Arab Academy for Science, Technology & Maritime Transport
Colleague of Engineering & Technology
Construction & Building Engineering

CB 523
Methods and Equipment for Construction 1

Lecture 8&9:
Construction Dewatering

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Courtesy of Dr. Ahmed Alhakeem & Dr. Ahmed Alhady

Construction Dewatering
Overview

- Soil dewatering means the removal of water from the soil.
- Construction dewatering means Control of the subsurface and surface water environment in order to allow construction to proceed.
- Techniques for dealing with the problems that result depend on the
  - excavation dimensions,
  - soil type,
  - groundwater control requirements

Construction Dewatering
Overview

- The simplest dewatering operations are carried out with little planning.

- Major operations in difficult conditions require advanced engineering and construction methods.

- *(An aquifer is a permeable geological stratum or formation that can both store and transmit water in significant quantities).*

Construction Dewatering
Introduction

- Construction dewatering can become a costly issue if overlooked during project planning.
- In most contracts, dewatering is the responsibility of the contractor.
- The contractor selects the dewatering method and is responsible for its design and operation.
- The **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."**

Construction Dewatering
Introduction

- If ground water issues are addressed appropriately at the investigation and design stage, construction dewatering is rarely a problem.
- Construction dewatering has existed as a specialty industry for a long time.
- Consequently, a number of well-established techniques have been developed to lower the ground water table during excavation.
- The geology, ground water conditions, and type of excavation all influence the selection of dewatering technology.

Construction Dewatering
Introduction

The most common methods for dewatering include sumps, wells and wellpoints.

- **Sumps** provide localized, very shallow dewatering (less than 3 feet) and consist of pumping from perforated drums or casings in a gravel-filled backhoe pit. Sumps work best in tight, fine grained soils, or very coarse, bouldery deposits.

Construction Dewatering
Introduction

- **Wells** are large-diameter (greater than 6 inches) holes, drilled relatively deep (greater than 10 feet), and contain slotted casings and downhole pumps. Wells work best in soils consisting of sand, or sand and gravel mixtures, and can dewater large areas to great depths.

Construction Dewatering
Introduction

- **Wellpoints** are small-diameter (less than 6 inches), shallow wells, and are closely spaced (2 to 10 feet apart).
  - effectively dewater coarse sands and gravels, or silts and clays.
  - They have a wide range of applications.
  - Use a vacuum system and their depth is limited to about 25 feet.
  - systems generally cost more than either sumps or wells, and require near-continual maintenance.

Construction Dewatering
Introduction

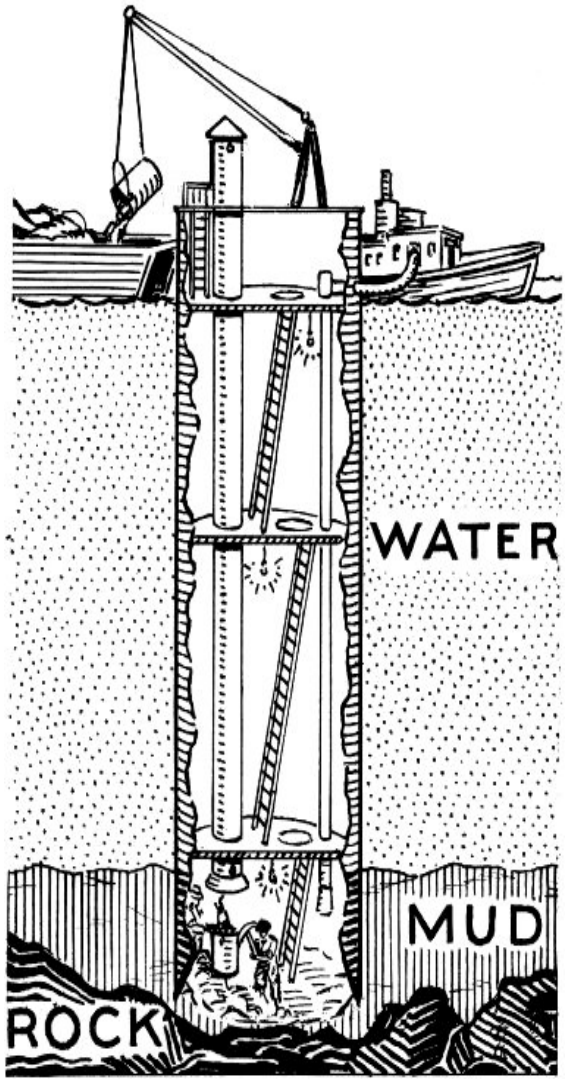
- Other dewatering techniques include:
  - ground freezing,
  - Electroosmosis,
  - Vertical Sand Drains,
  - Wick Drains,
  - Grouting, etc.
- However, such techniques are very costly and used only for particularly difficult dewatering applications.

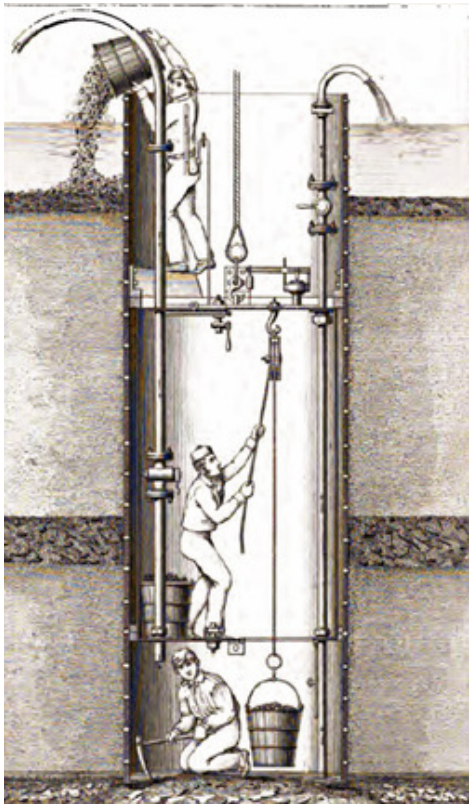
Construction Dewatering
Underwater Excavations

- In special cases where the soil is very pervious or when it is not possible or desirable to lower the groundwater table, underwater excavations can be considered.
- If underwater excavation is to be performed, the work area must be enclosed with an impervious structure. Once the impervious structure is in place, the excavation is performed within the structure.
- Once the desired excavation level is achieved within the structure, it is sealed with an impervious layer, such as concrete, in order to prevent water from sipping into the work area.
- After the impervious seal has been constructed, the water remaining within the structure is pumped out and construction is completed.

Construction Dewatering
Caissons

- Caisson is a structure that is constructed at location if the project site is on land, but if the project site is offshore, it is constructed on land and then floated to the site offshore.
- In the caisson method of construction, the excavation is performed from within the permanent structure.





Construction Dewatering
Caissons

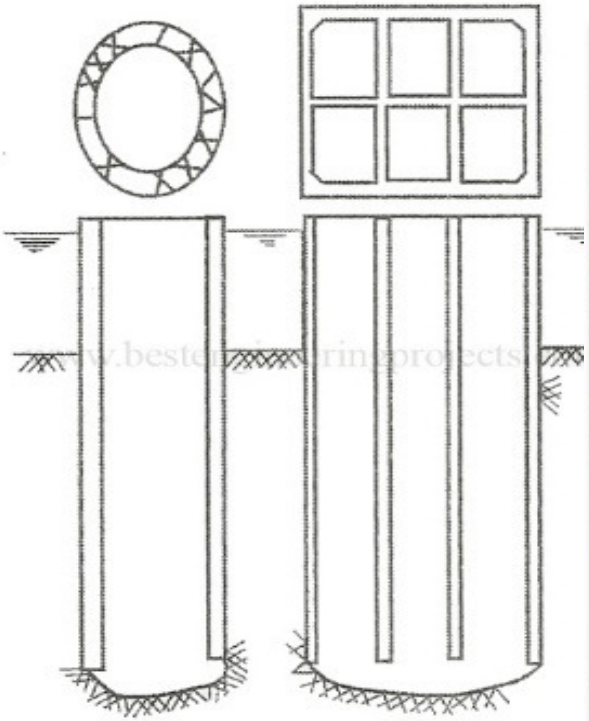


Fig 1 Open Caissons

Open Caisson

Construction Dewatering
Caissons

- After the caisson is in position, excavation from within the caisson structure begins.
- As the excavation is carried out, the caisson structure starts to sink by its own weight, or if necessary, by imposed loads.
- This procedure continues until the desired foundation level is achieved. Figure 1 shows this process schematically.

Construction Dewatering
Caissons

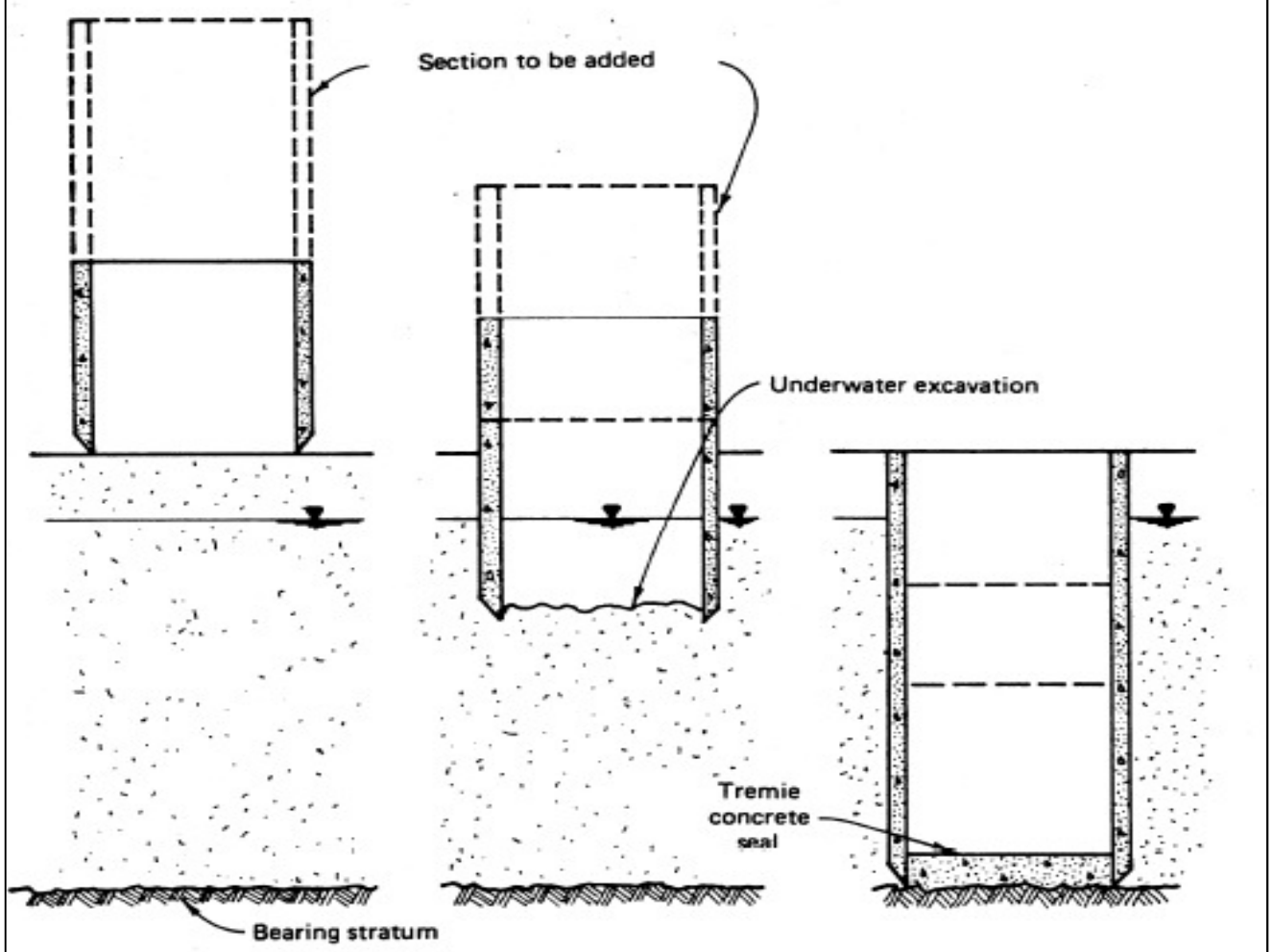


Figure 1 - Schematic sequence of caisson installation

Construction Dewatering
Caissons

- By injecting bentonite clay slurry at the soil-structure interface, adding weight, or in case of cohesive soils using jetting, the frictional resistance between the caisson and the surrounding ground may be significantly reduced.
- When a pile, or in this case caisson, must be driven through dense and hard materials, several driving aids have been developed.
- *The principal function of these driving aids is to speed the driving operation and to prevent damage to the structure that results from heavy driving.*

Construction Dewatering
Caissons

- Jetting is applicable to those situations where structure must be driven through cohesive soil materials to greater depths.
- Water jets can be used to displace granular soils from beneath the toe of a pile or caisson.
- Jetting is accomplished by pumping water through pipes attached to the side or center of the structure as it is driven. The flow of water creates a "quick" condition and thereby reduces skin friction along the sides of the driven structure. The result is that the structure drives more easily.

Construction Dewatering
Caissons

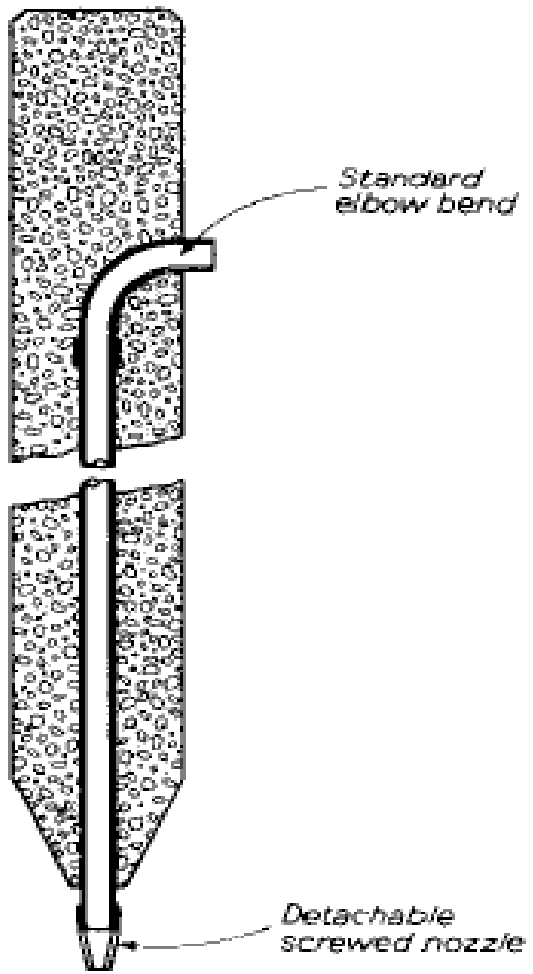


Figure 2 – Centrally-placed jetting pipe

Construction Dewatering
Caissons

- During unwatering (pumping the water to outside of caisson) a caisson in cohesive soils, the upward flow from the surrounding groundwater induces a quick condition, which results in loss of strength at the bottom of excavation.
- In other words, if the flow is upward then the water pressure tends to lift the soil element. If the upward water pressure is high enough the effective stresses in the soil disappear, no frictional strength can be mobilized and the soil behaves as a fluid.
- This is the quick condition and is associated with piping instabilities around excavations.

Construction Dewatering
Caissons

Quick condition is shown in Figure 3

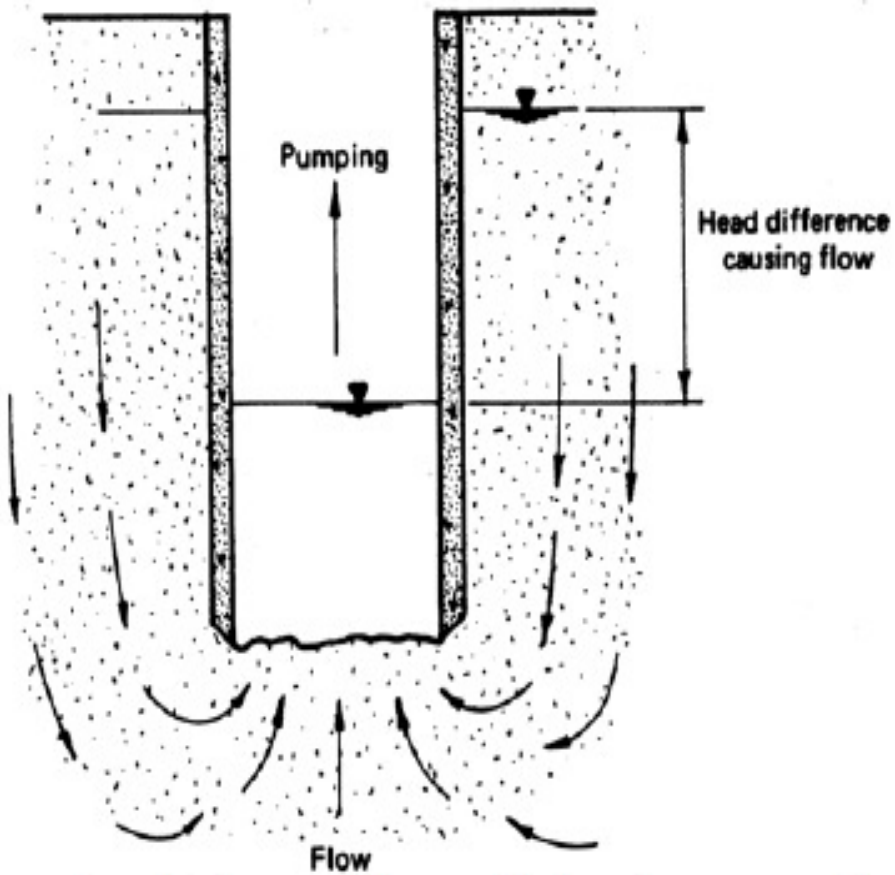


Figure 3 - Partially unwatered caisson with no seal, showing seepage from surrounding ground

Construction Dewatering
Caissons

- To prevent **quick condition**, the head difference causing flow, i.e. the difference between the groundwater table level and the standing water level within the caisson, should be kept low.
- Caissons should not be used in the case of existing structures that can be damaged due to loss of ground from beneath their foundations.
- At the desired excavation level, an impervious seal is placed, usually by using tremie concrete.
- Once the Tremie concrete seal is in place, the dewatering of the caisson can begin.

Construction Dewatering
Caissons

The **tremie concrete** placement method uses a vertical or near vertical pipe, through which **concrete** is placed by gravity feed below water level.

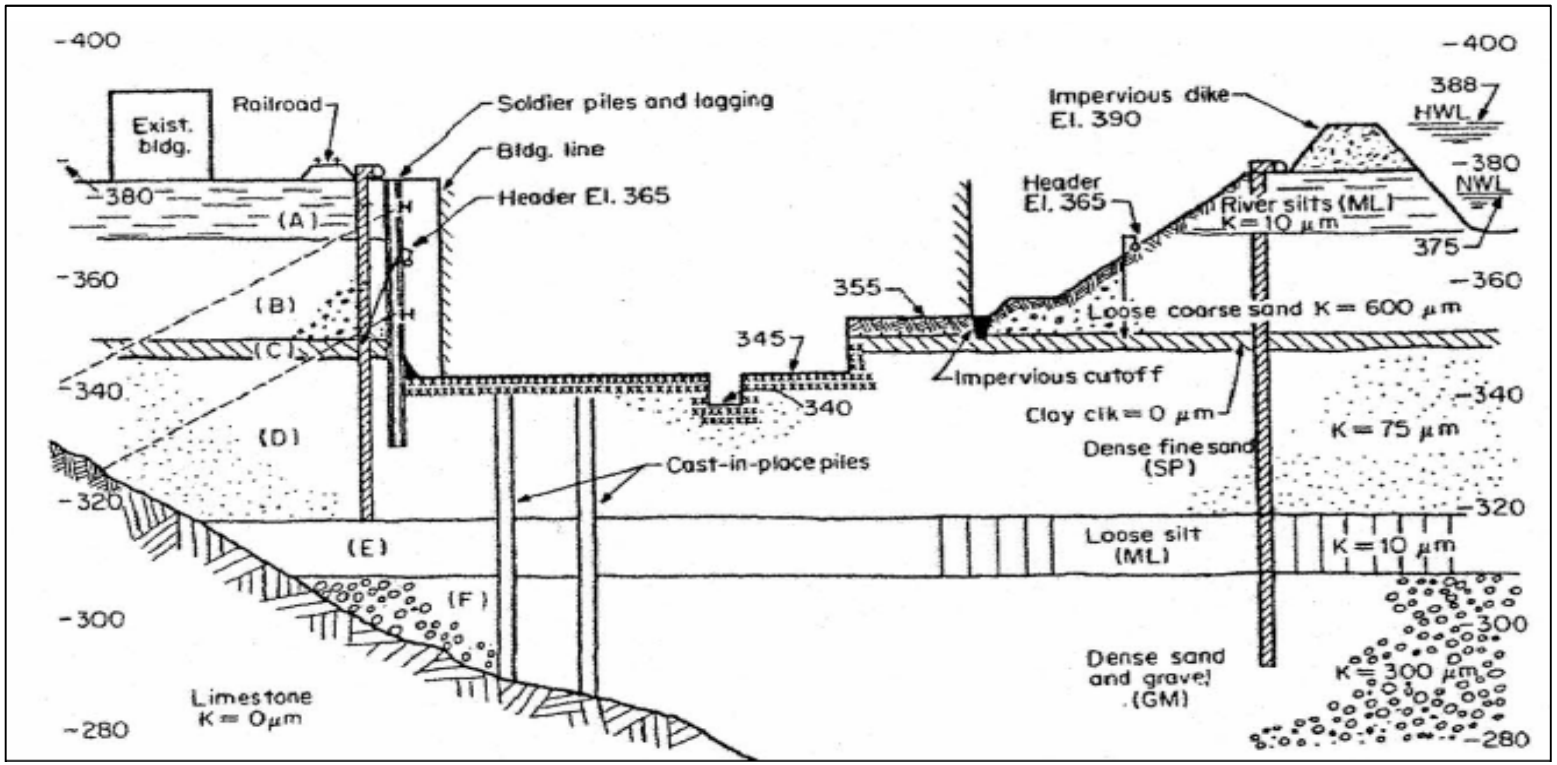
Construction Dewatering

Dewatering Analysis

What information is needed to properly <u>select and design a dewatering program</u>?

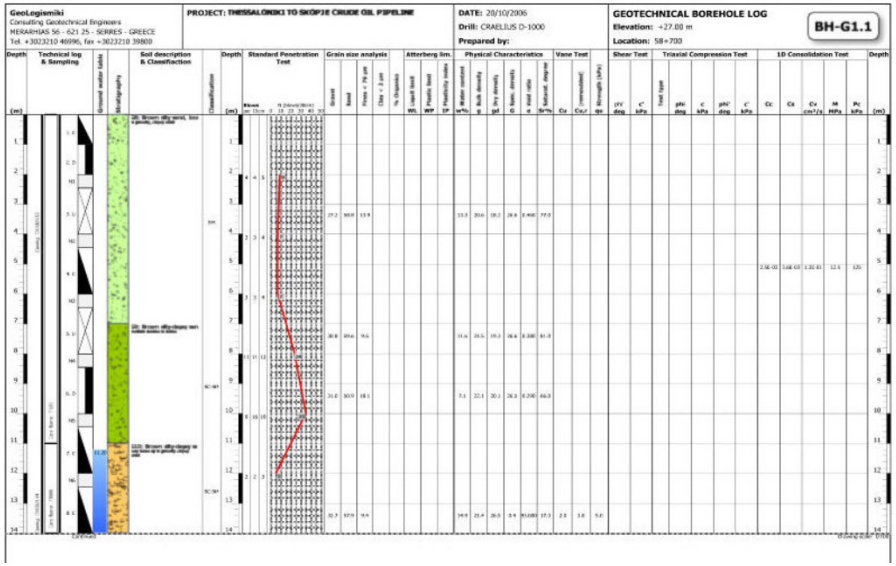
Construction Dewatering
Dewatering Analysis

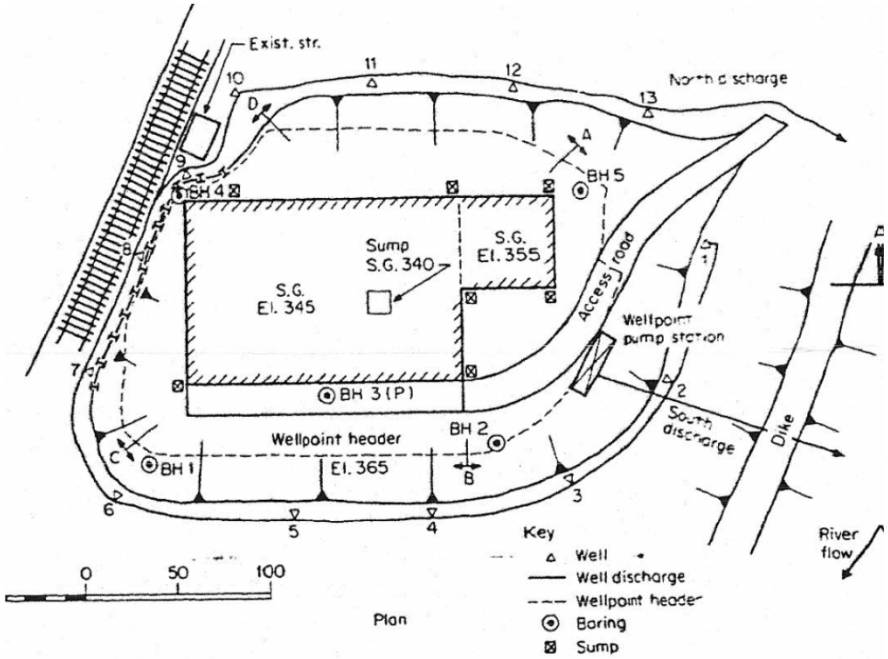
- Understand the objective of the dewatering program:
  - Dimensions of excavation
  - Adjacent structures
  - Construction sequence



Construction Dewatering
Dewatering Analysis

- Soil Data
  - Layering
  - Soil Properties (permeability and density)
  - Rock locations and formation
  - Water chemistry (corrosivity)





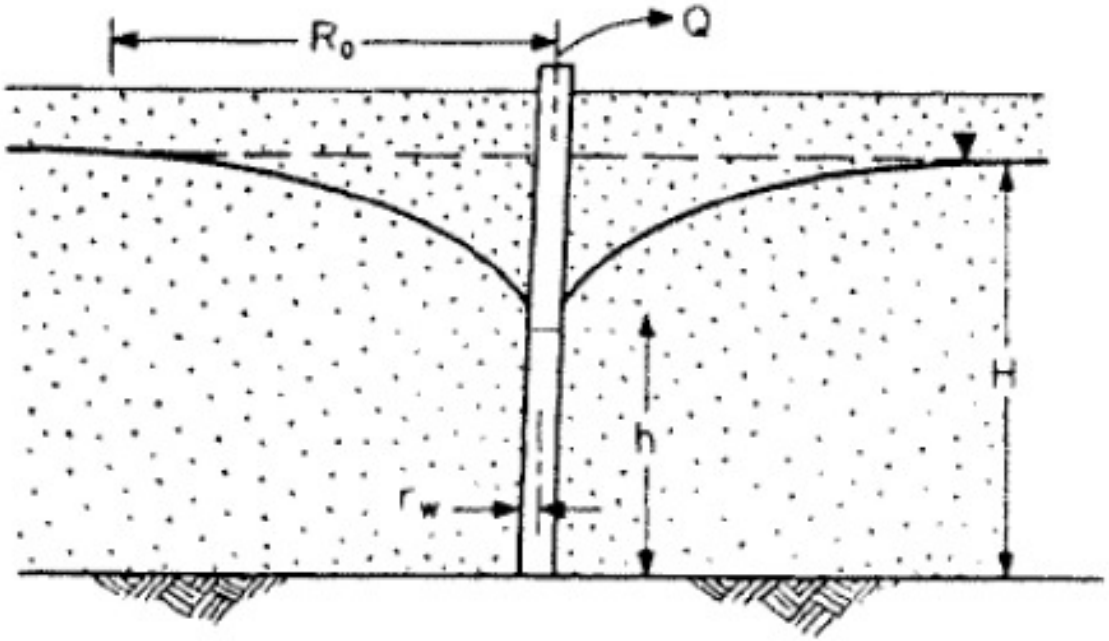
Construction Dewatering
Dewatering Analysis

- **Hydrology**
  - Water quantities have two components:
    - **<u>Storage:</u>** Water needed to be removed to lower ground water to intended level (can be up to 2/3 of total pumping volume) …*(Impact on schedule!!!)*
    - **<u>Steady-state recharge</u>**

- **Sequence and duration of work:**
  - Is uplift a consideration?
  - Requirements for pressure relief as the structure is being built
  - Must dewatering be relocated as construction proceeds?
  - Must portions of the system be installed inside the excavation?
  - How / Can we remove the dewatering system after construction?

Construction Dewatering
Design of Dewatering Analysis

- Typically water needs to be pumped out of the soil through the use of various types of pumps



Typical shape of ground water table after installation of a dewatering well

Construction Dewatering

Design of Dewatering Analysis

- **Un-confined Aquifer (Water Table Aquifer)**

$$Q = \frac{\pi K(H^2 - h^2)}{\ln R_o / r_w}$$

Q: Quantity of water pumped

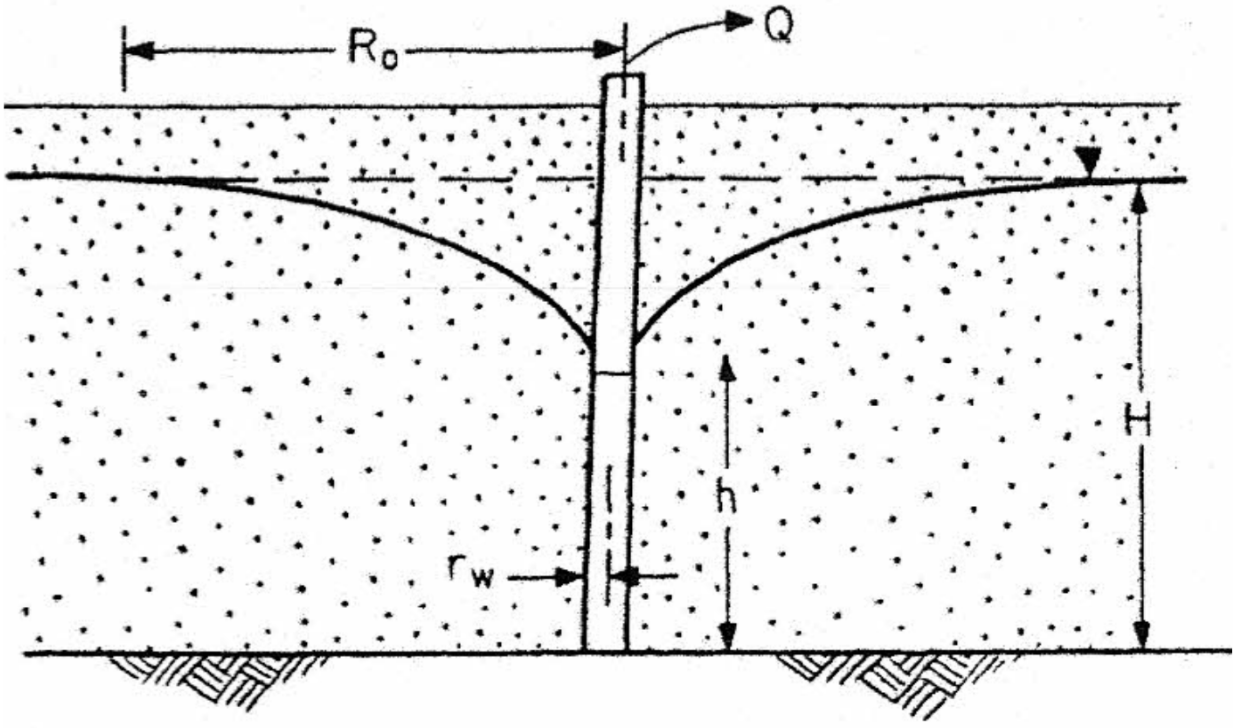
K: Soil permeability

H: Height of ground water table above impervious layer

h: Height of reduced ground water table

Ro: Radius of influence

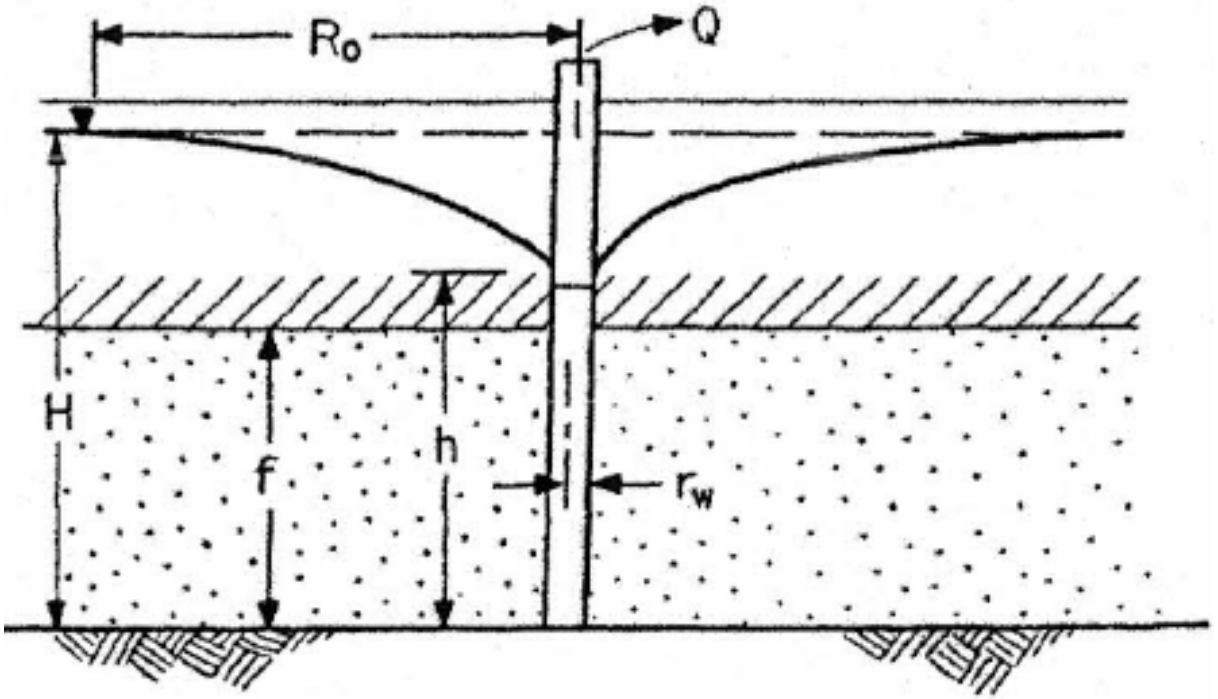
r: Radius of well



Construction Dewatering
Design of Dewatering Analysis

- **Confined Aquifer**

$$Q = \frac{2\pi K f (H - h)}{\ln R_o / r_w}$$



Construction Dewatering
Design of Dewatering Analysis

- **Soil Permeability**
  - **The ability of water to flow through a soil**

Soil	*Permeability Coefficient, k (cm/sec)*	*Relative Permeability*
Coarse gravel	Exceeds 10^{-1}	High
Sand, clean	10^{-1} to 10^{-3}	Medium
Sand, dirty	10^{-3} to 10^{-5}	Low
Silt	10^{-5} to 10^{-7}	Very low
Clay	Less than 10^{-7}	Impervious

Gravel is 1 million times more permeable that clay

Construction Dewatering
Design of Dewatering Analysis

- **Self-Practice Example**

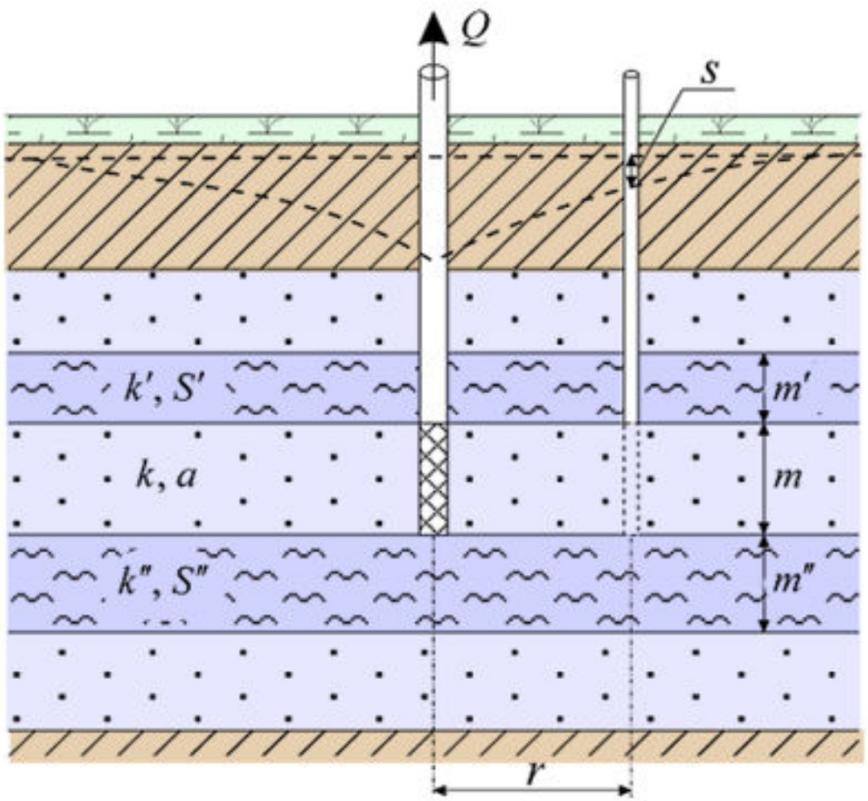
In a construction dewatering job in an unconfined aquifer of depth 20m you have installed a 30 m3/h pump. The radius of influence extends for 10m around the well. What is the expected drawdown?

Construction Dewatering
Design of Dewatering Analysis

- **Multi-layered Aquifers**

In the case where we have different soil layers that make up the aquifer we can calculate the effective permeability of the aquifer as follows:

$$K = \sum_i \frac{K_i B_i}{B}$$



where K is the effective permeability; Ki is the permeability of layer i; Bi is the thickness of layer i; and B is the overall thickness of aquifer.

Construction Dewatering

Design of Dewatering Analysis

- **Multi-well Analysis**
  - **How can we calculate the effect of multiple wells?**

If the drawdown in the aquifer is a small percentage (about 10–20%) of the aquifer thickness, the effect of each well can be superimposed on the other to determine the cumulative effect.

Unconfined Aquifer

$$D = MH - \sum_j \sqrt{H^2 - \left(\frac{Q_j}{\pi K} \times \ln\left(\frac{R_j}{r_j}\right)\right)};$$

Confined Aquifer

$$D = H - \sum_j \left[H - \left(\frac{Q_j}{2\pi KB} \times \ln\left(\frac{R_j}{r_j}\right)\right)\right];$$

M is the number of pump wells; H is the original water table level; K is the effective permeability; B is the layer thickness; Qj is the pumping rate of well j; Rj is the influence radius of well j; and rj is the distance between pumping well j and the

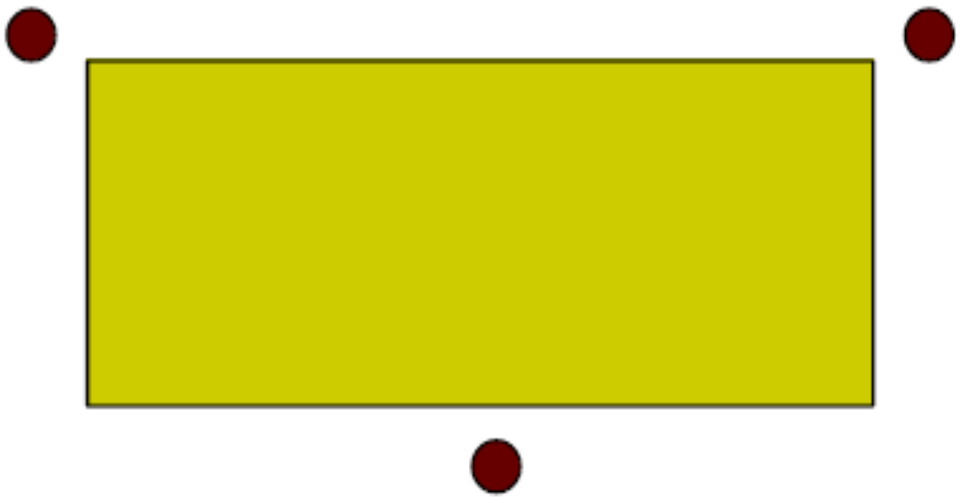
Construction Dewatering

Design of Dewatering Analysis

- **Self-Practice Example**

In the shown 20x50m excavation three dewatering wells are installed at an offset of 4m from the edge of the excavation.

The depth of the excavation is 5m and the ground water table is 2m below the natural ground level. The ground water is in an unconfined aquifer of 25m depth



Single Pump Data:

$Q = 30\ m^3/s$

$r_w = 0.4m$

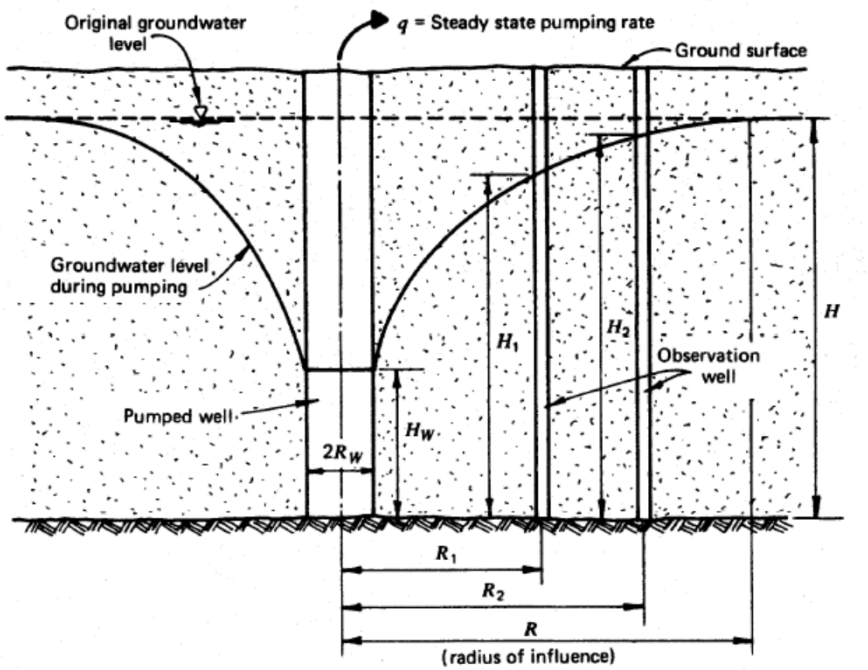
$R = 18m$

$K = 0.0005\ cm/s$

Construction Dewatering
Design of Dewatering Analysis

- **Site Pumping Tests**
- In order to determine actual well performance, a site pumping test is commonly performed prior to the final design of the dewatering system.

  - This will help determine the actual performance and soil permeability.
  - Observation wells / peizometers are installed to monitor the actual drawdown

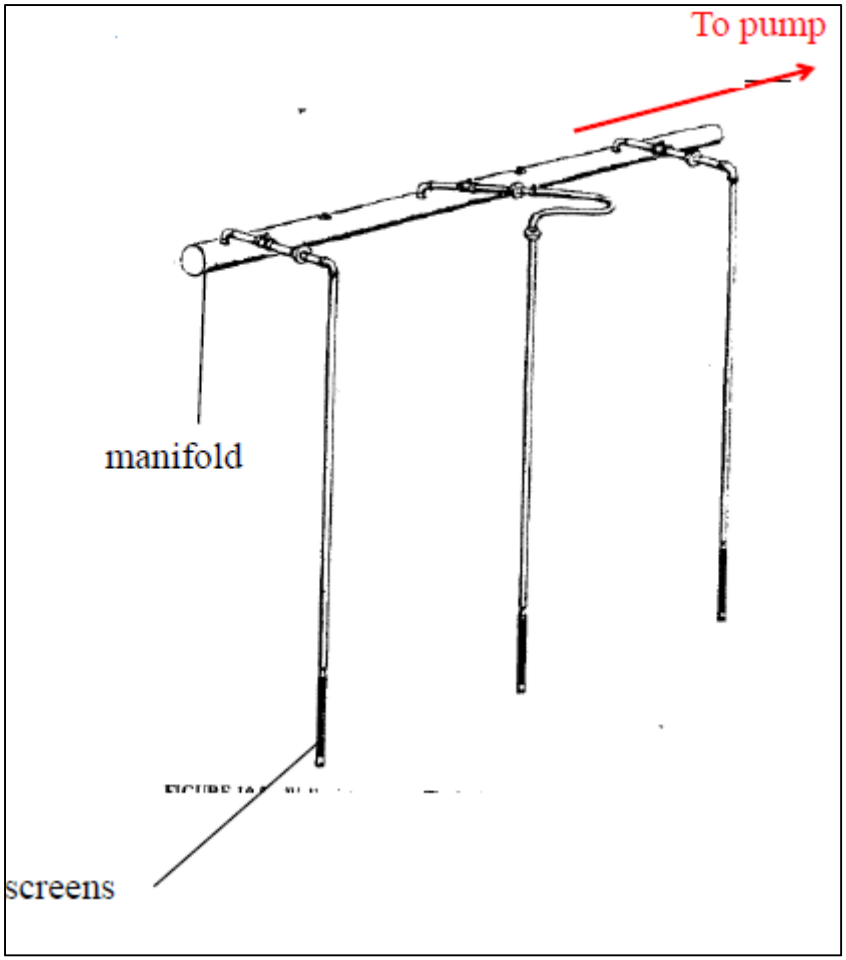


Construction Dewatering - Techniques
Sumps, Ditches and Trenches

- **A trench** is excavated around the area to be dewatered.
- Surface pumps with hoses are used to pump water from the ditches.
- Practical to be used with relatively small quantities of water and small water heads.

Construction Dewatering - Techniques
Well point system

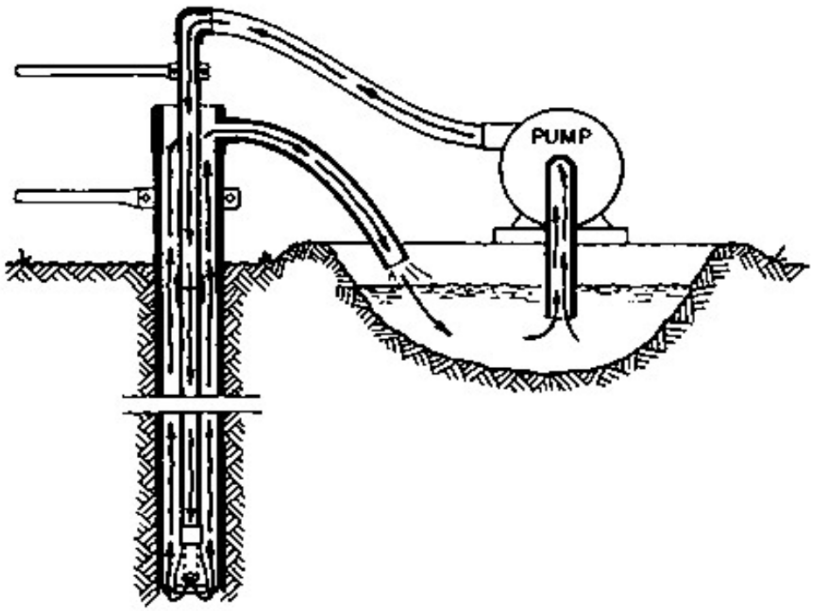
- Small pipes (up to 2.5” diameter) connected to screens at the bottom and a vacuum header pipe at the surface.
- Screens prevent soil particles from being pumped away with the water
- A centrifugal / vacum pump is connected to the manifold
- Wellpoint systems are constrained by the maximum possible suction head
- Common dewatering heights range from 4.5 - 7.5m



Construction Dewatering - Techniques
Well point system

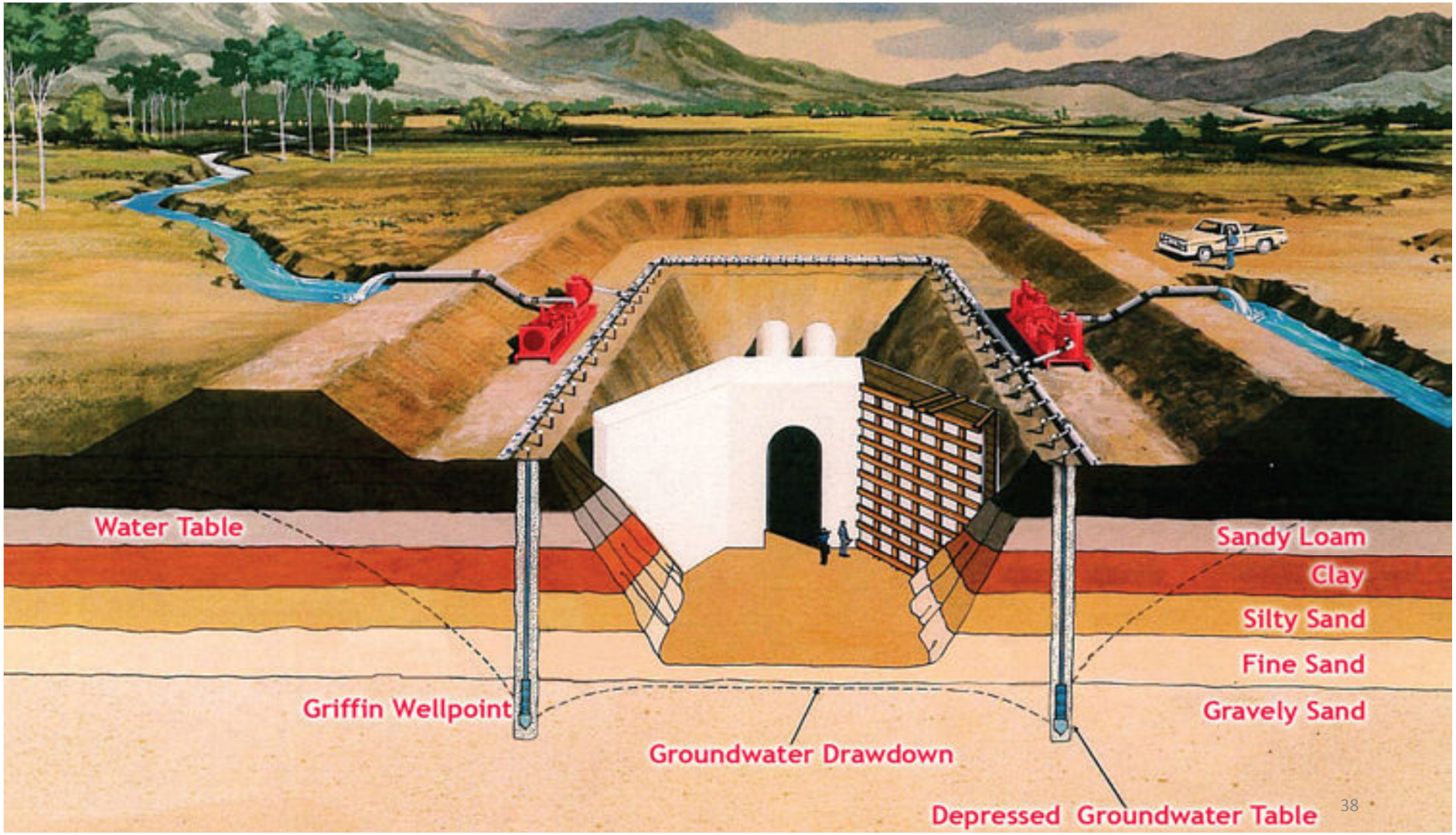
- **Construction Steps**

1. The wellpoints are jetted into the ground;
2. The annulars void is filled with filter media;
3. The wellpoints are connected to a header pipe by means of a riser;
4. The header pipe is connected to suction pumps for pumping



Construction Dewatering - Techniques

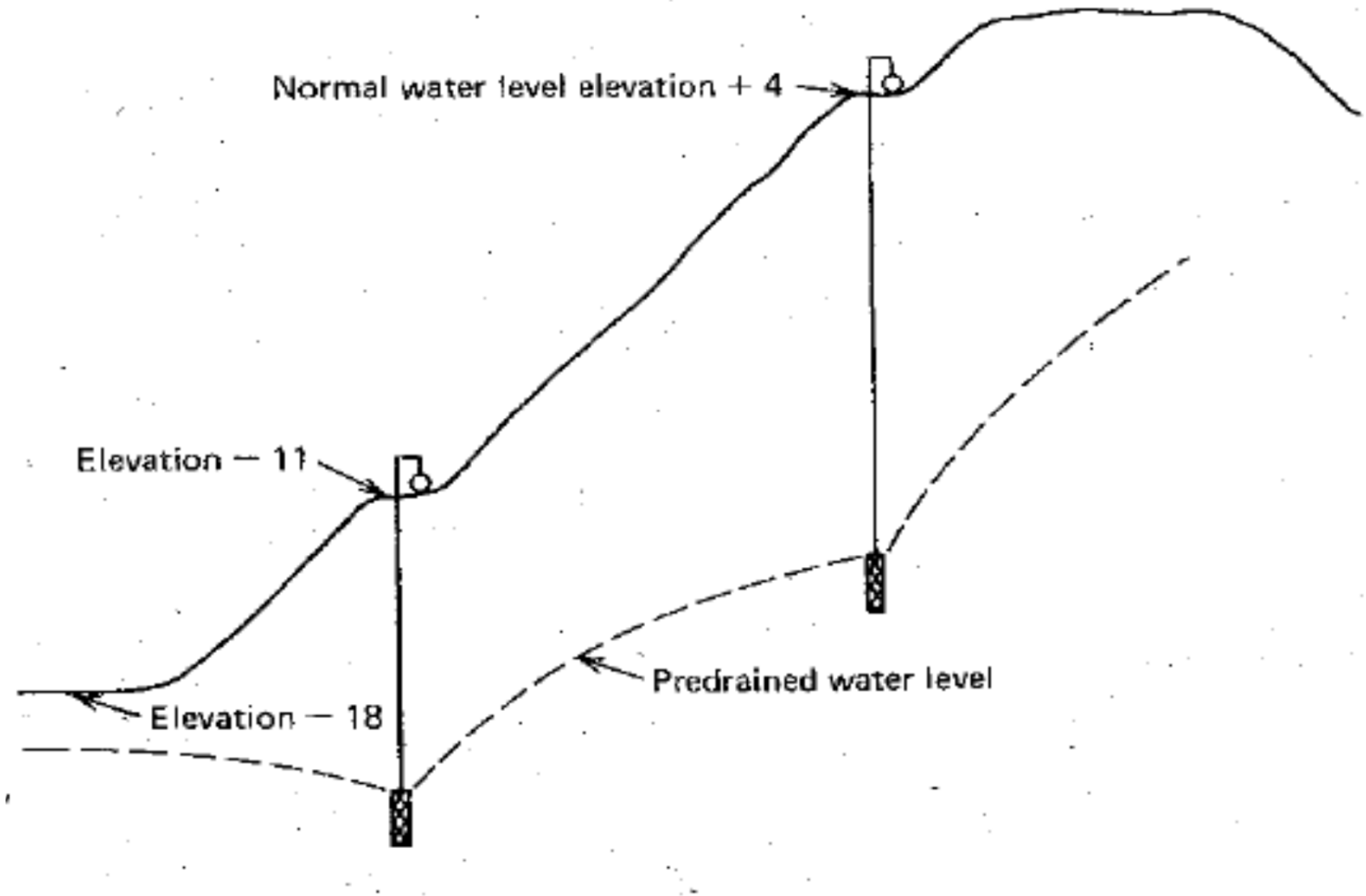
Well point system



Construction Dewatering - Techniques
Well point system

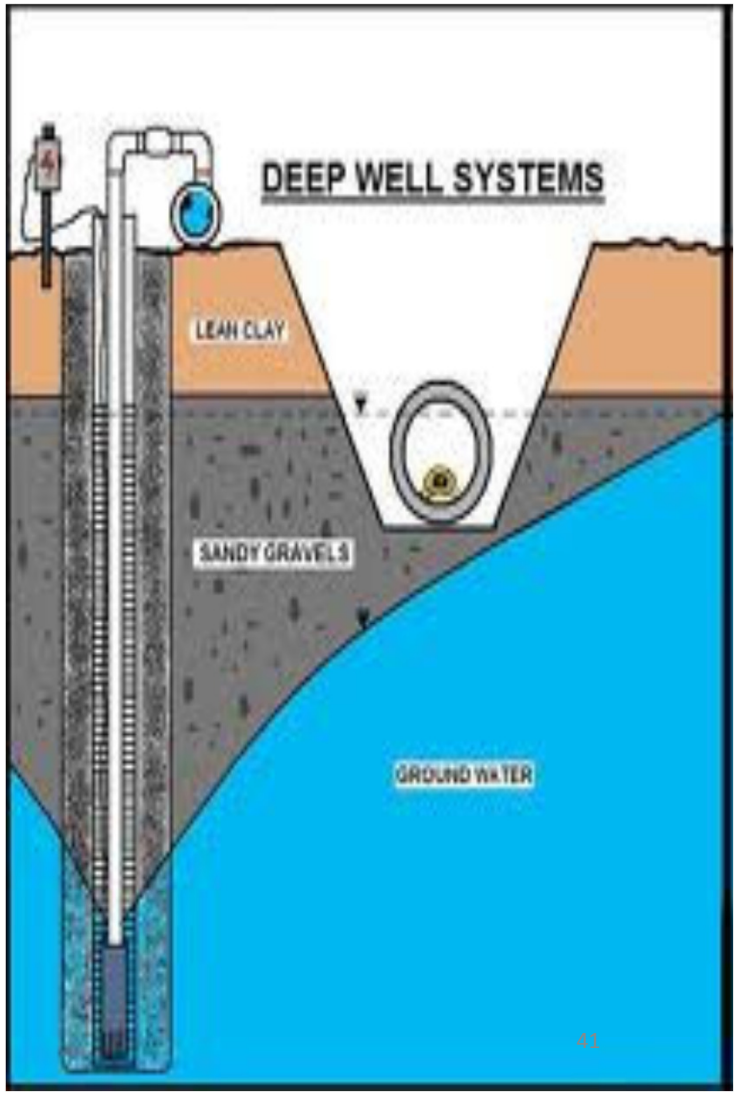
- **What if we need to lower the ground water table more than the well point can handle?**
  - 2-stage well point system
  - Deep wells

Construction Dewatering - Techniques
Well point system



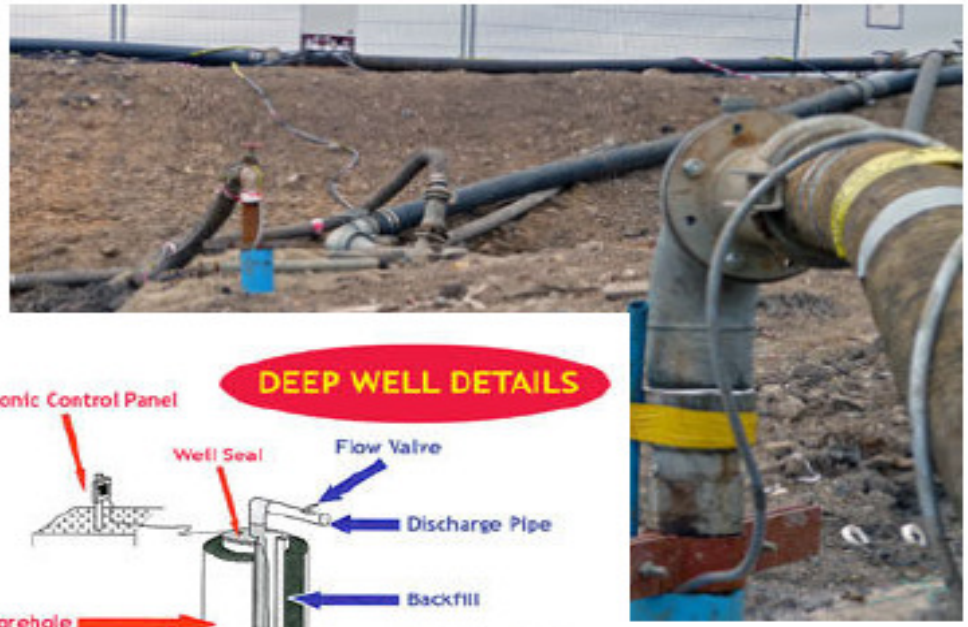
Construction Dewatering - Techniques
Deep Well

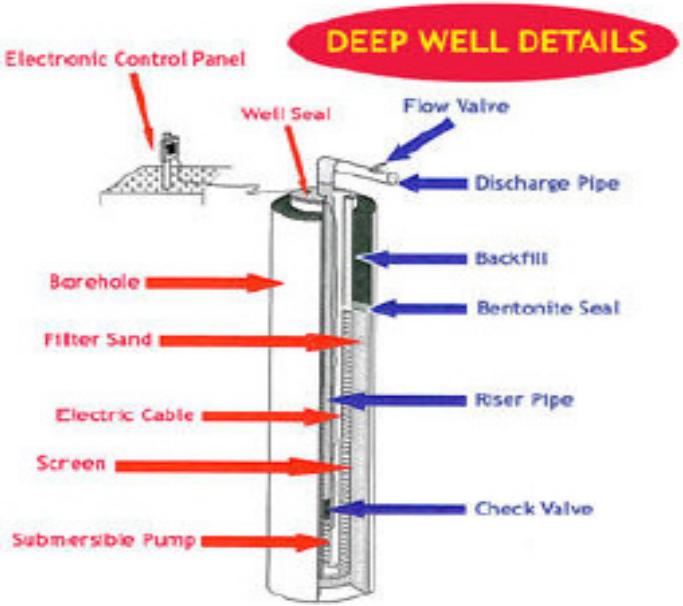
- Consists of a borehole fitted with a slotted liner and an electric submersible pump.
- As the pump is submersible, there is no suction head limitation as for well points.
- Deep wells work best in soils with specific permeability profiles ($k=1x10^{-5}$cm/s to $1x10^{-7}$cm/s) and the amount of drawdown that a well can achieve is limited only by the size of the pump.
- Pumps are engineered to withstand the aggressive corrosion factors associated with use over sustained periods of time in a saline environment.



Construction Dewatering - Techniques

Deep Well system





Construction Dewatering - Techniques
Deep Well system

- Advantages:
- Ability to penetrate strata impervious to the jetting method of wellpoint systems.
- Installation of up to 100 feet deep or more in a single stage.
- Capable of pumping tens to thousands of gallons per minute per well.
- Deep Wells can be effective when placed outside of the jobsite work area.

Construction Dewatering - Techniques
Ground Freezing

- Provides both a water cutoff and a structural cofferdam.

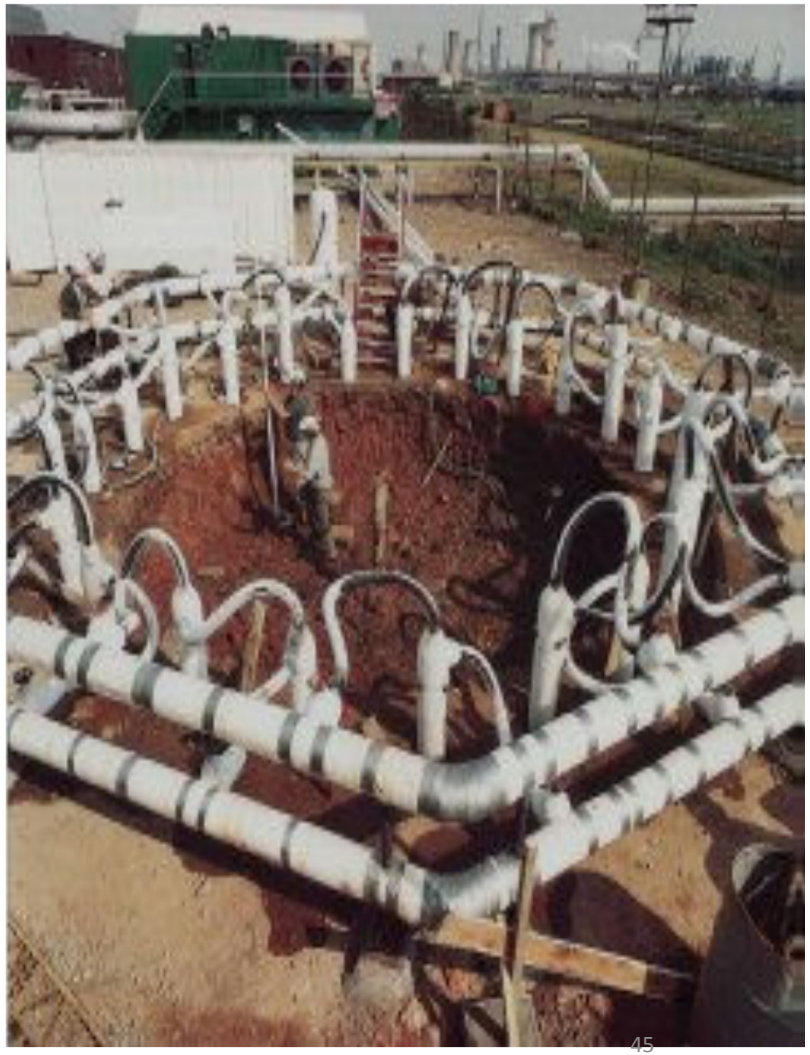
- Widely used in Europe.

Construction Dewatering - Techniques
Ground Freezing

- Freeze pipe are installed along the line of the wall to be frozen every 1m. Pipe consists of an external casing and an internal pipe.

- A refrigerated brine solution is circulated through the system and the freeze pipes.

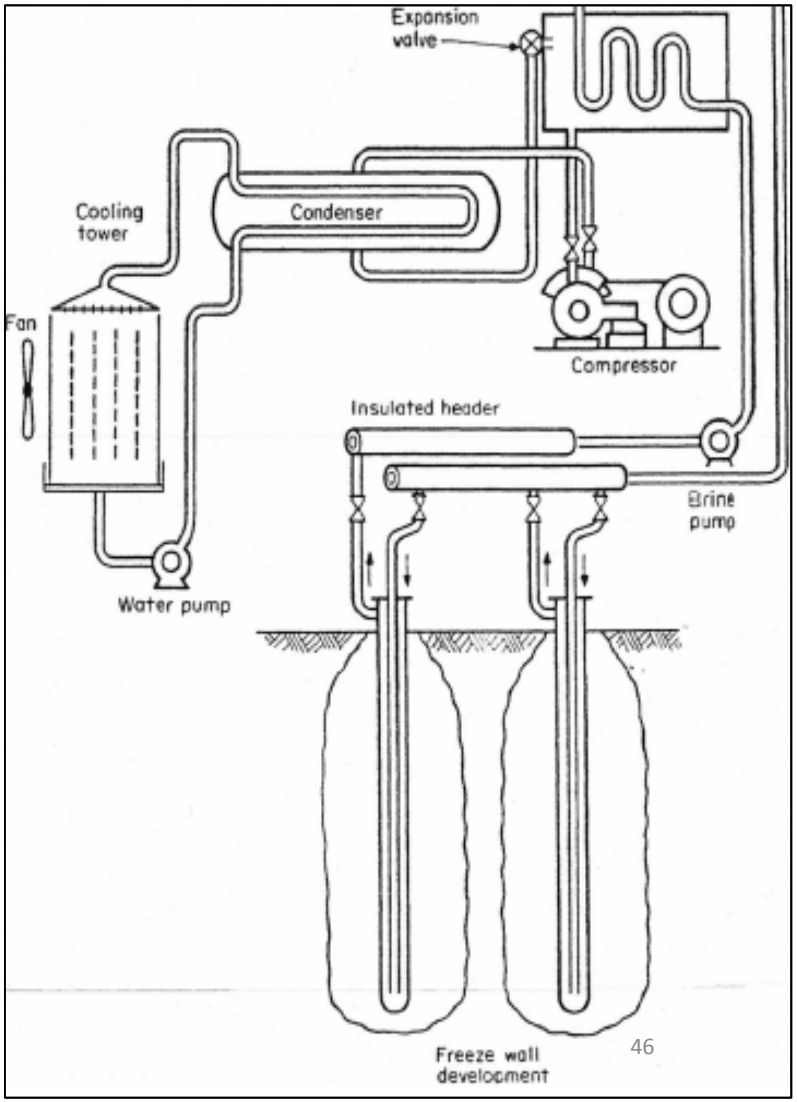
- At the freeze plant a heat exchanger transfers the heat to the ground.



Construction Dewatering - Techniques
Ground Freezing

- **Important Considerations:**
  - Natural ground water velocities.
    - Prevent formation of wall.
  - Presence of external heat source.

    (e.g. adjacent pipelines).
  - Soft clay will creep when frozen.
    - Ground movement.
  - This technique requires continuous temperature monitoring.
  - Not economic in hot climates.



Construction Dewatering
Other considerations during dewatering

- **Power supply:**
  - Provision of electricity source.
  - Safe electrical wiring on site.
  - Provision of backup power supply.

- **Environmental considerations during dewatering:**
  - Disposal of water.
  - Impact on ground water aquifers.
  - Impact on surrounding structures.

- **Conducting pumping tests to verify actual site performance**

Thank You

Questions ?