Environmental Geology Lab 3 – Groundwater Resources and Contamination

From our previous discussion of the hydrologic cycle we learned that groundwater is defined as all water below the earth's surface. The process (flux) that transfers water from the surface to the groundwater reservoir is infiltration. To understand the nature of groundwater one must be able to characterize the open spaces present within rock and sediment (henceforth referred to as an earth material; Figure 1).

> Porosity – The percentage of open spaces within an earth material
> Permeability – The degree of interconnectivity between open spaces; also influences how fast water will travel through an earth material, which is defined as hydraulic conductivity

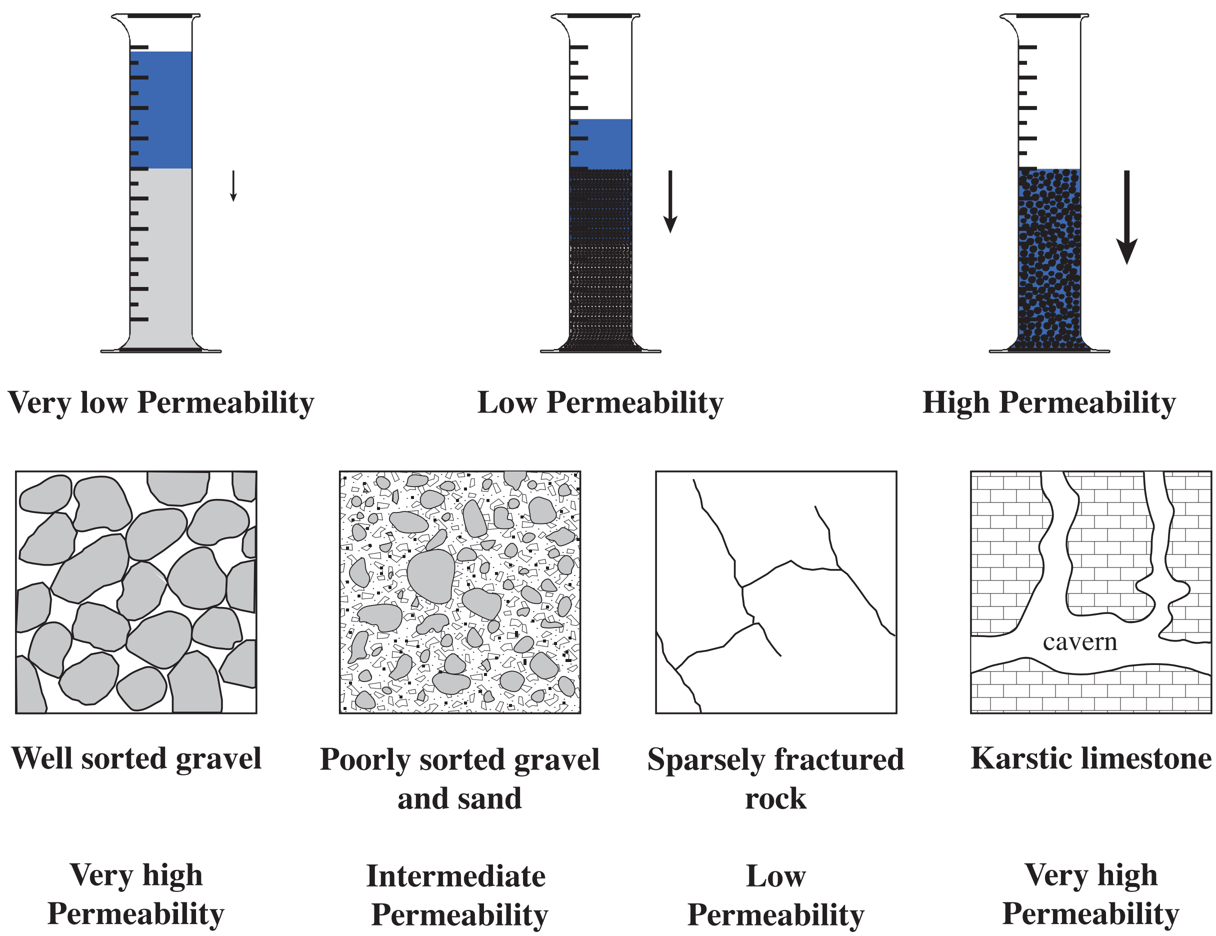

Figure 1. Basic diagram illustrating porosity and permeability

Rock Type	*Hydraulic Conductivity (K) (m/day)*	*Porosity (n)*
Gravel	100 - 100,000	0.30 - 0.40
Sand	0.1 - 1,000	0.35 - 0.40
Silt & Clay	0.0000001 - 1.0	0.30 - 0.60
Sandstone	0.00001 - 0.1	0.10 - 0.20
Shale	0.00000001 - 0.0001	0.01 - 0.10
Limestone		
- unfractured	0.0001 - 0.1	0.01 - 0.02
- karstic	0.1 - 1,000,000	0.02 - 0.20
Igneous & Metamorphic		
- unfractured	0.000000001 - 0.00001	<0.01 - 0.02
- fractured	0.001 - 10	0.01 - 0.05

Table 1. List of common earth materials with porosity and permeability indicated.

Fundamentally, there are two distinct zones of subsurface water defined based on the material that occupies the porosity within an earth material.

Zone of Aeration – Close to the surface with porosity filled with both water and air (think air = aeration)
Zone of Saturation – Deeper below surface with porosity filled with only water (think saturated with water)

The boundary between the zones of aeration and saturation is the water table. Basically, the top of the zone of saturation is defined as the water table.

Within the zone of saturation the permeability of earth materials can be high or low. Materials with high permeability are defined as an aquifer. More formally, an aquifer is a layer that is capable of transmitting large quantities of groundwater. In other words, if you are drilling a well you want your well to penetrate an aquifer. Aquifers can have both high and low porosities depending on earth material type. Aquifers consisting of sediment tend to have high porosities (30 to 40%) whereas aquifer within fracture bedrock have low porosity (1%). Permeability and not porosity is the defining parameter when designating an aquifer. Conversely, an aquitard is a subsurface layer that has a low permeability and prevents (or retards) the movement of subsurface water. Do not try to extract groundwater from an aquitard.

There are three basic types of aquifers. A confined aquifer is an aquifer that is surrounded both above and below aquitards. Note that if you drill a well into a confined aquifer the water level will rise due to pressure in the aquifer to the piesometric surface; a level above the elevation of the aquifer. Additionally, a confined aquifer can only obtain infiltration from a relative small area on the earth's surface where the earth materials that define the aquifer are present at the surface. This area is referred to as the recharge area.

An unconfined aquifer is not confined in any way and has a water table that is free to rise up and down without any constraints. Finally, a specific type of aquifer is a perched water table, which is an aquifer that sits on top of a aquitard but has a water table that is confined and is free to rise up during rainy conditions and down during droughts.

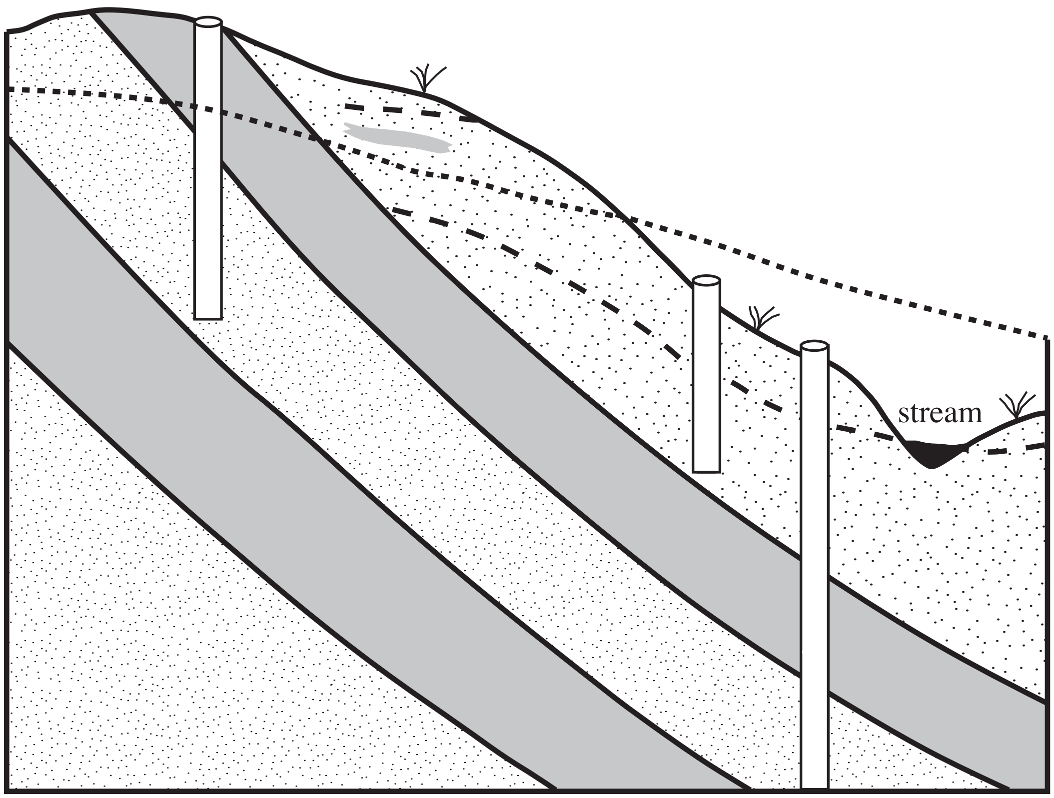

Figure 2. Summary diagram indicating the different features associated with groundwater.

QUESTIONS

1. How does the zone of aeration differ from the zone of saturation

2. In words define the water table.

3. What is the difference between porosity and permeability.

4. Describe the following two situations: (1) sediment with high porosity and permeability; (2) rock with high porosity and low permeability. Which situation is an aquifer and which one is an aquitard. Defend your answer.

5. Does the level of the water in a well always correspond with the elevation of the water table? Hint: Think about the level of water in a well drilled into a confined aquifer. What is the significance of the piesometric surface?

FOR QUESTIONS 6 AND 7 EXAMINE SAMPLES A (Sandstone) AND B (Shale) IN THE FRONT OF THE LAB

6. Which earth materials do you think would make a good aquifer? ____________________

7. Which earth materials do you think would make a good aquitard? ____________________

8. Is it possible to have an aquitard with high permeability but low porosity? Explain in detail.

9. Is it possible to have an aquifer with low permeability but high porosity? Explain in detail.

10. Drilling a well into a fractured bedrock aquifer can be problematic when compared with drilling into an aquifer consisting of loose sediment. Can you think of some of the problems associated with developing a fractured bedrock fracture as a source for extractable groundwater. By drilling a well are you guartaneed to hit a fractur filled with water. Explain!

11. Examine Figure 2 and correctly label the following features associated with groundwater. Examine the groundwater model in the rear of LVB 108.

Zone of Saturation (ZS)

Zone of Aeration (ZA)

Water Tables (WT)

Confined Aquifer (CA)

Unconfined Aquifer (UA)

Aquitards (A)

Perched Water Table (PWT)

Recharge Area (RA)

Piezometric Surface (PS)

Determining Groundwater Flow and Areas of Groundwater Contamination

Potential sources of groundwater contamination are divided into two categories: point sources and non-point sources. *Point sources* of contamination include domestic and hazardous waste landfills, leaky underground petroleum storage tanks, chemical spills at industrial sites, mine waste dumps, petroleum brine pits, and radioactive waste pits. Although contamination can sometimes be severe around such facilities (and they are often the focus of media attention), the impact of such contamination tends to be relatively local. *Non-point sources* of contamination such as overuse of pesticides, herbicides, fertilizers (including manure), septic tank fields, urban runoff and use of road salt in northern areas, may actually have a greater impact on groundwater resources, because they are so widespread.

Underlying a military base in northeastern Michigan is a shallow, sand and gravel unconfined aquifer. This subsurface layer is porous and permeable enough to conduct groundwater and to yield water readily to wells and springs. The water table lies between 10 and 25 feet below the ground surface. A leak in a storage drum has allowed a toxic organic liquid to enter the aquifer. This contamination is a potential threat to drinking water supplies on the base. The wells were drilled for various purposes, and their locations are shown on the map (Figure 3).

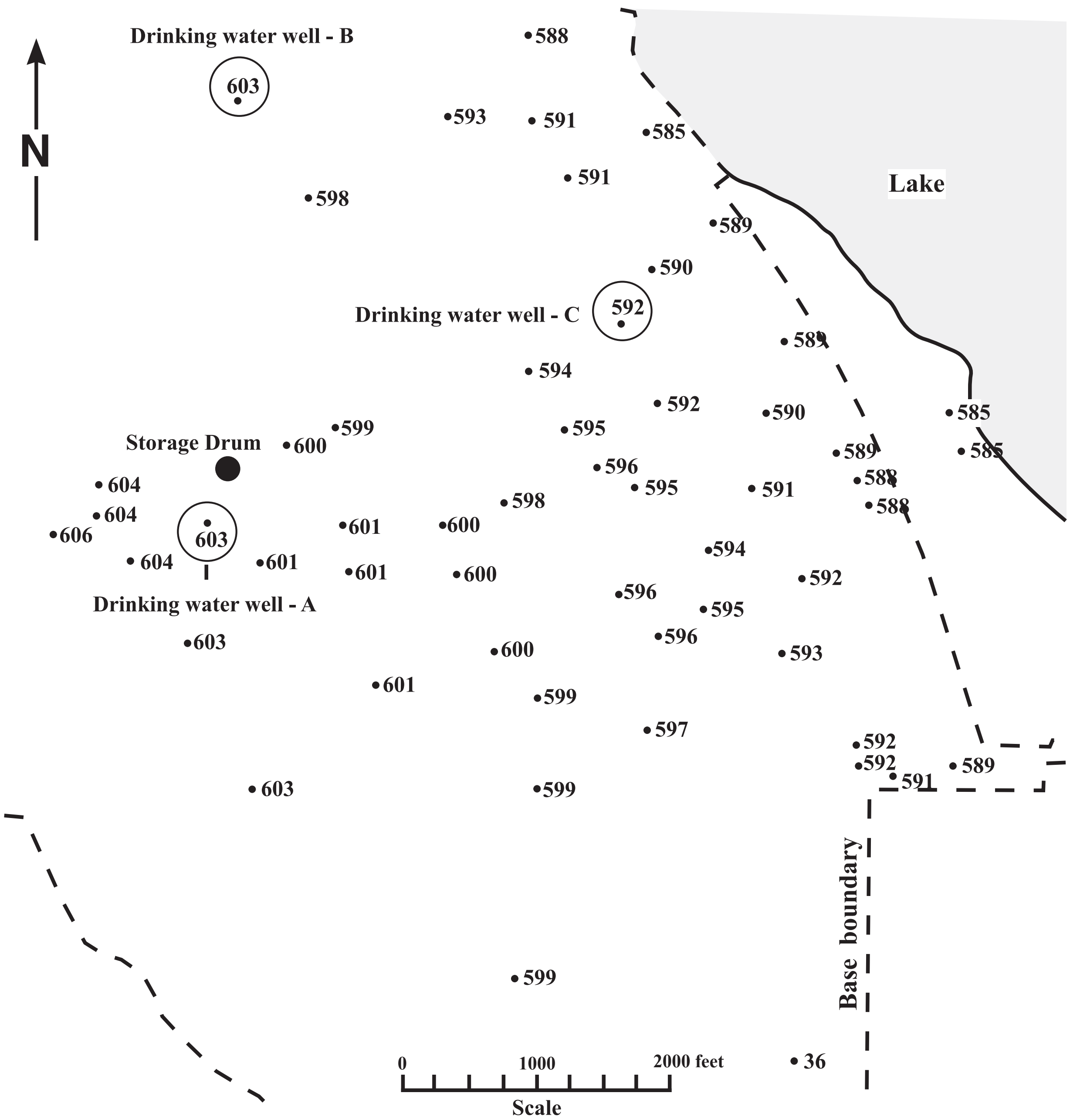

Figure 3. Well map

QUESTIONS

12. The pollution on this military base is leaking from the storage drum illstrated on Figure 3. This represents what type of pollution.

Point Source or Non-Point Source

13. Using a standard pencil, contour the water table elevation on the map for the following elevations.

600 ft - Just Below the Storage Drum
590 ft - Just Below Endangered Well C

Draw each line so that they seperate all elevations that are greater on one side from those that are less on the other side. **Follow the instructions given by your instructor**.

14. The direction of groundwater flow is generally perpendicular to the equipotential or contour lines, moving from higher to lower elevations. Using a red colored pencil, draw an arrow (or flow line) from the storage drum to well C indicating the direction of ground water movement. Hint: groundwater tend to move toward a surface water feature like a river or lake.

Some Math – Darcy's Law

The rate of groundwater flow in the saturated zone can be calculated with Darcy's Law:

(1)
$$V = K \frac{\Delta H}{\Delta L}$$

This equation shows that the velocity (V) of ground water movement is the product of the hydraulic conductivity (K) and the hydraulic gradient ($\Delta H / \Delta L$). The hydraulic gradient is the ratio of the vertical drop of the water table in feet (ΔH) to the horizontal distance of the groundwater flow in feet (ΔL). The hydraulic conductivity describes the rate at which groundwater can move through an aquifer. It is determined by experiment and depends on aquifer permeability and the properties of the transported fluid.

QUESTIONS

15. Determine the following elevations

Storage Drum ______________ ft

Endangered Well C ______________ ft

16. Calculate the ΔH between the storage drum and Endangered Well C.

17. Determine horizontal distance of the groundwater flow in feet (ΔL) between the storage drum and Endangered Well C by using a ruler and the scale on the map. Leave this distance in ft.

18. Determine the hydraulic gradient between the storage drum and the threatened well. Show your work. Round your answer to three digits pass the decimal place. This problem basically is a calculation of rise / run. Rise is the difference in elevation of the water table between the storage drum and the threatened well and the run is the horizontal distance between the storage drum and the threatened well. **Show your work.**

19. Calculate the Darcy's velocity of the ground water flow from the storage drum to the well (in feet per day). For the aquifer in this study, the hydraulic conductivity is 100 feet per day. **Show your work.** Round your answer to two digits pass the decimal place.

20. Using the formula, time = distance / velocity, determine how long it will take the contaminates to reach the well (in days). **Show your work.**

21. Convert your answer to question 20 into years by dividing by 365 days per year. **Show your work.**

22. In Figure 3, groundwater ultimately flows into the lake on the northeastern corner of the map? True or False

GROUNDWATER IN WEBB COUNTY

Examine the geologic map provided by the instructor. Key for map is given on the following page (Figure 4). This map focuses on an anormalous area to the east of Laredo along US Highway 83. It is a zone where the Laredo Formation is present at the surface. Interestingly, this is one of the few areas in the county where fresh groundwater is present. The county maintains a pumping station here. Locals outside town arrive with tanks that they fill with water to supply for their homes. The rocks in Laredo have a slight dip toward the east at about one degree. Examine the diagram provided by the instructor.

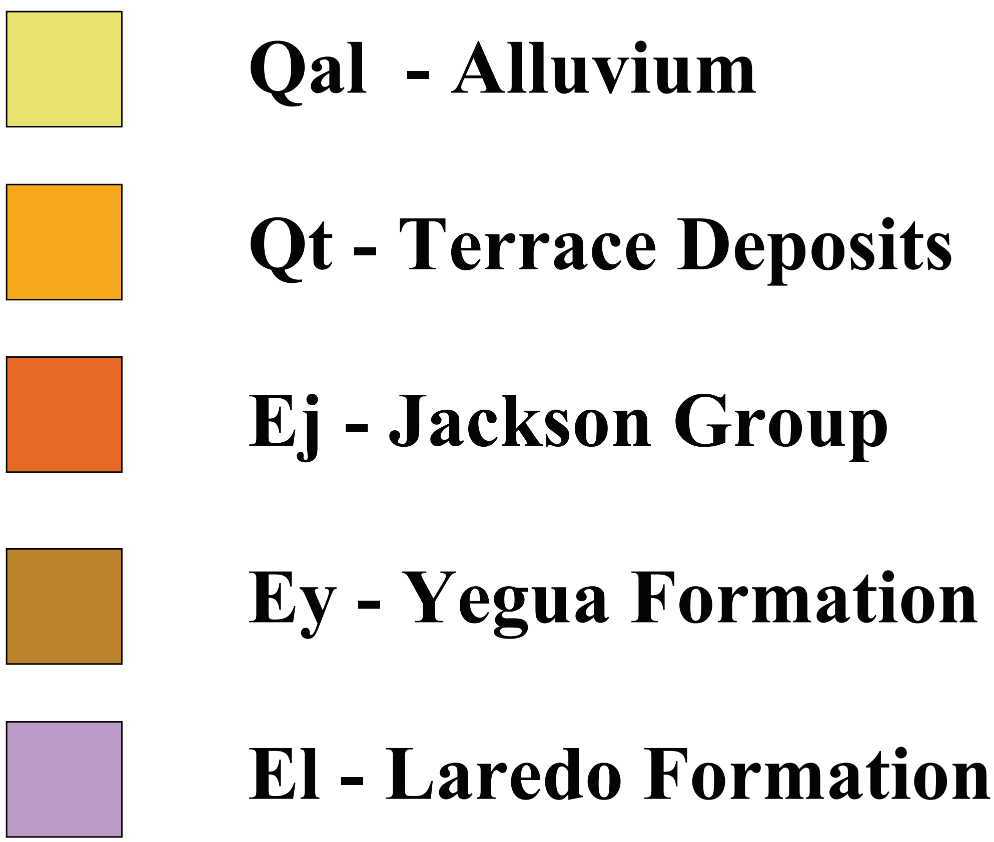

Figure 4. Key for geological map used in Lab 3.

23. In areas without any geological activity, like faulting, describe the location of the Laredo Formation in the following locations.

At TAMIU north of Lake Casa Blanca On the surface or Below the surface

Near the Pescadito Gas Field On the surface or Below the surface

About seven miles east of Lake Casa Blance there is an anormalous area. Here significant geologic forces uplifted the Laredo Formation to the surface. Interestingly this is where the small colonia La Lomas is located on either side of US highway 59. The thick black lines bound where the Laredo Formation outcrops represent faults. Between these faults which blocks of the Laredo Formation were brought to the surface. The 'U' represents the side of the fault that was uplifted and the 'D' the side of the fault that was down dropped. Faults provide and excellent conduit for fluid flow from the surface to the subsurface. Water can quickly transverse from the surface to the subsurface and remain fresh.

24. Examine these faults. The fault activity has caused the Laredo Formation to move how relative to the Yegua Formation?   Up   or   Down

25. Well yields from the Laredo aquifer on the high end are on the order of 10 liters per second. How many liters of water could be pumped from a single well during one day? There are 86,400 seconds in one day.

26. If an average family of four uses 3,000 liters /day of water. How many homes can be supplied from the well in question 22.

27. Water is a limiting resource. Without water life cannot exist. Based on your answers to questions 25 and 26 can La Lomas ever grow to be as big as Laredo. Justify your response.