# River Restoration and Rehabilitation

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**River Mechanics and Sediment Transport**
**Lima Peru – January 2016**

# Objectives

Brief overview of stream restoration and river rehabilitation guidelines:

1. River Dynamics and Response;
2. Three Laws for River Restoration;
3. Ten Guidelines for River Restoration.

# 1. River Dynamics and Response

## Objectives

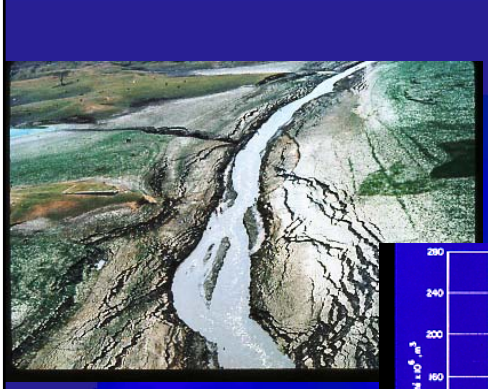
**Part I** – River Dynamics and Response

1. Deforestation impact on rivers
2. The concept of time scales
3. Headcutting and degradation

## Peligre Dam in Haiti (deforestation)


## Peligre Dam (sedimentation)

## Peligre Dam (reduced life expectancy)



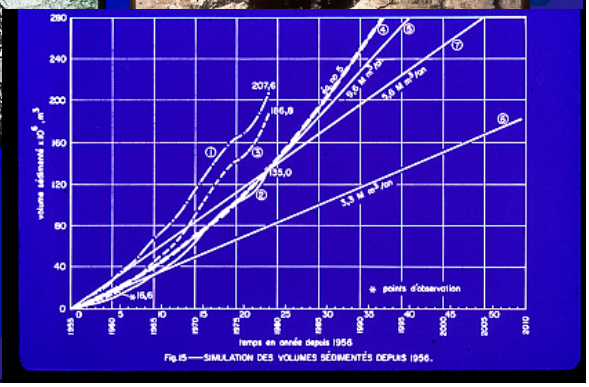



Fig.15—SIMULATION DES VOLUMES SÉDIMENTÉS DEPUIS 1956.

## River Dynamics

#1 Deforestation may impact river equilibrium for a very long time.

## Time Scale

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

## 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.

## Jetty fields and vegetation of the Rio Grande

Jetty System (near Bernardo), USACE 1963

Debris Deposition

Debris Deposition

# River Dynamics

#1 Deforestation may impact river equilibrium for a very long time.

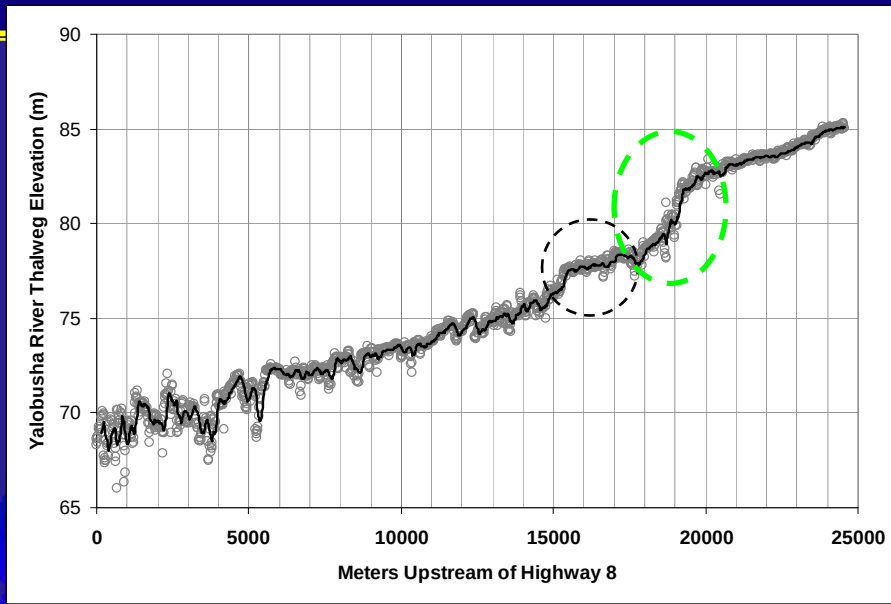
#2 Stream restoration/rehabilitation may be effective only after a long period of time

**Bank Caving**

Bank Caving

Bank Caving

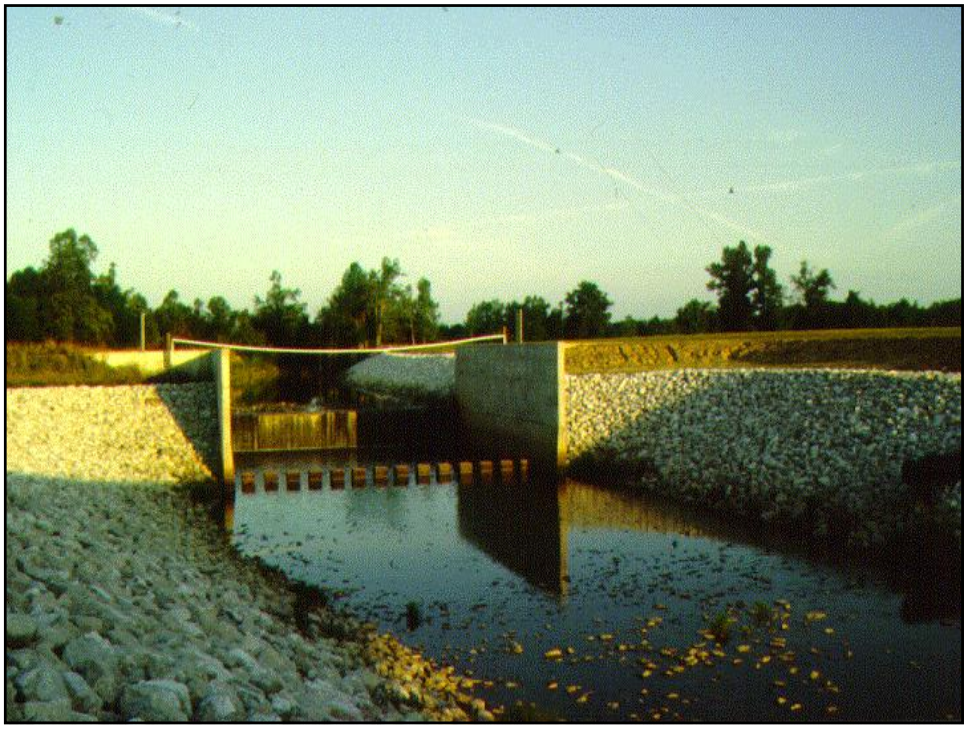
## Headcutting

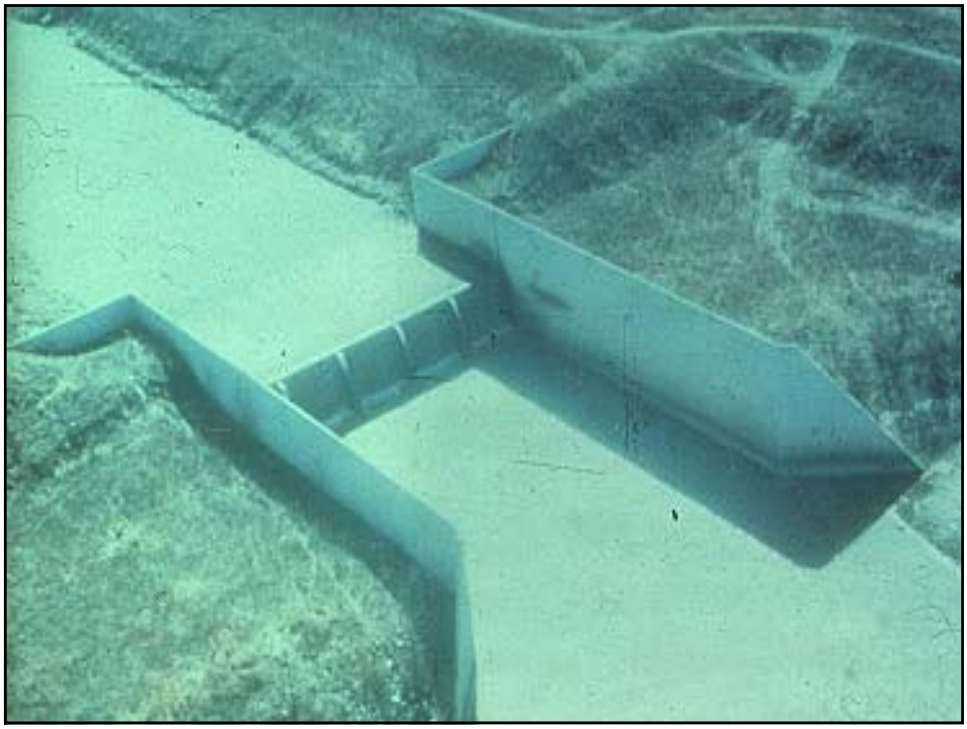


## Vertical Degradation

Headcutting

## Vertical Degradation





## River Dynamics

#1 Deforestation may impact river equilibrium for a very long time.

#2 Stream restoration/rehabilitation may be effective only after a long period of time

#3 Looking downstream may prevent headcutting and severe degradation problems

## 2. Three Laws for Stream Restoration

# Objectives

**Part II** – Equilibrium and Bank Protection

1. Concept of equilibrium, environmental river mechanics and bank protection
2. Provide three basic laws for Stream Restoration

# Three Laws of Stream Restoration

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

# Concept of Equilibrium

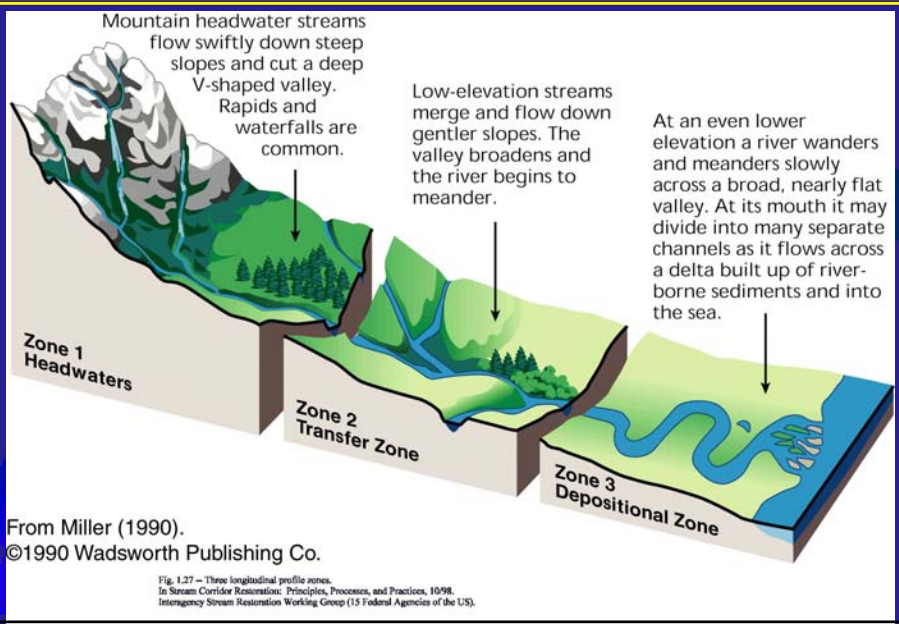
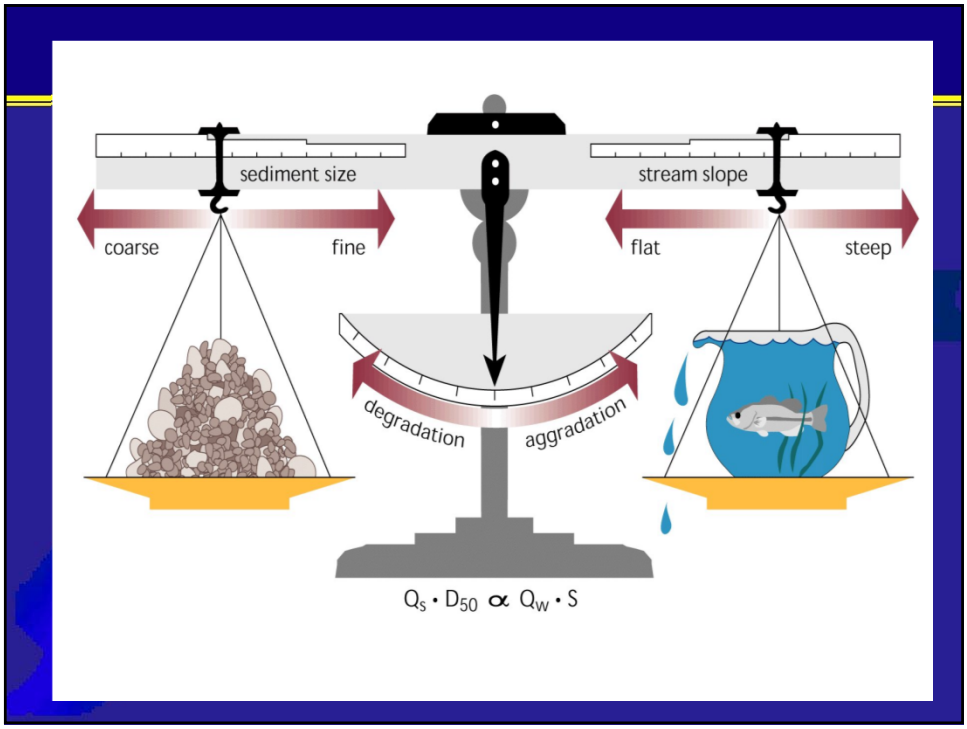



Fig. 1.27 – Three longitudinal profile zones.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (15 Federal Agencies of the US).

# Three Laws of Stream Restoration

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

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


sediment size
coarse
fine
stream slope
flat
steep
degradation
aggradation
$Q_s \cdot D_{50} \propto Q_w \cdot S$

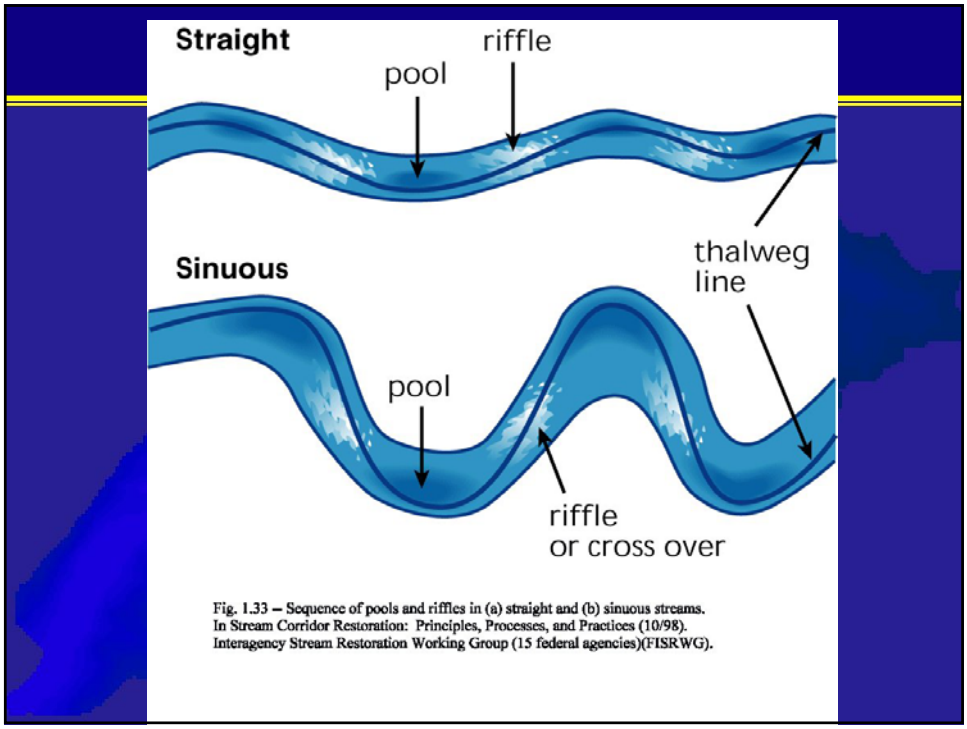
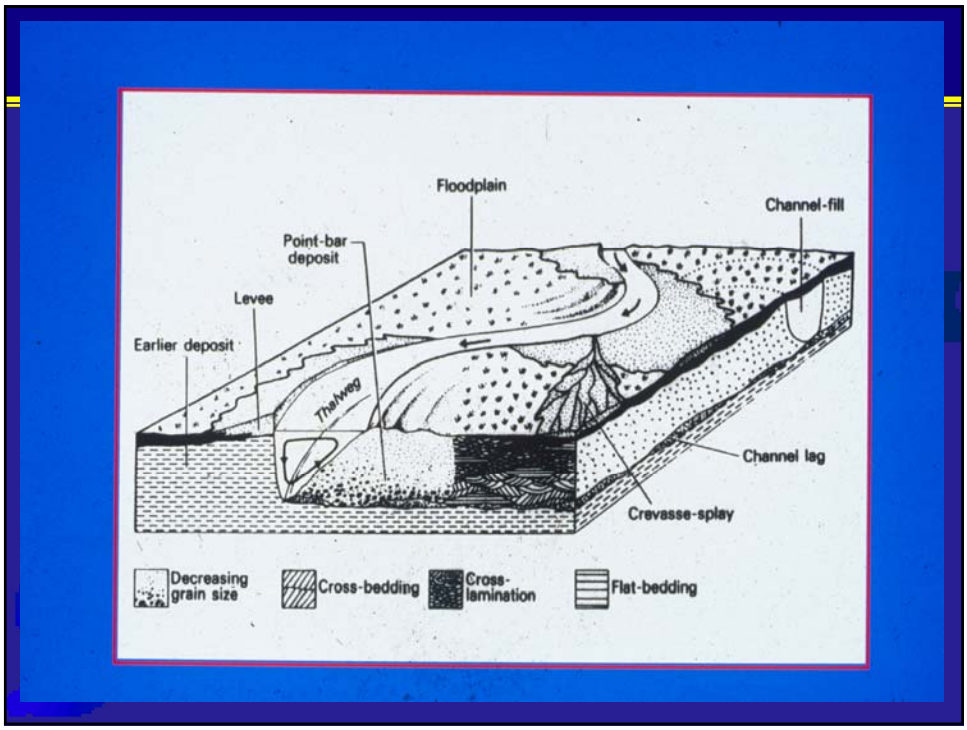
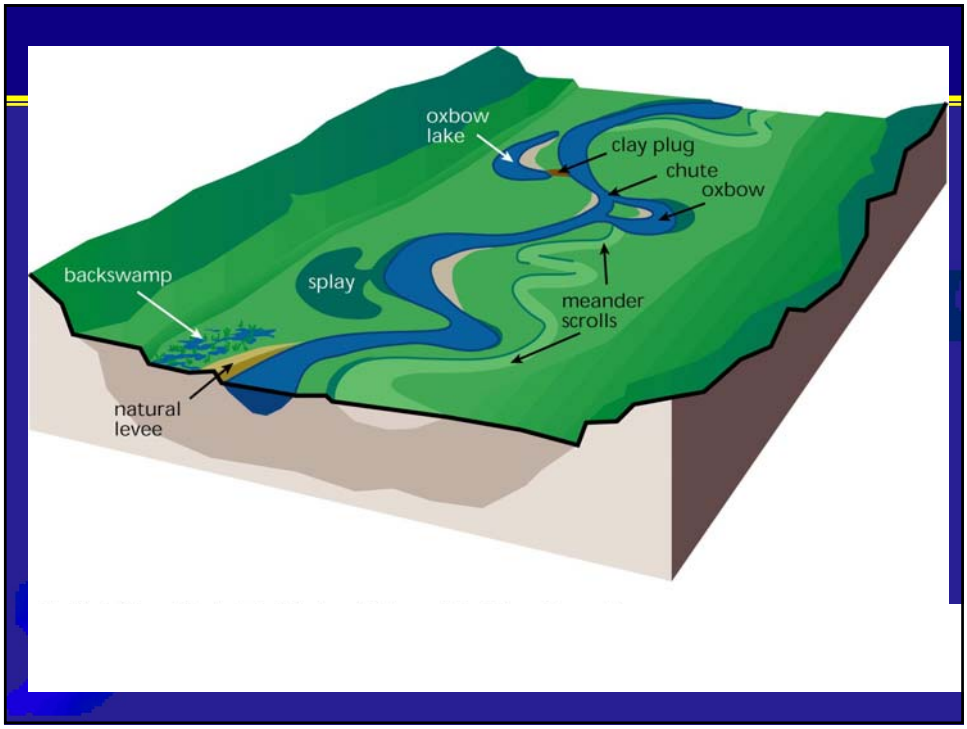
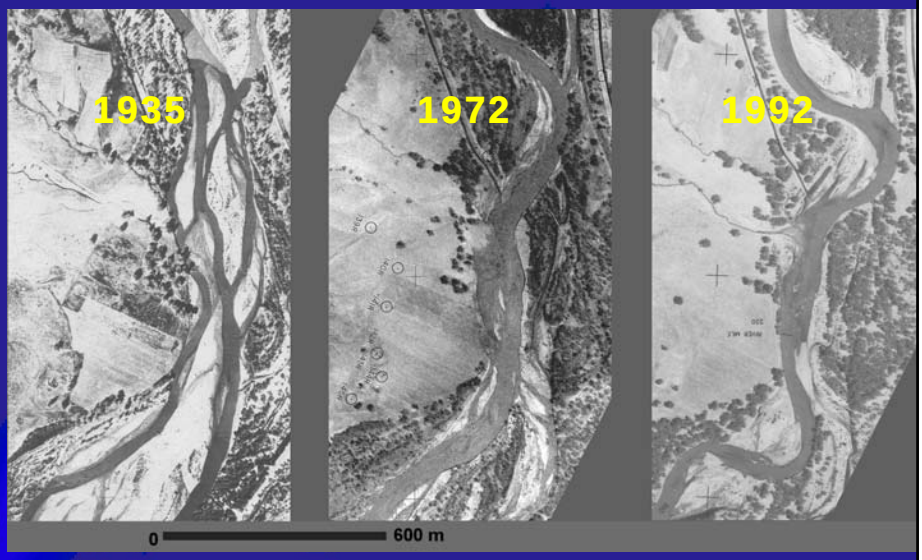


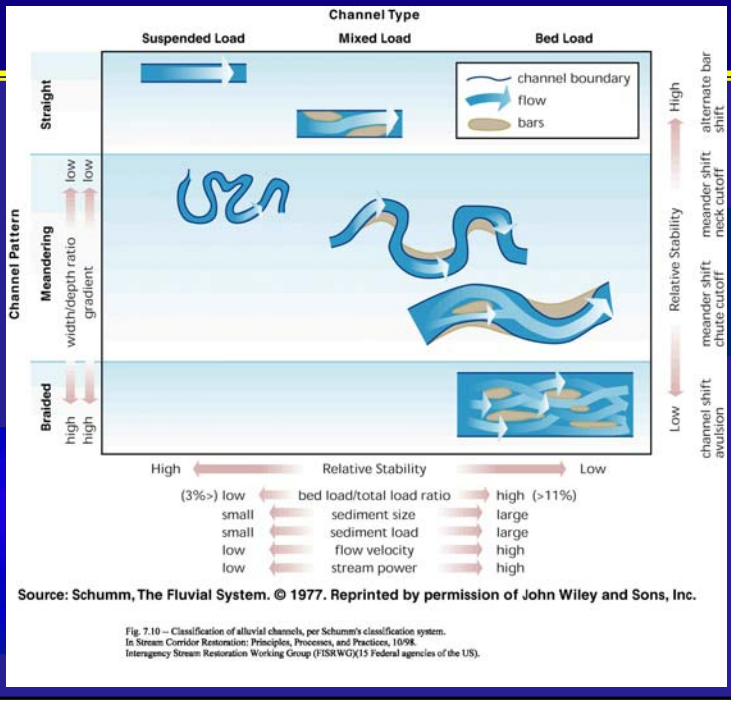

Fig. 1.33 – Sequence of pools and riffles in (a) straight and (b) sinuous streams. In Stream Corridor Restoration: Principles, Processes, and Practices (10/98). Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).




oxbow
lake
clay plug
chute
oxbow
backswamp
splay
meander
scrolls
natural
levee

# Hydraulic geometry of the Rio Grande




Source: Schumm, The Fluvial System. © 1977. Reprinted by permission of John Wiley and Sons, Inc.

Fig. 7.10 – Classification of alluvial channels, per Schumm's classification system.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

- 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.

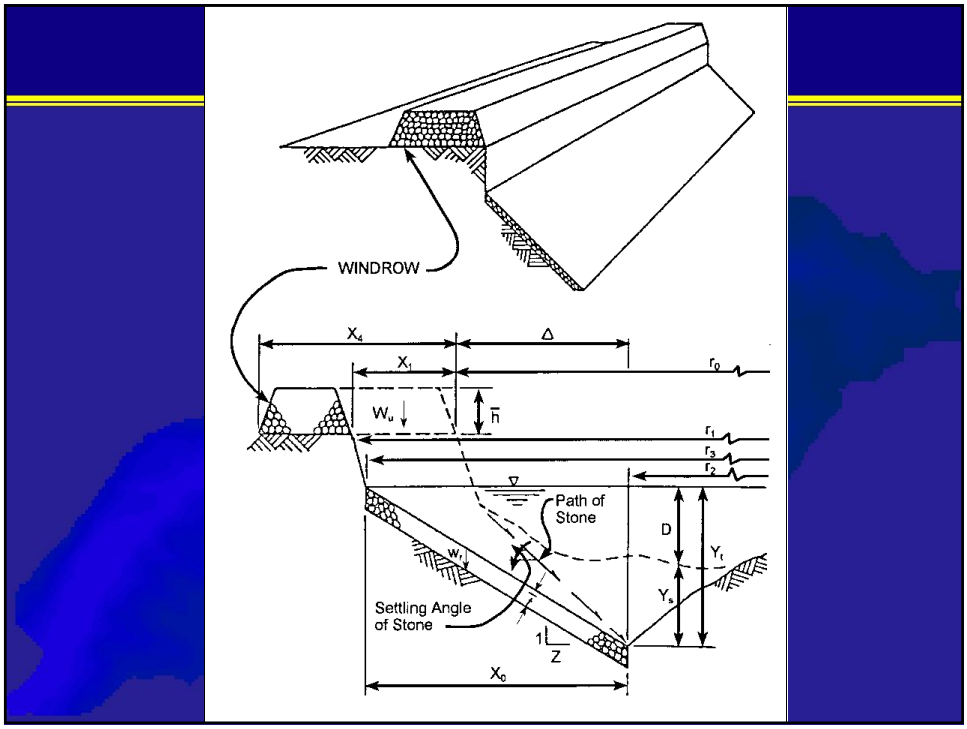
  *(… after Mackin, 1948)*

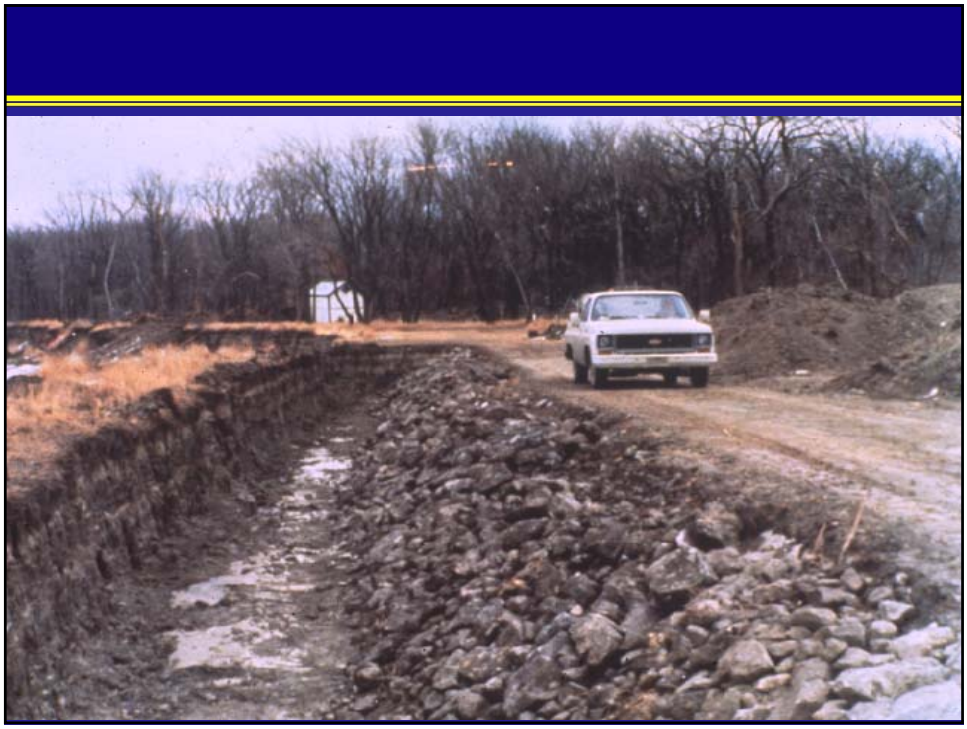
## REQUIREMENTS OF BANK STABILIZATION

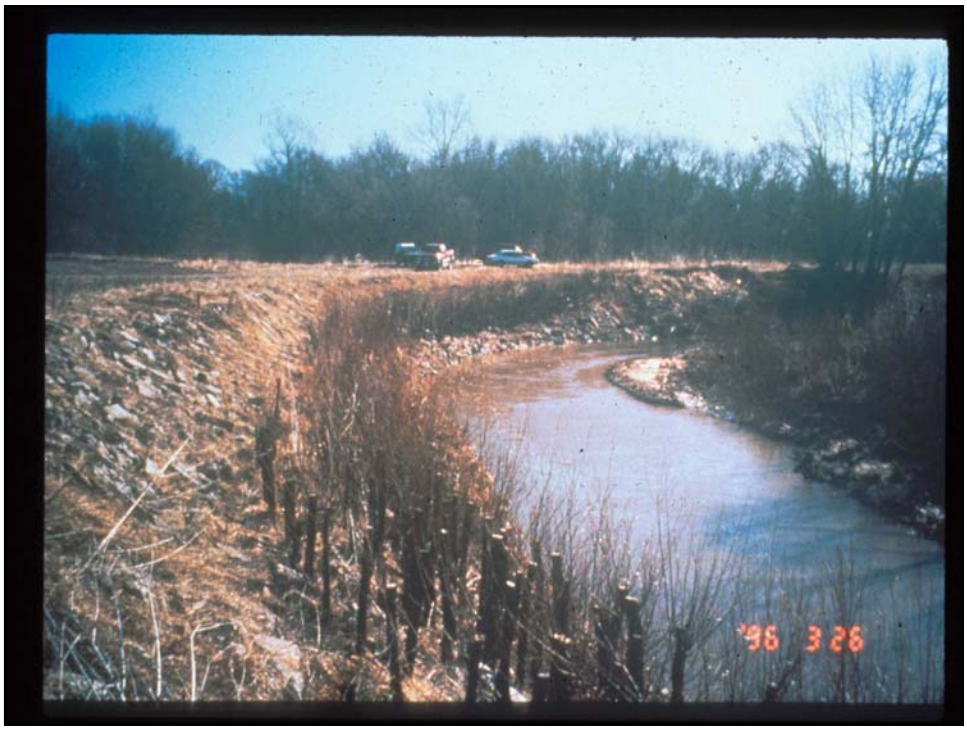
- Effective
- Environmentally Sound
- Economical

(Listed in order of necessity)


APR 1 '9


WINDROW
$X_4$
$\Delta$
$X_1$
$r_0$
$W_u$
$\bar{n}$
$r_1$
$r_3$
$r_2$
Path of Stone
D
$Y_1$
$W_r$
$Y_s$
Settling Angle of Stone
1
Z
$X_0$




'98 3 28

## Three Laws of Stream Restoration

#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.

## 3. Ten Guidelines for River Restoration

# Objectives

**Part III –** Ten Guidelines and Case Study

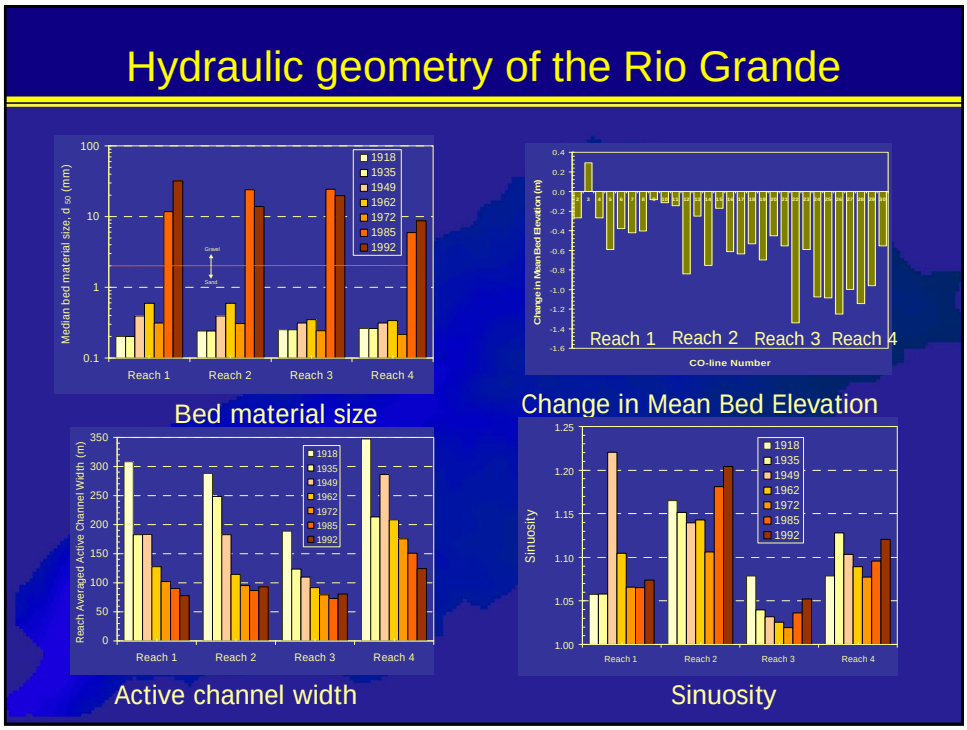
1. Guidelines for Stream Restoration Projects
2. Case-study on the Rio Grande

# 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.


Rio Grande Restoration – Santa Ana
Project Goals
• Protect Levee
• Create a Functioning Floodplain
• Improve Wildlife Habitat

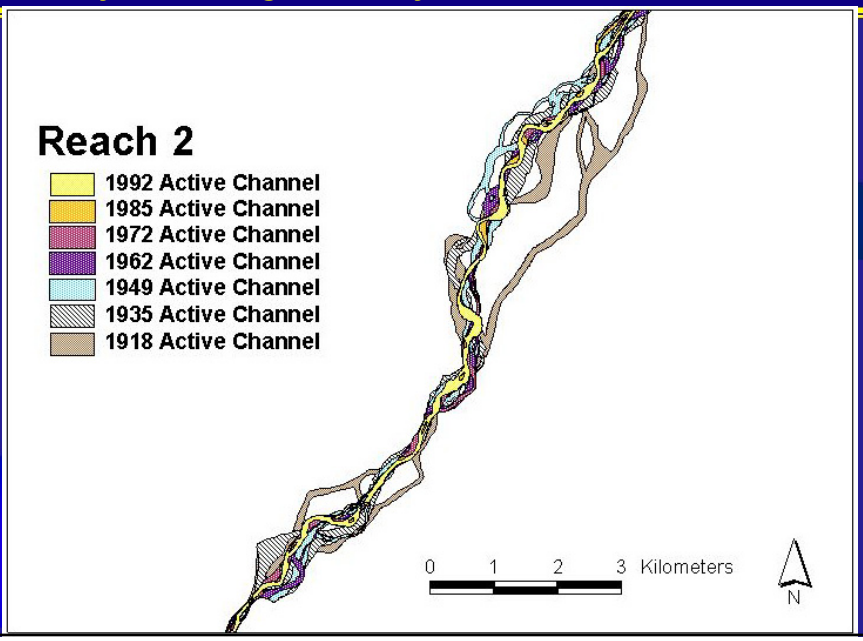

Hydraulic geometry of the Rio Grande
Median bed material size, d 50 (mm)
100
10
1
0.1
Gravel
Sand
1918
1935
1949
1962
1972
1985
1992
Reach 1
Reach 2
Reach 3
Reach 4
Bed material size
Change in Mean Bed Elevation (m)
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Reach 1
Reach 2
Reach 3
Reach 4
CO-line Number
Change in Mean Bed Elevation
Reach Averaged Active Channel Width (m)
350
300
250
200
150
100
50
0
Active channel width
Sinuosity
1.25
1.20
1.15
1.10
1.05
1.00
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

## 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


## Floodplain Maintenance

- Lower Terraces with Heavy Equipment

# Floodplain Restoration

- Excavated Sediment Placed near Pilot Channel


# Habitat Improvement

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

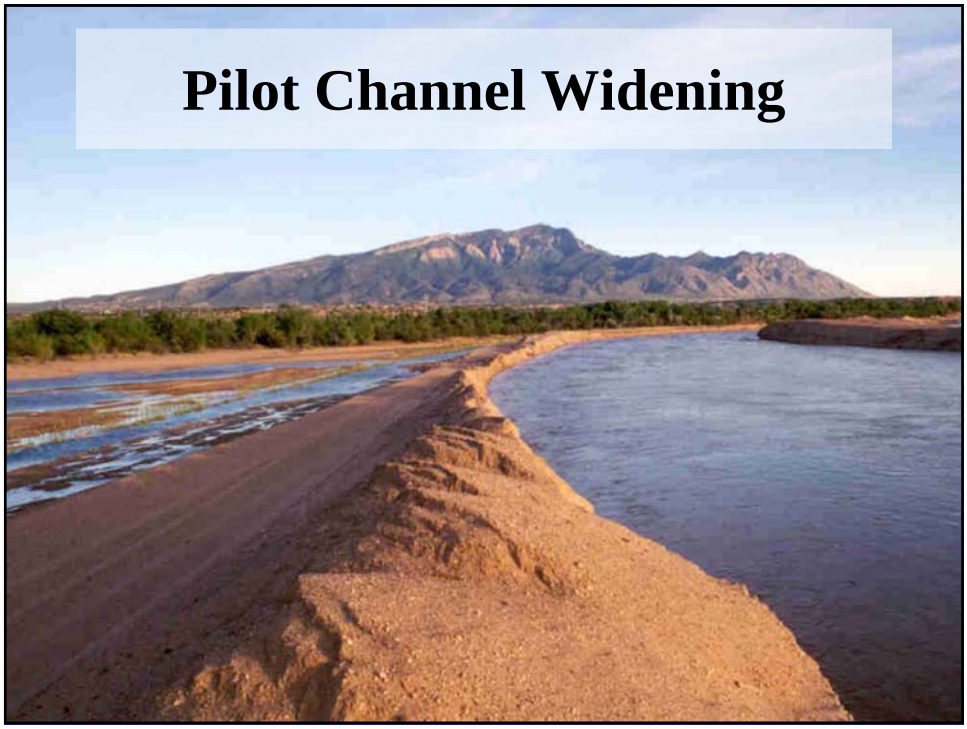

## Stream Restoration Guidelines

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

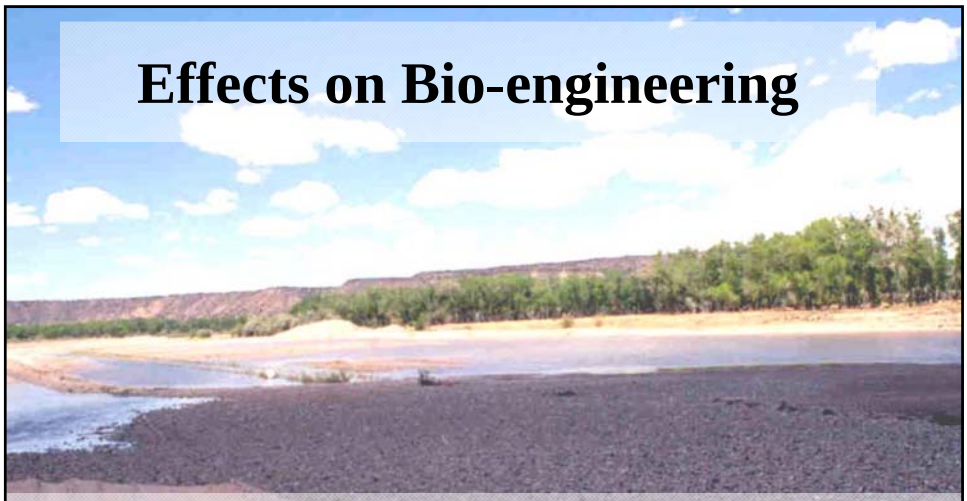

Pilot Channel Widening


Spring Runoff - 2001

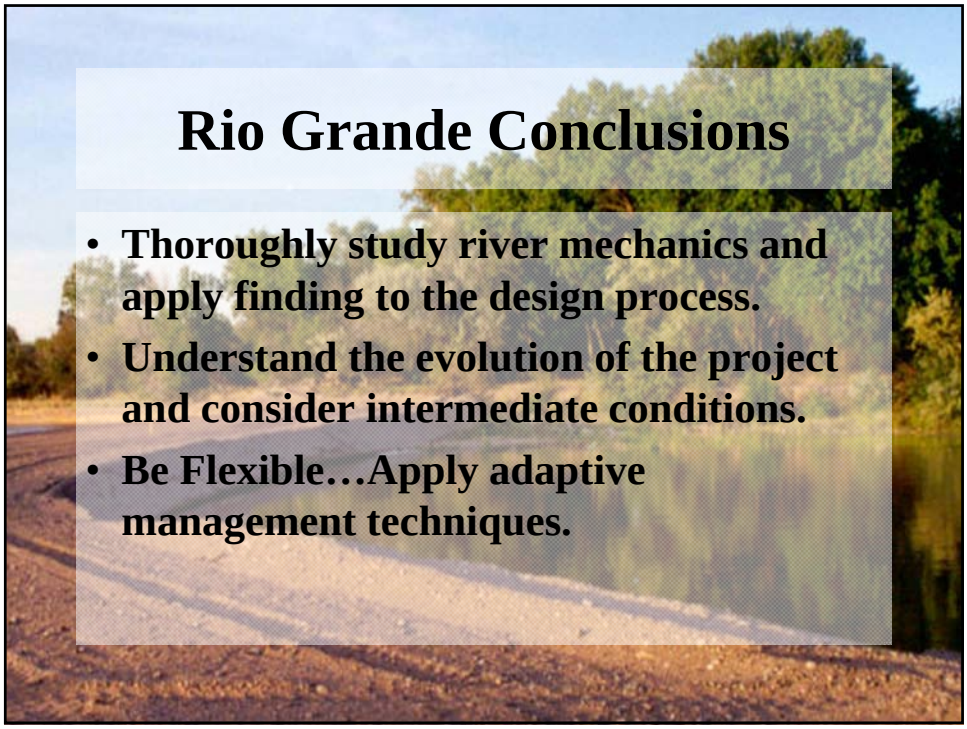
## Post-Runoff Assessment

- 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, Gonzaga
Dr. Billy Johnson, ERDC, Mississippi
Dr. Daryl B. Simons, CSU and SLA
Dr. Stan Schumm, CSU
Dr. Ellen Wohl, CSU
... so many others ...


Muchas
Gracias!
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