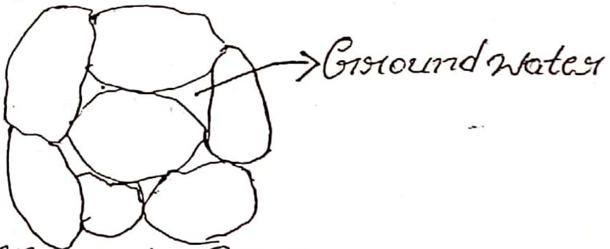
Module - 2

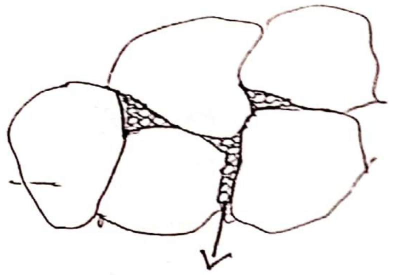
Aquifer parameters

-> Porosity
-> Specific yield
-> Permeability
-> Transmicibility
-> Specific retention
-> Storage co-efficient (or) Storetivity

-> Porosity(n)



More empty space
-> More porosity



Smaller soil partic
Less empty spaces
-> Less porosity

The ratio of volume of pore space (void space) to the volume of formation (rock's) is called porosity

i.e Porosity $(n) = \frac{V_v}{V}$ where V_v = volume of void space
V = Total volume of formation (rocks)

Sedimentary rocks -> Porosity is more
Igneous rocks -> } Porosity is less as these are forme
Metamorphic rocks -> } under high pressure and temperat-re

According to classification of sedimentary rocks
Well rounded -> Greater porosity
Poorly sorted -> Lesser porosity
Well cemented rocks -> Least porosity.

-> Specific yield (S_y)

It is the ratio of the volume of water which will drain freely from the material to the total volume of the formation

i.e Specific yield $(S_y) = V_d/V$
V_d = Volume of water which will drain
V = Total volume of formation (rock)

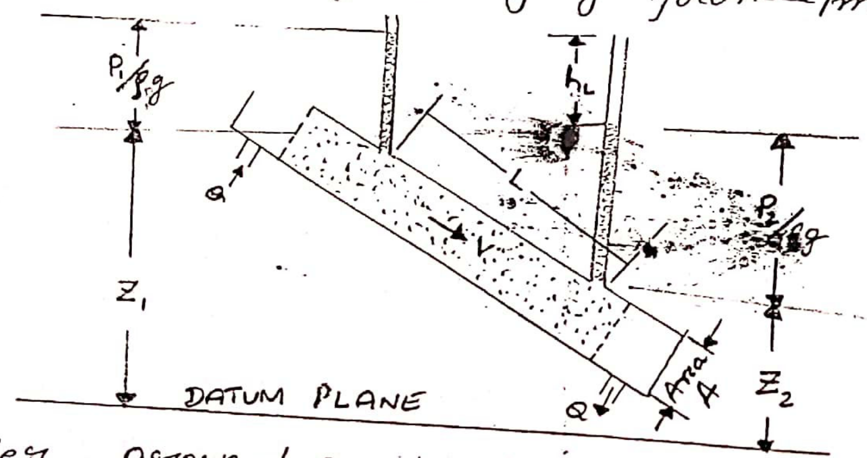
Specific yield depends on
* Grain Size
* Shape & Distribution of pores
* Compaction of formation.

for fine grained soil → Specific yield is less
for Coars grained soil → Specific yield is more

Permeability

The permeability of material is a measure of its capacity to transmit water (or) any other fluid through its voids or pores.

Ground water is transmitted through aquifer at very Small velocity ranging from 1m - 500m / year



Consider ground water flow through porus medium

Let $P_1/\rho g$ = Pressure head at Section ①

$P_2/\rho g$ = Pressure head at Section ②

Z_1 & Z_2 = Datum head at Section ① & ②.

$v_1^2/2g$ & $v_2^2/2g$ = velocity head at Section ① & ②

Applying Bernoulli's equation to Section 1 & 2)

$$\frac{P_1}{\rho g} + Z_1 + \frac{v_1^2}{2g} = \frac{P_2}{\rho g} + Z_2 + \frac{v_2^2}{2g} + h_L$$

h_L = Head loss

Neglecting the velocity heads as velocity of groundwater will be very small

$$\frac{P_1}{\rho g} + Z_1 = \frac{P_2}{\rho g} + Z_2 + h_L$$

$$\boxed{h_L = \left(\frac{P_1}{\rho g} + Z_1\right) - \left(\frac{P_2}{\rho g} + Z_2\right)}$$

Experimentally it is found that discharge Q from the aquifer depends upon h_L, L & A

Where L = length between section 1 & 2

A = Area of flow

$$\therefore Q \propto \left(\frac{h_L \times A}{L}\right)$$

$$Q/A \propto \left(\frac{h_L}{L}\right)$$

$$V \propto \left(\frac{h_L}{L}\right)$$

$$\boxed{V = -k\left(\frac{h_L}{L}\right)}$$

If distance b/w 2 piezometers is small then

$$V = -k\left(dh/dl\right)$$

The -ve sign indicates loss of head takes place in the direction flow (or) vice versa

Where k is known as hydraulic conductivity (or) Co-efficient of permeability.

V = velocity of water through porous medium (or) Darcy's velocity

$\frac{dh}{dl}$ = Hydraulic gradient

Imp

Darcy's Law states that rate of flow per unit area of an aquifer is proportional to gradient of potential head measured in the direction of flow i.e. ($Q/A \propto h_L/L$) (or) ($V \propto h_L/L$).

If $R_e < 1$, then Darcy's law is applicable

$R_e > 1$, then Darcy's law is not applicable

Where $R_e \rightarrow$ Reynolds number

$$R_e = \frac{\rho v d}{\mu}$$

$\rho \rightarrow$ Density of water

$v \rightarrow$ velocity of water / Darcy velocity

$d \rightarrow$ Diameter of void's space

$\mu \rightarrow$ Dynamic viscosity

Hydraulic Conductivity (or) Co-efficient of permeability (k)

It is defined as the rate of flow per unit area of aquifer under a unit hydraulic gradient

W.K.T from Darcy's law $v = -k \times \frac{dh}{dl}$

$$Q = A \times v$$

$$\left(\frac{Q}{A}\right) = v$$

$$\therefore \left(\frac{Q}{A}\right) = -k \times \left(\frac{dh}{dl}\right)$$

(or) $k = \dfrac{(Q/A) \rightarrow \text{Discharge per unit area}}{(dh/dl) \rightarrow \text{Hydraulic Gradient}}$

for unit Hydraulic Gradient i.e when $(dh/dl) = 1$

$k = (Q/A)$ (or) $k = v$

unit of v is m/s

Since velocity of Groundwater is very less it is expressed in terms of m/year

$\therefore$ The same unit holds good for co-eff of permeability

Intrensic permeability

Intrinsic permeability is the property of the medium only and it does not depend on the fluid properties.

Based on Hagen poiseuille equation for laminar flow

$$k = \frac{C \times d_m^2 \times \gamma}{\mu}$$

Where
$k \rightarrow$ Hydraulic Conductivity
$\mu \rightarrow$ Dynamic viscosity
$C \rightarrow$ Shape factor.
$d_m \rightarrow$ Average Grain Size
$\gamma \rightarrow$ Sp. weight

W.K.T $\gamma = \rho \times g$

$$k = \frac{(C \times d_m^2) \times \rho \times g}{\mu}$$

$$k = \frac{(C \times d_m^2) \times g}{\nu}$$

$\langle \nu \rightarrow$ kinematic viscosity

$\nu = \mu / \rho$

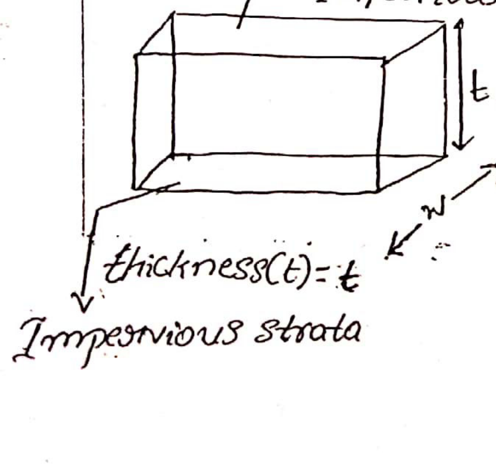
Intrensic permeability is the product of $(C \times d_m^2)$

unit of intrens[redacted]permeability $\rightarrow m^2$ or cm^2

1 Darcy = $0.987 \times 10^{-12} m^2$ (or)

1 Darcy = $0.987 \times 10^{-8} cm^2$

→ Transmissivity (or) Transmissibility (T) or Transmissivity co-effi



Discharge through an aquifer t is given by $Q = A \times V$

Where $A \rightarrow$ Area of flow

$V \rightarrow$ Darcy's

$t \rightarrow$ Thickness of aquifer

Width of aquifer$(w) = 1$

i.e $V = -k \times (dh/dl)$

$$Q = (t \times 1) \times -k \times (dh/dl)$$

$$Q = (t \times K)(-dh/dl) \quad \langle \text{thickness } (t) = 1 \rangle$$

The transmissibility of an aquifer is the product of hydraulic conductivity $\boxed{T = (t \times K)}$ K and of an aquifer.

The unit of hydraulic Conductivity(k) is m/year & of width (b) is m

∴ unit of Transmissivity is m^2/year

∴ $Q = T \times (-dh/dl)$ (or) $\boxed{T = \frac{Q}{(dh/dl)}}$

> Specific Retention (S_r)

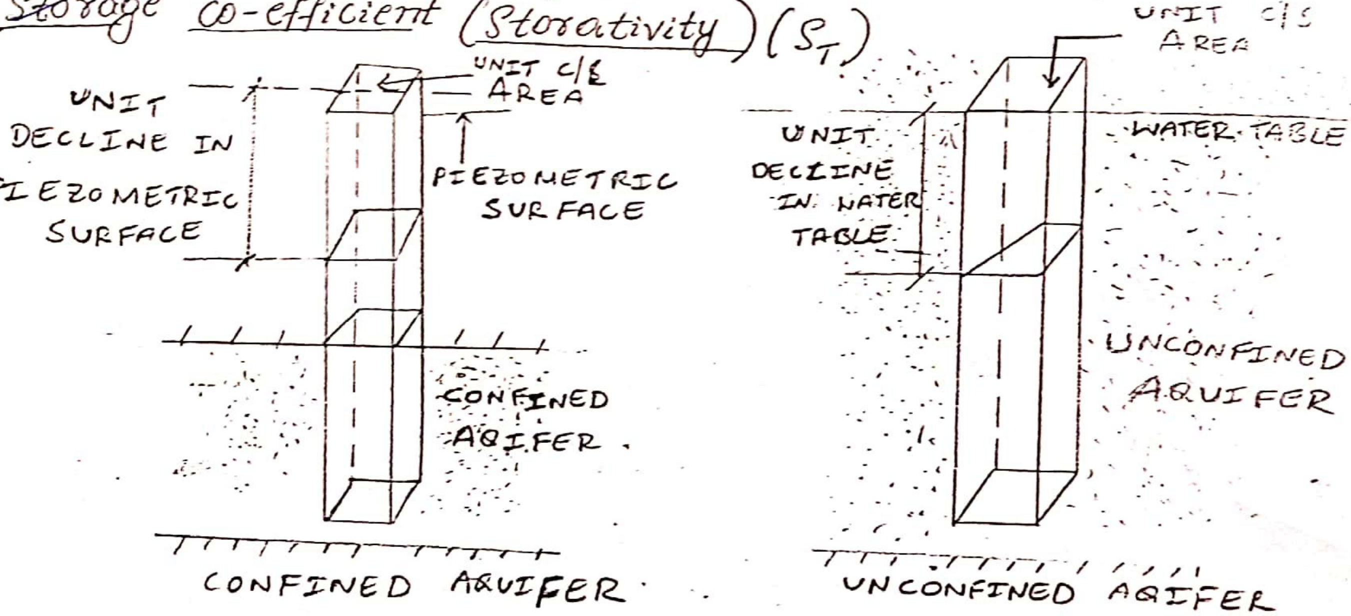
The specific retention is defined as ratio of volume of water retained in the material to the volume of formation (or) material (rock)

i.e Specific Retention $(S_r) = \frac{V_r}{V}$

$V_r \rightarrow$ volume of water retained

$V \rightarrow$ volume of formation or material

Storage co-efficient (Storativity) (S_T)



[St]orage co-efficient is defined as the volume of water that [a]n aquifer releases from (or) takes into storage per unit [s]urface area of the aquifer per unit drop of water [t]able in case of an unconfined aquifer & per unit drop [o]f piezometric surface in the case of confined aquifer

Permeability of isotropic and unisotropic soil

→ If the properties of soil has same value when measured in different directions, then such soils are called isotropic soil.

Permeability is the same along any direction in the isotropic soil mass

The permeability depends upon the grain size distribution, porosity, shape and arrangement of pores, properties of the pore fluid and entrapped air.

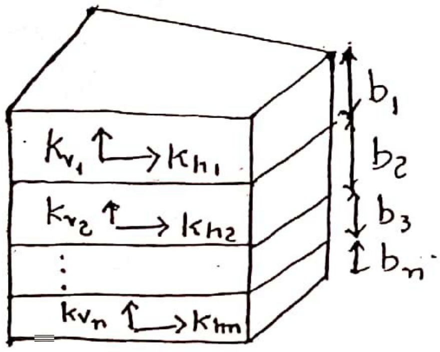
Unisotropic Layered Soil

→ If the values of properties of soil are not same when measured in different directions, then such soils are called unisotropic soil.

→ Permeability will not be same in the unisotropic soilmass

→ Many soils are formed in horizontal layers as a result of sedimentation through water. Because of seasonal variation such soil tend to be horizontally layered and this results in different permeabilities in horizontal & vertical direction

→ To determine permeability of unisotropic soil, samples are obtained from each layer and their permeabilities are determined.



The average permeability k_x & k_y in the horizontal and vertical directions are calculated as

$$K_x = \frac{1}{b}\left(k_{h_1} b_1 + k_{h_2} b_2 + k_{h_3} b_3 + \cdots k_{hn} b_n\right)$$

$$K_y = \frac{b}{\left(\frac{b_1}{k_{v_1}} + \frac{b_2}{k_{v_2}} + \frac{b_3}{k_{v_3}} \cdots + \frac{b_n}{k_{v_n}}\right)}$$

Where

$k_{h_1}, k_{h_2} \cdots k_{h_n}$ → Permeability of each layer in x-direction

$k_{v_1}, k_{v_2} \cdots k_{v_n}$ → Permeability of each layer in y-direction

b → Total thickness of the aquifer

$b = b_1 + b_2 + b_3 \cdots b_n$

Assumption's of Darcy's Law

According to Darcy's Law $v = -k \times (dh/dl)$

where $k \rightarrow$ co-efficient of permeability

$(dh/dl) \rightarrow$ Hydraulic Gradient

$v \rightarrow$ Darcy's velocity

The following assumptions are made in Darcy's law

→ The Soil is Saturated

→ The flow through Soil is laminar

→ The flow is continous and steady

→ The total cross sectional area of Soil mass is considered

→ During verification of Darcy's law from the experiment, the temperature at the time of testing is 27°c.

Limitation's

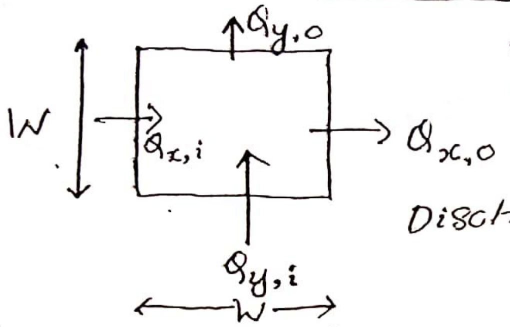
> Darcy's Law is based on the assumption that the flow occurs through the entire cross-section of the material without regard to Solid and pores. Actually the flow is limited to pore space only.

> Darcy's Law is found to be valid for the flows with Reynold's number less than 1(unity) only.

- Darcy's law is applicable only for steady flow
- Darcy's law is not applicable for the non continuous flow

* (Hydro 2) 9)

General ground water flow equation / 3-Dimensional equation (or) Laplace equation



(Thickness = unity)

Consider an aquifer having the dimens. of W metre & thickness of unity

Discharge through an aquifer is given by

$$Q = A \times V$$

$A \rightarrow$ Area of flow

$V \rightarrow$ Darcy's velocity (or) velocity of ground water

W.K.T

$$\text{Darcy's velocity } (V) = -k \cdot \frac{dh}{dl}$$

$k \rightarrow$ co-efficient of permeability

$\left(\frac{dh}{dl}\right) \rightarrow$ variation of head with respect to observed length

$$Q = (W \times 1) \times -k \times \frac{dh}{dl}$$ (Area of flow (A) = W × Unit thickn.)

Rate of flow of water in x-direction getting into aquifer is given by

$$Q_{x,i} = (W \times 1) \times -k_x \times \left(\frac{dh}{dx}\right)_i$$

$$\text{Transmissivity } (T) = K \times \text{Thickness of aquifer}$$

$$T = (k \times 1) \quad \text{i.e} \quad T_x = (k_x \times 1)$$

$$\therefore Q_{x,i} = W \times (-T_x) \times \left(\frac{dh}{dx}\right)_i$$

Rate of flow of water in x-direction getting out of aquifer is given by

$$Q_{x,o} = (W) \times (-T_x) \times \left(\frac{dh}{dx}\right)_o$$

|||ly

$$Q_{y,i} = (W) \times (-T_y) \times \left(\frac{dh}{dx}\right)_i$$

$$Q_{y,o} = (W) \times (-T_y) \times \left(\frac{dh}{dx}\right)_o$$

Volume of water in the aquifer is given by

$$= (Q_{x,i} - Q_{x,o}) + (Q_{y,i} - Q_{y,o})$$

W.K.T

$$\text{Storativity } (S_T) = \frac{\text{volume of water}}{\text{Surface} \times \left(\frac{dh}{dt}\right)}$$

volume of water $= S_T \times (S.A) \times \frac{dh}{dt}$ $S.A \rightarrow$ Surface Area of aquifer

$$(q_{x,i} - q_{x,o}) + (q_{y,i} - q_{y,o}) = S_T \times (S.A) \times dh/dt$$

$$w \times (-T_x) \times \left(\frac{dh}{dx}\right)_i - w \times (-T_x) \times \left(\frac{dh}{dx}\right)_o\Big) + \left(w \times (-T_y) \times \left(\frac{dh}{dy}\right)_i - w \times (-T_y) \times \left(\frac{dh}{dy}\right)_o\right)$$
$$= S_T \times (w^2) \times \frac{dh}{dt}$$

$$(-w \times T_x)\left(\left(\frac{dh}{dx}\right)_i - \left(\frac{dh}{dx}\right)_o\right) + (-w \times T_y)\left(\left(\frac{dh}{dx}\right)_i - \left(\frac{dh}{dy}\right)_o\right) = S_T \times \cancel{w}^2 \times \frac{dh}{dt}$$

$$\frac{T_x\left(\left(\frac{dh}{dx}\right)_i - \left(\frac{dh}{dx}\right)_o\right) + T_y\left(\left(\frac{dh}{dy}\right)_i - \left(\frac{dh}{dy}\right)_o\right)}{w} = S_T\left(\frac{dh}{dt}\right)$$

If w is very small then head difference h can be expressed interms of 2nd order differential equation of x & y

$$T_x\left(\frac{d^2h}{dx^2}\right) + T_y\left(\frac{d^2h}{dy^2}\right) = S_T\left(\frac{dh}{dt}\right) \rightarrow \text{2-dimensional G.W flow equation}$$

$$T_x\left(\frac{d^2h}{dx^2}\right) + T_y\left(\frac{d^2h}{dy^2}\right) + T_z\left(\frac{d^2h}{dz^2}\right) = S_T\left(\frac{dh}{dt}\right) \rightarrow \text{3-dimensional G.W flow equation}$$

The above equation is for unsteady flow

for Steady flow $\left(dh/dt\right) = 0$

$$\frac{d^2h}{dx^2} + \frac{d^2h}{dy^2} + \frac{d^2h}{dz^2} = \frac{S_T}{T}\left(\frac{dh}{dt}\right)$$

$$\boxed{\frac{d^2h}{dx^2} + \frac{d^2h}{dy^2} + \frac{d^2h}{dz^2} = 0} \rightarrow \text{Laplace equation}$$

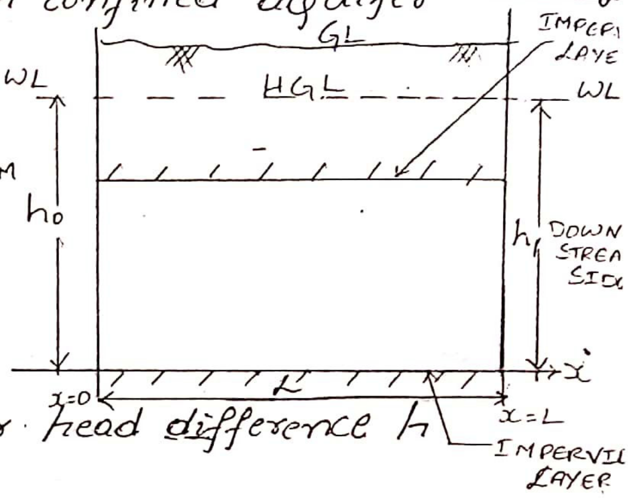
(or) $\boxed{\nabla^2 h = 0}$

(Dimensional)
1D Ground water Steady flow through confined aquifer's between two water bodies [Without Recharge]*

(or)

Steady unidirectional flow in confined aquifer's [Without Recharge]

Consider a steady 1D flow through confined aquifer



W.K.T for 3-Dimensional flow

$$\frac{d^2h}{dx^2}+\frac{d^2h}{dy^2}+\frac{d^2h}{dz^2}=0$$

for 1-Dimensional flow

$$\frac{d^2h}{dx^2}=0$$

To find the final expression for head difference h

Integrating $\frac{d^2h}{dx^2}$

$$h=c_1x+c_2 \longrightarrow eq^n 1)$$

$c_1=?$ & $c_2=?$

Consider the boundary condition's

i) @ $x=0$ $h=h_0$

$h_0 \to$ water level @ upstream side

$h_0=c_2$

(or)

$$\boxed{c_2=h_0}$$

ii) @ $x=L$ $h=h_1$

$h_1 \to$ water level @ down-stream side

$h_1=c_1 \times L+h_0$

$(h_1-h_0)=c_1 \times L$

$$\boxed{c_1=\frac{(h_1-h_0)}{L}}$$

$$\therefore h=\frac{(h_1-h_0)}{L}x+h_0$$

on re-arranging

$$\boxed{h=h_0-\left(\frac{h_0-h_1}{L}\right)x}$$

$L \to$ length b/w considered section

$$\boxed{\frac{dh}{dx}=-\left(\frac{h_0-h_1}{L}\right)\times 1}$$

Discharge /unit width is given by

$Q=A \times V$

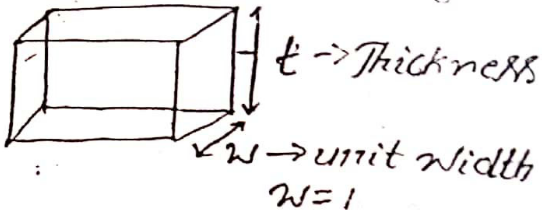
$A \to$ Area of flow

$V \to$ Darcy's velocity

W.K.T

$$v = -k \times \frac{dh}{dl} \rightarrow -k \times \frac{dh}{dx} \quad [k \rightarrow \text{Co-efficient of permeability}]$$

$$A = w \times t \ (m^2)$$



$$\therefore Q = (w \times 1) \times (-k) \times \left(\frac{dh}{dx}\right)$$

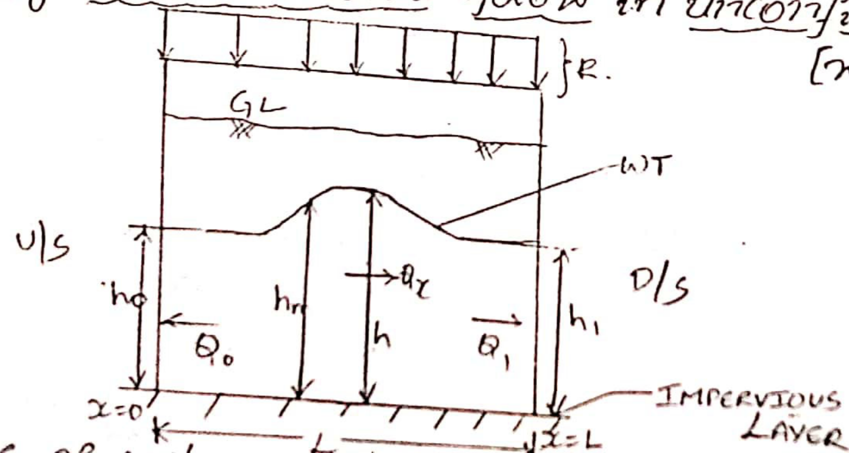
$$Q = -T \times \frac{dh}{dx} \quad \langle T = w \times k \rightarrow \text{Transmissivity} \rangle$$

$$Q = -T\left[x - \frac{(h_0 - h_1)}{L}\right] \quad (\text{or}) \quad \boxed{Q = T\frac{(h_0 - h_1)}{L}}$$

1 Dimensional Ground water flow through unconfined aquifer b/w 2 water bodies [with Recharge]

(or)

Steady unidirectional flow in unconfined aquifer [with Recharge]



-> Rate of recharge into the aquifer

-> Distance b/w 2 Section's (or) water bodies

h_m -> Maximum head of the water table

h -> General level of the water table

h_0 -> Level of water body in the upstream Side

h_1 -> Level of water body in the downstream Side

Q_0 -> Discharge toward's upstream Side

Q_1 -> Discharge toward's downstream Side

Q_x -> Discharge from general level of water table towards D/S

A -> Area of flow = General level of the water table x unit width)

$= (h \times 1)$

The General Ground water Steady flow governing equation is given by

$$\frac{d^2h^2}{dx^2} = \frac{-2R}{k}$$

on integration

$$d^2h^2 = \frac{-2R}{k} \times dx^2$$

$$h^2 = -\frac{2R}{k}\iint dx^2$$

$$h^2 = \frac{-2R}{k \times 2} x x^2 + c_1 x + c_2$$

$$h^2 = \frac{-R}{k} x x^2 + c_1 x + c_2 \longrightarrow eq^n\ 1)$$

Boundary Condition's

@ $x=0$ $h=h_0$ $\boxed{h_0^2 = C_2}$

@ $x=L$ $h=h_1$ $h_1^2 = \frac{-R}{k} \times L^2 + c_1 \times L + h_0^2$

$$\boxed{\frac{h_1^2 - h_0^2 + R/k \times L^2}{L} = C_1}$$

Substituting for C_1 & C_2 in equation 1

$$h^2 = \frac{-R}{k} x x^2 + \left[\frac{h_1^2 - h_0^2 + R/k \times L^2}{L}\right] x + h_0^2 \longrightarrow eq^n\ 2$$

$$h = \sqrt{\frac{-R}{k} x x^2 + \left[\frac{h_1^2 - h_0^2 + R/k \times L^2}{L}\right] x + h_0^2}$$

The above equation represents general level of watertable

W.K.T $Q = -K \times h \times \frac{dh}{dx}$ $\left[\begin{array}{l} \therefore Q = A \times V \quad V = -K\frac{dh}{dx} = -K \times dh/dx \\ A = h \times \text{unit width} \\ \therefore Q = -K \times h \times dh/dx \end{array}\right]$

Substituting for $h \times dh/dx$ on differentiating eq^n 2)

$$2 \times h \times \frac{dh}{dx} = \frac{-2Rx}{k} + \left[\frac{h_1^2 - h_0^2 + \frac{R \times L^2}{k}}{L}\right]$$

$$\therefore h \times \frac{dh}{dx} = \frac{-R \times x}{k} + \left[\frac{h_1^2 - h_0^2 + R/_k \times L^2}{2L}\right]$$

$$Q_x = -k \times \left[\frac{-R \times x}{k} + \frac{(h_1^2 - h_0^2 + R/_k \times L^2)}{2L}\right]$$

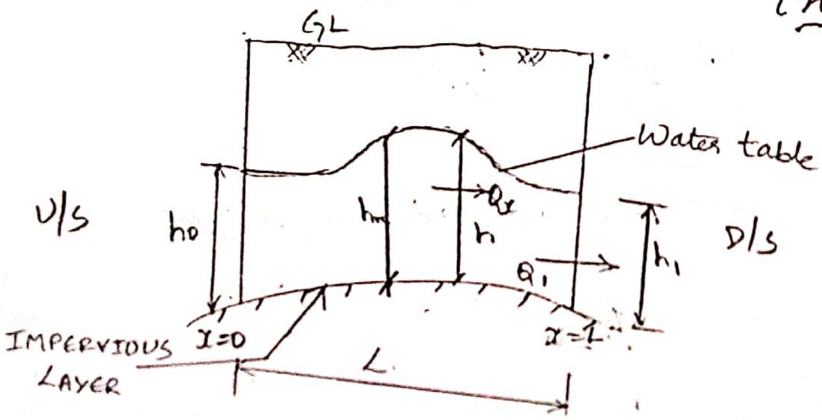
When $x = 0$ $\quad Q_{x=0}$

$$Q_{x=0} = -k \times \left[\frac{(h_1^2 - h_0^2) + (R/_k \times L^2)}{2L}\right]$$

When $x = L$

$$Q_{x=L} = -k\left[\frac{-R \times L}{k} + \frac{(h_1^2 - h_0^2 + R/_k \times L^2)}{2L}\right]$$

1 Dimensional Ground water flow through unconfined aquifer b/w 2 water bodies [without Recharge]
(or)
Steady unidirectional flow in unconfined aquifer [Without Recharge]



L → Distance b/w 2 Section's (or) waterbodies
hm → Maximum head of the water table
h → General level of the water table
h₀ → Level of water body in the upstream side
h₁ → Level of water body in the downstream side
Q₀ → Discharge towards upstream side
Q₁ → Discharge towards downstream side
Qx → Discharge from general level of water table towards D/S
→ Area of flow = (h × 1)

W.K.T $\frac{d^2h^2}{dx^2} = \frac{-2R}{k}$ [With Recharge] } General Groundwater Steady flow governing equation

$\frac{d^2h^2}{dx^2} = 0$ [without Recharge]

on integration

$h^2 = c_1 x + c_2 \longrightarrow$ eqⁿ 1)

Boundary condition's

i) @ $x = 0$ $h = h_0$

ii) @ $x = L$ $h = h_1$

Substituting 1st boundary condition in eqⁿ 1)

$$\boxed{h_0^2 = C_2}$$

Substituting 2nd boundary condition in eqⁿ 1)

$$h_1^2 = (C_1 \times L) + h_0^2$$

$$C_1 \times L = h_1^2 - h_0^2$$

$$\boxed{C_1 = \frac{h_1^2 - h_0^2}{L}}$$

Substituting for C_1 & C_2 in eqⁿ 1)

$$h^2 = \left(\frac{h_1^2 - h_0^2}{L}\right) \times x + h_0^2 \longrightarrow 2)$$

$$h = \sqrt{\left(\frac{h_1^2 - h_0^2}{L}\right) \times x + h_0^2}$$

W.K.T $q_x = -k \times \left(h \times \frac{dh}{dx}\right)$

Substituting for $\left(h \times \frac{dh}{dx}\right)$ on differentiation eqⁿ 2)

$$\therefore 2h \times \frac{dh}{dx} = \left(\frac{h_1^2 - h_0^2}{L}\right) \quad (\text{or}) \quad h \times \left(\frac{dh}{dx}\right) = \left(\frac{h_1^2 - h_0^2}{2L}\right)$$

$$\therefore \boxed{q = -k \times \left(\frac{h_1^2 - h_0^2}{2L}\right)}$$

Problems

When 3.68 million m^3 of water was pumped out from an unconfined aquifer of 6.2 km² aerial extent, the water table was observed to go down by 2.6 m. What is the specific yield of the aquifer.
During the monsoon season if the water table of the same aquifer goes up by 10.8 m, what is the volume of recharge.

i) Volume of water pumped out = $3.68 \times 10^6 m^3$

W.K.T Sp. yield = $\frac{\text{Volume of water drained (Pumped)/recharged}}{\text{Volume of the aquifer Considered}}$

$$S_y = \frac{3.68 \times 10^6}{\text{Area extent} \times \text{water level drawdown}}$$

$$S_y = \frac{3.68 \times 10^6}{6.2 \times 10^6 \times 2.6} = 0.228$$

ii) Volume of recharge = ?

W.K.T Sp. yield = $\frac{\text{Volume of water recharged}}{\text{Volume of the aquifer Considered}}$

$$0.228 = \frac{\text{Volume of water recharged}}{6.2 \times 10^6 \times 10.8}$$

Volume of water recharged = $0.228 \times 6.2 \times 10^6 \times 10.8$

$\Rightarrow 15.26 \times 10^6 m^3$

(or) 15.26 million m^3

The water table levels in two observation wells 350 m apart are 210.5 m and 206.25 m. If the hydraulic conductivity & porosity of the aquifer are 12.5 m/day & 15%, what is the actual velocity of flow in the aquifer.

S W.K.T

from

Darcy's Law $v = -K\left(\frac{dh}{dl}\right)$

Where V = Darcy's velocity

k = Hydraulic Conductivity = 12.5 m/day

$\left(\frac{dh}{dl}\right)$ = Hydraulic Gradient = $\frac{210.5 - 206.25}{350}$

$\therefore \left(\frac{dh}{dl}\right) = \frac{4.25}{350}$

$V = -12.5 \times \frac{4.25}{350} = -0.1518 \text{ m/day}$

W.K.T

Actual velocity of flow through aquifer (v_a)

$v_a = \frac{V}{n}$

where n = porosity of the aquifer

$v_a = \frac{0.1518}{0.15} = 1.01 \text{ m/day}$

3) A Sample has a hydraulic conductivity of 10m/day. What would be it's intrensic permeability? what is it's hydraulic conductivity in cm/s? what would be it's hydraulic Conductivity at 30°C

Note [20°C] { At std temp, Dynamic viscosity. $\mu = 0.01$ gm-cm/s

W.K.T Hydraulic Conductivity $(k) = \frac{(C \times d_m^2) \times g}{\nu}$

$\boxed{k_0 = C \times d_m^2}$ → Intrensic permeability

ν → kinematic visocosity

$k = \frac{k_0 \times g}{\nu}$ (or) $k_0 = \frac{k \times \nu}{g}$

μ = Dynamic viscosity

$\nu = \mu/\rho$

$\therefore \boxed{k_0 = \frac{k \times \mu}{\rho \times g}}$ (m^2 (or) cm^2) }

Ans
$$K_0 = \frac{K \times \mu}{\rho \times g} = \frac{10 \times \frac{100}{24 \times 60 \times 60} \, 0.01}{1000 \times 9.81 \times 1000 \times 10^3 \times 10}$$

$$\boxed{K_0 = 1.1798 \times 10^{-7} \, cm^2}$$

$K = \frac{10 \times 10^{0}}{24 \times 60 \times 60}$

$K = 0.0115 \, cm/sec$

NOTE 1 Darcy $= 0.987 \times 10^{-12} \, m^2$ (or)

1 Darcy $= 0.987 \times 10^{-8} \, cm^2$

for $0.987 \times 10^{-8} \, cm^2 \longrightarrow$ 1 Darcy

$1.1798 \times 10^{-7} \, cm^2 \longrightarrow$?

$$\boxed{\therefore K_0 = 11.95 \text{ Darcy}}$$

NOTE

for kinematic viscosity (ν) for water @ 20°c is 0.01 cm²/sec and @ 30°C is 0.008 cm²/sec

W.K.T $K \propto \frac{1}{\nu}$

$$\frac{K}{K_t} = \frac{\nu_t}{\nu}$$

$K = 10 \, m/day = 0.0115 \, cm/sec$

$$\frac{0.0115}{K_t} = \frac{0.008}{\frac{0.01}{1000 \times 1000 \times 10^{-6}}}$$

$K_t = 0.0137 \, cm/sec$

$\therefore$ Hydraulic Conductivity @ 30° (K_t) = 0.0137 cm/sec