Hydrogeology
GLI 101

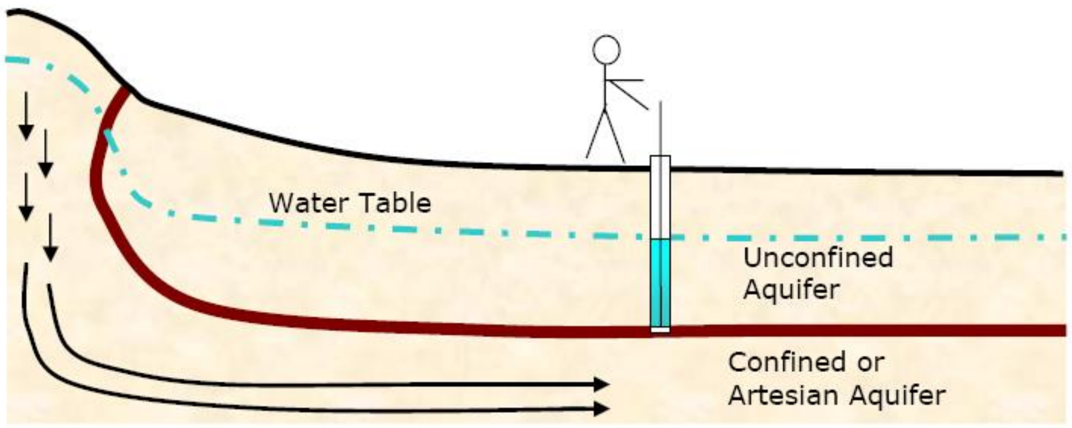
Lecture 3

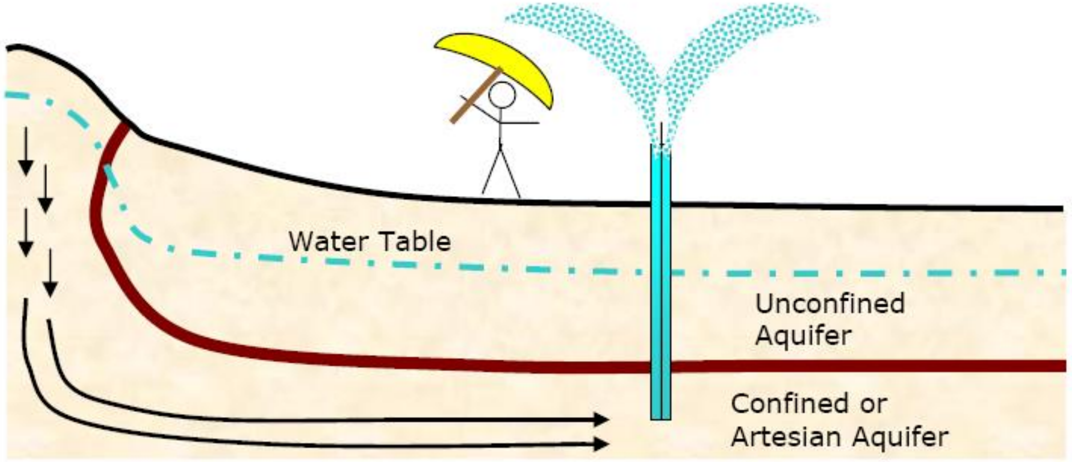
Natural Storage of Groundwater

- An **aquifer** is a geologic unit that can store and transmit water at sufficient rates to supply wells. E.g. unconsolidated Gravel, Sand, sandstone
- An aquifer should be able to transmit significant quantities of water under ordinary hydraulic gradients.
- A **confining layer** is a geologic unit that has low to no intrinsic permeability (which is a measure of how water flows through the rock layer) such as in clays.
- Confining layers are subdivided into **aquifuges** (absolutely impermeable), **aquitards** (impermeable relative to the adjacent units) and **aquifuges (**absolutely impermeable unit).

Natural Storage of Groundwater

- Water table aquifers, those with no confining layer above, are called **unconfined aquifers**. Aquifers overlain by a confining layer are called **confined aquifers or Artesian aquifers.**
- As water recharges a confined aquifer, pressure may build up in the aquifer. If one were to drill a well in a pressurized confined aquifer, the water level in the well might rise far above the aquifer.

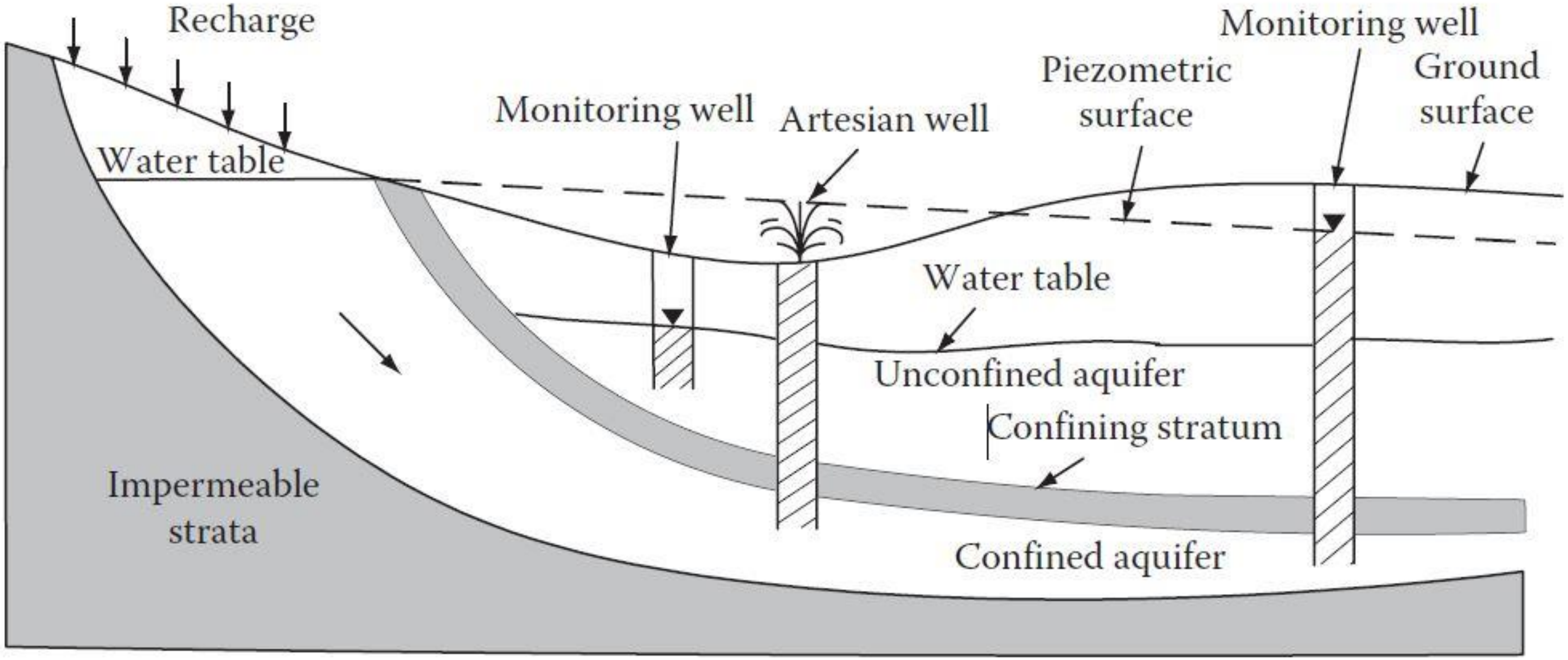




Natural Storage of Groundwater

- ***Piezometric/potentiometric surface*** represents the static head of groundwater and is defined by the level to which water will rise if a well is dug through a confined aquifer.
- If the potential level of piezometric surface is higher than the land surface, it results in *overflow* of the well and is called a **flowing well**.
- Groundwater will flow in the general direction that the potentiometric surface is sloping, i.e., from higher hydraulic head to lower hydraulic head.

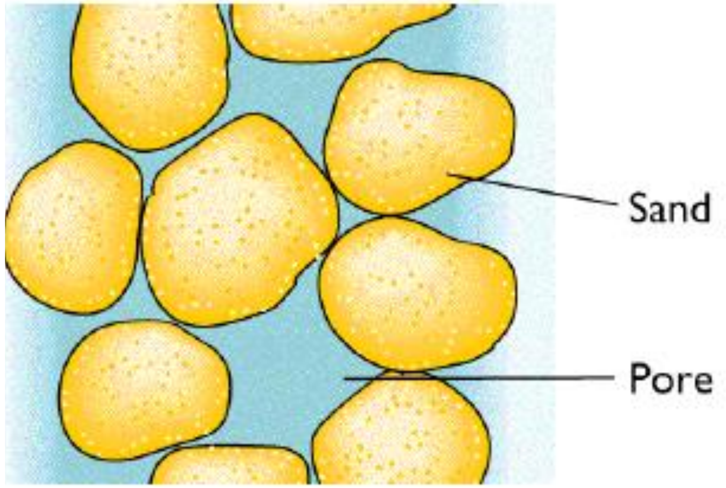
Natural Storage of Groundwater



Hydraulic properties of Earth Materials

- **Sediments** are assemblages of individual grains that were deposited by water, wind, ice, or gravity. There are openings or voids called **pore spaces** between the sediment grains, so that sediments are not solid.
- The ***porosity*** of a rock or soil is a measure of these contained interstices or voids expressed as the ratio of the volume of interstices to the total volume of the material.
- Mathematically Porosity (n) is

$$n = \frac{V_v}{V_T} = \frac{V_T - V_s}{V_T}$$



- In terms of density

$$n = 100\left[1 - \frac{\rho_b}{\rho_d}\right]$$

Where ρ_d is grain density and ρ_b is bulk density

Porosity

- **Void ratio** is the relative proportion of voids to the grain volume. Mathematically it is defined as $e = V_v/V_s$, and usually ranges from 0 to 3.
- The relation between *e* and *n* can be expressed as

$$e = \frac{n}{1-n} \quad or\ n = \frac{e}{1+e}$$

- **Effective porosity** is another concept of porosity that can be defined as the volume of the continuously connected path for water movement through the soil. In other words, it is the ratio of the continuous fissures (interconnected pore volume) over total volume of the medium.

Porosity

Problem 1: Given a wet bulk density, ρ_{bw}, of 2.25 g/cm^3 and a dry bulk density, ρ_{bd}, of 1.95 g/cm^3, and assuming the material as completely saturated with water, what is the porosity?

Answer: 0.3 or 30%

Problem 2: An undisturbed sample of a medium sand weighs 484.68 g. The cylindrical specimen of the undisturbed sample is 6 cm in diameter and 10.61 cm high. The sample is oven-dried for 24 hrs at 110°C to remove the water content. At the end of 24 hrs, the core sample weighs 447.32 g. Determine the bulk density, void ratio, water content, porosity, and saturation percentage of the sample.

Groundwater Composition

Common Cations	Eq.Wt.	Common anions	Eq.Wt.	Minor Constituents
Calcium	20.04	Carbonate	30.00	Iron
Magnesium	12.16	Bicarbonate	61.01	Aluminum
Sodium	23.00	Sulfate	48.03	Silica
Potassium	39.10	Chloride	35.46	Boron
		Nitrate	62.01	Fluoride
				Arsenic
				Selinium

Groundwater Analysis

Total Dissolved Solid (TDS)

- Residues left after evaporation of water, expressed in ppm (mg/L).
- Refractive index
  - Amount of refraction of light passing through water
  - Linearly related to concentrations of dissolved solids
- Conductivity/resistivity
  - Current carried by solution is proportional to dissolved ions

Groundwater Analysis

Total Dissolved Solid (TDS)

- The relationship of TDS and conductance of groundwater can be approximated by the following equation:

$$TDS = k_e EC$$

- where TDS is expressed in mg/L and EC is the electrical conductivity in microsiemens per centimeter at 25° C. The correlation factor k_e varies between 0.55 and 0.8.

Groundwater Analysis

Salinity

- Salinity – similar to TDS except includes only charged species
- Salinity is reported as the ratio of the electrical conductivity of a seawater sample to that of a standard potassium chloride (KCl) solution at the same temp and pressure.

Fresh water <1000mg/L

Low Saline 1000-3000mg/L

Moderately Saline3000-10,000 mg/L

Very Saline 10,000-35,000mg/L

Brine >35,000mg/L

Maximum for drinking water : 500mg/L

Groundwater Analysis

Hardness

- Water hardness is primarily the amount of calcium and magnesium, and to a lesser extent, iron in the water.
- Water hardness is measured by adding up the concentrations of calcium, magnesium and converting this value to an equivalent concentration of calcium carbonate ($CaCO_3$) in milligrams per litre (mg/L) of water.

$$H = Ca \times \frac{CaCO_3}{Ca} + Mg \times \frac{MgCO_3}{Mg}$$

Or, $H = (Ca)2.497 + (Mg)4.118$

where, Ca, Mg – in ppm

Groundwater Analysis

Hardness

mg/L as $CaCO_3$	Degree of Hardness
0-60	Soft water
61-120	Moderately hard water
121-180	Hard water
>180	Very hard water

Groundwater Analysis

- **Alkalinity, Acidity and pH**
- Alkalinity is the capacity of the water to neutralize acid. It is produced by **carbonate and bicarbonate ions** expressed as the equivalent concentrations of $CaCO_3$ (mg/L)
- Acidity is the capacity of the water **to react with hydroxyl ions**. It is expressed in terms of mg/L of H+ or equivalent concentration of H_2SO_4
- Alkalinity is mostly used in G.W analysis as it directly gives conc. of Carbonates and bicarbonates.
- pH – activity of concentration of hydrogen ions in water, expressed as $–\log_{10}{}^{H+}$ molar/L