Room to Roam: Floodplains and the Central Valley

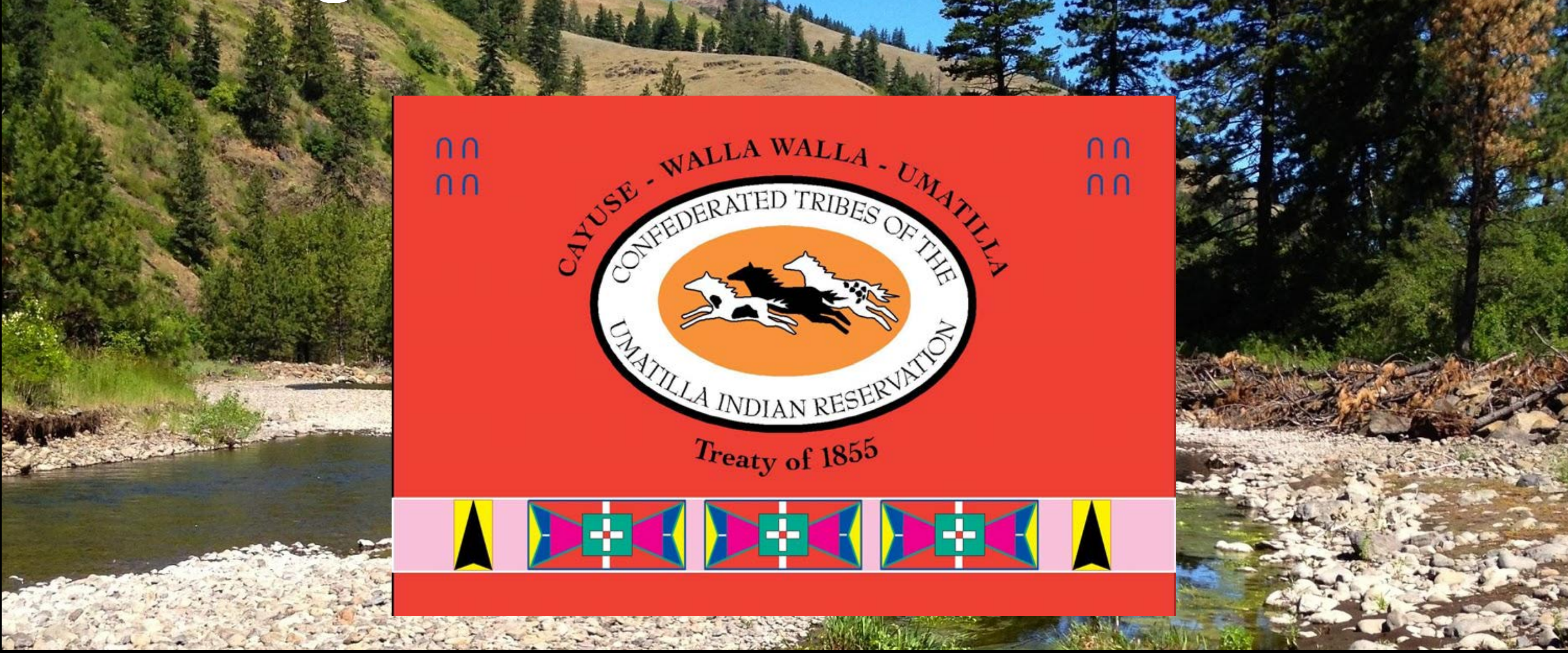
A Concurrent Session at the 42nd Annual Salmonid Restoration Conference
Santa Cruz, California, April 29 - May 2, 2025

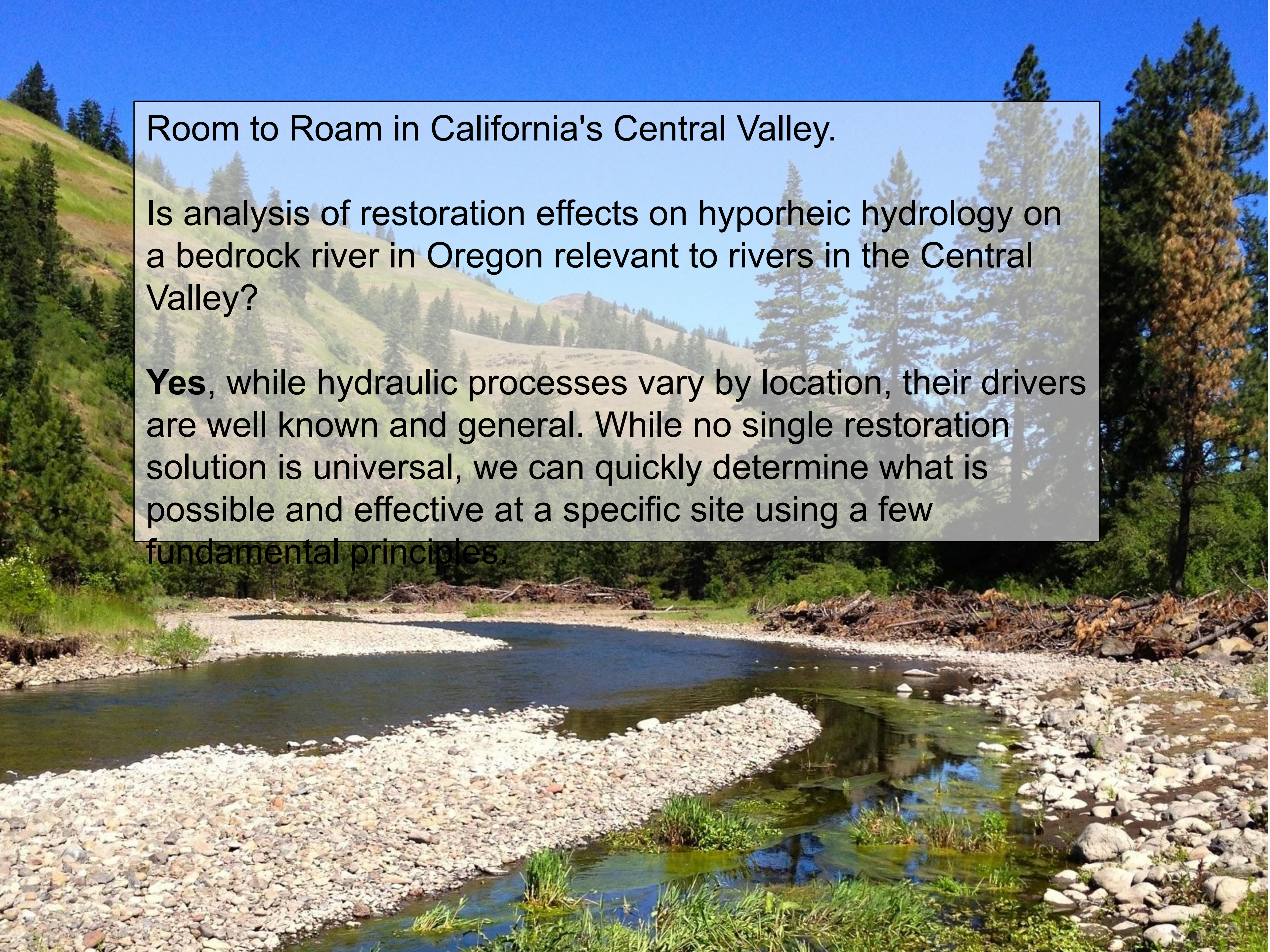
Session Coordinators: Sam DIaz and Chris Hammersmark, cbec eco engineering - a Verdantas company

Floodplains can provide salmonids with particularly-valuable habitat, especially for juvenile rearing. The flat valleys where these habitats typically exist are the same areas favored by humans for agriculture and development. Rivers are often confined to single-thread channels as a result of levees, other human-built infrastructure, and legacy-mining impacts. Floodplain restoration seeks to improve the area, frequency, and duration of inundation, providing fish with room to access complex and high-quality floodplain habitats. Restoration approaches include managing flows, removing levees, altering sediment deposition, and excavation to reduce floodplain elevation and build habitat features. This session will explore a range of floodplain restoration topics, including: 1) groundwater surface-water interactions in restored floodplains; 2) geomorphic changes; 3) biological responses including vegetation, macroinvertebrate production, juvenile salmonid growth and predation, and adult fish migration; 4) lessons learned; and 5) project design and implementation. The session's geographic focus is California's Central Valley, but an Oregon creek is also included.

Presentations

Wiggle, Elevate, Connect: Partitioning the Effects of Increased Aquifer Size, Channel Realignment, and Floodplain Reconnection on Streambed Exchange in a Large-Scale Channel Restoration

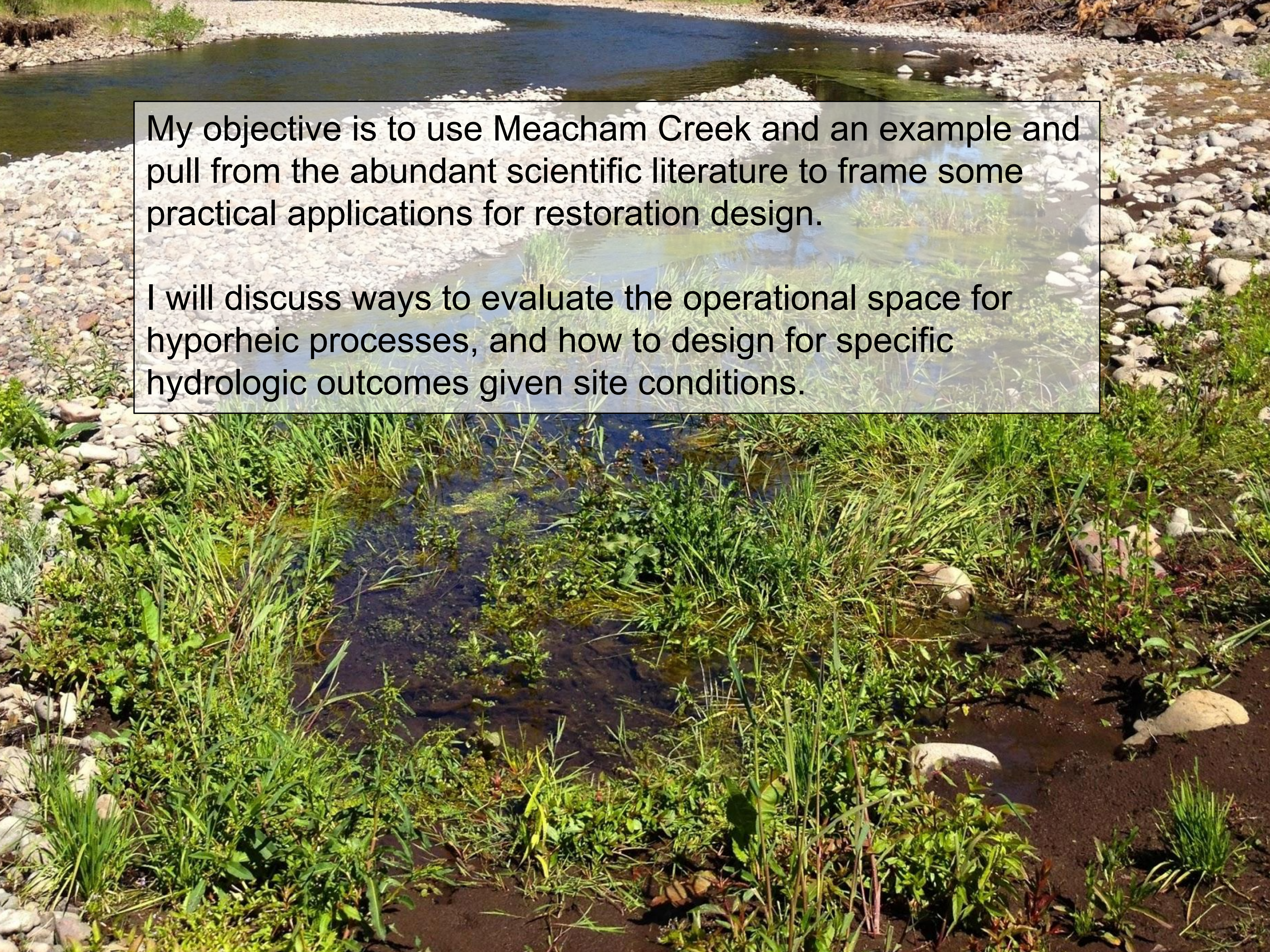


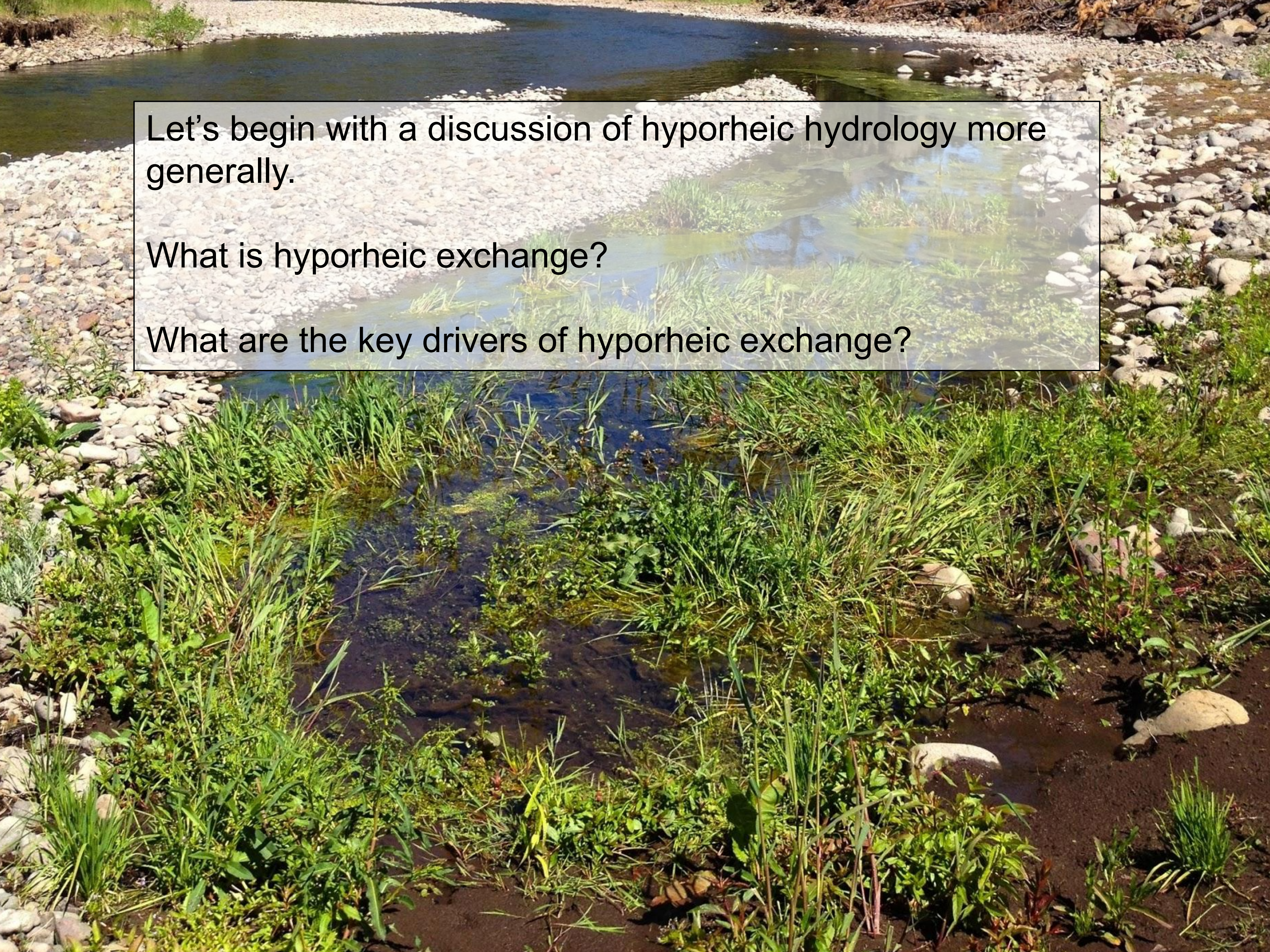


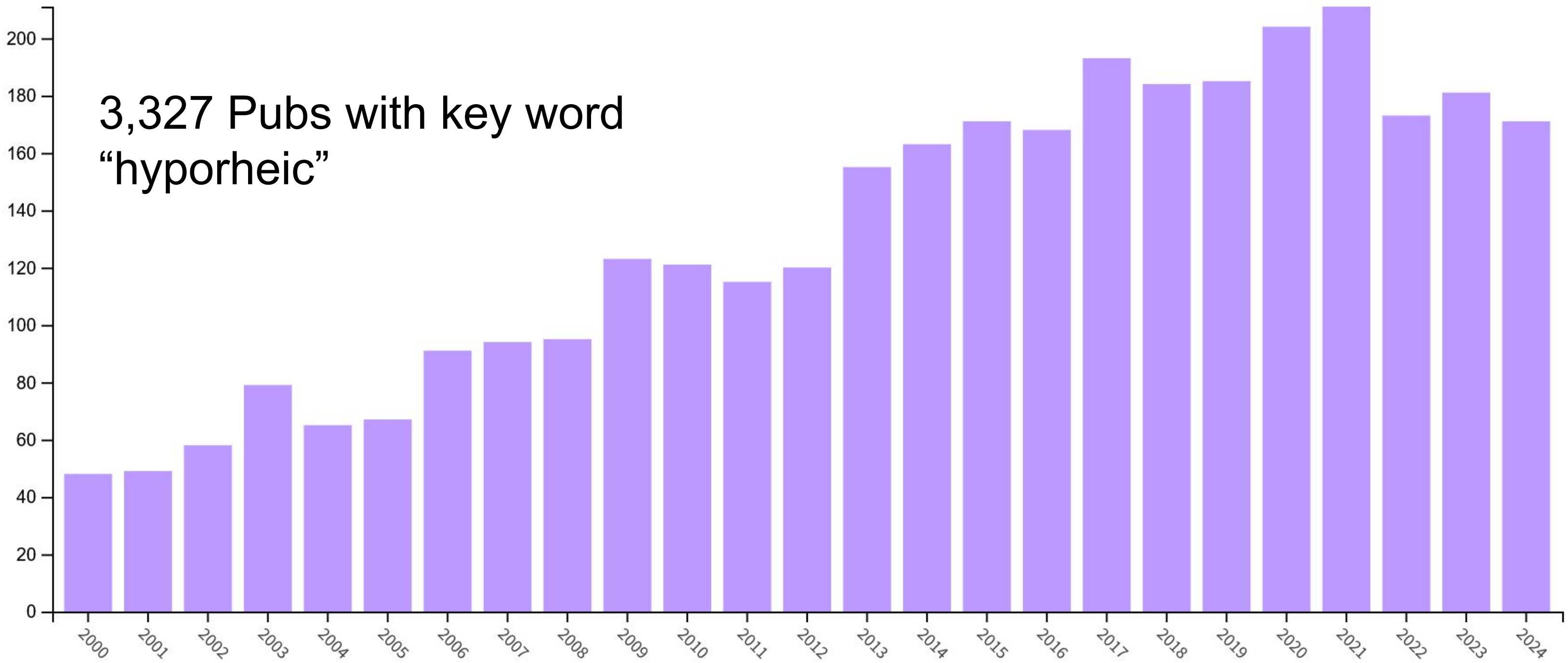
Room to Roam in California's Central Valley.

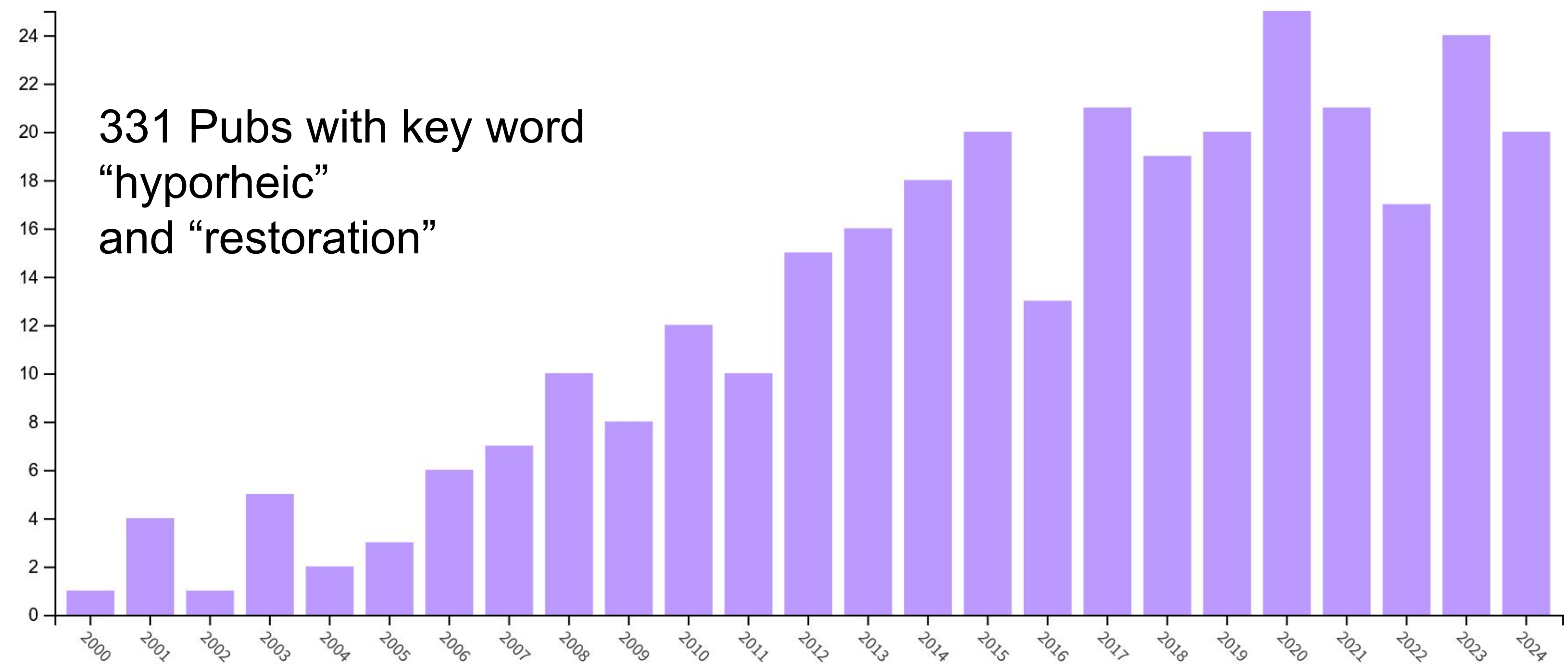
Is analysis of restoration effects on hyporheic hydrology on a bedrock river in Oregon relevant to rivers in the Central Valley?

Yes, while hydraulic processes vary by location, their drivers are well known and general. While no single restoration solution is universal, we can quickly determine what is possible and effective at a specific site using a few fundamental principles.


My objective is to use Meacham Creek and an example and pull from the abundant scientific literature to frame some practical applications for restoration design.
I will discuss ways to evaluate the operational space for hyporheic processes, and how to design for specific hydrologic outcomes given site conditions.


Let’s begin with a discussion of hyporheic hydrology more generally.
What is hyporheic exchange?
What are the key drivers of hyporheic exchange?


3,327 Pubs with key word
“hyporheic”
0
20
40
60
80
100
120
140
160
180
200
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024


331 Pubs with key word
“hyporheic”
and “restoration”
0
2
4
6
8
10
12
14
16
18
20
22
24
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024

Environ. Sci. Technol. 2010, 44, 1521–1525

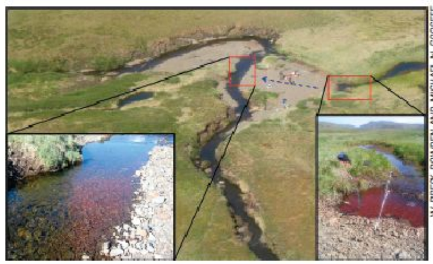
Environmental Science & Technology
Feature

Moving Beyond the Banks: Hyporheic Restoration Is Fundamental to Restoring Ecological Services and Functions of Streams

ERICH T. HESTER*
Virginia Tech, Blacksburg, Virginia

MICHAEL N. GOOSEFF
Pennsylvania State University, University Park, Pennsylvania

Stream restoration needs to consider the hyporheic zone just as much as the surface and benthic regions.



W. BRECK BOWDEN AND MICHAEL N. GOOSEFF

Hyporheic zones are aquifers beneath and adjacent to stream and river channels through which surface water exchanges and mixes with groundwater (Figure 1) (*1*). Hyporheic zones are intimately connected to the water column and benthic zones (Figure 2), and underpin stream ecosystem function through important contributions to biogeochemical cycling and biological habitat. Specifically, the movement of streamwater into the subsurface provides a vector for dissolved constituents (oxygen, nutrients, and pollutants) to come into direct contact with entrained carbon sources, microbial communities occupying the extensive surface area of sediment grains, and a unique array of biogeochemical conditions (e.g., both oxidative and highly reducing zones). Additionally, hyporheic exchange of water buffers surface water temperatures by facilitating heat exchange with relatively constant temperature groundwater. Thus the hyporheic zone contains gradients of physical, chemical, and thermal conditions; the water column and deeper groundwater are end members (Figure 2). The hyporheic zone therefore represents an ecotone between surface (stream) and groundwater ecosystems, is an important habitat for certain macroinvertebrates (*2*), and can be uniquely reactive relative to both surface water and deeper groundwater (e.g., denitrification (*1*)). Hyporheic zones are therefore important components of stream systems, and, similar to other stream habitats, have suffered degradation as a consequence of human activity. Deleterious human actions are diverse, ranging from direct channel and floodplain modifications to conversion of land to urban and agricultural uses both in the riparian zone (stream/riverbank) and in the larger watershed. Examples of the former are dam construction and channelization, while latter activities include deforestation and silt runoff from construction (*3*).

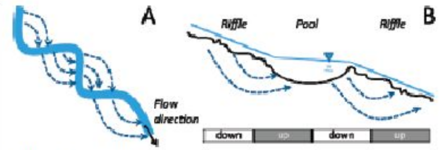


FIGURE 1. Idealized representations of hyporheic exchange in (A) plan view (lateral exchange) and (B) vertical cross-section (vertical exchange). In panel B, sections of channel that are upwelling (water moving from the bed into the channel) are noted by the gray bars and downwelling sections (water moving from the channel into the bed) are noted by the white bars.

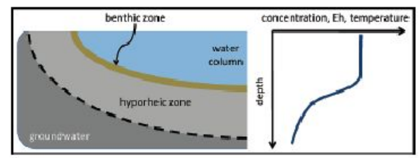


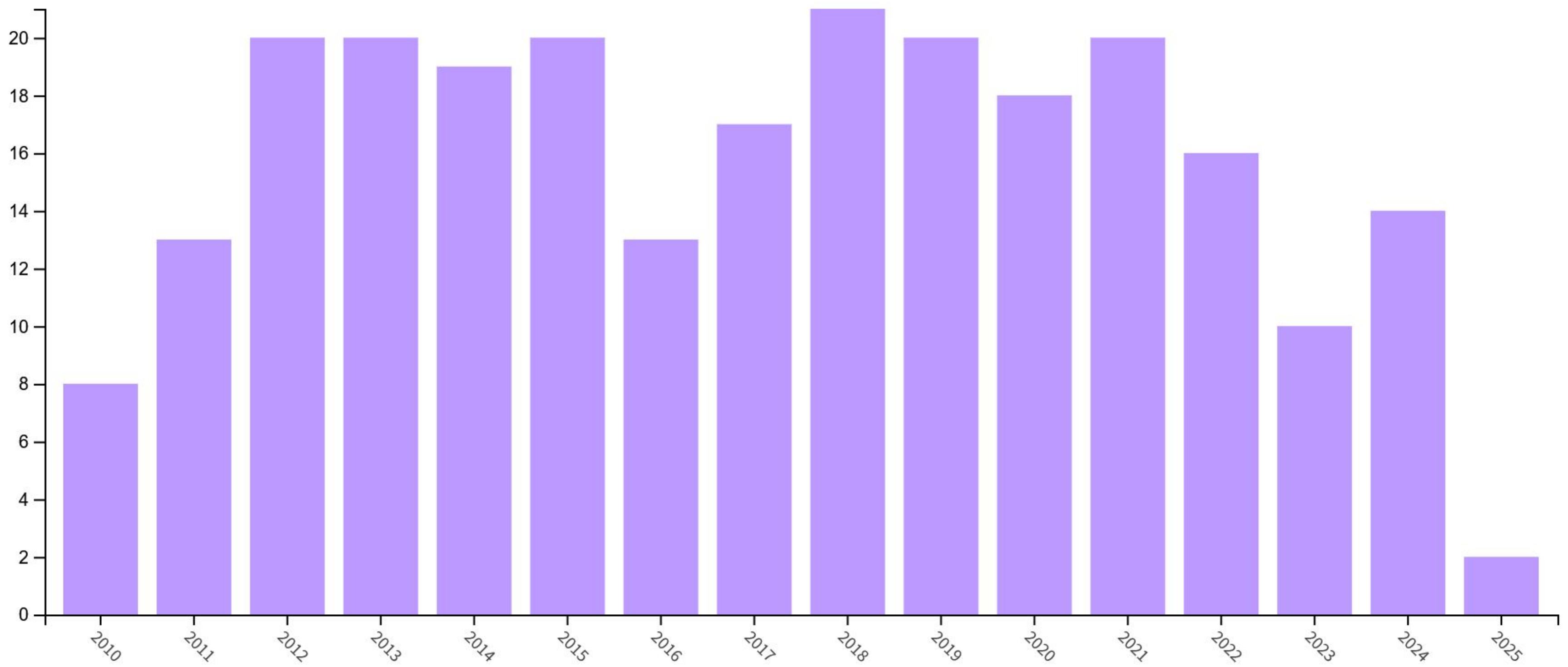
FIGURE 2. Conceptual cross-section of a stream system, made up of water column, benthic zone, and hyporheic zone. Associated typical gradients of redox state, dissolved oxygen (DO) concentration, and temperature variability are represented.

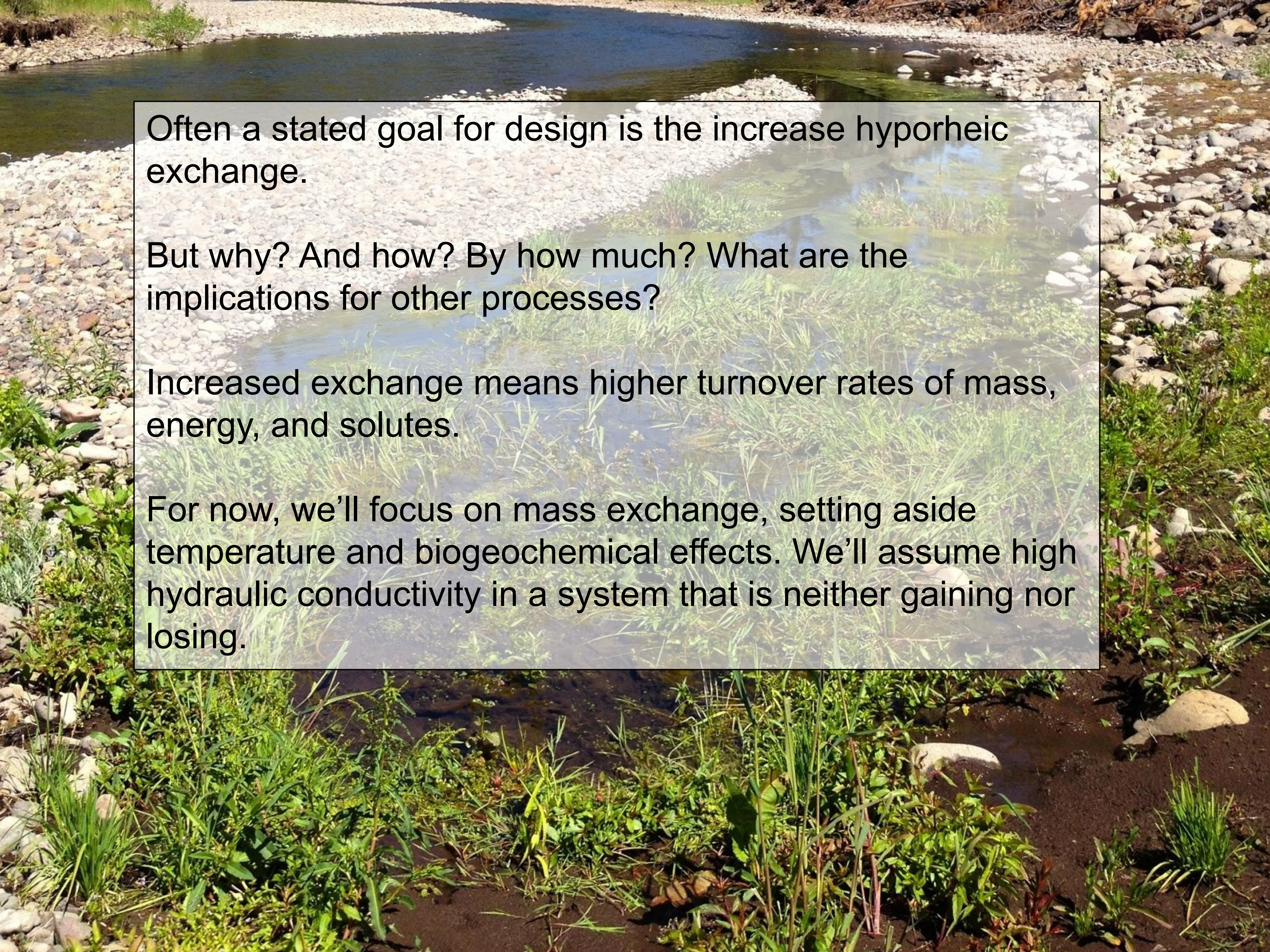
With increased recognition of their degradation, restoration of streams has become an increasingly popular activity (*4*). Common restoration goals include in-channel habitat recreation, riparian restoration, and in-stream species management (*5*). Coincidentally there is a desire to restore stream ecosystems and their associated functions (*6*). However, we currently lack restoration strategies that specifically address these broader, synergistic functions of streams (i.e., nutrient cycling and organic matter decomposition). Stream restoration activities have largely focused on modifying the form of the stream. For example, efforts like changing channel width and/or planform manipulate the spatial distribution of hydraulic energy on the bed and banks. Channel structures modify the distribution of hydraulic conditions in three dimensions, which may be important to reduce local erosion and impact available habitat. Nevertheless, there has been little study of how these structures might also influence

* Corresponding author e-mail: ehester@vt.edu.

10.1021/es902988n
Published on Web 02/04/2010

Cited 251 times since 2010 publication





Often a stated goal for design is the increase hyporheic exchange.

But why? And how? By how much? What are the implications for other processes?

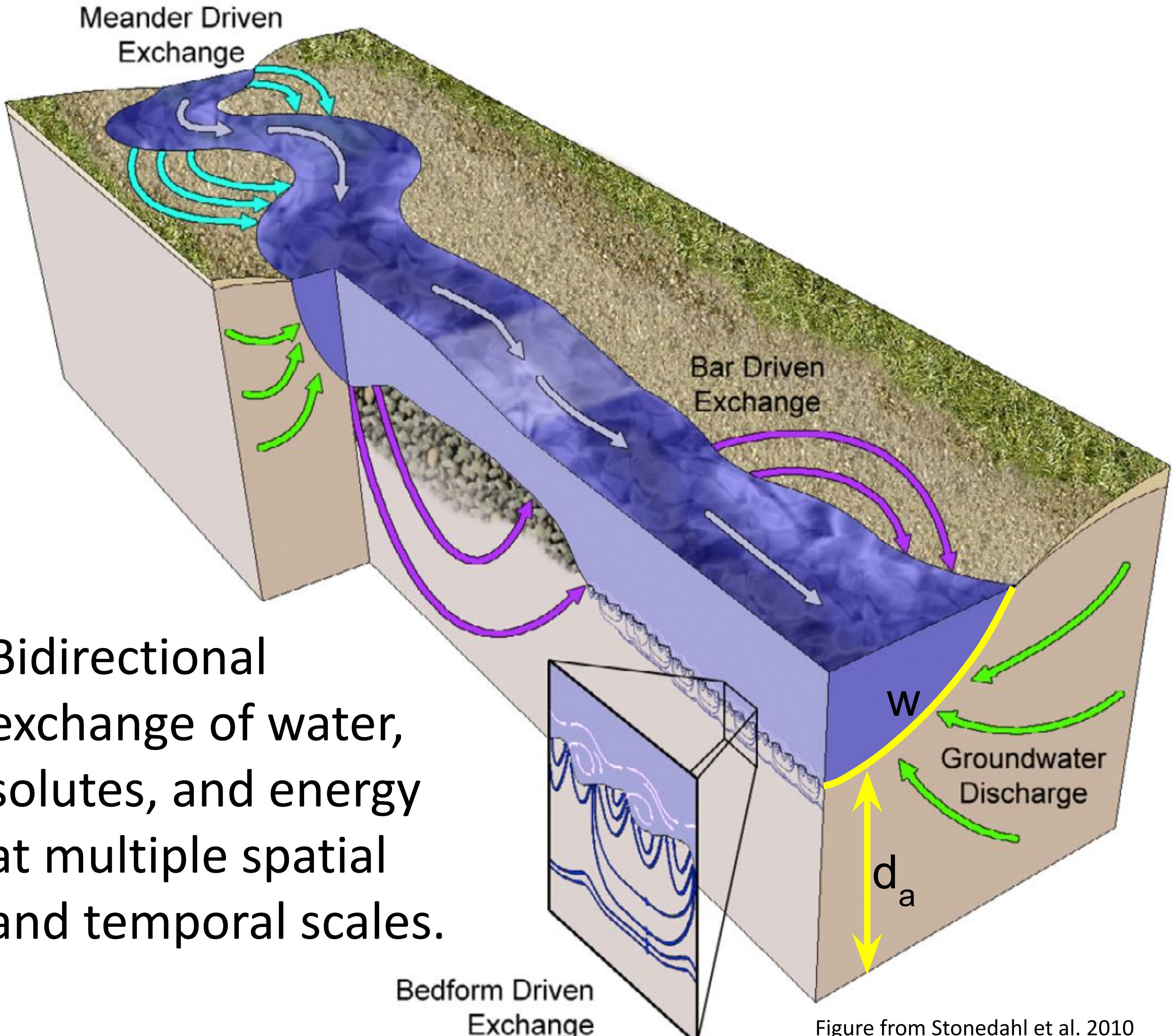
Increased exchange means higher turnover rates of mass, energy, and solutes.

For now, we'll focus on mass exchange, setting aside temperature and biogeochemical effects. We'll assume high hydraulic conductivity in a system that is neither gaining nor losing.

Hyporheic exchange (Q_H) is the continuous, bidirectional flow of water between a stream channel and its underlying alluvium as water moves downstream.

Bed roughness (sediment caliber), bedforms (such as pools and riffles), and channel planform (like meander bends) are widely recognized as driving hyporheic exchange at multiple scales. In general, Q_H increases with stream discharge.

Given site conditions, alluvial depth (S) and wetted width (A) are the key controls on the rate of magnitude Q_H.



Bidirectional exchange of water, solutes, and energy at multiple spatial and temporal scales.

Figure from Stonedahl et al. 2010

From a practical perspective, the key drivers of hyporheic exchange are **profile** and **planform** variability. AKA **wiggle**.

These features combined with stream flow generate the **hydrostatic and hydrodynamic forces** that drive hyporheic exchange.

The floodplain aquifer hosts the hyporheic volume and floodplain aquifer **storage** can limit exchange. AKA **elevate**.

The streambed is the hyporheic exchange interface and wetted **area** can limit exchange. AKA **connect**.

Restoration may yield **ΔH, ΔS, ΔA.** In other words, **wiggle**, **elevate**, **connect**.

Drivers of ΔH (and Q_H):

- Bedform amplitude (residual pool depth)
- Bedform wavelength (λ) (riffle crest to riffle crest distance)
- Meander radius
  - bigger or longer $\uparrow\Delta H$ and $\uparrow Q_H$

Alluvial depth (d_a) (aquifer storage, S):

The hyporheic volume is the max exchange volume.

- For pool-riffle channels is defined by $d_H \approx 0.3\ \lambda$
- $d_H < 0.3\ \lambda$: $\downarrow \Delta H$ and $\downarrow Q_H$
- $d_H \geq 0.3\ \lambda$: max ΔH and max Q_H.

Wetted Area

$\uparrow\Delta A$ yields $\uparrow\Delta H$ and $\uparrow Q_H$

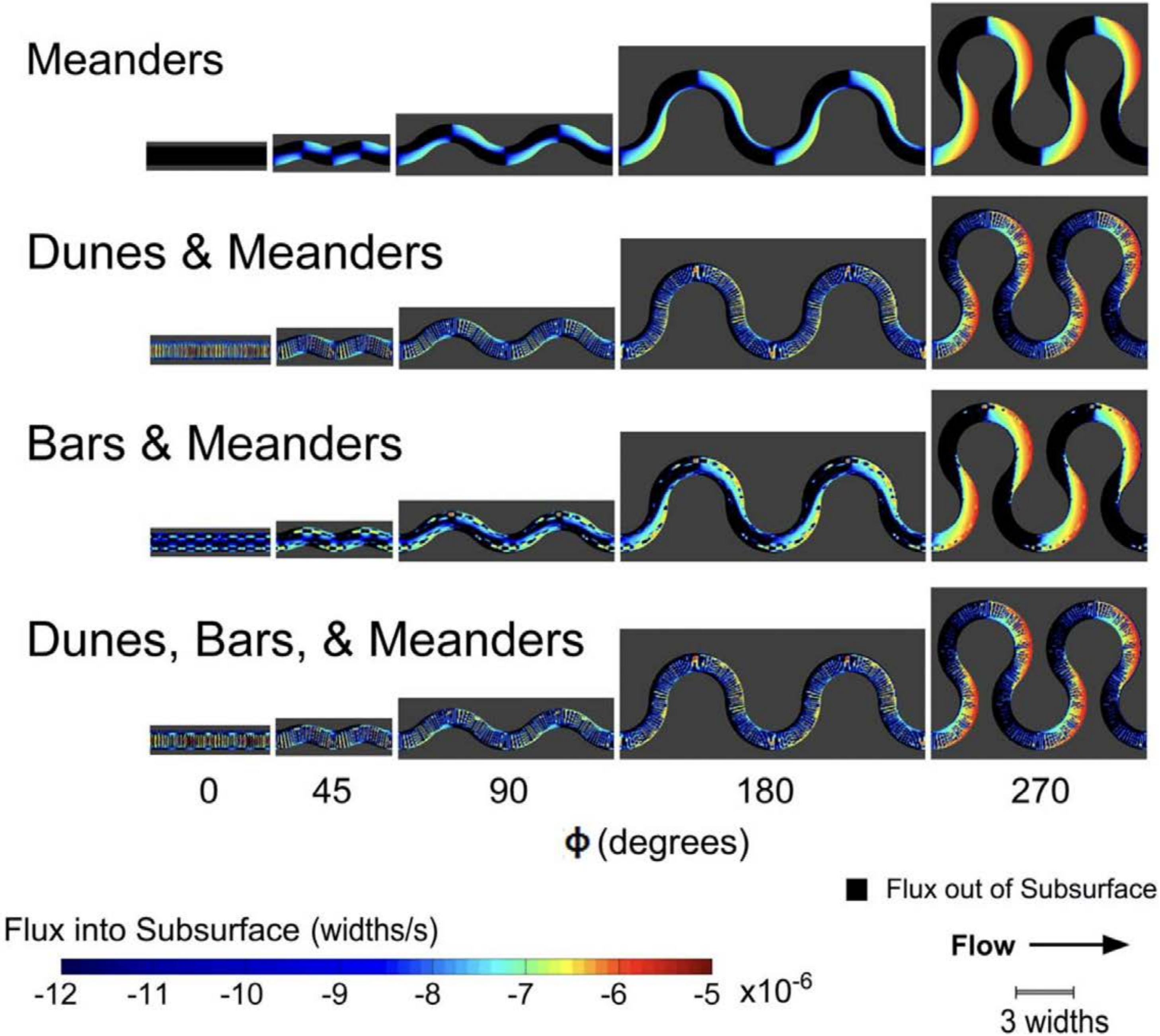
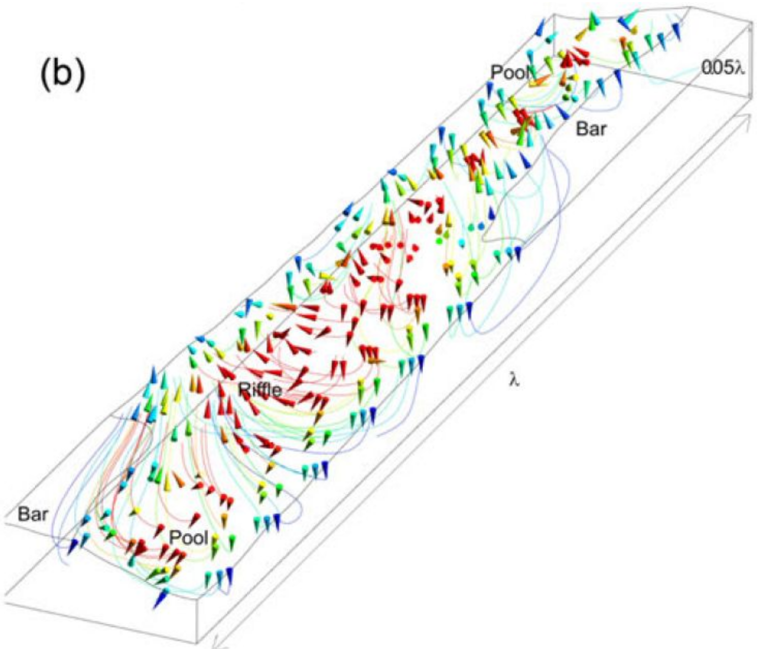
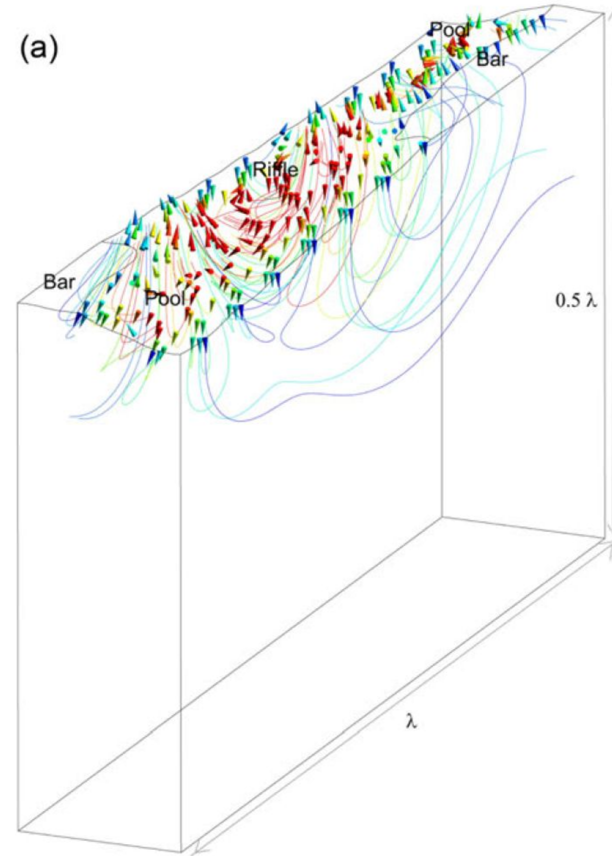


Figure 6. Distribution of interfacial flux (flux into the subsurface) associated with each case described in Table 2.

Figure from Stonedahl et al. 2013

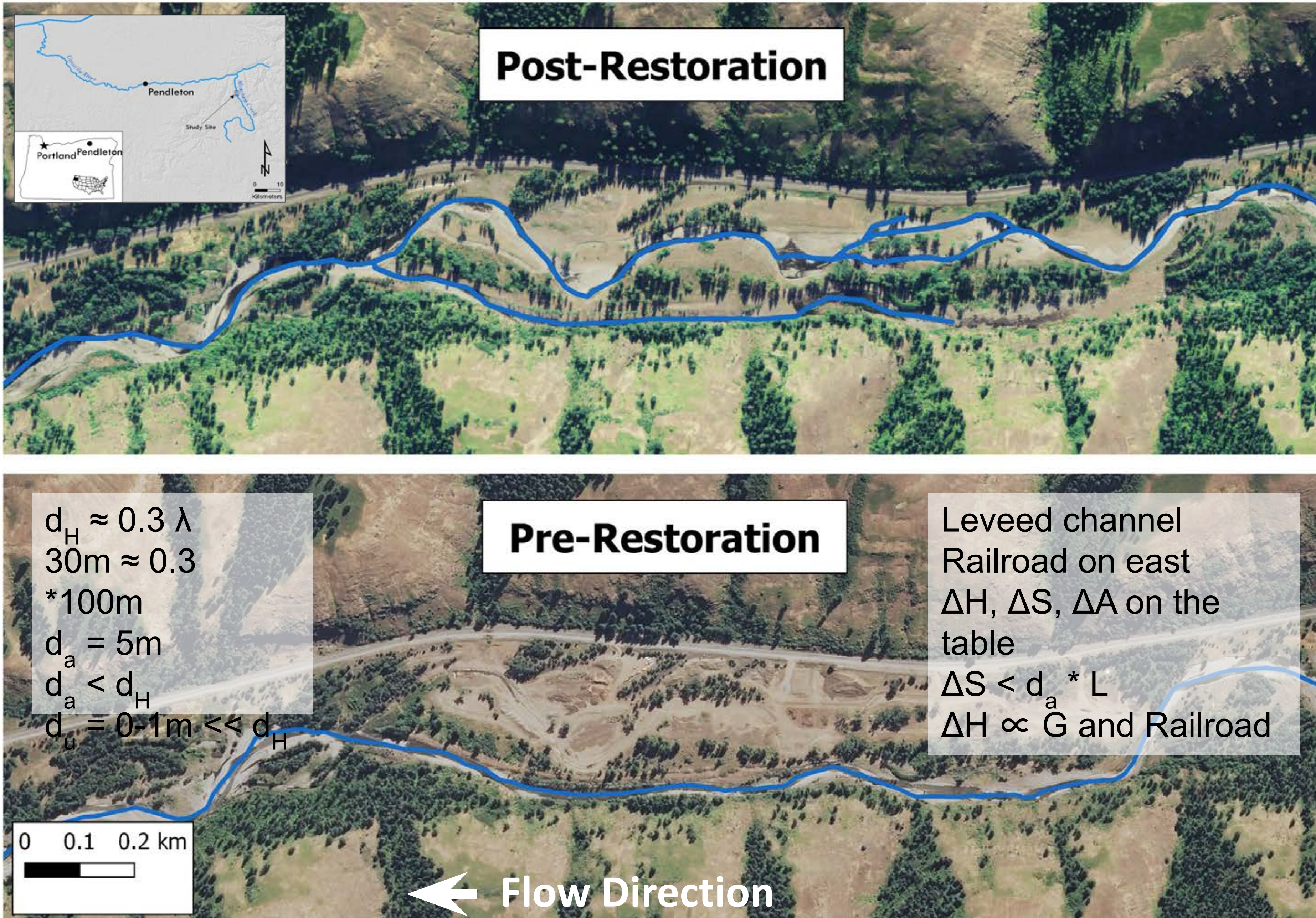


$d_H \ll 0.3\ \lambda$: ↓ ΔH and ↓Q_H

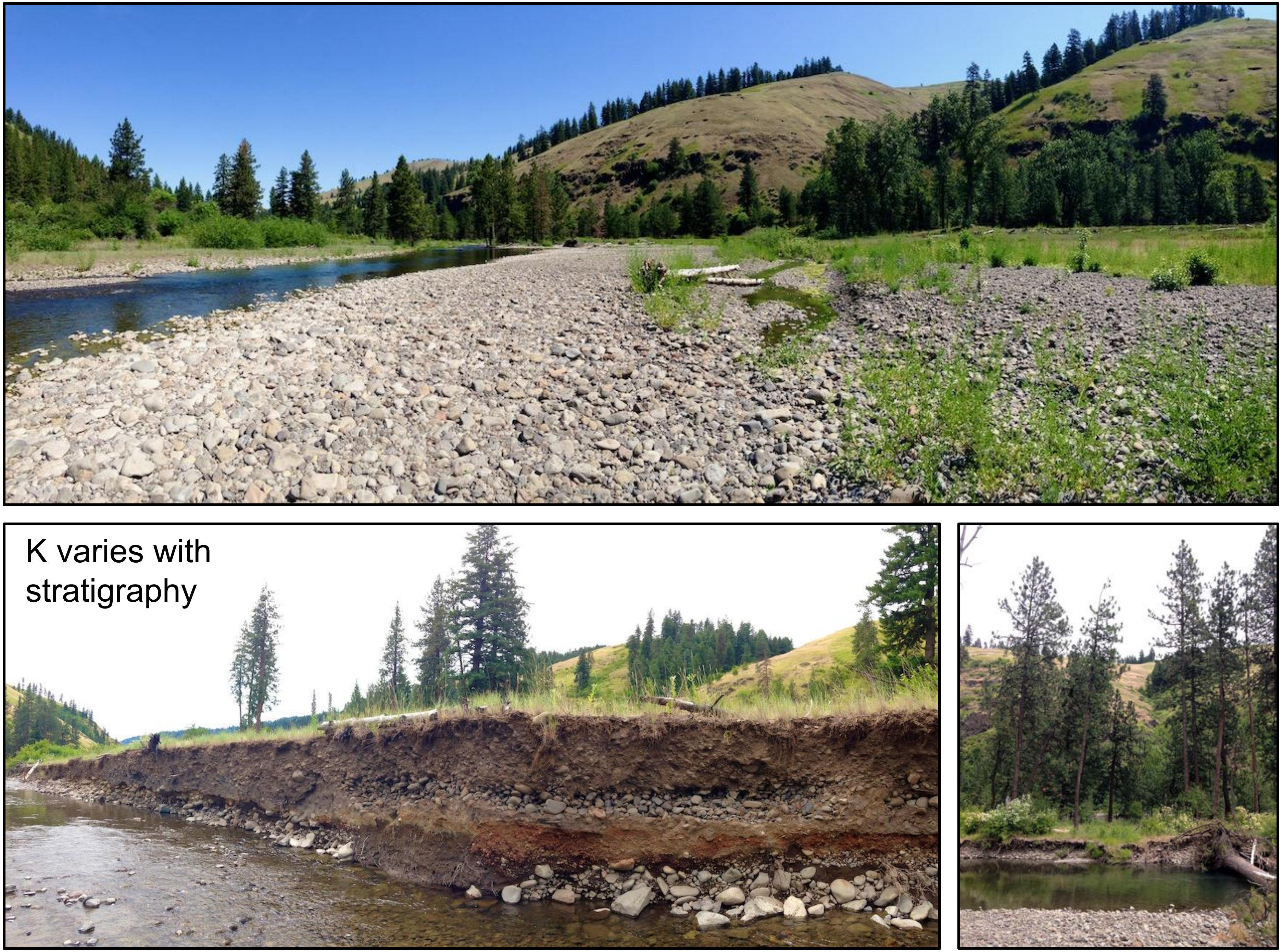


$d_H > 0.3\ \lambda$: max ΔH and max Q_H

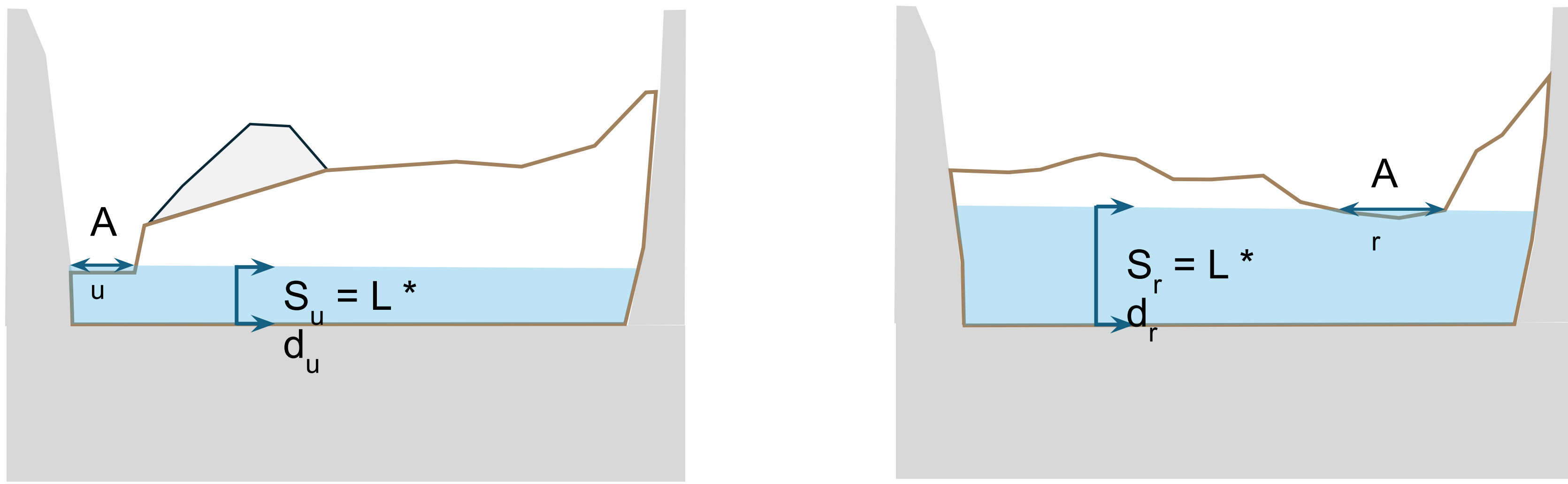
Figure 7 from Tonina and Buffington 2009


Post-Restoration
Pendleton
Study Site
Portland
Pendleton
0 10
Kilometers
N
Pre-Restoration
$d_H \approx 0.3\ \lambda$
30m ≈ 0.3
*100m
d_a = 5m
$d_a < d_H$
d_u = 0-1m << d_H
Leveed channel
Railroad on east
ΔH, ΔS, ΔA on the
table
$\Delta S < d_a * L$
ΔH ∝ G and Railroad
0 0.1 0.2 km
Flow Direction




K varies with stratigraphy

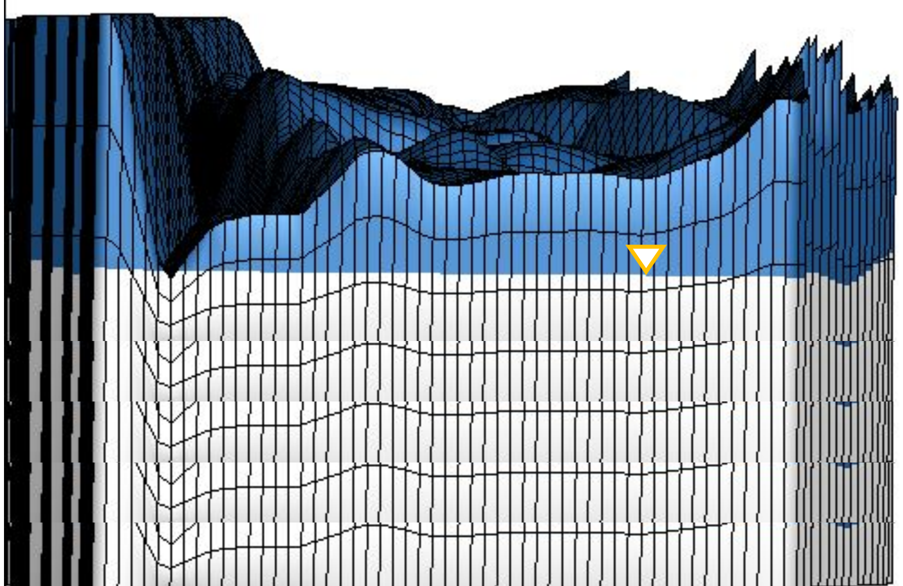
	Restoration Effects at Baseflow (0.31 m^3/s or 10 cfs)		
	Storage (m^3 x 1000)	Area (m^2 x 1000)	Aquifer Discharge (m^3/day x 1000)
Unrestored	331.2	23.9	5.3
Restored	401.0	58.3	22.8
Delta	+69.8	+34.4	+17.5



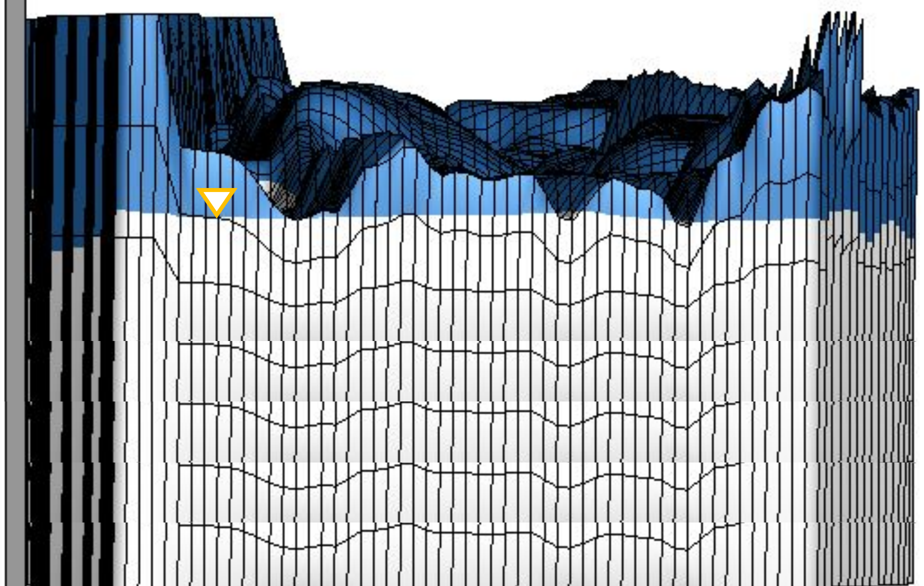
Modeled with HydroGeoSphere
Fully Coupled 3D surface-groundwater
Modeling software

Yields volumetric exchange across the streambed
And full SW-GW balance

Unrestored and Restored (2)
Q = baseflow, annual flood, bankfull, overbank (4)
5 aquifer volumes
2*4*5 = 40 model scenarios

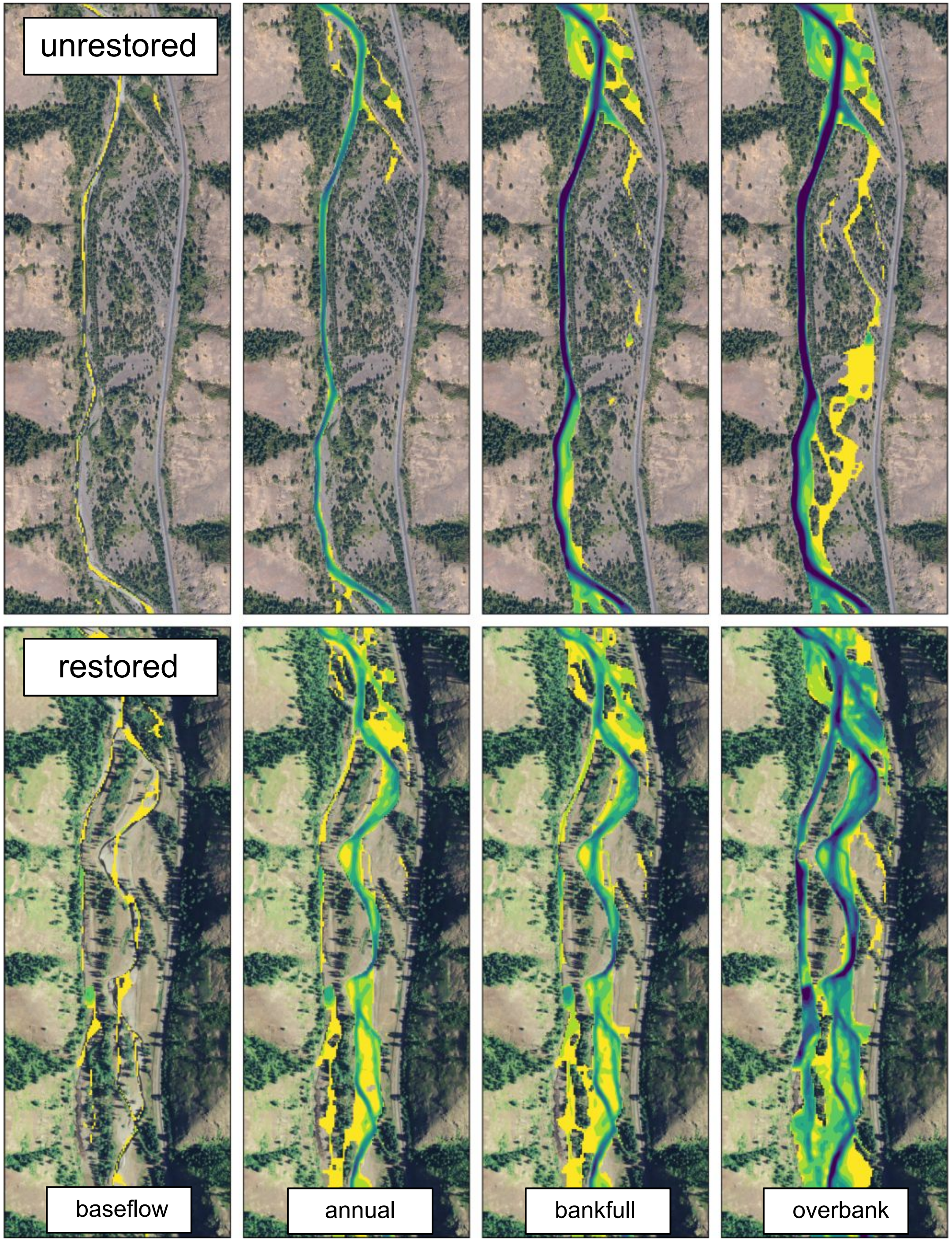


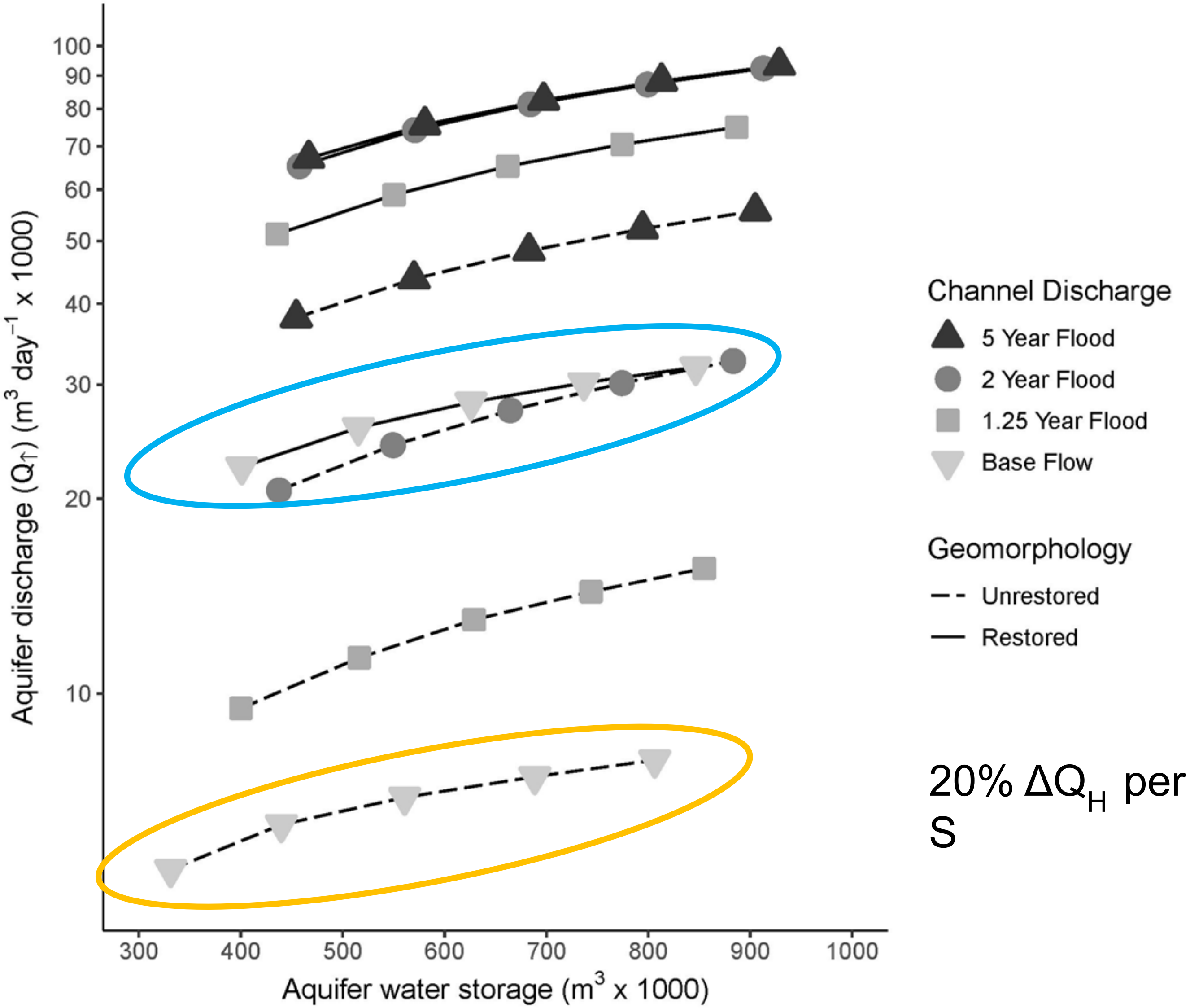
Unrestored
HGS Model Domain



Restored
HGS Model Domain

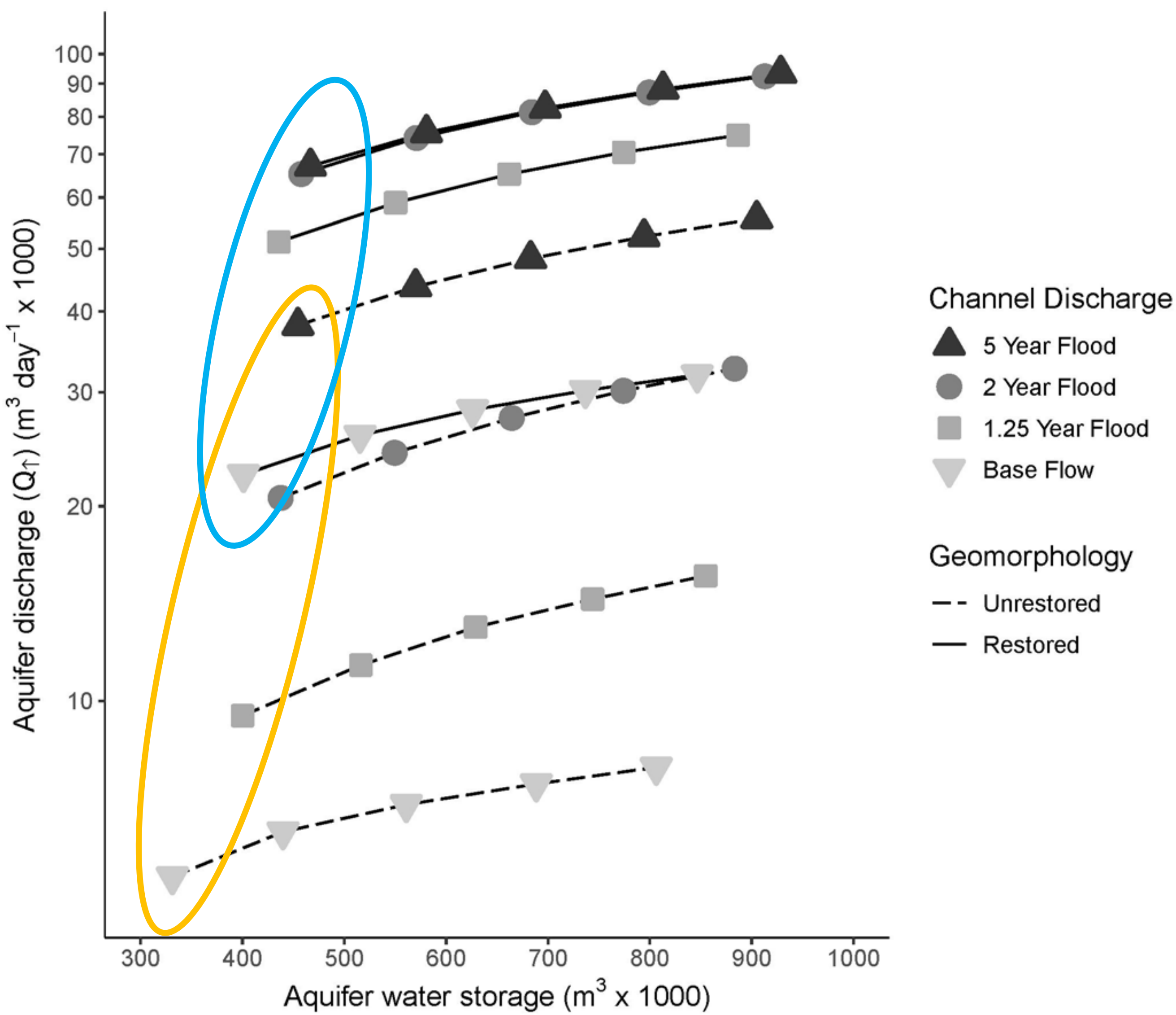
Simulated Area & Depth



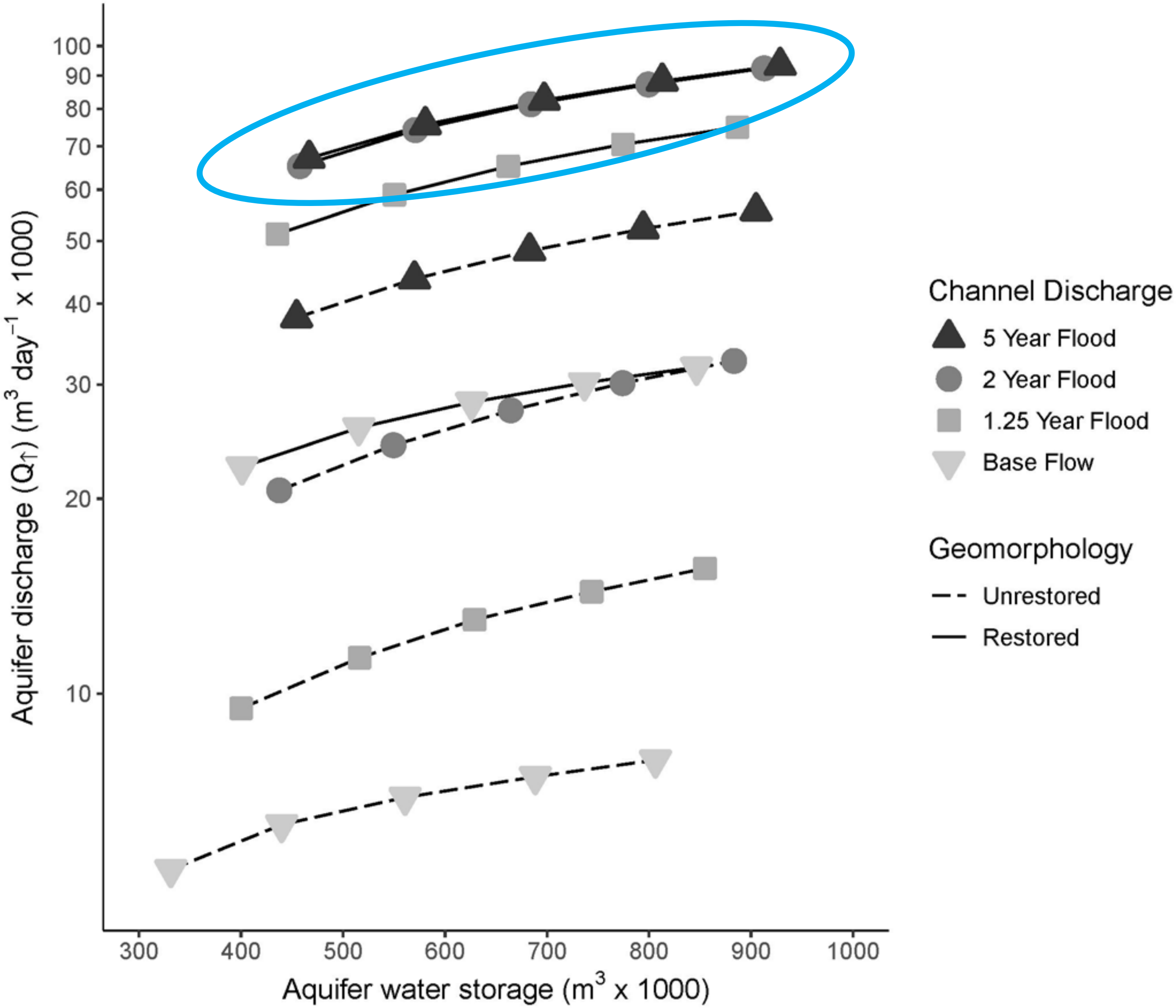


20% ΔQ_H per 100K Δ S

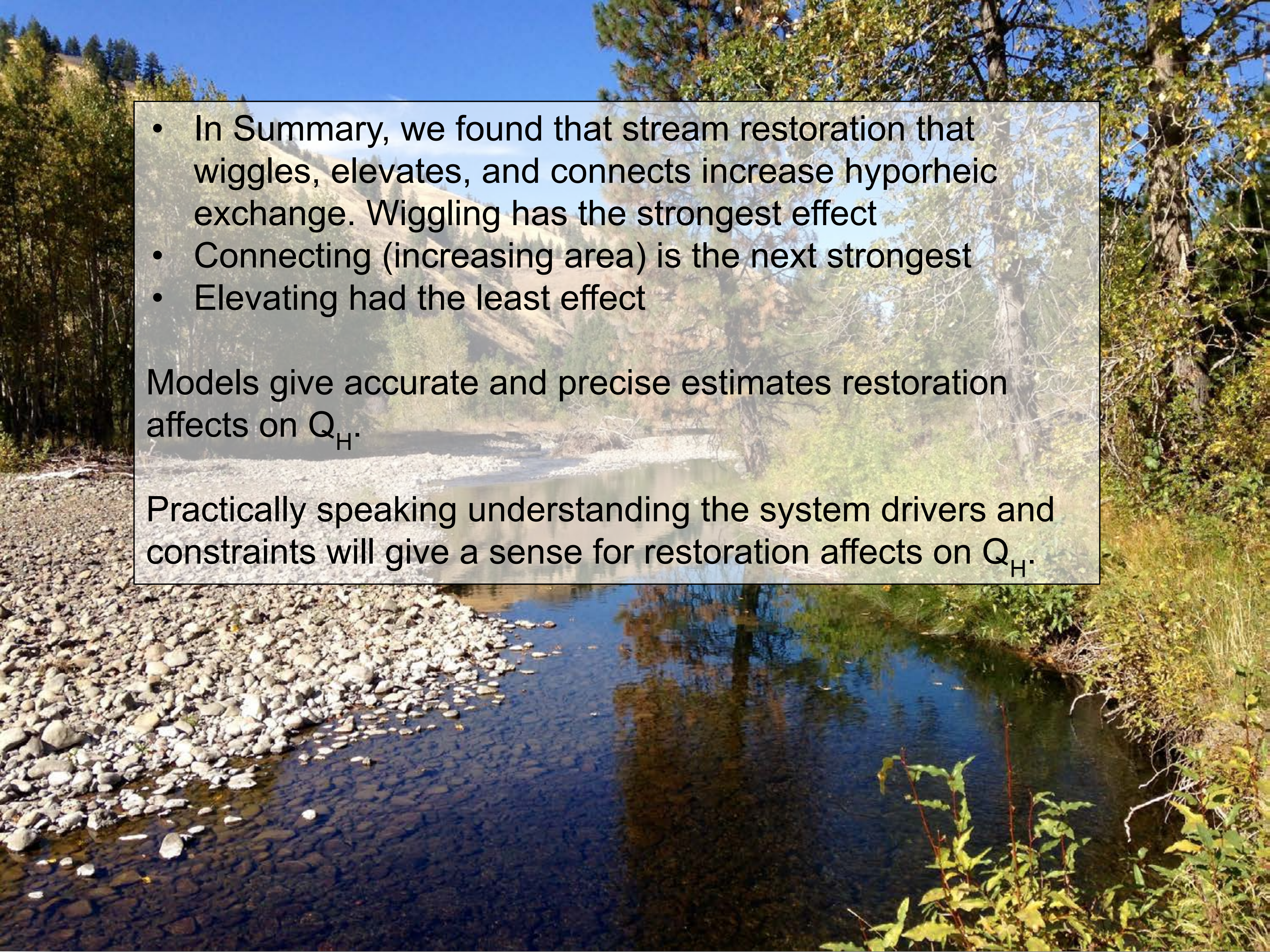
Partitioning ΔQ_H : ~44% ΔG; ~47$ ΔA; ~9% ΔS



Aquifer discharge (Q↑) (m³ day⁻¹ x 1000)
100
90
80
70
60
50
40
30
20
10
300
400
500
600
700
800
900
1000
Aquifer water storage (m³ x 1000)
Channel Discharge
5 Year Flood
2 Year Flood
1.25 Year Flood
Base Flow
Geomorphology
Unrestored
Restored



Aquifer discharge (Q↑) (m³ day⁻¹ x 1000)
100
90
80
70
60
50
40
30
20
10
300
400
500
600
700
800
900
1000
Aquifer water storage (m³ x 1000)
Channel Discharge
5 Year Flood
2 Year Flood
1.25 Year Flood
Base Flow
Geomorphology
Unrestored
Restored



- In Summary, we found that stream restoration that wiggles, elevates, and connects increase hyporheic exchange. Wiggling has the strongest effect
- Connecting (increasing area) is the next strongest
- Elevating had the least effect

Models give accurate and precise estimates restoration affects on Q_H.

Practically speaking understanding the system drivers and constraints will give a sense for restoration affects on Q_H.

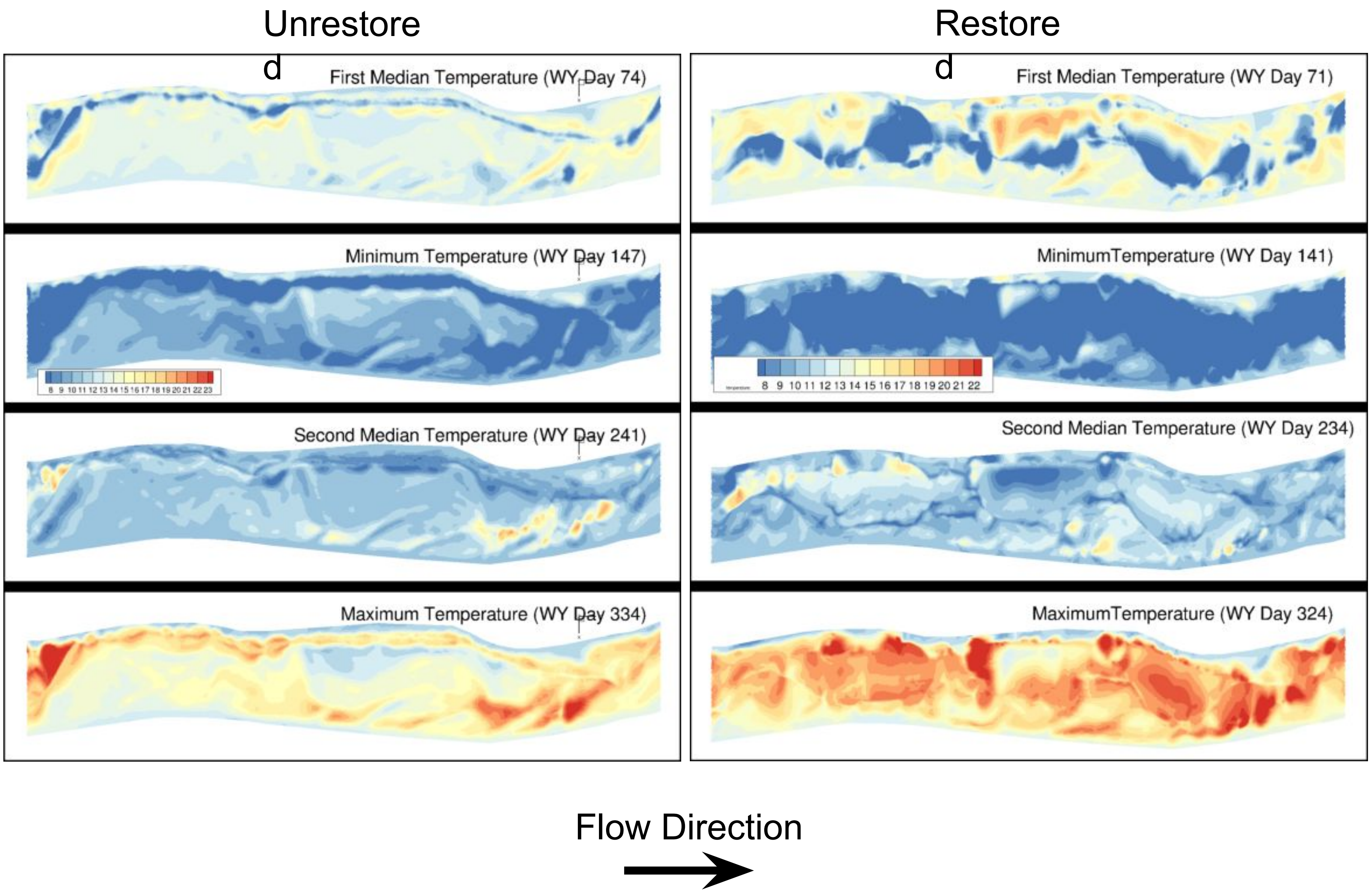
Let’s Get Practical!

Hyporheic degrees of freedom: **ΔH, ΔS, ΔA.**

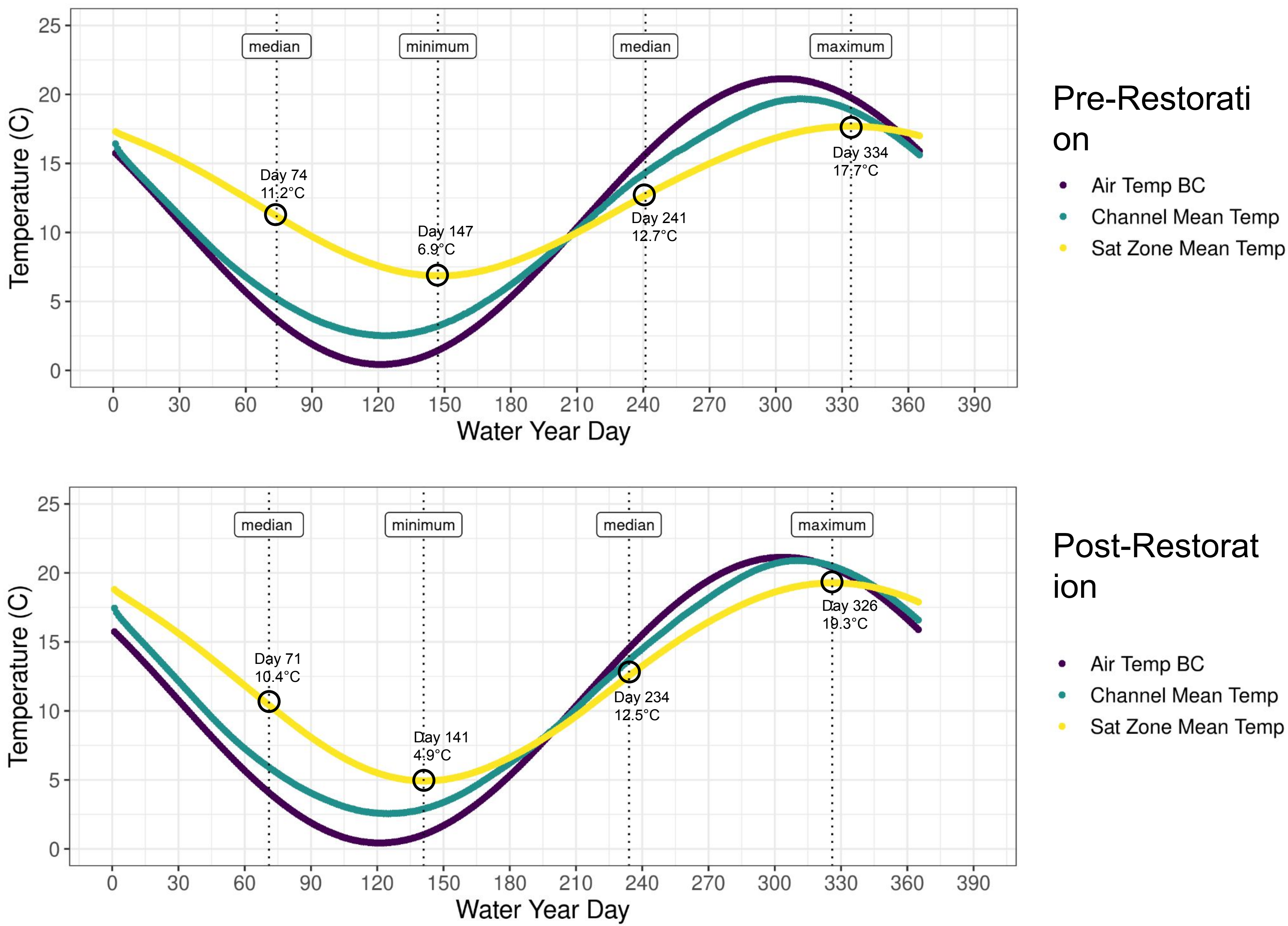
1. Number one method to increases exchange rates
   ↑wiggliness = ↑ΔH and ↑Q_H
   In practice ΔH and ΔA covary
   Site conditions and limits dictate the range

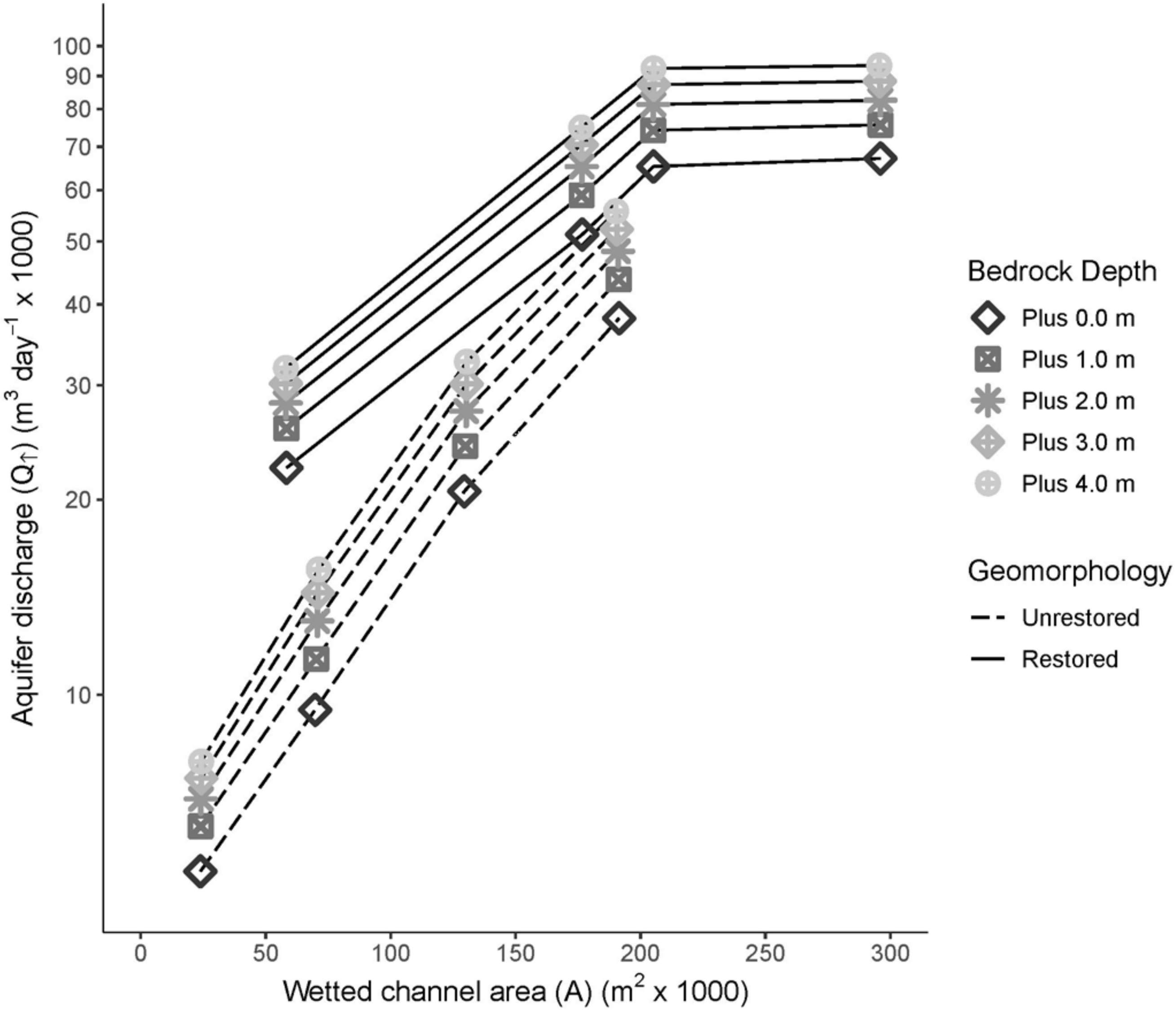
2. What are site limits and functional space?
   Recall that $d_H \approx 0.3\ \lambda$
   d_H - d_a = working volume
   If boundary > than d_H :
   ↑ΔH and ↑ΔA = ↑Q_H
   If boundary < d_H :
   ↑ΔH, ↑ΔS, and ↑ΔA = ↑Q_H

3. ↑**ΔS** is stronger when boundary << d_H :

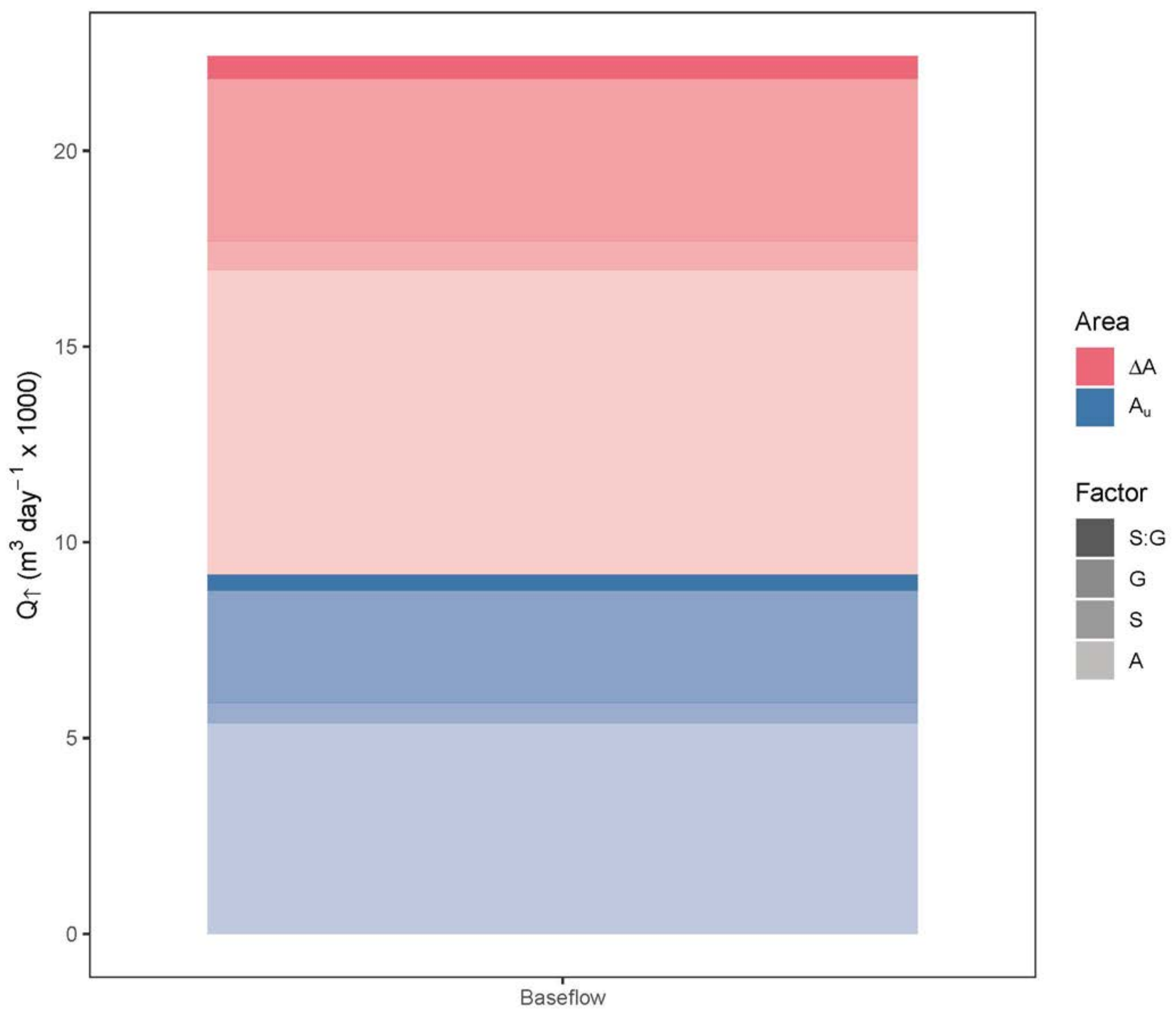


Unrestore
d
Restore
d
First Median Temperature (WY Day 74)
First Median Temperature (WY Day 71)
Minimum Temperature (WY Day 147)
MinimumTemperature (WY Day 141)
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Second Median Temperature (WY Day 241)
Second Median Temperature (WY Day 234)
Maximum Temperature (WY Day 334)
MaximumTemperature (WY Day 324)
Flow Direction

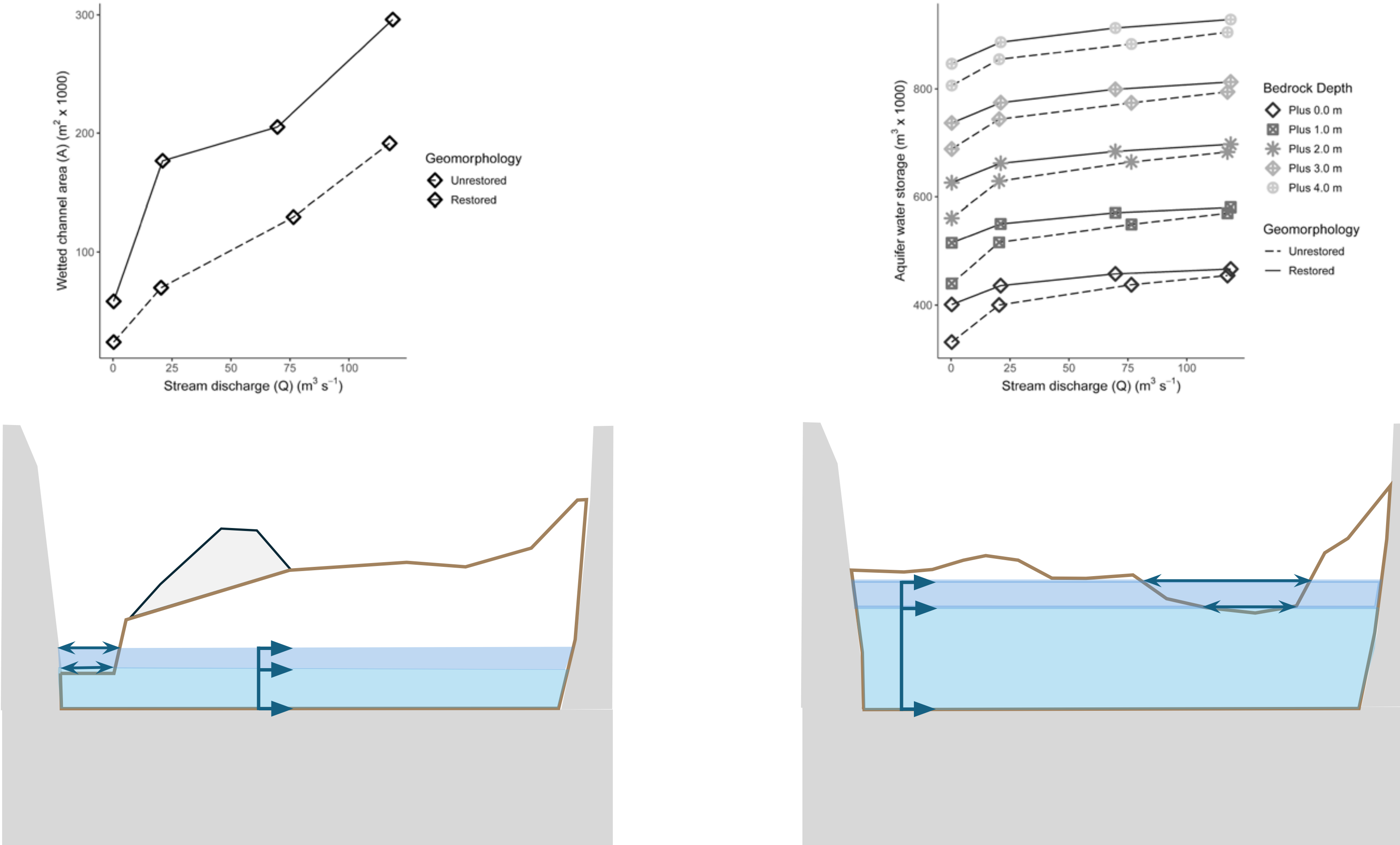

Pre-Restoration
Air Temp BC
Channel Mean Temp
Sat Zone Mean Temp
median
minimum
median
maximum
Day 74
11.2°C
Day 147
6.9°C
Day 241
12.7°C
Day 334
17.7°C
Temperature (C)
Water Year Day
Post-Restoration
Air Temp BC
Channel Mean Temp
Sat Zone Mean Temp
median
minimum
median
maximum
Day 71
10.4°C
Day 141
4.9°C
Day 234
12.5°C
Day 326
19.3°C
Temperature (C)
Water Year Day



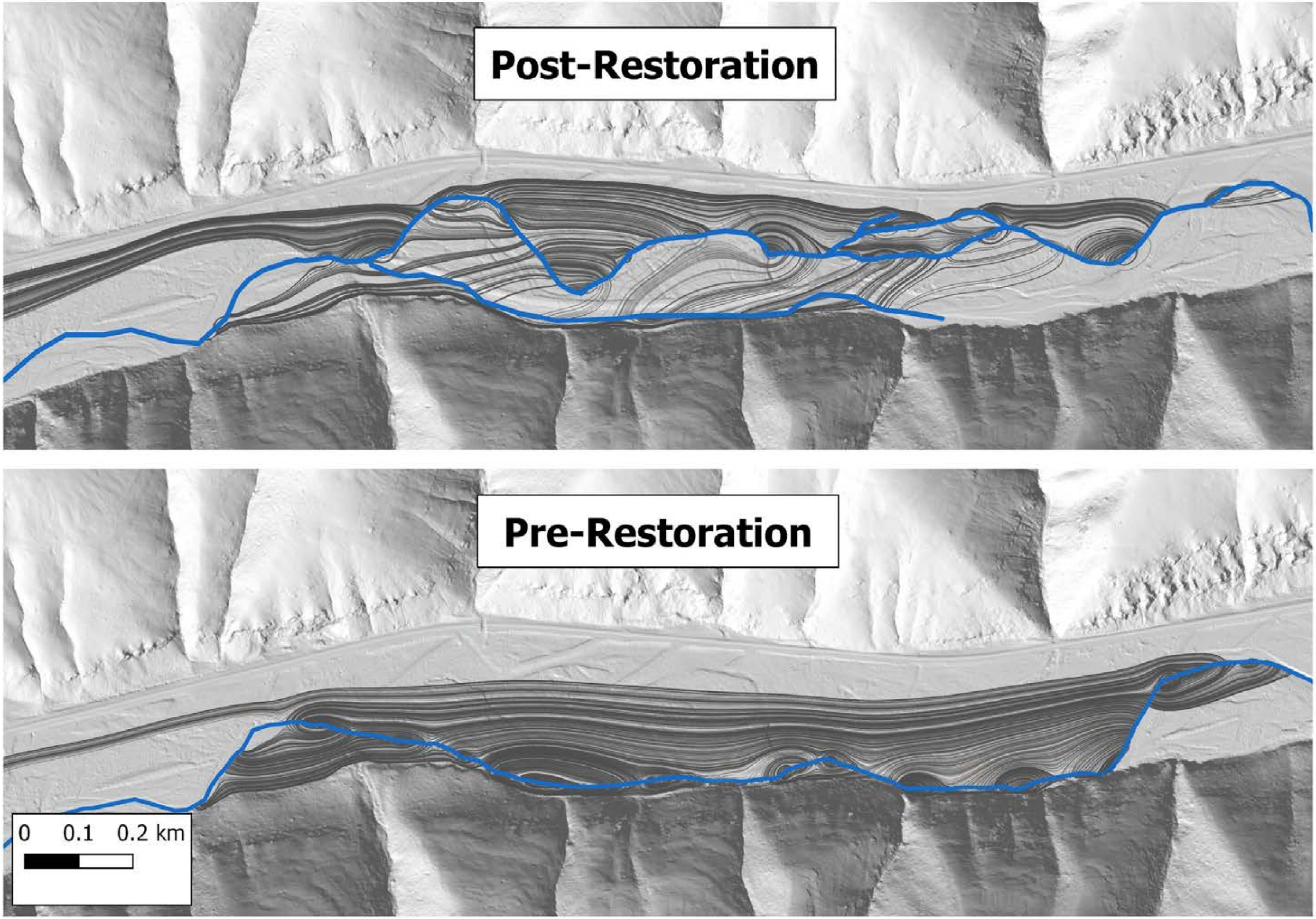
Aquifer discharge (Q↑) (m3 day-1 x 1000)
100
90
80
70
60
50
40
30
20
10
0
50
100
150
200
250
300
Wetted channel area (A) (m2 x 1000)
Bedrock Depth
Plus 0.0 m
Plus 1.0 m
Plus 2.0 m
Plus 3.0 m
Plus 4.0 m
Geomorphology
Unrestored
Restored



Q↑ (m³ day⁻¹ x 1000)
0
5
10
15
20
Baseflow
Area
ΔA
Aᵤ
Factor
S:G
G
S
A



300
200
100
0
25
50
75
100
Wetted channel area (A) (m² x 1000)
Stream discharge (Q) (m³ s⁻¹)
Geomorphology
Unrestored
Restored
800
600
400
Aquifer water storage (m³ x 1000)
Bedrock Depth
Plus 0.0 m
Plus 1.0 m
Plus 2.0 m
Plus 3.0 m
Plus 4.0 m


Post-Restoration
Pre-Restoration
0 0.1 0.2 km

Challenges and Lessons Learned Designing Rearing Habitat on Central Valley Rivers

Paul Frank and Michael MacWilliams

FlowWest

Salmonid Restoration Federation
Conference
May 1, 2025

Why Do We Build Side Channels?

- Salmon populations in decline
- Population cycles tend to track with flood/drought patterns
- Spring-run chinook most impacted

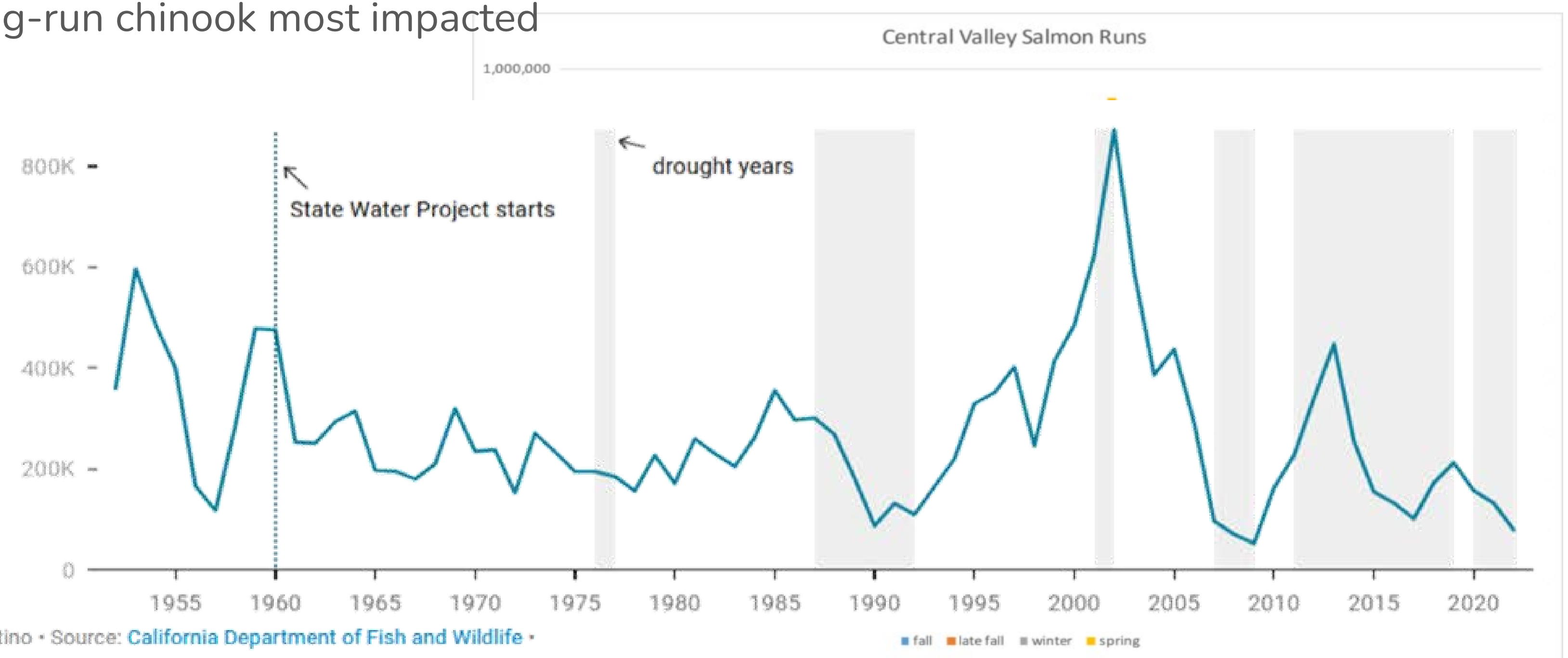
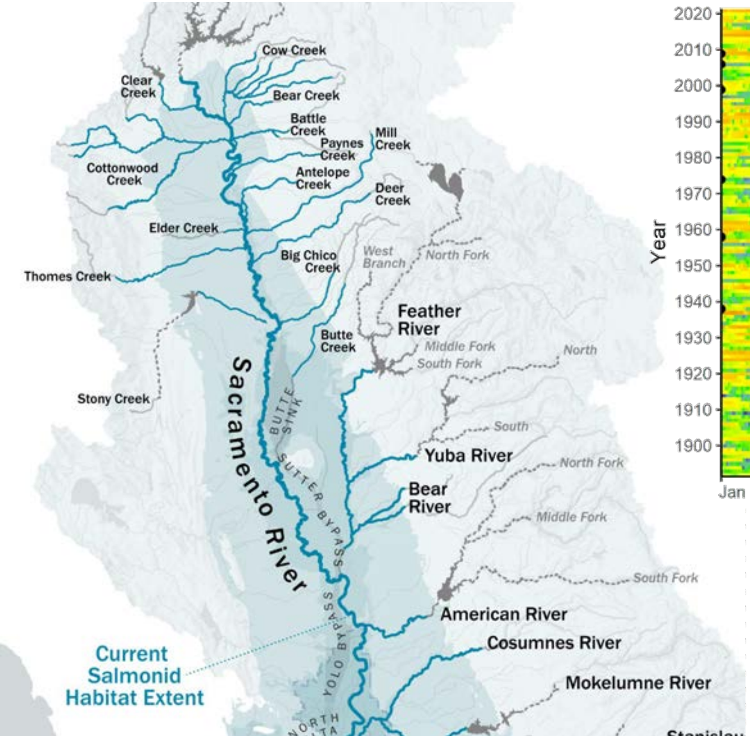


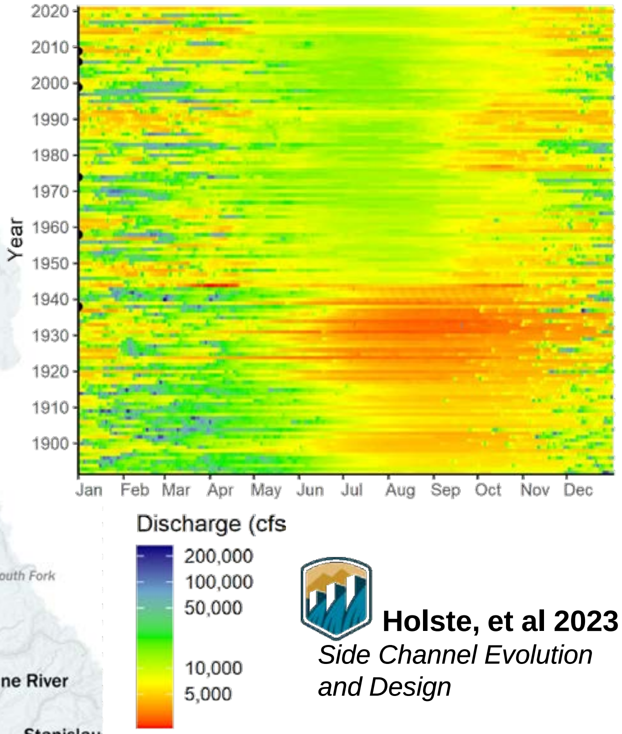
Chart: John Osborn D'Agostino • Source: California Department of Fish and Wildlife •

Why Do We Build Side Channels?

- Dams block best habitats



- Dam ops alter hydrology

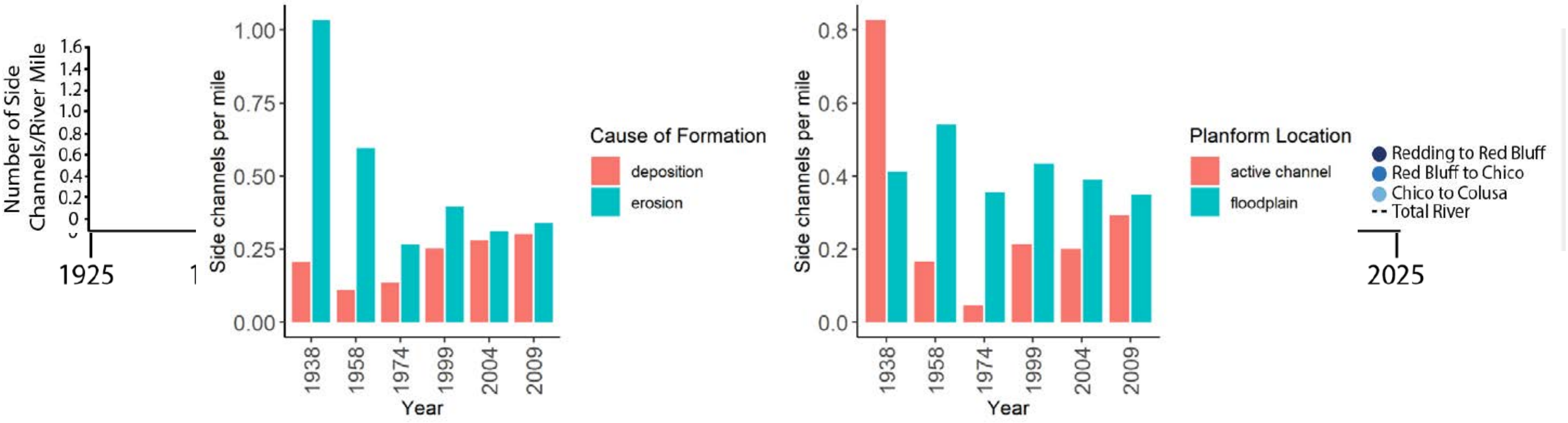


Holste, et al 2023
Side Channel Evolution and Design

- Levees / channelization remove rearing habitat

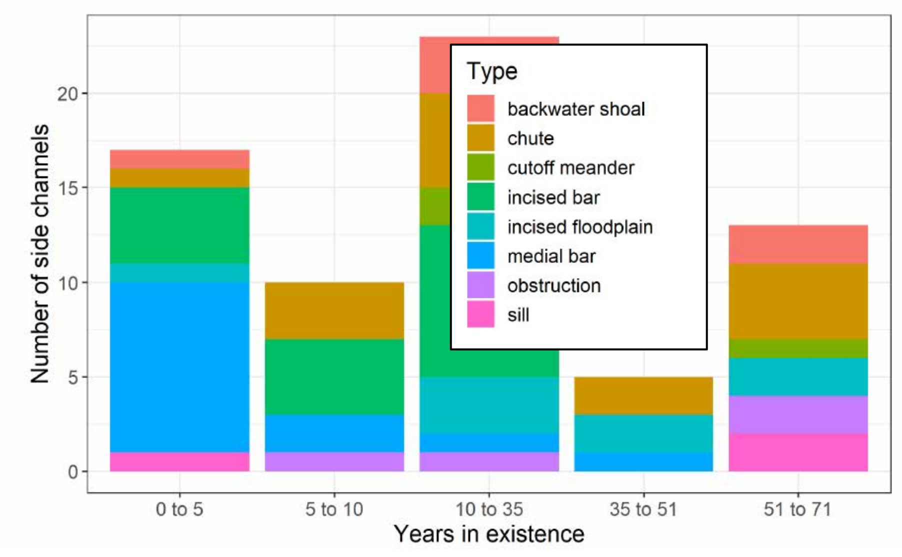
Why Do We Build Side Channels?

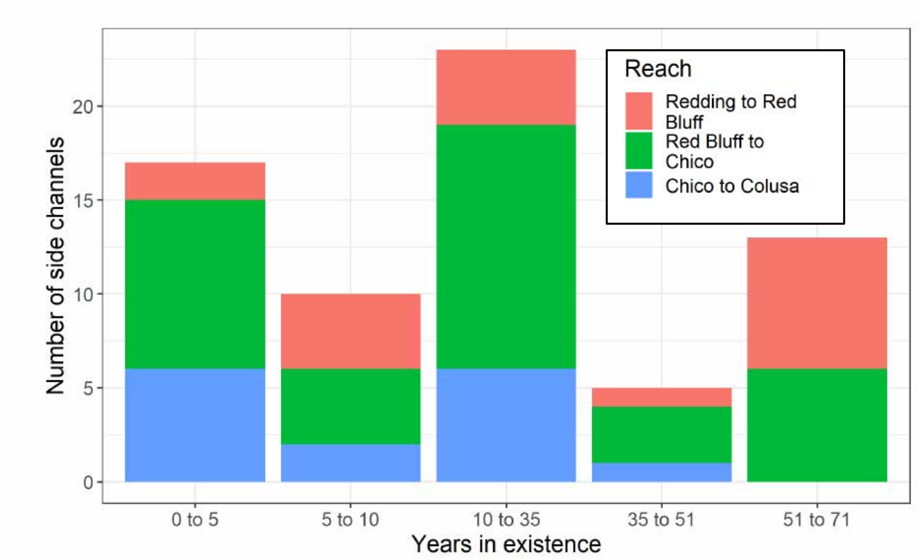
- Rearing / outmigrating juveniles need foraging and hiding habitat
- Side channels can offer appropriate depths / velocities / cover
- Natural side channels are decreasing with time



Side Channel Challenges: Mimicking Impermanent Features

- Natural side channels are created, abandoned, or changed in response to large hydrologic events and by both erosional and depositional processes
- Some last only a few years, others can last a half century or more!
- We should expect the same, or even less, longevity from constructed side channel projects

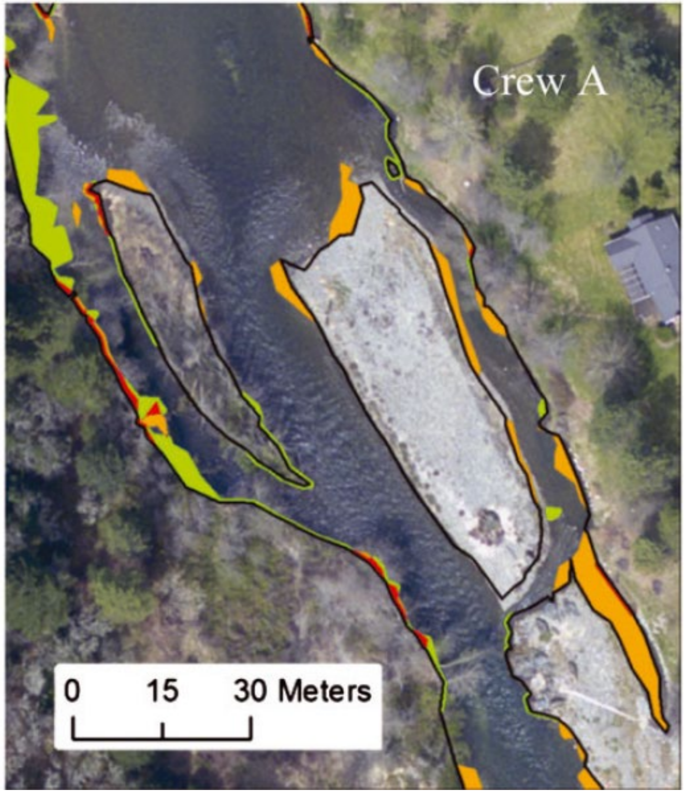




Side Channel Challenges: Creating Suitable Rearing Habitat

Habitat Type	Depth Suitability Range (ft)	Velocity Suitability Range (fps)	Distance to Cover	Temperature (°C)
Fry Rearing (Goodman et al. 2015)	>0.0 – 2.0 ft	0 – 0.5 fps	0 – 2 ft	n/a
Presmolt Rearing (Goodman et al. 2015)	>0.0 – 3.3 ft	0 – 0.8 fps	0 – 2 ft	n/a
Juvenile Rearing (SWRCB et al. 2023)	0.5 – 4.0 ft	0 – 3.0 fps	≥ 20 – 75% cover or cover features within 1 meter of any point in the stream	18

Side Channel Challenges: Creating Optimal Fry Rearing Habitat



Source: Goodman et al. 2015

Cover Criteria Only

Depth and Velocity Criteria Only

All Habitat Criteria

Depth Suitability Range (ft)	Velocity Suitability Range (fps)	Distance to Cover
>0.0 – 2.0 ft	0 – 0.5 fps	0 – 2 ft

Odds of observing rearing salmon within high-quality habitats was 10 - 16 times greater than in low quality habitat

Side Channel Challenges: How Do We Define Success?

- Length and area of side channel habitat created or enhanced
- Area of suitable salmonid rearing habitat created
  - What life stage?
  - At what flow?
- Number of rearing salmonids observed post-construction
- Minimize predation and stranding risks
- Minimize disturbance to mature trees and culturally important plants
- Avoid impacts to cultural resources
- Long-term sustainability

Case Study: Battle Creek Confluence Side Channel

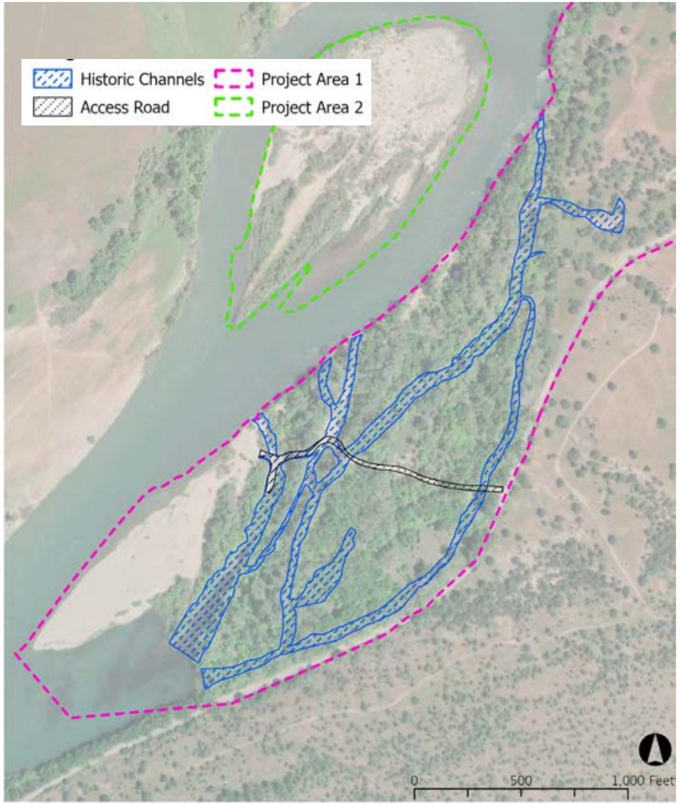
What's Ideal:

- Ideally situated on Sacramento River just downstream from the confluence of Battle Creek
- Site historically included multiple braided channels
- Mature riparian vegetation
- Publicly owned lands
- Active support from fishermen, tribes, and local agencies

Case Study: Battle Creek Confluence Side Channel

What's Ideal:

- Ideally situated on Sacramento River just downstream from the confluence of Battle Creek
- Site historically included multiple braided channels
- Mature riparian vegetation
- Publicly owned lands
- Active support from fishermen, tribes, and local agencies

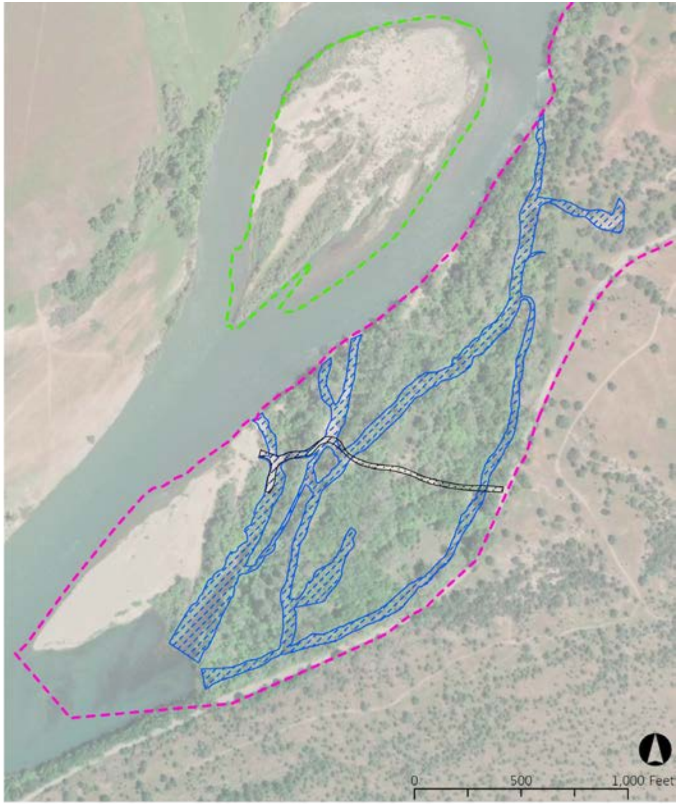


FlowWest

Case Study: Battle Creek Confluence Side Channel

What's *NOT* Ideal:

- Current side channels only activate at Sacramento River flows of about 35,000 cfs
- Large depth of excavation necessary to allow activation of historic side channels over full range of Sacramento River flows
- Potential for ongoing lateral erosion may eventually limit lifespan of channel
- Project needs to maintain existing recreational access to gravel bar



FlowWest

Case Study: Bonnyview Island Side Channel

What's Ideal:

- Site with a stable (>25 yrs) in-river bar and a stable "chute" type side channel
- Create a perennially flowing channel mid-bar, with riparian forest cover
- Bar material is gravel/cobble suitable for spawning, can be spoiled on the bar
- River/bar gradient supports varied slopes - sediment transport, varied velocities/depths

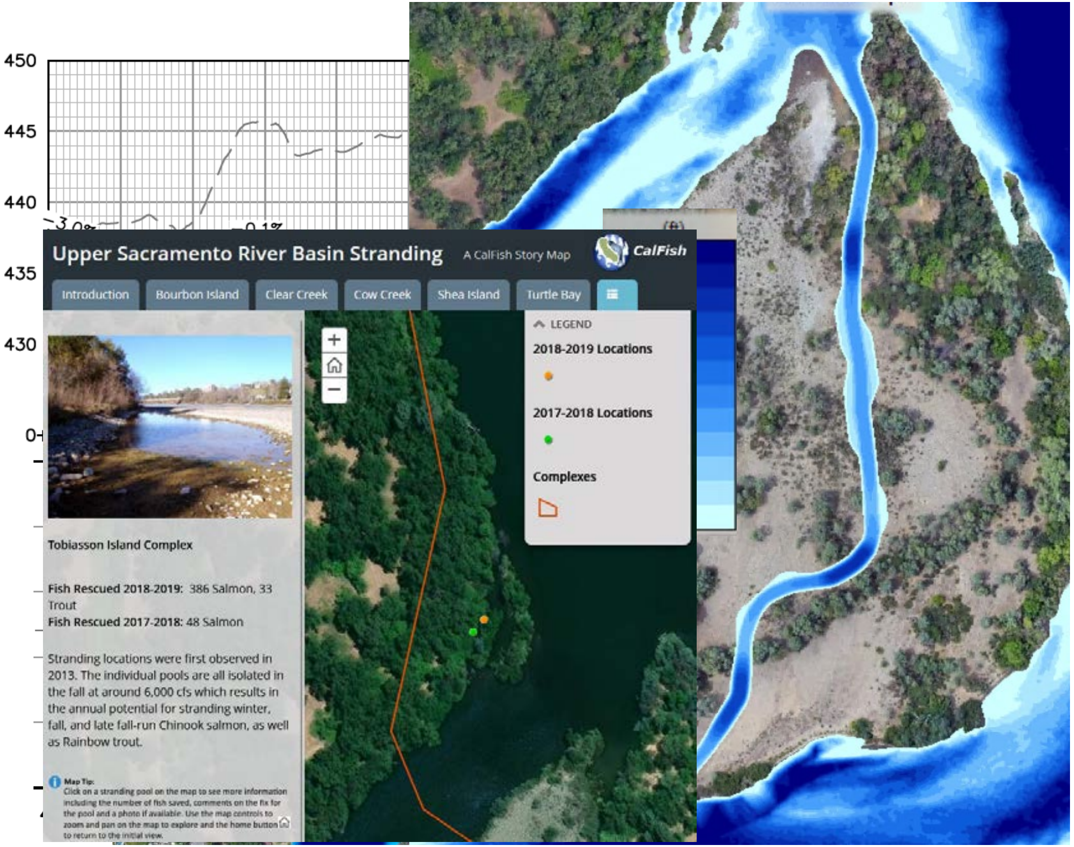
Case Study: Bonnyview Island Side Channel

What's Ideal:

- Creating 6 bench/terrace features, LWD, revegetation of new riparian forest at edges

- Presence of new channel should facilitate juvenile movement back to river as flows recede

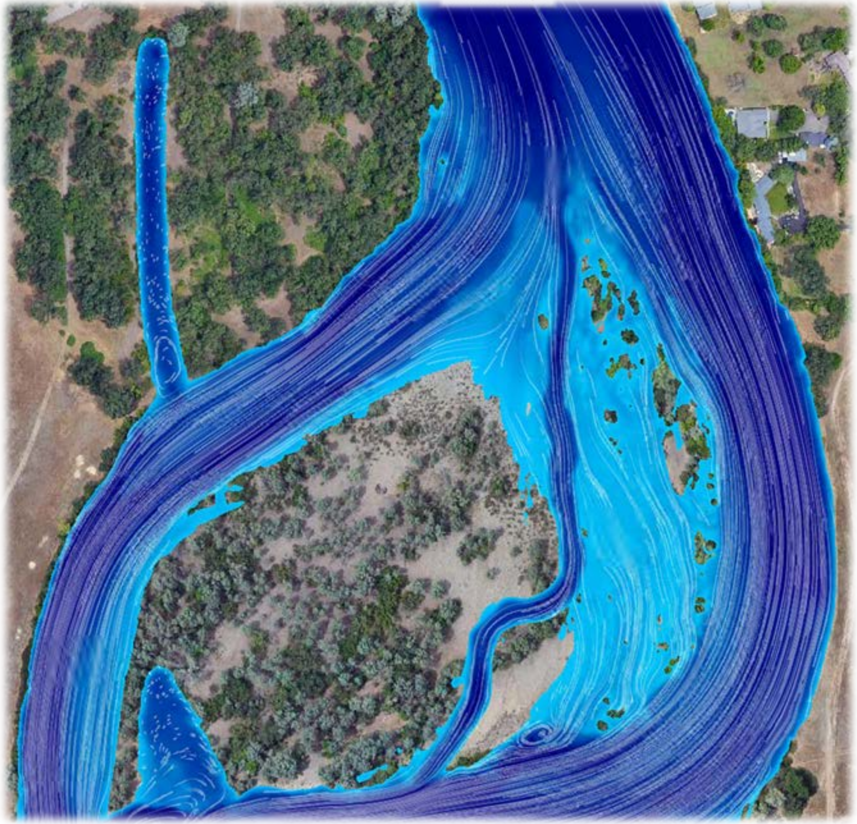
- Opportunity to fill known stranding depression nearby



Case Study: Bonnyview Island Side Channel

What's *NOT* Ideal:

- Privately owned; complicated access/use agreements
- Somewhat complex inlet conditions – could a large event rearrange inlet?
- Will existing side channel trend toward aggradation and abandonment?
- Could the River create a new cutoff through the channel, and rearrange its primary flowpath?
- Could "incised bar" – type side channel eventually fill in with sediment?

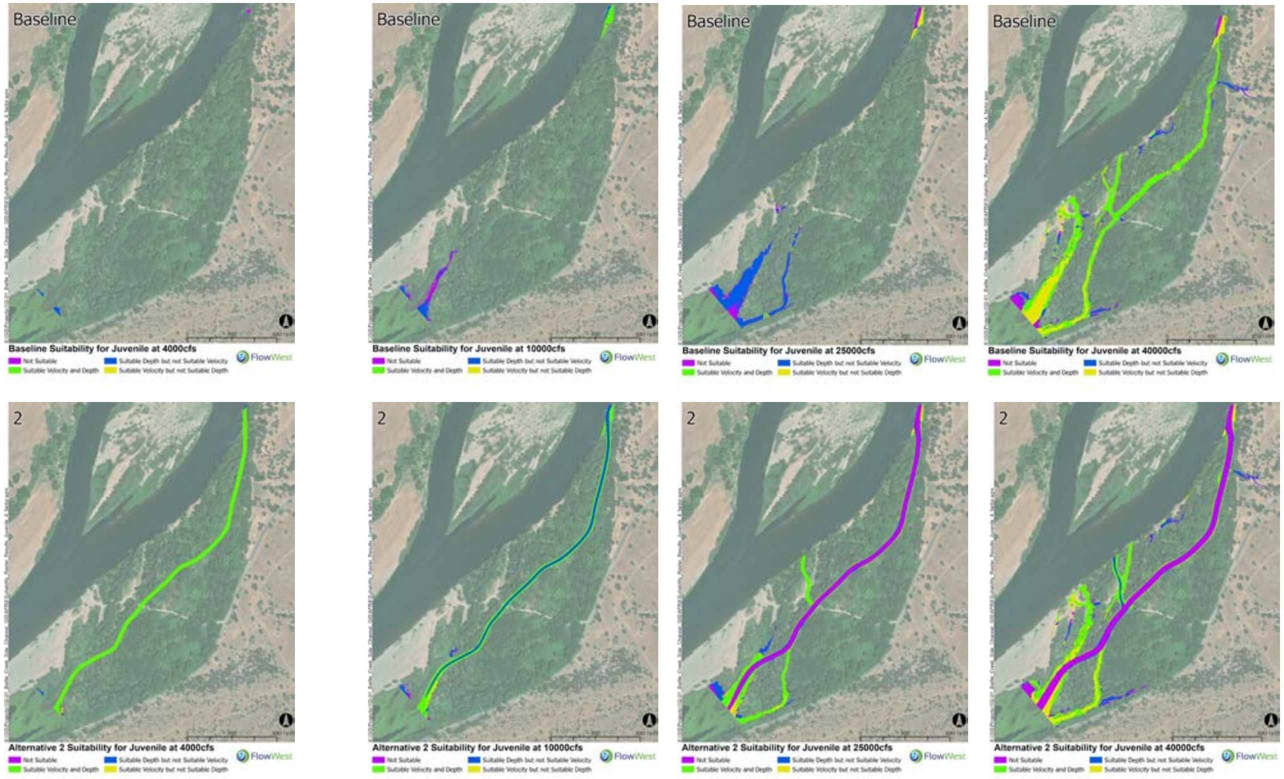


How Can We Improve Outcomes:

	4,000 cfs	10,000 cfs	25,000 cfs	40,000 cfs

Baseline

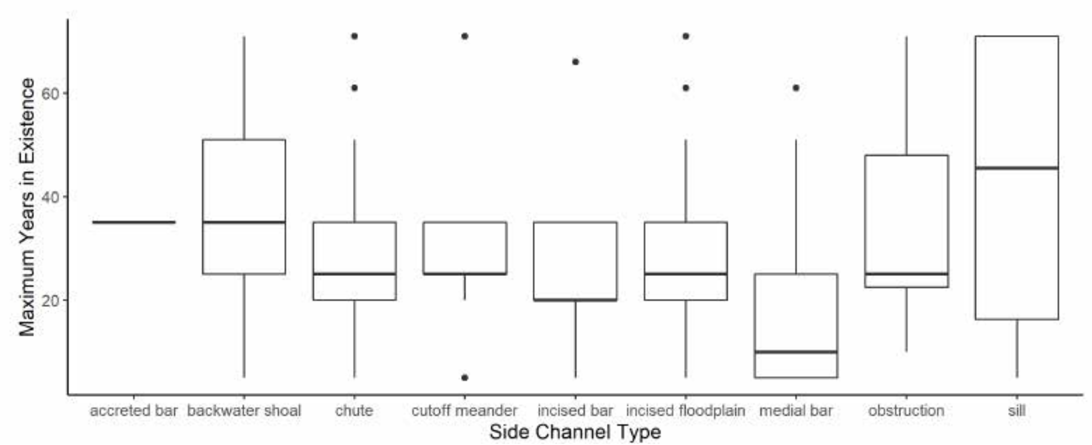
Example Alternative



- Not Suitable
- Suitable Velocity and Depth
- Suitable Depth but not Suitable Velocity
- Suitable Velocity but not Suitable Depth

How Can We Improve Outcomes

- **Monitoring**: Designs improve through better understanding of habitat utilization in side channels
- **Plan for dynamic evolution**: data show these environments are transient and evolve over time
- **Long-Term Maintenance**: If nature constantly evolves and abandons side channels, why should constructed side channels be any different?
    - Few if any funding programs pay for maintenance and adaptive management over project life span



Source: Holste et al. 2023

Closing Thoughts/Discussion Questions

- Side channels are a critical restoration tool to boost juvenile success
- Ever-increasing body of knowledge; designs must consider geomorphology, hydraulics, fish biology
- We are still in early days; there is still much to learn

- How long should we expect constructed side channels to last?
- Once built, should they be maintained as built or left to evolve?
- Should we have evolving success metrics as side channels evolve?

Restored seasonally inundated habitat supports juvenile salmonid rearing and growth on two San Joaquin River tributaries

Kirsten Sellheim, Avery Scherer, Rocko Brown, Jesse Anderson, Jamie Sweeney, and Joseph Merz

Cramer Fish Sciences

Salmonid Restoration Federation conference

Santa Cruz, CA

May 1, 2025

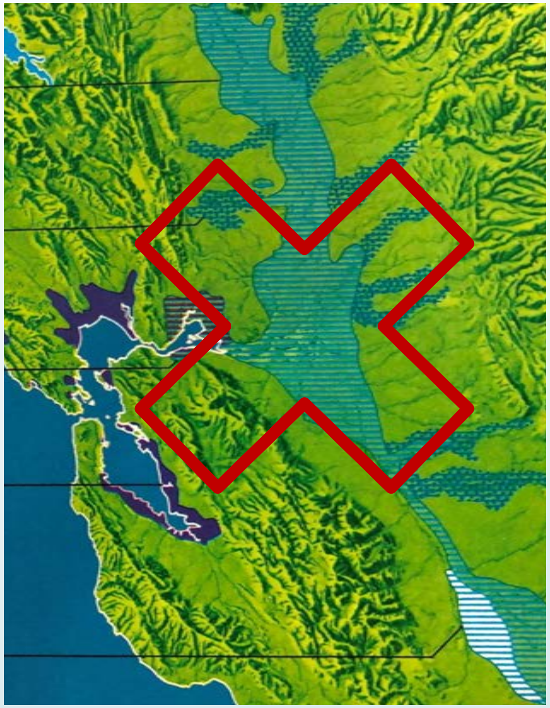
Historic Central Valley = Marsh and Riparian Forest

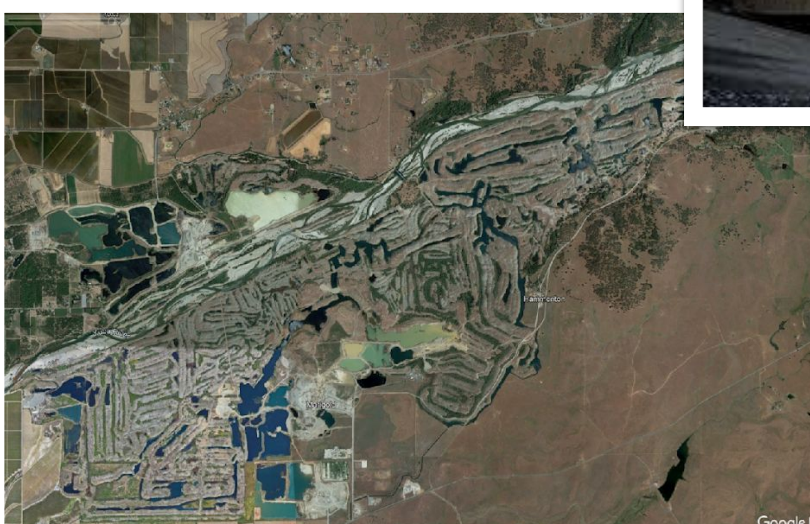
“Cienaga” depicted in map made by early explorers

Yuba River

DWR Water Atlas

Central Valley Today - A Highly Engineered System



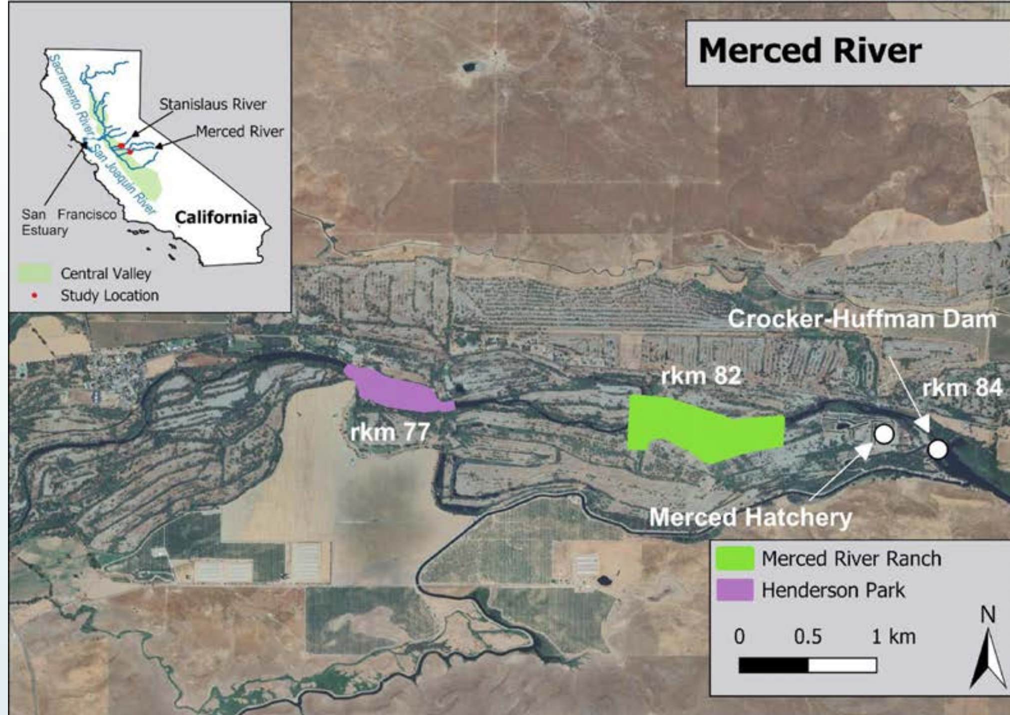


- Salmonid habitat restoration projects implemented throughout California for decades to address extensive habitat loss

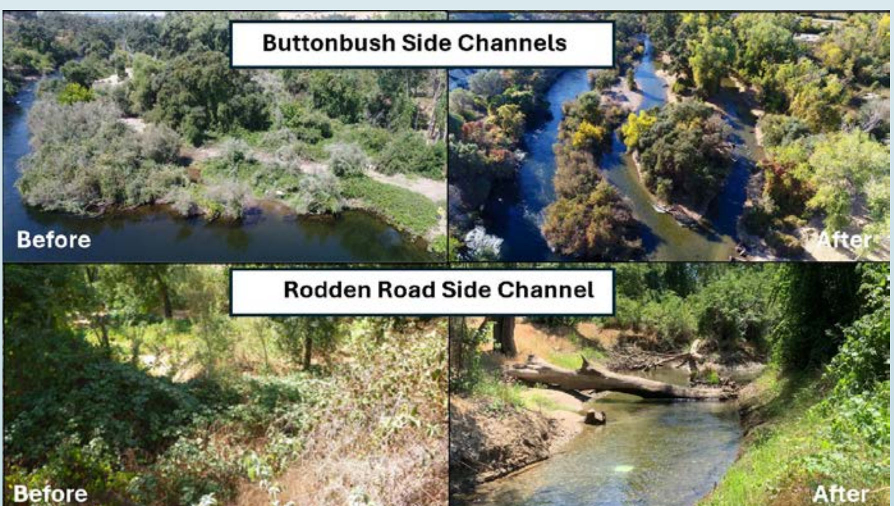
- Salmonid habitat restoration projects implemented throughout California for decades to address extensive habitat loss
- Project success rarely defined or measured

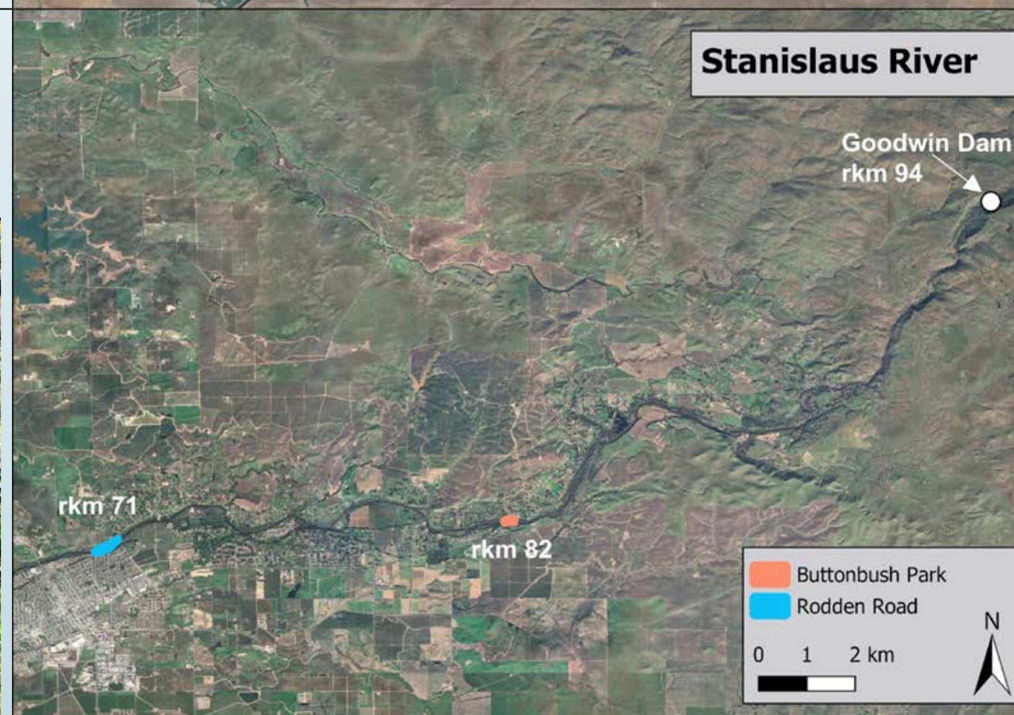
- Salmonid habitat restoration projects implemented throughout California for decades to address extensive habitat loss
- Project success rarely defined or measured
- Measuring success is essential for
  - adaptive management
  - wise public funding allocation
  - improving restoration design

Merced River
- two projects in dredger tailings reach
- 21 total acres of **floodplain** habitat



Stanislaus River
- two projects in agricultural/rural area
- 5.5 total acres of **side channel** habitat





Merced and Stanislaus River Restoration Projects

- Goal: expand off-channel salmon rearing habitat
- Tributaries to the San Joaquin River, below major dams
- CVPIA funded

Predicted off-channel rearing habitat benefits

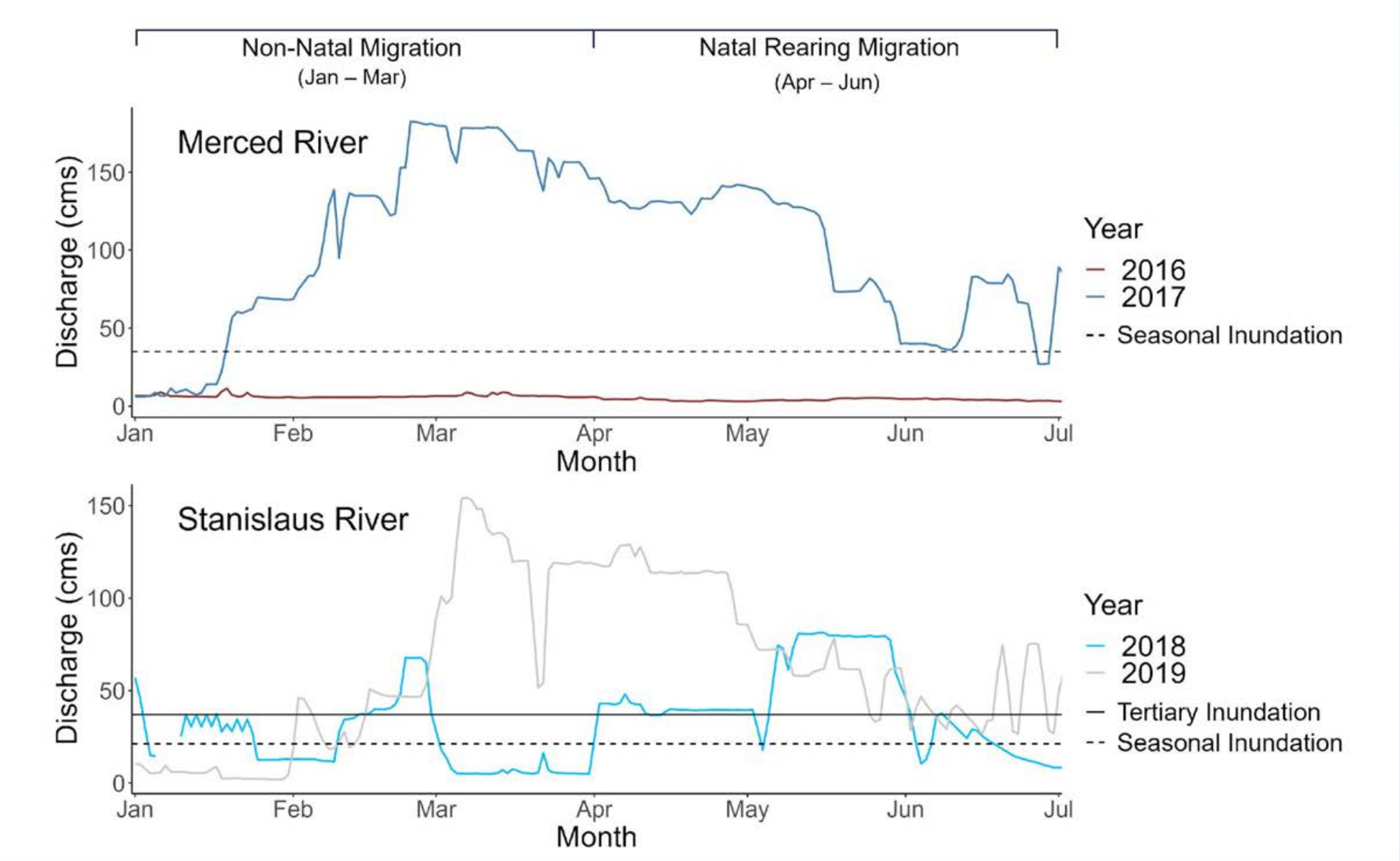
- Higher productivity - more prey
- Refuge from predation and high flows in main channel
- Longer in-river rearing
- Higher growth rates and total growth

Study questions

- Compared to the main channel,
  - Are juvenile salmon densities higher?
  - Do juvenile salmon grow more?
- Is response different between two rivers?

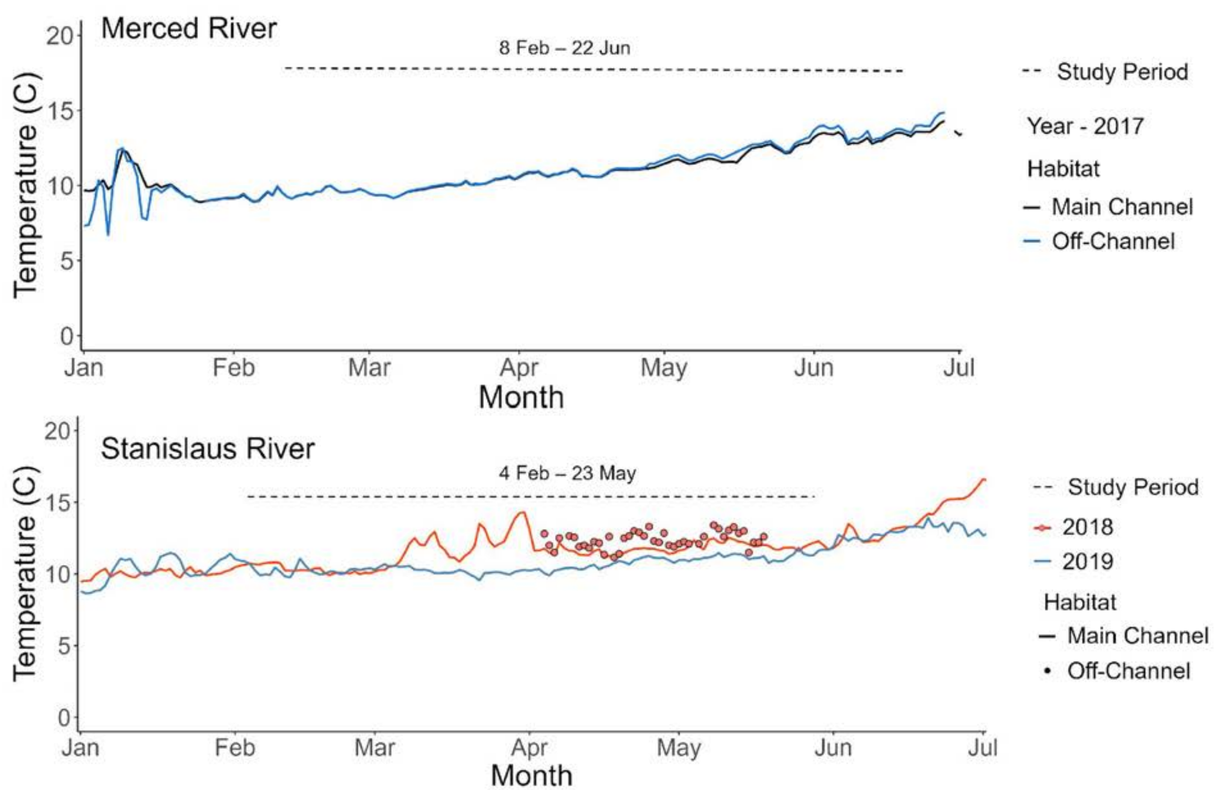
Hydrological conditions

- Merced - extreme wet year (2017)
- Stanislaus - below normal/wet years (2018-2019)



Temperature conditions

- Slight differences in water temperature across sites and years
  - Warmer further downstream
  - Warmer during below normal year

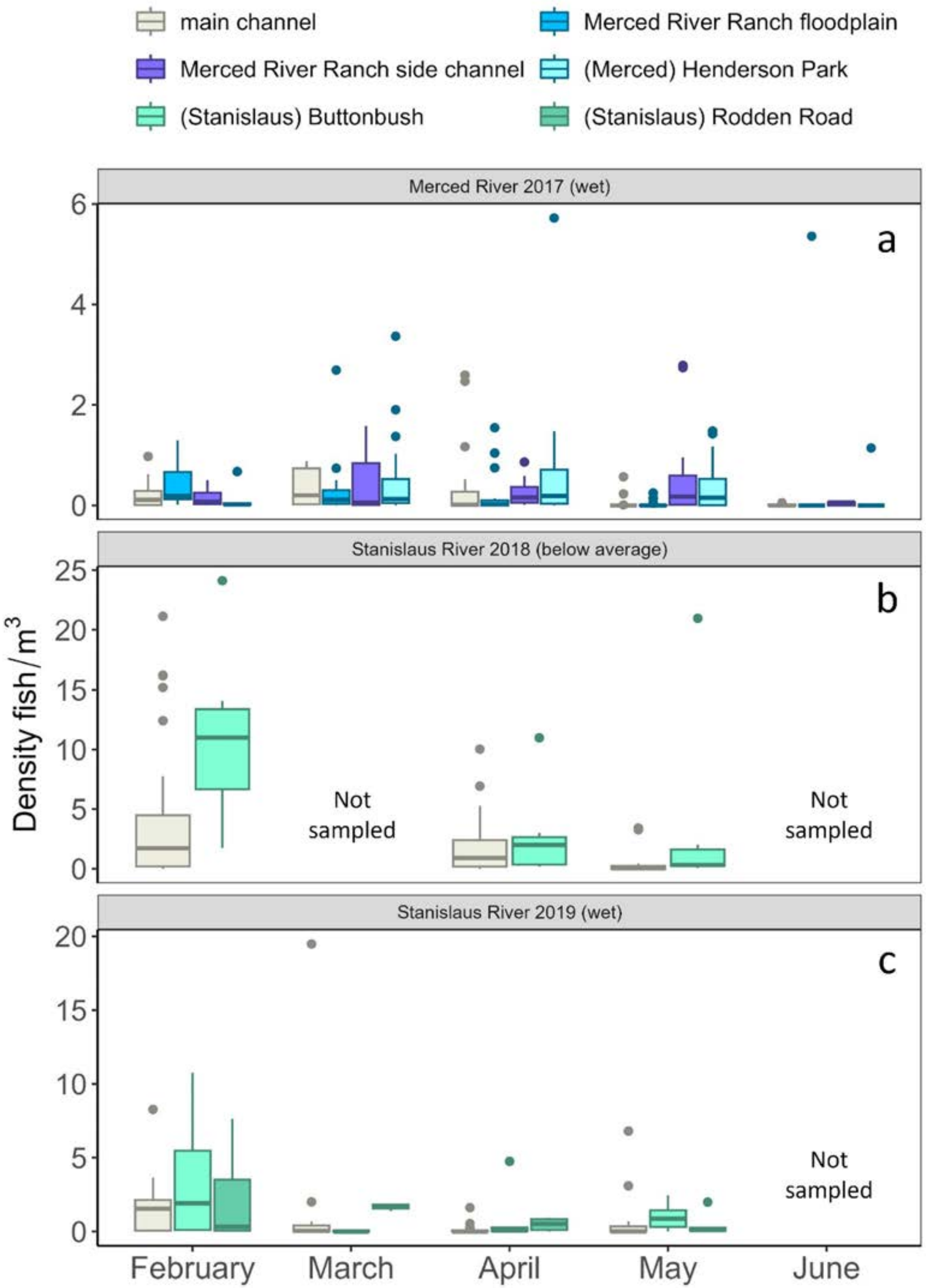


Measuring fish response

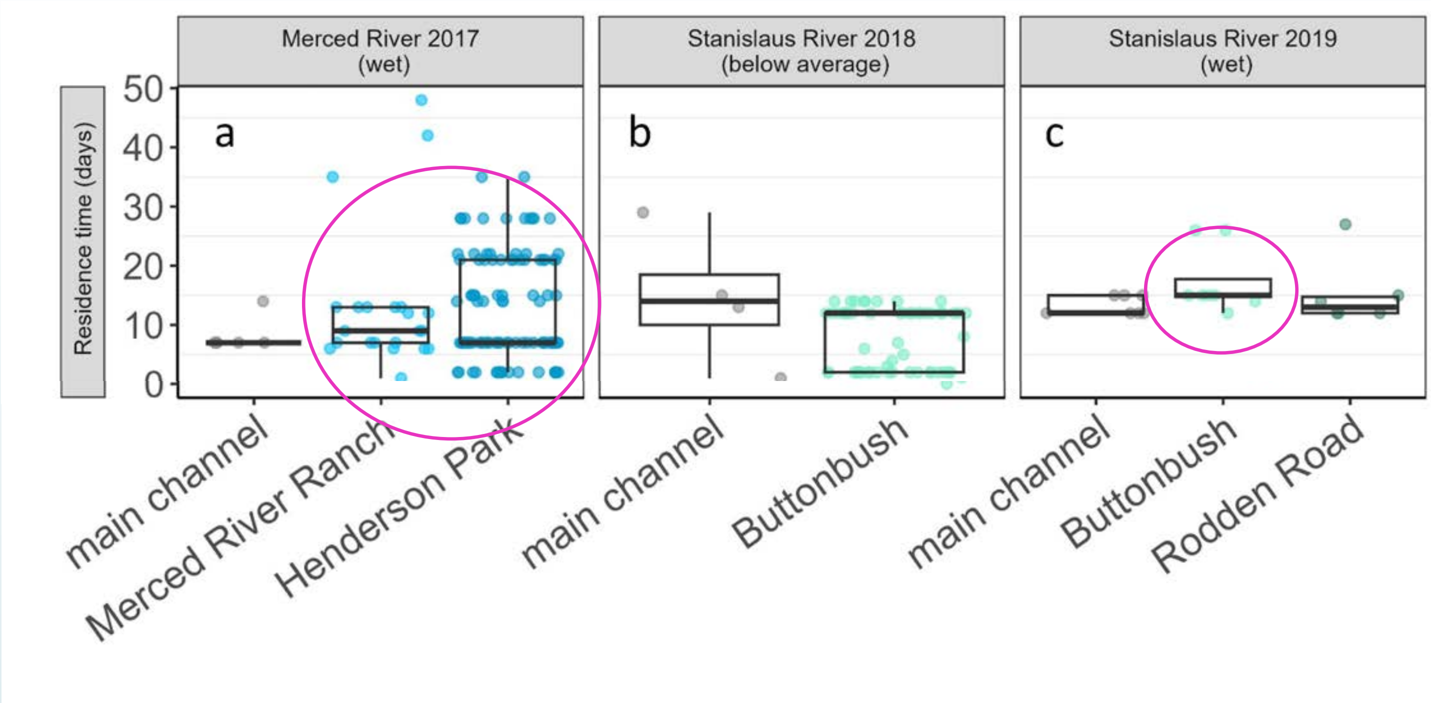
- Seine surveys (Feb-May/June)
- Mark-recapture study (Apr-May/June)
- PIT tagged wild juvenile Chinook Salmon in **unrestored main channel** and **restored off-channel** habitats
- Released fish and re-surveyed every 7-14 days

Do restored off channel habitats have higher juvenile salmon densities?

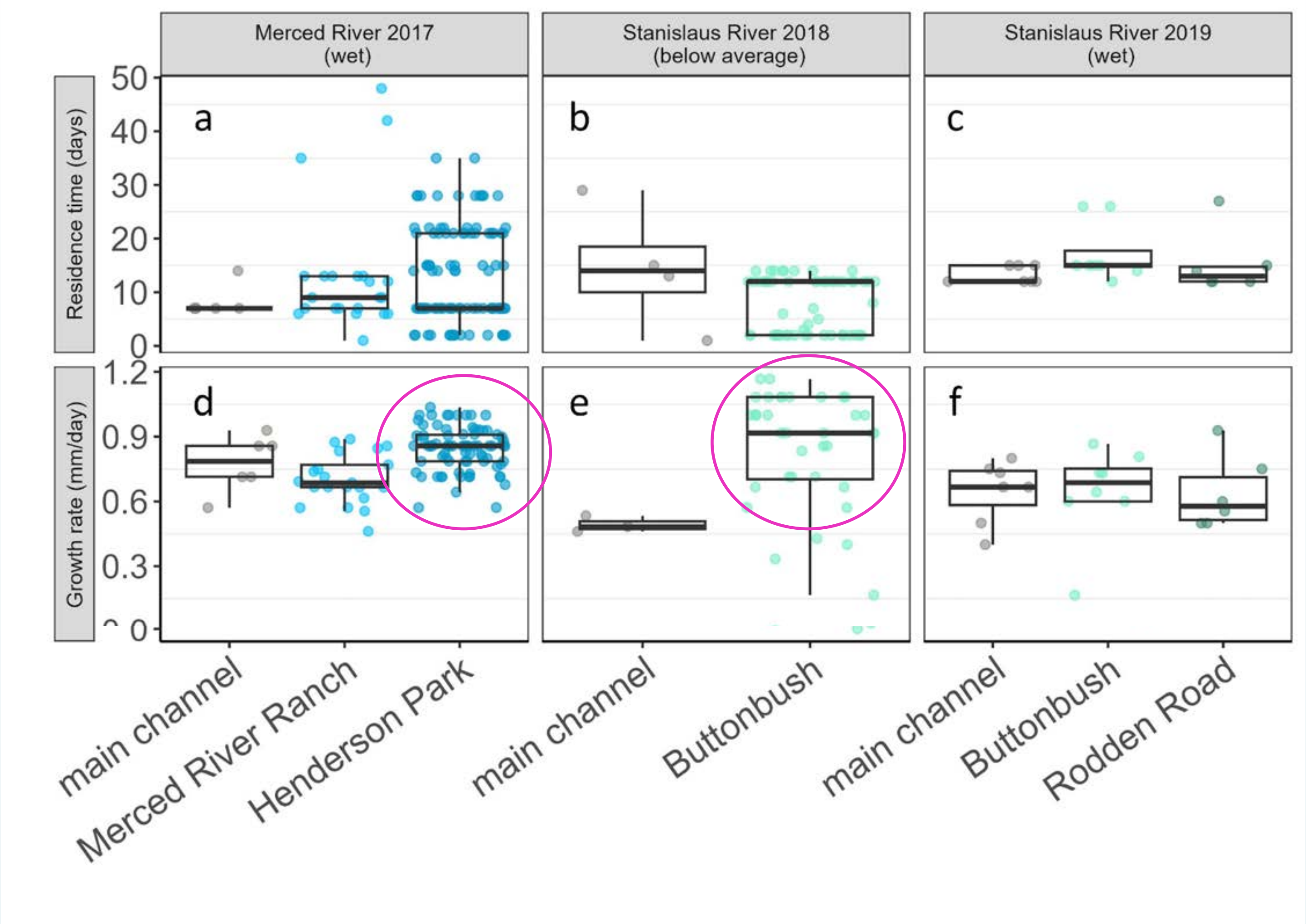
- Sites provided habitat where none existed before, increasing river carrying capacity
- **Slightly higher fish densities across sites early in the season**
- **Fish remained in river longer at restored sites**



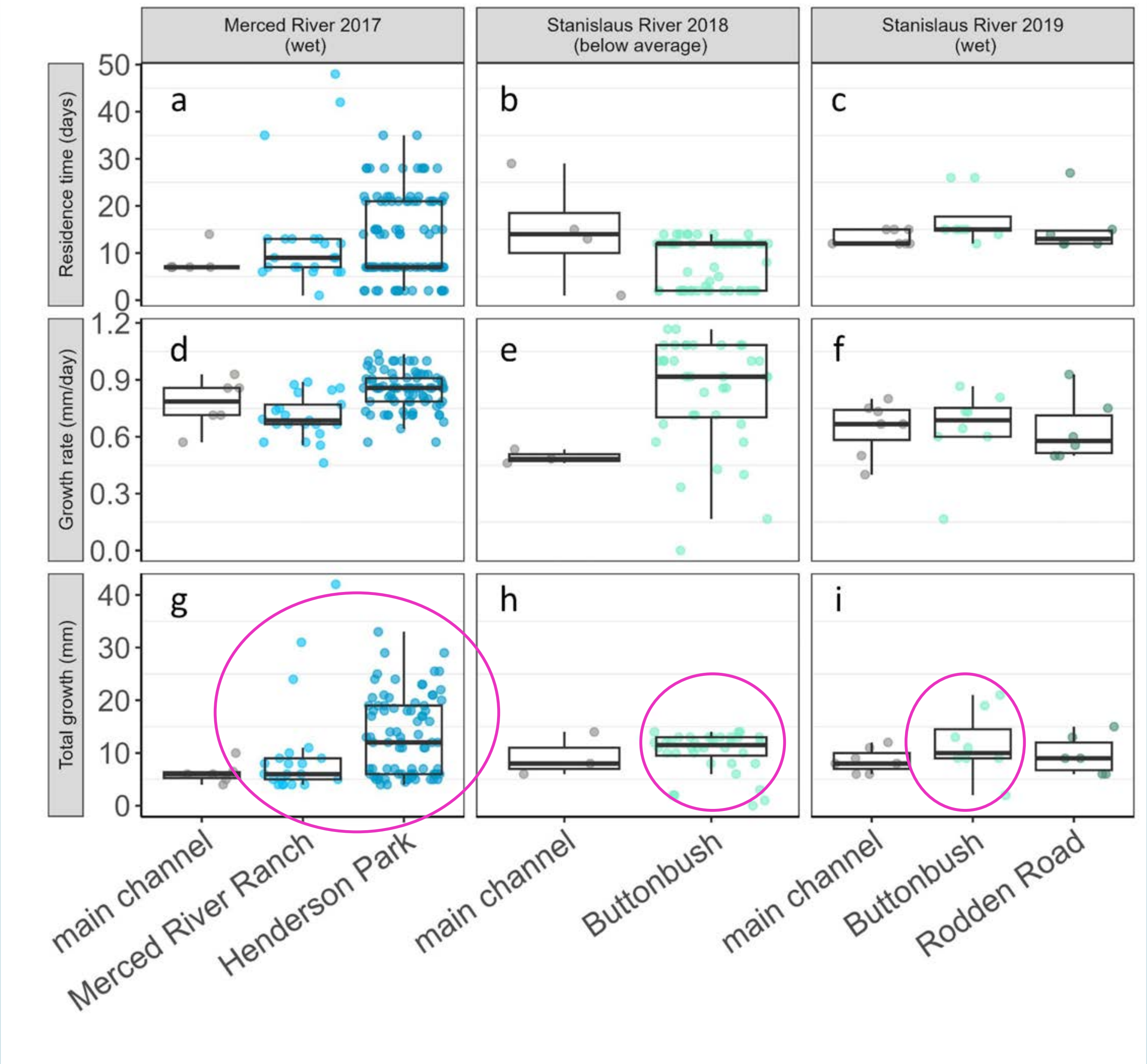
River	Treatment	Number of fish tagged	% recapture
Merced	**Restored**	814	**17%**
	Unrestored	164	4%
Stanislaus	**Restored**	1210	**6%**
	Unrestored	705	2%



- **Longer residence times** at Merced restored sites and at one of the Stanislaus sites during the wet water year

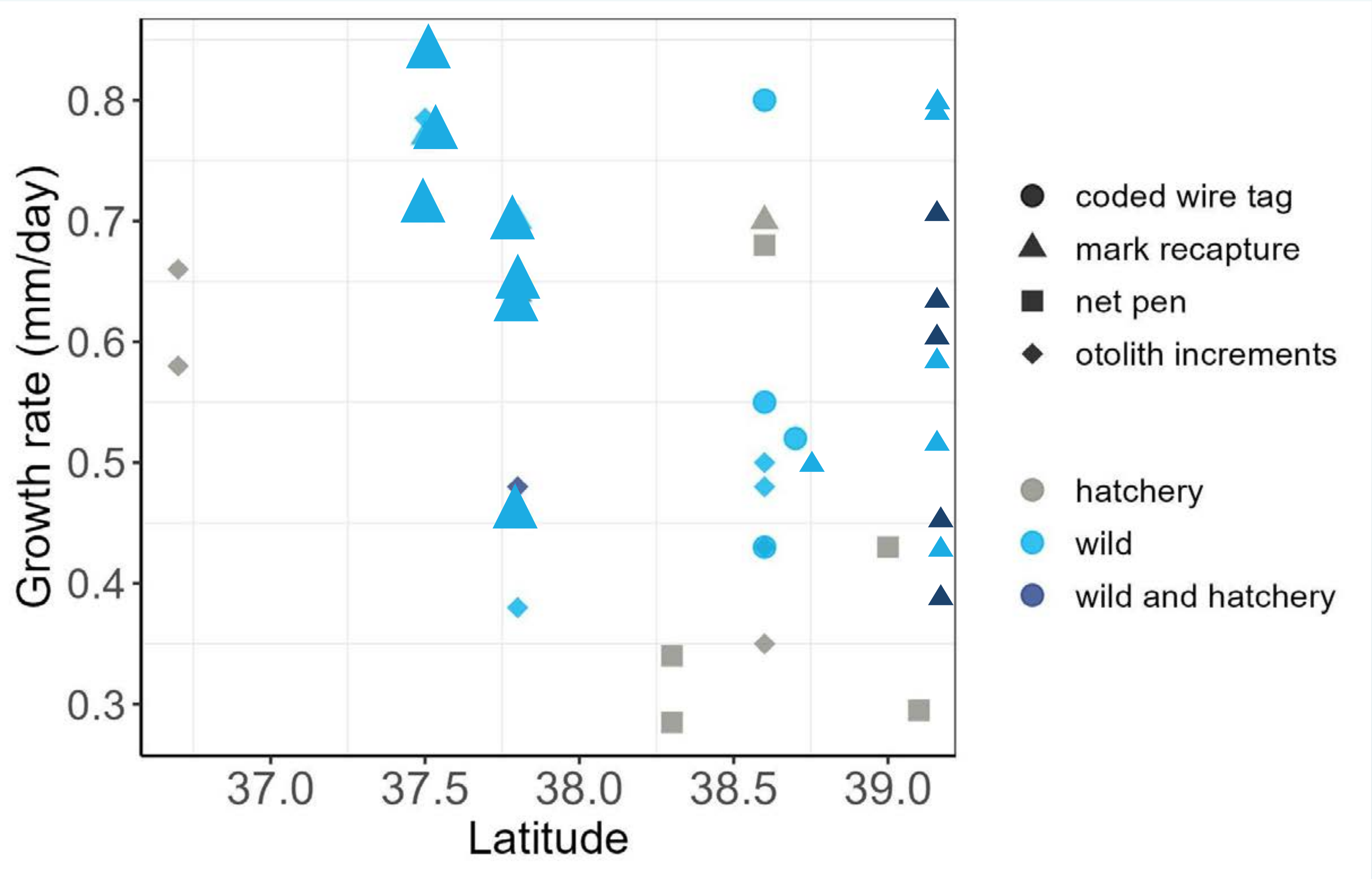


- **Higher growth rate** at Henderson Park on the Merced, and on the Stanislaus River during below average water year only



- **Higher *total* growth** in all years at restored sites due to combination of longer residence times and higher growth rates

How do Merced/Stanislaus River growth rates compare with other studies?



Why are growth differences between main and restored off channel habitats not as dramatic as the Yolo Bypass?

Low water residence time in in higher gradient tributary reaches results in:

- Similar temperature conditions
- Similar depth/velocity
- Similar prey biomass

Jeffres et al. 2008

Incorporating results into CVPIA adaptive management

- Study data incorporated into models to predict restoration benefits and prioritize restoration efforts
- Apply study results to future off-channel habitat restoration design to increase fish benefits per dollar spent

Take home message

Main benefit of tributary rearing habitat restoration is providing **more** habitat and supporting **longer rearing**, but not always significantly higher **growth rates**

Take home message

Main benefit of tributary rearing habitat restoration is providing **more** habitat and supporting **longer rearing**, but not always significantly higher **growth rates**

- Supports a broader diversity of outmigration strategies

Take home message

Main benefit of tributary rearing habitat restoration is providing **more** habitat and supporting **longer rearing**, but not always significantly higher **growth rates**

- Supports a broader diversity of outmigration strategies
- Increases invertebrate prey standing crop

Take home message

Main benefit of tributary rearing habitat restoration is providing **more** habitat and supporting **longer rearing**, but not always significantly higher **growth rates**

- Supports a broader diversity of outmigration strategies
- Increases invertebrate prey standing crop
- Allows more fish to grow larger before entering the Delta

Take home message

Main benefit of tributary rearing habitat restoration is providing **more** habitat and supporting **longer rearing**, but not always significantly higher **growth rates**

- Supports a broader diversity of outmigration strategies
- Increases invertebrate prey standing crop
- Allows more fish to grow larger before entering the Delta

This is an important benefit, as fish leaving the river at a larger size are more likely to survive to adulthood

If you want to learn more about this study:

Email or call me:
kirsten.sellheim@fishsciences.net
209-606-6653

Or read our paper:

North American Journal of Fisheries Management, 2025, 00, 1–18
https://doi.org/10.1093/najfmt/vqae003
Advance access publication: April 2, 2025
Article

American Fisheries Society

Restored seasonally inundated habitat supports juvenile salmonid rearing and growth in two California Central Valley rivers

Kirsten Sellheim[1,*], Avery Scherer[1], Rocko Brown[1], Jesse T. Anderson[1], Jamie Sweeney[1], and Joseph E. Merz[1,2]

Thank you!

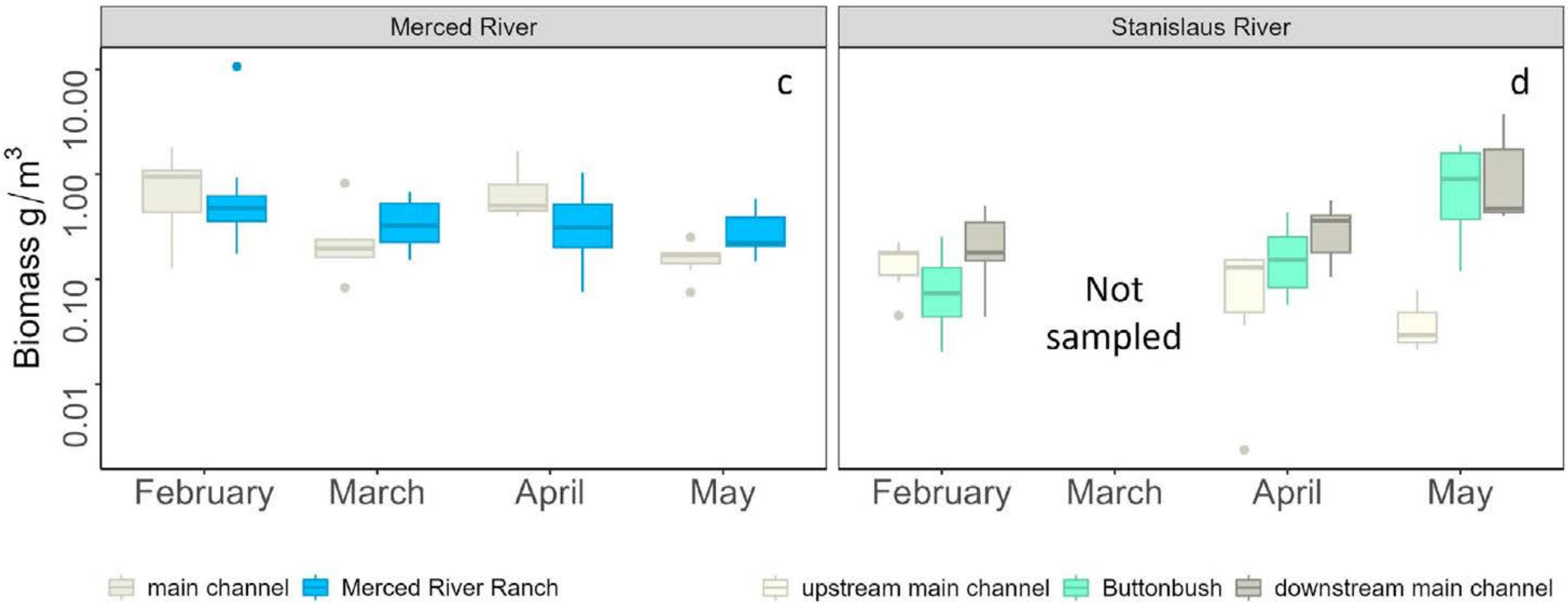
CRAMER FISH SCIENCES

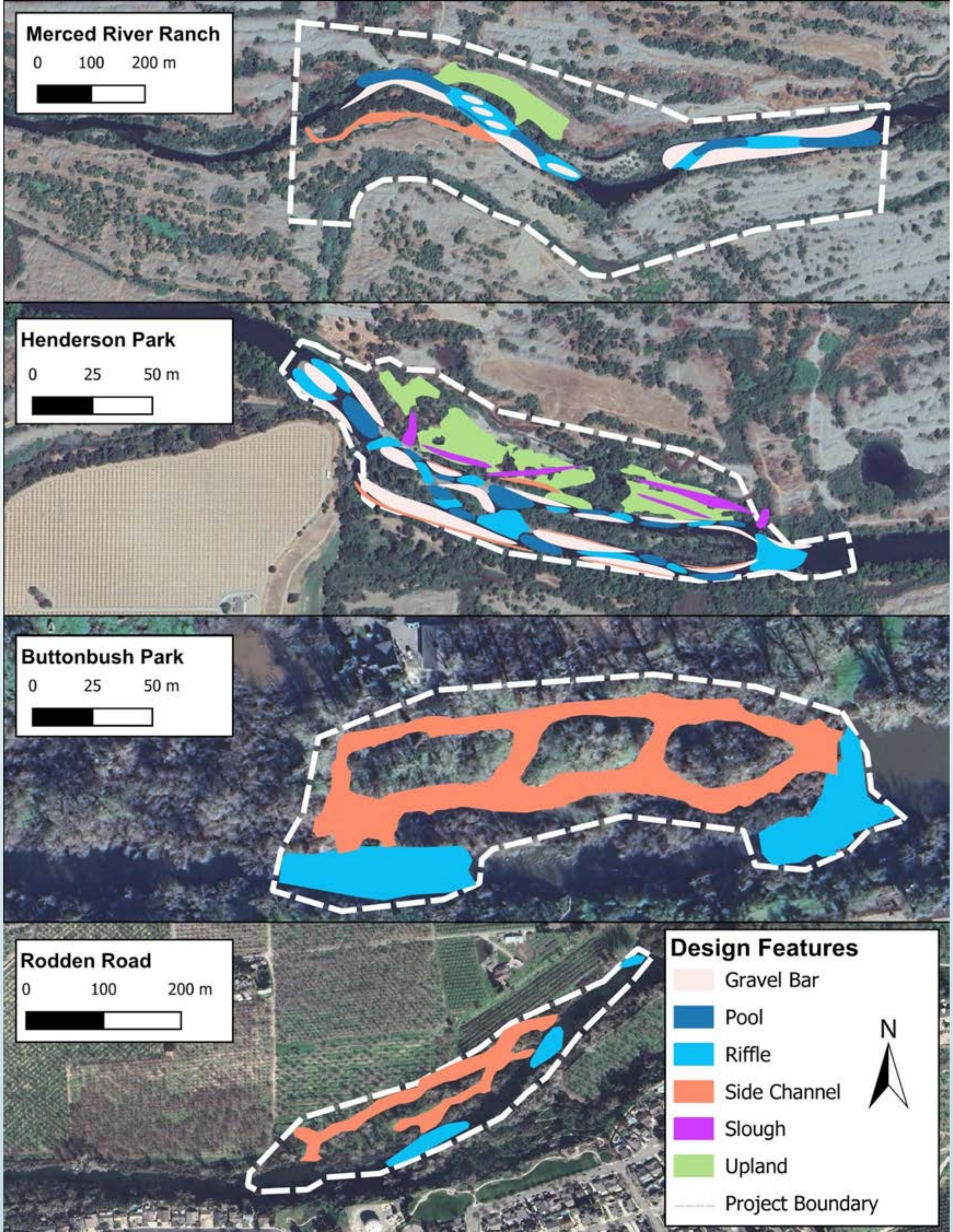
CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

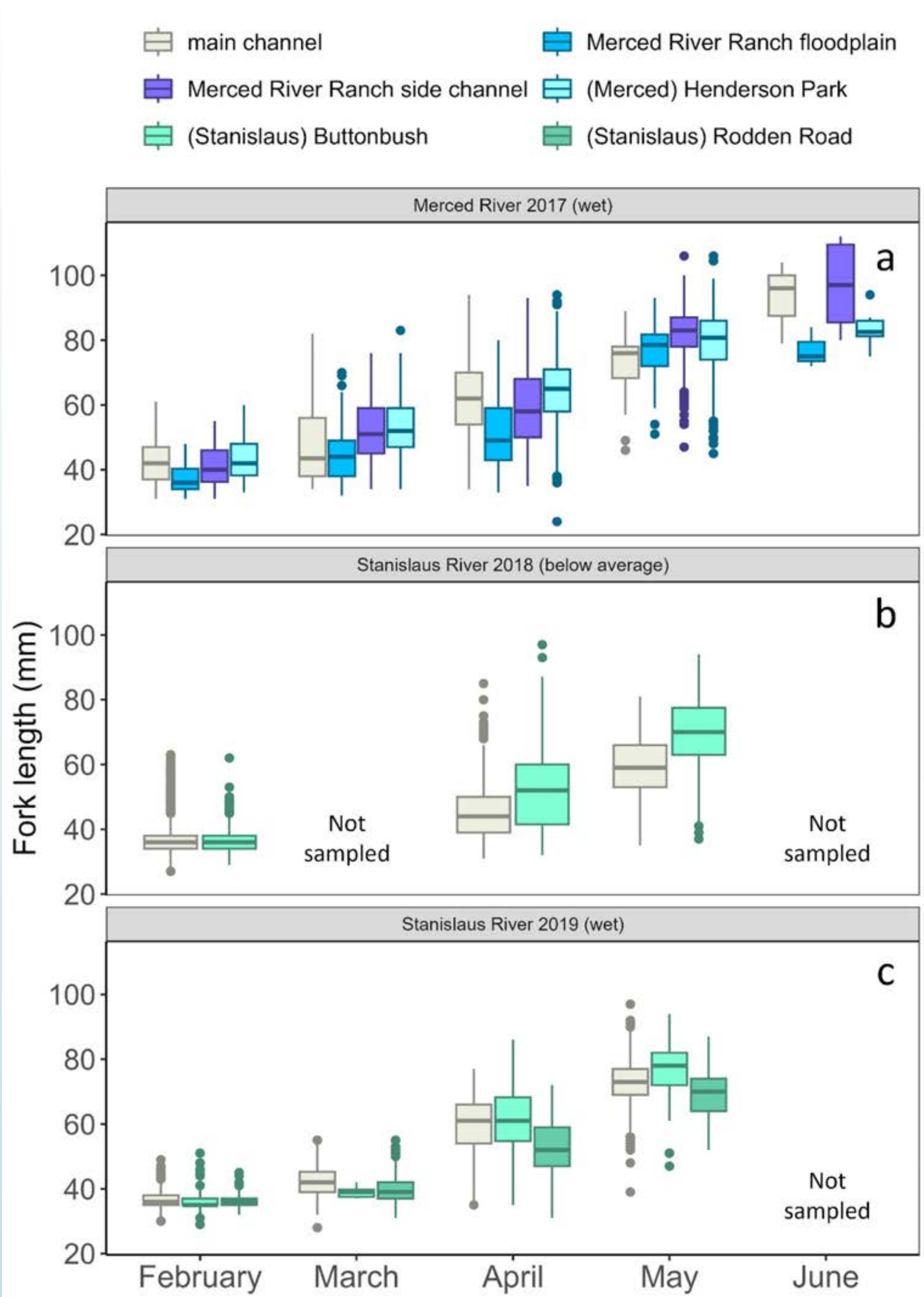
U.S. FISH & WILDLIFE SERVICE DEPARTMENT OF THE INTERIOR

Do restored off channel habitats produce more invertebrate prey biomass?

- Prey biomass similar between restored off channel and main channel
- Differed between rivers
  - More stable biomass over time on the Merced
  - Increased later in spring on the Stanislaus




Merced River Ranch
0 100 200 m
Henderson Park
0 25 50 m
Buttonbush Park
0 25 50 m
Rodden Road
0 100 200 m
Design Features
Gravel Bar
Pool
Riffle
Side Channel
Slough
Upland
Project Boundary
N



main channel
Merced River Ranch floodplain
Merced River Ranch side channel
(Merced) Henderson Park
(Stanislaus) Buttonbush
(Stanislaus) Rodden Road
Merced River 2017 (wet)
a
Stanislaus River 2018 (below average)
b
Not sampled
Not sampled
Stanislaus River 2019 (wet)
c
Not sampled
Fork length (mm)
20
40
60
80
100
February
March
April
May
June

Extra bits

	Merced	Stanislaus
Timeframe	February-July 2017	Feb-May 2018 & 2019
Total off-channel acres	21	5.5
Flow range during study	200-6,500 cfs	300-5,200 cfs
Total seine hauls	302	238
Total water volume sampled	6,000 m^3	8,000 m^3
Total fish PIT tagged	832	1,498

Predation of Juvenile Salmon in Managed Agricultural Floodplains

Peter G. Aronson[1],
Alexandra N. Wampler[1,2], Carson A. Jeffres[2], Dennis E. Cocherell[1],
Nann A. Fangue[1], Paul G. Buttner[3], and Andrew L. Rypel[1,2]

1) University of California, Davis Department of Wildlife, Fish, and Conservation Biology
2) University of California, Davis Center for Watershed Sciences
3) California Rice Commission

UCDAVIS DEPARTMENT OF WILDLIFE, FISH AND CONSERVATION BIOLOGY

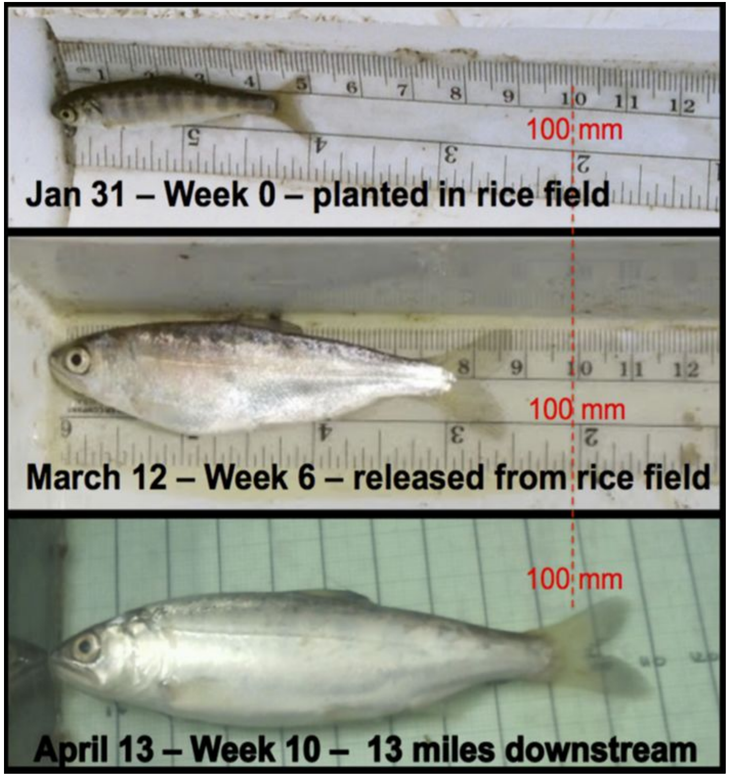
UCDAVIS COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

California Rice

Sacramento River Basin, USGS

Photo: Steve Martarano

Photo: Alexandra Wampler



Katz et al., 2017

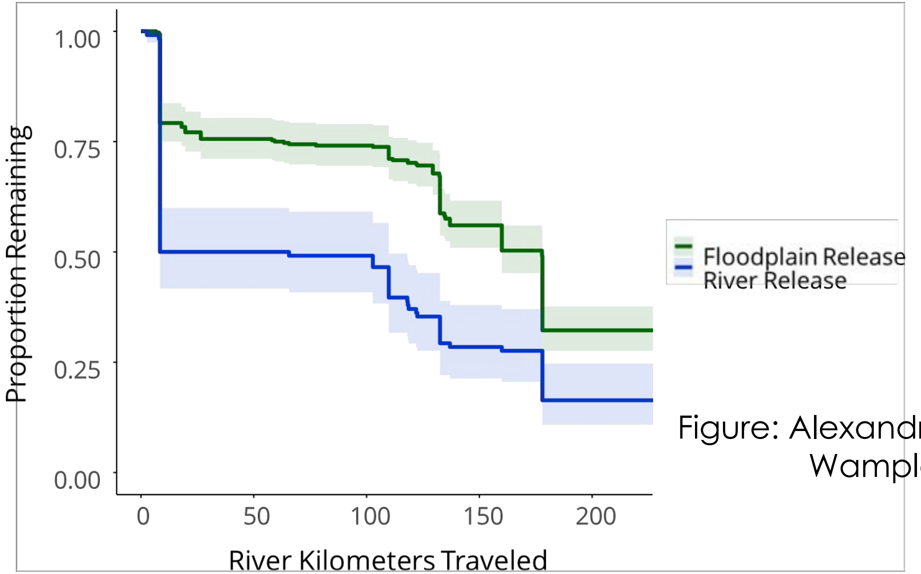
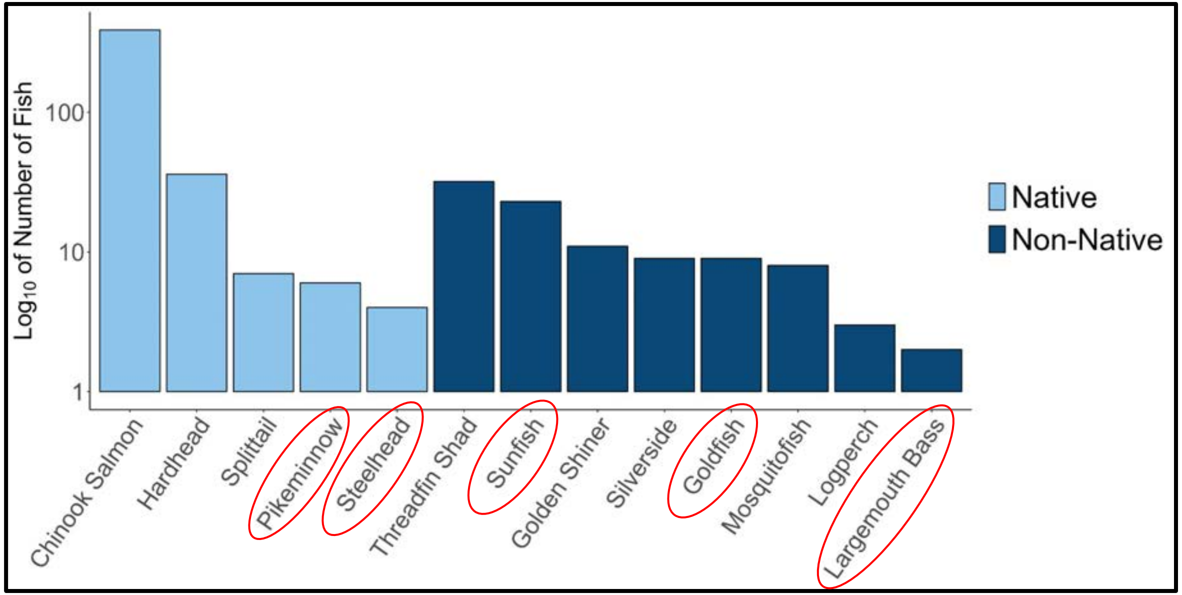


Figure: Alexandra Wampler

Photo: Carson Jeffres

Fish Community / Predator Presence



Number of fish found on 125-acre wet-side rice field in 2023

Study Questions

1) Does temperature affect predation on winter-flooded rice fields?

2) Do predation rates vary with predator density within winter-flooded rice fields?

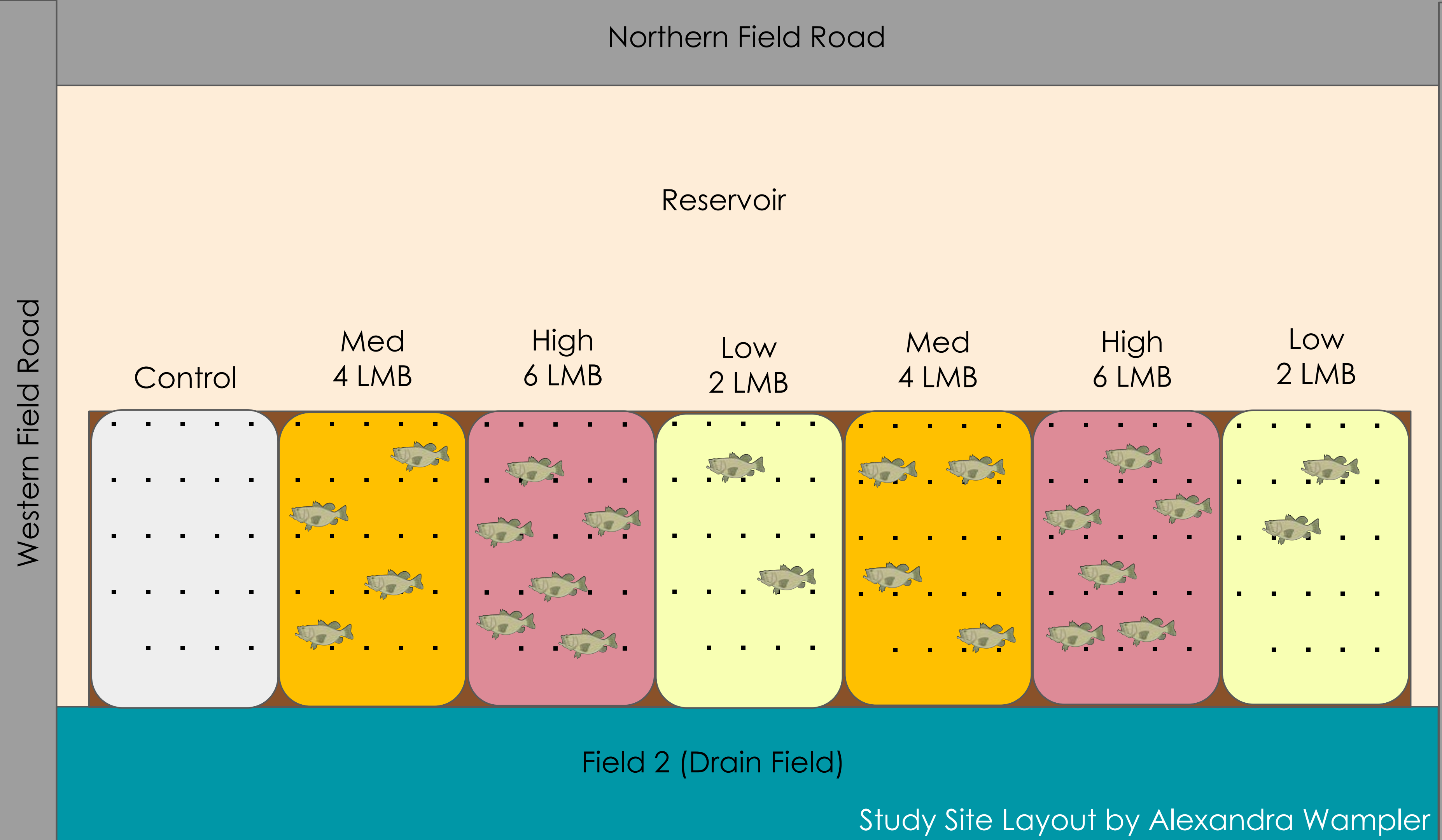
3) Do predation rates vary with time of day (sunrise vs sunset) or seasonality (early vs late)?

4) Does light intensity affect predation rate?

5) Does predation rate vary based on prey size?

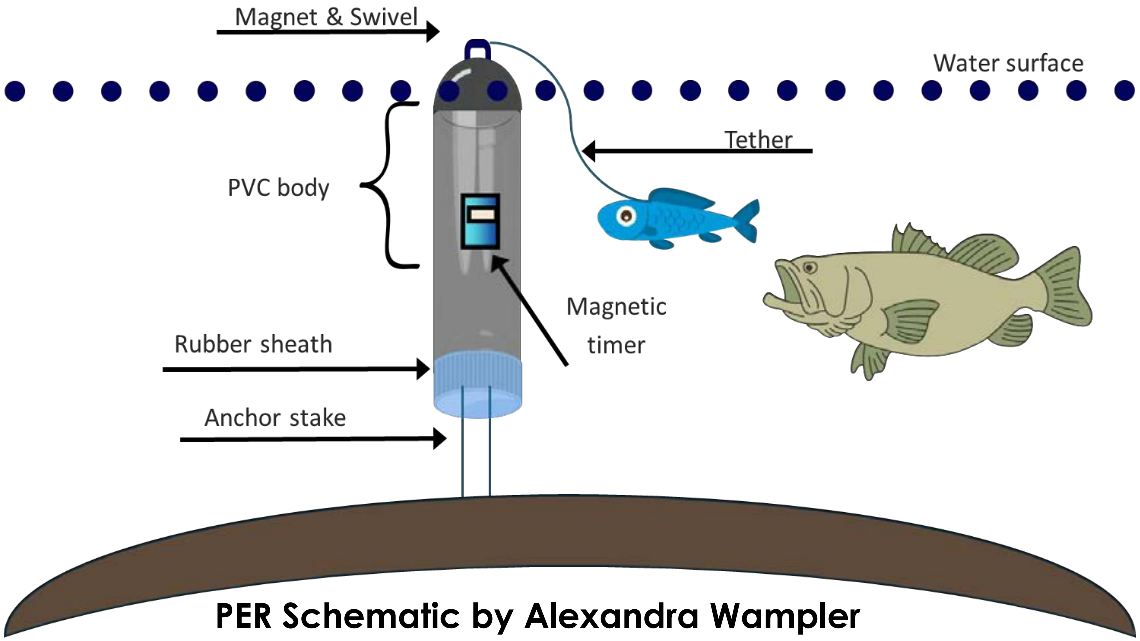
Photo: Brian Baer


Mt Vernon
Tierra Buena
Sutter
Tarke
Yuba City
Linda
Sutter Bypass
South Yuba City
Feather River
Olivehurst
Joesphine
Grimes
Study Site
Oswald
Sacramento River
Feather River
Tisdale
Abbott
Tisdale Bypass
Fraziers Landing
Plumas Lake
Tudor



Northern Field Road
Reservoir
Western Field Road
Eastern Field Road
Control
Med
4 LMB
High
6 LMB
Low
2 LMB
Med
4 LMB
High
6 LMB
Low
2 LMB
Field 2 (Drain Field)
Study Site Layout by Alexandra Wampler

Predation Event Recorders (PERs)



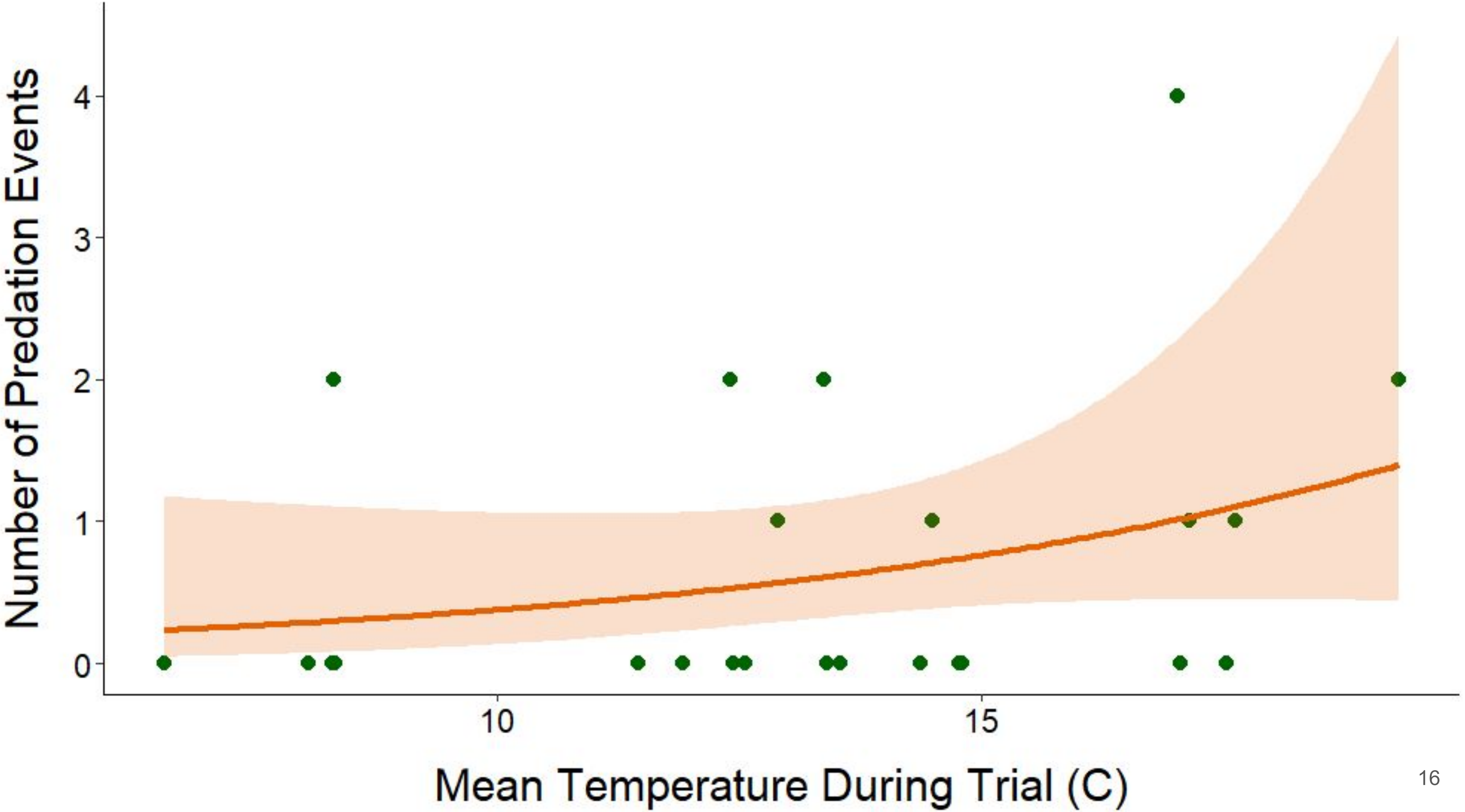
PER Schematic by Alexandra Wampler

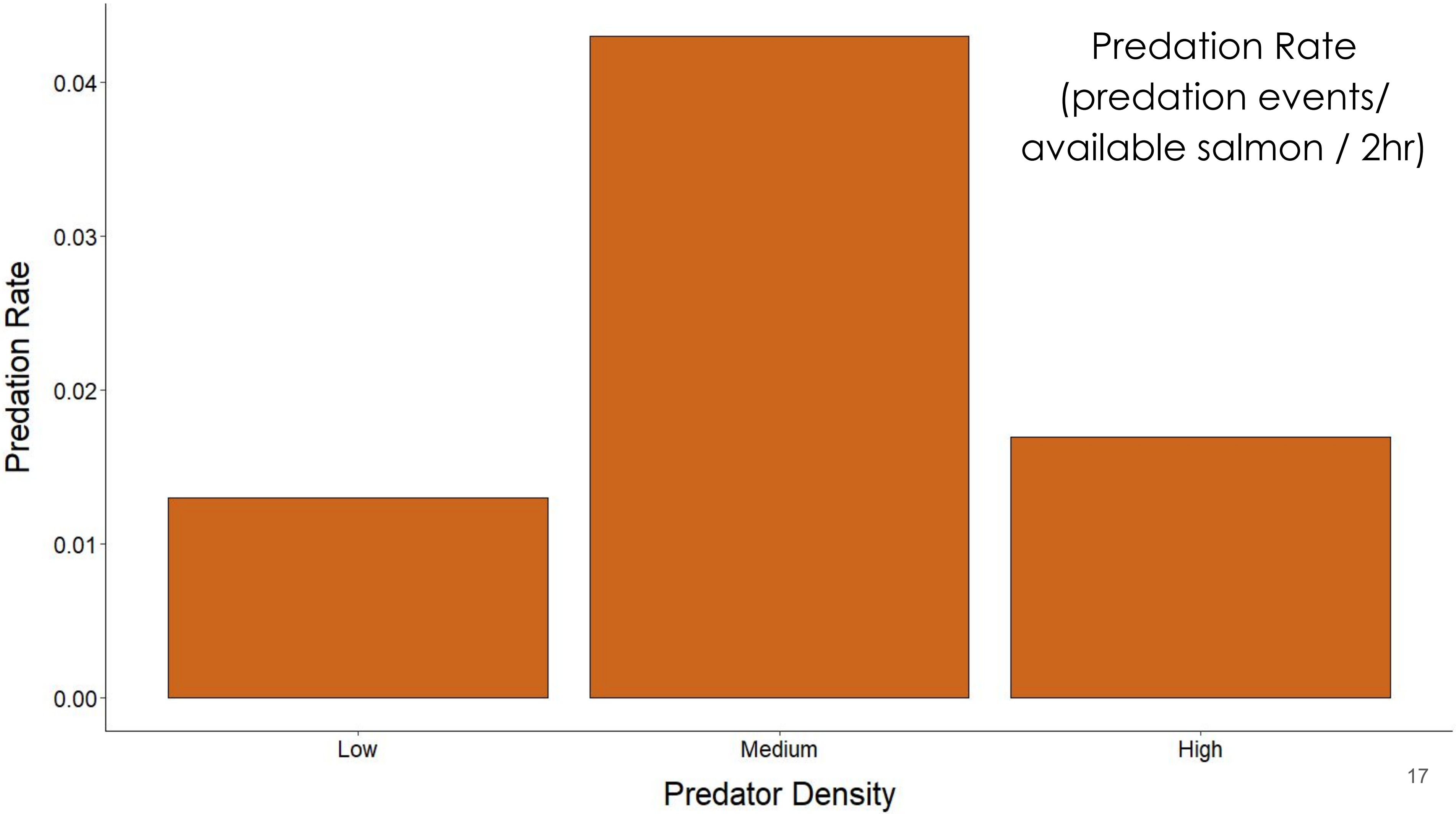
Photos: Brian Baer

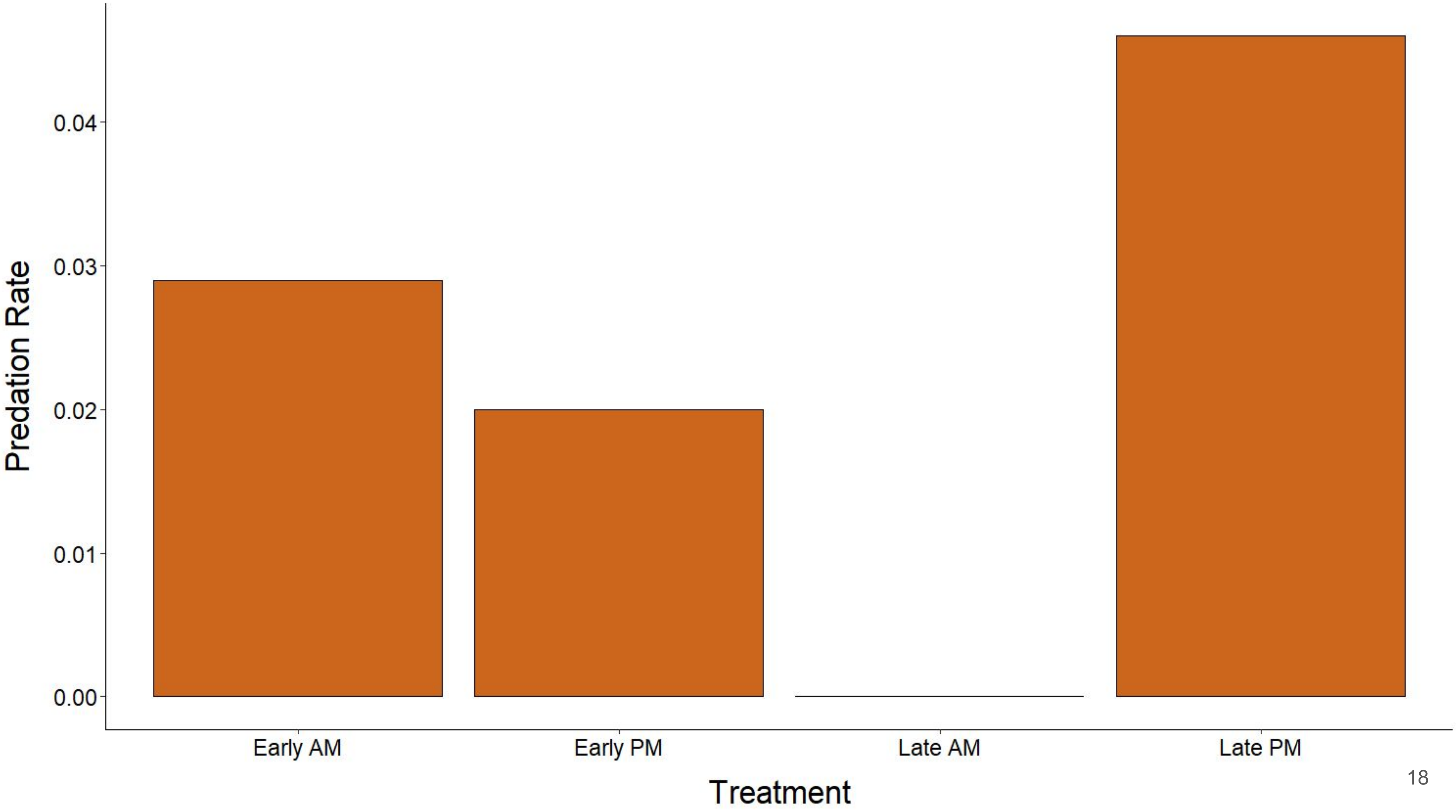
Variables

- Predator Density
- Early Season vs Late Season
- Sunrise vs Sunset

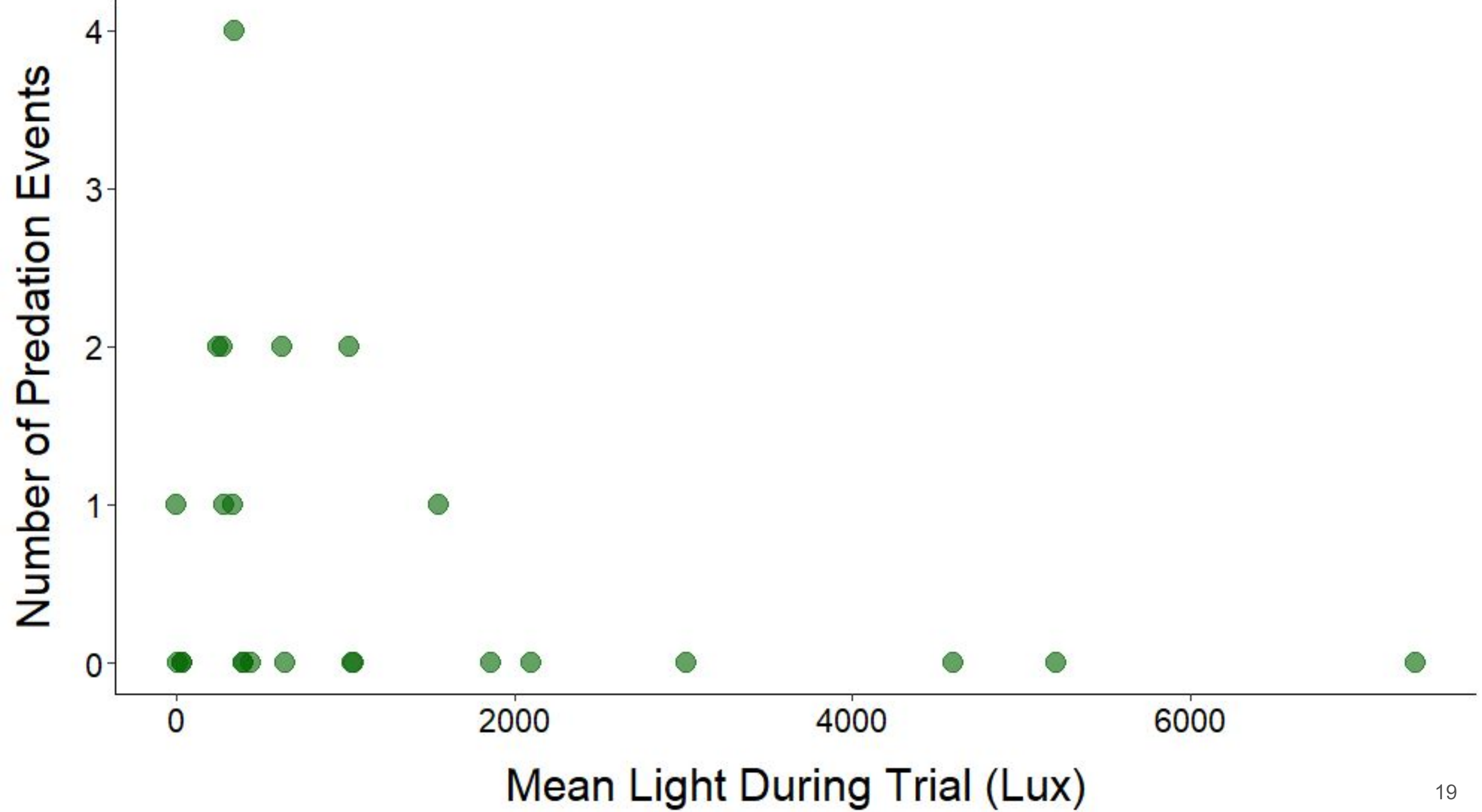
Photo: Brian Baer

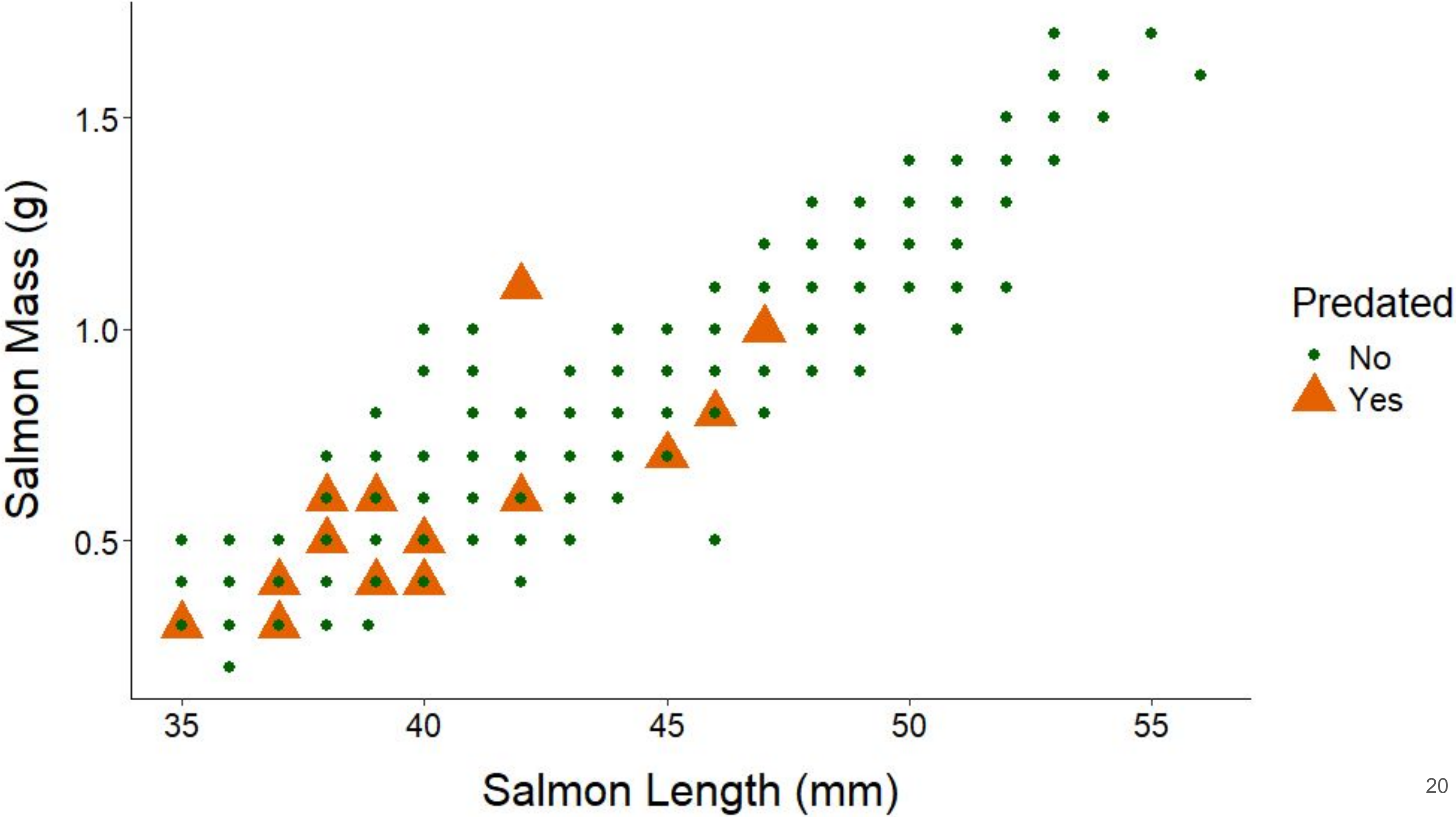

Number of Predation Events
0
1
2
3
4
10
15
Mean Temperature During Trial (C)


Predation Rate
(predation events/
available salmon / 2hr)
Predation Rate
0.00
0.01
0.02
0.03
0.04
Low
Medium
High
Predator Density



Predation Rate
0.04
0.03
0.02
0.01
0.00
Early AM
Early PM
Late AM
Late PM
Treatment


Number of Predation Events
4
3
2
1
0
0
2000
4000
6000
Mean Light During Trial (Lux)


Salmon Mass (g)
1.5
1.0
0.5
35
40
45
50
55
Salmon Length (mm)
Predated
No
Yes

Discussion

- In-field predation is low
- Medium bass density results in greatest predation
- Predator activity appeared to increase in the evening
- More studies are needed to assess predation risk to juvenile salmon in Bypass System

Photo: Brian Baer

Future Studies

- Predator - predator interactions
- Predation throughout the system
- Avian predation

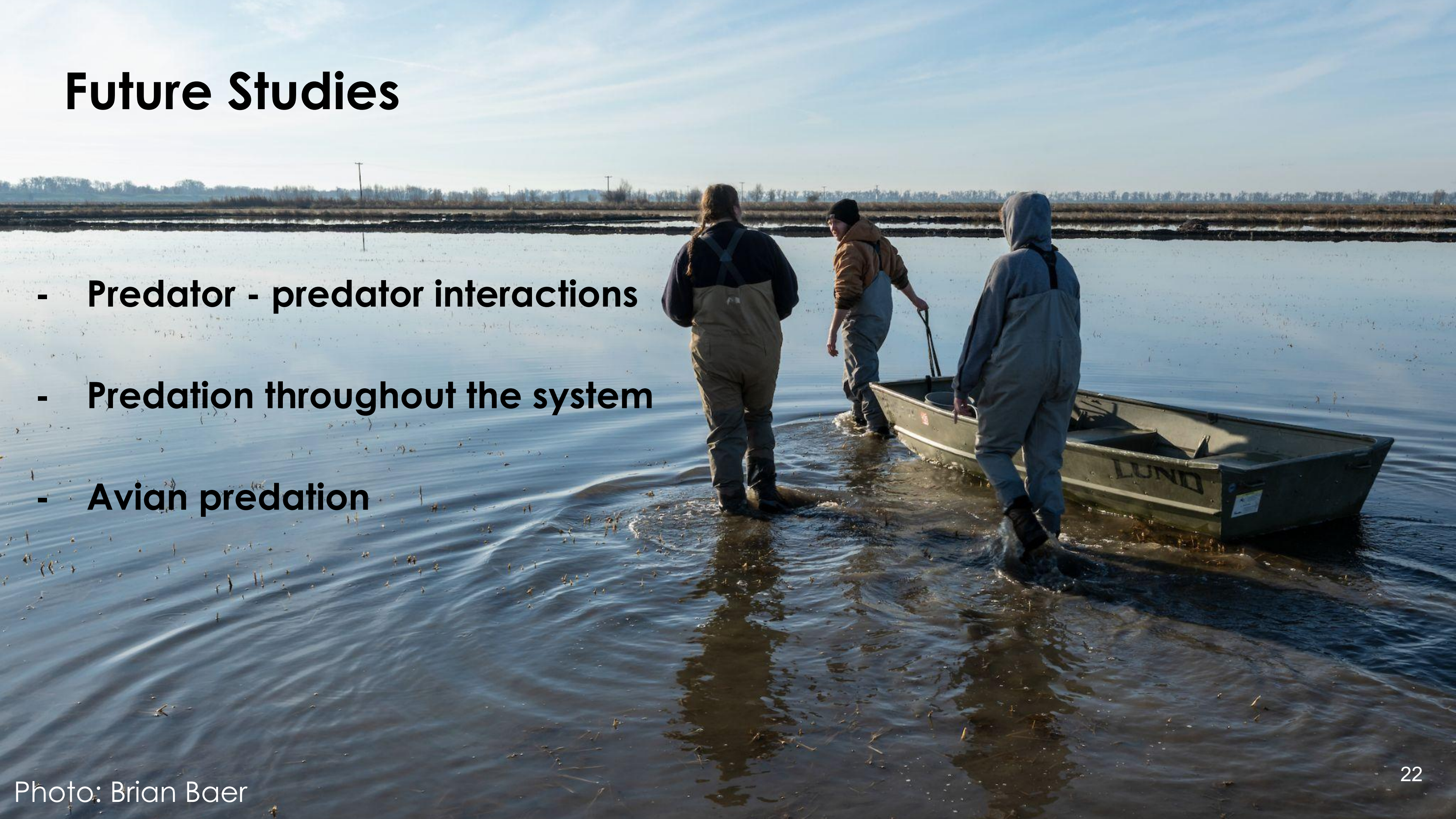


Photo: Brian Baer

References

The Bay Institute. (1998). From the Sierra to the sea: the ecological history of the San Francisco Bay-Delta watershed. San Francisco (CA): The Bay Institute.

Corline, N. J., Sommer, T., Jeffres, C. A., & Katz, J. (2017). Zooplankton ecology and trophic resources for rearing native fish on an agricultural floodplain in the Yolo Bypass California, USA. Wetlands Ecology and Management, 25, 533-545.

Fleskes, J. P., Casazza, M. L., Overton, C. T., Matchett, E. L., & Yee, J. L. (2018). Changes in the abundance and distribution of waterfowl wintering in the Central Valley of California, 1973–2000. Trends and traditions: Avifaunal change in western North America (WD Shuford, RE Gill Jr., and CM Handel, eds.), 50-74.

Jeffres, C. A., Opperman, J. J., & Moyle, P. B. (2008). Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental biology of fishes, 83, 449-458.

Katz, J. V., Jeffres, C., Conrad, J. L., Sommer, T. R., Martinez, J., Brumbaugh, S., ... & Moyle, P. B. (2017). Floodplain farm fields provide novel rearing habitat for Chinook salmon. PloS one, 12(6), e0177409.

Acknowledgements

California Rice Research Board

CORTEVA agriscience

Center for Watershed Sciences UC DAVIS

LUNDBERG FAMILY FARMS

GROW WEST

The Nigiri Project
CAL MARSH & FARM VETURES

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

ACC
AMERICAN COMMODITY COMPANY, LLC
P.O. Box 520 • 6133 Abel Road • Williams, CA 95987 • USA

SWC

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

NCWA
Northern California Water Association

CALIFORNIA TROUT
FISH · WATER · PEOPLE

NOAA FISHERIES

syngenta

Personal Acknowledgements:

Lance Matteoli
Megan Matteoli
Emily Mensch
Bryson Zheng
Maya Churi
Liliana West
Gabrielle Camba
Ruike Gong
Valentina Montes
Rachelle Tallman
Brian Baer

Photo collage by Michael Smith 2008

Butte Creek Floodplain Reconnection and Channel Restoration

Allen Harthorn Friends of Butte Creek
Anthony Falzone FlowWest

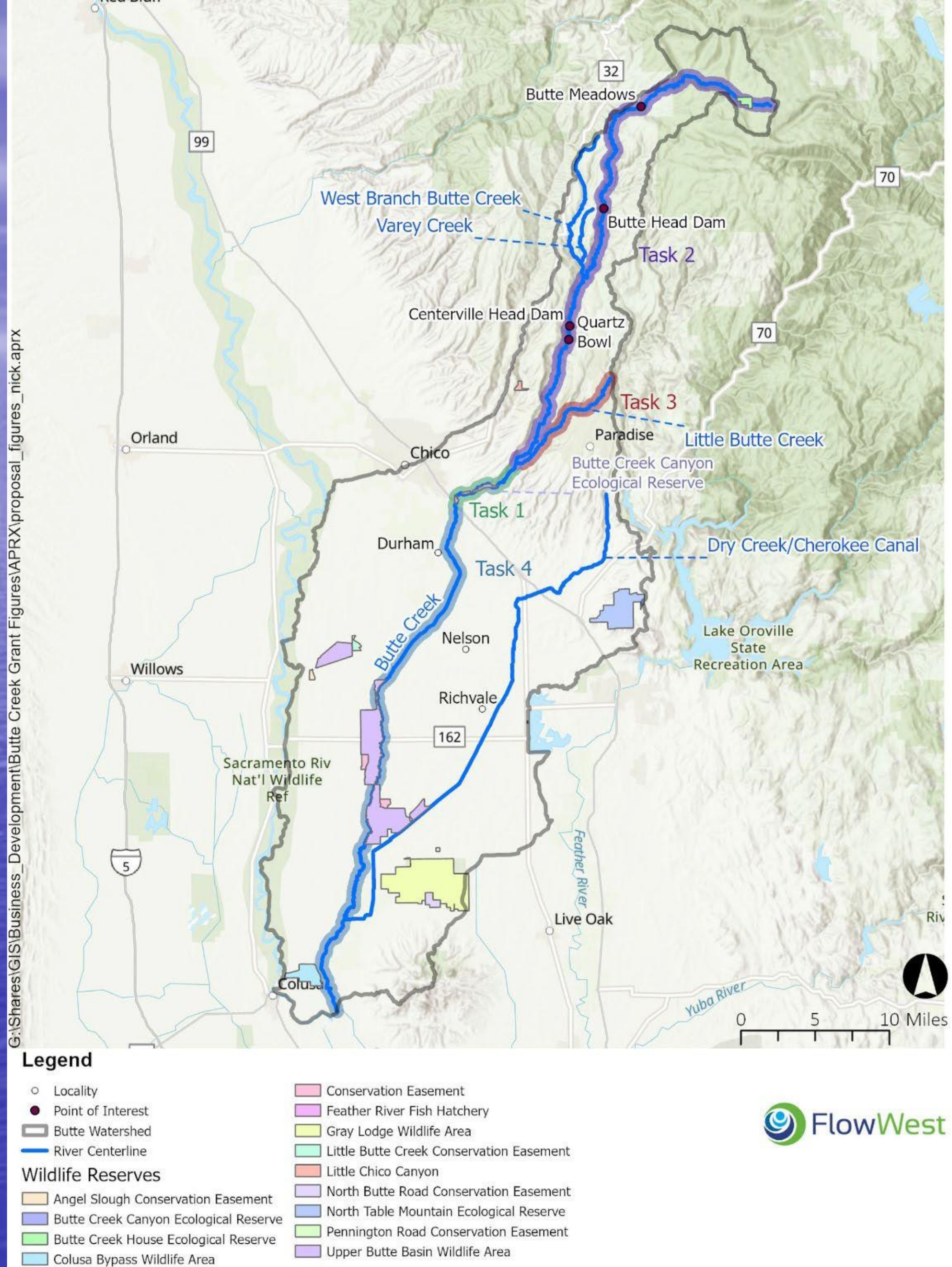
Salmonid Restoration Federation Conference

Santa Cruz

May 1, 2025

Presentation Outline

- Spring-run salmon and Butte Creek
- Hydropower development and future
- Restoration activities in the watershed
- Butte Creek Floodplain Reconnection and Channel Restoration Project
- Questions


Butte Meadows
32
99
70
West Branch Butte Creek
Varey Creek
Butte Head Dam
Task 2
Centerville Head Dam
Quartz
Bowl
Task 3
Little Butte Creek
Paradise
Orland
Chico
Butte Creek Canyon
Ecological Reserve
Task 1
Durham
Task 4
Dry Creek/Cherokee Canal
Butte Creek
Nelson
Lake Oroville
State
Recreation Area
Willows
Richvale
162
Sacramento Riv
Nat'l Wildlife
Ref
5
Feather River
Live Oak
Colusa
Yuba River
0
5
10 Miles
G:\Shares\GIS\Business_Development\Butte Creek Grant Figures\APRX\proposal_figures_nick.aprx
Legend
Locality
Point of Interest
Butte Watershed
River Centerline
Wildlife Reserves
Angel Slough Conservation Easement
Butte Creek Canyon Ecological Reserve
Butte Creek House Ecological Reserve
Colusa Bypass Wildlife Area
Conservation Easement
Feather River Fish Hatchery
Gray Lodge Wildlife Area
Little Butte Creek Conservation Easement
Little Chico Canyon
North Butte Road Conservation Easement
North Table Mountain Ecological Reserve
Pennington Road Conservation Easement
Upper Butte Basin Wildlife Area
FlowWest

Butte Creek

- One of three Central Valley streams that supports a self-sustaining population of spring-run Chinook salmon
- Suitable habitat for spring-run to survive high summer temperatures

Deep, cool, highly oxygenated pools and transfer of West Branch Feather River water via PG&E hydro project

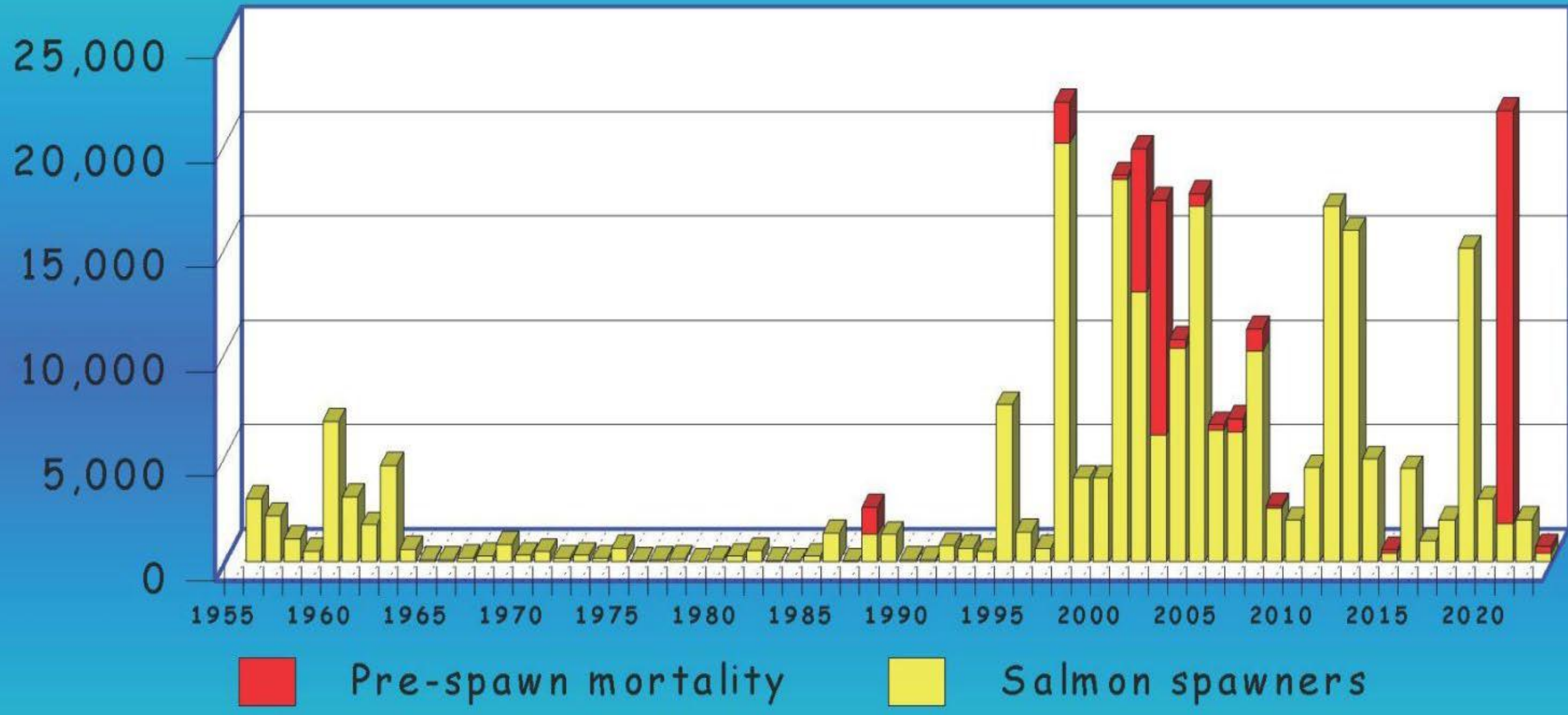
Presenter Notes
2025-05-01 16:47:51

Why is Butte Creek important?

Spring-Run Chinook Salmon

- Listed as threatened in 1999 under the CA and federal Endangered Species Act
- Enter freshwater in the late winter and spring, spend up to seven months in streams before spawning

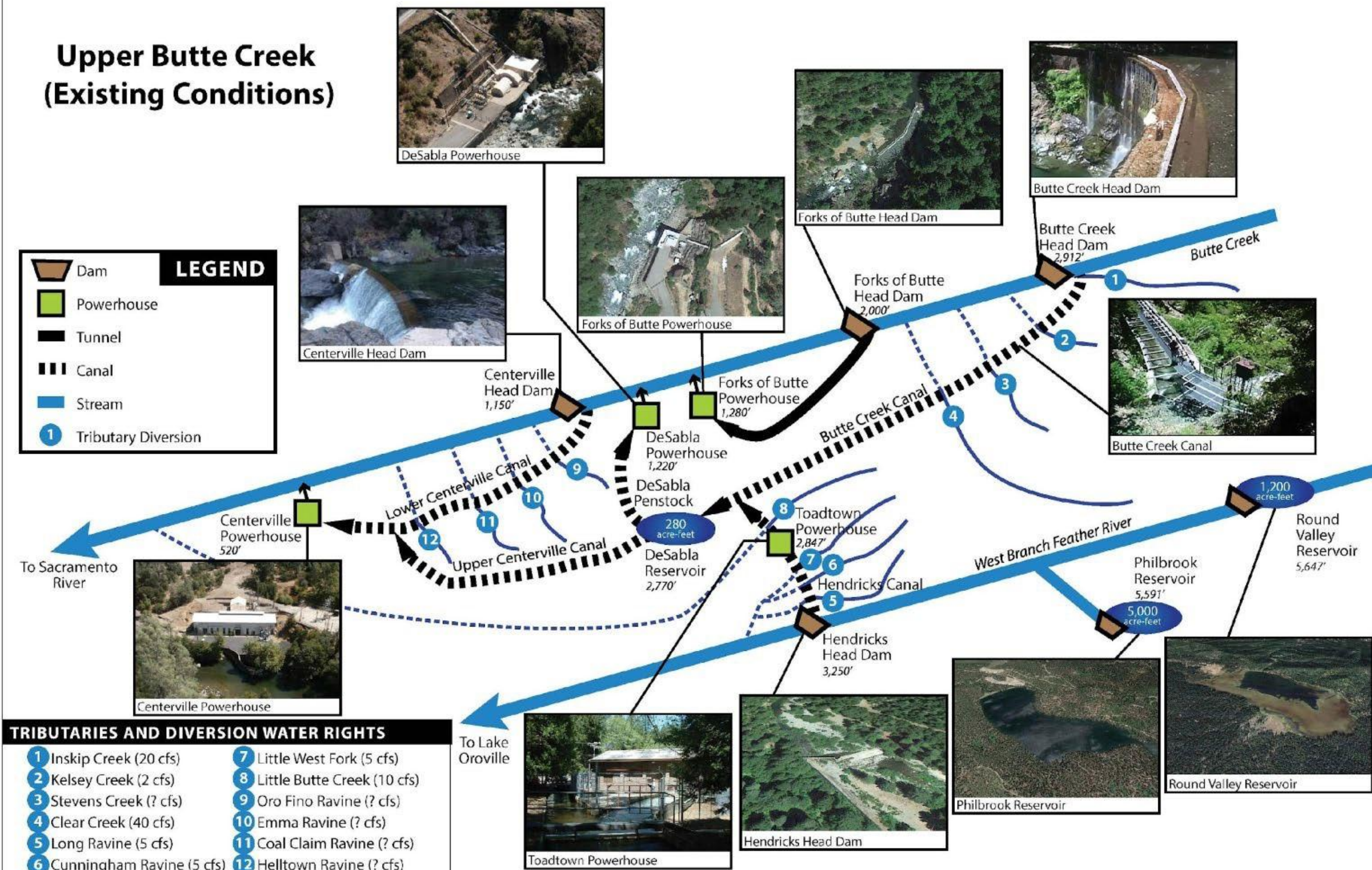
Butte Creek Spring Run Salmon Populations



Butte Creek Hydropower

- PG&E DeSabla-Centerville Hydropower Project
  - Non-operational powerhouse
  - Canal failures and dams
  - Feather River water import
  - Timing and water temp are critical
  - Uncertain future
- Forks of the Butte Diversion and Powerhouse

Upper Butte Creek (Existing Conditions)



TRIBUTARIES AND DIVERSION WATER RIGHTS

1. Inskip Creek (20 cfs)
2. Kelsey Creek (2 cfs)
3. Stevens Creek (? cfs)
4. Clear Creek (40 cfs)
5. Long Ravine (5 cfs)
6. Cunningham Ravine (5 cfs)
7. Little West Fork (5 cfs)
8. Little Butte Creek (10 cfs)
9. Oro Fino Ravine (? cfs)
10. Emma Ravine (? cfs)
11. Coal Claim Ravine (? cfs)
12. Helltown Ravine (? cfs)

Temperature Hazards

Salmon Pool July 12, 2003

Salmon Pool August 12, 2003

PG&E Canal Failure August 9-10, 2023

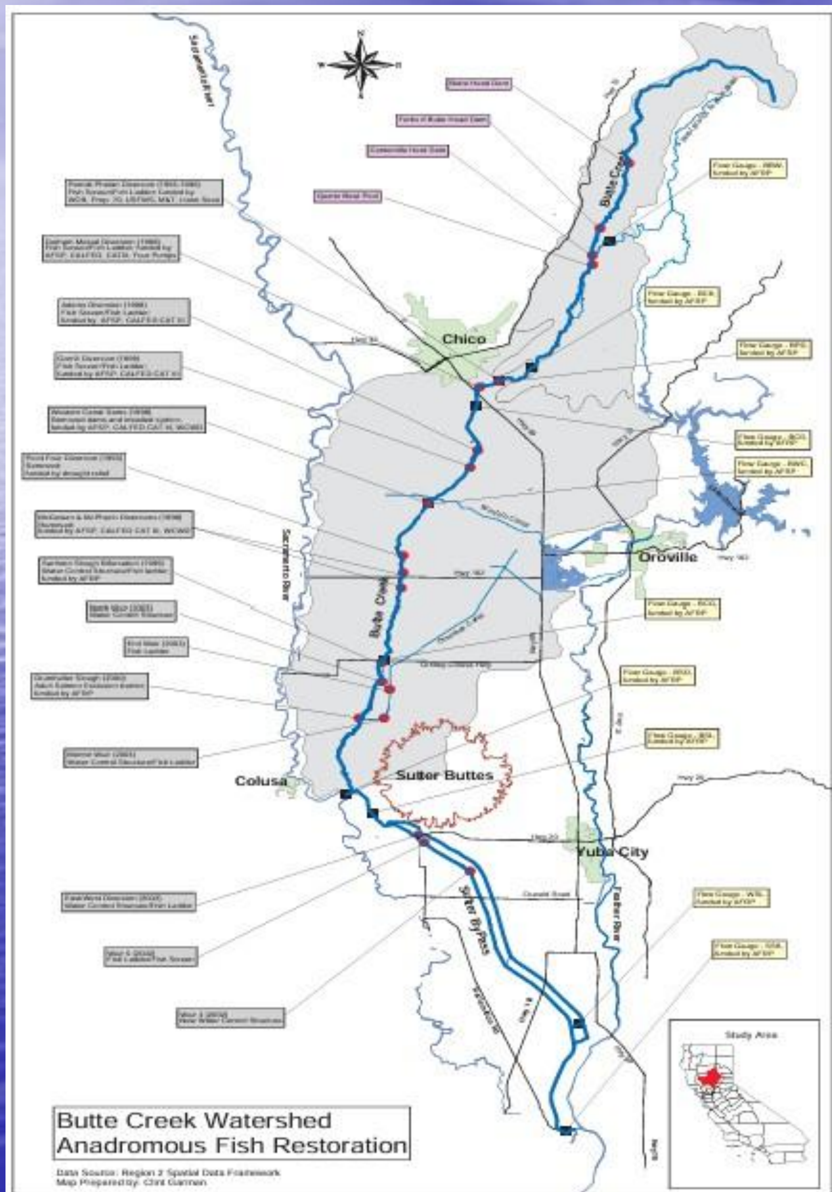
Watershed Restoration 2025

- Friends of Butte Creek water right acquisition (1707)
- PG&E relicensing and potential decommissioning
- Wild Salmon Center Strategic Action Plan
- CDFW Ecological Reserve Project
- Middle and Lower Watershed Restoration via Butte Sutter Bypass Coordinated Operations Group (BSBCOG)

Presenter Notes
2025-05-01 16:47:53

Table 1. Major Fishery Restoration Actions in Butte Creek for period 1993-2005

Leverage Previous Work



- Restoration Actions 1993-2005
- Over $34m invested
- Screens, dam removals, passage improvements
- Over 23 projects

California Department of Fish and Game – November 2005

Butte Creek Floodplain Reconnection and Channel Restoration Project

U.S. FISH & WILDLIFE SERVICE

Friends of Butte Creek
www.buttecreek.org

FlowWest

Goals and Objectives

- Increase rearing habitat for spring-run Chinook salmon and steelhead
- Enhance habitat for Western Pond Turtle, Yellow-Legged Frog, and cavity nesting species
- Increase riffles and spawning gravel
- Reduce stranding in abandoned pits
- Reconnect the floodplain
- Design drawings and permitting

Presenter Notes
2025-05-01 16:47:54

Adding rearing habitat is critical. Most rearing occurs in the sink, but timing is everything and additional rearing habitat in Upper Butte Creek is critical in some water years. A few days or weeks in good habitat while waiting for flushing flows could make the difference in survival during migration.

Opportunities and Constraints

- CDFW Butte Creek Canyon Ecological Reserve
  - 255 acres
  - impacted by gold and gravel mining
  - opportunity for restoration
- Parrott Phalen Diversion Dam
- Residential development

Butte Creek Community

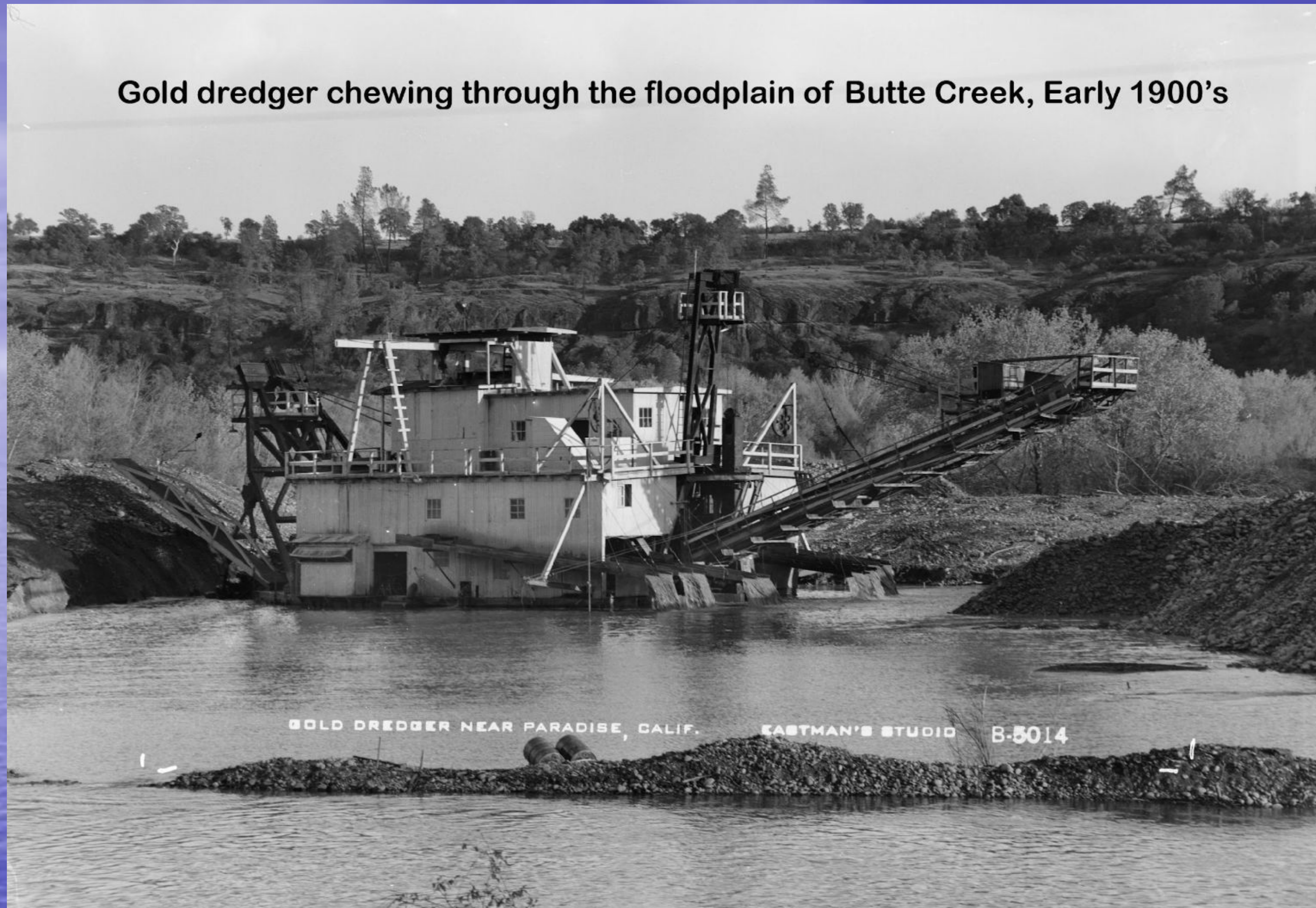
- CDFW
- USFWS
- CalTrout
- Mechoopda Tribe
- Private landowners
- Wild Salmon Center

Work to Date

- Historical analysis
- Field data collection
- Hydrology analysis
- HEC-RAS 2D existing conditions model
- Conceptual design

Gold Dredging Impacts

- Inverted soil profile
- Floodplain mining pits are stranding hazard
- Simplified channel form dominated by runs
- Limited recovery of native riparian vegetation

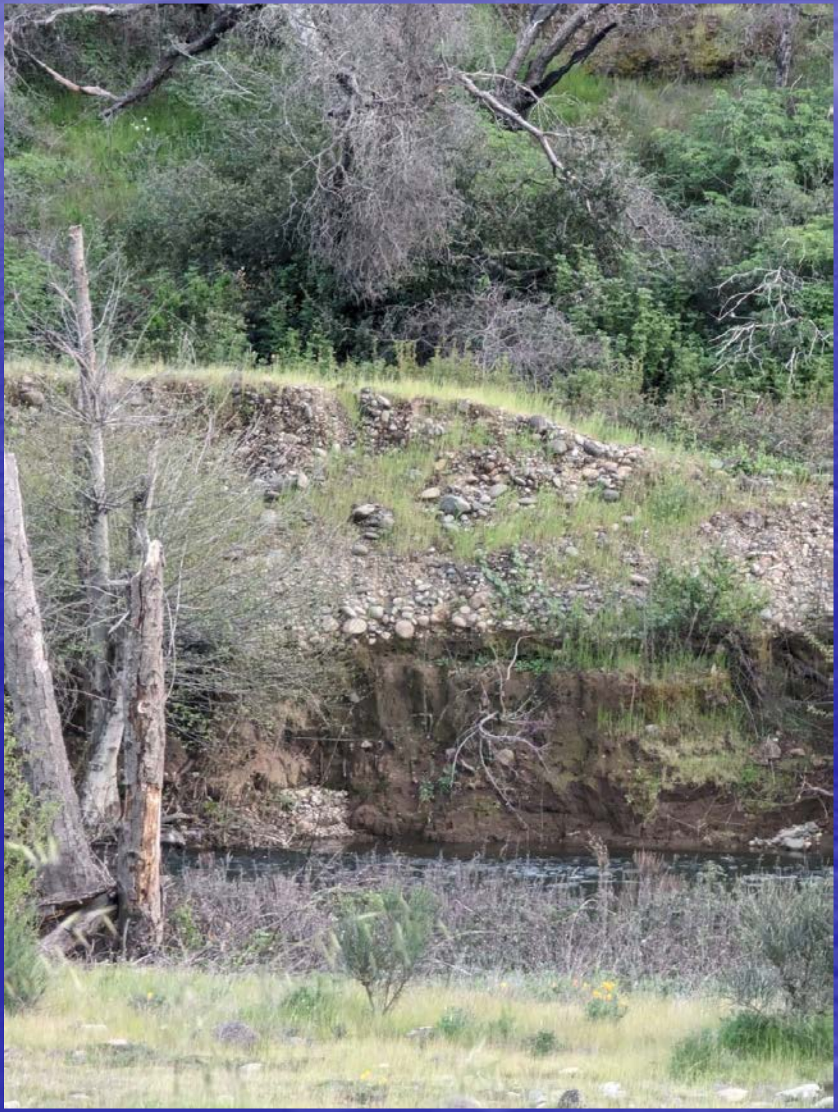


Gold dredger chewing through the floodplain of Butte Creek, Early 1900's

Dredger on Butte Creek, 1910

Source: CSU Chico Northeastern California Historical Photograph Collection

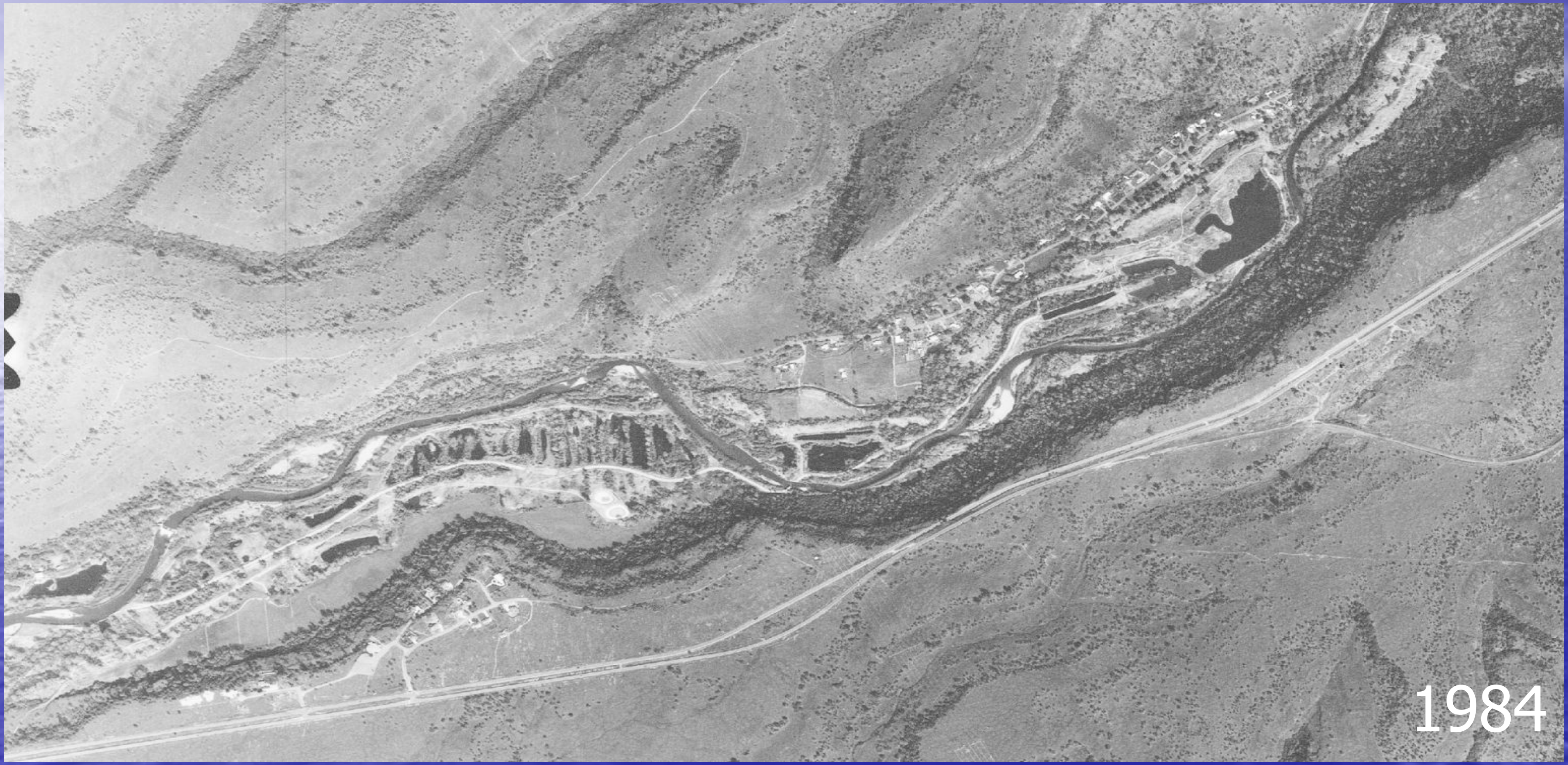
Inverted floodplain soil profile, 2023



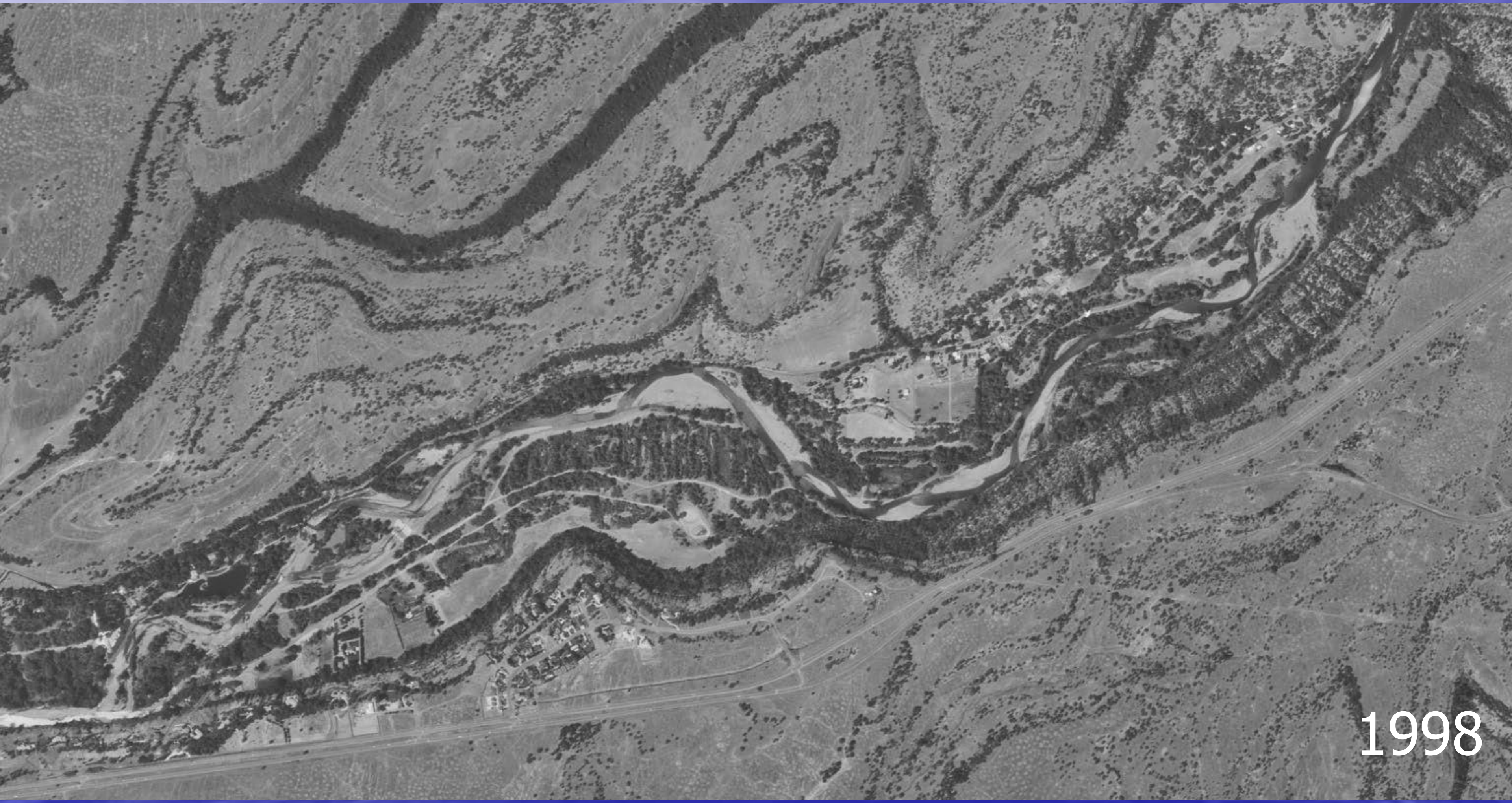
Gravel Mining

- Gravel miners reworked gold dredger tailings
- Floodplain mining pits at risk of channel capture and potential stranding
- Simplified channel form dominated by runs
- Abandoned infrastructure and road network
- Limited recovery of native riparian vegetation

Channel Avulsion 1986

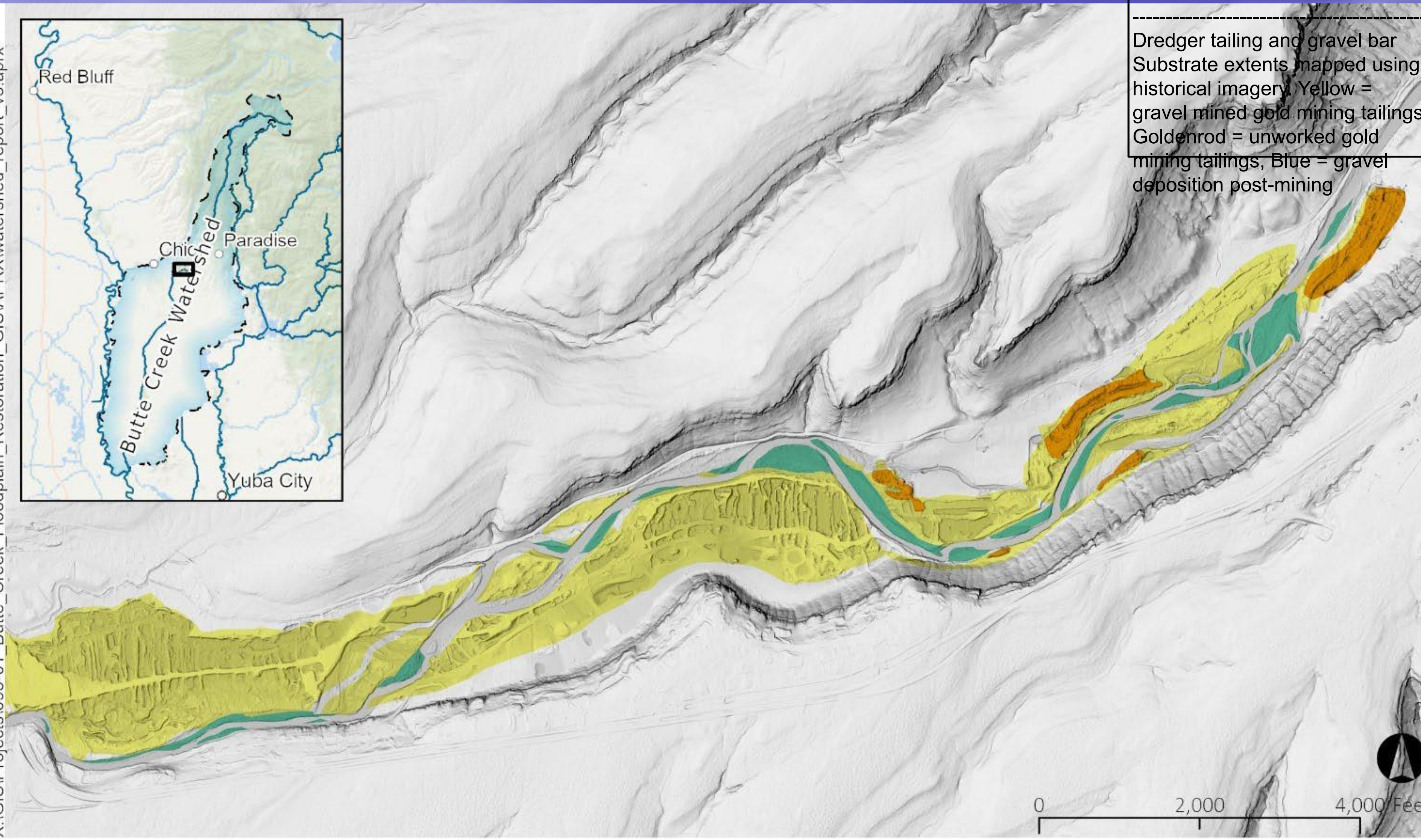


Channel Avulsion 1997



Presenter Notes
2025-05-01 16:47:58

Dredger tailing and gravel bar Substrate extents mapped using historical imagery. Yellow = gravel mined gold mining tailings, Goldenrod = unworked gold mining tailings, Blue = gravel deposition post-mining



Gold Dredge Tailings

- Extant Surface Tailings Piles
- Mined/Graded Tailings as Substrate
- Subsequent Gravel Bar Deposition

FlowWest

Peak Flows and Functional Flows

USGS 11390000 BUTTE CREEK NEAR CHICO CA

Peak Flows WY 1930-2023

AEP	RI	Flow (cfs)
90%	1.1-year	3,310
80%	1.2-year	4,110
66.67%	1.5-year	5,080
50%	2-year	5,720
20%	5-year	10,800
10%	10-year	14,800
4%	25-year	20,100
2%	50-year	24,400
1%	100-year	29,000
0.5%	200-year	33,700
0.2%	500-year	40,200

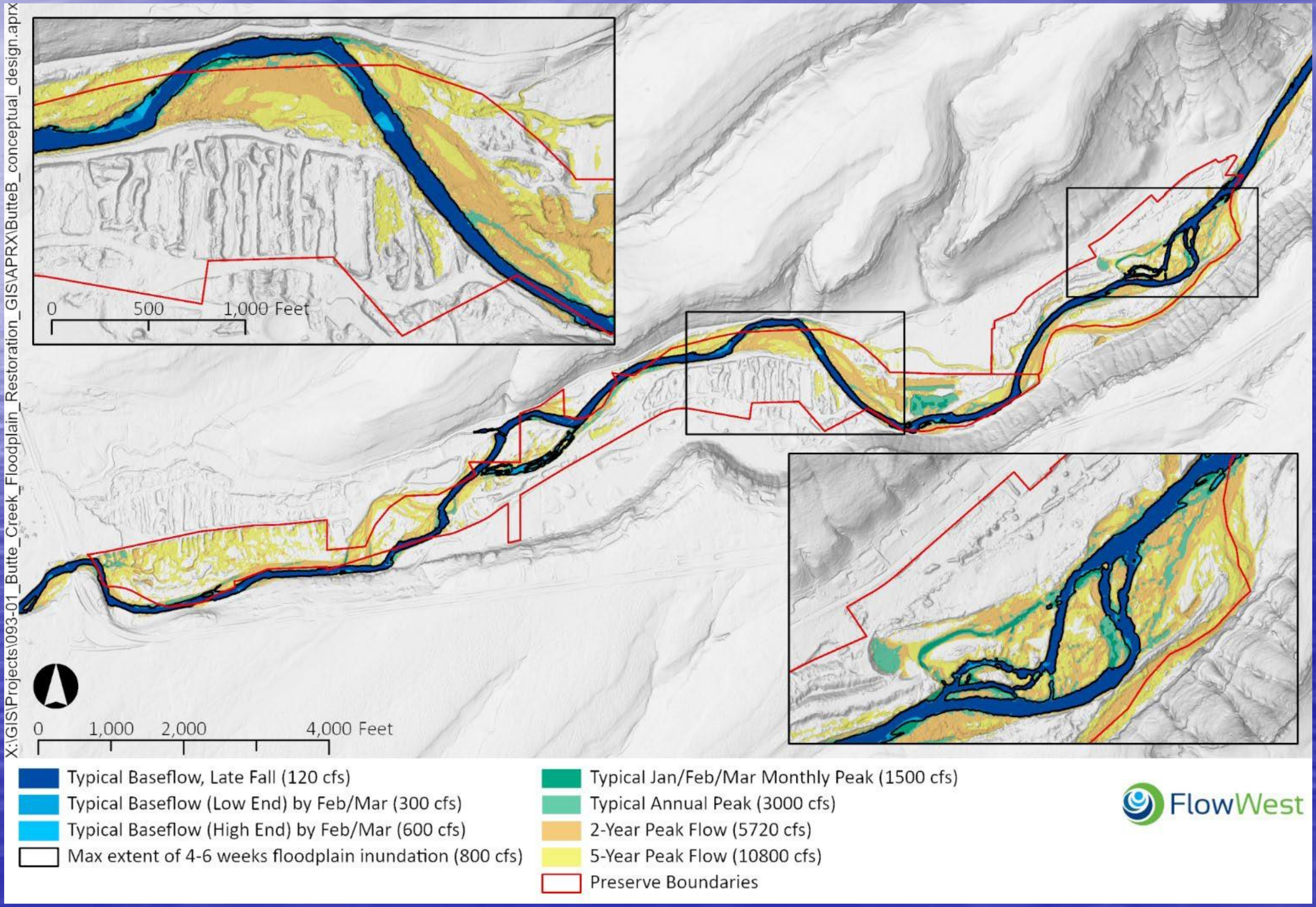
Source: FlowWest flow frequency analysis based on USGS 11390000 streamgage

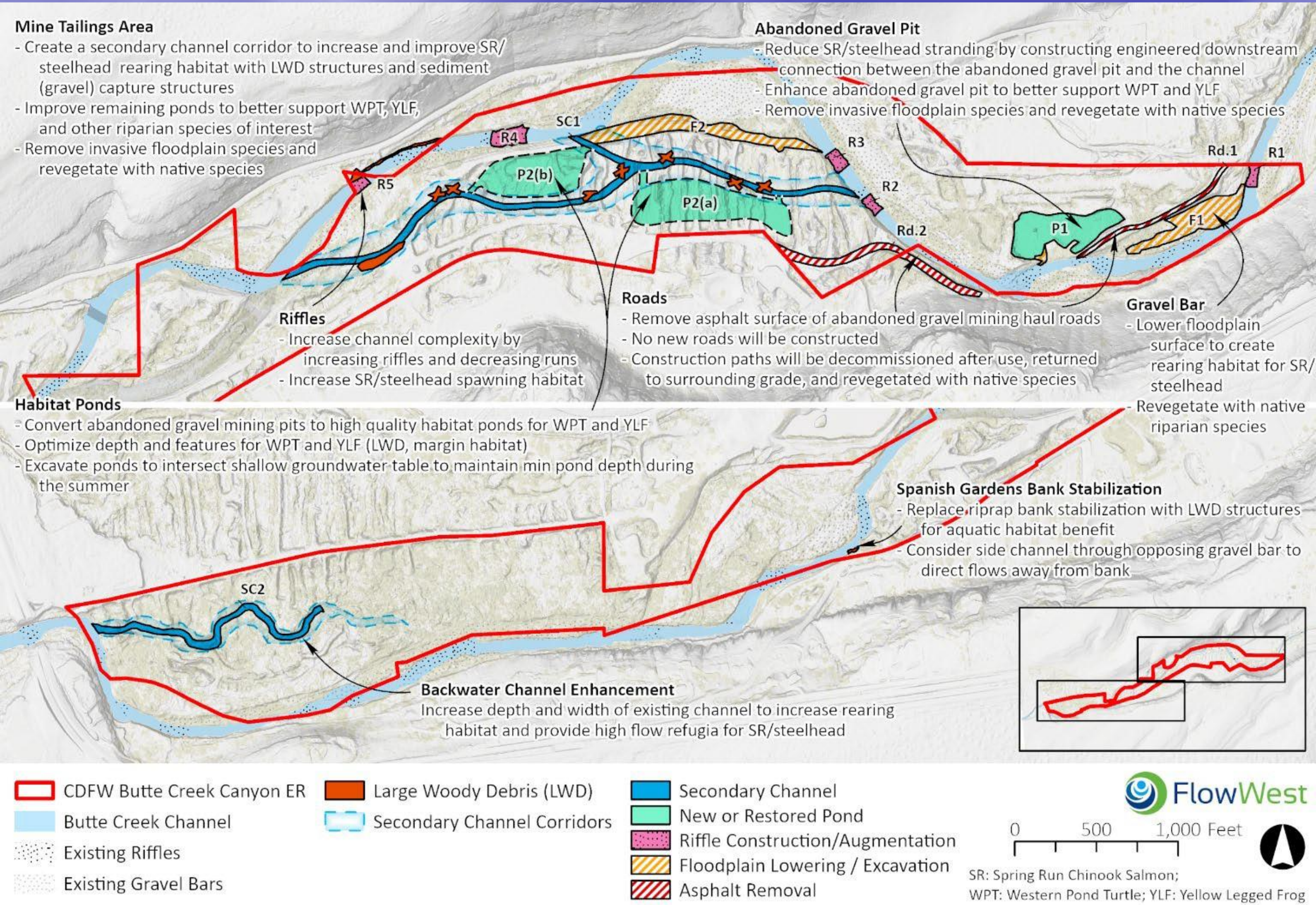
Observed Functional Flows

	Median Observed
Dry-season baseflow	122 cfs
Dry-season high baseflow	184 cfs
Dry-season start	July 31
Dry-season duration	126 days
Fall pulse magnitude	221 cfs
Fall pulse start	28 Oct
Fall pulse duration	3 days
Wet-season baseflow	258 cfs
Wet-season median flow	530 cfs
Wet-season start	December 6
Wet-season duration	149 days
Spring recession magnitude	938 cfs
Spring start	May 16
Spring duration	78 days
Spring rate of change	3%

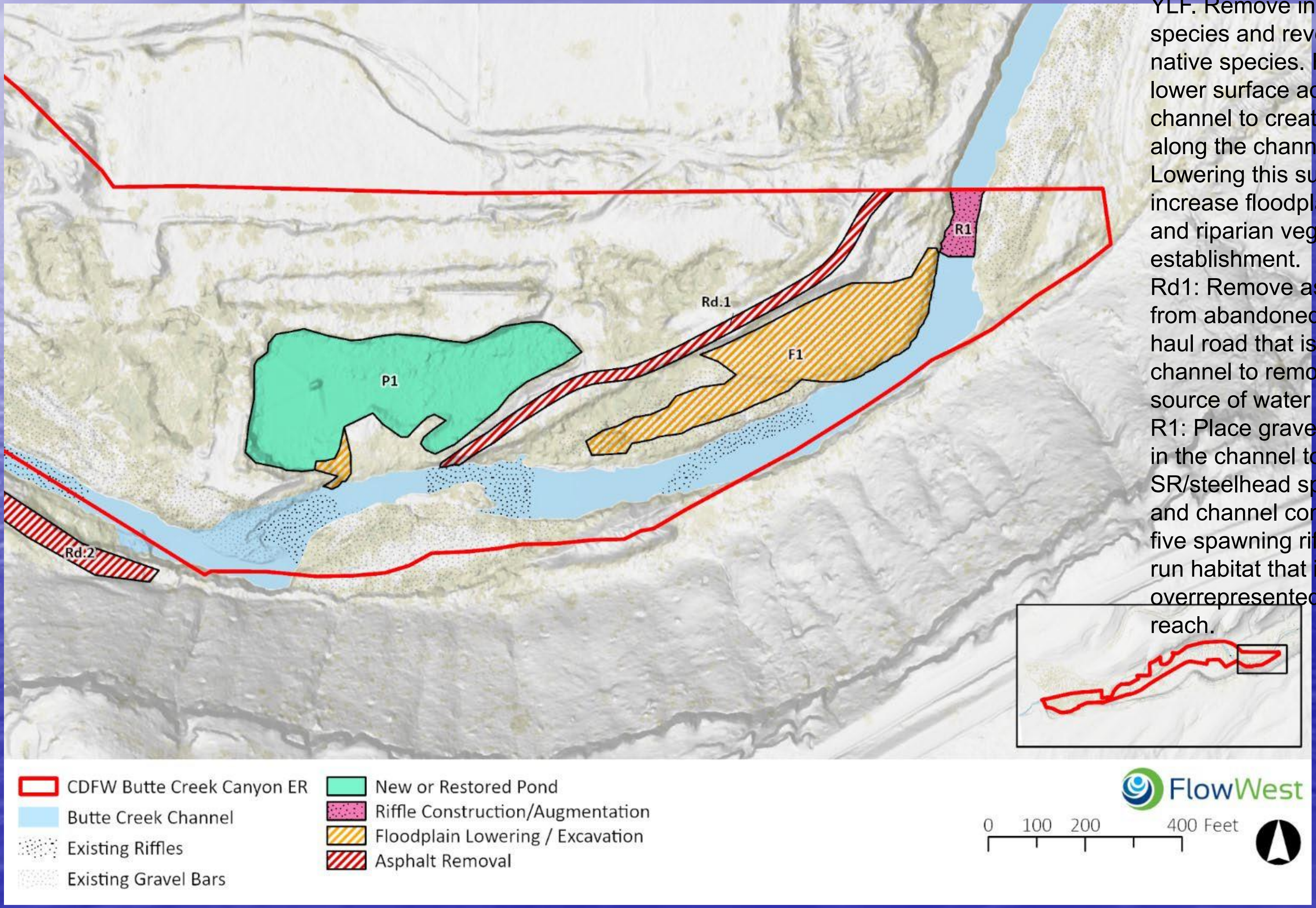
California Environmental Flows Working Group (CEFWG). California Natural Flows Database: Functional flow metrics v1.2.1, May 2021.

Floodplain Inundation




Mine Tailings Area
- Create a secondary channel corridor to increase and improve SR/ steelhead rearing habitat with LWD structures and sediment (gravel) capture structures
- Improve remaining ponds to better support WPT, YLF, and other riparian species of interest
- Remove invasive floodplain species and revegetate with native species
Abandoned Gravel Pit
- Reduce SR/steelhead stranding by constructing engineered downstream connection between the abandoned gravel pit and the channel
- Enhance abandoned gravel pit to better support WPT and YLF
- Remove invasive floodplain species and revegetate with native species
SC1
F2
R4
R3
R5
P2(b)
P2(a)
R2
Rd.1
R1
P1
F1
Rd.2
Riffles
- Increase channel complexity by increasing riffles and decreasing runs
- Increase SR/steelhead spawning habitat
Roads
- Remove asphalt surface of abandoned gravel mining haul roads
- No new roads will be constructed
- Construction paths will be decommissioned after use, returned to surrounding grade, and revegetated with native species
Gravel Bar
- Lower floodplain surface to create rearing habitat for SR/ steelhead
- Revegetate with native riparian species
Habitat Ponds
- Convert abandoned gravel mining pits to high quality habitat ponds for WPT and YLF
- Optimize depth and features for WPT and YLF (LWD, margin habitat)
- Excavate ponds to intersect shallow groundwater table to maintain min pond depth during the summer
Spanish Gardens Bank Stabilization
- Replace riprap bank stabilization with LWD structures for aquatic habitat benefit
- Consider side channel through opposing gravel bar to direct flows away from bank
SC2
Backwater Channel Enhancement
Increase depth and width of existing channel to increase rearing habitat and provide high flow refugia for SR/steelhead
CDFW Butte Creek Canyon ER
Butte Creek Channel
Existing Riffles
Existing Gravel Bars
Large Woody Debris (LWD)
Secondary Channel Corridors
Secondary Channel
New or Restored Pond
Riffle Construction/Augmentation
Floodplain Lowering / Excavation
Asphalt Removal
FlowWest
0
500
1,000 Feet
SR: Spring Run Chinook Salmon;
WPT: Western Pond Turtle; YLF: Yellow Legged Frog

Gravel Pit & Floodplain Enhancement

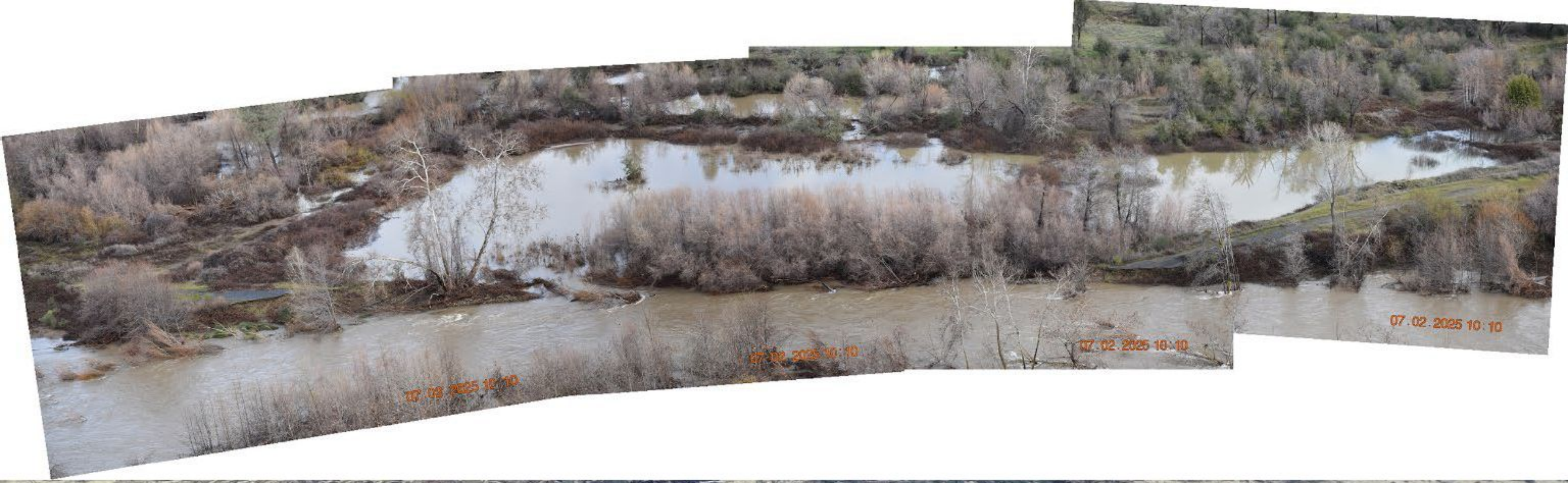


Presenter Notes
2025-05-01 16:48:00

P1: Engineer and construct a connection between downstream extent of the abandoned gravel pit and the channel to eliminate stranding in the pond. Enhance pond banks, optimize pond depth, and add habitat features to the pond to benefit WPT and YLF. Remove invasive floodplain species and revegetate with native species. F1: Excavate a lower surface adjacent to the channel to create rearing habitat along the channel margin. Lowering this surface would increase floodplain inundation and riparian vegetation establishment.

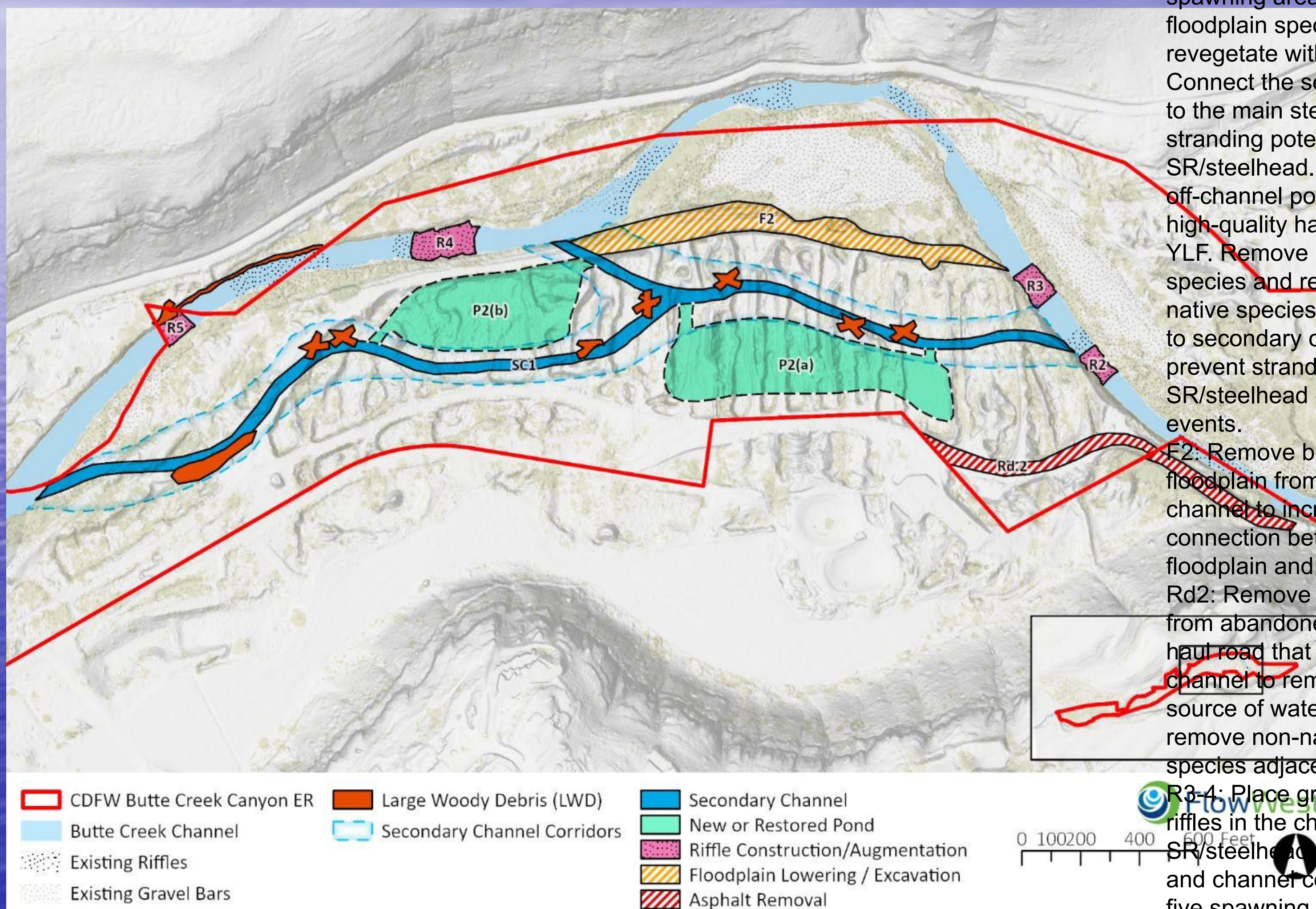
Rd1: Remove asphalt surface from abandoned gravel mining haul road that is eroding into the channel to remove a chronic source of water pollution.

R1: Place gravel to create riffles in the channel to increase SR/steelhead spawning habitat and channel complexity. Create five spawning riffles to break up run habitat that is overrepresented in the project reach.


07.02.2025 10:10
07.02.2025 10:10


Dec 11, 2024

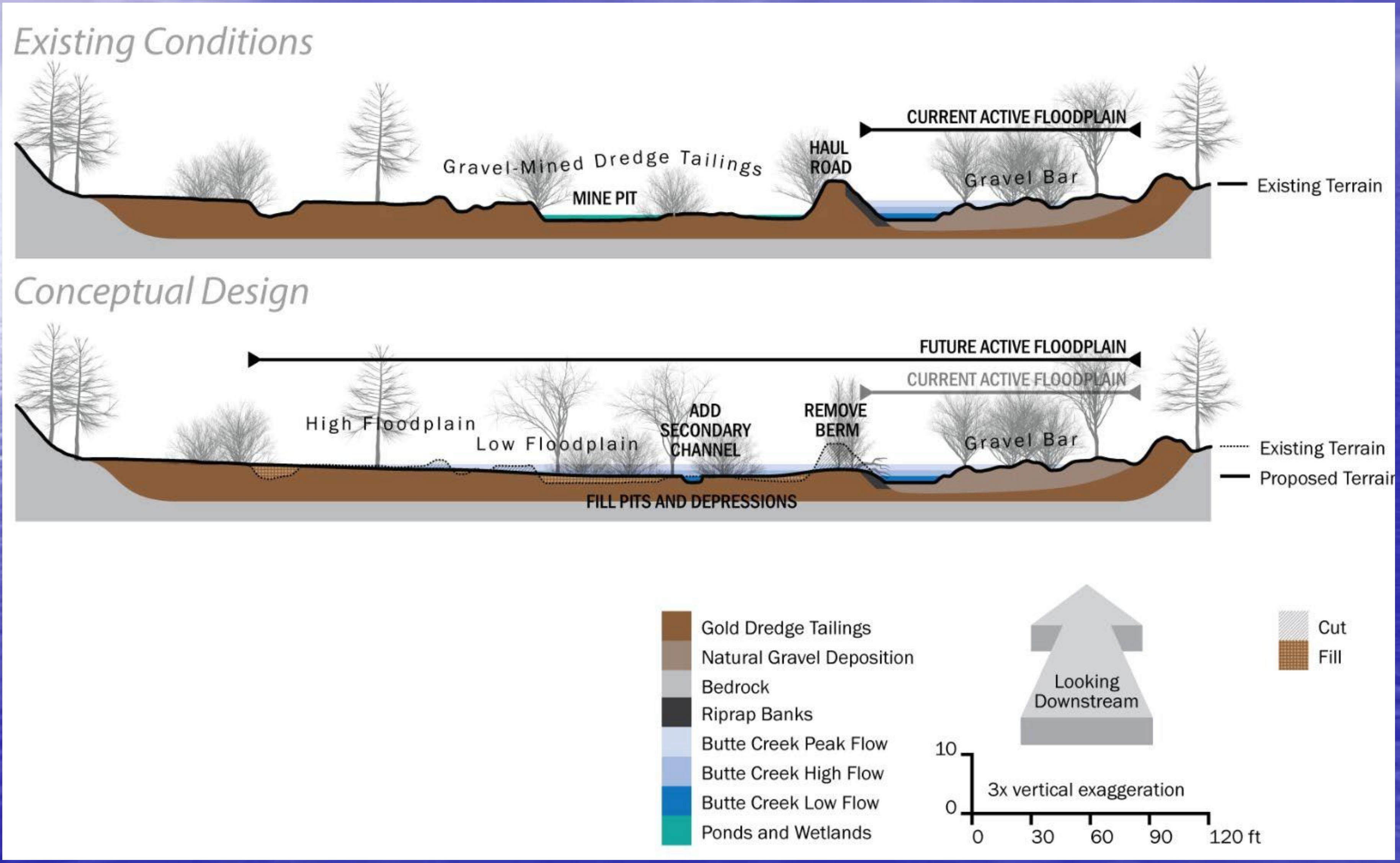
Floodplain Reconnection and Pond Enhancement



Presenter Notes
2025-05-01 16:48:01

SC1: Construct a secondary channel through abandoned, shallow gravel mining ponds to increase rearing habitat, restore physical channel processes, improve riparian vegetation, provide high flow refugia for SR/steelhead, and increase spawning area. Remove invasive floodplain species and revegetate with native species. Connect the secondary channel to the main stem to reduce stranding potential for SR/steelhead. P2a&b: Convert off-channel pond complex into high-quality habitat for WPT and YLF. Remove invasive floodplain species and revegetate with native species. Pond to connect to secondary channel (SC1) to prevent stranding of SR/steelhead during high flow events.
F2: Remove berm separating the floodplain from the active channel to increase the connection between the floodplain and the channel.
Rd2: Remove asphalt surface from abandoned gravel mining haul road that is eroding into the channel to remove a chronic source of water pollution and remove non-native invasive species adjacent to the road.
R3-4: Place gravel to create riffles in the channel to increase SR/steelhead spawning habitat and channel complexity. Create five spawning riffles to break up run habitat that is

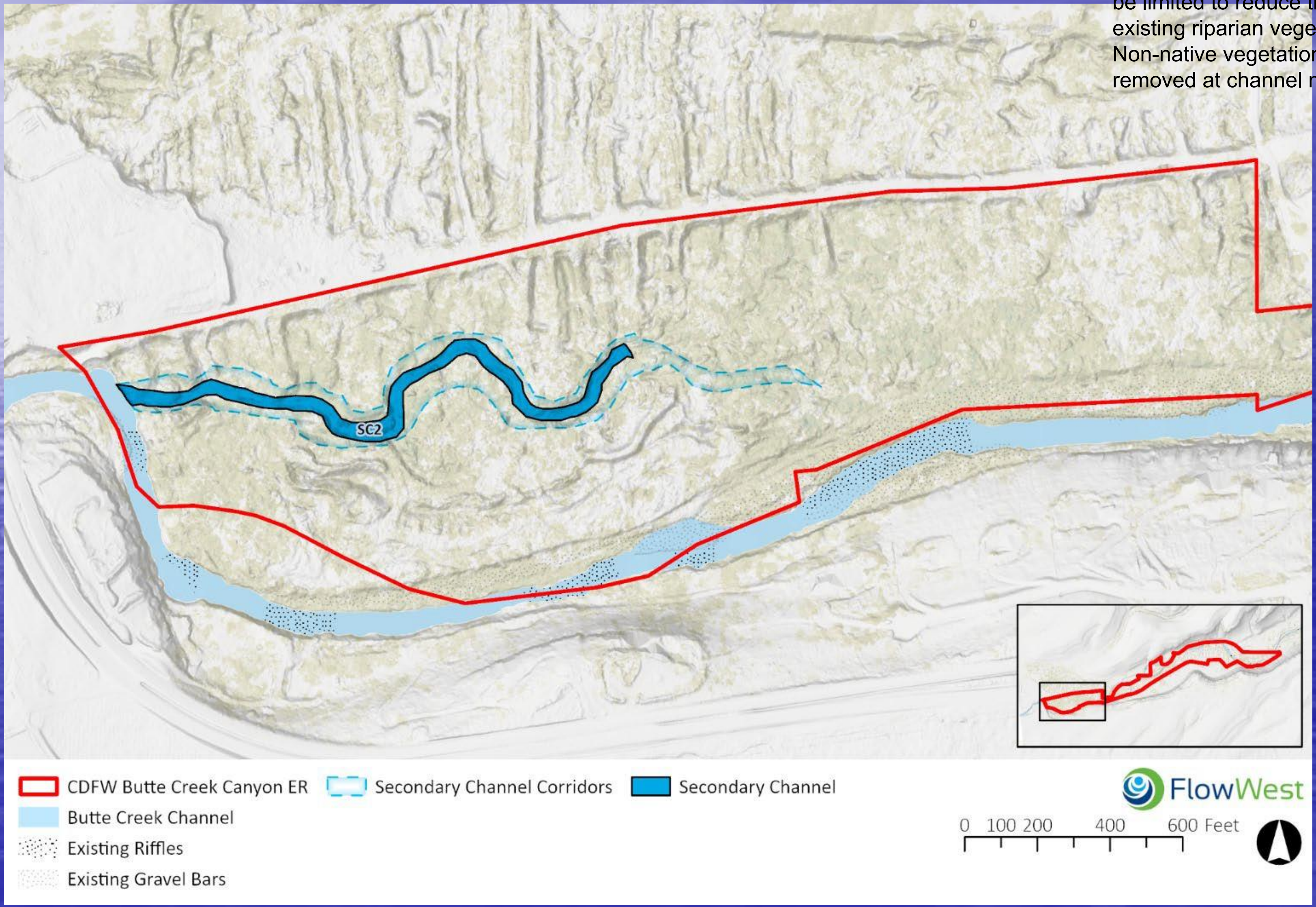
Conceptual Cross Section



Enhanced Backwater Channel

Presenter Notes
2025-05-01 16:48:02

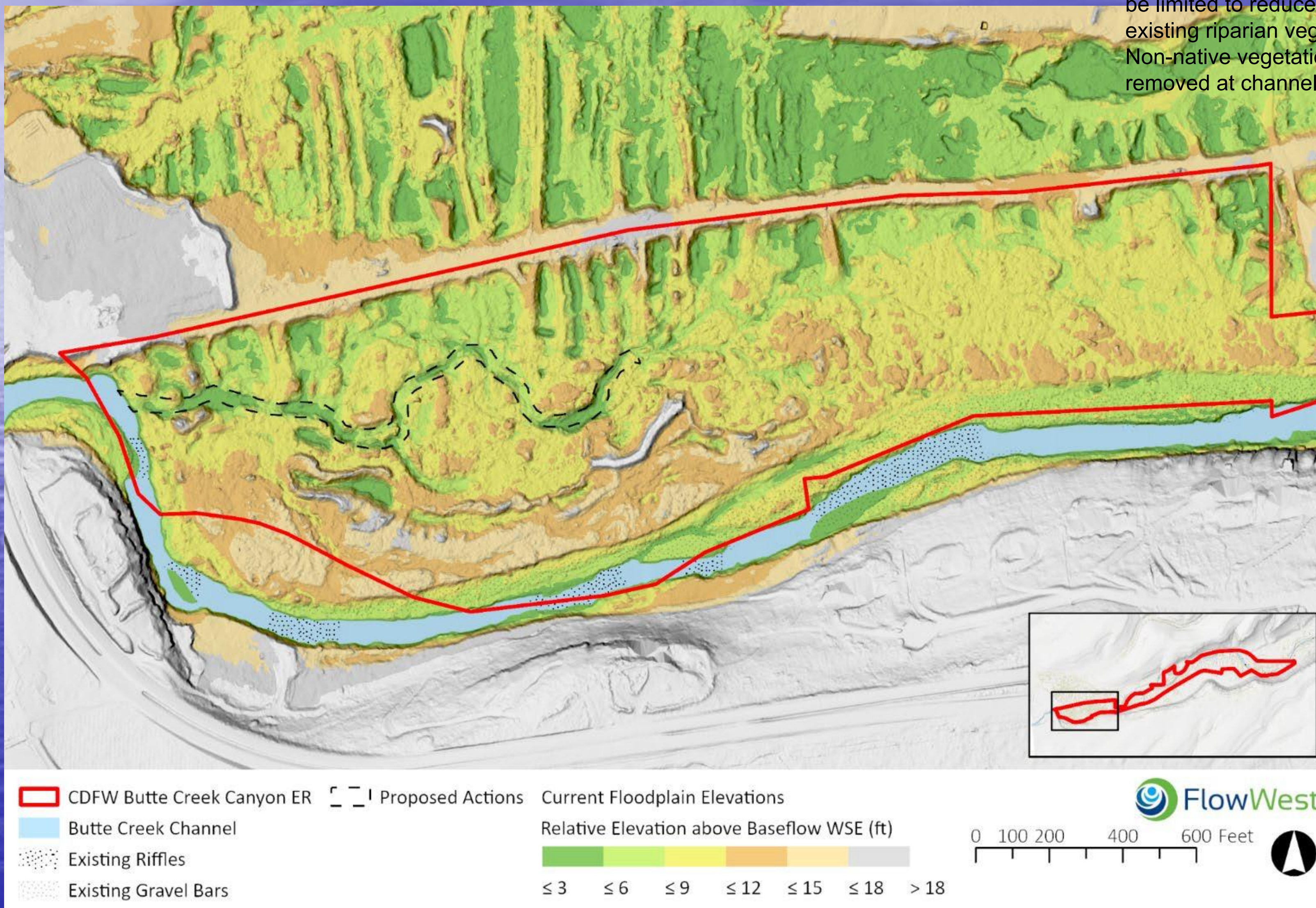
SC2: Expand existing backwater channel and increase connectivity to the main channel. SC2 will fill from downstream and serve as high flow refugia and rearing habitat. Excavation will be limited to reduce the impact to existing riparian vegetation. Non-native vegetation will be removed at channel margins.



Enhanced Backwater Channel

Presenter Notes
2025-05-01 16:48:03

SC2: Expand existing backwater channel and increase connectivity to the main channel. SC2 will fill from downstream and serve as high flow refugia and rearing habitat. Excavation will be limited to reduce the impact to existing riparian vegetation. Non-native vegetation will be removed at channel margins.



Take Action Today!

www.buttecreek.org

And….join our mailing list, donate if you can, and please join us for our

19th Annual Wild and Scenic Film Festival October 4, 2025 Paradise Performing Arts Center

Bringing the Floodplain to Life: Big Notch and Multi-Scale Restoration Efforts in the Yolo Bypass

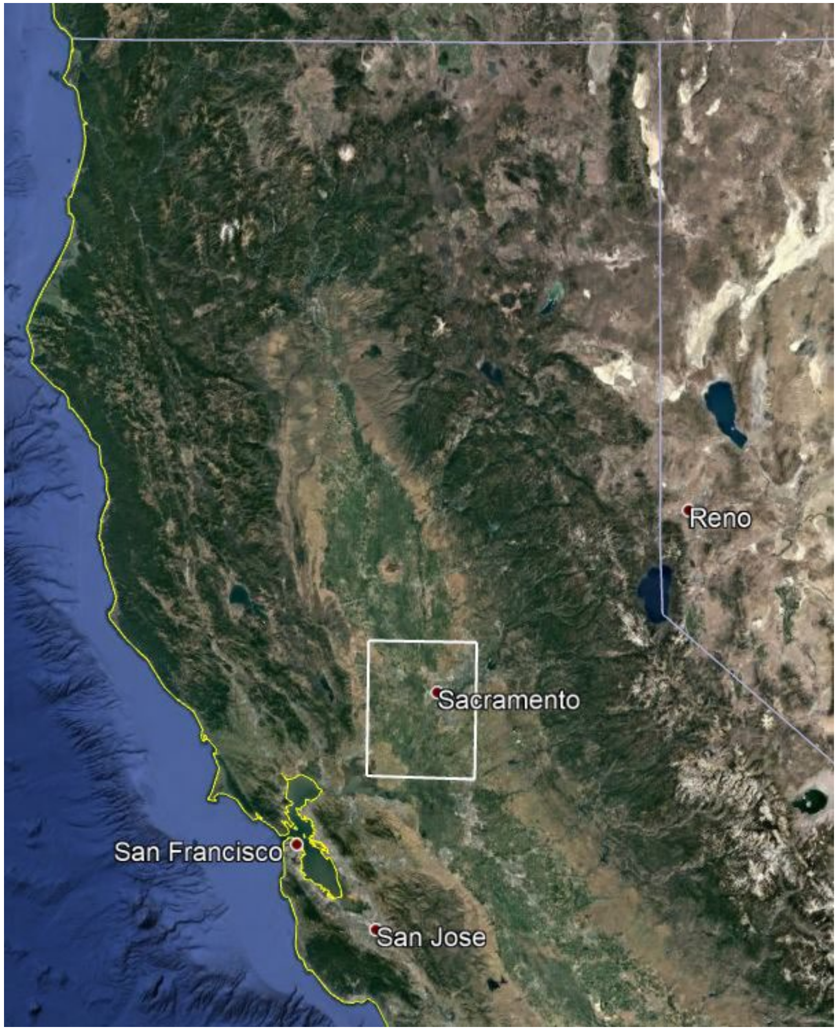
Dennis Finger and Brandy Smith

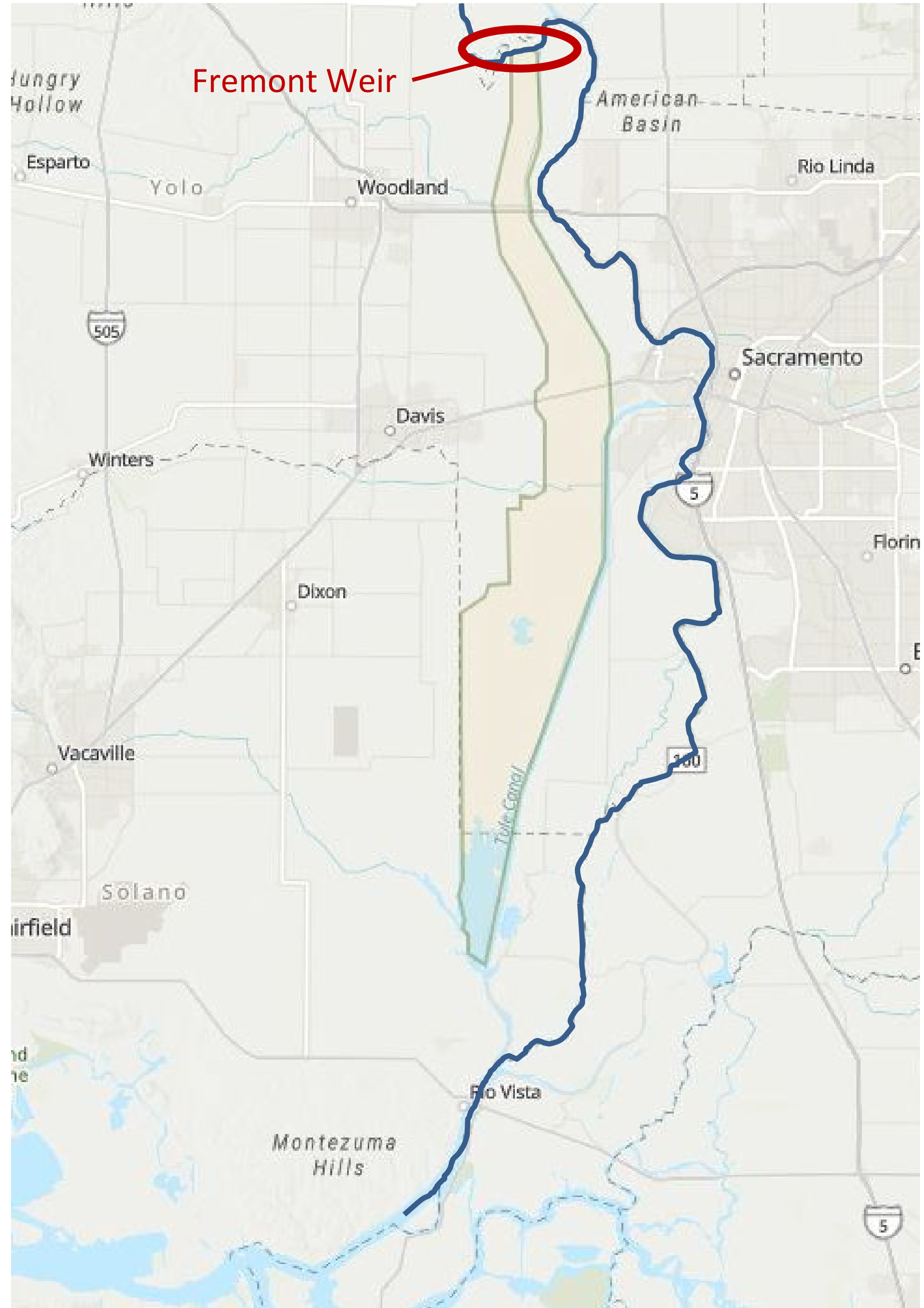
California Department of Water Resources

Outline

- Yolo Bypass and Fremont Weir
- Restoring Natural Flow Processes
- Big Notch Project
- Implications

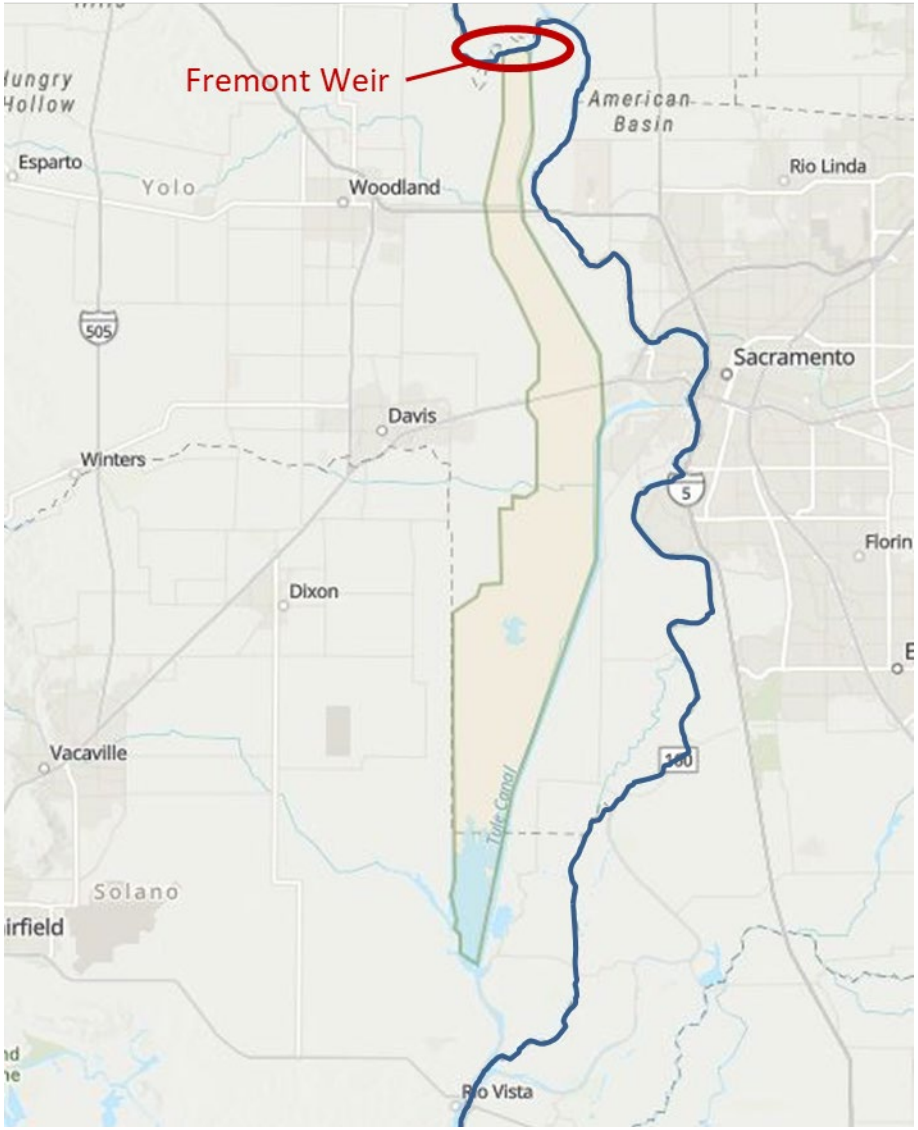
Yolo Bypass


Reno
Sacramento
San Francisco
San Jose


Fremont Weir
Hungry
Hollow
American
Basin
Esparto
Yolo
Woodland
Rio Linda
505
Sacramento
Davis
Winters
5
Florin
Dixon
Vacaville
160
Tule Canal
Solano
irfield
Rio Vista
Montezuma
Hills
5

Yolo Bypass

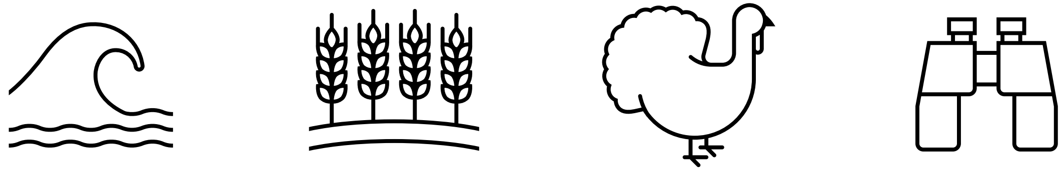
- Largest continuous floodplain remaining in California's Central Valley
- Critical migratory corridor for anadromous fishes
- Essential floodplain habitat for resident fishes





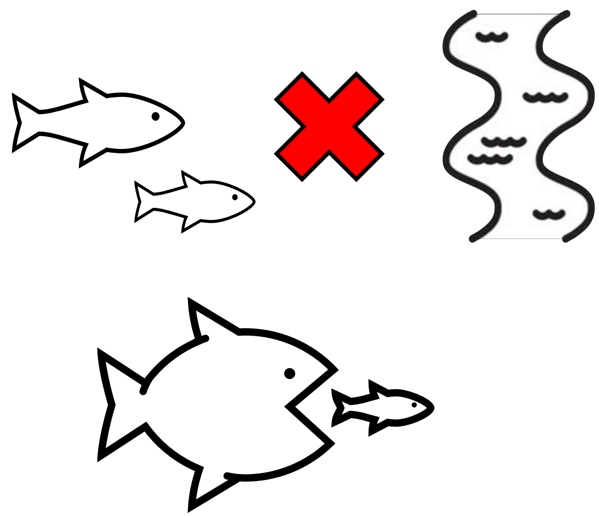

Yolo Bypass

- Multiple land uses



Flood Protection | Agriculture | Hunting | Recreation

- Disrupts natural flow patterns
  - Disconnection of floodplain
  - Fragmented migratory corridors
  - Impacts to foodweb
  - Altered species composition



Fremont Weir

- Installed 1924, 1.8 miles long
- Complete passage barrier, frequent stranding location
- Rescued 10,000+ individual fishes of 19 different species

Restoring Natural Flow Processes

- 43,200+ acres of restoration underway in the Yolo Bypass (approximately 67 $miles^2$)
- 13 projects completed or in progress
- Projects span localized passage improvements to landscape-scale restoration
- Intensively collaborative efforts including multiple agencies and partners

Migratory Passage at Fremont Weir

- 4’ wide fish ladder installed 1965
- **Ineffective!** High velocities, bottom elevation too high for consistent passage, usually closed

Migratory Passage at Fremont Weir

- Fremont Weir Adult Fish Passage Facility completed November 2018
- Operational following overtopping events
- Single gate 15’ wide x 10’ deep

Fremont Weir Adult Fish Passage Facility

Fremont Weir Adult Fish Passage Facility

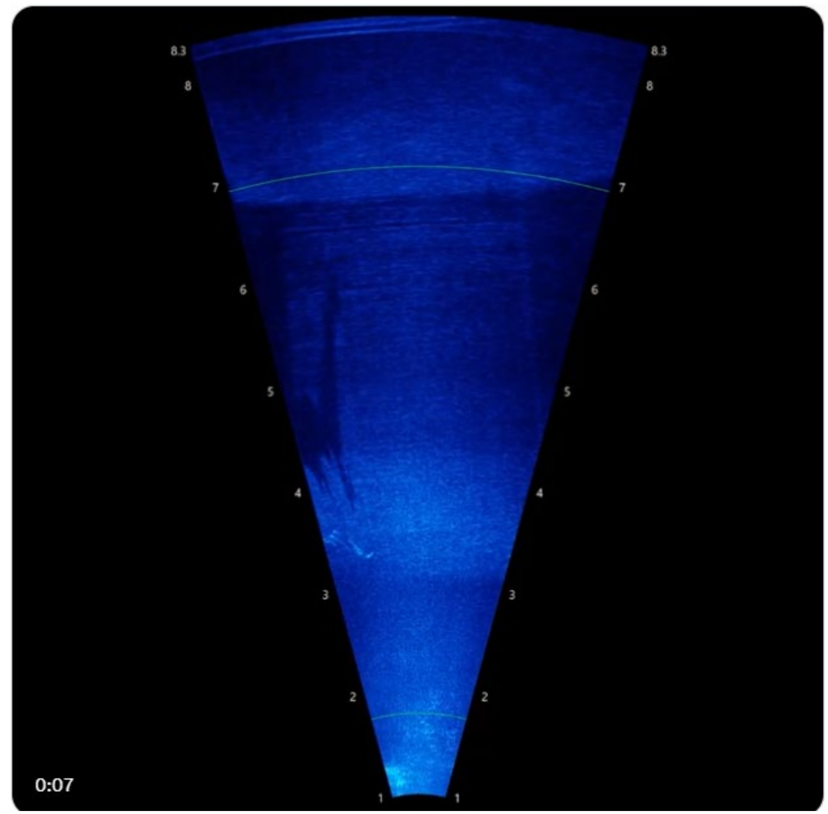
- Sonar monitoring has recorded 136 sturgeon and 4,861+ other fishes (including salmon) pass through the structure so far

CA - DWR
@CA_DWR

Caught on camera! Sonar video shows two sturgeon swimming through DWR's Adult Fish Passage at Fremont Weir.

State, federal, & local agencies collaborated with DWR for the fish passage's emergency operation, which saw THOUSANDS of fish swim through.

#fish #marchstorms



Fish Rescue Operations

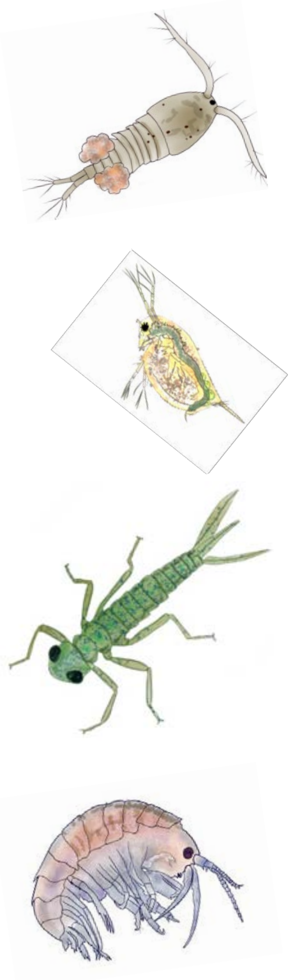
- Wallace Weir Fish Rescue Facility averages 315 adult Chinook Salmon rescued each year
- CDFW rescue operations following overtopping events and to address isolated strandings

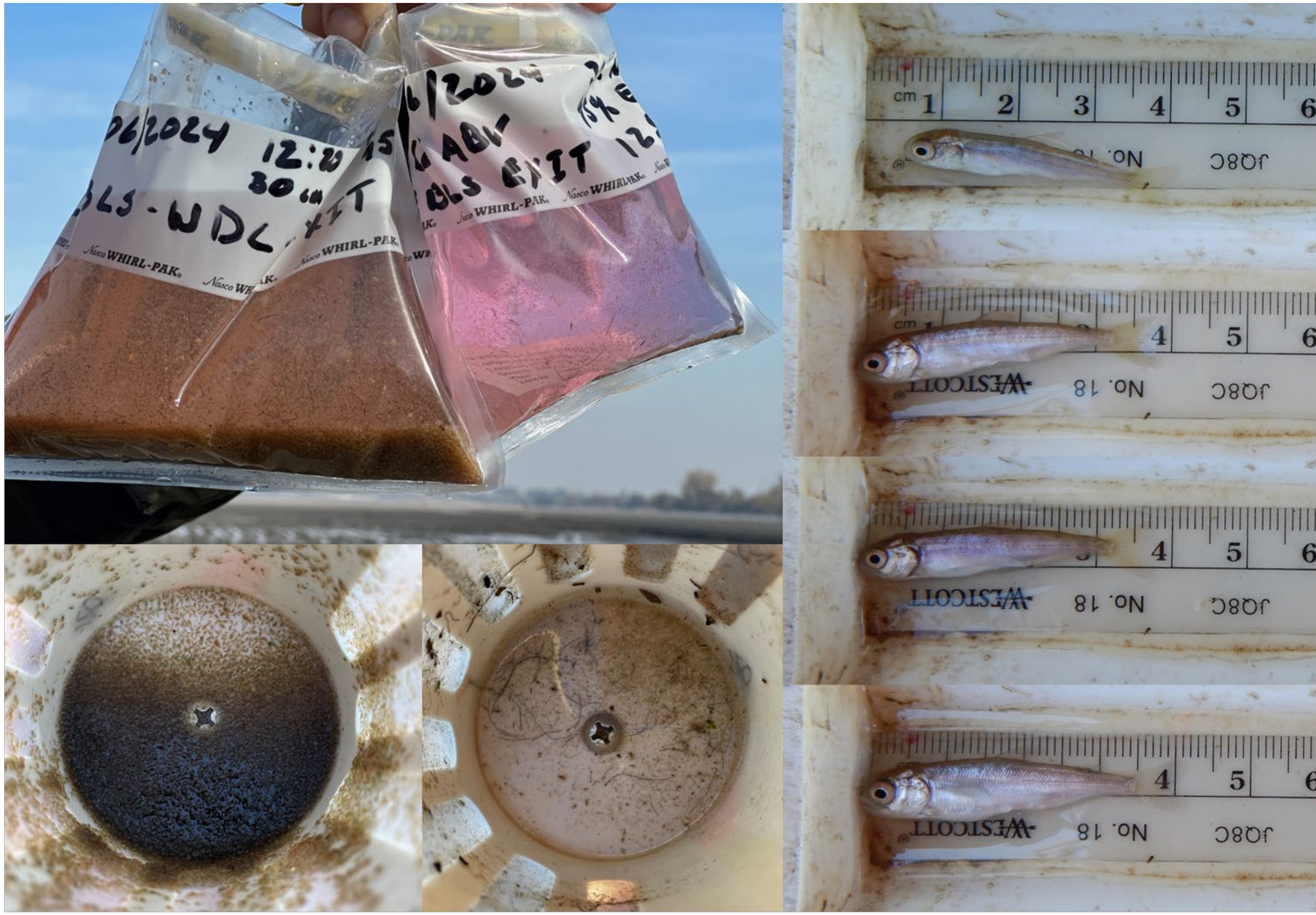
Flood Protection

Lower Elkhorn Basin Levee Setback Project

- Flow improvements throughout Yolo Bypass
- Increases the flood conveyance capacity of Yolo Bypass by 65,000 cfs

Floodplain salmonid rearing habitat



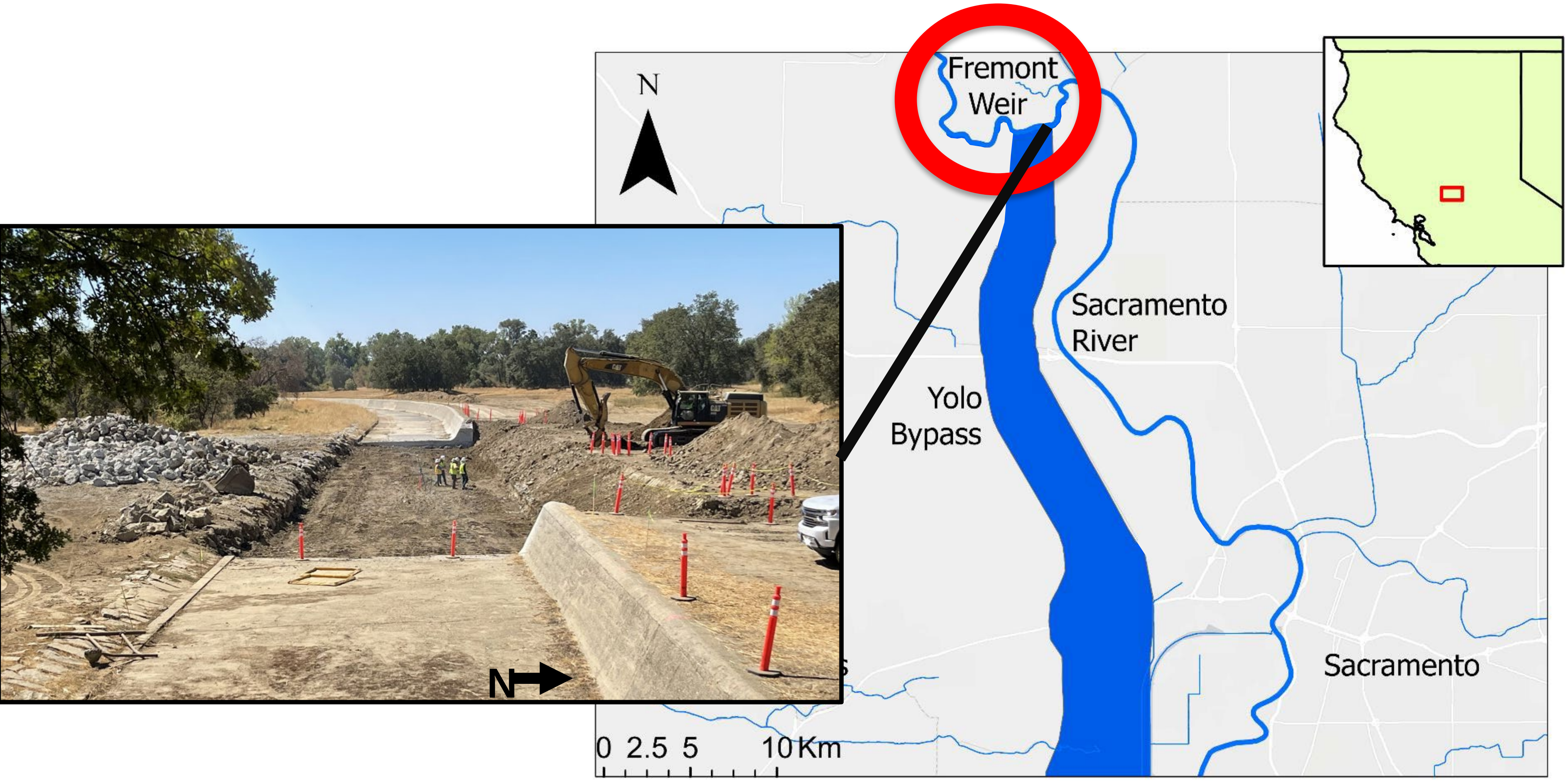


Eric Holmes, DWR

- Increasing inundated area within Yolo Bypass for food web benefits
- Increasing water retention time to bolster invertebrate production
- Lower Elkhorn Basin Levee Setback and Big Notch Projects

DWR Division of Multibenefit Initiatives & Integrated Science and Engineering

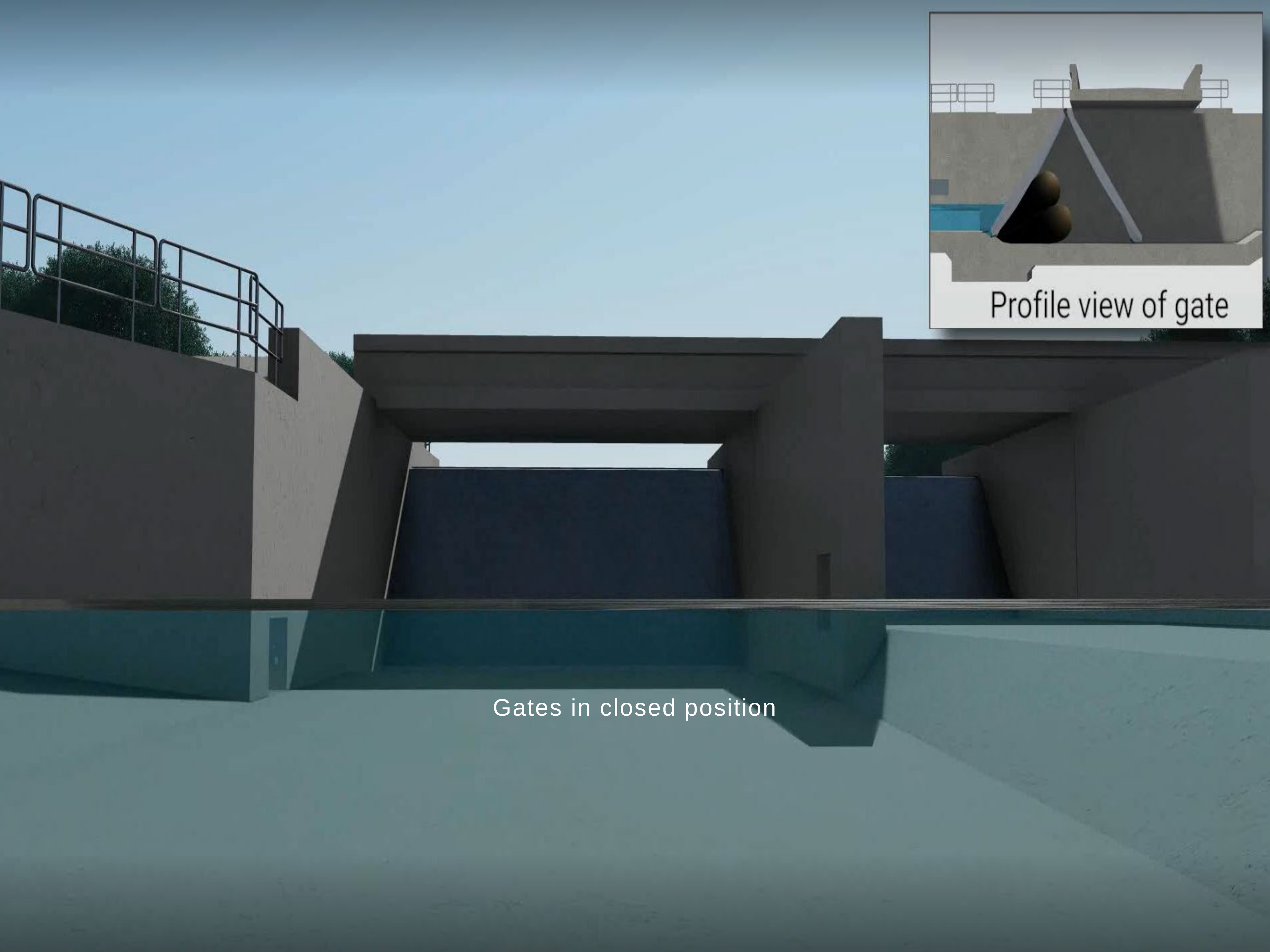
Case study: Big Notch



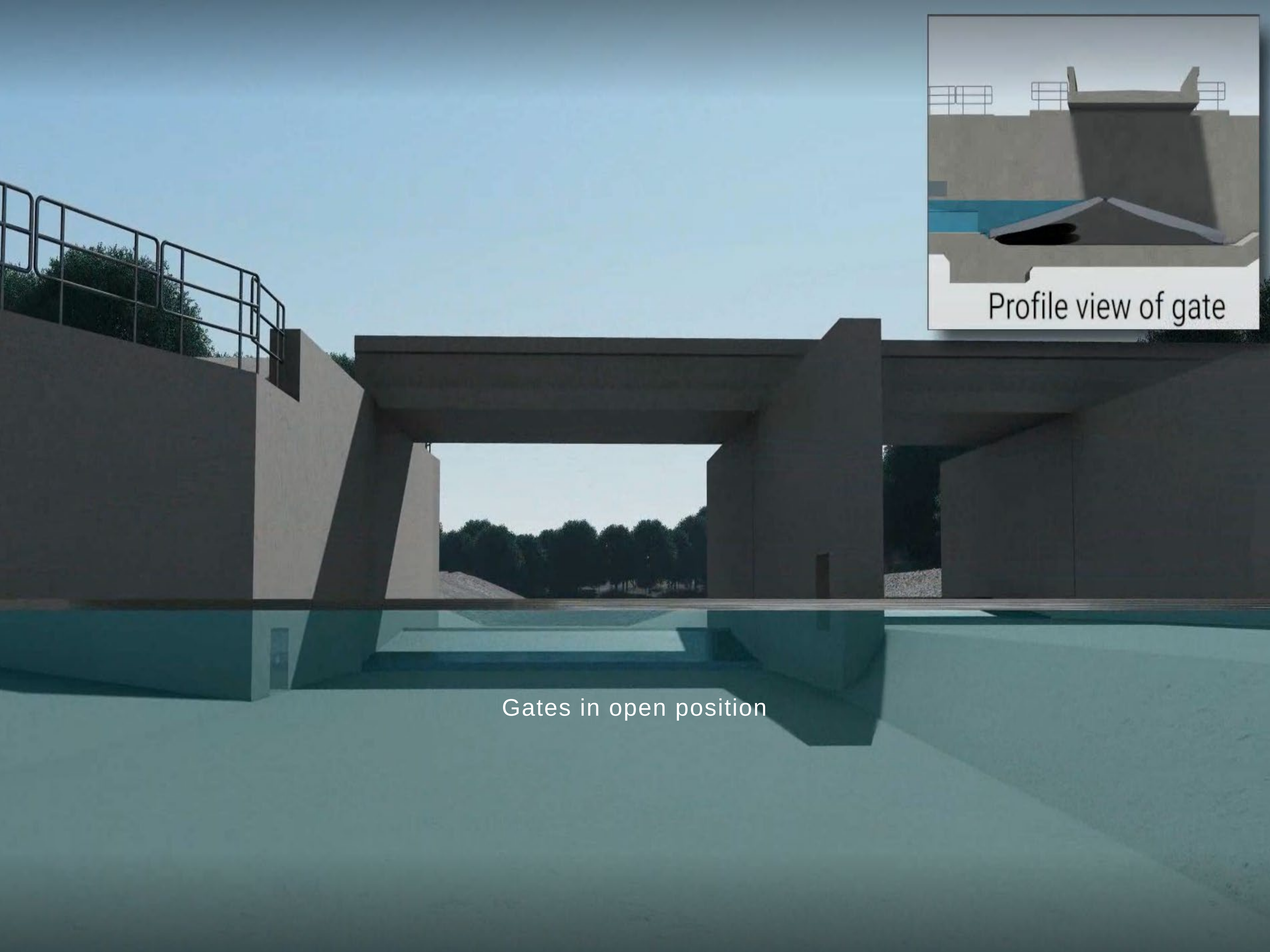
- Processes: floodplain salmonid rearing habitat & migratory passage


Yolo Bypass
N
Fremont Weir
Sacramento River


1
2
3
Gate 1: 18’ h x 34’ w
Gates 2 & 3: 14’ h x 27’w
Operation: Nov 1 – Mar 15
N



Gates in closed position


Profile view of gate
Gates in open position

Construction progress

June 2022:
Groundbreaking

Construction progress

June 2022: Groundbreaking

Channel excavation

Construction progress

June 2022: Groundbreaking

Channel excavation

Concrete placement

Construction progress

June 2022: Groundbreaking

↓

Channel excavation

↓

Concrete placement

Construction progress

June 2022: Groundbreaking

Channel excavation

Concrete placement

Gate installation and testing

Construction progress

June 2022: Groundbreaking

Channel excavation

Concrete placement

Gate installation and testing

Estimated project completion: Fall 2025


THEN WHAT?

Adaptive management studies

- Need a way to monitor project effectiveness
- Therefore, we are planning a series of adaptive management studies, including but not limited to:
  - ARIS sonar imagery
  - Juvenile salmon routing
  - Downstream stage monitoring
  - Adult salmon acoustic telemetry

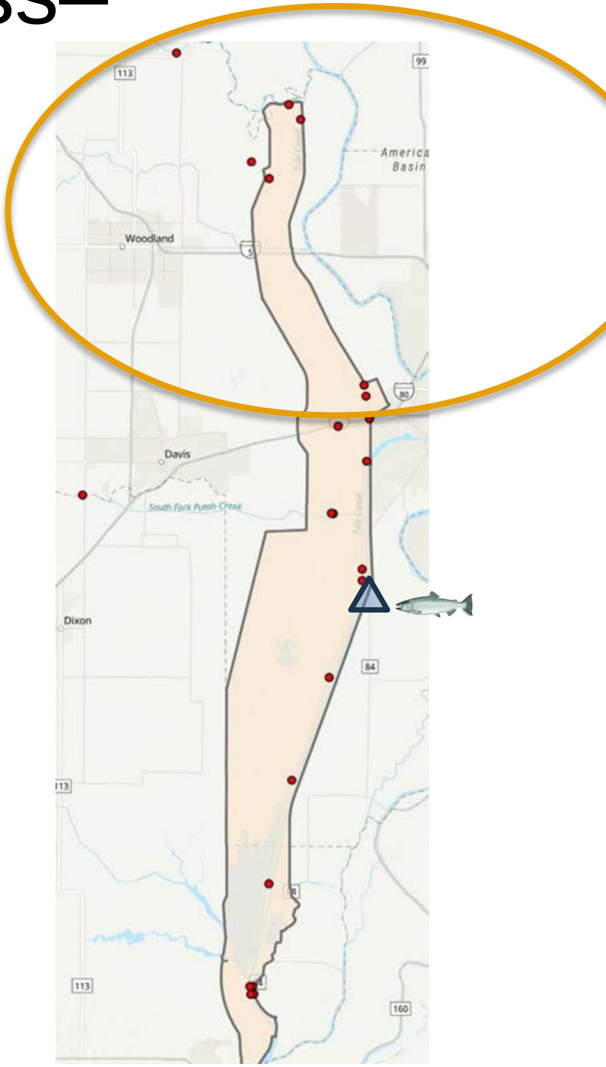
Adult fall-run Chinook tagging study

- Ongoing in Yolo Bypass since 2012
- Caught 141 salmon from 2022-24
- Results: where did they go?

Gill netting (video by DWR DISE UAV team/JT Casby)

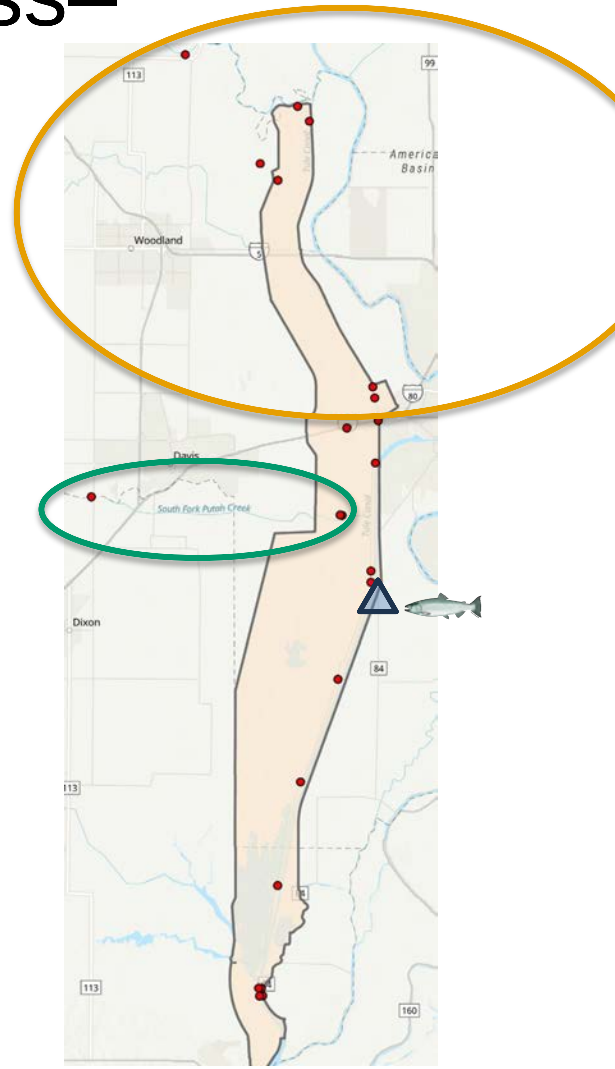
Salmon movement within bypass– Final detections

	2022-2024
Northern bypass	



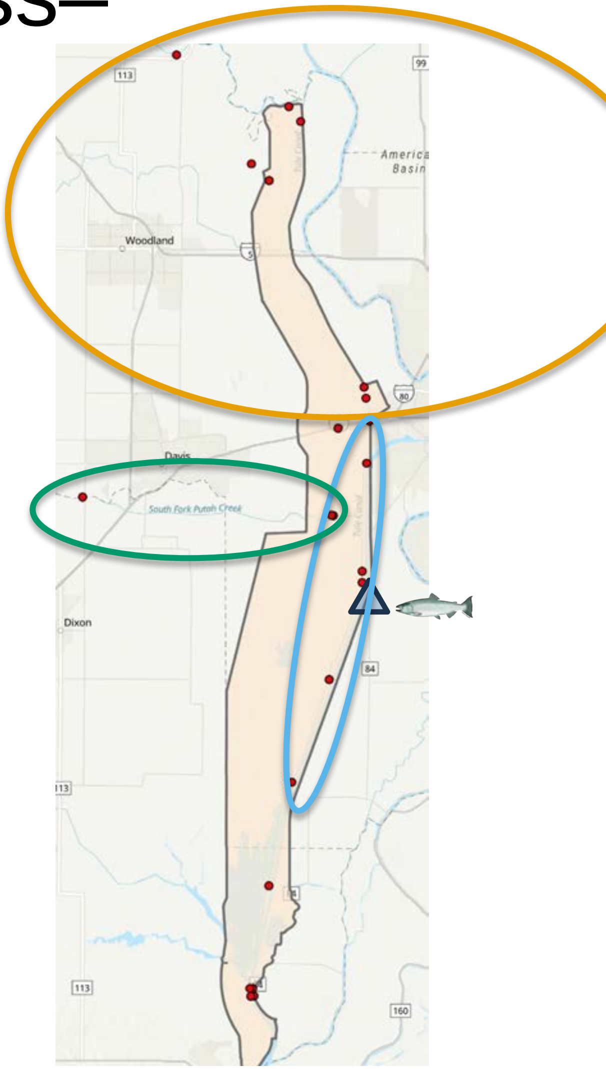
Salmon movement within bypass– Final detections

	2022-2024
Northern bypass	16%
Putah Creek	



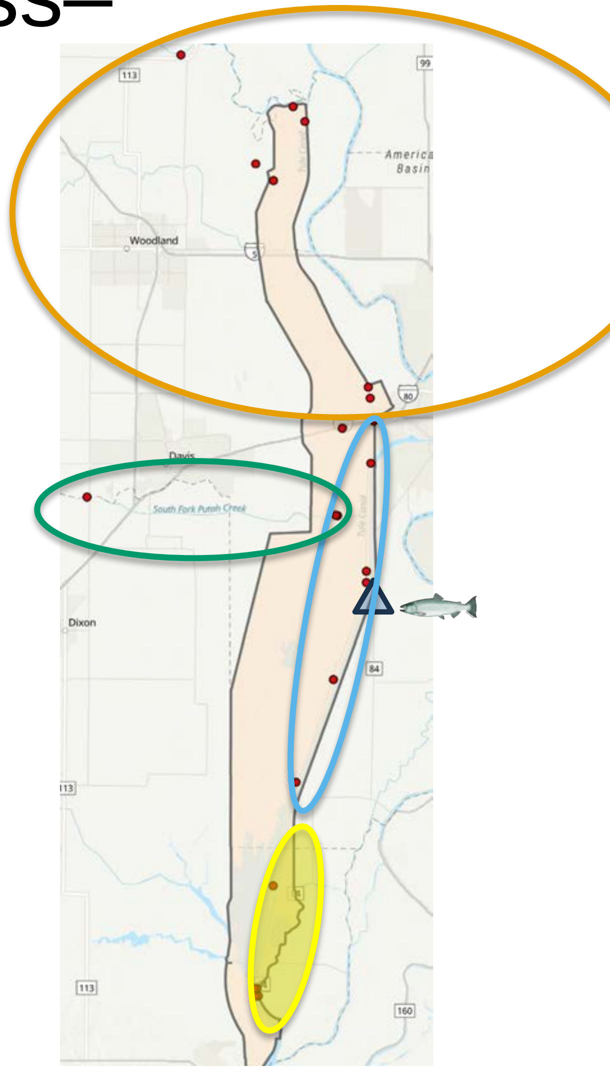
Salmon movement within bypass– Final detections

	2022-2024
Northern bypass	16%
Putah Creek	18%
Central bypass	



Salmon movement within bypass– Final detections

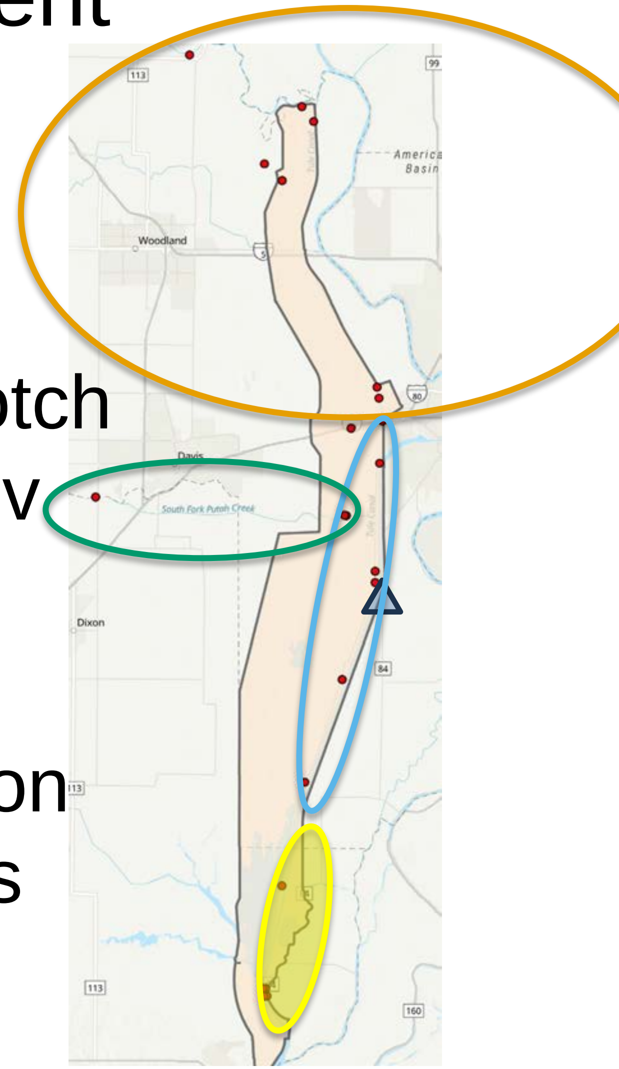
	2022-2024
Northern bypass	16%
Putah Creek	18%
Central bypass	39%
Southern bypass	



How may adult salmon movement change with Big Notch?

	2022-2024	2025?
Northern bypass	16%	
Putah Creek	18%	
Central bypass	39%	
Southern bypass	27%	

- 2025: Big Notch can open Nov 1st
- 2024: 31/42 tagged salmon still in bypass Nov 5th



Discussion: Implications of Yolo Bypass process restoration

- Big Notch: new migratory route and floodplain inundation available soon
- Synergy of restoration projects and ecosystem processes in Yolo Bypass
- Change in hydrology in Delta region
- More studies coming soon via adaptive management

Thank you!

Restoration Ecology Unit

- Hundreds of collaborators across DWR and IEP agencies for restoration and studies
- Brandy.Smith@water.ca.gov
- Dennis.Finger@water.ca.gov
- BigNotch@water.ca.gov for project-specific questions



Fish Rescue Operations

- Wallace Weir Fish Rescue Facility averages 315 adult Chinook Salmon rescued each year
- CDFW rescue operations following overtopping events and to address isolated strandings

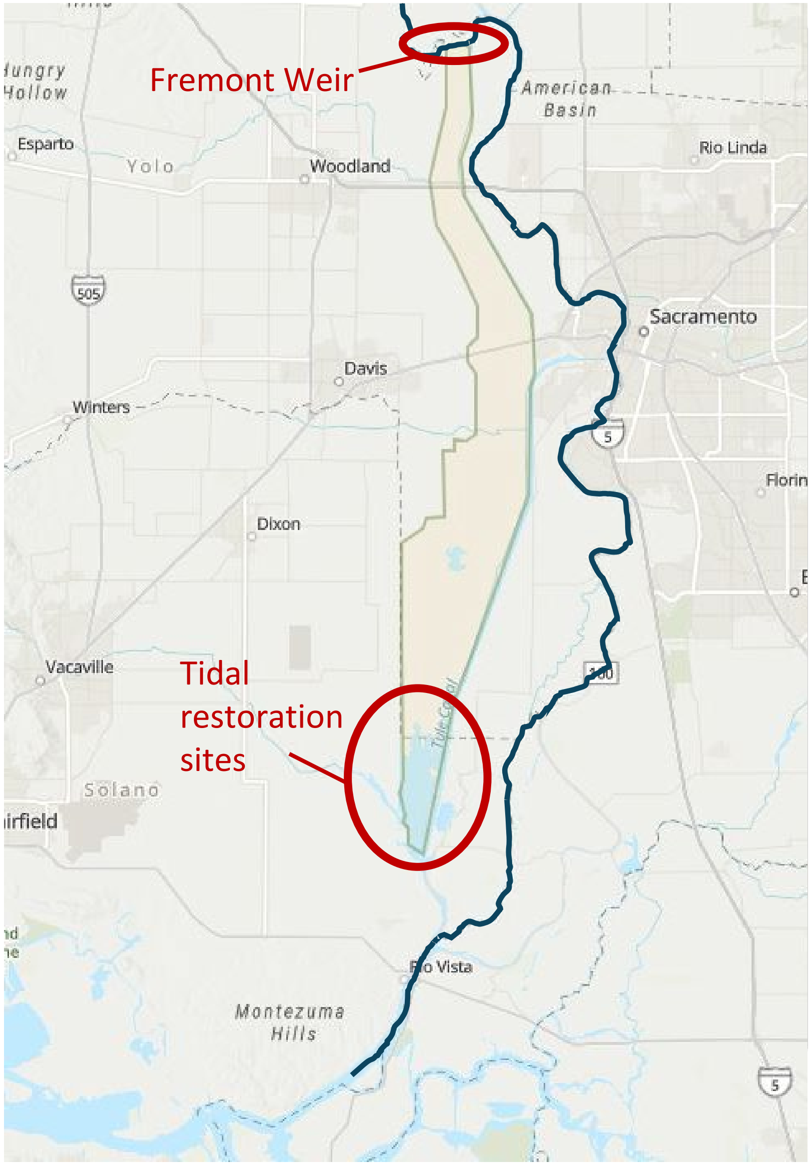
CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

108 RECLAMATION DISTRICT

Tidal Restoration

- Creating different habitat features to benefit juvenile and adult Chinook Salmon
  - Deep benthic swales, shallow benthic plains, tidal wetlands, and floodplain habitat
  - Additional benefits to Delta Smelt and White Sturgeon

- Projects include: Lookout Slough, Little Egbert, Tide's End, Lower Yolo Ranch, and Yolo Flyaway Farms



cbec eco engineering A Verdantas Company → verdantas Eco Engineering

SRF 2025

2025-05-01

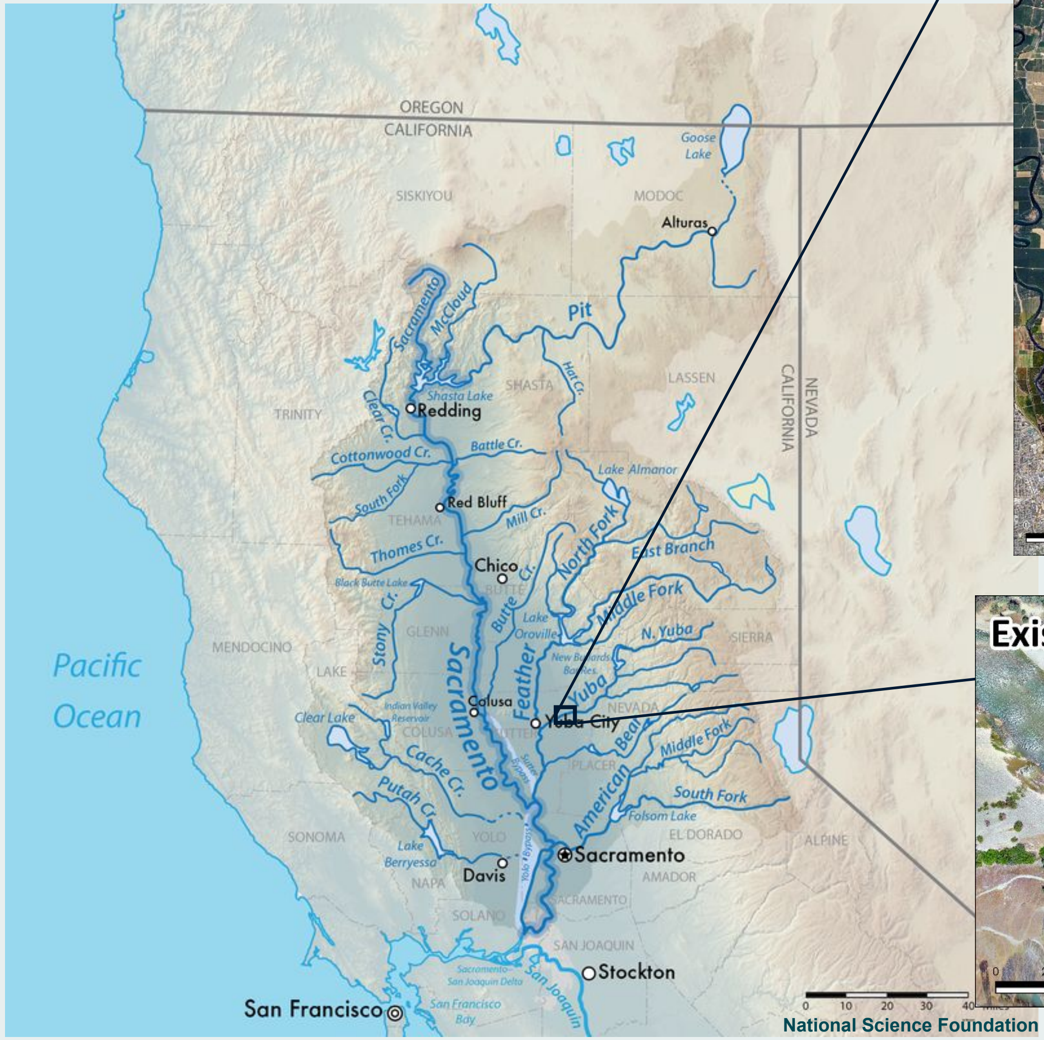
Geomorphic Progression, Habitat Use and Sustainability on a Floodplain Reconnection Project

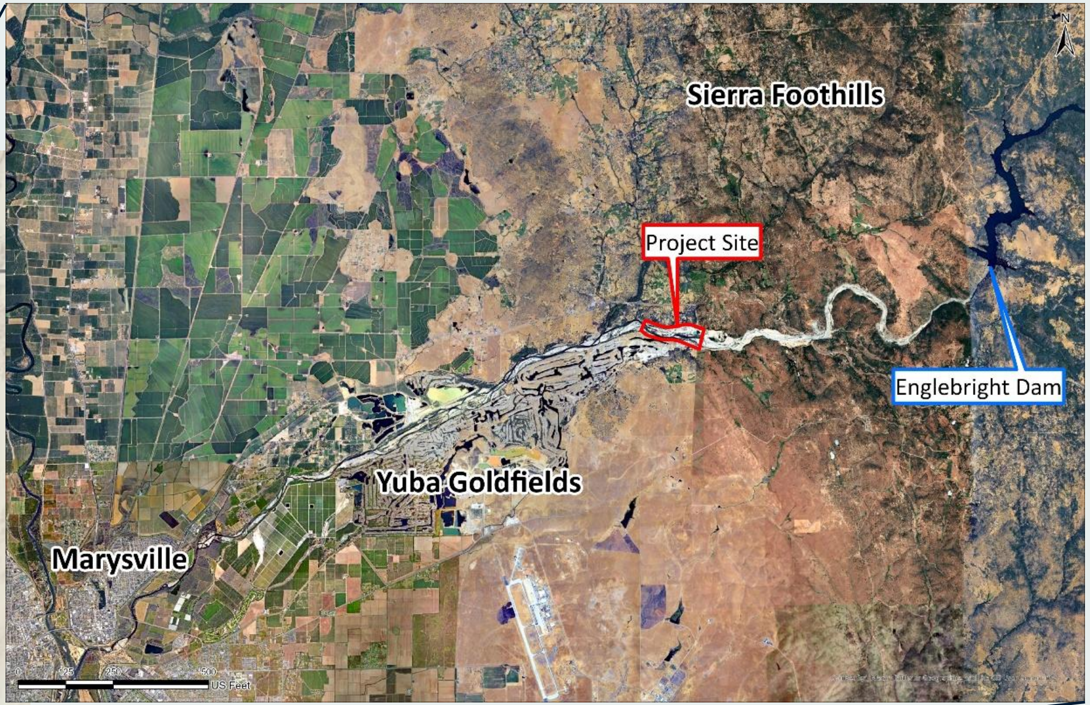
Yuba River, CA

Sam Diaz (cbec, Verdantas)

Coauthors:
Chris Hammersmark, Sam Diaz (cbec, Verdantas)
Kirsten Sellheim, Avery Scherer (Cramer Fish Sciences)
Aaron Zettler-Mann, Danielle Conway (SYRCL)
Paul Cadrett (USFWS)

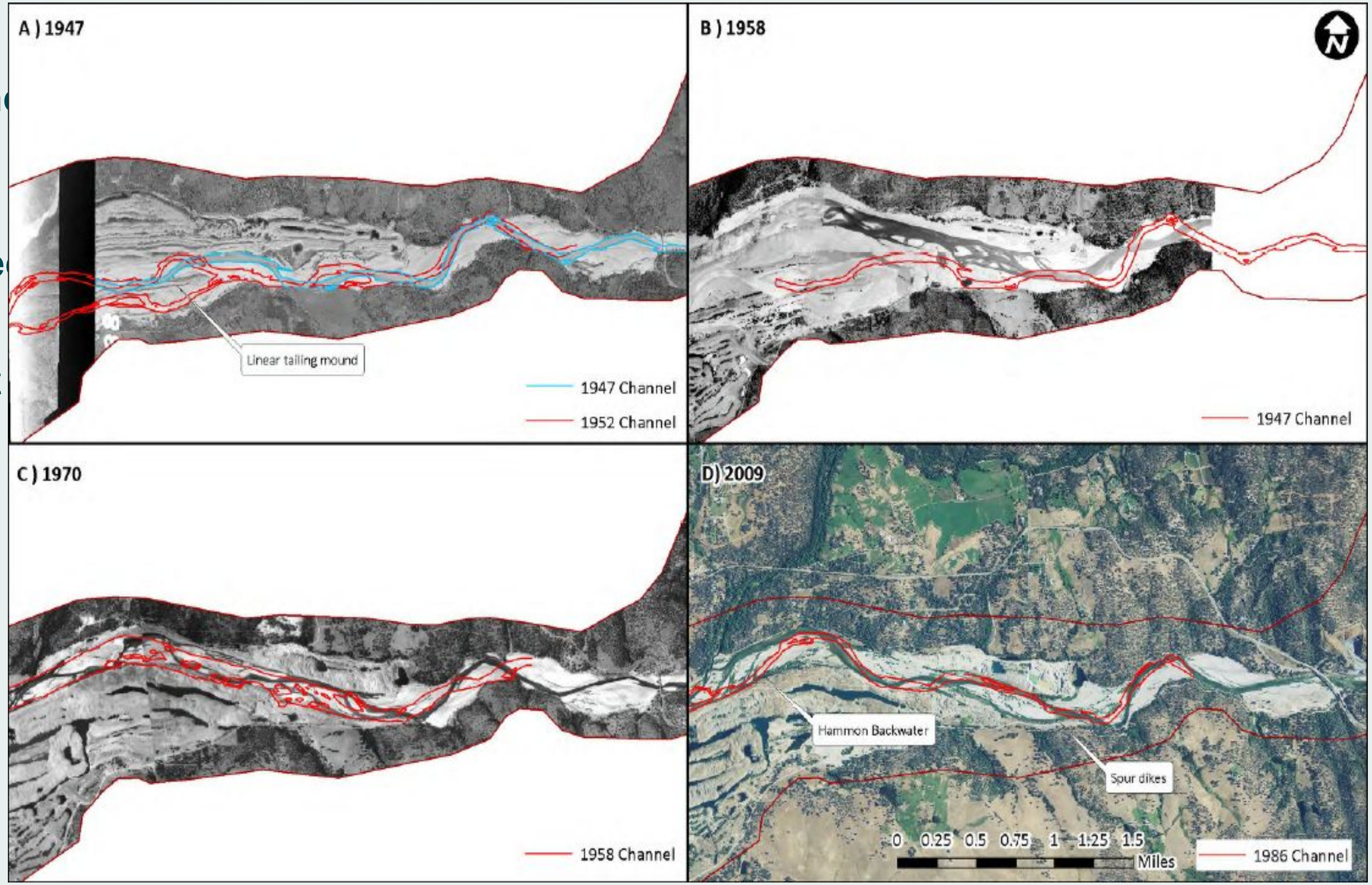
Project Location





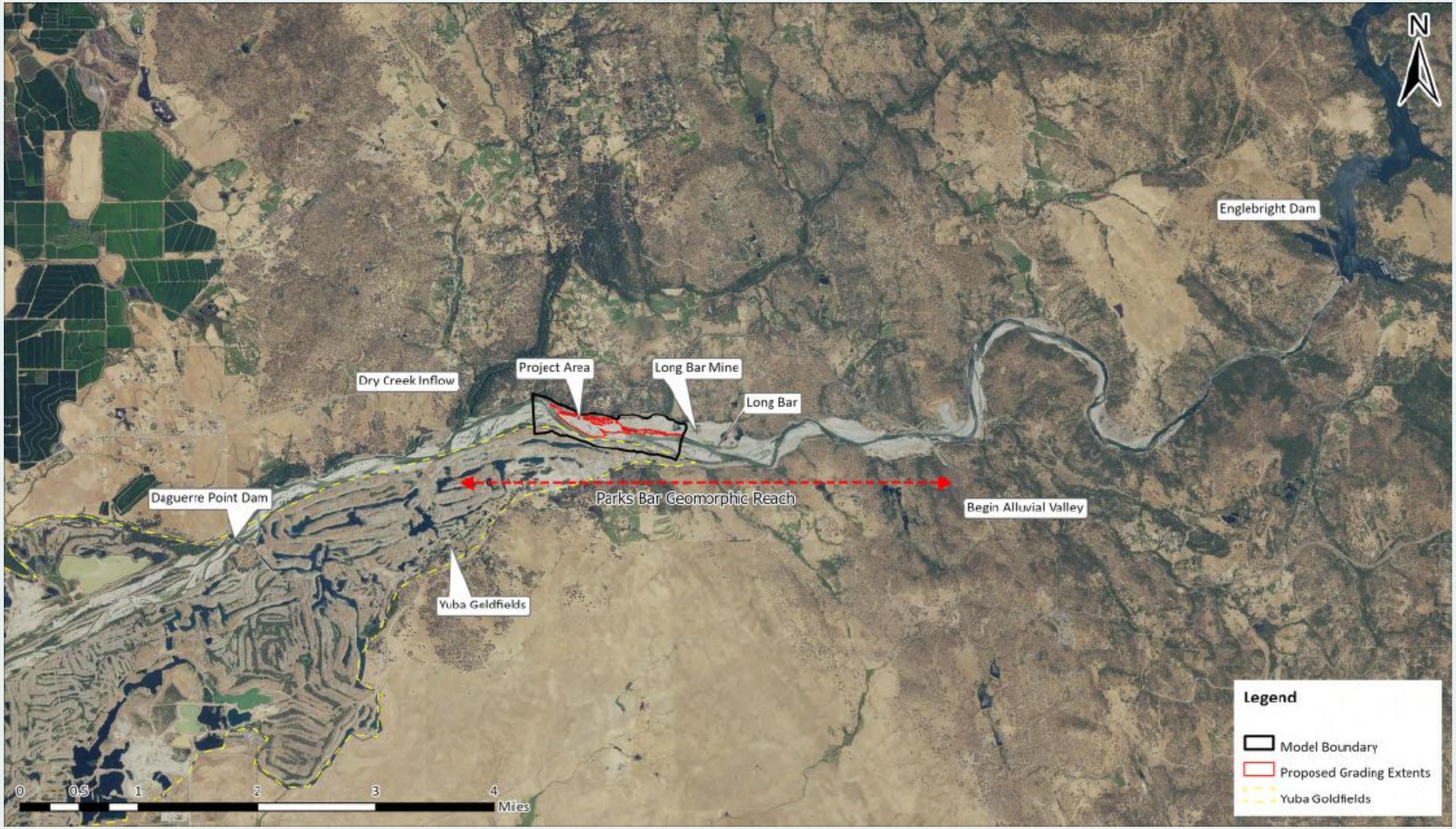
Historical Context

- 685 million CY of sediment washe
  (1853-1884)
- 331 million CY of sediment settle
- Estimated 32 ft of aggradation at
- Rapid channel incision followed
- Dredge mining bed and banks



Hydrology

Geomorphology



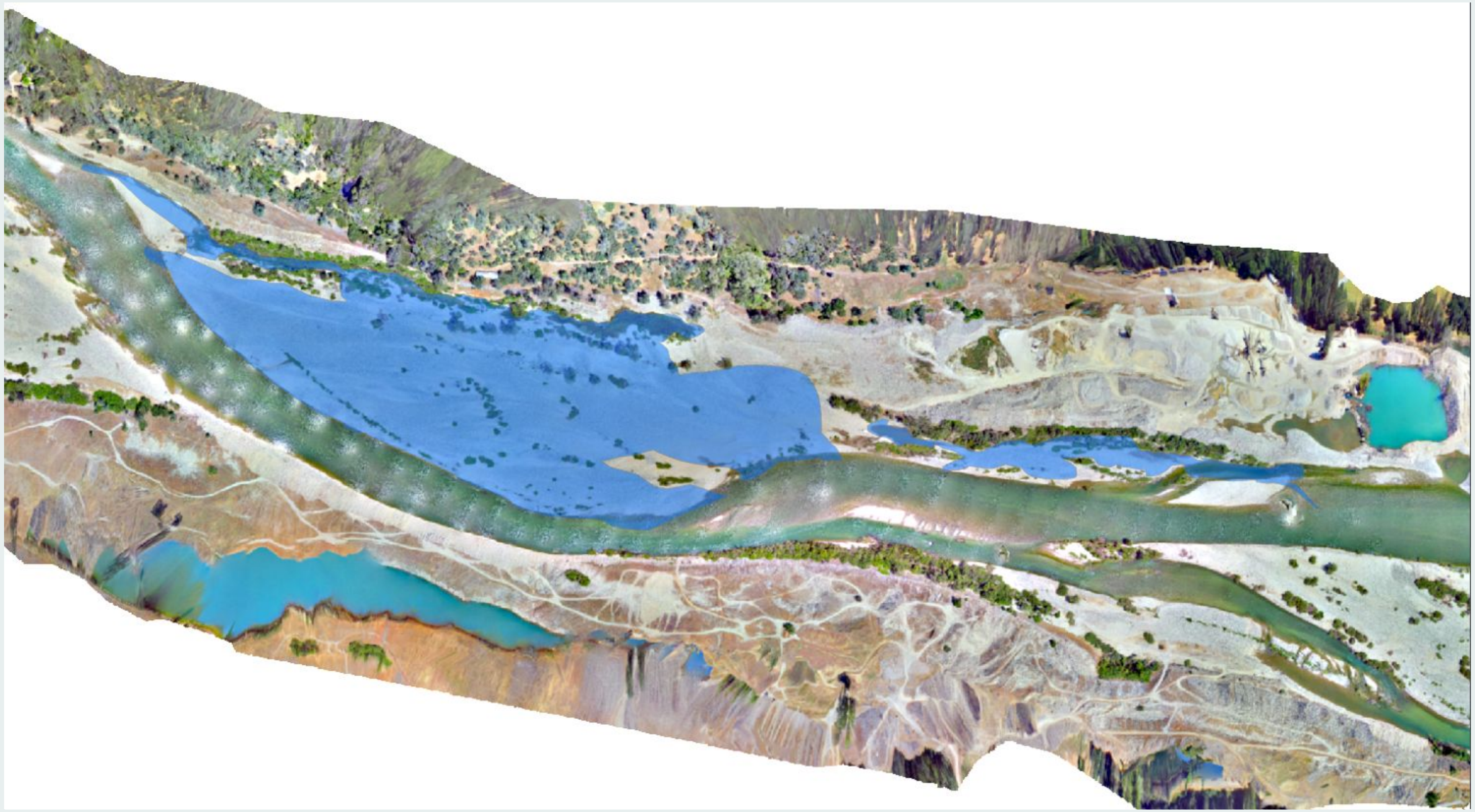
Significance of Yuba River

- The Yuba River still sees dynamic fround
- Historically productive
- Cold water...
  - Good spawning conditions
  - Slower growth rates

Project Development

- 2008 – Identify Opportunities
- 2010 – Rehabilitation Concepts
- 2013 – Hydrologic and Geomorp
- 2015 – SYRCL Relationship Bui

Project Partnership Opportunity



Project Goals

- Enhance floodplain connectivity and habitat heterogeneity
  - Salmonid rearing habitat
  - Riparian vegetation recruitment

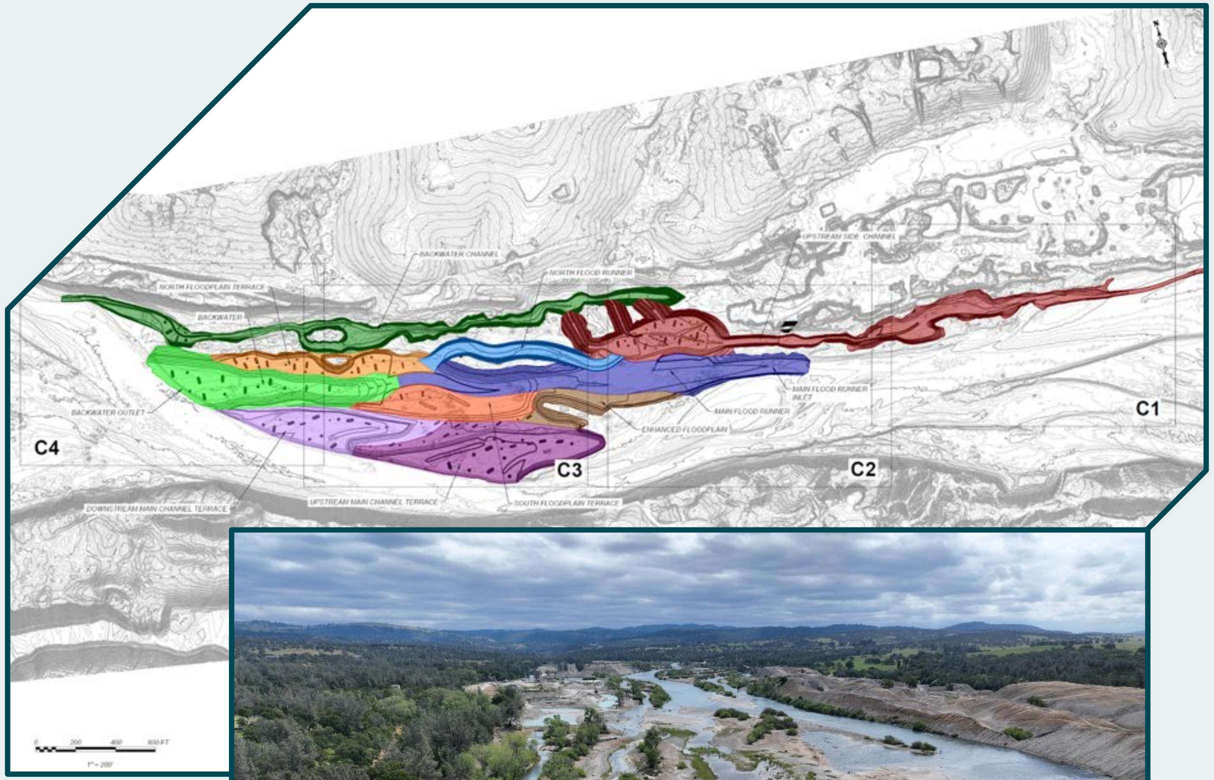
- Enhance seasonal and perennial juvenile salmonid rearing habitat
  - USFWS AFRP doubling goals

- Fulfill SRI's reclamation plan obligations for that portion of Long Bar Mine

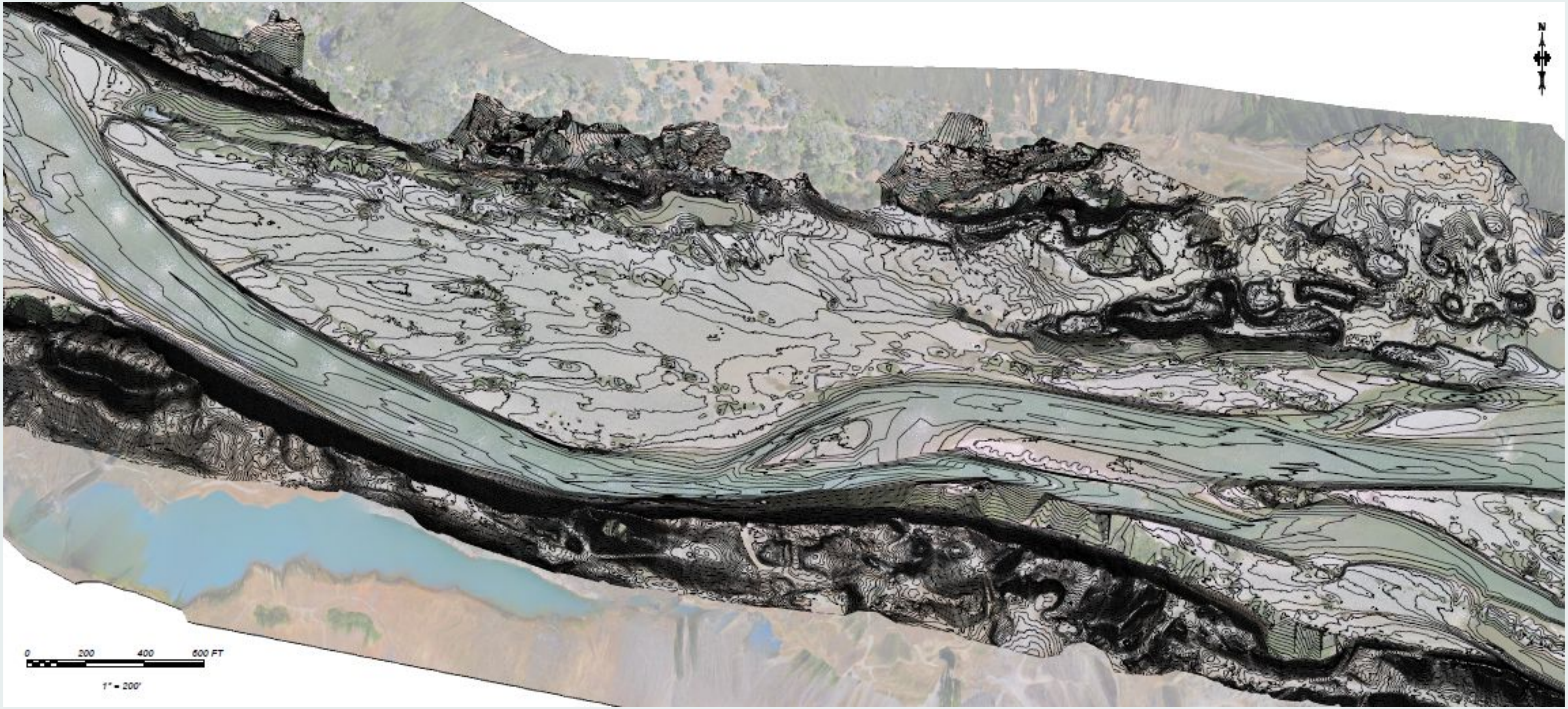
Project Objectives

Design Methodology

1. Determine species-specific, life-stage target periods and habitat needs.
2. Provide seasonal rearing habitat with sustained inundation.
3. Enhance perennial flow juvenile salmonid rearing habitat.
4. Reduce potential non-native fish predator holding, spawning, and rearing habitats.
5. Design habitat enhancement that considers climate variability and the generational component of California salmonids.



Topography and Bathymetry



Design Hydrology

Work with the current flow management regime to design floodplain that:

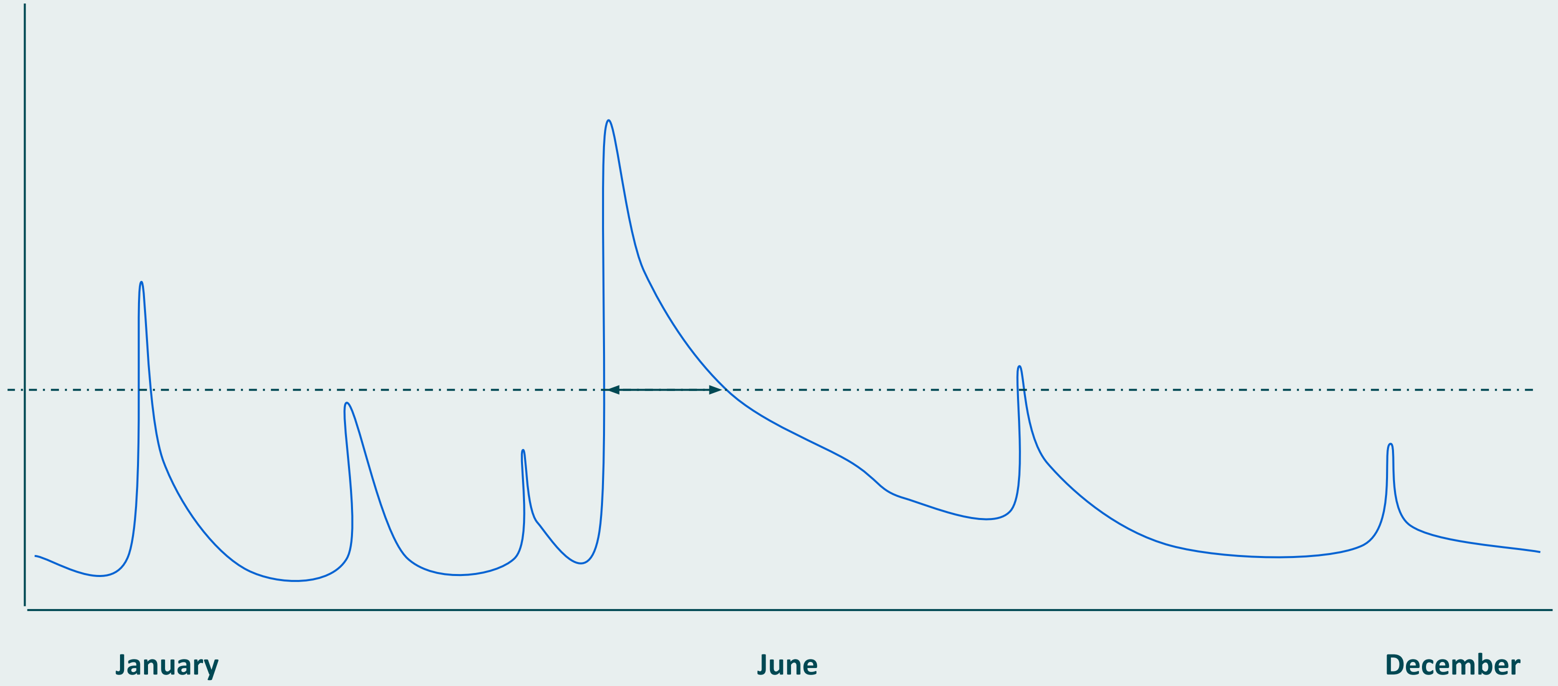
1. activates at the appropriate time,

2. functions for a beneficial duration.

Floodplain Productivity

Facilitate continuous inundation

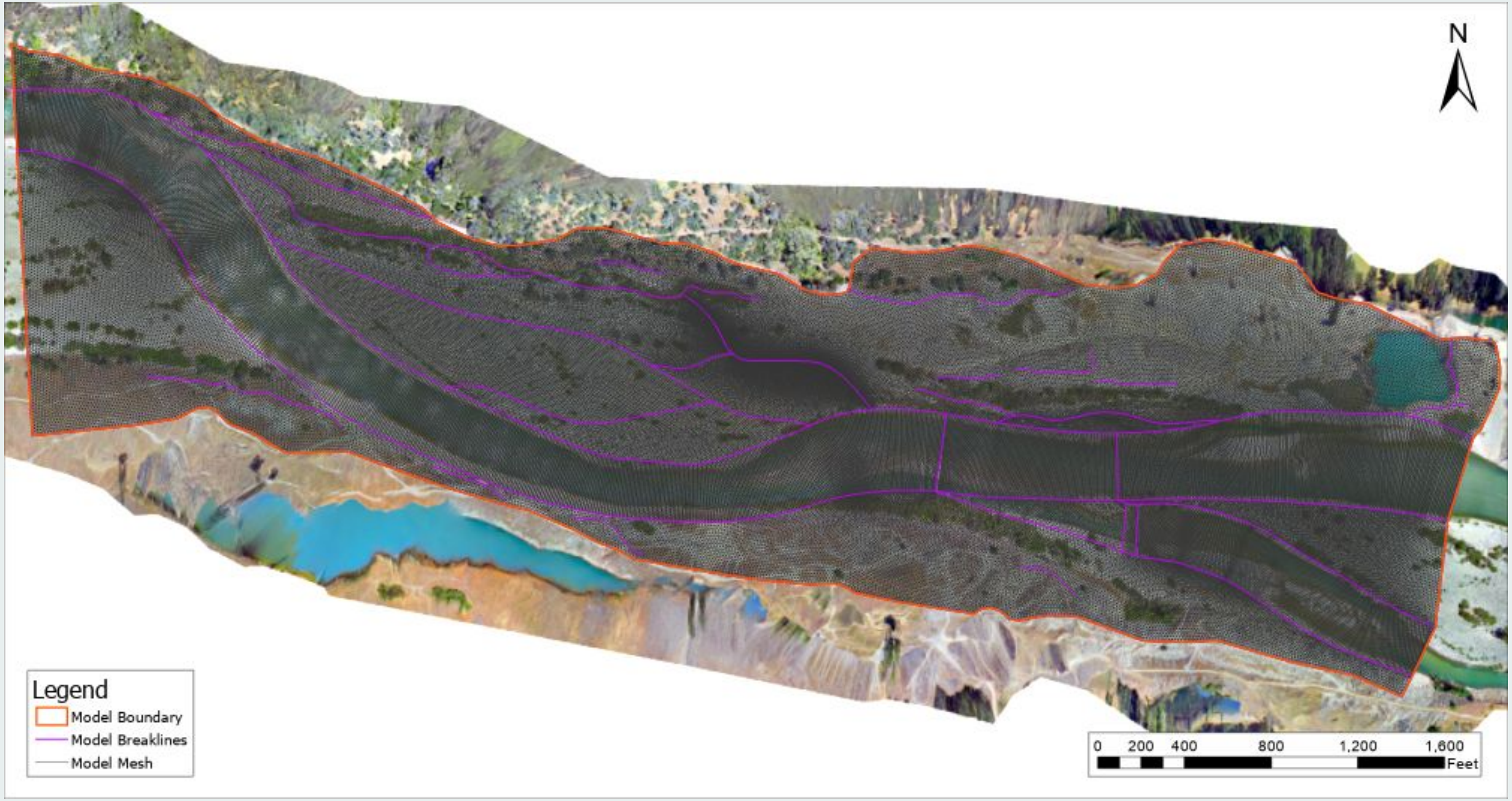
- Range of 14 to 24 days – target of 21 days
- Promote food production
- Invertebrates colonize off-channel areas



Ecologically Significant Flows

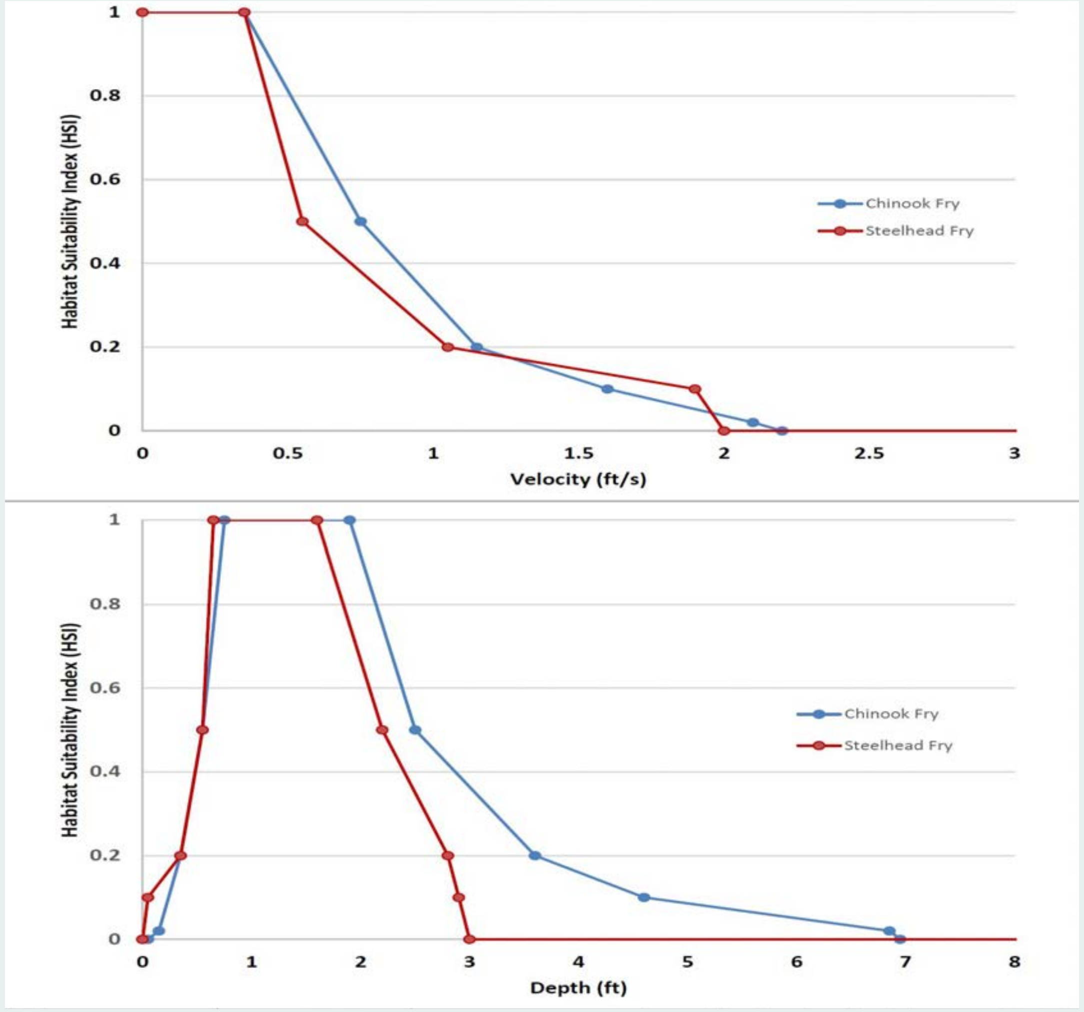
Flow (cfs)	Ecological Significance	Physical Process Significance
700	Minimum required flow September 1st – April 15th	Baseflow
880	Typical fall-run spawning flow	Main channel spawner bed modification (Hassan et al. 2008; DeVries 2012)
1,000	Upper end of fall-run spawning flow	Surface water flow disconnection to all floodplain features (cbec design)
2,000	21-day duration occurring almost every year (January to June); lower end of rearing range	Channel defining flow for Secondary Channel geometry (cbec design)
3,500	21-day duration about every other year; activates riparian corridor	Potential for vegetation and sediment recruitment feedbacks (cbec design)
5,000	21-day duration every third year to support yearly broods; upper end of steelhead spawning	LYR bankfull (Wyrick and Pasternack 2012)
7,500	Occurs for ~3 days every other year; provides access to floodplain	Potential for vegetation and sediment recruitment feedbacks (cbec design)
10,000	Upper end of rearing range	~1.5-year recurrence interval flood; Secondary Channel riffle-pool maintenance
40,000	Linked to implications for the floodway	~5-year recurrence interval flood; material critical grain size threshold (cbec design) for riffle crests, inlets and roughness features
70,000	Linked to implications for the floodway (scour and vegetation regeneration); vegetation recruitment assumptions	~10-year recurrence interval flood

Hydraulic Modeling

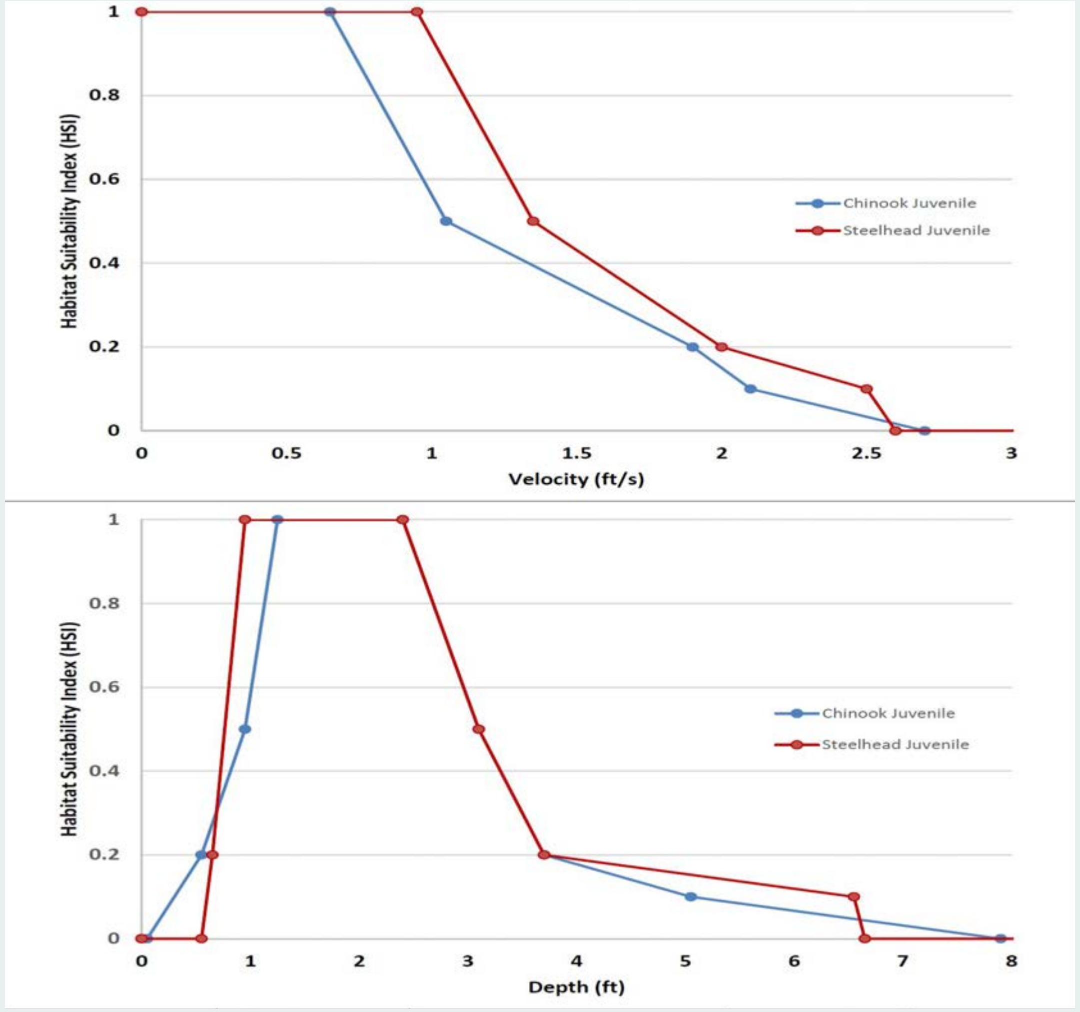


Habitat Suitability

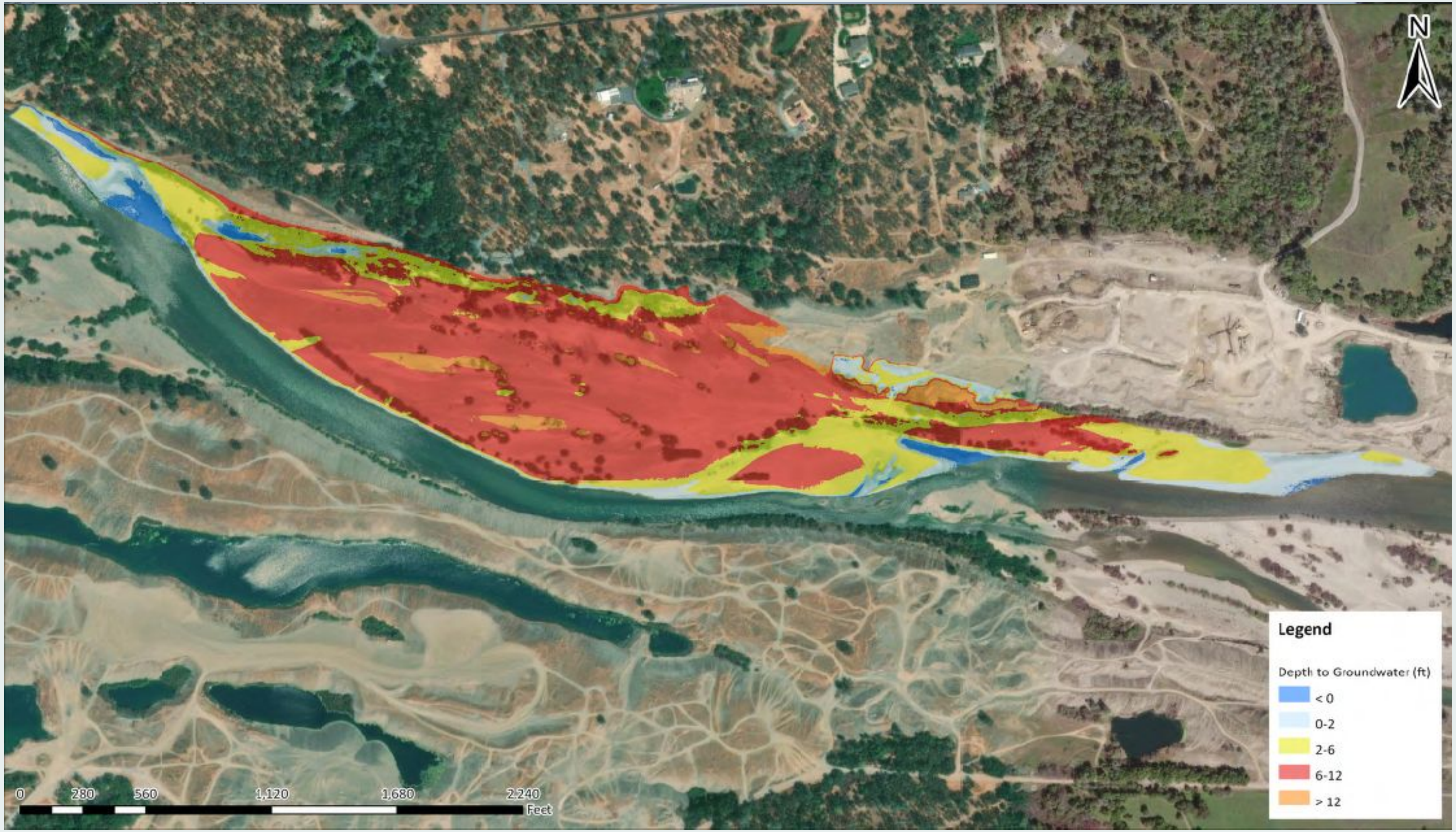
Juvenile Rearing – Depth, Velocity



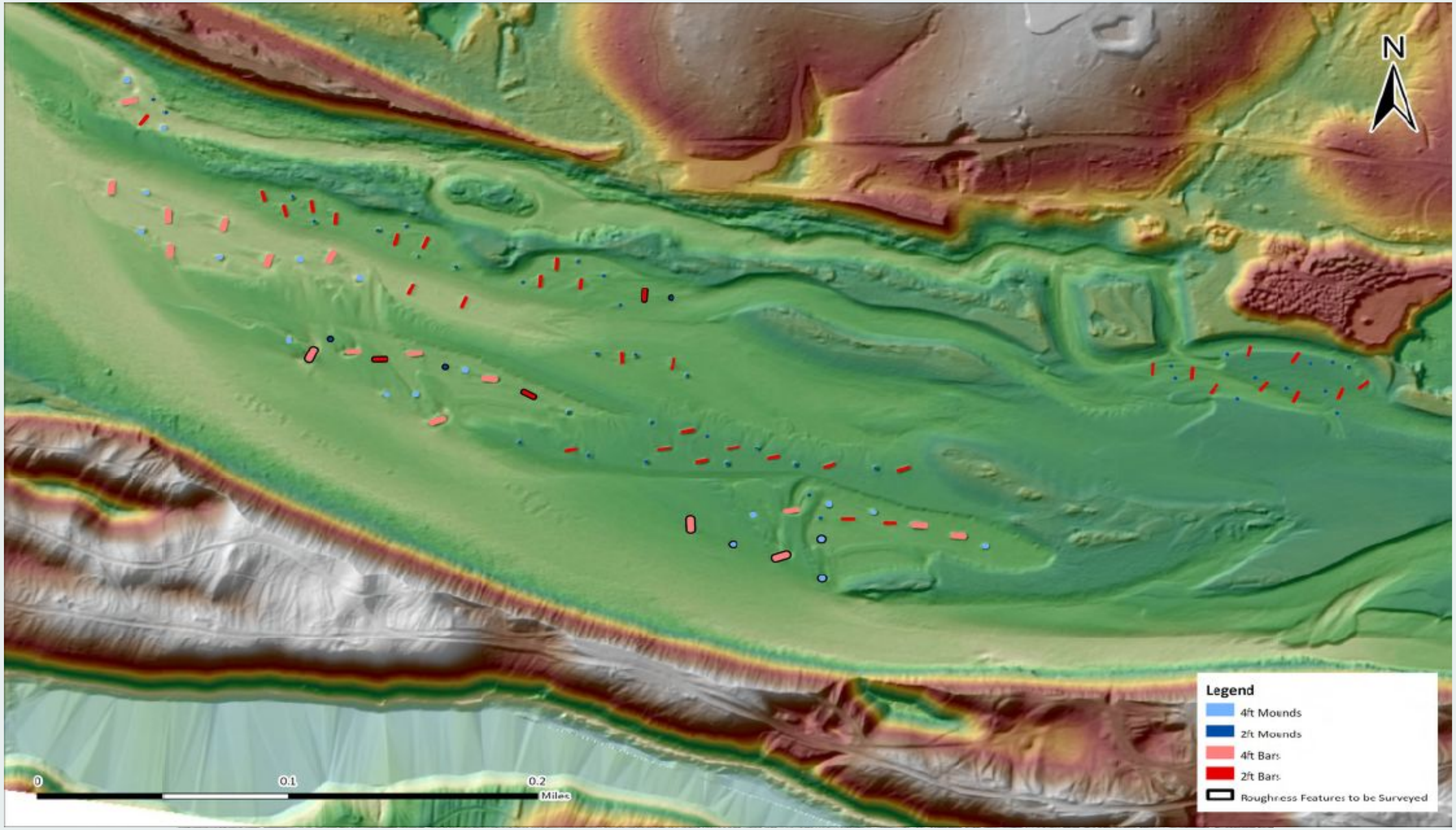
Fry Rearing – Depth, Velocity



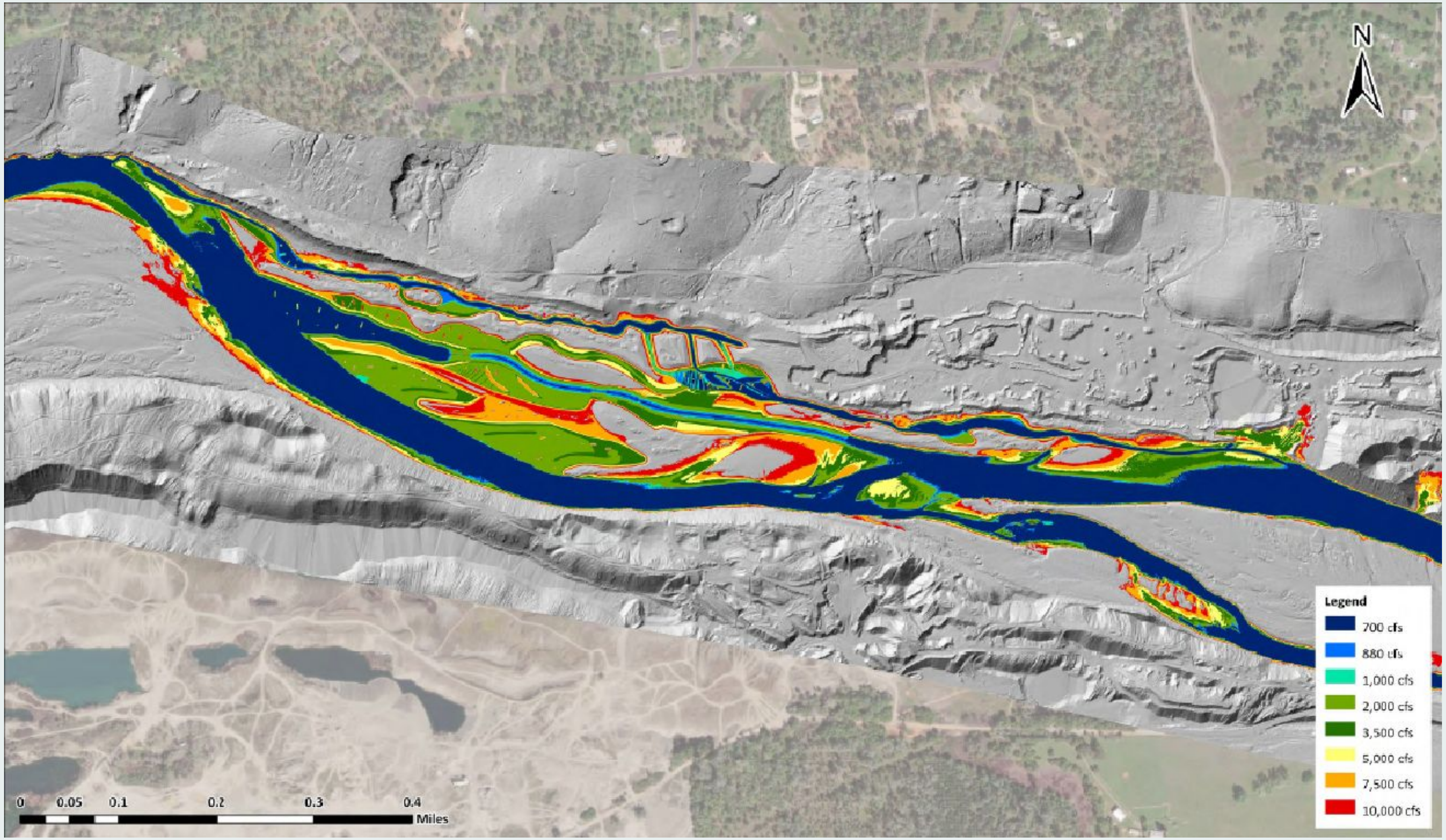
Vegetation Recruitment



Roughness Features



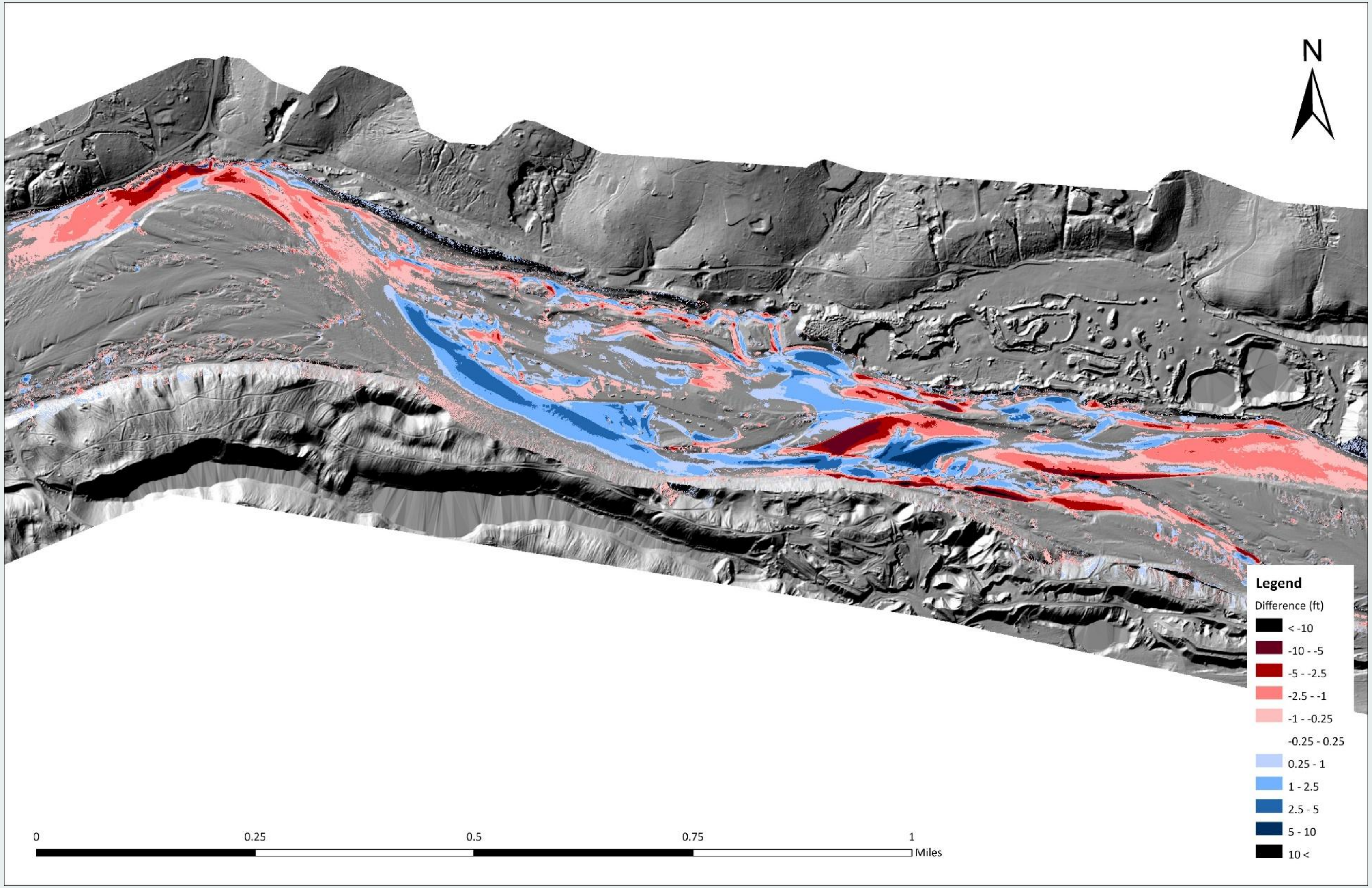
Sustainable Design



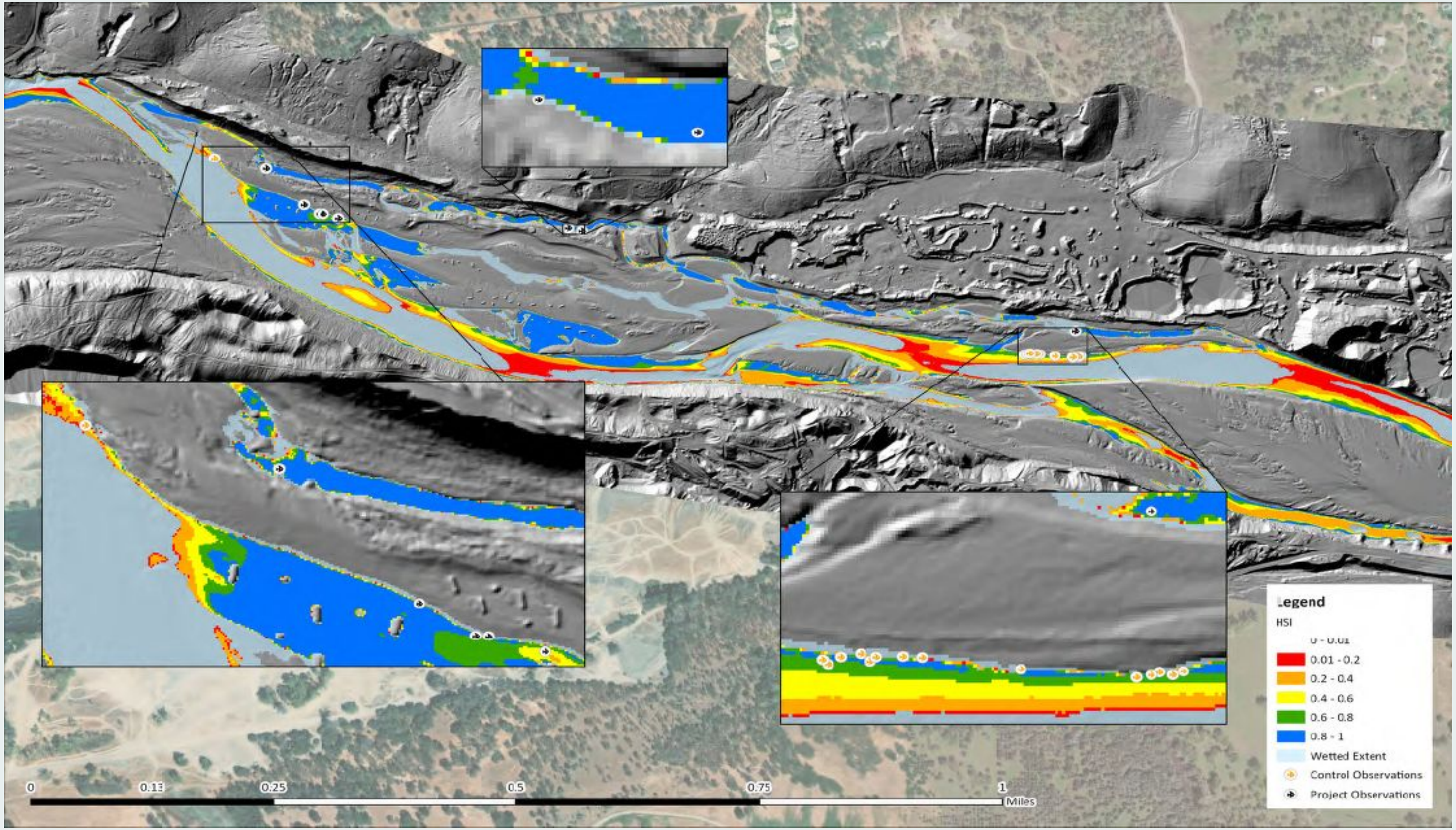
Construction

Post Construction Flows

Topographic Changes



Habitat Use


Legend
HSI
0 - 0.01
0.01 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
Wetted Extent
Control Observations
Project Observations
0
0.13
0.25
0.5
0.75
1
Miles

Project Sustainability