UNIT 2: HYDRAULIC MODIFICATION

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PRINCIPLE OF GROUND IMPROVEMENT BY DRAINAGE

The hydraulic modification process is aimed to improve fine grained saturated cohesive soil by consolidation resulting in a net decrease in the water content of the soil mass.

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DEWATERING DEFINITION

Dewatering is one type of temporary measure taken to lower the groundwater level so that excavation can take place in dry, and therefore more stable, conditions.

DEWATERING METHODS

Ground water can be controlled by adopting one or more types of dewatering systems or drain appropriate to the size and depth of excavation, geological conditions, and characteristics of the soil. (i.e. Factors affecting the dewatering system).

Following are the **different dewatering methods** :

1) Sumps, trenches, and pumps
2) Well point systems
3) Deep well drainage
4) Vacuum dewatering system
5) Electro-osmosis method

(1) Sumps, trenches, and pumps

- This is the simplest (and oldest) form of dewatering used in the shallow excavations in coarse grained soils whose permeability is greater than 10^{-3} cm/sec.
- Shallow pits, called sumps are dug along the periphery of the area - drainage ditches.

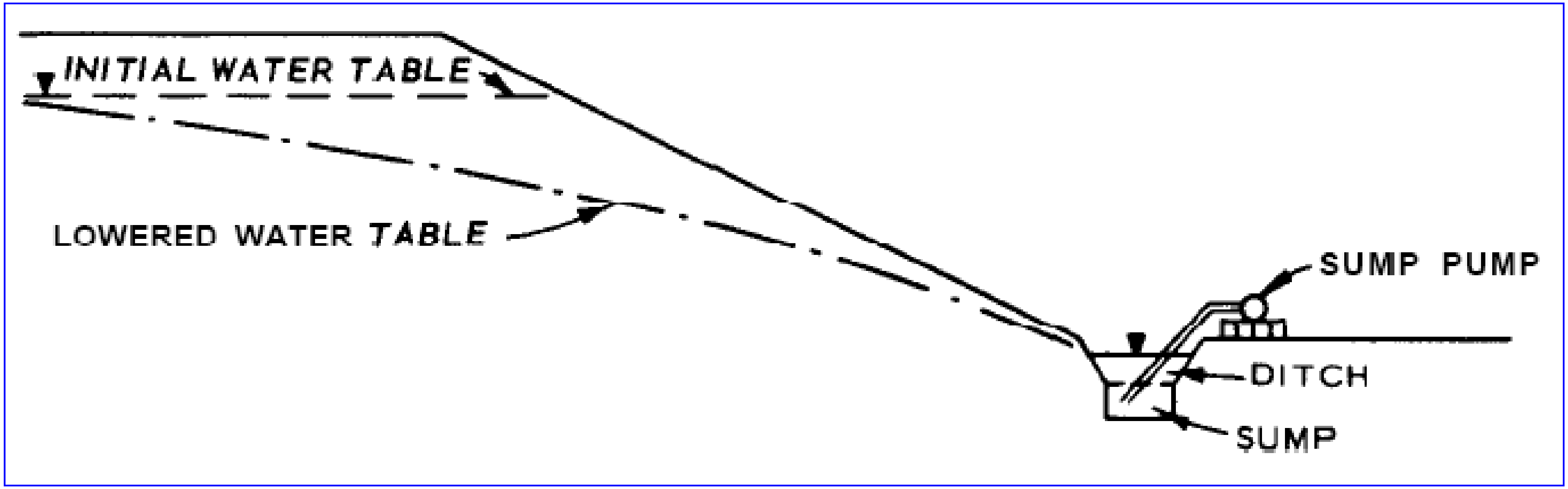
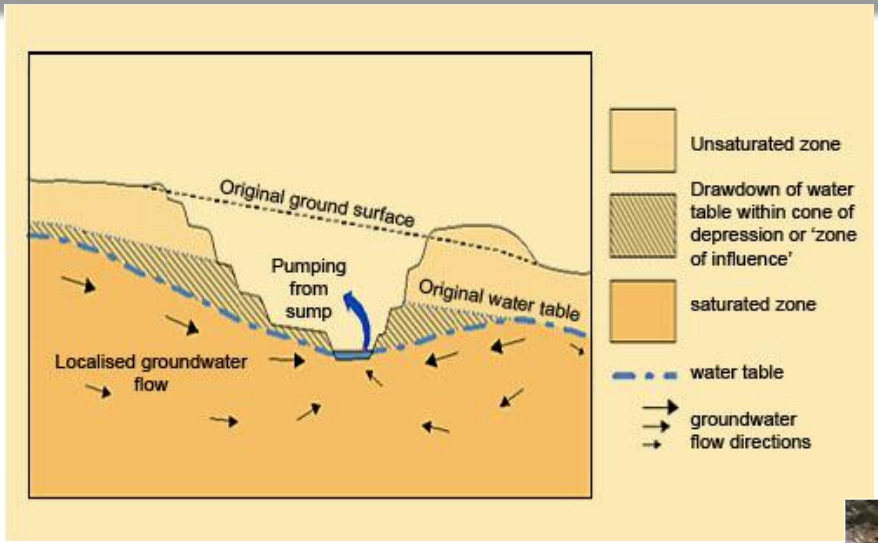
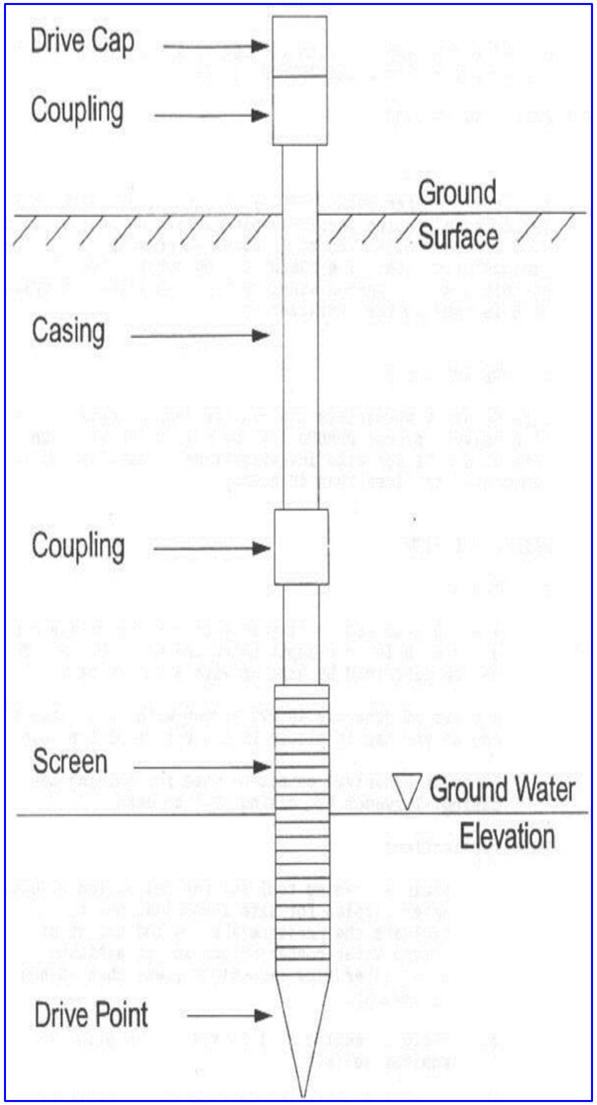


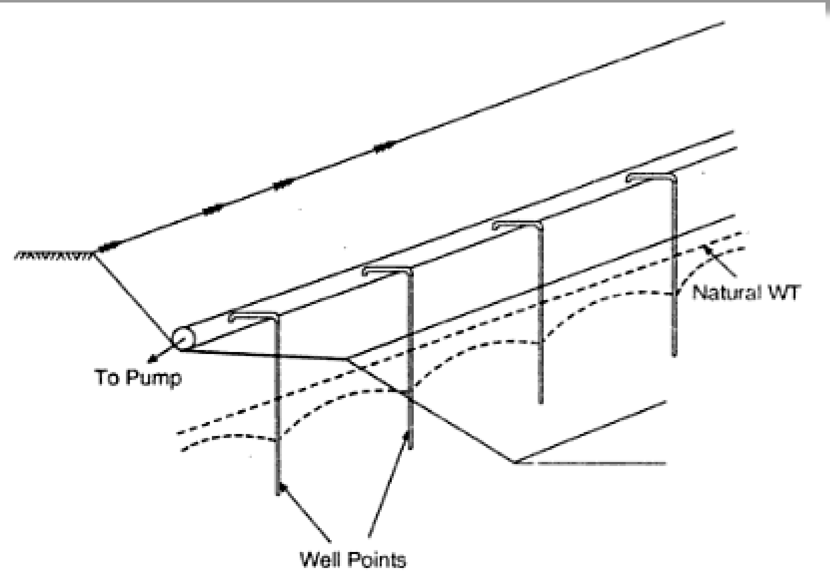
Figure: Dewatering through sump


Original ground surface
Pumping
from
sump
Original water table
Localised groundwater
flow
Unsaturated zone
Drawdown of water
table within cone of
depression or 'zone
of influence'
saturated zone
water table
groundwater
flow directions

(2) Well points

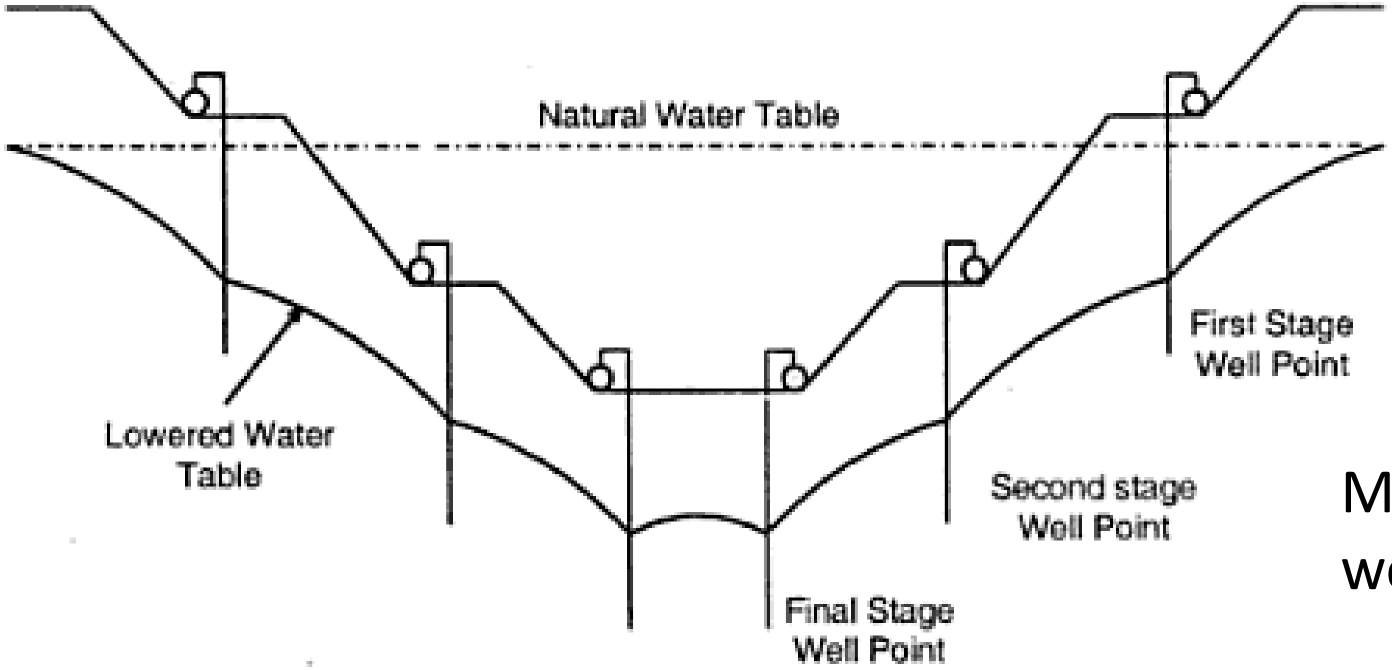
- A well point is a perforated pipe about 0.5 m to 1 m long and 5 to 8 cm in diameter covered by cylindrical wire-gauge screen. Various sizes of screen openings are available to correspond with the predominant grain size of the soil.
- A conical steel drive point is attached to the lower end of the pipe, with a ball valve fitted in the point to allow jetting of water to pass through it for driving it.




Natural WT
To Pump
Well Points

- The points are placed in a row or ring, and the riser pipes are attached through a common header pipe to a well point pump.
- For inserting the well point into ground by jetting, water is pumped down the well point under pressure from where it emerges with a great velocity through the top of the drive point.
- The hole formed around the riser pipe and the well point by jetting water is filled with coarse sand.
- When suction commences, the ball valve closes and the water is drawn in the well point only through the surrounding screen.
- Suction at the very bottom of the well point permits lowering of the ground water table.

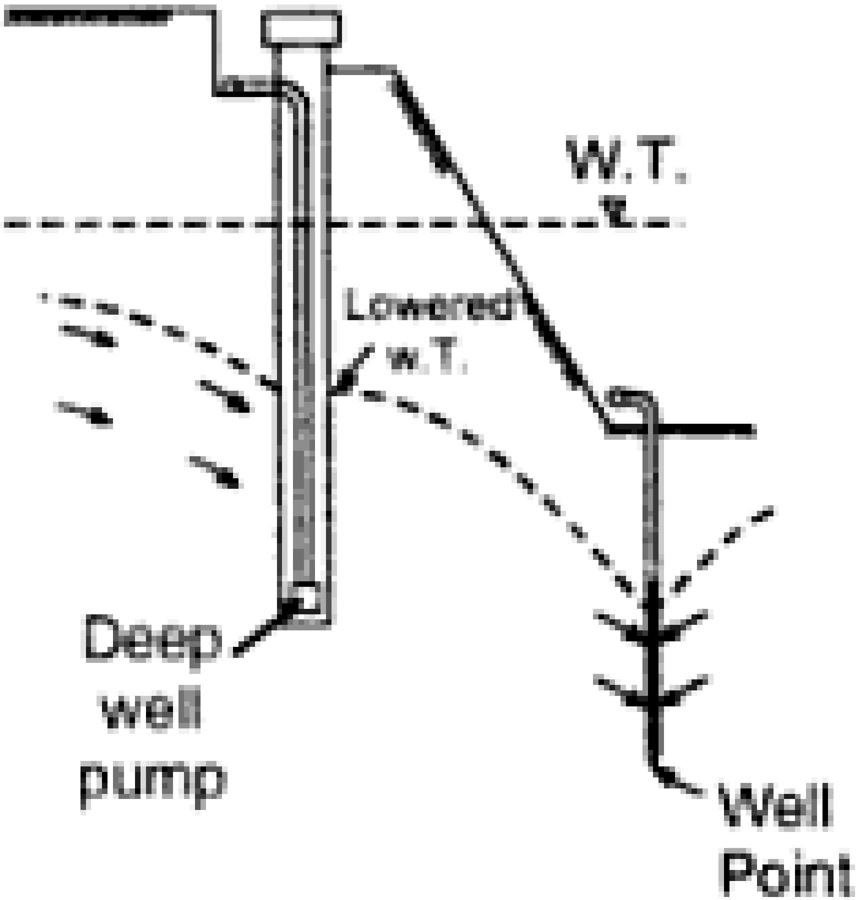
- The suction pump used in the well point system has a capacity of bringing water to the surface from a minimum depth of about 6 m.
- The well points are generally spaced between 1 to 2 m. 6 m below generally spaced.
- For dewatering excavations which are more than 6 m below the water table, a multiple stage well point system is used.



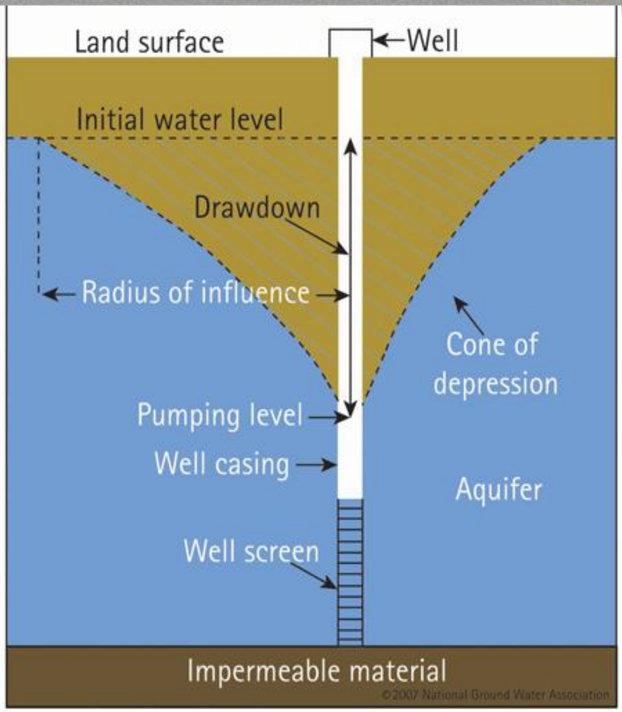
Multiple-stage well point system

(3) Deep well drainage

- When the depth of excavation is more than about 16 m below the water table, deep well drainage system may be used.
- The system is also useful where artesian water is present,
- A 15 to 60 cm diameter hole is bored and a casing with a long screen (5 to 25 cm) is provided.
- A submersible pump with a capacity to push the water upto a height of 30 m or more is installed near the bottom of the well.
- Each well has its own pump.
- Along with the deep well arranged on the outer side of the area under excavation a row of well points is frequently installed at the toe of the side slopes of the deep excavation.

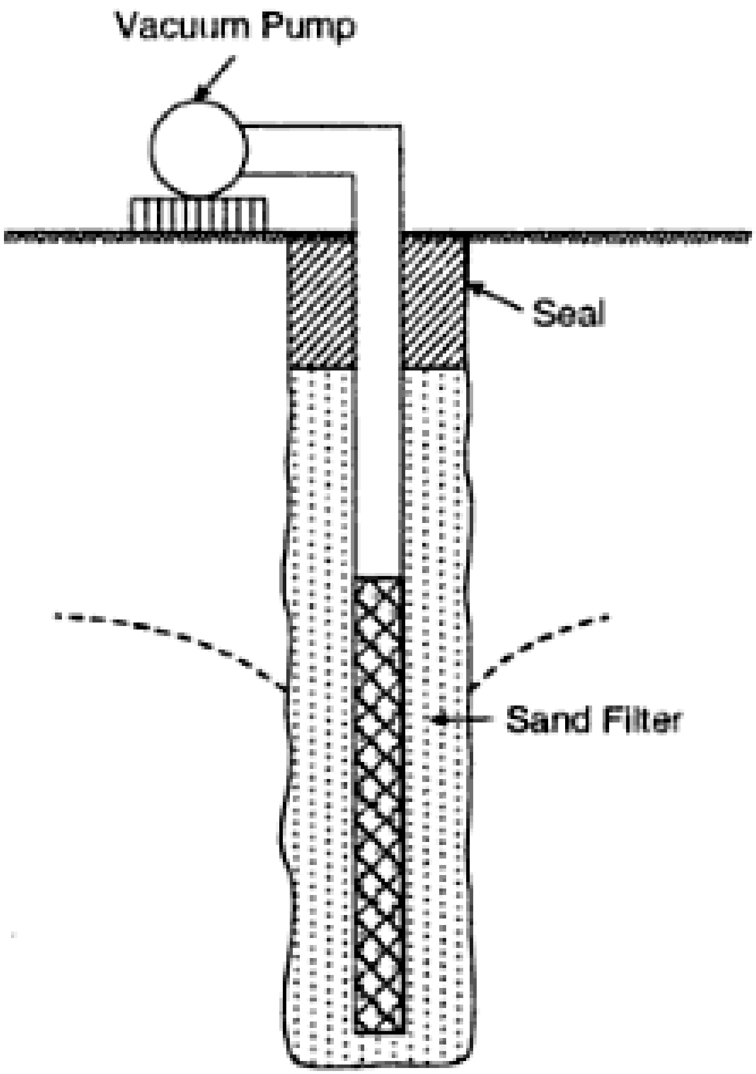


Deep well drainage system



(4) Vacuum dewatering system

- For fine-grained soils, whose permeability between 10^{-3} to 10^{-5} cm/sec, vacuum dewatering method is being used.
- In such type of soils it is necessary to apply suction head to the dewatering system.
- Both the well point system and the deep well system can be adopted for dewatering such soils by maintaining a vacuum in the well with the use of airtight seals for all points.



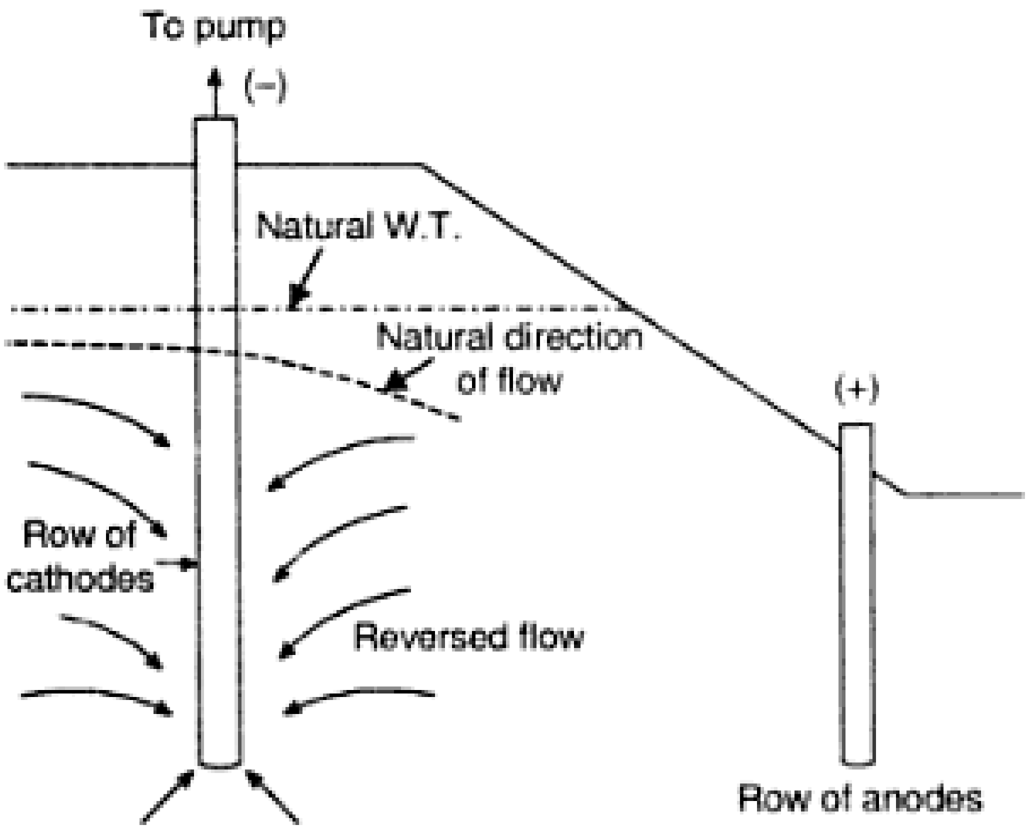
Vacuum dewatering system

Vacuum dewatering system

- A hole of about 25 cm diameter is created around the well point and the rise pipe by jetting water under sufficient pressure.
- While jetting water is still flowing, medium to coarse sand is rapidly inserted into the hole to fill it upto about 0.75 or 1 m from the top.
- The top portion of the hole is then sealed up by tamping bentonite, soil-cement or clay.
- Vacuum pumps are used to create a vacuum in the sand filling.
- When the vacuum is drawn on the well point, the ground surface is subjected to unbalanced atmospheric pressure.
- The unbalanced atmospheric pressure acting on the ground surface consolidates the sub-soil.

(5) Electro-osmosis method

- This method is applied to fine gain cohesive soil.
- If direct current is passed between two electrodes into saturated soil mass, the water will travel from the positive electrode (anode) to negative electrode (cathode).
- The cathode is made in the from of a well point or a metal tube for pumping out the seeping water.
- A steel rod, a pipe or sheet piling of excavation can serve as the anode.
- The arrangement of electrode is done in such a way that the natural direction of flow of water is reserved away from the excavation, thereby increasing the shear strength of the soil and stability of the slope.



(a) The Arrangement

DESIGN CONSIDERATION OF DEWATERING SYSTEMS

- The design of a dewatering system include estimation of the inflow quantities, permeability of the soil, the depth and plan dimensions of the excavation duration of dewatering.

Well Size

- The size of well points varies by manufacturer but is usually between about 25 and 76 mm in diameter.
- A single well point seldom discharges more than about 10 to 20 gal/min.
- The rate of flow into a pumped well or well point depends upon the area and permeability of the ground immediately outside of the well and upon the hydraulic gradient causing the flow.
- Bush (1971) gives the following formula for approximating flow into a well:

$$Q = 44\, k^{1/2} r_w h_0$$

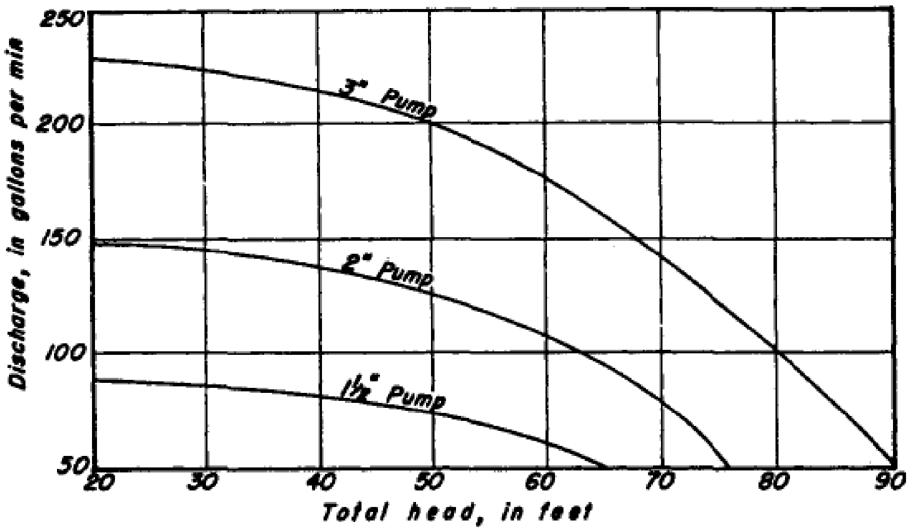
k = permeability, ft/min

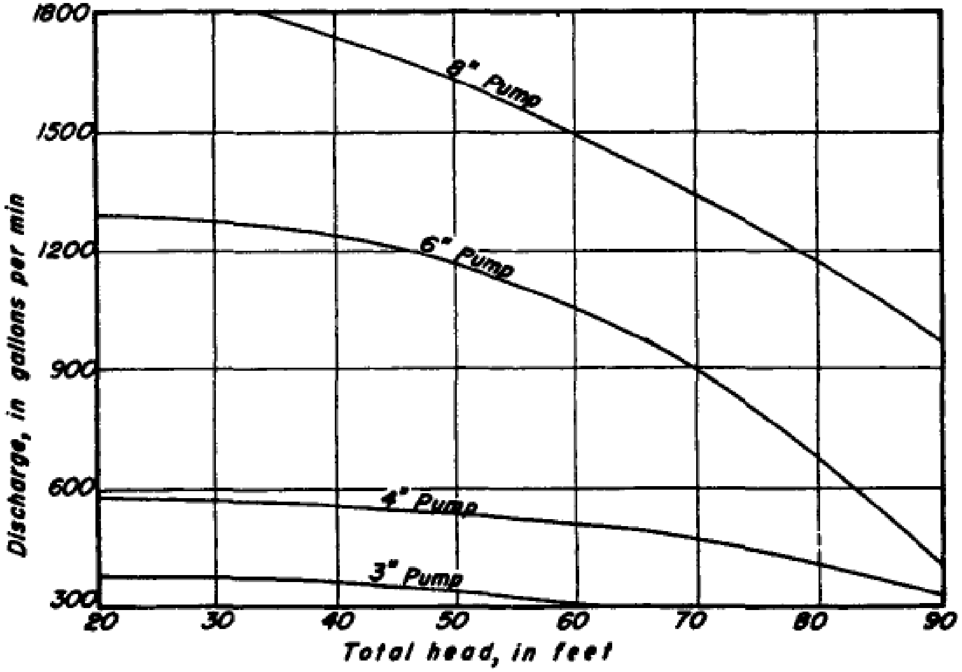
r_w = effective radius of the well, ft

h_0 = depth of immersion of well, ft

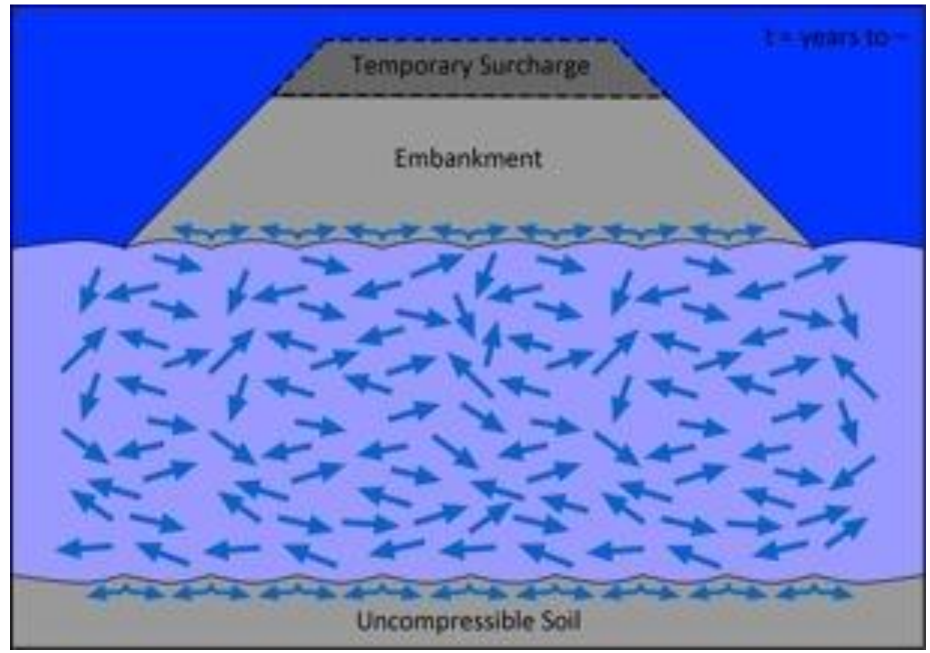
Pump Size

- Centrifugal pumps are usually used for well point and deep well collection systems.
- The selection of a pump and motor depends on the required discharge, total dynamic head, suction lift, air-handling capacity, power available, fuel economy, and durability of units.
- A chart demonstrating the relationship between head and discharge for different size pumps is shown in Figure 1-46.
- Well point pumps may be driven by gasoline, diesel, or electric power and are often 1500 gal/min, self-priming, centrifugal type. They can have up to a 4000 gal/min capacity.





Head versus discharge for typical pump sizes



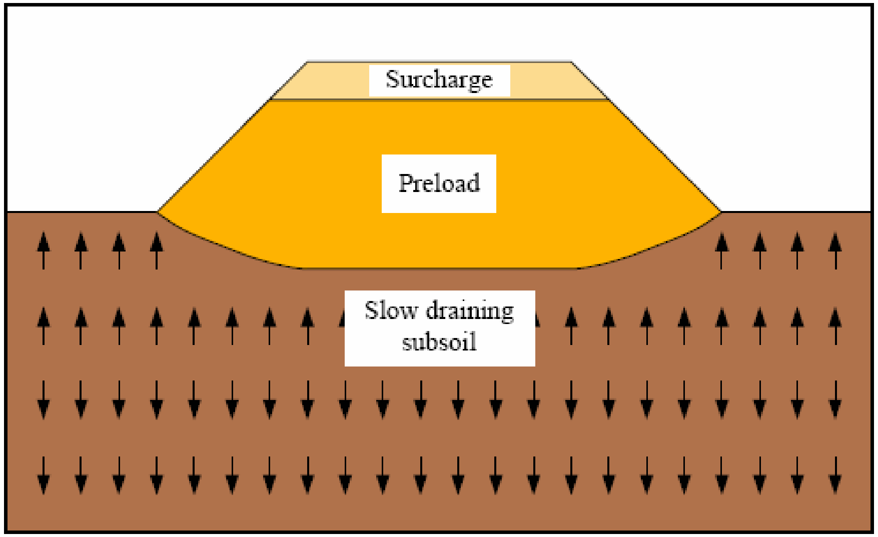
PRELOADING

Definition of Pre-loading

Preloading generally refers to the process of consolidation of the soil under applied vertical stress before the construction and placement of the final construction load.

Principle

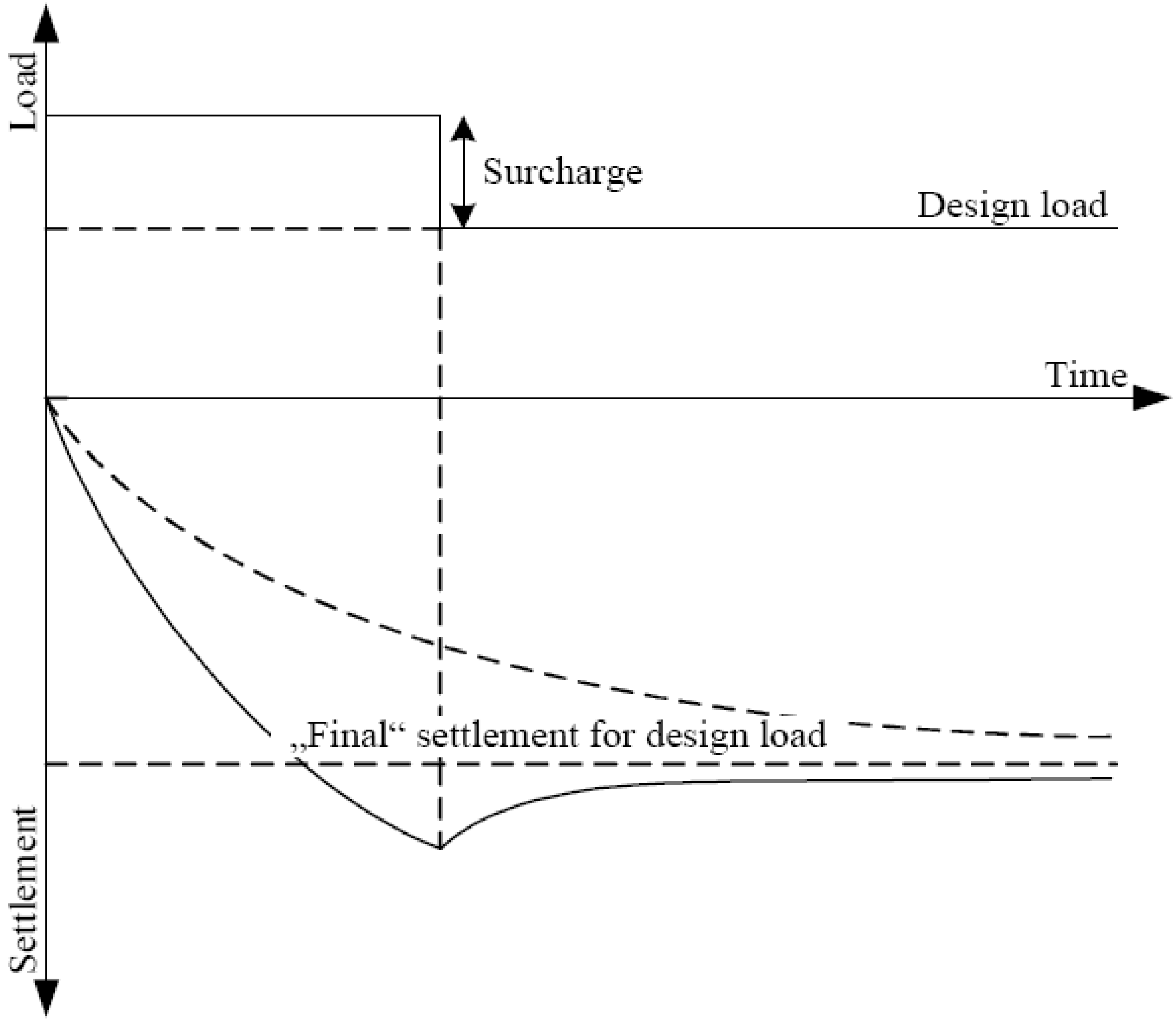
Preloading increases the pore water pressure in the soil and, as the consolidation process occurs, an increase in the effective stress takes place in the soil accompanied by surface settlement.



Pre-loading Methodology/Working Mechanism

- When highly compressible, normally consolidated clayey soil layers lie at limited/large depths, large consolidation settlements are expected as the result of the loads from large buildings, highway embankments, or earth dams etc.
- Pre-compression (Pre-loading) and provision of vertical drains in soft soil may be used to minimize post construction settlement.
- If the temporary load exceeds the final construction load, the excess refers to as surcharge load.
- The simplest solution of preloading is a preload, e. g. by means of earth fill or other suitable material. When the load is placed on the soft soil, it is initially carried by the pore water.
- The magnitude of the pre load pressure usually rages from 1.2 to 1.3 times of the actual structural pressure or is slightly greater than the maximum pressure that is generated by the proposed structural load.

- When the soil is not very permeable, the water pressure will decrease gradually because the pore water is only able to flow away very slowly in vertical direction.
- The temporary surcharge can be removed when the settlements exceeds the predicted final settlement.
- Time required to achieve final consolidation varied directly as the square of the layer thickness of filling material and inversely as the permeability. So, this method is suitable for stabilization of thin layers.
- When consolidation of the foundation soil is practically complete (generally 90% consolidation), the surcharge is removed and the structure is constructed.
- Time required for final consolidation is reduced with the use of preloading.
- Pre-loading has been successfully used for all types of soil, such as loose sand and silt, soft silty clays, recently filled up soil, etc.


Load
Surcharge
Design load
Time
„Final“ settlement for design load
Settlement

Advantages of Pre-loading

- Requires only conventional earthmoving equipment
- Any grading contractor can perform the work
- Long track record of success

Disadvantages of Pre-loading

- Surcharge fill must extend horizontally at least 10 m beyond the perimeter of the planned construction, which may not be possible at confined sites
- Transport of large quantities of soil required
- Surcharge must remain in place for months or years, thus **delaying construction**

PRE LOADING WITH VERTICAL DRAIN

Need Of Pre-loading With Vertical Drain

For deep clay deposits; pre-loading alone will take more time because of the long drainage path available for consolidation. An effective way to do this is by providing vertical drains.

What Is Vertical Drain?

Vertical drain is continuous vertical columns of pervious material installed in clayey soil for the purpose of collecting and discharging the water expelled during consolidation.

Classification Of Vertical Drain

According to the material used for the draining the soil, vertical drain may be classified as **sand drain and wick drain (or pre-fabricated vertical drain).**

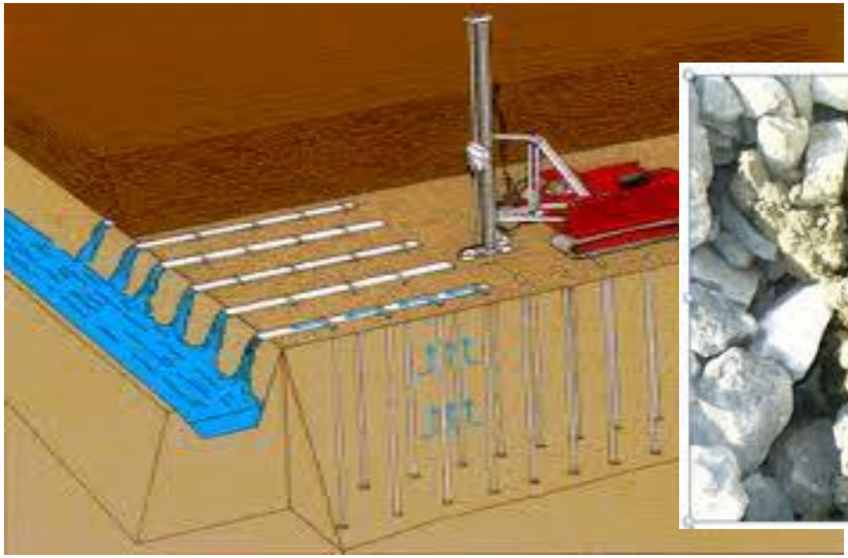
(1) SAND DRAIN

Sand drains consist of columns of sand placed in vertical holes in compressible soil at sufficiently close spacing so that the horizontal drainage path for consolidation is less than the vertical path. They can be installed within mandrel-driven or conventionally driven pipes or rotary- or auger-drilled boreholes. **The sand** can be placed in the hole or pipe by gravity or by jetting it into place. **Sand** drains can be from **6 to 30 (usually 16 to 20) in. in diameter and are typically spaced** between **5 and 20 (usually 6 and 10) ft** apart.

(2) WICK DRAIN/PRE-FABRICATED VERTICAL DRAIN

- These drains are of flexible corrugated plastic pipe, fabricated inside a filter.
- The prefabricated band drains are used for accelerating the consolidation of marine deposits or soft soils.
- Prefabricated band drains consist of a central core, whose function is primarily to act as a free drainage channel, and a non-woven filter jacket, which prevents the soil surrounding the drain from entering the central core but allows water to flow in.
- Vertical drains are generally installed in either triangular or square patterns.
- The size of wick drain is typically 100 mm in width and 3 to 9 mm in thickness.
- They are installed in the ground using a specially made mandrel.





Advantages Of Pre-fabricated Vertical Drain (PVD) Over Sand Drains

- The installation rate of PVDs is typically 5,000 linear meters per day, which results in a significantly lower project cost.
- There is no risk of shear failure of PVDs during settlement, while sand drains are vulnerable to shear failure during settlement.
- PVDs have discharge capacities, typically 30×10^{-6} to 90×10^{-6} m^3/s, while a 0.35 m diameter sand drain has a discharge capacity of 20 × 10-6 m^3/s.
- For typical projects, the cost of PVD is around $1/5^{th}$ to $1/10^{th}$ that of 300 mm to 450 mm sand drain.

It's End?

Man has soared high, but lost his foothold in the soil….The secret needed to win the struggle for survival is simple; to be soil minded; to realize that the roots of organism of life are in the soil………

____(K. M. Munshi)