Incised Stream Channels: Causes and Environmental Impacts, and Practical Restoration Solutions

A Conference Session at the 34th Annual Salmonid Restoration Conference held in Fortuna, CA from April 6-9, 2016.

Session Overview

- Session Coordinators:
  - Thomas H. Leroy, Pacific Watershed Associates
  - John Green, Gold Ridge Resource Conservation District

Incised stream channels are something most environmental restorationists encounter on a frequent if not regular basis. They have been known to form in most geomorphic environments from relatively flat meadows to steep mountain streams. The environmental impacts from channel incision are as diverse as their causes but often they are observed as simplified channel geometry, disconnection of floodplains, and altered groundwater hydrology. For this session we are soliciting abstracts that address the causes, implications, and solutions to identified environmental impacts from incised channels. We are particularly interested in case studies that exhibit some of the challenges and successes related to identifying and mitigating causes of channel incision as well as site specific projects that provide other restoration practitioners with practical advice on identifying, characterizing, analyzing, and mitigating for the negative impacts of channel incision on their restoration project.

Presentations

(Slide 4) Stream Channel Incision and Coho Salmon Restoration in Coastal California
John Green, Project Manager, Gold Ridge Resource Conservation District

(Slide 30) A Stream Evolution Model for Incised Stream Channels
Brian L. Cluer, NOAA Fisheries-West Coast Region

(Slide 74) The Evolution and Restoration of Incised, Lower Order Stream Channels in Managed, Fish Bearing, Mountain Streams of North Coastal California
Thomas H. Leroy, Engineering Geologist, Pacific Watershed Associates

Morphologic Effects of Anthropocene Sediment Pulses on the South Fork Eel River of Northwestern California
Tim L. Bailey, Geology Department, Humboldt State University,
*presentation not included

(Slide 99) Using Biogenic Structures to Restore Complexity to Incised Streams
Michael M. Pollock, Ph.D., NOAA Fisheries-Northwest Fisheries Science Center

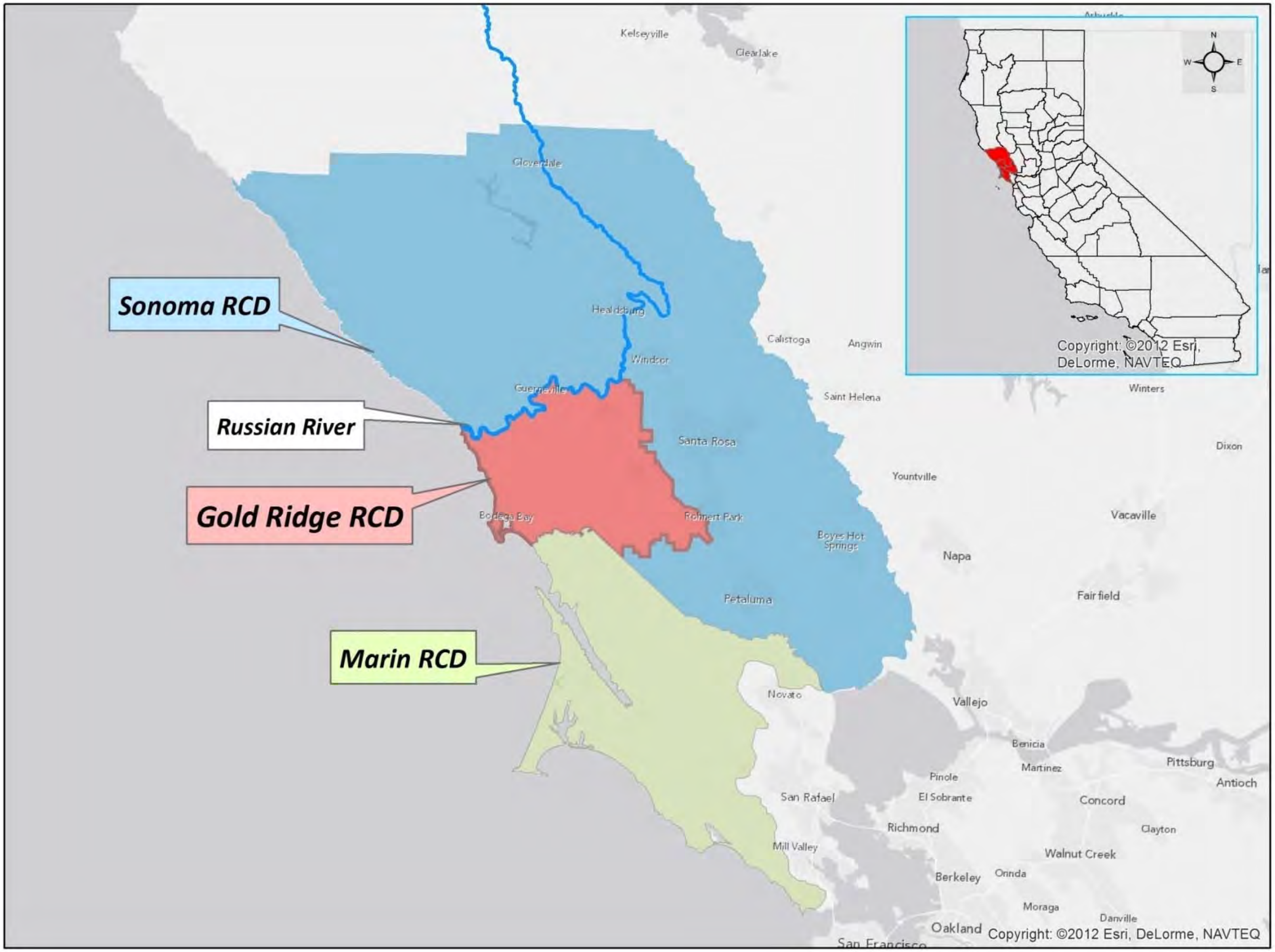
(Slide 142) Addressing Channel Incision in the Mattole River Headwaters – It Takes a Valley
Sam Flanagan, Bureau of Land Management

Stream channel incision and salmonid restoration in coastal California

John Green, Lead Scientist
Gold Ridge Resource Conservation District
www.goldridgercd.org
March 2016

Stream channel incision

- Description
- Geomorphology and hydrology
- Causes
- Impacts on salmonids
- Addressing incision


Sonoma RCD
Russian River
Gold Ridge RCD
Marin RCD
Kelseyville
Clearlake
Cloverdale
Healdsburg
Windsor
Guerneville
Calistoga
Angwin
Saint Helena
Santa Rosa
Bodega Bay
Rohnert Park
Yountville
Boyes Hot Springs
Napa
Petaluma
Winters
Dixon
Vacaville
Fairfield
Novato
Vallejo
Benicia
Martinez
Pittsburg
Antioch
Pinole
El Sobrante
San Rafael
Concord
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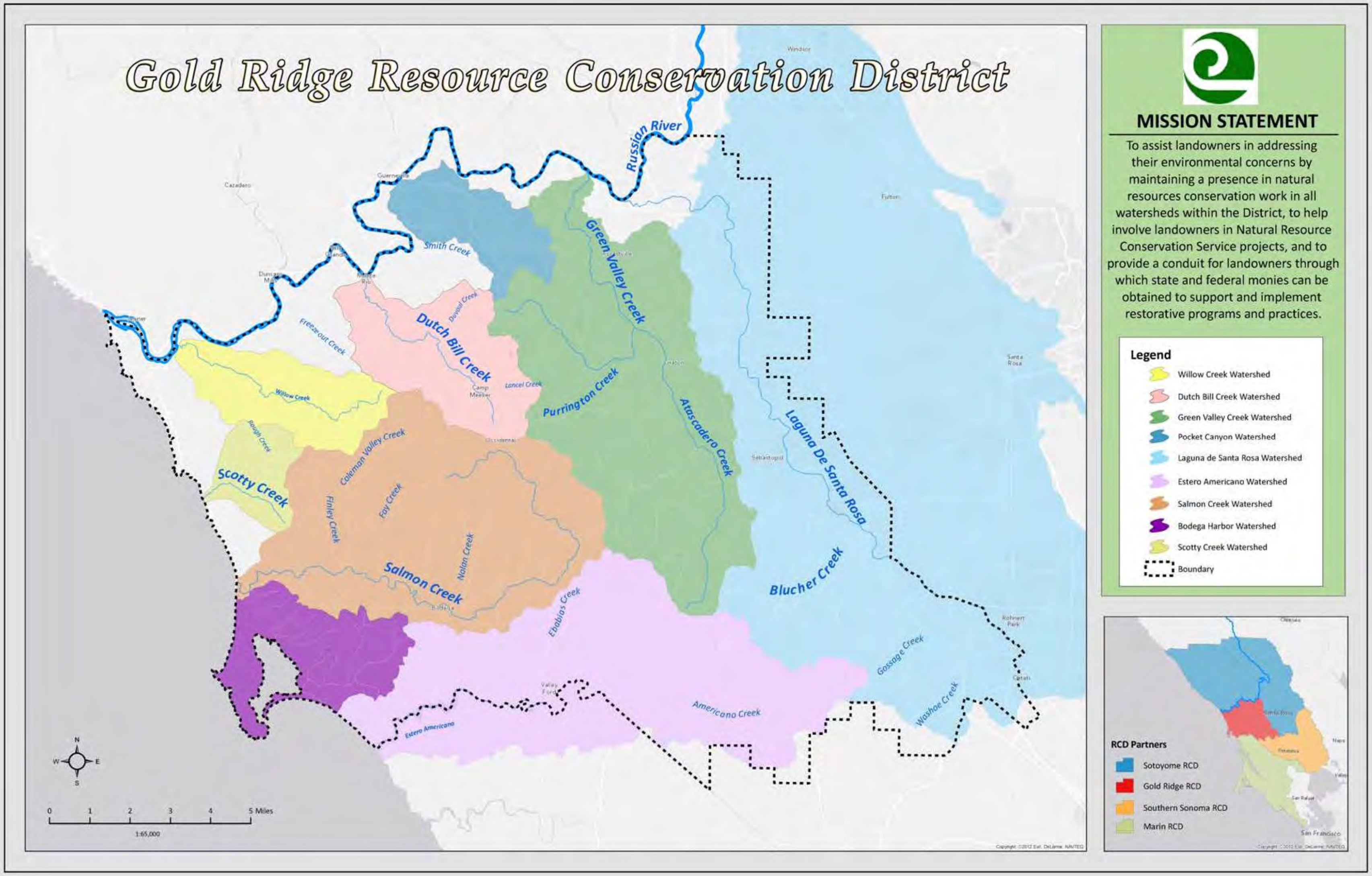
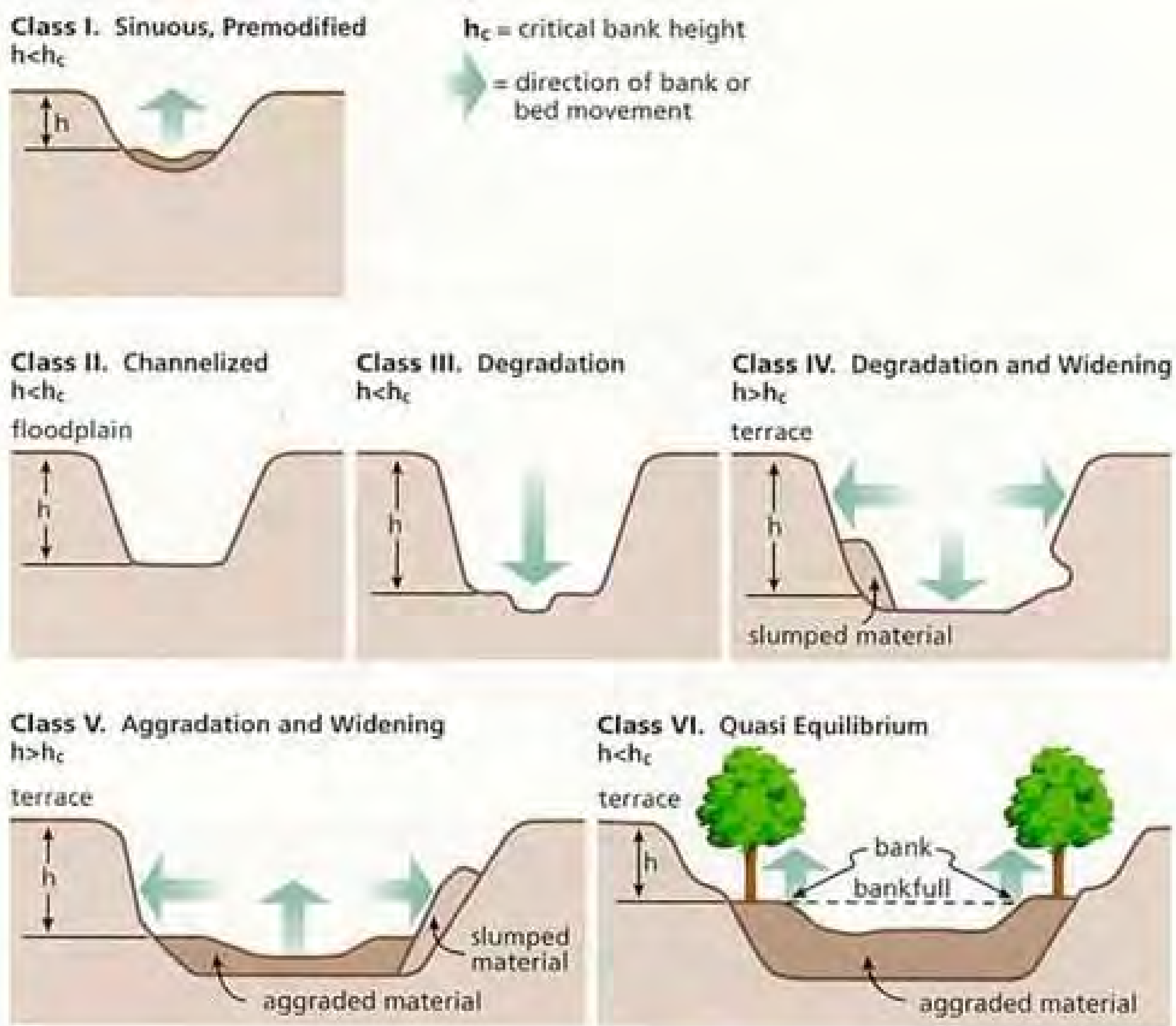
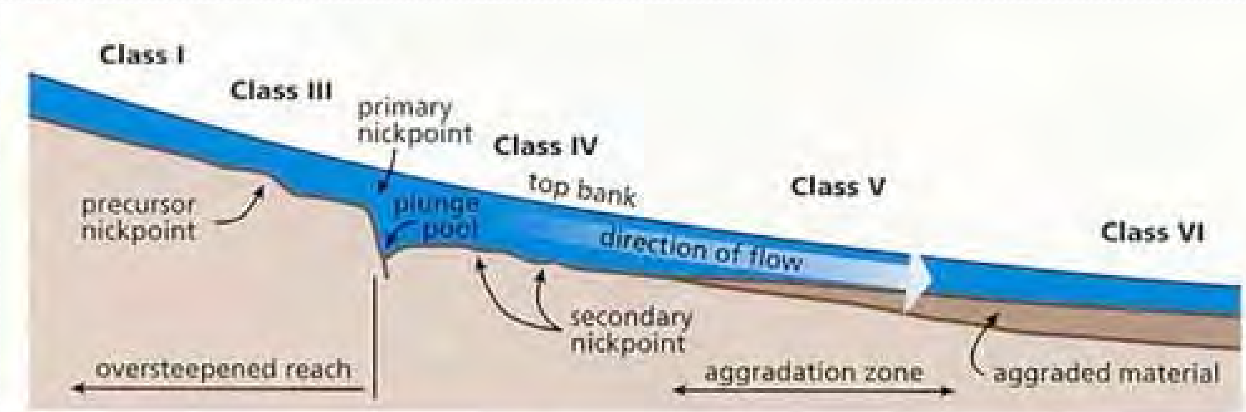
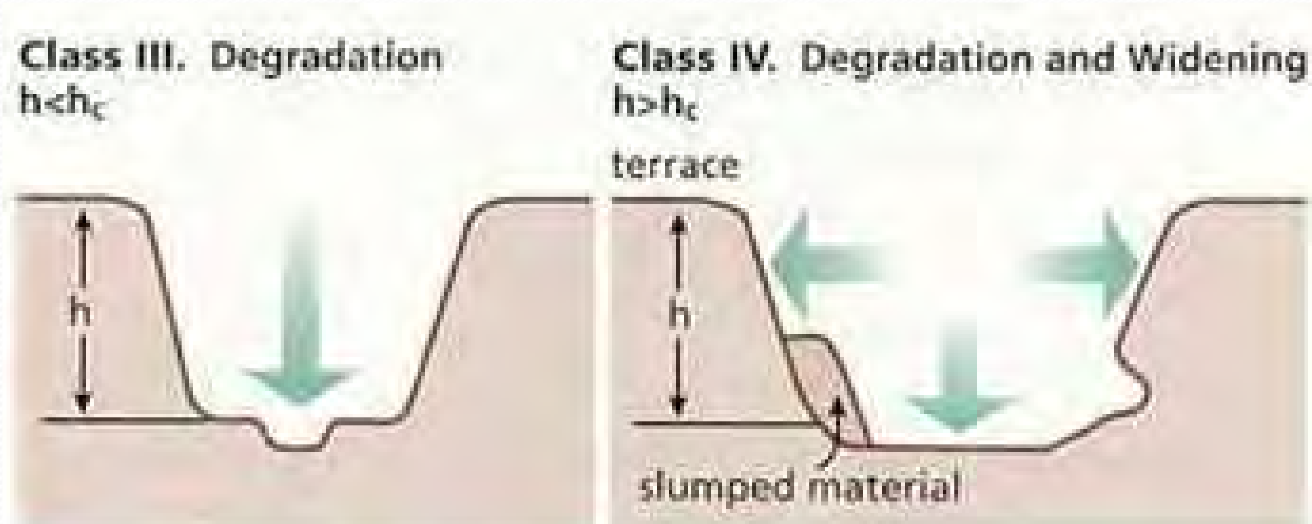

Gold Ridge Resource Conservation District
MISSION STATEMENT
To assist landowners in addressing their environmental concerns by maintaining a presence in natural resources conservation work in all watersheds within the District, to help involve landowners in Natural Resource Conservation Service projects, and to provide a conduit for landowners through which state and federal monies can be obtained to support and implement restorative programs and practices.
Legend
Willow Creek Watershed
Dutch Bill Creek Watershed
Green Valley Creek Watershed
Pocket Canyon Watershed
Laguna de Santa Rosa Watershed
Estero Americano Watershed
Salmon Creek Watershed
Bodega Harbor Watershed
Scotty Creek Watershed
Boundary
RCD Partners
Sotoyome RCD
Gold Ridge RCD
Southern Sonoma RCD
Marin RCD
Russian River
Smith Creek
Green Valley Creek
Dutch Bill Creek
Purrington Creek
Atascadero Creek
Laguna De Santa Rosa
Blucher Creek
Willow Creek
Scotty Creek
Coleman Valley Creek
Finley Creek
Fay Creek
Nolan Creek
Salmon Creek
Ebabias Creek
Americano Creek
Estero Americano
Gossage Creek
Washoe Creek
0 1 2 3 4 5 Miles
1:65,000



Simon and Rinaldi, 2006



Simon and Rinaldi, 2006



Class III. Degradation
h<hc
h
Class IV. Degradation and Widening
h>hc
terrace
h
slumped material

Incised stream channel:
Green Valley Creek

Incised stream channel:
Green Valley Creek

- Incised up to 25 feet
- Several miles of stream

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- Disconnected floodplain

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- Several miles of stream
- Disconnected floodplain
- Loss of aquifer function
- Low summer streamflows

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- Bank erosion and mass failure

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- Embedded gravels

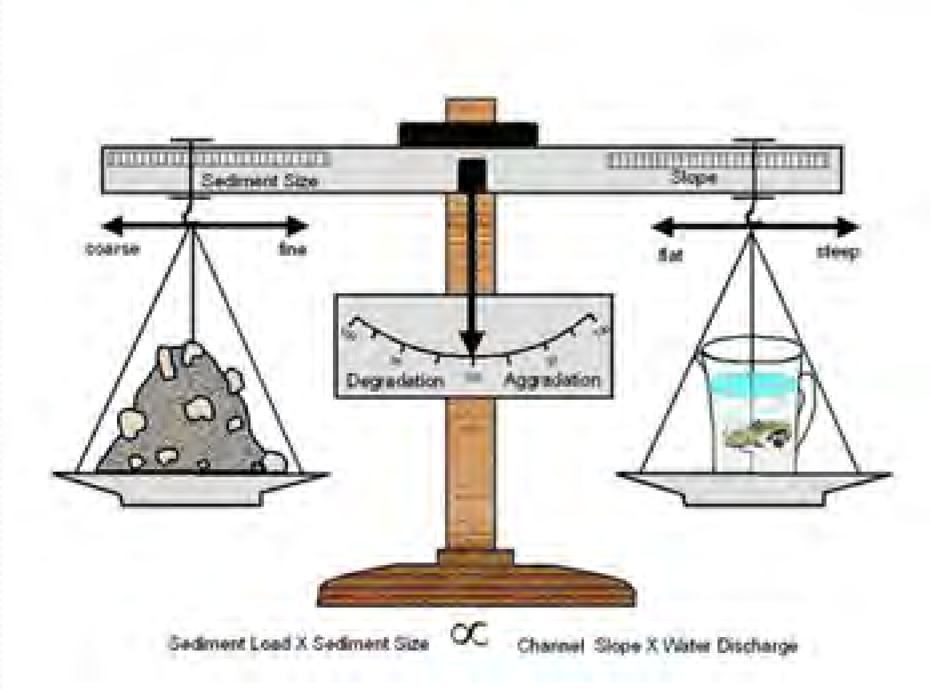
Incised stream channel:
Green Valley Creek

- Incised up to 25 feet
- Several miles of stream
- Disconnected floodplain
- Loss of aquifer function
- Low summer streamflows
- Bank erosion and mass failure
- Embedded gravels
- Unhappy restorationist

Incision is both a symptom and a cause

Results from:

- Change in base level
- Increased slope
- Increased runoff
- Decreased channel roughness
- Decreased sediment load



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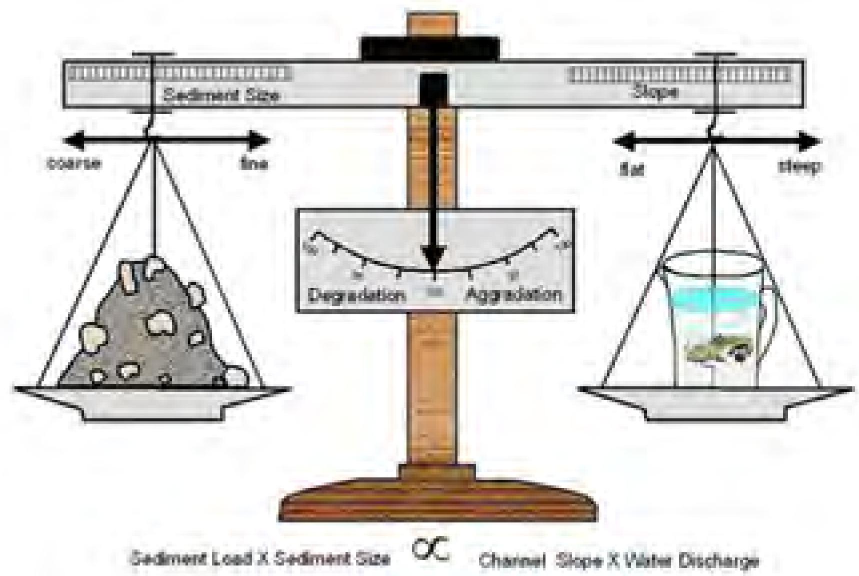


Increased runoff

- Land cover and use changes
- Decrease in permeability
- Extension of channel network

Decreased channel roughness

- Channelization
- "Stream cleaning"

Fish habitat impacts

Confinement of flow

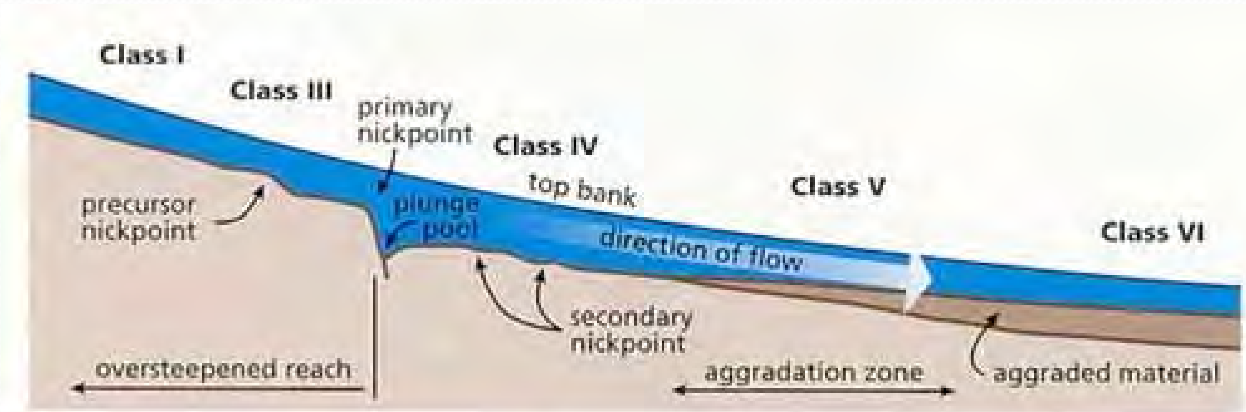
- More frequent gravel mobilization

Sedimentation

- Pool filling
- Gravel embeddedness

Impaired hydrology

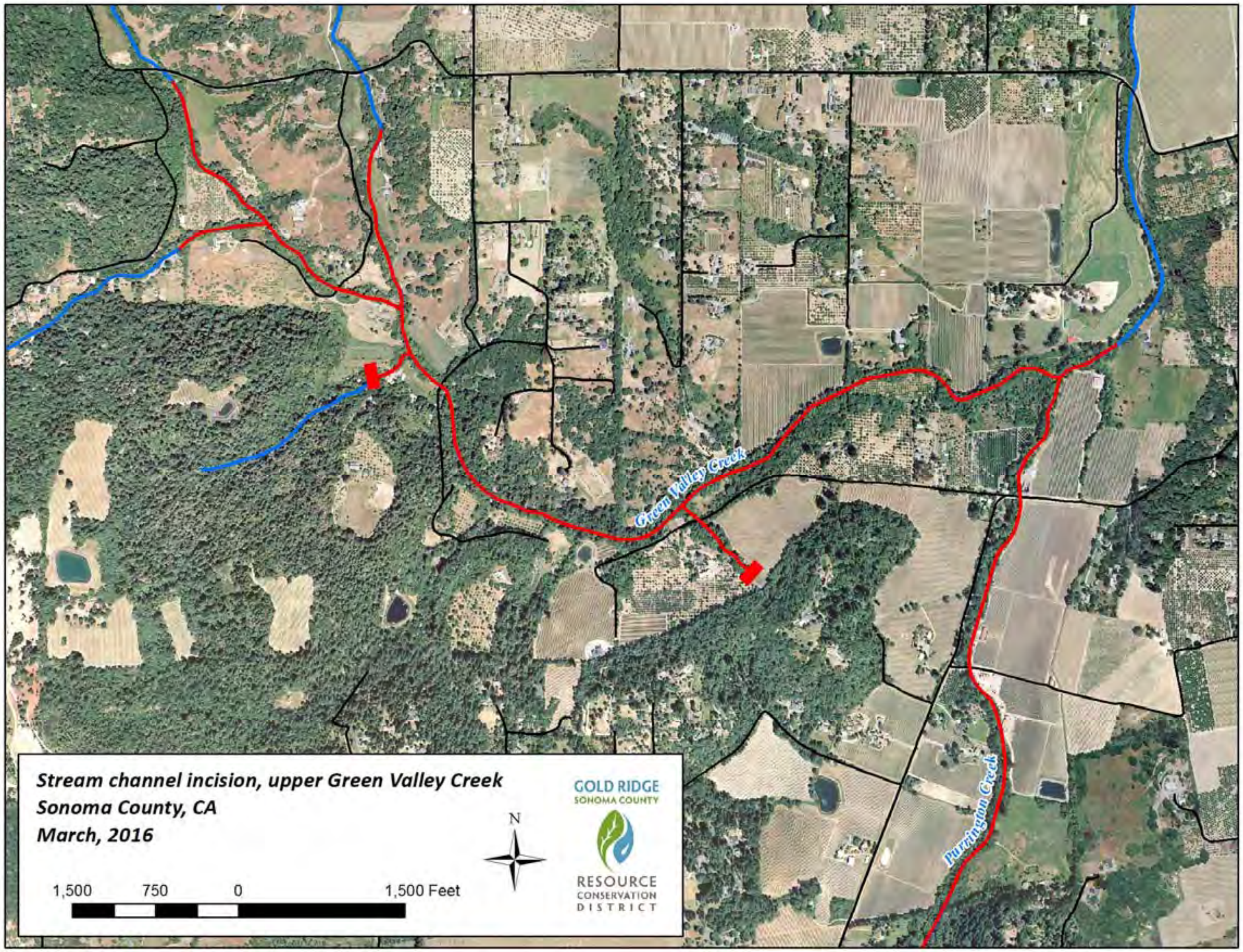
- Low summer streamflows



Simon and Rinaldi, 2006

Mainstem channel incision lowers base level

- Tributary incision
- Gully formation


Green Valley Creek
Purrington Creek
Stream channel incision, upper Green Valley Creek
Sonoma County, CA
March, 2016
1,500
750
0
1,500 Feet
N
GOLD RIDGE
SONOMA COUNTY
RESOURCE
CONSERVATION
DISTRICT

Addressing incision

Actions in the channel

- Control grade
- Raise streambed elevation
- Increase channel roughness

Addressing incision

Watershed actions

- Normalize hydrology:
  Improve road drainage and land surface permeability
- Runoff retention

The Stream Evolution Model and Incised Channel Restoration

Brian Cluer, NOAA-NMFS, West Coast Region – Santa Rosa CA

Check in; knowledge transfer and communication.

- How many biologists? Geomorphologists?   ????
- How many think climate change is a significant stressor facing salmonid populations?
- How many think incised channels dominate valleys?
- How many think the loss of historic habitat formerly in valleys is a significant stressor on salmonid populations?
- How many think incision of valleys is a much bigger problem than climate change?

- Outline:
  - SEM overview, linking habitat to geomorphic processes
  - Applying the SEM to your watershed
  - History of land & water development
    - Scale of impacts to habitat and ecosystem
  - Implications
    - Functional restoration, standard practices
  - Conclusions
    - Many stable forms, we have choices
  - Recommendations
  - Q and A

Geomorphic Context for Habitat

RIVER RESEARCH AND APPLICATIONS

River Res. Applic. (2013)

Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/rra.2631

A STREAM EVOLUTION MODEL INTEGRATING HABITAT AND ECOSYSTEM BENEFITS

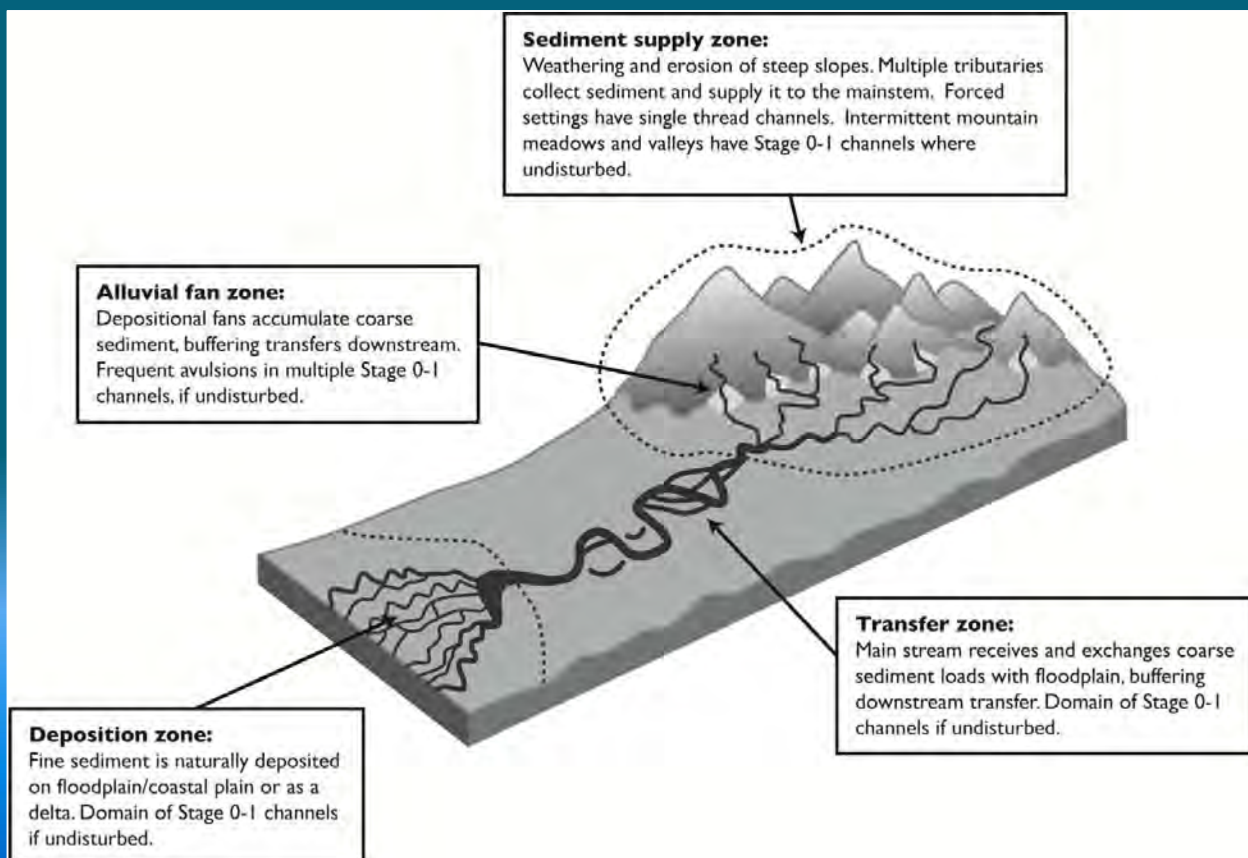
B. CLUER[a]* and C. THORNE[b]

[a] *Fluvial Geomorphologist, Southwest Region, NOAA's National Marine Fisheries Service, Santa Rosa, California, USA*
[b] *Chair of Physical Geography, University of Nottingham, Nottingham, UK*

- PART I Geomorphology
  - Channel pattern continuum:
  - Channel evolution models:
  - Stream Evolution Model:
- PART II Linkages:
  - Hydrogeomorphic attributes
  - Habitat and Ecosystem Benefits
- Management and Restoration Implications

SEM - basic idea is that there is a continuum of stream conditions across a watershed, and each condition is the result of the dominant physical processes driven by geology/hydrology/history.

Each condition is associated with characteristic habitat and ecosystem benefits.



SEM based on

1. **continuum of channel patterns, and**
2. **CEM concepts.**

Channel patterns reflect the processes that created them. There exists a continuum of patterns because there is a continuum of processes.

CONTINUUM

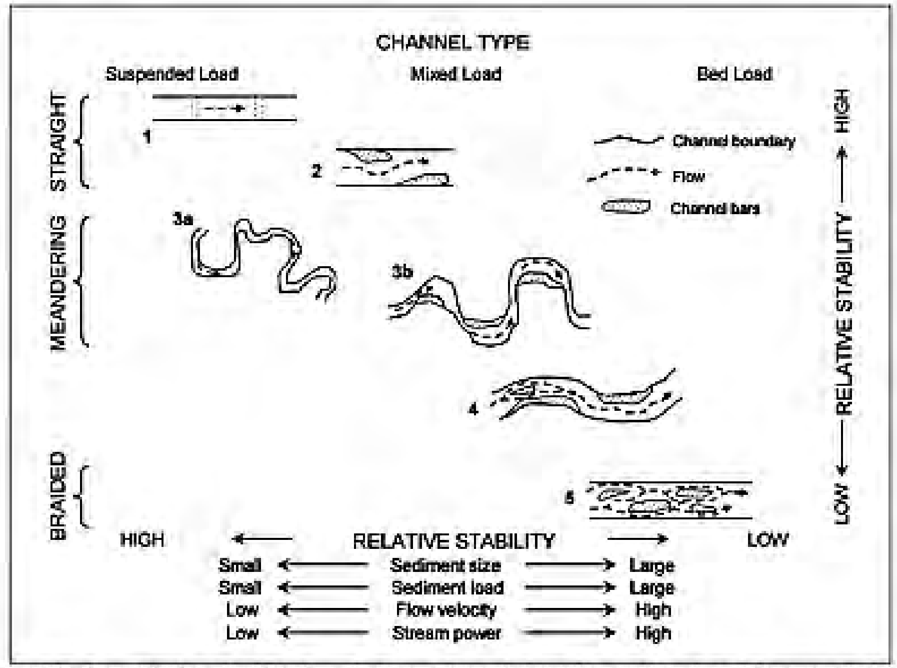
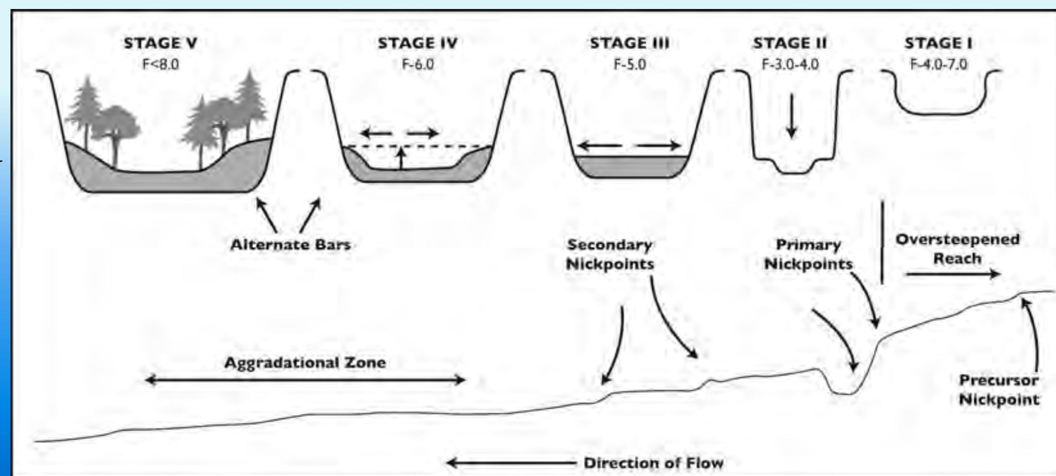
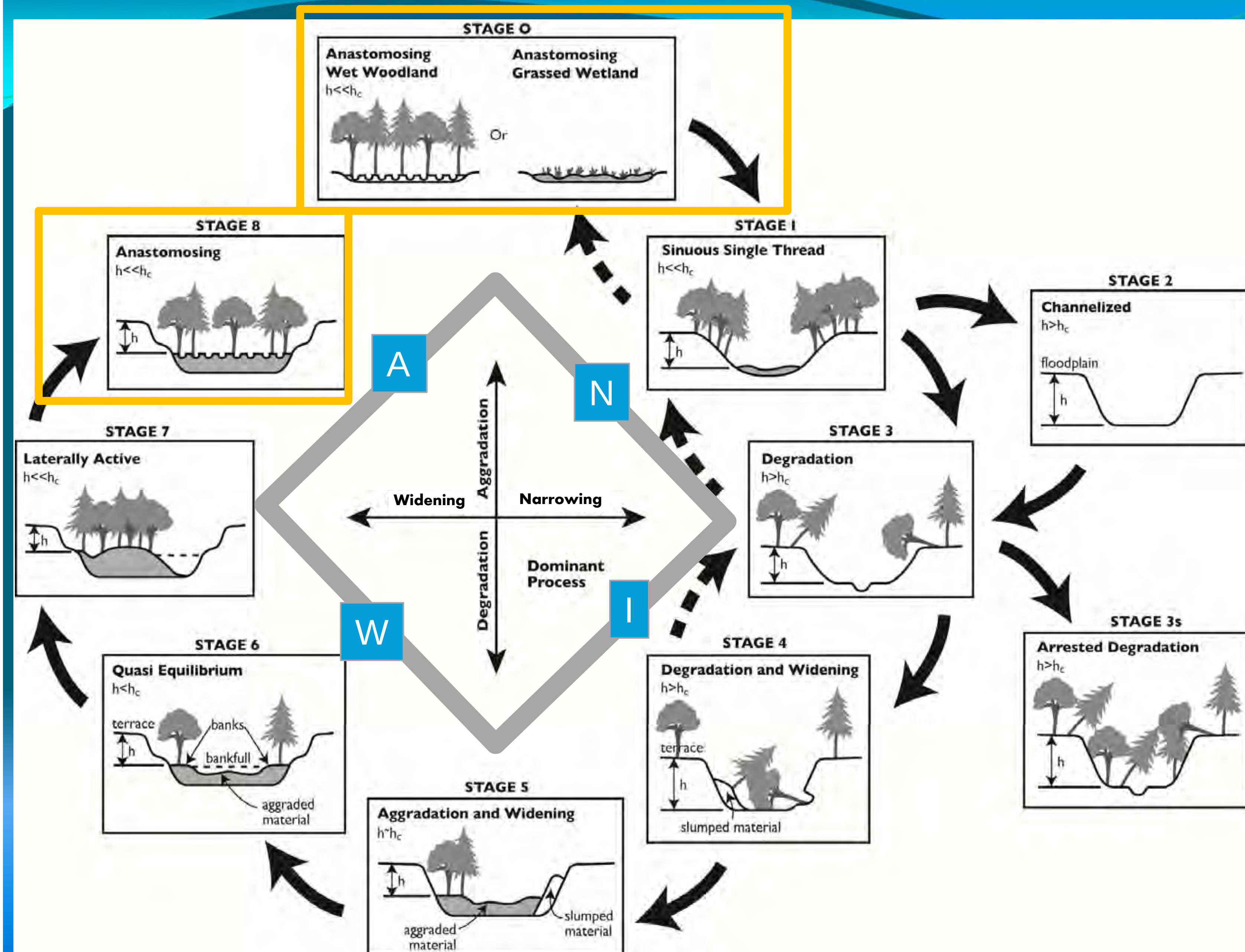


Figure 13. A qualitative classification of stream channels based on pattern (straight, meandering, or braided) and type of sediment load, along with flow and sediment variables and relative stability with regard to average erosional activity. From Schumm (1981).

CHANNEL EVOLUTION

Alluvial channels, when disturbed, evolve through stages dominated by erosion, widening, aggrading, and relaxation to meta-stability.

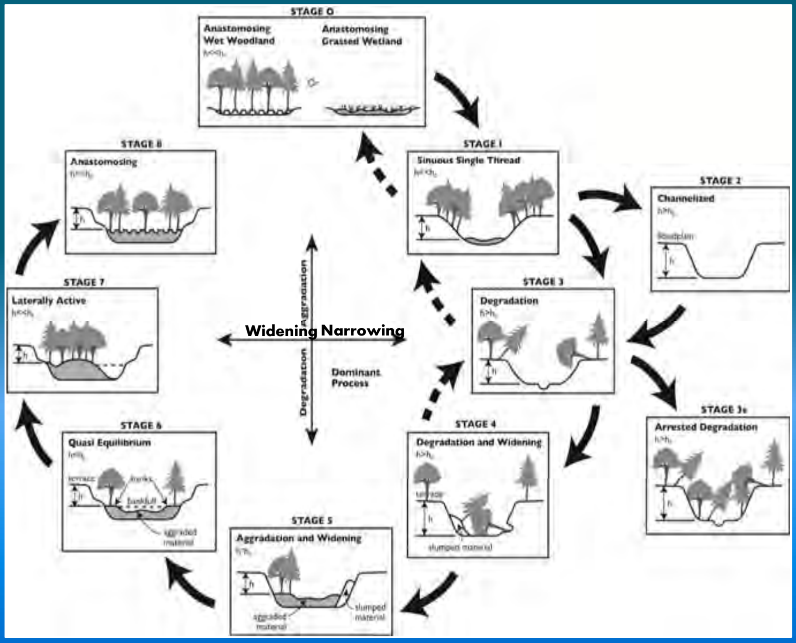




Multiple Paths
Dead Ends *

SEM highlights two ideas:

- Stream systems are not represented by their channel; there is a web of bio-geo process interactions upstream, across the valley and nearby hillslopes, and events in the past resulting in a dynamic stream corridor and a continuum of channel forms.
- There is no “start point” or “end point” to channel evolution.



Principles of functional ecology link habitat and ecosystem benefits to each SEM Stage.

- Stream morphology interacts with flow and sediment regimes, channel boundary characteristics, and water quality to produce, maintain and renew habitat.
- The potential for a stream to support resilient and diverse ecosystems increases with 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

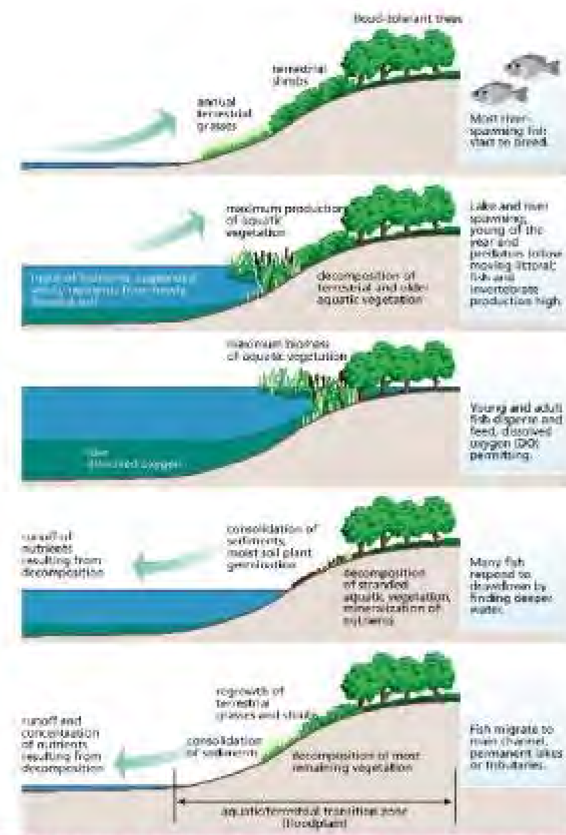
Physical Attributes

Hydrologic regime

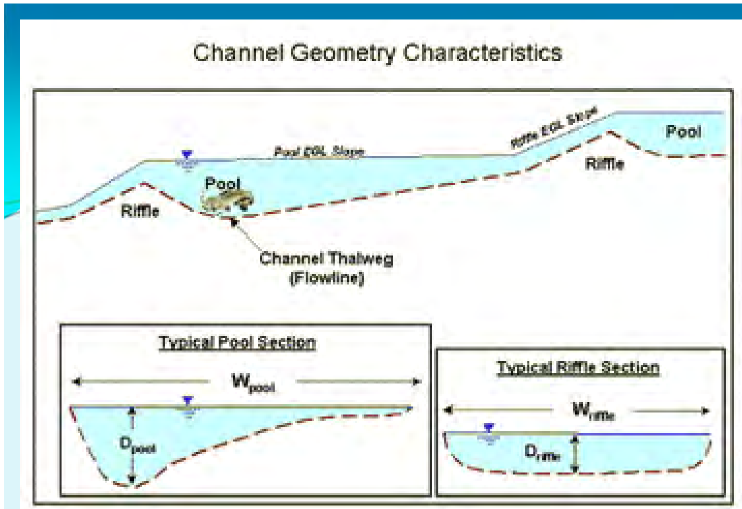
- Base flows
  - Habitability and biodiversity
- Floods and flood pulses - timing
- Floodplain connectivity
  - Hydro-period, attenuation, recharge

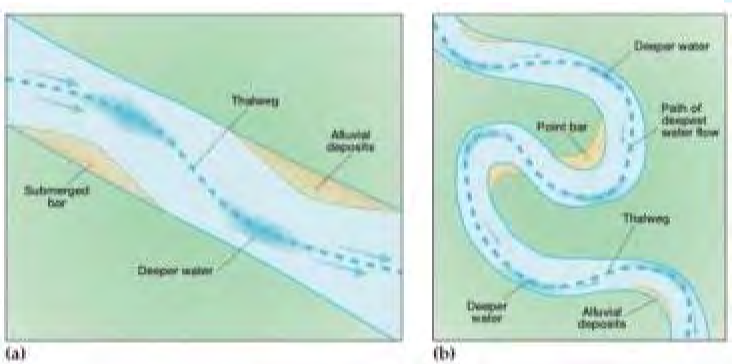
Hydraulics

- Hydraulic diversity
  - Dead water
  - White 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

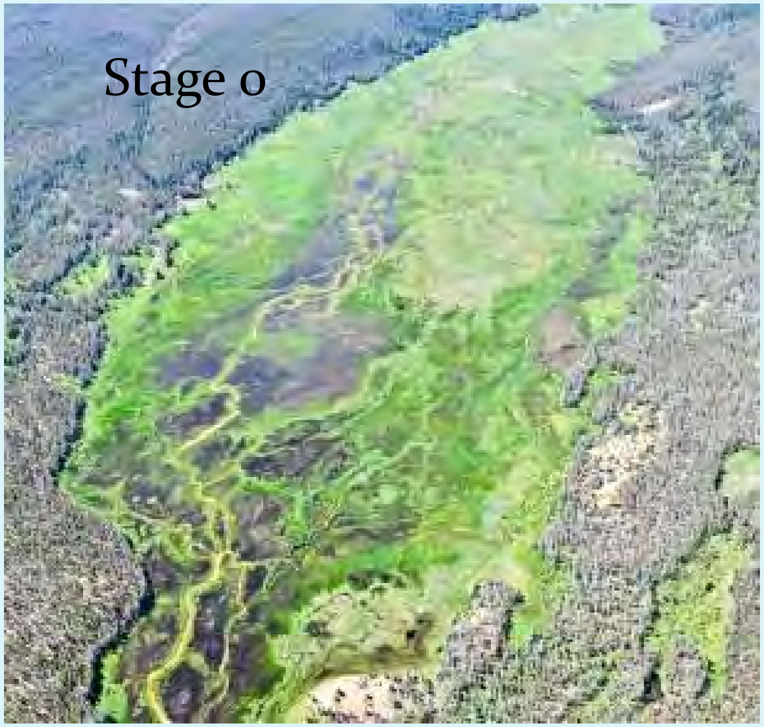
Physical Attributes

- 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

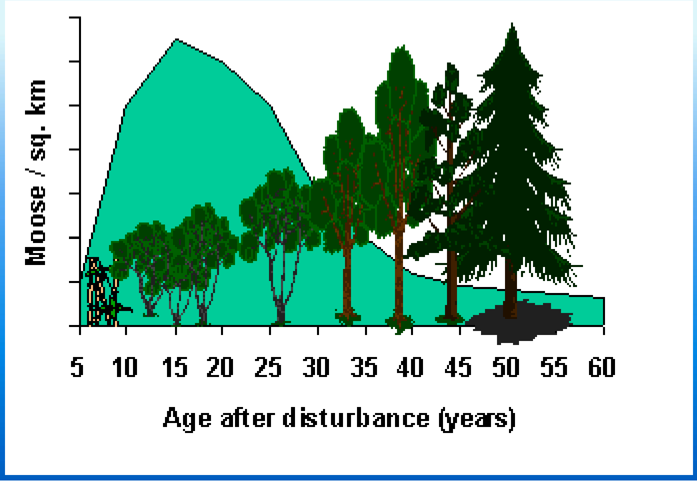
Physical Attributes

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



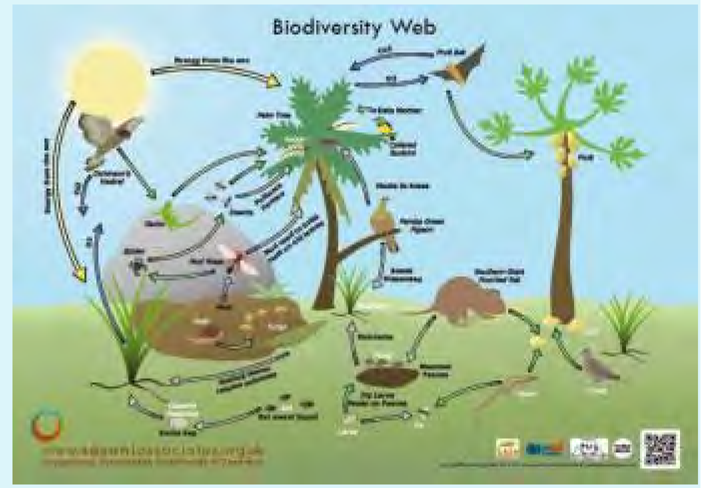
Vegetation attributes

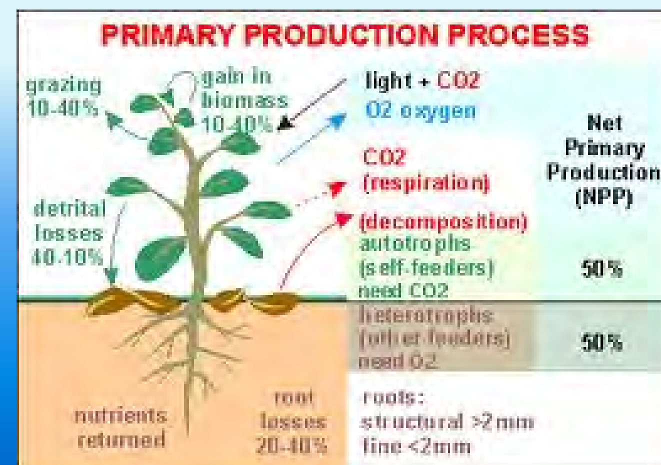
- Presence of plants
  - Aquatic, emergent, riparian, floodplain
- Leaf litter
  - Primary production support
- Tree trunk recruitment
  - Cycling nutrients and carbon
  - Hydraulic and morpho diversity
  - Channel stability
  - Sediment storage
  - Sorting and patchiness
  - Forcing hyporheic flow
- 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 edges
  - Floodplain
- Droughts
  - Water table connection
  - Availability of deep pools
- Able to withstand disturbances

Each stream Stage is associated with a gradient of hydrogeomorphic processes, attributes, and ranges and qualities of 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° & 2° 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

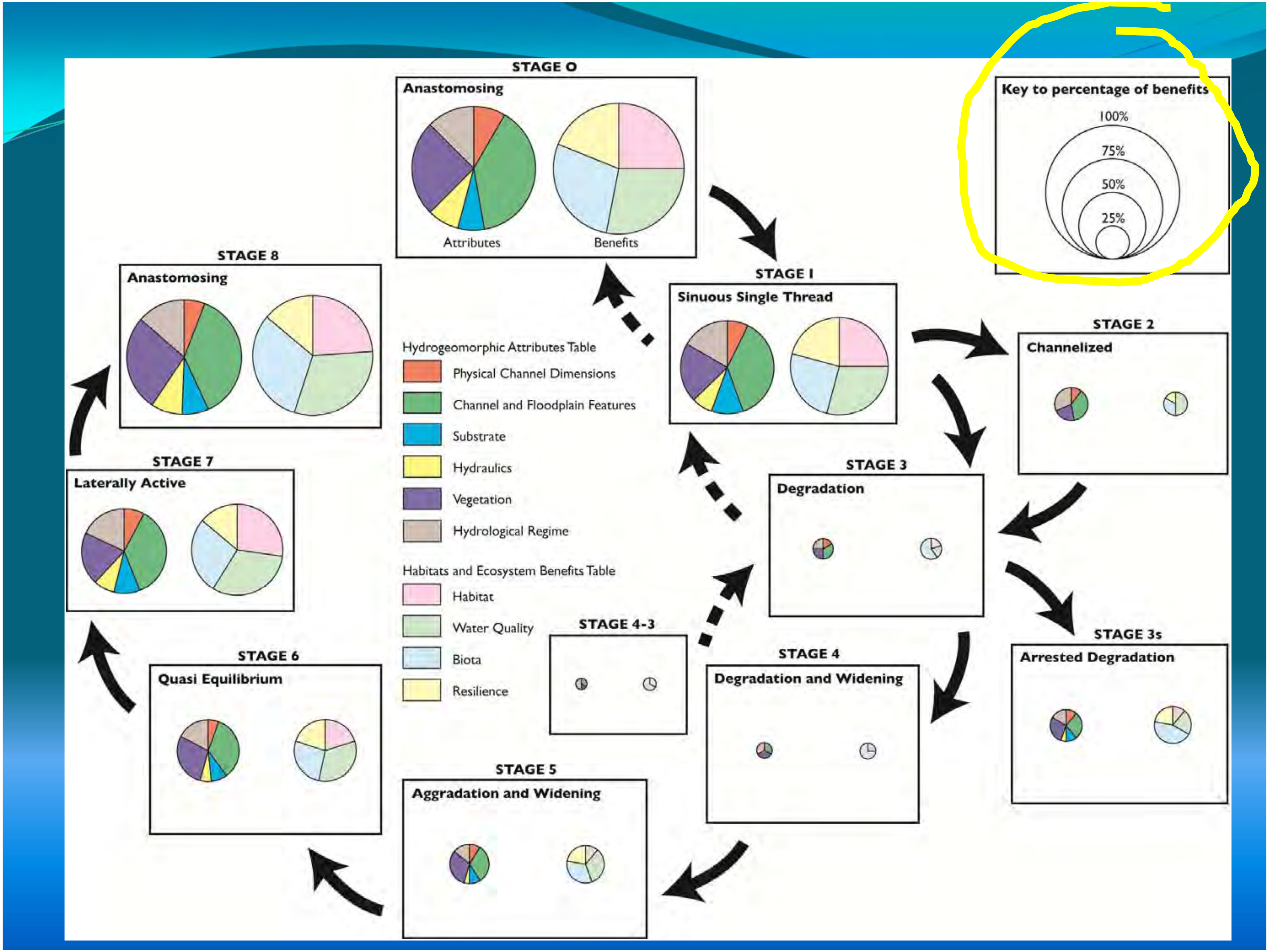

1


0

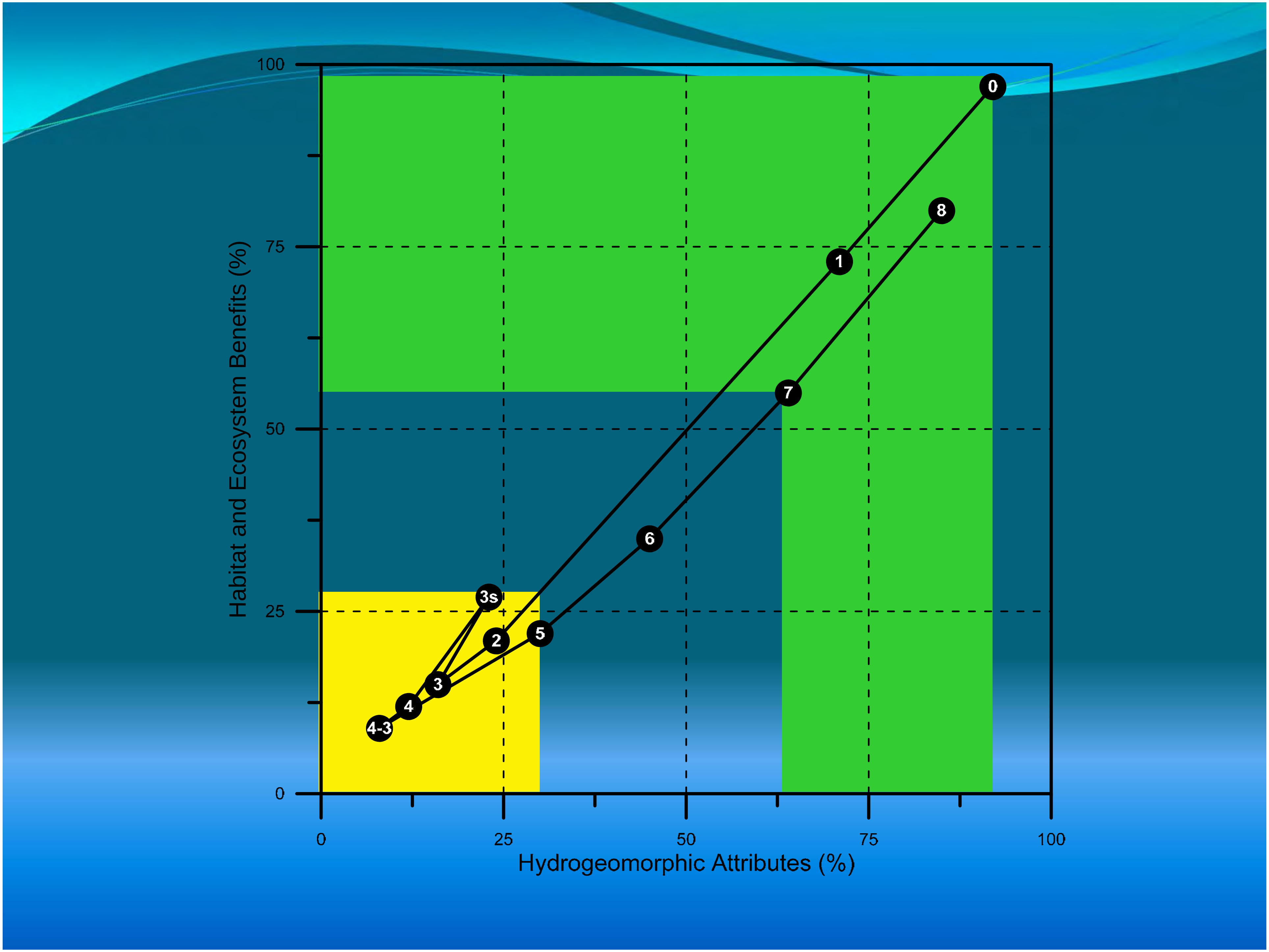
Habitat and Ecosystem Benefits Table

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
Hydrogeomorphic Attributes Table
Physical Channel Dimensions
Channel and Floodplain Features
Substrate
Hydraulics
Vegetation
Hydrological Regime
STAGE 2
Channelized
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

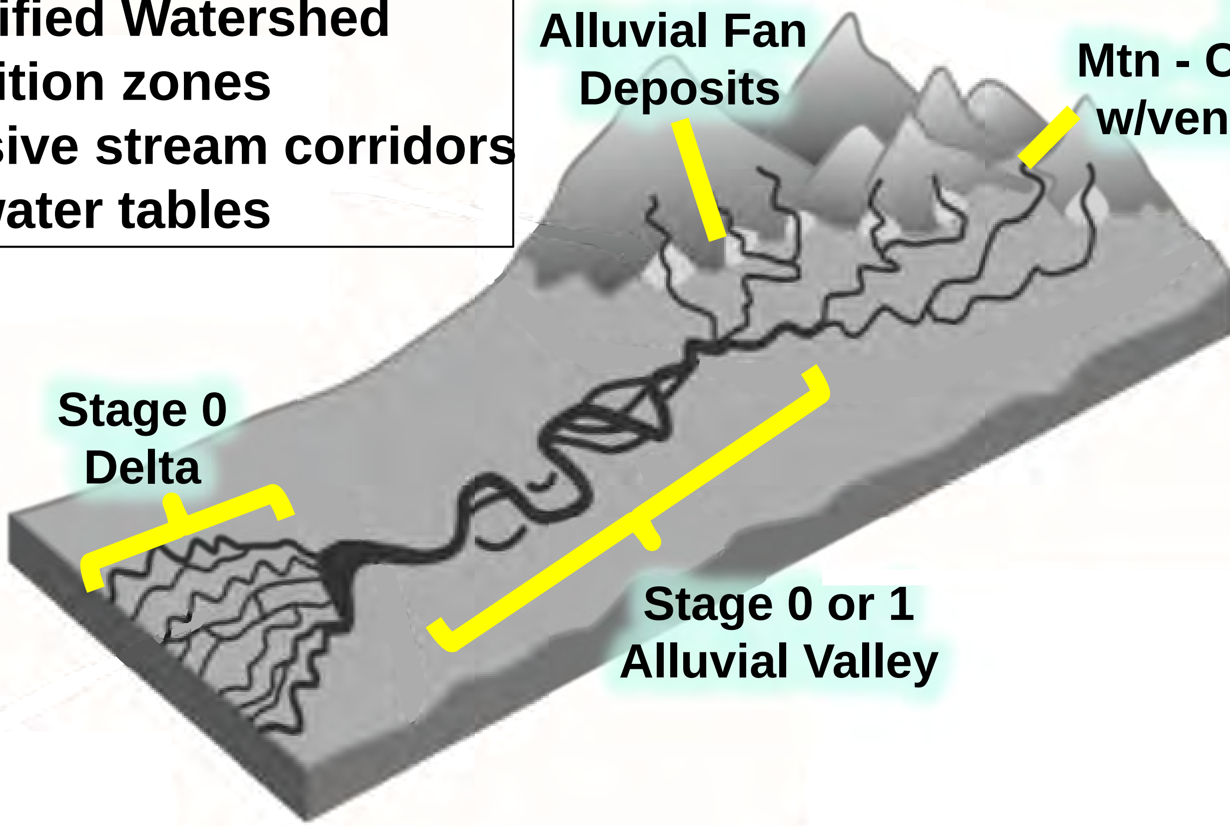

100
75
50
25
0
Habitat and Ecosystem Benefits (%)
0
25
50
75
100
Hydrogeomorphic Attributes (%)
0
1
8
7
6
5
2
3s
3
4
4-3

SEM helps us establish restoration goals that are process-based and ecosystem linked.

Applying the SEM

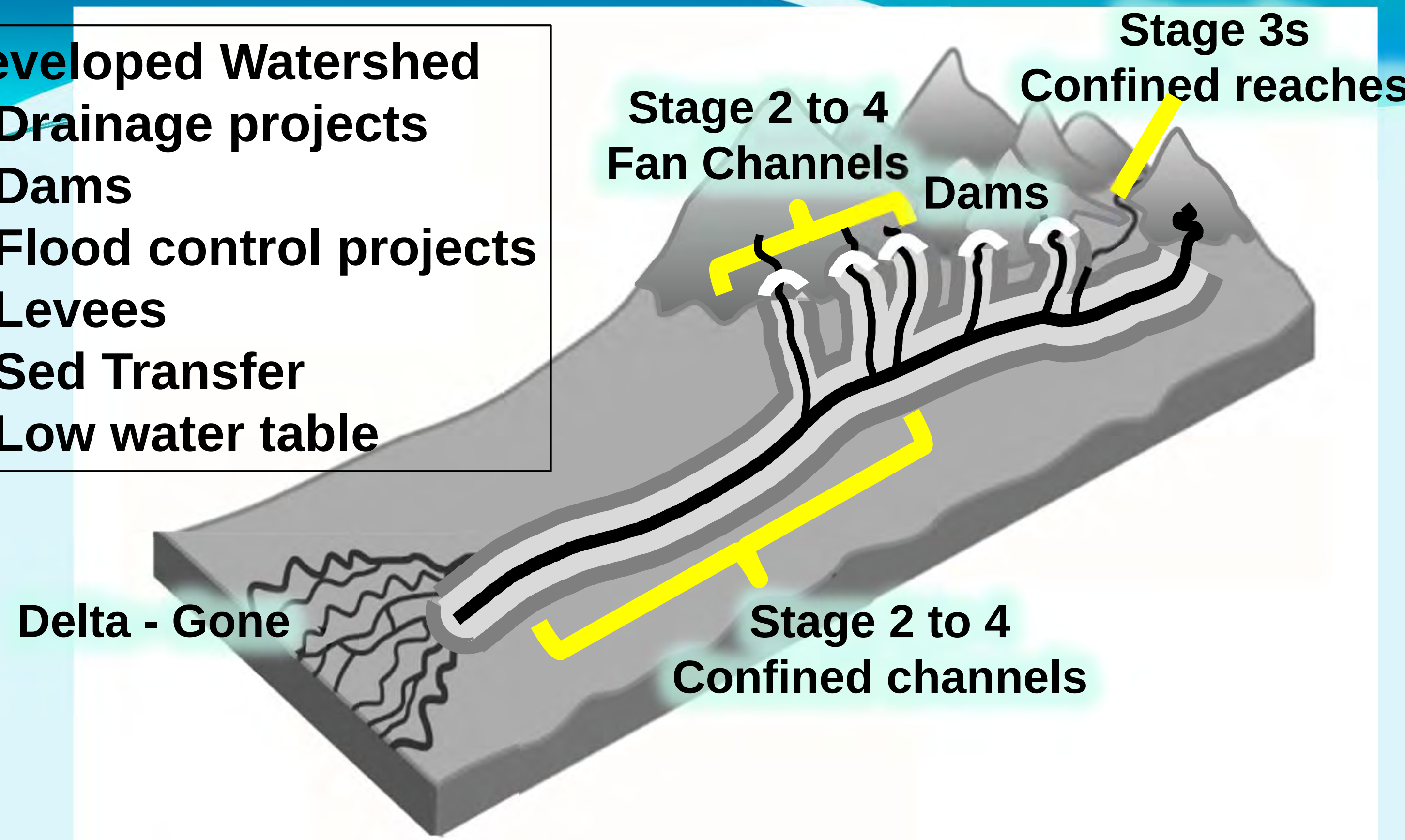
Pre-modified Watershed

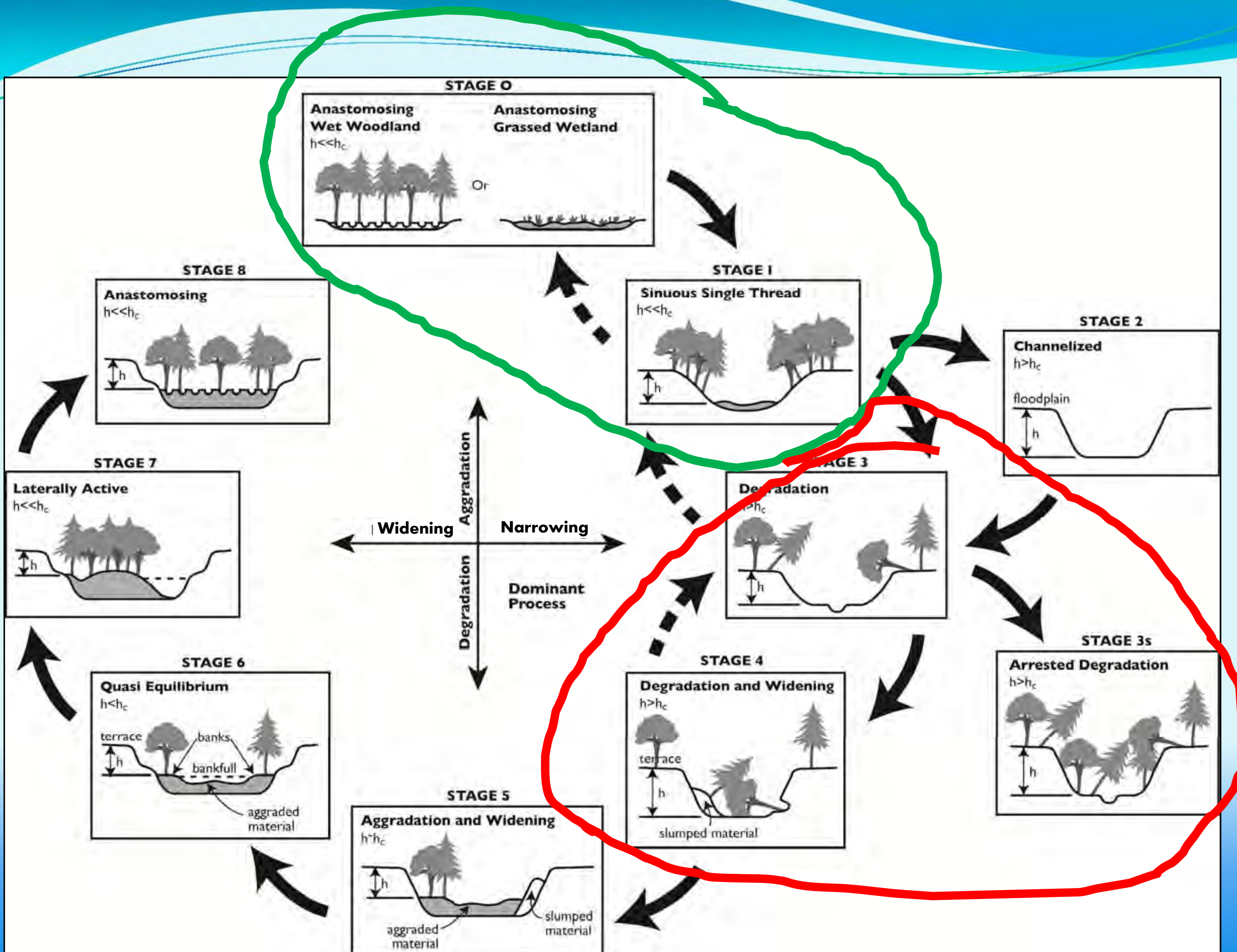
- **Deposition zones**
- **Extensive stream corridors**
- **High water tables**



Developed Watershed

- Drainage projects
- Dams
- Flood control projects
- Levees
- Sed Transfer
- Low water table




STAGE O
Anastomosing Wet Woodland
h<<hc
Or
Anastomosing Grassed Wetland
STAGE 1
Sinuous Single Thread
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STAGE 2
Channelized
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floodplain
h
STAGE 3
Degradation
h>hc
h
STAGE 3s
Arrested Degradation
h>hc
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STAGE 4
Degradation and Widening
h>hc
terrace
h
slumped material
STAGE 5
Aggradation and Widening
h~hc
h
aggraded material
slumped material
STAGE 6
Quasi Equilibrium
h<hc
terrace
banks
bankfull
h
aggraded material
STAGE 7
Laterally Active
h<<hc
h
STAGE 8
Anastomosing
h<<hc
h
Aggradation
Degradation
Widening
Narrowing
Dominant Process

Historic Stage 0's and 1's converted into 2 – 4's

- Incised channels:
- nuisance for landowners
- poor fish habitat
- deliver few ecosystem benefits

Enhanced 2 – 4's

- poor fish habitat
- deliver few ecosystem benefits an only marginally improved habitat

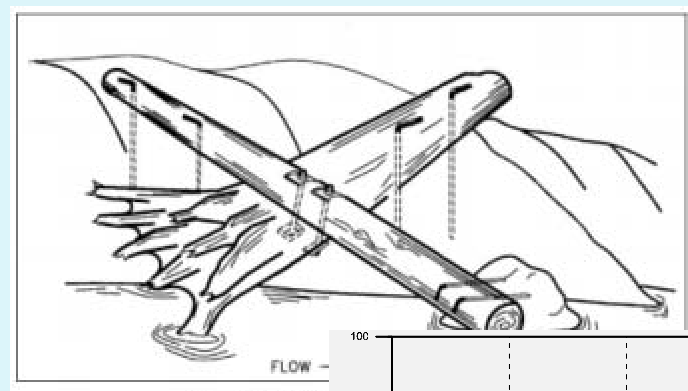
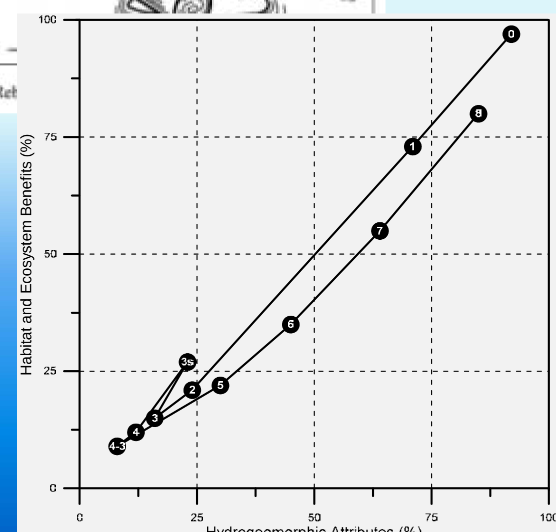


Figure VII-11. Ret



Historic Stage 0's

Conditions that existed before human modifications represent an integration over centuries or longer the physical processes and disturbance histories of that place.

An historic understanding is therefore a valid perspective even though we do not understand all of the processes that shaped that system

FLOODPLAINS
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.)*

Swamp Land Act of 1850 [1] essentially

DRAINING FLOODPLAINS - AND BUILDING DEFENSES FROM FLOODS.

Restoration practice for incised stream channels is typically; stabilize the banks and often the bed too, and
add some habitat features such as wood and rock and vegetation to increase complexity and cover.

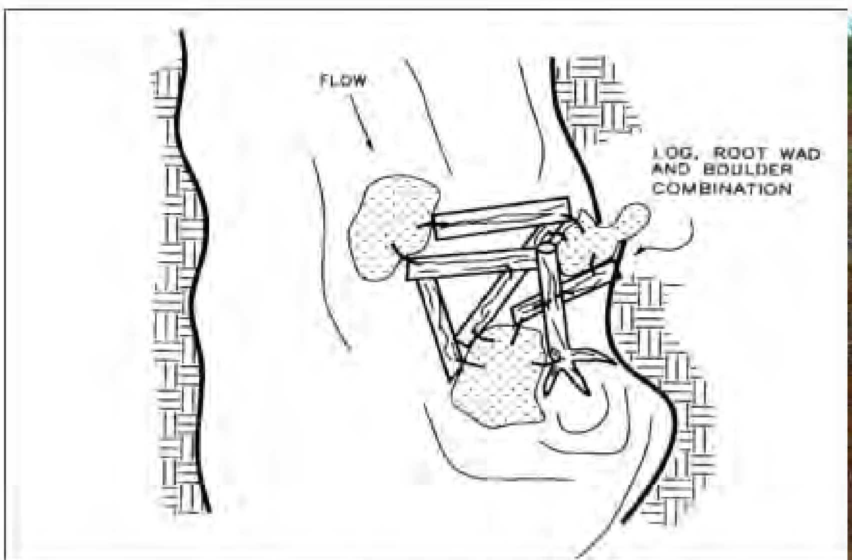
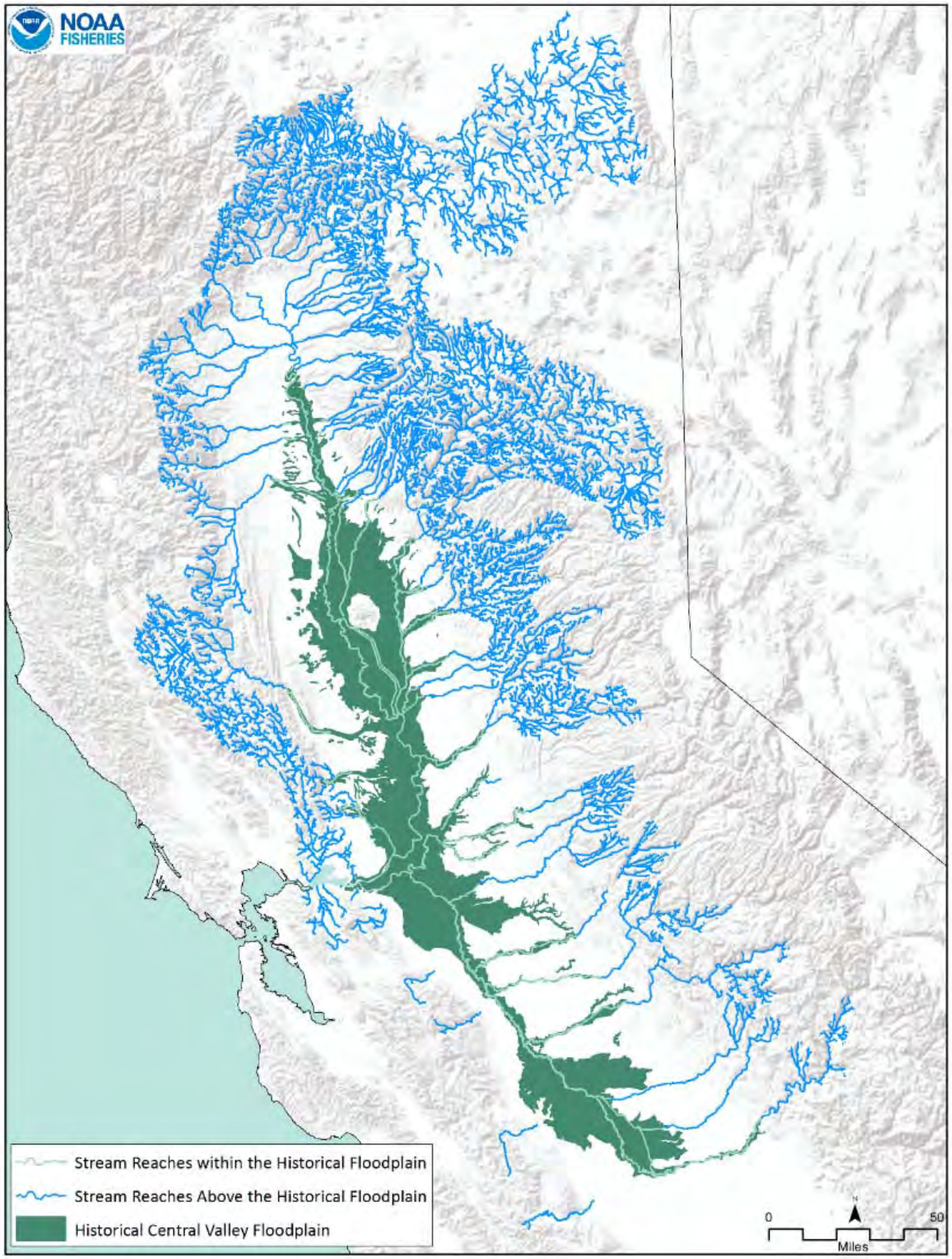


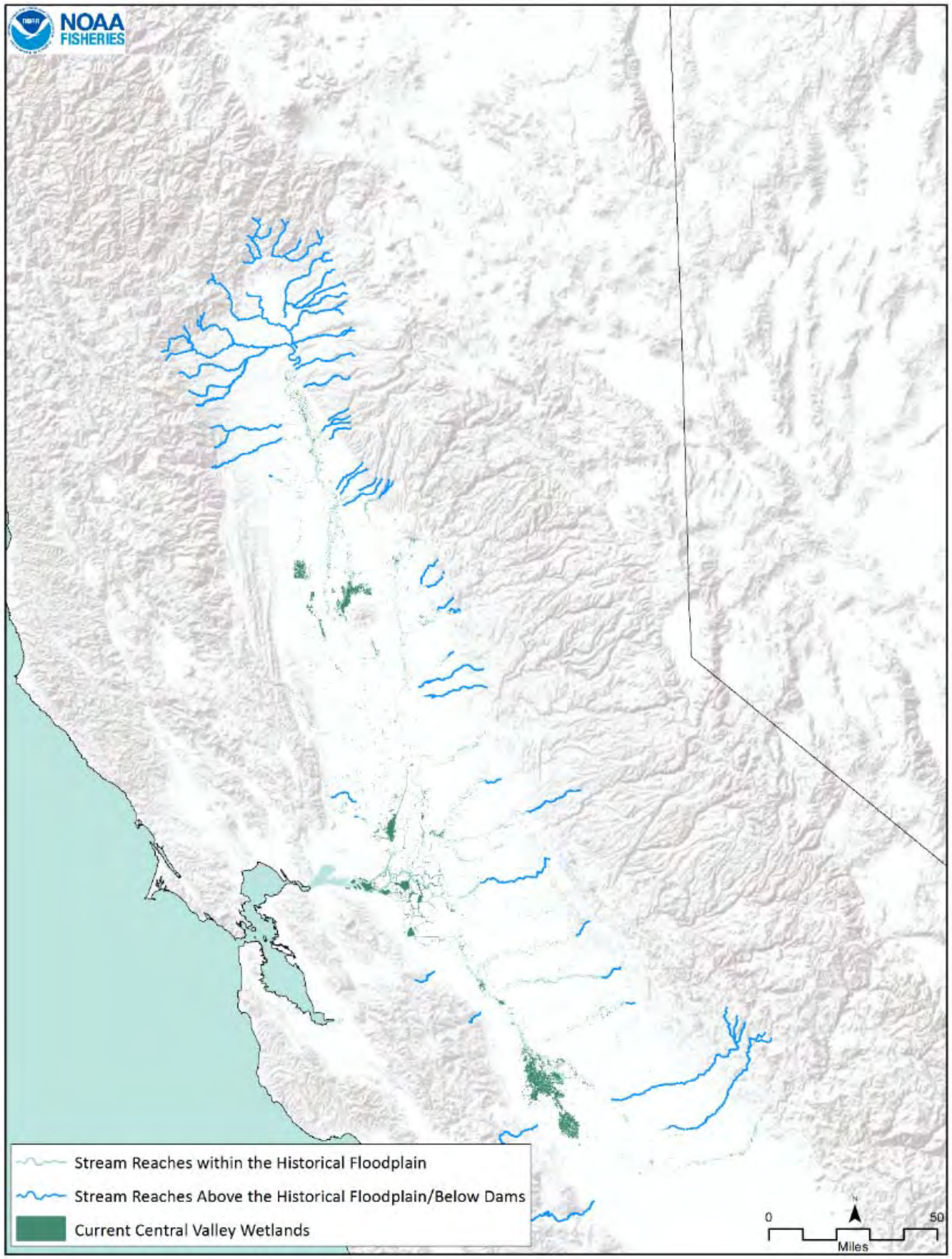
Figure VII-20 Log, root wad, and boulder combination

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)



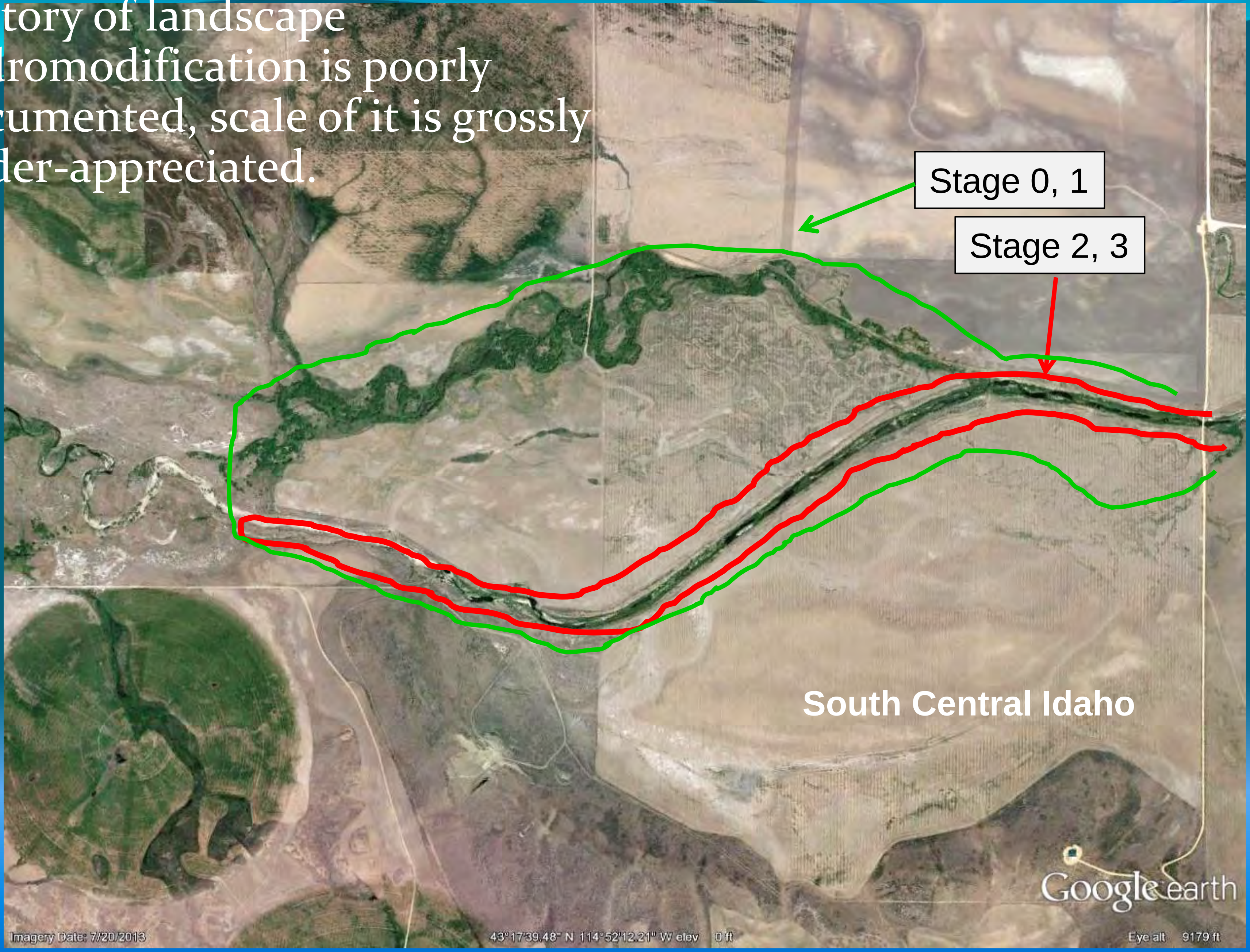
Historical Central Valley with Intact Floodplain and Streams



What's Left

~5% of original habitat

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



River Management Implications

- Simply put, human modifications to alluvial valley reaches turned the once rich floodplain reaches into habitat poor mountain-canyon equivalents.
- Restoration typically enhances and stabilizes the current habitat-poor form, but does NOT restore the former processes or services.
- Stabilization is actually counterproductive.

Conclusions:

- River management and restoration practice are rooted in goals for channel stability and land drainage
  - Not in Habitat and Ecosystem Benefits
- Degraded / manipulated channels can evolve to a better condition.
- Restoration can speed or stall evolution.
- Many channel forms are stable
  - We have choices: Rich or Poor

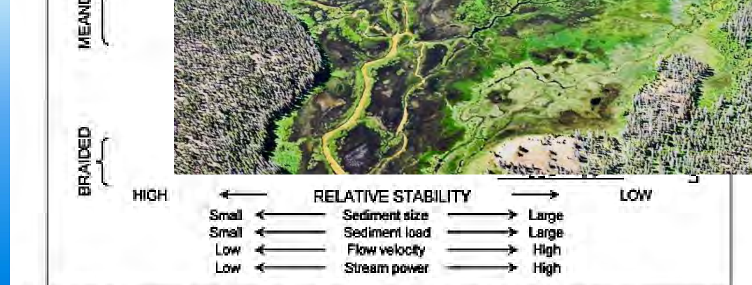


Figure 13. A qualitative classification of stream channels based on pattern (straight, meandering, or braided) and type of sediment load, along with flow and sediment variables and relative stability with regard to average erosional activity. From Schumm (1981).

Recommendations:

1. Stop stabilizing banks, stop building habitat
2. Set Stage 0 goals
   1. Expand stream corridors
   2. Increase water storage, raise water table
   3. Increase sediment storage, restore deposition zones
3. Raise channel bed and lower channel banks

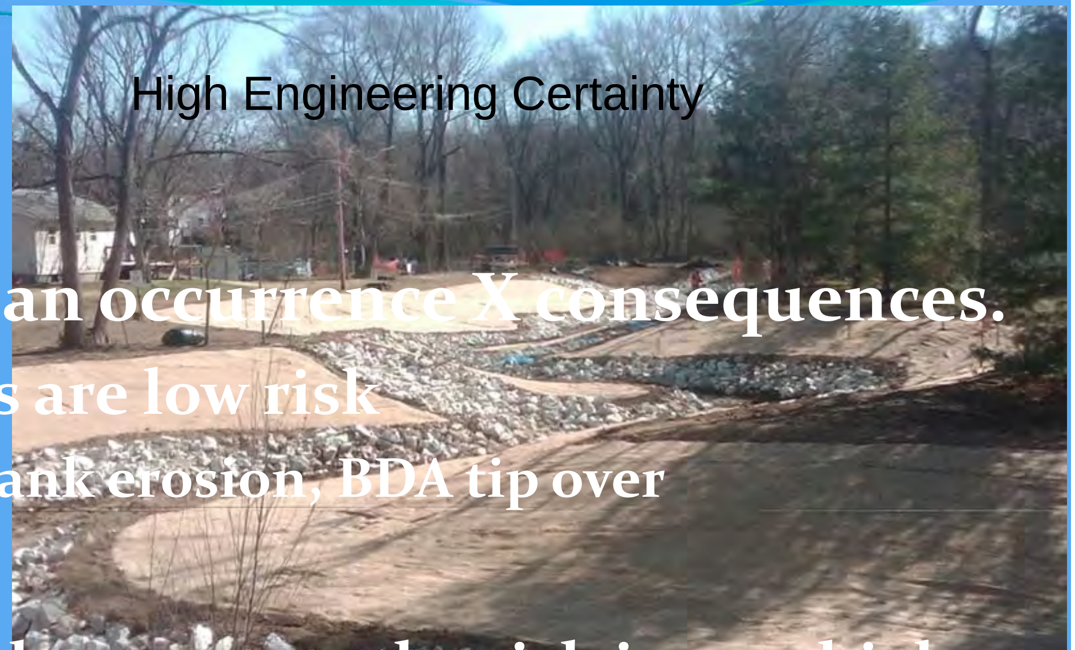
Challenges:

- **Two general areas we need to work on.**

1. **Cost / Benefit**
    1. **Good long-term investments in ecosystem restoration**
    2. **Not simply a new era of 'green' drainage canals**
2. **Inexperience and uncertainty.**
    1. **Science is by definition applicable to similar settings.**
    2. **Yet, often hear "it's different here" or "was that study done in CA, or in xyz county?"**
    3. **Inexperience and uncertainty are not the same as risk.**

Challenges:

- Risk = probability of an occurrence X consequences.
  - Minor consequences are low risk
    - LWD deformation, bank erosion, BDA tip over
- Risk of extinction.
  - Without a functional ecosystem the risk is very high.
- Funders, permiters, reviewers;
  - Encourage 'right' actions, process-based ecosystem restoration, not lean on safe or familiar actions that are ineffective



Wisconsin: lunkers

Questions ?
Comments ?


The Evolution and Restoration of Incised, Lower-Order Stream Channels in Managed, Fish-Bearing Mountain Streams of North Coastal California
Thomas H. Leroy
Pacific Watershed Associates
Arcata, CA
toml@pacificwatershed.com

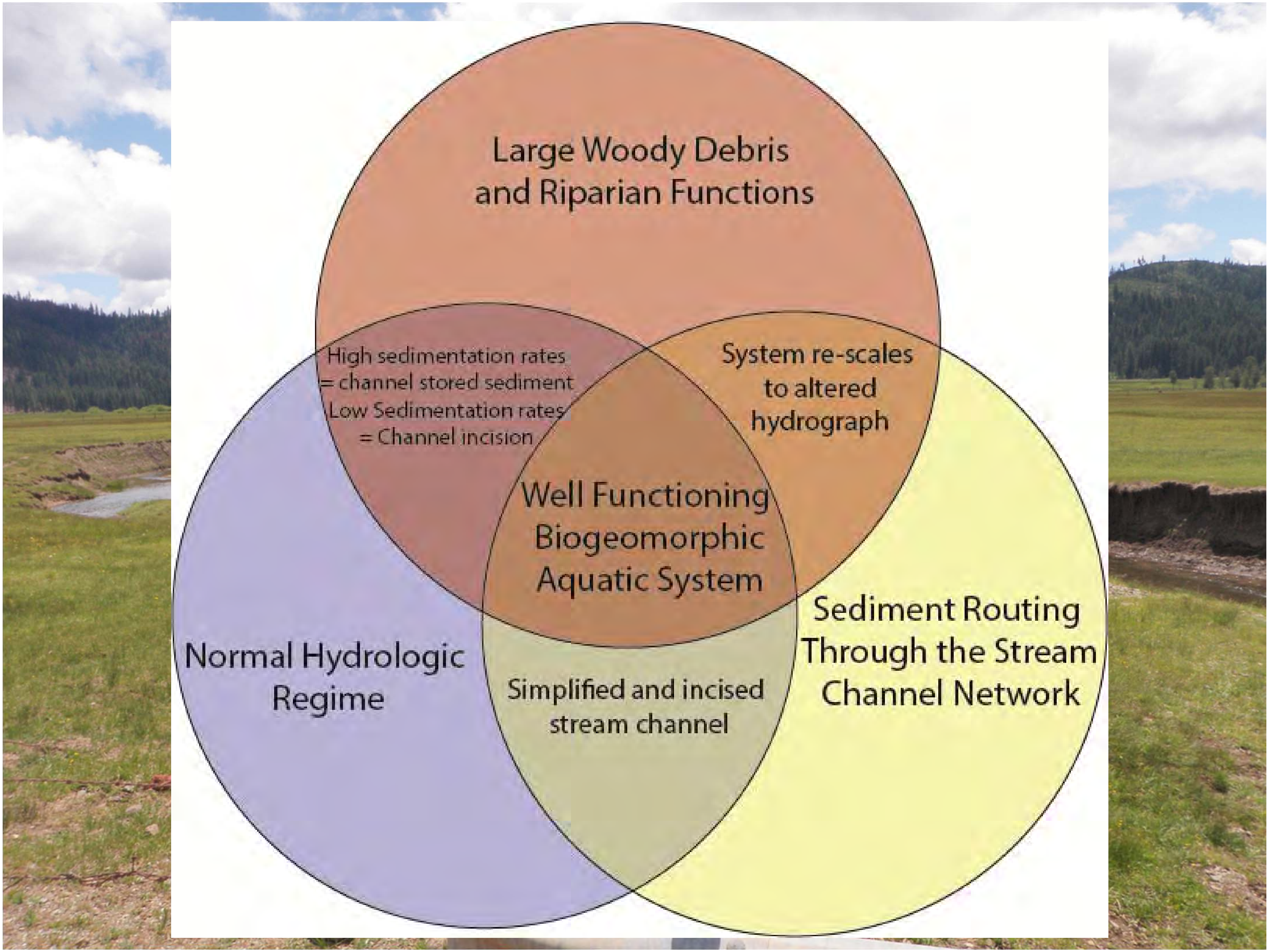
4 primary disturbance events that leave a legacy of stream dysfunctionality in the smaller fish bearing streams of northern California

(1) Unprecedented accelerated delivery of upslope sediment and wood to the stream system from unregulated logging within the watershed,

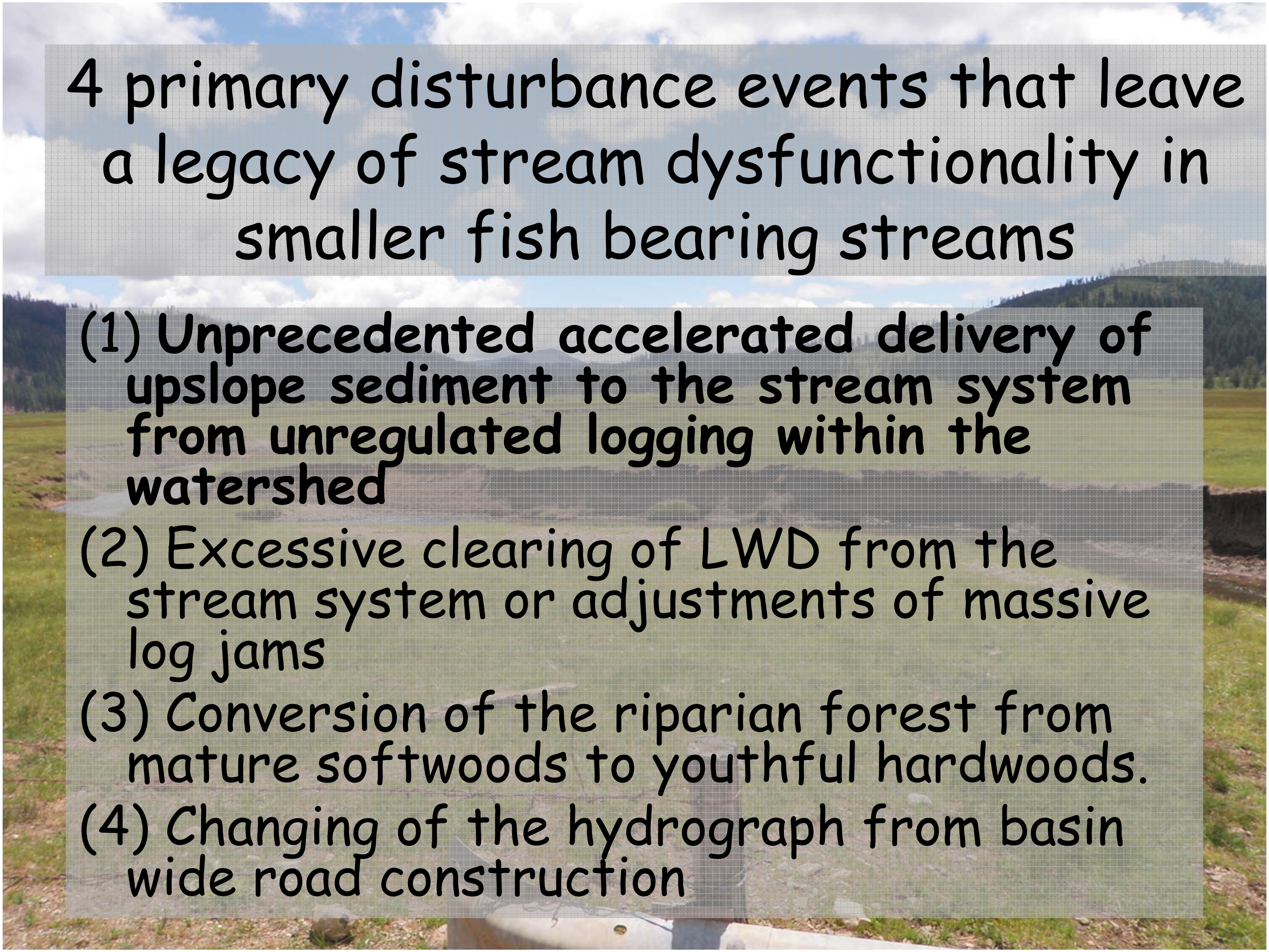
(2) Excessive clearing of LWD from the stream system or vertical adjustments of massive log jams

(3) Conversion of the riparian forest from mature softwoods to youthful hardwoods.

(4) Changing of the hydrograph from basin wide road construction



Large Woody Debris and Riparian Functions
High sedimentation rates = channel stored sediment
Low Sedimentation rates = Channel incision
System re-scales to altered hydrograph
Well Functioning Biogeomorphic Aquatic System
Normal Hydrologic Regime
Simplified and incised stream channel
Sediment Routing Through the Stream Channel Network


4 primary disturbance events that leave a legacy of stream dysfunctionality in smaller fish bearing streams
(1) Unprecedented accelerated delivery of upslope sediment to the stream system from unregulated logging within the watershed
(2) Excessive clearing of LWD from the stream system or adjustments of massive log jams
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4 primary disturbance events that leave a legacy of stream dysfunctionality in smaller fish bearing streams

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4 primary disturbance events that leave a legacy of stream dysfunctionality in smaller fish bearing streams

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(2) Excessive clearing of LWD from the stream system or adjustments of massive log jams

(3) **Conversion of the riparian forest from mature softwoods to youthful hardwoods**

(4) Changing of the hydrograph from basin wide road construction


Deciduous forest

What used to be a conifer dominated riparian forest is now dominated by deciduous forest

3 primary disturbance events that leave a legacy of stream dysfunctionality in smaller fish bearing streams

(1) Unprecedented accelerated delivery of upslope sediment to the stream system from unregulated logging within the watershed,

(2) Excessive clearing of LWD from the stream system or adjustments of massive log jams

(3) Conversion of the riparian forest from mature softwoods to youthful hardwoods.

(4) **Changing of the hydrograph from basin wide road construction**


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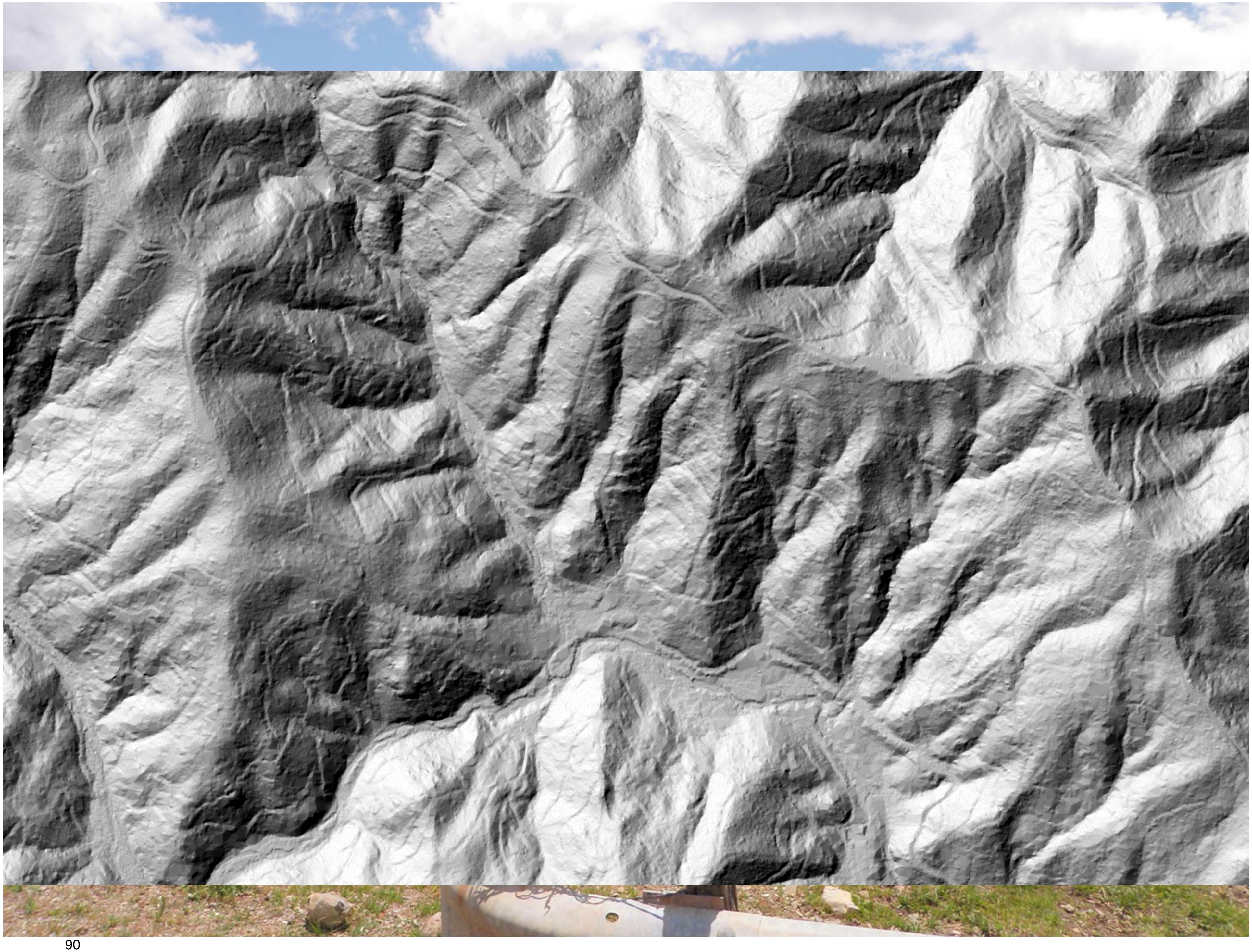
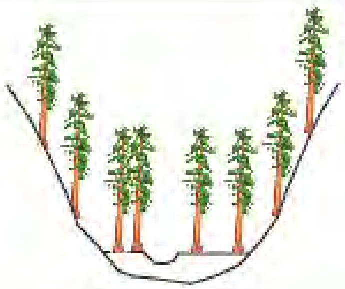
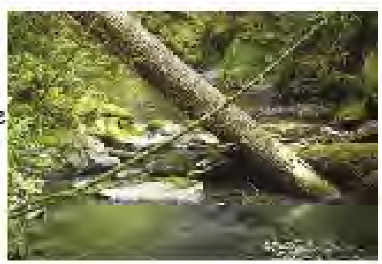


Channel Evolution Model for Heavily Managed Landscapes in Some Northern California Streams

Status	Original Conditions	Immediate Post Disturbance Conditions	Post Disturbance Geomorphic adjustment (after storm events)	Current Conditions
Typical Cross section				
Defining Characteristics	- Riparian dominated by old growth conifer - Floodplain (if present) fully connected to channel - Sediment transport in quasi balance with natural flux and disturbance events -Bank heights low and relatively stable - Biogeomorphic system resilient to natural disturbance events - Habitat diverse and resilient	- Riparian and hillside mostly devoid of trees - Floodplain unprotected - Increased potential for higher sediment input - Bank heights low and unstable - Biogeomorphic system highly vulnerable to natural disturbance events - Habitat vulnerable	- Riparian and hillside mostly devoid of trees - Floodplain buried by heavy sedimentation - Sediment being stored in channel reaches - minimal channel banks evident - Biogeomorphic system succumbs to anthropogenic disturbance - Habitat severely impacted	- Riparian dominated by hardwoods - Floodplain disconnected from channel due to incision through recent sediment deposits - Sediment locked in storage by hardwood forest, no basal flare observed on old growth stumps - Channel banks relatively stable and supported by tree roots - Biogeomorphic system dysfunctional and out of balance with watershed characteristics. - Habitat simplified
Representative photo				

So what options do we have available to fix this mess?.....Part of the solution is treat the cause not the symptom…

- Normalize the hydrograph…Don't forget the roads…
- Reduce to the extent possible anthropogenic contributions to the sediment budget…
- Accelerate the recruitment of conifers in the riparian corridor
- Revise land management strategies

Strategies to deal with the channel stored sediment

- Direct excavation of stored sediment to reconfigure the channel
- Create a system that encourages raising the stream channel to allow more frequent connection between the channel and floodplain
- Develop techniques to route the sediment out of the system
- Parachute beavers in wooden cages into the watershed
- Develop channel restoration projects that encourage widening of the incised channel so the stream can have some width to develop complex channel geomorphic features
- Develop an understanding of site specific conditions and determine the most appropriate restoration strategy based on current and expected future channel reach conditions

I guess sometimes you have to think outside the box

So here's is one way were going about it in Standley Creek

Using Biogenic Obstruction to Restore Complexity to Incised Streams

Michael M. Pollock NOAA Fisheries-Northwest Fisheries Science Center, Seattle Washington
Brian "Hayduke" Cluer NOAA Fisheries Western Regional Office, Santa Rosa, California

1

Topics

- **What is a biogenic obstruction?**
- **Why obstruct streams to restore them?**
  - **Answer: To create stage zero streams, and in particular, in the context of this conference, off-channel habitat**
- **Stage zero streams/valleys**
  - ~~**Attributes**~~
  - ~~**Occurrence**~~
  - **Natural examples**
  - **Design considerations and example**

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Biogenic Obstructions

- Definition: Structures created by living organism that affect the fluvial transport rates (movement) of water, sediment, organic material, nutrients, thermal energy or living organisms,
- Examples
  - Beaver Dams, Lodges, Burrows, Caches
  - Tree Boles and Roots, Living and Dead
  - Emergent Vegetation Above and Below Ground, Living and Dead.

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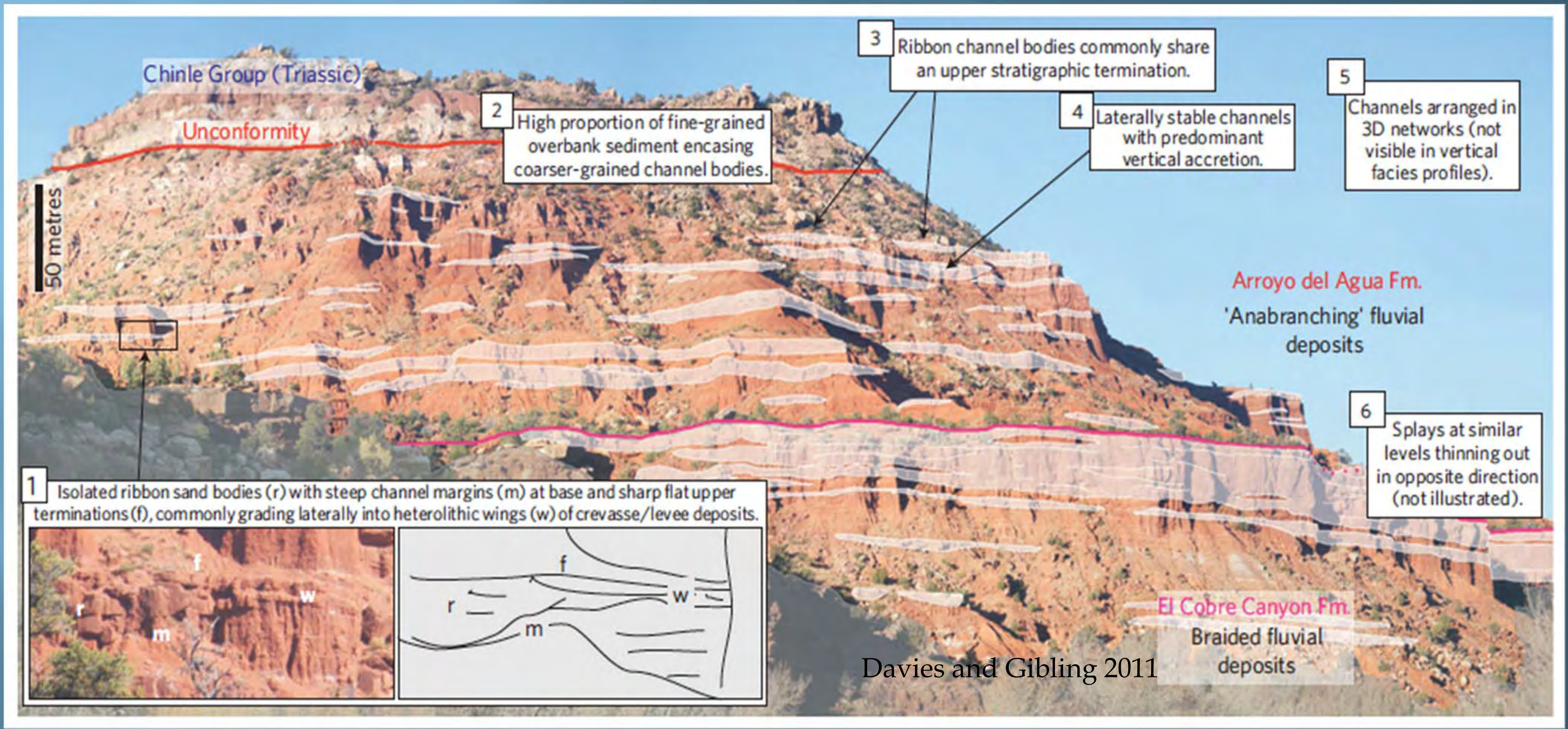
Rivers, plants and instream obstructions have been around for a long time (>500 Mya)-plants have shaped the form of channels



Davies and Gibling 2011

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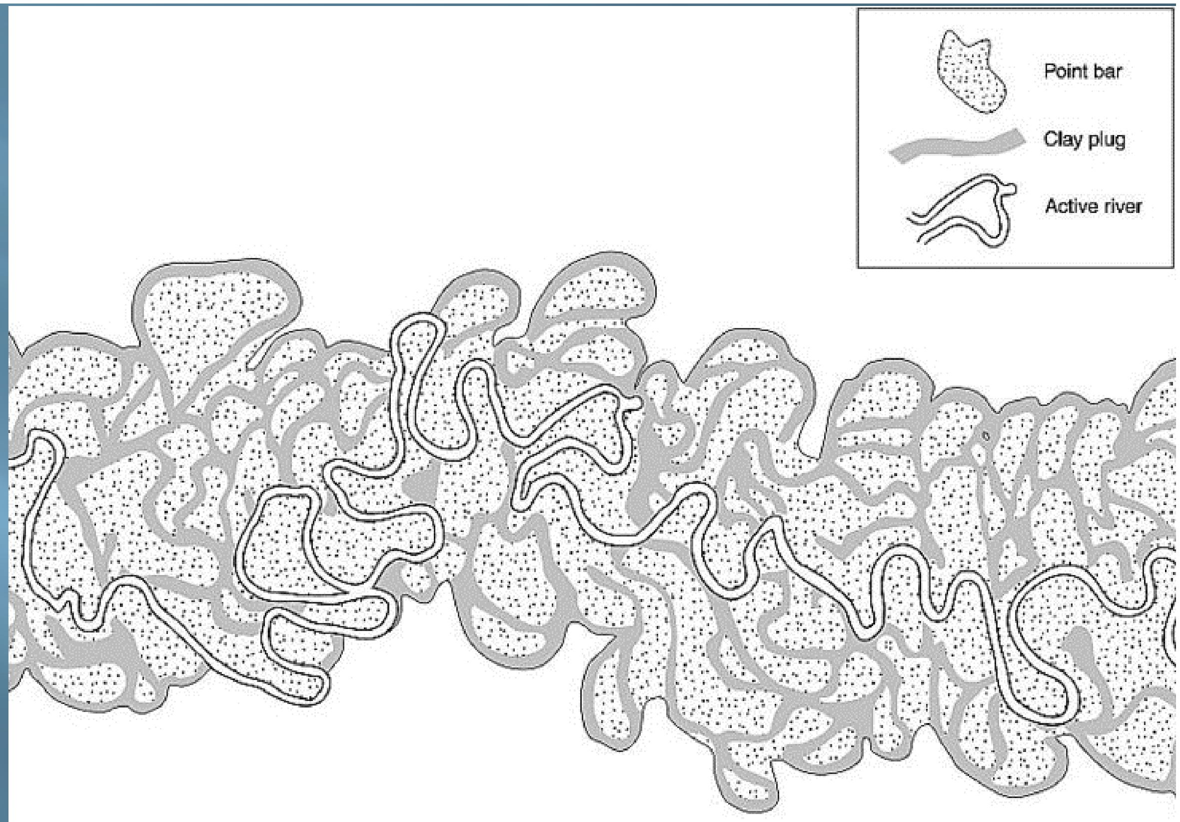
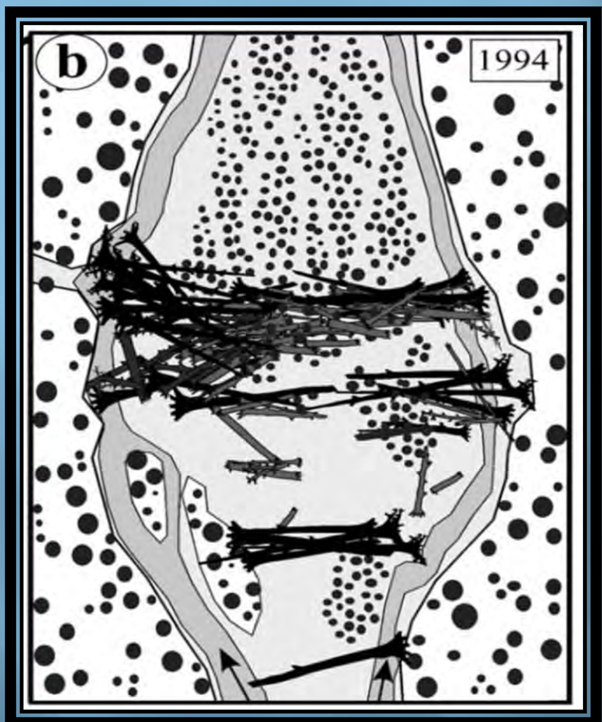
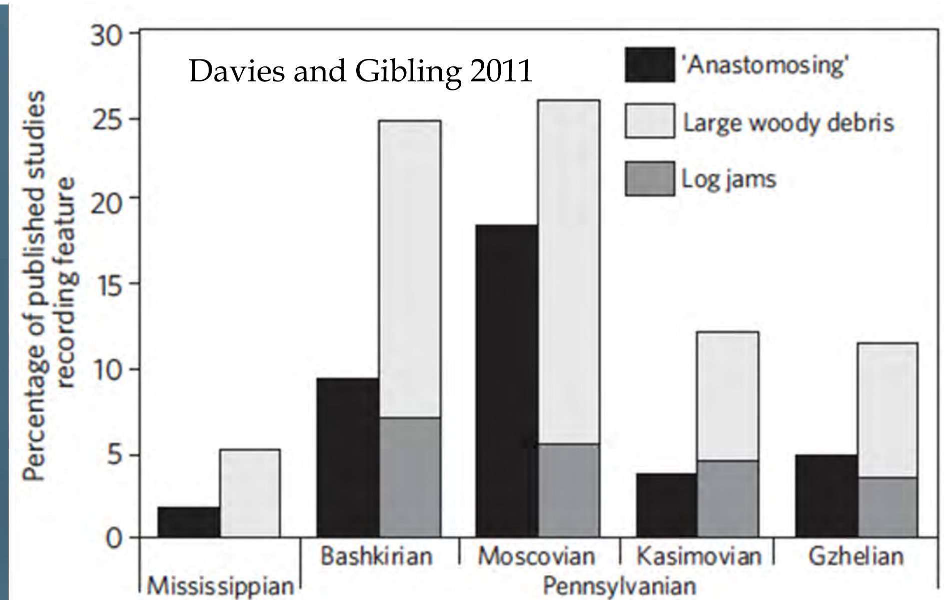
Planview of anastomosing stream

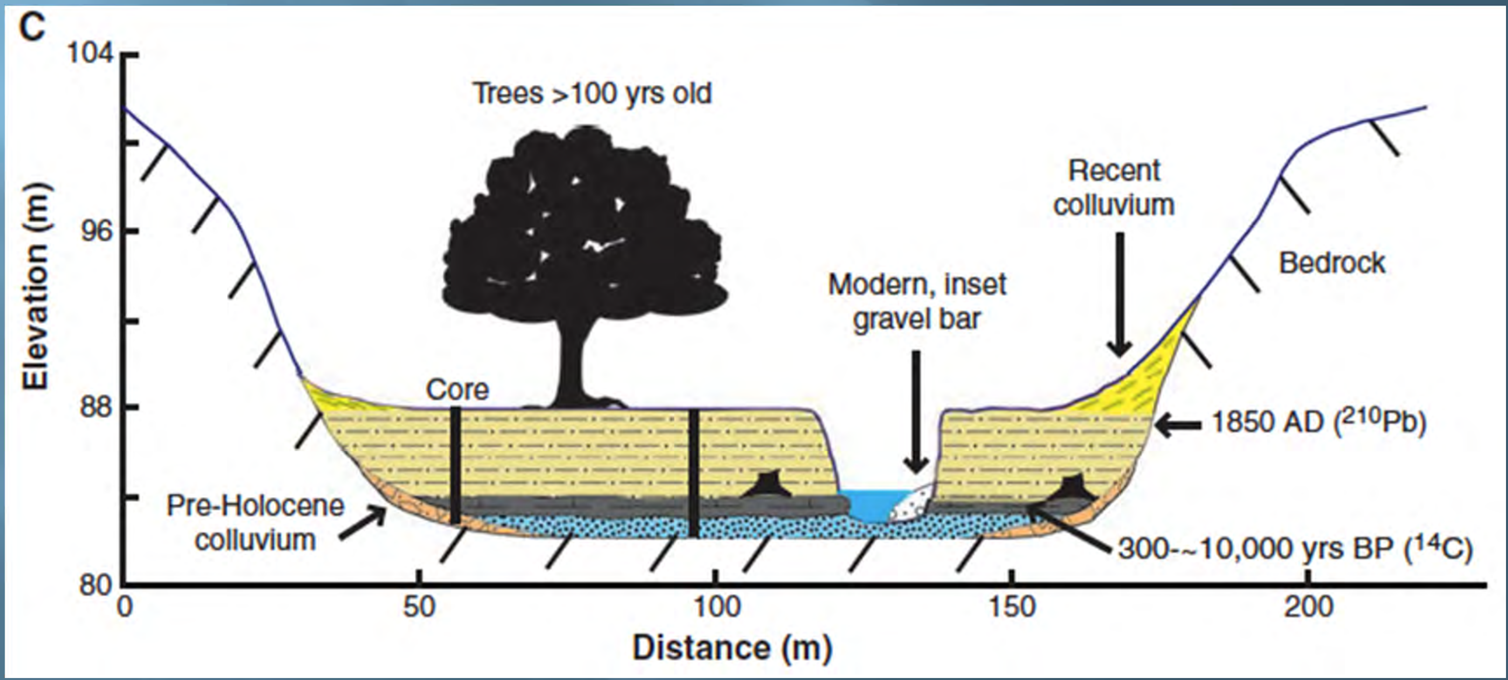


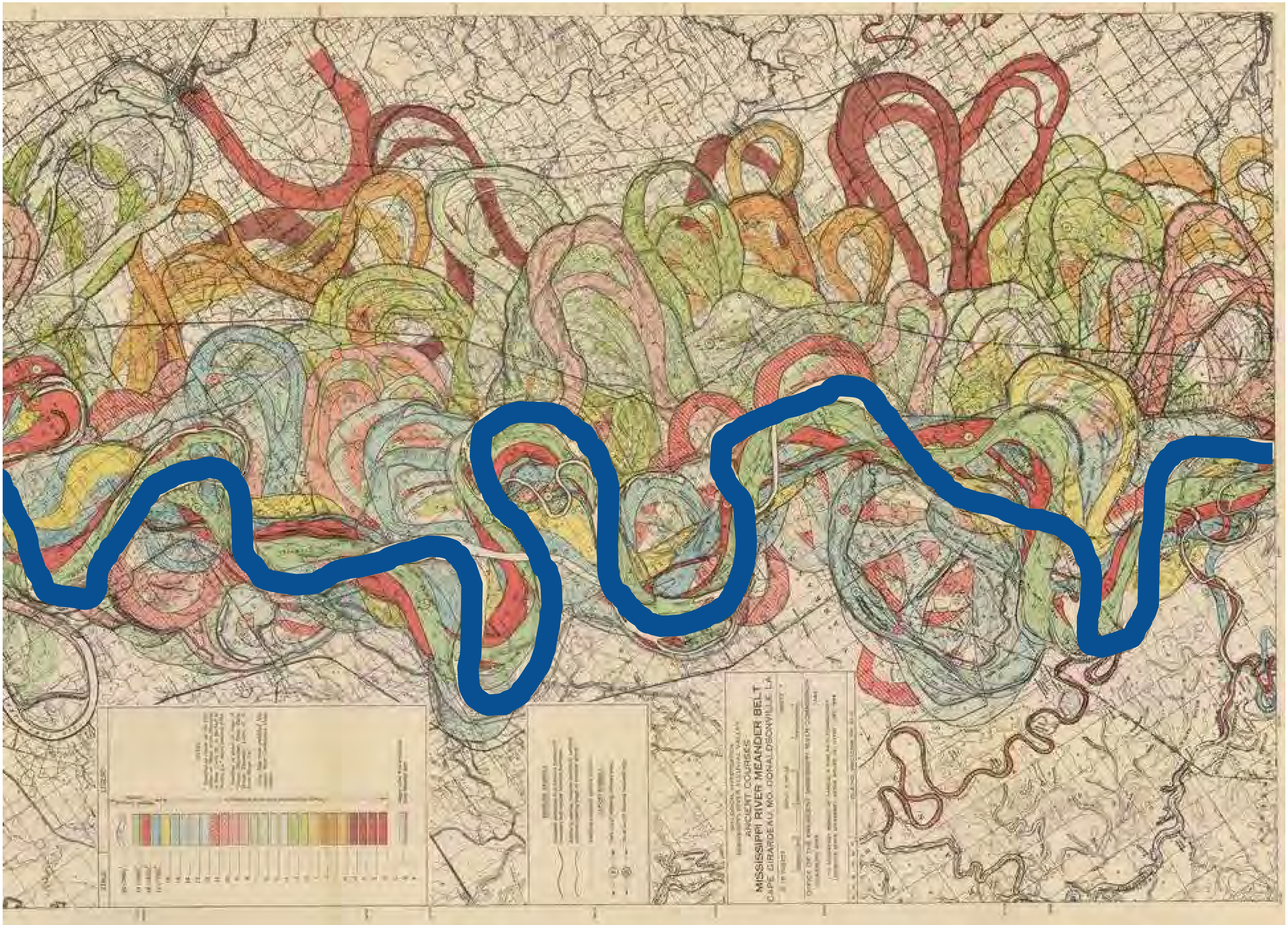


Anastomosing, large wood and log jams (obstructions) all arose together in the geologic record



"Gravel-bedded streams are thought to have a characteristic meandering form bordered by a self-formed, fine-grained floodplain. This ideal guides a multibillion-dollar stream restoration industry. We have mapped and dated many of the deposits along mid-Atlantic streams that formed the basis for this widely accepted model. These data, as well as historical maps and records, show instead that before European settlement, the streams were small anabranching channels within extensive vegetated wetlands…."-Walter and Merritts 2008.





From lmvmapping.erdc.usace.army.mil

Taku River (southeast) Alaska

Kuskokwim River, Alaska

8

Salmon River, Idaho

Stage Zero Examples

MacKenzie River, Canada

Yukon River, Alaska

Peel River, Canada

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Everglades (River of Grass), Florida

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Okavango River, Botswana

Sudd Swamp, South Sudan

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Sacramento-San Joaquin Rivers- 150 ybp

150 years ago, 5% of California was "wetlands", mostly in the Central Valley, really more of a wetland-river complex.

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Types of "Obstructions" that Build Stage Zero Channels/Valleys

- Beaver Dams
- Live Vegetation
- Large Wood
- Landslides
- Alluvial Fans
- Sea Level Rise
- Tectonics

Increasing Time Scales

Key Functions:

- Increase flow resistance,
- Lower slope
- Reduce stream power/unit width

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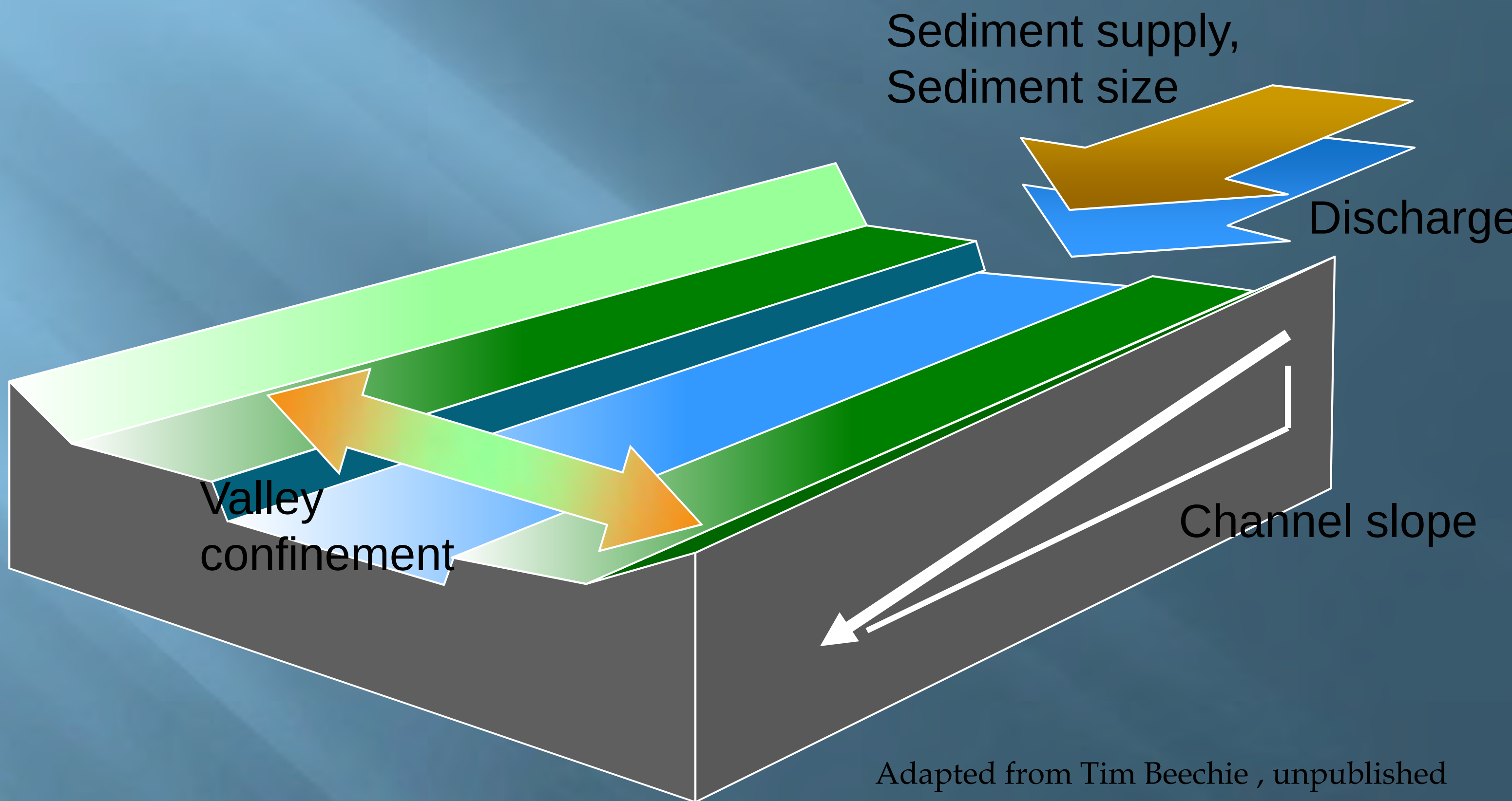
Factors Controlling Stage Zero Stream/Valley Formation



Adapted from Tim Beechie , unpublished

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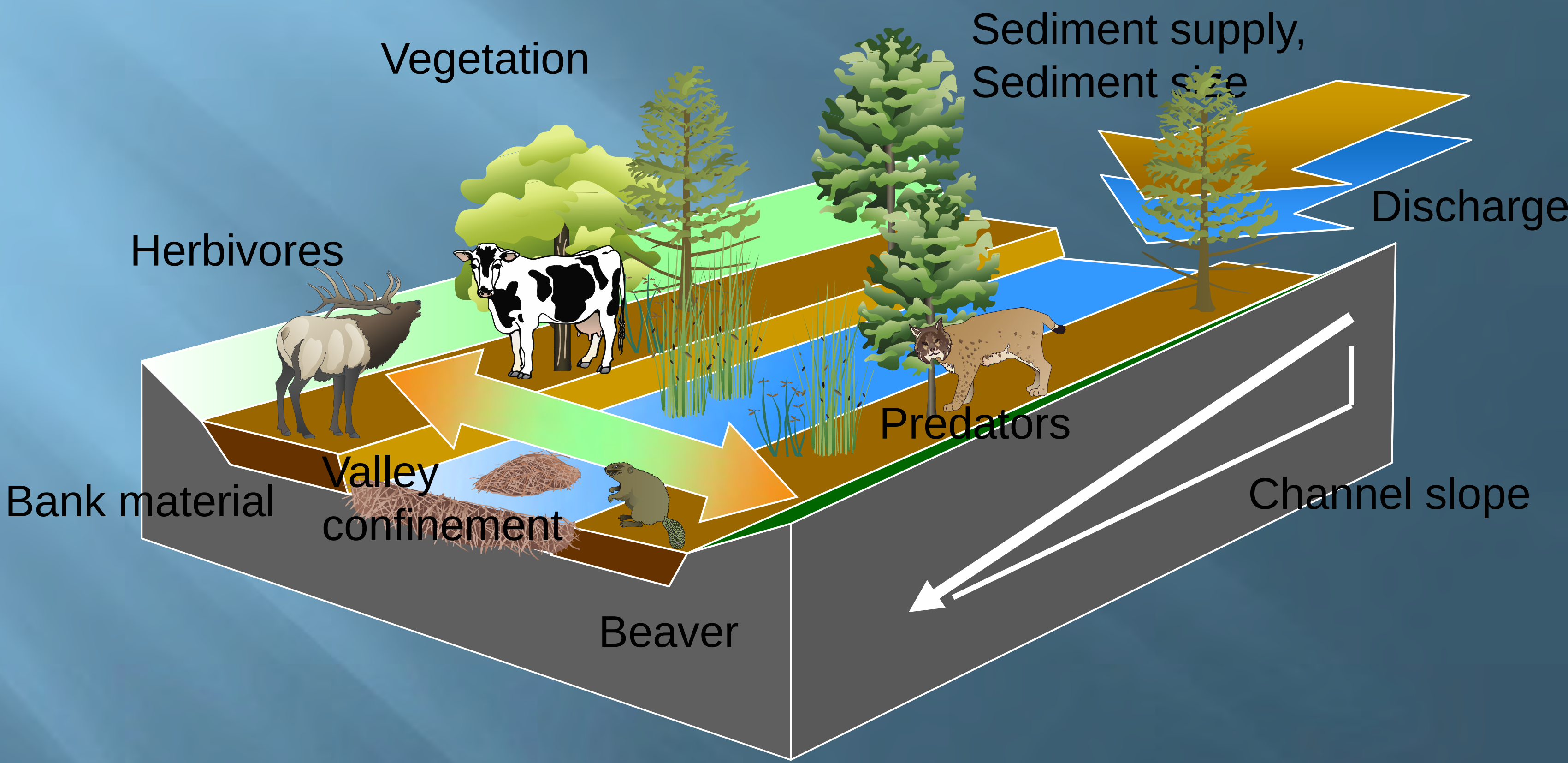
Factors Controlling Stage Zero Stream/Valley Formation



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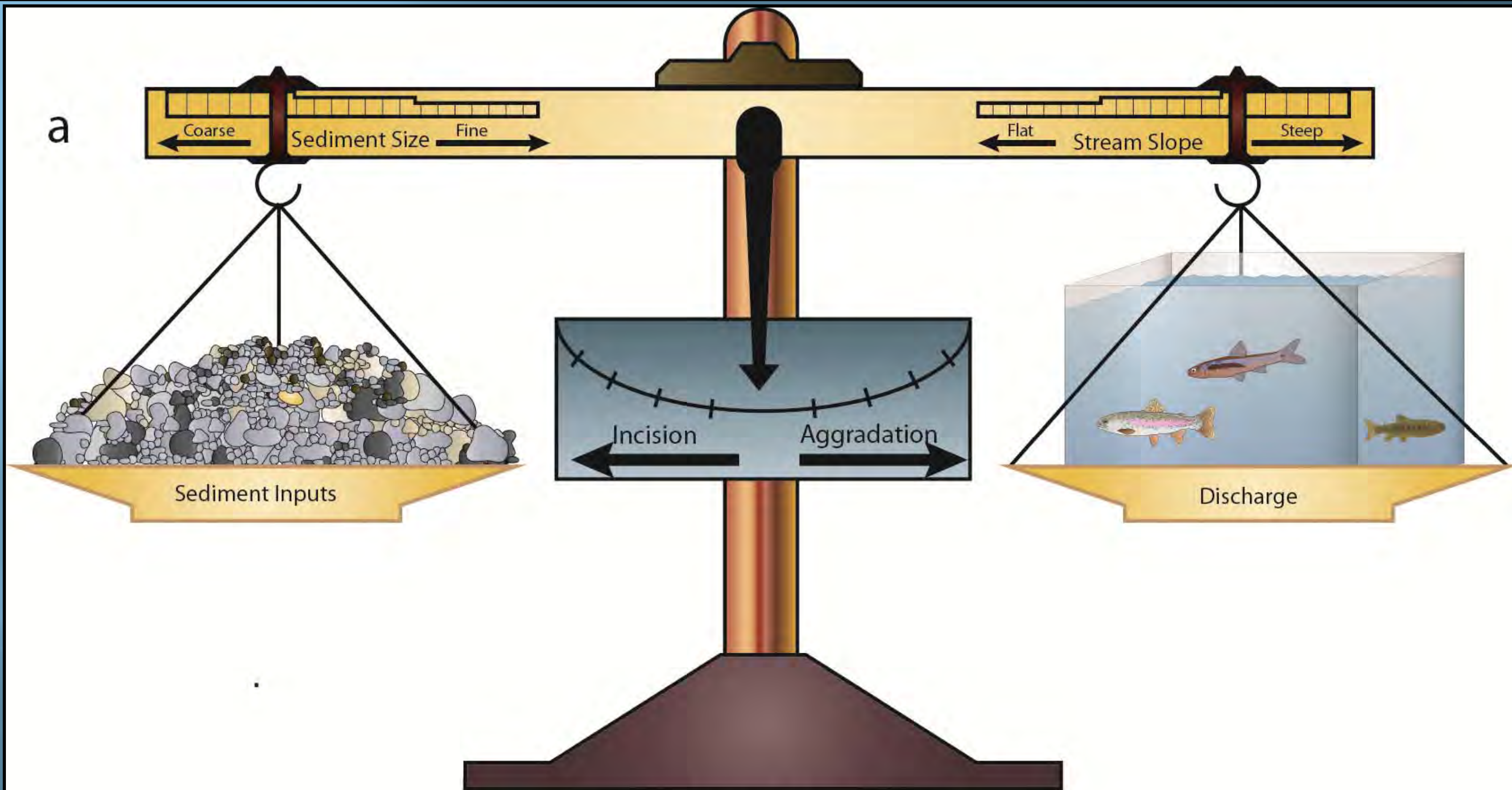
How Do You Build a Stage Zero System?



From Pollock et al. 2014

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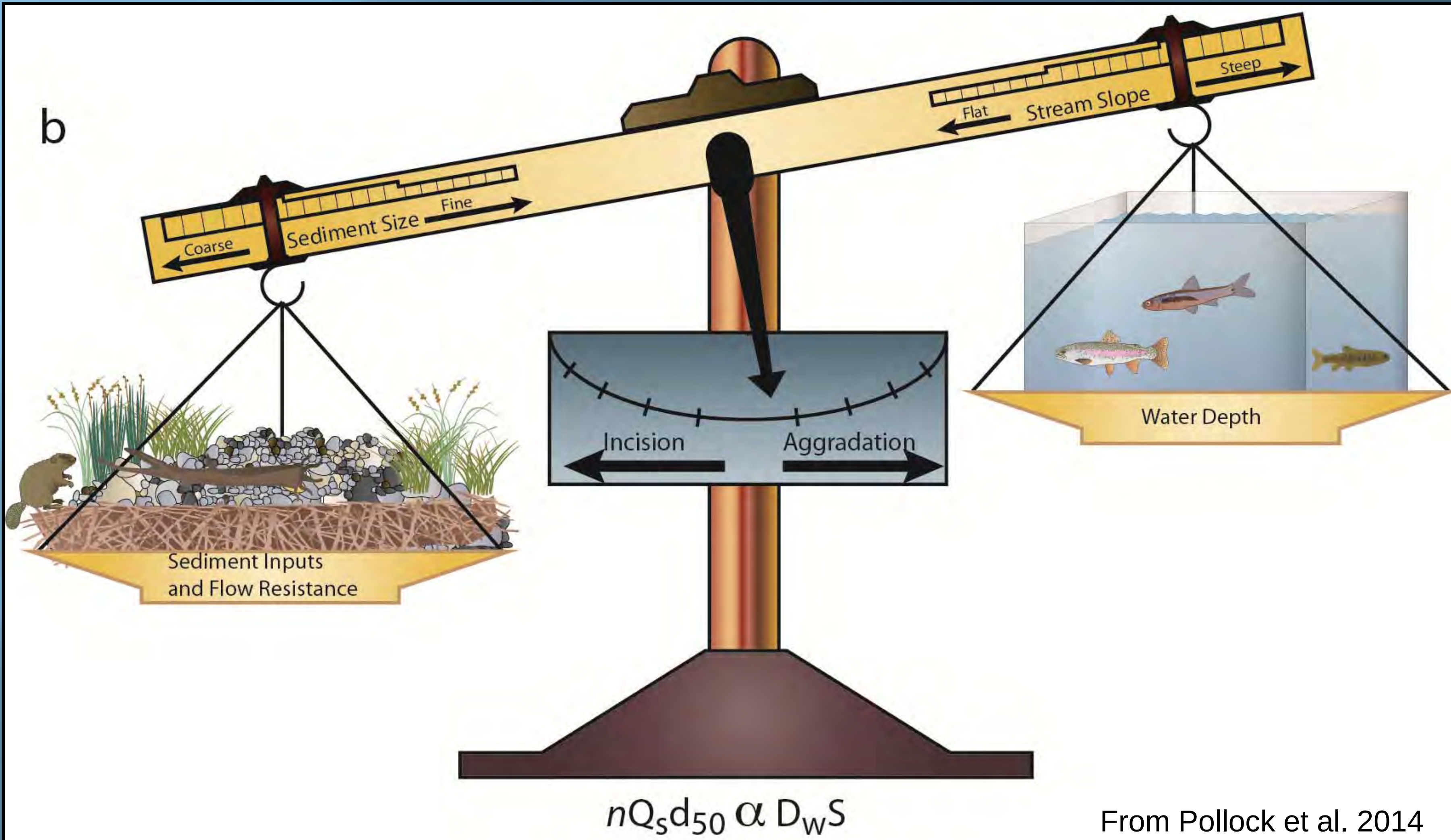
A: Increase Flow Resistance



From Pollock et al. 2014

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Restoration "Toolkit" for (Re)Building Stage Zero Channels/Valleys

- Beaver Dams
- Live Vegetation
- Large Wood
- Levee Setbacks
- Landslides
- Alluvial Fans
- Sea Level Rise
- Tectonics

Increasing Time Scales

These Tools:

- Increase Flow Resistance,
- Lower Slopes
- Reduce Stream Power/Unit Width

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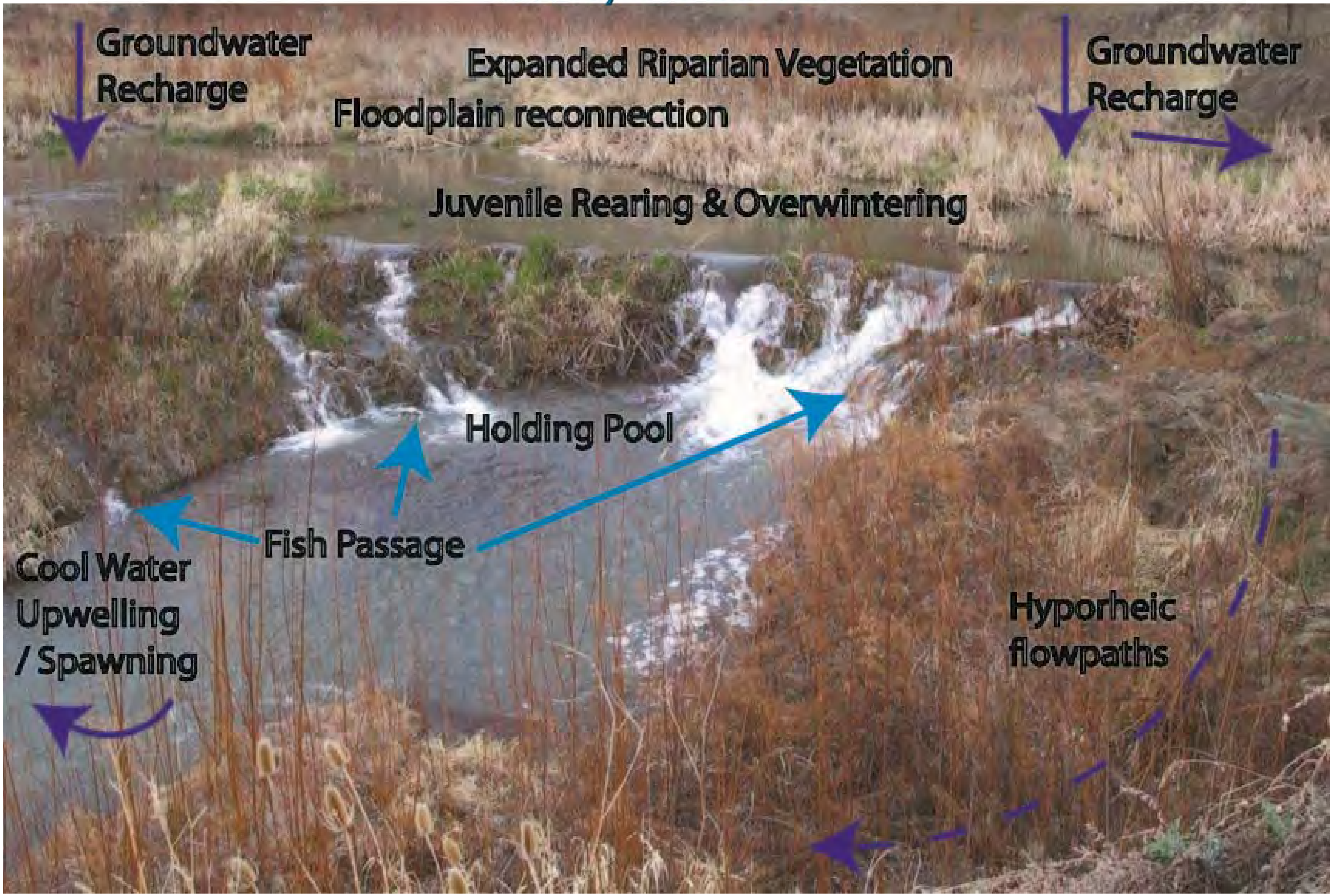
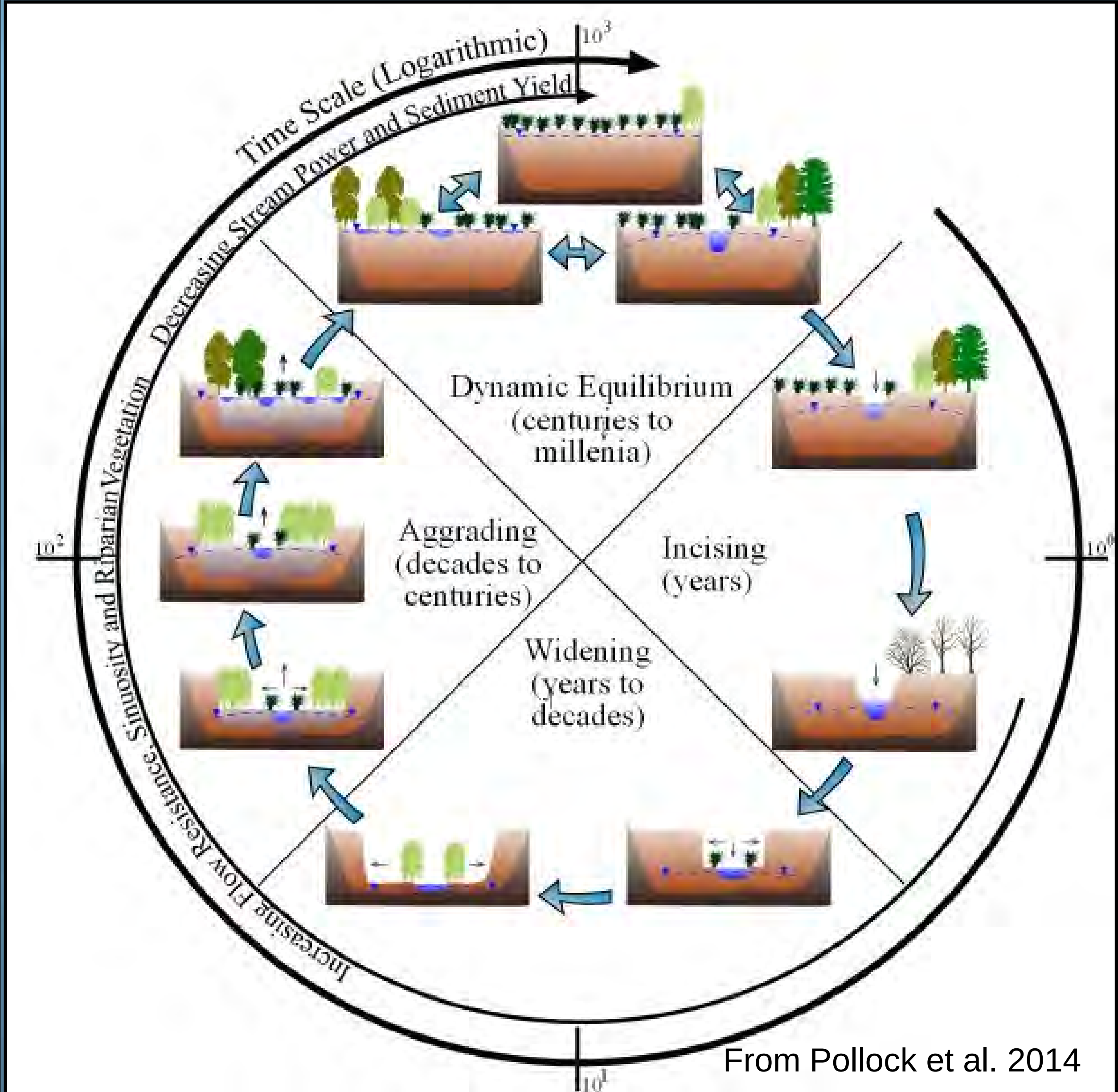
Beaver dams create complex habitat that provide many benefits



Natural Recovery Rates Can be Long



From Pollock et al. 2014

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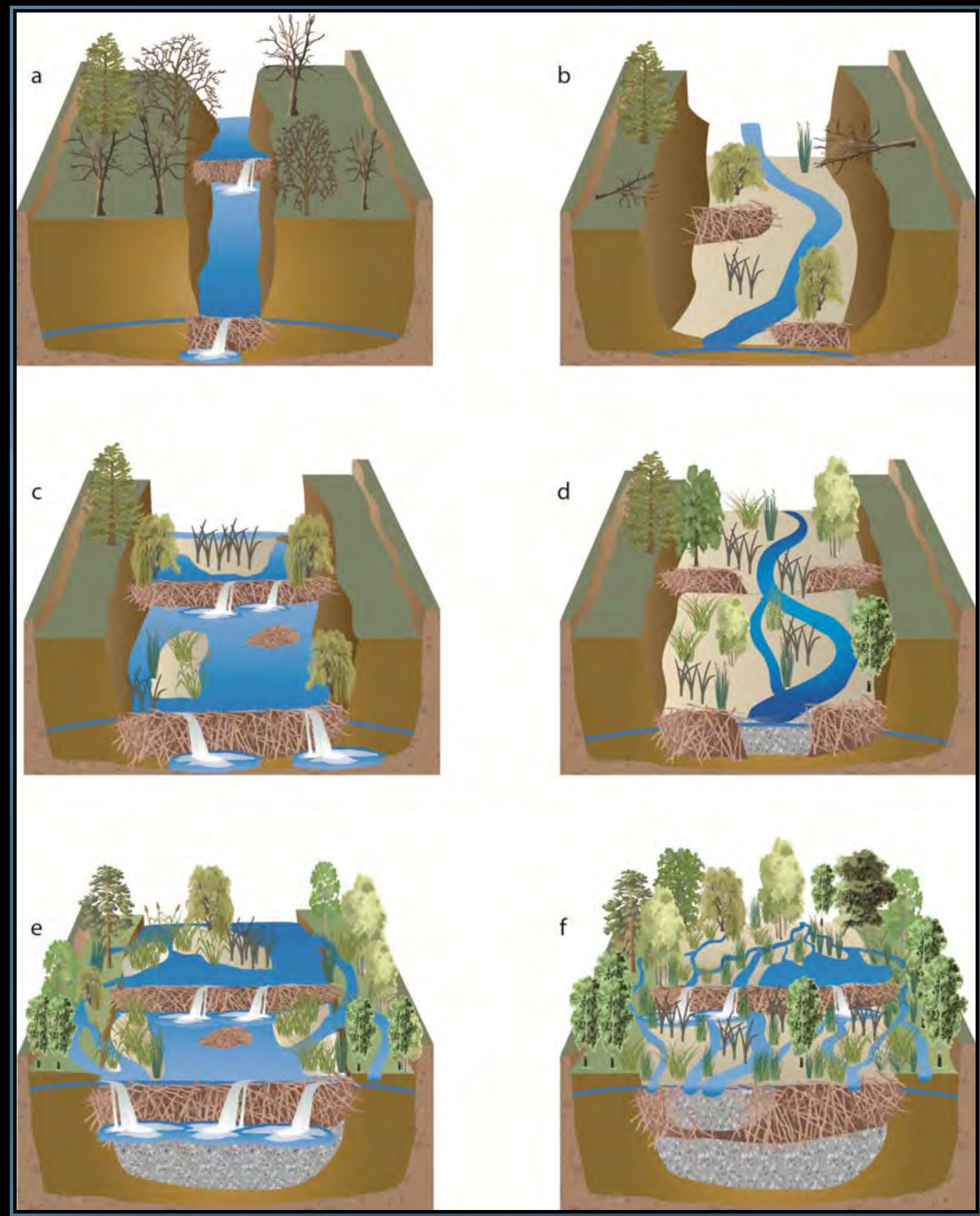
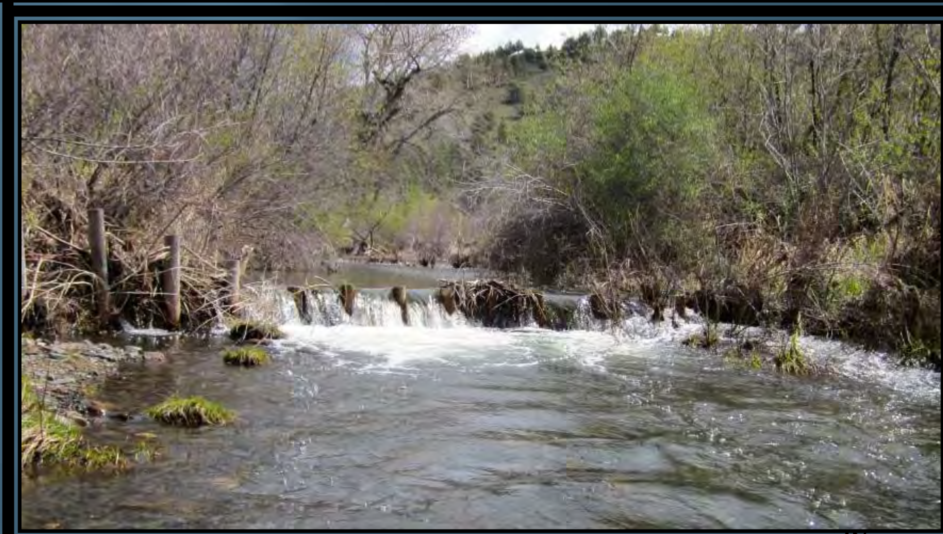
Beaver Dams

-Can reduce recovery times from Stage 1 to Stage 7-8/0 systems by 1-2 orders of magnitude (year to decades instead of decades to centuries)



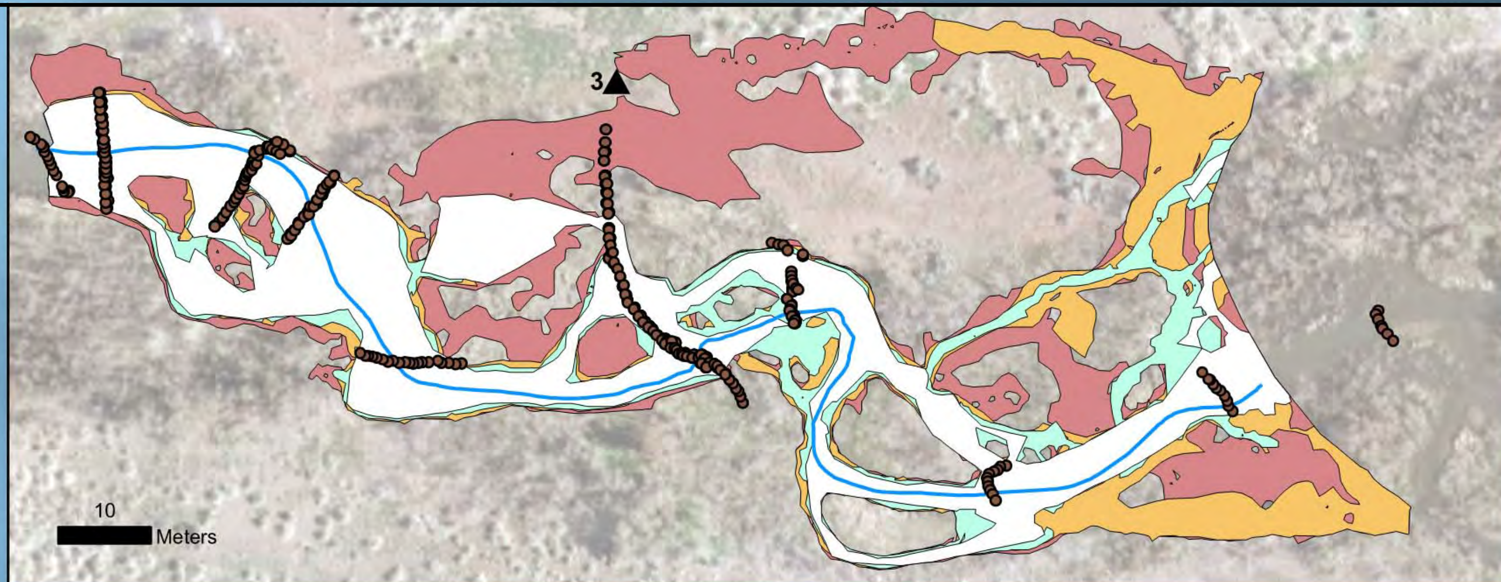
From Pollock et al. 2014

Beaver Dam Analogues

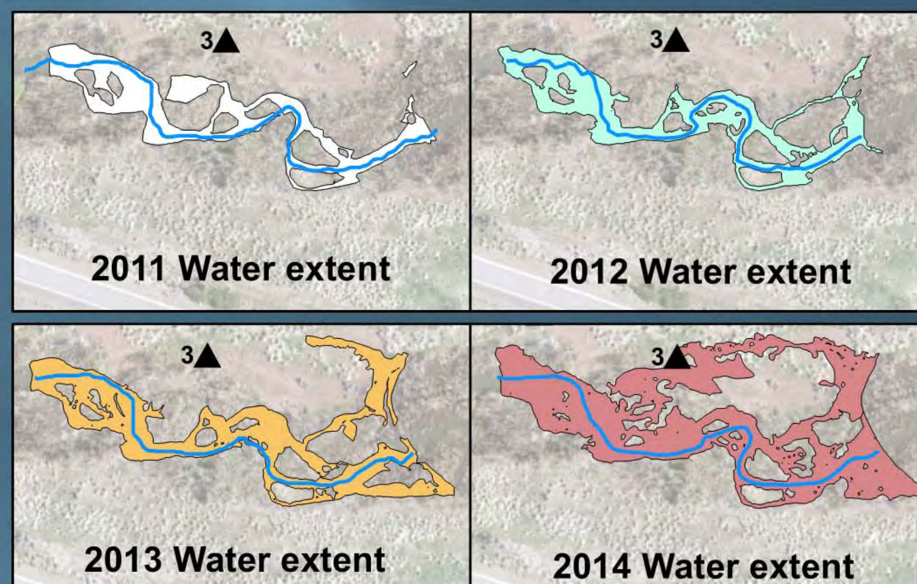


Example: Beaver and BDAs creating a zero order “channel”

Beaver and BDAs-a 5 year sequence



Carol Volk, Unpublished



Since 2009, a combination of BDAs and beaver turned a narrow single thread channel with an infrequently inundated floodplain into a multi-threaded channel with water levels close to the floodplain surface most of the year

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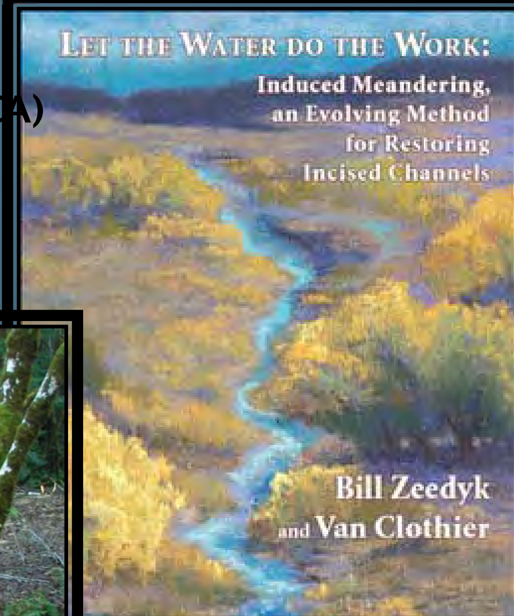
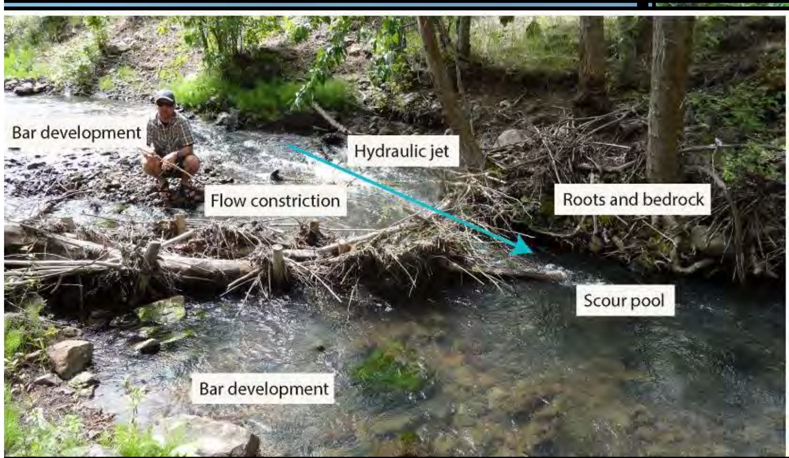
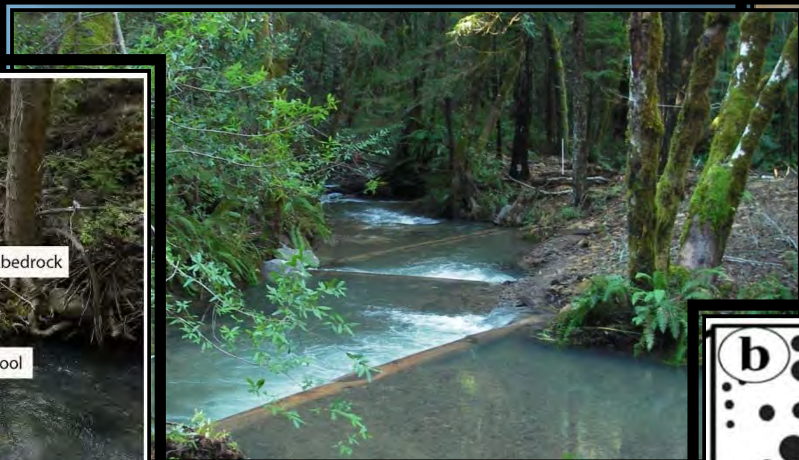
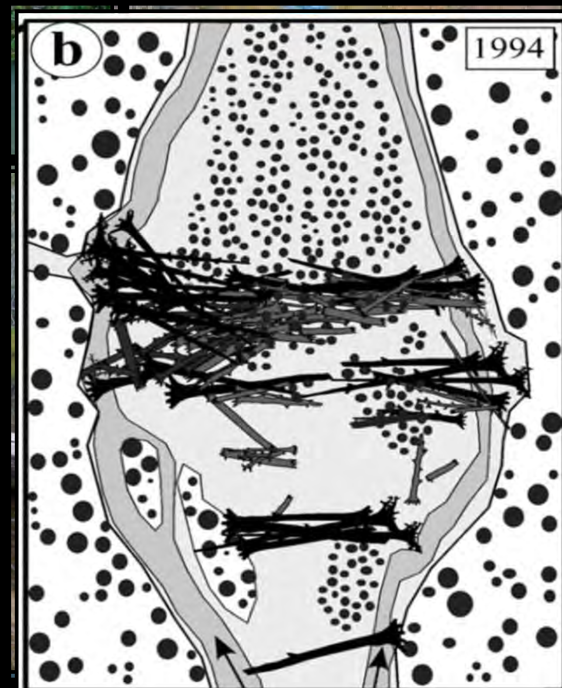
Other Biogenic Tools

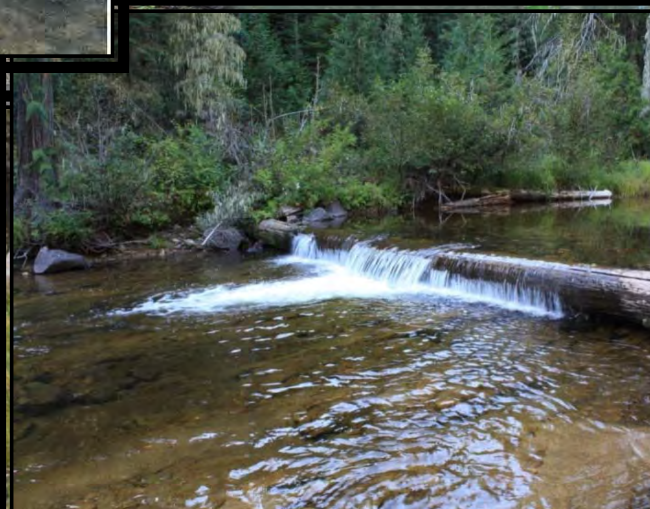
Log Steps (USFS-many locales, T. McKee-Mattole R., CA)
Wood Jams (Many locales, e.g. Rocco Fiori, Klamath River, CA)
Gravel Dams (Campbell Ranch-Silvies R., OR, CDA Tr., ID)
Meander Dams (Quivira Coalition, NM)
Constriction Dams (N. Bouwes-Asotin R., WA)
Choke Dams (P. Devries-Idaho)











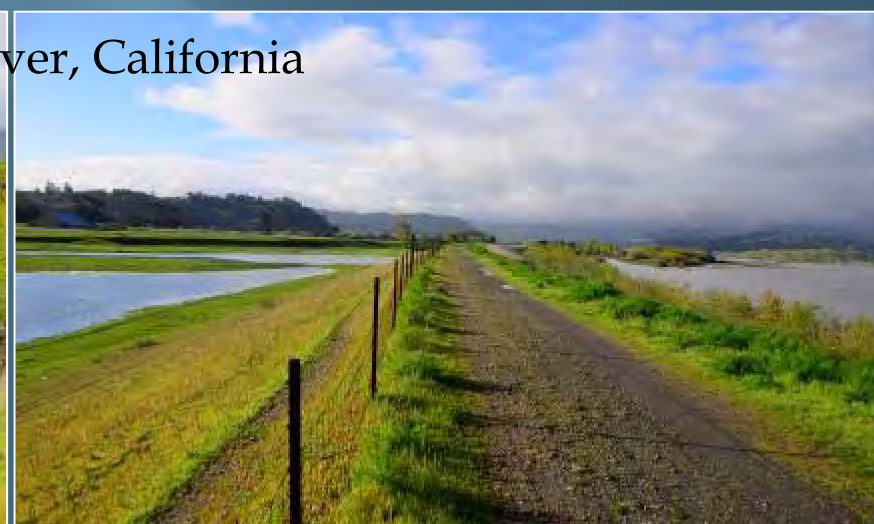
Wood Jams


Hunter Ck-First
flows 2014


Post 5-yr RI flood WY15
Courtesy of Rocco Fiori

Levee Removal

- Can (re)create stage zero systems if channel is at grade or perched
- In incised systems, flow/sediment obstructions can accelerate habitat recovery

Eel River, California

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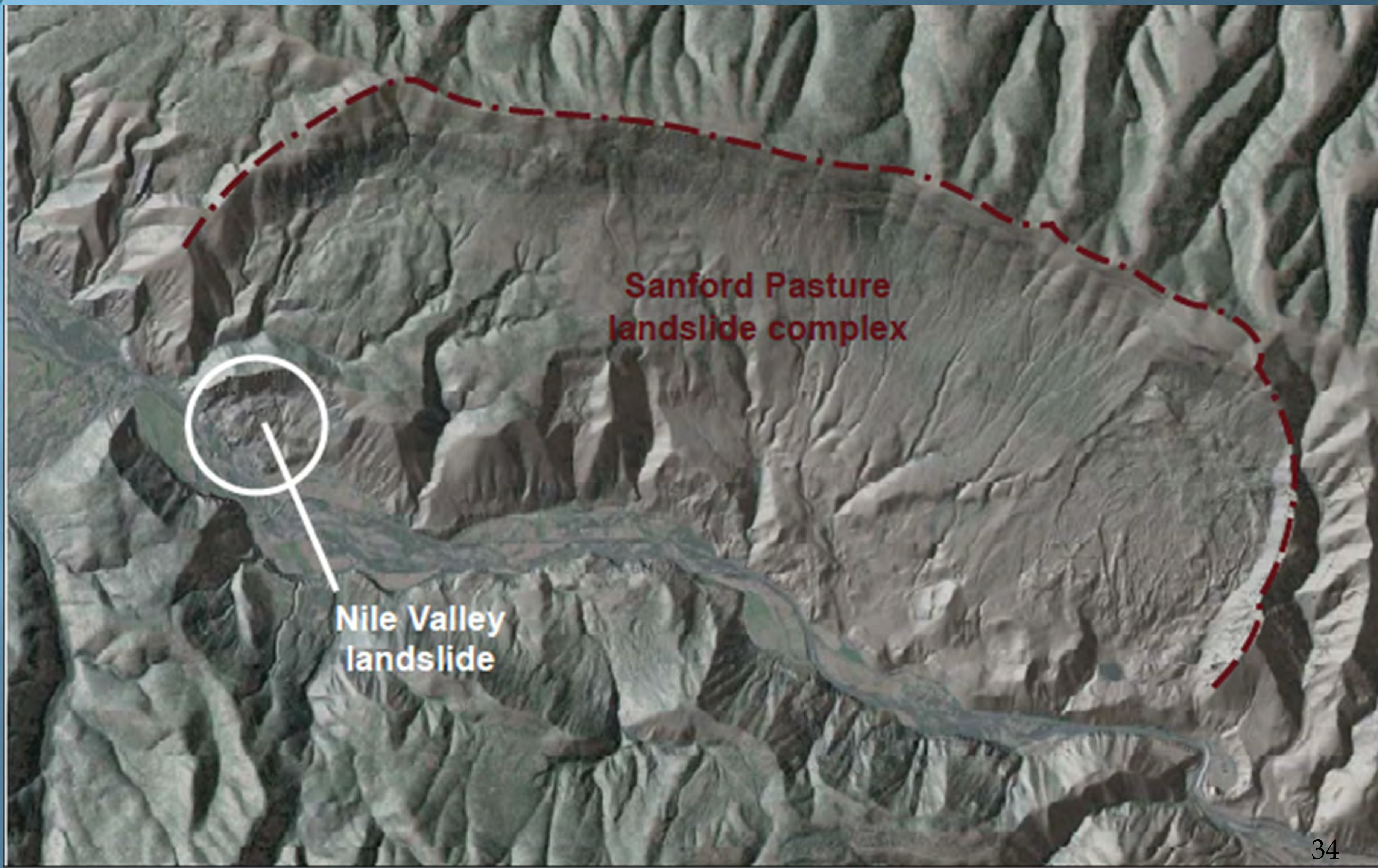
Landslides-Naches River, WA (Nile Valley)



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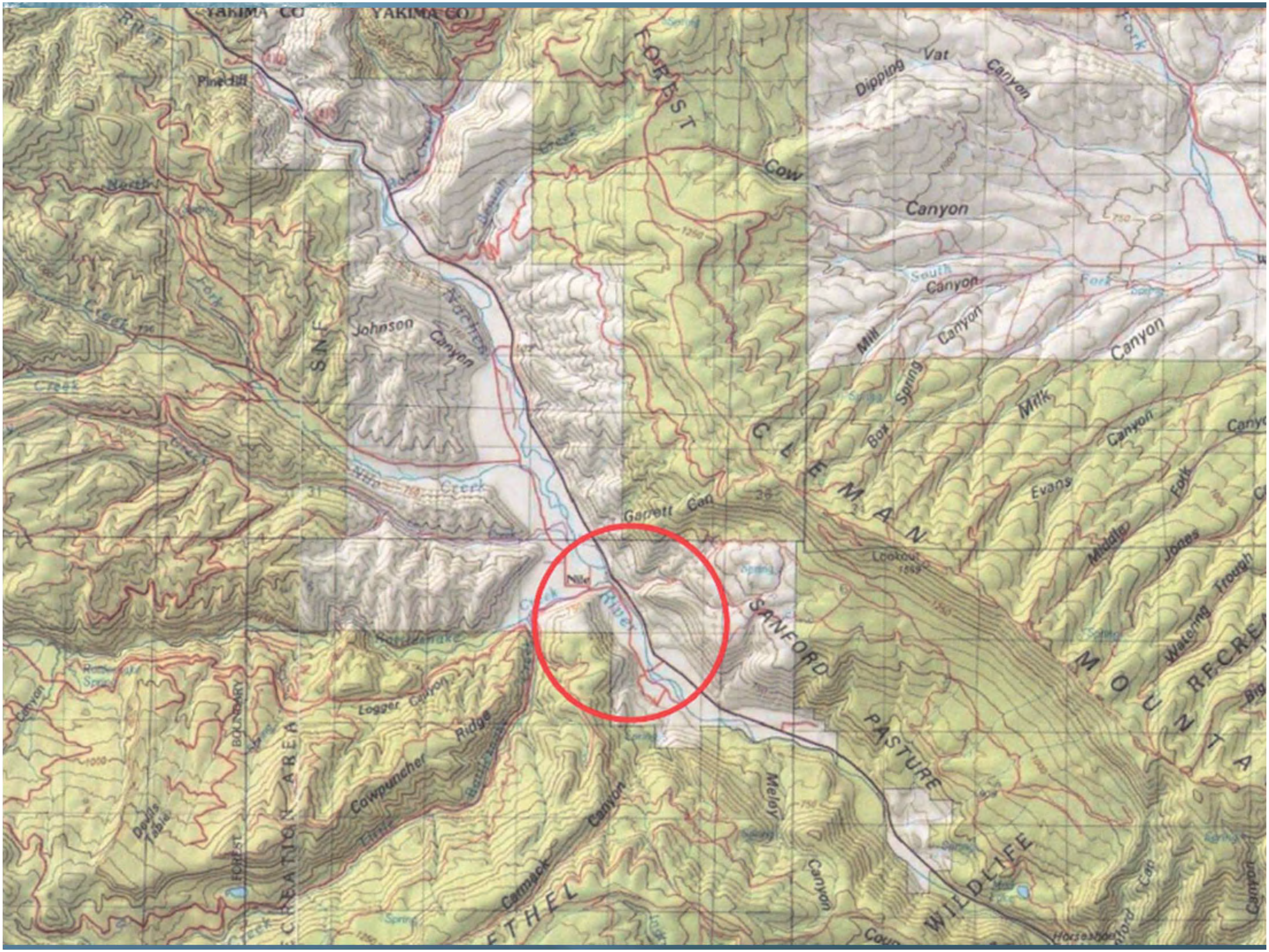
YAKIMA CO
YAKIMA CO
Pinecliff
FOREST
Cow
Dipping
Vat
Canyon
Canyon
South
Canyon
Fork
Mill
Canyon
Canyon
Johnson
Canyon
Naches
North
Fork
Creek
Creek
Nile
Creek
Box
Spring
Milk
Canyon
Canyon
Evans
Middle
Fork
Jones
Trough
Watering
Gapett Can
CLEMAN
Lookout
SANFORD
PASTURE
WILDLIFE
MOUNTA
RECREA
Nile
River
Creek
Rattlesnake
Logger Canyon
Ridge
Cowpuncher
Devils Table
BOUNDARY
FOREST
RECREATION AREA
Canyon
Carmack
ETHEL
Meloy
Canyon
Spring
Horseshoe
Canyon

Landslides Create Good Salmon Habitat

Controls on valley width in mountainous landscapes: The role of landsliding and implications for salmonid habitat

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ABSTRACT

A fundamental yet unresolved question in fluvial geomorphology is what controls the width of valleys in mountainous terrain. Establishing a predictive relation for valley floor width is critical for realizing links between aquatic ecology and geomorphology because the most productive riverine habitats often occur in low-gradient streams with broad floodplains. Working in the Oregon Coast Range (western United States), we used airborne lidar to explore controls on valley width, and couple these findings with models of salmon habitat potential. We defined how valley floor width varies with drainage area in a catchment that exhibits relatively uniform ridge-and-valley topography sculpted by shallow landslides and debris flows. In drainage areas >0.1 km^2, valley width increases as a power law function of drainage area with an exponent of ~0.6. Consequently, valley width increases more rapidly downstream than channel width (exponent of ~0.4), as derived by local hydraulic geometry. We used this baseline valley width–drainage area function to determine how ancient deep-seated landslides in a nearby catchment influence valley width. Anomalously wide valleys tend to occur upstream of, and adjacent to, large landslides, while downstream valley segments are narrower than predicted from our baseline relation. According to coho salmon habitat-potential models, broad valley segments associated with deep-seated landsliding resulted in a greater proportion of the channel network hosting productive habitat. Because large landslides in this area are structurally controlled, our findings indicate a strong link between geologic properties and aquatic habitat.

sediment by providing space for the formation of debris flow fans. In addition, low-gradient broad valleys with old-growth forest store the great majority of above-ground and below-ground carbon in mountain streams (Wohl et al., 2012). Understanding the links between hillslope processes and riverine habitat is particularly important for Pacific salmon (*Oncorhynchus* spp.) because these fish are intricately tied to Pacific Rim topography (Montgomery, 2000; Waples et al., 2008).

The goals of this paper are twofold. First, we seek to define an empirical relation between valley width and drainage area (akin to hydraulic geometry for river channels) in a setting with negligible influence from variable rock properties and deep-seated landslide activity. Our approach uses high-resolution topography generated from airborne lidar to define this baseline

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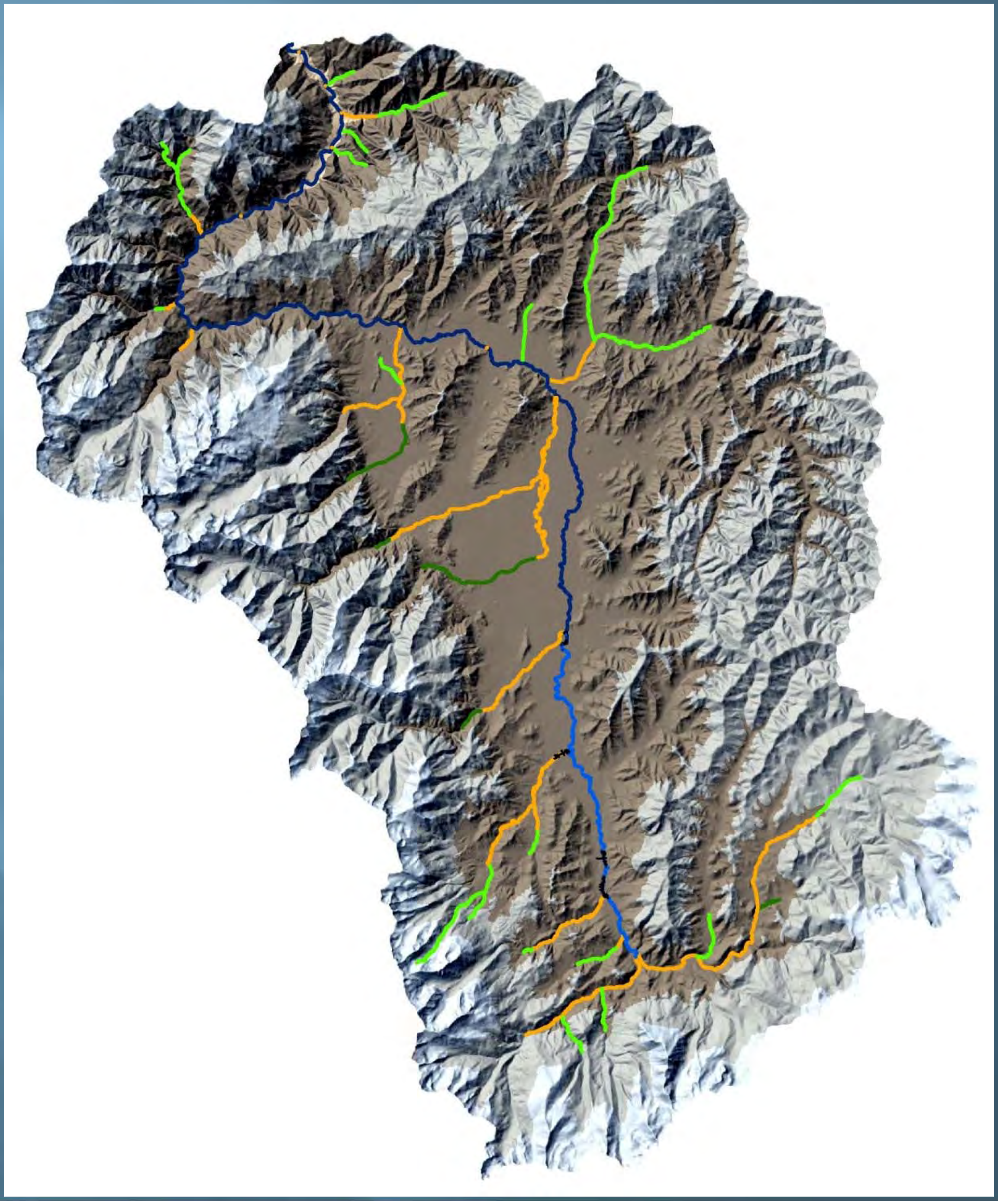
A Tectonic Dam-Scott River, Klamath Basin, CA




Oregon
Pacific
Ocean
Klamath Falls
Dorris
Tulelake
Happy Camp
Yreka
Montague
Fort Jones
Etna
Weed
Klamath
Orleans
Willow Creek
Helena
Weaverville
Lewiston
Hayfork
Scott River
Watershed
California

Sea Level Rise-
A Grade Changer

If all the ice melts, >200 ft sea level rise

- 1-10+ foot rise predicted in next 85 yr, but predicted rates keep increasing.
- Circa 5000 yrs for 200 foot rise (big error bars), but on the scale of the rise and fall of civilizations
- Need sediment to counteract rising seas.

National Geographic 2014

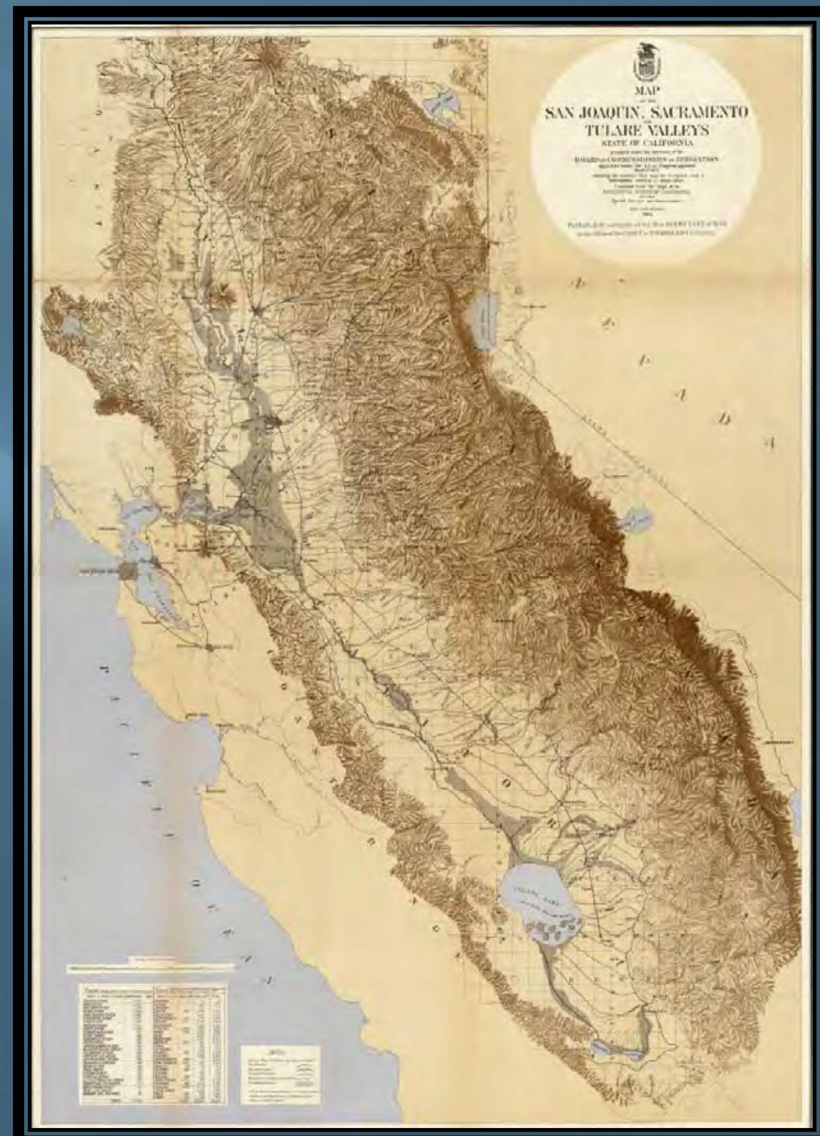
Current River Management Paradigms are Causing Big Problems

-Is this a map of the past or a blueprint for the future?

-A 150 Year Restoration Plan? (Delta is currently sinking)

-No farms, no food, but…
No (fresh)water no farms,
No sediment, no farmland

-Floods are inconvenient but droughts destroy civilizations



Conclusions

- Sediment is a resource
  - No sediment = no alluvial valleys
  - Base flow water elevation is key design feature
- Three components to stream restoration
  - Sediment, Water and Biota
- These processes play out at multiple spatio-temporal scales to:
  - Lower stream and valley slopes
  - Lower stream power per unit width
  - Increase retention rates of both sediment and water
  - Good for salmon (and farmers)

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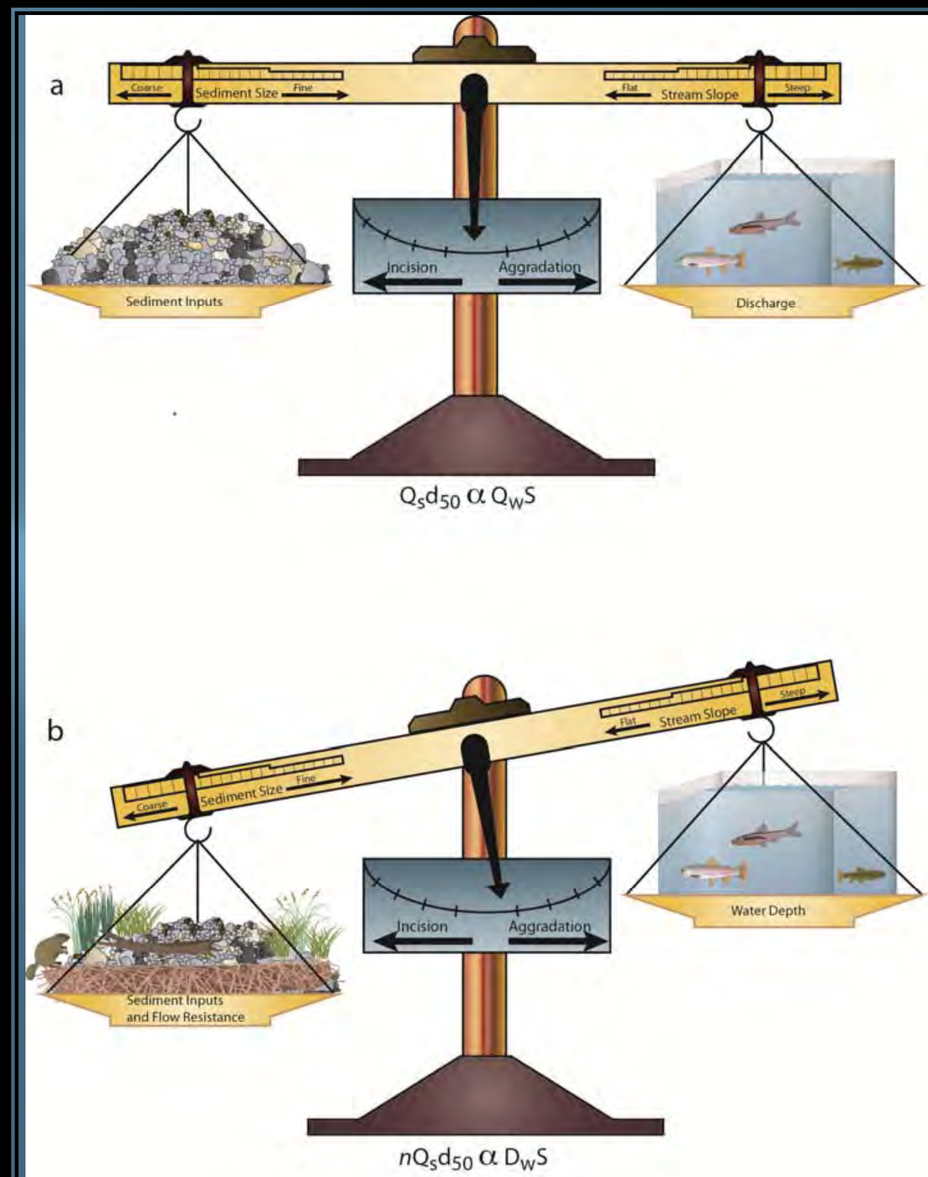
Continuity of Sediment Transport or Habitat formation?



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Stage Zero Restoration:
= Process discontinuity management = habitat management,
Does not = continuity mgmt=transport mgmt

- **Sediment = Essential ingredient**
  - Deposition and sorting
  - Aggradation
  - Erosion and avulsions
  - Sediment = a resource
  - No Sediment = No Valley floor
- **Water**
  - Flow diffusion
  - Groundwater recharge
  - Hyporheic exchange
  - Long inundation periods
  - Less distinction between wetlands and channels and floodplains

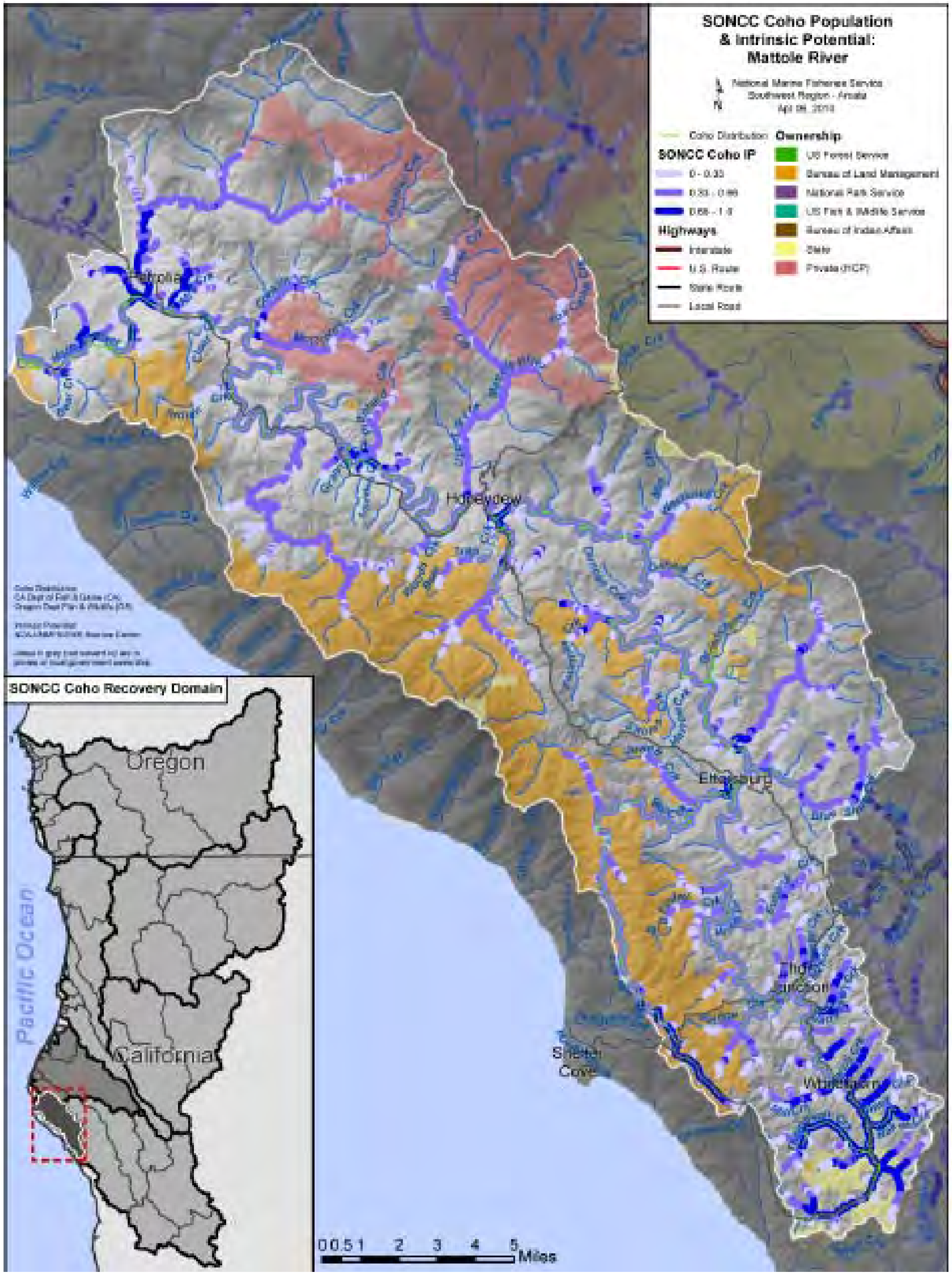
Addressing Channel Incision in the Mattole River headwaters

- Sam Flanagan, Bureau of Land Mgt., Arcata
- Brad Job, Pacific Watershed Associates
- Tasha McKee, Sanctuary Forest

with much support from:

- USFWS, Partners for Fish and Wildlife Program
- NOAA, Northwest Fisheries Science Center
- Mattole Salmon Group

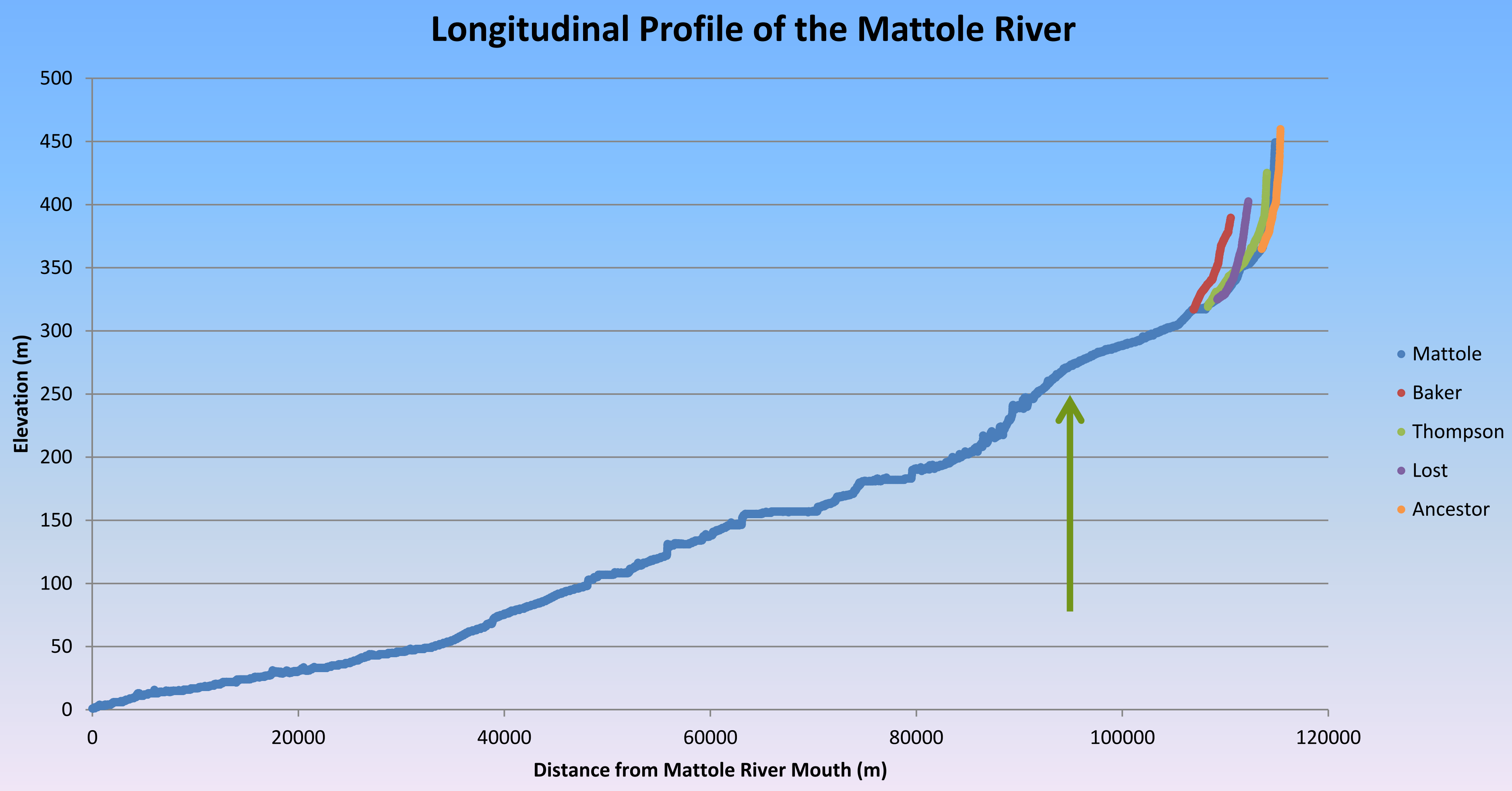

Processes
Objectives
Implementation
Preliminary Findings
Lessons learned
(so far)

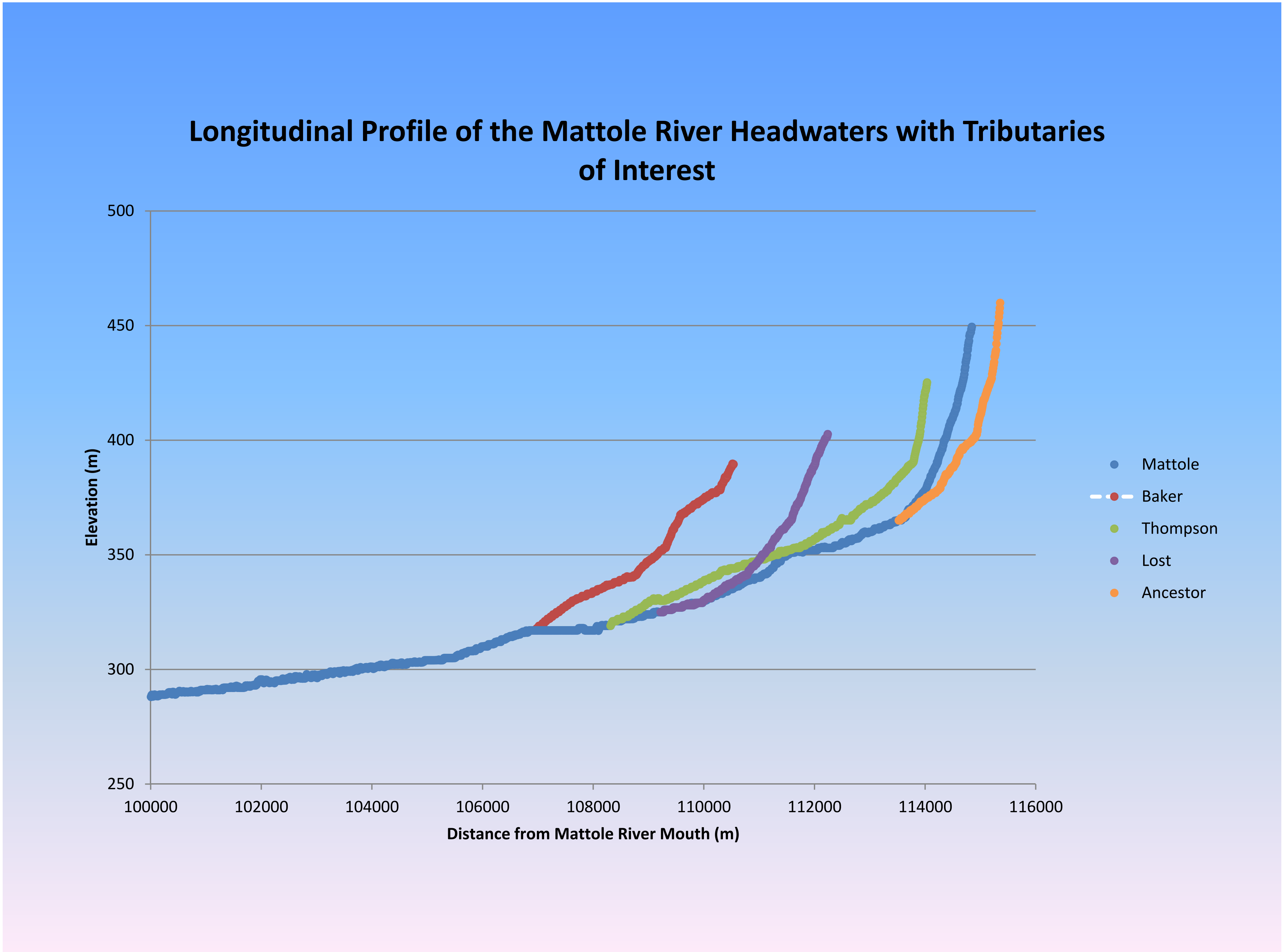


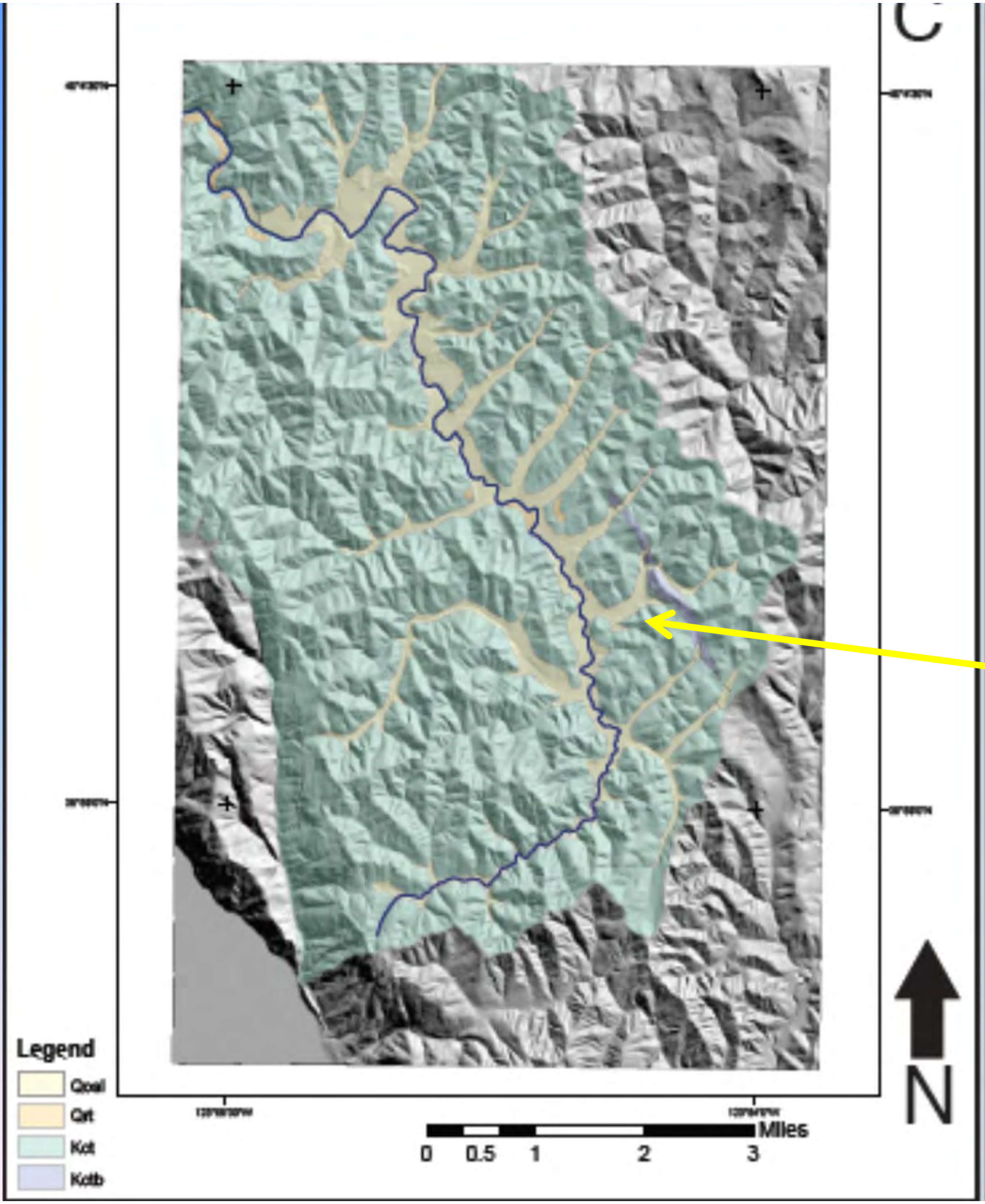
What incision looks like in the upper Mattole River

Drainage area: 790 km^2
(300 mi^2)

Low gradient headwaters




Longitudinal Profile of the Mattole River Headwaters with Tributaries of Interest
500
450
400
350
300
250
Elevation (m)
100000
102000
104000
106000
108000
110000
112000
114000
116000
Distance from Mattole River Mouth (m)
Mattole
Baker
Thompson
Lost
Ancestor

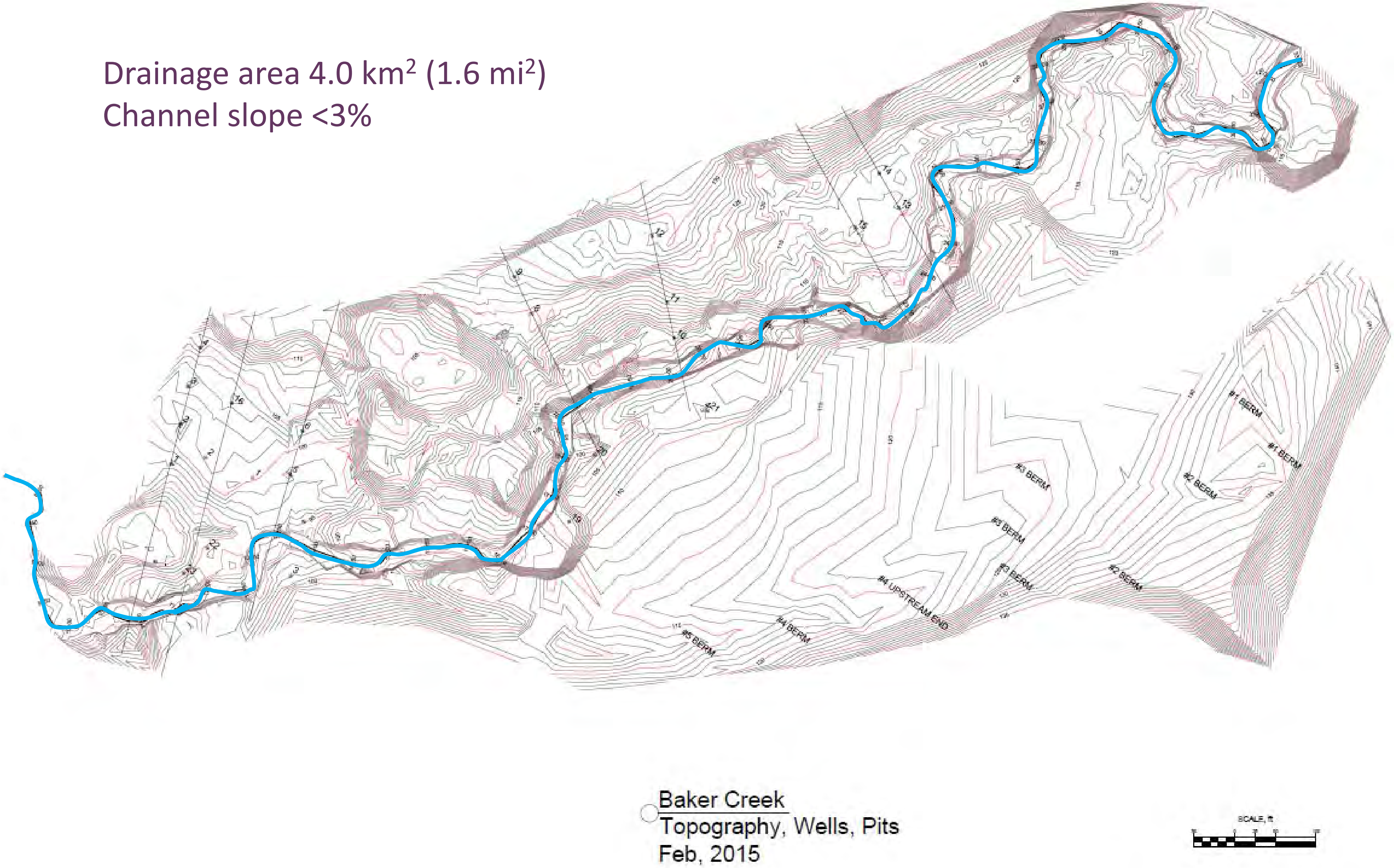


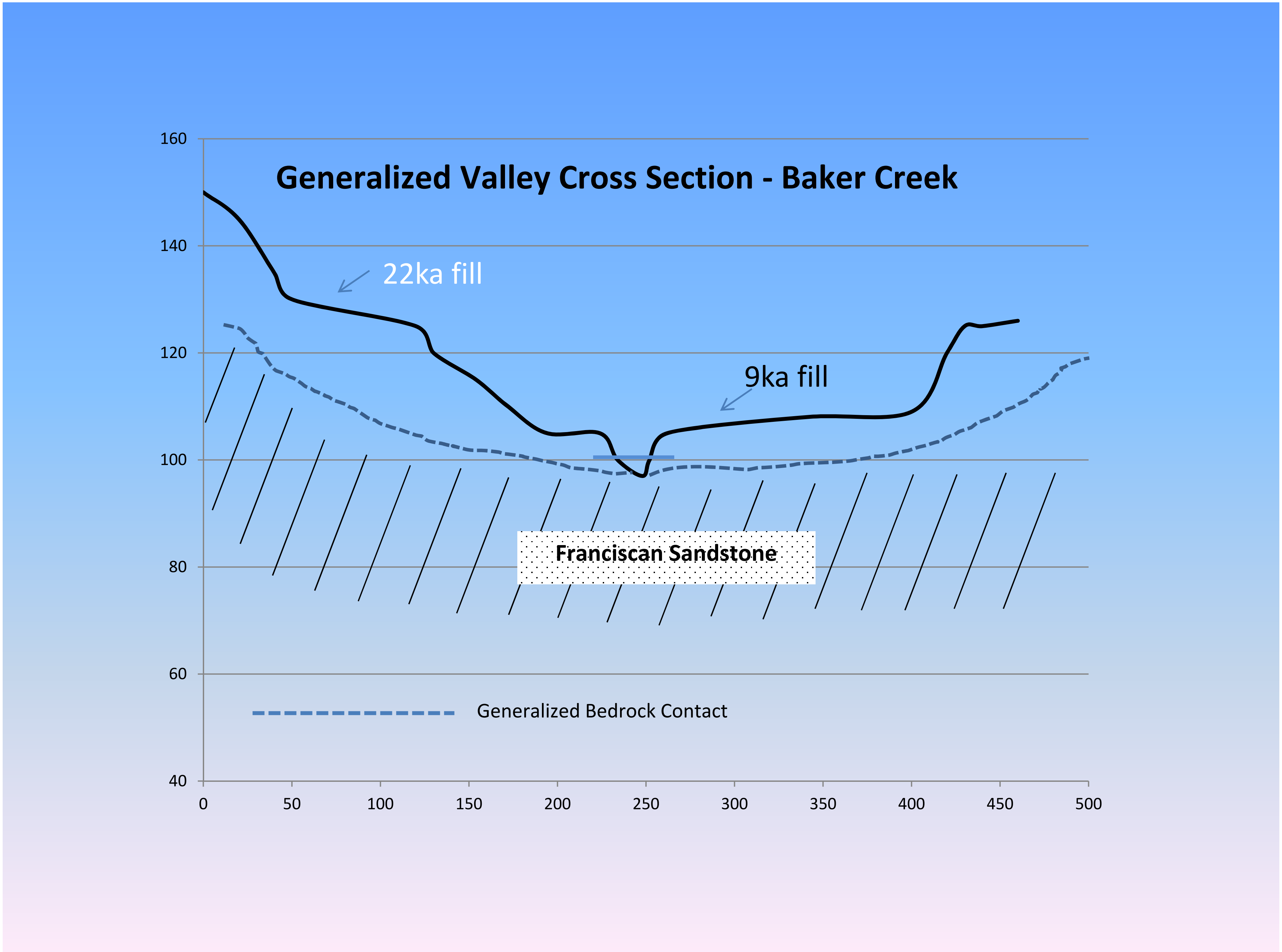
Gradients 1-3% in
lower reaches of tributaries.

Baker Creek

Baker Creek Project reach ~400m

Drainage area 4.0 km^2 (1.6 mi^2)
Channel slope <3%



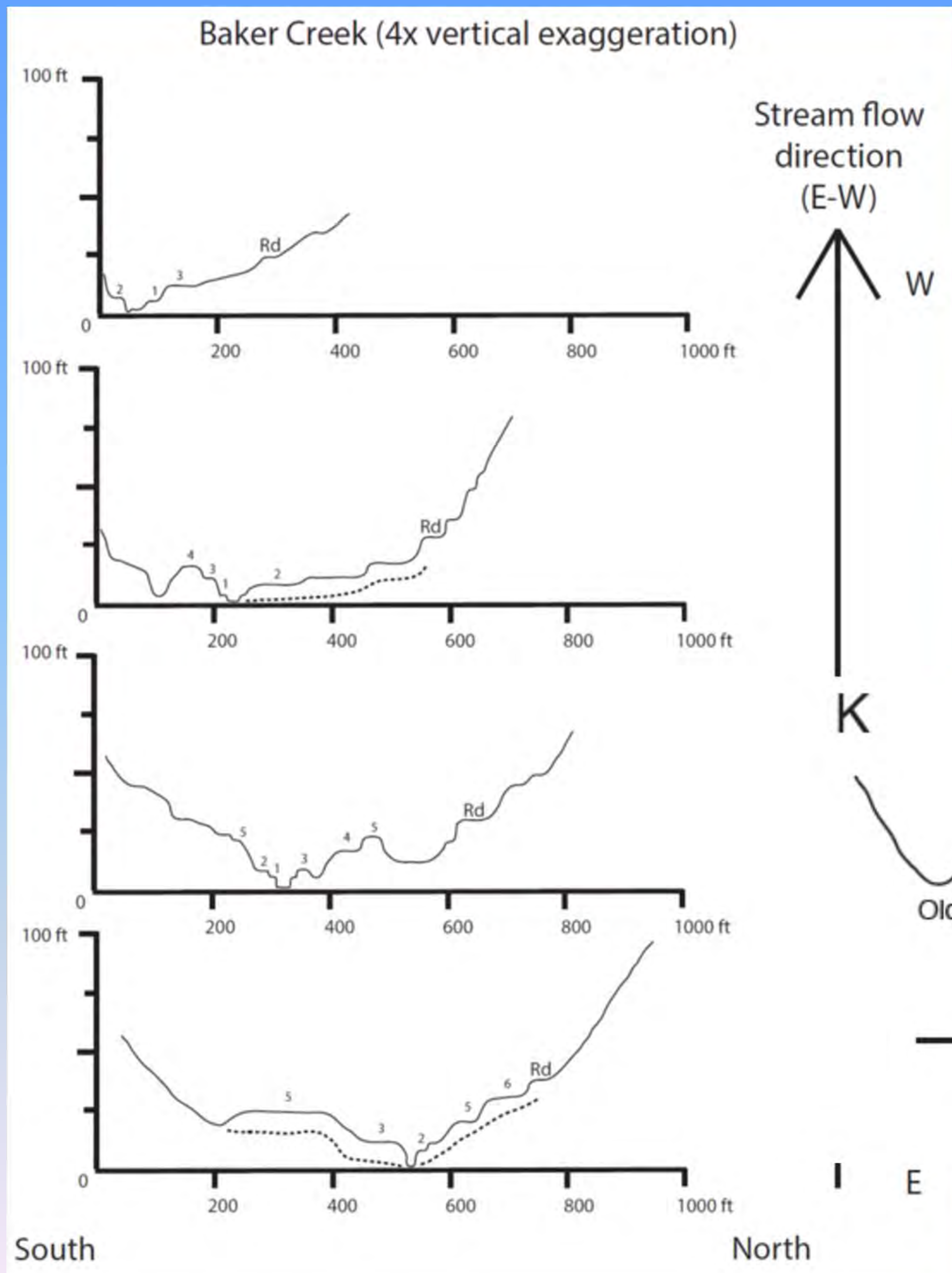

Generalized Valley Cross Section - Baker Creek
22ka fill
9ka fill
Franciscan Sandstone
Generalized Bedrock Contact
160
140
120
100
80
60
40
0
50
100
150
200
250
300
350
400
450
500

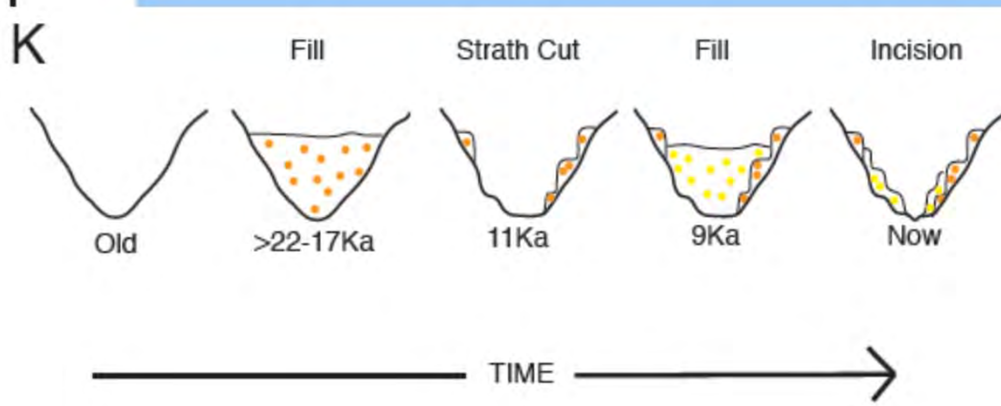
Why the Incision?

1. Cycles of cut and fill

2. Wood removal

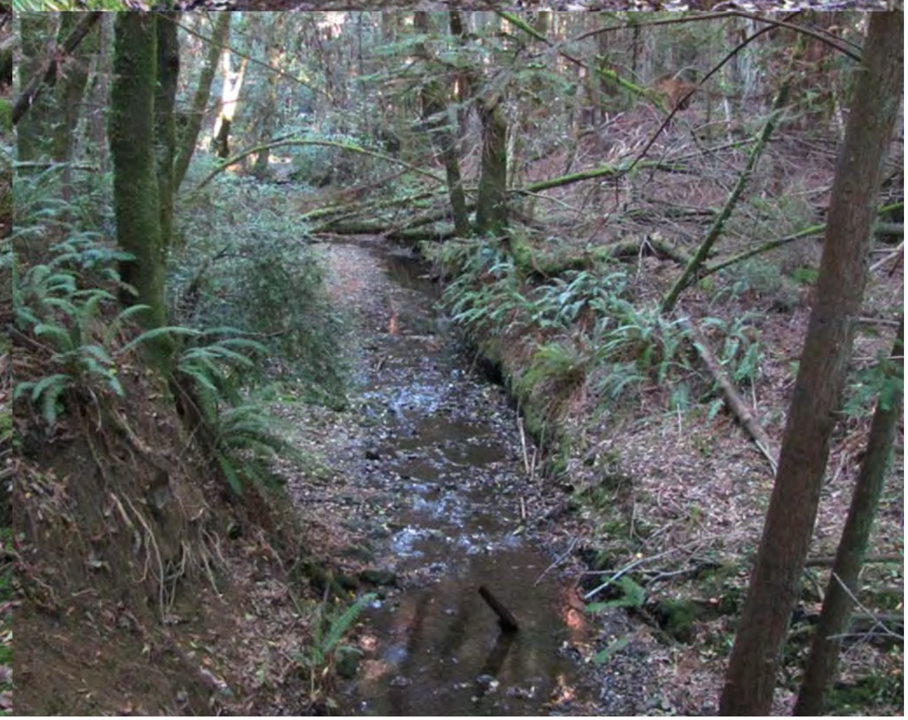
3. Channel relocation





Incision to bedrock

- No pool scour
- Lack of sediment accumulation
- High winter velocity
- BLAND reach



Salmonids in the Upper Mattole

- Mattole Coho Recovery Strategy 2011

- Extant coho in upper watershed

- Factors identified:
  - Loss of velocity refuge
  - floodplain disconnection
  - LWD removal up to 1983
  - Summer low flows w/ continued decline

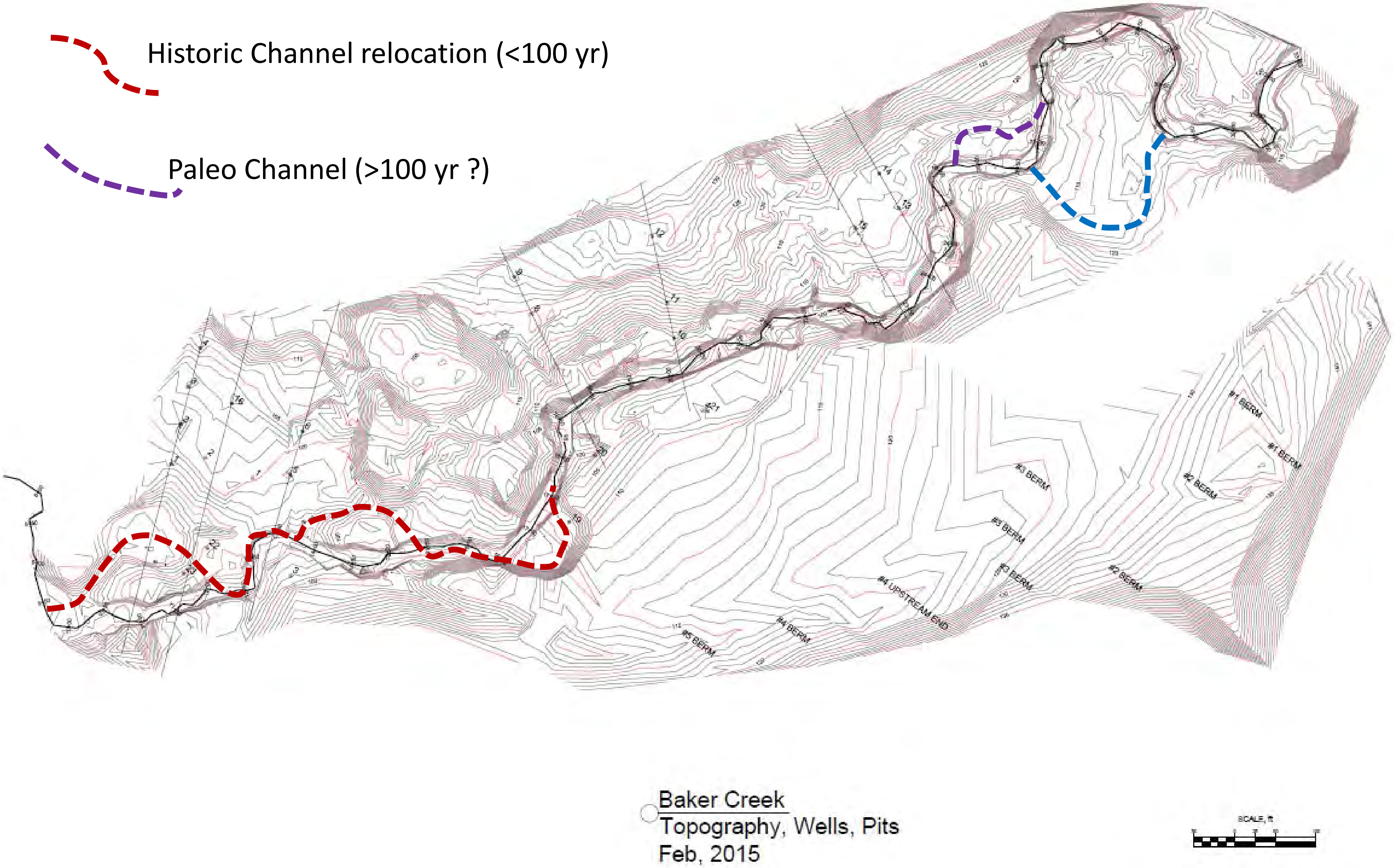
- No coho seen in Baker since 2006, but high I.P.

Opportunities and Objectives

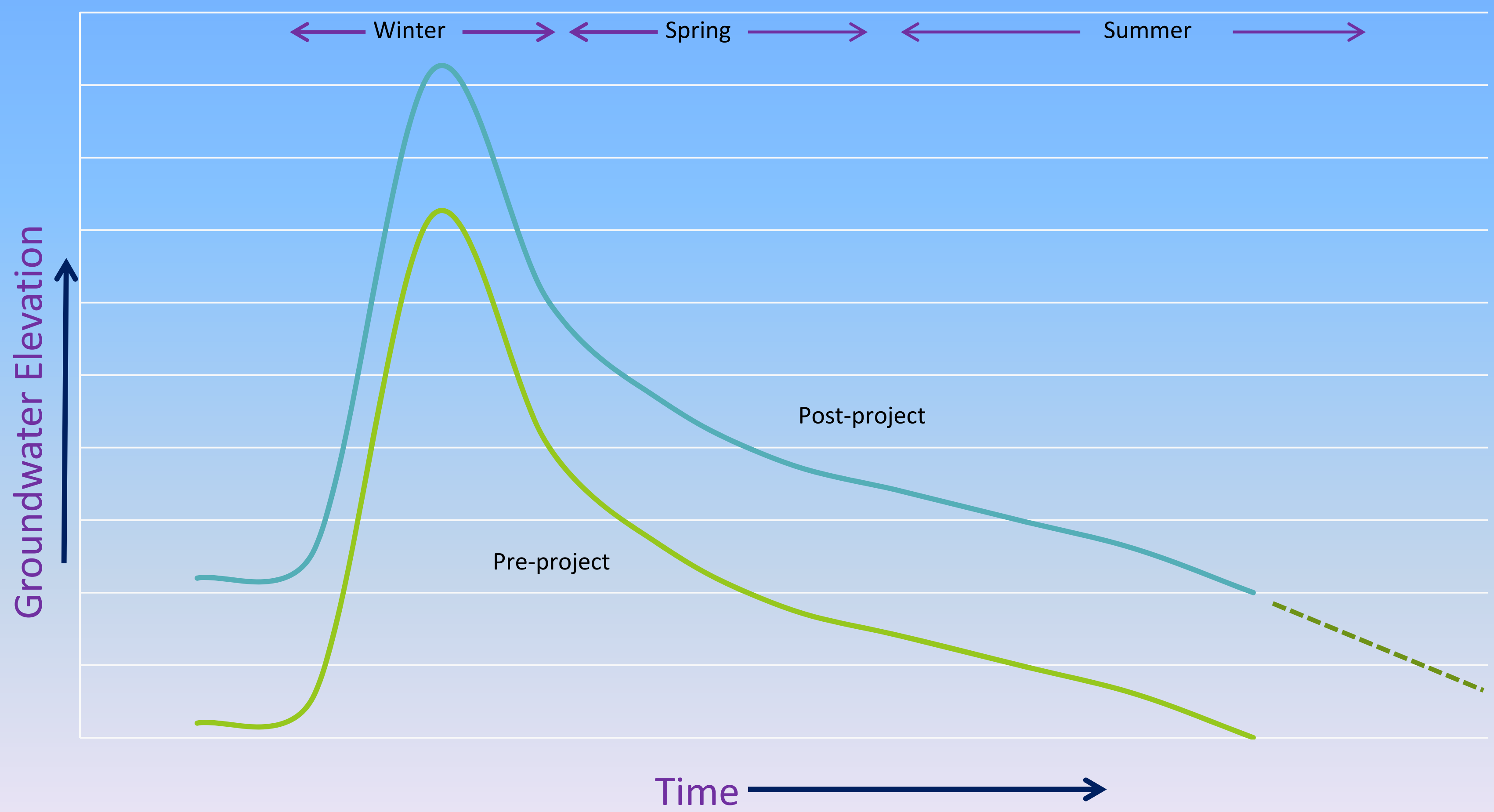
Objectives

- Inundate historic and paleo channel topography (off channel habitat)
- Increase Groundwater Storage in strath terrace alluvium (low flows)
- Improve in-channel habitat complexity

Leveraging Historic and Paleo Channel Features



Groundwater Objective



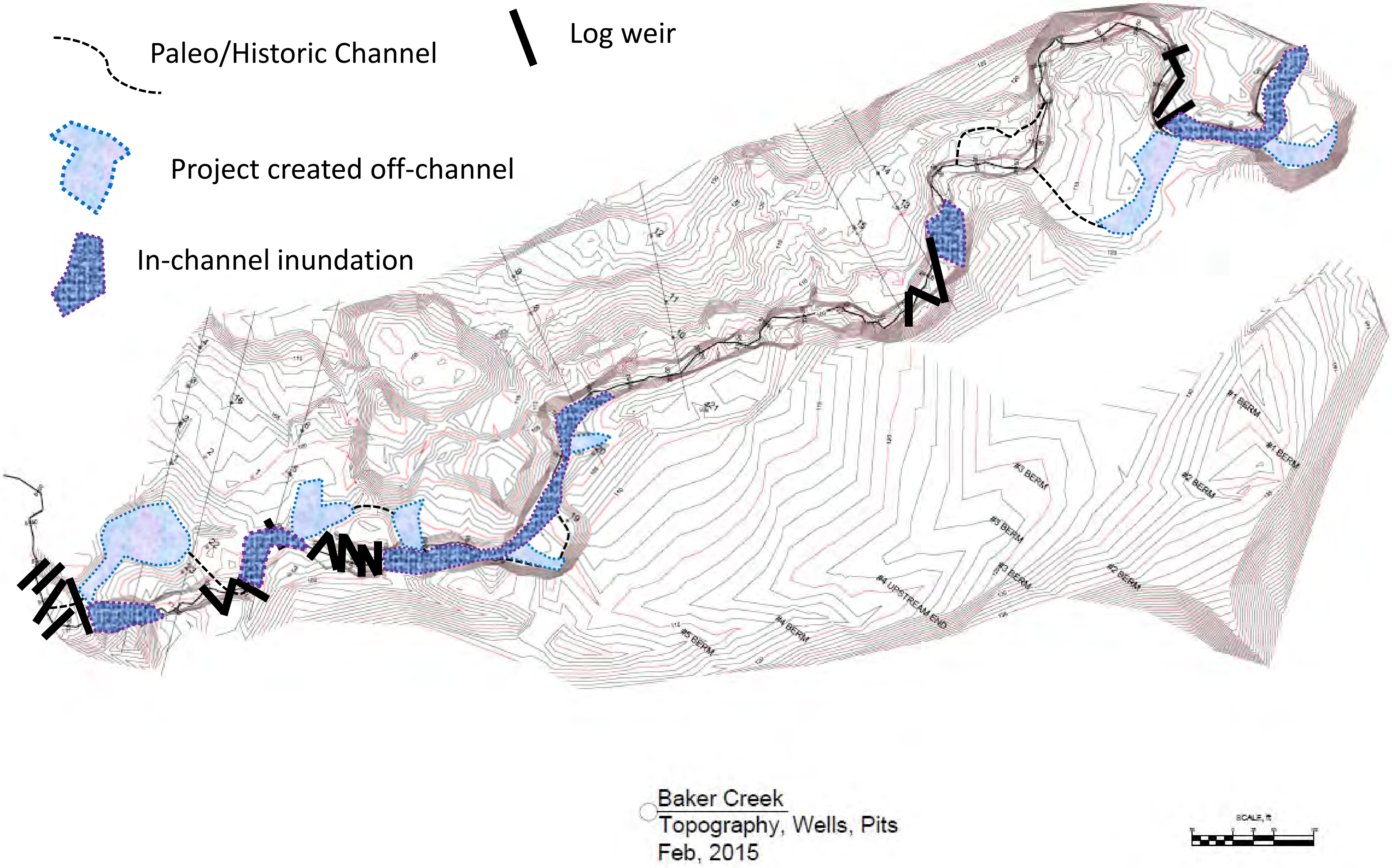
In-channel complexity

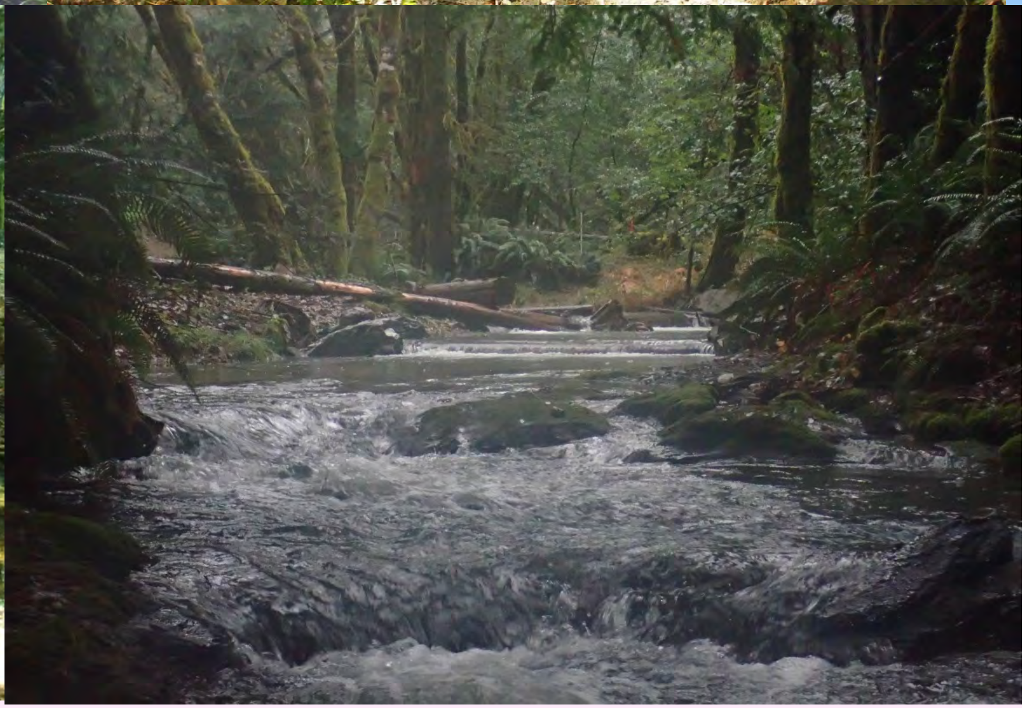
Two components

Designed log weirs

In-channel debris jams

Leveraging Historic and Paleo Channel Features



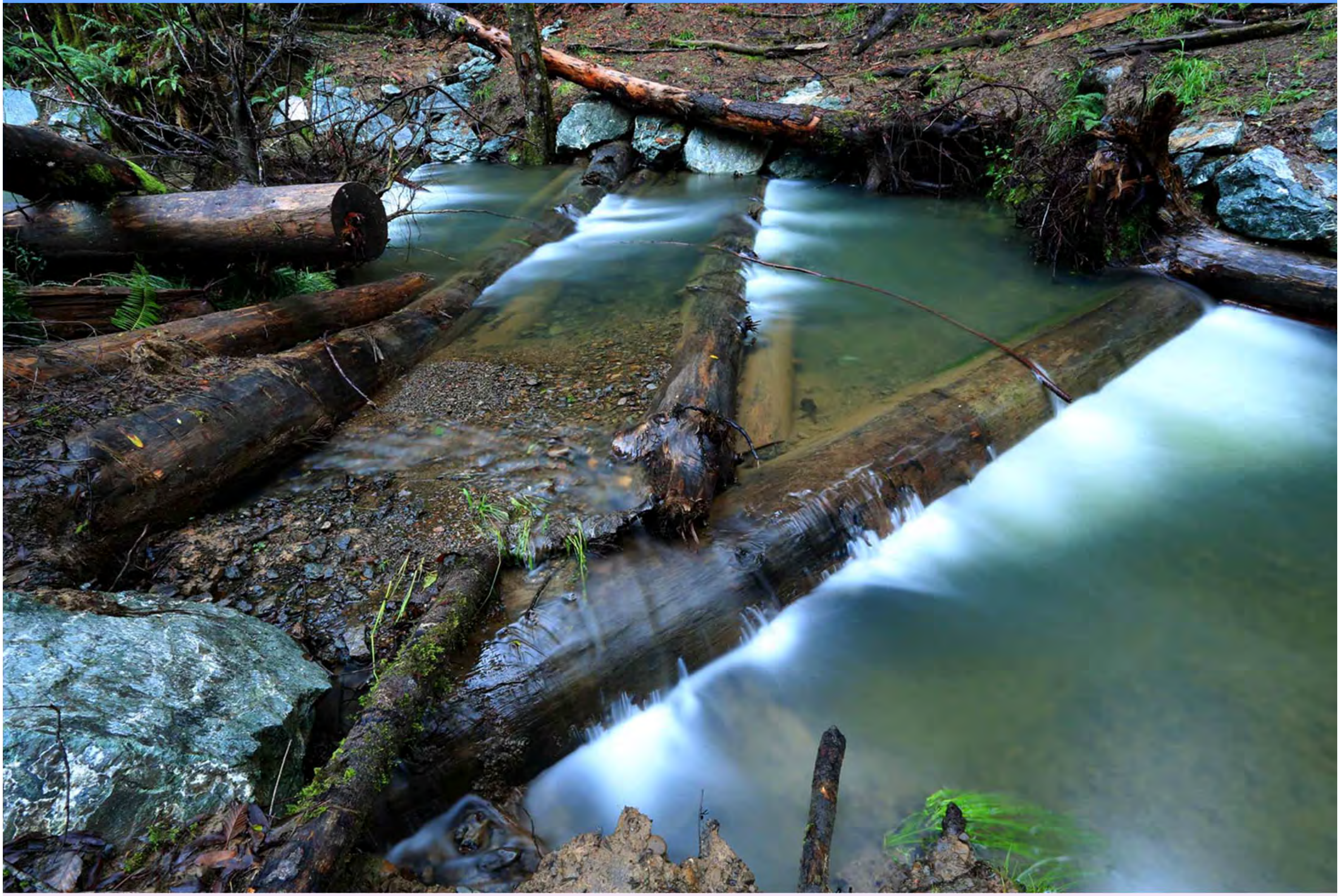




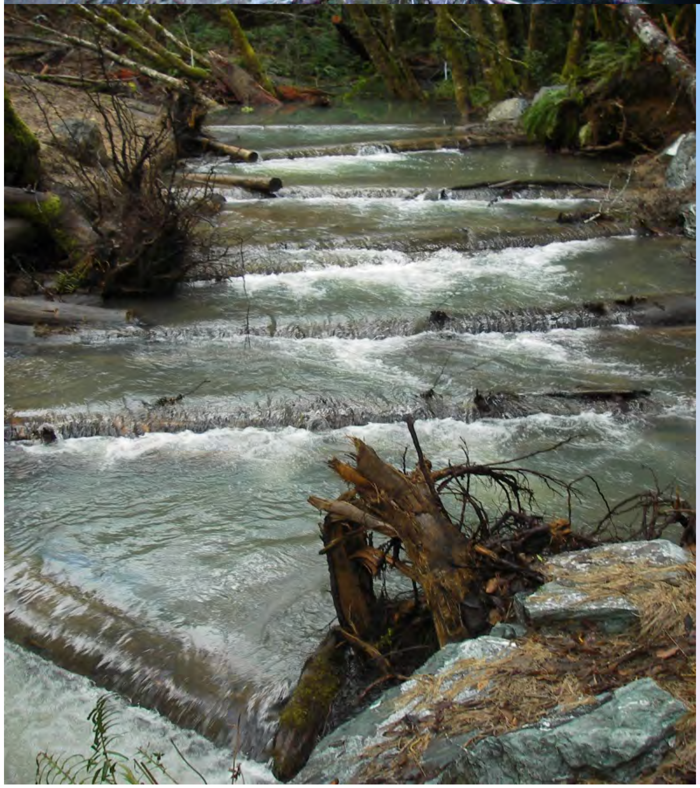
Secondary structures
in impounded segments

Weir Design Considerations

- Exposed, complex joints are, *well*, complex and subject to leakage
- Slope logs ~3% with sufficient bank armoring
- Lengthen flow path trough multiple weirs through a see-saw design
- Strive for weir spacing on the order of 1 channel width *
- Curved reach can employ a fan shape with lowermost log serving as key log and upstream logs radiating from key log – bank contact
- Expect sediment deficit




2014/03/06

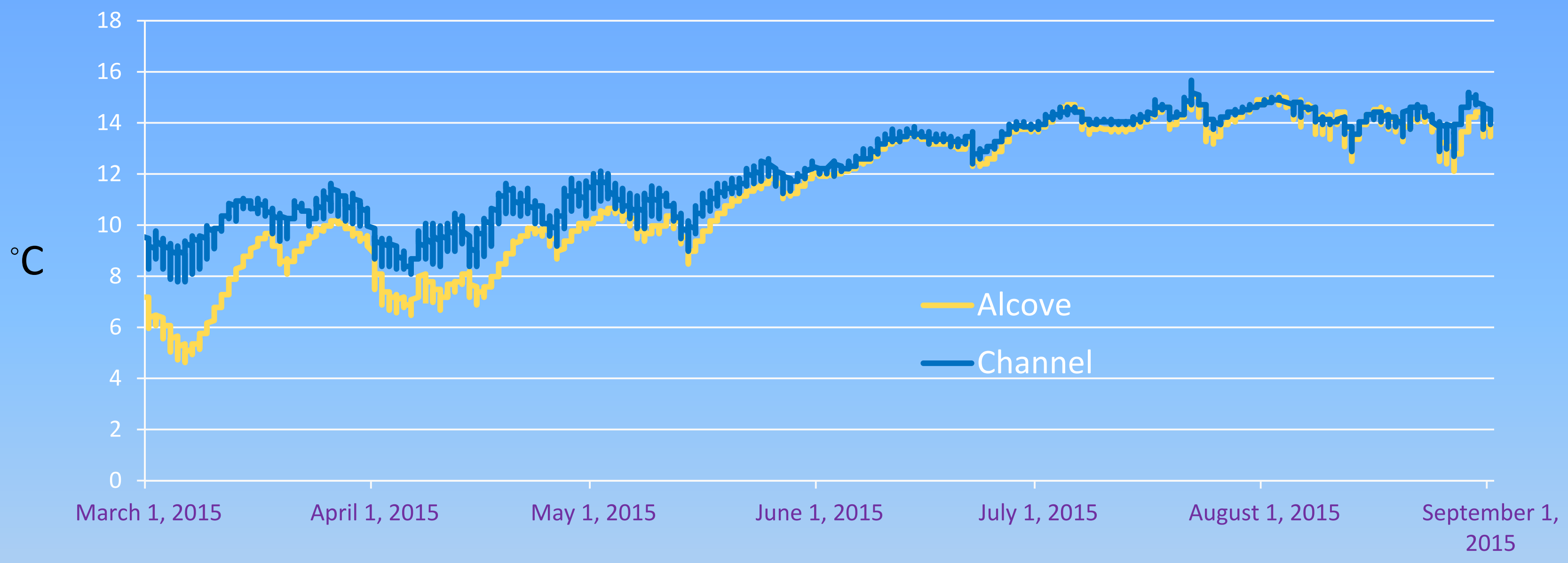



2014/03/06


2014/09/07

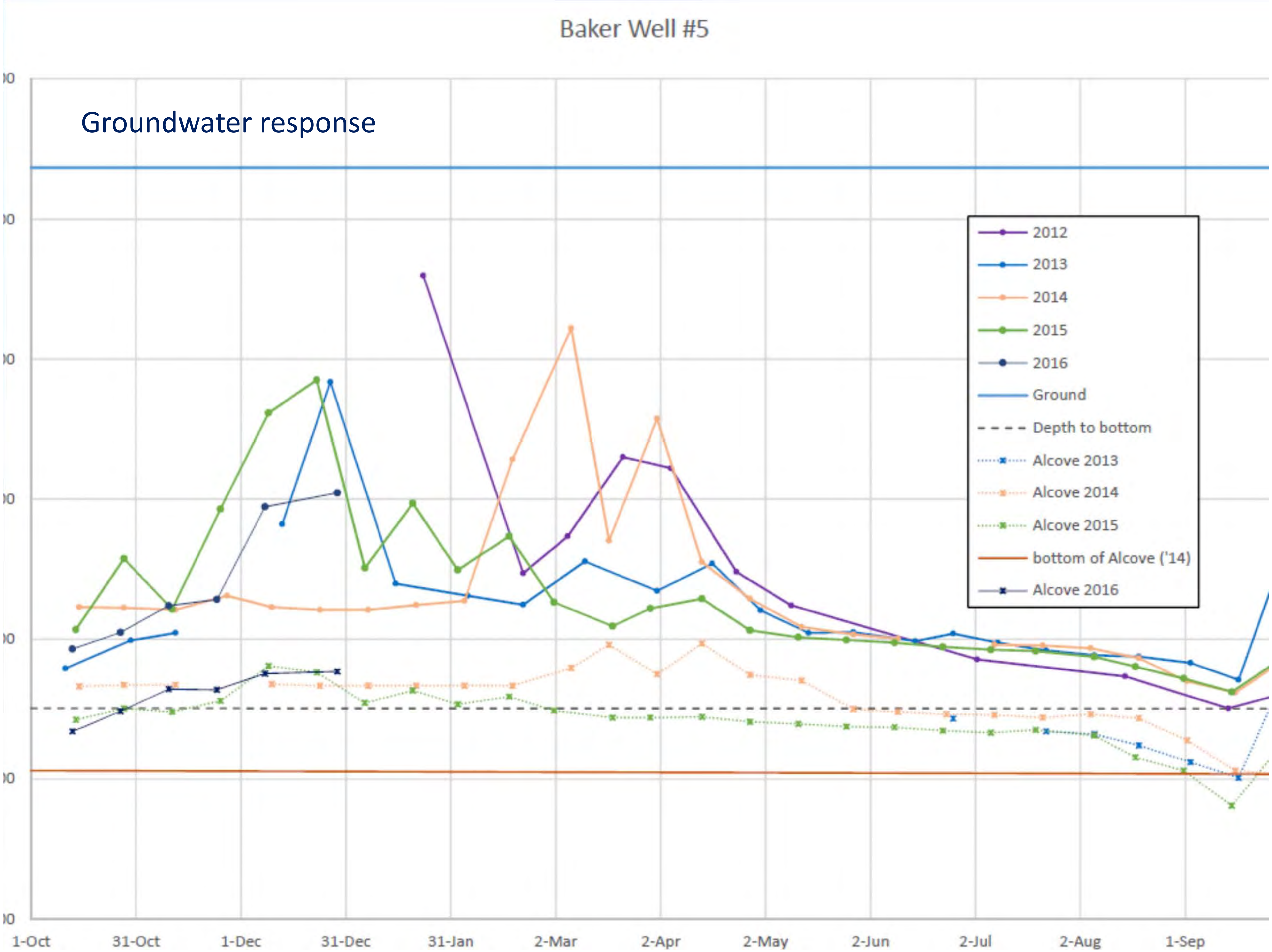
Physical and Biological Responses

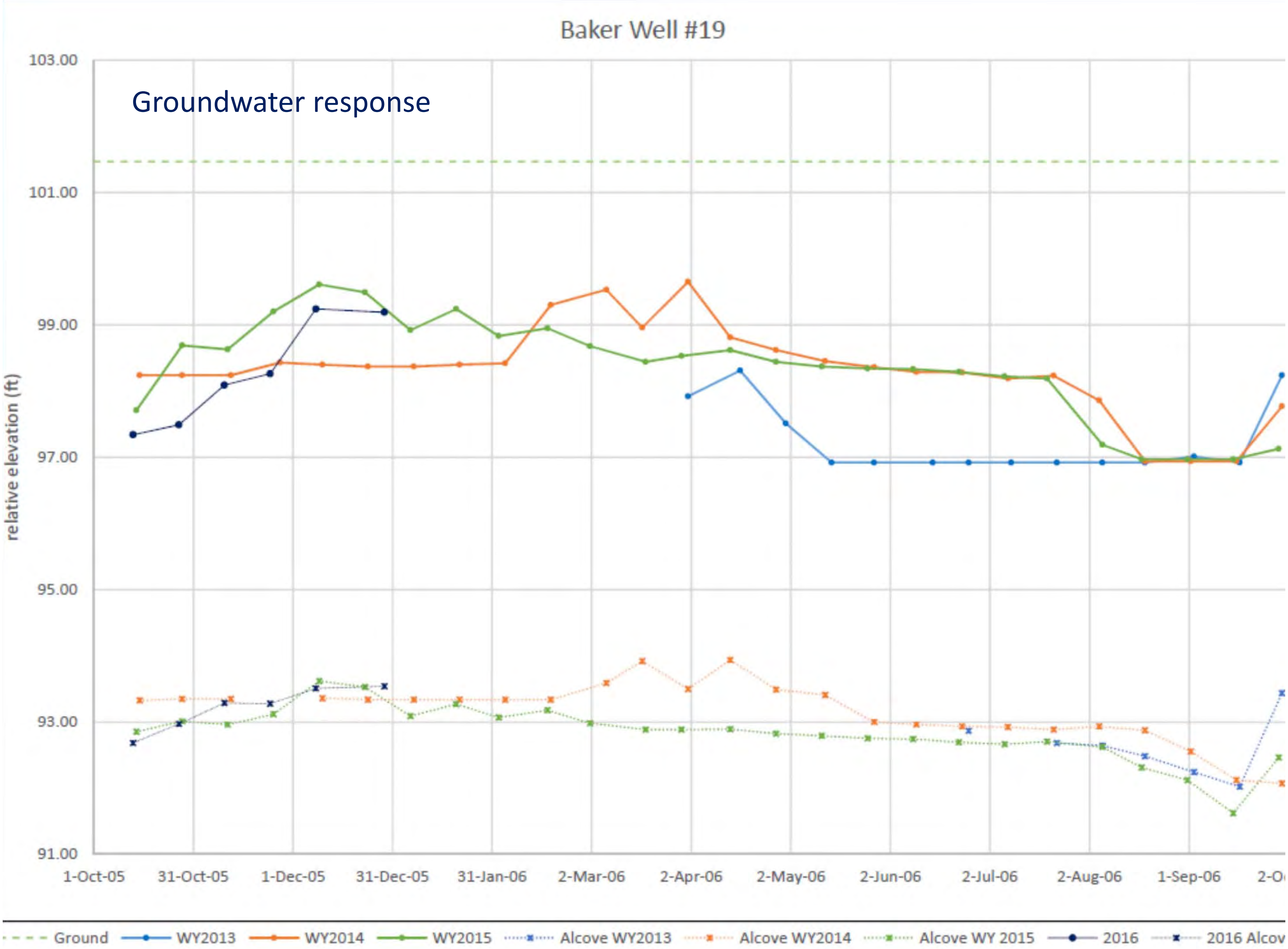
Temperature Comparison – Alcove and mainstem Baker Creek



<u>Dissolved Oxygen</u>

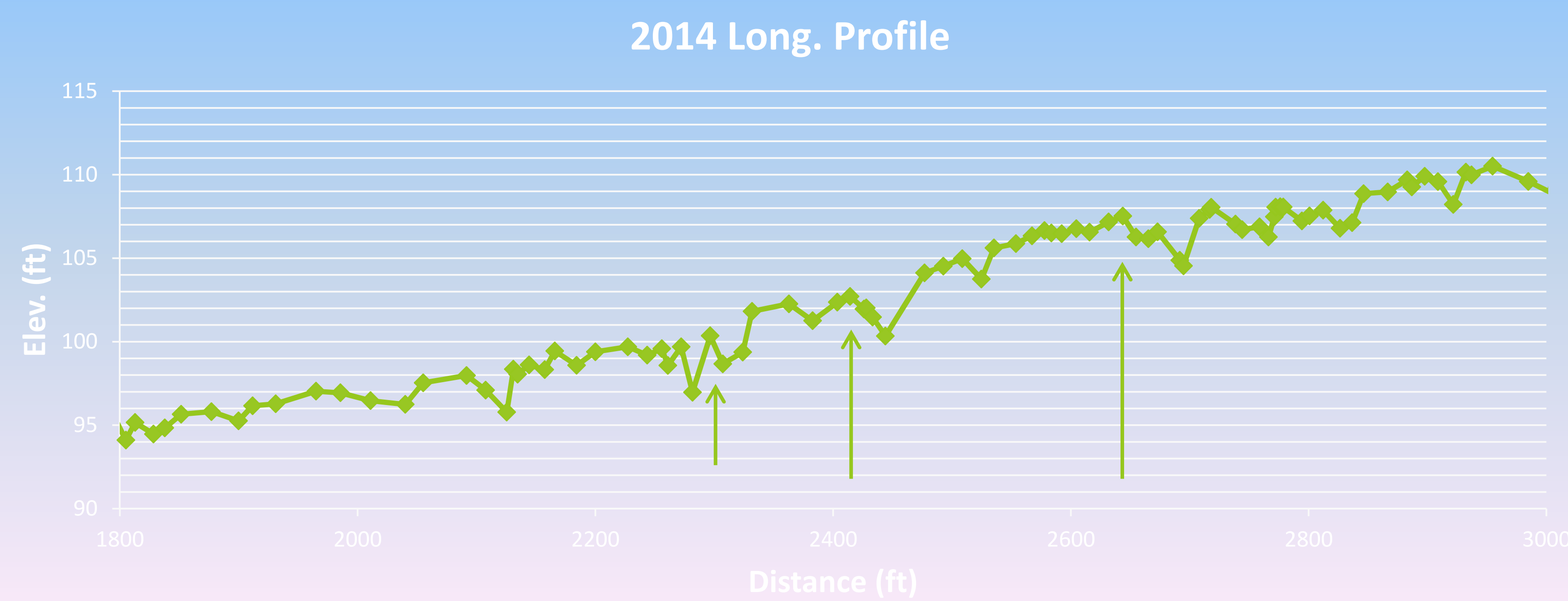
- “Curing period” for new log pools?
- Late summer DO deficit?


Baker Well #5
Groundwater response
2012
2013
2014
2015
2016
Ground
Depth to bottom
Alcove 2013
Alcove 2014
Alcove 2015
bottom of Alcove ('14)
Alcove 2016
1-Oct
31-Oct
1-Dec
31-Dec
31-Jan
2-Mar
2-Apr
2-May
2-Jun
2-Jul
2-Aug
1-Sep



Baker Well #19
Groundwater response
relative elevation (ft)
103.00
101.00
99.00
97.00
95.00
93.00
91.00
1-Oct-05
31-Oct-05
1-Dec-05
31-Dec-05
31-Jan-06
2-Mar-06
2-Apr-06
2-May-06
2-Jun-06
2-Jul-06
2-Aug-06
1-Sep-06
Ground
WY2013
WY2014
WY2015
Alcove WY2013
Alcove WY2014
Alcove WY 2015
2016

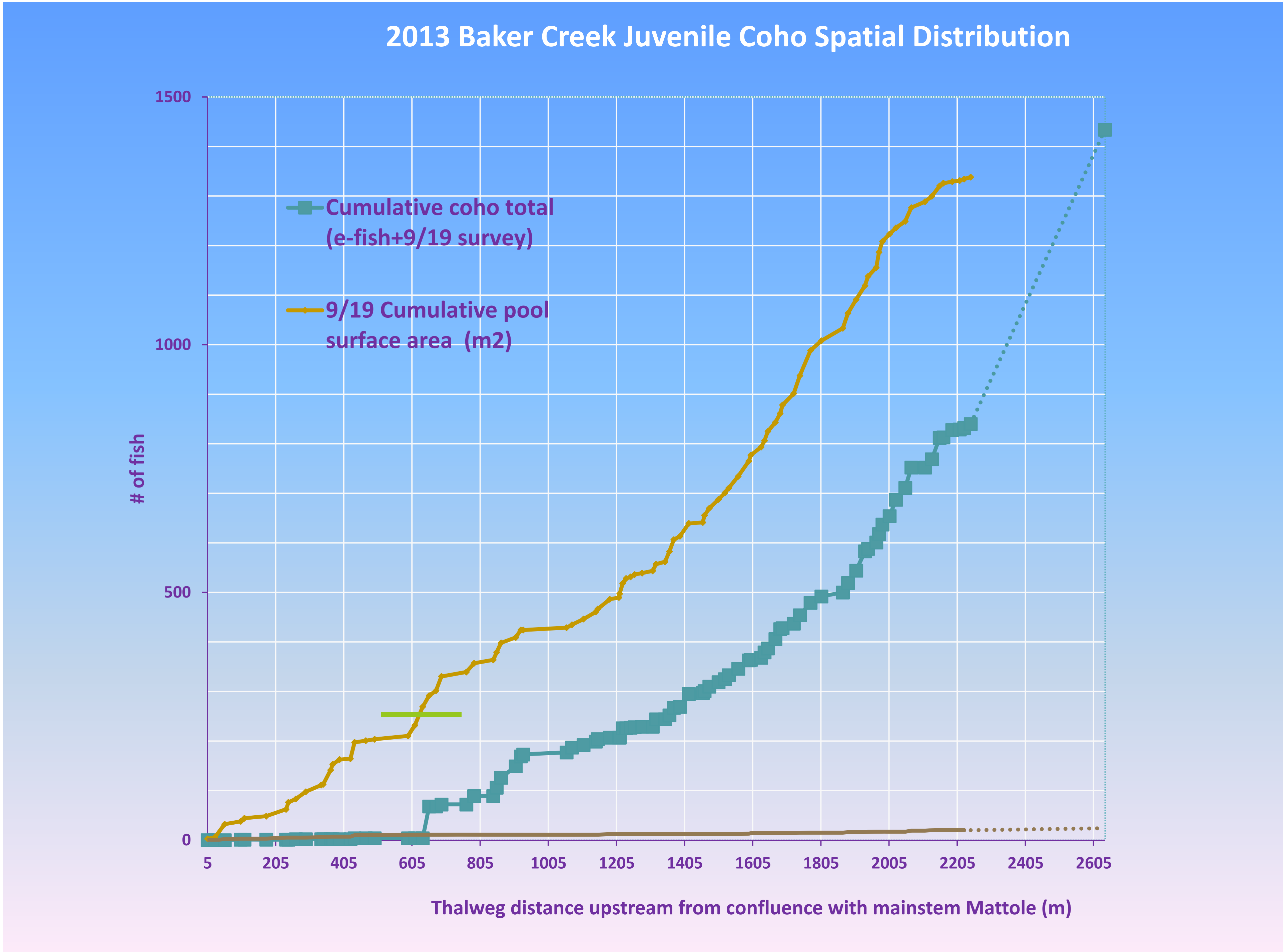

2012 Long. Profile
Elev. (ft)
115
110
105
100
95
90
1800
2000
2200
2400
2600
2800
3000
Distance (ft)


2014 Long. Profile
Elev. (ft)
115
110
105
100
95
90
1800
2000
2200
2400
2600
2800
3000
Distance (ft)

Coho salmon observations

Build it and they will come???

- No coho in reach since 2006
  - Project implementation summer 2012
- Upstream Spawning in Winter 2012/2013
- 0+ Utilization of off-channel features in spring/summer 2013
- Overwintering 2013/2014
- Summer rearing in 2014
- Twice overwintering juveniles 2014
- Emigration into reach fall/winter 2014/2015 ?
- Winter 2015/2016 Coho adults spawning above project reach


2013 Baker Creek Juvenile Coho Spatial Distribution
1500
1000
500
0
# of fish
Cumulative coho total
(e-fish+9/19 survey)
9/19 Cumulative pool
surface area (m2)
5
205
405
605
805
1005
1205
1405
1605
1805
2005
2205
2405
2605
Thalweg distance upstream from confluence with mainstem Mattole (m)

Questions ???