Beaver and Process-Based Restoration: Opportunities and Obstacles 1

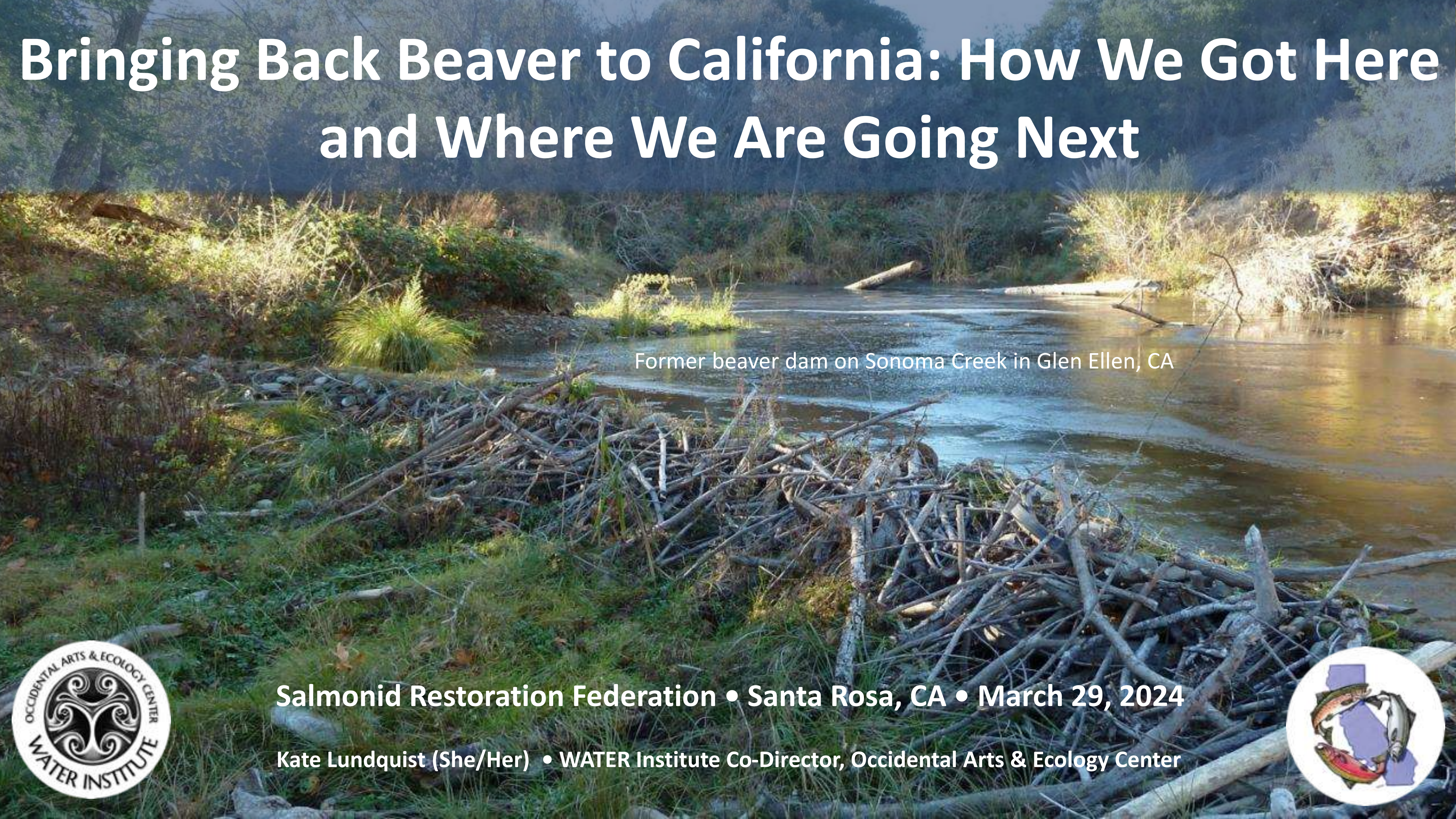
A Concurrent Session at the 41st Annual Salmonid Restoration Conference
Santa Rosa, California, March 26-29, 2024

Session Coordinator: Karen Pope, *USDA Forest Service*

Climate change represents a major threat to freshwater aquatic ecosystems in California and the Pacific Northwest, home to important but increasingly sensitive taxa, including salmonids. The impacts of climate change on certain freshwater ecosystems may be ameliorated by the engineering activities of beavers (Castor canadensis), which were once common throughout North America but experienced dramatic declines due to fur harvest in the 18th and 19th centuries. Many streams and rivers have not been recolonized by beavers due to a lack of local source populations or because the habitats have been simplified and degraded, impairing beaver recolonization. Strategic stream, meadow, and river restoration applications with beaver and process-based restoration (PBR) have the potential to play a larger role in the multi-tiered efforts to manage pressing climate-related threats to forests and water supply by increasing resistance to wildfire, increasing base flows, and reducing sedimentation in unwanted reaches and reservoirs. In these systems, beaver restoration and PBR have the potential to recover stream complexity, increase surface and groundwater storage, and regain floodplain connectivity, resulting in improved salmonid habitat. However, we are just beginning to develop the restoration tools, scientific backing, and workforce to meet the demand for increasing the pace and scale. For example, we launched the new California Process-Based Restoration Network in 2022 with the goal of increasing capacity to restore degraded riverscapes in California (calpbr.org). In addition to building the human capacity to implement restoration projects, research and monitoring remain important for understanding and identifying where and when beaver restoration and PBR can succeed and what approaches are best to maximize ecohydrological benefits. The primary goals of this session are to (1) share what has been done, how it is working, and the scientific basis that supports it; and (2) explore the various impediments to scaling up the more effective practices.

Presentations

Bringing Back Beaver to California: How We Got Here and Where We Are Going Next



Former beaver dam on Sonoma Creek in Glen Ellen, CA

Salmonid Restoration Federation • Santa Rosa, CA • March 29, 2024

Kate Lundquist (She/Her) • WATER Institute Co-Director, Occidental Arts & Ecology Center

OCCIDENTAL ARTS & ECOLOGY CENTER

CELEBRATING 30 YEARS OF COLLABORATIVE RESTORATION FROM RIDGELINE TO REEF

WATER INSTITUTE

WATERSHED ADVOCACY, TRAINING, EDUCATION AND RESEARCH

Painting: adamwolpert.com


Brock Dolman

Occidental Arts & Ecology Center

ING BACK THE BEAVER CAMPAIGN

Occidental Arts & Ecology Center Water Institute

- Education & Outreach
- Citizen Science
- Research & Demonstration
- Policy Change

BIG WINS THE PAST TWO YEARS!

In June 2022 the CA legislature passed Governor Newsom's budget that funded the creation of the new CDFW-led Beaver Restoration Program

- 5 permanent positions, ongoing funding
- Promote human-beaver coexistence strategies
- Develop Beaver Management and Restoration Plan
- Conduct beaver translocations (for restoration purposes)
- Conduct outreach and education

NEW CDFW DEPREDATION PERMIT GUIDANCE ISSUED IN JUNE 2023

CDFW shall:

- Document all nonlethal measures taken by the landowner to prevent damage prior to requesting a depredation permit.

- Require implementation of feasible nonlethal corrective actions by the landowner to prevent future beaver damage.

- Determine whether a property is located within the range of listed species and add permit terms and conditions to protect native wildlife.

- Continue to prioritize issuance of depredation permits if it determines that an imminent threat to public safety exists, such as flooding or catastrophic infrastructure damage.

FOR THE FIRST TIME IN NEARLY 75 YEARS CDFW RELEASES BEAVER

At Tásmam Koyóm (Plumas County) in collaboration with the Maidu Summit Consortium


HOW DID WE GET HERE?

BUILDING ALLIANCES & STRATEGIC PLANNING FOR THE LONG GAME

IDENTIFYNG AND RESOLVING HISTORIC AND CURRENT SOCIAL AND INFORMATIONAL BARRIERS

Novel Physical Evidence that Beaver were Native to the Sierra Nevada

James and Lanman 2012
California Fish and Game Journal

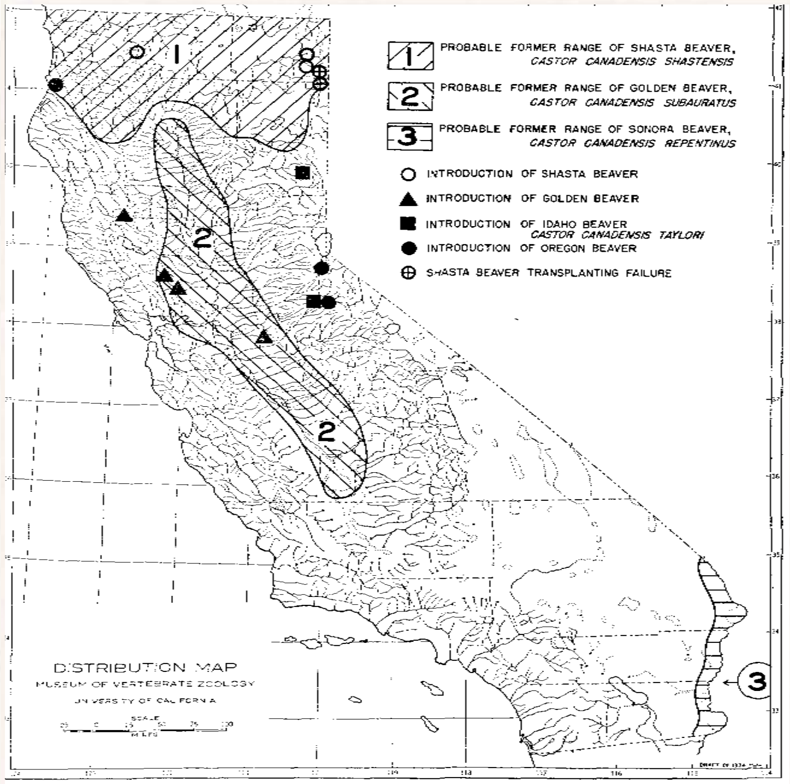
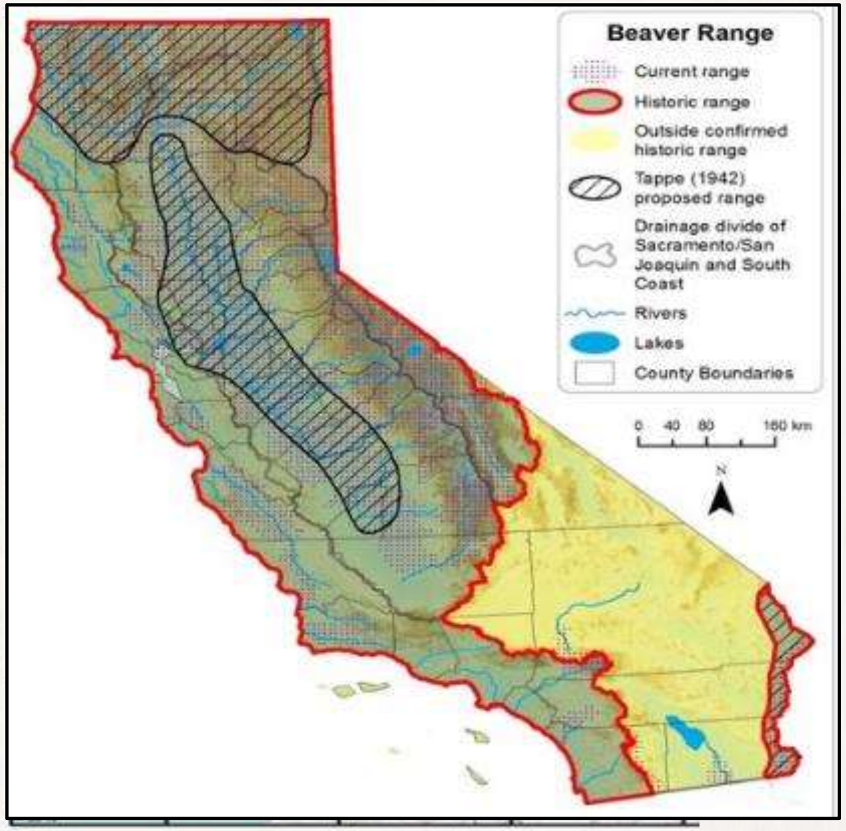


FIG. 2. Probable former range of beavers in California, with location of sites where beavers have been transplanted by governmental agencies in recent years.

The Historic Range of Beaver in the Sierra Nevada

Lanman et al. 2012
California Fish and Game Journal



The Historical Range of Beaver in Coastal California (Update)

Lanman et al. 2013
California Fish and Game Journal

https://oaec.org/publications/historical-range-of-beaver-update/

PROMOTING UNDERSTANDING THAT BEAVER RESTORATION REQUIRES A HOLISTIC APPROACH WITH A VARIETY OF ACTIONS

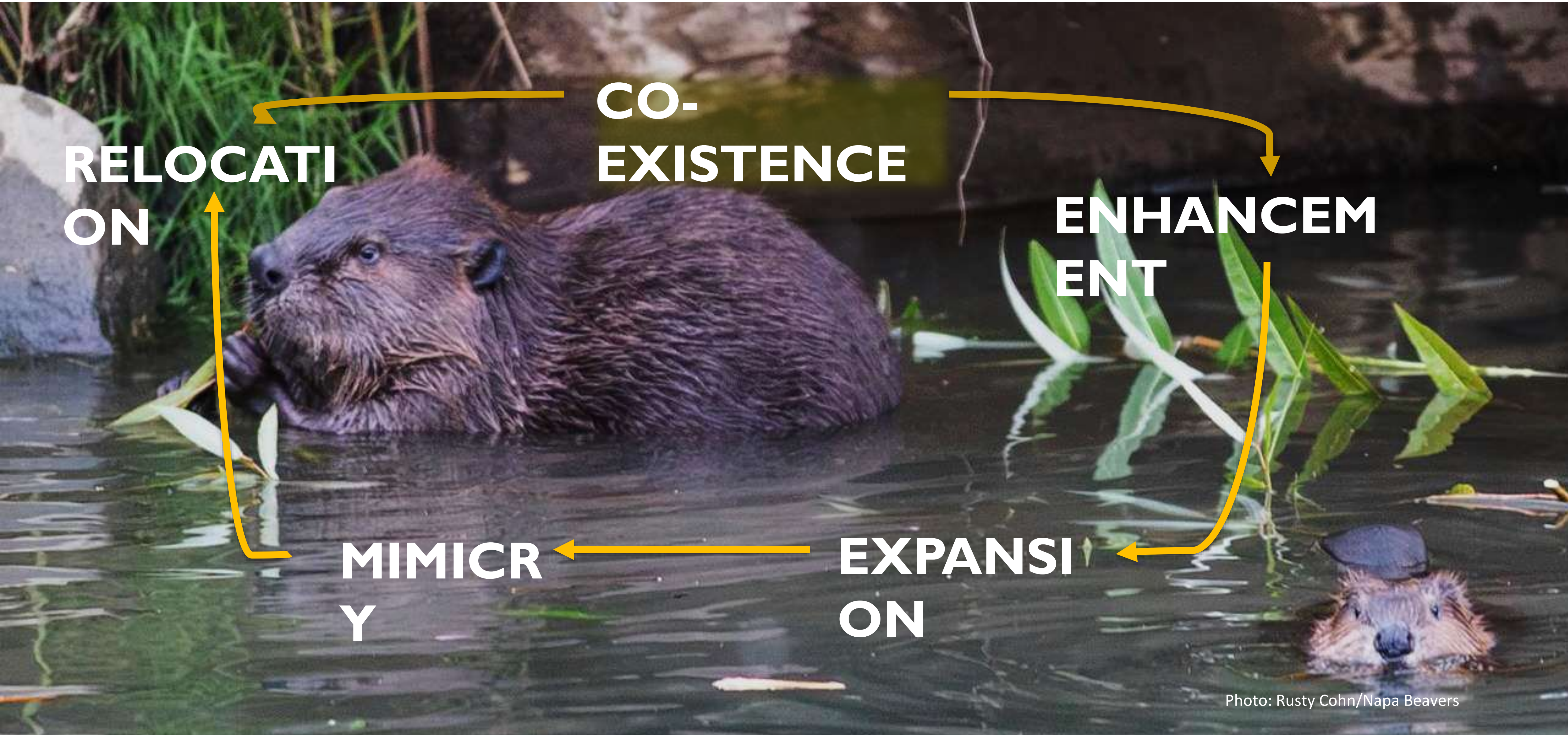


Photo: Rusty Cohn/Napa Beavers

HIGHLIGHTING REGIONAL SPECIES OF CONCERN THAT BENEFIT FROM BEAVER AND PROCESS-BASED RESTORATION


Photo: Kate Lundquist


Photo: Brock Dolman


Photo: Brock Dolman

"Smokey the Beaver: beaver–dammed riparian corridors stay green during wildfire throughout the western USA" by Fairfax and Whittle, 2020

http://doi.org/10.1002/eap.2225

HELPING AUDIENCES CONNECT THE SCIENCE OF BEAVER BENEFITS TO PRESSING CLIMATE RESILIENCE ISSUES

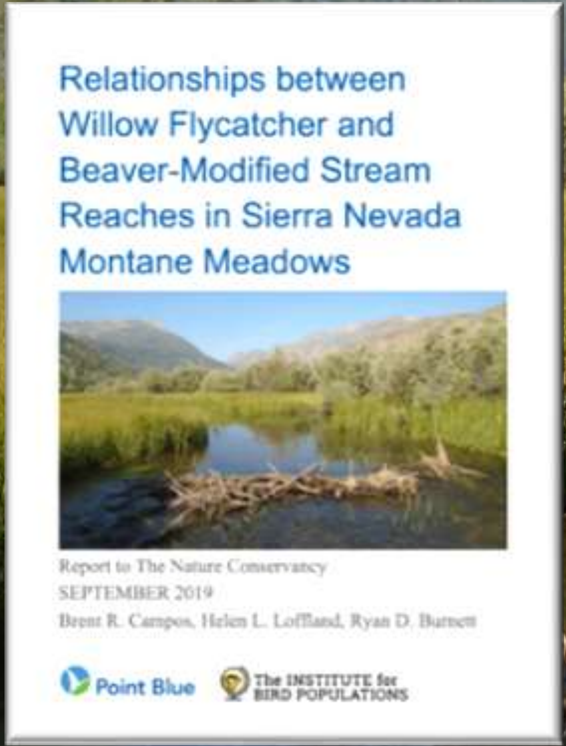
Photo: www.joewheaton.org

LEGITIMIZING AND INCREASING LITERACY BY GATHERING PRACTIONERS TO SHARE THEIR RESULTS WITH TARGETED AUDIENCES

The Sierra Meadows Partnership

California Rangeland Conservation Coalition

SUPPORTING THE SCIENTIFIC COMMUNITY IN STUDYING AND SHARING RESULTS ABOUT POTENTIAL BENEFITS OF BEAVER


Relationships between Willow Flycatcher and Beaver-Modified Stream Reaches in Sierra Nevada Montane Meadows

Report to The Nature Conservancy
SEPTEMBER 2019
Brent R. Campos, Helen L. Loffland, Ryan D. Burnett

Point Blue
The INSTITUTE for BIRD POPULATIONS


CWS TECHNICAL REPORT

A Demonstration of the Carbon Sequestration and Biodiversity Benefits of Beaver and Beaver Dam Analogue Restoration Techniques in Childs Meadow, Tehama County, California

Center for Watershed Sciences

Prepared for California Department of Fish and Wildlife

March, 2020

Photo: Jason Gregg

BUILDING BEAVER AND PBR NETWORKS TO GATHER AND SHARE INFO

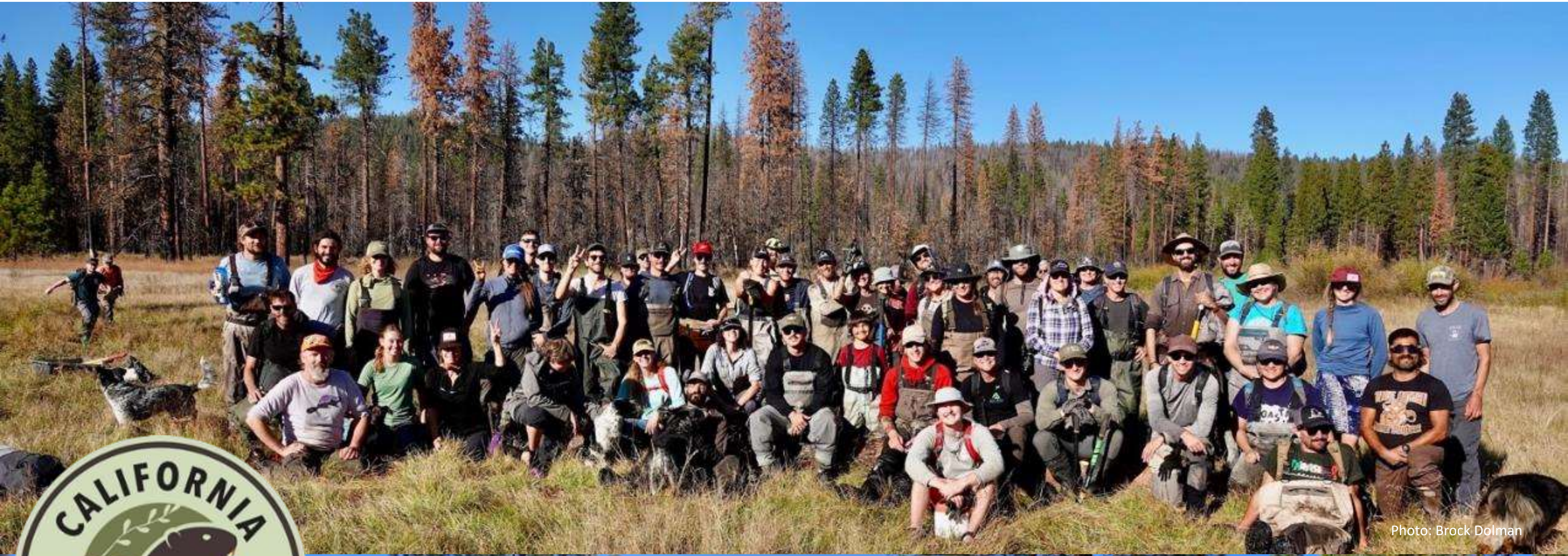


Photo: Brock Dolman

Photo: Jeremey Kelley

CALIFORNIA PROCESS BASED RESTORATION NETWORK

www.calpbr.o

DEMONSTRATING AND SHARING SUCCESSFUL CO-EXISTENCE EFFORTS

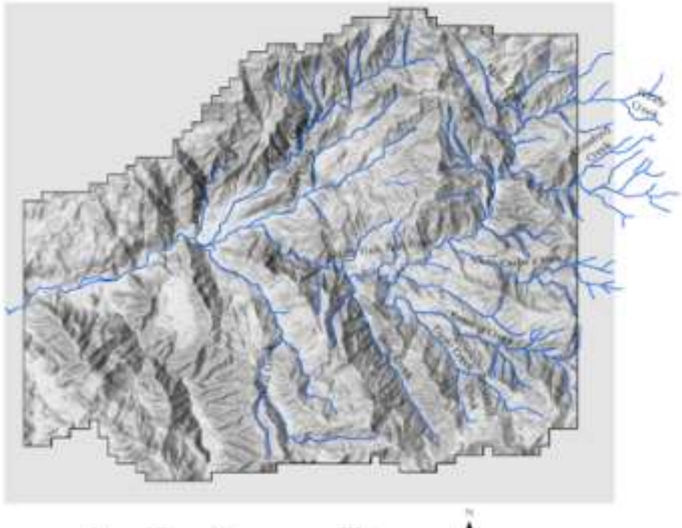
CREATING AND SHARING RESULTS FROM BEAVER RESTORATION DEMO SITES WITH STRATEGIC AUDIENCES

PLACER LAND TRUST

U.S. FISH & WILDLIFE SERVICE

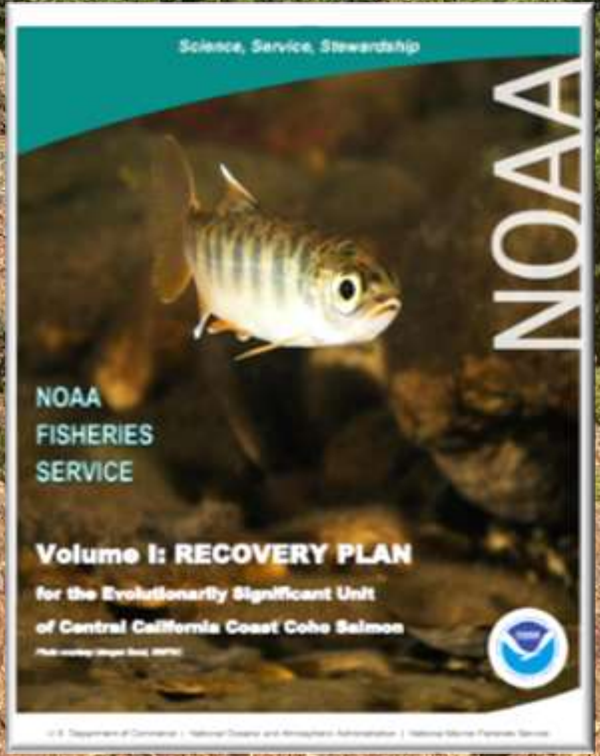
Swift Water Design

WHEN INVITED, LEVERAGING PRIVILEGE TO SUPPORT TRIBES AND UNDERRECOGNIZED ALLIES



ENSURING BEAVER RESTORATION IS INCLUDED IN LISTED SPECIES RECOVERY PLANS, FOREST PLANS AND OTHER CONSERVATION STRATEGIES

Photo: Kate Lundquist



COALITIONS HELP BUILD MOMENTUM

Photo: Kate Lundquist

Photo: Rusty Cohn

Photo: Rusty Cohn

November 19, 2021

Wade Crowfoot, Secretary
Amanda Hansen, Deputy Secretary for Climate Change
California Natural Resources Agency
715 P Street, 20th Floor
Sacramento, CA 95814

Submitted via email: CaliforniaNature@resources.ca.gov

RE: Comments on Draft Climate Smart Strategy - Support inclusion of beaver and process-based restoration in the California Natural and Working Lands Climate Smart Strategy

Dear Secretary Crowfoot and Deputy Secretary Hansen,

We are long-time proponents and practitioners of nature-based solutions on natural and working lands. While the draft Climate Smart Strategy identifies many excellent solutions, we strongly advocate for the

AGING THE MEDIA

Photo: Rusty Cohn

ASSESSING AND CHANGING POLICY
HIRING A BEAVER LOBBYIST

fearless
Advocacy

PERSISTENCE PAYS OFF - CHANGE IS POSSIBLE!

- Relationships
- Ripeness
- Resources
- Retirements

WHERE ARE WE GOING NEXT?

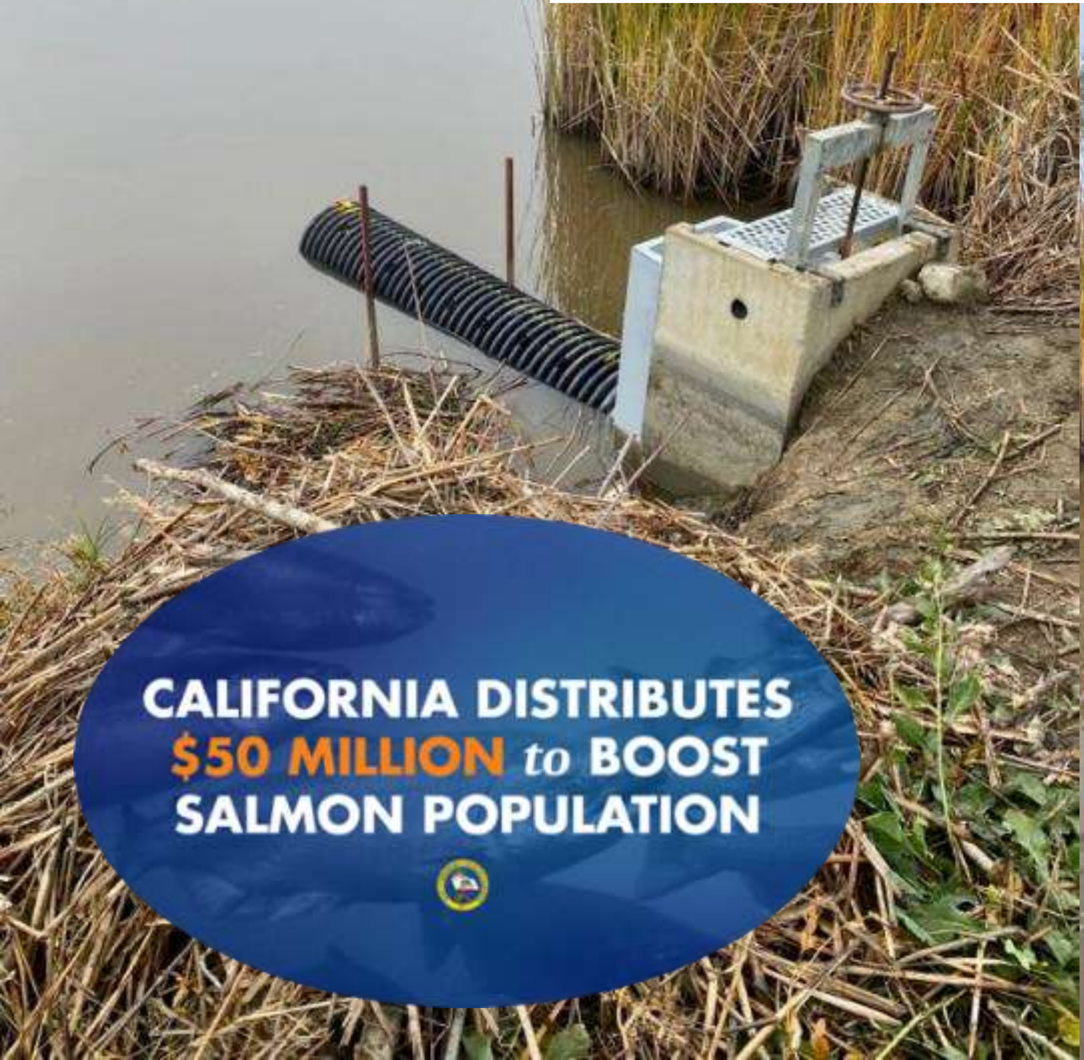
CONNOLLY INTRODUCES CA BEAVER BILL AB 2196

- Translocation to the Tule River Reservation
- Third translocation site to be selected
- Beaver Management and Restoration Plan Development

Photo: Rusty Cohn/Napa Beavers


Beaver Restoration Project Proposal Form
Beaver Restoration Program
https://wildlife.ca.gov/Conservation/Mammals/Beaver

CDFW AWARDS OAEC GRANT TO CREATE BEAVER COEXISTENCE PROGRAM



OUR WORK HAS JUST BEGUN!

THANK YOU!

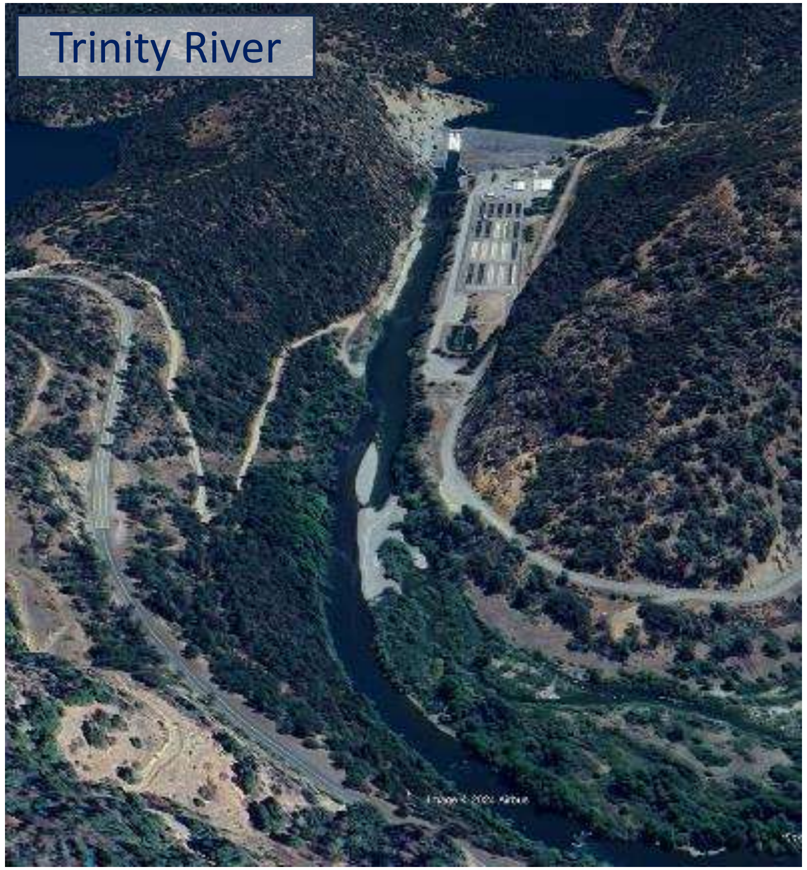
kate@oaec.org

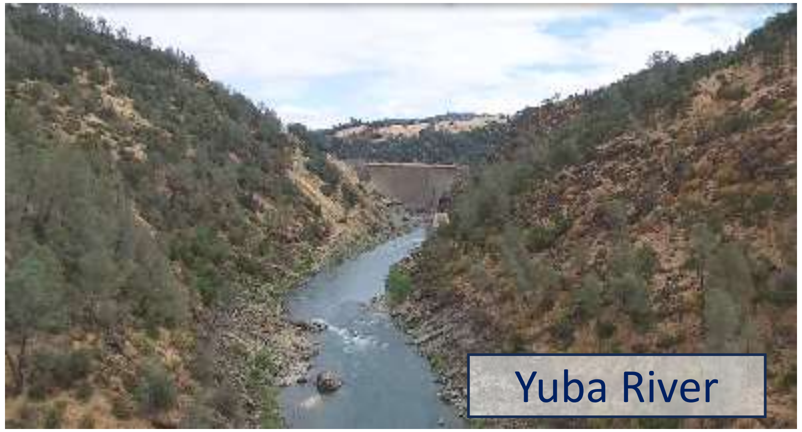
The Process Paradox: Overcoming challenges for process-based restoration in the regulated rivers of California's Central Valley

Rocko A. Brown, PhD, PE

Cramer Fish Sciences

River Science and Restoration Lab





PBR in highly degraded and regulated rivers without dam removal?

Process-based restoration (PBR) principles

Target the root causes of habitat and ecosystem change

Tailor actions to potential

Match the scale of the solution to the scale of the problem

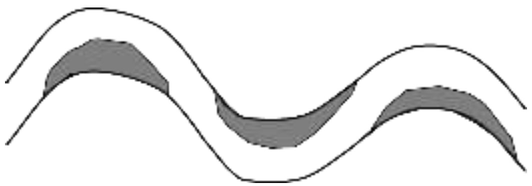
Be explicit about expected outcomes

Beechie, T.J., Sear, D.A., Olden, J.D., Pess, G.R., Buffington, J.M., Moir, H., Roni, P. and Pollock, M.M., 2010. Process-based principles for restoring river ecosystems. *BioScience*, *60*(3), pp.209-222.

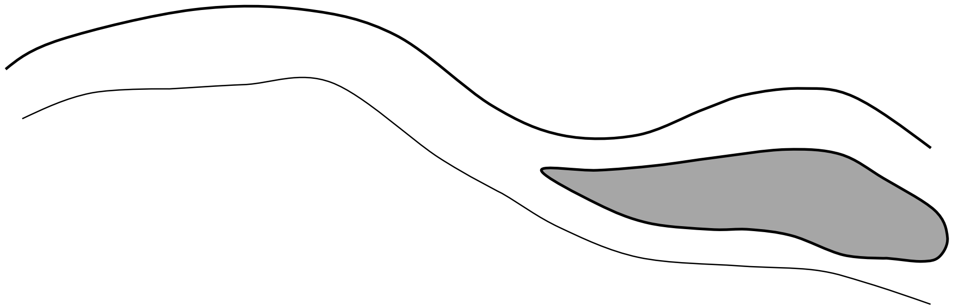
What processes, what scales, and how much?

Form-Process paradox – it’s complicated

Curvature



Expansions



Certain forms are always associated with certain processes – like river bars

Crosato, A. and Mosselman, E., 2020. An integrated review of river bars for engineering, management and transdisciplinary research. *Water*, *12*(2), p.596.

But many processes can create the same form – equifinality

Meandering can develop in straight channels with enough sediment

A false dichotomy… PROCESS VS FORM

Similar form and process but the distinction is that one ***evolves***

“Lest we forget!”

Ingredients for healthy rivers

1-A FLOW REGIME THAT MATCHES THE PHYSIOGRAPHIC SETTING

2-A SUPPLY OF SEDIMENT FOR FLOW TO DISSIPATE ENERGY

3-SPACE TO ALLOW FOR LATERAL PROCESSES

1-Poff et al. 1997. The natural flow regime; Trush et al. 2000. Attributes of an alluvial river and their relation to water policy and management.
2-Wohl et al. 2015. The natural sediment regime in rivers…
3-Biron et al. 2014. Freedom space for rivers: a sustainable management approach to enhance river resilience. Trush et al. 2000

Given how altered these rivers are we should start over?

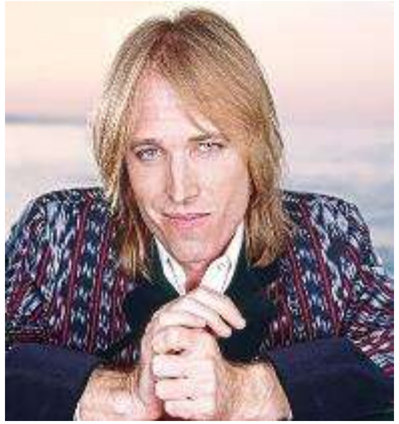
Impediments to PBR/ valley resetting in regulated CV Rivers

Public safety

Remnant habitats and refugia

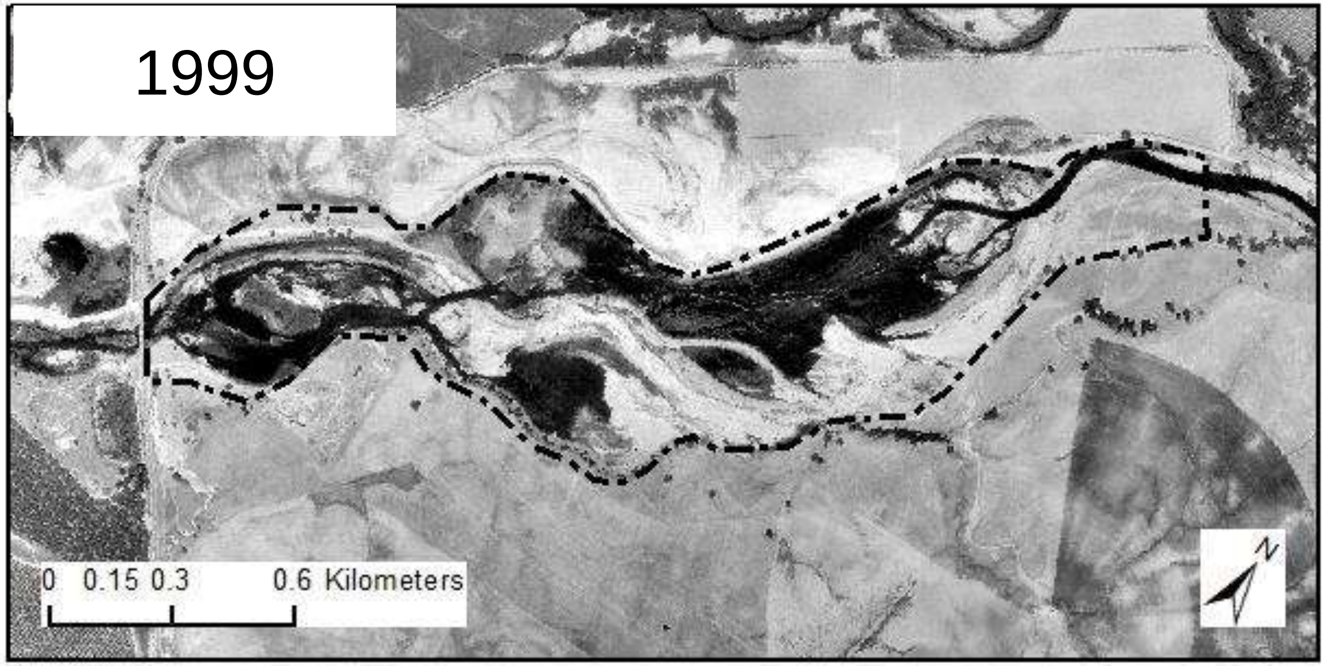
Navigation

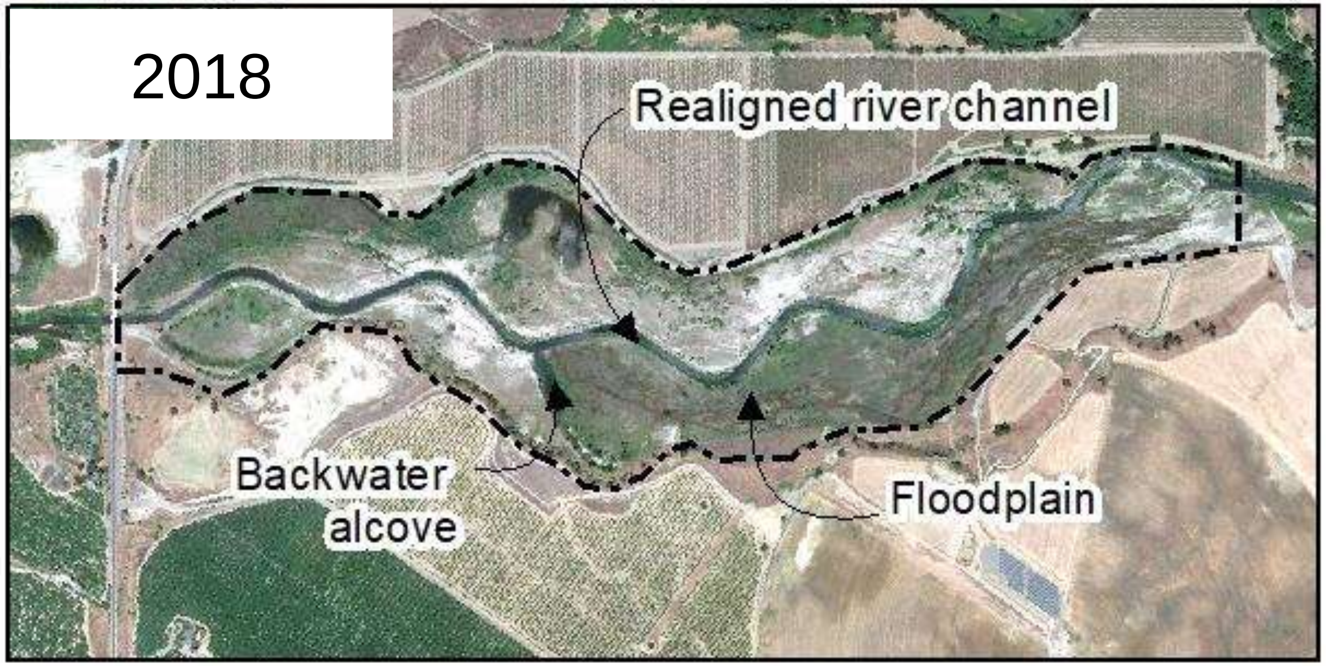
Flood/water conveyance



Waiting…

An engineered attempt?

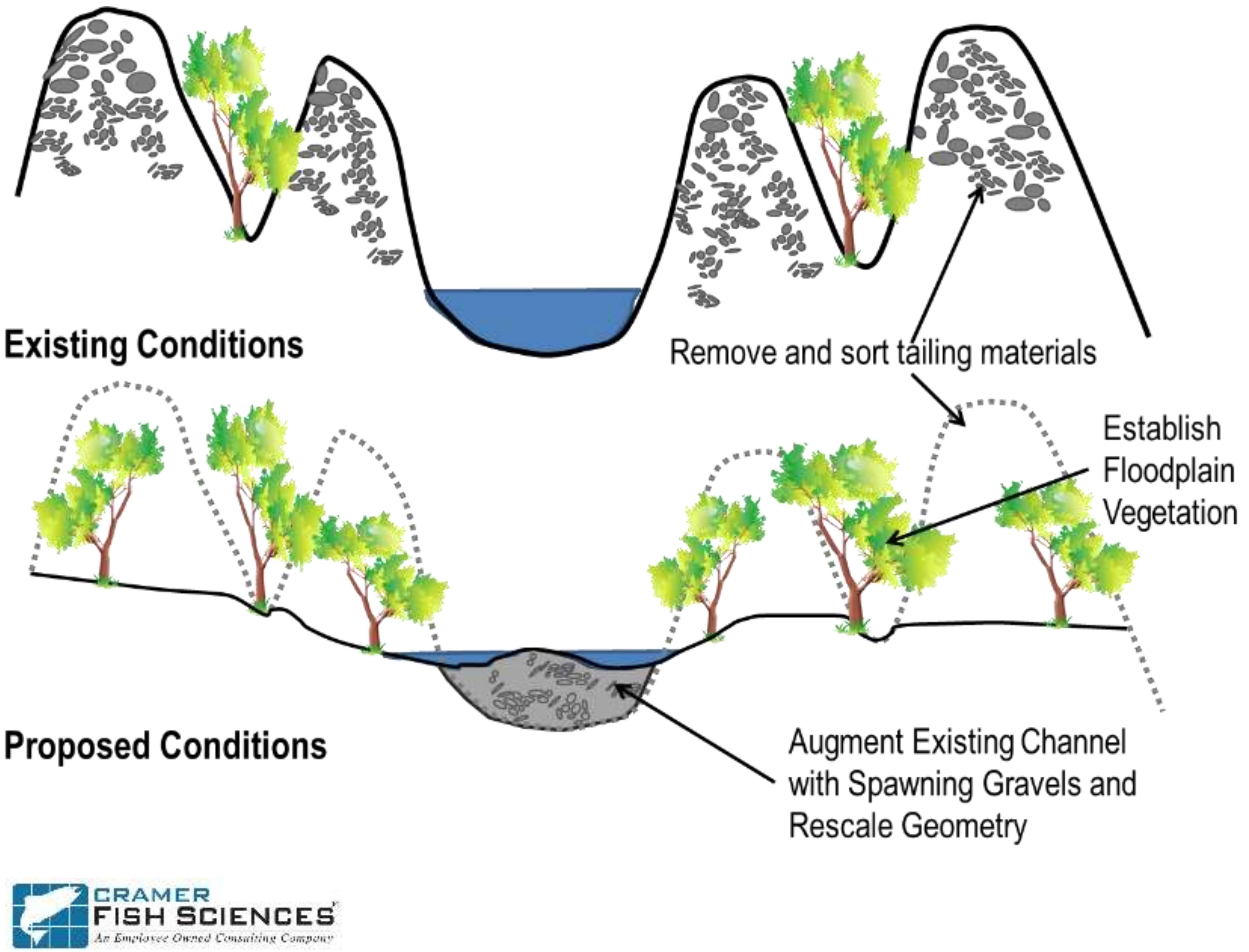


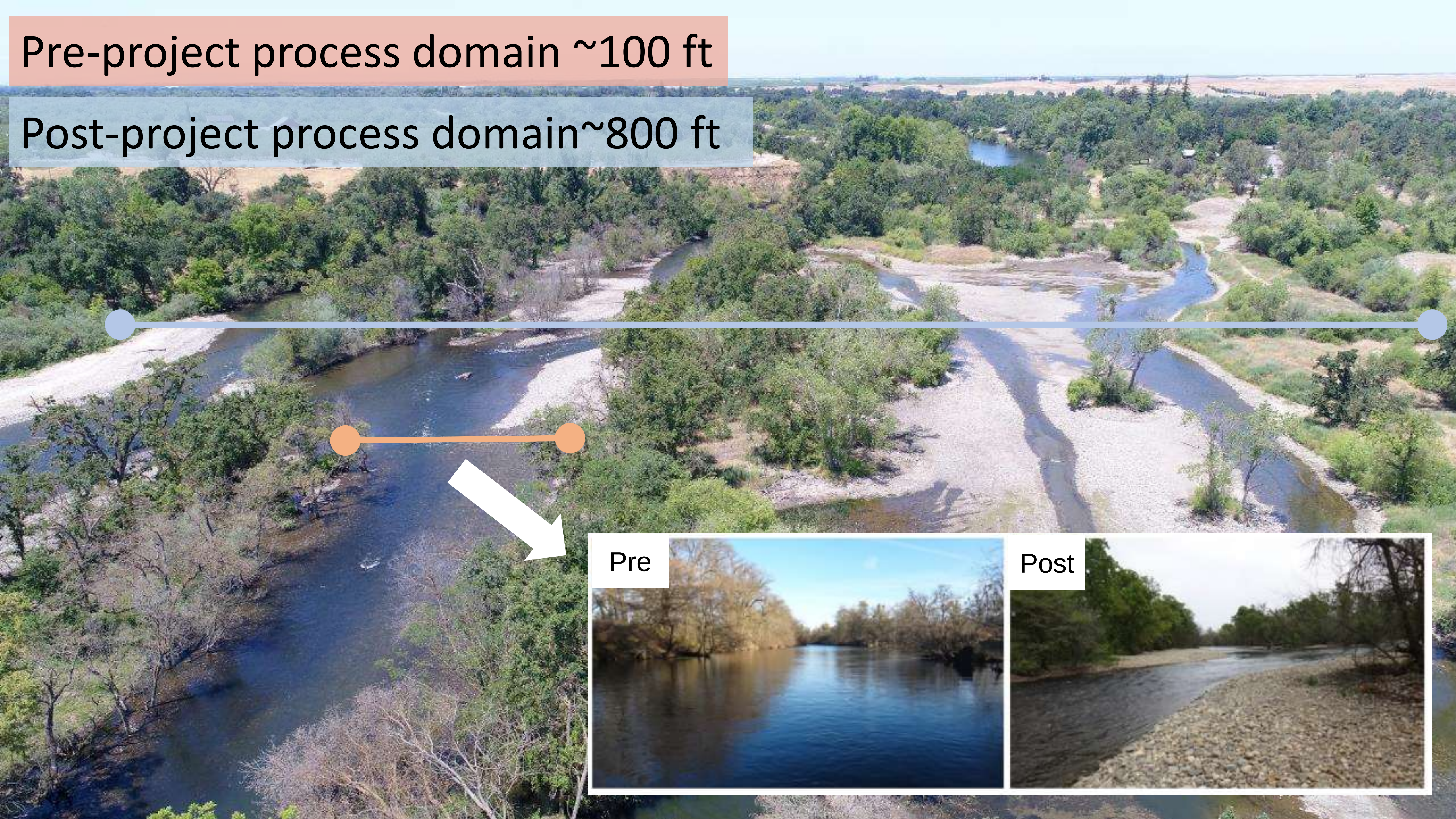


Harrison, L.R., Bray, E., Overstreet, B., Legleiter, C.J., Brown, R.A., Merz, J.E., Bond, R.M., Nicol, C.L. and Dunne, T., 2019. Physical controls on salmon redd site selection in restored reaches of a regulated, gravel-bed river. *Water Resources Research*, *55*(11), pp.8942-8966.

Form and Process

Dredger tailings provide opportunity for partial resetting




Pre-project process domain ~100 ft
Post-project process domain~800 ft
Pre
Post

Merced River
Henderson Park

FORM AND PROCESS

3 yrs Post project

5 yrs Post project (50 yr flood)

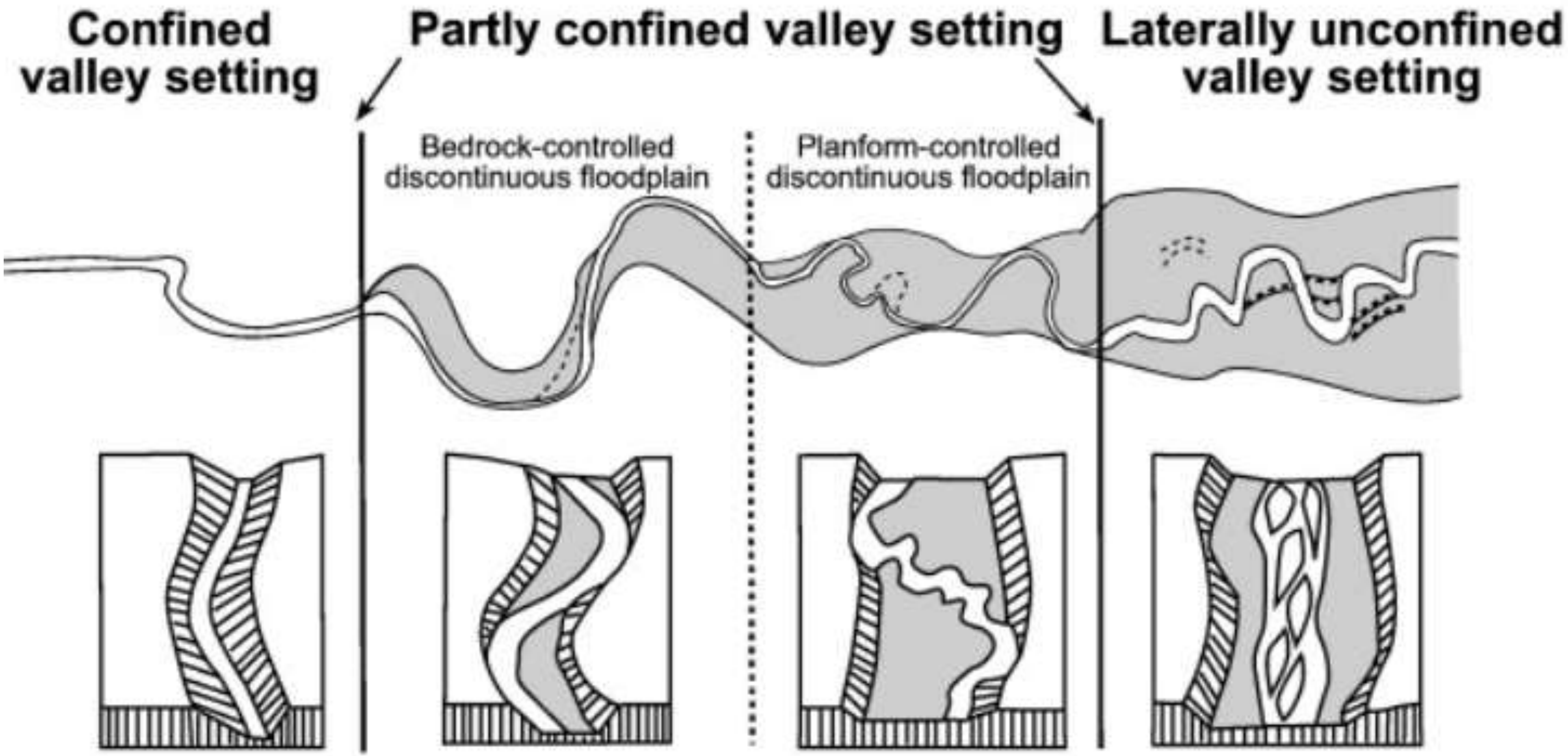
By incorporating flow reversals and surcharging LOCAL sediment supply, habitat improved following floods

Brown, R.A., Sellheim, K., Anderson, J.T. and Merz, J.E., 2022. Chinook Salmon habitat evolution following river restoration, drought, and flood. *Journal of Ecohydraulics*, pp.1-23.

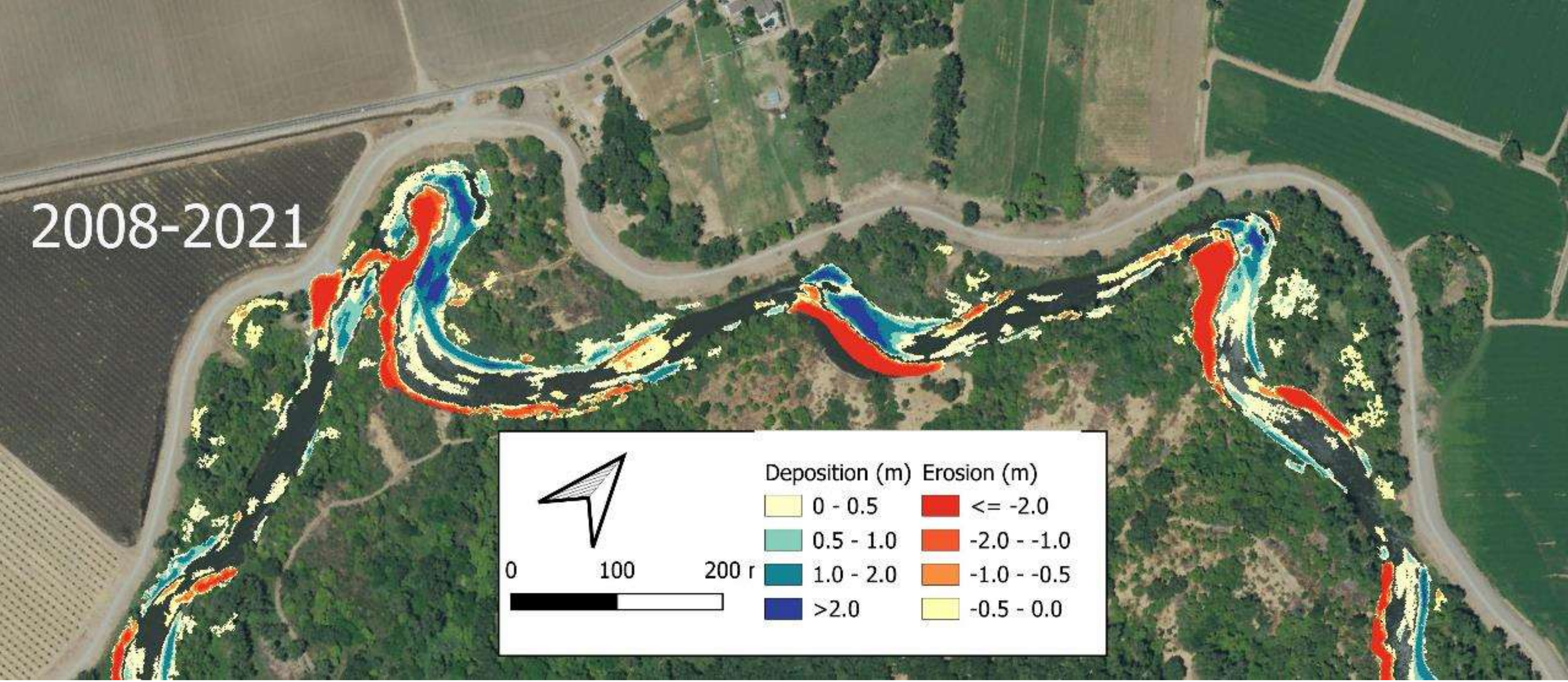
Engaging fish as agents of bed disturbance

Processes occur, but lack of tools close to dam is apparent

Downstream changes in sediment supply



Brierley, G., and K. Fryirs 2005. Geomorphology and River Management: Applications of the River Styles Framework. Blackwell Publishing, Victoria, Australia.



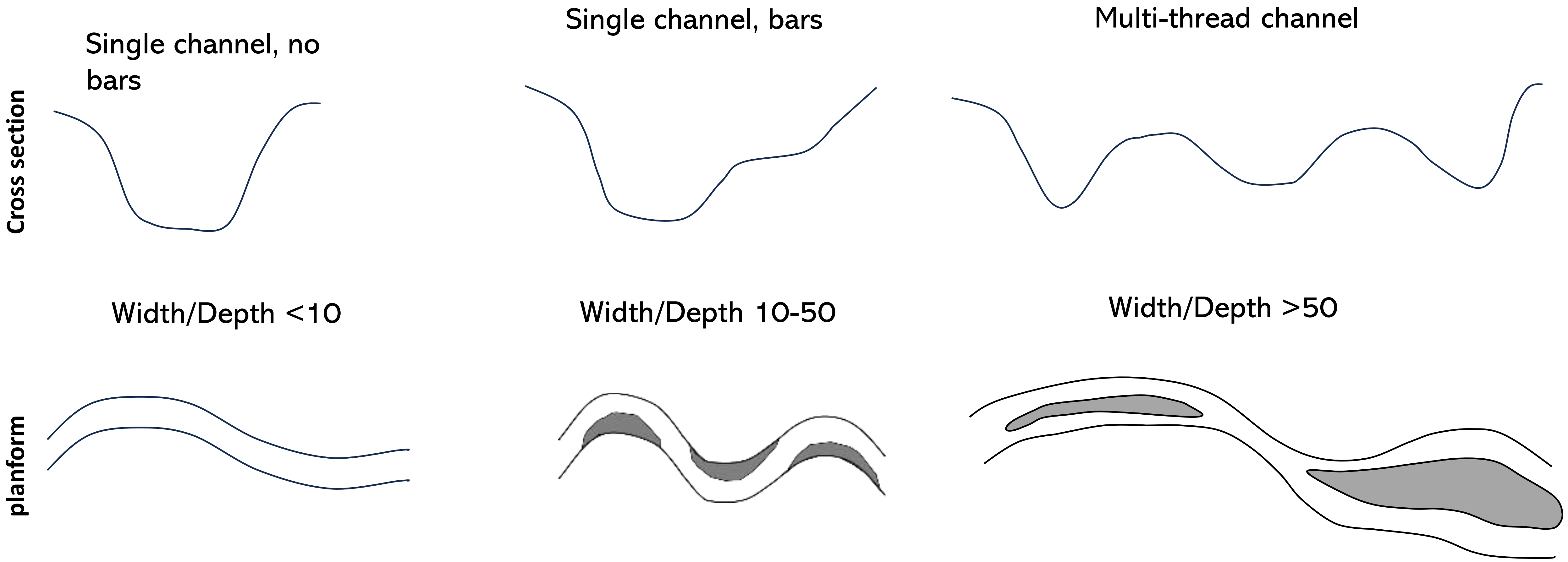
Bank erosion and point bar creation yielded ~20 acres of shallow water habitat naturally

We need space!

Erodible corridors

A false dichotomy… PROCESS VS FORM

Reach corridor form can set the processes



Don’t give up – PBR is possible

Target the root causes of habitat and ecosystem change

Not entirely possible, but can mitigate with maintenance (scaled flow regime, sediment and wood augmentation)

Tailor actions to potential

Work with process domain with an eye toward the future and what we want

Match the scale of the solution to the scale of the problem

Not entirely possible, but can articulate quantitatively what this means for the future- How many fish? Floodway? Recreation? Process domain, sed and wood budget

Be explicit about expected outcomes

Monitoring of biological utilization and population response ;
Make and test quantifiable geomorphic predictions

To get there:

- FOCUS
- CLEAR, MEASURABLE GOALS
- FORESIGHT/VISION
- SOCIAL ENGAGEMENT

Thank you!

Rocko.brown@fishsciences.net

Evaluating and Forecasting Restoration Benefits for Trout and Salmon with Spatially Explicit Modeling

Bret Harvey

USDA Forest Service, PSW Arcata

Example “fishy” goals for restorationists

- Increased:
  - “habitat complexity”
  - spawning gravel availability
  - off-channel habitat
  - “habitat suitability” for juvenile fish

- *True goal: sustain populations*


Brown trout
50c
AUSTRALIA
☺ ?
?
?
? ?

Individual-based, behavior-based, process-based, spatially explicit modeling: an approach to address sustainability

- Simulate individuals that behave reasonably in seeking to survive and reproduce
- Simulate environmental scenarios of interest
- Examine population dynamics that emerge from the success and failure of individuals under those scenarios

Included in the modeling approach

- Bioenergetics
- Competition
- Predation risk
- ***Adaptive*** *habitat and activity selection by individuals on each model time-step*
- Daily variation in streamflow, water temperature and turbidity
- All major effects of physical drivers, e.g. temperature: 1) mortality; 2) energetics; 3) egg development; 4) timing of spawning

Excluded from the modeling approach

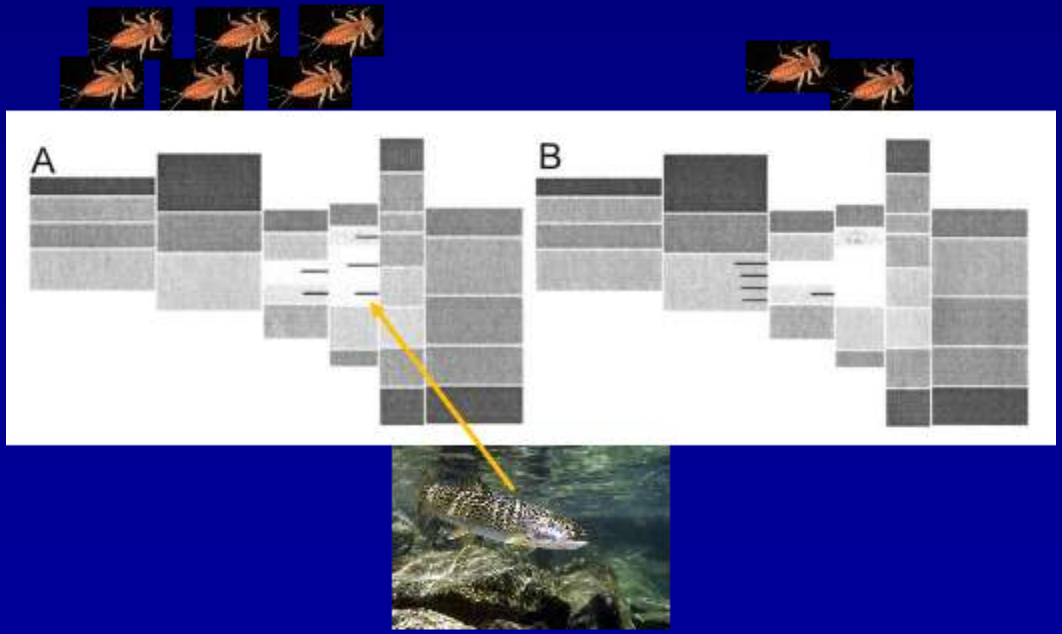
- Categorical measurement or assessment of "Habitat suitability" or "Habitat availability"
- Imposed life-stage-specific demographic rates
- Imposed frequencies of movement

Required for application of the modeling approach

- Hydraulic modeling to estimate habitat-cell-specific depth and velocity from streamflow
- Streamflow, temperature, turbidity regimes
- Estimation of habitat-cell parameters:
  - distance to cover
  - # of concealment spaces
  - velocity shelter
  - spawning gravel
- Fish data for model calibration

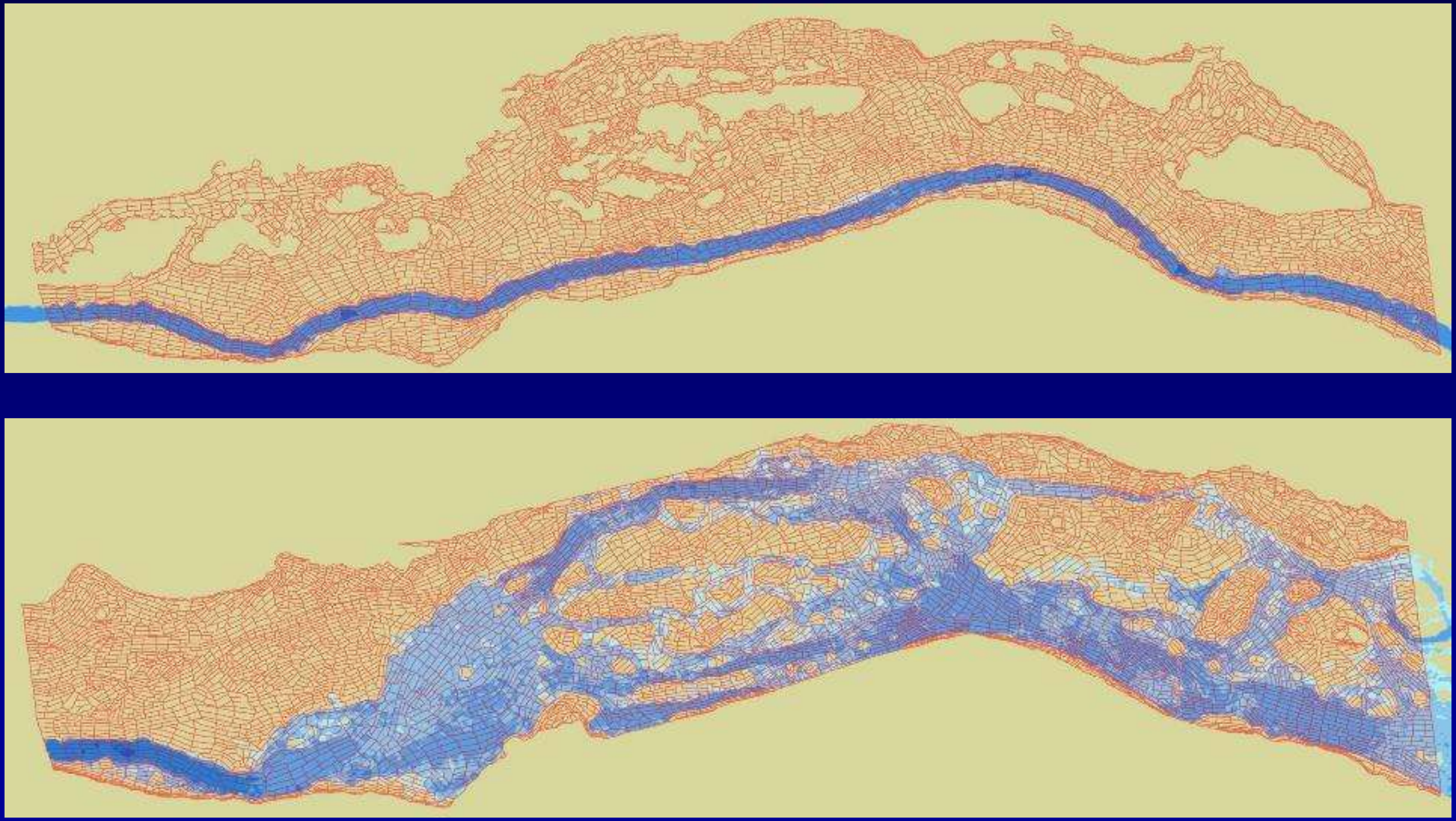
Main reason to give the approach credibility:

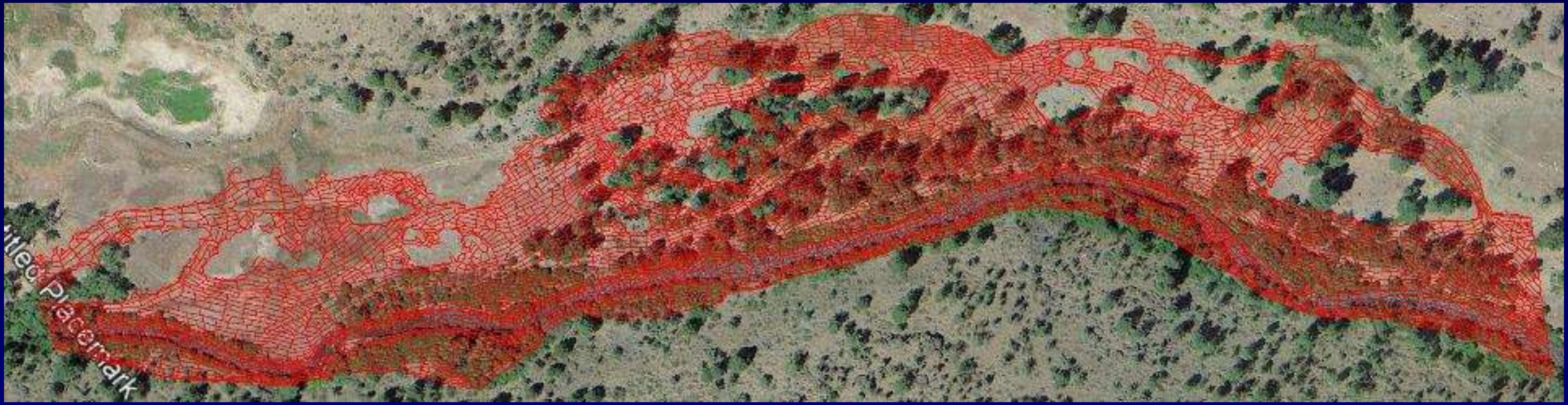
- Its broad capability to reproduce patterns observed in real salmonids
  - Habitat selection
  - Diel behavior / activity selection
  - Population
  - Community

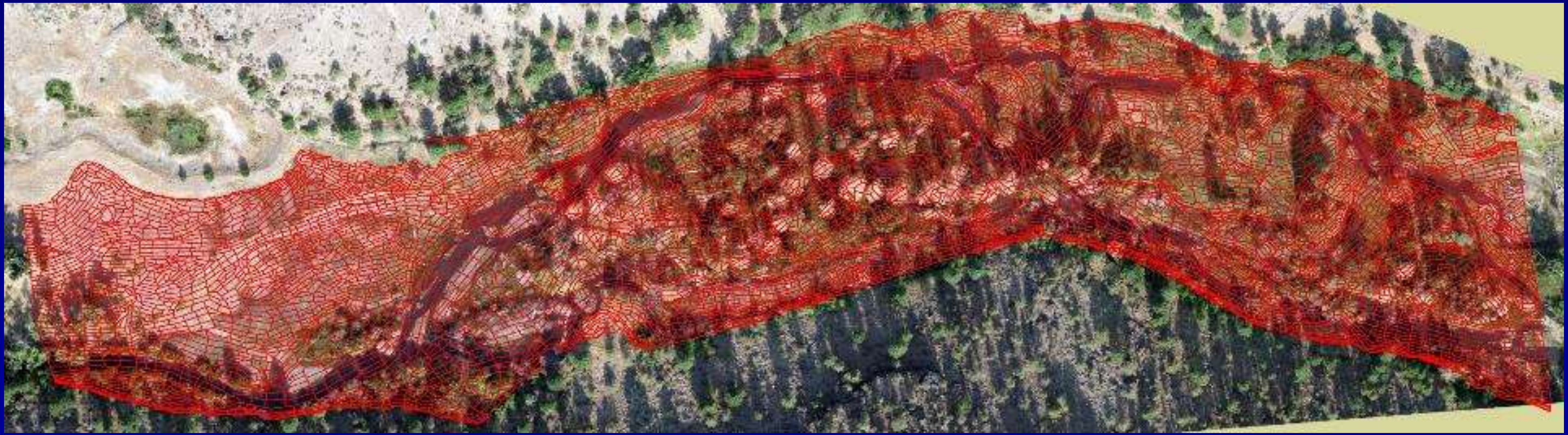


Example application: Whychus Creek, Oregon

650 m



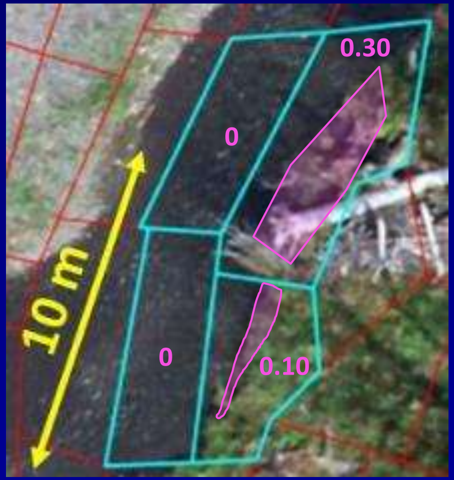

Placemark



Habitat Cell Delineation I

Habitat Cell Delineation II

Velocity shelter (proportion of area)



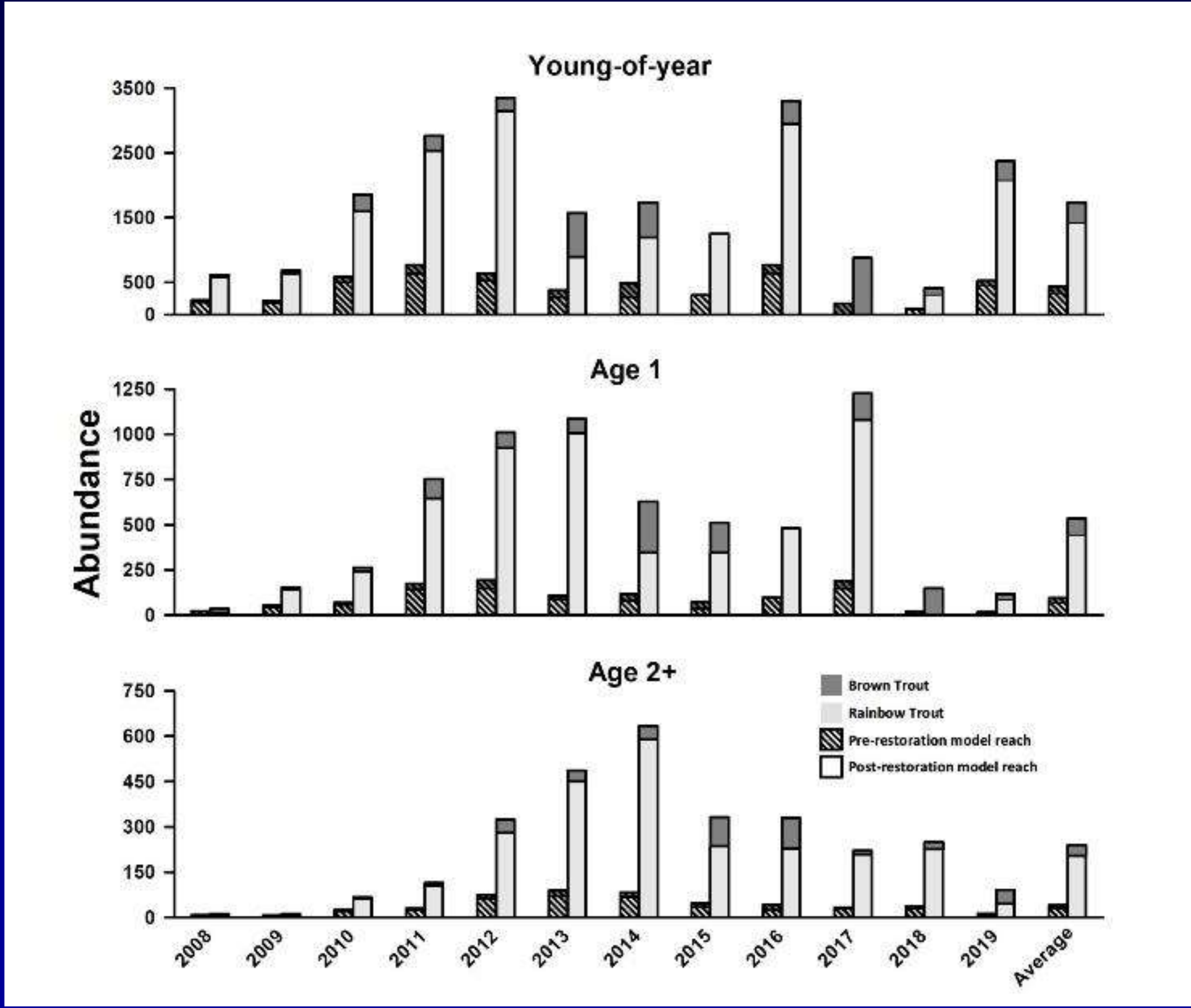
Distance to cover (m)

Concealment spaces (count)

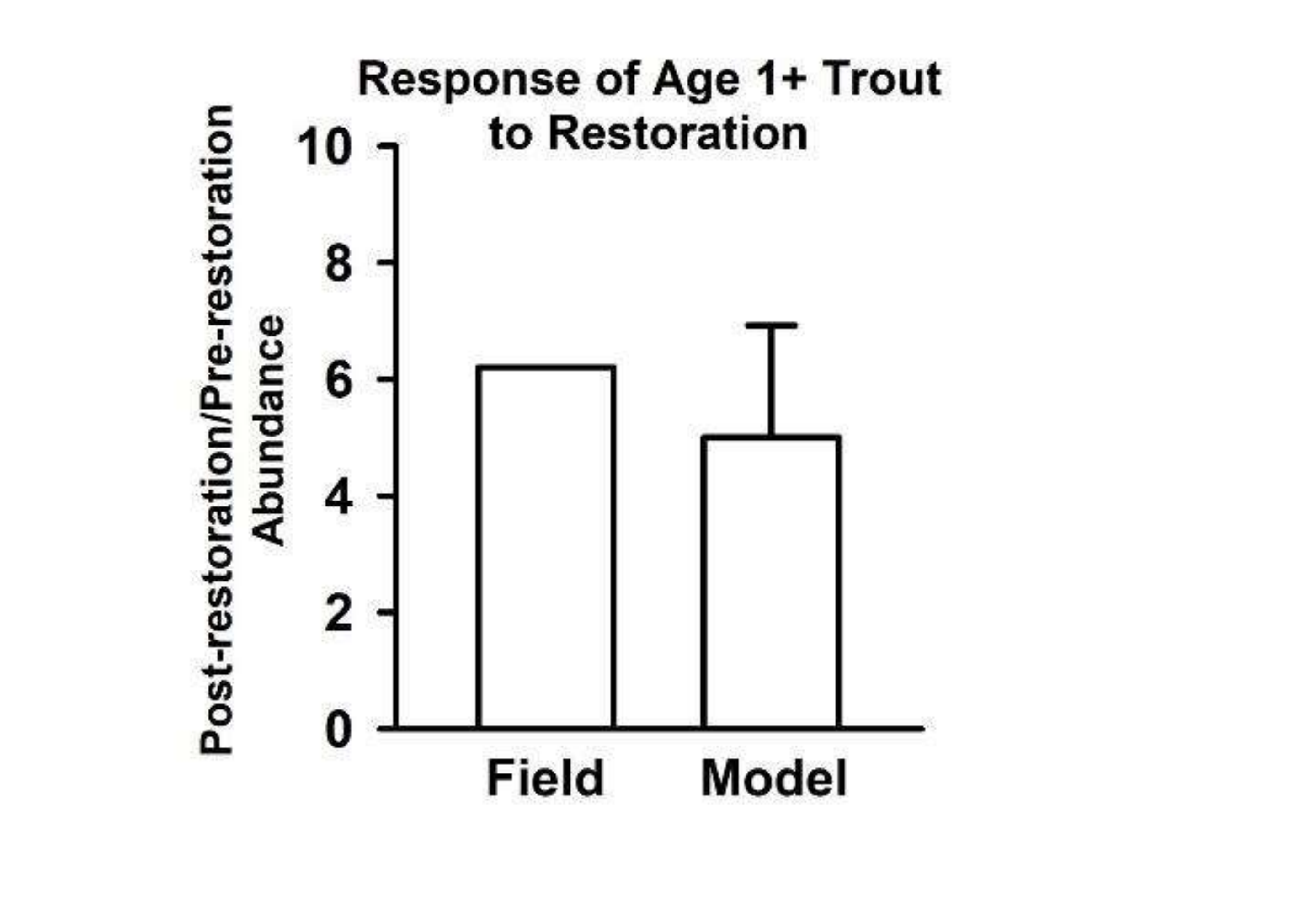
Typical pre- *versus* post-restoration comparison:

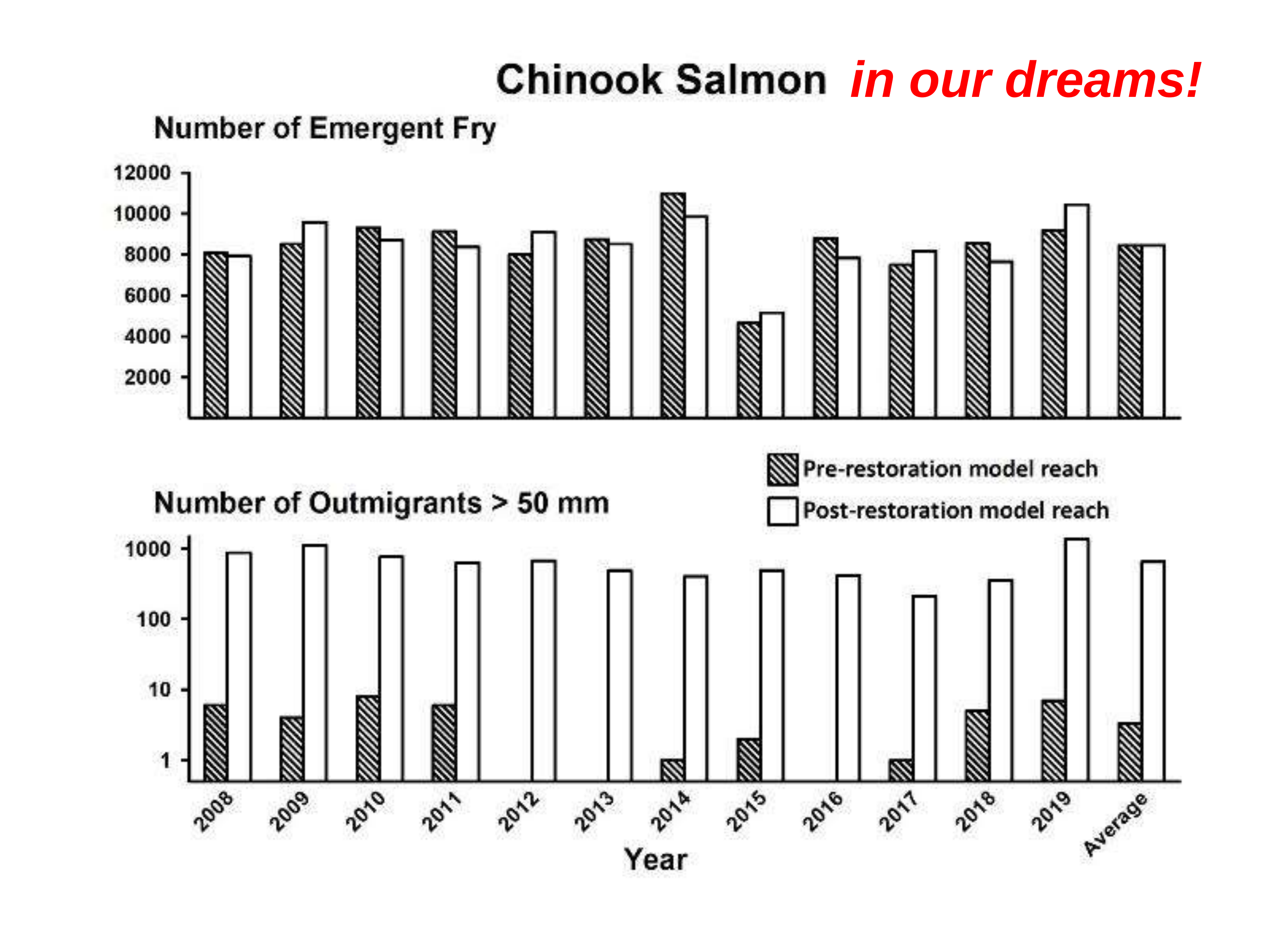
- same time period
- same starting fish populations
- same streamflow, temperature and turbidity regimes

Resident Trout



Model v Field sampling comparison: quantity




Chinook Salmon
in our dreams!
Number of Emergent Fry
12000
10000
8000
6000
4000
2000
Pre-restoration model reach
Post-restoration model reach
Number of Outmigrants > 50 mm
1000
100
10
1
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Average
Year

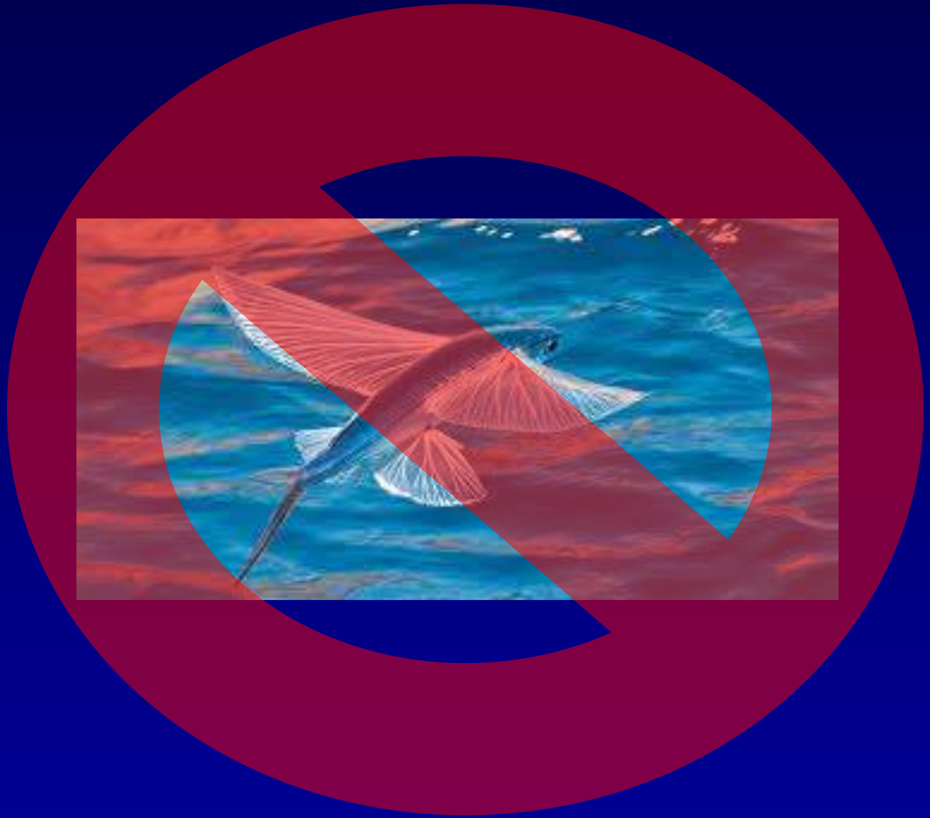
Conclusions from the example

- Modeling indicated big benefits of restoration for trout
- Spawning success probably doesn’t strongly influence the productivity of the reach
- “Shoulder season” stream temperatures and flows deserve attention in forecasting populations

General conclusions:

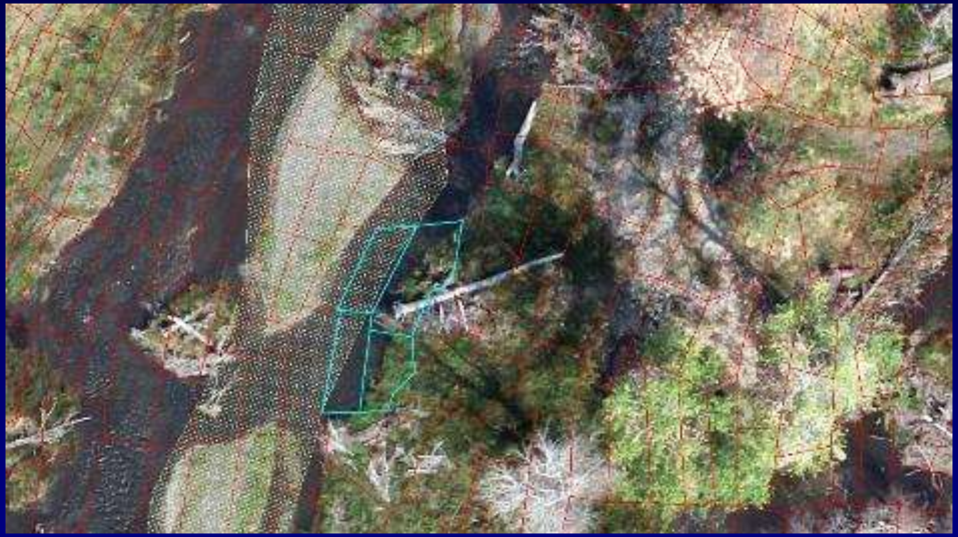
- ***Yes We Can*** usefully forecast restoration effects for salmonids, while including real-world complexities
- ***Yes We Can*** incorporate new information likely to be important to fish, as it arises (e.g. restoration effects on thermal heterogeneity and food availability)

Modeling note:

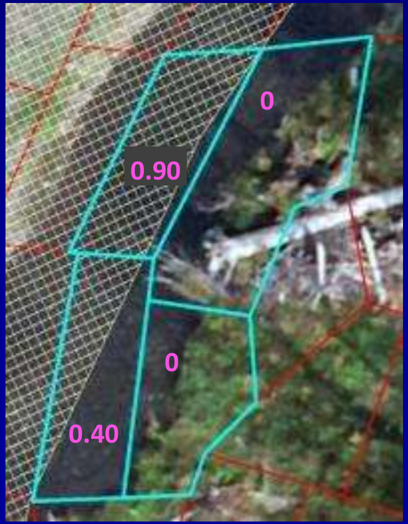


No flying fish!

Habitat Cell Delineation III

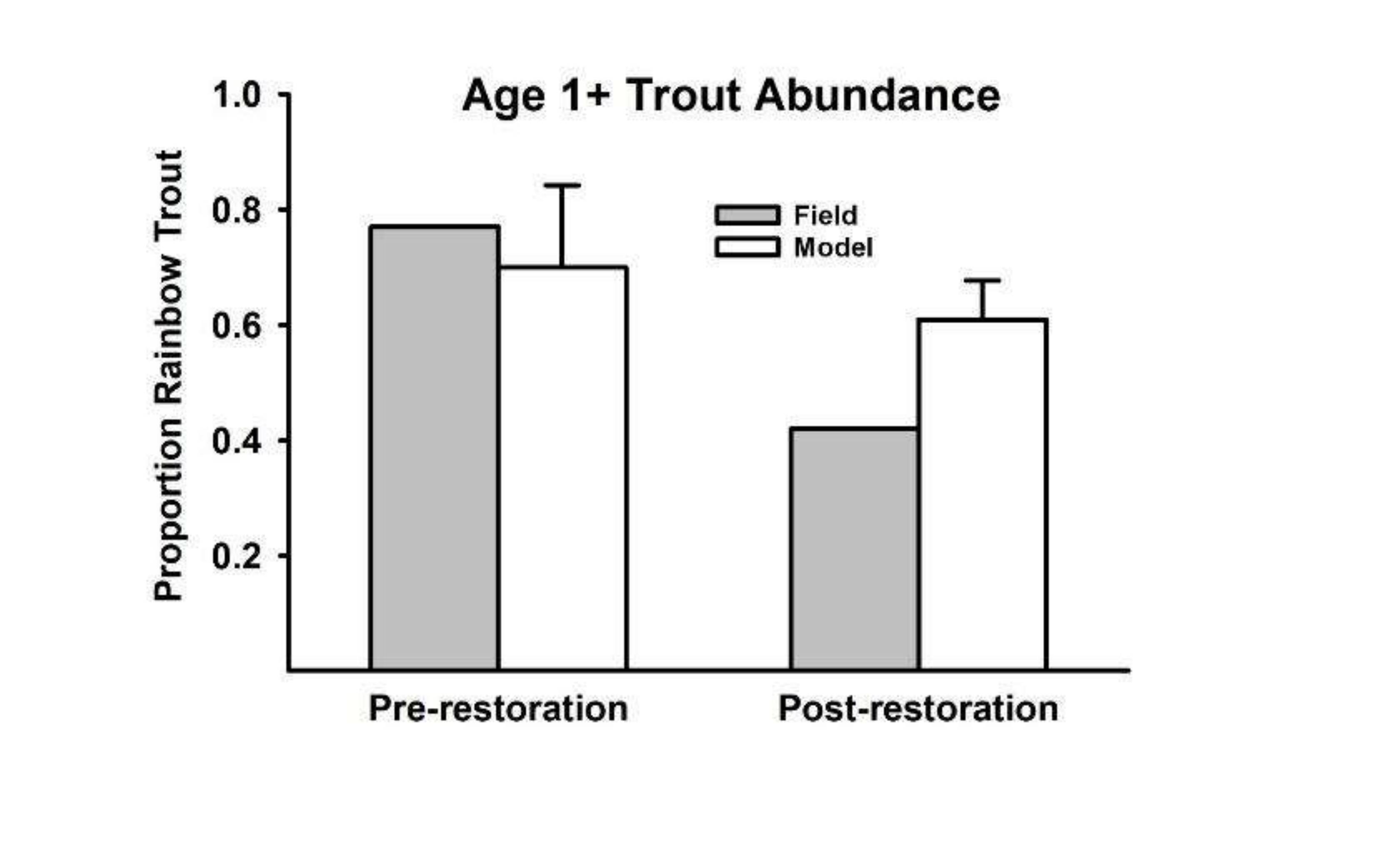


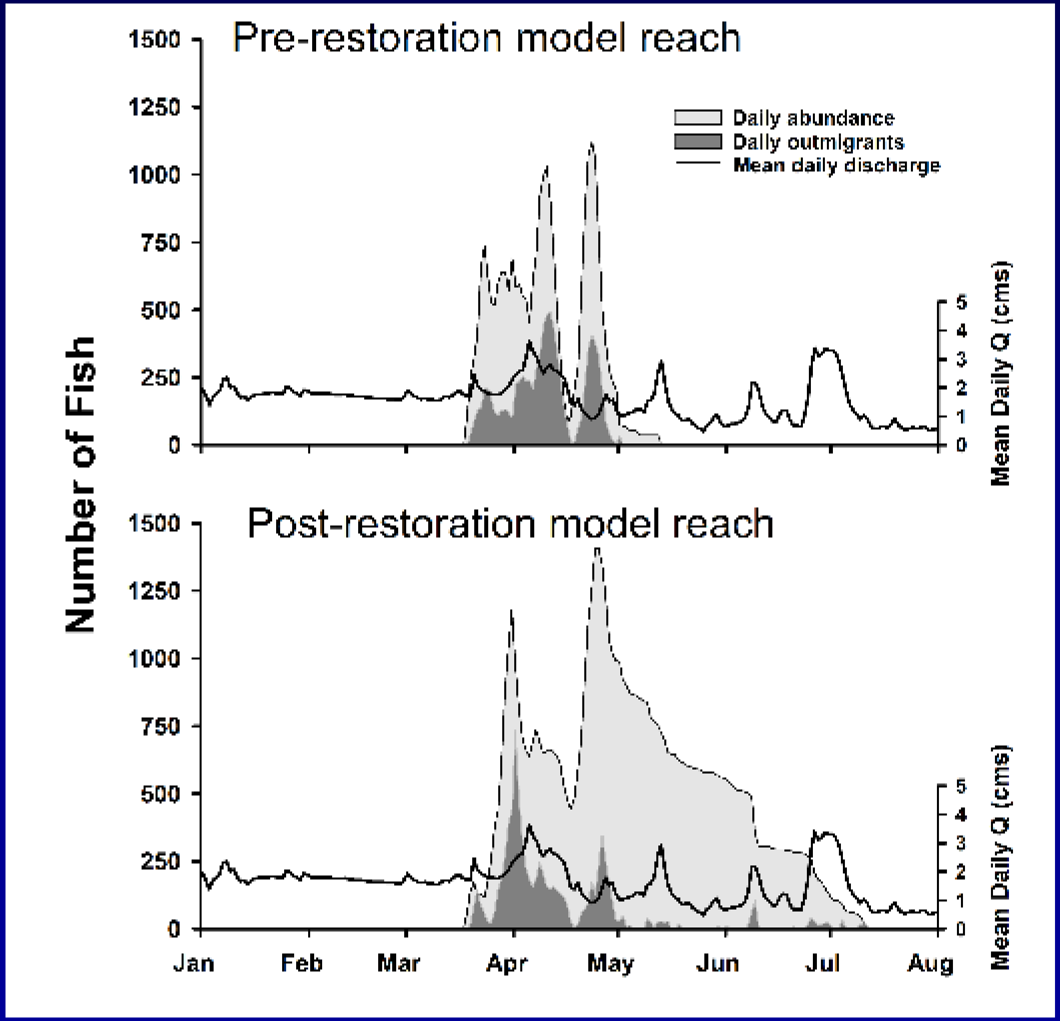
Spawning gravel (proportion of area)



Calculated in ArcMap from field-surveyed spawning beds

Model v Field sampling comparison: identity





Pre-restoration model reach
Daily abundance
Daily outmigrants
Mean daily discharge
Number of Fish
Mean Daily Q (cms)
Post-restoration model reach
1500
1250
1000
750
500
250
0
5
4
3
2
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug

Short-term hydrologic responses to ecological meadow restoration

Emma Sevier[1]

Margaret Lang[1], David Dralle[2], Karen Pope[2], Joe Wagenbrenner[2], Adam Cummings[2] Kate Wilcox[2], Jordin Jacobs[2], Kevin Swift[3]

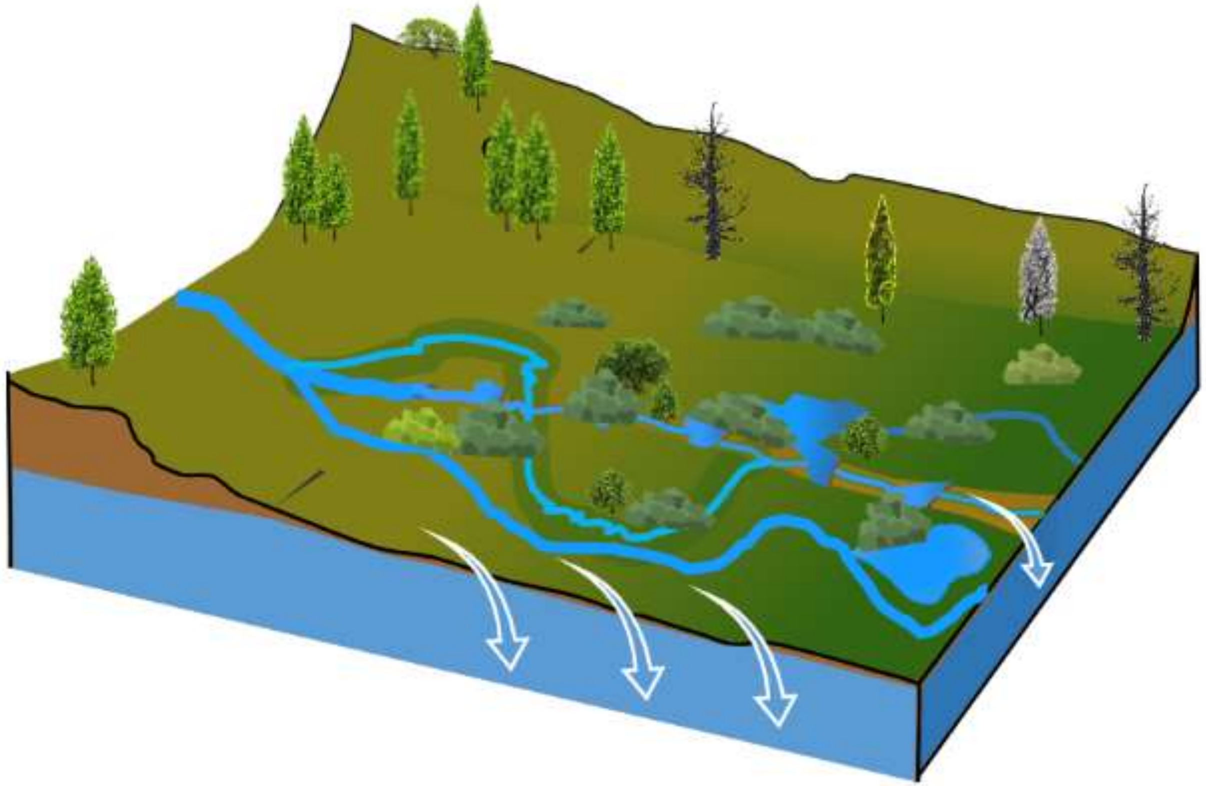
(1) California State Polytechnic University, Humboldt,

(2) USDA Forest Service, Pacific Southwest Research Station,

(3) Swiftwater Design

What are **riparian meadows** and why are they important?

- Improve water yield[1]
- Support water quality through flood dispersion & attenuation[1]
- Foster groundwater dependent ecosystems[2]
- Sequester carbon and create fire breaks[3]

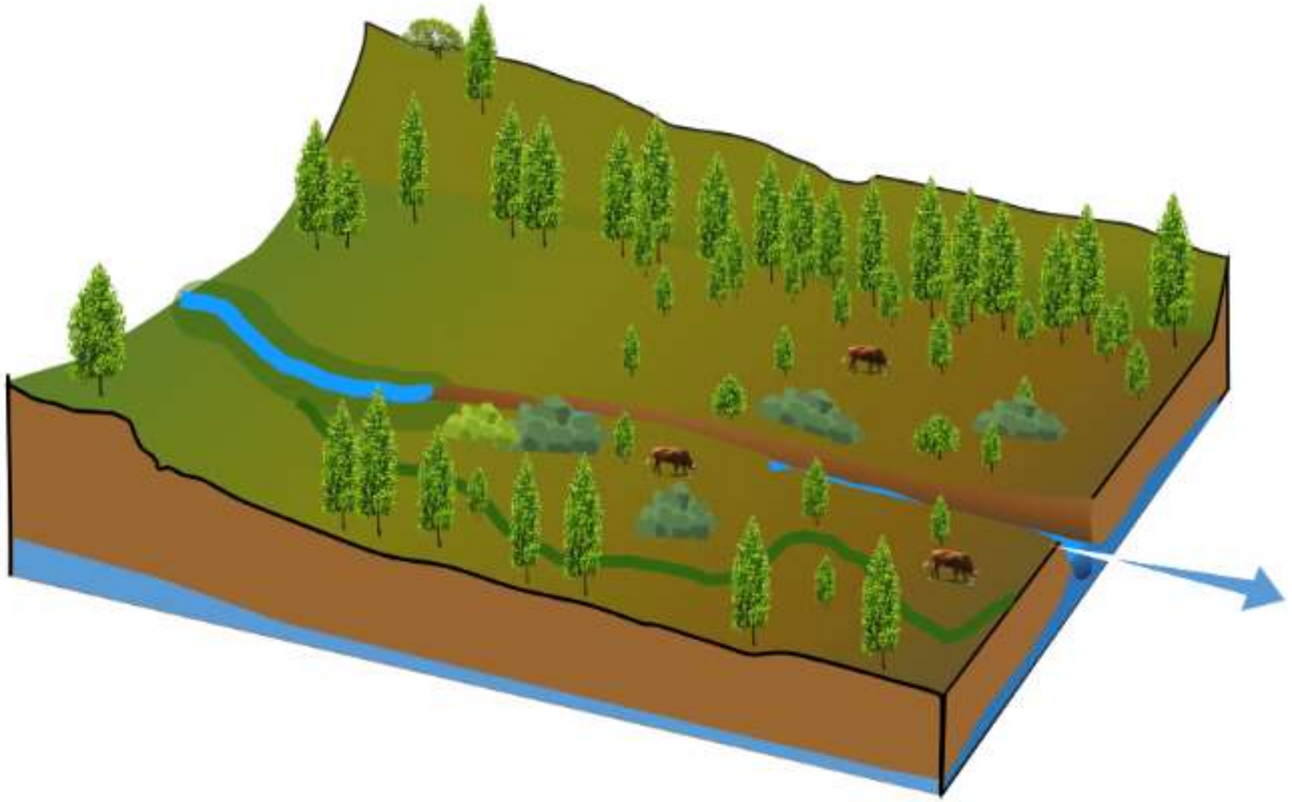


Ecologically functioning meadows promote groundwater recharge!

1. Viers et al. 2013
2. Loheide and Booth 2011
3. Reed et al. 2021

History of Degradation

- Most Sierra Nevada meadows are degraded (>60%)
- Impacts include livestock overgrazing, railroad grades, diversion and ditching
- *Channel Incision* – erosion of sediment exceeds deposition



Meadow degradation initiates channel incision

Process-Based Restoration (PBR)

PBR is a design philosophy which harvests the fluvial and biologic energy of the system to increase restoration efficiency

Beaver Dam Analog at Middle Creek Meadow.
Photo Credit: Patrick Jarrett

PBR Tools: Beaver Dam Analogs (BDAs)

BDAs found to:

- Attenuate flood peaks and slow water velocities[1]
- Improve health and quality in meadow vegetation[2]
- Raise groundwater tables[1]
- No significant influence on groundwater tables[3]

1. Pollock et al. 2014
2. Nash et al. 2018
3. Scamardo and Wohl, 2020

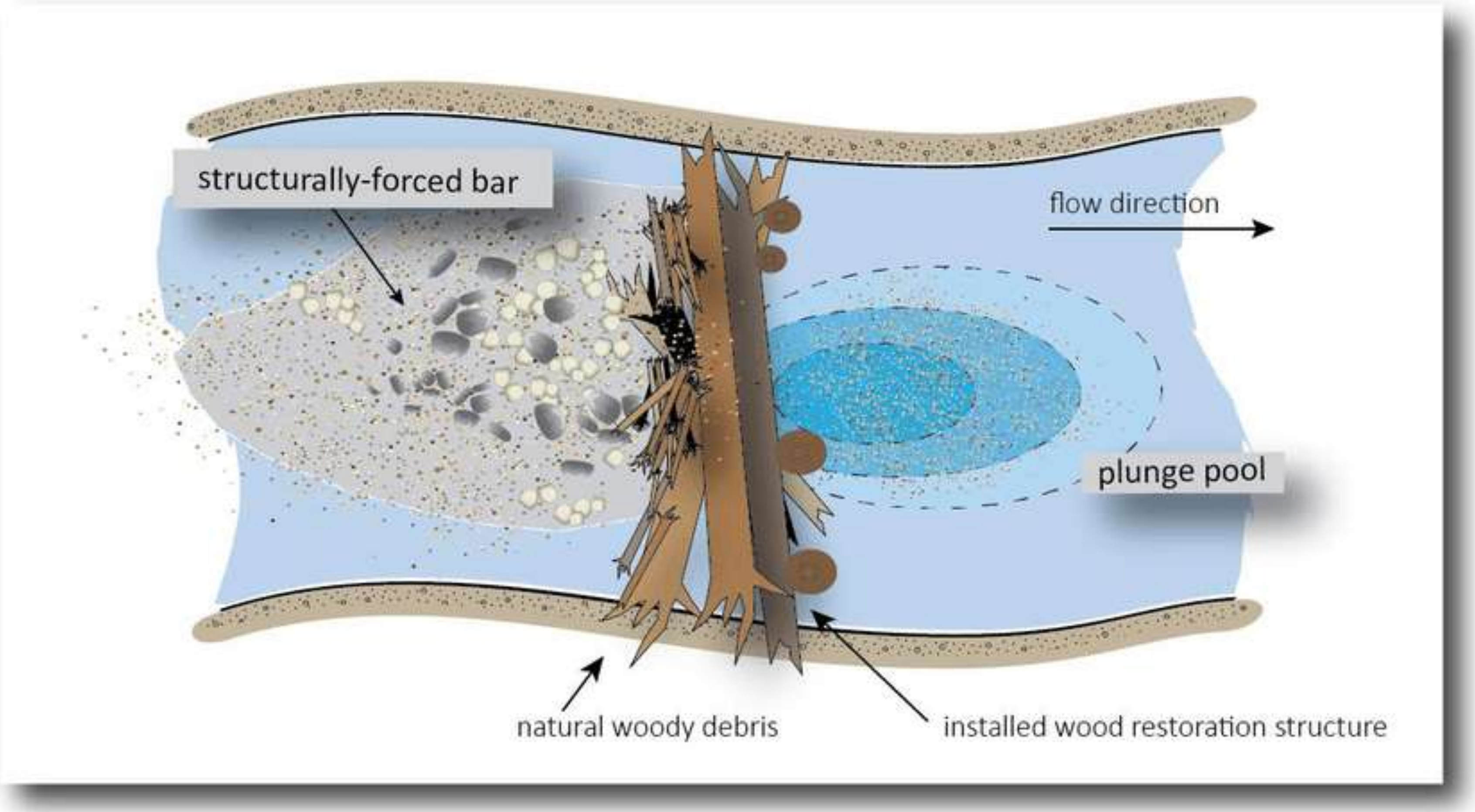
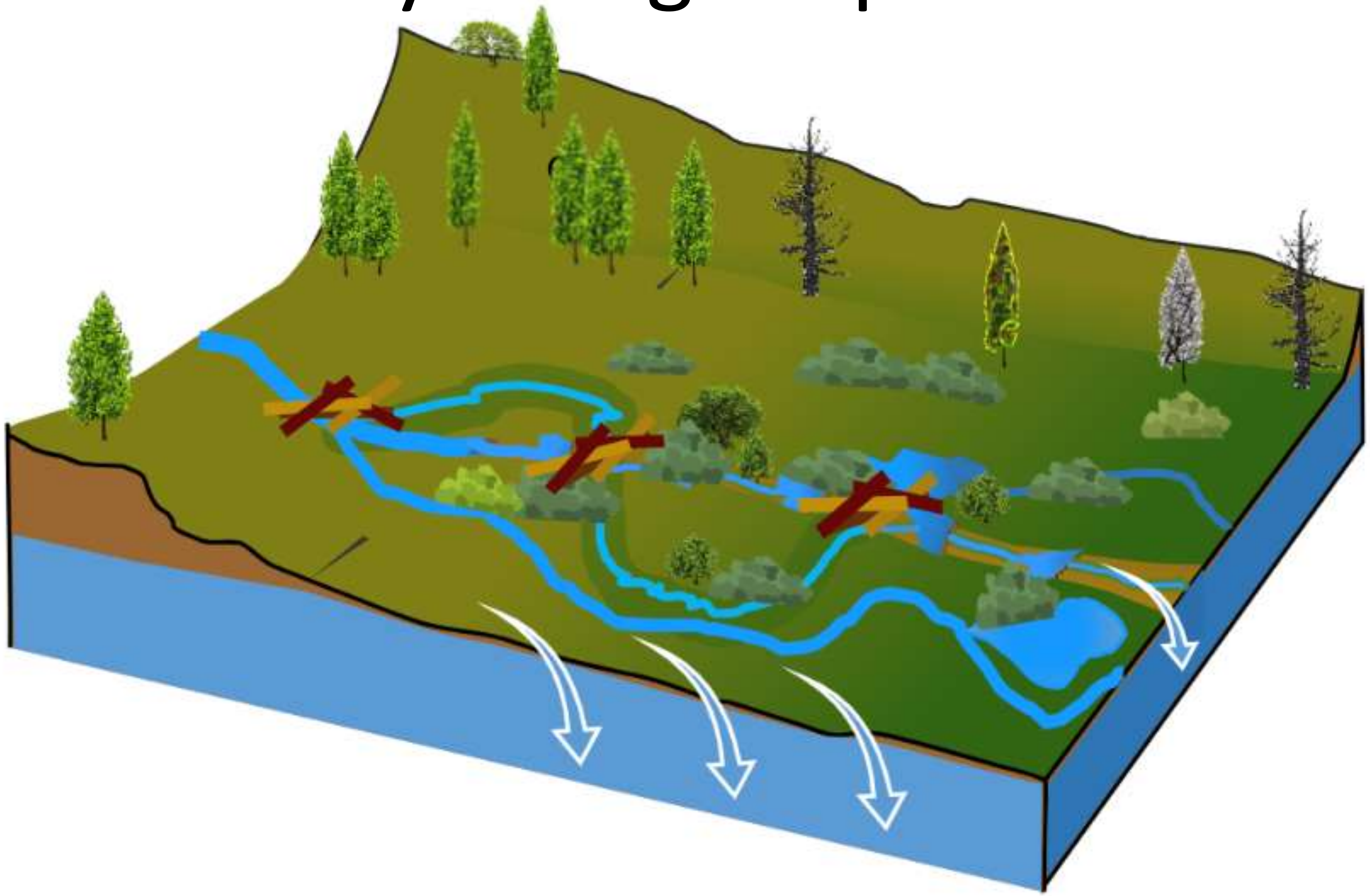
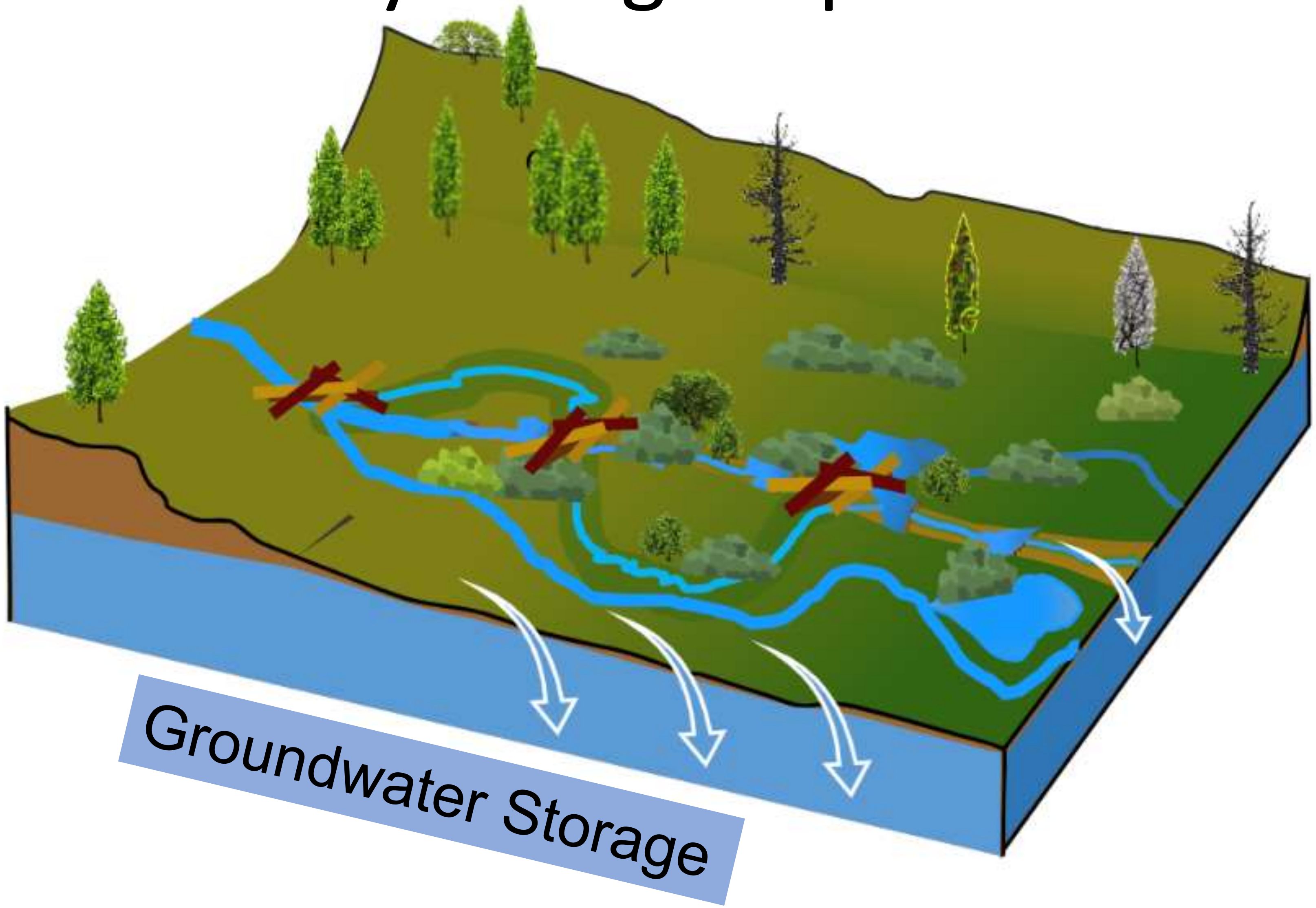


Image Source: *Shahverdian et al. 2019*

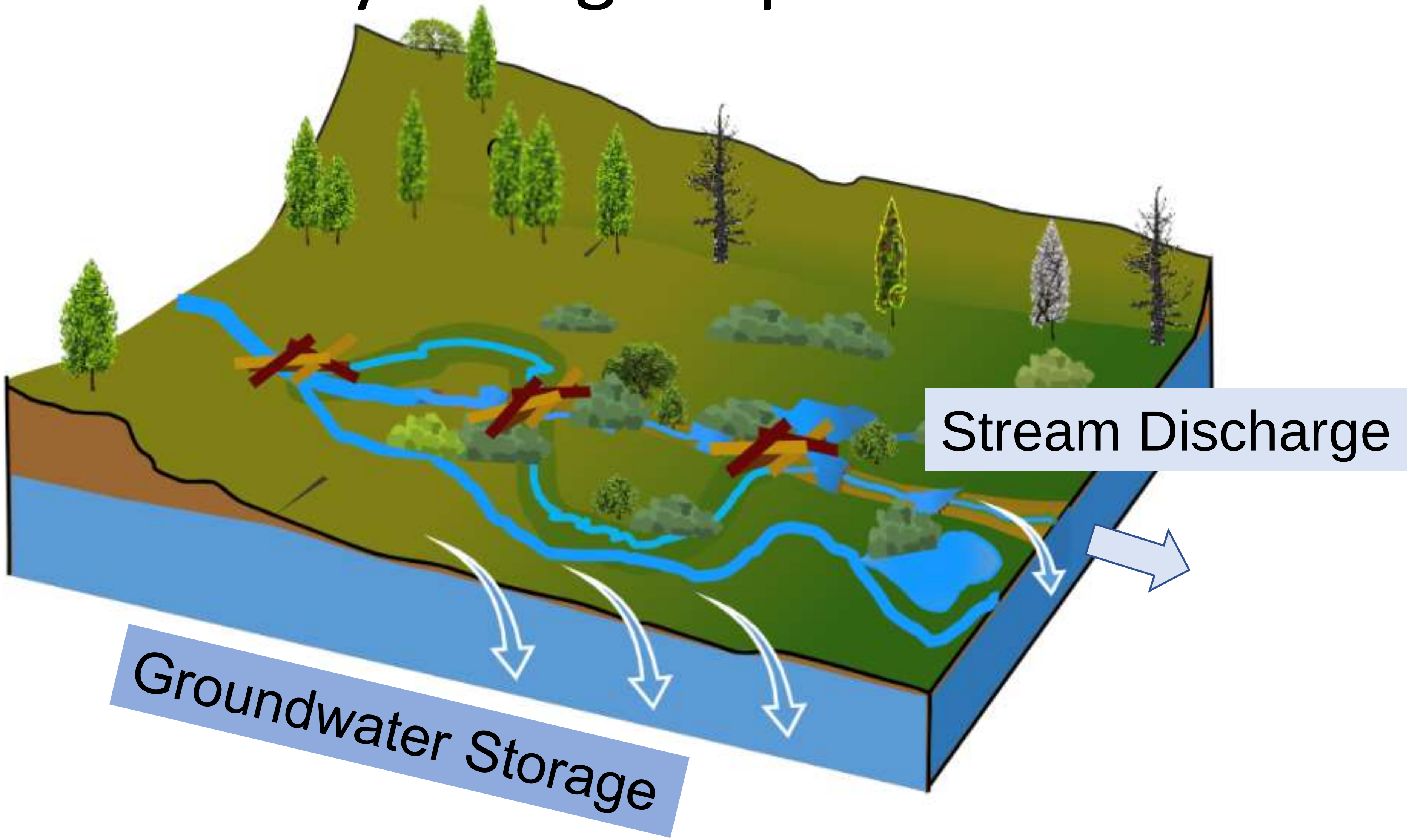
How does process-based meadow restoration affect hydrological processes?



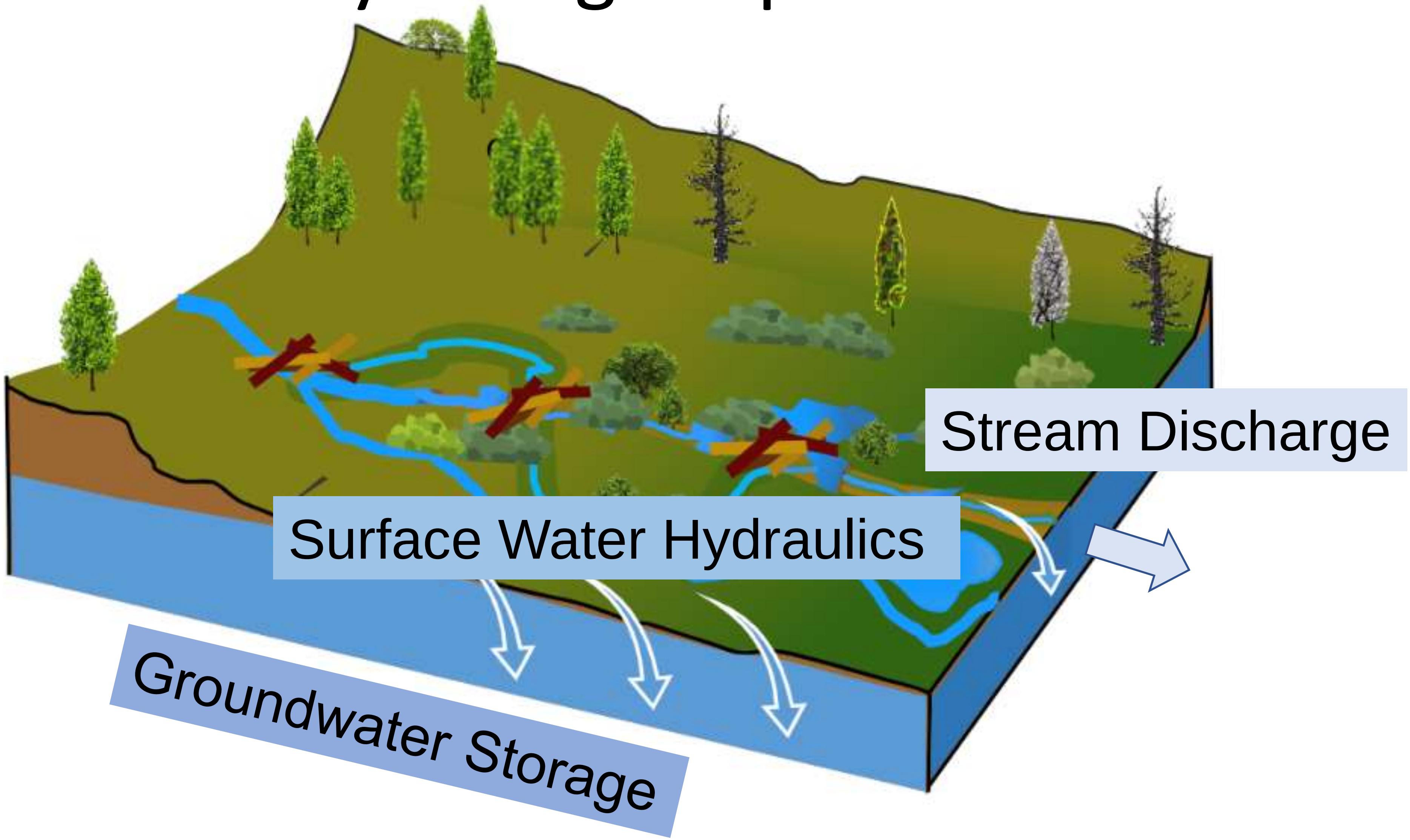
How does process-based meadow restoration affect hydrological processes?



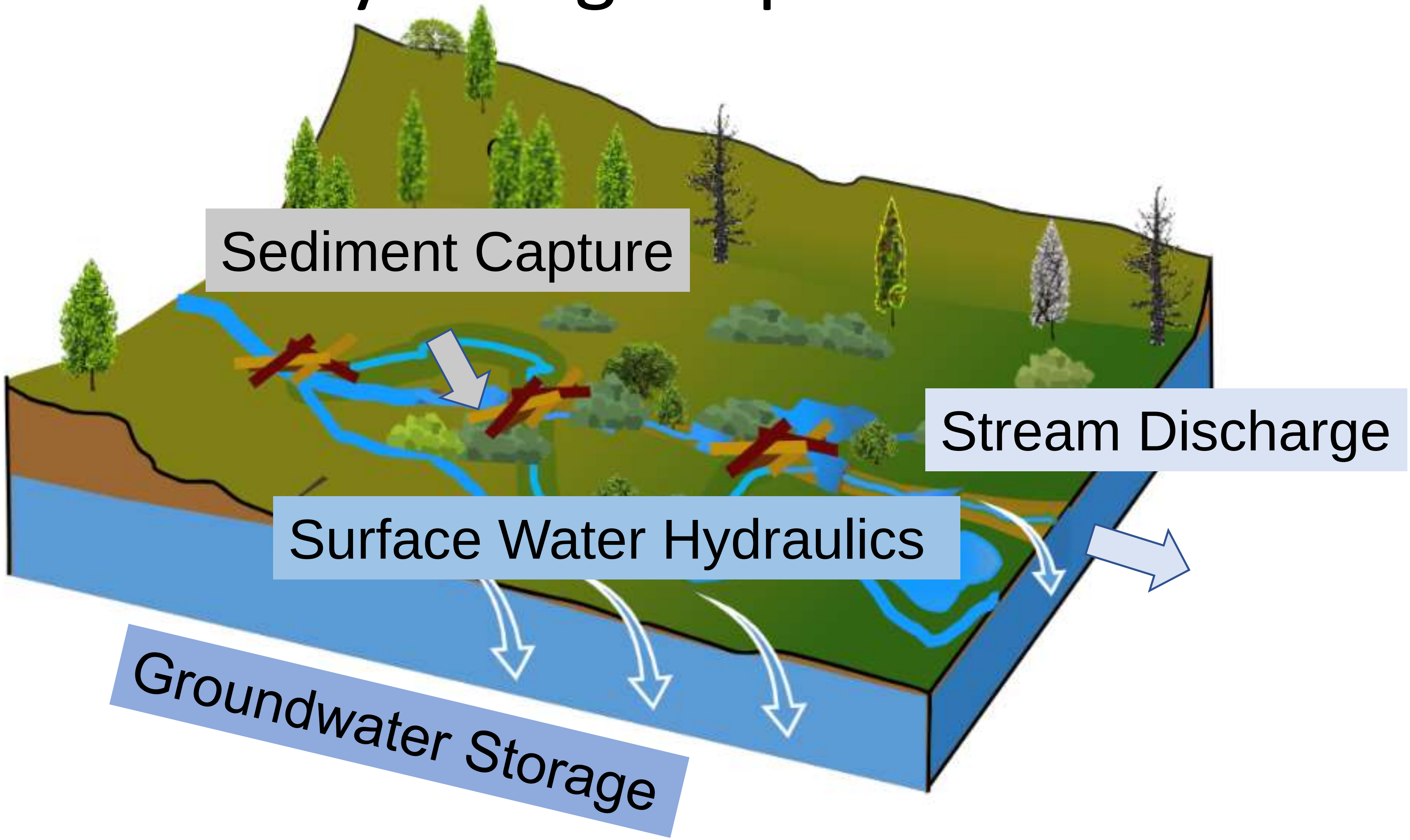
How does process-based meadow restoration affect hydrological processes?



How does process-based meadow restoration affect hydrological processes?

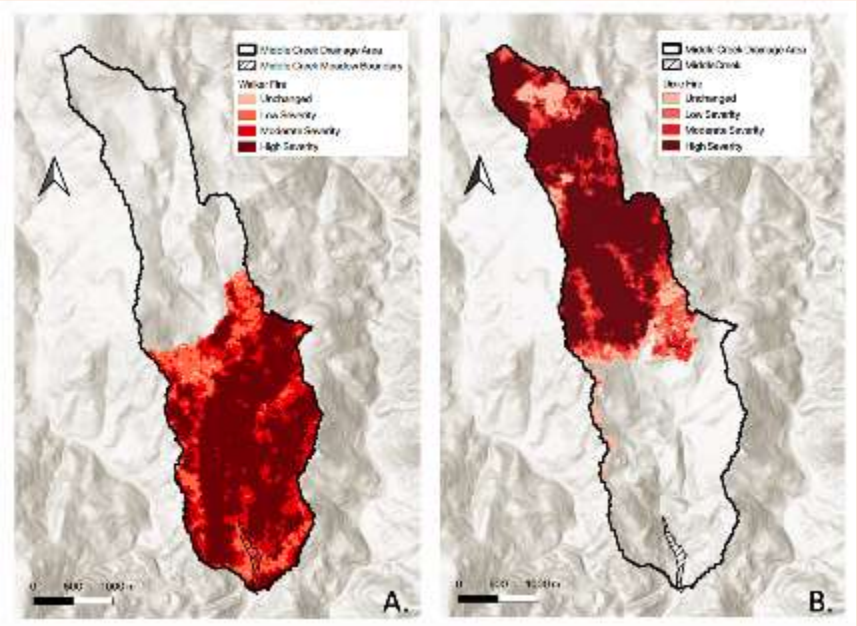


How does process-based meadow restoration affect hydrological processes?

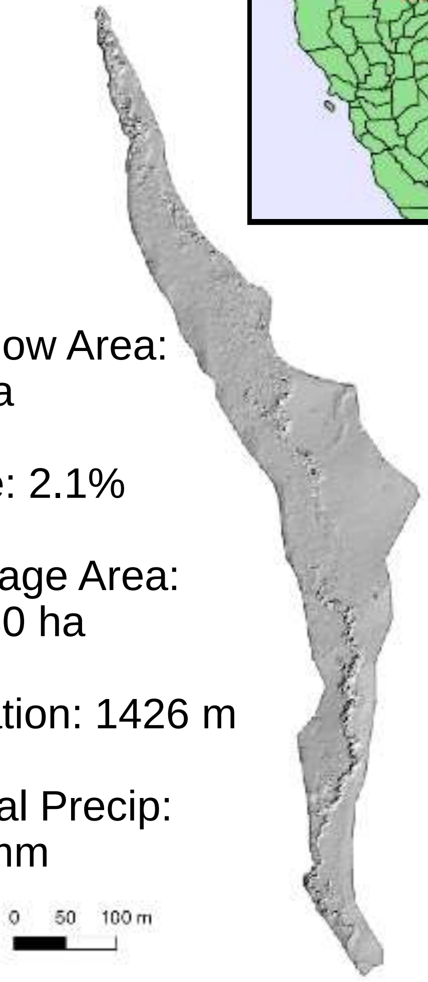


Middle Creek Meadow: Study Meadow

Fire History



Composite Burn Index or cbi4 for Middle Creek Meadow and Watershed burned in A. Walker Fire (2019) and B. Dixie Fire (2021)



Meadow Area:
6.4 ha

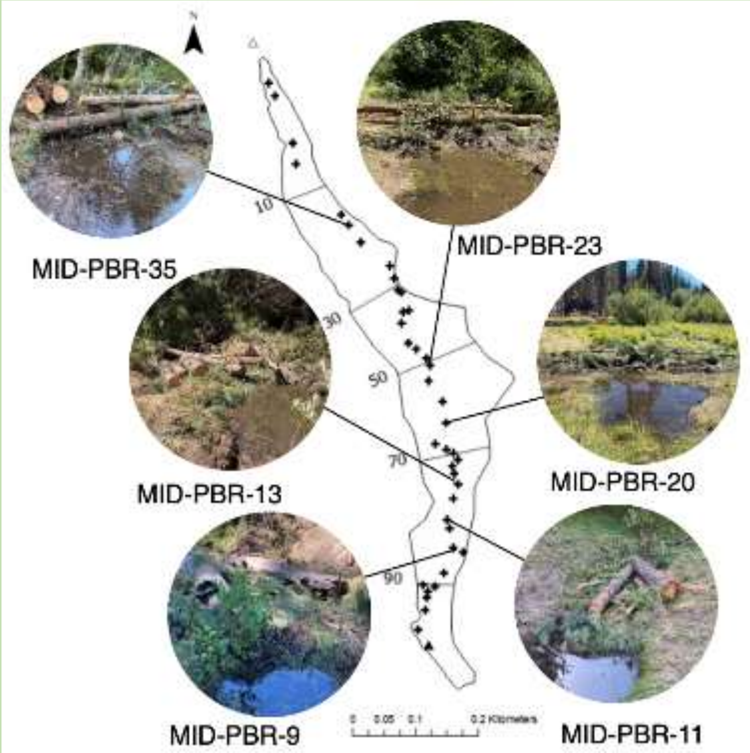
Slope: 2.1%

Drainage Area:
958.30 ha

Elevation: 1426 m

Annual Precip:
594 mm

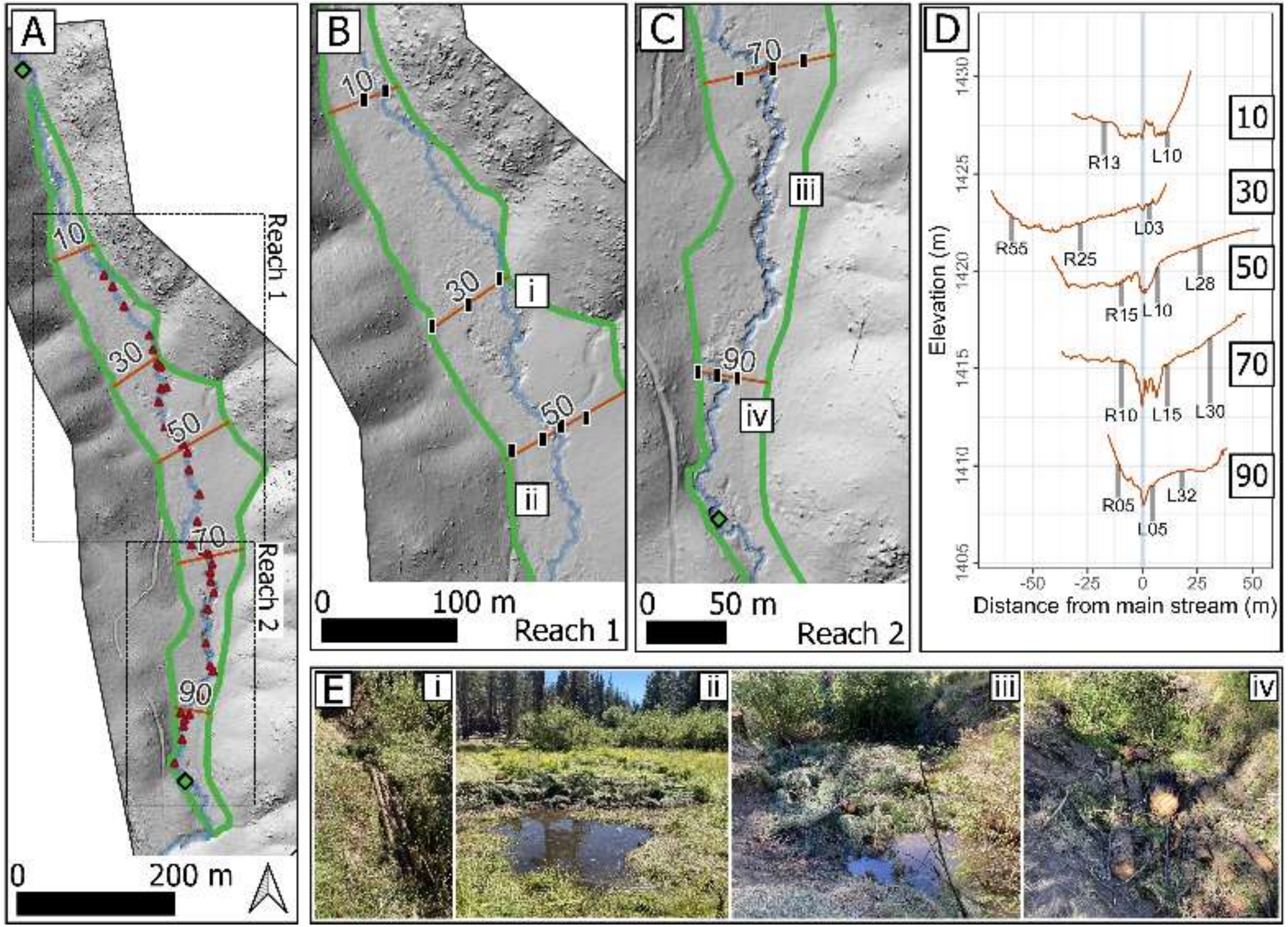
Restoration Treatment



Restoration structures including BDAs at Middle Creek Meadow, built August, 30 – September, 4 2022

Surface Water & Groundwater Wells

- 2 stream gages
- 5 transects
- 15 groundwater wells
- 2 distinct geomorphic reaches
- 35 restoration structures



A. Meadow boundary with restoration structures. B. Reach 1. C. Reach 2. D. Groundwater wells E. Restoration Structures Credit: Adam Cummings

Stream Gage

Restoration Structure

Groundwater Well

Groundwater & Surface Water

Middle Creek Meadow Upstream Gaging Station

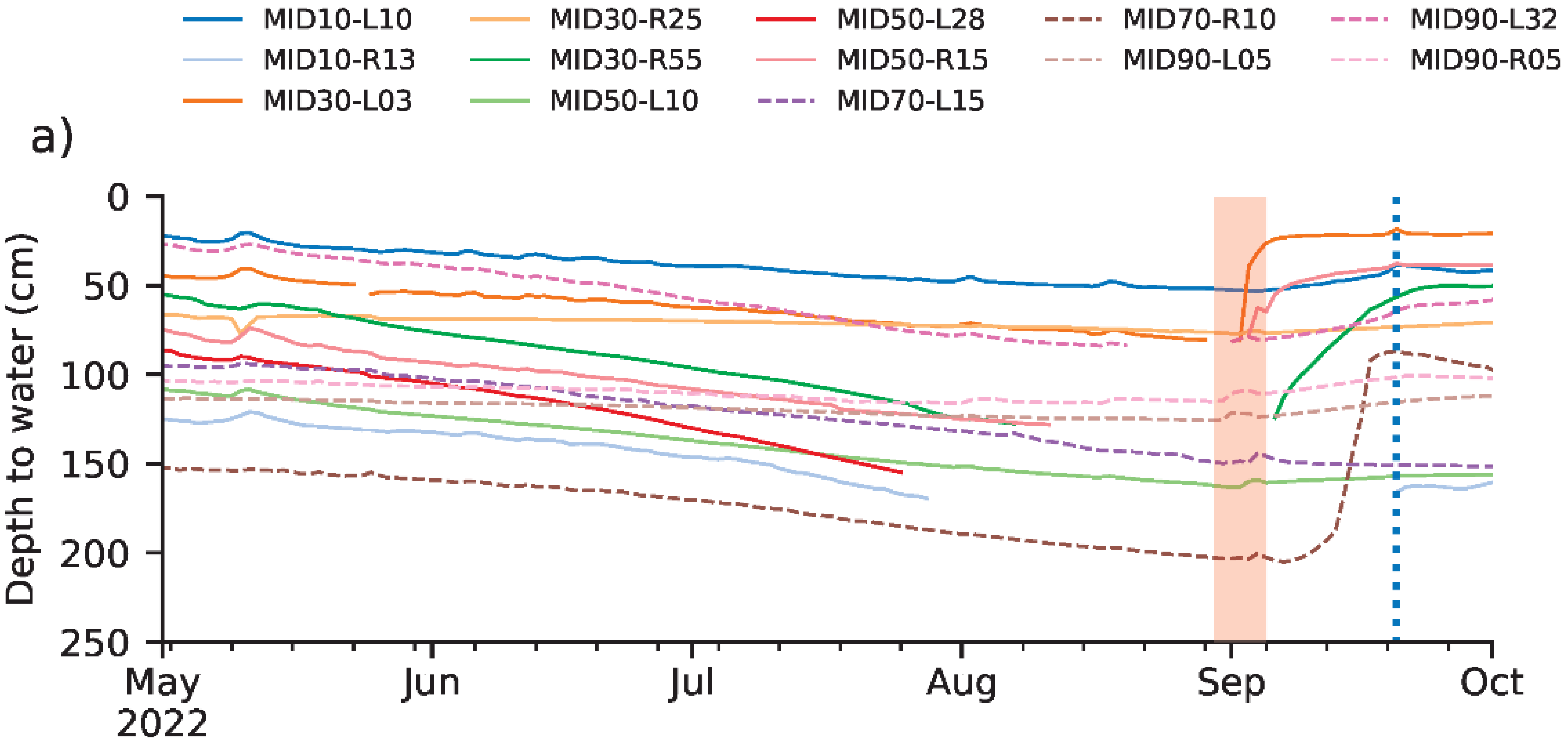
Groundwater

- 15 wells instrumented with pressure transducer
- Manual measurements made with E-line

Surface Water

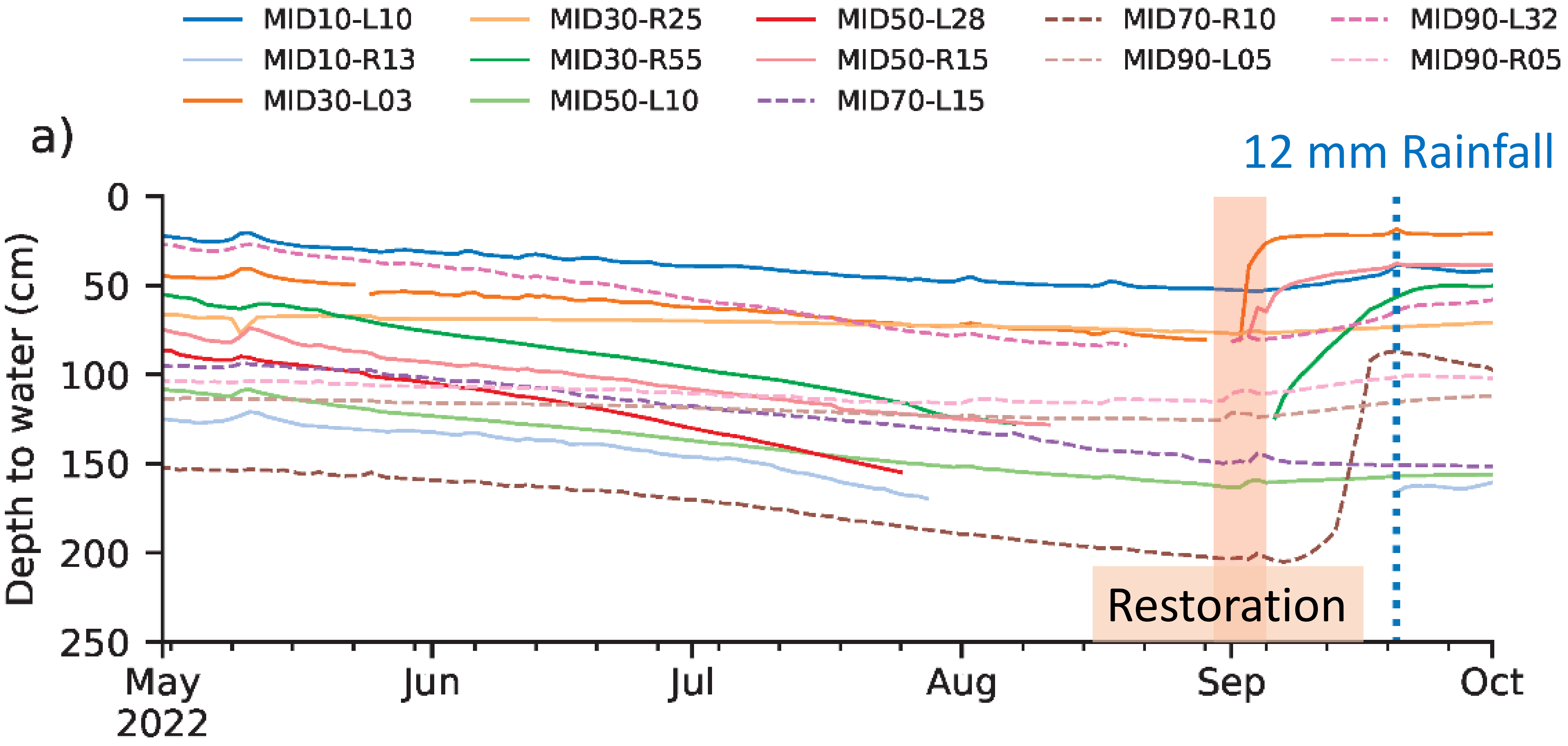
- Discharge collected in 2021 using flowtracker acoustic doppler velocimeter and fit to rating curve

Groundwater table increases following restoration



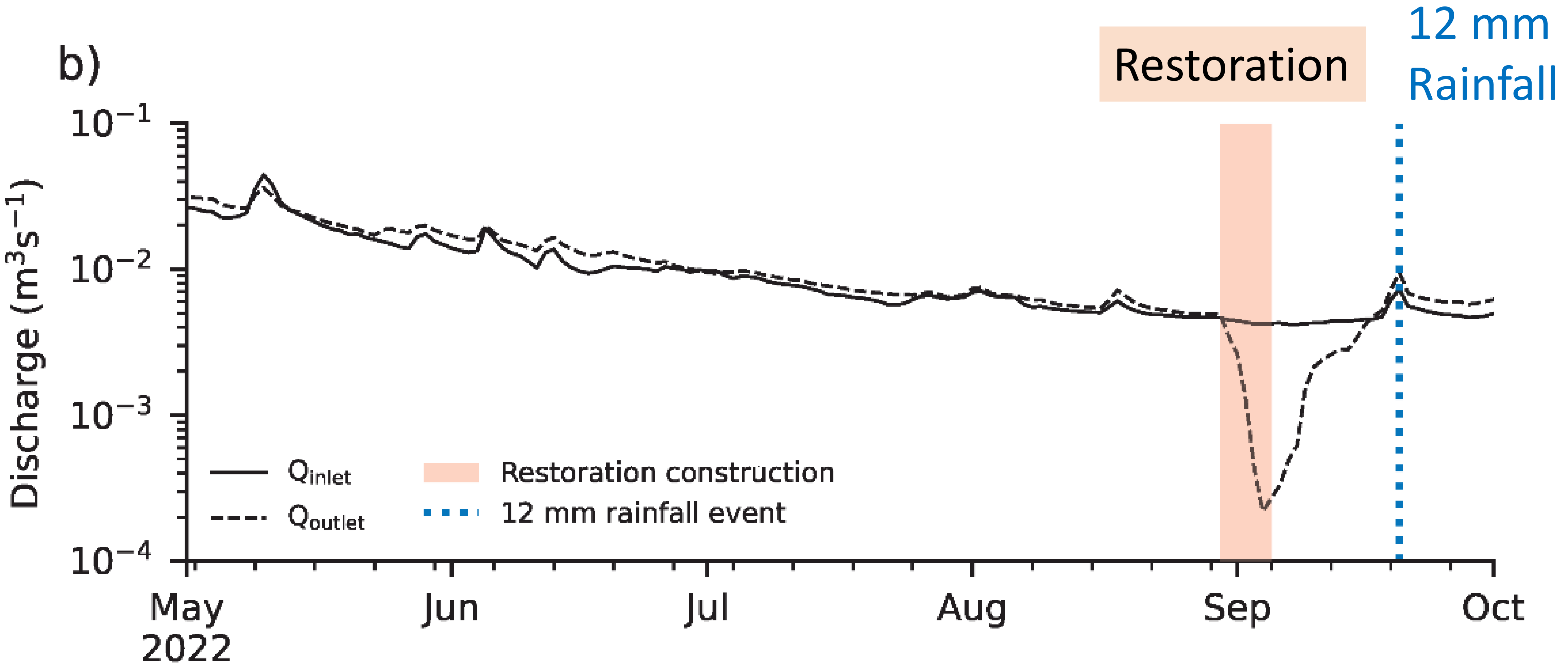
Groundwater before, during (red shading), and after restoration. Groundwater wells in (a) are plotted with dashed lines for Reach 1 and solid lines for Reach 2. Credit: David Dralle

Groundwater table increases following restoration



Groundwater before, during (red shading), and after restoration. Groundwater wells in (a) are plotted with dashed lines for Reach 1 and solid lines for Reach 2. Credit: David Dralle

Short-term decrease in outlet discharge



Streamflow (b) for the upper (Q_{inlet}) and lower (Q_{outlet}) before, during (red shading), and after restoration. Groundwater wells in (a) are plotted with dashed lines for Reach 1 and solid lines for Reach 2. Credit: David Dralle

Linking Surface Water and Groundwater

How much water was stored in Middle Creek Meadow following restoration?

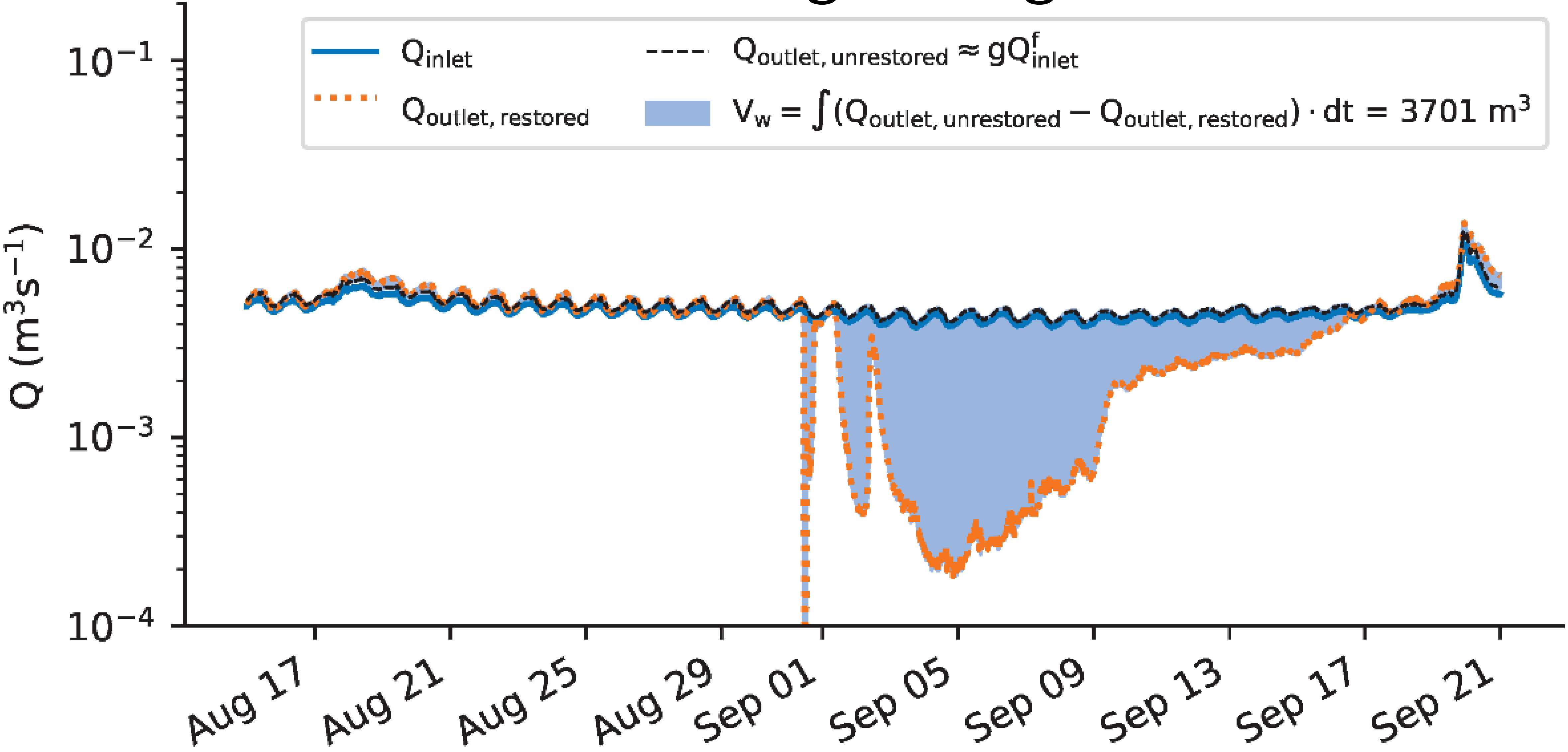
- Use simple power law model to estimate discharge if restoration hadn't occurred ($Q_{outlet,unrestored}$)

$$Q_{outlet} = gQ_{inlet}{}^{f}$$

*g and f are model coefficients

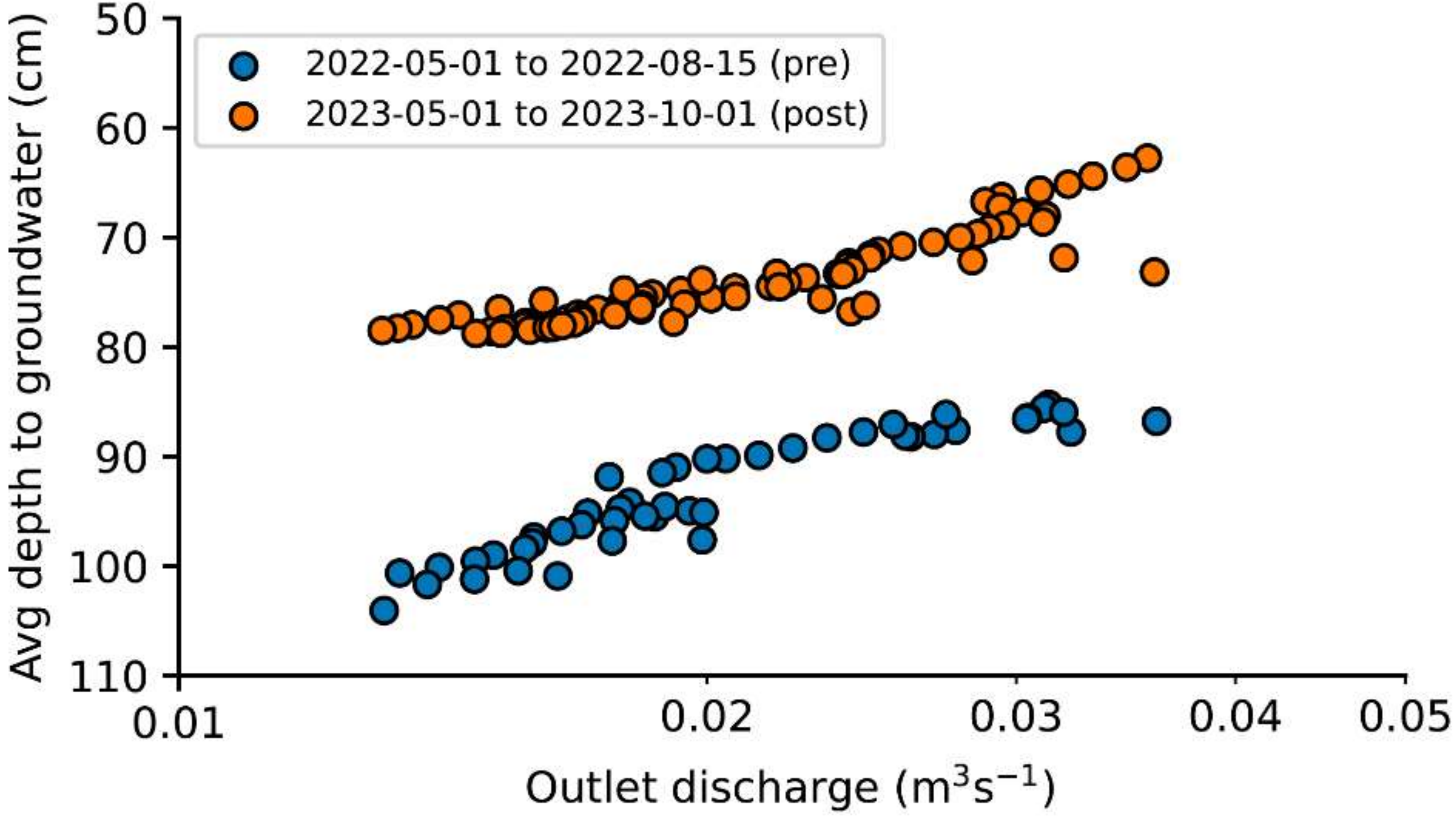
- Assume decreases in outlet discharge could explain groundwater increases following restoration
- Integrate the difference to estimate water stored in Middle Creek Meadow

Estimating Storage



Estimated increase in meadow water storage due to restoration. Credit: David Dralle

Change in Depth to Groundwater Pre- and Post-Restoration



Average depth to groundwater across all meadow wells before (blue) and after restoration (orange) as a function of shared outlet discharge (log scale). Credit: David Dralle

Changes in Surface Water Hydraulics

SRH-2D – Sedimentation and River Hydraulics 2 Dimension

Developed by United States Bureau of Reclamation (USBR)

Changes in Surface Water Hydraulics

SRH-2D – Sedimentation and River Hydraulics 2 Dimension

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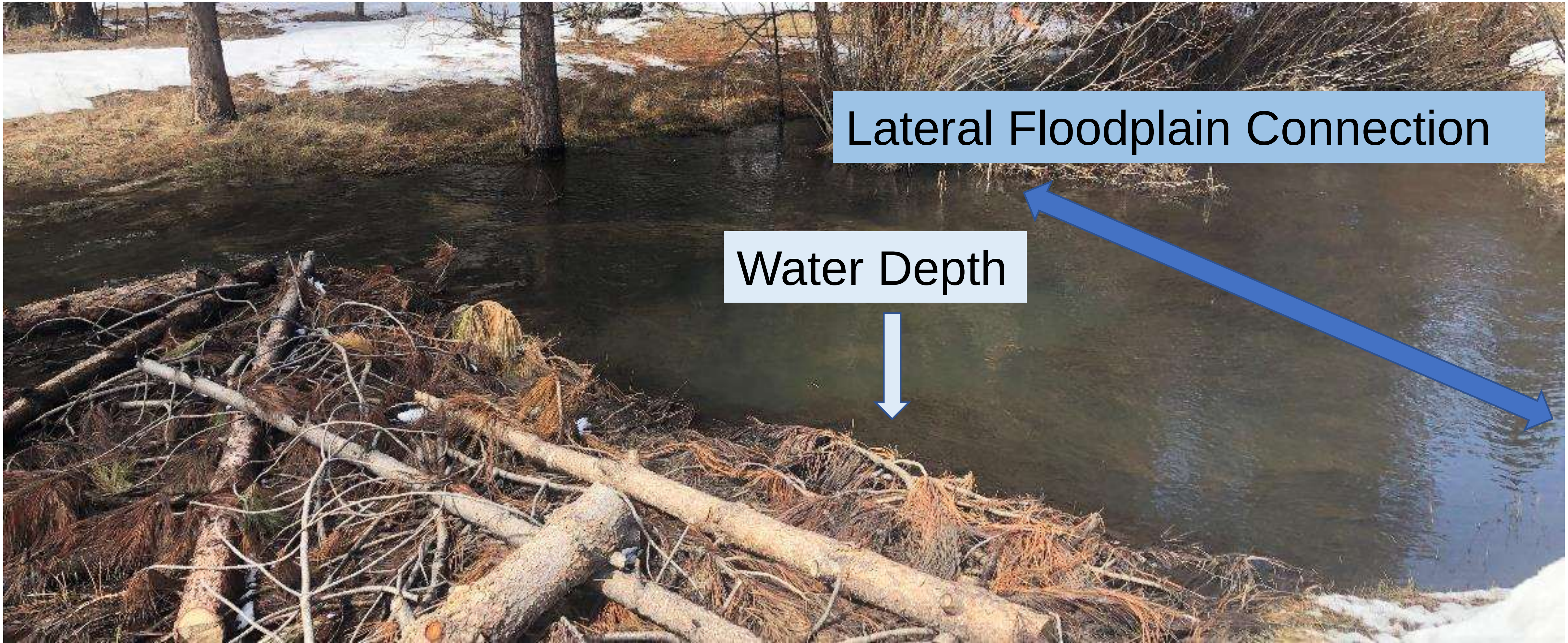
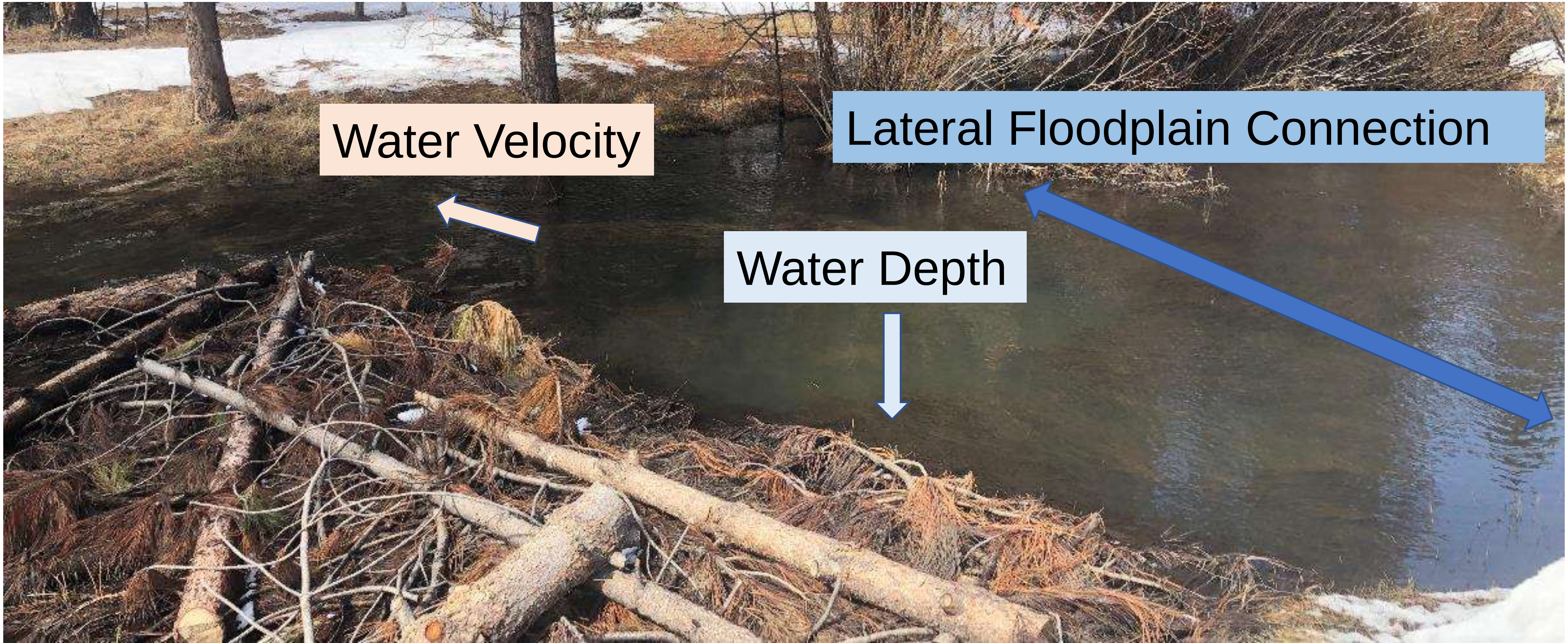


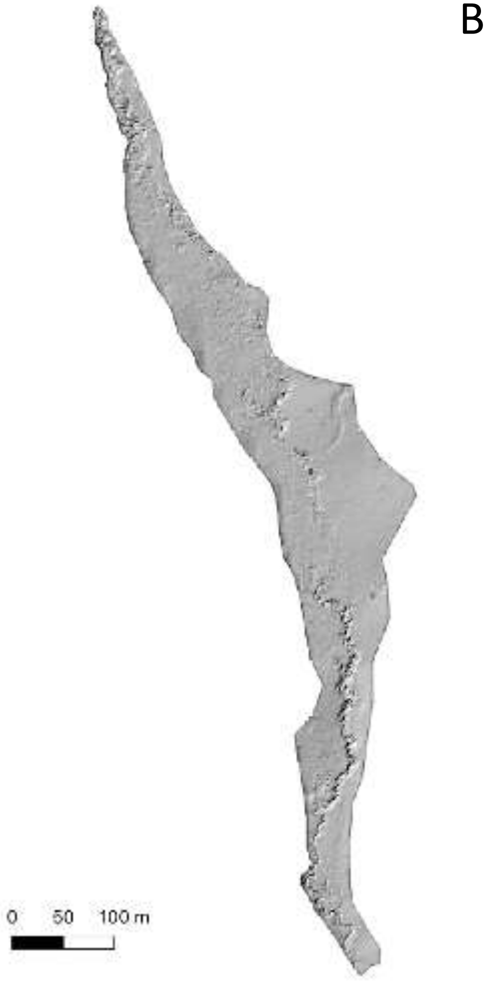
Changes in Surface Water Hydraulics

SRH-2D – Sedimentation and River Hydraulics 2 Dimension

Developed by United States Bureau of Reclamation (USBR)



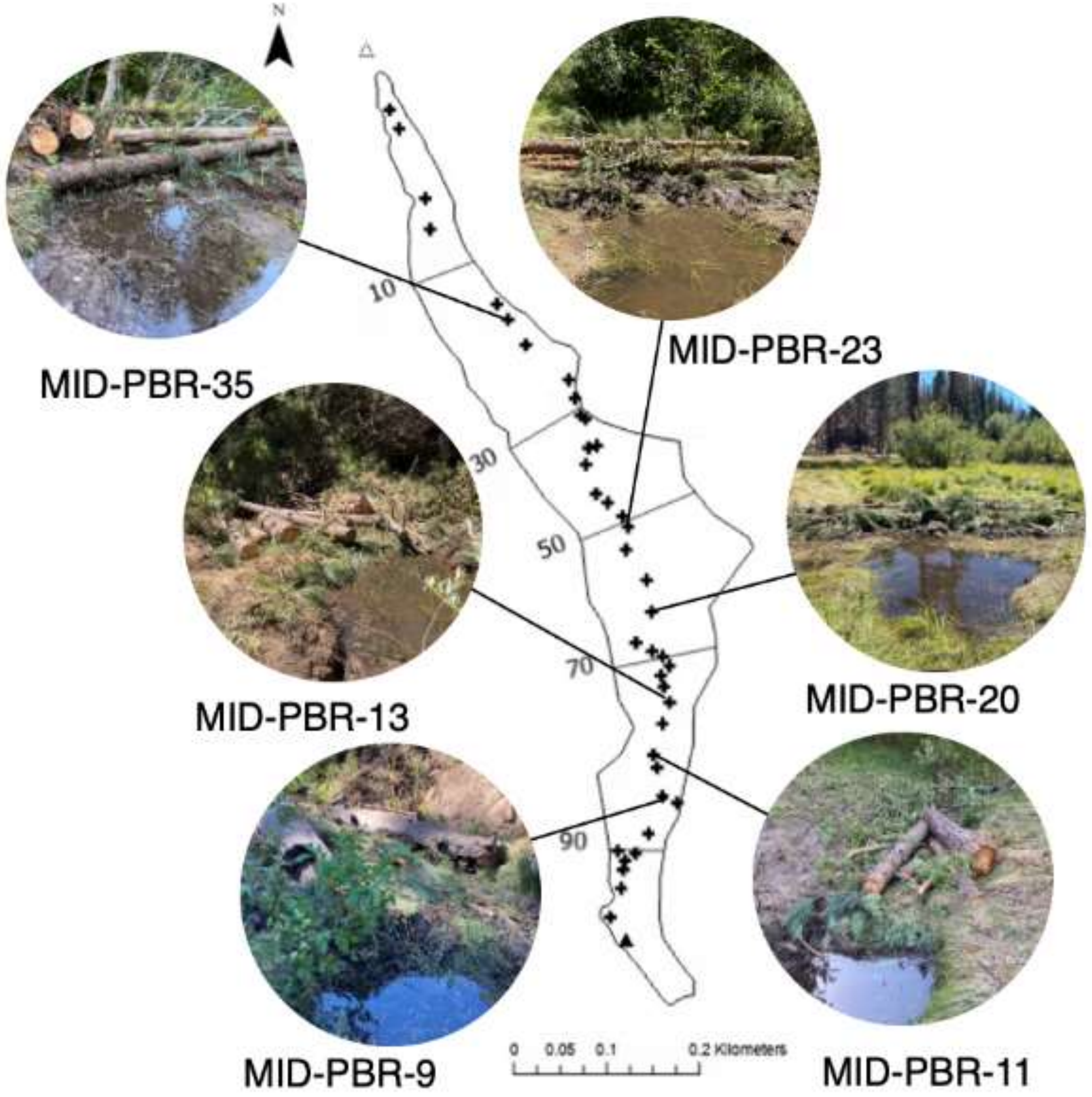
Pre-Restoration Model Surface Using LiDAR

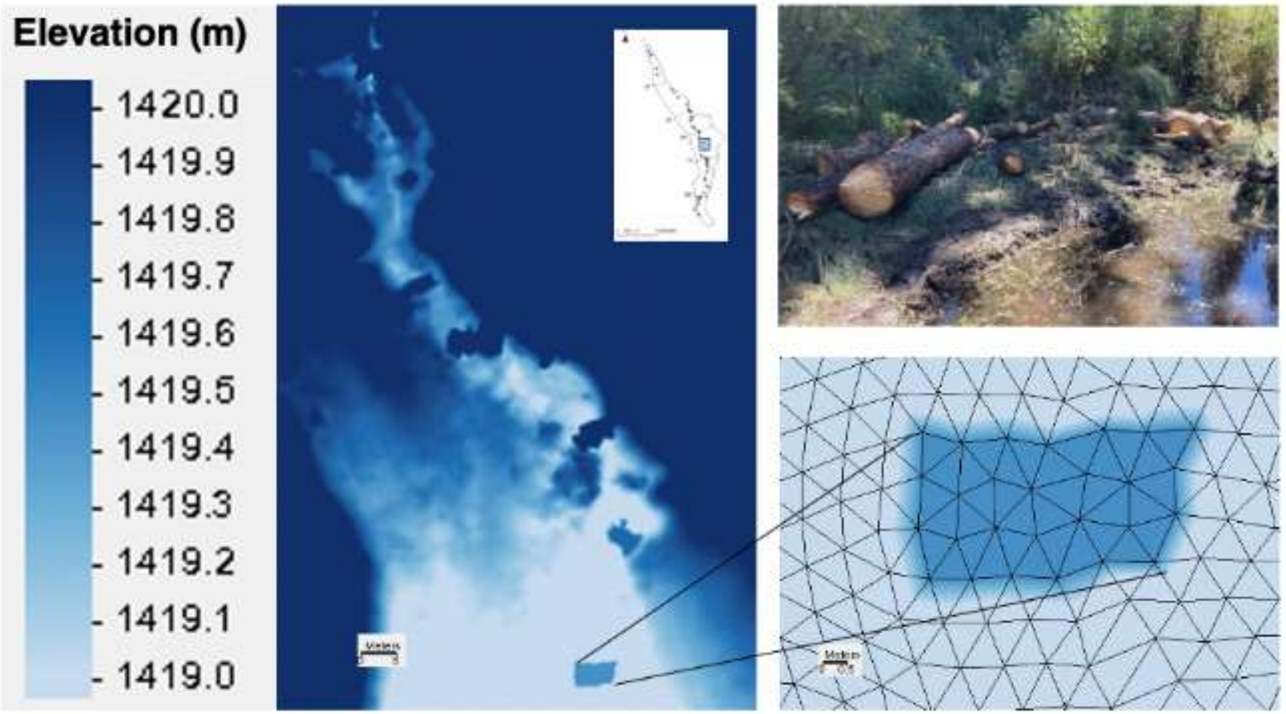


- LiDAR flown September 26 to October 4, 2021
- 50 cm resolution Digital Elevation Model (DEM)
- Merged with topographic survey data

A. GTAC Drone collecting LiDAR at Southern Sierra partner site Lower Grouse Meadow B. Middle Creek Meadow Hillshade

Simulate restoration structures for post-restoration condition

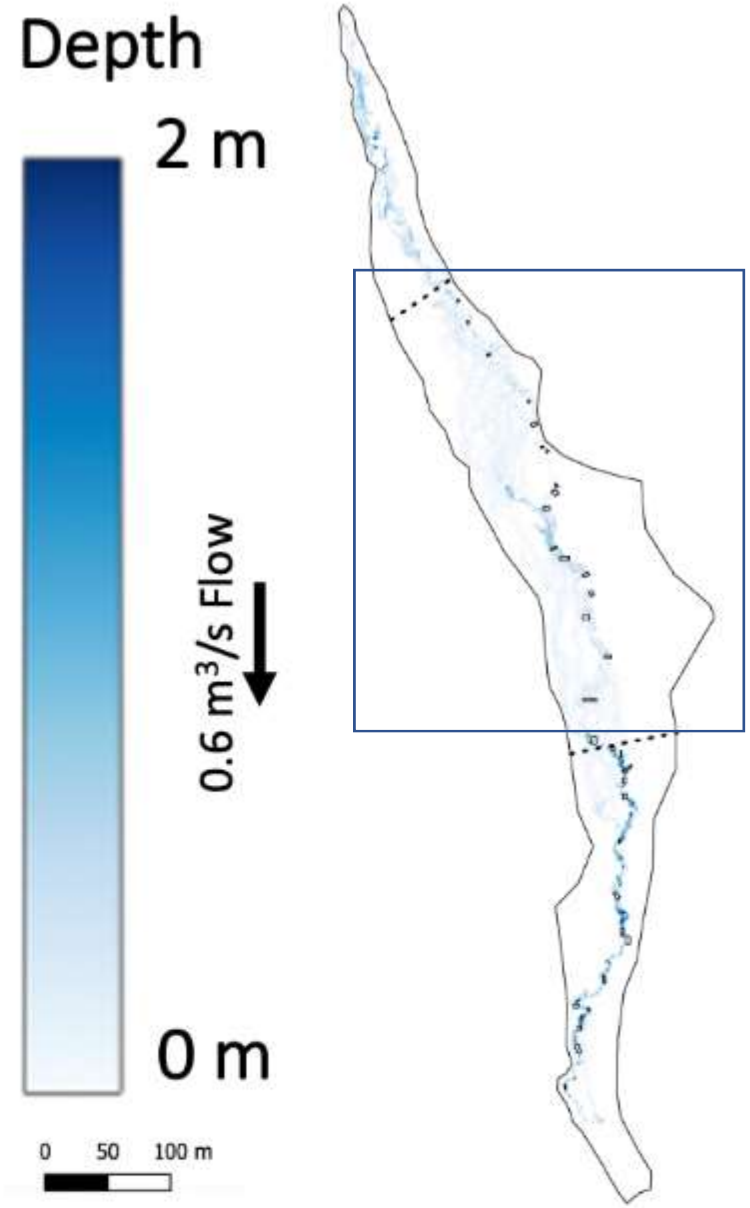




- Model mesh modified with 35 structures added iteratively to verify model performance

- Field measurements of restoration structures including average length, width, and height used to modify mesh elevations

Hydrogeomorphic Regions within Middle Creek Meadow



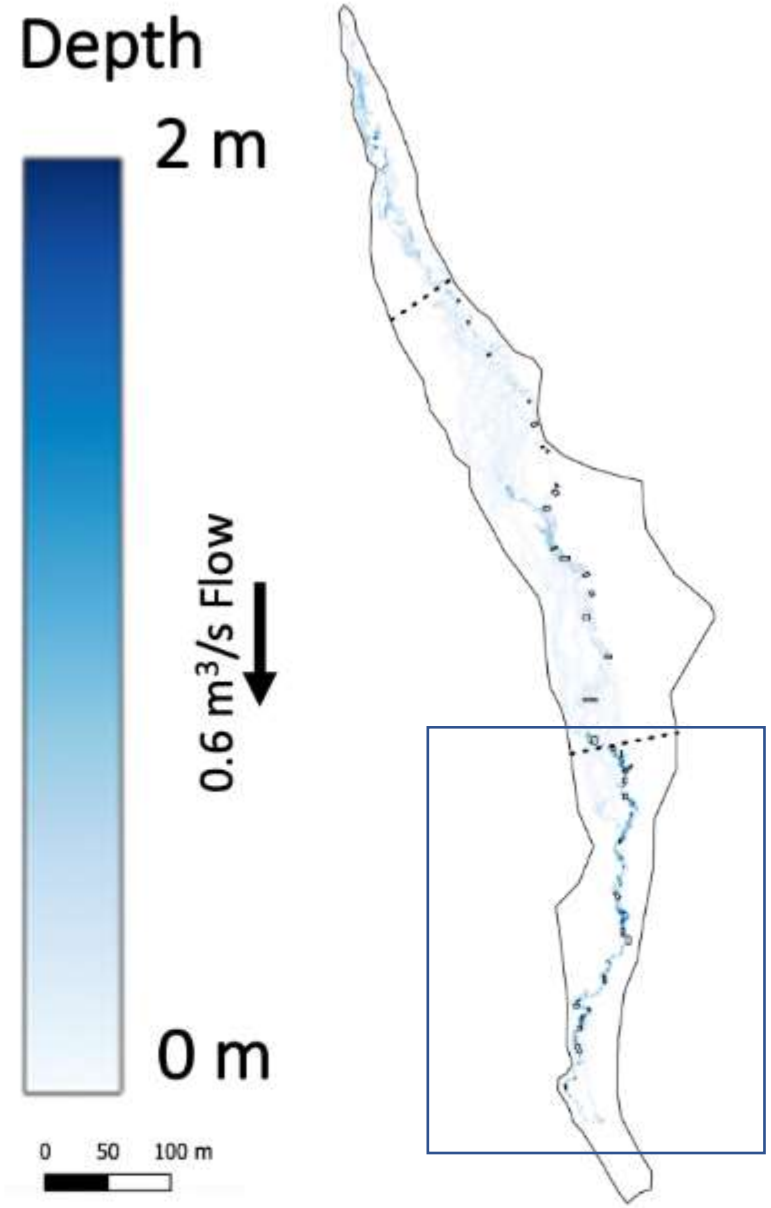
Reach 1

- Average Width (cm): 50
- Incision (cm): 15 - 80
- Region of lateral floodplain connection

Reach 2

- Average Width (cm): 100
- Incision (cm): 50 to 260
- Region of severe channel incision

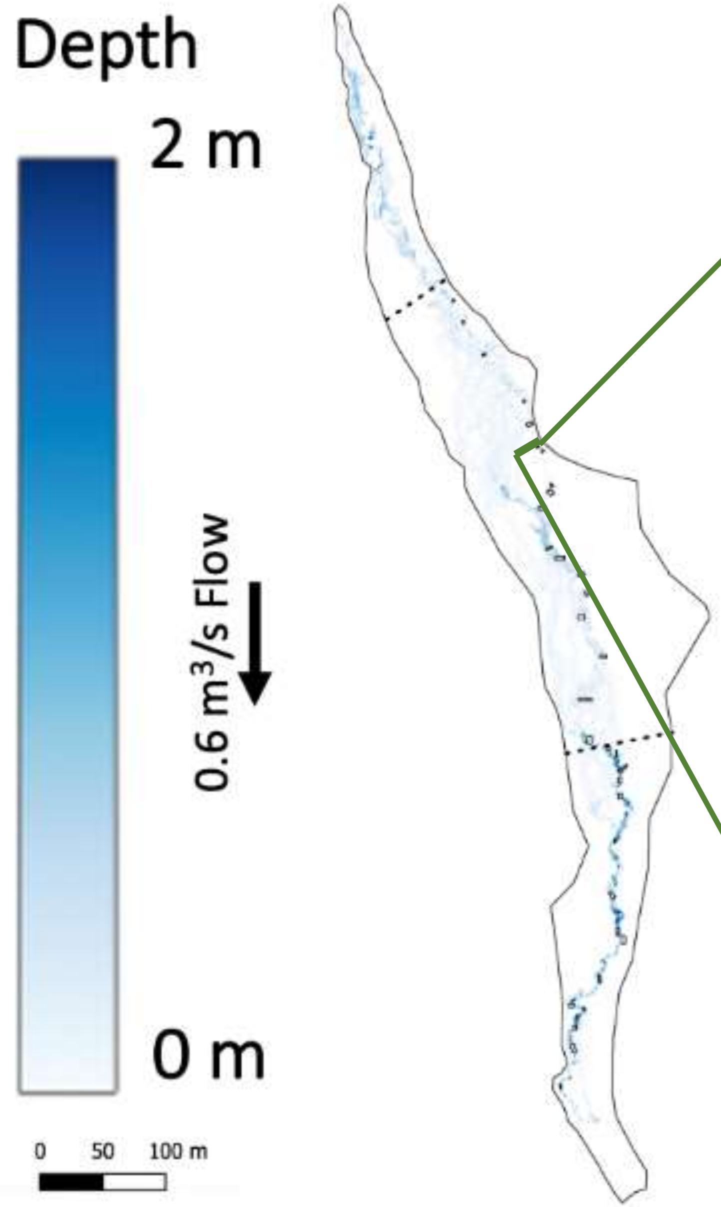
Hydrogeomorphic Regions within Middle Creek Meadow



Reach 1
- Average Width (cm): 50
- Incision (cm): 15 - 80
- Region of lateral floodplain connection

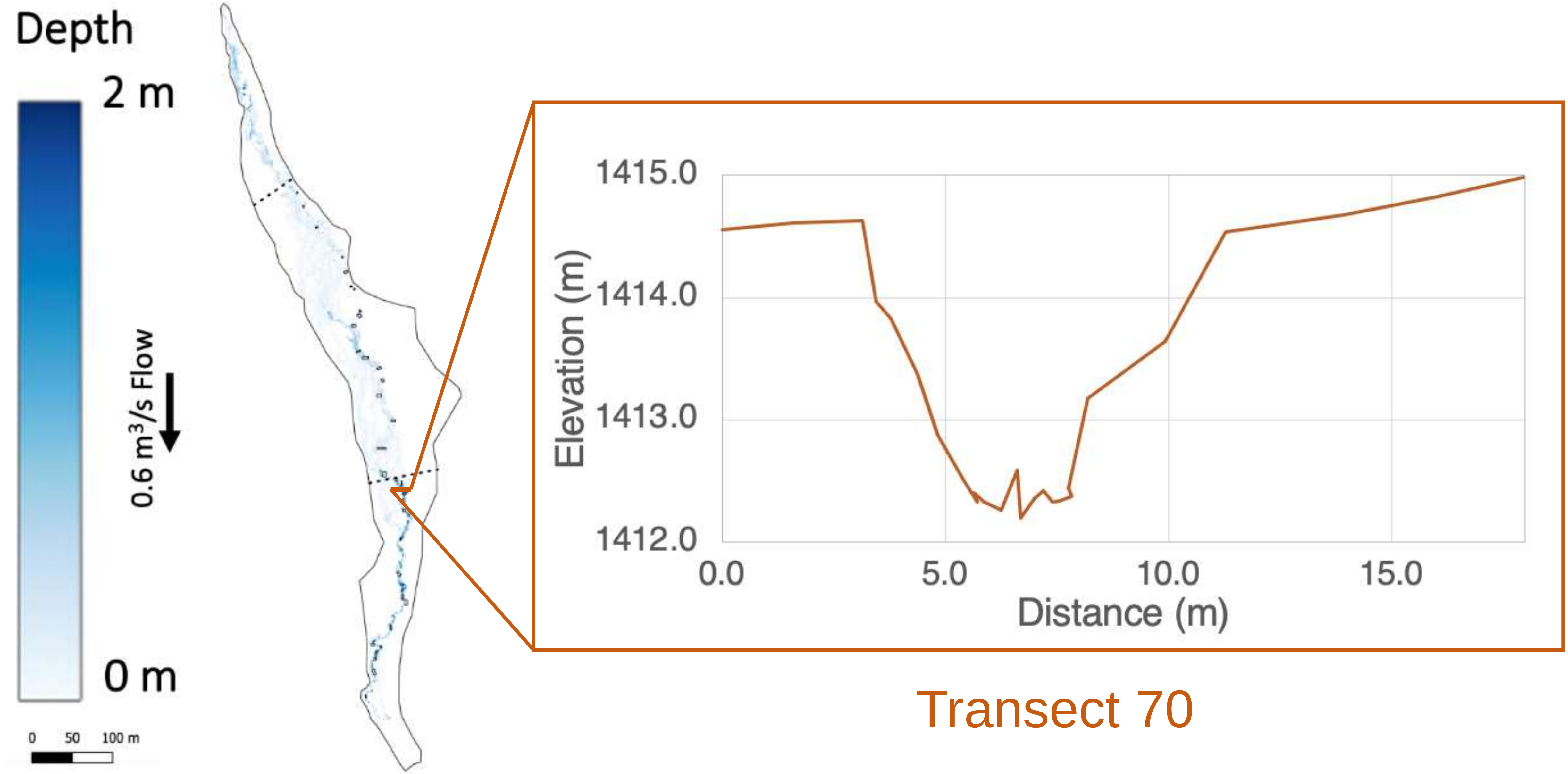
Reach 2
- Average Width (cm): 100
- Incision (cm): 50 to 260
- Region of severe channel incision

Reach 1 is laterally connected



Cross Section 30

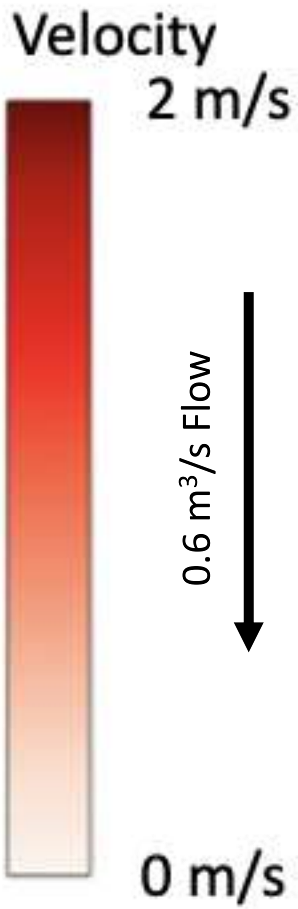
Reach 2 is deeply incised



Transect 70

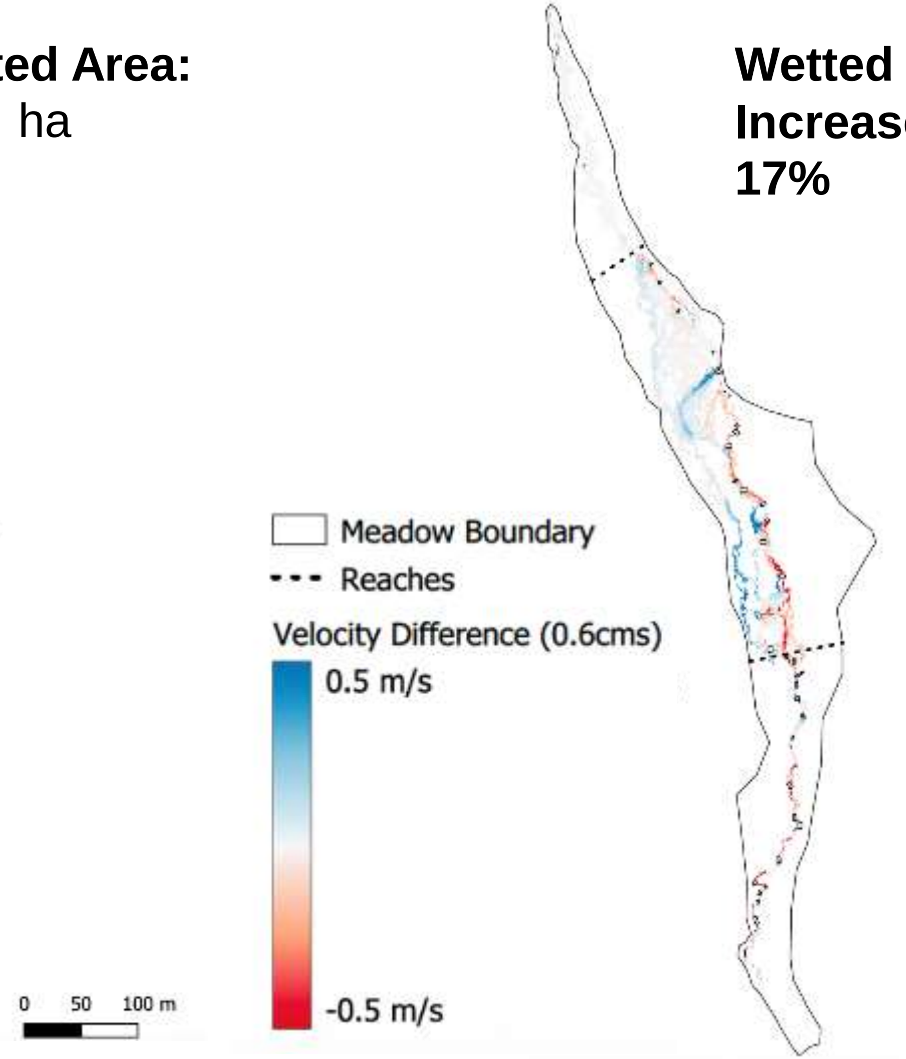
Velocity Predictions

Restoration Scenario - Pre-Restoration Scenario = Velocity Difference



Wetted Area:
2.08 ha

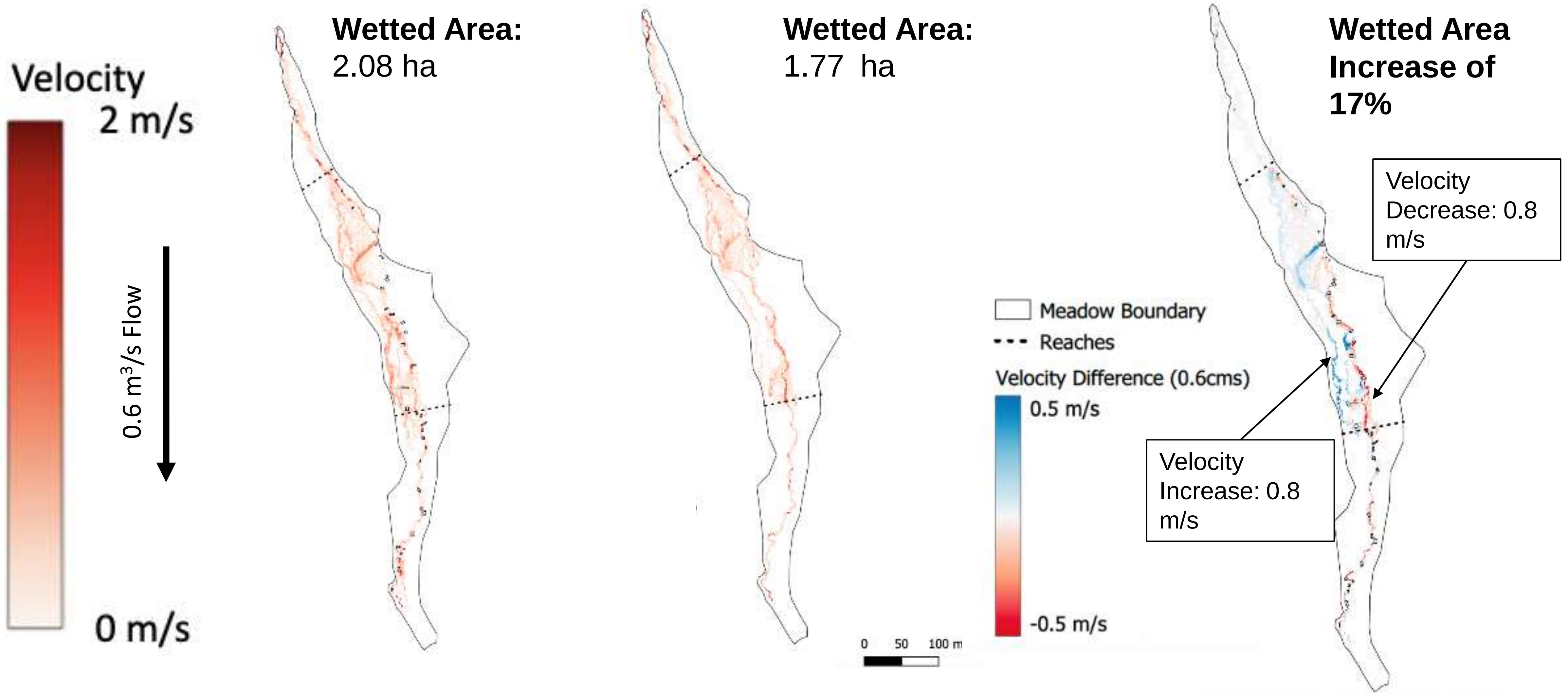
Wetted Area:
1.77 ha

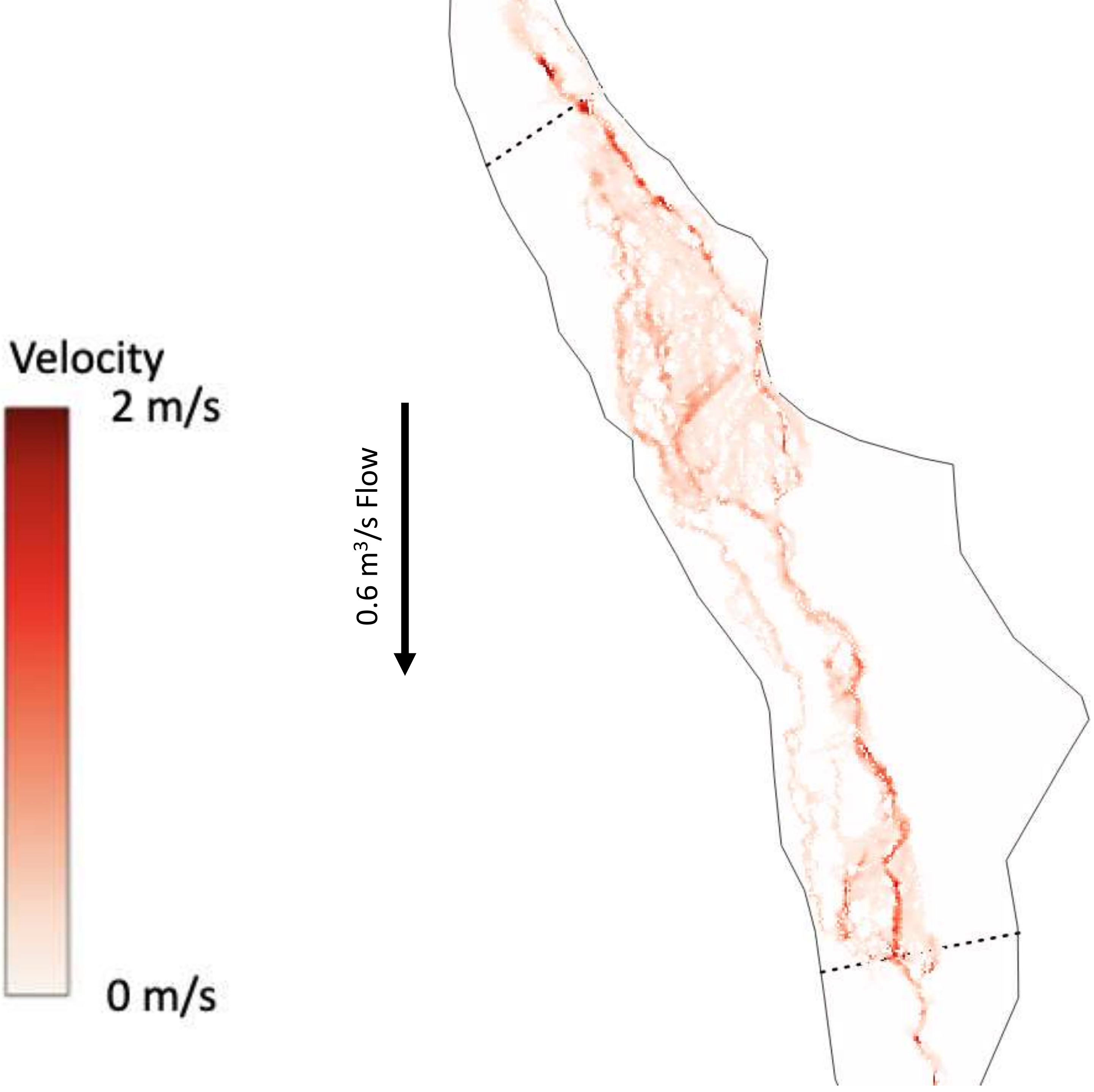


Wetted Area Increase of 17%

Velocity Predictions

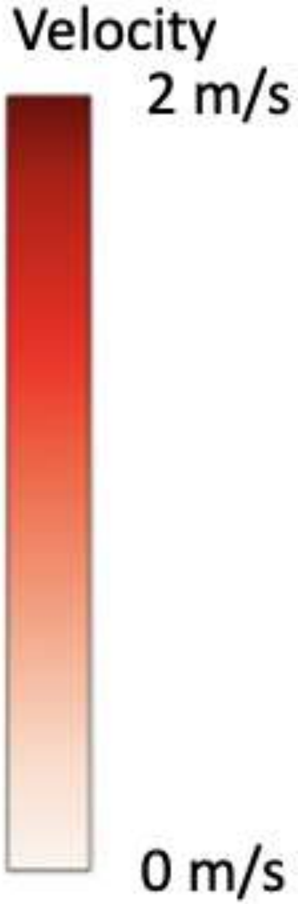
Restoration Scenario - Pre-Restoration Scenario = Velocity Difference

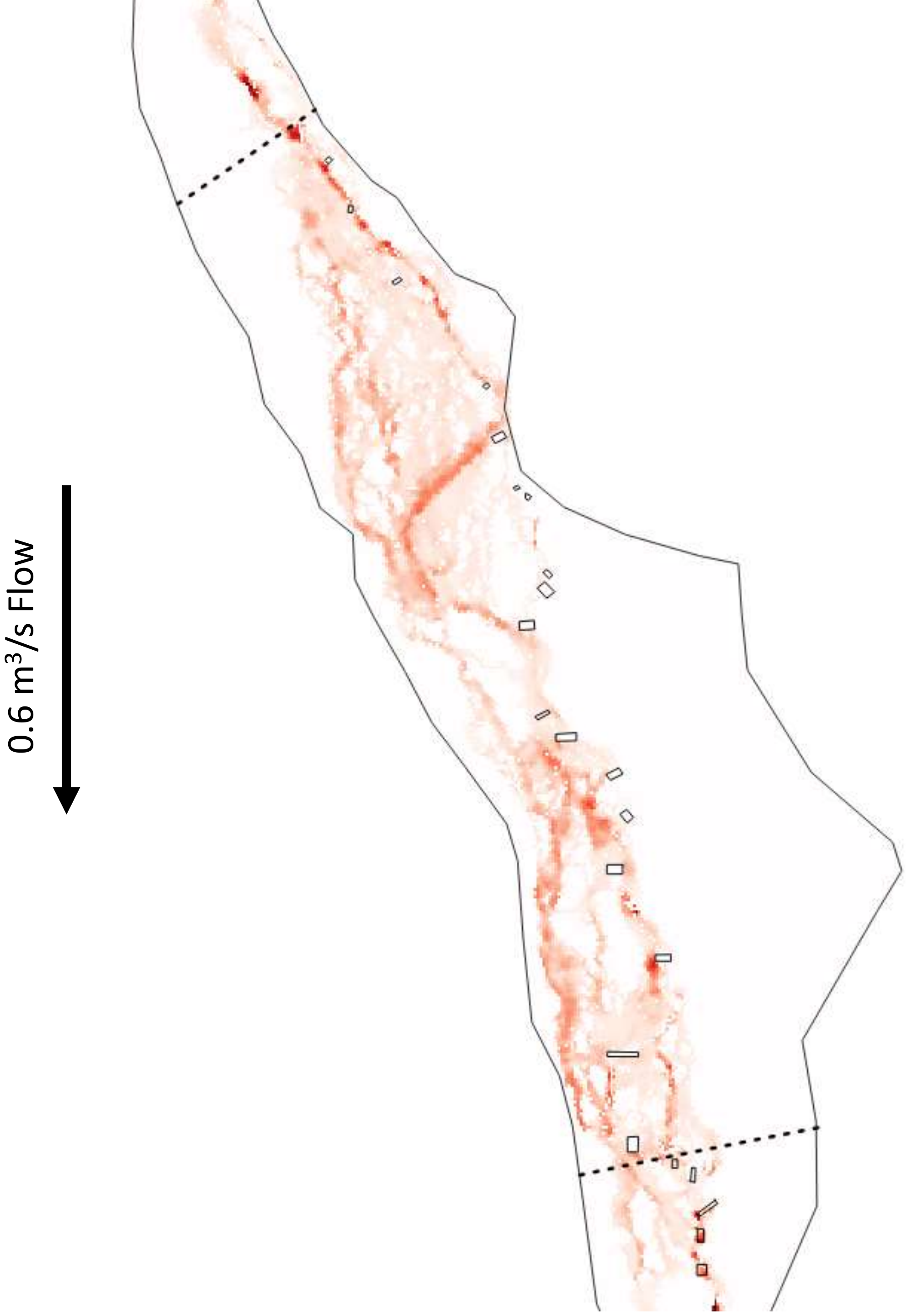


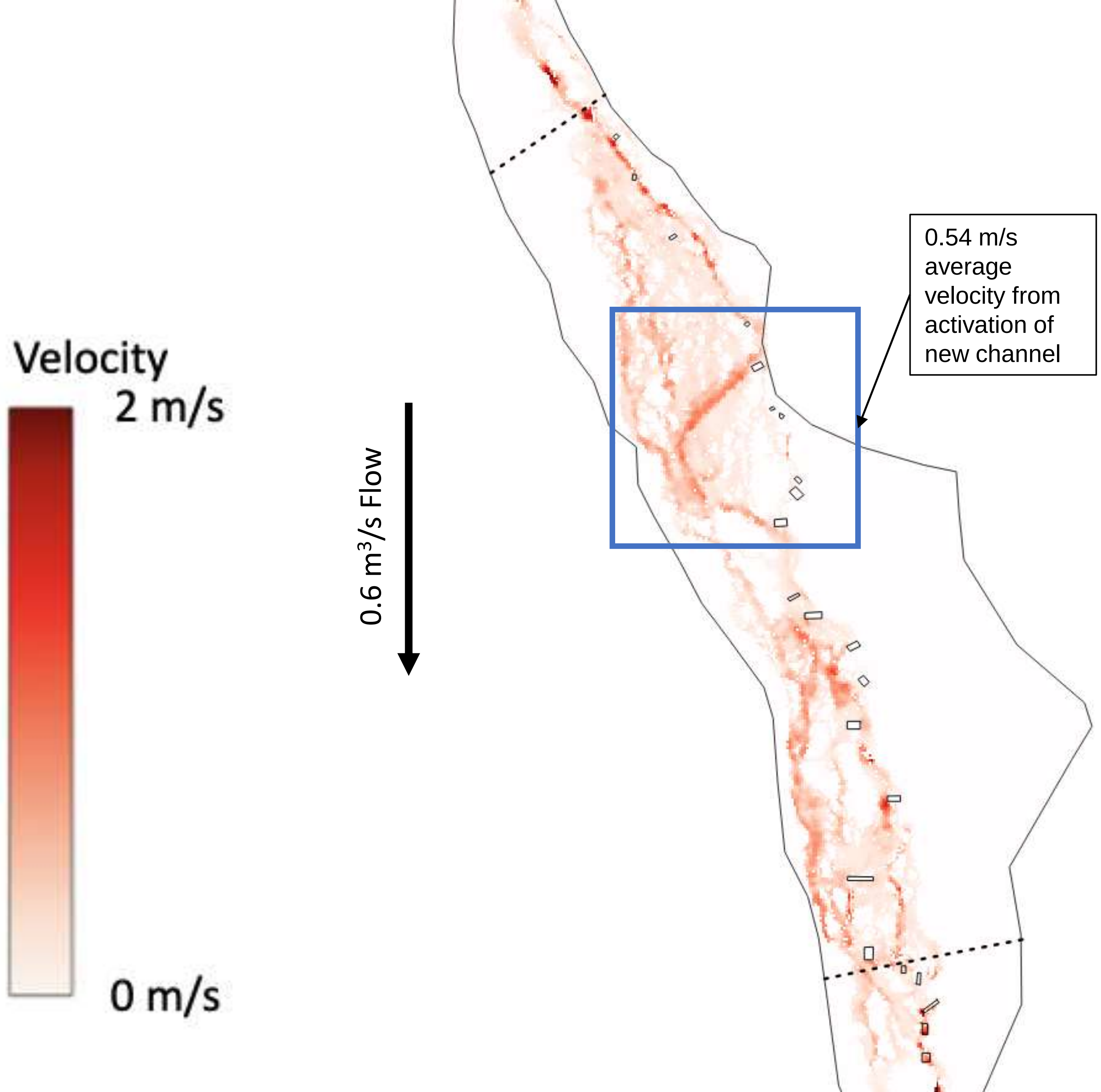


Reach 1:
Pre-Restoration

Reach 1: Post-Restoration

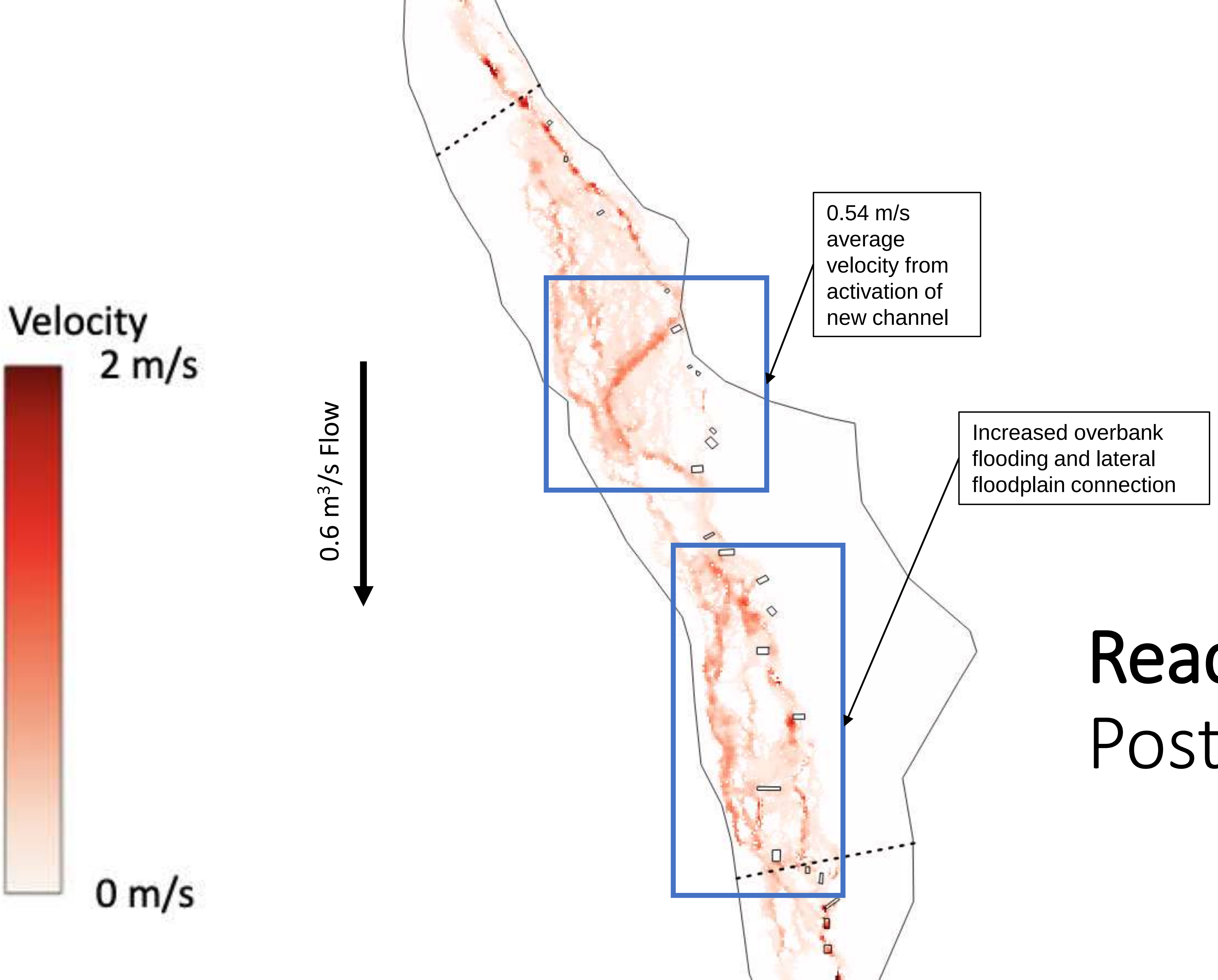


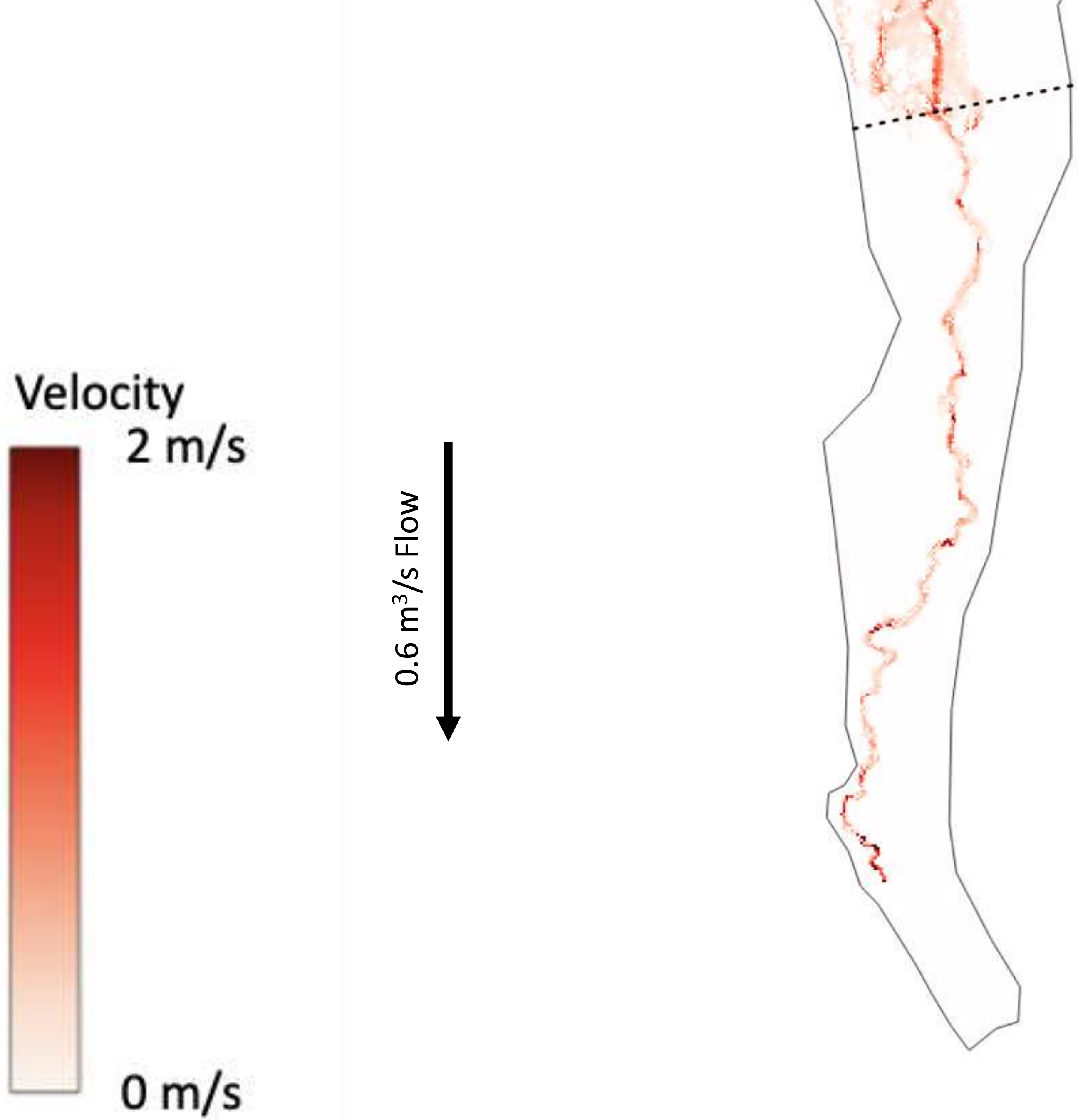




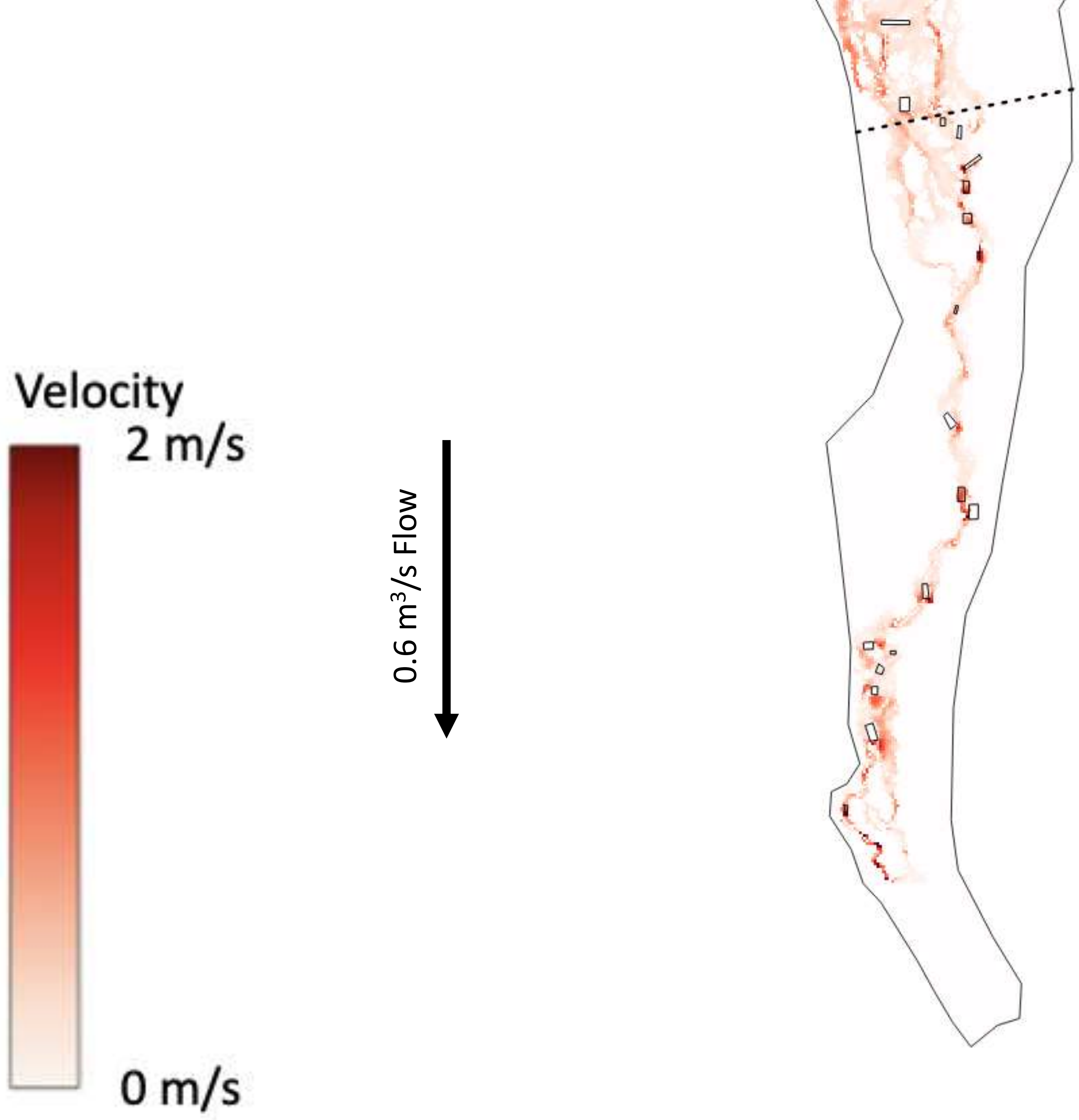
Reach 1: Post-Restoration

Reach 1: Post Restoration

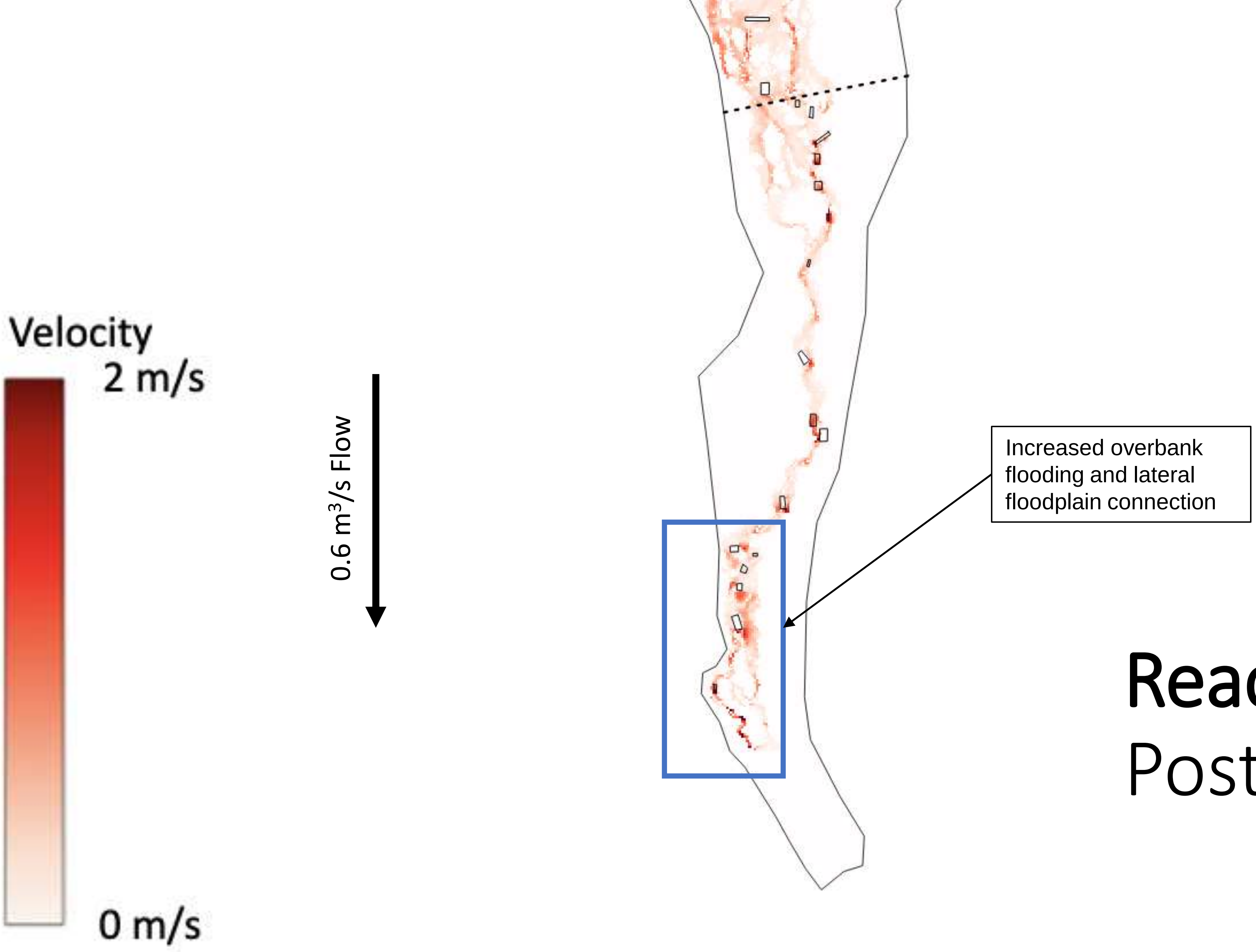




Reach 2:
Pre-Restoration

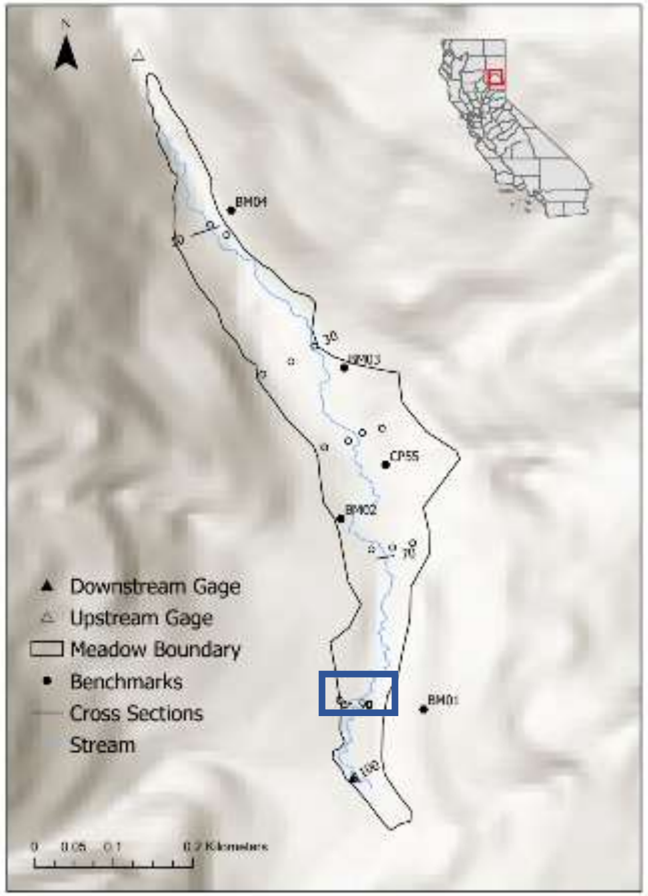


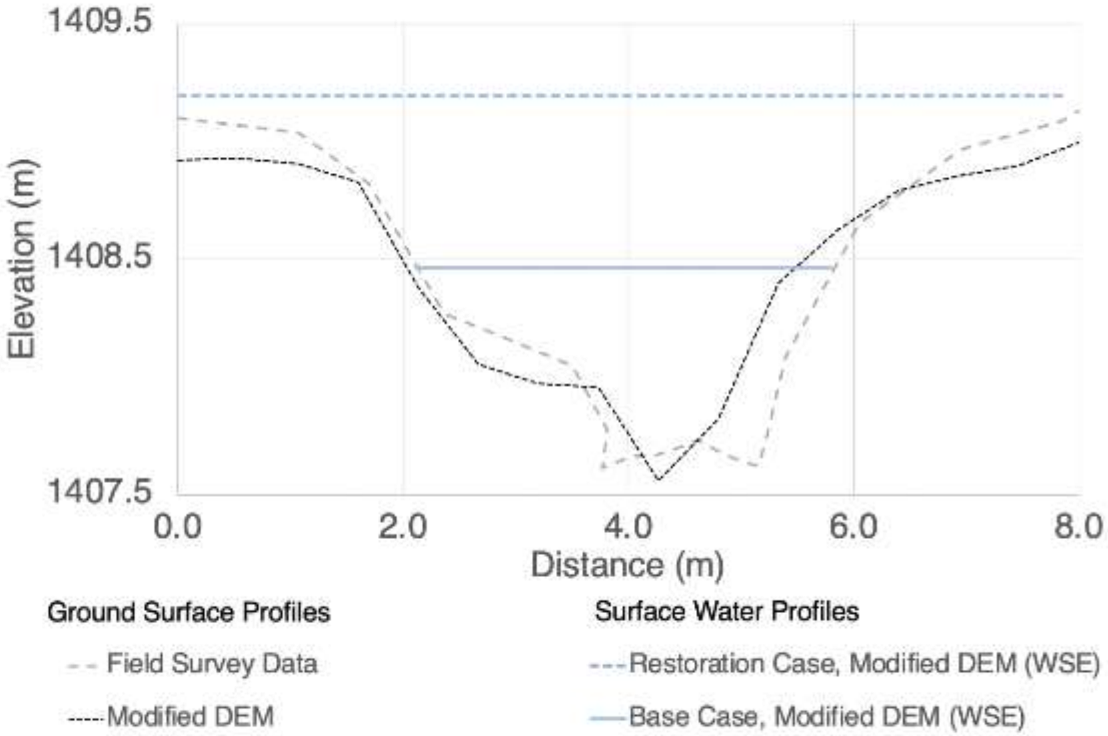
Reach 2:
Post-Restoration



Reach 2: Post-Restoration

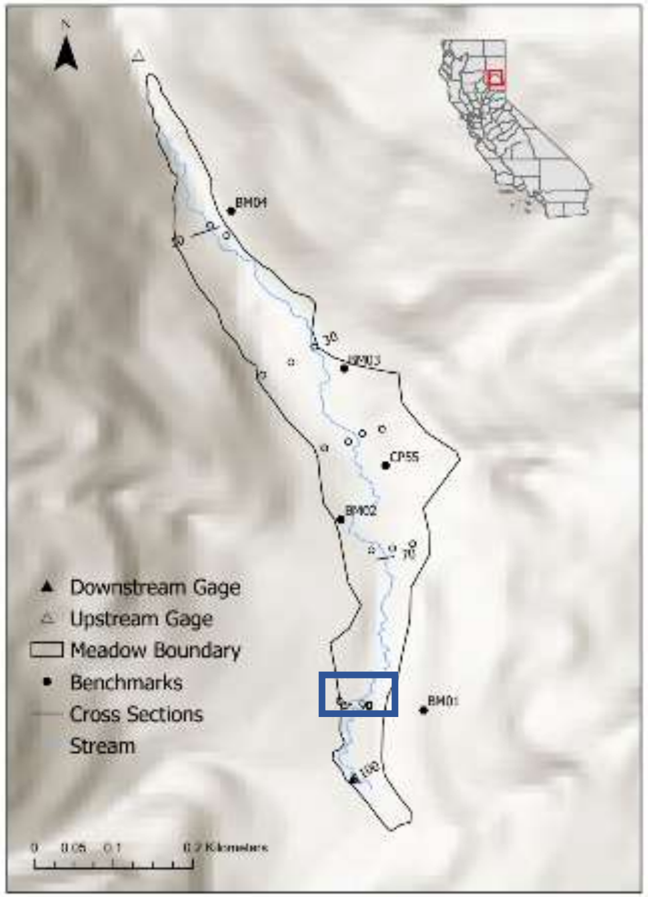
Predicted Water Surface Elevation Cross Section 90

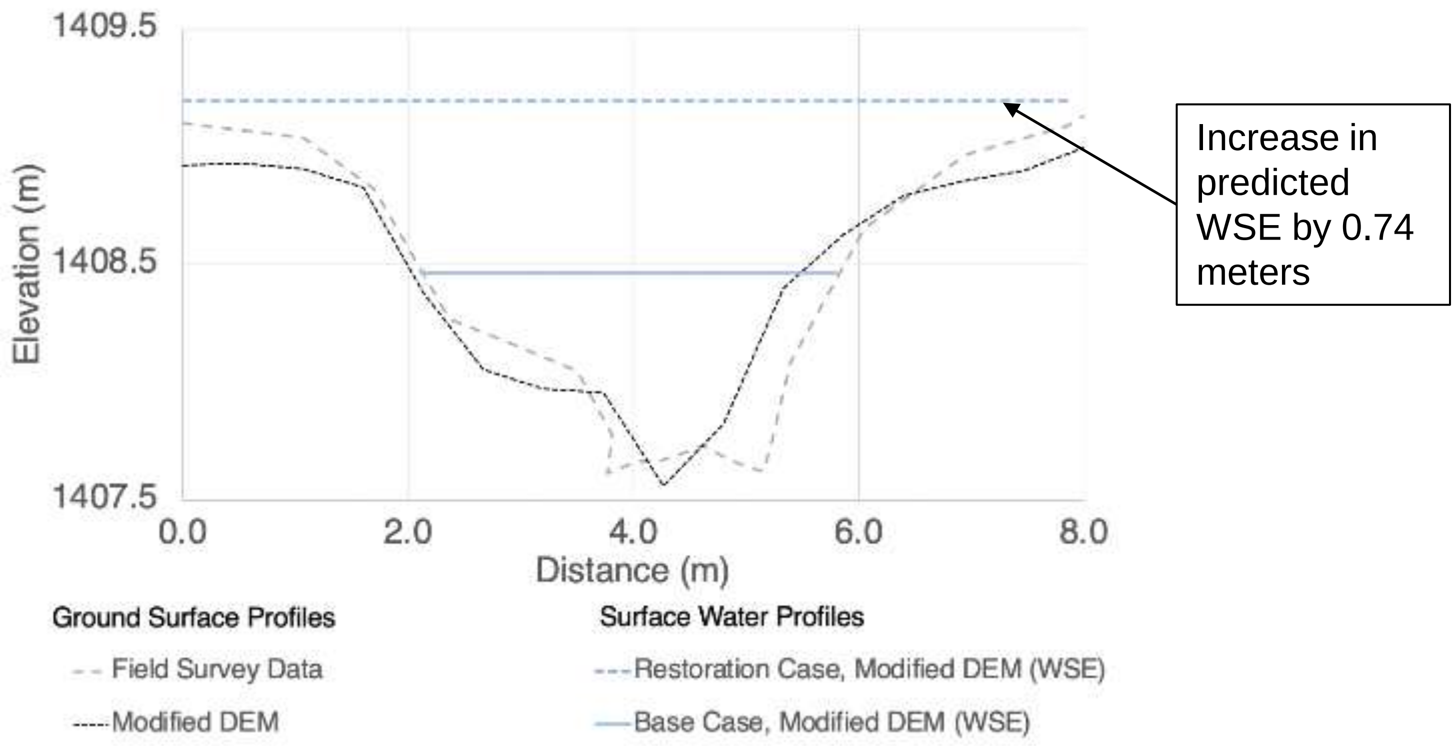




Cross Section 90 showing field survey data, DEM, and modified DEM. Predicted water surface elevations for 0.6 m^3/s flowrate for base case and restoration scenario using modified DEM as input topography

Predicted Water Surface Elevation Cross Section 90





Cross Section 90 showing field survey data, DEM, and modified DEM. Predicted water surface elevations for 0.6 m^3/s flowrate for base case and restoration scenario using modified DEM as input topography

Meadow Restoration Response

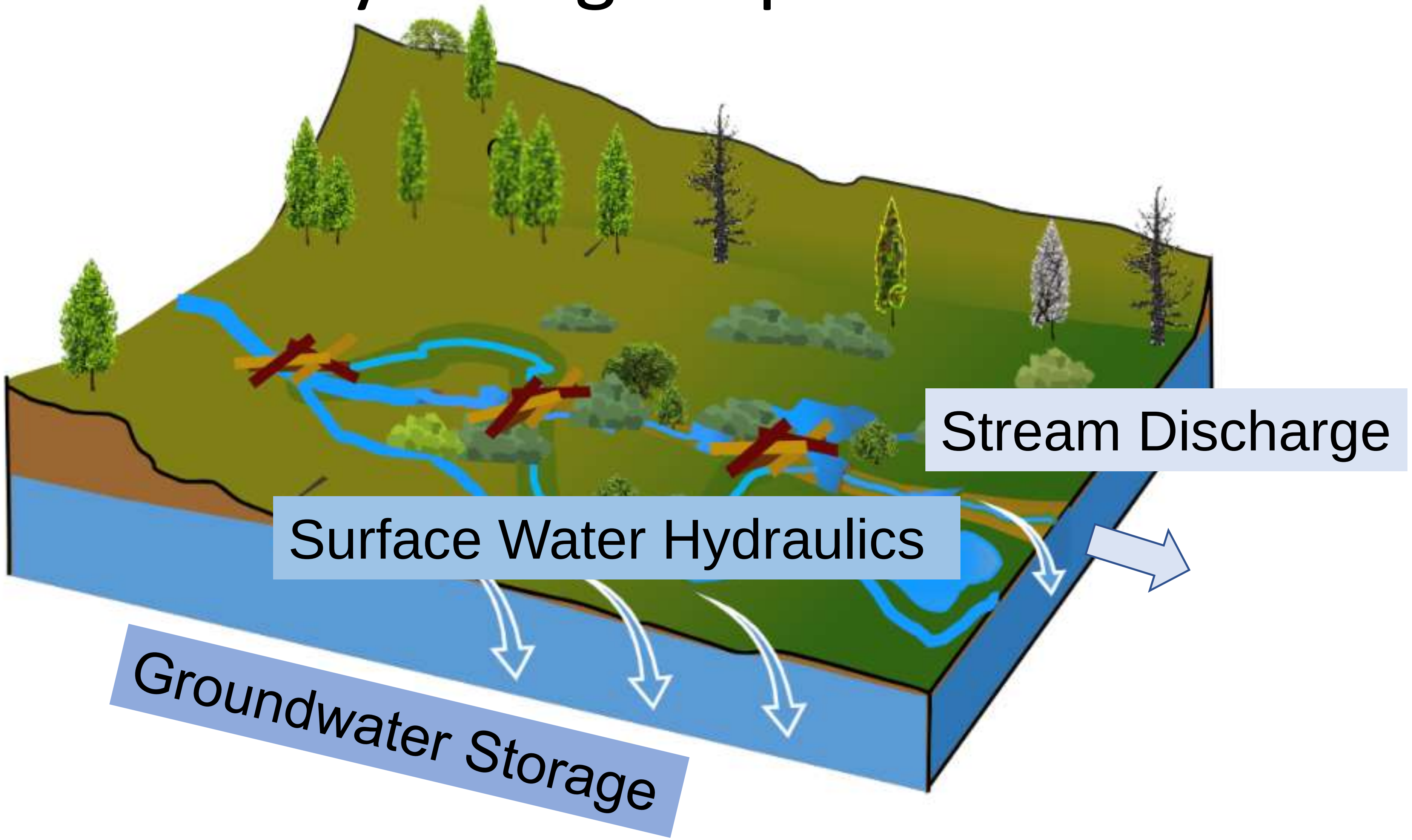
Different responses to treatment observed in different regions of the meadow

- **Reach 1** – primarily increase in lateral floodplain connection and development of new flow paths

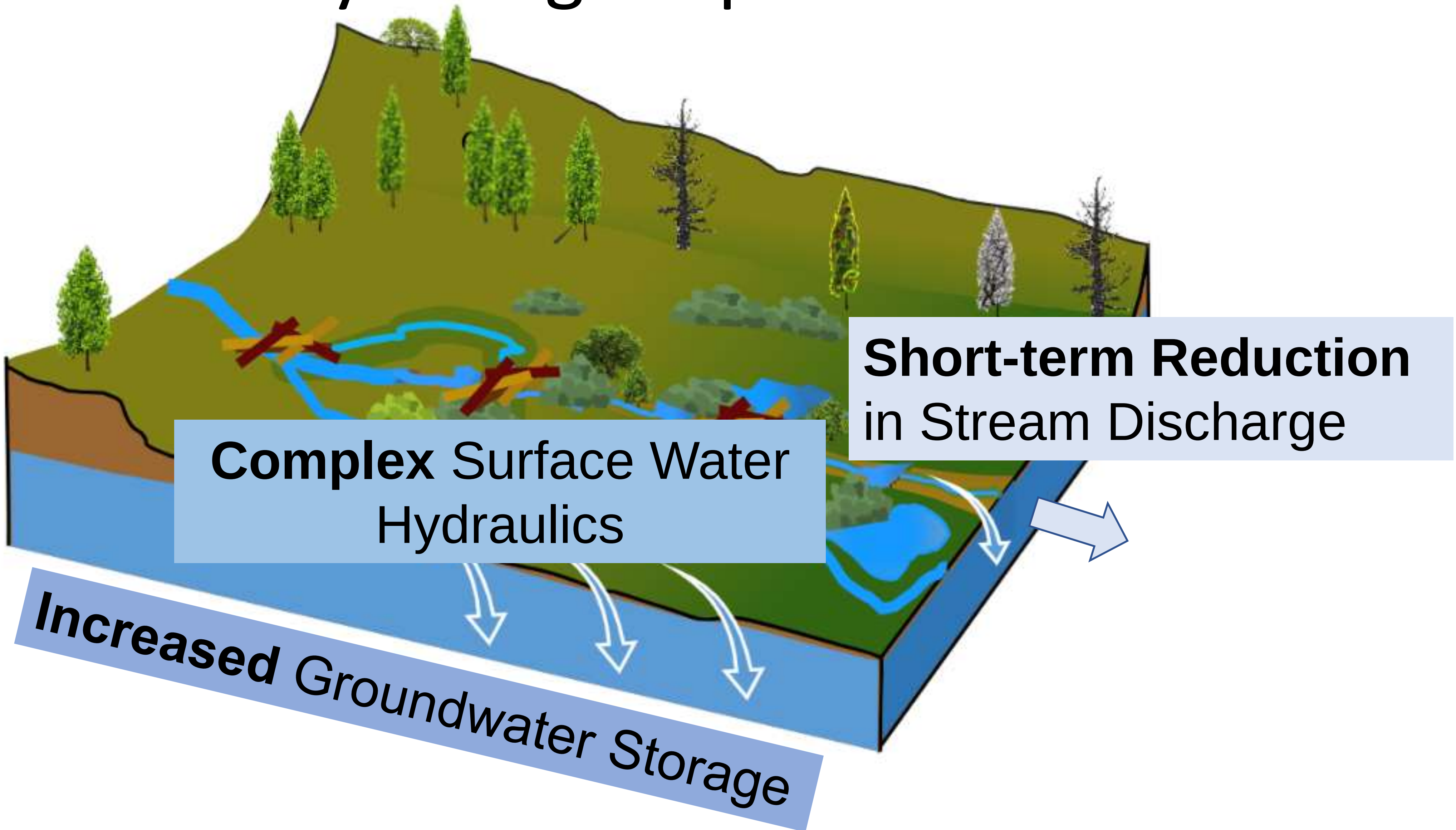
- **Reach 2** – primarily increase in depth within the incised channel

Degree of channel incision may have important controls on function and performance of restoration structures

How does process-based meadow restoration affect hydrological processes?



How does process-based meadow restoration affect hydrological processes?



Conclusions

- **Process-based restoration** has the capacity to
  - **increase floodplain connectivity**
  - **raise groundwater elevations**
  - **capture sediment**
- Meadows are groundwater dependent ecosystems and are highly responsive to restoration treatment.
- Low gradient and broad floodplains may be the low-hanging fruit!

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Thank you to Catherine Carbajal, Angel Ortiz, David Topete, Ana Rubio, and Sam Willis for field support.

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Questions?

Contact:
emmasevier@gmail.com

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Influence of scale on predictability of beaver dam density and implications for habitat modeling

Caroline Gengo, UC Davis Center for Watershed Sciences

Influence of scale on predictability of beaver dam density and implications for habitat modeling

1. Background
   Why do spatial scales matter when describing habitats?
2. Study Approach
   Model Predictions vs. Observed beaver dam density
   Habitat conditions at different scales
3. Next steps and other questions

Influence of scale on predictability of beaver dam density and implications for habitat modeling

1. **Background**

   Why do spatial scales matter when describing habitats?

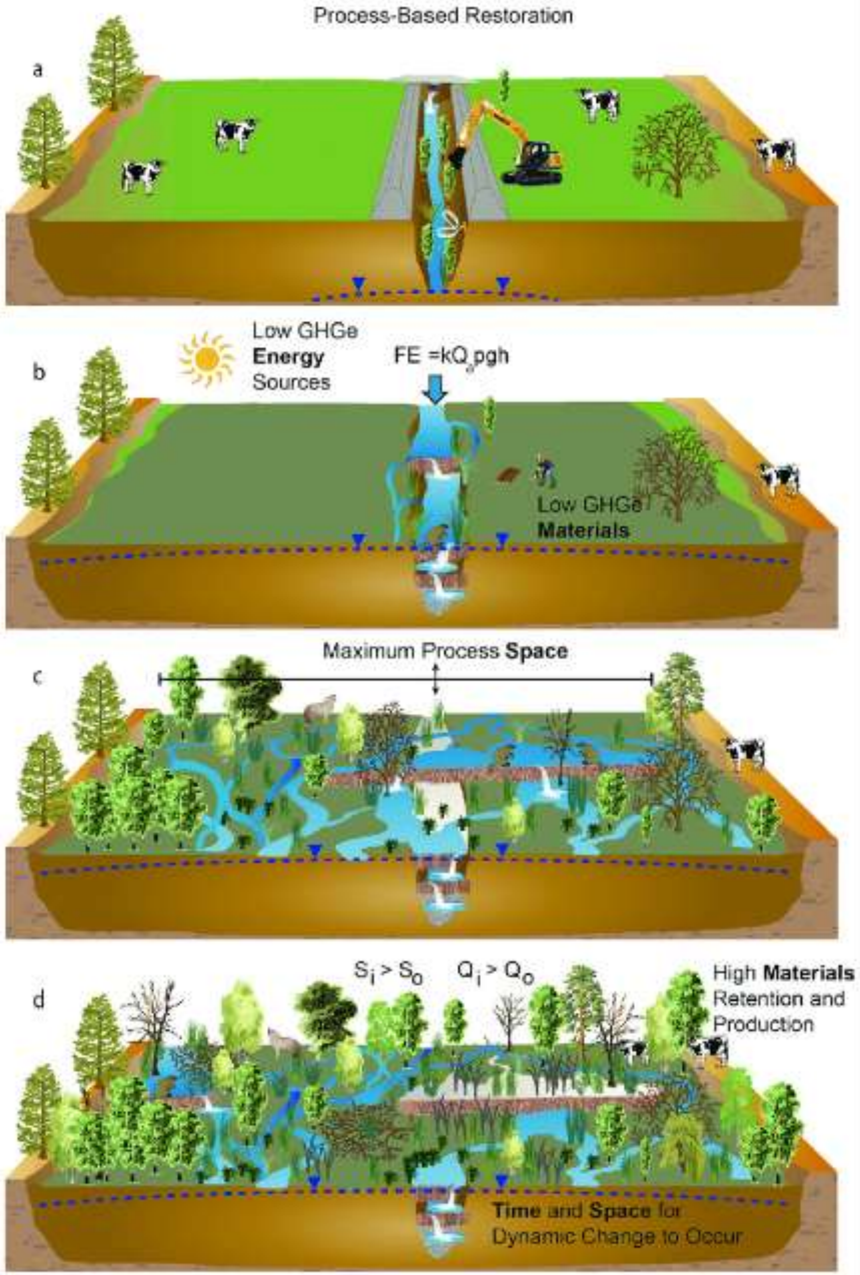
2. Study Approach

   Model Predictions vs. Observed beaver dam density

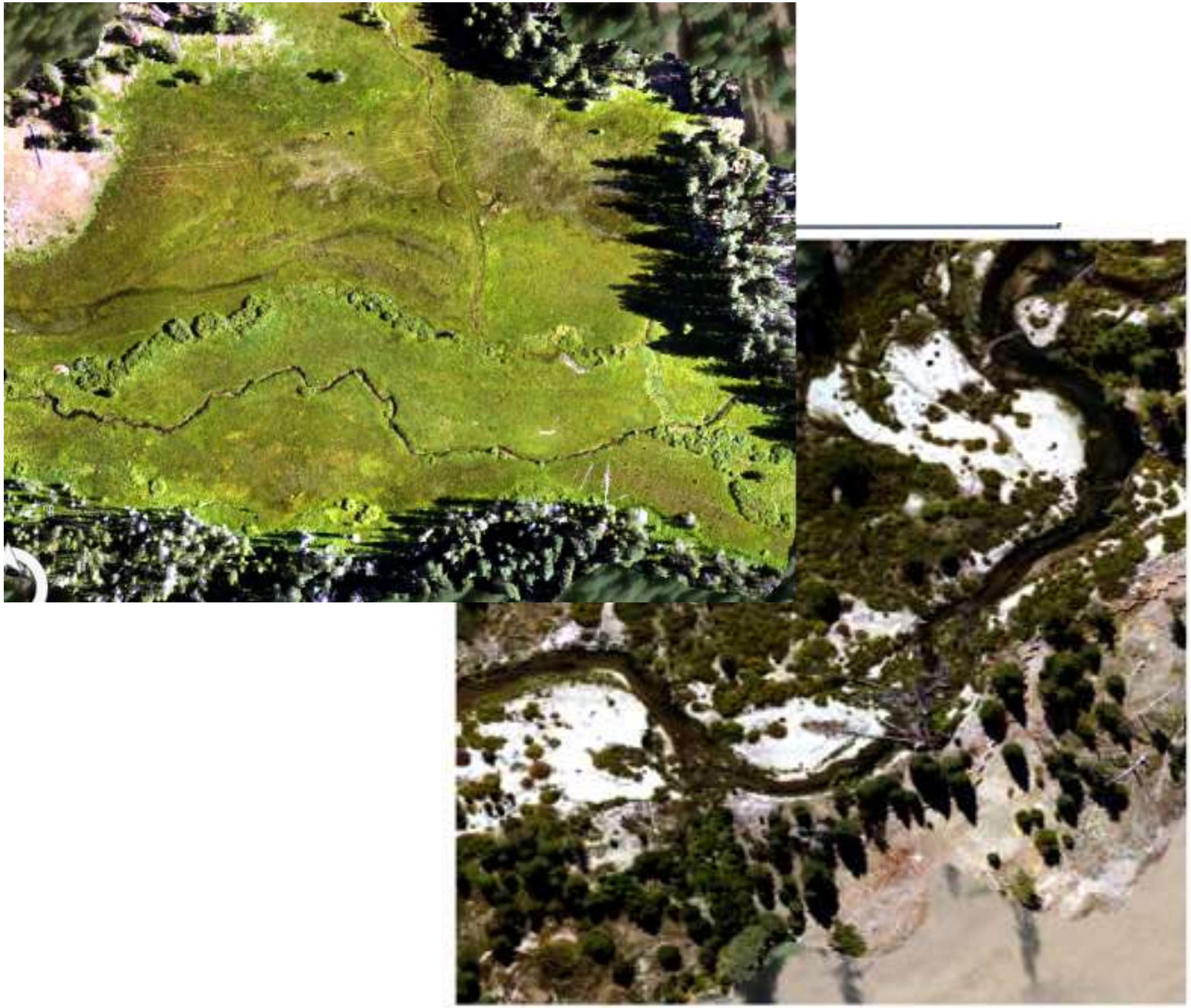
   Habitat conditions at different scales

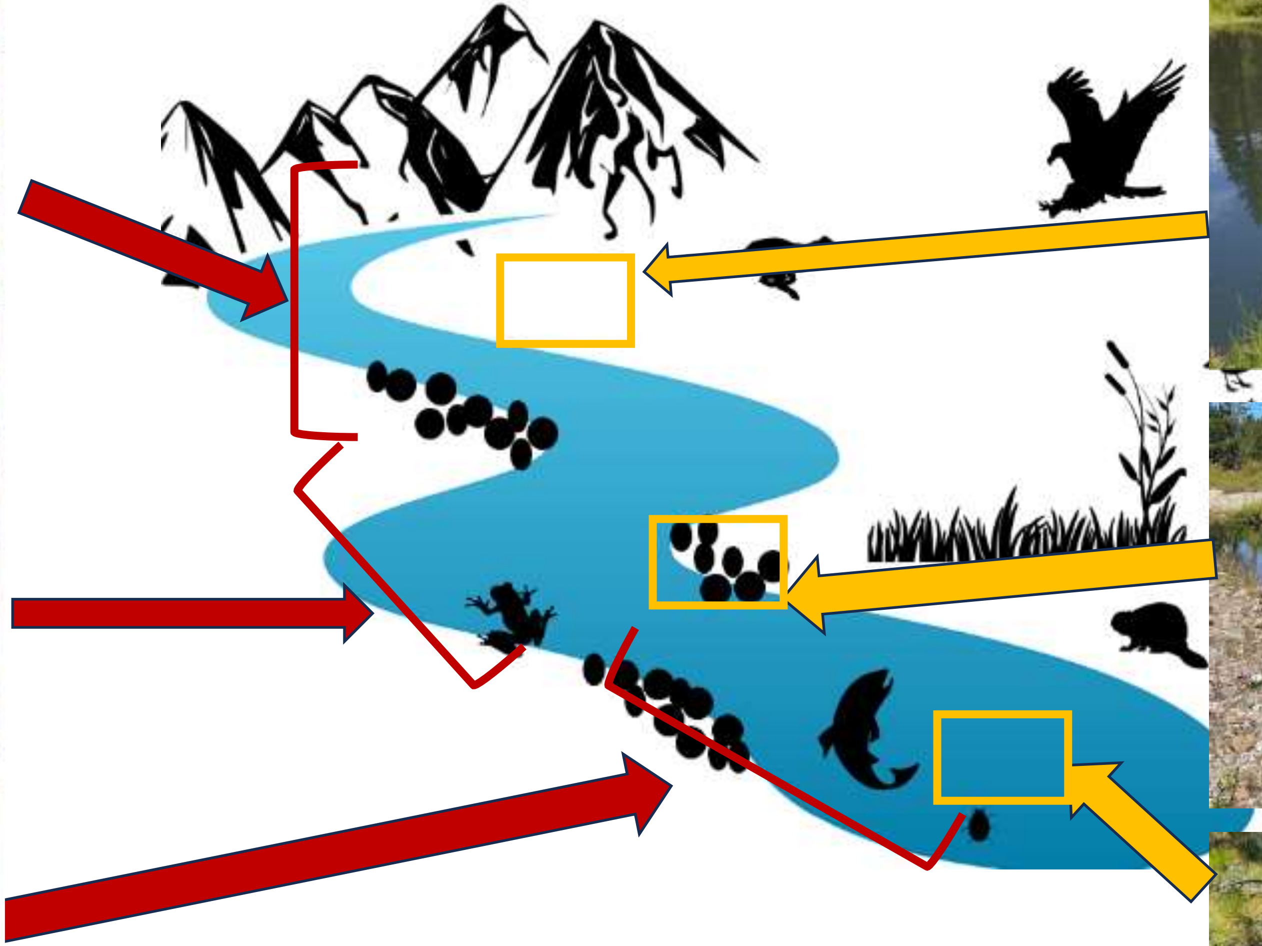
3. Next steps and other questions

Habitats are nested at different scales.



Ciotti et al. (2021) Bioscience





Looking for patterns at different scales tell us different stories.

Beaver Restoration Assessment Tool (BRAT)

Inputs:

- USGS National Hydrography Dataset
- LANDFIRE 2011 (EVT and BPS)
- USGS baseflow equations
- USGS 2-year peak flow equations
- 10m DEM

Are these inputs accurate for our system?

Are these inputs at the appropriate scale?

Fuzzification:

Assigning categorical representations of 7 lines of evidence:

- Dam building material preference score 0-4
- 30m streamside vegetation buffer suitability score 0-4
- 100m streamside vegetation buffer suitability score 0-4
- Baseflow stream power impact on dam building (can build, can probably build, cannot built)
- 2-year flood impact on dams (persist, occasionally breach, blow, occasionally blow)
- Reach slope impact on dam building (can build, can probably build, cannot built)
- Depth and width of stream impact on dam building (can build, can probably build, cannot build)

Fuzzy Inference System:

List of 52 rules reflecting lines of evidence based on human interpretation of beaver ecology including:

- A reliable water source
- Streambank vegetation conducive to foraging and dam building
- Vegetation within 100m of edge of stream
- Likelihood that dams could be built across the channel during low flows
- The likelihood that a dam would withstand a typical flood
- Suitable stream gradient
- Suitable stream size

Defuzzification:

Combining hydrology and vegetation predictions using 3 rules:

- If building materials do not exist, dams will not exist regardless of flows.
- If stream power is too high, dams will not exist regardless of building materials
- If building materials are present and dams persist at high flows, dams will exist

Output:

Predicted range of dams per km that a stream can support.

Influence of scale on predictability of beaver dam density and implications for habitat modeling

1. Background

   Why do spatial scales matter when describing habitats?

2. Study Approach

   Model Predictions vs. Observed beaver dam density

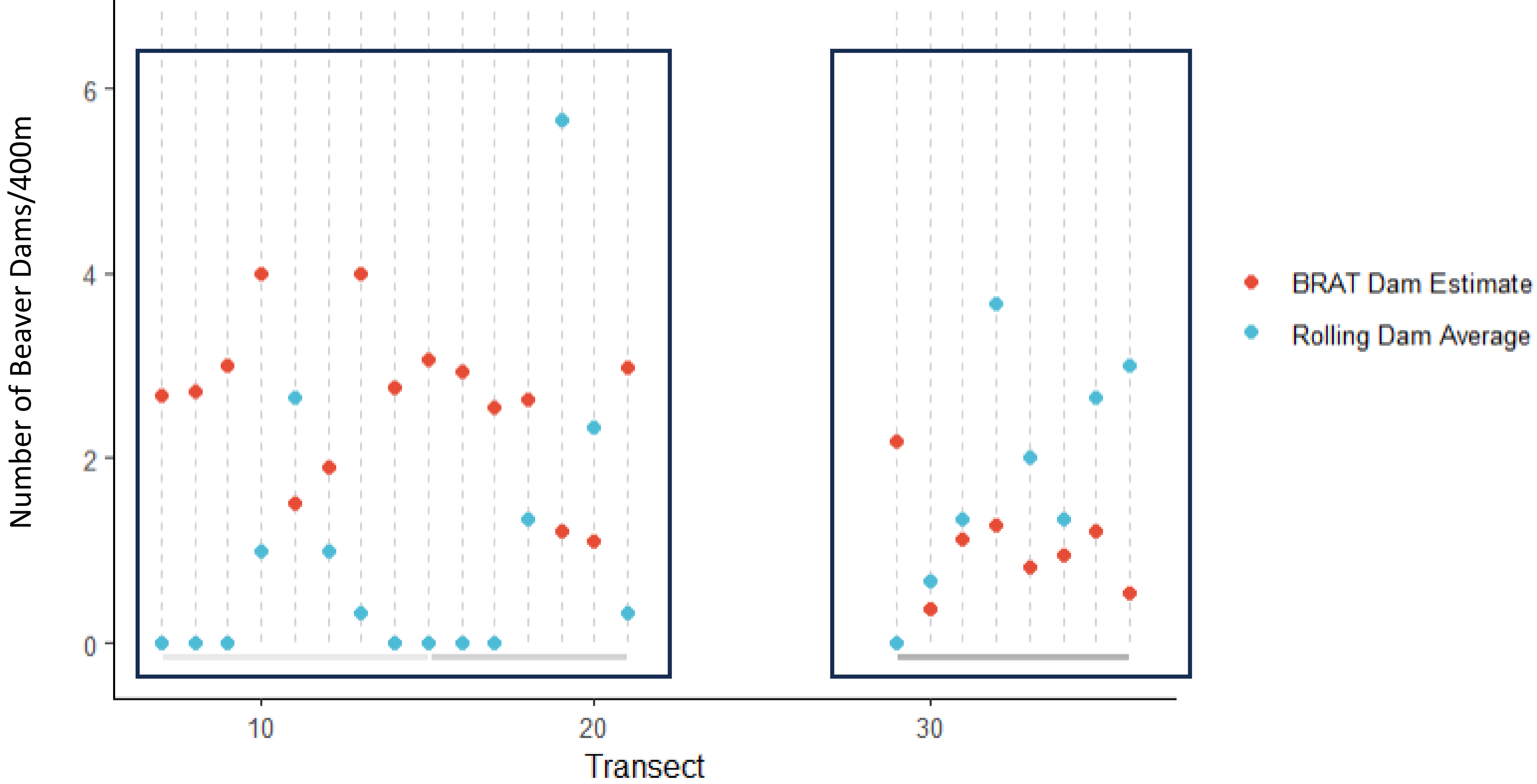
   Habitat conditions at different scales

3. Next steps and other questions

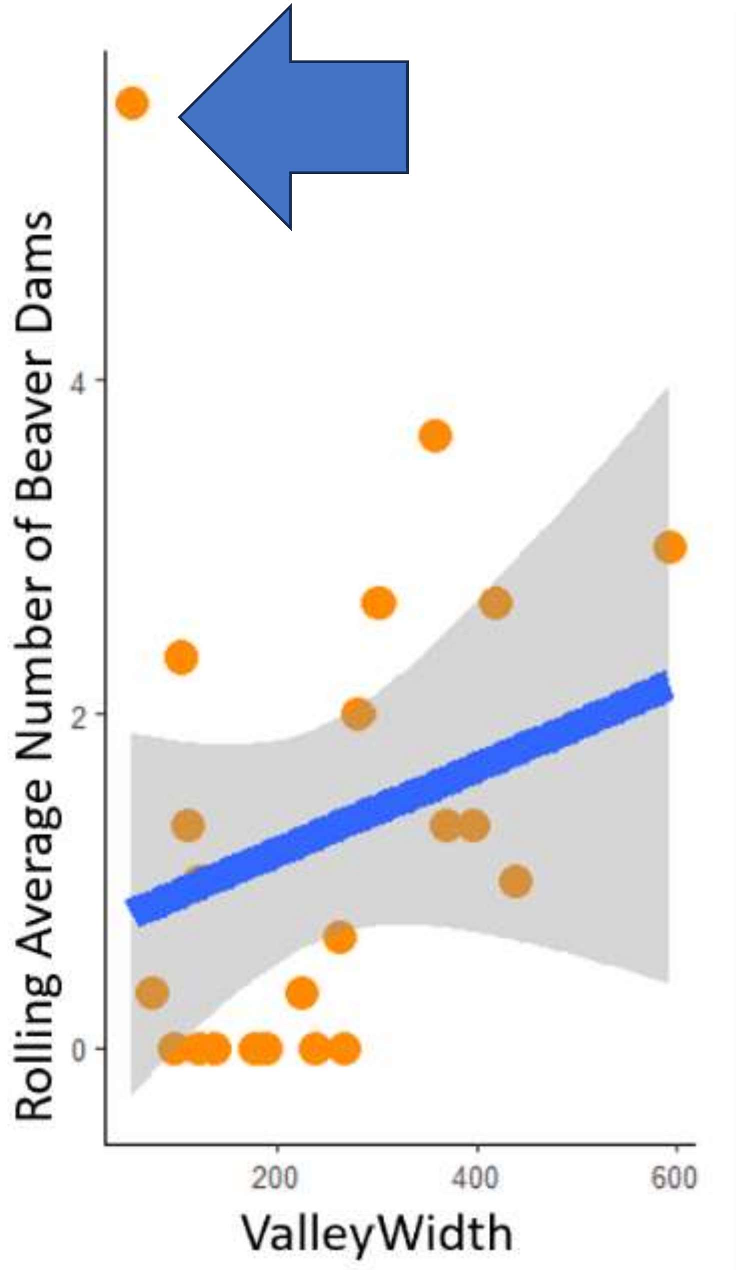
Study Site: Gurnsey Creek, Tehama County CA

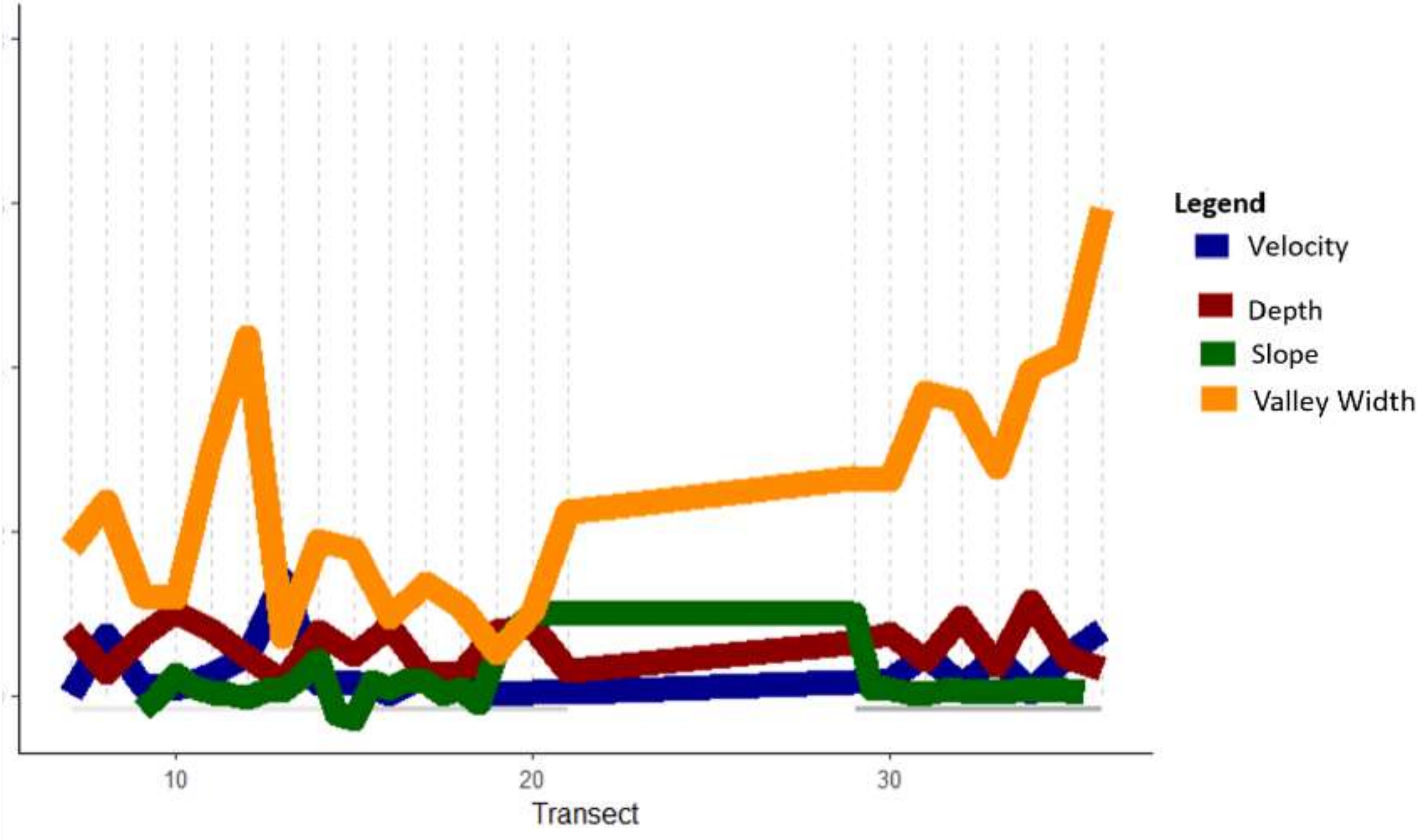
In our **Lower Childs** meadow and **Forested** reach, the BRAT model over predicted the number of dams in 11 out of 15 cases.

In our **Gurnsey meadow** reach the BRAT model underpredicted the number of dams in 7 out of 8 cases.

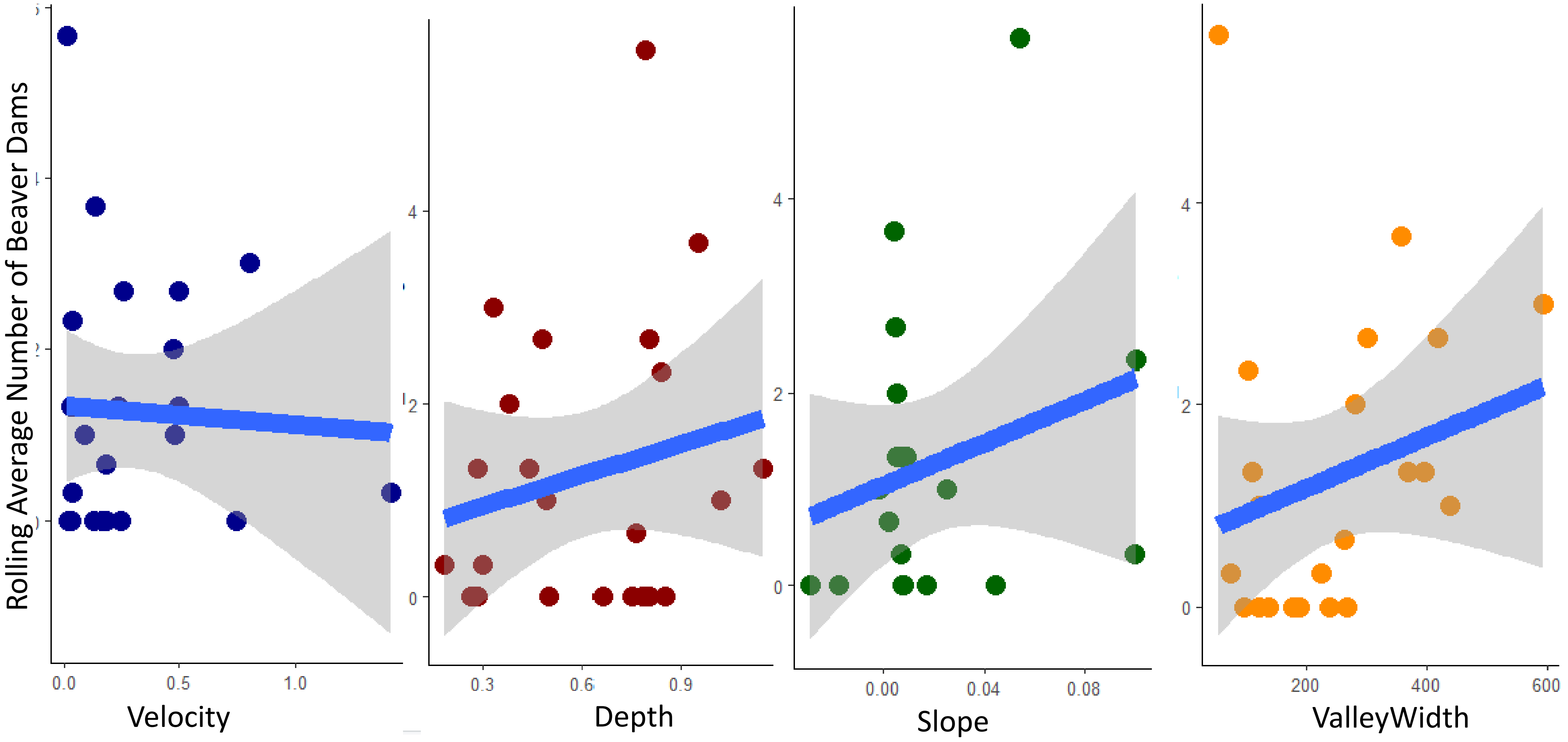


Do we see a relationship between **patch scale characteristics** and beaver dam density?

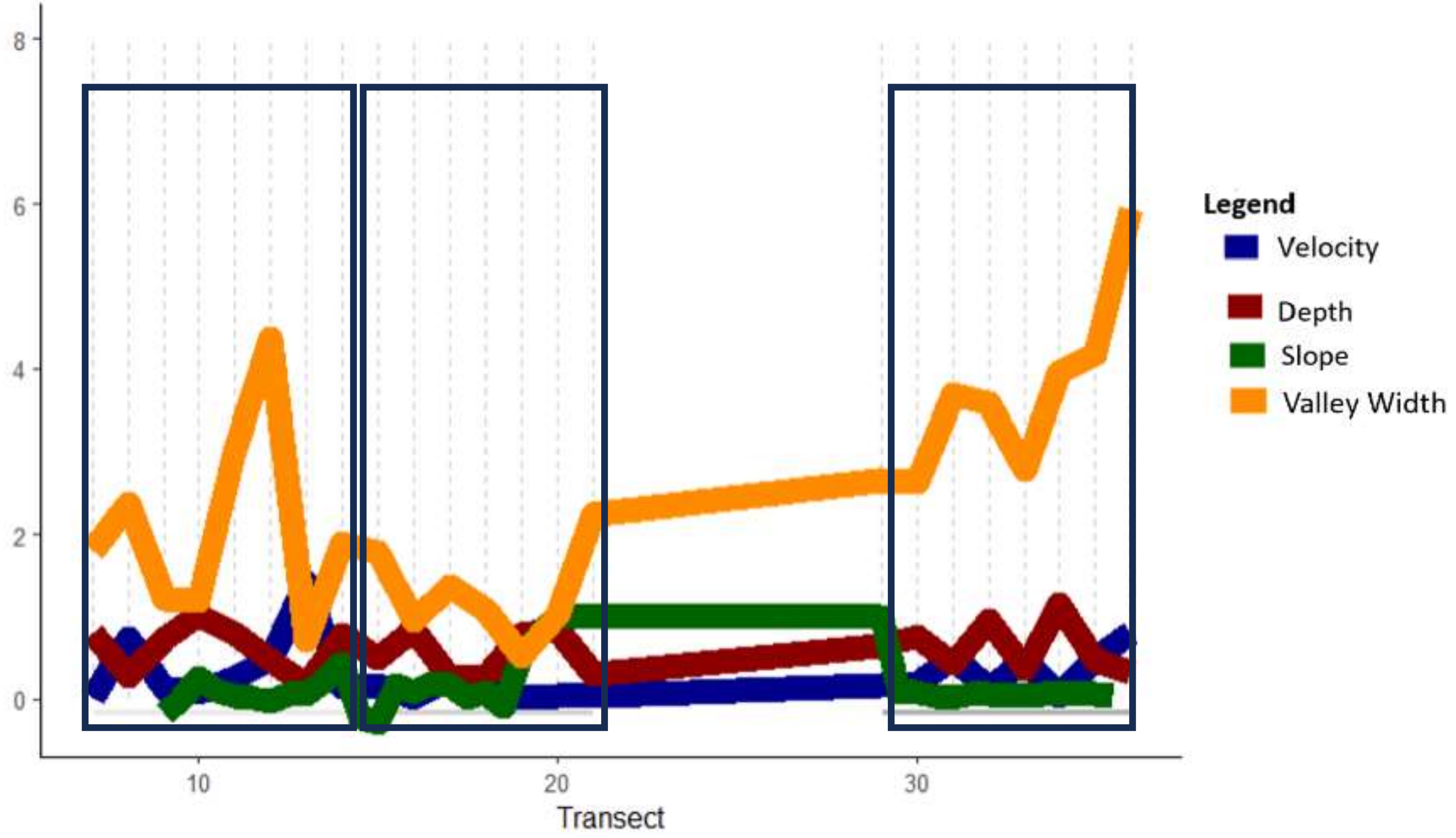




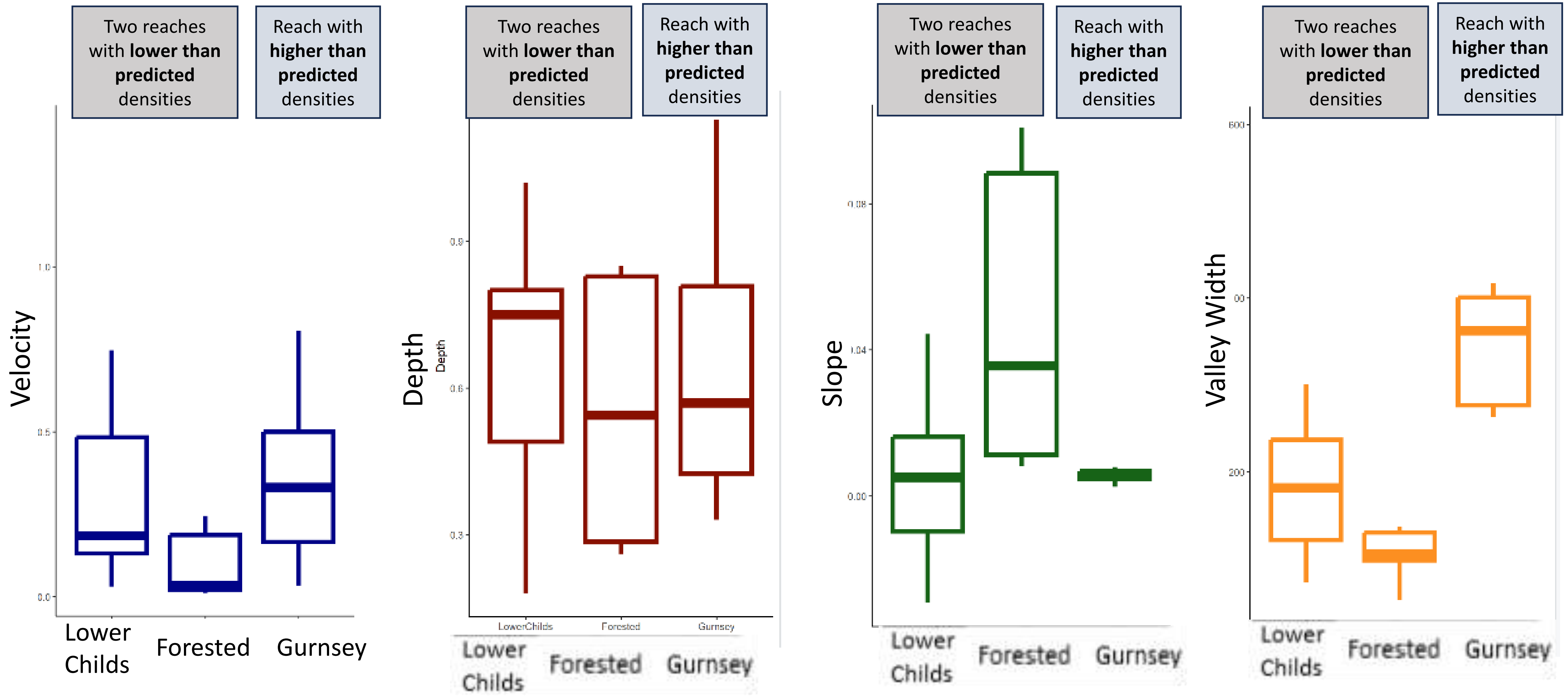
Do we see a relationship between **patch scale characteristics** and beaver dam density? **Preliminary Data**



Do we see a relationship between **reach scale characteristics** and beaver dam density?



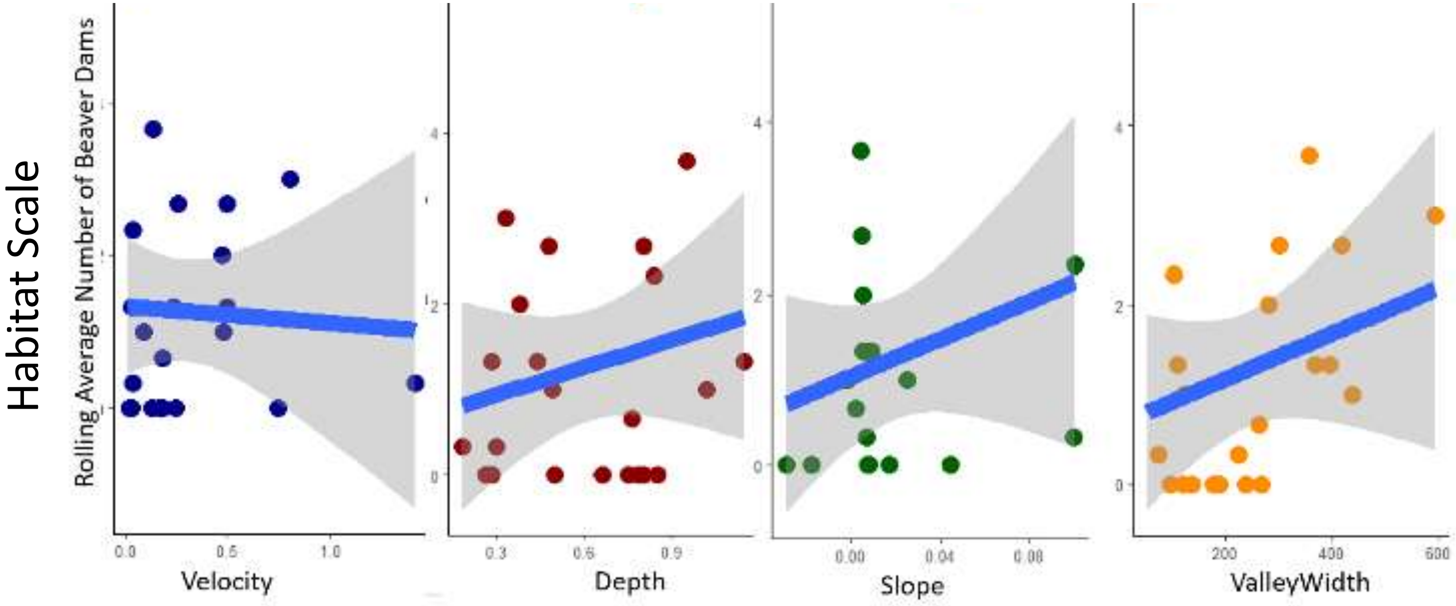
Do we see a relationship between **reach scale characteristics** and beaver dam density? **Preliminary Data**

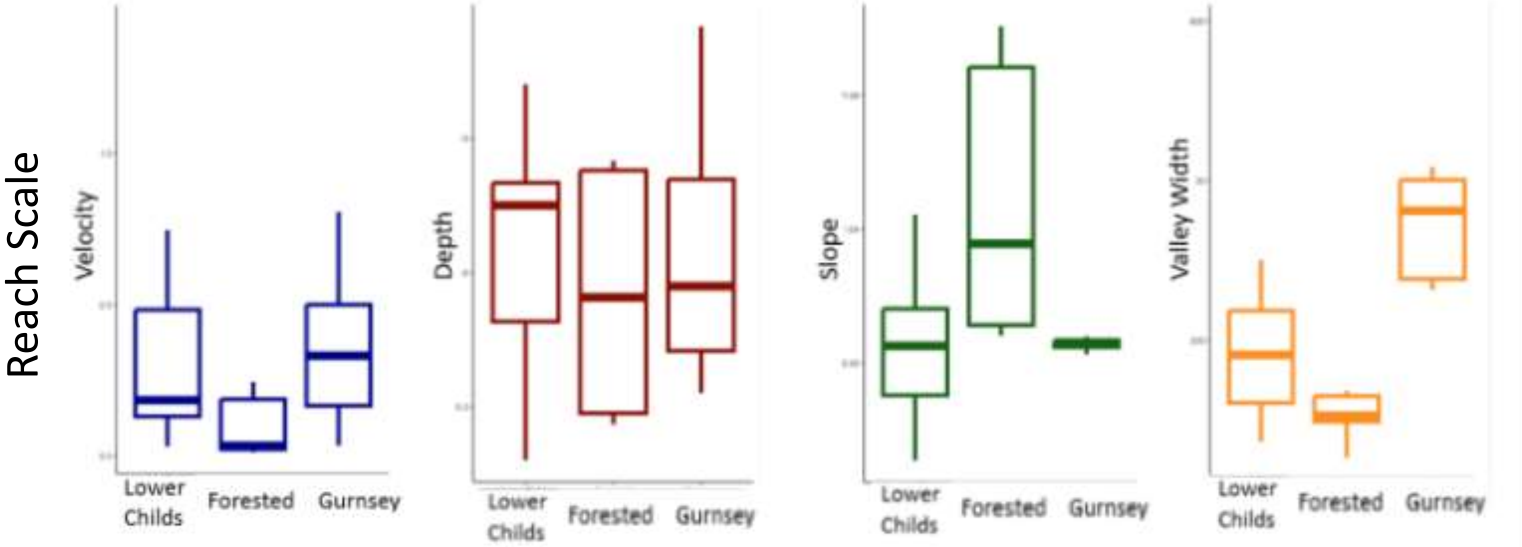


Influence of scale on predictability of beaver dam density and implications for habitat modeling

1. Background
   Why do spatial scales matter when describing habitats?
2. Study Approach
   Model Predictions vs. Observed beaver dam density
   Habitat conditions at different scales
3. **Next steps and other questions**

Next steps – Include additional data from more meadows…





Beaver Restoration Assessment Tool (BRAT)

Inputs:

- USGS National Hydrography Dataset
- LANDFIRE 2011 (EVT and BPS)
- USGS baseflow equations
- USGS 2-year peak flow equations
- 10m DEM

Are these inputs accurate for our system?
Do we need additional inputs?
Are these inputs at the appropriate scale?

Fuzzification:

Assigning categorical representations of 7 lines of evidence:

- Dam building material preference score 0-4
- 30m streamside vegetation buffer suitability score 0-4
- 100m streamside vegetation buffer suitability score 0-4
- Baseflow stream power impact on dam building (can build, can probably build, cannot built)
- 2-year flood impact on dams (persist, occasionally breach, blow, occasionally blow)
- Reach slope impact on dam building (can build, can probably build, cannot built)
- Depth and width of stream impact on dam building (can build, can probably build, cannot build)

Fuzzy Inference System:

List of 52 rules reflecting lines of evidence based on human interpretation of beaver ecology including:

- A reliable water source
- Streambank vegetation conducive to foraging and dam building
- Vegetation within 100m of edge of stream
- Likelihood that dams could be built across the channel during low flows
- The likelihood that a dam would withstand a typical flood
- Suitable stream gradient
- Suitable stream size

Defuzzification:

Combining hydrology and vegetation predictions using 3 rules:

- If building materials do not exist, dams will not exist regardless of flows.
- If stream power is too high, dams will not exist regardless of building materials
- If building materials are present and dams persist at high flows, dams will exist

Output:

Predicted range of dams per km that a stream can support.

Fine scale habitat selection and movement patterns.

Photo from Smithsonian Science article about nuisance beaver relocation in Washington
https://www.smithsonianmag.com/science-nature/taking-nuisance-beavers-out-suburbs-can-help-save-salmon-180977491/

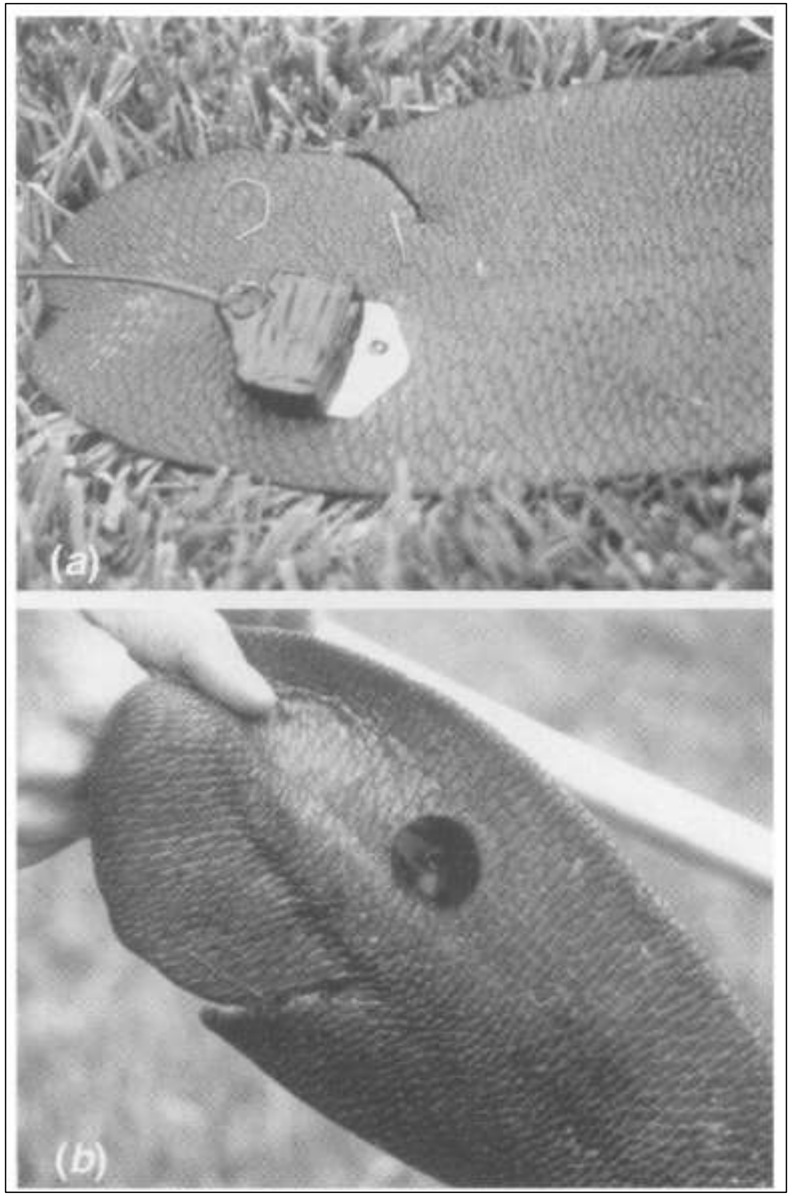


Photo from Rothmeyer et al. 2002

What habitat characteristics are beaver **selecting for** in established home ranges?

Proportion Habitat Type **Used**

Proportion Habitat Type **Available**

Beaver Restoration Assessment Tool (BRAT)

Inputs:

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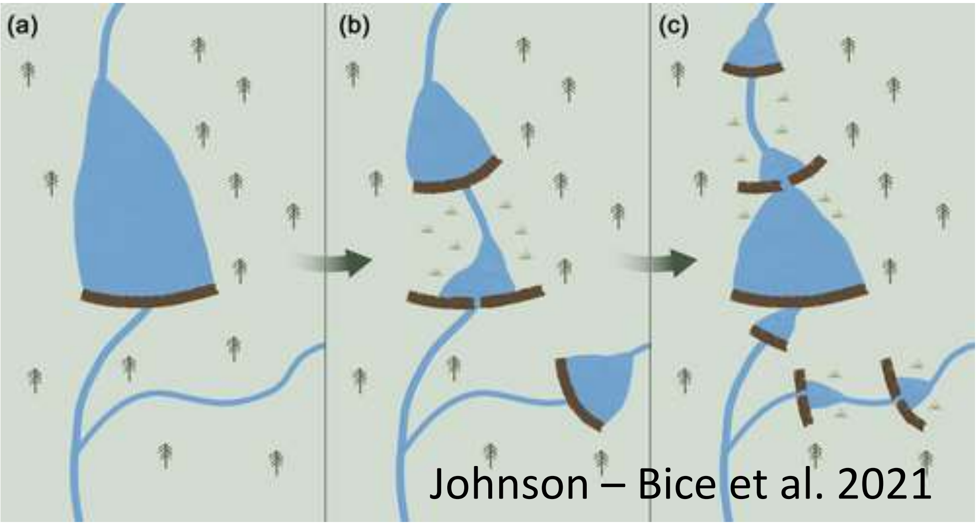
Decisions about restoration:
Beaver reintroductions or BDAs?
How do they impact systems differently?

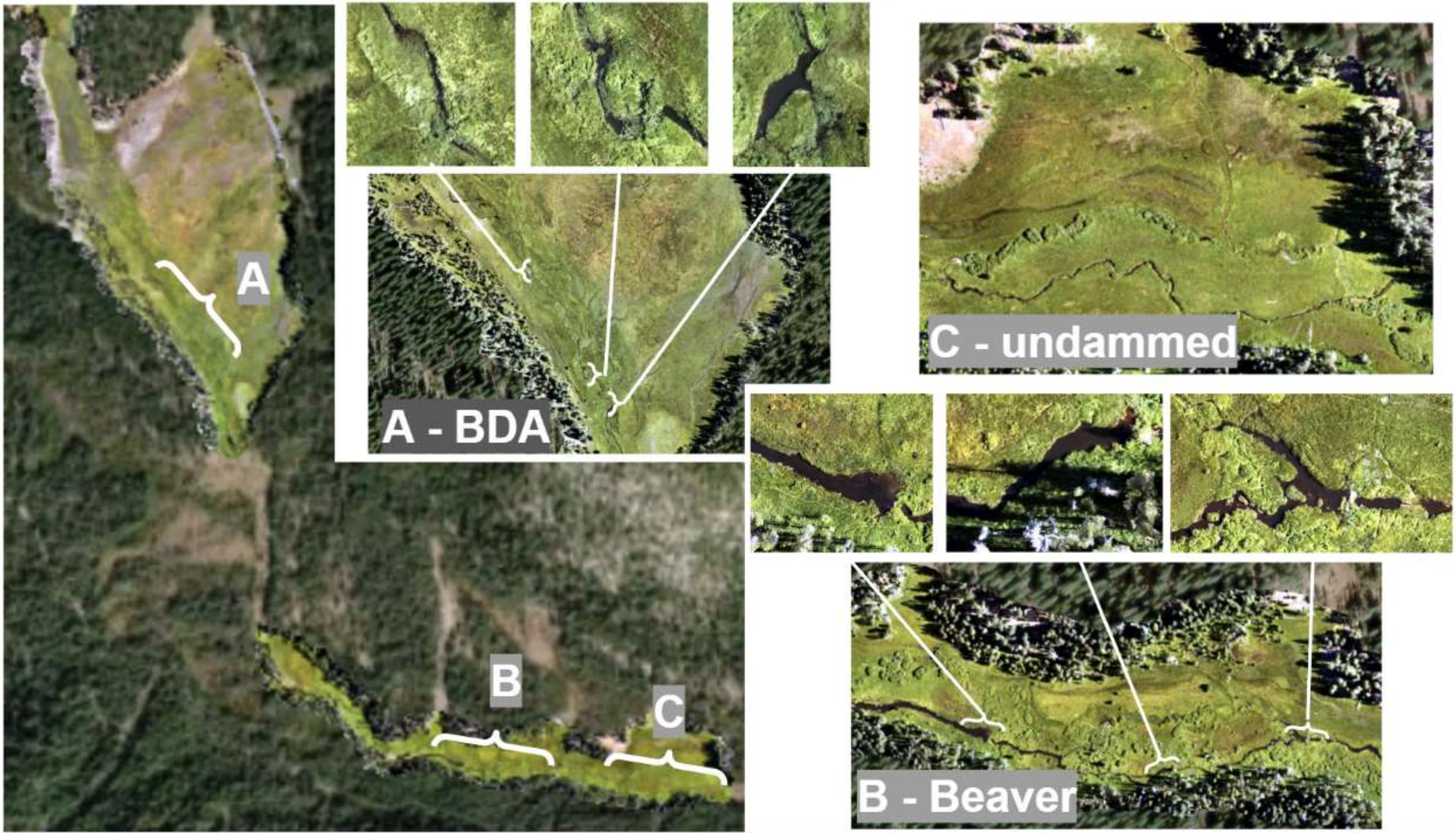
Output:

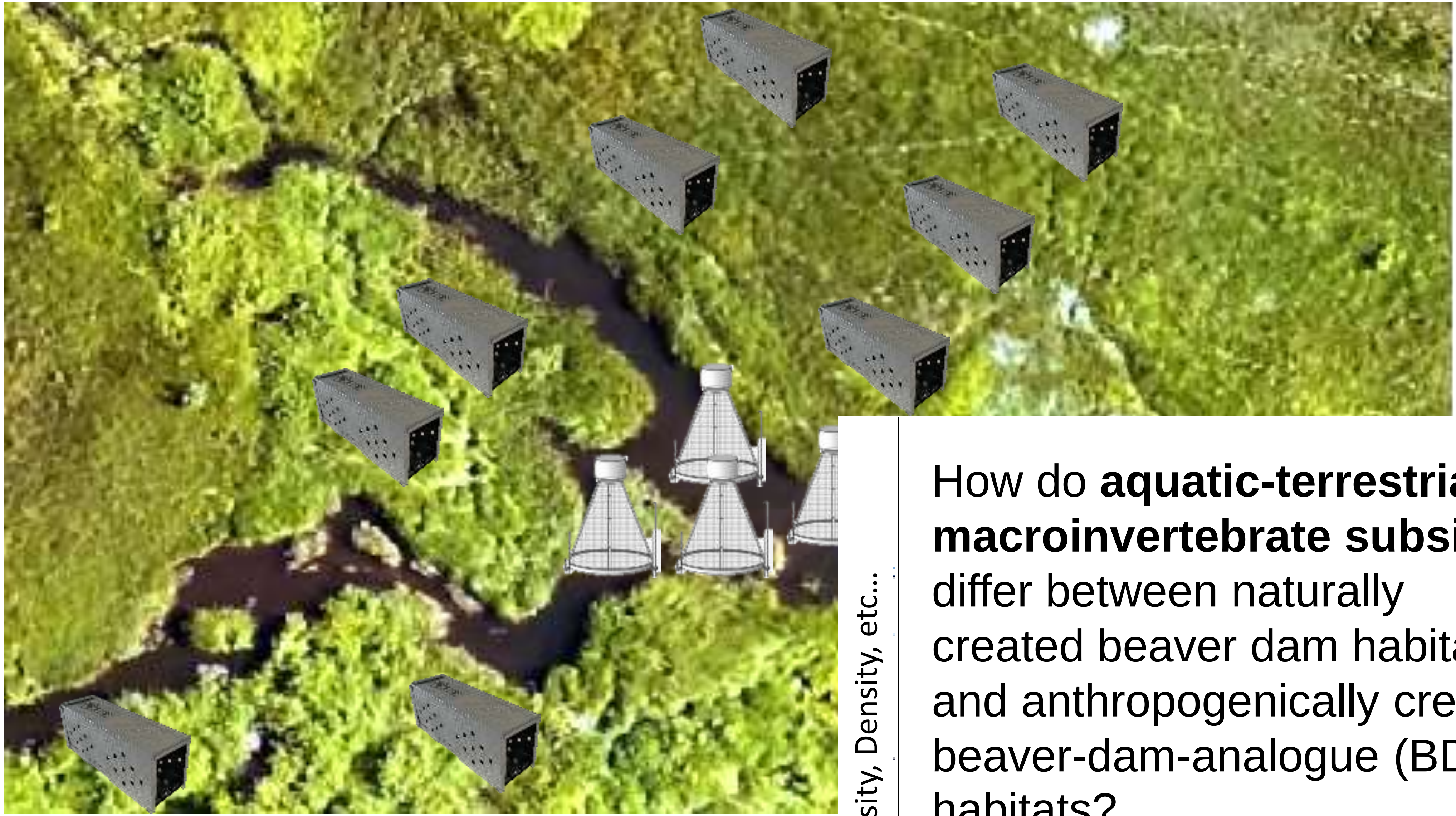
Predicted range of dams per km that a stream can support.

Communities around beaver dams and how they compare to BDA facilitated communities.



Ignore the coloration! Focus on surface water

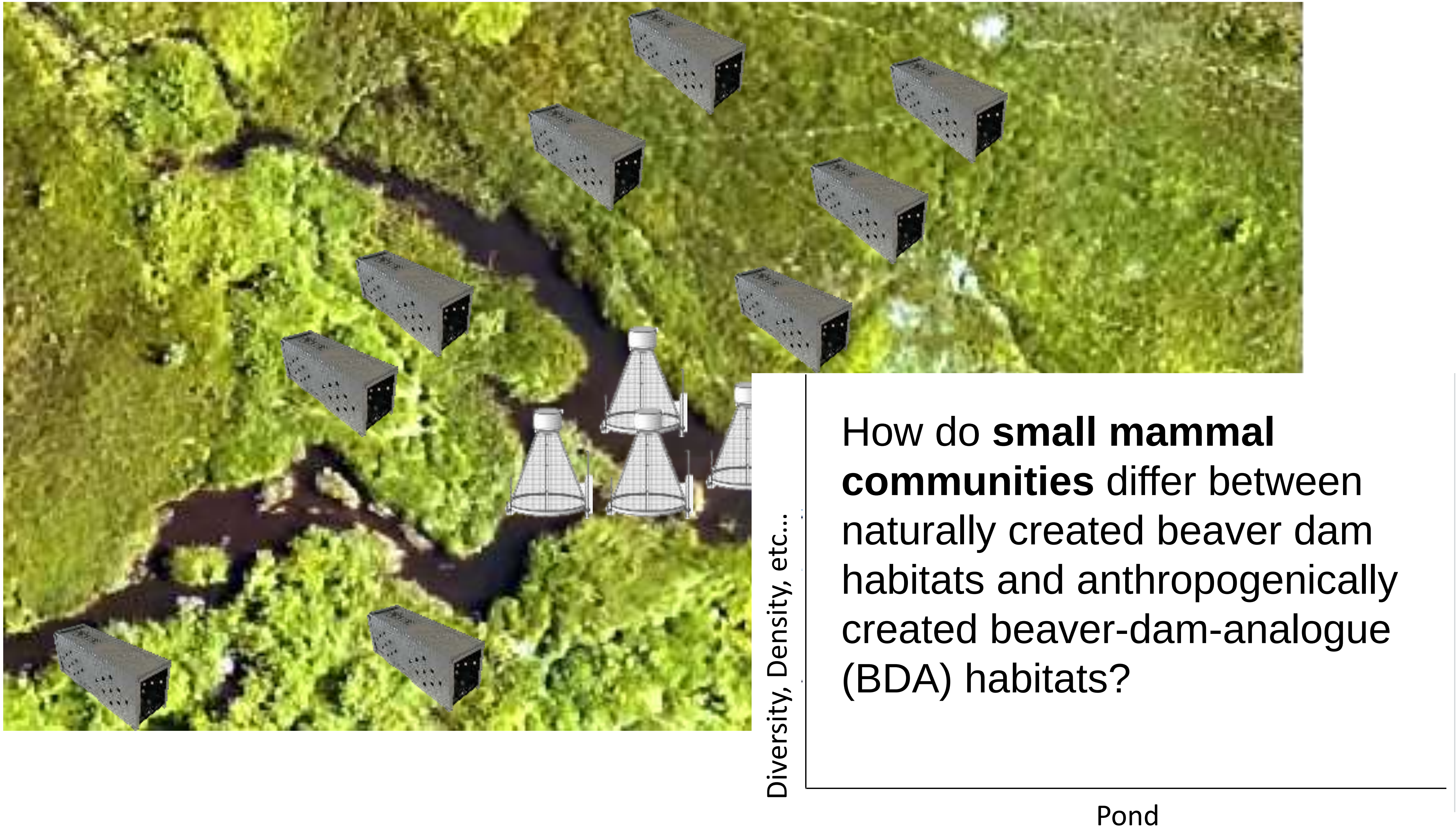

A
B
C
A - BDA
C - undammed
B - Beaver



How do **aquatic-terrestrial macroinvertebrate subsidies** differ between naturally created beaver dam habitats and anthropogenically created beaver-dam-analogue (BDA) habitats?

Diversity, Density, etc…

Pond



How do **small mammal communities** differ between naturally created beaver dam habitats and anthropogenically created beaver-dam-analogue (BDA) habitats?

Beaver Restoration Assessment Tool (BRAT)

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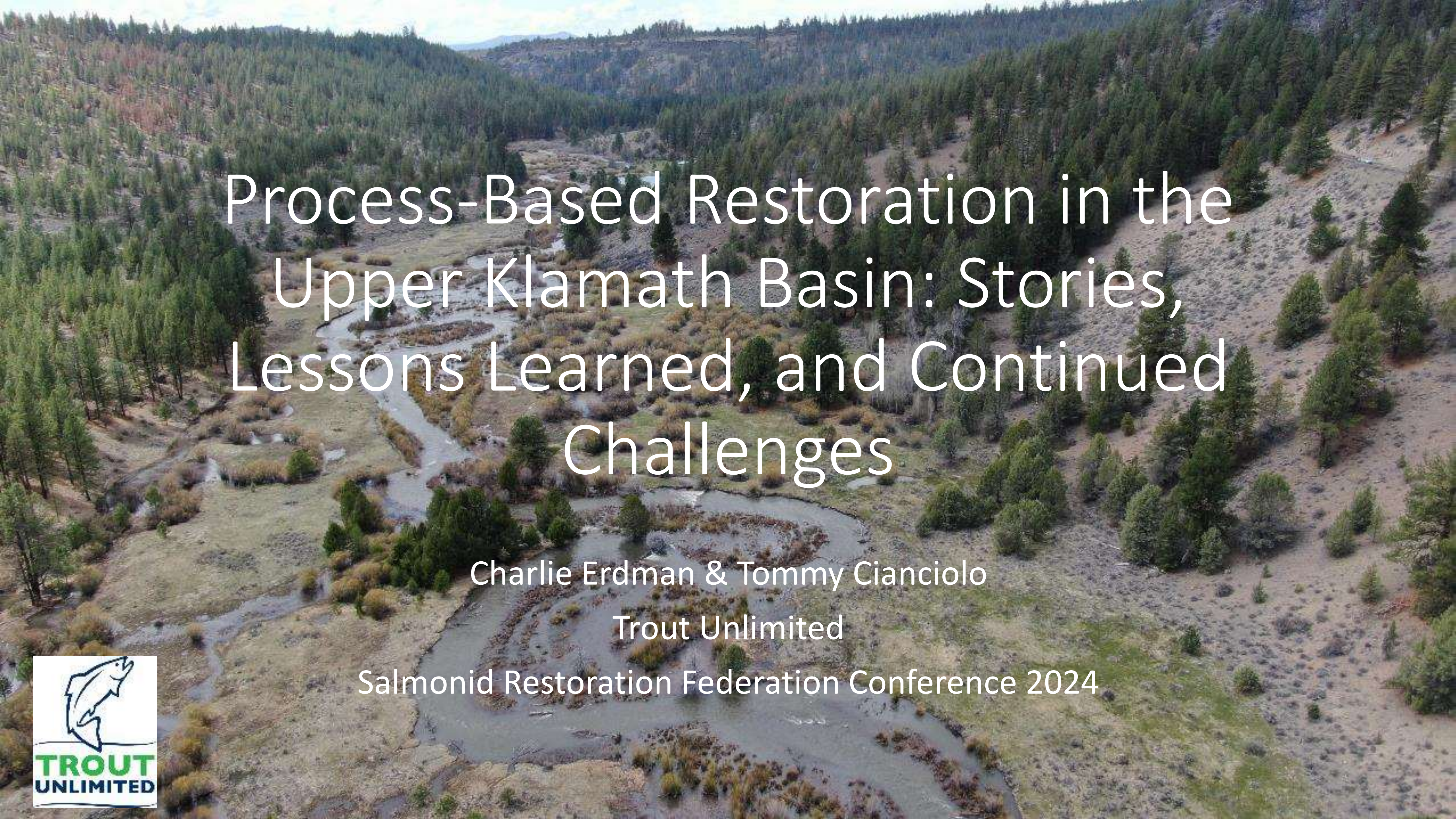
How do they impact systems differently?

Output:
Predicted range of dams per km that a stream can support.

Questions?

Caroline Gengo
UC Davis
caristuccia@ucdavis.edu

UCDAVIS
CENTER FOR WATERSHED SCIENCES



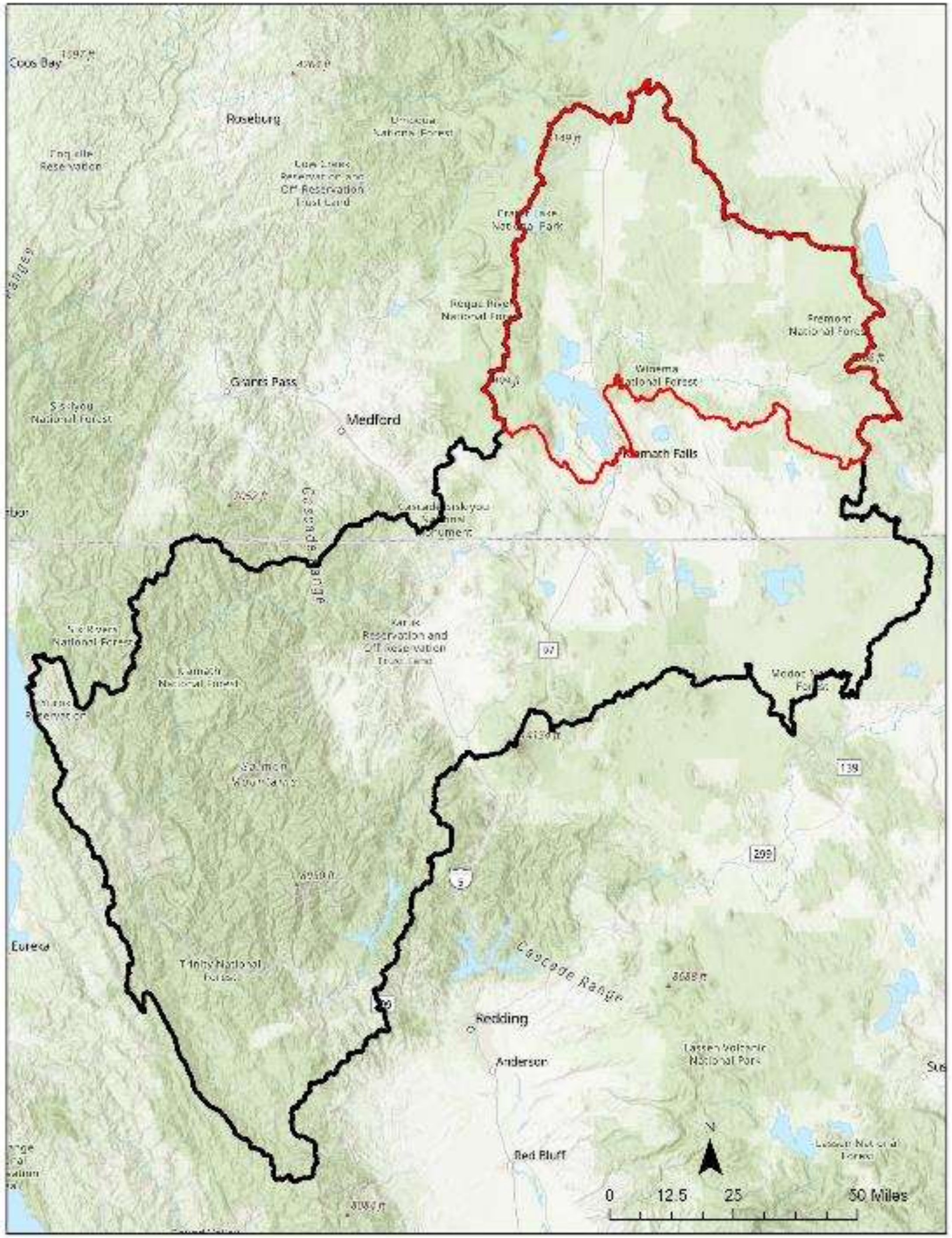
Process-Based Restoration in the Upper Klamath Basin: Stories, Lessons Learned, and Continued Challenges

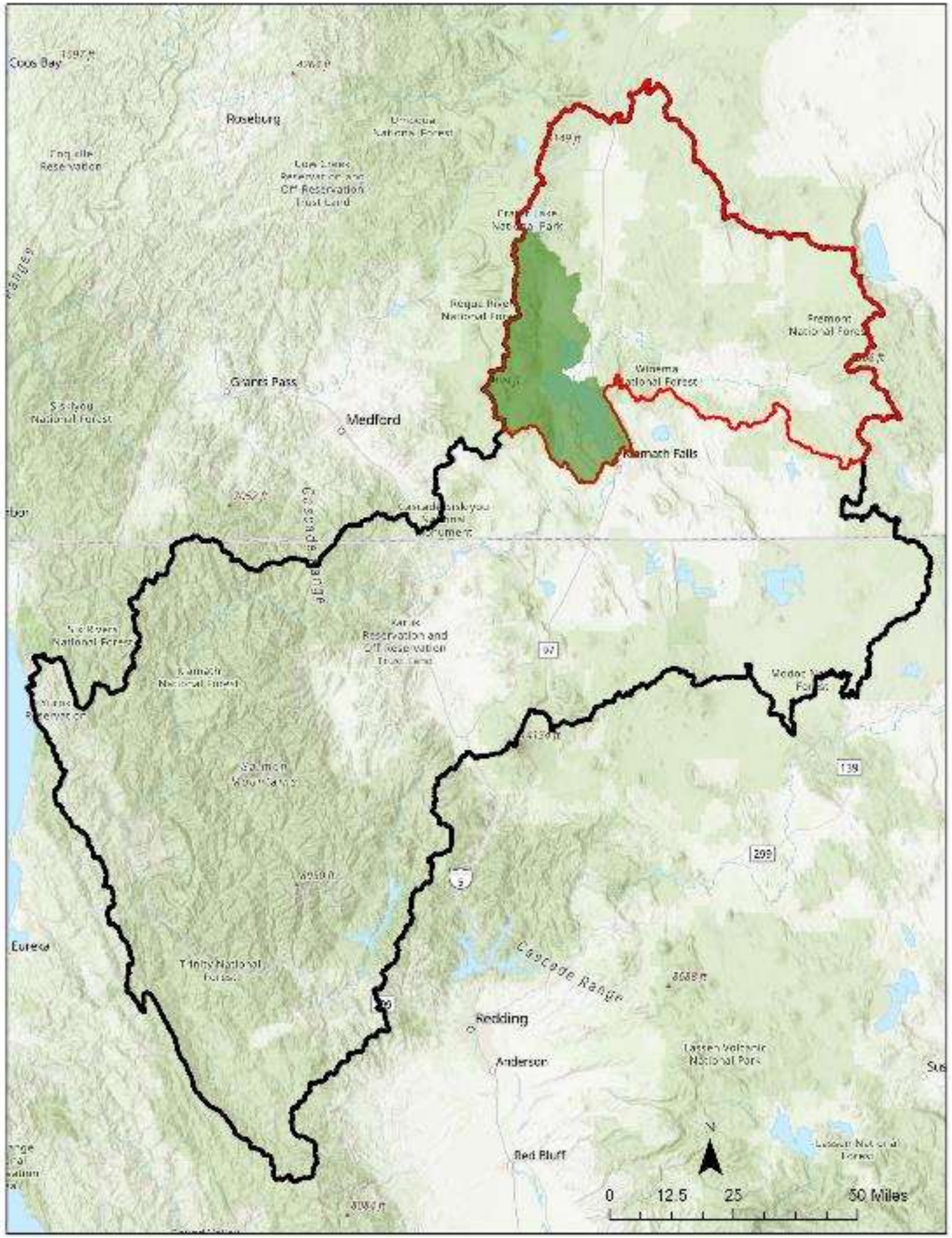
Charlie Erdman & Tommy Cianciolo

Trout Unlimited

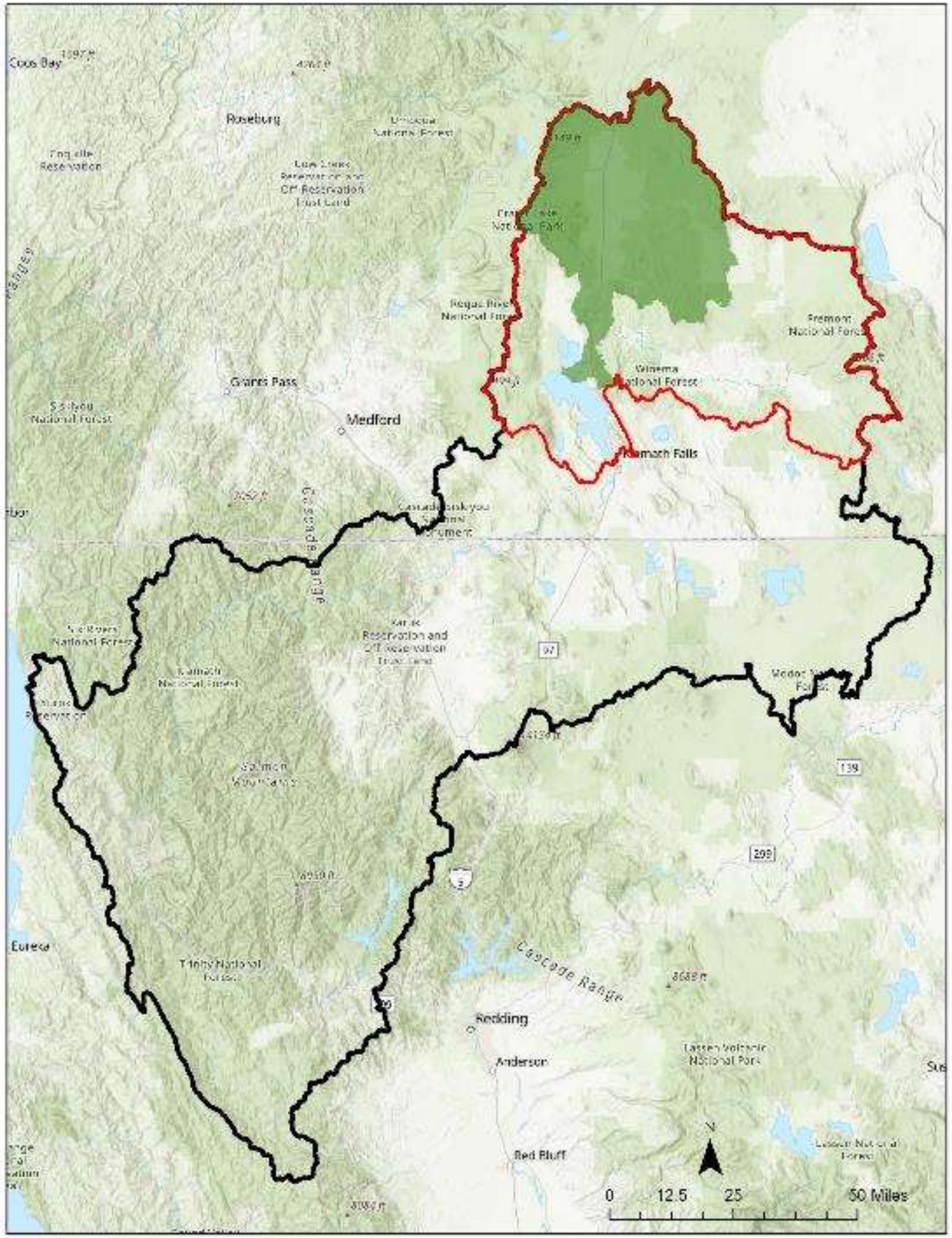
Salmonid Restoration Federation Conference 2024

TROUT UNLIMITED


Coos Bay
Roseburg
Umpqua National Forest
Crater Lake National Park
Rogue River National Forest
Fremont National Forest
Winema National Forest
Grants Pass
Medford
Siskiyou National Forest
Klamath Falls
Cascade Range
Six Rivers National Forest
Klamath National Forest
Salmon Mountains
Trinity National Forest
Eureka
Redding
Anderson
Red Bluff
Lassen Volcanic National Park
Lassen National Forest
N
0
12.5
25
50 Miles



Coos Bay
Roseburg
Coquille Reservation
Medford
Grants Pass
Klamath Falls
Fremont National Forest
Klamath National Forest
Salmon Mountains
Trinity National Forest
Eureka
Redding
Anderson
Red Bluff
Lassen Volcanic National Park
Cascade Range
0
12.5
25
50 Miles
N


Coos Bay
Roseburg
Umpqua National Forest
Coquille Reservation
Cow Creek Reservation and Off-Reservation Trust Land
Rogue River National Forest
Fremont National Forest
Winema National Forest
Grants Pass
Medford
Siskiyou National Forest
Klamath Falls
Cascade Range
Six Rivers National Forest
Klamath National Forest
Karuk Reservation and Off-Reservation Trust Land
Modoc National Forest
Salmon Mountains
Eureka
Trinity National Forest
Redding
Anderson
Lassen Volcanic National Park
Lassen National Forest
Red Bluff
N
0
12.5
25
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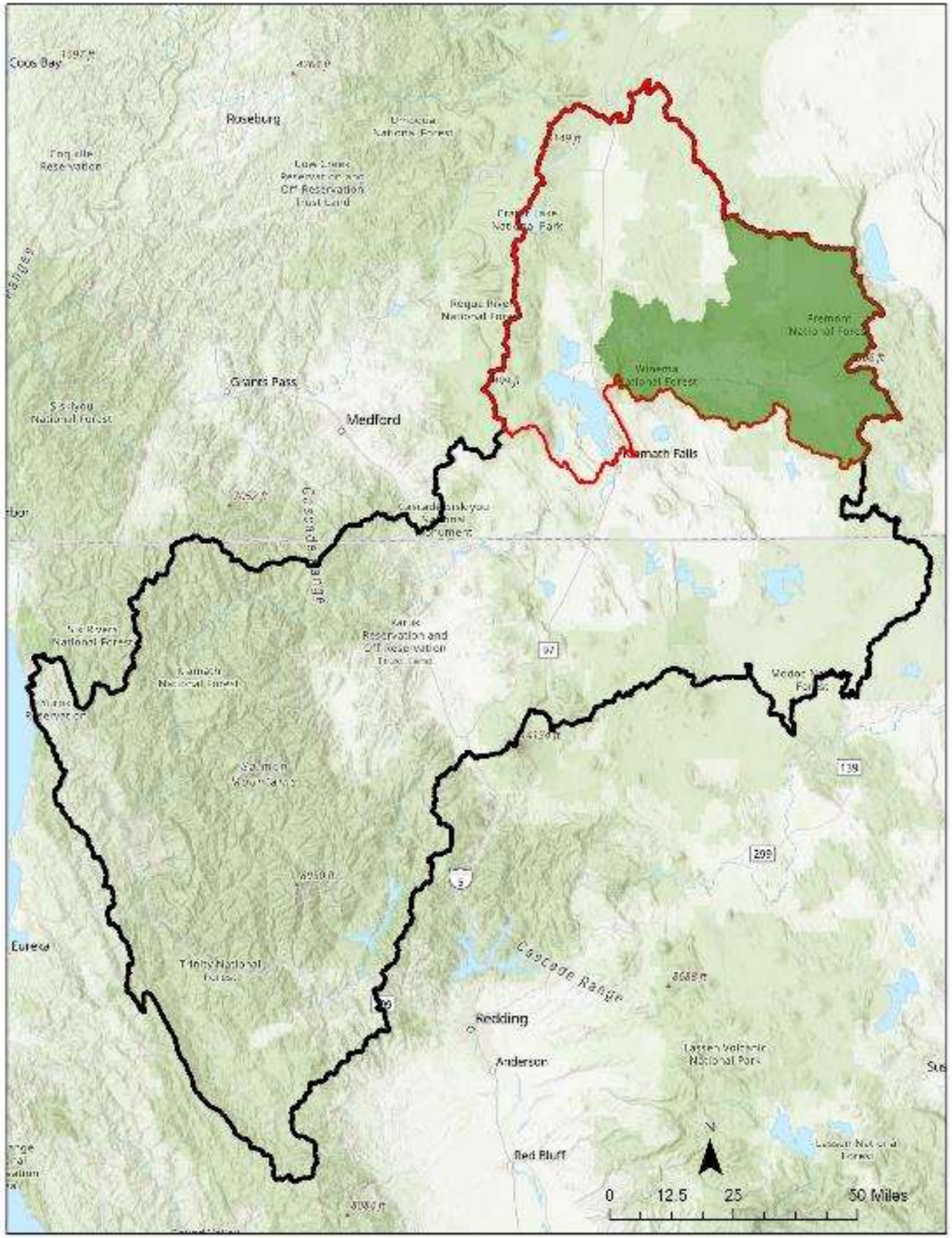
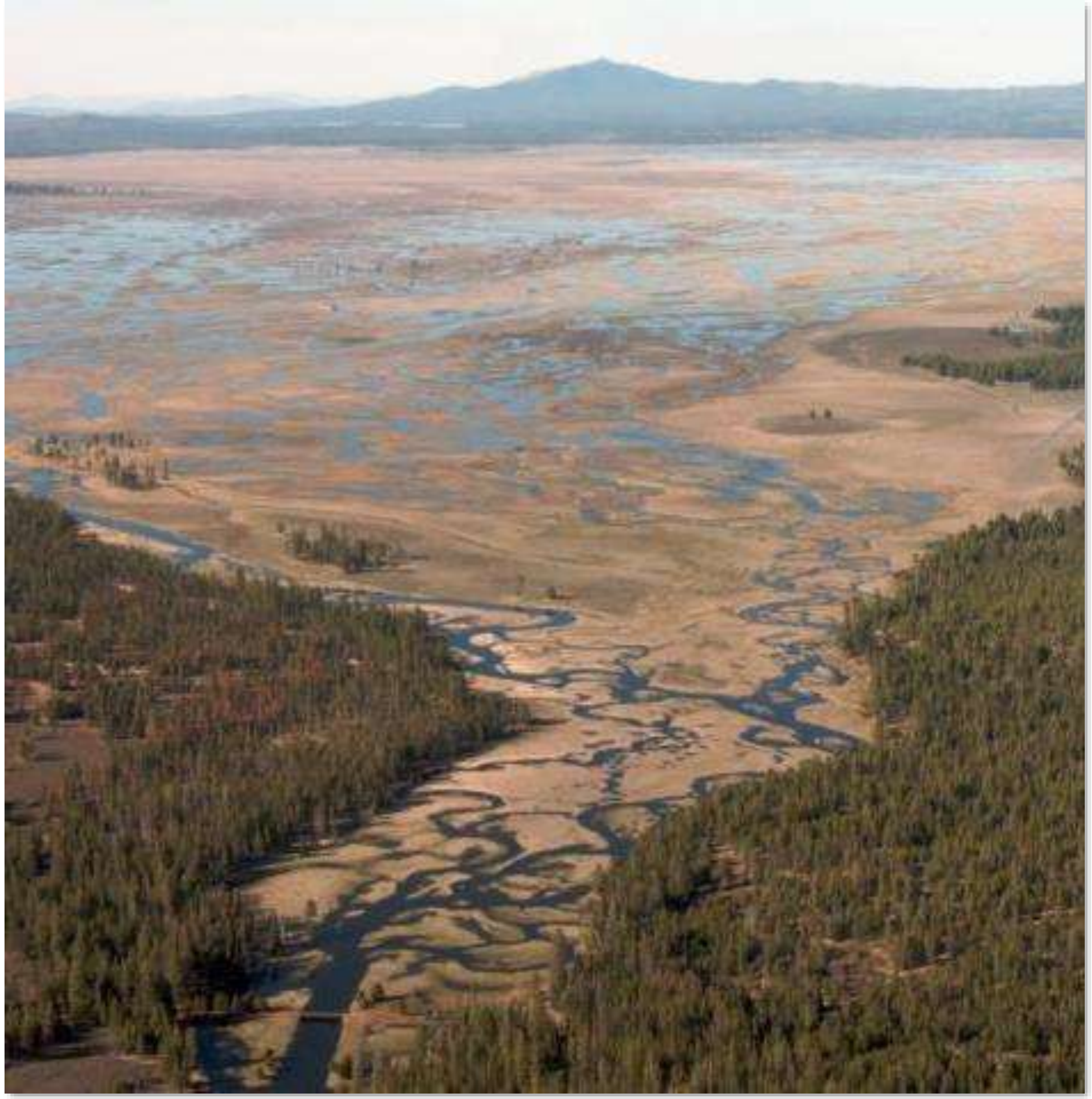


Coos Bay
Roseburg
Grants Pass
Medford
Eureka
Redding
Anderson
Red Bluff
Cascade Range
Salmon Mountains
Lassen Volcanic National Park
97
139
299
N
0
12.5
25
50 Miles



Lost Space

Too many of these

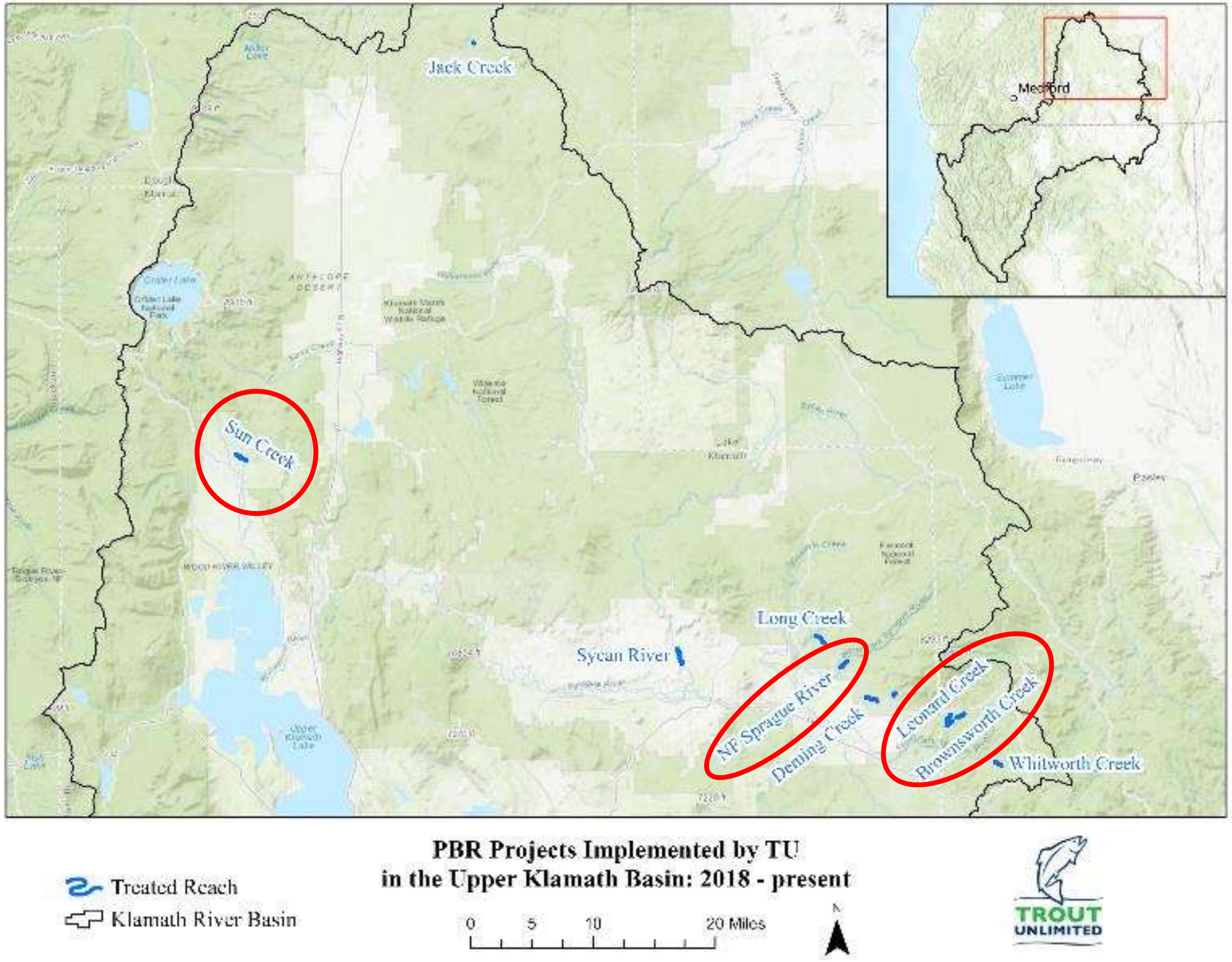
Not enough of these

LTPBR in the UKB – Why?

Restoration Goals in the UKB

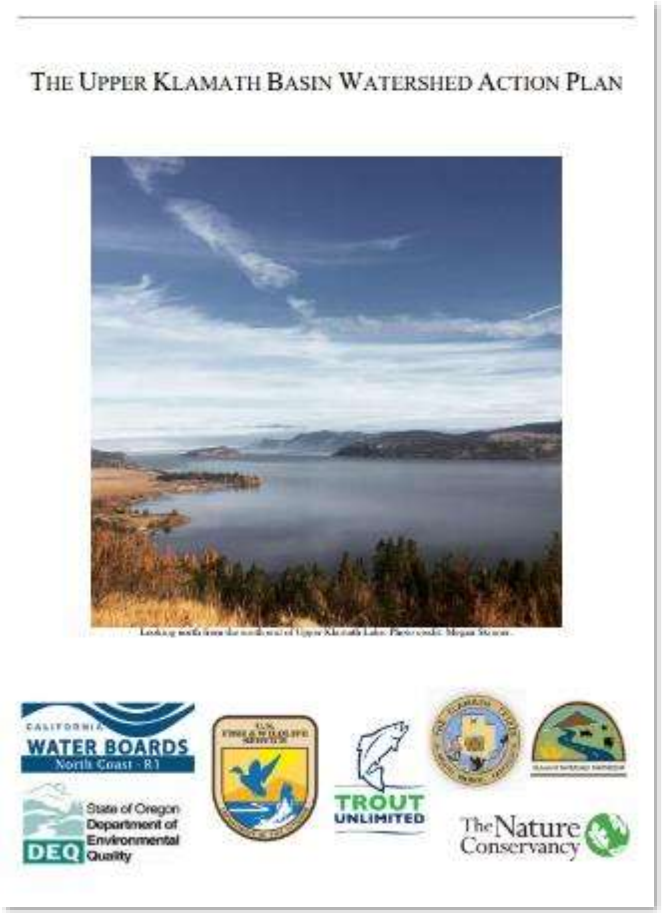
- Increase groundwater levels
- Reduce suspended sediment
- Improve floodplain connectivity
- Encourage beaver activity
- Increase habitat complexity
- Promote riparian productivity

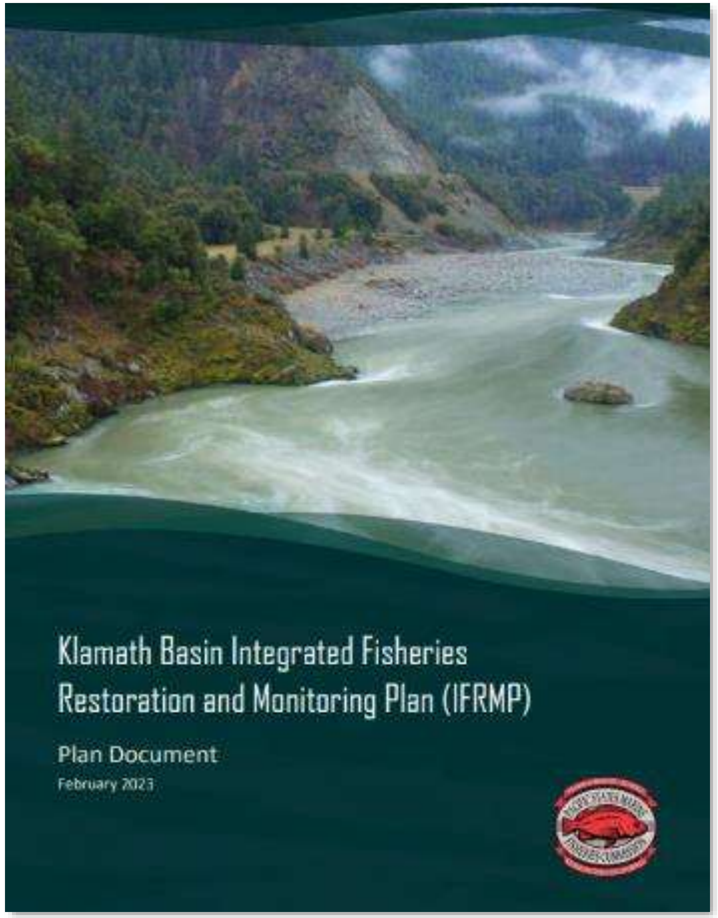
LTPBR in the UKB – Where and When?

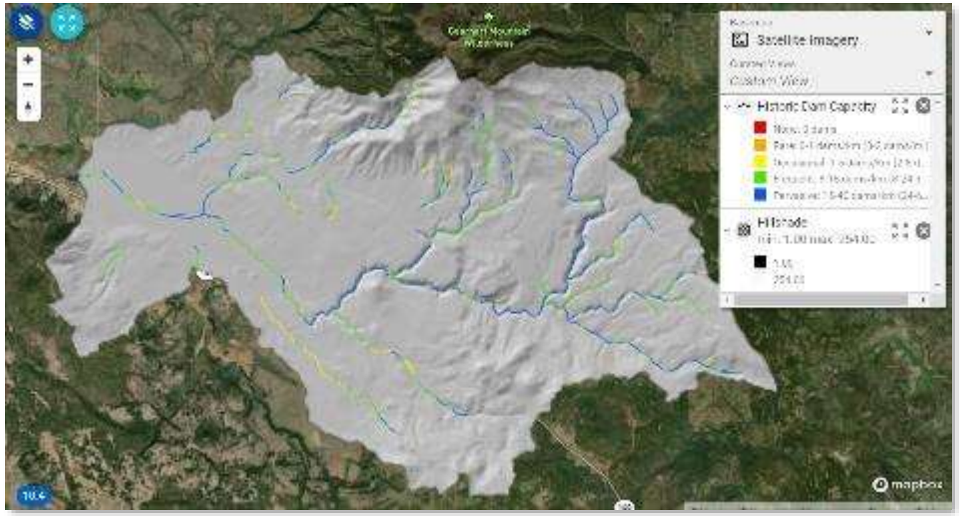


Year	Miles (new)	Miles (adptv man)
2018	0.5	-
2019	-	0.2
2020	0.2	-
2021	0.9	-
2022	5.6	0.5
2023	5.3	2.3
Total	**12.5**	**3.0**

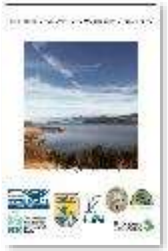
LTPBR in the UKB – How?





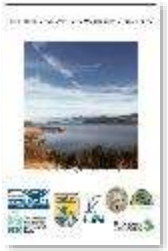


LTPBR in the UKB – How?





LTPBR in the UKB – How?



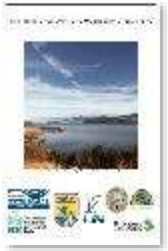


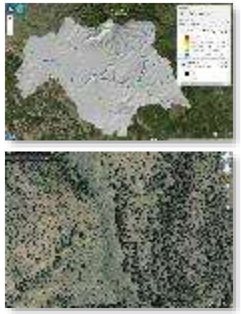



FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

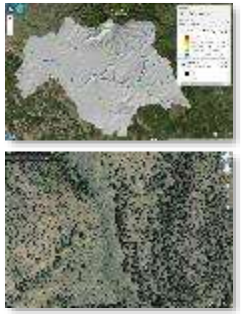
GREEN DIAMOND

LTPBR in the UKB – How?





LTPBR in the UKB – How?



FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

GREEN DIAMOND

U.S. FISH & WILDLIFE SERVICE

OREGON WATERSHED ENHANCEMENT BOARD OWEB

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

CATENA FOUNDATION

SWIFTWATERDESIGN

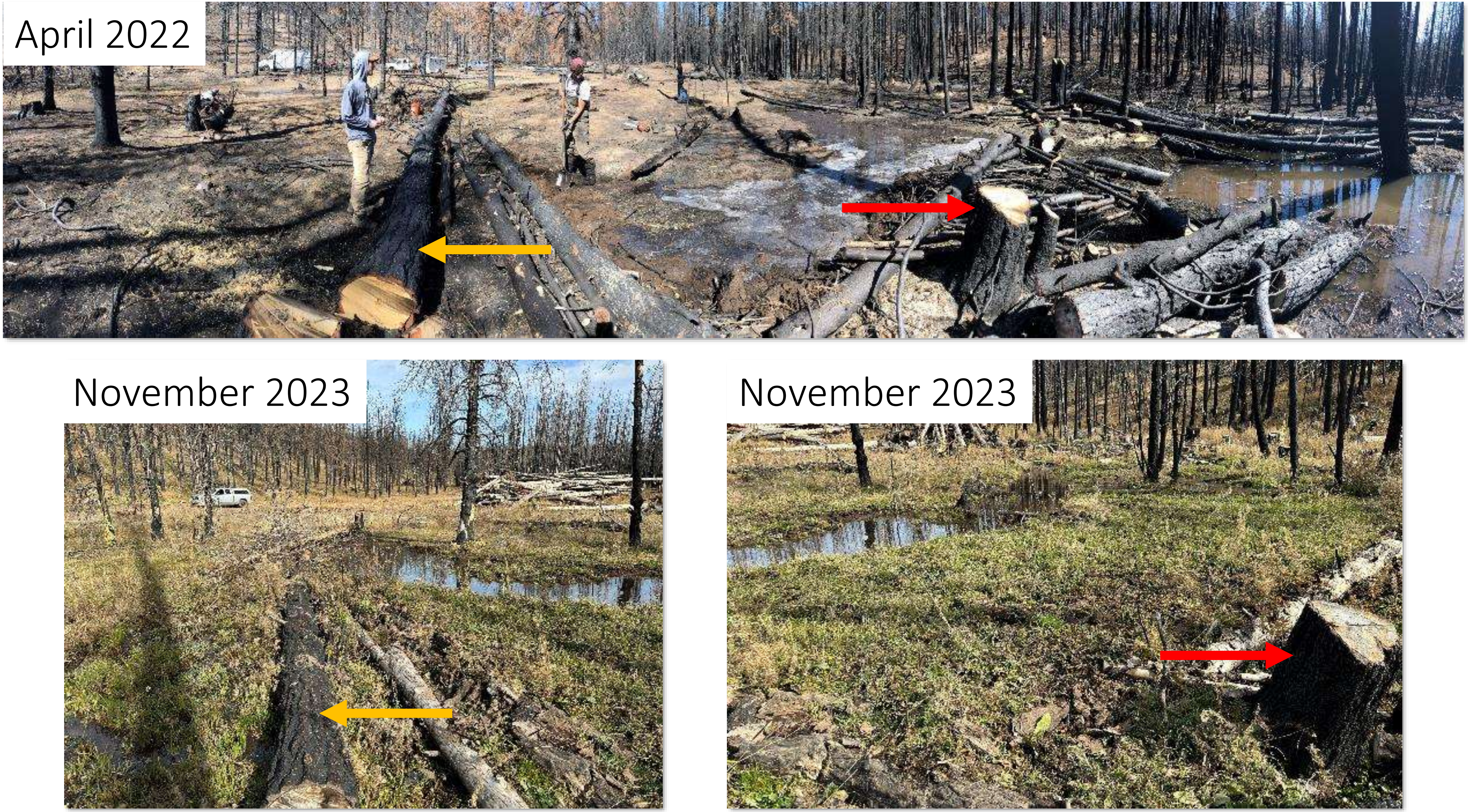
ANABRANCH SOLUTIONS

LTPBR in the UKB – Case Studies

Leonard and Brownsworth Creeks

- Primary Goals:
  - Sediment capture
  - Post-fire riparian vegetation recovery
- Phase 1 (2022) – 48 structures, 1.2 miles of stream
- Phase 2 (2023) – 140 structures, 1.6 miles of stream
- Monitoring activities:
  - Turbidity stations
  - Multispectral drone flights
  - Temperature


SWIFTWATERDESIGN


April 2022
November 2023
November 2023

Sun Creek

- Primary Goals:
  - Reduce Incision
  - Increase groundwater levels
  - Provide habitat complexity
- Phase 1 (2022) – 52 structures, 1.3 miles of stream
- Phase 2 (2023) – 15 structures, 0.25 miles of stream
- Monitoring activities:
  - Turbidity stations
  - Multispectral drone flights
  - Shallow groundwater monitoring wells
  - Fish populations

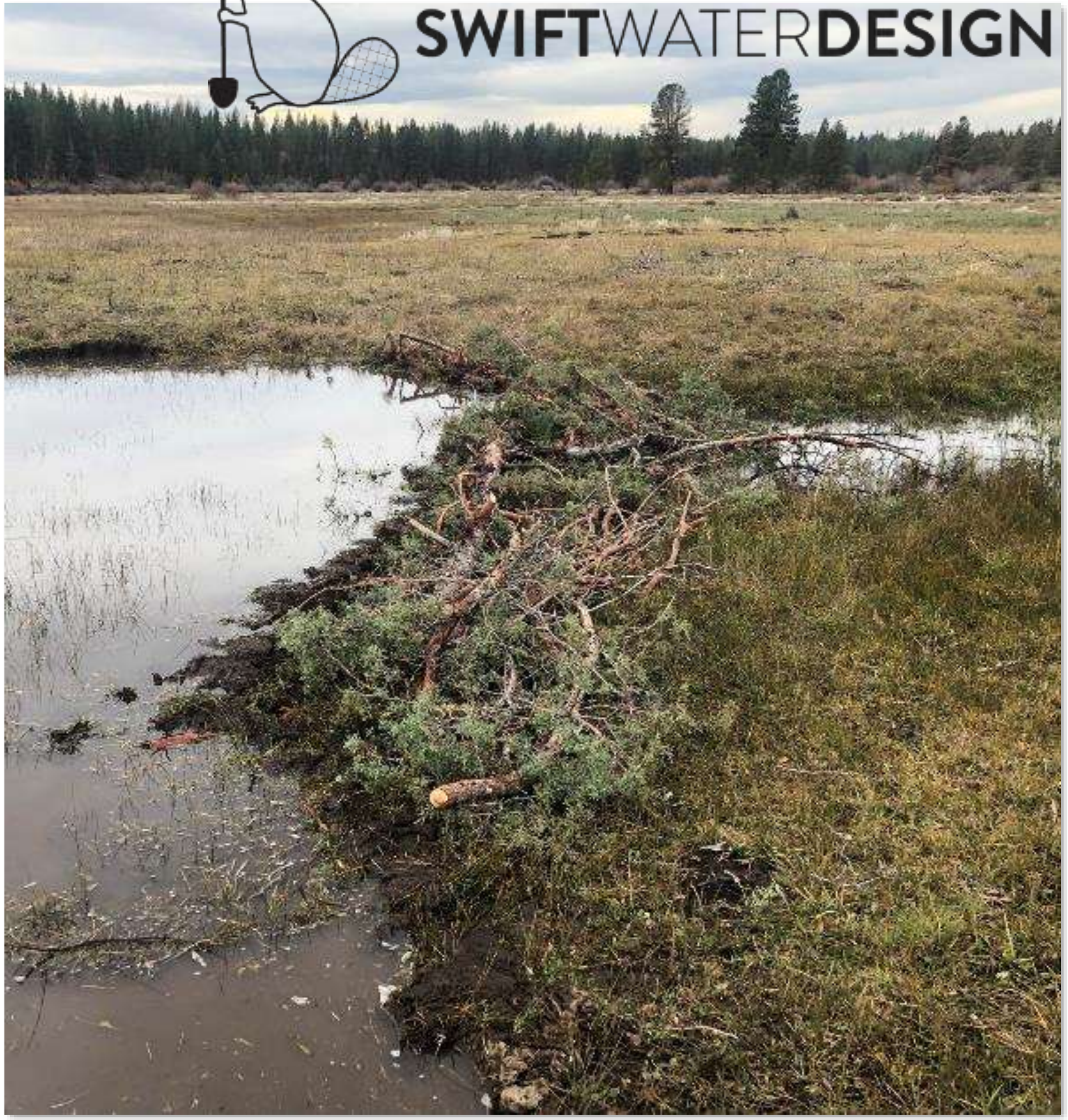

May 2023


October 2023

NF Sprague River

- Primary Goals:
  - Sediment capture
  - Provide habitat complexity
- Phase 1 (2021) – 107 structures, 0.9 miles of stream
- Phase 1.5 (2022) – 12 structures, 0.9 miles of stream
- Phase 2 (2023) – 62 structures, 0.9 miles of stream
- Monitoring activities:
  - Multispectral drone flights


ANABRANCH
SOLUTIONS


SWIFTWATERDESIGN


November ‘21 – 52 cfs


April ‘22 – 140 cfs


May ‘23 – gauge broken


Jul ‘23 – 35 cfs


LTPBR in the UKB – Monitoring

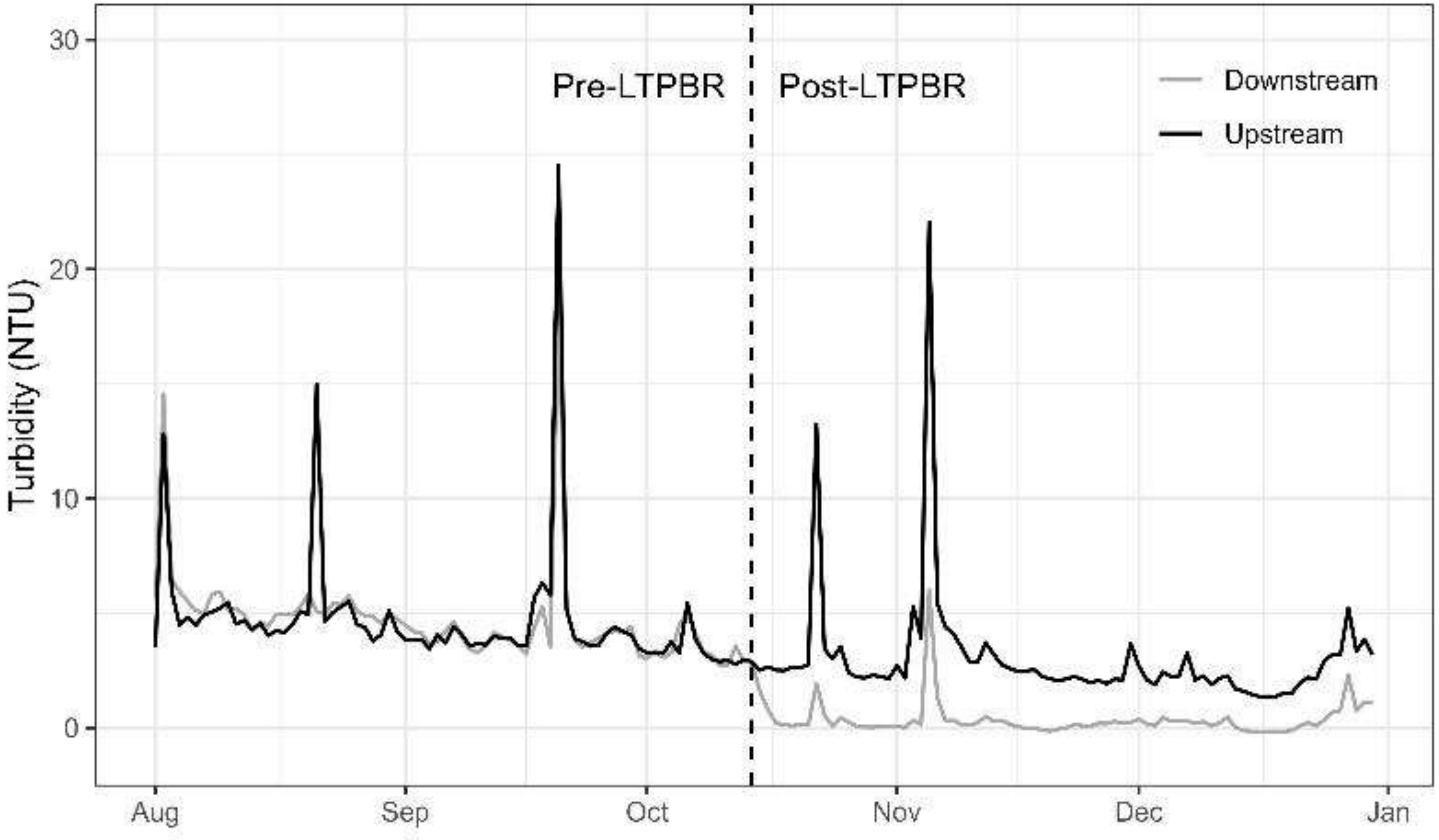
Monitoring Parameters and Resources

- Parameters
  - Turbidity
  - Groundwater
  - NDVI
  - Temperature
  - Fish populations
  - Floodplain connection
  - Instream habitat
  - Channel morphology

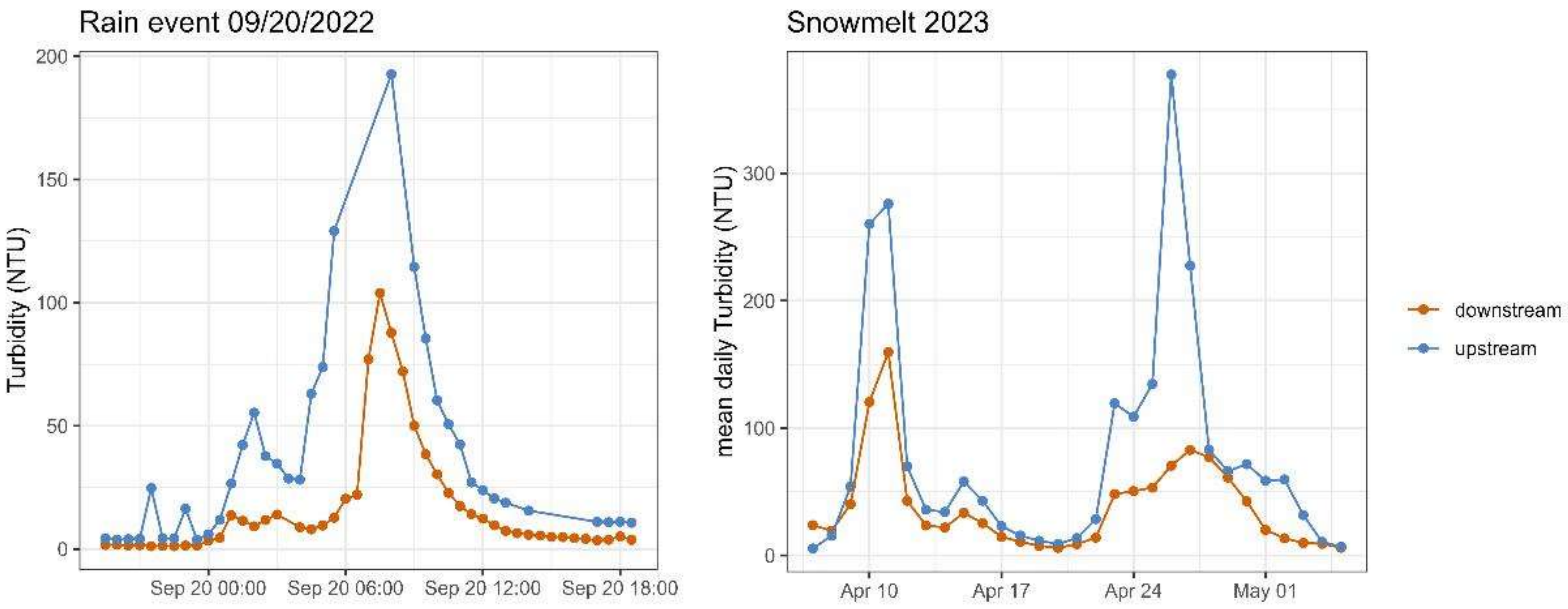
- Resources
  - Sierra Meadows Wetland & Riparian Area Monitoring Plan
  - Low-Tech Process Based Restoration Project Implementation and Monitoring Protocol

Turbidity Monitoring – Sun Creek

- Monitoring stations upstream and downstream of LTPBR activities show a dramatic decrease in turbidity post-LTPBR

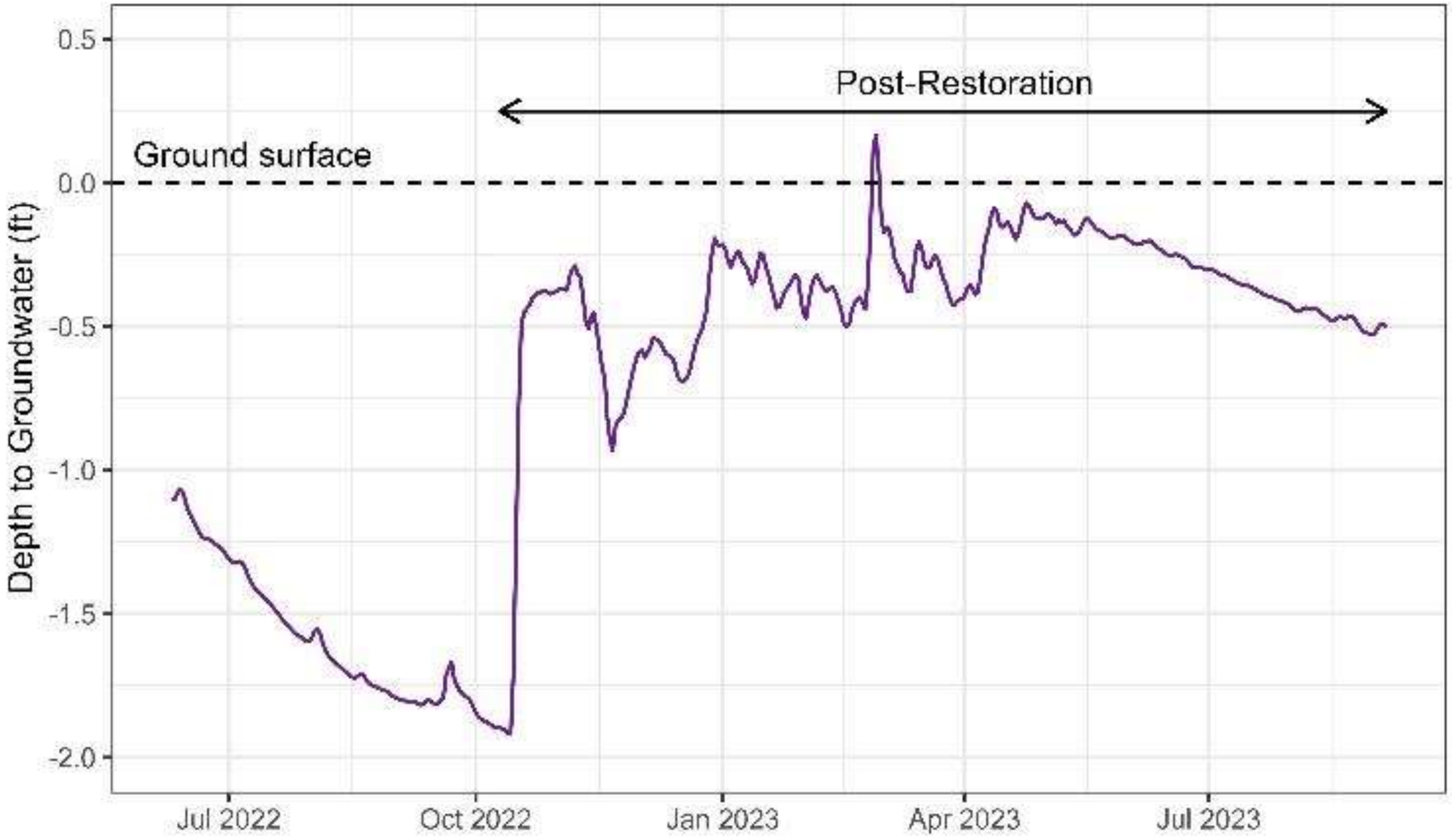


Turbidity Monitoring – Leonard Creek



Groundwater Monitoring – Sun Creek

- ≥1 ft. increase immediately after installation of a BDA complex

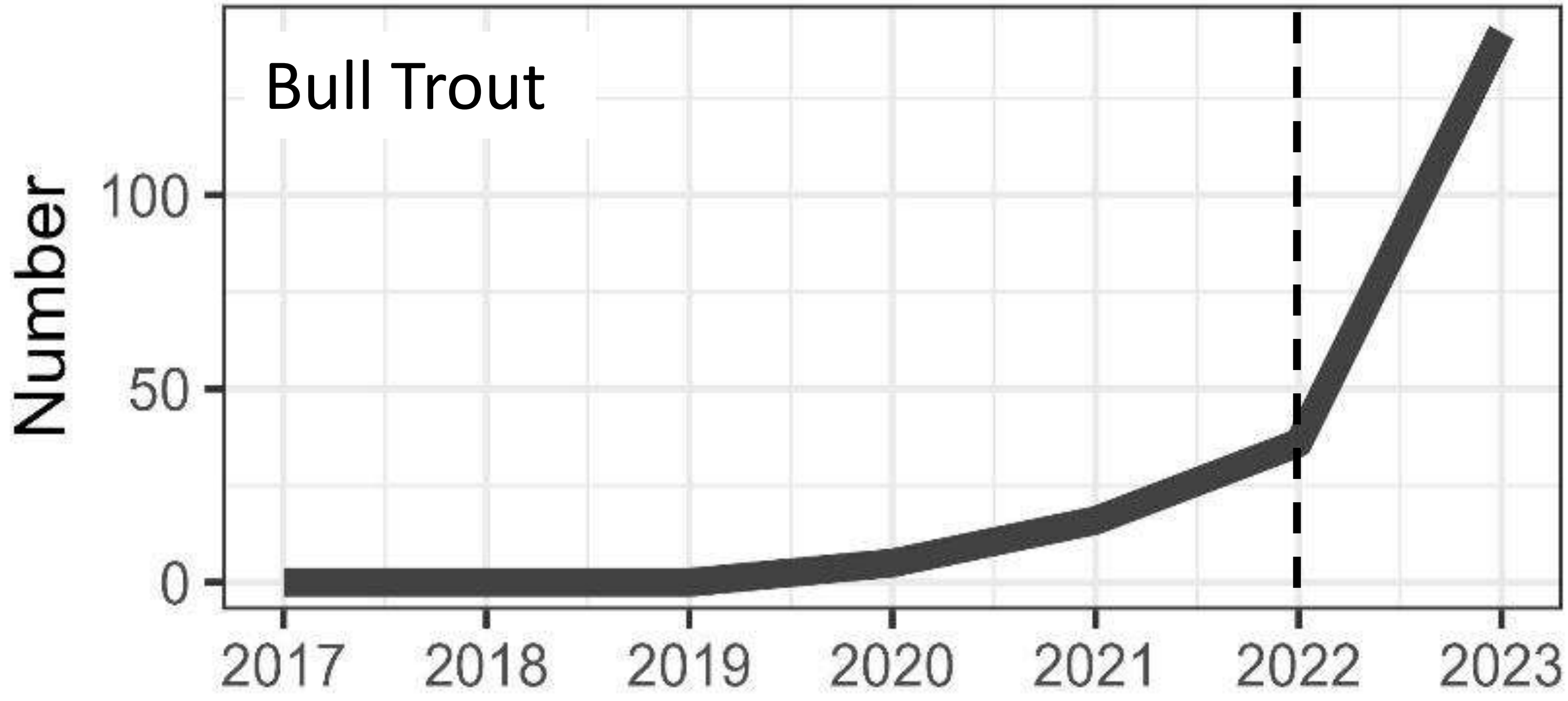


Fish Monitoring – Sun Creek

- One-year post implementation, Bull Trout population in the project has continued to increase.

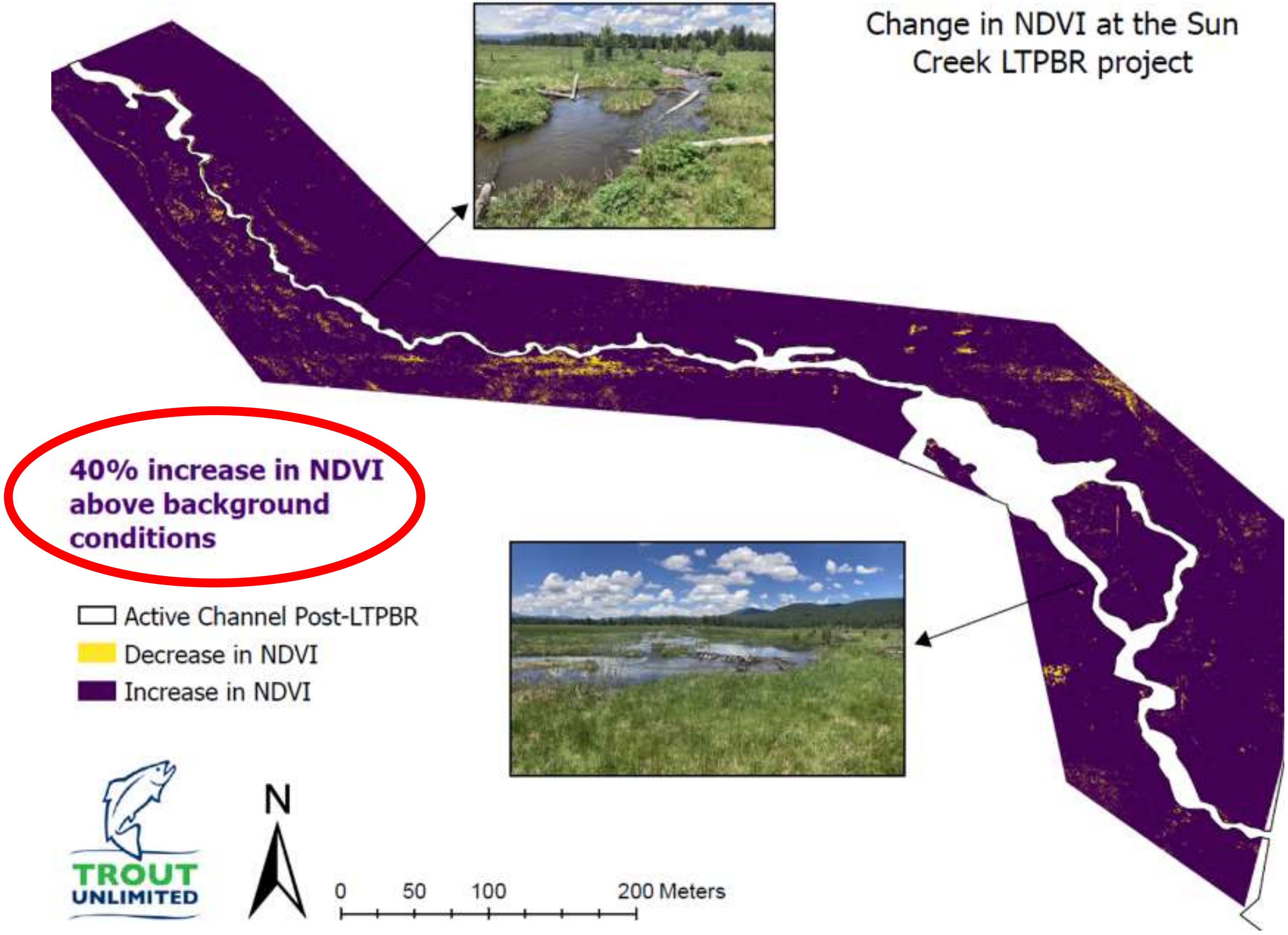
CLNP
ODFW

LTPBR implementation

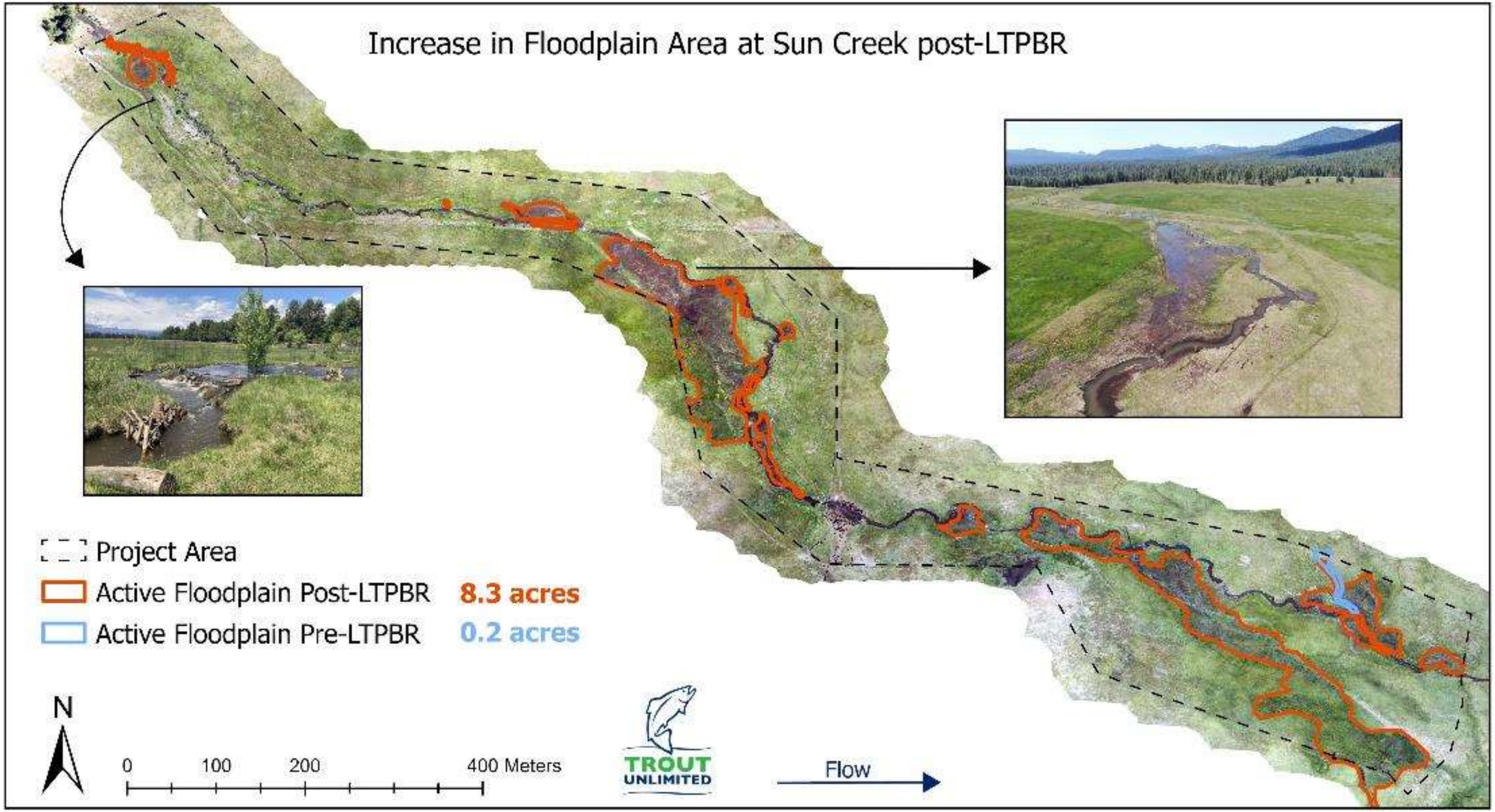


Vegetation Monitoring – Sun Creek

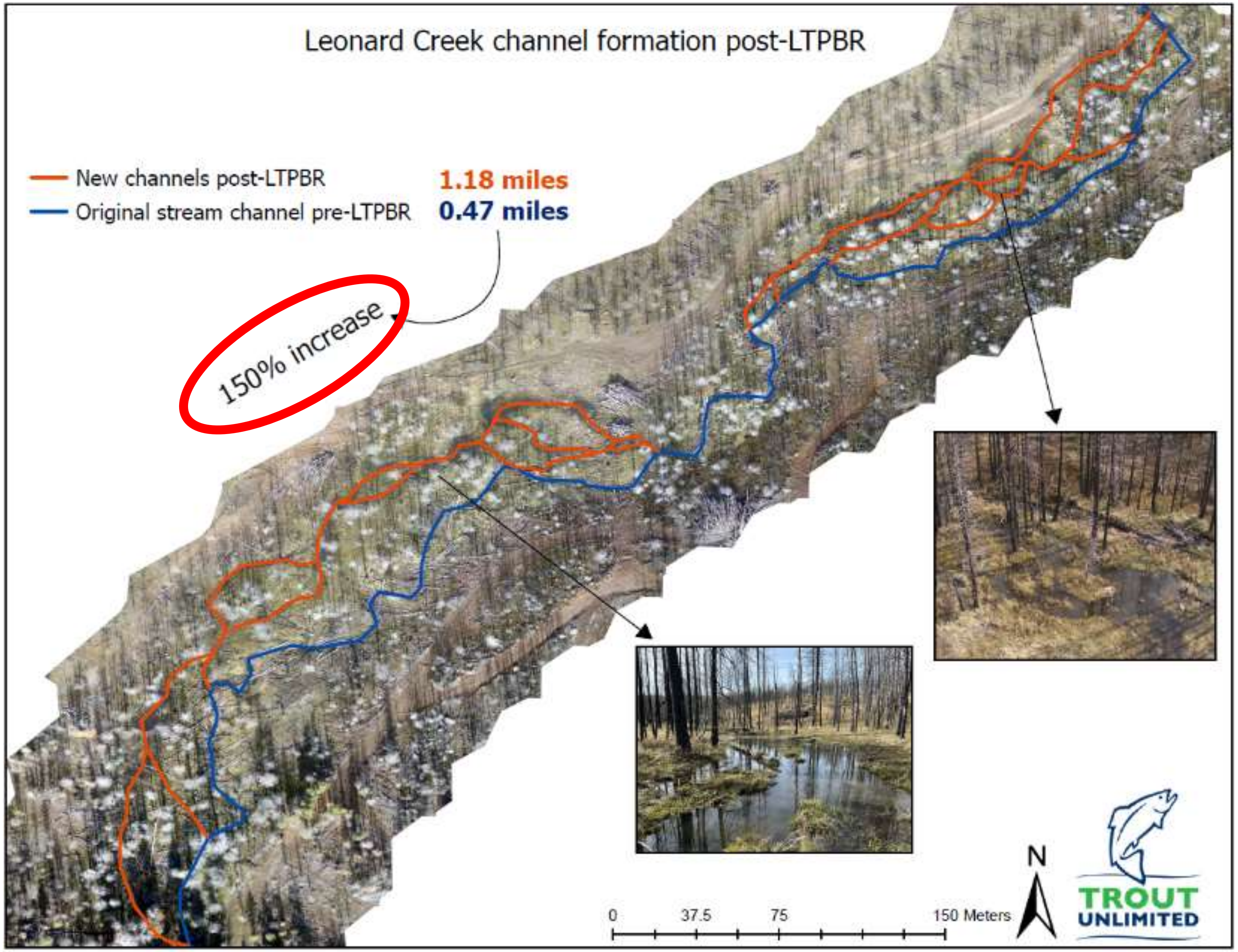
- Normalized Difference Vegetation Index:
    - Quantitative estimate of plant greenness



Floodplain Monitoring – Sun Creek



Channel Monitoring – Leonard Creek



Geomorphic Unit Monitoring – NF Sprague

- 56% Increase in pools per mile
- 212% Increase in bars per mile
- 2021 – 1 LWD Jam
- 2023 – 49 LWD Jams

LTPBR in the UKB – Lessons Learned and Challenges

Lessons Learned

This work is impactful!

- Human Elements:
  - Site visits before and after
- Geomorphic Elements:
  - Fire and importance of sediment
- Ecological Elements:
  - Natural recruitment of vegetation

Challenges

- Human Elements:
  - Permitting
- Geomorphic Elements:
  - Structure and channel stability
- Ecological Elements:
  - Meadows and wood
- Working Landscape Elements:
  - Cattle

10 Years of Experience Working with Beaver for Restoration in a Human Dominated Landscape

Betsy Stapleton (Presenter) and Co-Authors Charnna Gilmore and Erich Yokel, Scott River Watershed Council

SCOTT RIVER
WATERSHED COUNCIL

The Story of French Creek

and the Entire Scott Watershed

Water, Beaver, Fish, Restoration, Agriculture, and Place Based Stewardship

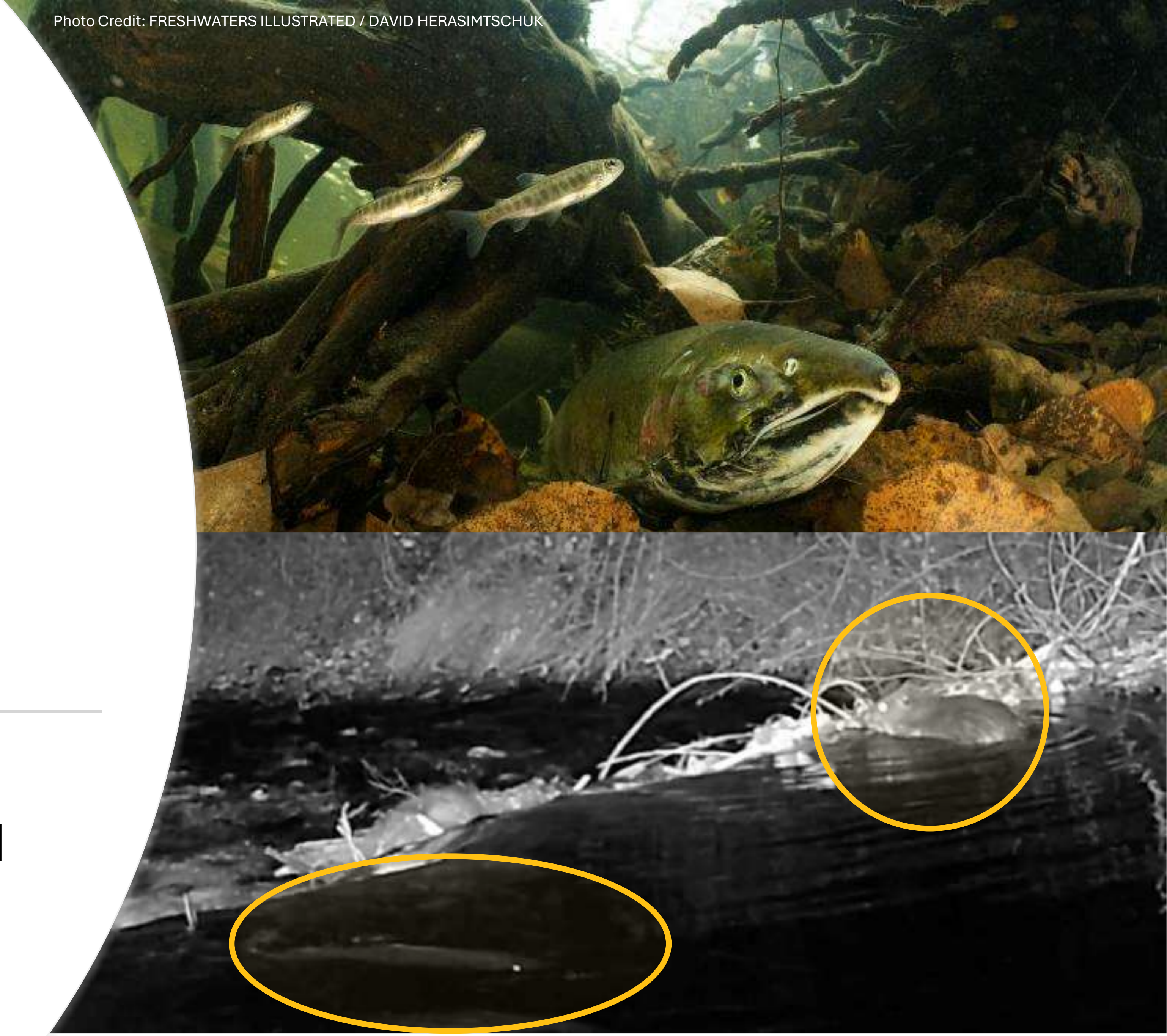


Photo Credit: FRESHWATERS ILLUSTRATED / DAVID HERASIMTSCHUK

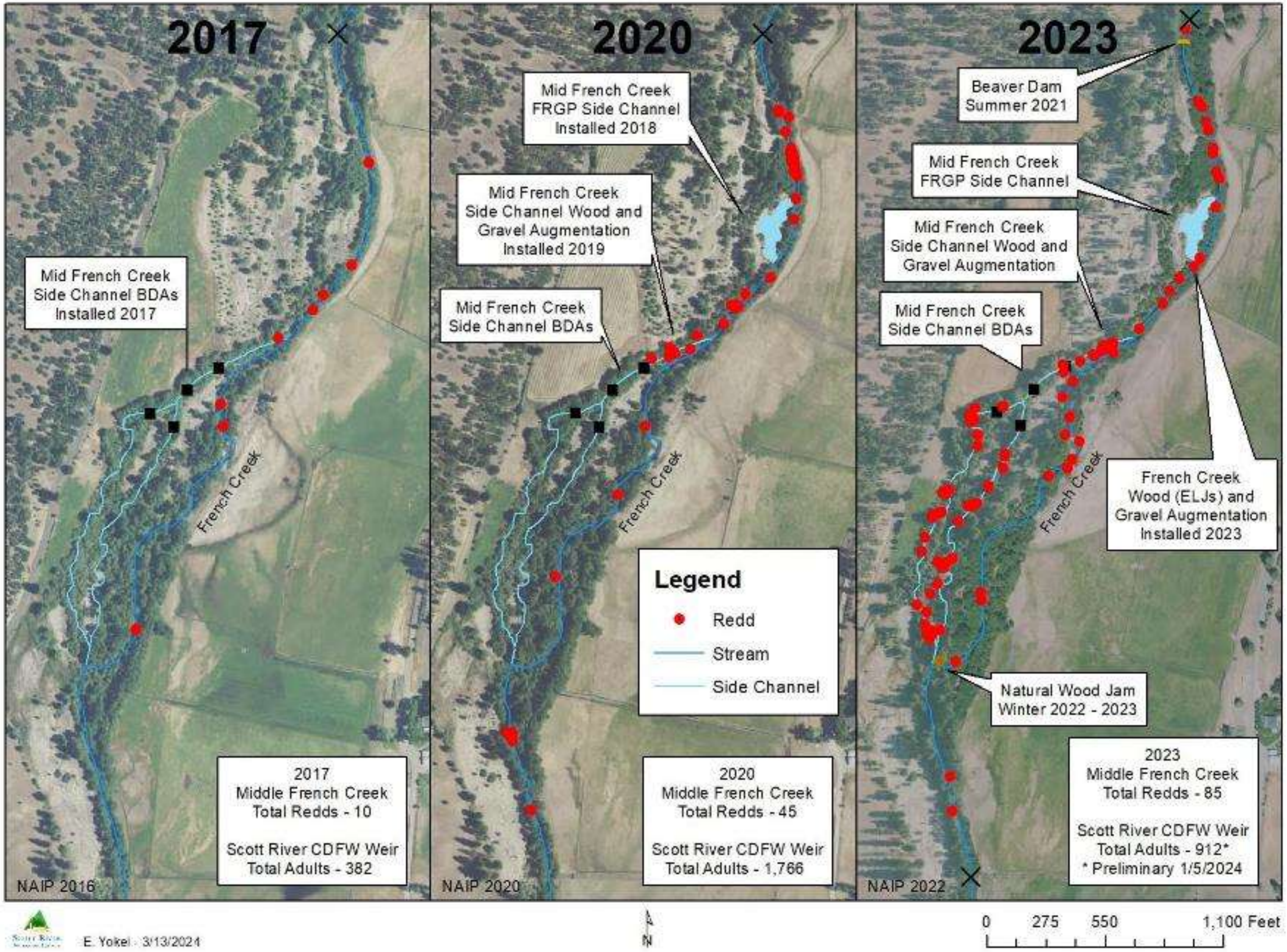
Cliff Note Summary

2017: First restoration & 10 redds from 382 adults @ weir

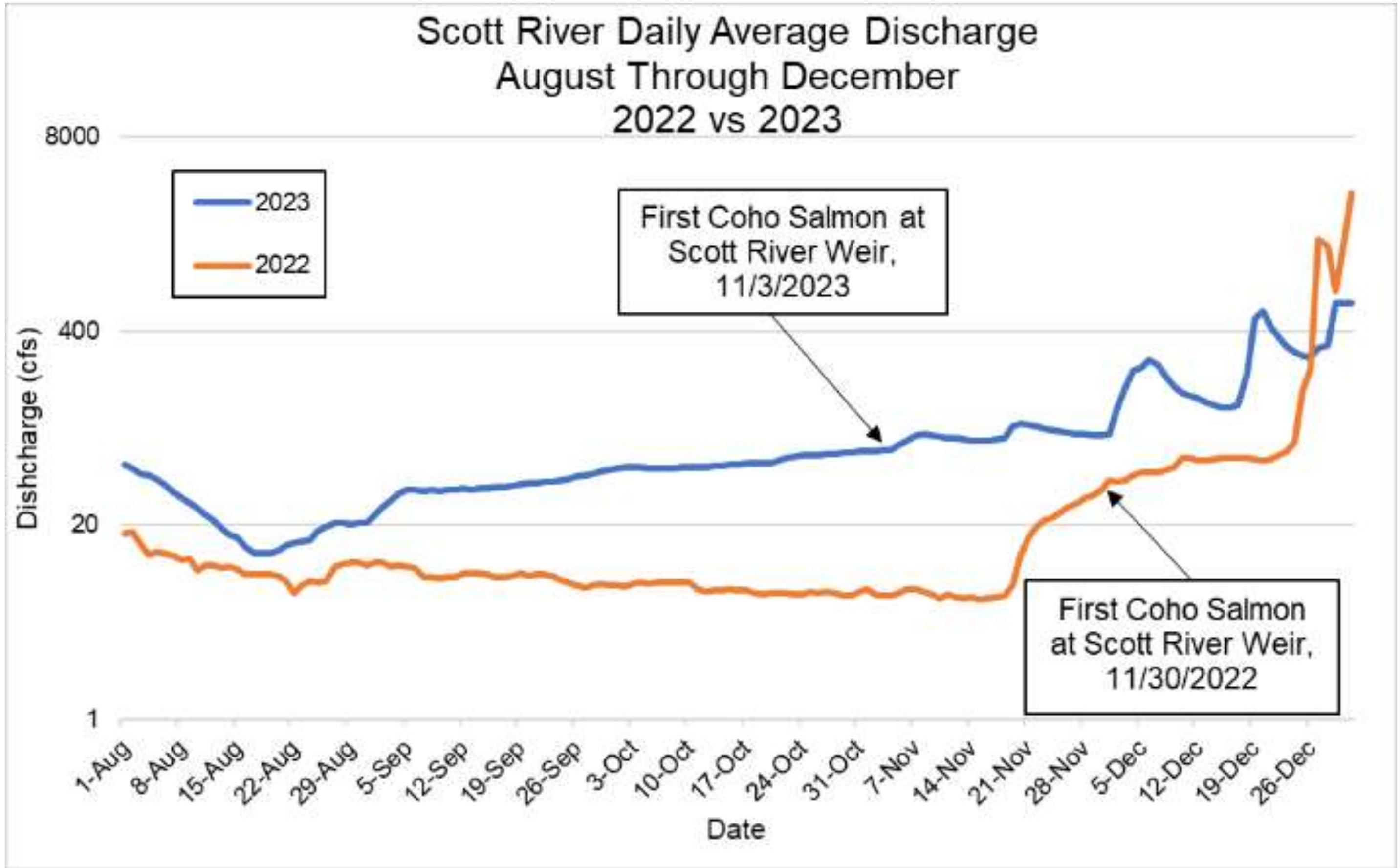
2020: Some restoration & 45 redds from 1,766 adults @ weir (spawning run concentrated in French Creek)

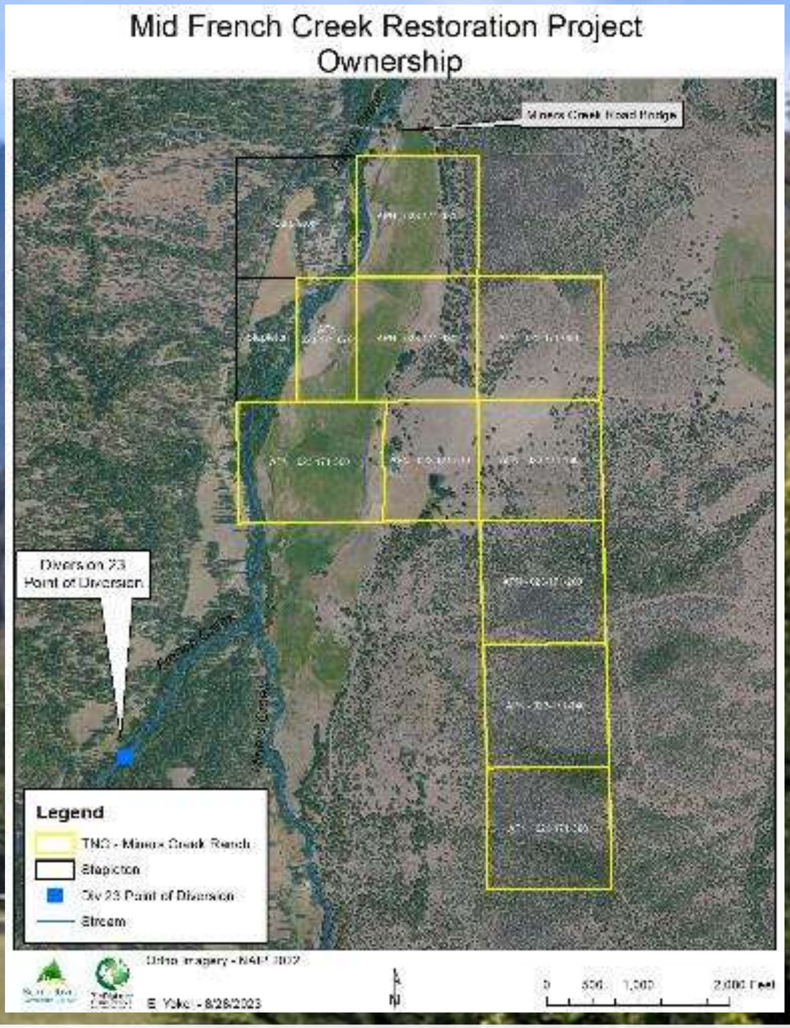
2023: More restoration & 85 redds from 912 Adults @ weir (spawning run widely dispersed across the watershed)

Middle French Creek - Spawning Ground Surveys - Coho Salmon Redds - 2017, 2020 and 2023



First Comes Water





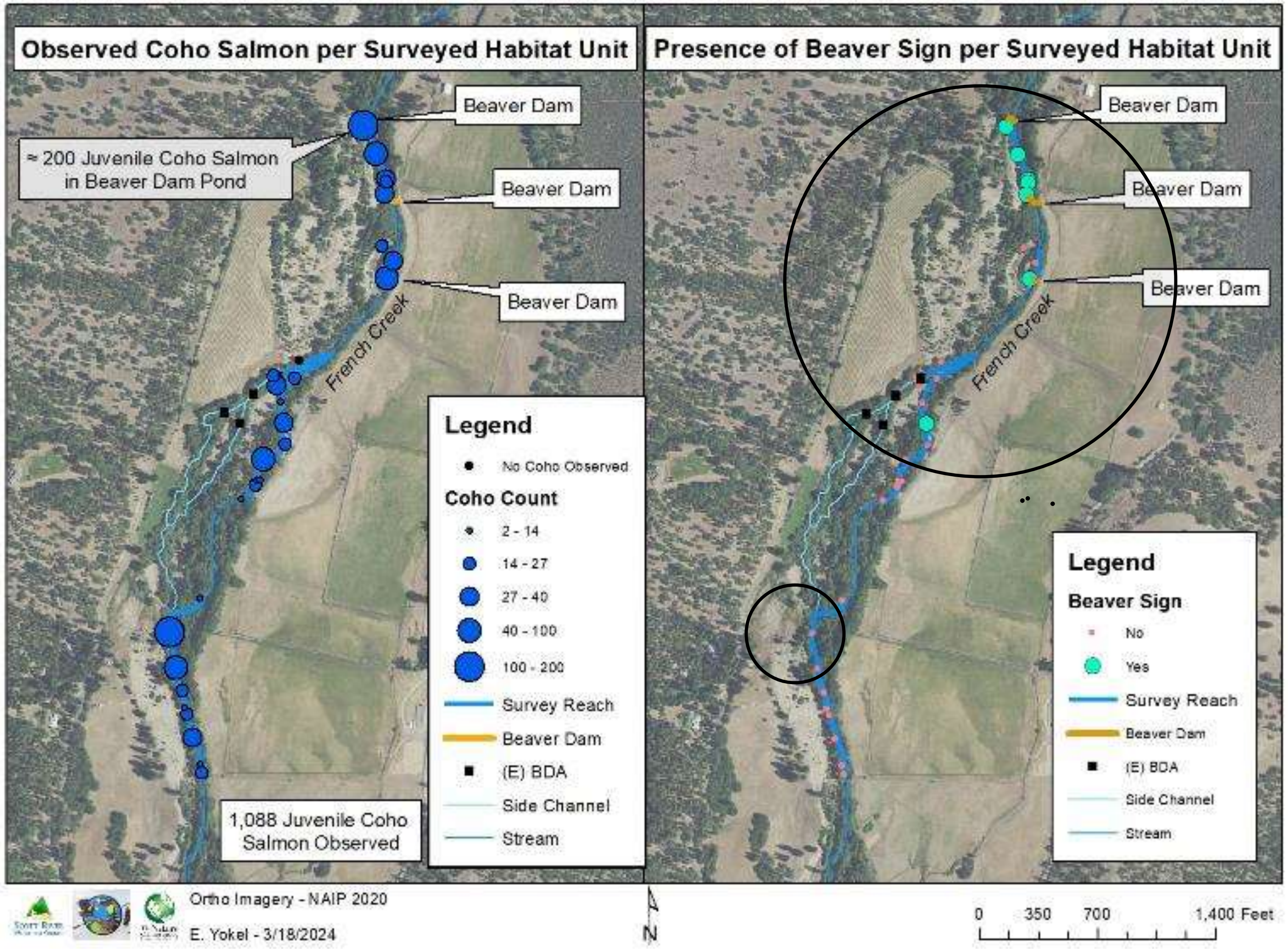
Agriculture: Irrigation, Infrastructure, Landowner Interests

Water, Again (and Again)

French TNC		
Date	Staff Height (ft)	Q (cfs)
7/31/23	2.03	5.84
8/2/23	2.6	6.8
8/8/23	2.04	5.93
8/21/23	1.99	4.22
8/28/23	1.7	5.01
9/6/23	1.9	3.3
9/18/23	1.94	2.89
10/4/23	2.4	5.01
11/8/23	2.27	13:35
12/6/23	2.5	34.71
12/16/23	2.32	17.8

Beaver and Juvenile Coho

Mid French Creek - Direct Observation Survey -7/28, 7/29 & 8/2/2023

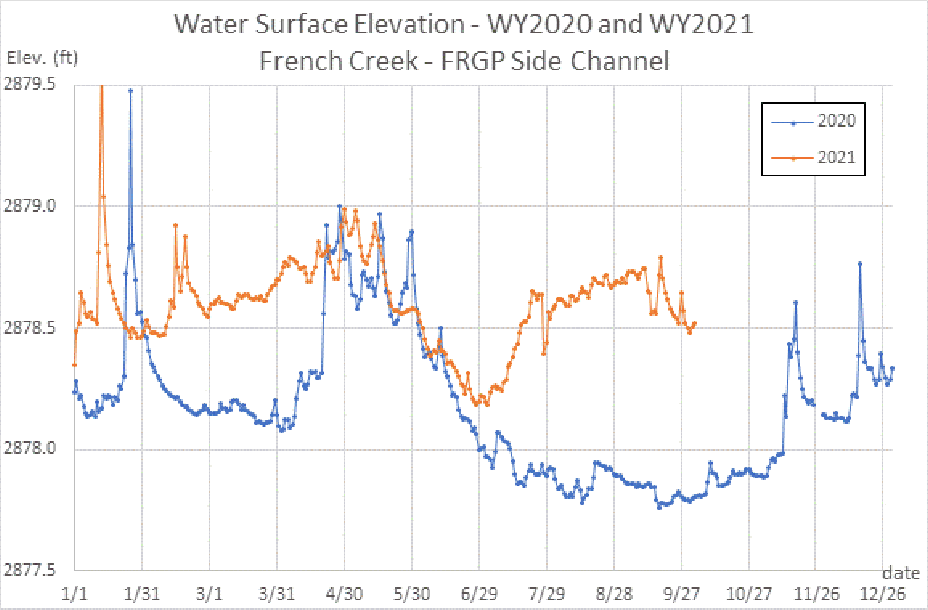


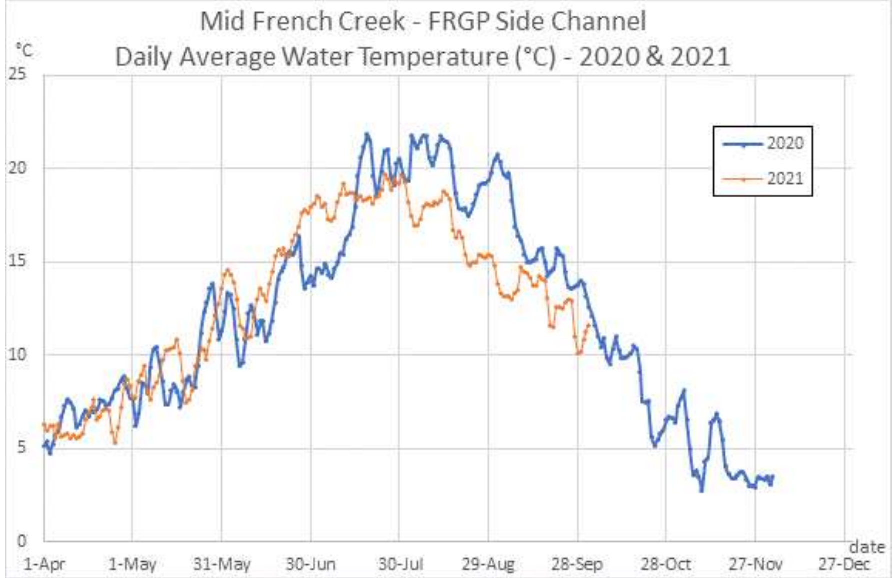
   

BDAs: Human Ecosystem Issues (Permitting)

Form Based Restoration: Beavers, Site Evolution and Stewardship

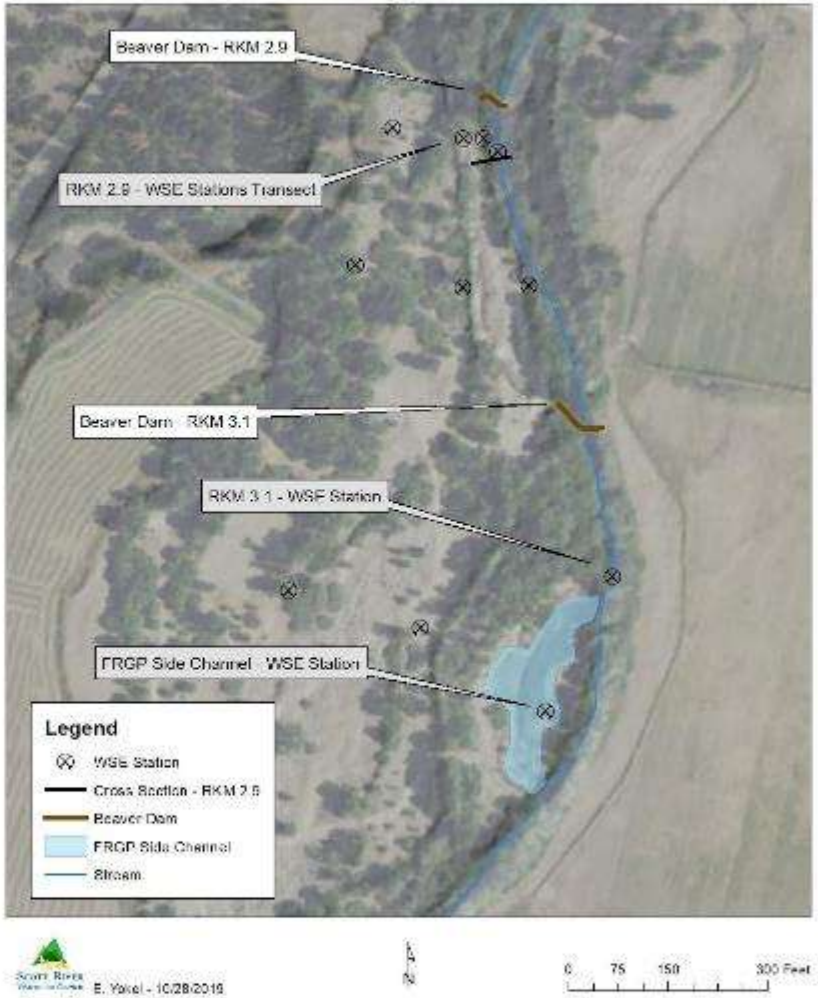
- Even with Engineering, Oops Happen
- Sediment
- Food Sources:
  - Beavers Alders, Cottonwood, and Willows





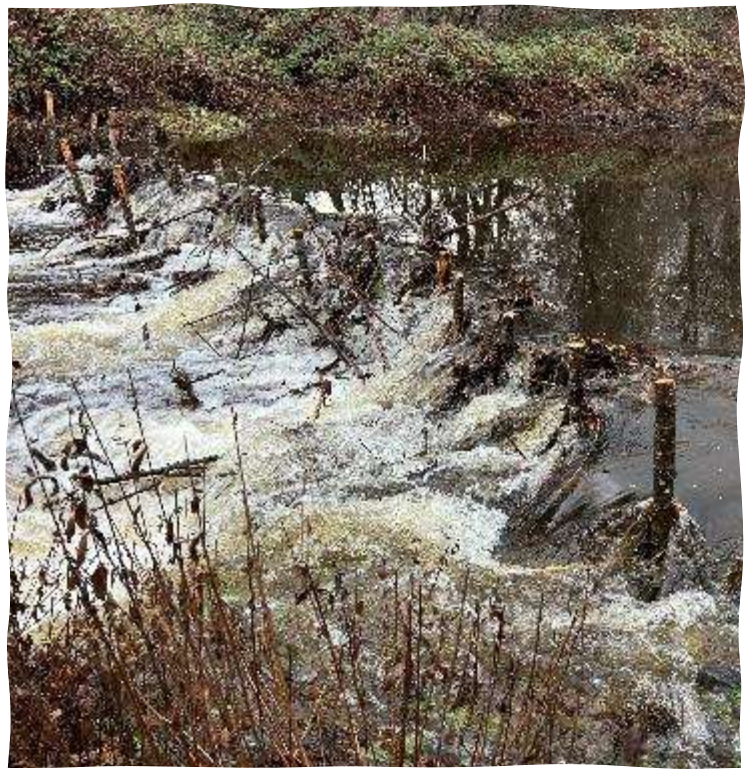
More About Beavers and Form Based Restoration

Mid French Creek - 2021 Beaver Dams
Monitoring Network



Wood: Low Tech and Engineered

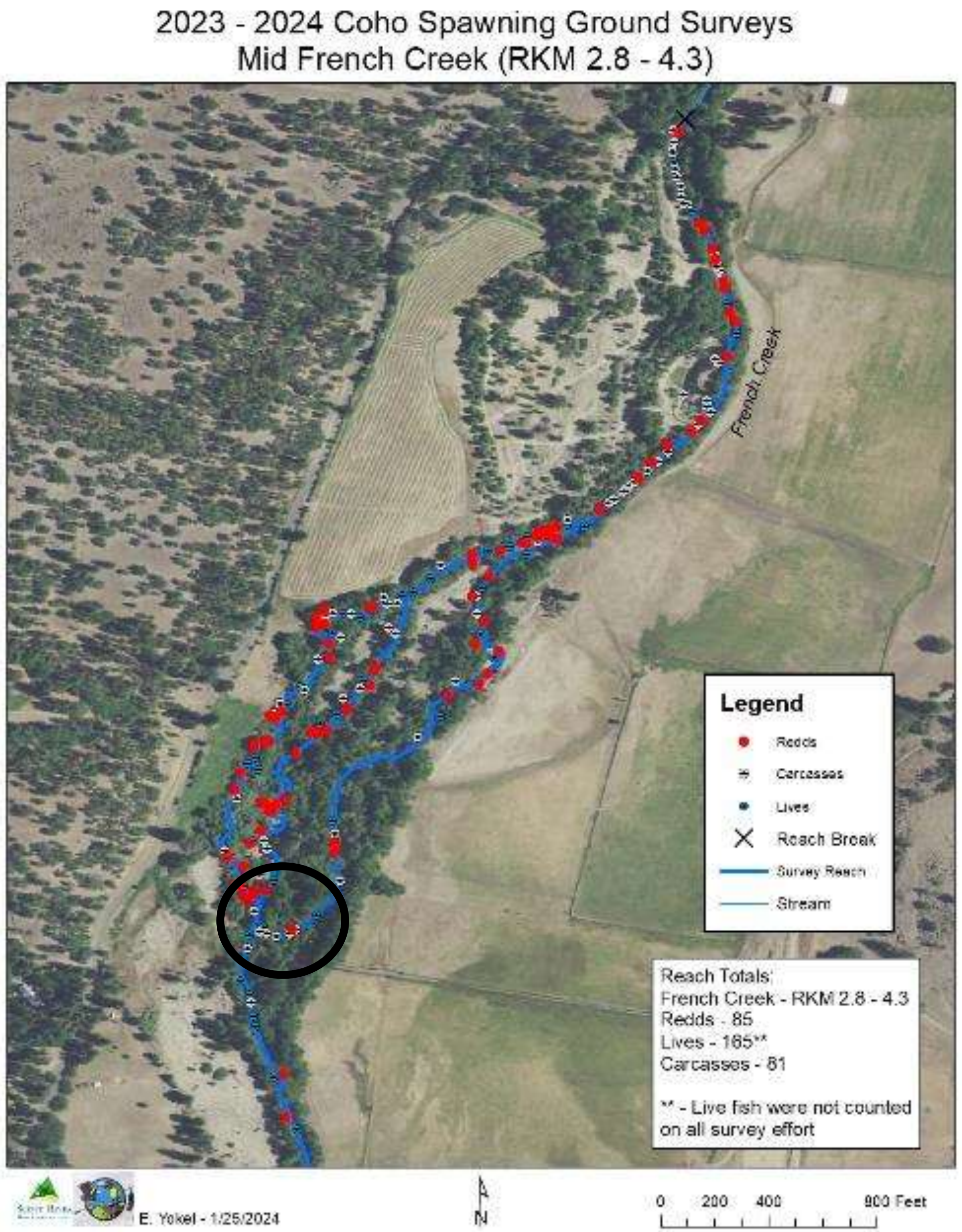
Intensive Care and Rehabilitation for an Ill System



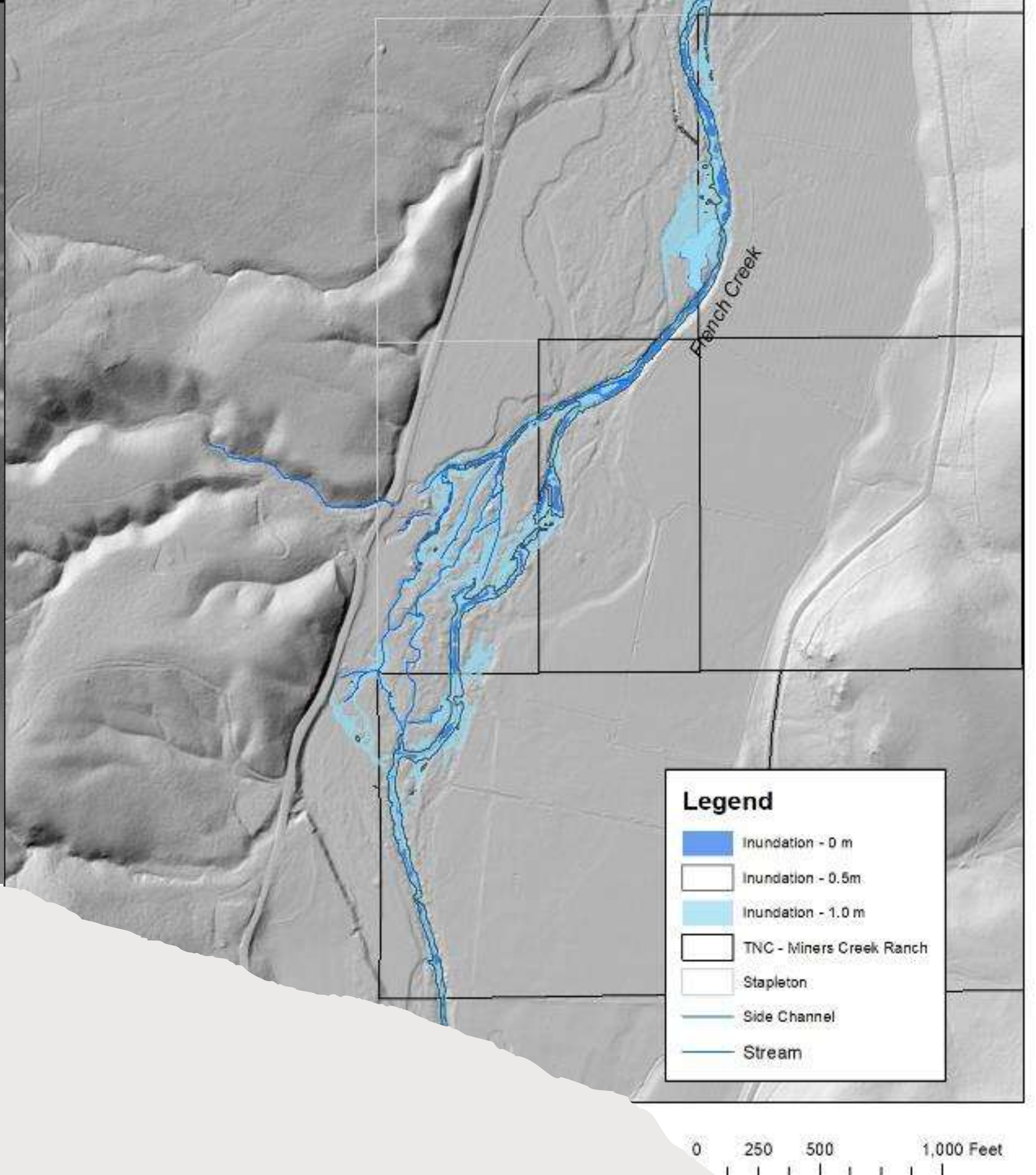
Beaver Dams in Modified and Incised Streams

- Don’t Forget Upslope Issues

Simple Actions with Big Results



That Upslope Sediment:
Friend or Foe?



What's next?

Landownership: New Opportunities

Multi Species Management.

Use
All
the
Tools

BUREAU OF RECLAMATION

U.S. FISH & WILDLIFE SERVICE

CALIFORNIA WATER BOARDS North Coast - R1

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

Quartz Valley Indian Reservation

SSW

SRWT

WCB State of Californ Wildlife Conservatic

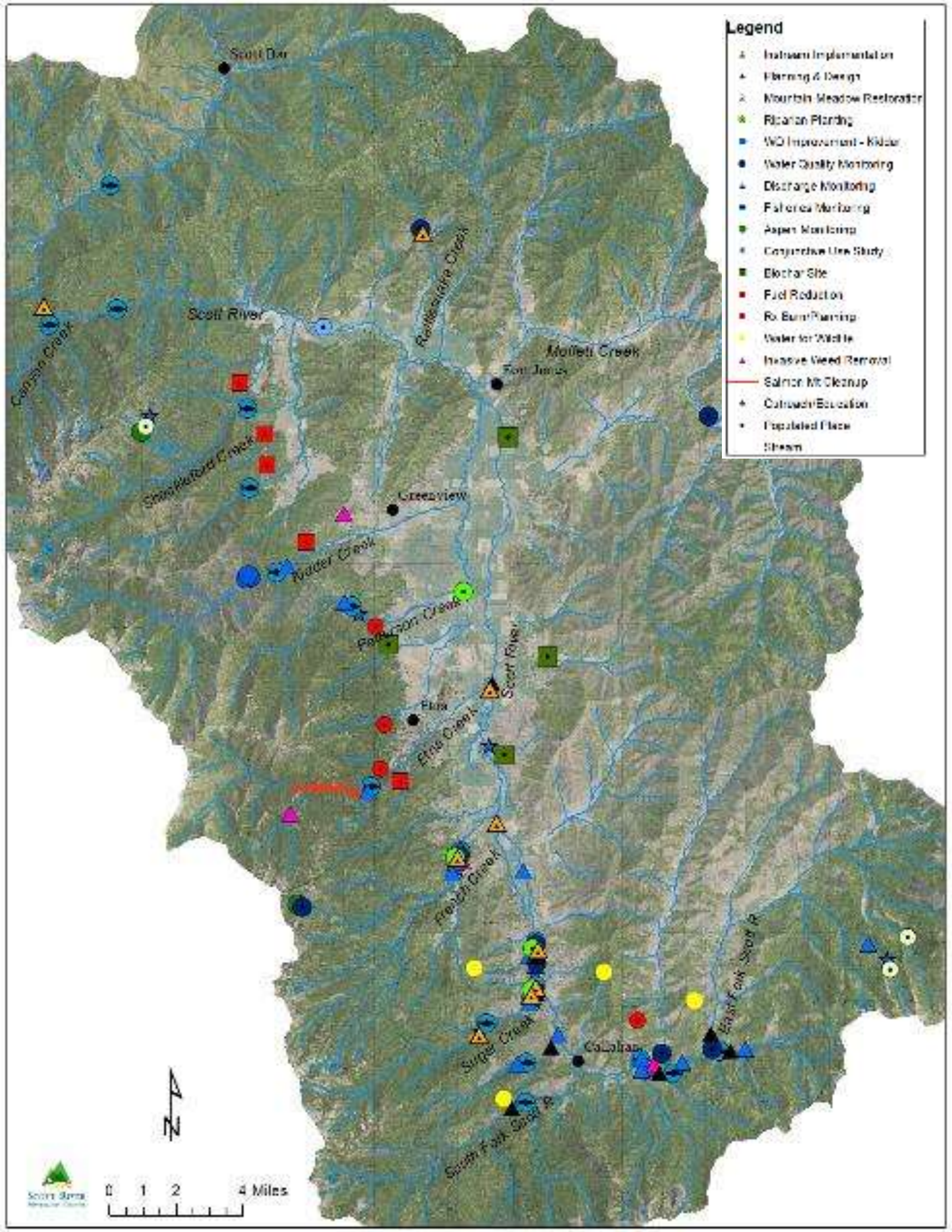
National Fish and Wildlife Foundation

NOAA

NRCS Natural Resources Conservation Service

PRUNUSKE CHATHAM, INC.

The Nature Conservancy



A Whole Watershed Approach with a Generational Mindset