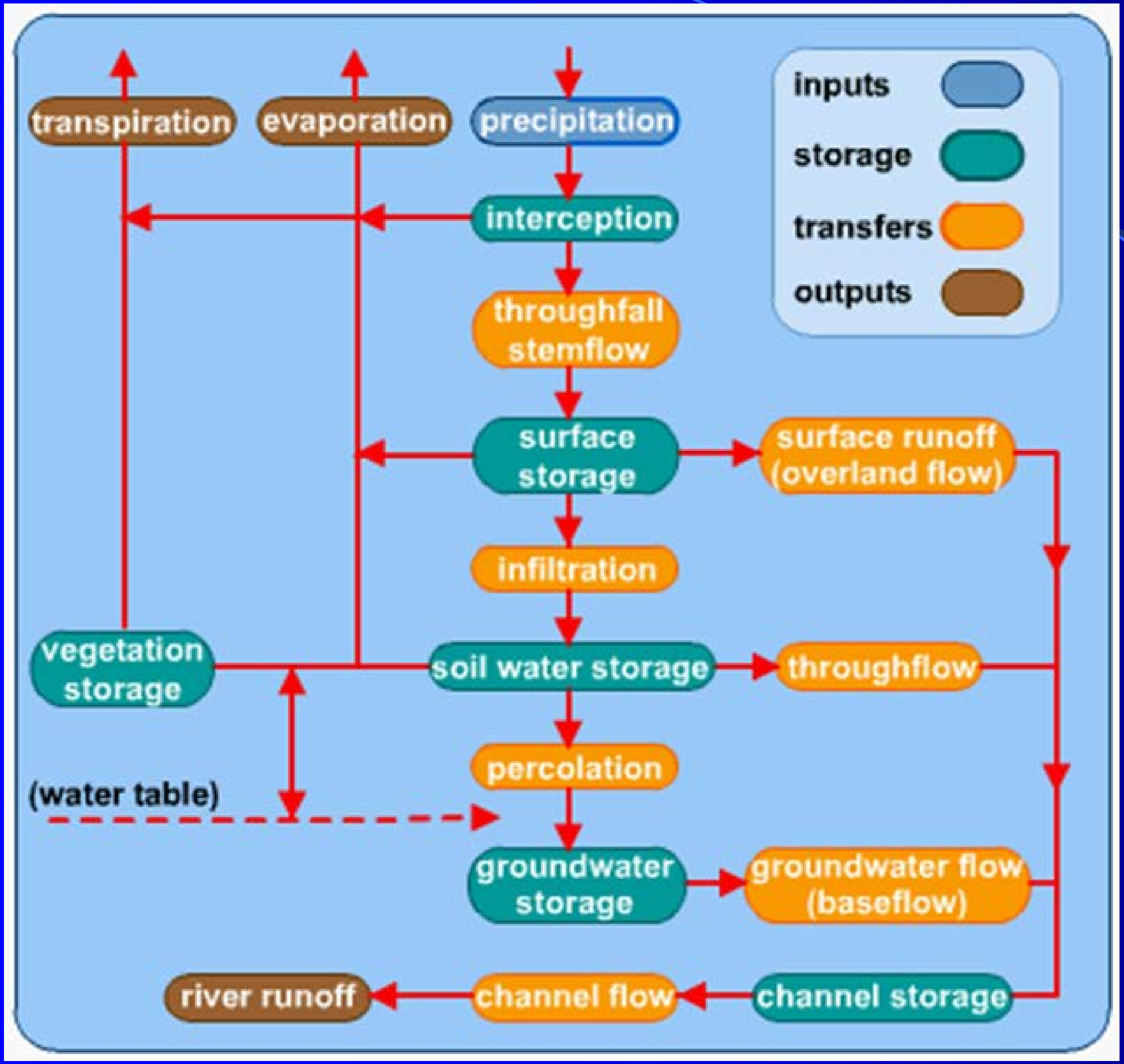
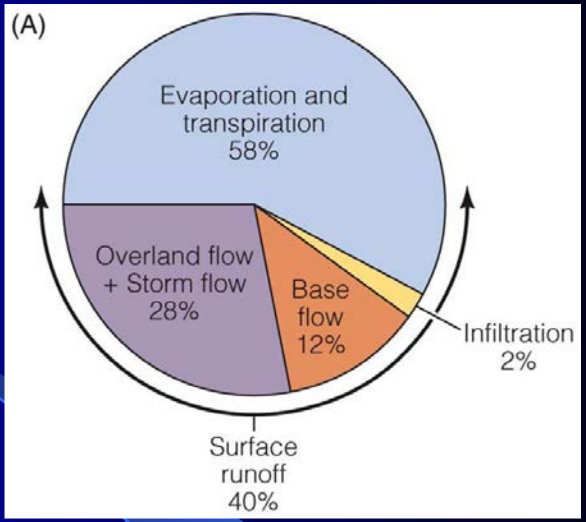
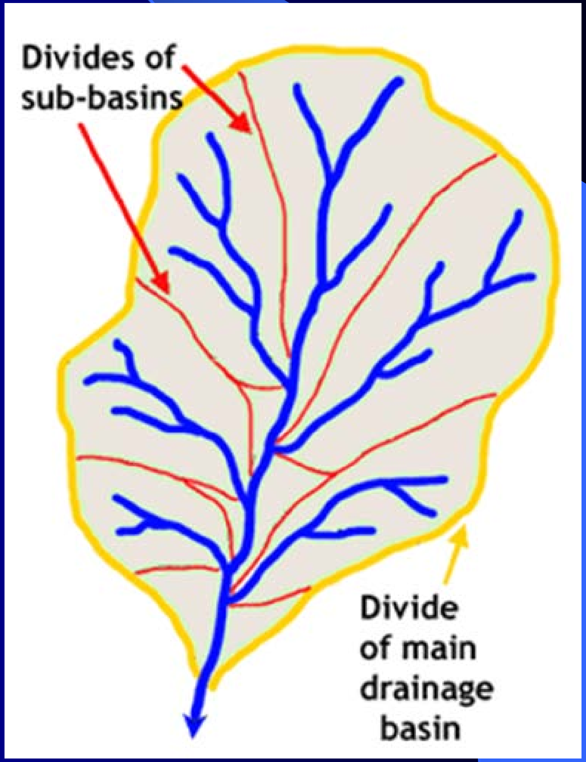
89.325 Geology for Engineers
Rivers



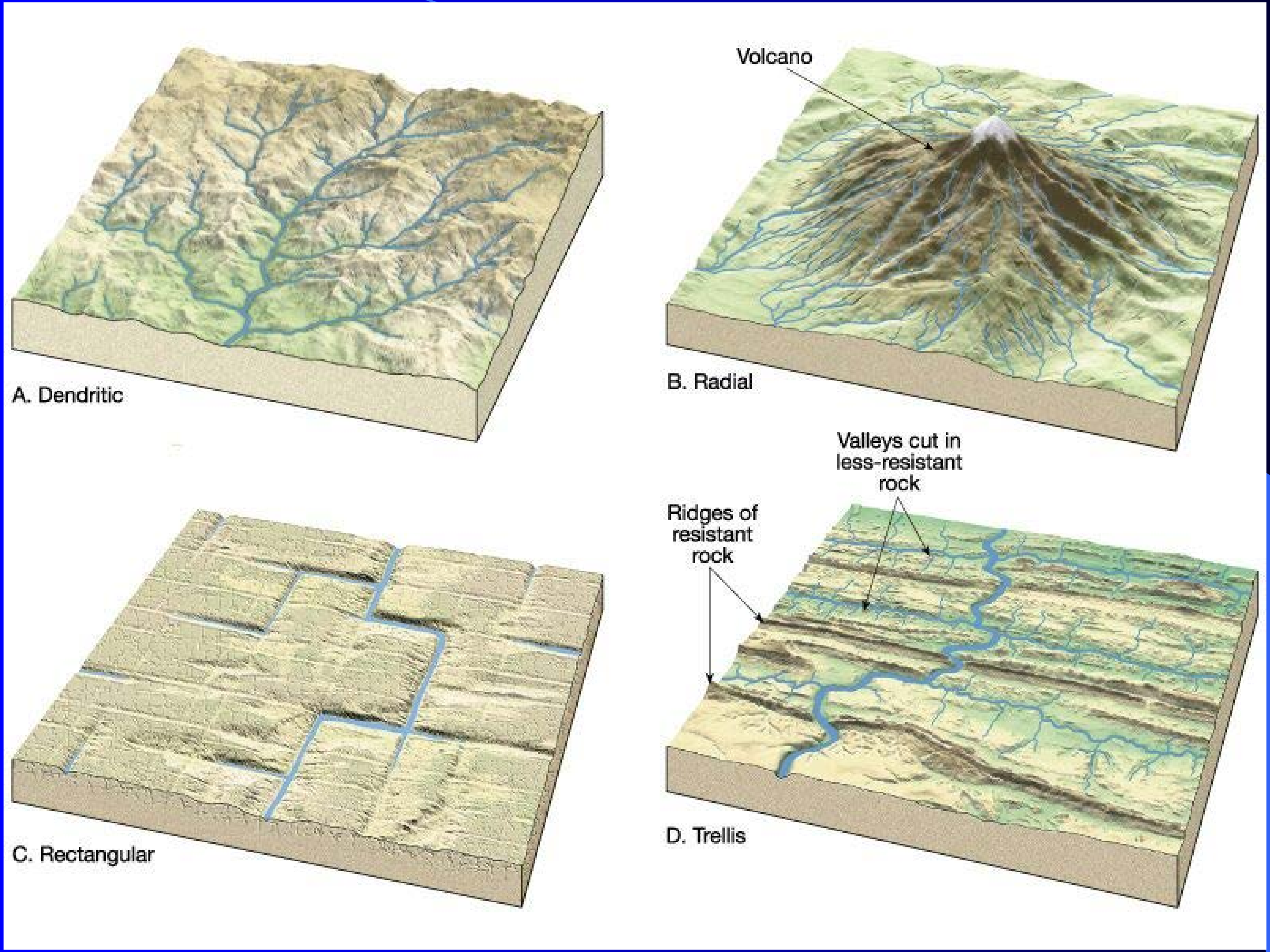

Precipitation and streams

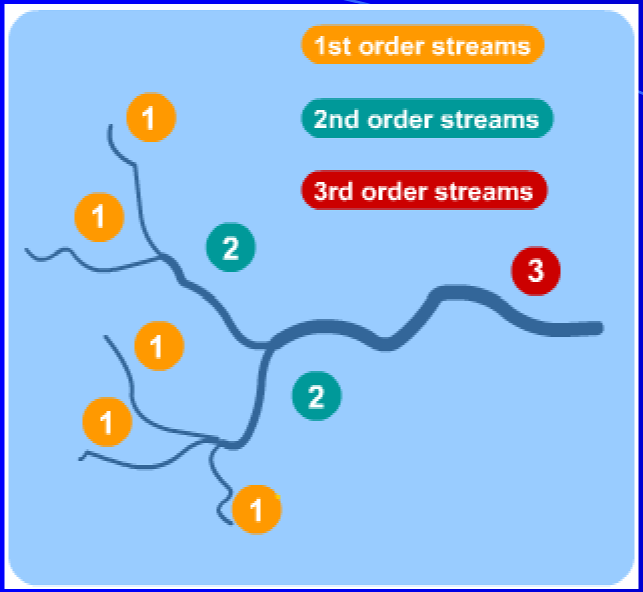


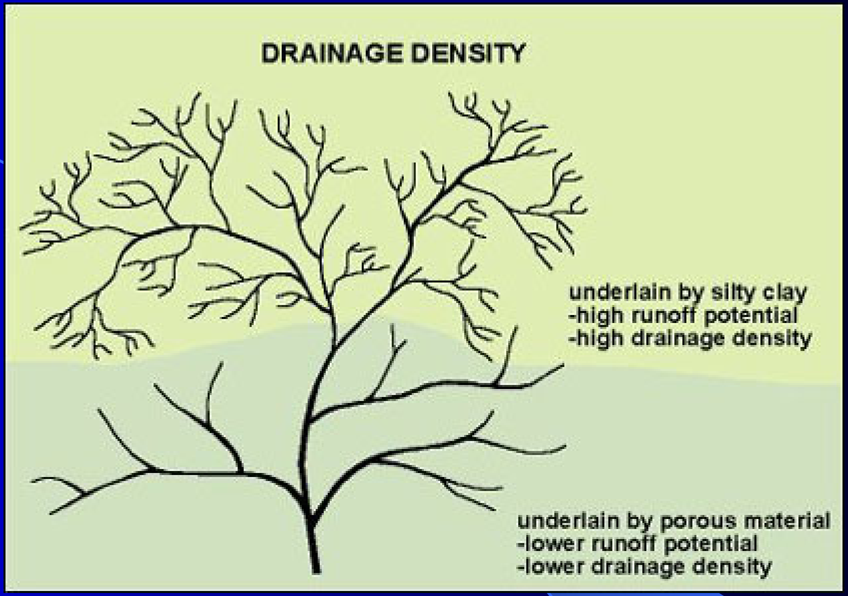


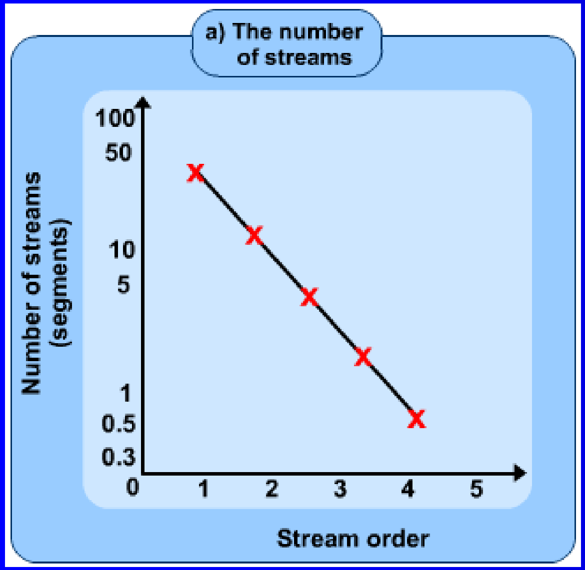


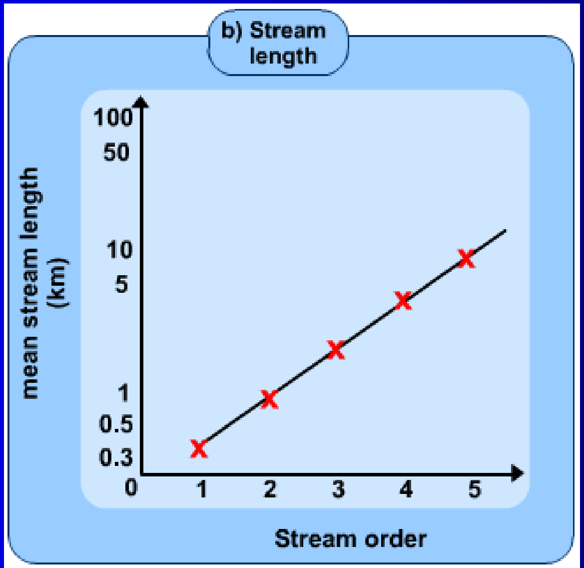
Drainage patterns

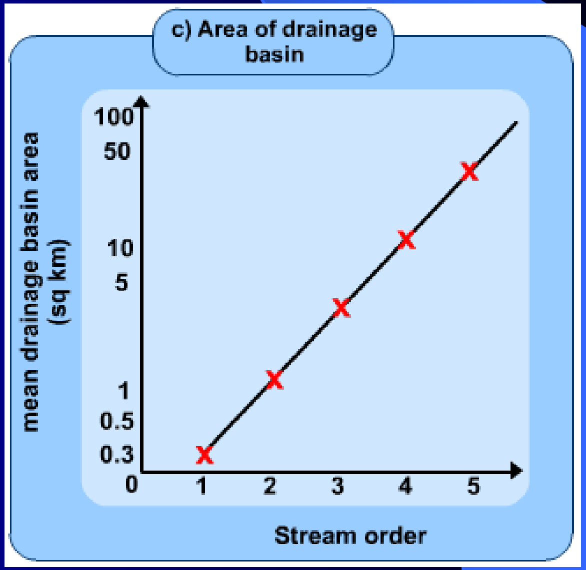



1st order streams
2nd order streams
3rd order streams
1
1
2
3
1
2
1
1


DRAINAGE DENSITY
underlain by silty clay
-high runoff potential
-high drainage density
underlain by porous material
-lower runoff potential
-lower drainage density


a) The number of streams
Number of streams (segments)
100
50
10
5
1
0.5
0.3
0
1
2
3
4
5
Stream order


b) Stream length
mean stream length (km)
100
50
10
5
1
0.5
0.3
0
1
2
3
4
5
Stream order


c) Area of drainage basin
mean drainage basin area (sq km)
100
50
10
5
1
0.5
0.3
0
1
2
3
4
5
Stream order

The Hydrologic Budget

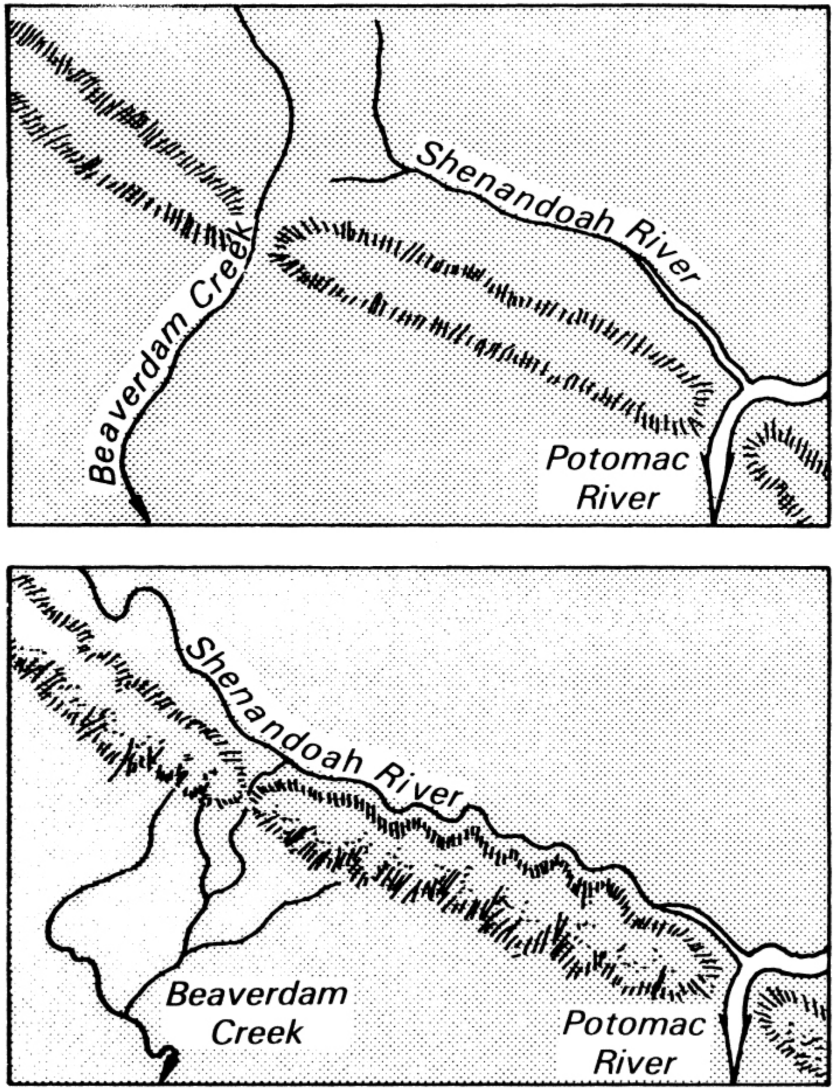
$$(P + GW_{in} + SW_{in}) - (E + ET) = (\Delta SW + \Delta GW + \Delta SM)$$

← inflows → ← outflows → ← change in storage →

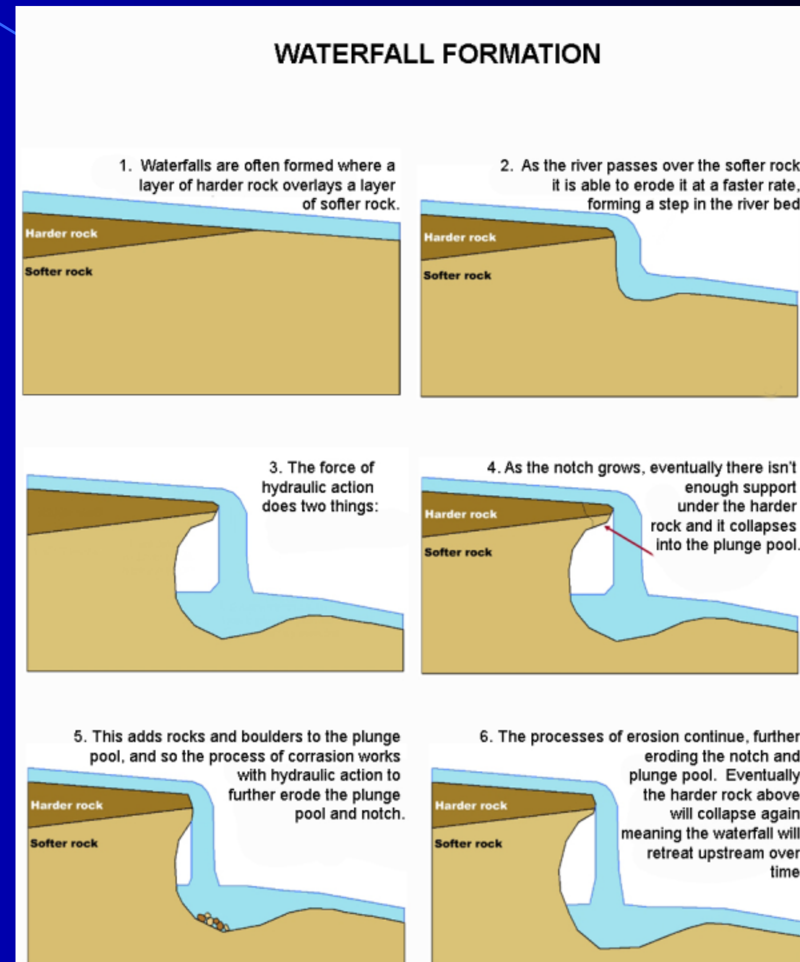
where:

- P is precipitation as rain or snow,
- GW_{in} is ground-water inflow volume,
- SW_{in} is surface-water inflow volume,
- E is open-water evaporation,
- ET is evapotranspiration from emergent vegetation,
- ΔSW is change in standing volume of surface water,
- ΔGW is change in ground-water volume of the saturated zone, and
- ΔSM is change in ground-water volume of the unsaturated zone.

Stream capture



Waterfall formation

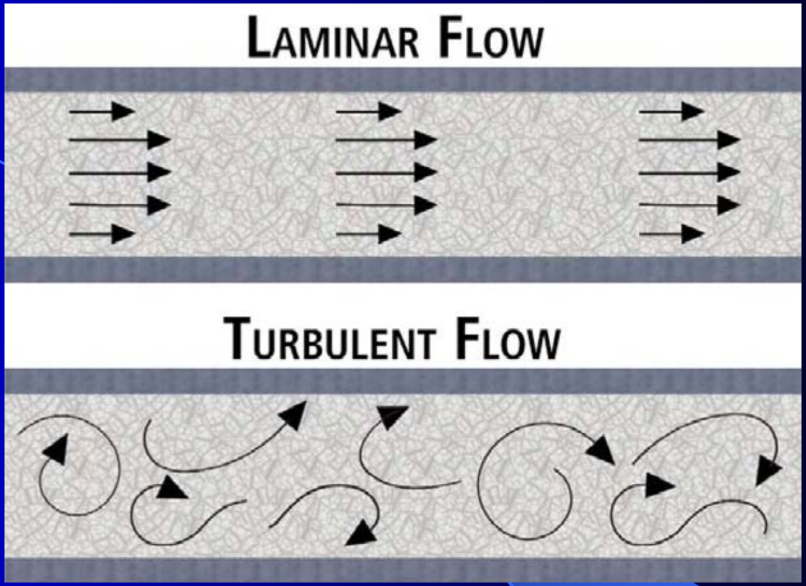


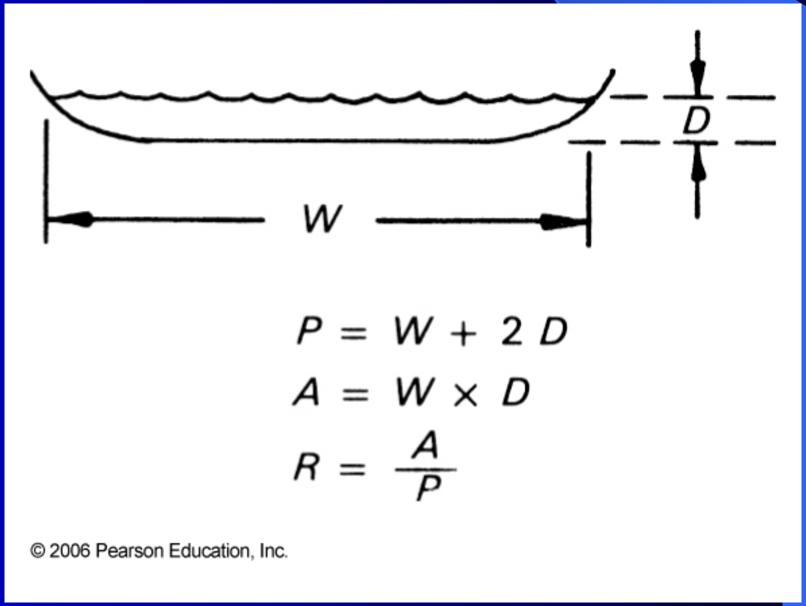
Reynolds Number
Laminar versus turbulent flow

$$Re = \frac{\rho_w v R}{\mu}$$

P_w = density of water (1000 kg/m^3)
v = velocity (m/s)
R = hydraulic radius (m)
μ = dynamic viscosity (for water at 20°C
= 1.002 x 10^{-3} Pa s)

	Reynolds Number
Laminar flow	<2000
Unstable flow	2000 – 4000
Turbulent flow	>4000

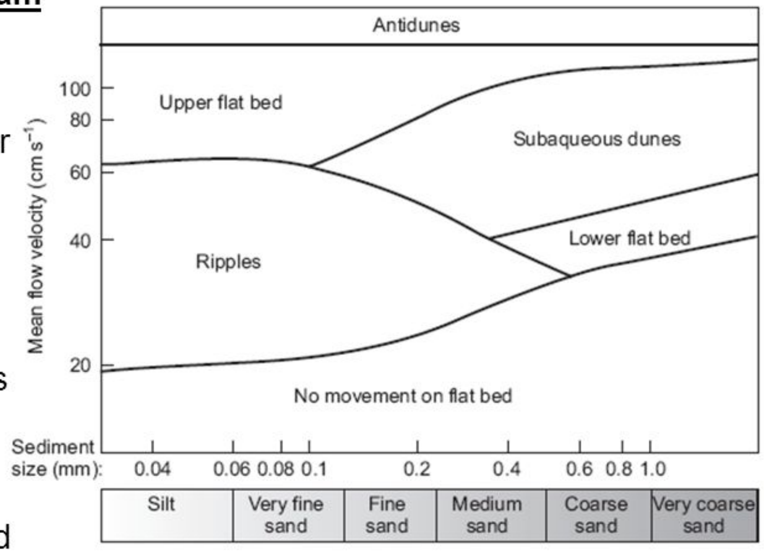




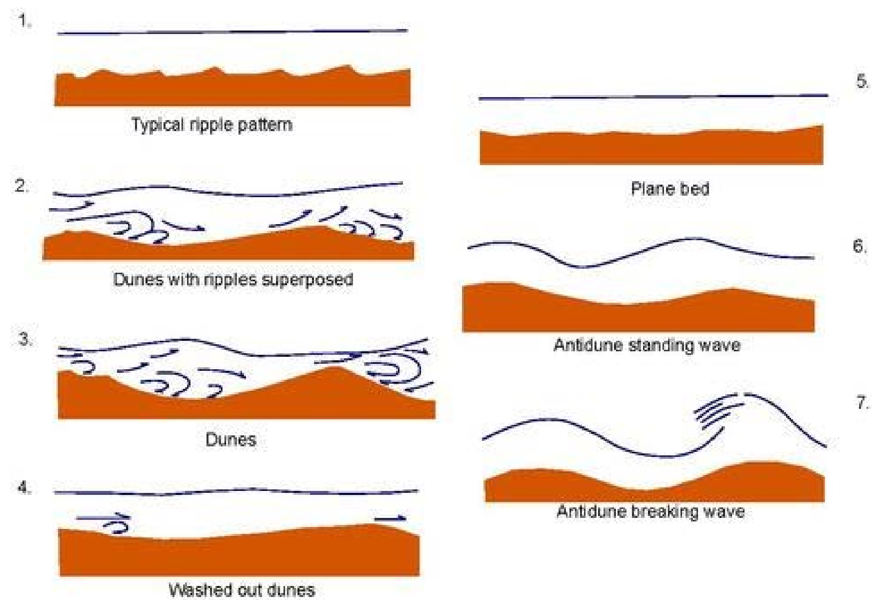
Bedform stability diagram

This bedform stability diagram indicates the bedform that will occur for a given grain size and velocity and has been constructed from experimental data.

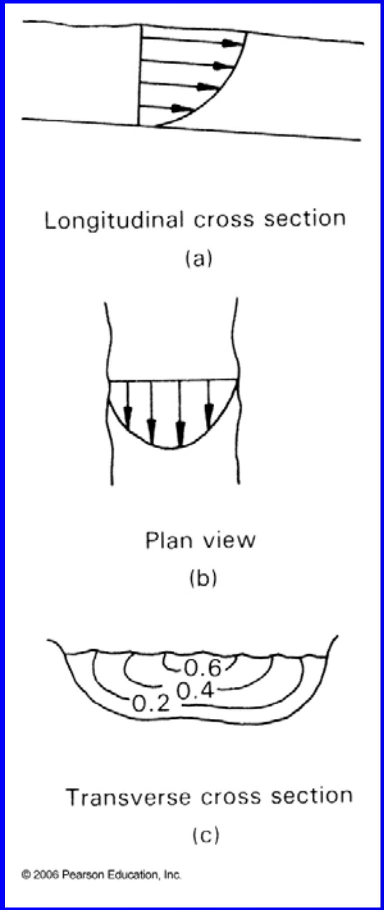
Two general flow regimes are recognised: a lower flow regime in which ripples, dunes and lower plane beds are stable and an upper flow regime where plane beds and antidunes form.

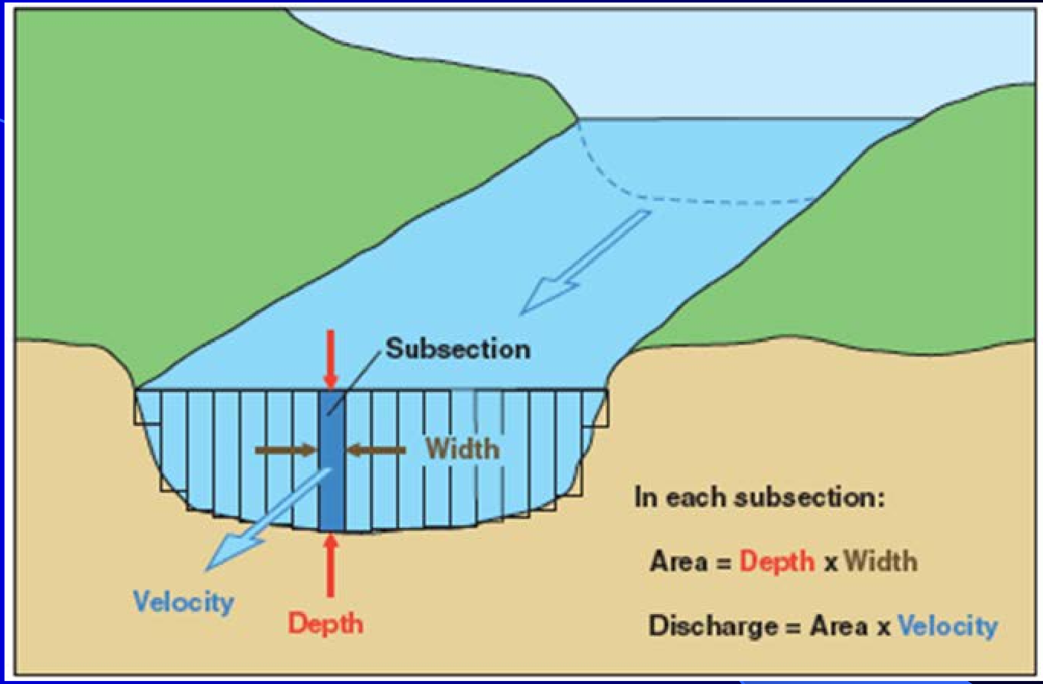


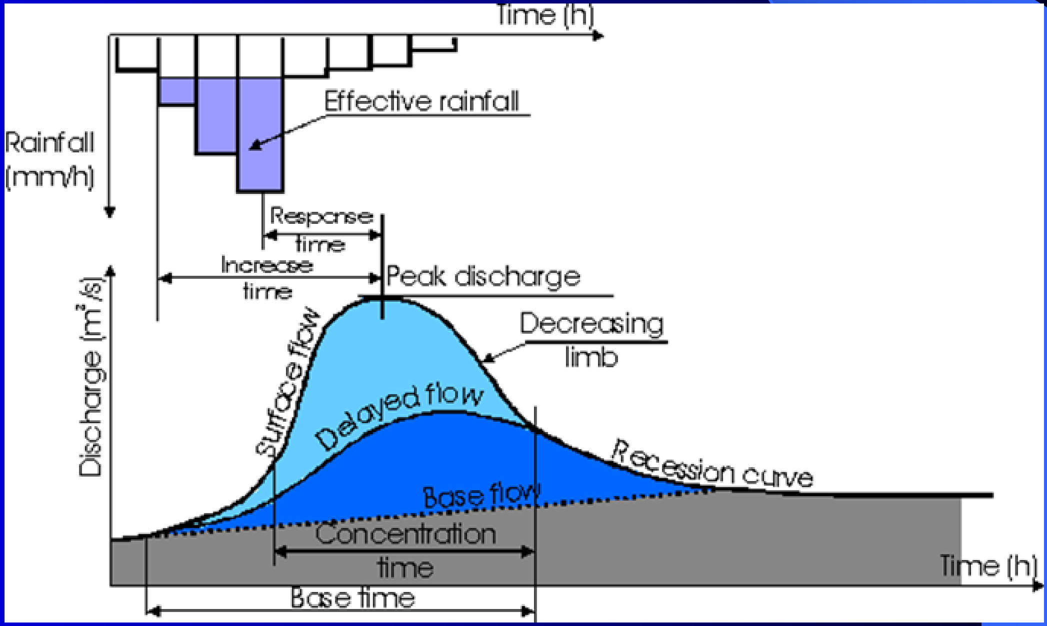
A bedform stability diagram which shows how the type of bedform that is stable varies with both the grain size of the sediment and the velocity of the flow.



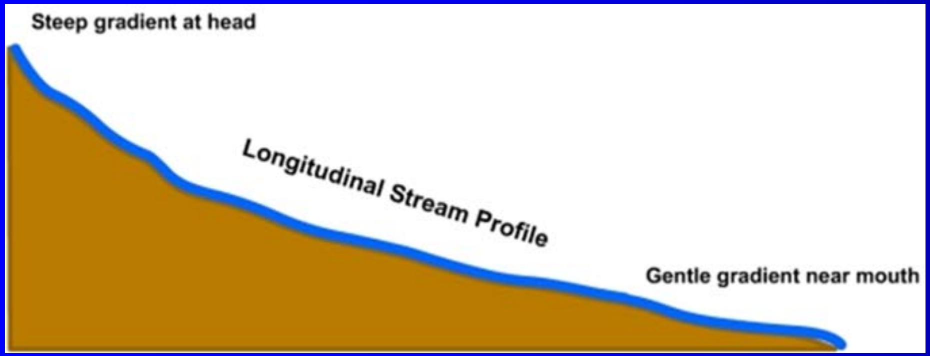
Stream discharge and Velocity

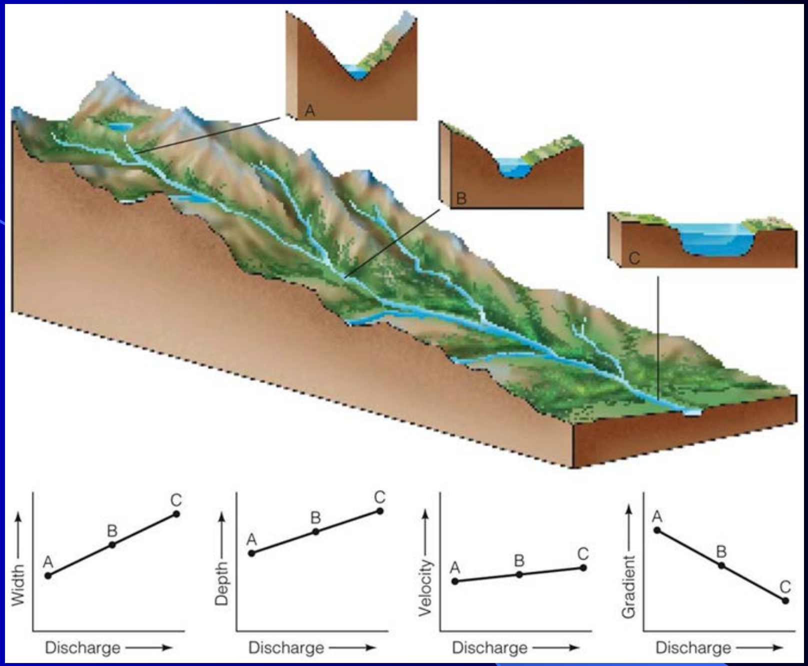


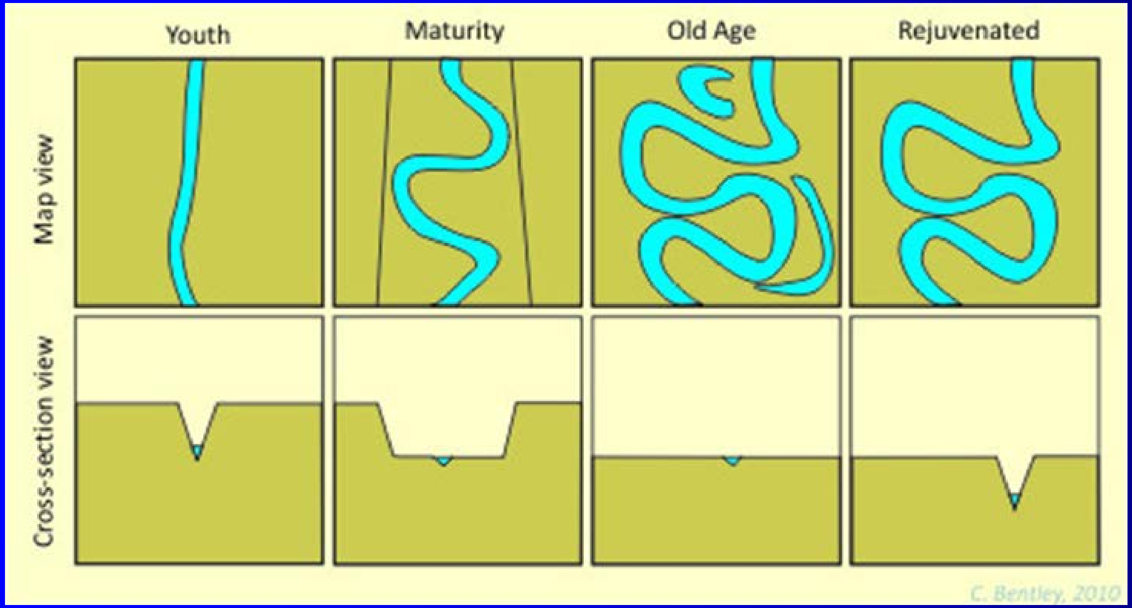




Stream profiles, discharge, and stream maturity





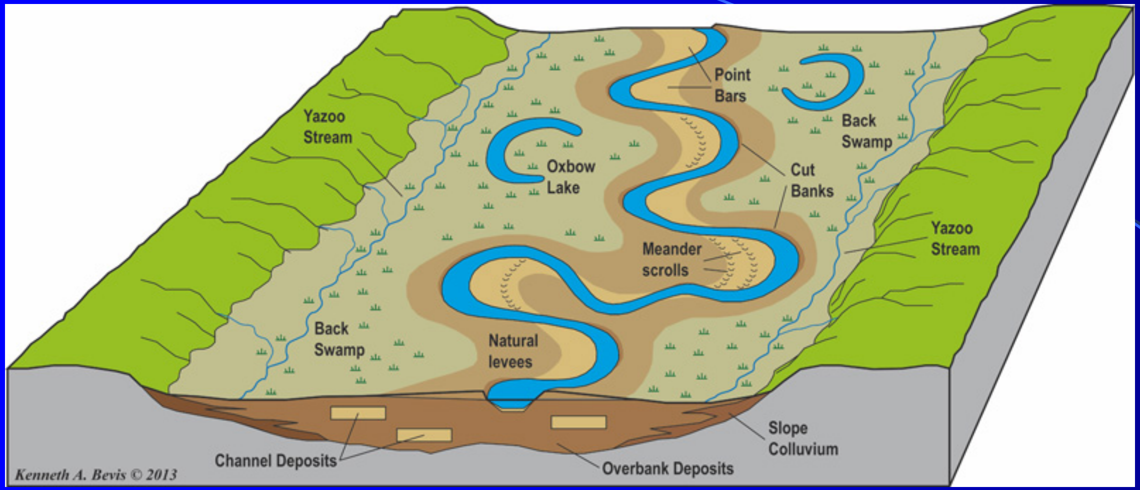


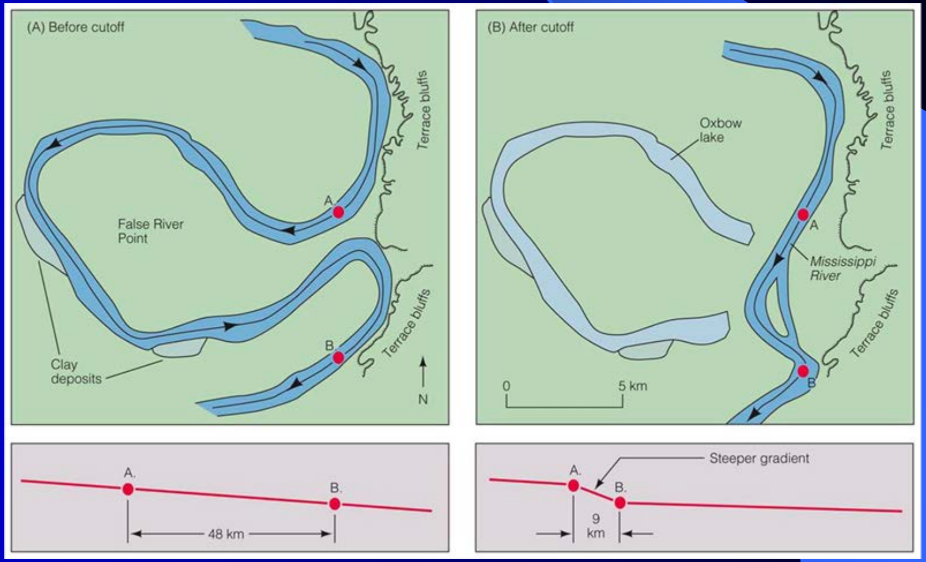
Stream behavior is controlled by 5 basic factors

1. Average channel width and depth
2. Channel gradient
3. Average water velocity
4. Discharge
5. Sediment load

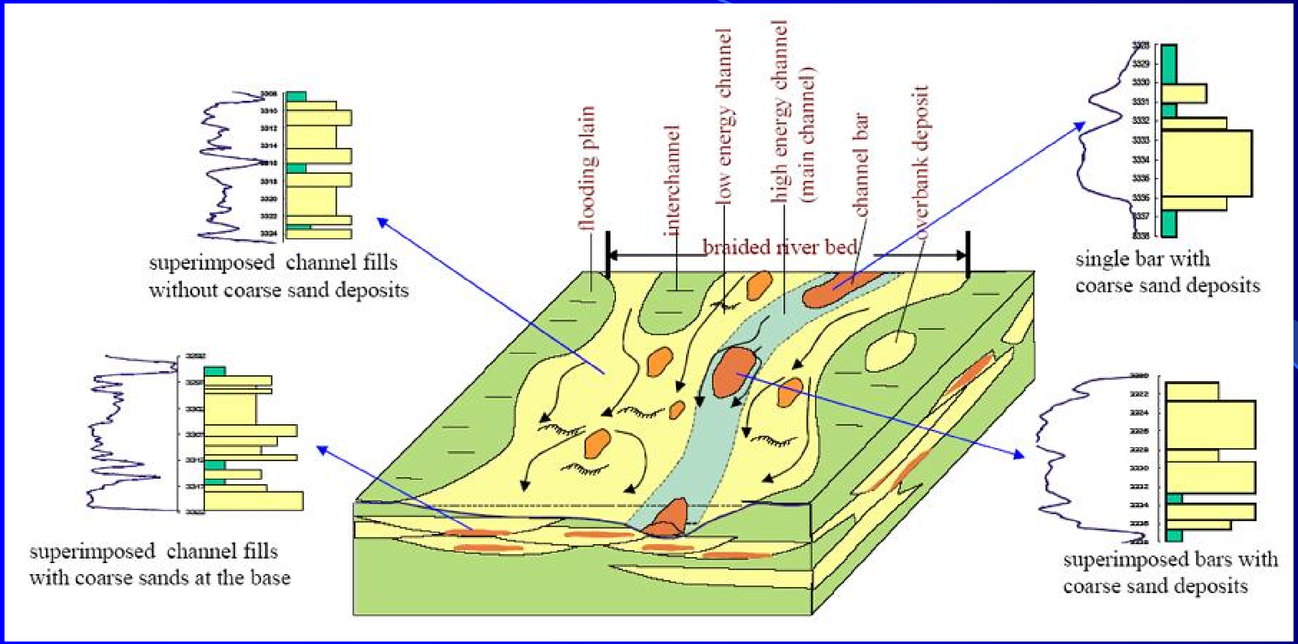
All streams experience a continuous interplay among these factors

Meandering River

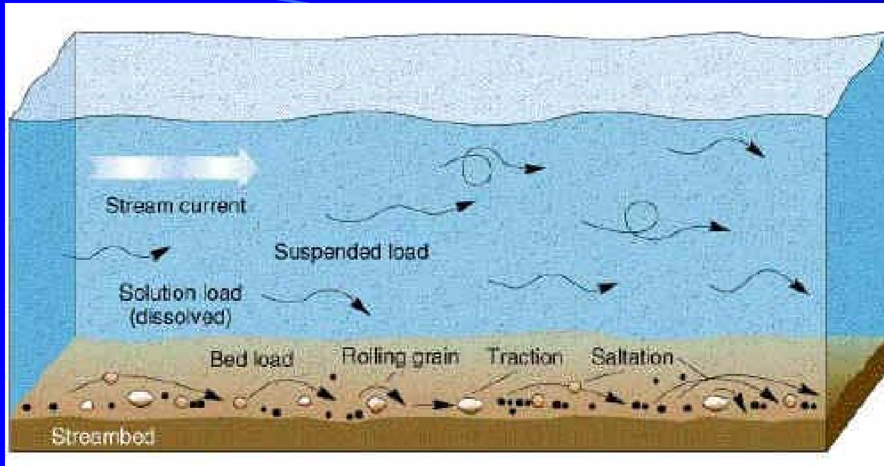


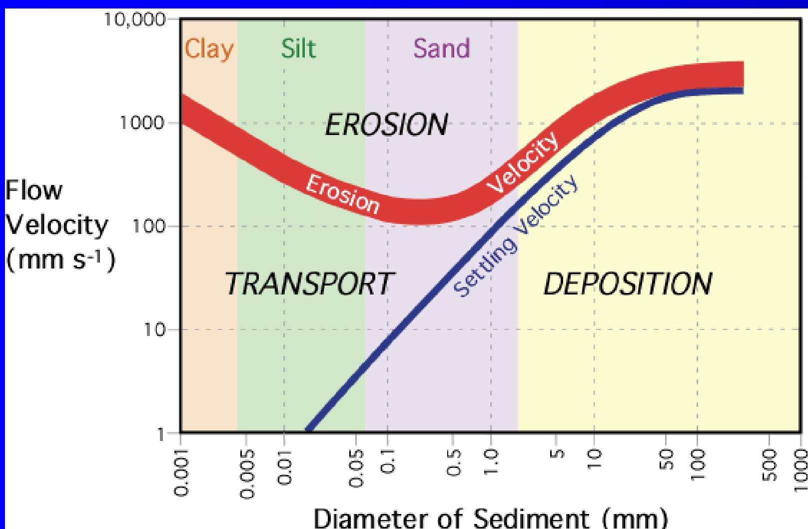


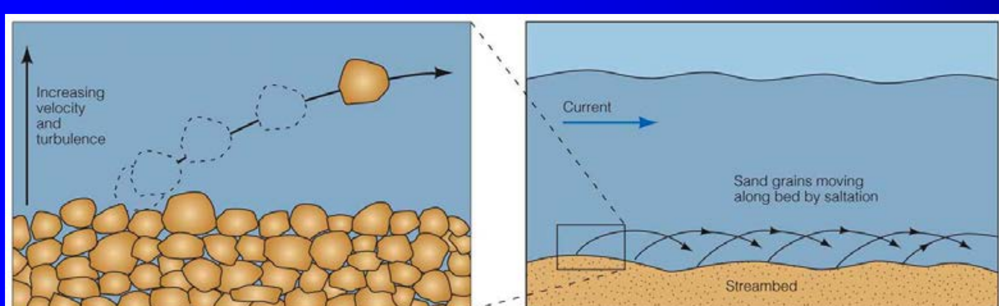
Braided River

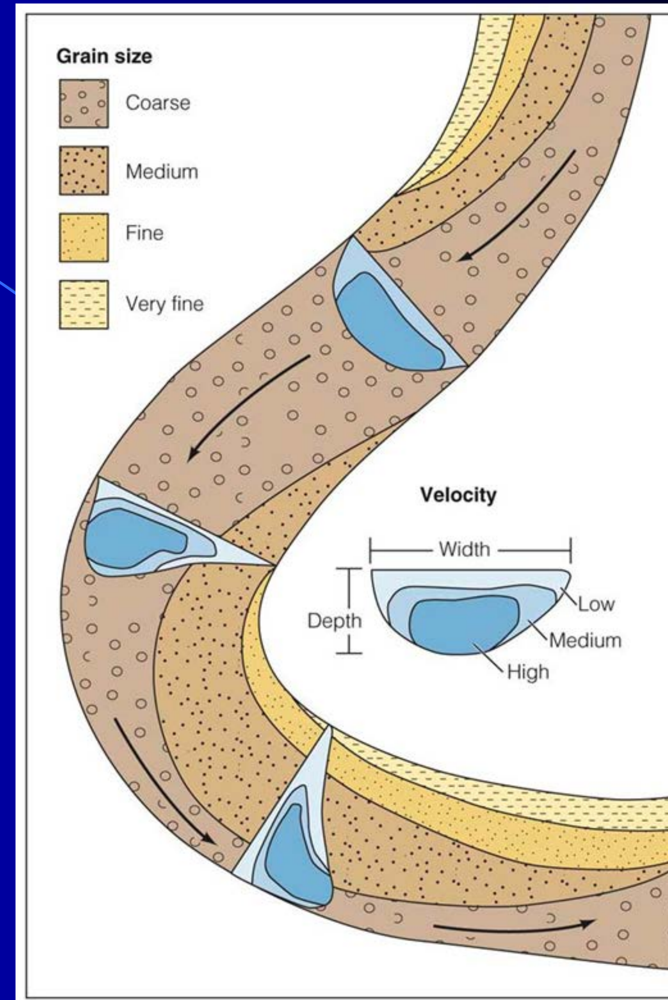


- The size of clasts a stream can transport is mainly related to velocity
- The size of clasts decreases downstream from the rocky headwaters
- A stream's load consists of three parts
  - Bed load
  - 5-50% of total sediment load
  - Move by rolling, sliding, or saltation
  - Suspended load
  - Particles of silt and clay provide the muddy character of many streams
  - Dissolved load
  - Comprised primarily of 7 ions
    - Bicarbonate, calcium, sulfate, chloride, sodium, magnesium, and potassium


Stream current
Suspended load
Solution load
(dissolved)
Bed load
Rolling grain
Traction
Saltation
Streambed


Clay
Silt
Sand
EROSION
Erosion Velocity
Settling Velocity
TRANSPORT
DEPOSITION
Flow
Velocity
(mm s-1)
10,000
1000
100
10
1
0.001
0.005
0.01
0.05
0.1
0.5
1.0
5
10
50
100
500
1000
Diameter of Sediment (mm)

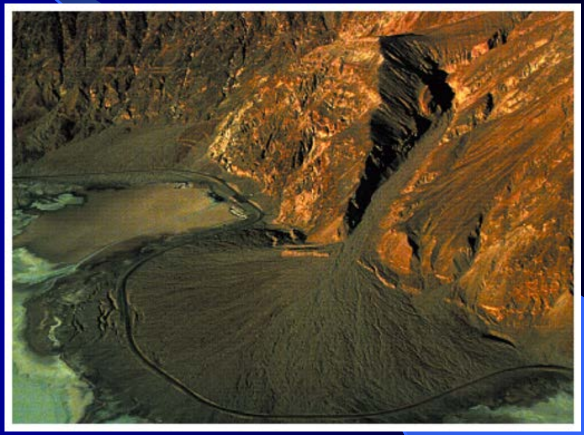

Increasing
velocity
and
turbulence
Current
Sand grains moving
along bed by saltation
Streambed


Grain size
Coarse
Medium
Fine
Very fine
Velocity
Width
Depth
Low
Medium
High

Streams form three major depositional landforms

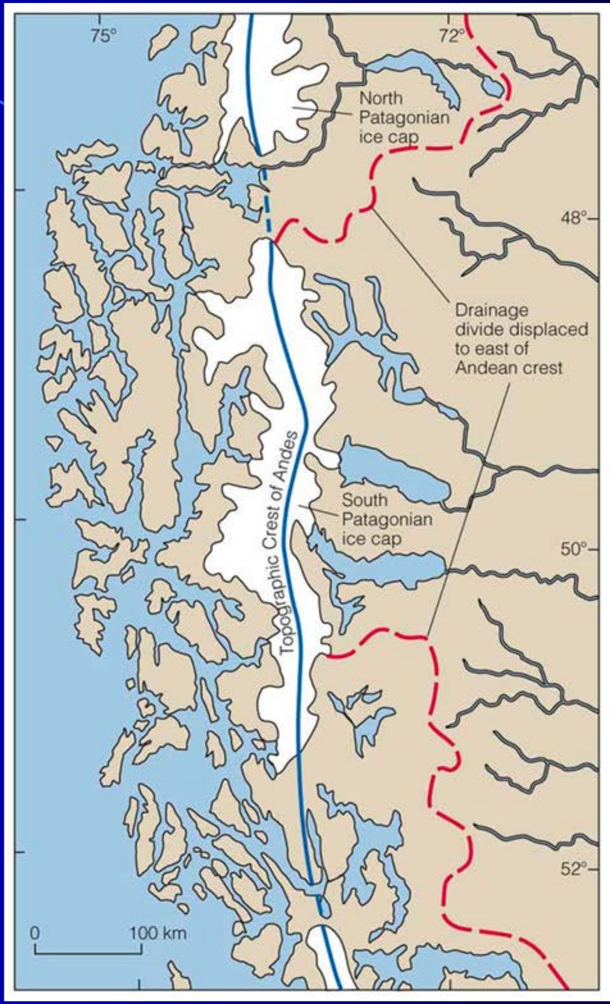
Floodplain: deposition of fine sediment beyond natural levees during a flood

Alluvial fan: a fan-shaped body of alluvium at the base of an upland area

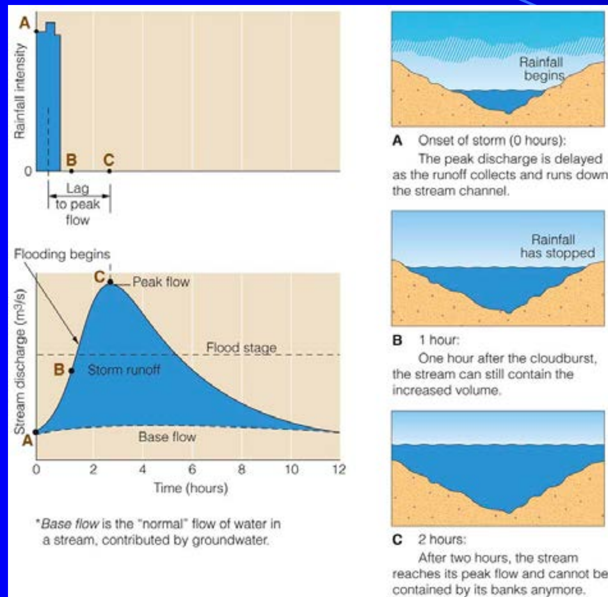


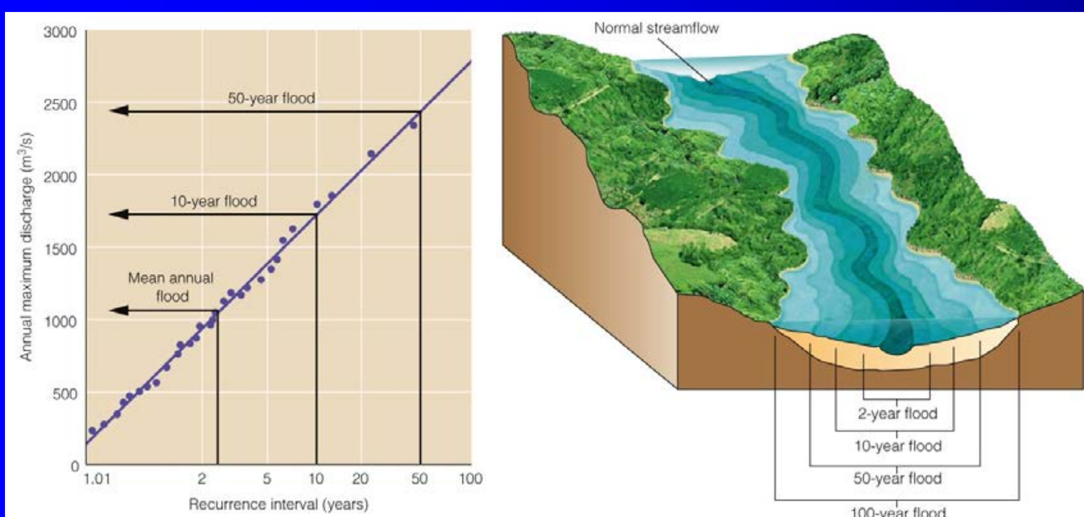
Delta: triangular shaped deposit formed when a stream enters the standing water of a sea or lake

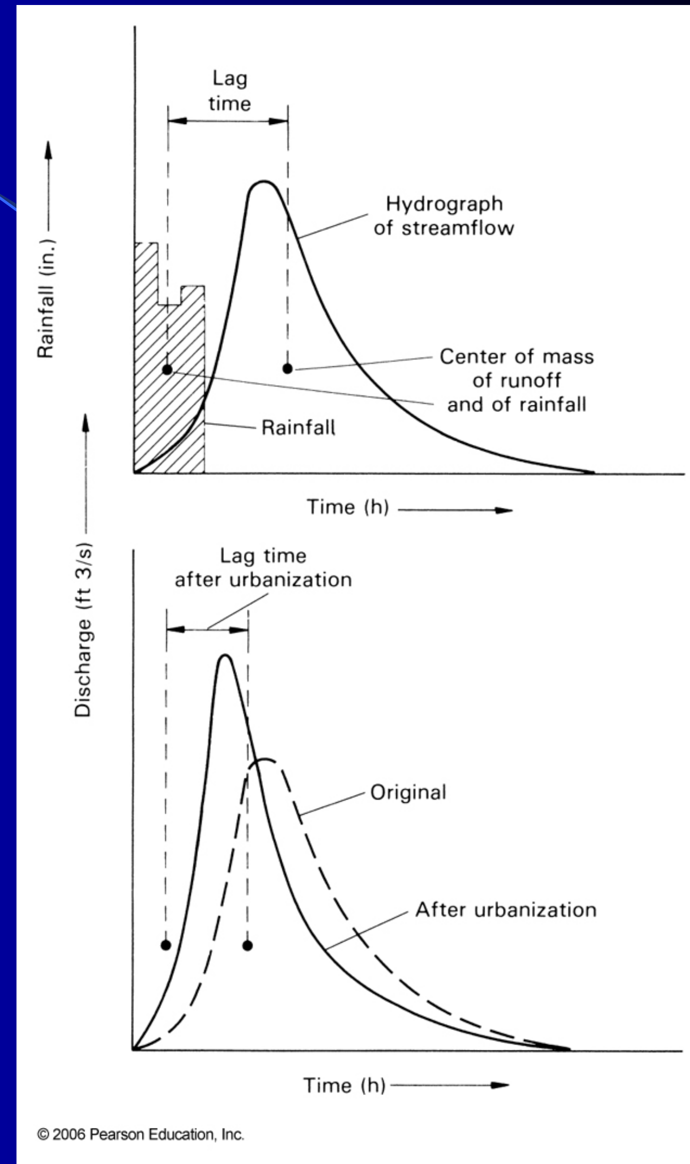
Continental Divides

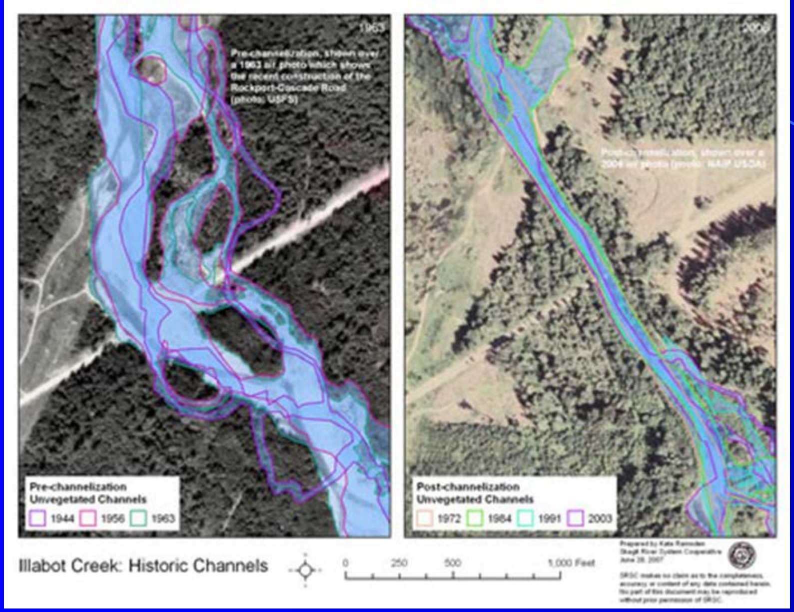


Flooding and Flood control

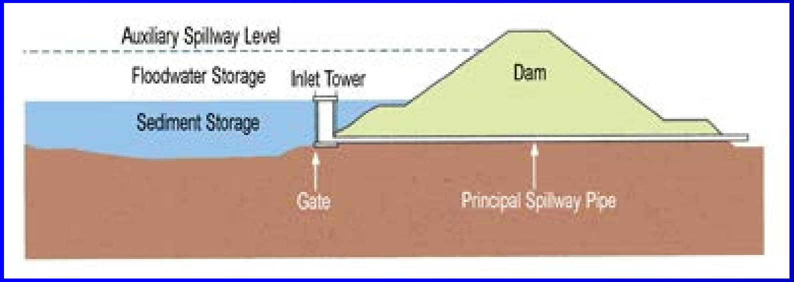






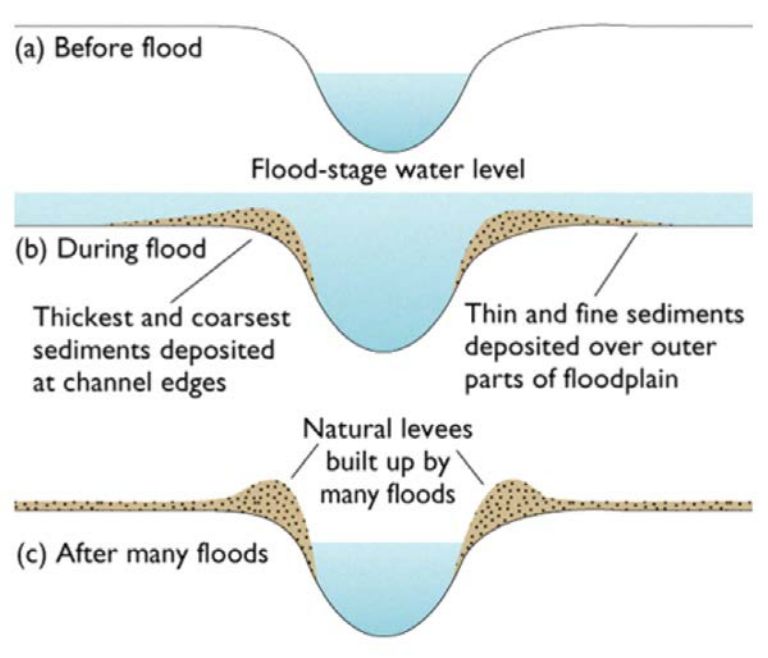


Channelization

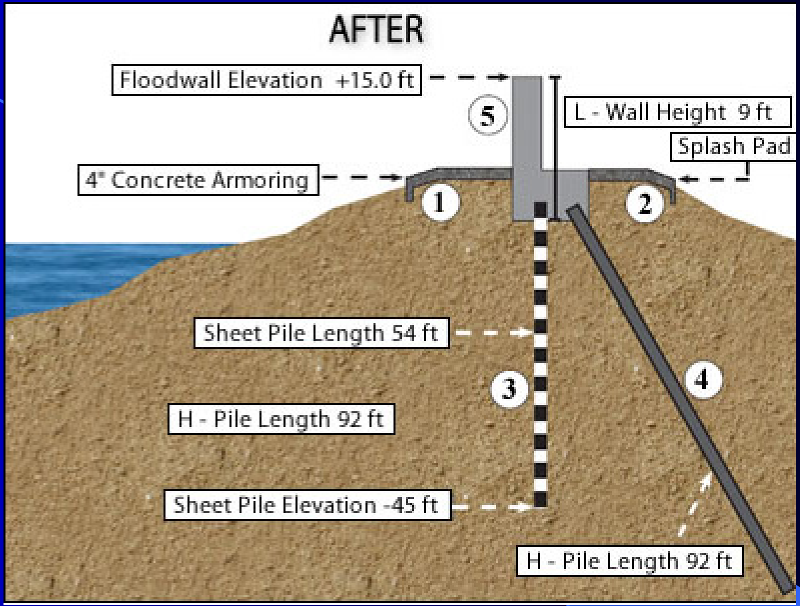


Dams

Levees



(a) Before flood
Flood-stage water level
(b) During flood
Thickest and coarsest sediments deposited at channel edges
Thin and fine sediments deposited over outer parts of floodplain
Natural levees built up by many floods
(c) After many floods



AFTER
Floodwall Elevation +15.0 ft
L - Wall Height 9 ft
Splash Pad
4" Concrete Armoring
Sheet Pile Length 54 ft
H - Pile Length 92 ft
Sheet Pile Elevation -45 ft
H - Pile Length 92 ft
1
2
3
4
5