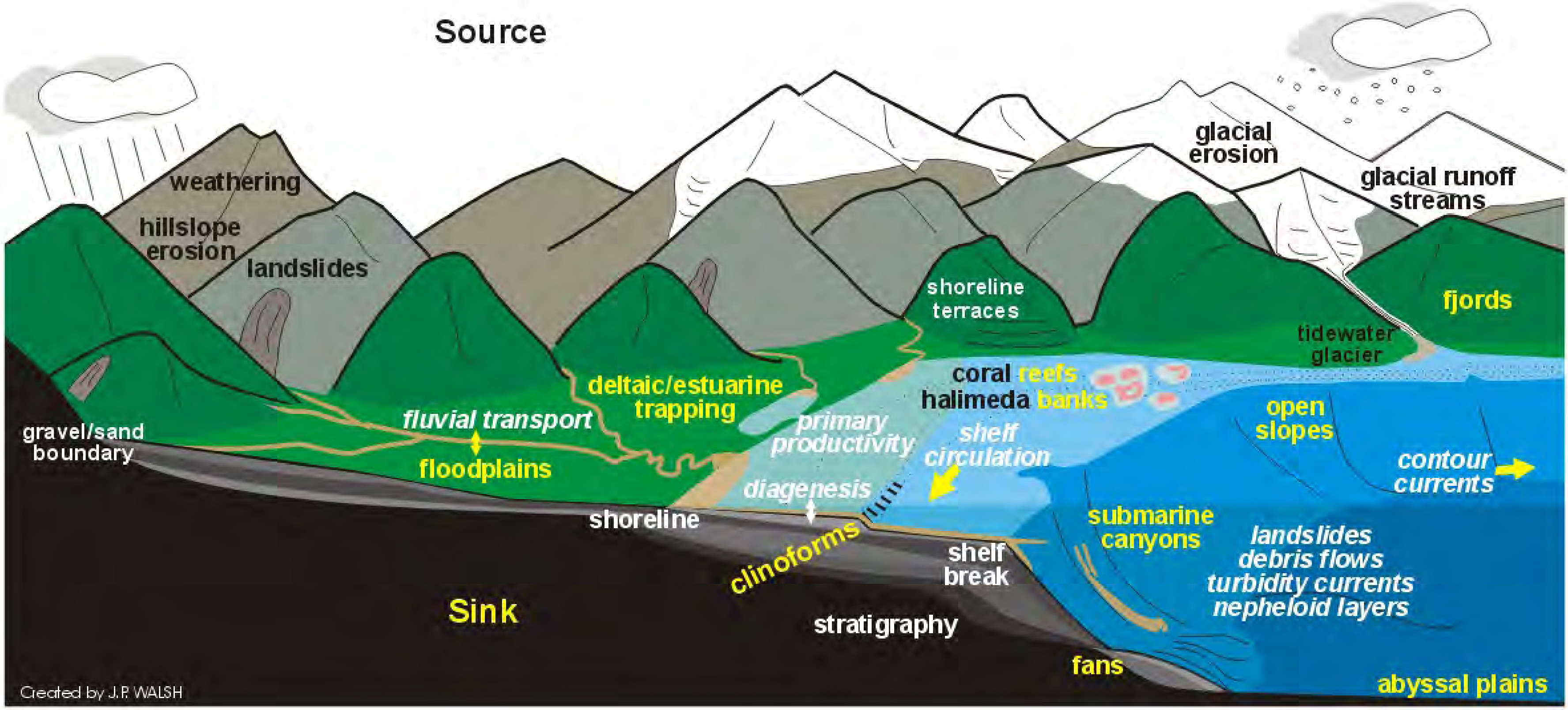
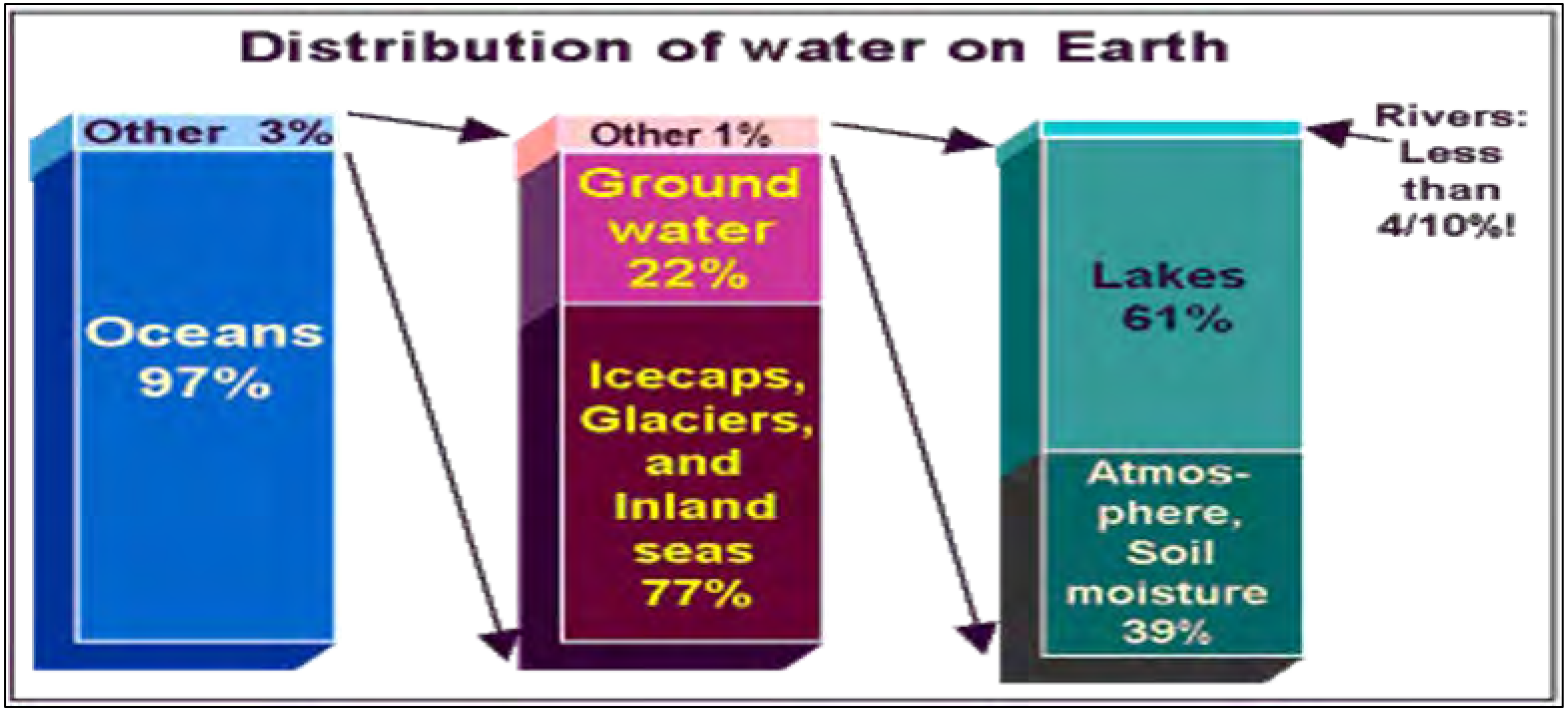
River Material & Sediment Transport



Distribution of Water on Earth

Rivers represent a tiny fraction of Earth's water

- only 3% of water on land
- of that, 99% in inland seas, ice & groundwater



Hydrologic Cycle (water cycle)

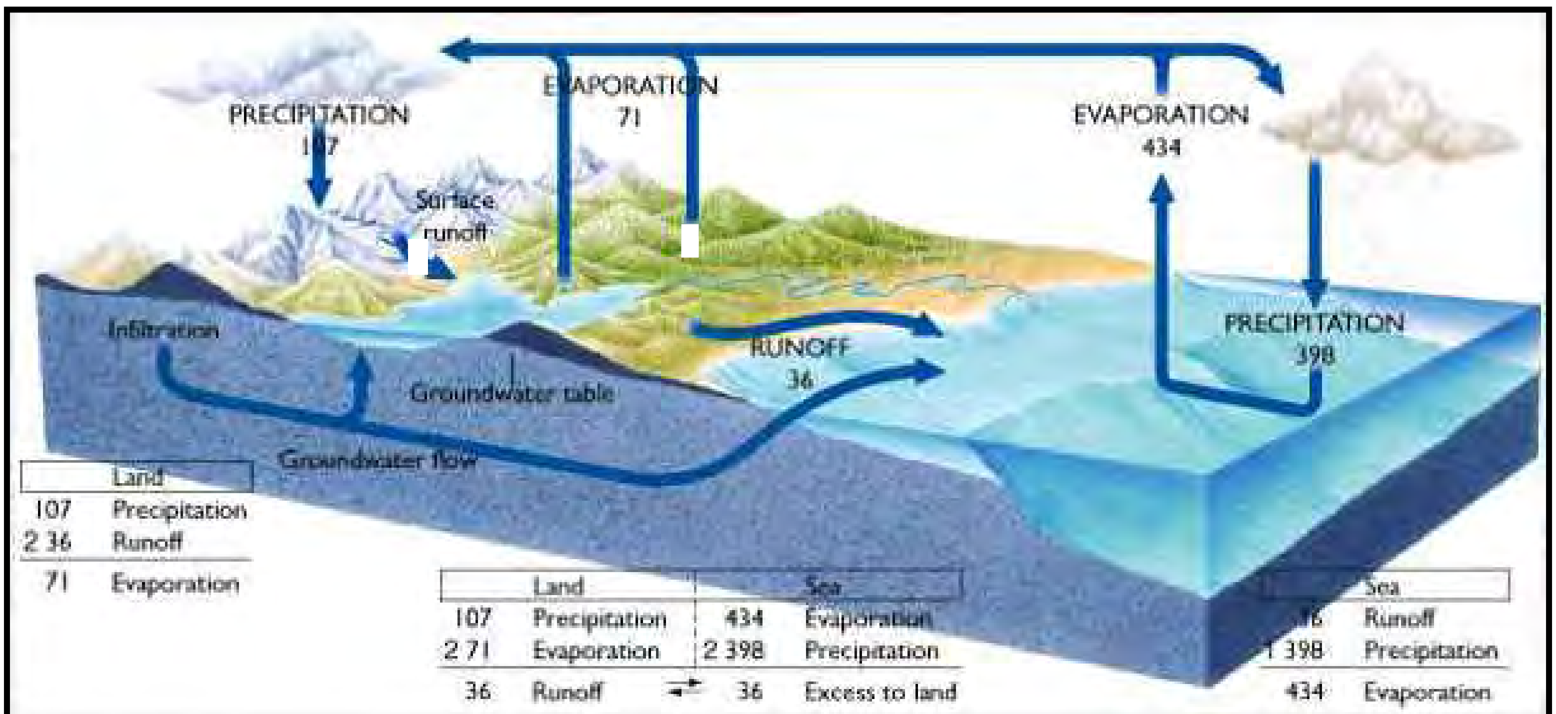
Precipitation: rainfall and snow

Runoff: surface water system

runoff = precipitation – (infiltration + evaporation)

Infiltration: groundwater system

Evaporation: return of water to atmosphere

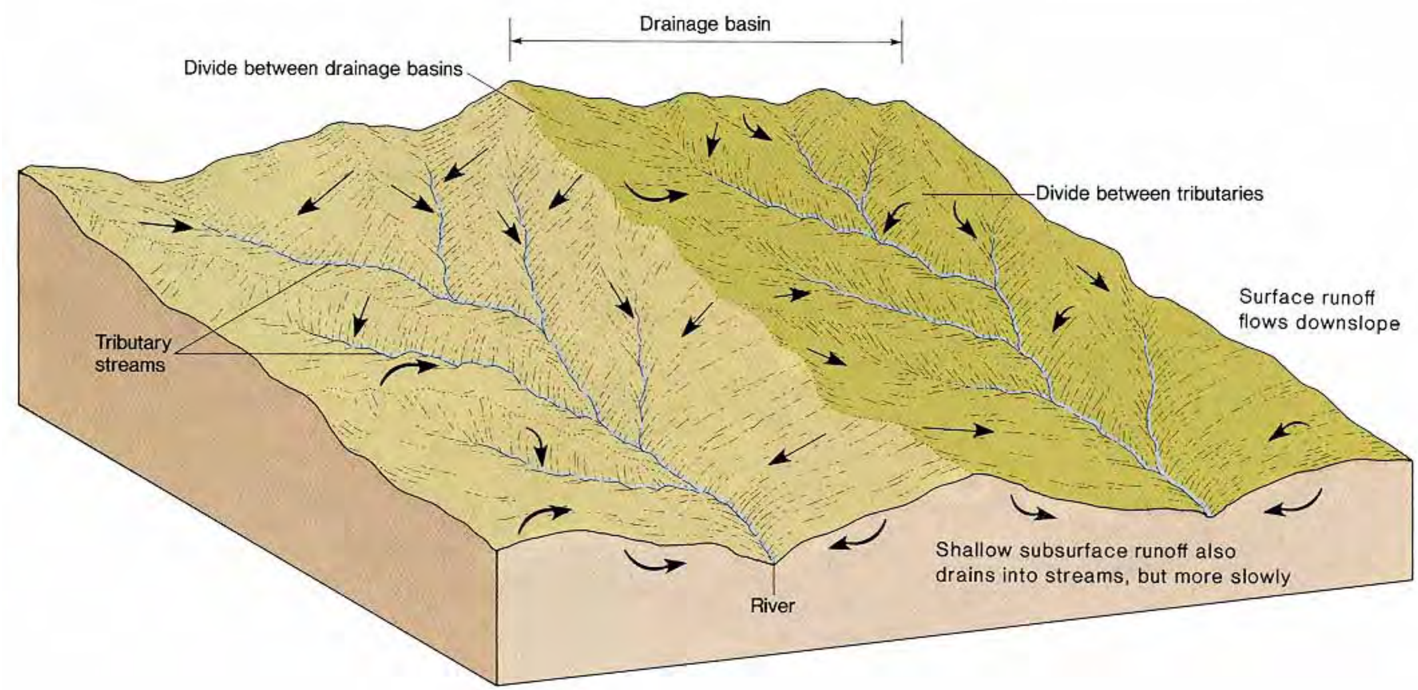


Stream Systems

Each stream drains a specific portion of the landmass, this is called the **watershed** or **drainage basin**

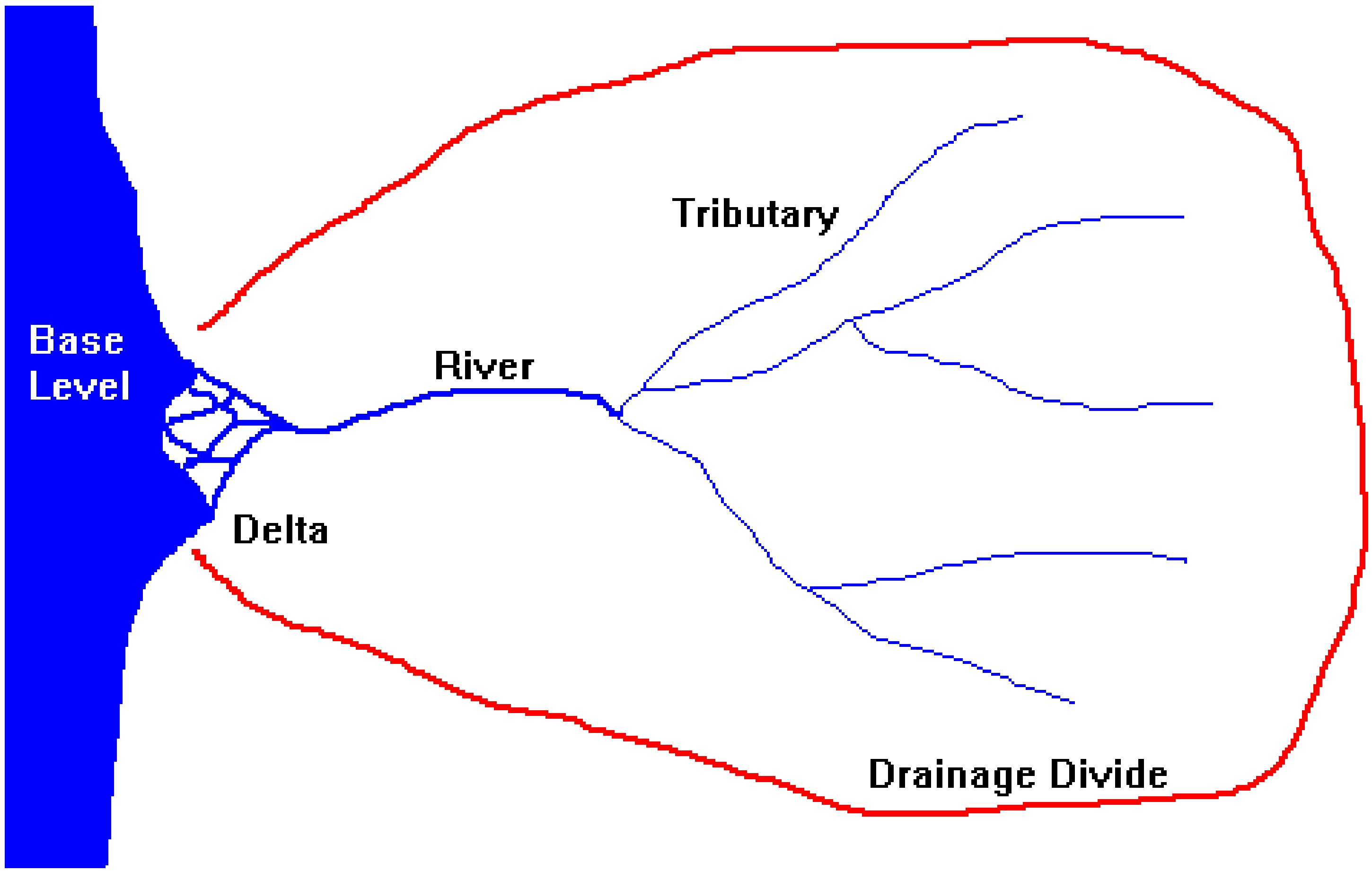
Drainage basins are separated by **drainage divides**

Drainage divides may be distinct (mountain ridges) or much more subtle



Stream Systems

Anatomy of a drainage basin



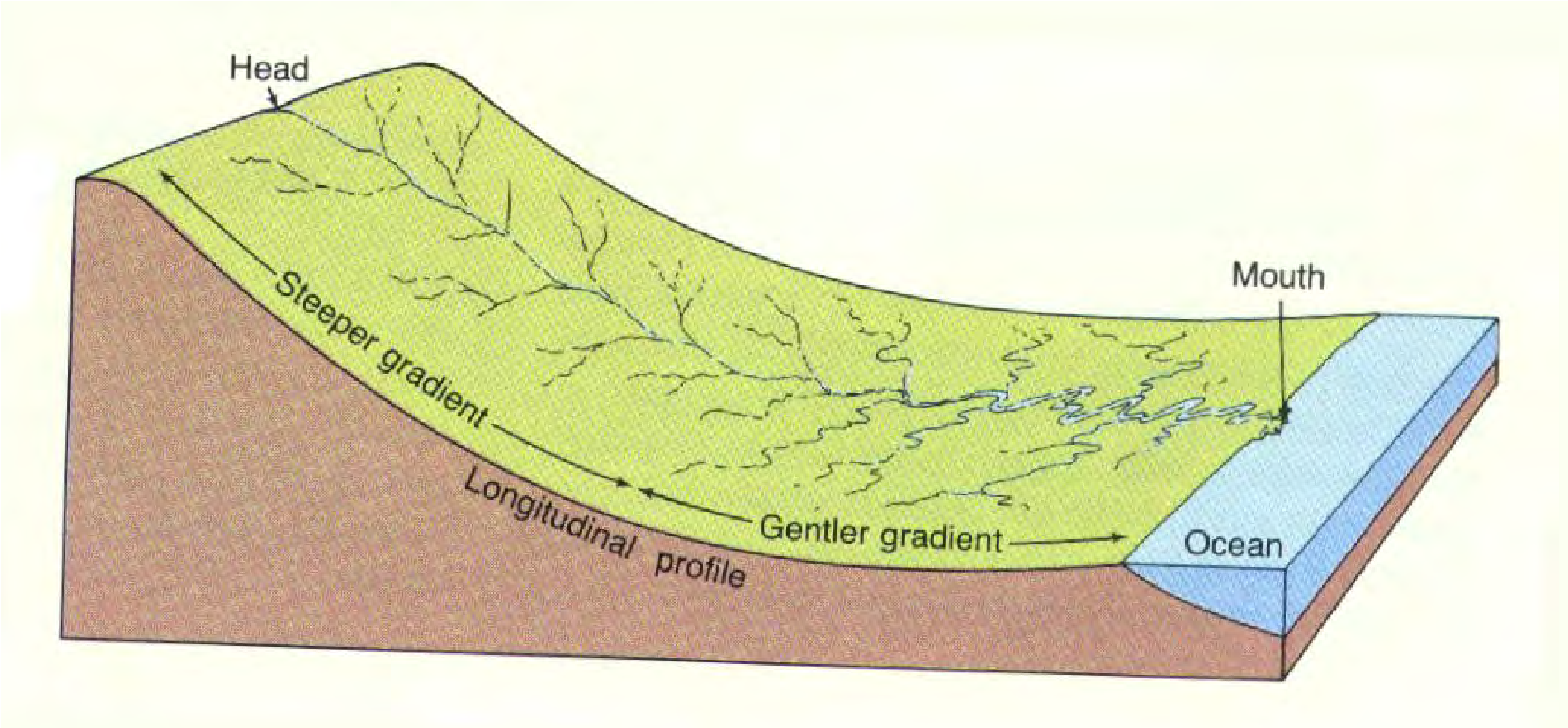
Stream Systems

Tributaries are any smaller streams that feed larger streams within a drainage basin.

Base Level

Base level it the level below which a river or stream cannot incise

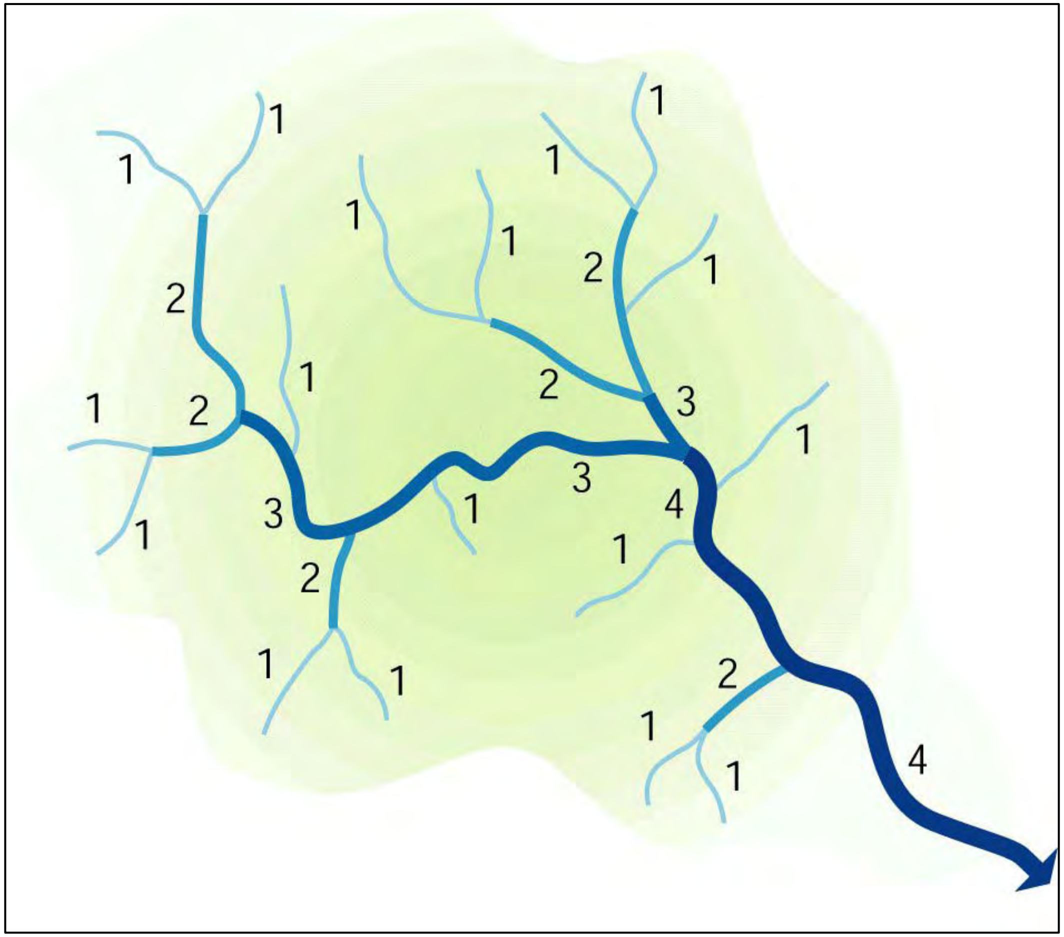
What happens if base level changes?



Stream Order

A method of classifying or ordering the hierarchy of natural channels.

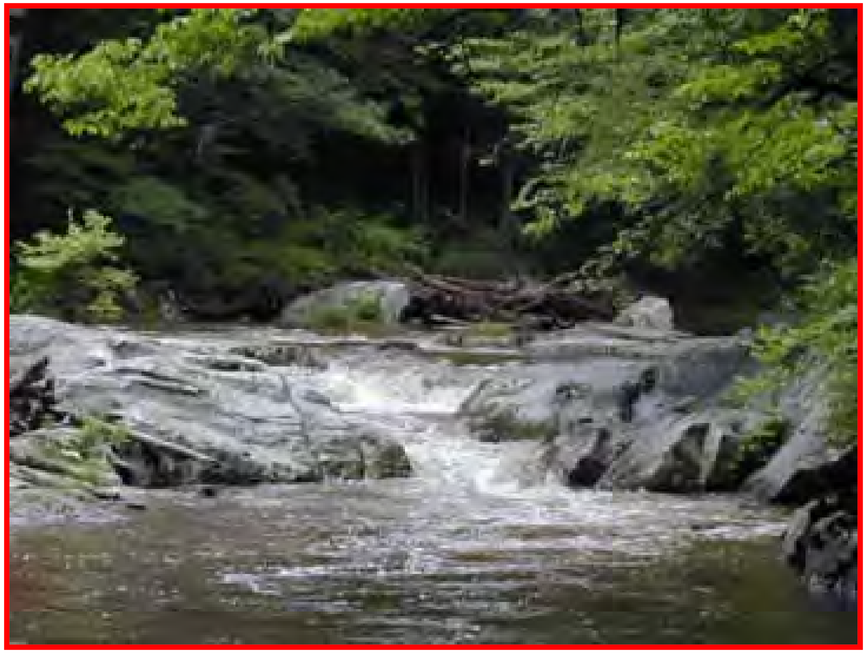
Stream order correlates well with drainage area, but is also regionally controlled by topography & geology.



Rivers vs. Streams

stream and **river** can be used interchangeably;

a stream is a small river



Some Definitions

A stream (or river) is a body of water that:

- Flows downslope along a *clearly defined natural passageway*
- Transports particles and/or dissolved substances **(load)**

The passageway is called the stream's **channel**

The quantity (volume) of water passing by a point on the stream bank in a given interval of time is the stream's **discharge**

A stream's discharge may vary because of changes in precipitation or the melting of winter snow cover.

In response to varying discharge and load, the channel continuously adjusts its shape (and location).

Factors Controlling Stream Behavior

gradient / slope

rise over run, meters per kilometer [S]

cross-sectional area

width x average depth, expressed in square meters [A]

velocity of waterflow

expressed in meters per second [V]

discharge

expressed in cubic meters per second [Q]

load

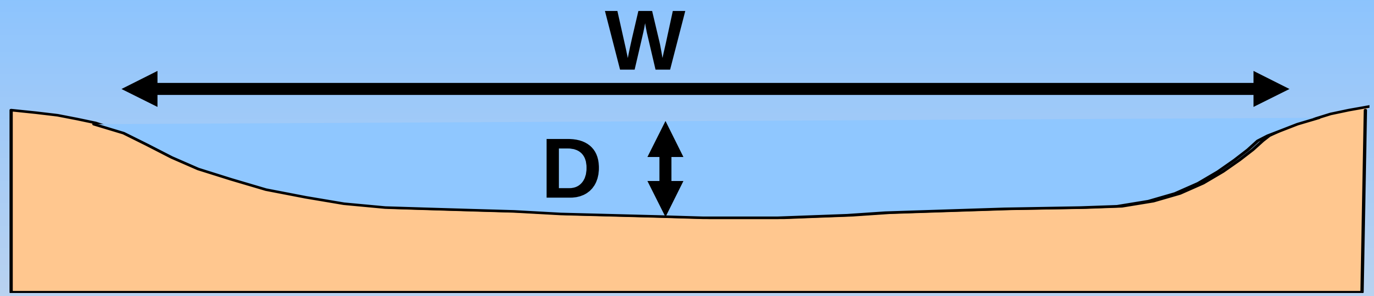
expressed as kilograms per cubic meter

dissolved matter generally does not affect stream behavior

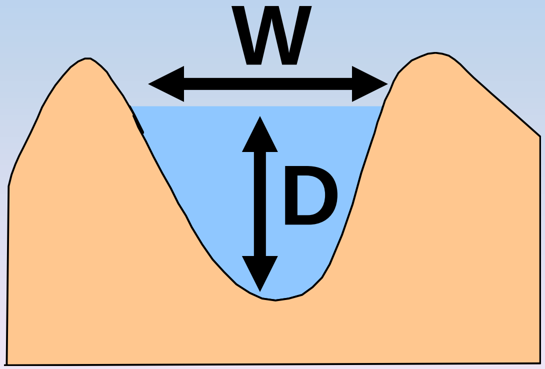
Cross section profile

width [W] & depth [D]

A = W x D



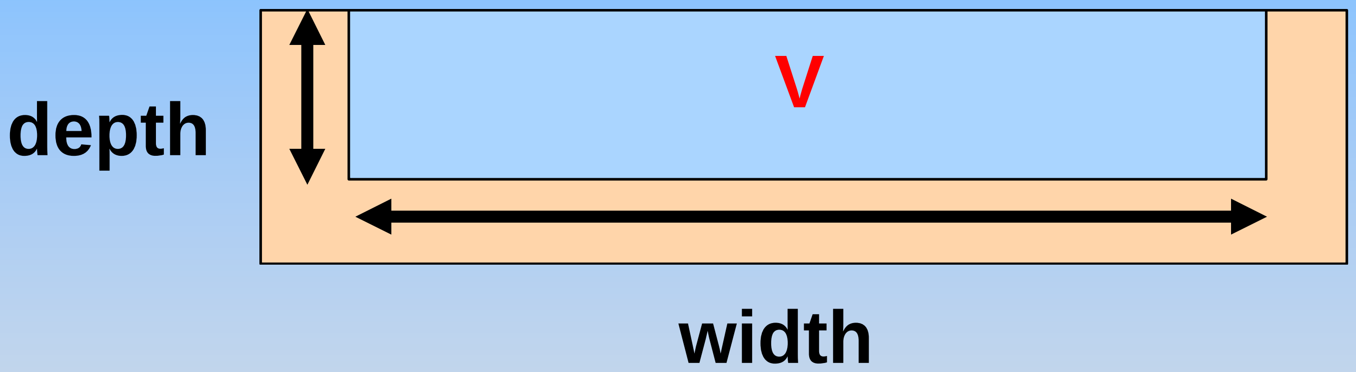
Flat terrain W >> D



Steep terrain W ~ D

Discharge [Q]

Channel dimensions times the average velocity



Simple channel:

Q = W x D x V

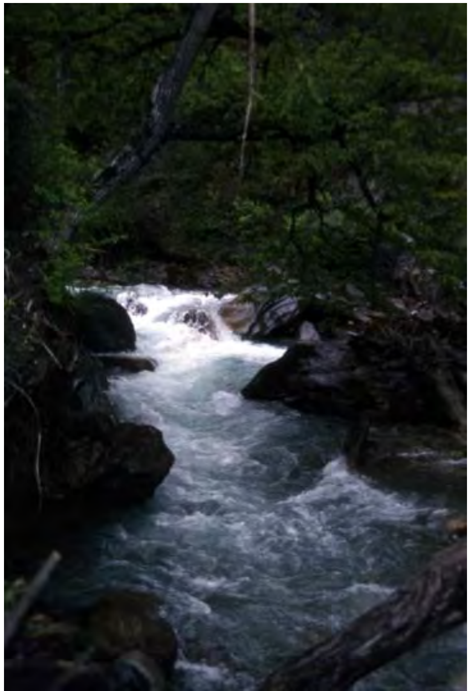
Downstream Evolution

Due to tributary contributions, discharge increases downstream but how do W, D, and V adjust to the increasing discharge?

$$Q = W\,D\,V$$

Traveling down a typical stream from its head to its mouth:

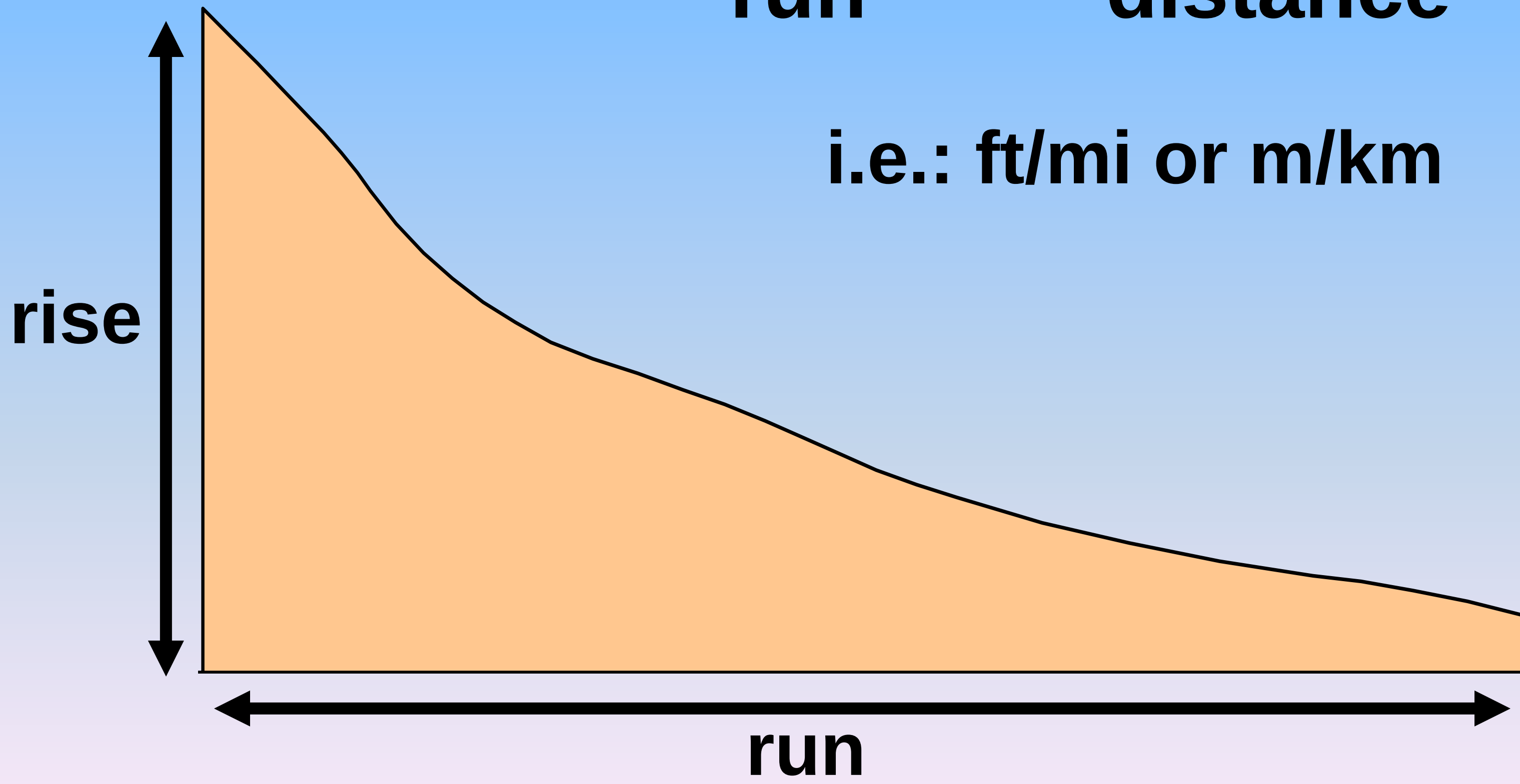
- Discharge increases
- Gradient decreases
- Stream cross-sectional area increases
- Width to depth ratio increases



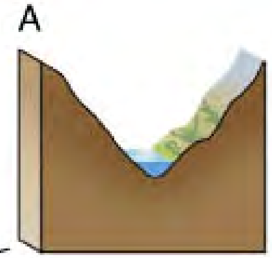
Long profile

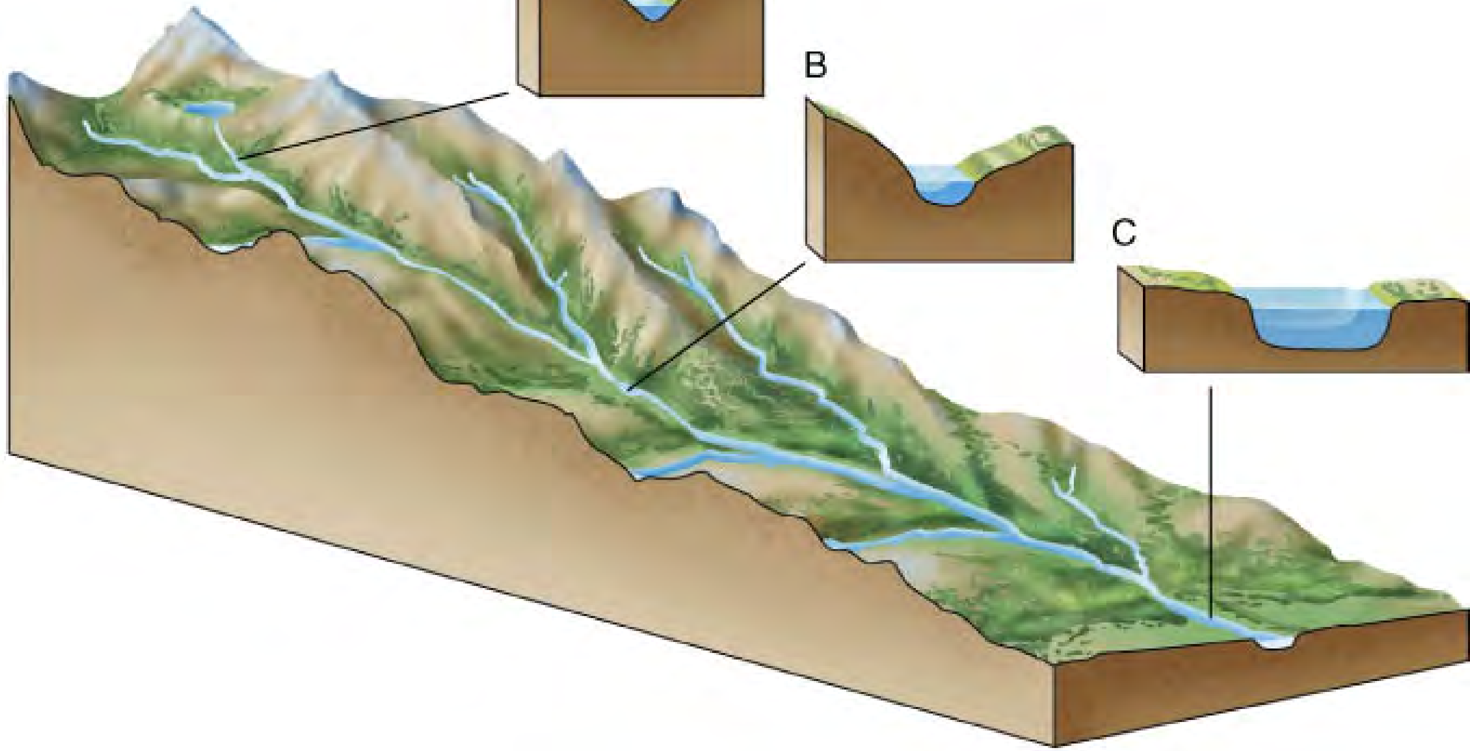
$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{\text{elevation}}{\text{distance}}$$

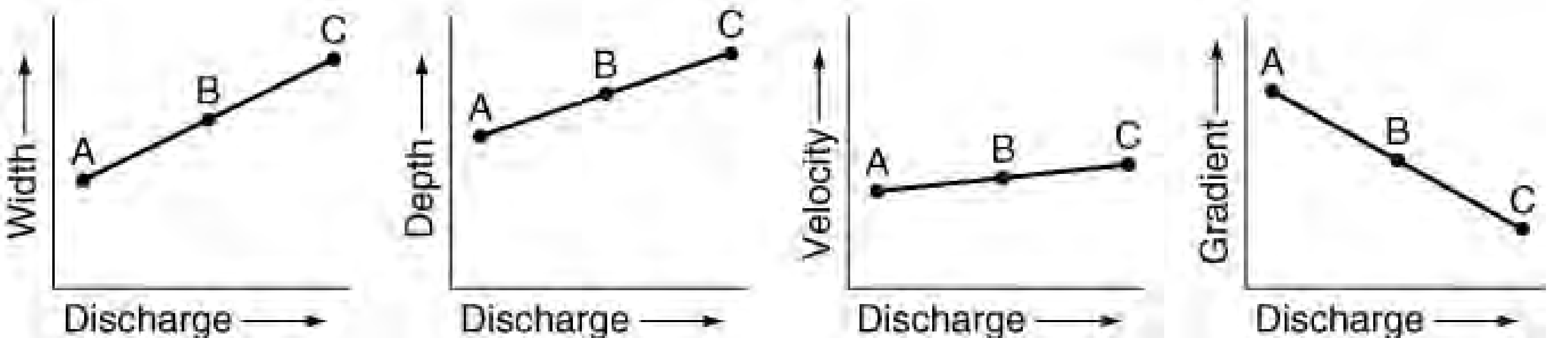
i.e.: ft/mi or m/km

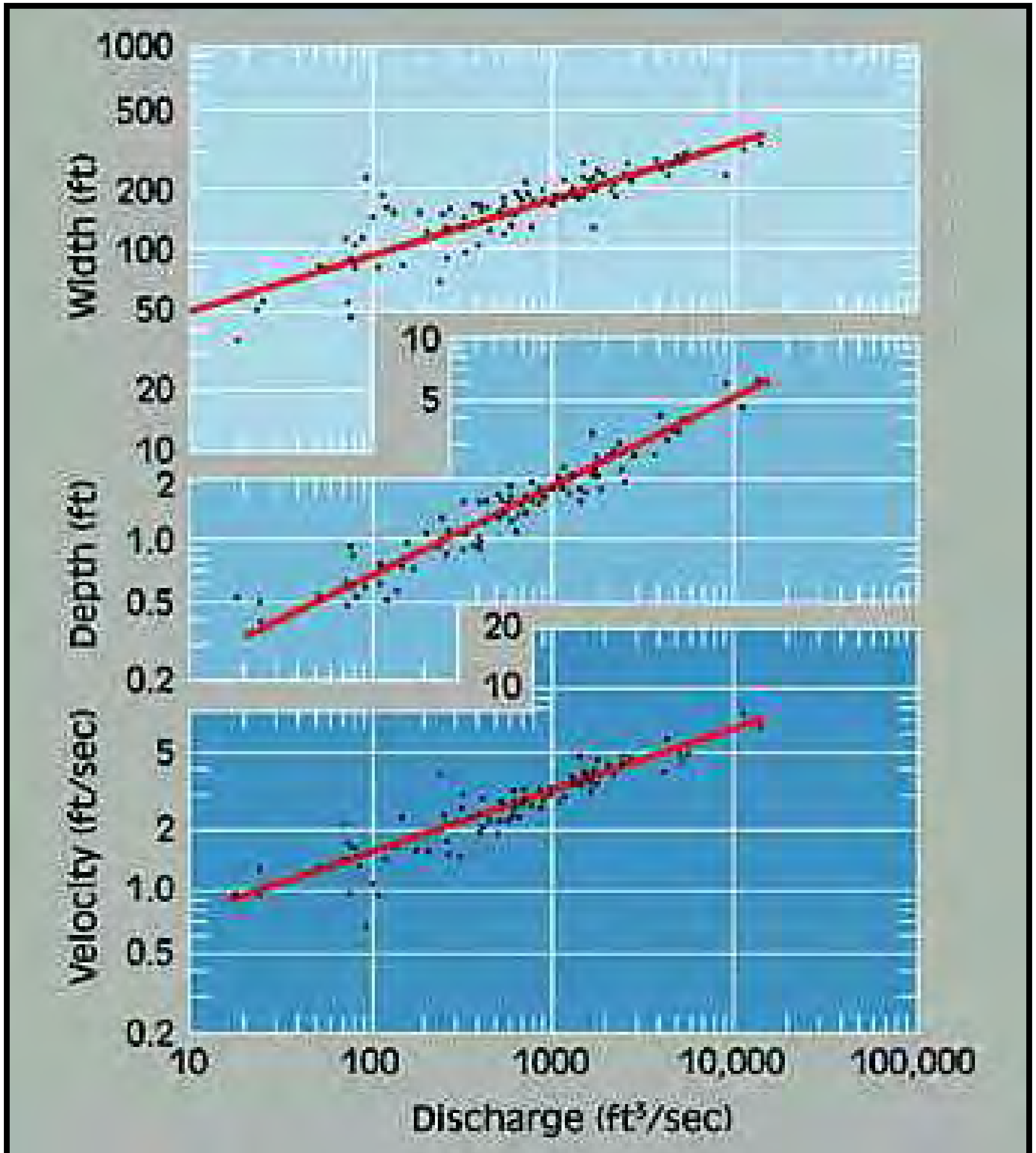


Where does a stream move fastest?









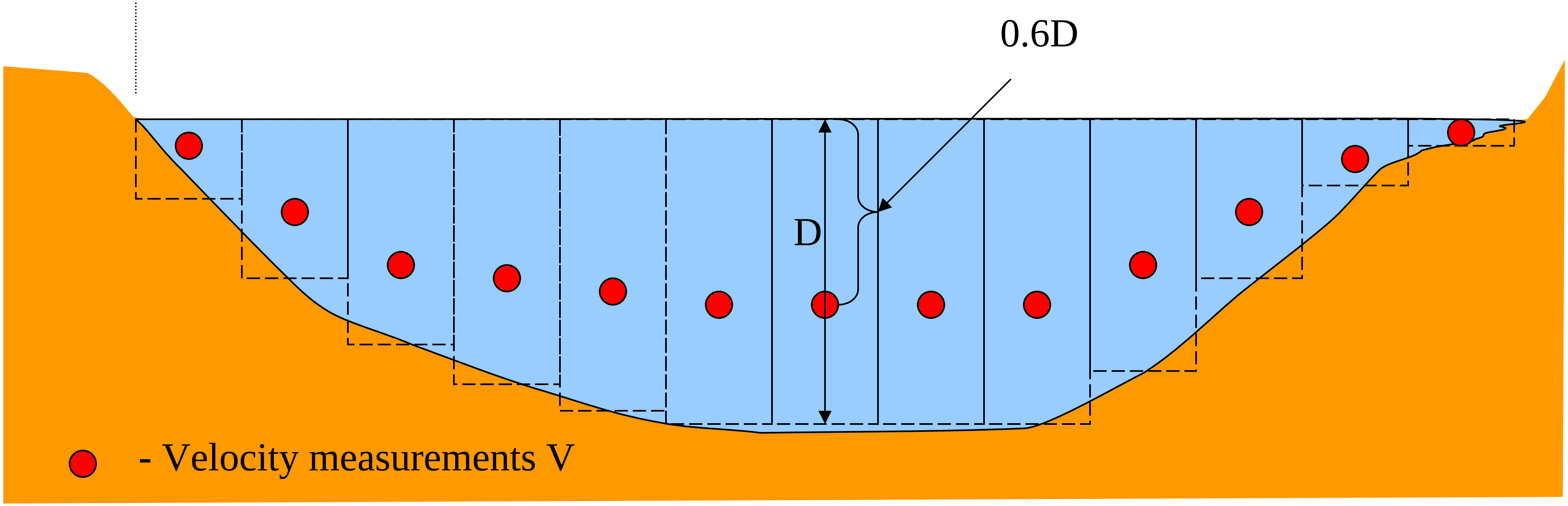
Headwater streams move slowest

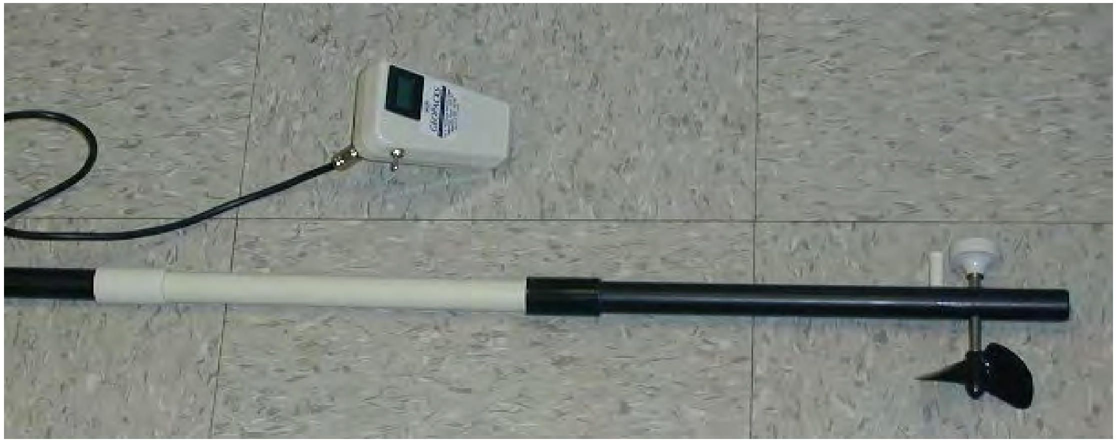
Mouth of stream moves fastest

Deeper stream move faster than shallow streams –

less resistance from the stream bed

Discharge Measurement



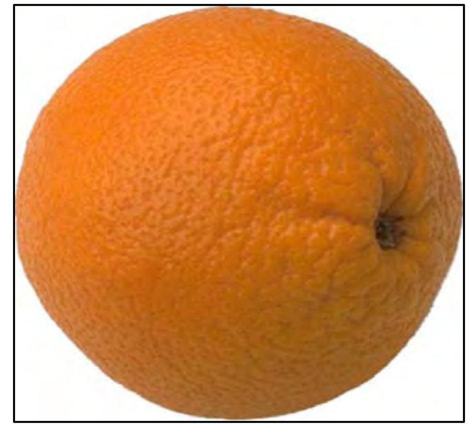


Velocity Determination: Float Method

Inexpensive and simple

Measures surface velocity

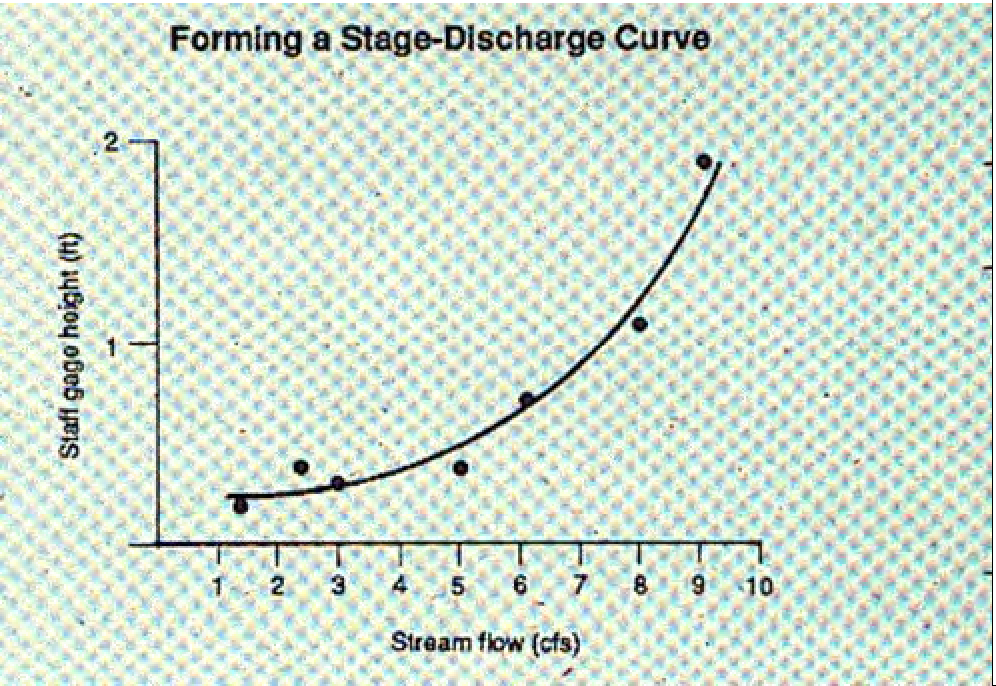
Basic idea: measure the time that it takes an object to float a specified distance downstream

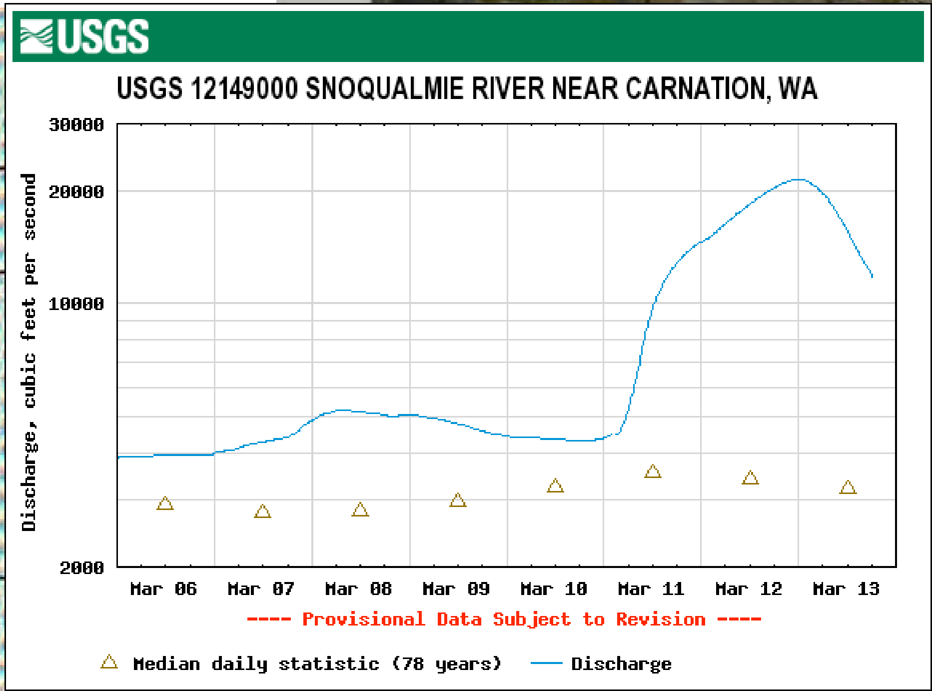


Stage & Rating Curves

River levels are typically measured as a **stage**

Stage must be converted to discharge via a **rating curve**





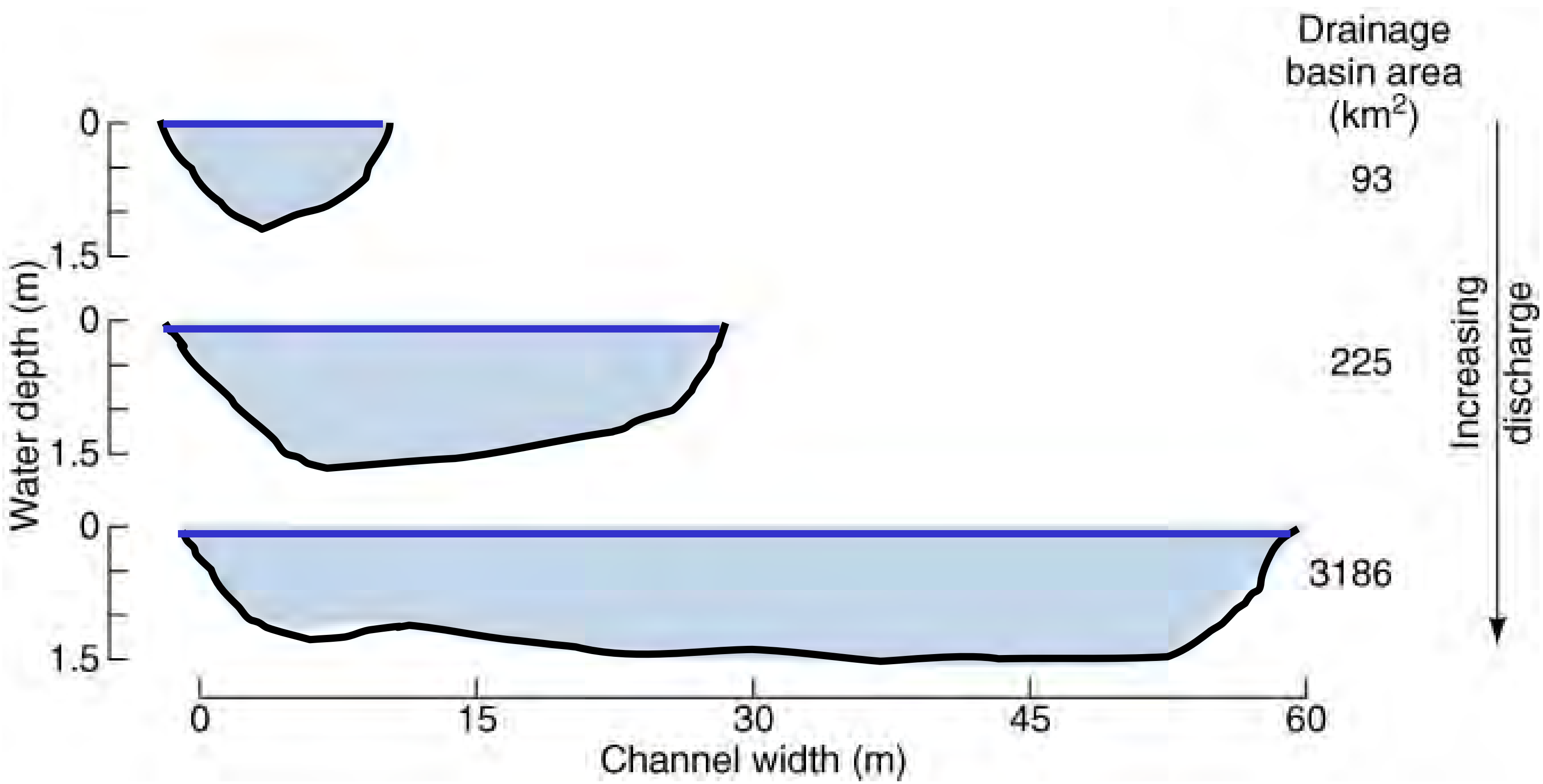
Field data generally indicate that channel width varies approximately as the square root of discharge

$W \sim a(Q)^{1/2}$

where a is some multiplier...

Cross-Sectional Shape

The ratio of channel width to channel depth generally increases down stream.



Floods

A **flood** occurs when a stream's discharge becomes so great that it exceeds the capacity of the channel, therefore causing the stream to overflow its banks.

Geologists view floods as *normal* and expected events.

Recurrence interval: the average time between floods of a given size.

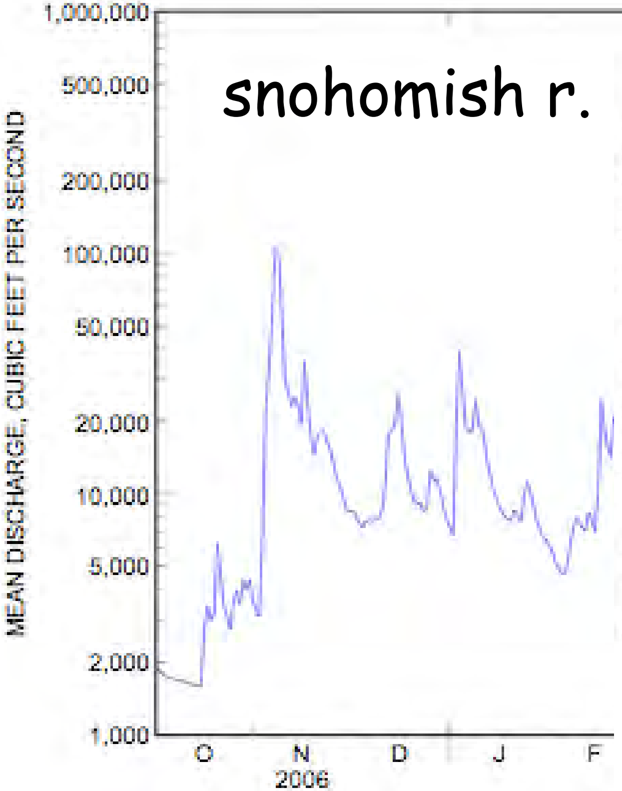
A flood having a recurrence interval of 10 years is called a "10-year flood."

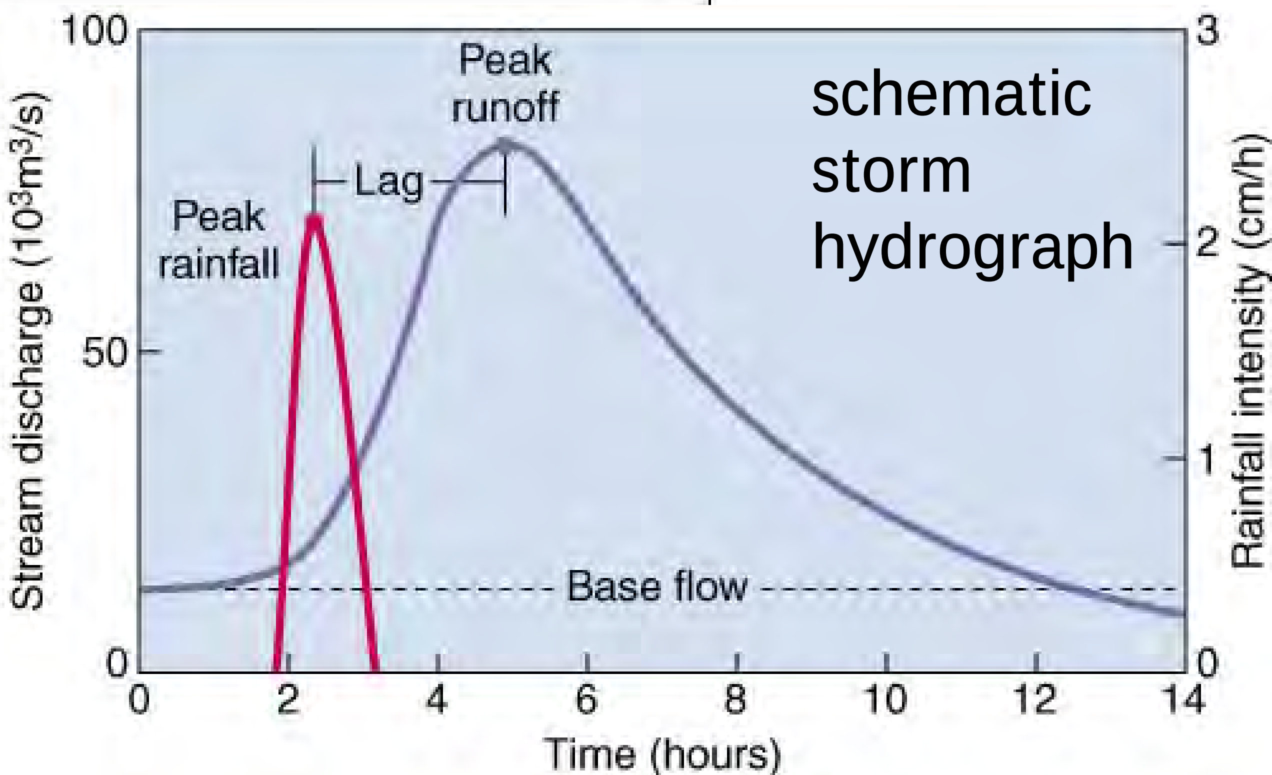
Hydrographs

stream discharge is not constant with time

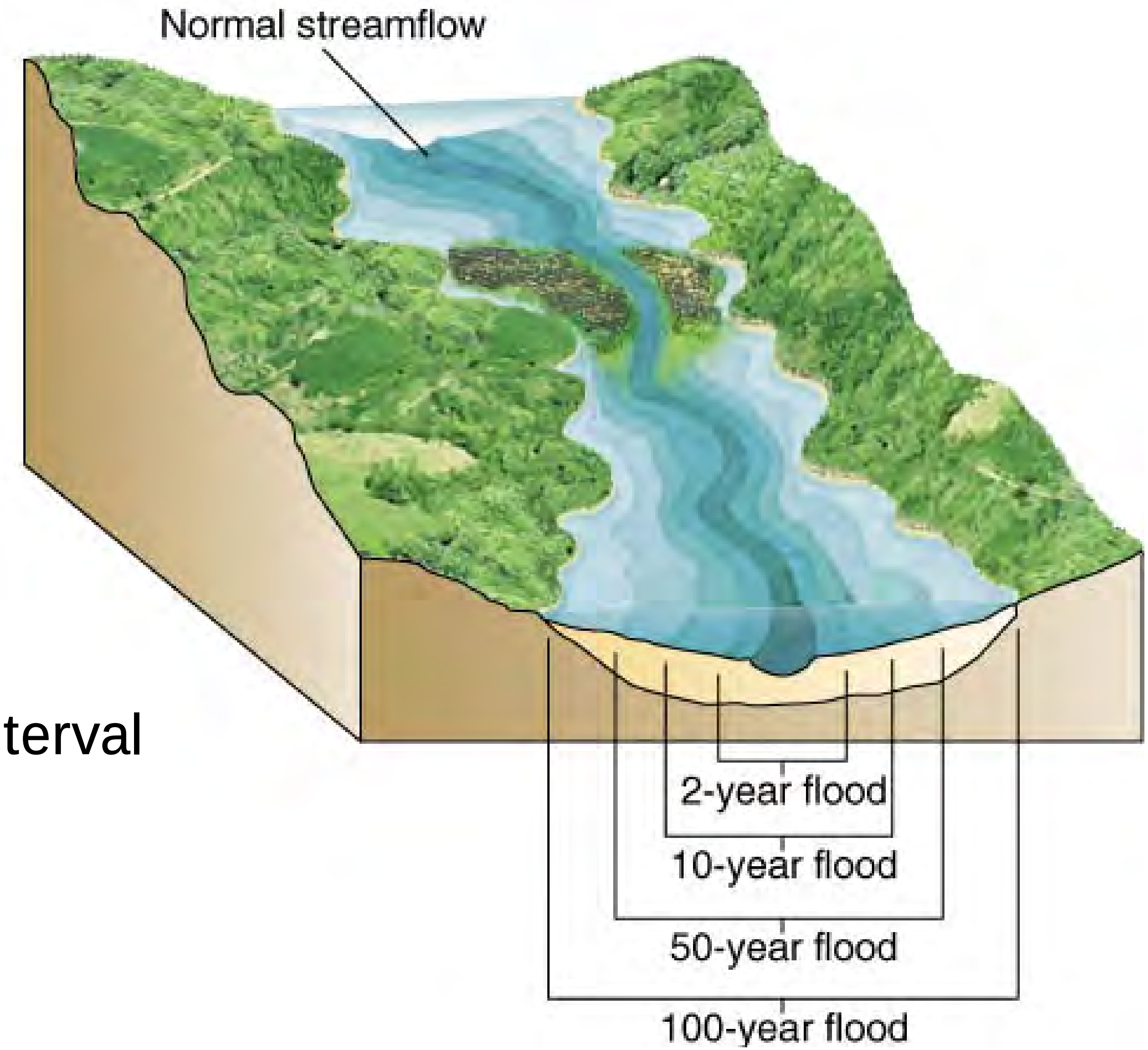
discharge varies with:

- seasonal climate variation
- individual rainfall events – note lag between rainfall peak & Q peak





Floods

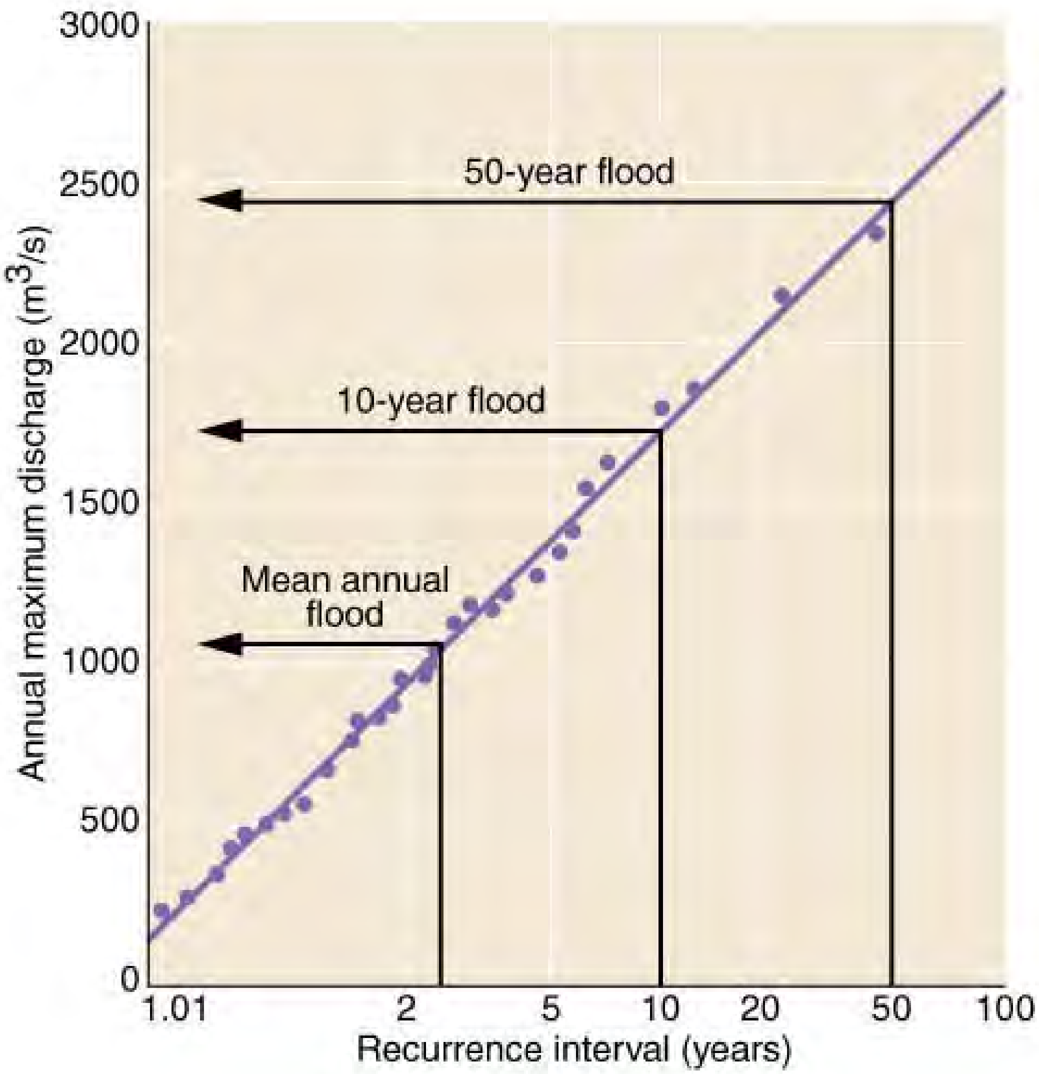


Recurrence interval
magnitude

Flood Frequency

Bankfull flood occurs on average about every 1 to 2 years

100 year flood occurs on average about every 100 years.

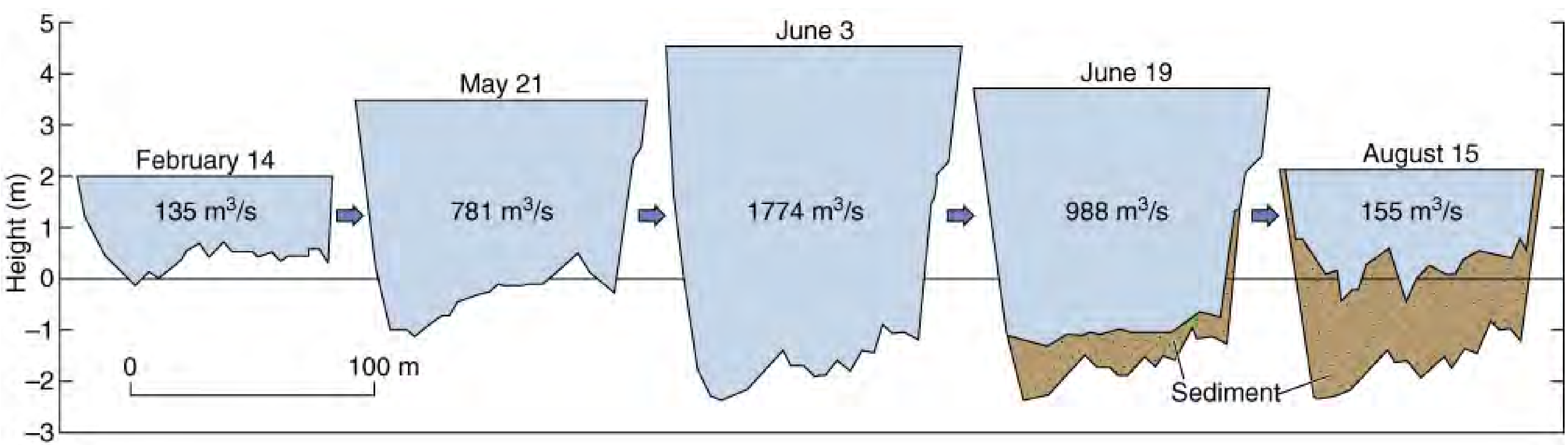


Floods

With an increased discharge and velocity during a flood, a channel can carry a greater load.

As discharge falls, the stream is unable to transport as much sediment.

At the end of the flood it returns to its pre-flood dimensions.



Carrying the Load

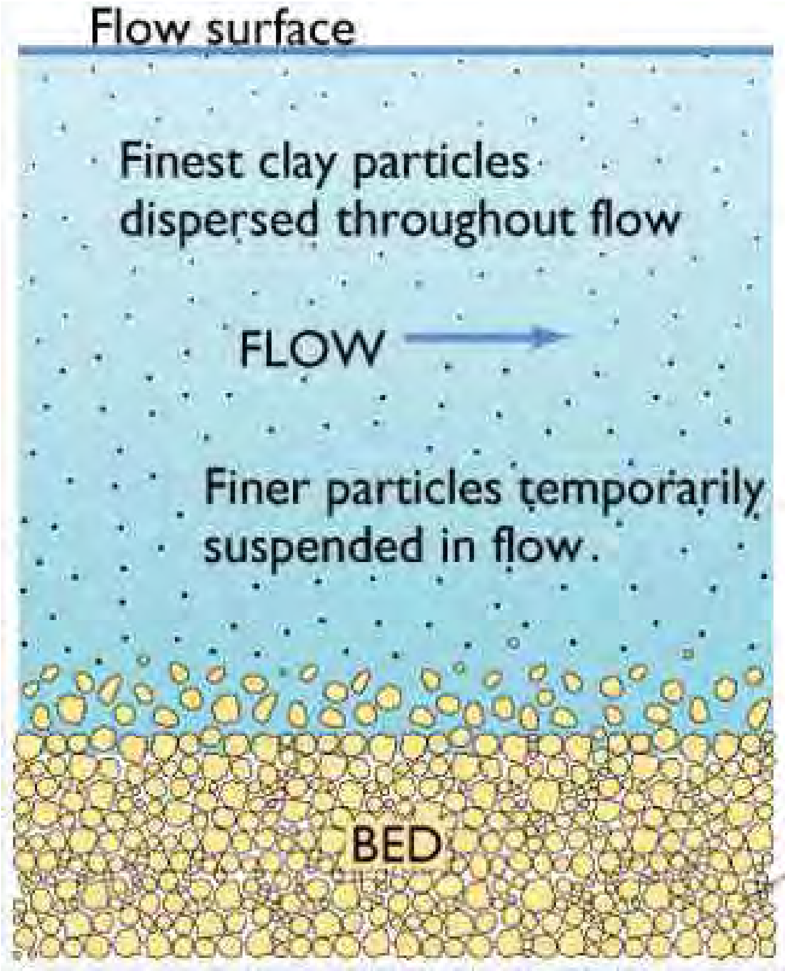
The material transported by a river is called its load.

There are three basic classes of load:

Bed load: sediment rolling, bouncing, and creeping along the river bed

Suspended load: sediment that is fine enough to remain in suspension in stream (size depends on velocity and turbulence)

Dissolved load: the invisible load of dissolved ions (e.g. Ca, Mg, K, HCO3)

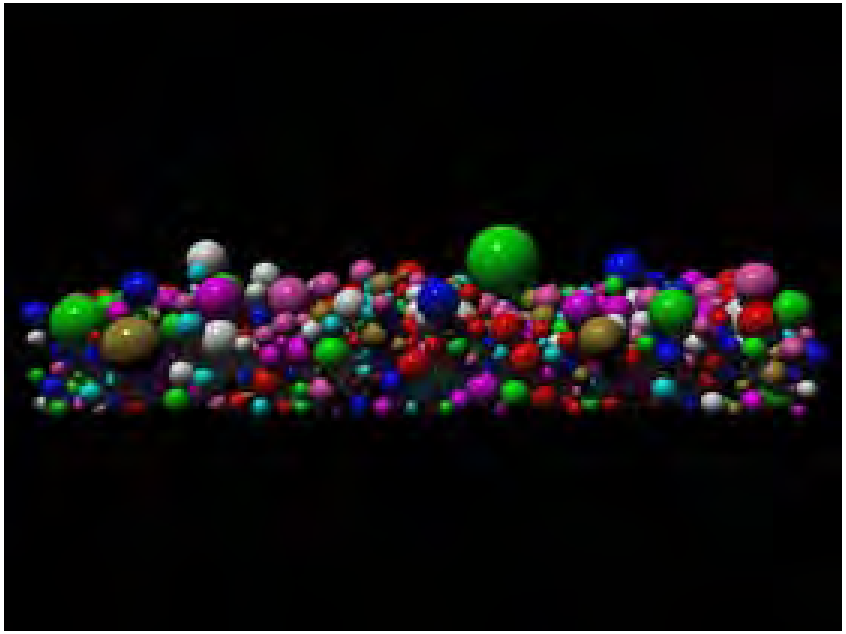


Bed Load

The bed load generally constitutes between 5 and 20 percent of the total load of a stream.

Particles move discontinuously by rolling or sliding at a slower velocity than the stream water.

The bed load may move short distances by **saltation** (series of short intermittent jumps).



Suspended Load

Particles tend to remain in suspension when upward moving currents exceed the velocity at which particles of silt and clay settle toward the bed under the pull of gravity.

They settle and are deposited where velocity decreases, such as in a lake or in the oceans.

Dissolved Load

All stream water contains dissolved ions and anions

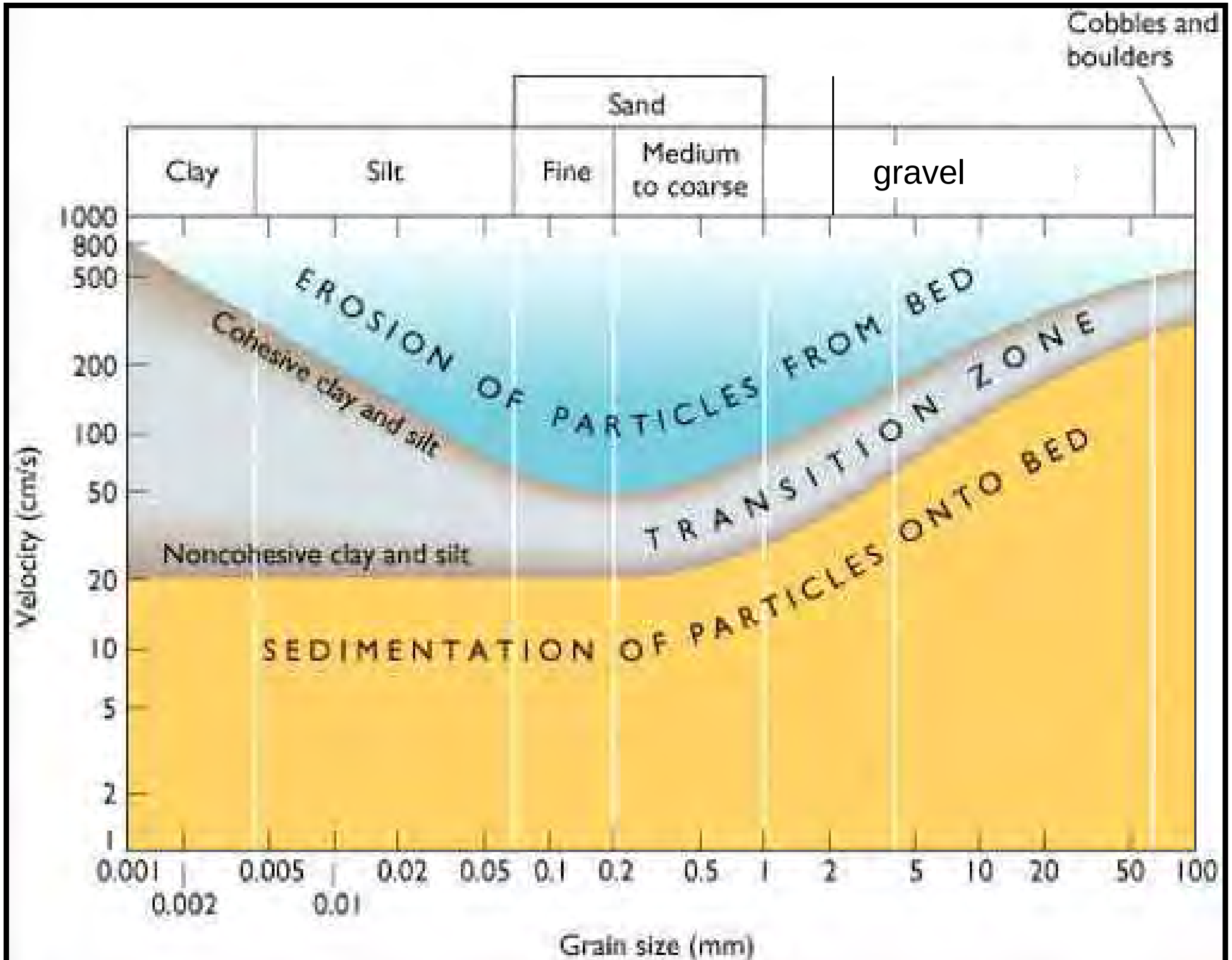
The bulk of the dissolved content of most rivers consists of seven ionic species:

- Bicarbonate (HCO_3^-)
- Calcium (Ca^{++})
- Sulfate (SO_4^{--})
- Chloride (Cl^-)
- Sodium (Na^+)
- Magnesium (Mg^{++})
- Potassium (K^+)
- Dissolved silica as $Si(OH)_4$

Sediment Size

Boulders	> 256 mm
Cobbles	80 mm - 256 mm
Gravel	2 mm - 80 mm
Sand	0.05 mm - 2 mm
Silt	0.002 mm - 0.05 mm
Clay	< 0.002 mm

The ability of a stream to pick up particles of sediment from its channel and move them along depends on the velocity of the water.



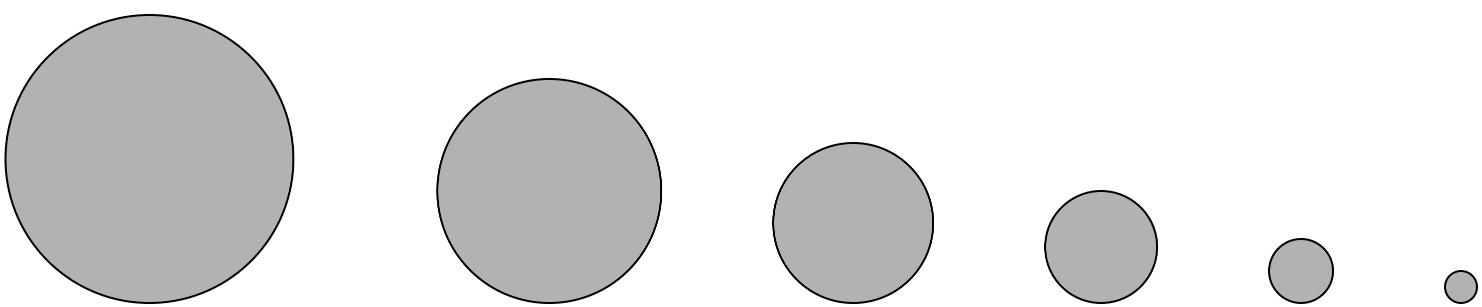
Downstream Changes in Particle Size

The size of river sediment normally decreases in size downstream

- boulders in mountain streams → silt and sand in major rivers

2 primary reasons:

- coarse bed load is gradually reduced in size by abrasion
- coarser, heavier materials generally settle out first...



When a river eventually reaches the sea, its bed load typically consists mainly of sand and silt.