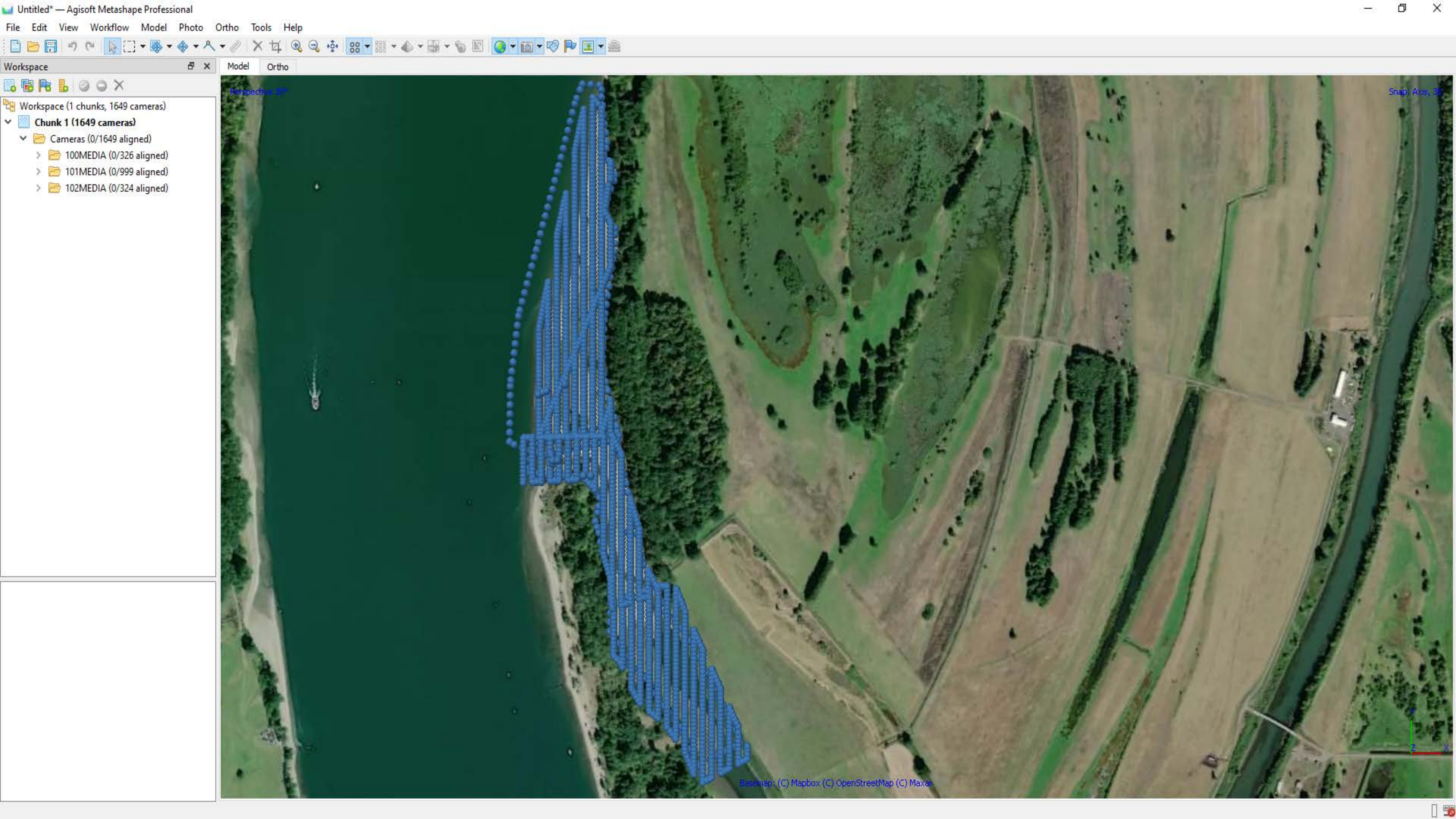


5. South Bachelor Island

- Most recent flight: 10/6/2021
- Monitoring a salmon habitat enhancement project
- Reconnection of 40 acres of lake to the mainstem Columbia

Add Help


7/2018
Columbia River
WA/OREGON
Henrici Lake
Bachelor Island
Widgeon Lake
Widgeon Lake
Smith Lake Rd
Smith Lake Rd
W Bachelor Island
Bachelor Island Slough
Warrior Rock Lighthouse Point Trailhead
Bachelor Island Slough
Google Earth
lat 45.815576° lon -122.806475° elev 10 ft eye alt 10048 ft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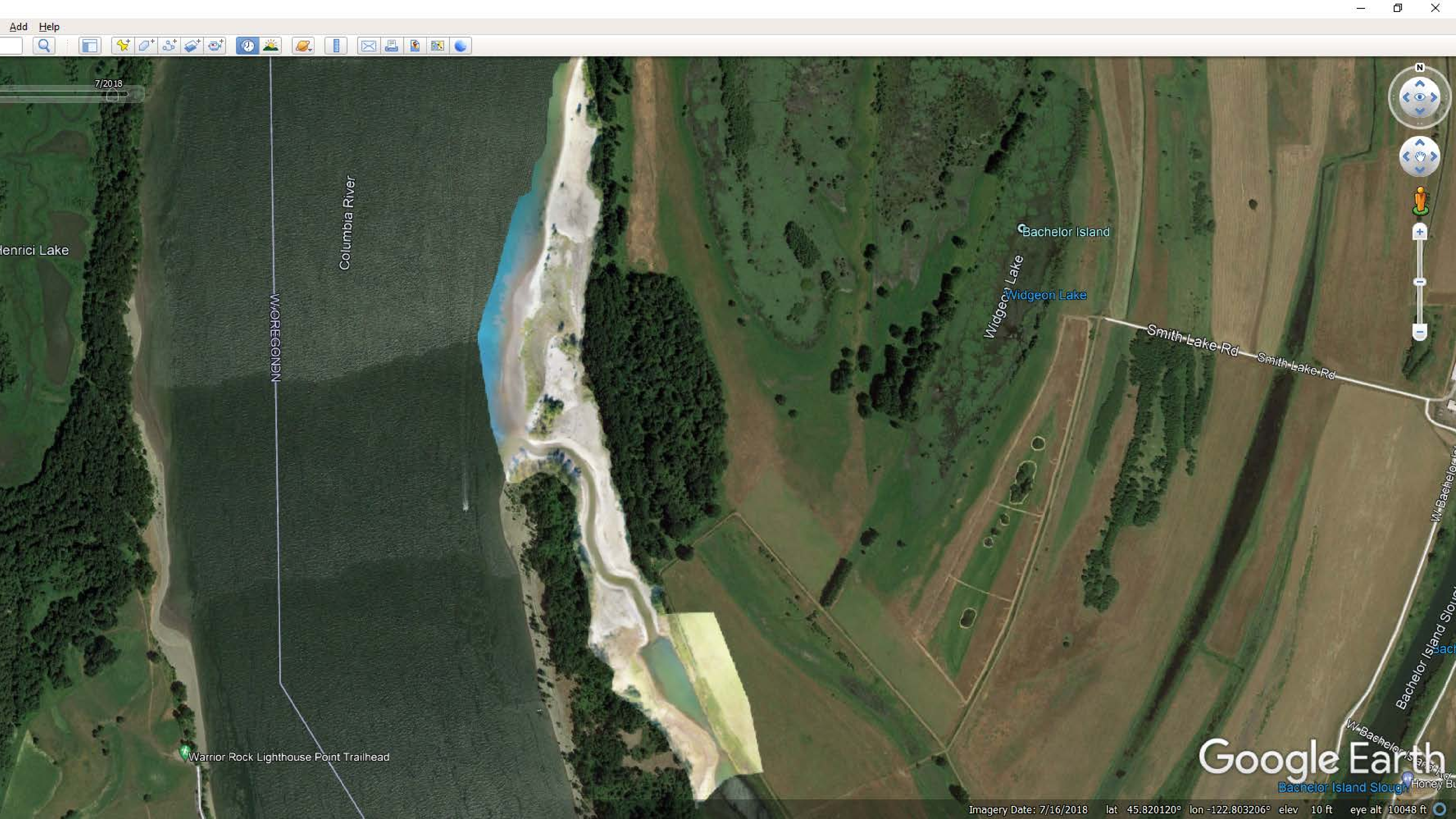
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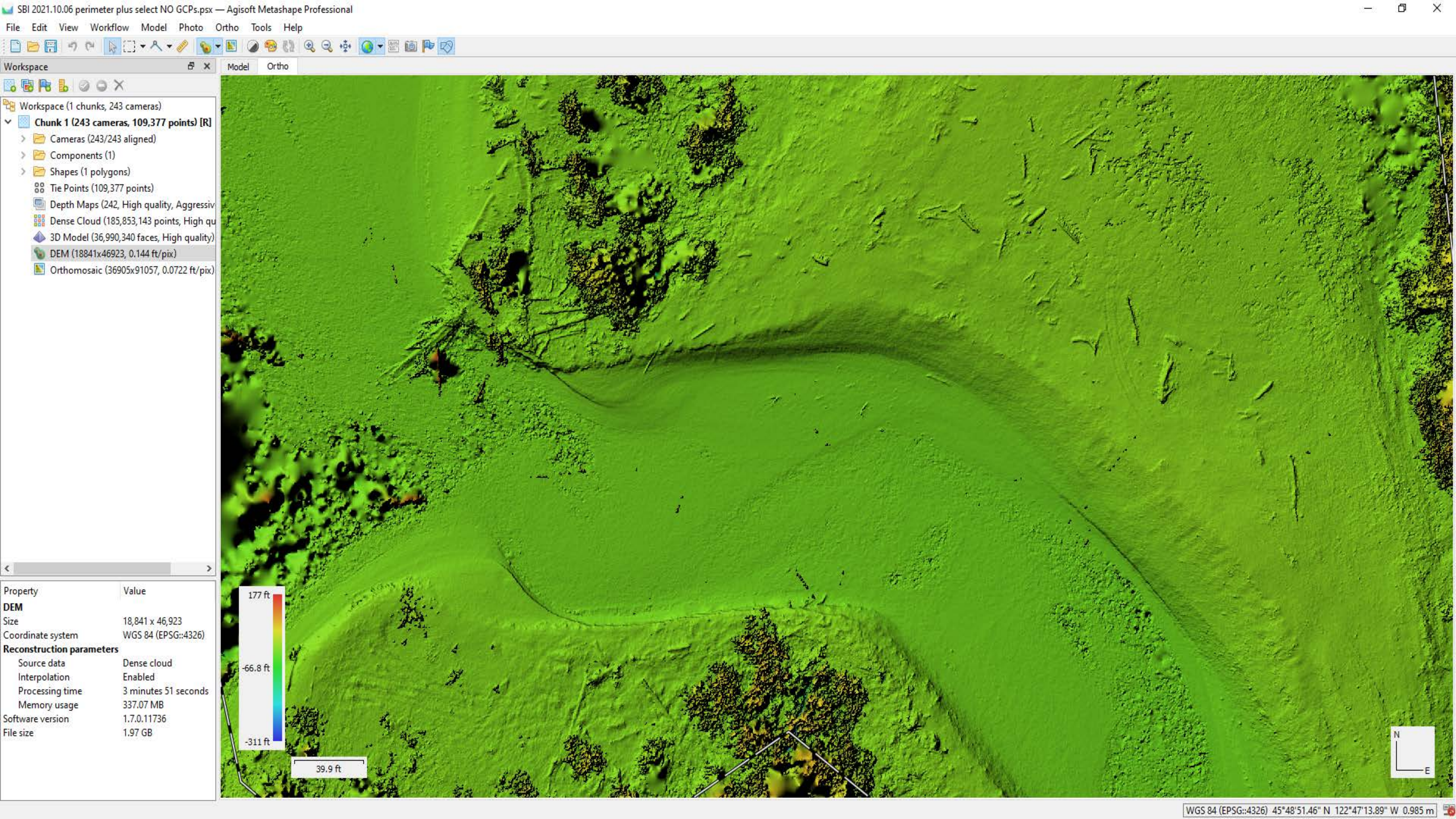
eye alt 10048 ft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Workspace (1 chunks, 243 cameras)
Chunk 1 (243 cameras, 109,377 points) [R]
Cameras (243/243 aligned)
Components (1)
Shapes (1 polygons)
Tie Points (109,377 points)
Depth Maps (242, High quality, Aggressiv
Dense Cloud (185,853,143 points, High qu
3D Model (36,990,340 faces, High quality)
DEM (18841x46923, 0.144 ft/pix)
Orthomosaic (36905x91057, 0.0722 ft/pix)
Property
Value
DEM
Size
18,841 x 46,923
Coordinate system
WGS 84 (EPSG::4326)
Reconstruction parameters
Source data
Dense cloud
Interpolation
Enabled
Processing time
3 minutes 51 seconds
Memory usage
337.07 MB
Software version
1.7.0.11736
File size
1.97 GB
177 ft
-66.8 ft
-311 ft
39.9 ft
N
E
WGS 84 (EPSG::4326) 45°48'51.46" N 122°47'13.89" W 0.985 m


1/2/2020


9/30/2020


10/6/2021


1/2/2020

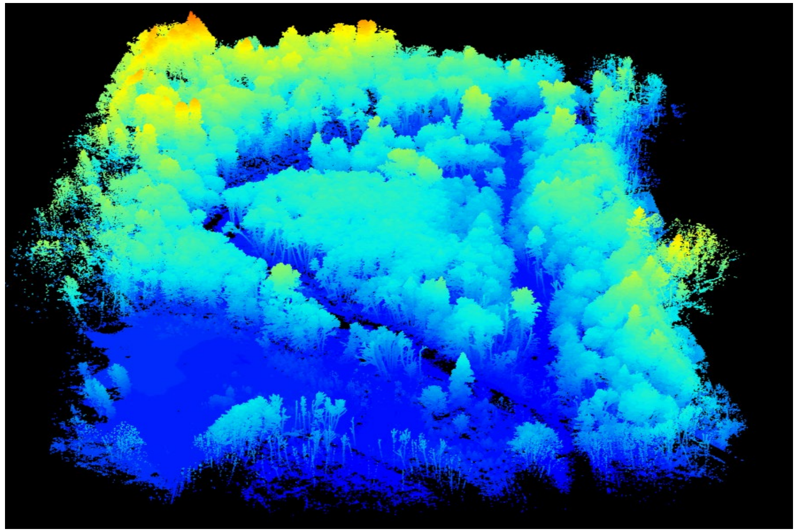
9/30/2020

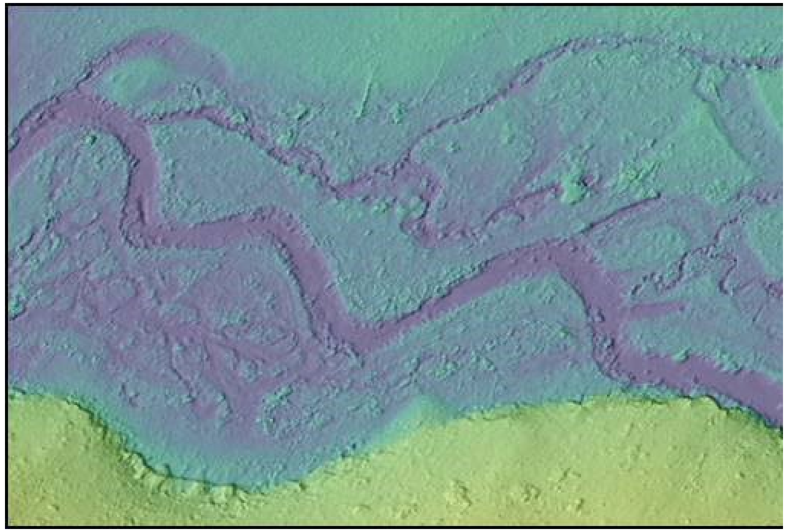

10/6/2021

6. Bonus - Enforcement Program

- Search and rescue

Advances in monitoring floodplain restoration: what has changed and how should monitor future projects?





Phil Roni[1,2], Jason Hall[1], Kai Ross[1], Chris Clark[1] and Derek Arterburn[1]

[1]Watershed Sciences Lab, Cramer Fish Sciences
[2]School of Aquatic and Fisheries Sciences, University of Washington

Background

- 120 Years of River Restoration
- Initially mostly instream, fencing, riparian
- Much more focus on floodplain restoration in recent years
- Evolution of floodplain monitoring
  - ADCP, RTK GPS, LiDAR, SfM, ALS, AUV!!

Photo Methow Salmon Recovery Foundation

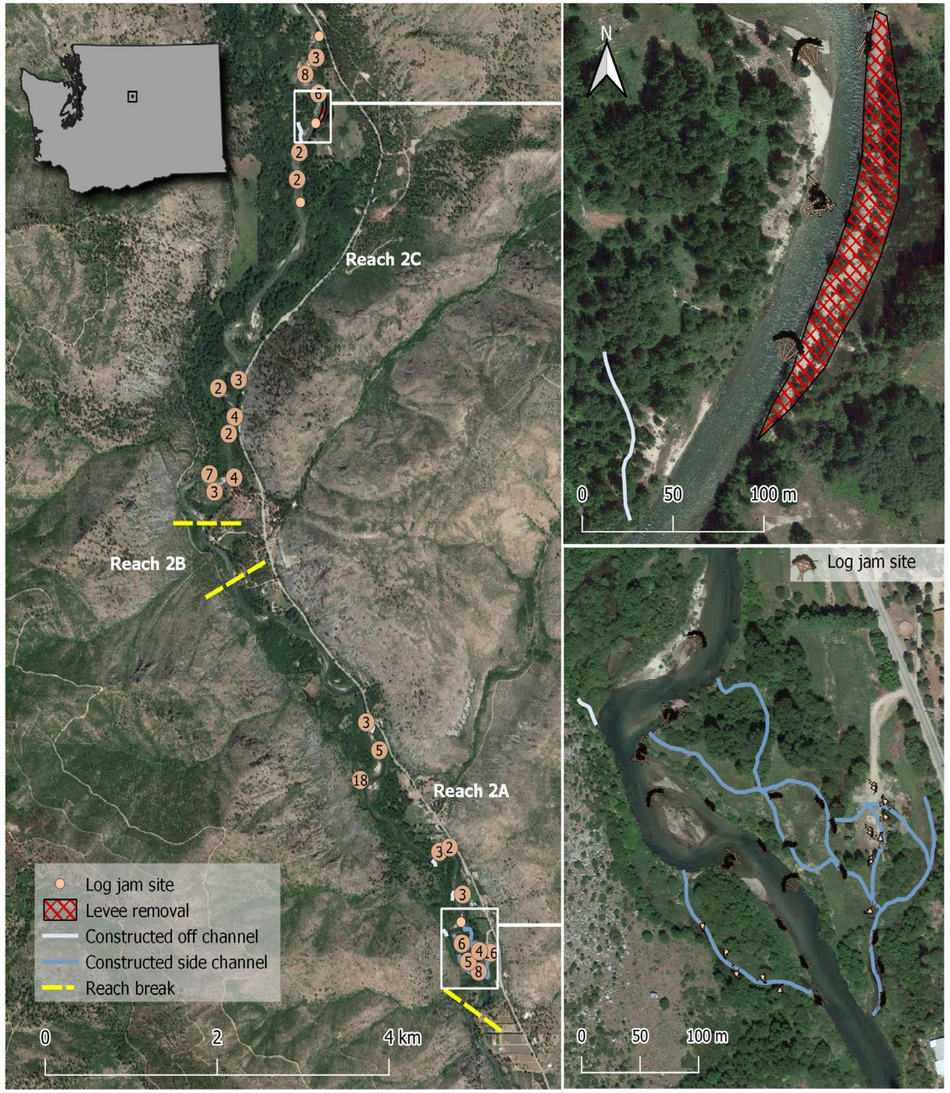
Monitoring Floodplain Restoration –

three main differences to wadable stream monitoring

1. Need coverage of all floodplain and side channels

2. Need at both low and high flow (and potentially others)

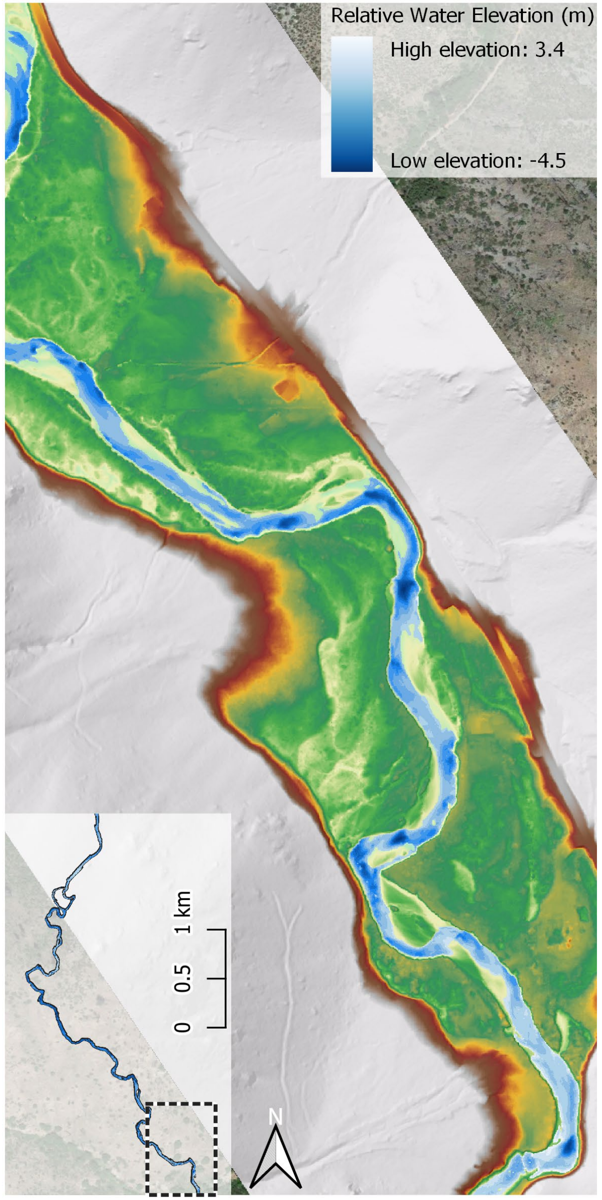
3. Need to be able to monitor very large projects covering many kilometers and hectares



Outline/Goals

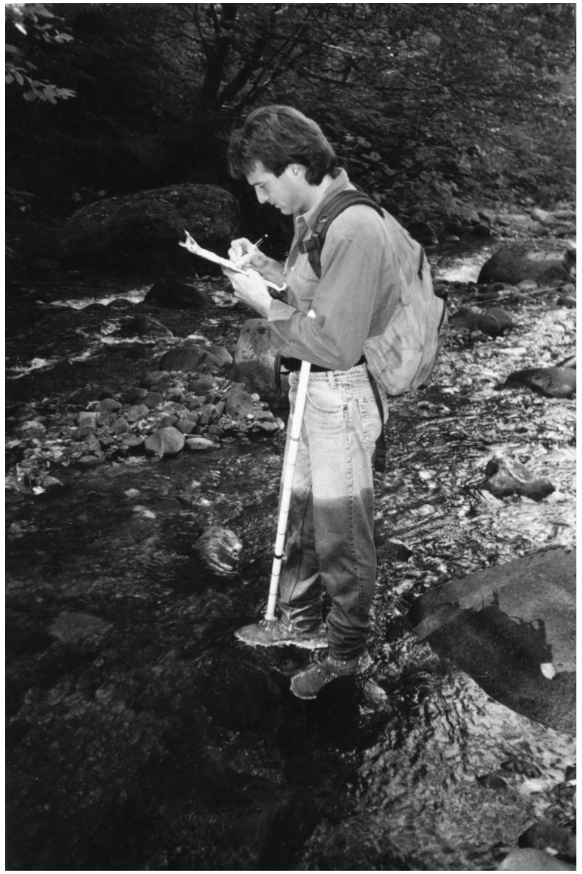
Based on review of literature and recent pilot studies comparing techniques, we will provide:

- Overview of traditional and newer methods
  - Physical (channels, habitat, wood)
  - Biological (fish, riparian)
- Pros and cons of some of methods
- Recommendations M&E based on project # and size

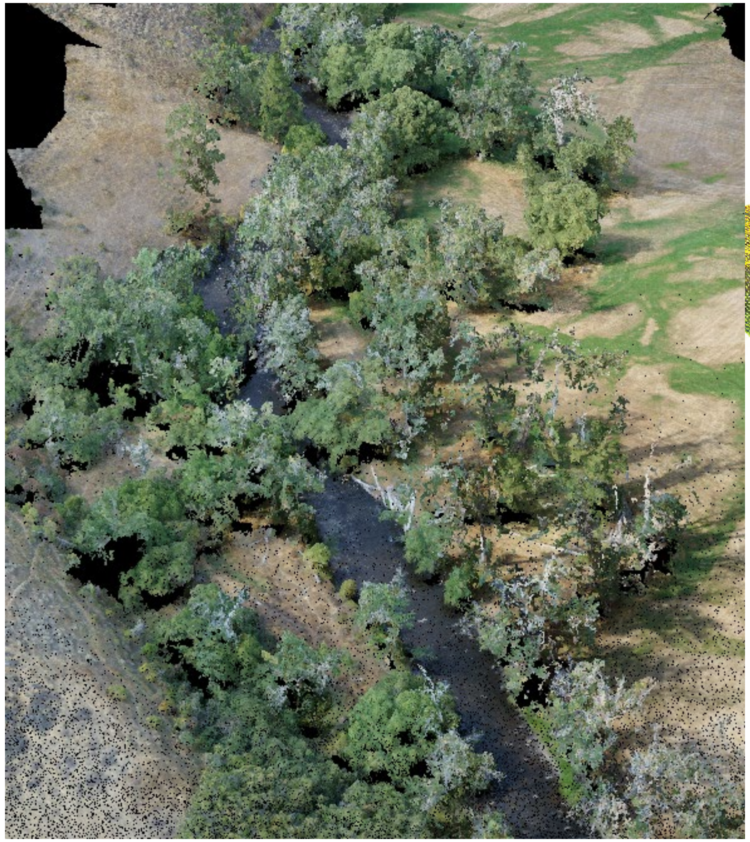


Channel and Floodplain Morphology

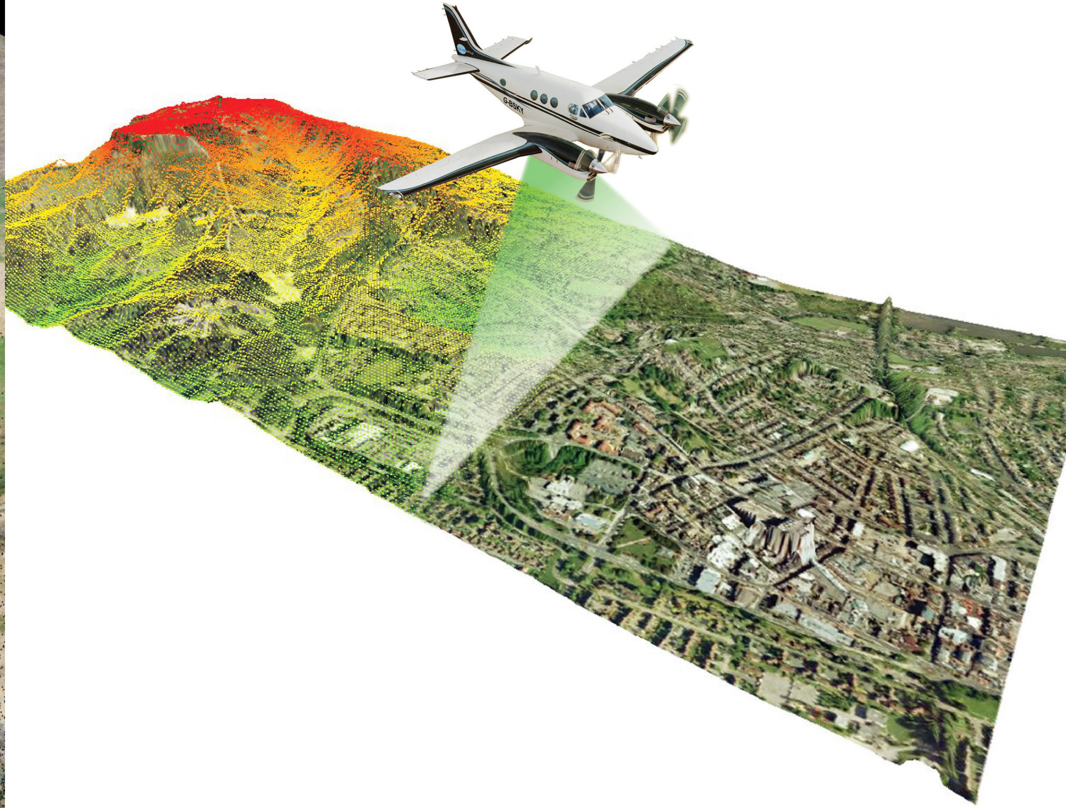
Historical – Stick n Tape



New – SfM

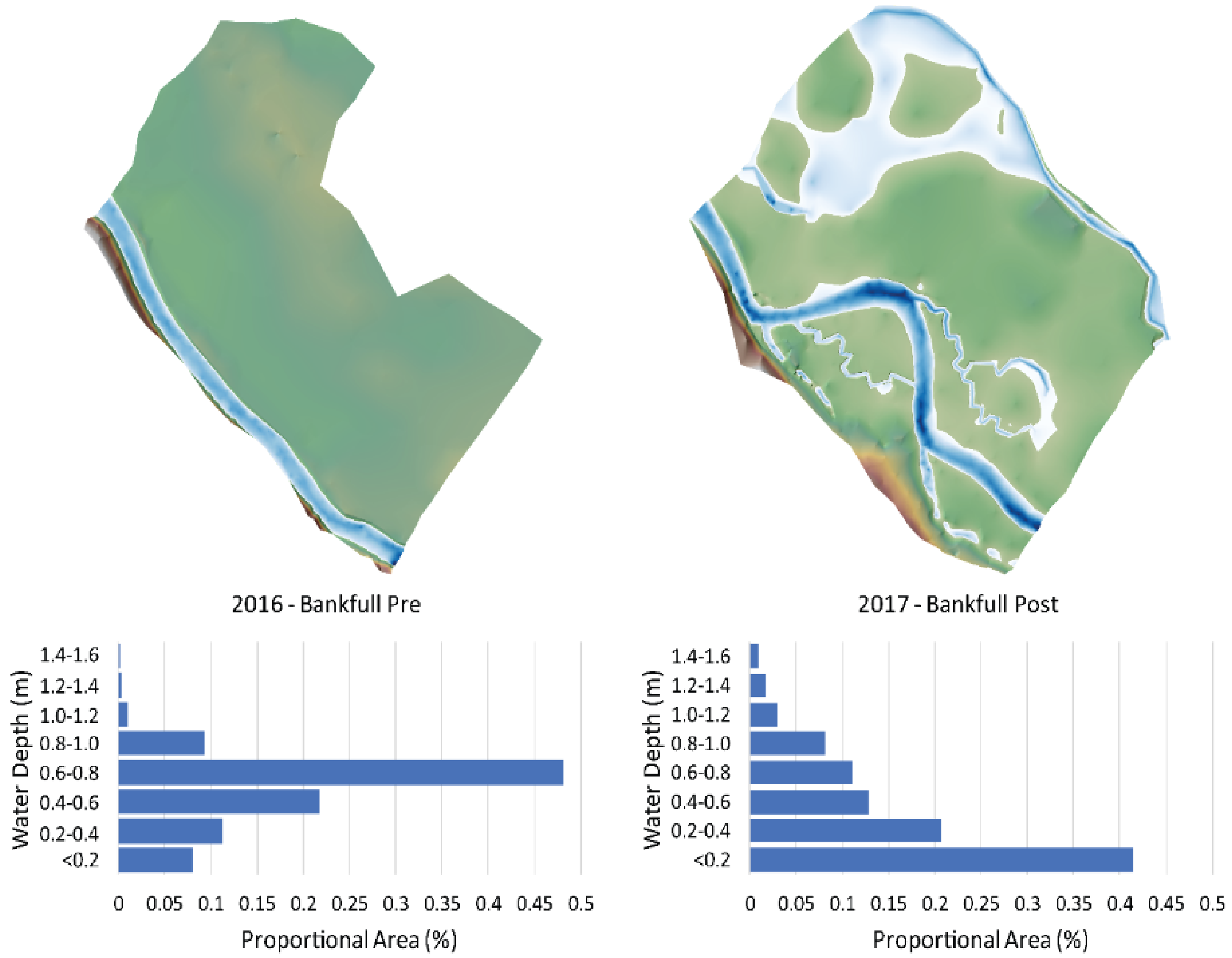


LiDAR

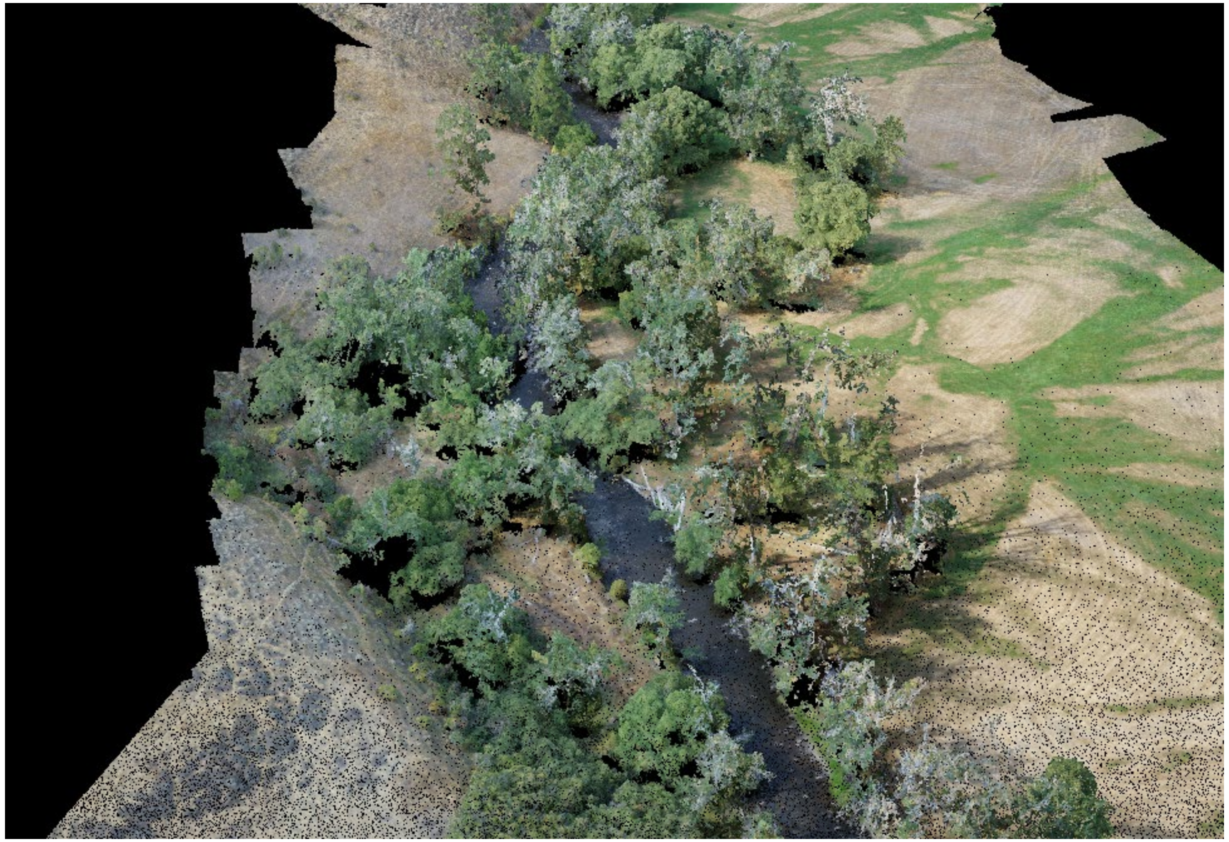


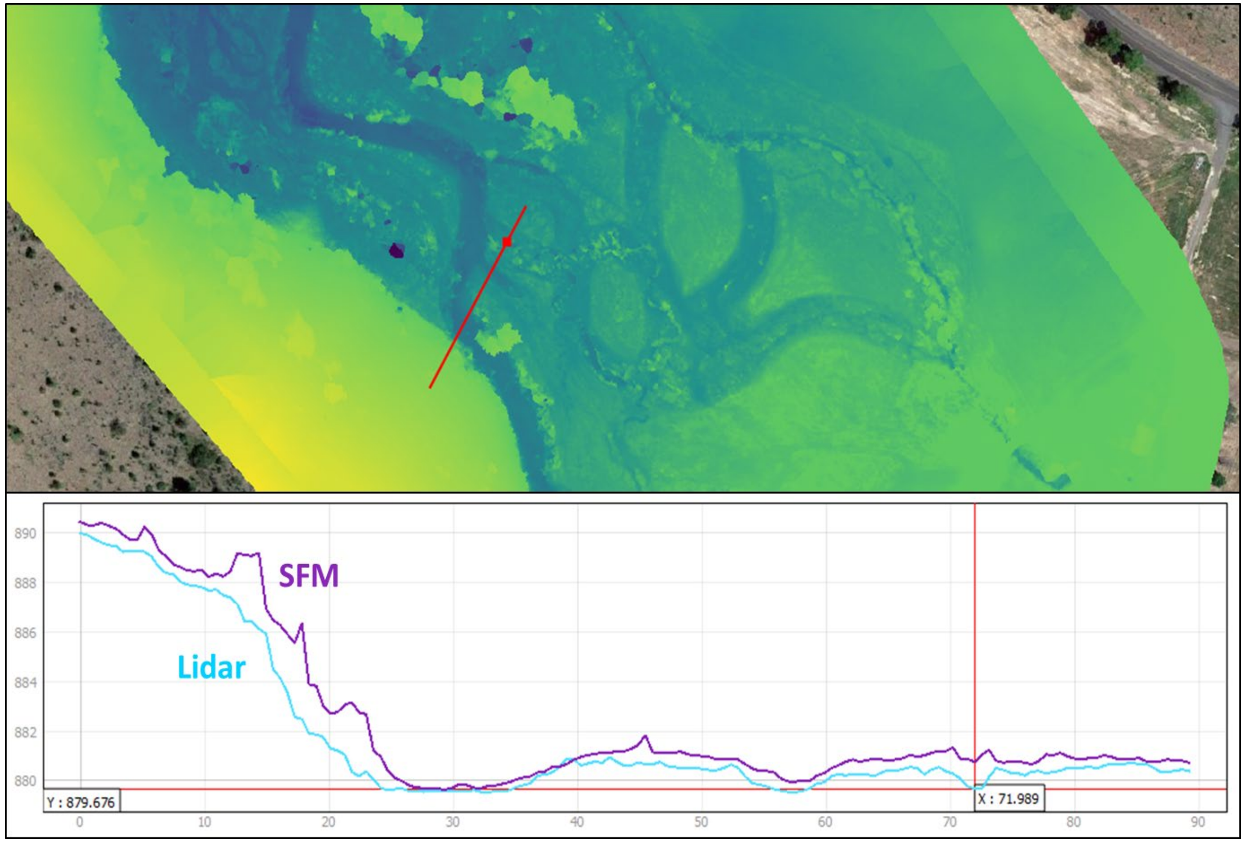
Surveys – Field vs. Remote Sensing + Field

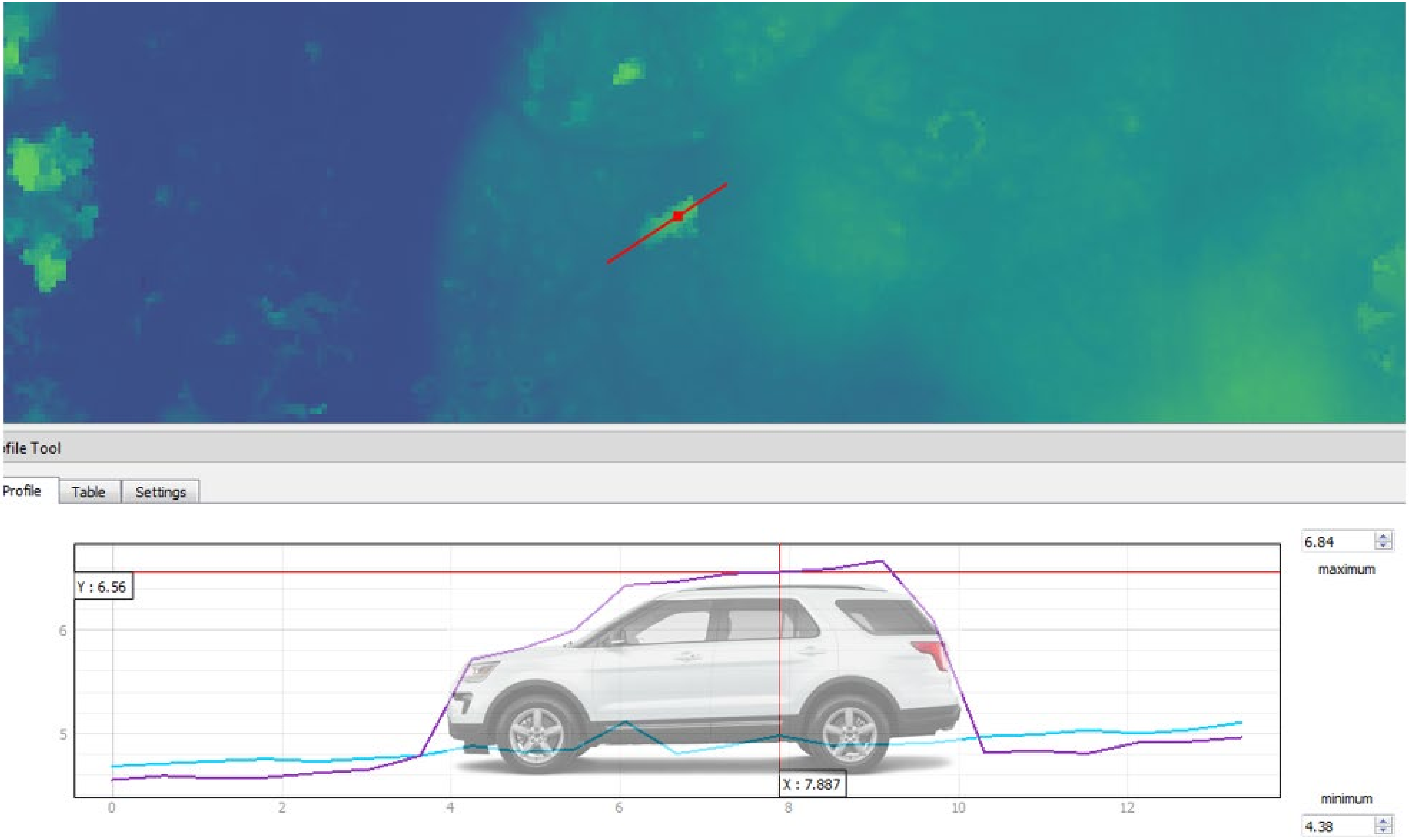
- Continuous coverage
- Point density (~12/m^2 with LiDAR)
- Can map entire floodplain and habitats quickly
- Allows modeling of habitats at different flows



Floodplain Morphology – SFM vs LiDAR







file Tool
Profile
Table
Settings
6.84
maximum
Y : 6.56
6
5
X : 7.887
0
2
4
6
8
10
12
minimum
4.38

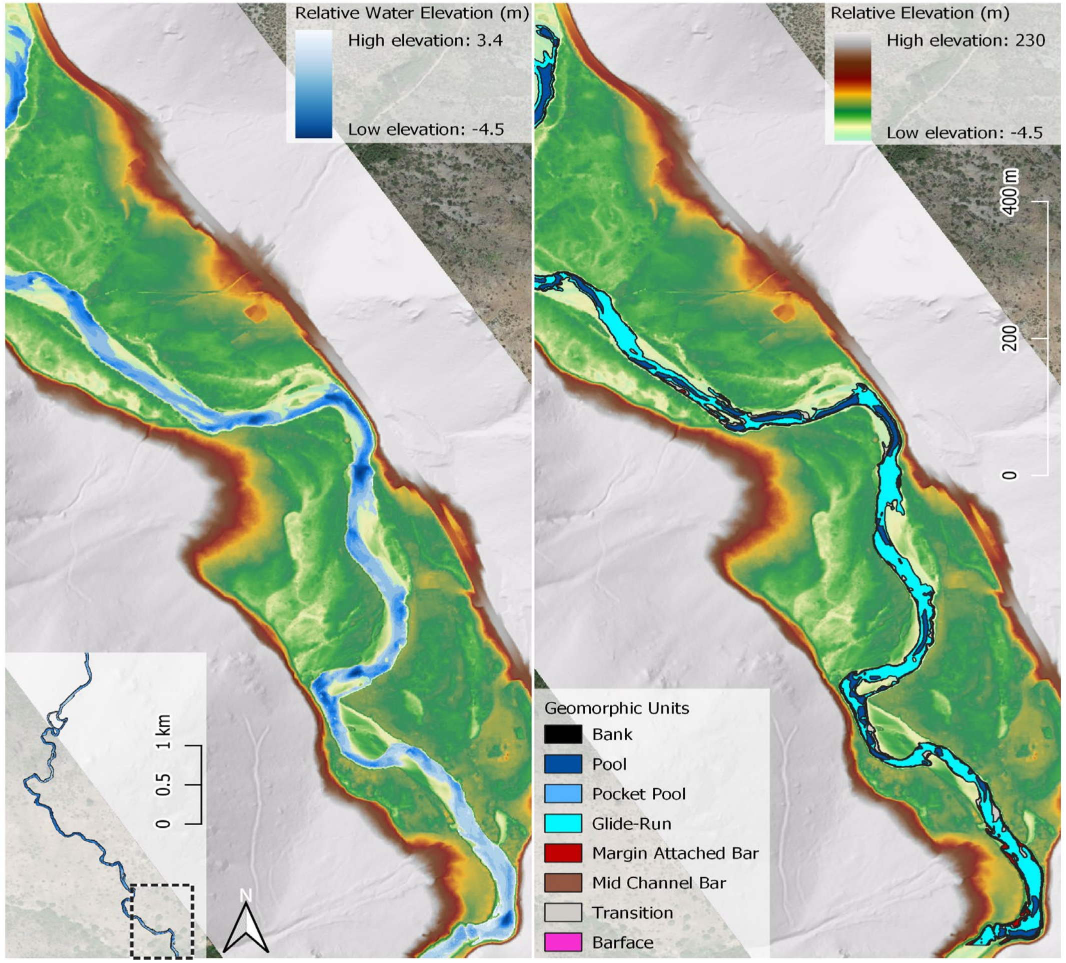
Remote Sensing and Bathymetry

To get bathymetry you need

- A. Green LiDAR
  - Not suitable for all streams

- B. Conduct field survey and map using other methods
  - RTK (real-time kinematic) GPS
  - Acoustic Doppler current profiler (ADCP)
  - Total station

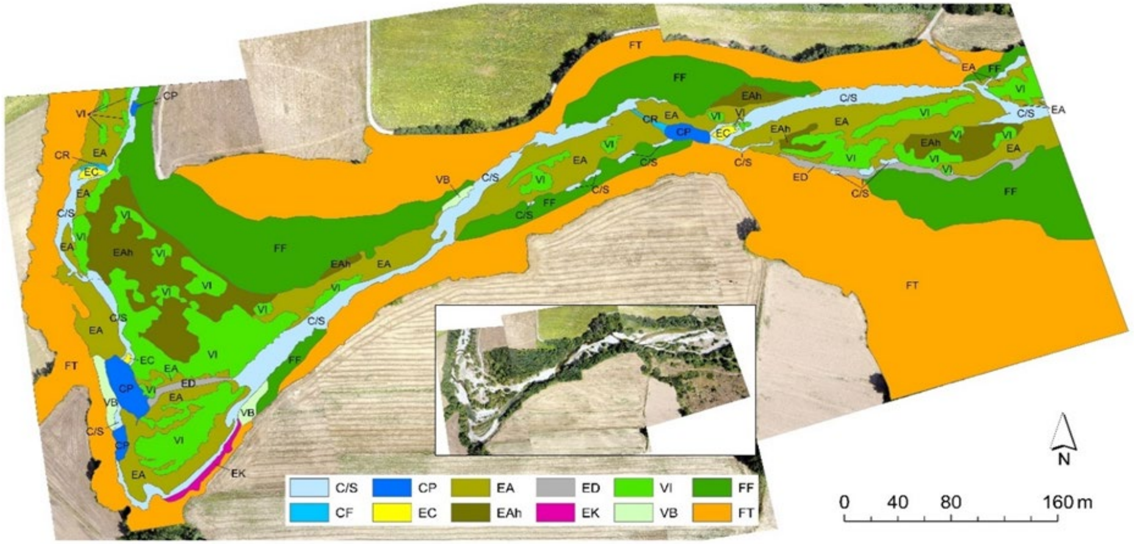
- Bathymetry on Entiat River from green LiDAR



Habitat Units

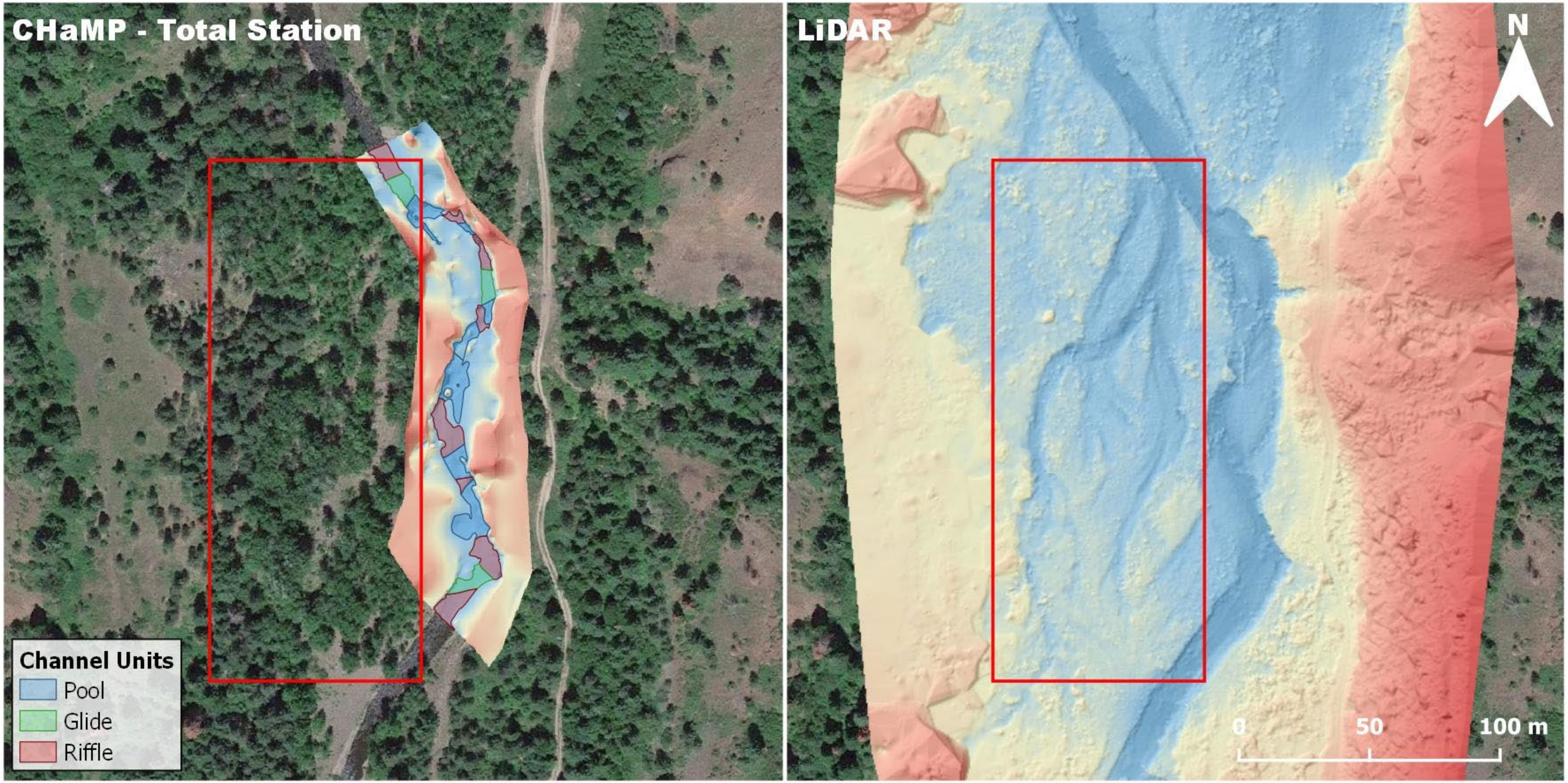
- Historical – Field surveys

- New – RTK, LiDAR, Aerial Imagery

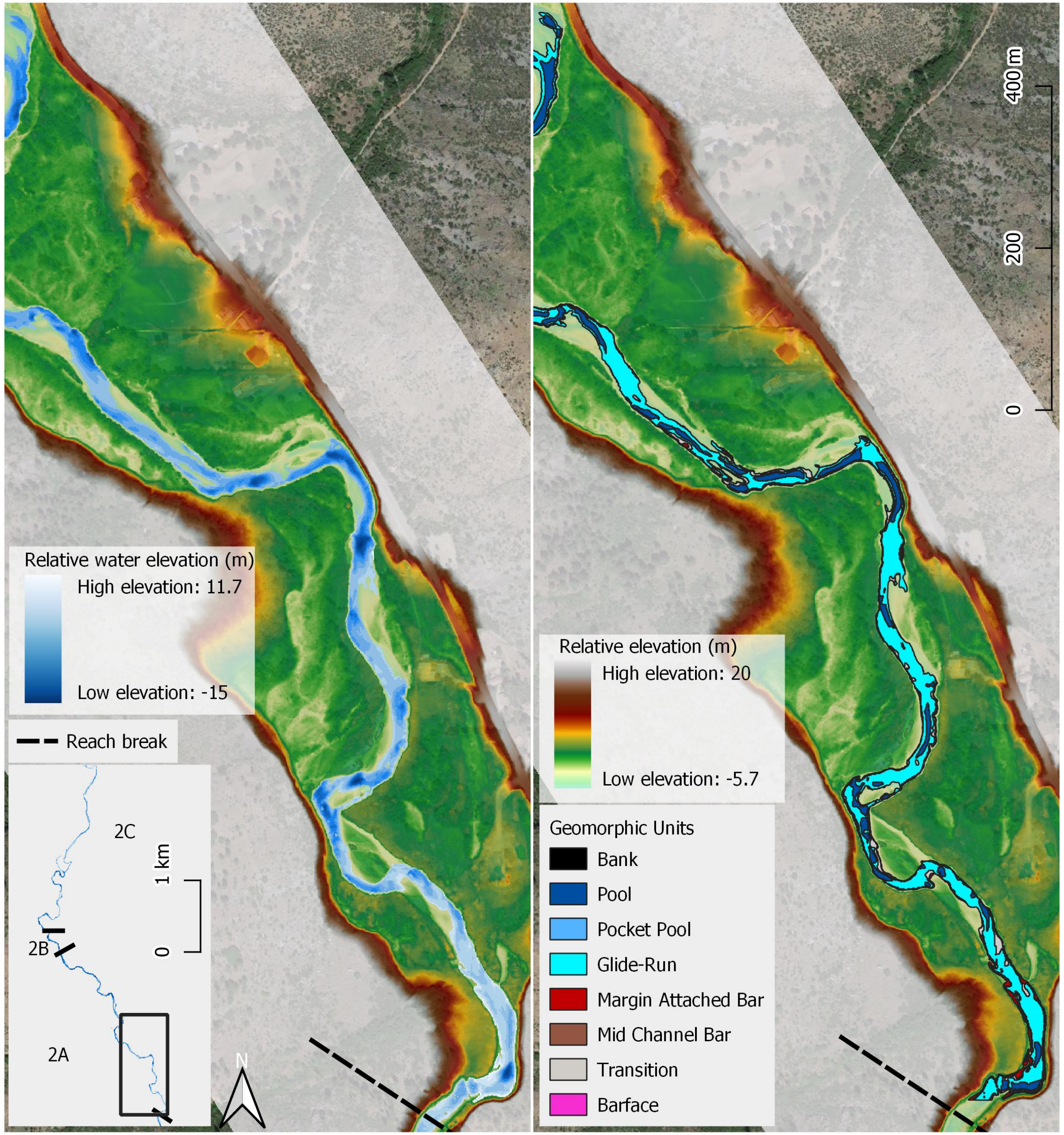


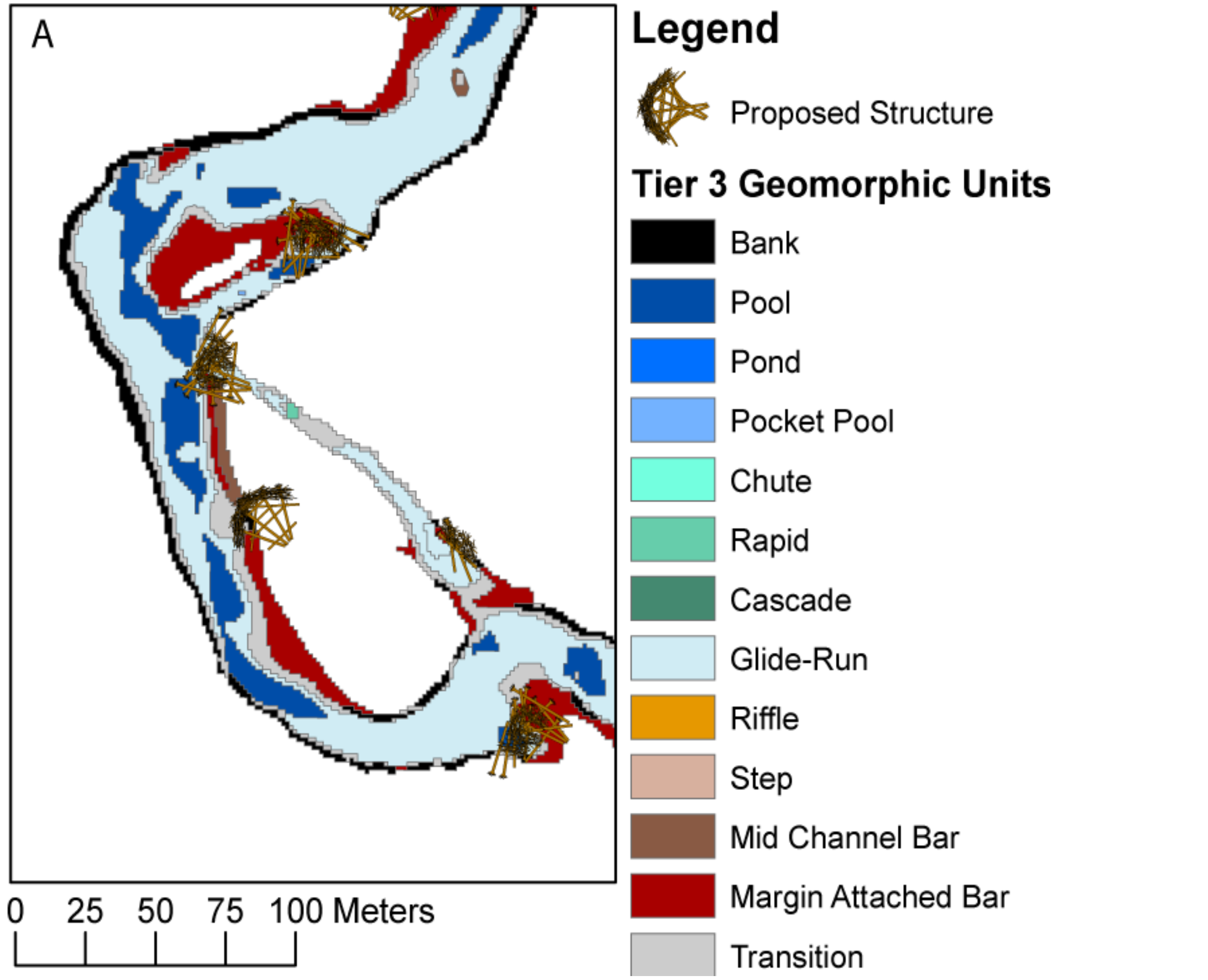
Rinaldi et al. 2017

Surveys – Field vs. Remote Sensing (w/ Field survey)

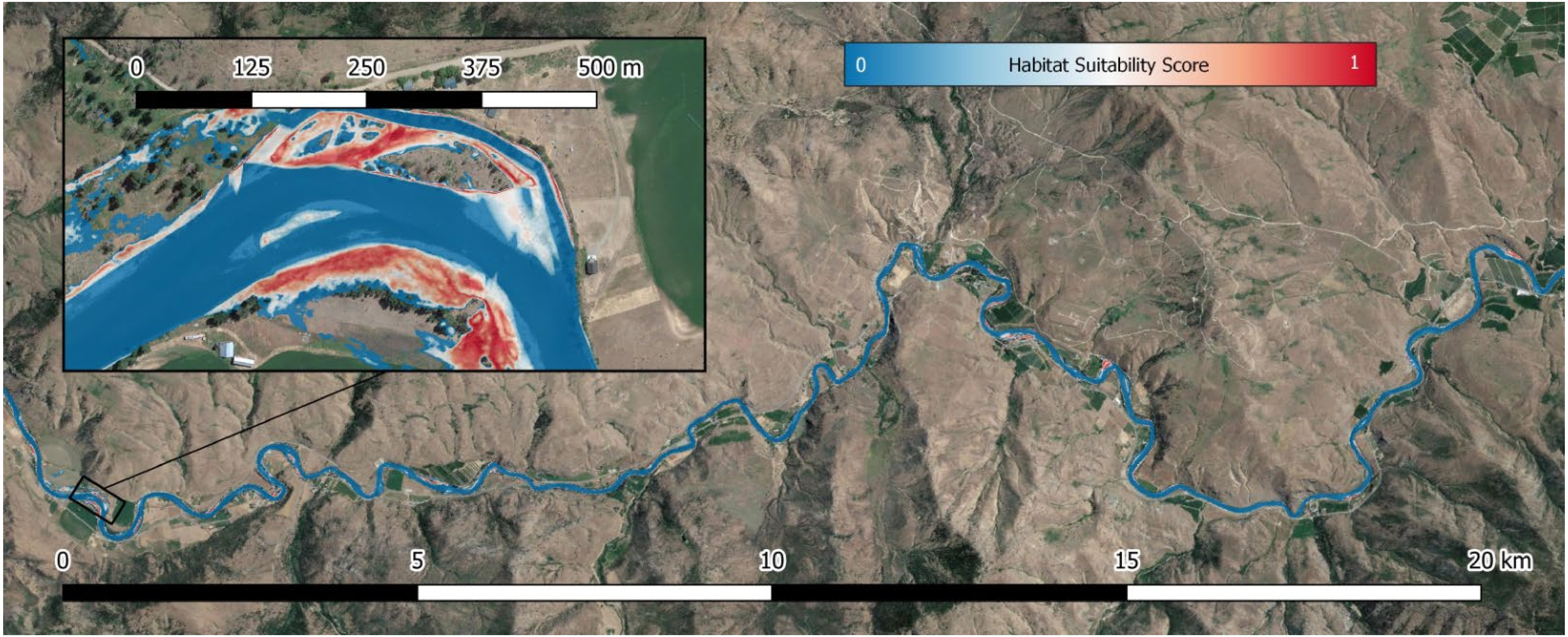


Geomorphic Unit Tool vs. Fish Habitat?





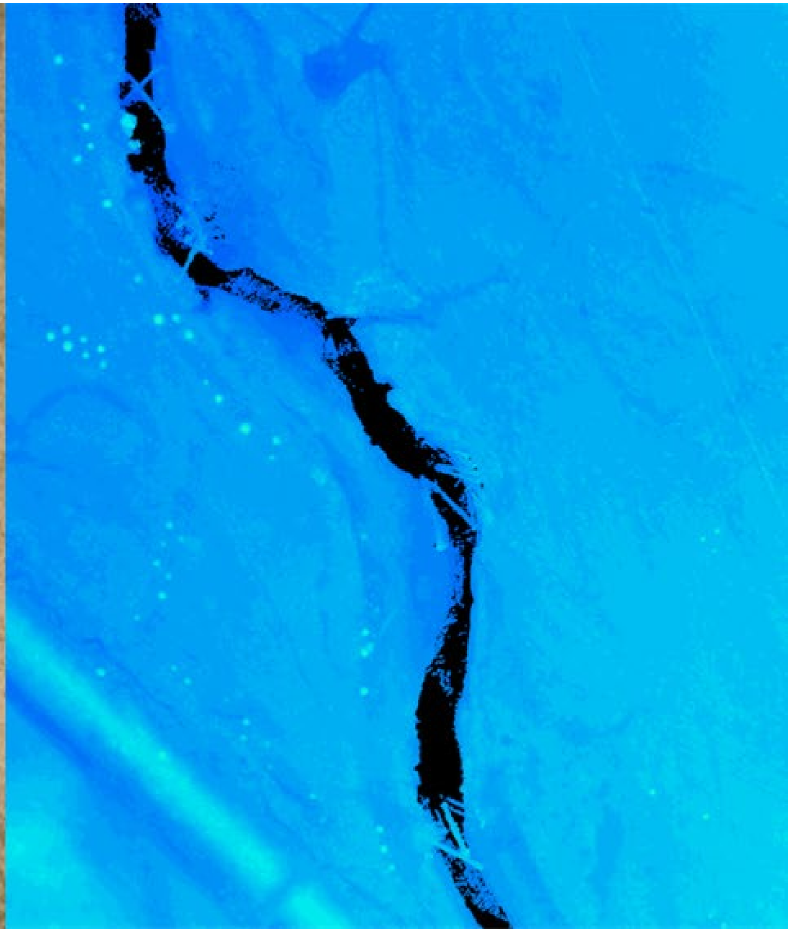
Fish Habitat Suitability Index (HSI) – can now process large areas with click of button

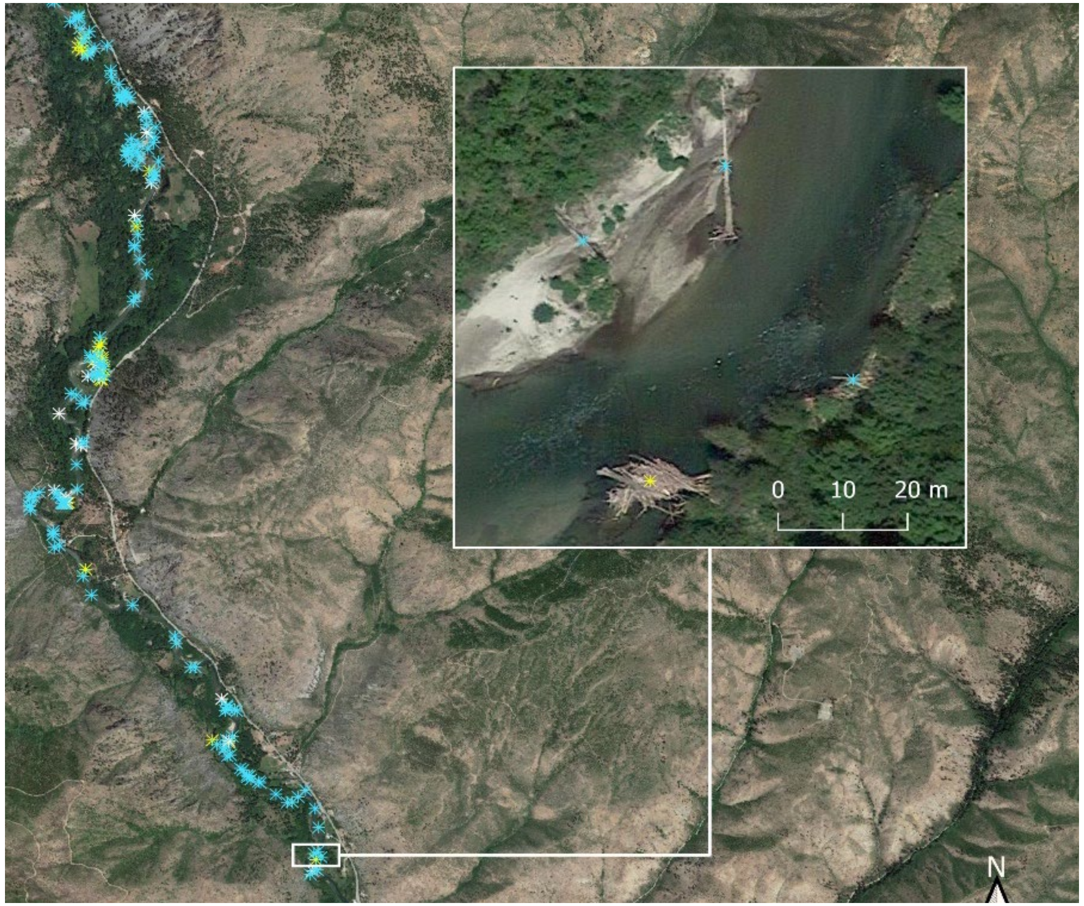


Large Wood

- Historical

New – Aerial Imagery or LiDAR





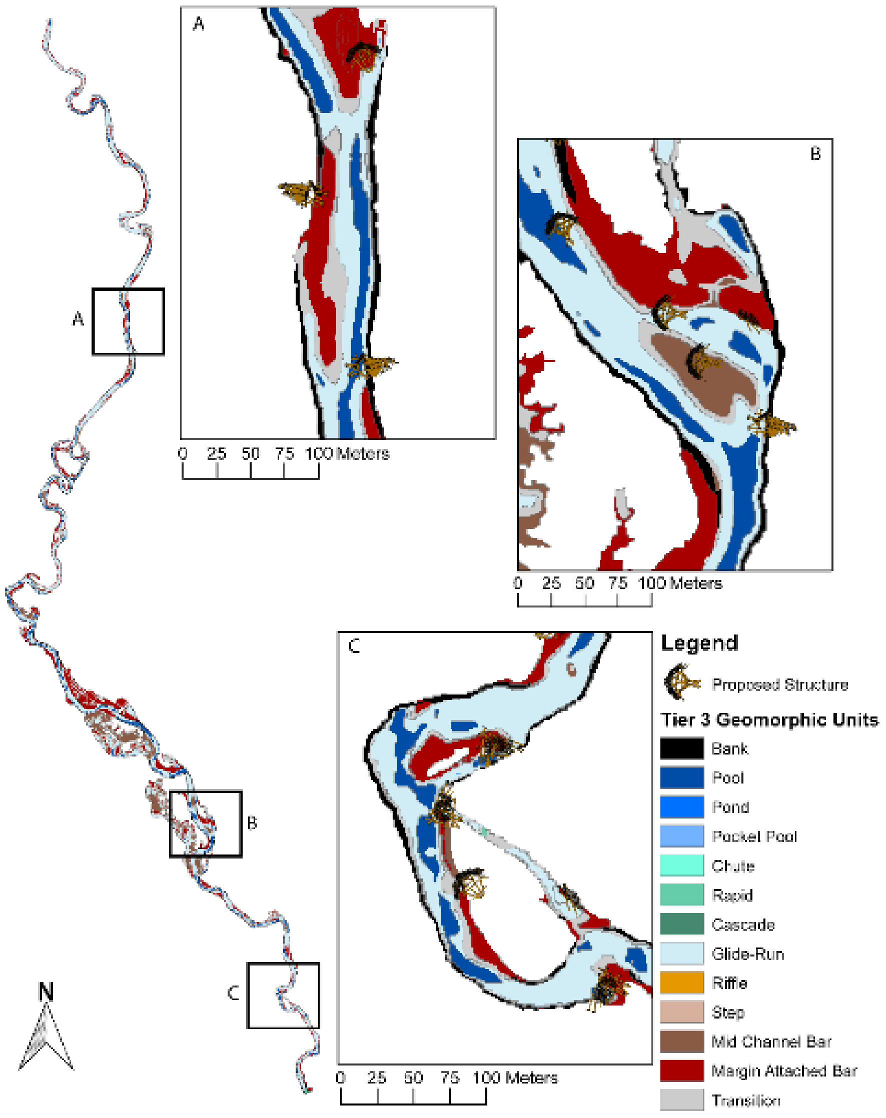
LW category	Count	Frequency	Low flow	Bankfull	> Floodplain
Piece (<3 pieces)	92	1.06 / 100 m	19.6%	51.1%	29.4%
Small jam (3-4 pieces)	16	0.18 / 100 m	12.5%	56.3%	31.3%
Large jam (≥4)	14	0.16 / 100 m	7.1%	64.3%	28.6%
Total	122	1.41 / 100 m	17.2%	53.3%	29.5%

Recommendations for Monitoring floodplain projects – Traditional vs. Remote Sensing

River size (bankfull width)	Project size (stream length)		
	Small (<0.5 km)	Medium (0.5m to 2 km)	Large (> 2 km)
Small <15 m BFW	Field surveys	Field & remote sensing	Remote sensing
Medium 15 to 30 m BFW	Field surveys	Remote sensing	Remote sensing
Large > 30 m BFW	Field surveys	Remote sensing	Remote sensing

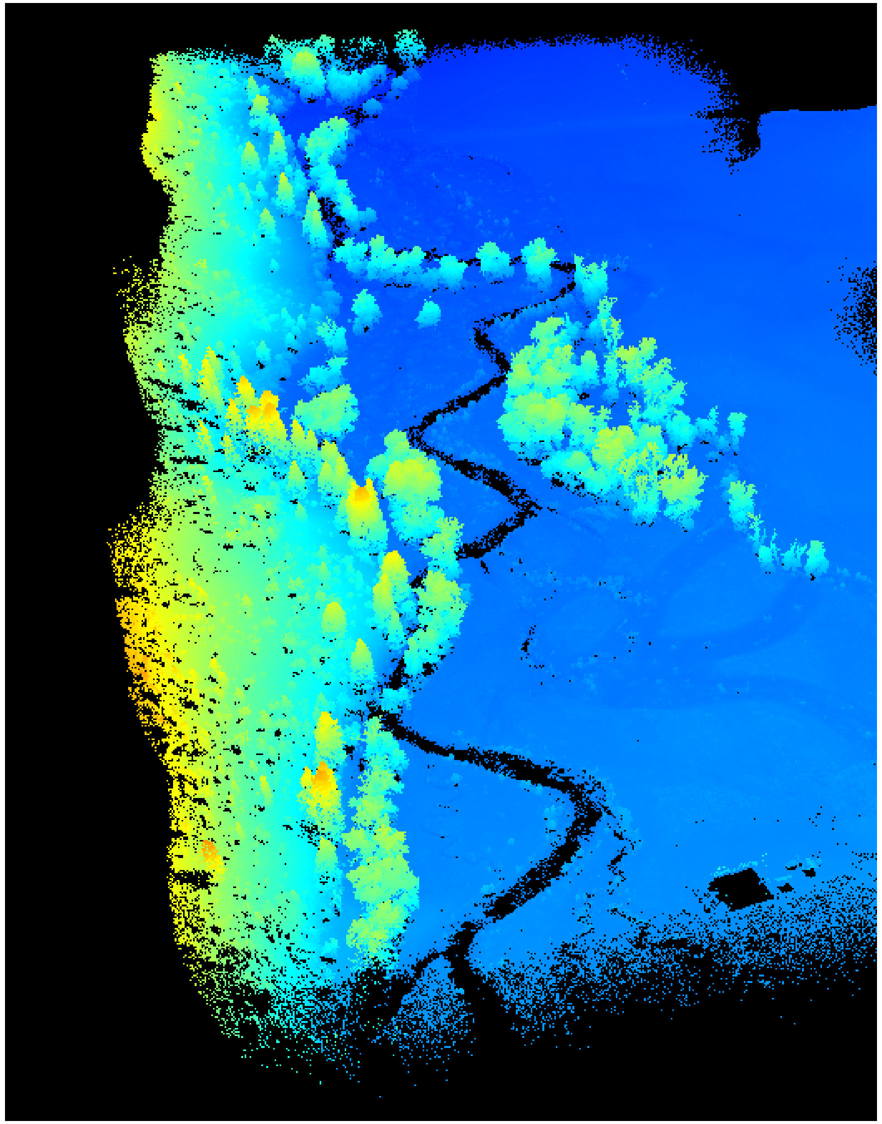
Challenges – New isn't always better!

- Save field time, but increase office/lab time
- Remote sensing doesn't eliminate need for field work – often need to combine techniques
- Higher equipment costs and complex processing
- Analytical methods are changing rapidly
- Need extensive training and knowledge to use equipment and do analysis
- Increased level of precision might not be needed, depends upon scale and cost…
- Monitoring questions should determine method!



Summary

- Rapid advances in floodplain monitoring methods particularly remote sensing
- LiDAR can map large floodplain areas quickly with continuous coverage
- Newer methods not best for all applications
- Monitoring questions, scale, and cost STILL determine most appropriate methods
- Ideally some combination of LiDAR coupled with field surveys
- Biggest recent advances are in processing and analysis of remote sensing
- See Roni et al. 2019. Wiley Interdisciplinary Reviews: Water 6(4):e1355. for additional details

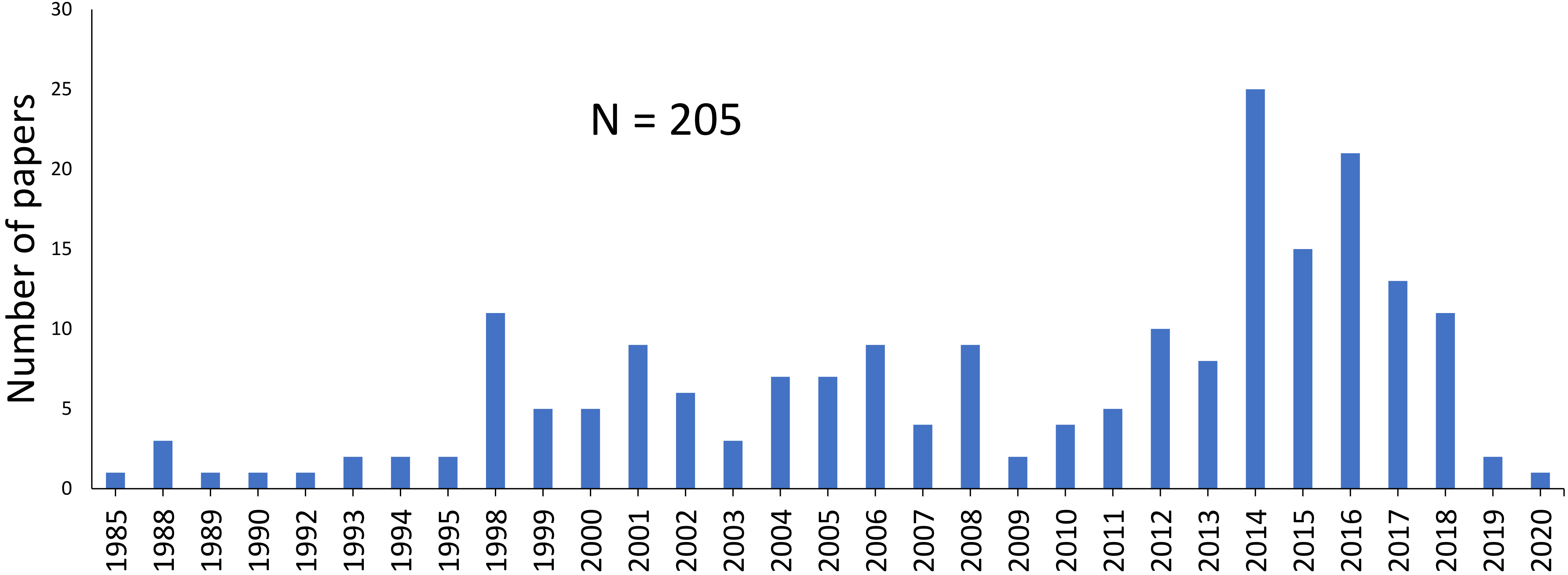


Extra Slides

Additional readings

- Roni, P., J. E. Hall, S. M. Drenner, and D. Arterburn. 2019. Monitoring the effectiveness of floodplain habitat restoration: A review of methods and recommendations for future monitoring. Wiley Interdisciplinary Reviews: Water 6(4):e1355.
- Tomsett, C., and J. Leyland. 2019. Remote sensing of river corridors: A review of current trends and future directions. River Research and Applications 35(7):779-803.
- Harris, J. M., J. A. Nelson, G. Rieucau, and W. P. Broussard. 2019. Use of Drones in Fishery Science. Transactions of the American Fisheries Society 148(4):687-697.

Papers On Floodplain Restoration Effectiveness



Roni et al. 2019 WIREs Water

Examples of Common Metrics (Parameters)

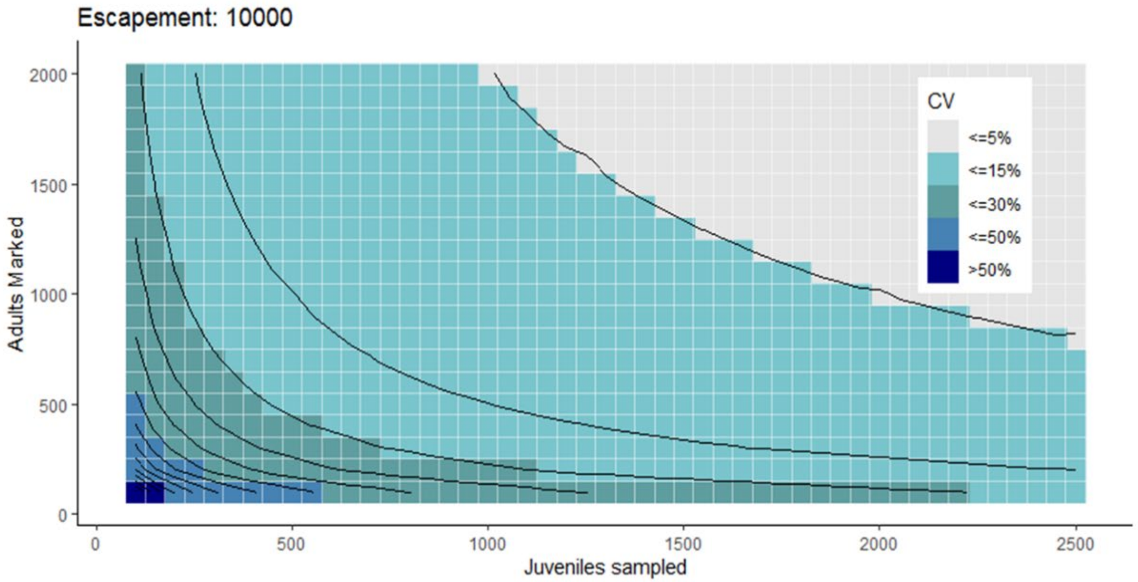
Category	Metric	Number of Studies
Physical	**Channel/ floodplain morphology***	52
	Meso-habitats*	98
	Large wood*	13
	Sediment	60
Biological	**Fish***	79
	Macroinvertebrates	54
	Aquatic macrophytes	34
	Periphyton	10
	Riparian vegetation	59

* For sake of time I will focus on these four categories of metrics today

Fish

- Historical (electrofishing, Mark-Recapture, snorkeling)

- New Methods
  - eDNA (presence/absence)
  - Otolith microchemistry (life history, residence time)
  - Genetic Mark Recapture (population estimate, survival)



TIR/FLIR (Thermal Infrared/Forward Looking Infrared)

- Pros
  - Can cover broad area
  - Identify cool-water refuges
  - Identify areas for locating continuous monitoring

- Cons
  - Snapshot in time
  - Surface temperatures
  - Costly to repeat
  - Spatial and temporal resolution

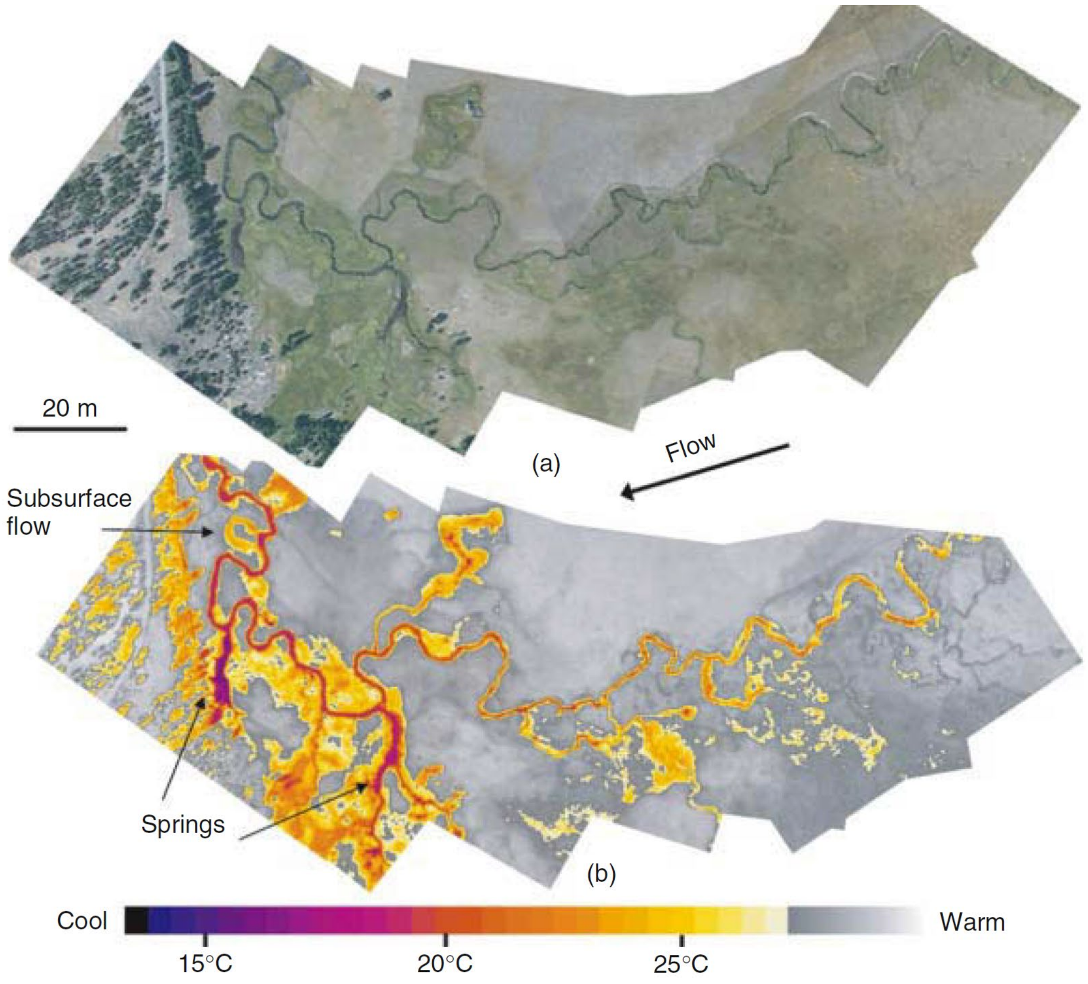
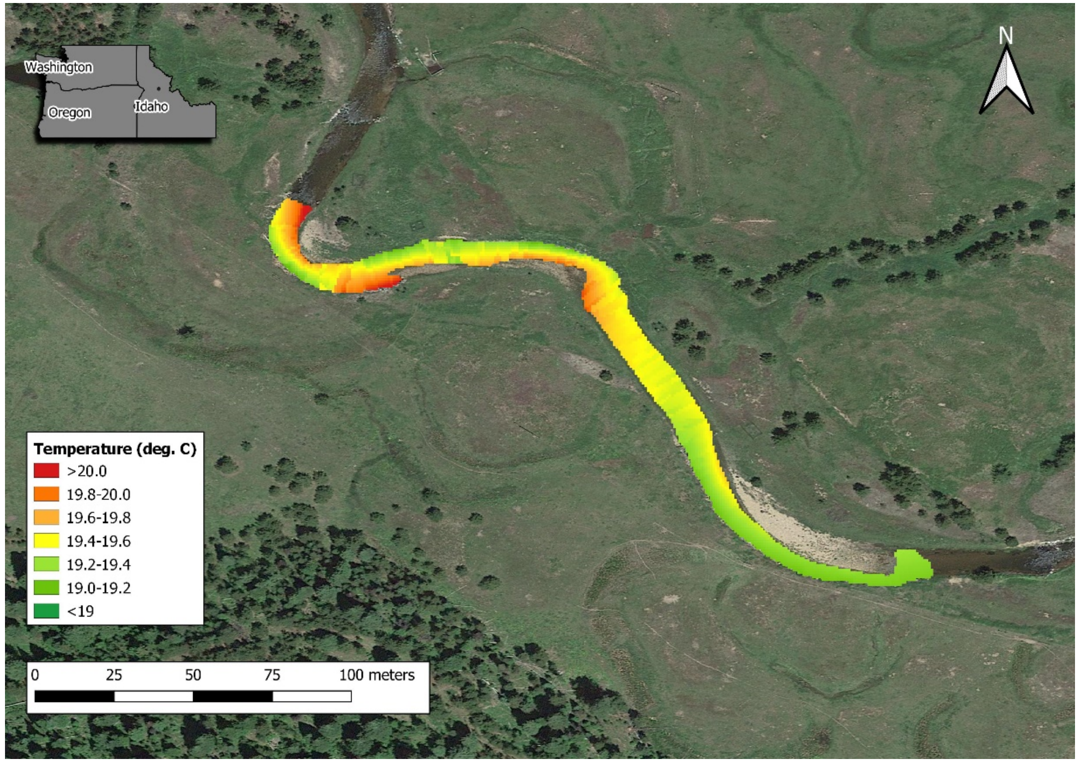


Figure 5.2 Handcock et al. 2012

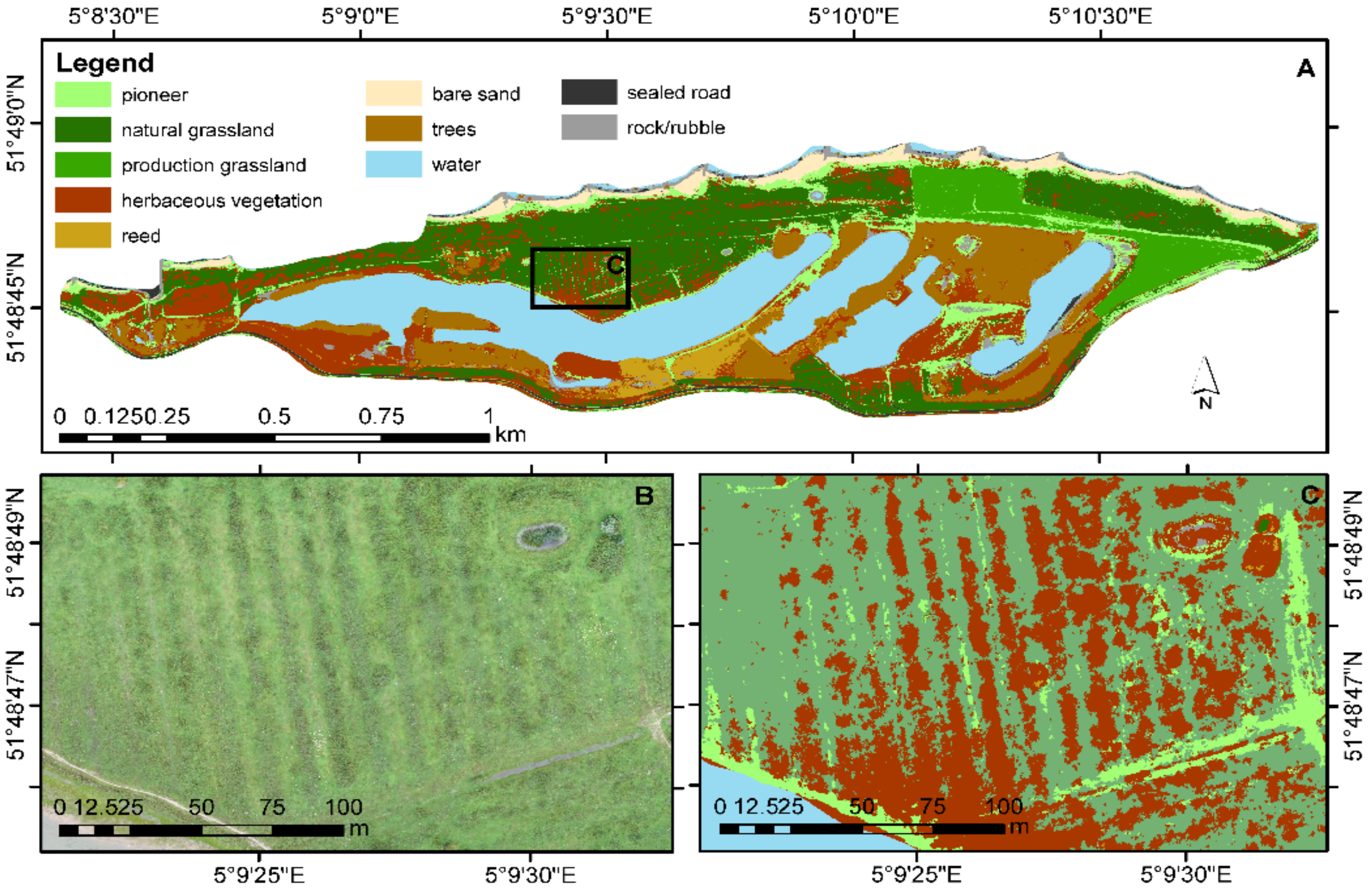
Temperature – thermometer, data logger, remote sensing?



Riparian vegetation

- Historical – Field Survey

- Remote Sensing – Aerial Photography or LiDAR



Van Iersel et al. 2018 from false color orthophotos

Common Floodplain Metrics and Remote Sensing

Parameter/metric	LiDAR (Green or w/ bathymetric survey)	LiDAR (near-Infrared)	SfM	Multispectral Imagery	Aerial Photography	Satellite Imagery	FLIR
Channel morphology	Y	Y	Y	N	M	M	N
Bathymetry	Y	N	N	N	N	N	N
Topography	Y	M	Y	N	N	N	N
Habitat units	Y	M	M	M	M	N	N
Floodplain inundation	Y	Y	M	N	N	N	N
Side channel no., length	Y	Y	M	M	M	M	N
Wetland area	Y	Y	M	M	M	M	N
Sediment deposition	Y	N	M	N	N	N	N
Large wood	Y	Y	Y	Y	Y	M	N
Surface temperature	N	N	N	N	N	N	Y
HSI (Habitat suitability index)	Y	N	M	N	N	N	N

Y = Yes	M = Maybe	N = No

Common Riparian Metrics and Remote sensing

Parameter/metric	LiDAR	SfM	Multispectral Imagery	Aerial Photography	Satellite Imagery
Riparian composition	M	M	Y	M	N
Riparian stem density	M	M	N	N	N
Plant survival	N	N	M	N	N
Species diversity	N	N	N	N	N
Growth	Y	M	N	N	N
Area vegetation extent by class	Y	N	N	N	N
Bank stability	Y	M	N	N	N
Organic inputs (leaf litter)	Y	N	N	N	N