

HYDROGEOLOGY: MODULE NOTES

The objective of this module is to measure different parameters which we use to understand how water flows through the subsurface. This portion of the course is designed assuming you have taken hydrogeology. If you have not taken hydrogeology let us know so we can give you any extra help you might need. These notes are designed as a refresher of the principles which we are applying.

The goals of a hydrogeologist are very often to determine how much groundwater is available and how fast it might be moving. The how much is important for determining how much water can be pumped from a given well, and the how fast is important for knowing how quickly a groundwater contaminant might move. The objective of this module is to measure some parameters which can be used to quantify groundwater flow.

Figure 1 shows a schematic groundwater flow system. In this module we will be looking at numerous parts of this system.

- **Aquifer Geology:** Behind the Ogilvie camp you will look at and make a well log of shallow sediments which are part of the aquifer near this site.
- **Recharge:** We will not be doing a specific recharge activity, but we will visit the recharge area of the aquifer at the AECL site.
- **Water Table:** You will be measuring water levels at AECL and you will make a water table map as well as a groundwater flow cross section.
- **Hydraulic Conductivity:** At AECL you will conduct a bail tests to determine they hydraulic conductivity.
- **Water sampling:** Behind the Ogilvie camp we will sample water from some of the pizeometres and measure ph and electrical conductivity.
- **Groundwater Discharge:** In the lake at the Ogilives you will install closed top seepage metres to measure groundwater discharge or recharge in the lake.

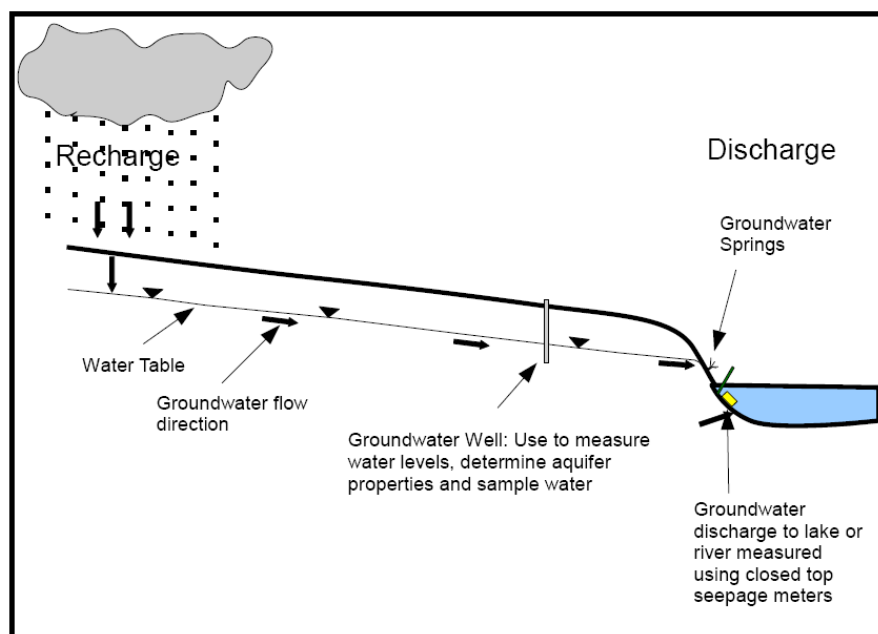


Figure 1: Schematic diagram of a groundwater flow system.

REVIEW OF HYDROGEOLOGY:

The focus of hydrogeology is the aquifer, an underground water bearing formation. Water may flow through unconsolidated sediments or through rock. Water flow may take place in "primary porosity" the spaces between grains, or in "secondary porosity" which is the fractures which may be present in a rock. In general there are two types of aquifers: unconfined and confined. In an unconfined aquifer the water table is where we first encounter water below the surface. A confined aquifer has a subsurface layer above the aquifer which traps the aquifer and means that the water level is not necessarily the same as the water table (Figure 2).

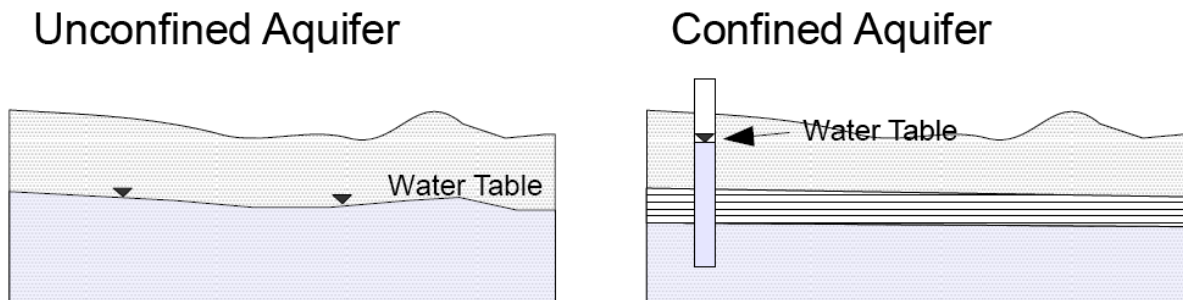


Figure 2: Diagram of confined and unconfined aquifer.

SEDIMENT TYPES AND SIZES

The type of rock or sediment an aquifer is formed in will change both water chemistry, how much water the sediment can hold and the ease at which water may pass through it. Some important definitions:

Porosity: The amount of void space in rock or sediment

Permeability: The ease at which water can flow through a rock or sediment.

In general, hydraulic conductivity (permeability) increases with larger grain size due to higher porosity, however this is not a rule. High porosity sediments may have very low permeability. Clay sediments can have very high porosity, yet has extremely low permeability. The mineralogy of the sediment or rock type will affect the chemistry of the water discharging from it.

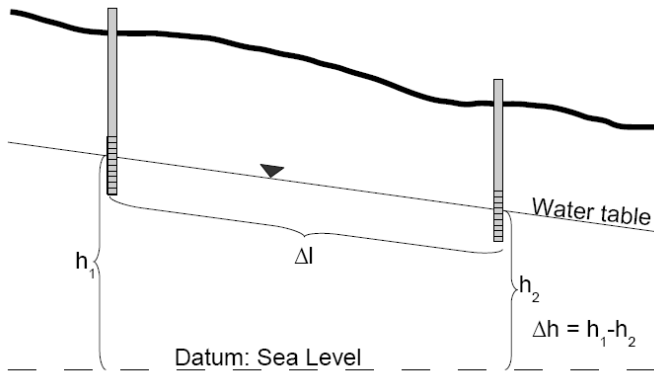
DARCY'S LAW

Darcy's is the law used to describe the flow of water through an aquifer.

$$q = \frac{Q}{A} = -K \frac{\Delta h}{\Delta l}$$

- q = Darcy flux (m/s) **NOT VELOCITY** However if we know q , and n (porosity) we can solve for the velocity with the equation: $v = \frac{q}{n}$
- Q = Discharge (m^3/s)
- A = Cross sectional area (m^2)

- K = Hydraulic conductivity (m/s)
- Δh = change in pressure head (water table) (m)
- Δl = distance between two measurement points (m)



Various hydrogeological tests aim to find out what hydraulic conductivity is. In this field school we will be doing bail tests. We will not be doing pumping tests in this course, however these allow us to determine aquifer yield.

BAIL TEST

The idea of a bail test is we remove a known volume of water from the well causing a stress on the aquifer and we see how long it takes for the well to recover. We record the recovery and can calculate the hydraulic conductivity. The equations that are used for the analysis of bail test data depend on the nature of the aquifer. For a confined aquifer we can use the Hvorslov method; however we are dealing with an unconfined aquifer so you will use equations developed by Bower and Rice (1976).

Bower and Rice (1976) (adapted from Bouwer, Groundwater 1989, 27: 304-309)

By this method the hydraulic conductivity is found by the below equation:

$$K = \frac{r^2 \ln(R_e/R)}{2LT_0}$$

- $r = 0.05$ m (screen radius)
- $R = 0.05$ m (sand pack radius)
- $L = 1.52$ m (screen length)

We find $\ln(R_e/R)$ using the below equation:

$$\ln\left(\frac{R_e}{R}\right) = \left\{ \frac{1.1}{\ln\left(\frac{L_w}{R}\right)} + \frac{A + B \ln\left(\frac{L_t}{R}\right)}{\frac{L}{R}} \right\}^{-1}$$

Where:

- L_w = distance between bottom of screen and static water level (i.e. the depth of water in the well at static equilibrium) **Measure in the field**
- $R = 0.05\text{m}$ (sand pack radius)
- L_i = distance between bottom of screen and impermeable layer below
- $L = 1.52\text{ m}$ (screen length)
- A & B: We solve for using L and R on the below graph

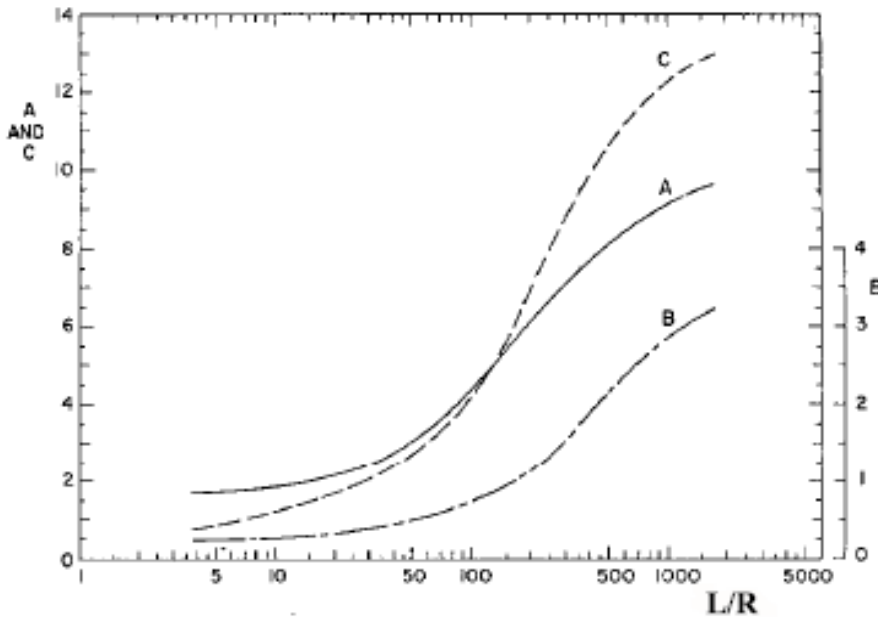


Fig. 2. Dimensionless parameters A, B, and C as a function of L/R for calculation of $\ln(Re/R)$

We find T_0 by graphing:

Plot $\ln(H-h)$ vs time (s). Use the straight-line portion of the plot in the middle of the range. Do a regression of this segment of the plot and obtain the slope of the resulting line. Put the line on the same plot with your data. From the slope, calculate $T_0 = (-1 / \text{slope})$. Using this value of T_0 calculate the hydraulic conductivity of the formation.

In the Field:

What to record:

- Important site and equipment information, including bailer volume, well information, aquifer information (confined or unconfined)
 - L_w = distance between bottom of screen and static water level (i.e. the depth of water in the well at static equilibrium) [L]
 - $r = 0.05\text{ m}$ (screen radius)
 - $R = 0.05\text{m}$ (sand pack radius)
 - $L = 1.52\text{ m}$ (screen length)
 - $L_i = 8.00\text{ m}$ (distance between bottom of screen and impermeable layer below)
 - Water levels, volume of the bail (to calculate initial change in head)

WATER LEVELS

At AECL you will measure water levels in piezometers. These wells are old, as such some are no longer in working order. From the water levels you will measure you will make a water level map, and a piezometric cross section. Figure 3 shows a sample water table map taken from a report prepared by A&A Environmental services for the Township of Larder Lake Ontario. Figure 4 shows a sample flow net cross section.

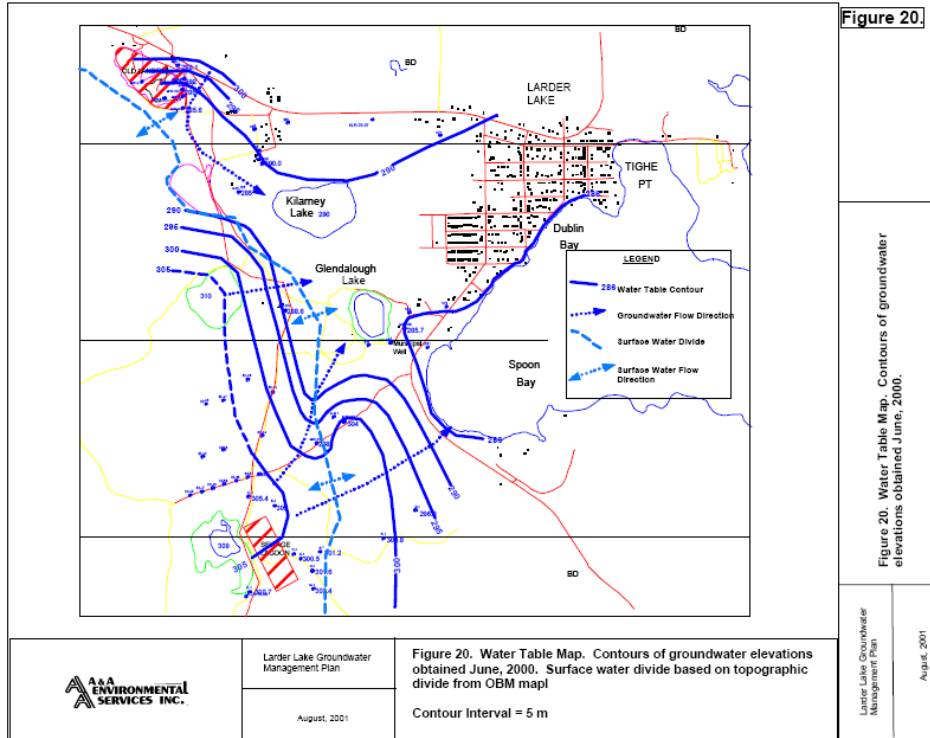


Figure 3: Water table map

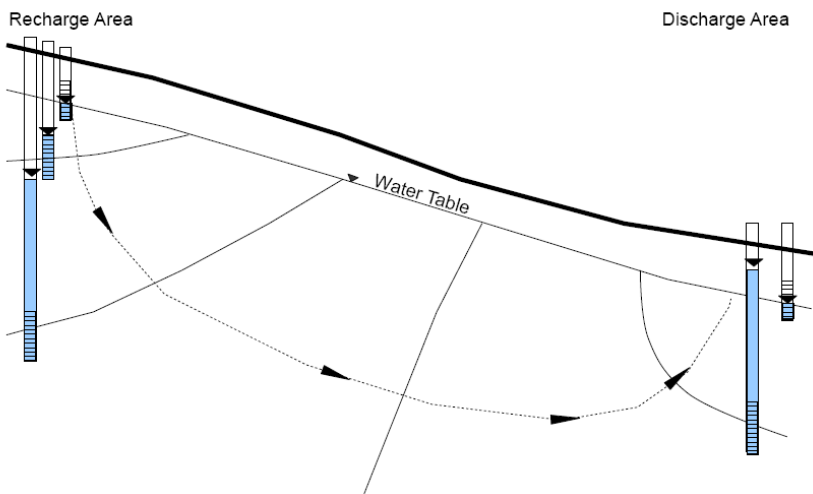
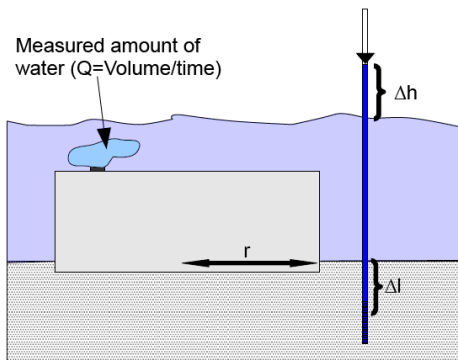


Figure 4: Flow net cross section

SEEPAGE METER

To determine the hydraulic conductivity of the sediment in the lake we can use a closed top seepage metre. With the seepage metres we can apply Darcy's law directly and measure Q (volume of water/time), A (area of seepage metre), Δh and Δl .

$$\frac{Q}{A} = -K \frac{\Delta h}{\Delta l}$$



GROUNDWATER SAMPLING

Sampling groundwater from a water well is not as straight forward as it may sound. The method for sampling will be different depending on what you are interested in measuring in your water sample. Prior to undergoing a real life sampling campaign numerous factors should be considered:

- How easily is my sample contaminated
- How much water do I need for the analysis
- If sampling site is contaminated you may need to put a tarp down to prevent equipment from being contaminated and you may need a well specific water tape. Once a sample is collected chain of custody forms may be needed.
- How am I going to sample bailer or peristaltic pump

For the sampling in this course we will be using a peristaltic pump and measure pH, conductivity and alkalinity.