CE40460: Groundwater Hydrology

Homework 2 – The Hydrologic Cycle

Due: September 18, 2018

(1) A constant head permeameter has a cross-sectional area of 78.5 cm^2. The sample is 23 cm long. At a head drop of 3.4 cm, the permeameter discharges 50 cm^3 in 38 seconds.

(a) What is the hydraulic conductivity in cm/s and ft/day?
(b) What is the intrinsic permeability if conductivity was measured at 15^{o}C?
(c) From the conductivity value, estimate the type of soil you think it might be.
(d) Imagine you wanted to know how quickly oil would move through the column. What is the hydraulic conductivity for oil in this porous medium?
(e) You know that in a real system there is a head drop between two connected points of 1m over a distance of 1 km in an aquifer that is packed with the very same material as in your constant head permeameter. Assuming a linear drop in head with distance, estimate the Darcy velocity between these two points?
(f) *Conceptual Question*: What does this experiment tell us about porosity? How might it be modified in such a way that it would tell us more?

(2) The data below is from **Henry Darcy's original data set** showing the relationship between specific discharge and Hydraulic gradient for two different sands. Plot the data; check whether the trends are indeed linear; estimate the hydraulic conductivity of these two sands.

Sand 1: Outlet head is always equal to 0, Inlet head varies, Length of column =58 cm.

Specific discharge (**mm/s**): [0.624,1.33,2.08,2.47,2.63,3.78,4.06,4.24,4.82,5.09]
Inlet head (**m**): [1.11,2.36,4,4.9,5.01,7.63,8.13,8.58,9.86,10.89]

Sand 2: Outlet and Inlet head vary, Length of column =1.1 m.

Spec, discharge (**mm/s**): [3.26,3.17,3.12,3.01,3.14,2.58,2.1,1.7,1.37,1.5,0.78,0.719]
Inlet head (**m**): [9.48,12.88,9.8,12.87,12.8,8.86,12.84,6.71,12.81,5.58,2.98,12.86]
Outlet head (**m**): [-3.6,0,-2.78,0.46,0.49,-0.83,4.4,0,7.03,0,0,9.88]

Note: In performing this exercise, do not plot the data as continuous lines (keep them as discrete data points on the graph) and then perform a best linear fit to the data and assess the hydraulic conductivity from this best fit line. Feel free to do this by any means you wish (i.e. Excel, Matlab or any other software you may feel more comfortable with), but please do it rigorously.

(3) An aquifer has three different parallel formations. Formation A has a thickness of 22ft and a hydraulic conductivity of 17 ft/day. Formation B has a thickness of 3.5 ft and a conductivity of 99 ft/day. Formation C has a thickness of 26 ft and a conductivity of 22 ft/day. Assume that each formation is isotropic and homogeneous. Compute the overall effective conductivities for (a) flow parallel with the formations and (b) perpendicular to the formations.

Conceptual Question: If flow were somewhere between parallel to perpendicular to the formations do you expect the effective hydraulic conductivity to lie between (a) and (b) or might it take a value outside these bounds? What might the absolute smallest or largest effective conductivities be? Can you explain and reason your answer?

(4) The following data set is taken from 11 samples from the same aquifer. These are measured values for the hydraulic conductivity.

K =[4.3 x10-4, 6.1 x10-3, 2.5 x 10-5, 1.2 x 10-4, 1.0 x10-6, 7.1 x 10-3, 9.1 x10-6, 2.2 x 10-3, 4.2 x 10-5,8.7 x10-4, 3.5x 10-5] m/s

As you can see the hydraulic conductivity varies from sample to sample. Perform the following statistical analyses.

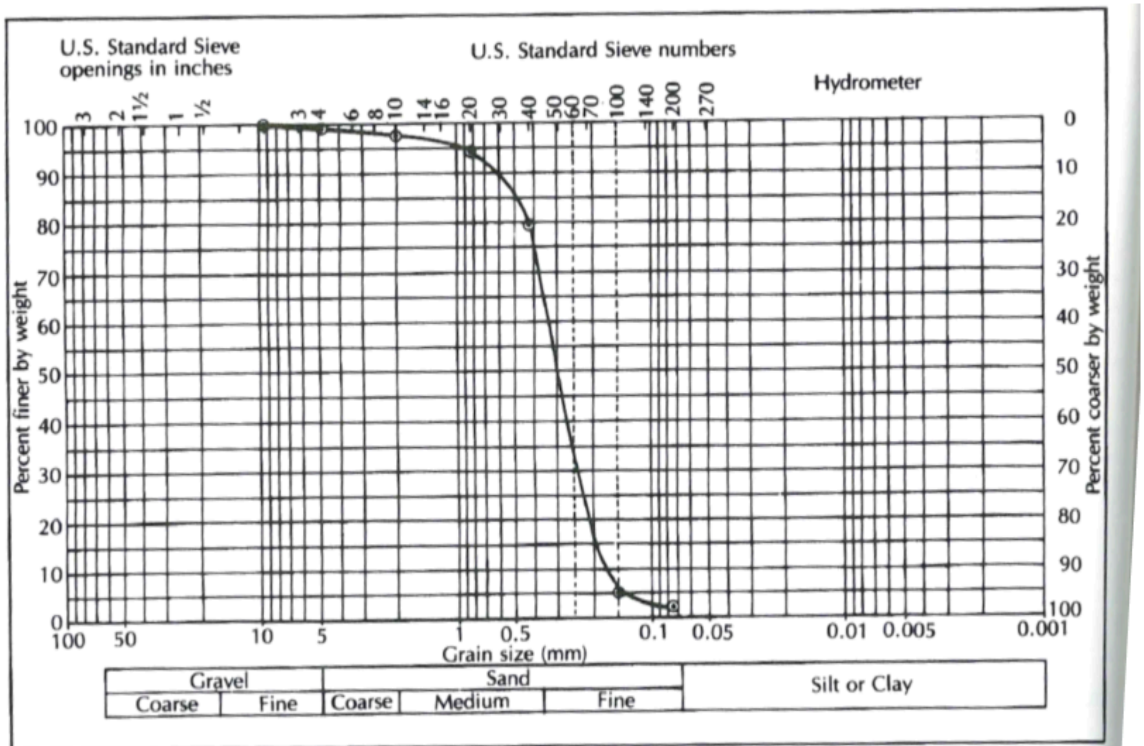
(a) Calculate the arithmetic mean of the data set
(b) Calculate the geometric mean of the data set
(c) Calculate the harmonic mean of the data set

Conceptual Question: Based on calculations (a)-(c), if you were to perform a calculation or build a model of this aquifer what value of hydraulic conductivity would you use? Why? Use what you have learned in class and your physical intuition, but also don't be shy in performing some quick Google searches and reviewing literature to help with this. What extra information might you need in order to really nail this down?

Note: You are probably all very familiar with the arithmetic mean and less so with the other two. Reasonably good descriptions of these different means are available on Wikipedia:

http://en.wikipedia.org/wiki/Arithmetic_mean
http://en.wikipedia.org/wiki/Geometric_mean
http://en.wikipedia.org/wiki/Harmonic_mean

(5) Use the Hazen method to estimate the hydraulic conductivity of the sediments graphed in figure 3.33. State and justify any assumptions that you making clearly. Is this sample well or poorly sorted. Why?



▲ FIGURE 3.33

(6) You are provided with the following tensor for the hydraulic conductivity and the following hydraulic gradient.

a. Does the tensor follow the basic requirements for a hydraulic conductivity tensor? Explain.
b. Calculate each of the Darcy velocity components in the x, y and z directions.
c. Determine the magnitude of the resulting Darcy velocity. Units on the conductivity tensor are meters/second.
d. Provide the final magnitude in meters per year.

$$K = \begin{bmatrix} 0.0004 & 0.00004 & 0.00002 \\ 0.00004 & 0.0002 & 0.00006 \\ 0.00002 & 0.00006 & 0.0001 \end{bmatrix} \qquad \nabla h = \begin{bmatrix} dh/dx \\ dh/dy \\ dh/dz \end{bmatrix} = \begin{bmatrix} 0.013 \\ -0.0021 \\ -0.08 \end{bmatrix}$$