Ground Water

→ Hydrogeology is the area of geology that deals with the distribution & movement of ground water in the soil & rocks of earth's crust.

GROUND WATER

→ G.W is considered as a very important natural resource. And in arid, semi-arid & dry regions G.W is only source of water supply.

→ <25 cm annual rainfall.
↳ 25–75 cm of rainfall
→ <60 cm

→ G.W is free from turbidity, pathogenic organisms & surface water impurities.

→ G.W requires less treatment when compared with surface water.

→ It is present below the surface of the earth strictly speakin below the water table.

SOURCES OF GROUND WATER:-

1. Meteoric water.
2. Connate water.
3. Juvenile water.

1 Meteoric Water:-

→ Water derived from precipitation (rain & snow).

→ Through infiltration, water reaches W.T.

→ Almost entire water obtained from G.W belong to this category.

2. Connote Water:-

→ Water present in the rocks right from the time of their deposition.

→ During the process of formation of sedimentary rock in lake (or) river, deposition is followed by compaction which leads to squeezing out of water present b/w the sediments.

→ Sometimes, inadequate compaction may cause retention of some water by these rocks is known as "connote water".

→ It is found in limestone, sandstone & gravels.

→ It is of no importance as a source for exploitable ground water.

3. Juvenile Water:-

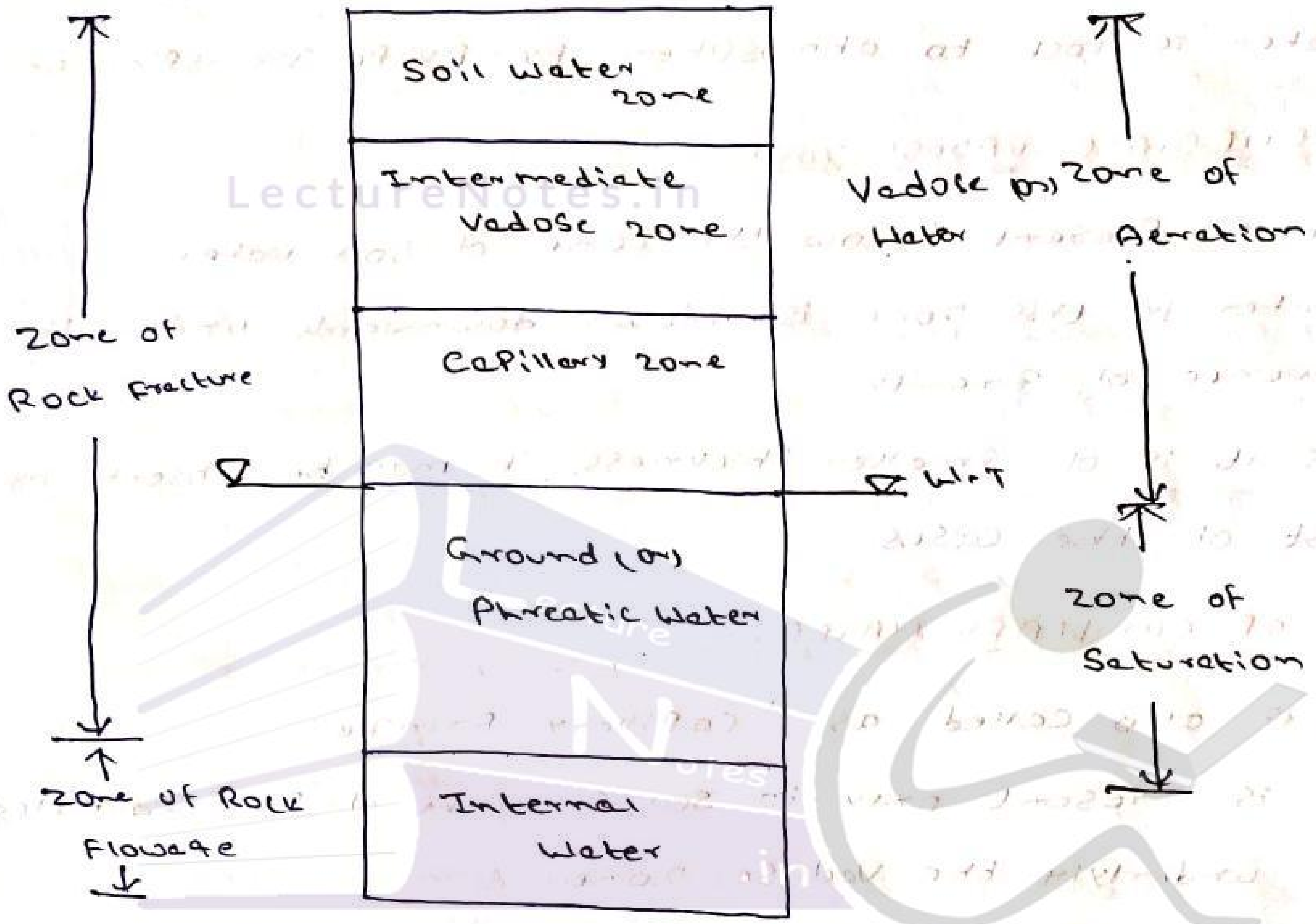
→ It is also called as magmatic water and it is of only theoretical importance.

→ It is formed by condensation of molten magma in which steam converted into water.

→ In simple words, formed by cooling of molten magma.

Distribution (or) Division of G.W:-

1. Vadose zone. (i) zone of rock ~~Formation~~ fracture.
(ii) zone of rock flowage.
2. Phreatic water (or) Ground water.



1. Vadose zone:-

It is divided into three zones. They are:-

1. Soil-water zone.
2. Intermediate vadose water zone.
3. Capillary water.

SOIL WATER:-

→ It forms a thin layer confined to the near surface depth of the land.

→ It may occur at depth btwn 1m to 9m and the water in it is held by the root zone of vegetable cover.

→ Water is lost to atmosphere by Evapo-Transpiration.

INTERMEDIATE VADOSE ZONE:-

→ It is present below the zone of soil water.

→ Water in this zone is movin downwards under the influence of gravity.

→ As it is of smaller thickness, it may be absent in most of the cases.

ZONE OF CAPILLARY WATER:-

→ It is also called as "Capillary Fringe".

→ It is present only in soil & rocks of fine particles size underlyin the vadose zone.

→ G.W is drawn upward by capillary action, to a height of 2-3m above saturated zone.

→ Growth of vegetation in some desert is very often dependent on presence of capillary fringe.

PHREATIC WATER ZONE:-

→ It lies below the capillary zone

→ It is also called as "zone of Saturation".

→ In real sense, water held in this zone is called as "Ground water.".

→ Water Table form an upper surface in this zone

→ In this zone, the layers of rocks are Porous & Permeable which are interconnected and filled with water.

→ If a well is dug in this zone, the water will enter the wells through these interconnected Pores.

→ In all G.W Exploration programmes, the main objective is to locate this zone & determine its extent, geometry & character.

SATURATED FORMATIONS:-

→ Saturated formations are classified into four categories
(i) Aquifer (ii) Aquitard (iii) Aquiclude (iv) Aquifuge.

AQUIFER:-

→ It is a geological formation which not only stores water but yields in sufficient Quantity.

→ Unconsolidation deposits of sand & gravel form good aquifer.

→ Consolidated Sediment → A Sediment that has been converted into rock by compaction.

→ Unconsolidated Sediment → Derived from dis-integration & erosion of consolidated rocks.

→ Recharge to aquifer is done by the process of Preci-
-pitation & Infiltration.

AQUITARD:-

→ It is a geological formation through which only seepage is possible & yield is insignificant compared to an aquifer.

→ Silty clay material is an example.

AQUICLUDE:-

→ These are geological formation which are impermeable to flow of water.

→ It contains large amount of water because of its high porosity but cannot transmit water.

→ Clay layer is an example of aquiclude

Clay - Small particles & dense packed - Less Drainage

Silt - Medium Drainage

Sand - Large particles & loosely packed - more drainage.

AQUI~~TARD~~FUGE:-

→ It is neither porous nor permeable.

→ Neither contains water nor transmits water.

→ Massive compact rock without any fracture is an example of Aquifuge

	Holds	Transmits	Example
Aquifer	✓	✓	
Aquifuge	×	×	Massive compact Rock
Aquitard	Partial	Partial	Silty clay
Aquiclude	✓	×	Shale, clay

Classification of Aquifers:-

1. Unconfined Aquifer.
2. Confined Aquifer.
3. Leaky Aquifer.
4. Perched Aquifer.

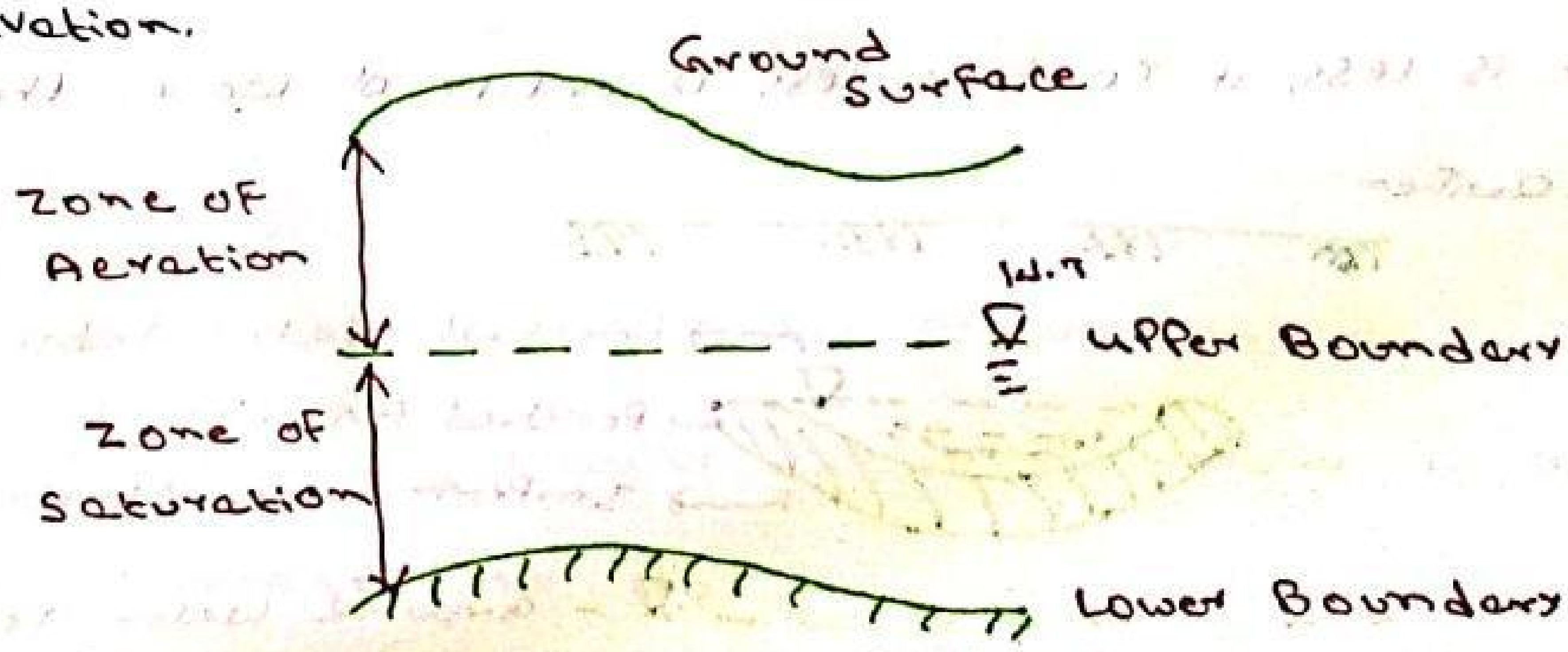
Unconfined Aquifer:-

→ Aquifers which are bounded by a free surface (water Table) at the upper boundary & a confining layer [Less Permeable Layer] at the lower boundary are called unconfined Aquifers.

→ Also called as "Water-Table Aquifer" (or) "Phreatic Aquifers", "Free Aquifer" (or) "Non-Artesian Aquifer".

→ Recharge of this aquifer is done by rainfall through the process of Infiltration & Percolation.

→ A well driven into unconfined aquifer indicates the static water level corresponding to the water table at that elevation.



Confined Aquifer:-

→ Aquifers which are bounded both above & below by impervious (or) semi-impervious layer called "confined Aquifer"

→ Water present in these aquifer are under pressure.

→ It is also called as "Pressure Aquifers" or "Artesian Aquifers".

→ If a well penetrates into the confined aquifer, water level in the well rises to piezometric level.

→ These are filled with water & they do not have a free water table.

Leaky Aquifer:

→ If an aquifer (confined/unconfined) losses/gains water through adjacent semi-permeable layers, it is called as a "Leaky Aquifer".

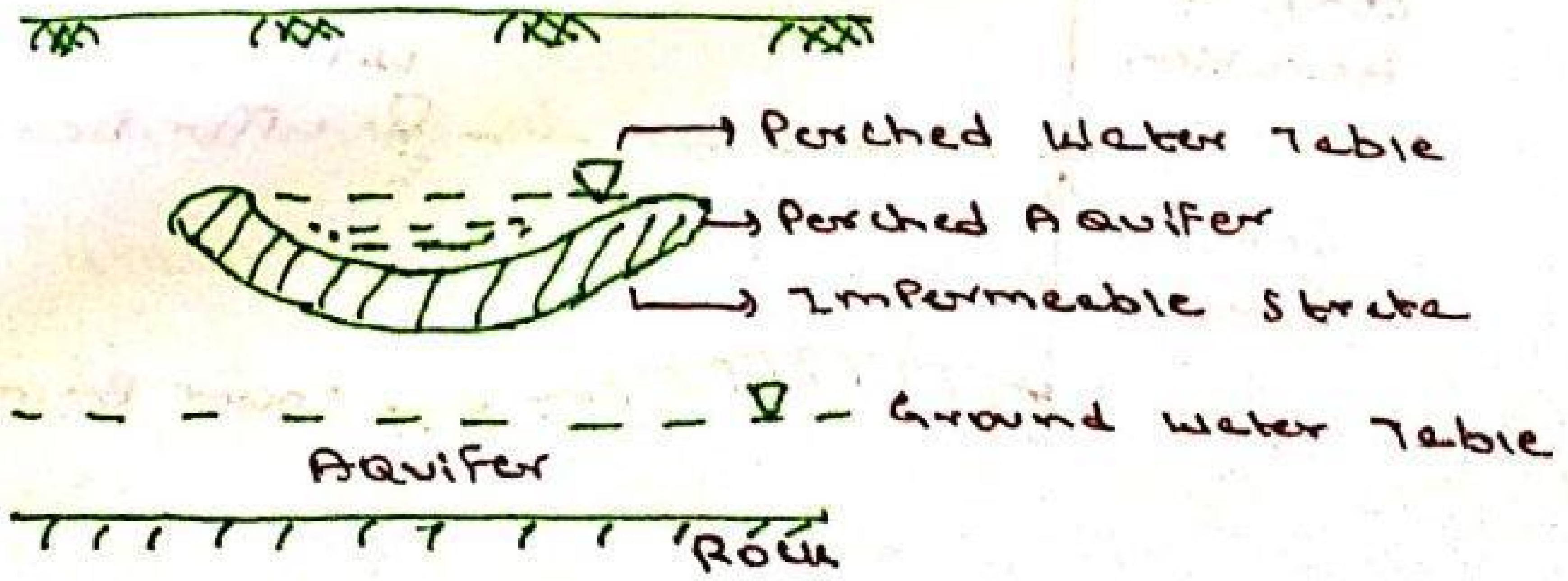
Perched Aquifer:

→ It is a special type of unconfined aquifer occur above the regional water table.

→ This occur whenever a ground water body is separated from the main ground water by a relatively impermeable stratum of small areal extent in the vadose zone.

→ It is smaller in size when compared with unconfined aquifer.

→ As its size is less, it contain less quantity of water than the unconfined aquifer



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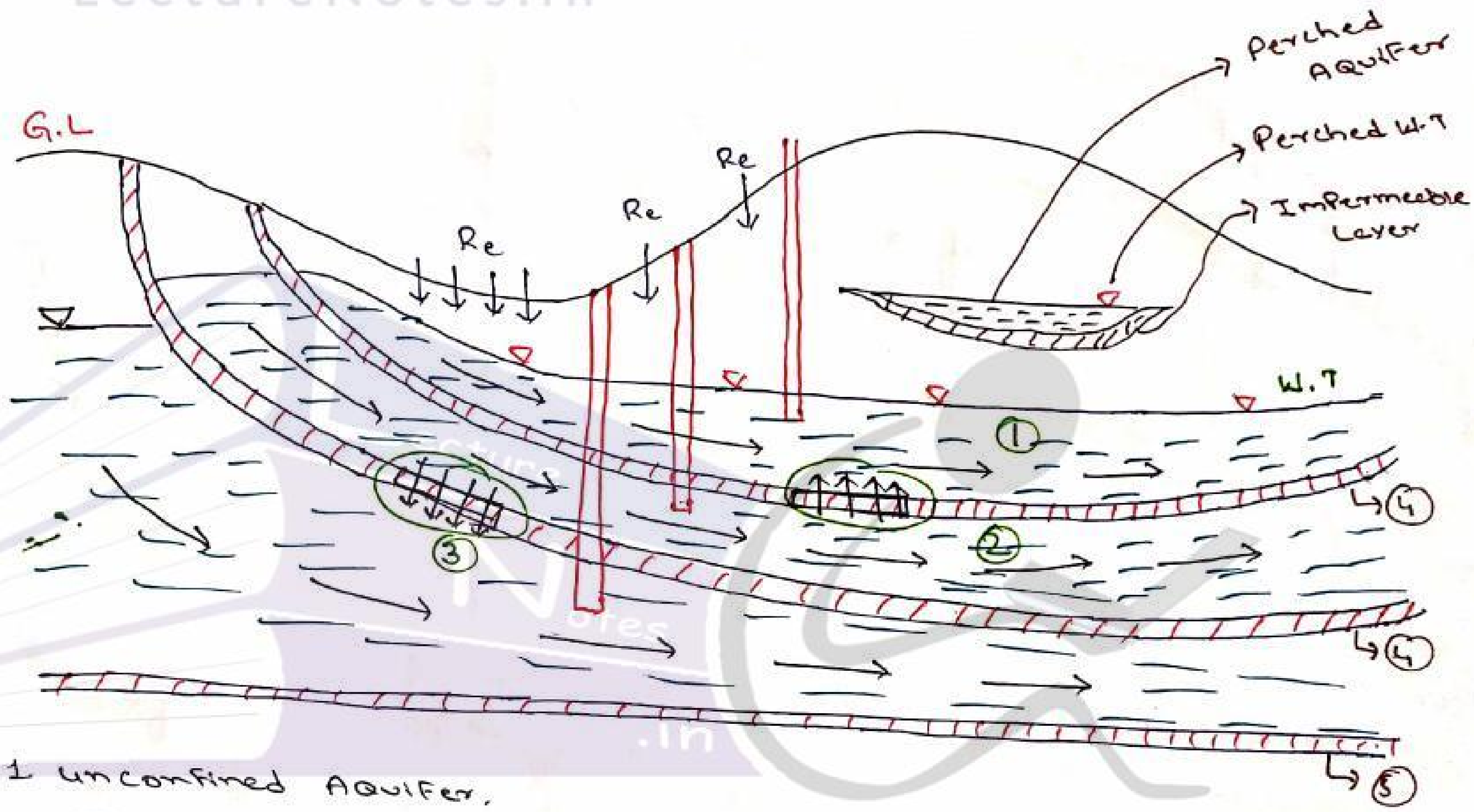


1. Unconfined Aquifer.
2. Confined Aquifer.
3. Leaky Aquifer.
4. Less - Permeable (or) Impermeable layer.
5. Impermeable layer.

Characteristics (or) Parameters of Aquifers:-

1. Hydraulic Conductivity:-

→ It is defined as its ability or ease of fluid to pass through material.

→ It is generally measured in m/s.

→ It depends on density & viscosity of fluid along with the permeability of the porous medium.

→ Hydraulic conductivity - Ability of fluid

→ Permeability - Ability of the material.

2. Porosity:-

→ It is the measure of storage property of water.

→ It is denoted by 'n' & it is expressed as percentage.

→ It is defined as the ratio of volume of voids to the total volume.

$$n = \frac{V_v}{V} \times 100$$

n = Porosity

V = Total volume

V_v = Volume of voids.

$$0 < n < 100$$

→ $n > 25\%$ - Appreciable amount of water is present in ground

→ $n = 5\text{-}25\%$ - Moderate amount of water.

→ $n < 5\%$ - Less amount of water.

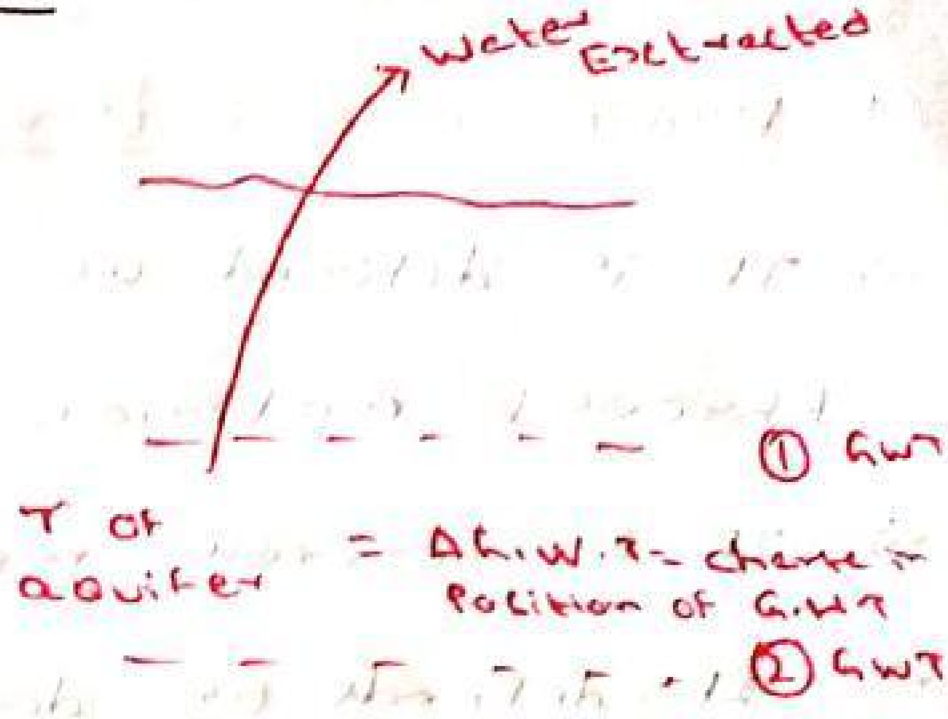
3. Specific yield:-

→ It is defined as the ratio of volume of water extracted by the force of gravity per unit volume of aquifer.

→ It is denoted by S_y.

→ It has no units.

$$S_y = \frac{\text{Volume of water extracted}}{\text{Volume of aquifer}}$$



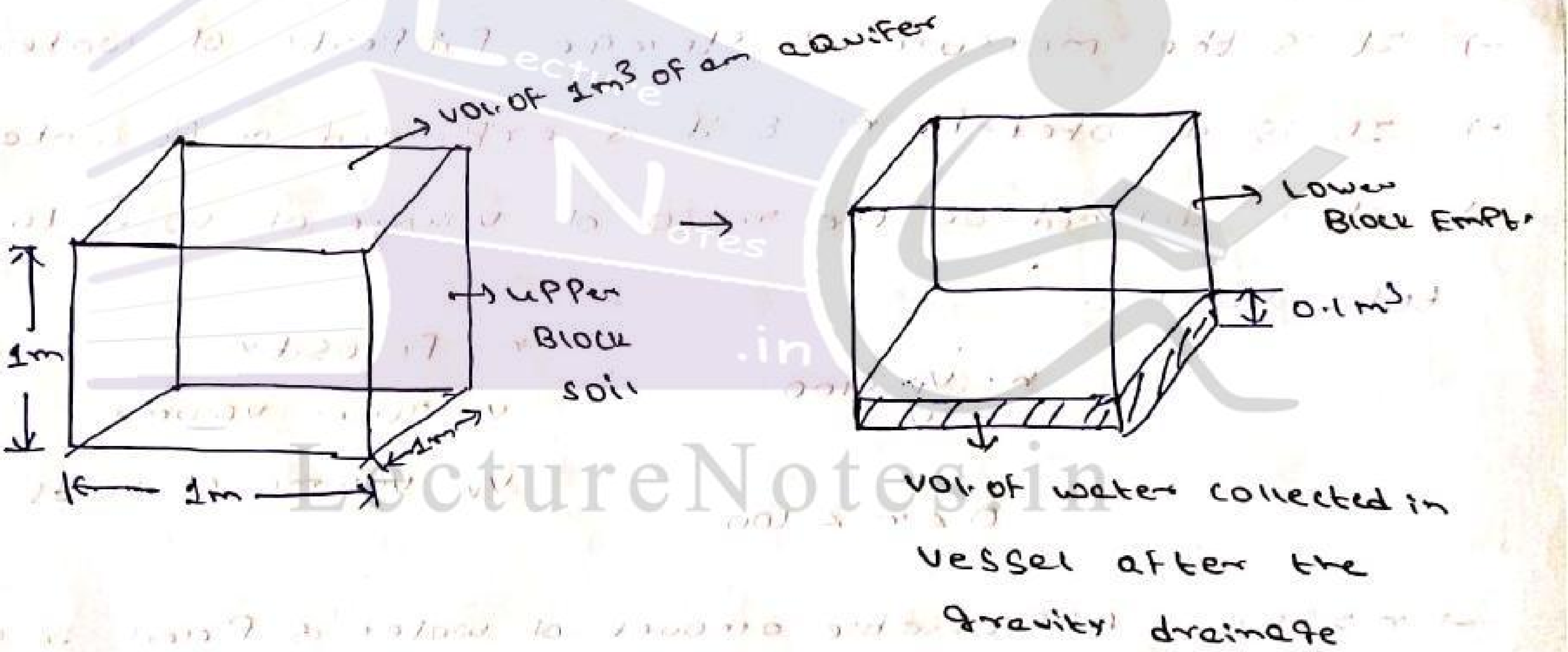
→ Thickness of aquifer from which water extracted = $\Delta G.W.T$

→ Surface area of aquifer from which water extracted = A_S

→ Vol. of aquifer from which water is extracted = $\Delta G.W.T \times A_S$

→ [change in G.W.S = Vol. of water extracted = $\Delta G.W.T \times A_S$ ×

$= S_y \times A_S \times \Delta G.W.T$]



Specific Retention (S_r):-

→ It is defined as the ratio of volume of water which is retained against the force of gravity per a unit volume of an aquifer material is known as "Specific Retention".

→ It is denoted by S_r.

$$n = S_y + S_r$$

Transmissibility:-

→ It is defined as the rate of flow of water through a vertical strip of the water bearing material of unit width & full depth under a unit hydraulic gradient.

→ It is also called as "Transmissivity".

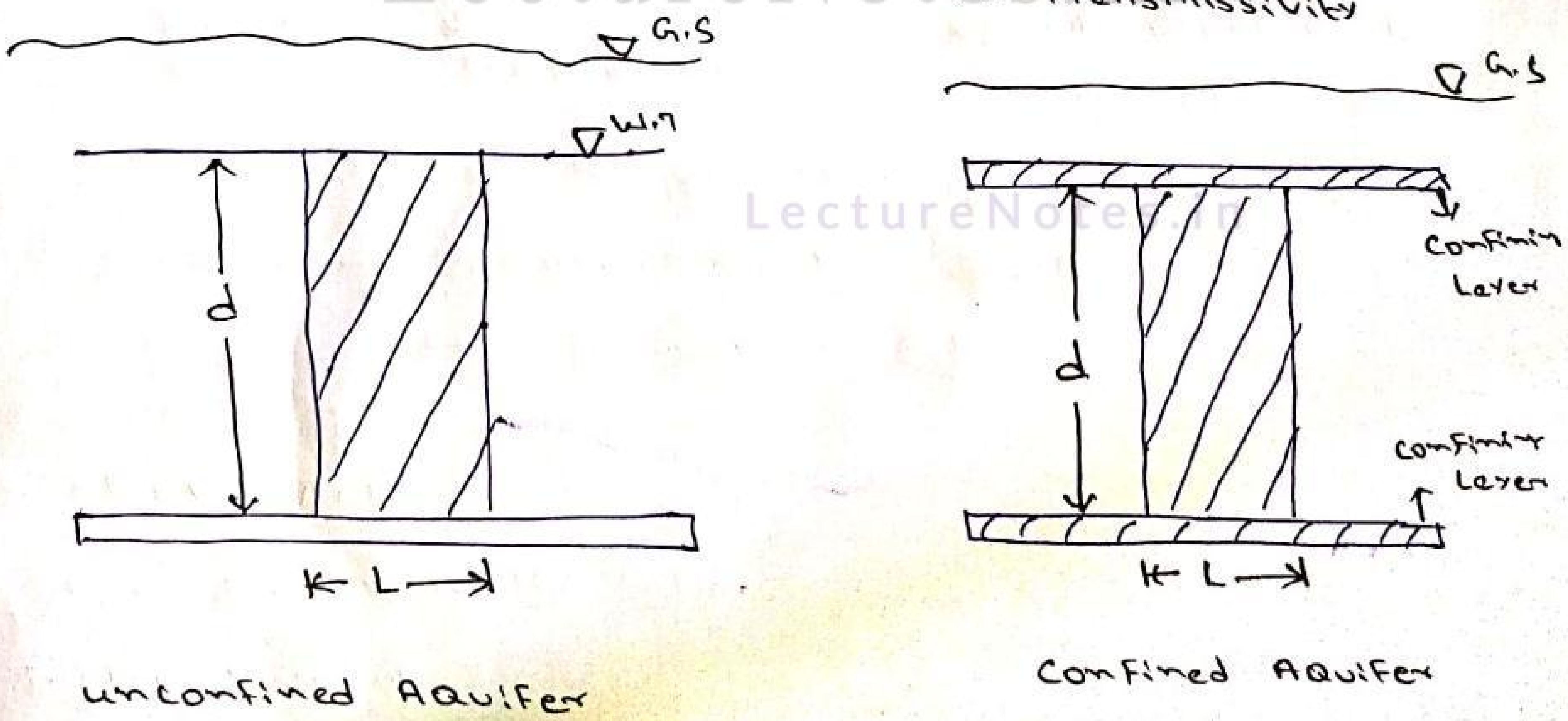
→ It is dentoted by 'T'.

$$T = k.d$$

k = Permeability

d = Depth

T = Transmissivity



Specific capacity:

→ It is defined as the ratio of rate of ~~well~~ flow from a well per unit drawdown

→ It should be determined for the fall of first meter depth because it is not same for all drawdowns.

→ It is denoted by S_c.

$$S_c = \frac{\text{Discharge}}{\text{unit drawdown}}$$

Darcy's Law:-

→ The Percolation of water through soil was first Studied by Darcy (1856).

→ The rate of flow (or) discharge per unit time is Propor-tional to the hydraulic gradient and it is expressed as:

$$Q = k \cdot i \cdot A$$

$$v = \frac{Q}{A} = k \times i$$

Q = Rate of flow; i = Hydraulic Gradient; v = Flow velocity

k = Darcy's co-eff of Permeability

A : Total C/S area of soil mass ⊥ler to direction of flow.

→ Darcy's law is valid only for laminar flow.

→ A flow is said to be laminar flow if in reynold's numb is ≤ 1.

$$R_e = \frac{\rho v d}{\mu} \leq 1 \rightarrow \text{Laminar Flow}$$

ρ = Mass Density; μ = Dynamic viscosity; v = velocity of flow

d = diameter of Particle size

Steady Radial Flow to a well:- (DuPuit's Theory)

→ When a well is Penetrated into an extensive homogeneous aquifer, the water table remains horizontal in the well.

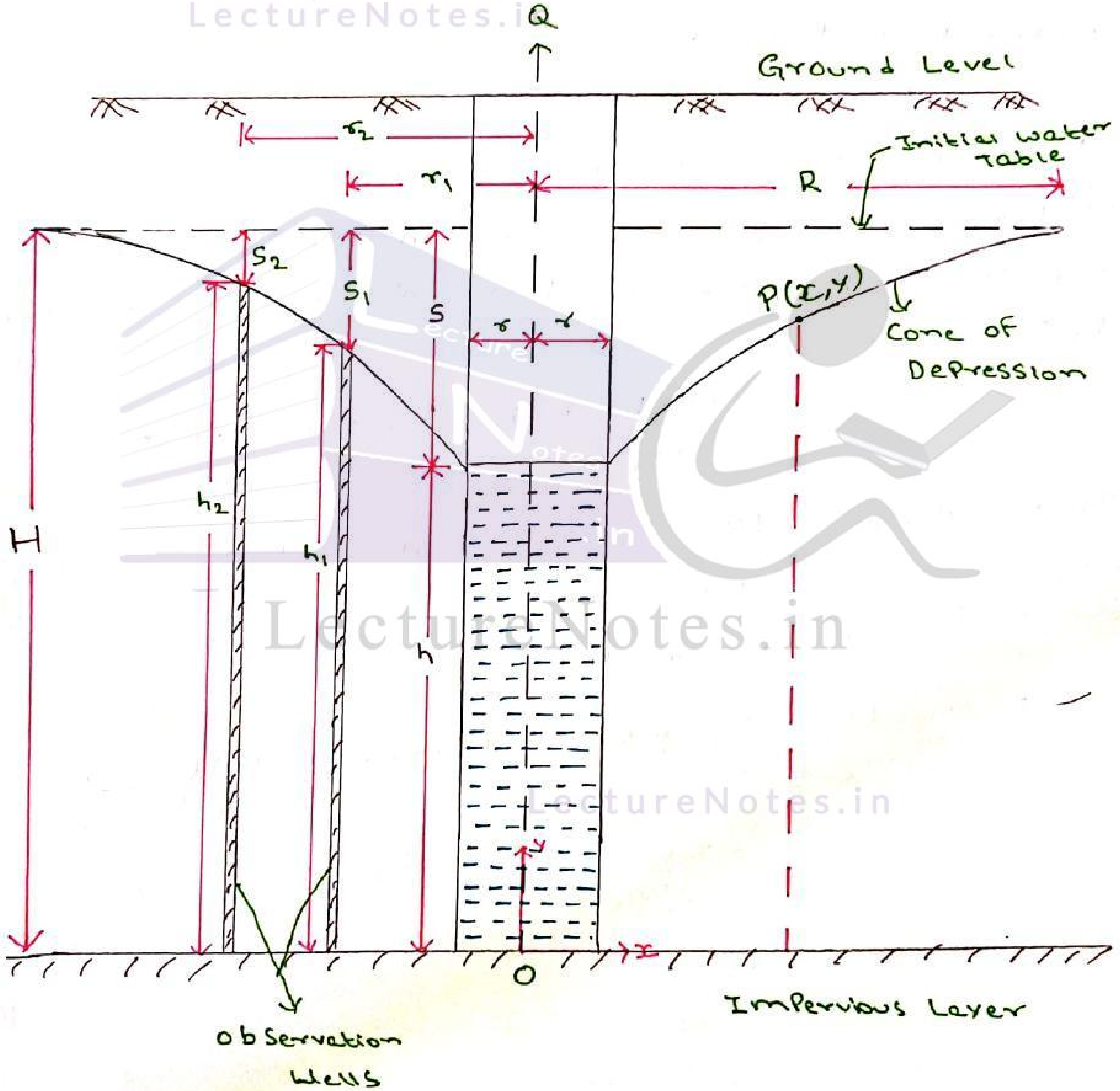
→ When the well is Pumped, water is removed from the aquifer and the water table or Piezometric surface dependint upon the type of aquifer, is lowered resultin in a circular depression in the water table.

→ This depression is called "cone of depression" (or) the "draw down curve".

→ At any Point, away from the well, the drawdown is the vertical distance by which the water table or Piezometric Surface is lowered.

→ And such radial flow towards a well was Proposed by Dupuit in 1863 & later modified by Thiem (1906).

1. Unconfined Aquifer:-



Unconfined Aquifer:- Well in a unconfined Aquifer

r = radius of the well

H = Thickness of the aquifer measured from the impermeable layer to the Initial level of W.T.

S = Drawdown at the well

h = Depth of water in the well measured above impermeable layer.

Considering the origin of co-ordinates at a point 'O' at the centre of the well at its bottom, let the co-ordinates of any point 'P' on the drawdown curve be (x, y). Then from Darcy's Law

$$V \propto i \Rightarrow V = K \times i \Rightarrow V = \frac{Q}{A} = K \times i$$

$$Q = K i A$$

$$Q = K . i_x . A_x$$

A_x = Area of c/s of the saturated part of aquifer at P

$= (2\pi x) \times y = 2\pi x y$ [Lateral surface area of a cylinder]

i_x = Hydraulic Gradient at point P $= \frac{dy}{dx}$

$$Q = K \times i_x . A_x$$

$$= K \times \frac{dy}{dx} \times 2\pi x y$$

$$Q \times \frac{dx}{x} = K . 2\pi y . dy$$

$$Q \cdot \left(\frac{dx}{x}\right) = 2\pi k \cdot y \cdot dy$$

Integrating between the limits (R, r) for x & (H, h) for y' we get,

$$Q \cdot \int_r^R \left(\frac{dx}{x}\right) = 2\pi k \cdot \int_h^H y \cdot dy$$

$$Q \cdot \left[\log_e x\right]_r^R = 2\pi k \left[\frac{y^2}{2}\right]_h^H$$

$$Q \cdot \left[\log_e R - \log_e r\right] = 2\pi k \left[\frac{H^2}{2} - \frac{h^2}{2}\right]$$

$$= 2 \times \pi k \times \frac{1}{2}\left[H^2 - h^2\right]$$

$$= \pi k \left[H^2 - h^2\right]$$

$$Q = \frac{\pi \cdot k\left[H^2 - h^2\right]}{\log_e\left(\frac{R}{r}\right)} = \frac{1.36\, k\left[H^2 - h^2\right]}{\log_{10}\left(\frac{R}{r}\right)} \quad -(1)$$

k = Co-efficient of Permeability = $m^3/day/m^2$ = m/day

Q = Discharge = m^3/day

R = Radius of zero drawdown

$\log(x) = \log_{10}(x) \Rightarrow \log_{10} 10 = 1$

$\ln(x) = \log_e(x) \Rightarrow \log_e 10 = 2.30$

Radius of zero drawdown (R):-

$$R = 3000 S \sqrt{K}$$

It is the radius measured from the center of the well to a point where the drawdown curve meets the original water table tangentially.

$$R = 3000 S \sqrt{K} \quad [R \& S - m;\ K = m/s]$$

If there are two observation wells at radial distance r_1 and r_2 and if the depth of water in them are h_1 and h_2 and if $r_2 > r_1$, then

$$Q = \frac{\pi . K (h_2^2 - h_1^2)}{\log_e \frac{r_2}{r_1}} \quad (2) = \frac{1.36 K (h_2^2 - h_1^2)}{\log_{10} \frac{r_2}{r_1}} \quad (3)$$

If the drawdown is measured at well face, we have

$$S = H - h$$

$$S + h = H$$

$$S + h + h = H + h \Rightarrow S + 2h = H + h$$

From Equation (1)

$$Q = \frac{\pi K (H^2 - h^2)}{\log_e \frac{R}{r}} = \frac{\pi . K (H-h)(H+h)}{\log_e \frac{R}{r}}$$

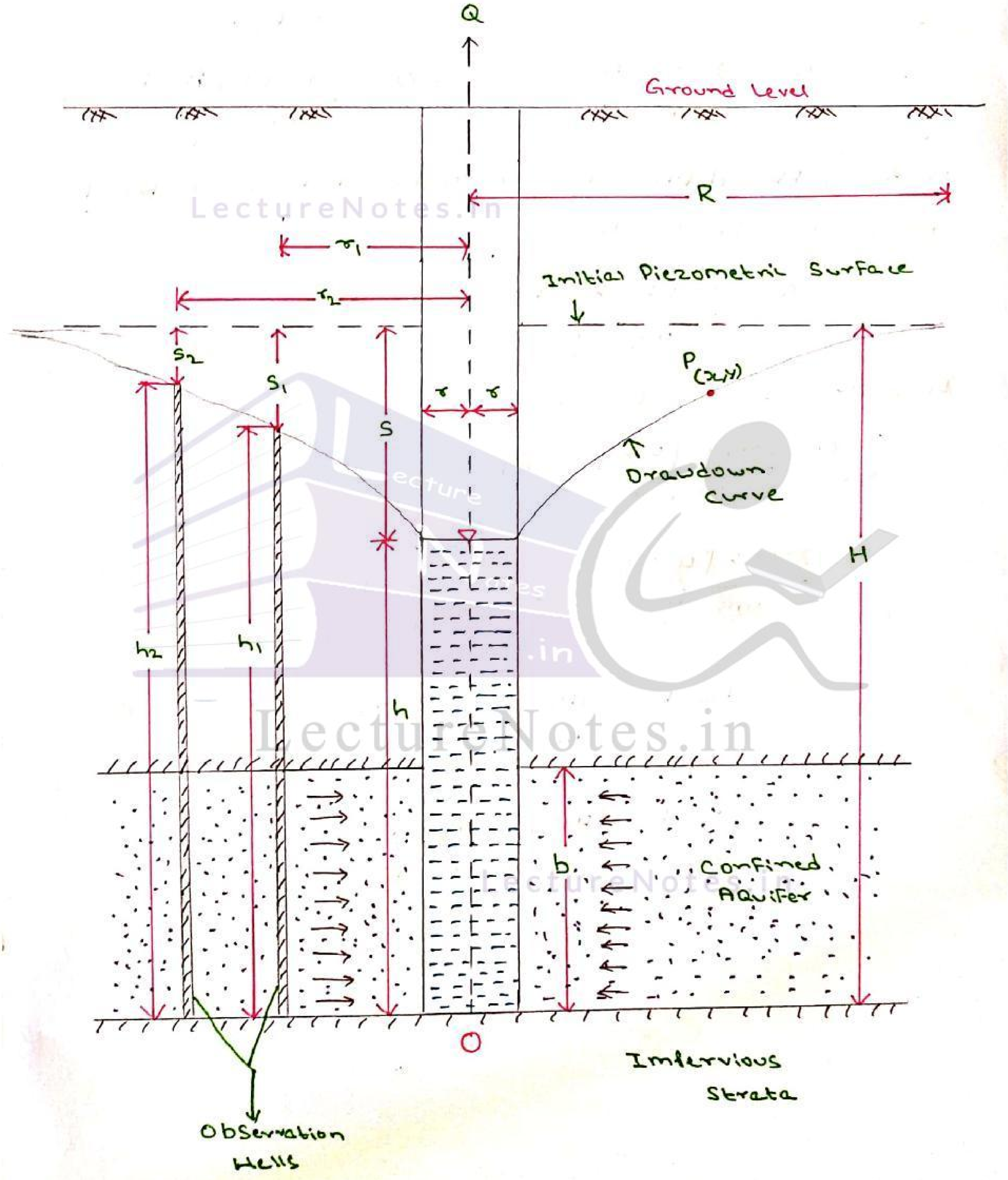
$$Q = \frac{\pi . K . S . (S + 2h)}{\log_e \frac{R}{r}}$$

~~S~~h = Length of strainer $[h = L]$

$$Q = \frac{\pi . K . S (S + 2h)}{\log_e \frac{R}{r}} = \frac{\pi . K . S (S + 2L)}{\log_e \frac{R}{r}} = \frac{2 . \pi . K . S (L + \frac{S}{2})}{\log_e \frac{R}{r}}$$

$$Q = \frac{2.72\ \cancel{\pi} K S (L + \frac{S}{2})}{\log_{10} \frac{R}{r}}$$

CONFINED AQUIFER



Confined Aquifer:-

Figure Shows a fully Penetrating confined aquifer. Let (x,y) be the co-ordinates of any Point 'P' on the drawdown curve, measured w.r.t origin 'O'. Then from Darcy's law, flow crossing a vertical Plane through 'P' is given by

$$Q = K \cdot i_x \cdot A_x$$

A_x = c/s area of flow at P = $(2\pi x) \times b$

b = Thickness of confined Aquifer

i_x = Hydraulic Gradient at P = $\frac{dy}{dx}$

$$Q = K \cdot i_x \cdot A_x$$

$$Q = K \cdot \left(\frac{dy}{dx}\right)(2\pi x \times b)$$

$$Q \cdot \left(\frac{dx}{x}\right) = K \cdot 2\pi b \cdot dy$$

Integrating between the limits (R, r) for x and (H, h) for y, we get

$$Q \int_r^R \left(\frac{dx}{x}\right) = 2\pi K b \int_h^H dy$$

$$Q \cdot \log_e [x]_r^R = 2\pi K b [y]_h^H$$

$$Q \cdot \log_e R - \log_e r = 2\pi K b [H - h]$$

Equilibrium (or) Thiem Equation

$$Q = \frac{2\pi K b [H-h]}{\log_e \frac{R}{r}} = \frac{2.72 K b [H-h]}{\log_{10} \frac{R}{r}} \quad \text{— (4)}$$

$$= \frac{2\pi T S}{\log_e \frac{R}{r}} = \frac{2.72\, T \cdot S}{\log_{10} \frac{R}{r}} \qquad [T = Kb]$$

If h_1 and h_2 are measured depth of water in two observation wells situated radially at distances r_1 & r_2 respectively, the above equation can be written as

$$S = H-h \Rightarrow S = h_2 - h_1$$

$$Q = \frac{2.72\,kbS}{\log_{10}\frac{R}{r}} \quad \text{is} \Rightarrow Q = \frac{2.72\,kb(h_2-h_1)}{\log_{10}\frac{r_2}{r_1}} \quad -(5)$$

If h_x is the depth at any radial distance x, the discharge can be written as

$$Q = \frac{2\pi kb(h_x-h)}{\log_e\frac{r_x}{r}} \quad -(6)$$

Equating Eq. 4 & 6, we get

$$Q = \frac{2\pi kb[H-h]}{\log_e\frac{R}{r}} \quad -(4)$$

$$\frac{\cancel{2\pi kb}[H-h]}{\log_e\frac{R}{r}} = \frac{\cancel{2\pi kb}(h_x-h)}{\log_e\frac{r_x}{r}}$$

$$h_x - h = \frac{[H-h]}{\log_e\frac{R}{r}} \times \log_e\frac{r_x}{r}$$

$$h_x - h = (H-h) \times \frac{\log_e\frac{r_x}{r}}{\log_e\frac{R}{r}}$$

Q) A tube well of 30cm Ø, Penetrates fully in an artesian aquifer. The Strainer length is 15m. Calculate the yield from the well under a drawdown of 3m. The aquifer consists of sand of effective size of 0.2mm having co-eff of Permeability equal to 50 m/day. Assume radius of drawdown equal to 150 metres

$$Q = \frac{2.72\, kbS}{\log_{10} \frac{R}{r}}$$

$d = 30cm = 0.30\, m$; $k = 50\, m/day$; $b = 15\, m$; $S = 3m$; $R = 150\, m$

$r = 15cm = 0.15\, m$

$$Q = \frac{2.72 \times 50 \times 15 \times 3}{\log_{10} \frac{150}{0.15}}$$

$Q = 2040\, m^3/day = 85\, m^3/hour = 23.6\, lit/sec$

Q) A tube well Penetrates fully an unconfined aquifer. Calculate the discharge from the tube well under following conditions:

Dia. of well = 30cm; Drawdown = 2m; Eff. length of Strainer under above drawdown = 10m; Co-eff. of Permeability of aquifer = 0.05 cm/sec; Radius of zero drawdown = 300 m

$d = 30cm$; $r = 0.15\, cm = 0.15 \times 10^{-2}\, m$; $S = 2m$; $L = 10m$

$k = 0.05\, cm/sec = 0.05 \times 10^{-2}\, m/sec$; $R = 300m$

$$Q = \frac{2.72\, kS \left[L + \frac{S}{2}\right]}{\log_{10} \frac{R}{r}}$$

$$= \frac{2.72 \times 0.05 \times 10^{-2} \times 2 \left[10 + \frac{2}{2}\right]}{\log_{10} \frac{300}{0.15}}$$

$Q = 9.06 \times 10^{-3}\, m^3/sec = 9.06\, lit/sec$

Q) Design a tube well for following data:

(i) yield Required = 0.08 m^3/s

(ii) Thickness of Confined Aquifer = 30 m

(iii) Radius of Circle of Influence = 300 m

(iv) Permeability Co-efficient : 60 m/day

(v) Drawdown = 5 m

$Q = 0.08\ m^3/s$; $L = 30m = b$; $R = 300m$; $K = 60\ m/day$; $S = 5m$

$$Q = \frac{2.72\,KbS}{\log_{10}\frac{R}{r}}$$

$$0.08 = \frac{2.72 \times 60 \times \frac{1}{24\times60\times60} \times 30 \times 5}{\log_{10}\frac{300}{r}}$$

$r = 0.086\ m = 8.62\ cm \simeq 9\ cm$

∴ Hence adopt a well of 18 cm diameter.

Q) An artesian tube well has a diameter of 20 cm. The thickness of aquifer is 30 m and its Permeability is 38 m/day. Find its yield under a drawdown of 4 m at the well face. Use radius of influence as suggested by Sichardt.

$d = 20cm = 0.20m$; $r = 0.10\ m$; $b = 30m$; $k = 38\ m/day$; $S = 4m$

$R = 3000\,S\sqrt{K} = \cancel{3000 \times 4 \times \sqrt{38}} = 245_m = 3000 \times 4 \times \sqrt{\frac{38}{24\times60\times60}}$

$$Q = \frac{2.72\,kbS}{\log_{10}\frac{R}{r}} = \frac{2.72 \times 38 \times 30 \times 4}{\log_{10}\frac{245}{0.10}} = 3467\ m^3/day$$

$= 40.12$ lit/sec

Q) A well Penetrates fully a 10 m thick water bearing Stratum of medium Sand havin $k = 0.005$ m/sec. The well radius is 10 cm and is to be worked under a drawdown of 4m at the well face. calculate the discharge from the well. what will be the % increase in discharge if the radius of well is doubled. $R = 300$ m

$b = 10m$; $k = 0.005$ m/sec ; $r = 10$ cm $= 0.10$ m ; $S = 4m$

$$Q = \frac{2.72 kbS}{\log_{10} \frac{R}{r}} = \frac{2.72 \times 0.005 \times 10 \times 4}{\log_{10} \frac{300}{0.10}} = 0.1564 \ m^3/s$$

$Q = Q_1 = 0.1564 \ m^3/s$ (If $r = 0.10m$)

If $r = 0.20m$; $Q_2 = \frac{2.72 kbS}{\log_{10} \frac{R}{r}} = \frac{2.72 \times 0.005 \times 10 \times 4}{\log_{10} \frac{300}{0.20}}$

$Q_2 = 0.171 \ m^3/sec$

% Increase in discharge $= \frac{0.171 - 0.1564}{0.1564} \times 100 = 9.33$ %

Q) Two tube wells each of 20cm diameter are spaced at 100 m distance. Both the wells Penetrate fully a confined aquifer of 12 m thickness. Calculate the discharge if only one well is discharging under a depression head of 3m. What will be the % decrease in the discharge of the well if both the wells are discharging under the depression head of 3m. Take radius of influence for each well equal to 250m & k as 60 m/day.

Case (a):- $S = 3m$; $k = 60$ m/day; $R = 250m$; $r = 20cm = 0.20m$

$b = 12m$

$$Q = \frac{2.72 kbS}{\log_{10} \frac{R}{r}} = \frac{2.72 \times 60 \times \frac{1}{24 \times 3600} \times 12 \times 3}{\log_{10} \left(\frac{250}{0.20}\right)}$$

$Q = 0.022 \ m^3/sec$

Case (b) :-

When both the wells are discharging, the discharge from each well is given by

$$Q_1 = Q_2 = \frac{2\pi k b (H-h)}{\log_e \frac{R^2}{rB}}$$

B = 100 m

H − h = S = 3 m

$$= \frac{2\times\pi\times 60\times\cancel{\frac{1}{24\times60\times60}}\times 12\times 3}{\log_e \frac{250^2}{0.10\times100}}$$

$$Q_1 = Q_2 = \frac{2.72\, kbS}{\log_{10} \frac{R^2}{rB}}$$

$$= \frac{2.72\times 60\times\frac{1}{24\times60\times60}\times 12\times 3}{\log_{10}\left(\frac{250^2}{0.10\times100}\right)}$$

$$Q_1 = Q_2 = 0.018\ m^3/s$$

% decrease in discharge $= \frac{0.022 - 0.018}{0.022}\times 100 = 18.18\ \%$.

Q) A gravity well has a diameter of 60 cm. The depth of water in the well is 40 m before pumping is started. When pumping is being done @ 2000 lit/min. The drawdown in a well 10 meters away is 4 meters and in another well 20 meters away is 2 meters. Determine

a) Radius of zero drawdown

b) Co-efficient of Permeability.

c) Drawdown in the well.

d) Specific capacity of the well.

e) Maximum rate at which water can be pumped from the well.

$$Q = \frac{1.36\,k\,(H^2 - h^2)}{\log_{10} \frac{R}{r}}$$

$H = 40m$; At $r_1 = 10m$; $h_1 = H - S_1 = 40 - 4 = 36m$

At $r_2 = 20m$; $h_2 = H - S_2 = 40 - 2 = 38m$

$$\frac{40^2 - 36^2}{\log_{10} \frac{R}{10}} = \frac{40^2 - 38^2}{\log_{10} \frac{R}{20}}$$

$R = 41.52\ m$

b) $R = 41.52m$; $Q = 2000$ lit/min $= 2 \times 10^3 \times 10^{-3}\ m^3/min = 2\ m^3/min$

$= \frac{2}{60} = 0.033\ m^3/s$

$H = 40m$; $h = 36m$; $r = 10m$

$$Q = \frac{1.36\,k\,(H^2 - h^2)}{\log_{10} \frac{R}{r}}$$

$$0.033 = \frac{1.36 \times k \times (40^2 - 36^2)}{\log \frac{41.52}{10}}$$

$k = 4.26$ m/day $= 0.003$ m/min

c) Depth of water in well is given by

$$Q = \frac{1.36\,k\,(H^2 - H_0^2)}{\log_{10} \frac{R}{r}}$$

$$2 = \frac{1.36 \times 0.003 (40^2 - H_0^2)}{\log_{10} \frac{41.52}{0.30}}$$

$H_0 = 23.46m$

Hence drawdown at well $= 40 - 23.46 = 16.54m$

Assumptions & limitation of dupuits theory:

→ Flow is laminar & darcy's law is applicable.

→ The velocity of flow is proportional to the tangent of the hydraulic gradient instead of sine.

→ The flow is horizontal & uniform everywhere in the vertical section.

→ Aquifer is homogeneous, isotropic and of infinite aerial extent.

→ Co-efficient of transmissibility is constant at all places and at all times.

Efficiency of a well:-

→ It is defined as the ratio of theoretical drawdown of the well to the actual drawdown of the well.

→ It shows how effective the well is during pumping.

→ It depends upon the well loss and it is expressed as percentage.

→ If a well is efficient, then there is no well loss.

$$E = \frac{S_t}{S_a} \times 100$$

S_t = Theoretical drawdown of the well.

S_a = Actual drawdown of well.

INTERFERENCE BETWEEN WELLS:-

→ When two wells situated near to each other and are discharging, their drawdown curves intersect within their radius of zero drawdown.

→ Due to interference, the total discharge is increased and the discharge in individual well is decreased.

→ Figure shows interference between ~~to~~ wells. If the two wells are at a distance 'B' apart and have the same diameter and drawdown and discharge over the same period of time, discharge through each well is given by

$$Q_1 = Q_2 = \frac{2\pi k b (H-h)}{\log_e \frac{R^2}{rB}} \quad [R >> B]$$

If there is only one well, then the discharge under the same drawdown is,

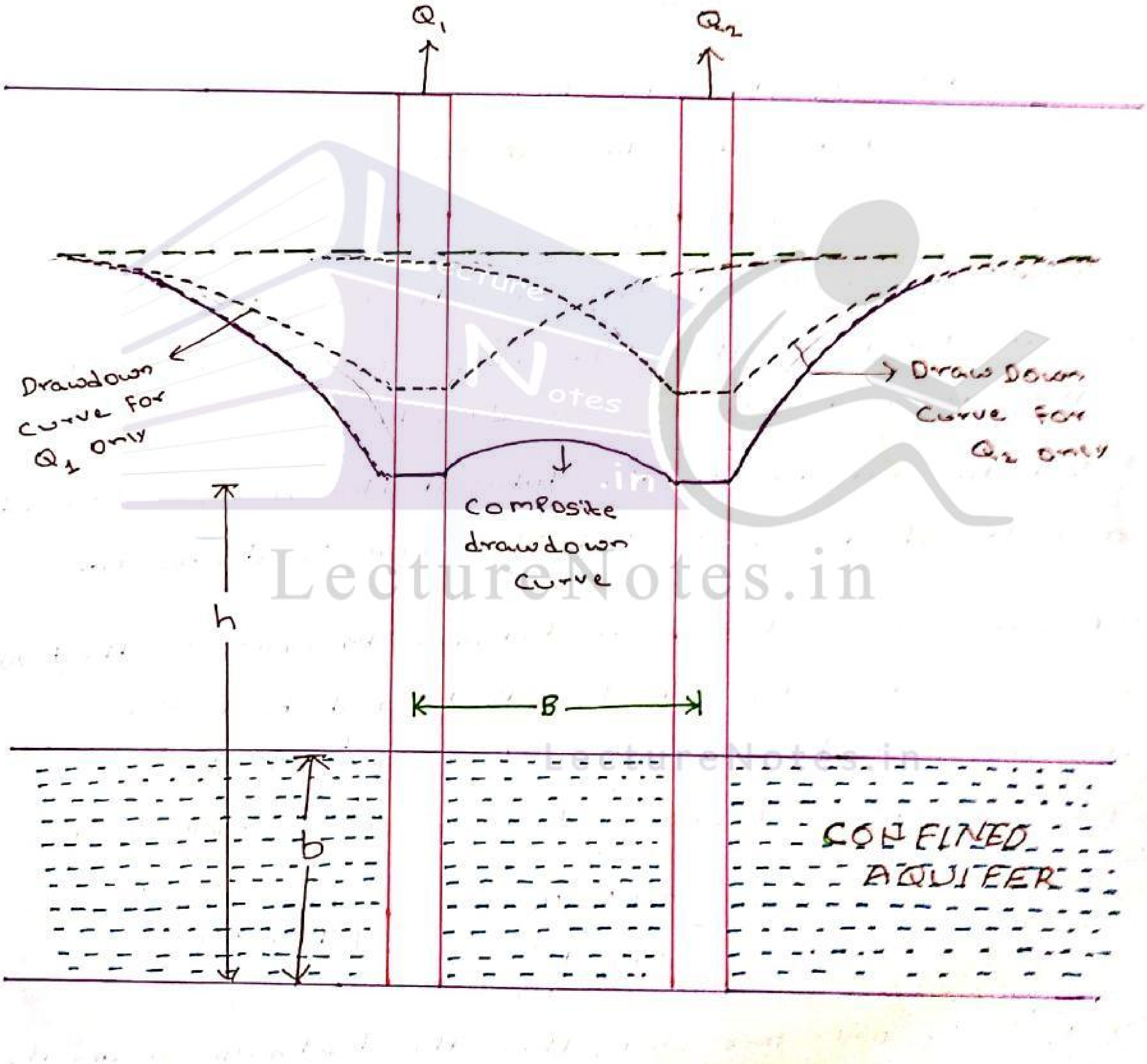
$$Q = \frac{2\pi k b (H-h)}{\log_e \frac{R}{r}}$$

Since $R >> B$, $\frac{R^2}{rB} > \frac{R}{r}$

Hence $Q > Q_1$

If there were three wells, the discharge through each well is given by

$$Q_1 = Q_2 = Q_3 = \frac{2\pi k b (H-h)}{\log_e \frac{R^3}{rB}}$$



STRATIFICATION OF AQUIFER:

→ Sometimes, the aquifers may be stratified and each strata have different permeability and different width. For finding the equivalent permeability (or) transmissibility we assume two types of flow condition.

(i) When the flow is parallel to strata,

$$\text{Equivalent Permeability, } K_e = \frac{B_1K_1 + B_2K_2 + B_3K_3 + \dots + B_nK_n}{B_1 + B_2 + B_3 + \dots + B_n}$$

(ii) When the flow is normal to strata,

$$\text{Equivalent Permeability, } K_e = \frac{L_1 + L_2 + L_3 + \dots + L_n}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \dots + \frac{L_n}{K_n}}$$

$B_1, B_2, \dots B_n$ = Thickness of layer

$L_1, L_2, \dots L_n$ = Length of layer

$K_1, K_2, \dots K_n$ = Co-efficient of Permeability

Wells:

→ It is a hydraulic structure which if properly designed and constructed, permits the economic with-draw of water from a water bearing formation namely an aquifer.

→ Well is the most important mode of ground water extraction from an aquifer.

→ Wells are used in different applications mainly in water supply and Irrigation.

Classification of wells:

- Well
  - Open Well
    - Based on Depth
      - Shallow Well
      - Deep Well
    - Based on Lining
      - Unlined Well (or) Kacha Well
      - Well with Impervious Lining
      - Well with Pervious Linim
  - Tube Well
    - → Strainer Well.
    - → Cavity Well.
    - → Slotted Well.

Open Well:-

→ An open well is essentially of a bigger diameter than that of tube well and derives its water only from one pervious stratum.

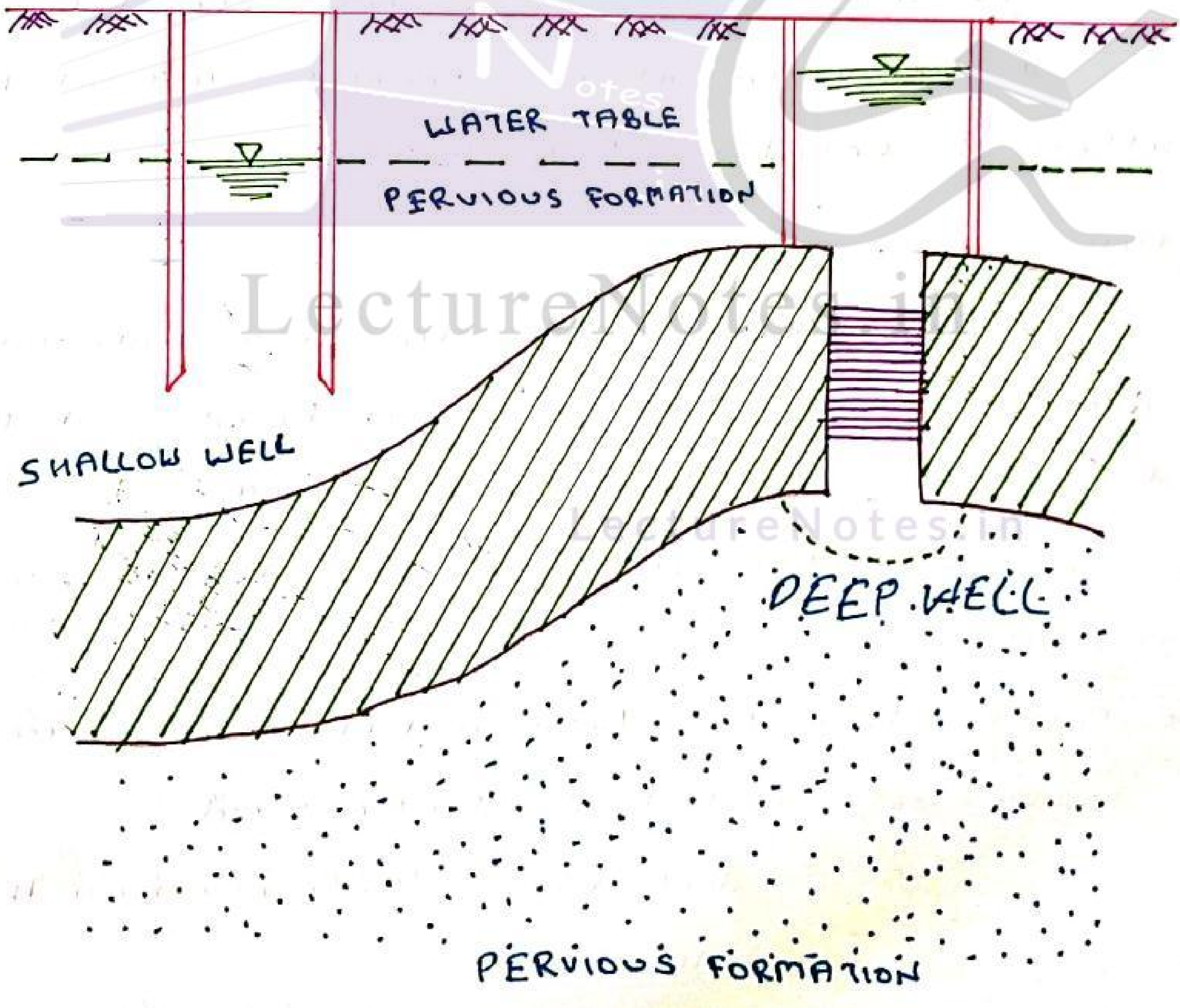
→ Feasible depth of open well is limited to 30m below the ground surface.

→ These wells are extensively used for drinking water supply in rural communities and in small farming operations.

→ They are also called as "Dug Well".

An open well is classified as:-

(i) Shallow Well (ii) Deep Well



Shallow Well

→ It is a well which derives water from the Pervious Stratum and does not rest on a mota layer.

→ A shallow well draws water from the first Pervious Stratum (Top Formation) and the water in it is liable to be contaminated by rain water Percolating in the vicinity and may take with it minerel orgenic watter such as decomposin Plant & animals.

Mota Layer:- (or) Matbarwa (or) Nagasan

→ It refers to a layer of clay, cemented sand, kankar or any other hard material.

→ It is an impervious Stratum. It may be continuous or localised sand & may be found in diff. thicknesses & depth at diff. Places.

→ When such a layer occurs below the water-table and when it is entrapped between Pervious layers at top & bottom is called a "mota layer."

Deep Well:-

→ It is a well which is supported on a mota layer and draws its water through a hole bored in it from the Pervious formation below the mota layer.

→ The water in a deep well is not liable to get impurities & infection.

→ The Pervious formation below a mota layer normally has greater water content & specific yield.

→ Discharge from a deep well is generally more than that of a shallow well.

Classification of Open well:-

Open wells are classified as:-

(i) Kachha (or) unlined well.

(ii) Well with Impervious lining.

(iii) Well with Pervious lining.

Kachha Well:-

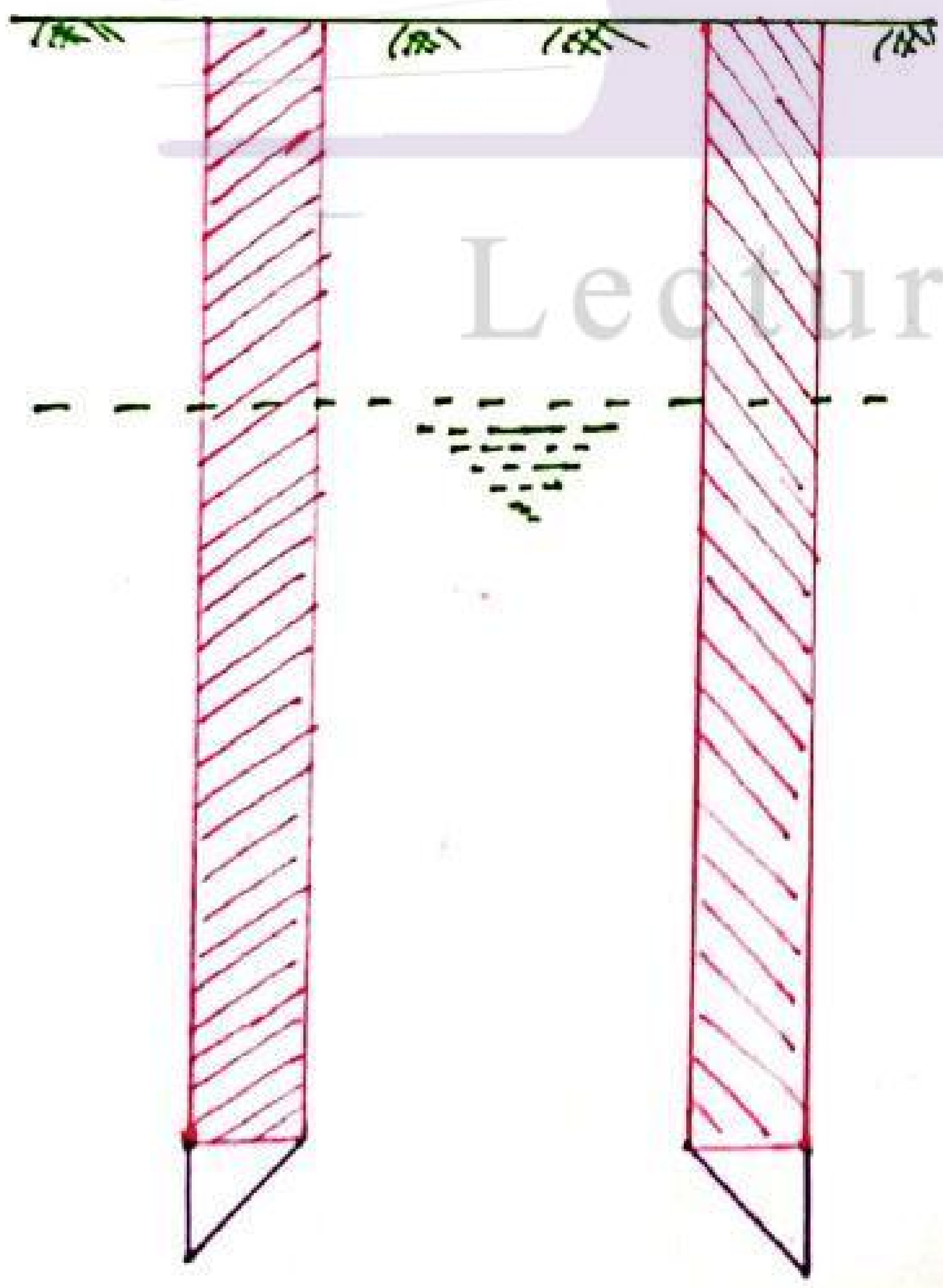
→ It is a temporary well of a very shallow depth.

→ It is suitable only in hard formations the walls of which can stand vertically.

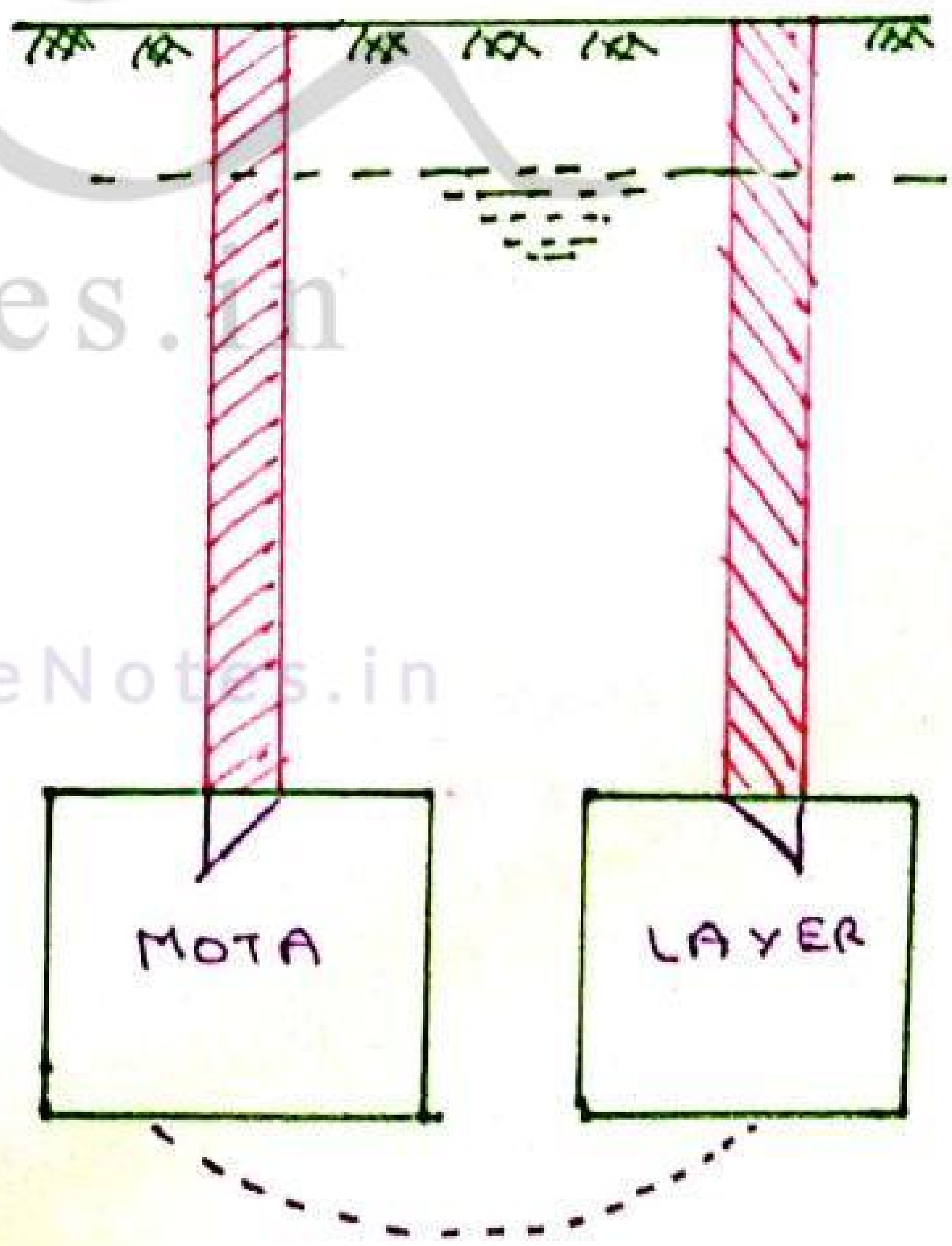
→ They are suitable only when the water table is very near the ground surface.

→ Such well often collapse after some time and are dangerous.

Well with Impervious (or) Pucca Lining:-



SHALLOW WELL WITH PUCCA LINING



DEEP WELL WITH PUCCA LINING

→ The thickness of impervious lining (Steining) varies from 30cm to 60cm and may be either in brick masonry or in stone masonry.

→ The linings carry well curbs under them.

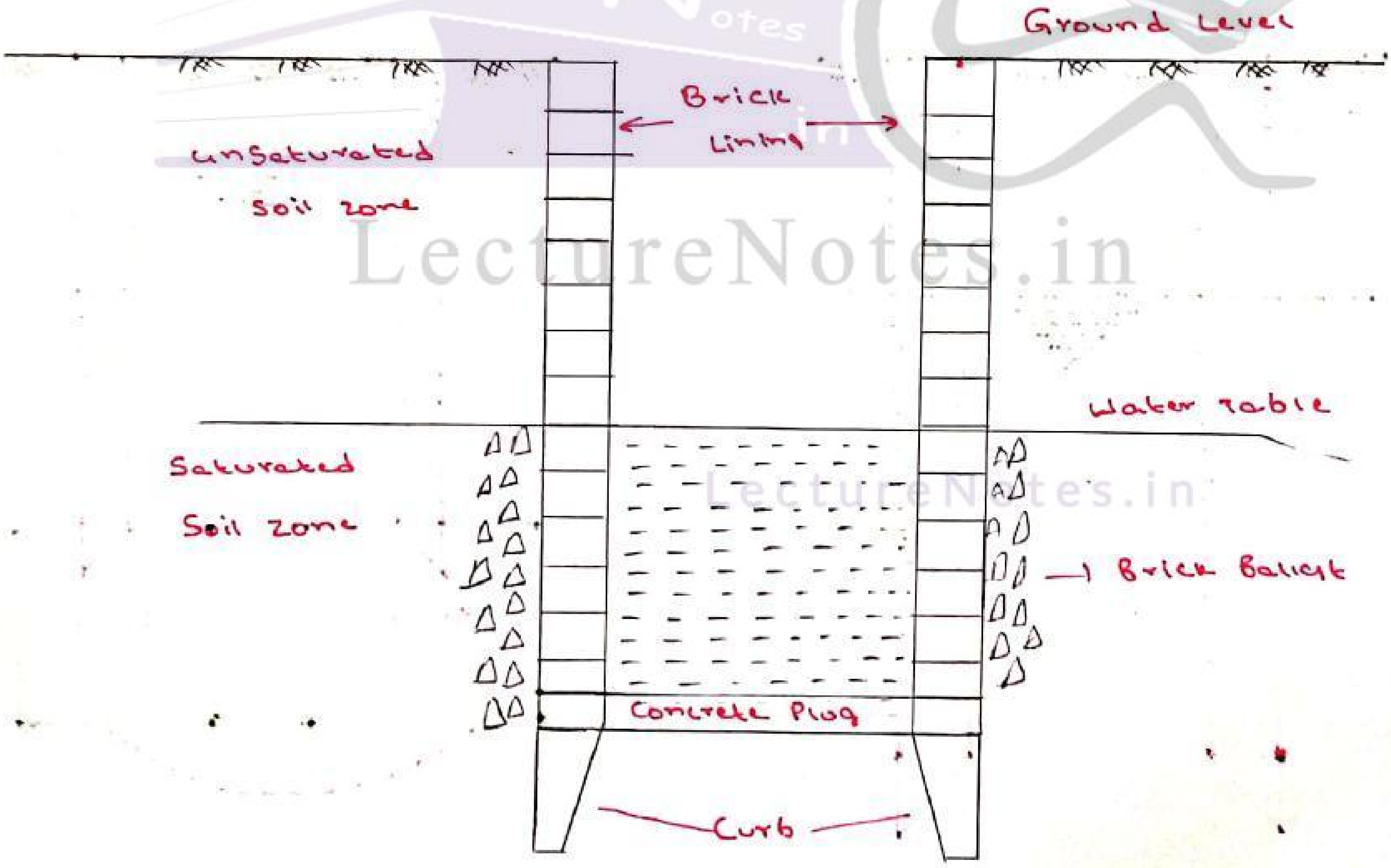
→ Well curbs may be constructed of either wood, iron or reinforced concrete.

→ Water only enters from bottom.

Well with Pervious Lining:

→ The lining consists of dry bricks (or) stones with no mortar (or) binding material.

→ Due to this, water enters from the sides and the flow is therefore radial.



Tube Well:-

→ A tube well is a long pipe sunk into the ground with a strainer which allows water to pass through it but prevents sand from coming in.

→ Because of strainer, high velocity of flow can be permitted without danger of soil particles being carried away with water.

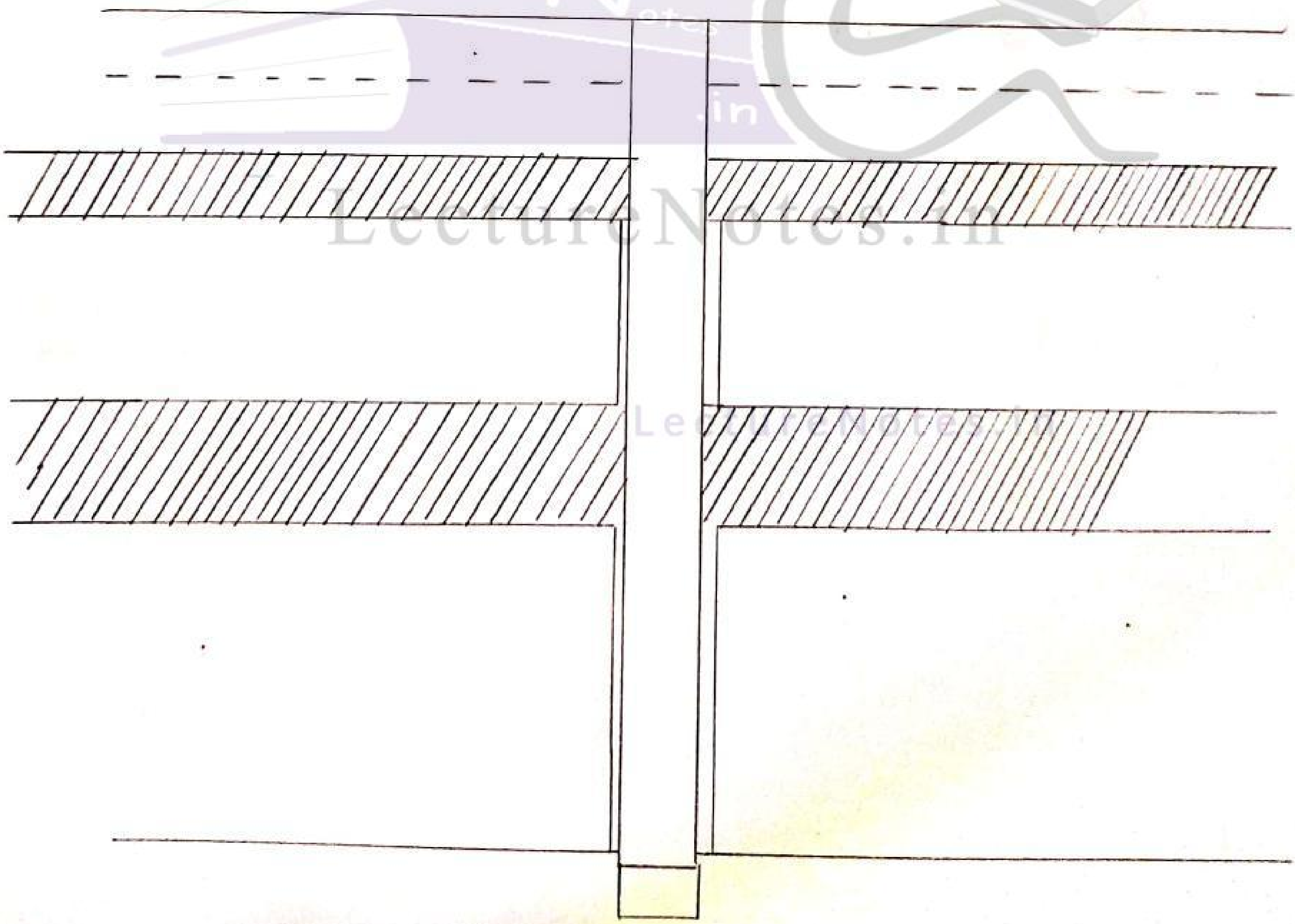
→ The diameter of the tube well is less than that of a open well but it gives discharge many times more than the open well.

Types of Tube Wells:-

The tube well may be of three types. They are:-

1. Strainer well.   2. Cavity well.   3. Slotted well.

1. Strainer Type Tube Well:-



→ It is the most common and widely used well.

→ In common term, the word "tube well" refers to the Strainer type of tube well.

→ In this type of well, a Strainer which is a Special type of wire mesh is wrapped round the main tube of the well.

→ A Strainer well may draw either from an unconfined aquifer of unlimited extent or from one (or) more confined aquifer layers.

→ Strainers are Provided only in that length of the Pipe where it crosses the aquifer.

→ In the rest of the Portion, Plain (or) blind Pipe is Provided.

→ The well is generally Plugged at the bottom.

Cavity Type Tube Well:-

→

→ It is a Special type of tube well in which water is not drawn through the Strainer, but it is drawn through the bottom of the well, where a cavity is formed (19)

→ In cavity tube well the flow is Spherical.

Slotted Type Tube Well:-

Well Development:-

It is the process of removing fine material from the aquifer formation surrounding the strainer pipe and it is aimed at

(i) Increasing the specific capacity of the well.

(ii) Preventing sand flowing in.

(iii) Obtaining maximum economic well life.

→ The actual yield of the well will be known only after well development.

Depending upon formation characteristics of the aquifer, a well may be developed by one of the following methods:

1. Development by pumping.
2. Development by surging.
3. Development by compressed air.
4. Development by back washing.
5. Development by dry ice.

1. Development by Pumping:-

→ In this method, a variable speed pump is used.

→ This method is based on the principle that irregular and non-continuous pumping agitates the fine material surrounding the well so that it can be carried into the well and pumped out.

→ Initially, the pump is started with a very low discharge. And the fine particles starts coming out.

→ Then after, the discharge is increased gradually until maximum discharge or well capacity is reached.

→ The Pump is then stopped and levels permitted to increase till it comes to normal.

→ The Pump is then again started and the procedure repeated till no fine particles come.

2. Development by Surging:-

→ In this method, surging effect is created by up and down movement of a surge block (or) bailer.

→ Calgon (Sodium hexametaphosphate) is added to water so that it acts as dispersing agent for fine grained particles.

→ When the surge block is moved up, it sucks the water.

→ When it is moved down, it forces water-calgon solution back in the formation.

→ Further upward motion brings with it the fine material.

→ The surge block is connected to a string of hollow pipe from which the water charged with fine particles is pumped out continuously.

→ The procedure is repeated by increasing the speed of surgin until the clear water comes.

3. Development by Dry Ice (Solid Sodium Dioxide):-

→ In this method, the well is developed by using two chemicals (Hydrochloric acid and solid sodium dioxide).

→ Firstly, hydrochloric acid is poured into the well and the well is capped at the top and compressed air is forced into the well.

→ The pressure of the compressed air forces the chemical into the water.

→ The cap at the top is removed and blocks of dry ice are dropped into the well.

→ The sublimation releases gaseous carbon dioxide and a high pressure of this gas is built up in this well.

→ On releasing the pressure, the muddy water is forced up in the form of a jet and it is thrown automatically out of the well.

4. Development by compressed Air

→ In this method, the development is done with the help of an air compressor, a discharge pipe and air pipe.

→ The air pipe is put into the discharge pipe and it is lowered down into the tube well, till the assembly reaches the bottom of the strainer pipe section.

→ The lower end of the air pipe is kept emerging out of the discharge pipe by a small length.

→ The air entry to the air pipe is first closed and the compressor is then started till a pressure of 6 - 10 kg/cm2 is built up.

→ The air is then suddenly made to enter the pipe, at this pressure with the help of suitable quick opening valve.

→ This sudden entry of air into well creates a powerful surge with in the well causing the loosening of the fine material surrounding the perforations.

→ When pressure decreases, water enters the well bringing the loosened material with it. And it is pumped out. 21

→ This process is repeated until clear water comes and the well is fully developed.