Chapter 6

Subsurface Water and Engineering Works

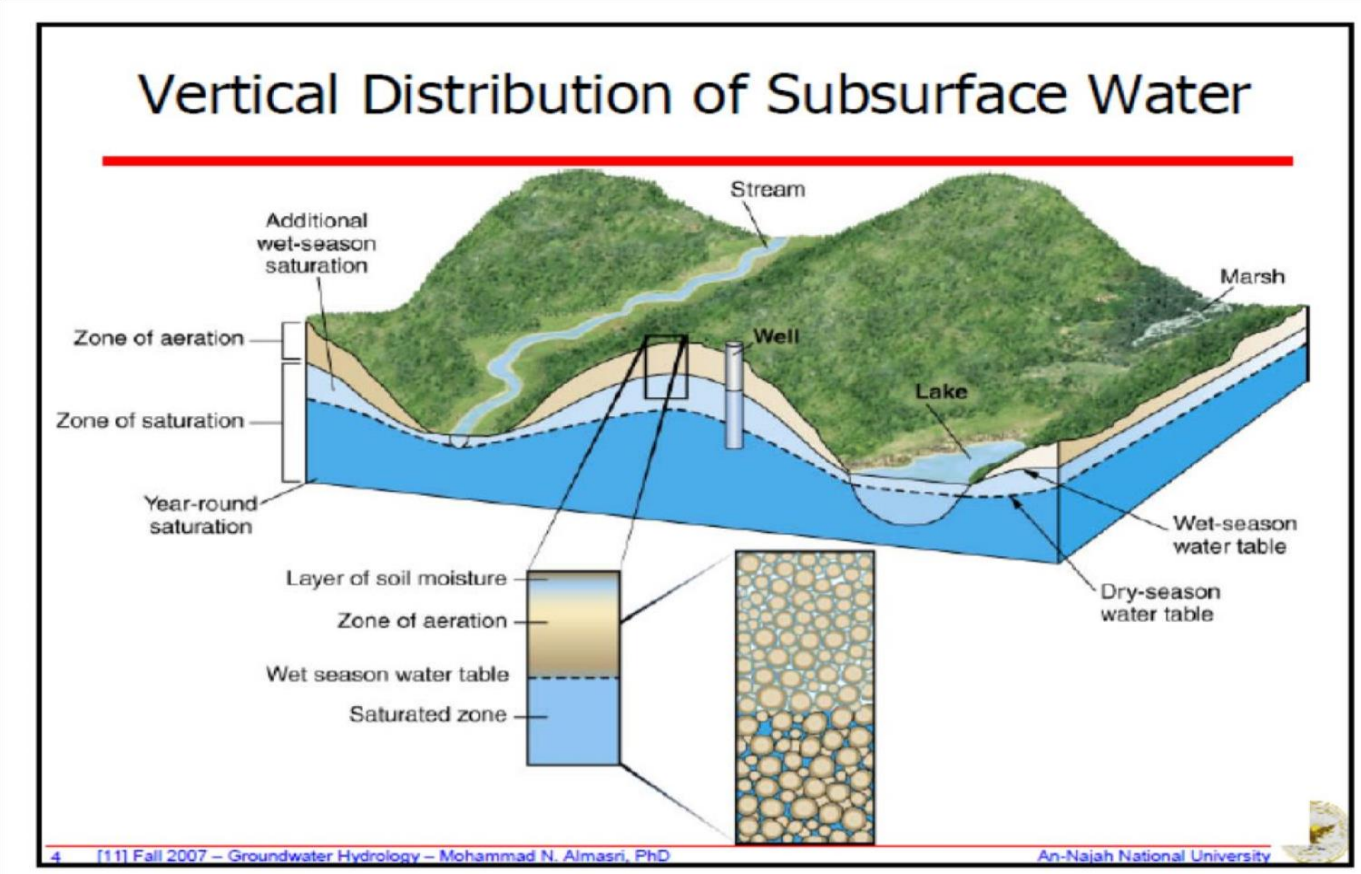


Figure : groundwater table related with a given topography

Aeration zone and saturation zone.

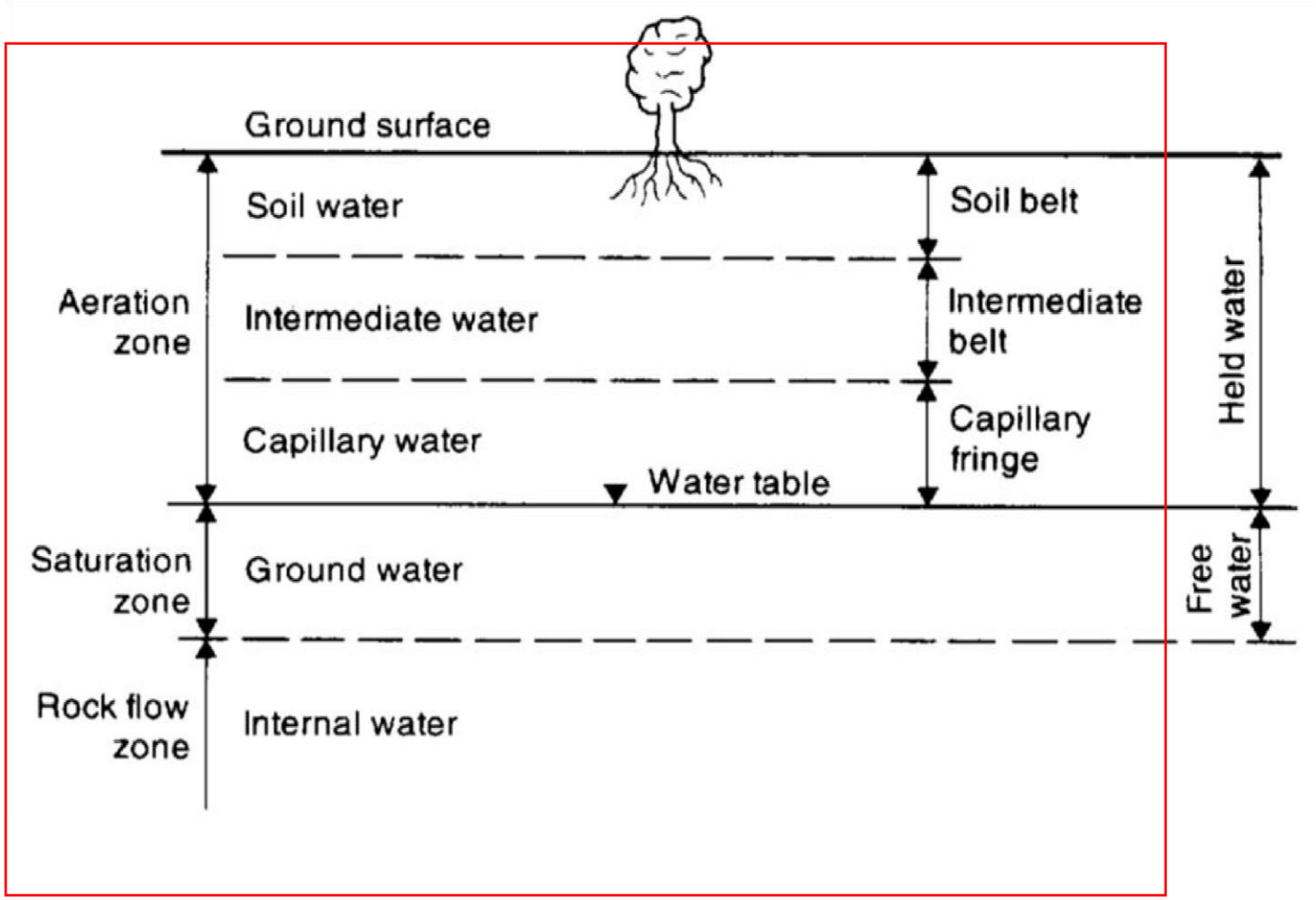


Figure : Diagram illustrating aeration zone and saturation zone

What are the IMPACTS of Subsurface Water on Engineering Works?

- Subsurface water is often a critical factor in various engineering works.
- Problems **during and after** the construction stage.
- ***Subsurface water may affect:***
  - ✔ Affect the safety of the structures of an engineering project.
  - ✔ The design of the structure
  - ✔ The construction procedures, and
  - ✔ The overall project cost…major delays, often requiring drastic re-designs, and
  - ✔ Durability
- Subsurface water plays a prominent part in:
  - ✔ Slope movement
  - ✔ Volume changes by shrinkage and swelling and collapse of loose soils.
  - ✔ It may also erode the foundation of the structures.

Subsurface water may lead to:

- Failure of engineering projects…abandoned thus causing loss of life and property.

❖ **Water in soils and rocks:**

- ✔ Reducing effective stresses
- ✔ A reduction in strength ……slopes becoming unstable.

❖ **Changes in groundwater conditions can cause:**

- ✓ Collapse of subsurface voids……Subsidence.
- ✓ Changes in moisture content…swelling and shrinkage…structural damage of buildings founded in it.
- ✓ The movement of water…. Leads Weathering…changes in the mechanical properties during the life of a structure placed on or in them.

❖ Therefore: Engineering geological investigation to assess:

✔ *Subsurface water*… ✔ adverse effects… ✔ proposed engineering projects.

❑ The construction of engineering structures will be responsible in changing the *subsurface water.*

- Location of water within the rock
- Direction and velocity of its movement

Changes in both location and motion in time, seasonal.

- ❖ Particularly the underground structures and the reservoir projects have a potential to change the subsurface water regimes considerably.
- Therefore, it becomes important that engineering geological investigation of a proposed site must address and evaluate:

✔ The possible impact of construction on existing subsurface water regime conditions and The existing subsurface water regimes on the proposed construction to anticipate what can be expected during construction besides to develop criteria for design and construction.

- ❑ Engineering geologist should understand….

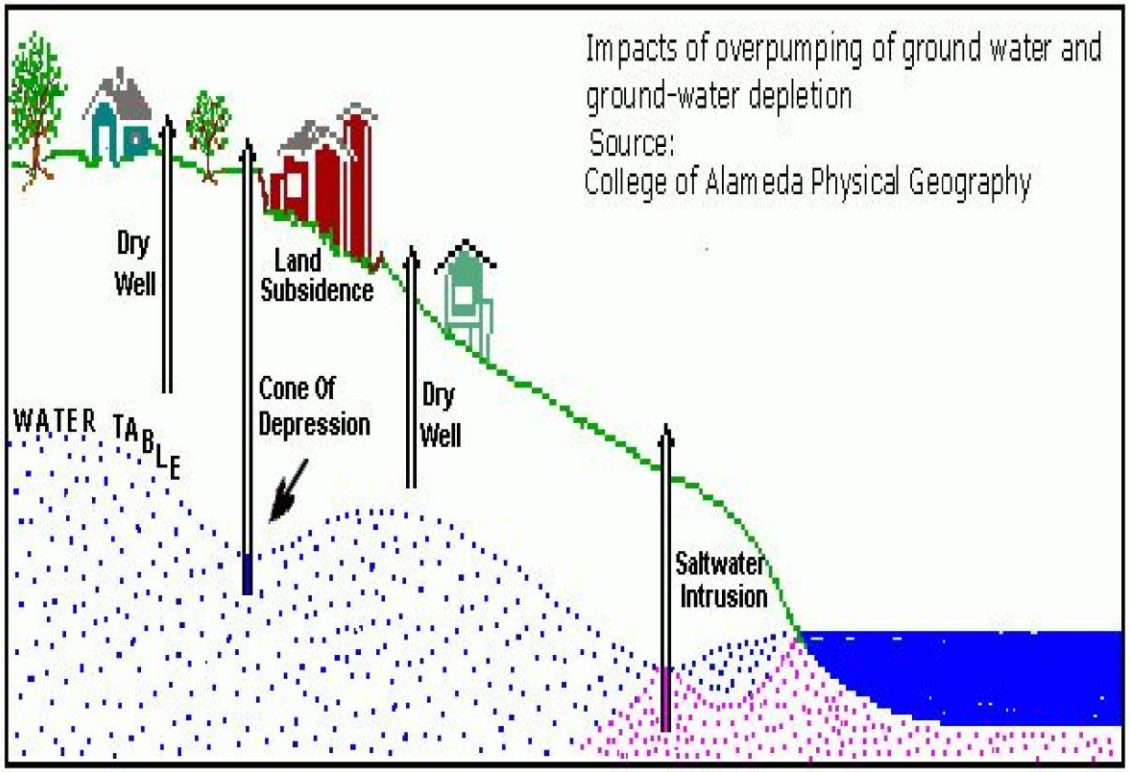
✔ Occurrence

✔ Engineering significance, and ✔ Control of subsurface water

✔ **Subsurface water may influence:**

- Excavation and construction methods by flowing into excavations
- Seepage forces
- Uplift pressures ✔ Corrosive action.

Fig. impacts of GW over pumping.



- In engineering geological investigation the following important information on subsurface water conditions should be evaluated;

- ✓ The distribution of sub-surface water
- ✓ Water content/quantity
- ✓ Direction and velocity of subsurface water flow
- ✓ Springs and seepages from individual water bearing horizons
- ✓ Depth to water table and its range of fluctuation
- ✓ Regions of confined water and piezometric levels
- ✓ Hydro chemical properties such as pH, salinity, corrosiveness
- ✓ **Problems Created in Constructions**

- ✔ Construction of engineering structures may be made difficult or even impossible by subsurface water.
- ✔ Neither excavations nor constructions can be properly carried out with the presence of excessive water.
- ✔ This fact is true not only for major projects like dams and big underground cavities but equally important for small constructions like building foundations.

- More significant are groundwater changes brought about by engineering works, either intentionally (e.g. dewatering to carry out excavations in the dry) or as an unintended consequence, for example, where tunneling below a site.

- **Lowering of the water table inevitably causes**:

- Water migration and
- potentially internal erosion,
- a loss of buoyancy,
- Self-weight compaction of soil and rock.

- **This may result in:**

- settlement and damage to adjacent structures
- piles can become overloaded by negative skin friction.

- Similarly, rising water levels can cause difficulties due to buoyancy, which could require holding down anchors or piles.

- Rising water might also weakened the ground on the supporting a structure, sometimes due to dissolution of cementing agents.

- ❖ Subsurface water has the potential to cause great difficulties for underground works; efforts should be made to define the subsurface water regime.

✔ ***Data/ information on:***

- ✔ *Aquifers,*
- ✔ *Sources of water,* ✔*Water quality and*
- ✔ *Depth to subsurface water* should be collected.

- ✓ Mapping of perennial streams and other water bodies should be carried out.
- ✓ Proximity of the subsurface water table may be judged by the type of vegetation growth on the site.
- As a part of the subsurface water survey, all existing water wells in the area should be located and the subsurface water levels should be taken.
- Additional hydro geological work including measurements of subsurface water levels or pressure in boreholes, permeability testing using packers etc.

✔ The most serious problem encountered during excavation is the sudden inflow of large quantities of water.

- ❖ The ground water table in the rock may be either local or bounding a limited water accumulation or continuous over a certain distance.
- ✔ It is obvious that *a tunnel located above the water table is safe from water invasion***,** hence it is desirable to locate the tunnel above the water table.
- ✔ However, this is not possible always.
- ✔ Construction of tunnel not only modifies the sub-surface water regime, but also influences the surface flow of water in the locality with a corresponding lowering of the water table.
- ✔ Even in some cases the water in wells and spring drained dry by the excavation of a tunnel.
- ✔ Correct estimate of water inflow into the tunnel to be constructed is of great importance, as it influence the construction works.

Subsurface Water in Dam Projects

- ✔ The subsurface water has a great significance in the dam projects.
  - ✔ The dam foundations are laid down at great depths depending upon the height of the dam and the foundation conditions.
  - ✔ In most of the cases the deepest foundation level of the dams are below the natural subsurface water levels.
  - ✔ Thus, there will always be an inflow of water into the excavation for foundation, which may hinder the construction activities.
  - ✔ In most of the cases this inflow of water may be checked by pumping out this water however, in exceptional cases the inflow of water may be more than what is being pumped out. Such conditions may create great problems in excavation and concreting.
- ✔ The presence of subsurface water in rock mass causes water pressure within the discontinuities, which results in **reduction of cohesion** and may cause problem of **instability of reservoir** rim slopes and the abutments.

❖ Dams are generally constructed across the river valleys to impound water behind it to form reservoirs.

- An ideal site for a large impounding reservoir is a gorge with steep banks upstream so that a small dam can impound a large volume of water with a minimum extent of water spread.

✔ Leakage from a reservoir takes the form of sudden increases in stream flow downstream of the dam site with boils in the river and the appearance of springs on the valley sides.

- It may be associated with major defects in the geological structure such as solution channels, fault zones or buried channels through which large and essentially localized flows takes place.

✔ Seepage is generally more difficult to trace especially in connection with the investigation of solution channels in limestone.

✔ In some cases leakage from reservoirs can be a potential source of trouble.

✔ When a dam impounds a body of water behind it, the rocks forming the floor of the reservoir are subjected to considerable hydraulic pressure.

- The water under hydraulic head will find its way through interconnected joints, bedding planes and porous rocks.
- If these joints and bedding planes dips towards the adjoining valleys this leakage from the reservoir will be considerable.

- **Engineering Significance of Subsurface Water in Dam Projects**

✔ Dams seepage through the foundations and abutments of dams containing soluble rocks may produce settlements and redistribution of pore pressures which could threaten stability or cause leakage and waste of water sufficient to render the dam uneconomic.

✔ Dissolution of the fine fractions of filters may make them inoperative and threaten the safety of the dam.

✔ The role of subsurface water is **instability condition** of a slope .

✔ it has a potential to saturate the soil mass and thus increases the overall weight of the soil mass.

✔ This increase in weight of the soil mass is a negative factor as far as the stability of the slope is concerned.

❖ The presence ***of subsurface water*** will reduce the ***shear strength of the soil mass*** and also it may generate the pore water pressure which ultimately affects the stability condition of the slope.

- **Engineering Significance of Subsurface Water in stability conditions of slopes**

✔ The subsurface water in the discontinuity planes of the rock mass develops an uplift water force thus reducing the strength of the rock mass.

- The water not only reduces the shear strength of the rock mass but it also works as a lubricant and facilitates the process of sliding along possible failure surfaces.
- In majority of the cases the subsurface water is the most important parameter, which affects the stability condition of the slopes.

✔ For this reason only most of the slope failures takes place during rainy season.

Effect of subsurface water chemistry on engineering structures

✔ In engineering structures subsurface water is an agent of solution by virtue of its acidity and in soils it is an agent of piping by virtue of its dissolved solids.

✔ Carbonic acid attacks concrete structures by stripping of Ca++ and Mg++ , which are then carried off in solution and sulfuric acid attacks concrete by driving of the Ca++.

✔ This phenomena is common for all concrete foundation structures.

- ❖ Moreover, the **corrosiveness** of subsurface water affects the weathering intensity of the rocks, buried **pipes** and **structures**.
- ✔ Hydrogen sulfide may result sulfuric acids by the action of oxygen and water. The sulfuric acid will facilitates the weathering process of the native foundation rock causing decrease in strength. The foundations in soils are not susceptible to acidity of the subsurface water. The effect of subsurface water chemistry is on the piping effect. The dispersive nature of soils depends on the 'exchangeable sodium percentage'(ESP), however values of ESP causes serious piping when the ESP value of the foundation soils is greater than 15 and the subsurface water has a ESP value lower than 0.5. The ESP can be determined as

$$\textbf{ESP} = \textbf{Na/ (Na+K+Ca+Mg) *100}$$

- ✔ Total sulphate content of 300 ppm (75 milligram/litre) in subsurface water have been classified as potentially aggressive.
- ✔ **Sulfate** when present in large amount, is aggressive to concrete, metallic structures, like rock bolts, steel used as reinforcement etc.
- ✔ Hydrogen sulfide may result sulfuric acids by the action of oxygen and water.
- ✔ The sulfuric acid will facilitates the weathering process of the native foundation rock causing decrease in strength.

Corrosivity of Subsurface Water

- ✔ The coexistence of sulphate and chloride ions in subsurface water causes deterioration of reinforcement (concrete or other steel structures).
- ✔ In corrosive subsurface water conditions, while doing excavations, a proper precaution has to be taken to reduce the effect of corrosion, especially in permanent excavations.
- According to Mahadevaswamy (2002), the value of the corrosivity coefficient can be determined from the following expression;

$$CR = \frac{0.028Cl + 0.021SO_4}{0.02(HCO_3 + CO_3)}$$

- Thus if the CR value is >1 the subsurface water is corrosive. Therefore, it is desirable to determine the corrosivity ratio coefficient, CR for the safety of the concrete and other reinforcements.

Control of Subsurface Water

✔ A variety of methods exist for controlling subsurface water.

✔ Choosing the method or combination of methods to use depends on:

Type of engineering work

- Site conditions
- Purpose for controlling the water

✔ Control methods can be reasonably grouped into four categories: ✔ Barriers

- Liners
- Wells
- Drains

✔ Each method has advantages and disadvantages that require careful attention when choosing the control method or methods for a specific project.

Control of Subsurface Water

❖ *Barriers*

✔ Barriers are generally employed to reduce both amount and velocity of subsurface water.

✔ The common types of barriers are:

- Sheet pile cutoff walls
- Impervious cutoff trenches and

✔ For example, earth dams may incorporate a cutoff wall or grout curtain in their foundation to reduce the amount and speed of water flowing under the structure.

✔ The type of barrier to use at a site is dictated as much by subsurface conditions as by the type of structure involved.

✔ For instance, coarse grained material and stratified soil with alternating layers of pervious and impervious material are ideal for use of sheet pile barriers.

✔ Grouted or injected cutoff curtains

✔ Barriers are often part of structures.

- Grouted anchors
- cutoff walls

✔ Conditions affecting the ability to excavate a trench to the necessary depth and maintain its shape will determine whether placement of impervious soil barriers are approximate.

❑ Control of Subsurface Water Liners

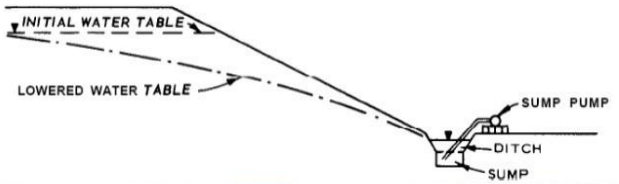
- ✔ Liners are used to prevent the movement of subsurface water.
- ✔ Liners are used to prevent the **seepage**.
- ✔ This may involve preventing loss of water retained in a canal or impoundment or keeping water out of an area such as a waste disposal site to prevent migration of contaminations.
- ✔ Bentonite and related clays are often favored as liners to prevent water from reaching isolated waste.
- ✔ Some caution in relying on this method, however, should be exercised due to questions concerned their long term efficiency.

Control of Subsurface Water Drains

- ✔ Drains reduces the **quantity of water** and **direct** its movement.
- ✔ Effective drains depends on the relative permeability of the drain materials and the surrounding materials.
- ✔ Besides the selection of the drain material must be such that it must retain the migration of the fine particles from the surrounding.
- ✔ Such type of drains are used for structures where the subsurface water has to be drained out from the likely affected area and the uplift water pressures developed by the subsurface water has to be checked.
- ✔ The relative sizing of drain materials is critical to proper operation.
- ✔ It must have a sufficiently greater permeability than the soil it is protecting in order to intercept the subsurface flow.
- ✔ At the same time, it must not permit excessive passage of the smaller particles in the adjacent materials to avoid piping of the soil or clogging of the drain.

Control of Subsurface

CONTROLLING GROUNDWATER ON CONSTRUCTION SITES

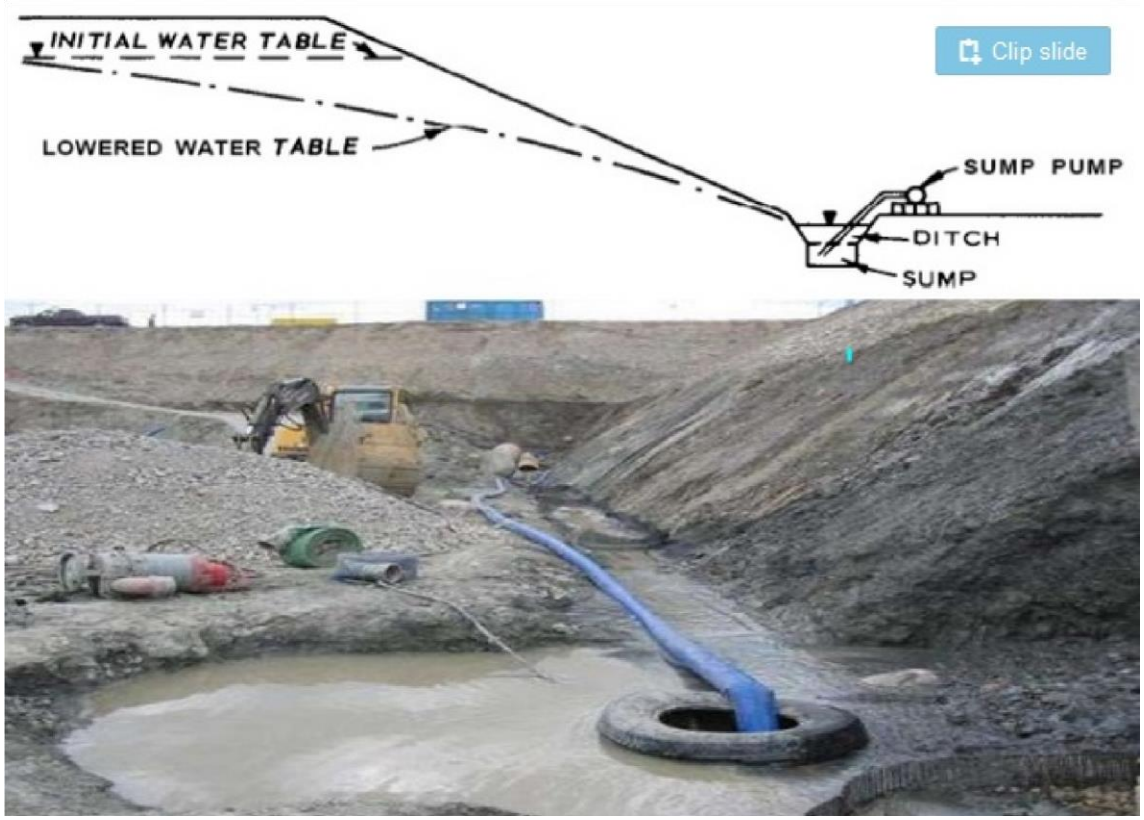


Control of Subsurface Water

- ✔ **Dewatering**, the elimination of subsurface water, is accomplished through the use of wells.
- ✔ Common types of wells used to dewater a site are:
  - ✔ Sumps,
  - ✔ Well points
  - ✔ Pumping wells
  - ✔ Relief wells and
  - ✔ Horizontal drains
- ✔ **A sump** is merely a collection **trench**, or **hole**, **deeper** than the area being protected from subsurface water.
- As the water collects, it is pumped away from the area, effectively drawing down the water table.

❖ **Well points** accomplish the same purpose by being drilled to a shallow depth and attached to a suction pump to draw out the water.

✔ **Pumping wells** are drilled and equipped in a manner nearly identical to a well being developed as a water source. **Fig.** dewatering from sumps



❖ **Relief wells** are employed to decrease water in a confined aquifer.

✔ The artesian pressure forces the water upward through the relief well.

✔ The relief well is, in essence, a vertical interceptor drain.

✔ It is often used for dewatering during construction and to relieve uplift pressure on foundations.

❖ **Horizontal wells** depends on gravity to move water through them.

✔ These wells are effective in maintaining cut slope stability and in stabilizing landslides.

✔ The geology and topography of a location will dictate the most desirable location to intercept the subsurface water before it reaches an area of possible instability. ✔ Attention should be paid to lateral as well as vertical changes in lithology when analyzing a site.

✔ By knowing these factors, spacing of wells and their length can achieve a better result than equal spacing and predetermined lengths.

- Horizontal drain holes drilled into the slope face can be very effective in reducing water pressure near the base of the suspected tension crack or along a potential failure plane