# State of Beaver Restoration in California

A Workshop at the 35th Annual Salmonid Restoration Conference held in Davis, CA from March 29 – April 1, 2017.

# Session Overview

- Session Coordinator:
  - Eli Asarian, Riverbend Sciences

This workshop provided an overview of current efforts to restore streams in California using beavers and beaver dam analogues. Presentation topics included:

- Effects of beavers, beaver dams, and beaver dam analogues on geomorphology, hydrology, habitat, and salmonids in stream ecosystems
- Updated progress reports on case studies of restoration projects utilizing beavers and beaver dam analogues, including in the Scott Valley, Trinity River, Sierra Nevada, and Columbia River Basin
- Informational resources and guidelines for beaver restoration and co-existing with beavers
- The evolving framework for permitting beaver dam analogues and managing beavers in California

Following the presentations there was in-depth group discussions about how restorationists and permitting agencies can move forward together to improve beaver management and the process for permitting innovative and adaptive restoration projects in California.

# Presentations

(1) The Physical Process Foundation for Stream Ecosystems: Why Restoring Beaver Dams Is Important, Brian Cluer, Ph.D., NOAA Fisheries

(2) Lessons Learned From a 15-Year Beaver Dam Analogue Restoration and Monitoring Project — Applying Results to Other Watersheds, Michael Pollock, Ph.D., NOAA Fisheries

(3) Do Beaver Have a Role in the Recovery of California Coho Salmon? Stephen Swales, Ph.D., Fisheries Branch, California Department of Fish and Wildlife

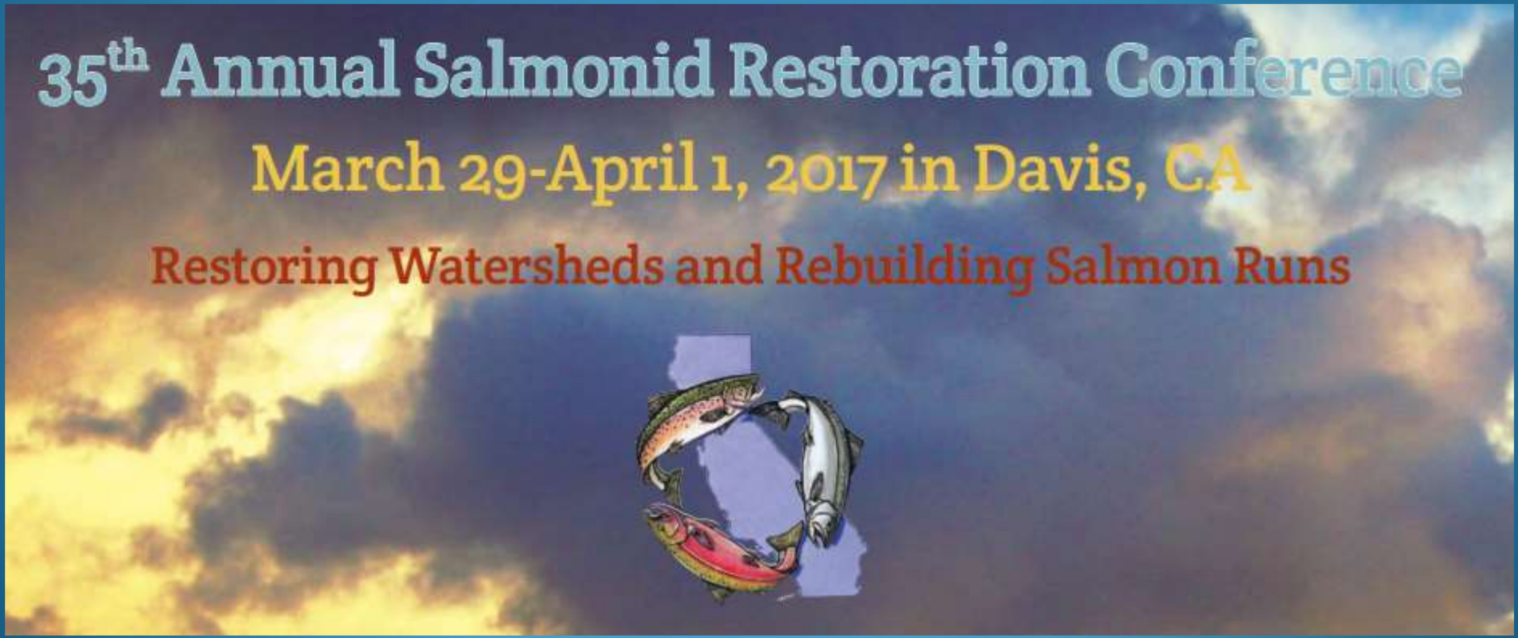
(4) Bucktail Beaver Dam Analogue Construction Process and Near-Term Results, James Lee, Hoopa Valley Tribe and Trinity River Restoration Program

(5) Demonstration of Carbon Sequestration and Biodiversity Benefits of Beaver and BDA Restoration Techniques in Childs Meadow, Tehama County, CA, Sarah Yarnell, Ph.D., Center for Watershed Sciences, UC, Davis

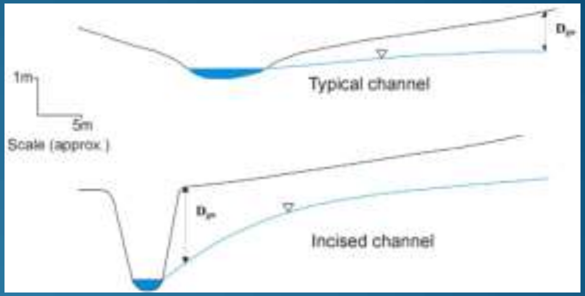
(6) Applications of Beaver Restoration Techniques in the Sierra Nevada, Damion Ciotti, U.S. Fish and Wildlife Service

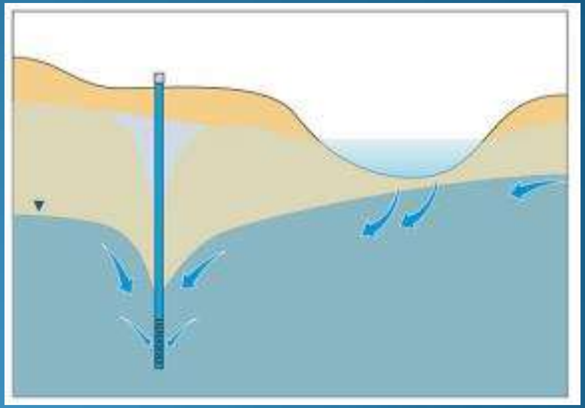
# The physical process foundation for stream ecosystems: why beaver dams are important.

*Brian Cluer, NOAA-NMFS, West Coast Region*



# The problem: widespread land drainage and water withdrawals, driving severe loss of aquatic habitat.

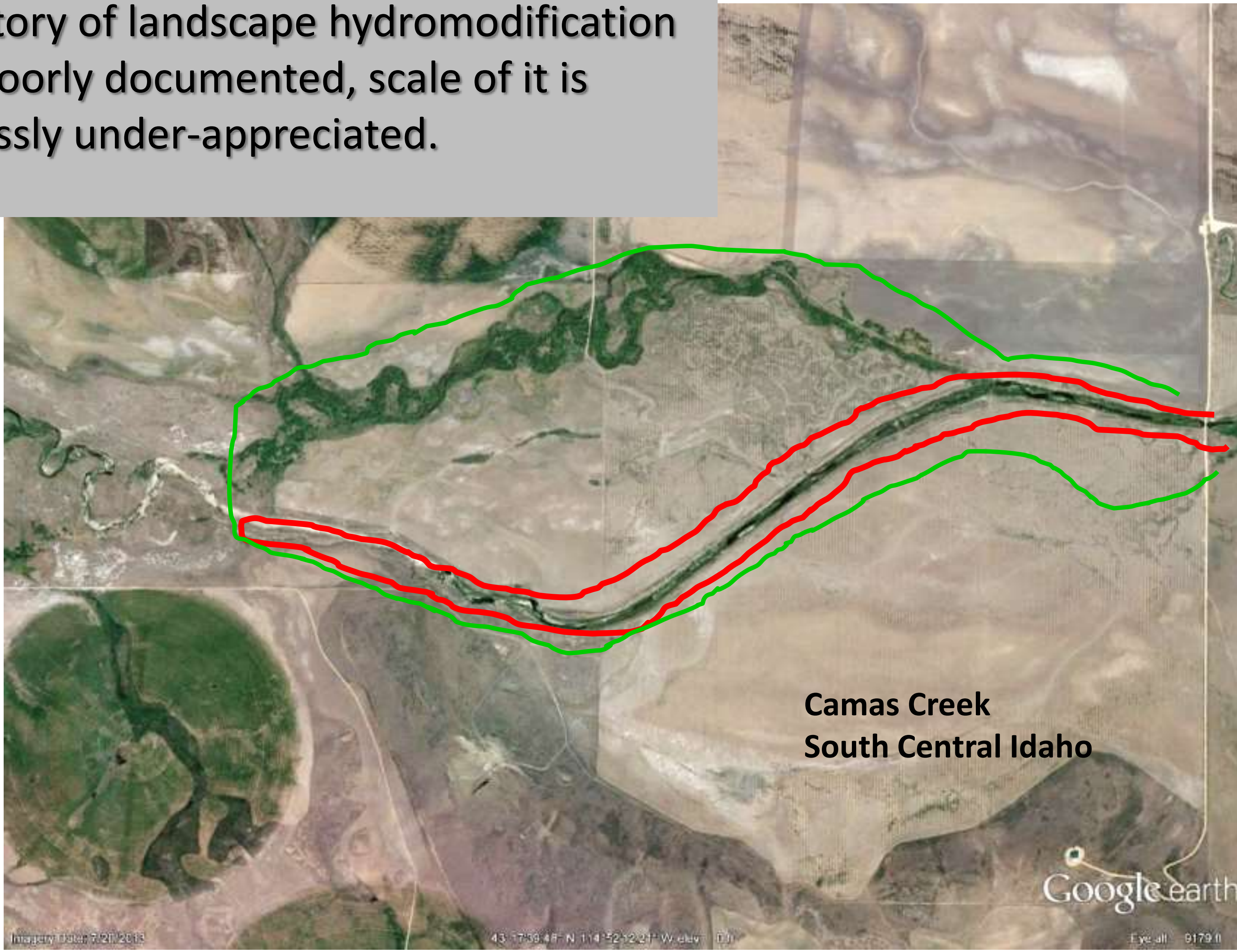


History of landscape hydromodification is poorly documented, scale of it is grossly under-appreciated.

North Central Nevada
Edge of Arable

History of landscape hydromodification is poorly documented, scale of it is grossly under-appreciated.



# History and Development

For 1-2 centuries in US and several more centuries in Europe there has been an all-out effort to maximize agricultural land

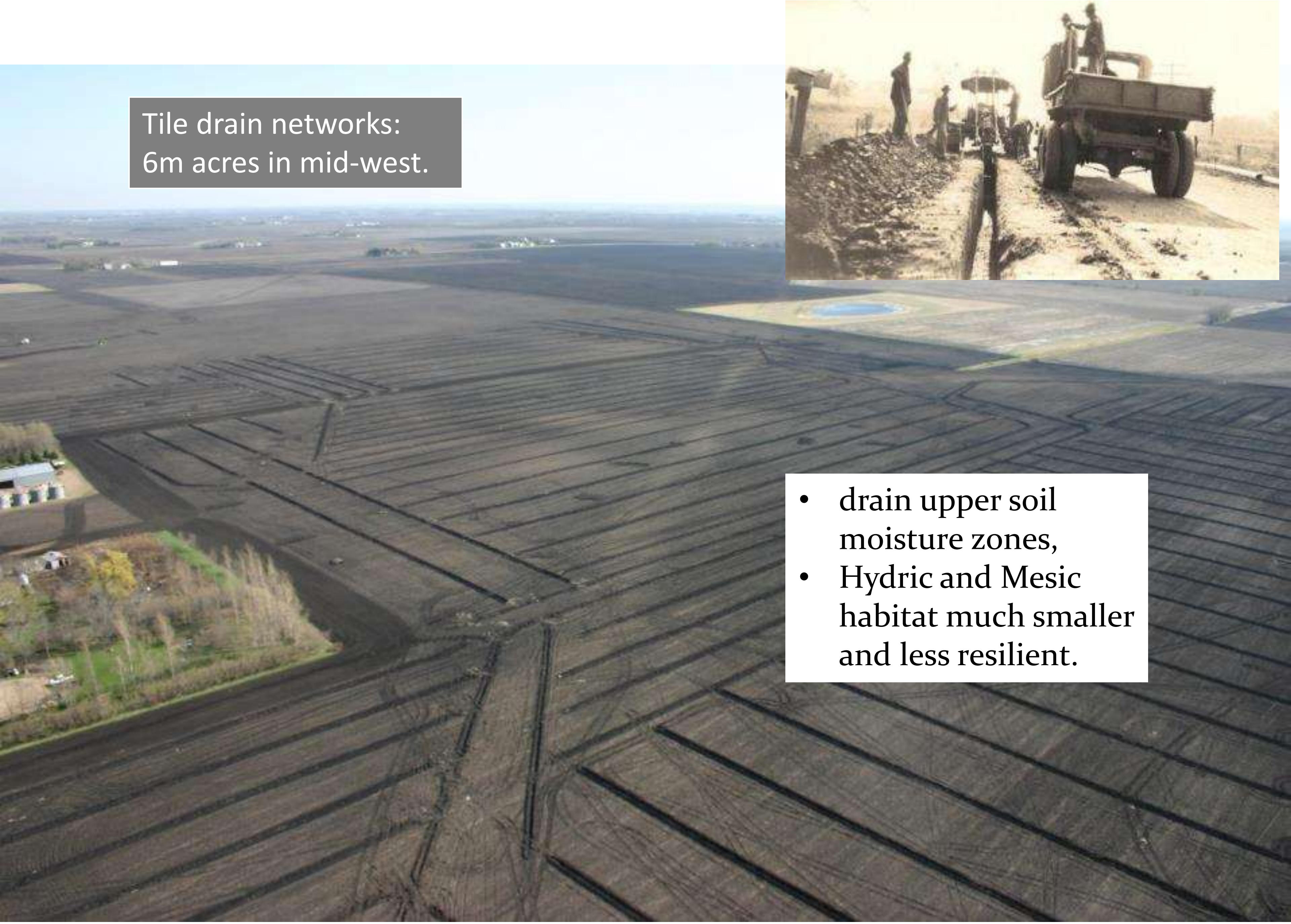

Oil-powered dredge digging a 30-foot-wide ditch to drain wetlands near Carroll, Iowa. *(Photograph courtesy of National Archives, 8–D–2214–2570.)*

**US Swamp Land Act of 1850** [1] essentially provided a mechanism for reverting title of federally owned swampland to states

Eel River, CA

**DRAINING FLOODPLAINS - AND BUILDING DEFENSES FROM FLOODS.**

LaGrand River, OR



Tile drain networks:
6m acres in mid-west.

- drain upper soil moisture zones,
- Hydric and Mesic habitat much smaller and less resilient.

Scale of hydromodification is
difficult to grasp.

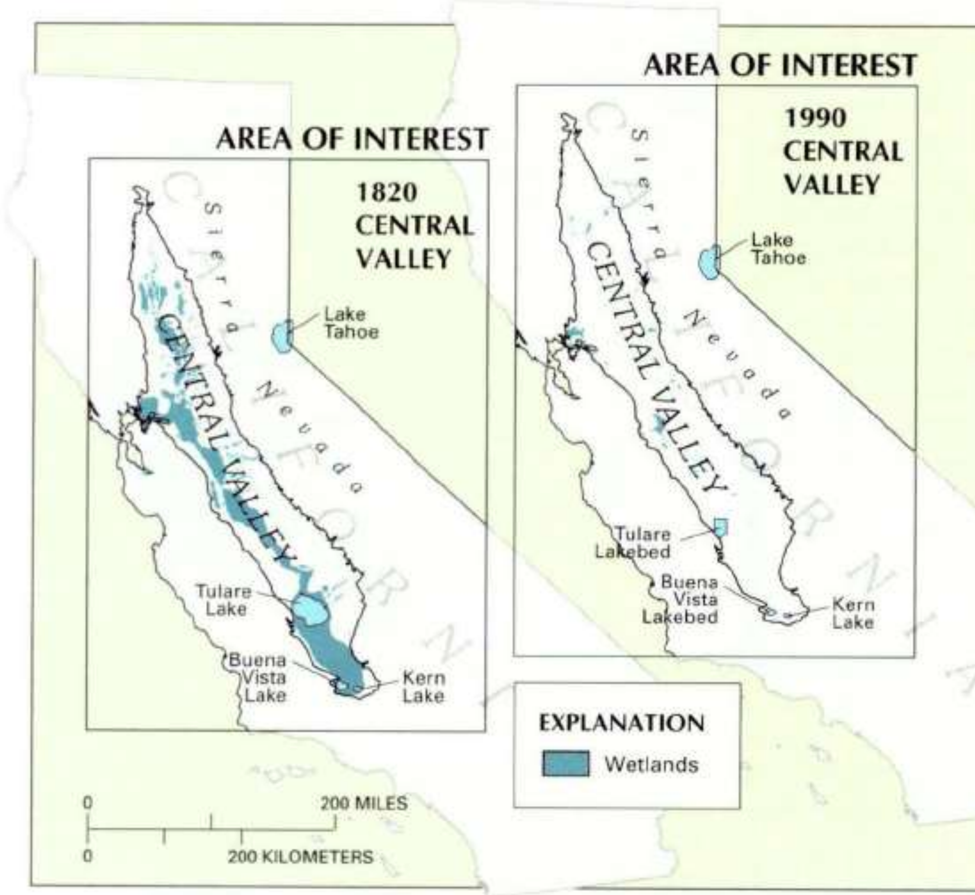

**Figure 2.** States with notable wetland loss, 1780's to mid-1980's. *(Source: Modified from Dahl, 1990.)*

[1] U.S. Fish and Wildlife Service.
[2] U.S. Geological Survey.

U.S. Geological Survey Water-Supply Paper 2425

# History of Valley Modifications

CA, formerly 4m acres wetland, almost 3m acres accessible to fish

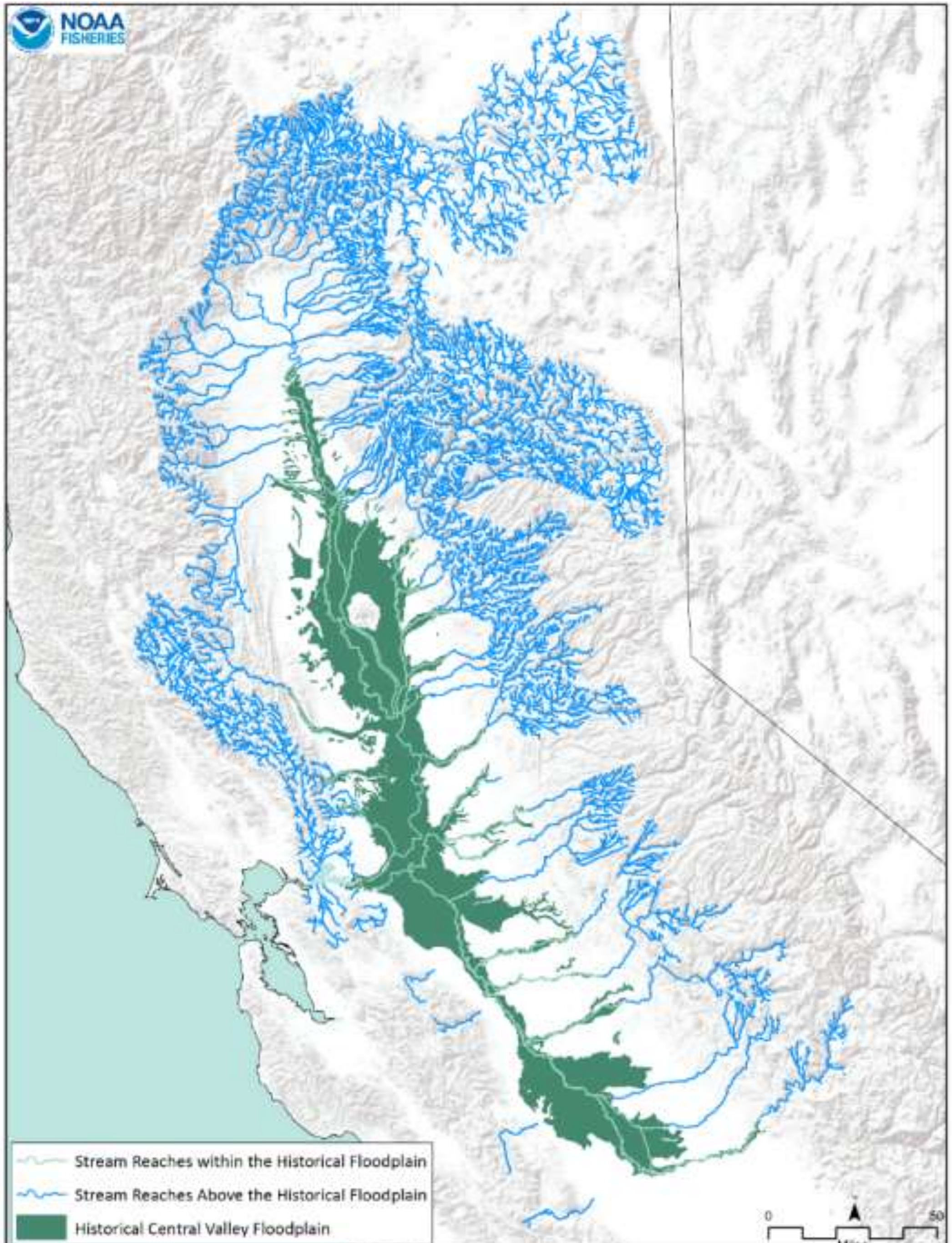



Originally the Central Valley of California was very different than it is now. Tulare Lake held water in a basin with a surface area approximately four times the surface area of Lake Tahoe. Buena Vista and Kern Lakes also held water as runoff accumulated from the Sierra Nevada. The rivers and streams that flowed into the Central Valley were lined with bottom-land forests composed of willow, sycamore, oak, elder, poplar, and alder; lush stands of wetland grasses and tules dominated the valley floors and prairies (Hundley, 1992). Prior to the mid-1800's, about 4 million of the 13 million acres that made up California's Central Valley were estimated to be wetland.

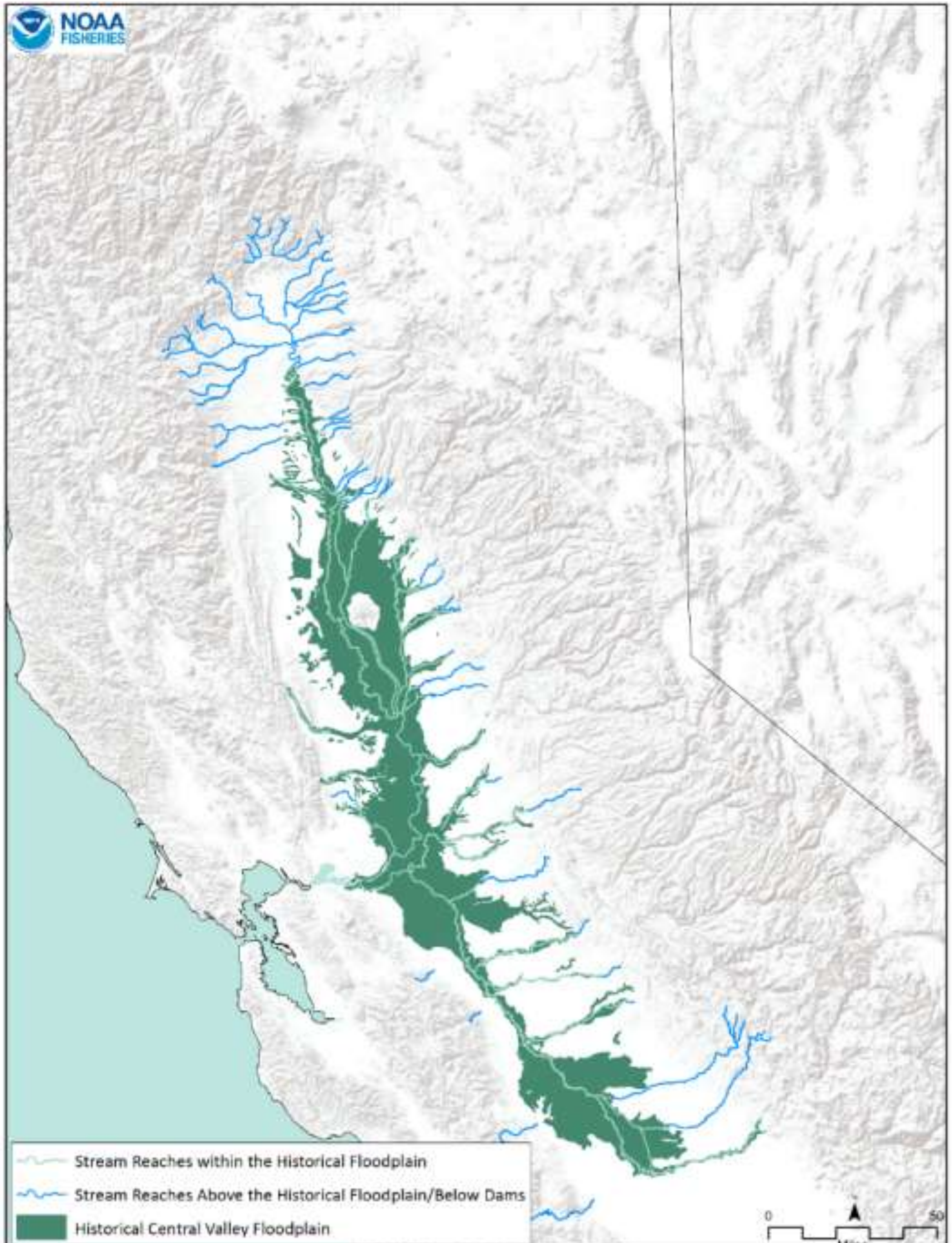
**Figure 9.** Wetlands of the Central Valley of California, circa 1820 (left) and 1990 (right). *(Source: U.S. Fish and Wildlife Service, Status and Trends, unpub. data, 1994.)*

Data from the SWFSC IP model (streams)

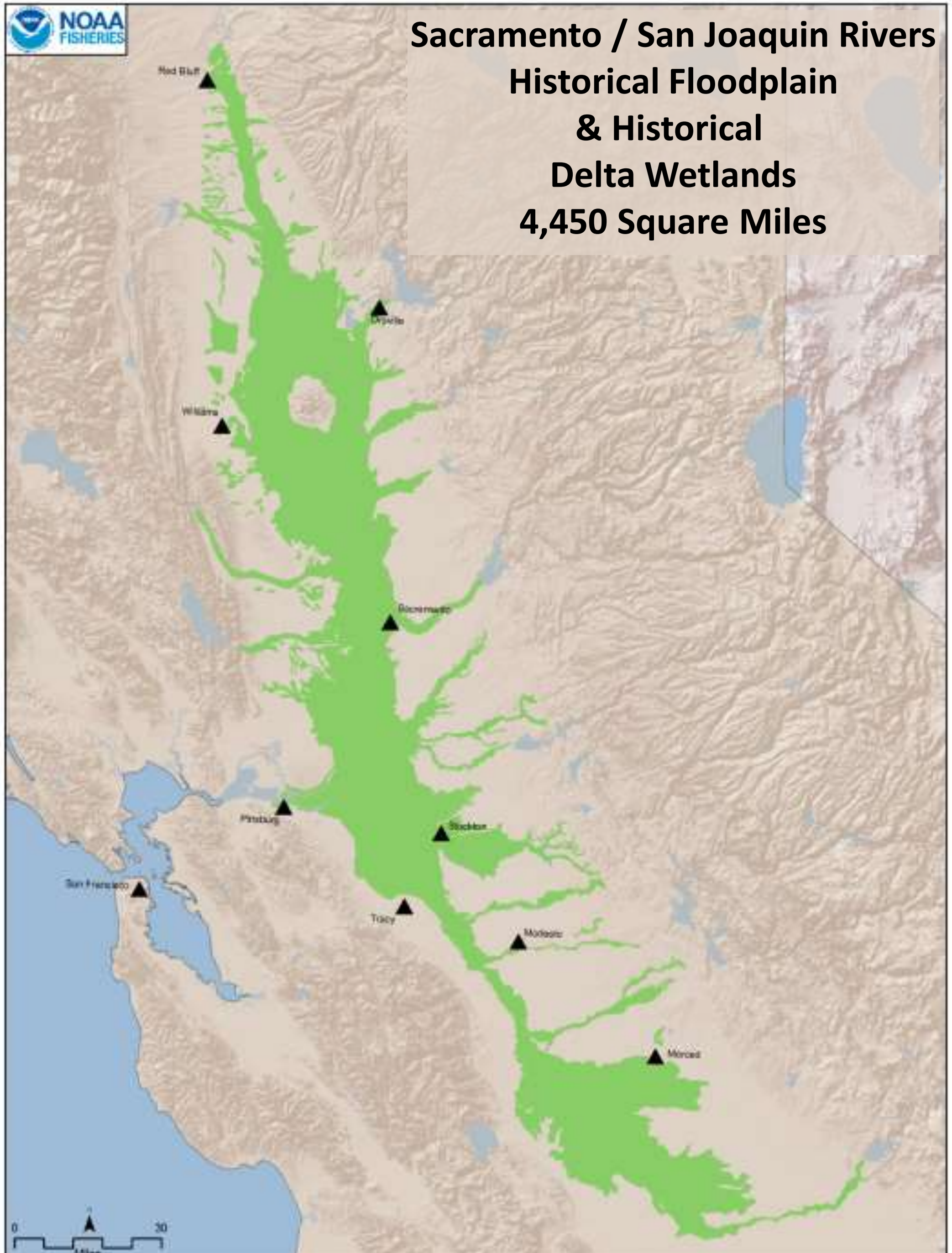
The Bay Institute “From the Sierra to the Sea - The Ecological History of the San Francisco Bay Delta Watershed” 1998 (floodplain)




Historical Central Valley Salmon Habitat

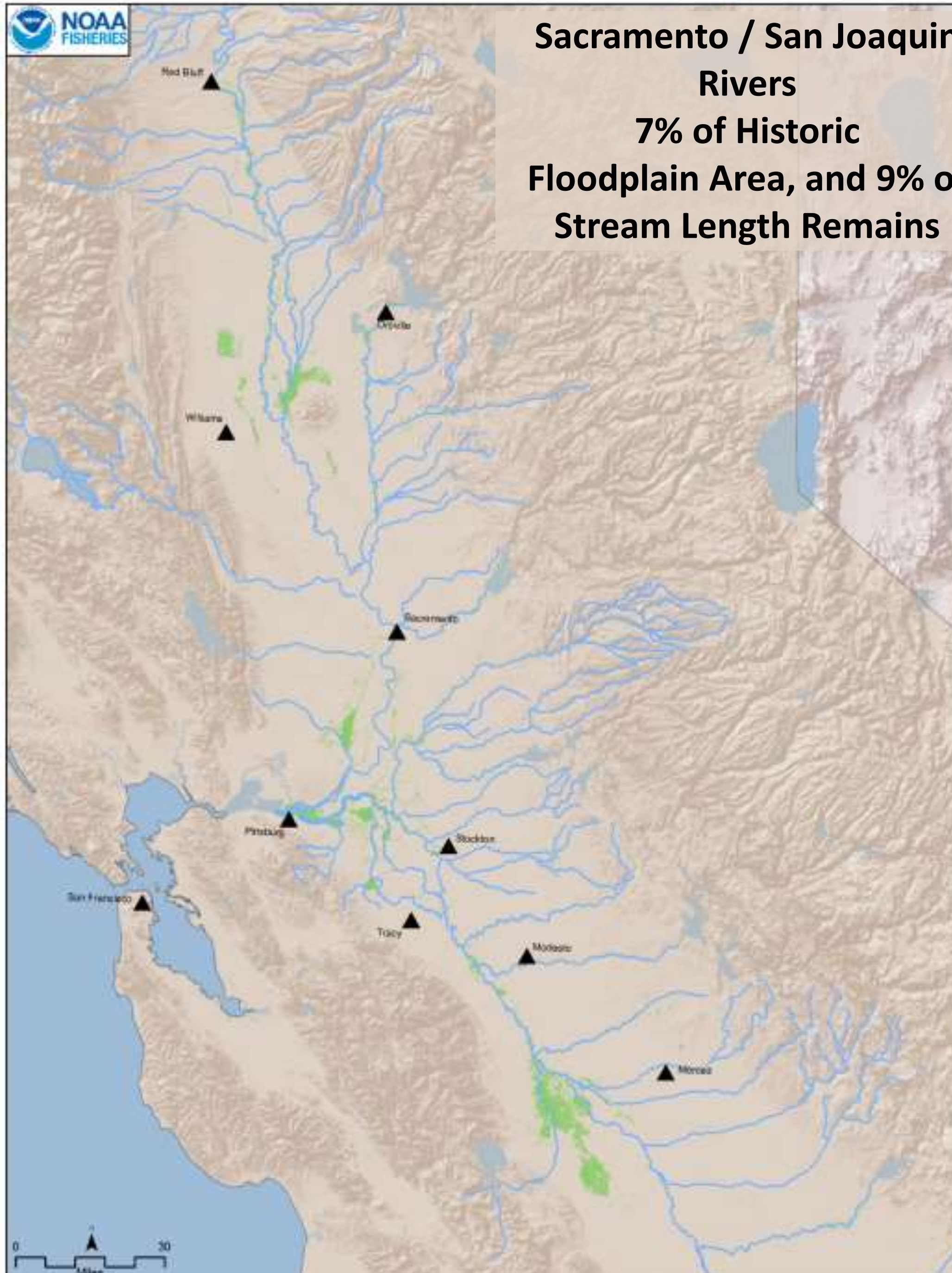



Historical Central Valley with Intact Floodplain and Stream Reaches currently accessible



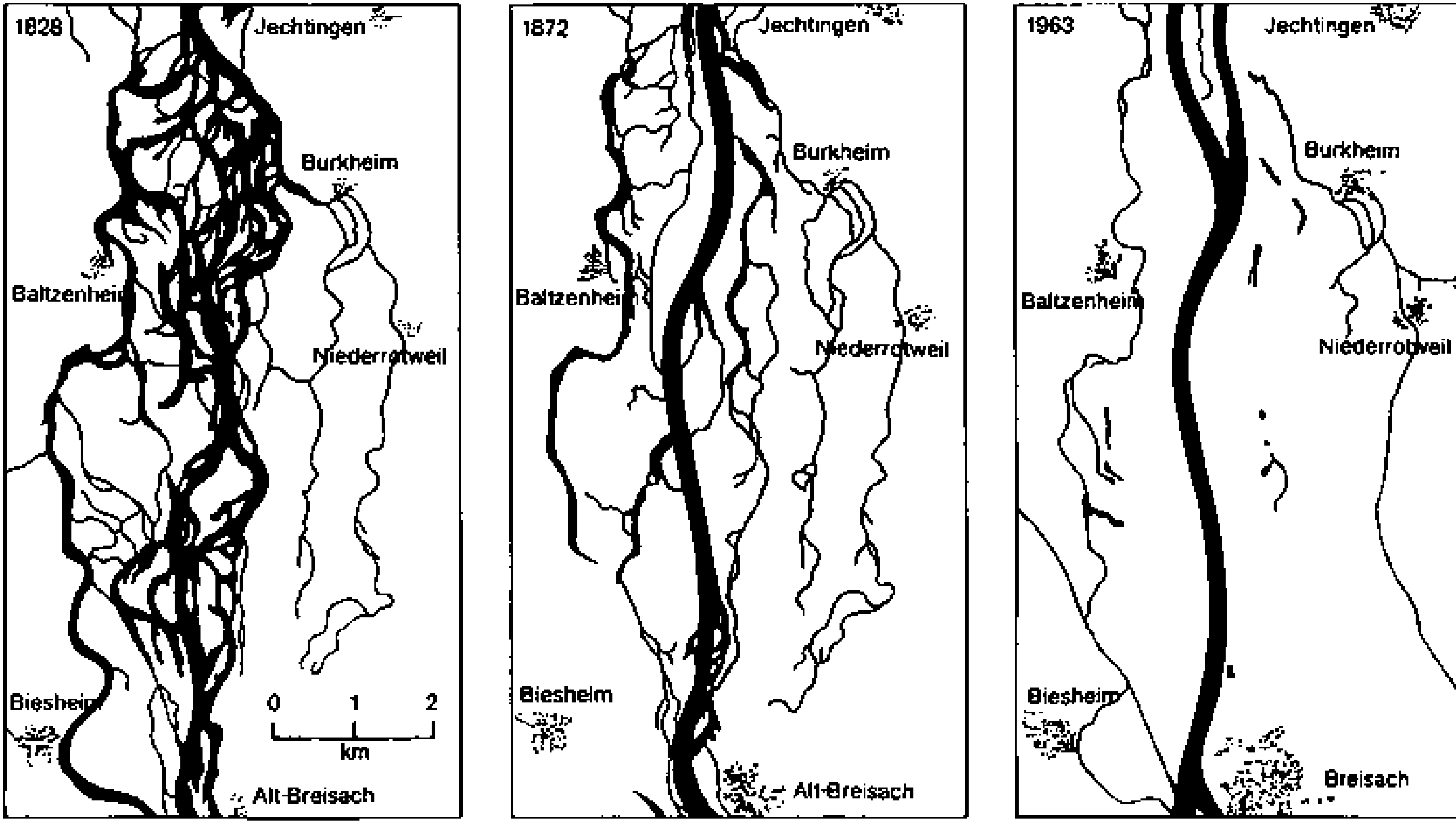

Source:
The Bay Institute
Sierra to the Sea GIS Maps

**Sacramento / San Joaquin Rivers 7% of Historic Floodplain Area, and 9% of Stream Length Remains**




Quantity, but quality is degraded too.

# Example from Europe - Upper River Rhine at Breisach Germany



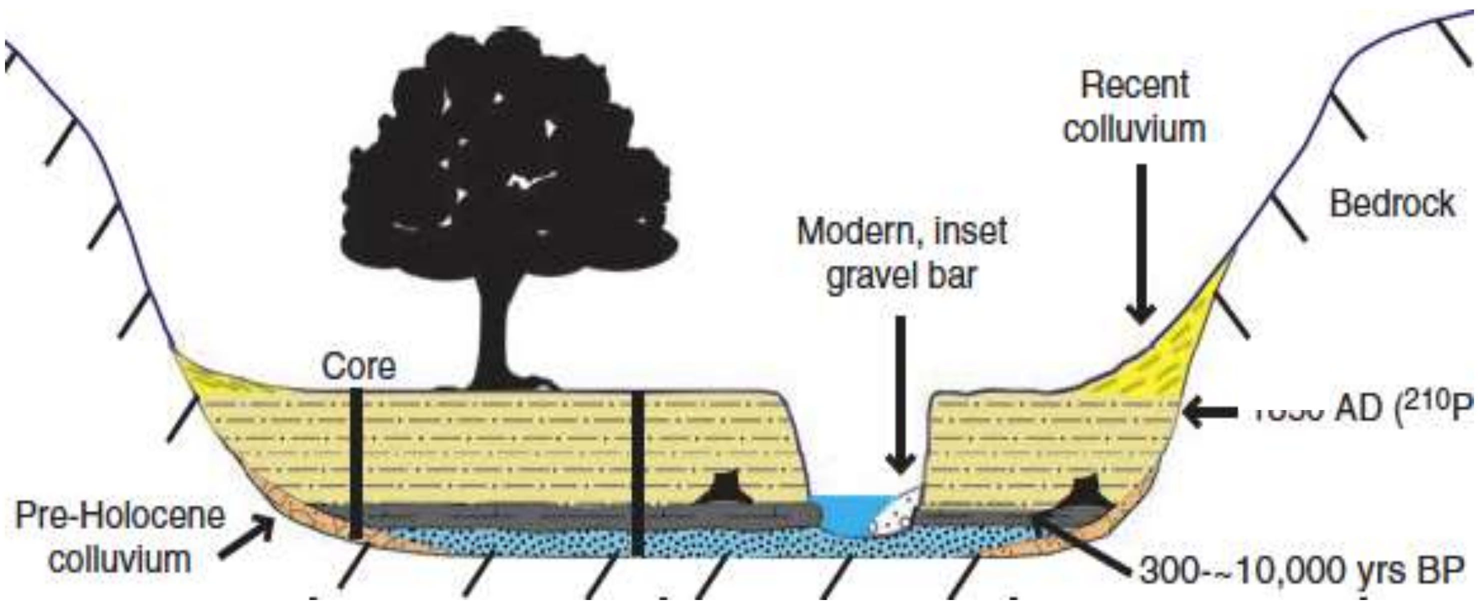

Anastomosed
1828 – Prior to
river training

Anabranched
1872 – after re-alignment
by Johann Gottfried Tulla

Meandering
1963 – fully canalised
single-thread

# *Walter and Merritts: 2008*

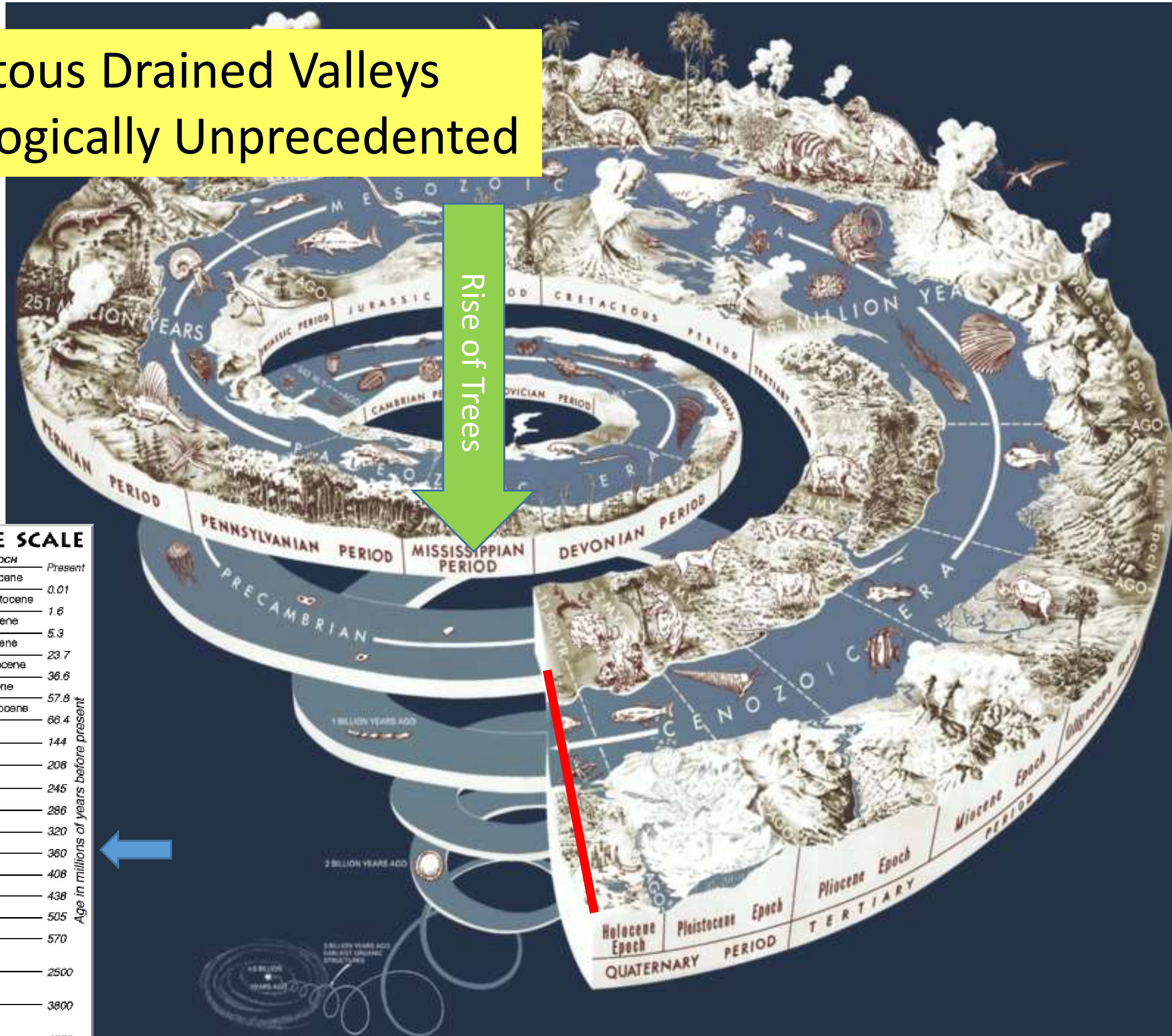
Challenge the idea that meandering gravel-bed channels and 2-year Bankfull Return Periods are functional restoration targets




*Eastern Seaboard Province: "…before European settlement, the streams were small anabranching channels within extensive vegetated wetlands"*

Walter, R.C. and Merritts, D.J., 2008. Natural streams and the legacy of water-powered mills. *Science*, *319*(5861), pp.299-304.

# Ubiquitous Drained Valleys Is Geologically Unprecedented




**GEOLOGIC TIME SCALE**

| EON | ERA | PERIOD | | EPOCH | Age in millions of years before present |
|---|---|---|---|---|---|
| | | | | | Present |
| Phanerozoic | Cenozoic | Quaternary | | Holocene | 0.01 |
| | | | | Pleistocene | 1.6 |
| | | Tertiary | Neogene | Pliocene | 5.3 |
| | | | | Miocene | 23.7 |
| | | | Paleogene | Oligocene | 36.6 |
| | | | | Eocene | 57.8 |
| | | | | Paleocene | 66.4 |
| | Mesozoic | Cretaceous | | | 144 |
| | | Jurassic | | | 208 |
| | | Triassic | | | 245 |
| | Paleozoic | Permian | | | 286 |
| | | Carboniferous | Pennsylvanian | | 320 |
| | | | Mississippian | | 360 |
| | | Devonian | | | 408 |
| | | Silurian | | | 438 |
| | | Ordovician | | | 505 |
| | | Cambrian | | | 570 |
| Precambrian | Proterozoic | | | | 2500 |
| | Archean | | | | 3800 |
| | Hadean | | | | 4550 |

We have some context on the quantity lost. What ecosystem functions and habitat attributes have been lost ?

RIVER RESEARCH AND APPLICATIONS

*River Res. Applic.* (2013)

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# A STREAM EVOLUTION MODEL INTEGRATING HABITAT AND ECOSYSTEM BENEFITS

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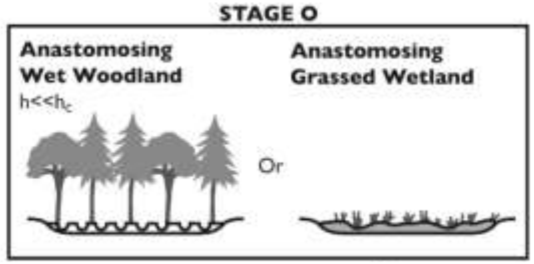
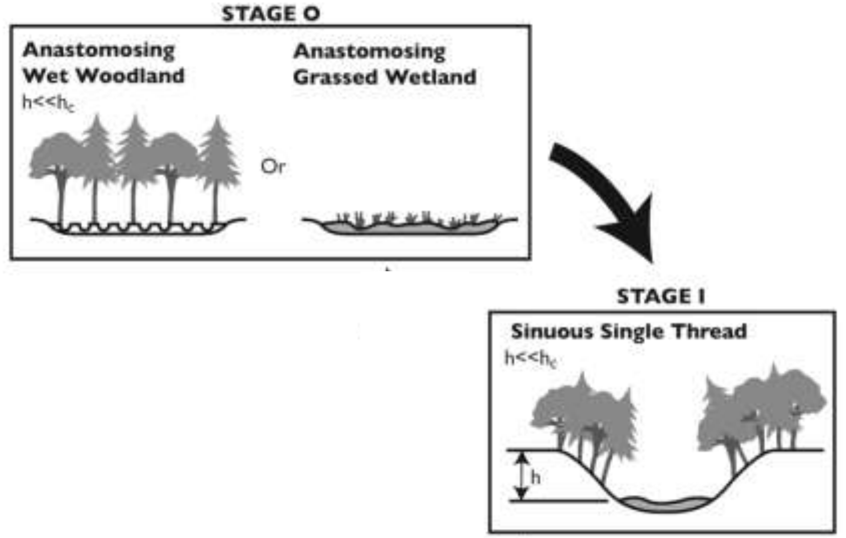
[b] *Chair of Physical Geography, University of Nottingham, Nottingham, UK*




Cluer and Thorne, RRA, 2013

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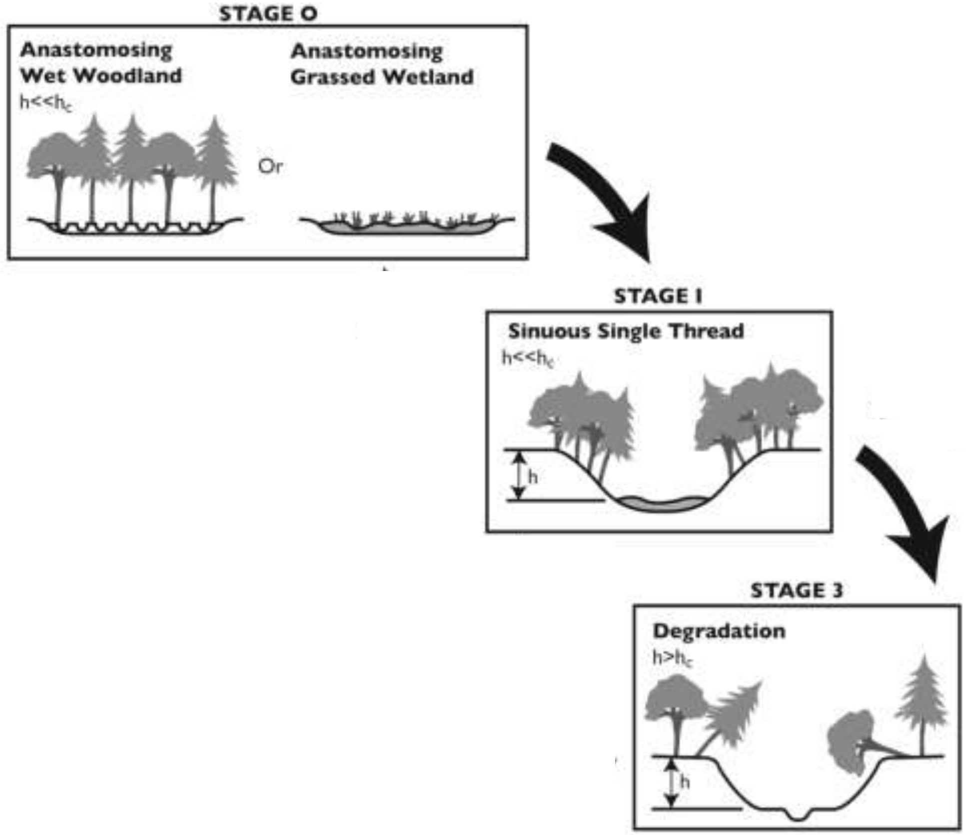


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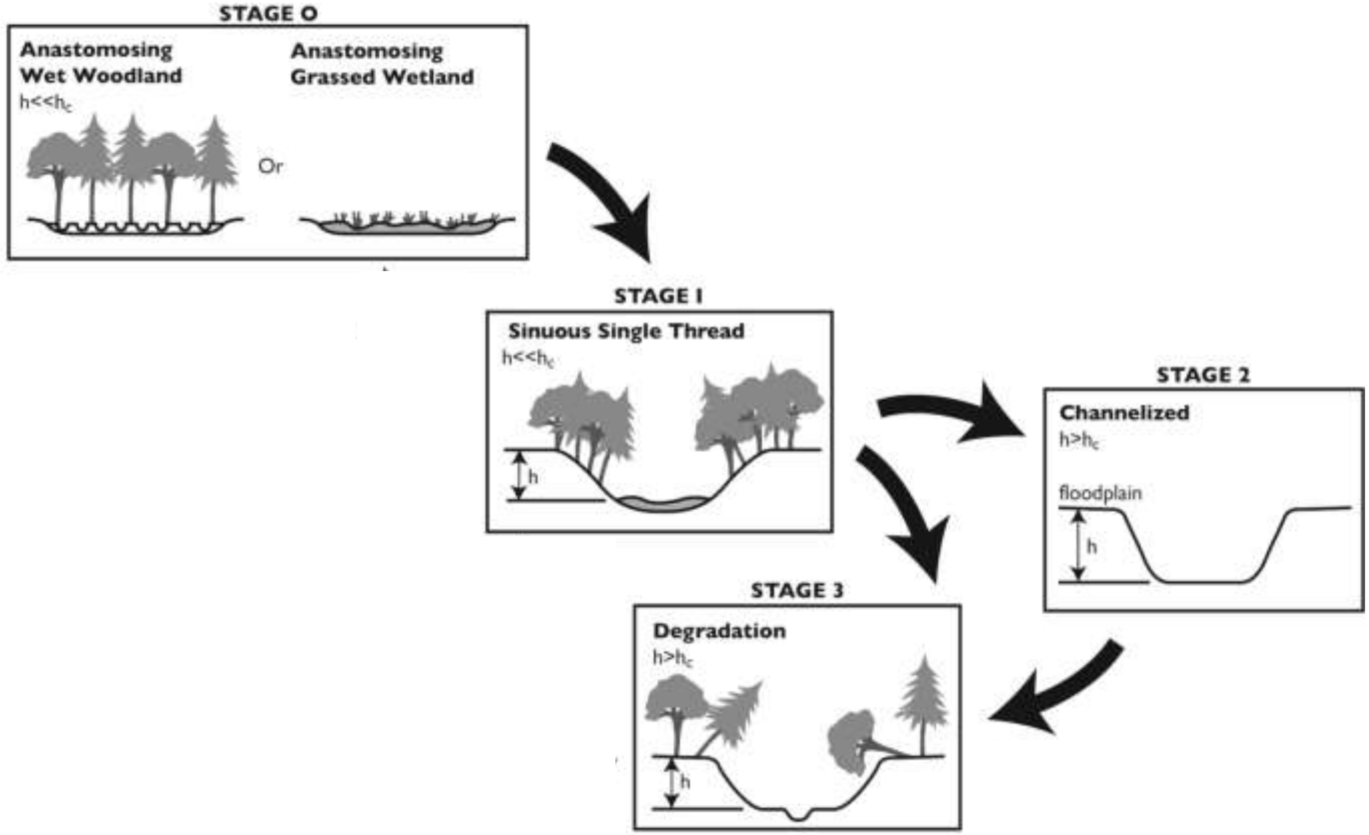


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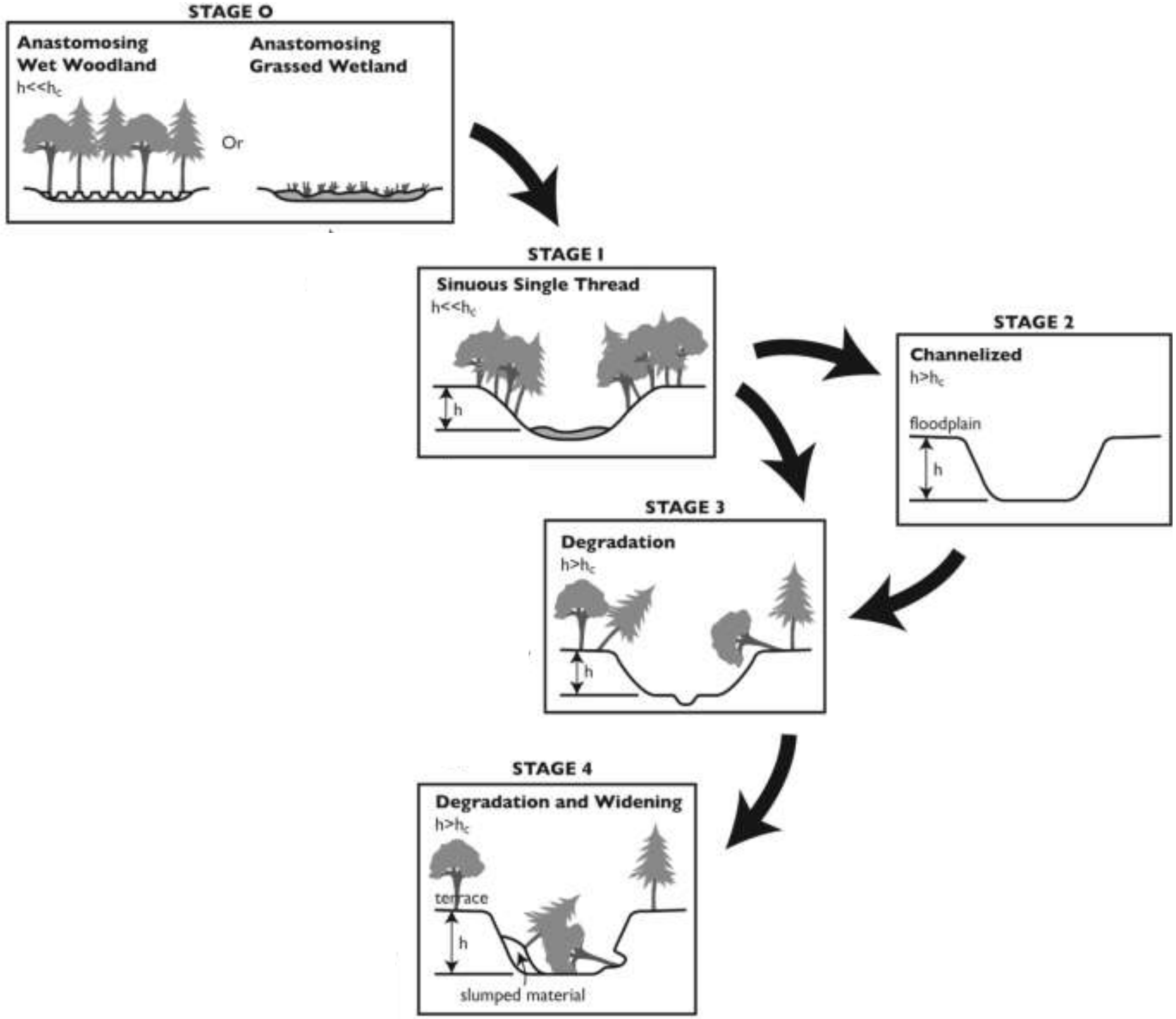


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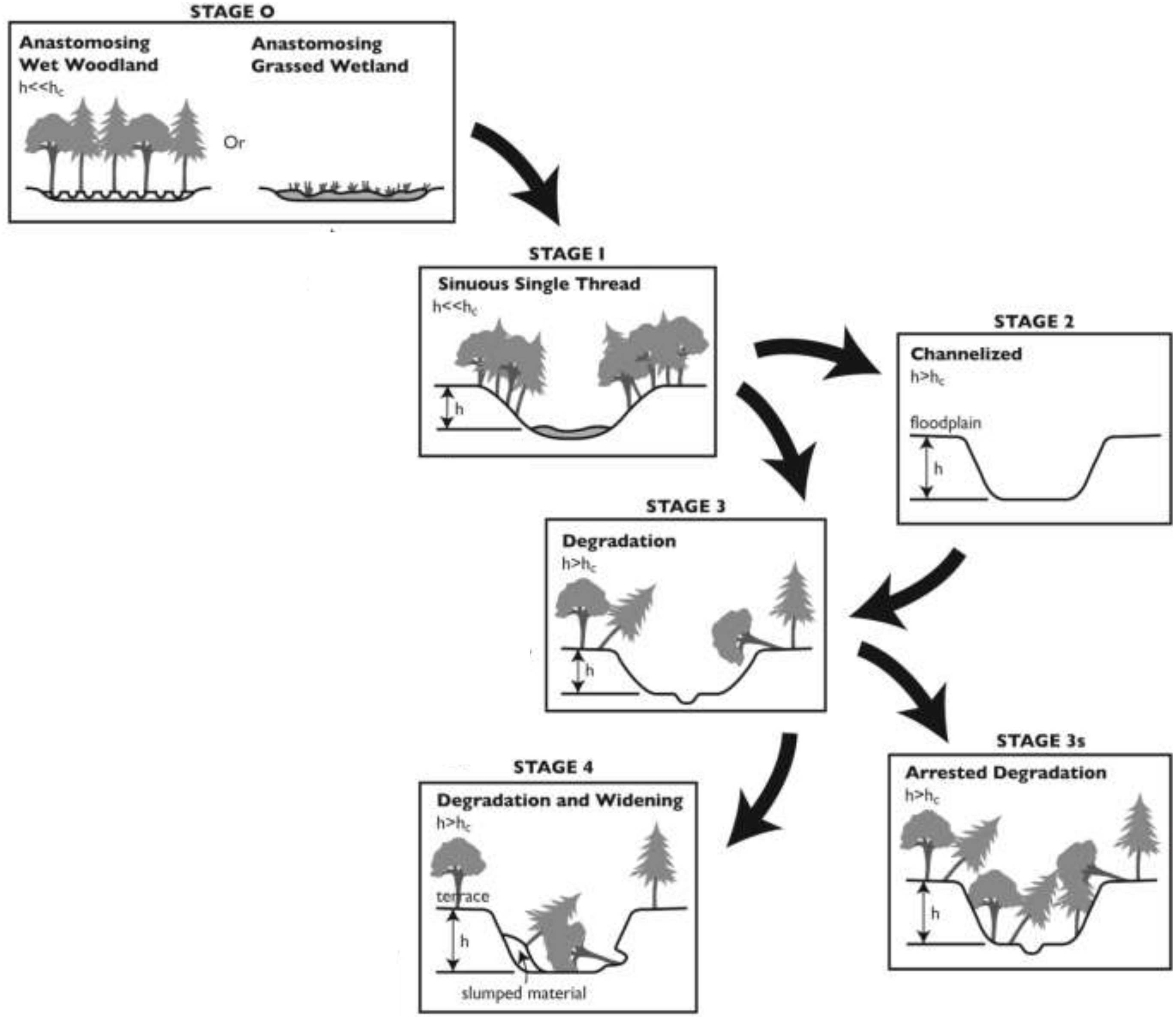


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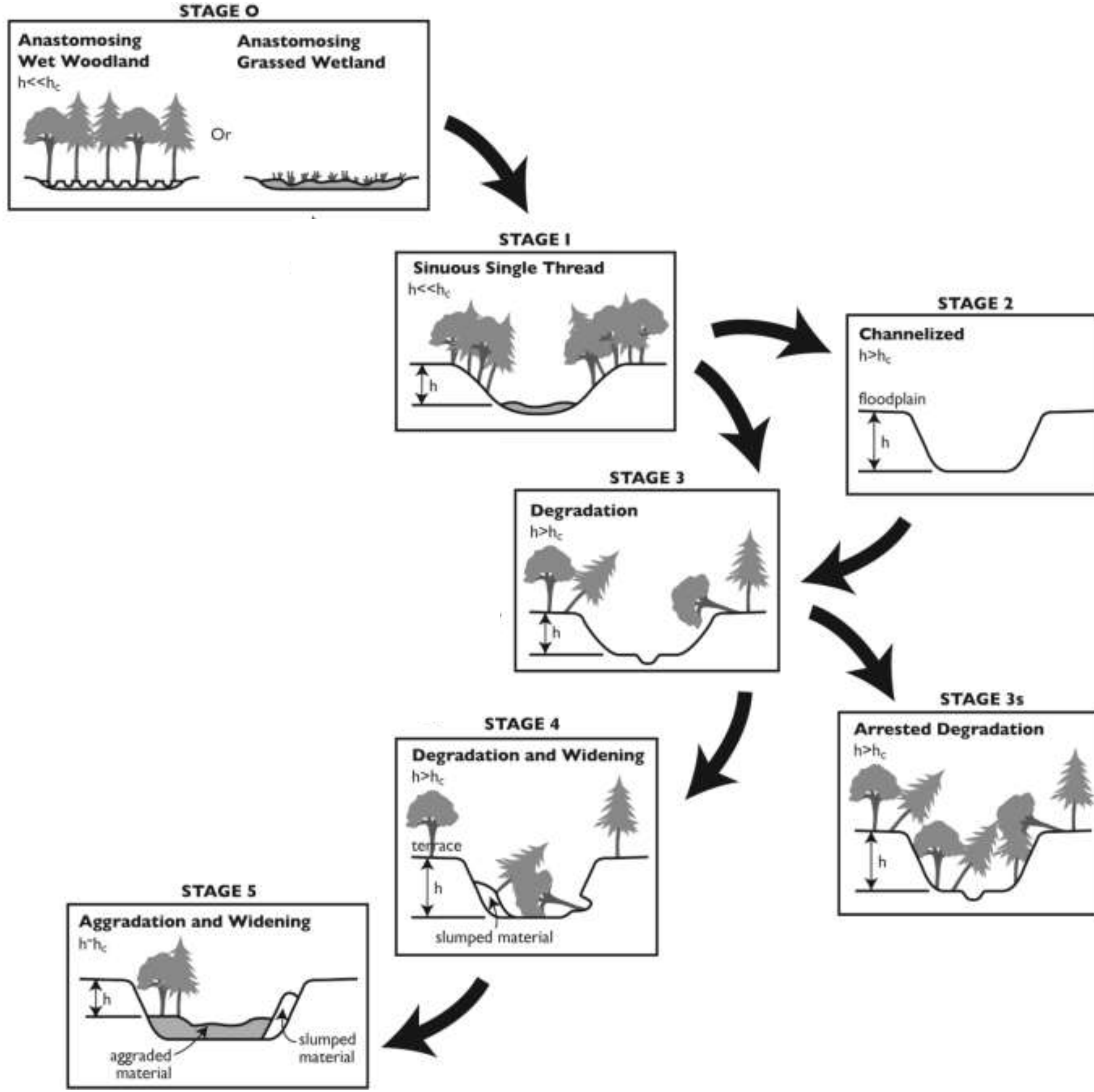


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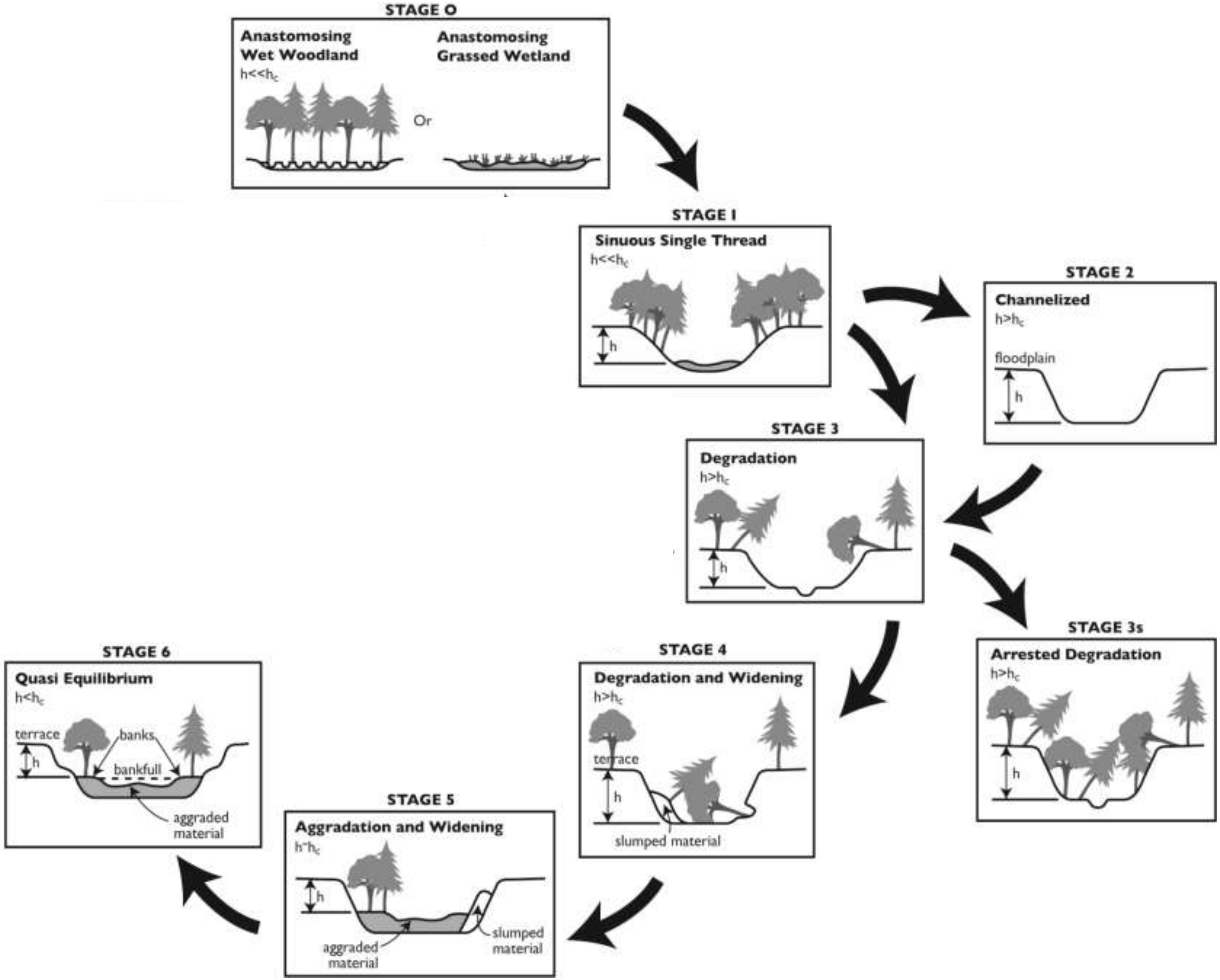


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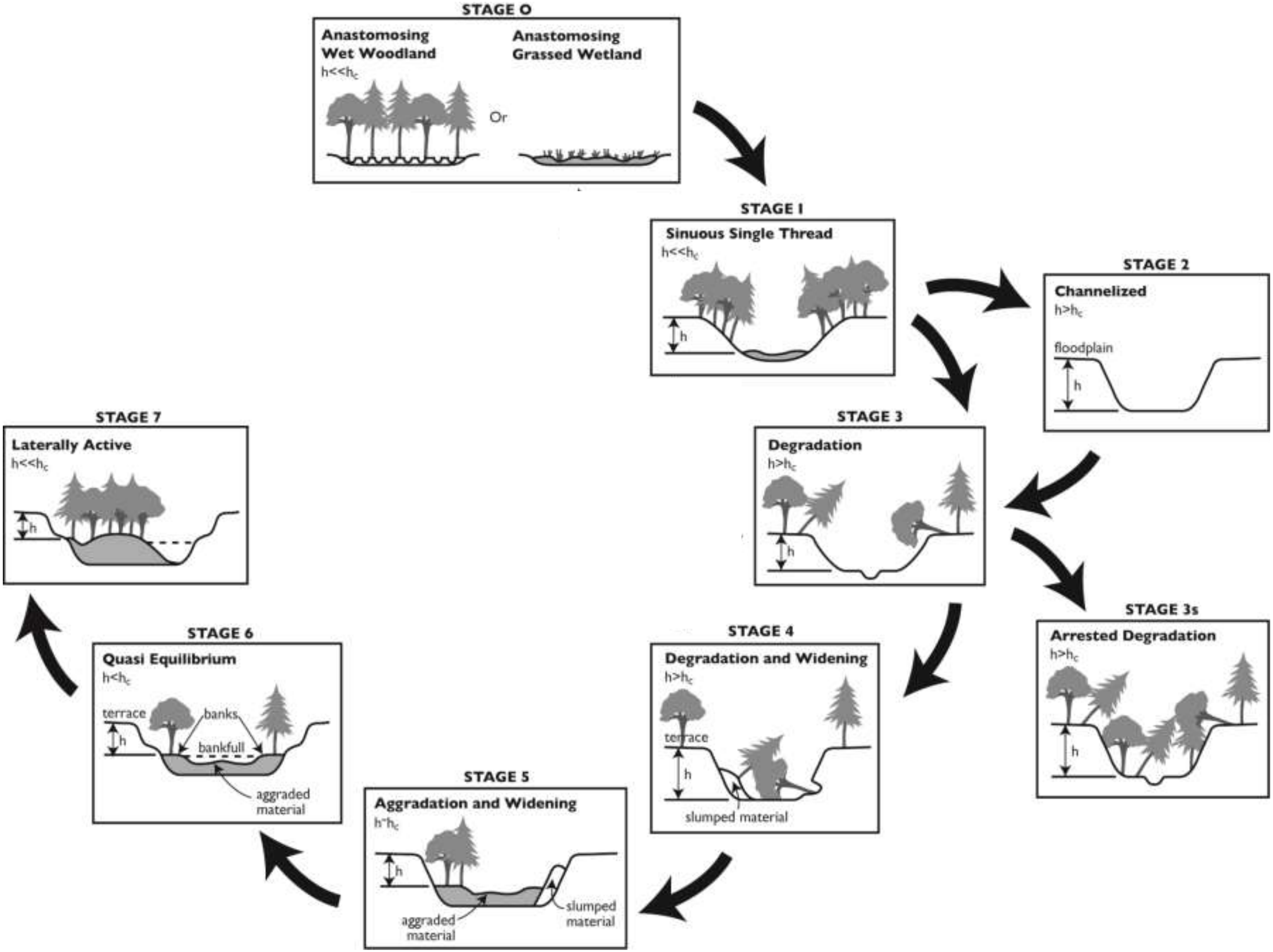


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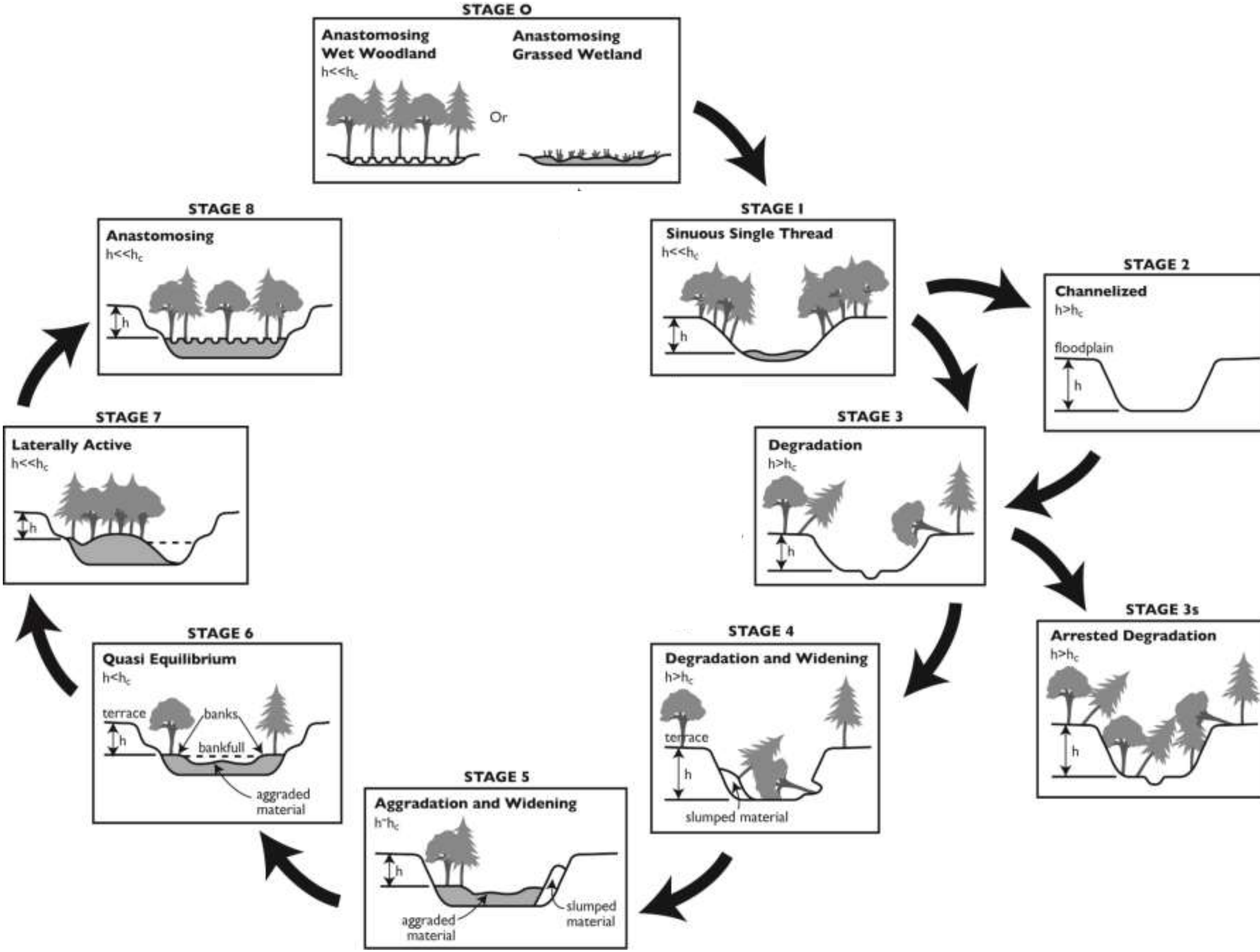


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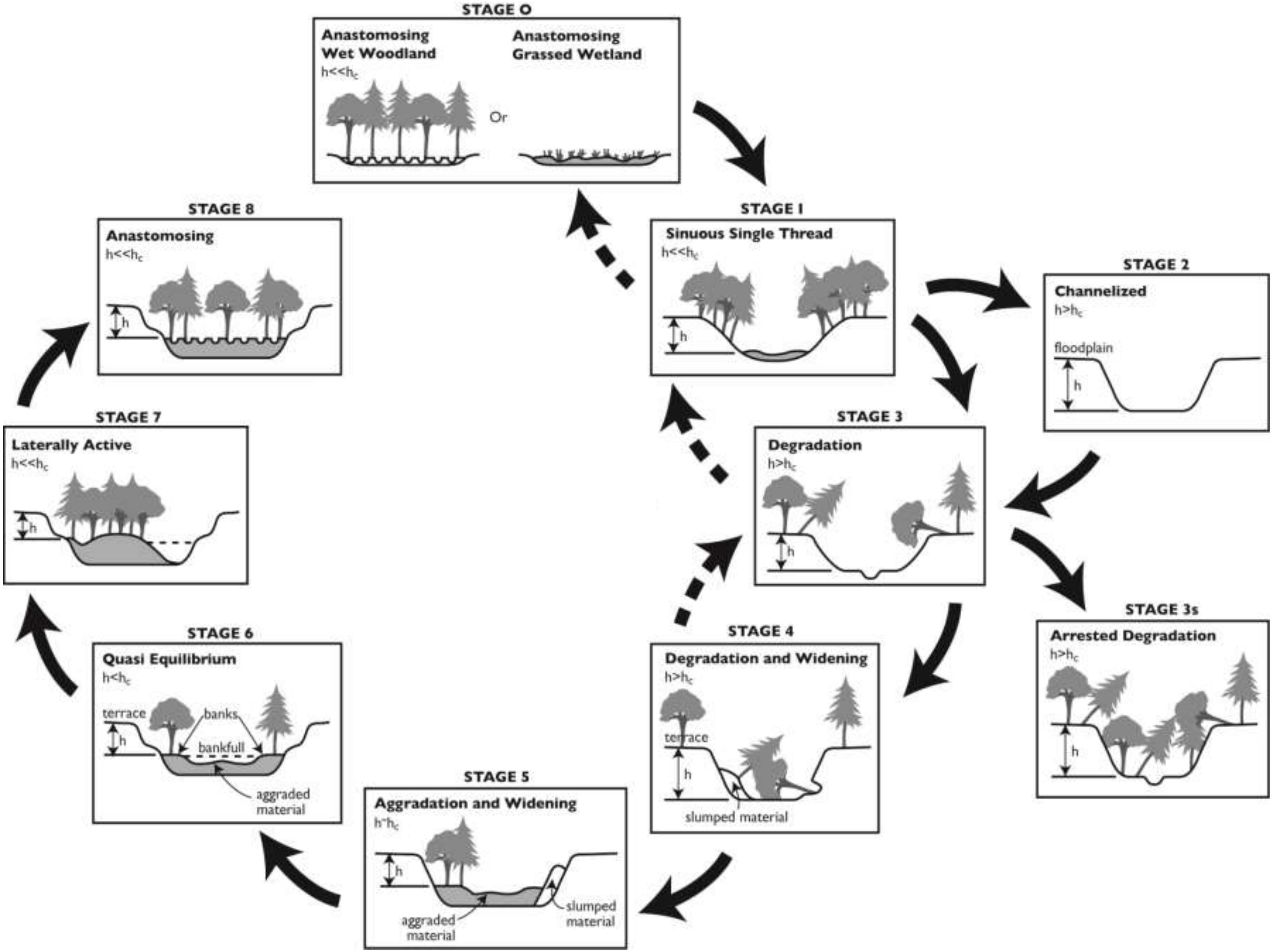


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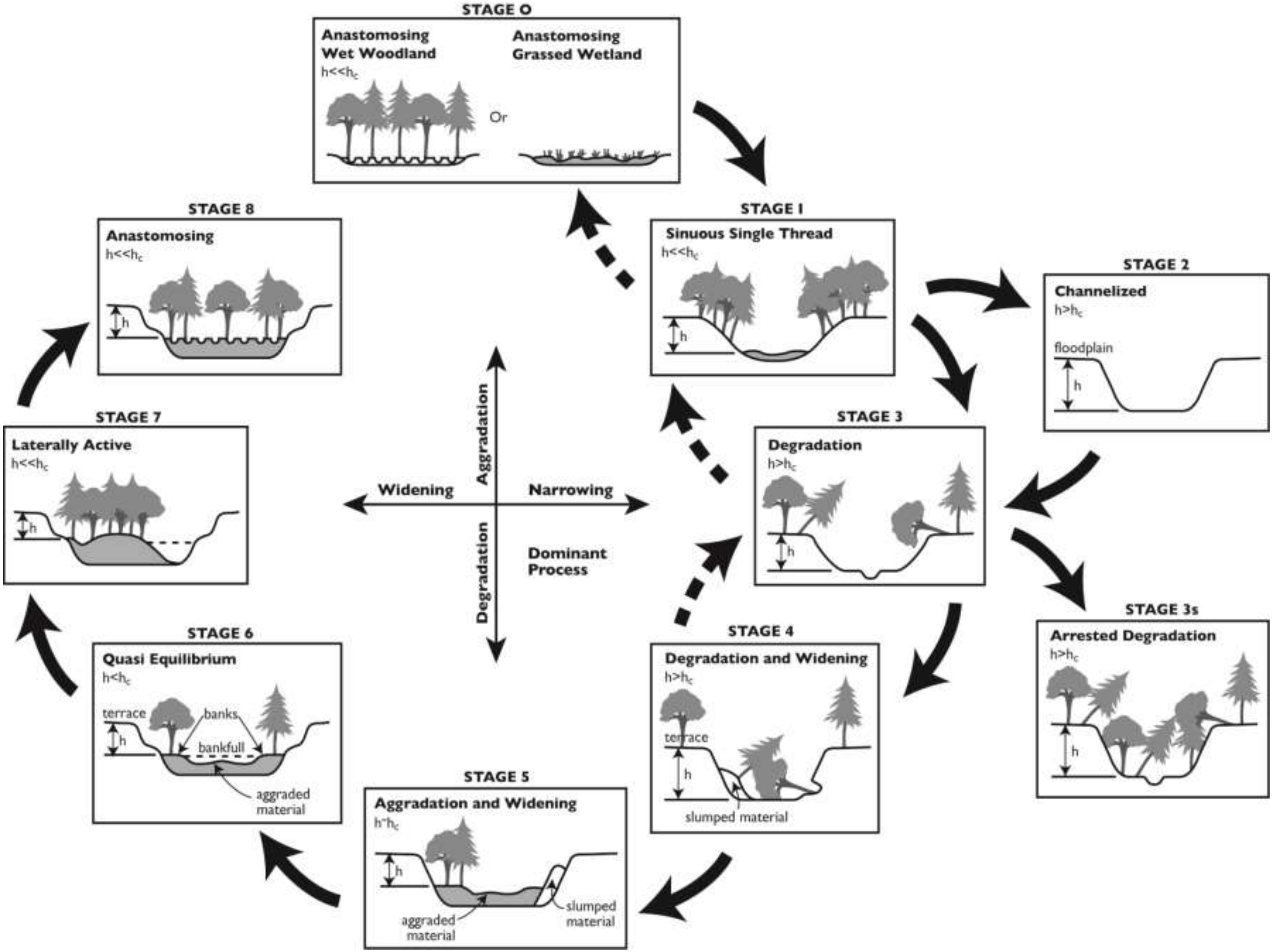



Cluer and Thorne, RRA, 2013

# Each SEM Stage is associated with habitat and ecosystem benefits using principals of functional ecology.

- The potential for a stream to support resilient and diverse ecosystems increases with hydroperiod and morphological diversity.
- Morphological adjustments (SEM Stage) have implications for diversity and richness of habitat and ecosystem services.

Primary literature: Harper et al 1995, Padmore 1997, Newson and Newson 2000, Thorpe et al 2010

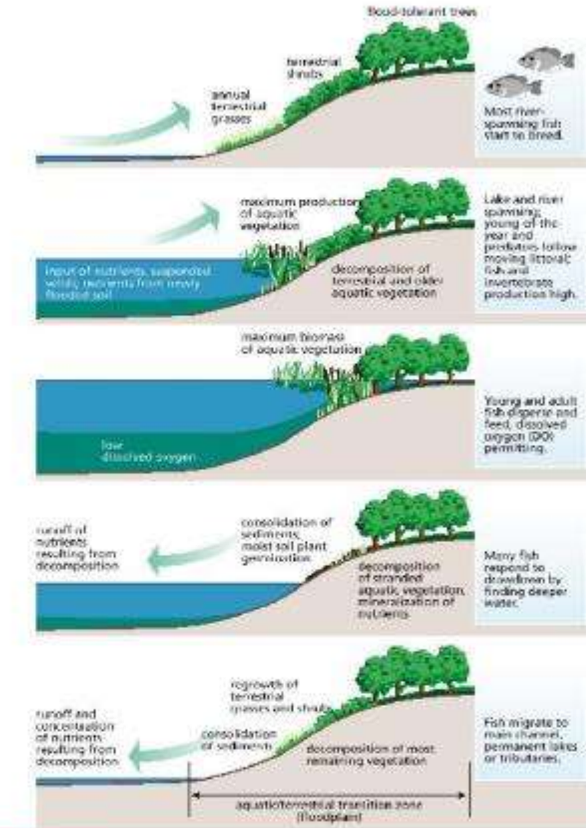
# Physical Attributes

## Hydrologic regime

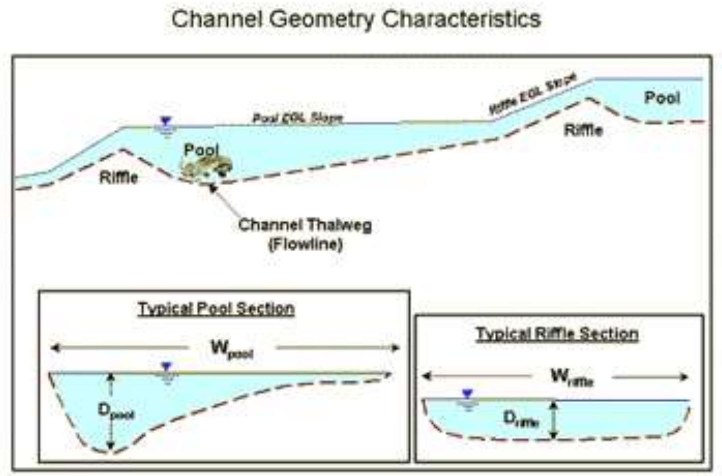
- Base flows
  - Habitability and biodiversity
- Floods and flood pulses - timing
- Floodplain connectivity
  - Hydro-period, attenuation, recharge

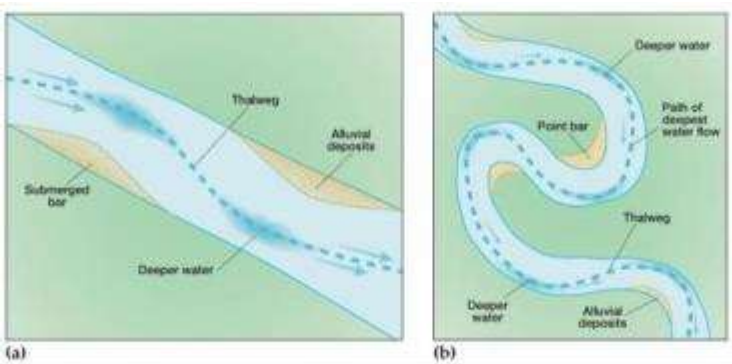
## Hydraulics

- Hydraulic diversity
  - Dead water
  - Rapid moving water




The flood-pulse concept diagrammed in five stages of an annual hydrologic cycle. The left column describes nutrient movement, the right describes typical life history traits of fish.



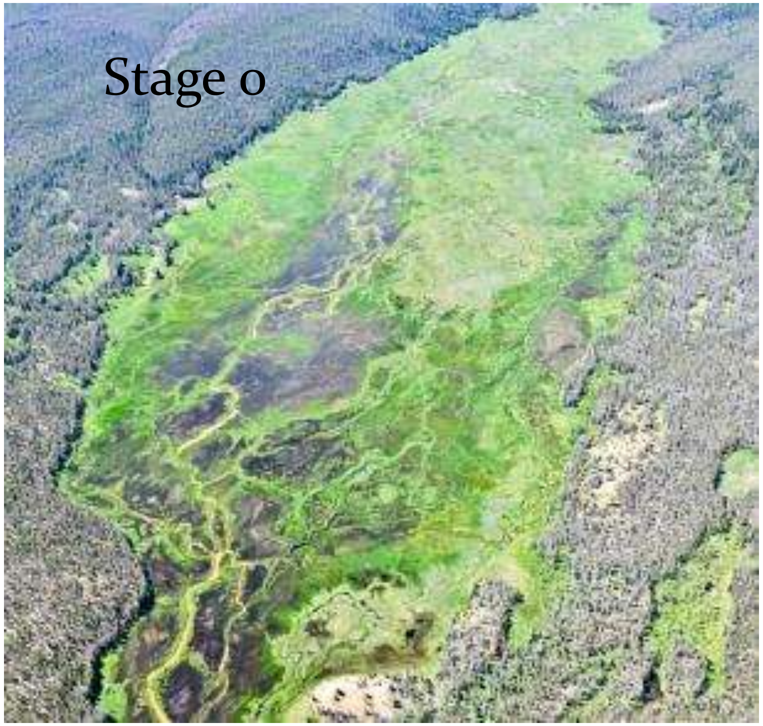




# Geomorphic attributes

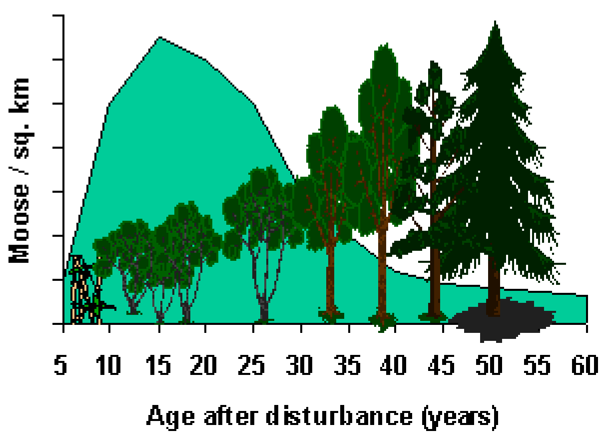
- Channel dimensions and geometry
  - Wetted area
  - Length and complexity of the shoreline
- Channel features
  - Bedforms, bars, islands, riparian margins
- Instream sediment storage
- Proportion of shoreline stable or unstable
- Substrate
  - Size and distribution, sorting, patchiness

# Floodplain attributes

- Extent and Connectivity
  - Inundation surfaces
    - Duration, timing
  - Topo variation on floodplain
  - Processes
    - Sediment storage
    - Carbon sequestration
    - Nutrient processing



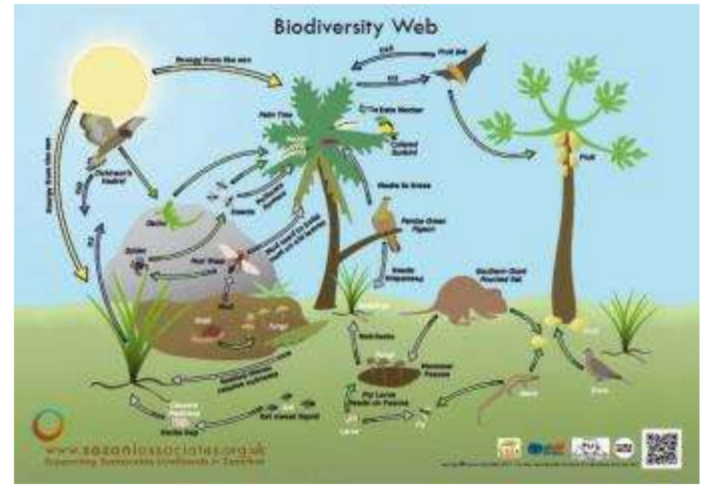

# Vegetation attributes

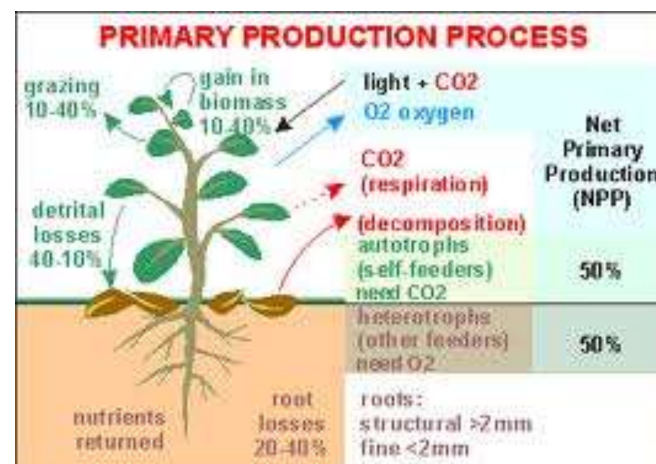



- Presence of plants
  - Aquatic, emergent, riparian, floodplain
- Leaf litter
  - Primary production support
- Tree trunk recruitment
  - Cycling nutrients and carbon
  - Hydraulic and morpho diversity
  - Channel stability
  - Sediment storage
  - Sorting and patchiness
  - Forcing hyporheic flow
- Riparian succession, dynamic landscape

# Habitat and ecosystem benefits

- Biota
  - Biodiversity (species richness and trophic diversity) varies in relation to morphologic diversity of the channel and the extent and frequency of floodplain connectivity
  - Proportion of native plants
  - $1^o$ and $2^o$ productivity; in proportion to the hydrologic, hydraulic, morphologic and vegetative diversity



- Resilience
  - Floods
    - Stage resilient slopes
    - Floodplain slope and roughness
  - Droughts
    - Water table connection
    - Availability of deep pools
- Able to withstand disturbances

# Each stream Stage is associated with a gradient of hydrogeomorphic processes and habitat and ecosystem benefits.

- Assessment per stage:
  - Interpretation of processes and resulting physical attributes,
  - Informed by published relationships between stream attributes, functional habitats, and freshwater ecology.

# Attributes and Benefits, scoring scheme:

- Hydrogeomorphic attributes (26)
  - Hydraulic complexity
  - Physical channel dimensions, #
  - Hydrologic regime, floodplain
  - Channel and floodplain features
  - Substrate – sorting/patchiness
  - Vegetation – sediment interaction

**Ordinal Score:**
0 = absent
1 = scarce/partly functional
2 = present and functional
3 = abundant/fully functional

- Habitat and Ecosystem Benefit attributes (11)
  - Refugia from extremes – flood/drought
  - Water quality – clarity/temperature/nutrient cycling
  - Biota – diversity/natives/$1^{o}$ & $2^{o}$ productivity
  - Resilience to disturbance

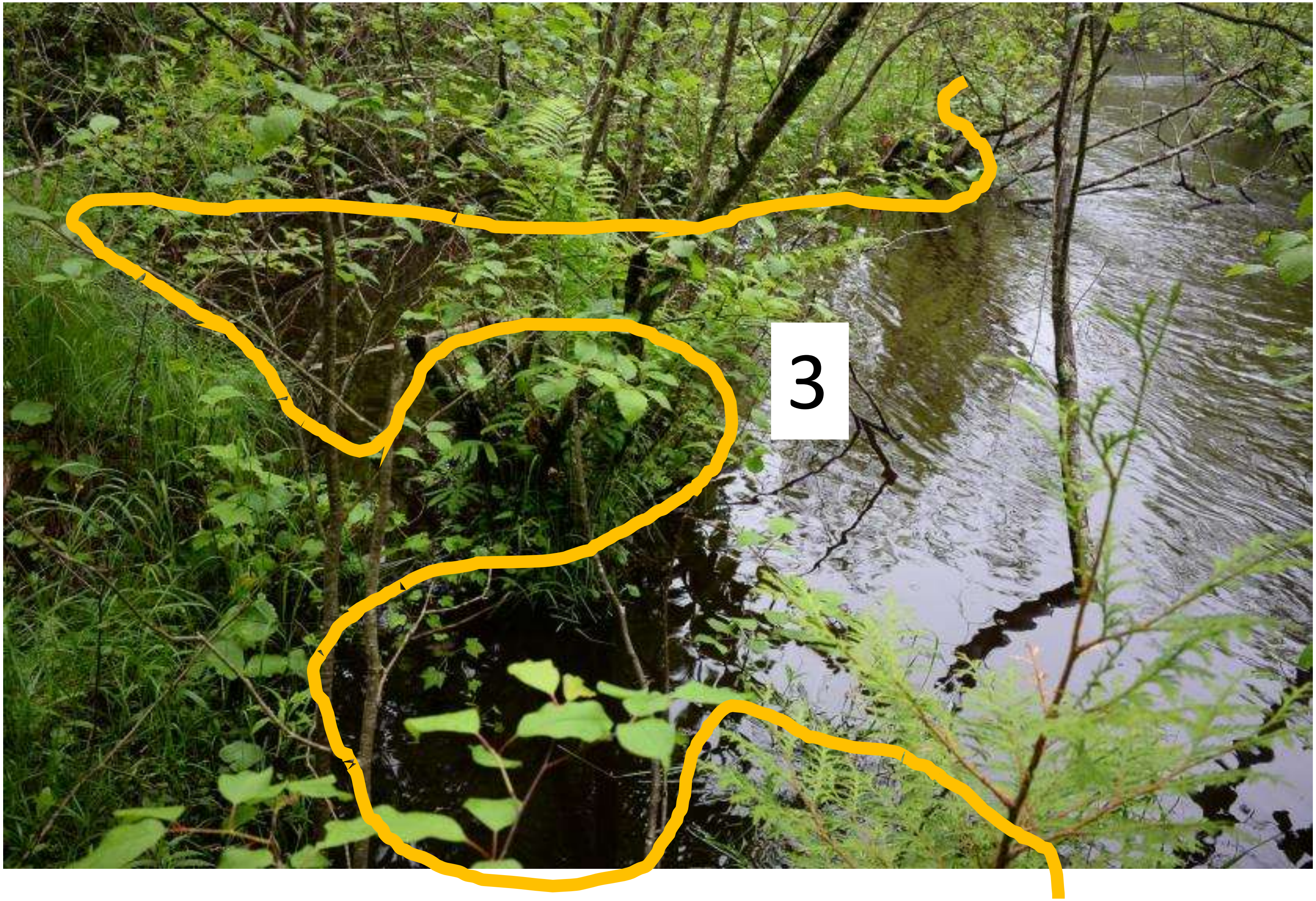
, Valley Creek, ID

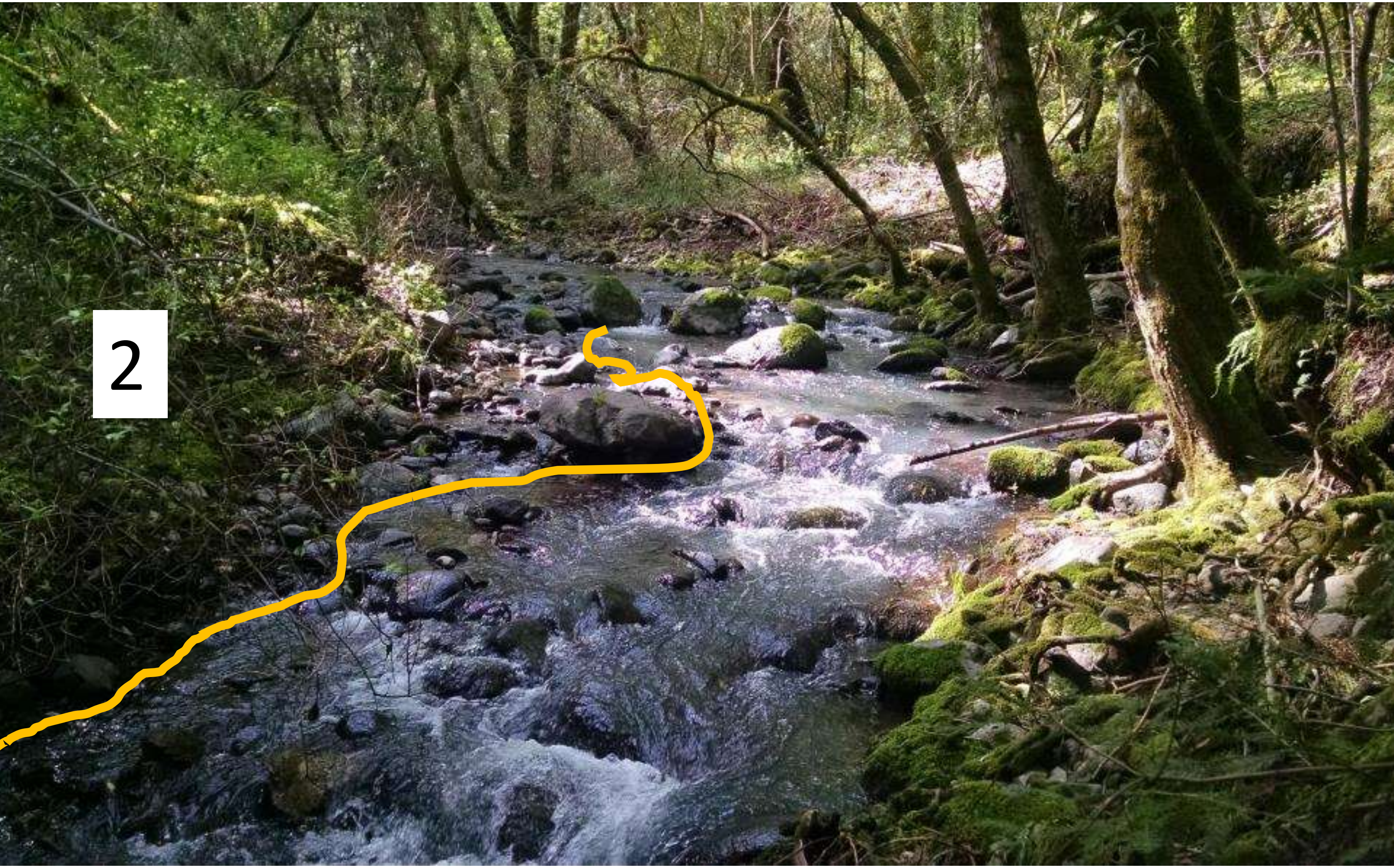
## Hydrogeomorphic Attributes Table

| Stage | 0 | 1 | 2 | 3 | 3s | 4 | 4-3 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Physical Channel Dimensions** | | | | | | | | | | | |
| Wetted Area Relative to Flow | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 2 |
| Shoreline Length and Complexity | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 2 |
| **Channel and Floodplain Features** | | | | | | | | | | | |
| Bedforms and bars | 2 | 3 | 1 | 0 | 0 | 1 | 0 | 2 | 3 | 3 | 2 |
| Islands | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| Local Confluence/Diffluences | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| Stable banks | 3 | 2 | 2 | 2 | 2 | 0 | 0 | 1 | 2 | 2 | 3 |
| River cliffs | 2 | 2 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 |
| Riparian Margins | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 2 | 3 |
| Floodplain Extent and Connectivity | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 |
| Side channels | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 |
| sediment storage | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| Connected Wetlands | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| **Substrate** | | | | | | | | | | | |
| Substrate Sorting | 2 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 2 |
| Substrate Patchiness | 3 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 3 | 3 |
| **Hydraulics** | | | | | | | | | | | |
| Hydraulic Diversity | 3 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 3 |
| Marginal Deadwater | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| **Vegetation** | | | | | | | | | | | |
| Aquatic plants | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 3 |
| Emergent Plants | 3 | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 2 | 1 | 3 |
| Riparian plants | 3 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 3 |
| Floodplain plants | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| Woody debris | 3 | 1 | 0 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 3 |
| Leaf litter | 3 | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 2 | 2 | 3 |
| **Hydrological Regime** | | | | | | | | | | | |
| Flood pulse | 1 | 1 | 2 | 3 | 3 | 3 | 3 | 2 | 2 | 1 | 1 |
| Flood attenuation | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| Base flow | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 |
| Hyporheic connectivity | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 |
| **Results** | | | | | | | | | | | |
| possible | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 | 78 |
| sum | 72 | 54 | 19 | 12 | 18 | 9 | 6 | 22 | 35 | 50 | 67 |
| ratio | 92% | 69% | 24% | 15% | 23% | 12% | 8% | 28% | 45% | 64% | 86% |

Table IV

Shoreline Length and Complexity

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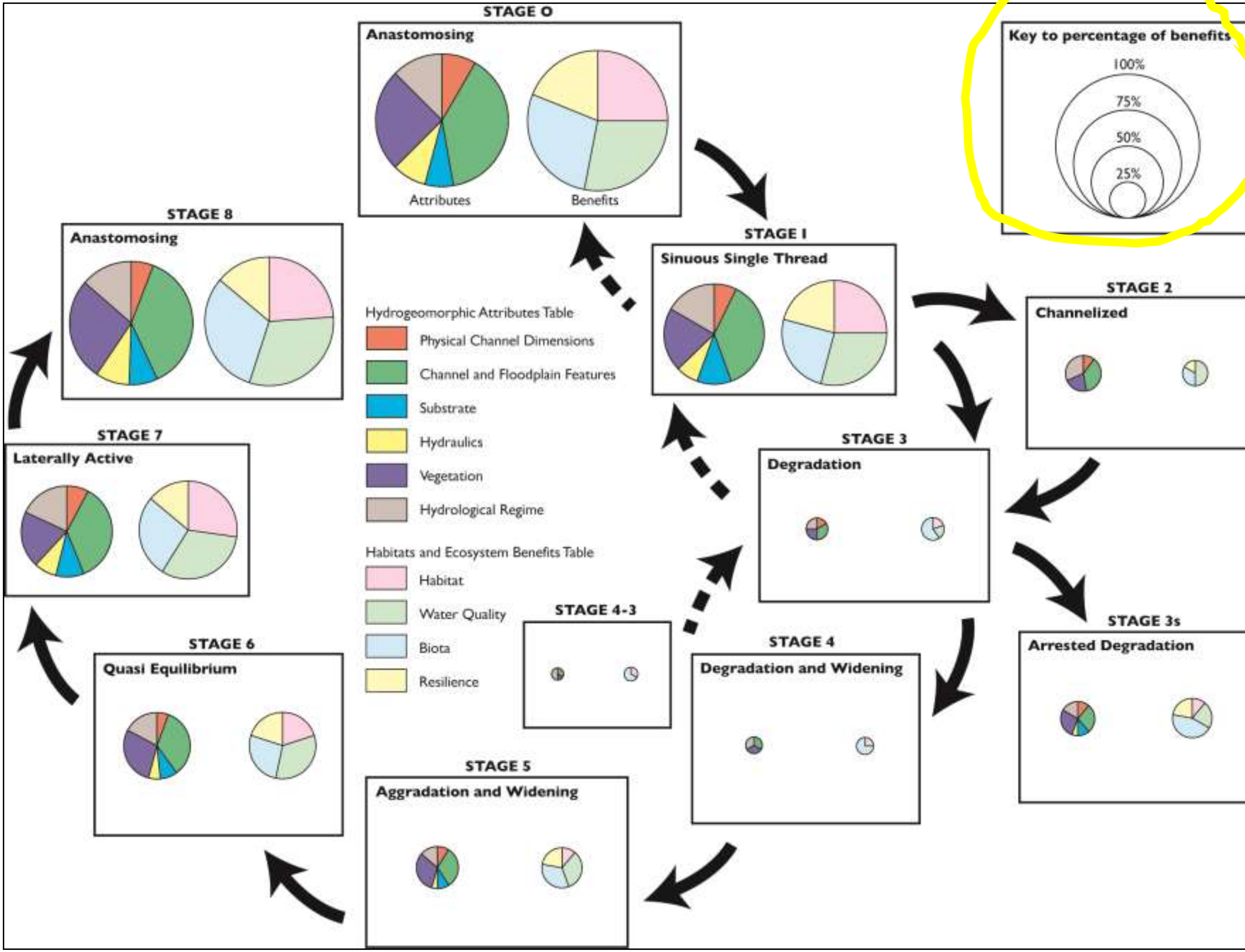
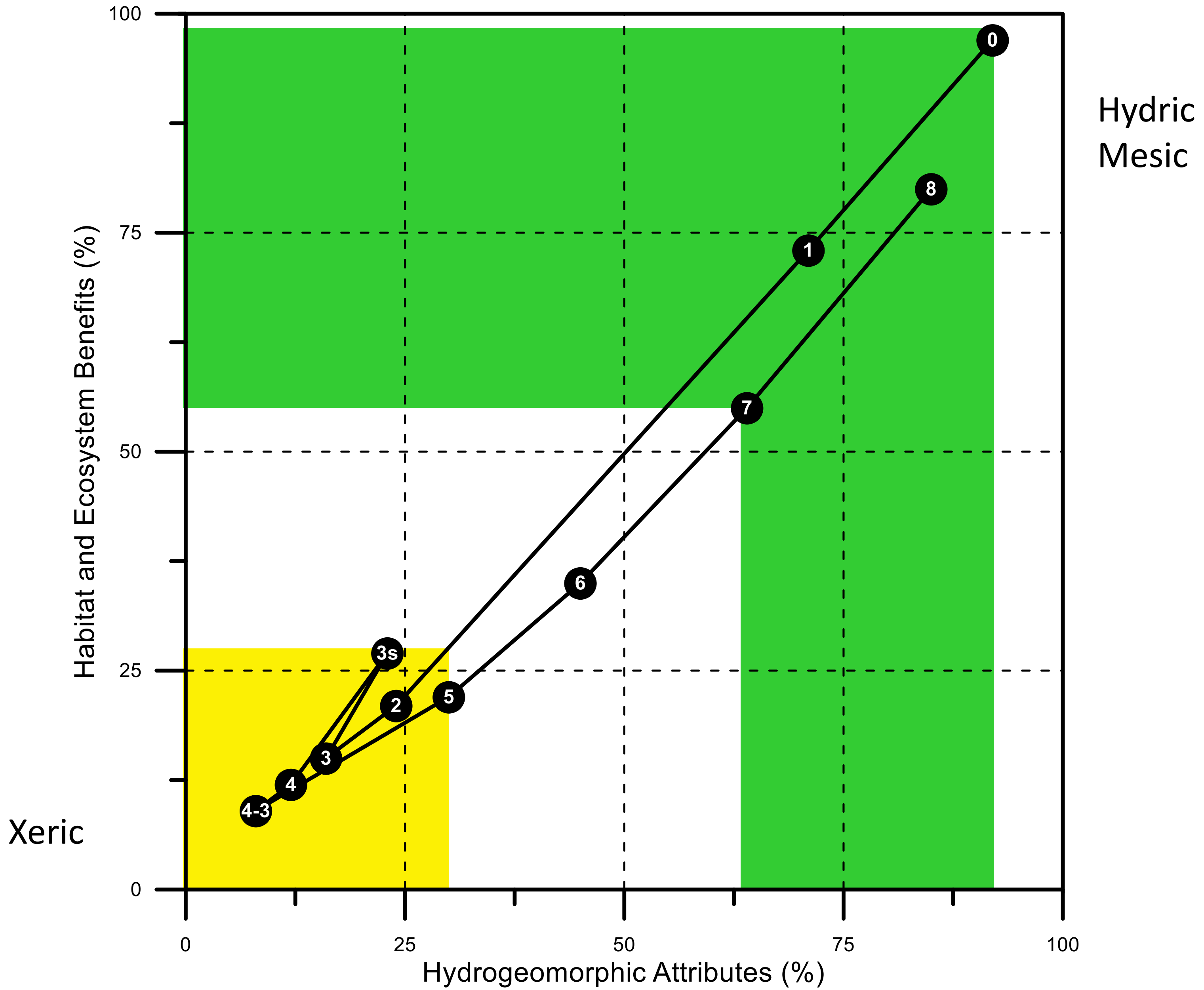
## Habitat and Ecosystem Benefits Table

| Stage | 0 | 1 | 2 | 3 | 3s | 4 | 4-3 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Habitat** | | | | | | | | | | | |
| Flood Refugia | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 |
| Drought Refugia | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 |
| Exposed tree roots | 3 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 3 |
| **Water Quality** | | | | | | | | | | | |
| Clarity | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 3 |
| Temperature amelioration (shade and hyporheic flow) | 3 | 3 | 1 | 1 | 2 | 0 | 0 | 1 | 2 | 3 | 3 |
| nutrient cycling | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 |
| **Biota** | | | | | | | | | | | |
| Biodiversity (species richness and trophic diversity) | 3 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 |
| Proportion of Native Biota | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 |
| 1st and 2nd Order Productivity | 3 | 2 | 1 | 1 | 2 | 1 | 0 | 1 | 2 | 2 | 3 |
| **Resilience** | | | | | | | | | | | |
| Disturbance | 3 | 3 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 2 |
| Flood and Drought | 3 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 2 |
| **Results** | | | | | | | | | | | |
| possible | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| sum | 32 | 24 | 6 | 5 | 9 | 4 | 3 | 9 | 15 | 22 | 29 |
| ratio | 97% | 73% | 18% | 15% | 27% | 12% | 9% | 27% | 45% | 67% | 88% |

Table V

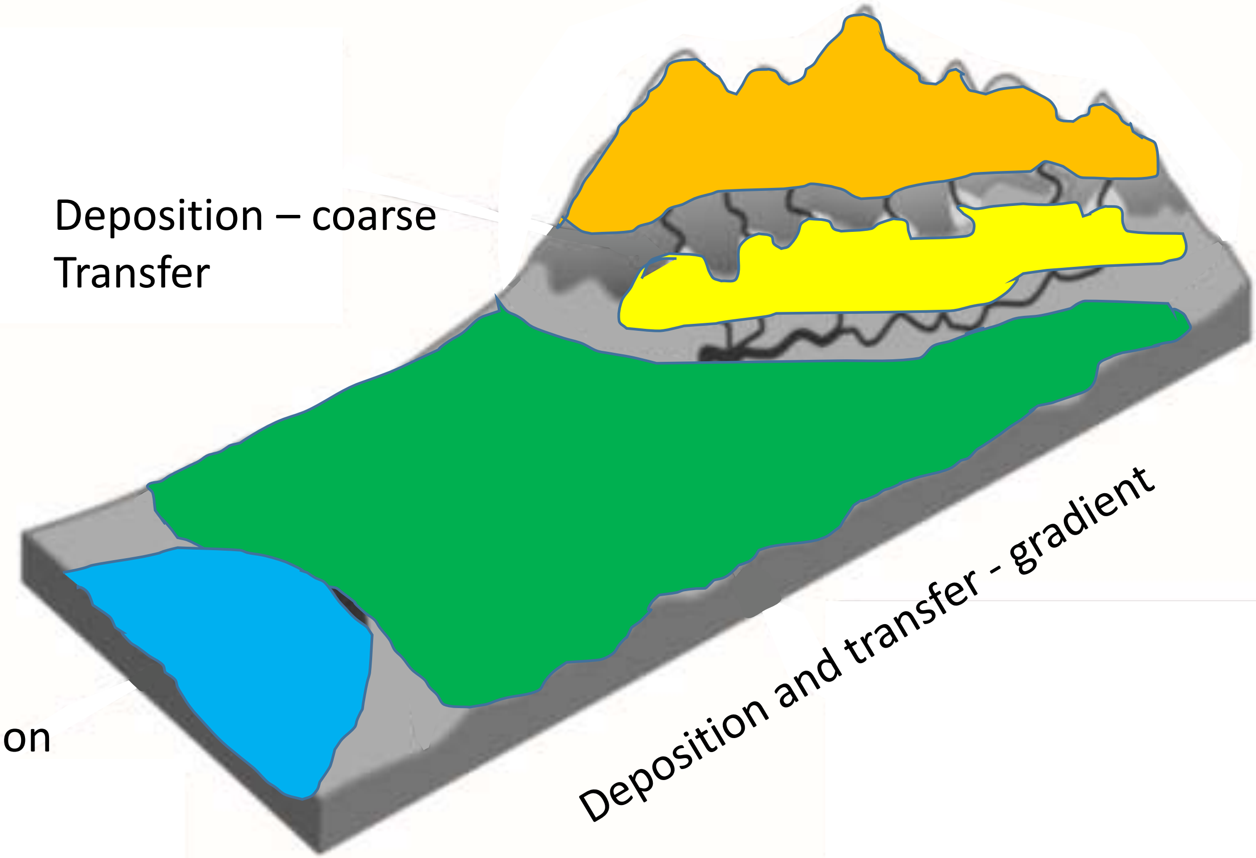


STAGE 0
Anastomosing
Attributes
Benefits
Key to percentage of benefits
100%
75%
50%
25%
STAGE 8
Anastomosing
STAGE 1
Sinuous Single Thread
STAGE 2
Channelized
Hydrogeomorphic Attributes Table
Physical Channel Dimensions
Channel and Floodplain Features
Substrate
Hydraulics
Vegetation
Hydrological Regime
STAGE 7
Laterally Active
STAGE 3
Degradation
Habitats and Ecosystem Benefits Table
Habitat
Water Quality
Biota
Resilience
STAGE 4-3
STAGE 3s
Arrested Degradation
STAGE 6
Quasi Equilibrium
STAGE 4
Degradation and Widening
STAGE 5
Aggradation and Widening

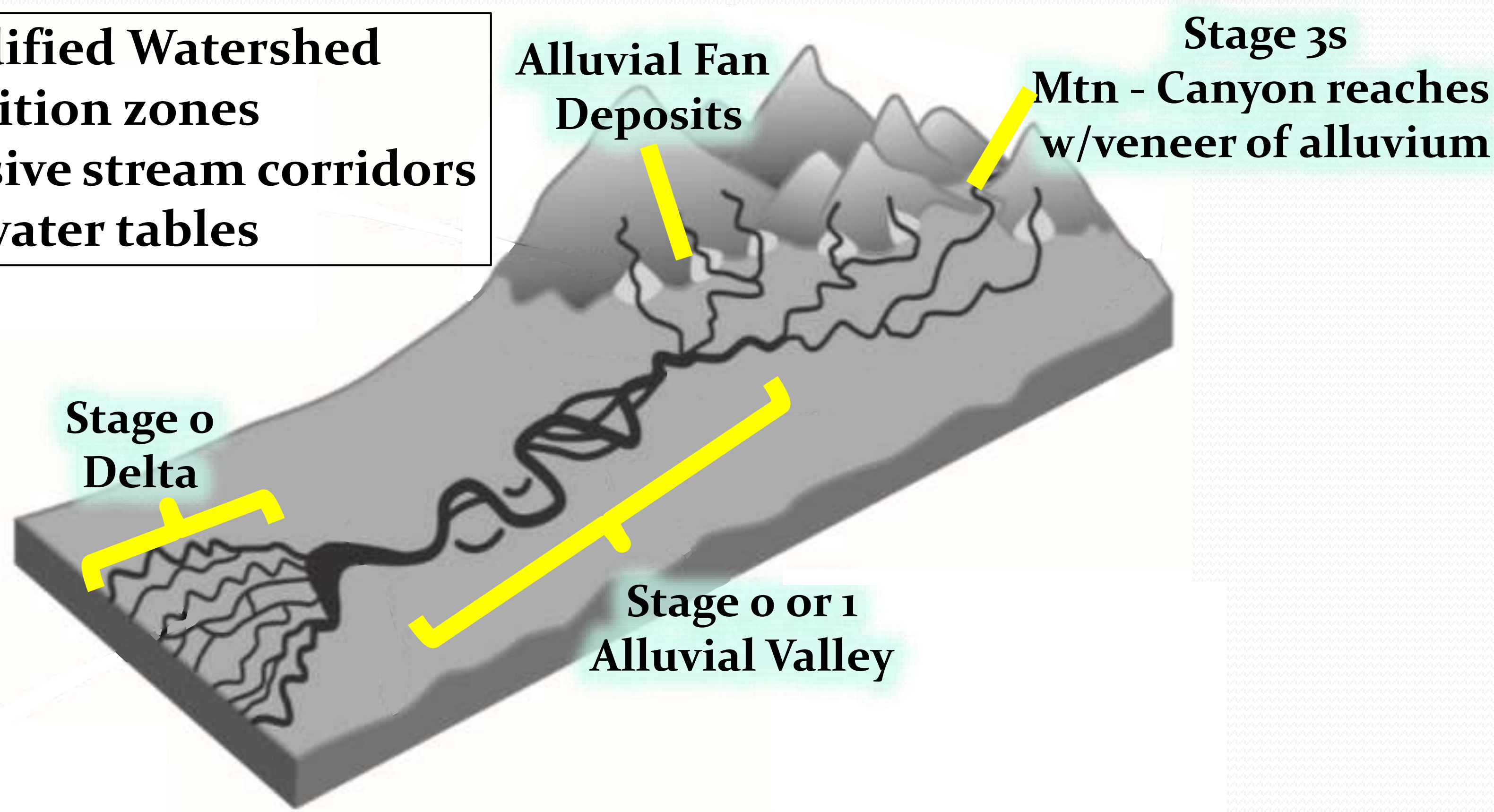


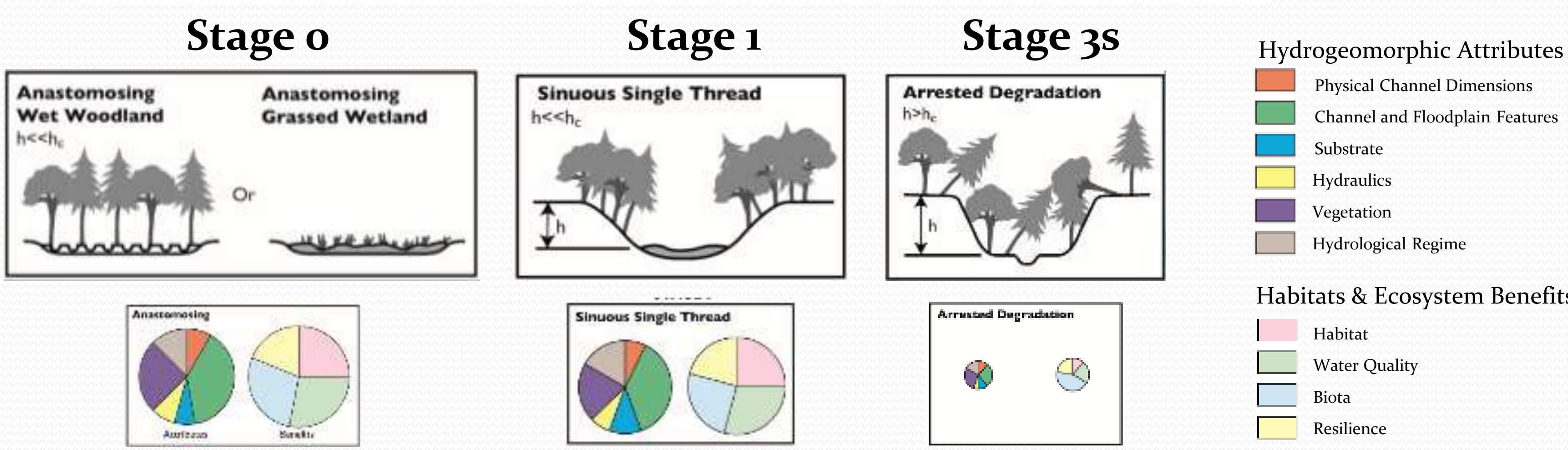
100
75
50
25
0
0
25
50
75
100
Habitat and Ecosystem Benefits (%)
Hydrogeomorphic Attributes (%)
Hydric
Mesic
Xeric
0
1
8
7
6
5
2
3s
3
4
4-3

# Applying the SEM Watershed Process Domains - Why Place Matters



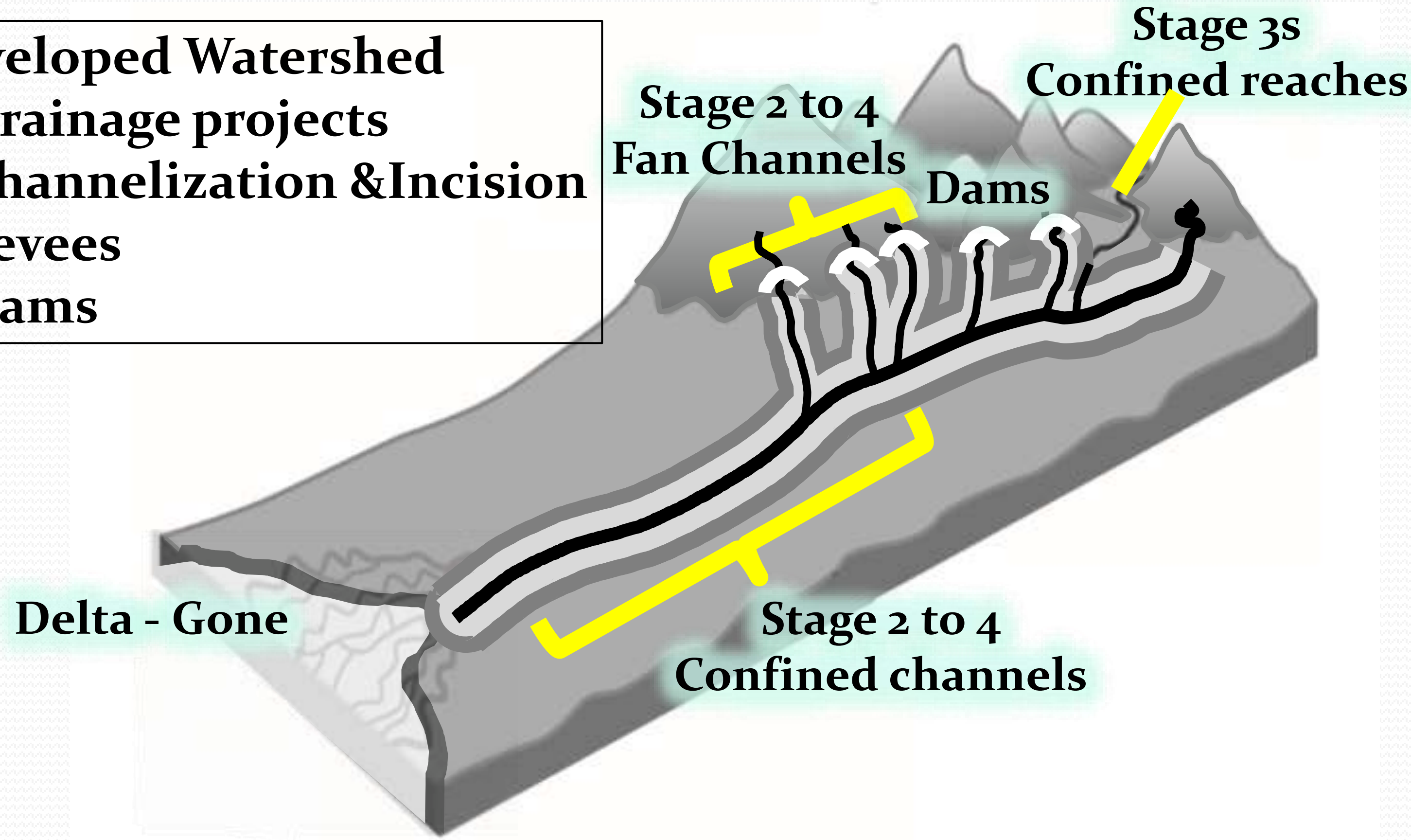
**Pre-modified Watershed**
- **Deposition zones**
- **Extensive stream corridors**
- **High water tables**

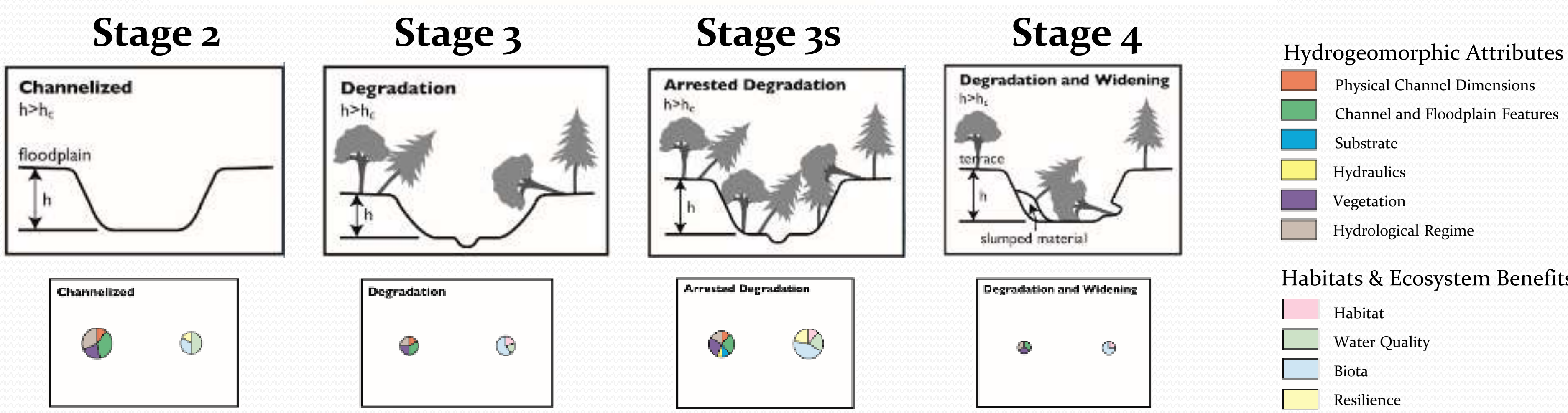


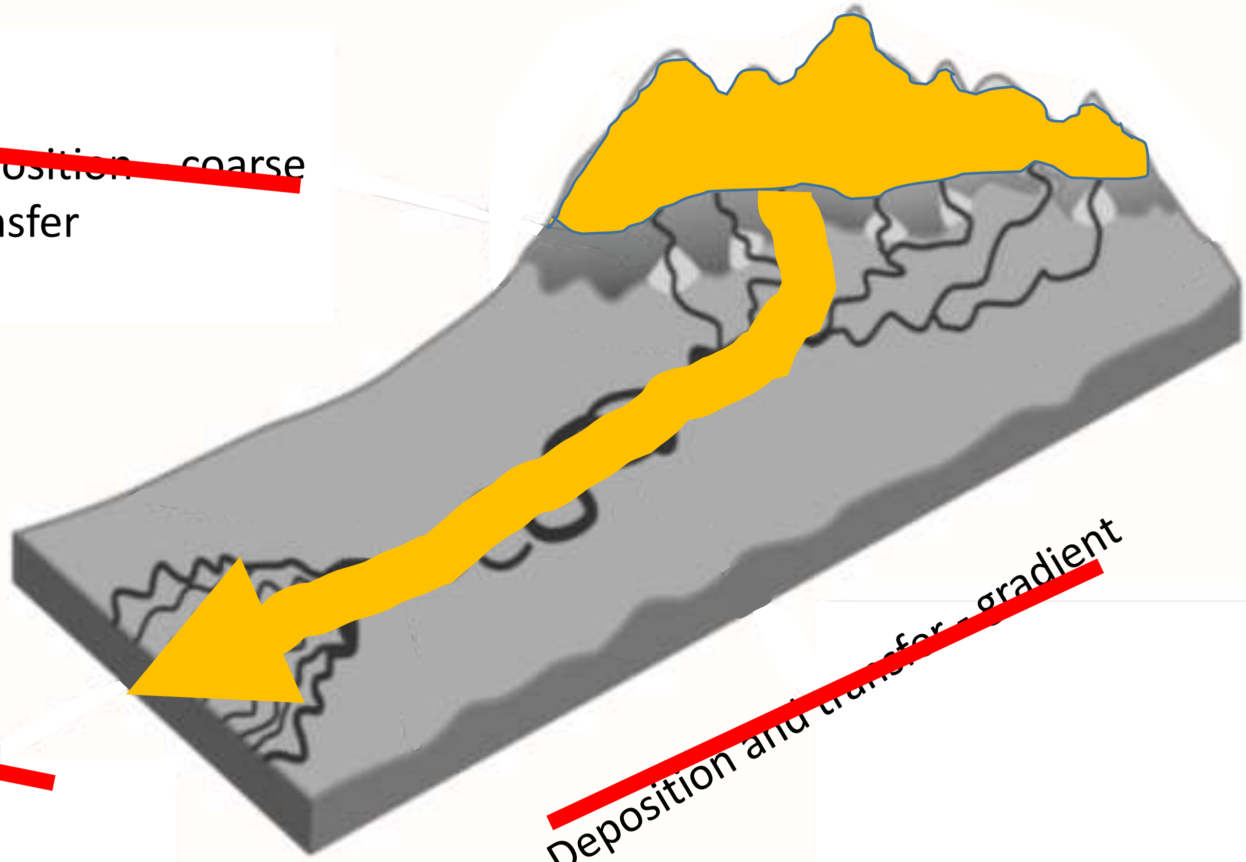
# Developed Watershed

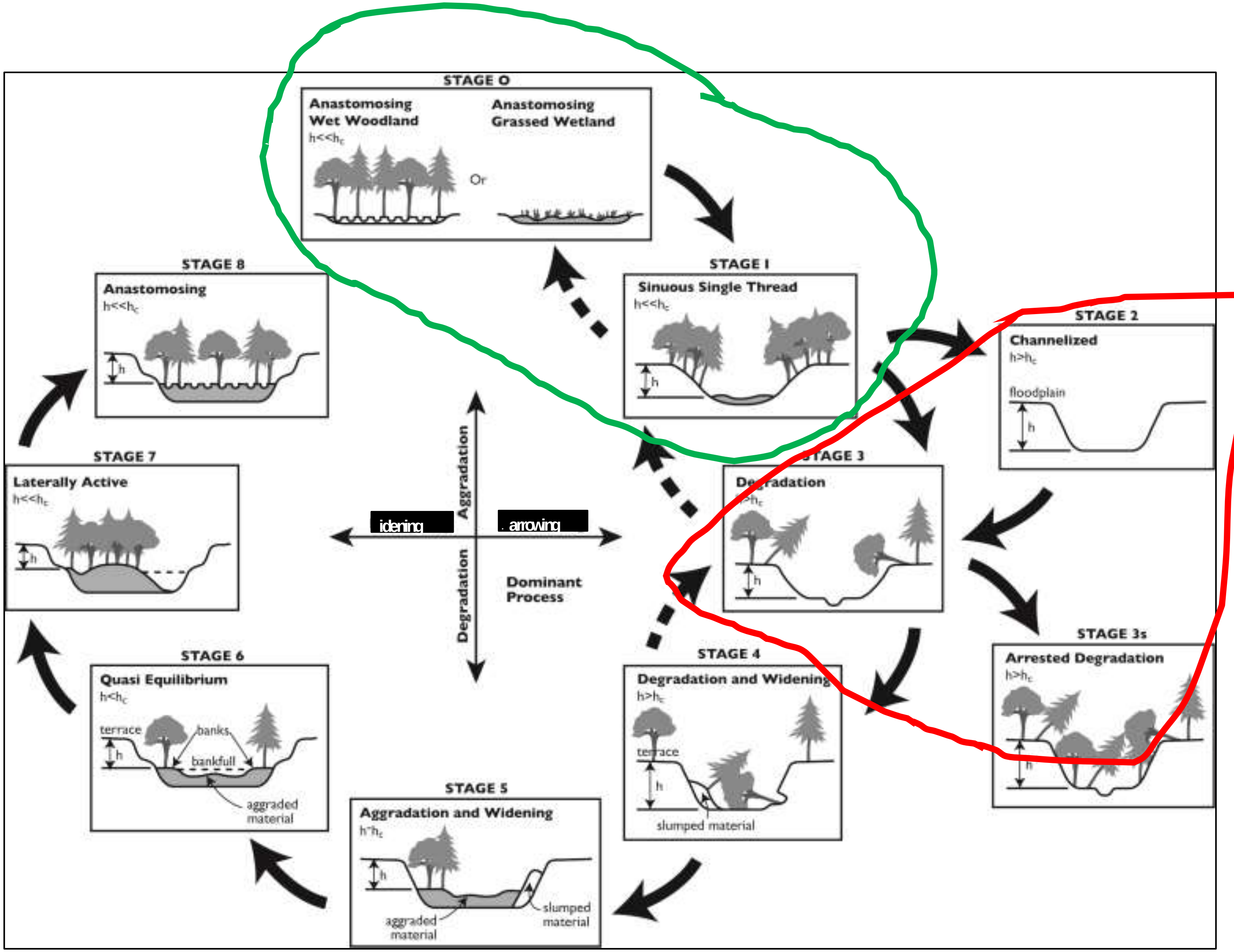
- Drainage projects
- Channelization &Incision
- Levees
- Dams



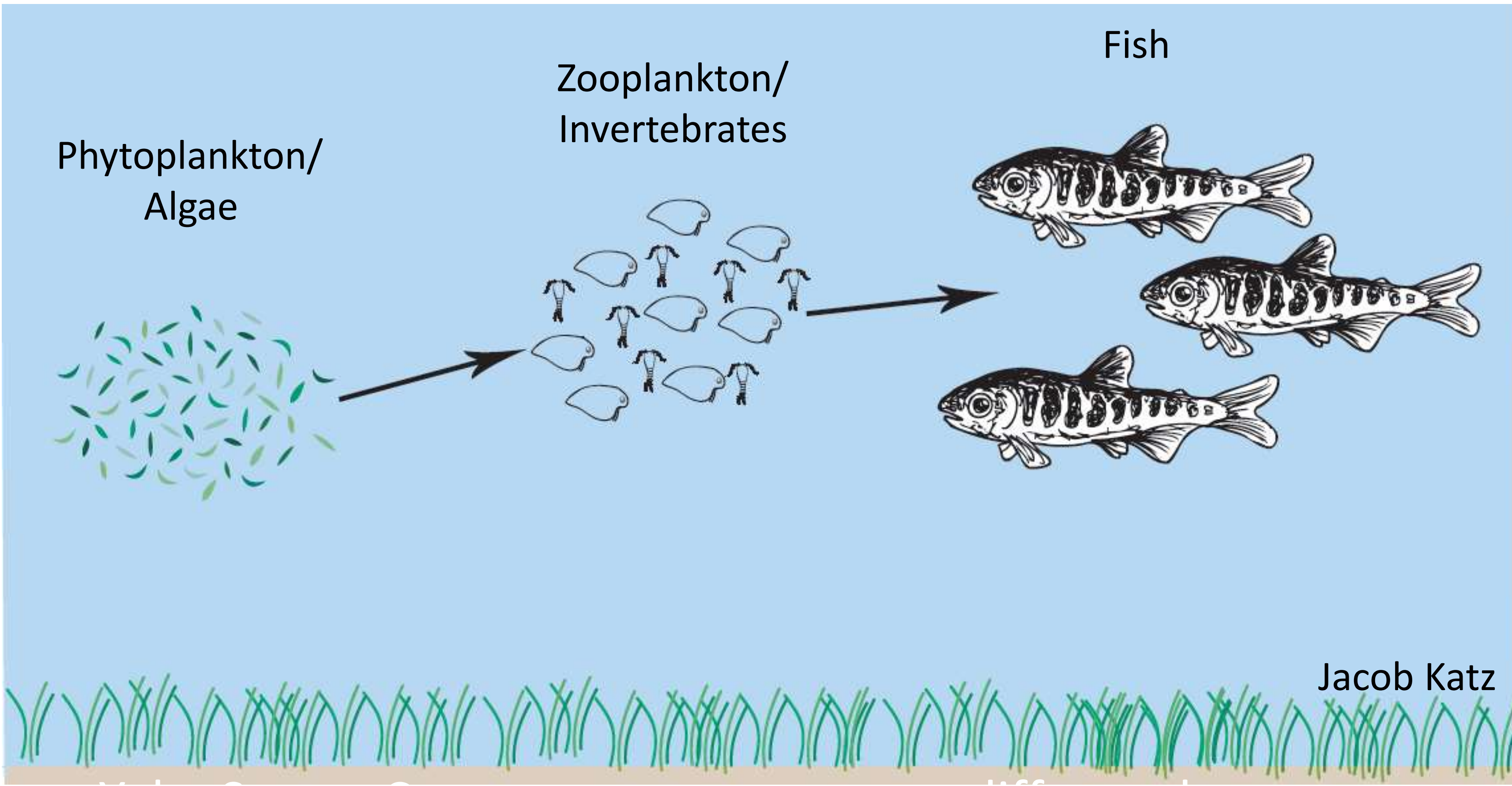
# Watershed Process Domains
# - Current Conditions






Evolving takes time and accommodation space. Poor forms may be very stable.

# Stage 0 stream –
## extensive floodplain interaction
## $1^{o}$ and $2^{o}$ production feeds juvenile salmon



# Damages – short list:

- Floodplains and wetlands drained
    - Floodplains converted to uplands
    - Water stored on-land diminished
    - Rivers converted to conduits, drain canals
- Ecosystem benefits diminished
    - Biological productivity collapsed
    - All aquatic functions diminished
    - Climate resiliency diminished
- Habitat diminished
    - Physically contracted to minimal space
    - Quality and attributes diminished
    - Resiliency and robustness diminished
    - Fish food source and flood refuge collapsed

# 21st century river management

- Streams are conduits for water – maximum drainage – minimum storage
- Water development extracts from the minimized storage and stream flow
- Conduits for sediment – deposition zones eradicated
- Sediment is considered a problem - pollutant

# We are conserving channels severed from their floodplains

- Stabilizing channels
  - Fossilizing poor condition
  - Retarding stream evolution
  - Counterproductive
- Adding habitat features
  - Combined with stabilization
  - Preventing geomorphic work or evolution
- Institutions discouraging process restoration
  - Roadblocks to sediment storage or bank erosion
  - Deterring floodplain restoration

# How can we “undrain” the land?

- Plug the channels that drain the water table
  - Immediate results
- Restore sediment deposition
  - Progressive results
  - Monitor – Adapt - Maintain

- Examples:

Butano Creek – plug channel and lower levee to connect 100 acre floodplain

# Add wood or restore wood recruitment in incised channels



**Add roughness and block cross section area**



Wallerstein, N.P. and Thorne, C.R., 2004. Influence of large woody debris on morphological evolution of incised, sand-bed channels. *Geomorphology*, *57*(1), pp.53-73.

# Fill Channels

*‘Stage Zero Rehabilitation’* Paul Powers, Deschutes NF Regional Restoration Team
Oregon AFS Meeting

*'Stage Zero Rehabilitation'* Paul Powers, Deschutes NF Regional Restoration Team
Oregon AFS Meeting

Whychus Creek, OR

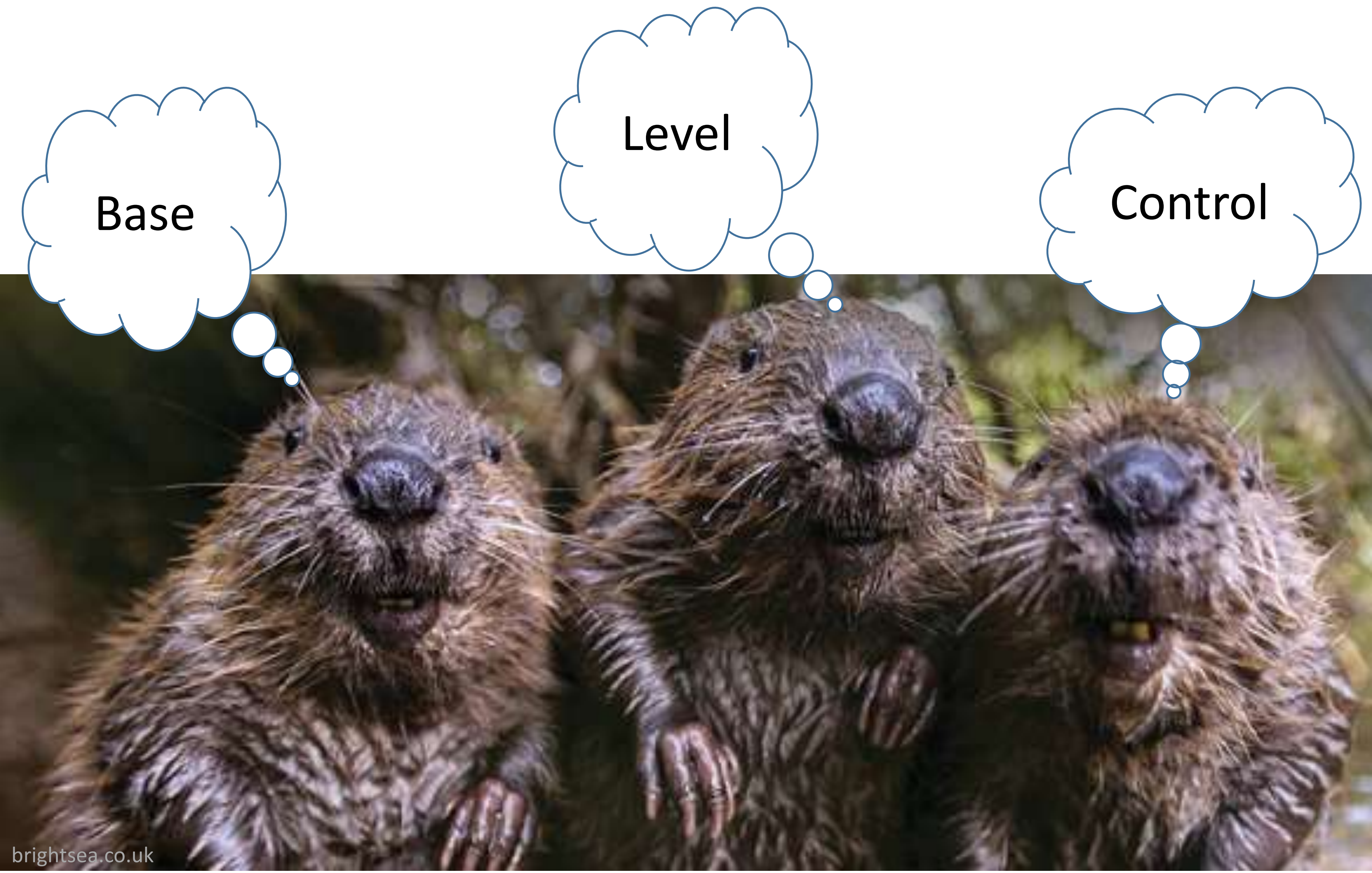
Richard Scott Nelson


Richard Scott Nelson

# Lost Cr- During Construction
View of the Upper Meadow
(HC#6)
October 2012

8,000 cubic yards fill


Pre-Construction
May 29, 2012

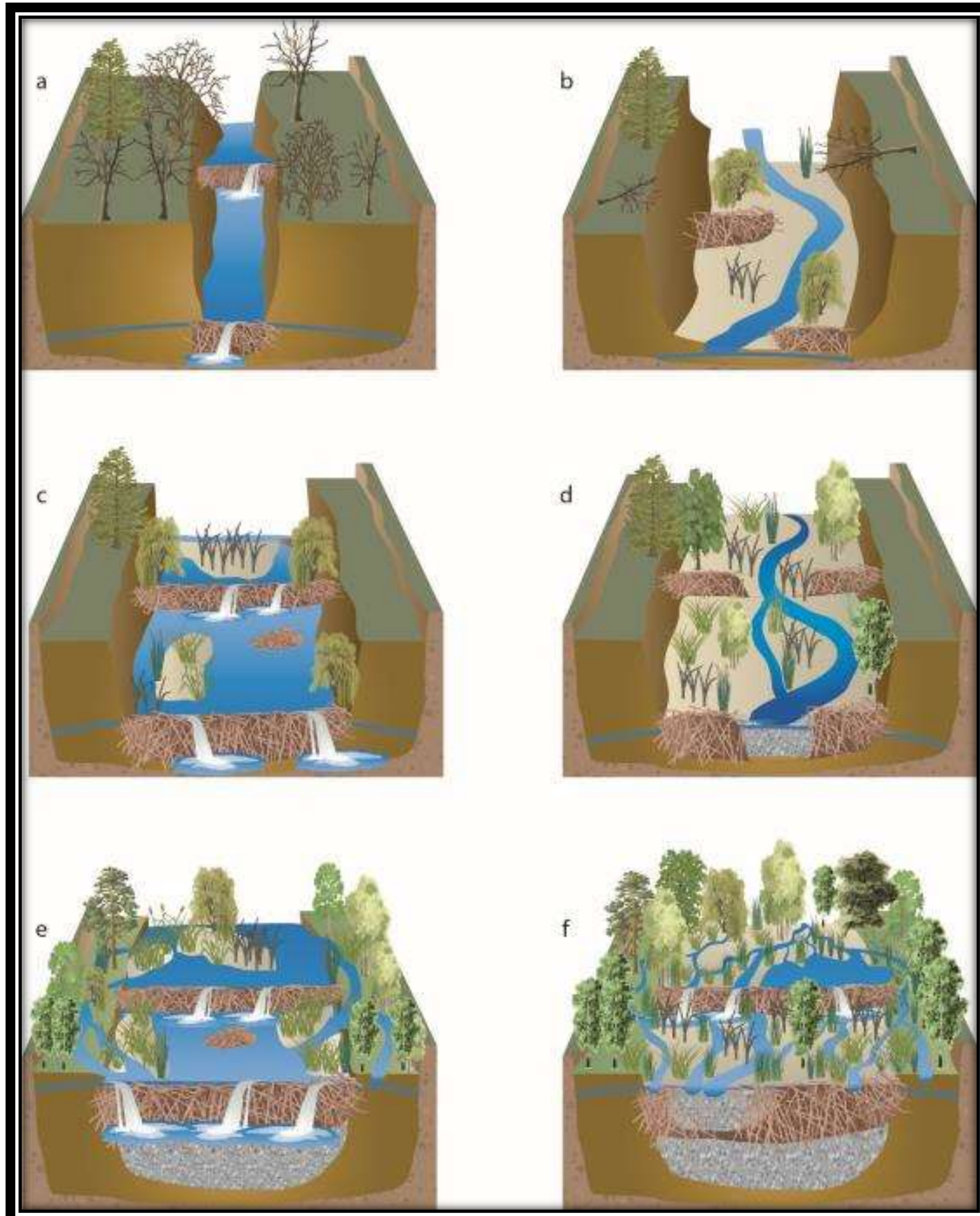



Born to manage wood in streams,
and incrementally trap sediment


# Beaver Dams in Incised Channels

*"can reduce Stage 1 to Stage 7-8/0 recovery times by 1-2 orders of magnitude"*

Recovery in years to decades instead of decades to centuries




Pollock et al., 2014. using beaver dams to restore incised stream ecosystems. *Bioscience*, 64(4).


2014.05.19 16:06

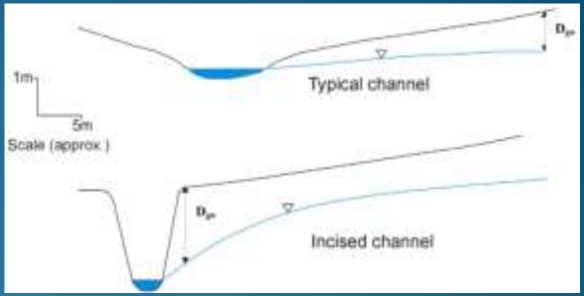
# Barriers

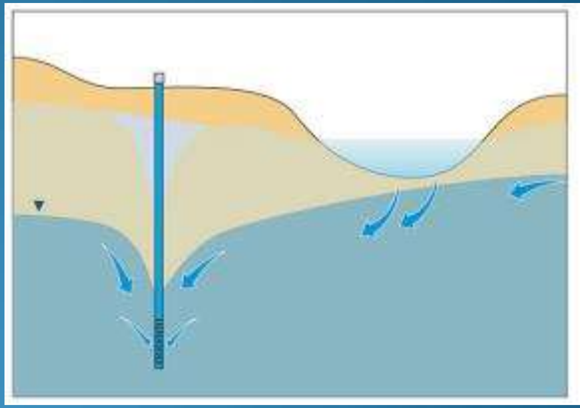
- Knowledge – historic vs current geomorphology and ecology
- Practice – natural channel design and continuity concepts don't apply to floodplain restoration
- Concept - building habitat (intolerant of dynamics) rather than assisting processes (embrace dynamics)
- Policy –
  - enforcing laws and guidelines intended to conserve vs restore
  - FRGP considers floodplain experimental
- Sociopolitical – dominance over nature
- Funds – costs may be high, but benefits great
- Vision – few people encouraging
- Leadership – agencies cautious or uncooperative

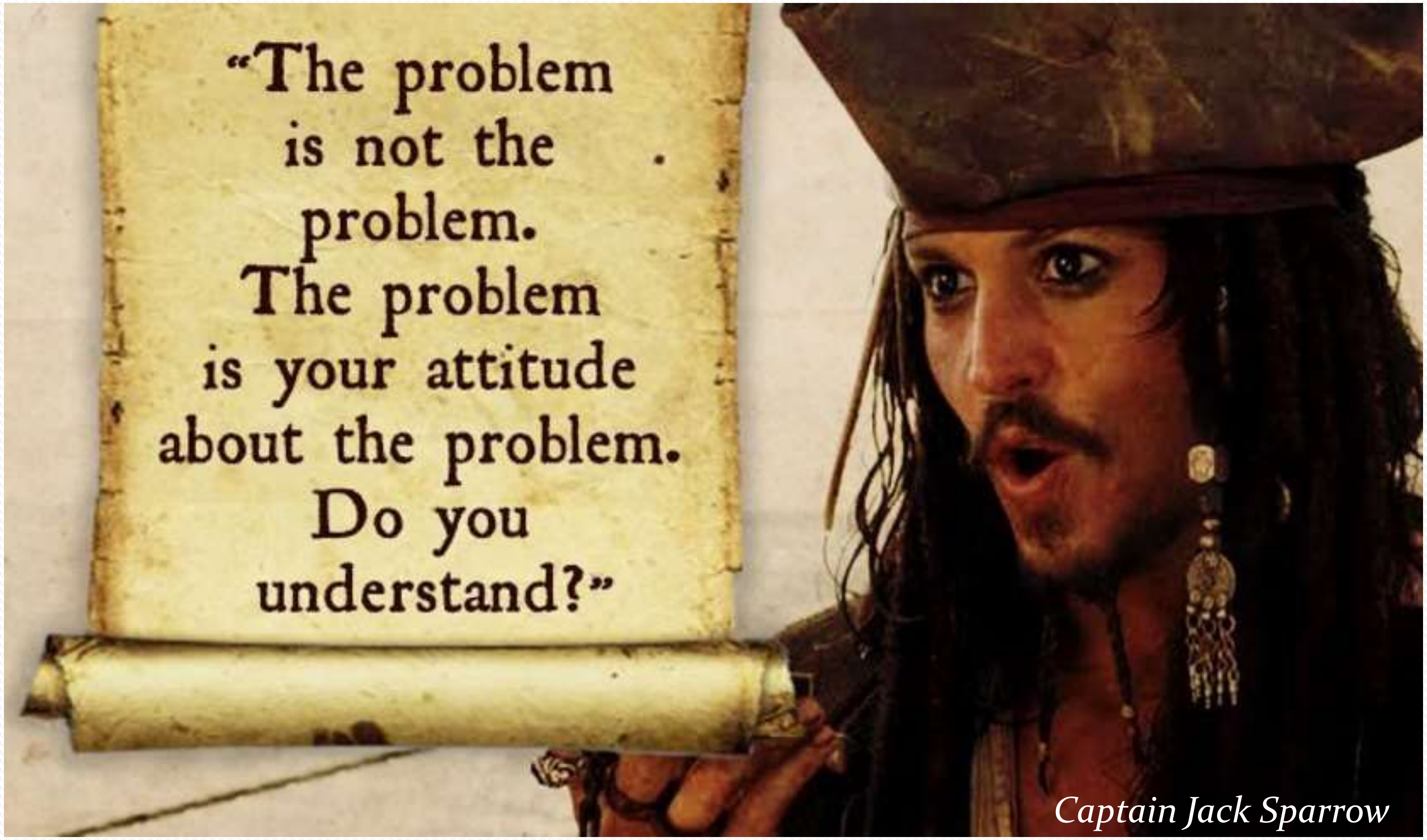
# Not barriers

- Science
- Voluntary land owners

# The problem: widespread land drainage and water withdrawals, driving severe loss of aquatic habitat. Solutions will ‘undrain’ the floodplains.




"The problem
is not the .
problem.
The problem
is your attitude
about the problem.
Do you
understand?"
Captain Jack Sparrow








# Beaver-Based Restoration in Bridge Creek
# What have we learned?


Eco Logical Research

Nick Weber

Nick Bouwes

NOAA

Michael Pollock

Chris Jordan

Utah State University

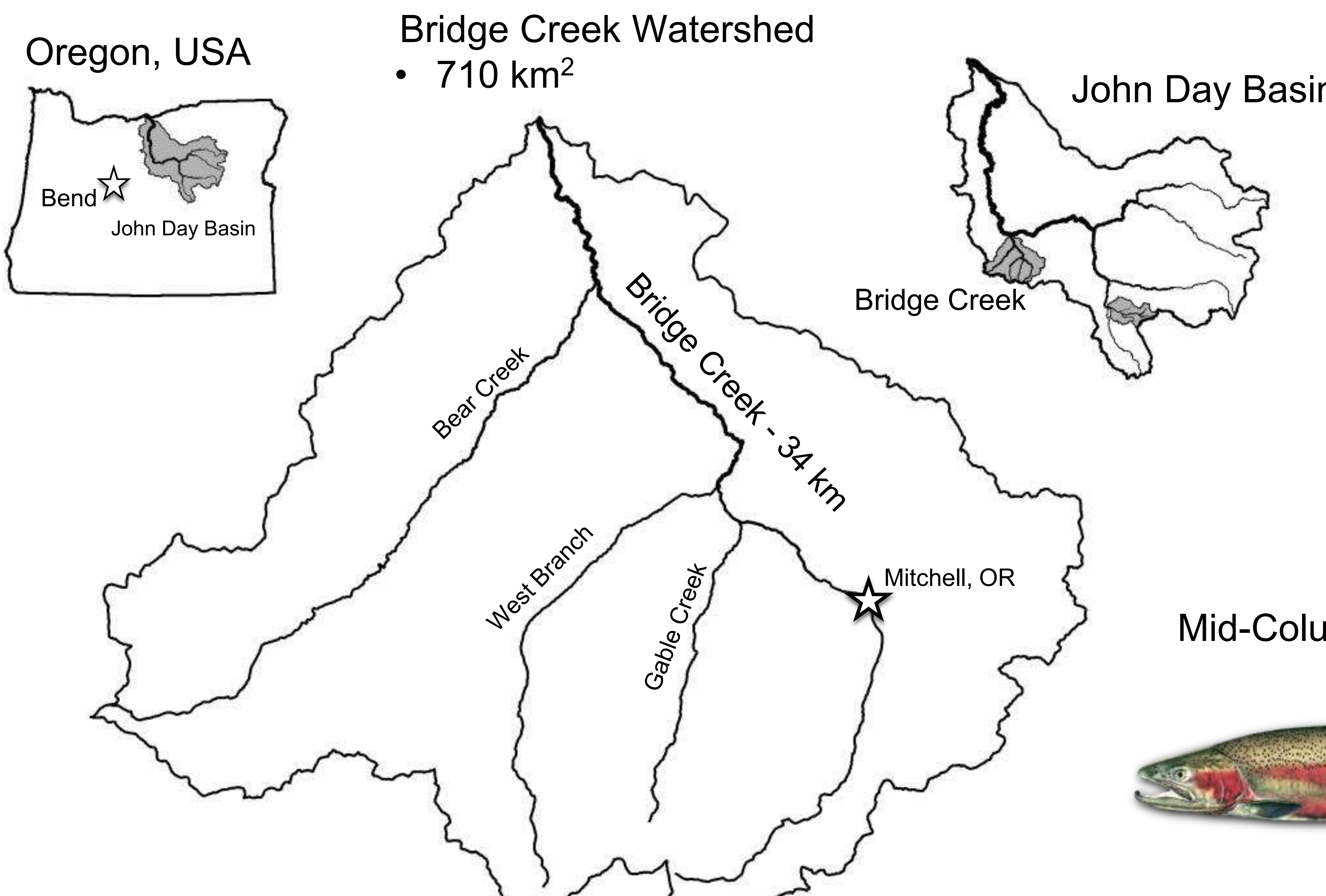
Joseph Wheaton

South Fork Research, Inc.

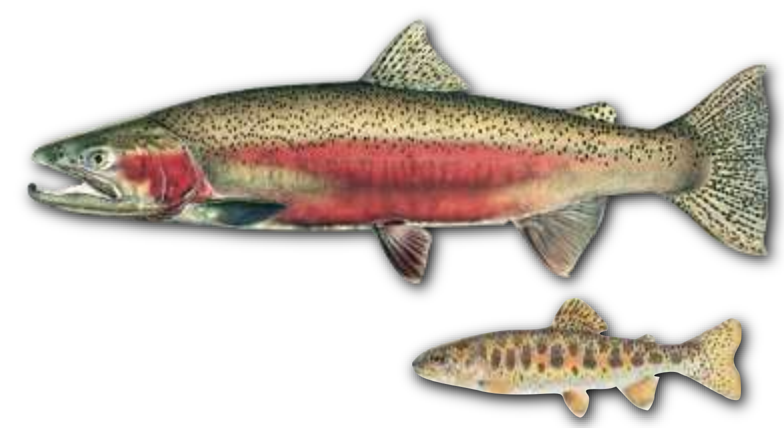
Carol Volk

# Bridge Creek

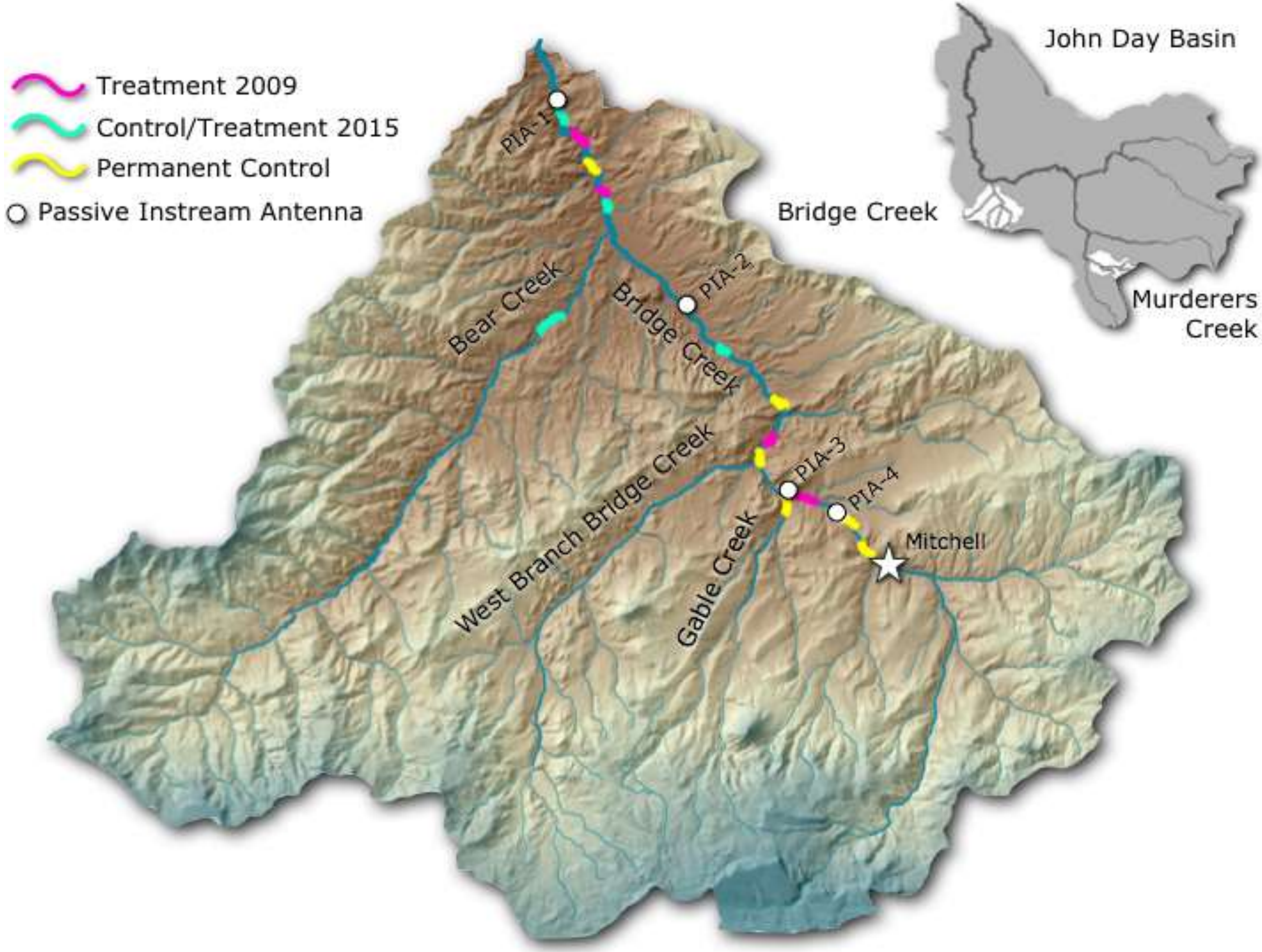
## Restoration and Monitoring Project




Mid-Columbia Steelhead

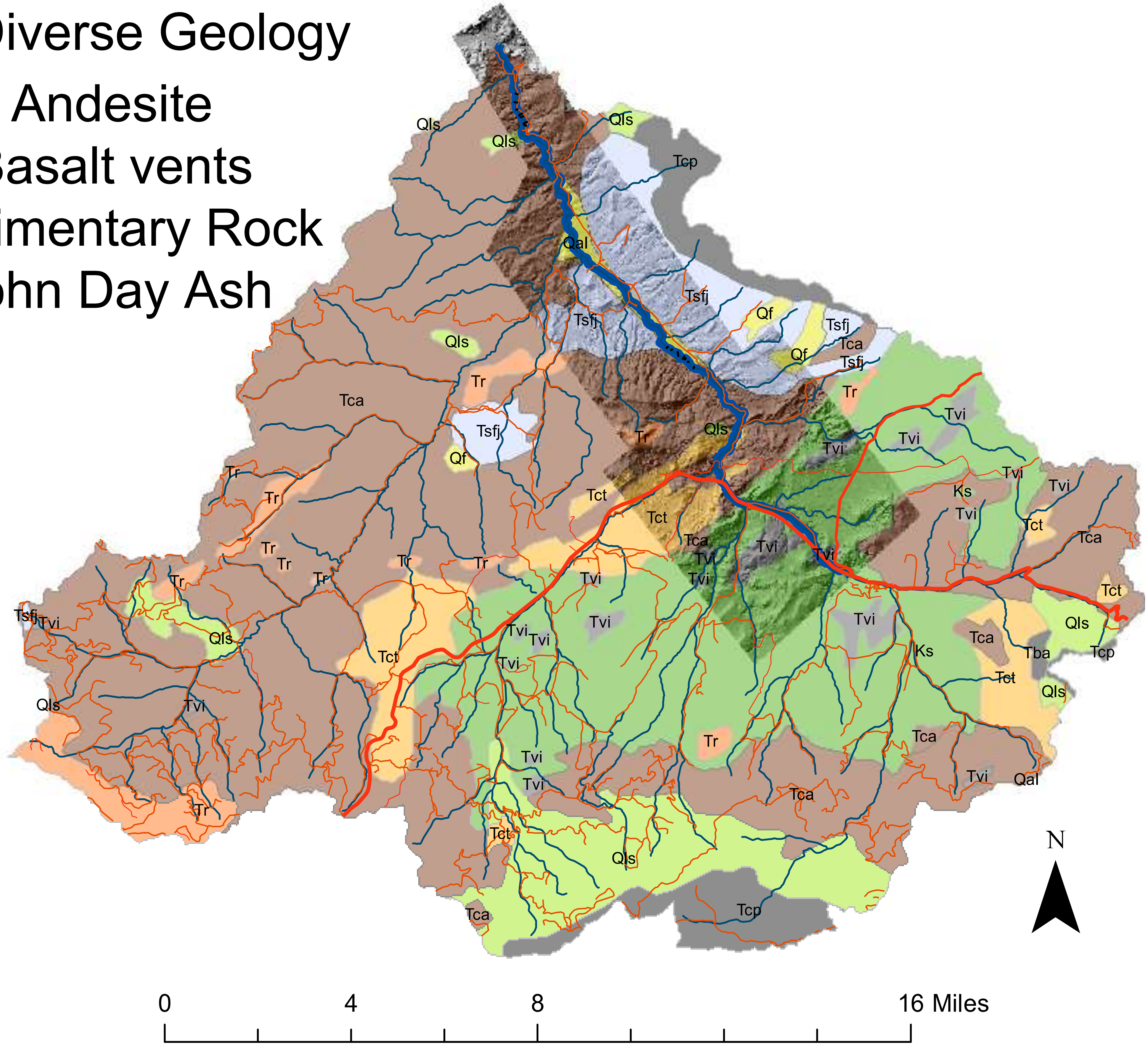


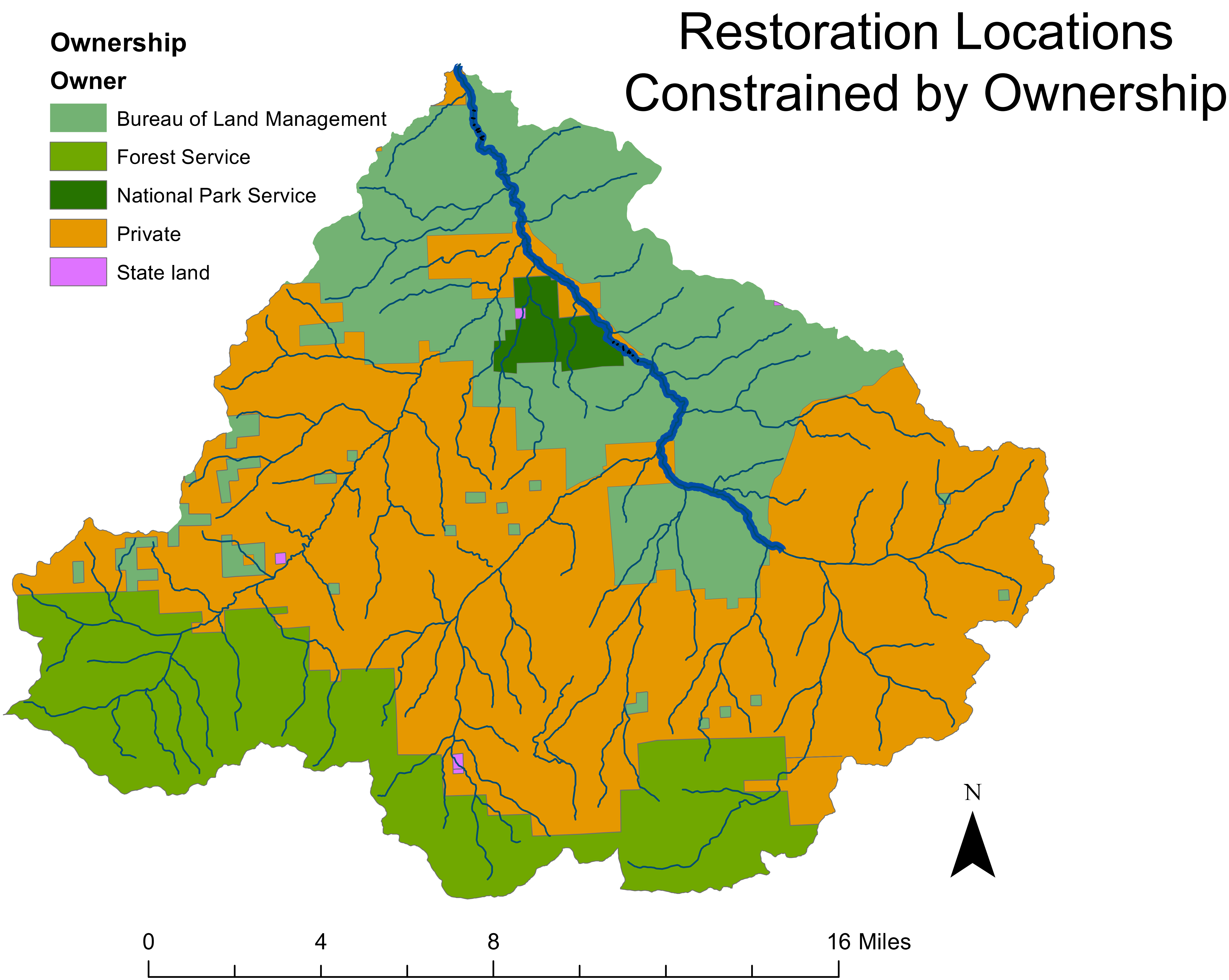
# Treatment and Controls, Before and After Monitoring



# A Diverse Geology

Andesite
Basalt vents
Sedimentary Rock
John Day Ash



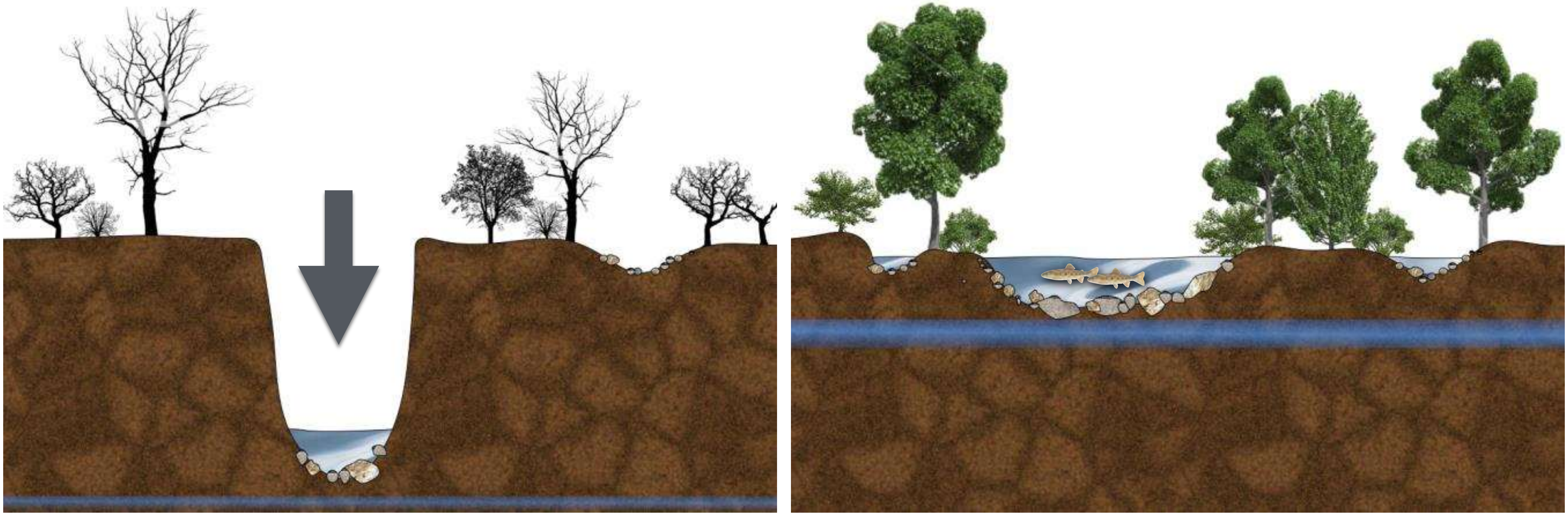

Restoration Locations
Constrained by Ownership
Ownership
Owner
Bureau of Land Management
Forest Service
National Park Service
Private
State land
N
0
4
8
16 Miles

# Channel Incision

Incised Channel

$10^3$ years

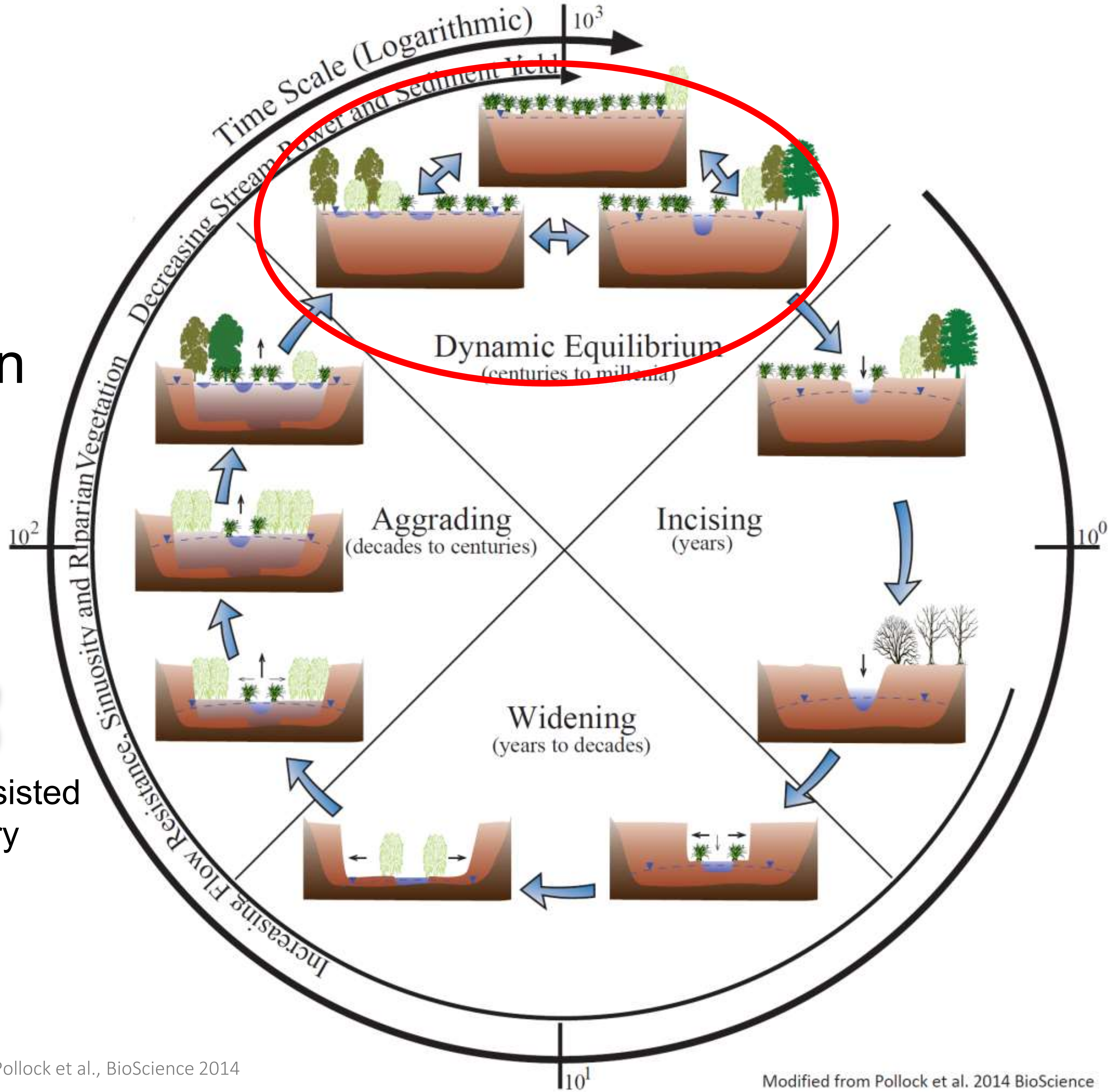
Incision Recovery



- Simplified and static channel
- Hydrologically Disconnected
- Low habitat quality

- Complex and dynamic channel
- Floodplain and groundwater connectivity
- High habitat quality

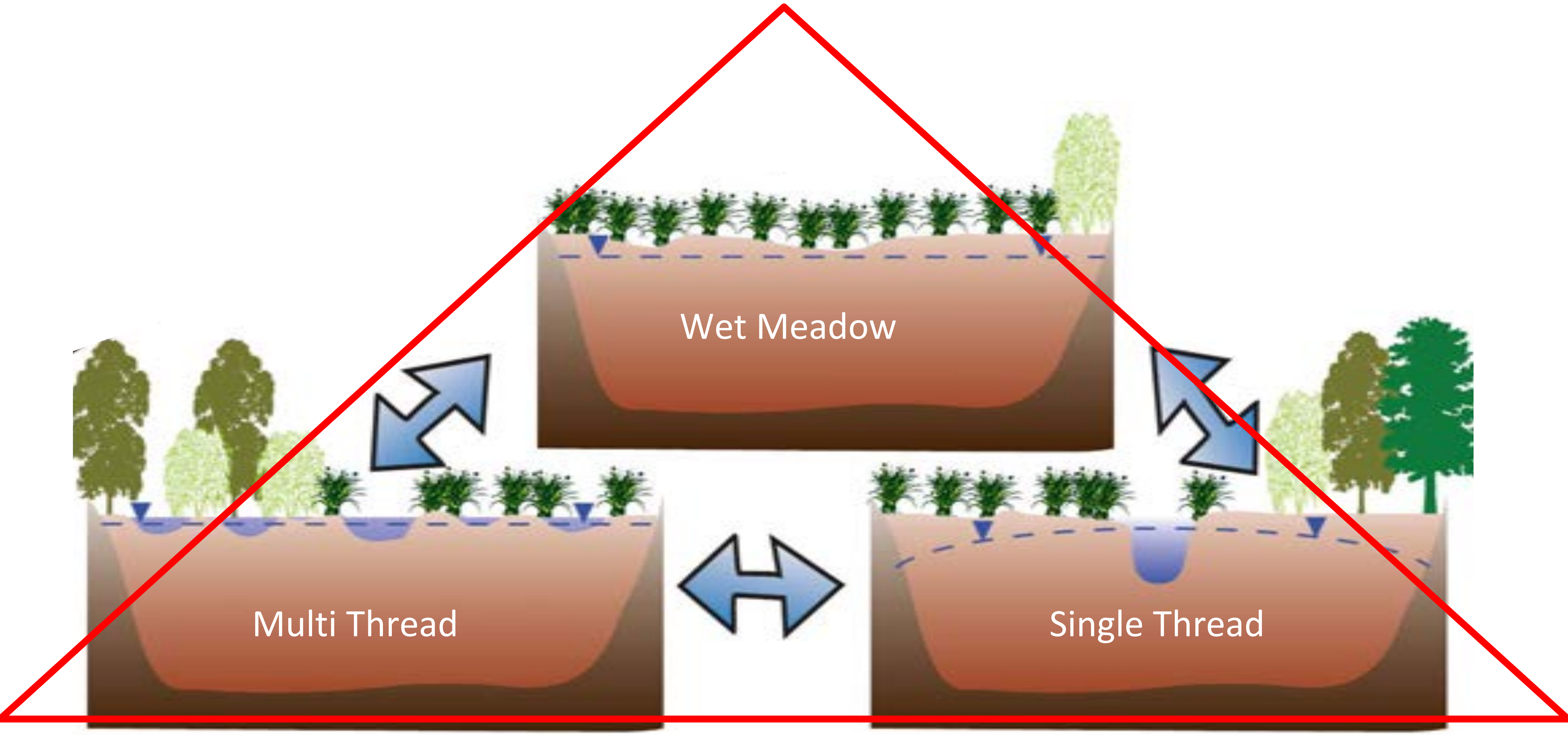
# Bridge Creek Restoration




- Testing BDA Assisted Incision Recovery
- Benefits to Fish Populations and Habitat

Modified from Pollock et al., BioScience 2014

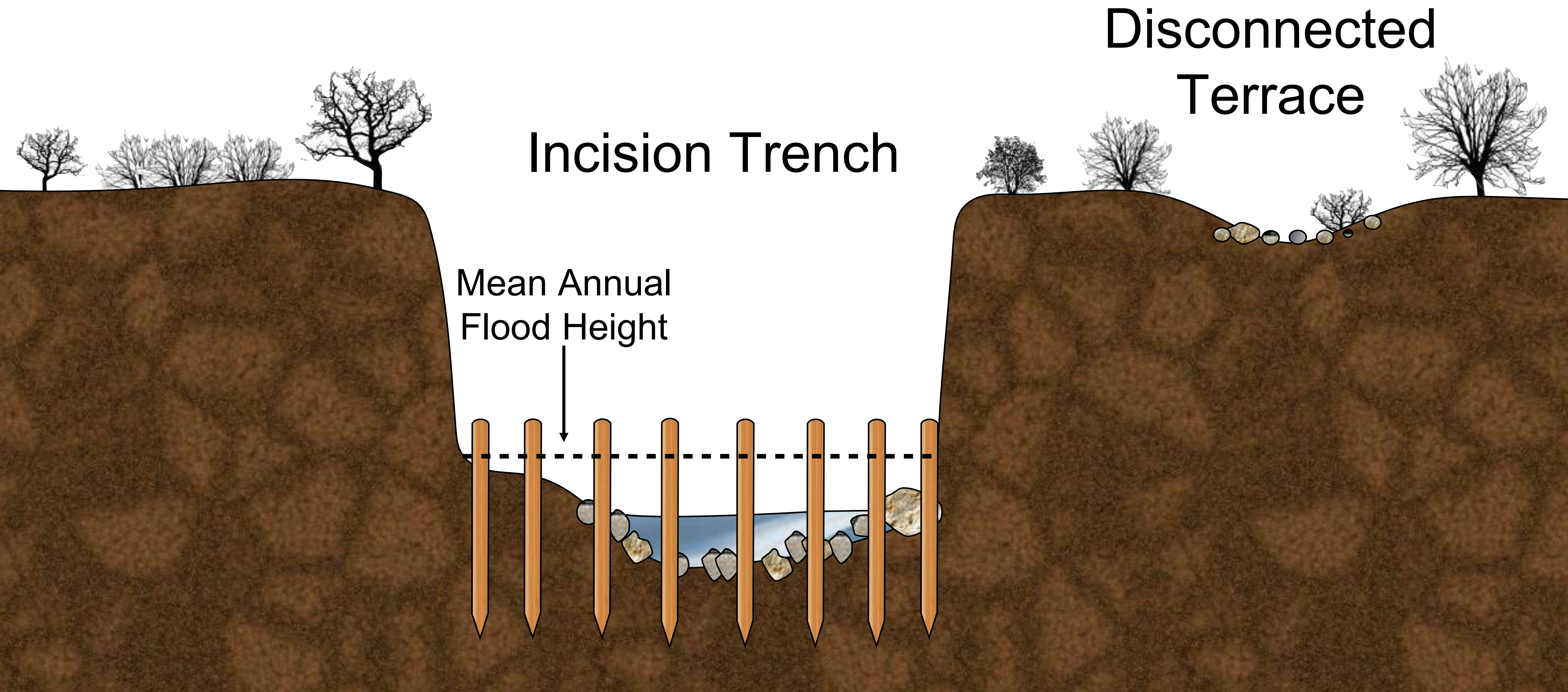
# Highly Functional Streams are in Dynamic Equilibrium




Modified from Pollock et al., BioScience 2014

# BDAs

## Beaver Dam Analog Structures

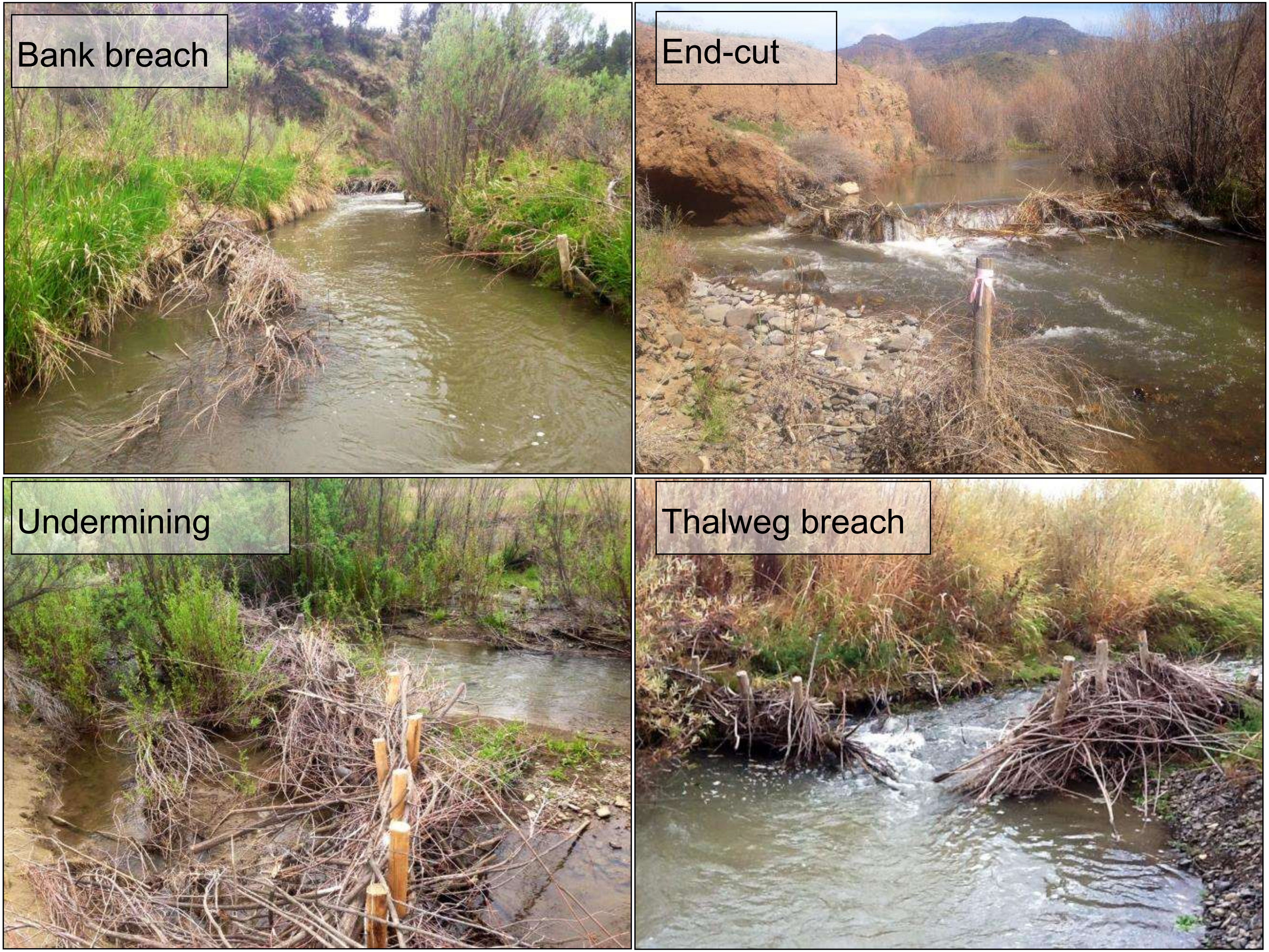


- Eco-friendly equipment = Low impact
- Semi-permanent = Easy to adjust = Low risk
- Rapid implementation = Increase spatial extent = Extend restoration $

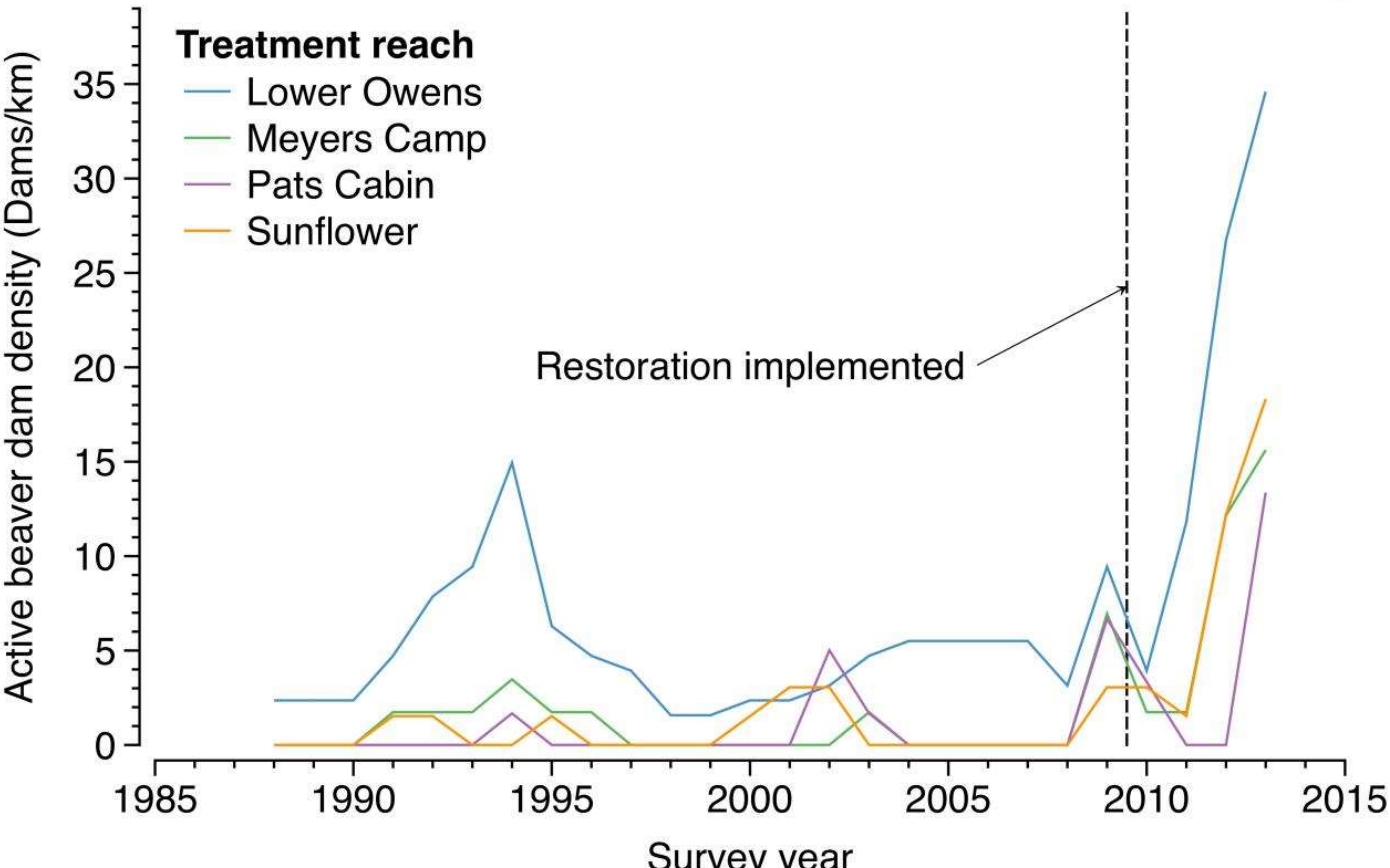

4 Treatment Reaches ~ 1 km

114 Total BDA Structures

- Multi-year restoration plan - pilot structures
- Effectiveness monitoring - Adaptive management framework
  - Structure modifications, maintenance, additions, decomission
- System - specific restoration approach

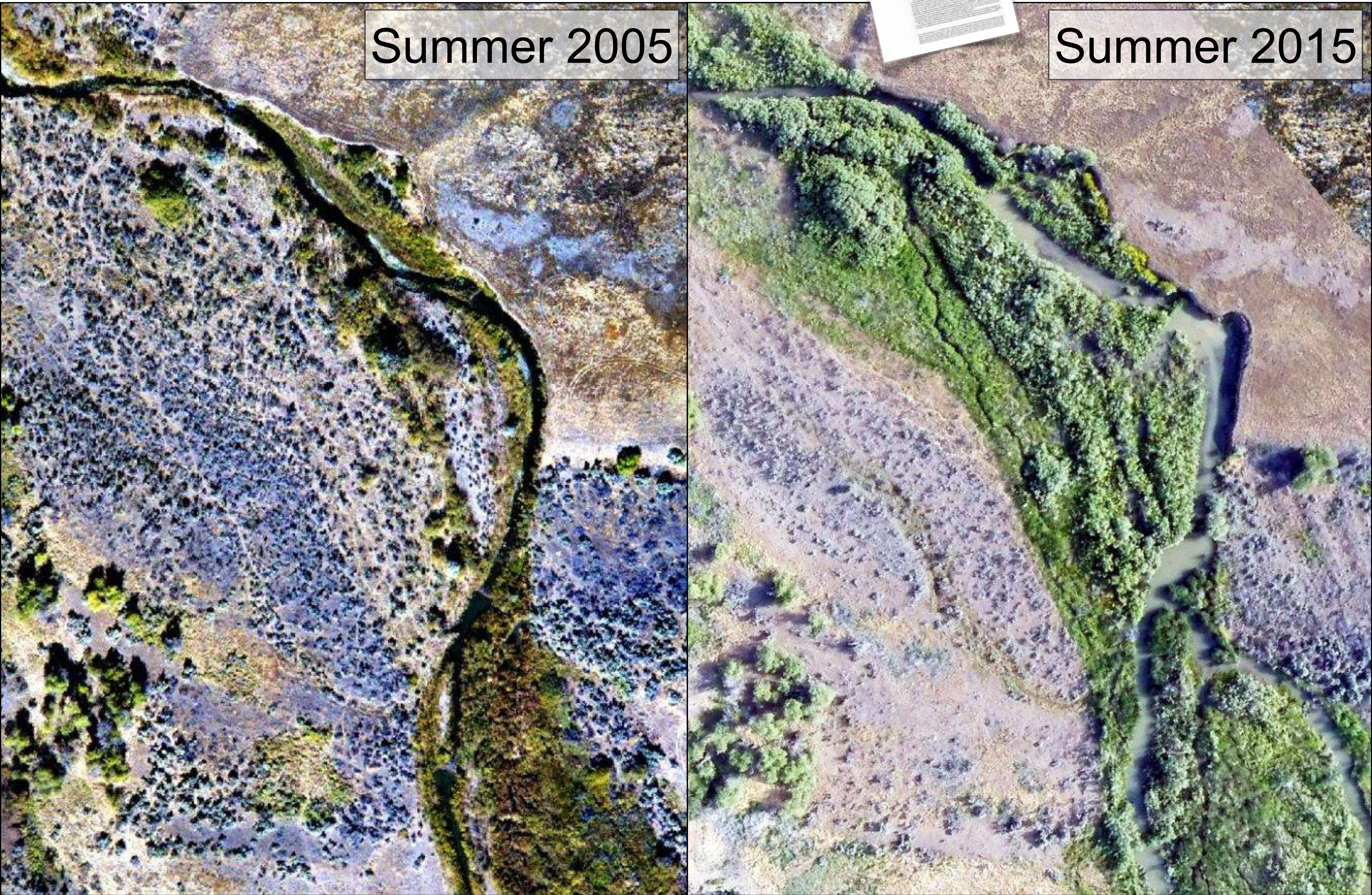

Bank breach
End-cut
Undermining
Thalweg breach

# Active Beaver Dams



# Repeat Aerial Photos - 10 years


Bouwes et al. 2016
*Scientific Reports*



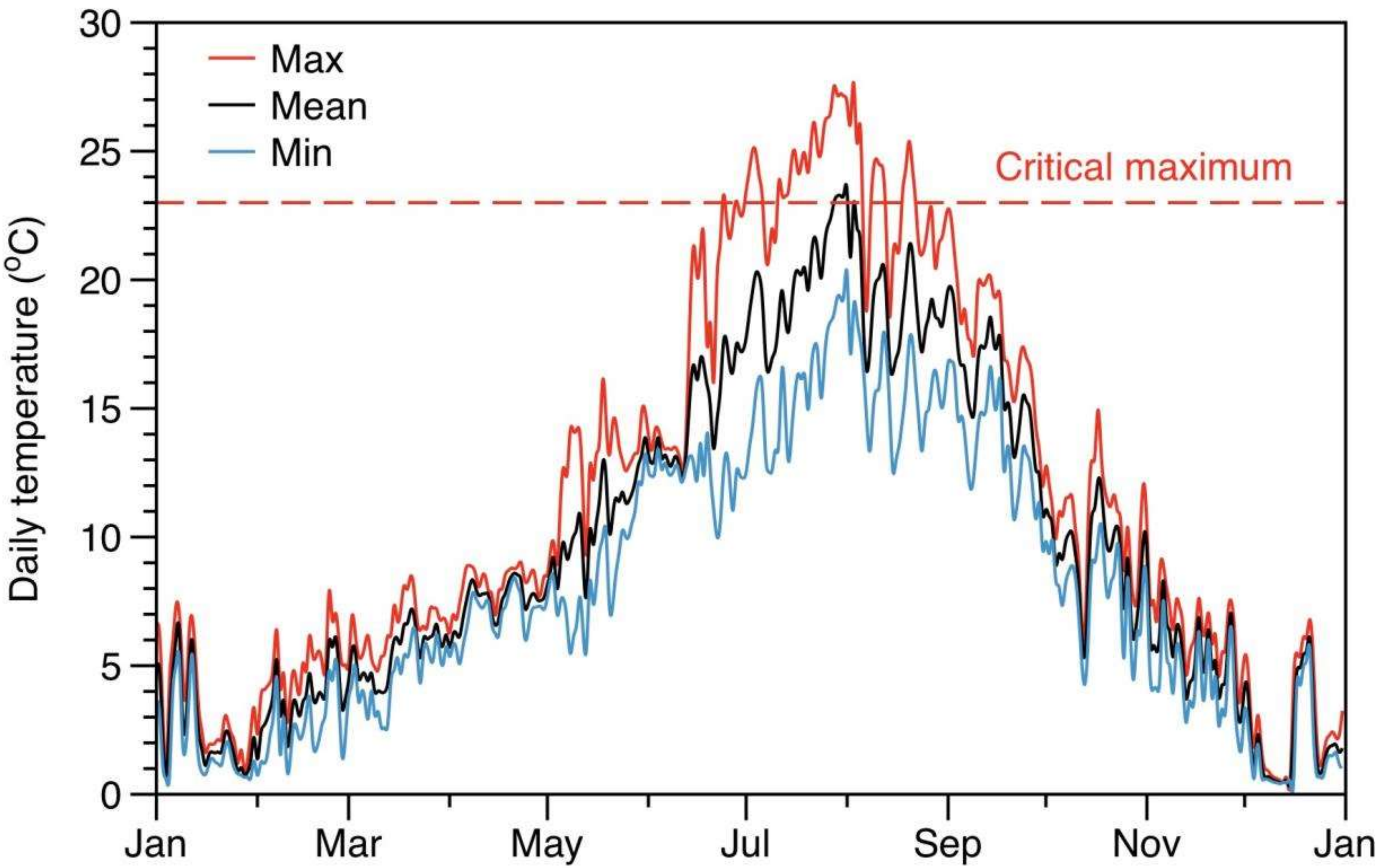
# Beaver Dam - Salmonid Habitat Interactions

- Stream Temperature
- Fish Passage

?

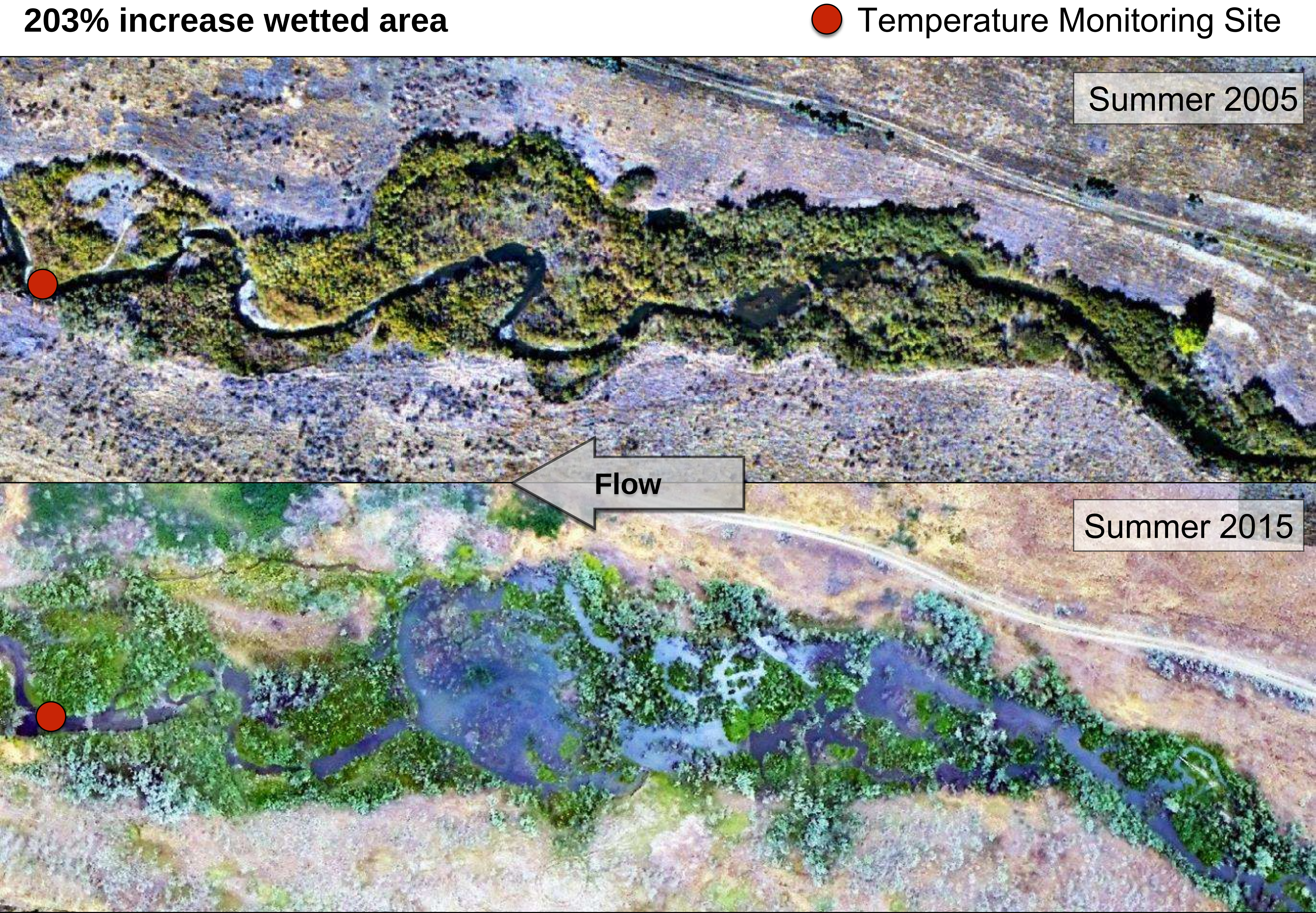
# Bridge Creek Annual Temperature

Pre-beaver dam increase - 2009

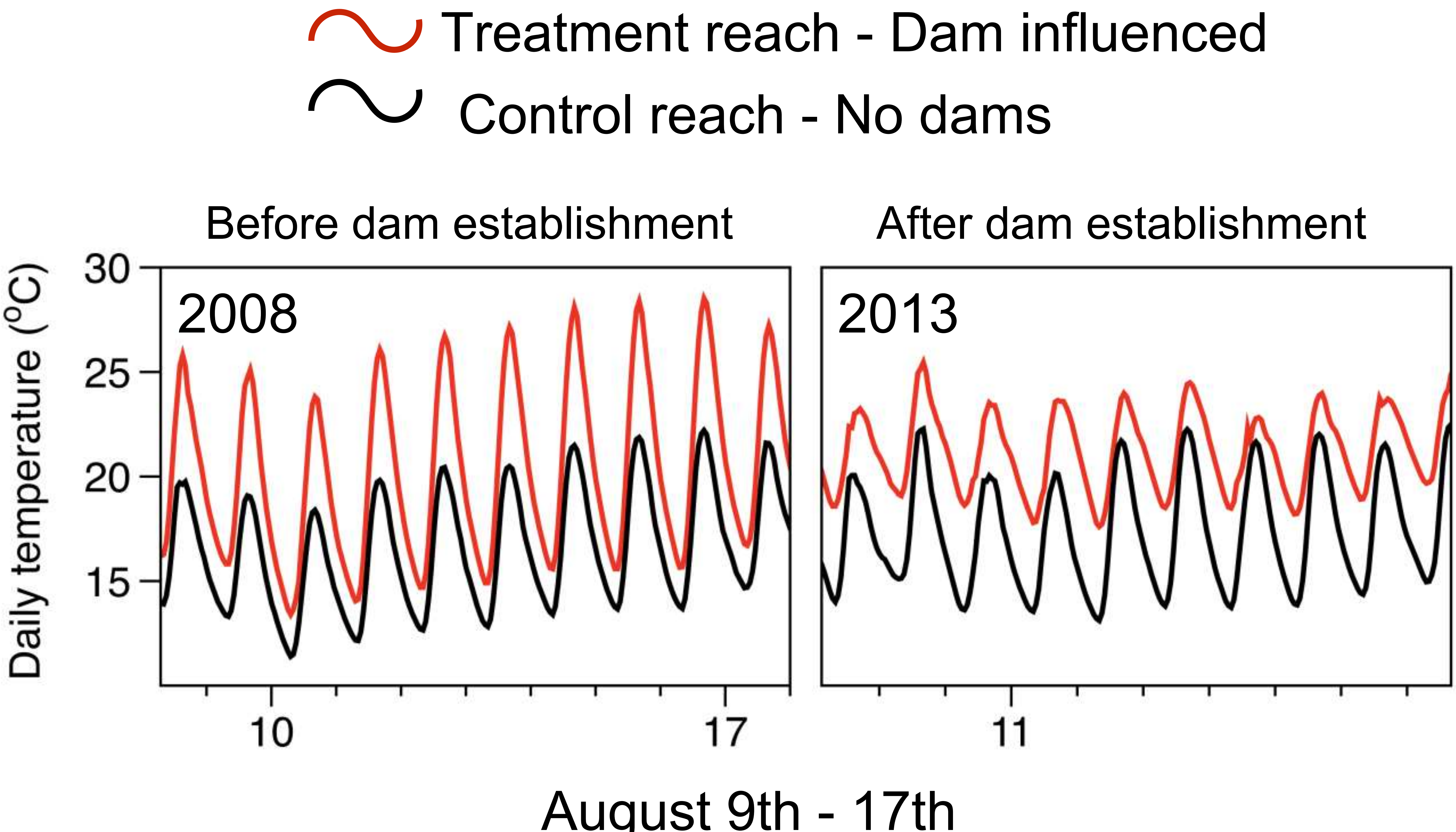


# Treatment Reach - BDA Complex

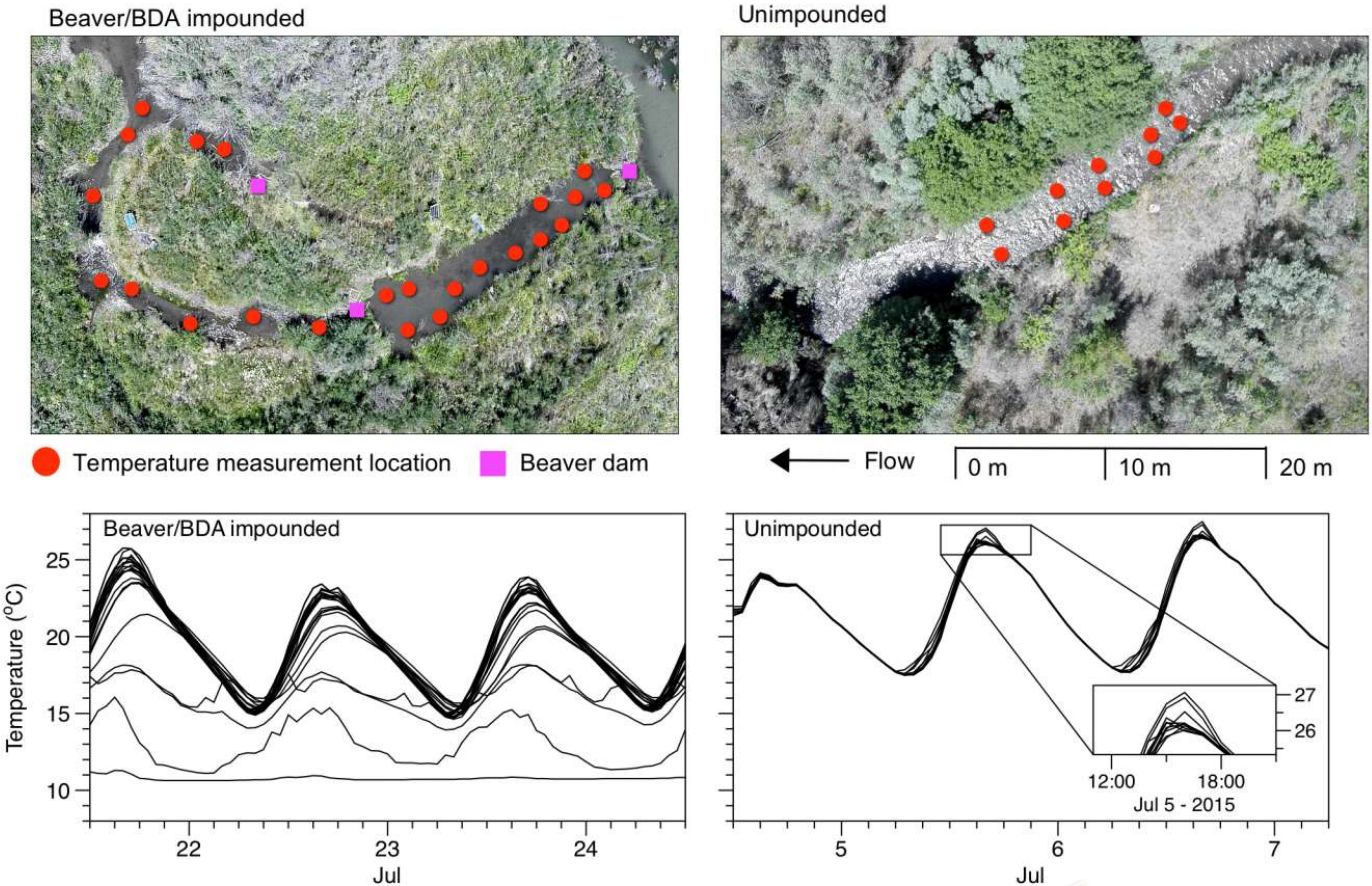
**203% increase wetted area**



# Compressed diel temperature range

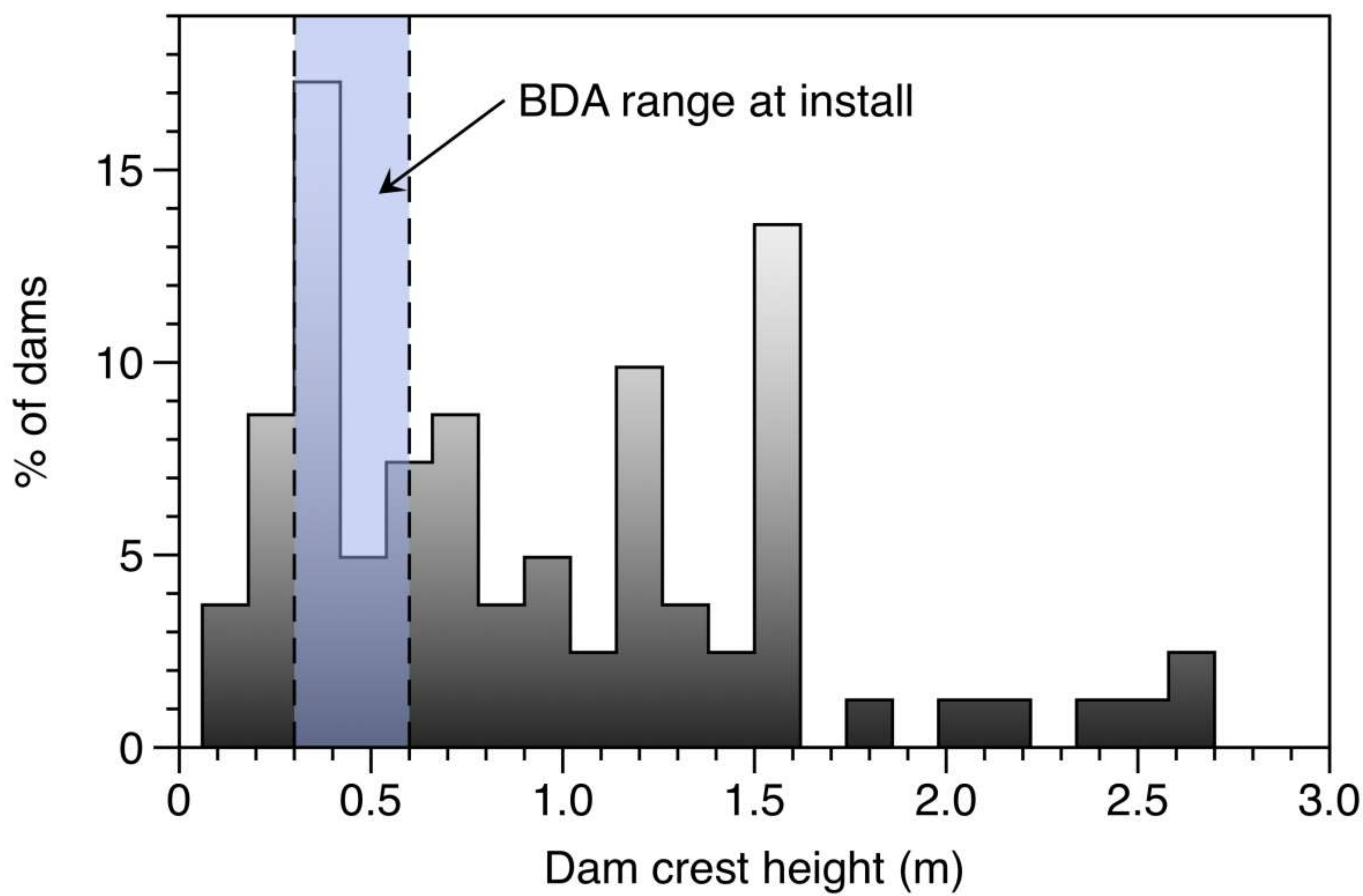


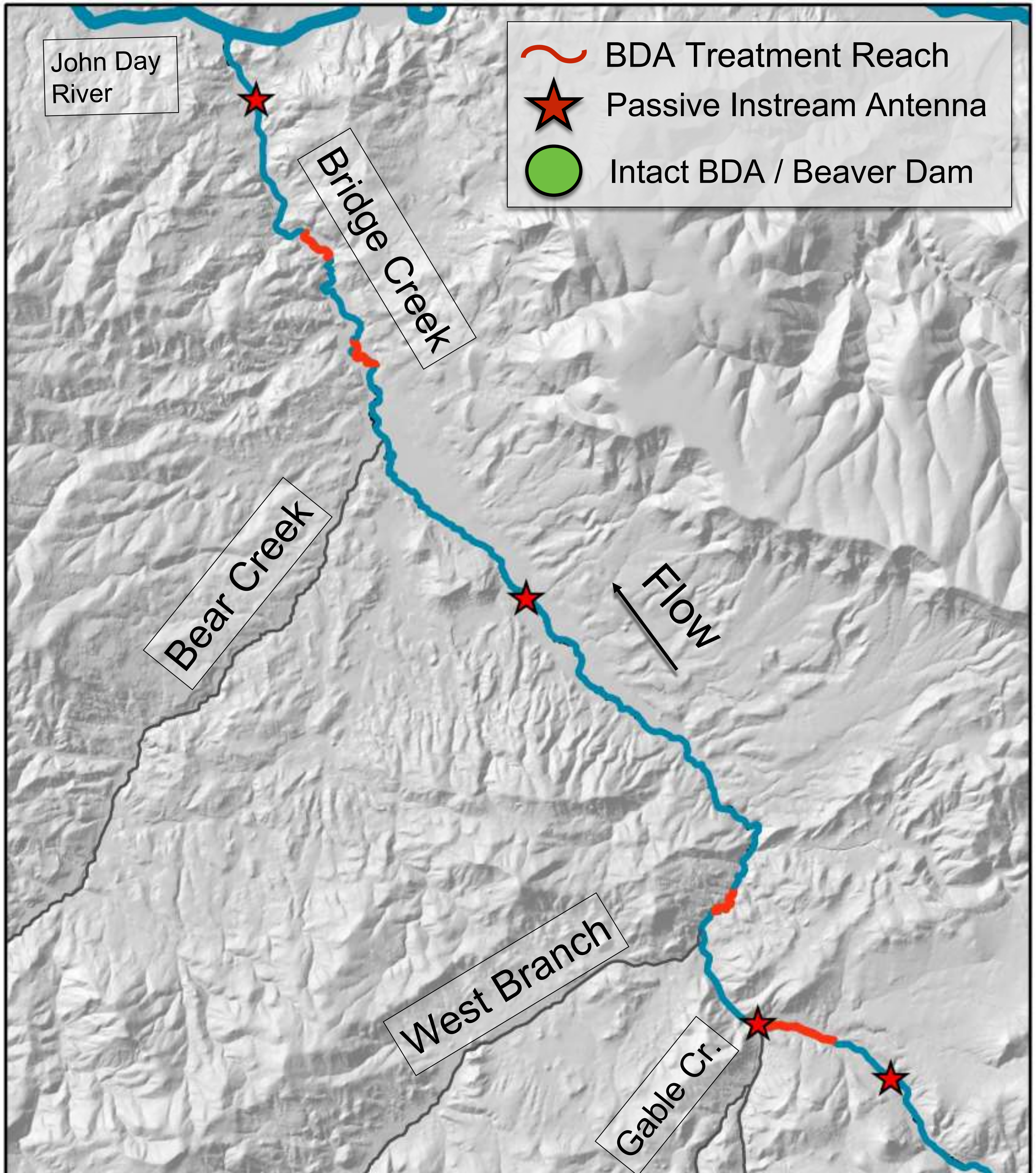
# Channel Temperature Heterogeneity




Weber et al. 2017
*PLoS ONE*

# BDA and Beaver Dam Crest Height

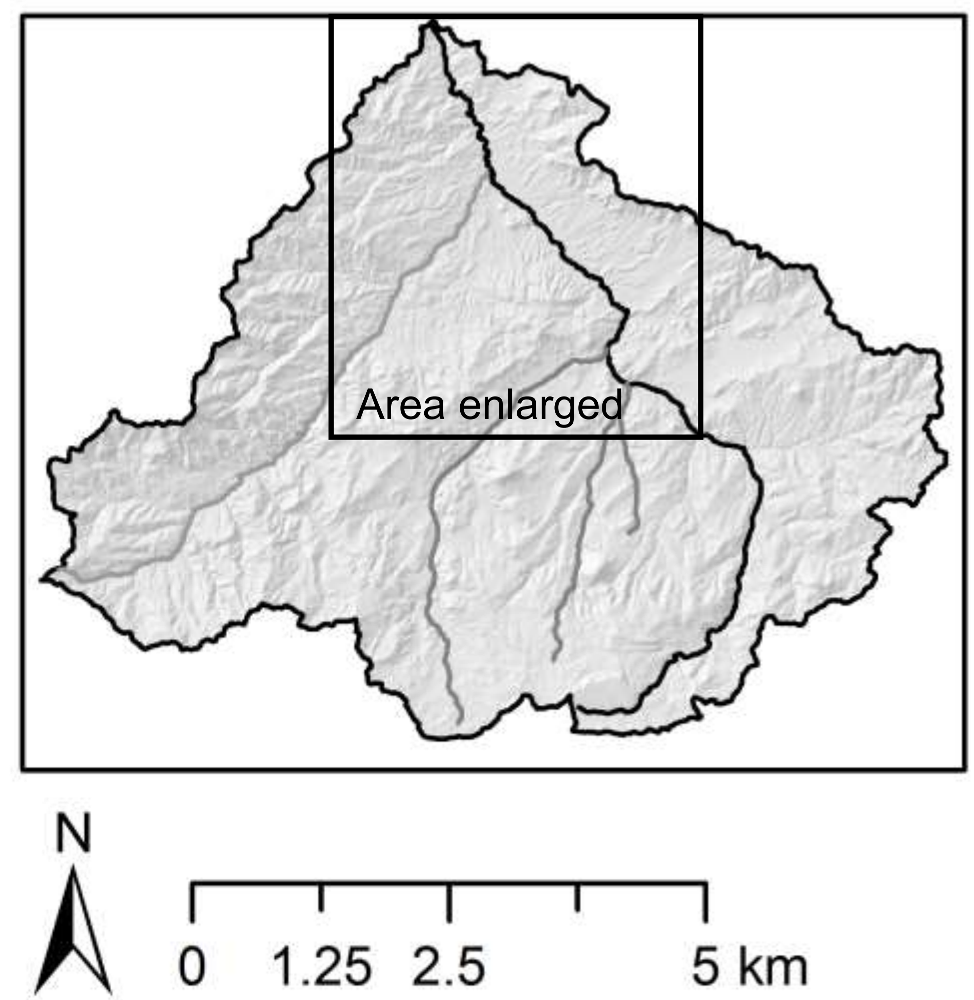


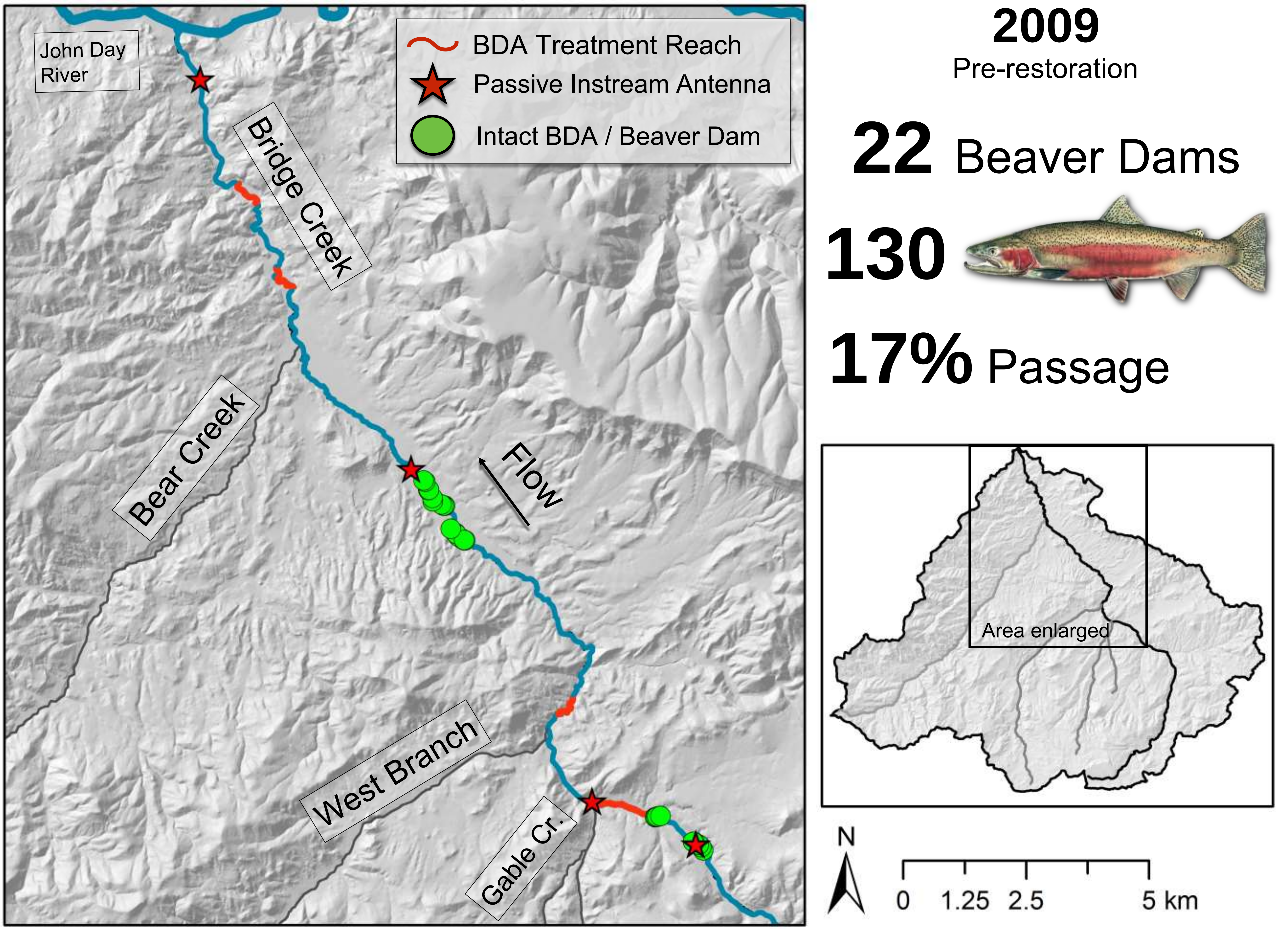



4 Passive Instream Antennas

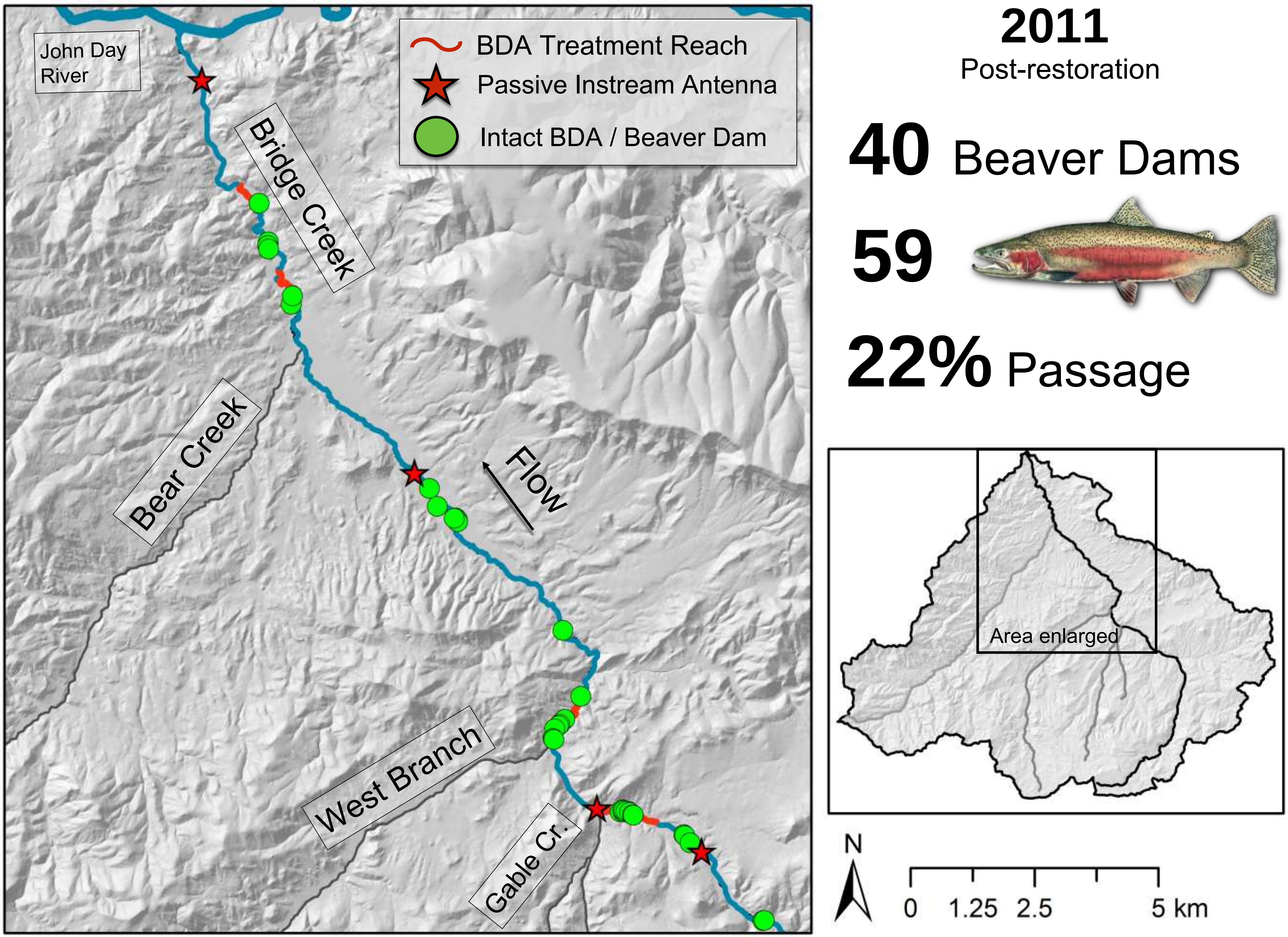
• 2009 - Present

78,000 PIT-tagged *O.mykiss*

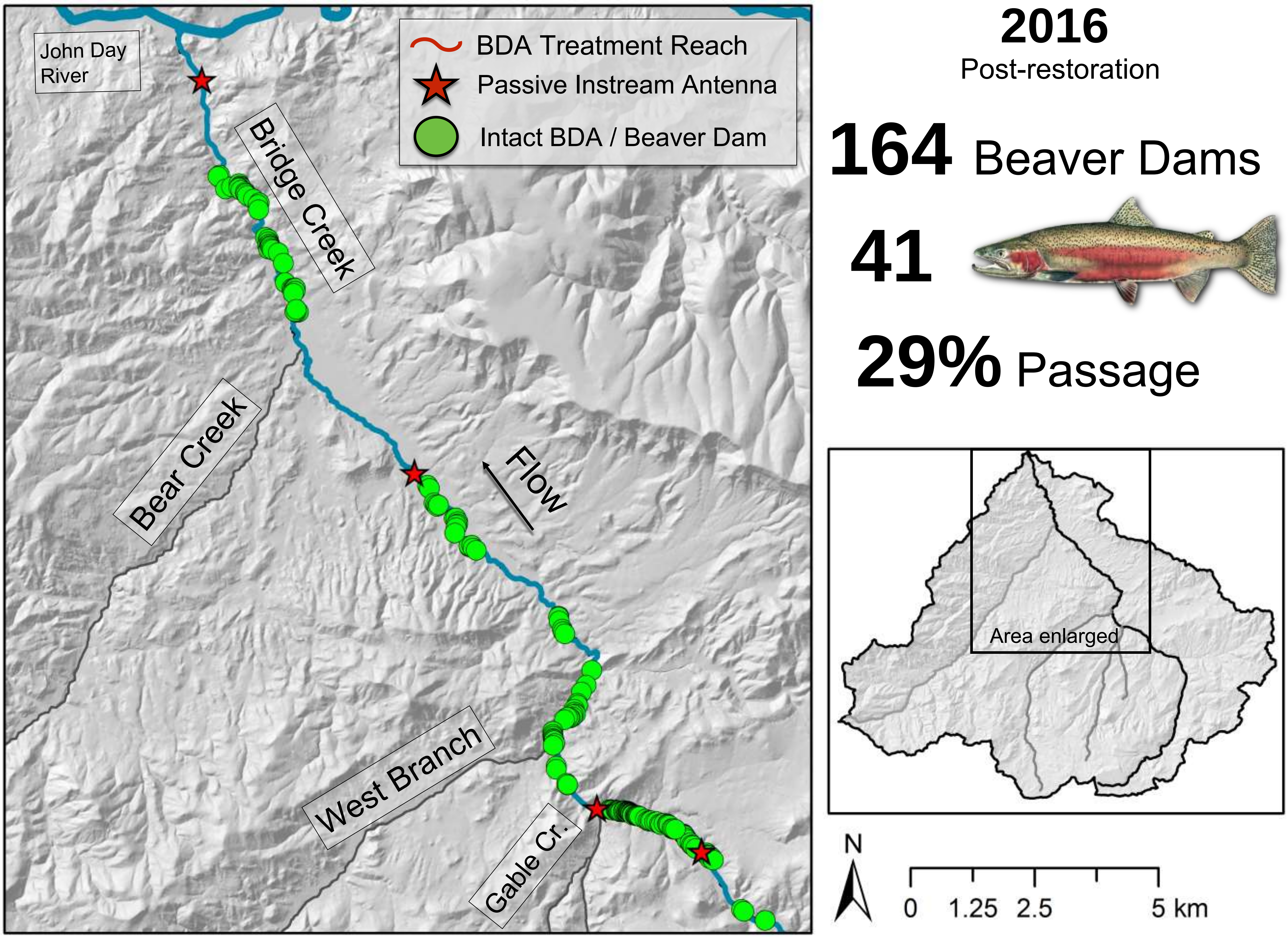




2009
Pre-restoration
22 Beaver Dams
130
17% Passage
BDA Treatment Reach
Passive Instream Antenna
Intact BDA / Beaver Dam
John Day River
Bridge Creek
Bear Creek
Flow
West Branch
Gable Cr.
Area enlarged
N
0
1.25
2.5
5 km



John Day River
Bridge Creek
Bear Creek
Flow
West Branch
Gable Cr.
BDA Treatment Reach
Passive Instream Antenna
Intact BDA / Beaver Dam
2011
Post-restoration
40 Beaver Dams
59
22% Passage
Area enlarged
N
0 1.25 2.5 5 km



John Day River
BDA Treatment Reach
Passive Instream Antenna
Intact BDA / Beaver Dam
Bridge Creek
Bear Creek
Flow
West Branch
Gable Cr.
2016
Post-restoration
164 Beaver Dams
41
29% Passage
Area enlarged
N
0 1.25 2.5 5 km

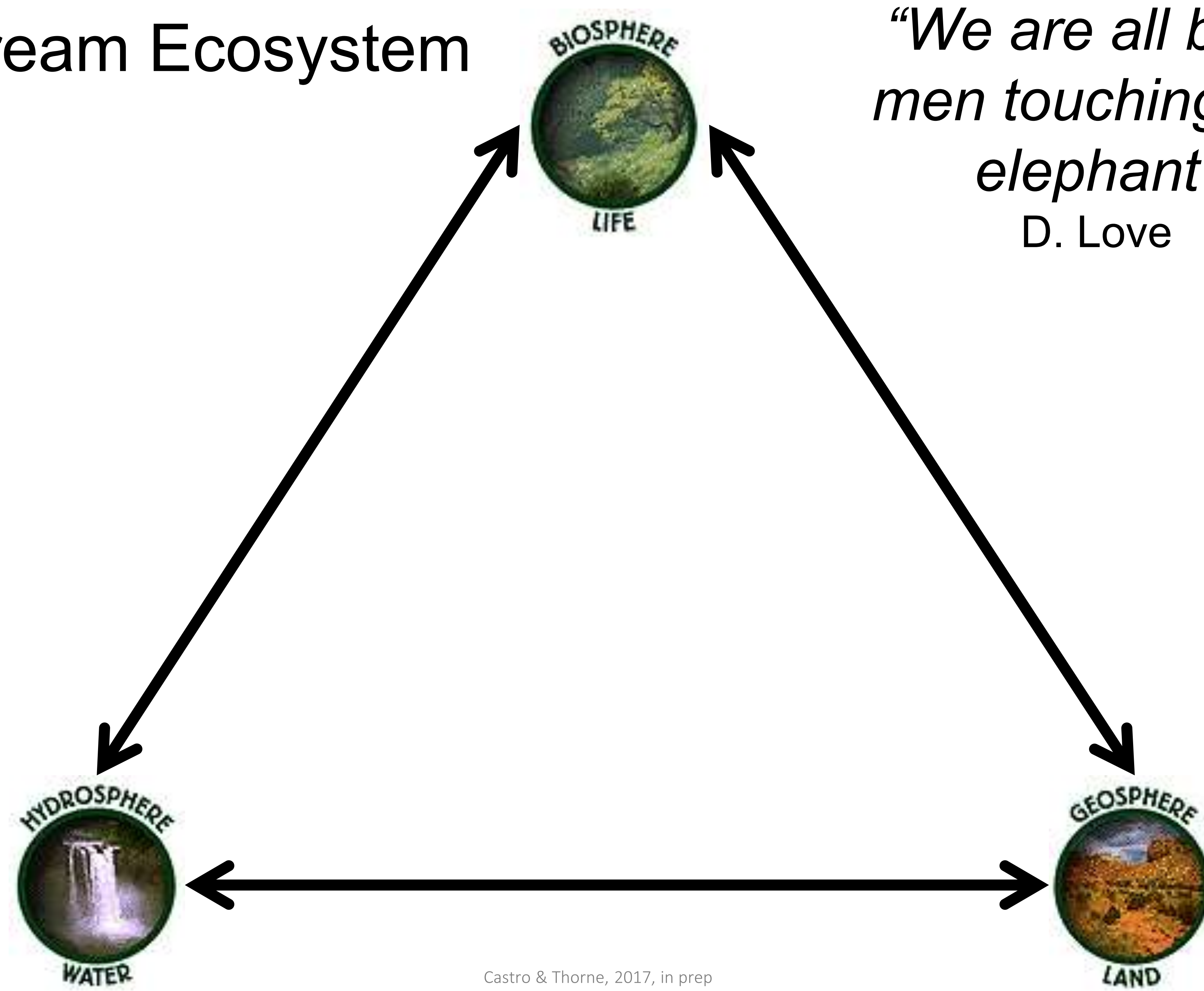
# o what have we learned?

# Biosphere is not just a beneficiary of stream restoration, it is an active participant

Beaver as Stream Ecosystem
Engineers?
Managers?
Stewards?
Farmers?

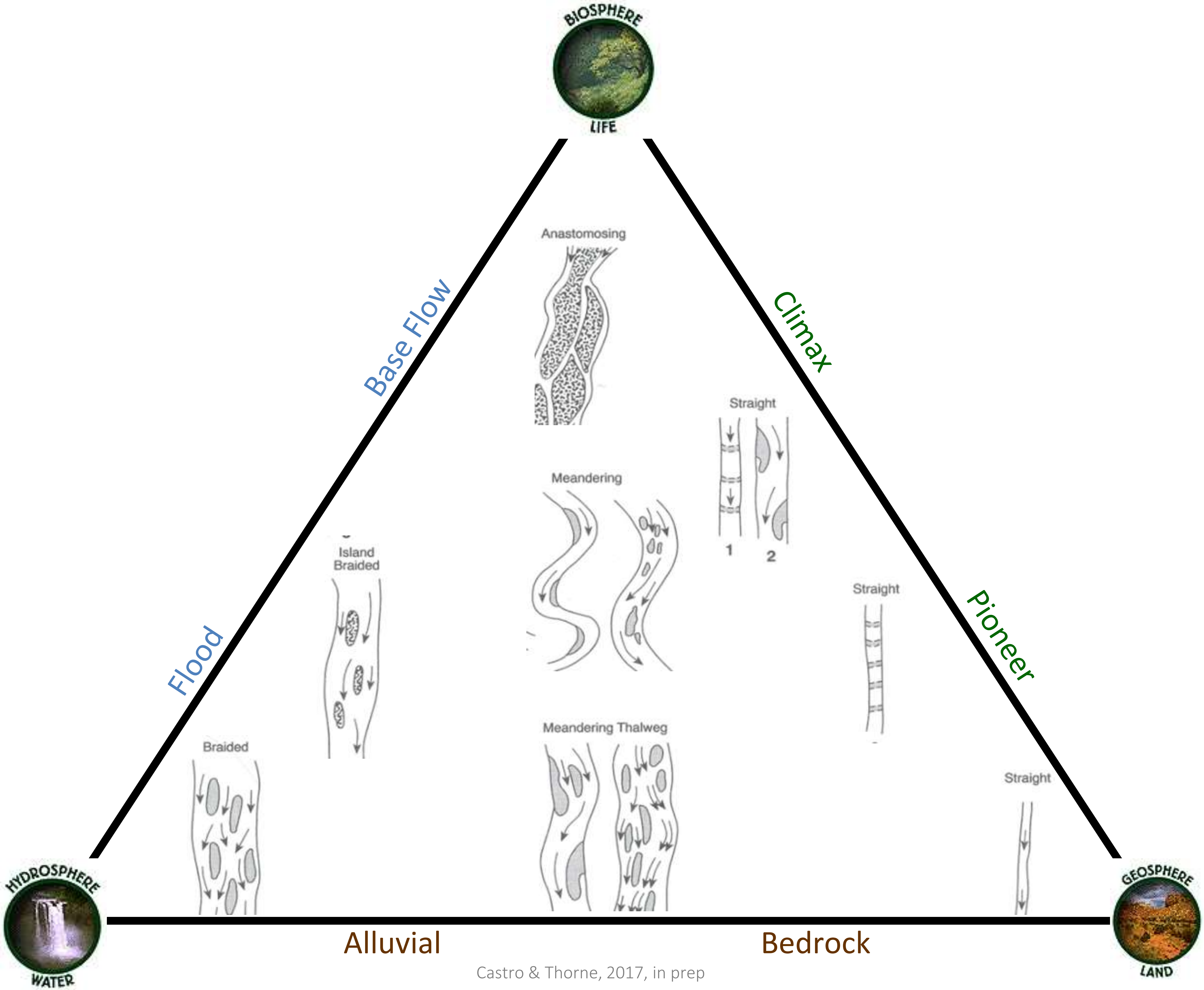
What is the
Paradigm for
Restoration
Practioners?

*"We are all blind men touching the elephant"*
D. Love

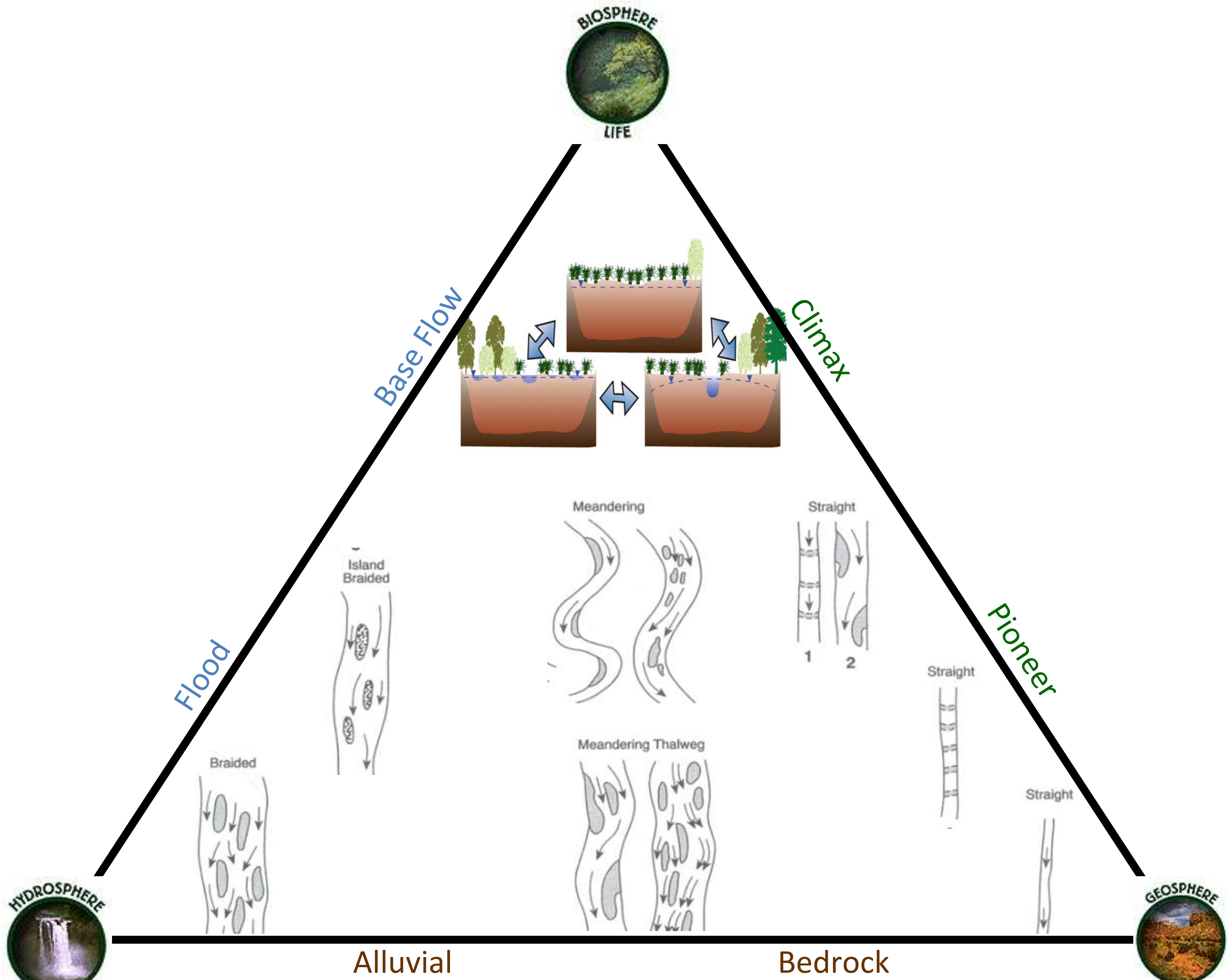



Images by thinglink.com, Joey Wells

Castro & Thorne, 2017, in prep




Castro & Thorne, 2017, in prep




Castro & Thorne, 2017, in prep

# Do Beaver Have a Role in the Recovery of California Coho Salmon?

Stephen Swales Ph.D.
California Department of Fish and Wildlife
Michael Pollock Ph.D.
NOAA Northwest Science Center

# Talk Outline

- Background - Coho and Beaver in **Canada and PNW**
- Coho and Beaver in **California**
  - **Distribution** patterns
  - **Habitat** preferences
  - **Beaver pond studies**

- Beaver in State and Federal **coho recovery plans**
- **Pros and cons** of beaver in coho recovery
- Do beaver have a **role** in coho recovery?

# Fisheries and Oceans Canada

Salmon Roe

# Coho in Fraser River Ponds Study Results

- Juvenile coho migrated into beaver ponds in **September-October**
- Juvenile coho **overwintered** in the ponds and **out-migrated** the following spring
- Coho were much **more abundant** in the ponds than in the main channel
- Coho in the ponds **grew faster** than coho in the main channel (62-79 mm at age 1, compared to a mean of 53 mm in main channel)
- Smolt **out-migration** from the ponds occurred in **late Spring**, with peak in May-June – over 1,200 fish

## Role of Off-Channel Ponds in the Life Cycle of Coho Salmon (*Oncorhynchus kisutch*) and Other Juvenile Salmonids in the Coldwater River, British Columbia

S. Swales[1] and C. D. Levings

*West Vancouver Laboratory, Biological Sciences Branch, Department of Fisheries and Oceans, West Vancouver, B.C. V7V 1N6*

Swales, S., and C. D. Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (*Oncorhynchus kisutch*) and other juvenile salmonids in the Coldwater River, British Columbia. Can. J. Fish. Aquat. Sci. 46: 232–242.

Off-channel ponds in the upper reaches of the Coldwater River, British Columbia, were major rearing areas for juvenile coho salmon (*Oncorhynchus kisutch*). Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Salmo gairdneri*), and Dolly Varden char (*Salvelinus malma*) were generally scarce in the ponds, although they were numerous in the main river. Coho salmon were predominant at "natural" river sites while steelhead trout was the main species at sites with "rip-rap" bank stabilization. Catches of juvenile coho were much lower in the main river than in the ponds where they were the main species, and were more variable in the river. Population density and biomass estimates of juvenile coho in the ponds ranged from 0.100 fish·m$^{-2}$ and 1.00 g·m$^{-2}$ to 1.00 fish·m$^{-2}$ and 5.15 g·m$^{-2}$, compared with density estimates of 0.08–0.23 fish·m$^{-2}$ in the river. The coho population in the ponds consisted of 0+ and 1+ age-groups in similar proportions, while in the main river the 0+ age-group was much more abundant. The growth rate of coho in the ponds was faster than in the main river, with pond fish reaching mean lengths of 62–79 mm at the end of the first growing season, compared with 53 mm in the main river. Smolt outmigration from the main study pond occurred in late spring with peak outmigration in May and June coinciding with peak river discharge and increasing water temperatures in the main river and pond.

# Coho and Beaver Ponds in Stillaguamish River, Washington

- Study evaluated the **population level effects** of loss of beaver ponds on coho salmon habitat
- Overall, **current** habitat capacity was reduced by 61% compared with **historic** levels, most of the reduction resulting from the loss of beaver ponds
- Current **summer** smolt production potential (SPP) from beaver ponds and sloughs was reduced by 89% and 68%, respectively, compared with historic levels
- Loss of **winter** SPP was even higher – 94% reduction from beaver ponds and 68% loss from sloughs

**The Importance of Beaver Ponds to Coho Salmon Production in the Stillaguamish River Basin, Washington, USA**

MICHAEL M. POLLOCK,* GEORGE R. PESS, AND TIMOTHY J. BEECHIE

*National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center, Seattle, Washington 98112, USA*

DAVID R. MONTGOMERY

*Department of Earth and Space Sciences, University of Washington, Seattle, Washington 98195, USA*

*Abstract.*—The use of beaver *Castor canadensis* ponds by juvenile coho salmon *Oncorhynchus kisutch* and other fishes has been well established. However, the population-level effects on coho salmon resulting from the widespread removal of millions of beaver and their dams from Pacific Coast watersheds have not been examined. We assessed the current and historic distributions of beaver ponds and other coho salmon rearing habitat in the Stillaguamish River, a 1,771-km² drainage basin in Washington and found that the greatest reduction in coho salmon smolt production capacity originated from the extensive loss of beaver ponds. We estimated the current summer smolt production potential (SPP) to be 965,000 smolts, compared with a historic summer SPP of 2.5 million smolts. Overall, current summer habitat capacity was reduced by 61% compared with historic levels, most of the reduction resulting from the loss of beaver ponds. Current summer SPP from beaver ponds and sloughs was reduced by 89% and 68%, respectively, compared with historic SPP. A more dramatic reduction in winter habitat capacity was found; the current winter SPP was estimated at 971,000 smolts, compared with a historic winter SPP of 7.1 million smolts. In terms of winter habitat capacity, we estimated a 94% reduction in beaver pond SPP, a 68% loss in SPP of sloughs, a 9% loss in SPP of tributary habitat, and an overall SPP reduction of 86%. Most of the overall reduction resulted from the loss of beaver ponds. Our analysis suggests that summer habitat historically limited smolt production capacity, whereas both summer and winter habitats currently exert equal limits on production. Watershed-scale restoration activities designed to increase coho salmon production should emphasize the creation of ponds and other slow-water environments; increasing beaver populations may be a simple and effective means of creating slow-water habitat.

# California Coho Salmon


- California is at the **southern end of the geographic range** of coho distribution
- Climate is more **Mediterranean** and conditions are generally **warmer and drier**, and there is **higher inter-annual variability in precipitation** relative to Oregon, Washington, and British Columbia
- Precipitation is **less frequent and more variable**, temperatures are higher, and droughts more frequent

# Habitat Preferences of Juvenile Coho Salmon

- The **preferred habitat** of coho salmon is **low-gradient streams** flowing through **wide valleys**
- Juvenile coho salmon rear in **slow water habitat** types such as **sloughs**, **wetlands** (perennial and seasonal), **off channel ponds, small lakes, side channels, alcoves, backwaters, spring fed channels, and small tributaries** with relatively stable flow.
- Juvenile coho salmon use beaver ponds as both **overwintering and summer rearing habitat**

# Habitat Preferences of Beaver

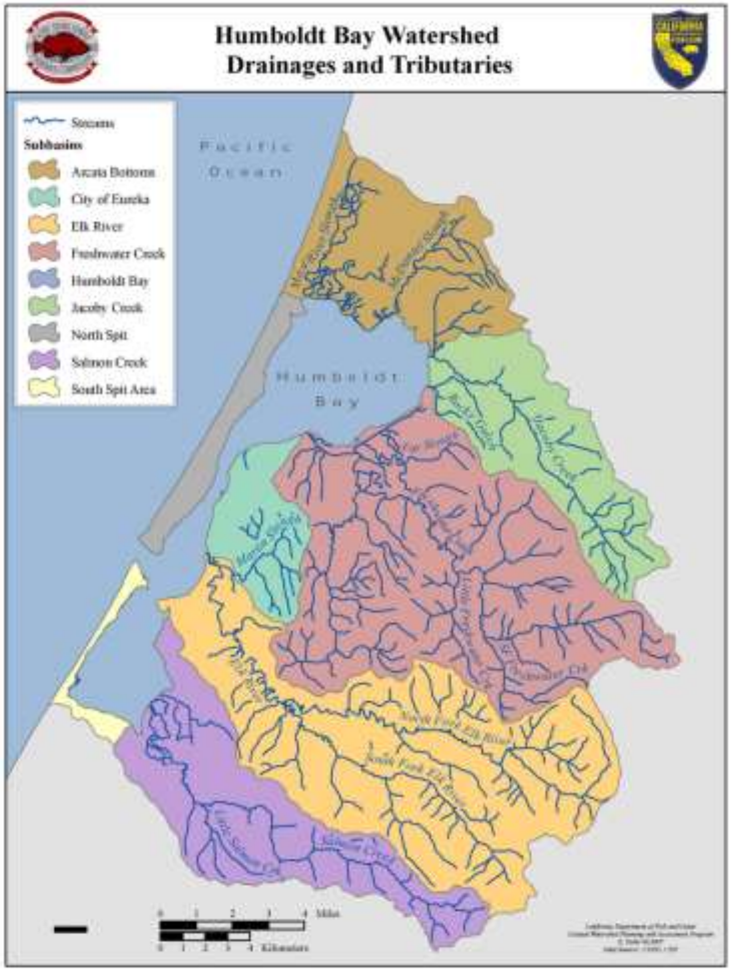
- Beaver are found in hydrogeomorphic conditions **similar** to those for coho salmon.
- Beaver prefer to build dams on **small to medium sized, low gradient streams flowing through unconstrained valleys**; they generally avoid constrained, high gradient streams
- Beaver dams are also built in **off channel habitat**, such as side channels fed by hyporheic flow, groundwater channels, and tributary channels flowing across the floodplain of a larger river

# Coho Habitat and Beaver in CA Case Studies

- **Natural beaver ponds** – **widespread in north coast watersheds** e.g. lower Klamath ponds, Scott/Shasta –**… few studies so far**
- **Artificial ponds, side-channels, alcoves** – some examples in  the Lower and mid-Klamath and Humboldt Bay
- **Beaver dam analogues** – installed in Scott R. and Trinity River

# Humboldt Bay Artificial Ponds – CDFW/PSMFC

- Historically, the Humboldt Bay watershed would have had **extensive flood plain wetlands**
- **Artificial off-channel ponds** have been recreated in **Jacoby Creek** and **Wood Creek**, by DFW and PSMFC.
- Project lead **Mike Wallace**, DFW, 2012-present



# RESULTS (Jacoby Creek Ponds)

1. **Water quality** conditions in the ponds **varied seasonally** - water temperatures were usually **warmer** and DO levels were **lower** in lower pond, but not in upper pond
2. Most coho were captured in the **upper pond**, with smaller numbers of **steelhead** - yearling-plus Coho and a few juvenile steelhead **moved into the upper pond by January**.
3. Most fish **remained in the ponds through April** and left the pond by May - **peak catches** occurred in February for yearling-plus Coho and February and March for juvenile steelhead.
4. Juvenile Coho rearing in the upper pond **grew faster** than their cohorts rearing in mainstem Jacoby Creek

- Upper Pond

- Lower Pond

# RESULTS (Wood Creek Pond)

- **209 sub-yearling and 15 yearling coho salmon** were recorded in the pond, with the highest catch occurring in November
- Numerous PIT tagged coho salmon have resided in the pond for a month or more and have shown a **fast growth rate** - mean FL increased from 72 mm in November to 103 mm in February
- Likely that improving or creating access to off channel habitat will **provide important rearing habitat** for juvenile salmonids throughout Humboldt Bay and other northern CA streams.

# Lower Klamath Beaver Ponds
# Yurok Tribe – Sarah Beesley

Figure 11. Photographs of an off-estuary beaver pond located in Spruce Creek (Top – February 2009); and Yurok Tribal Fisheries Program crews monitoring salmonid populations in Panther Creek Pond (Bottom – Spring 2008), Lower Klamath River Sub-basin.



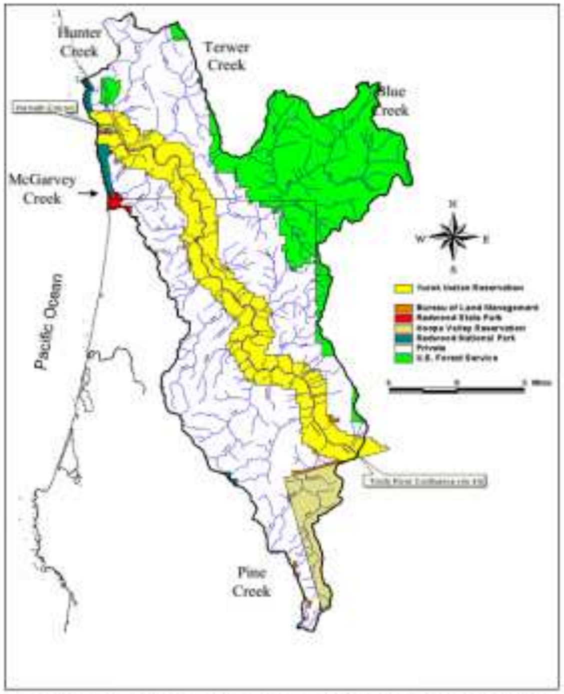


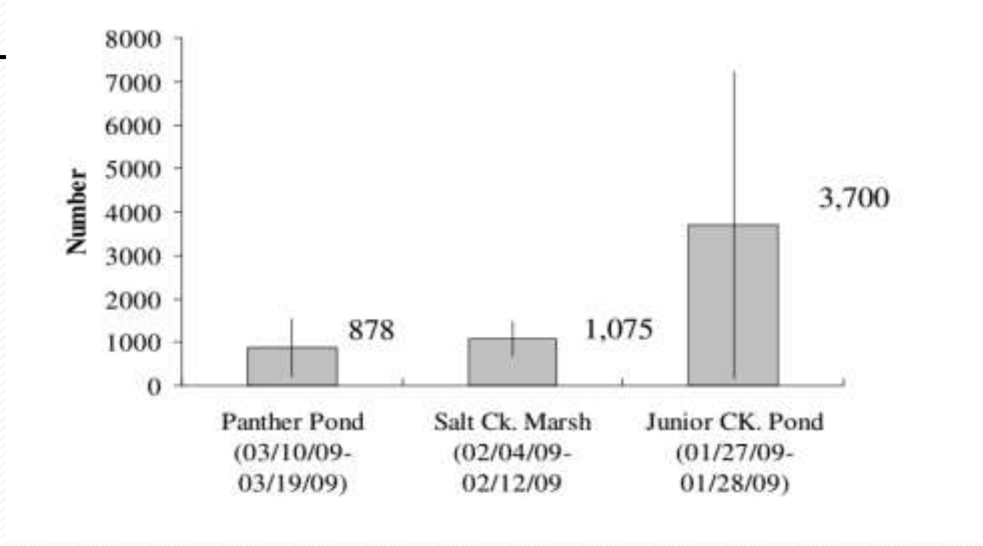

Figure 1. Map depicting landownership in the Lower Klamath River Sub-basin, California.

**Field Tour Sites**

Hunter Creek is a fourth order watershed that enters the north side of the Klamath River ~1.2 river miles upstream of the Pacific Ocean (Figure 1). McGarvey Creek is a third order watershed that enters the south side of Klamath River ~ 6.0 river miles upstream of the Pacific Ocean (Figure 1). Both watersheds support wild runs of coho salmon, chinook salmon, steelhead trout, coastal cutthroat trout, and several species of lamprey. The systems also provide critically valuable rearing habitat for juvenile coho from throughout the Klamath Basin (non-natal fish) and the tributary confluences provide thermal refuge for native fish migrating through the river during summer.

# Main Findings

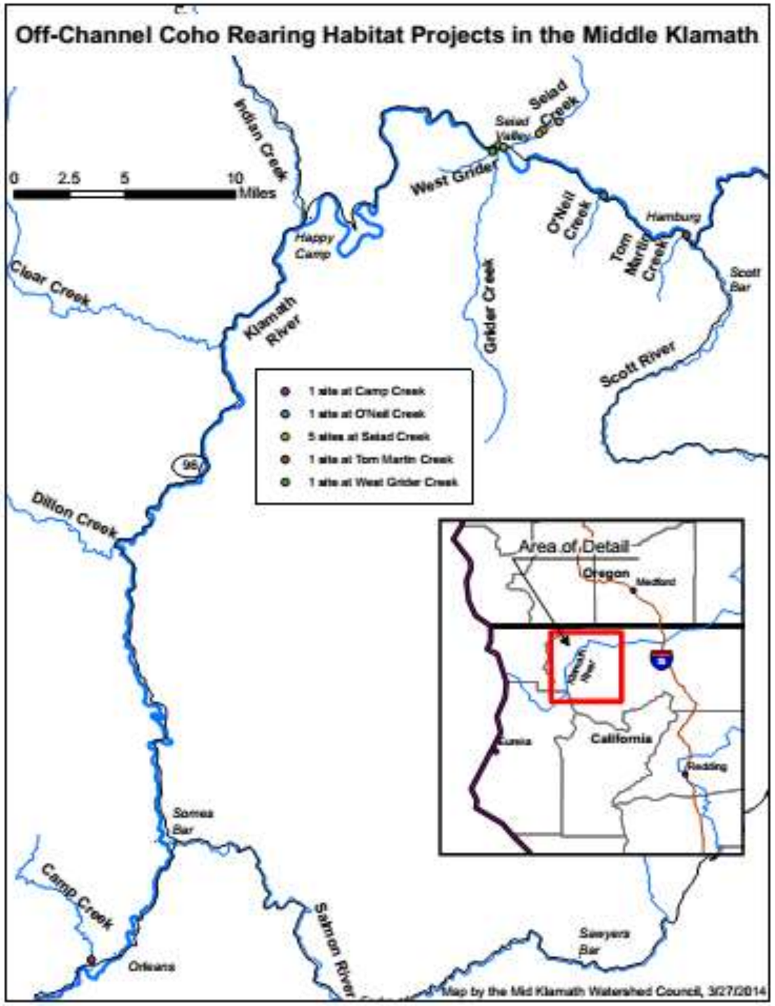
- **Constructed alcoves** – McGarvey Creek
- **Natural beaver ponds** – Salt Creek, West Fork McGarvey Creek
- **Juvenile coho abundance estimates up to 4,000** in natural ponds and **several hundred** in **constructed alcoves**




Mark-recapture population estimates in Panther Creek Pond, Salt Creek marsh, and Junior Creek Pond (coho brood year 2008-2009) Source: Yurok Tribe

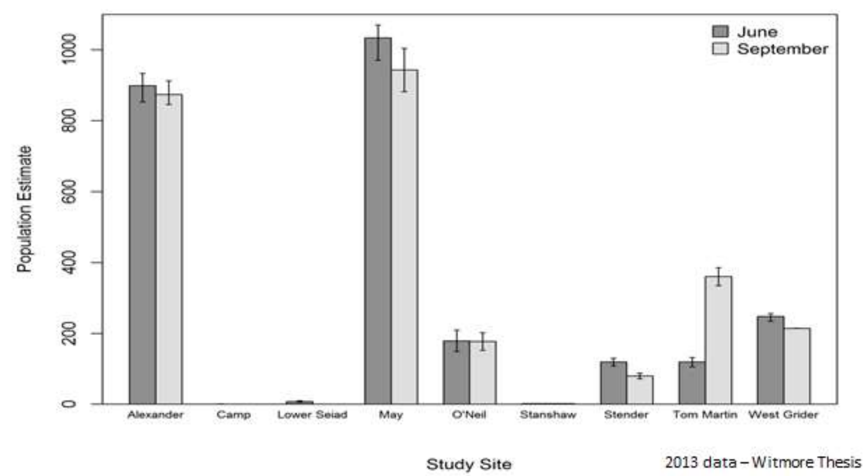
# Mid-Klamath Artificial Ponds
# Mid Klamath Watershed Council

- **Winter rearing habitat is a limiting factor** for threatened coho salmon recovery in the Mid Klamath and other watersheds in the Klamath River basin
- The MKWC has constructed 8 **off-channel rearing habitats** for coho between 2010-2013
- Source: Will Harling, MKWC



# Main Findings

- Primary objective was to rapidly **increase coho winter rearing habitat**, however **summer use** was documented in all ponds
- Extensive **monitoring**: water quality (DO, temp), snorkel surveys, mark/recap population estimates, maintaining habitat connectivity
- **Source**: **Shari Witmore** – 2014 MS thesis HSU



# Scott River - CDFW

- Scott River in Siskiyou County was known historically as ‘**Beaver Valley**’
- In 2011 CDFW (lead: Mary Olswang) investigated **juvenile coho rearing above a beaver dam** in Sugar Creek
- Pond and back-water provided **summer and winter rearing habitat** for juvenile coho

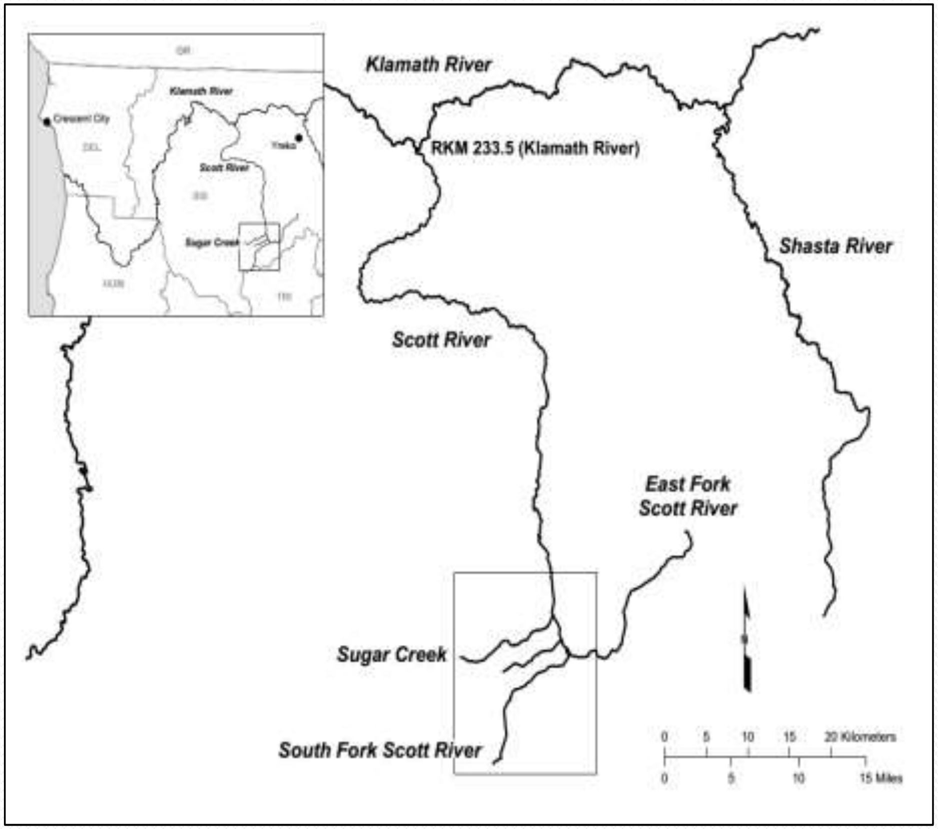



**Figure 1: Location of Sugar Creek, tributary to the Scott River, Siskiyou County, CA**

# Main Findings

- The pond and the back watered stream created by the beaver dam on Sugar Creek provided **both summer and winter habitat** for juvenile coho salmon
- Redd surveys also documented coho salmon **spawning** both **below and above** the dam

**Looking upstream from the dam at the pond. Beaver lodge is on the right**

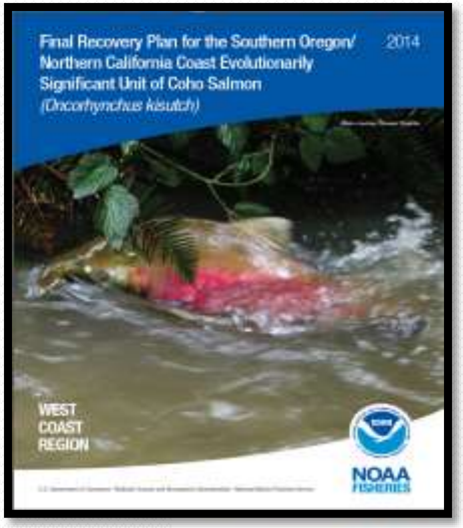
# Beaver Dam Analogues

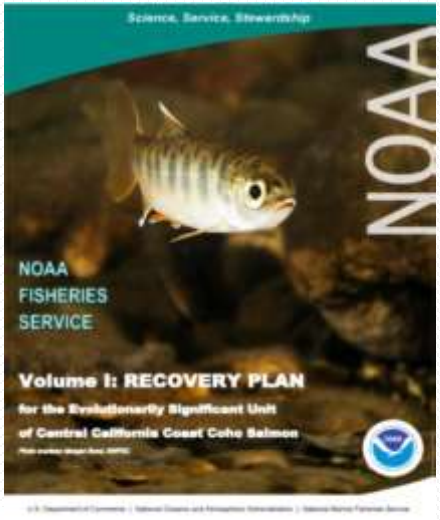
- Several are currently installed in **Scott River**, others pending permit approval
- Not yet proven – in CA are still regarded as an **unproven, experimental habitat restoration tool**
- Main issue may be **fish passage**
- How do **beaver** respond?

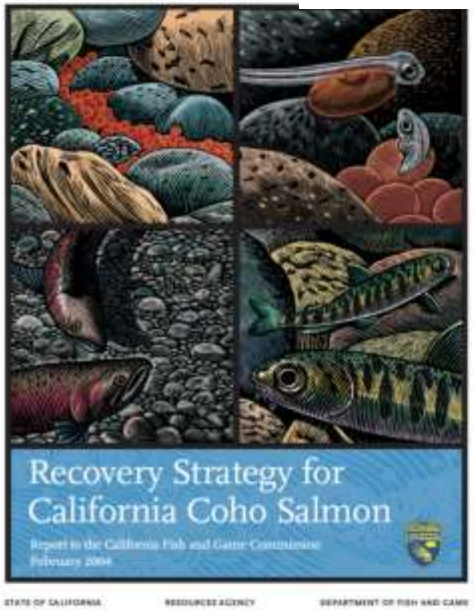
# Do Beaver Have a Role in California Coho Salmon Recovery?

# Beaver in Coho Recovery Plans

- **Develop management guidelines** that will promote the use of beaver as a **tool in coho habitat restoration**
- **Educate the public** regarding the **benefits** of beaver to **aquatic ecosystems**, especially the benefits to **coho salmon** and **groundwater recharge**
- **Restoration efforts** that create beaver dam or pond analogues for the purposes of **fish recovery** and improving aquatic ecosystems



# The Future – where are we going?

1. **Rigorous scientific evaluation is needed if artificial beaver ponds or analogues are to have a role in coho recovery – more experimental studies and assessments are needed.**
2. **Beaver dam analogues and coho recovery – in addition to their benefits, we need to assess potential *liabilities*, including fish passage issues, water quality, predators, flooding, bank erosion etc. and manage accordingly**
3. **Habitat and population monitoring - long term experimental studies are essential if we are to demonstrate species recovery.**
4. **Adequate maintenance programs - required for analogues, artificial beaver dams etc. to ensure their continued effectiveness – as with fish screens and fish ladders**
5. **Restore ecosystem processes at the watershed level - combine analogues, artificial ponds, side-channels etc. with other types of habitat restoration**
6. **Increased inter-agency and stakeholder involvement - collaborative studies are needed to implement and develop recovery plans**


California Coho Salmon

~Keep~Them~Running~

Priority Action Coho Team


# The Bucktail Beaver Dam Analog Construction Process and Near-term Results

James Lee
Riparian Ecologist
Hoopa Valley Tribe
and Trinity River Restoration Program




Trinity River
Restoration Program

To search, type and hit enter

Tuesday, March 28

**Tuesday, March 28**
9:00am TMC Meeting (D

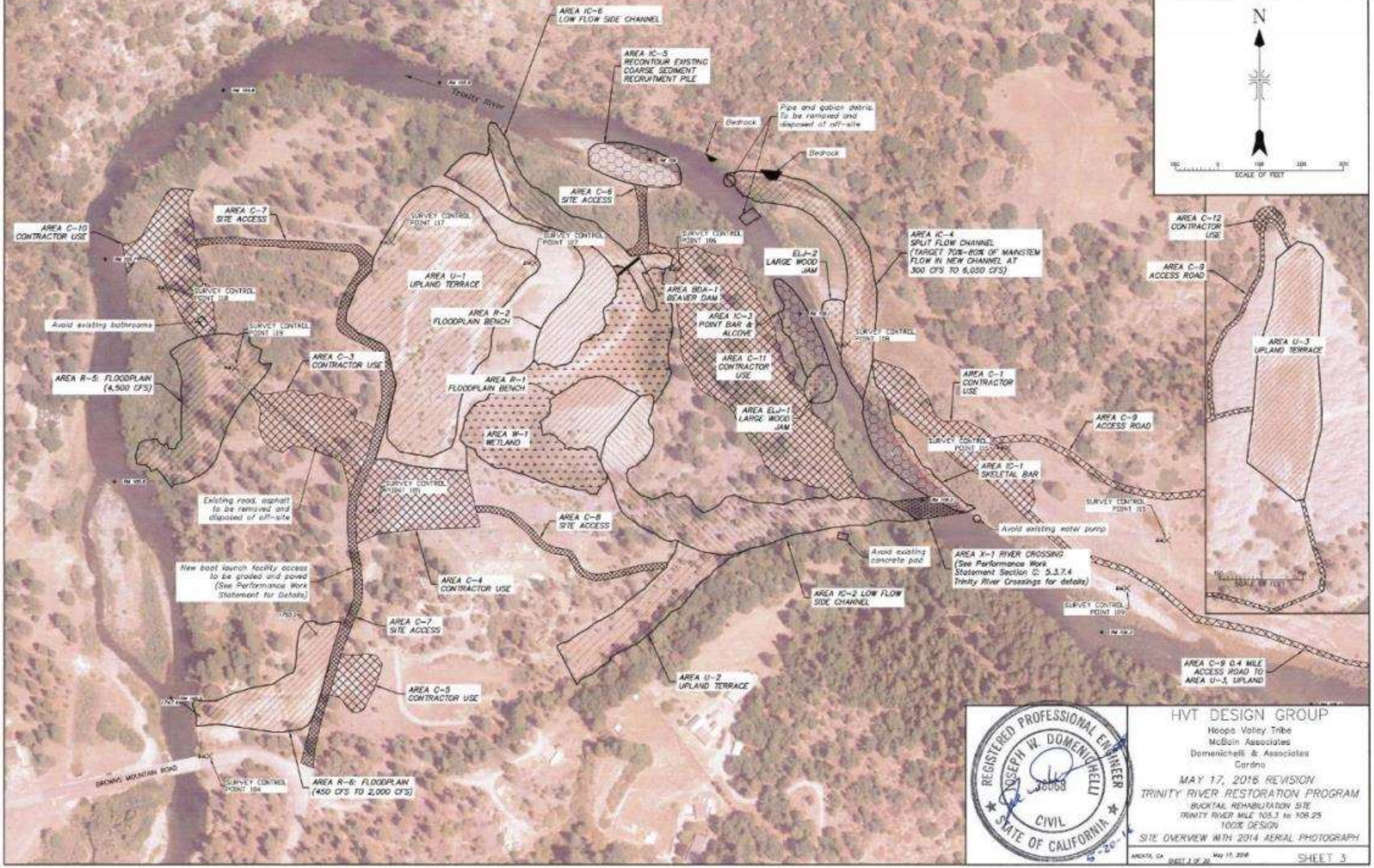
**Tuesday, April 11**
9:00am Flow Work Grou

*"to restore and maintain the Trinity River's anadromous fishery resources"*

– U.S. Department of Interior, Record of Decision, 2000

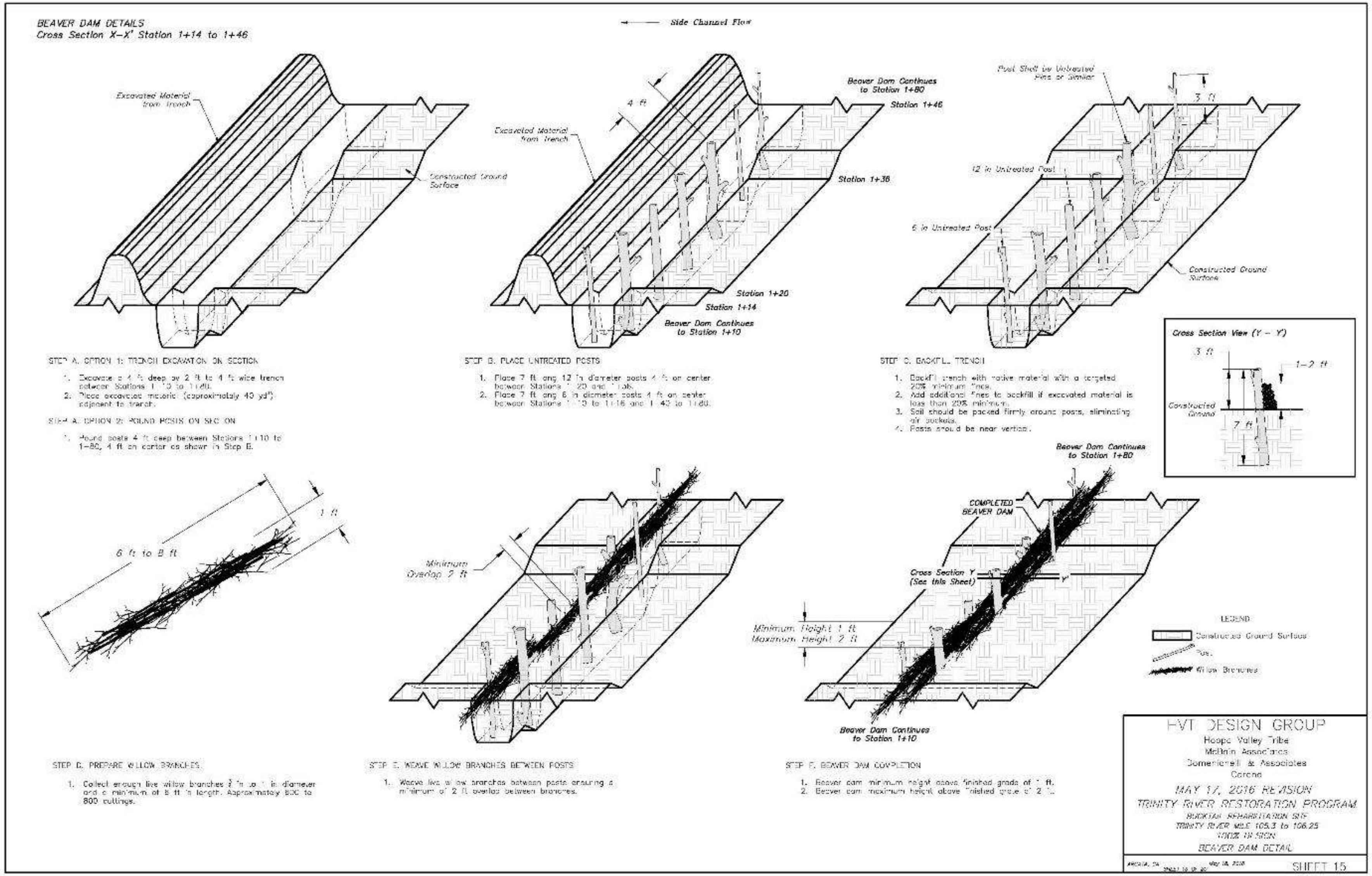
The reason for restoring ecological function to the Trinity River below the dams is to restore and maintain natural fish populations. Learn about how TRRP assesses progress.

Klamath
River
Orleans
Yurok Indian Reservation
Weitchpec
Hoopa Valley Indian Reservation
Hoopa
Willow Creek
Trinity
River
New River
Salyer
Burnt Ranch
South Fork Trinity
Trinity Center
Trinity Lake
Trinity Dam
Trinity River Fish Hatchery
Weaverville
Lewiston
Lewiston Lake
Lewiston Dam
Clear Creek
Clear Creek Tunnel
Whiskeytown Lake
Redding
Sacramento River
Trinity River Basin
Redding
Sacramento
Pacific Ocean
San Francisco
California



AREA IC-6
LOW FLOW SIDE CHANNEL
AREA IC-5
RECONTOUR EXISTING
COARSE SEDIMENT
RECRUITMENT PILE
Trinity River
Bedrock
Pipe and gabion debris.
To be removed and
disposed of off-site
Bedrock
N
SCALE OF FEET
AREA C-10
CONTRACTOR USE
AREA C-7
SITE ACCESS
AREA C-6
SITE ACCESS
SURVEY CONTROL POINT 117
SURVEY CONTROL POINT 106
AREA U-1
UPLAND TERRACE
AREA R-2
FLOODPLAIN BENCH
SURVEY CONTROL POINT 118
AREA BDA-1
BEAVER DAM
ELJ-2
LARGE WOOD
JAM
AREA IC-4
SPLIT FLOW CHANNEL
(TARGET 70%-80% OF MAINSTEM
FLOW IN NEW CHANNEL AT
300 CFS TO 6,050 CFS)
AREA C-12
CONTRACTOR
USE
AREA C-9
ACCESS ROAD
Avoid existing bathrooms
SURVEY CONTROL POINT 119
AREA IC-3
POINT BAR &
ALCOVE
SURVEY CONTROL POINT 108
AREA U-3
UPLAND TERRACE
AREA C-3
CONTRACTOR USE
AREA C-11
CONTRACTOR
USE
AREA R-5: FLOODPLAIN
(4,500 CFS)
AREA R-1
FLOODPLAIN BENCH
AREA C-1
CONTRACTOR
USE
AREA ELJ-1
LARGE WOOD
JAM
AREA C-9
ACCESS ROAD
AREA W-1
WETLAND
AREA IC-1
SKELETAL BAR
SURVEY CONTROL POINT 105
Existing road, asphalt
to be removed and
disposed of off-site
AREA C-8
SITE ACCESS
Avoid existing water pump
New boat launch facility access
to be graded and paved
(See Performance Work
Statement for Details)
AREA C-4
CONTRACTOR USE
Avoid existing
concrete pad
AREA X-1 RIVER CROSSING
(See Performance Work
Statement Section C: 5.3.7.4
Trinity River Crossings for details)
AREA IC-2 LOW FLOW
SIDE CHANNEL
SURVEY CONTROL POINT 109
AREA C-7
SITE ACCESS
AREA C-5
CONTRACTOR USE
AREA U-2
UPLAND TERRACE
AREA C-9 0.4 MILE
ACCESS ROAD TO
AREA U-3, UPLAND
BROWNS MOUNTAIN ROAD
SURVEY CONTROL POINT 104
AREA R-6: FLOODPLAIN
(450 CFS TO 2,000 CFS)
REGISTERED PROFESSIONAL ENGINEER
JOSEPH W. DOMENICHELLI
CIVIL
STATE OF CALIFORNIA
HVT DESIGN GROUP
Hoopa Valley Tribe
McBain Associates
Domenichelli & Associates
Cardno
MAY 17, 2016 REVISION
TRINITY RIVER RESTORATION PROGRAM
BUCKTAIL REHABILITATION SITE
TRINITY RIVER MILE 105.3 to 106.25
100% DESIGN
SITE OVERVIEW WITH 2014 AERIAL PHOTOGRAPH
ARCATA, CA
May 17, 2016
SHEET 3

# Details from Bucktail 100% civil design



Installed 6 inch and 12 inch posts 3 to 4 ft on center

# Spec called for 1,000, 12' cottonwood and willow poles

# Wove individual willow poles 6 to 8 ft long around posts

Arroyo willow and narrowleaf willow were used

Added the final posts to complete the dam

Wove willows around corner and into the newly placed posts being careful to bolster the corner


Added straw to help plug the larger gaps

Added fine sediment to the toe of the dam on the front and back side to plug the smaller gaps

Removed a plug in a constructed side channel to provide water


# Construction Summary

- ~ 40 cubic yards material excavated/replaced
  - 2 hours with medium-sized excavator
  - Most material was backfilled into trench; fines and cobbles were replaced separately
- 25- 6 to 12” diameter, 10’ long conifer logs
  - Tops from large wood structures
  - 4 hours with medium-sized excavator
- >>1,000 12-14’ willow poles (4 truckloads)
  - 1 day with 8-person crew; most material was salvaged from stands removed during construction of other project features
- 4 bales straw
- Willow weave and straw plug took less than 1 day with an 8-person crew
- Efficiency of BDA construction was enhanced because it was a component of a much larger project

# Preliminary Results-

- Documented beaver use
- Documented fish presence- multiple species of salmonids and three-spined stickleback
- Documented waterfowl use
- Western toad breeding
- Persisted through higher flows (~ 40-50 cfs)
- Observed elevated water table in adjacent excavated features


28.11 inHg
48°F
01/01/1970
12:00AM
TL 23

# Higher-than expected water table throughout site

# What we learned:

- Simple to plan and build

# An Experimental Study of Beaver and Beaver Dam Analogue Restoration Techniques in Childs Meadow

Center for Watershed Sciences, UC Davis
The Nature Conservancy
USFS Pacific Southwest Research Station
Point Blue Conservancy

# Childs Meadow Project Partners

**UC Davis** - Sarah Yarnell
(hydrology, geomorphology, restoration)

**The Nature Conservancy** – Kristen Podolak, Rodd Kelsey, Andrea Craig,
(restoration and grazing management, geomorphology)

**UC Davis** – Evan Wolf
(carbon, restoration)

**Point Blue** –Ryan Burnett
(birds, restoration)

**USFS PSW** – Karen Pope
(amphibians, restoration)

# Childs Meadow Project Partners

**U.S. Fish & Wildlife Service, Partnership Program -** Jacob Byers and Sheli Wingo

**Plumas Corporation**
Leslie Mink
(Permitting)

**Scott River Watershed Council**
Charna, Leslie, Peter
(BDA Construction)

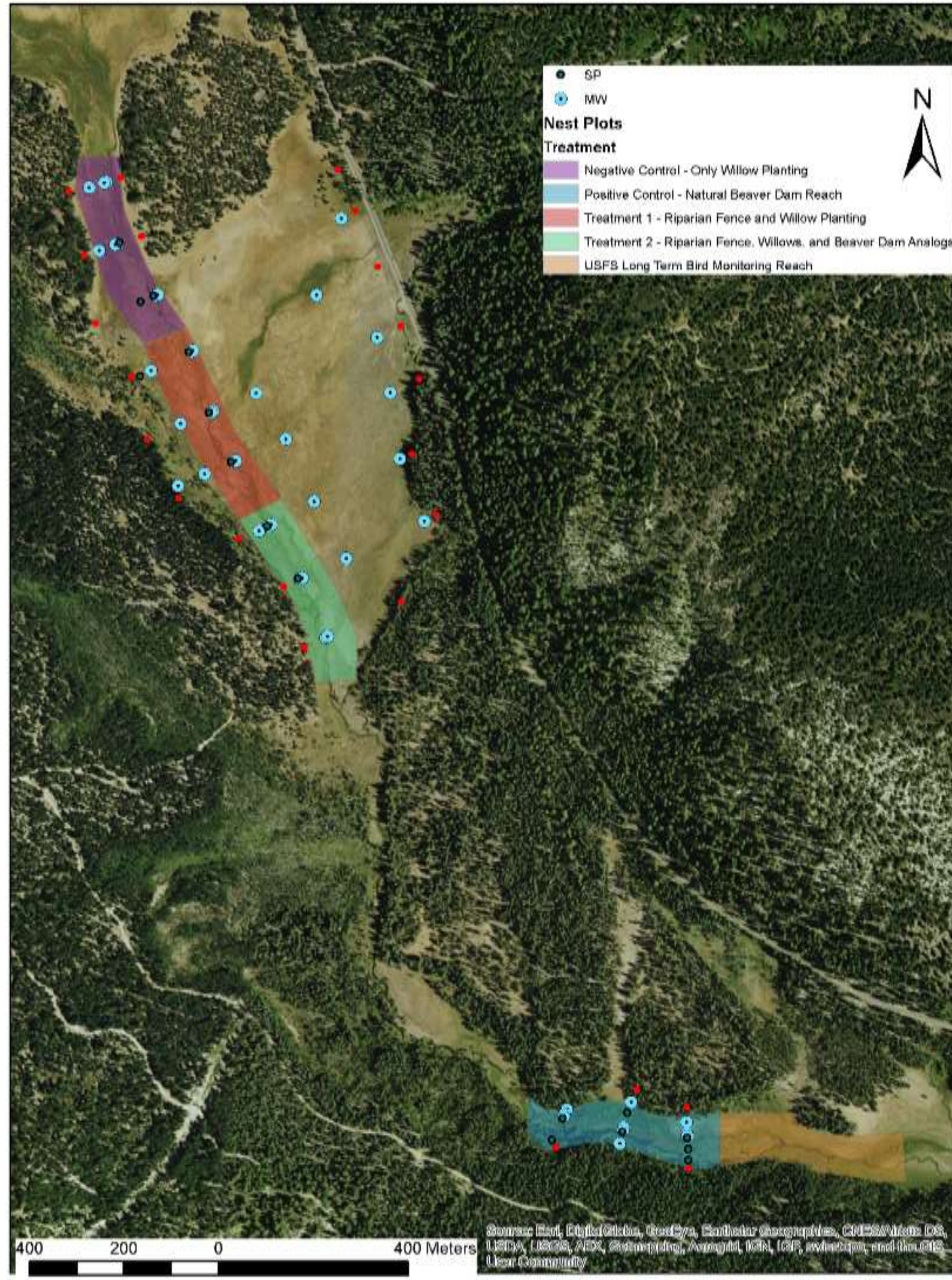
# Study Design

BACI Design:

- 2 treatments
- 2 controls

Monitoring:

- Above and below-ground carbon
- Hydrogeomorphic conditions
- Response of targeted wildlife species:
  - Willow flycatcher
  - Cascades frog



# Timeline

May 2015-Today

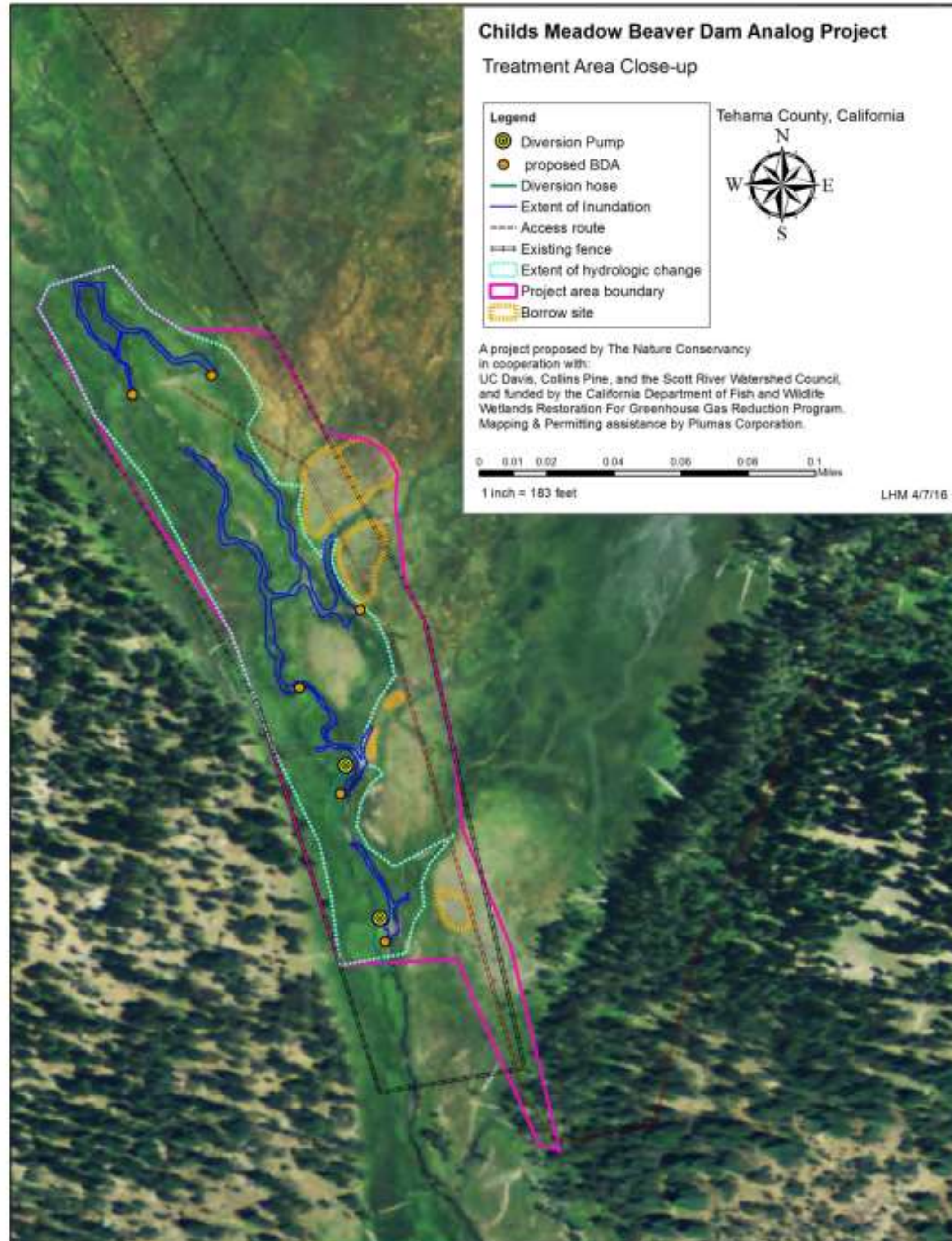
- Collect data

Fall 2015

- Cattle exclosure fence
- Planted willow stakes

Fall 2016

- Installed 6 BDAs



# Pre-restoration Meadow Conditions

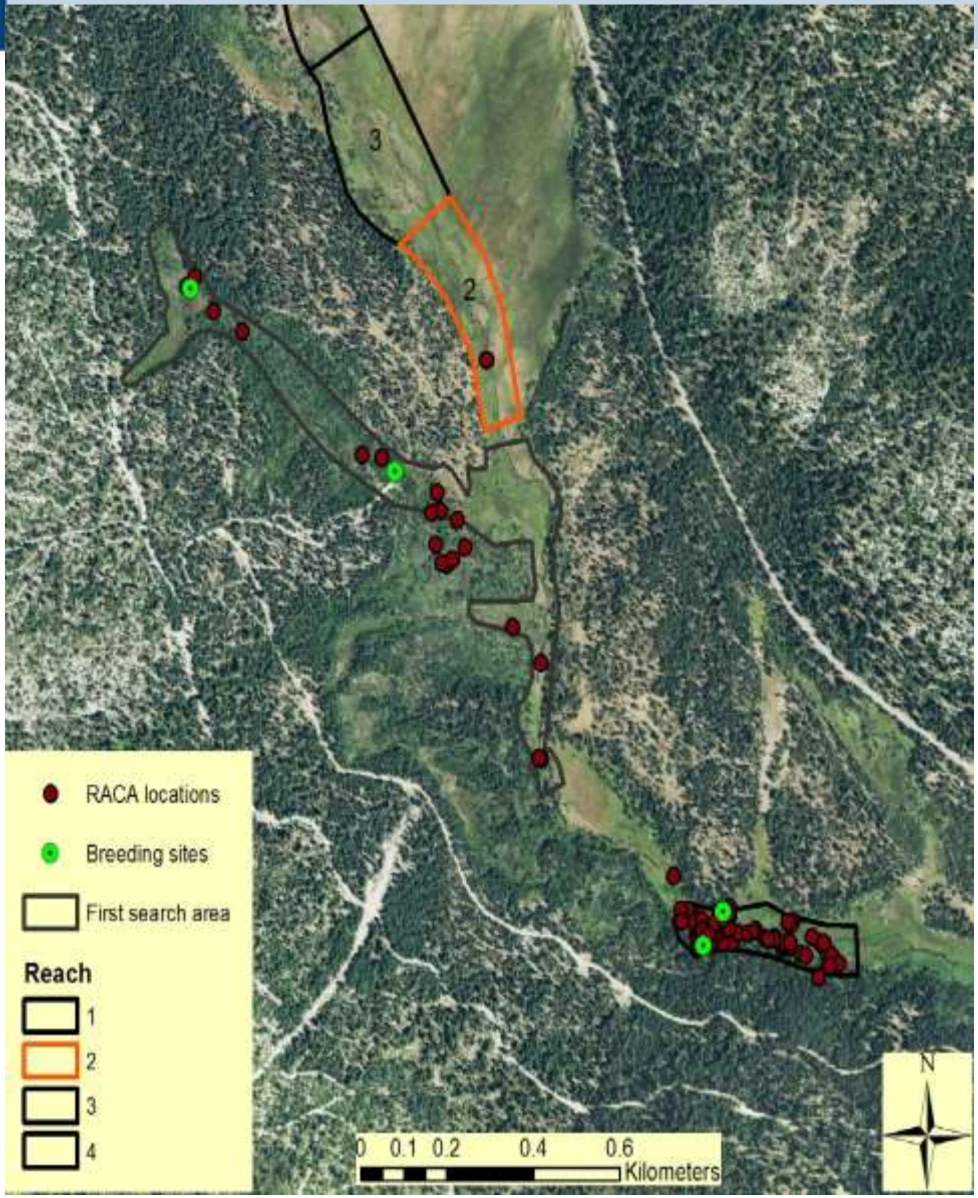
## Pre-treatment Reaches

## Natural Beaver Reach

*Images flown same day, Oct. 2014*

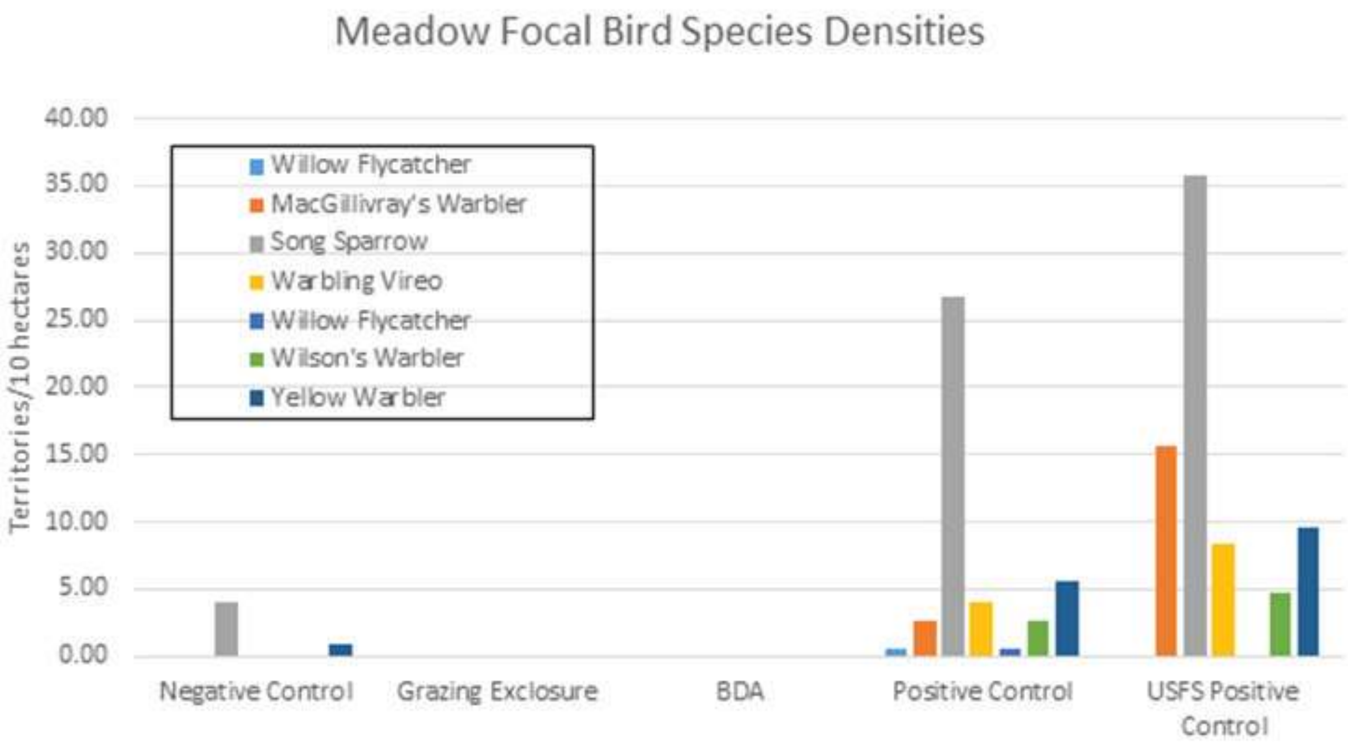
- 100+ years of grazing
- Removal of timber from 1941-1974
- Ditching on edges of meadow by 1974
- Channel incised on average 1.6 ft, lacks woody vegetation
- Historic removal of beaver?

# Pre-restoration Meadow Conditions




**Critical species**:
Cascades frog
(Karen Pope's research)

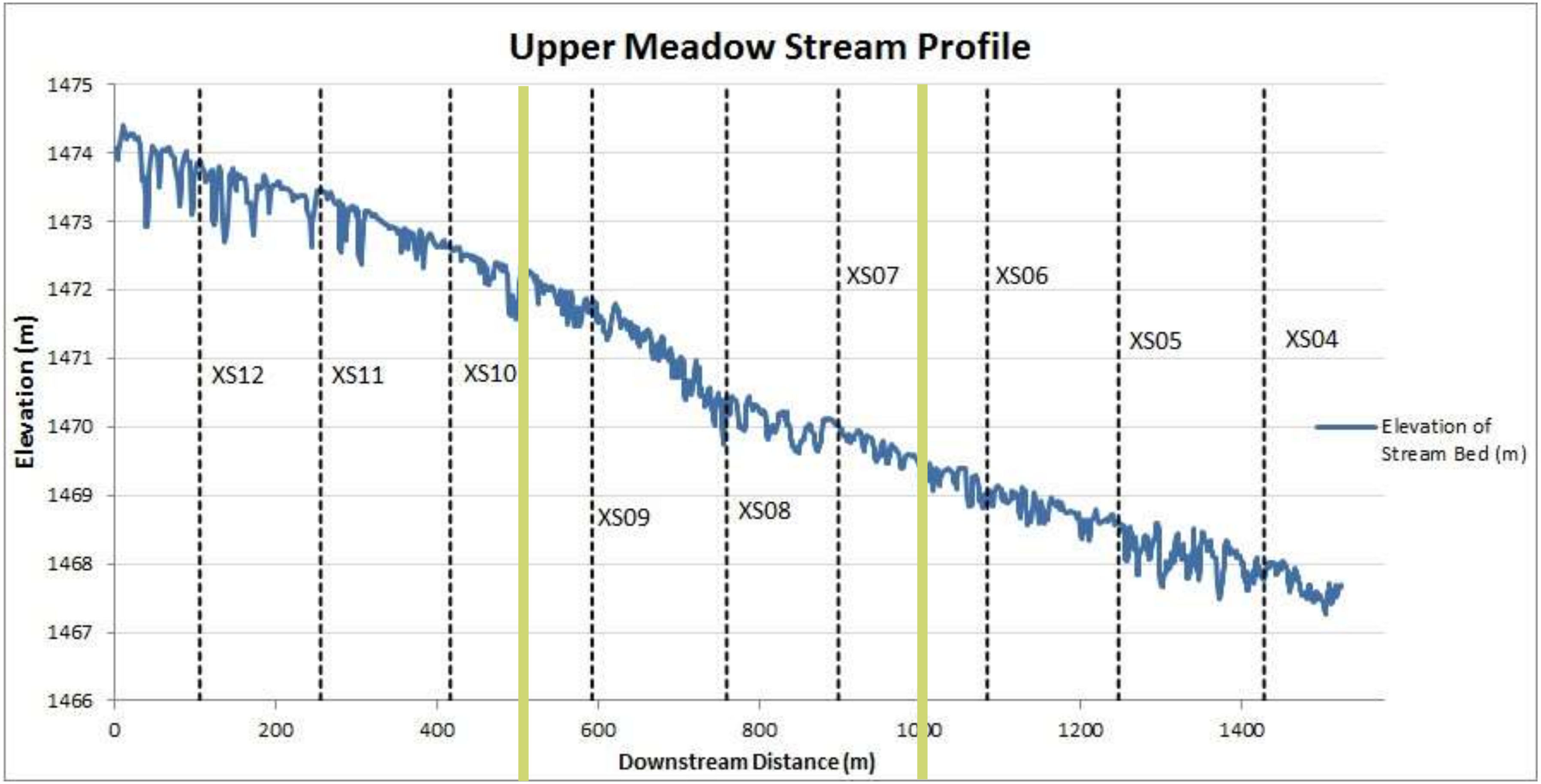
# Pre-restoration Meadow Conditions




**Critical species**: Willow flycatcher (Ryan Burnett's research)

# Pre-restoration Meadow Conditions

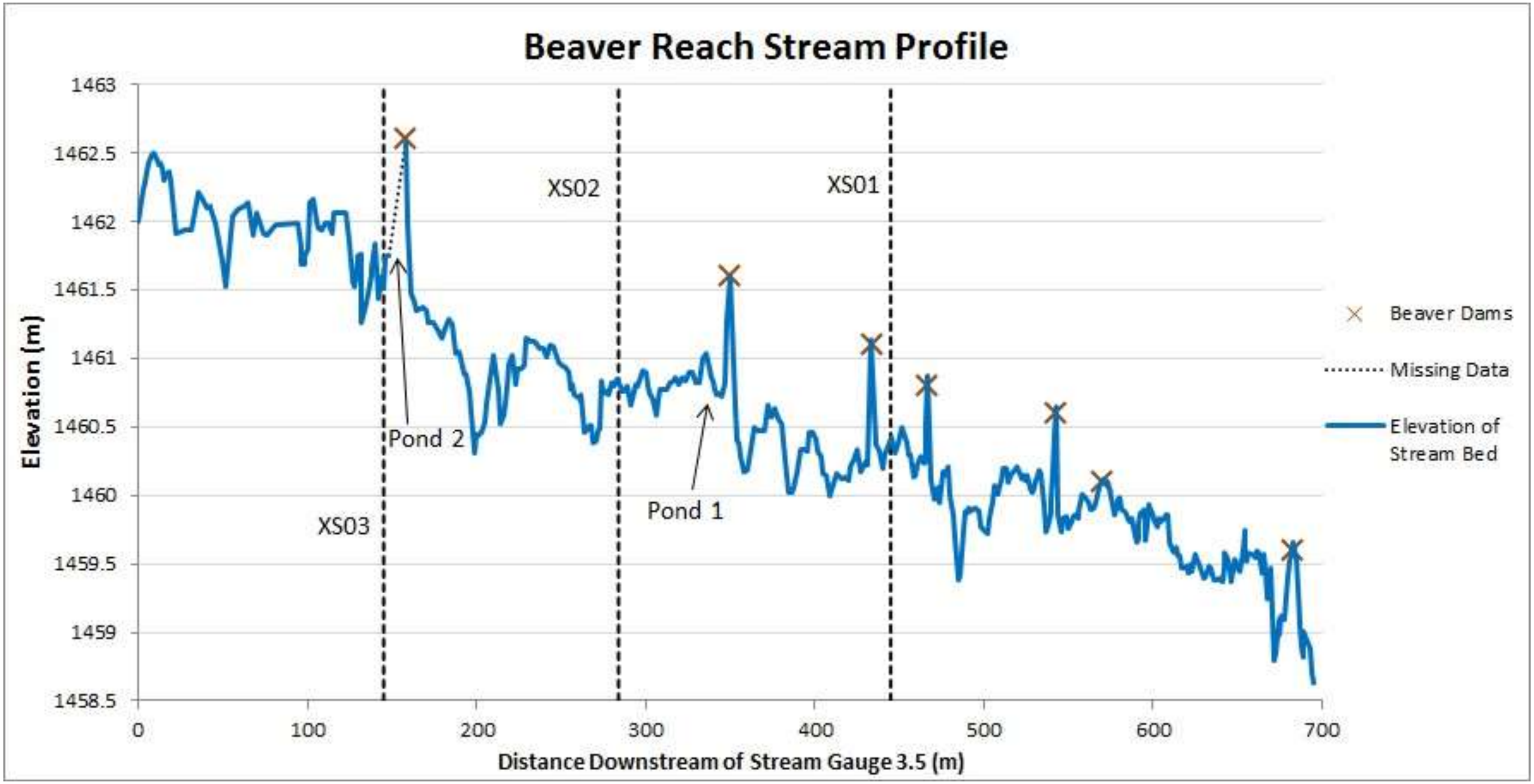
Pre-treatment Reaches




Negative Control　　Fence Only　　BDA

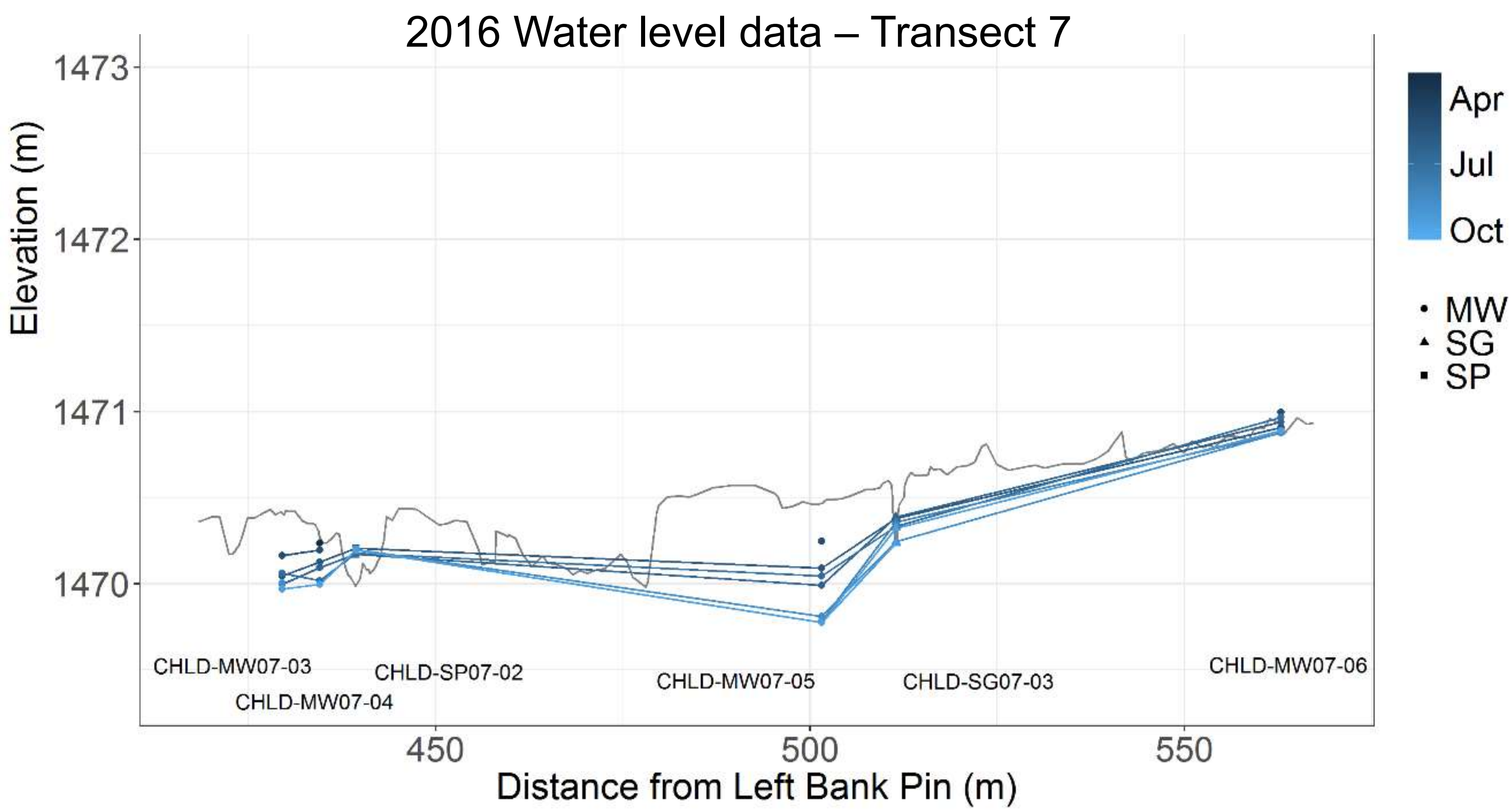
# Pre-restoration Meadow Conditions

Natural Beaver Reach



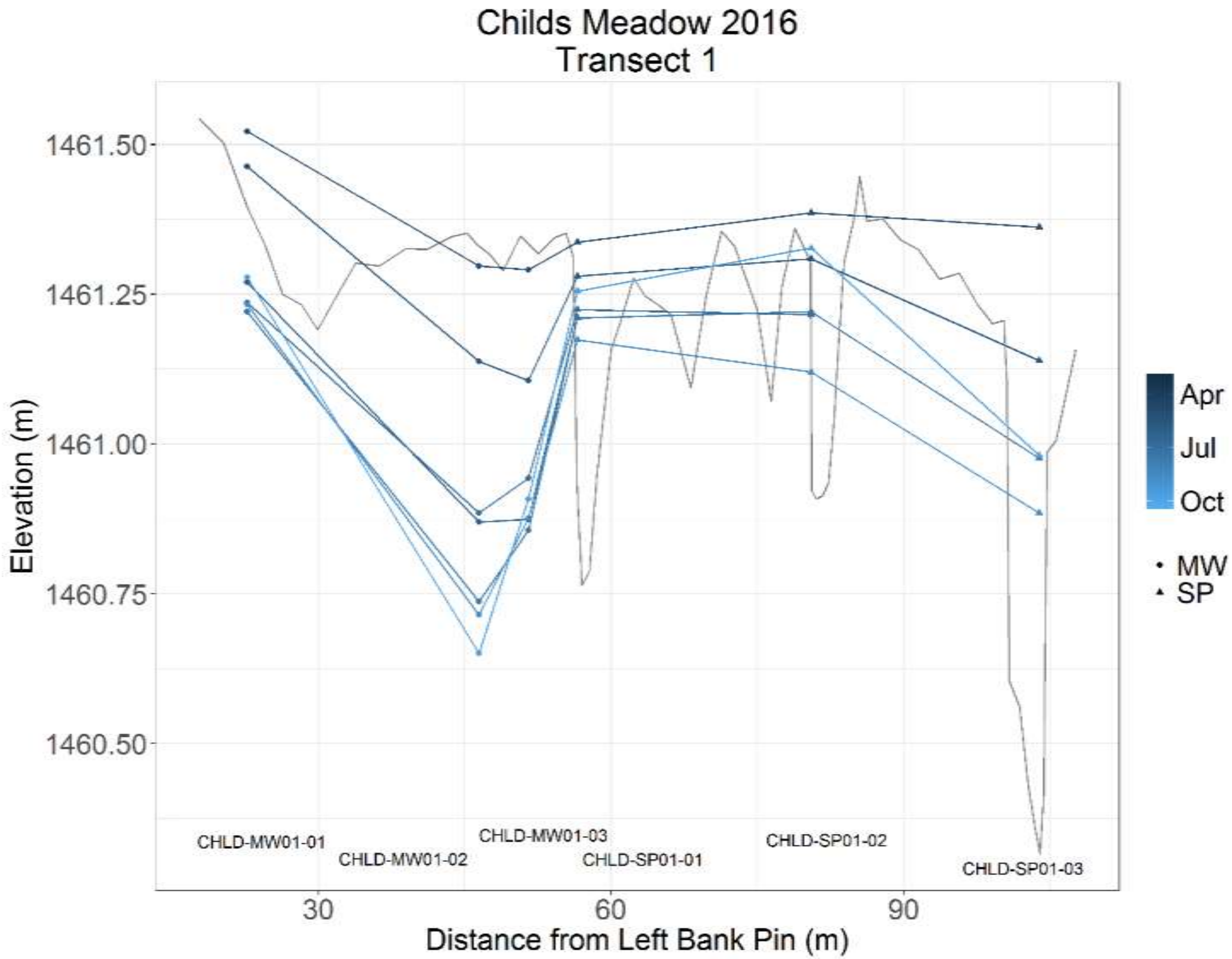
# Pre-restoration Meadow Conditions

## Pre-treatment Reaches – Cross-sectional profile



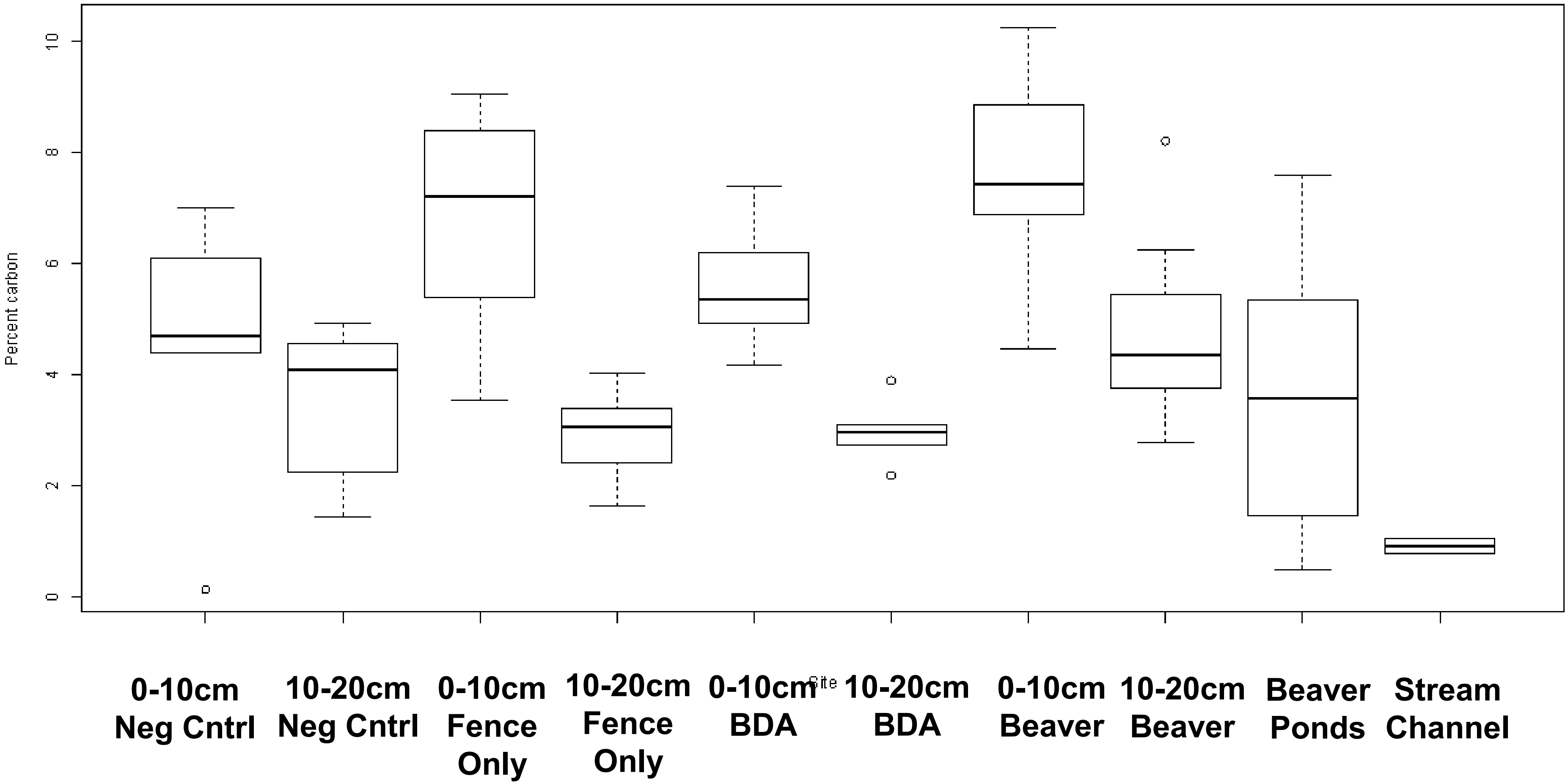
# Pre-restoration Meadow Conditions

Natural Beaver Reach – Cross-section Profile

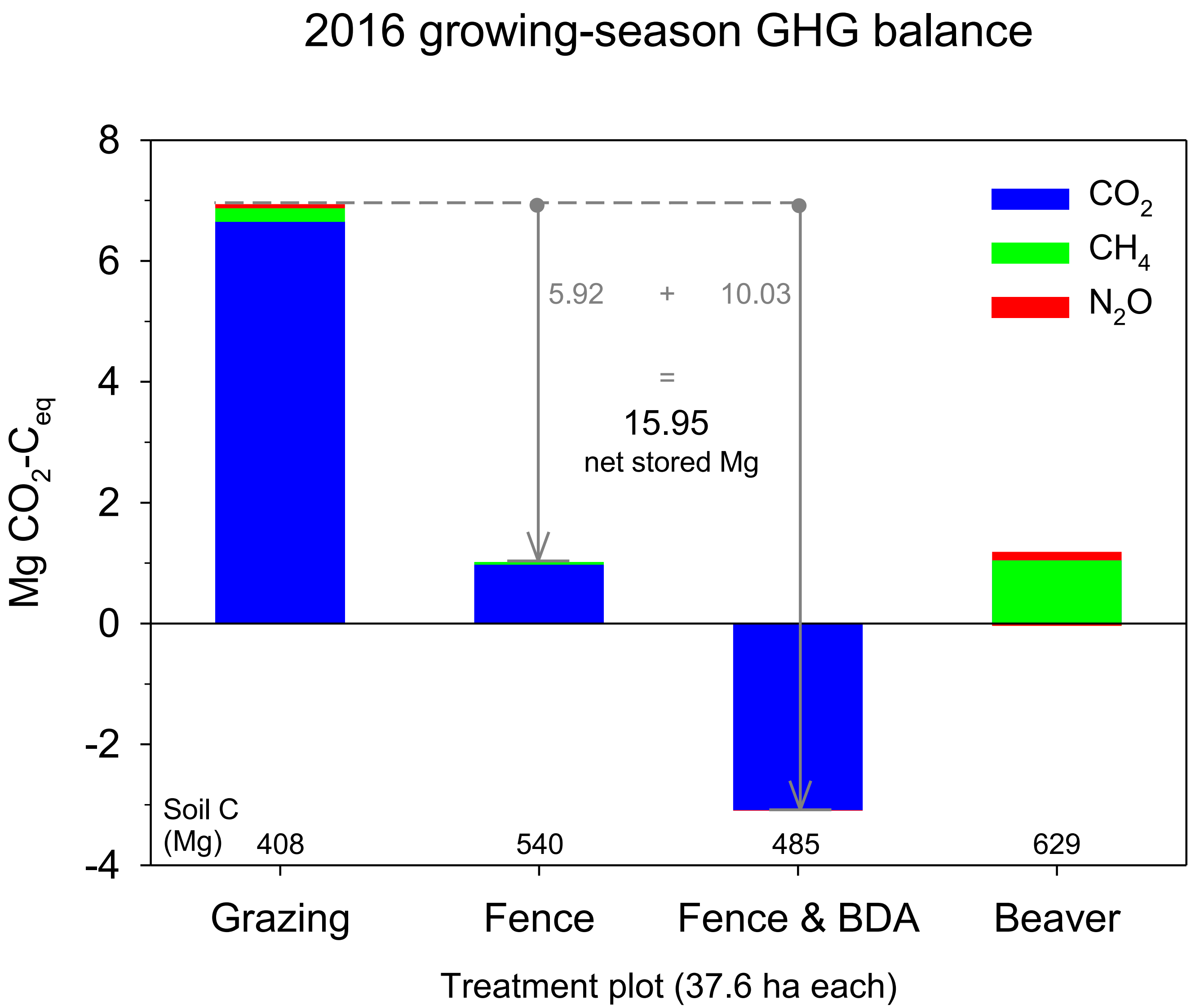


# Carbon Sequestration – Effect of fencing

2016 Soil Core Data



# Carbon Sequestration – Effect of fencing



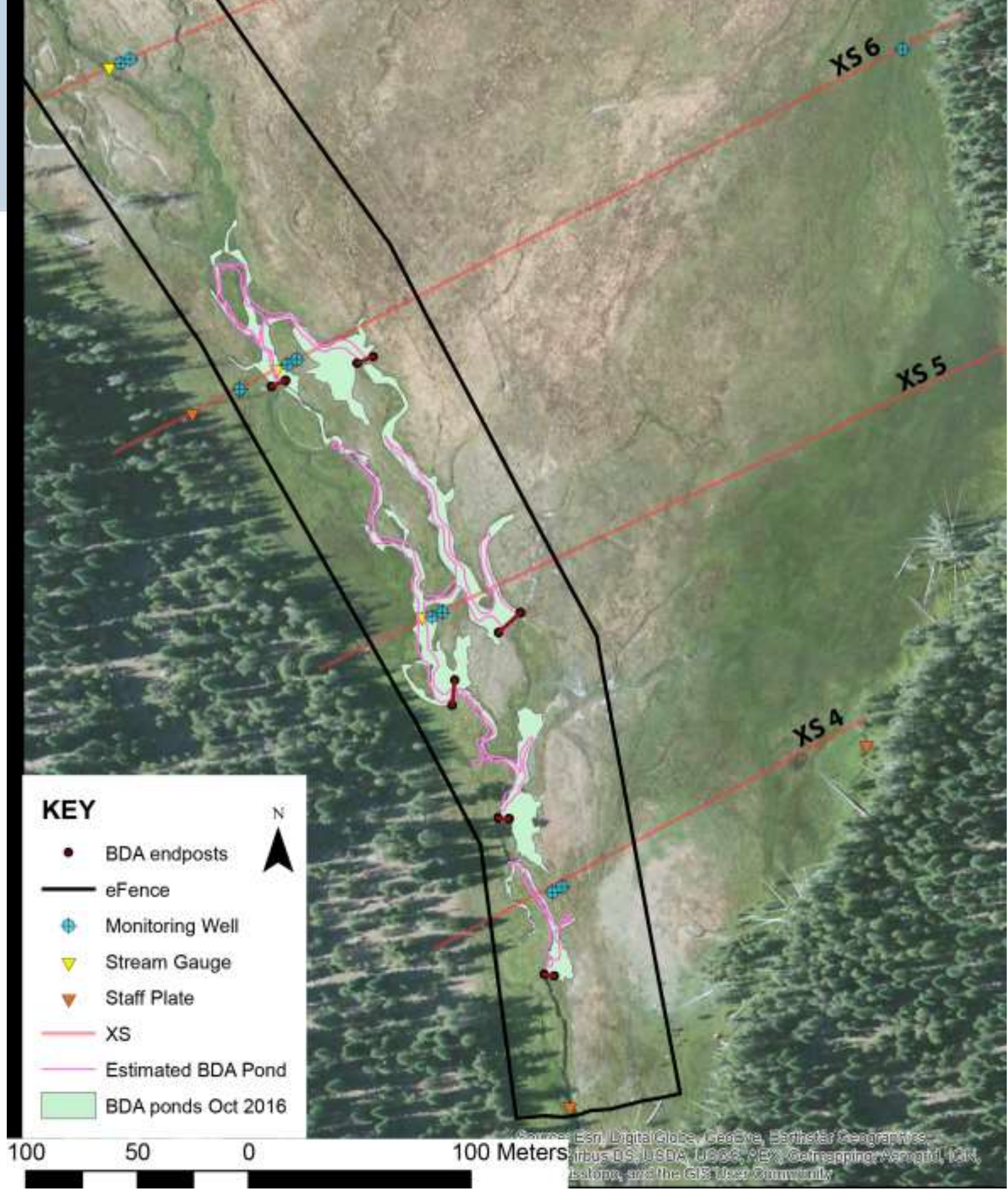
BDA installation – Oct 2016

# BDA Installation – Oct 2016


The Nature Conservancy

# BDA Inundation

- Full inundation in less than 24 hours
- Mapped surface water extent from aerial drone flight approximately 2 weeks after install = roughly 3-4x predicted extent

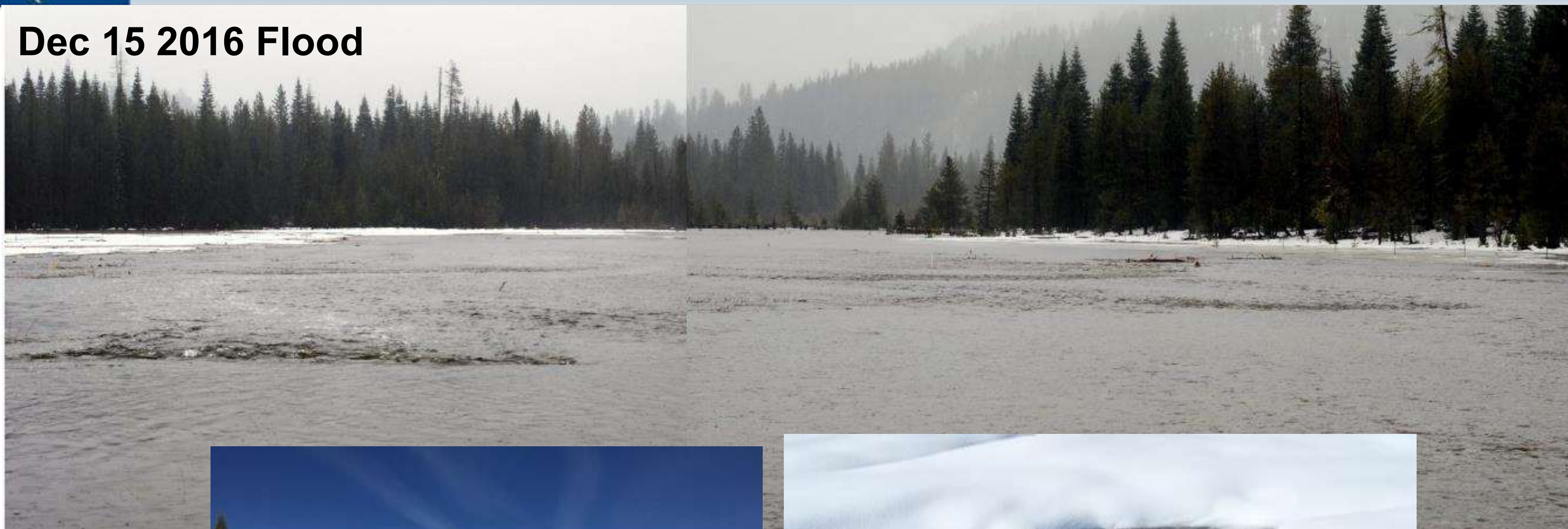


# Post-Treatment Monitoring

- 3 seasons:  2017-2019
- Continued hydrogeomorphology, GHG monitoring, and amphibian and avian ecology
- BDA maintenance if needed

Dec 15 2016 Flood

# Thank you - Questions?



Dec 15 2016 Flood

Jan 30 2017 Snow and Ice on BDA

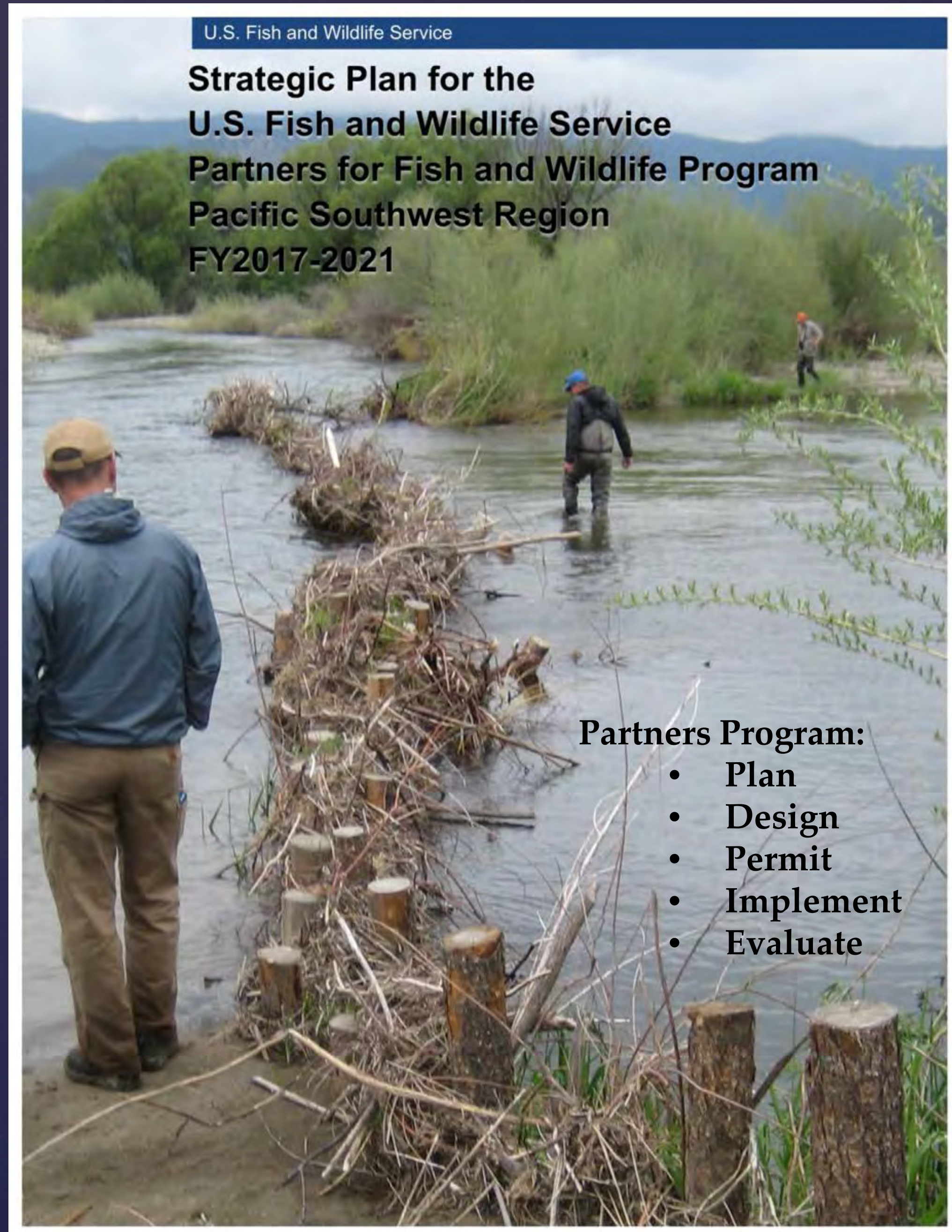

# Beaver Restoration:
# Design and Application in the Sierra Nevada

Damion Ciotti and Jared McKee
Habitat Restoration Office
Auburn, CA

# Presentation Overview

1. Beaver and restoration design

2. Two examples implementation
   - Sierra meadow
   - Sierra foothill floodplain

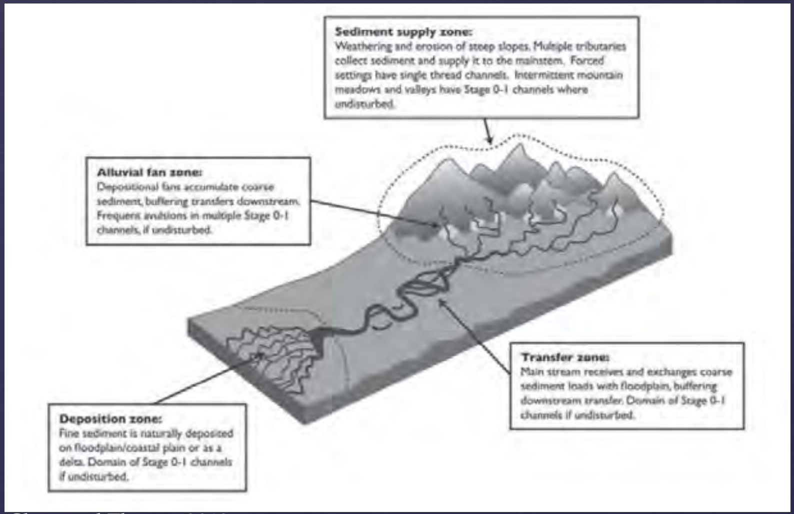

U.S. Fish and Wildlife Service
Strategic Plan for the
U.S. Fish and Wildlife Service
Partners for Fish and Wildlife Program
Pacific Southwest Region
FY2017-2021
Partners Program:
• Plan
• Design
• Permit
• Implement
• Evaluate

# Increase Production of Sensitive Species Populations

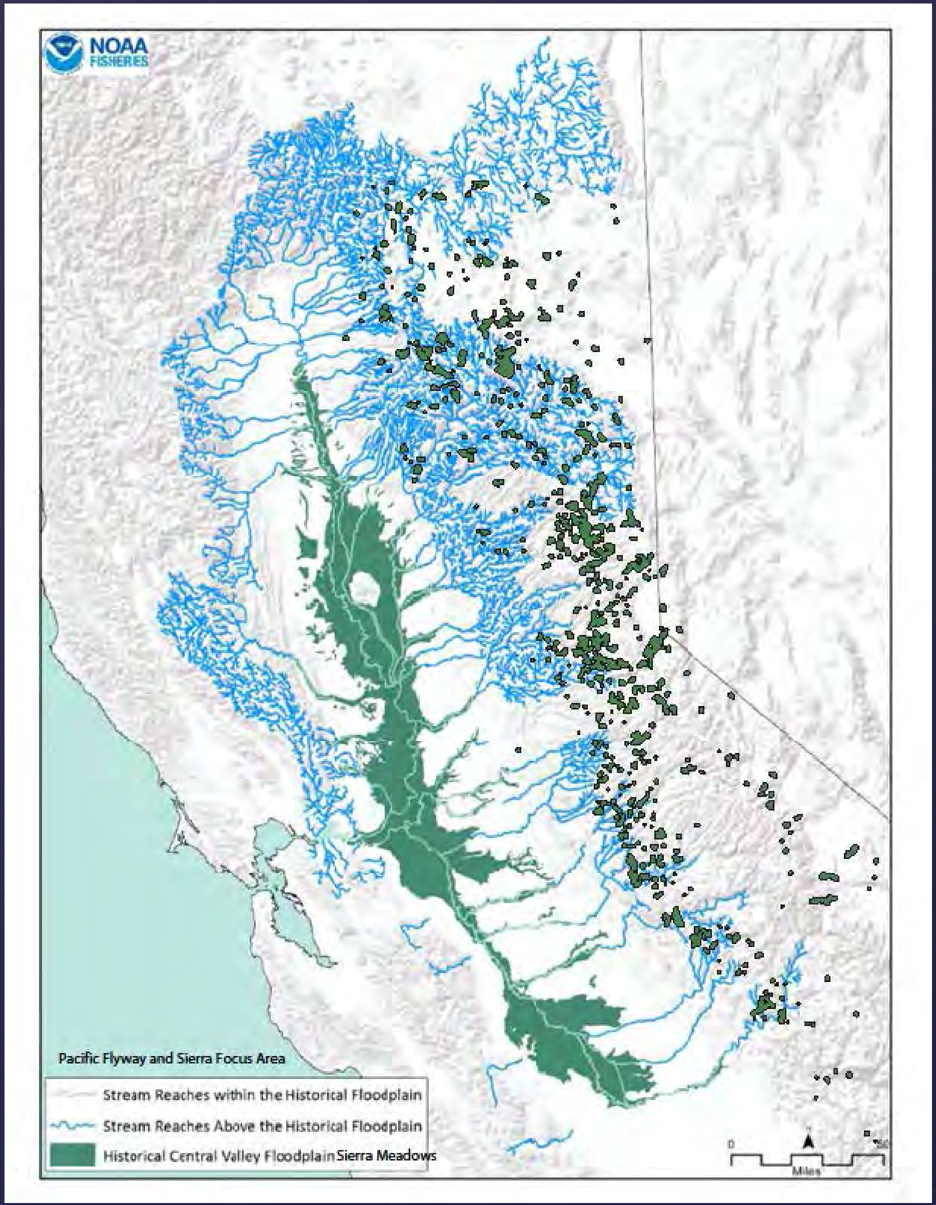
1. Work with ecosystem process to restore and maintain dynamic habitat

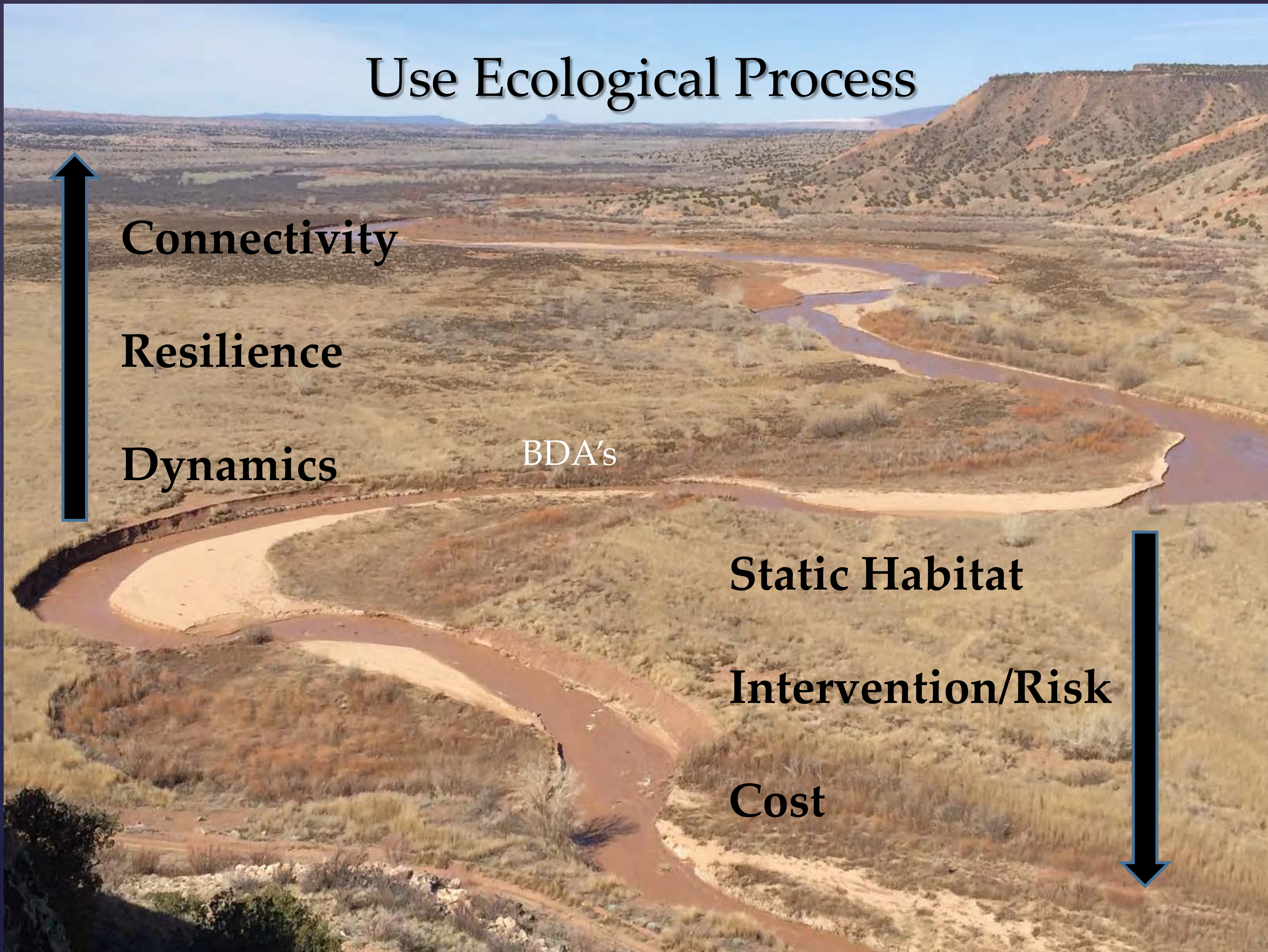
2. Build strong working relationships with private landowners, Native American Tribes and other partners

# Sierra Floodplains and Meadows




Cluer and Thorne, 2013




Use Ecological Process
Connectivity
Resilience
Dynamics
BDA's
Static Habitat
Intervention/Risk
Cost

# Design Objectives

<u>Habitat Diversity</u>
- Channel mobility
- Patch dynamics/disturbance
- Increase floodplain and channel interaction (deposition/erosion)
- Groundwater recharge
- Bar development
- Wood/bio complexes
- Channel length

<u>Socio Economic and Infrastructure</u>
- Define channel zones
- Limit channel migration
- Grade control
- Channel stability
- Manage erosive force
- Manage water surface elevation

# Objectives:

Successional change to →

- Wetter meadow conditions
- Stage 0 anastomosing channels

# Stream Migration Zone, Erodible Corridor and Process Based Restoration

# Channel Mobility Design Criteria

Stream Migration Zone (SMZ) – An area over which the stream has migrated through history

Erodible Corridor (EC) – An area, defined by land managers, through which the channel can migrate without interference from infrastructure or bank protection, can be as large as the SMZ but typically smaller

**Pre Anthropogenic Influence**

$$SMZ = EC$$

**Post Anthropogenic Influence**

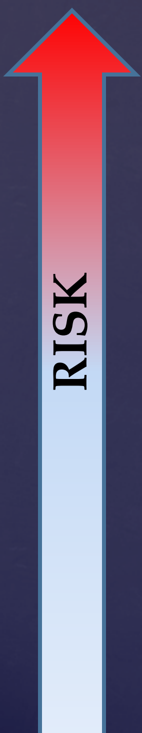
$$EC_i \ll SMZ$$

**Process Based Restoration Criteria**

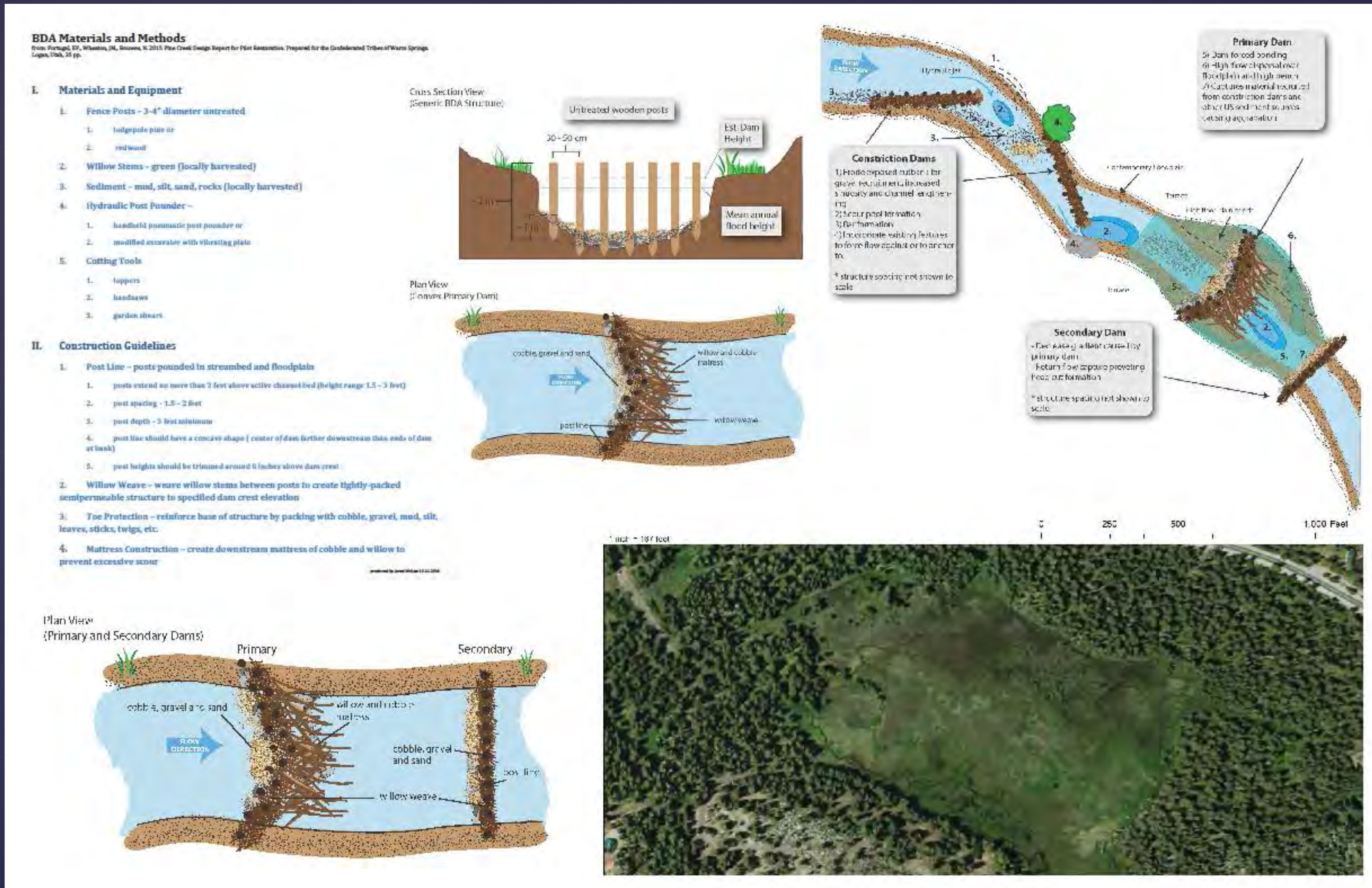
$$EC_f > ECi \quad \text{or} \quad \frac{EC_f}{EC_i} > 1$$

$SMZ$ = Stream Migration Zone
$EC$ = Erodible Corridor
$EC_i$ = Initial Erodible Corridor
$EC_f$ = Final Erodible Corridor

# Maximum Restoration with Minimum Intervention




| Practice | Adaptability | Cost | Disturbance |
|---|---|---|---|
| Engineered Restoration<br>Channel/Floodplain Construction<br>(Promotes stability) | Low | High | High |
| Erodible Corridor Management<br>Culverts, levees etc..<br>(Promotes dynamics) | Medium | High | Medium |
| BDA's<br>(Promotes dynamics) | High | Low | Low |
| Restore Riparian Function<br>(Promotes dynamics) | Low | Low | Low |



**BDA Materials and Methods**

from: Portugal, EP., Wheaton, JM., Bouwes, N. 2015. Pine Creek Design Report for Pilot Restoration. Prepared for the Confederated Tribes of Warm Springs. Logan, Utah, 35 pp.

I. **Materials and Equipment**

1. Fence Posts – 3-4" diameter untreated
   1. lodgepole pine or
   2. redwood
2. Willow Stems - green (locally harvested)
3. Sediment – mud, silt, sand, rocks (locally harvested)
4. Hydraulic Post Pounder –
   1. handheld pneumatic post pounder or
   2. modified excavator with vibrating plate
5. Cutting Tools
   1. loppers
   2. handsaws
   3. garden shears

II. **Construction Guidelines**

1. Post Line – posts pounded in streambed and floodplain
   1. posts extend no more than 3 feet above active channel bed (height range 1.5 – 3 feet)
   2. post spacing - 1.5 - 2 feet
   3. post depth - 3 feet minimum
   4. post line should have a concave shape ( center of dam farther downstream than ends of dam at bank)
   5. post heights should be trimmed around 6 inches above dam crest
2. Willow Weave – weave willow stems between posts to create tightly-packed semipermeable structure to specified dam crest elevation
3. Toe Protection – reinforce base of structure by packing with cobble, gravel, mud, silt, leaves, sticks, twigs, etc.
4. Mattress Construction – create downstream mattress of cobble and willow to prevent excessive scour

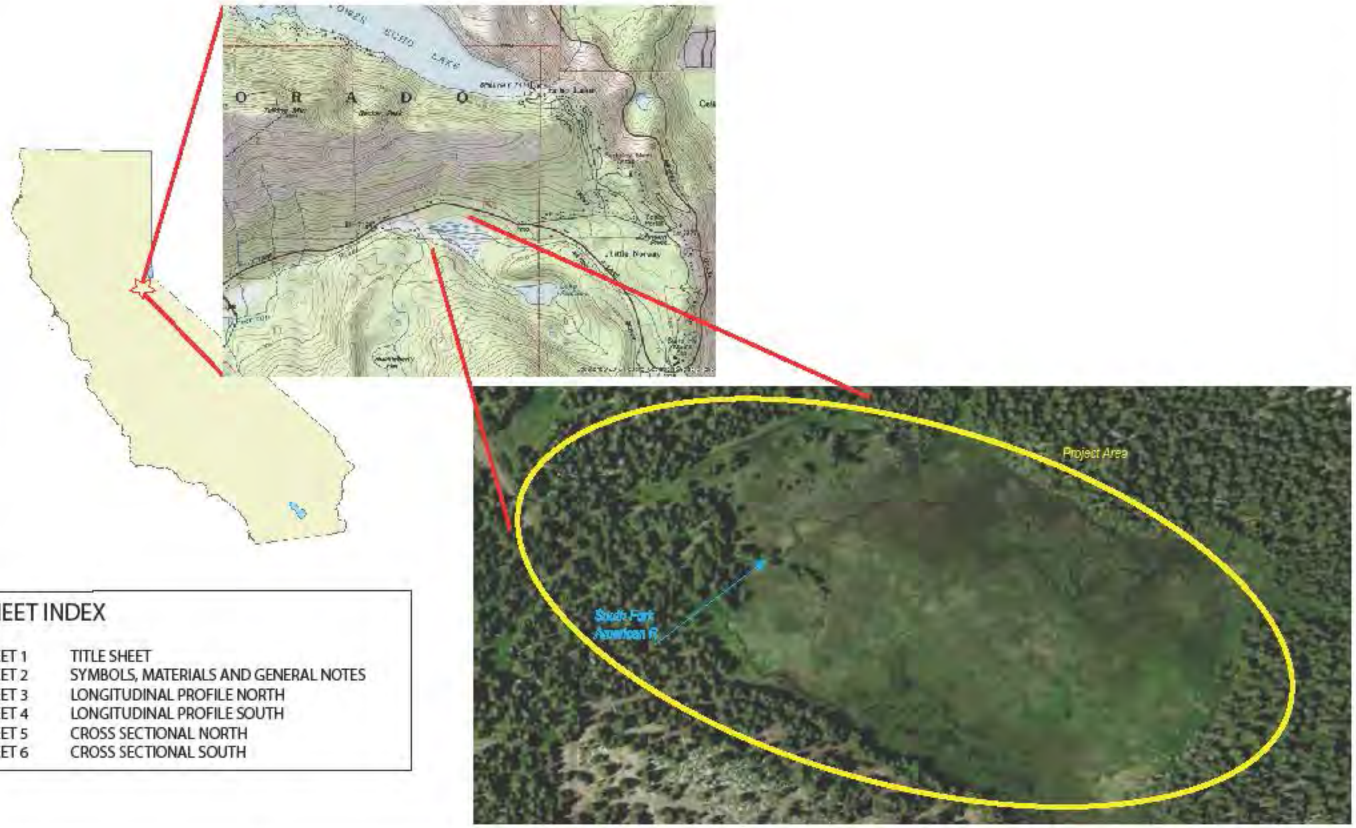


adapted from Portugal, EP., Wheaton, JM., Bouwes, N. 2015. Pine Creek Design Report for Pilot Restoration. Prepared for the Confederated Tribes of Warm Springs. Logan, Utah, 35pp.

DRAFT

# Audrain Meadow Habitat Restoration

El Dorado County, California




SHEET INDEX

| | |
|---|---|
| SHEET 1 | TITLE SHEET |
| SHEET 2 | SYMBOLS, MATERIALS AND GENERAL NOTES |
| SHEET 3 | LONGITUDINAL PROFILE NORTH |
| SHEET 4 | LONGITUDINAL PROFILE SOUTH |
| SHEET 5 | CROSS SECTIONAL NORTH |
| SHEET 6 | CROSS SECTIONAL SOUTH |

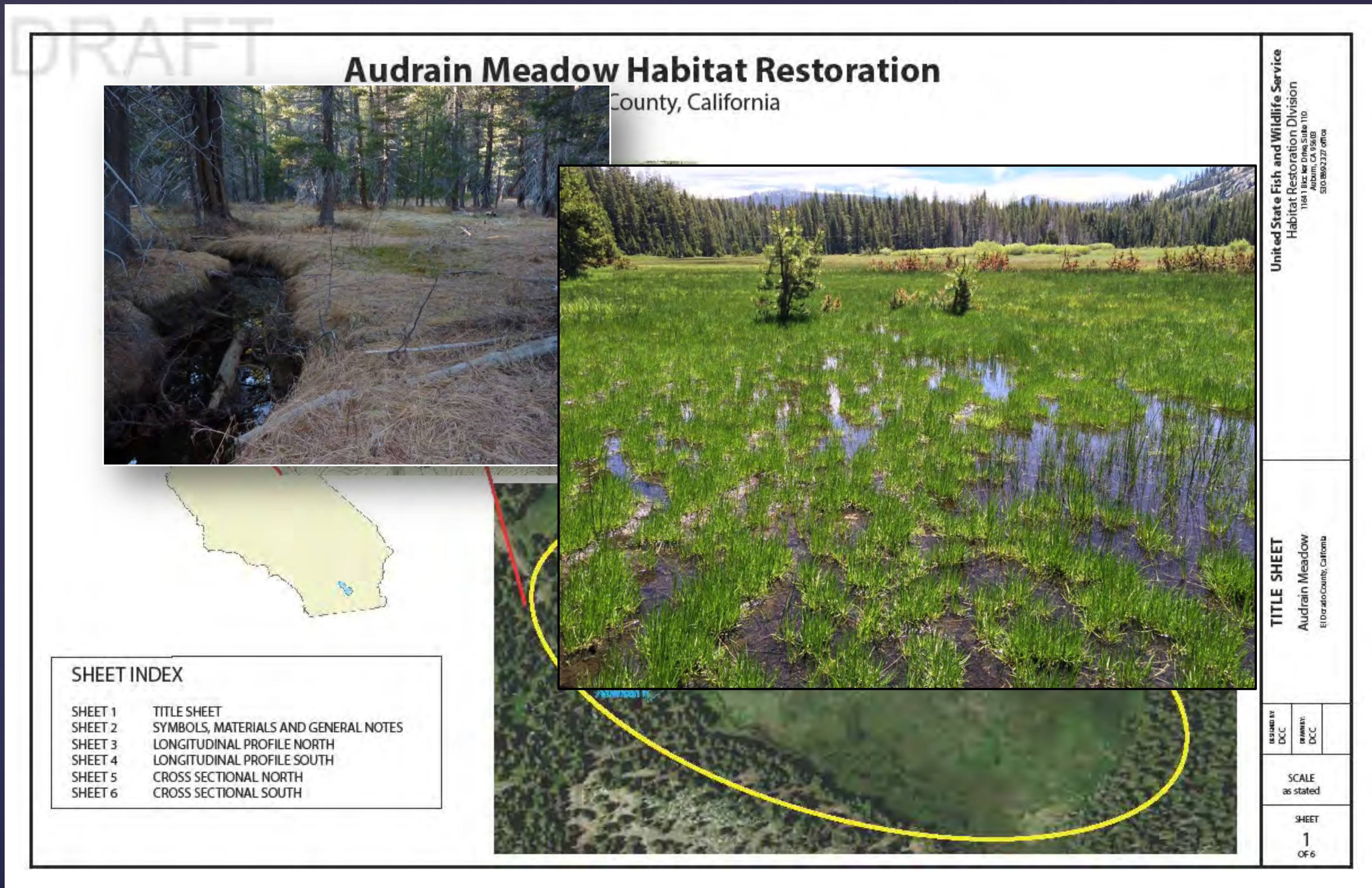
United State Fish and Wildlife Service
Habitat Restoration Division
11641 Blocker Drive, Suite 110
Auburn, CA 95603
530 889 2327 office

TITLE SHEET
Audrain Meadow
El Dorado County, California

DESIGNED BY: DCC
DRAWN BY: DCC

SCALE
as stated

SHEET
1
OF 6


DRAFT
Audrain Meadow Habitat Restoration
County, California
SHEET INDEX
SHEET 1 TITLE SHEET
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TITLE SHEET
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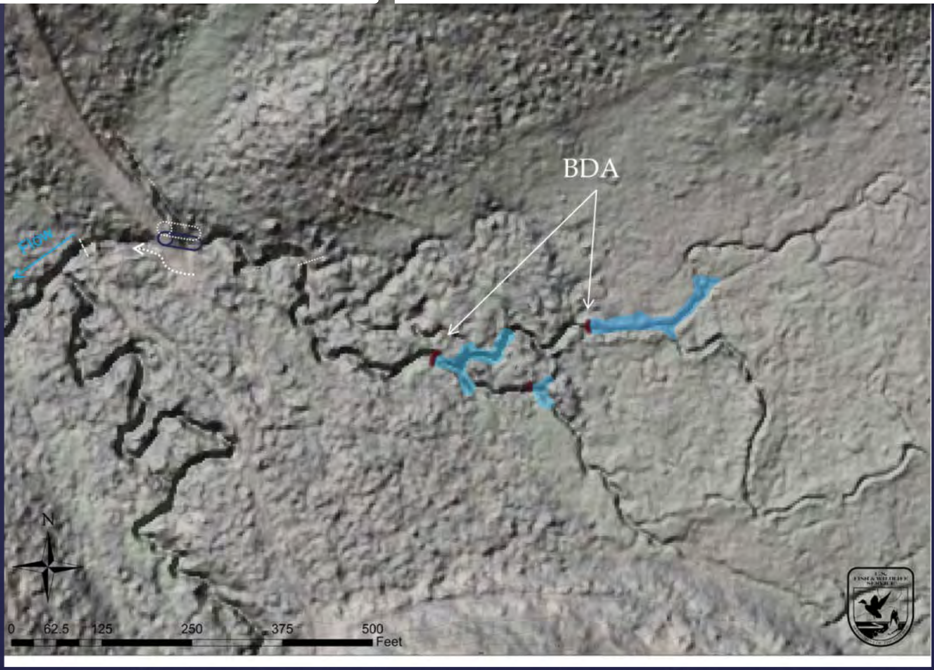
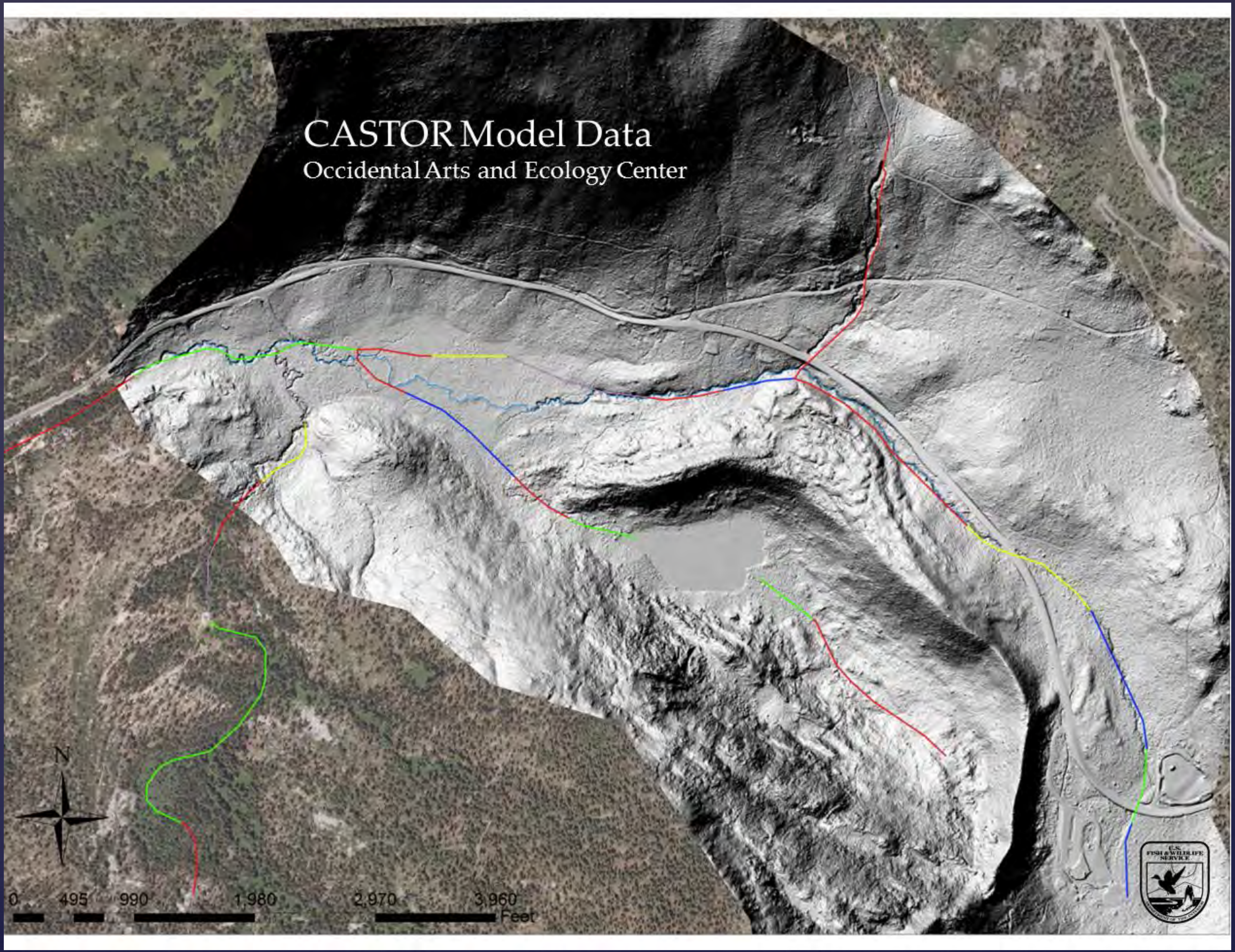
SHEET
1
OF 6


Pre Project Audrain Meadow peat soils eroding July 2016


BDA
Flow
N
0
62.5
125
250
375
500
Feet

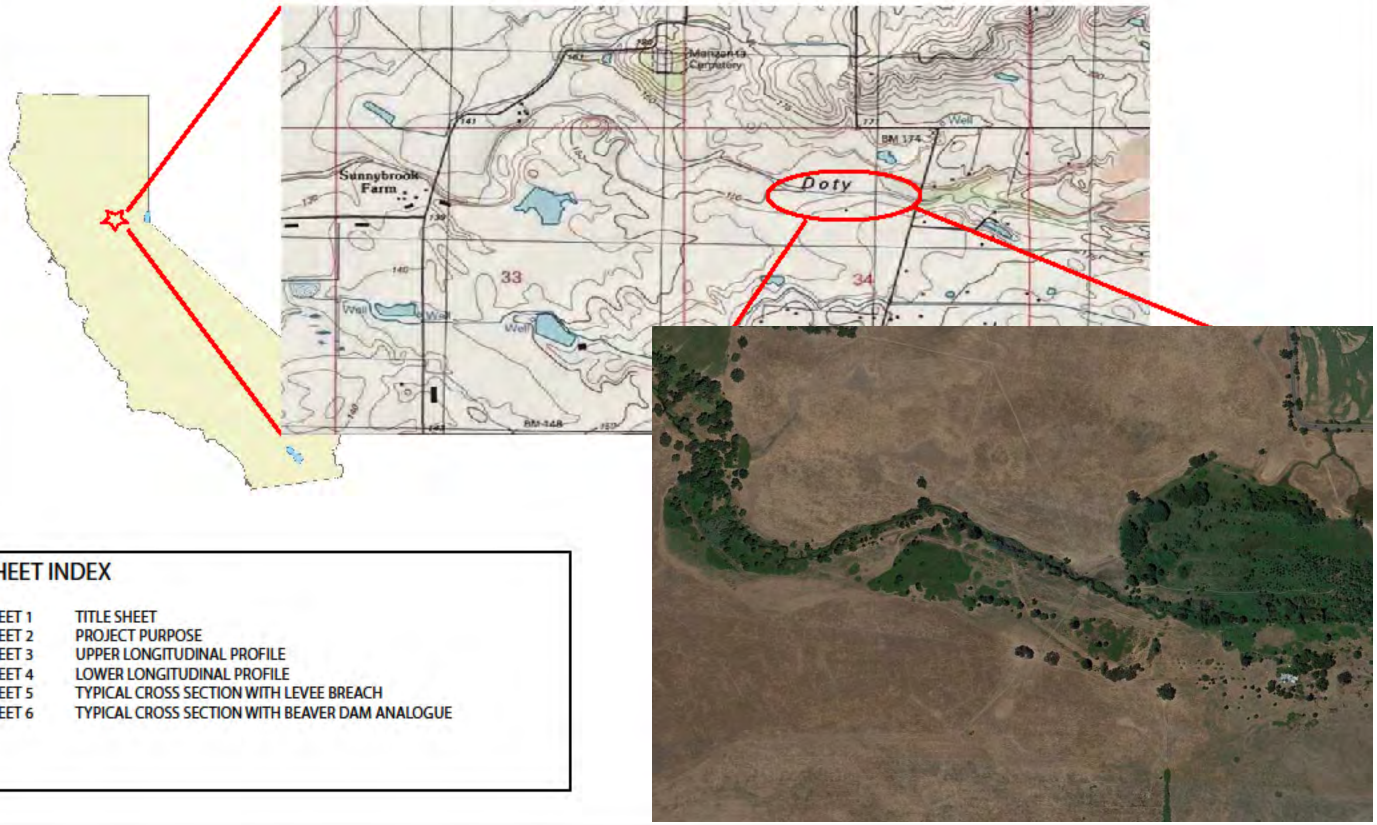


CASTOR Model Data
Occidental Arts and Ecology Center
N
0 495 990 1,980 2,970 3,960
Feet

# Doty Ravine Floodplain Reconnection

## Placer Land Trust Reserve

Placer County, California




### SHEET INDEX

| | |
|---|---|
| SHEET 1 | TITLE SHEET |
| SHEET 2 | PROJECT PURPOSE |
| SHEET 3 | UPPER LONGITUDINAL PROFILE |
| SHEET 4 | LOWER LONGITUDINAL PROFILE |
| SHEET 5 | TYPICAL CROSS SECTION WITH LEVEE BREACH |
| SHEET 6 | TYPICAL CROSS SECTION WITH BEAVER DAM ANALOGUE |

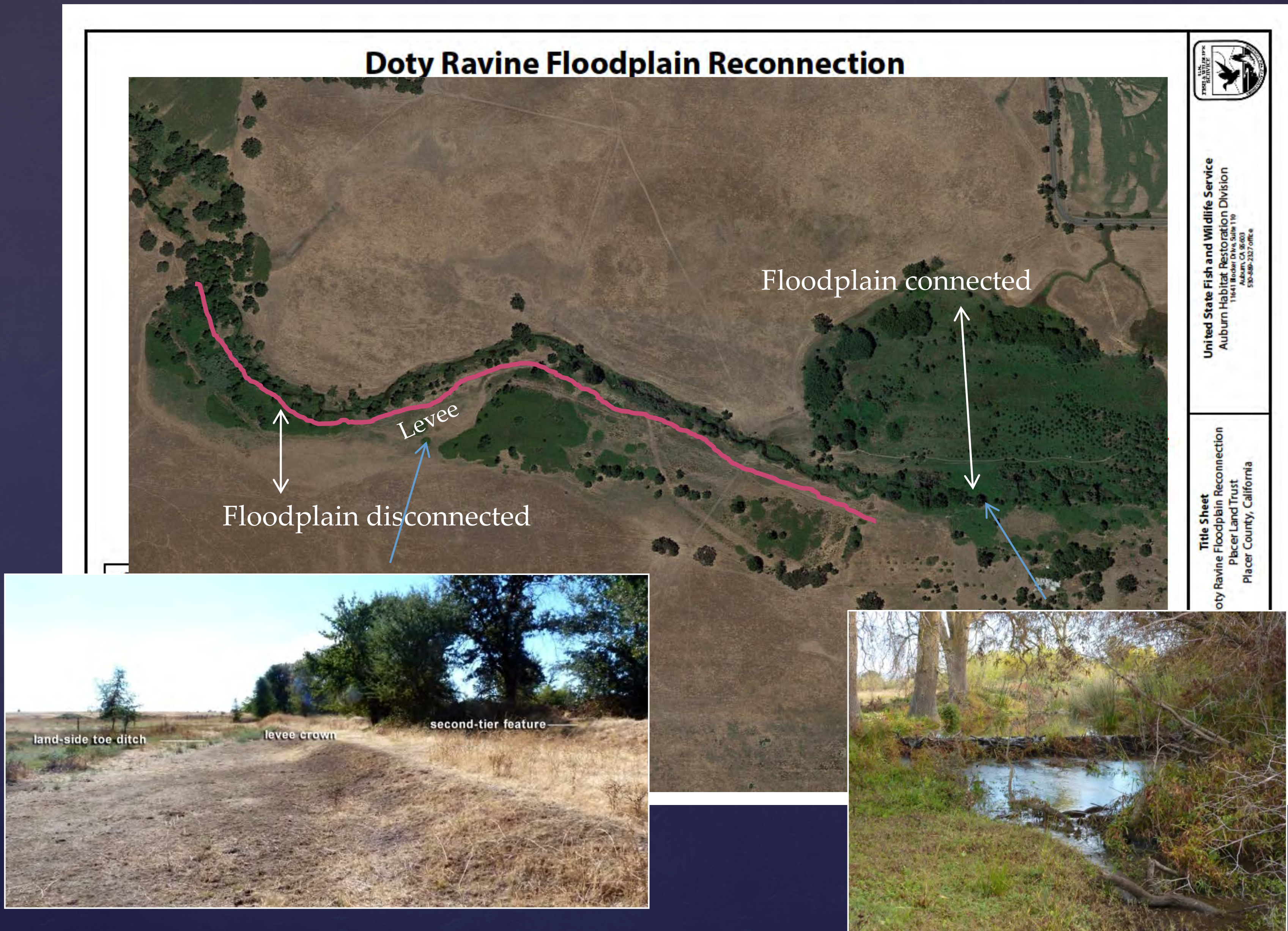

**United State Fish and Wildlife Service**
Auburn Habitat Restoration Division
11641 Blocker Drive, Suite 110
Auburn, CA 95603
530-889-2327 office


**Title Sheet**
Doty Ravine Floodplain Reconnection
Placer Land Trust
Placer County, California

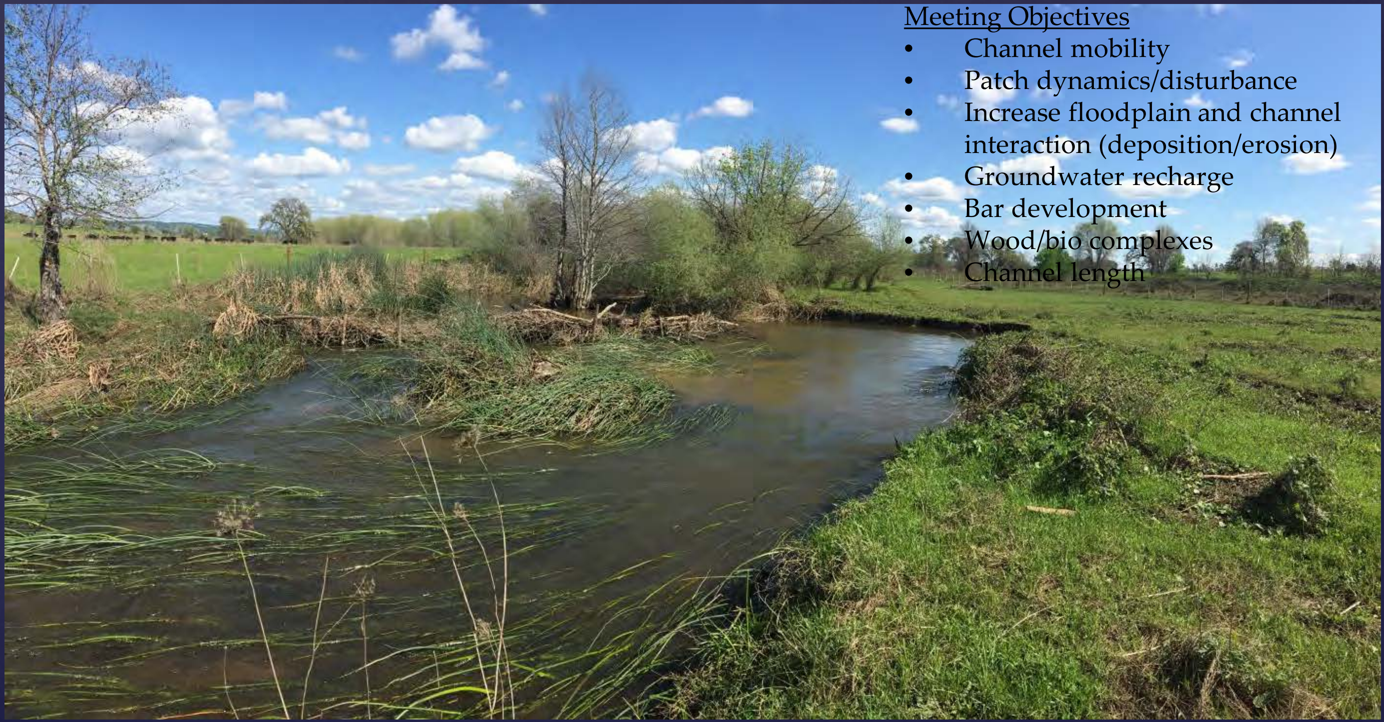
DCC
DCC

SCALE
as stated

SHEET
1
OF 6


Doty Ravine Floodplain Reconnection
Floodplain connected
Levee
Floodplain disconnected
United State Fish and Wildlife Service
Auburn Habitat Restoration Division
11641 Blocker Drive, Suite 110
Auburn, CA 95603
530-889-2327 office
Title Sheet
oty Ravine Floodplain Reconnection
Placer Land Trust
Placer County, California
land-side toe ditch
levee crown
second-tier feature

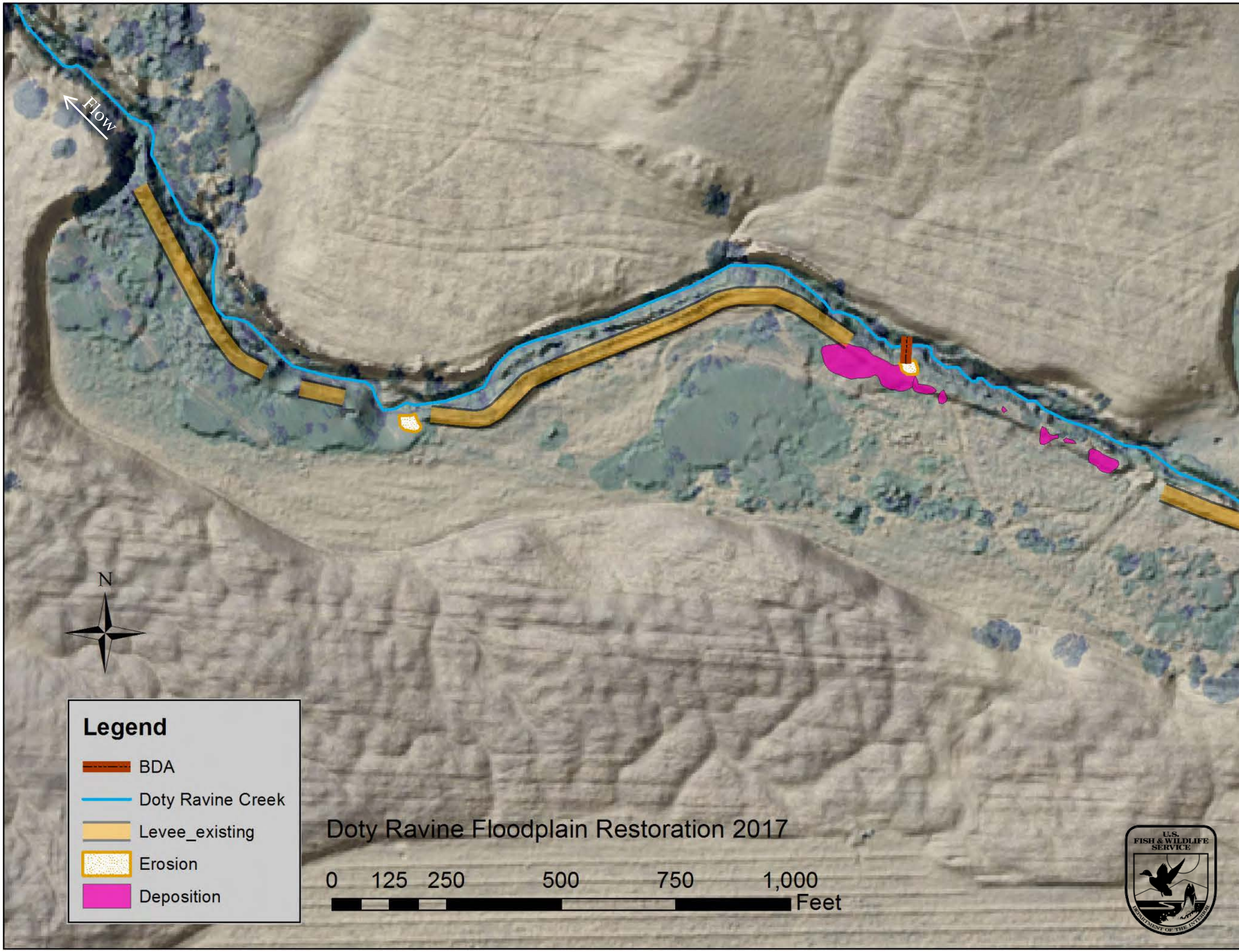

Add water



Meeting Objectives

- Channel mobility
- Patch dynamics/disturbance
- Increase floodplain and channel interaction (deposition/erosion)
- Groundwater recharge
- Bar development
- Wood/bio complexes
- Channel length

# Deposition and Erosion


Flow
N
Legend
BDA
Doty Ravine Creek
Levee_existing
Erosion
Deposition
Doty Ravine Floodplain Restoration 2017
0 125 250 500 750 1,000
Feet
U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

Riparian Management Corridor smaller than the Erodible Corridor?

Cattle in the chaos

## Beaver Restoration

- Important tool for process based approach
- Level of risk tends to be lower than standard channel manipulation
- Should be accompanied with:
    1. Opening floodplain
    2. Modifying infrastructure to tolerate more dynamic system
    3. Riparian management
    4. Integrate land use with long range site change

U.S. Fish and Wildlife Service
Partners Program
damion_ciotti@fws.gov


Low Response Stream
High Impact Project
Full Review
High Response Stream
High Impact Project
Deep Review
Medium Response Stream
Medium Impact Project
Full Review
Low Response Stream
Low Impact Project
Light Touch Review
High Response Stream
Low Impact Project
Full Review
Increasing Project Impact Potential
Increasing Stream and Site Response Potential
Project Screening Matrix