

UNIT - IVGround Water Hydrology

## Ground Water Occurance

## Ground water and features of ground water

\*The water occurring in saturated zones and below the earth's crust is called as ground water.

\*The erosional work through solution is done by ground water.

\*Ground water is present beneath Earth's surface in soil pore spaces and in the fractures of rock formations.

\*Depositional features of ground water:

a. stalactite and stalagmite

b. Geode

c. Replacement

a. stalactite and stalagmite:

\*The deposits formed in a cone shape pillar of carbonate, due to water dripping from roof of caverns. The water evaporation occurs with the deposition of calcite. These cone shaped pillars hang from the roof of cavern, which are called as stalactites.

\*When these carbonate containing water drops on the floor, it forms a pile growing upwards

from the cavern floor. These pillar forms are called as stalagmites.

b. Geode:

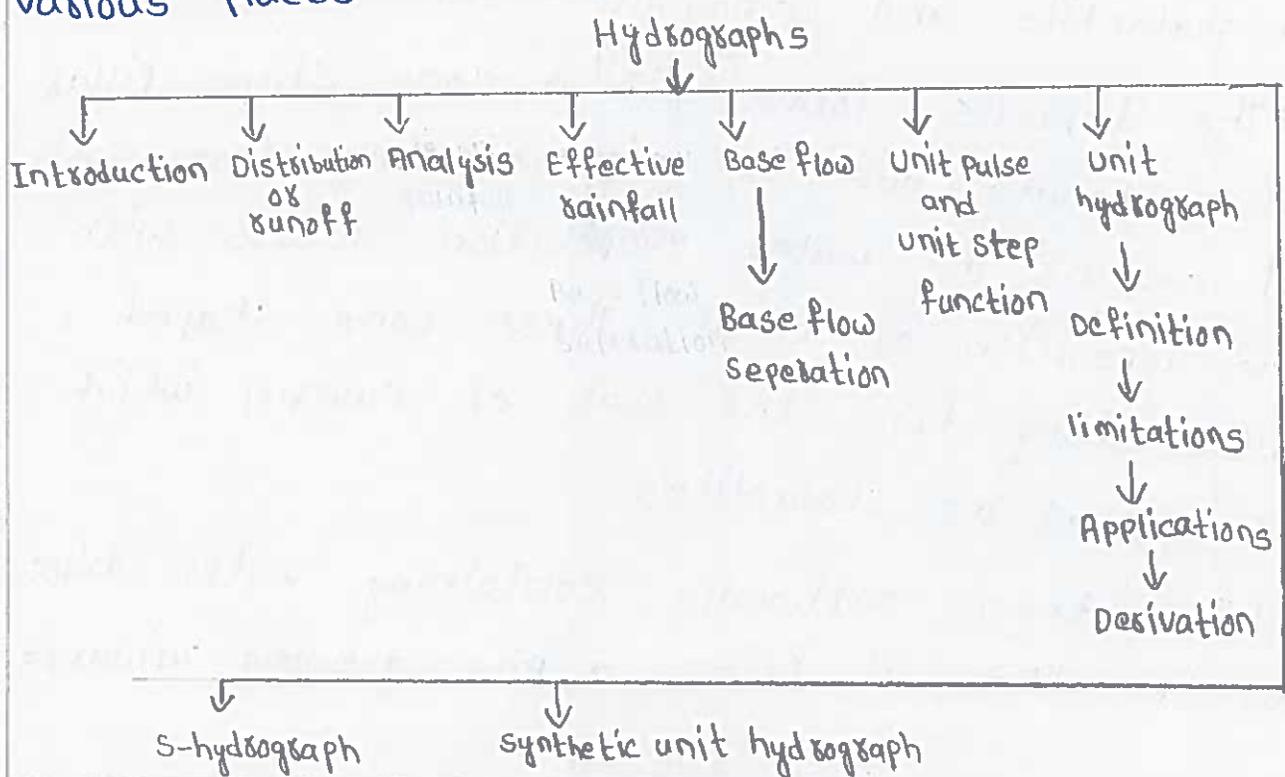
\* When ground water deposits crystals of quartz, calcite or other minerals in the rock cavities, geodes are formed.

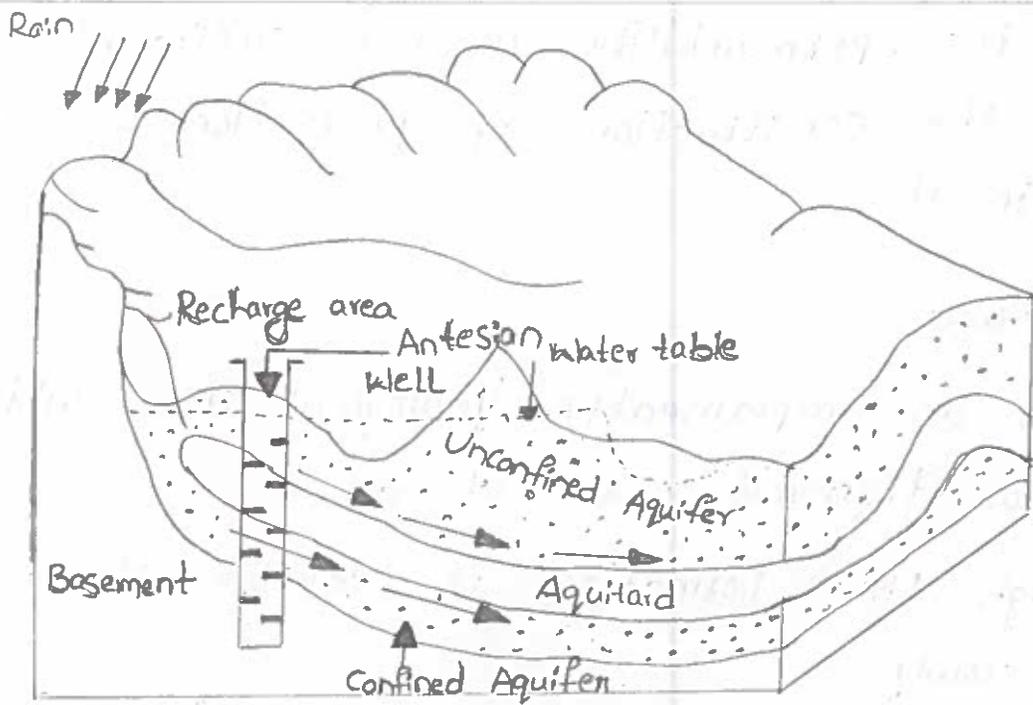
c. Replacement:

\* Ground water replaces the silica or calcium-carbonate with any other substance that comes into its contact. Replacement removes the amount of silica and gains the same amount of other substance.

Occurrence of ground water with neat sketches

\* Ground water occurrence mainly depends upon the physical properties of various formations existing. Generally, the ground water occurs at various places beneath the earth surface.





### Effluent stream and influent stream:

Streams which receive groundwater flow are called as effluent stream and the stream which contribute to the groundwater are known as influent streams.

### Aquifer:

\*It is defined as a saturated permeable geological unit that is permeable enough to yield economic quantities of water to wells.

\*In other words, it is defined as a saturated geological unit that can transmit significant quantities of water under hydraulic head.

### 1. Aquitard

\*It is a geological unit that is permeable enough to transmit water in significant quantities for large area and long period.

\*But, its permeability is not sufficient to justify the construction of production well to be placed in it.

## 2. Aquiclude

\*It is an impermeable geological unit which does not transmit water at all.

\*Although this formation is capable of absorbing water slowly.

\*It means that this geological formation can store water, but cannot transmit it easily.

## 3. Aquifuge

\*It is a geological formation that can neither absorb nor transmits water.

## Types of Aquifer

There are three types of aquifer

1. confined aquifer
2. unconfined aquifer
3. Leaky aquifer

### 1. confined aquifer:

\*It is an aquifer which is bounded by an aquiclude both at the lower and upper part.

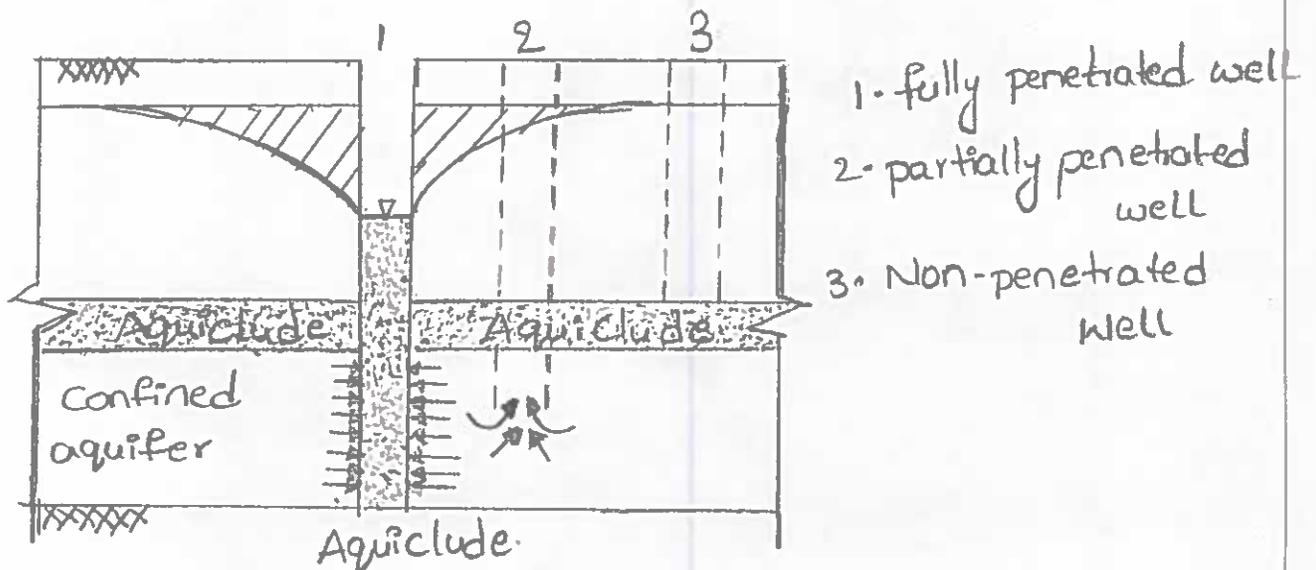
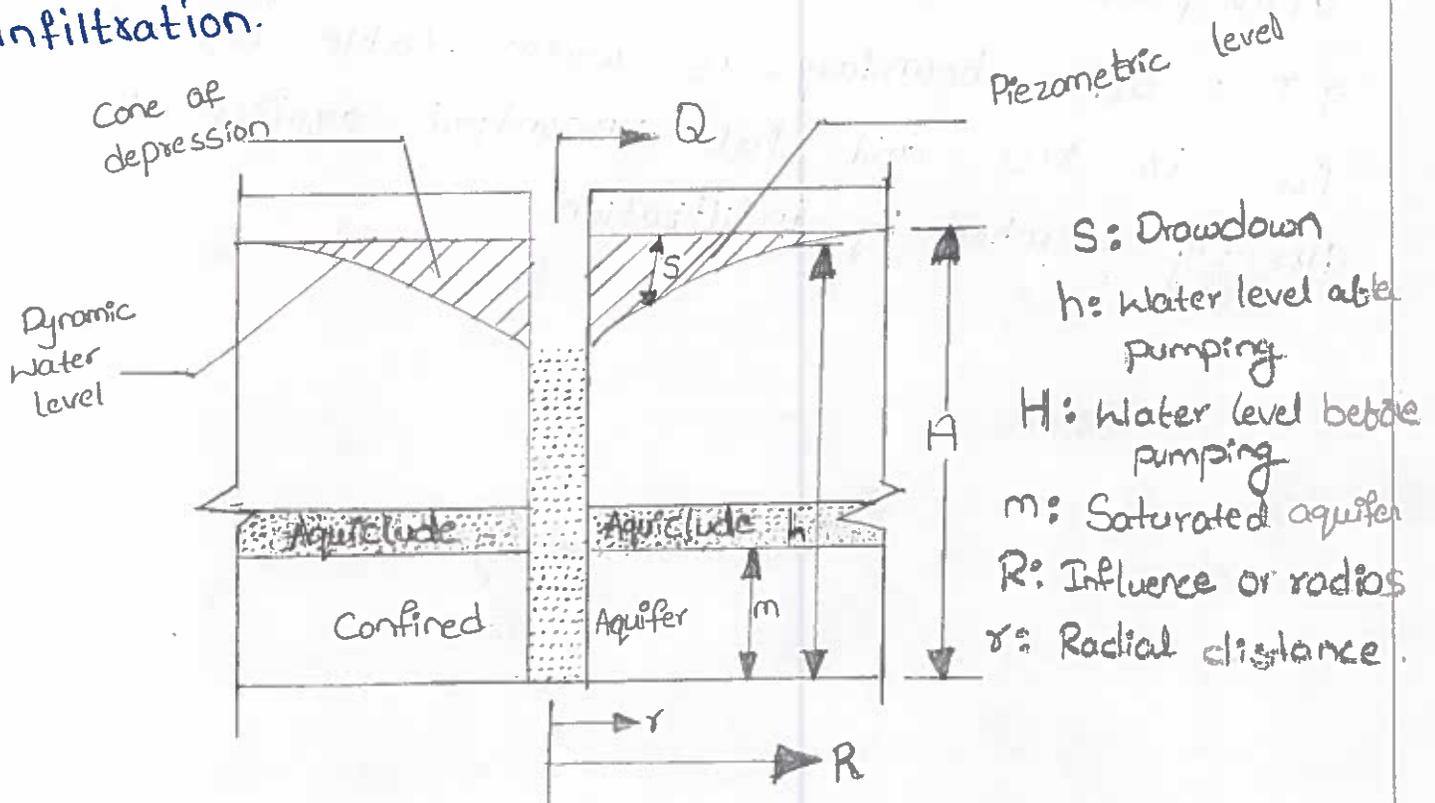
\*In other words, this aquifer is confined between two impervious layers.

\*It is also known as pressure aquifer.

\* In a confined aquifer, the pressure of water is higher than atmospheric pressure.

\* The water in a well which is constructed in such an aquifer rises usually above the aquifer and even above the ground surface due to high pressure.

\* By the way, the groundwater pressure can be either equal or greater than atmospheric pressure. Confined aquifer cannot be recharged directly by infiltration.

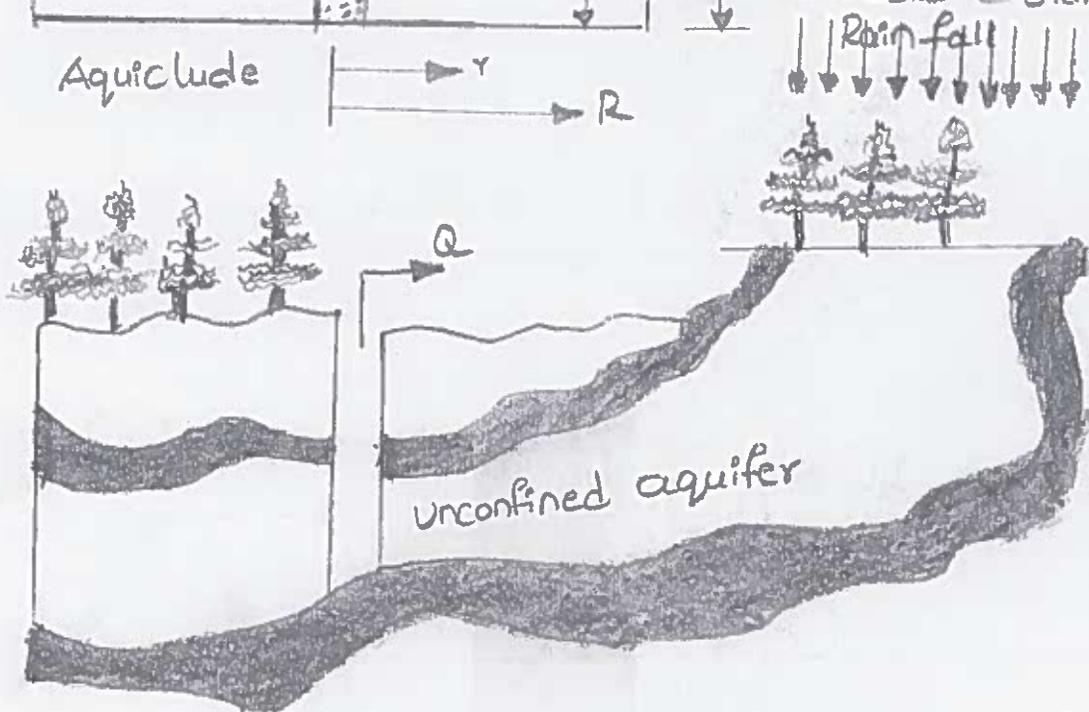
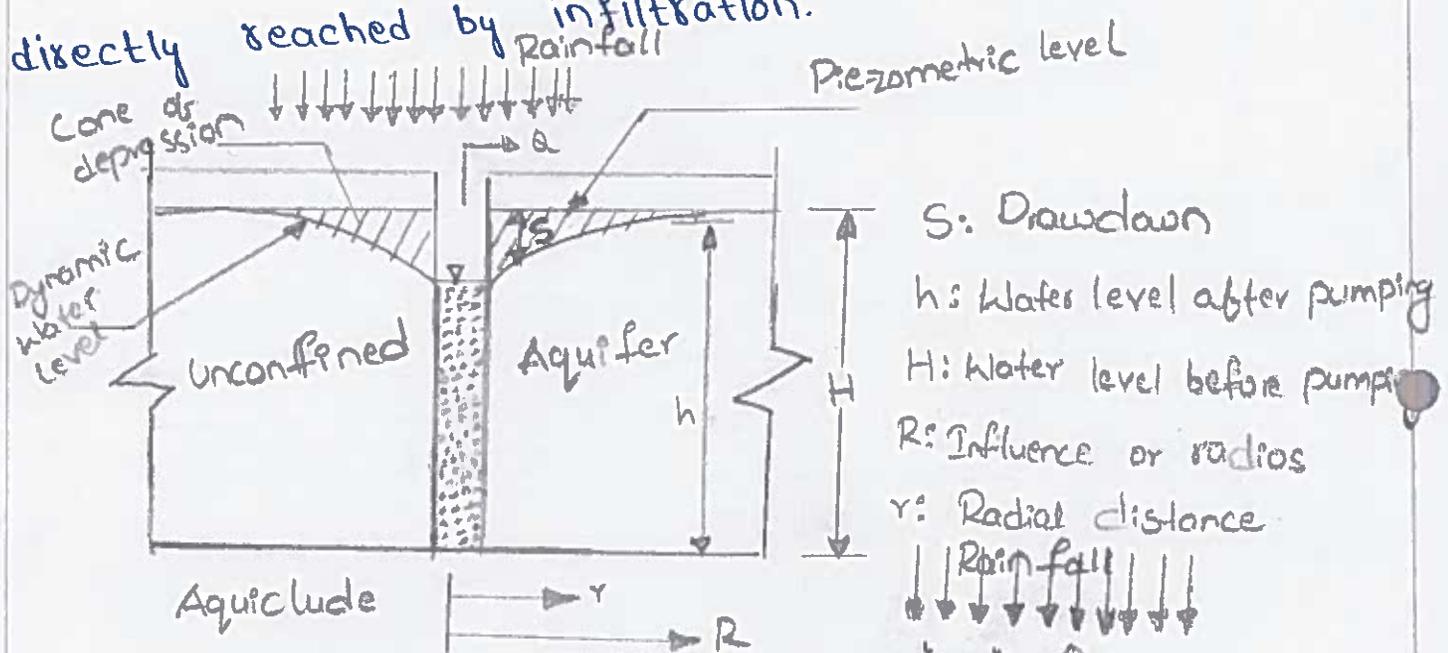


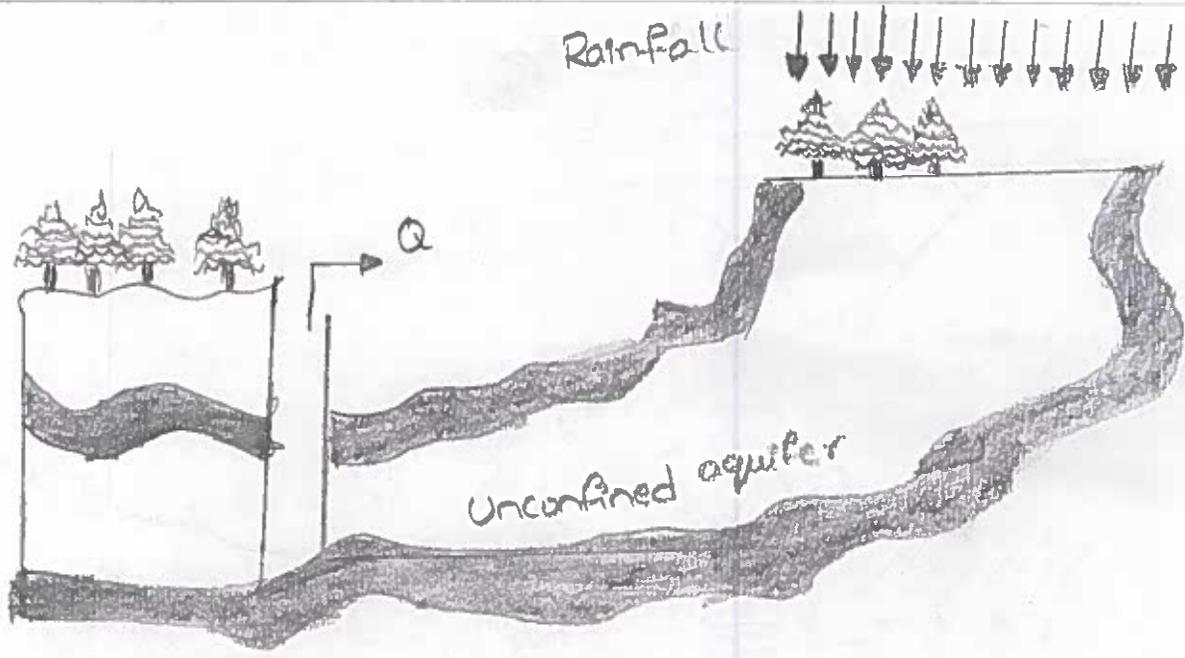
## 2. Unconfined aquifer:

\*It is an aquifer which is bounded by aquiclude at its lower side and by water table at its upper side.

\*In other words, the flow of water in the upper part of the aquifer is not restricted by any confining layer and that makes the upper part a bounded free surface. consequently, the free surface of unconfined aquifer is under atmospheric pressure.

\*Its upper boundary is water table which is free to rise and fall. unconfined aquifer is directly reached by infiltration.

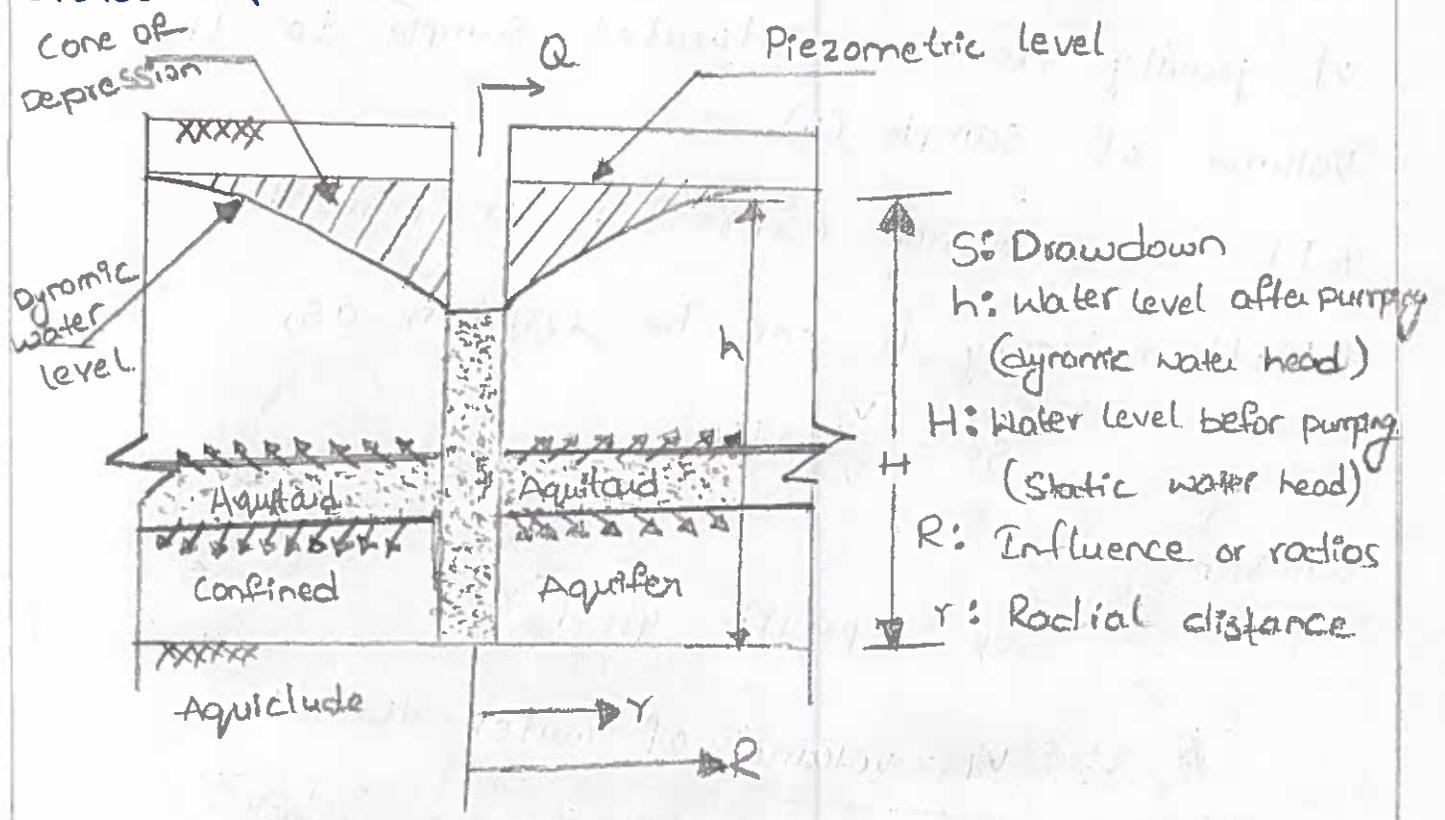


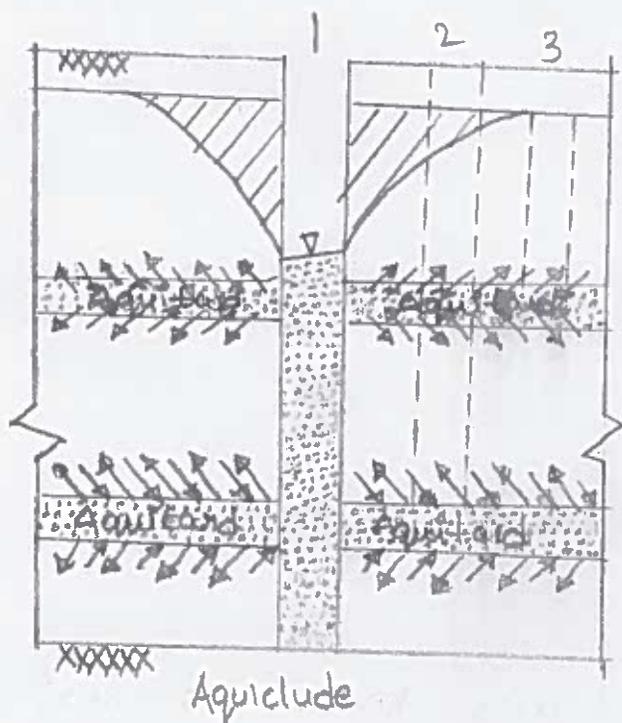


3. Leaky aquifer:

\* A leaky aquifer is also known as semi-confined aquifer as either both the upper and the lower boundaries are aquitards or one of them is aquiclude and the remaining is aquitard.

\* The water is free to move through aquitards either upward or downward.





1. Multi-leaky aquifer
2. Leaky aquifer
3. Unconfined aquifer.

Specific yield:

Specific yield ( $S_y$ ):

\* It is the ratio between the volume of water that can be released under influence of gravity from a saturated sample to the volume of sample ( $V$ ).

\* It is generally expressed in percent.

\* Mathematically it can be written as,

$$S_y = \frac{V_d}{V} \times 100$$

where,

$S_y$  = specific yield

$V_d$  = volume of water drained

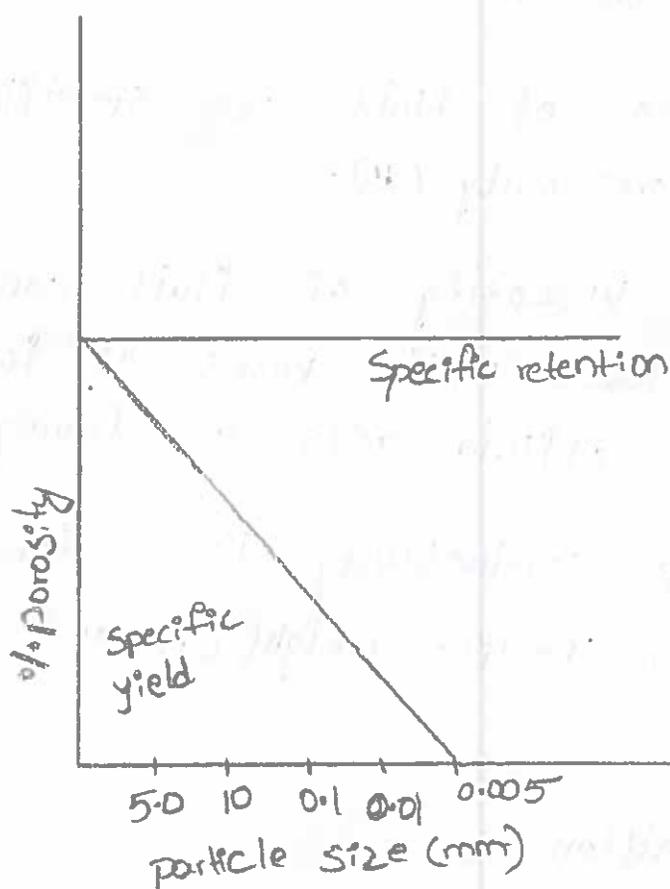
$V$  = volume of sample.

\* Here any reduction of head involves giving drainage of water contained in the voids.

\* The whole of contained water, it is obvious, cannot be drained out of the formation because part of it is held back in smaller pores as well as junctions of voids by capillary forces, while other part of held around the smaller particles hygroscopically.

\* It is pertinent to point out that the specific yield for sand may be as little as 0.1 to 0.2.

\* It is evident that though porosity is an index of the amount of water that can be stored in an aquifer, it does not indicate the capacity of the formation to yield water.



\*The specific yield of an aquifer is a function of pore size and interconnections between pores.

\*Above figure shows that with, reducing particle size the specific yield reduces while specific retention.

permeability:

\*In geotechnical engineering, engineers use permeability coefficient concept in place of hydraulic conductivity.

\*Actually, hydraulic conductivity is different from permeability coefficient. Because, hydraulic conductivity is based on properties of both porous medium and fluid flowing through the formation, whereas, permeability depends only on properties of the porous medium.

\*The properties of fluid are specific weight ( $\gamma$ ) and dynamic viscosity ( $\mu$ ).

\*The dynamic viscosity of fluid can be taken as resistive force within pores of formation. Also, specific weight of fluid acts as driving force.

\*The hydraulic conductivity is a function of permeability,  $k$ , specific weight ( $\gamma$ ) and dynamic viscosity ( $\mu$ ).

\*It can be written as:

$$K = f(k, \mu, \gamma, g)$$

\* A relationship can be obtained between hydraulic conductivity and these parameters by using Dimensional analysis.

$$k = \frac{K\gamma}{\mu}$$

$k$  permeability and is based on only properties of porous medium.

\* permeability is proportional with square of a mean grain diameter.

This means:

$$k \propto d^2$$

where

$d$  = Mean grain diameter

\* This proportionality is converted to equality by introducing a constant coefficient,  $c$ .

Therefore, the permeability coefficient can be expressed as:

$$k = cd^2$$

Here,

$c$  = constant of proportionality and is based on porosity of the medium which are distribution of grain sizes, the sphericity and roundness of grain.

## Storage coefficient ( $S_c$ ):

\* It is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the head that acts normal to that surface.

\* This coefficient is dimensionless.

\* The storativity of unconfined aquifer corresponds to its specific yield.

\* It depends upon the elasticity of the aquifer material and the fluid.

\* The value of  $S_c$  varies with saturated thickness (b) of the aquifer.

$$S_c = 3 \times 10^{-6} b \text{ (approximately)}$$

\* For saturated confined aquifers, variations in pressure produces only slight change in the storage volume.

\* The weight of the overburden is supported partly by hydrostatic pressure and partly by the solid material of the formations.

\* Hydrostatic pressure in a confined aquifer is reduced by pumping and the load on the aquifer material increases.

\* The storage coefficient of a confined formation is expressed as:

$$S_c = \gamma_w n b \left[ \frac{1}{E_w} + \frac{1}{n E_s} \right]$$

Where,

$\gamma_w$  = specific weight of water

$n$  = porosity of aquifer material

$b$  = Thickness of the aquifer

$E_w$  = Bulk modulus of elasticity of water

$E_s$  = modulus of vertical compression of the aquifer.

### Transmissivity

\* These are six basic properties of fluid and porous media that must be known in order to describe hydraulic aspects of groundwaters. These are specific mass ( $\rho$ ), dynamic viscosity ( $\mu$ ) and compressibility ( $\beta$ ) for water, whereas porosity ( $n$ ), permeability ( $k$ ) and compressibility ( $\alpha$ ) for porous media.

\* In unconfined aquifer, the transmissivity is not as well defined as in confined aquifer.

\* Transmissivity is the product of the average hydraulic conductivity,  $k$ , and the saturated thickness of the aquifer,  $m$ , (Freeze and Cherry, 1979).

\* Consequently, transmissivity is the rate a flow under a unit hydraulic gradient through a cross section of unit width over the whole saturated thickness of the aquifer (Bear, 1979).

\* This definition is invalid if groundwater flow is non-linear.

\* In other words, this definition is valid only for Darcian flow.

\* This means that this definition is valid only for neither fractured medium nor karstic medium, but just for only porous medium.

\* Based on the definition given above, transmissivity can be written as:

$$T = m \cdot k$$

\* The equation to determine transmissivity can also be given in another form

We know that the discharge,

$$Q = A \cdot v$$

Where,

A = Area given as a product of the saturated thickness of the aquifer (m) and width of the aquifer (W),

v = Groundwater flow velocity.

Therefore

$$Q = m \cdot W$$

But, since  $v = ki$ ,  $Q = m \cdot W \cdot k \cdot i$

We also know that,  $m \cdot k = T$

Substituting this in the above equation gives:

$$Q = T \cdot W \cdot i$$

Therefore, the transmissivity,  $T$  can be given as:

$$T = \frac{Q}{wi}$$

Here,

$T$  = Transmissivity coefficient

$Q$  = Rate of flow

$w$  = Width of saturated aquifer

$i$  = Hydraulic gradient.

\* Transmissivity coefficient can be defined as the amount of water transmitted through the whole saturated thickness under unit width and unit change of hydraulic gradient.

\* The transmissivity is defined well in confined aquifer, where as in unconfined aquifer, it is not well defined.

\* This is because the saturated thickness of aquifer is well defined in confined aquifer.

\* Transmissivity and storage coefficients are defined for using well hydraulics in confined aquifer.

Darcy's Law:

\* Darcy expressed that the specific discharge through porous medium is directly proportional to hydraulic head or head loss and inversely proportional to length of flow path.

This means that  $v \propto \Delta h$  and

$$v \propto \frac{1}{\Delta l}$$

In other words,

$$V \propto \frac{\Delta h}{\Delta l}$$

$\frac{\Delta h}{\Delta l}$  is defined as hydraulic gradient,  $i$ . This means,  
hydraulic gradient,  $i = \frac{\Delta h}{\Delta l}$

Therefore

$$V \propto i$$

\* This proportionality is converted to equality by introducing a constant coefficient,  $k$  that has logical physical meaning.

\* This coefficient depends on the characteristics of porous medium and the groundwater.

\* It refers to a resistance coefficient and is called hydraulic conductivity.

This can be written mathematically as:

$$V = k \frac{\Delta h}{\Delta l}$$

or in differential form

$$V = k \frac{dh}{dl}$$

This is what is known as Darcy's law.

Here

$V = \frac{Q}{A}$  is specific discharge (also known as Darcy velocity or Darcy flux (length/time)),

$Q$  = Volume rate of flow (Length<sup>3</sup>/time)

$A$  = cross-sectional area normal to flow  
direct,

$\Delta h$  = Head loss which is the difference between hydraulic heads measured at points 1 and 2 (Length),

$\Delta l$  = The distance between the two wells as indicated earlier.

As defined above,

$\frac{dh}{dl}$  = is hydraulic gradient (dimensionless) and  $K$  is proportionality constant which is termed as hydraulic conductivity (Length/Time)

\* In geotechnical engineering, permeability is used in place of hydraulic conductivity.

\* Hydraulic conductivity is a property of both the fluid and the porous medium, whereas permeability depends only on the property of the porous medium.

\* We have to know that Darcy law has its range of validity.

\* Darcy's Law is valid for laminar flow, but not for turbulent flow.

\* Turbulent flow can happen in cavernous limestone and fractured basalt.

\* In case of doubt, we can use Reynolds number in order to determine whether a flow is laminar or turbulent flow.

\*The Reynolds number is described as the ratio of inertial forces to viscous forces, and is given as:

$$Re = \frac{\rho \cdot v \cdot d}{\mu}$$

Here,

$\rho$  = Specific mass of fluid

$v$  = Specific discharge

$\mu$  = Dynamic viscosity of fluid

$d$  = Representative length of porous medium which is a mean grain diameter (Length) or a mean pore diameter.

\*If  $d$  increases, the value of Reynolds number increases, affecting the flow regime.

\*Darcy concluded that the law's range of validity is between  $1 < Re < 10$ .  $Re = 10$  is upper limit of the validity of Darcy's flow.

\*Most ground water flow occur when  $Re$  number is less than 1.

\*Therefore, Darcy's Law applies in ground water flow conditions.

\*Exceptional situations are rock wide opening, vicinity of pumped well and where steep hydraulic head exists.

\*Darcy's law is invalid at low hydraulic gradient.

\*Consequently, Darcy's law is valid if the Reynolds number stays in range from 1 to 10.

\*All flow through granular media is laminar.

Steady Radial Flow in confined and Unconfined Aquifer :

\*Consider a steady flow from a well completely penetrating an unconfined aquifer.

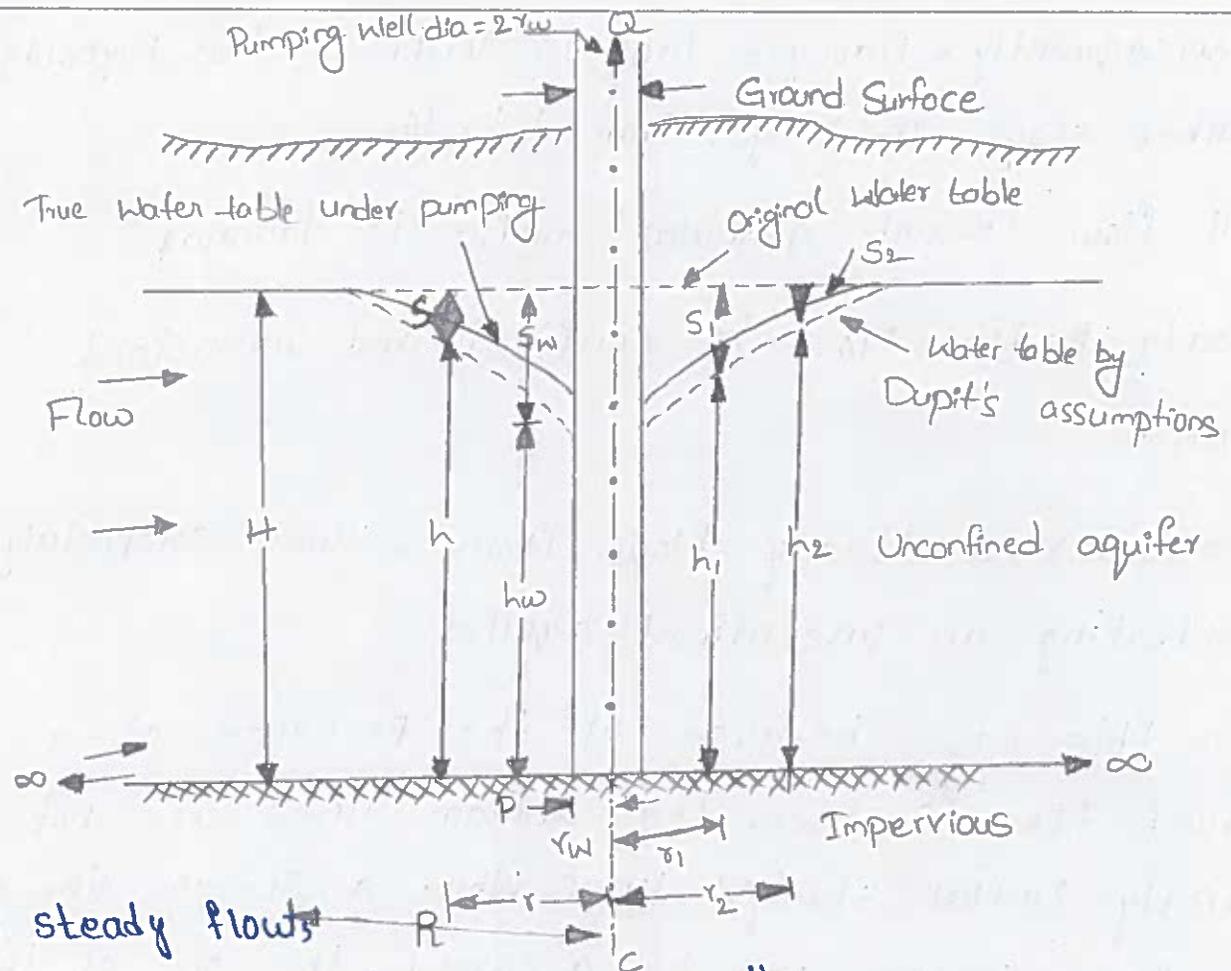
\*In this case because of the presence of a curved free surface, the stream lines are not strictly radial straight lines. While a stream line at the free surface will be a curved, the one of the bottom of the aquifer will be a horizontal line, both converging to the well

\*Consider the well of radius  $r_w$  penetrating completely an extensive unconfined horizontal aquifer.

\*The well is pumping a discharge  $Q$ . At any radial distance  $r$ , the velocity of radial flow into the well is,

$$v_r = k \left( \frac{dh}{dr} \right)$$

$h$  = height of water table above the aquifer bed



For steady flows

$$Q = (2\pi r h) v_r = 2\pi r k h \frac{dh}{dr}$$

$$\frac{Q}{2\pi k} \frac{dr}{r} = h dh$$

Integrating between limits  $r_1$  and  $r_2$  where the water table depths are  $h_1$  and  $h_2$  respectively

$$\therefore Q = \frac{\pi k (h_2^2 - h_1^2)}{\ln \left( \frac{r_2}{r_1} \right)}$$

This is the equilibrium equation for a well in an unconfined aquifer. As at the edge of the zone of influence of radius  $R$ ,  $H$  = saturated thickness of the aquifer.

$$Q = \frac{\pi k (H^2 - h_w^2)}{\ln \left( \frac{R}{r_w} \right)}$$

$h_w$  = depth of water in the pumping well of radius  $r_w$ .

If the drawdown at the pumping well  $s_w = (H - h_w)$

$$\therefore KH = T$$

$$Q = \frac{2\pi T s_w}{\ln \frac{R}{r_w}}$$

$$\text{As } (h^2 - h_w^2) = (H + h_w)(H - h_w) \approx 2Hs_w$$

Derive the expression to determine the discharge for the steady radial flow to a well in a confined aquifer.

Ans: In a steady state condition, the discharge is given by,

$$Q = 2\pi r b k \frac{dh}{dr}$$

$$\therefore dh = \frac{Q}{2\pi r b k} \frac{dr}{r}$$

Integrating equation,

$$h_1 - h_2 = \frac{Q}{2\pi b k} \ln \left[ \frac{r_1}{r_2} \right]$$

$$\therefore T = kb$$

$$\therefore Q = \frac{2\pi T (h_1 - h_2)}{\ln \left( \frac{r_1}{r_2} \right)}$$

Applying boundary conditions to the wells in the absence of observation wells,

$$Q = \frac{2\pi T (H - h_w)}{\ln \left( \frac{R}{r_w} \right)}$$

$H_w$  = Height of well

$r_w$  = Radius of well

$H - h_w$  = Drawdown of well  $s_w$

$$\therefore Q = \frac{2\pi T s_w}{\ln\left(\frac{R}{r_w}\right)}$$

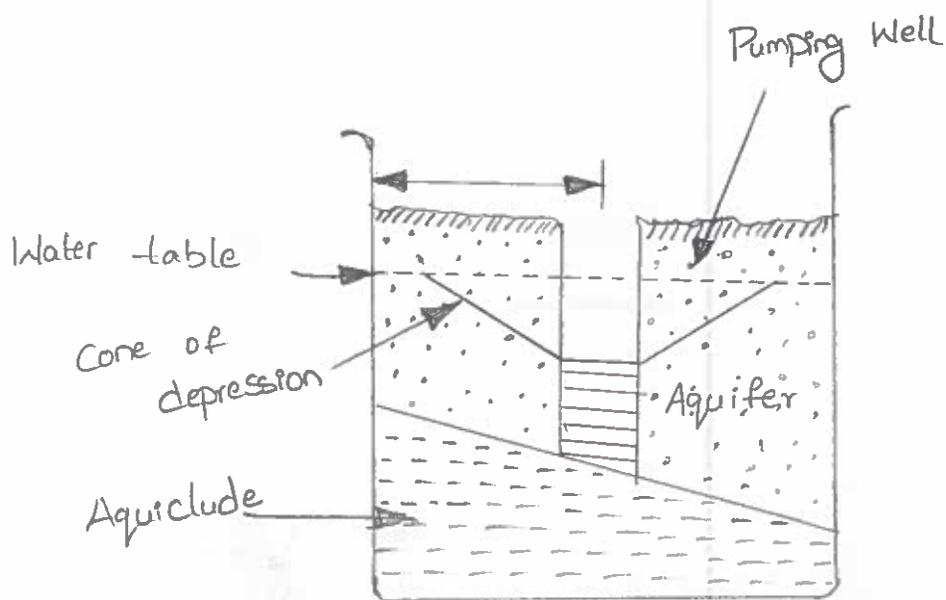
Terms cone of depression and radius of influence

\*considering the water in an unconfined aquifer being pumped at a constant rate from a well. prior to the pumping the water level in the well indicates the static water table.

\*cone of depression:

A lowering of water level takes place on pumping and if the aquifer is homogeneous and isotropic and water table horizontal initially, due to the radial flow into the well through the aquifer the water table assumes a conical shape called cone of depression.

\*The areal extent of the cone of depression called area of influence and radial extent is called as radius of influence.



### Recuperation Test

\* A recuperation test may be adopted which is described below.

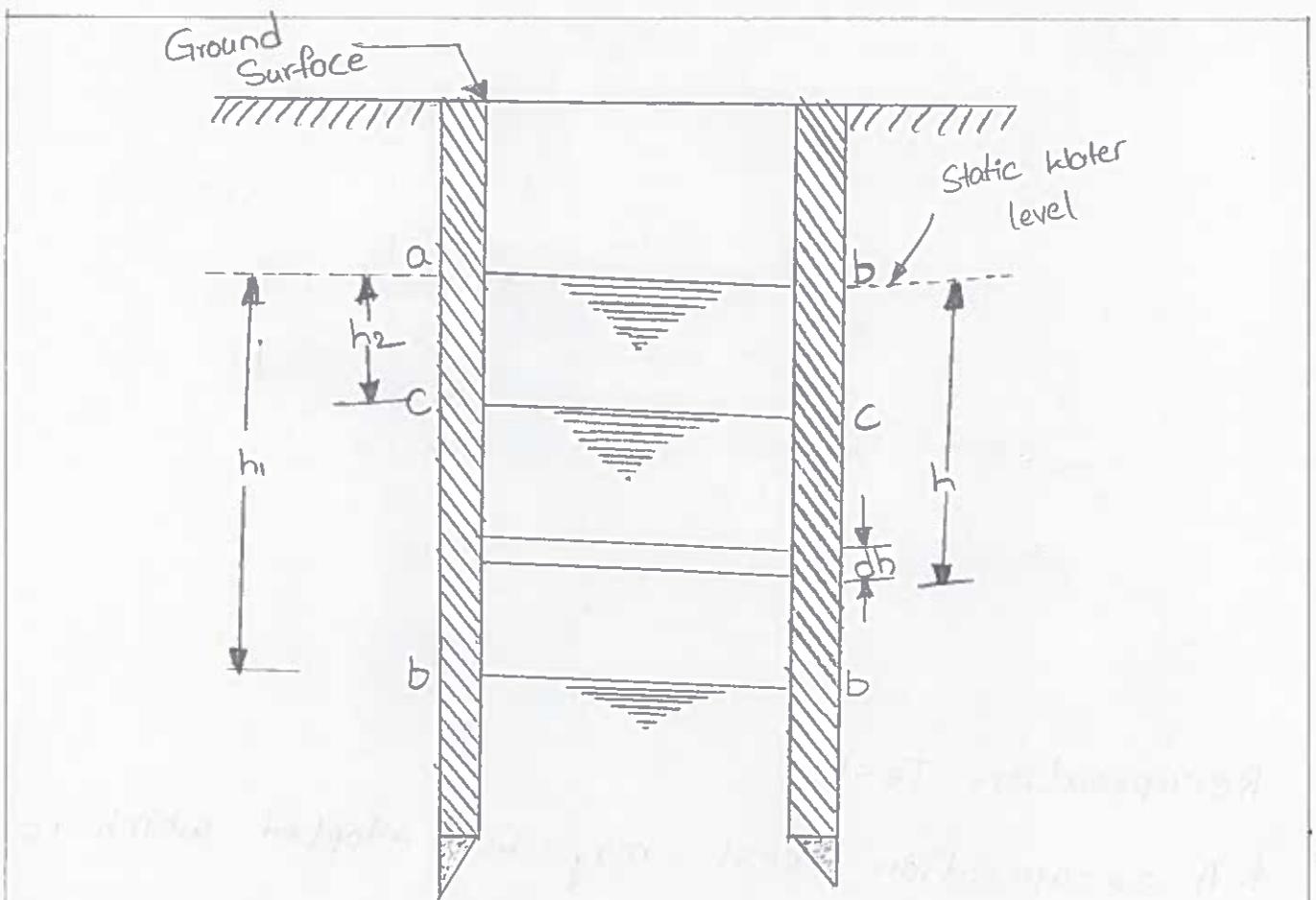
\* In the recuperation test water is pumped from the well so that sufficient depression head is developed.

\* The depression head is measured and the pumping is then stopped.

\* The water level in the well will start rising.

\* The time taken by the water to come back to the initial static level before the pumping was started or any other measured level is then noted.

\* The rate of yield (or) discharge may then be determined as indicated below:



Let,

aa = static water level in the well before the pumping was started

bb = Water level in the well when the pumping was stopped

$h_1$  = Depression head in the well when the pumping was stopped

cc = Water level in the well at some noted time  $t'$  after the pumping was stopped

$h_2$  = Depression head in the well at time  $t'$  after the pumping was stopped

$h$  = Depression head in the well at time  $t$  after the pumping was stopped

dh = Decrease in depression head in time  $dt$ .

\* Thus in time  $t$  after the pumping was stopped the water level in the well recuperated by  $(h_1 - h)$ .

\* It again recuperates by  $dh$  in a time  $dt$  after this.

∴ Volume of water entering the well when the head recuperated by  $dh$  is

$$dV = A dh$$

Where

$A$  = cross-sectional area of the well at its bottom.

\* Again if  $Q$  is the rate of recharge into the well at time  $t$  under a depression head  $h$ , then the volume of water entering the well in a time  $dt$  is

$$dV = Q dt \dots (i)$$

But  $Q \propto h$

$$\text{or } Q = kh \dots (ii)$$

\* Where  $k$  is a constant the value of which depends on the type of soil at the base of the well through which water enters the well.

$$dV = kh dt \dots (iii)$$

Equating the values of  $dV$  given by Equation (i) and (iii), we get

$$kh dt = -A dh \dots (iv)$$

The negative sign is introduced because as time  $t$  increases the depression head  $h$  decreases.

From equation (iv), we have

$$dt = -\frac{A}{k} \frac{dh}{h} \dots (iv)$$

\*Integrating both sides of the above equation between the limits  $t=0, h=h_1$ ; and  $t=t', h=h_2$  we get

$$\int_0^{t'} dt = -\frac{A}{K} \int_{h_1}^{h_2} \frac{dh}{h}$$

or  $t' = -\frac{A}{K} \log_e \left( \frac{h_2}{h_1} \right)$

or  $\frac{K}{A} = \frac{1}{t'} \log_e \left( \frac{h_1}{h_2} \right)$

or  $\frac{K}{A} = \frac{2.303}{t'} \log_e \left( \frac{h_1}{h_2} \right) \dots \dots (v)$

\*since  $h_1, h_2$  and  $t'$  are measured in this test, the same are known and by introducing their values in equation (v), the value of  $\left( \frac{K}{A} \right)$  can be calculated.

$\left( \frac{K}{A} \right)$  is known as the specific yield or specific capacity of an open well which is defined as the volume of water that percolates into the well per unit time per unit area under a unit depression head.

\*The value of  $\left( \frac{K}{A} \right)$  is usually expressed in cubic metre per hour per square metre of area under one meter depression head. The approximate value of  $\left( \frac{K}{A} \right)$  for different types of soils as indicated by

Maxxiot are given in Table.

Types of soil	$\left(\frac{K}{A}\right)$ (m <sup>3</sup> per hour per m <sup>2</sup> of area under 1m depression head)
Clay	0.25
Fine sand	0.50
coarse sand	1.00

Values  $\left(\frac{K}{A}\right)$  for different soils

\* Knowing the value of  $\left(\frac{K}{A}\right)$  the rate of yield (or) discharge  $Q$  from a well under a constant depression head  $H$  may be determined as follows;

From equation (ii), we have

$$Q = KH \quad \dots (vi)$$

$$\text{or} \quad Q = \left(\frac{K}{A}\right) AH \quad \dots (vii)$$

$$\text{or} \quad Q = \frac{2.303 AH}{t'} \log_{10} \left(\frac{h_1}{h_2}\right)$$

\* It may however be noted that in equation (vi) time  $t'$  is in hours then  $Q$  will be in m<sup>3</sup> hour and if  $t'$  is in seconds then  $Q$  will be in cumec.

\* Further if  $H$  is the maximum depression head then the corresponding value of  $Q$  obtained from equation (vi) will be the maximum yield of the well.

\* However, if  $H$  is the average depression head,  $Q$  will be the average yield of the well.

## Water Requirement of crop

### crop water requirement:

- \*It is essential to know the water requirement of a crop which is the total quantity of water required from its sowing time up to harvest.
- \*Naturally different crops may have different water requirement at different places of the same country, depending upon the climate, type of soil, method of cultivation, effective rain etc.
- \*The total water required for crop growth is not uniformly distributed over its entire life span which is also called crop period.
- \*Actually, the watering stops some time before harvest and the time duration from the first irrigation during sowing up to the last before harvest is called base period.
- \*Though crop period is slightly more than the base period, they do not differ from practical purposes.
- \*Sometimes, in the initial stages before the crop is sown, the land is very dry.
- \*In such cases, the soil is moistened with water as it helps in sowing the crops. This is known as pre-irrigation.
- \*A term kor watering is used to describe the watering given to a crop when the plants are still young.

\*It is usually the maximum single watering required, and other waterings are done at usual intervals.

\*The total depth of water required to raise a crop over a unit area of land is usually called delta.

Cropping seasons in India:

\*There are mainly two crop seasons in India.

1. Rabi (winter crops) season

2. Kharif (monsoon crops) season

\*There is also a crop season called Zaid in addition to Rabi and Kharif.

\*Sometimes in between Rabi and Kharif, intermediate crops are also grown.

1. Rabi season:

\*This season spans generally over October to March.

\*This season needs relatively cool climate during the period of growth but warm climate during the germination of their seed and maturation.

\*Important crops in this season are wheat, barley, gram, pea, mustard.

2. Kharif season:

\*This season spans between April to September.

\*In this season crops are sown at the beginning of the South West monsoon and harvested as the

end of the south west monsoon

\* Important crops in this season are rice, jowar, bajra, groundnut, jute.

3. Zaid season:

\* There are certain crops besides rabi and kharif which are being raised throughout the year with the help of artificial irrigation.

\* Zaid crops are divided into (a) zaid kharif (b) zaid Rabi crops.

Cropping Patterns

Cropping Pattern in India

\* Cropping pattern refers to the proportion of land under cultivation of different crops at different points of time.

\* This indicates the time and arrangement of crops in a particular land area. Any change in the cropping pattern would cause:

a. change in the proportion of land under different crops.

b. change in space sequence and time of crops.

\* In India, the cropping pattern is determined by rainfall, temperature, climate, and technology and soil type.

\* In order to obtain maximum yields, different patterns of cropping are practiced.

\* The major cropping patterns include the following:

### 1. Monocropping:

- \* Monocropping reduces soil fertility and destroys the structure of the soil
- \* Chemical fertilizers are required to upgrade production. This practice allows the spread of pests and diseases.

### 2. Mixed cropping:

\* When two or more crops are grown on the same land simultaneously, it is known as mixed cropping. For e.g. growing wheat and gram on the same land at the same time is mixed cropping.

\* This practice minimizes the risk of failure of one of the crops and insures against crop failure due to abnormal weather conditions.

\* The crops to be grown together should have a different maturation time and different water requirements. one tall and one dwarf crop should be grown together.

\* The nutrients required by one crop should be less than those required by the other. one crop should have deep roots, others should be shallow. All this criteria lead to a successful mixed cropping pattern.

### Advantages:

- \* The crop yield increases
- \* The pest infestation is minimized
- \* Reduction in the risk of crop failure.

\* The soil is utilized properly

\* More than one variety of crops can be harvested at the same time.

### 3. Intercropping:

\* Intercropping is the practice of growing more than one crop on the same field at the same time in a definite row pattern.

\* After one row of the main crop, three rows of intercrops can be grown. This increases productivity per unit area.

Intercropping can be of different types:

#### a. Row intercropping

\* When the component crops are arranged in alternate rows it is known as row intercropping.

\* It helps in optimum utilization of land space and suppression of weeds during the early stage of the main crop.

#### b. Strip intercropping

\* When two or more crops are grown in wide strips so that the two crops can be managed separately, it is known as strip cropping. However, the crops are close enough to interact.

#### c. Relay intercropping

\* In this type of intercropping a second crop is planted when the existing crop has flowered but not harvested.

\* For e.g. Rice - Cauliflower - onion - summer

Advantages of intercropping:

- \* The fertility of the soil is maintained
- \* The spread of diseases and pests is controlled
- \* optimum utilization of resources.
- \* The space and time of growing more than one crop are saved.
- \* Maximum utilization of nutrients present in the soil.

4. crop rotation:

- \* In this pattern, different crops are grown on the same land in preplanned succession.
- \* The crops are classified as one-year rotation, two year rotation, and three-year rotation, depending upon their duration.
- \* Legumes are included in the crop rotation programme to increase soil fertility.
- \* The crops which require high fertility level (wheat) can be grown after the legumes.
- \* The crops which require low inputs can be grown after the crops that require high inputs.

Duty and Delta

i. Duty represents the irrigating capacity of a unit of water. It is the ratio between the area of a crop irrigated and the entire period of the growth of that crop.

Delta: Delta is the total depth of water required by a crop during the entire period the crop is in the field and is denoted by the symbol  $\Delta$ .

Base period: Base period for a crop refers to the whole period of cultivation from the time when irrigation water is first issued for preparation of the growth planting the crop to its last watering before harvesting.

Relation between duty and delta

Let,

$D$  = Duty in hectares/cumec

$\Delta$  = Total depth of water supplied

$B$  = Base period of days

i. If we take a field of area  $D$  hectares, water supplied to the field corresponding to the water depth  $\Delta$  meters will be  $= \Delta \times D$  hectare-meters.

ii. Again for the same field of  $D$  hectares, one cumec of water is required to flow during the entire base period. Hence, water supplied to this field.

$$= (1) \times (B \times 24 \times 60 \times 60) \text{ m}^3$$

Equating (1) and (2)

$$D \times \Delta \times 10^4 = B \times 24 \times 60 \times 60$$

$$\Delta = \frac{B \times 24 \times 60 \times 60}{D \times 10^4} = 8.64 \frac{B}{D} \text{ meters}$$

## Factors affecting duty

The duty of water of canal system depends upon a variety of the factors and they are:

1. Methods and systems of irrigation
2. Mode of applying water to the crops.
3. Method of cultivation
4. Time and frequency of tilling
5. Type of the crop
6. Base period of the crop
7. climate conditions of the area
8. Quality of water
9. Method of assessment of irrigation method
10. canal conditions
11. character of soil and subsoil of the canal.
12. character of soil and subsoil the canal irrigation field.

## Quality of Irrigation Water:

\*The concentration and composition of soluble salts in water will determine its quality for various purpose (human and livestock drinking, irrigation of crops, etc.)

\*The quality of water is, thus, an important component with regard to sustainable use of water for irrigated agriculture, especially when salinity development is expected to be a problem in an

irrigated agricultural area

There are four basic criteria for evaluating water quality for irrigation purpose:

1. Total content of soluble salts (salinity hazard)
2. Relative proportion of sodium ( $\text{Na}^+$ ) to calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ) ions - Sodium adsorption ratio (Sodium hazard).
3. Residual sodium carbonates (RSC) - bicarbonate ( $\text{HCO}_3^-$ ) and carbonate ( $\text{CO}_3^{2-}$ ) anions concentration, as it relates to  $\text{Ca}^{2+}$  plus  $\text{Mg}^{2+}$  ions.
4. Excessive concentrations of elements that cause an ionic imbalance in plants or plant toxicity.

\* In order to achieve the first three important criteria, the following characteristics need to be determined in the irrigation waters: electrical conductivity (EC), soluble anions ( $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$ ) where  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  are optional and soluble cations ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ) where K is optional.

\* Finally, boron level must also be measured. The pH of the irrigation water is not an acceptable criterion of water quality because the water pH tends to be buffered by the soil, and most crops can tolerate a wide pH range.

\* A detailed description of the techniques commonly employed for the analysis of irrigation water is

available

## Soil Water Relations

### Soil water Relationships

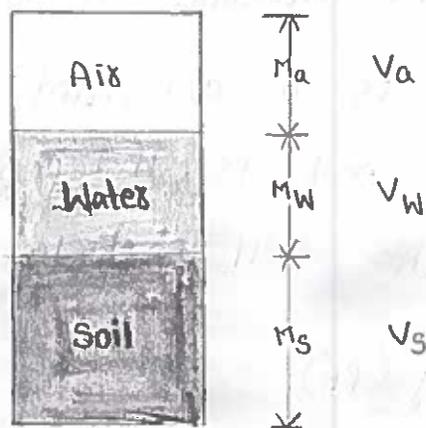
\* The physical properties of the soil, including its ability to store water, are highly related to the fraction of the bulk soil volume that is filled with water and air.

\* For plant growth and development to be normal, a balance of water and air in the pore space must be attained.

\* If water is limited, plant growth may be inhibited by water stress

\* If air (aeration) is limited, usually by too much water, then growth may be limited by insufficient relationships.

\* These relationships can be used to calculate one soil property from another.



Three phases of soil

$V_a$  = volume of air

$V_w$  = volume of water

$V_s$  = volume of solids

$V_v$  = volume of voids ( $V_a + V_w$ )

$V_t$  = Total volume ( $V_a + V_w + V_s$ )

$M_a$  = Mass of air (negligible)

$M_w$  = Mass of water

$M_s$  = Mass of solids

$M_t$  = Total mass ( $M_a + M_w + M_s$ )

### 1. Particle Density ( $\rho_s$ )

\* It is the ratio of a given mass (or weight) of soil solids to that of its volume and it is given by

$$\rho_s = \frac{M_s}{V_s} \dots \dots (1)$$

\* Sometimes it is referred to as true density. It is usually expressed in terms of  $\text{g/cm}^3$  and varies between the narrow limits of 2.6 to 2.75  $\text{g/cm}^3$

\* particle density is a constant for a soil with a given texture and is independent of size and arrangement of the soil particles.

### 2. Dry Bulk Density ( $\rho_b$ )

\* It is the density of the undisturbed (bulk) soil sample which is the ratio of dry mass of the soil to its total volume.

\*It is given by

$$P_b = \frac{M_s}{V_t} = \frac{M_s}{V_s + V_a + V_w}$$

\*This is expressed as gm/cm<sup>3</sup>. Dry bulk density can be calculated by collecting a known volume of soil to get the soil volume (V<sub>t</sub>) and drying the associated soil to get the mass of dry soil (M<sub>s</sub>).

### 3. Total (Wet) Bulk Density (P)

\*It is the mass of moist soil per unit volume is represented as:

$$P = \frac{M_t}{V_t} = \frac{M_s + M_a + M_w}{V_s + V_a + V_w} \dots (3)$$

\*Bulk density has a pronounced effect on the soil properties like permeability of soil for water and air, and penetration of plant roots through the soil.

\*compression of soil particles can increase bulk density but it reduces the soil porosity and in turn the soil water storage capacity.

### 4. Porosity (n)

\*Porosity is the void space in a given volume of soil that is occupied by air and water.

\*The total porosity is calculated as follows:

$$n(\%) = \left(1 - \frac{P_b}{P_s}\right) \times 100 \dots (4)$$

$$n(\%) = \left( 1 - \frac{V_a + V_w}{V_t} \right) \times 100 \dots (5)$$

\* Generally total porosity varies from 30% to 60% for agricultural soils.

\* coarse textured soils are normally less porous (35% - 50%) than the fine textured soils (40% - 60%).

### 5. Void Ratio (e)

\* It is the ratio of the pore space to the volume of solids and is given by

$$e = \frac{V_v}{V_s} = \frac{V_a + V_w}{V_t - V_v}$$

$$= \left( \frac{P_g}{P_b} - 1 \right) = \frac{n}{1-n}$$

### 6. Soil Water content

\* The mass water content or soil moisture content ( $\theta_m$ ) is the ratio of the mass of water in a sample to the dry soil mass, expressed as either a decimal fraction or as percentage.

\* It is often referred to as 'gravimetric water content'.

\* The mass water content is found by

$$\theta_m = \frac{M_w}{M_s} \dots (7)$$

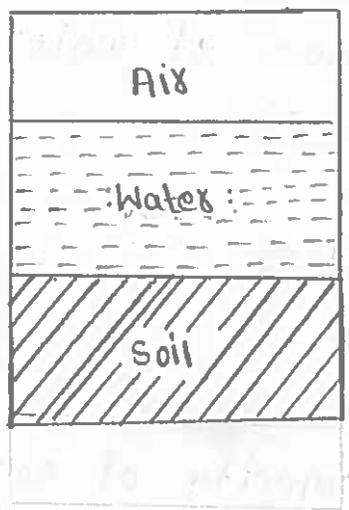
\* It is determined by weighing the soil sample collected from field, drying the sample for at least 24 hours at 105°C, and then weighing the dry soil

\*Difference in mass of the wet and dry sample represents the mass of water in the soil sample ( $M_w$ ).

\*The mass of the sample after drying represents the mass of dry soil ( $M_s$ ).

### Root zone Soil Water

Formula for depth of water stored in the root zone of the soil:



We know that

$$\text{Field capacity} = \frac{\text{Weight of water retained in a certain volume of soil}}{\text{Weight of dry soil of the same volume}}$$

consider, unit area of soil (i.e.  $1m^2$ )

Let, Depth of root zone =  $d$  (in meter)

Dry unit weight of soil =  $\gamma_d$  (in  $kN/m^3$ )

Total volume of soil,  $V = d \times 1$ .

$$\begin{aligned} W_s &= \gamma_d \times V \\ &= \gamma_d \times (d \times 1) \\ &= \gamma_d \times d \text{ (in } kN) \end{aligned}$$

Where,

$\gamma_d = D_{ry}$  unit weight of soil

Now,

Field capacity (F.C)

$$F.C. = \frac{W_w}{W_s} = \frac{\gamma_w V_w}{\gamma_s \cdot d} \dots (1)$$

$$V_w = \frac{\gamma_d \cdot d (F.C)}{\gamma_w}$$

Equation (1) gives volume of water retained in unit area of soil =  $\frac{\gamma_d \cdot d (F.C)}{\gamma_w}$

$$d_w = \frac{\gamma_d \cdot d (F.C)}{\gamma_w}$$

Now

Total water storage capacity of soil

= Depth of water retained in unit area of soil.

### Infiltration

\* It is the process by which water on the ground surface enters the soil

\* It is governed by two forces, gravity, and capillary action.

\* While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even against the force of gravity.

\* Infiltration rate in soil science is a measure of the rate at which a particular soil is able to absorb rainfall or irrigation

\* It is measured in inches per hour or millimeters per hour.

\* The rate decreases as the soil becomes saturated.

\* If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier

\* It is related to the saturated hydraulic conductivity of the near-surface soil.

### Consumptive Use

Consumptive use of water and factors affecting on it:

\* It is the quantity of water used by the vegetation growth of a given area.

\* It is the amount of water required by a crop for its vegetated growth to evapotranspiration and building of plant tissues plus evaporation from soils and intercepted precipitation.

\* It is expressed in terms of depth of water

\* Consumptive use varies with temperature, humidity, wind speed, topography, sunlight hours, method of irrigation, moisture availability.

### Mathematically

Consumptive use = Evapotranspiration = Evaporation + Transpiration.

It is expressed in term of depth of water

Factors affecting the consumptive use of water

Consumptive use of water varies with:

1. Evaporation which depends on humidity
2. Mean Monthly temperature
3. Growing season of crops and cropping pattern
4. Monthly precipitation in area
5. Wind velocity in locality
6. Soil and topography
7. Irrigation practices and method of irrigation
8. Sunlight hours

Irrigation Requirements of crops

\* It is the quantity of water, exclusive of rainfall required by a crop in a given time period for their normal growth under field condition.

\* It includes evapotranspiration not met by the rainfall.

\* It also includes surface runoff and percolation losses.

\* Irrigation requirements of crops can be categorized under the following categories.

1. Consumptive Irrigation Requirement (CIR)

\* CIR is the amount of irrigation water that is required to meet the evapotranspiration needs of crop during its full growth.

\*  $CIR = C_u - R_e$

Where

$C_u$  = Consumptive use of water

$R_e$  = Effective rainfall during growth period of crop.

## 2. Net irrigation requirements (NIR)

\* NIR is the amount of irrigation water required to be delivered at the field to meet the evapotranspiration needs of crops as well as other needs like leaching, pre-sowing requirements etc.

$$NIR = CIR + LR + PSR$$

## 3. Field Irrigation Requirements (FIR):

\* FIR is the amount of water required to meet the NIR plus the amount of water lost as surface runoff and deep percolation.

$$FIR = \frac{NIR}{\eta_a}$$

Where

$\eta_a$  = Water application efficiency

## 4. Gross Irrigation Requirement (GIR)

\* GIR is the amount of water required to meet the FIR plus the amount of irrigation water lost in conveyance through canal system by evaporation and seepage.

## Frequency of Irrigation:

\* Irrigation frequency refers to the number of days between irrigation during periods without rainfall.

\*It depends on consumptive use of a crop and on the amount of available moisture in the crop root zone.

\*It is function of crop, soil and climate. sandy soils must be irrigated more often than fine texture deep soils.

\*A moisture use ratio varies with the kind of crop and climate conditions and increases as crop grows larger and days become longer and hotter.

\*In general, irrigation should start when about 50 percent and not over 60 percent of the available moisture has been used from the root zone in which most of the roots are concentrated.

\*The stage of crop growth with reference to critical periods of growth is also kept in view while designing irrigation frequency.

\*The interval that can be safely allowed between two successive irrigations is known as frequency of irrigation:

$$\text{Irrigation interval} = \frac{\text{Allowable soil moisture depletion}}{\text{Daily water use}}$$

Methods of Application of Irrigation Water:

Irrigation water may be applied to the crops by three basic methods:

- i. Surface irrigation method
- ii. subsurface irrigation method
- iii. sprinkler irrigation method

## Surface irrigation method:

i. In surface irrigation, water is allowed to flow above the soil surface through supply channel at upper reach of the field.

ii. In India, it is mostly adopted for irrigation of crops.

• Surface irrigation is classified into three types:

a. Flooding

b. Furrow method

c. Contour farming

## 2. Sub-surface irrigation method:

i. In subsurface irrigation, water is excreted to crops by constructing perforated pipelines and trenches under the soil surface and carry water through pipes and trenches.

ii. Sub-surface irrigation can also be made artificially by positioning the perforated pipes and the crop zone beneath the surface of the soil.

iii. Subsurface irrigation is classified into two classes:

a. Natural sub-irrigation

b. Artificial sub-irrigation

Refer above description of point (i) and (ii)

a. Natural sub-irrigation:

In this system, water is supplied to the root zone of the plants by controlling the level of

local water table and maintaining the supply of water to the root zone.

3. Sprinkler irrigation method:

i. The sprinkler method consist of applying the water in the form of a spray, it is done in the garden lawn sprinkling

ii. The greatest advantage of sprinkler is its adaptabilities to use under conditions where the surface irrigation methods are not efficient.

• Sprinkler system can be classified under three heads:

- i. permanent system
- ii. semi-permanent system
- iii. portable system

Advantages:

- i. Erosion can be controlled
- ii. Uniform applications for water is possible
- iii. Irrigation is better controlled
- iv. Land preparation is not required

Disadvantages:

- i. Wind may distort sprinkling pattern
- ii. Constant water supply is needed
- iii. Water must be clean and free from sand.
- iv. Power requirement is high.

## Drip irrigation system

i. In drip irrigation, also known as trickle irrigation, water is applied in the form of drops directly near the base of the plant.

ii. Water is conveyed through a system of flexible pipe lines, operating at low pressure and applied to the plants through drip nozzles.

iii. This technique is also known 'feeding bottle' technique.

### III - effects of irrigation:

Excess irrigation may give rise to the following ill-effects:

#### 1. Breeding places for mosquitoes:

Due to excess application of water, and due to leakage of water, ponds and depressions get filled up with water and create breeding places for mosquitos and they spread malarial conditions.

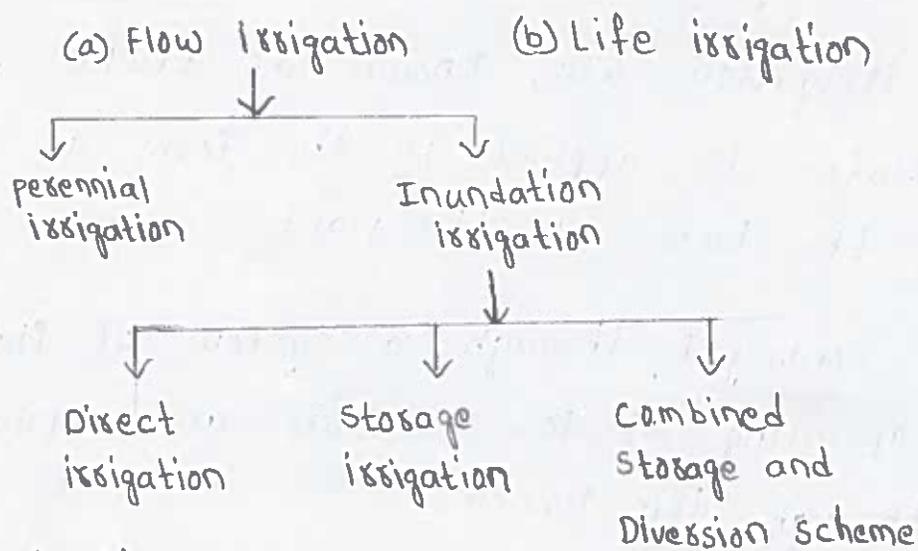
#### 2. Water logging:

If the water table is near the ground surface, over irrigation may rise the water table and due to that whole area becomes waterlogged.

#### 3. Damp climate:

The area which are already damp and cold, become damper and colder due to irrigation.

## Types of irrigations



Flow irrigations:

Flow irrigation is that type of irrigation in which the supply of irrigation water land by the gravity flow.

• It is divided in the two types:

1. Perennial irrigation system:

In perennial irrigation system, the water required for irrigation is supplied in accordance with the crop requirements throughout the crop period.

2. Inundation irrigation:

Inundation irrigation is carried out by deep flooding and through saturation of the land to be cultivated which is then drained off prior to the planting of the crop.

Depending upon source of water flow irrigation is divided into three types

i. Direct irrigation

ii. Storage irrigation

iii. Combined storage and diversion scheme.

### i. Direct irrigation :

In this system, water is directly diverted to the canal without attempting to store the water. For this system, a low diversion weir or diversion barrage is constructed across the river, this raises the water level in the river and thus diverts the water to the canal taking out off upstream of the weir.

### ii. Storage irrigation:

In storage irrigation system, a solid barrier, such as a dam or a storage weir is constructed across the river and water is stored in the reservoir or lake so formed.

### iii. Combined system:

i. In this direct system and storage irrigation are combined.

ii. In this first water is stored in the reservoir then water is used for power generation.

### Numericals

An undisturbed rock sample has an oven-dry weight of 1305 gm. When it is completely saturated with kerosene it weighed 1463 gm. The saturated sample, when immersed in kerosene displaced 605 gm of kerosene. What is the porosity of the sample?

Given:

oven dry weight of sample,  $W_1 = 1305 \text{ gm}$

Weight of saturated sample,  $W_2 = 1463 \text{ gm}$

i. Weight of kerosene required for saturating the sample.

$$= W_2 - W_1$$

$$= 1463 - 1305$$

$$= 158 \text{ gm}$$

ii. Weight of kerosene that is displaced by the saturated sample

$$W_3 = 605 \text{ gm}$$

iii. Porosity of sample  $n = \frac{W_2 - W_1}{W_3} = \frac{158}{605} = 0.261$

$$= 26.10\%$$

In a certain alluvial basin of  $120 \text{ km}^2$ ,  $10 \text{ Mm}^3$  of ground water was pumped in a year and the ground water table dropped by  $5 \text{ m}$  during the year.

Assuming no replenishment, estimate the specific yield of the aquifer. If the specific retention is  $12\%$ , what is the porosity of the soil?

Ans: Area of alluvial basin =  $120 \text{ km}^2$

change in capacity of ground water storage =  $100 \text{ mm}^3$

Drop in water table =  $5 \text{ m}$

i. change in ground water storage

$$= \Delta GWS = A_{aq} \times \Delta GWT \times S_y$$

$$100 \times 10^6 = 120 \times 10^6 \times 5 \times S_y$$

$$S_y = \frac{100 \times 10^6}{120 \times 10^6 \times 5}$$

$$S_y = 0.167$$

$$\begin{aligned} \text{ii. porosity } = \eta &= S_y + S_x \\ &= 0.167 + 0.12 = 0.2870 \\ &= 28.70\% \end{aligned}$$

An artesian aquifer 25m thick has a porosity of 17% and bulk modulus of compression  $2400 \text{ kg/cm}^2$ . Estimate the storage coefficient of the aquifer. What fraction of this is attributable to the expansibility of water? Bulk modulus of elasticity of water  $= 2.14 \times 10^4 \text{ kg/cm}^2$ .

Ans:

Thickness of artesian aquifer = 25m

Porosity = 17%

Bulk modulus of compression =  $24 \text{ m kg/cm}^2$

$$= 2.4 \times 10^4 \text{ kg/m}^2$$

$$= 2.4 \times 10^8 \text{ kg/m}^2$$

specific weight of water  $\gamma_w = 1000$

i. Storage coefficient:

$$S = \gamma_w n \cdot b \left( \frac{1}{k_w} + \frac{1}{n k_s} \right)$$

$$S = 1000 \times 0.17 \times 25 \left[ \frac{1}{2.14 \times 10^8} + \frac{1}{0.17 \times 2.4 \times 10^8} \right]$$

$$S = 1.1 \times 10^{-3}$$

$$\text{ii. Expansibility of water} = \frac{\frac{1}{2.14 \times 10^8}}{\frac{1}{0.17 \times 2.4 \times 10^7}}$$

$$= 1.90\%$$

A 20 cm diameter well penetrates fully a confined aquifer of thickness 25m. When the well is pumped at rate of 200 l/min. The steady drawdown in the two observation wells located at 10m and 100m distance from the pumping well are found to be 3.05m and 0.05 m respectively. Calculate the permeability and the transmissivity of the aquifer.

Given:

- i. Diameter of wells = 200cm
- ii. Thickness of aquifer = 25m
- iii.  $r_1 = 10\text{m}$  and  $r_2 = 100\text{m}$
- iv.  $h_1 = 25 - 3.05 = 21.95\text{m}$   
 $h_2 = 25 - 0.05 = 24.95\text{m}$
- v.  $Q = 200 \text{ litre/min} = 200 \times 10^{-3} \text{ m}^3/\text{min}$ , and

$$\frac{200 \times 10^{-3}}{60} = 3.33 \times 10^{-3} \text{ m}^3/\text{s}$$

$$i. \quad Q = \frac{2\pi KH(h_2 - h_1)}{2.3 \log_{10} \frac{r_2}{r_1}}$$

$$3.33 \times 10^{-3} = \frac{2\pi K \times 25 \times (24.95 - 21.95)}{2.3 \log_{10} \left(\frac{100}{10}\right)}$$

$$\boxed{K = 1.62 \times 10^{-5} \text{ m/s}}$$

$$ii. \quad T = KH$$

$$T = 1.62 \times 10^{-5} \times 25$$

$$\boxed{T = 4.05 \times 10^{-4} \text{ m}^2/\text{s}}$$

A tube well penetrates fully an unconfined aquifer. calculate the discharge from the well in lpm from the following data:

Diameter of well = 30cm

Drawdown in the well = 3m

Effective length of the strainer under the above drawdown (1) = 10m.

coefficient of permeability of the aquifer

$\Sigma = 40 \text{ m/day}$

Radius of zero drawdown = 300m

Given:

Diameter of well = 30cm

Drawdown in the well = 3m

Effective length of the strainer under the above drawdown (2) = 10m

coefficient of permeability of the aquifer

$\Sigma = 40 \text{ m/day}$

Radius of zero drawdown = 300m

i. coefficient of permeability of the aquifer (k)

= 40m/day

$$k = \frac{40}{60 \times 60 \times 24}$$

$$= 5 \times 10^{-4} \text{ m/s}$$

ii. Radius of zero drawdown = 300m

$$r = 0.15 \text{ m}$$

$$\text{Discharge } Q = \frac{2.72 k S \left( L + \frac{S}{2} \right)}{\log_{10} \left( \frac{R}{r} \right)}$$

$$Q = 0.0142 \text{ m}^3/\text{s}$$

Determine the yield from a 35cm diameter well under a drawdown of 10m in the well, if the radius influence and hydraulic conductivity are 200 m and 5m/day respectively. The aquifer is unconfined with a thickness of 60m.

Given: Thickness of aquifer =  $b = 60\text{m}$

Drawdown = 10m

Hydraulic conductivity =  $k = 5\text{m/day}$

Radius influence,  $R = 200\text{m}$

Diameter of well,  $d = 35\text{cm} = 0.35\text{m}$

$$\therefore r = 0.175\text{m}$$

i. Discharge  $Q = \frac{2.72 \times b \times k \times s}{\log_{10} \frac{R}{r}} \text{ m}^3/\text{day}$

$$= \frac{2.72 \times 60 \times 5 \times 10}{\log_{10} \left( \frac{200}{0.175} \right)}$$

$$Q = 2668 \text{ m}^3/\text{day}$$

In a water table aquifer of 50m thickness, a 20cm diameter well is pumped at a uniform rate of  $0.05 \text{ m}^3/\text{sec}$ . If the steady state drawdowns measured in the observation wells located at 10m and 100m distance from the pumped well are 6.5m and 0.25m respectively, determine the average hydraulic conductivity of the aquifer.

Given: Thickness of water table aquifer,  $t = 50\text{m}$

Diameter,  $D = 20\text{cm}$

Discharge,  $Q = 0.05 \text{ m}^3/\text{s}$ .

Drawdown observation  $s_1 = 0.25\text{m}$  and  $s_2 = 6.5\text{m}$  at a distance of  $d_1 = 100\text{m}$  and  $d_2 = 10\text{m}$  respectively.

i. Discharge  $Q = \frac{\pi k [t_1^2 - t_2^2]}{\ln \left( \frac{d_1}{d_2} \right)}$

Where  $t_1 = t - s_1 = 43.750 \text{ m}$

$t_2 = t - s_2 = 43.500 \text{ m}$

$\ln\left(\frac{d_1}{d_2}\right) = \ln\left(\frac{100}{10}\right) = 2.303$

From equation (1) we get

$$k = \frac{0.05 \times 2.303}{\pi [49.75^2 - 43.5^2]}$$

$$k = 6.289 \times 10^{-5} \text{ m/s}$$

A well with a radius of 0.5m penetrates completely a confined aquifer of thickness 40m and a permeability of 30m/day. The well is pumped so that the water level in the well remains at 7.5 m below the original piezometric surface. Assuming that the radius of influence is 500m, compute the steady state discharge from the well.

Given:

Radius of well = 0.5m

Thickness of well = 40m

permeability = 30m/day

Drawdown,  $s = 7.5 \text{ m}$

Radius of influence =  $R = 500 \text{ m}$

i. steady state discharge is given by,

$$Q = \frac{2.72 k b s}{\log_{10}\left(\frac{R}{r}\right)}$$

$$= \frac{2.72 \times 40 \times 30 \times 7.5}{\log_{10}\left(\frac{500}{0.5}\right)}$$

$$Q = 8160 \text{ m}^3/\text{day}$$

A tube well of 30m diameter penetrate fully in the artesian aquifer. The strainer length is 15m. calculate the yield from the well under a drawdown of 3m. The aquifer consists of sand effective size of 0.2mm having coefficient of permeability equal to 50m/day. Assume radius of influence is equal to 150m.

Given:

$$d_w = 30\text{m}$$

$$r_w = 15\text{m}$$

$$B = 15\text{m}$$

$$R = 150\text{m}$$

$$s_w = 3\text{m}$$

$$k = 50\text{m/day} = \frac{50}{(60 \times 60 \times 24)}$$
$$= 5.78 \times 10^{-4} \text{ m/s}$$

$$T = kB = 8.68 \times 10^{-3} \text{ m}^2/\text{s}$$

i.

$$Q = \frac{2\pi T s_w}{2.30 \frac{R}{r_w}} = \frac{2\pi \times 8.68 \times 10^{-3} \times 3}{2.30 \left(\frac{150}{15}\right)}$$
$$= \frac{0.163}{2.30} = 0.071 \text{ m}^3/\text{s}$$
$$= 71.13 \text{ lps}$$
$$= 71.13 \times 60$$
$$= 4268 \text{ lpm}$$

The following data pertains to a check basin system:

- i. size of check basin =  $15\text{m} \times 60\text{m}$
- ii. cumulative infiltration  $I_c = 8.6 t^{0.4}$ , in which  $I_c$  is in mm and  $t$  is in minutes.

iii. Advance function

a.  $L = 5.8 t_L^{0.60}$  for a stream size of  $1.50 \text{ lps/m}$

b.  $L = 8.6 t_L^{0.60}$  for a stream size of  $3.00 \text{ lps/m}$

iv. Depth of irrigation =  $76 \text{ mm}$

calculate a. Deep percolation losses

b. water application efficiency

$E$ : Time of irrigation

Given:

i. Breadth of basin =  $15\text{m} = B$

ii. Length of basin =  $60\text{m} = L$

iii. Depth =  $76\text{mm}$

iv. cumulative and infiltration =  $I_c = 8.6 t^{0.4}$

$$k = 8.6, n = 0.4$$

a. For  $L = 5.8 \text{ ft}^{0.6}$  for stream size of 1.5 lps/m:

$$a = 5.8, b = 0.6$$

$$q = 1.5 \text{ lps}$$

$$\therefore Q = qB$$

$$Q = 1.5 \times 15 \times 10^{-3} \text{ m}^3/\text{s}$$

$$Q = 0.0225 \text{ m}^3/\text{s}$$

$$t_L = \left[ \frac{L}{a} \right]^{1/b} = \left[ \frac{60}{5.8} \right]^{1/0.6}$$

$$t_L = 49.11 \text{ min}$$

$$t_d = \left[ \frac{d}{k} \right]^{1/n} = \left[ \frac{76}{8.6} \right]^{1/0.4}$$

$$t_d = 232.16 \text{ min}$$

$$\text{Total time} = T = t_L + t_d = 281.27 \text{ min}$$

$$1. P = \left[ 1 - \left( \frac{t_d}{T} \right)^n \right]$$

$$= \left[ 1 - \left( \frac{232.16}{281.27} \right)^{0.4} \right]$$

$$P = 0.0738$$

$$P = 7.38\%$$

2. water application efficiency:

$$\eta_a = (1 - P)$$

$$= (1 - 0.0738) = 0.9262$$

$$\eta_a = 92.62\%$$

3. Time of irrigation

$$T_i = \frac{d_{LB}}{\eta_a Q} = \frac{76 \times 10^{-3} \times 60 \times 15}{0.9262 \times 0.0225} \times \frac{1}{60}$$

$$T_i = 54.7 \text{ min}$$

b.  $L = 8.6 \text{ ft}$ ,  $b = 0.6$  for stream size of 3.00 lps/m

$$a = 8.6, b = 0.6, q = 3 \text{ lit/sec}$$

$$Q = qB$$

$$Q = 3 \times 15 \times 10^{-3}$$

$$Q = 0.045 \text{ m}^3/\text{s}$$

$$t_L = \left[ \frac{L}{a} \right]^{1/b}$$

$$t_L = \left[ \frac{60}{8.6} \right]^{1/0.6}$$

$$t_L = 25.74 \text{ min}$$

$$t_d = \left[ \frac{d}{K} \right]^{1/n}$$

$$t_d = \left[ \frac{76}{8.6} \right]^{1/0.4}$$

$$t_d = 232.16 \text{ min}$$

$$\text{Total time} = T = t_L + t_d$$

$$T = 25.47 + 232.16$$

$$T = 257.63 \text{ min}$$

1. Deep percolation loss

$$P = \left[ 1 - \left( \frac{t_d}{T} \right)^n \right]$$

$$= \left[ 1 - \left( \frac{232.16}{257.63} \right)^{0.4} \right]$$

$$P = 0.0407$$

$$P = 4.07\%$$

2. Water application efficiency

$$\eta_a = (1 - P)$$

$$= (1 - 0.0407)$$

$$\eta_a = 0.9593 = 95.93\%$$

3. Time of irrigation,

$$T_i = \frac{dLB}{\eta_a Q}$$

$$= \frac{76 \times 10^{-3} \times 60 \times 15}{0.9593 \times 0.045} \times \frac{1}{60}$$

$$T_i = 26.4 \text{ min}$$

In a certain area paddy crops requires 14cm of depth of water at an interval of 10 days for a base period of 110 days where as wheat crop requires 9.0cm of depth of water after 35 days with a base period of 140 days. Determine the delta of paddy crops and duty of wheat crop of that area.

Ans :

a. Delta of paddy crop:

Depth of water,  $D = 14\text{cm}$

Water is needed at an interval = 10 days

Base period =  $B = 110\text{days}$

$$\therefore \text{No. of watering } n = \frac{\text{Base period}}{\text{Interval}} = \frac{110}{10} = 11$$

Delta of paddy =  $\Delta = n \times D$

$$= 11 \times 14 = 154\text{cm}$$

b. Wheat crop:

Depth of water,  $D = 9\text{cm}$

Water is needed at an interval = 35 days

Base period,  $b = 140\text{days}$

$$\therefore \text{No. of watering required, } n = \frac{\text{Base period}}{\text{Interval}} = \frac{140}{35} = 4$$

$\therefore$  Delta of wheat crop,  $= \Delta = n \times D$

$$= 4 \times 9 = 36\text{cm}$$

$$\text{Duty, } D = \frac{864B}{\Delta} = \frac{864 \times 140}{36}$$

$$= 3360 \text{ hectares/cumec}$$

An outlet has 600 ha, out of which only 75% is culturable. The intensity of irrigation for Rabi and Kharif seasons are 70% and 30% respectively.

Assuming losses in conveyance system as 10% of the outlet discharge, determine the discharge at the head of the irrigation channel. Take outlet discharge factor for Rabi season as 1500 ha/cumecs and for Kharif season as 750 ha/cumecs.

Given

i. Total area = 600 ha

ii. Intensity for Rabi season = 70%

iii. Intensity for Kharif season = 10%

iv. outlet discharge factor for Rabi season = 1500 ha/cumecs

v. For Kharif season = 750 ha/cumecs

I. Total culturable area =  $600 \times \frac{75}{100} = 450$  hectares

II. Irrigation area under Rabi season =  $450 \times \frac{70}{100}$   
= 315 hectares

III. Irrigation area under Kharif season =  $450 \times \frac{30}{100}$

Assuming 10% loss in conveyance system, = 315 hectares

I. Discharge factor

i. For Rabi season =  $1500 \times \frac{9}{100} = 1350$  hectares

ii. For Kharif season =  $750 \times \frac{90}{100} = 675$  hectares

Discharge (a)

1. For Rabi season =  $\frac{315}{1350} = 0.23$  cumecs

2. For Kharif season =  $\frac{315}{675} = 0.2$  cumecs

The following data has been obtained while gauging a stream:

Main gauge reading (m) = 20.10, 2.10

Auxiliary gauge reading (m) = 19.82, 19.13

Discharge (cumecs) = 5.40, 9.35

Calculate discharge when the main gauge is 20.10 m and auxiliary gauge is 19.52 m.

Given:

Main gauge reading  $R_1$  (m) = 20.10, 20.10, 20.10

Auxiliary gauge reading  $R_2$  (m) = 19.82, 19.13, 19.52

Discharge,  $Q$  (cumecs) = 5.40, 9.35

$$\text{Fall } (f) = [R_1 - R_2]$$

$$= [20.10 - 19.82] = 0.28 \text{ m}$$

$$Q_1 = 5.40 \text{ m}^3/\text{s} \text{ and } Q_2 = 9.35 \text{ m}^3/\text{s}$$

$$\text{Fall}(f_2) = [R_1 - R_2] = (20.10 - 19.13)$$

$$= 0.97 \text{ m}$$

By using equation,

$$\left[ \frac{Q_1}{Q_2} \right] = \left[ \frac{f_1}{f_2} \right]^m$$

$$\left[ \frac{5.40}{9.35} \right] = \left[ \frac{0.28}{0.97} \right]^m$$

$$m = 0.44$$

$$f_3 = (20.10 - 19.52) = 0.58 \text{ m}$$

$$Q = Q_2 \left[ \frac{f_1}{f_2} \right]^m$$

$$= 9.35 \left[ \frac{0.58}{0.97} \right]^{0.44}$$

$$Q = 7.457 \text{ m}^3/\text{s}$$

A tube well of 4cm diameter penetrate fully in the artesian aquifer. The strainer length is 17m. calculate the yield from the well under a drawdown of 4m. The aquifer consists of sand effective size of 0.3mm having coefficient of permeability equal to 60m/day. Assume radius of influence is equal to 160m.

Given:

$$d_w = 40 \text{ cm}$$

$$s_w = 17 \text{ m}$$

$$B = 17 \text{ m}$$

$$R = 160 \text{ m}$$

$$S_w = 4 \text{ m}$$

coefficient of permeability = 60 m/day

$$k = 60 \text{ m/day}$$

$$= \frac{60}{(60 \times 60 \times 24)}$$

$$= 6.94 \times 10^{-4} \text{ m/s}$$

$$T = kB = 6.94 \times 10^{-4} \times 17$$

$$= 0.0117 \text{ m}^2/\text{s}$$

$$Q = \frac{2\pi T S_w}{\ln \frac{R}{r_w}} = \frac{2 \times \pi \times 0.0117 \times 4}{\ln \left[ \frac{160}{17} \right]}$$

$$= \frac{0.297}{2.24} = 0.132 \text{ m}^3/\text{s}$$

$$= 12.05 \text{ lps}$$

$$= 12.05 \times 60 = 723 \text{ lpm}$$