



# **DYNAMIC PLANET: HYDROLOGY**

## **Division C**

# DYNAMIC PLANET: HYDROLOGY

- This **PowerPoint** contains a plethora of material covered in hydrology.
  - It touches on those topics and definitions that may be covered or needed for the Texas state exam.
- Learn the specifics for each cause, mechanism, equipment use and purpose, topic mentioned, formula, picture, illustration components, etc.
- The student must be able to apply knowledge of one subject in order to answer related topics.
- There will be “hands-on” activities for this test.
- Students must have knowledge of the use of graphs/charts, topographic maps, aerial photographs, and basic calculator skills.
- Reference: Google

# HYDROLOGY

- The study of the distribution and movement of water **on and below** the earth's surface, as well as the impact of human activity on water availability and conditions (National Geographic)

Disciplines include:

Hydrogeology

Geohydrology

Limnology

\*Glaciation

\*Oceanography

\*Not included in this Science Olympiad

# WATER **ON AND BELOW** THE EARTH'S SURFACE

- **Surface**

- Lakes
- Rivers / streams
- Glaciers \*
- Oceans\*

- **Combination**

- Karst
- Wetlands

- **Ground water**

- **Manmade**

\*Not included in this Science Olympiad

# WATER TYPES

- **Fresh**

- **Brackish**

- Besides encroachment, not included in this topic

- **Saline**

- Besides inland lakes, not included in this topic

# WATER CHEMISTRY

- **Pure Water**
  - Chemical composition
  - Properties
- **Dissolved Ion Components**

$K^+$ ,  $Na^+$ ,  $Fe^{2+}$ ,  $SO_4^{2-}$ , etc.
- **Common Solid Components**
  - Sediment Type
    - Soil
    - Rock
    - Minerals
  - Sediment Size

# WATER FLOW

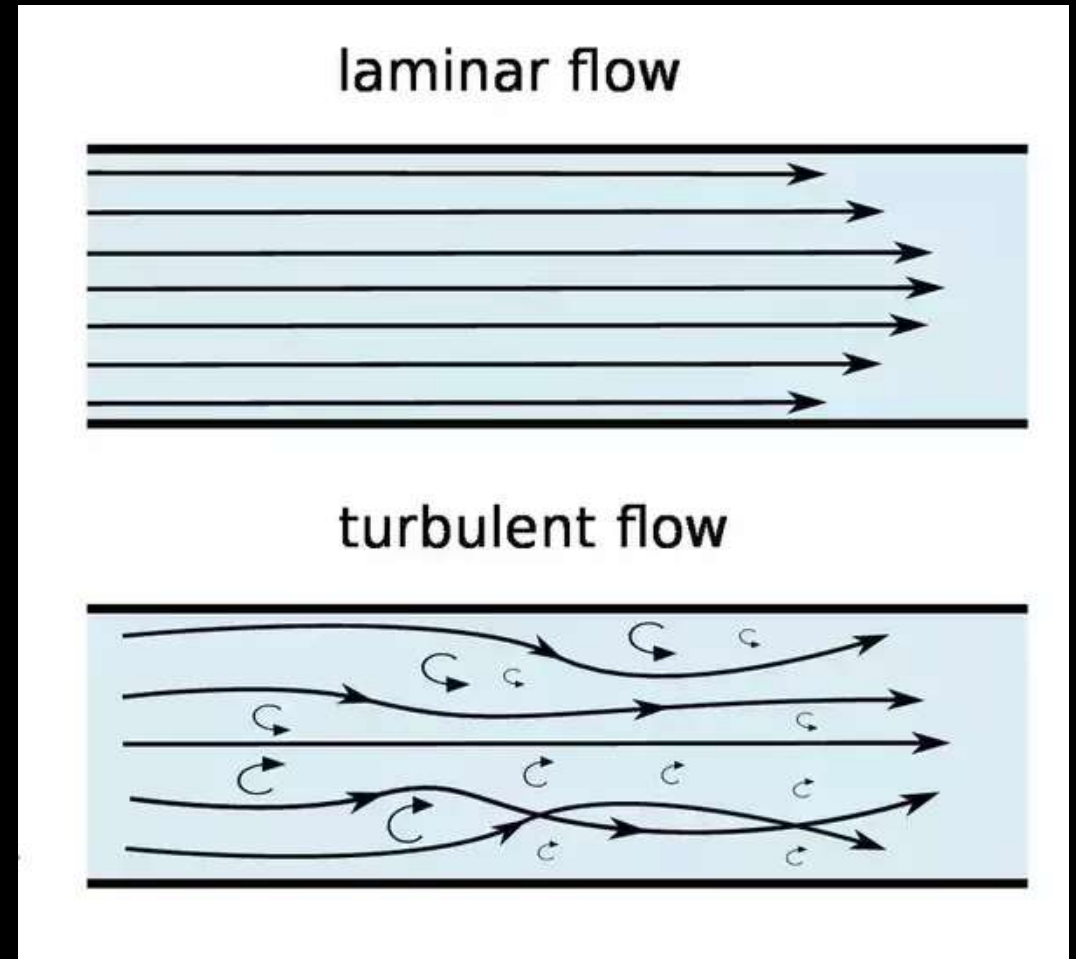
- **Types**

- **Laminar**

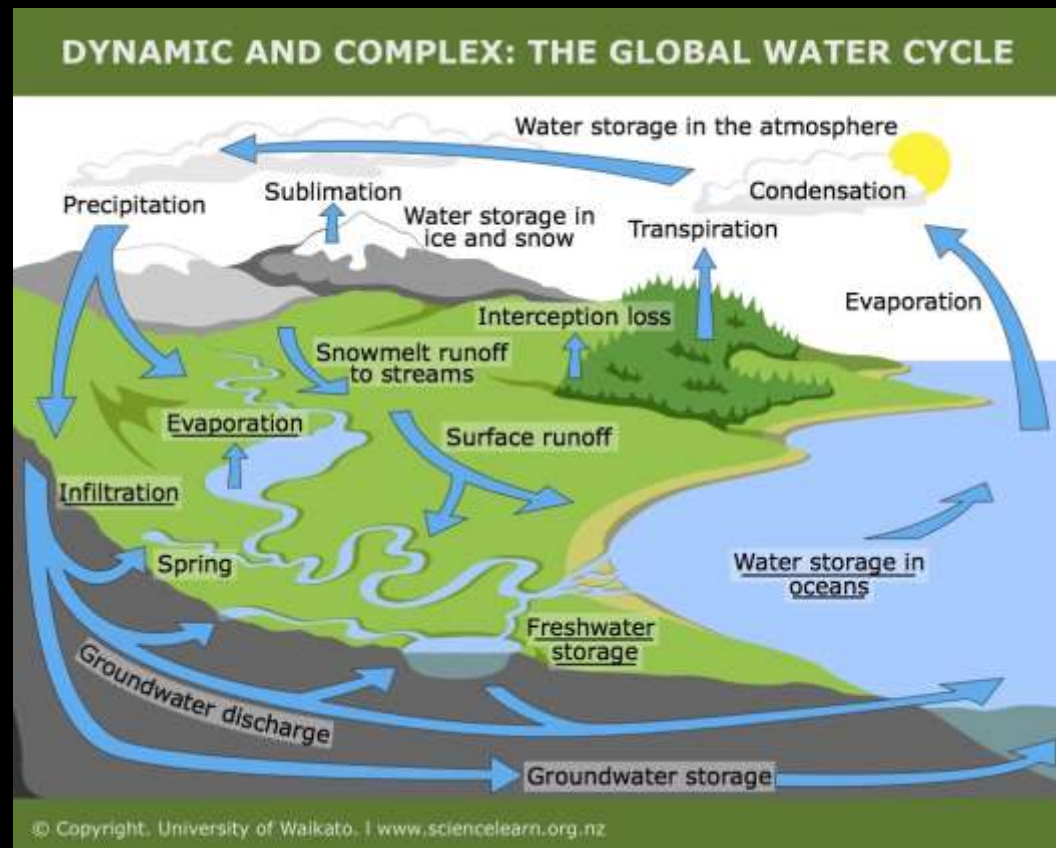
- Molecules flow in parallel paths

- **Turbulent flow**

- Molecules do not follow a parallel path and are irregular



# HYDROLOGIC CYCLE





# COMPONENTS OF HYDROLOGIC CYCLE

- Evaporation
- Transpiration
- Evapotranspiration
- Condensation
- Precipitation
- Advection
- Infiltration
- Surface Runoff
- Interception

# WATER BALANCE / WATER BUDGET

- **Water Balance / Water Budget**
  - The inflow to any water system or area is **equal** to its outflow plus change in storage during a time interval

$$I = O + \Delta S$$

mass inflow – mass outflow  
= change mass storage

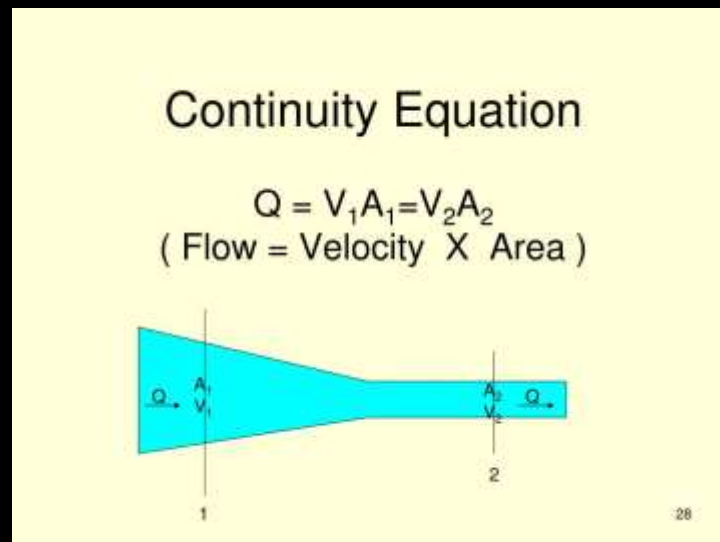
$$V_i - V_o = \Delta S$$

$$P - R - G - E - T = \Delta S$$

P: precipitation, R: surface runoff, G: net groundwater flow out of the catchment, E: evaporation, T: transpiration,  $\Delta S$ : change in storage

# CONTINUITY PRINCIPLE

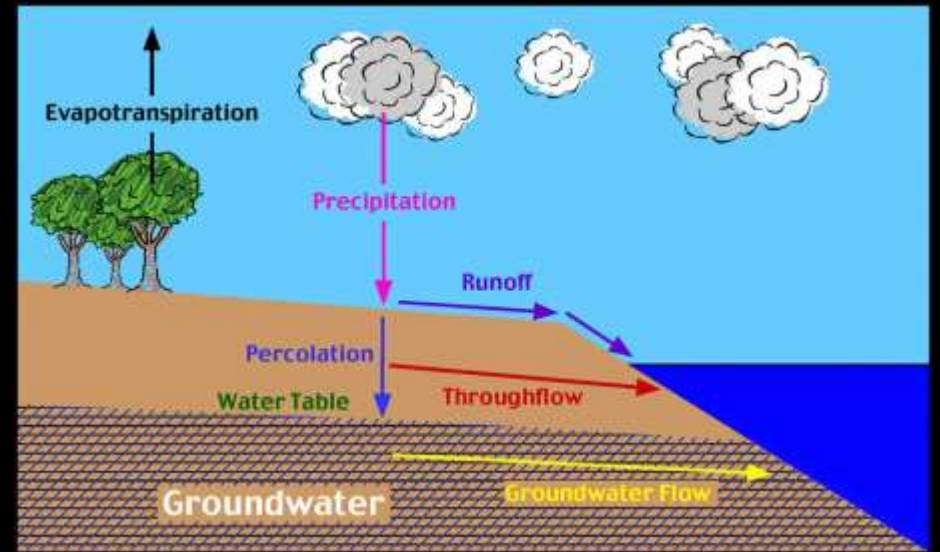
- What flows into a defined volume in a defined time minus what flows out of that volume in that time
- Consequence of the law of mass conservation



# HYDROLOGY: WATER TYPES

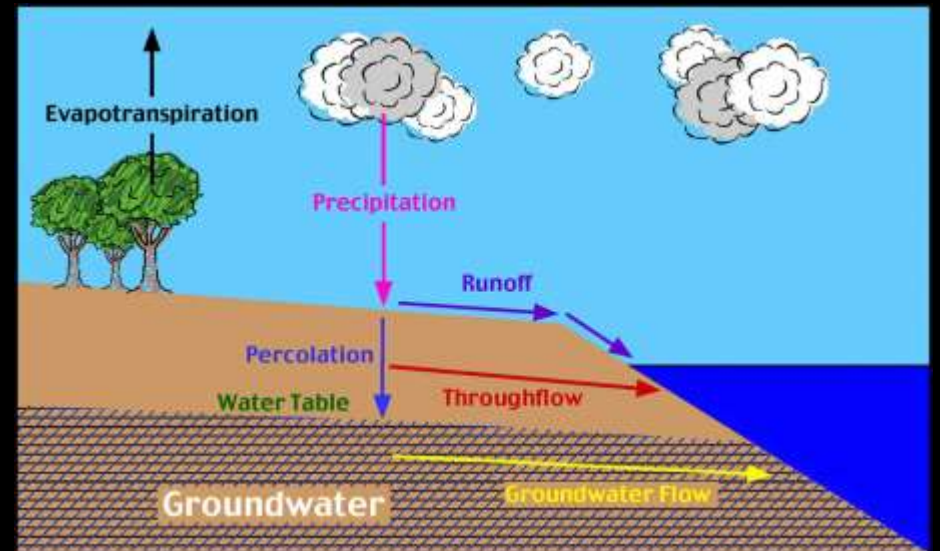
- **Overland flow**

- The tendency of water to flow horizontally across land surfaces when rainfall has exceeded infiltration capacity and depression storage capacity
- Runoff
- Does not include water naturally infiltrated in normal farming operations



# HYDROLOGY: WATER TYPES

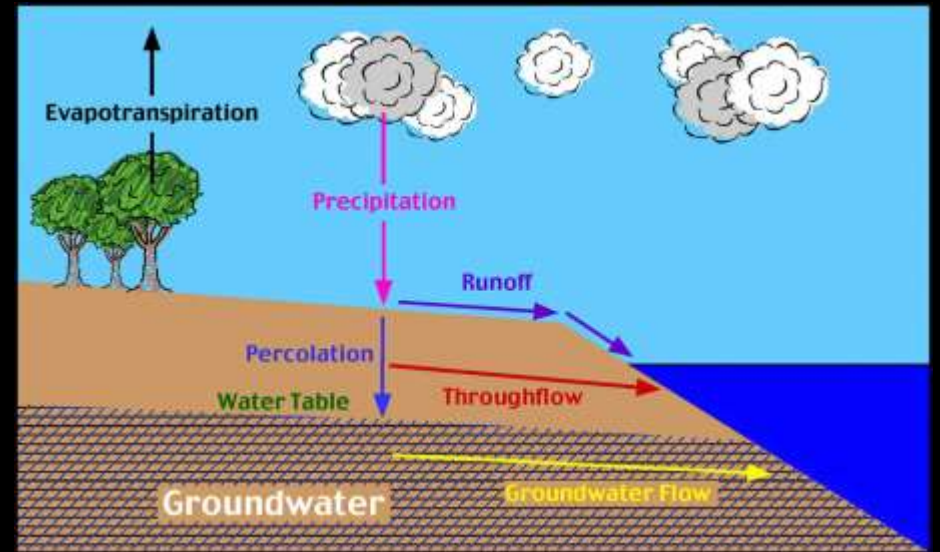
- **Through flow**
- Lateral unsaturated flow of water in the soil zone
- Flow is usually through a highly permeable geologic unit overlying a less permeable one



# HYDROLOGY: WATER TYPES

- **Groundwater flow**

- Part of streamflow that has infiltrated the ground, entered the phreatic zone and has been discharged into a stream channel or spring
- Moves along flow paths from areas of recharge to discharge



# DRAINAGE SYSTEMS

## Morphology

- Comprised of Lake and Rivers Features
- Systems are separated by divides
  - Divides do not always respect the underground path of water

- Watersheds
- Basins
  - Exorheic
  - Crytorheic
  - Endorheic
  - Arheic
- Subbasins
- Tributaries
  - Stream Order
    - Hack
    - Strahler
    - Shreve
  - Type
    - Consequent
    - Subsequent
    - Resequent
    - Obsequent
    - Insequent
- Distributaries



# DRAINAGE SYSTEMS

- Watersheds are classified by land use
  - Urban
  - Agriculture
  - Forest
  - Mountain
  - Desert
  - Coastal
  - Wetlands/Marshes

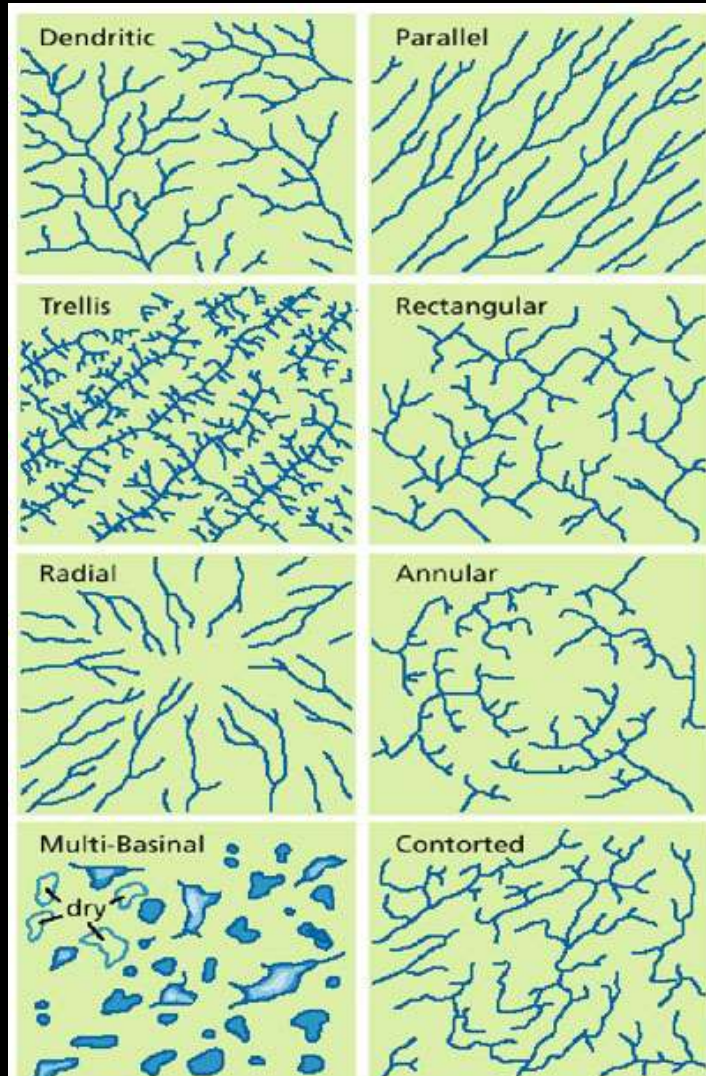


# DRAINAGE SYSTEMS

- **Factors affecting water runoff**
  - Precipitation characteristics
    - Duration
    - Intensity
    - Areal Distribution
  - Shape and size of catchment basin
  - Topography
  - Geologic characteristics
  - Meteorological characteristics
  - Storage Characteristics
  - Reduction of peak flow



# DRAINAGE MORPHOLOGY



## Drainage **Patterns**

Development controlled by structural and / or stratigraphic features

# SURFACE HYDROLOGY



**Lakes**

**Rivers / Streams**

# SURFACE HYDROLOGY: LAKES

## Lake **Formation** Mechanisms:

Prevalence of springs

Faulting

Rifting

Volcanic Action

Glaciation

River Damming

Landslides

Biologic

Manmade

# SURFACE HYDROLOGY: LAKE CHARACTERISTICS

- **Physical Features**
  - Water surface
  - Water color
  - Water temperature
  - Surface
  - Subsurface
  - Turbidity
  - Transparency

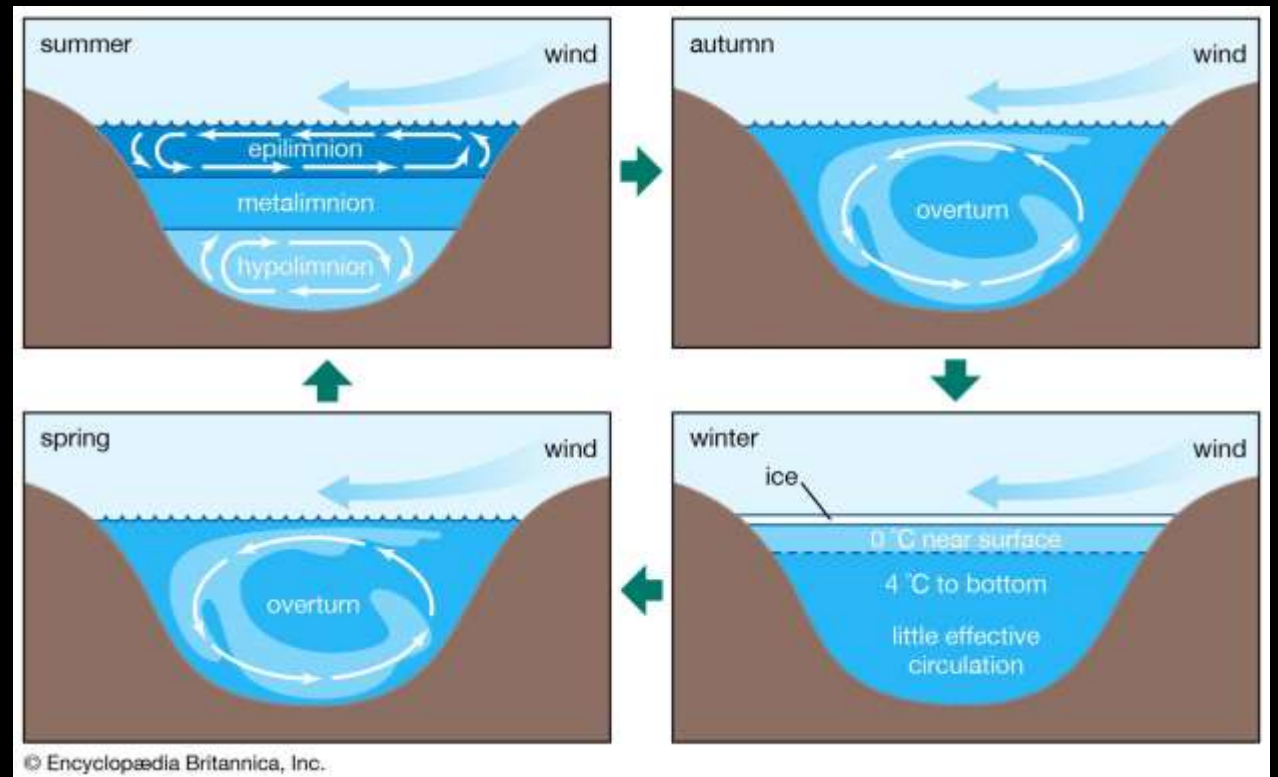
# SURFACE HYDROLOGY: LAKE CHARACTERISTICS

- **Turnover** – Seasonal mixing of the entire water column resulting in the replenishment of dissolved oxygen levels
- **Lake Categories based on turnover**
  - Amictic
  - Cold monomictic
  - Demictic
  - Warm monomictic
  - Oligomictic
  - Polymictic

# SURFACE HYDROLOGY: LAKE CHARACTERISTICS

- **Stratification**

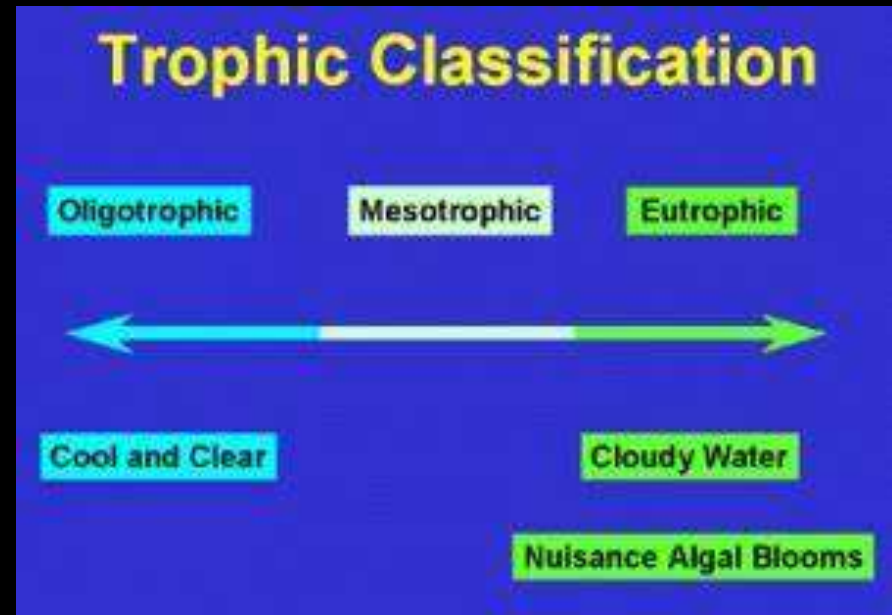
- Seasonal
- Chemical
  - Salinity Difference
  - Oxygen Difference
- Physical
  - Thermal
    - Epilimnion
    - Metalimnion
    - Hypolimnion
    - Thermocline
    - The point of greatest temperature difference (therefore density difference)



# SURFACE HYDROLOGY: LAKE CHARACTERISTICS

- **Trophic State**

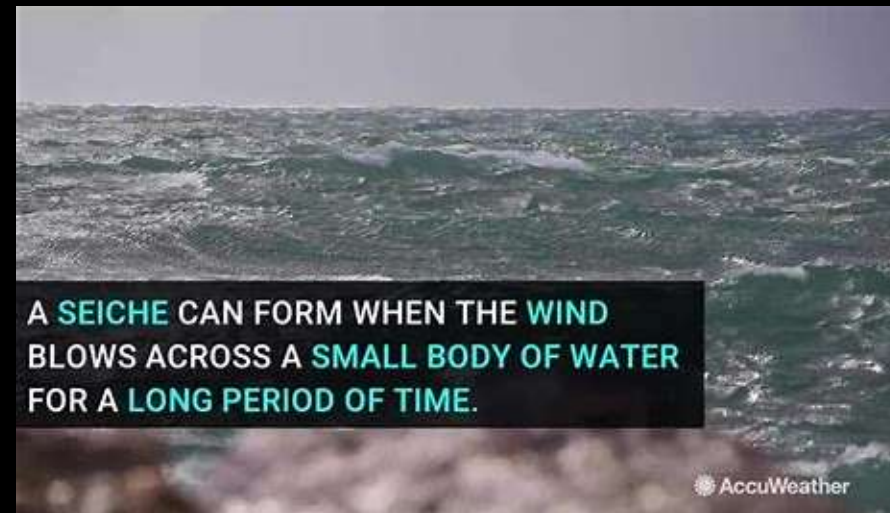
- Oligotrophic
- Mesotrophic
- Eutrophic





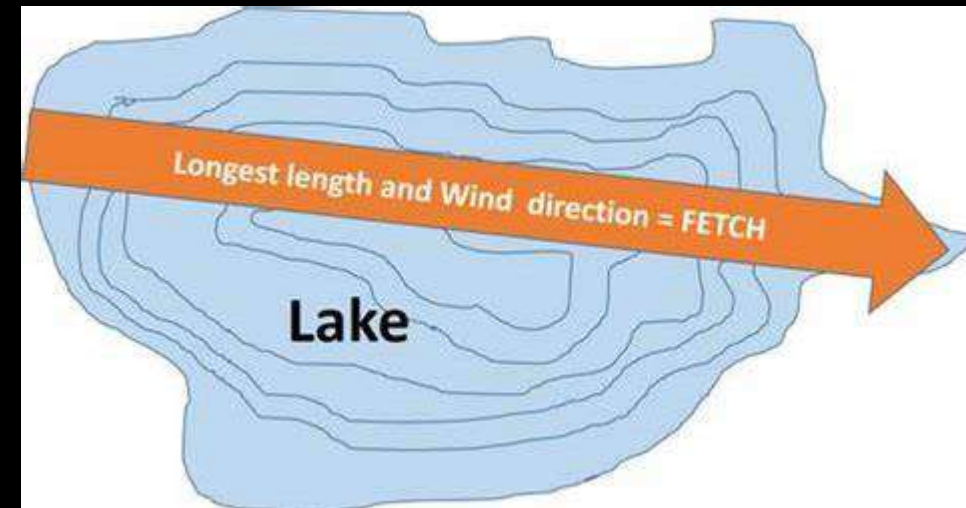
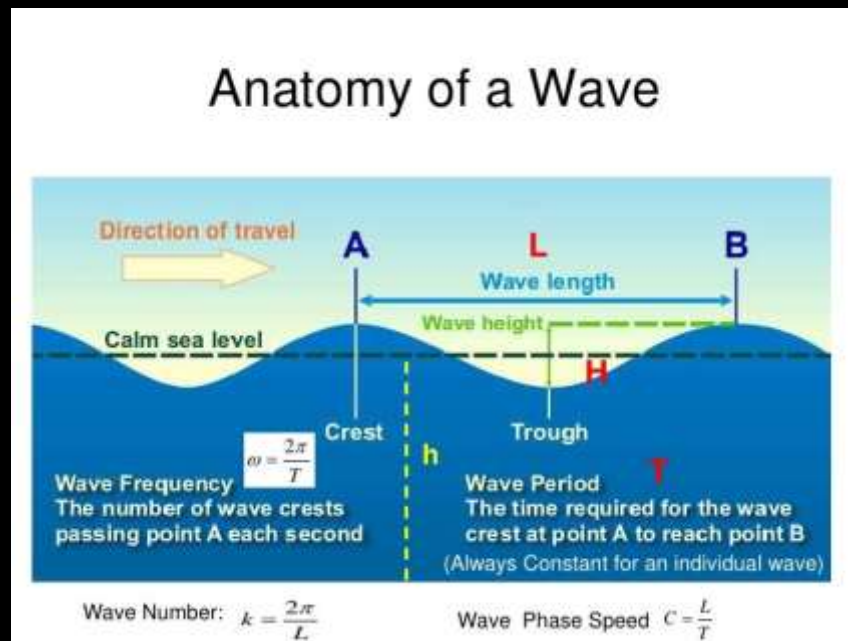
# SURFACE HYDROLOGY: LAKE CHARACTERISTICS

- **Wave Types**
  - **Capillary**
  - **Seiche**



# SURFACE HYDROLOGY: LAKE CHARACTERISTICS

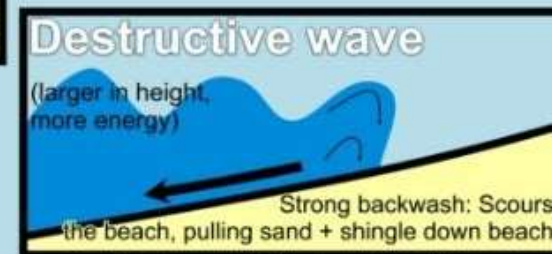
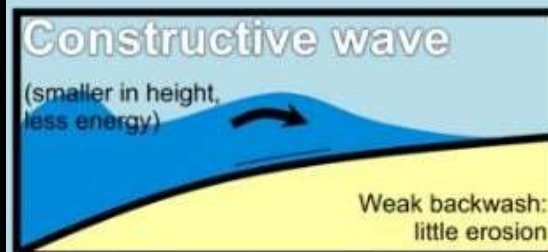
## • Wave Features



# SURFACE HYDROLOGY: LAKE CHARACTERISTICS

## Waves

- There are two main types of waves:
- **Constructive vs Destructive**



Weak swash: little beach building

# SURFACE HYDROLOGY: STREAMS / RIVER CLASSIFICATION

## • YOUTH



### Stage #1: Youth Stage

- \* River cuts a deep V-shaped valley (steep gradient)
- \* Flows in **highlands of mountainous areas** with very little shifting of its channel
- \* **Usually small in size**
- \* Dominated by **erosion** → fast, violent water → little deposition
- \* Little floodplain, but rapids, waterfalls, and boulders may be found

Upper Stage

Middle Stage

Lower Stage

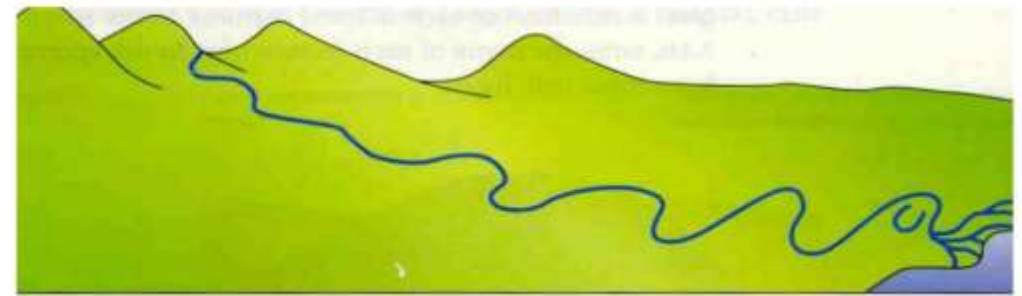


# SURFACE HYDROLOGY: STREAMS / RIVER CLASSIFICATION



## Stage #2: Mature Stage

- \* Receives the waters of many tributaries
- \* River **increases in size** and **slows in velocity** → more deposition
- \* Eroded the bed downward and gotten closer to the base level
- \* Though it is still eroding downwards, it **mainly erodes laterally** to form **meanders** and eventually **flood plains**



Youth

Maturity

Old age

# SURFACE HYDROLOGY: STREAMS / RIVER CLASSIFICATION

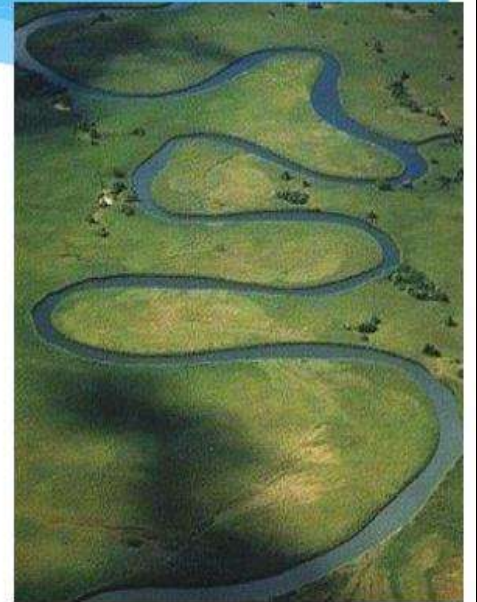
## • OLD AGE



### Stage #3: Old Age stage

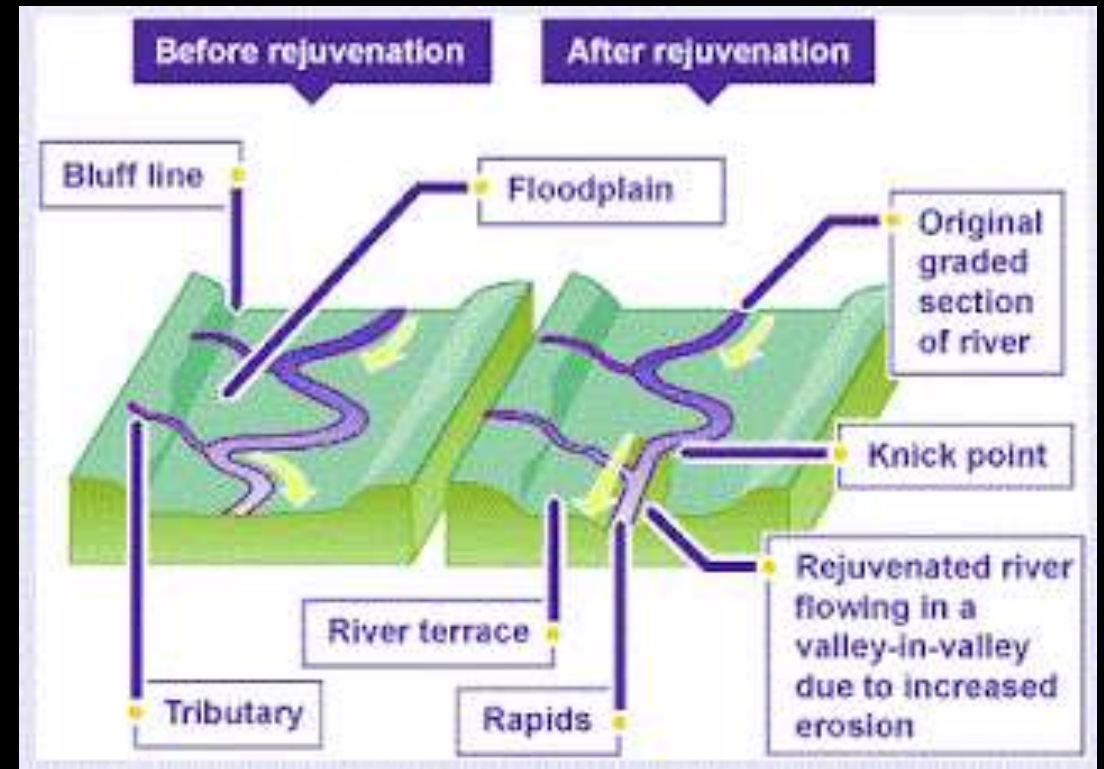
- \* Extensive meandering forms **oxbow lakes**
- \* Its **gradient and speed are very slow,**
- \* Because of this it has lost the power to erode downwards and carry as much sediment load → deposits **rich alluvium** on the floodplain

<http://www.igeography.ie/mature-stage.html>



# SURFACE HYDROLOGY: STREAMS / RIVER CLASSIFICATION

- REJUVENATED



# SURFACE HYDROLOGY: STREAMS / RIVER WATER SOURCE

- **Type**

- Effluent streams

- A stream which gains water from the saturated zone or groundwater

- Influent streams

- A stream that is found primarily in arid regions that loses water due to evaporation, groundwater, vegetation, etc.

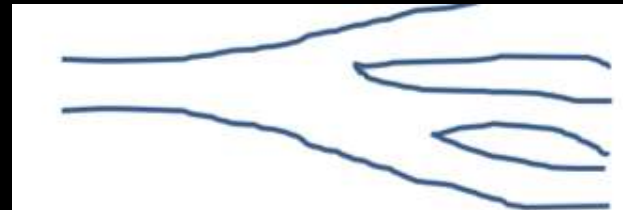


# SURFACE HYDROLOGY: STREAMS / RIVER WATER PATTERNS

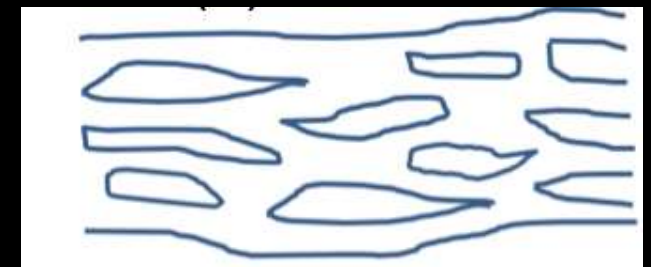
**Straight / Single Channel**



**Meandering / Wandering**



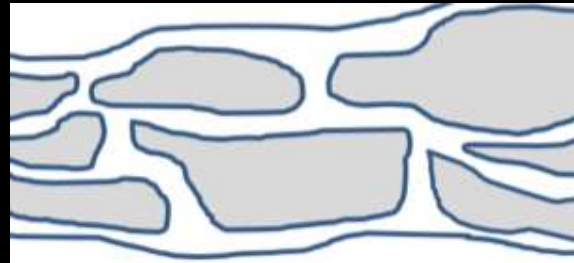
**Braided (Multi-channel)**



# SURFACE HYDROLOGY: STREAMS / RIVER WATER PATTERNS

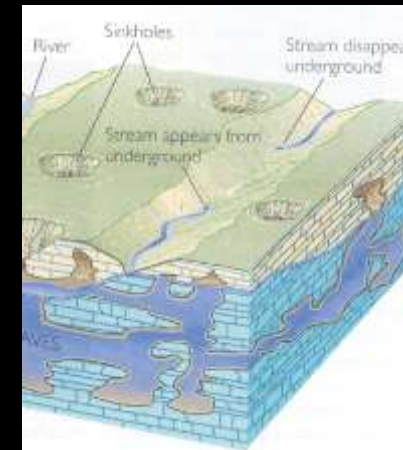
## Anastomosing

- Multiple interconnecting channels that enclose flood basins and consist of semi-permanent channels separated by flood plains rather than channel bars



## Discontinuous

- Streams that disappear then reappear within the same channel basin

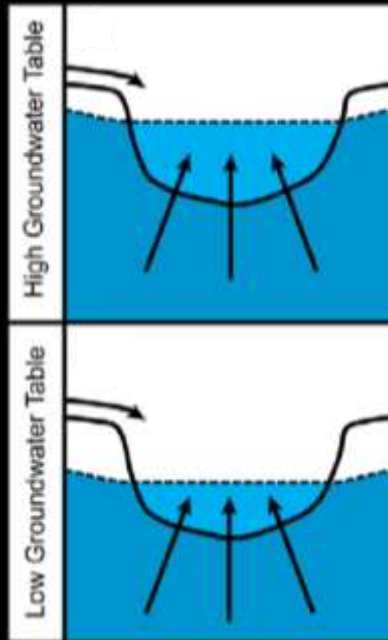


discontinuous



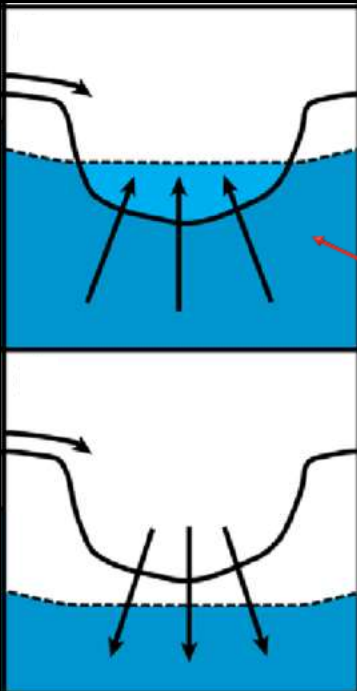
# SURFACE HYDROLOGY: STREAMS / RIVER WATER BEHAVIOR

Perennial (Year Round)



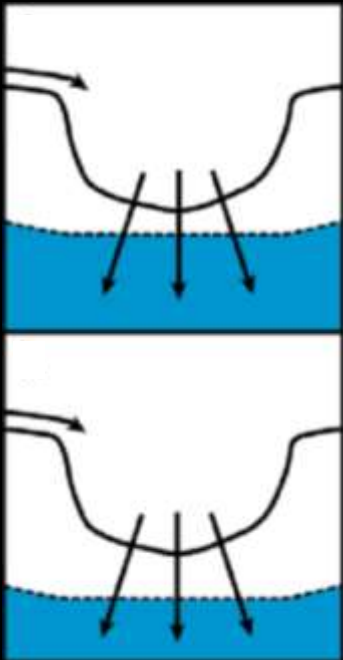
# SURFACE HYDROLOGY: STREAMS / RIVER WATER BEHAVIOR

Intermittent (Temporary)



# SURFACE HYDROLOGY: STREAMS / RIVER WATER BEHAVIOR

**Ephemeral** (Temporary)



# SURFACE HYDROLOGY: STREAMS / RIVER TRANSPORT CHARACTERISTICS

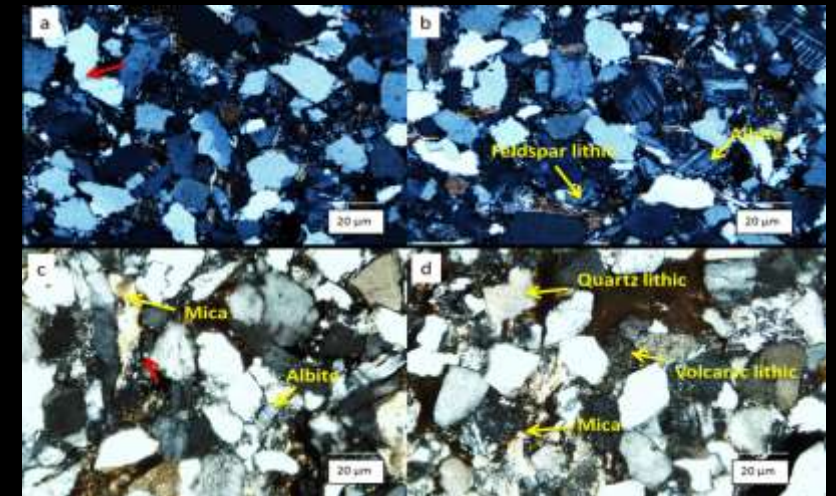
- Stream Competence
  - The ability of a stream to transport a particular size of particle



Clastic Sedimentary Rocks		
Texture (grain size)	Sediment Name	Rock Name
Coarse (over 2 mm)	Gravel (rounded fragments)	Conglomerate
	Gravel (angular fragments)	Breccia
Medium (1/16 to 2 mm)	Sand	Sandstone
Fine (1/16 to 1/256 mm)	Mud	Siltstone
	Mud	Shale

Chemical Sedimentary Rocks		
Composition	Texture (grain size)	Rock Name
Calcite	fine to coarse crystalline	Crystalline Limestone
	Shells and cemented shell fragments	Travertine
	Shells and shell fragments cemented with calcite cement	Cocquina
Quartz	Microscopic shells and clay	Fossiliferous Limestone
	Very fine crystalline	Chalk
Gypsum	Fine to coarse crystalline	Chert (light color) Flint (dark color)
Halite	Fine to coarse crystalline	Rock Gypsum
Altered plant fragments	Fine to coarse crystalline	Rock Salt
	Fine-grained organic matter	Bituminous Coal



Thin section - Sandstone

# SURFACE HYDROLOGY: STREAMS / RIVER TRANSPORT CHARACTERISTICS

## Stream Load

- ▣ The materials other than water carried by a stream are called the **stream load**.
  - The **dissolved load** is mineral matter transported in liquid solution.
  - The **suspended load** consists of particles of fine sand and silt.
    - The speed of the water keeps these particles suspended, so they don't sink to the bottom.
  - The **bed load** is made of larger, coarser materials such as coarse sand, gravel, and pebbles.



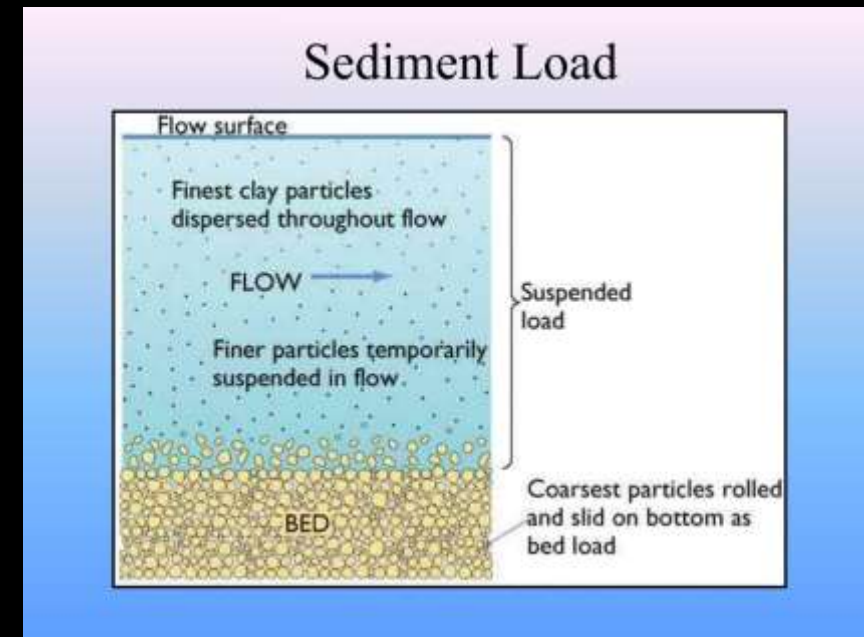
# SURFACE HYDROLOGY: STREAMS / RIVER TRANSPORT CHARACTERISTICS

- **What are the effects** of sediments in water during:
  - Erosion
  - Deposition
  - Chemical Weathering
- All dependent on stream velocity



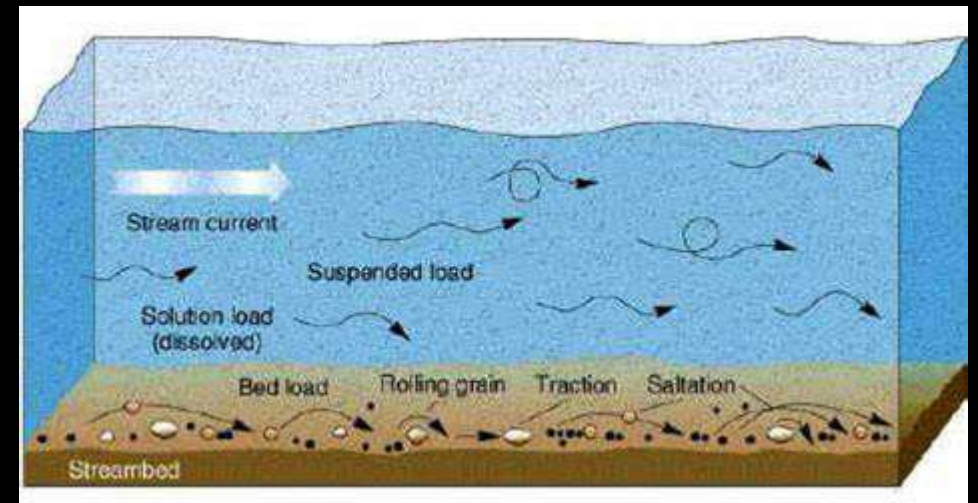
# SURFACE HYDROLOGY: STREAMS / RIVER TRANSPORT CHARACTERISTICS

- Stream Capacity
  - A measure of the total **solid** matter a stream can carry
    - AKA solid load
  - Increases with an increase of stream velocity



# SURFACE HYDROLOGY: STREAMS / RIVER TRANSPORT CHARACTERISTICS

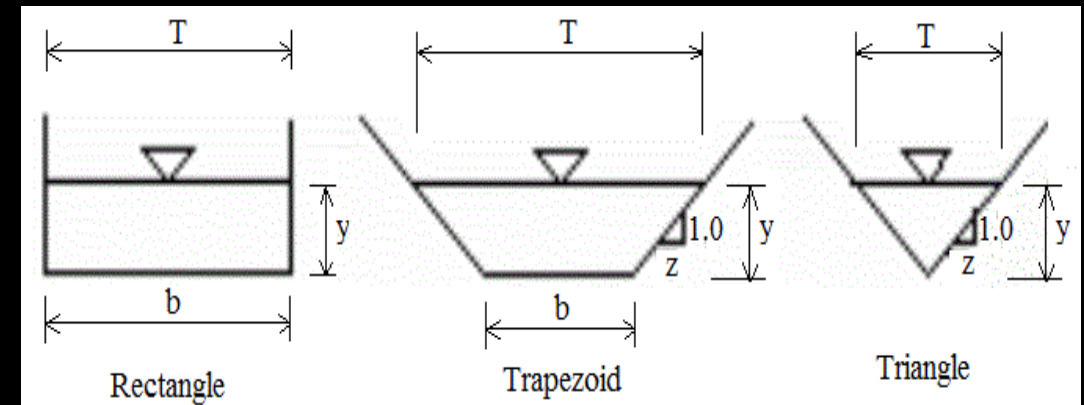
- Stream Competence
  - Maximum size of particles that can be carried as **suspended** load
- Increases with increasing velocity (discharge)



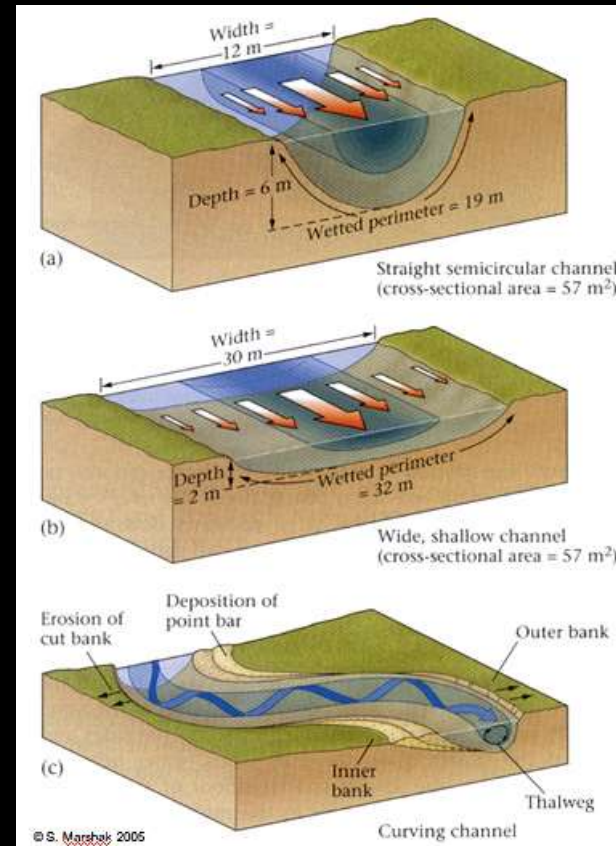
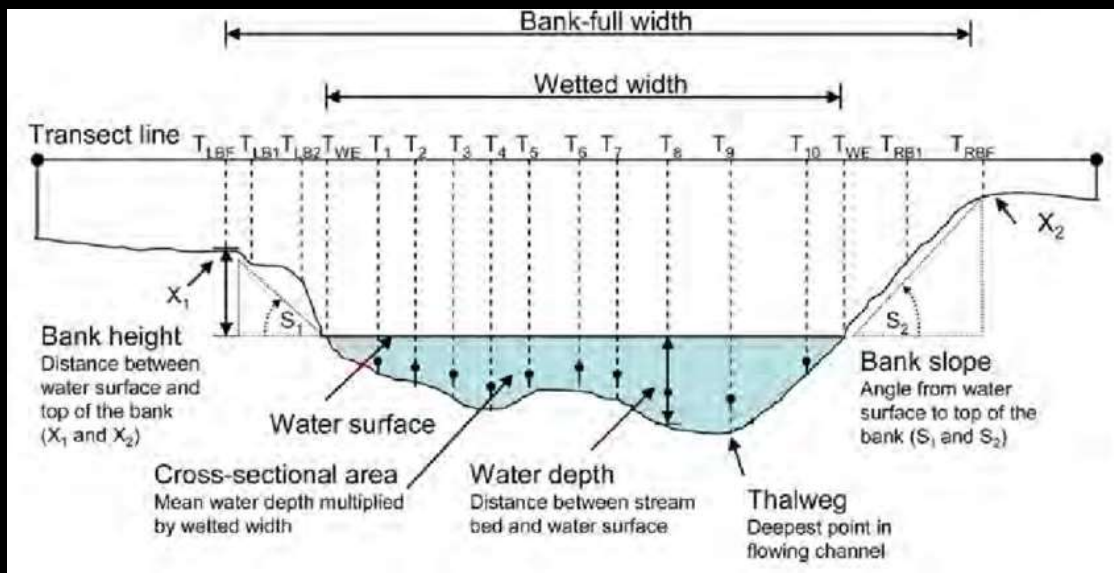
# SURFACE HYDROLOGY: STREAMS / RIVER FEATURES

## • Channel Shape

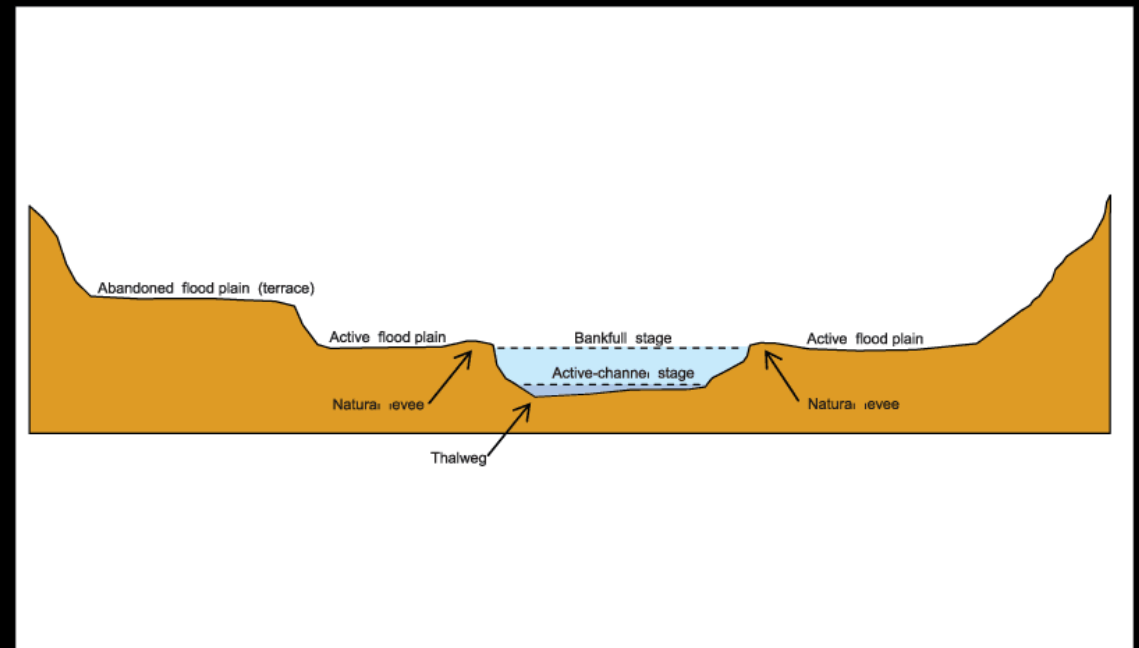
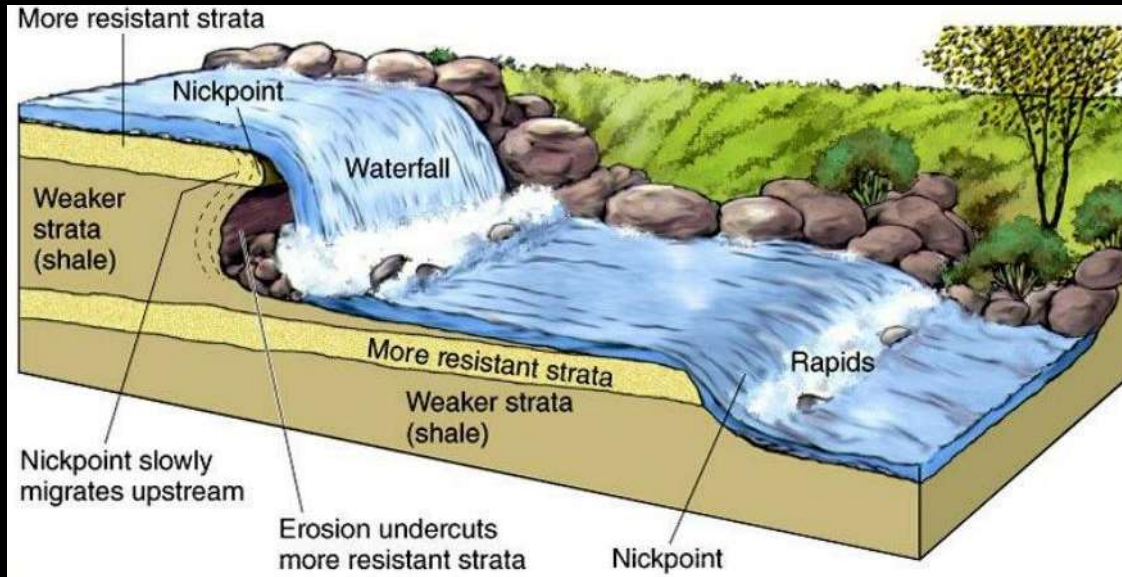
- **Depends on**
  - Velocity of flow
  - Stream classification
  - Type of terrain
  - Tectonic activity in the area
  - Environmental factors



# SURFACE HYDROLOGY: STREAMS / RIVER FEATURES

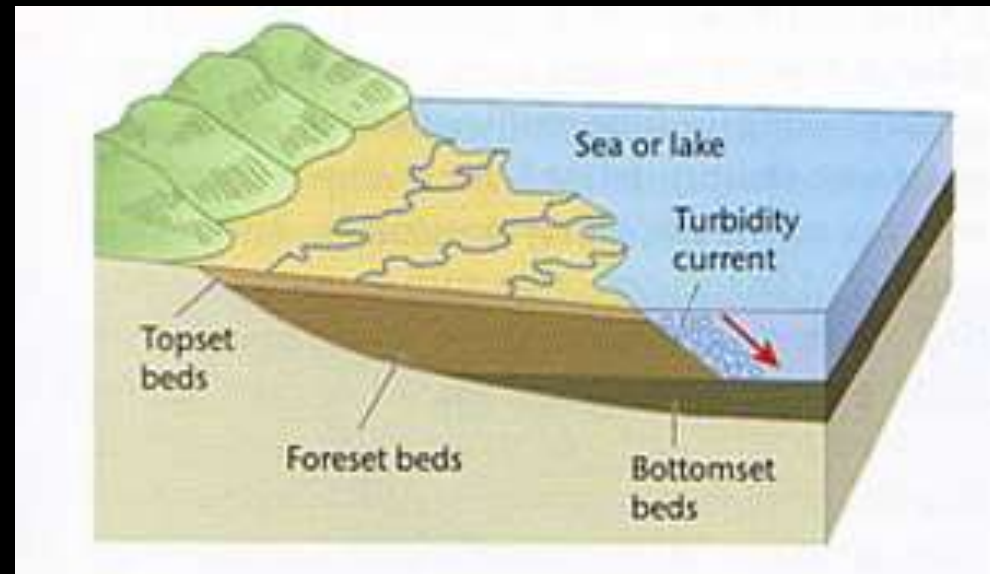


# SURFACE HYDROLOGY: STREAMS / RIVER FEATURES



# SURFACE HYDROLOGY: STREAMS / RIVER FEATURES

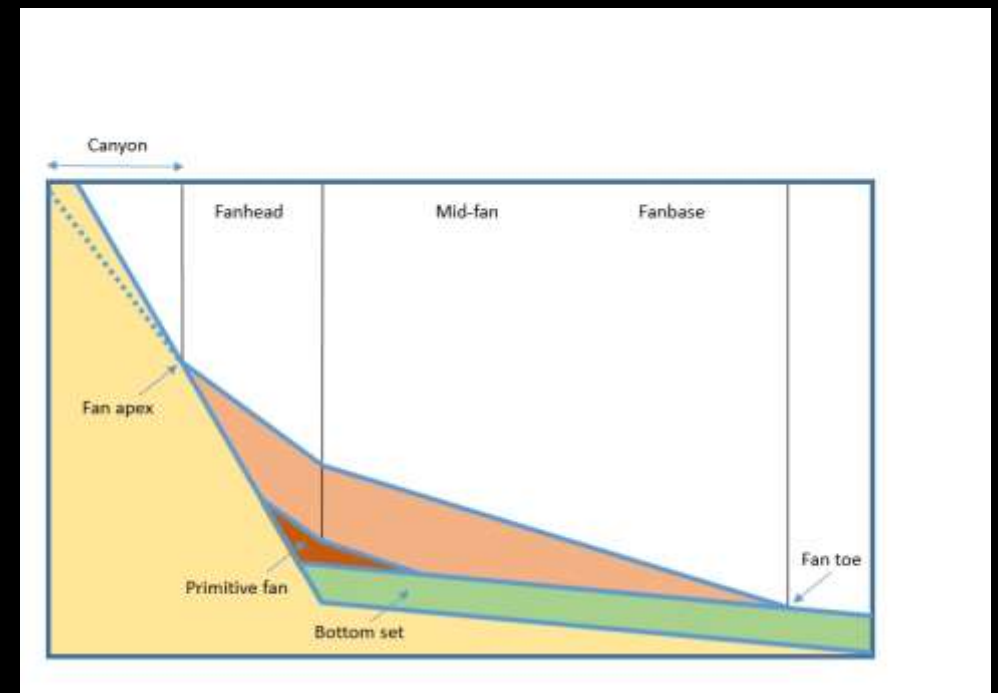
- Deltas



Sediment bedding

# SURFACE HYDROLOGY: STREAMS / RIVER FEATURES

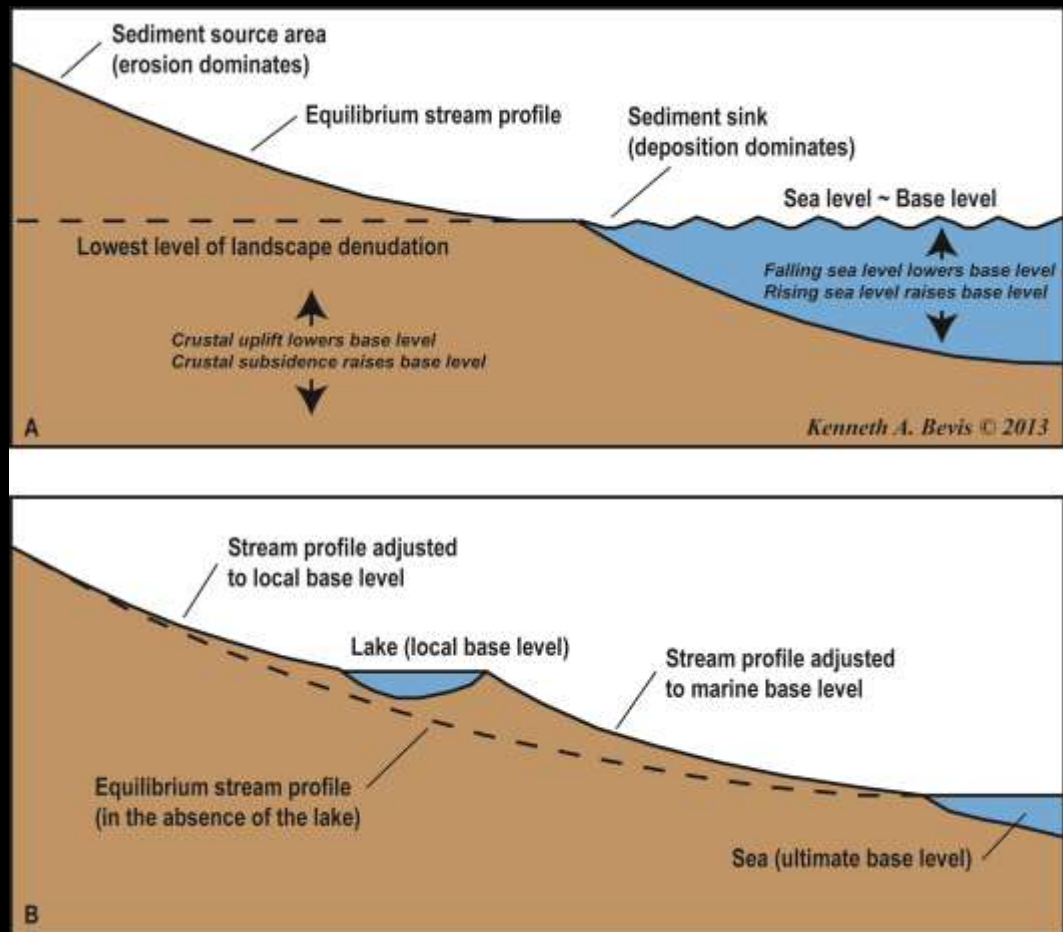
- Alluvial Fans



Sediment bedding

# SURFACE HYDROLOGY: STREAMS / RIVER FEATURES

- **Base Level**
  - Lowest point to which a stream can erode
    - Raising base level increases deposition
    - Lowering base level increases erosion



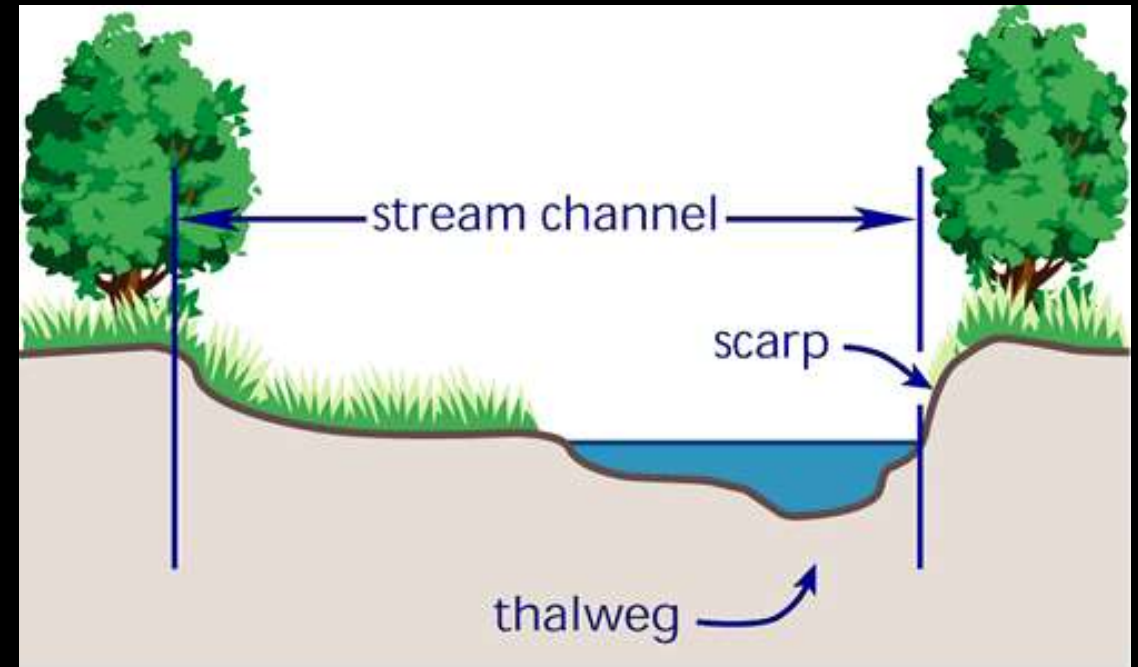


# SURFACE HYDROLOGY: STREAMS / RIVER FEATURES

## • Thalweg

### ❖ FORMATION

- The thalweg in a river (which is the line of the deepest part of the channel where there is the highest velocity flow) is not straight even if the channel banks are straight and parallel. It will follow a sinuous path moving from side to side along the length of the channel. In any part of the river, the bank closest to the thalweg has relatively fast flowing water against it while the opposite bank has slower flowing water alongside



# SURFACE HYDROLOGY: STREAMS / RIVER FLOW MONITORING

- **Purpose:**
  - Water Quality
  - Water Use
  - Catastrophic Events
    - Flooding
  - Environmental Impact
    - Animal Use
    - Human Use



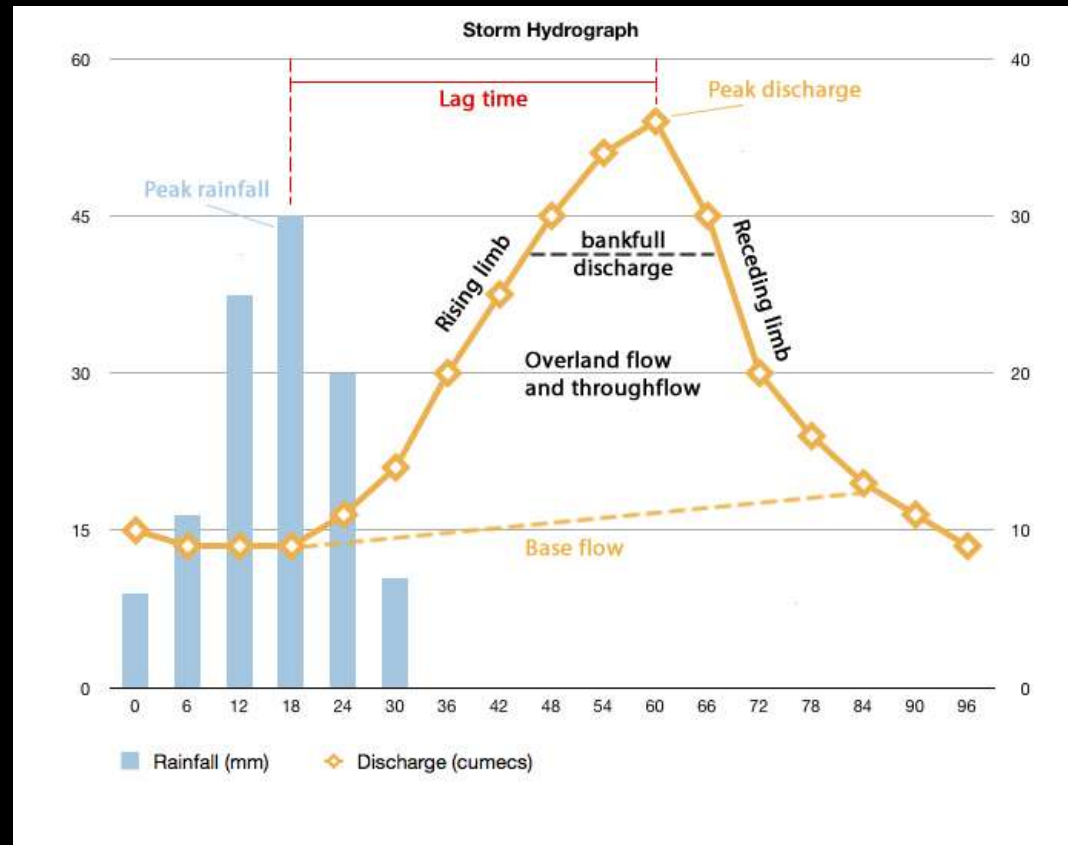
# SURFACE HYDROLOGY: STREAMS / RIVER FLOW MONITORING

- **Equipment**

- **Hydroacoustic**
  - **Acoustic Doppler Velocimeter (ADV)**
  - **Acoustic Doppler Current Profiler (ADCP)**
- **Gages**
  - **Staff**
  - **Float**
  - **Wire weight**
- **Flow meters**
- **Hydrographs**



# SURFACE HYDROLOGY: STREAMS / RIVER FLOW MONITORING



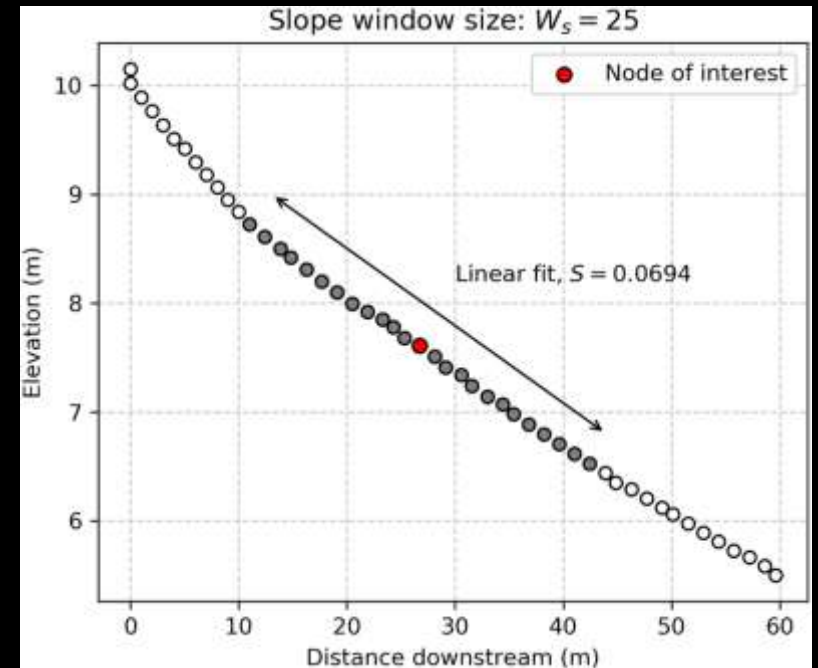
# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

- **Depends on:**
  - Channel Shape
  - Channel Gradient
  - Amount of Vegetation
    - Sinuosity
  - Precipitation Amounts
- Groundwater Contributions
  - Man-made Interference

# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

## • Channel Gradient

- The change in slope of a river /stream over a known distance (measured in ft/mile or m/km usually)
- Channel Gradient =  $\frac{\text{Elevation Point A} - \text{Elevation Point B}}{\text{Horizontal Distance Point A to Point B}}$



# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

- Amount of Riparian Vegetation

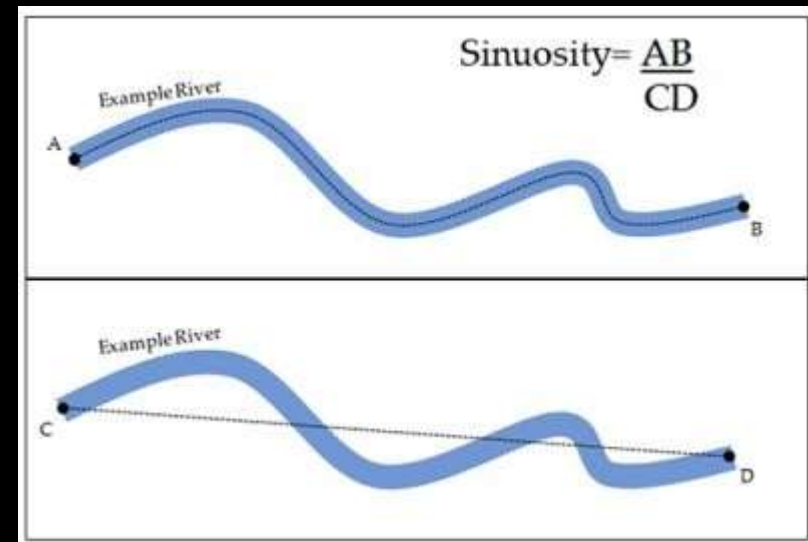


Increase in vegetation decreases velocity of fluvial feature

# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

- **Sinuosity**

- Ratio of the stream length to the valley length
- The greater the sinuosity the less the velocity (normal conditions)
- The greater the sinuosity the older the stream morphology





# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

- Precipitation Amounts
  - The greater the amount of precipitation the higher
    - Stream velocity
    - Stream capacity
    - Stream erosion
      - Horizontal (lateral)
      - Vertical (downcutting)



# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

## Flooding

- Overflow of water from a body of water or channel onto land that is normally semi-dry (marshes) or dry due to atmospheric conditions that lead to heavy rain or rapid melting of snow and ice



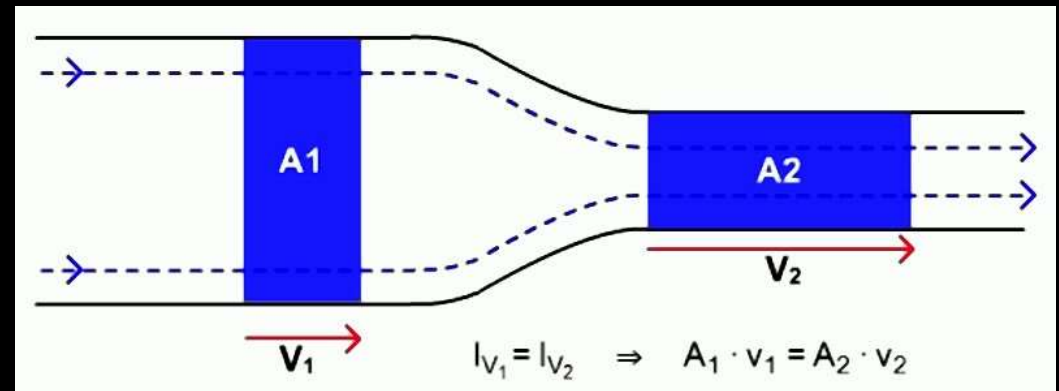
# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

- **Flood Prediction by Stream / River Monitoring**
- **Important variables considered:**
  - The amount of real-time rainfall occurring
  - The rate of change in real-time river stage
  - Type of storm producing the moisture, such as duration, intensity and areal extent
  - Characteristics of a river's drainage basin
    - Soil-moisture conditions
    - Ground temperature
    - Snowpack
    - Topography
    - Vegetation cover
    - Impermeable land area

# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

## • Continuity Principle

- Flow into a defined volume over a known time minus what flows out during that time must accumulate in that volume
- Based on the conservation of mass
- i.e. inflow = outflow ideally
- Basis for stream discharge formula
- A negative volume means the volume has depleted



I = interval  
A = area  
V = volume

# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

- **Stream Discharge Formula**

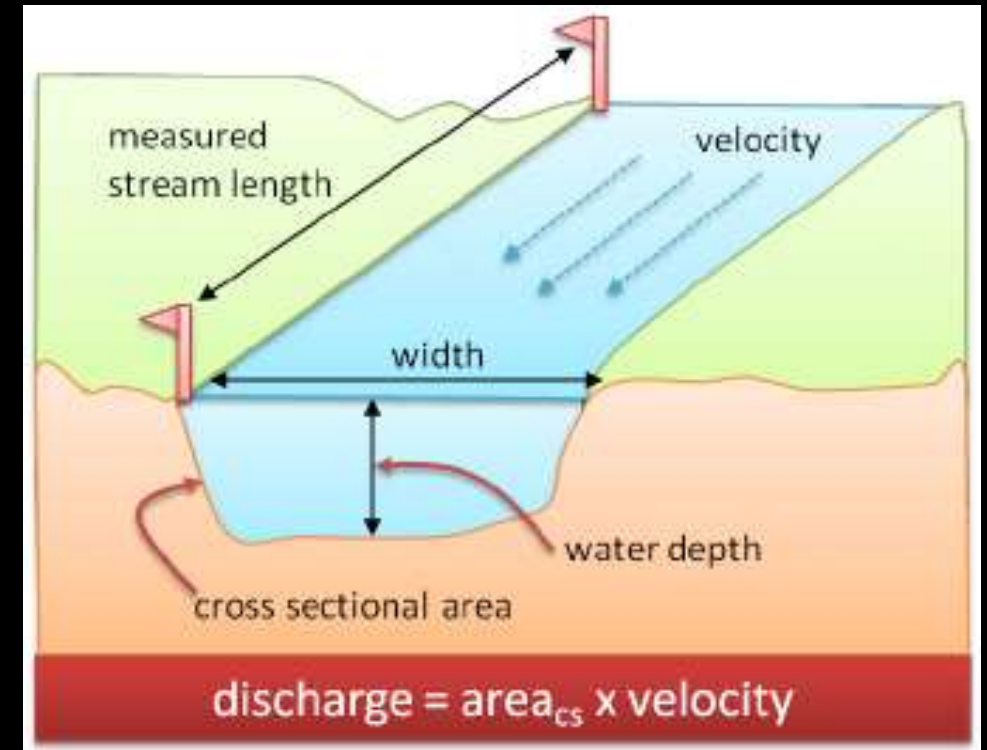
$$Q = V * A$$

where

$Q$  = stream discharge

$V$  = stream velocity

$A$  = Area



# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS / RIVER FLOW DYNAMICS

- **Flood Probability**

- The probability of a certain size flood occurring in a single year

$$\text{Flood Probability} = \frac{\text{Rank number of flood on record} \times 100}{\text{Number of years} + 1}$$

# SURFACE HYDROLOGY STREAMS / RIVER FLOW DYNAMICS

- **Flood Recurrence Interval**
  - The average time or an estimated average time between flood events

$$\text{Recurrence Interval} = \frac{\text{Number of Years on Record} + 1}{\text{Rank Number}}$$



# GROUNDWATER

- Water present in soil and rock in the earth's crust

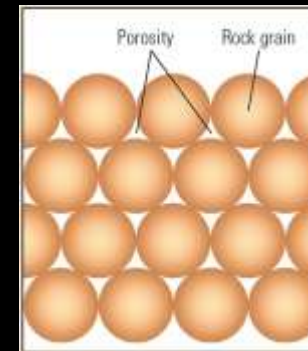


# GROUNDWATER

- Water flow and penetration through the crust is directly related to the amount of:

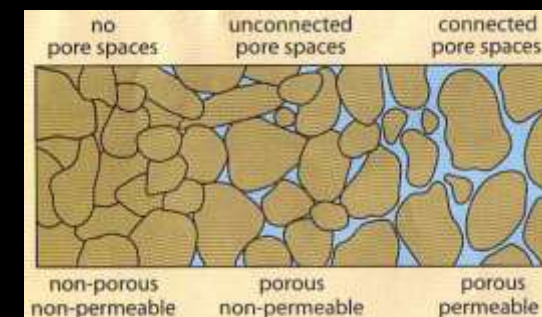
- Porosity

- A measure of the void space in a substrate



- Permeability

- A measure of the ease of flow of a fluid through a porous medium



# GROUNDWATER TERMINOLOGY

- **Unconfined water**

- Water that is vertically in direct contact with the atmosphere through open spaces and impermeable material

- **Confined water**

- Water that is separated from the atmosphere by an impermeable medium
- AKA – artesian water

# GROUNDWATER TERMINOLOGY

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- **Aquifer**
  - An underground layer of water bearing permeable stratum that releases water in appreciable amounts
- **Aquitard**
  - An underground layer of water with a limited amount of permeable stratum that **can not** release water in appreciable amounts
- **Aquiclude**
  - A saturated, but poorly permeable strata that does not yield water freely to a well or spring
- **Aquifuge**
  - A material that **neither** transmits or stores water

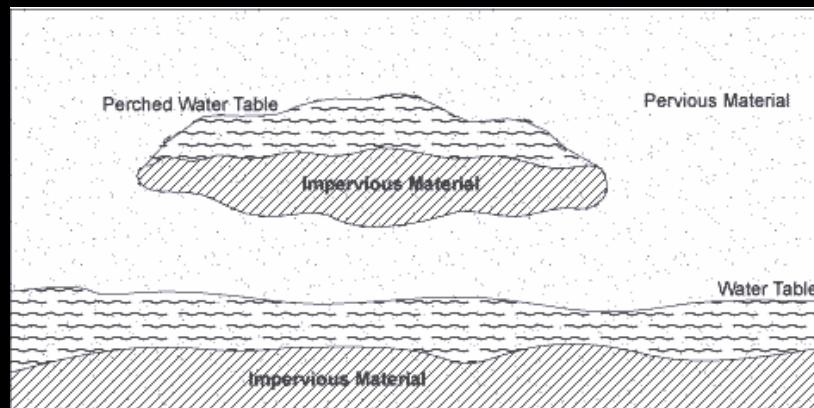
# GROUNDWATER TERMINOLOGY

- **Water table**

- Subsurface boundary between the saturated material and the unsaturated material

- **Perched water table**

- Water table that is separated from a lower one by an impermeable zone



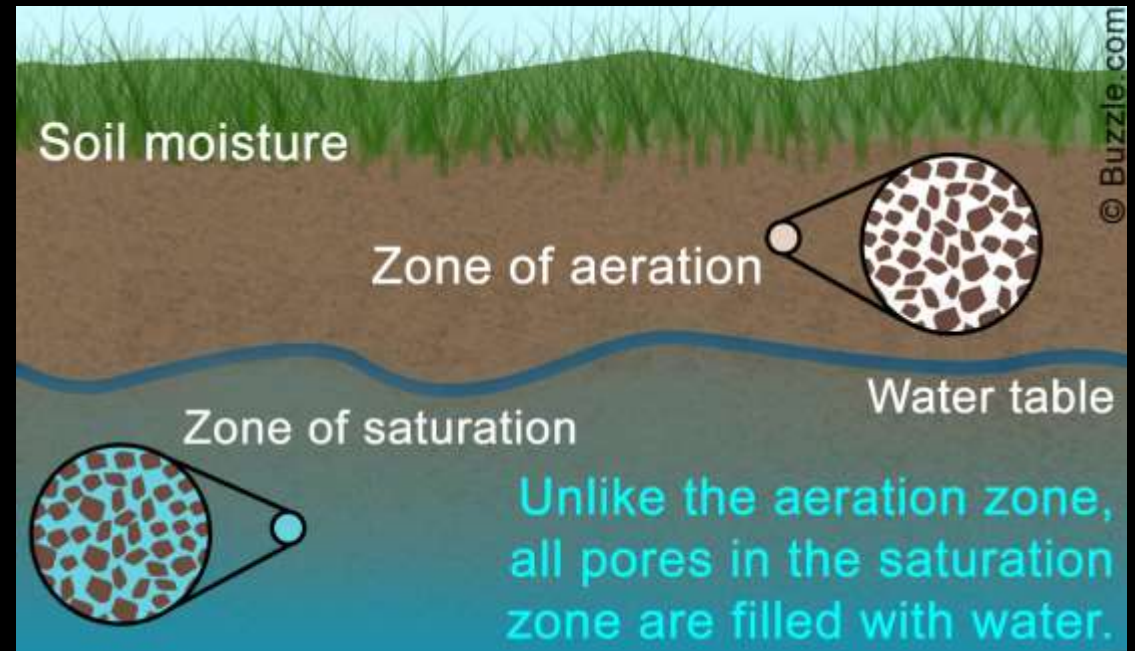
# GROUNDWATER TERMINOLOGY

- **Zone of Aeration**

- The area of an unconfined aquifer above the water table where the pore spaces within soil particles and rock are filled with air
- AKA – vadose zone; zone of unsaturation

- **Zone of Saturation**

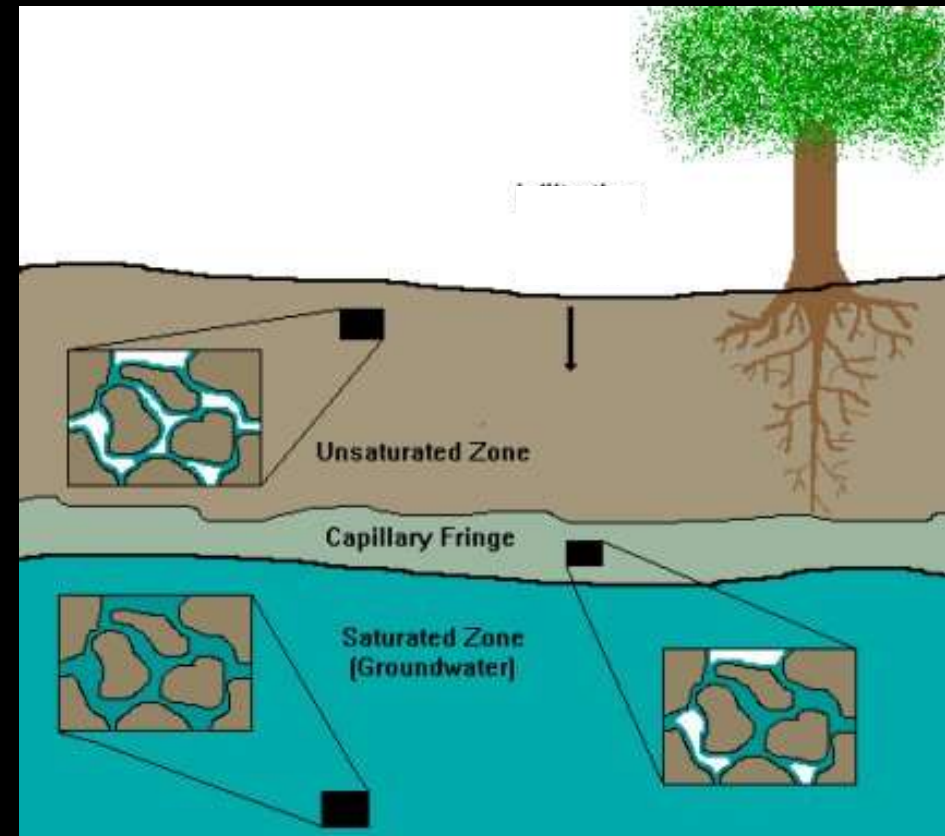
- Area of a water-bearing formation in which all spaces between soil particles and rock are filled with water
- AKA- phreatic zone



# GROUNDWATER TERMINOLOGY

- **Capillary Fringe**

- The vicinity located at the base of the zone of aeration where ground water seeps upward as a function of capillary action (via surface water tension) to fill pore spaces



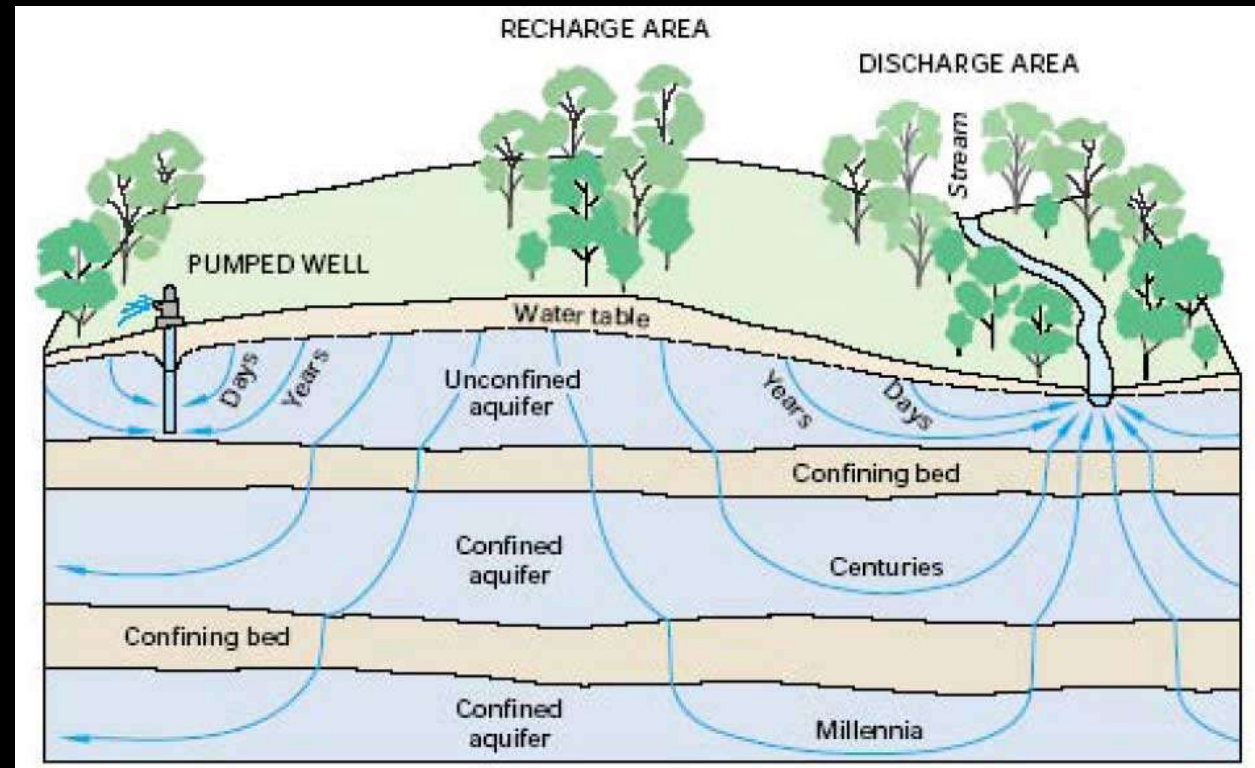
# GROUNDWATER TERMINOLOGY

## Discharge

The upward movement of water to the surface by hydraulic flow or pumping (outflow)

## Recharge

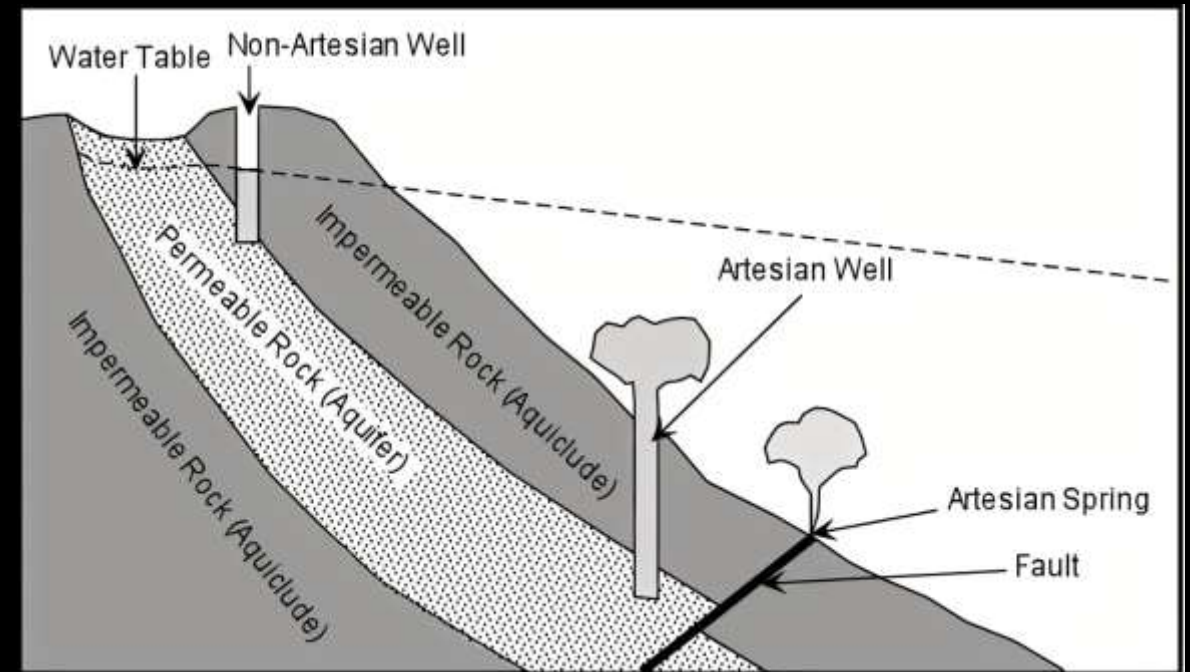
The downward movement of water by infiltration or injection (inflow)



# GROUNDWATER TERMINOLOGY

- **Artesian Systems**

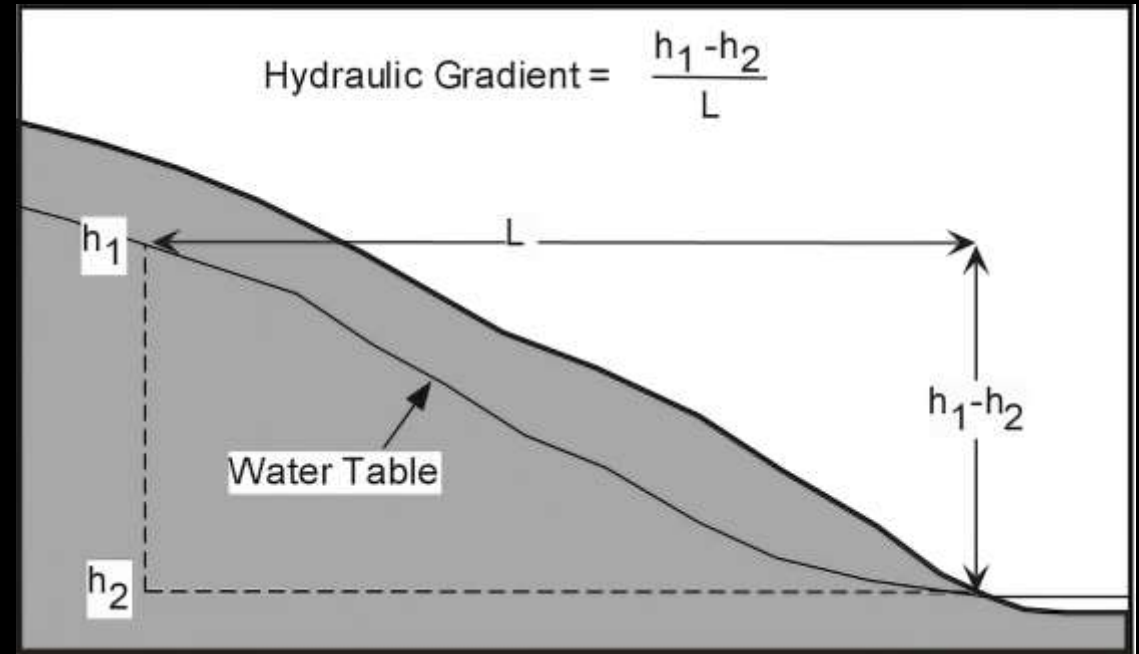
- Water is confined under pressure below layers of impermeable strata





# GROUNDWATER TERMINOLOGY

- **Hydraulic head**
  - Liquid pressure above a vertical datum
  - AKA piezometric head
- **Hydraulic gradient**
  - The difference in hydraulic head between two points on a flow path divided by the distance between those two points

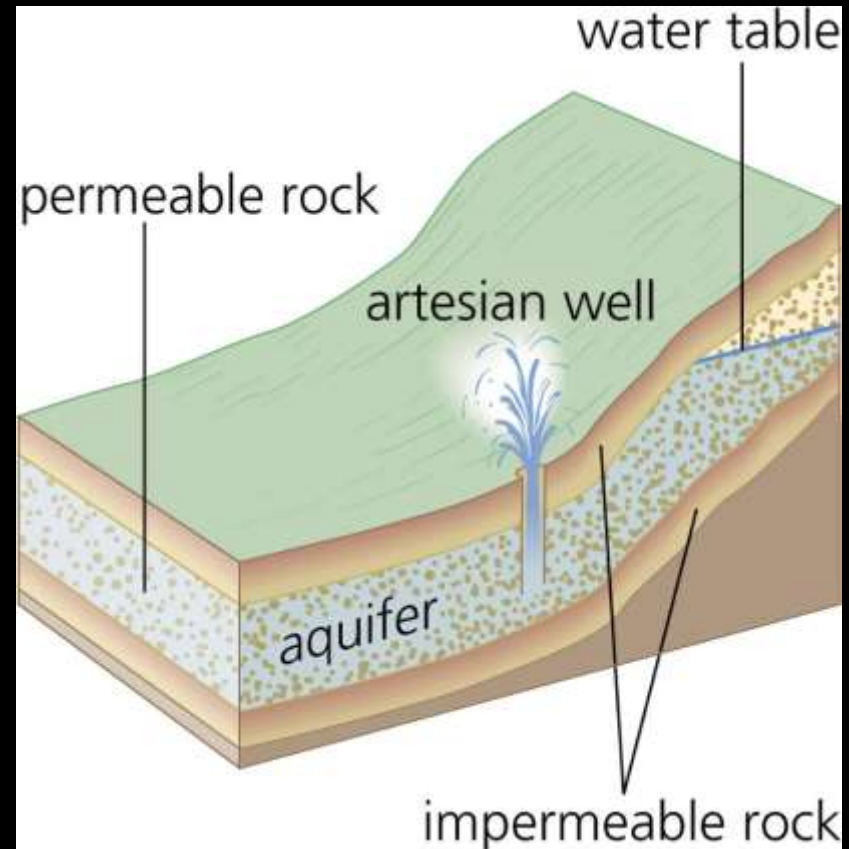


# GROUNDWATER STORAGE

- The amount of water storage in an aquifer is a function of the following:
  - The amount of water infiltration
  - Soil / Rock type
  - Soil / Rock porosity
  - Soil / Rock permeability
  - Transmissibility
  - Compaction
  - Associated pressures
  - The amount of discharge

# GROUNDWATER FLOW

- **Artesian Flow**
  - Water that flows under natural pressure without pumping



# GROUNDWATER FLOW

- **Darcy's Law**

- Describes flow through a porous medium
- Applies only to **laminar flow** low friction

$$\frac{Q}{A} = -K \left( \frac{\Delta h}{\Delta L} \right)$$

Q = volumetric flow rate (discharge)

A = cross-sectional area

K = hydraulic conductivity / permeability

h = elevation

L = Length between points

# GROUNDWATER FLOW

## • Darcy's Law

$$\frac{Q}{A} = -K \left( \frac{\Delta h}{\Delta L} \right) \text{ or substituting } \frac{Q}{A} = v_q$$

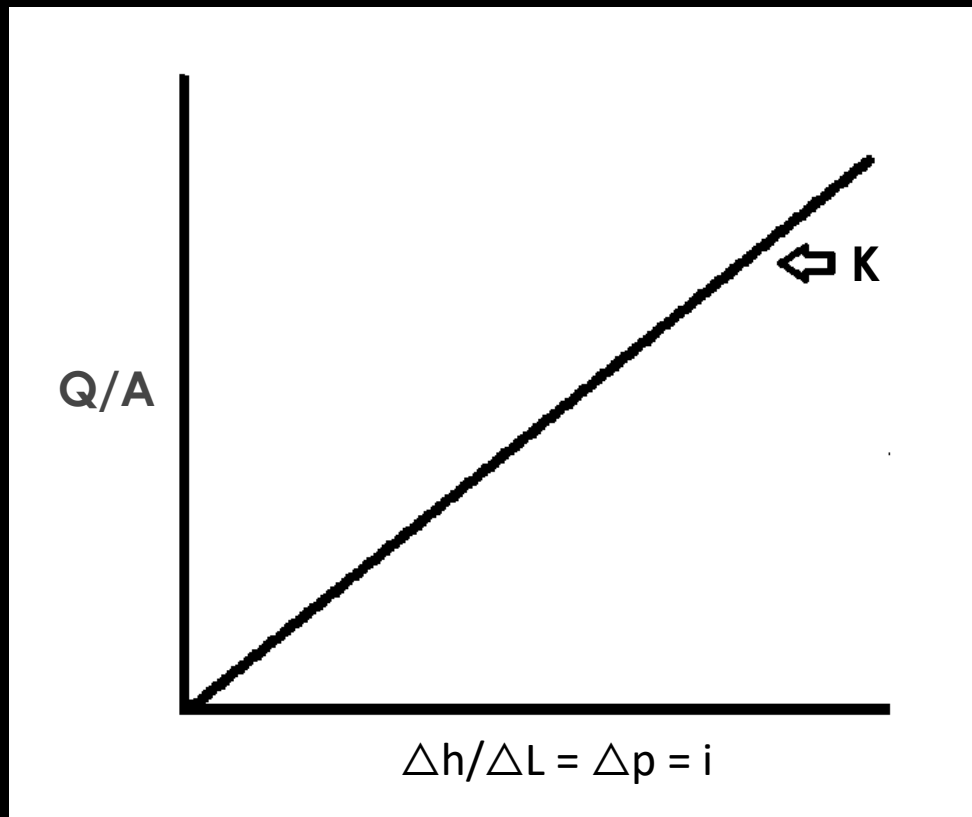
$$v_q = -K \left( \frac{\Delta h}{\Delta L} \right)$$

accounting for friction (n) then

$$v_q = -\frac{K}{n} \left( \frac{\Delta h}{\Delta L} \right)$$

Q = volumetric flow rate (discharge)  
A = cross-sectional area  
K = hydraulic conductivity / permeability  
h = elevation  
L = Length between points  
n = roughness or porosity factor  
v<sub>q</sub> = specific discharge in direction of flow (Darcy flux/Darcy velocity/apparent velocity)

# GROUNDWATER FLOW



$$\frac{Q}{A} = -K \left( \frac{\Delta h}{\Delta L} \right)$$

$\Delta p$  = pressure drop

$i = \frac{\Delta h}{\Delta L}$  = head gradient

Flow is proportional to head gradient

# GROUNDWATER FLOW

- **Chezy Formula**

- Represents the mean flow velocity of **turbulent** open channel flow where smooth boundaries are present

- $v = C\sqrt{Ri}$  or  $v = C\sqrt{RS}$

$$v = C\sqrt{mi}$$

$$v = C\sqrt{\frac{Ai}{p}}$$

V = velocity

C = Chezy coefficient

R = hydraulic radius

m = hydraulic mean depth where  $m = \frac{A}{p}$

S, i = hydraulic gradient or bottom slope

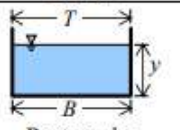
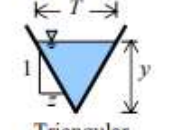
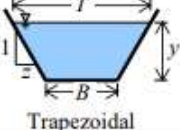
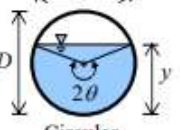
A = area

p = wetted perimeter

# GROUNDWATER FLOW

## • Wetted perimeter

- The width of the streambed and stream banks in contact with water for a given cross-section
- The perimeter of the cross-sectional area that is “wet”
- Calculation is based on the channel or pipe shape

Section	Area $A$	Top width $T$	Wetted perimeter $P$
 Rectangular	$By$	$B$	$B + 2y$
 Triangular	$zy^2$	$2zy$	$2y\sqrt{1+z^2}$
 Trapezoidal	$By + zy^2$	$B + 2zy$	$B + 2y\sqrt{1+z^2}$
 Circular	$\frac{D^2}{8}(2\theta - \sin 2\theta)$	$D \sin \theta$	$\theta D$



# GROUNDWATER FLOW

- **Chezy Coefficient**

- A dimensionless number dependent on surface roughness and hydraulic mean depth

$$C = \frac{1}{n} r_h^{\frac{1}{6}}$$

C = Chezy coefficient, found in tables

$r_h$  = hydraulic radius

n = roughness coefficient, found in tables

# GROUNDWATER FLOW

- Relationship between Chezy coefficient (C ) and Manning's equation

$$C = \frac{1.486}{n} R^{\frac{1}{6}}$$

C = Chezy coefficient

n = roughness factor

R = hydraulic radius

# GROUNDWATER FLOW

- **Manning Formula**

- Used to determine the average velocity of a liquid flowing in a conduit that **doesn't completely enclose a liquid** or **open channel flow**
- Used more than Chazy's formula because the majority of channels are open and flow in turbulent regions, it's well proven and its easier to calculate

- $v = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$  (metric)

- $v = \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$  (imperial)

V = cross sectional average velocity

n = roughness coefficient

R = m = hydraulic radius

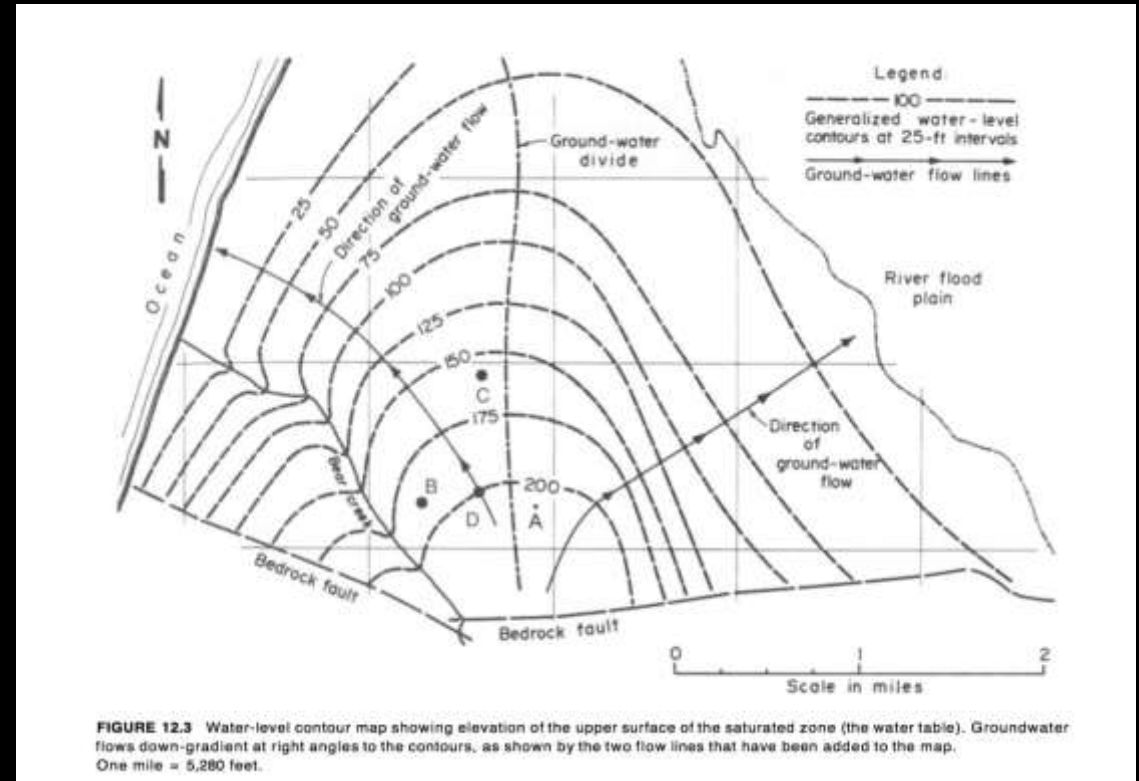
S = slope / grade

# GROUNDWATER FLOW

- Water flows from regions of **high** hydraulic head (recharge zones) to regions of **low** hydraulic head (discharge Zones)
- Applies to confined and unconfined aquifers

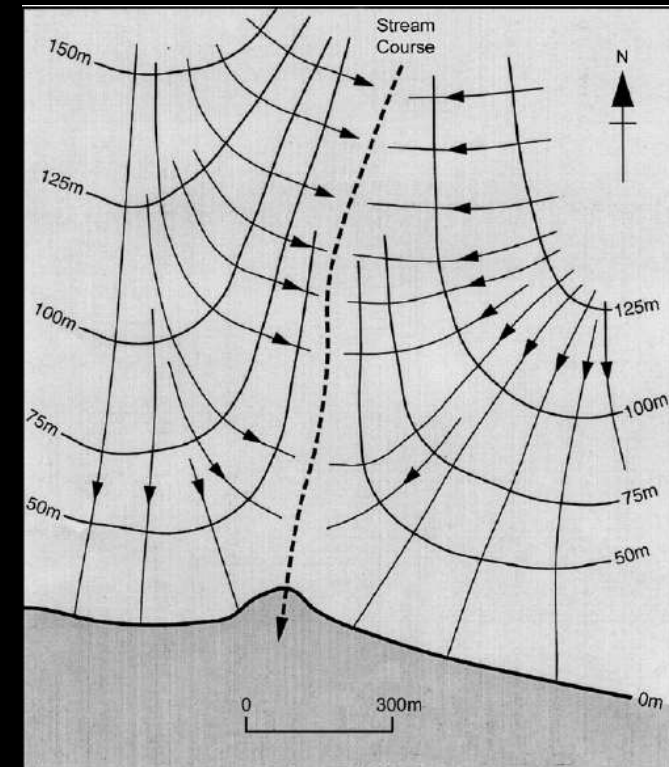
# GROUNDWATER FLOW

- **Water – level contour map**
- A map that uses the **naturally** occurring water table depth to determine flow direction based on the principle that flow occurs at right angles to the contour lines



# GROUNDWATER FLOW

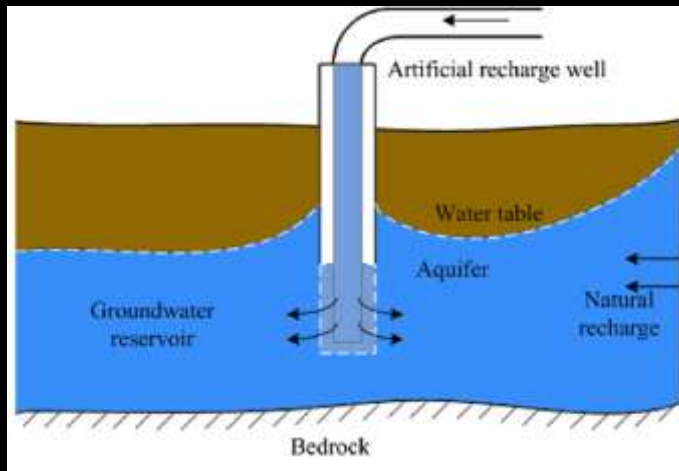
- **Piezometric surface**
  - An imaginary surface to which confined groundwater rises under hydrostatic pressure in **wells** or springs
  - AKA potentiometric surface
  - Piezometer used to measure elevation of water in well



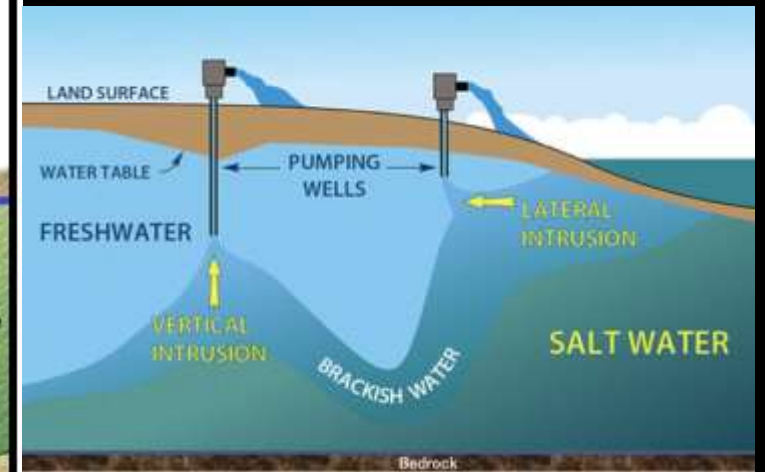
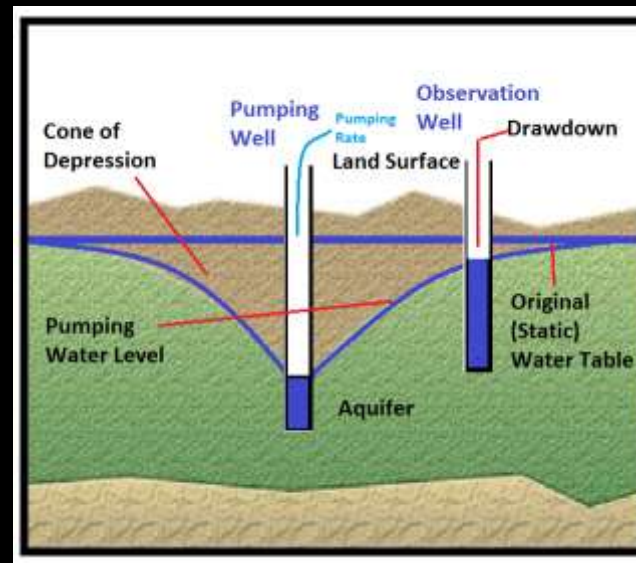
# GROUNDWATER FLOW

Mechanisms that effect water table:

**Injection**



**Pumping**



# GROUNDWATER

- **Factors that affect aquifers:**

- Salt water intrusion
  - Causes contamination of the fresh water and associated environments
  - Movement can be a function of higher density and higher hydraulic pressure pushing its way beneath the water and laterally with flow
- Over pumping
  - Causes draw down of the aquifer water in the nearby area
- Over injecting
  - Causes fracturing of the aquifer in the nearby area



# COMBINATION

- **Karst Systems**

- The term originates from the topography formed by the dissolution of soluble rocks such as limestone, dolomite and gypsum
- Dissolution occurs on both the surface and in groundwater thus a combination of both environments
  - Creation occurs due to chemical reaction with water primarily below surface
- Students must be able to **identify** these features on a **topographic map**

# COMBINATION

- Karst formation due to **surface** chemical and physical erosion



- Karst formation due to **groundwater** chemical action



# COMBINATION

- Karst features created
- Sink holes



- Caves



# COMBINATION

Karst features created

Springs



Disappearing / sinking  
streams



Mogote



# COMBINATION

- Karst features created:  
Solution valley with multiple sink holes



# COMBINATION

- **Wetlands**

- Place where water covers the land either at or near the surface for part or all of the year
- The water may be fresh, brackish or saline depending on the environmental topography
- Water can originate from **both** surface and groundwater sources
- Places of recharge and discharge in the hydrologic cycle

# COMBINATION

- **Wetland criteria:**

- A predominance of hydric soils
- Inundated or saturated by surface or groundwater at a frequency and duration sufficient to support hydrophytic vegetation adapted to saturated soil conditions
- The substrate is saturated with water or covered by shallow water at some time during the growing season

# COMBINATION

- **Wetland categories:**
- Marshes
  - Feature dominated by herbaceous plants such as **grasses**, rushes or sedges with small shrubs along its perimeter as it transitions to drier land along lakes and rivers





# COMBINATION

- **Wetland categories:**
- Swamps
  - A forested wetland characterized by various species of **trees** that are inundated most of the year



# COMBINATION

- **Wetland categories**
- Bogs
  - Freshwater wetland depression of soft, spongy ground consisting mainly of partially decayed plant matter (peat) that derives most of their water from **precipitation** rather than groundwater



# COMBINATION

- **Wetland categories**
- Fens
  - Peat forming wetlands that rely on **groundwater** input and require thousand of years to develop and cannot be easily restored once destroyed



# MANMADE

- **Hydrologic Features:**
  - Dams
  - Weirs
  - Levees
  - Canals
  - Aqueduct
  - Culverts
  - Seawalls

# MANMADE

- **Dam**

- A barrier constructed to control water
- Reasons for use:
  - Flood control
  - Water supply
  - Irrigation
  - Energy generation
  - Recreation
  - Pollution control



# MANMADE

- **Weirs**
- A structure that has water flowing across the top and built to raise the level of water upstream or regulate flow but



# MANMADE

- **Levee**
- A structure built to prevent the overflow of water from a fluvial feature



# MANMADE

- **Canals**
  - An artificial waterway constructed to allow the passage of boats /ships or convey water for irrigation





# MANMADE

- **Aqueduct**
  - An artificial channel for conveying water
  - Water added by precipitation or pumping by artificial means



# MANMADE

- **Culvert**
  - An artificial tunnel for conveying water under a roadway or railroad



# NEGATIVES AFFECTING HYDROLOGIC SYSTEMS

- **Wetland destruction**
  - Destroys habitat
  - Increases flood and drought damage
  - Nutrient runoff
  - Erosion



# NEGATIVES AFFECTING HYDROLOGIC SYSTEMS

- **Dam / levee / weir construction**
  - Destroys and changes biological habitats
  - Uproots communities (human and animal)
  - Traps sediment
  - Buries fish spawning river beds
  - Changes fluvial flow dynamics



# NEGATIVES AFFECTING HYDROLOGIC SYSTEMS

- **Seawalls used in lakes / oceans**
- Cause beach loss directly in front but causes increased erosion in adjacent areas of the beach that don't have them



# NEGATIVES AFFECTING HYDROLOGIC SYSTEMS

## • **Runoff**

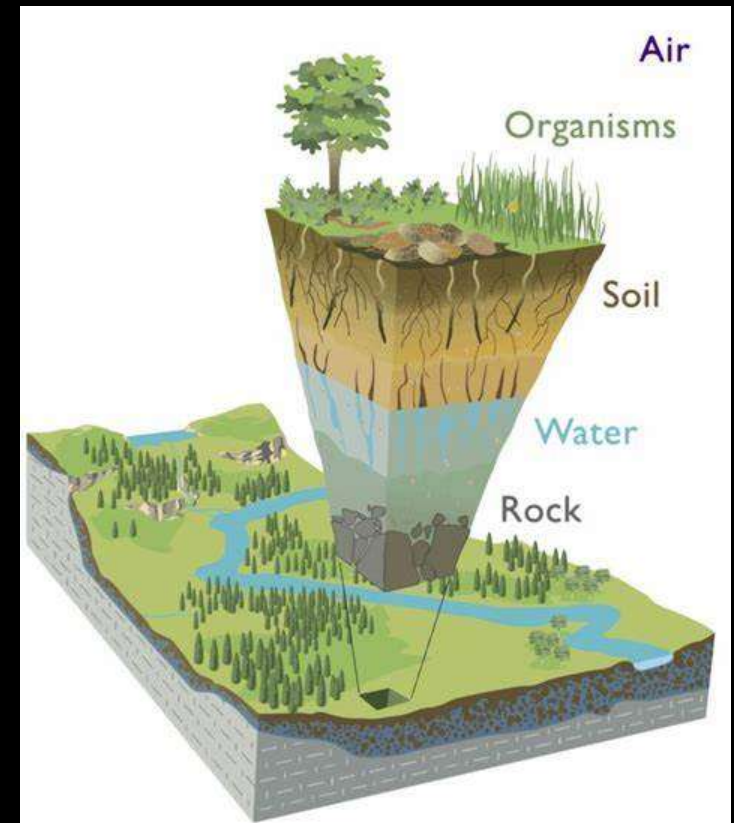
- Urban
  - Paved land Increases flooding opportunities
- Agricultural
  - Transport of effluent from fertilizers and animal waste infiltrate or runoff into rivers/lakes/streams
    - Tainted water sinks into soil and groundwater system
- Industrial
  - Heavy metals and organic pollutants leach or runoff into the surface and groundwater systems
- Environmental
  - Increased erosion (downcutting)
  - Increased sediment deposition in low areas as a result of mudslides



# CRITICAL ZONE HYDROLOGY

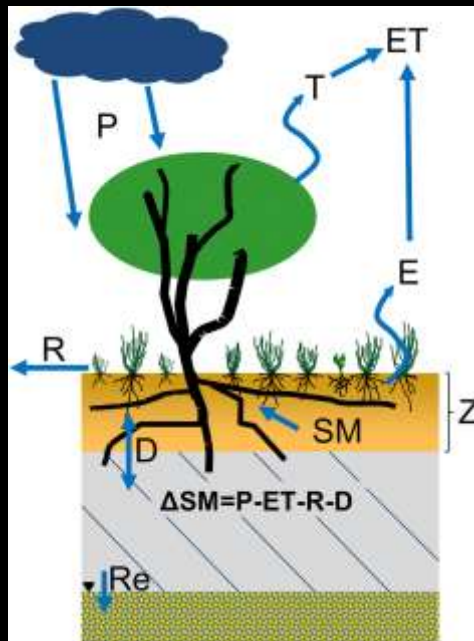
- **Critical Zone**

- The outer surface of the terrestrial earth where rock meets **life** (plants and animals) and where water cycle dynamics connect the subsurface to the atmosphere and climate
- Critical zone science comprises and thus is investigated by several disciplines
- Sustains nearly all terrestrial life



# CRITICAL ZONE HYDROLOGY

- Soil is the controlling influence that connects bedrock and the atmospheric boundary layer with **water** as a major driving force and transport agent between these two zones



P – Precipitation

ET – Evapotranspiration

T- Transpiration

E- Evaporation

SM -Soil Moisture

R – Runoff

D- Drainage

Z – maximum measurement depth

$R_e$  - Recharge



# CRITICAL ZONE HYDROLOGY

- Components of the hydrologic cycle are key to the critical zone processes
- Examples
  - Runoff
    - Too much and flooding occurs which affects soils, vegetation, erosion, deposition, etc.
  - Transpiration
    - In an effort to keep the vegetation living during dry intervals, moisture from the soil is released into plants after which, the plant releases water to the atmosphere
  - Evaporation
    - Soil moisture evaporates into the atmosphere drying out the top soil thus directly affecting the vegetation

# CRITICAL ZONE HYDROLOGY

- Not all environments are considered part of the critical zone
  - Aquatic systems
    - Lakes, ponds, seas, and oceans
    - Lack soil interface

# CRITICAL ZONE HYDROLOGY

- Not all environments are considered part of the critical zone
  - Artic regions
    - Human, animals, vegetation and water are temporary



Pingo



Palsa Bog



Permafrost

- Landforms are affected by temperature change and/or human interaction

# CRITICAL ZONE HYDROLOGY

- **Factors affecting critical zones**
  - Climate
  - Land Use
  - Soil quality
  - Stream flow and runoff
  - Contaminant transport
  - The carbon cycle
  - Human and animal interaction

# HYDROLOGIC POLLUTION

- The **contaminates** in water bodies as a result of human or natural affects



# HYDROLOGIC POLLUTION

- **Sources**
  - Saltwater Incursion
  - Oil Spills
  - Sewage
  - Industrial Waste
  - Radioactive Waste
  - Wastewater
  - Agriculture