# What is drainage?

***Drainage:*** *Is the removal of excess water and dissolved salts from the surface and subsurface of the land in order to enhance crop growth.*

- Land drainage plays an important role in maintaining and improving crop yields
- It prevents a decrease in the productivity of arable land due to rising water tables and the accumulation of salts in the root zone
- **A** large portion of the land that is currently not being cultivated has problems of waterlogging/ponding and salinity. Drainage is the only way to reclaim such land.

## Con’d…

- **Surface Drainage :** The removal of excess water from the surface of the land by diverting it into improved natural or constructed drains.
- **Subsurface Drainage :** Is the removal of excess water and dissolved salts from soils via groundwater flow to the drains, so that the water table and root-zone salinity are controlled.
- **Ponding :** The accumulation of excess water on the soil surface.
- **Waterlogging** : The accumulation of excess water in the root zone of the soil.
- **Salinization :** The accumulation of soluble salts at the soil surface, or at some point below the soil surface, to levels that have negative effects on plant growth and/or on soils.

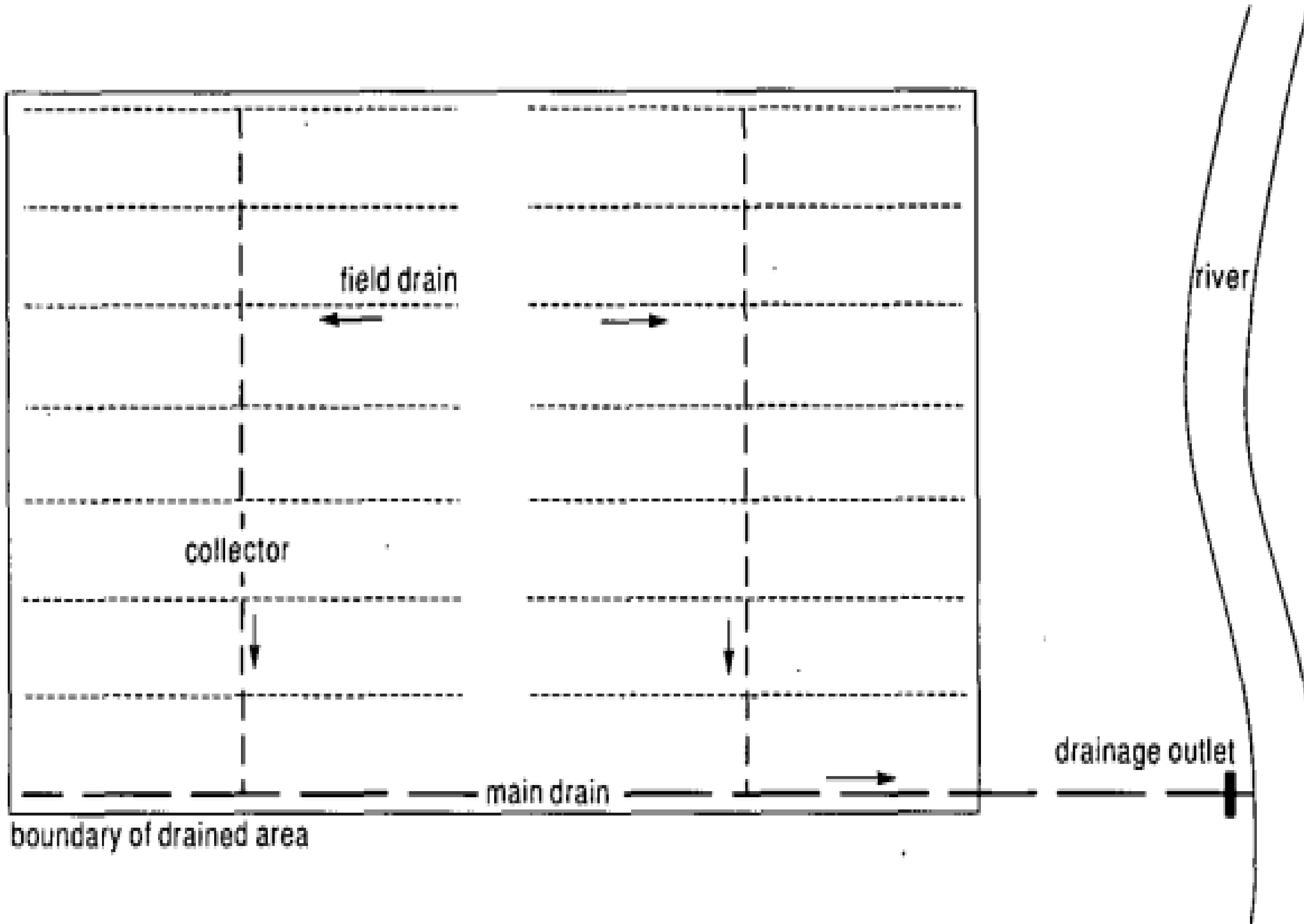
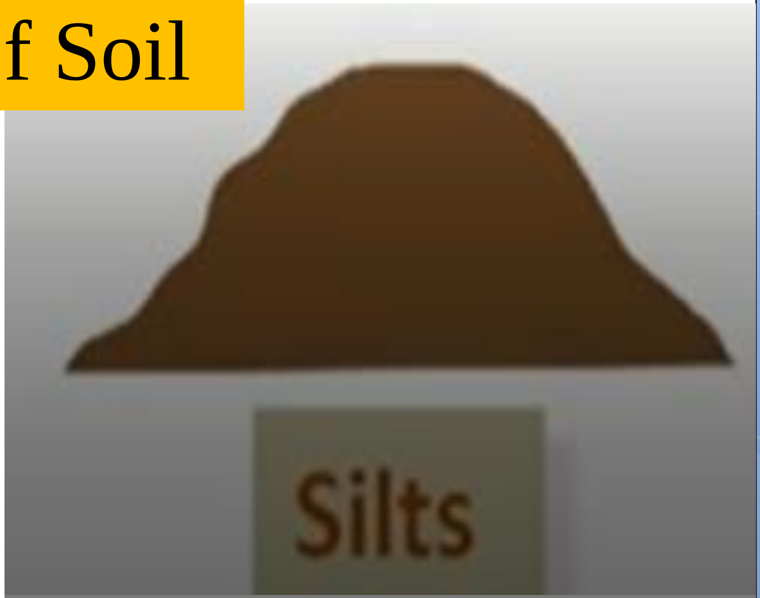
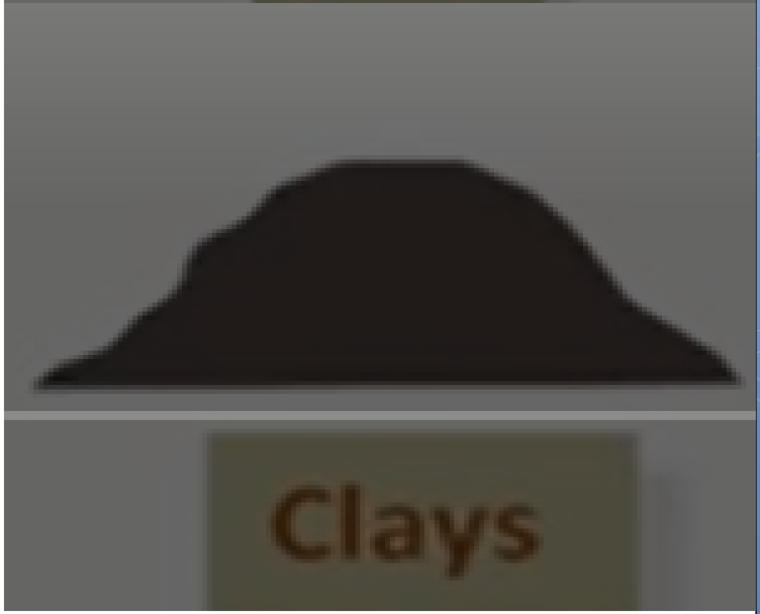



Figure 1.1:Schematic drainage system

# Types of Soil





# Types of Soil Water

**Soil contains**

- 25% Water
- 25% Air
- 5% Organic Matter and
- 45% Minerals.

**Soil Pores Are of Two Types:**

- Macrospores (size greater than 0.006mm)
- Microspores (size less than 0.006mm)

## Con't…

- The water added to a soil mass during irrigation or otherwise is held in the pores of the soil which is termed as soil water or soil moisture.
- The soil water may exist in the soil in various forms, ***it can be classified in three categories as:***
  - ✓ **Hygroscopic water**
  - ✓ **Capillary water, and**
  - ✓ **Gravitational water**

# I. Hygroscopic Water

- Is the water which is absorbed by the particles of dry soil from the atmosphere **(water sources…).**
- Is held as a very thin on the surface of the soil particles due to adhesion or attraction between surface of particles and water molecules.
- Below the permanent wilting point the soil contains only hygroscopic water.
- It is not available to the plant.

## II. Capillary Water

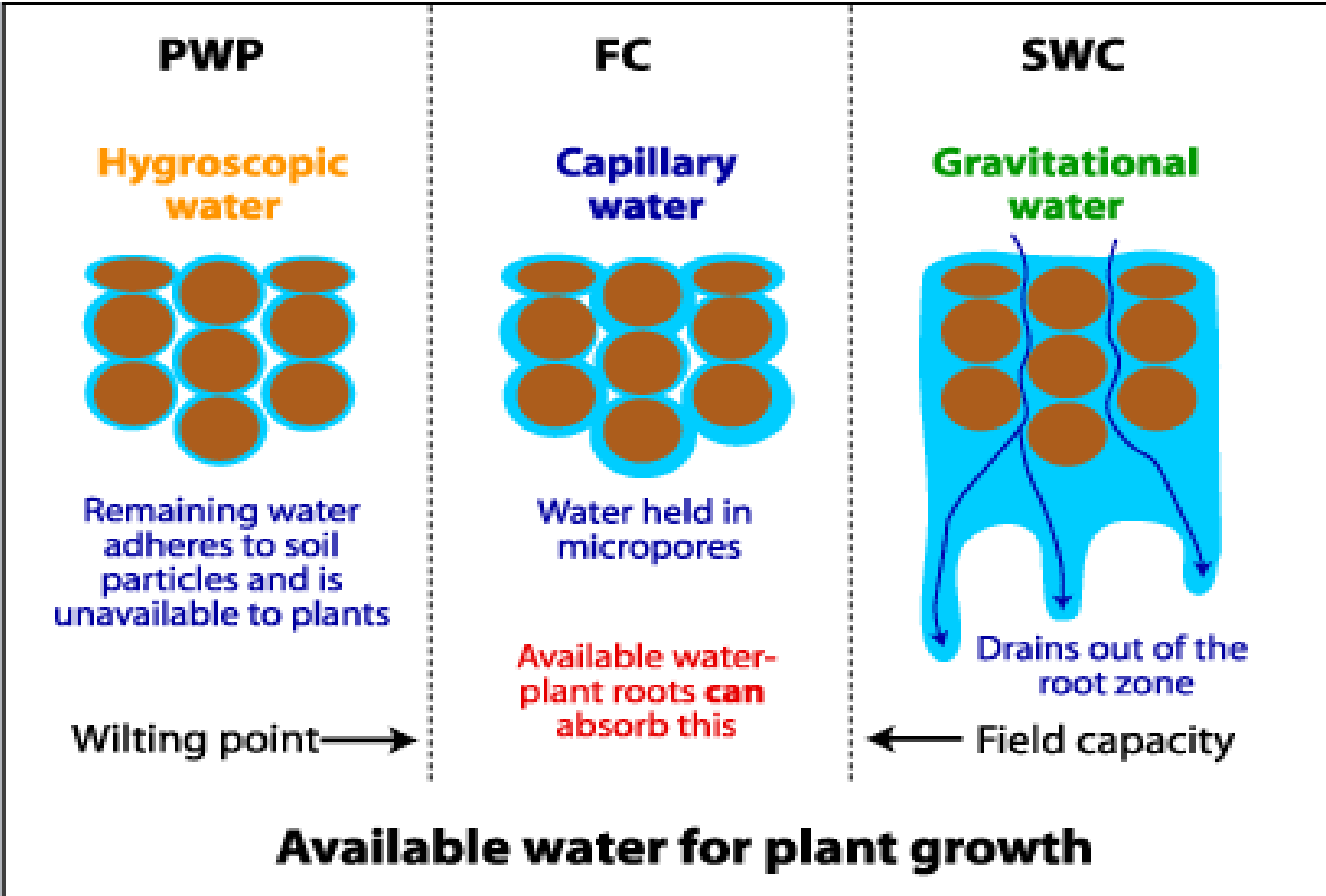
- The water content retained in the soil after the gravitational water has drained off.
- It is held in micropores of the soil due to surface tension properties of the soil (microspores are stronger than the force of gravity).
- It is the main water that is available to plants as it is trapped in the soil solution.
- Thus, it constitutes the principal source of water for plant growth.
- Main factors that influence the amount of capillary water in the soil are the:

***(Structure, Texture and Organic matter content of the soil)***

**III. Gravitational Water (Sat=100%)**

- Within the adhesion of water to the soil during irrigation or otherwise, the water content of the soil is raised to a state of saturation.
- At this point the soil pores are completely filled with water and the soil contains the maximum possible water content, which thus constitutes the upper limit of the gravitational water.
- It is free water moving through soil by the force of gravity.
- Largely found in macropores of soil and very little gravitational water is available to the plants as it drains rapidly down the water table in all except the most compact of soils.
- *It is that water which is not held by the soil but drains out freely under the influence of gravity.*

# Con'd…


PWP
FC
SWC
Hygroscopic water
Capillary water
Gravitational water
Remaining water adheres to soil particles and is unavailable to plants
Water held in micropores
Drains out of the root zone
Available water- plant roots can absorb this
Wilting point
Field capacity
Available water for plant growth

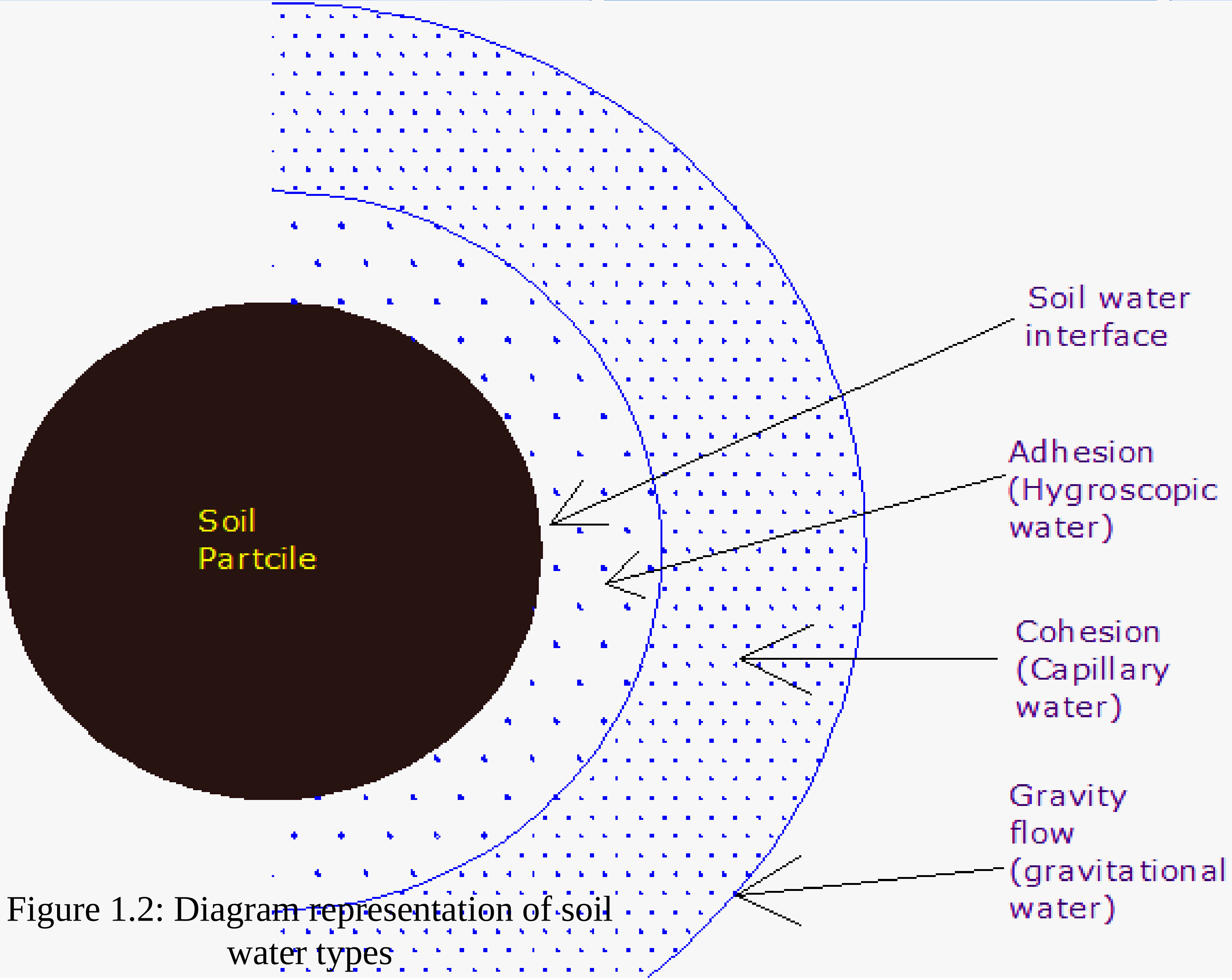



Figure 1.2: Diagram representation of soil water types

# SOIL MOISTURE CHARACTERISTICS

- Moisture extraction curves, also called moisture characteristic curves, which are plots of moisture content Vs moisture tension.
- Soil moisture tension depends on the texture, structure and other characteristics of the soil.

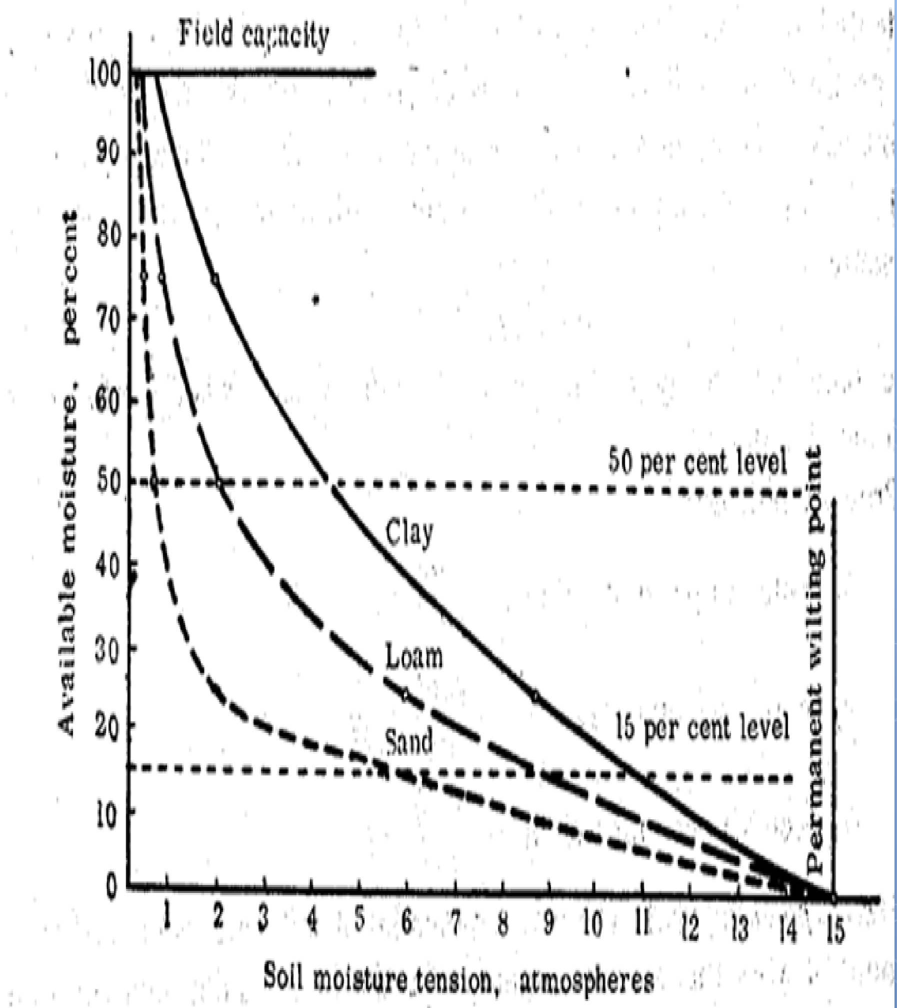



Figure 1.3 : Typical moisture characteristics curves of clay, silt loam and sand soils (From USDA, SCS).

Table 1: Generalized influence of soil separates on other soil properties and behavior

| Property/behavior | Sand | Silt | Clay |
|---|---|---|---|
| Water-holding capacity | Low | Medium to High | High |
| Aeration, when moist | Good | Medium | Medium to poor |
| Hydraulic (water) conductivity | High | Slow to Medium | Slow to very slow |
| Soil organic matter level | Low | Medium to High | High to Medium |
| Decomposition of organic matter | Rapid | Medium | Slow |
| Warm-up in spring | Rapid | Moderate | Slow |
| Compactability | Low | Medium | High |
| Susceptibility to wind erosion | Moderate (high if fine sand) | High | Low |
| Susceptibility to water erosion | Low (unless fine sand) | High | Low if aggregated, High if not |
| Shrink-swell potential | Very low | Low | Moderate to very high |
| Sealing of ponds and dams | Poor | Poor | Good |
| Suitability for tillage when wet | Good | Medium | Poor |
| Pollutant leaching potential | High | Medium | Low (unless cracked) |
| Cation exchange capacity (CEC) | Low | Medium | High |
| Resistance to pH change | Low | Medium | High |

# SOIL MOISTURE CONSTANTS

**Field capacity (FC):**

- Is the amount of water remaining in the soil after the large pores have drained.
- The optimum water content for plant growth is considered to be close to field capacity.
- Plants continuously take this up until there is no more water available for crop growth and wilting occurs

**Permanent welting point (PWP)**

- Is the moisture content level at which the plants are water stressed and irreversibly wilt.
- The soil is said to be at the permanent wilting point when plants can no longer exert enough force to extract the remaining soil water.

## con’d…

- The plant will wilt and may die later if water is not available.
- Water tension of soil at PWP is generally taken as **15 bars**.

**Saturation capacity**

- When all pores of soil are filled with water, it drains out so fast that it is not available to the crops.
- The time of draining out varies from sandy soils to clay soils.

**Available Water (AW):**

- The soil moisture between field capacity and permanent wilting point is referred as available moisture.

**Readily Available Water (RAW):**

- This is the level to which the available water in the soil can be used up without causing stress in the crop.
- For most crops, 50 to 60% available water is taken as readily available.

Con'd…

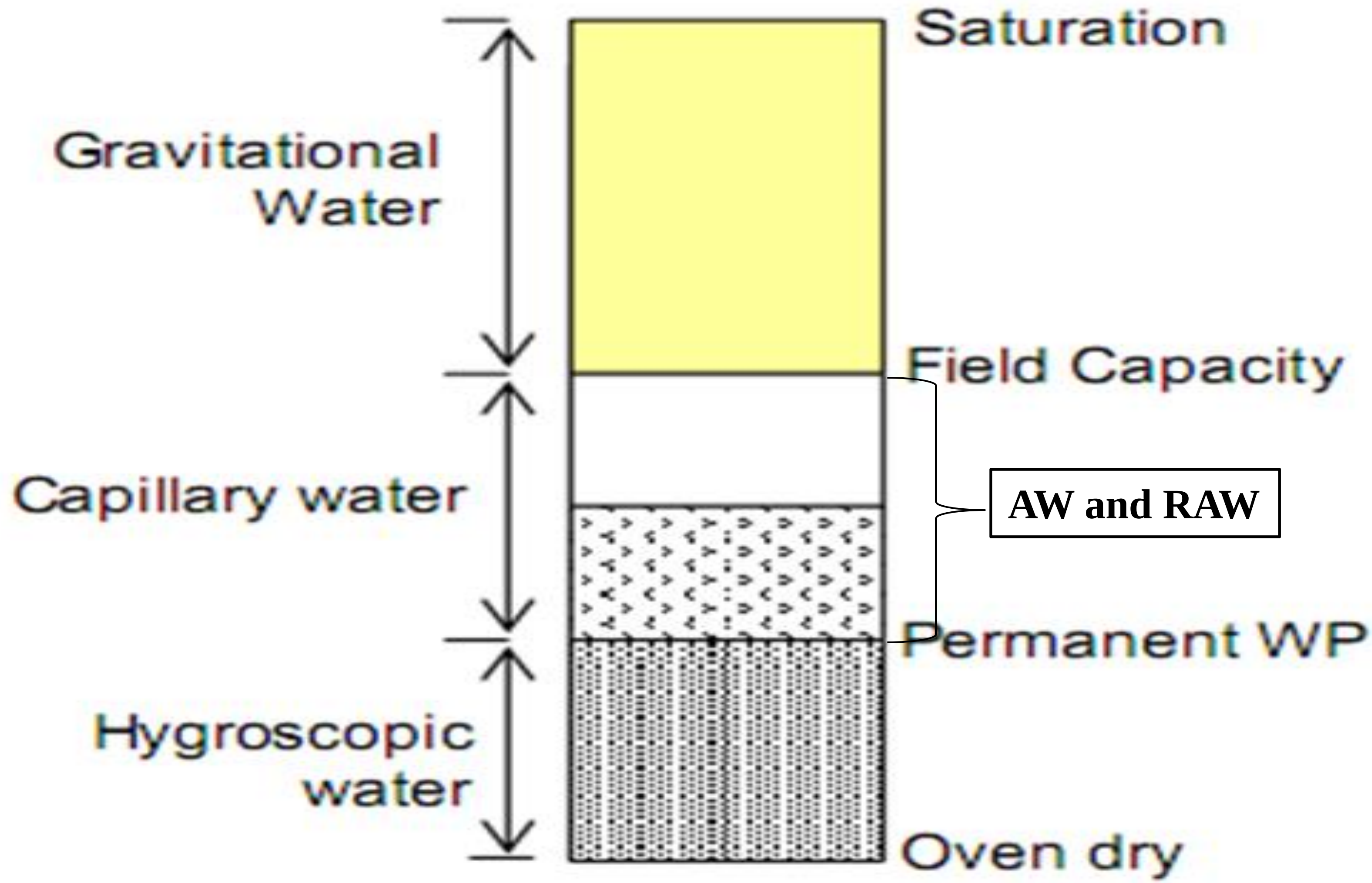



Fig 1.3 Classification of soil water

# Water Movement in the Soil

- Water movement in the soils is quite simple and easy to understand.
- Mass of water tends to move from an area of higher potential energy to one of lower potential energy.

**SOIL WATER POTENTIAL**

Soil-water potential is defined as the work expended on or by the soil water during the transfer of an infinitesimal quantity of water from point A to a reference pool or point B in the soil.

- The total potential energy of water is the sum of the potentials from all sources.

$$\boldsymbol{\varphi T = \varphi m + \varphi g + \varphi p + \varphi o}$$

Where, $\boldsymbol{\varphi}$ (psi)= symbol for water potential

$\boldsymbol{\varphi m}$= matric potential, $\boldsymbol{\varphi g}$= gravitational potential

$\boldsymbol{\varphi p}$= pressure potential, $\boldsymbol{\varphi o}$= osmotic/solute potential

# Gravitational Potential

- It was determined by the height of water above reference level
- Water moves downward under gravity.
- It is zero at reference level and positive above RL & negative below RL.
- According to principle of energy, water moves from points with higher energy status to points with lower energy status.
  - ***N.B Differences in head determine the direction and the magnitude of soil - water flow.***

# pressure potential($\varphi p$,+ve/-ve)

- The pressure potential is a measure of the ***positive pressure*** potential and is measured in ***saturated soil conditions***.
- The ***negative pressure potential*** has been referred to as ***capillary potential, tension, suction, and matric potential.***
- $\boldsymbol{\varphi p}$ is zero above and at level of water in the pizeometer.
- These forces bind the water to the soil matrix and lower the potential.
- ***The matric potential is a negative pressure and is measured in unsaturated soil.***

# Matric potential ($\varphi m$,-ve)

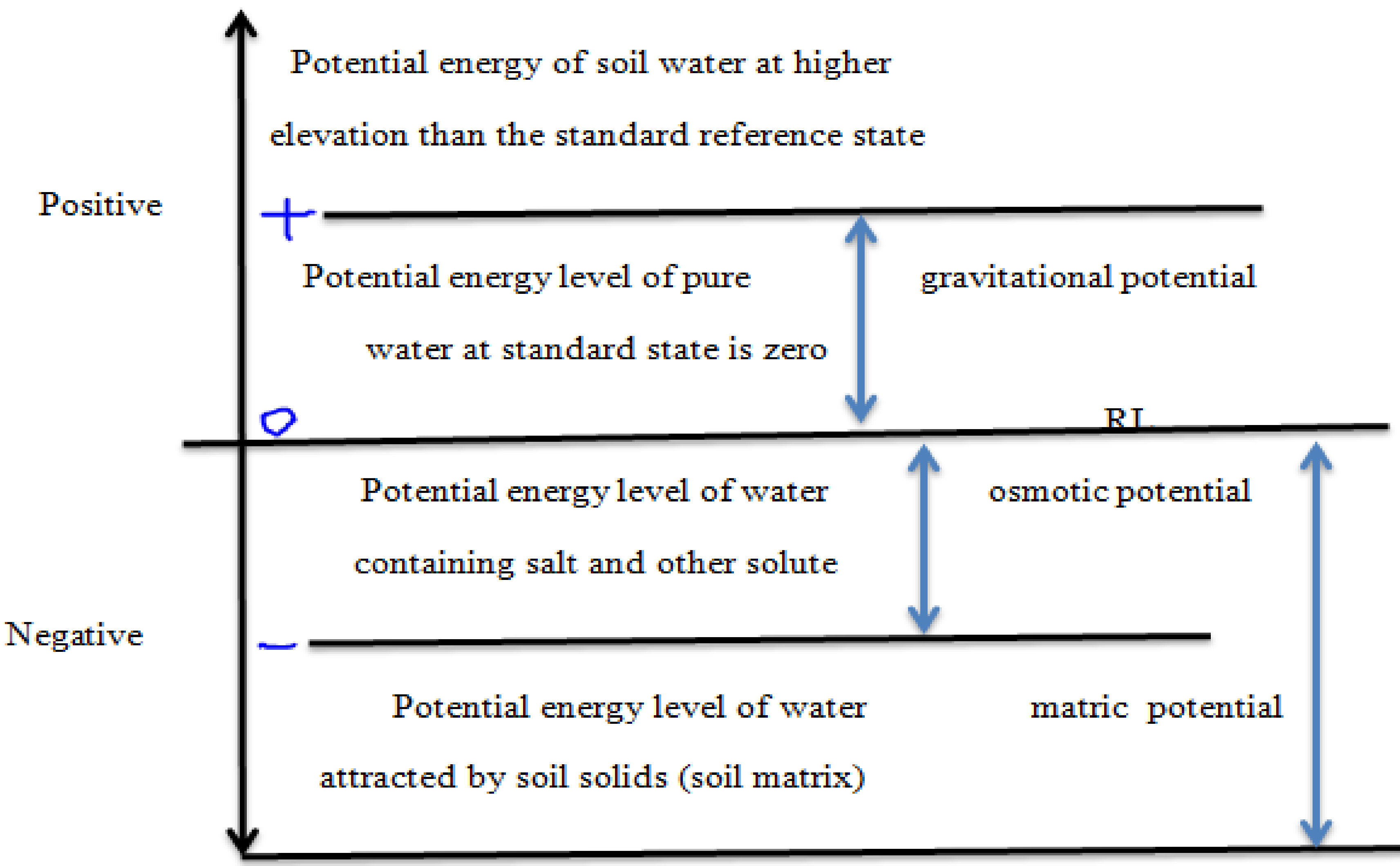
- It was determined by the strength of the ***attraction of water*** to the ***soil particle***.
- It is the most important part for the unsaturated flow(dry soil) Water flows from zone of wet soil to zone of dry soil (less negative to more negative).
- It is zero for saturated cause ( ***at and below water table***).
- The matric potential is a negative pressure and measured in unsaturated soil.

**Solute or osmotic pressure ($\varphi o$,-ve)**

- Presence of solutes in soil water decreases the potential energy of water in the soil.
- The potential energy of water in the solution is lower than that of pure water.
- It was determined by the concentration of solutes in the soil water.
- It is more negative for high solute concentration. ***Water moves from zone of low solute to high solute concentration***.

con'd…

Water movement in unsaturated zone



Con’t…

Components of Soil Water Potential

| Factor affecting Potential Energy | Component name | Reference State | Sign |
|---|---|---|---|
| Adsorption of water to soil | Matric Potential | Free Water | **neg** "-" |
| Dissolved solutes | Osmotic or Solute Potential | Pure Water | **neg** "-" |
| Elevation in gravitational field | Gravitational Potential | Reference Elevation | **pos** "+" (above ref. elev.) or **neg** "-" (below ref. elev.) |
| Applied pressure | Pressure Potential | Atmospheric Pressure | **pos** "+" (applied pressure) or **neg** "-" (applied suction) |

# Darcy’s Law and Richard’s Equation

- **Darcy’s Law and Richard’s Equation**

## A. Darcy’s Law

- Darcy’s law can be Validated for **Saturated** ,unsaturated and ***laminar*** flow conditions.
- Darcy's law says that the ***discharge rate q*** is proportional to the ***gradient in hydraulic head and the hydraulic conductivity*** or
- It states that volume of water flowing through a unit cross-sectional area per unit time (flow flux density) is proportional to the hydraulic gradient i.e.

$$(q = Q/A = -K * \dot{\Delta} h / \dot{\Delta} L)$$

- The proportionality factor, K, is called the hydraulic conductivity.

# Con't…

(1). Q was directly proportional to the difference in water levels from inlet to outlet, $h_1 - h_2 = \Delta h$:

$$Q \propto \Delta h$$

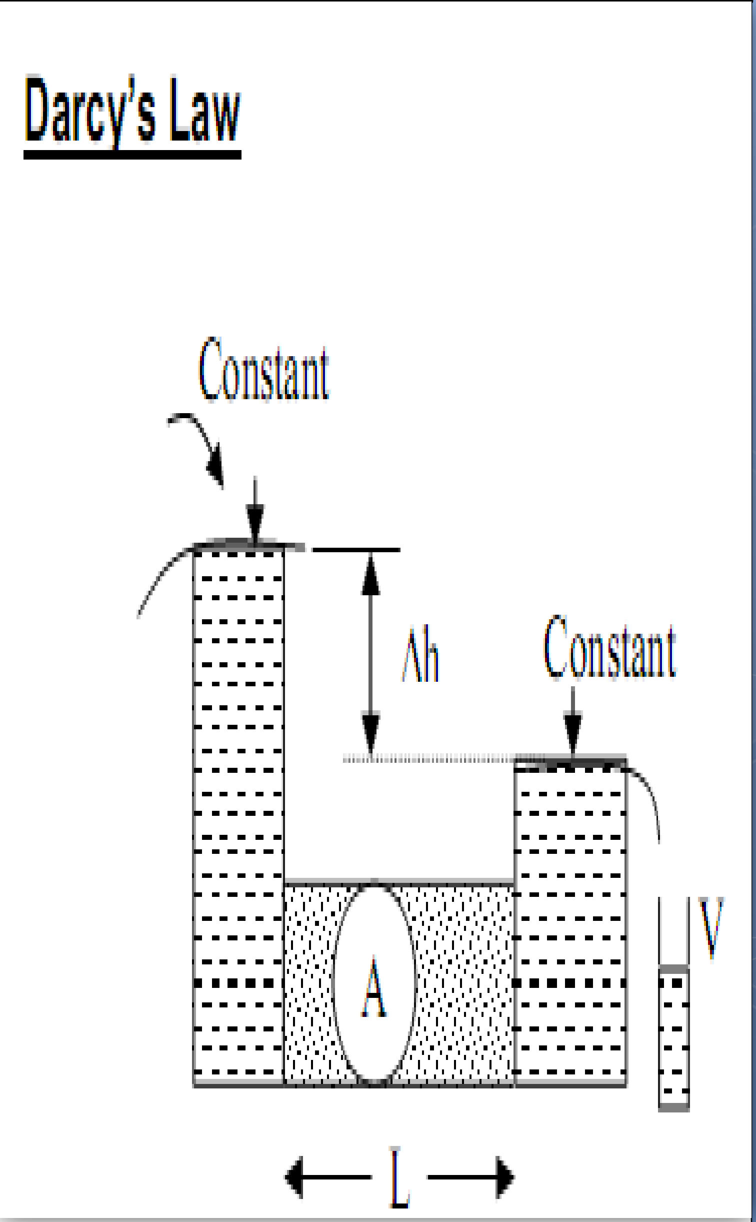
(2). Q was directly proportional to the cross sectional area of the tube:

$$Q \propto A$$

(3). Q was inversely proportional to the length of the column:

- .

$$Q = KA(\Delta h/\Delta L)$$



# Con’t…

- The above equation can also be recast in terms of:

- *The water volume flux per unit area, Q/A (also called "Darcy flux" or "Darcy velocity" with units of length per time):*

$$Q/A = -K(\Delta h/\Delta L)$$

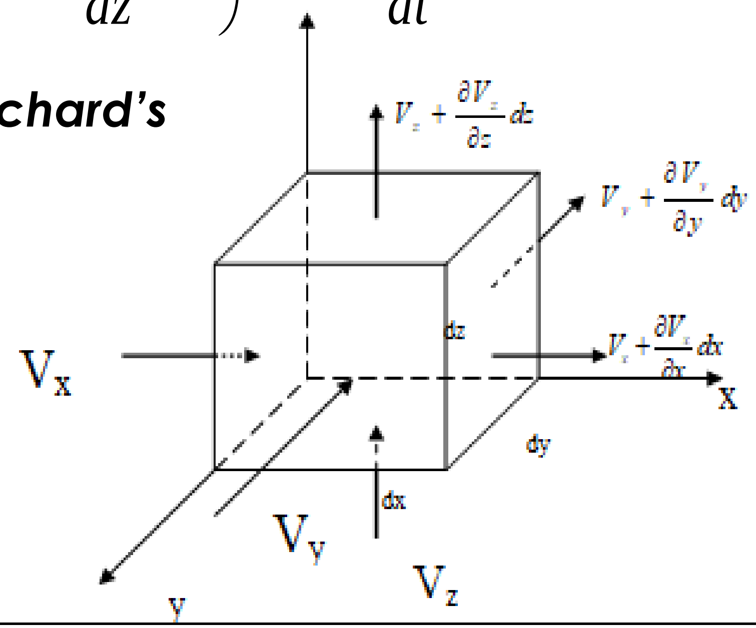
- *The negative sign in the above equations means that water flows in the direction of decreasing potential or against the positive direction of* ***z****.*

# Richard’s Equation

- Consider a volume element of soil in the shape of cubic parallelepiped inside a space defined by a set of the rectangular coordinates x, y, z as shown in the figure below; profe the equation given below using the figure.

$$\frac{\partial}{dx}\left(K(h)\frac{dh}{dx}\right)+\frac{\partial}{dy}\left(K(h)\frac{dh}{dy}\right)+\frac{\partial}{dz}\left(K(h)(\frac{dh}{dz}+1)\right)=C_{(h)}\frac{dh}{dt}$$

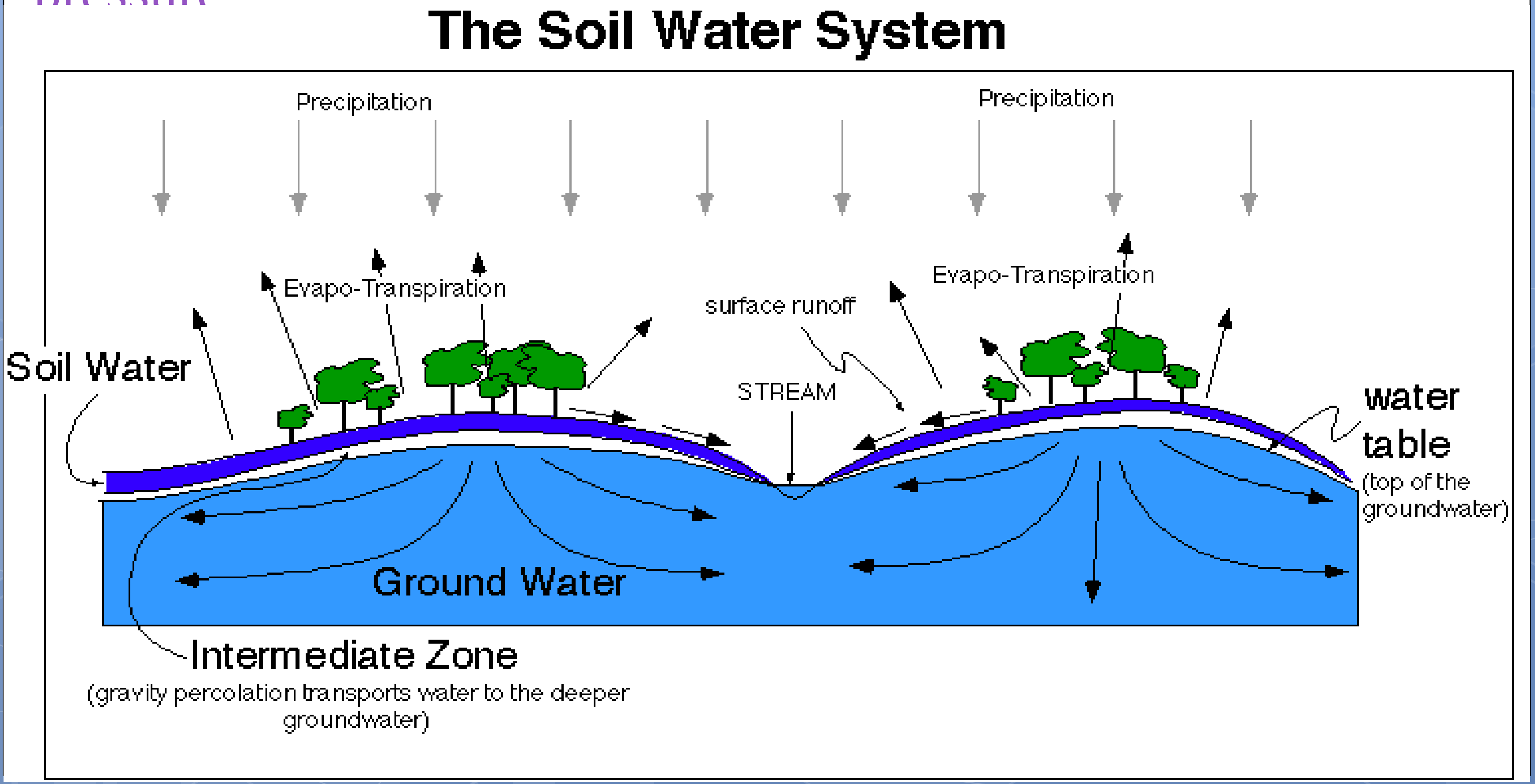
This expression is known as ***Richard’s equation***



# Soil Water Movement Above Water Table

- The **Water Table** is the upper surface of the zone of saturation.

Where, the water **pressure head** = The atmospheric pressure



# Con'd…

- Sometimes the natural drainage is inadequate to remove the extra water or salts brought in by irrigation; in such a case, an artificial or man-made drainage system is required.