Stream Restoration

Pierre Y. Julien

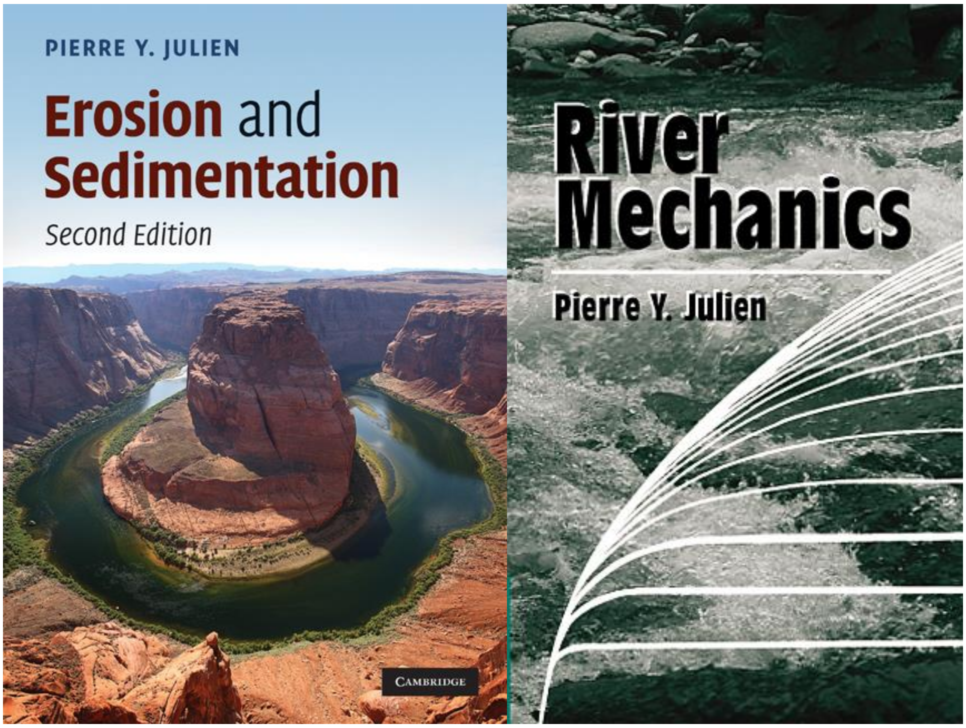
Department of Civil and Environmental Engineering
Colorado State University
Fort Collins, Colorado

Short Course on
Restauracion Fluvial e Ingenieria de Rios
Lima Peru – September 27, 2016

Objectives

Brief overview of stream restoration and rehabilitation guidelines:

1. Stream Dynamics and Equilibrium;
2. Stream Degradation;
3. Streambank Stabilization;
4. Ten Guidelines for Stream Restoration.



1. Stream Equilibrium and Dynamics

Objectives

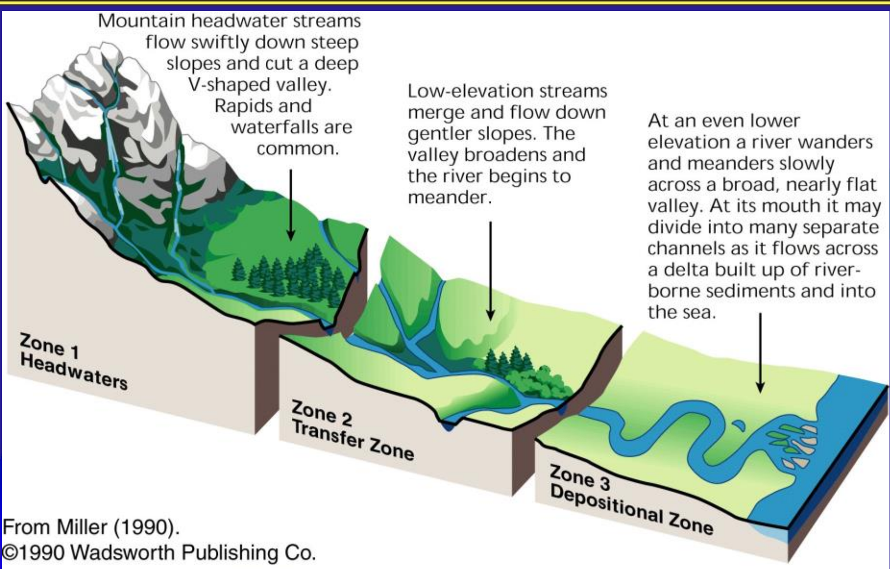
Stream Equilibrium and Dynamics

a) Concept of equilibrium

b) Dynamic changes

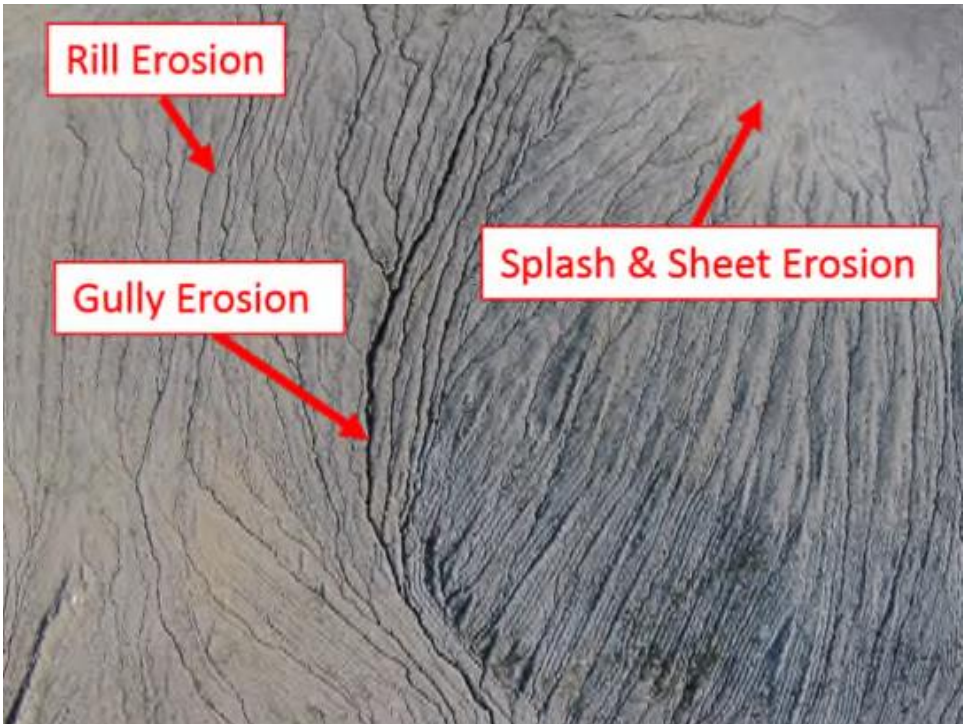
c) Concept of time scales

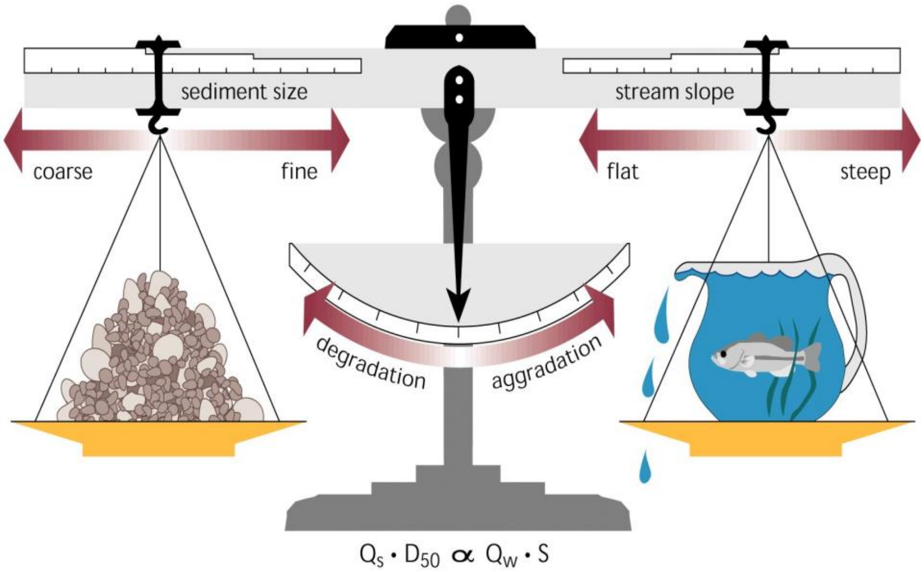
1a) Concept of Equilibrium



From Miller (1990).
©1990 Wadsworth Publishing Co.

Fig. 1.27 – Three longitudinal profile zones.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (15 Federal Agencies of the US).

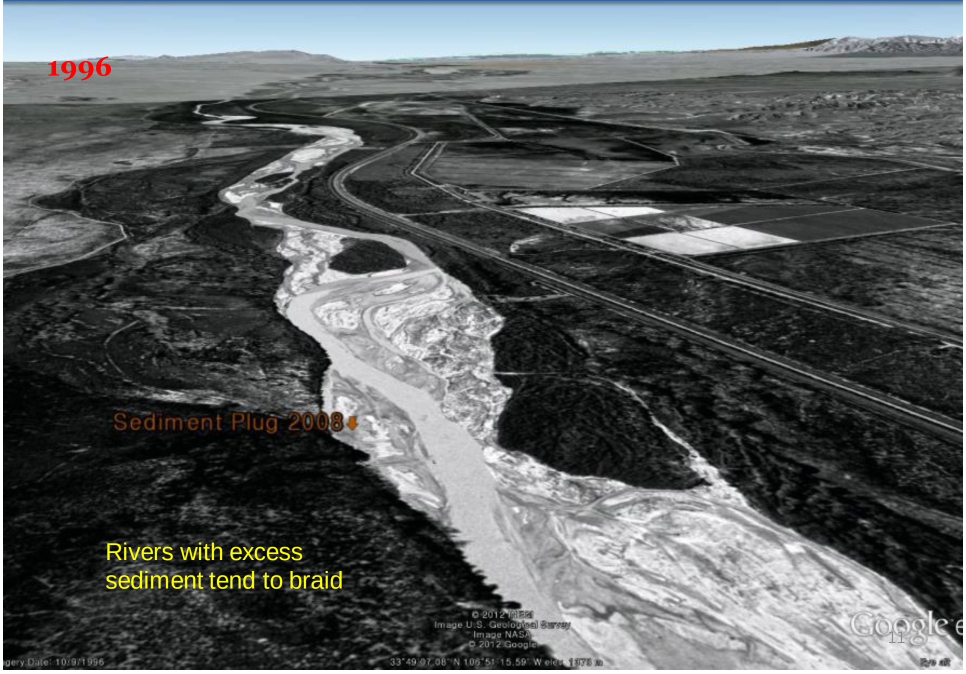

Rill Erosion
Splash & Sheet Erosion
Gully Erosion



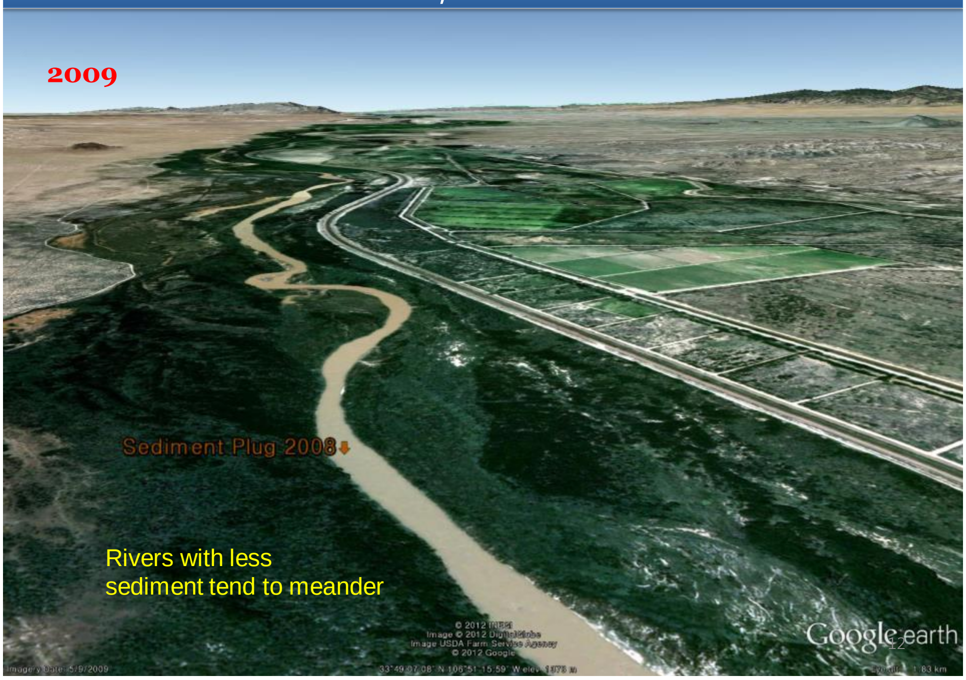
1b) Dynamic changes

- The system is dynamic
- A stable river is one in which, over a period of years, slope is delicately adjusted to provide just the velocity required to transport the available water & sediment supplied from the drainage basin.
  (… after Mackin, 1948)

Middle Rio Grande, 1996



Middle Rio Grande , 2009




Pine beetle and the Colorado Forest


Waldo Fire
Colorado June 2012

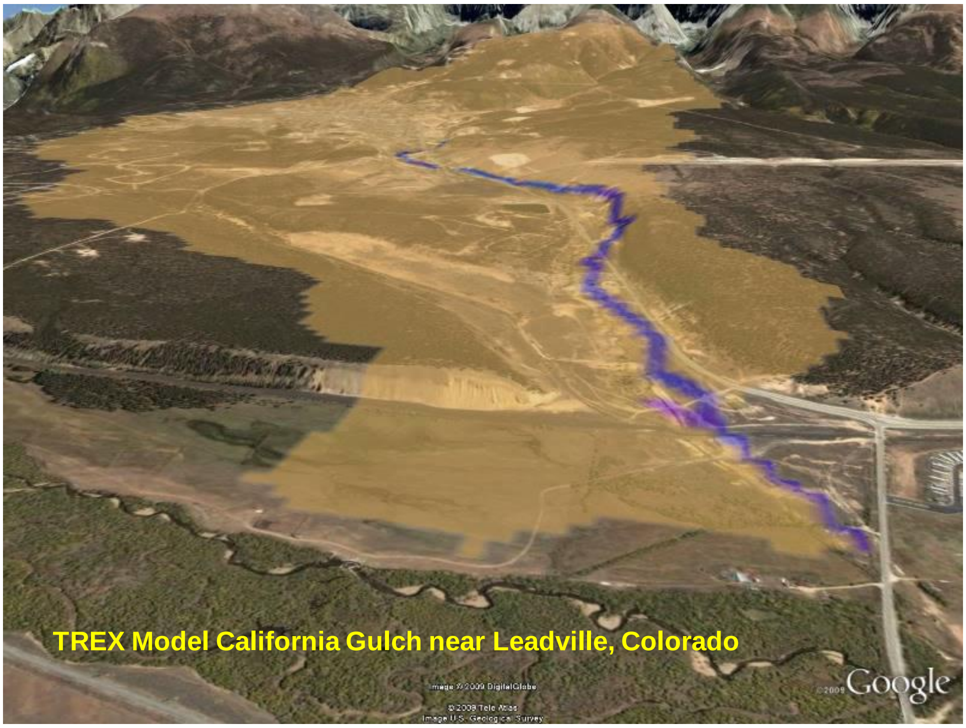

Waldo Fire
Colorado June 2012


Post- fire erosion
Buffalo Creek, CO
Photo from US Geological Survey


Post-fire erosion
Buffalo Creek, CO
Photo from US Geological Survey


Impact on water quality


EPA Superfund Site Restoration
California Gulch near Leadville, Colorado



1c) Concept of Time Scales

- Geological ~ 1,000,000 years
- Glaciation ~ 10,000 years
- Engineering ~ 100 years
- Vegetation ~ 10 years
- Aquatic life ~ 1 year

" … four glaciations were recognized, each lasting approximately 100,000 years…

the maximum ice thickness was close to 4,000 metres"

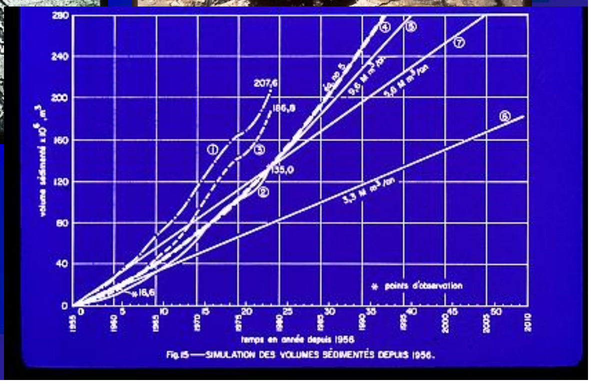
The Canadian Encyclopedia

Peligre Dam in Haiti (deforestation)

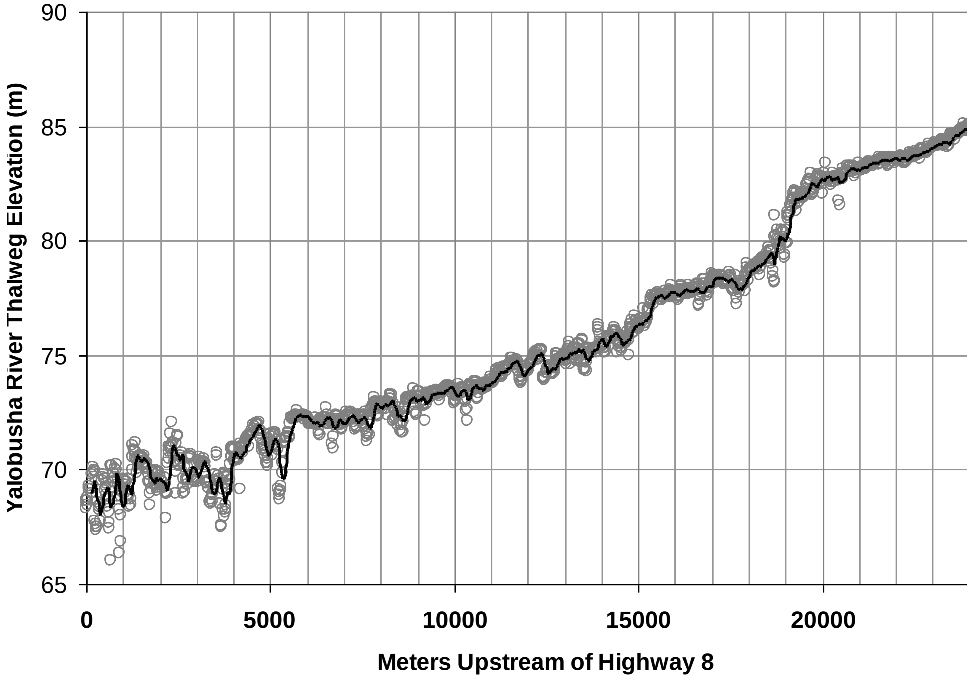
Subsistence Farming

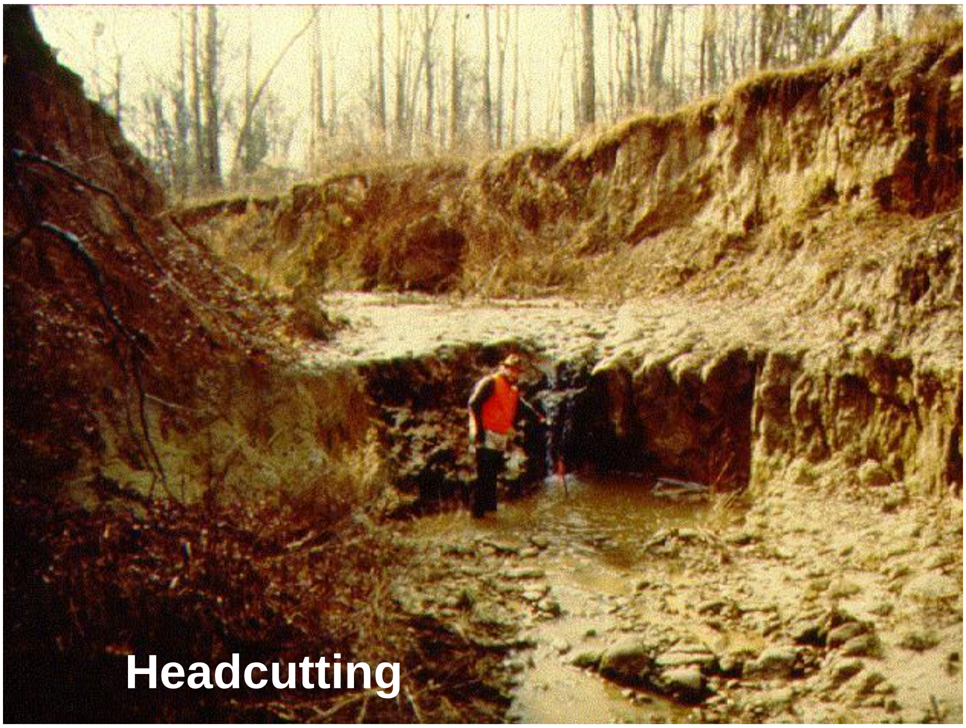
Peligre Dam (sedimentation)

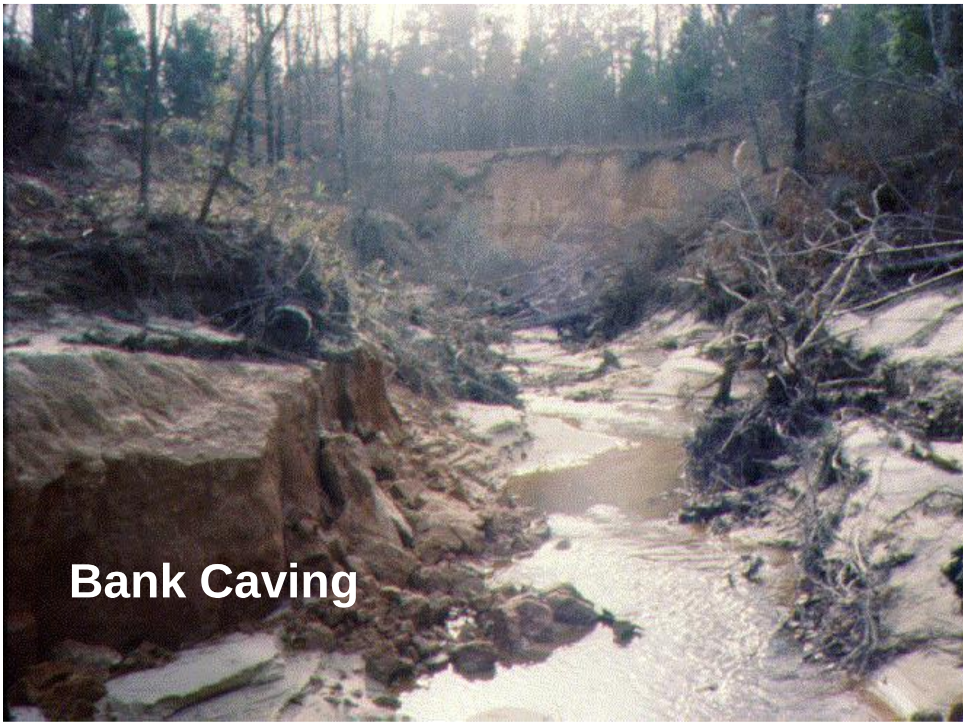
Peligre Dam (reduced life expectancy)



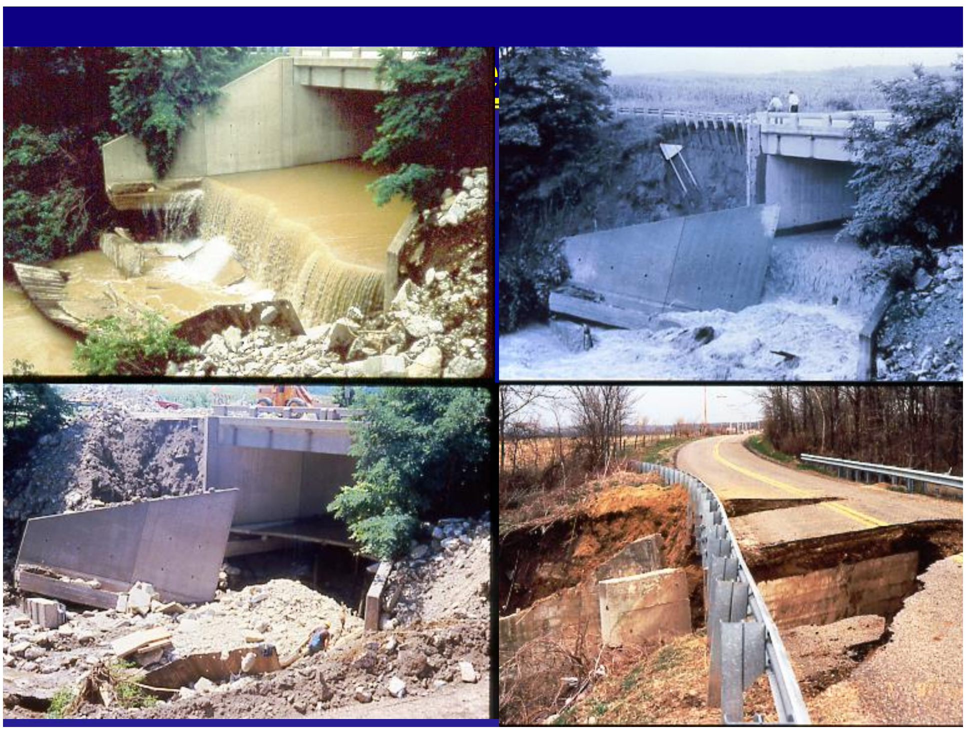
2. Stream Degradation


Yalobusha River Thalweg Elevation (m)
90
85
80
75
70
65
0
5000
10000
15000
20000
Meters Upstream of Highway 8

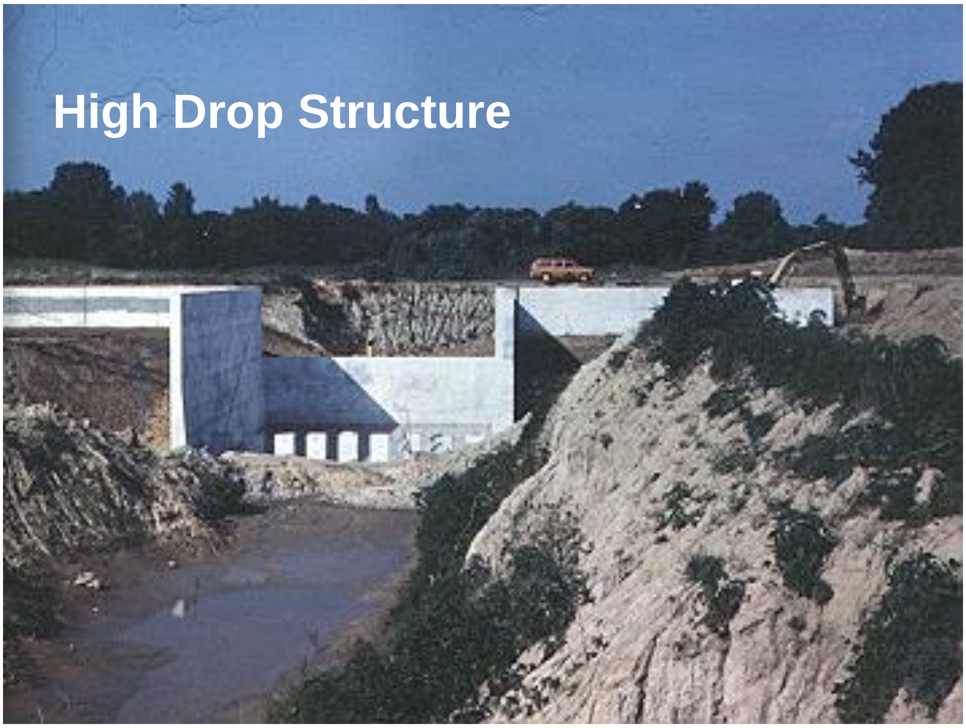

Headcutting

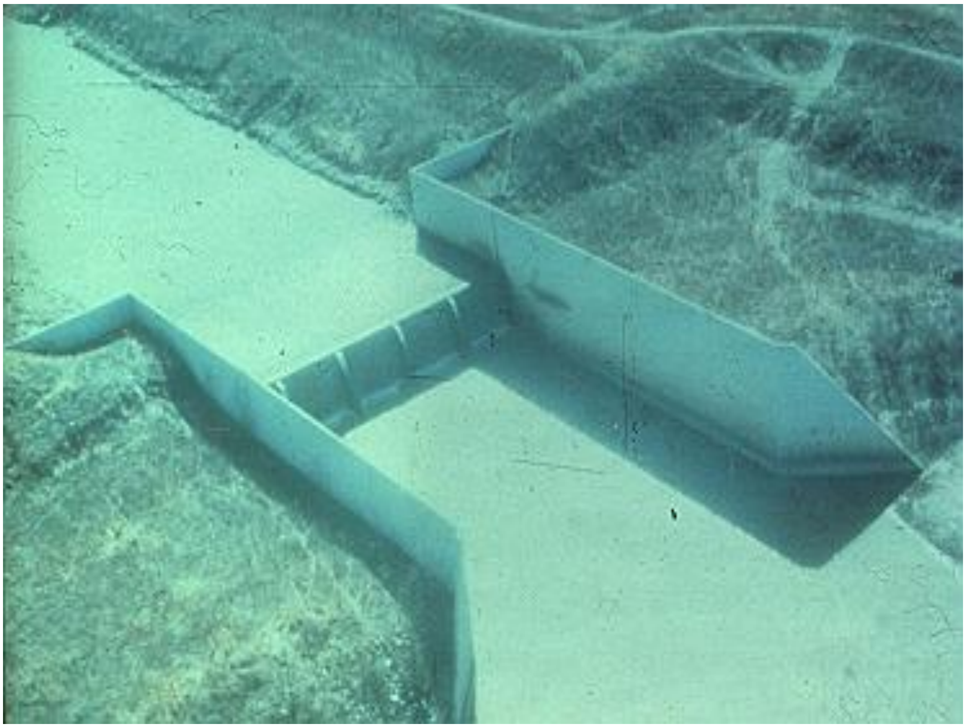

Bank Caving

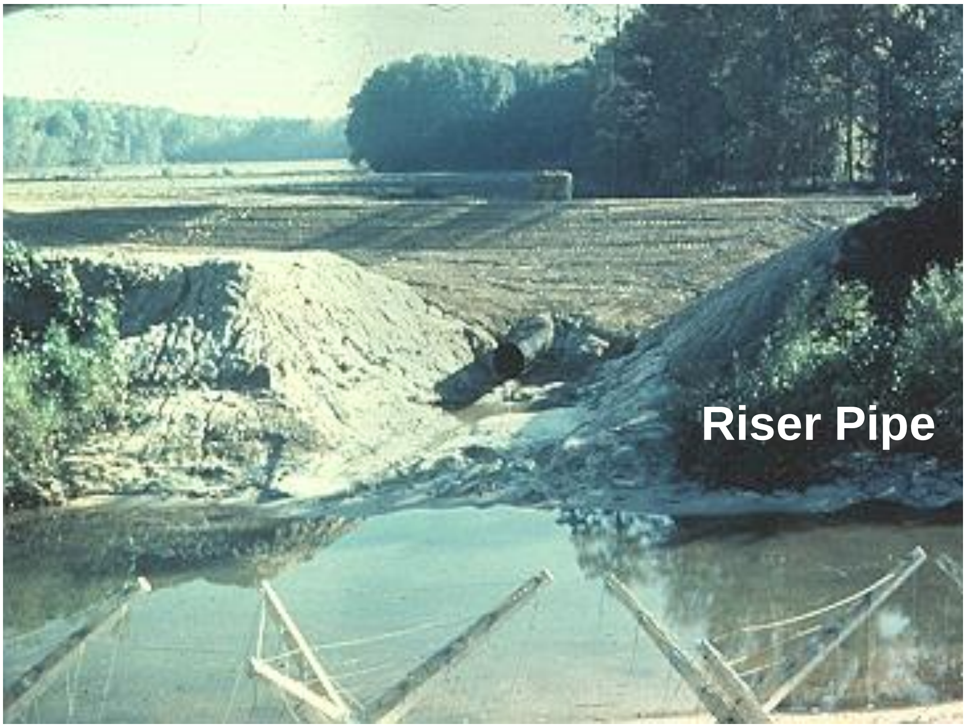

Crush




Low Drop Structure


High Drop Structure




Riser Pipe

3. Streambank Stabilization

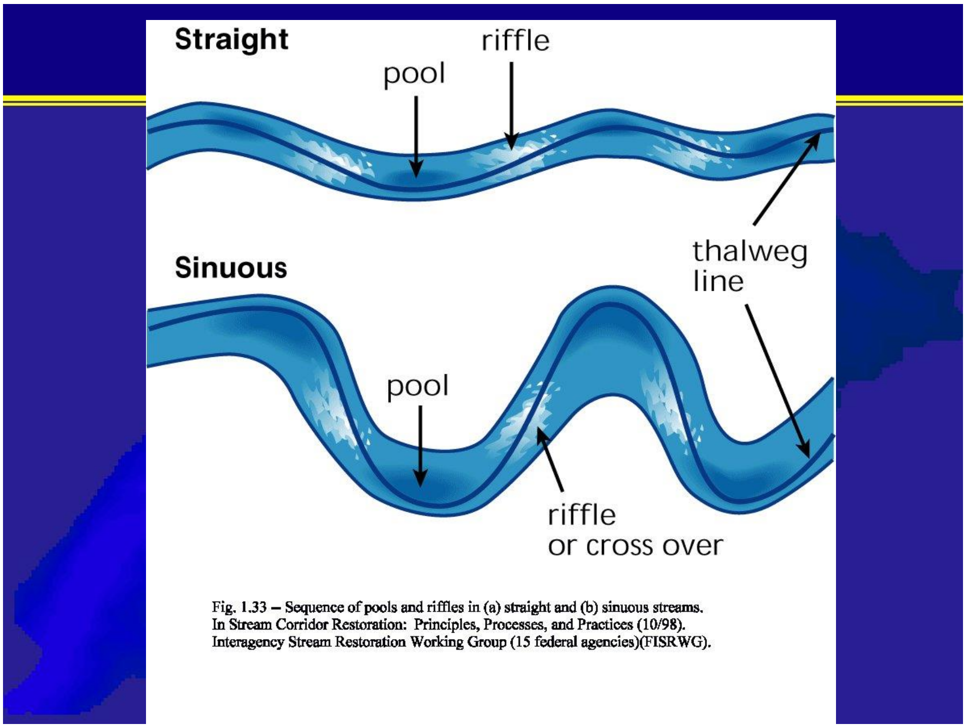
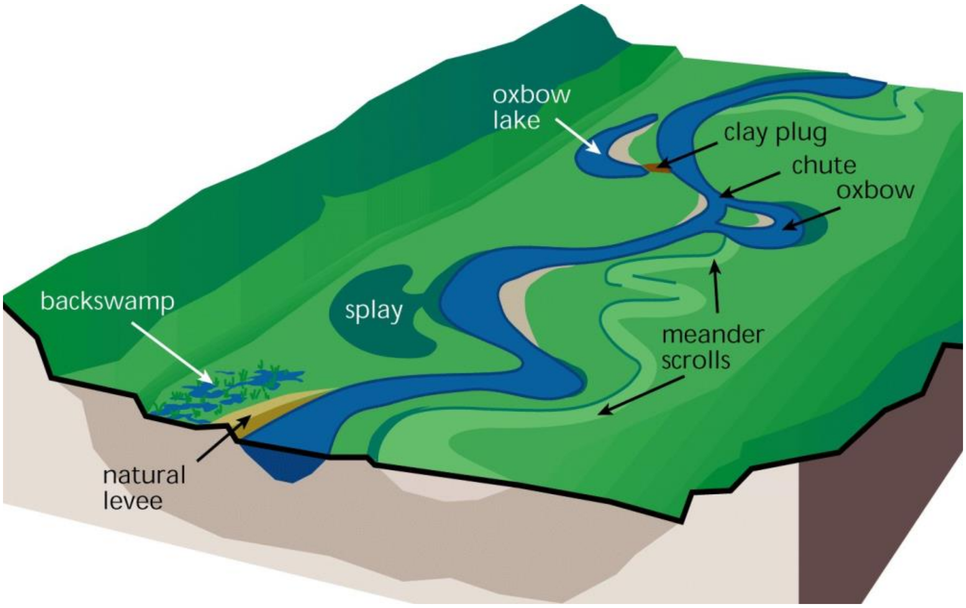
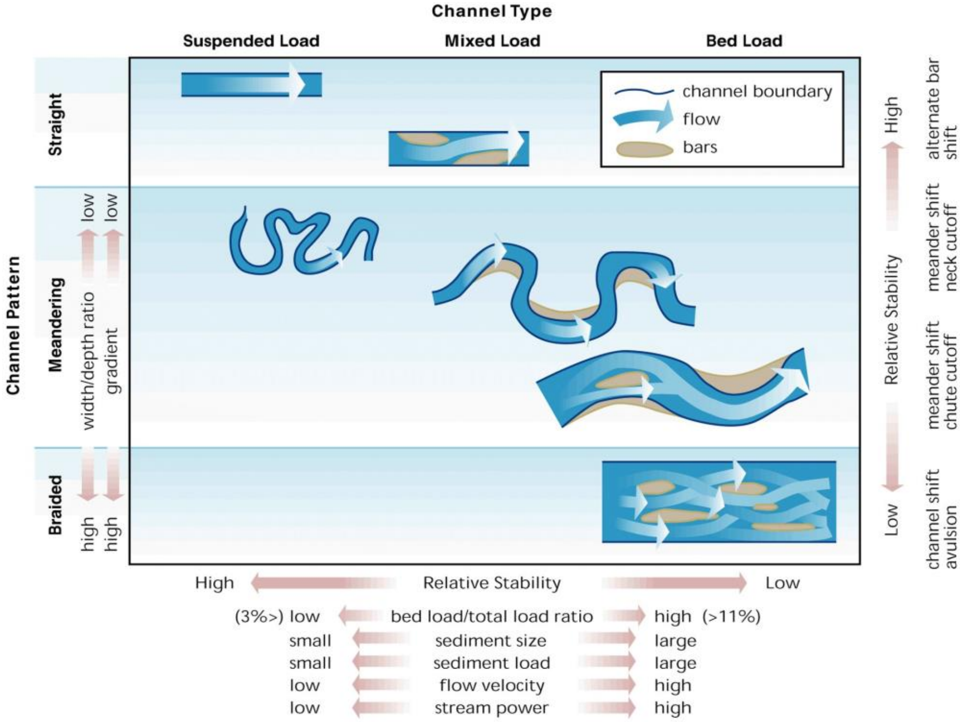


Fig. 1.33 – Sequence of pools and riffles in (a) straight and (b) sinuous streams.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).

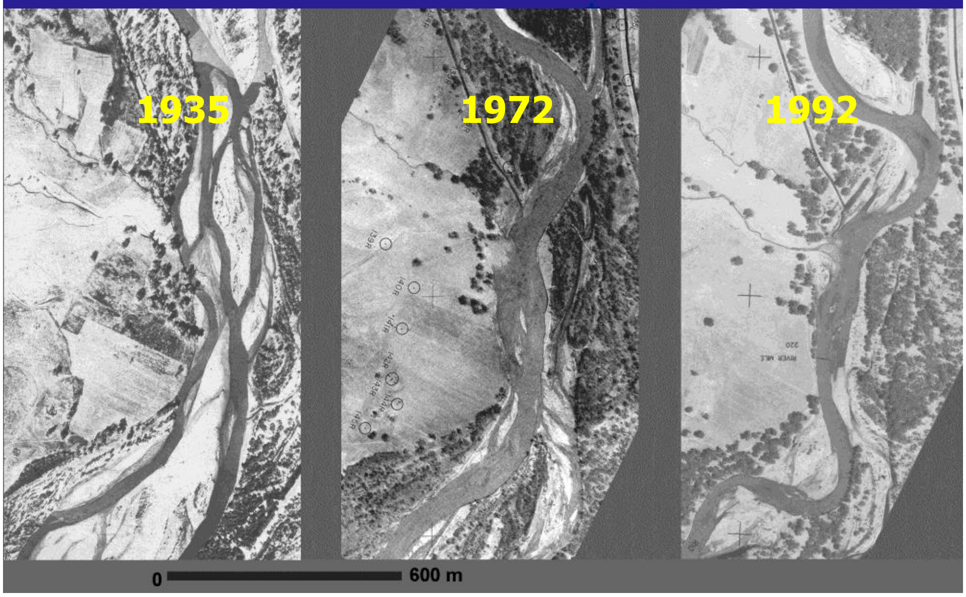



Meandering
Channel


Braided Channel



Hydraulic geometry of the Rio Grande

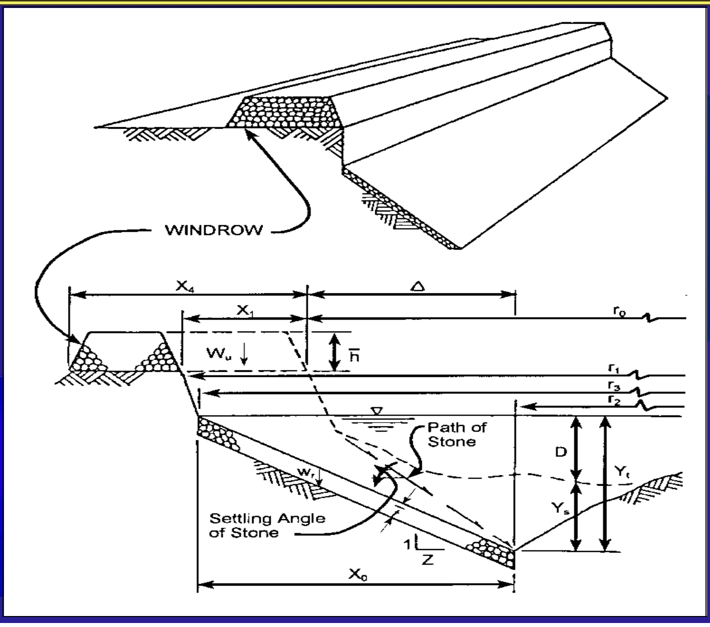


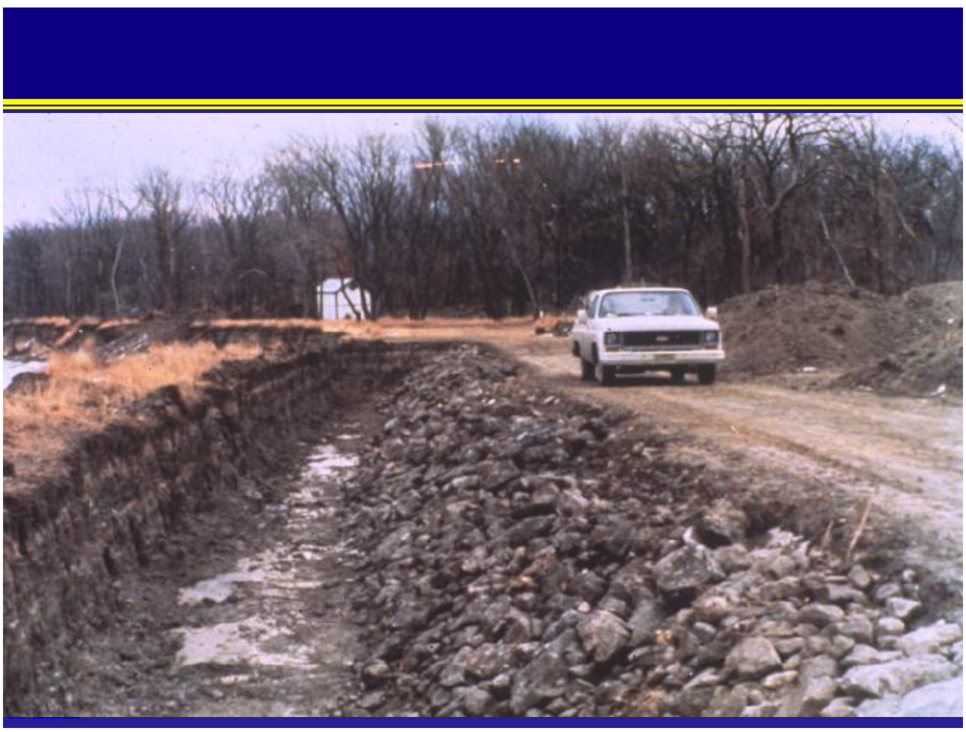

REQUIREMENTS OF
BANK STABILIZATION
• Effective
• Environmentally Sound
• Economical
(Listed in order of necessity)


Willow posts
'96 3 26


Retards

Windrows






APR 1 '9


Hardpoints


Fence Dikes

Jetty fields and vegetation of the Rio Grande

Jetty System (near Bernardo), USACE 1963


Debris Deposition

Stream Restoration Summary

#1 There is no cookbook approach to stream restoration projects.

#2 Solutions normally require equilibrium conditions between sediment regime and stream ecology.

#3 Solutions need to be effective, environmentally acceptable and economical.

4. Ten Guidelines for Stream Restoration

Restoration vs Rehabilitation

Restoration

•returning a resource to some former condition.

Rehabilitation

•maximize the potential beneficial uses of a resource to some reasonable and practical level.

Objectives

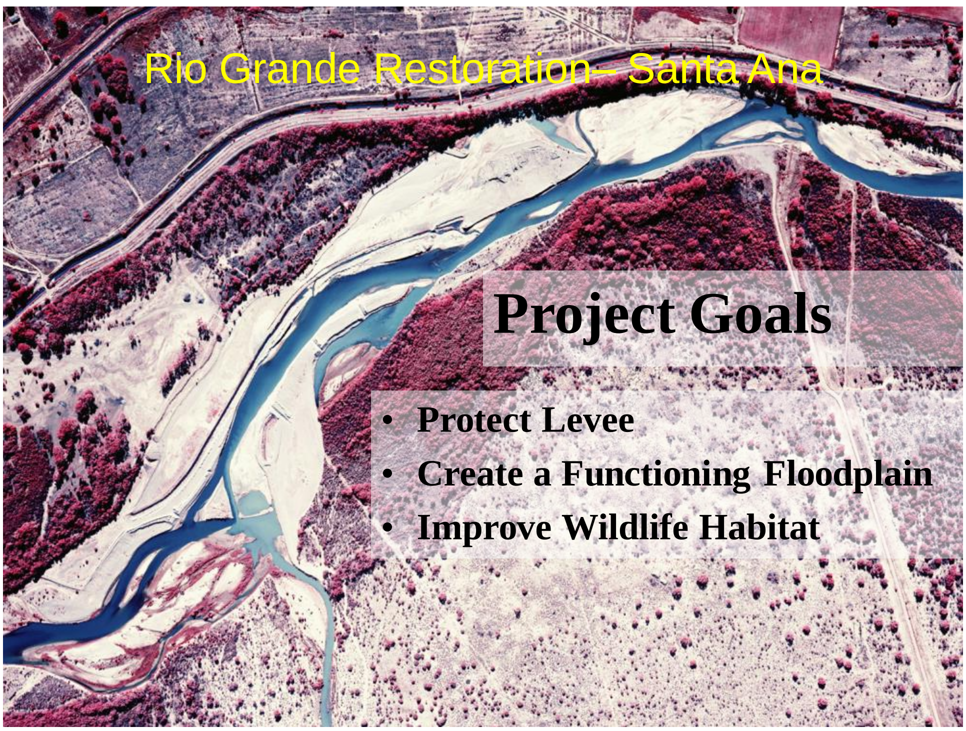
Ten Guidelines and Case Study

1. Guidelines for Stream Restoration Projects
2. Case-study on the Rio Grande with special thanks to Dr. Drew Baird

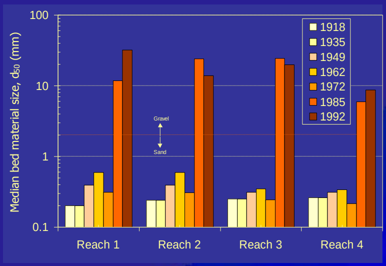
Stream Restoration Guidelines

1. **OBJECTIVES** - Clearly define the engineering and ecological objectives - restoration vs rehabilitation.

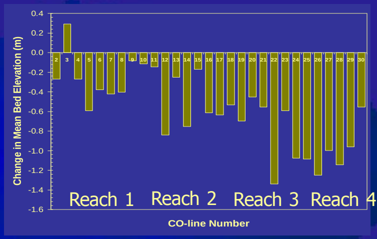
2. **PAST, PRESENT and FUTURE** – Consider present conditions in the perspective of past events and examine future changes.



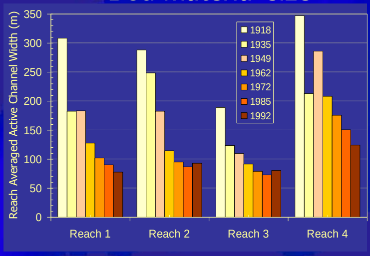
Hydraulic geometry of the Rio Grande



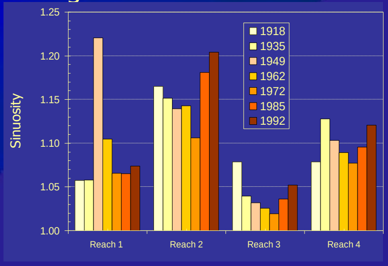
Bed material size



Change in Mean Bed Elevation



Active channel width



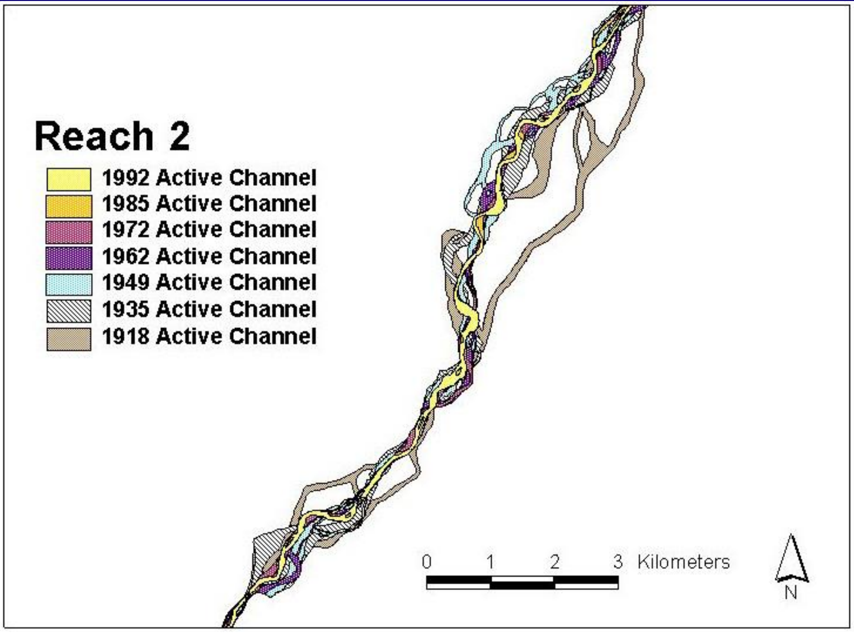
Sinuosity

Stream Restoration Guidelines

3. **UPPER WATERSHED** – Look at the geology, deforestation, land use changes, urbanization, climate and extreme events. Examine water and sediment supply, flood frequency curves, sediment mass curves sediment concentrations, water quality, etc.

4. **DOWNSTREAM REACH** – Look at possible changes in the downstream reach that may affect current conditions – like reservoirs, base level changes, headcutting, etc.

Hydraulic geometry of the Rio Grande



Stream Restoration Guidelines

5. **CHANNEL GEOMETRY –** Determine equilibrium downstream hydraulic geometry in terms of width, depth, velocity, slope, discharge and morphology.

6. **AQUATIC HABITAT**– determine appropriate aquatic habitat conditions including low and high flow periods, pools, riffles, spawning grounds, shade, aeration, migration, etc.

Rio Grande Restoration– Floodplain restoration

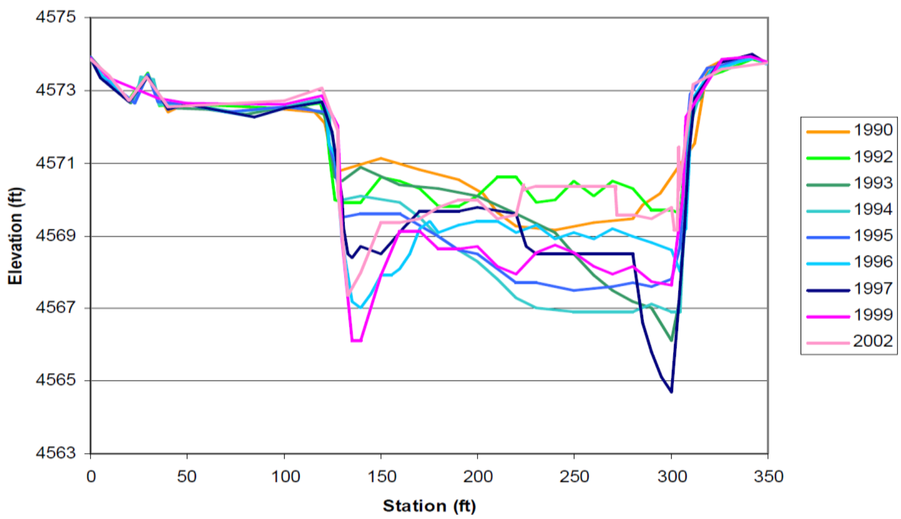


Figure A.18 Cross-section survey at SO-line 1410

Rio Grande Restoration– Endangered Species

- **Bimodal sand/gravel bed**
- **Deep water h ~ 1.20 m**
- **Water velocities 1.4 m/s**

Restoration

- **Create wider channels**

- **Sandy/silty substrate**
- **Shallow water h < 0.4 m**
- **Water velocities**
  0.1 m/s < V < 0.5 m/s

Stream Restoration Guidelines

7. **EXAMINE ALTERNATIVES –** Identify several different stream rehabilitation schemes that would suit the engineering and environmental needs.

8. **DESIGN SELECTION –** examine the various alternatives and select the best possible alternative and proceed with the design. Solution must be effective, environmentally sound and economical.


Link-Belt


Gradient Restoration Facility
• Raise Riverbed with GRF


River Realignment
• Construct Bio-engineering bankline with Fabric Encapsulated Soils
9 29 '01


Floodplain Maintenance
• Lower Terraces with Heavy Equipment


Floodplain Restoration
• Excavated Sediment Placed near Pilot Channel
1 18 '01


Habitat Improvement
• Sediment Storage Upstream from GRF
• Low Velocity Overbank Flows
• Planting and Natural Reseeding of Native Vegetation

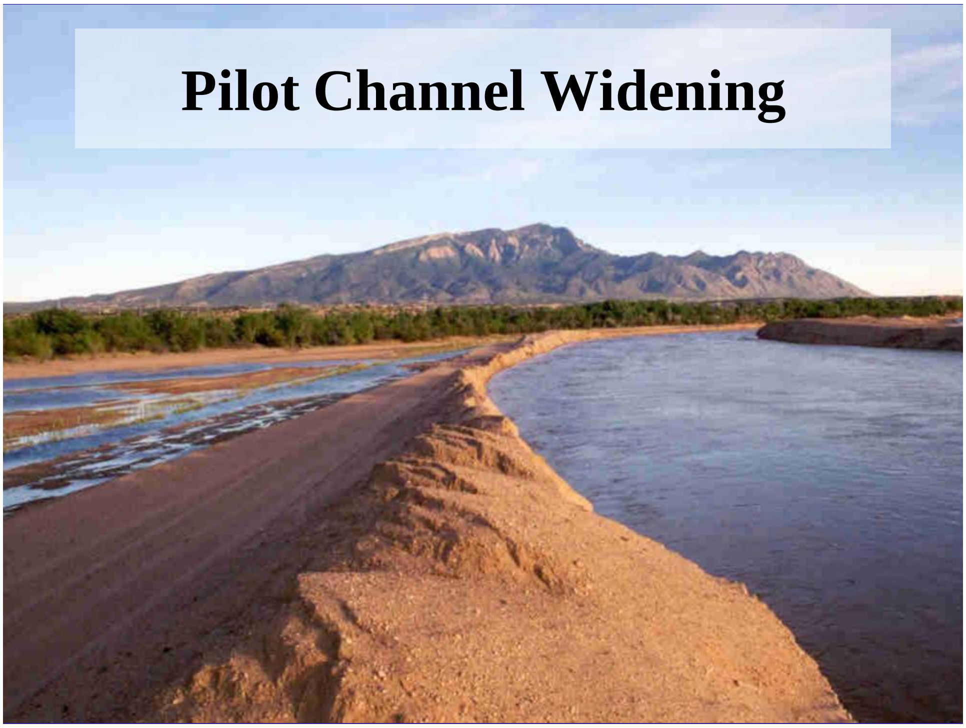
Stream Restoration Guidelines

9. **CONSTRUCTION –** Carefully plan the construction and consider the possible impact of possible extreme events during the construction period.

10. **MONITORING –** Things may not work as planned. A post-construction analysis and monitoring should be carried out until the objectives have been met.


Opening Pilot Channel


River Realignment
• Divert River into Pilot Channel

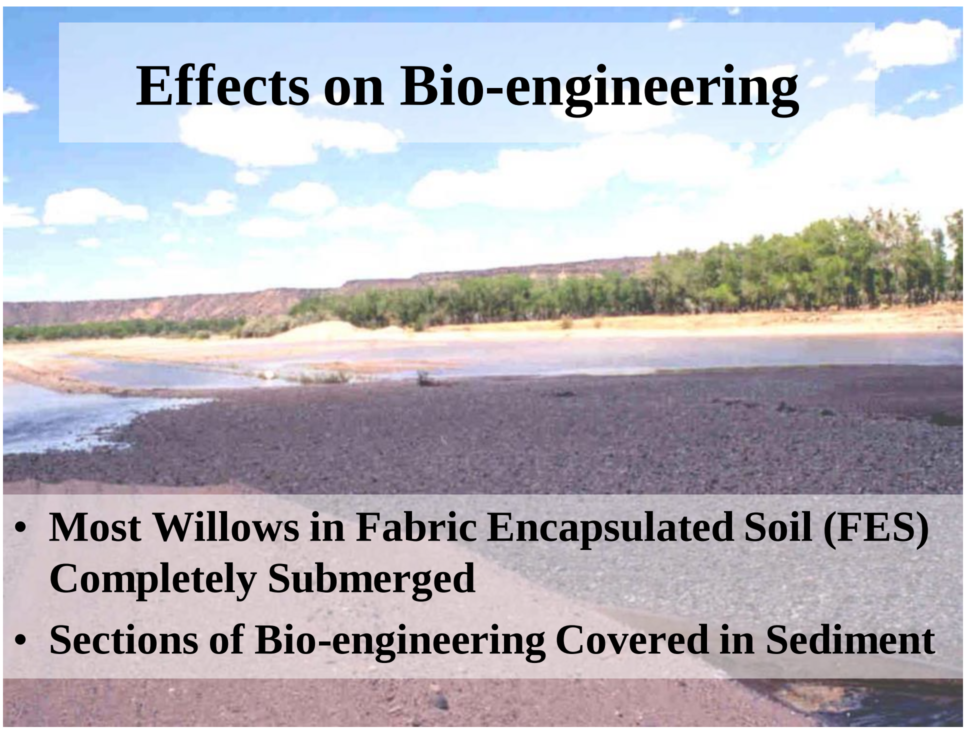

Pilot Channel Widening


Spring Runoff - 2001

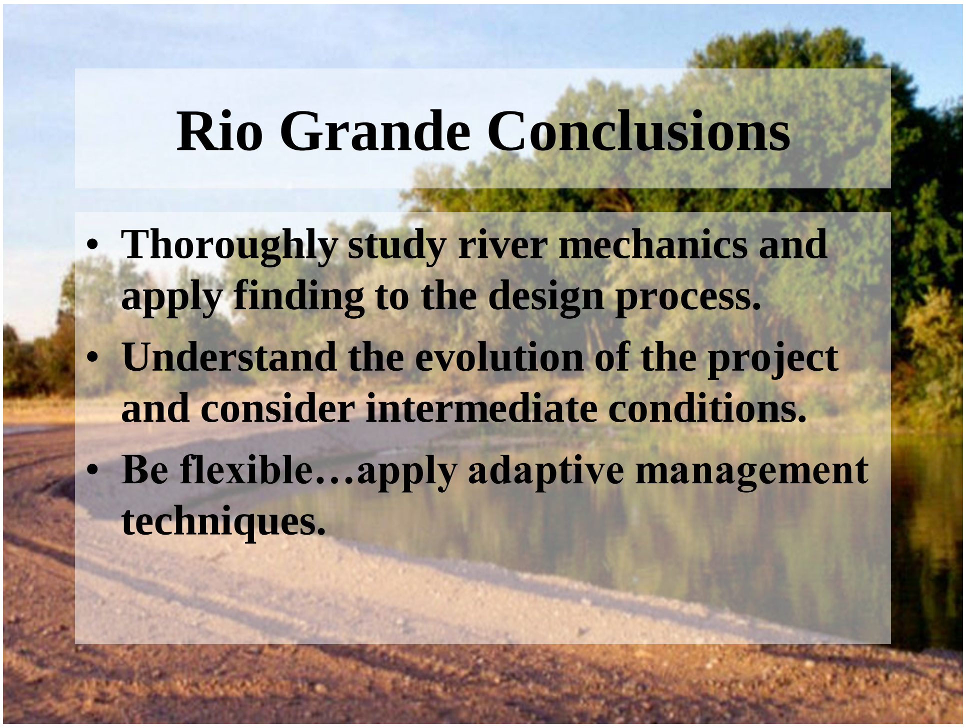
Post-Runoff Assessment

- More Gravel than Anticipated
- Mean Bed Elevation 2 ft Higher than Anticipated
- Pilot Channel 50-100 ft Narrower than Desired

Effects on Bio-engineering



- Most Willows in Fabric Encapsulated Soil (FES) Completely Submerged
- Sections of Bio-engineering Covered in Sediment



Stream Restoration Guidelines

1. Clearly define the **OBJECTIVES**
2. **PAST,** Present and **FUTURE**
3. Look at the **UPPER WATERSHED**
4. Look **DOWNSTREAM** for degradation
5. **EQUILIBRIUM** Hydraulic Geometry
6. Appropriate **AQUATIC HABITAT**
7. Examine various design **ALTERNATIVES**
8. **DESIGN** must be Effective, Environmentally sound and Economical
9. Plan **CONSTRUCTION** for the unexpected
10. Post-construction **MONITORING**


ACKNOWLEDGMENTS
Dr. Drew Baird, USBR
Jonathan Aubuchon, USBR
Robert Padilla, USBR
Dr. Craig Fischenich, ERDC
Patrick O'Brien, CRREL and ERDC
Dr. Tom Pokrefke, ERDC
Dr. Otto Stein, MSU
Dr. Noel Bormann, GU
Dr. Billy Johnson, ERDC, Mississippi
Dr. Daryl B. Simons, CSU and SLA
Dr. E.V. Richardson, CSU
Dr. Stan Schumm, CSU
Dr. Marcel Frenette, Canada
Dr. Ellen Wohl, CSU
… so many others …


Muchas
Gracias!
pierre@engr.colostate.edu