Ground Water

Introduction:-

Ground water is that portion of the water, beneath the surface of the earth that can be collected with wells, tunnels or drainage gallaries or which flows naturally to the earth's surface via seeps or springs.

This water is due to infiltrated part of the rainfall. This water may have infiltrated directly into the ground where it landed or it may first have collected in streams and lakes and then seeped into the ground - The water moves downwards under the influence of gravity until it reaches the impervious strata - It then begins to move in a lateral direction towards some outlet.

Importance of Ground water:-

* Because ground water is relatively free of pollution it is especially useful for domestic purposes, particularly for isolated farms and small towns in the arid regions.
* In such places ground water is often the only source of water for irrigation - As per data collected in 2004, there are about 400,000 tube wells in Pakistan which pump about 66 million cubic meters of ground water annually - In villages almost every house hold has a hand pump to pump ground-water for domestic use -

* About one sixth of the total water used in the country exclusive of hydroelectic -power generation comes from groundwater pumped each day.
* Grand water temperature remains relatively low during the summer and is therefore also used for air conditioning and industrial cooling.

Types of water- Bearing Units:-

Geologic Formation:- The geologic formations are classified in relation to their capacity to store and transmit the water i.e. the porosity.

* Aquifers:- Ground water bearing formations sufficiently permeable to transmit and yield water in sizeable quantities are called aquifers.

* Aquiclude:- An aquiclude is a soil formation which can store water but cannot transmit it. Its permeability is negligibly small. A clay layer is an example of an aquiclude. For all practical purposes an aquiclude is considered an impervious formation.

Aquitard:-

A soil formation which is permeable in vertical direction is impermeable in lateral direction is called an aquitard.

It transmits water at a very low rate compared to the aquifer.

Aquifuge:- Soil formation which can neither store water nor can transmit it is called an aquifuge

Its permeability is nearly zero.

*Aquifers:- A geological unit which can store and supply significant quantities of water.

Aquifers have the following two types:-

1) Unconfined Aquifers:-

The top of an unconfined aquifer is the water table which is the plane where ground water pressures are equal to atmospheric pressure.

It is soil formation which can store water and can transmit it in vertical as well as in lateral direction.

The top surface having atmospheric pressure is called the water table.

The water in unconfined aquifers comes from direct rainfall recharge over the aquifers, from connections to surface waters and from other aquifers.

The lower boundary of unconfined aquifers is a layer of much less permeable material than the aquifer it self.

2) Confined Aquifers:-

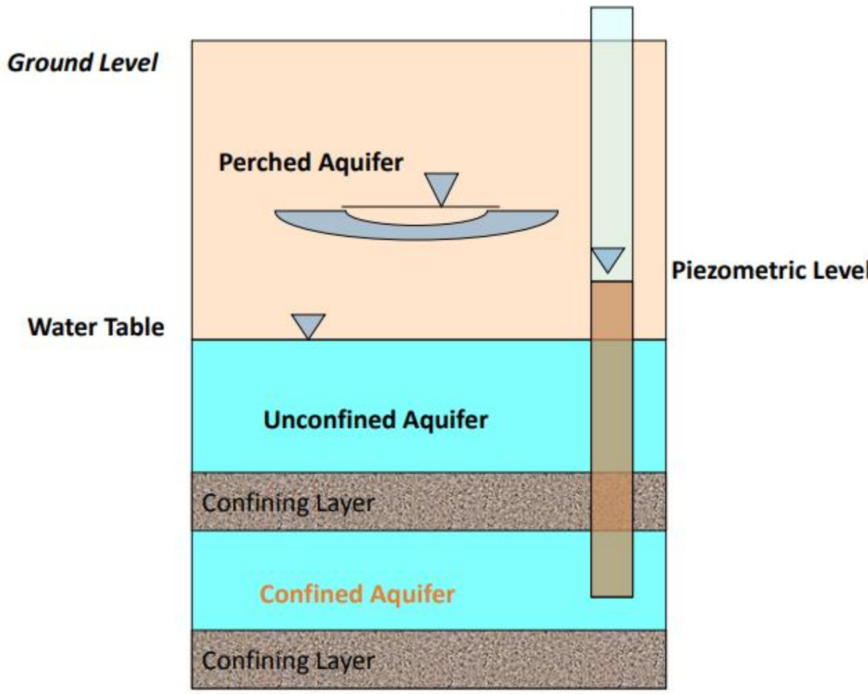
An aquifer bounded from above and from below by impervious formation.

It is a soil formation which can store and can transmit water under pressure. There is no atmospheric pressure on the top surface of ground water.

It is found b/w two impervious strata.

Confined aquifers are completely filled with ground water and they donot have a free water table.

The pressure condition in a confined aquifer is characterized by the piezometric surface, which is the surface obtained by connecting equilibrium water levels in tubes/wells or piezometers, penetrating the confined aquifers.



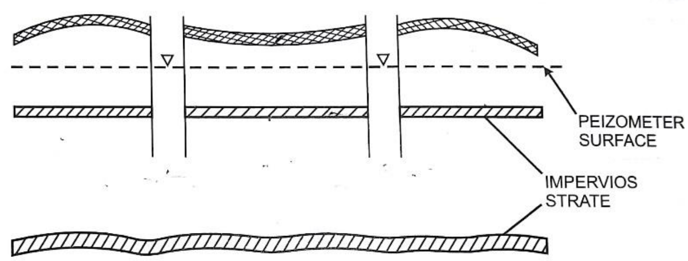


Fig. 7.1 Confined Aquifer

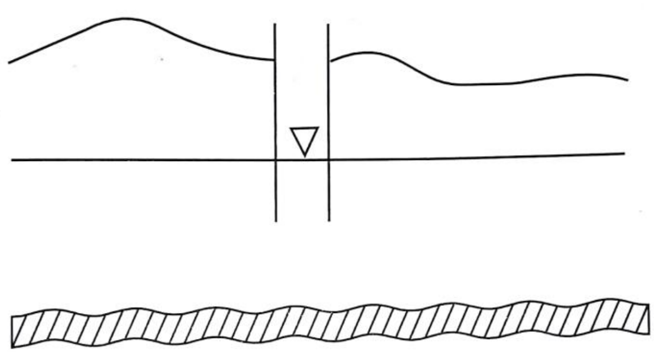


Fig. 7.2 Unconfined Aquifer

Storage Coefficient and Specific Yield:-

The storage coefficient of an aquifer is defined as the volume of water yielded/released per unit horizontal area and per unit drop of water table in case of unconfined aquifer.

In case of confined aquifers it is volume of water yielded/released per unit horizontal area and per unit drop of piezometric surface.

* for unconfined aquifers, the storage coefficient can also be called specific yield.

$$S = \frac{dV_w}{dh} \cdot \frac{1}{A}$$

V_w = Volume of water released from storage $[L^3]$

h = hydraulic head $[L]$

A = Area $[L^2]$

Storage coefficient is the dimension less quantity.

Darcy's law:-

Darcy's law states that the velocity flux "V" is directly proportional to hydraulic gradient.

$$V \propto \frac{dh}{dl}$$

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

→ Velocity flux "v" is the discharge divided by total cross sectional area of soil formation perpendicular to the flow

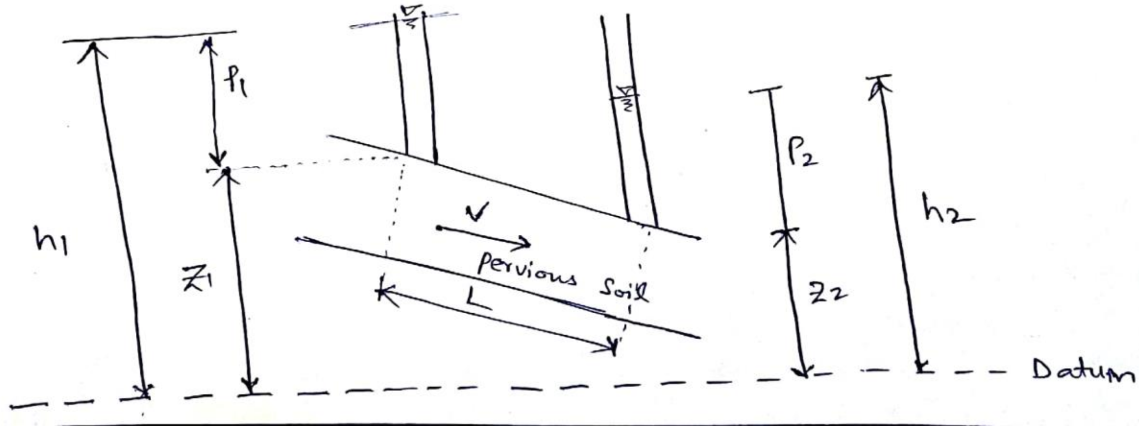
"K" is the factor of proportionality is a property of the soil or rock material and it is called the hydraulic conducitivity.

$\frac{dh}{dl}$ = hydraulic gradient, that is the change in head over the length of interest

If piezometers are placed at two points on a ground water stream line (point 1 and 2) - The velocity of the ground water in that stream can be calculated with the equation:

$$V = \frac{K (z_1 + h_1) - (z_2 + h_2)}{L}$$

Where
V = Darcy velocity (length/time)
h_1 = pressure head at point 1 (length)
z_1 = Elevation head at point 1 (length)
h_2 = Pressure head at point 2 (length)
z_2 = Elevation head at point 2 (length)
L = Distance along flow b/w point 1 and 2 as measured along stream line



In modern formate, Darcy's law is usually written as

$$Q = KA \frac{dh}{dl}$$

Q = rate of water flow (Volume per time)

k = hydraulic Conductivity.

A = Cross Sectional Area.

$\frac{dh}{dl}$ = Hydraulic gradient, the change in head over the length of interest.

Ground water Recharge and Discharge:-

* water is continually recycled through aquifer Systems
* Groundwater recharge is any water added to the aquifer zone.
* Process that contribute to ground water recharge include precipitation, stream flow, leakage and wells.
* Ground water discharge is any process that removes water from an aquifer System - Natural Springs are example of discharge processes.
* Ground water Supplies 30% of the water present in our streams.

Flow of Ground water towards well:-

* water wells operate according to the principles of hydraulics.
* When a well is pumped, the water flows into the well from the aquifer because the pumping creates a difference in pressure.

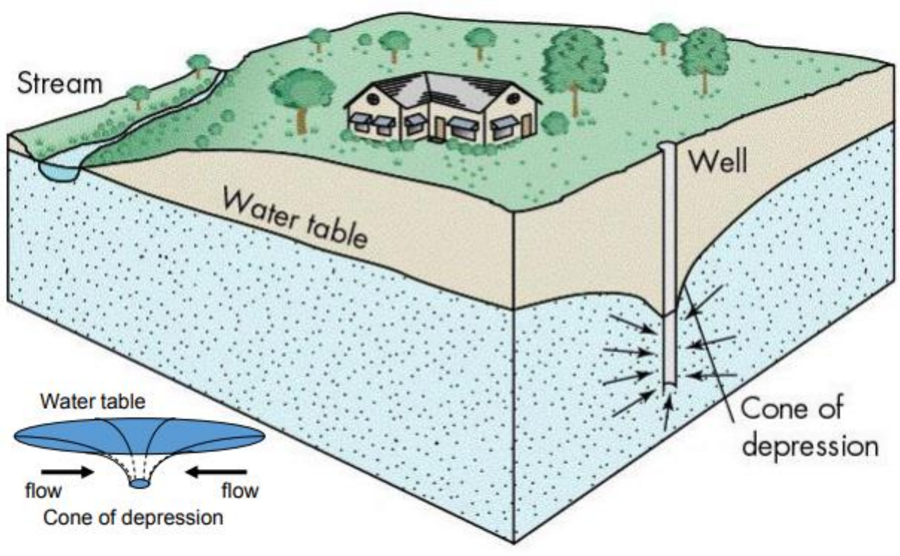
* During the pumping, water is removed from the aquifer surrounding the well and the water table or piezometric surface, depending upon the type of aquifer.

* Before pumping in every water well, the water stands at a height equal to the static water level.

* When pumping starts, the water in the well is pulled and the water starts to flow into the well from the aquifer b/c water level inside the well during the pumping is lowered.

* This pressure difference cause the water to move through the water bearing formations towards the well

Groundwater Movement -- Cone of Depression



Pumping water from a well causes a **cone of depression** to form in the water table at the well site.

Cone of depression for steady state pumping:-

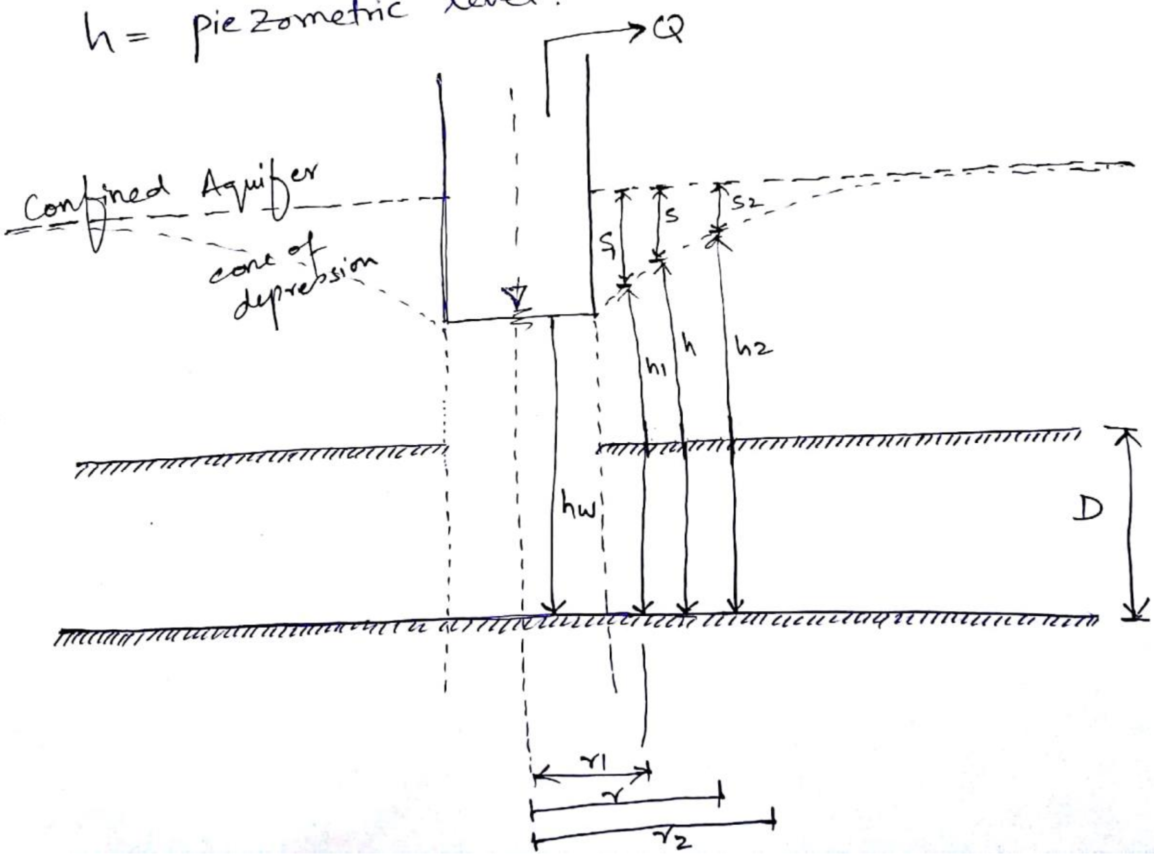
Confined Aquifer:-

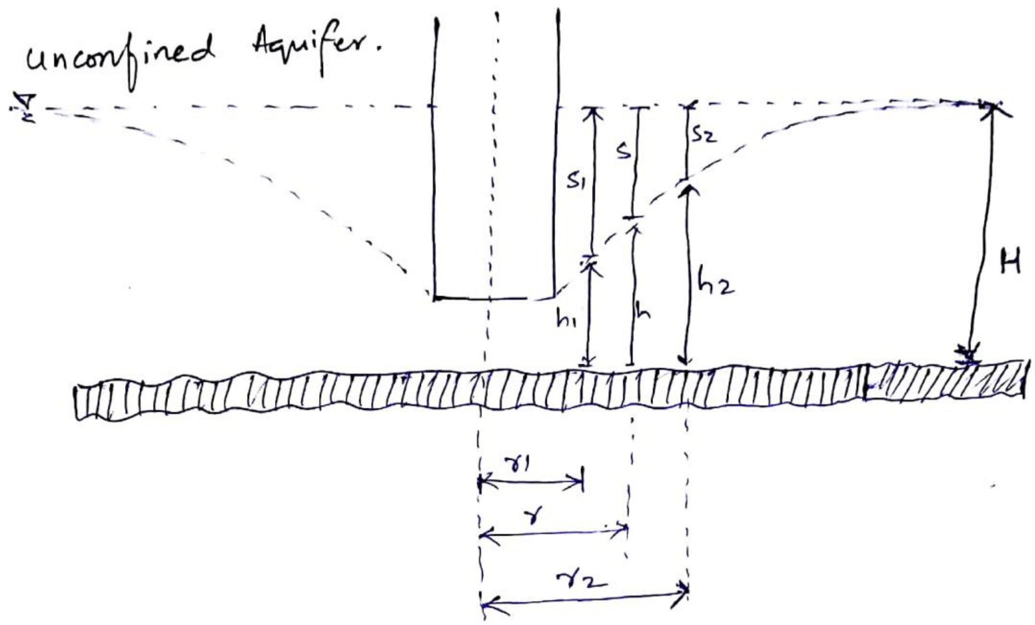
$$Q = \frac{2\pi K D (h_2 - h_1)}{\ln\left(\frac{r_2}{r_1}\right)}$$

Unconfined Aquifer:-

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

Q = Flow from well.
K = Hydraulic conductivity of aquifer.
r = Radial distance from well centre.
h = piezometric level.





Example 1 :-

A well with a radius of 0.5m completely penetrates an unconfined aquifer with $K = 30 \frac{m}{day}$ and water table height from an impermeable strata at the bottom of aquifer H = 50m. The well is pumped so that the water level in the well remains at 40 m above the bottom of the aquifer. assuming that pumping has no effect on water table height at r = 500m
What is steady state well discharge ?

Given data:-

$K = 30 m/day$

$K = \frac{30 m}{24 \times 60 \times 60} = 0.0003472 m/sec$

$r_1 = 0.5 m$
$h_1 = 40 m$
$r_2 = 500 m$

$h_2 = H = 50m$

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

$$Q = \frac{3.1415 \times 0.00037472\ (50^2 - 40^2)}{\ln\left(\frac{500}{0.5}\right)}$$

$$\boxed{Q = 0.142\ \frac{m^3}{sec}}$$

Example 2:-

Observational wells were drilled in a cone of depression of artesion (confined) well, being pumped at the rate of $0.028\ \frac{m^3}{sec}$. The draw down in the observational well at 4.57m and 12m were found to be 7.5m and 3m respectively. Calculate "K" of the aquifer if the average thickness of the aquifer is 30m.

Given data:-

$b = 30m$

$Q = 0.028\ \frac{m^3}{sec}$

$r_1 = 4.57m$

$r_2 = 12m$

draw down $S_1 = 7.5m$

drawdown $S_2 = 3m$

$K = ?$

$h_1 = H - S_1$

$h_2 = H - S_2$

As we know that

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

$$Q = \frac{2\pi Kb\,(H - S_2 - (H - S_1))}{\ln\left(\frac{r_2}{r_1}\right)}$$

$$Q = \frac{2\pi Kb\,(\cancel{H} - S_2 - \cancel{H} + S_1)}{\ln\left(\frac{r_2}{r_1}\right)} = \frac{2\pi Kb\,(S_1 - S_2)}{\ln\left(\frac{r_2}{r_1}\right)}$$

$$0.028 = \frac{2 \times 3.1415 \times K \times 30\,(7.5 - 3)}{\ln\left(\frac{12}{4.57}\right)}$$

$$K = \frac{\ln\left(\frac{12}{4.57}\right) \times 0.028}{2 \times 3.1415 \times 30 \times (7.5 - 3)}$$

$$\boxed{K = 3.20 \times 10^{-5}\ m/sec}$$

Example 3:- A 0.20m diameter well is pumped at a rate of 440 gallons/min - observations of drawdowns taken at 1m and 10m distances from the centre of the well were found to be 10m and 0.5m respectively. Determine the K if the water bearing strata assuming that the thickness of the aquifer is 30m.

Given data:-

$$Q = 440 \frac{gal}{min} = \frac{440}{220 \times 60}$$

$1 m^3 = 220$ imperial Gallons

$$Q = 0.033 \, m^3/sec$$

$H = 30m$

$D = 0.20m$

$r_1 = 1m$

$r_2 = 10m$

$S_1 = 10m$

$S_2 = 0.50m$

$K = ?$

Solution:- $h_1 = H - S_1 = 30 - 10 = 20m$

$h_2 = H - S_2 = 30 - 0.5 = 29.50m$

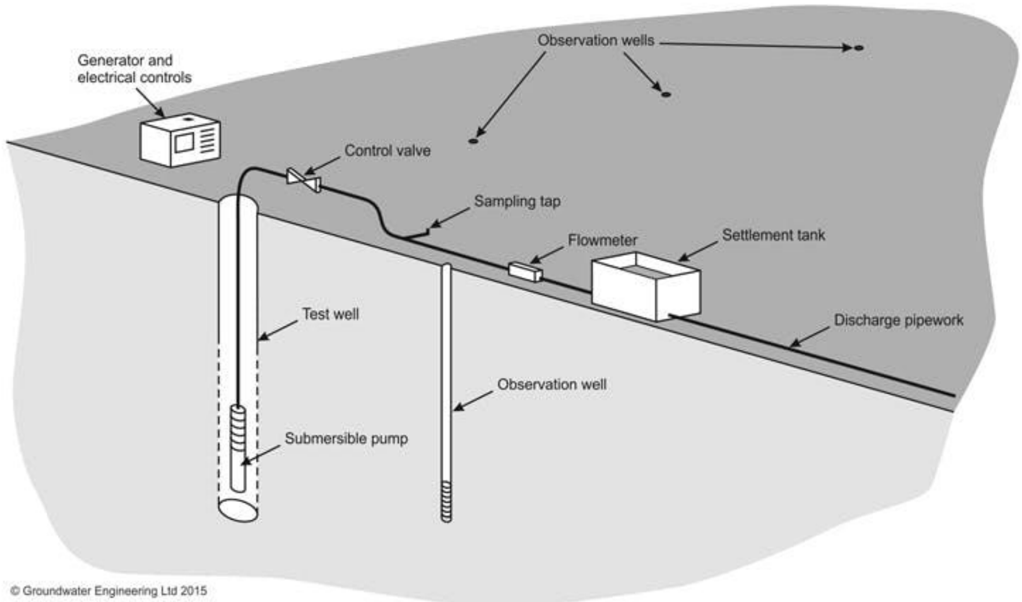
As

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

$$0.033 = \frac{3.1415 \times K (29.5^2 - 20^2)}{\ln\left(\frac{10}{1}\right)}$$

$$\boxed{K = 5.2 \times 10^{-5} \, m/sec}$$ Answer.

PUMPING TESTS



Pumping tests can be an important part of the investigations for dewatering and other construction projects. Supported by other types of groundwater investigations and groundwater monitoring they can provide valuable information for the planning and design of construction projects.
A pumping test involves pumping from a test well at a controlled rate and monitoring the flow rate from the well and the drawdown in an array of observation wells at varying radial distances from the test well.
Analysis of data from a correctly executed pumping test can be one of the most reliable methods of determining the mass permeability of water-bearing soils.

Pumping tests and groundwater investigations can be carried out for different purposes:

- To obtain permeability values for groundwater control and geotechnical design purposes
- To investigate water.
- To assess the performance of new water supply wells.