Mountain Meadows: Restoring Functions in Headwater Catchments under Changing Climate and Wildfire Regimes

A Concurrent Session at the 39th Annual Salmonid Restoration Conference held in Santa Cruz, California from April 19 – 22, 2022.

- **Session Coordinator:**
  - Jay Stallman, Stillwater Sciences
  - Gabrielle Bohlman, US Forest Service

The importance of mountain meadows for hydrologic function, ecological diversity, and climate resilience has become increasingly recognized over the past few decades, especially within the context of recent catastrophic wildfires and severe drought throughout California. This session will focus on restoration and management of mountain meadow systems with emphasis on current tools and approaches, linkages between hydrogeomorphic processes and aquatic habitat responses, and the role of mountain meadows in landscape-scale fire resilience and post-fire recovery.

Presentations

Slide 5- **Restoring Ecological Function to California's Montane Meadows**, Karen Pope, Ph.D., *US Forest Service Pacific Southwest Research Station*

Slide 27- **Twenty Years of Plant and Ecosystem Recovery Following Grazing Cessation in the Golden Trout Wilderness**, Devyn Orr, Ph.D., *USDA ARS*

Slide 88- **LTPBR in Sierra Nevada Meadow Systems: A Case Study from the Golden Trout Wilderness**, Sabra Purdy, *Trout Unlimited/Anabranch Solutions*

Slide 127- **Tasmam Koyom: The Hundred-Year Summer**, Kevin Swift, *Swift Water Design*

Slide 160- **Restoring a Sierra Meadow Complex: A Decade of Data and Lessons Learned**, David Shaw, PG, Principal Hydrologist/Geomorphologist and President/CEO, *Balance Hydrologics*

Slide 204- **Restoring Headwaters along Munch & Davy Brown Creeks in the Los Padres National Forest**, Mauricio Gomez, *South Coast Habitat Restoration*

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Mountain Meadows: Restoring Functions in Headwater Catchments under Changing Climate and Wildfire Regimes

Session Coordinators: Jay Stallman, Stillwater Sciences and Gabrielle Bohlman, US Forest Service

PART 1

Restoring Ecological Function to California's Montane Meadows

Presenter: Karen Pope,
USFS Pacific Southwest Research Station

Effects of twenty years of climate warming and livestock grazing on high elevation meadows in the Golden Trout Wilderness

Presenter: Devyn Orr,
USDA Agricultural Research Center

LTPBR in Sierra Nevada Meadow Systems: A case study from the Golden Trout Wilderness

Presenter: Sabra Purdy,
Trout Unlimited/Anabranch Solutions

PART 2

The Hundred-Year Summer—PBR, Fire, Flood, and the Return of Beavers to Tasmam Koyom

Presenter: Kevin Swift,
Swift Water Design

A Decade of Data and Lessons Learned from Restoring a Sierra Meadow Complex

Presenter: David Shaw,
Balance Hydrologics

Restoring Headwaters along Davy Brown Creek in the Los Padres National Forest

Presenter: Mauricio Gomez,
South Coast Habitat Restoration

Restoring Ecological Function to California's Montane Meadows

Karen Pope and Adam Cummings

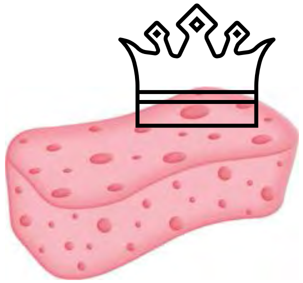
USDA Forest Service, Pacific Southwest Research Station

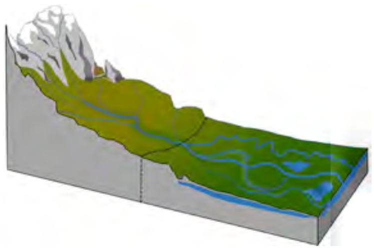
Talk objectives:

- We are underestimating the potential of mountain meadows
- We have the tools to re-evaluate the potential
- We have the techniques to tap into the potential

Mountain meadow characteristics

- Low gradient
- Supported by seepage water
- Where fines accumulate
- Annually recharged by snowmelt
- Shallow water table
- Vegetation dominated by graminoids, herbs, and shrubs





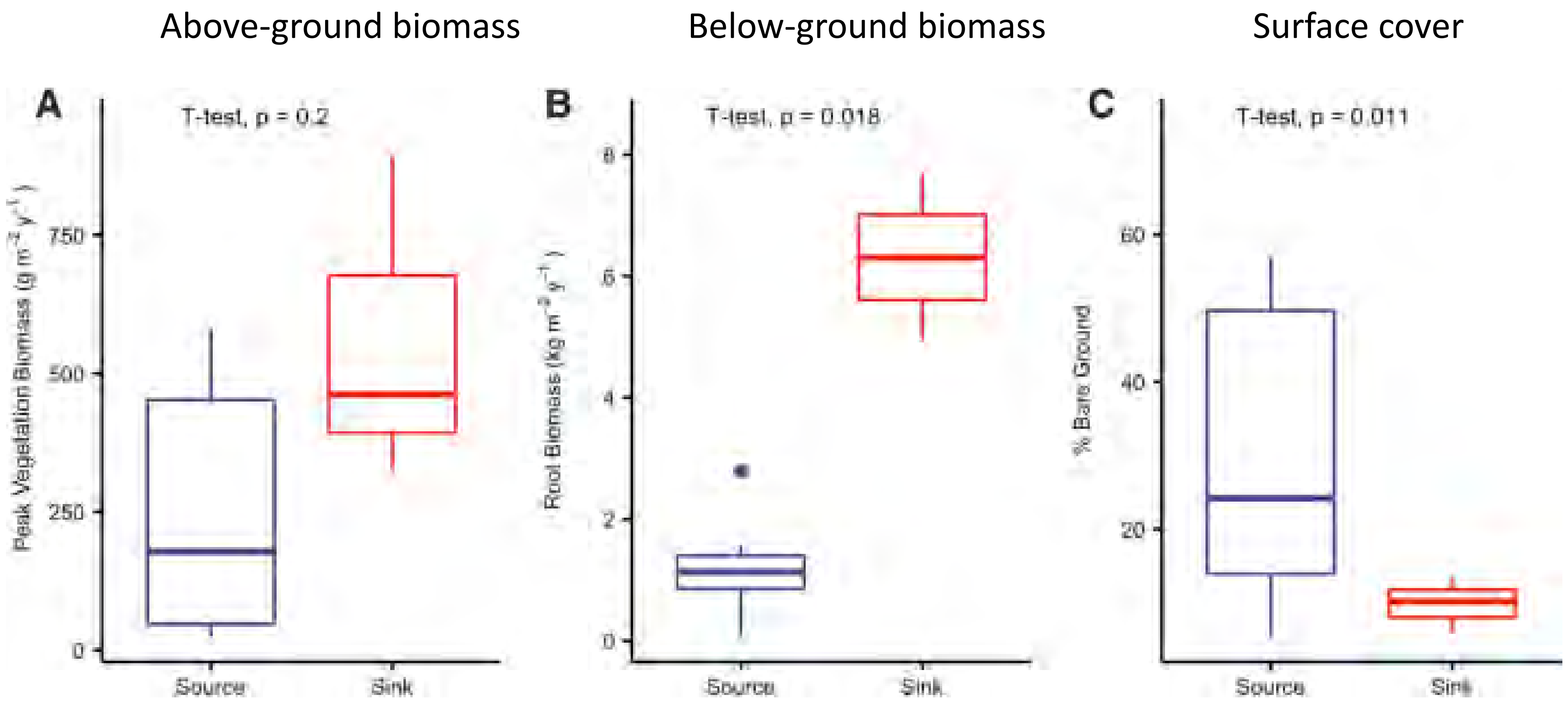
Why are mountain meadows important?

They are groundwater-connected habitats that:

- Retain water
- Attenuate peak flows, extend low flows
- Improve water quality
- Support high biodiversity
- Sequester carbon
- Resist wildfire

Briggs et al. 2013, Dauwalter & Walrath 2018, Hood & Bayley 2008, Naiman et al. 1986, Pollock et al. 2014, Wegener et al. 2017, Reed et al. 2020, Fairfax and Whittle 2020.

Meadows as Carbon sources or sinks?

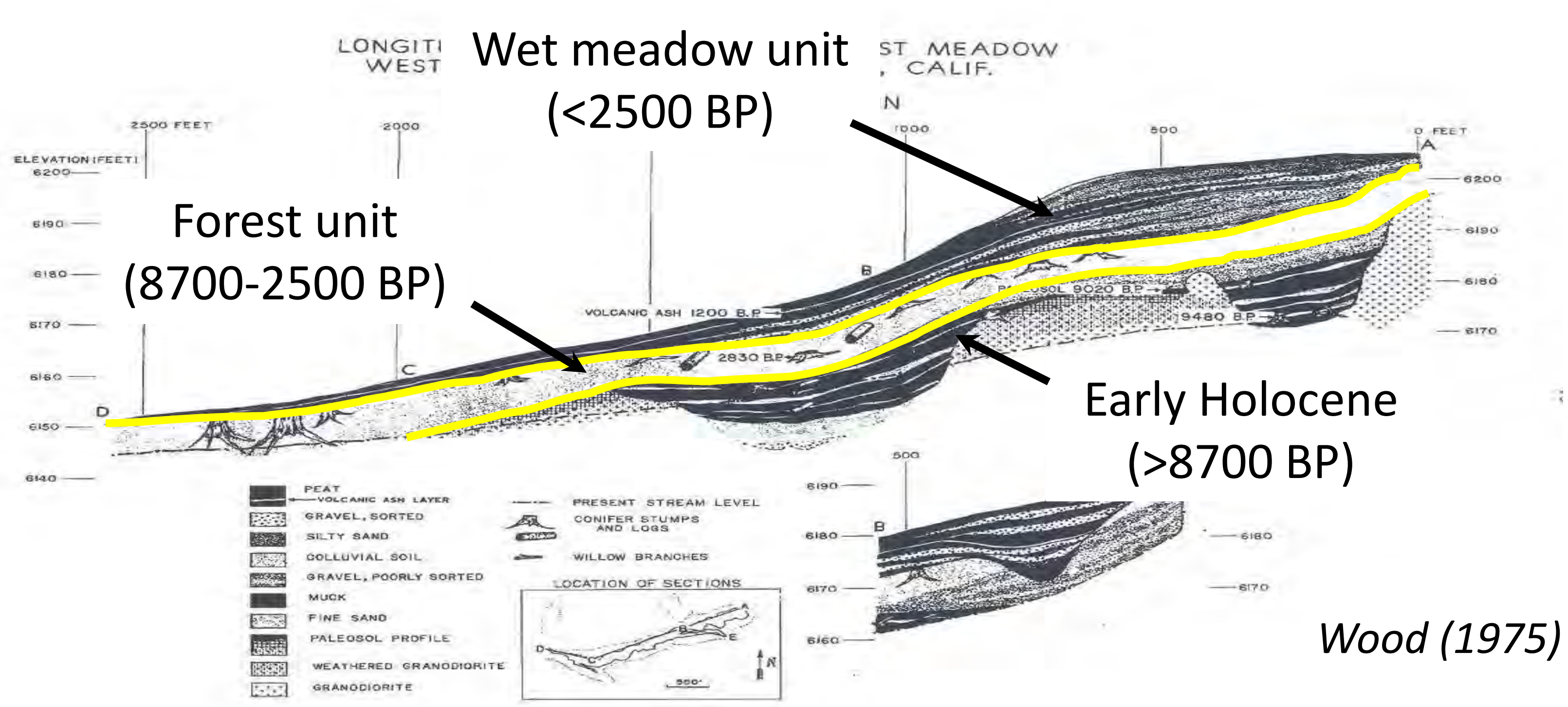


Reed et al., 2020. Montane Meadows: A Soil Carbon Sink or Source?

Current conditions in the Sierra Nevada

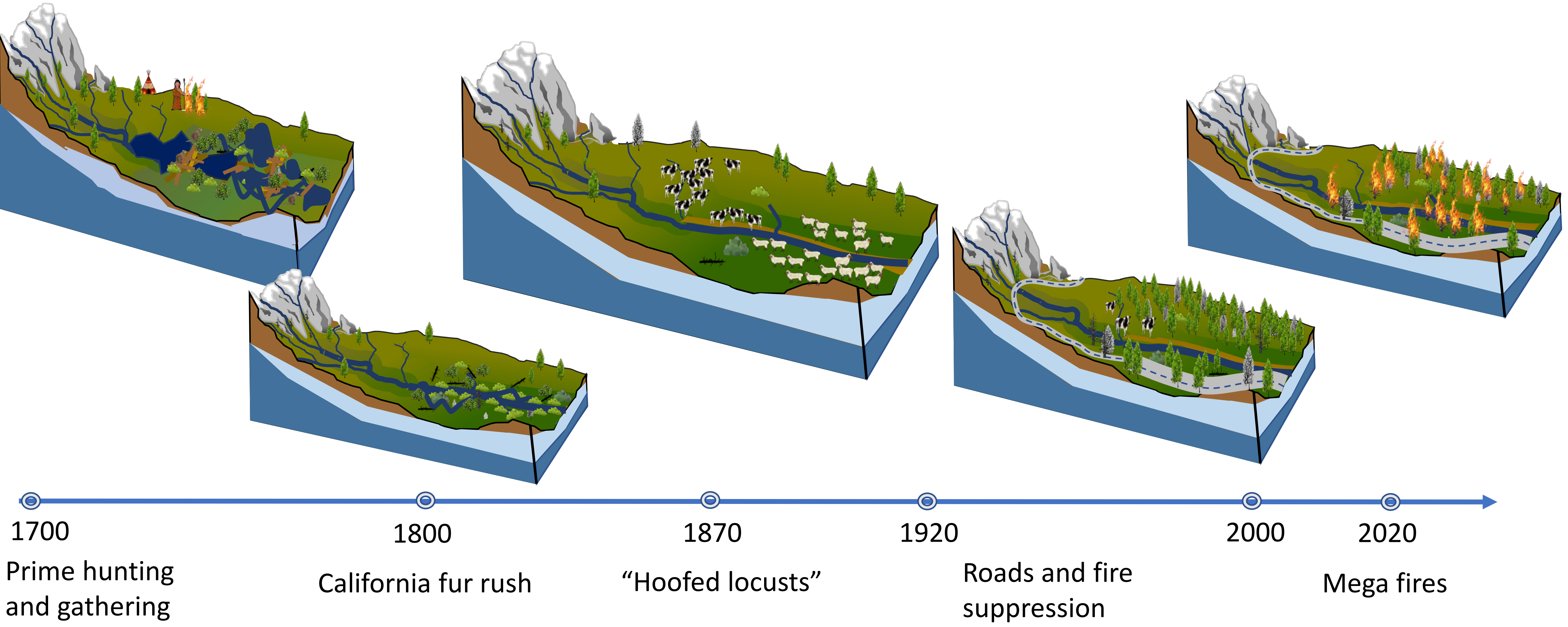
- 50-80% of >20,000 meadows are in a degraded state.
- Meadows make up 1-6% of a watershed's area.
- Median size is 3 acres and mean is 15 acres.

History of Meadows: Formation

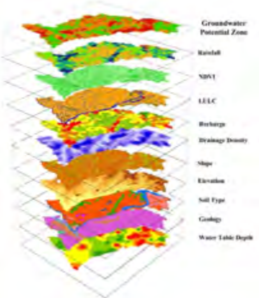


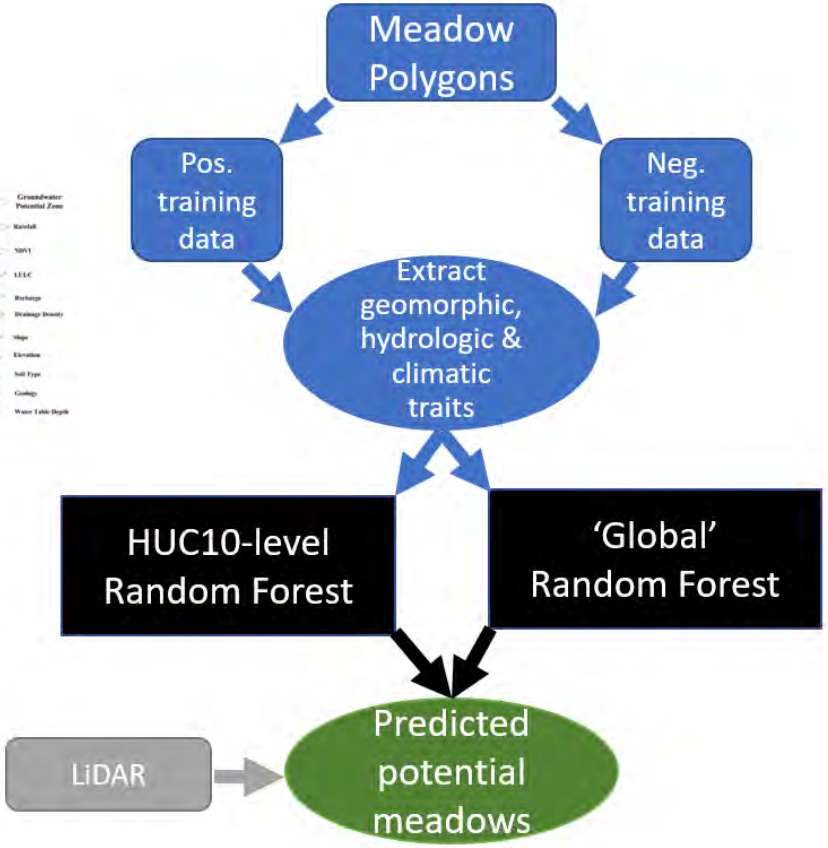
1. Groundwater dependent
2. Stable habitat
3. No evidence of gullying

History of Meadows: Degradation

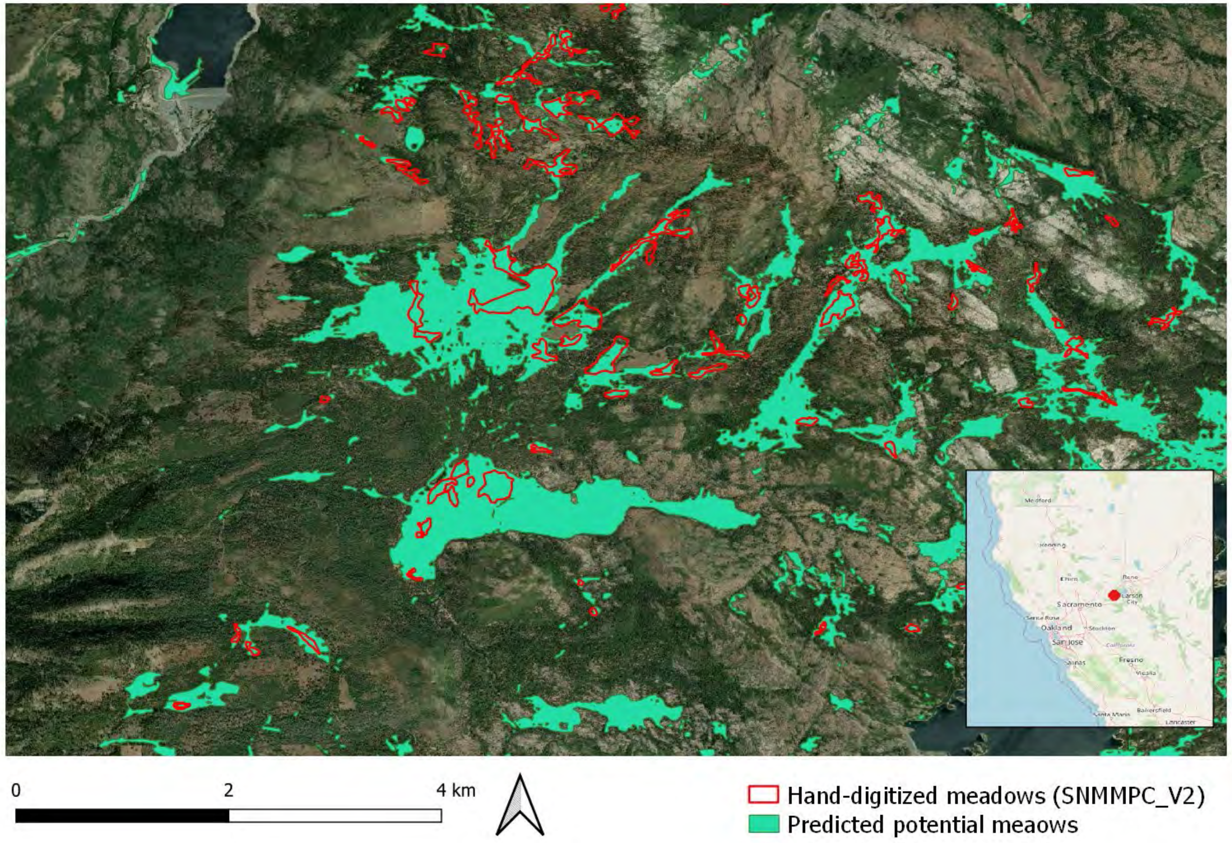


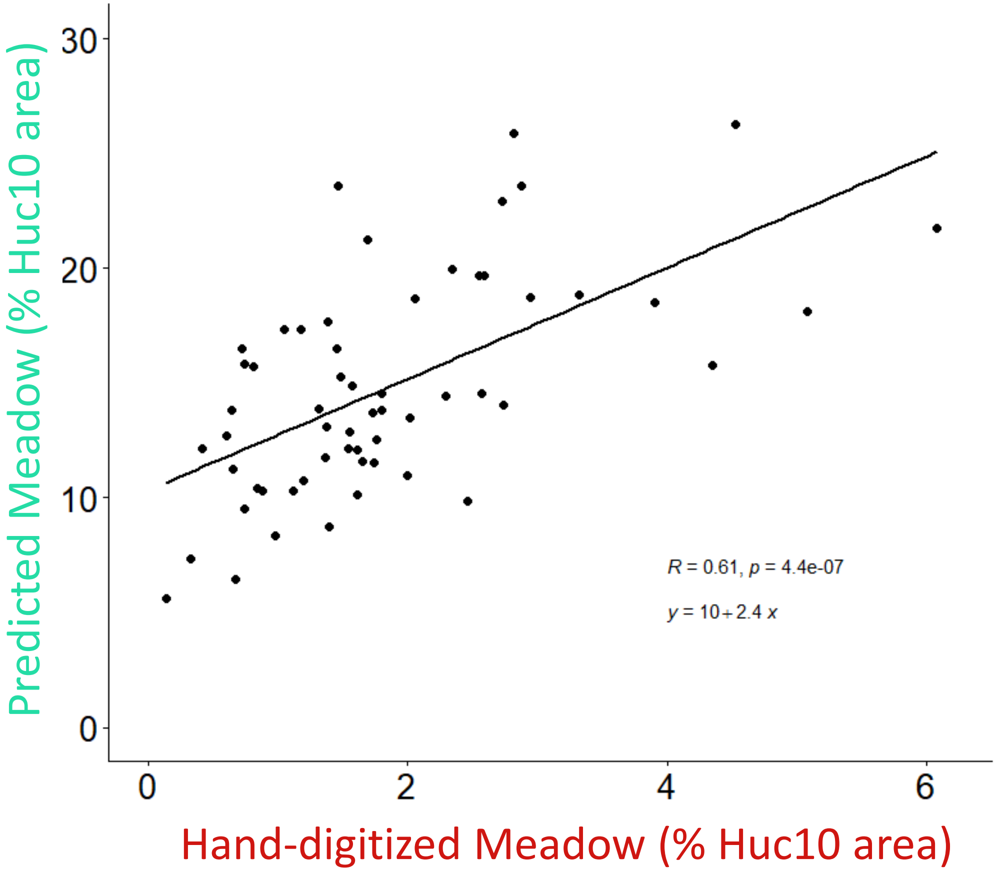
We have the tools to envision the potential





Reset the baseline to envision the potential

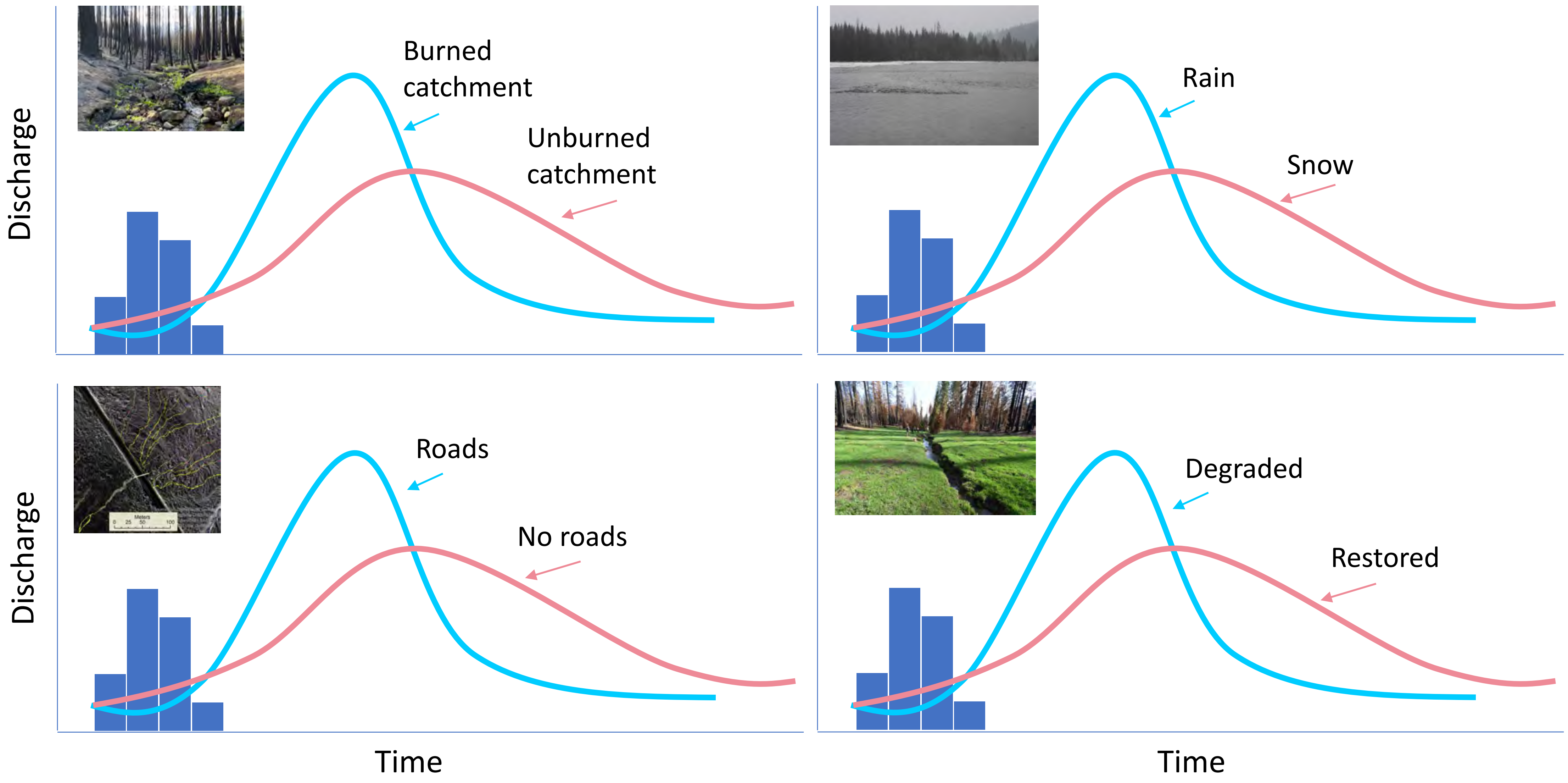





Maxar


It’s time to start keeping the water in the forest

Forest Hydrology



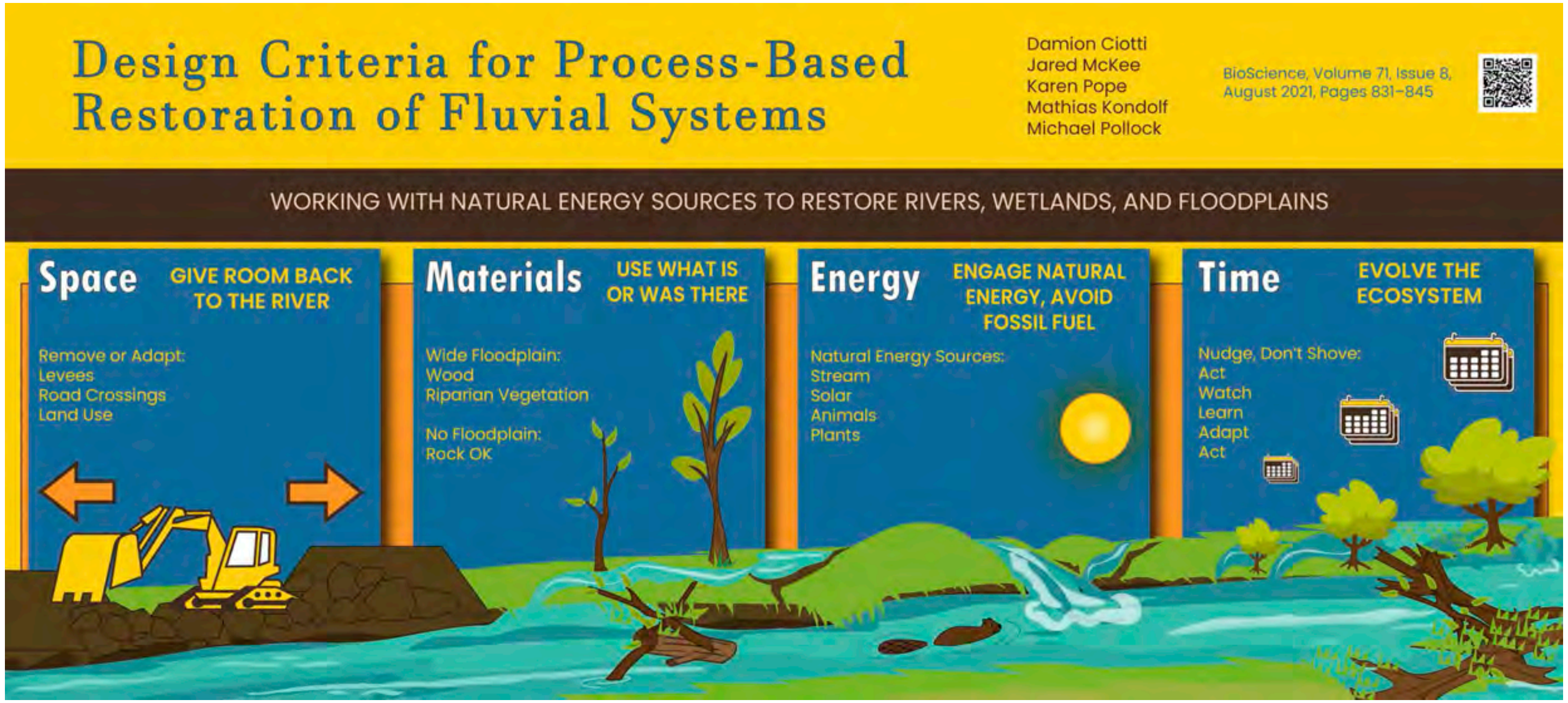
Wildfire: Scott 1997; Moody et al. 2008; Leopardi & Scorzini 2015; Kean et al. 2016; Havel et al. 2018; Srivastava et al. 2018; Williams et al. 2022. **Roads**: Wemple & Jones, 2003; Dymond et al. 2014; Wemple et al. 2016; Surfleet & Marks 2021. **Climate**: Sui & Koehler 2007; Bavay et al. 2008; Perkins & Jones 2008; Sui et al. 2010; Hunsaker et al. 2012. **Meadows**: Loheide & Gorelick 2007; Moore et al. 2014; Majerova et al. 2015; Ciotti et al. 2021.


Nature’s answer

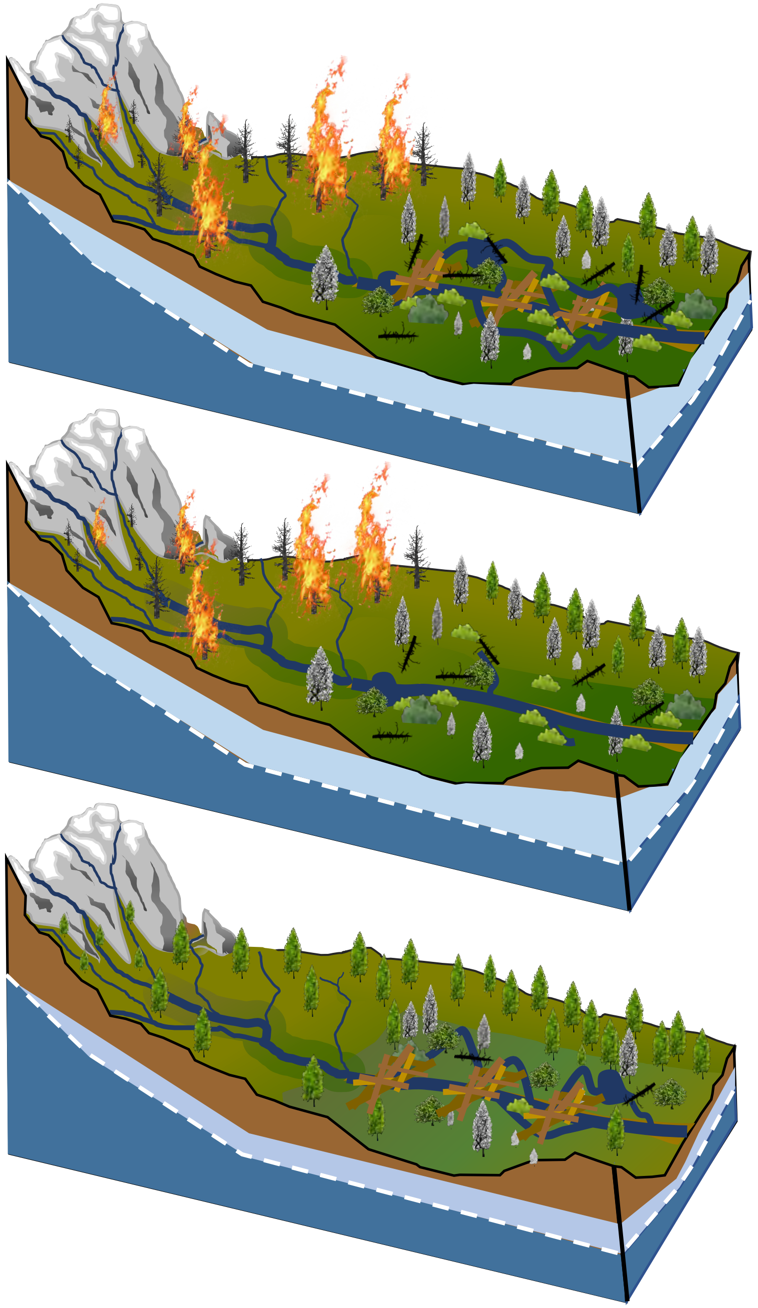
Application of beaver-based restoration

- Partner with natural processes
- Address sources of degradation
- Add complexity to slow and spread flow

Ciotti et at. 2021. BioScience



Act strategically



Meadow Restoration Experiment
2021-2023

- Sediment budget
- Surface water hydrology
- Ground water elevation
- Water quality
- Ecological change

Build capacity

- Cal PBR Network – Mission: *Promote process-based restoration approaches to increase the capacity of degraded river and stream ecosystems to retain water, support biodiversity, create fire resiliency, and adapt to climate change.* (***calpbrnetwork.org***)
- Involve local communities

Conclusions

Meadows were bigger, more plentiful, and more complex than they are now

Remote sensing and LiDAR help us reset the baseline and reevaluate the potential of these ecological hotspots

Process-based restoration techniques tap into the potential by using natural materials and the system's energy

Acknowledgements

- Gilbert Mak
- Pat Manley
- Dave Weixelman
- UC Davis Meadows Clearinghouse


Questions?

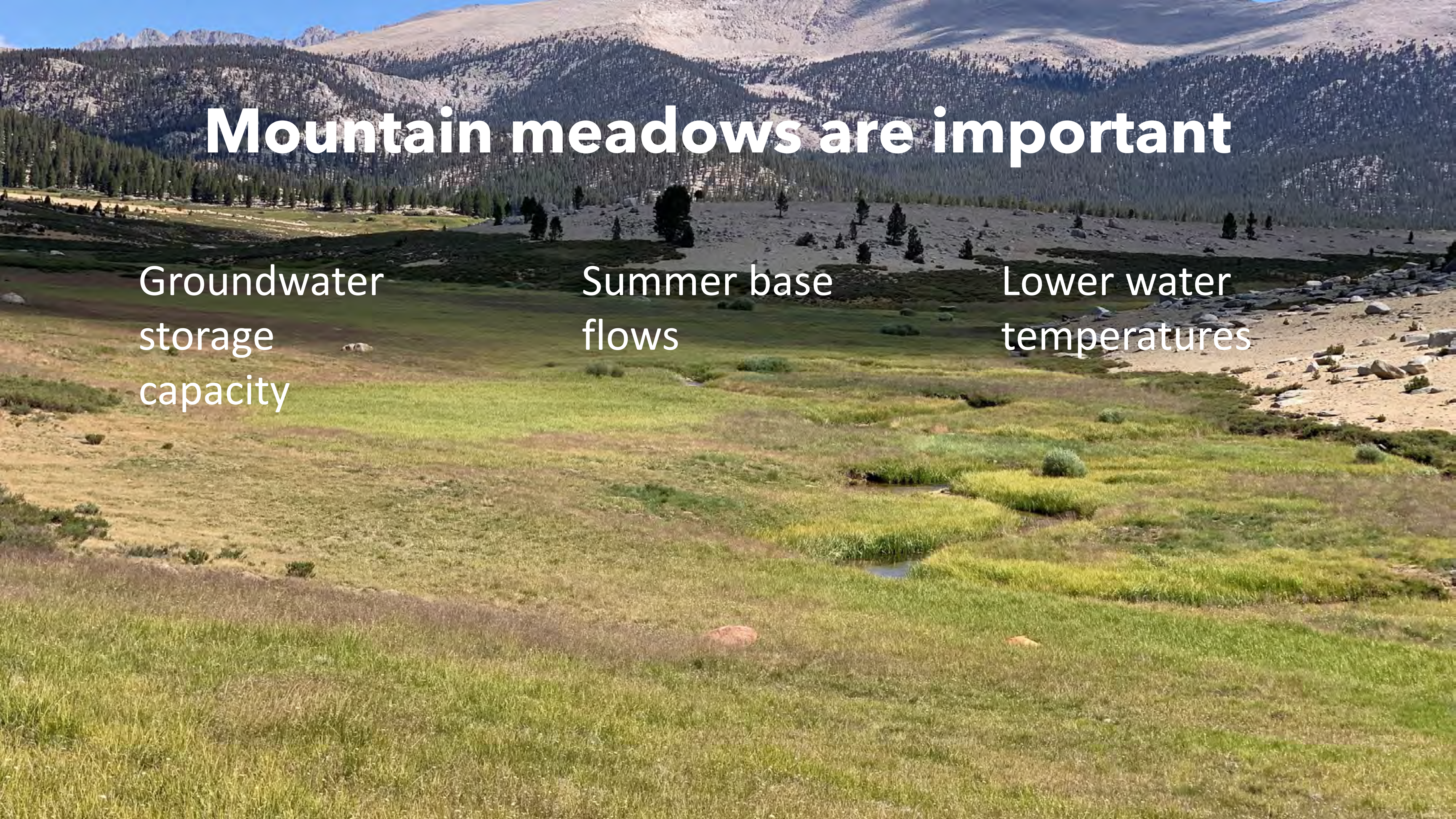
20 years of plant and ecosystem recovery following grazing cessation in the Golden Trout Wilderness

Devyn Orr, Kayla Goldstein, Hugh Safford
United States Department of Agriculture

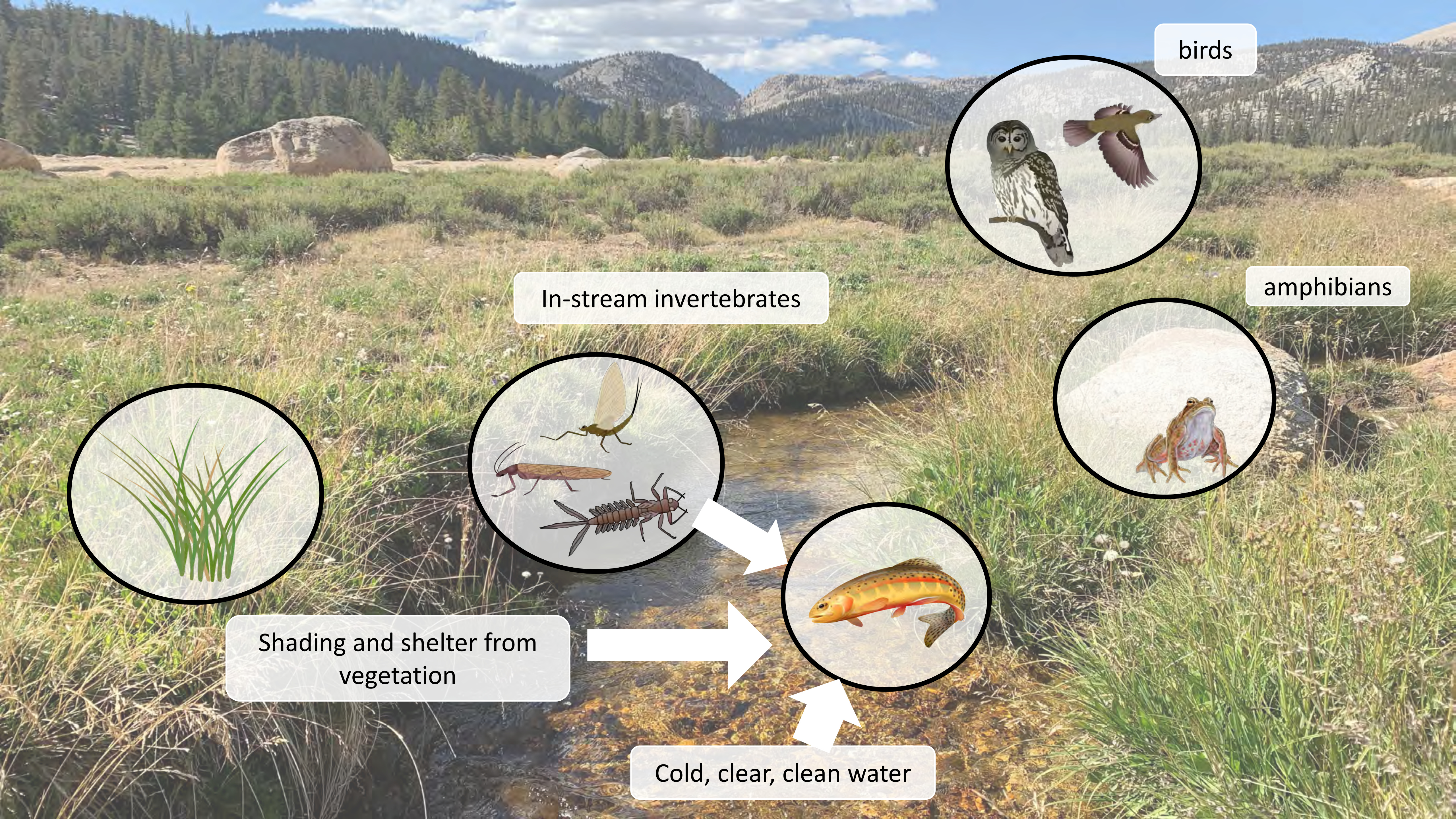
Thank you USDA crews!


Mountain meadows are important

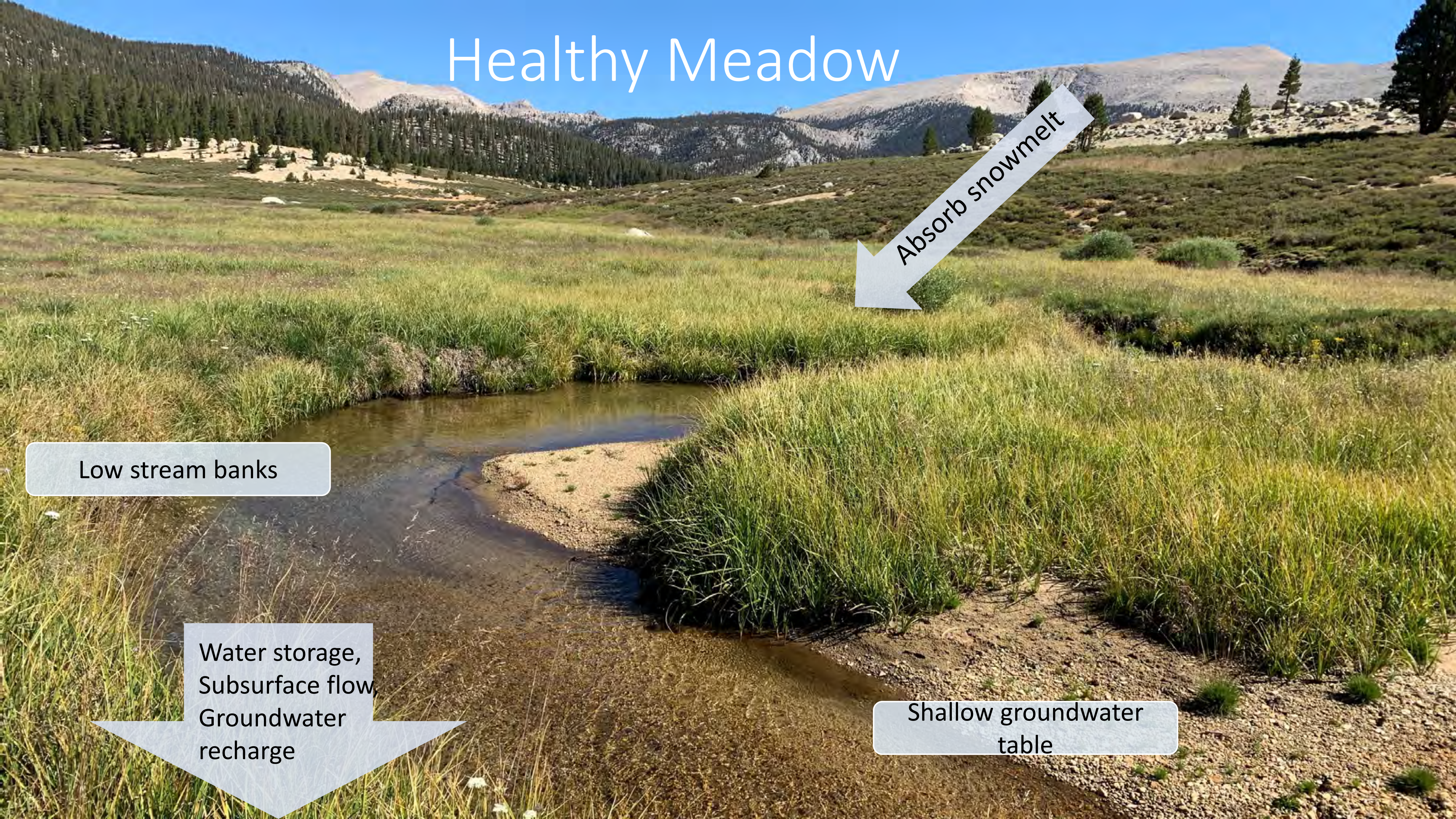

Mountain meadows are important


Mountain meadows are important
Groundwater storage capacity
Summer base flows
Lower water temperatures

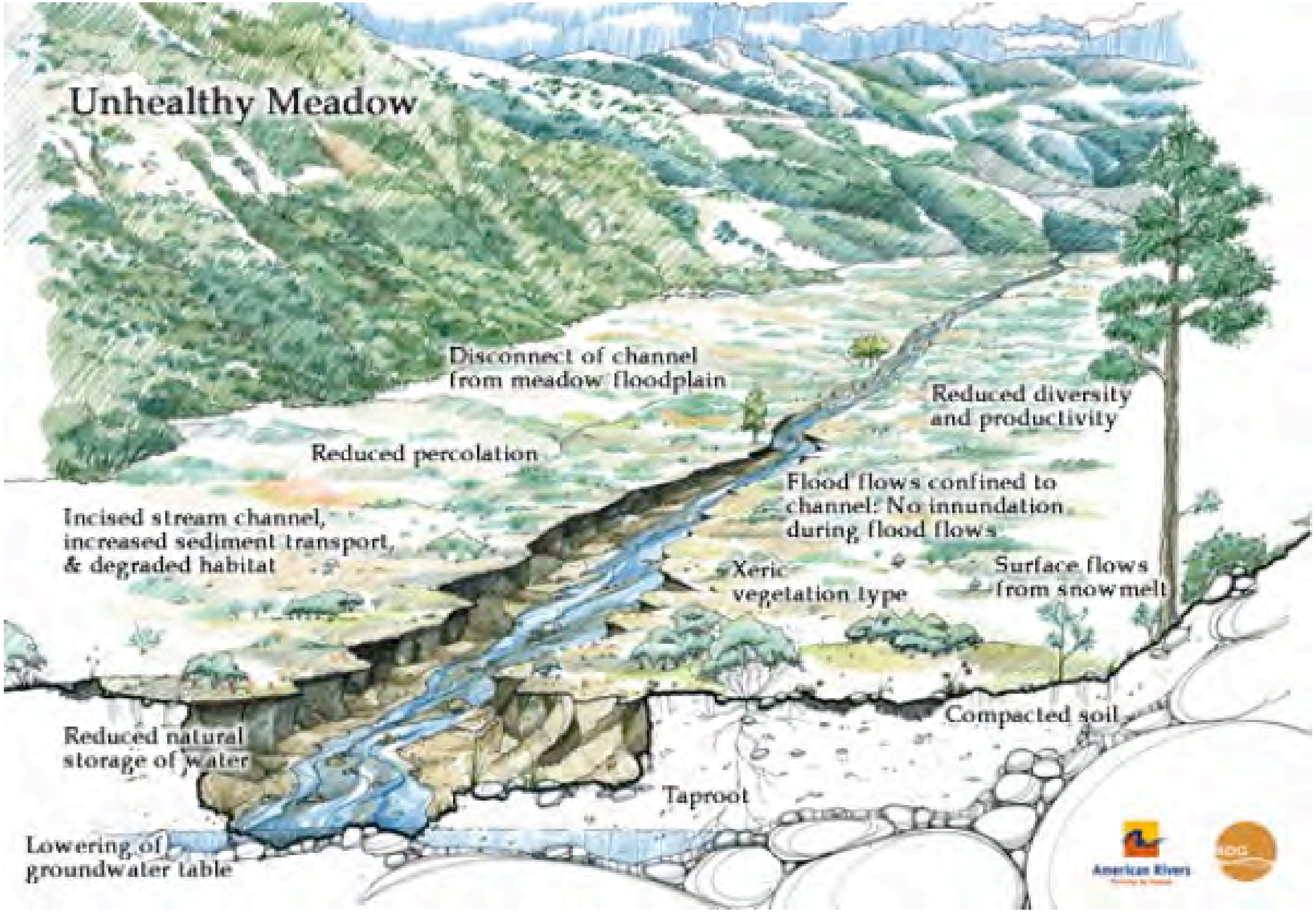

birds
amphibians


birds
amphibians
In-stream invertebrates
Shading and shelter from vegetation
Cold, clear, clean water

Healthy Meadow



Unhealthy Meadow



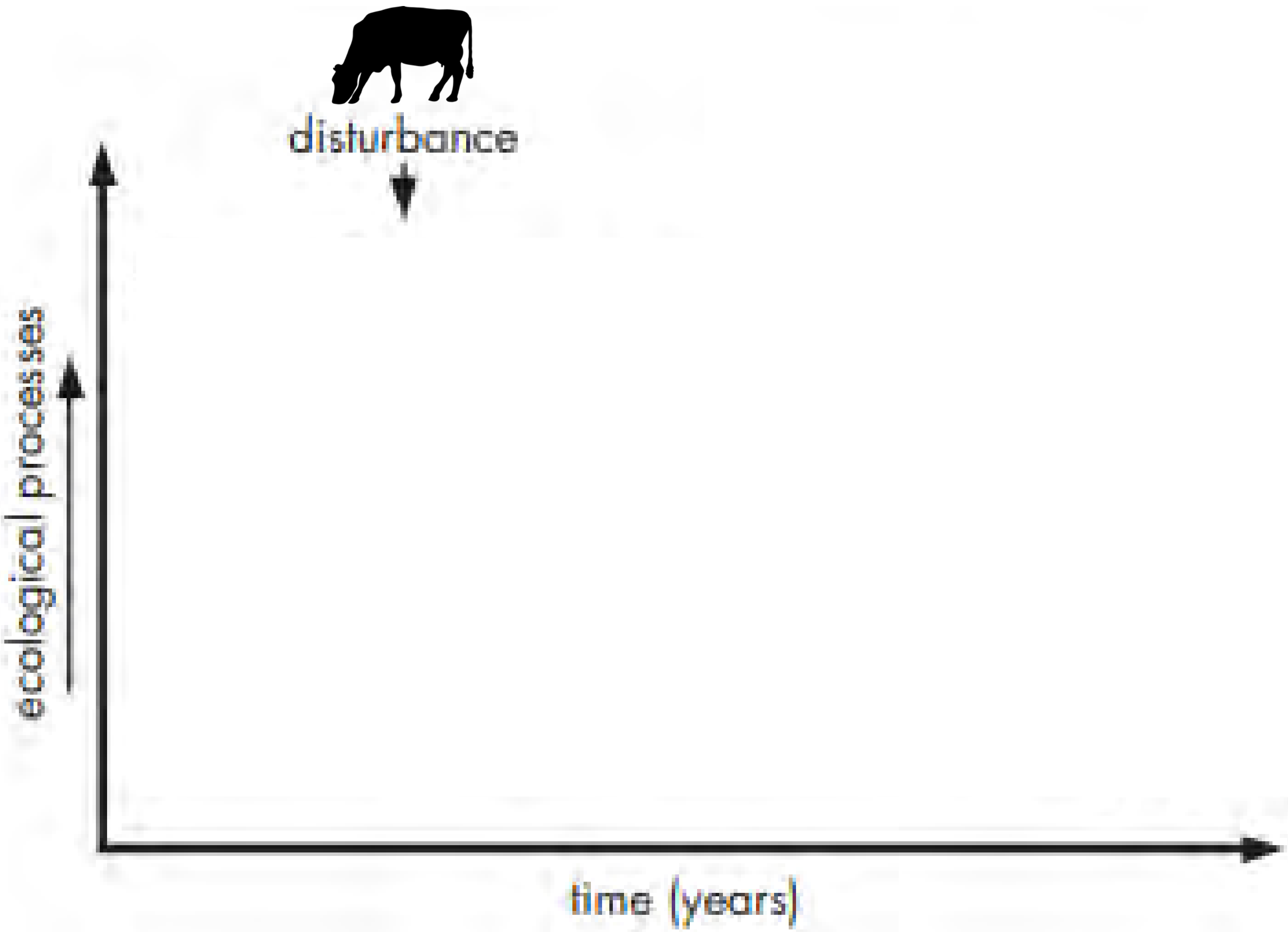
Varied impacts of grazing

- Grazing often negative; however, properly managed grazing is not necessarily detrimental to the environment
- Techniques utilized for minimizing cattle impact to riparian areas include pasture rotation, grazing alternate years, decreased stock levels, and riparian exclosures

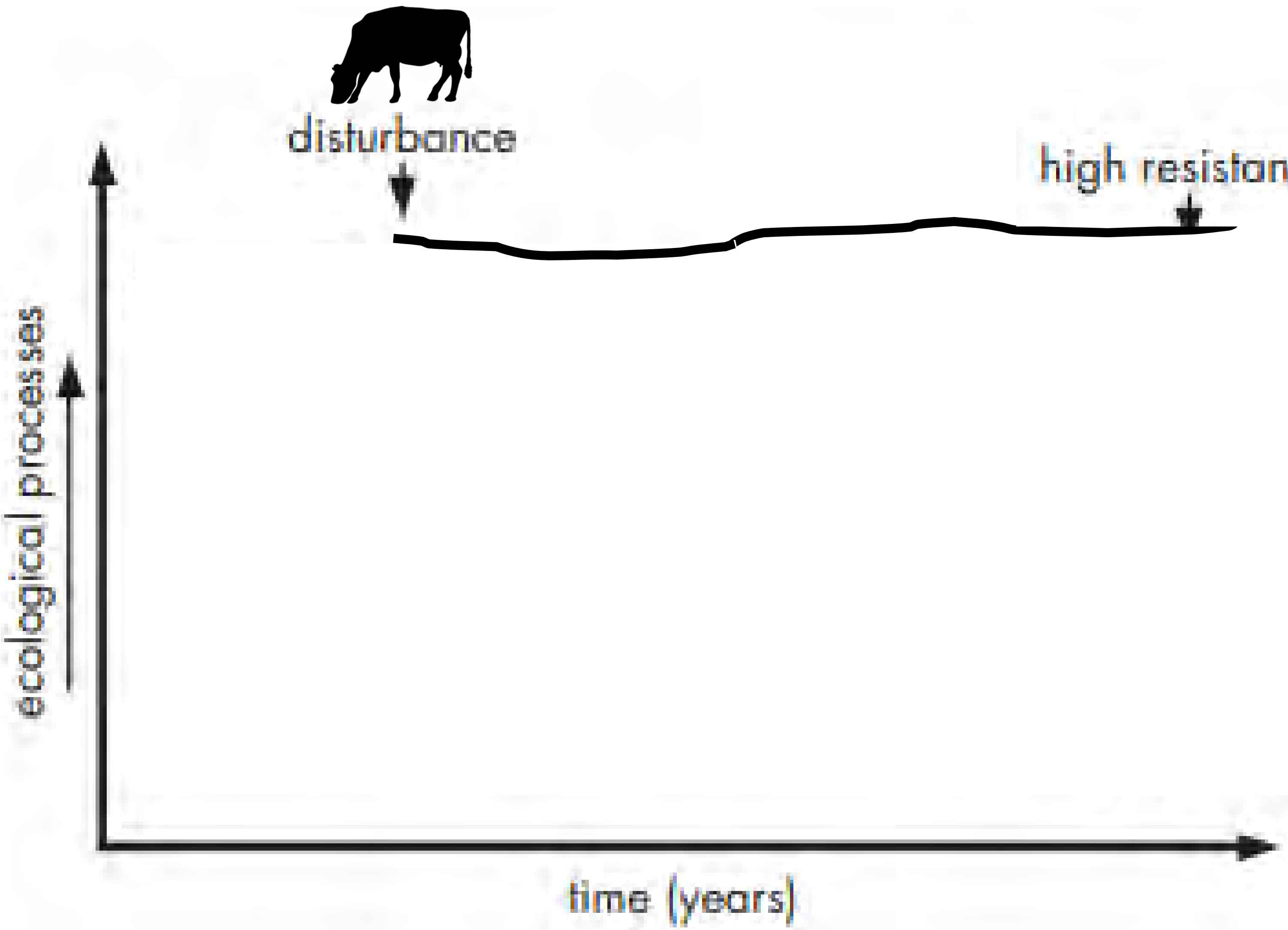
Varied impacts of grazing

- few of these management tools receive pre-post study; many set out only to document patterns associated with overgrazing, rather than quantitative analysis of processes (both degradation and recovery) (Sarr 2002)
- economic interest versus ecosystem health has generated decades of debate; yet, there are relatively few conclusive studies about quantitative effects of grazing (though some vegetation changes are fairly well-documented)

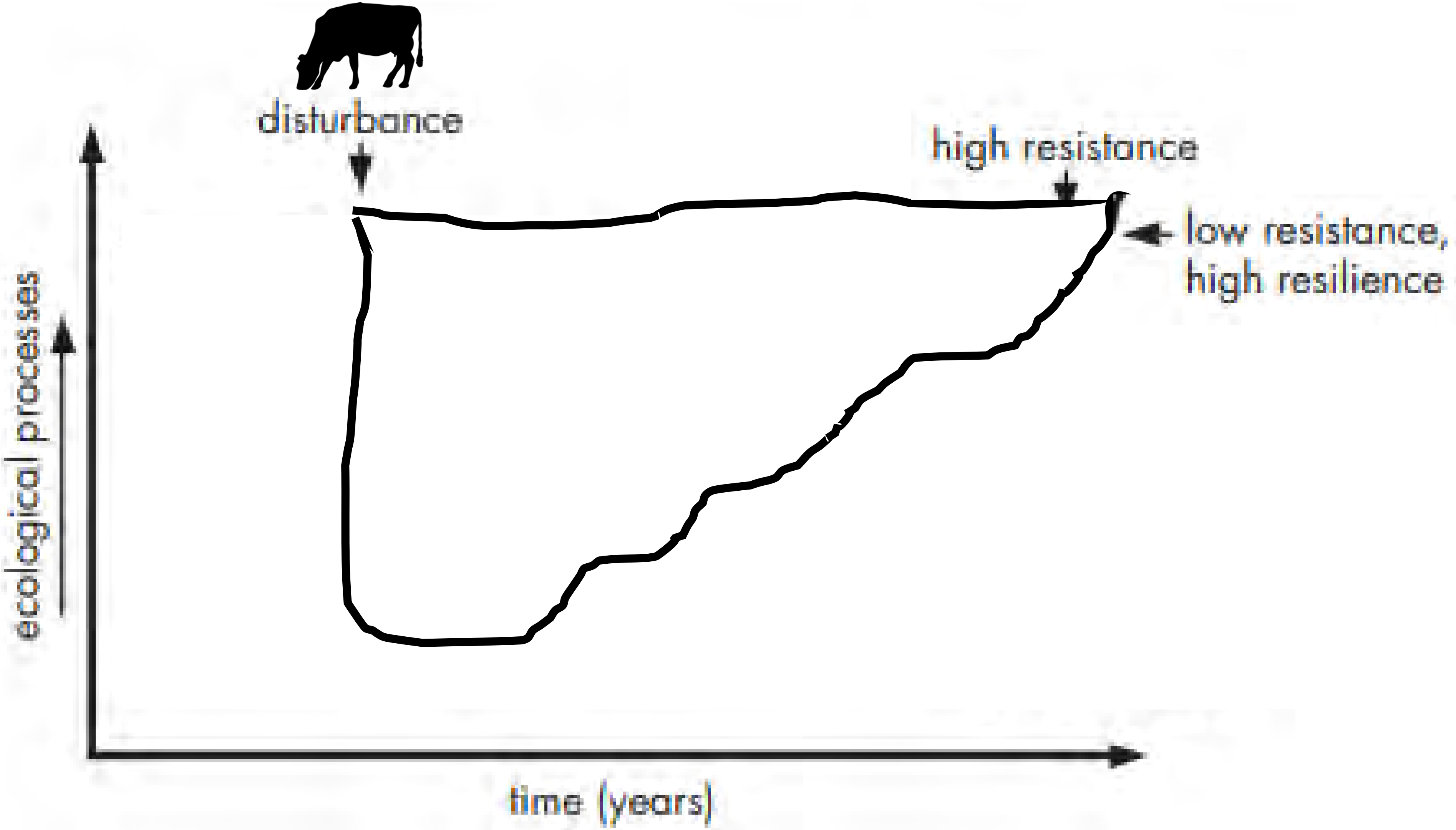
Effects of disturbance on mountain meadows



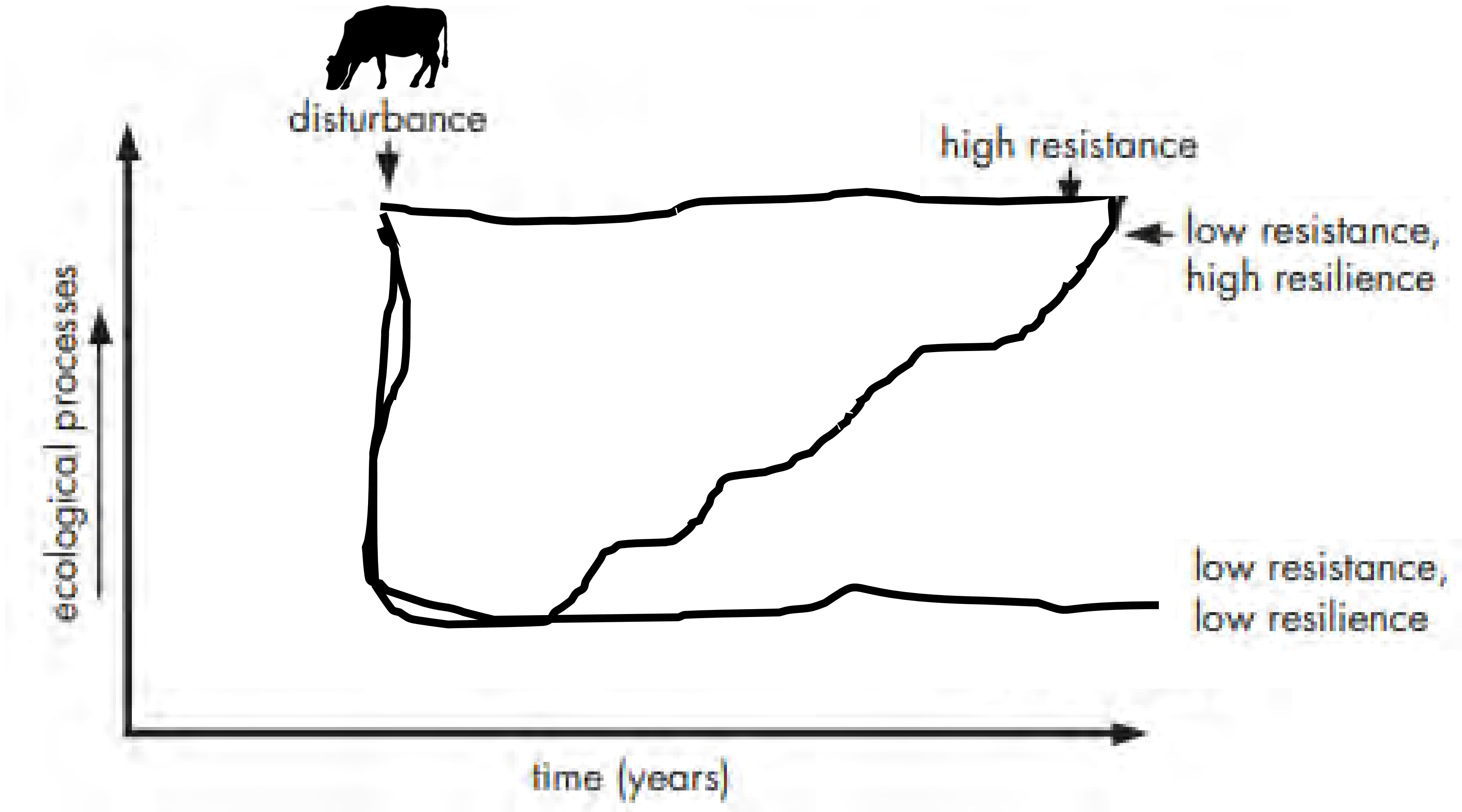
Effects of disturbance on mountain meadows



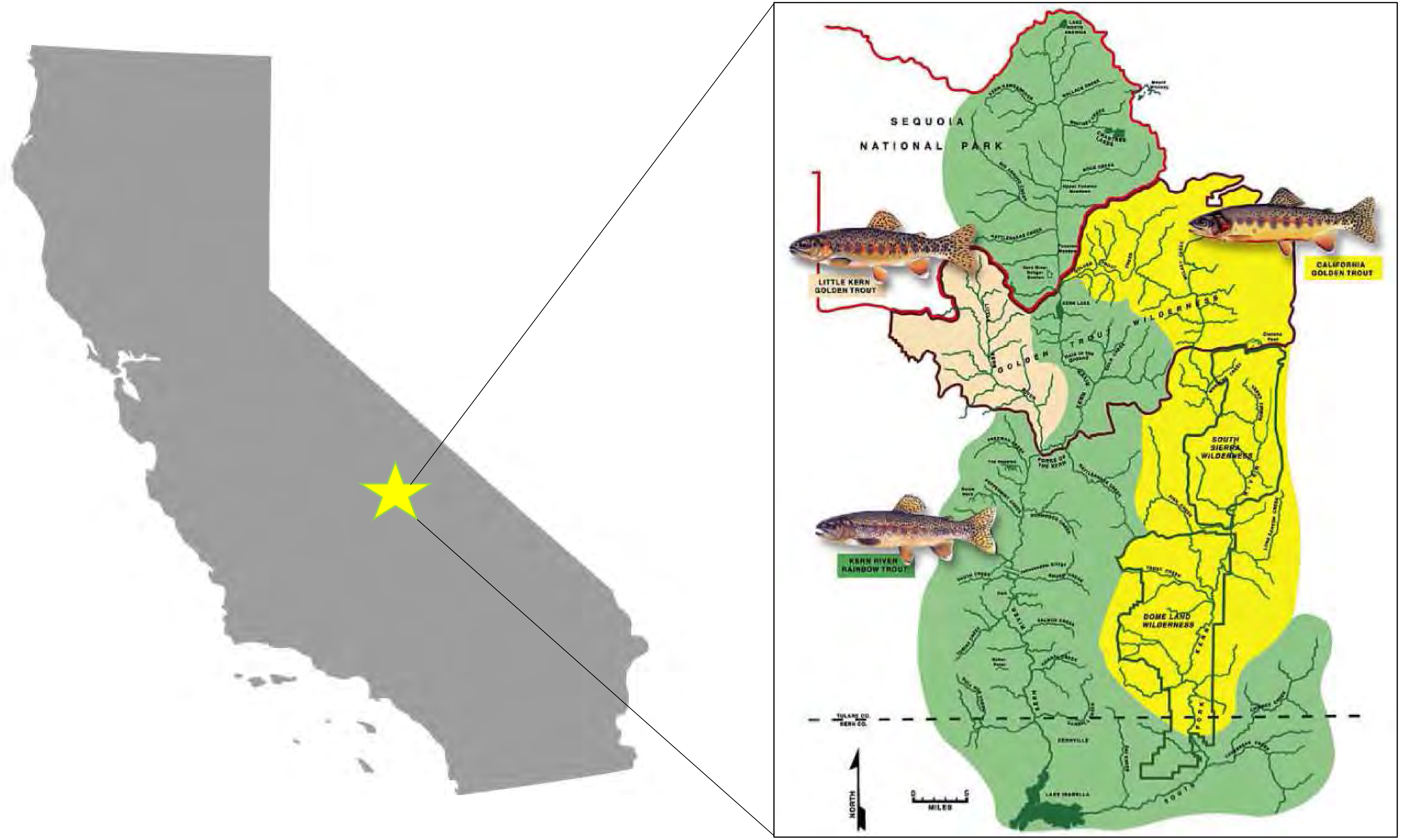
Effects of disturbance on mountain meadows



Effects of disturbance on mountain meadows



Case Study: California Golden Trout (*Oncorhynchus aguabonita*)


SEQUOIA NATIONAL PARK
LITTLE KERN GOLDEN TROUT
CALIFORNIA GOLDEN TROUT
GOLDEN TROUT WILDERNESS
SOUTH SIERRA WILDERNESS
KERN RIVER RAINBOW TROUT
DOME LAND WILDERNESS
TULARE CO.
KERN CO.
NORTH
MILES
LAKE ISABELLA

Should cattle grazing continue in the GTW?

Mulkey

Templeton

Monache

Whitney

1) Is there a difference in meadow vegetation between grazed and rested sites?

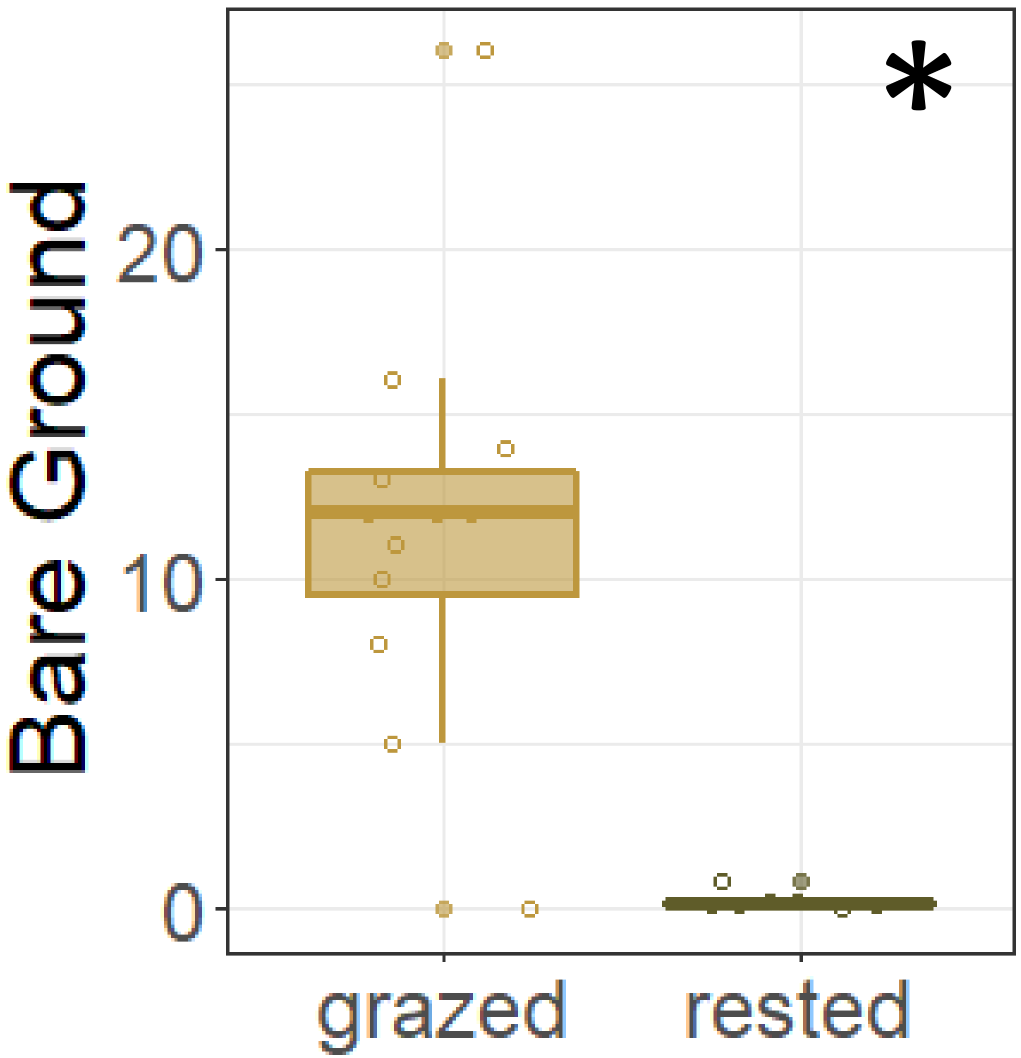
2) Is there a difference in ecological condition and hydrology between grazed and rested sites?

Monitoring Methods

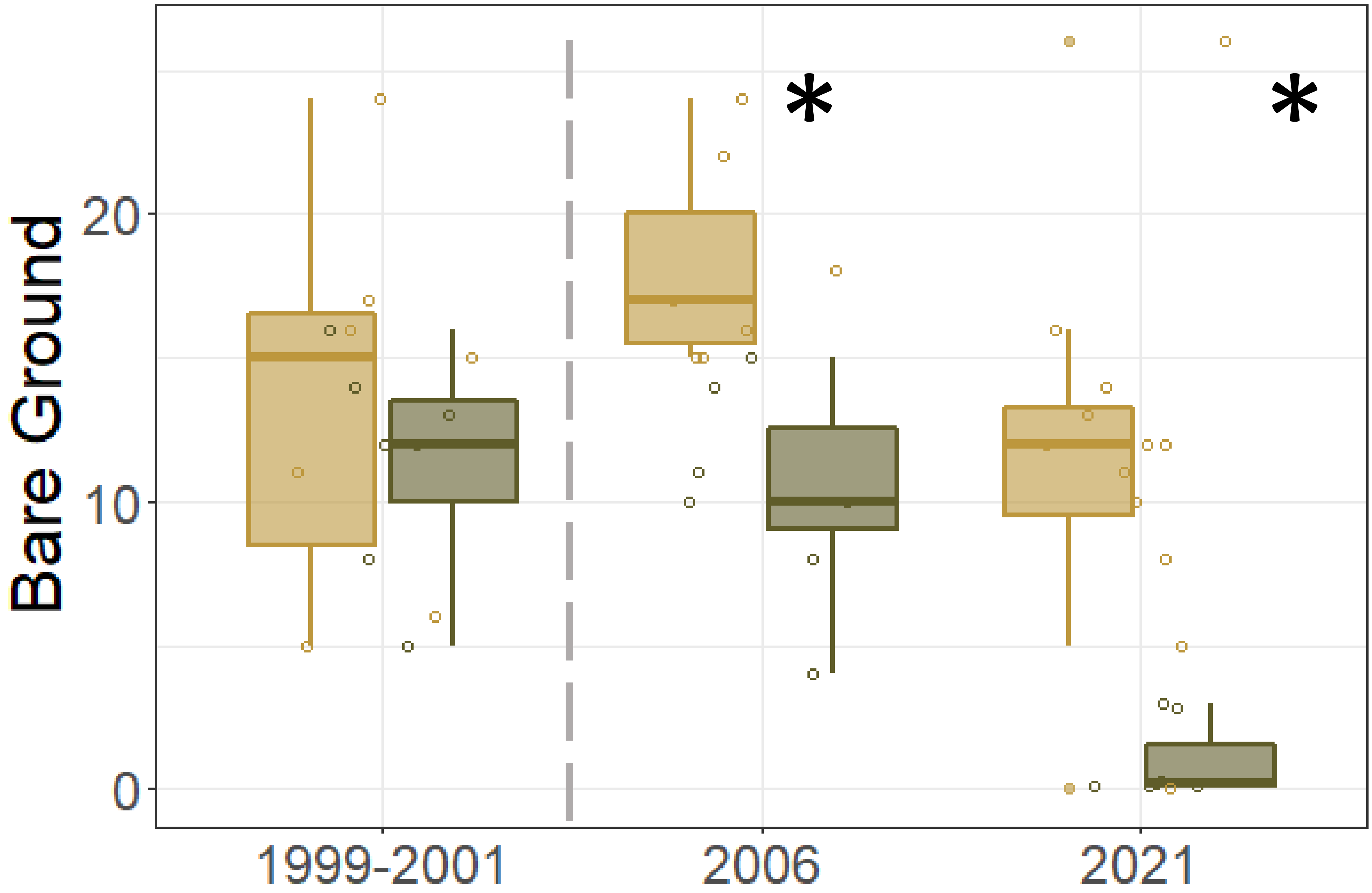
Monitoring Responses

Plant community:
species richness
species evenness
Community dissimilarity & trajectory
Seral status
Functional group

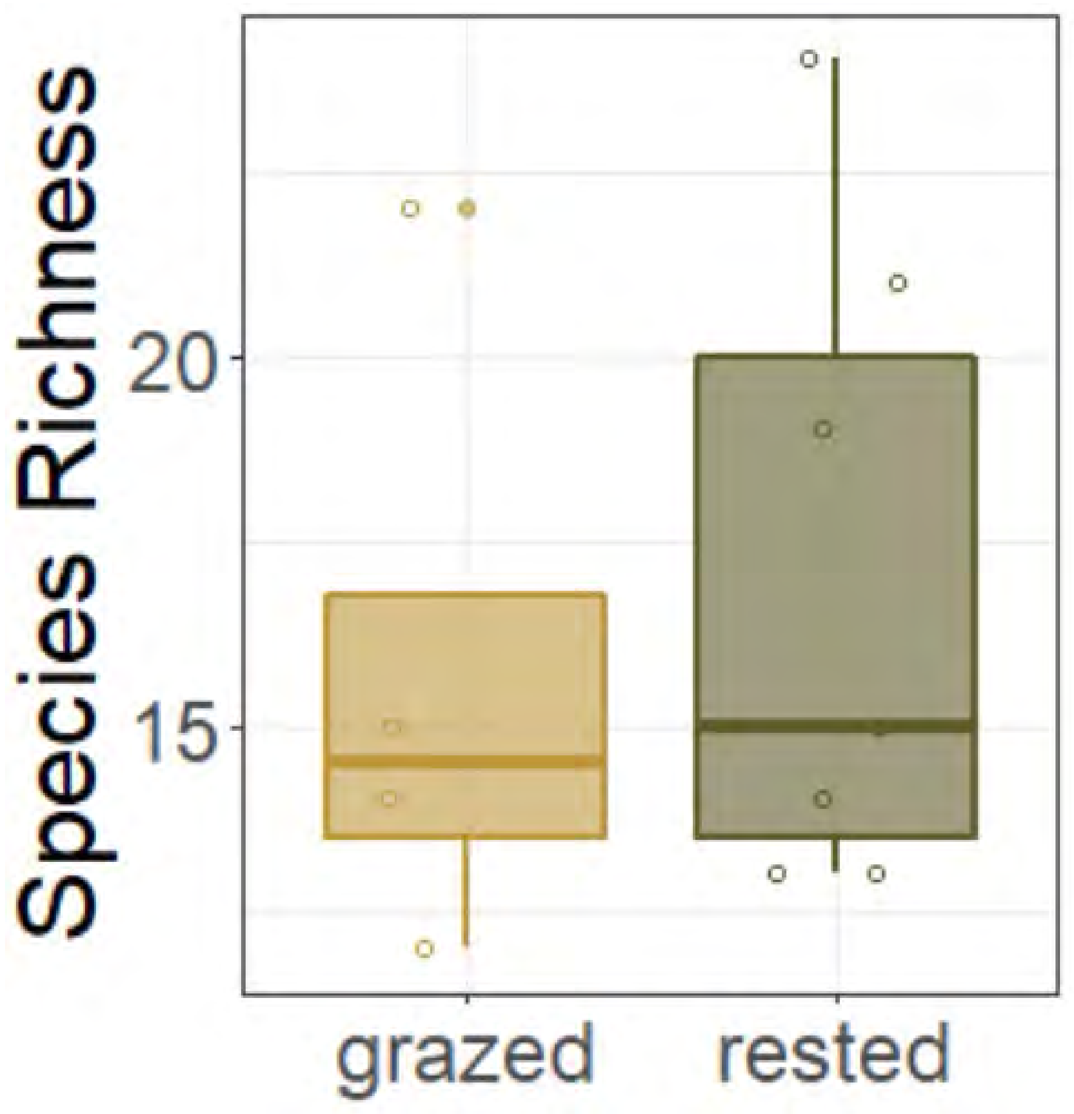
Ecological condition:
plant rooting depth (soil compaction & seral status)
Mottling depth (meadow hydrology)
depth to soil saturation (meadow hydrology)
Bare soil
NDVI (productivity)

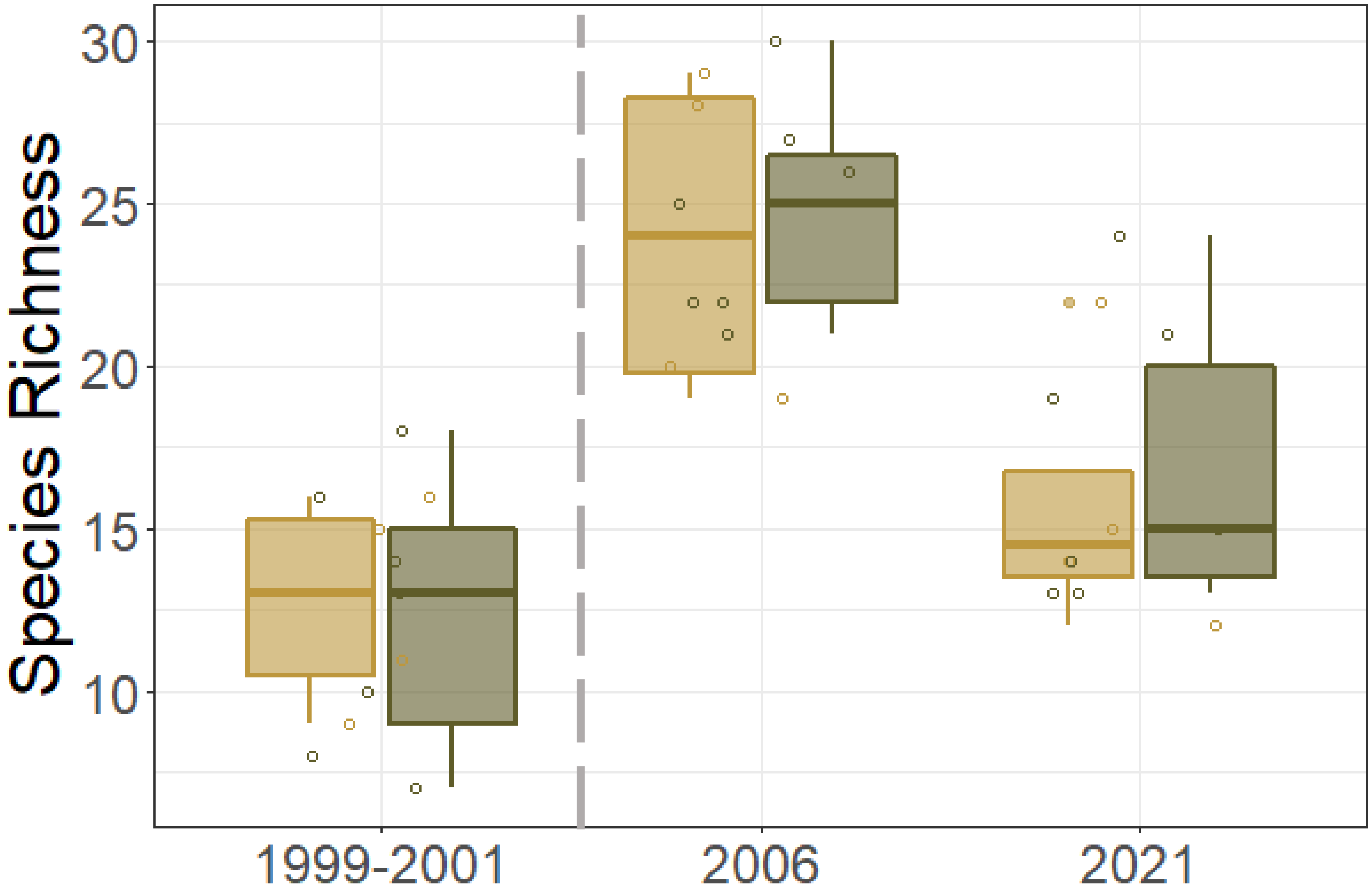


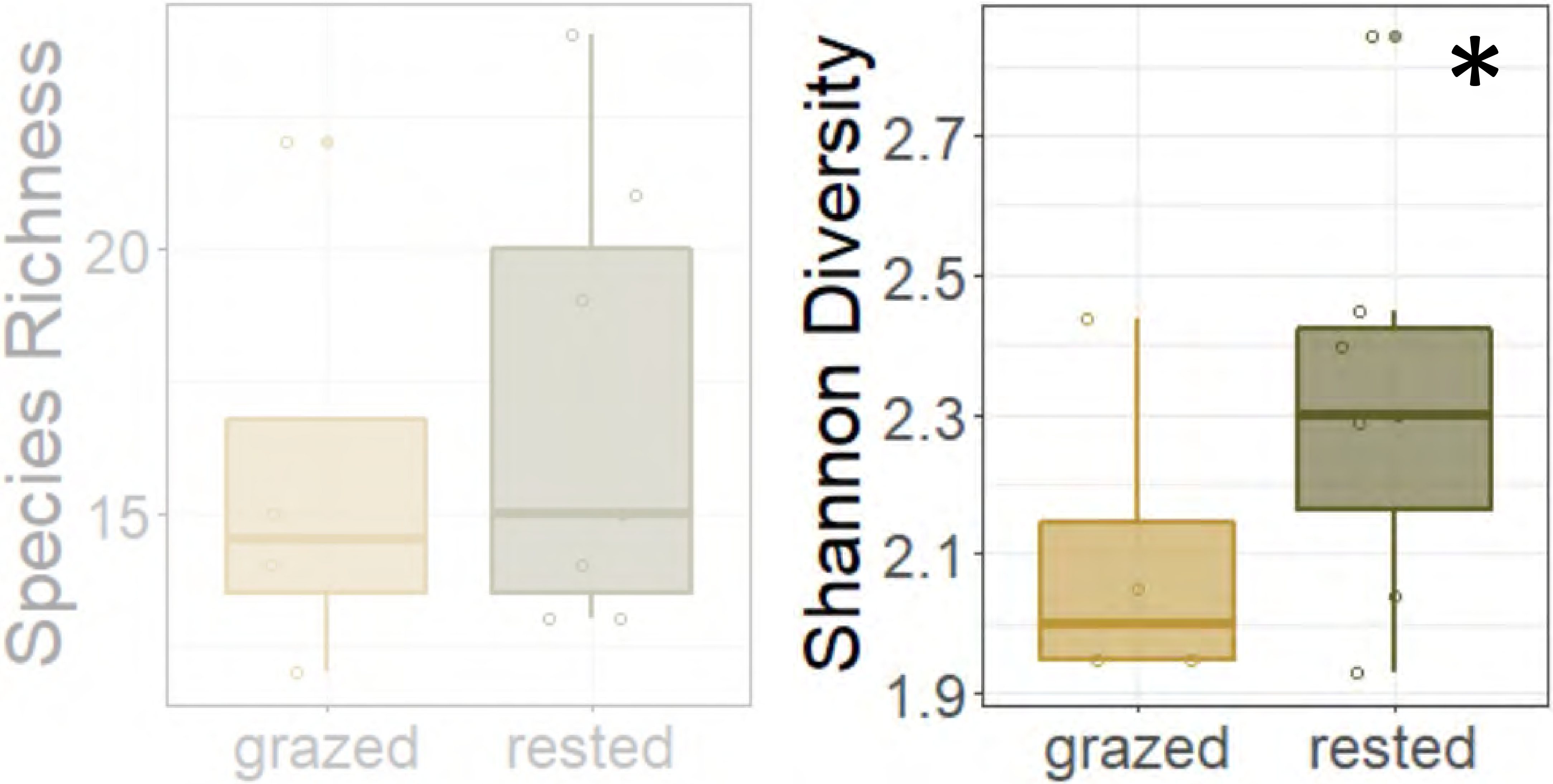
*
Bare Ground
20
10
0
grazed
rested



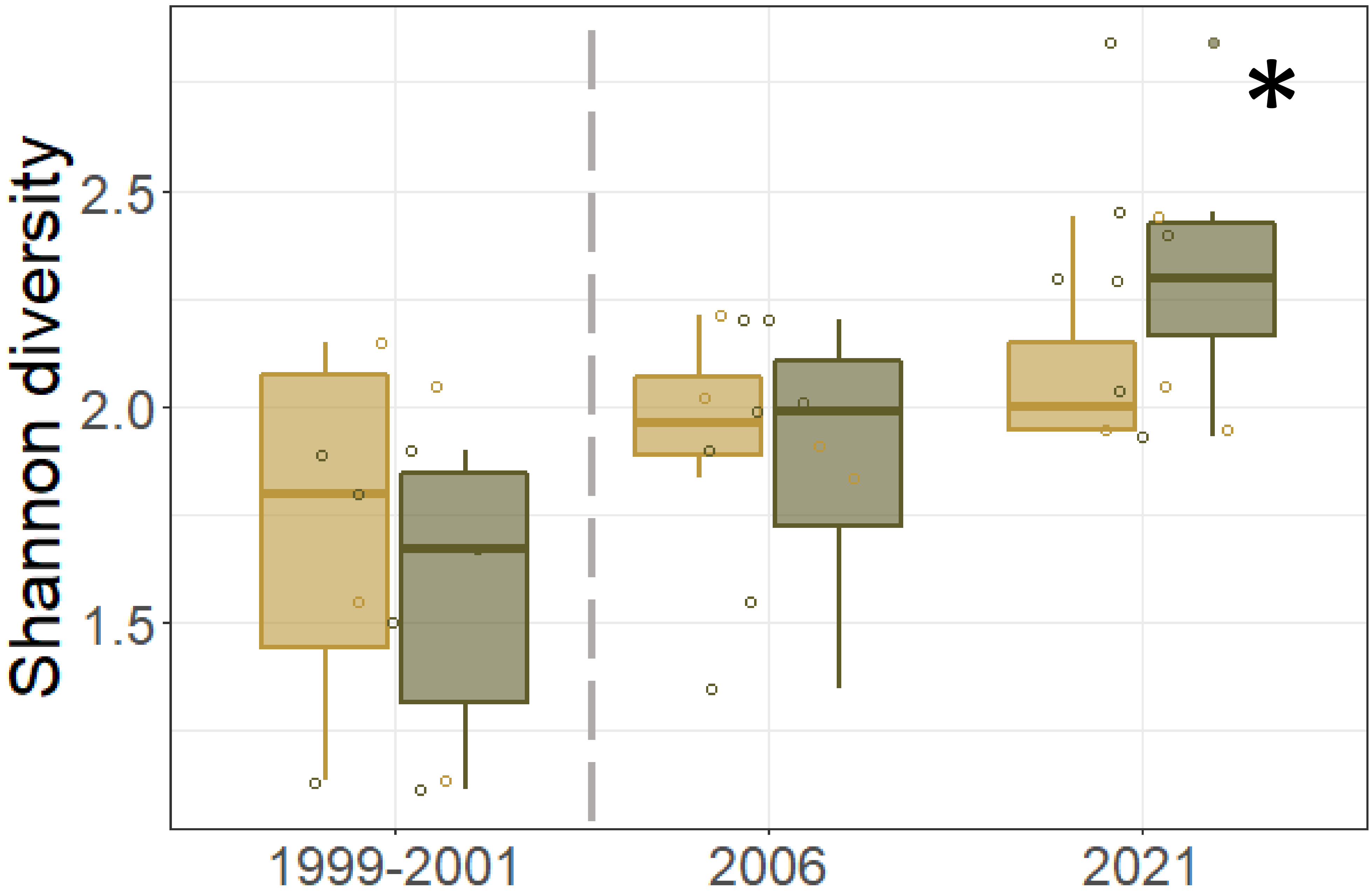
Bare Ground
20
10
0
1999-2001
2006
2021
*
*


Species Richness
20
15
grazed
rested

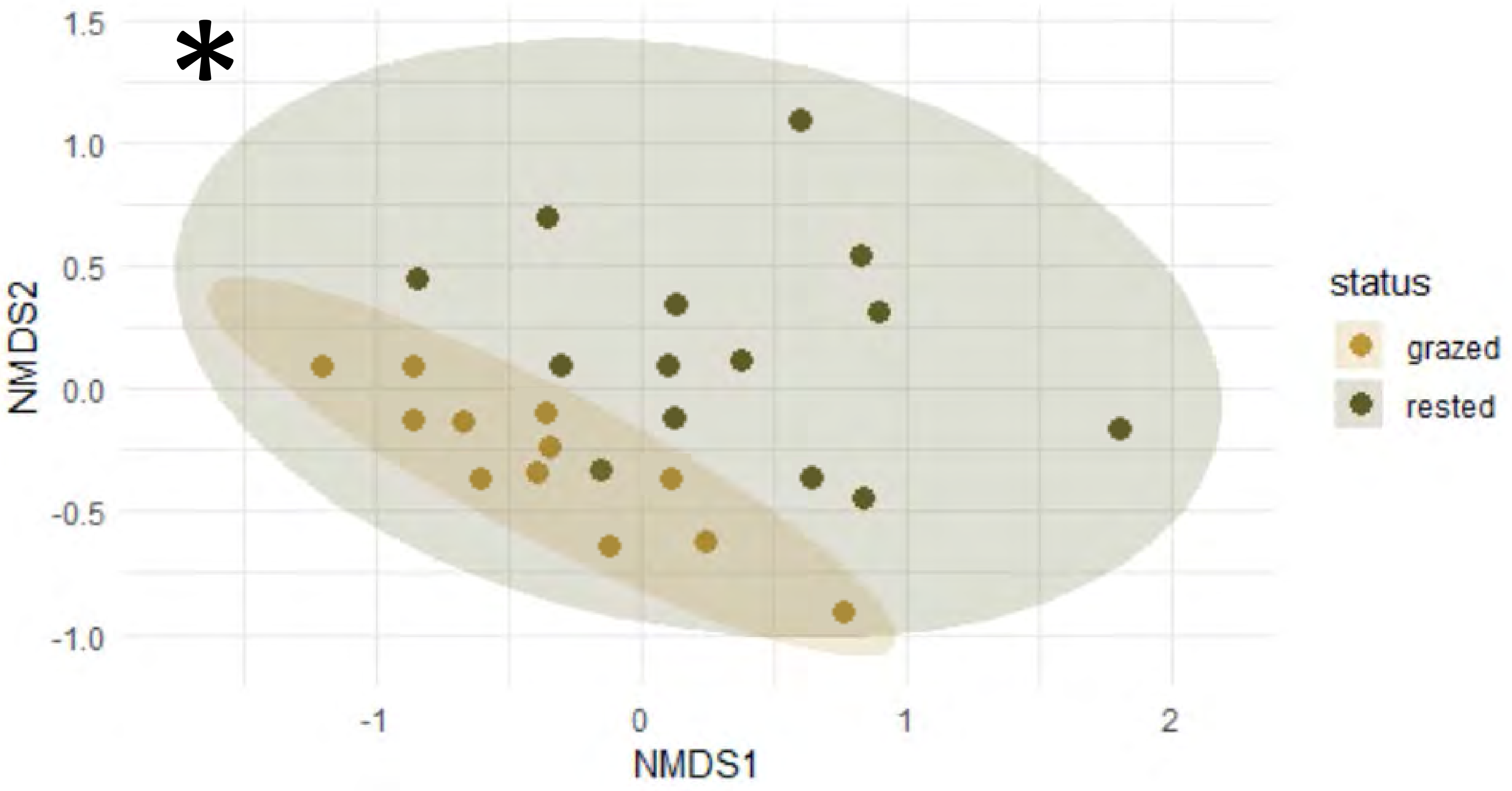

Species Richness
30
25
20
15
10
1999-2001
2006
2021



Species Richness
20
15
grazed
rested
Shannon Diversity
2.7
2.5
2.3
2.1
1.9
grazed
rested
*


Shannon diversity
2.5
2.0
1.5
1999-2001
2006
2021
*

Grazed meadows contain a subset of species found in rested meadows



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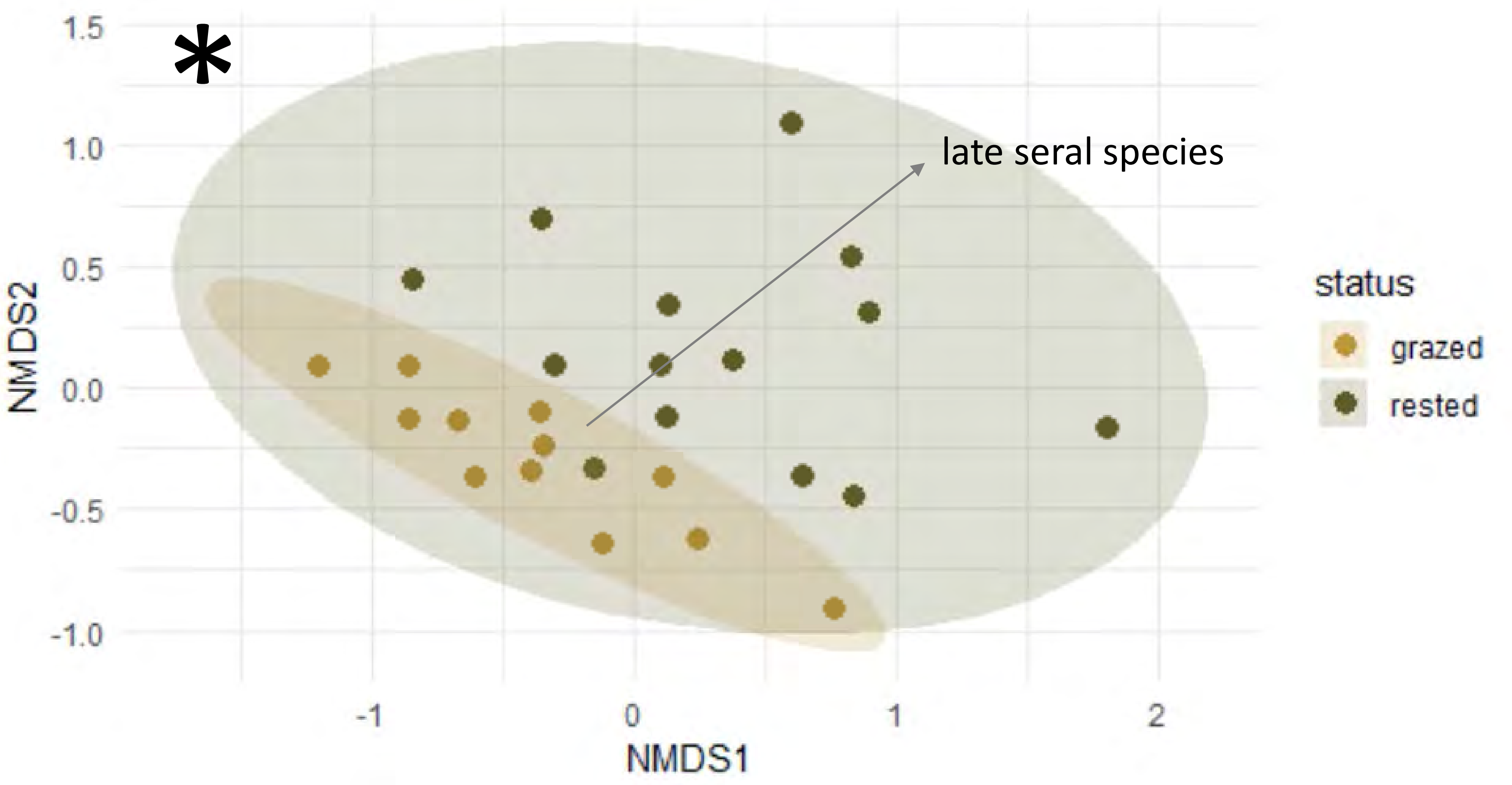
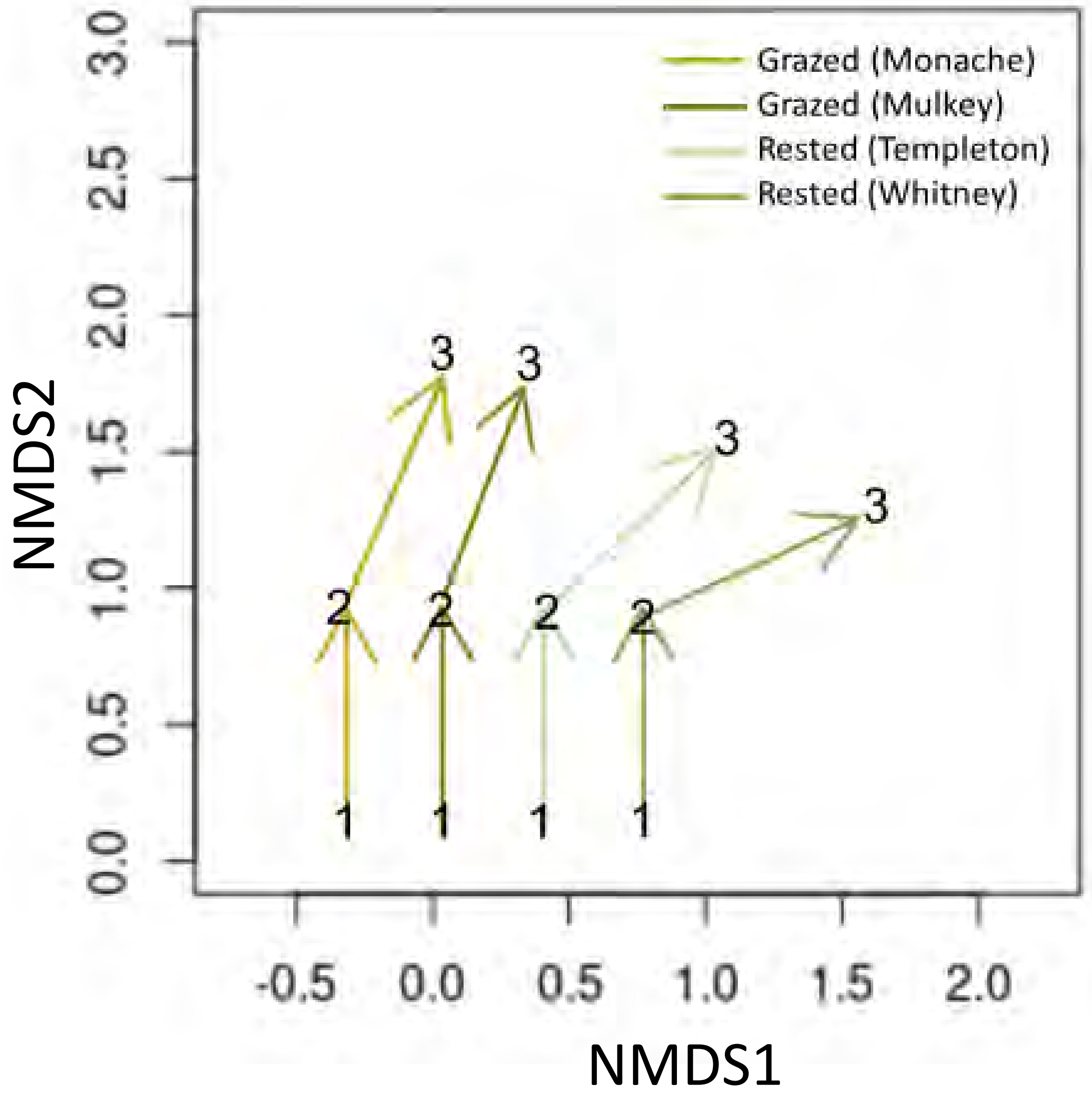


Grazing alters community trajectories through time



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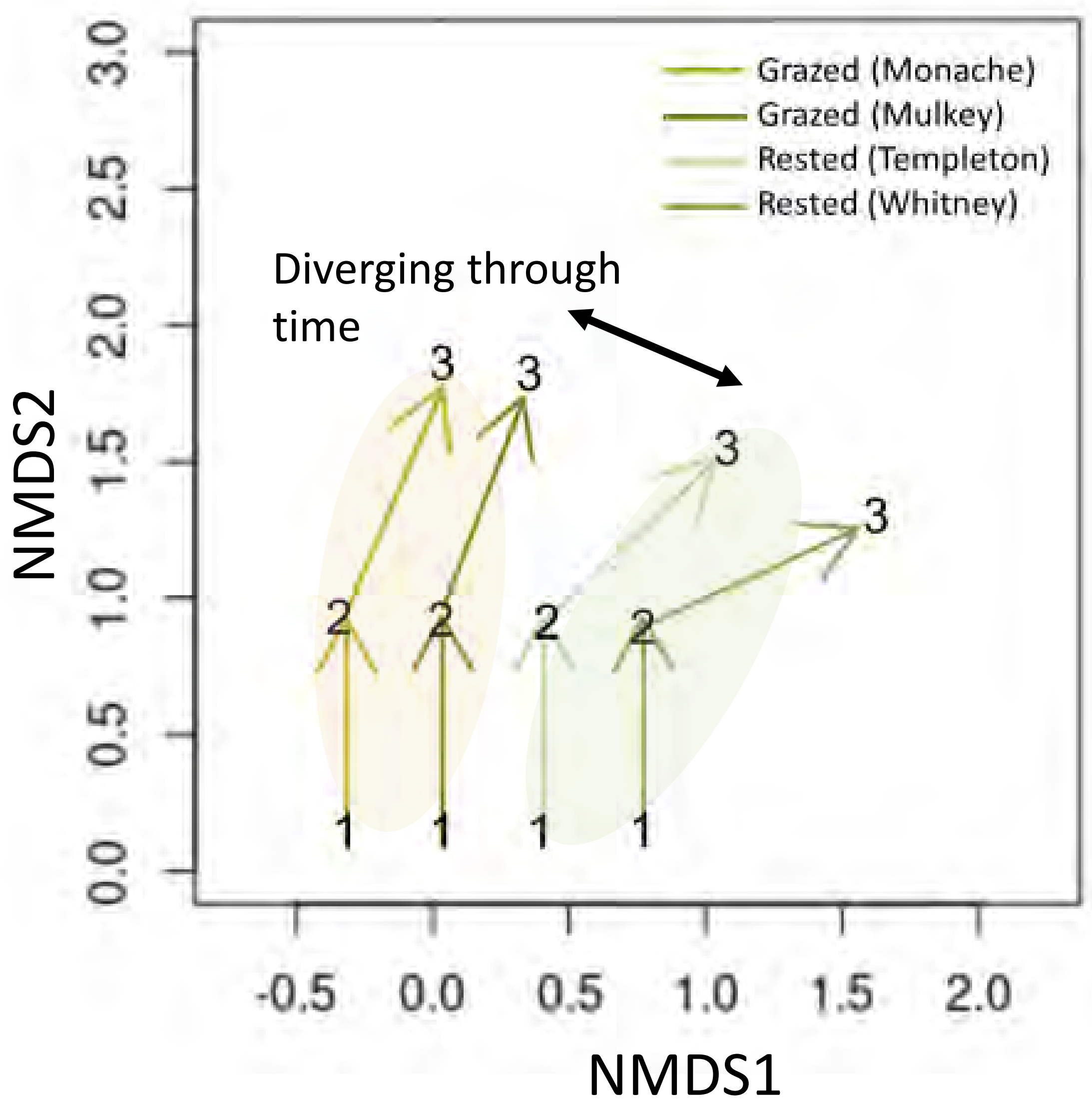
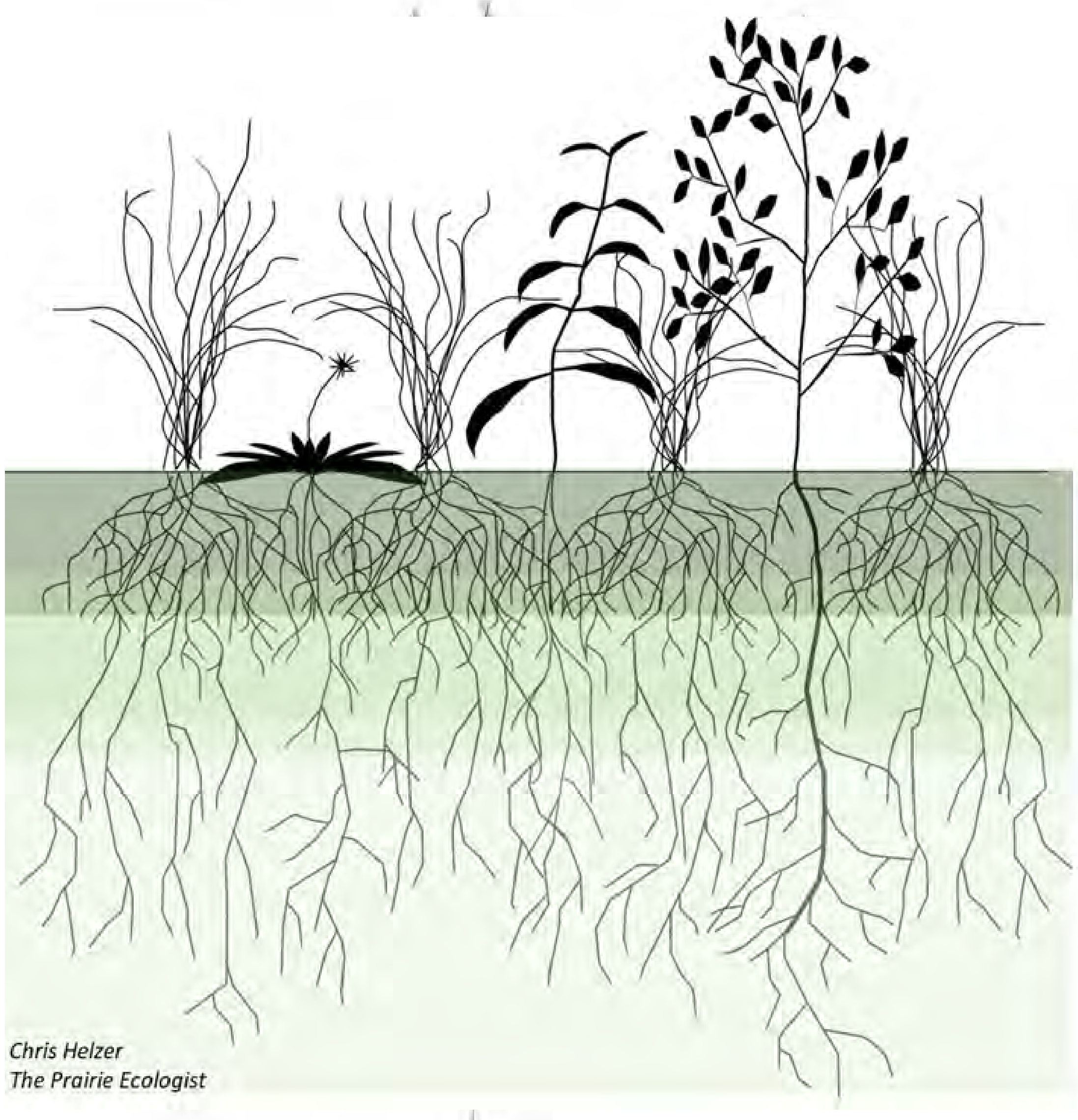
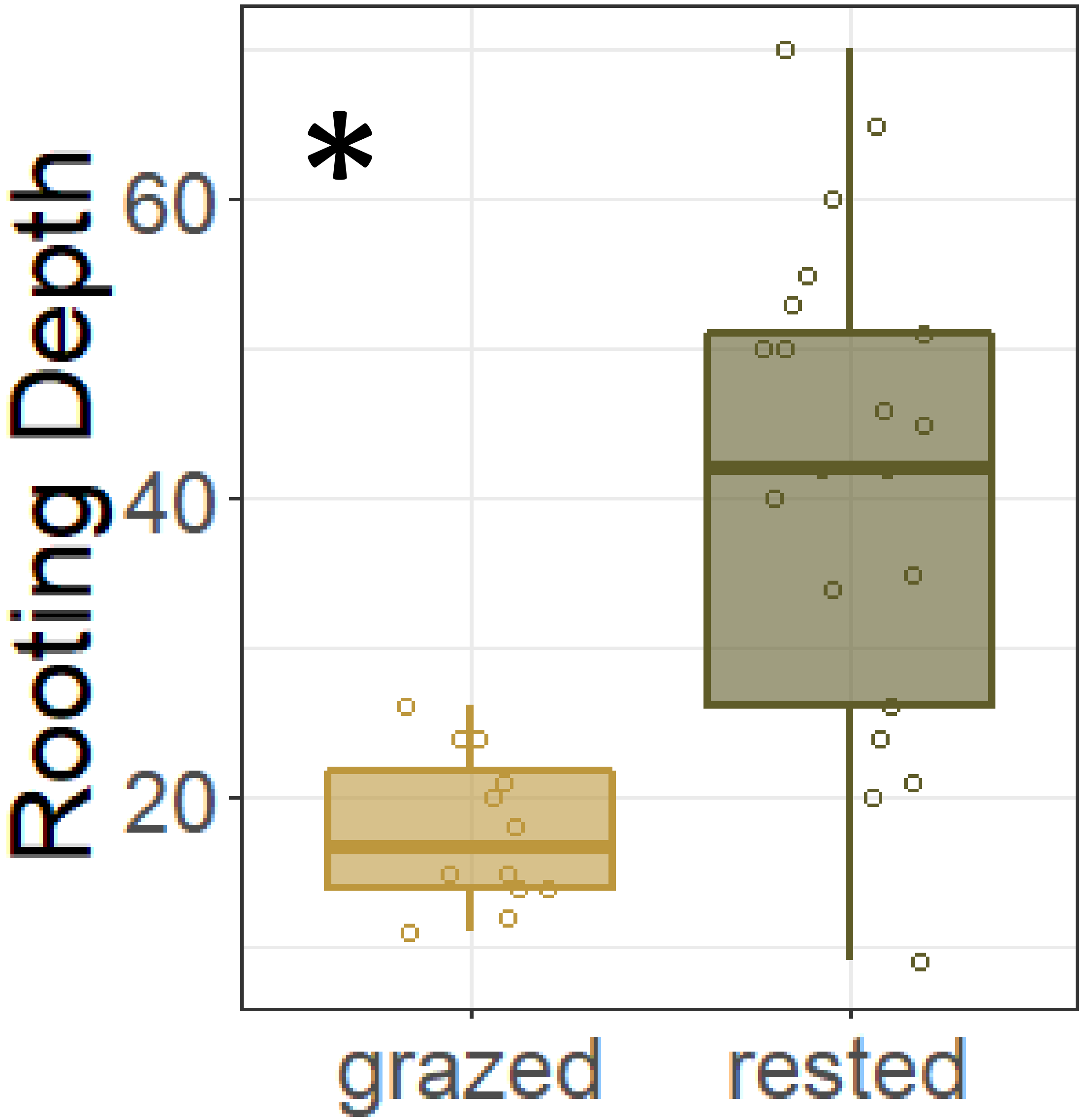
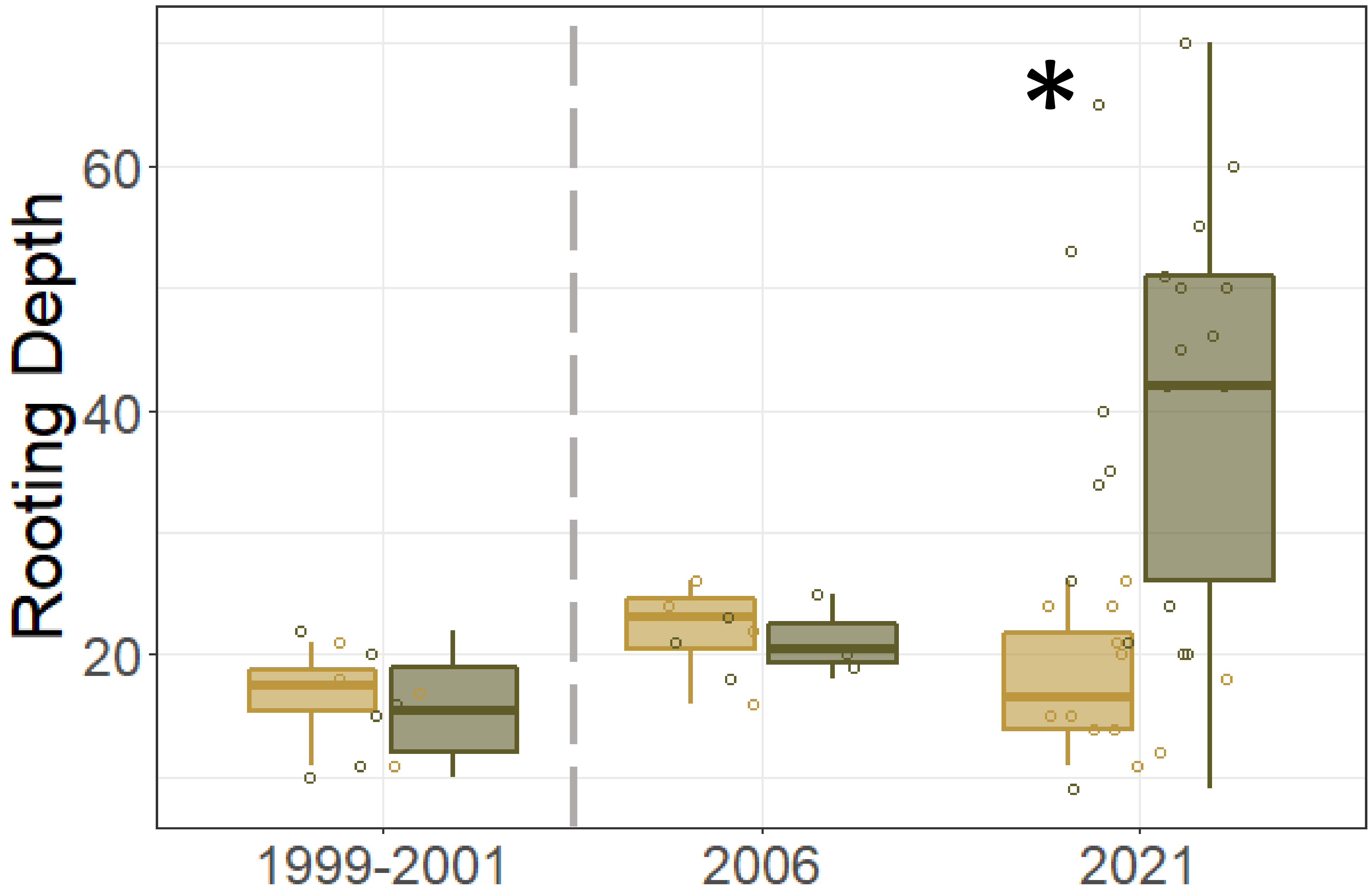


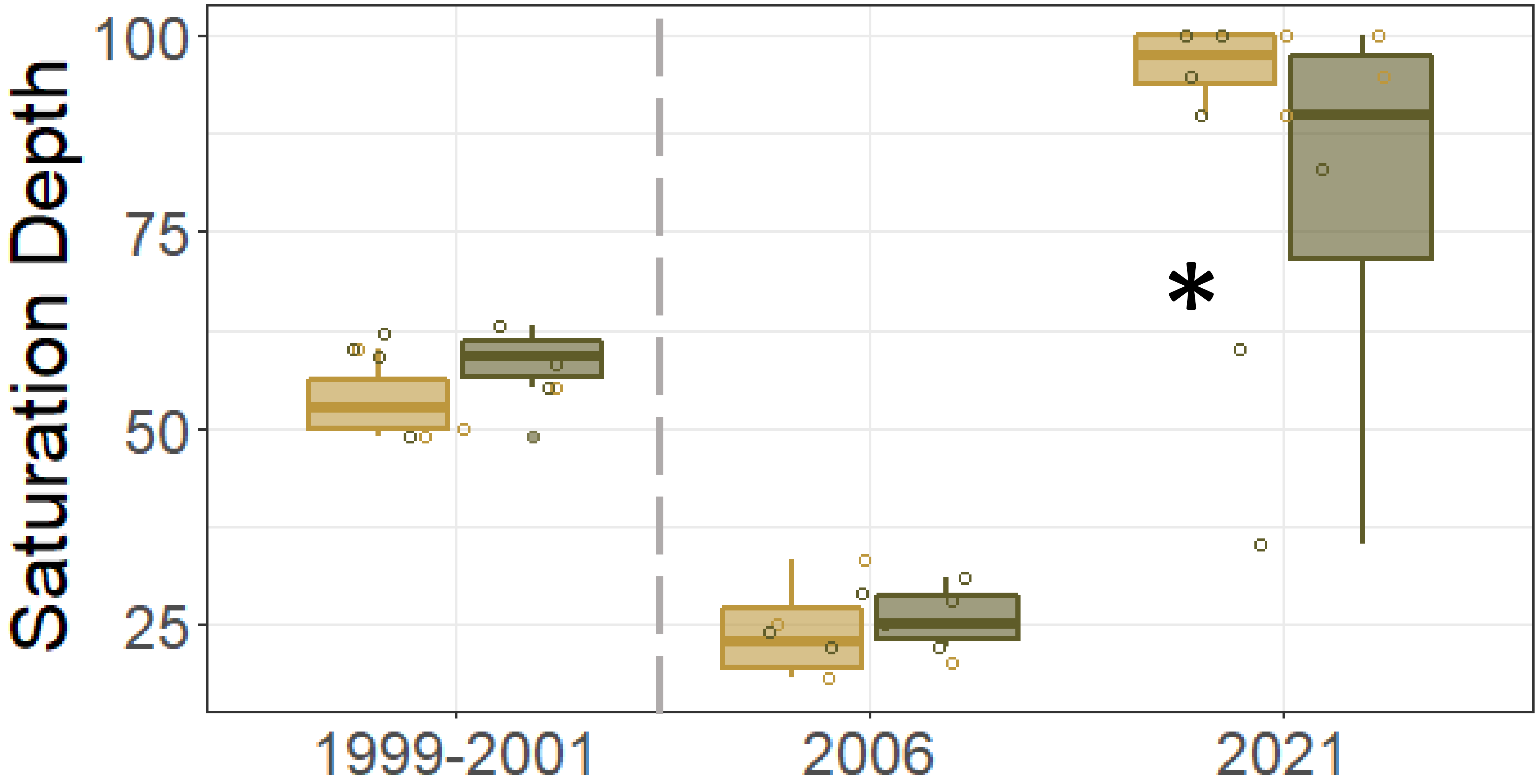

Chris Helzer
The Prairie Ecologist


Rooting Depth
60
40
20
*
grazed
rested

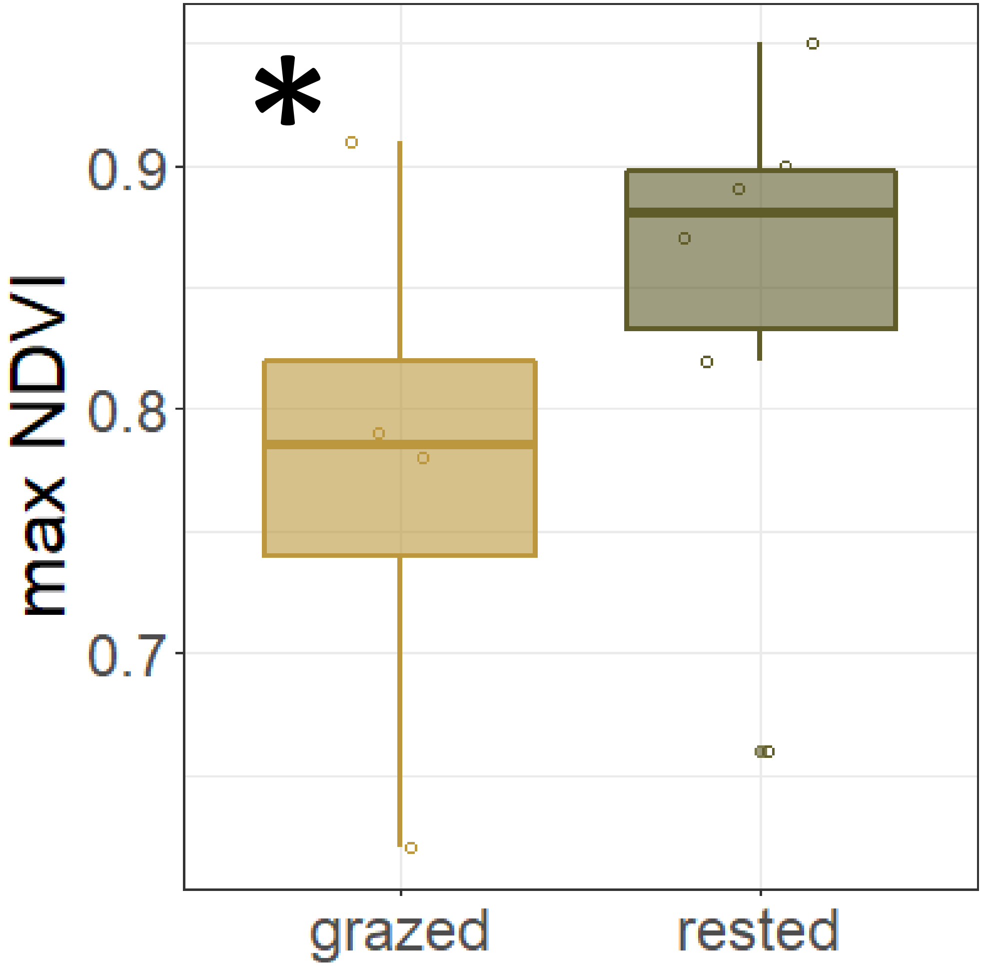


Rooting Depth
60
40
20
*
1999-2001
2006
2021

Saturation Depth
100
80
60
40
*
grazed
rested


Saturation Depth
100
75
50
25
*
1999-2001
2006
2021

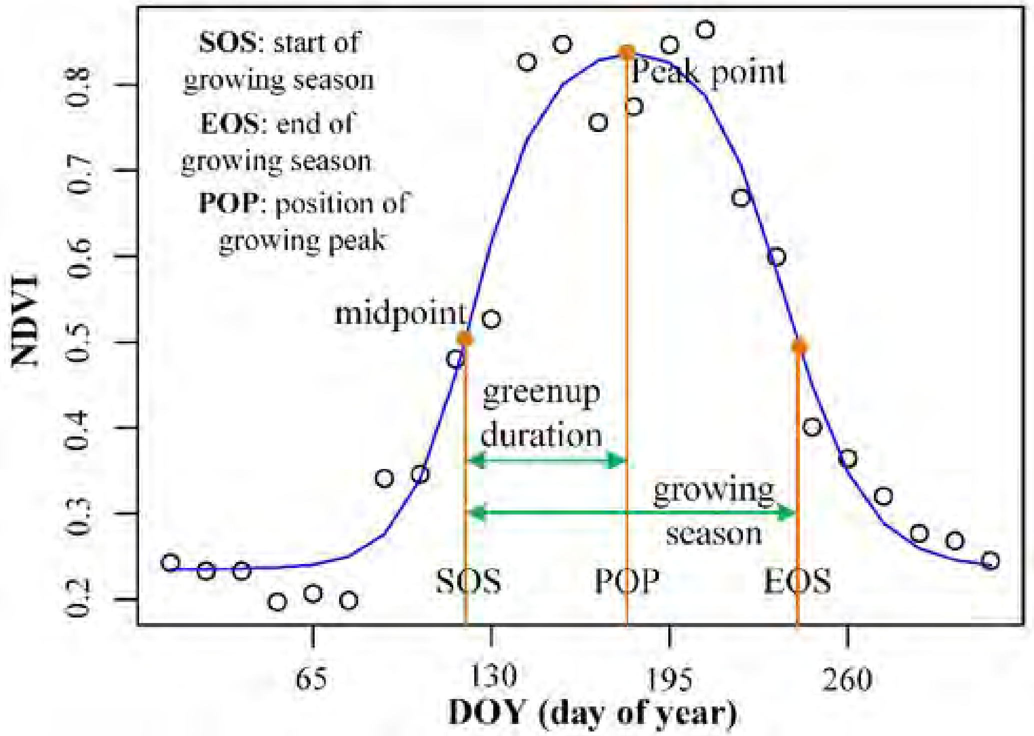
NDVI (productivity proxy) is higher in rested meadows than grazed



NDVI (productivity proxy) is higher in rested meadows than grazed

-changes in phenology?

track timing of growth and senescence with grazing and across years



Next steps

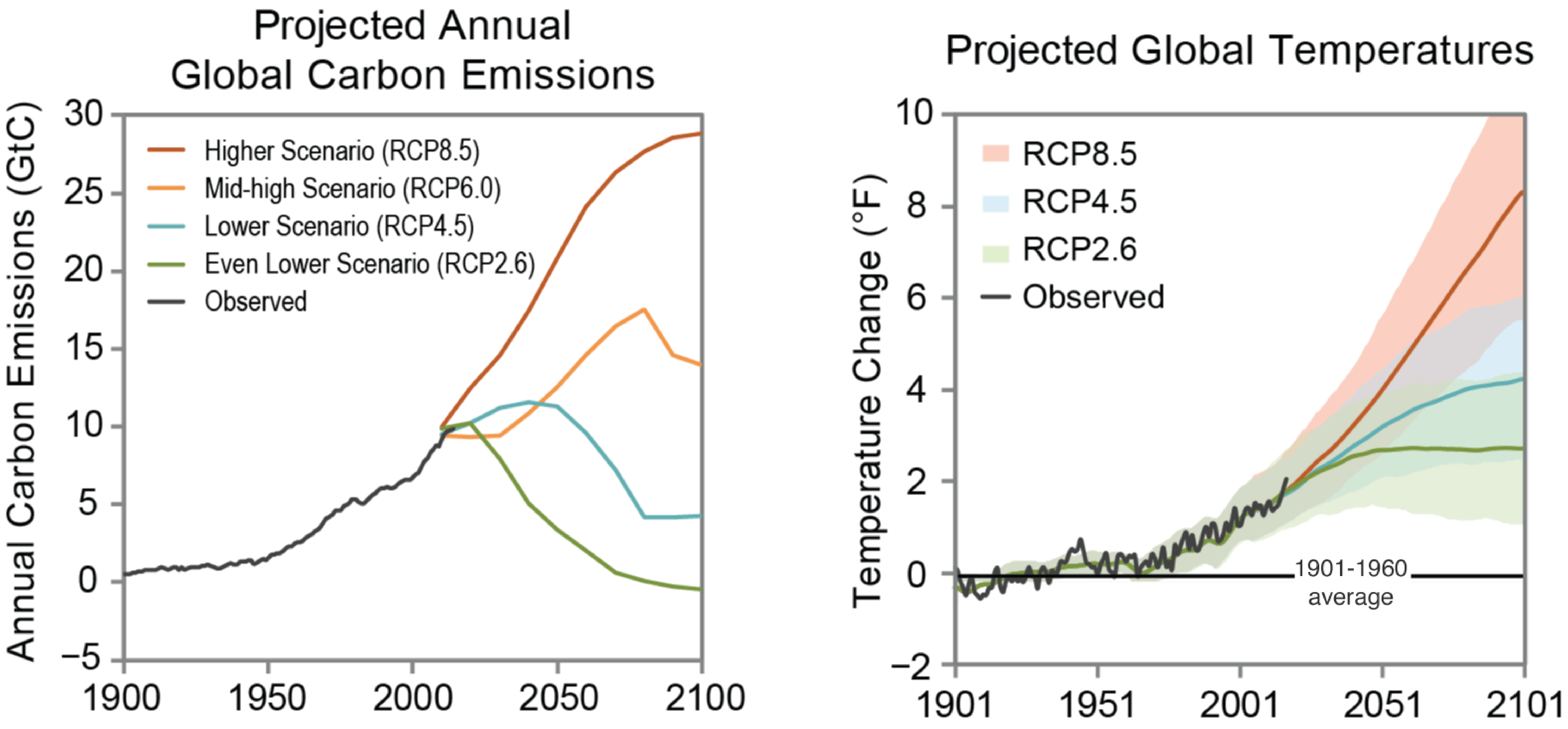
Planned 2022: soil carbon sampling across our 31 plots

Looking for mechanisms driving meadow resistance and resilience

-plant functional traits and physiological mechanisms of response to grazing and abiotic conditions

Utilize additional FS data in combination with LANDSAT to more finely track interannual variation

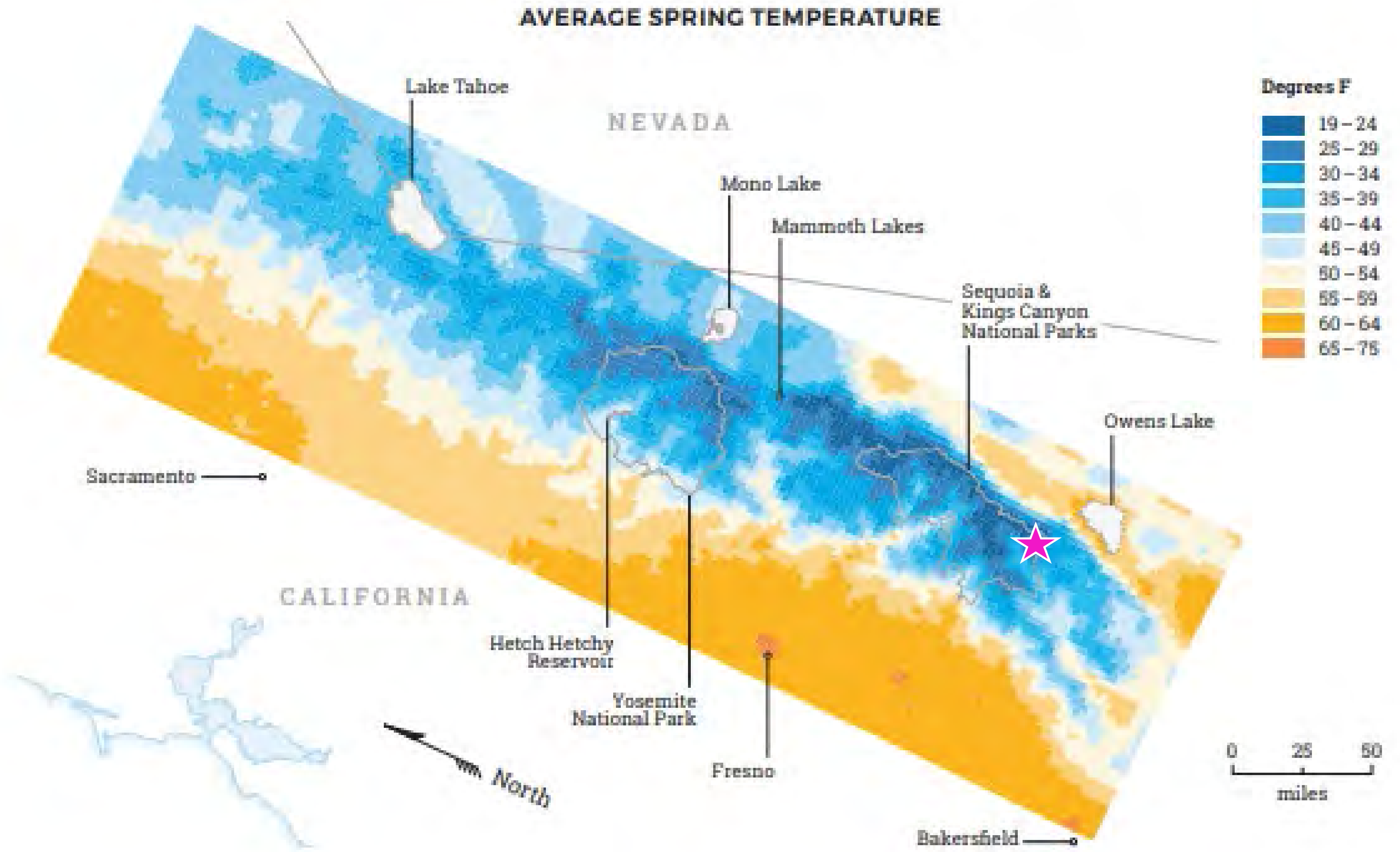
-Link to work others are doing, especially in-stream conditions



2017 Climate Science Special Report, Figure ES-3

Historical Climate, 1981–2000

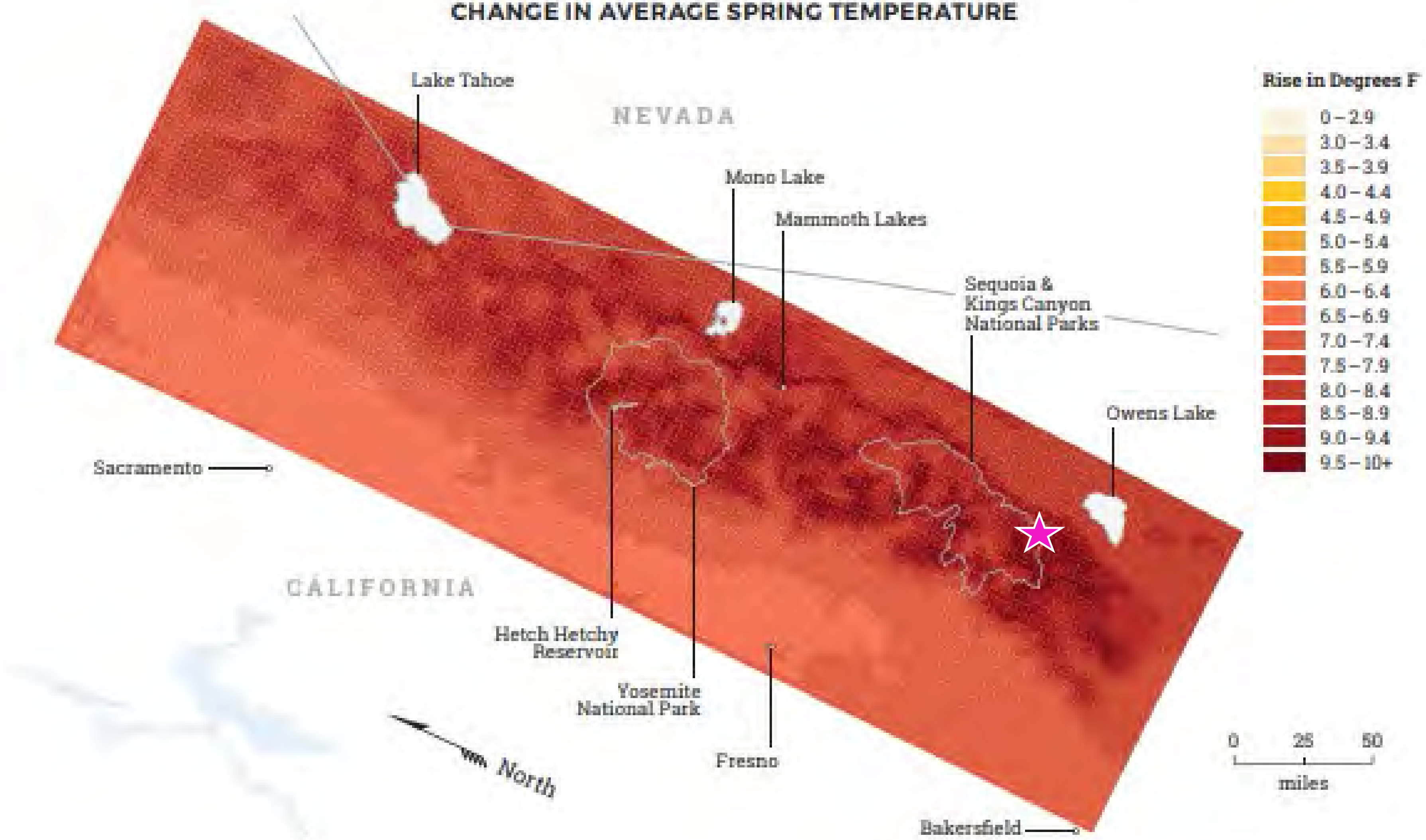
This map shows average 24-hour temperatures, in degrees Fahrenheit, for March–May during the study's historical period. Temperatures decrease rapidly with elevation, dropping from the 50's in the foothills to the high teens at the highest peaks.



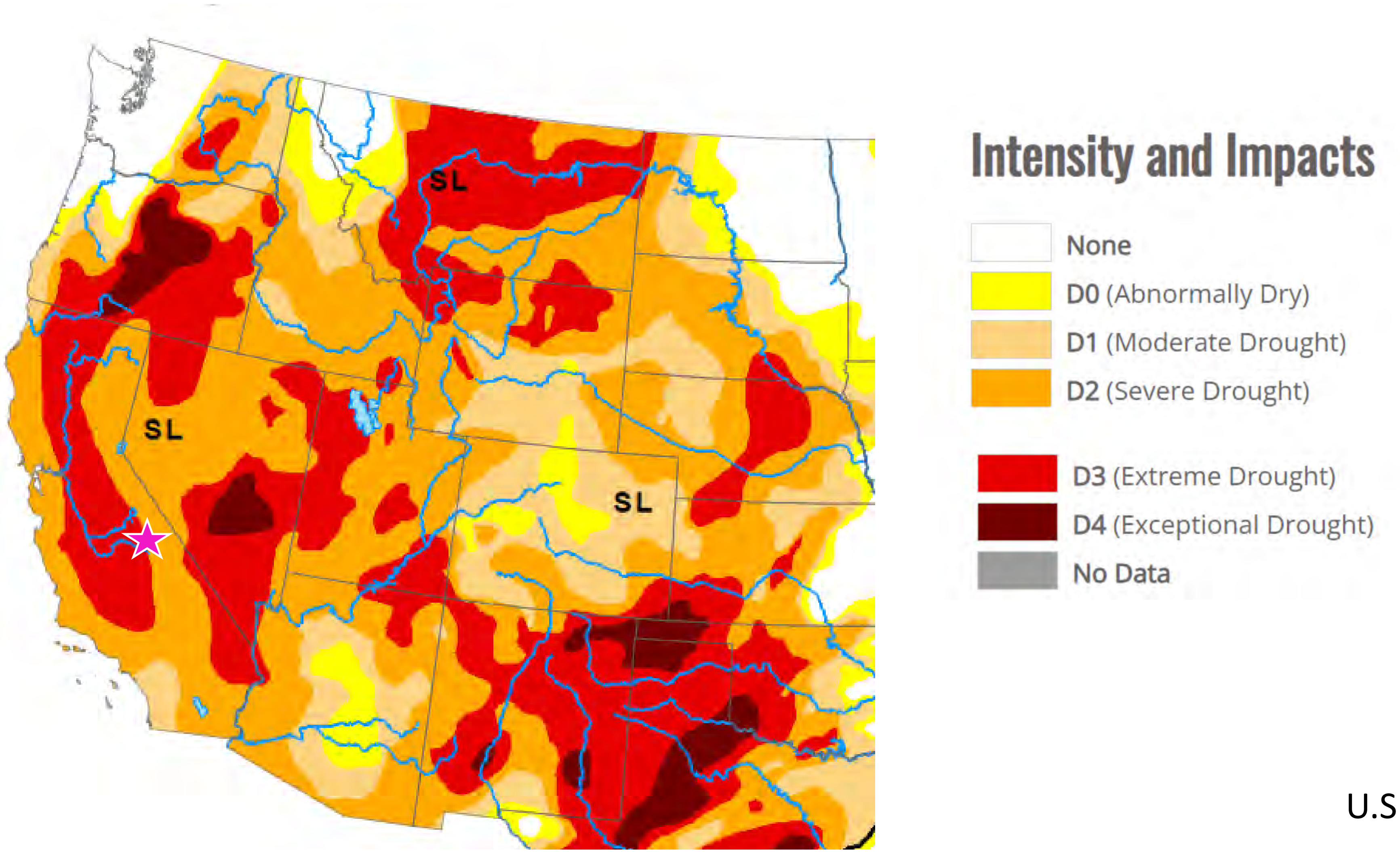
Business-as-Usual Warming, 2081–2100

This map shows the change in average 24-hour temperatures, in degrees Fahrenheit, for the months of March, April, and May at the end of the century. Warming is greatest at elevations between 5,000 and 8,000 feet, where snow albedo feedback is occurring.

CHANGE IN AVERAGE SPRING TEMPERATURE

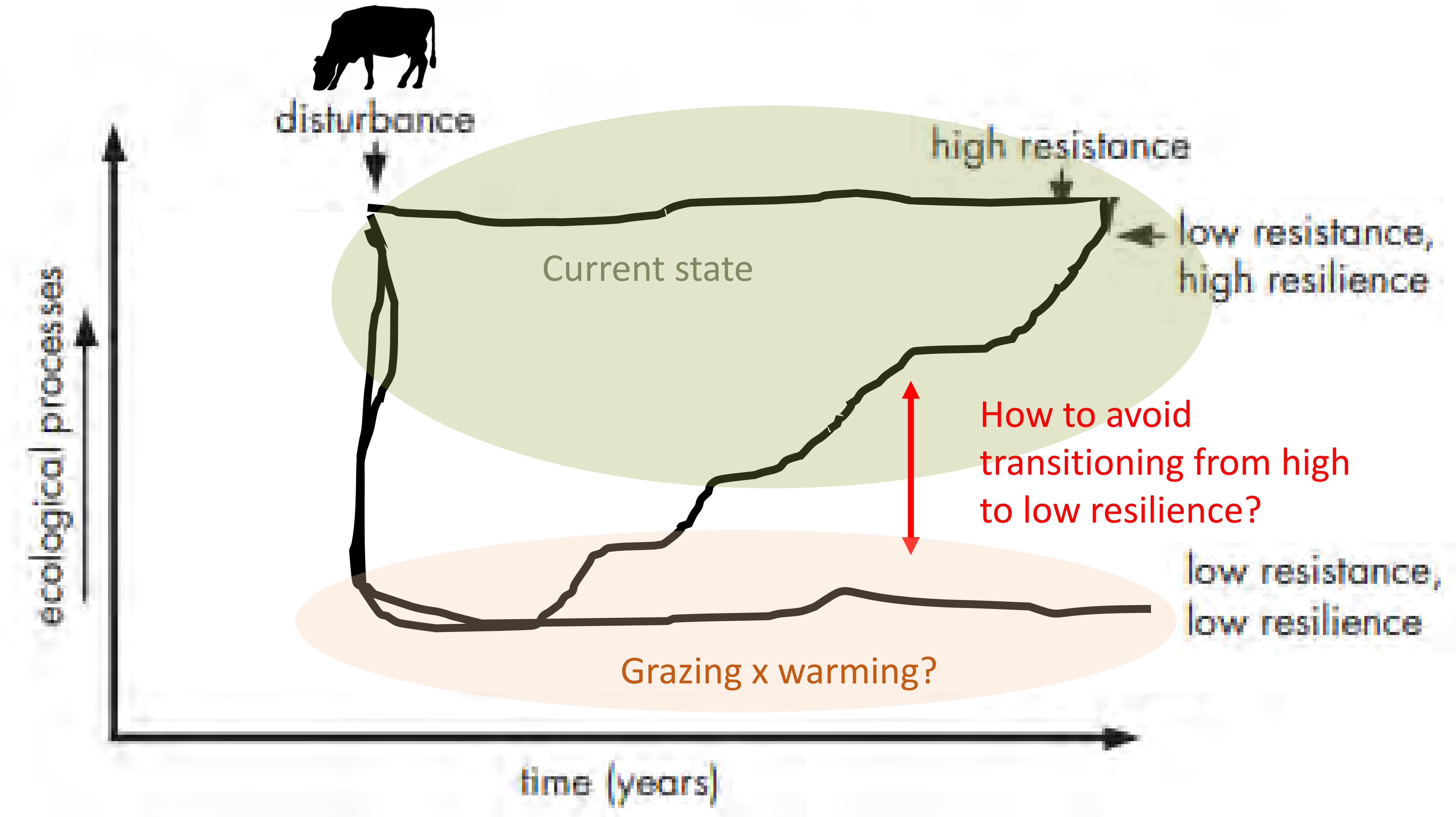


Drought is affecting fish habitat in the GTW and across the western U.S.



U.S. Drought Monitor

Stability of mountain meadows



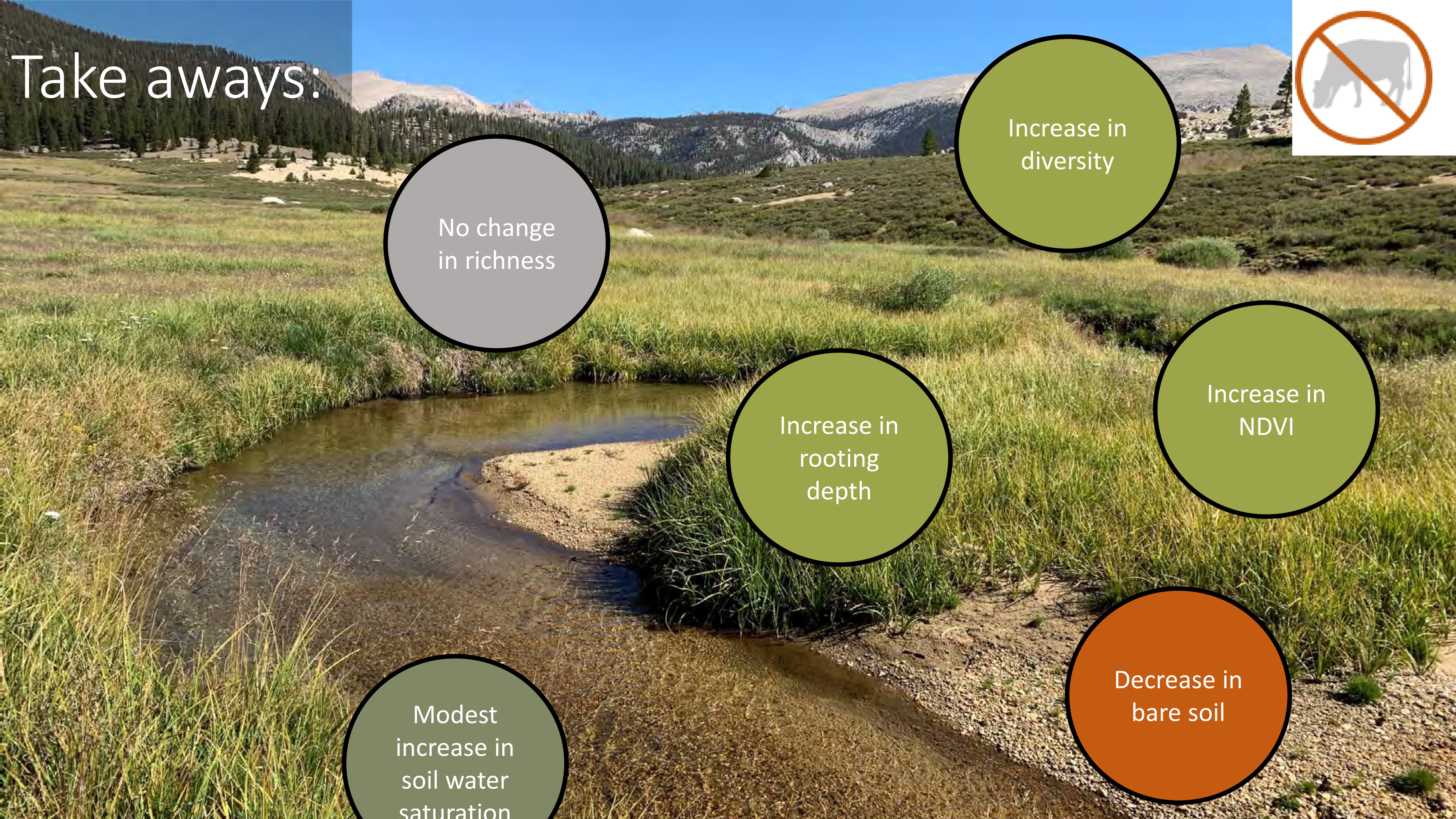
Take aways:

Take aways:


Take aways:
No change in richness
Decrease in bare soil

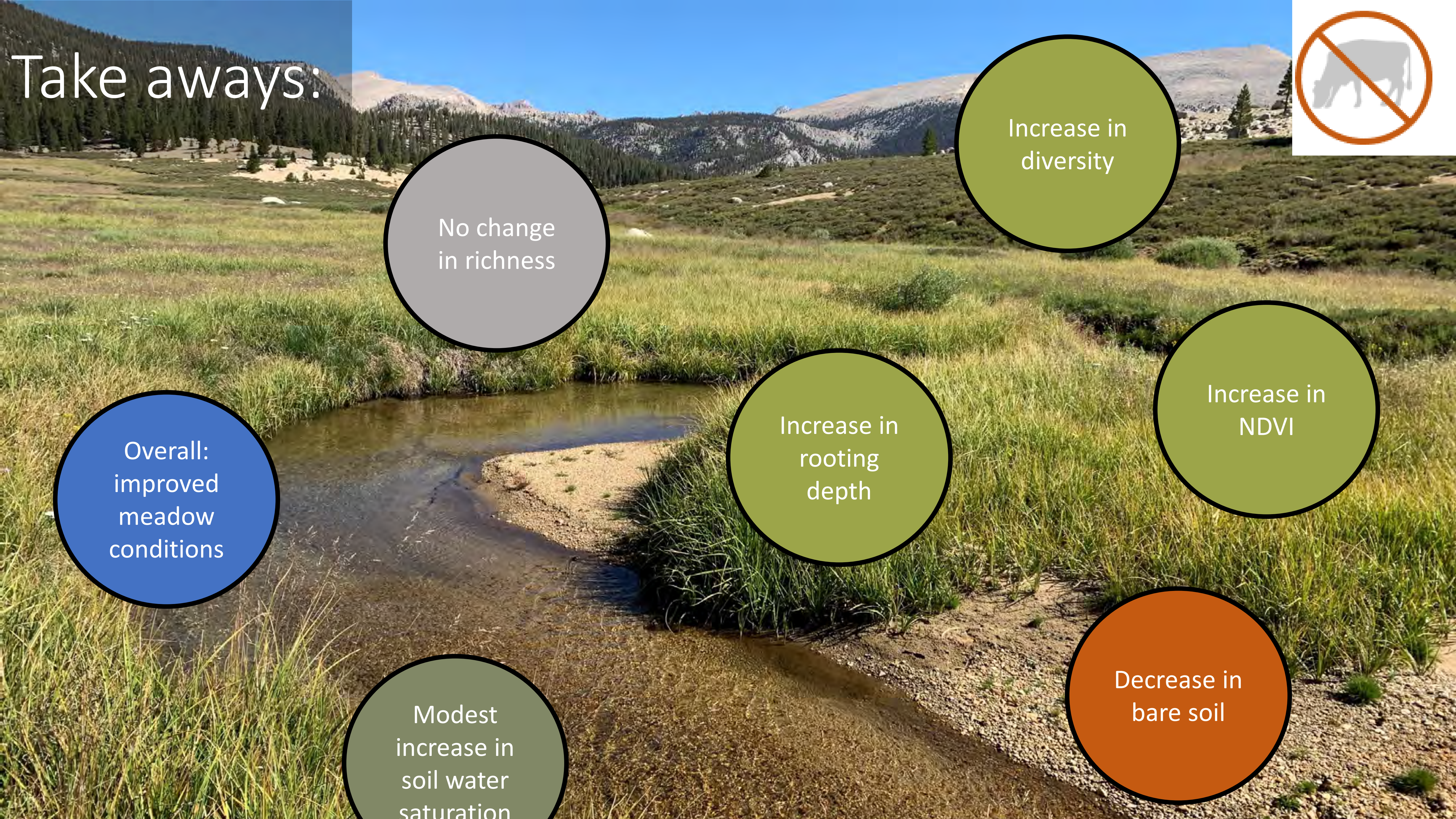

Take aways:
No change in richness
Modest increase in soil water saturation
Decrease in bare soil

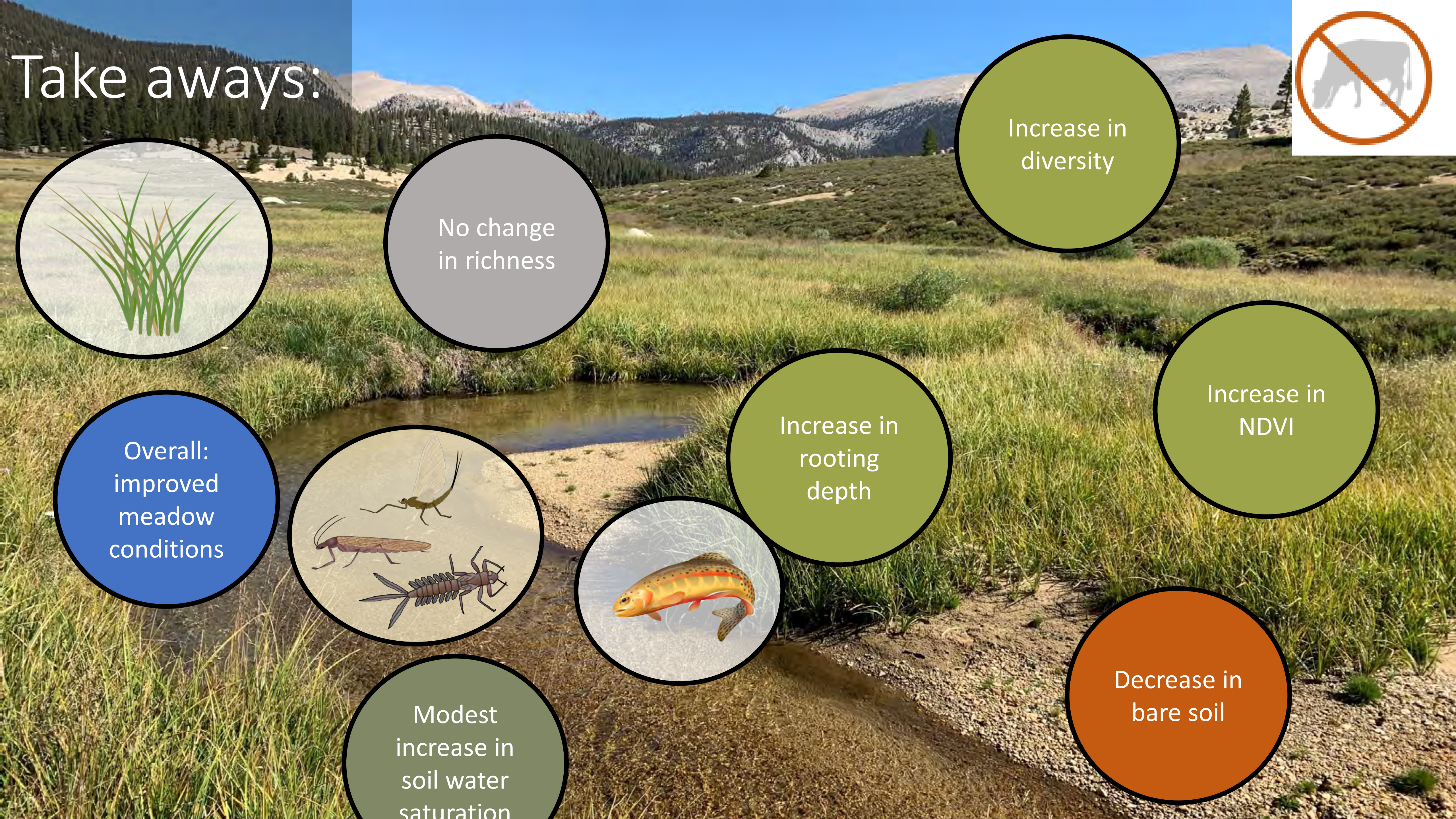
Take aways:



- Increase in diversity
- No change in richness
- Increase in rooting depth
- Increase in NDVI
- Decrease in bare soil
- Modest increase in soil water saturation

Take aways:


No change in richness
Increase in diversity
Increase in rooting depth
Increase in NDVI
Overall: improved meadow conditions
Decrease in bare soil
Modest increase in soil water saturation



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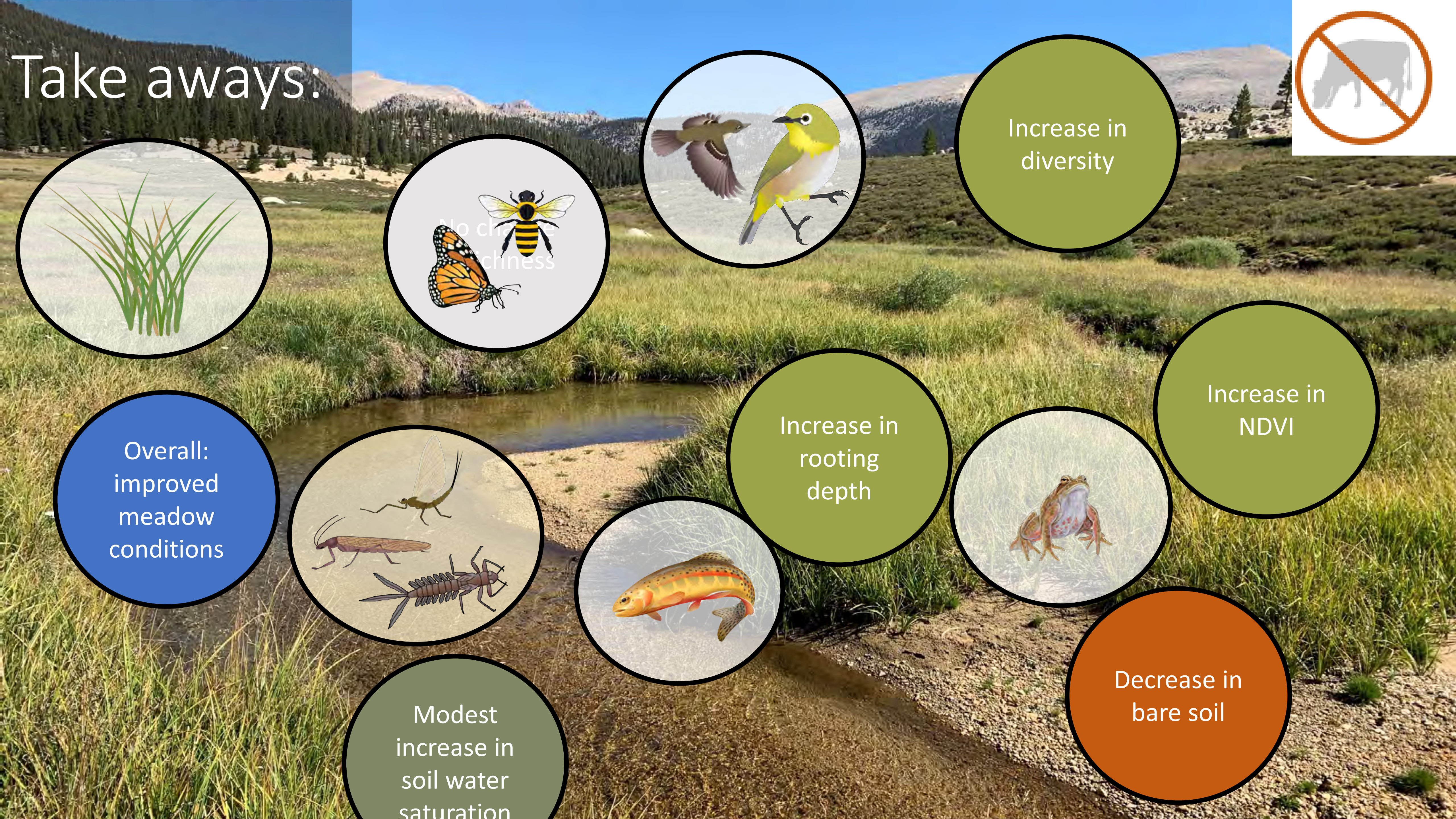
Take aways:
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Overall: improved meadow conditions
Increase in rooting depth
Increase in NDVI
Modest increase in soil water saturation
Decrease in bare soil

Conclusions: grazing has negative effects on trout and trout habitat

Conclusions: longterm monitoring across both wet and dry years is key for understanding recovery (and degradation) trends.

Conclusions: warming and drying climatic conditions may potentially amplify negative effects of grazing in the future

Contact me: orrdev@oregonstate.edu

• **Healthy Meadow Soil.** The meadow features productive, healthy soil characterized by high levels of soil organic matter that have a high water holding capacity and net carbon sequestration.

-rooting depth, soil mottling, [soil carbon measurements forthcoming] groundwater depth,

• **Meadow Plant Species.** The meadow's hydrologic regime and forage utilization supports native meadow graminoid species and, where ecologically appropriate, riparian shrubs and trees of diverse age classes; high diversity of meadow plants

• **Functional Meadow Hydrology.** The meadow exhibits hydrologic connectivity both laterally across the floodplain and vertically between surface and subsurface flows, contributing to groundwater recharge, late season stream flow, high water table, and attenuation and delay of peak flows.

-• **Good Water Quality**. The meadow contributes to good water quality characterized by streams with low sediment outputs, low turbidity, and cool temperatures.

• **Meadow Wildlife.** The meadow supports diverse native terrestrial and aquatic wildlife, including birds, amphibians, and fish, that depend on meadows for some or all portions of their life cycle.

LTPBR in Sierra Nevada Meadow Systems: A case study from the Golden Trout Wilderness

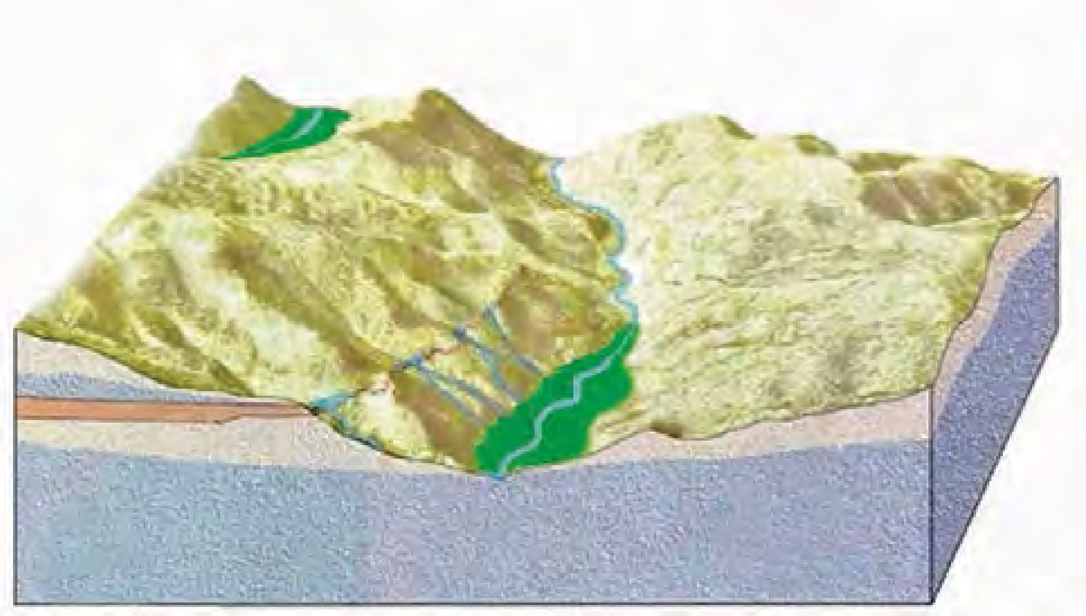
Prepared by Sabra Purdy

Thanks to partners Trout Unlimited, Inyo National Forest, Anabranch Solutions, Waterways Consulting, and California Department of Fish and Wildlife

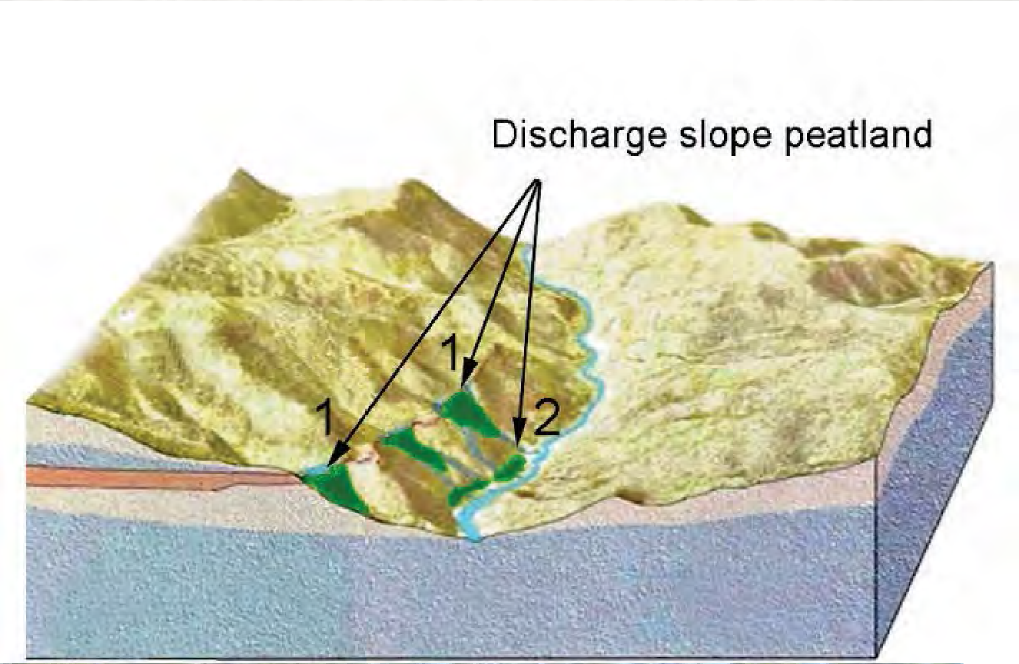
Montane Meadows in the Sierra Nevada

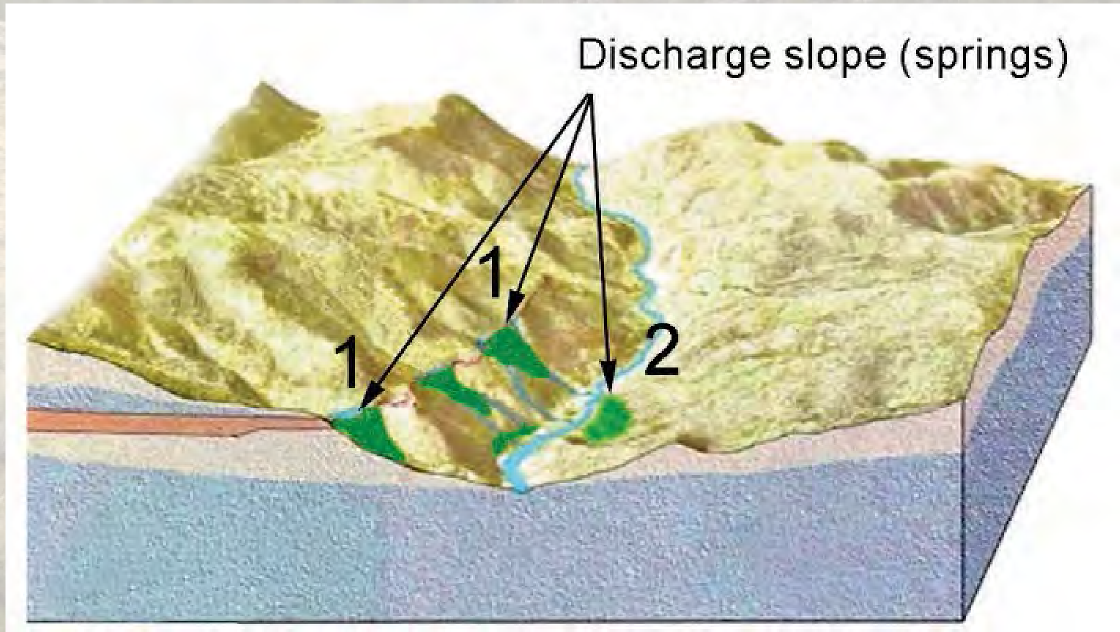
- The Sierra Nevada Meadows has more than 18,000 meadows comprising almost 280,000 acres of which 102,000 acres are located on California's National Forests.
- Numerous hydrogeomorphic types, most common in Golden Trout are Riparian meadows, Discharge Slope Peatlands and Springs, and Subsurface Meadows
- Riparian Meadows (those with a well-defined stream channel) are typically depositional habitats, we have spent the last 200 years disrupting the processes that create and maintain these systems
- Anthropogenic impacts (livestock grazing, culverts, roads, trails) interrupt depositional processes and alter structure, dynamics of flow and flooding drive erosion in damaged landscapes reversing the depositional process
- Tend to show the highest amount of channel incision, bank erosion, gulley formation, head cutting, and loss of floodplain connectivity

- Riparian Low Gradient Meadow Position



From Weixelman et al. 2011


Discharge slope peatland
1
1
2


Discharge slope (springs)
1
1
2


From Weixelman et al. 2011

We’ve had a lot of Impacts




The Airstrip at Tunnel Meadow


Mulkey Meadows
Google Earth
N

We've tried a lot of treatment approaches


How do we do the greatest good for the largest area, with the least harm and risk to existing resources?

How do we identify restoration goals under a changing climate?

How do we know what a site “should” look like?

How do we reconcile what is feasible under current conditions and constraints with historic conditions?

Restoration Principles

1. Target root causes of habitat and ecosystem change
2. Tailor restoration actions to local potential
3. Match the scale of restoration to the scale of the problem
4. Be explicit about expected outcomes

Adapted from Beechie et al. (2010).

LOW-TECH PROCESS-BASED RESTORATION PRINCIPLES FOR STRUCTURALLY-STARVED RIVERSCAPES

Riverscapes Principles

1. Streams need space
2. Structure forces complexity and builds resilience
3. The importance of structure varies
4. Inefficient conveyance of water is healthy

By which we mean complex, dynamic, longer residence time, slow, variable

Restoration Principles

1. It's okay to be messy
2. There is strength in numbers
3. Use natural building materials
4. Let the system do the work
5. Defer decision making to the system
6. Self-sustaining systems are the solution

From Wheaton et al. 2019 LTPBR Design Manual

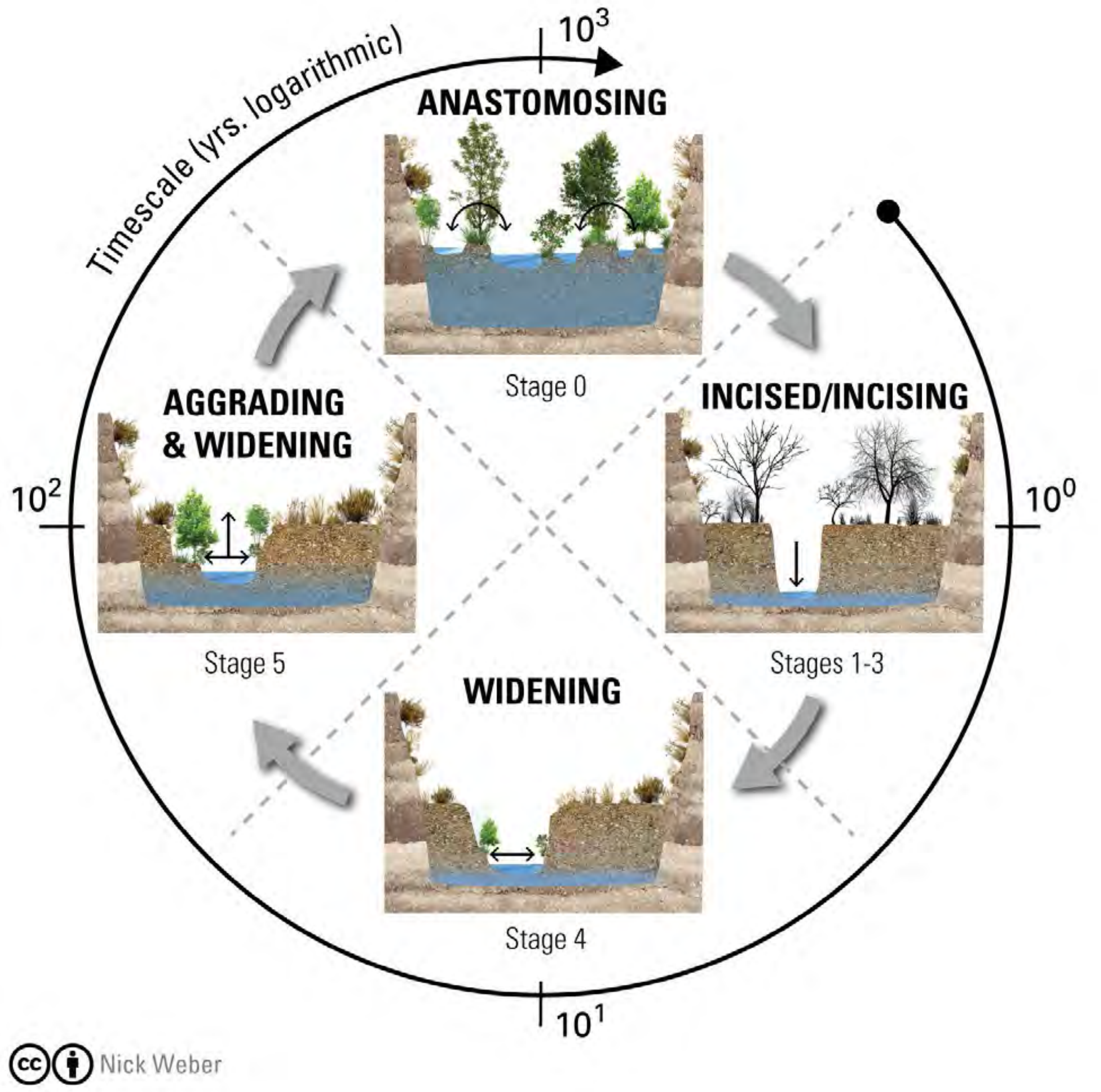
How do we get from this to this?

In Wilderness!

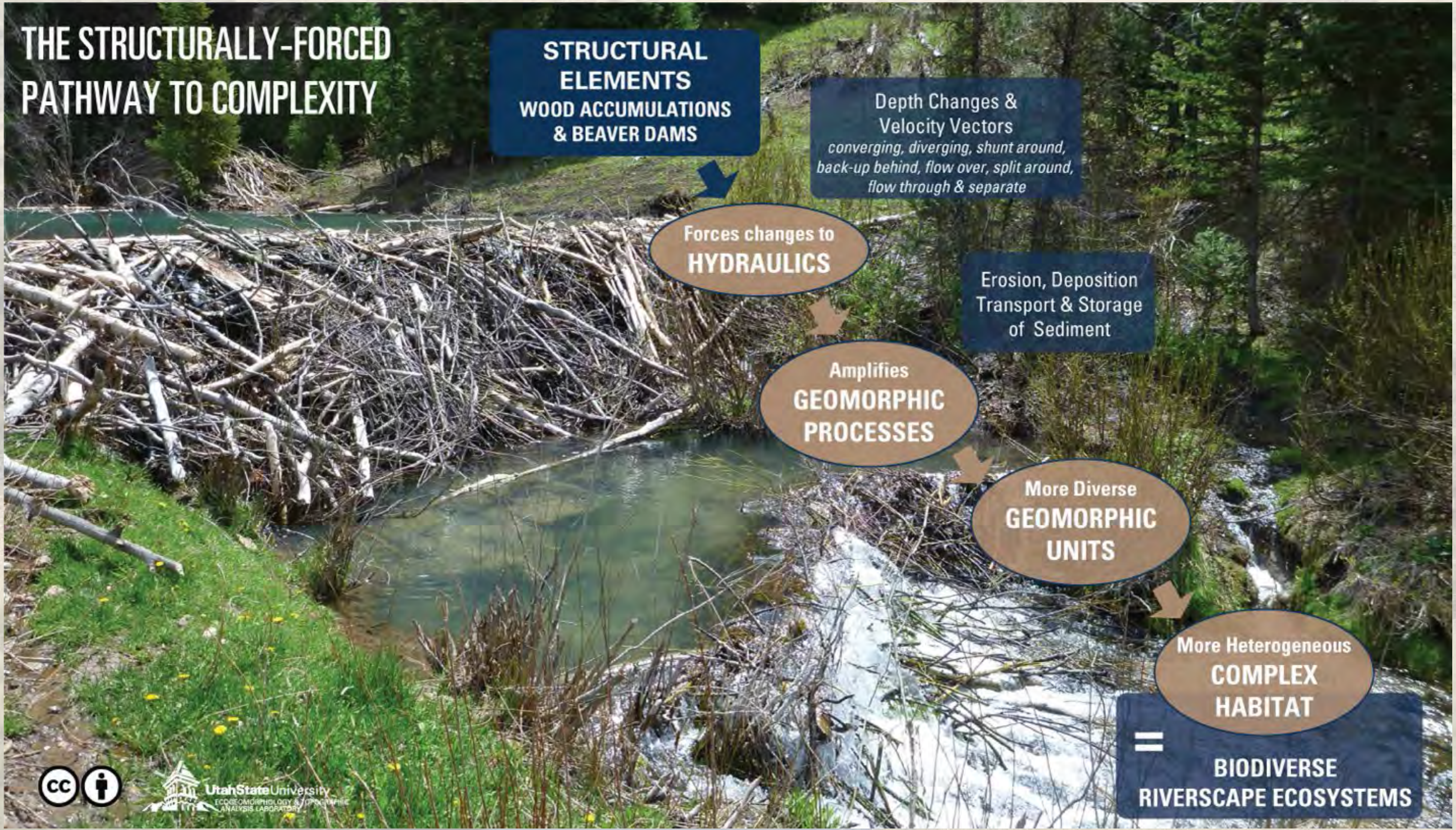
- No Motors (no hydraulic post pounder, no chainsaw, no earth moving equipment)
- No wheels, no wheelbarrows
- Remote backcountry setting, no easy access
- Just brute strength, enthusiasm, and a high tolerance for suffering

Goals and Objectives for Depositional Habitats

- Multi-thread, Anastomosing channel
- Fully connected Floodplain
- Use structure to force complexity
- Reduce and capture unchecked bank erosion and sediment loss from the system
- Encourage Sediment Deposition and Aggradation
- Increase Hydraulic Complexity, Sediment sorting
- Increase area of Active Valley Bottom

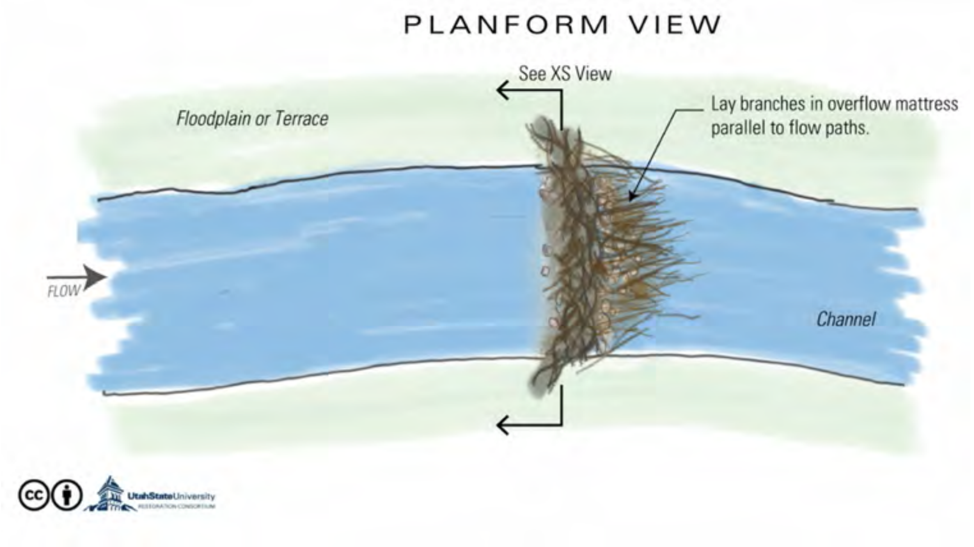


Adapted from Cluer and Thorne 2014

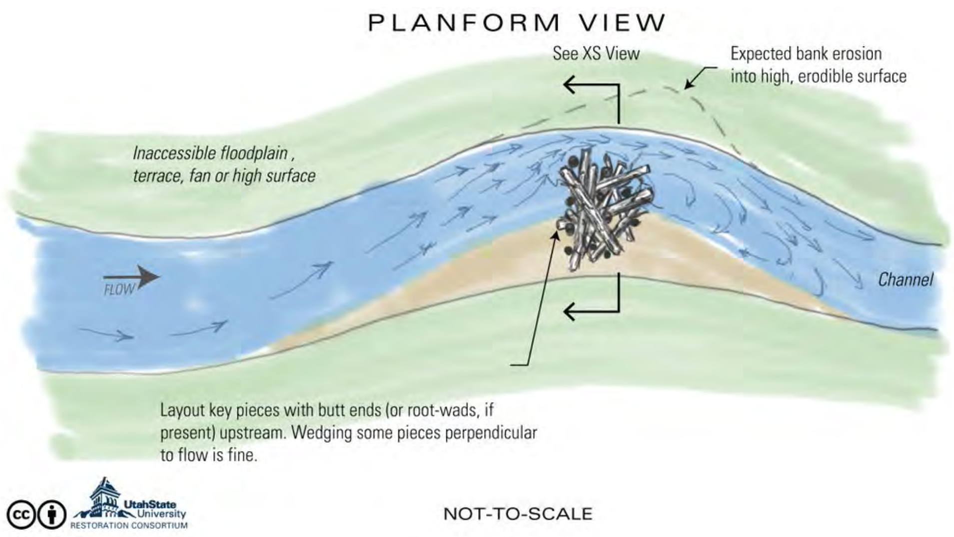

THE STRUCTURALLY-FORCED PATHWAY TO COMPLEXITY
STRUCTURAL ELEMENTS
WOOD ACCUMULATIONS & BEAVER DAMS
Depth Changes & Velocity Vectors
converging, diverging, shunt around, back-up behind, flow over, split around, flow through & separate
Forces changes to HYDRAULICS
Erosion, Deposition Transport & Storage of Sediment
Amplifies GEOMORPHIC PROCESSES
More Diverse GEOMORPHIC UNITS
More Heterogeneous COMPLEX HABITAT
= BIODIVERSE RIVERSCAPE ECOSYSTEMS
UtahStateUniversity



Using structure to help regenerate the processes that create and maintain meadow habitats is the key to creating complex, resilient, dynamic meadow ecosystems



Beaver Dam Analog



Bank Attached Post Assisted Log Structure

From Wheaton et al. 2019

Structure Comes in many forms




Structure

- Wood
- Beaver dams
- Sod/Sedge
- Riparian Vegetation

Complexity

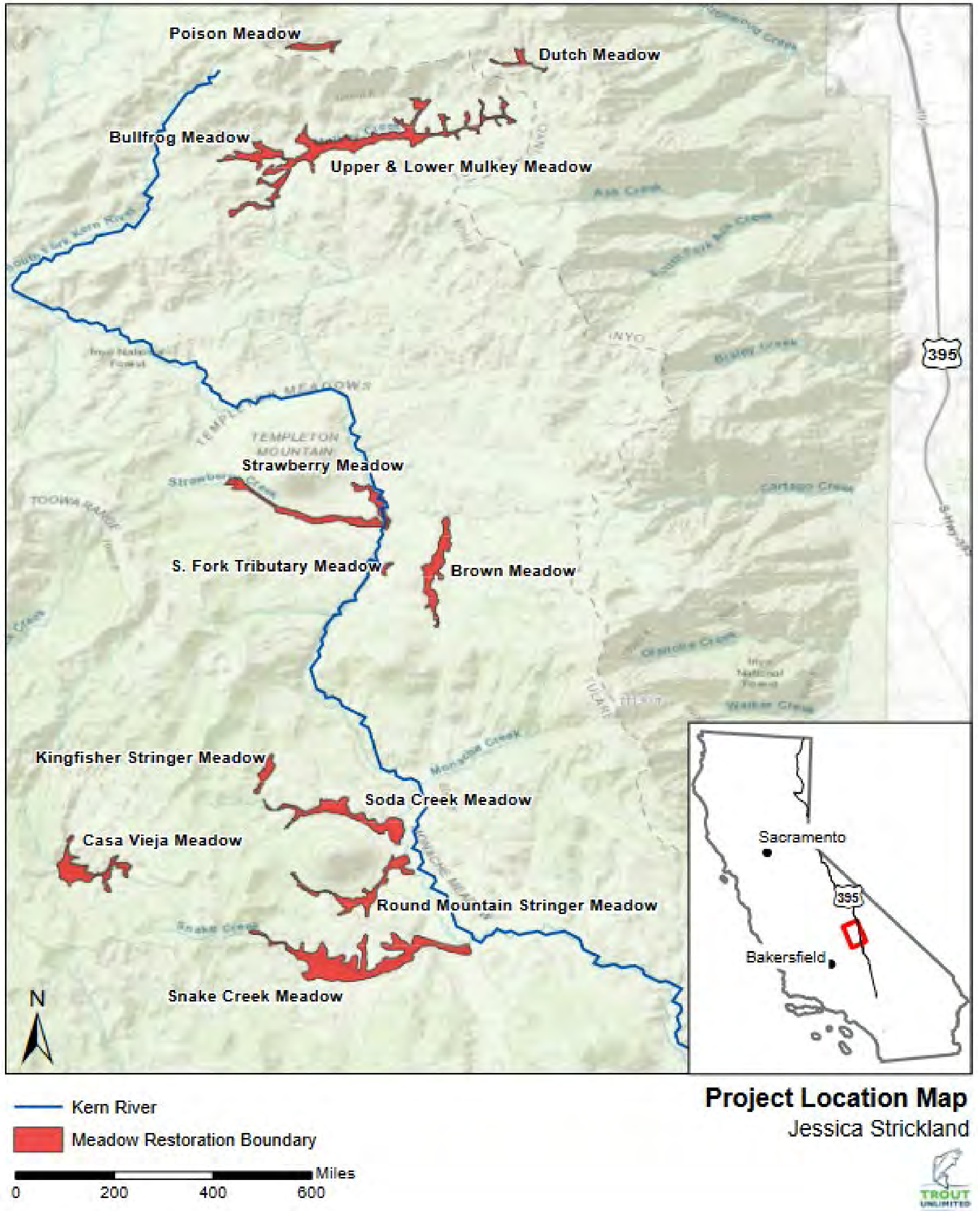
- Water Velocity
- Sediment Sorting
- Channel Heterogeneity

Diversity

- Flows
- Habitat Types
- Vegetation
- Bugs
- Fish

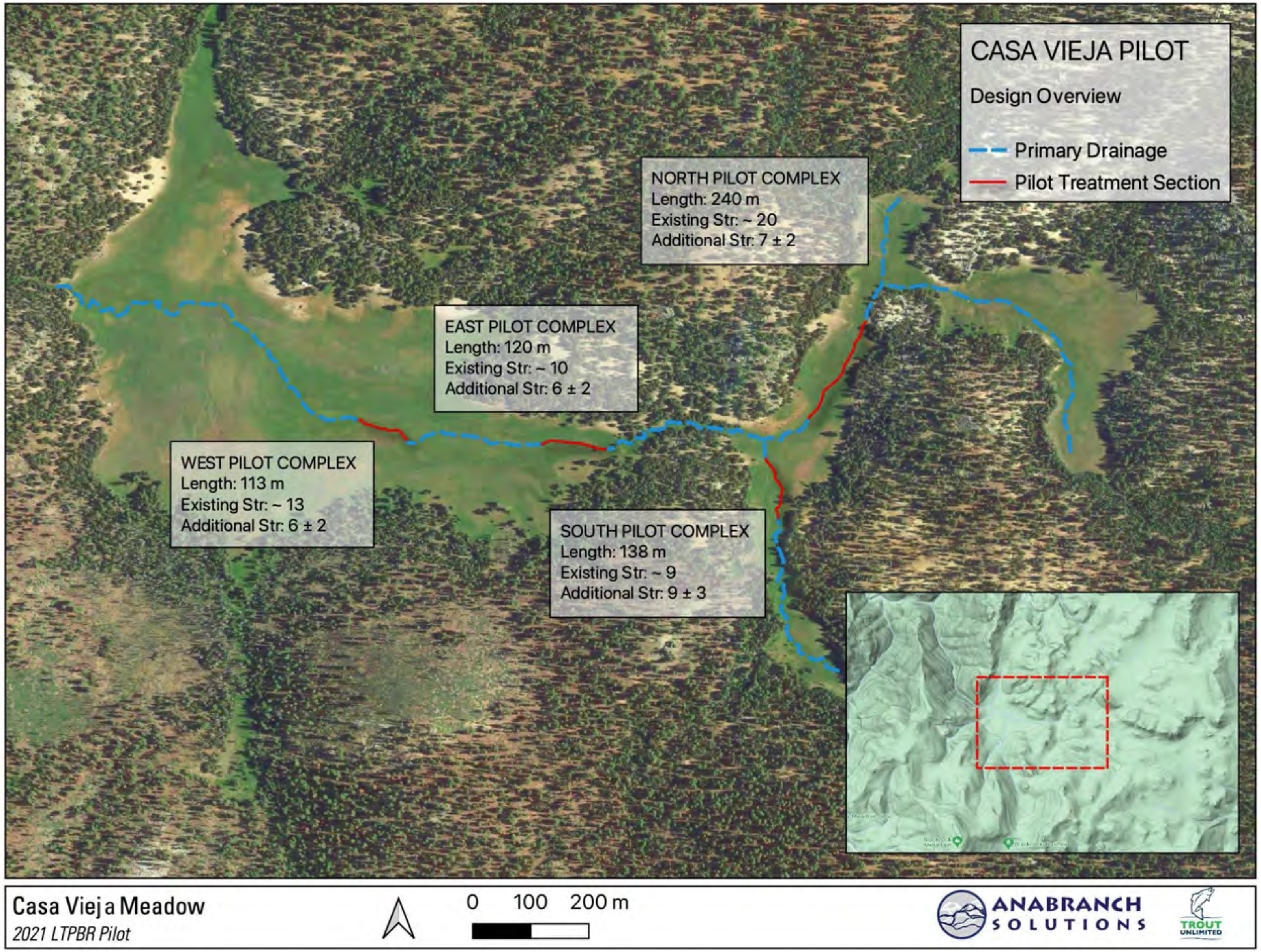
No Fences!


Goldentrout Wilderness - Kern Plateau Meadow Restoration Panning Project



Project Location Map

Jessica Strickland



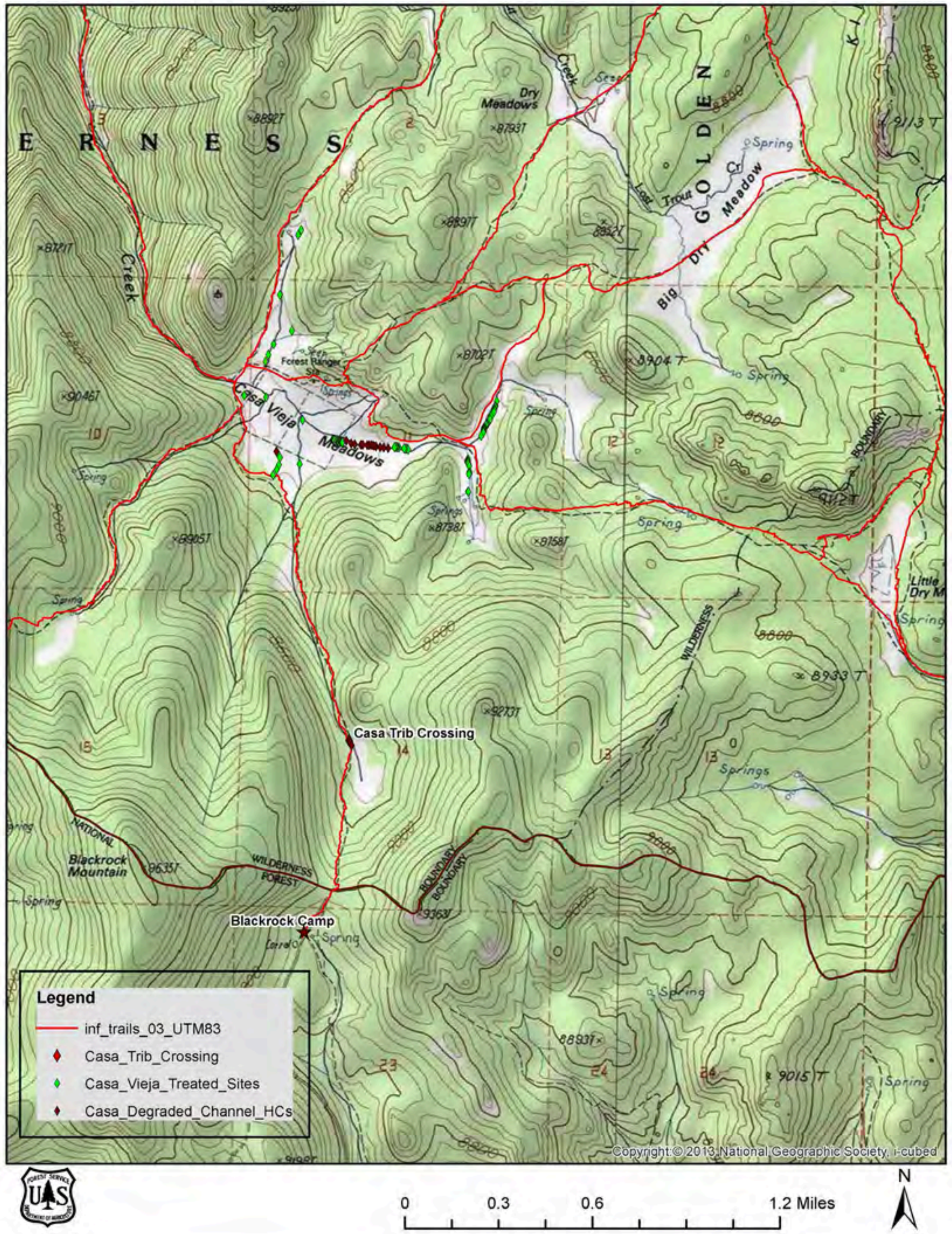
- In partnership with the USDA Forest Service, Trout Unlimited and Anabranch Solutions are undertaking the most ambitious meadow restoration project in Wilderness that has ever been attempted in California involving 14 meadows within designated wilderness funded by CDFW

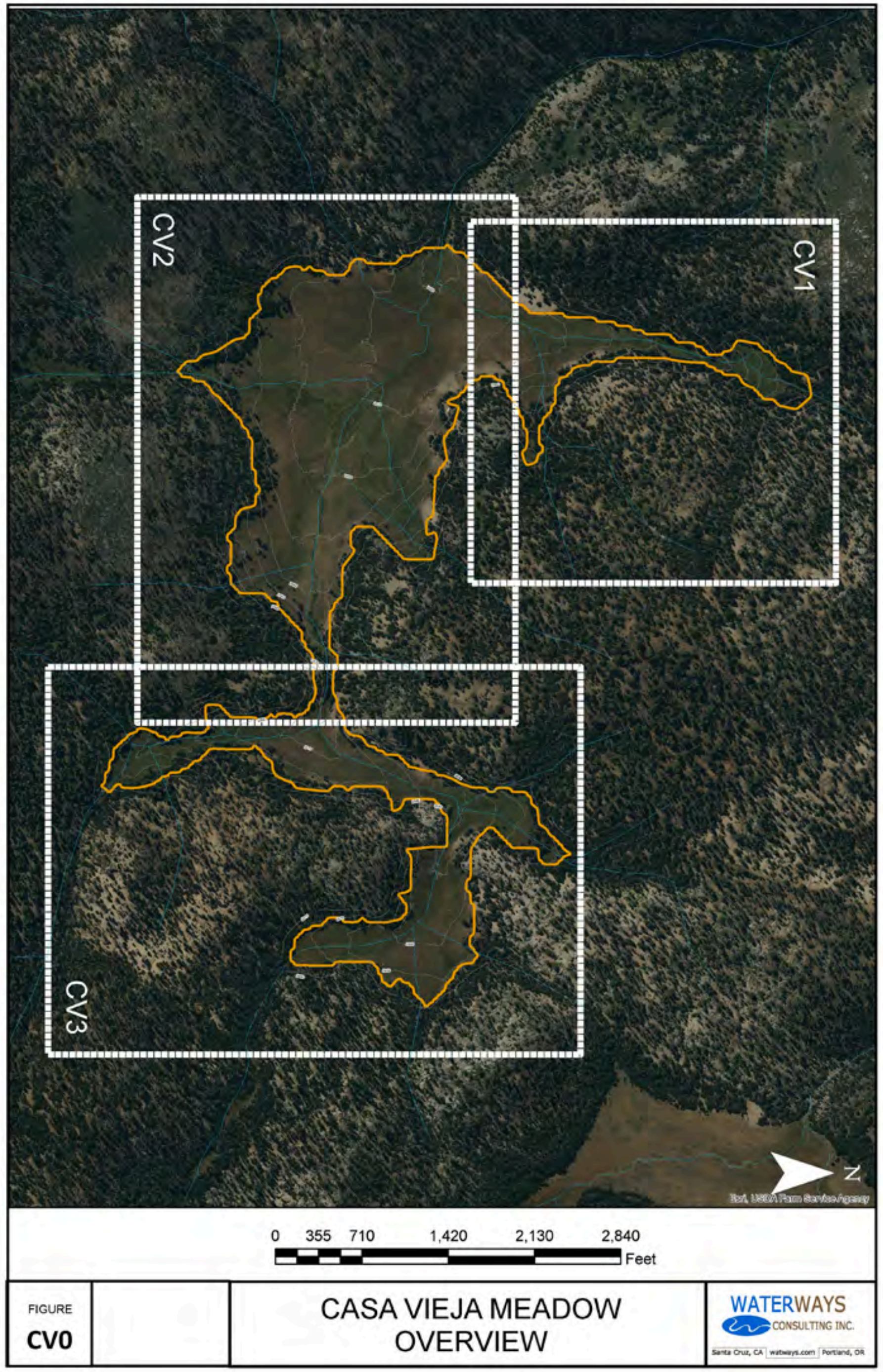
CASA VIEJA MEADOW

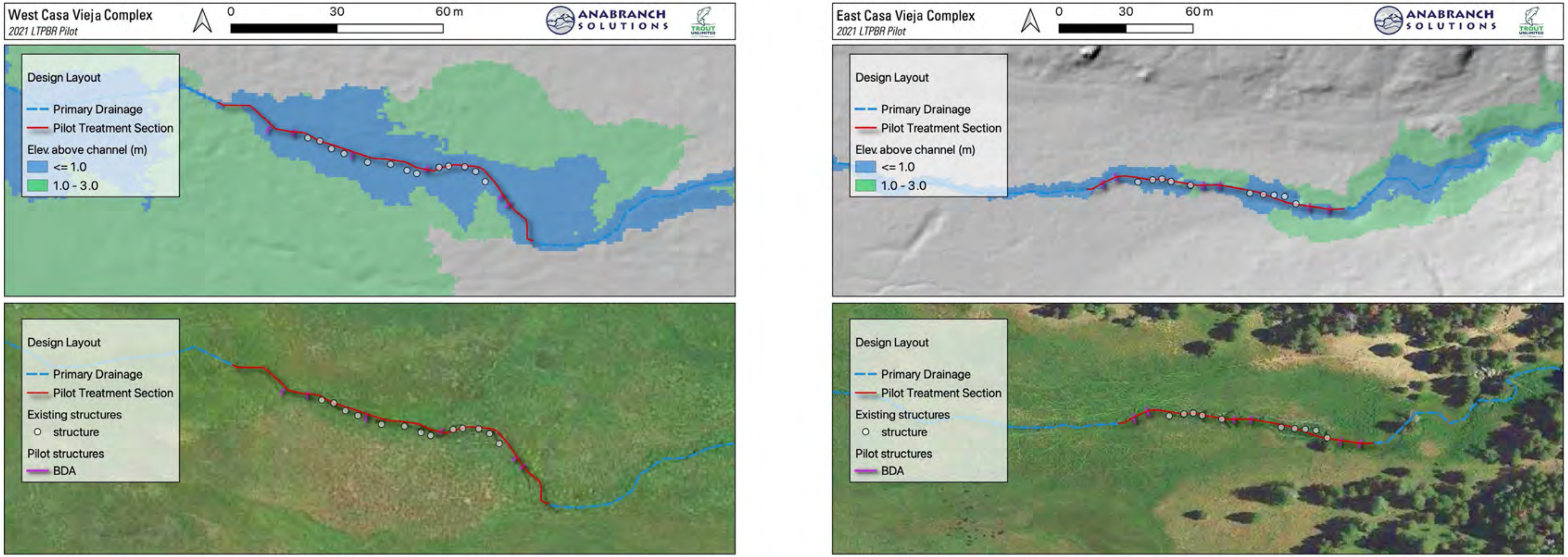
GENERAL INFO

- **Meadow Polygon:** 192 Acres
- **Stream Miles:** 4.5
- **Contributing Watershed:** 1732 acres
- **Wilderness:** Yes
- **Grazed:** Yes (Monache Allot.)
- **Existing Data:**
  - (1) Head Cut monitoring 2003 and 2010;
  - (2) PCF 2011 (raw data) and PFC Report 2011 (Grazing EA)

Casa Vieja Meadow Site Locations



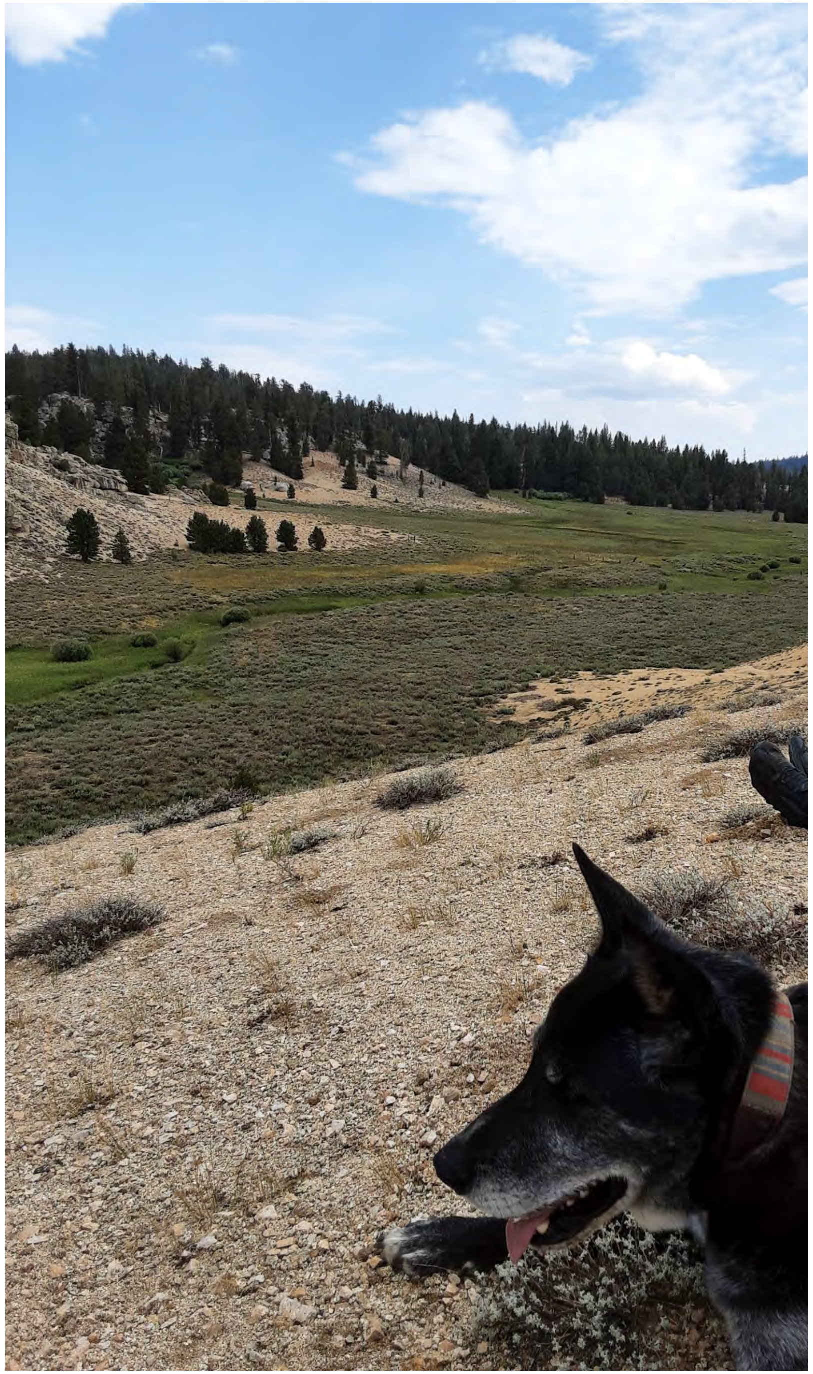


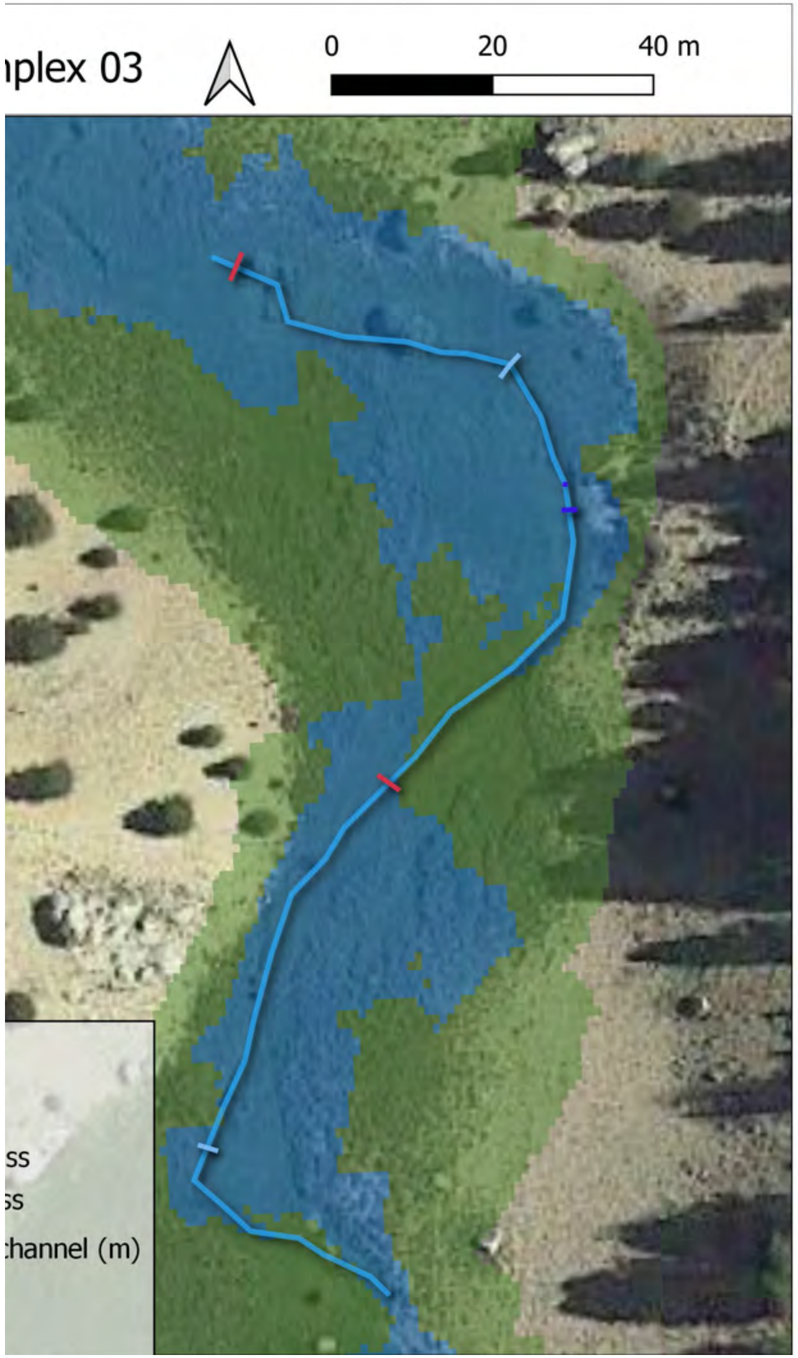


Aerial imagery and location the Main complexes with existing and proposed new structure locations (Bottom Panel). Inundation extent (blue area) estimated from a relative elevation model where the valley slope has been removed (i.e. the channel gradient is normalized to 0) with up to a 1 m increase water surface elevation and potential influence on vegetation assuming a 1-3 m increase in water table elevations (Top Panel).




Brown Meadow
01
02
03
04
05
06
10
11
15
16
17
18
19
20
21
23
26

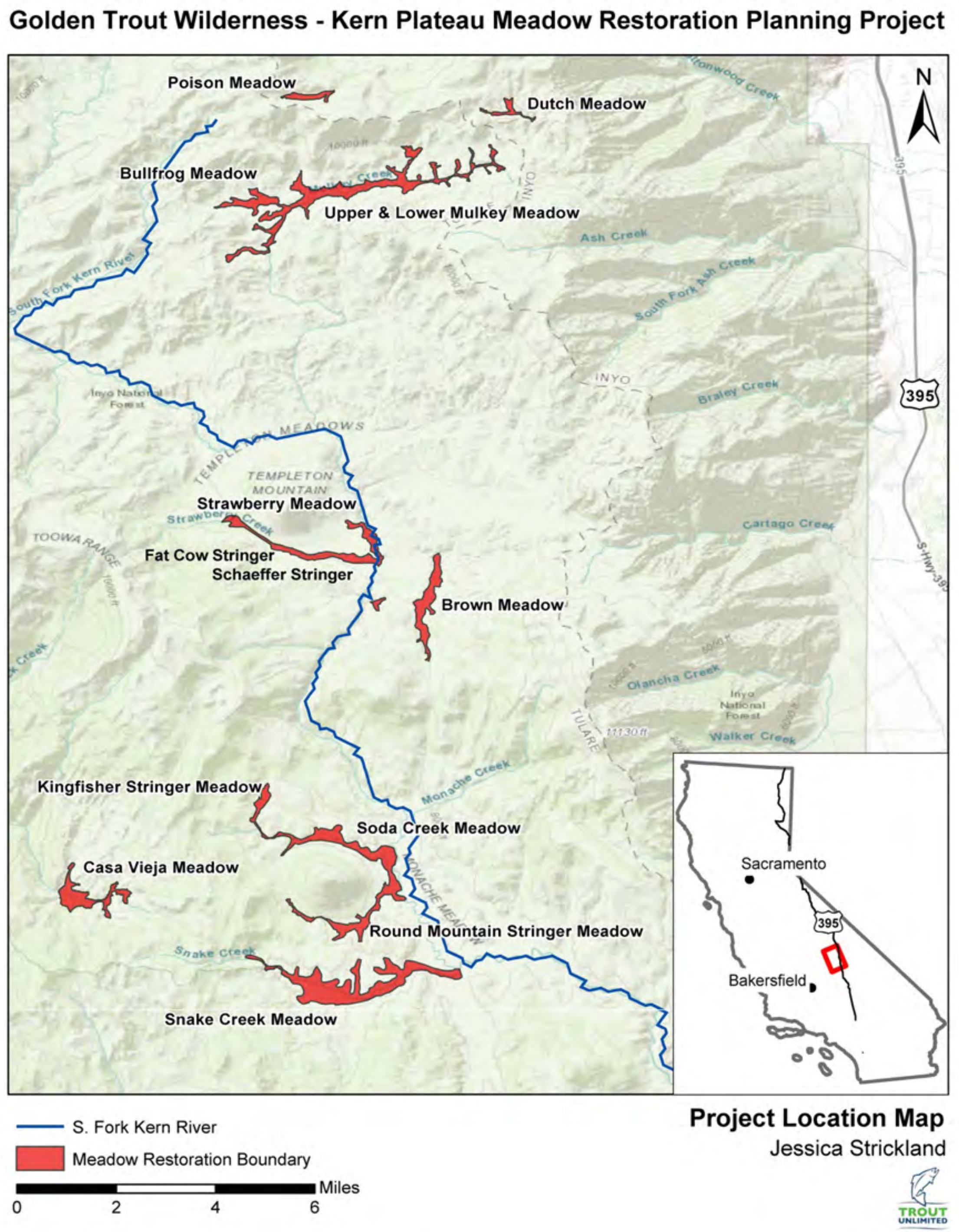




plex 03
0
20
40 m
ss
ss
channel (m)

FUNDER: CA Dept of Fish and Wildlife
TERM: Summer 2020 – Spring 2023
SCOPE: PLANNING PHASE ONLY

1. **Complete Site Assessments & Pre-Implementation Baseline Monitoring:**
   - Stream Condition
   - Botany/Wildlife/Aquatics
   - Archeology
   - Hydrogeomorphology
2. **Complete Conceptual Restoration Design**
3. **Complete Environmental Compliance and Permitting**
   - NEPA (EA or Cat Ex)
   - CEQA (MND or Cat Exp)
   - USACE 404 Permit
   - SWB 401
   - CDFW LSAA 1600
4. **Complete Final Design**



MEADOWS INCLUDED:

Northern Cohort:

- Mulkey
- Bullfrog
- Dutch
- Poison
- Round
- Horseshoe

Southern Cohort:

- Strawberry
- Brown
- Fat Cow Stringer
- Schaeffer
- Kingfisher Stringer
- Soda Creek
- Round Mountain Stringer
- Snake Creek
- Casa Vieja

Come Help!

- Over 70 miles of stream channel in project area
- Help Golden Trout survive in increasingly adverse climatic conditions
- 2nd Pilot in June at Round Meadow
- Learn effective LT-PBR techniques and best practices
- Be part of an extraordinary cooperative
- We're going to be busy for years to come
- Join Cal-PBR group www.calpbr.org

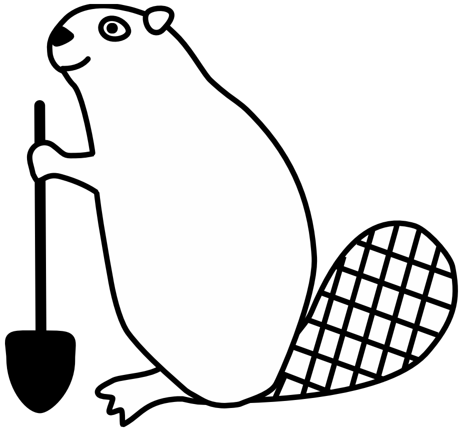
Thanks to all the incredible people working on this project!

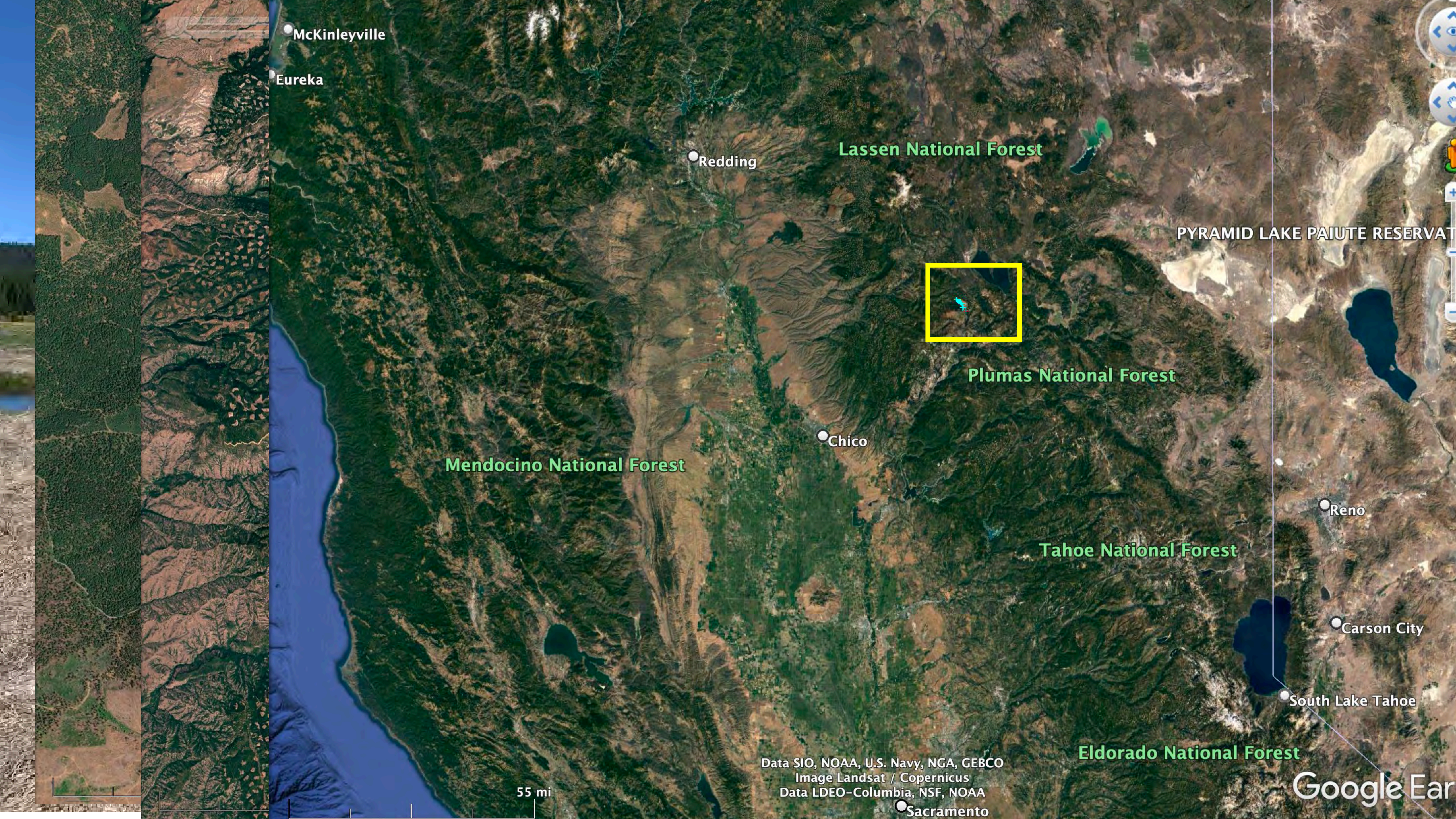
Tasmám Kóyóm

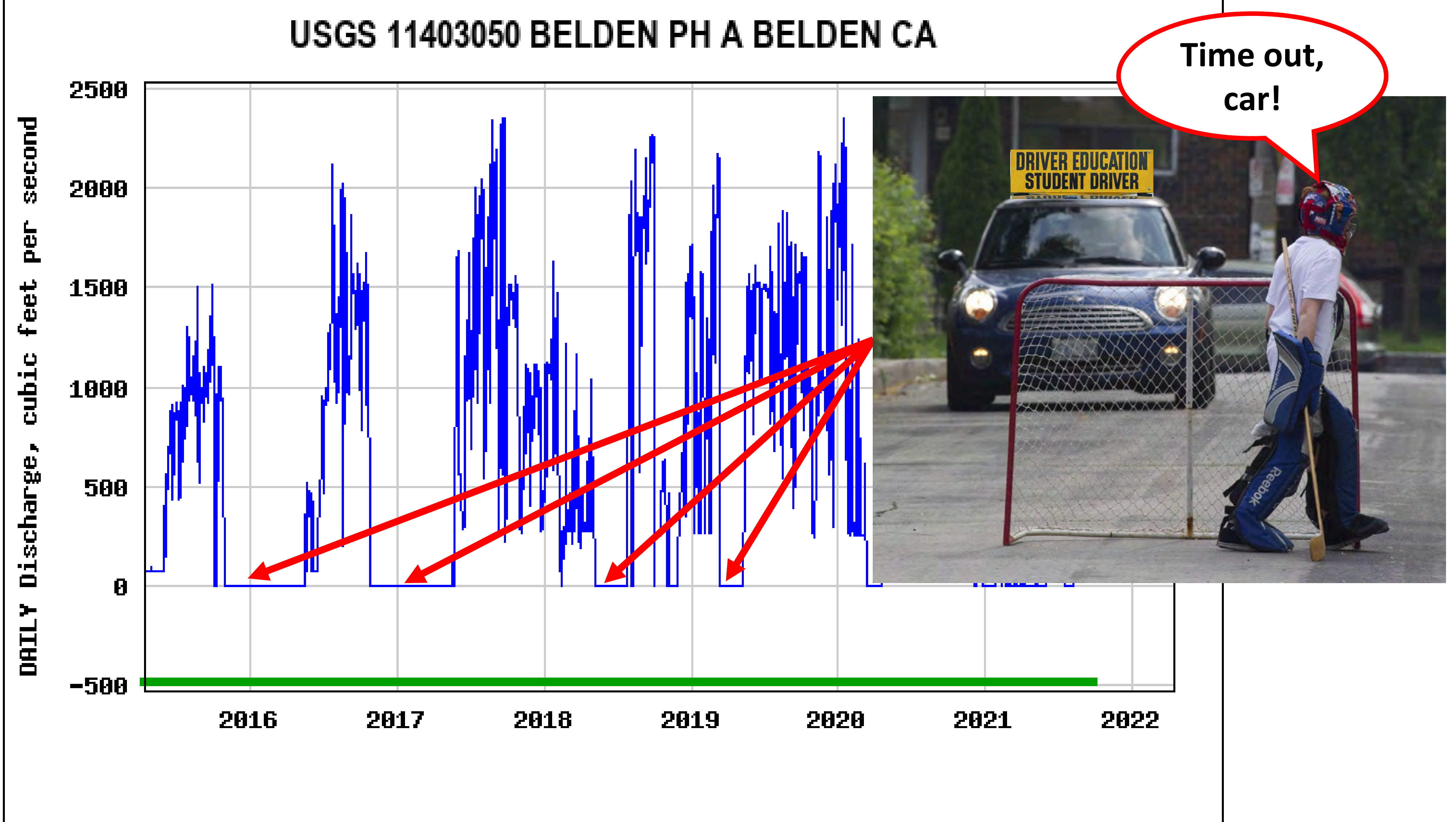
The Hundred Year Summer

Swift Water Design

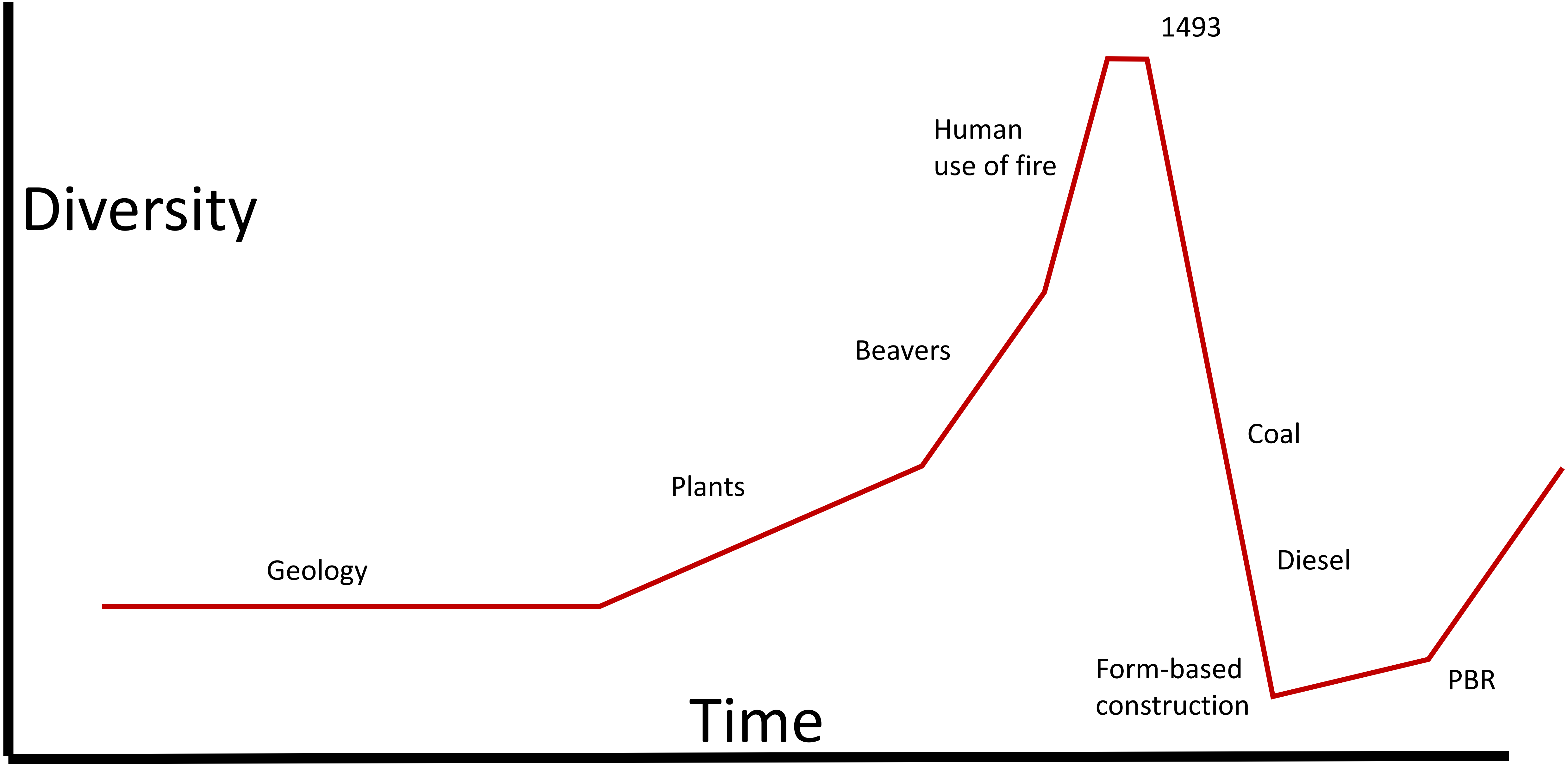
Process Based Restoration and Beaver Coexistence



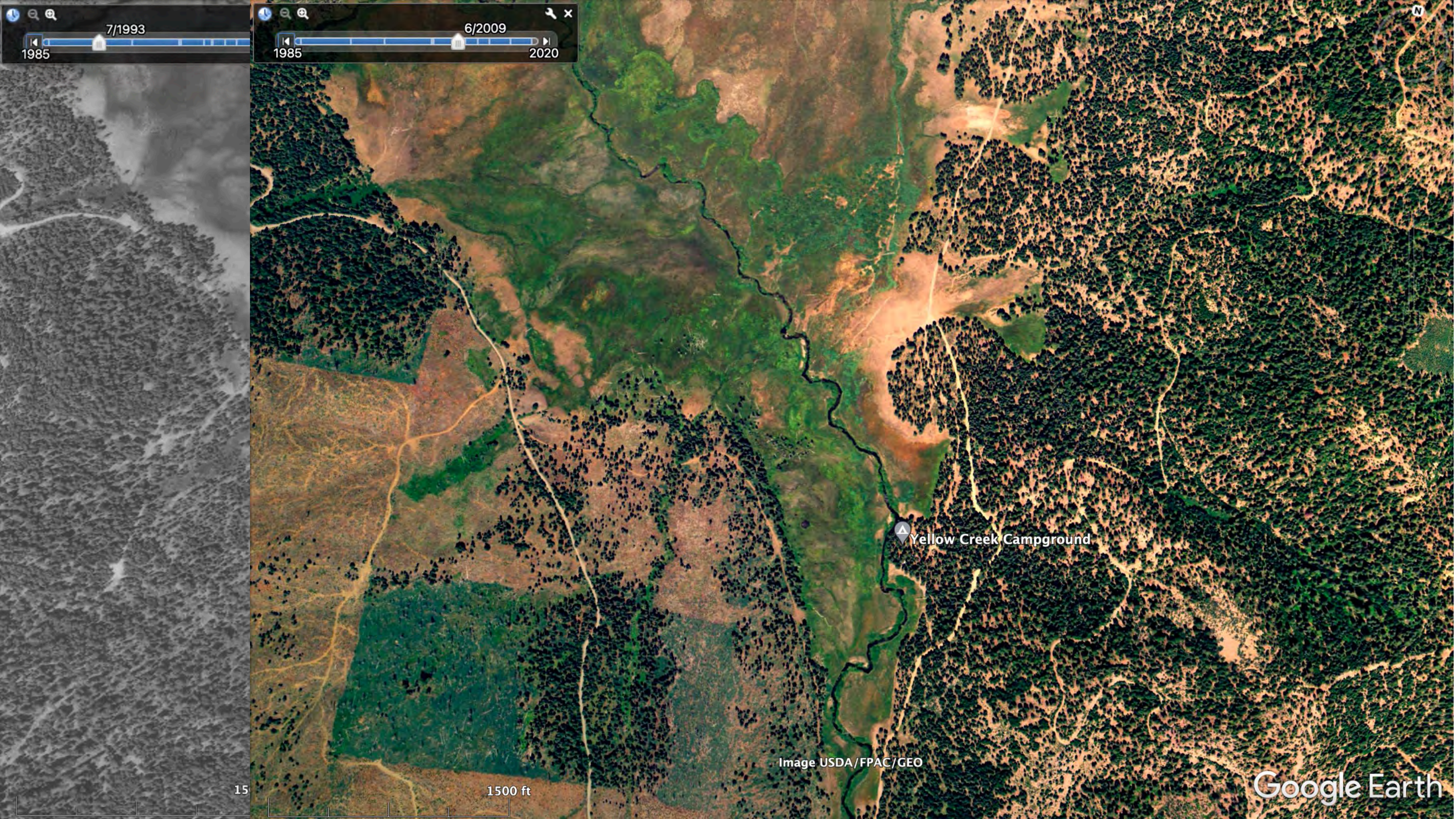

McKinleyville
Eureka
Redding
Lassen National Forest
PYRAMID LAKE PAIUTE RESERVAT
Plumas National Forest
Chico
Mendocino National Forest
Reno
Tahoe National Forest
Carson City
South Lake Tahoe
Eldorado National Forest
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Data LDEO-Columbia, NSF, NOAA
55 mi
Sacramento


USGS 11403050 BELDEN PH A BELDEN CA
DAILY Discharge, cubic feet per second
2500
2000
1500
1000
500
0
-500
2016
2017
2018
2019
2020
2021
2022
Time out, car!
DRIVER EDUCATION
STUDENT DRIVER
Reebok

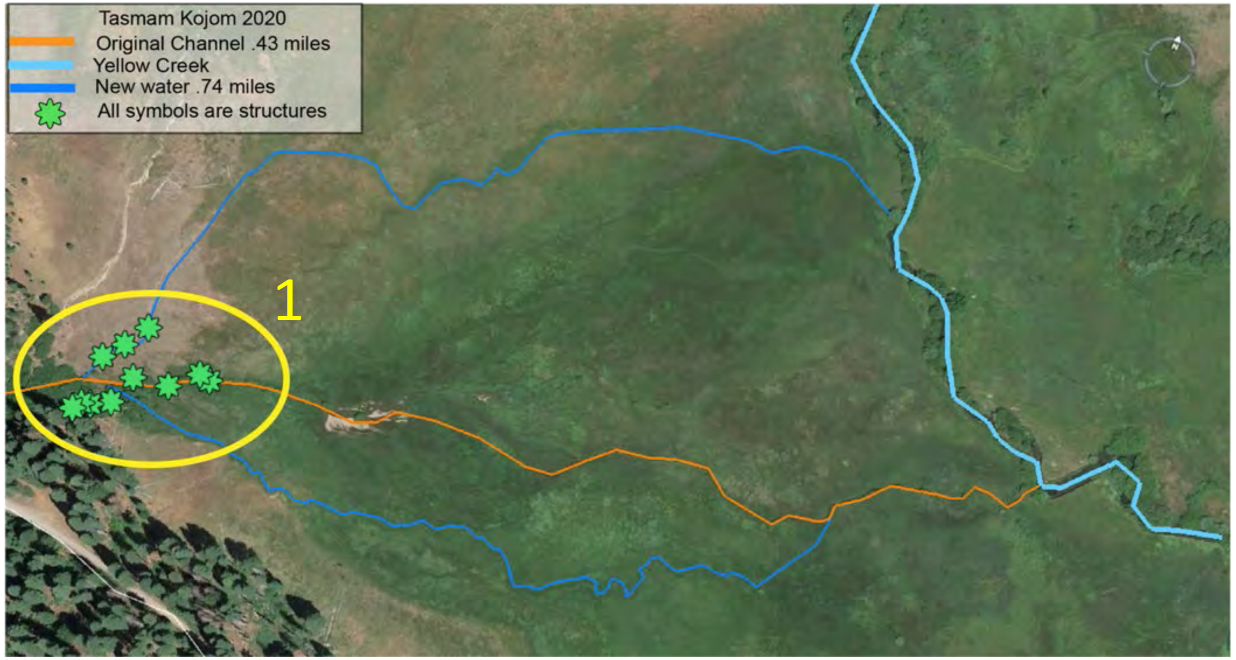
Drivers of Riverscape Process

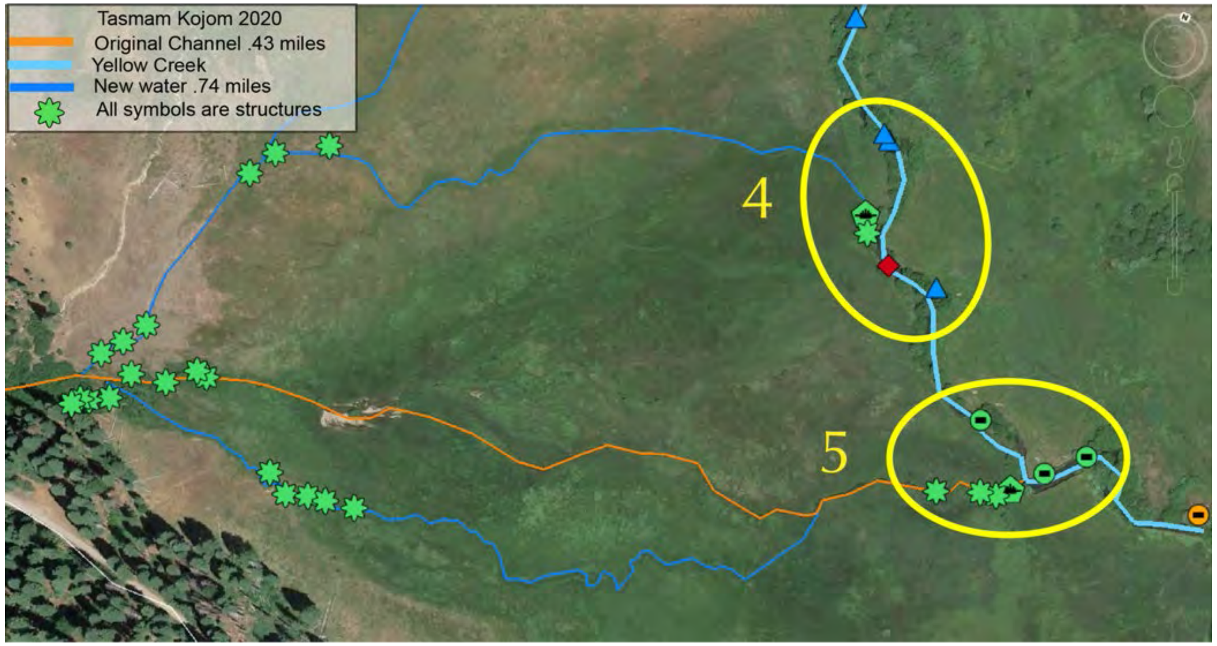


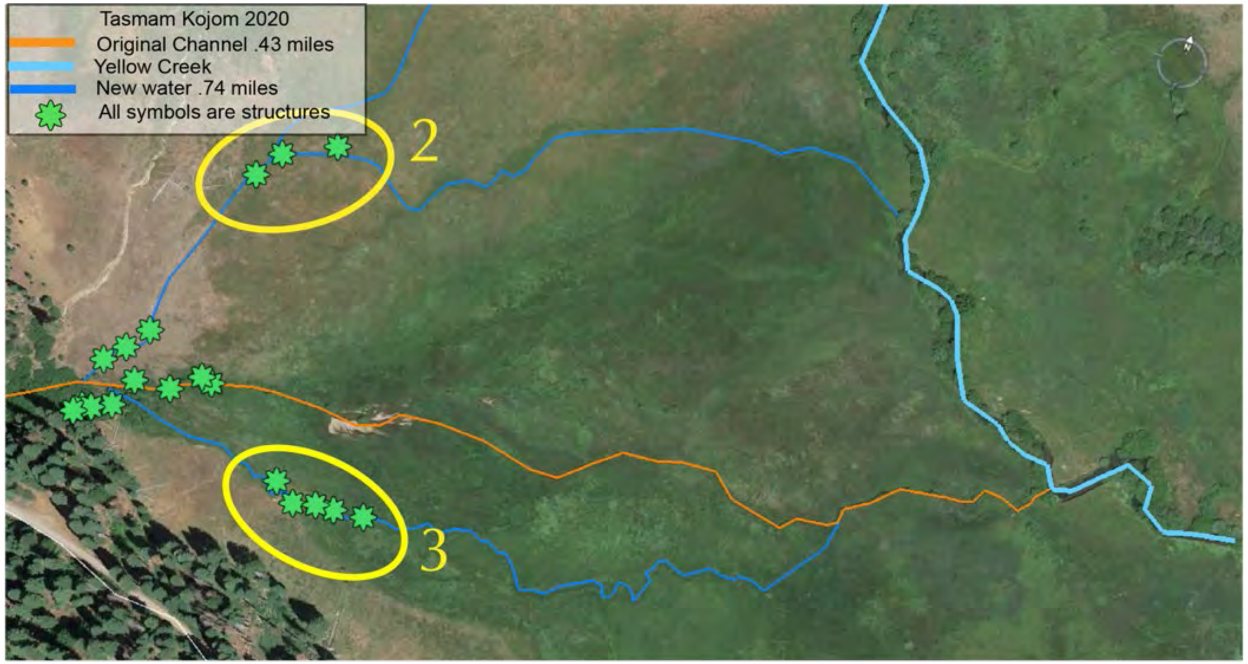

Discovery


7/1993
1985
6/2009
1985
2020
Yellow Creek Campground
Image USDA/FPAC/GEO
15
1500 ft
Google Earth


Tasmam Kojom 2020
Original Channel .43 miles
Yellow Creek
Downstream
Downstream


Tasmam Kojom 2020
Original Channel .43 miles
Yellow Creek
New water .74 miles
All symbols are structures
1

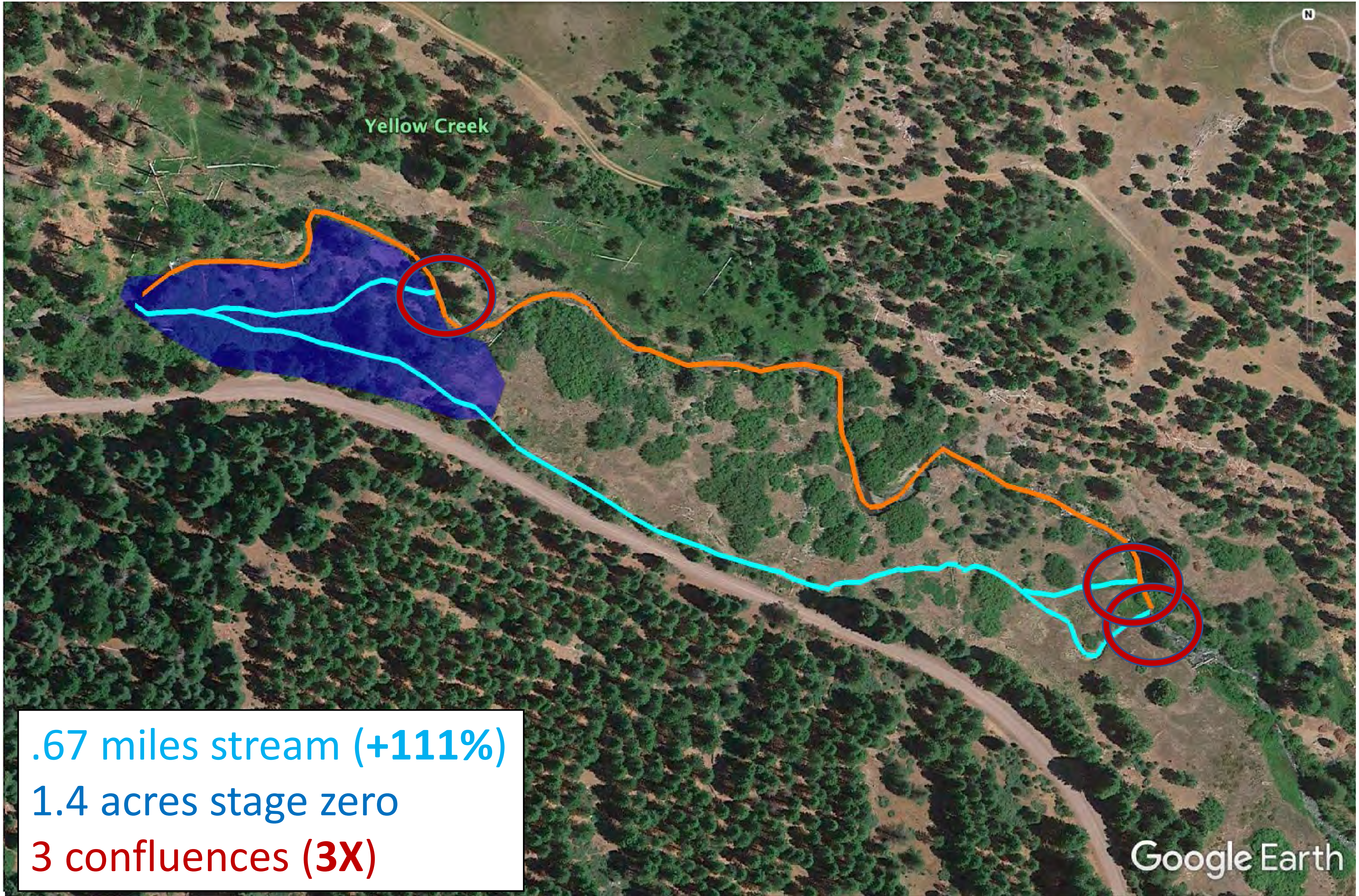

Tasmam Kojom 2020
Original Channel .43 miles
Yellow Creek
New water .74 miles
All symbols are structures
4
5

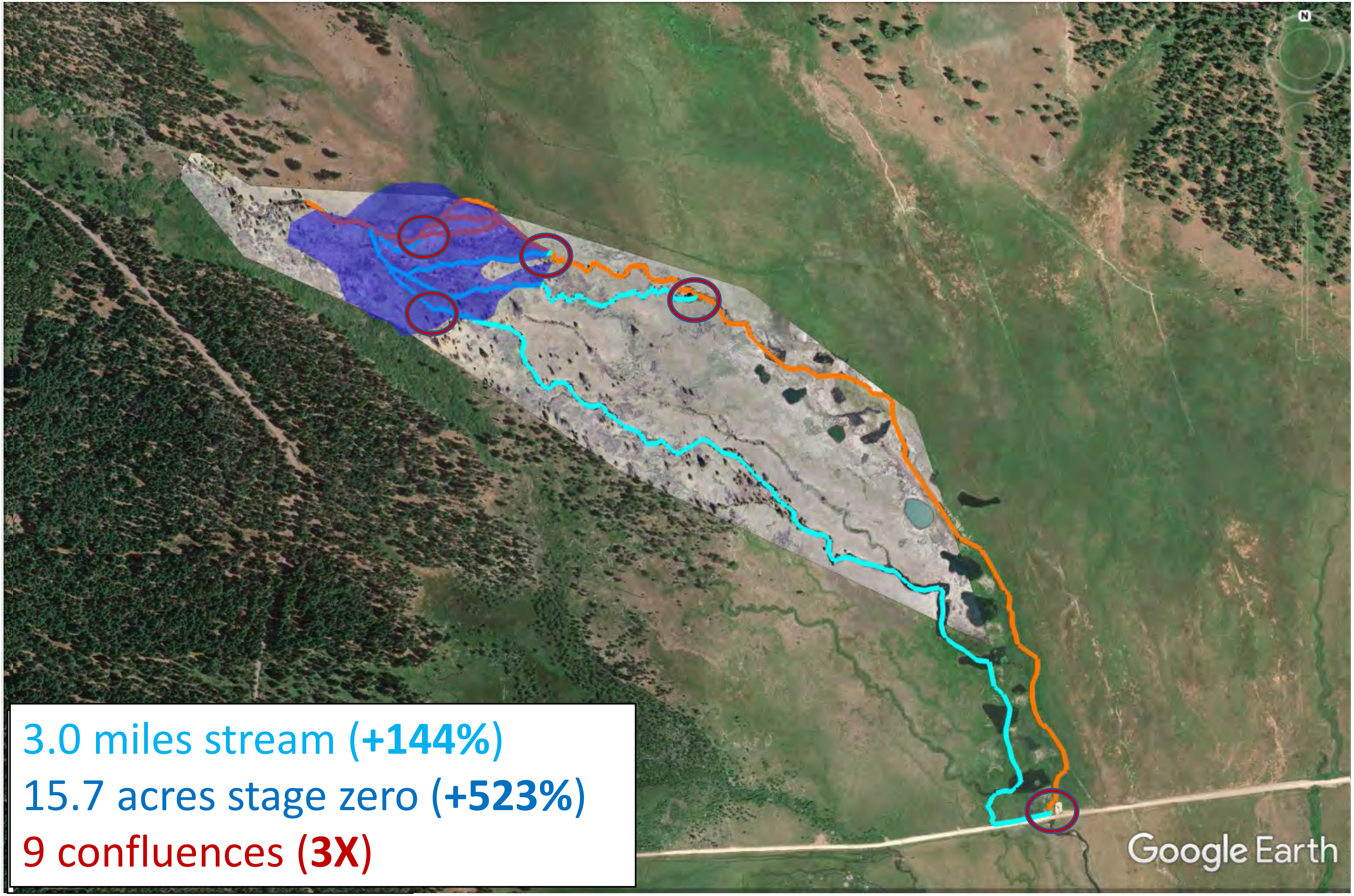

Tasmam Kojom 2020
Original Channel .43 miles
Yellow Creek
New water .74 miles
All symbols are structures
2
3







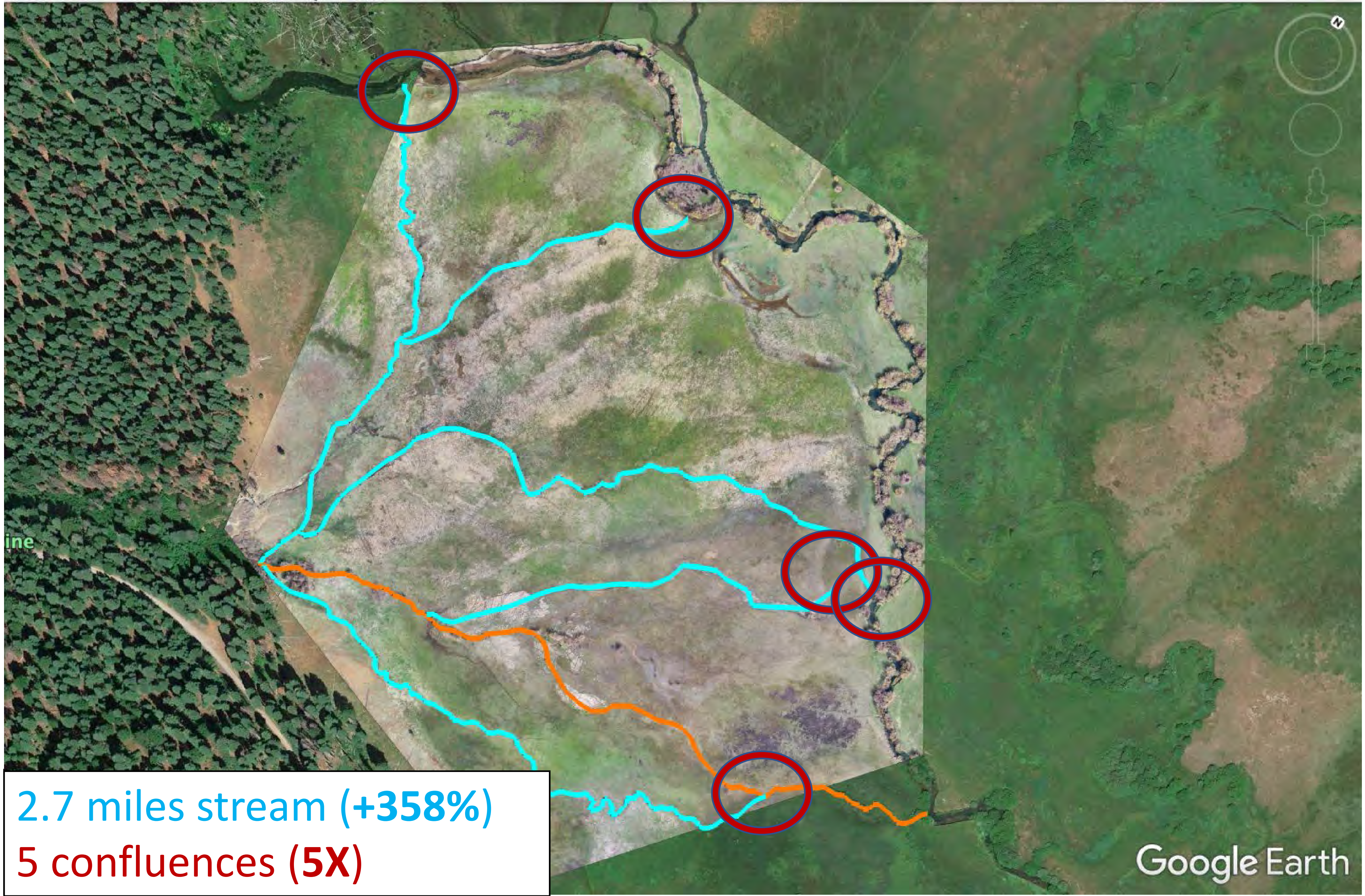

Yellow Creek
.67 miles stream (+111%)
1.4 acres stage zero
3 confluences (3X)



3.0 miles stream (**+144%**)

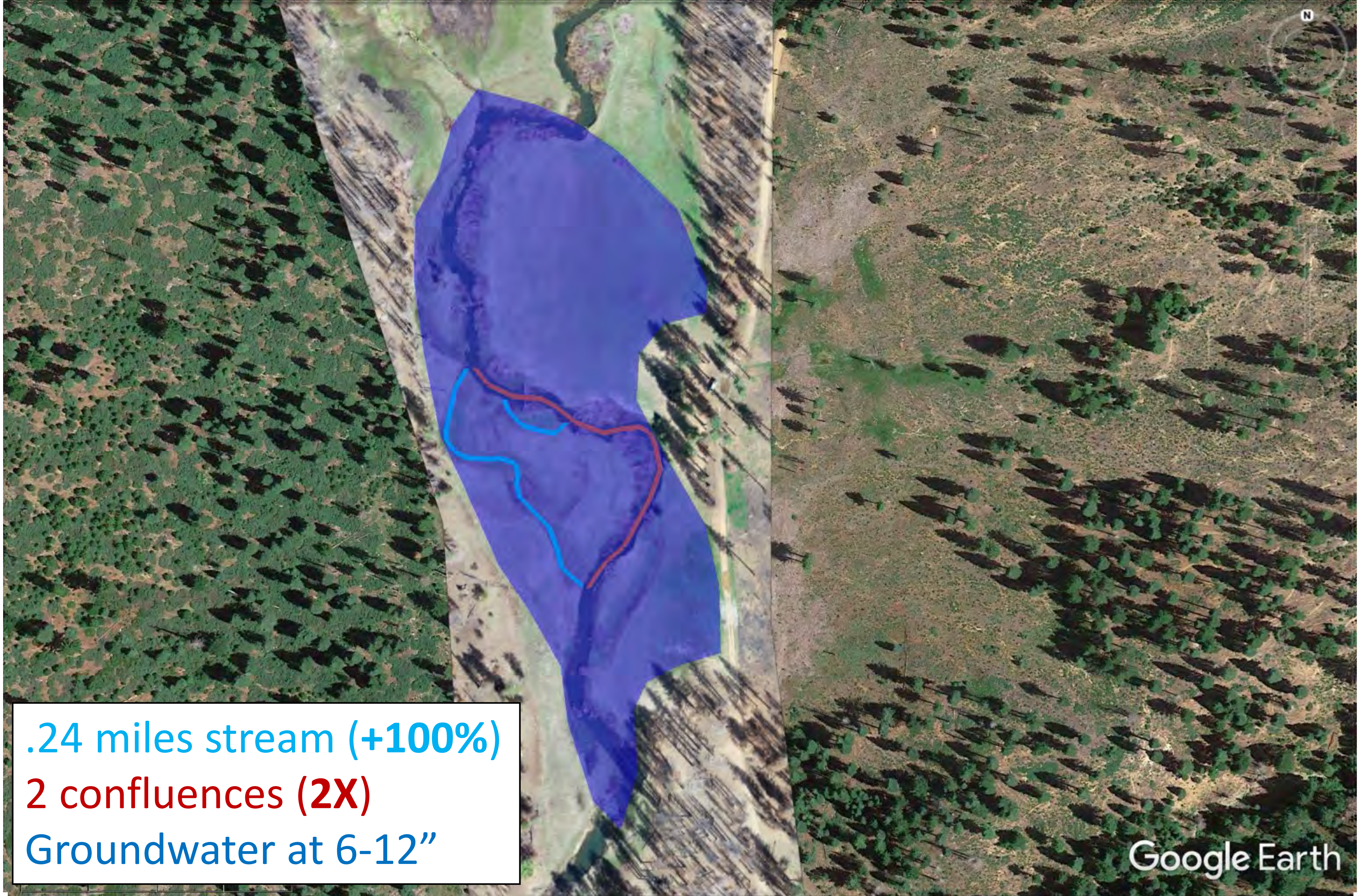
15.7 acres stage zero (**+523%**)

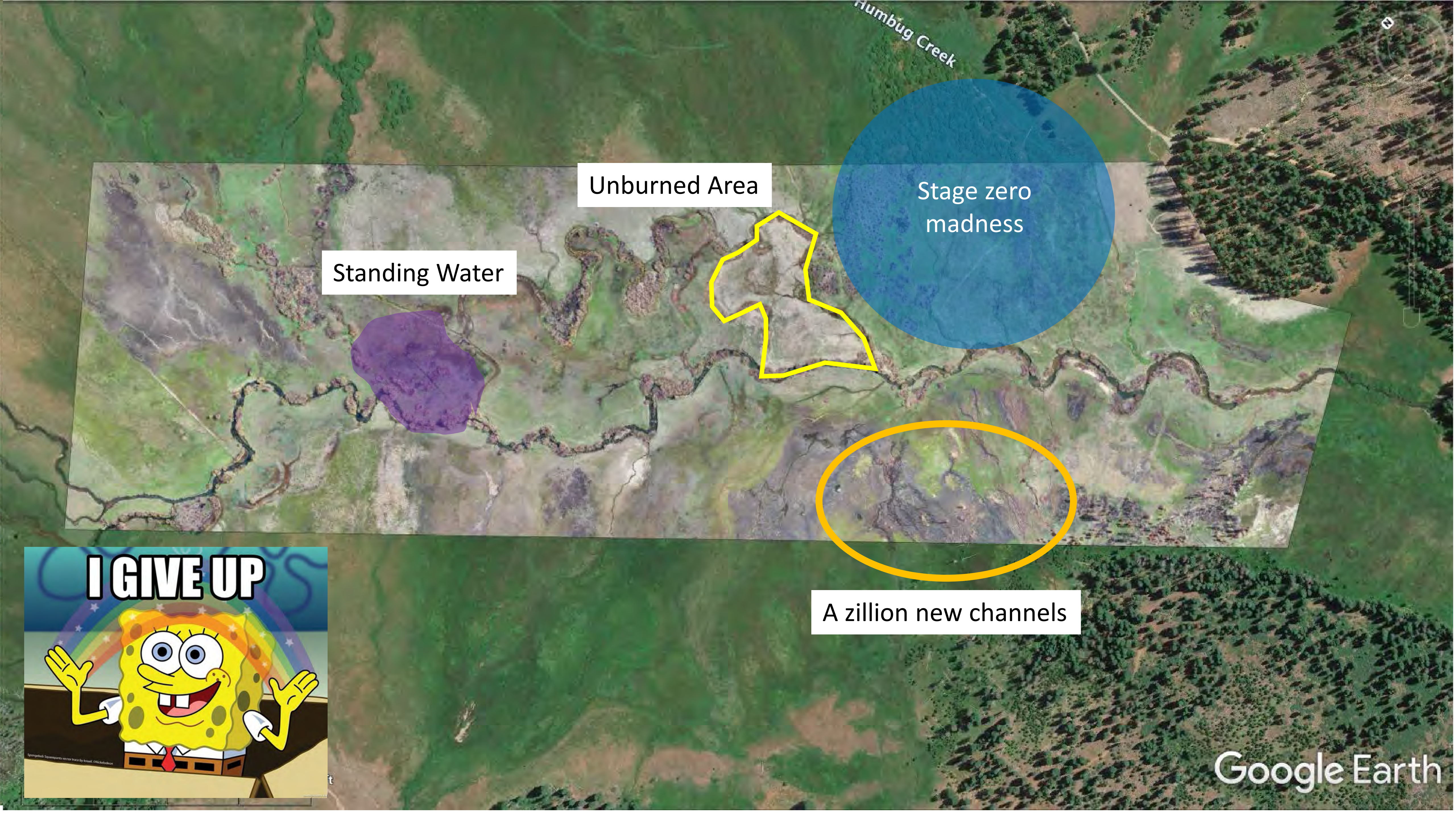
9 confluences (**3X**)



2.7 miles stream (**+358%**)

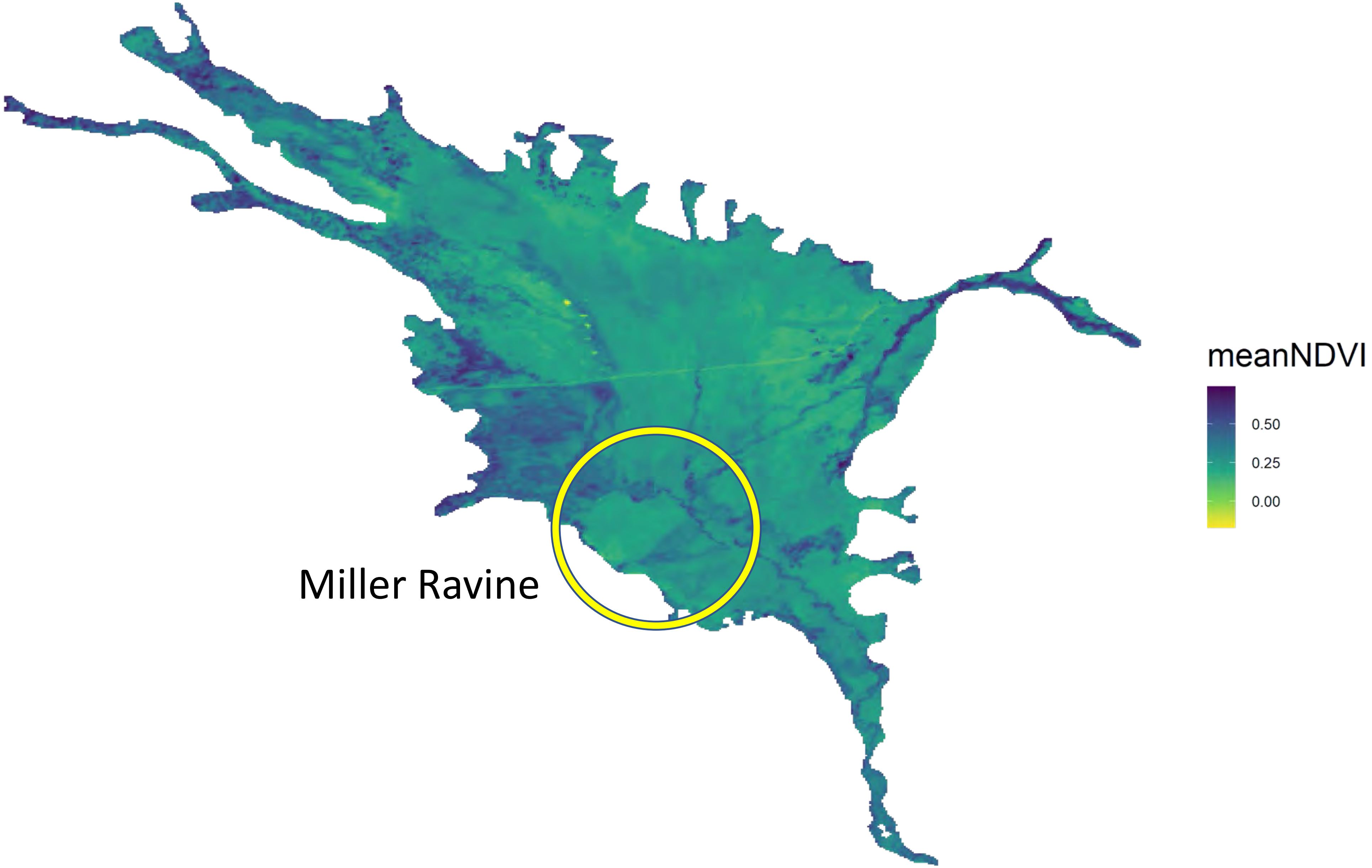
5 confluences (**5X**)


.24 miles stream (+100%)
2 confluences (2X)
Groundwater at 6-12”
Google Earth


Humbug Creek
Unburned Area
Standing Water
Stage zero
madness
A zillion new channels
I GIVE UP
Google Earth

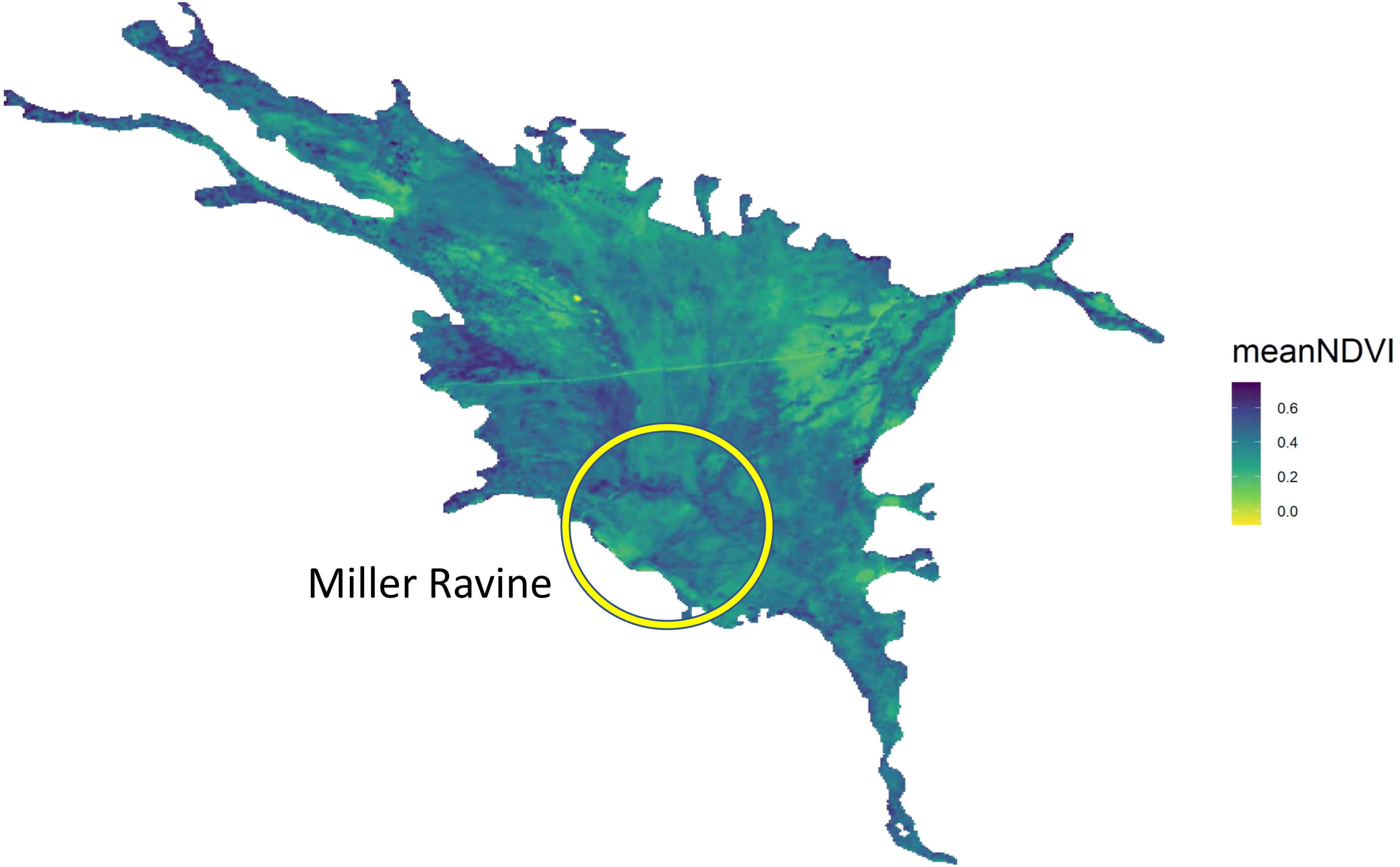
Average Monthly NDVI

Oct. 2018



Average Monthly NDVI

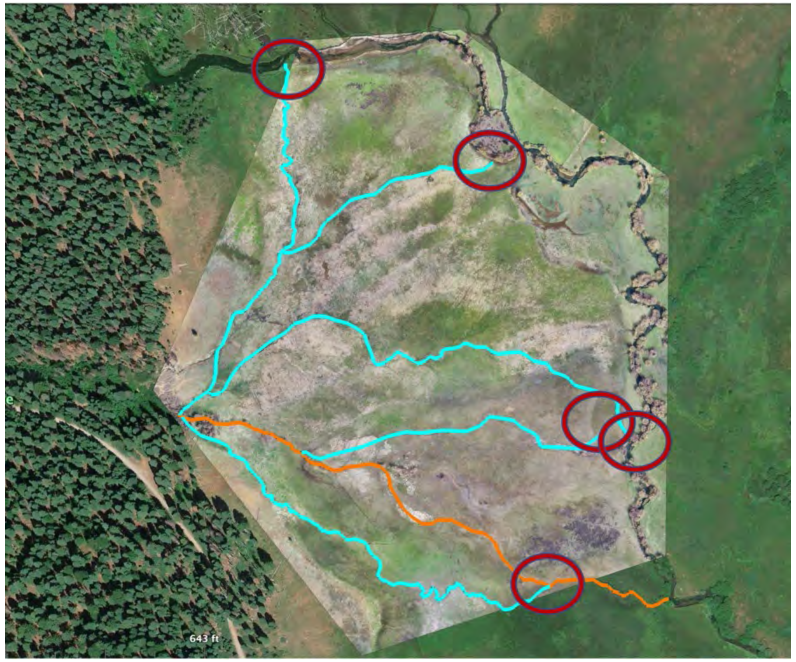
Oct. 2019

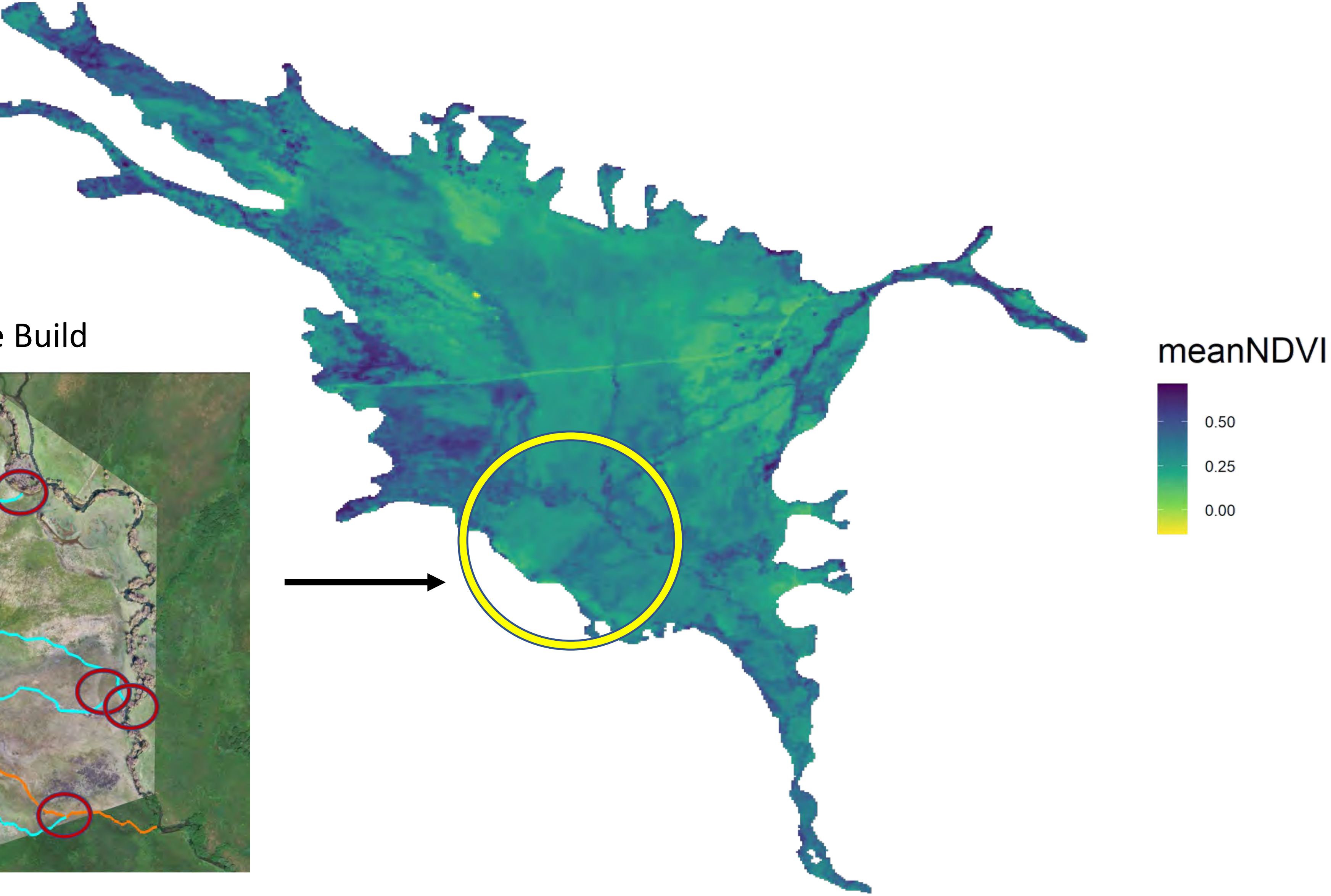


Average Monthly NDVI

Oct. 2020

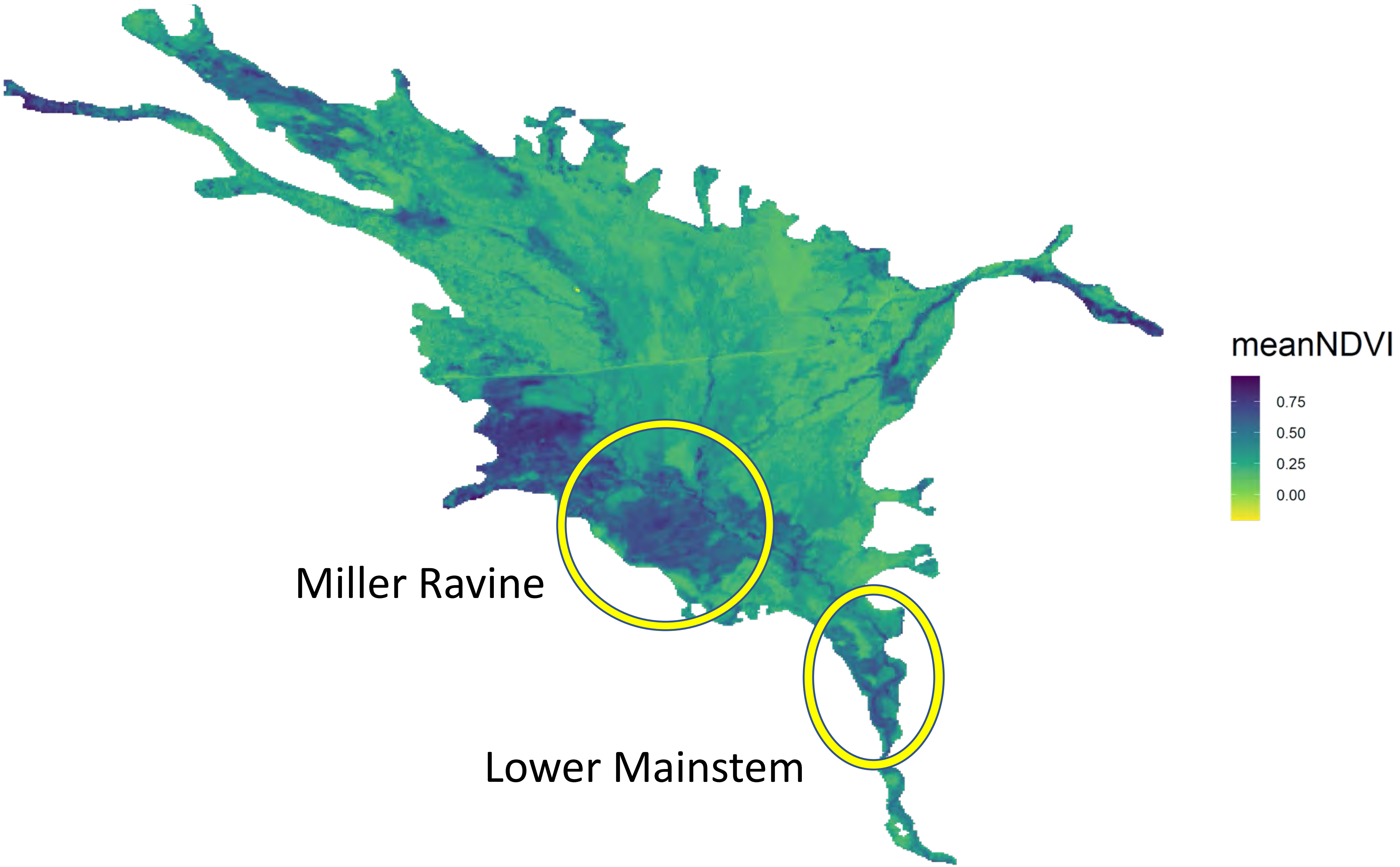
Miller Ravine Build





Average Monthly NDVI

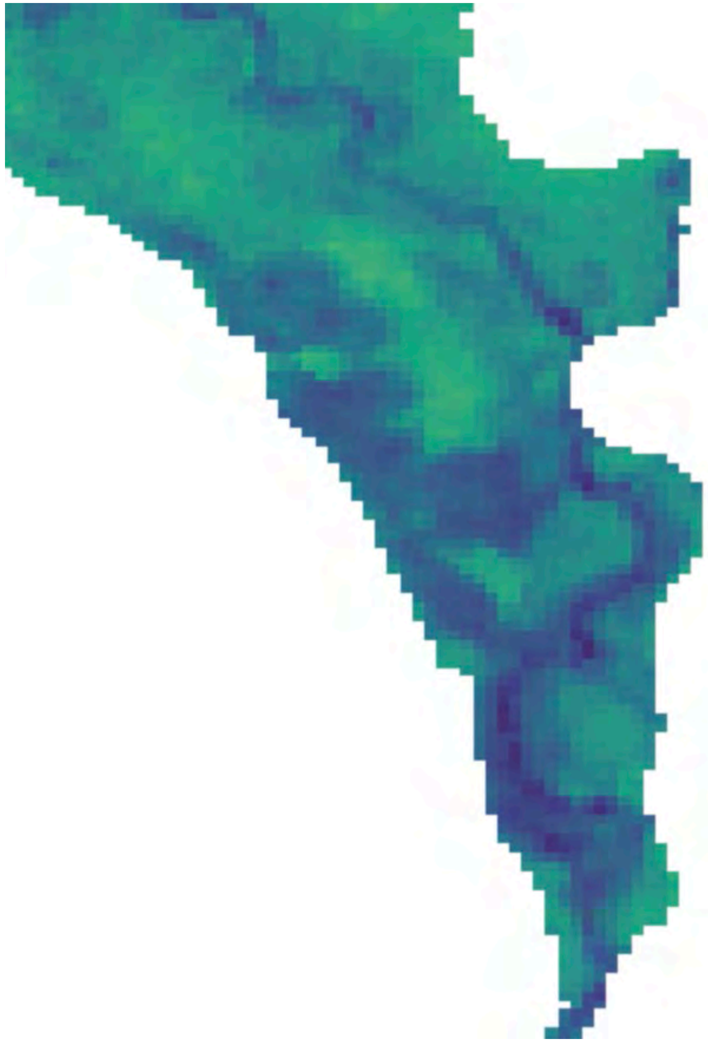
Oct. 2021



Lower Mainstem Yellow Creek

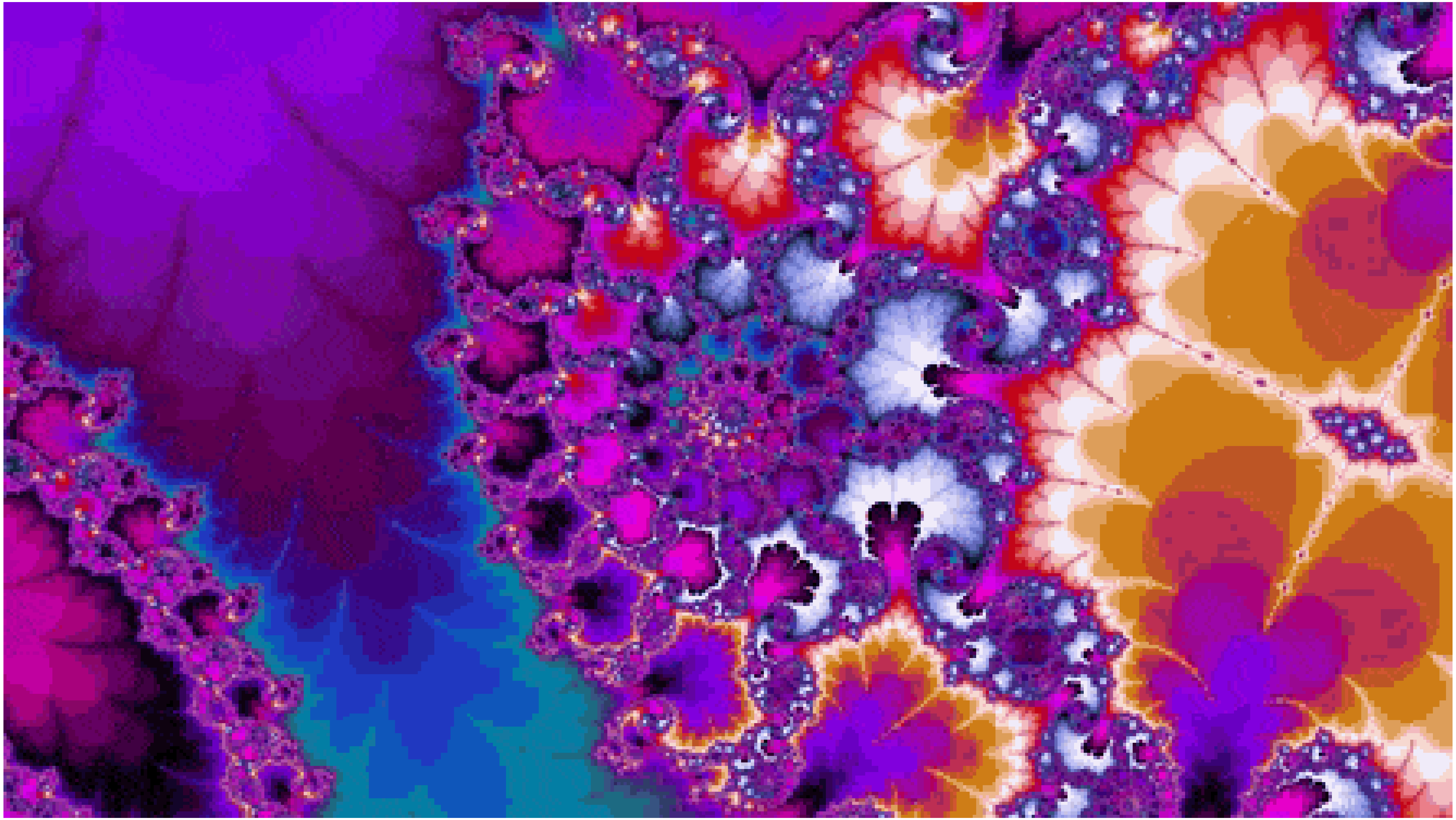
2020

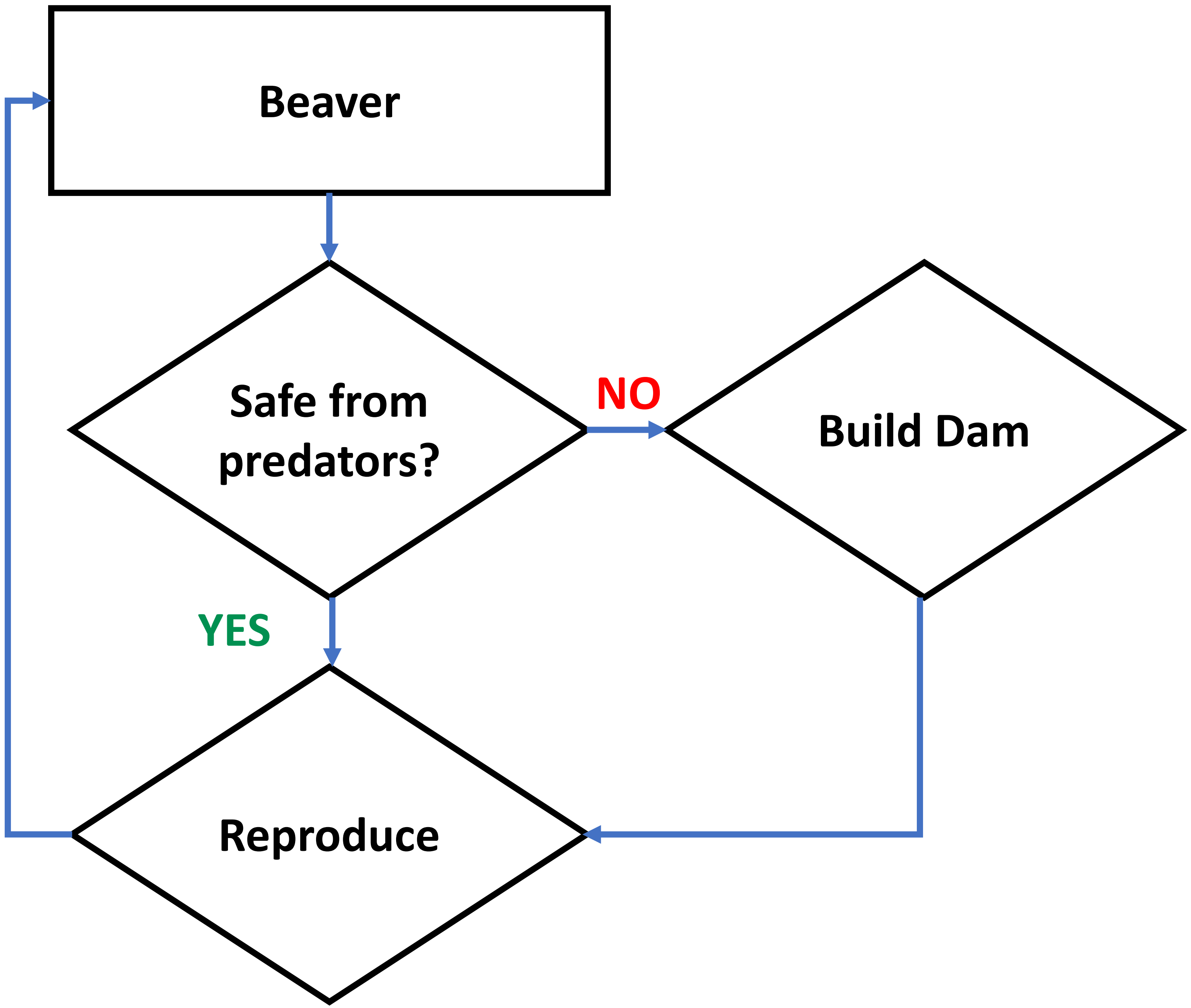
2021

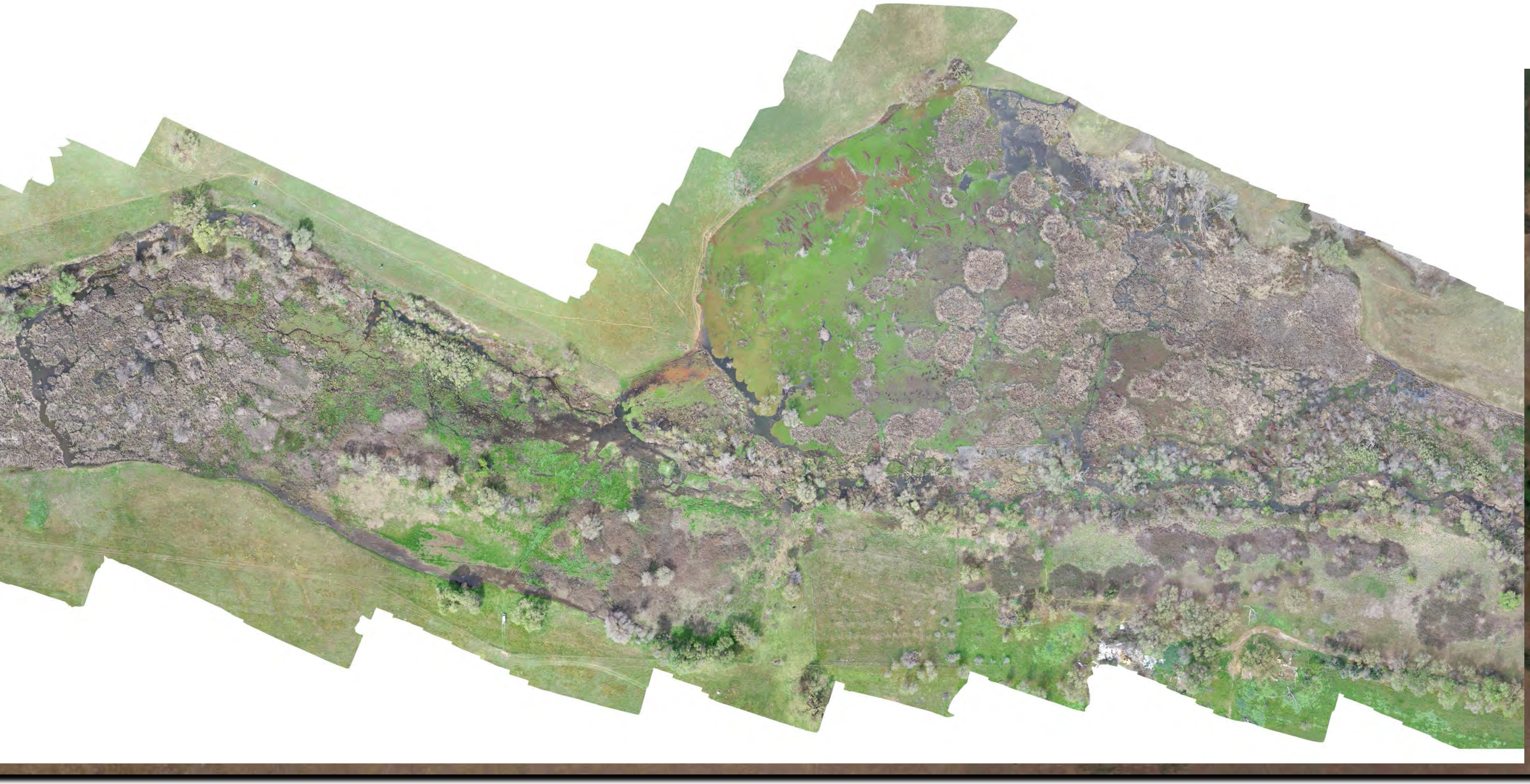


October 30, 2021
Beaver Sign!

$$z_{n+1} = z_n^2 + C$$



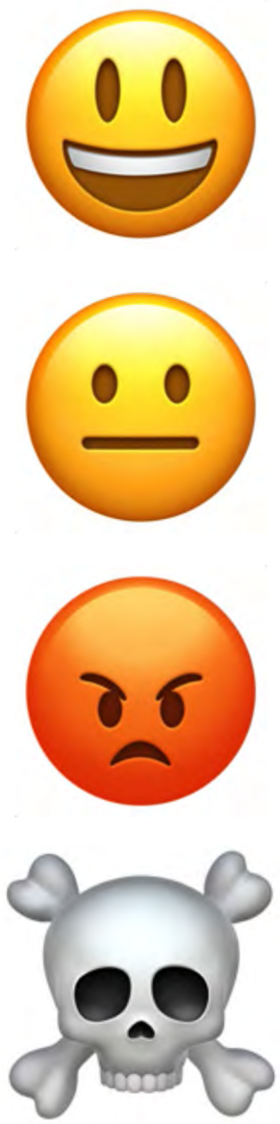

Beaver
Safe from predators?
NO
Build Dam
YES
Reproduce



Facilitation

All The Tools?

A Simplified Monitoring Protocol



Project Failure

Phase 1

Phase 2

Project Complete

You're not alone in considering process based restoration.

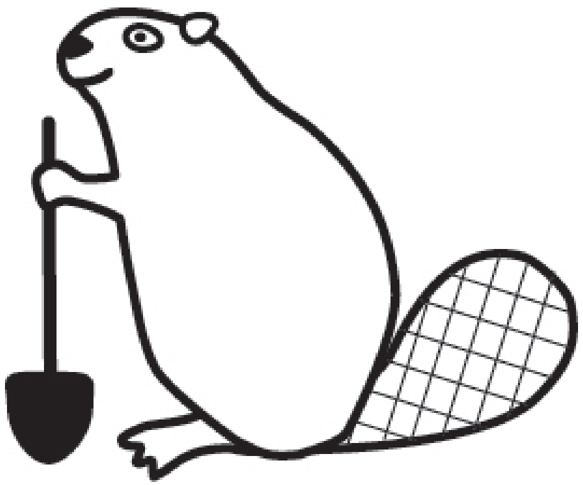
Here are some of the great folks we've worked with—many thanks to all of you, and apologies to anyone I've forgotten.

If you have any questions or would like to visit a build, please get in touch.

Swift Water Design

Process Based Restoration
and
Beaver Coexistence

530-416-1907
kevin@swiftwaterdesign.com



Restoring a Sierra Meadow Complex: A Decade of Data and Lessons Learned

David Shaw, Kealie Pretzlav, Mark Llorente, Ben Trustman (Balance Hydrologics)
Beth Christman (Truckee River Watershed Council)

Balance Hydrologics

22 April 2022

Outline

01 Background

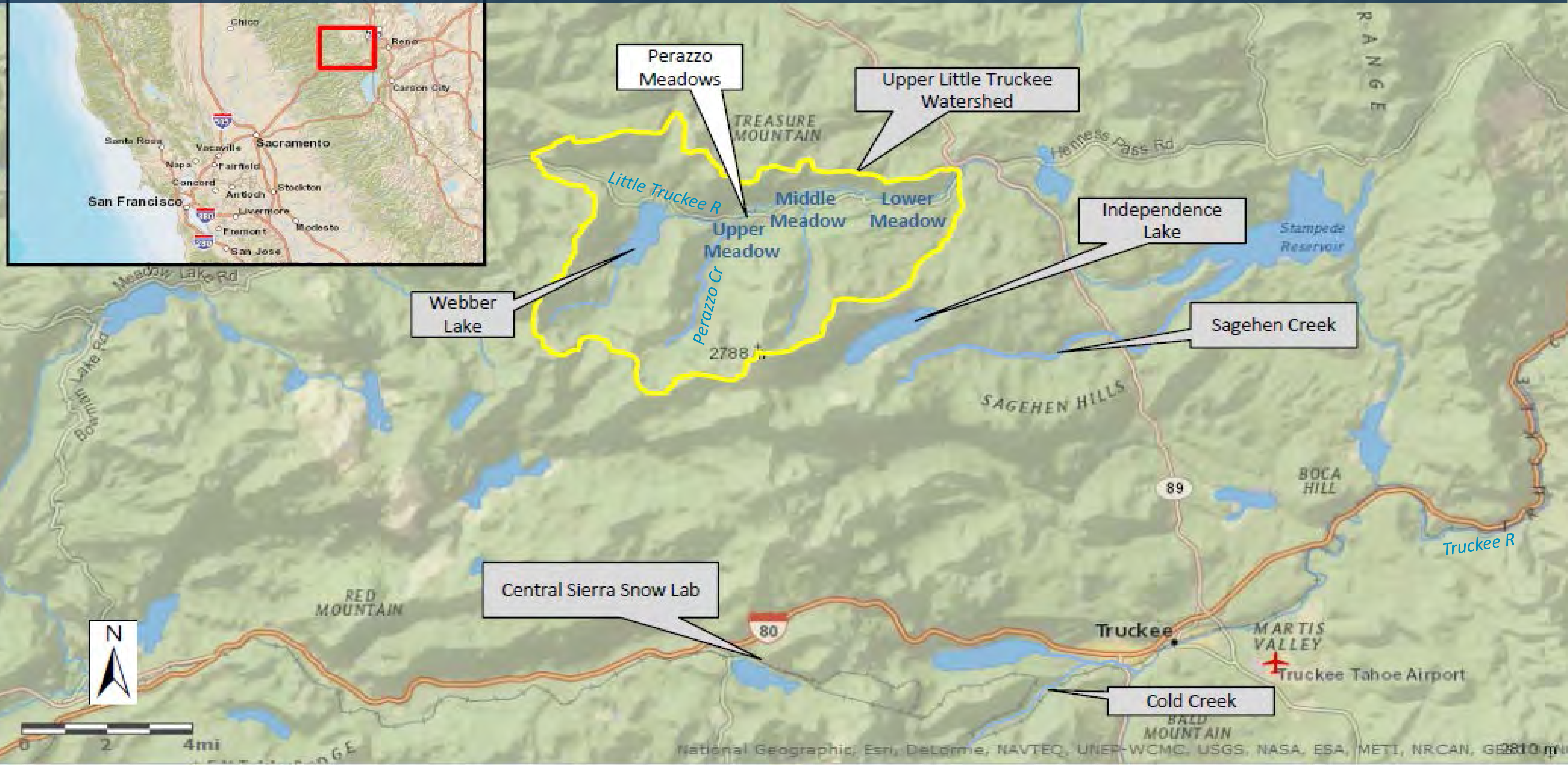
02 Restoration Approaches

03 Monitoring Methods

04 Data Analysis and Findings


01
Background

Location and Setting

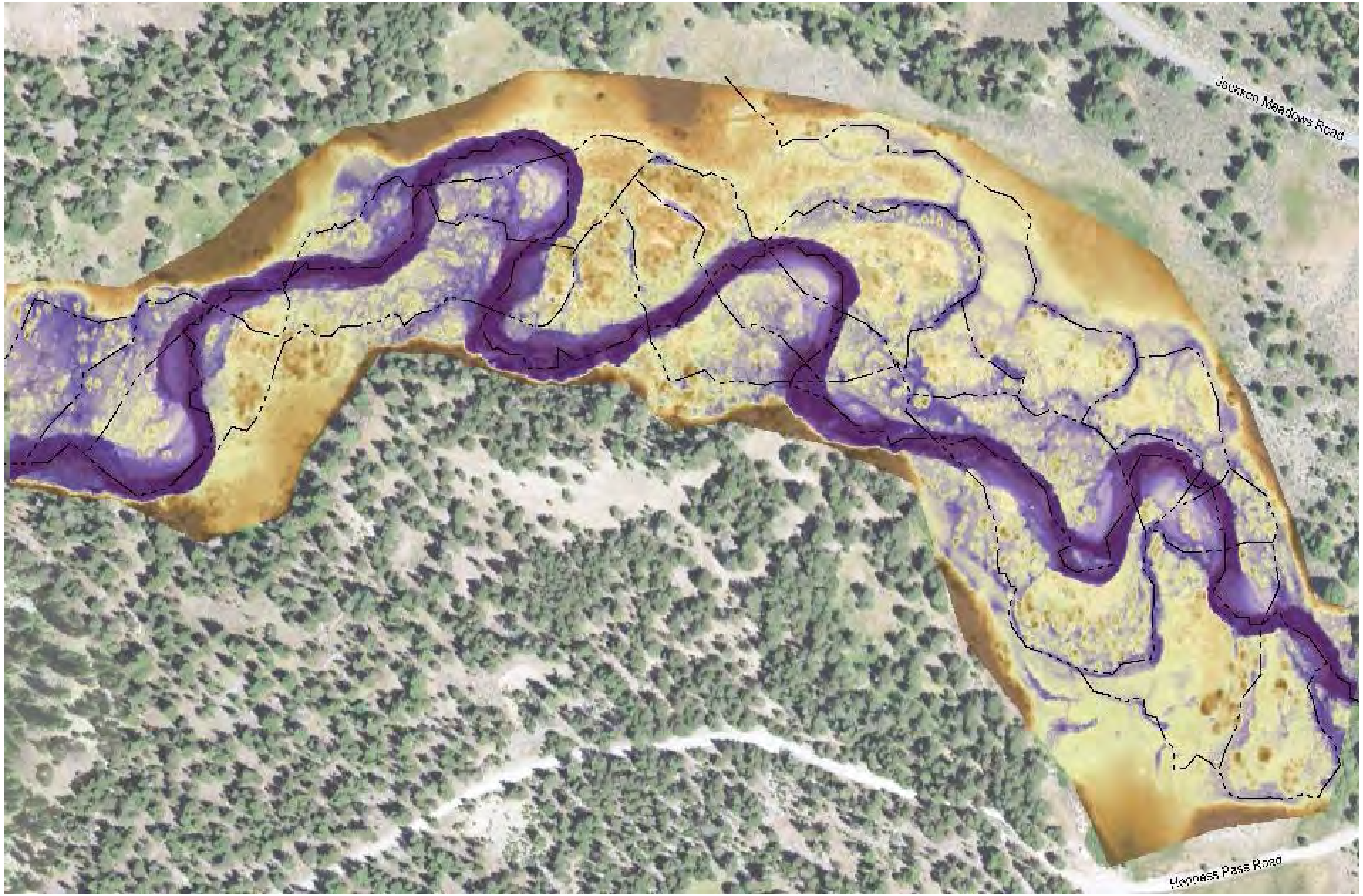


Location and Setting

Conditions Prior to Restoration

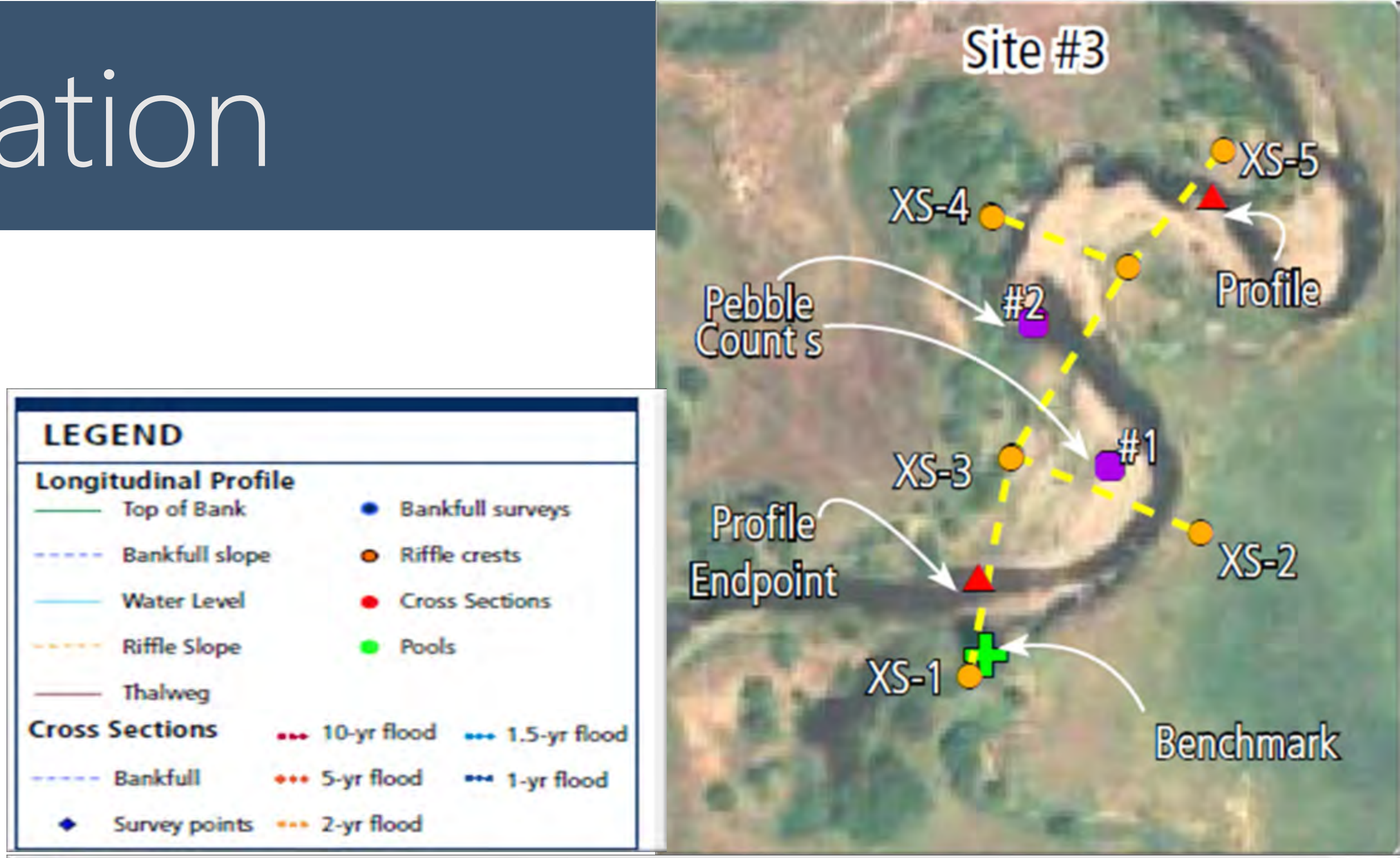
- Volcanic bedrock underlying outwash terraces and moraines
- History of logging, road-building, railroads, channelization
- Conversion from multi-thread braided system to single-thread

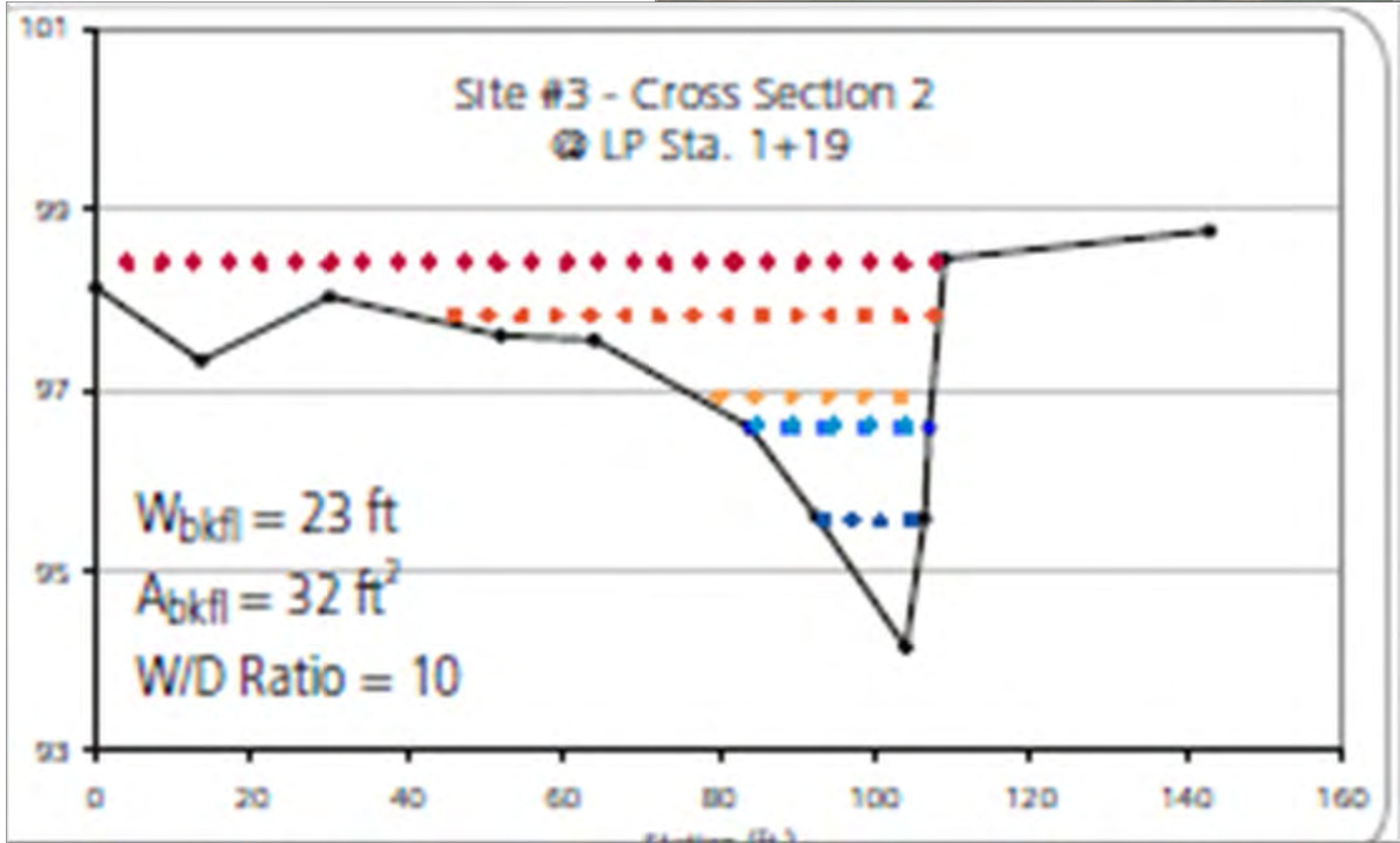
Relative Elevation Model (REM) showing abandoned primary and remnant secondary channels in Lower Perazzo Meadow



Conditions Prior to Restoration

- Hydraulic modeling indicated that channel-floodplain hydrologic connectivity had become limited. (Swanson Hydrology and Geomorphology, 2007)





02 Meadow Restoration Approaches

TRUCKEE DONNER LAND TRUST

foriver
TRUCKEE RIVER WATERSHED COUNCIL

USDA

Plug and Pond

- Upper Perazzo Meadow (2009)
- Middle Perazzo Meadow (2010)

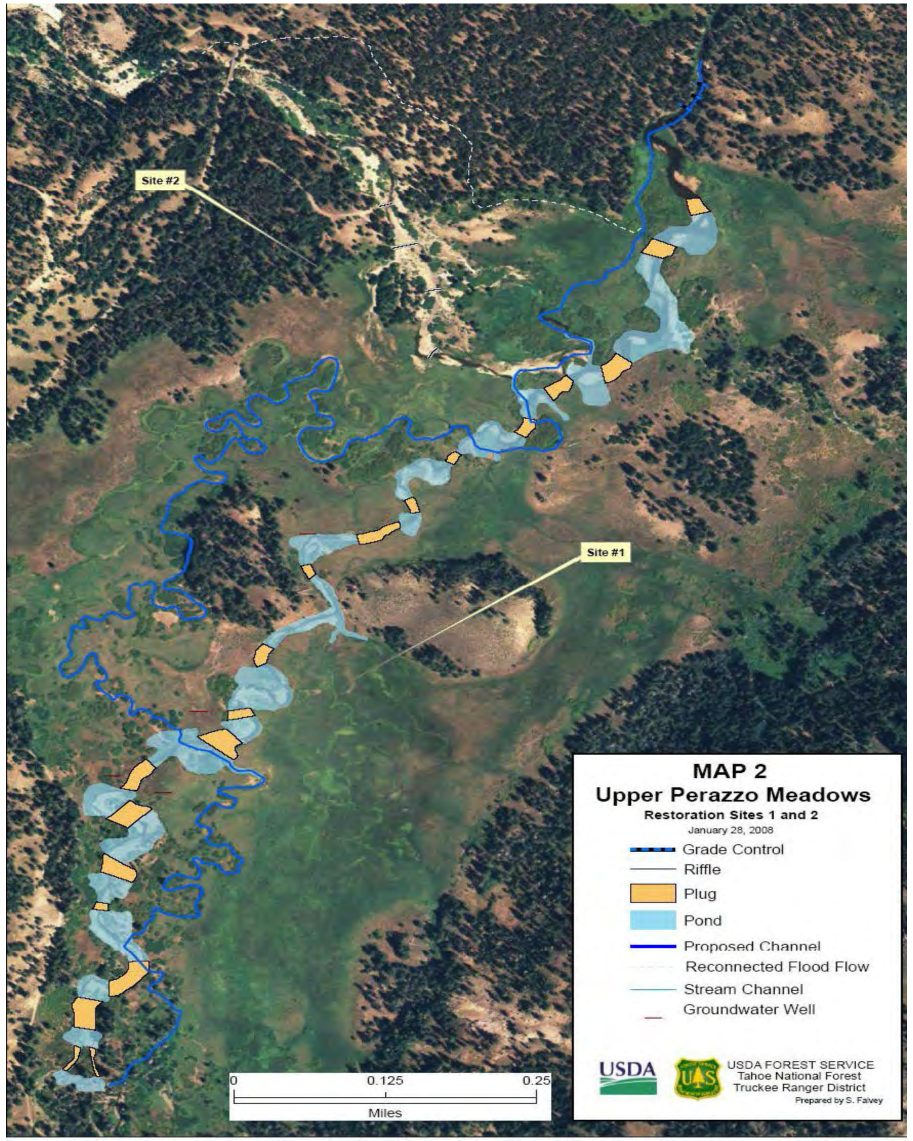
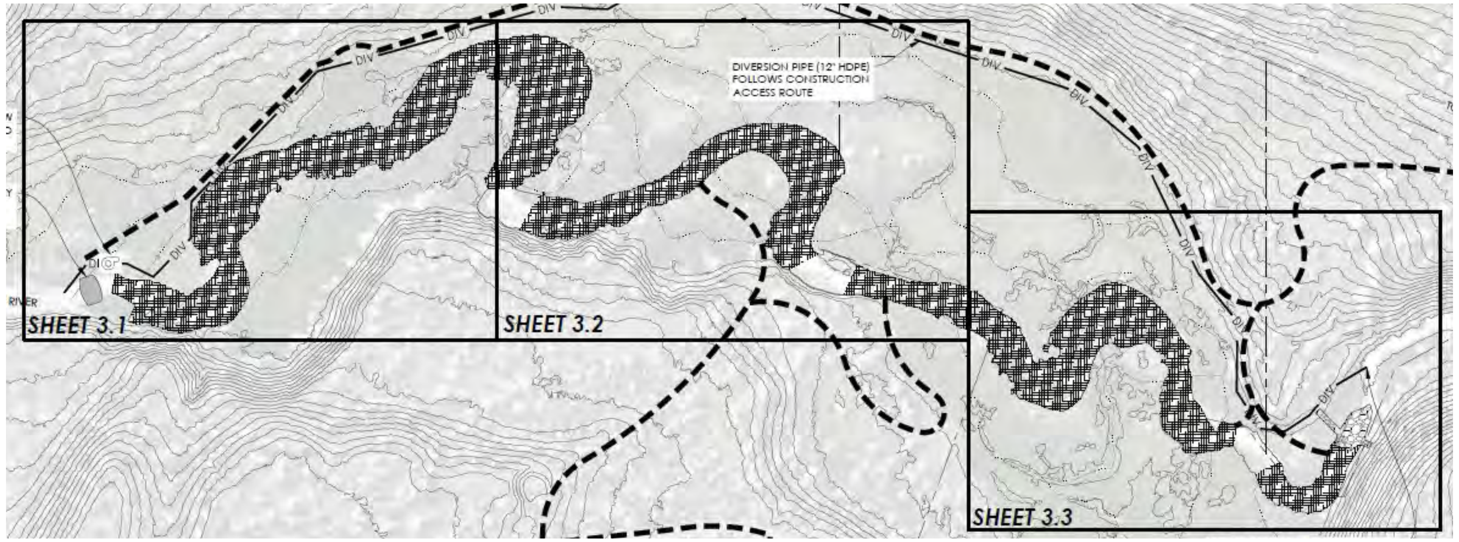


Figure 2. Final Restoration Plan for the Upper Meadow Site – Site 1

Channel Fill

- Lower Perazzo Meadow (2019)



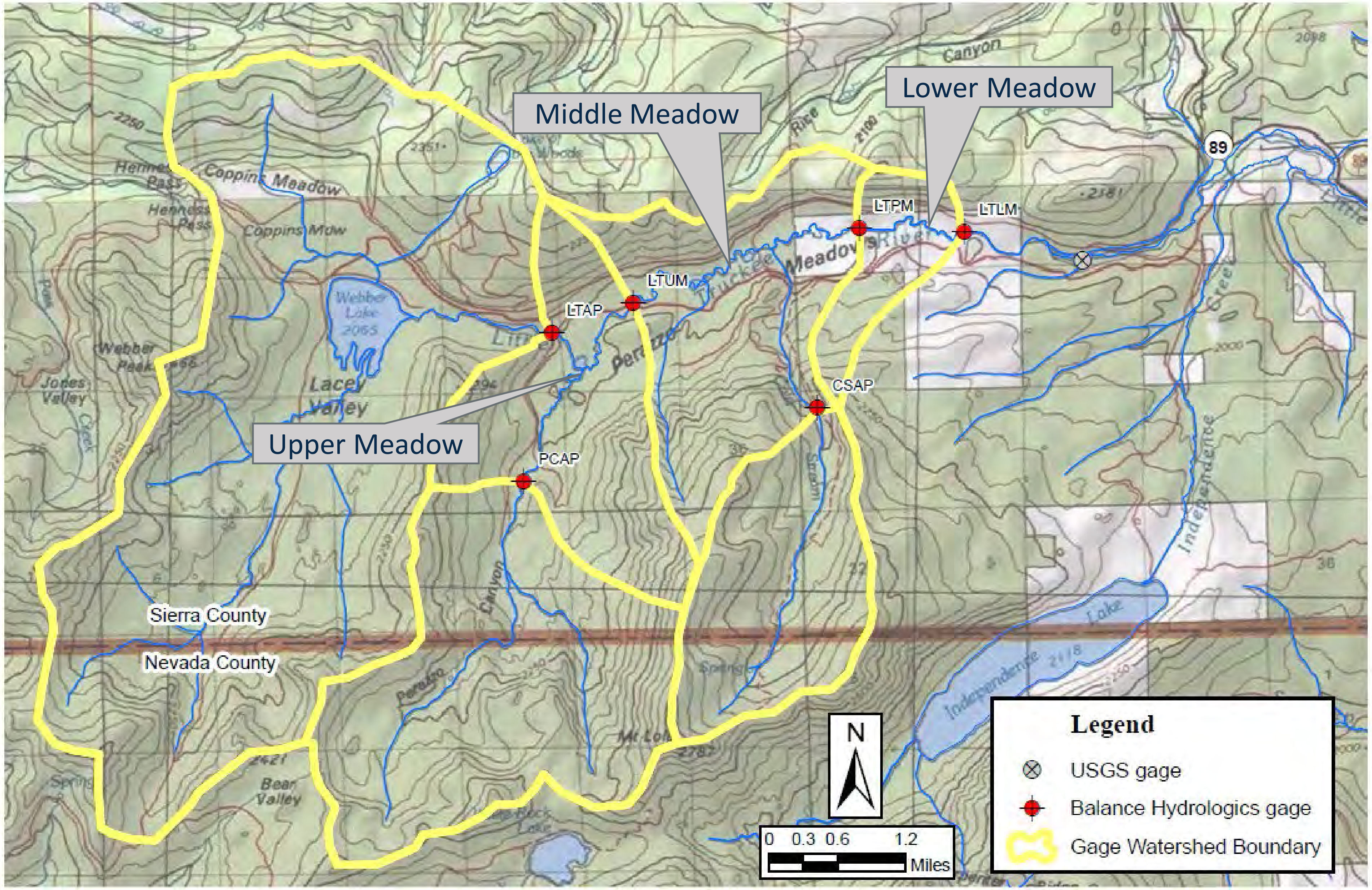
Channel Fill

- Lower Perazzo Meadow (2019)

03 Hydrologic Monitoring Methods

Monitoring methods

- 6 Streamflow gaging stations, WY2010 - ongoing

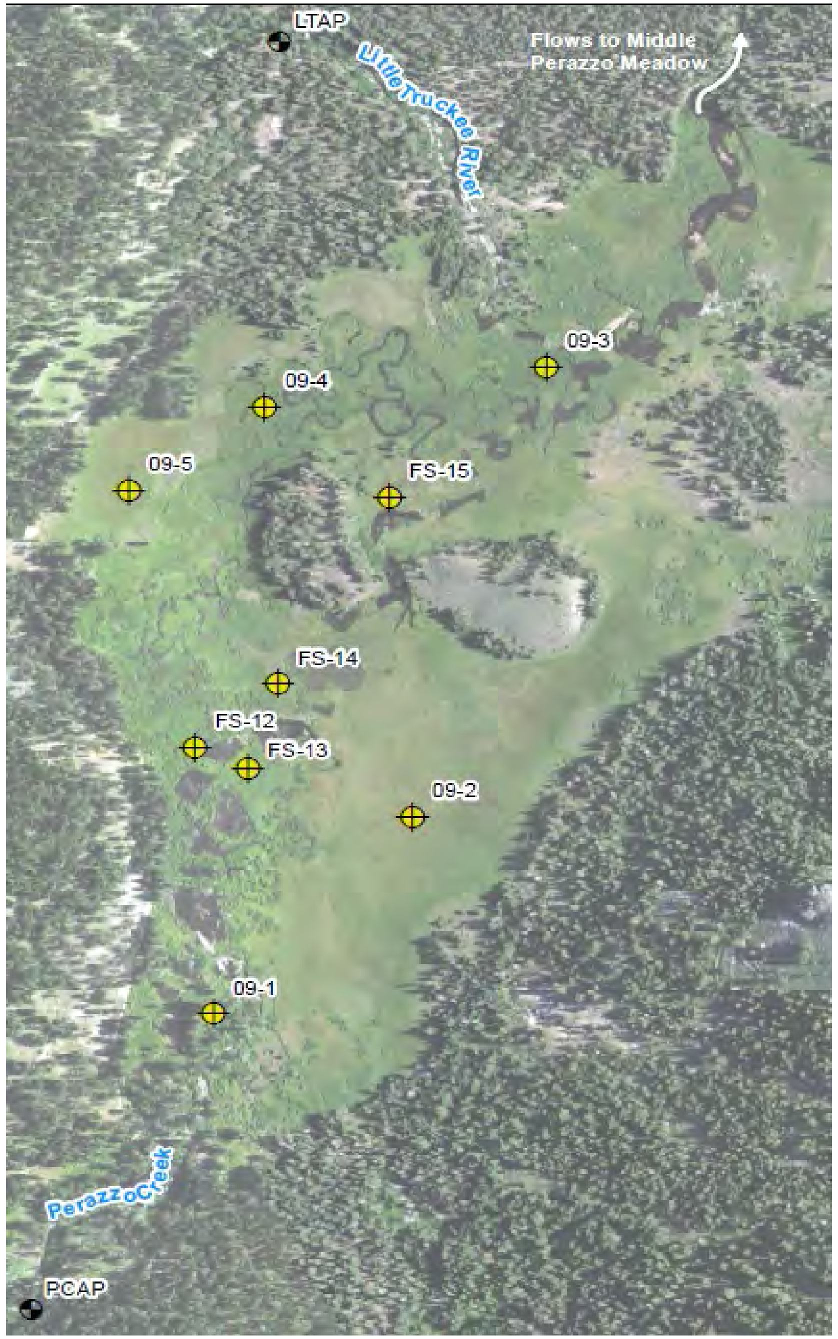


Monitoring methods

- Drive-point piezometers
- 2009 – ongoing (Upper and Middle Meadow)
- 2012 – ongoing (Lower Meadow)

Lower Perazzo Meadow piezometer locations

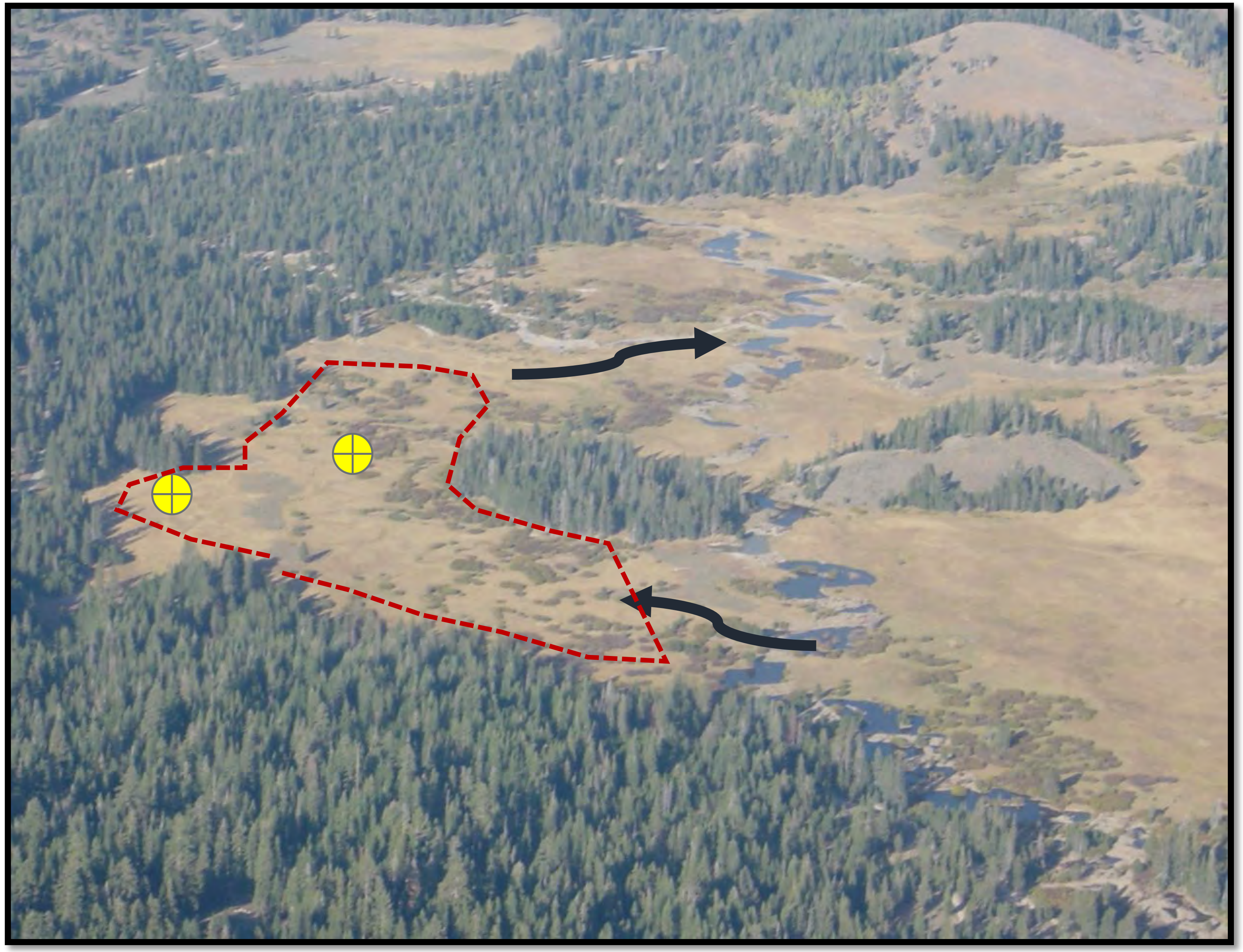
Upper Perazzo Meadow piezometer locations



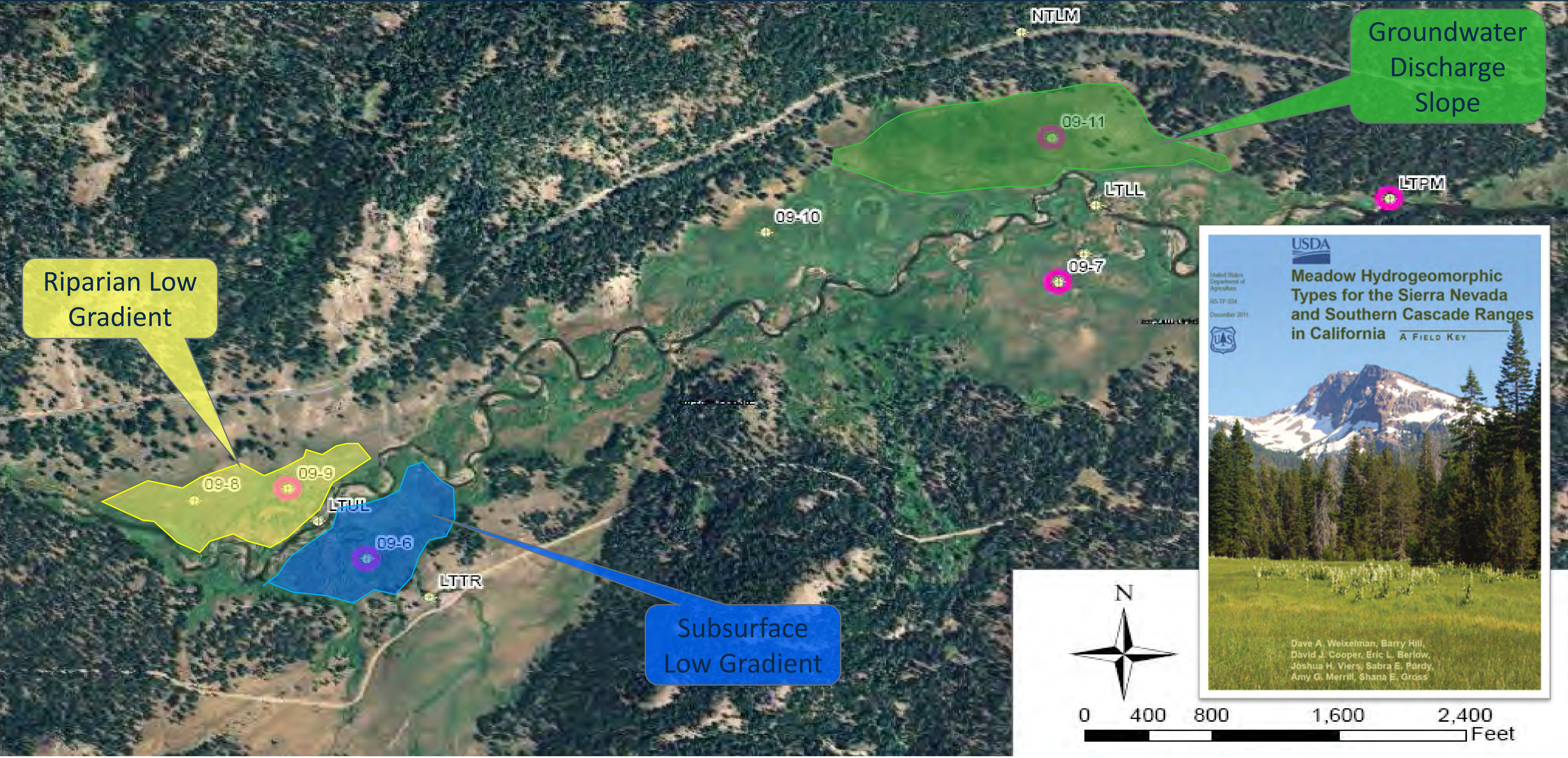
04 Findings

Findings

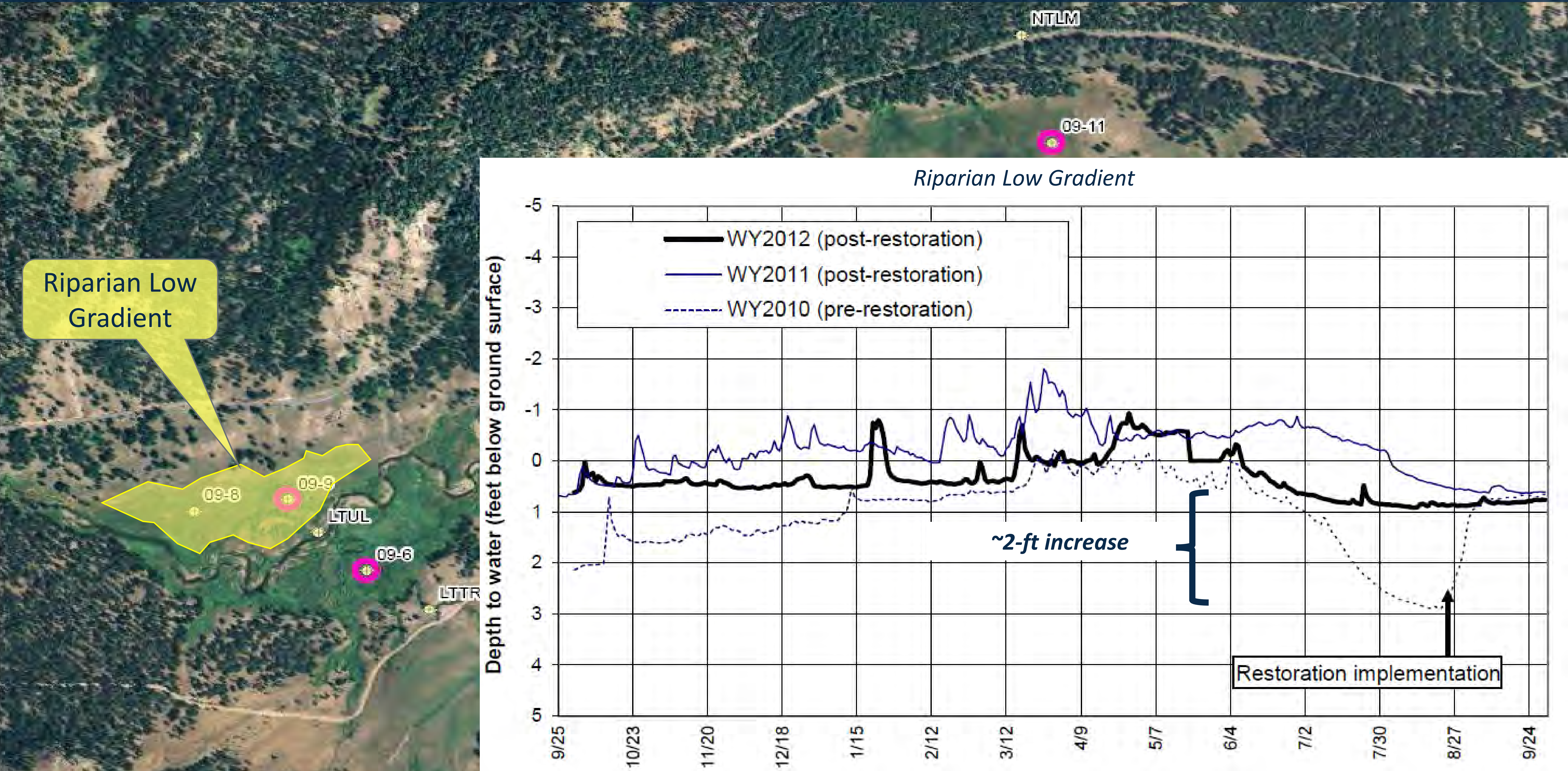
1. Increased groundwater storage
2. Release of stored groundwater can increase late-season baseflow
3. Channel adjustment can offset these initial effects
4. Remotely-sensed data can be related to field-collected data to synthesize pre-restoration and unrestored conditions



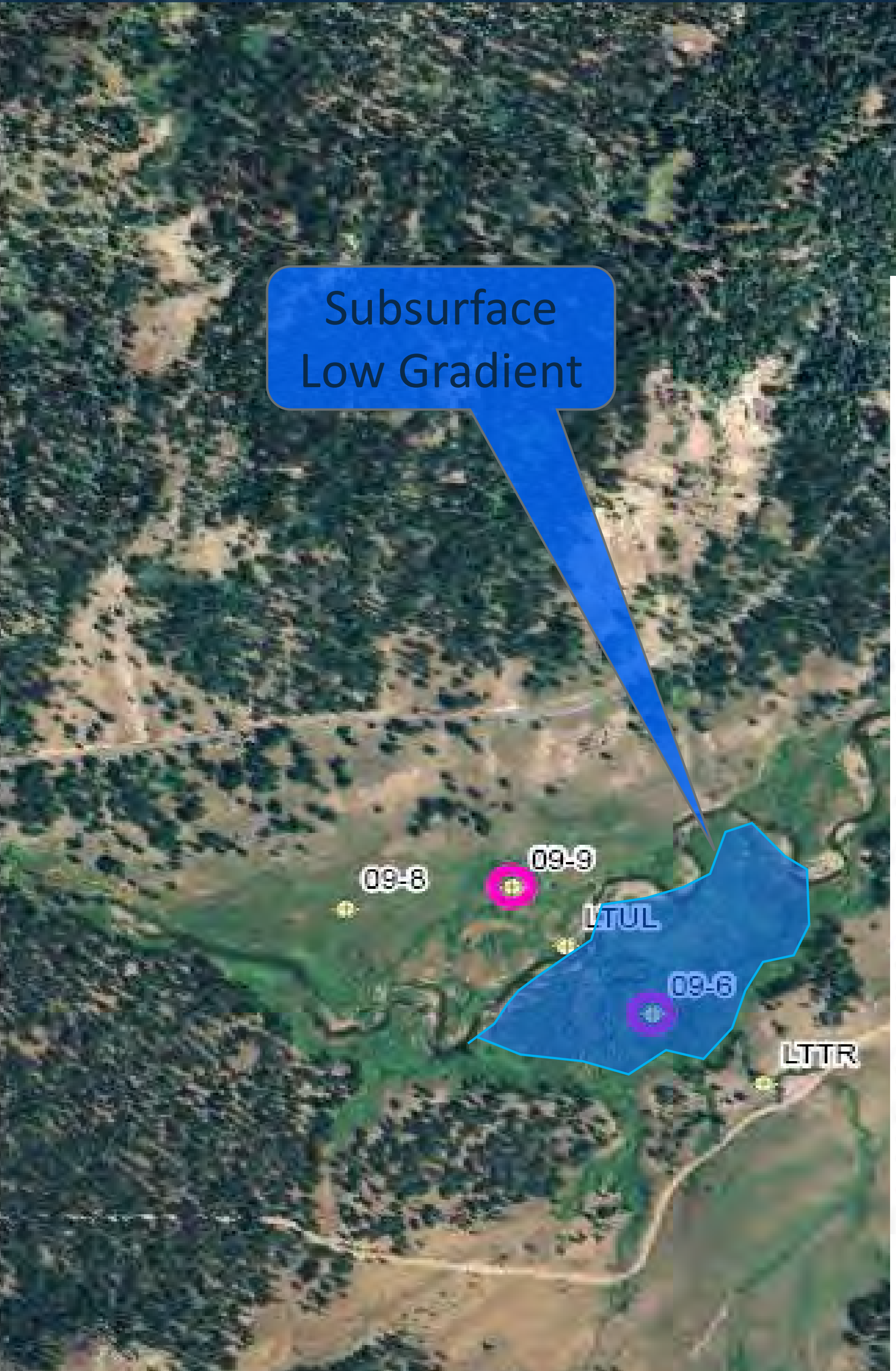
Findings – HGM and initial reponse

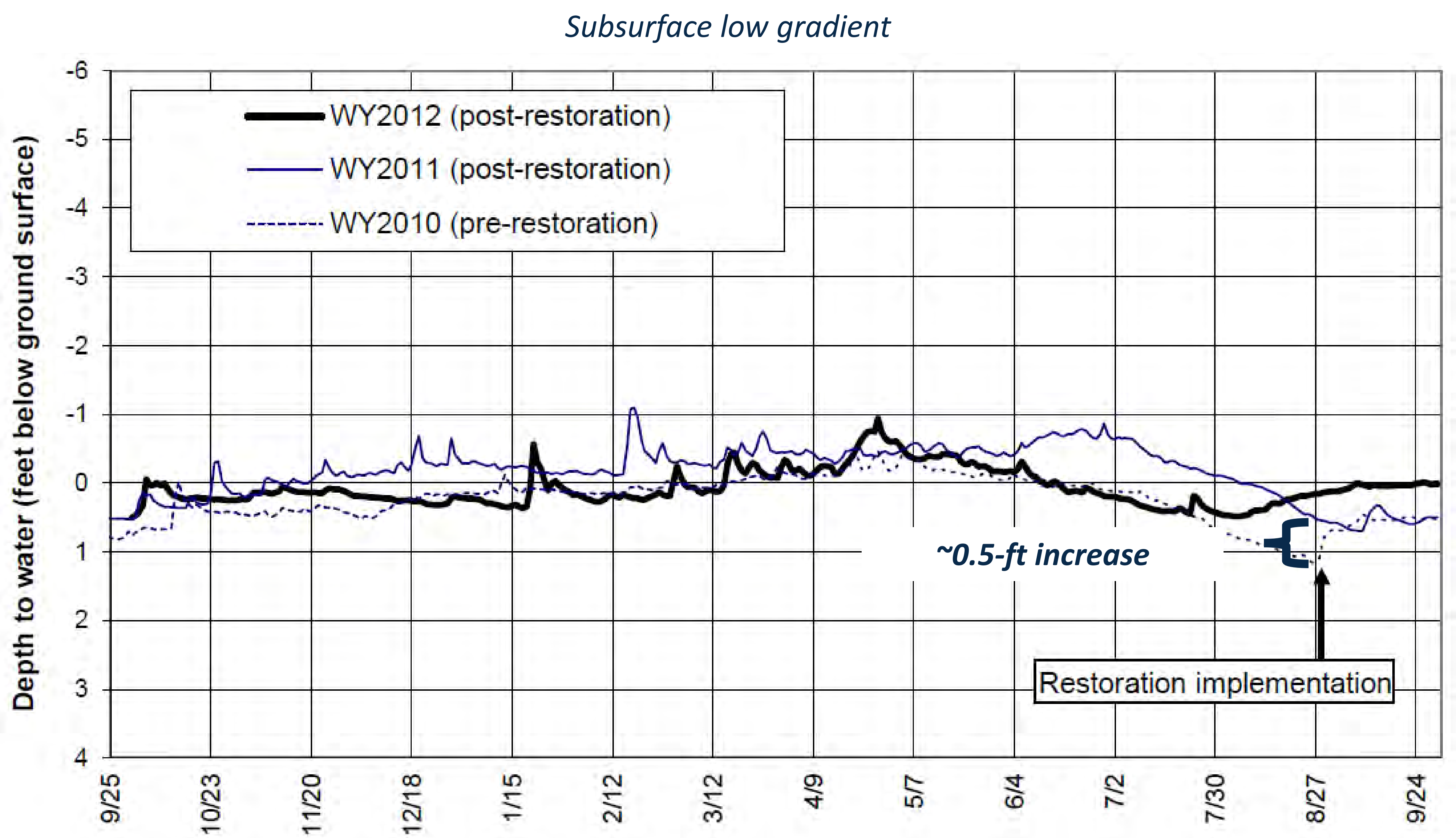


Findings – HGM and initial reponse

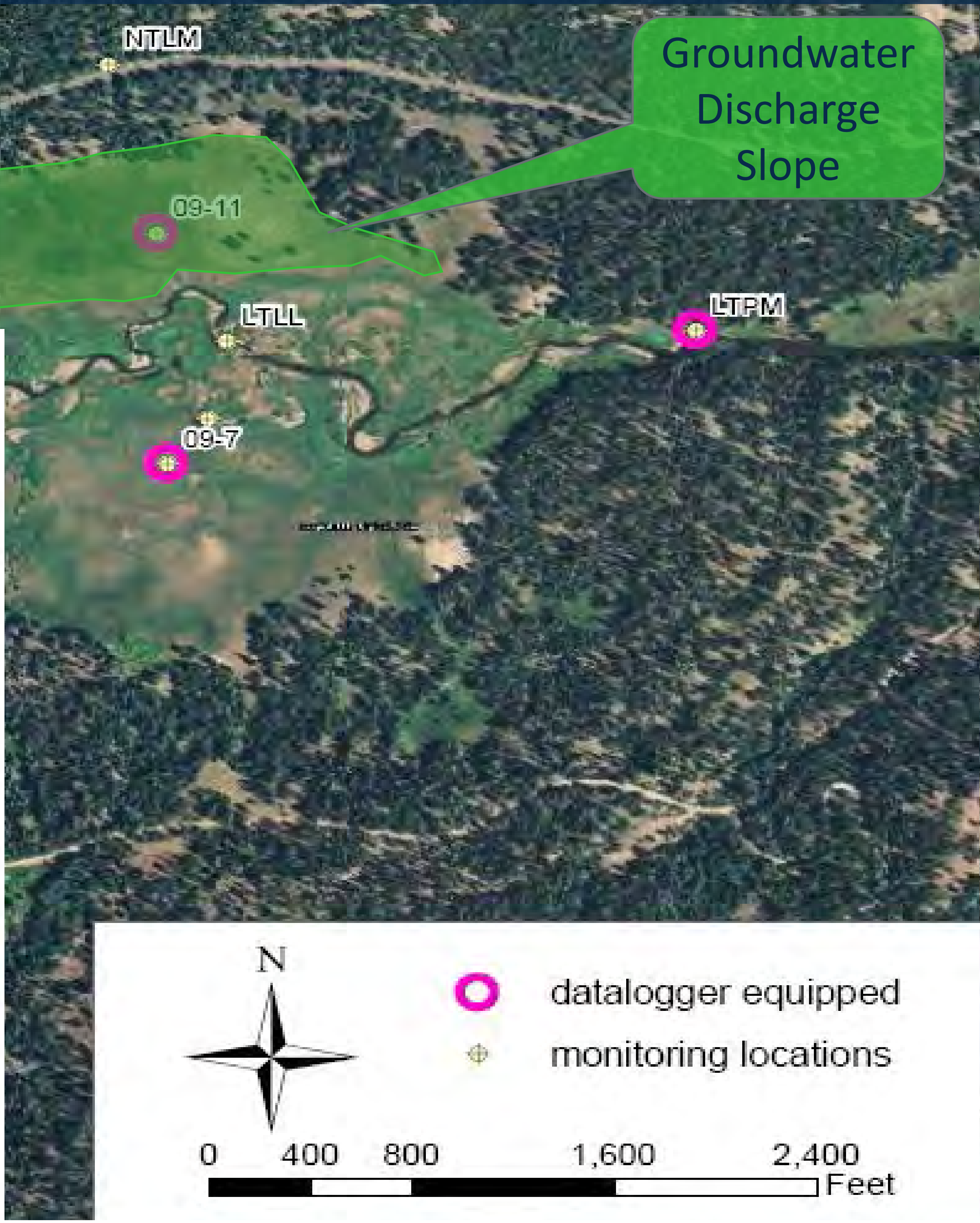


Findings – HGM and initial reponse

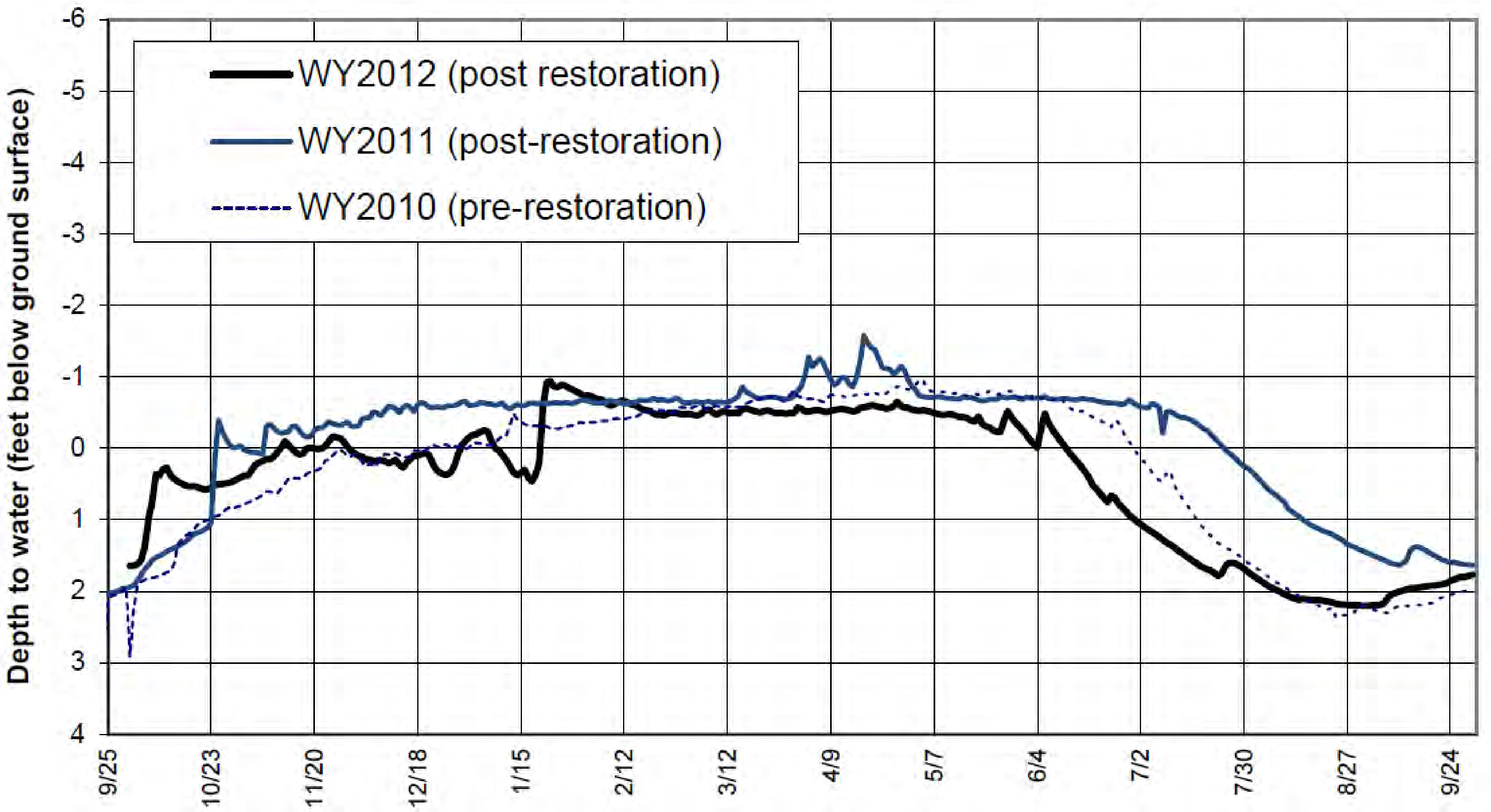




Findings – HGM and initial reponse



Discharge Slope: NO CHANGE



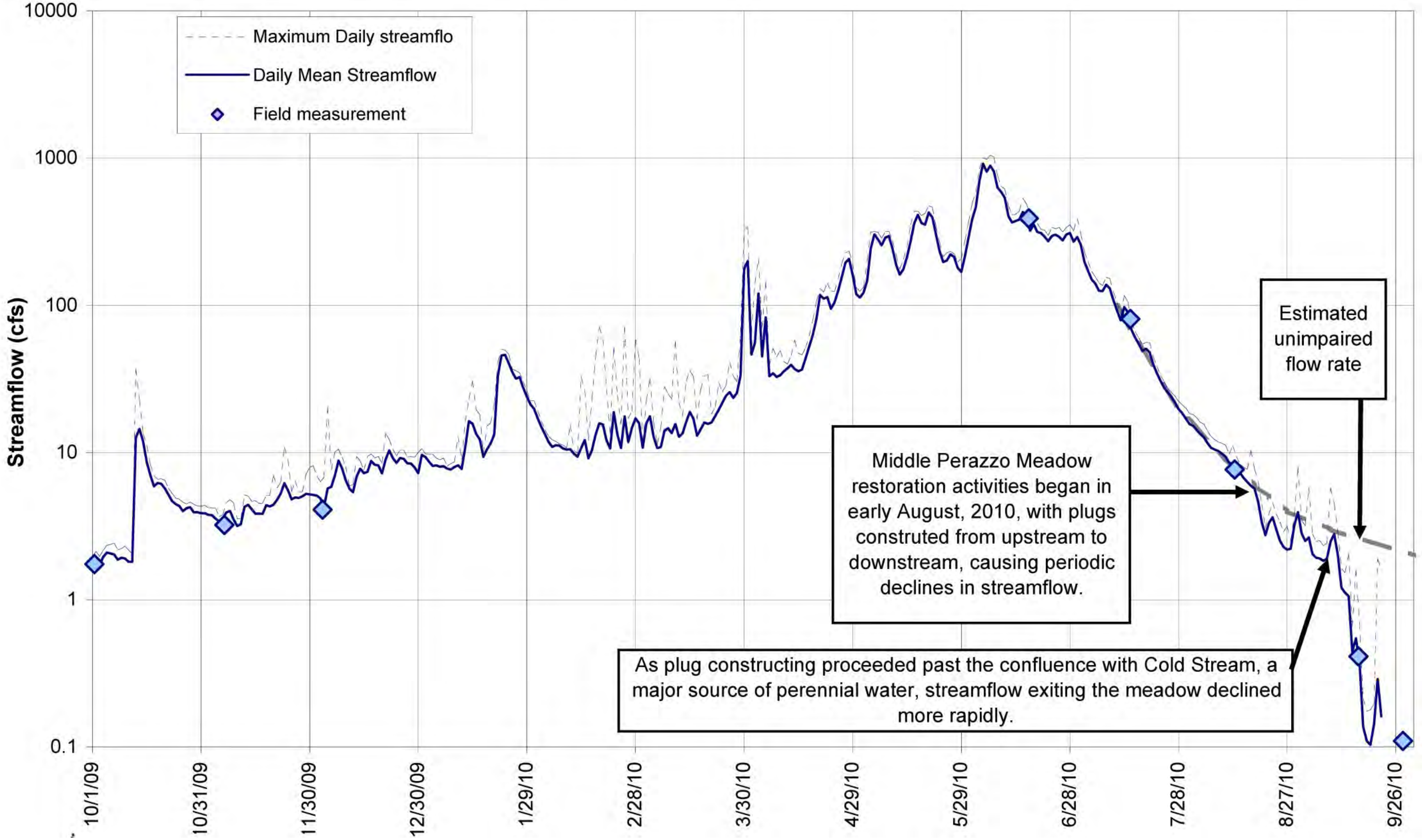
Findings

Estimated total storage increase:

110 acre-feet

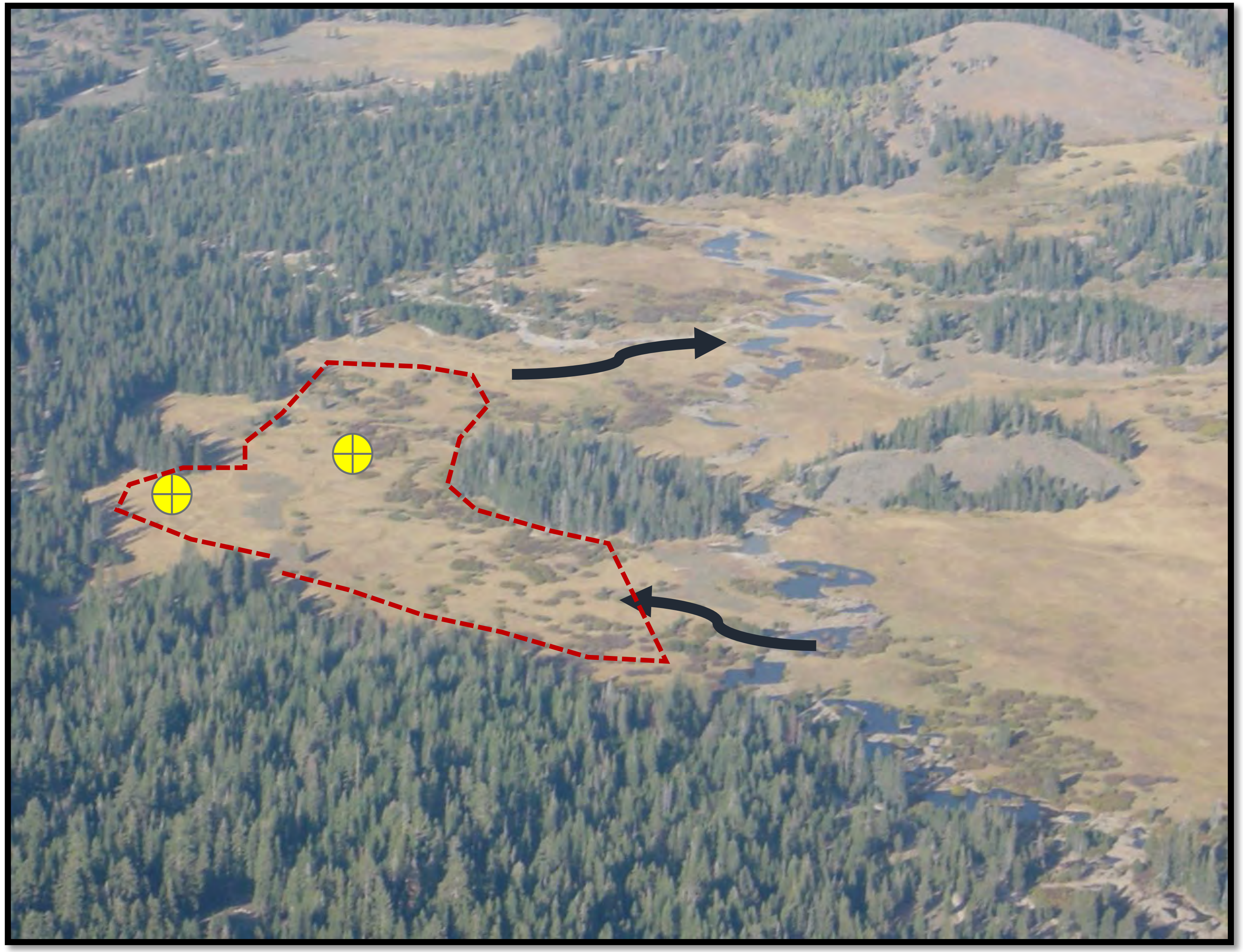
(0.6 acre-feet per acre)

Reduced streamflow from increased storage during restoration implementation



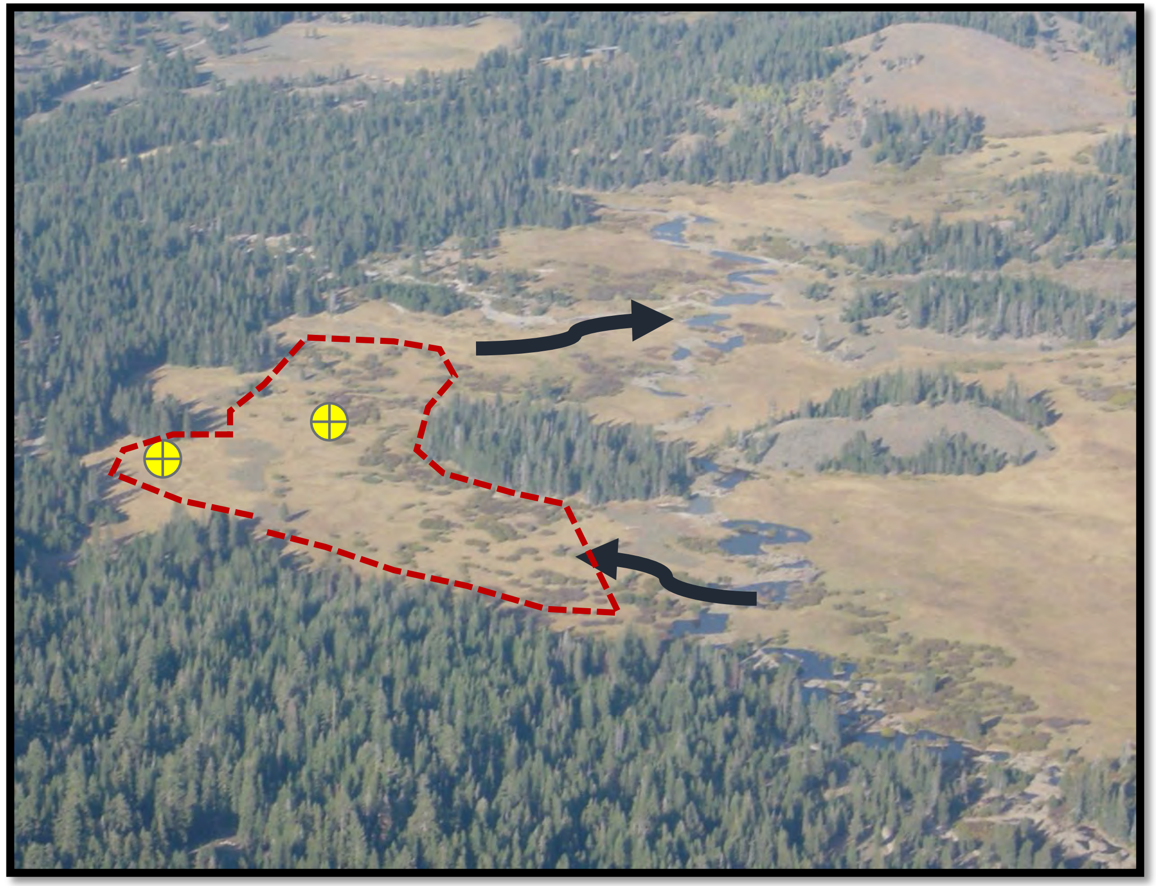
Findings

- Release of stored groundwater can increase late-season baseflow

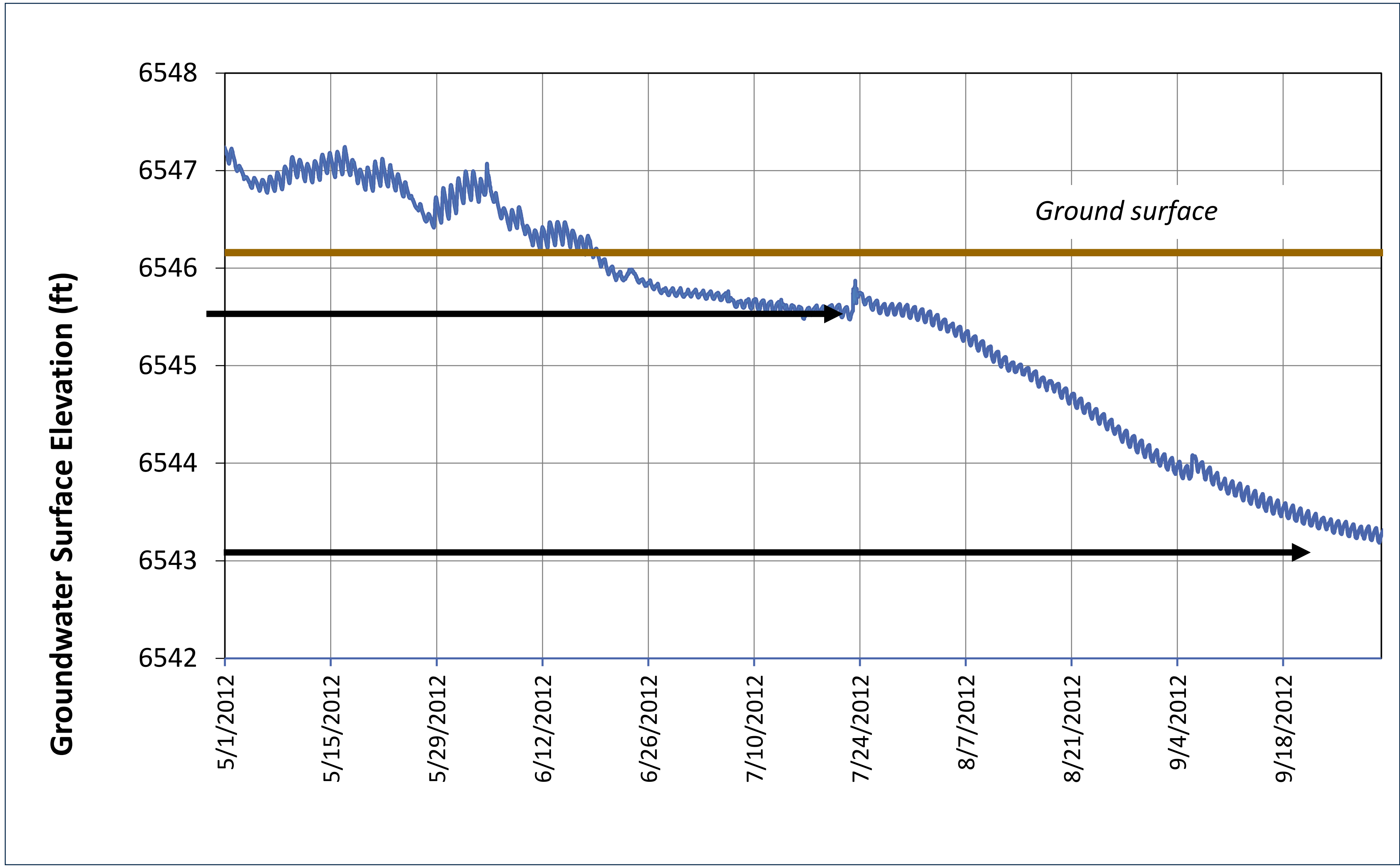


Findings

- Late summer drainage of stored water can increase late season baseflow, especially during drought conditions



2.5-foot decline in groundwater during the late summer in a drought year



Findings

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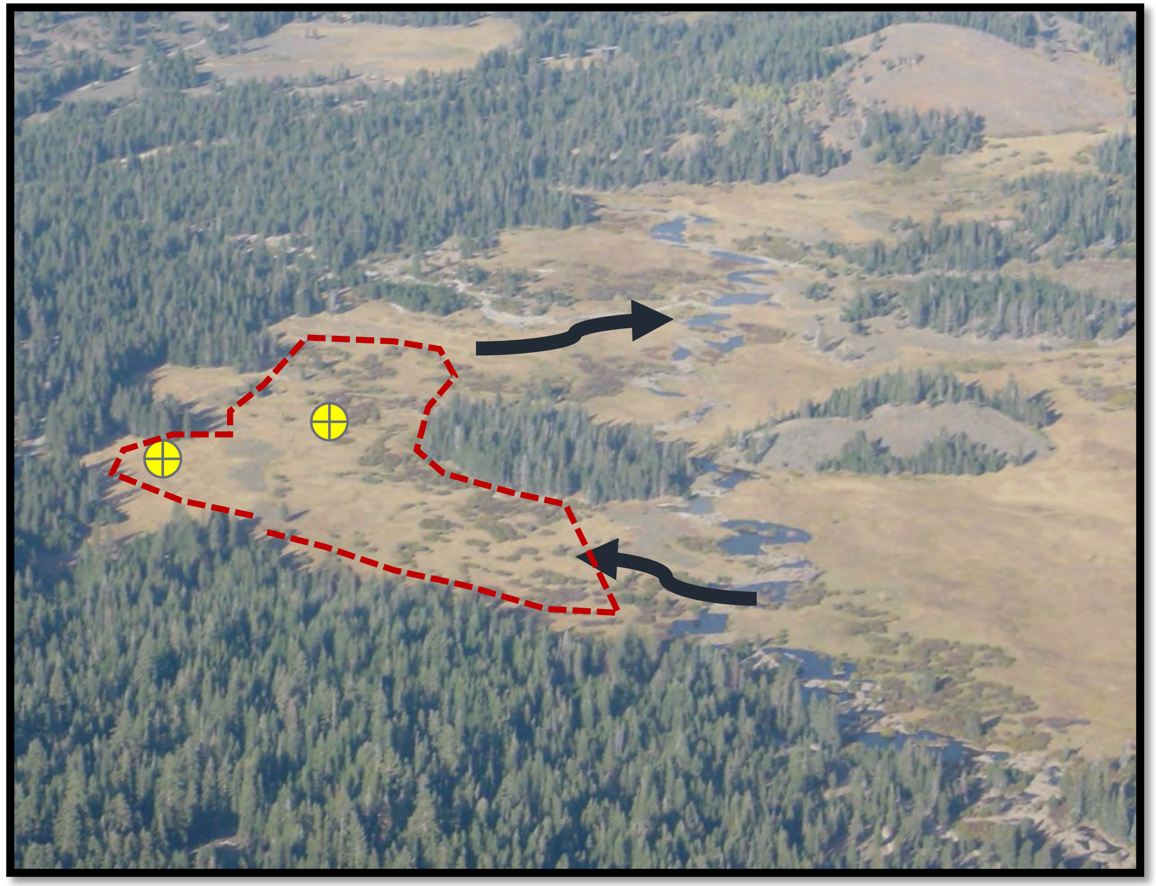
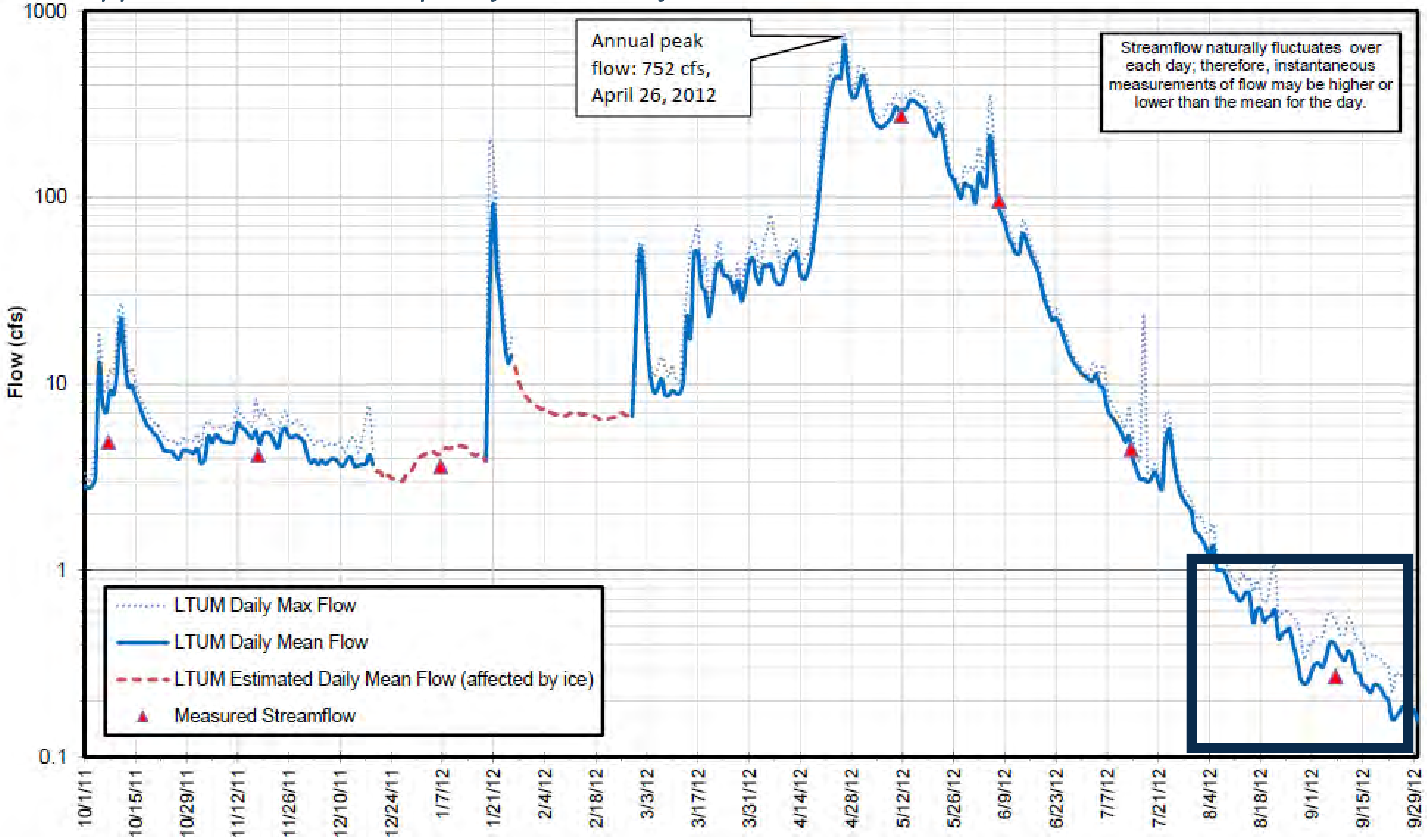
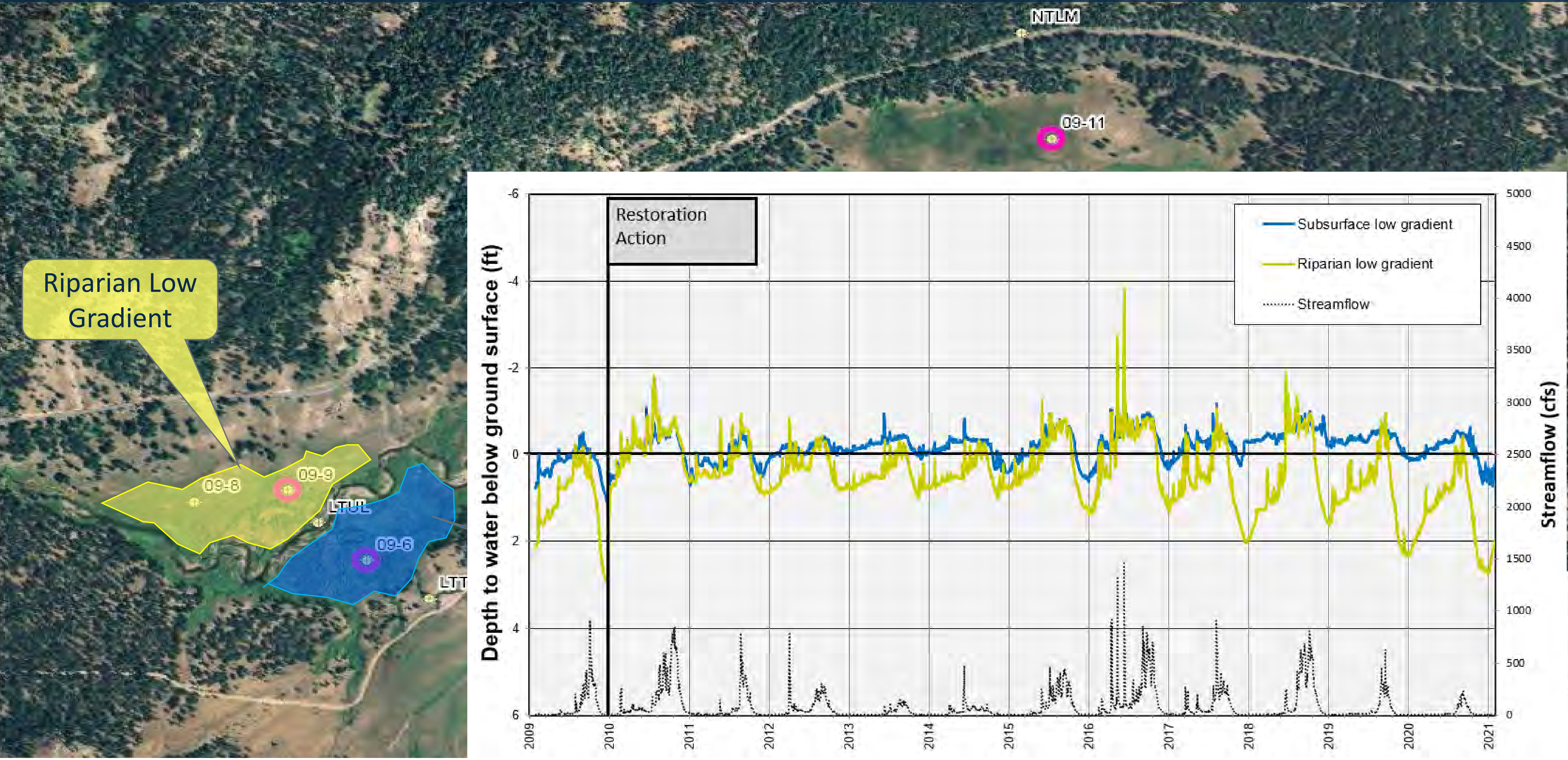


Upper Meadow monthly inflow = 0.3 cfs

Upper Meadow monthly outflow = 0.5 cfs



Findings

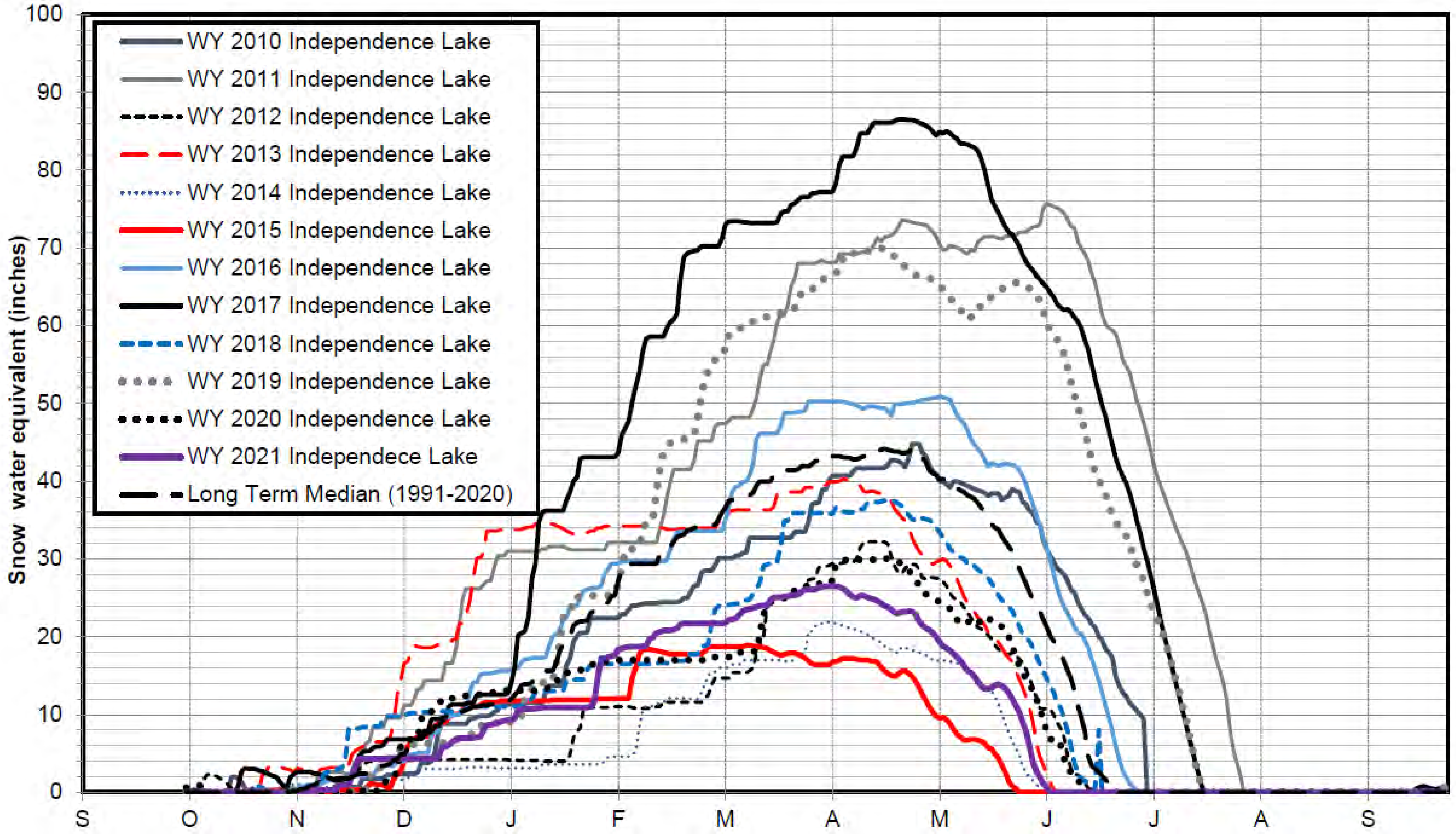


NTLM
09-11
Riparian Low Gradient
09-8
09-9
LTUL
09-6
LTT
Restoration Action
Subsurface low gradient
Riparian low gradient
Streamflow
Depth to water below ground surface (ft)
Streamflow (cfs)
-6
-4
-2
0
2
4
6
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

Findings

- Ambient climate conditions can mask the effects of restoration
- We often have little pre-restoration monitoring data
- How to compare restored to unrestored conditions?

Annual Snow Water Equivalent (SWE)



Satellite Spectometry

- Historical satellite imagery can be used to calculate:

    Normalized Difference Water Index (NDWI)

    Enhanced Vegetation Index (EVI)

    Normalized Difference Vegetation Index (NDVI)

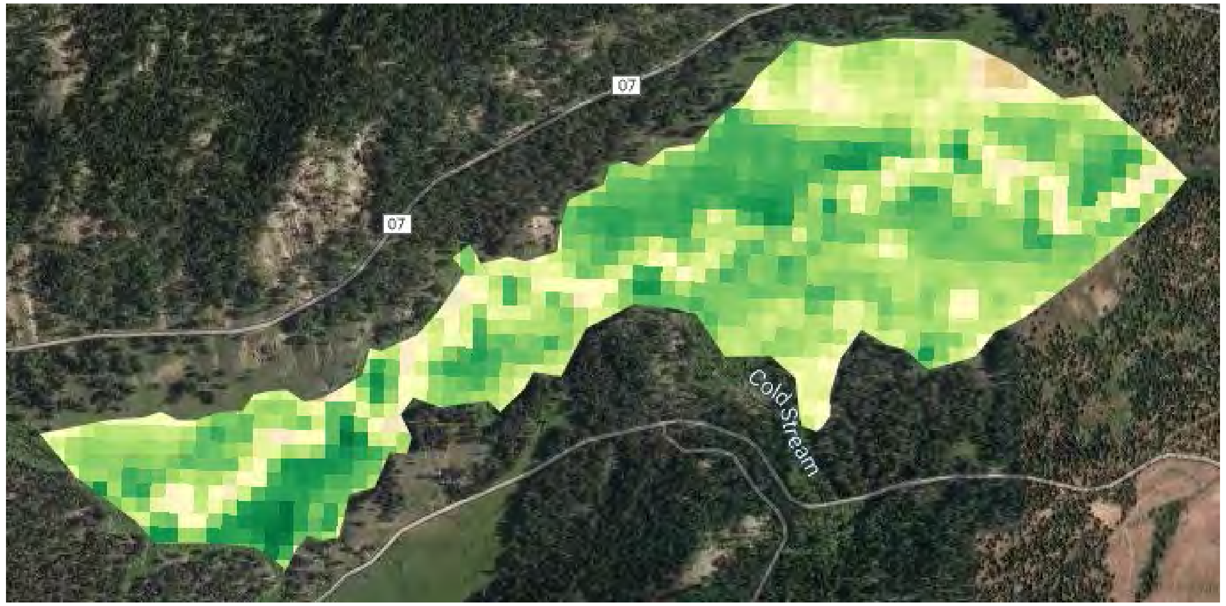
  for the pre- and post-restoration period

$$\text{NDWI} = \frac{(Xnir - Xswir)}{(Xnir + Xswir)}$$

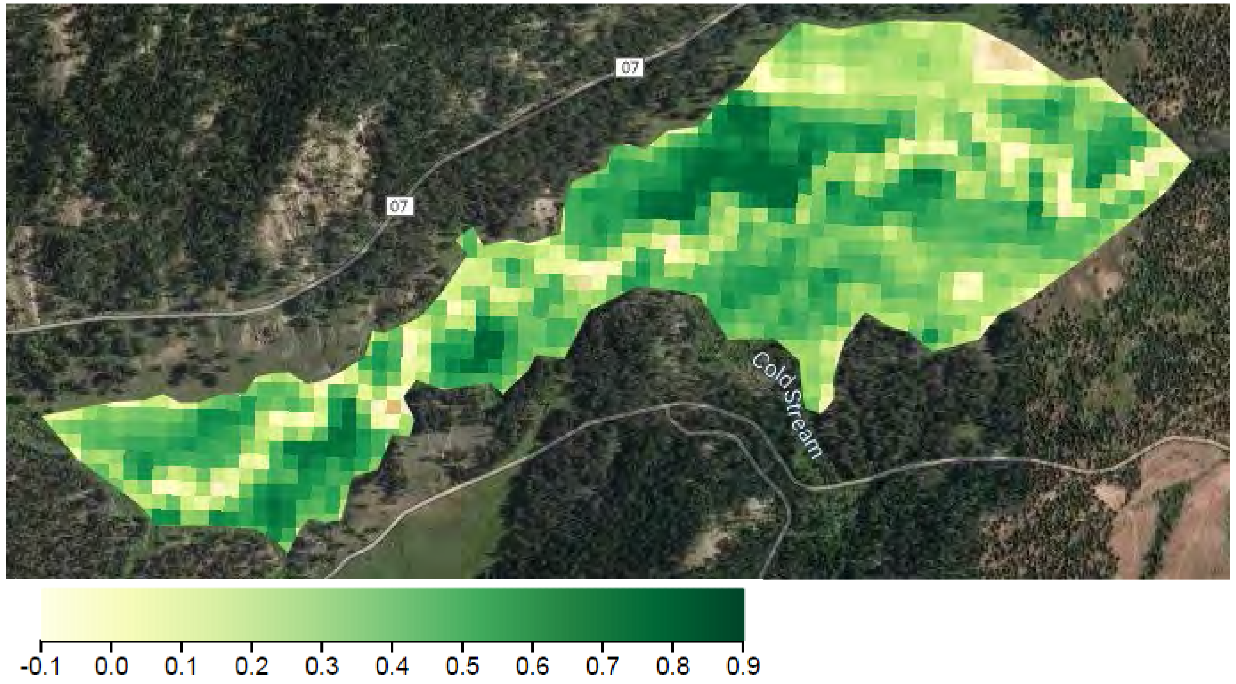
$$Xnir = \text{Near-infrared}$$

$$Xswir = \text{Short-wave infrared}$$

Pre-restoration EVI (1990-2008)

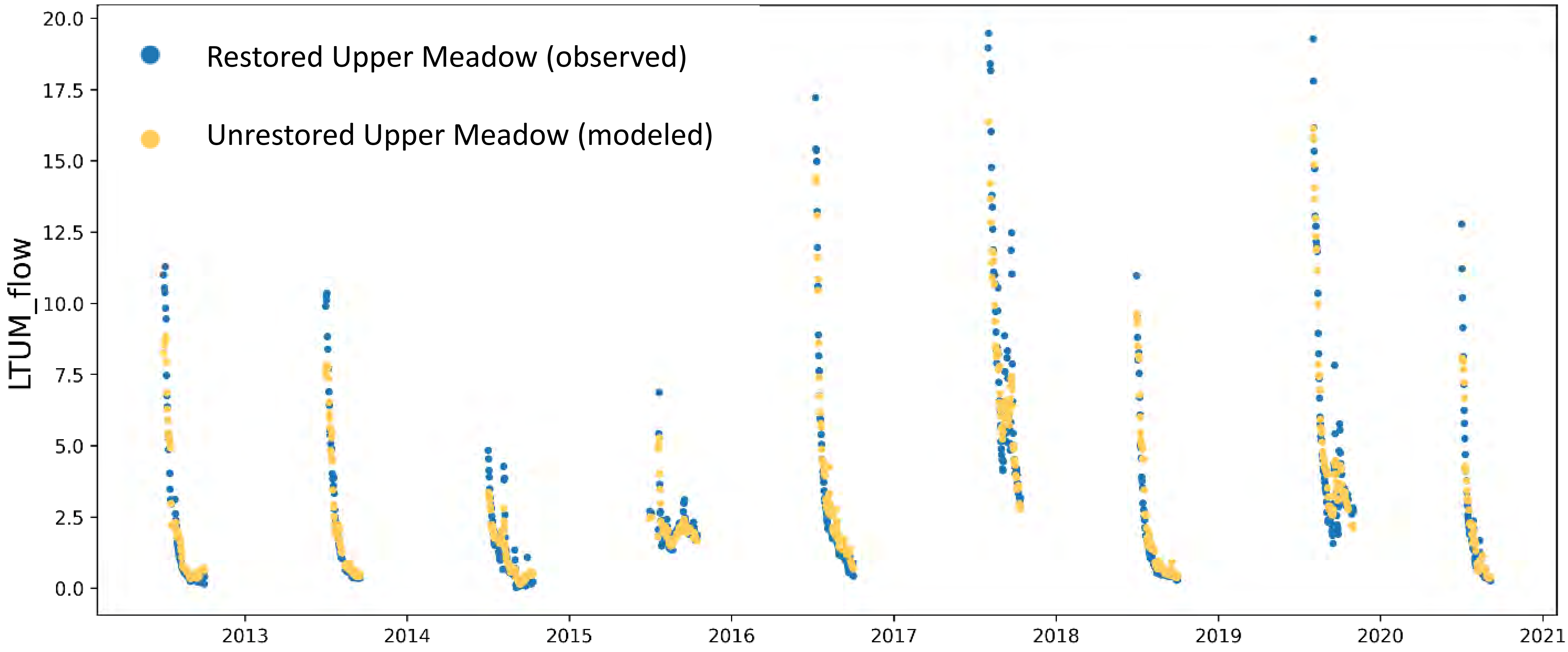


Post-restoration EVI (2009-2020)



Machine Learning

How are observed restored conditions different from modeled unrestored conditions?



Machine Learning

How is are observed restored conditions different from modeled unrestored conditions?

Available long – term data:

Precip

Snowpack

Temp

→ LSTM Machine Learning Model → Predicted (Unrestored) NDWI

- 1996-2020

Post-restoration monitoring data

Streamflow

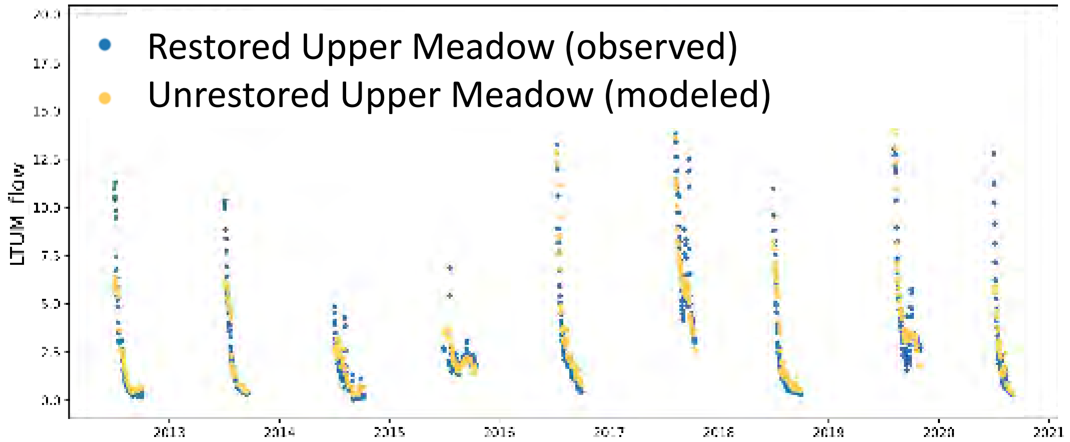
Groundwater

→ RFR Machine Learning Model → Predicted (Unrestored) Streamflow

Field-Observed (Restored) Streamflow

- 2010-2020

RESTORATION EFFECTS ON STREAMFLOW



Findings

- <u>LSTM Modeling:</u> NDWI can be reasonably predicted by antecedent precipitation and SWE in the surrounding watershed

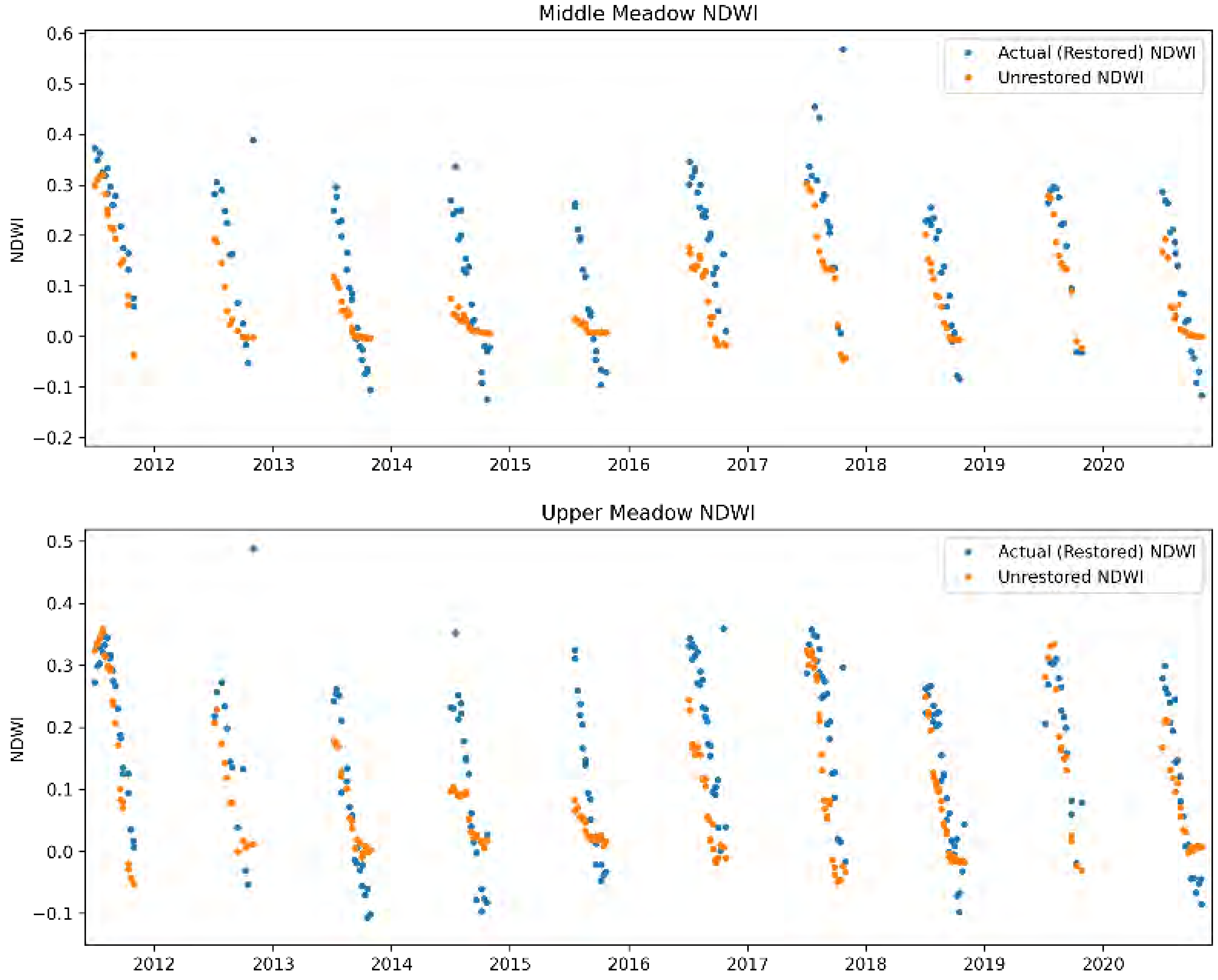
Upper Meadow Training Data
Actual NDWI (Blue) and Predicted NDWI (Yellow)

Training $r^2 = 0.837$
Validation $r^2 = 0.739$

Findings

- <u>LSTM Modeling:</u>

Given the antecedent precipitation and SWE experienced during the post-restoration period, NDWI would have been lower than what was recorded by satellite imagery.



Findings

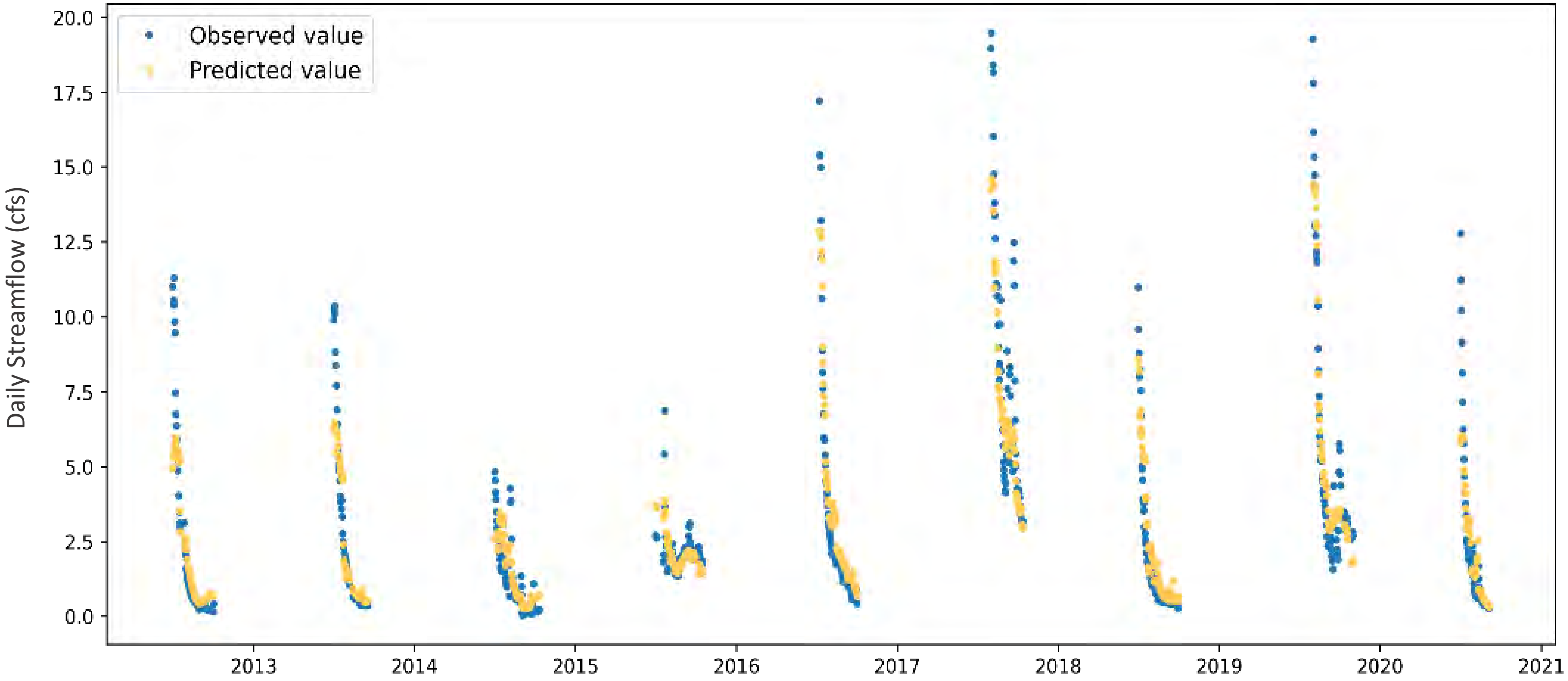
- <u>RFR Modeling:</u> Baseflow can be reasonably predicted by antecedent SWE, Precipitation, and NDWI

Input Parameter	Importance
6-month SWE	39%
6-month Precip	36%
EVI	25%

Observed

Actual NDWI (Blue) and Predicted NDWI (Yellow)

$R^2 = 0.95$

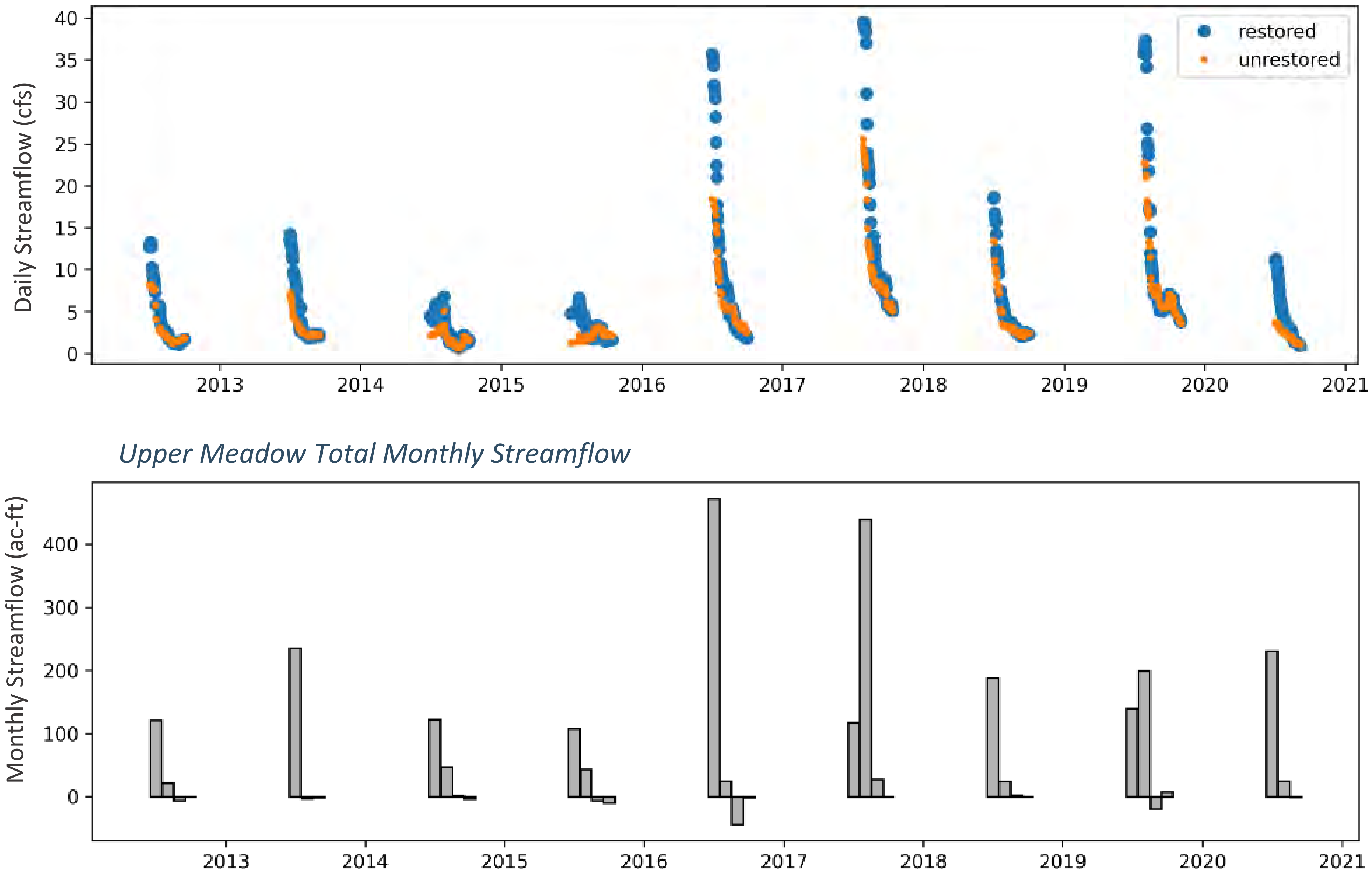


Findings

- <u>RFR Modeling:</u> Synthesized (unrestored) versus actual (restored) NDWI values can be extrapolated to estimate restored versus unrestored streamflow rates and monthly volumes

Upper Meadow Daily Streamflow

Upper Meadow Total Monthly Streamflow



Next steps

Next Steps

- Development of predictive relationships to groundwater storage
- Future restored and unrestored meadow conditions under projected climate scenarios

Next Steps

- Continue trying to understand the processes that lead to channel incision
- Continue to address those processes through watershed-wide restoration actions
- Plan for ongoing management and stewardship of restored systems

"…not merely a thing to be enshrined in outdoor museums, but a way of living on the land." -Aldo Leopold

Thank you!

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224 Walnut Avenue, Suite E, Santa Cruz, CA 950600

Funders

Wildlife Conservation Board
California Dept of Fish and Wildlife
Bella Vista Foundation
National Fish and Wildlife Foundation

Partners

Truckee River Watershed Council
Tahoe National Forest
Truckee Donner Land Trust
NV5
Habitat Restoration Sciences
California Conservation Corps

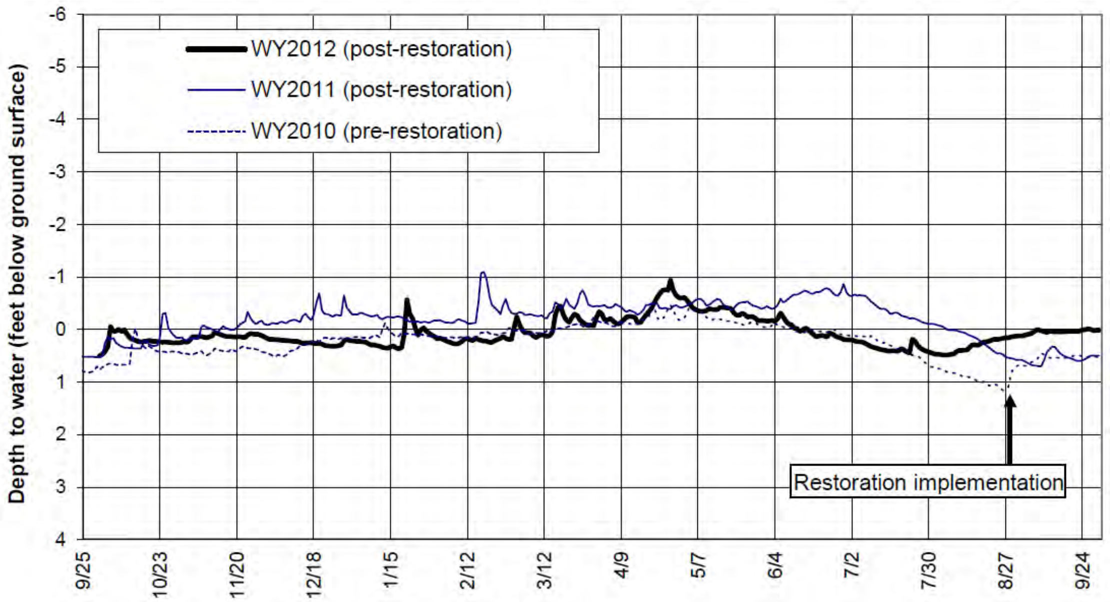
Beth Christman, Ben Trustman, Kealie Pretzlav, Mark Llorente, Randy Westmoreland

05 Questions

Findings

- Groundwater storage increases are variable and dependent on hydrogeomorphic position

Subsurface low gradient: ~0.5-ft increase



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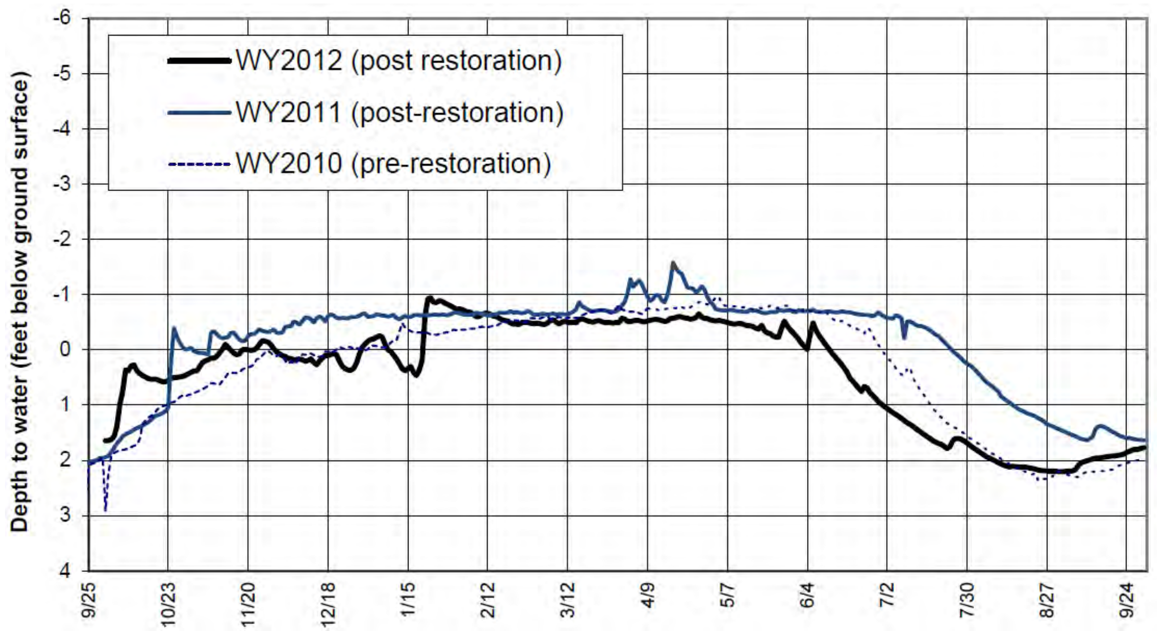
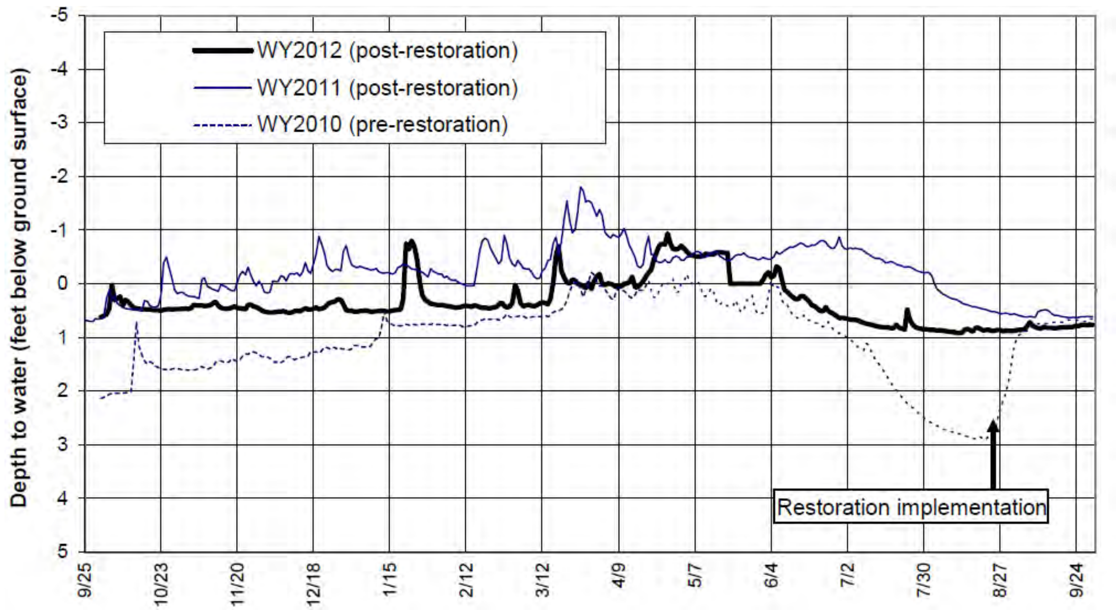


Riparian low gradient: ~2-ft increase



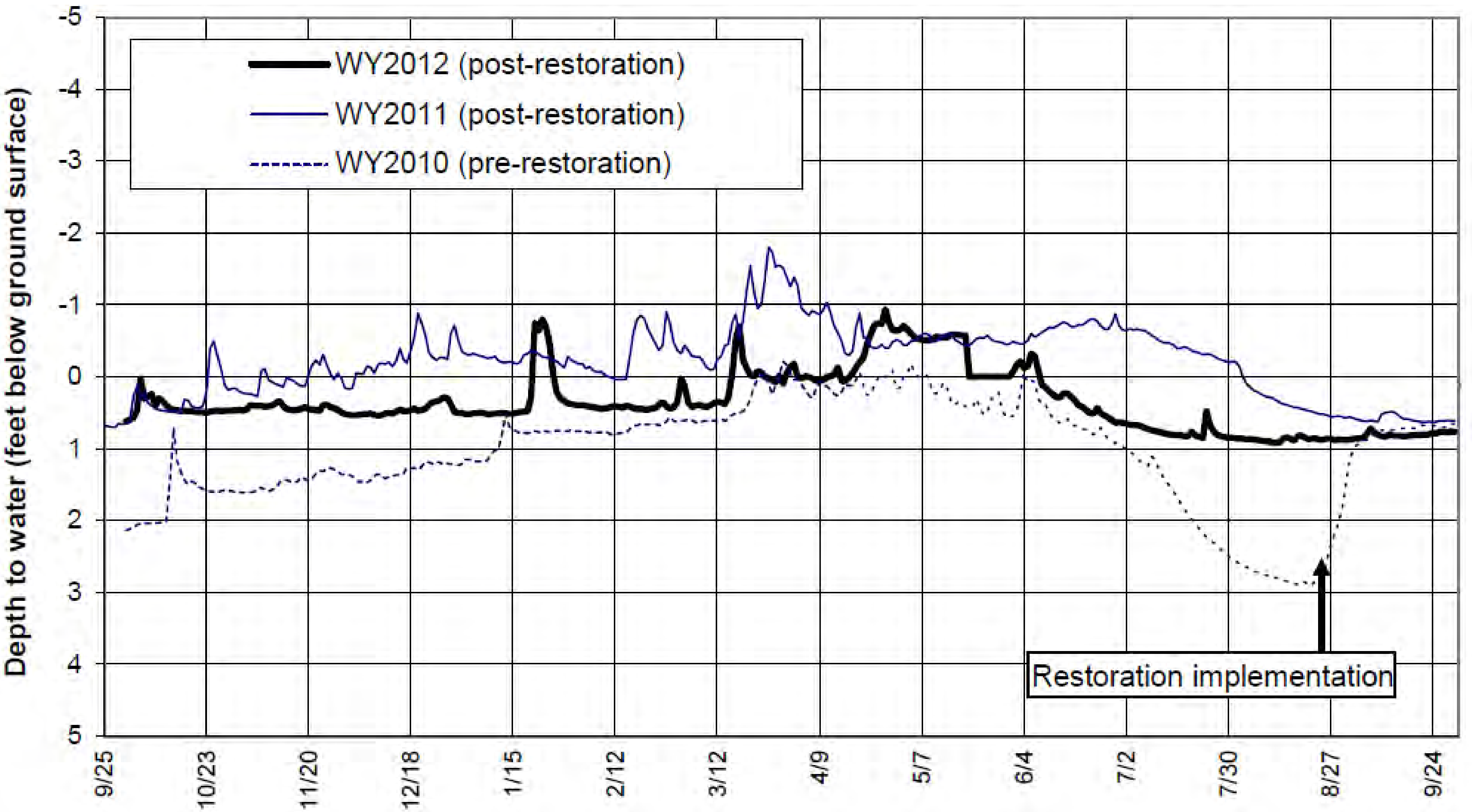
Channel Fill

Conditions Prior to Restoration

- Outwash terraces and moraines
- History of logging, road-building, railroads, channelization

Findings

Initial response: Increases in seasonal groundwater storage are variable, averaging about 0.6 acre-feet per acre of restored meadow



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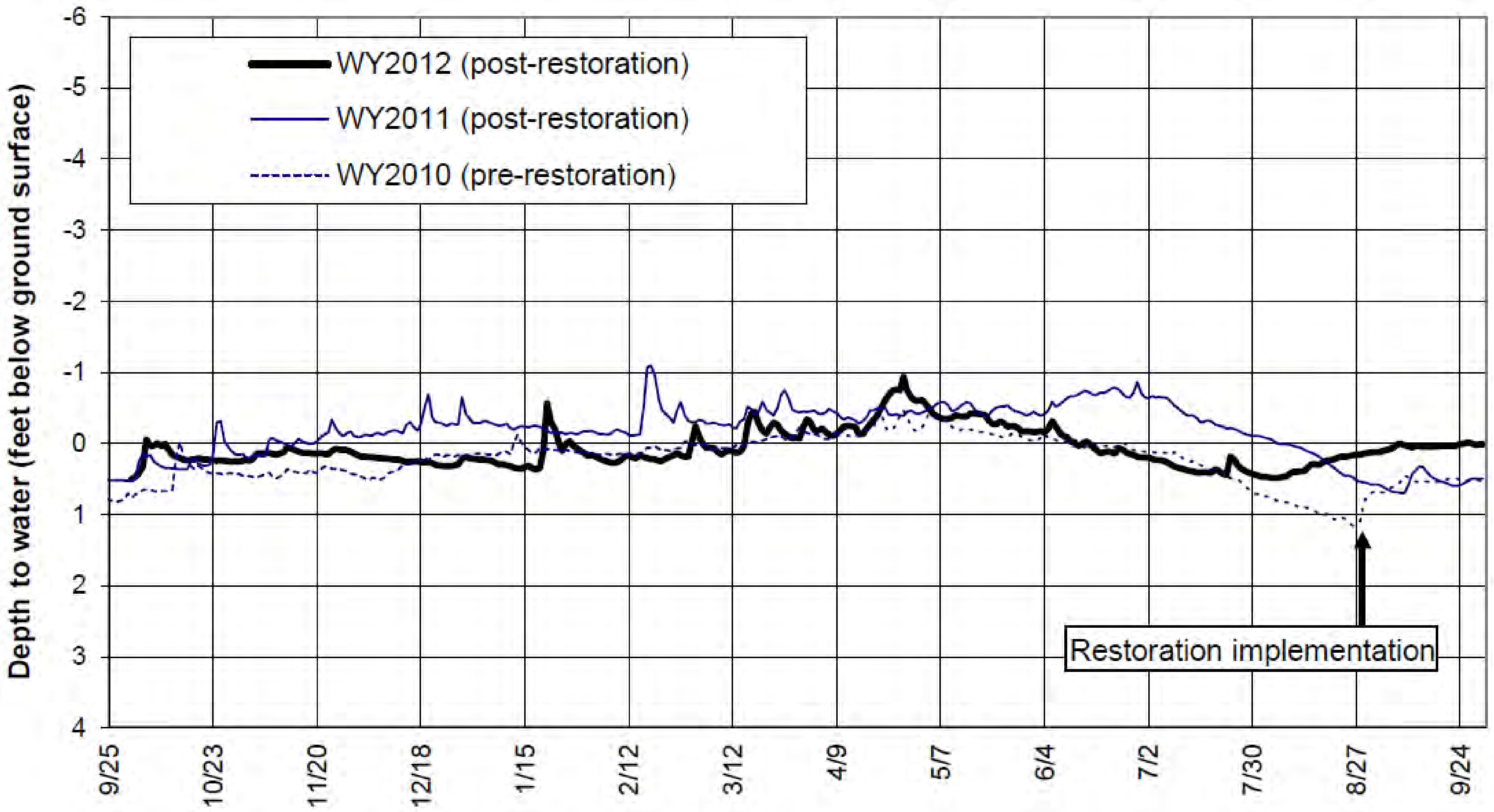

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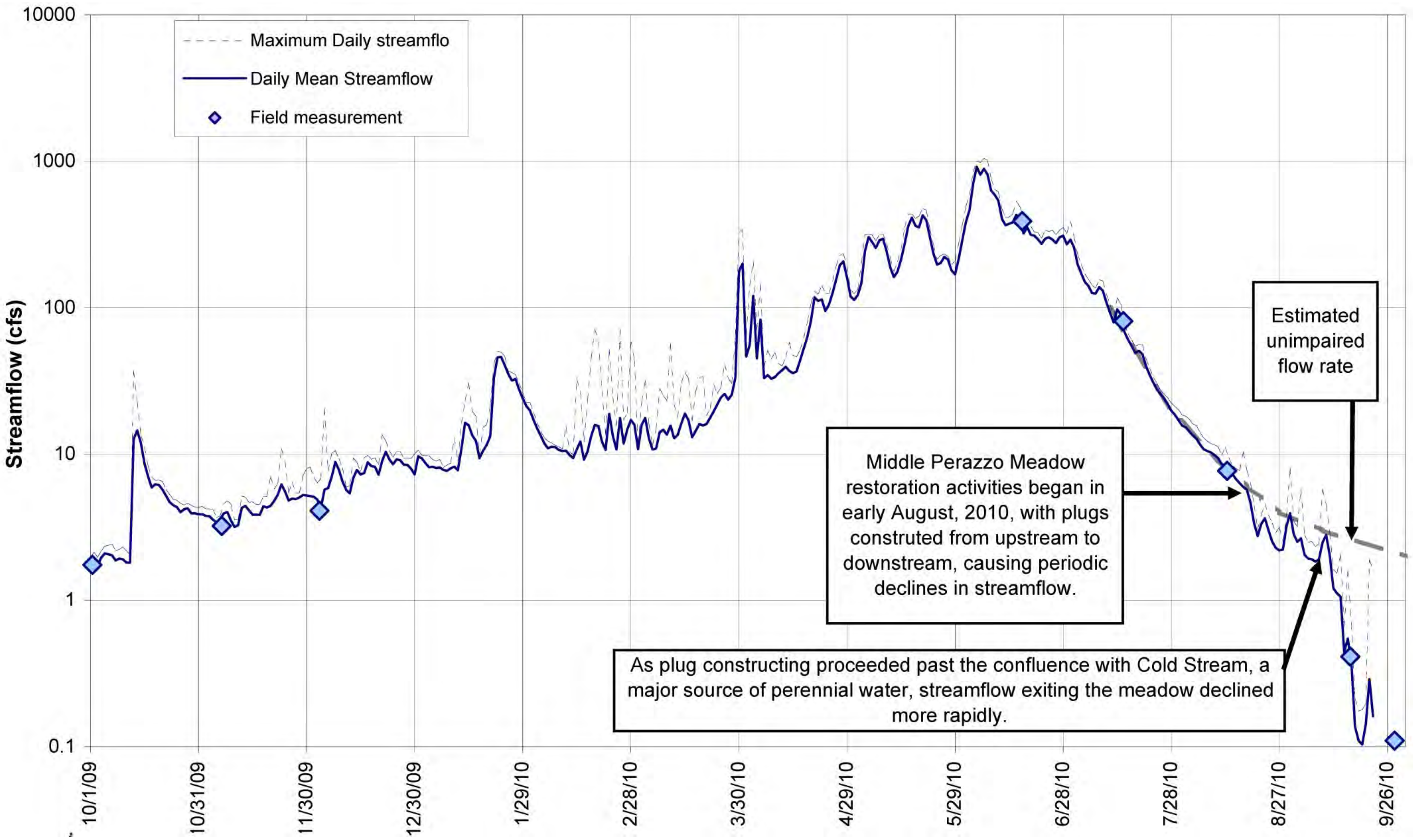


39th Annual Salmonid Restoration Conference: Reconnecting with Resilience

Restoring Headwaters Along Munch & Davy Brown Creeks in the Los Padres National Forest

Mauricio Gomez, South Coast Habitat Restoration; Kristie Klose, Los Padres National Forest;
Jason White, South Coast Habitat Restoration
April 22, 2022

About South Coast Habitat Restoration

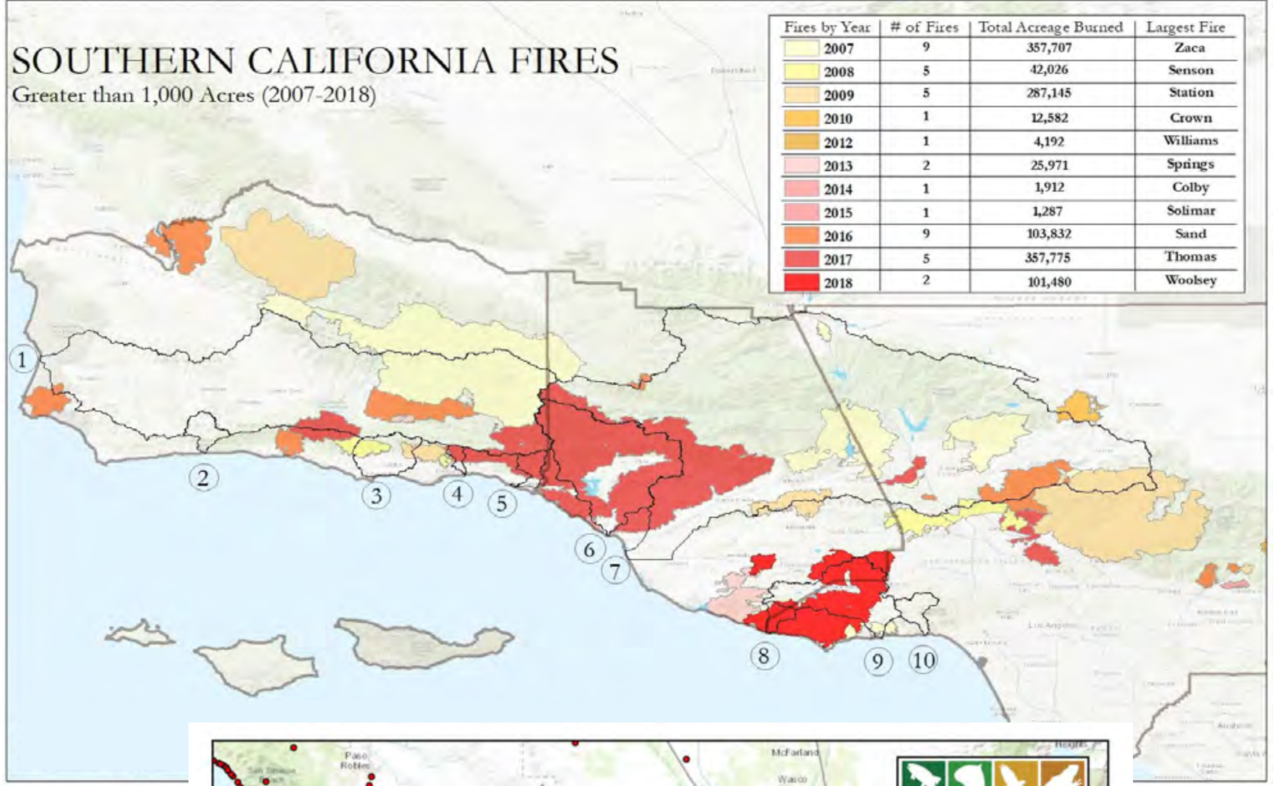
Non-Profit organization working to protect, conserve, and restore the various habitats and native biodiversity of the Santa Barbara and Ventura region.

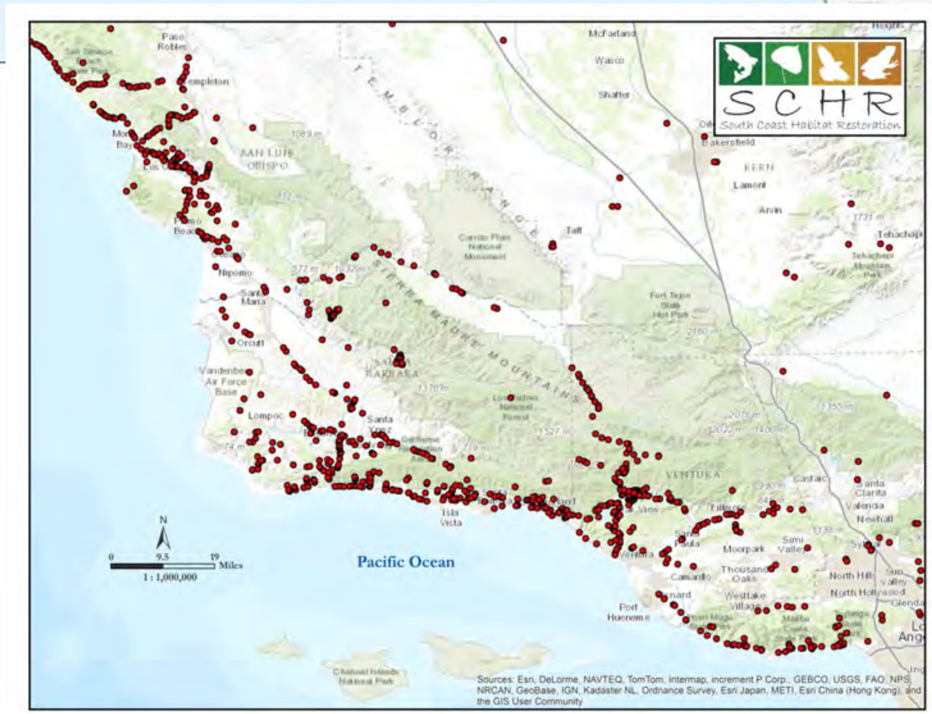
How do we do this?

- Perform habitat assessments
- Landowner outreach/identification
- Apply for and manage grants
- Coordinate consultants
- Obtain permits
- Hire and oversee contractors
- Monitor permit conditions
- Community outreach and education

Outline

- Steelhead Trout: History/Pics
- Examples of Fire/Debris Flow Impacts
- Aquatic Invertebrate Community Impacts
- Strategies for Improving Habitat
- Future projects





Historic Steelhead Photos

Carpinteria Creek - Bliss Family

Santa Maria River – ca. 1948 (M. Capelli)

Steelhead Trout -Spawning

Steelhead Trout Examples

Steelhead Trout Examples

Examples of Pre-Fire Impacts


Examples of Post-Fire Impacts

Examples of Debris Flow Impacts


KEEP
CALM
SCORE

Aquatic Invertebrate Community Response to Fires

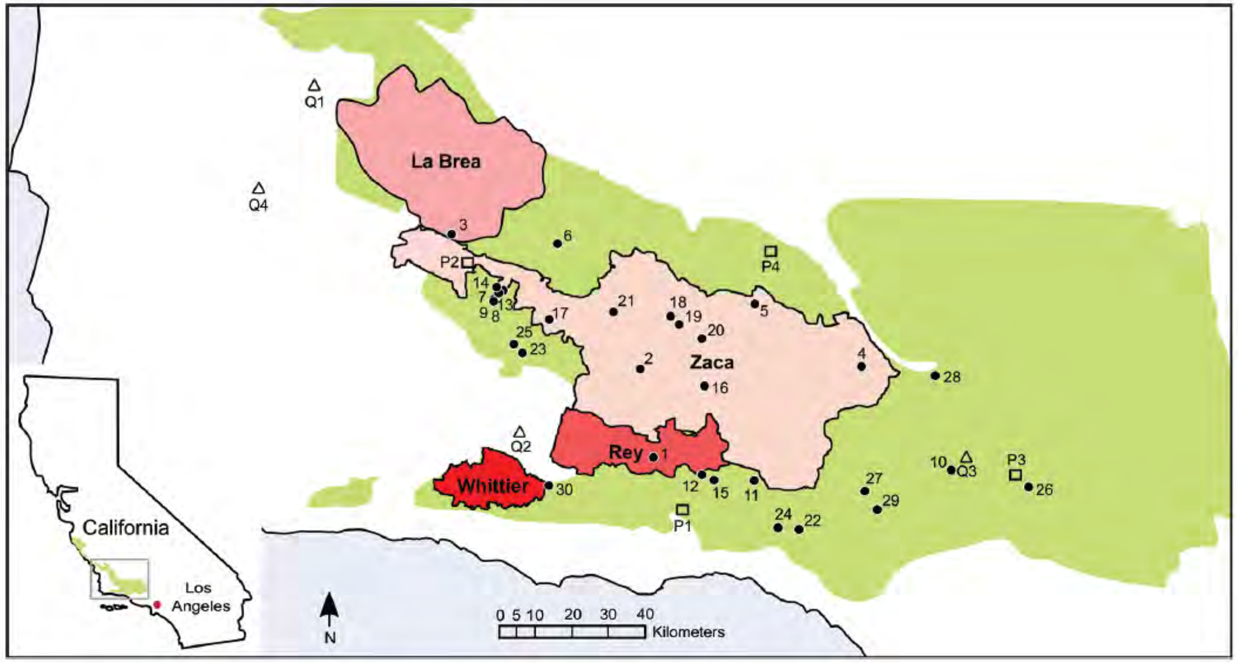
Wildfire and drying legacies and stream invertebrate assemblages

Scott D. Cooper, Kristie Klose, David B. Herbst, Jason White, S. Matthew Drenner, and Erika J. Eliason

UCSB & LPNF study (Cooper et. al. 2021)
https://www.journals.uchicago.edu/doi/full/10.1086/717416

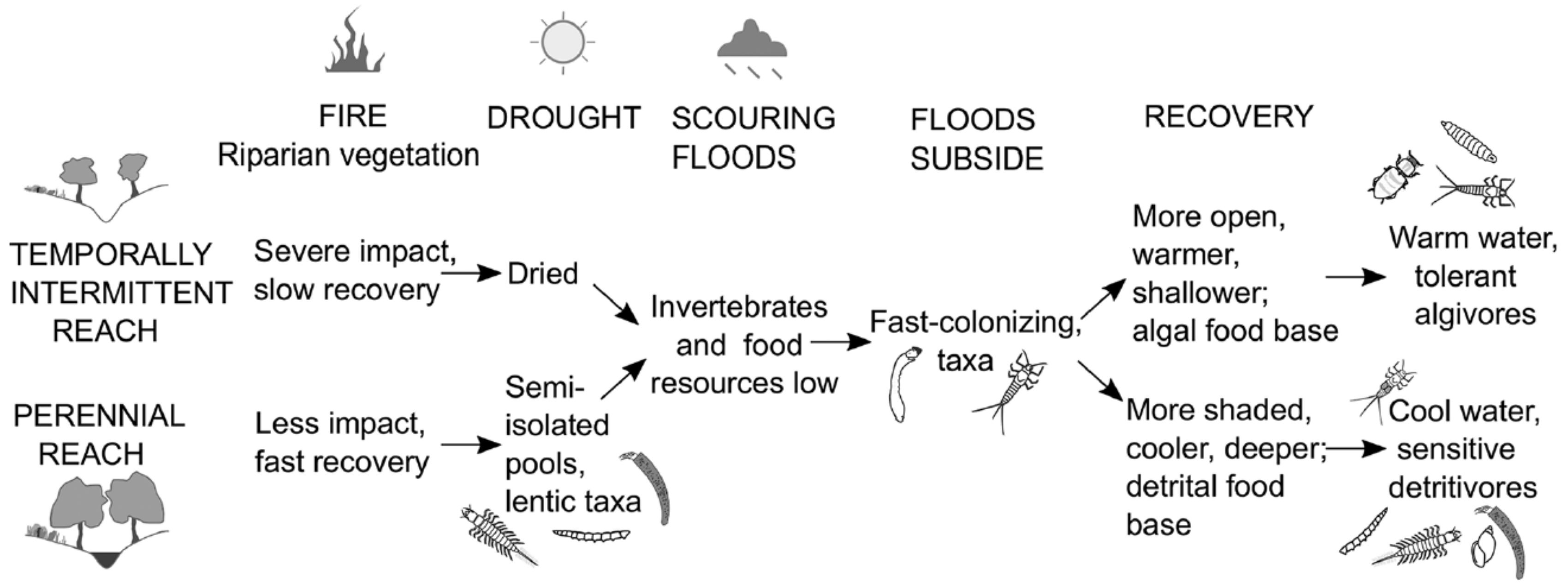
10 year study analyzing the impacts of wildfires and drought on aquatic invertebrates

Los Padres National Forest sites within and near fires (Zaca, La Brea, Rey and Whittier) totaling over 380,000 acres between 2007 and 2017. 30 miles of streams surveyed.



Scott Cooper, UCSB

Kristie Klose, LPNF



Conceptual diagram summarizing the physical and biological responses to fire and drought in temporarily intermittent and perennial streams observed in the study.

Summary of Results:

- Drought and wildfires can shift stream invertebrate composition from taxa associated with wet or unburned sites to taxa associated with dry or burned sites

- Riparian loss results in increased runoff, erosion and sediment inputs that ultimately can change animals found in and around streams

- Results indicate that deep, shaded, perennial, spring-fed pools in headwater areas can act as refuges from drought and wildfires for the aquatic and riparian biota

- Where possible, humans should sustain these refuges by protecting or restoring riparian vegetation (<u>and habitat accessibility</u>)

Strategies For Improving Habitat

Davy Brown/Munch Creek Fish Passage Project

Project Goal:
To increase access to 3.13 miles of habitat for the federally endangered steelhead trout by removing three barriers to migration and build two vehicular bridges

Partners:
United States Forest Service/Los Padres National Forest

Funders:
National Fish and Wildlife Foundation
California Dept. of Fish and Wildlife
State Coastal Conservancy
County of SB – CREF
CA Fish Passage Forum
CalTrout

Project Cost:
~$4,000,000

Engineers:
Waterways Consulting – Civil Engineers
Streeter Group – Structural Engineers
Earth Systems – Geotechnical Engineers

Cultural Monitor:
Santa Ynez Band of Chumash Indians

Bridge Manufacturer:
Contech/Big R Bridge

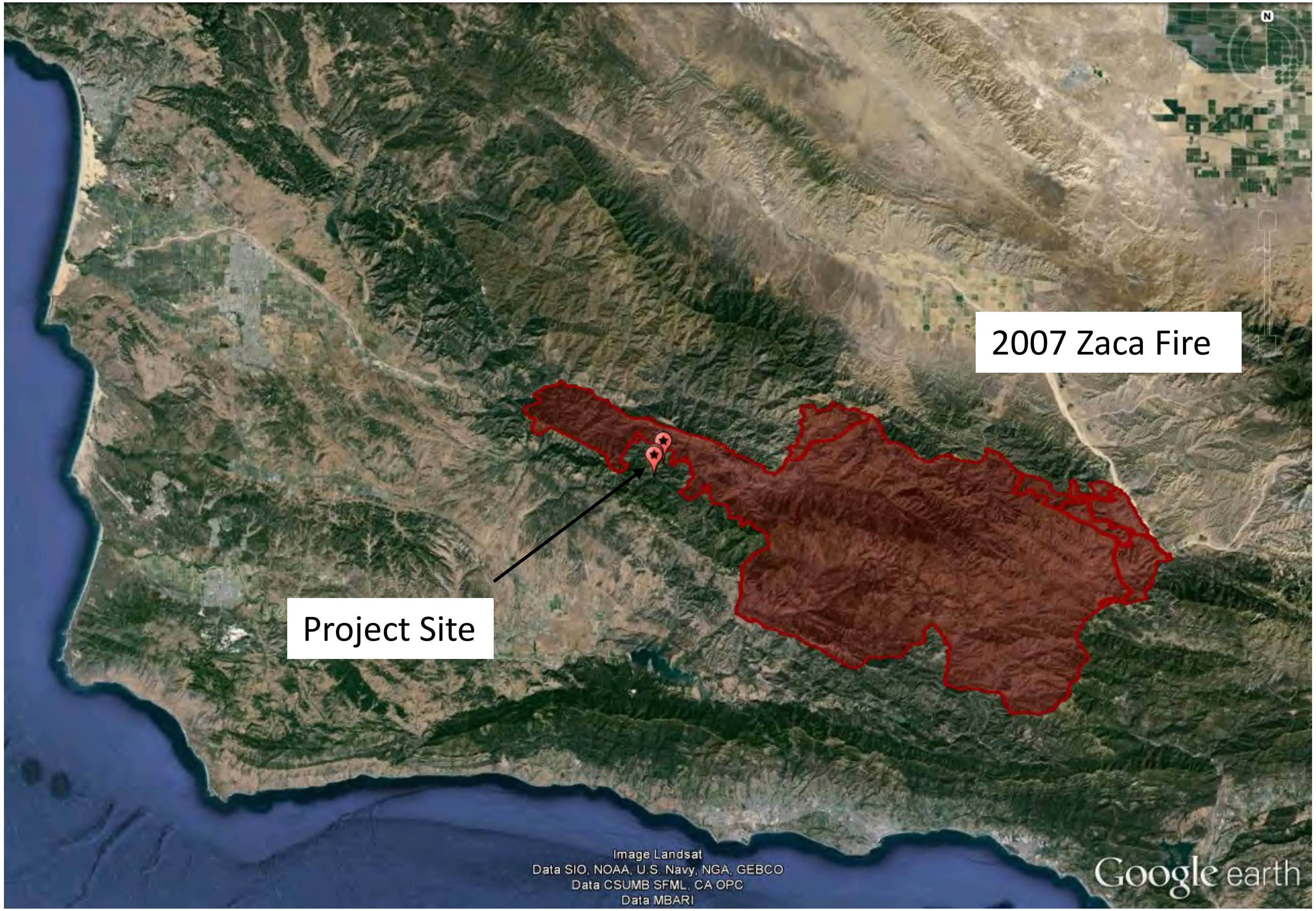
Contractors:
Peter Lapidus Construction, Inc.
California Conservation Corps

Davy Brown/Munch Creek Fish Passage Project

Michael Love & Associates

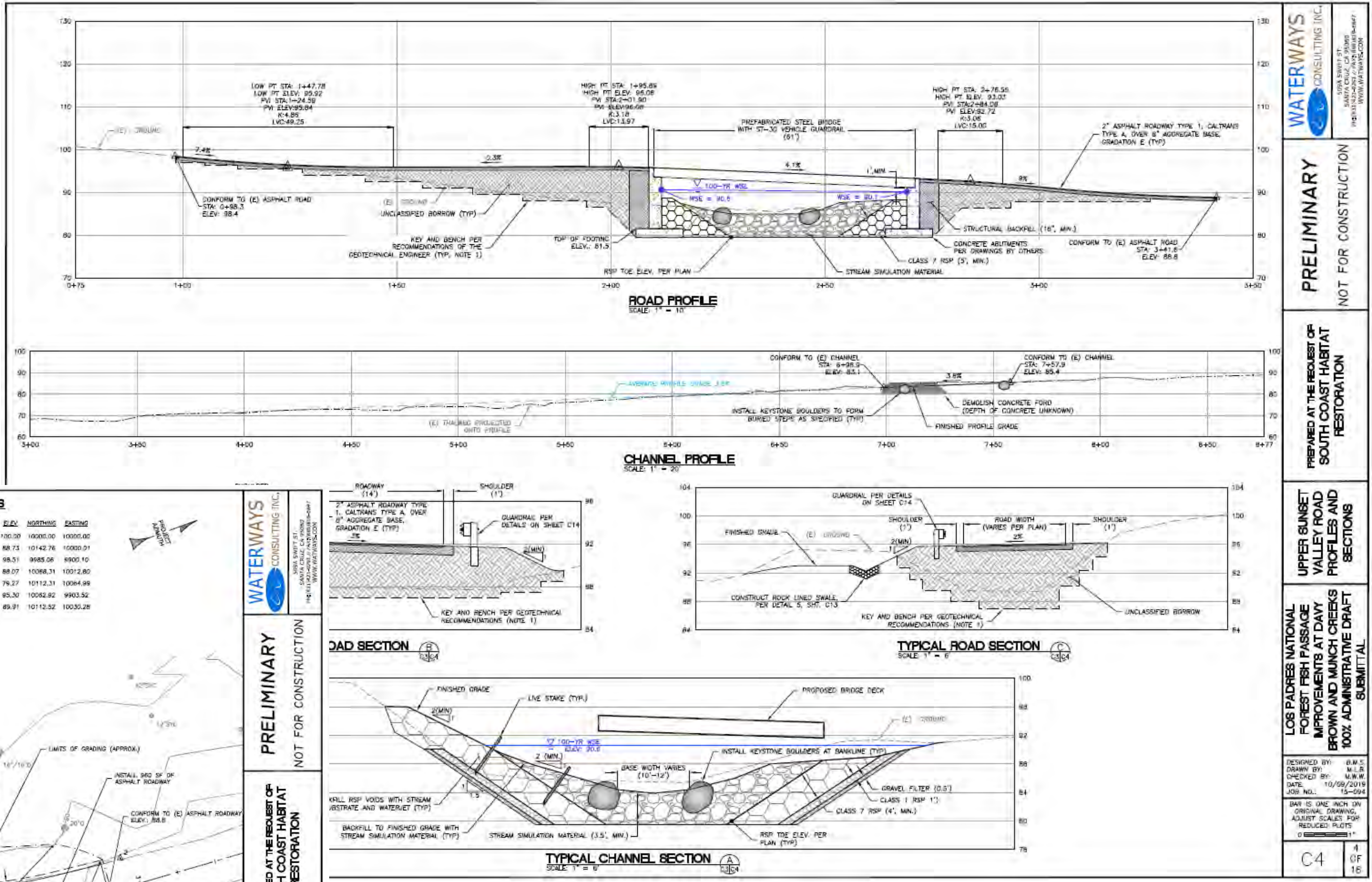
Barrier Removal – Davy Brown & Munch Creek

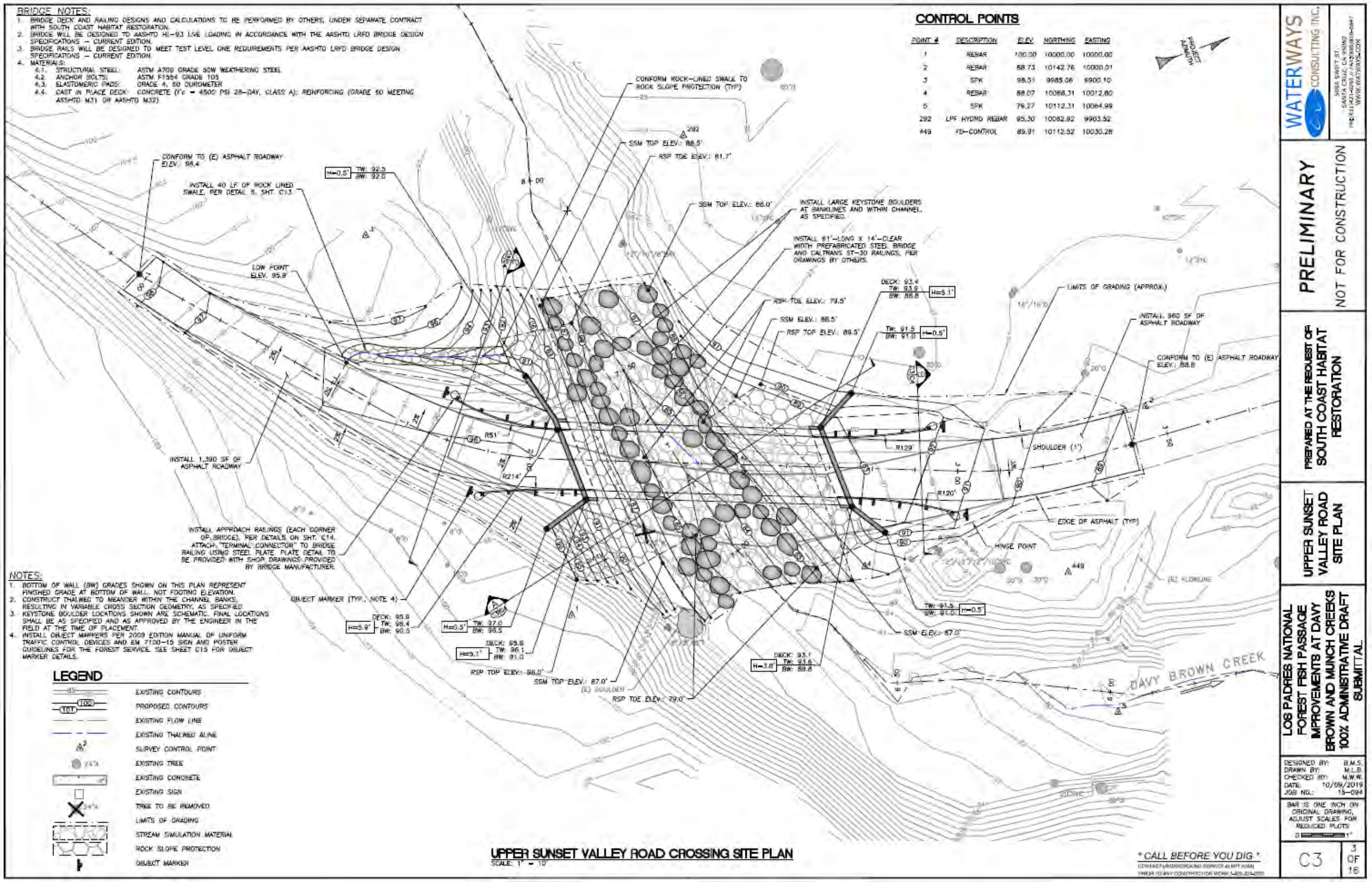
Barrier Removal – Davy Brown & Munch Creek



Barrier Removal – Davy Brown & Munch Creek

Engineering





Munch Creek

Before

After

Upper Davy Brown Creek along Sunset Valley Road

Before


After


After

<u>Lower</u> Davy Brown Creek along Sunset Valley Road

Before


After

After

California State Legislature
Certificate of Recognition
Presented to
Davy Brown & Munch Creek
Aquatic Organism Passage Projects
In celebration of the completion of your multi-year habitat restoration project allowing endangered species viable paths of migration across the region.
In commendation for the skillful collaboration between South Coast Habitat Restoration, Earth Island Institute, and the Los Padres National Forest Service, we celebrate your successful project!
Santa Barbara County, California
Assemblymember
Senator

Certificate of Special
Congressional Recognition
Presented to
South Coast Habitat Restoration
In Honor of Dedication to Complete the Davy Brown Creek Restoration Project and
in recognition of outstanding and invaluable
service to the community.
March 30, 2022
DATE
MEMBER OF CONGRESS
Salud O. Carbajal

Other Wildlife


Bushnell
TROPHY CAM
74°F 23°C
09-09-2021 21:17:15


Bushnell
TROPHY CAM
74°F 23°C
09-09-2021 21:17:15

Bushnell
TROPHY CAM
76°F 24°C
09-20-2021
19:15:33


Bushnell
TROPHY CAM
76°F 24°C
09-20-2021
19:15:33

TROPHY CAM
76°F 24°C
09-20-2021
19:15:34


Bushnell
TROPHY CAM
76°F 24°C
09-20-2021
19:15:35


Bushnell
TROPHY CAM
75°F 23°C
09-12-2021 19:44:49


Bushnell
TROPHY CAM
75°F 23°C
09-12-2021
19:44:49

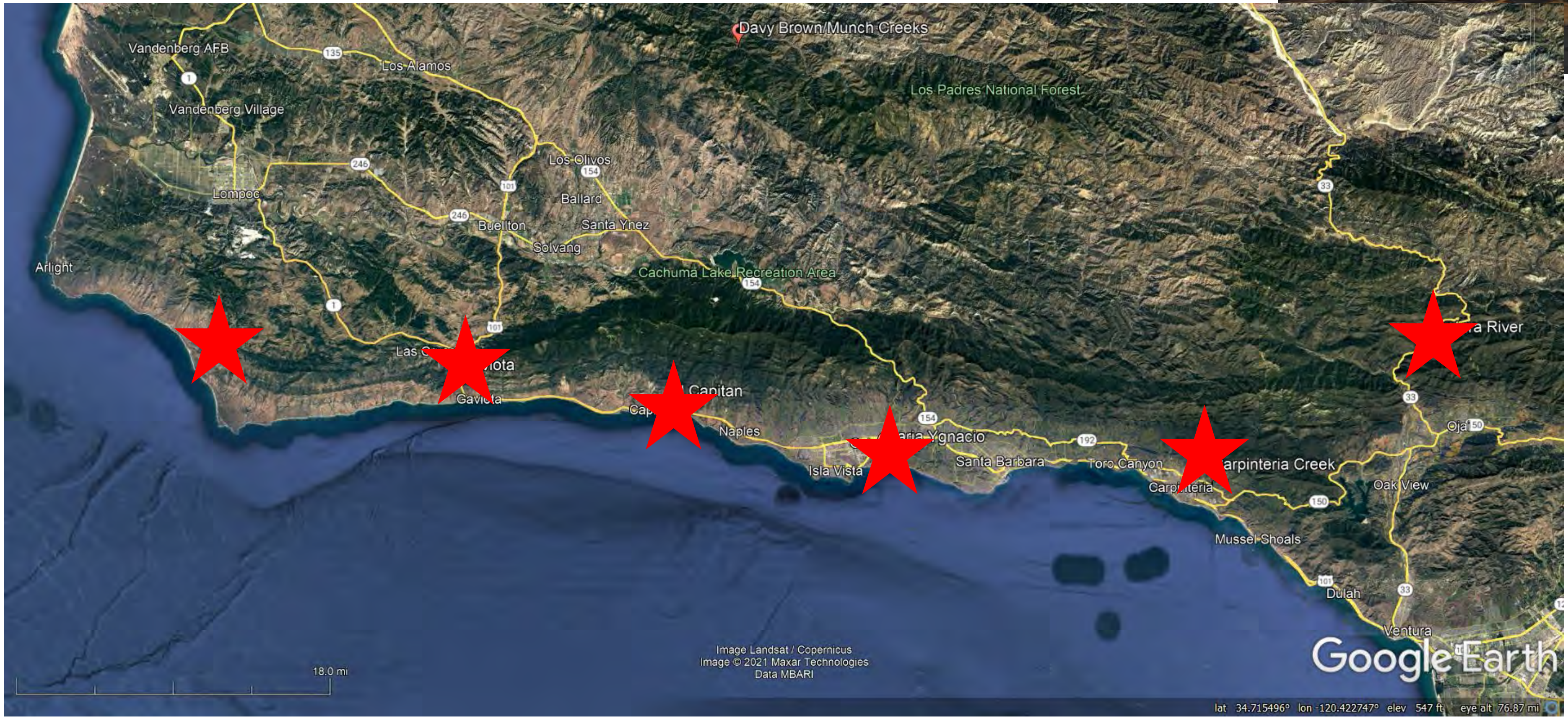

Bushnell
TROPHY CAM
72°F 22°C
09-13-2021
20:18:35


Bushnell
TROPHY CAM
53°F 11°C
09-16-2021
22:55:21


Bushnell
TROPHY CAM
60°F 15°C
10-20-2021 18:08:17

Future Steelhead Projects

- **Jalama Creek**
- **Gaviota Creek**
- **El Capitan Creek**
- **Maria Ygnacio Creek**
- **Carpinteria Creek**
- **Ventura River**



Thank You

Arroyo Hondo – Sally Isaacson

Mauricio Gomez

South Coast Habitat Restoration

805-729-8787

mgomez@schabitatrestoration.org