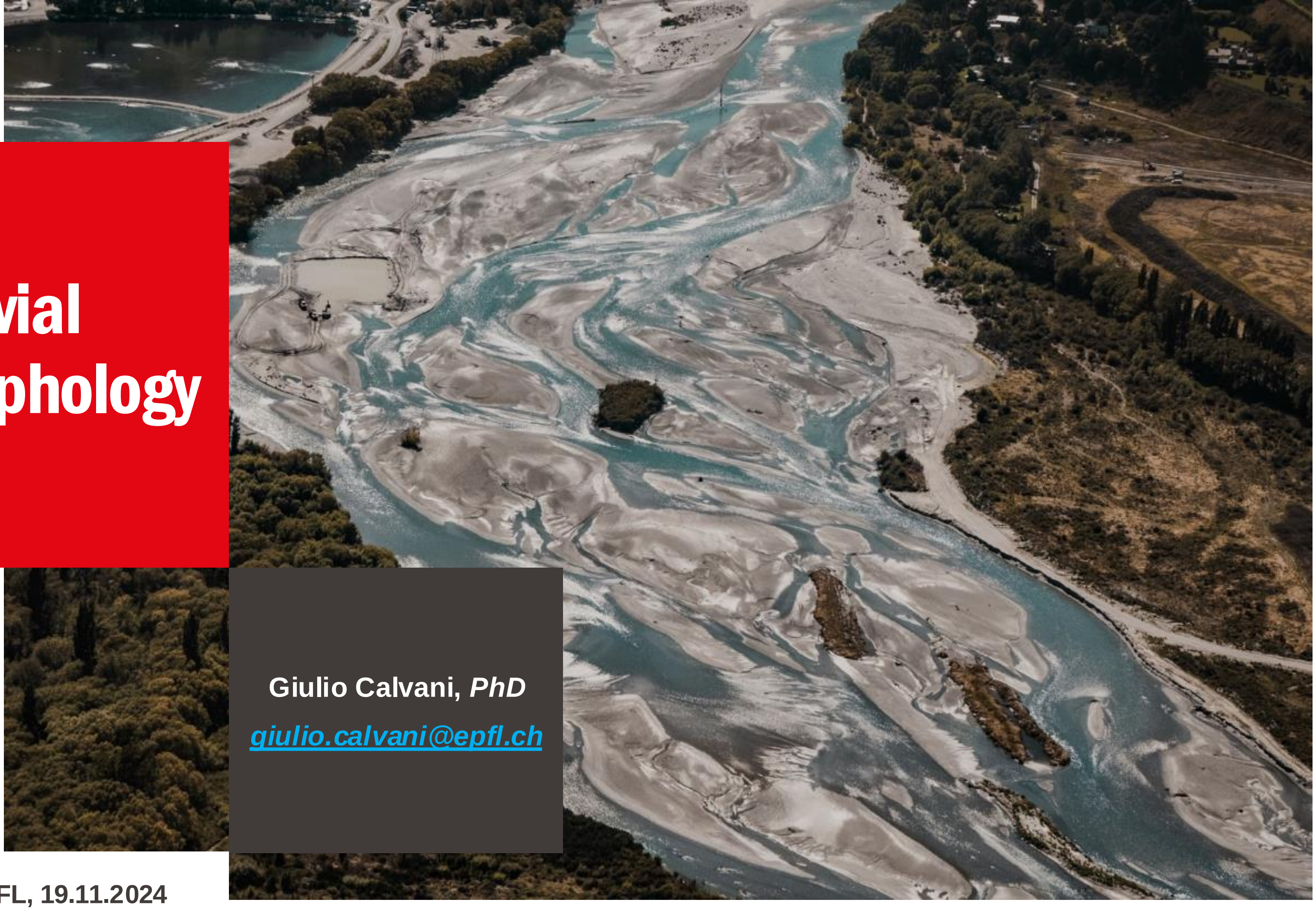
Fluvial geomorphology



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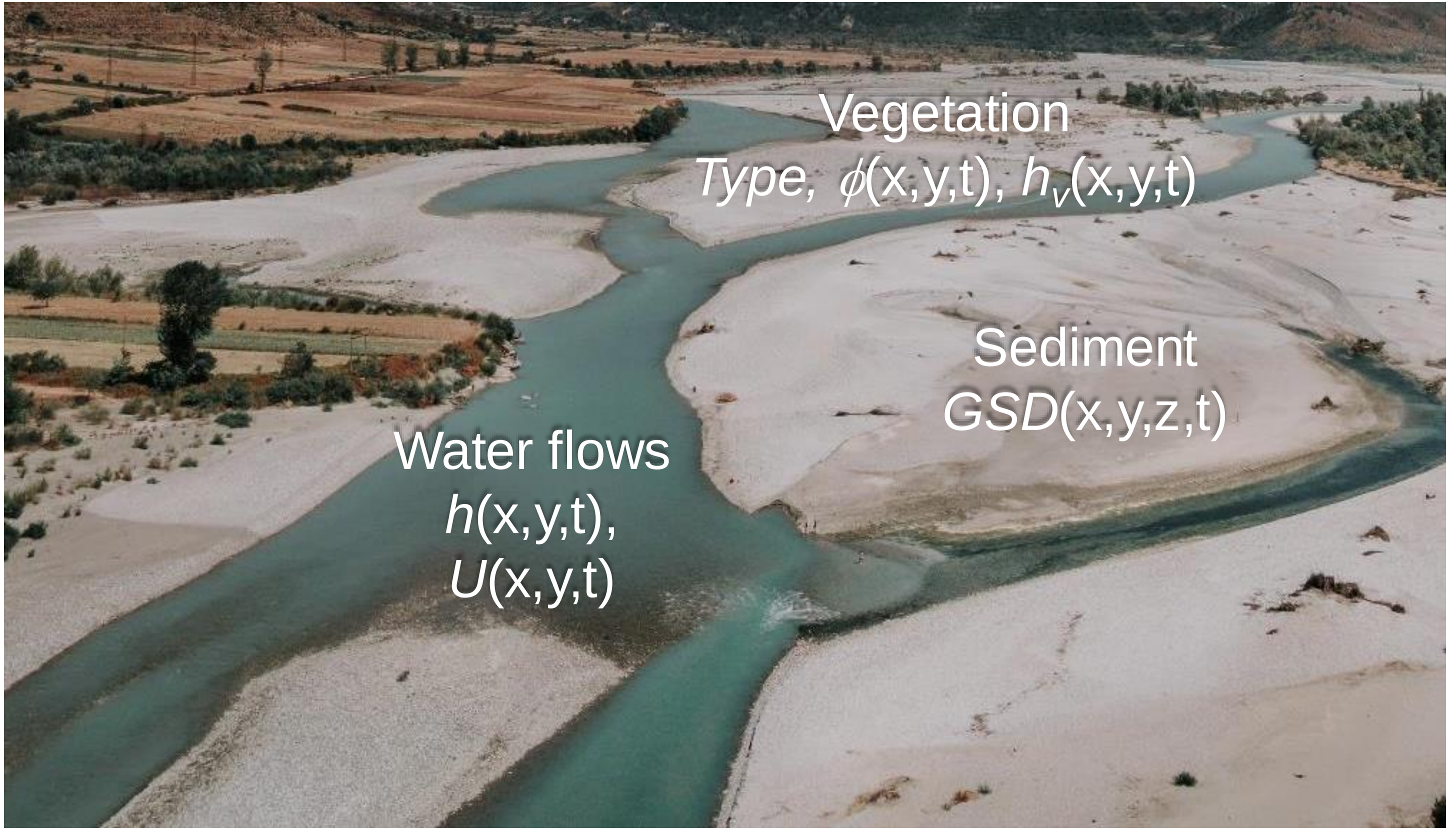
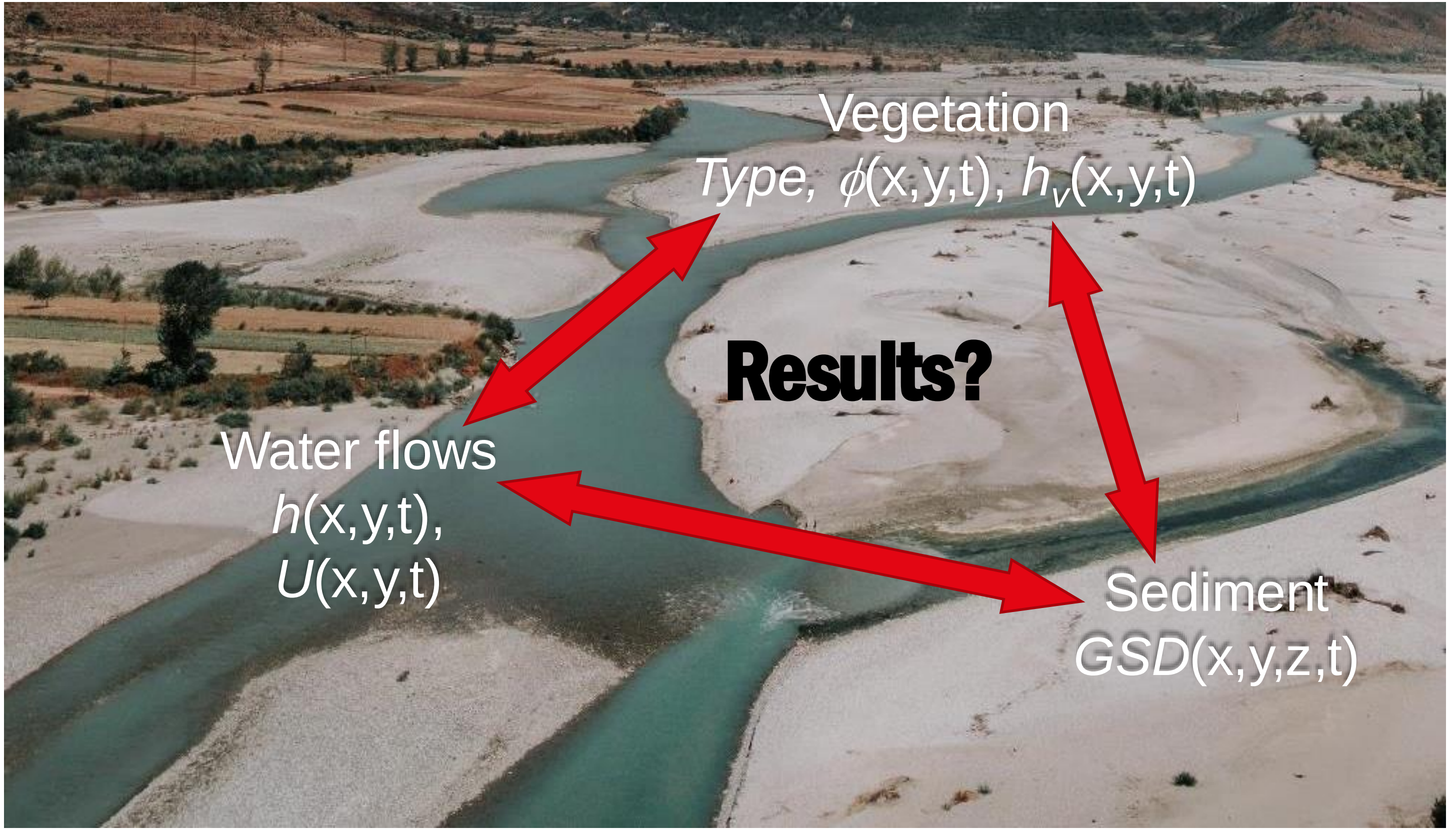
Hydraulique fluviale et aménagement de cours d'eau

EPFL, 19.11.2024

What are we dealing with ?



What are we dealing with ?



What are we interested in ?

Factors

WATER

SEDIMENT

Other factors?

Plants

Animals

Human activities

What are we interested in ?

Factors

Flow discharge
$q=q(\text{time, space})$

Sediment discharge
$q_s=q_s(q, \text{grains, slope})$

Outcomes

Longitudinal profile

Cross-section shape

Planimetric configuration

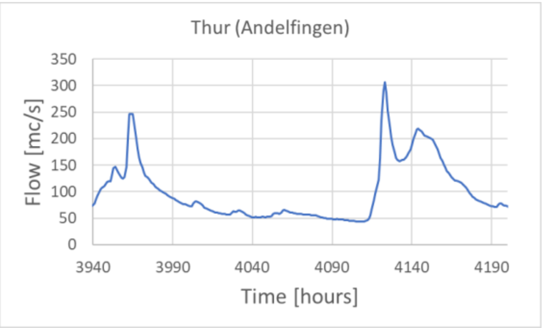
Flow discharge

Variables

- Climate
  - Precipitations: types and amount
  - Seasonality
- Soil
  - Type (permeability)
  - Saturation
- Human activities (e.g., regulation by dams)

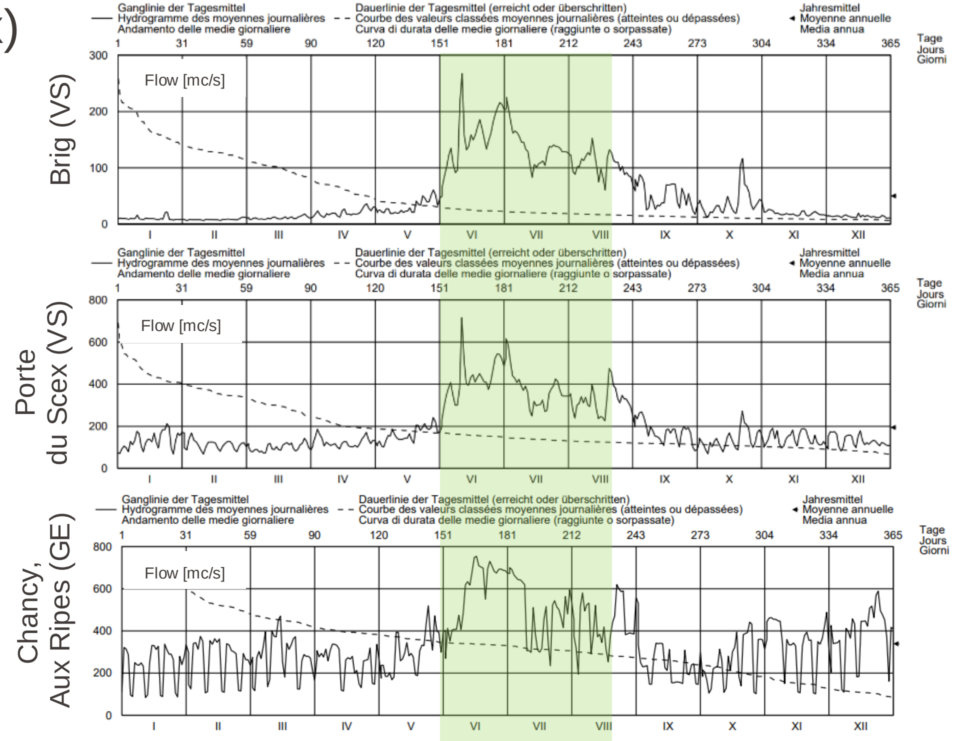
Temporal variability

- q=q(t)



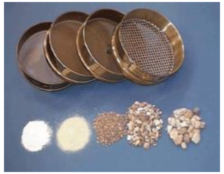
Spatial variability

- q=q(x)



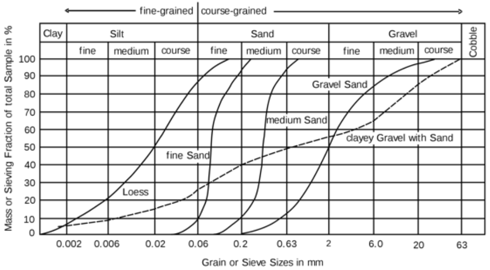
Sediment

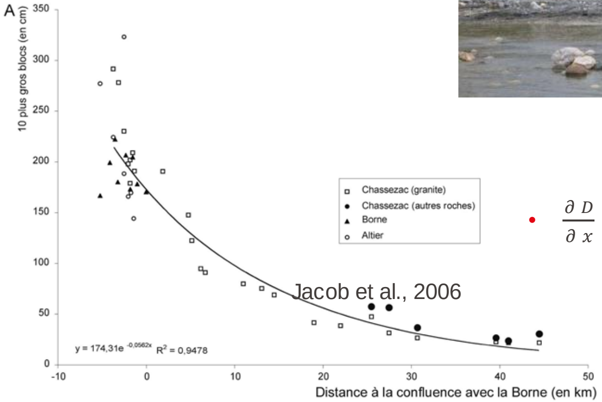
- Particle size (D)



- inside the channel: riverbed
- outside the channel: bank erosion,
  landslide (eventually with organic material)
- Usually D=D(x,y,z,t)

- Gravel bed rivers
- Sand bed rivers





Jacob et al., 2006

- $\frac{\partial D}{\partial x} < 0$ downstream fining

- Availability of bed material

Supply limited

(usually in bedrock rivers)

vs.

Transport capacity limited

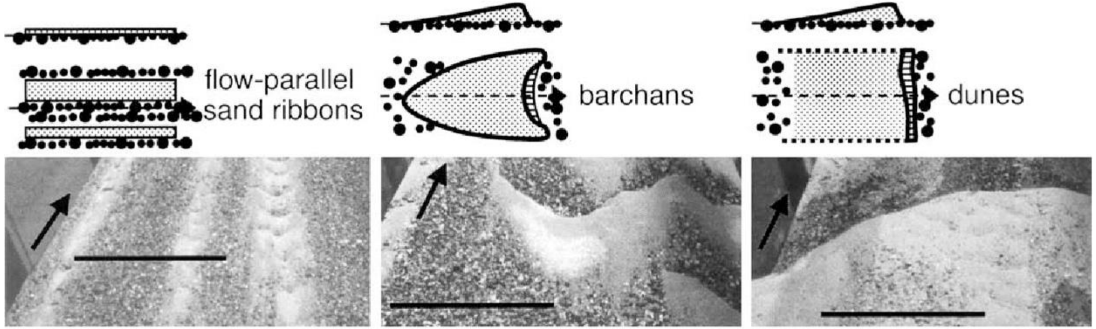


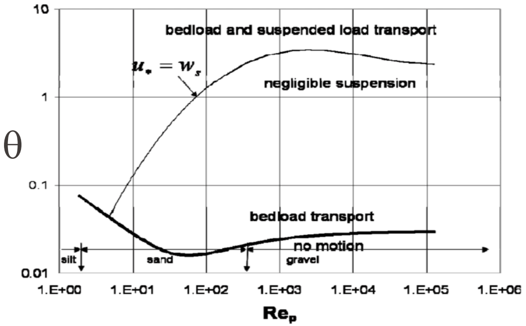
Fig. 3—Bedform types observed in the flume experiments. Arrows denote flow direction, and scale bars are 0.5 m. Stippled areas are sand and dots are gravel

Sediment transport rate

Transport capacity

$$q_s = q_s\,(q(x,t)\ ,\ D_{50})$$

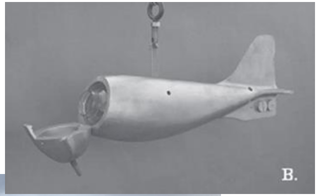
$$q_s = q_s\,(\theta(x,t)\ ,\ Re_p)$$



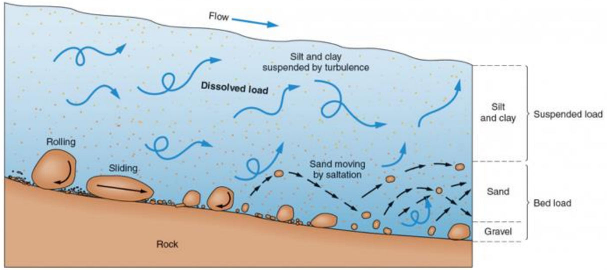
Real sediment transport rate

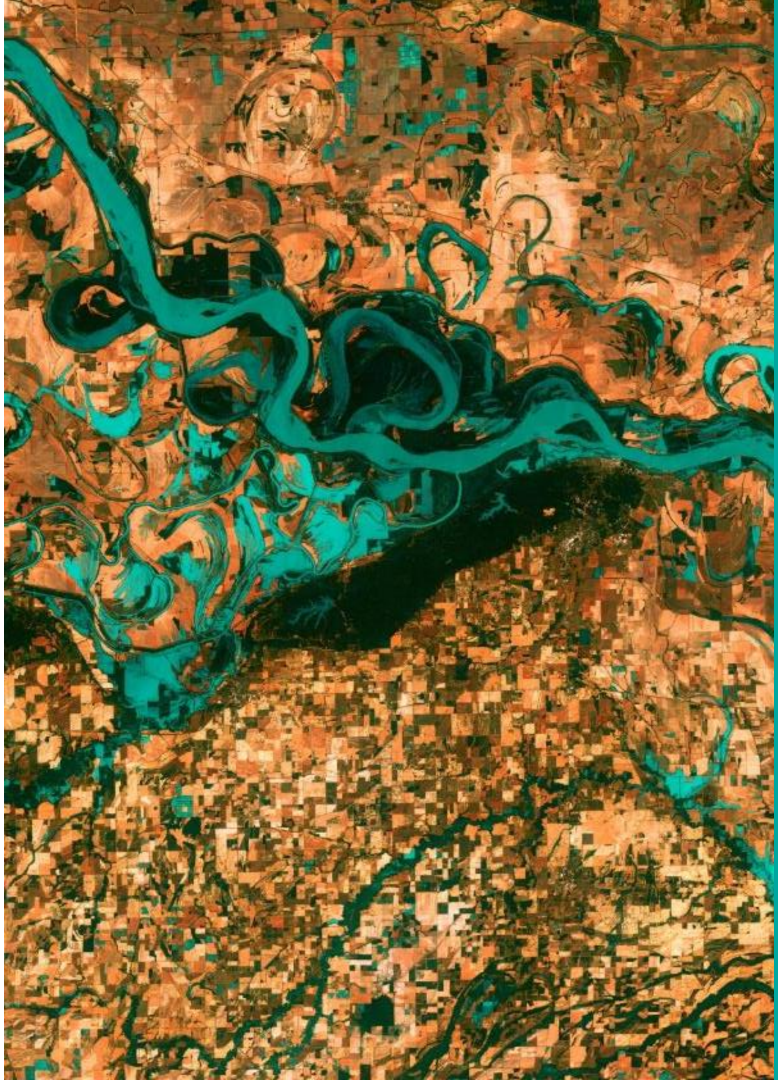
- Bedload measurements with Helley-Smith sampler

- Suspended load measured through vertical integrated samplings



Several relationships depending on transport mechanism





Morphological response

- ✓ Planimetric configuration (previous lecture)

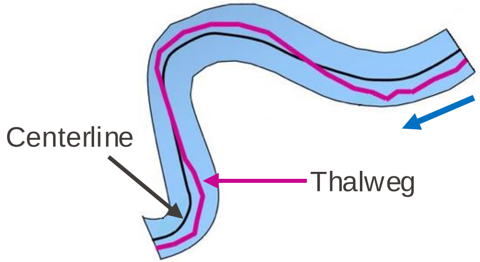
Longitudinal profile

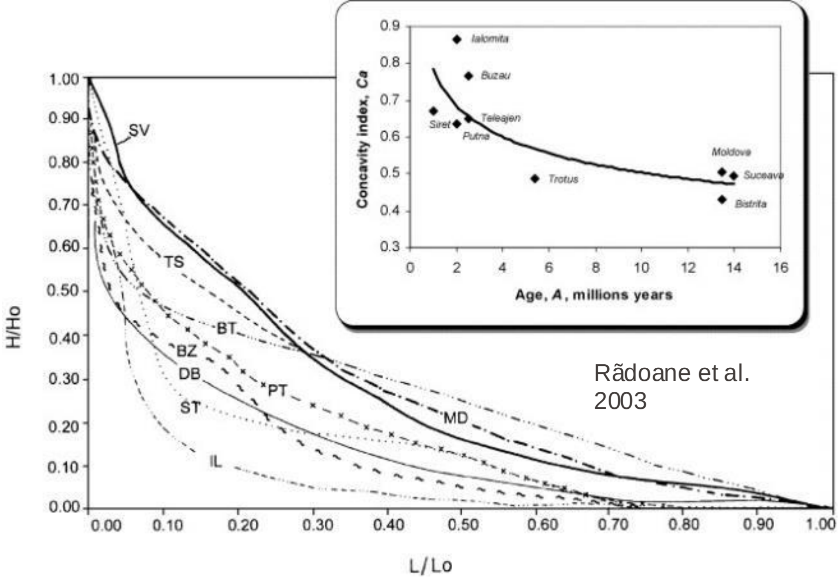
Cross-section geometry

EPFL

Longitudinal profile

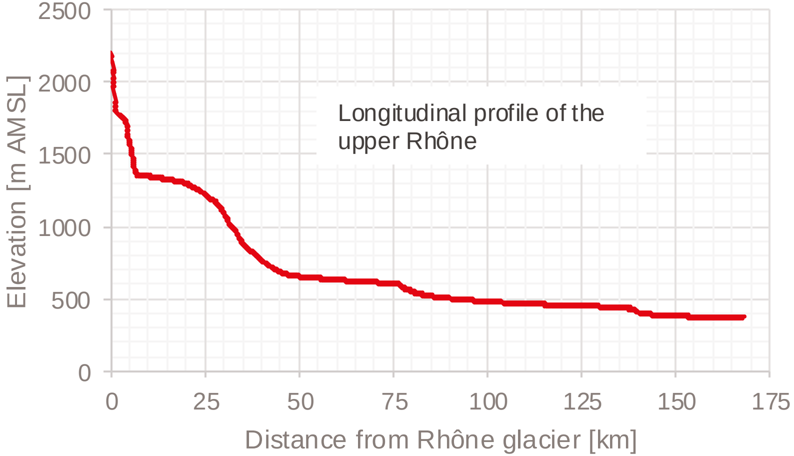
Elevation of the thalweg





Common characteristics among rivers

- Progressive decrease of bed slope
- Concave shape
- Smoothing over time



The longitudinal profile appears to follow a sort of «universal law»

Longitudinal profile

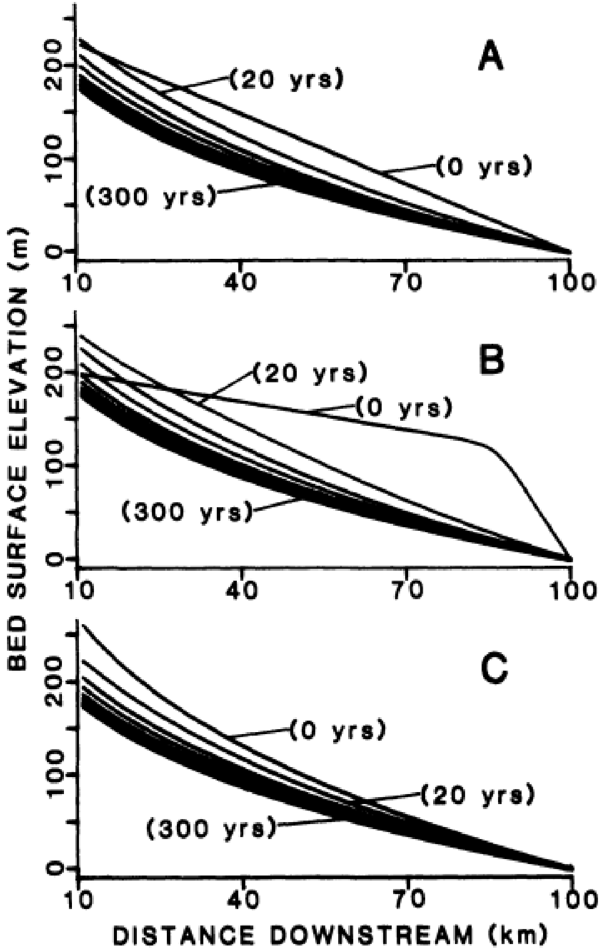
Achievement of an equilibrium profile

Continuous adjustments between erosion and deposition processes

Long-term evolution predicted by numerical models (e.g., Snow and Slingerland, 1987)

Temporal space between profiles = 20y

Different initial bed profile (different concavity) → information on the I.C. is lost just after the first timestep (t=20y)



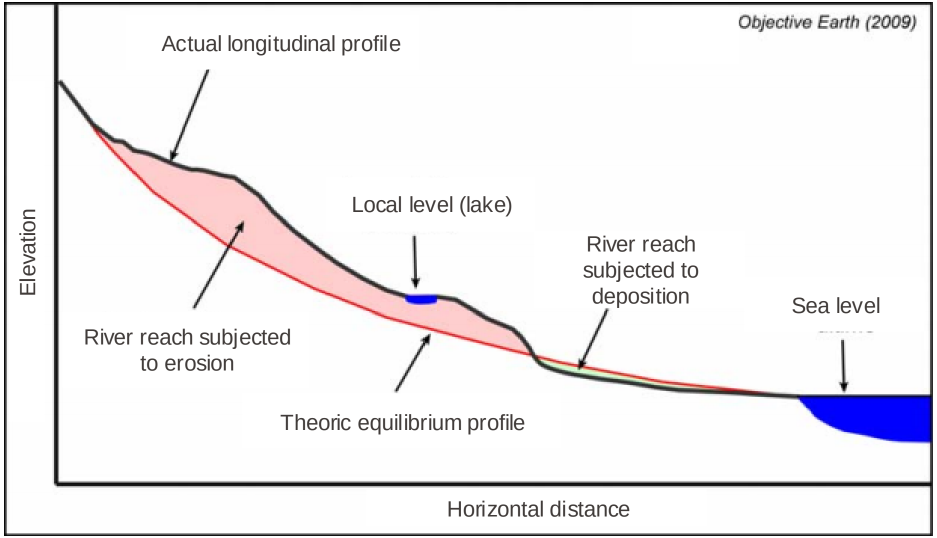
Longitudinal profile

Downstream control on the profiles

Usually the BC is defined by the sea level

Local/Temporal BC:

- a lake
- an alluvial fan
- channel narrowing/widening
- bed material composition



Société Suisse de Géomorphologie (SSGm) – Schweizerische Geomorphologische Gesellschaft Fiches – Géomorphologie de la montagne – Août 2009

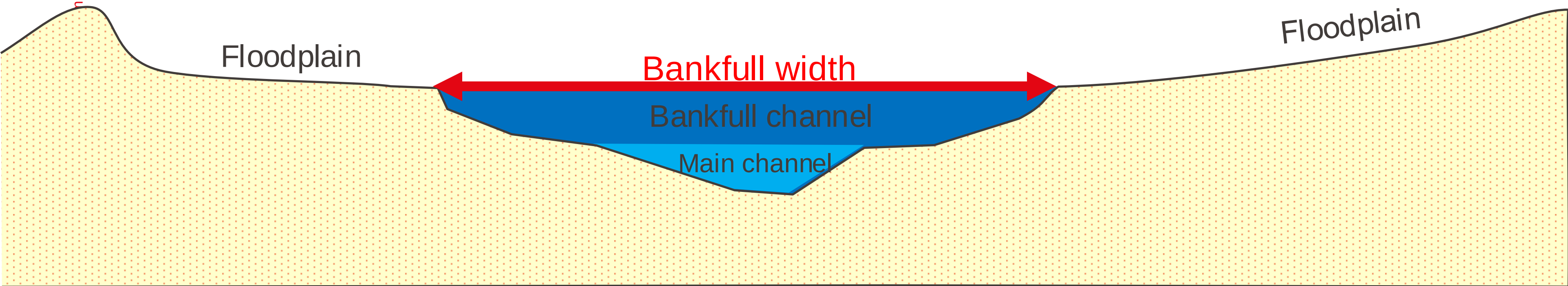
Transversal profile (cross section geometry)

Bed decomposition

- Main channel, corresponding to low water flows → q<mean(q)
- Bankfull channel
- Floodplain

Relationships between bankfull channel and…

offshore discharge, vegetation, catchment area, grain size (Schumm, 1960; Hey and Thorne, 1986; Parker et al., 2007)



nent de cours d'eau

Transversal profile (cross section geometry)

Assuming rectangular cross-section:

$$Q = A * \bar{v} = \mathrm{B} * h * \bar{v}$$

- $B = aQ^b$ (bankfull)
- $h \ = cQ^f$ (water depth)
- $\bar{v} \ = kQ^m$ (mean flow velocity)

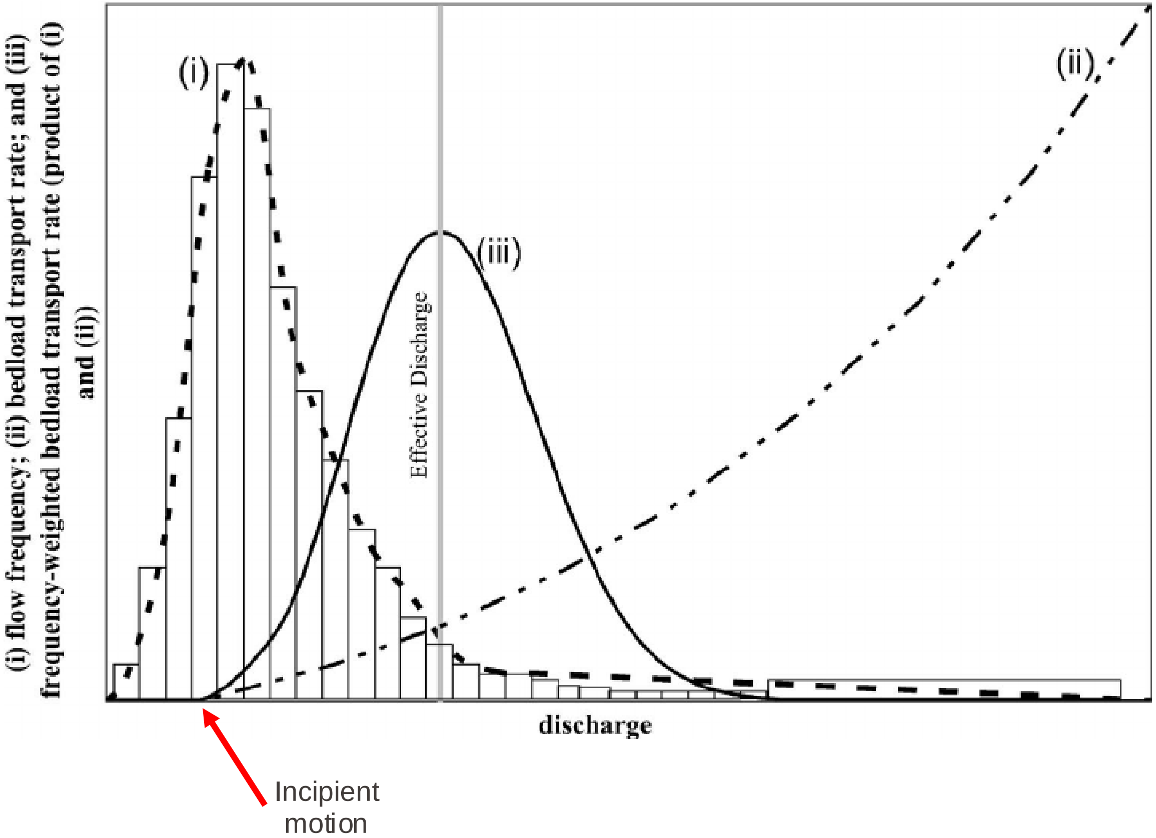
According to the literature:

- *b*, *f* and *m* > 0   usually, b ≅ 0.6, f ≅ 0.3 and m ≅ 0.1
- *a*, *c* and *k* depend on watershed properties (e.g., catchment area, land use)

Can all flow rates lead to an adjustment of the hydraulic geometry?

Transversal profile (cross section geometry)

Barry et al. (2008)



Formative discharge

$q_f = q_{bf}$
(bankfull discharge)

$q_f = q(Tr=2\text{-}5 \text{ years})$