CGEO UNAM 2017

Curso de sismologia ambiental

2- Fluvial Geomorphology

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With thanks to:

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Fluvial geomorphology themes

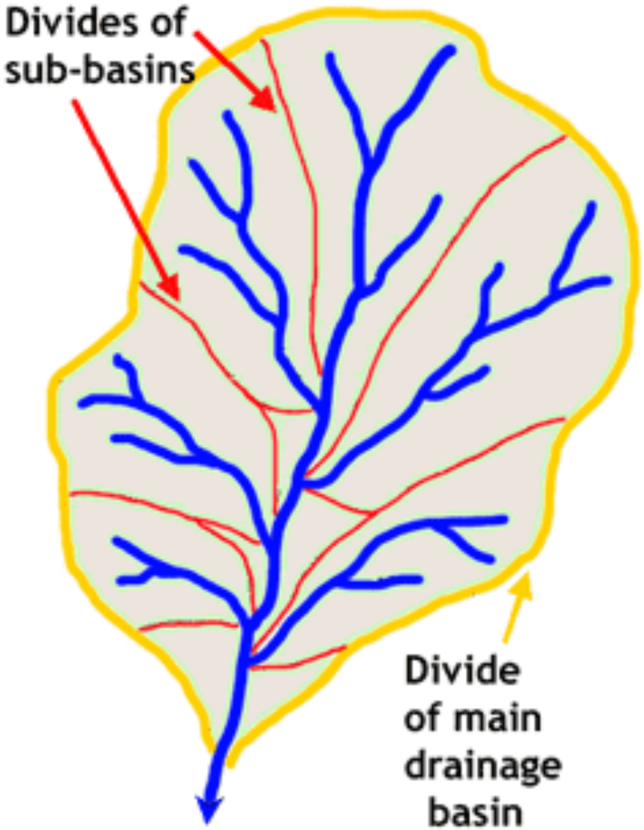
1. Drainage basin & hydrology (discharge)
2. Channel pattern
3. Channel x-sectional geometry & slope
4. Grain size & sediment transport regime
5. Flood plain & relation to channel
6. Flow process characterization

1. Drainage basin

Drainage Basin: The drainage area which contributes water to a particular channel or set of channels.

Synonymous with *watershed* (America) and *catchment* (everywhere else).

NB: there are others ”sheds” and generally they may not coincide with the watershed, e.g. the groundwater-shed



Drainage Basin Components

Hillslopes:
undissected elevated
areas between valleys

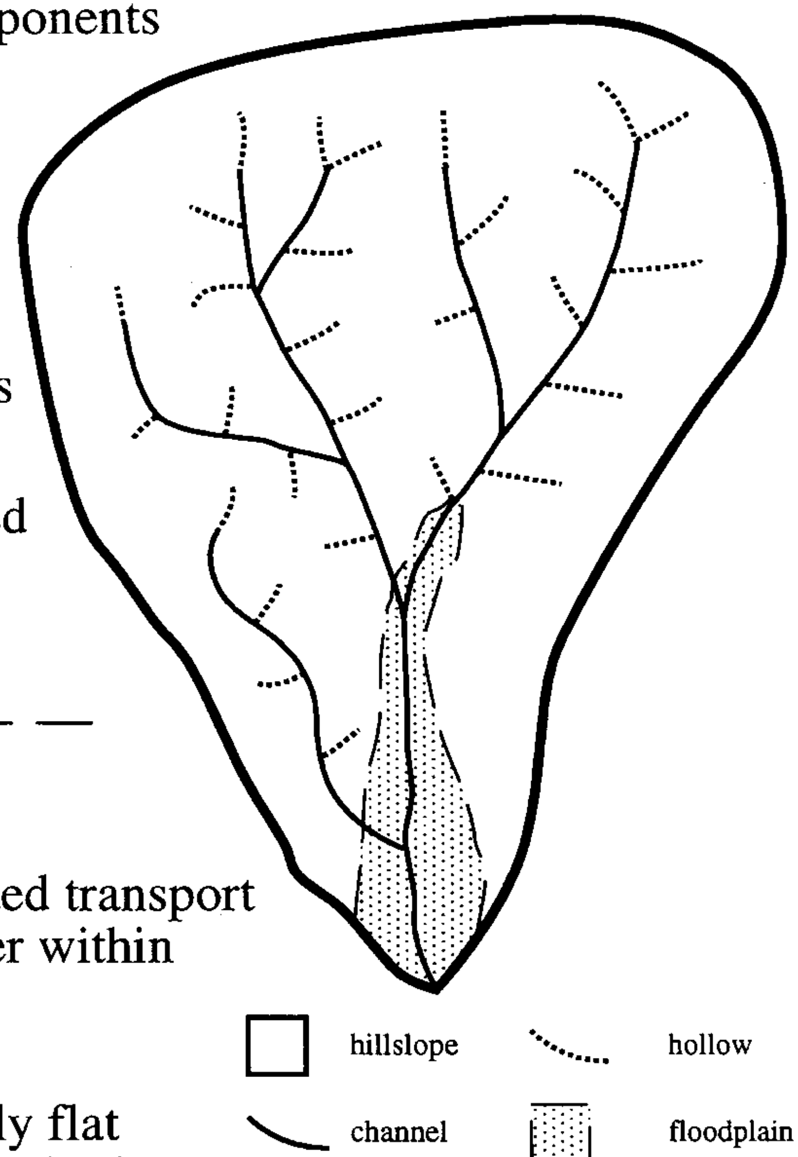
Hollows: unchanneled
valleys

Hillslope Geomorphology

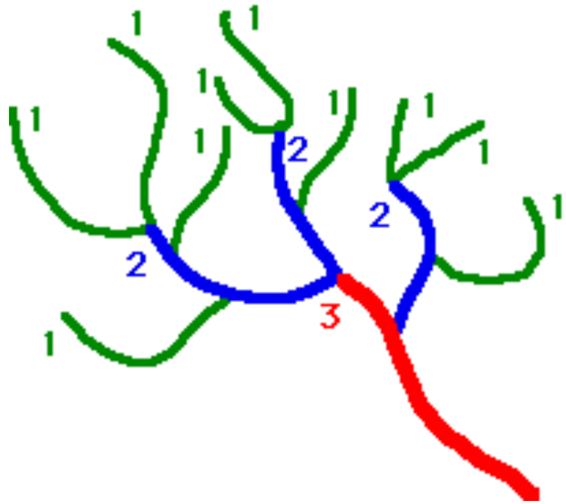
Fluvial Geomorphology

Channels: concentrated transport
of sediment and water within
defined banks

Floodplains: relatively flat
land formed by a river in the
present climate and inundated
every one or two years



Structure of drainage basins



Strahler stream ordering

Stream order	Number of segments
1	9
2	3
3	1

Drainage basins

$L_{max} \sim A^{0.6}$ Hack's Law

L_{max} : length of longest stream

Order, ω	Number of Stream	Average Length (*km*)	Average Area (*km*^{2})
1	60	2	5
2	13	5	12
3	9	13	40
4	4	20	110
5	1	55	330

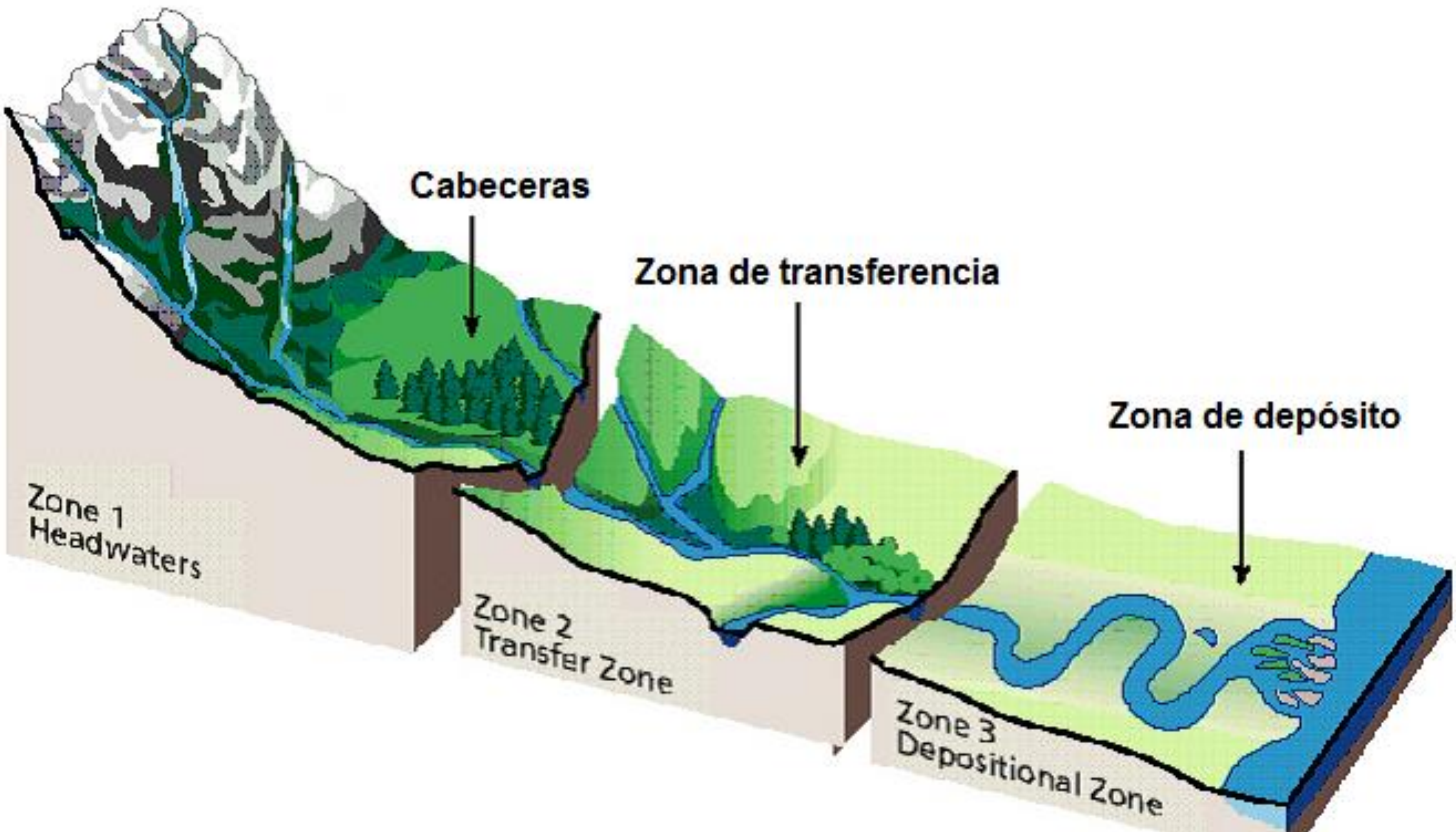
Horton's Laws

$$R_N = \frac{N_i}{N_{i+1}} \cong 2 - 4$$

$$R_L = \frac{L_i}{L_{i-1}}$$

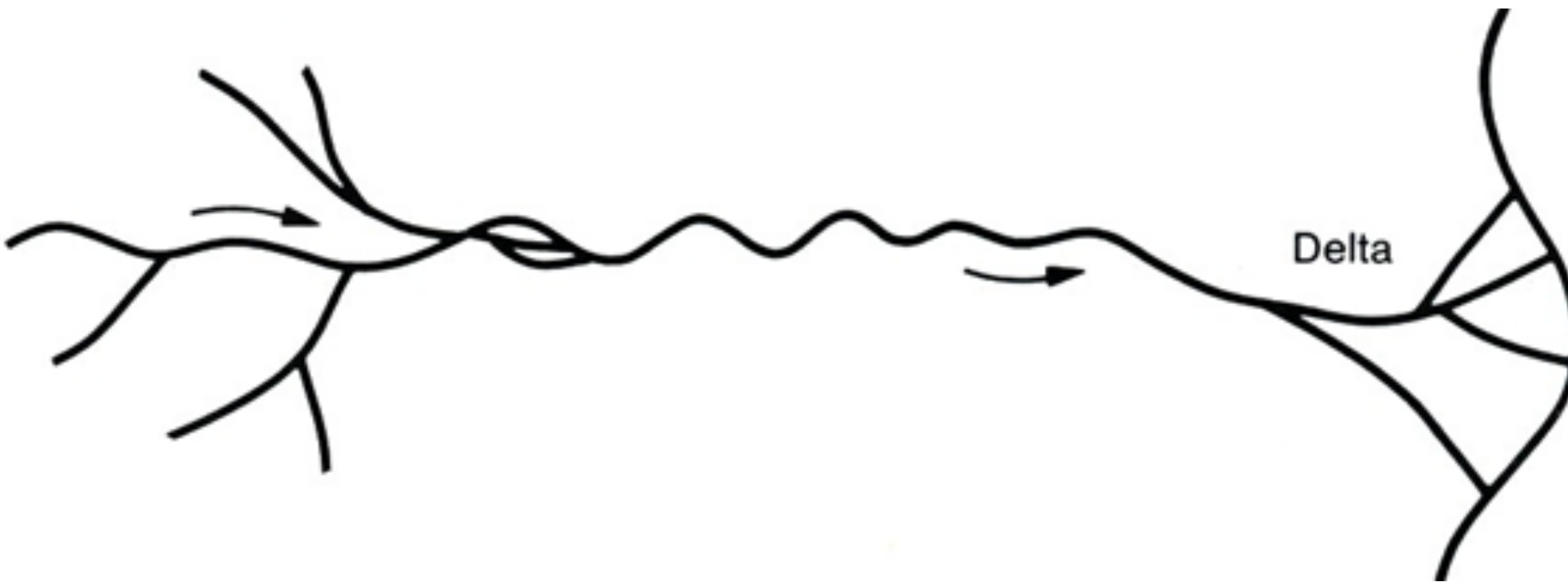
N_i: number of stream segments of order *i*
L_i: mean length of stream segments of order *i*

Drainage basin processes



Drainage basin processes

i > 0.3 | 0.3 > i > 0.1 | i < 0.1



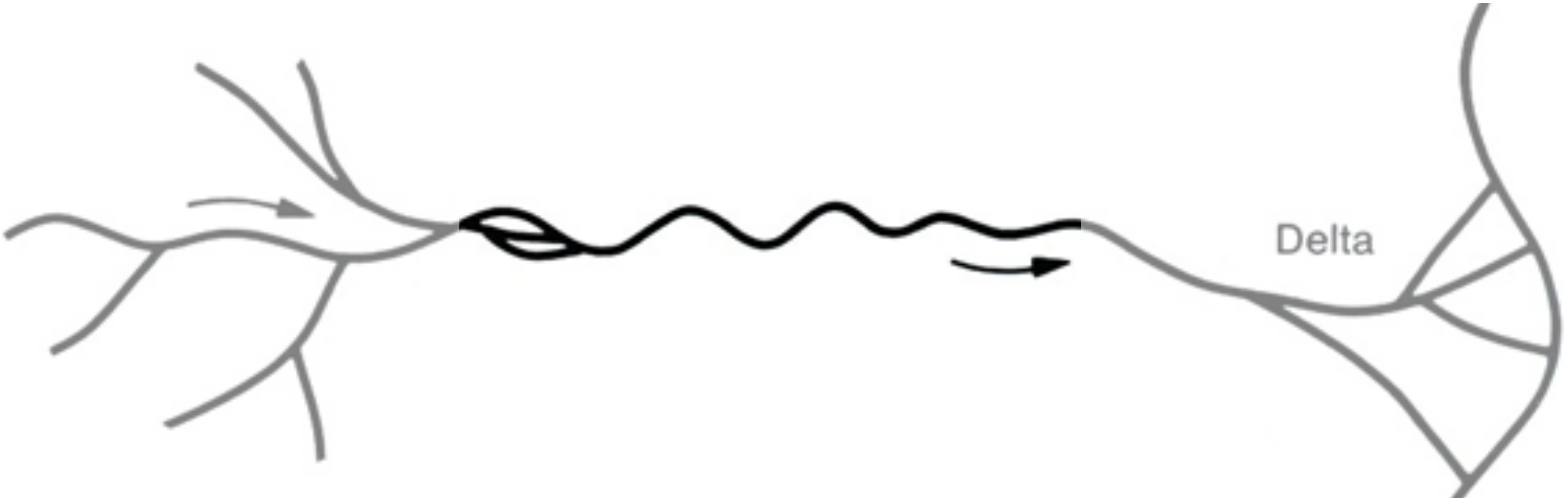
Sediment supply, erosion | Alluvial-transport zone | Deposition

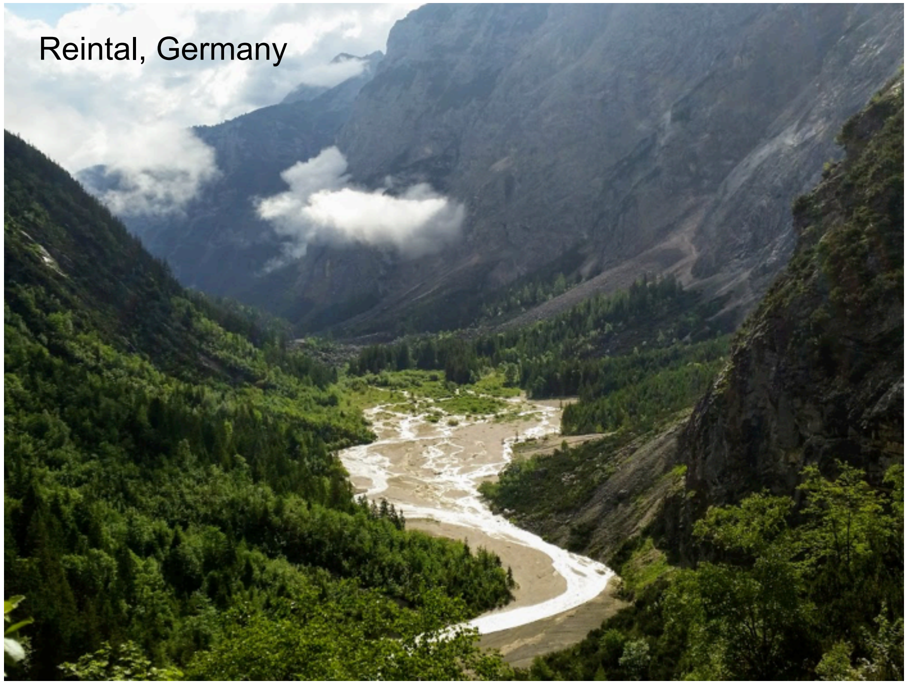
Upper basin

Chiapas, Mexico

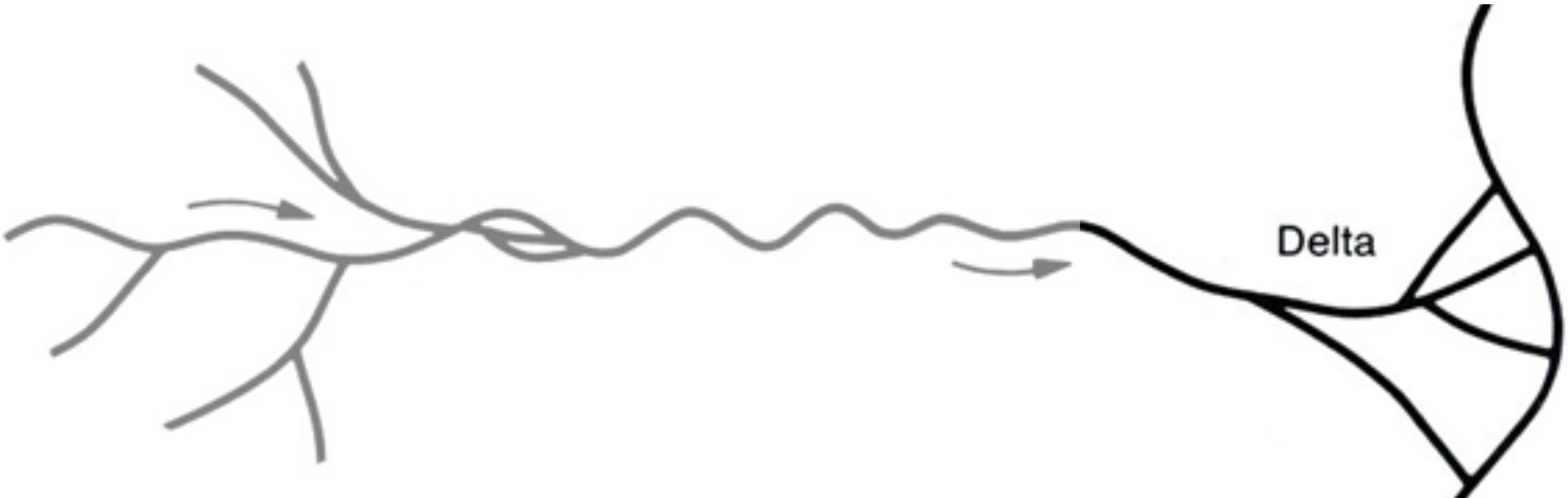
Rio Solda, Italia

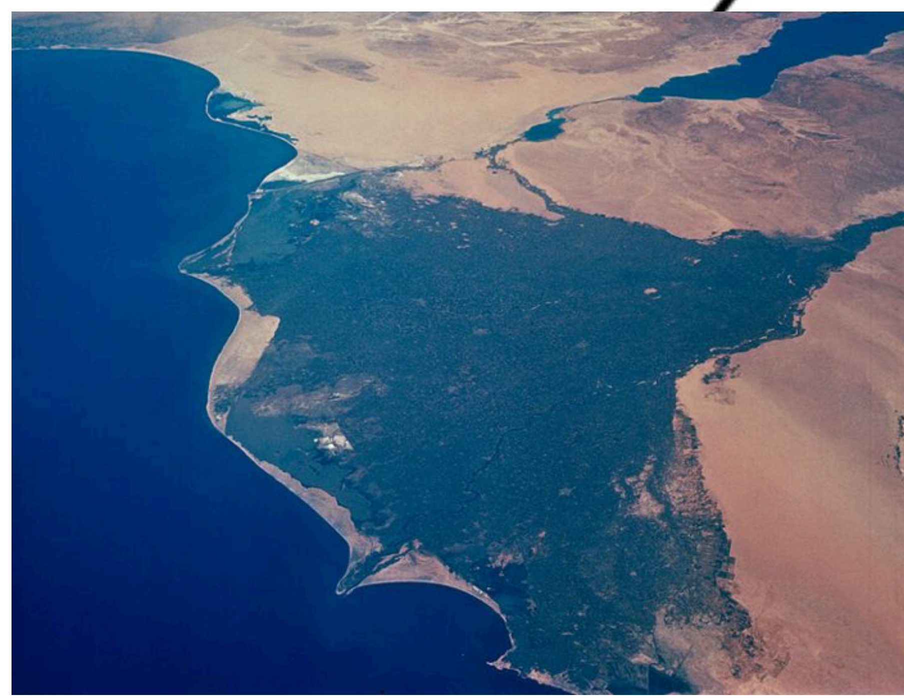
Alluvial-transport zone





Deposition





Key watershed points

- Land use: agriculture, grassland, forest… urbanization
- Water pathways to stream: drain tiles, parking lots, ditches & culverts
- Gradient & physiography
- Lithology
- AND DON' T LOOK ONLY UPSTREAM!

River channel morphology and processes

Alluvial channels

Channels formed in and by sediment transported by the river (= "**alluvium**") under its current hydrologic and climatologic regime (and so could be transported again). These "self-formed channels" are free to adjust their shape in response to changes in flow.

Photo: J. Michael Daniels, 2002

self adjusting container

Non-alluvial channels

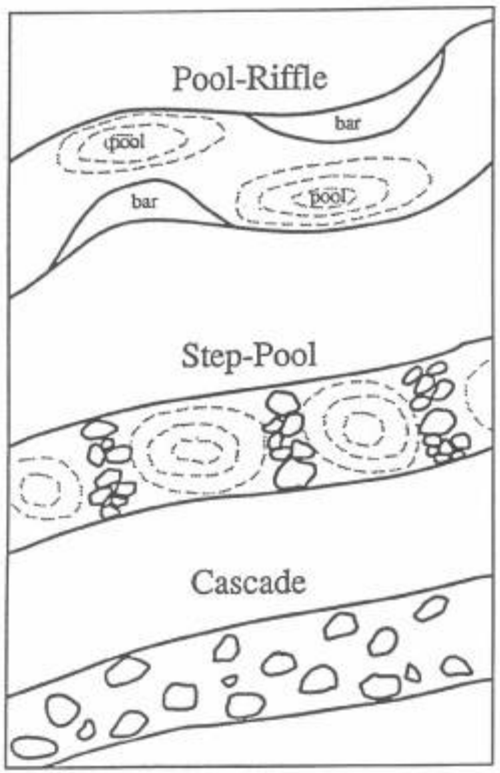
Channels *not* formed in alluvium, such as--

- bounded by bedrock or concrete;
- deeply incised into bedrock;
- choked by relatively immovably objects such as logs or boulders or landslide sediment;
- rimmed with thick and deeply rooted bank vegetation;
- channels that have "inherited" a valley geometry from some other geologic process (such as glaciation) in the recent past; or
- channels that have undergone a significant change in hydrologic regime (as a result of diversion or watershed disturbance)

USFWS

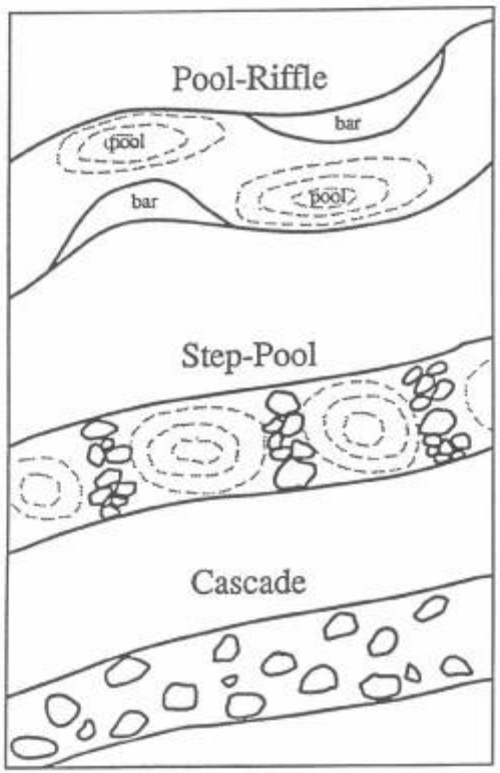
imposed container

Steep channel morphologies



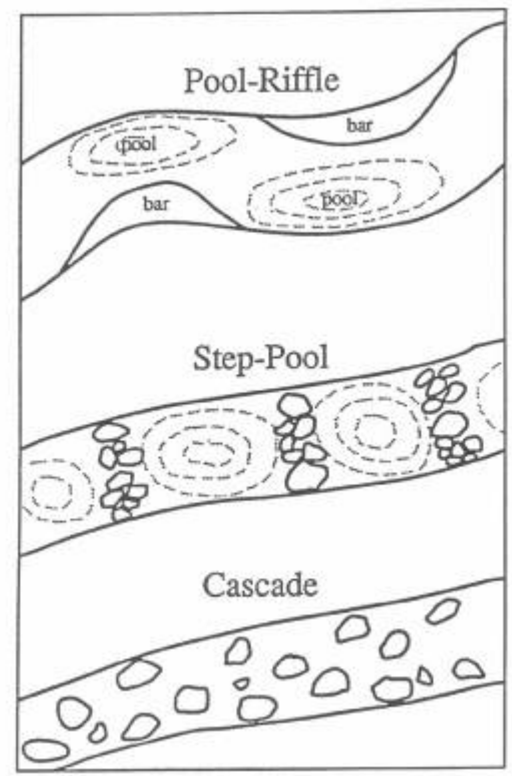
Step-pool

Steep channel morphologies



Step-pool

Steep channel morphologies

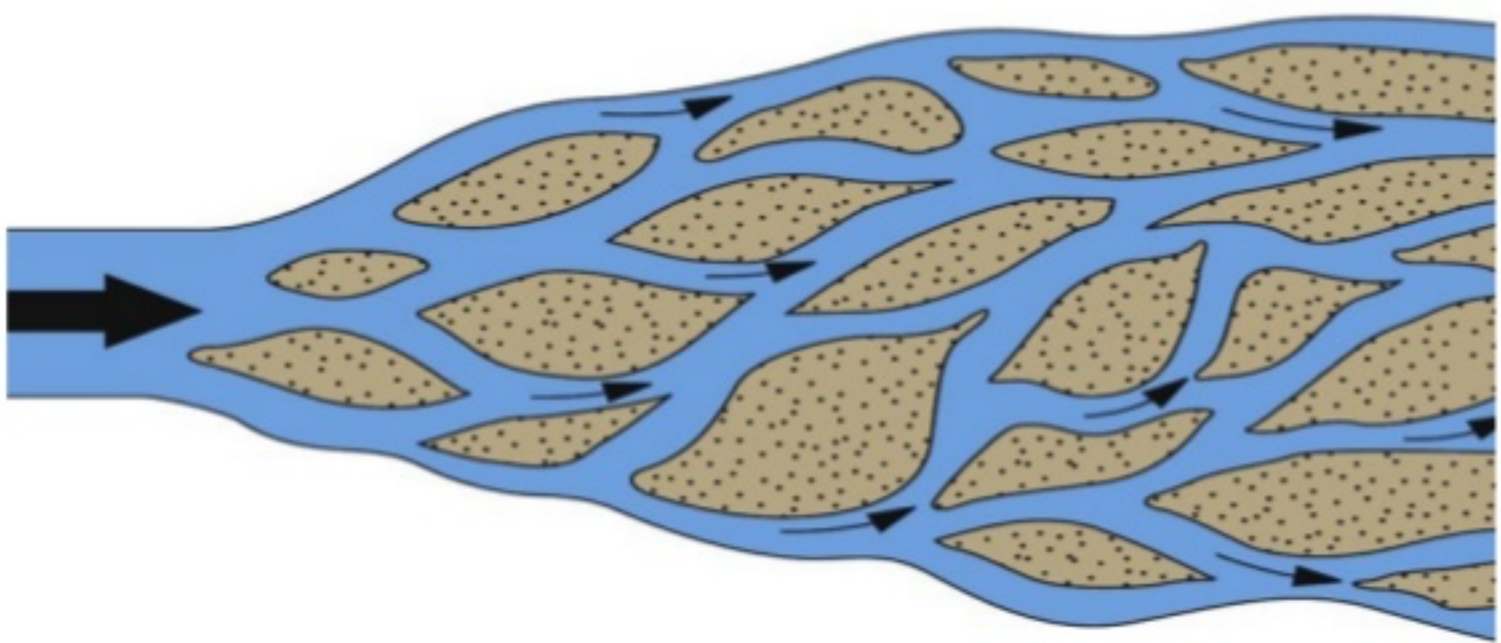


Pool-riffle

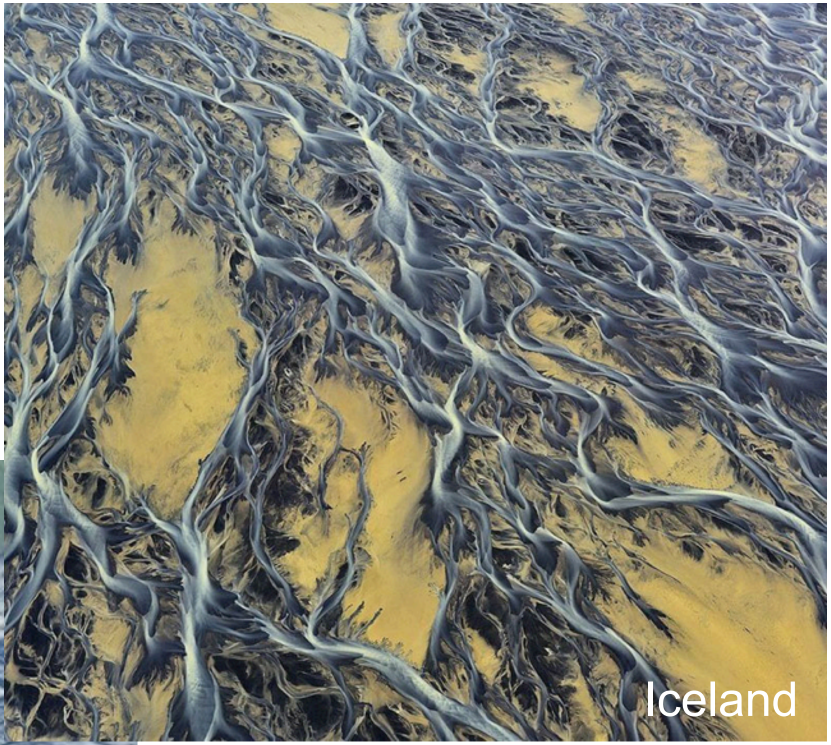
Lower-gradient channels

STRAIGHT CHANNELS are naturally uncommon in alluvial channels because unless they are narrow relative to their depth (b/h <~ 20) they are inherently unstable: any minor perturbation of the flow, such as caused by a hard projection or a bump in the bank, will tend to establish the oscillation of the thalweg that leads to concentrated scour of pools, point-bar formation, and a meandering pattern. Delta distributary channels are often straight, however.

BRAIDED CHANNELS have flow divided into more than one thread. Island width is comparable to channel width. Rates of local lateral shifting and local bank erosion are generally greater than meandering channels.



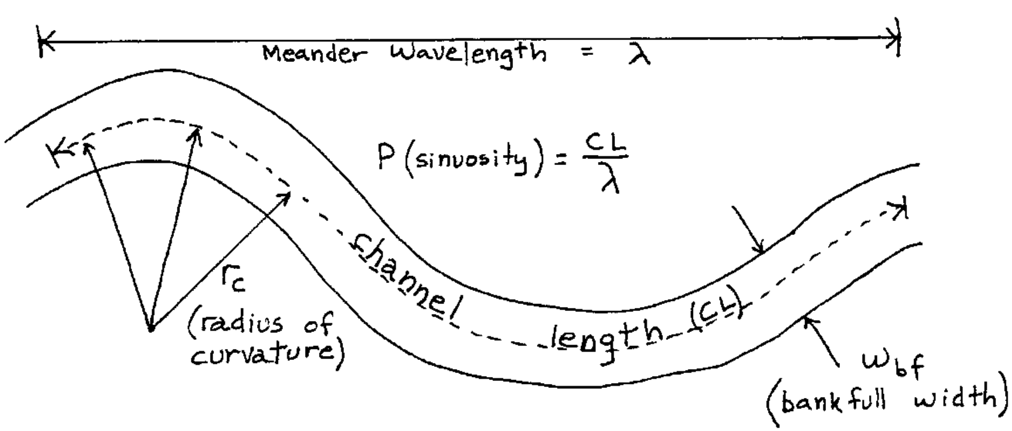
Lower-gradient channels

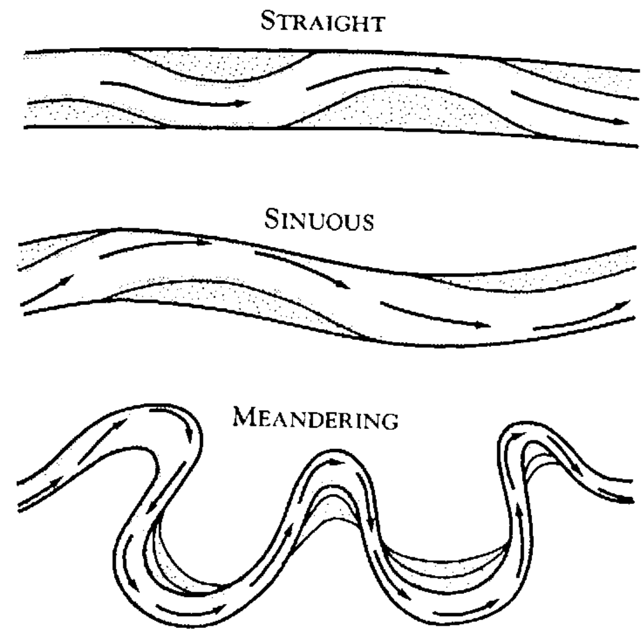


Lower-gradient channels

MEANDERING: The most common type of channel, where the main thread of the flow (the *thalweg*) oscillates from one side of the channel to the other. *Pools* and *riffles* form in predictable locations along meandering rivers, which become more precisely fixed in place as the magnitude of the meanders increases.

In most natural meandering channels the ratio of *channel length* to straight-line *down-valley* distance lies between 1.5 and 2. Where this ratio, called the ***sinuosity***, is less than 1.3 the channel is not termed "meandering" but instead is "sinuous" or "straight."





Lower-gradient channels

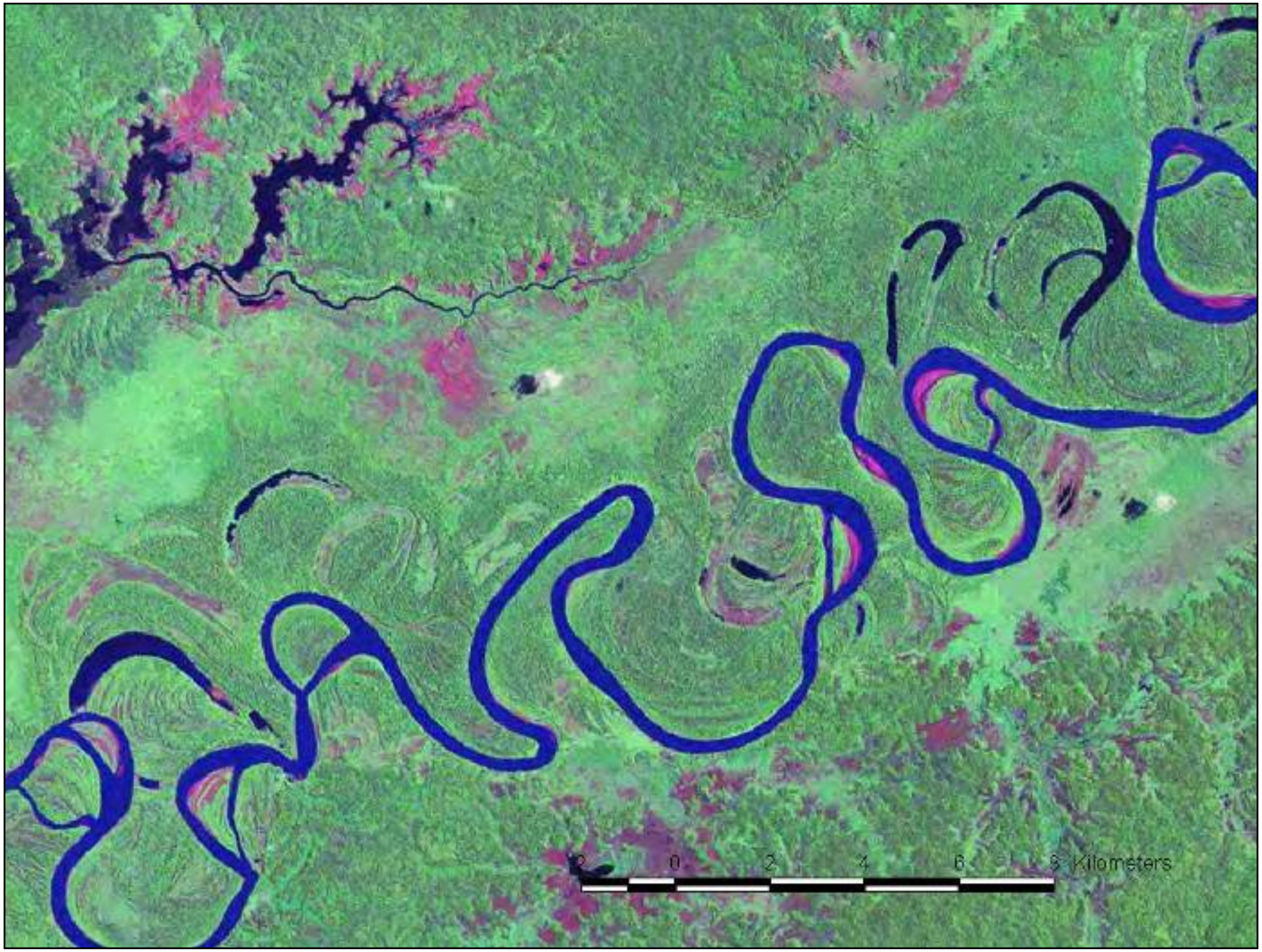
MEANDERING**:** The most common type of channel, where the main thread of the flow (the *thalweg*) oscillates from one side of the channel to the other.

Pembina, Alberta

Mississippi

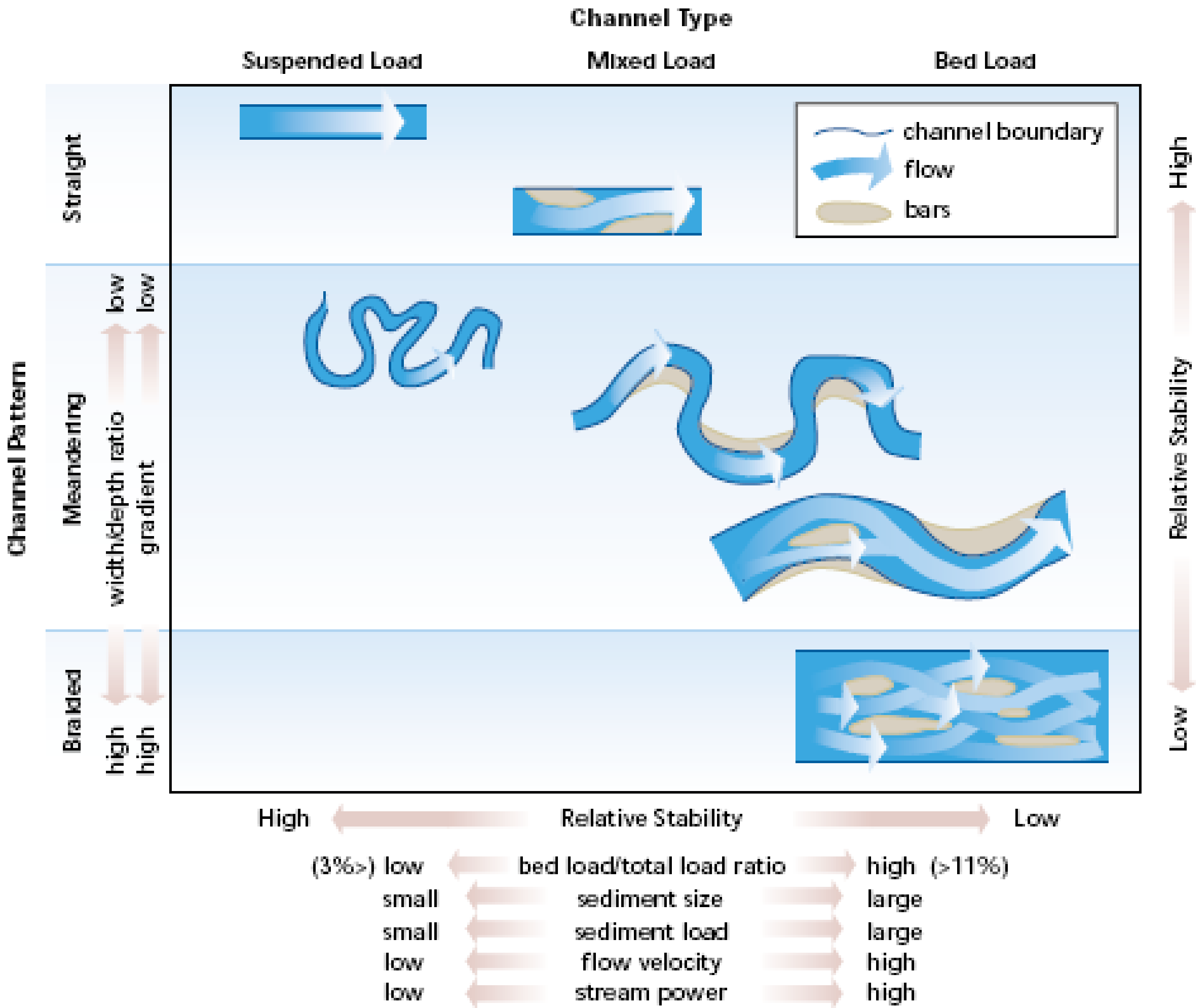
Mississippi (Fisk)

Lower-gradient channels



Strickland (Wes Lauer)

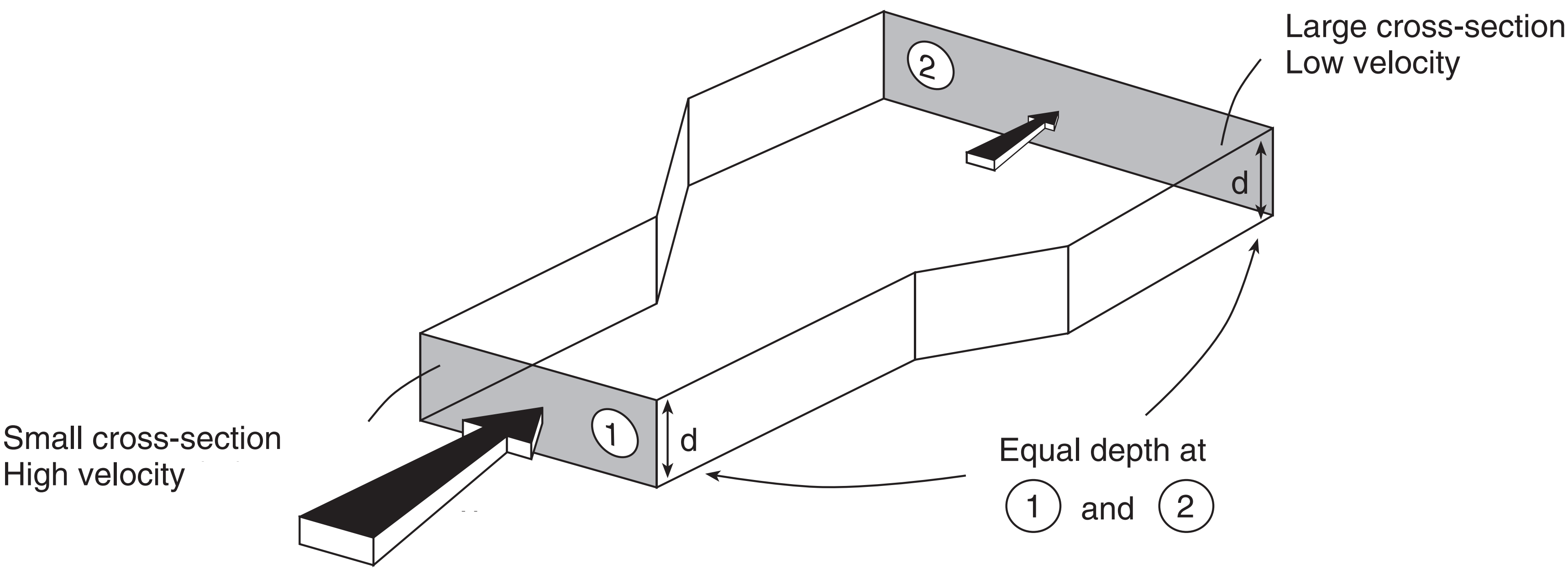
Stream type (Schumm)



Flow dynamics

$$Q_w = A \cdot u$$

Q_w total water discharge



Discharge at 1 = Discharge at 2

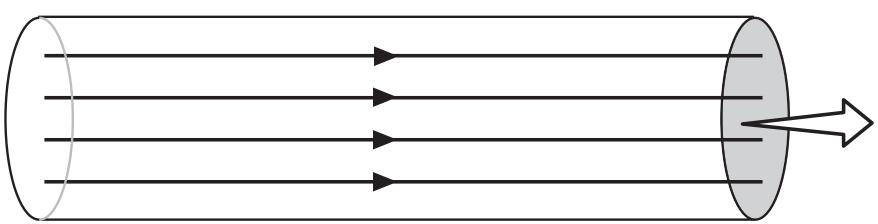
Flow dynamics

Reynolds number (Re): dimensionless quantity that indicates if a flow is **laminar** or **turbulent**, is obtained by relating the velocity of flow (u), a "characteristic length" (L – diameter of a pipe or flow depth) and the ratio between the density and viscosity of the fluid (*v* – kinematic viscosity):

$$R_e = u \cdot \frac{L}{v}$$

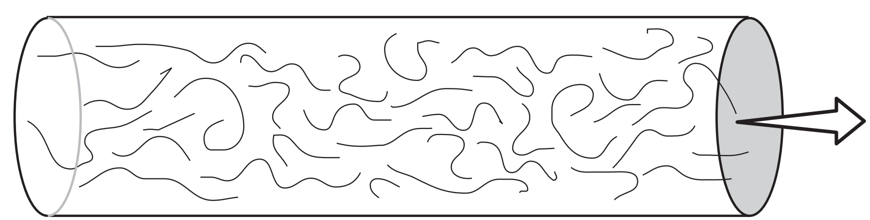
Fluid flow in pipes and channels is found to be laminar when the Reynolds value is low (< 500) and turbulent at higher values (> 2000). With increased velocity the flow is more likely to be turbulent and a transition from laminar to turbulent flow in the fluid occurs.

Laminar flow



At all points in the flow all molecules are moving downstream

Turbulent flow



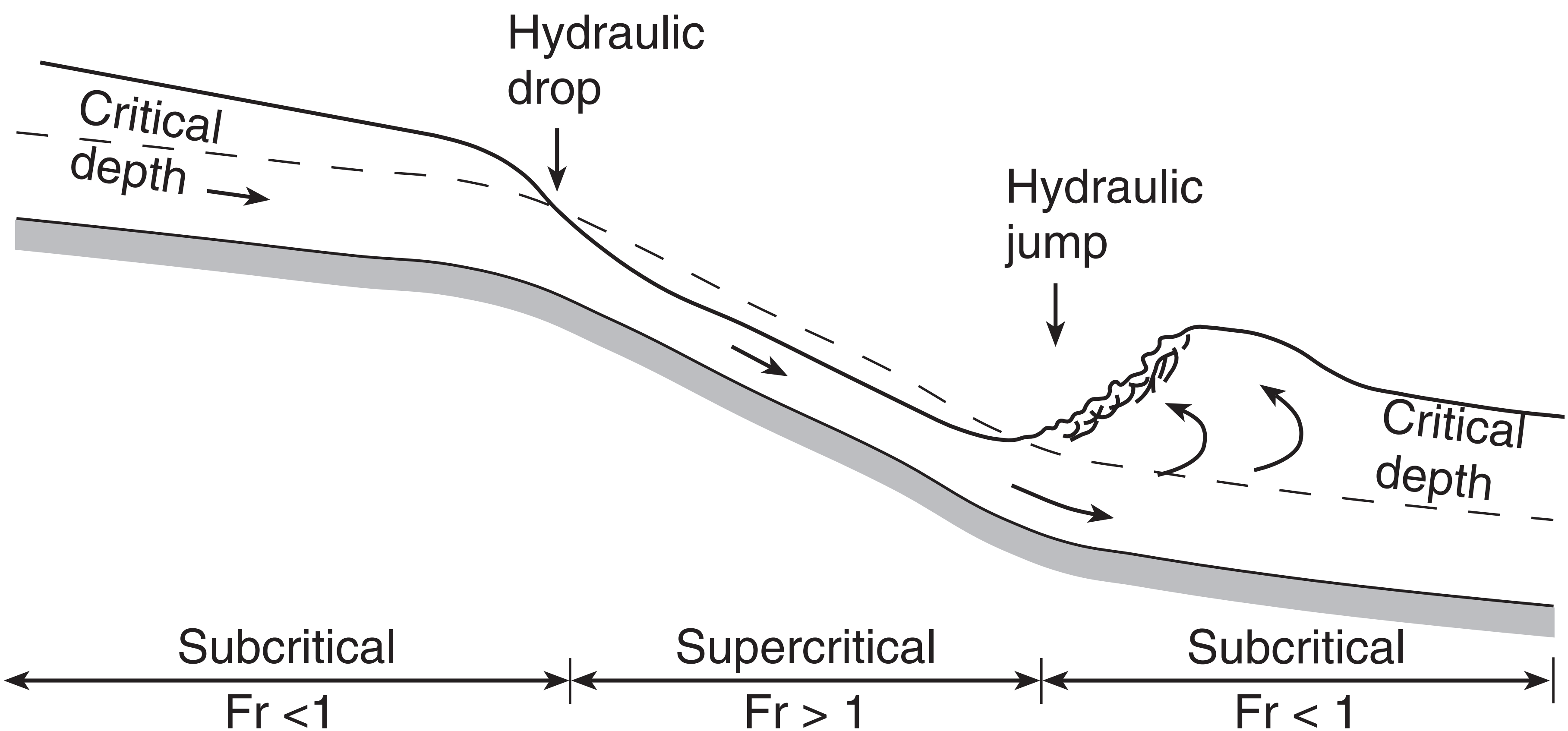
At any point in the flow a molecule may be moving in any direction, but the net flow is downstream

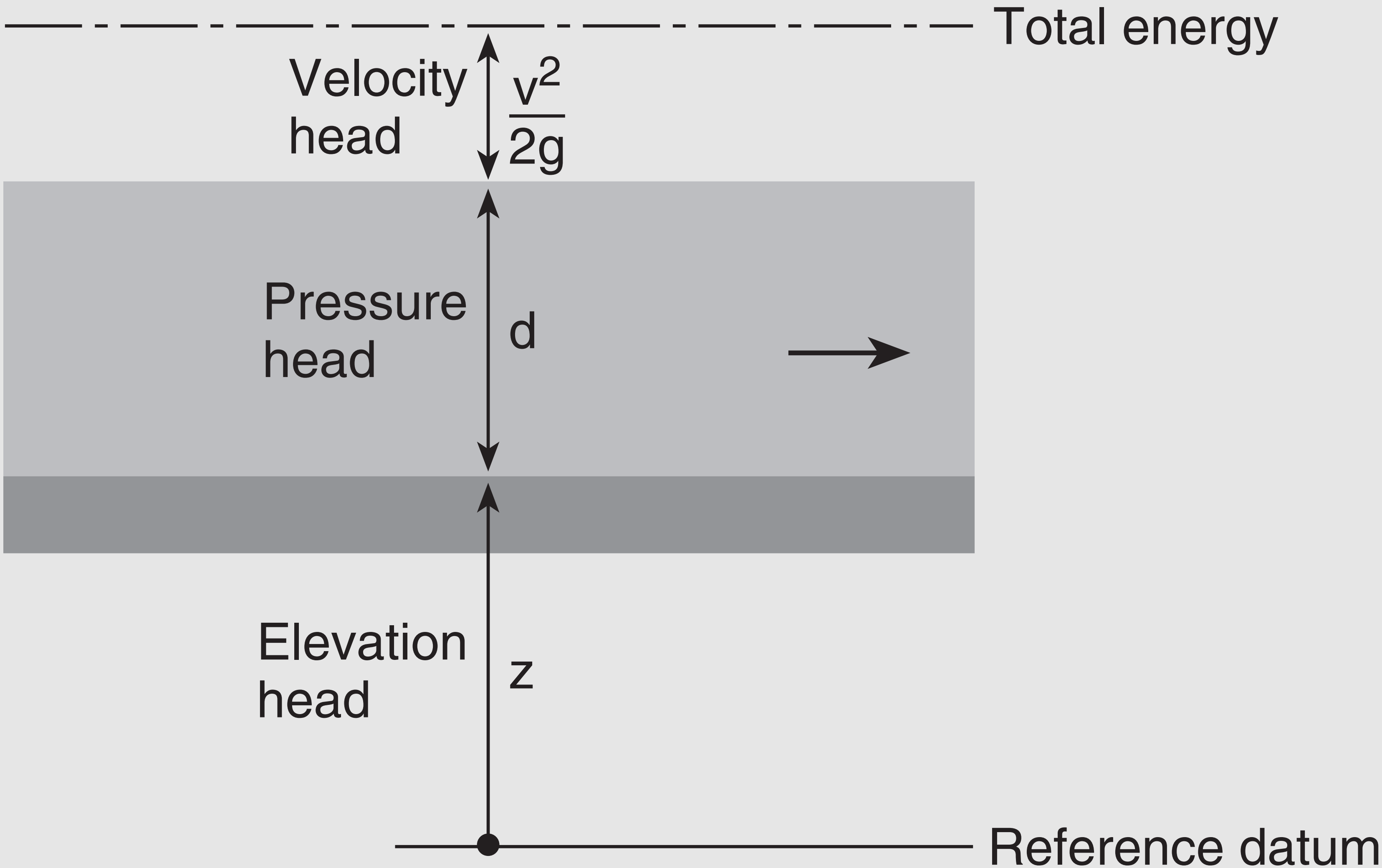
Flow dynamics

The unsteady, gradually varied flow in most natural channels is subcritical. Within supercritical flows, turbulent mixing is less intense, with less deviation from the main downstream direction. Supercritical flows move rapidly and efficiently through the channel. The different types of flow behaviour can be predicted by calculating the ratio between the inertial and gravitational forces.

Flow dynamics

$$F_r = \frac{u}{\sqrt{g \cdot d}}$$

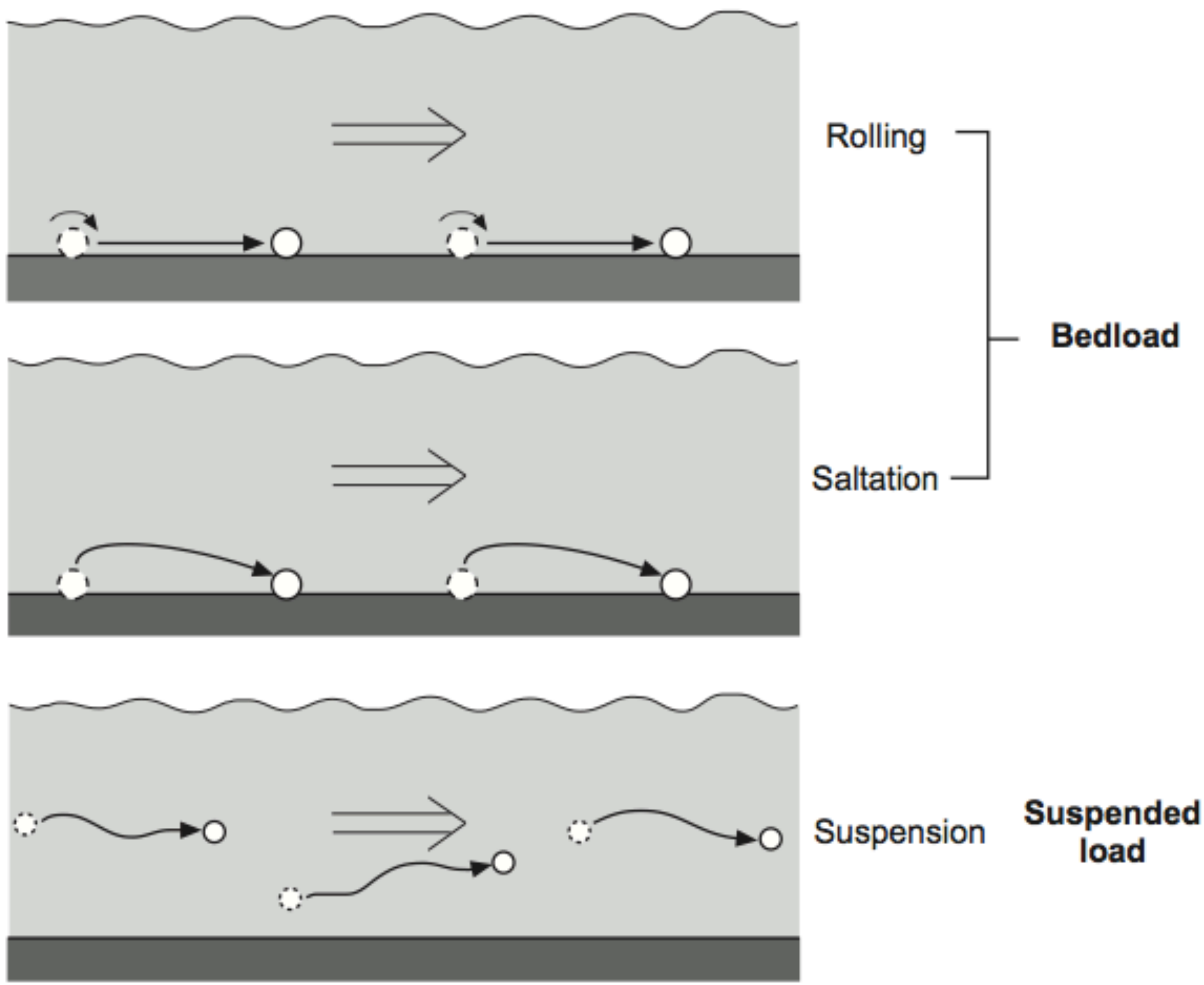




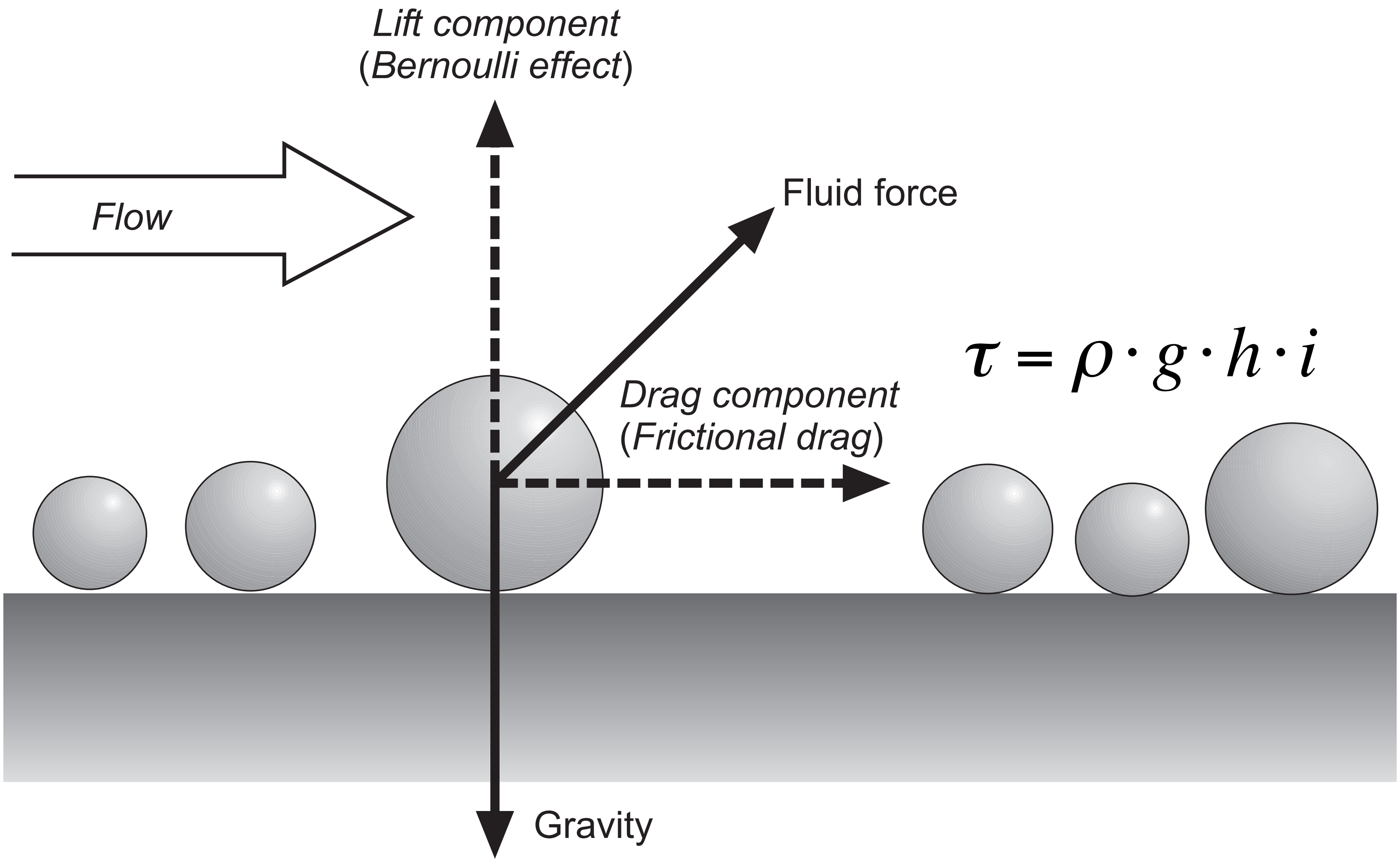
Total energy = Elevation head + Pressure head + Velocity head

$$TE = z + d + \frac{v^2}{2g}$$

Sediment transport processes

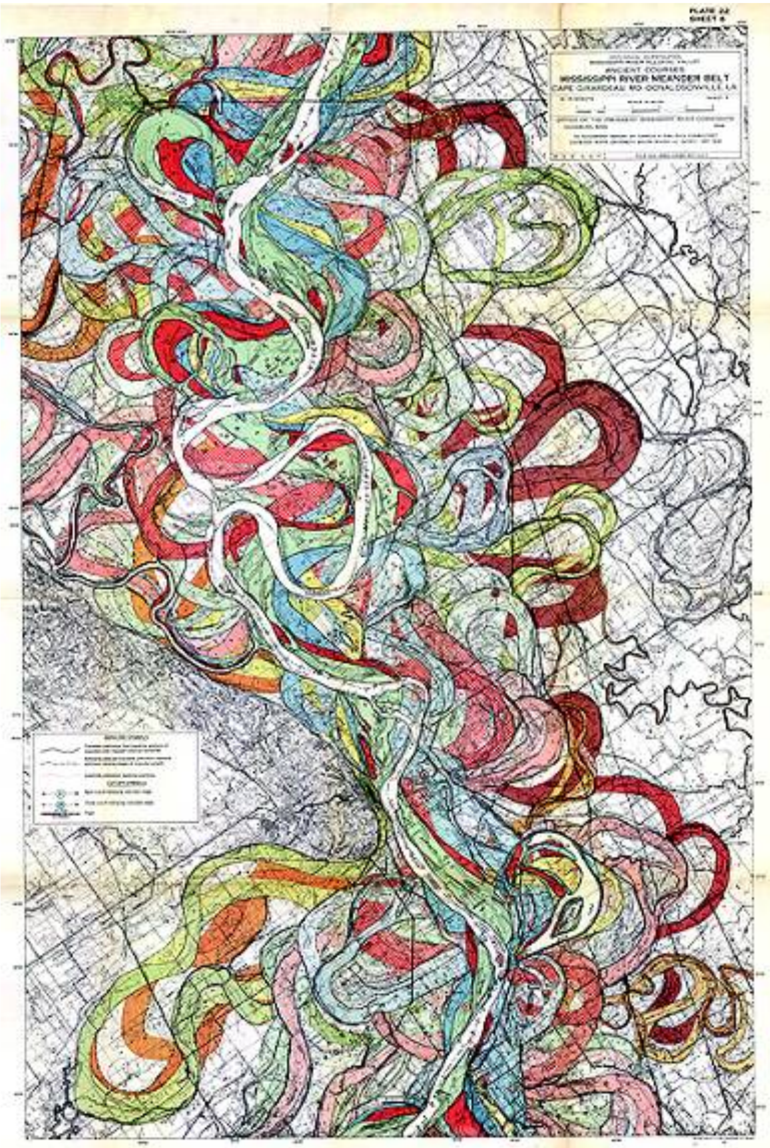


Sediment transport processes



$$\tau = \rho \cdot g \cdot h \cdot i$$

Rivers record evidence of change



Fisk, Mississippi River

Pembina

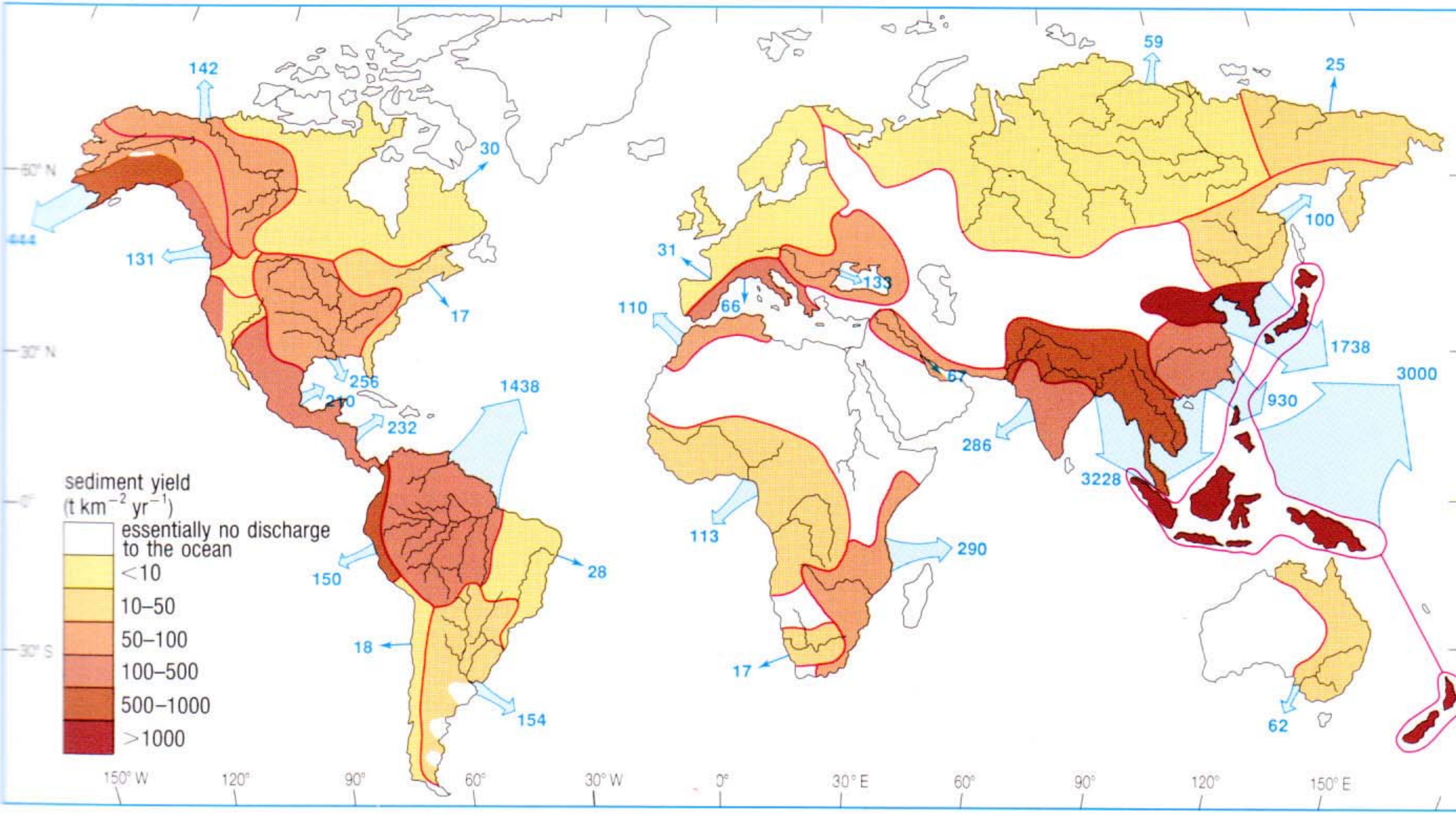
Rivers record evidence of change

Piemonte, Italy, 1994

Valle d’Aosta, Italy, 2000

Global sediment sources

Rivers account for 85% of inputs to global ocean



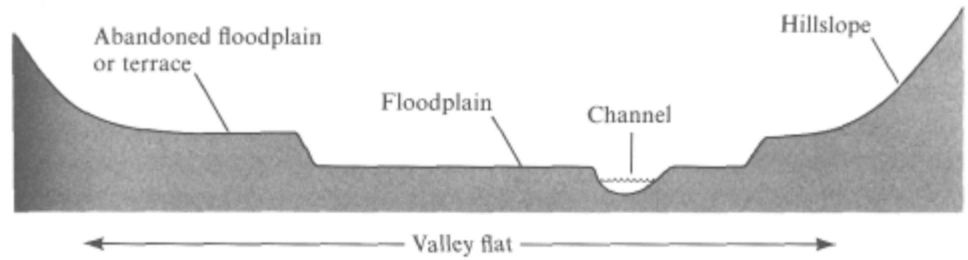
Some general trends

- In general, incision→ narrowing, deposition→ widening
- Bedrock rivers: high rates of incision and/or stronger lithologies → steeper, narrower channels [step-pool, cascade]
- Alluvial rivers: width ~ bed-material transport rate; vegetation and/or strong banks act to reduce width
- Meandering vs braiding mainly controlled by b/h (threshold ~50-100)

Floodplains

Floodplains and Terraces

A **floodplain** is the surface that has been built up next to a river channel under the current hydrologic and sedimentological regime. It is composed of *alluvium*, the sediment carried by the river.

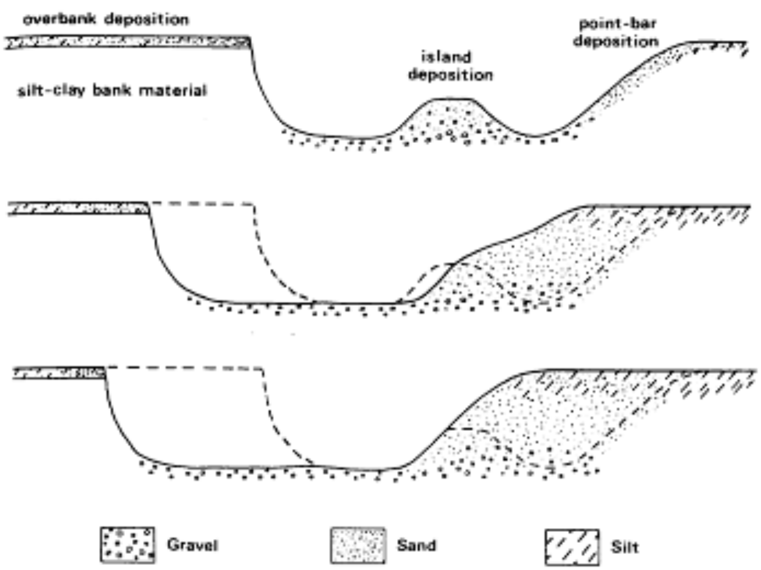


In contrast, a **terrace** is also a constructed surface and also underlain by alluvium, but it has *not* formed under the current regime of the river. Instead it represents floodplain formation at an earlier time when, for whatever reasons, deposition was occurring at a higher elevation.

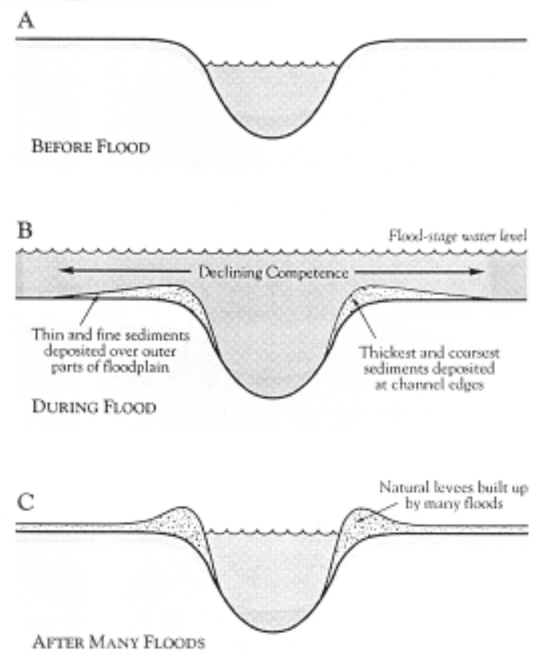
Floodplain formation

2 Basic processes for floodplain formation

1. Lateral accretion



2. Overbank deposition



Artificial levees

Erosion control levee has broken connection between channel & floodplain