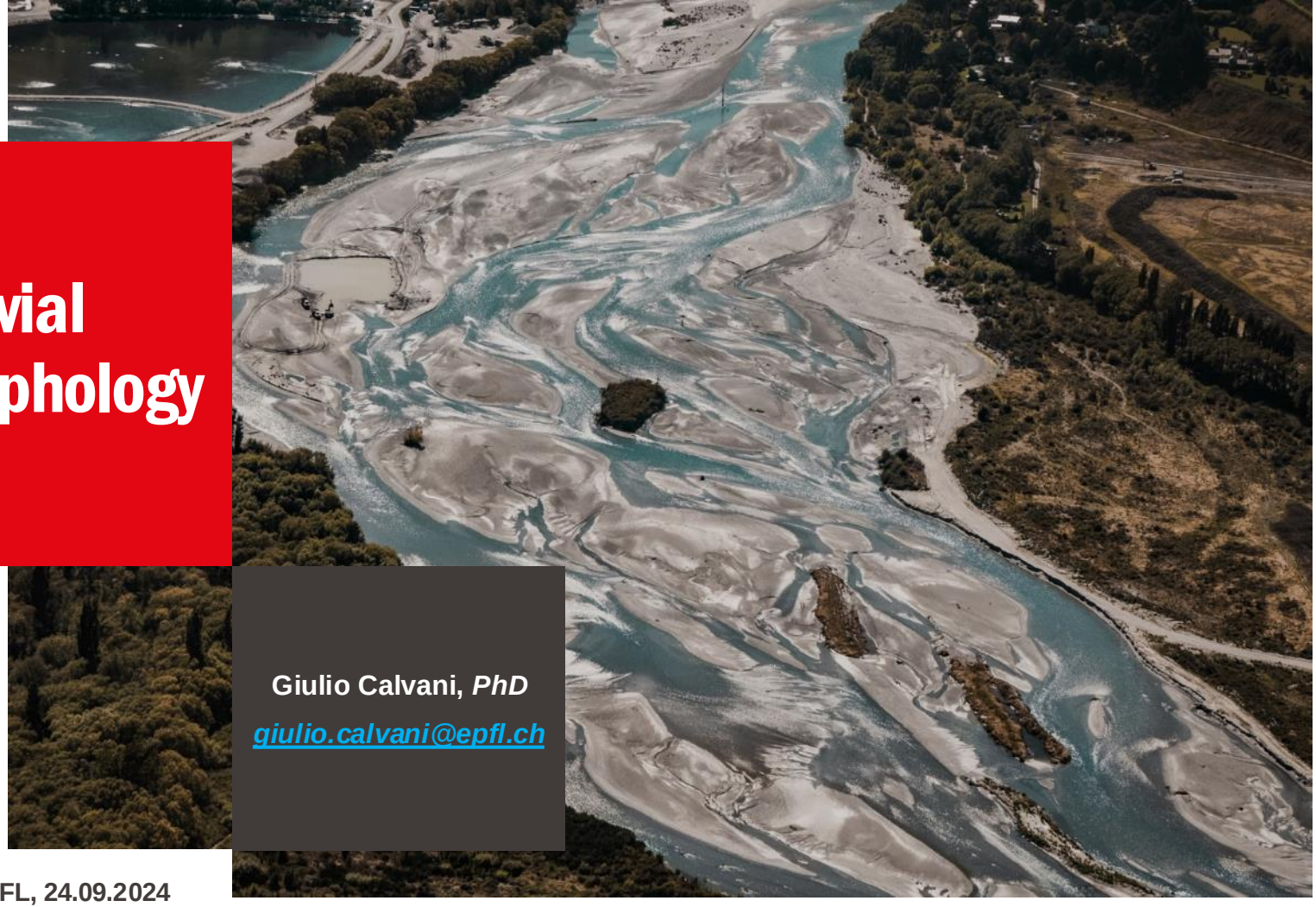
Fluvial geomorphology



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Hydraulique fluviale et aménagement de cours d'eau

EPFL, 24.09.2024

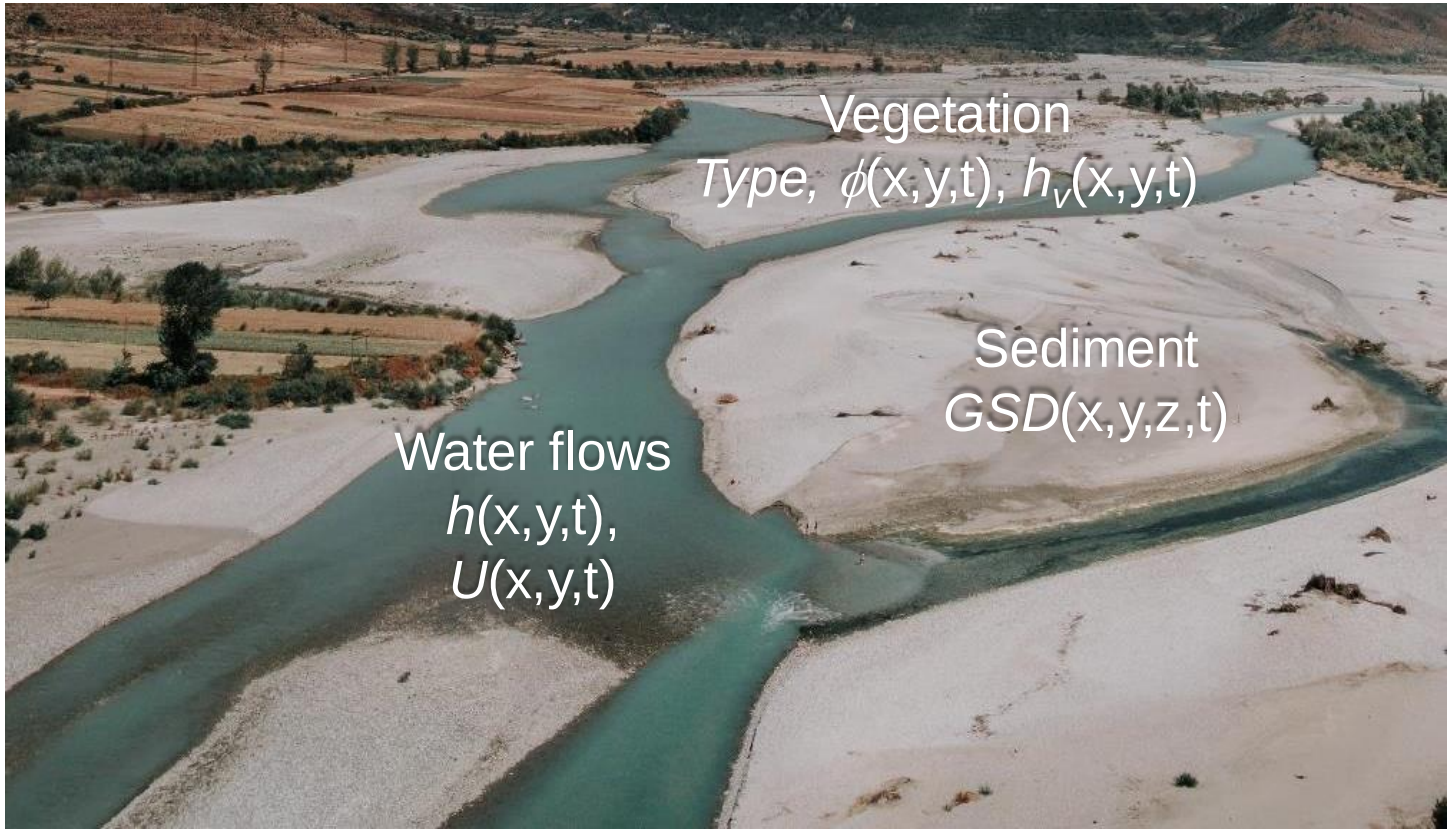
Fluvial geomorphology
(River hydro-morphology)

Study of the physical and the resulting bedforms for a watercourse.

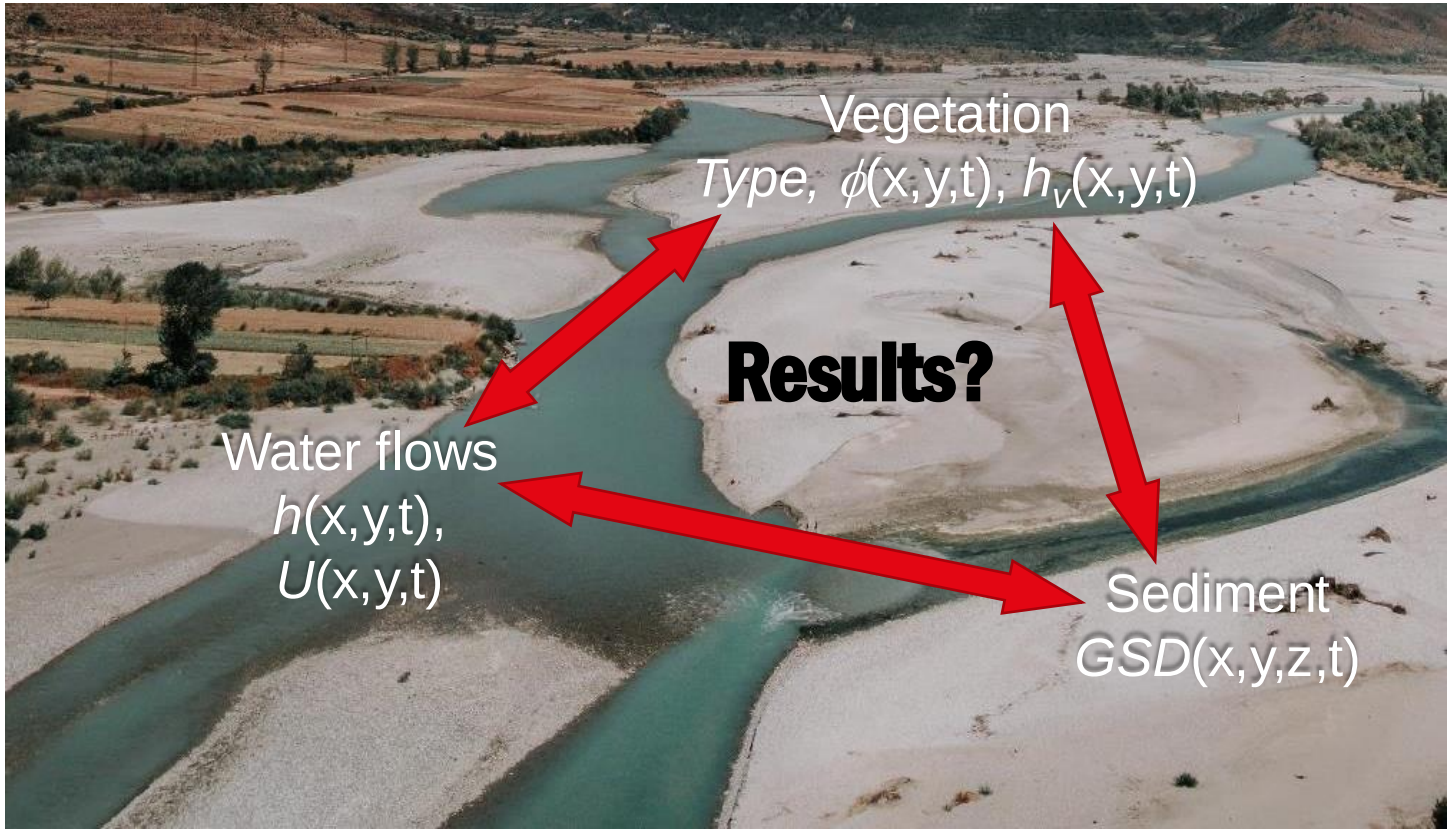
Discipline appeared in the 1940s in the United States.

Nowadays it gained importance for the design of effective renaturalization and restoration projects.

What are we dealing with ?



What are we dealing with ?



Planimetric configuration

Tilt River, Scotland

Green River, US

Columbia River, Canada

Upper Amazon River, Brazil

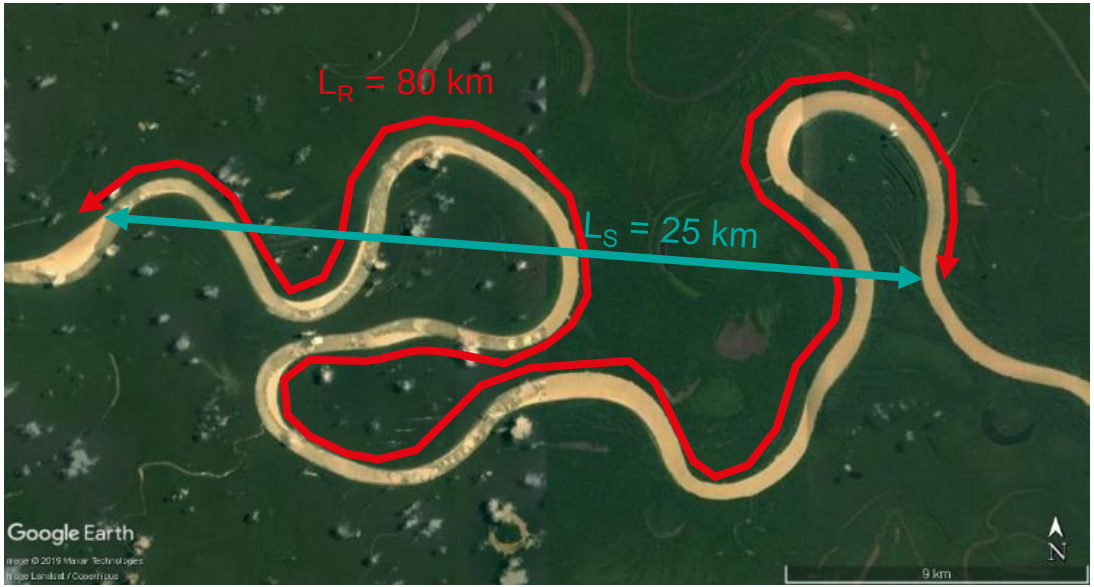
Waimakariri River, New Zealand

Planimetric configuration

Planform configuration = f(x,t)

$$\frac{\partial f(x,t)}{\partial t} \approx \frac{f(x,t)}{T}$$

with T the timescale of planform evolution (1 y < T < ~10^5 y)



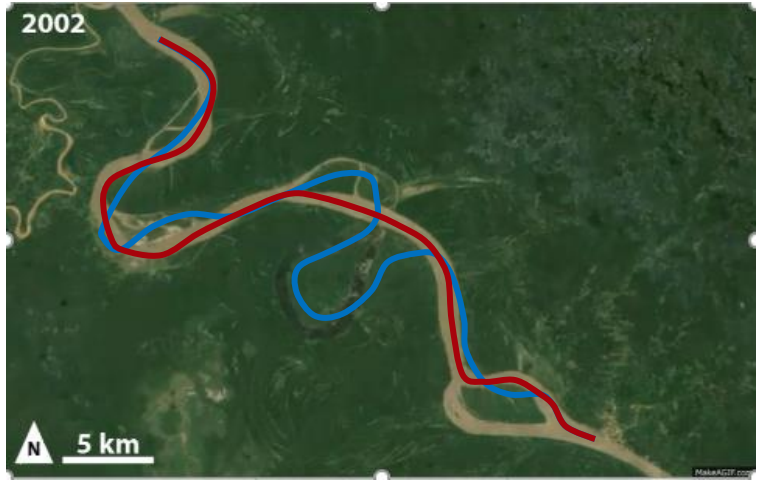
- Length as the crow flies (i.e. straight line between two points = L_S)
- Length along the water course (i.e. actual river length = L_R)
- Sinuosity Index I_S = L_R / L_S (e.g., I_S = 80 km / 25 km = 3.2)

Planimetric configuration

Classification based on I_S

- $I_S < 1.05$ ⇔ rectilinear
- $1.05 < I_S < 1.25$ ⇔ sinuous
- $1.25 < I_S < 1.5$ ⇔ very sinuous
- $1.5 < I_S$ ⇔ meandering

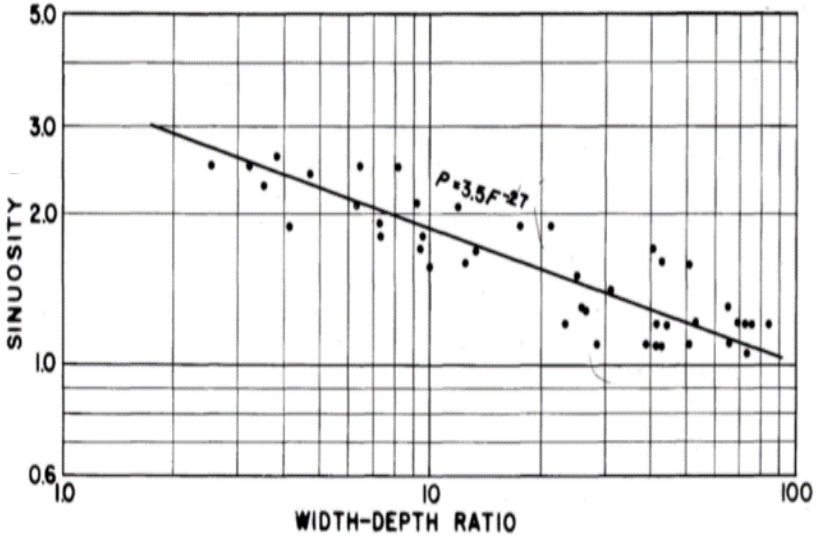
$I_S = I_S(t)$ particularly for highly active meandering river

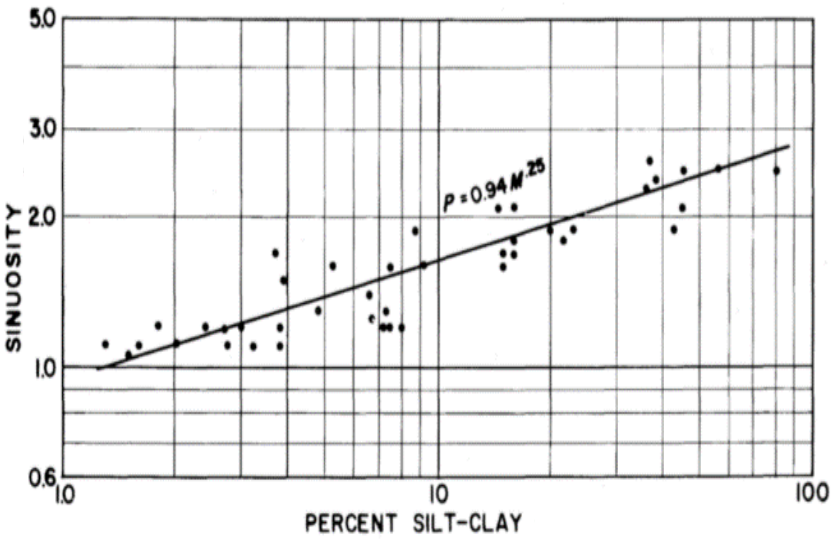


Planimetric configuration

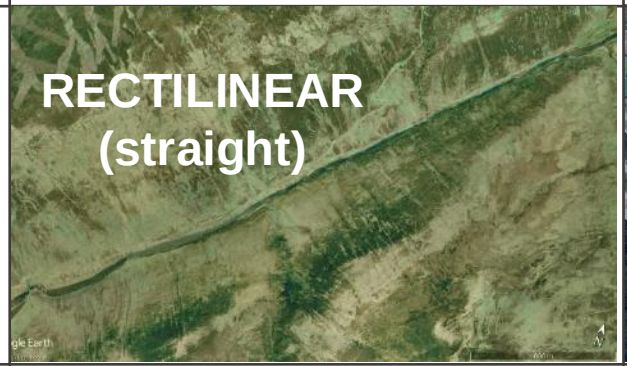
Schumm (1963): correlation between sinuosity index and…

- Width-to-depth ratio (i.e. aspect ratio)
- Bed slope
- Bank composition (with particular regards to silt and clay fractions)





Planimetric configuration

Index of sinuosity, I_S	Number of channels, N: N=1 → Single-thread channel	Number of channels, N: N>1 → Multiple channels
I_S<1.05-1.25		
I_S>1.25		

Planimetric configuration

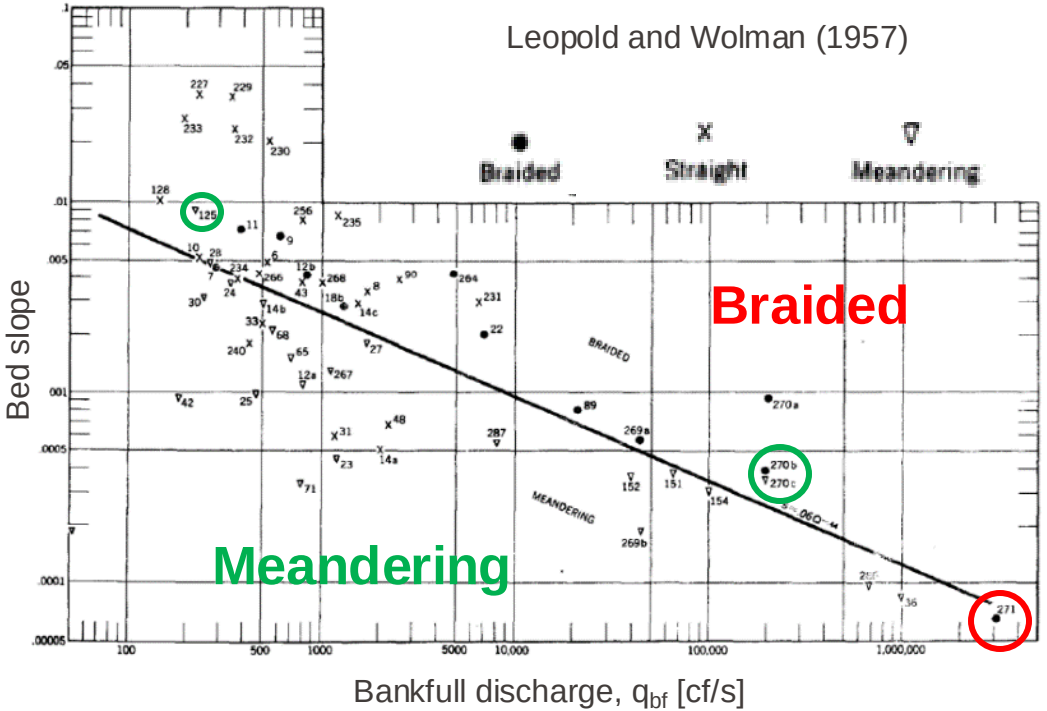
Relationship between bankfull discharge and bed slope

Empirical relationship based on field studies

$$s[°/°°] = 0.013 * {q_{bf}}^{-0.44} \ [\frac{m^3}{s}]$$

Some rivers do not obey the relationship

Leopold and Wolman (1957)



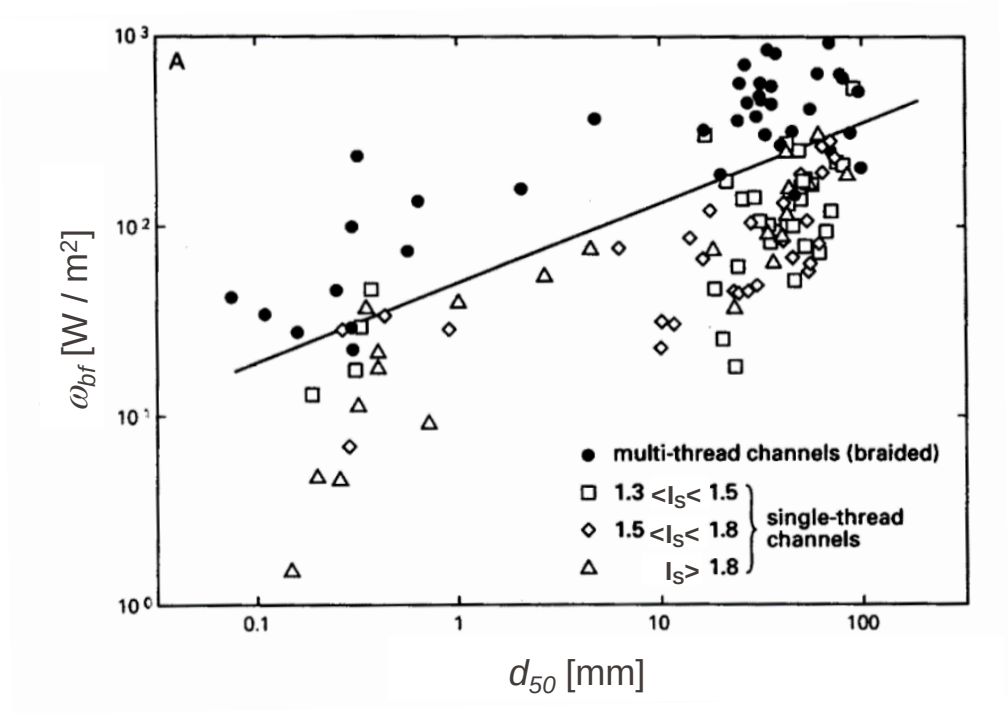
Planimetric configuration

Empirical relationship between bankfull discharge, bankfull width, bed slope and bed material (Ferguson, 1987)

$$\omega_{bf} = \rho\, g \frac{q_{bf}}{W_{bf}} s$$

ω_{bf} = bankfull stream-power per unit-width [W / m^2]

$$\omega_{bf} = 900 * {d_{50}}^{0.42}$$



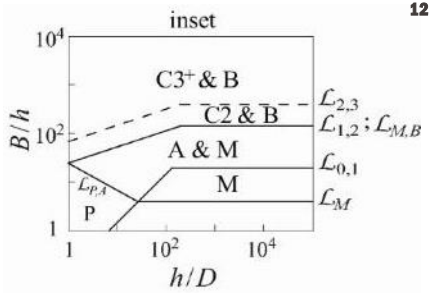
Planimetric configuration

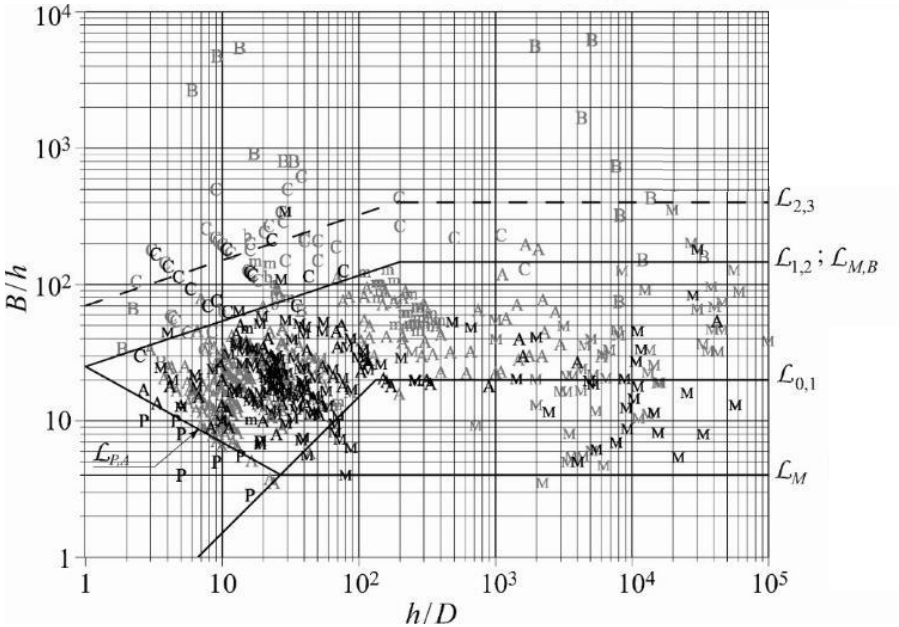
Classification based on the width, and the water depth in bankfull conditions and a characteristic grain size, d_m (usually $d_m \rightarrow d_{50}$).

- Empirical formulations based on real rivers and flume experiments
- Presence of bars (bedforms)

Ahamri and da Silva (2001)

A - Alternate bars
C - Multiple bars
M - Meandering rivers
m - Meandering lab. channel
B - Braiding rivers
b - Braiding lab. channels
P - Plane Bed





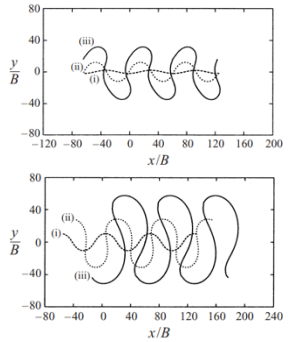
Meandering rivers

Meandering rivers

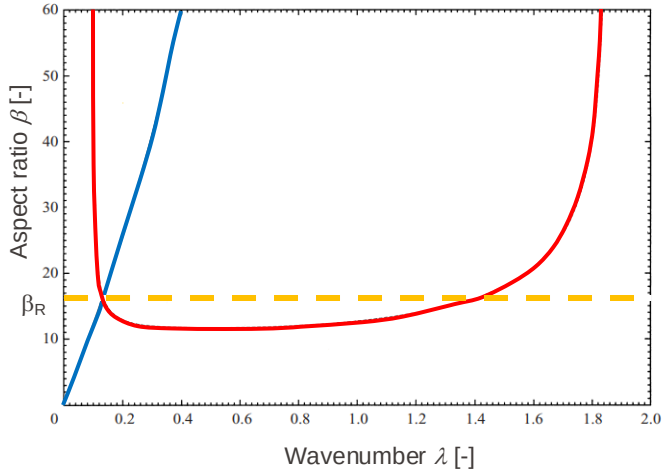
Meander skewness

- depends on aspect and resonant conditions
- $\beta < \beta_R$ (sub-resonant) → upstream skewness (more common, with regular meanders)
- $\beta > \beta_R$ (super-resonant) → downstream skewness (less common, multi loops)

Seminara et al., 2000

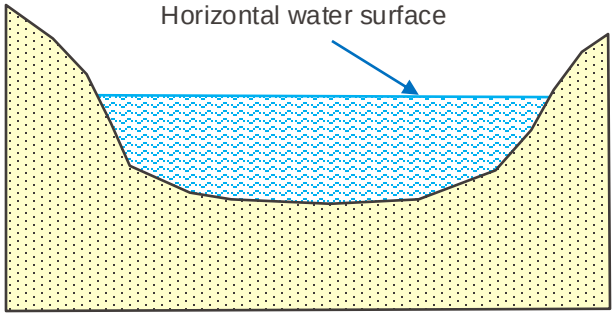


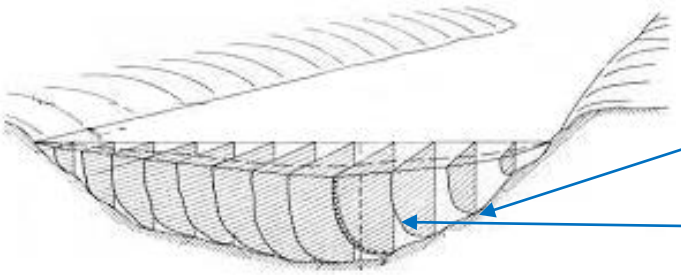
Zolezzi and Seminara (2000)



Meandering rivers

Average velocity profile in straight channel

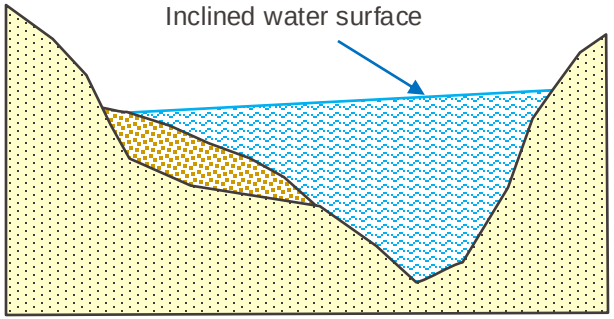


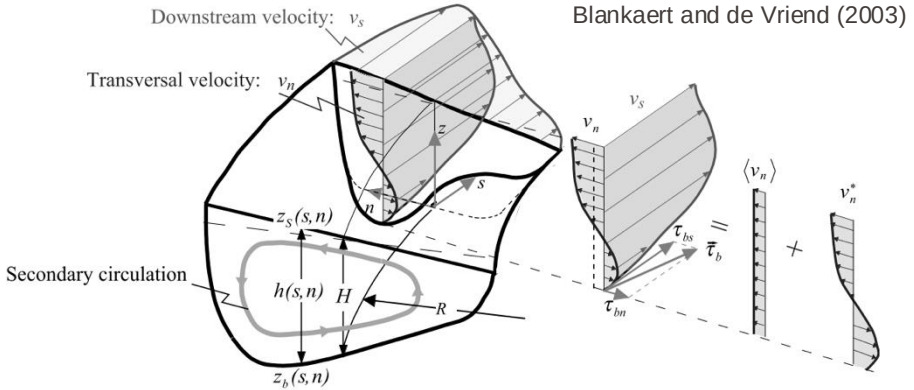


No-slip condition at the river bed

Typical logarithmic profile along the vertical direction

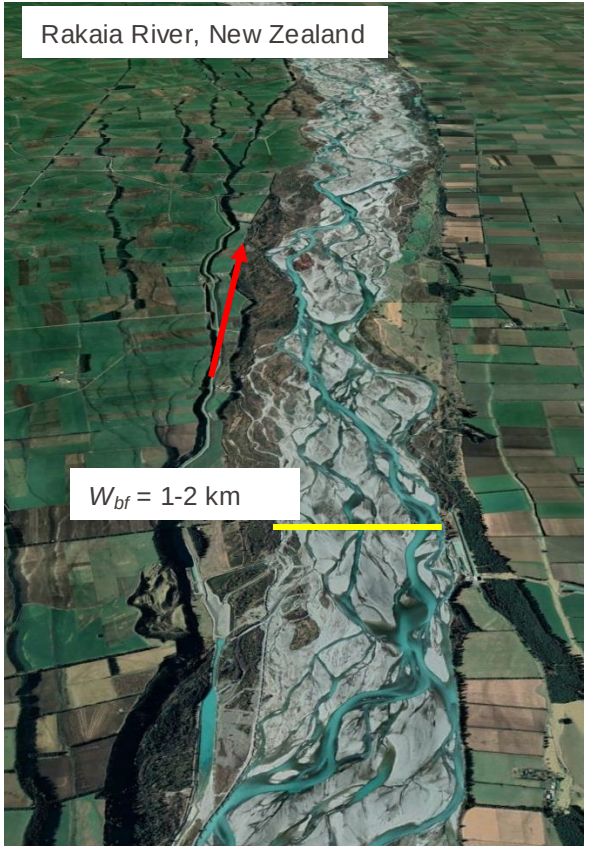
Secondary current in river bends

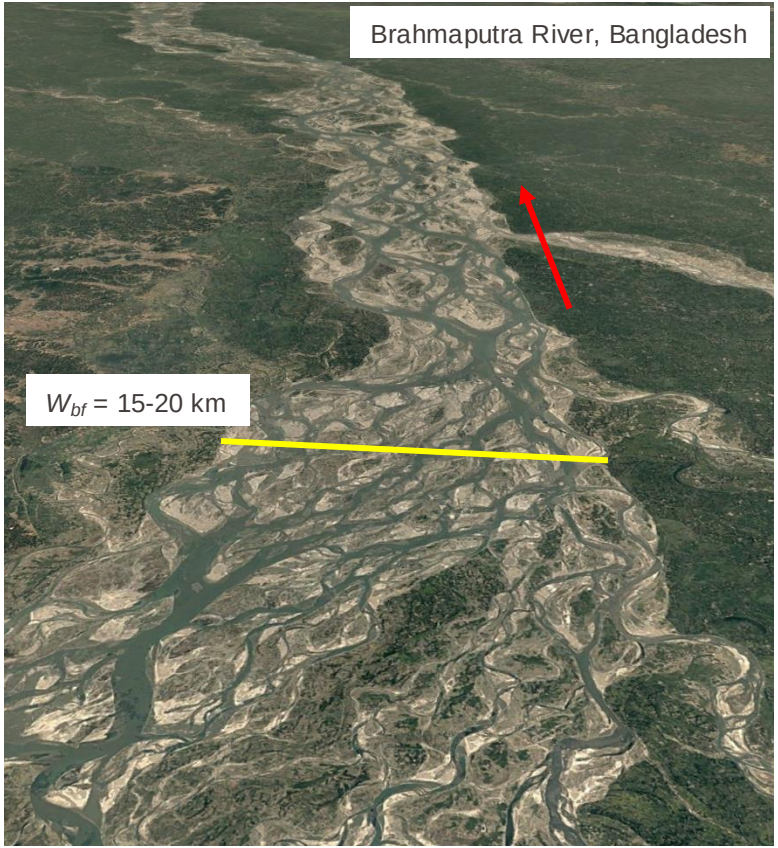




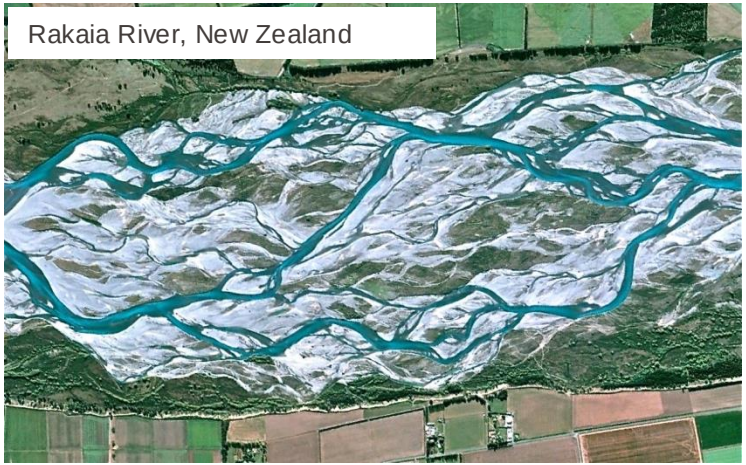
Blankaert and de Vriend (2003)

Braided rivers





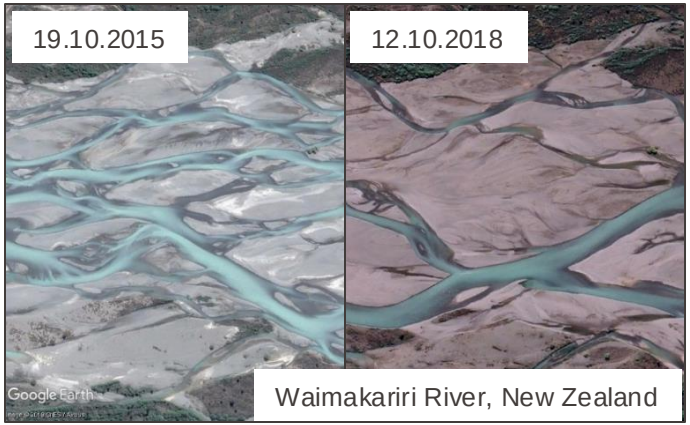
Braided rivers



Main characteristics

- Rivers with the largest sediment transport and lateral mobility in short temporal scales
- One or two main channels
- Number of secondary channels depending on q
- Multiple channels separated by alluvial deposits, sometimes vegetated (no islands)
- Main channel is almost rectilinear (I_S < 1.1)
- If I_S > 1.1, planform configuration is «wandering»

- Secondary channels have I_S <1.5
- Braiding Index I_B - Number of active channels
  - q=0 → I_B = 0
  - q > q_{bf} → I_B = 1
  - 0 < q < q_{bf} → I_B >1
  - I_B = I_B (x,t)



Braided-Meandering comparison

Braided rivers

- Usually located in the upstream part of the water basin (NZ rivers!)
- High bed slope
- Coarser bed material (gravel, sand)
- High stream power per unit width
- Low sinuosity (almost rectilinear)
- High bankfull discharge

Meandering rivers

- Located in the downstream part of the water basin
- Lower bed slope
- Finer bed materials (sand, silt, clay)
- Low stream power per unit width
- High to very-high sinuosity
- Low bankfull discharge