# BASIC FLUVIAL GEOMORPHOLOGY

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## BASIC FLUVIAL GEOMORPHOLOGY

- Interest of the FluvialGeomorphology in the river restoration projects
- Morphological analysis of the rivers
- The sediments in the fluvial processes
- The river in equilibrium: natural dynamics
- Dominant discharge concept
- Response of rivers to natural/human disturbances

## Why the Fluvial Geomorphology is important in river restoration

Use and abuse of rivers

•Physical degradation is one of the most important problems of river ecosystems, affecting their ecological status by means of:

- Lost of natural forms and processes
- Unwanted erosion and sedimentation processes
- Decrease of habitat quality and biodiversity
- Lost of environmental values of rivers

## Why the Fluvial Geomorphology is important in river restoration

•The geomorphological analysis of rivers helps to:

- •Identify problems related to the physical degradation
- •Interpretate causes and consequences
- •Propose alternatives for enhancing and restoring rivers

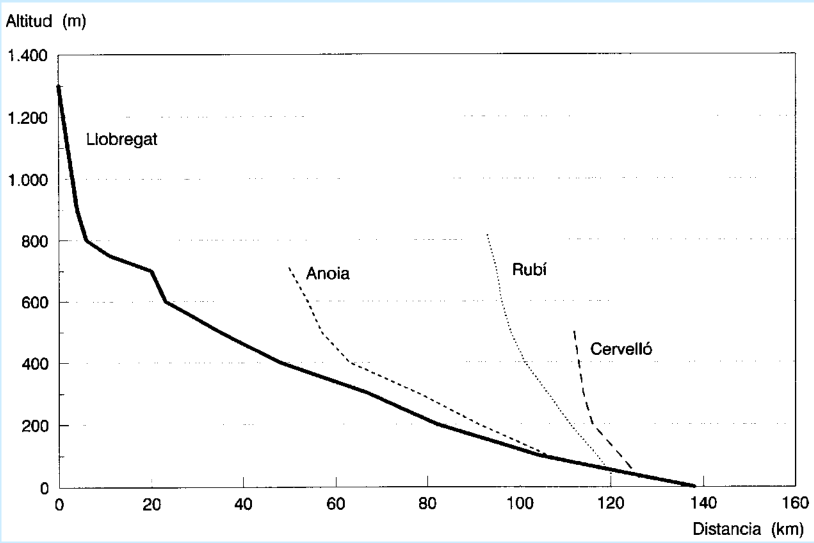
## Examples of physical degradation in rivers


## Analysis of Fluvial Forms

FORMS:

- Longitudinal Profile
- Pattern and Sinuosity
- Hydraulic geometry
- Sediments and Bed forms

## LONGITUDINAL PROFILE



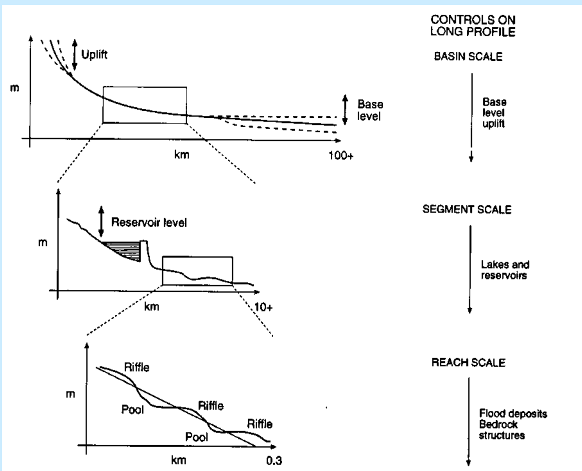

## LONGITUDINAL PROFILE IN RIVERS

The longitudinal profile shows the slope of the river, which can be considered at different spatial scales

**Watershed (Valley):**
Geology and Relief

**Fluvial segment:**
Dams and local controls

**Fluvial reach:**
Sediments and bed forms



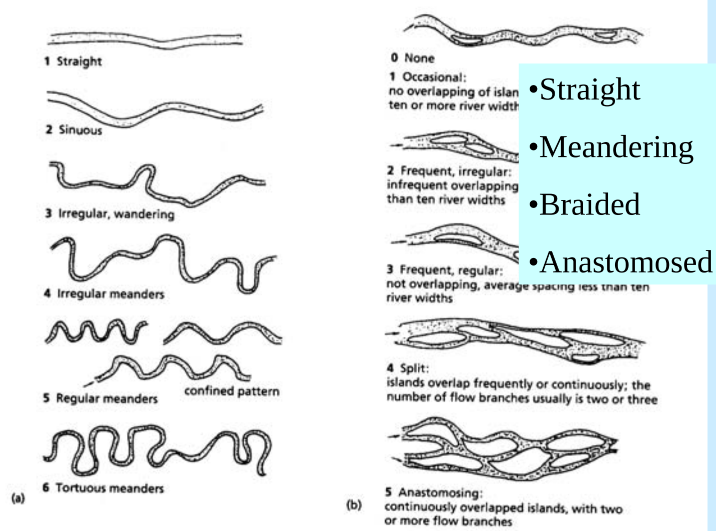
## VARIABLES RELATED TO THE LONGITUDINAL PROFILE OF RIVERS

- The <u>slope</u> of the channel is one of the most important hydraulic variables, determining the hydraulic power and channel stability
- The slope is related to the <u>water velocity</u> and the <u>shear stress</u>
- It is related to the sediment size:

$$S = 18\left(\frac{d}{A_d}\right)^{0,6}$$

S: Slope (m/m)
$A_d$: Drainage area(milla $^2$)
d: Medium diameter of sediments (mm)

## PATTERN OF RIVERS




- Straight
- Meandering
- Braided
- Anastomosed

**Fig. 6.9** Morphological classification of large channels: plan-form pattern (Kellerhals & Church 1989). (a) Channel pattern; (b)channel islands.

## VARIABLES RELATED TO THE PATTERN OF RIVERS

- Slope
- Discharge

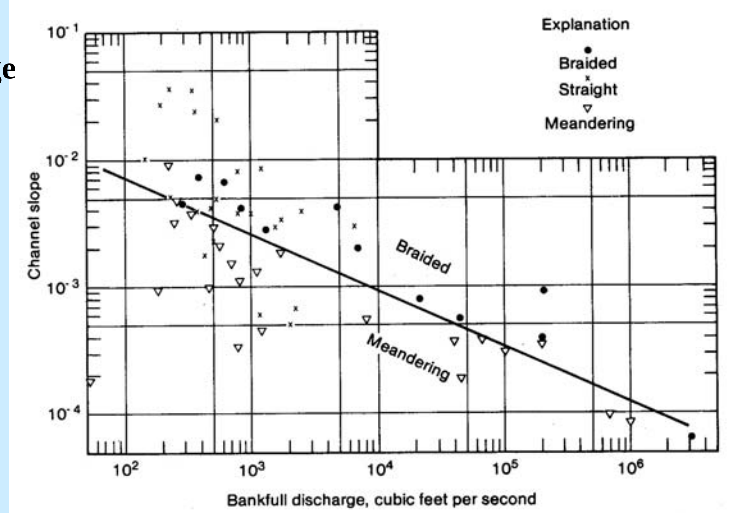
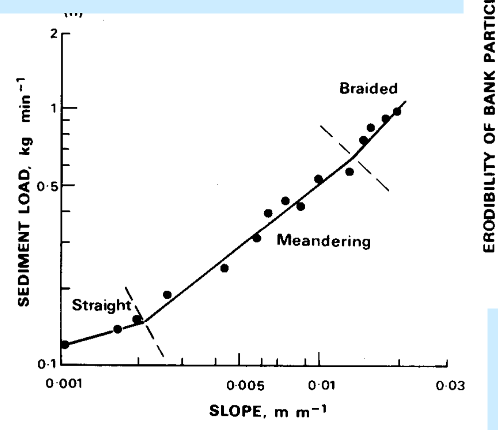
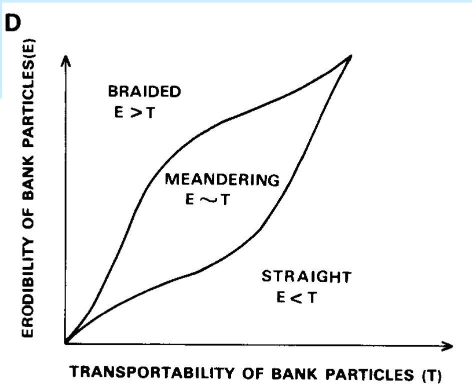



**Figure 2.11** Values of slope and bankfull discharge for natural channels as well as a threshold distinguishing braided from meandering rivers (Leopold and Wolman, 1957).

## PATTERN OF RIVERS

- Slope
- Sediment load




Bank materials

## EXAMPLES OF RIVER PATTERNS

Straight reaches:

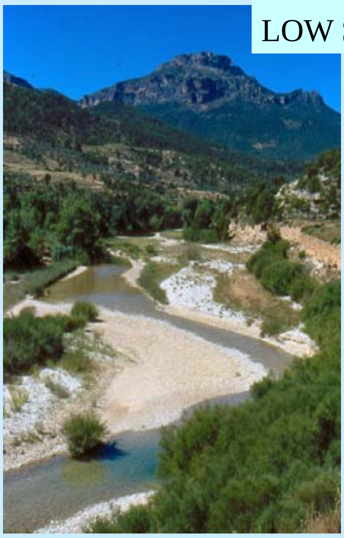
LATERAL CONTROLS

## EXAMPLES OF RIVER PATTERNS

Meandering rivers

STABLE PATTERN

LOW SLOPE

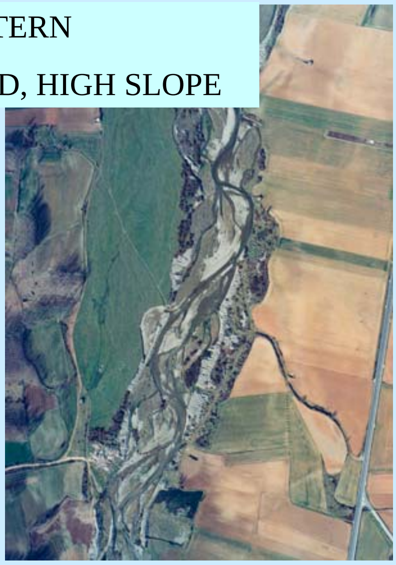


## EXAMPLES OF RIVER PATTERNS

Braided rivers

UNSTABLE PATTERN

SEDIMENT LOAD, HIGH SLOPE



## RELATIONSHIP BETWEEN SLOPE, SEDIMENT SIZE AND PATTERN


Valle glacial: Low slope, fine sediments, high sinuosity

Valle fluvial: High slope, coarse sediment, straight pattern (sinuous valley)

## CROSS SECTIONS - HIDRAULIC GEOMETRY

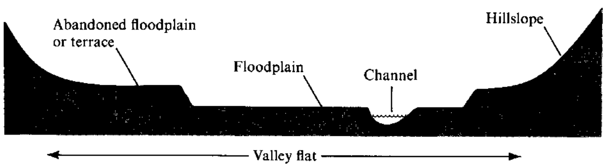
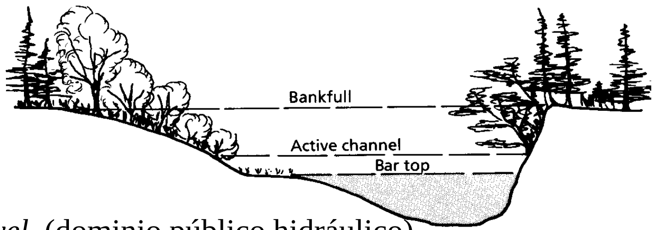



**Figure 16-9** Diagrammatic cross section of a valley showing relation of present channel to the floodplain and to a terrace (abandoned floodplain).




- Base level
- B*ankfull level*, (dominio público hidráulico)
- Floodplain (riberas, llanura de inundación)

## HIDRAULIC GEOMETRY

$$w = C_a Q^a \qquad Q = wdu$$
$$d = C_b Q^b \qquad C_a C_b C_c = 1$$
$$u = C_c Q^c \qquad a + b + c = 1$$

**At-a-station:**

$$a = 0{,}26$$
$$b = 0{,}40$$
$$c = 0{,}34$$

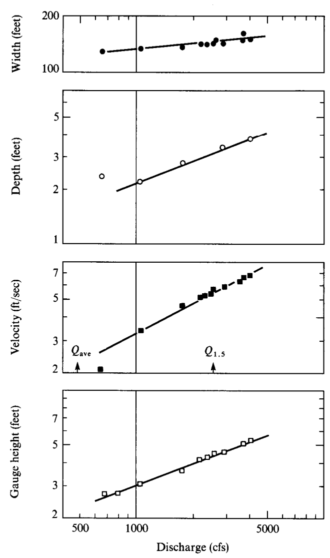



**Figure 16-32** At-a-station curves and rating curve for Green River at Warren Bridge, Wyoming.

## HIDRAULIC GEOMETRY

$$w = C_a Q^a \qquad Q = wdu$$

$$d = C_b Q^b \qquad C_a C_b C_c = 1$$

$$u = C_c Q^c \qquad a + b + c = 1$$

**Downstream, at bankfull:**

$$a = 0{,}39 - 0{,}60$$

$$b = 0{,}29 - 0{,}40$$

$$c = 0{,}09 - 0{,}28$$

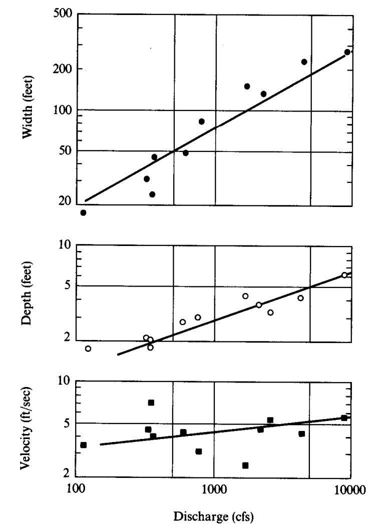



**Figure 16-34** Downstream change of width, depth, and velocity with bankfull discharge, upper Green River basin, Wyoming.

## SEDIMENTS IN RIVERS

They come from watershed erosion or channel erosion and determine the turbidity of the water, the size of the substratum and the slope of the channel banks

| | Transport | Origin |
|---|---|---|
| Wash load | Suspension | Watershed erosion<br>Channel erosion (fine particles) |
| Bed load | Siltation | Channel erosion (coarse particles)<br>Bed erosion |

- Cohesive materials
- Non-cohesive materials →
  - Sandy Rivers
  - Gravel-bed Rivers

## SANDY RIVERS

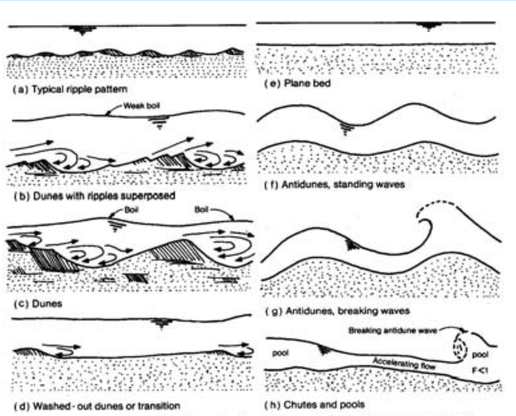



**Figure 6.2** Idealized bed forms in alluvial channels (after Simons et al., 1966).

## SANDY RIVERS

Bed forms determine the roughness of the channel (Manning´s *n*), which varies according to the discharge

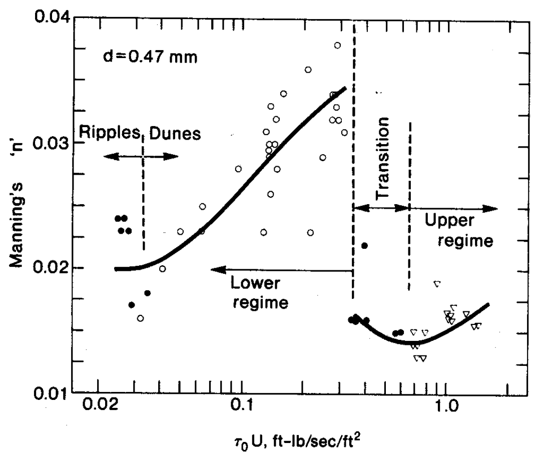



**Figure 6.3** Relationship between bed roughness and bed form based on flume data by Guy et al. (1966).

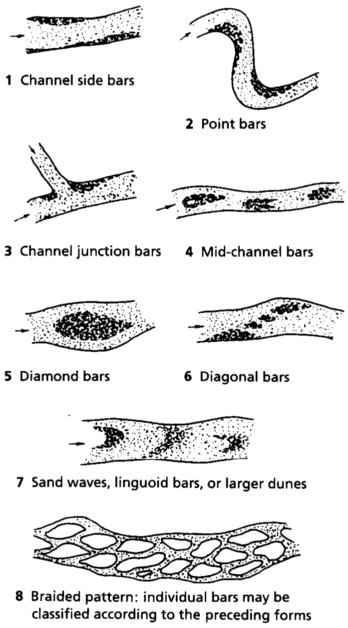


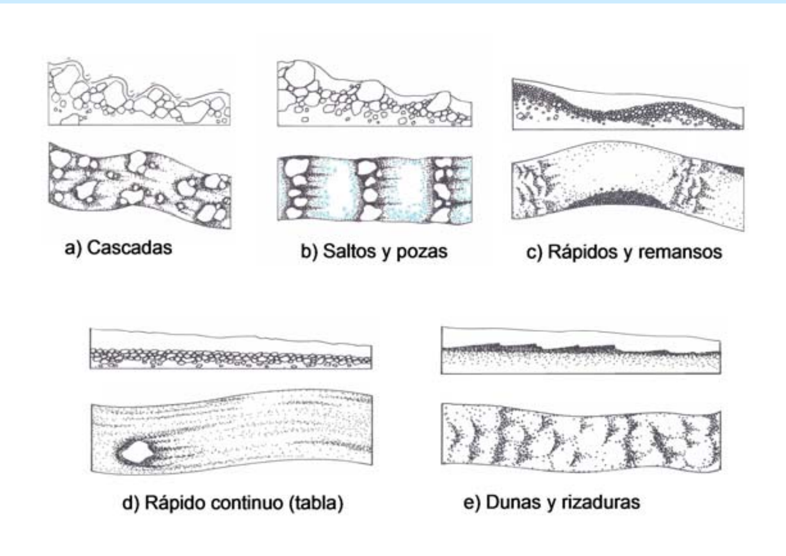

**Fig. 6.10** Morphological classification of large channels: sediment storage in bar structures (Kellerhals & Church 1989).

## GRAVEL-BED RIVERS

Gravel bars and islands modify the roughness of the channel and increase the **diversity of hydraulic conditions** (physical habitats)

## GRAVEL-BED RIVERS

Bed forms according to the sediment size:



## GRAVEL-BED RIVERS

Bed forms according to the sediment size:

**Cascade**

**Steps**

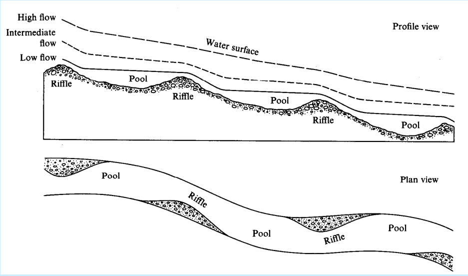
**Plane bed**

## GRAVEL-BED RIVERS

Bed forms according to the sediment size:

**Pools and Riffles**

## POOLS AND RIFFLES



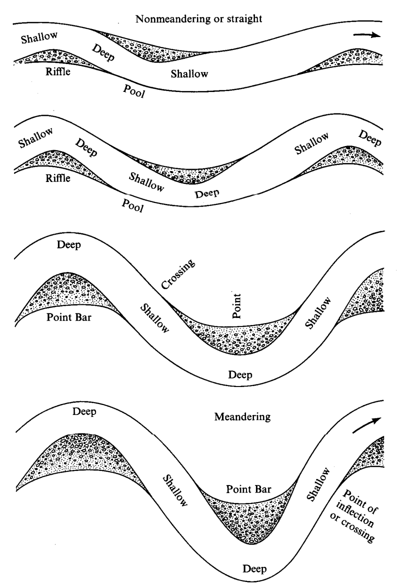




**Figure 16-23** Locations of shallow and deep zones in channels of different sinuosity. Riffle bars on alternate banks characterize straight channels, but point bars on convex banks characterize meander bends.

## POOLS AND RIFFLES

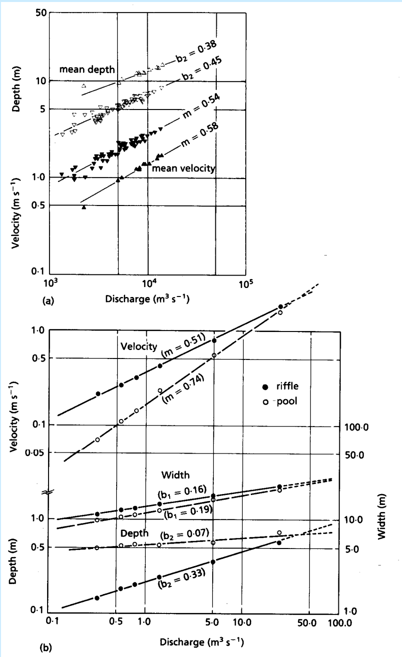



**Fig. 6.13** At-a-station hydraulic geometry. (a) Fraser River, British Columbia at Agassiz (gravel bed (▽ ▼)) and at Mission (sand bed (△ ▲)); $m = 1 - b_1 - b_2$. (b) Hangover Creek, Queen Charlotte Islands, British Columbia, a boulder–gravel stream of intermediate size, averaged over major morphological units (Hogan & Church 1989)

## TYPES OF EQUILIBRIUM

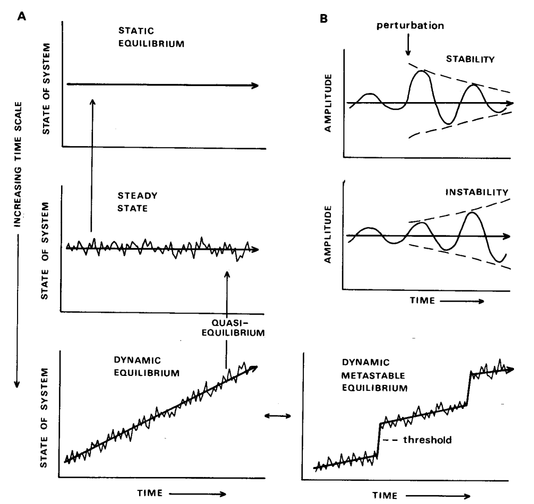
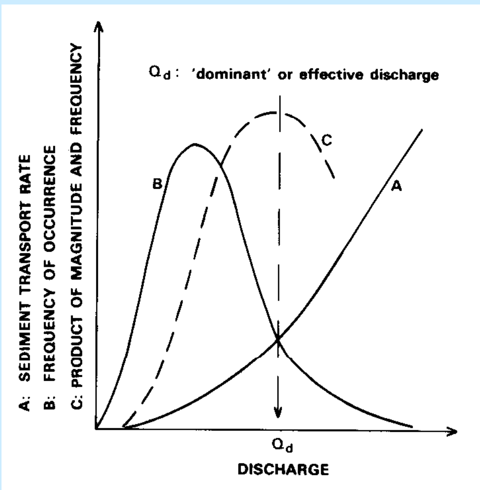


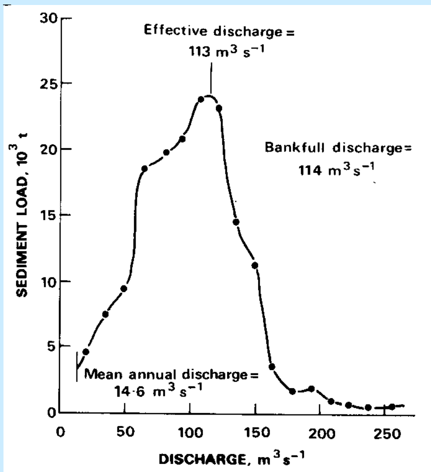

**Fig 4.2** A. Diagrammatic representation of types of equilibrium.
B. Definition sketches of stability and instability in an oscillating mechanical system subject to a perturbation.

More probable state:

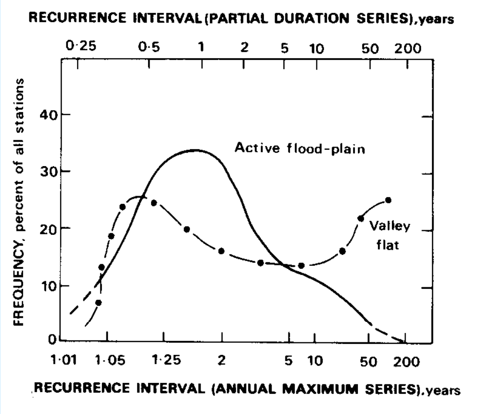
- •Uniform distribution of power
- •Minimum work (minimum energy lost per unit length)
- •Minimum hydraulic power v*S

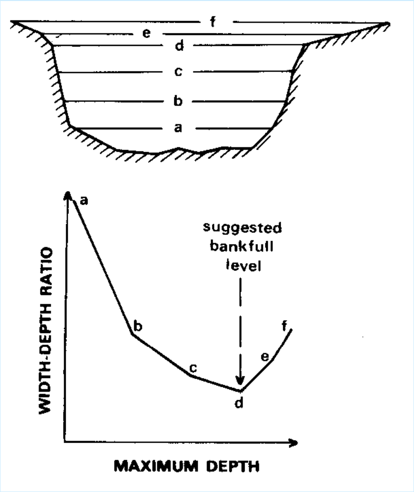
## DOMINANT DISCHARGE



# DOMINANT DISCHARGE




# FLUVIAL RESPONSE

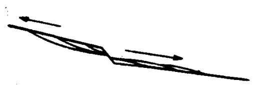
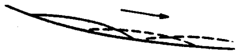
Lane´s equation (1955) for predicting fluvial responses:

$$Q * S \approx Q_s * D_{50}$$

## FLUVIAL RESPONSE

$$Q * S \approx Q_s * D_{50}$$

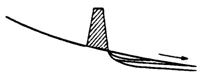
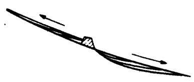
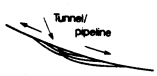
**Table 1.2 Channel response to natural or man induced changes.**
(+ = increase; - = decrease; above line = control; below line = response)

| | | | |
|---|---|---|---|
| NATURAL | | | |
| Meander cut-offs | $S^{+}Q_{+} \leftrightarrow Qs_{+}D_{+}$ | up |  |
| | $S_{+}Q_{-} \leftrightarrow Qs^{+}D_{-}$ | down | |
| Landslide: | | | |
| Large sustained supply | $S^{+}Q_{+} \leftrightarrow Qs_{+}D_{+}$ | up |  |
| | $S_{+}Q^{-} \leftrightarrow Qs^{++}D_{-}$ | down | |
| Small limited supply | $S_{+}Q_{-} \leftrightarrow Qs^{+}D_{-}$ | |  |

## FLUVIAL RESPONSE

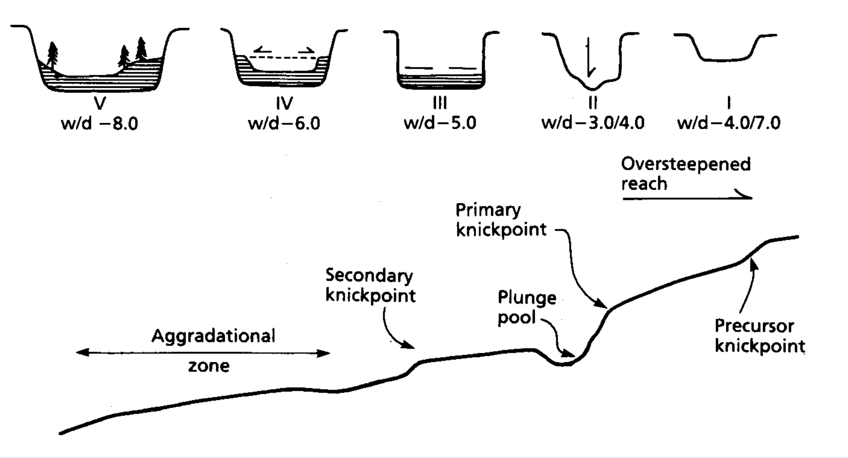
$$Q * S \approx Q_s * D_{50}$$

**Table 1.2 Channel response to natural or man induced changes.**
(+ = increase; - = decrease; above line = control; below line = response)

| | | | |
|---|---|---|---|
| ARTIFICIAL | | | |
| Dam construction | $S_{-}Q^{-} \leftrightarrow Qs^{--}D_{+}$ | |  |
| Weir construction | $S^{-}Q_{-} \leftrightarrow Qs_{-}D_{-}$ | up |  |
| | $S_{-}Q_{+} \leftrightarrow Qs^{-}D_{+}$ | down | |
| Weir failure | $S^{+}Q_{+} \leftrightarrow Qs_{+}D_{+}$ | up |  |
| | $S_{+}Q_{-} \leftrightarrow Qs^{+}D_{-}$ | down | |
| Channel straightening | $S^{+}Q_{+} \leftrightarrow Qs_{+}D_{+}$ | up |  |
| | $S_{+}Q_{-} \leftrightarrow Qs^{+}D_{-}$ | down | |
| Channel dredging and/or gravel mining | $S^{+}Q_{+} \leftrightarrow Qs_{+}D_{+}$ | up |  |
| | $S^{--}Q_{-} \leftrightarrow Qs_{-}D_{-}$ | centre | |
| | $S_{-}Q_{+} \leftrightarrow Qs^{-}D_{+}$ | down | |
| Interbasin transfers (flows above sediment transport threshold) | $S^{+}Q_{+} \leftrightarrow Qs_{+}D_{+}$ | up |   |
| | $S_{-}Q^{++} \leftrightarrow Qs_{+}D_{+}$ | down | |

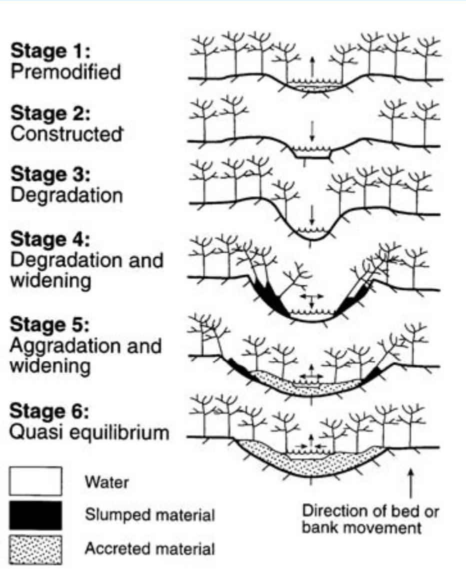
FLUVIAL RESPONSE

INCISED CHANNELS

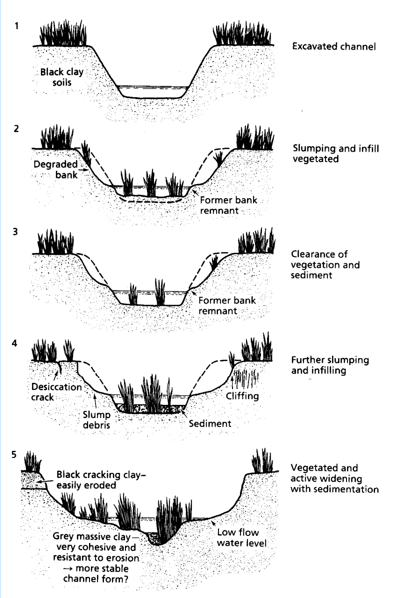


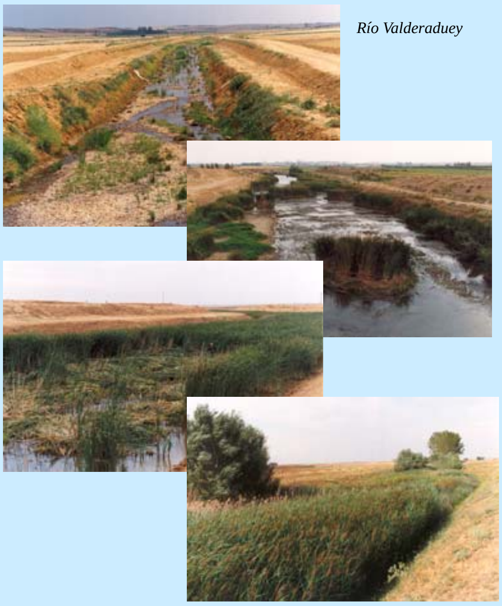

FLUVIAL RESPONSE

INCISED CHANNELS




## FLUVIAL RESPONSE

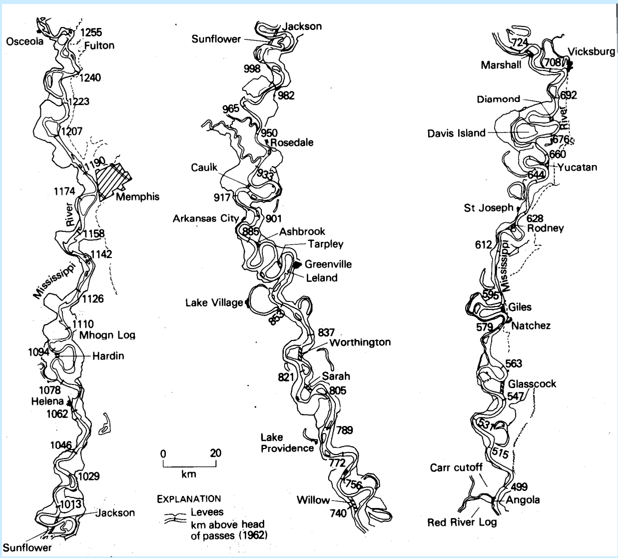


*Río Valderaduey*

## FLUVIAL RESPONSE

Meandering cutoffs in the Mississippi River

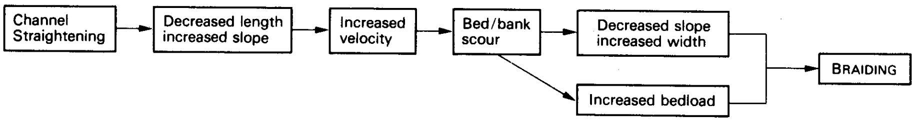


# FLUVIAL RESPONSE

Table 11.10 Artificial cutoffs on the Mississippi River, 1932–42. After Winkley (1973)

| *Cutoff* | *Year* | *Shortening* (km) |
|---|---|---|
| Hardin | 1942 | 27.2 |
| Jackson | 1941 | 14.0 |
| Sunflower | 1942 | 16.7 |
| Caulk | 1937 | 24.5 |
| Ashbrook | 1935 | 18.4 |
| Tarpley | 1935 | 13.8 |
| Leland | 1933 | 15.8 |
| Worthington | 1933 | 6.9 |
| Sarah | 1936 | 8.5 |
| Willow | 1934 | 12.4 |
| Marshall | 1934 | 6.8 |
| Diamond | 1933 | 19.3 |
| Yucatan | 1929 | 15.4 |
| Rodney | 1936 | 9.3 |
| Giles | 1933 | 17.9 |
| Glasscock | 1933 | 17.4 |
| Total | | 244.3 |

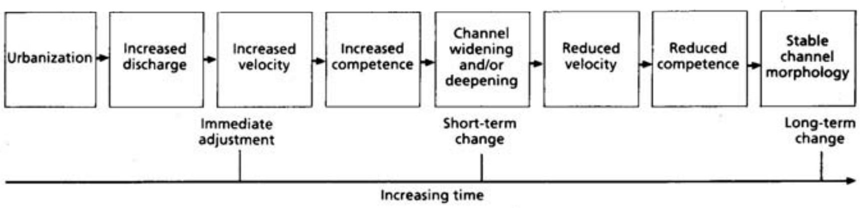
Fig. 11.21 Reaction of a river to a cutoff or channel straightening and its readjustment over time



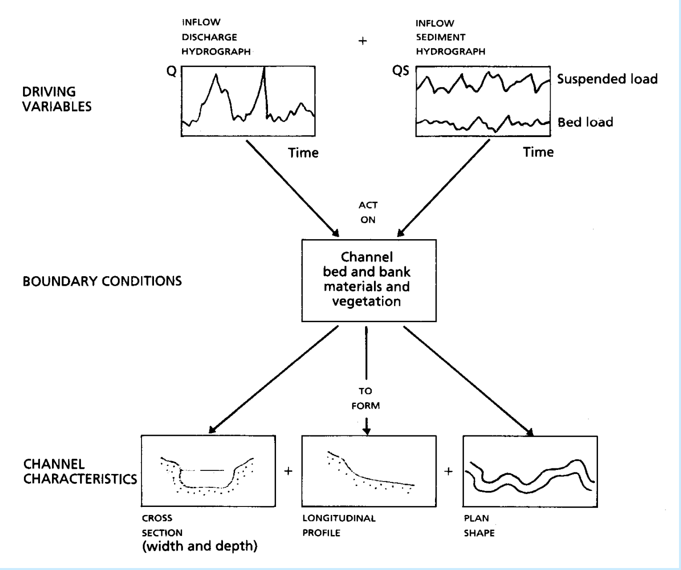

# FLUVIAL RESPONSE

Table 11.4 Ratio of discharge after urbanization to discharge before urbanization

| *Area* | *Inc.* $Q_p$ | *Source* |
|---|---|---|
| Chicago | 2.5 | Ramey (1959) |
| Michigan | 3.0 | Wiitala (1961) |
| Washington, D.C. | 1.8 | Carter (1961) |
| Texas | 2–5.0 | Van Sickle (1962) |
| Long Island, New York | 2.5 | Seaburn (1964) |
| Mississippi | 2–3.5 | Wilson (1967) |
| East Coast | 2–3.0 | Anderson (1968) |
| Texas | 2–2.5 | Espey and Wislow (1974) |



## FLUVIAL DYNAMICS




- •Watershed Hydrology
- •Land uses

**Human disturbance**

- •Channel forms
- •Fluvial Processes

**River Response**

## BASIC FLUVIAL GEOMORPHOLOGY

- •Interest of the FluvialGeomorphology in river restoration projects
- •Morphological analysis of the rivers
- •The sediments in the fluvial processes
- •The river in equilibrium: natural dynamics
- •Dominant discharge concept
- •Response of rivers to natural/human disturbances