GEOTECHNICAL ENGINEERING – II

Subject Code : 06CV64 Internal Assessment Marks : 25

PART A

UNIT 2

1. DRAINAGE AND DEWATERING

1.1 Location of ground water table in fine and coarse grained soils
1.2 Determination of ground water level by Hvorselev method
1.3 Control of ground water during excavation : Dewatering – Ditches and sumps, Well point system, Shallow well system, Deep well system, Vacuum method, Electro – osmosis method

(5 Hours)

Chapter -2

DRAINAGE AND DEWATERING

2.0 Introduction:

Ground water conditions play an important part in the stability of foundations. If the water table lies very close to the base of footings, the bearing capacity and settlement characteristics of the soil would be affected. The level of the water table fluctuates with season. During the end of monsoons, the water table level will be closer to the ground surface as compared to the period just before the monsoons. The difference in levels between the maximum and the minimum may fluctuate from year to year. In many big projects, it is sometimes very essential to know these fluctuations. Piezometers are therefore required to be installed in such areas for measuring the level of water table for one or more years. In some cases clients may demand the depth of water table during the period of site investigation. The depth can be measured fairly accurately during boring operation. Normally during boring, the water table drops down in the borehole and attains equilibrium condition after a period of time. In a fairly draining material such as sand and gravel, the water level returns to its original position in a matter of few minutes or hours, whereas, in soils of low permeability it may take several days. In such cases, the water table level has to be located by some reliable method.

In some cases, the ground water flows under pressure through a pervious layer of soil confined from its top and bottom between impermeable geological formations. If the water flows from a higher elevation to a lower level, an *artesian pressure* is created and such a ground water is termed as *artesian water*. It is essential to investigate the possibility of existence of artesian water in a project area.

Permeability of soils is another important factor, which needs to be known in many of the major projects. Selection of pumps for pumping out water from excavated trenches or pits depends on the permeability of soils. The settlement and stability of foundations also depend on the permeability of soils.

2.1 Ground water table

Ground water is sub-surface water, but not all sub-surface water is ground water.

The upper surface of ground water is the water table. Below this surface, all the pore spaces and cracks in sediments and rocks are completely filled (saturated) with water. These saturated layers, known as the saturated zone (or the phreatic zone), are where ground water occurs. Strictly speaking only water found in the saturated zone is ground water.

2.2 Water Table Location

Borehole observation is the simplest technique. Boreholes drilled during a subsurface investigation can be kept open for 24 hours. The level of water is normally determined by lowering a tape with a float or by an electrical switching device, which is, actuated on contact with water.

In a **cohesive soil stratum**, the stabilization of water table may take time. In such situations, the location may be ascertained by adopting the **extrapolation method**. In this case, a plot of water level versus time is made and the groundwater level is estimated by extrapolating the curve until it becomes parallel to the time axis. If several levels are noted at equal time intervals the following computational method is used.

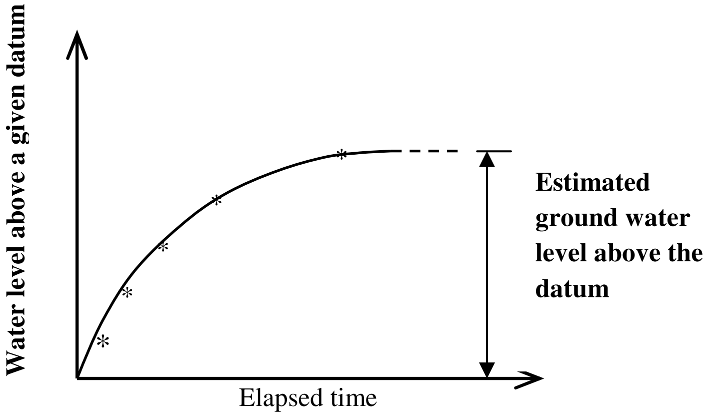


Fig.2.1 Water level versus elapsed time

2.3 Rising water level method

This method is normally used for determining the water table location. This method is also referred to as the *time lag method or computational method*. It consists of bailing the water out of the casing and then observing the rate of rise of water level in the casing at intervals of time until the rise in water level becomes negligible. The rate is observed by measuring the elapsed time and the depth of the water surface below the top of the casing. The intervals at which the readings are required will vary somewhat with the permeability of the soil. In no case should the elapsed time for the readings be less than 5 minutes. In freely draining materials such as sands, gravels etc., the interval of time between successive readings may not exceed 1 to 2 hours, but in soils of low permeability such as fine sand, silts and clays, the intervals may rise from 12 to 24 hours, and it may take a few days to determine the stabilized water level.

Let the time be t_o when the water table level was at depth H_o below the normal water table level (Ref Fig. 2.2). Let the successive rise in water levels be h_1, h_2, h_3 etc., at times t_1, t_2, t_3 respectively, wherein the difference in time $(t_1 - t_o)$, $(t_2 - t_1)$, $(t_3 - t_2)$, etc., *is kept constant*.

Now, from Fig.

$H_o - H_1 = h_1$

$H_1 - H_2 = h_2$

$H_2 - H_3 = h_3$

Let $(t_1 - t_o) = (t_2 - t_1) = (t_3 - t_2)$ etc $= \Delta t$

The depths H_o, H_2 , H_3 of the water level in the casing from the normal water table level can be computed as follows:

$$H_o = \frac{h_1^2}{h_1 - h_2}$$

$$H_1 = \frac{h_2^2}{h_1 - h_2}$$

$$H_2 = \frac{h_3^2}{h_2 - h_3}$$

Let the corresponding depths of water table level below the ground surface be h_{w1}, h_{w2}, h_{w3} etc. Now we have

First estimate, $h_{w1} = H_w - H_o$

Second estimate, $h_{w2} = H_w - (h_1 + h_2) - H_1$

Third estimate, $h_{w3} = H_w - (h_1 + h_2 + h_3) - H_2$

Where, H_w is the depth of water level in the casing from the ground surface at the start of the test. Normally $h_{w1} = h_{w2} = h_{w3}$; if not an average value gives h_w, the depth of ground water table.

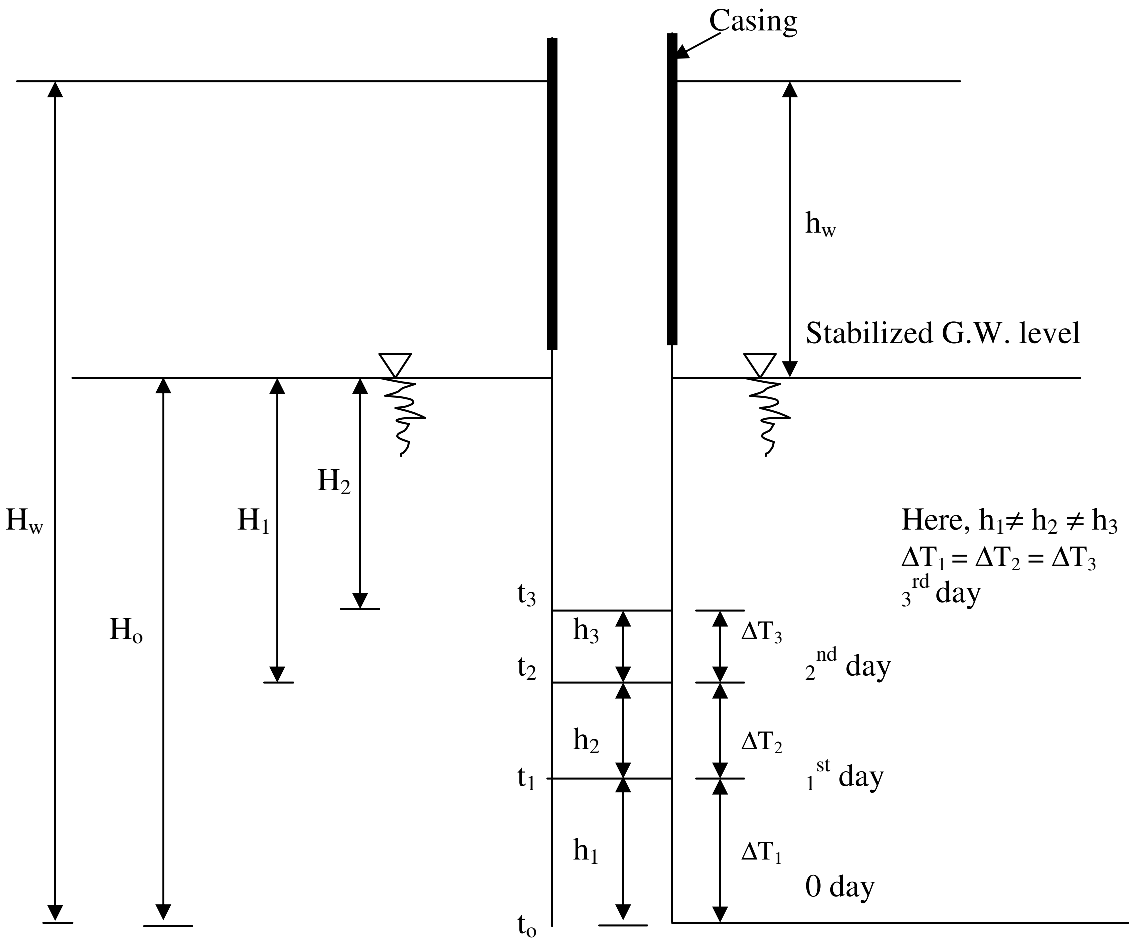


Fig.2.2 Rising water level method of location of ground water level.

Numerical Example

2.1 Establish the location of ground water in a clayey stratum. Water in the borehole was bailed out to a depth of 10.5 m below ground surface, and the rise of water was recorded at 24 hour intervals as follows

$h_1 = 0.63$ m , $h_2 = 0.57$ m, $h_3 = 0.51$ m

Solution:

$$H_o = \frac{h_1^2}{h_1 - h_2} = \frac{0.63^2}{(0.63 - 0.57)} = 6.615\,m$$

$$H_1 = \frac{h_2^2}{h_1 - h_2} = \frac{0.57^2}{(0.63 - 0.57)} = 5.415\,m$$

$$H_2 = \frac{h_3^2}{h_2 - h_3} = \frac{0.51^2}{(0.57 - 0.51)} = 4.335\,m$$

1st day $h_{w1} = H_w - H_o = 10.5 - 6.615 = \underline{3.885\text{ m}}$

2nd day $h_{w2} = H_w - (h_1 + h_2) - H_1 = 10.5 - (0.63 + 0.57) - 5.415 = \underline{3.885\text{ m}}$

3rd day $h_{w3} = H_w - (h_1 + h_2 + h_3) - H_2 = 10.5 - (0.63 + 0.57 + 0.51) - 4.335$

$= \underline{4.455\text{ m}}$

2.4 Dewatering

Dewatering means "*the separation of water from the soil*," or perhaps "*taking the water out of the particular construction problem completely*."

2.5 Control of ground water during excavation

In many situations water table may be encountered at a shallow depth below the ground level. The presence of water table may create difficulties while excavating soil to place foundations. It may also lead to instability problems. To overcome this it is essential to do dewatering.

Thus the main purpose of construction dewatering is to control the surface and subsurface hydrologic environment in such a way as to permit the structure to be constructed "in the dry."

2.6 Purposes for dewatering

2.6.1 During construction stage

- Provide a dry excavation and permit construction to proceed efficiently
- Reduce lateral loads on sheeting and bracing in excavations
- Stabilize "quick" bottom conditions and prevent heaving and piping
- Improve supporting characteristics of foundation materials
- Increase stability of excavation slopes and side-hill fills
- Cut off capillary rise and prevent piping and frost heaving in pavements
- Reduce air pressure in tunneling operations

2.6.2 Post construction stage

- Reduce or eliminate uplift pressures on bottom slabs and permit economics from the reduction of slab thicknesses fro basements, buried structures, canal linings, spillways, dry docks, etc.,
- Provide for dry basements
- Reduce lateral pressures on retaining structures
- Control embankment seepage in all dams
- Control seepage and pore pressures beneath pavements, side-hill fills, and cut slopes.

2.7 Methods of dewatering

There are several methods commonly used to drain or dewater a construction site:

- *Gravity flow*
- *Pumping and Vacuum*
- *Electro-Osmosis.*

2.7.1Gravity Flow Method

Done through channels and ditches

- This is the less costly method.
- The site is drained through channels placed at intervals, that permit the water to flow away from the high points.
- This method has been used for thousands of years.
- It has the disadvantage of requiring a long time to properly drain the land.

2.7.2 Pumping and Vacuum Method

Done through Open sumps and Ditches, Well points system and Vacuum

- This method is more expensive than gravity, but is faster in results.
- It requires pumps that suck the water out of the soil and remove it to a distant place or river or lake.

2.7.3 Electro-Osmosis

- This method is most expensive
- It is only effective method of dewatering in deep clay soils.

2.8. Dewatering - Open Excavation by Ditch and Sump

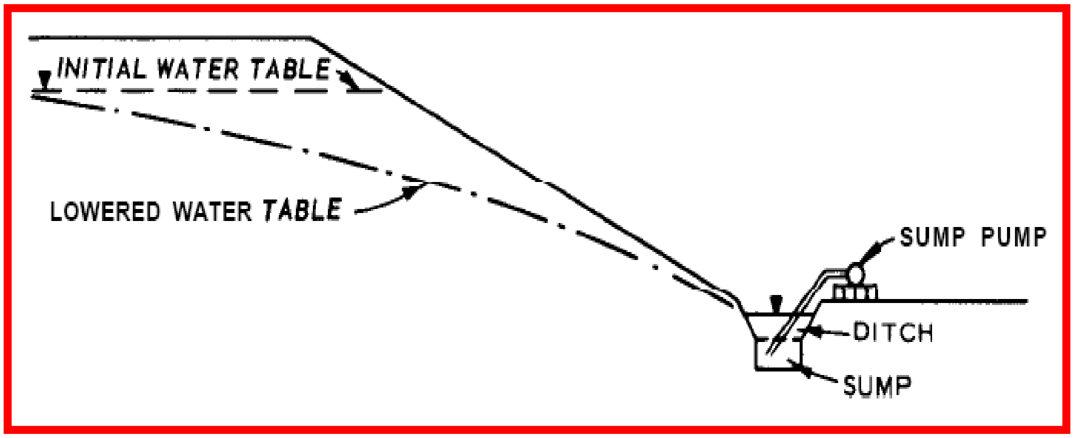


Fig.2.3 Dewatering by ditch and sump

Plate 2.1 Water being dewatered from a ditch

Plate 2.2 Water being dewatered from an open sump

2.8.1 Advantages of Open Sump and Ditches

- Widely used method
- Most economical method for installation and maintenance
- Can be applied for most soil and rock conditions
- Most appropriate method in situation where boulders or massive obstructions are met with in the ground

Note: Greatest depth to which the water table can be lowered by this method is about 8 m below the pump.

2.8.2 Disadvantages of Open Sump and Ditches

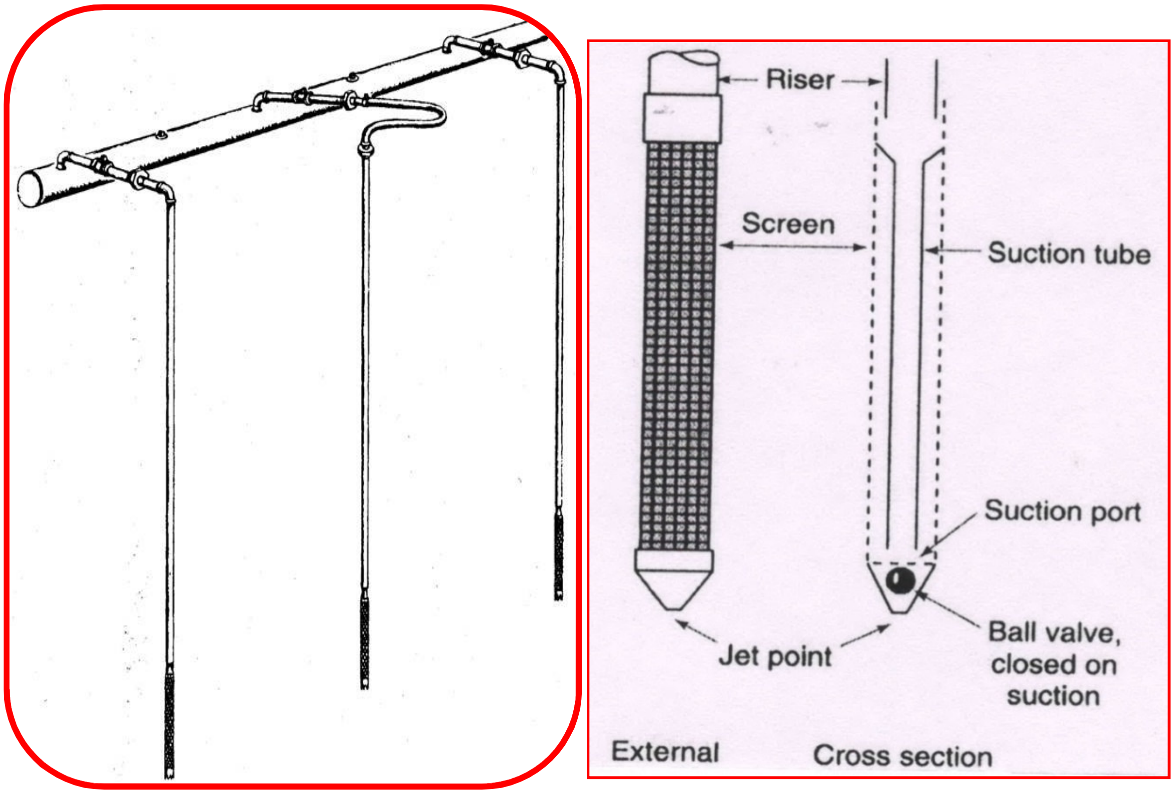
- Ground water flows towards the excavation with high head or a steep slope and hence there is a risk of collapse of sides.
- In open or timbered excavations there is risk of instability of the base due to upward seepage towards pumping sump.

2.9. Well points

Small pipes, 50-80 mm in diameter, connected to screens at the bottom and to a vacuum header pipe at the surface constitute a well point system.

2.9.1 Details of Well points

- Small well-screens of sizes of 50 to 80 mm in diameter and 0.3 to 1 m length.
- Either made with brass or stainless-steel screens
- Made with either closed ends or self jetting types
- Plastic (nylon mesh screens surrounding flexible riser pipes) well point system used in situations requiring long period presence ground (e.g., for dewatering dry dock excavation).



a) Well point assembly **b) Details of well point assembly**

Fig.2.4 Well point system

2.9.2 Well-point system

- A well point system consists of a number of well points spaced along a trench or around an excavation site.
- These well points in turn are all connected to a common header that are attached to one or more well point pumps.
    - Well point assemblies-are made up of a well point, screen, riser pipe, and flexible hose swinger and joint with tuning.
    - These are generally installed by jetting.
    - They provide for entry of water into the system by creation of a partial vacuum.

•The water is then pumped off through the header pipe.

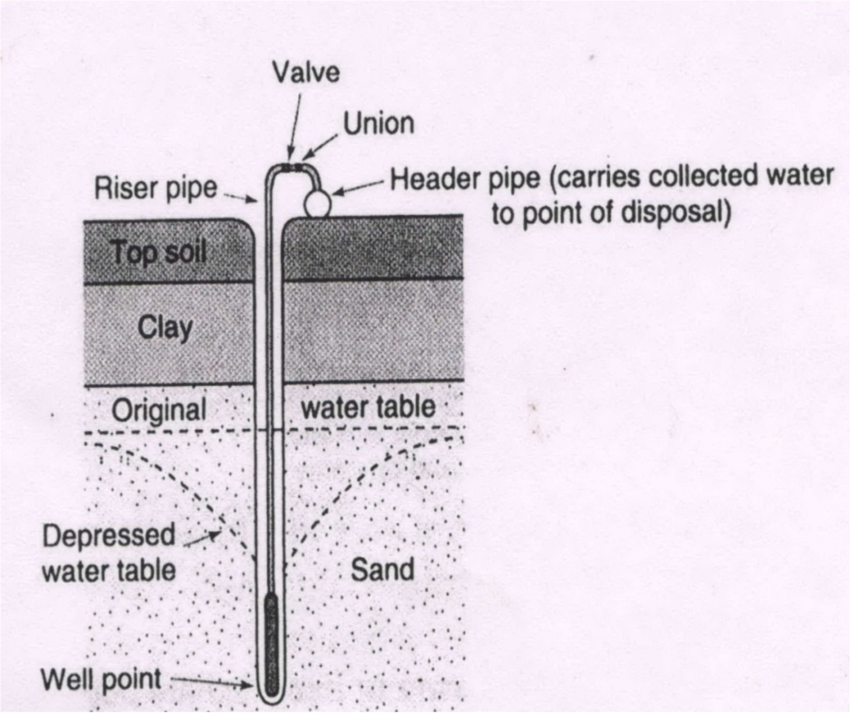


Fig. 2.5 Cross section of a typical well-point system

(a) **(b)**

Plate 2.3 Well point arrangement

2.9.3 Single Stage Well-point system

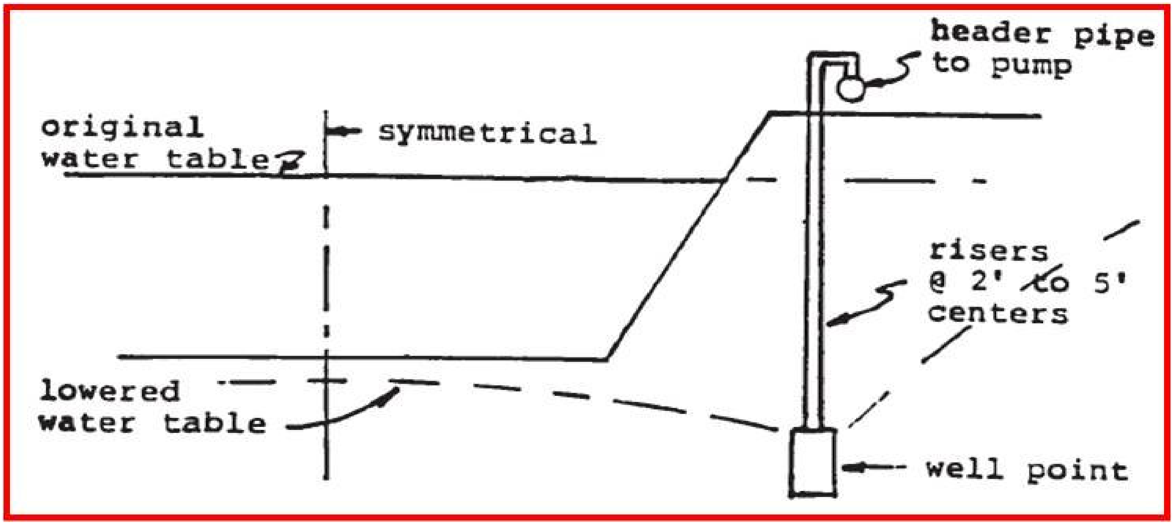


Fig. 2.6 Single-stage well-point system

2.9.4 Depth of lowering water table through well point system

- Well point systems are frequently the most logical and economical choice for dewatering construction sites where the required lowering of ground water level is approximately 6 m (20 feet) or less. However, greater lifts are possible by lowering the water in two or more stages.
- The 20-foot lift restriction results from the fact that the water is lifted by difference between ambient air pressure and the lowered pressure created by the pump.

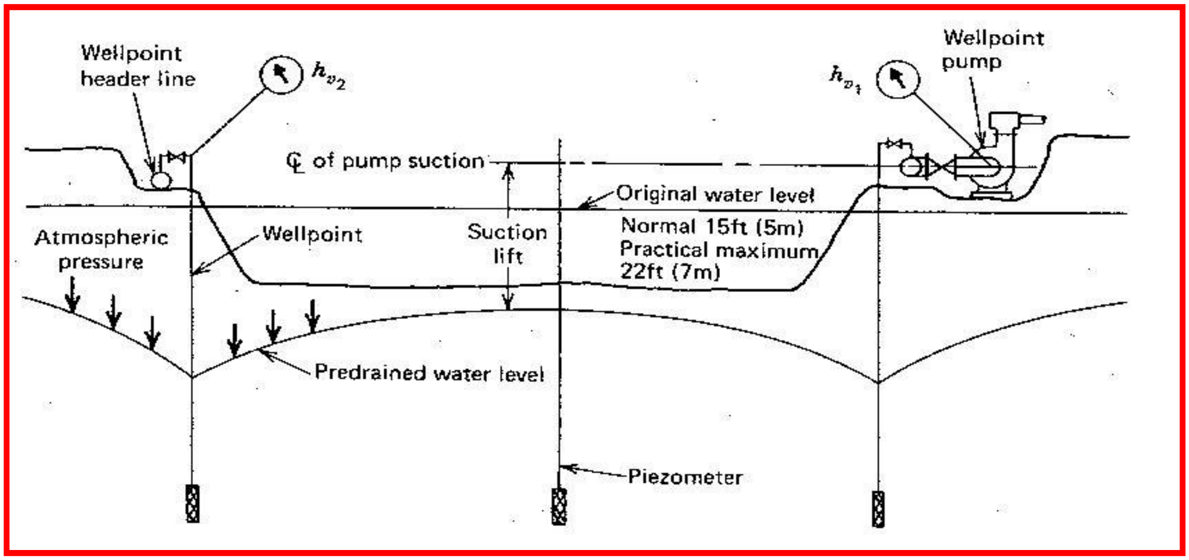
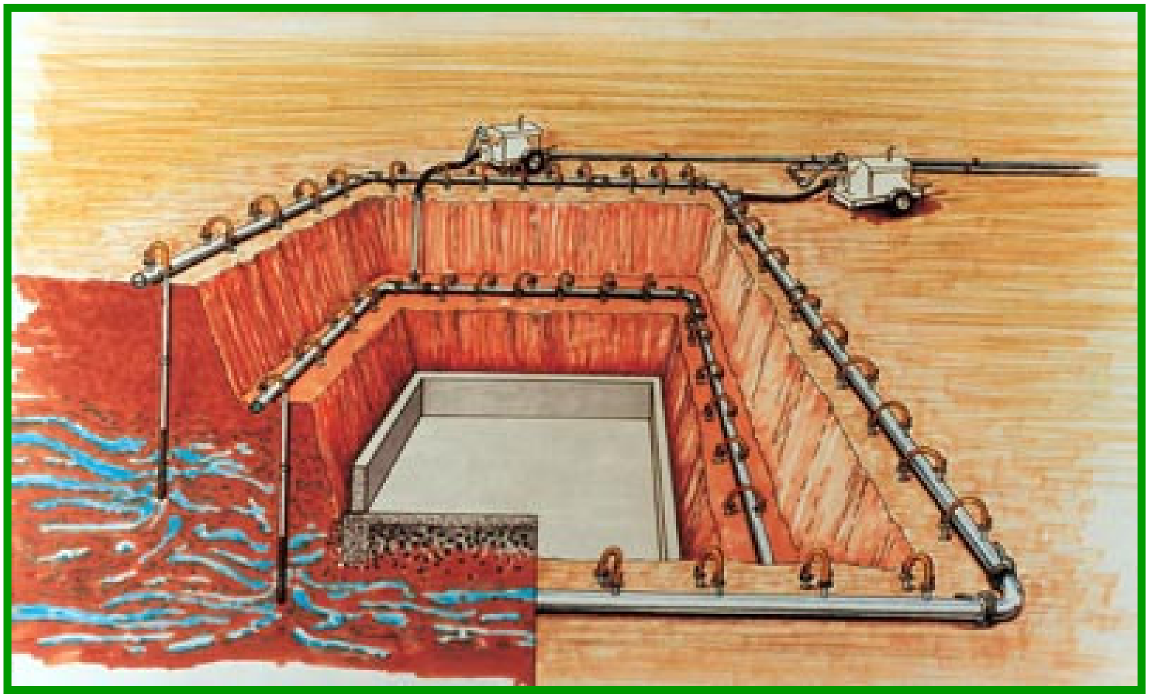


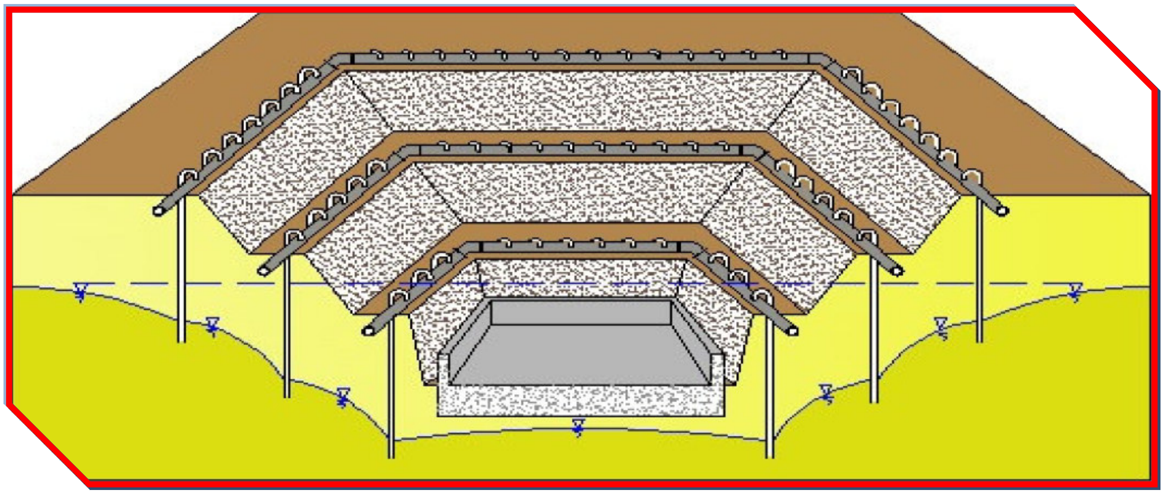
Fig. 2.7 Depth of lowering water table through well point system

2.9.5 Multi - Stage Well Point System

Greater lifts are possible by lowering the water in two or more stage



(a)



(b)

Plate 2.4 Multi-stage well point arrangement

2.9.6 Spacing of well point system

- *Depends on the permeability of the soil.*
- *Availability of time to effect the drawdown*

2.9.7 General guidelines

- In fine to coarse sands or sandy gravels – 0.75 to 1 m is satisfactory
- Silty sands of fairly low permeability – 1.5 m is suitable
- In highly permeable coarse gravels – as close as 0.3 m centres

In a typical system, well points are spaced at intervals of from 3 to 10 feet.

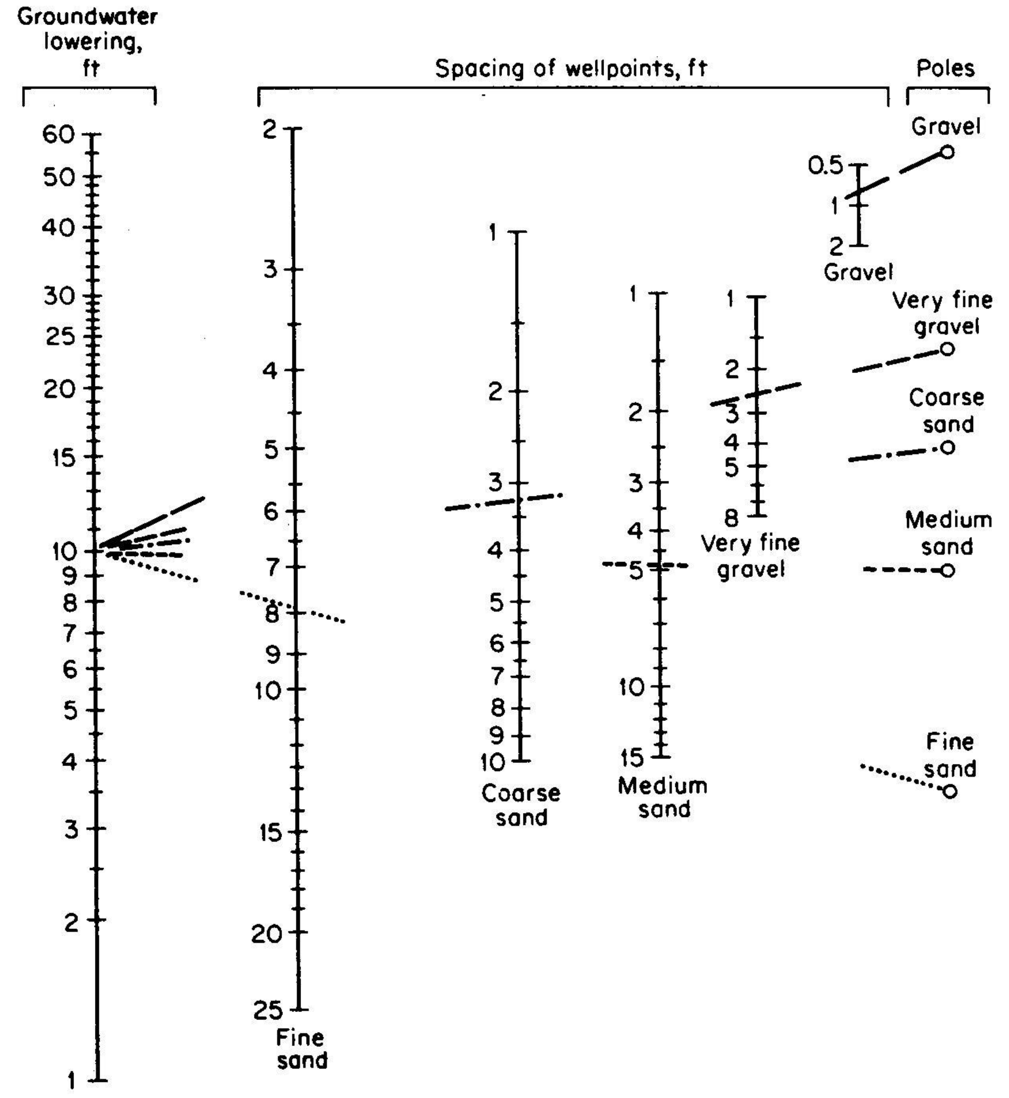


Fig. 2.8 Nomogram to find the spacing of well point system in granular soils as suggested in IS:

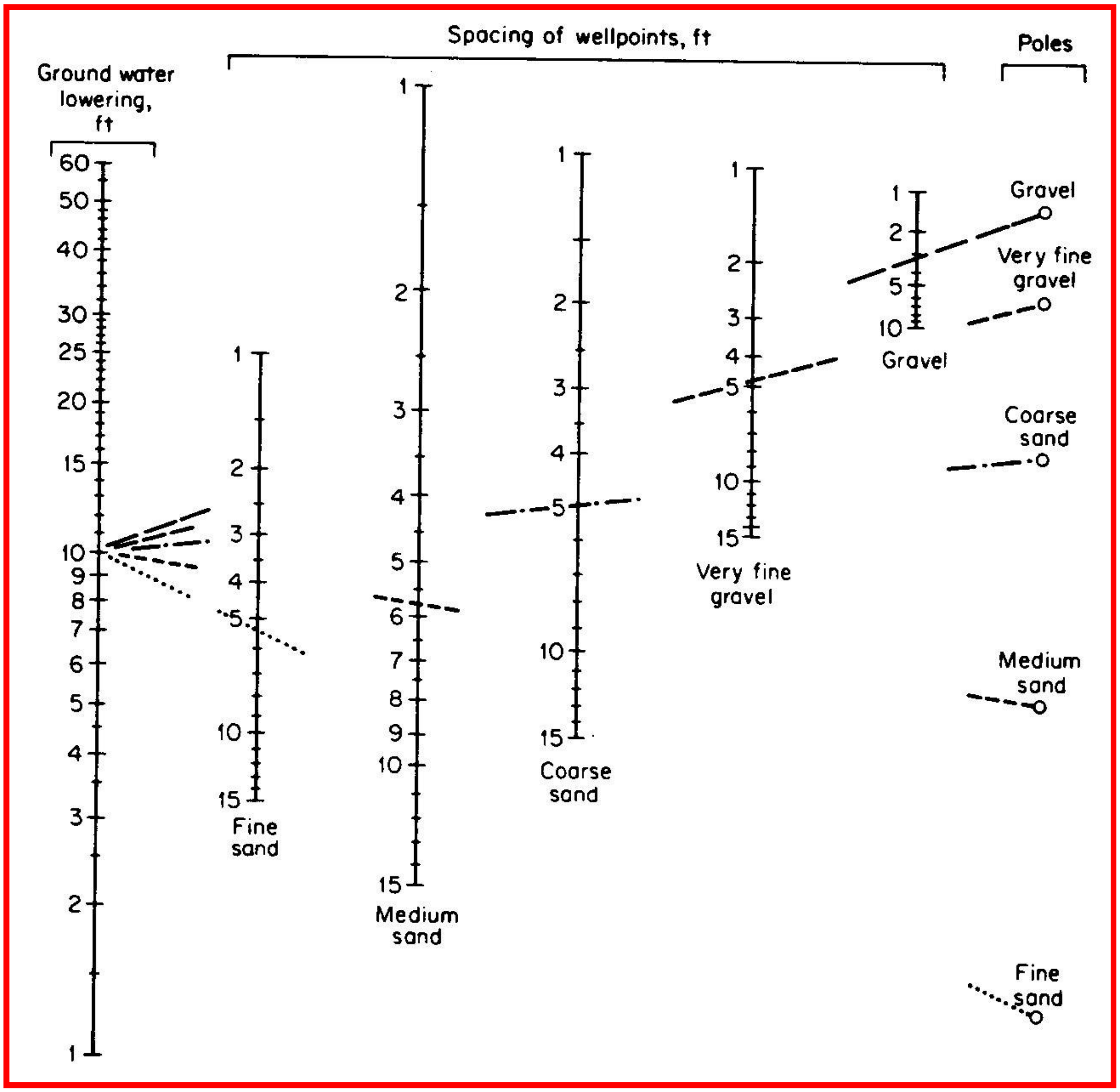


Fig. 2.9 Nomogram to find the spacing of well point system in stratified soils as suggested in IS:

2.9.8 Well point system

In general a well point system comprises 50 to 60 well points to a single 150 or 200 mm pump with a separate Jetting pump. The well point pump has an air/water separator and a vacuum pump as well as the normal centrifugal pump

2.9.9 Suitability of well point system

- Practical and effective under most soil and hydrological conditions.
- Suitable in shallow aquifers where the water level needs to be lowered

no more than 15 or 20 feet.

- Site is accessible
- Most effective in sands and sandy gravels of moderate permeability

2.9.10 Situations where other systems of dewatering of are preferred to Well point system

- Where water levels must be lowered greater distance than can be practically handled by the well point systems
- where greater quantities of water must be moved than is practical with well points
- where the close spacing of well points and the existence of the above-ground header might physically interfere with construction operations.

2.9.11 Capacity of well point system

The capacity of a single well point with a 50 mm riser is about 10 litres/min. Depending on their diameter and other physical characteristics, each well point can draw from 0.1 to 25 gallons and more per minute. Total systems can have capacities exceeding 20 000 gallons per minute (Gallon is a measure of capacity equal to eight pints and equivalent to 4.55 litres (British); equivalent to 3.79 litres (U.S); used for liquids).

2.9.12 Design considerations of well-point system of dewatering

When designing a well point system, it is necessary to give first consideration to the physical conditions of the site to be dewatered.

Following is the list of information to be collected:

- The physical layout
- Adjacent areas
- Soil conditions
- Permeability of the soil
- The amount of water to be pumped
- Depth to imperviousness
- Stratification

2.9.13 Advantages of well point system

- Installation is very rapid
- Requires reasonably simple and less costly equipment
- Water is filtered and carries little or no soil particles.
- There is less danger of subsidence of the surrounding ground than with open-sump pumping

2.9.14 Limitations of well point system

- A lowering of about 6 m (20 ft) below pump level is generally possible beyond which excessive air shall be drawn into the system through the joints in the pipes, valves, etc., resulting in the loss of pumping efficiency.
- If the ground is consisting mainly of large gravel, stiff clay or soil containing cobbles or boulders it is not possible to install well points.

2.10 Deep-well dewatering

Deep well systems consist of one or more individual wells, each of which has its own submersible pump at the bottom of the well shaft. Such systems are particularly suitable where large volumes of water in highly permeable sand and gravel areas permitting rapid recharging of ground water from surrounding areas exist. Fig. 2.10 shows the range of permeability under which the deep well system is applicable.

2.10.1 Deep well system

A typical deep well consists of a drilled hole within which is a lower screened casing which admits water to the pump; an upper casing which prevents soil from reaching the pump and, within the casing, the pump and its discharge pipe. The discharge pipe supports the pump to which it is attached. Electrical wiring for the pump motor runs between the discharge pipe and the casing. The space between the drilled hole and the casing is normally packed with filter material (for example, coarse sand and/or gravel) to minimize the pumping of solid material from the soil surrounding the well.

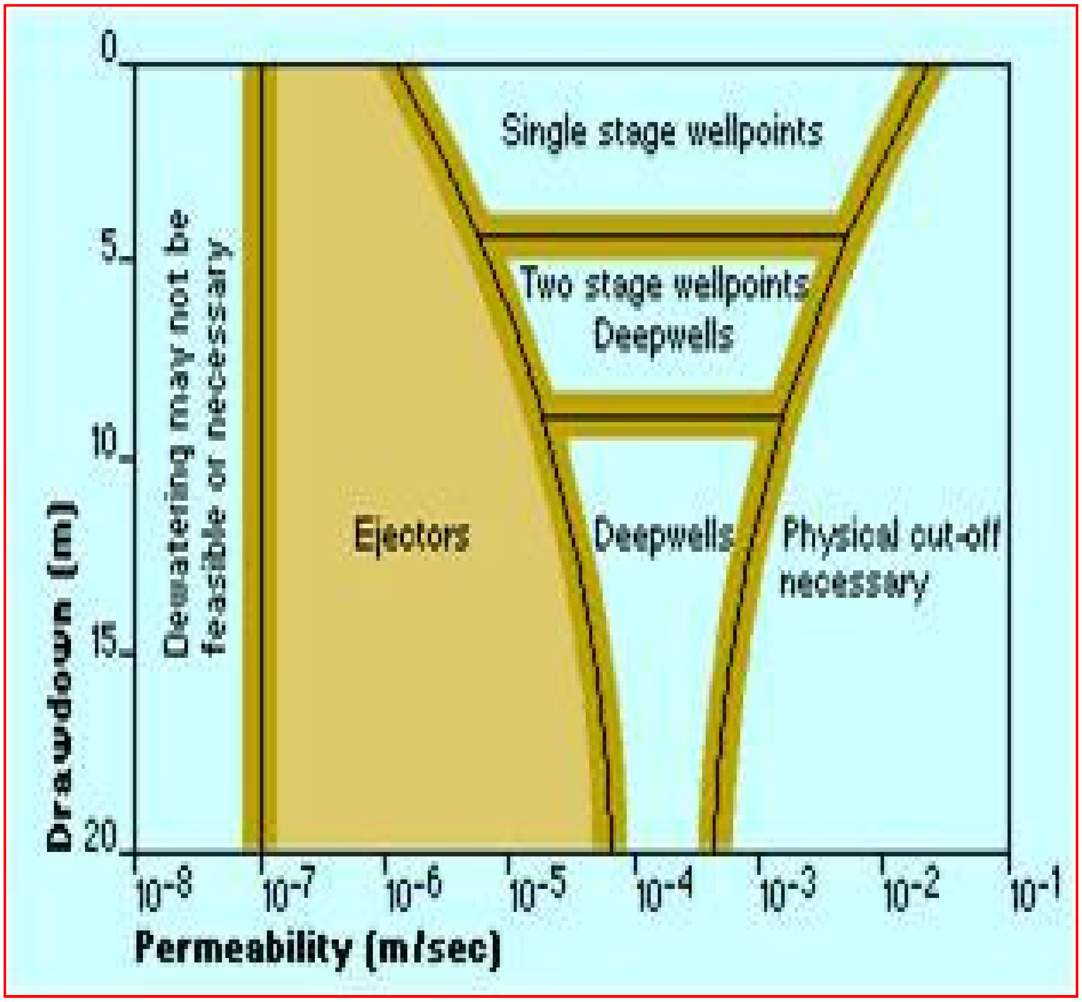


Fig. 2.10 Robert's diagram showing the range of soil permeability under which the deep well system is applicable

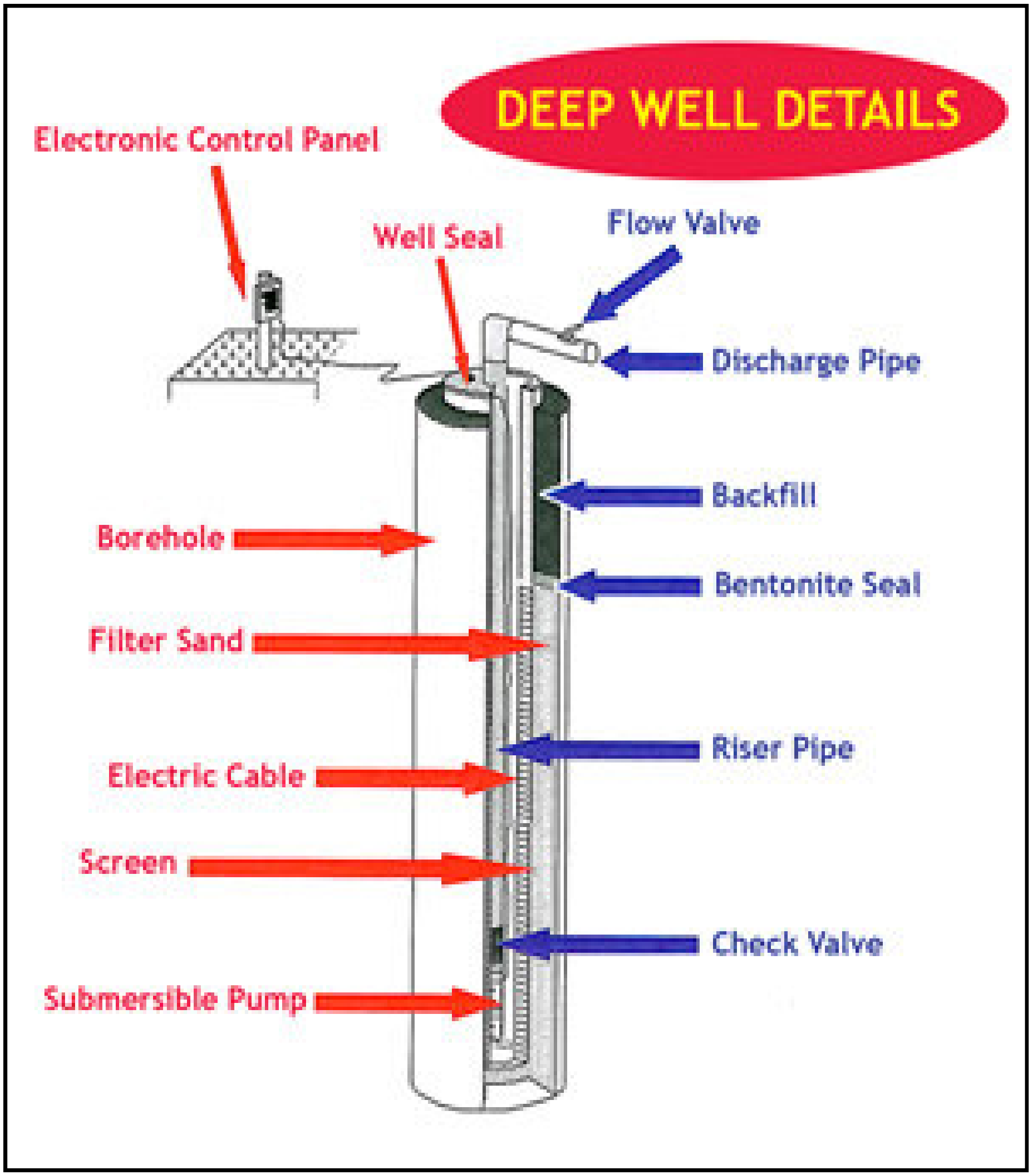


Fig. 2.10 Details of a deep well

Plate 2.5 Installed deep well point

2.10.2 Spacing of deep well point system

Normally, individual wells are spaced at an approximate distance of 15 m (50 feet) apart. However, depending upon soil conditions and the dewatering plan the spacing may need to be just a few meters apart.

2.10.3 Dewatering Capacity of deep well point system

Individual well capacities are from 21 to 3 000 gallons per minute and with total systems the capacities can be as high as 60 000 gallons per minute. Deep well pumps can lift water 30 m (100 feet) or more in a single stage and the variation of the typical deep well system is a pressure within an aquifer. Deep well points require no pump as the water is forced to the surface by its own pressure. To boost the water flow a vacuum pump is frequently used.

2.10.4 Design considerations of deep well-point system of dewatering

When designing a deep well point system, it is necessary to take into consideration the following:

- The soil investigation report
- The grain size analysis and permeability tests
- The hydrology of the area
- The topography
- The space limitations of the site and surrounding structure.
- The projected method of excavation and shoring if any
- The construction schedule

2.11 Vacuum dewatering or Ejector/Eductor dewatering systems

Ejector/Eductor dewatering systems are employed to control pore pressures and to lower groundwater levels to provide stable working conditions in excavations. They are particularly suited to operating in fine soil conditions. Fig. 2.10 shows the range of permeability under which the Eductor system is applicable.

Eductor systems are able to extract groundwater and generate a high vacuum at the base of wells up to 50 m deep and of as little as 50 mm diameter. Vacuum drainage can provide dramatic improvement in the stability of silty fine sands and laminated silts and clays by the control of excess pore pressures. Eductor wells have been successfully installed in raking boreholes to dewater beneath inaccessible areas such as railway lines and canals.

2.11.1 Working of Eductor dewatering system

Supply pumps at ground level feed high-pressure water to each Eductor well head via a supply main. The supply flow passes down the well and through a nozzle and venturi in the Eductor. The flow of water through the nozzle generates a vacuum in the well and draws in groundwater. The supply flow and extracted groundwater mix, return to the surface and feed back to the pumping station via a return main. The return flow is used to prime the supply pumps and the excess water extracted is discharged by overflow from the priming tank. A single pumping station can be used to operate up to about 75 Eductor wells installed in an appropriate array around the works.

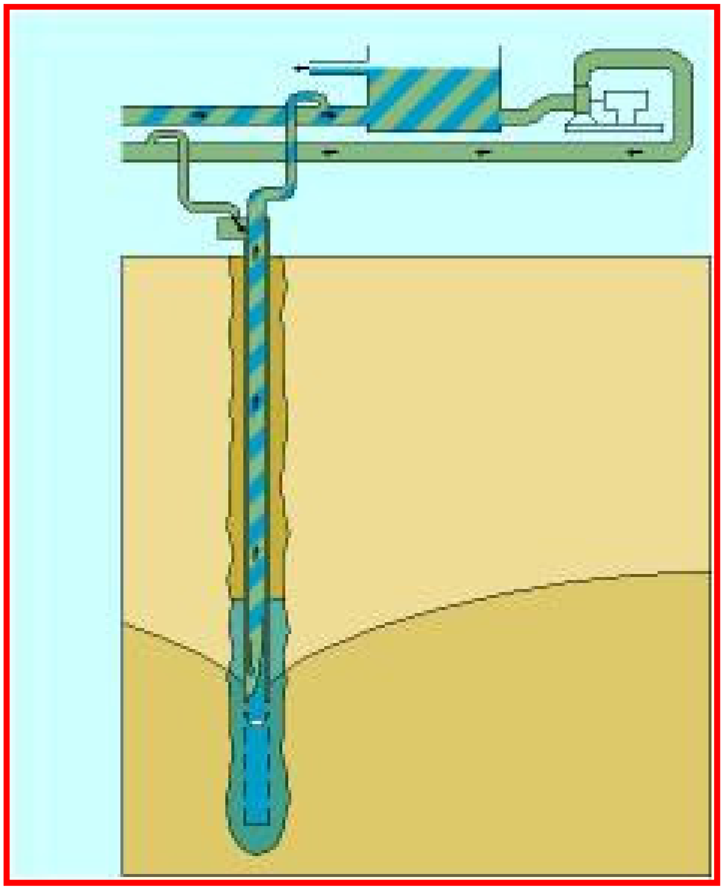


Fig. 2.11 working principle of an Eductor well system

(a) (b)

Plate 2.6 Installed Eductor well point system

Plate 2.7 Pump used in Eductor well point system

2.11.2 Advantages of Eductor dewatering system

- They are flexible in level and layout
- Stable in operation
- Able to run dry without damage
- Not limited by depth. Also effective to greater depths
- Best in low-yielding wells
- Energy intensive
- Venturi in base of well creates vacuum

2.12 Electro-Osmosis

Dewatering Technique of dewatering done through the use of cathodes and anodes with passage of Electrical current.

Electro-osmosis is defined as "*the movement of water (and whatever is contained in the water) through a porous media by applying a*
direct current (DC) field".

It is the only effective method of dewatering in deep clay soils.

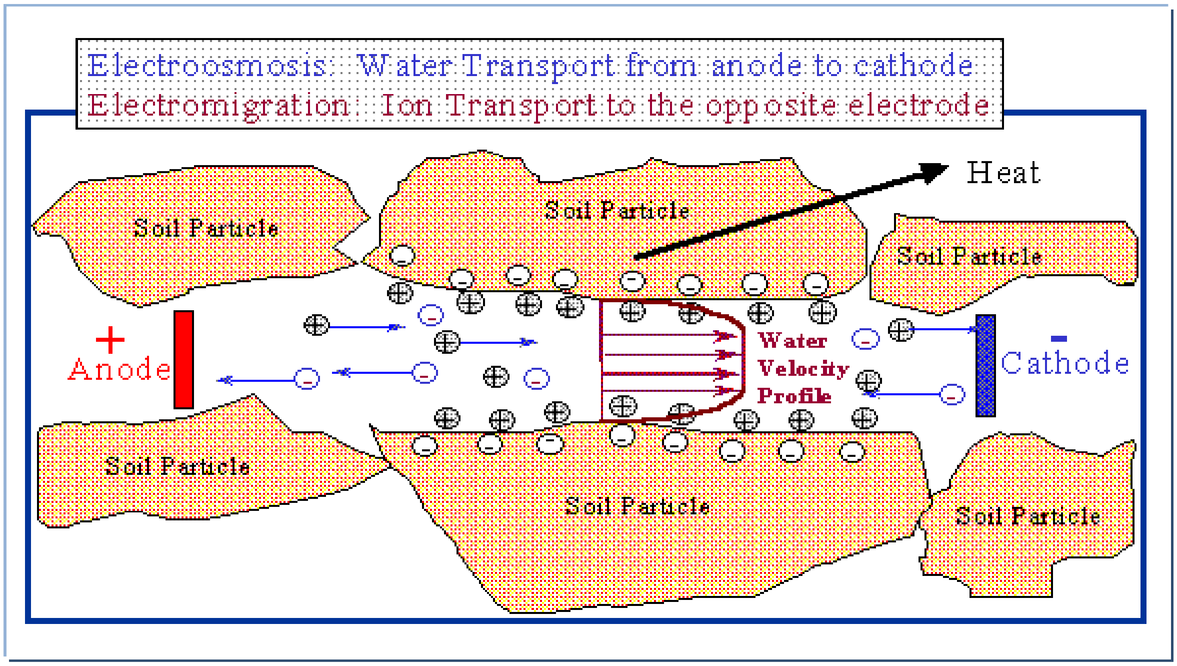


Plate 2.8 Principle of Electro-Osmosis

2.12.1 Mechanism of Electro-osmosis

When electrodes are placed across a clay mass and a direct current is applied, water in the clay pore space is transported to the cathodically charged electrode by electro-osmosis. Electro-osmotic transport of water through a clay is a result of diffuse double layer cations in the clay pores being attracted to a negatively charged electrode or cathode. As these cations move toward the cathode, they bring with them water molecules that clump around the cations as a consequence of their dipolar nature. In addition, the frictional drag of these molecules as they move through the clay pores help transport additional water to the cathode. The macroscopic effect is a reduction of water content at the anode and an increase in water content of the clay at the cathode. In particular, free water appears at the interface between the clay and the cathode surface. This excess of free water at the cathode has lubricating effects.

2.12.2 Effectiveness of Electro-osmosis

Electro-osmosis provides the follwing benefits when properly applied:

- First, electro-osmosis provides uniform pore water movement in most types of soil. Since the boundary layer movement towards the cathode provides the motive force for the bulk pore water, the size of the pore is not important.
- Unlike hydraulic conductivity, electro-osmotic flow rate is NOT sensitive to pore size. Electro-osmotic flow rate is primarily a function of applied voltage. The electro-osmotic permeability for any soil at 20^{o}C is around 1×10^{-5} cm/s at 1 volt/cm.
- The entire soil mass between the electrodes is basically treated equally.

This is why electro-osmosis is so effective in clayey and heterogeneous soils.

2.13 Typical past VTU Exam questions

1. List the methods of control ground water during excavation (Dewatering methods). Explain any one. [6 M – VTU – July 2006-New Scheme]
2. Estimate the position of the Ground water table from the following data obtained from filed. Depth up to which water is bailed out is 32 m. Water rise on first day 2.4 m, second day 2.0 m and third day 1.6 m. [4 M – VTU – July 2006-New Scheme]
3. Write short note on Vacuum method of dewatering

   [5 M – VTU – Dec-08/Jan-09- 2002 Scheme]