EWCE 341: Principles of Soil Mechanics

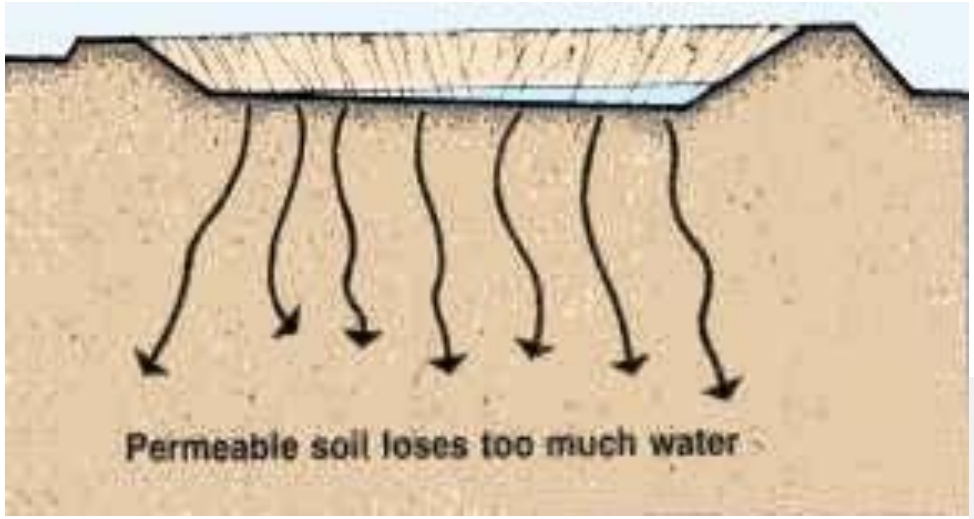
Permeability of Soil

What we are going to learn today?

- What is permeability of soil?
- Permeability is an important engineering property of soils.
- Hydraulic heads.
- Factors Affecting Permeability of soils
- Uses of Permeability of Soils

What is permeability of soil?

- **Property of soil** which ***permits flow of water*** through the interconnected voids/pores of it**.**
- Permeability is the **ease with which water can flow through voids/pores of soils**.



Soil type	Permeability k (m/sec)	Reducing permeability
Gravel	>0.1	↓
Sand	$0.1 - 10^{-4}$	
Silt	$10^{-4} - 10^{-8}$	
Clay	$<10^{-8}$	



Permeability is an important engineering property of soils?

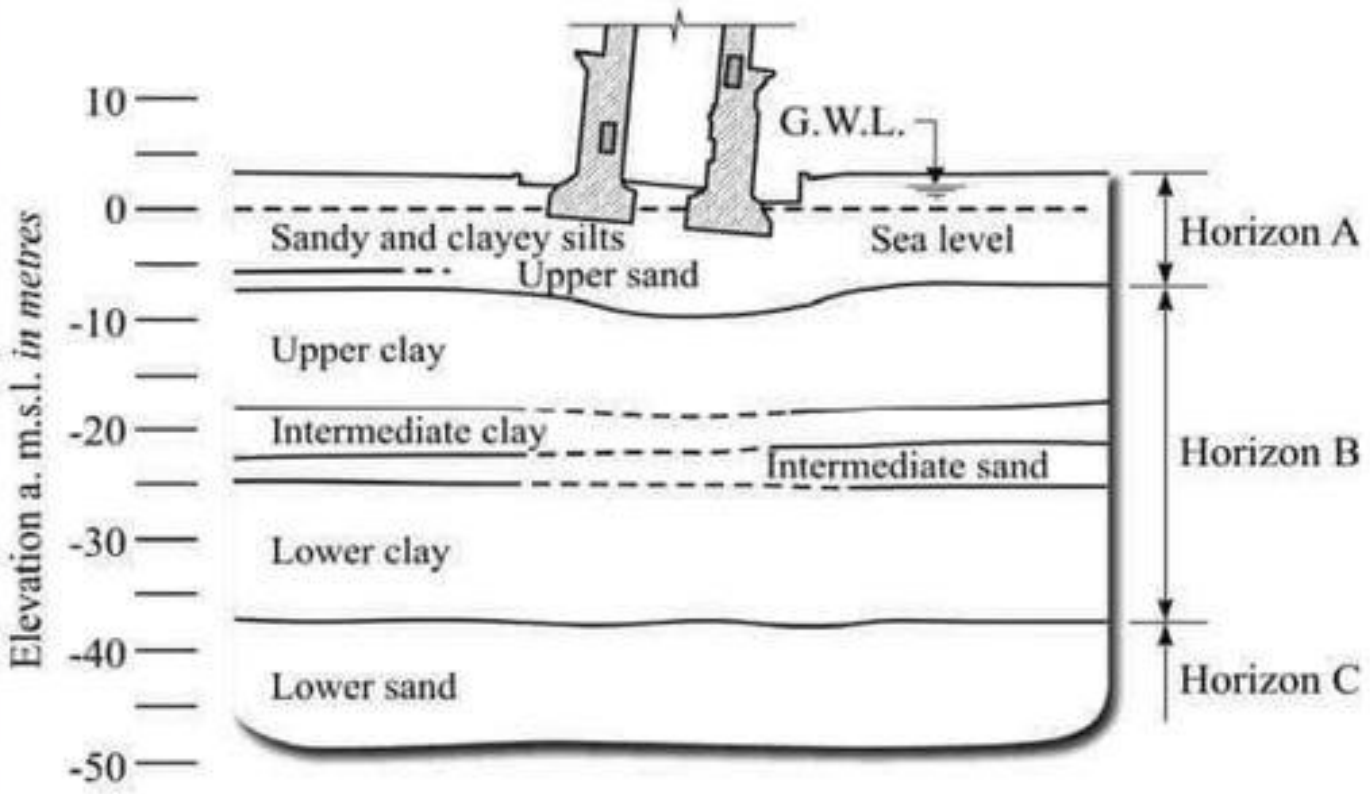
A **knowledge of permeability is essential** in a **number of soil engineering problems:**

- **Influences** the **rate of settlement** of a saturated soils under load.
- **Stability of slopes and retaining structures** can be greatly affected by the permeability of soils.
- **Design of earth dams** is very much based upon the permeability of soils used.
- **Design of Filters (to prevent piping and erosion)** are based upon their permeability.
- **Rate of flow of wells** from an aquifer is dependent on permeability.
- **Performance of land fill liners** is based upon their permeability.

Question: Why permeability is an important engineering property of soil?

- **Influences** the **rate of settlement** of a saturated soils under load.





Settlement of a structure

- **Stability of slopes and retaining structures** can be greatly affected by the permeability of soils.

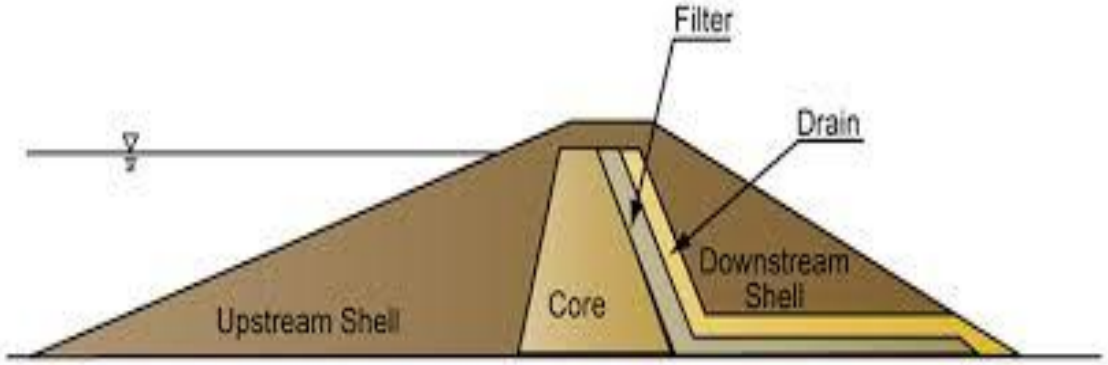


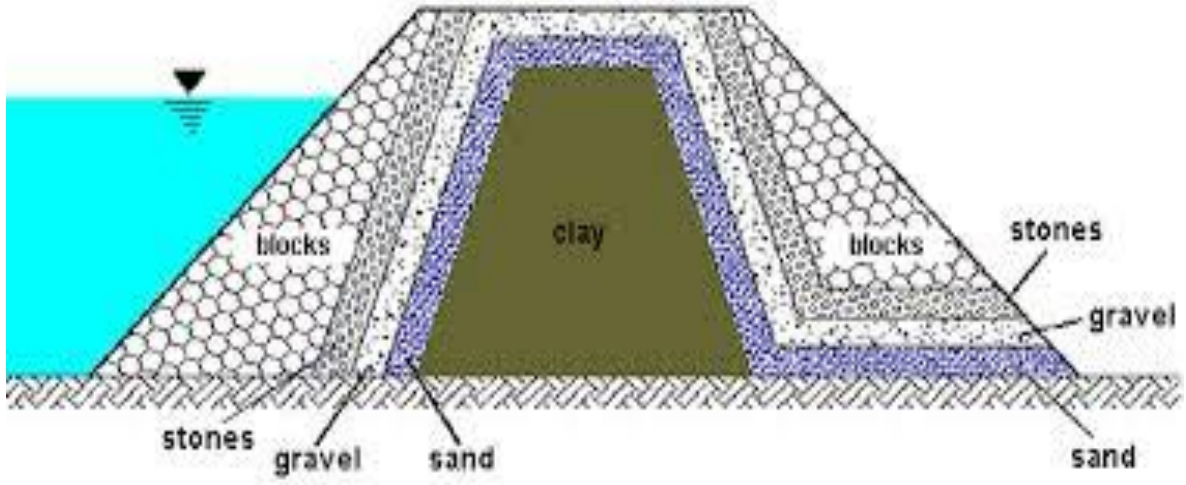




Stability of Slope and Retaining Structure

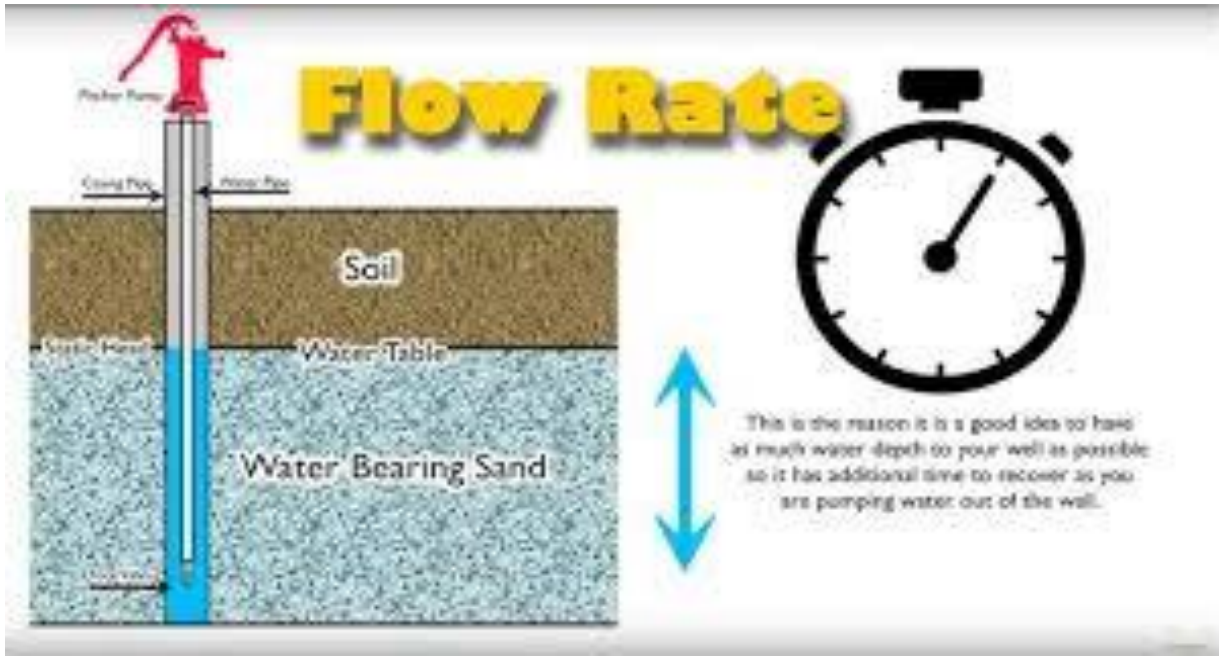
- **Design of earth dams** is very much based upon the permeability of soils used.
- **Design of Filters (to prevent piping and erosion)** are based upon their permeability.







Earth Dam and its Typical X-Section



- **Rate of flow of wells** from an aquifer is dependent on permeability.
- **Performance of land fill liners** is based upon their permeability.

Landfill Liners: A **landfill liner**, is intended to **be a low permeable barrier**, which is laid down under **engineered landfill** sites.

A landfill bottom liner system can consist of:

- **A base layer of clay** that has low permeability.
- **A synthetic membrane bottom liner.**



Hydrology

Definition: Study of water movement across the earth.

Surface Water Hydrology: Assessment of rainfall intensities, streams flow, lake water level

Ground Water Hydrology: Study of Ground Water





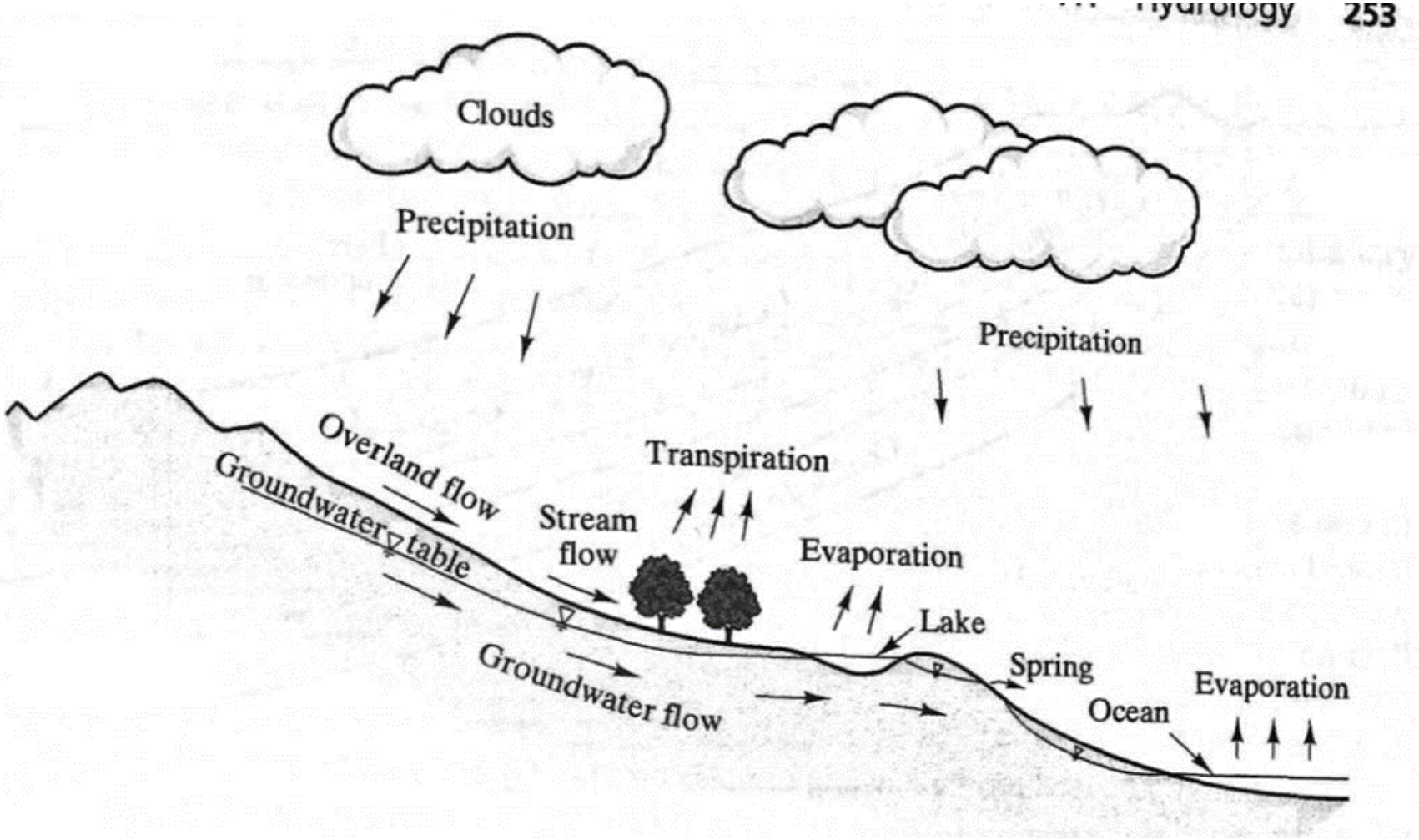
Hydrologic Cycle

Movement of water across the earth is ultimately driven by energy received from the sun.

- **Evaporation and Transpiration:** – water rises in to the sky and form clouds
- **Precipitation**:- (rain, sleet, hail, snow)
- **Infiltration**:- recharge GW. Some remains near the GS but much of it reaches GW level, fully saturated zone

Process occurs both in high land and low lands. **GW eventually gains enough potential energy and begins to flow, reappears** on ground surface as spring or seeps to low spots then to ocean.

Hydrologic Cycle



Groundwater Hydrology

Geotechnical Engineers are **mostly concerned with that portion of hydrologic cycle that occur underground**.

- **Subsurface water**: all under ground water, specially all water located within **soil voids** and **rock fissures**.

GWT:-Most important of **subsurface water**.

- GWT location is important and finding it is one of the primary objectives of **site characterization program.**
- Located by **installing observation wells** and allowing GW to seep into them until it reaches equilibrium.
- **Water elevation** inside wells is GWT.
- Soil **profiles represent GWT** as a line marked with a triangle.
- GWT often **changes with time**, depending on the season of the year, recent patterns of rainfall, irrigation practices, pumping activities and other factors. Fluctuation may very from 1m to 10m or even more in only a year or two.

Groundwater Hydrology (cont--)

- GWT conditions **encountered in an exploratory boring** are not necessarily those we use for design.
- Often need to use observed conditions as a basis for **estimating the worst condition** that are likely to occur during the project life.

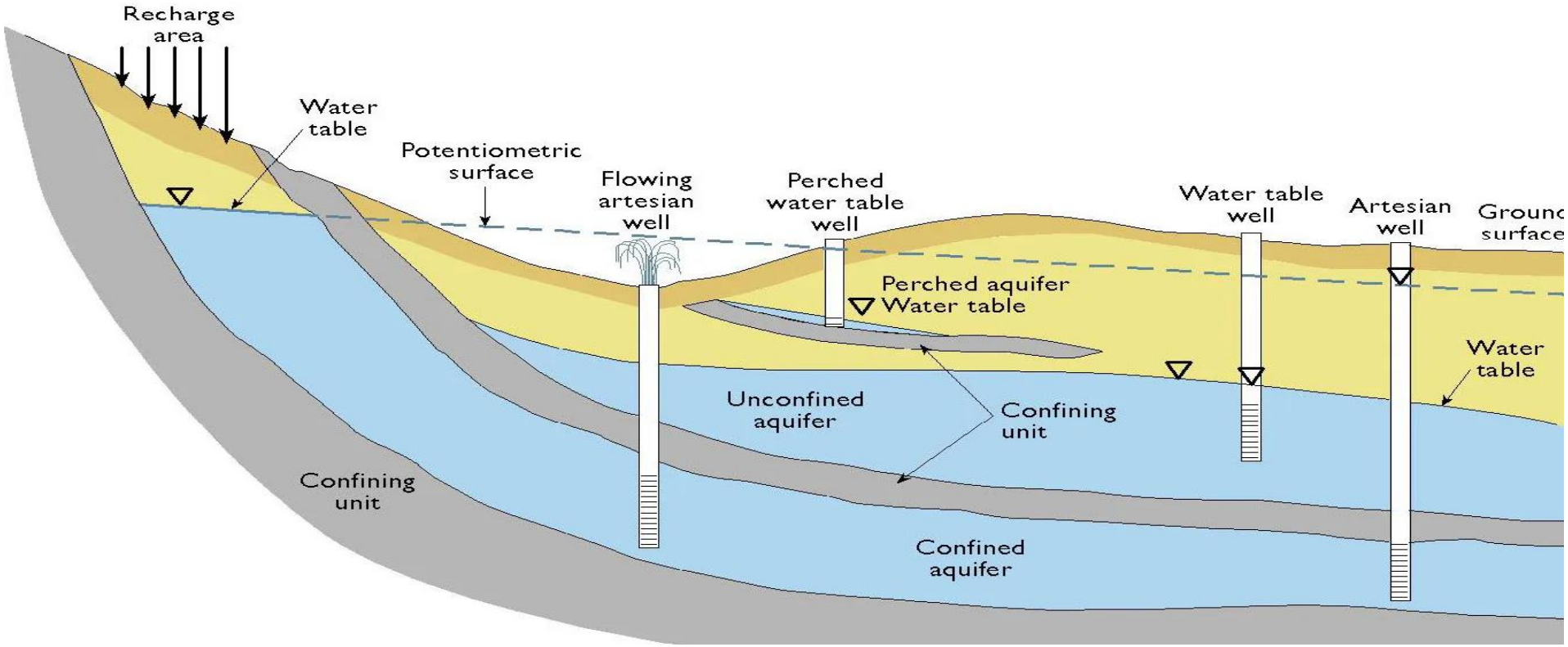


Figure: Soil Profile showing complex nature of groundwater

Groundwater Hydrology (cont…)

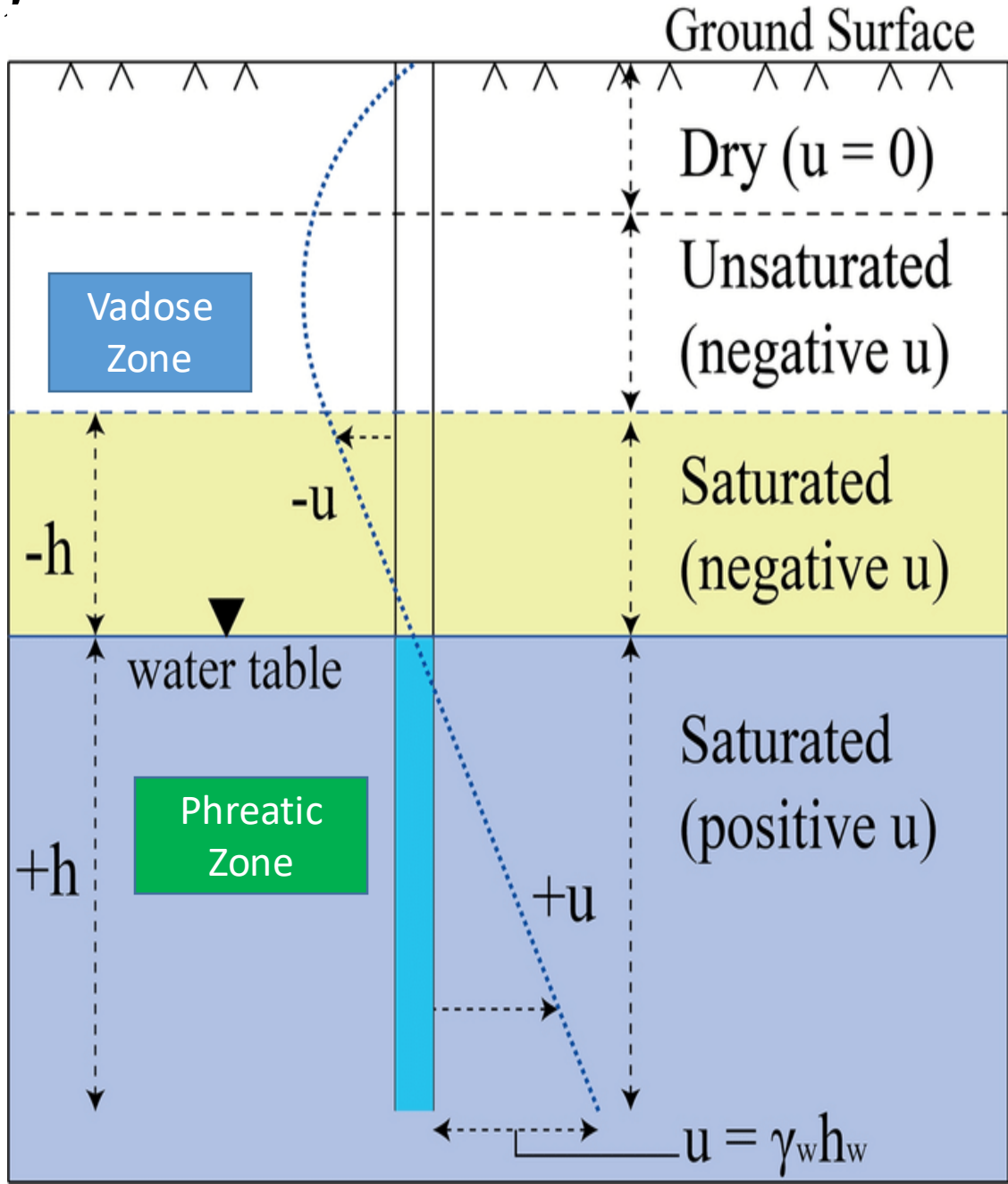
Division of subsurface water:

Phreatic Zone:

- Portion below the GWT
- Water is subjected to +ve pressure as a result of weight of overlying water and other causes.
- Most subsurface water is in phreatic zone.

Vadose Zone:

- Portion **above** GWT
- Water has **-ve pressure**.
- Held in place by capillary action and other forces present in soils.



Groundwater Hydrology (cont..)

Technically **Only water in phreatic zone is true GW**. But often the term GW to describe all subsurface water

- **Aquifers**: Soils that can **transmit large quantities** of water. (**sands and gravels**).
- **Aquicludes**: Transmit water slowly, **clays**
- **Aquitards**: Flow of water at **low to moderate rate**, silty sands.

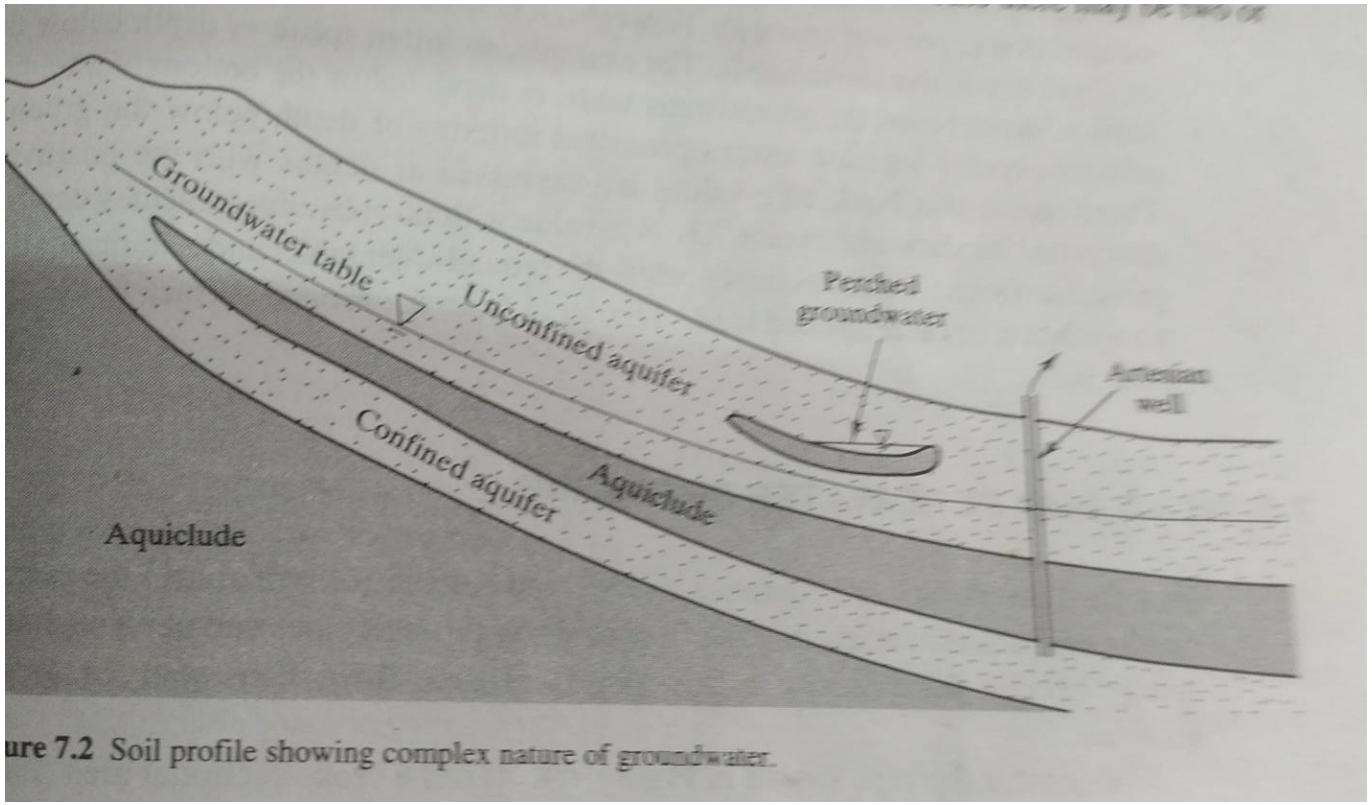
All three may be in a single soil profile, flow can be more complex.

Unconfined Aquifers:

- Upper aquifer in which **bottom flow** boundary is defined by an **aquiclude** but **upper b**oundary is free to reach it own natural level.
- **GW occupies lower portion of aquifer**.
- **Flow regime-** zone of soils through the water flows.
- If GW arrives at site, GWT would rise accordingly.

Confined aquifers:

- **Lower aquifer** in which **both lower and upper flow boundaries** are defined by aquiclude and **similar to a pipe** that is flowing full.
- **Most are artesian**, **water at top of aquifers is** under pressure.
- People often drill wells into because **water will rise up** through the aquiclude without pumping.
- If water pressure is high enough, artesian wells **deliver water all the way to GS without pumping.**



ure 7.2 Soil profile showing complex nature of groundwater.

GW Exploration and Monitoring

- Presence of water in soil pores and rock fissures has a very significant impact on engineering behaviors of soils.
- **Site characterization program needs to assess GW conditions.**

How to assess:

- **Drilling a Boring or Excavation**

i. May **observe small seeps**, with moisture tickling in to hole.
ii. May be due to small **non-uniformities in soil conditions** that have **trapped water** at certain level.

Perched GW –Large zone of trapped water.

- **Continuous Drilling**

i. To a great enough depth, **GW eventually encountered**.
ii. It is the level to which **water fills open boring**.

Determination of GWT



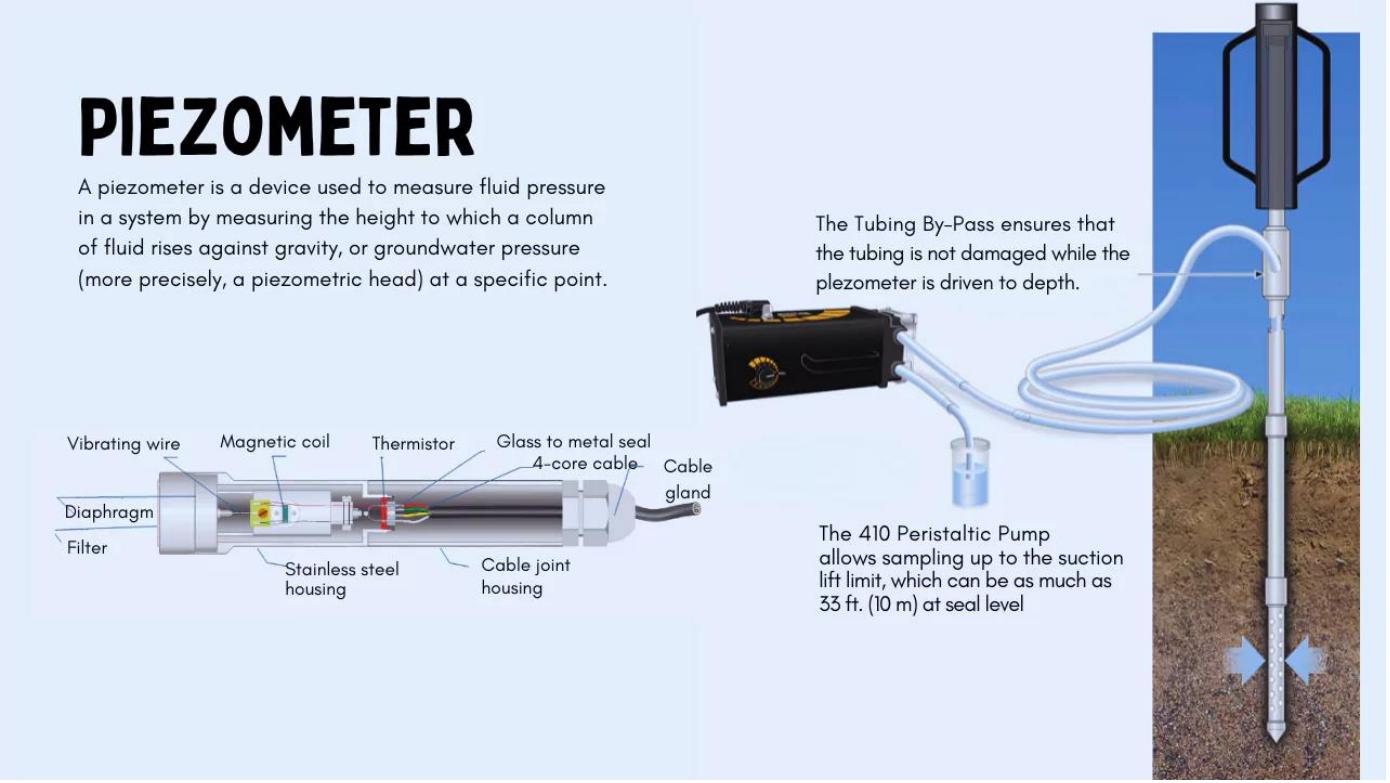
Open Boring

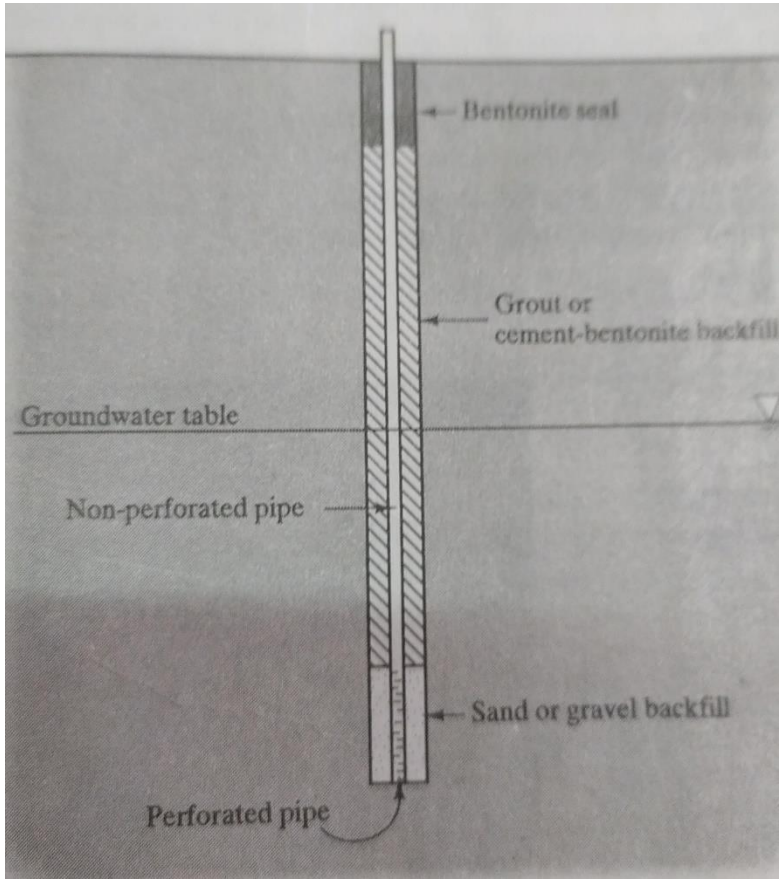
- Sometimes, water **quickly flows** (**sands, gravels**) into hole, **reaching equilibrium** in an hour or less.
- In these case, **GWT can be located** in the open hole before it is backfilled.
- In silty or clayey soil, **may require hours** or even days to reach equilibrium.
- Leaving hole open long time, may **pose safety problems**.
- GWT table often **changes with time** and may require to monitor these changes.
- Both problems can be **solved by installing instrument** in the observation well in the field.

Field Instrumentation – to monitor GWT

- **Install piezometers** in the observation well of ground.

- **Open stand pipe piezometer**, similar to observation well except the inside of pipe is hydraulically connected on one point in the soils.

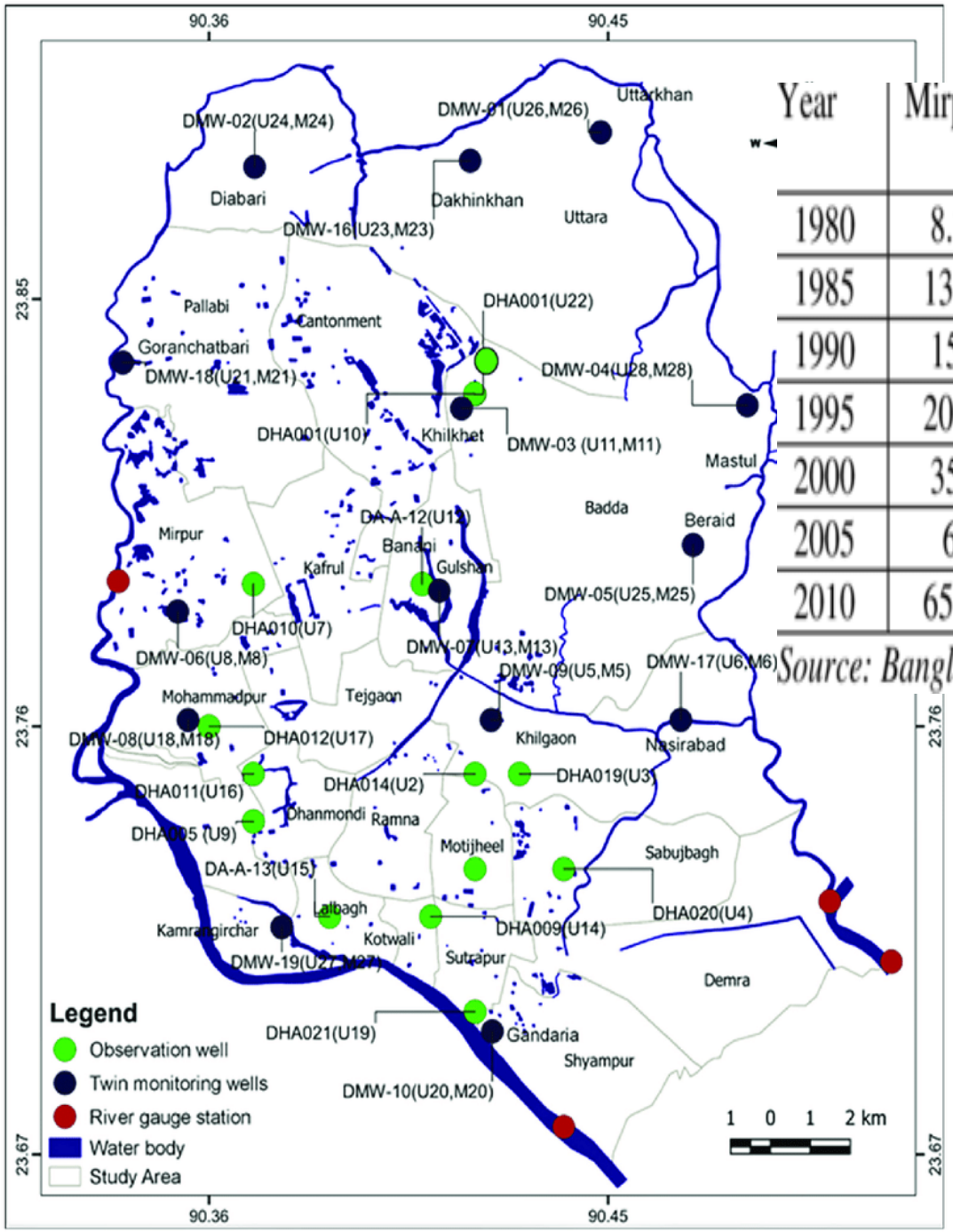




- **Observation well**, which is hydraulically open along the entire length.

GW is able to **flow freely** in and out of the pipe, so the water level inside is GWT

Depth can be **measured by electronic probe / electronic** WL indicator or simply **lowering a cloth tape**.



Year	Mirpur	Mohammadpur	Dhanmondi	Gulshan	Cantonment	Lalbag	Sabujbag	Sutrapur
1980	8.36	9.3	10.12	9.91	-	1.67	3.13	5.88
1985	13.57	13.5	12.76	9.95	-	16.06	13.63	8.93
1990	15.3	14.52	15.4	10	-	17.71	21.49	11.08
1995	20.76	20.48	24.27	24.25	18.46	19.78	26.43	15.67
2000	35.2	20.87	40.12	27.59	27.88	36.57	46.45	18.79
2005	63	32.21	60.85	37.3	27.8	44.77	54.4	20.12
2010	65.97	31.24	66.32	42.66	27.81	44.77	54.4	21.1

Source: Bangladesh Water Development Board, 2014

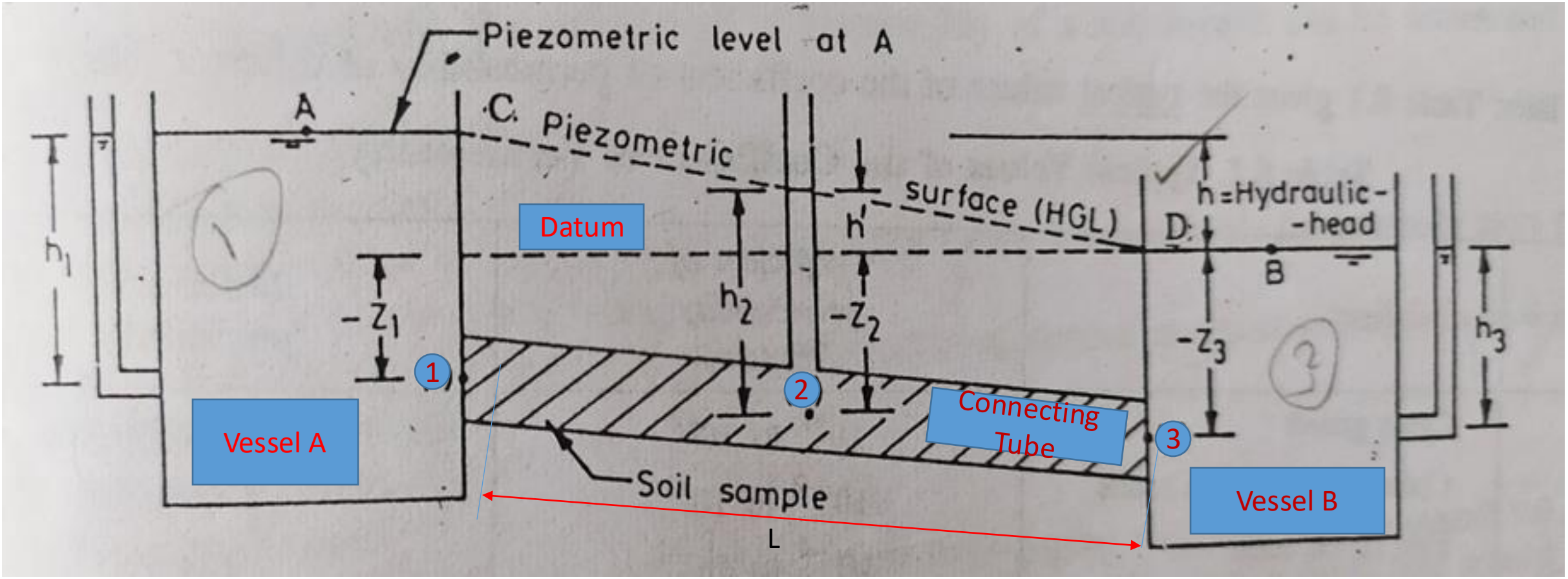
Hydraulic head or **piezometric head:** It is a specific measurement of liquid pressure above a vertical of datum.

Different Types Hydraulic Head:

- **Total Head** at any point in a flowing fluid
  = **elevation (datum) head**+ **pressure head** + **velocity head**.
- **Elevation Head** = vertical distance of the point from the **datum**.
- **Pressure Head**= head indicated by a **piezometer.**
- **Velocity Head**= $\frac{v^2}{2g}$, for flow of water through soils, as velocity is extremely small, the velocity head is **neglected**.

Total Head at any point in a flowing water= **elevation (datum) head**+ **pressure head**

Various Heads



Point	Elevation Head	Pressure Head	Total Head
1.	$-z_1$	h_1	$h_1 + (-z_1)$
2.	$-z_2$	h_2	$h_2 - z_2$
3.	$-z_3$	h_3	0

- Two **vessels** A & B containing water at different levels and connected by a **small tube** (of length L) containing soil sample.
- **Flow takes** place from vessel A (with high head) to vessel B (with low head) through the tube.
- **Datum** at the water level in vessel B.

- Elevation head, pressure head and total head **at points 1, 2 and 3** are shown in the figure.

Hydraulic Head:

- **Total head** at point at 1, $\boldsymbol{h_1 - z_1 is\ h}$ and at point 3, is zero $\boldsymbol{ie. h_3 - z_3}$.
- Head **h** is known as the **hydraulic head** for which water flows from **vessel A to vessel B.**
- **h** = differences in elevations of water levels at the entry and exit points of soil mass (h_1 - h_3) at point 3.
- h'= **Loss of head** through soil at point 2, also known as **effective head**.

Hydraulic Gradient:

- **Loss of head per unit length of flow** through the soils.
- $i = \frac{h}{L}$, h= hydraulic head, L= length of the soil specimen.
- A large hydraulic gradient reflects extensive friction.

Hydraulic Gradient Line (HGL):

- Line CD drawn by joining the points of head variations.
- Also known as **Pressure Gradient Line**.
- If piezometer is inserted at he intermediate point 2, water will rise up to the level of HGL, CD, which is also known as **Piezometric Surface**.
- Assumed that **the loss of head over the length** over the length of soil sample is **uniform** and **variation is linear**.

Factors Affecting Permeability of soils

- **Grain or particle size**

  $k=CD_{10}^{2}$

Alan Hazen equation

- **Void Ratio (e)**

  More void ratio more permeability, $k \propto e^{2}$

- **Soil Composition**

  Gravel, sands and Silts – **Presence of mica** can decrease the permeability

  Clay – water attracted between clay particles reduce permeability

- **Structural Arrangement**

  Remolding of natural soils reduces permeability

- **Stratification**

  Water flowing parallel to strata, permeability will be more.

- **Presence of Foreign Particles and Entrapped Air**

  Reduces void spaces and block interconnected pores, affects permeability.

- **Degree of Saturation**

  If soil is **saturated or dry**, permeability will be more or less.

What we have discussed today?

- What is permeability of soil?
- Permeability is an important engineering property of soils.
- Hydraulic heads.
- Factors Affecting Permeability of soils

Thank You