

## **River Engineering and Stream Restoration**



**P. Julien**



**S. Ikeda**

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## **River Engineering and Stream Restoration I - Stream Restoration**

**Pierre Y. Julien**

Hong Kong - December 2004

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## **Objectives**

Brief overview of River Engineering and  
Stream Restoration with focus on :

1. River Equilibrium;
2. River Dynamics;
3. River Engineering;
4. Stream Restoration.

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## Objectives

### **Part Ia** – Equilibrium and Bank Protection

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

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## Three Laws of Stream Restoration

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

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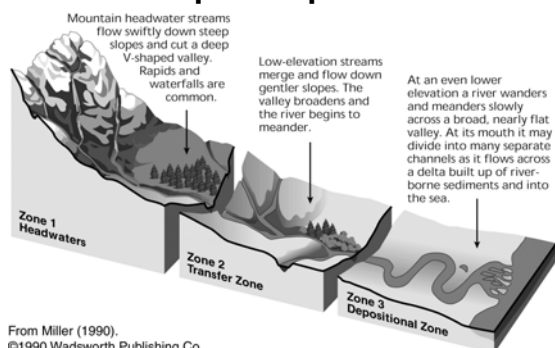
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## Concept of Equilibrium



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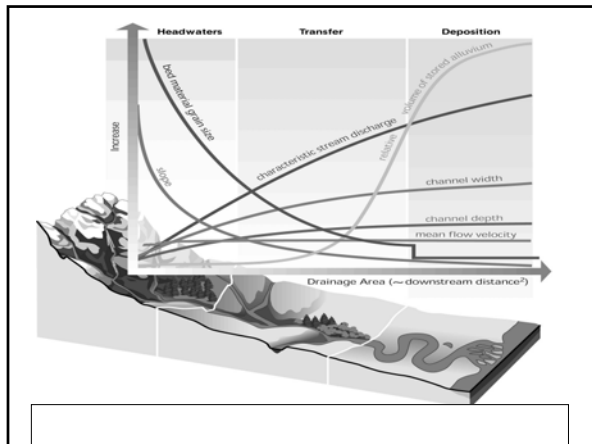
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## Three Laws of Stream Restoration

- #1 There is no cookbook approach to stream restoration projects.
- #2 Solutions normally require **equilibrium** conditions between sediment regime and stream ecology.

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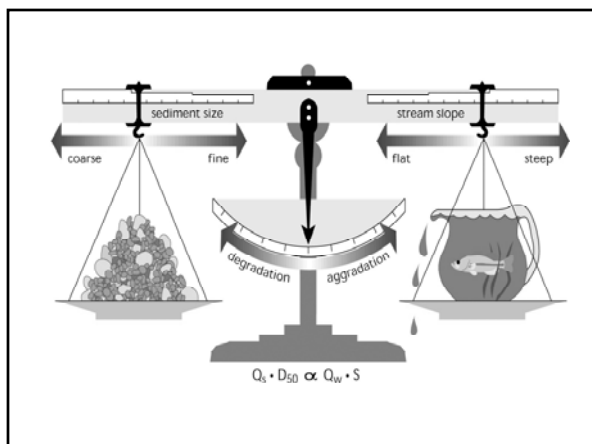
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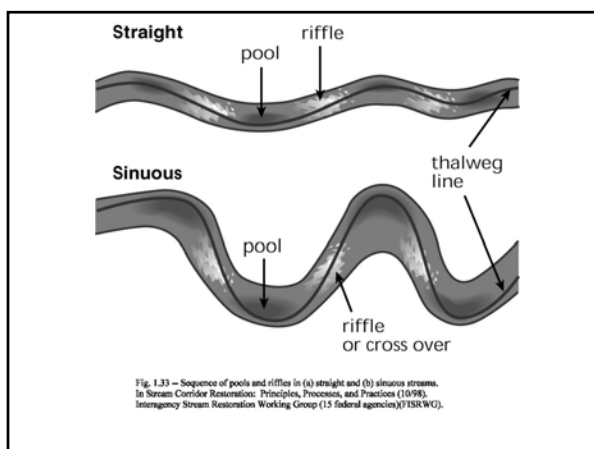
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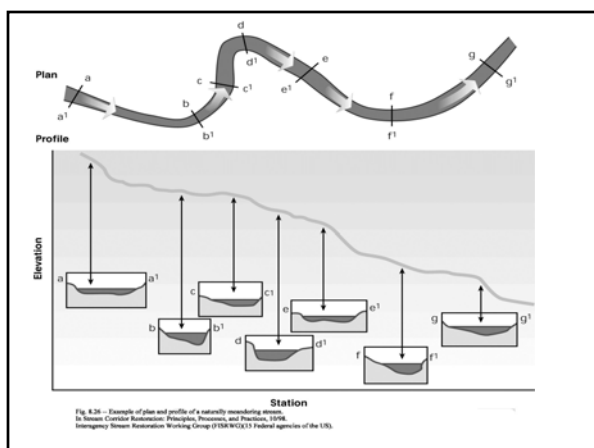
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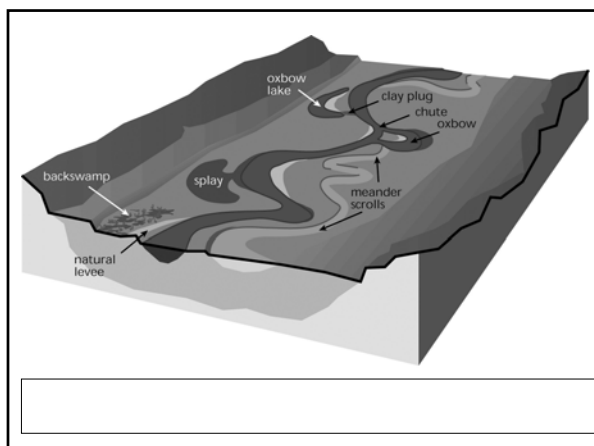
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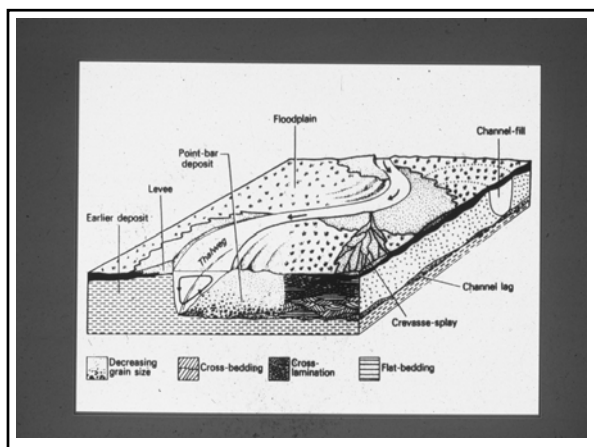
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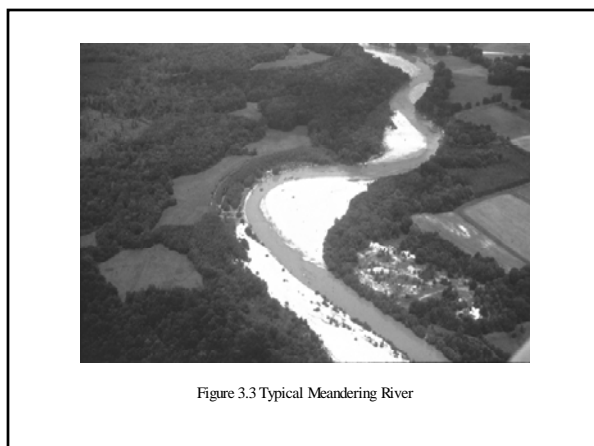


Figure 3.3 Typical Meandering River

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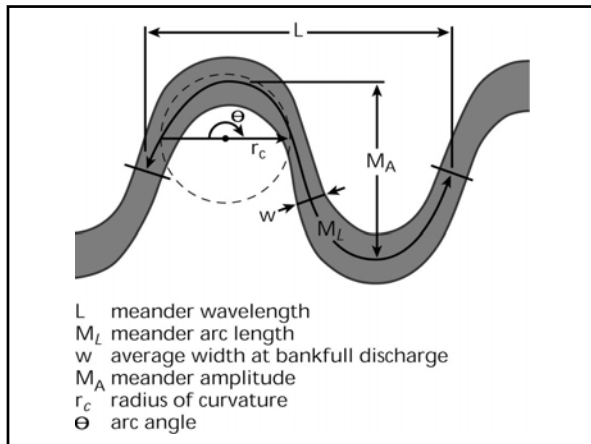
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- The system is dynamic
- A stable river is one in which, over a period of years, slope is delicately adjusted to provide just the velocity required to transport the available water & sediment supplied from the drainage basin.  
*(... after Mackin,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

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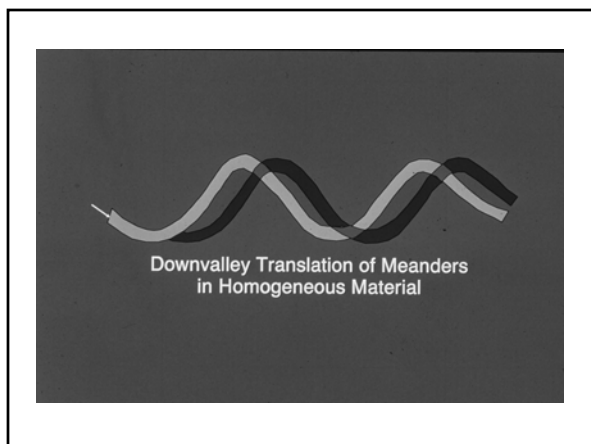
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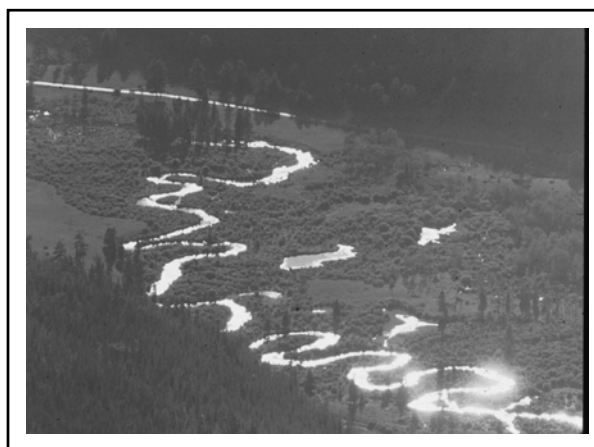
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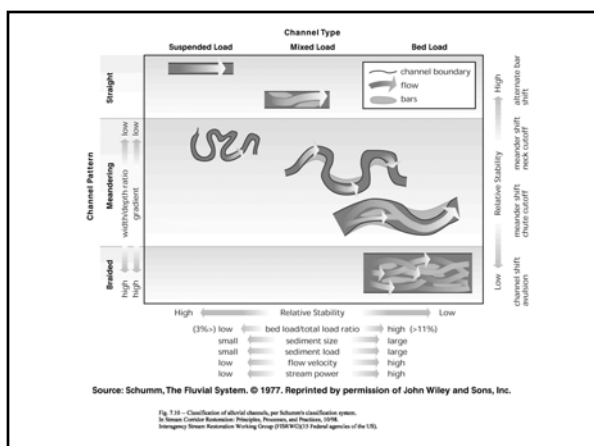
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## 2. Bank Protection



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## REQUIREMENTS OF BANK STABILIZATION

- Effective
- Environmentally Sound
- Economical

(Listed in order of necessity)

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Figure 7.6 Launched Windrow Rock

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Figure 7.10 Longitudinal Stone Fill Toe Protection Placed Adjacent to Bank With Tiebacks

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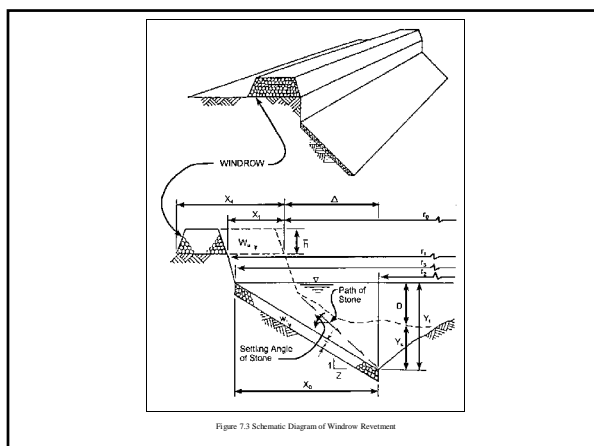
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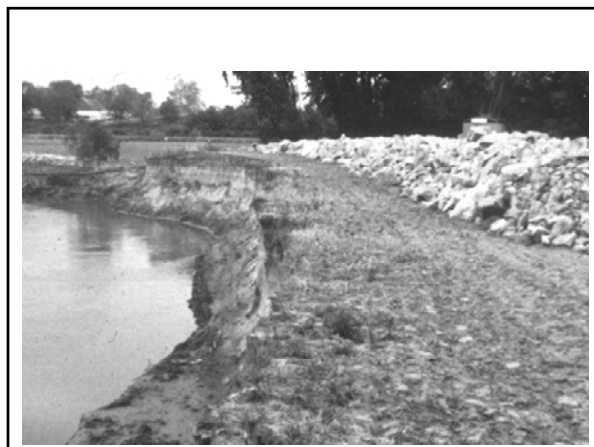
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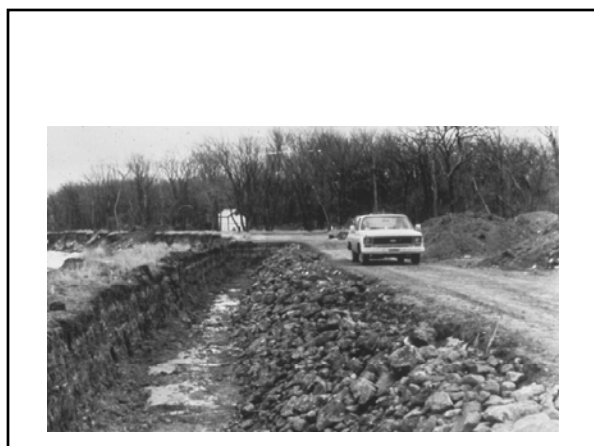
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Figure 8.2 Typical Impermeable Dikes

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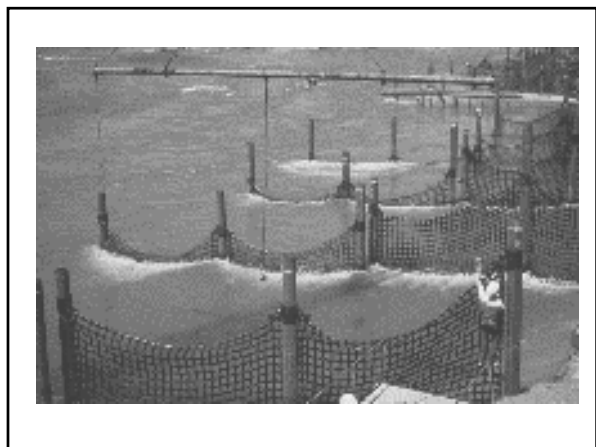
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## Three Laws of Stream Restoration

- #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.

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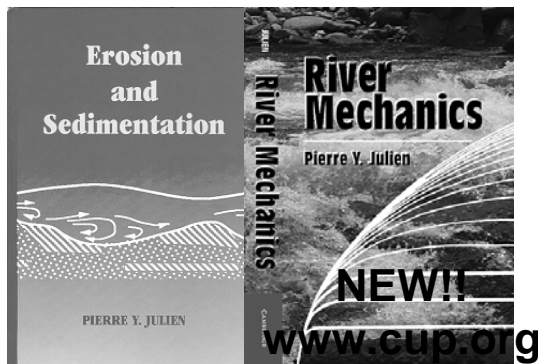
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## Erosion and River Mechanics Textbooks



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## Objectives

### **Part Ib** – River Dynamics and Response

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

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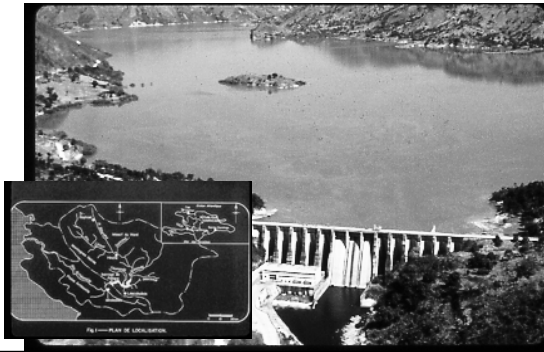
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### Peligre Dam in Haiti (deforestation)



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### Peligre Dam (sedimentation)



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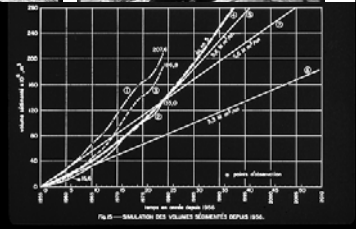
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#1 Deforestation may impact river equilibrium for a very long time.

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

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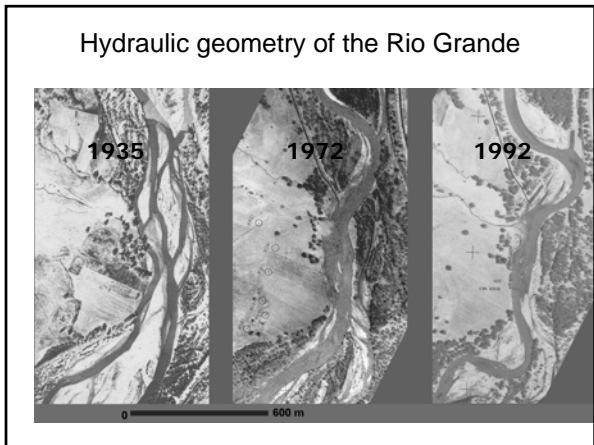
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### Restoration vs Rehabilitation

***Restoration***

- returning a resource to some former condition.

***Rehabilitation***

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

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Jetty fields and vegetation of the Rio Grande

Jetty System (near Bernardo), USACE 1963



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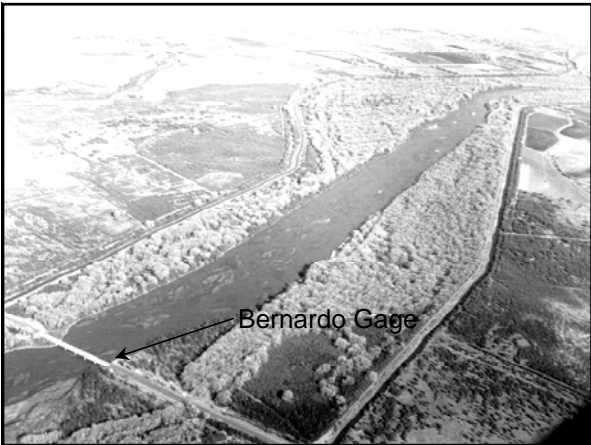
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**Debris Deposition**

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**Debris Deposition**

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### **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

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**Bank Caving**

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**Bank Caving**

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**Bank Caving**

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**Headcutting**

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**Headcutting**

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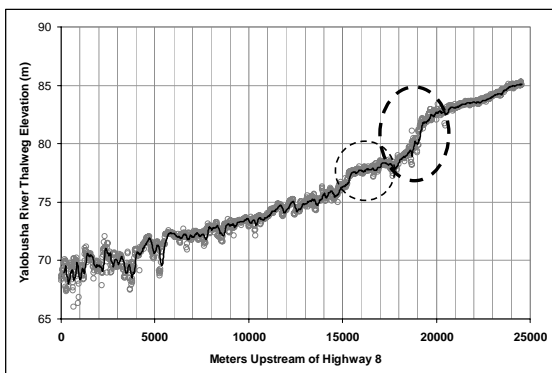
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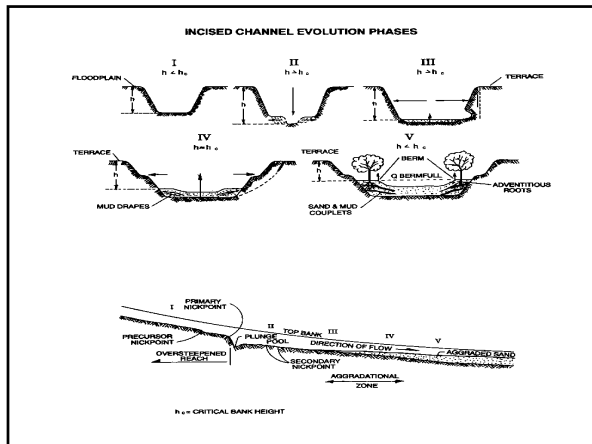
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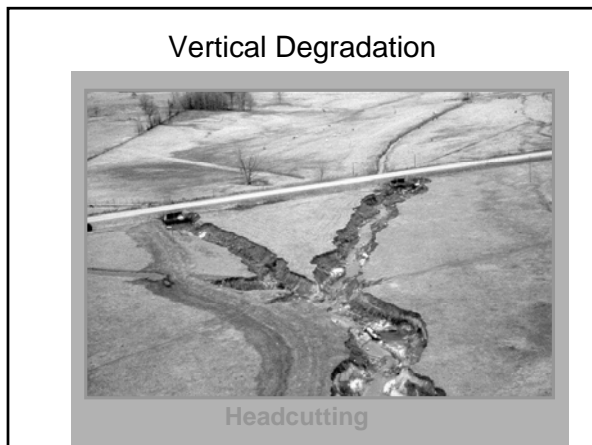
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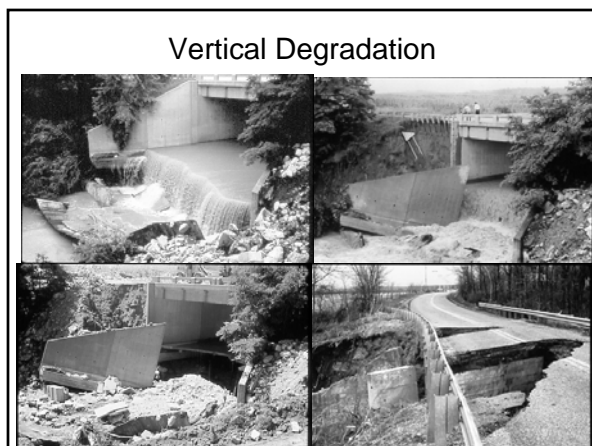
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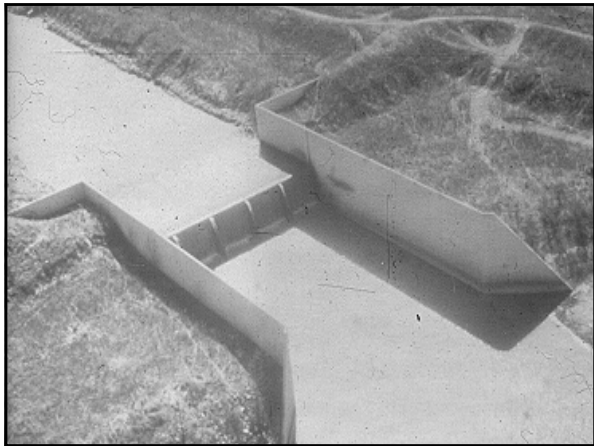
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## River Dynamics

- #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

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## ASCE Journal of Hydraulic Engineering




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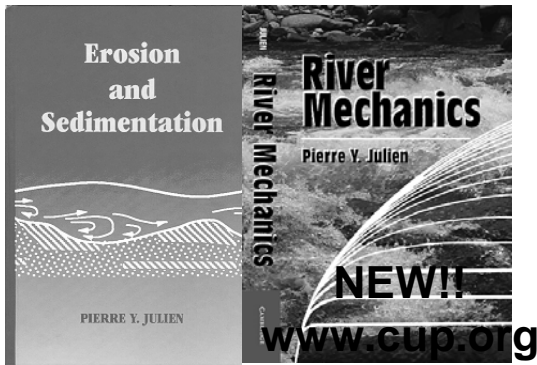
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## Erosion and River Mechanics Textbooks



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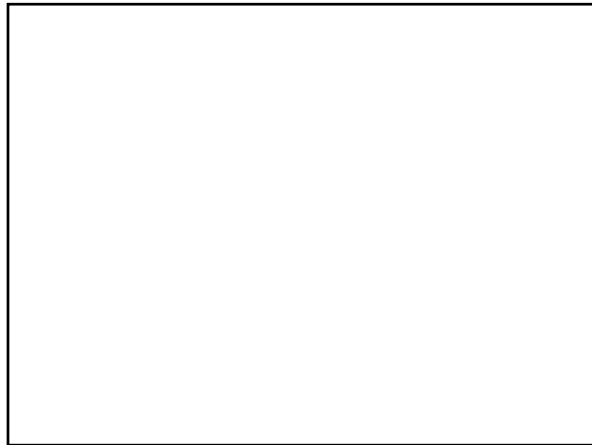
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## Objectives

### **Part Ic** – Guidelines and Case Study

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

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## 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.

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## Rio Grande Restoration– Santa Ana

### Project Goals

- **Protect Levee**
- **Create a Functioning Floodplain**
- **Improve Wildlife Habitat**

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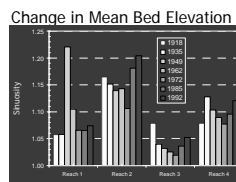
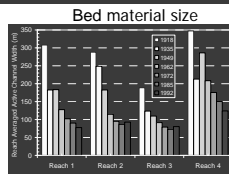
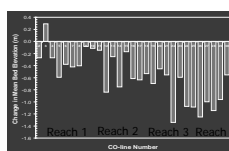
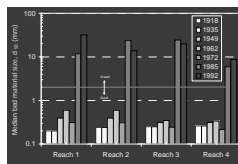
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## Hydraulic geometry of the Rio Grande



Active channel width

Sinuosity

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## 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.

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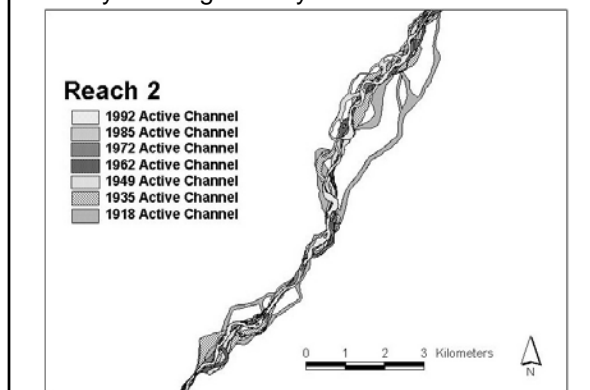
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### Hydraulic geometry of the Rio Grande



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## 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.

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## Rio Grande Restoration– Floodplain restoration

### Santa Ana Reach - Mid 80's



Santa Ana Reach – Mid 90's

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## Rio Grande Restoration– Endangered Species



- Bimodal sand/gravel bed
- Deep water  $h \sim 1.20$  m
- Water velocities  $1.4$  m/s



### Restoration

- Create wider channels



- Sandy/silty substrate
- Shallow water  $h < 0.4$  m
- Water velocities  $0.1 \text{ m/s} < V < 0.5 \text{ m/s}$

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## 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.

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## Floodplain Maintenance

- Lower Terraces with Heavy Equipment



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## Floodplain Restoration

- Excavated Sediment Placed near Pilot Channel



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## Habitat Improvement

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



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### Pilot Channel – Pre-Watering



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### 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.

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### Opening Pilot Channel



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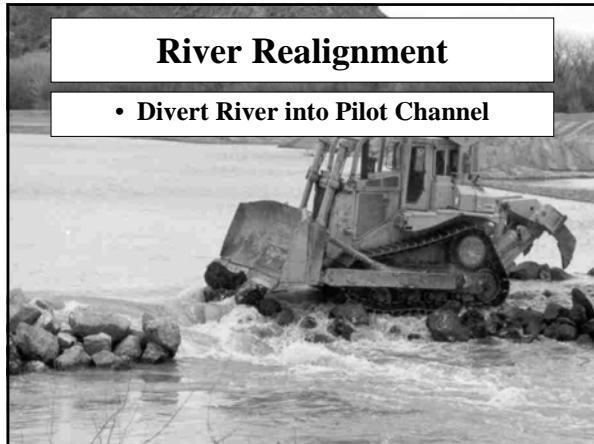
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## River Realignment

- Divert River into Pilot Channel

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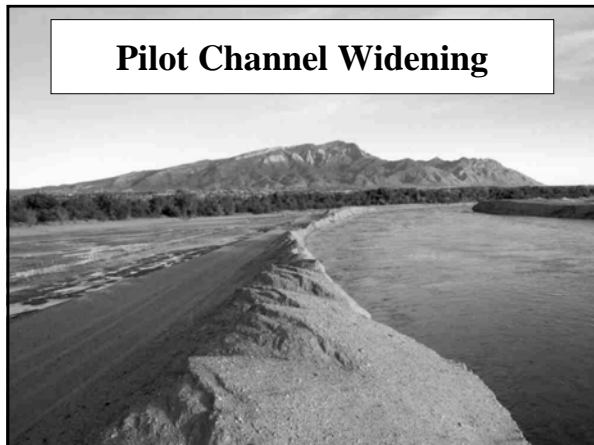
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## Pilot Channel Widening

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## Spring Runoff - 2001

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### Post-Runoff Assessment



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

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### Effects on Bio-engineering



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

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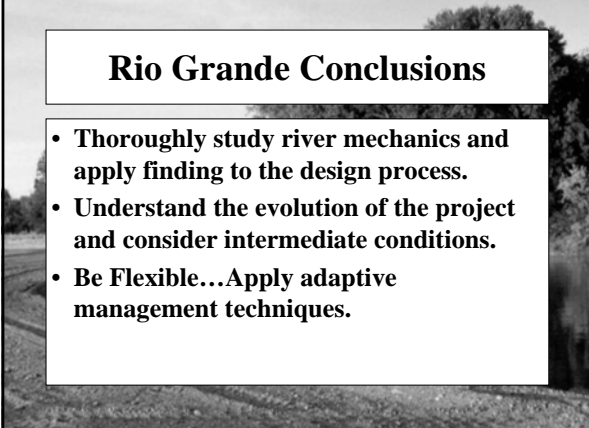
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### Rio Grande Conclusions



- Thoroughly study river mechanics and apply finding to the design process.
- Understand the evolution of the project and consider intermediate conditions.
- Be Flexible...Apply adaptive management techniques.

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## 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**

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**pierre@engr.colostate.edu**



**THANK YOU  
for your  
Attention!**

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