Stream Restoration:

A perplexing challenge amongst mixed messages

Wildland Hydrology

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Mid-Atlantic Stream Restoration Conference

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Warning…Viewer discretion advised…the following slides are quite graphic and may not be suitable for a luncheon experience

Should we be attempting stream restoration?

...some demand we do

…others demand we don't!

The Mixed Messages: #1

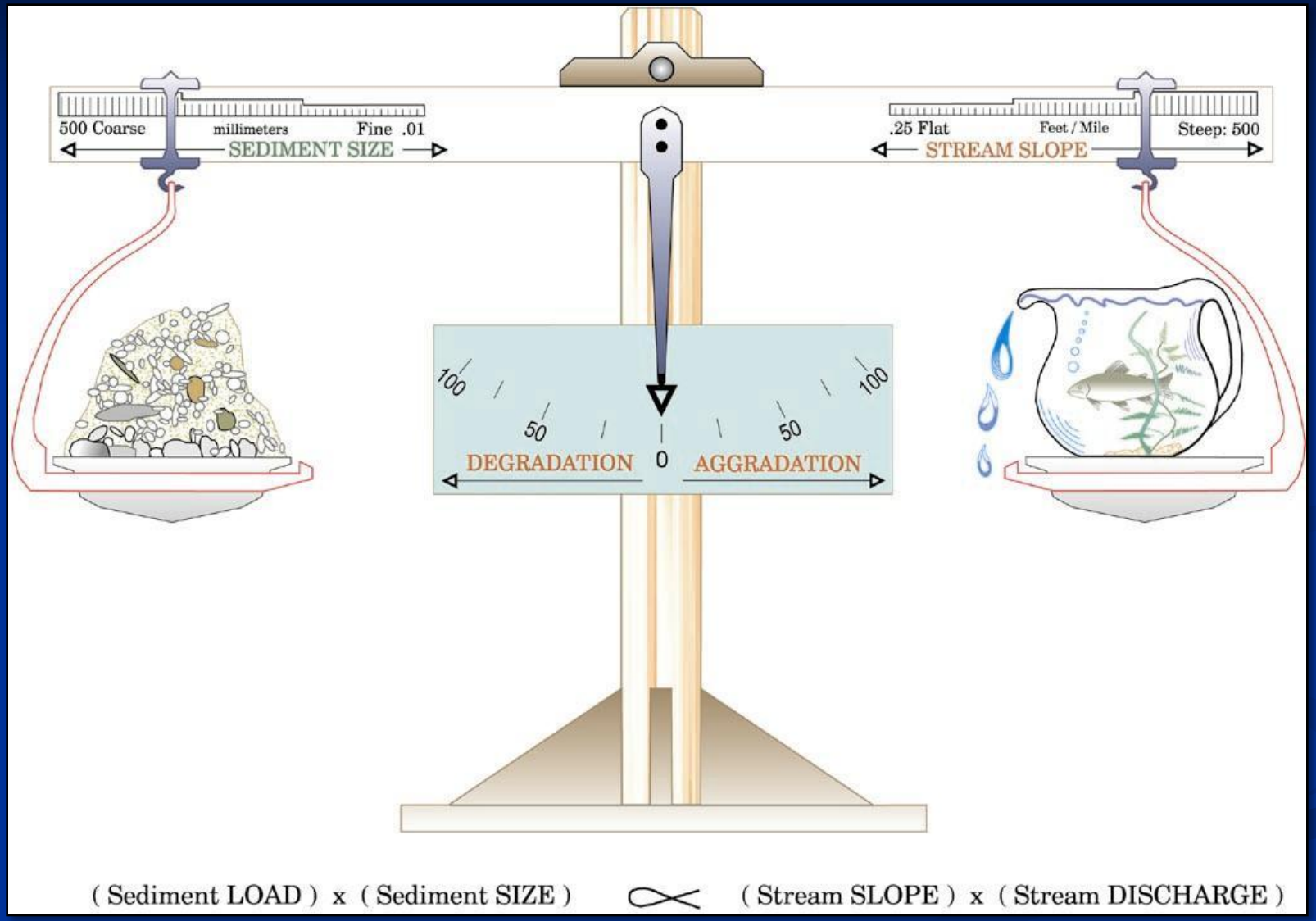
"Due to their high risk and complexity, we do not yet know enough to provide solutions to river problems"

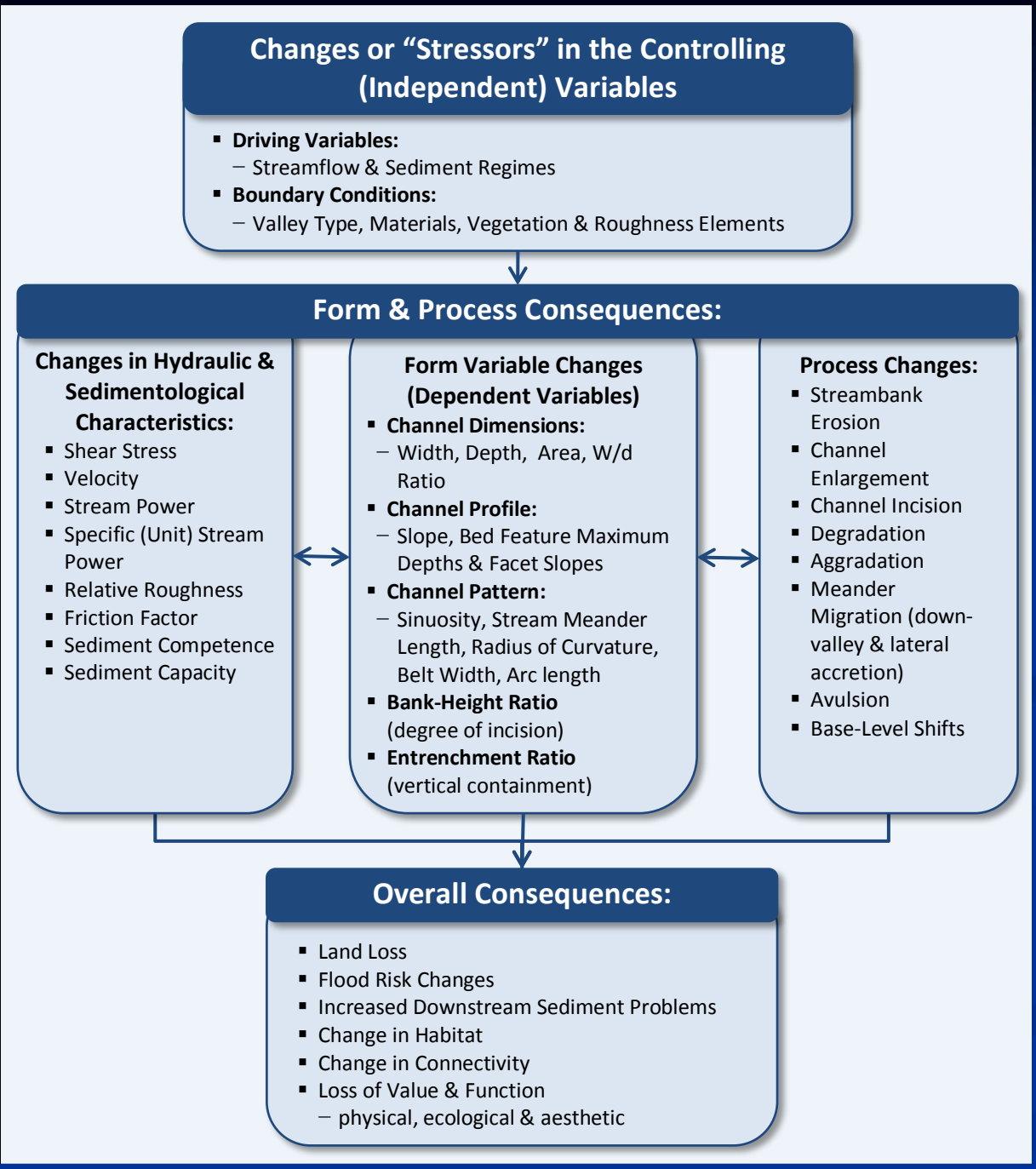
Recommendation:

Understand river fundamentals & interrelationships of natural stable rivers and apply such principles to restoration designs

Mixed Message #1: We don't know enough yet to restore rivers

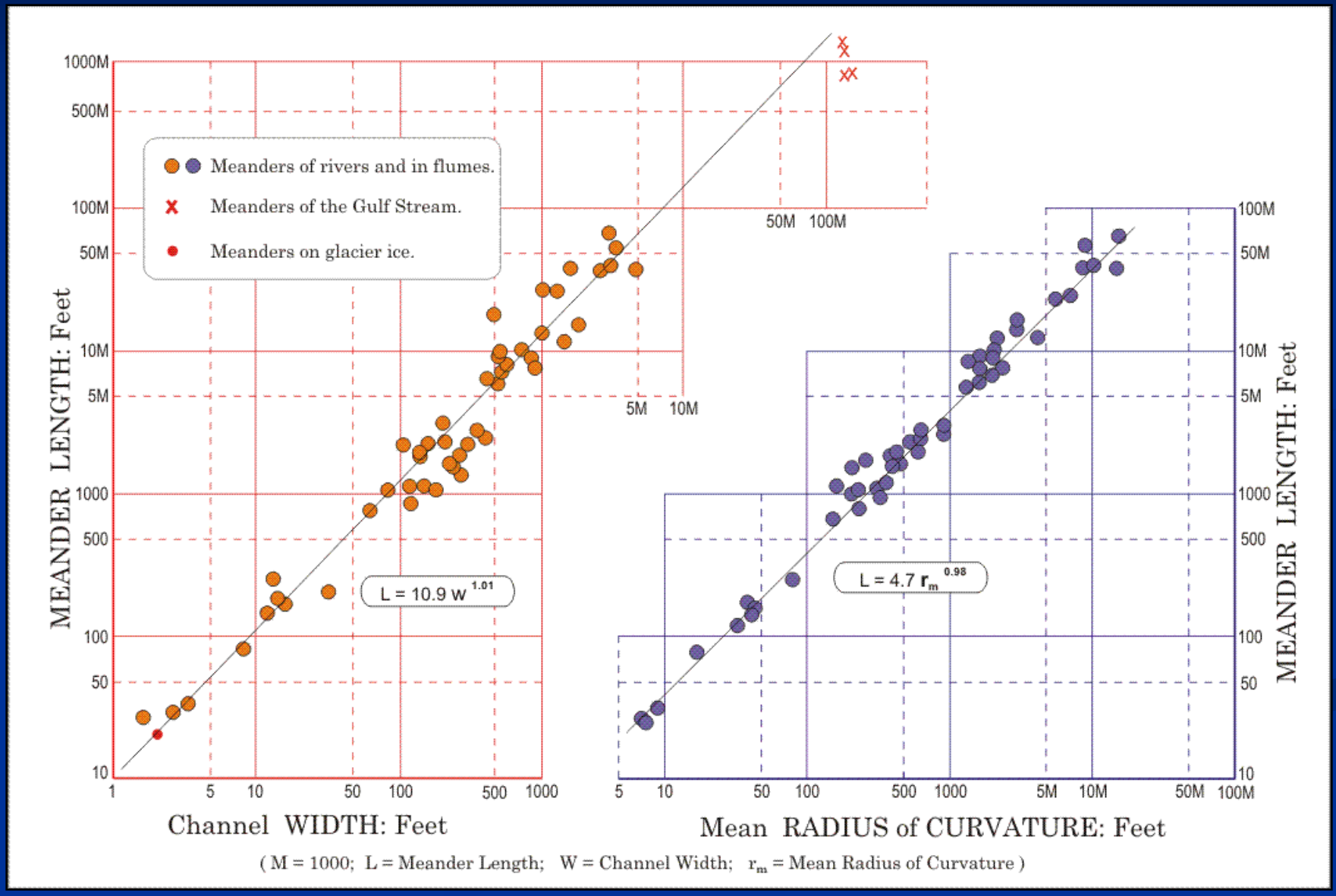
“Realizing the complexity and uncertainty, the restorer is well advised to take lessons from the stable river…its dimension, pattern and profile…and whose intricate, complex process and form interactions have yet to be totally defined by any analytical model”


500 Coarse
millimeters
Fine .01
SEDIMENT SIZE
.25 Flat
Feet / Mile
Steep: 500
STREAM SLOPE
100
50
0
50
100
DEGRADATION
AGGRADATION
(Sediment LOAD) x (Sediment SIZE)
(Stream SLOPE) x (Stream DISCHARGE)

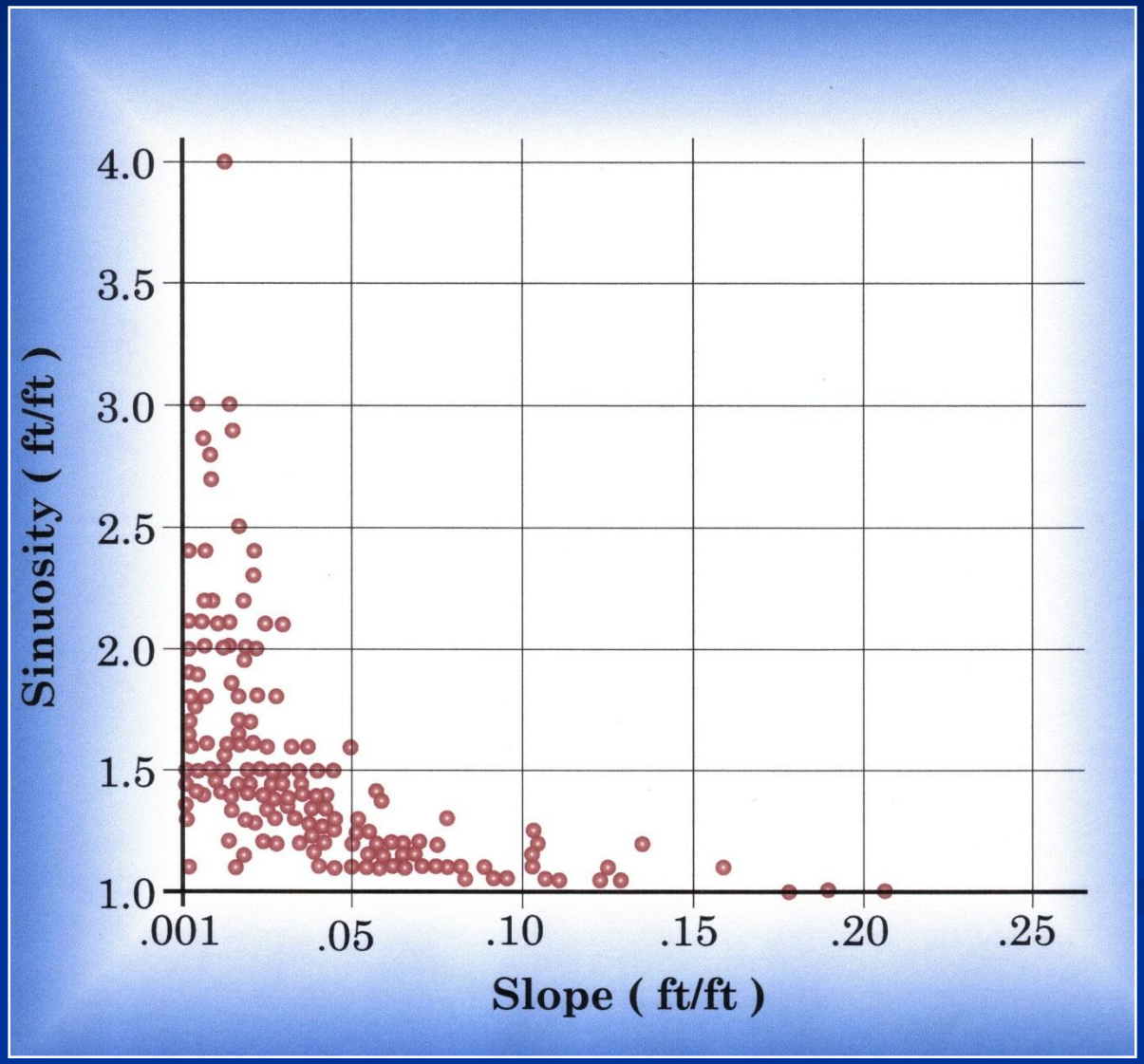


Linkage between ***Form*** and ***Process*** & consequences due to changes in ***Controlling Variables***

Relations between meander length *vs.* channel width and radius of curvature



Relation of *Sinuosity* to *Slope* for natural rivers



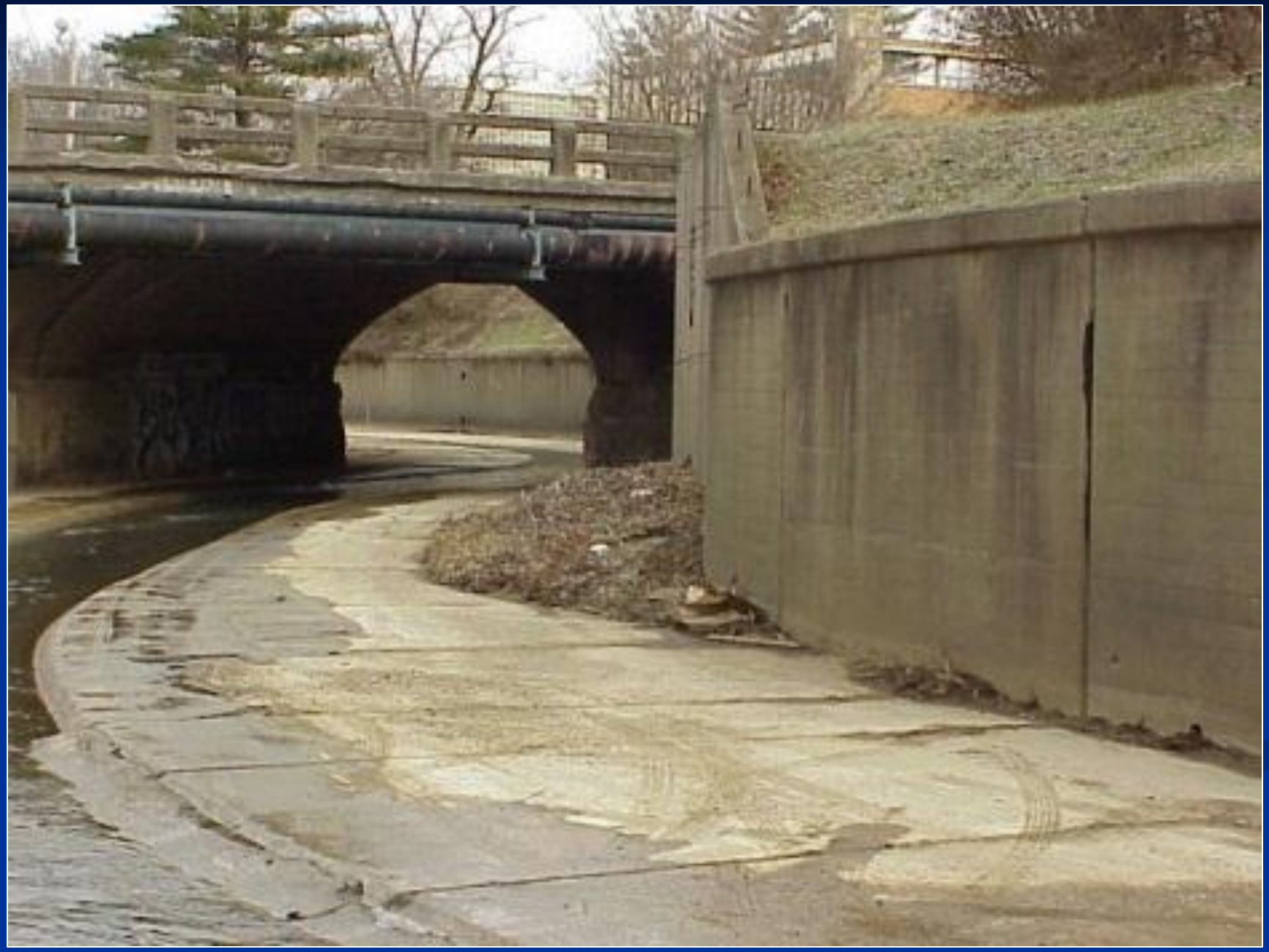
Check dam deposition…know what isn't working and why

Check dam blowout

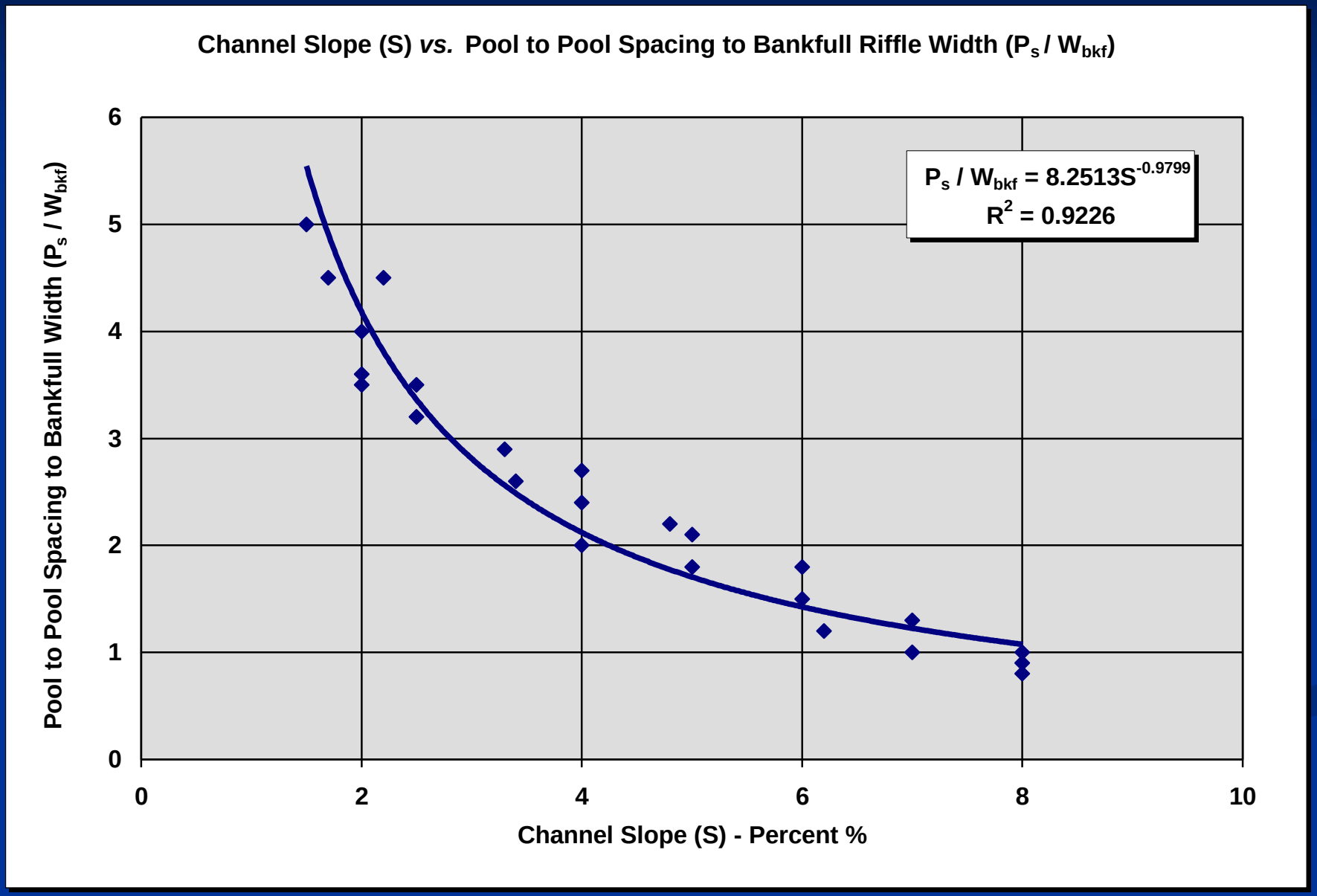
What is the river telling us?

The meandering tendency of rivers

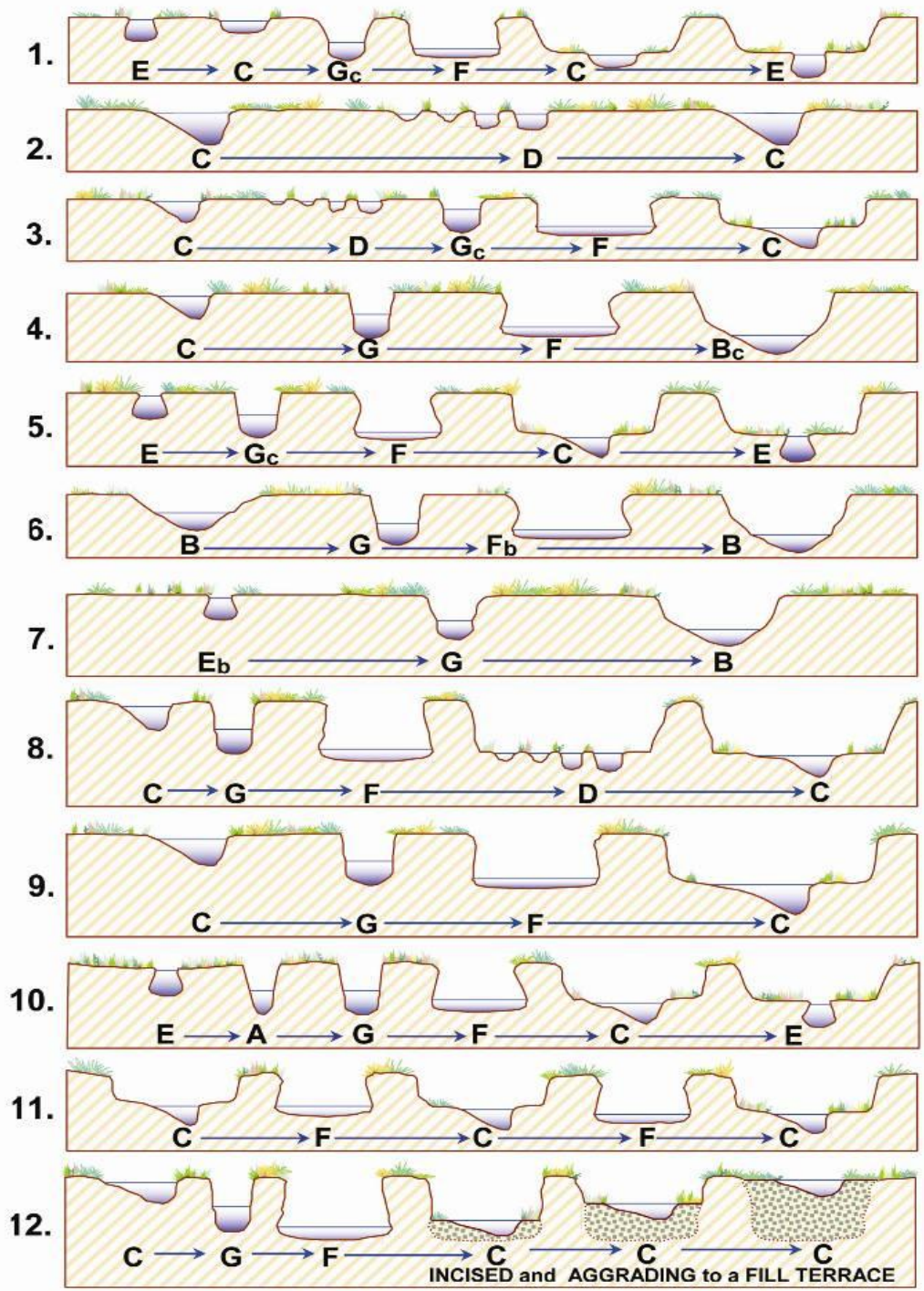
Point Bar Formation



Ratio of Pool Spacing to Bankfull Width as a function of Channel Slope



Field evidence of successional shifts from C4→G4 →F4→C4 stream type



Central Tendency of Rivers:

Re-establish stable form following disturbance

Successional stage shifts from E4→G4→F4

10 years later successional states F4→C4→E4: Note rip-rap on two right banks

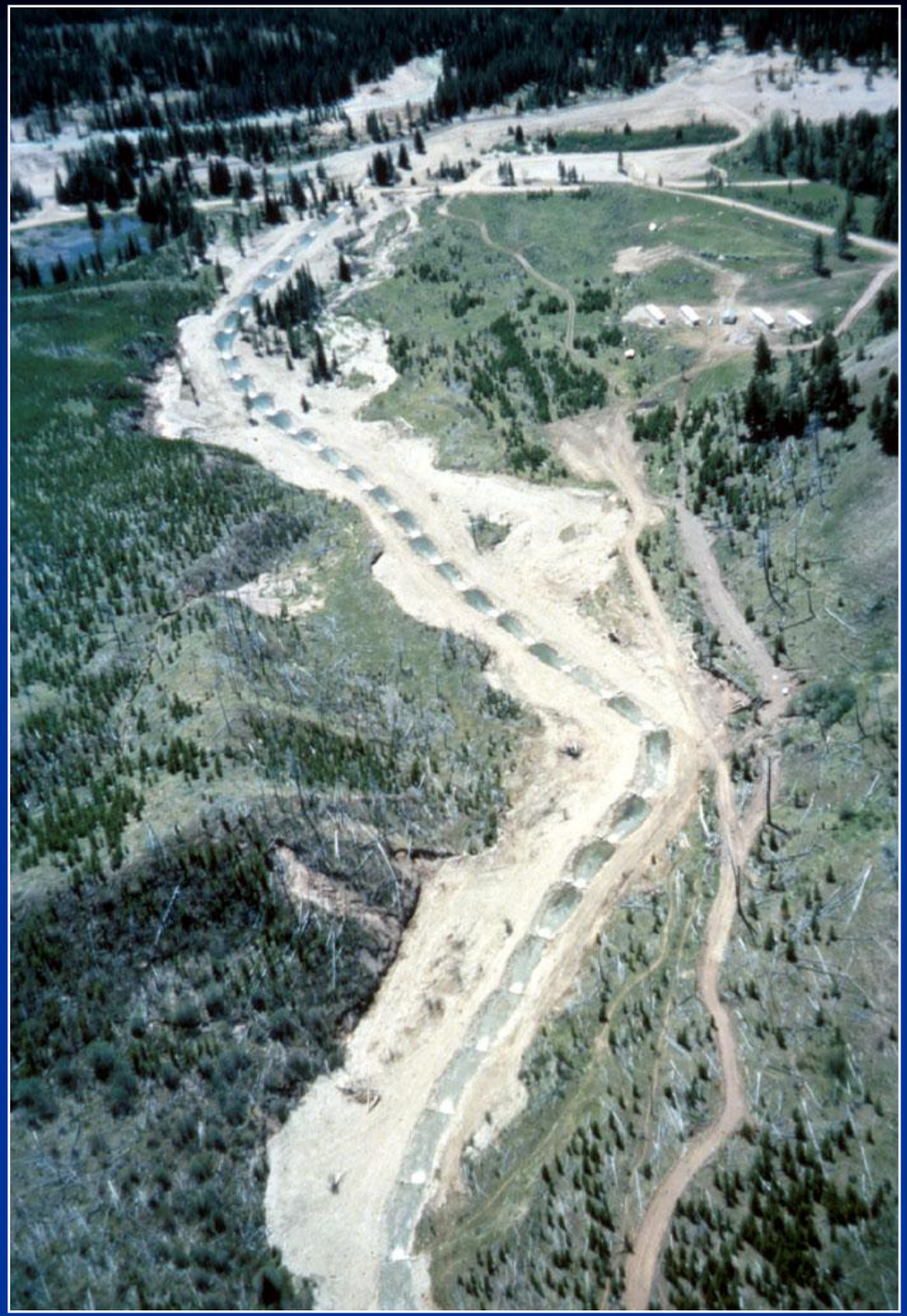
O’Neil Creek - Reference Width/Depth Ratio

O’Neil Creek - Width/Depth Ratio Increase

Width/Depth Ratio Decrease

Consequences of not understanding linkage among:

1. Controlling variables (sediment & flow regime)
2. Boundary conditions (valley types)
3. Form (stream types)
4. Process (erosion, aggradation, degradation, etc.)



Benchmark Creek "Restoration" following 1964 flood, Montana (looking downstream)

Benchmark Creek Gabions

(self-propelling, time-release bedload capsules)

Benchmark Creek Restoration
10 years later (looking upstream)

Benchmark Creek — 10 years later

Single-thread channel constructed on an alluvial fan

Leading sediment from an alluvial fan directly into the receiving channel

Constructed F4 stream type between two B3 stream types

Natural B3 stream type above highway project

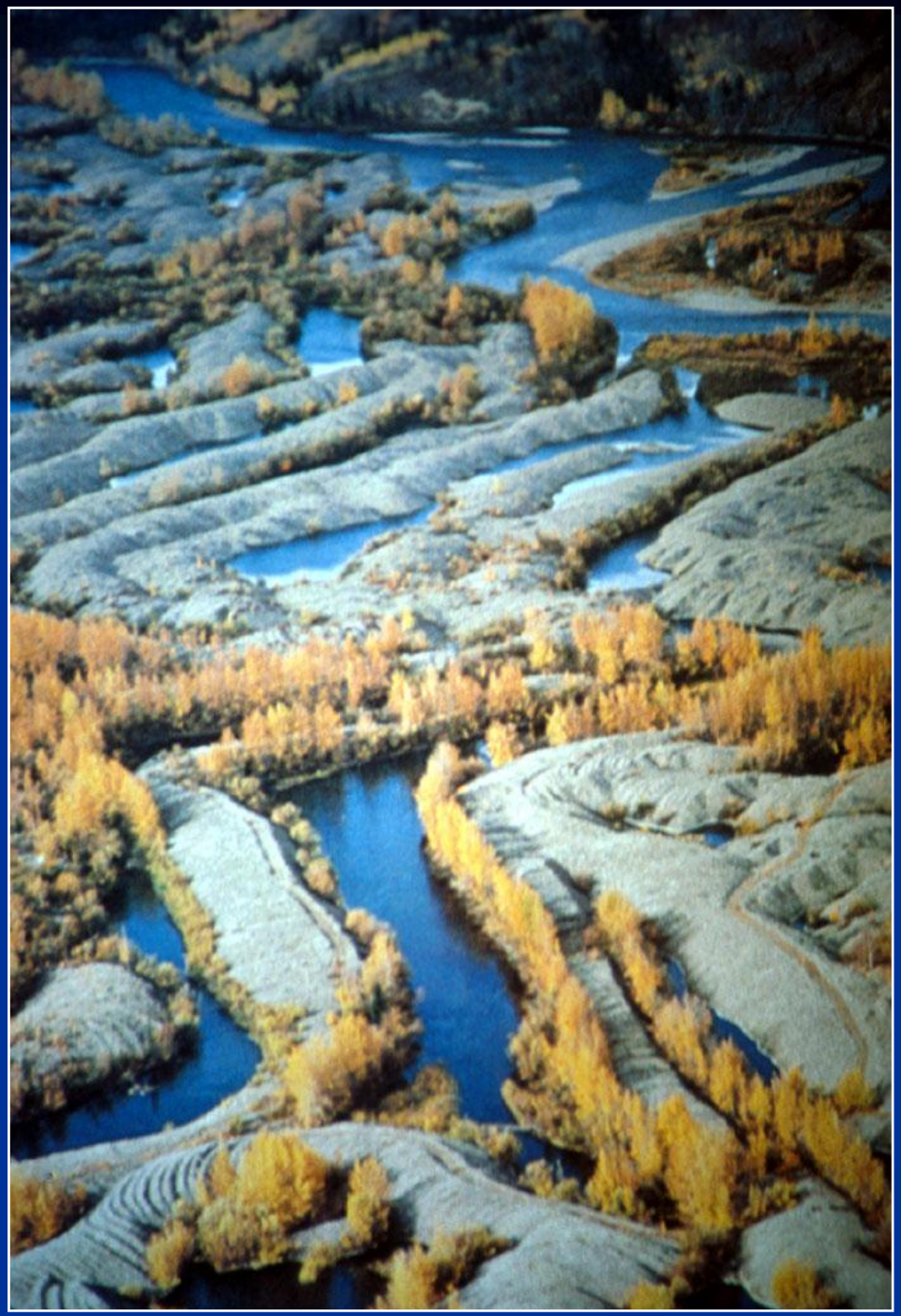
“Toe rock, bio-engineered” streambank

Laramie River Fish Habitat Project:

Note sacrificial rip-rap on banks and bar

The Mixed Messages: #2

"It is better to leave rivers alone and let them seek their own direction and stability"



Major disturbance to river & riparian systems creates a major challenge in restoration…no self-recovering tendency over a 60 year period…and none in sight!

Pennsylvania
http://www.wnep.com/

The Big Thompson Flood, Colorado, 1976 (Should You Put it Back?)

Restored view – 35 years later, August, 2011

Recommendation:

Understand the recovery potential & cause of impairment

Mixed Message #2: Let the river be

Proper grazing management system below fence-line: F4→C4→E4 stream type

Unstable F4 stream type, 110 years old

Weminuche Creek aggradation & potential avulsion due to willow spraying

These heifers are saying, “We didn’t cause this bank erosion — It was the 2-4-D”

High sediment supply & associated accelerated streambank erosion

C4→D4 stream type shift due to imported water below headgate and poor grazing practices

Accelerated streambank erosion due to riparian vegetation removal

Headcut gully system

Degradation (Muddy Creek, Montana)

Patching symptoms (Muddy Creek, Montana)

Channel enlargement & aggradation

Lateral instability

Degradation

The Mixed Messages: #3

"Natural stable rivers are supposed to erode so stabilizing their streambanks is unnatural"

Recommendation:

- Understand the rates and natural variability associated with erosional and depositional processes in *stable* rivers
- Establish & document an acceptable range of adjustment of the channel's dimension, pattern & profile developed from dimensionless relations of the reference reach
- Utilize materials and methods compatible with natural rivers

Mixed Message #3: "Rivers are supposed to erode"

Fall River following the 10,000 yr flood event through C4 stream type

Thurra River, SE Australia

- A meandering, riffle-pool, sand-bed stream (C5) has maintained its dimension, pattern and profile over recent time. The channel position has been static for over 1,900 years.

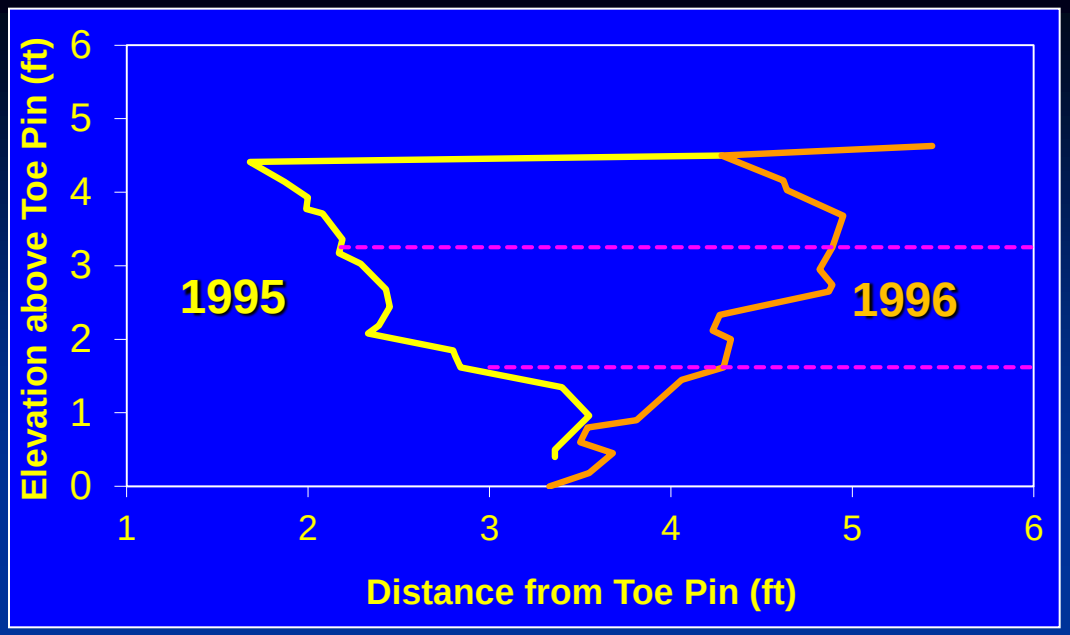
  (Brooks and Brierley, 2002, *Earth Surface Processes and Landforms*)

C4 stream type – reference reach

Recommendation:

Quantify and understand bank erosion rates, sediment competence & capacity relations of reference reaches compared to impaired conditions

Mixed Message #3: "Rivers are supposed to erode"



Average Lateral Erosion: 1.6 ft.

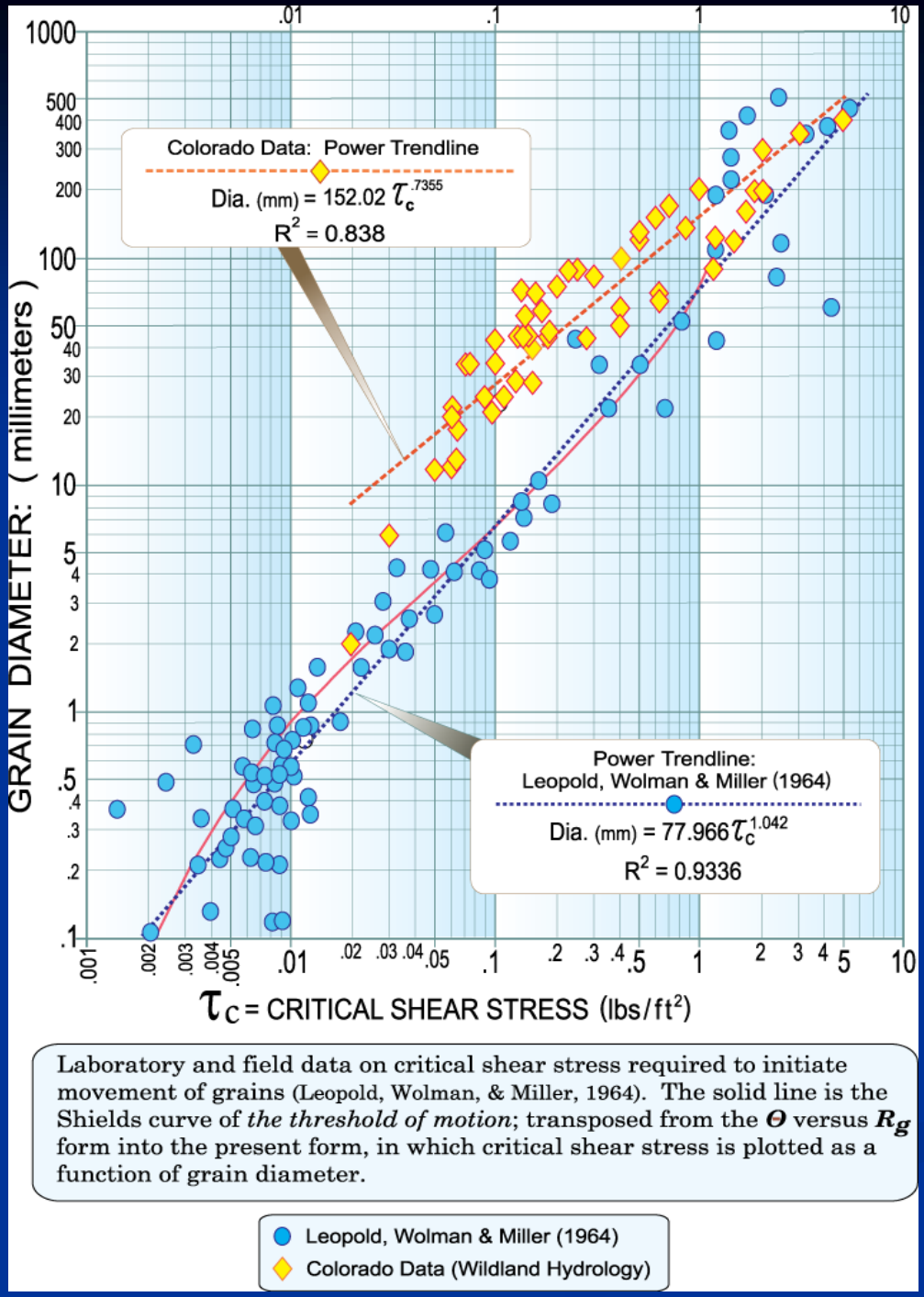
Install bank pins & survey bank profiles

…especially on Reference Reaches

Bank Profile

Demonstrate that stable alluvial channels commonly mobilize the D_{84} of riffle bed material (as long as it can be replaced based on upstream bar sample)

Collect bar samples or pavement/sub-pavement samples



Laboratory and field data on critical shear stress required to initiate movement of grains (Leopold, Wolman, & Miller, 1964). The solid line is the Shields curve of *the threshold of motion*; transposed from the Θ versus R_g form into the present form, in which critical shear stress is plotted as a function of grain diameter.

Calculate sediment competence & entrainment

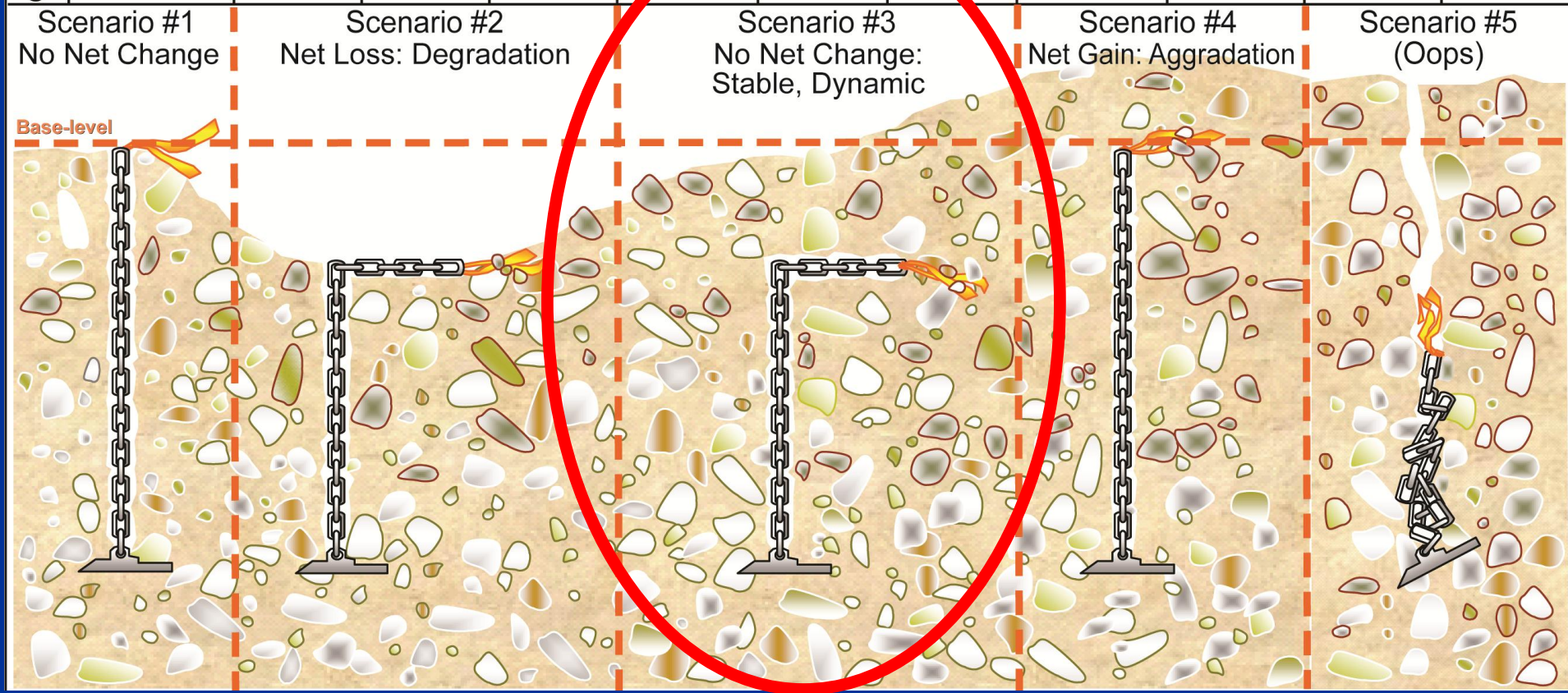
Install Scour Chains

Stable channels scour & deposit sediment

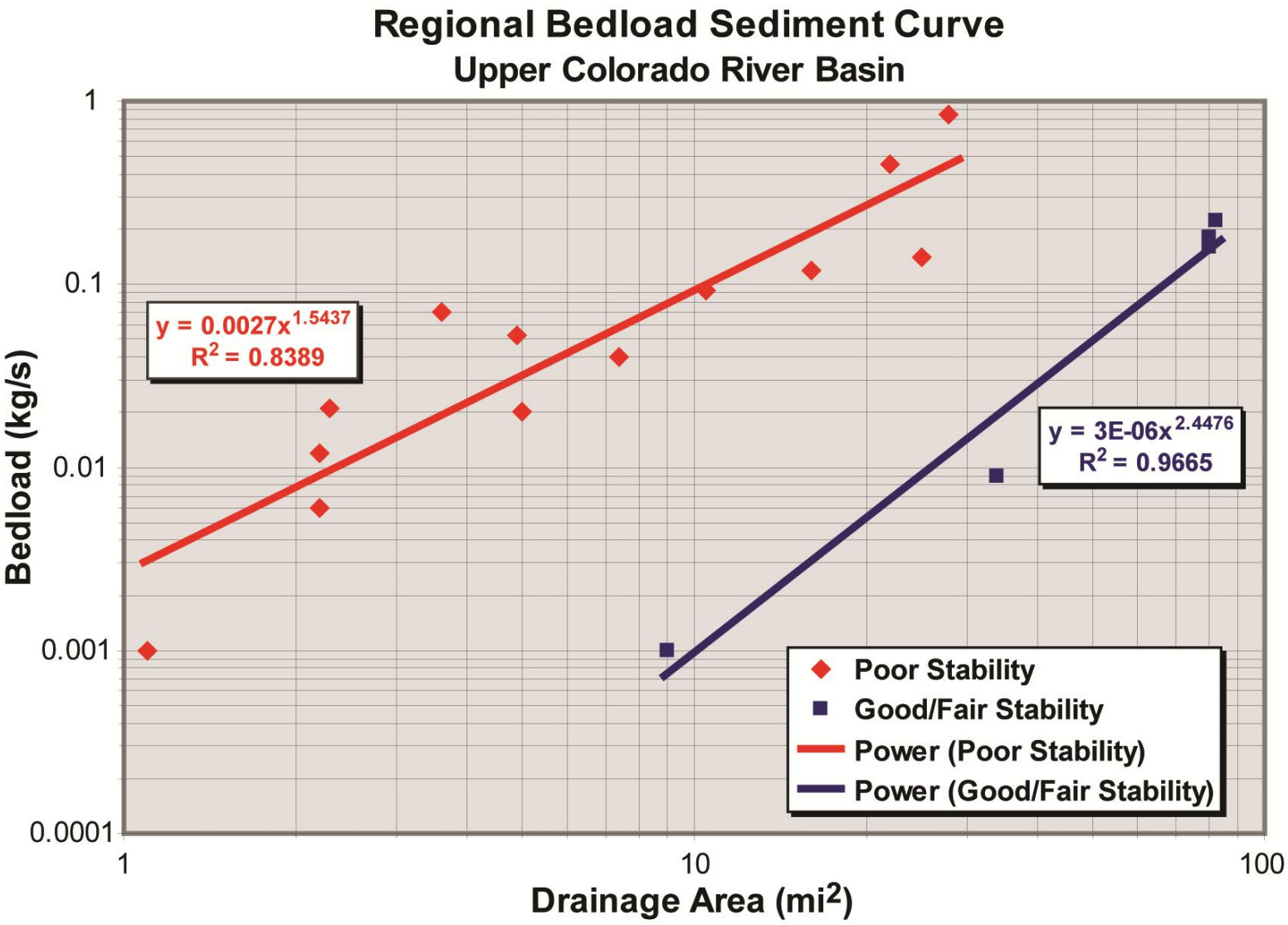
Stream: Location:

Observers: Stream Type: Valley Type: Date:

		Installation Data (1st Year)				Recovery Data (2nd Year)					
		From Cross-Section		Particles Near Chain		Chain Recovery				Particles Near Chain	
		Station (ft)	Elevation (ft)	Largest (mm)	2nd Largest (mm)	Scenario # (1–5)	Scour depth[a] (ft)	Elevation[b] (ft)	Net change[c] (ft)	Largest (mm)	2nd Largest (mm)
Riffle											
Glide											



Develop regional sediment relations



Consequences of *not* understanding sediment transport & competence:

Avoid armor plating entire riffle lengths

Over-sized, high width/depth ratio channel in urban area inducing sediment aggradation

Aggradation of over-wide, three cell bridge

Aggradation of over-wide, three cell bridge

Structures *Do Not* substitute for the correct dimension, pattern and profile

Recommendation:

Design channel and structures to match the appropriate dimension, pattern and profile

Functioning floodplain drain culvert design

High flow performance

The Mixed Messages: #4

The double standards for Traditional River Work *vs*. Natural Channel Design

Perception: failure and frequent maintenance of hard control structures (e.g., gabions) is <u>Accepted</u> vs. <u>Unaccepted</u> channel adjustments following restoration using natural channel design

The Evolution of Bank Stabilization

If stream stabilization work allows channel adjustment, it is called a failure;

if it is too “hard” it is called not natural by “fixing” a stream in place

Consequences:

1. Overbuilding & oversizing channels to be “conservative”

Traditional over-wide, trapezoidal channel for flood “relief”

Consequences:

2. Armor-plating banks & beds with rock to avoid “failure” resulting in unnatural and nonfunctioning designs

Hard control river works that are *NOT* river restoration or "Natural Channel Design"

Traditional, over-wide “gabion” F4 stream type channel requiring annual sediment dredging

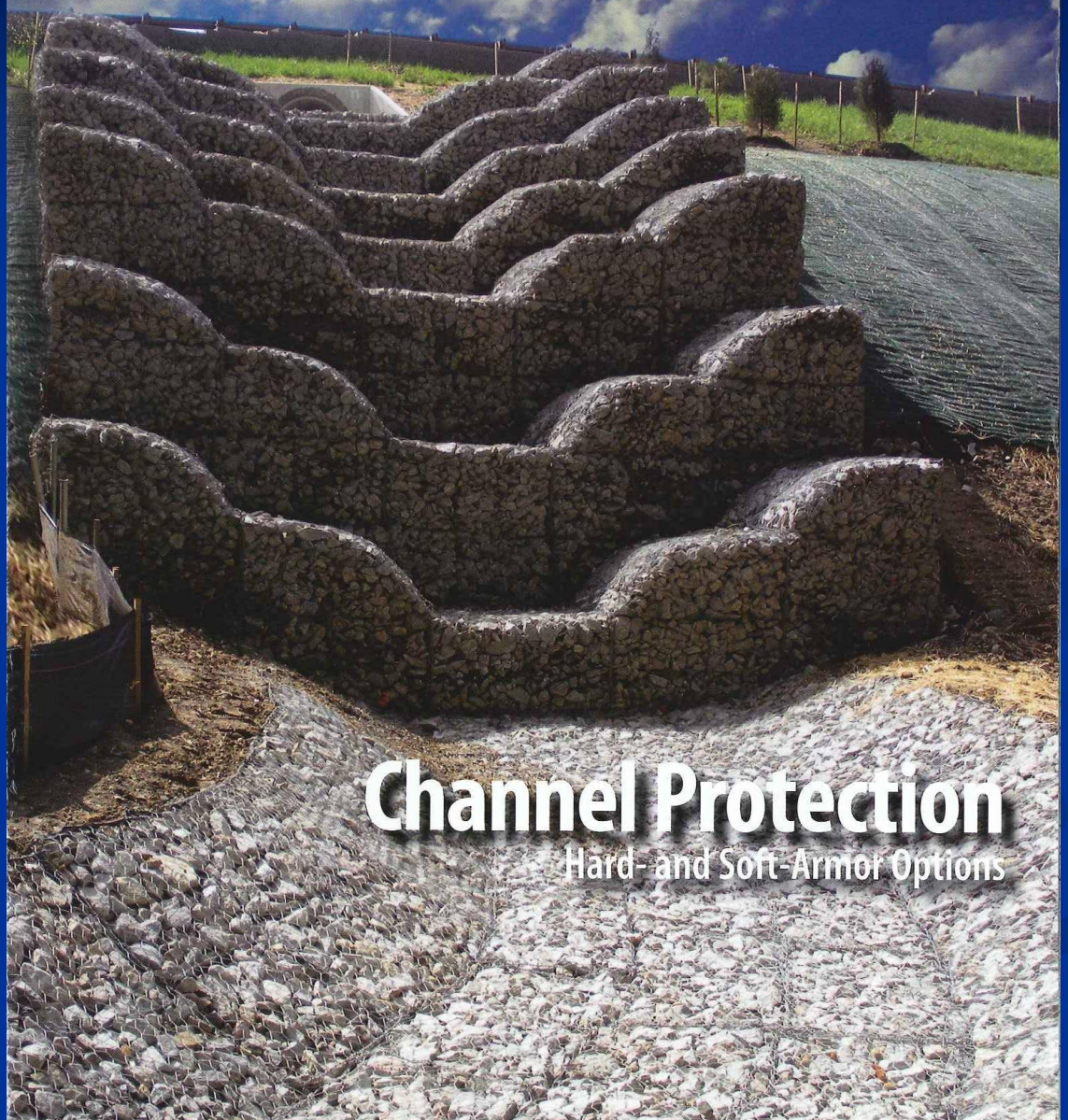
Over-widened, hardened & unnatural Spring Creek “Restoration”…even with the root wads

…Would you fish this?
Spring Creek “Restoration”

January/February • 2009
www.erosioncontrol.com

EROSION CONTROL

OFFICIAL JOURNAL OF THE INTERNATIONAL EROSION CONTROL ASSOCIATION



Channel Protection

Hard- and Soft-Armor Options

“Hard” control, Ohio

Hardened F4 stream type with "Interlocking Block"

Consequences:

3. Loss of value and function at great costs per foot of construction

Recommendation:

Provide clear *objectives* and develop specific *success criteria* accounting for natural variability in stable streams

Typical trapezoidal, hardened channel

What objectives have or have not been met?

The Mixed Messages: #5

"Natural Channel Design does not work; it has a high risk for failure"

Weminuche Creek (pre-construction)

Weminuche Creek (Post-construction, 20 years later)

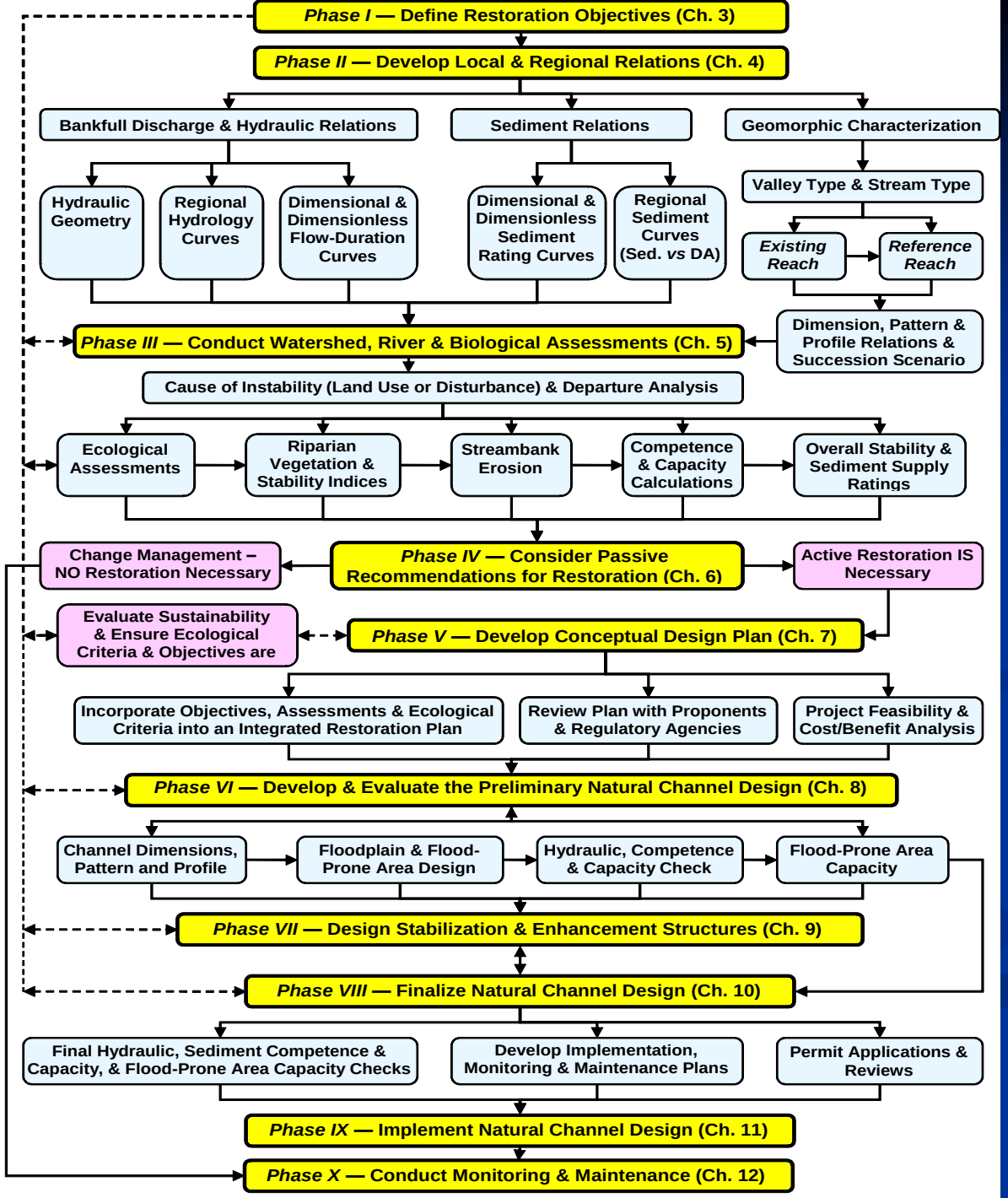
Recommendation:

Investigate NCD approach and understand the ten phases and 20 minimum requirements

Mixed Message #5: NCD doesn't work

Overview Flowchart of Ten Phases

(see handout)



20 Minimum Natural Channel Design Requirements

Rosgen, 2011, "Natural Channel Design: Fundamental Concepts, Assumptions, and Methods"

In AGU, Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools

(See Handout for 20 minimum requirements)

Recommendation:

Investigate:

- Where do these messages come from?
- Do the senders of such messages understand the approach?
- Do the critics have applied restoration experience?
- Was a full, fair and unbiased investigation conducted?

Mixed Message #5: NCD doesn't work

Recommendation:

Monitor the physical & biological response of restoration and publish or make such data available

- Require monitoring as a condition of the permit
- Include implementation, effectiveness and validation monitoring

Mixed Message #5: NCD doesn't work

Recommendation:

Understand & document restoration successes *and* failures:

a) Did project meet objectives and associated success criteria?

b) If not, why?

- Did project follow minimum requirements?
- Was the design implemented correctly?
- Were all those involved in the restoration trained and experienced?

Mixed Message #5: NCD doesn't work

Poor Design Implementation: *The "M-Weir"*

The Mixed Messages: #6

Using wood in stream restoration is high risk since wood floats and causes downstream problems following floods…use of rock structures is unnatural

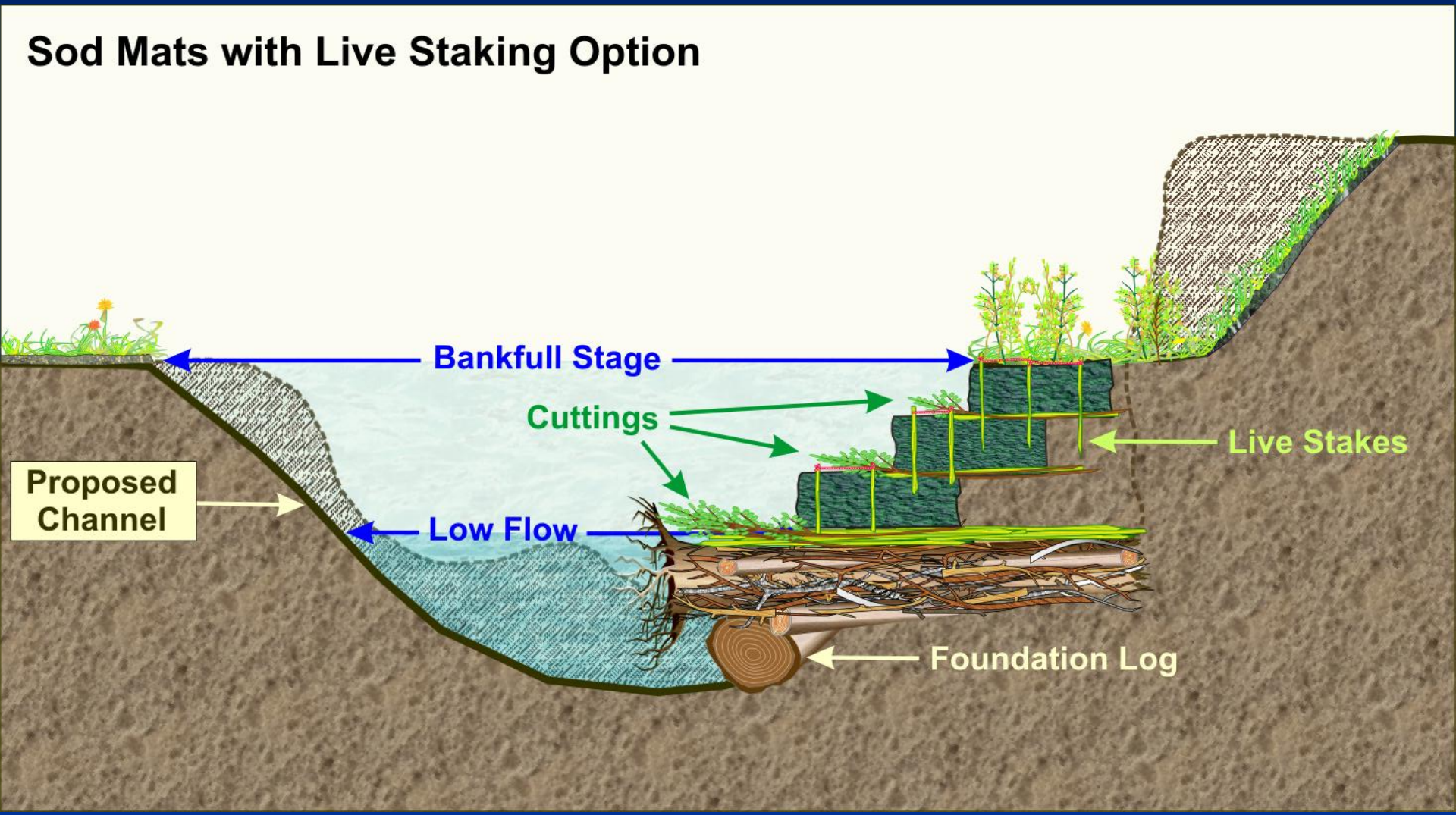
Recommendation:

Understand how wood can be successfully incorporated into design to meet multiple specific objectives

Mixed Message #6: Structures are high risk

Poor use of wood: the root wad for airborne fish

Toe wood to stabilize banks, enhance fish habitat & maintain low width/depth ratio



Prior to toe wood implementation

Toe wood with willow cuttings, sod mats & woody transplants

Toe wood using willow cuttings & transplants

Eroding streambank prior to toe wood installation

Completed toe wood with sod & transplants on constructed bankfull bench below terrace, 7/2010

Same location during flood following restoration

Post flood response on constructed bankfull bench at same location, 7/2010

Post flood response – Note shroud line between live stakes, 7/2010

Live stake sprouting in sod mat, 7/2010

Bitterroot River, Montana

Pre-restoration, existing condition, 9/2010

Post-restoration using toe wood with sod mats & willow cuttings on bankfull bench, 11/2010

Toe wood installation post-construction, 08/2011

Toe wood installation post-construction, 07/2011

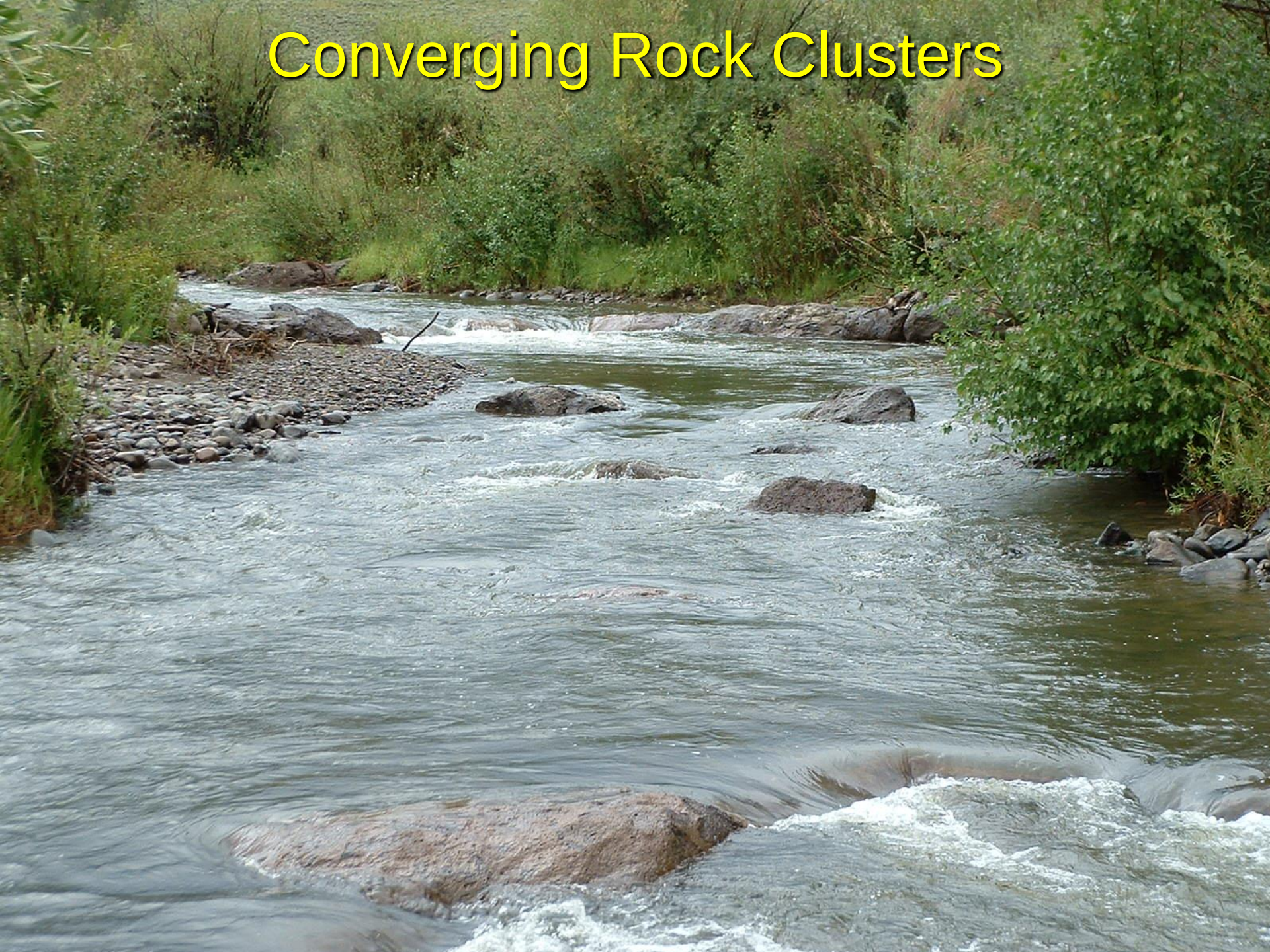
Recommendation:

Understand which structures & materials are compatible with local conditions; vary the structure type to create diversity

(e.g., avoid boulder structures in a sand-bed channel)

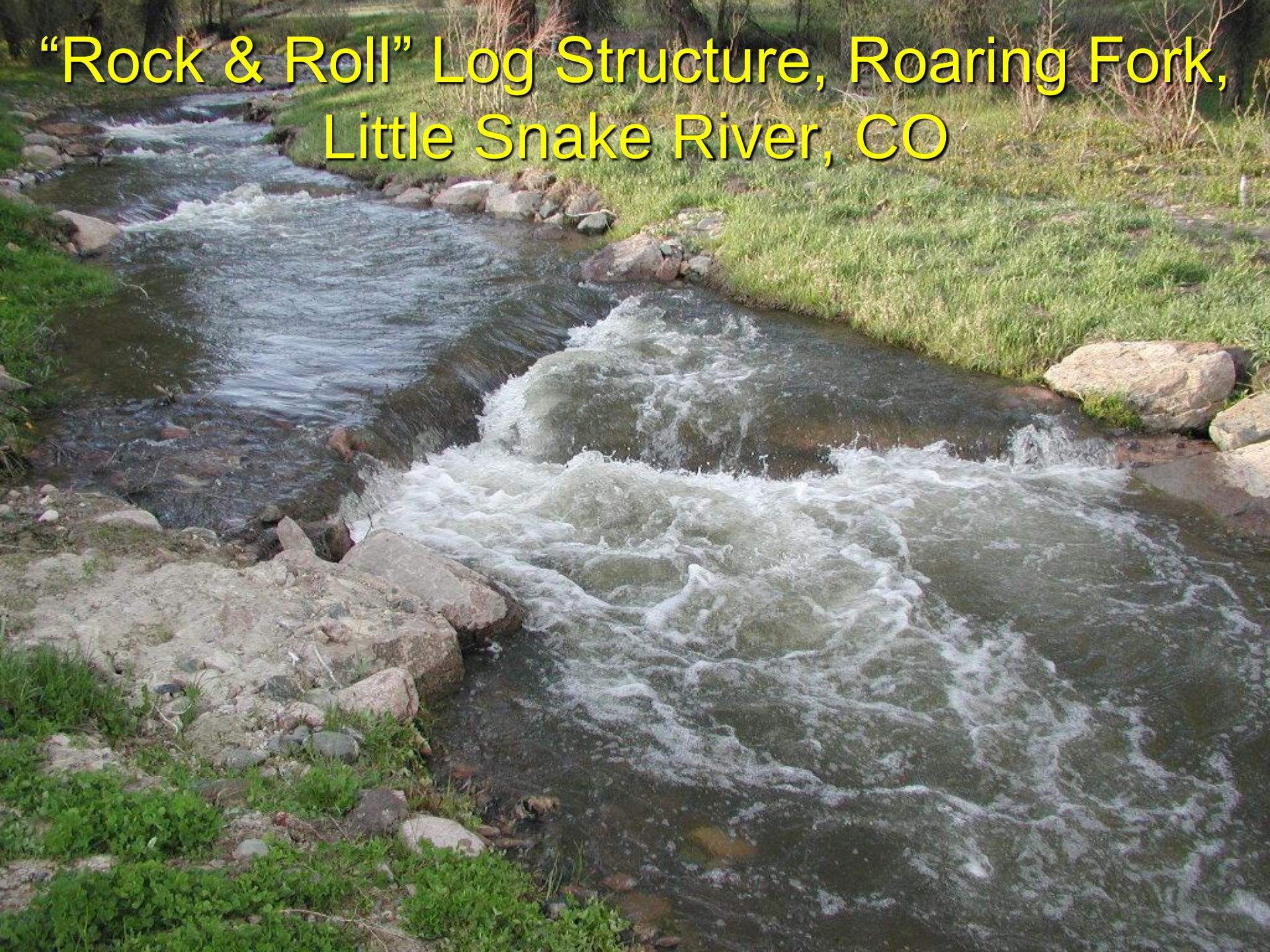
Mixed Message #6: Structures are high risk and unnatural

Converging Rock Clusters



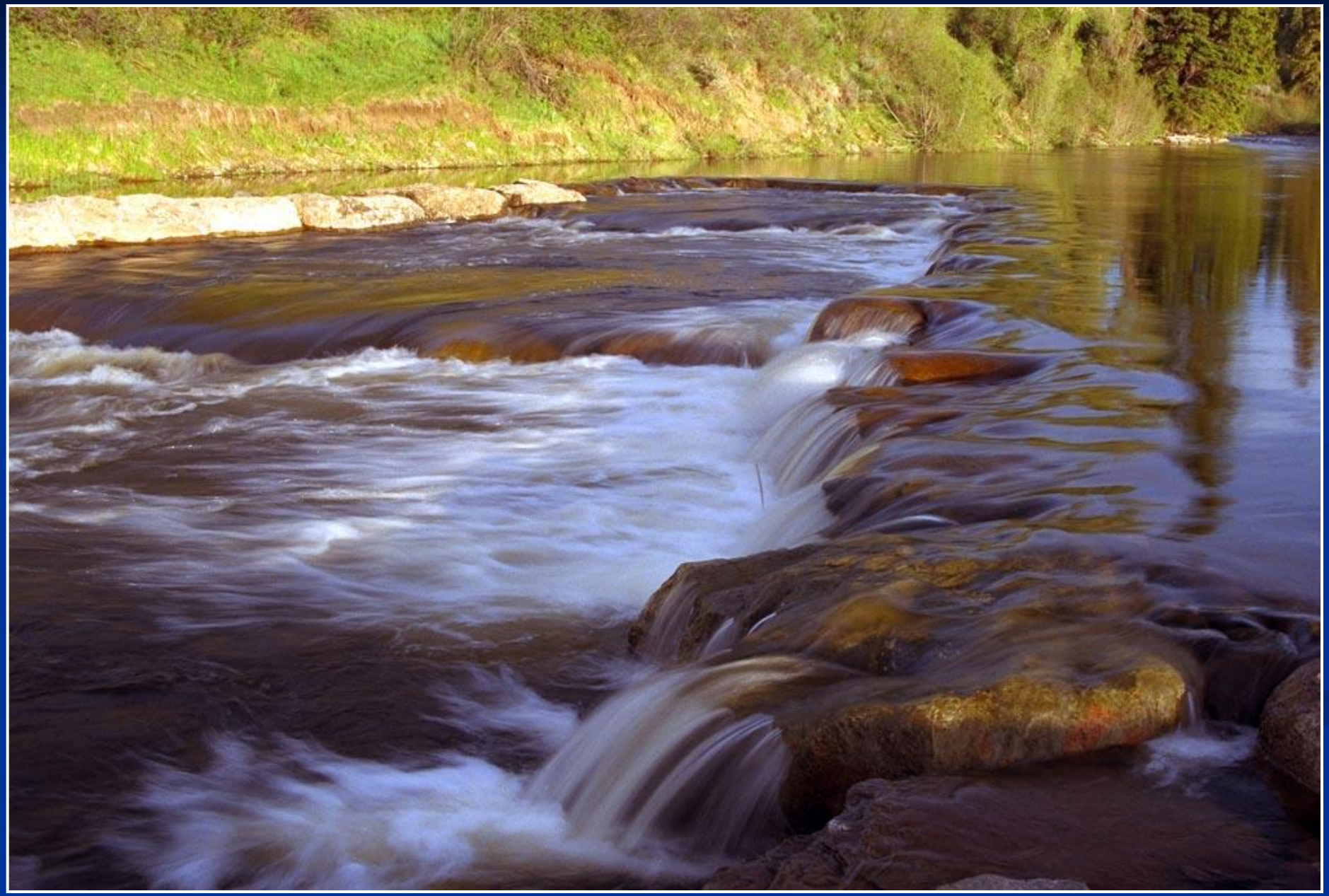
Ohio Creek, Colorado

Double W-Weir: Blue River, Colorado


“Rock & Roll” Log Structure, Roaring Fork,
Little Snake River, CO

Roaring Fork - Log and Rock Steps

Middle Fork, Little Snake cross-vane diversion



Converging rock clusters for grade control installed at head of riffles, post-construction, 07/2011

Recommendation:

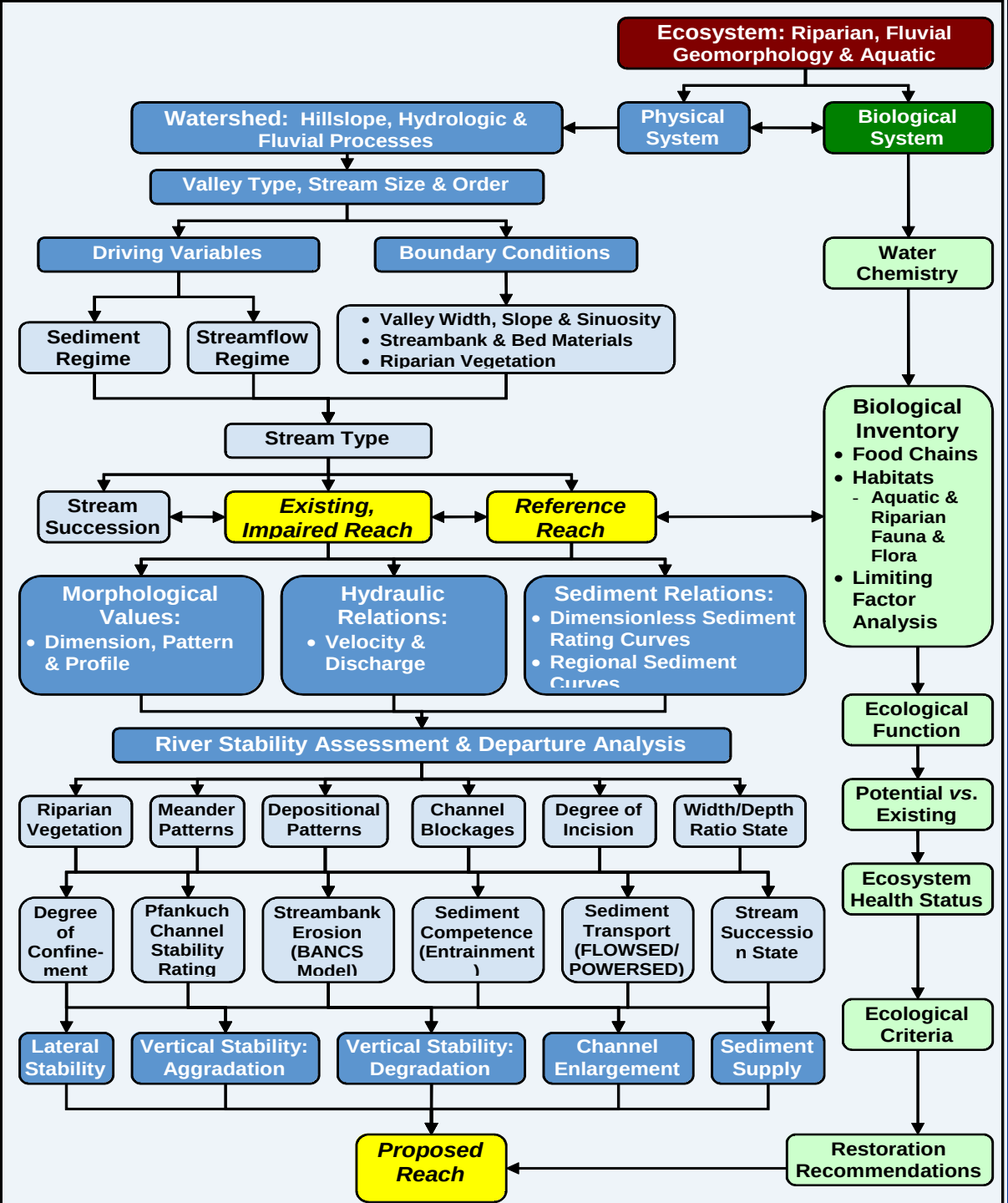
Properly train contractors & consultants to implement design correctly

The Mixed Messages: #7

"Natural Channel Design has not demonstrated that fisheries or ecological functions are improved"

Recommendation:

Develop specific criteria to fulfill ecological requirements & goals with design recommendations to offset limiting factors

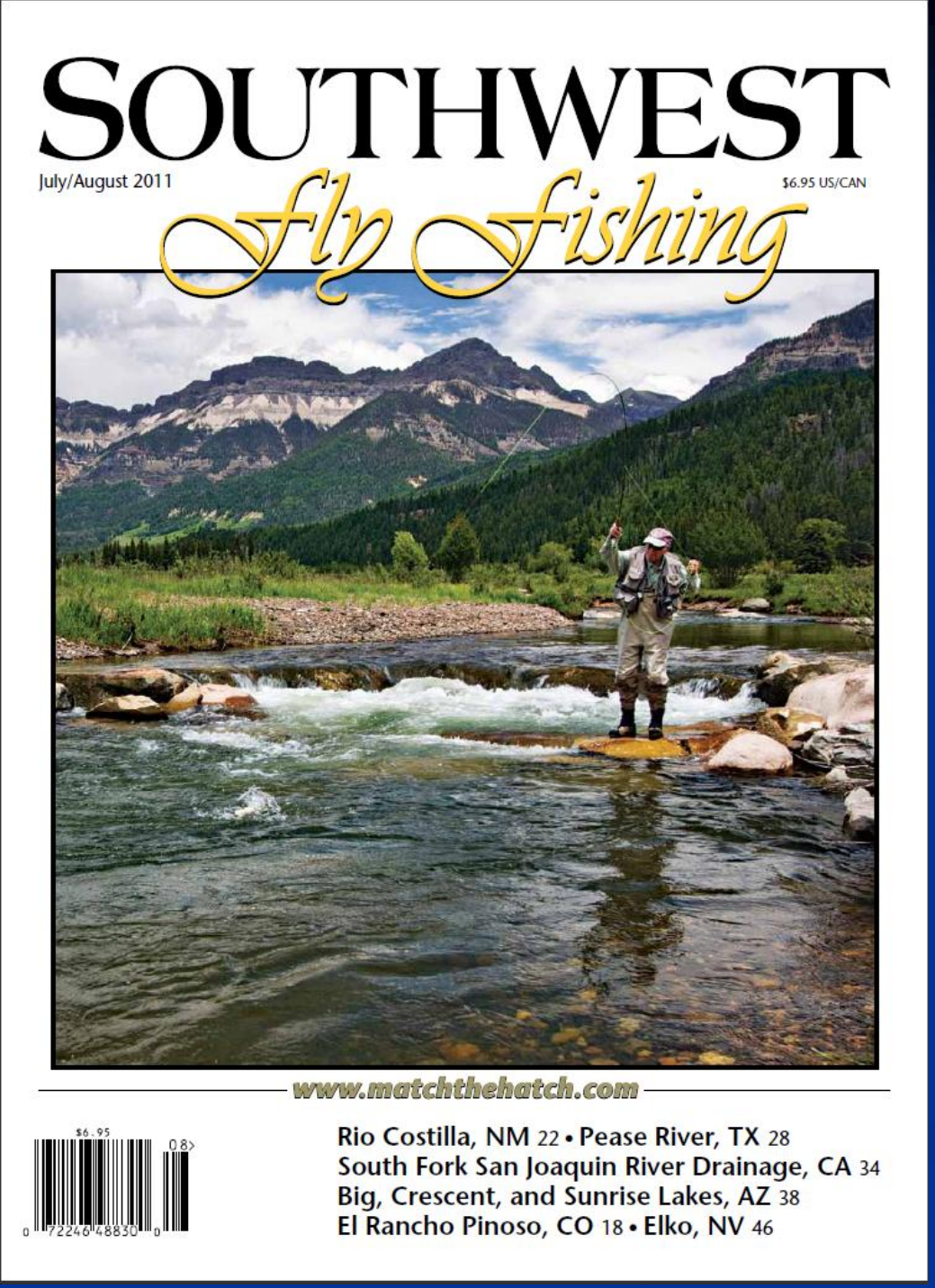


Must integrate physical & biological relations for *Impaired Reach*, *Reference Reach* & *Design Reach*

Recommendation:

Understand *river system* components and how to design various features to meet multiple objectives

Mixed Message #7: NCD doesn't improve ecological function



Weminuche Creek, constructed in 2003

Inside *Southwest Fly Fishing:*
E.F. Piedra River constructed in 2002

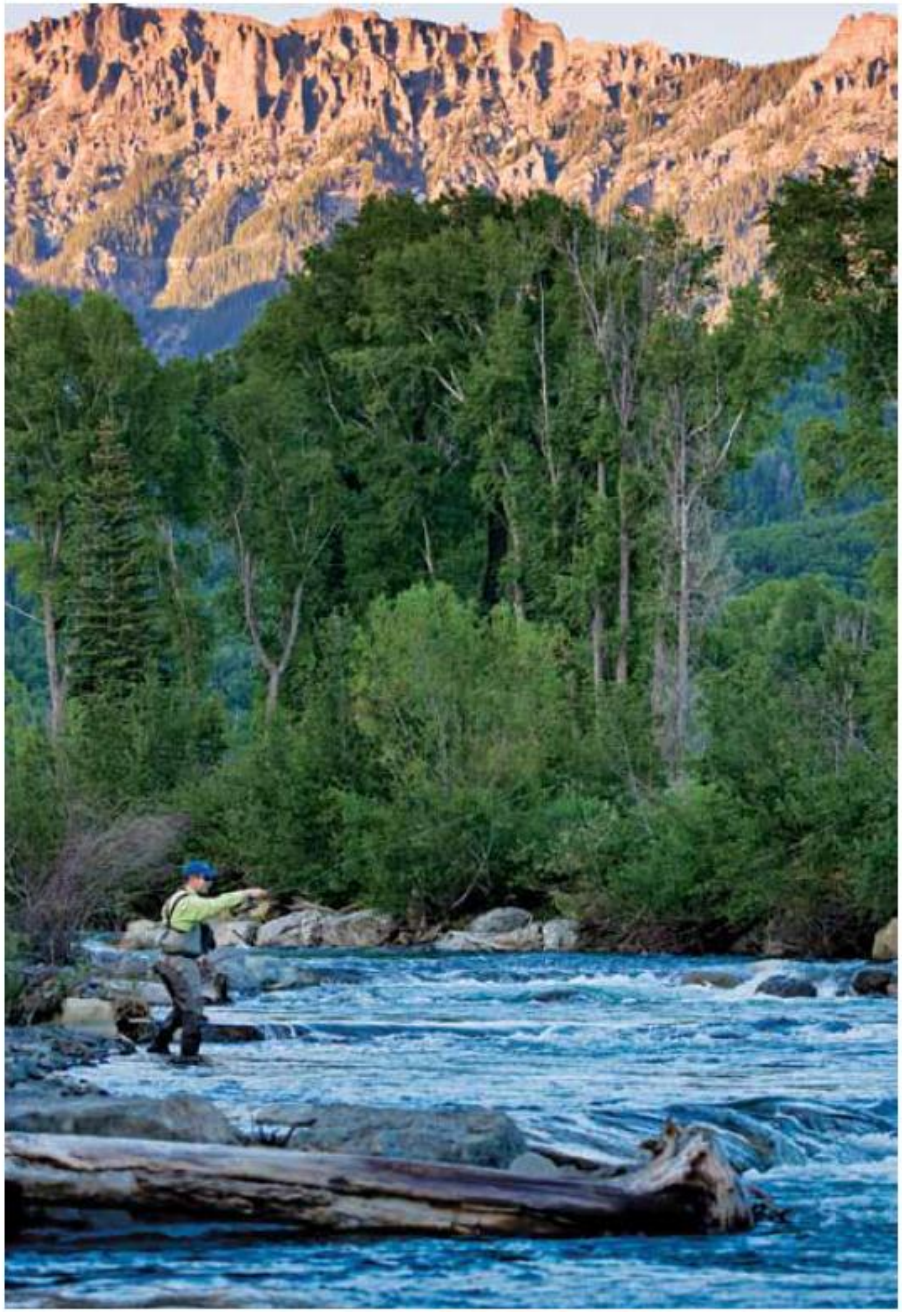
Exposure

El Rancho Pinoso, CO/By Ken Morrish

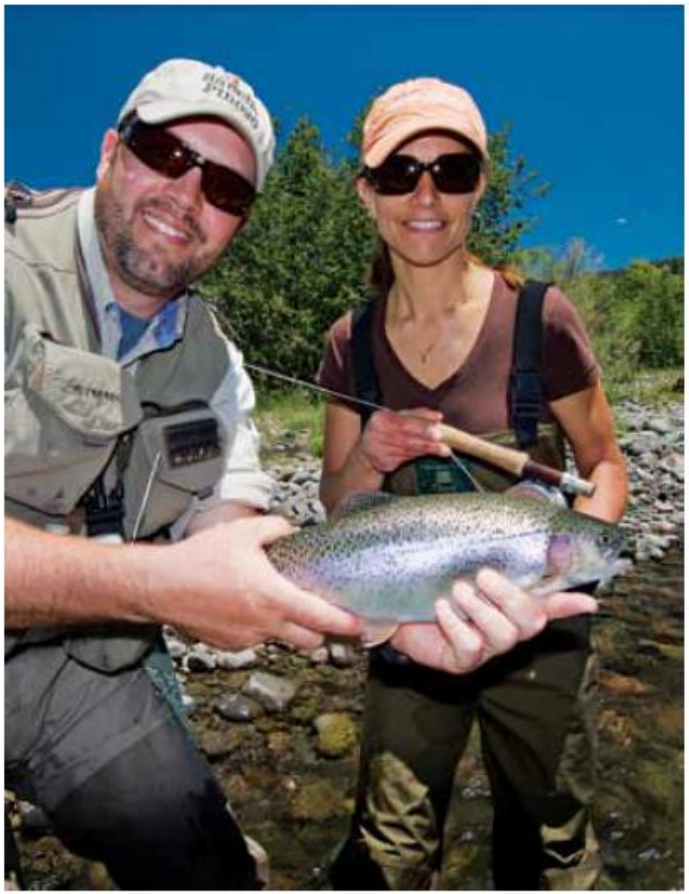
Ned Patton works the freestone flows of the upper Piedra River.

In Southwest Fly Fishing:

Blanco River constructed in 1987



Ned Patton works the Rio Blanco's Stairway to Heaven run.



Head guide Damon Scott and Mia Morrish with an average rainbow

Biological consequences of stream type stage shifts

Variable	Aquatic Habitat Response C → G	G →F	F → C	C → D
Instream Cover	↓	↓	↑	↓
Overhead Cover	↓	↓	↑	↓
Substrate Composition	↑	↓	↑	↓
Pool Quality	↓	↓	↑	↓
Holding Cover	↓	↓	↑	↓
Surface Water Temp.	→	↑	↓	↑
Dissolved Oxygen	→	↓	↑	↓
Macro Invertebrates	↓	↓	↑	↓
Spawning Habitat	↓	↓	↑	↓
Habitat Diversity	↓	↓	↑	↓
Rearing Habitat	↓	↑	↑	↑
IBI Score	↓	↓	↑	↓

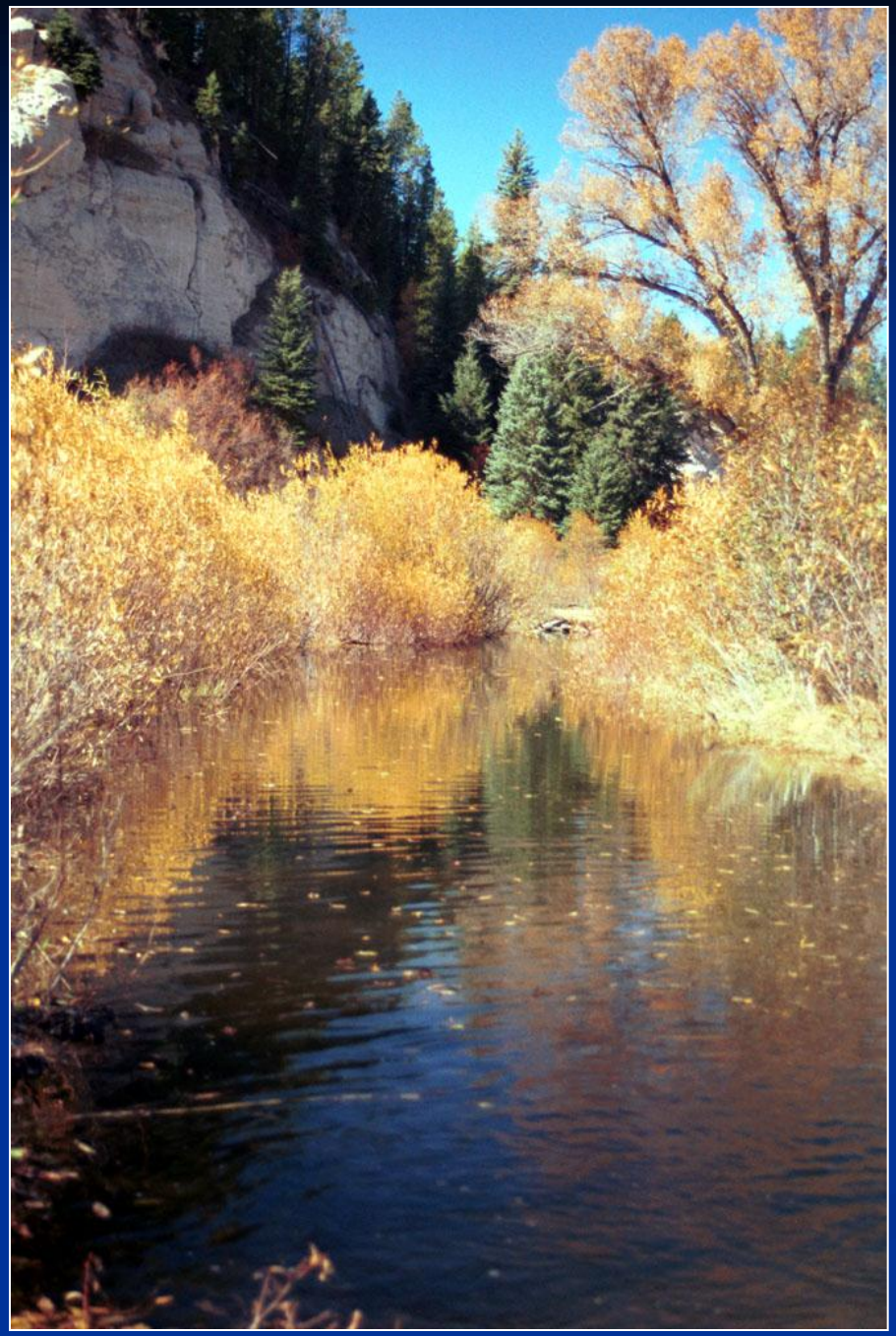
↑ Indicates Increase, ↓ Indicates Decrease, →Indicates No Change

Contrast of “restoration” methods applied, August, 2011

Contrast of “restoration” methods applied, August, 2011

Restoration 35 years later using NCD principles, 8/2011

Combination of root wad, bank vegetation and rock weir structures



Off-Channel Habitat: Middle Fork Little Snake, Colorado

Constructed food plots, interconnected with channel

Food plot & emergent wetland area constructed out of old channel, post-construction, 7/2011

Emergent wetland area constructed off-channel, post-construction, 7/2011

Constructed waterfowl habitat, emergent wetland & food plot area, post-construction, 7/2011

Constructed waterfowl habitat, emergent wetland & food plot area, post-construction, 7/2011

Step-pool structure out of oxbow lake

Step-pool outflow channel into oxbow lakes, connected to Blue River, Colorado

Oxbow Lake, Little Snake River, CO

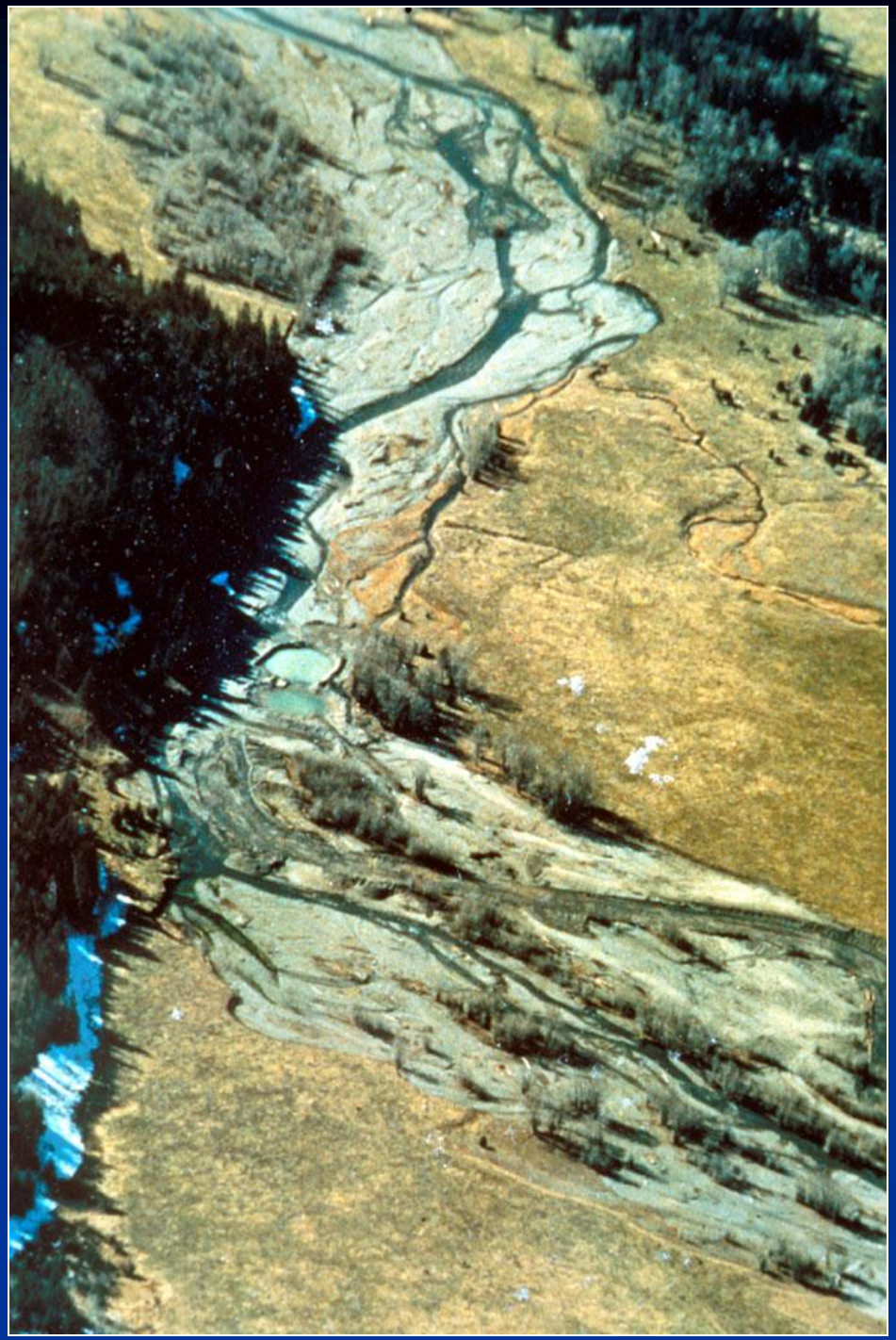
The East Fork San Juan River Restoration: 1987

Created meandering channel for physical and biological function, and recreated floodplain.

Featured in National Geographic "Special Edition-Water", 1993

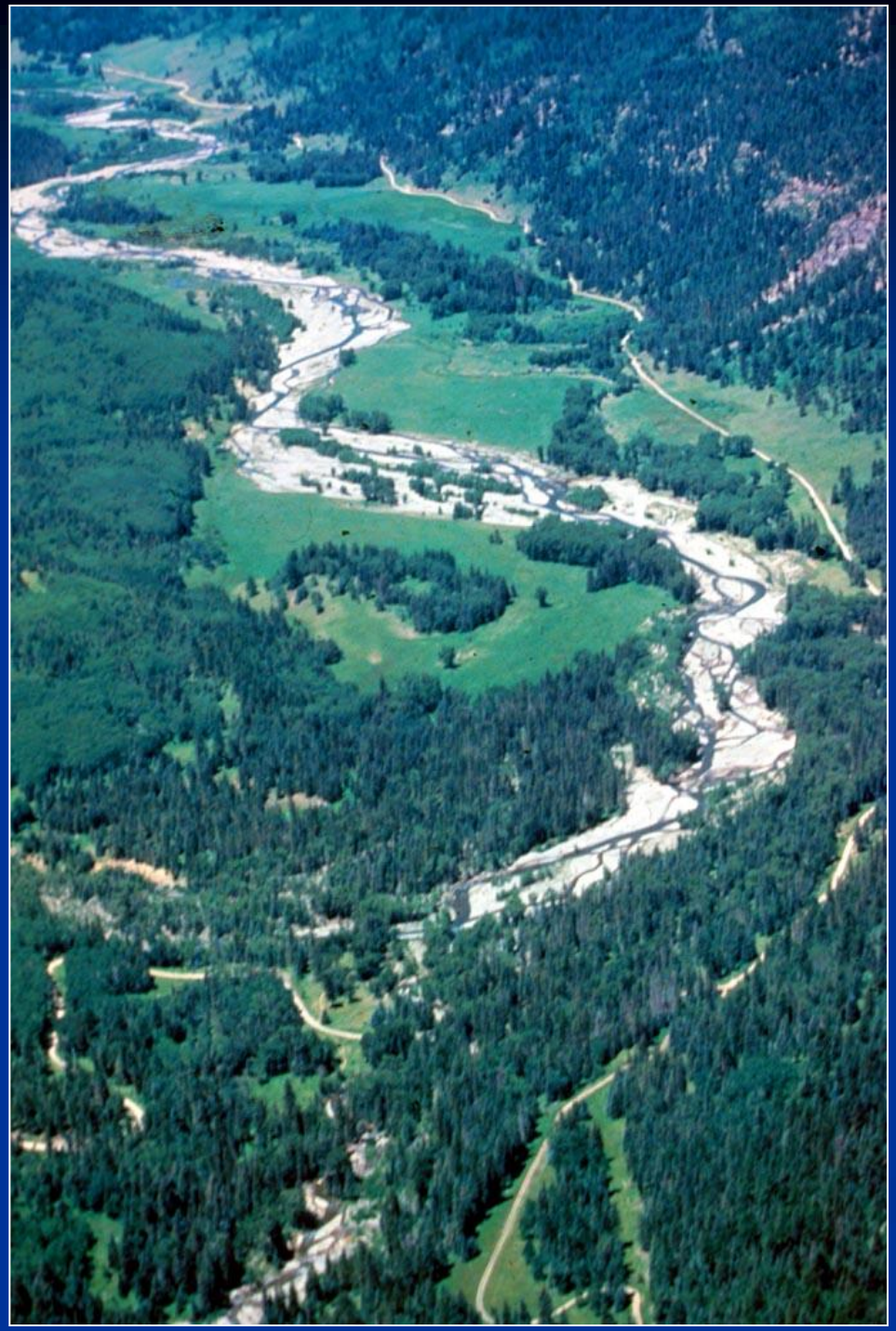
Typical braided reach cross-section, pre-restoration East Fork River, Colorado

Reference reach C4 stream type, two miles downstream of braided reach



East Fork San Juan River, Colorado, 1986

Off-channel sediment settling ponds downstream of construction (looking downstream)



East Fork San Juan River, Colorado, 1986

Prior to construction – looking downstream

Post-construction near bankfull stage (looking downstream)

Pre-restoration, start of project looking upstream on braided river

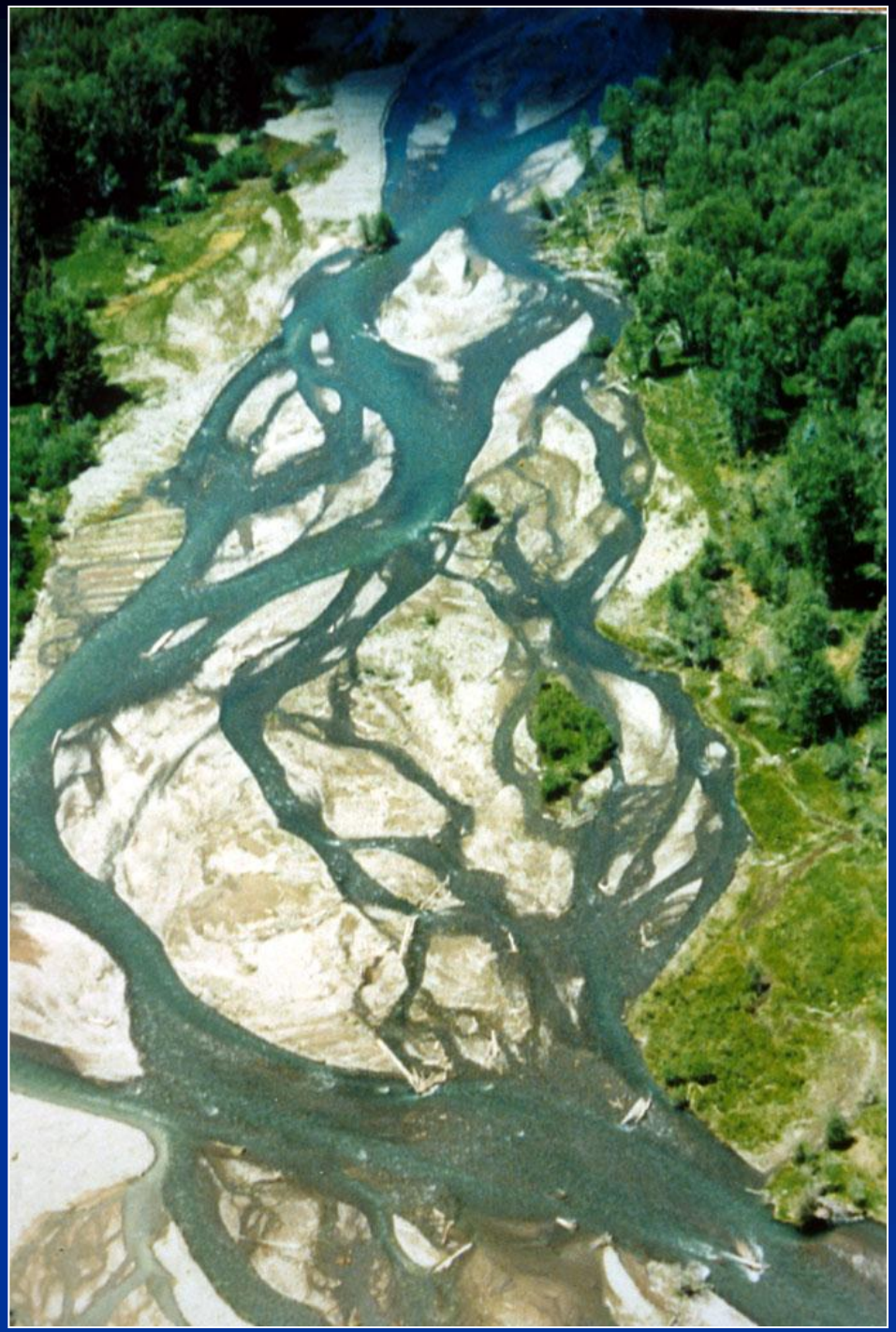
Construction (1986), shaping new channel *and* floodplain

Constructed C4 stream type and floodplain, following 5-year return period flood

The Blanco River Restoration: 1987

Created meandering channel for physical and biological function, and recreated floodplain.

Documented in National Research Council publication "restoration of Aquatic Ecosystems, 1991



Pre-restoration, braided reach – Blanco River

Post-restoration (same reach) – Blanco River

Pre-restoration braided Reach – Blanco River

Post-restoration reach – Blanco River

Blanco River flood 4x bankfull, 1995

Recession stage following 1995 flood

Blanco River constructed floodplain and riparian vegetation – 1996

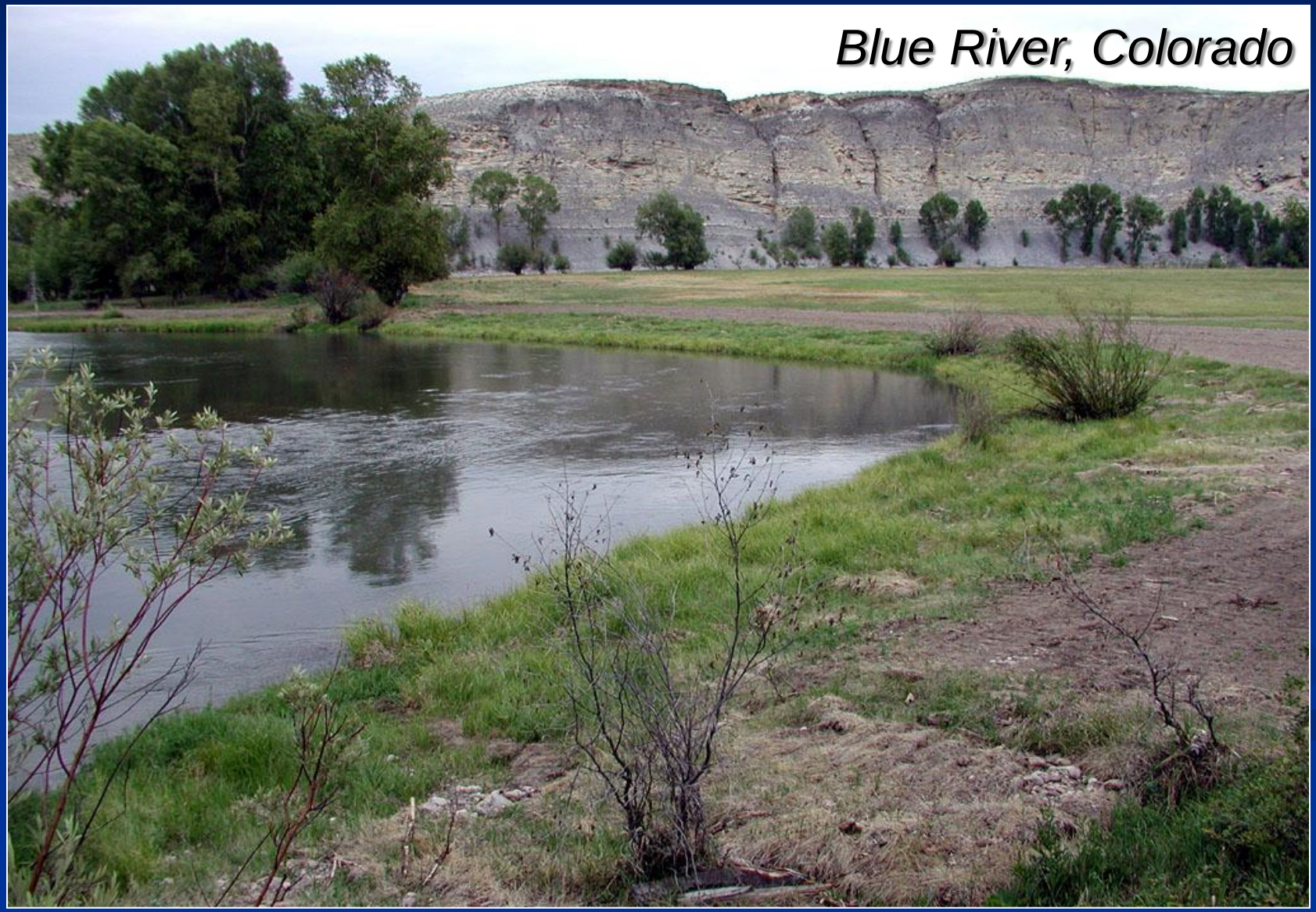
Blanco River floodplain, 24 years after restoration, August, 2011

The Blue River Restoration:

Created stable morphology of river channel and provided off-channel features for a diversity of habitats

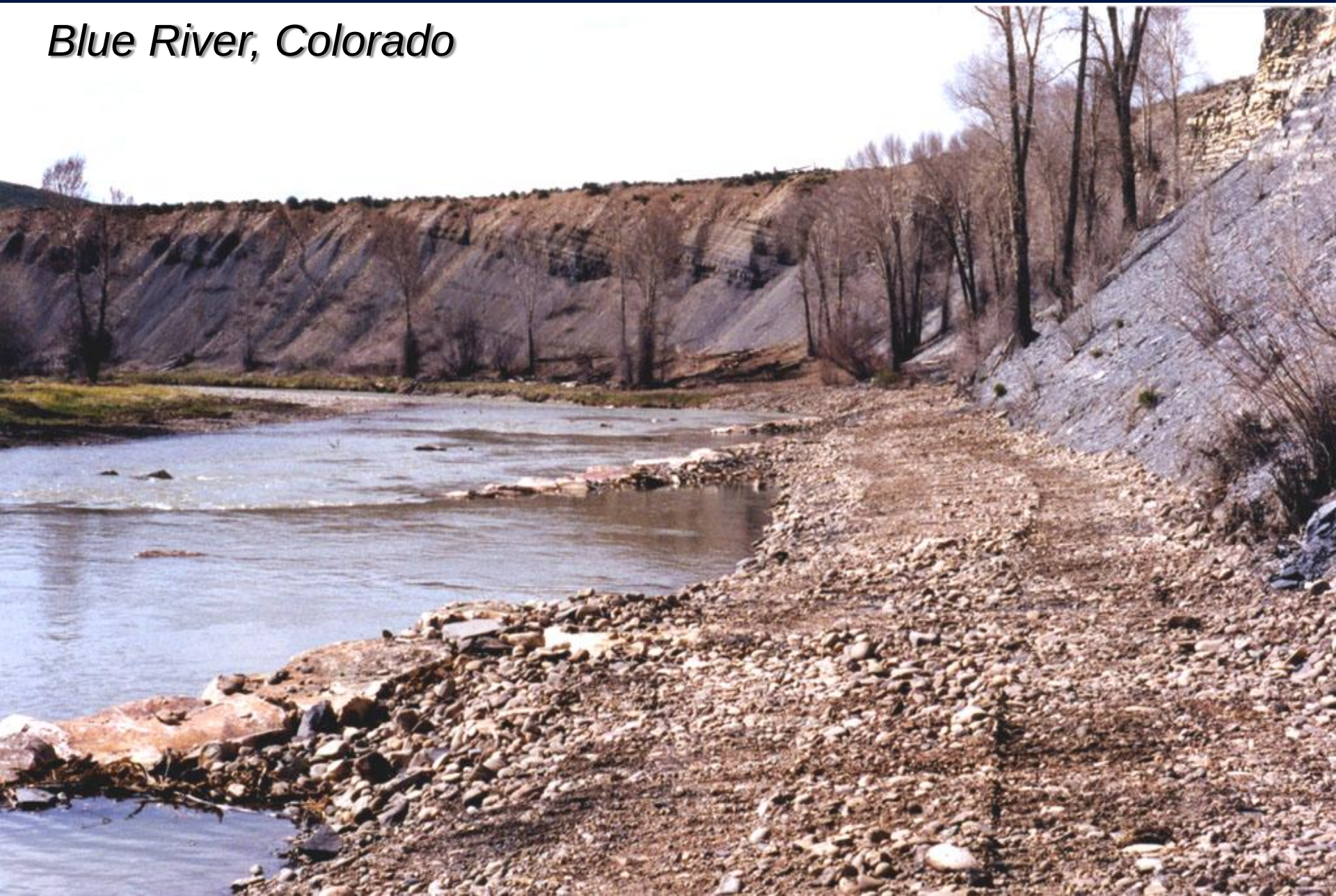
Blue River (Colorado) streambank erosion

Sod mat layers & willow transplants to stabilize streambank



J-Hook Vane with constructed bankfull bench

Blue River, Colorado



J-Hook Vane & bankfull bench after flood

Blue River bankfull bench in 2009

Summary

1. Provide training, mentoring and peer review opportunities
2. Develop consistent design criteria, standards & requirements

Summary

3. Promote fundamental requirements for NCD, including:
   a) Clear objectives (phase I) carried through all remaining phases
   b) Appropriate selection of reference reach stratified by controlling variables
   c) Physical & biological assessments
   d) Hydraulic, competence & capacity checks

Summary

e) In-channel & off-channel design components, and structure selection appropriate for boundary conditions and objectives

f) Monitoring and documenting results of successes ***and*** failures

"Learn all you can from the mistakes of others. You won't have time to make them all yourself."

- Alfred Sheinwold

River Restoration & Fish Habitat Enhancement have "Big" Rewards (Blue River Restoration, Colorado)