Hydrogeology/Soil Physics Lesson Plan (Prepared by Dr. Stephen Osborn)

Lesson: Darcy's Law and fluid flow in sedimentary environments

Timeframe: Pre-class = 40 minutes; In-class = 75 minutes

Learning Objectives

Basic: The student should be able to…

1) explain the Darcy experiment and derivation of Darcy's Law,
2) identify necessary physical data and observations related to Darcy's Law, and
3) analyze Assumptions and Limitations of Darcy's Law.

Advanced: The student should be able to…

1) practice problem solving skills,
2) predict fluid movement in differing geologic environments, and
3) apply flow equations at multiple scales (i.e., molecular, pore, field scales).

Background: The student should have an understanding of soil/sediment texture, particle size distribution, basic algebra, and graphical analysis in spreadsheet applications.

Introduction to Lesson Plan: Darcy's Law is the most fundamental equation that describes fluid (water and gas) movement in geologic materials in one dimension (1-D). Combined with Mass balance equations, it leads to the continuity equation, which describes fluid movement that is variable in time and 3-D space (described later in the term). Henri Darcy was charged with providing drinkable water to his municipality in Dijon, France. He recognized, as many others did at the time, that water flow through sediment tended to clean water of bacteria and viruses. So, he designed an experiment that would allow him to predict how much water he could deliver to the fountains of Dijon using sediment filled pipes as a conveyance. To do this, he varied the diameter of the pipes (A), the length of flow path (L), and applied water pressure (ΔH), while measuring the volume flow rate (Flux, Q) through the columns. The result of this experimentation leads to the empirical form of Darcy's Law (equation 1). At the time, the "K" term in Darcy's Law was considered a

$$Q = -KA\frac{\Delta H}{L} \quad (1)$$

constant of proportionality that he called Hydraulic Conductivity. Later Darcy's Law was derived theoretically and the K term took on physical meaning related to the properties of water and the system (e.g., density, viscosity, and porosity). The class will be divided into small groups of three or four students. Each group will perform the Darcy experiment on varied sand columns (e.g., different kinds of sand and size columns). Students will be expected to make the same measurements and confirm the same observations.

Procedure

Pre-Class

Students will be expected to read (~10 minutes) a short selection on Darcy's Law in their books as well as view a 10-minute lecture style video presentation. In addition, students will be given the procedures for the Darcy Experiment that they will read before class. The pre-class assignment should address the basic learning objectives 1 through 3. (Basic LO 1-3; ~30 minutes)

In-Class (Total In- Class time = 75 minutes)

Step 1:The class will begin with a short quiz on the pre-class assignments to test comprehension and preparedness of the students (Basic LO 1-3; ~10 minutes).

Step 2: Students (in small groups) will conduct the Darcy experiment as outlined in their methods pre-class assignment. They will need to measure the dimensions of the sand columns, and the volume flow rate of water passing through the columns. To do this, they will be given rulers, a stopwatch, and volumetric beaker to estimate the volume of water as a function of time. The purpose of this step is to strengthen the students understanding of the Darcy experiment through hands-on measurement and observation. Students will be expected to calculate the hydraulic conductivity term (K), given their measurements (Basic LO 1-3 and Advanced LO 1; ~30 minutes)

Step 3: As a class, we will compile results from each of the student groups. Together, we will plot the data that the students compiled in excel and have a discussion of what the data means, how it leads to the Darcy Equation and use in various geologic conditions. The purpose of this step is to reinforce problem solving skills and a deeper understanding of Darcy's Law from simple laboratory experiment to more complex geologic conditions in nature. Discussion will involve graphical analysis, use of spreadsheets, correlation between measured parameters, use of Darcy's Law at various scales and geologic conditions (All LO's, ~35 minutes)

Closure/Evaluation

Analysis:

Each student will be expected to turn in a paper with all of his or her measurements and observations for evaluation. They will be required to provide at least three observations by the end of the in-class portion.

Post-Class Individual Space Activities: None

Connection to Future Lesson Plans:

Mass balance and Continuity Equation lessons as well as the theoretical derivation of Darcy's Law later in the term