Lab #12: Groundwater (GetWET Field Trip)

Meet your TA at the GetWET Observatory south of the Hilton Inn off Centre Drive on the south side of Spring Creek

G121 Introductory Geology Lab

Introduction

You have already become familiar with the processes and landforms associated with rivers and streams. Rivers and streams are one important, easily visible source of freshwater on Earth. Another vast supply of freshwater is **groundwater**, or that water that exists within sediment and rock underground, in the **zone of saturation,** where all pore spaces in the rock or sediment are filled with water. The top of the zone of saturation is the **water table**. Groundwater is derived from rain and snow melt that infiltrates the ground through fractures and pores in the soil and bedrock where it flows underground through rock bodies called **aquifers**. An aquifer is a permeable rock or sediment layer through which groundwater flows. **Wells** are holes dug or drilled into the ground to extract groundwater. Usually wells are drilled into aquifers that are known for their high **porosity** and **permeability**. Porosity refers to the volume of empty space in sediment or rock relative to the entire volume of rock, expressed as a percentage. Higher porosity (or a higher percentage) implies larger voids and a greater number of voids. Permeability refers to the interconnectedness of the pore spaces, so that fluids can migrate or move from pore space to pore space. Permeable rock makes good aquifers because the water can move easily through the material, like sandstone and some limestones. Impermeable rock prevents the flow of water and forms a confining bed, such as a tightly compacted shale layer.

The water table is linked directly to water levels in nearby streams, rivers, and lakes. If the water table is above the level of a stream bed (or lake), it is called a **gaining stream (effluent stream)**, such as might occur in humid environments. In such a situation, the stream will flow even when it is not raining because of additions from groundwater. The source of the water in the stream is rain water that is absorbed by the ground over the last several months and is **discharging** to the stream. If the water table is below the stream bed, it is called a **loosing stream (influent stream)**, and is common in arid environments where the water table is deep. Rain water that hits the ground surface and washes into stream channels will gradually soak into the streambed and help **recharge** the groundwater, thus raising the water table. Northern Colorado has both types of rivers (effluent and influent) because we live in a semi-arid environment.

Groundwater flows away from areas where the water table elevation is high toward areas where the water table is low, because of differences in potential energy. The gradient or slope of the water table, therefore, determines the direction of groundwater flow. Also, water in an aquifer is under pressure from overlying water. Thus, the total energy, or **hydraulic head**, that drives groundwater motion is the sum of the potential energy, related to elevation, and pressure energy, related to the weight of the overlying water.

Darcy's law describes steady state (doesn't change with time) groundwater flow in one direction through porous material. Darcy's law is an empirical relationship that was developed by Henry Darcy (1803-1858), a French hydrologist who conducted experiments on groundwater movement. The equation for Darcy's law is:

$$Q=AK\Delta h/\Delta x$$

where Q=discharge (in units of volume per second: e.g. m^3/sec)
K=hydraulic conductivity (includes permeability and fluid properties, in units of velocity: e.g. cm/sec) (see Table 12.1)
$\Delta h/\Delta x$ =hydraulic gradient (head loss divided by length of flow: dimensionless)
A=cross sectional area of flow (in length squared: e.g. m^2)

Note that $q=K\Delta h/\Delta x$ (in m/s), so by substitution into the equation above, $Q=Aq$ (in m^3/s per meter width of aquifer). While Q in the lab on rivers quantified the magnitude of flow in rivers, Q for groundwater measures groundwater discharge, or the volume of flow that passes through a given cross section within the saturated zone in a period of time. Think about how the Continuity Equation and Darcy's Law are similar.

Groundwater is increasingly becoming an important source of municipal water for communities, especially those in semi-arid and arid climates like the western U.S. In certain areas, Tucson, AZ for example, groundwater is the only source of drinking water and is heavily used for agricultural irrigation. As a result, even tiny concentrations of pollutants that reach the groundwater are a cause of concern for human health and the environment. One final equation will be useful for calculating groundwater velocity, or *v*, to determine the transport rates of water that might be carrying contaminants.

$$v = q/porosity$$

Four common **water quality parameters** that you will measure today include 1) **temperature**, 2) **pH**, 3) **electrical conductivity** (EC) and 4) **dissolved oxygen** (DO). Water temperature is an important component of natural waters because of the amount of dissolved oxygen and total dissolved solids that exist in water depends on temperature. Warmer water has lower DO and more dissolved constituents, and temperature may vary between groundwater and surface water sources. pH measures the hydrogen ion activity of water with low pH indicating acid conditions, and high pH indicating alkaline or basic conditions. Most natural waters have a pH in the range of 5-9. (Pepsi and Coke have a pH of 2.5.) Electrical conductivity measures the total dissolved solids in solution in the water, and is a useful indicator of water hardness. Dissolved oxygen measures how much O_2 is available (dissolved) in the water. Fish and macroinvertebrates consume O_2 molecules that are trapped between water molecules during respiration. Natural waters range from 0 to around 16 mg/L of dissolved oxygen.

In this lab you will investigate groundwater flow and water quality within a groundwater well field on the CSU campus. The well field is part of the GroundWater Education and Teaching (GetWET) Observatory south of the Hilton Inn off Centre Drive.

Table 12.1. Hydraulic conductivity and porosity for various materials.

Material	Porosity	Hydraulic Conductivity (m/sec)
Unconsolidated deposits: Gravel	30-50% (well sorted)	$3x10^{-4}$ to $3x10^{-2}$
Coarse sand	25-50% (well sorted)	$9x10^{-7}$ to $6x10^{-3}$
Fine sand	30-45%	$2x10^{-7}$ to $2x10^{-4}$
Silt	30-60%	$1x10^{-9}$ to $2x10^{-5}$
Clay	30-60%	$1x10^{-11}$ to $5x10^{-9}$
Rocks: Limestone	1-30%	$1x10^{-9}$ to $2x10^{-2}$
Sandstone	3-30%	$3x10^{-10}$ to $6x10^{-6}$
Siltstone		$1x10^{-11}$ to $1x10^{-8}$
Shale	0-10%	$1x10^{-13}$ to $2x10^{-9}$
Fractured crystalline rocks		$8x10^{-9}$ to $2x10^{-2}$
Massive crystalline rocks		$3x10^{-14}$ to $2x10^{-10}$

(modified from Frank, 1998)