1 WRE

(Pg No 791 sk garg)

UNIT-V

Ground water :-

Occurrence ~~of~~ (Produce) of Ground water :-

The rain fall that percolates below the ground water surface, passes through the voids of the rocks, and joins the water table. These voids are generally inter-connected, permitting the moment of the ground water. But some rocks they may be isolated (alone) and this preventing the moment of water b/w the intersities.

The mode of occurrence of ground water ~~there ford~~ depends upon the type of formation and hence depends upon the geology of the area.

Types of aquifers :-

Aquifer :-

* It is defined as the geological formation of permiable (permitted) materials.
* Aquifer allows storage as well as transmission of water.
* Aquifer are highly permeable (gaps b/w the particle to particle and pores) in nature

Ex:- The common example of a aquifer are un consolidated sand and gravel.

Aquifuge:-

* It is defined as the geological formation of impermeable (not permitted) materials

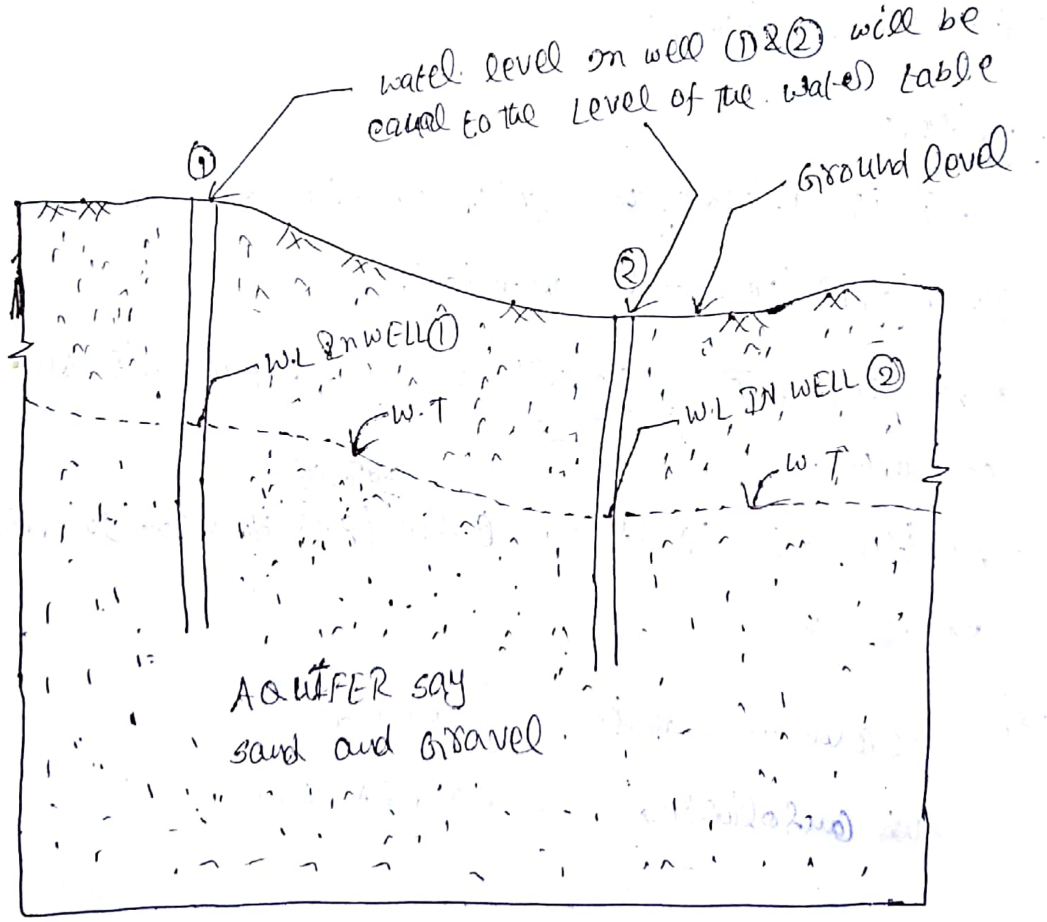
* A aquifuge does not allow storage and transmission of water

* A aquifuge is neither permeable nor porus in nature

Ex:- The common example of Aquifuge are rocks without fissures like basalt and granite etc

The aquifers are two categories
1) unconfined (or) Non - artesian aquifers
2) Confined (or) Artesian aquifers

(1) unconfined (or) Non-artesian aquifers:-



2 ~~When aquifer unconfined on it's upper surface~~

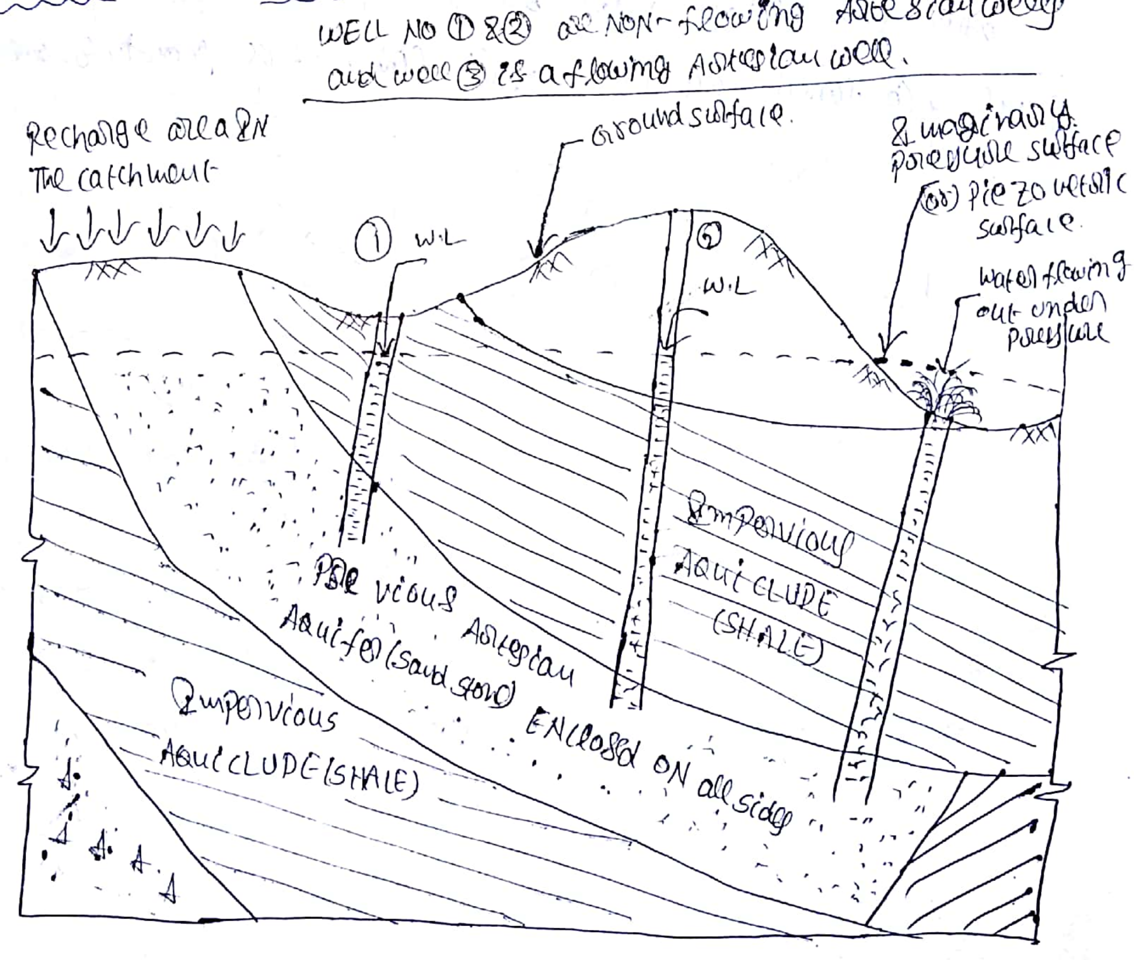
An aquifer which contains water table is known as unconfined aquifer. In unconfined aquifer the water table serves as the upper surface of saturation zone.

Ex: The ordinary gravity wells of 2 to 5 m diameter, which are constructed to tap water from the top most water bearing strata (top of the layer) (i.e) unconfined aquifer (or) non artesian aquifer. (or) non artesian wells

* The water level in these wells will be equal to the level of the water table. These wells also known as gravity wells

* The thickness of water table varies with slope, depending on areas of recharge and discharge.

(2) Confined Aquifers (or) Artesian Aquifers:-



When an aquifer is kept in b/w two permeable layers such an aquifer is called confined aquifer.

Confined aquifer is also called pressure aquifer (or) artesian aquifer.

Confined aquifer have water under pressure and pressure condition is ~~specified~~ recognized (గుర్తించు) with piezometric surface.

* The piezometric surface is obtained by combining water level at equilibrium.

* In confined aquifer the water table will be uniform. can be assumed as the approximate piezometric surface.

When well penetrating (push) onto confined aquifer. The water level increase upto piezometric surface

When the piezometric surface is above the ground level, confined aquifer result form free flowing well.

3 Aquifer Parameters :-

Porosity:-

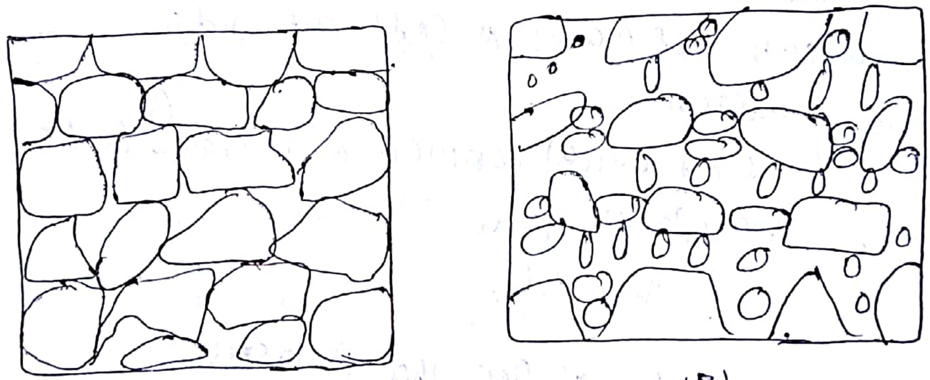
The porosity of a rock, which is the geological formation use (occurrence) of ground water, the measurement of voids present in the rock.

It is generally defined as the percentage of the voids present in a given volume of aggregate. Mathematically it can be expressed as

$$\text{Porosity} = \frac{\text{Total volume of voids in the aggregate (i.e) the volume of water required to saturate the dry sample } (V_v)}{\text{Total volume of the aggregate } (V)}$$

It is generally denoted by the letter n

$$n = \frac{V_v}{V} \times 100 \text{ (Percent)}$$



(A) (B)

* In Diagram (A) is more water is stored (A) and less water is stored (B).
* Porosity of A is greater than that B because the grains of A are all equal in size. In B small grains are filled the space b/w the large grains thus reducing the volume of void space.

Specific yield:-

It is defined as the ratio of volume of water is drained to the total volume of the formation.

$$S_y = \frac{W_y}{V}$$

W_y → volume of water drained

V → total volume of the formation.

S_y → specific yield.

The specific yield depends on

1) Grain size
2) Shape
3) Compaction of formation.

* Specific yield of fine grained aquifer is low, coarse grained aquifer is high.

After the material is drained in the pore spaces, some quantity of water is left out under capillary tension.

So the volume of water drained is not equal to the volume of pore spaces then

$$W_y < V_v$$

Hence specific yield is less than porosity.

Permeability:-

Permeability can be defined as the capacity to transmit water through itself.

* It is transmitted by aquifer (ground water table) at velocities ranging from 1m/year to 500m/year.

Darcy's law is applicable to the laminar flow of ground water in aquifers.

Notes:- laminar flow means on water above the earth surface some amount of bacteria fungous is there but the water will be flowing witted to aquifer the earth particles will remove all the bacteria.

* The capacity of the entire soil full width (b) and depth (d) (i.e area bd) is represented by permeability while that the soil of unit width and full depth (i.e b=1 and d=d, i.e A=d) is known as transmissibility.

The various methods including Constant head permeameter and variable head ~~permeame~~ permeameter, are used to measure permeability.

Transmissivity:-

~~It is~~ It can be defined as product of ~~hydraulic gradi~~ hydraulic conductivity (The ability of soil fluid to flow through the soil) and aquifer thickness. Its units are m^2/day. It is also called "Transmissibility."

$$Q = \text{Area} \times \text{velocity}$$

$$= (b \times 1) \times k\left(\frac{-dh}{dL}\right)$$ [∵ change of pressure head per unit distance]

$$= kb\left(\frac{dh}{dL}\right)$$

$$= T\left(\frac{dh}{dL}\right)$$

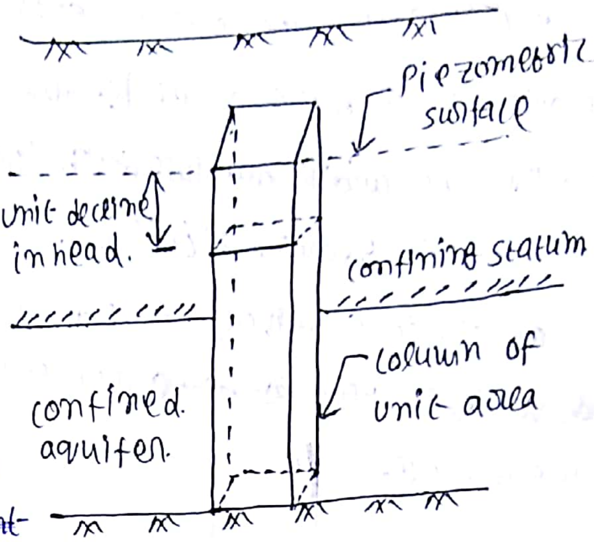
$T = kb$ is transmissivity

when hydraulic gradient = 1 discharge = T, the value of (T) ranges from 12 m^2/day to 1200 m^2/day. It can be determined by pumping tests.

Storage co-efficient :- (avg, 24th Purnia)

Storage coefficient is defined as the volume of water that an aquifer releases from (or) take into storage per unit surface area.

(or)



The water yielding (using) capacity of a confined ~~aquifer~~ aquifer can be expressed in terms of it's storage coefficient.

Let us consider a vertical column of unit area (1m x 1m) extending through ~~coefficient~~ a confinde aquifer (see the fig)

Then the storage coefficient "S" is the value of water in cubic metres released from aquifer when the piezometric surface declines by 1m In most confined aquifers the value of storage coefficient range b/w 0.00005 to 0.005 In unconfined aquifer the water table is lower by 1m.

Types of wells:-

wells:- A well is hole normally vertical, excavated in the earth for bringing ground water to the surface.

The wells may be classified into two types

(1) open wells ; and (2) Tube wells

(1) open wells:- (or) Dug wells

* small amount of ~~water~~ ground water has been utilised from the ancient times by open wells.
* open wells are generally open masonry wells having comparatively bigger diameter

5 * The low discharge of water 1-5 litres per second.

* The diameter of open wells generally vary from 2 to 9 m.

* The depth is generally less than 20 m.

* These wells are built in pre cast concrete rings (or) in brick or stone masonry.

* Their thickness generally varies from 0.45 to 0.75 m, according to the depth of the well.

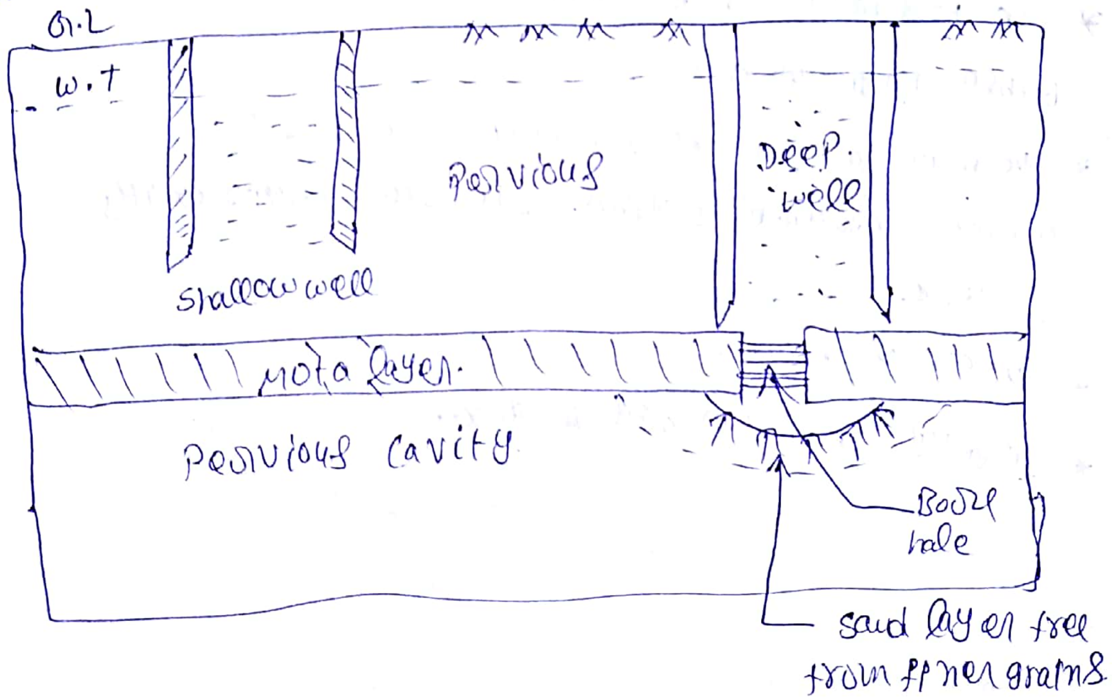
The open wells may be classified into the following types

Open wells

(a) Shallow open wells. (b) Deep open wells.

(a) Shallow open wells:-

*



(i) Shallow wells

* Shallow wells are rests impervious layer.
* In shallow wells are to supply water from the surrounding materials.
* The water level is equal to the level of the ground water table.
* Water is not a good quality

(ii) Deep wells:-

* Deep wells are rests in impervious mota layer.
* ~~The~~ A bore hole is made into the mota layer as shown in fig
* These layer are commonly in hard materials like clay, cemented sand, kankar or other material
* The bore hole is made few meters below the water table in the sub soil.
* The main advantage of such a mota layer lies in giving structural support. open well resting on it's surface.
* yield is more.
* Quality of water will be good.

6 (b) Tube wells :- (Bore wells, Drilled wells) :-

The tube wells can be broadly classified into the following types

(1) Cavity type tube wells

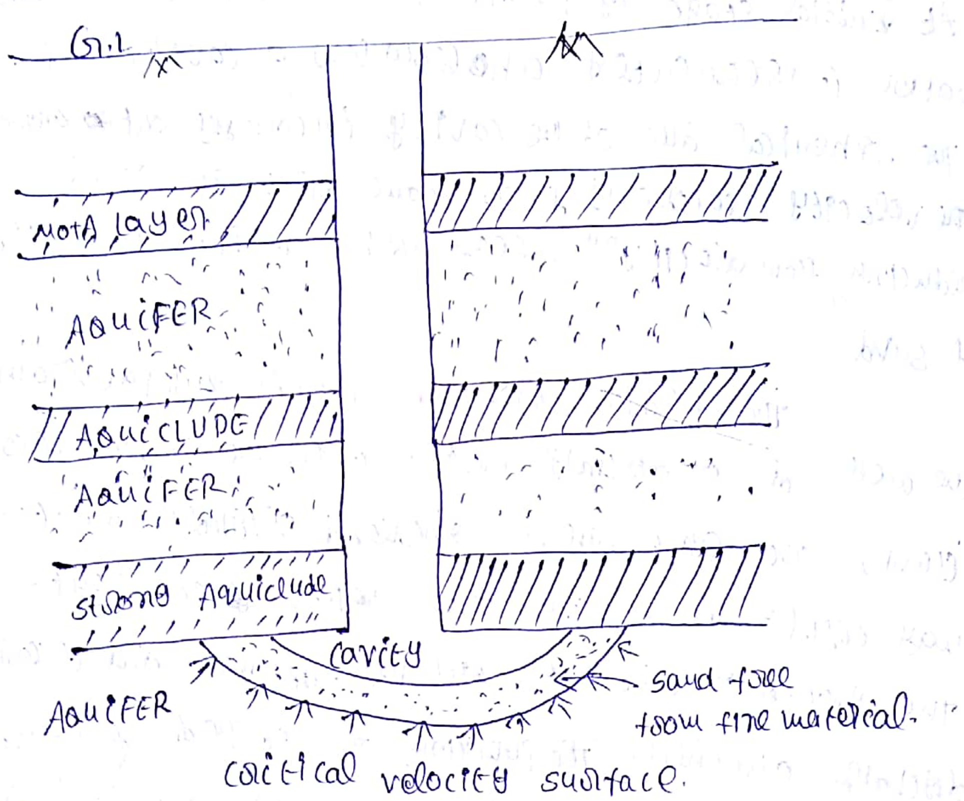
(2) Screen type tube wells

(i) Strainer type tube wells

(ii) Slotted pipe gravel-pack tube wells

(1) Cavity type tube well :-

* A cavity type tube well draws water from the bottom of the well, and not from the sides.



* The flow in a cavity well, therefore, is essentially spherical (flow one direction -> but spiral) and not radial

radial

* These tube wells are very economical.

* The principle behind the working of a cavity-type tube well is essentially similar to that of a deep open well. Only the difference is the deep well is taps (opening) the first aquifer, just below the mota layer a cavity tube well need not do

* A cavity type tube well essentially consists of of a pipe bored (bore) through the soil. and resting on the bottom of a strong clay layer.

~~* A cavity is formed at the bottom. as shown in fig~~

* A cavity is formed. at the bottom. water from the aquifer. enters the well pipe through this cavity as shown in fig.

* At initial stage of pumping fine sand comes out with water. Consequently a hollow (or) a cavity is formed the spherical area of the cavity increases outwards the velocity decreases for the same discharge. Thus reducing flow velocity and consequently. stopping the entry of sand

The begin: with the water is pumped from the well at. low discharge rate. when the water becomes clear, the space will be increased slightly in bottom. may result in further sand being comes out. The process is repeated. till the normal and clear. discharge obtained. The pumping then stoped for an hour or so, and resumed again. The discharge. of water is restarting again. sand will be comes out again. The pumping is continued till the water is clear again. The procedure may be restarted till the the tube well is fully developed.

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7 (2) Screen type tube wells:-

The screen type tube wells are constructed in our country particularly for irrigation purposes.

* The tube well construction is started in 1931.

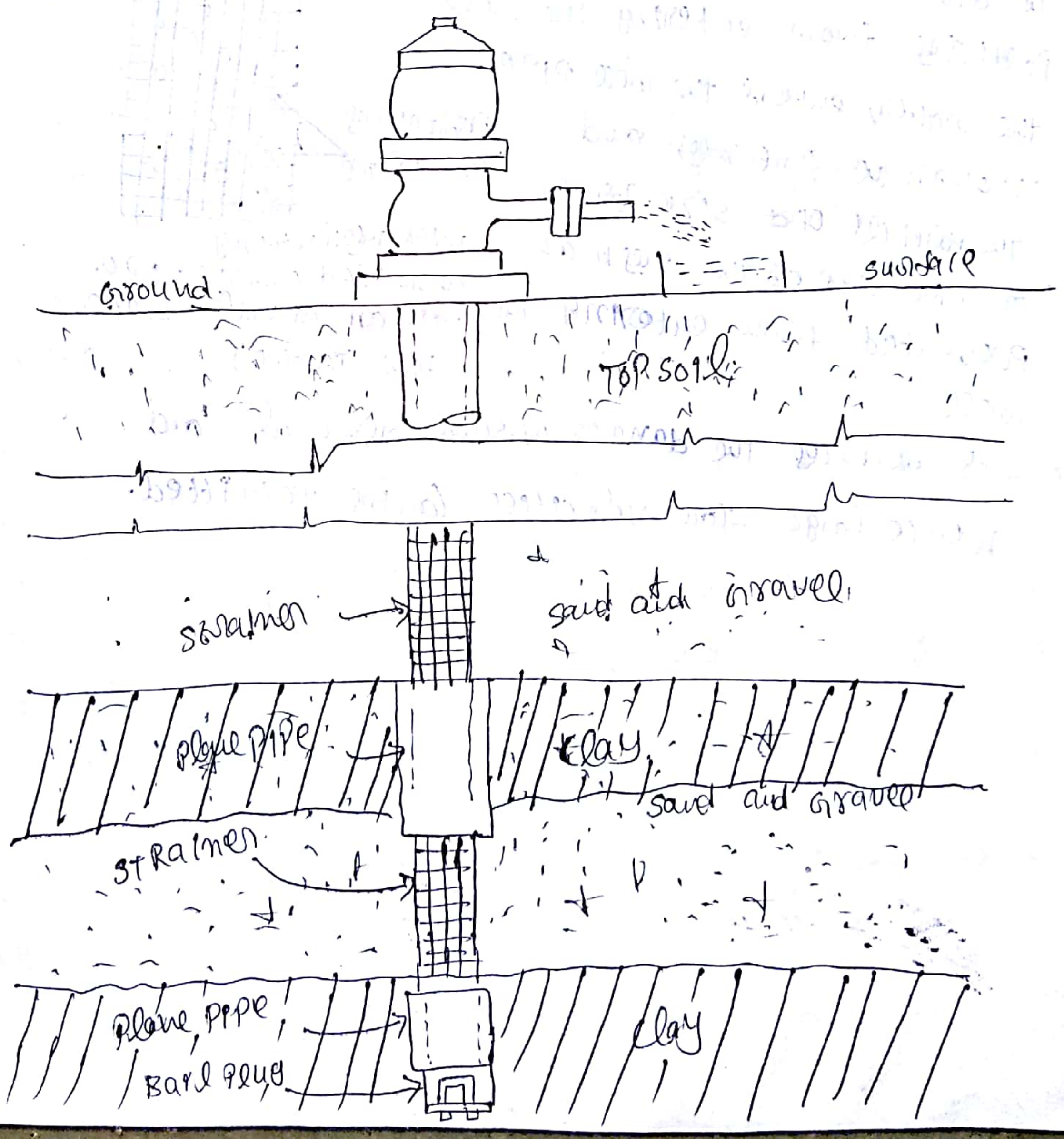
* These wells can easily tap a number of aquifers, and hence does not depend only on one aquifer, like a cavity well.

The screen type tube wells can be further divided into the following two types

(i) Strainer tube wells

(ii) Slotted pipe gravel-pack tube wells

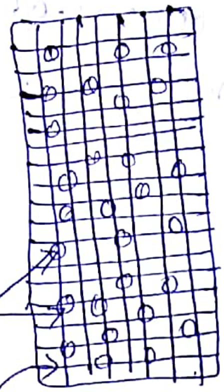
(i) Strainer tube wells



* A strainer type tube wells uses strainer lengths lowered into the bore hole and located the opposite the water bearing formations, where as, plain pipe lengths are located opposite the non water bearing formations as shown in fig

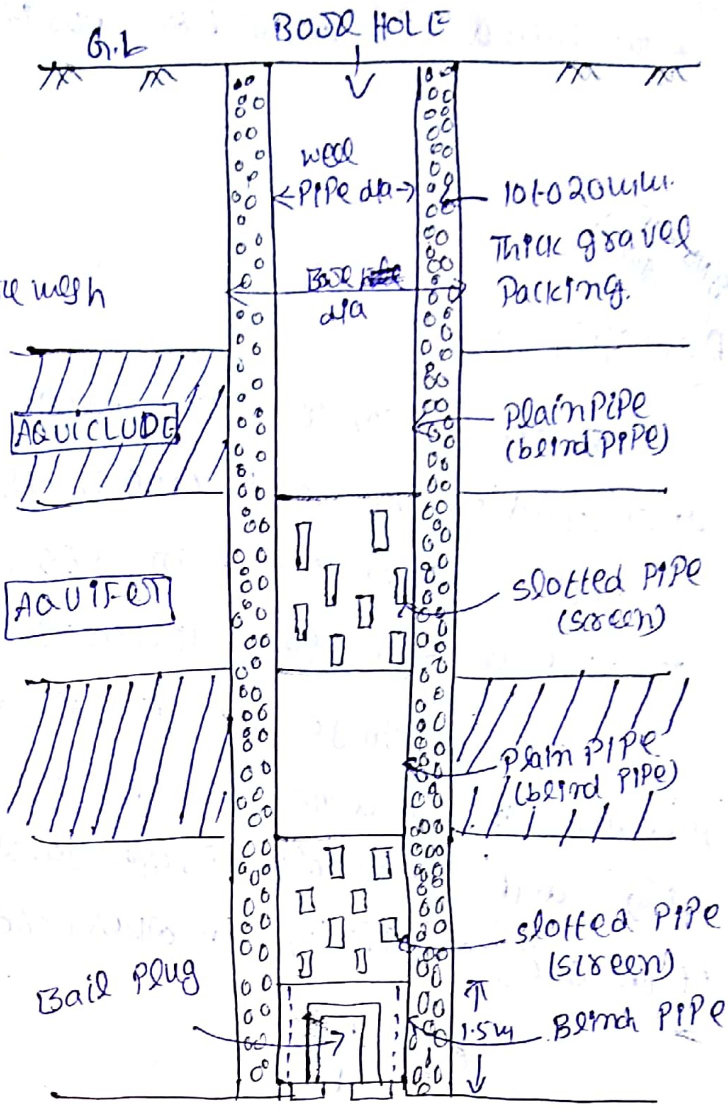
* A bail plug is provided at the bottom.
* water enters into the well through these strainers from the sides, and the flow is radial.

* A strainer essentially consists of a perforated or a slotted pipe wire mesh wrapped round the pipe
* with small annular space b/w the two.
* The wire screen prevents the sand particles from entering the well pipe.
* the water, enters the well pipe through the fine mesh and the particle of size larger than the size of the mesh are prevented from entering the well.



* this reduces the danger of sand removal and hence large flow velocities can be permitted.

(II) A slotted pipe gravel pack tube well:-



* In this method uses a slotted pipe ~~with out being~~
* with out using any wire mesh
* such slotted pipe lengths are located opposite to the water bearing formations
* After placing the assembly of the plain and slotted pipes in the bore hole, a mixture of gravel and bajri (called gravel shrouding) is poured in to the bore hole in surround the well pipes
* so as to surround the well pipes by designed optimum thickness of gravel pack
* The gravel pack is specifically required around the screen pipes
* The material is poured from the ground level to top level,
* Gravel pack wells are generally provided in fine aquifers, the grain size (D_{10}) may be less than 0.25 mm. and uniform coefficient (cu) may be 2.0 or less.
* Gravel pack is therefore highly preferred for deep tube wells which are tap (lower water) more than one aquifer.

* ~~The water enters onto the plator pipe~~

* The slotted pipe are used to purification of water

(pg no 795 g&9)

Darcy's law :-

The percolation of water through the soil was first studied by Darcy (1856) is a French scientist enunciated in 1865, a law governing the rate of flow (i.e the discharge) through the soils

This discharge was directly proportional to the head loss (H_L), and the area of cross-section (A) of the soil, and inversely proportional to the length of the soil sample (L) in other words.

$$Q \propto \frac{H_L}{L} A$$

But $\frac{H_L}{L}$ represents the rate of loss of head (i.e) the hydraulic gradient (I)

$$Q \propto I A$$

$$Q = K I A$$

where K is the proportionality constant and was found to be changing with the type of soil, property of the soil.

The Darcy's law ~~was~~ has been demonstrated to be valid only for laminar flow (fluid move parallel layers) (not changing) condition

Ex:- flow in sands, silts and clay is invariably laminar

Dividing both sides of equation by 'A', we get

$Q/A = K.I$ $[\because Q = AV$, $V = Q/A]$ Discharge = Area x velocity

(or) $V = KI$

where 'V' is the discharge velocity and is not the actual flow velocity through the soil medium since the flow occurs through the voids of cross-sectional area A_V and not 'A' itself.

If A_V is the area of voids, ~~Then A_V~~ V_a is the velocity of the flow of water through the soil

$A_V \cdot V_a = A \cdot V$

$V = V_a \frac{A_V}{A}$

when 'A' is large in ~~composition~~ Comparison, we can safely assume that the ratio of the area of the voids (A_V) to the total area (A) is the same as the ratio of the volume of the voids (V_V) to the total volume (V) (i.e) equal to porosity (n)

Hence $\frac{A_V}{A} = n$ (Porosity)

substituting this value in above eq'n we get

$$V = n \cdot V_a$$

knowing the value of 'V' from the eq'n $V = KI$ and dividing porosity n the actual velocity of flow (V_a) of water through the soil. Can be worked out.

Dupuit's equation

In Dupuit's formula can be useful for finding the discharge

* In Dupuit's formula there is no any observation wells are not constructed.
* In the main well pumped out the water at sufficient depth
* After that the rate of pumping is so adjusted to equilibrium conditions.

(i,e) The rate of inflow becomes equal to the rate of out-flow, and the water level in the ~~level~~ well becomes constant.

Assumptions:-

1) The flow is laminar and darcy's law is valid
2) soil mass is isotropic and homogeneous
3) The well penetrates the entire thickness of aquifer.
4) coefficient of permeability remains constant through out.
5) The flow towards the well is radial and horizontal.

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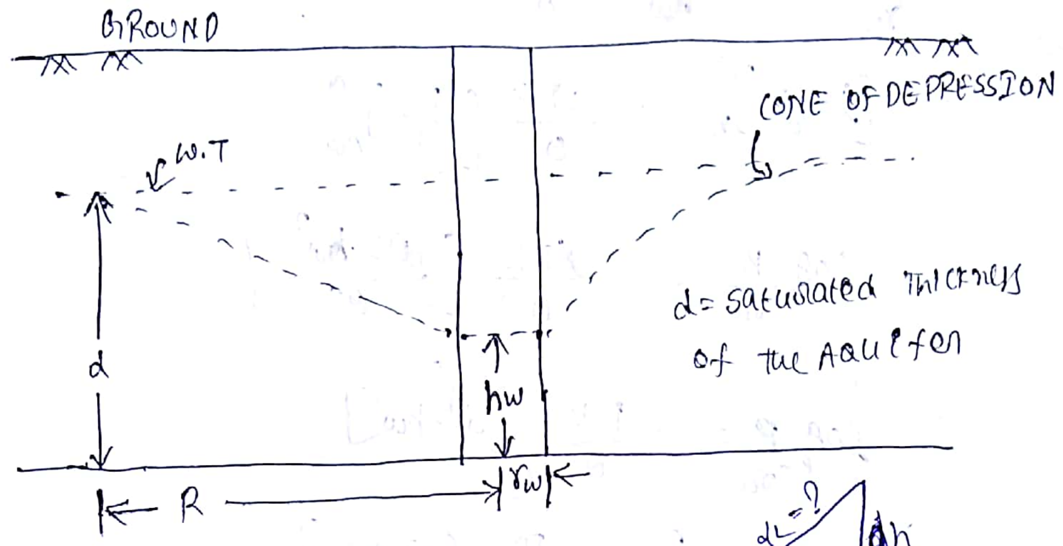
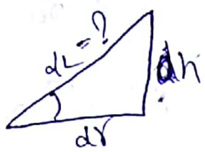
Dupuit's formula for an Confined Acquifer (Gravity well)

(Pg No 890 Garg)





~~Dupuit's formula Q = KIA~~

~~let us consider the flow through a cylindrical surface of hight 'h' at a radius (r) from the centre of well from~~ Darcy's law

$$Q = KIA \rightarrow ①$$

The slope of I is small, and can be taken as the tangent of the angle in place of the surface angle

$$I = \frac{dh}{dr}$$

Substitute the I value in ① eqn

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

let us consider a flow through a cylindrical surface of hight 'h' at a radius (r) from the center of the well. [∵ Area $A = 2\pi r h$]

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

$$\frac{dr}{r} = \frac{2\pi K}{Q} h \cdot dh.$$

Integrating the above eqn with limits rw and R we get

$$\int_{rw}^{R} \frac{dr}{r} = \int_{hw}^{d} \frac{2\pi K}{Q} (h \cdot dh)$$

$$\left[\log_e r\right]_{rw}^{R} = \frac{2\pi K}{Q} \left[\frac{h^2}{2}\right]_{hw}^{d}$$

$$\log_e \frac{R}{rw} = \frac{2\pi K}{Q} \left[\frac{d^2 - hw^2}{2}\right]$$

$$\log_e \frac{R}{rw} = \frac{\pi K}{Q} \left[d^2 - hw^2\right]$$

$$2.3 \log_{10} \frac{R}{rw} = \frac{\pi K}{Q} \left[d^2 - hw^2\right]$$

$$K = \frac{2.3\, Q \log_{10} \frac{R}{rw}}{\pi (d^2 - hw^2)}$$

$$\boxed{Q = \frac{\pi K (d^2 - hw^2)}{2.3 \log_{10} \frac{R}{rw}}}$$

In thiem's formula only the difference is that the integration which was done b/w the limits r1 and r2 in Dupuit's formula the limits are rw and R

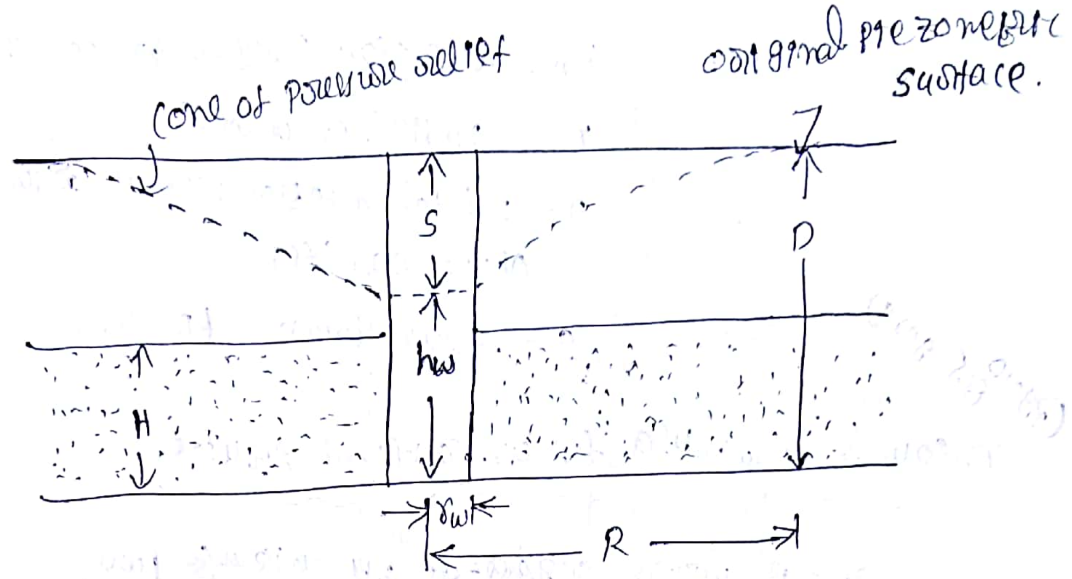
rw = radius of the main pumped well

R = radius of influence.

Dupuit's formula for confined aquifer:-

(pg no 814 5k garg)

Procedure and assumptions same unconfined aquifer.



$$Q = KIA$$

$$Q = K \frac{dh}{dr} 2\pi r H$$

$$\frac{dr}{r} = \frac{2\pi K H}{Q} dh$$

Integrating b/w rw and R we get

$$\int_{r_w}^{R} \frac{dr}{r} = \frac{2\pi K}{Q} \cdot H \int_{h_w}^{D} dh$$

where D = depth of the well (or) height of the aquifer below the original piezometric surface.

$$\left[\log_e r\right]_{r_w}^{R} = \frac{2\pi K}{Q} H \left[h\right]_{h_w}^{D}$$

$$2.3 \log_{10} \frac{R}{r_w} = \frac{2\pi K H}{Q} \left[(D - h_w)\right]$$

$$K = \frac{2.3 \log_{10} \frac{R}{r_w}}{2\pi H (D - h_w)}$$

$$Q = \frac{2\pi K H (D - h_w)}{2.3 \log_{10} R/r_w}$$

(or) $Q = \frac{2\pi K H s}{2.3 \log_{10}\left(\frac{R}{r_w}\right)}$

where H = total height of the confined aquifer :

h_w = artesian pressure in the well.

r_w = radius of the well

D = Initial artesian pressure at the bottom of the aquifer

s = draw-down = $(D - h_w)$.

(Pg no 805 garg)

Thiem's formula for un confined Aquifer :-

In this method suggested by Thiem's two observation wells lying in the circle of influence of the main pumped well are to be drived.

Let these wells be numbered as 1 and 2 the distances of r_1 and r_2 from the main well. (center to center distance) Let a is the depth of the well or the aquifer, below the static water table

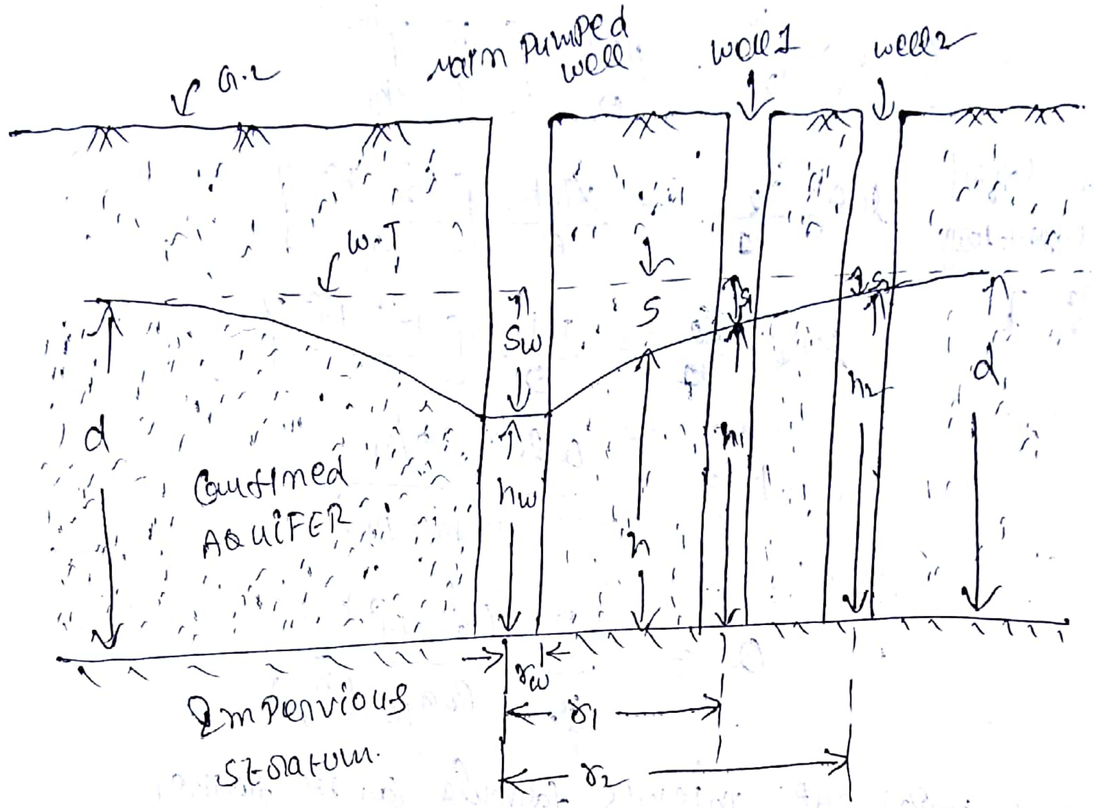
Now let the main well is pumped at a sufficient rate. So as to cause heavy draw down. then the pumping is to adjust the equilibrium conditions (i.e the rate of inflow becomes equal to the rate of out flow the water level becomes constant

Let S_1 and S_2 be the draw down. into the two corresponding observations wells. at this equilibrium stage

the Darcy's law.

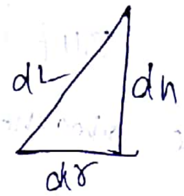
$Q = KIA$

using the cylindrical components, we take 'r' as the radius of any cylinder and 'h' as the height of the cone of depression at a distance 'r' from the main well.



Assuming that the inclination of the water surface is small so that the tangent can be used in place of sine for the hydraulic gradient i in Darcy's law

$$I = \frac{dh}{dr}$$



Assuming that the water flows through the full height of aquifer and also flow is radial & horizontal the area of flow (A) is equal to "$2\pi rh$"

Substituting these values of I & A in Darcy's law we get

$$Q = KIA$$

$$= K\frac{dh}{dr} 2\pi rh$$

$$\frac{dr}{r} = \frac{2\pi Kh\,dh}{Q}$$

Integrating b/w the limits r_1 and r_2 and h_1 & h_2.

$$\int_{r_1}^{r_2} \frac{dr}{r} = \int_{h_1}^{h_2} \frac{2\pi k}{Q} h\,dh$$

$$\left[\log_e r\right]_{r_1}^{r_2} = \frac{2\pi k}{Q}\left[\frac{h^2}{2}\right]_{h_1}^{h_2}$$

$[\because \log_e r_2 - \log_e r_1]$
$[\because \log(a) - \log(b) = \log\frac{a}{b}$
$\log\frac{r_2}{r_1}]$

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

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

$$k = \frac{Q \log_e r_2/r_1}{\pi (h_2^2 - h_1^2)}$$

$$Q = \frac{\pi k.(h_2^2 - h_1^2)}{2.3 \log_{10}\left(\frac{r_2}{r_1}\right)}$$

This important thiem's formula can be further simplified, if required as follows.

$$h_2^2 - h_1^2 = (h_2 - h_1)(h_2 + h_1) \quad [\because a^2 - b^2 = (a+b)(a-b)]$$

But $(h_2 - h_1) = S_1 - S_2$

If the amount of draw down (depth) is small compared to the saturated thickness of the water bearing material, then h_2 & h_1 are nearly equal and each is approximately equal to this saturated thickness say "d".

$$\therefore h_1 + h_2 \approx d + d = 2d.$$

$$(h_2^2 - h_1^2) \approx (S_1 - S_2)(h_2 + h_1)$$

$$= (S_1 - S_2)\, 2d$$

These $(h_2^2 - h_1^2)$ value substitute in 'Q'

$$Q = \frac{\pi K (h_2^2 - h_1^2)}{2.3 \log_{10}\left(\frac{r_2}{r_1}\right)}$$

$$= \frac{\pi K\, 2d\, (s_1 - s_2)}{2.3 \log_{10}\left(\frac{r_2}{r_1}\right)}$$

[∵ T = Kd
T = transmissibility]

$$= \frac{2\pi T (s_1 - s_2)}{2.3 \log_{10}\left(\frac{r_2}{r_1}\right)}$$

=

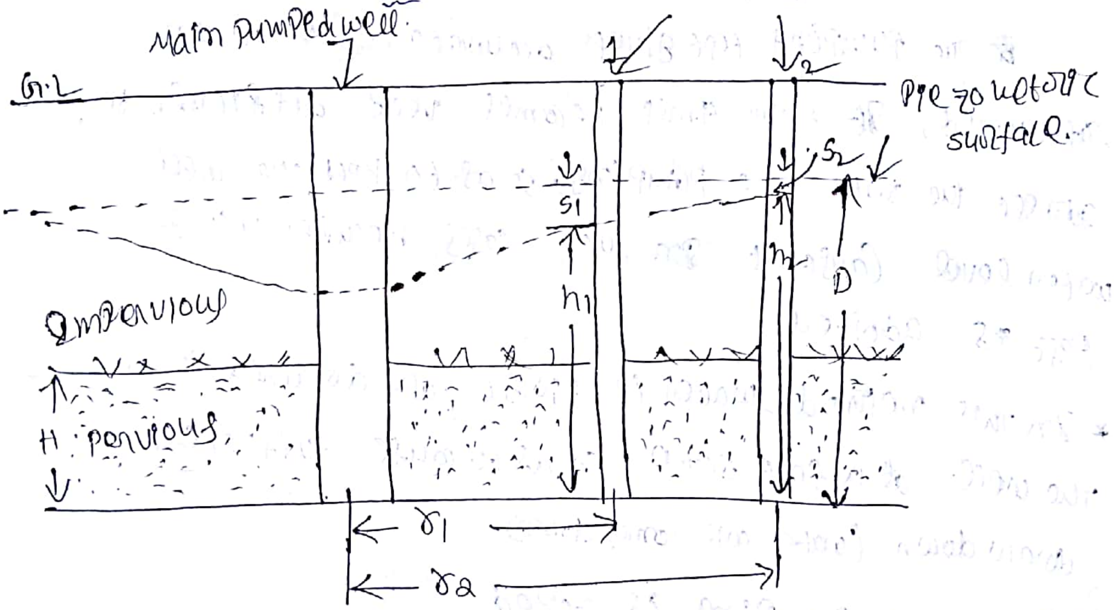
(Pg No 808 garg)

Thiem's formula for Confined aquifer:-

The above formula has to be slightly modified in this case. In Confined aquifer the flow is radial and horizontal procedure is same for unconfined aquifer.

$$Q = KIA$$

$$Q = K\frac{dh}{dr} 2\pi r H$$



$$\frac{dr}{r} = \frac{2\pi K H}{Q} dh$$

Integrating both sides

$$\int_{r_1}^{r_2} \frac{dr}{r} = \frac{2\pi KH}{Q} \int_{h_1}^{h_2} dh.$$

$$\log_e \frac{r_2}{r_1} = \frac{2\pi KH}{Q} [h_2 - h_1]$$

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

But $h_2 - h_1 = s_1 - s_2$.

therefore $$Q = \frac{2\pi KH (s_1 - s_2)}{2.3 \log_{10} (r_2/r_1)}$$

$$= \frac{2\pi T (s_1 - s_2)}{2.3 \log_{10} (r_2/r_1)}$$ [∵ T = KH]

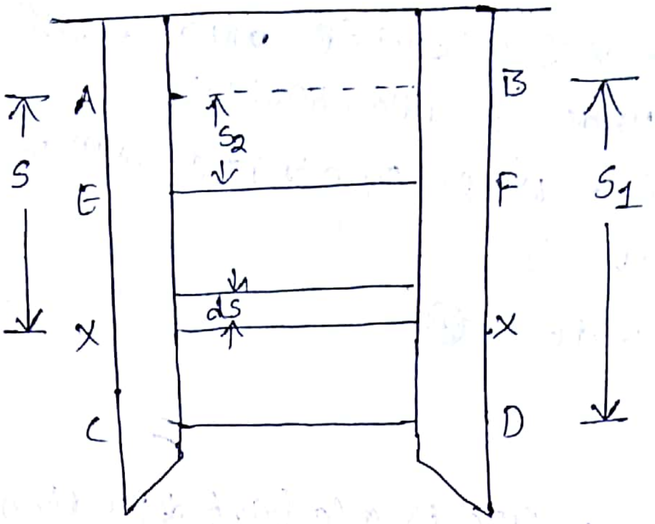
T = Transmissibility

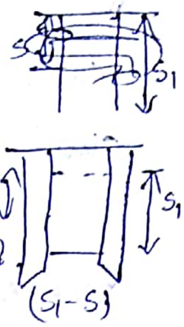
(Pradhan Gary)

Yield of a open well - recuperation test:-

The pumping test gives accurate value of the safe yield, It some times becomes very difficult to adjust the rate of pumping, so as to keep the well water level constant. In such cases recuperating test is adopted.

* In this method water is first all drained from the well at a fast rate so as to cause sufficient draw down (water will comes down)
* After that pumping is stoped.
* After that the water level in the well will start rising.
* After that some time is taken the water to come back to it's normal level (or) some other measured level is then noted.





let

AB = water level in the well before pumping was started

CD = water level in the well after pumping was stoped.

S_1 = Depression head in the well at the time the pumping was stoped. at the noted time (After a time "T")

EF = water level in the well ~~at noted at time T~~ when pumping was stoped. [∴ sodp

S_2 = ~~Remaining~~ Depression head in the well at time 'T' after the pumping was stopped.

let X-X be the position of the water level at a time t after pumping was stopped

let corresponding the remaining depression head 'S'

let 'ds' be the decrease in the depression head in a time 'dt' after the time 't'

Hence in a time 't' after the pumping is stopped, the water level recuperates by $(S_1 - S)$

It again recuperates by ds in a time dt after this

∴ volume of water entering the well in the small interval of time (dt)

$dv = A\,ds \rightarrow (1)$

where A is the cross-sectional area of the well at the bottom.

[∵ the volume of water enter into the well the depression head will be reduce so take −ve]

Also if Q is the rate of recharge into the well at the time 't' under depression head 's'. then the volume of water entering the well in this small time interval is

$$dV = Q \cdot dt \rightarrow (2)$$

But $Q \propto s$

$Q = c's$ where c' is a constant depending on the soil through which water enters the well

~~∴ dV = c'~~

substitute the 'Q' value in eq(2). we get

$$dV = c's\,dt \rightarrow (3)$$

eqn (1) & (3) we get

$$-A\,ds = c's\,dt$$

(the -ve sign indicates that "s" decreases as 't' increases)

$$\frac{c'\,dt}{A} = -\left(\frac{ds}{s}\right)$$

Integrating b/w the limits

$t = 0 \quad s = s_1 \quad t = T \quad s = s_2$.

we get $\frac{c'}{A}\int_0^T dt = -\int_{s_1}^{s_2}\frac{ds}{s}$

$$\frac{c'}{A}[t]_0^T = -[\log_e s]_{s_1}^{s_2}$$

$$\frac{c'}{A}[T] = -\log_e\frac{s_2}{s_1}$$

$$= -2.3\log_{10}\frac{s_2}{s_1}$$

$$= 2.3\log_{10}\frac{s_1}{s_2}$$

$$\frac{c'}{A} = \frac{2.3}{T}\log_{10} s_1/s_2$$

knowing the values of S_1, S_2 and 'T' from the above test, the value of $\frac{c'}{A}$ can be calculated

knowing the value of c'/A the discharge 'Q' for a well under a constant depression head 's' can be calculated as follows

$$Q = c' s$$

$$Q = \left[\frac{c'}{A}\right] A S$$

$$Q = \left[\frac{2.3}{T} \log_{10} \frac{S_1}{S_2}\right] A \cdot S$$

A and S are known, discharge for any amount of drawdown (s) can be easily worked out

In the absence of recuperation test, the following rough value of c'/A as given by marriot, can be used

Type of soil	c'/A specific yield capacity in cubic metres per hour per sq.metre of area under unit drawdown.
Clay	0.25
Fine sand	0.50
Coarse sand	1.00

Problems for Thiem's formula. ①

Regd. No.

K.W

UNIT - V

Problems

Pg No 819.
B C Punmia.

1) A pumping test was made in a medium sand and gravel to a depth of 15m where a bed of clay was encountered. The normal ground water level was at surface. observation holes were located at a distance of 3m and 7.5m from the pumped well. At a discharge of 3.6 liters/sec from the pumping well, a steady state was attained in about 25hrs. The draw-down at 3m was 1.65m and 7.5m was 0.36m compute the coefficient of permeability of the soil.

Sol: $Q = 3.6$ lit/sec.

$r_1 = 3m \qquad s_1 = 1.65m \qquad h_1 = 15 - 1.65 = 13.35\,m.$

$r_2 = 7.5m \qquad s_2 = 0.36m \qquad h_2 = 15 - 0.36 = 14.64\,m$

using Thiem's formula for unconfined aquifers ie equation we get.

$$Q = \left[\frac{\pi K}{2.3}\right]\left[\frac{(h_2^2 - h_1^2)}{\log_{10}\left(\frac{r_2}{r_1}\right)}\right]$$

$$\frac{3.6}{1000}\,\frac{m^3}{sec} = \frac{\pi K}{2.3}\left[\frac{(14.64)^2 - (13.35)^2}{\log_{10}\left(\frac{7.5}{3}\right)}\right]$$

$$\frac{3.6}{1000}\,\frac{m^3}{sec} = \frac{\pi K}{2.3}\left[\frac{36.1071}{0.398}\right]$$

36.10

$$K = \left[\frac{2.3 \times 0.398}{\pi \times 36.1071}\right] \times \frac{3.6}{1000} \times 100\ cm/sec$$

2.90×10^{-3}

$= 0.00289$ cm/sec

(2) A well penetrates into an unconfined aquifer having a saturated depth of 1000 metres. The discharge is 250 litres per minute at 12 meters draw down. Assuming equilibrium flow conditions and a homogeneous aquifer. Estimate the discharge at 18 metres draw down. The distance from the well where the draw down influences are appreciable may be taken to be equal for both the cases.

Sol:-

$d = 1000$ metres

$s_1 = 12m$ $\quad\quad s_2 = 18m$

$Q_1 = 250$ lit/minute. $\quad Q_2 = ?$

using Dupuit's formula for unconfined aquifers

$$Q = \frac{\pi K (d^2 - h_w^2)}{2.3 \log_{10}\left[\frac{R}{r_w}\right]}$$

In the first case: draw down = 12 m

$h_w = (1000m - 12m) = 88m.$

$$\therefore 250 \text{ lit/minute} = \frac{\pi K \left[(1000)^2 - (88)^2\right]}{2.3 \log_{10}\left[\frac{R}{r_w}\right]}$$

[∵ Here R and r_w are the same for both the cases

$$\frac{\pi K}{2.3 \log_{10}\left[\frac{R}{r_w}\right]} = \frac{250}{\left[(100)^2 - (88)^2\right]}$$

$$= \frac{250}{2256}$$

In the 2nd case: Draw down = 18m.

$h_w = 100-18$
$= 82$ m.

$\therefore Q_2 = \left[\frac{\pi K \times (100)^2 - (82)^2}{2.3 \log_{10}\left[\frac{R}{r_w}\right]} \right]$

Putting the value from (A) we get.

$Q_2 = \left[\frac{250}{2256} \right] \times \left[(100)^2 - (82)^2 \right]$

$Q_2 = 363$ lit/minute

Problems for Recuperation test (3)

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA

KAKINADA - 533 003.

ADDITIONAL ANSWER SHEET

Regd. No.

Subject :

Date :

Pg No 845
BC Punmia.

(1) Design an open well in coarse sand for a yield of 0.004 cumec when operated under a depression head of 3 metres

Sol:- The discharge required from the well.

$= 0.004$ cumec $= 0.004$ cubic metre per second

$= 0.004 \times 60 \times 60$ cubic metres per hour

$= 14.4\ m^3/hr$

From the table.

The value of C'/A for coarse sand may be taken as $1.0\ m^3/hr/m^2/m$ of depression head.

Also depression head $s = 3m$

Now from Eq.

$$Q = \left[\frac{C'}{A}\right] A \cdot s$$

$$14.4 = 1 \times A \times 3$$

$$A = \frac{14.4}{3} = 4.8\ m^2$$

If d_w is the diameter of the well, then $\frac{\pi d_w^2}{4} = 4.8$.

$$d_w = \sqrt{\frac{4.8 \times 4}{\pi}}$$

$= 2.48\ m$. say $2.5\ m$.

(2) During a recuperation test, the water level in an open well was depressed by pumping by 2.5 metres and is recuperated by an amount of 1.6 metres in 70 minutes

(a) Determine the yield from a well of 3m diameter under a depression head of 3.5 metres.

(b) Also determine the diameter of the well to yield 10 litres/second under a depression head of 2.5 metres.

Sol:- From equation $\frac{c'}{A} = \frac{2.3}{T} \log_{10} \frac{S_1}{S_2}$

where S_1 = initial draw down = 2.5 m.

S_2 = Final draw down = 2.5 − 1.6 = 0.9 m.

T = Time = 70 minutes

= 70 × 60 = 4,200 sec.

$$\frac{c'}{A} = \frac{2.3}{4200} \log_{10} \frac{2.5}{0.9}$$

$$= \frac{2.3}{4200} \log_{10} 2.778$$

$$= 0.244 \times 10^{-3}$$

(a) yield from a well of 3m diameter, under a depression head of 3.5 m, is obtained from the equation.

$$Q = \left[\frac{c'}{A}\right] A \cdot S$$ (Area = $\pi/4\, d^2$)

$$= \left[0.244 \times 10^{-3}\right] \times \left[\frac{\pi}{4} \times 3^2\right] \times \left[3.5\right]$$

$$= 6.02 \times 10^{-3}\ m^3/sec$$ (or) 6.03 lit/sec.

(b) Q = 10 lit/sec

S = 2.5 m.

$$Q = \left[\frac{c'}{A}\right] A \cdot S$$

$$10 \times 10^{-3} = \left[0.244 \times 10^{-3}\right] \times A \times \left[2.5\right]$$

$$A = \frac{10 \times 10^{-3}}{\left[0.244 \times 10^{-3}\right] \times \left[2.5\right]} \Rightarrow 16.4$$

(or)

$$\pi/4\, d^2 = 16.4$$

$$d = \sqrt{\frac{16.4 \times 4}{\pi}}$$

d = 4.57 m. say 4.6 m