Final Exam
Environmental Science 318

1. Describe the hydrologic cycle.

The hydrologic cycle describes the manner in which water moves through the environment. It does not have a beginning or ending. We can start with evaporation from oceans and land masses. The water vapor rains out--water runs off back to lakes, rivers, and oceans. Some water infiltrates to become groundwater, which can move toward lakes or oceans to begin the cycle again.

2. What is the hydrologic equation? Give examples of inputs and outputs.

$\Delta S = Inflow - Outflow$

Inflow: Precipitation, runoff
Outflow: Evaporation

3. The antarctic ice cap has an average thickness of 1.6 Km. We will model it as a disk of radius 2000Km.

a. What volume of ice is contained in the ice cap?

$$V = \pi r^2 h = \pi (2000 \times 10^3)^2 \cdot 1600m = 2 \times 10^{16} m^3$$

b. Assuming that the ice begins at -30C, what quantity of energy is necessary to melt all of the ice to liquid at 0C?

$$m = 2 \times 10^{16} m^3 \cdot \frac{1000kg}{1m^3} \cdot \frac{1000g}{1kg} = 2 \times 10^{22} g$$

$$Q = mc\Delta T + mL = 2 \times 10^{22} g \cdot 0.5 \frac{cal}{g°C} \cdot (0 - (-30°C)) + 2 \times 10^{22} g \cdot 79.7 \frac{cal}{g}$$

$$= 1.894 \times 10^{24} cal$$

c. Assuming that the sun provides 1300 J/s m^2, how long would this take?

$$Q = 1.894 \times 10^{24} cal \cdot \frac{4.1868J}{1cal} = 7.93 \times 10^{24} J$$

$$P = \frac{1300J}{m^2 s} \cdot \pi r^2 = \frac{1300J}{m^2 s} \cdot \pi (2000 \times 10^3)^2 = 1.63 \times 10^{16} \frac{J}{s}$$

$$Q = P \cdot t$$

$$t = \frac{Q}{P} = \frac{7.93 \times 10^{24} J}{1.63 \times 10^{16} \frac{J}{s}} = 4.87 \times 10^8 s$$

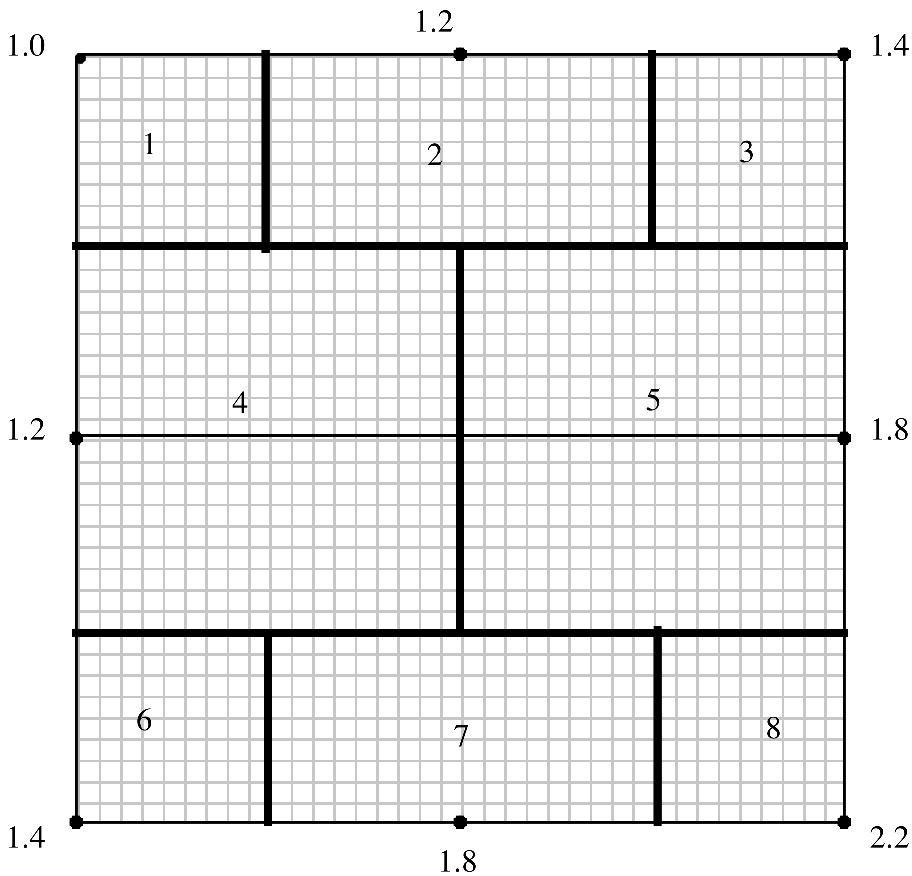
4. Consider the precipitation map at the end of the exam. Compute the estimated uniform depth of precipitation using:

a. Simple Arithmetic Mean

$$EUD = \frac{1.0 + 1.2 + 1.4 + 1.2 + 1.8 + 1.4 + 1.8 + 2.2}{8} = 1.5$$

b. By drawing Thiessen polygons

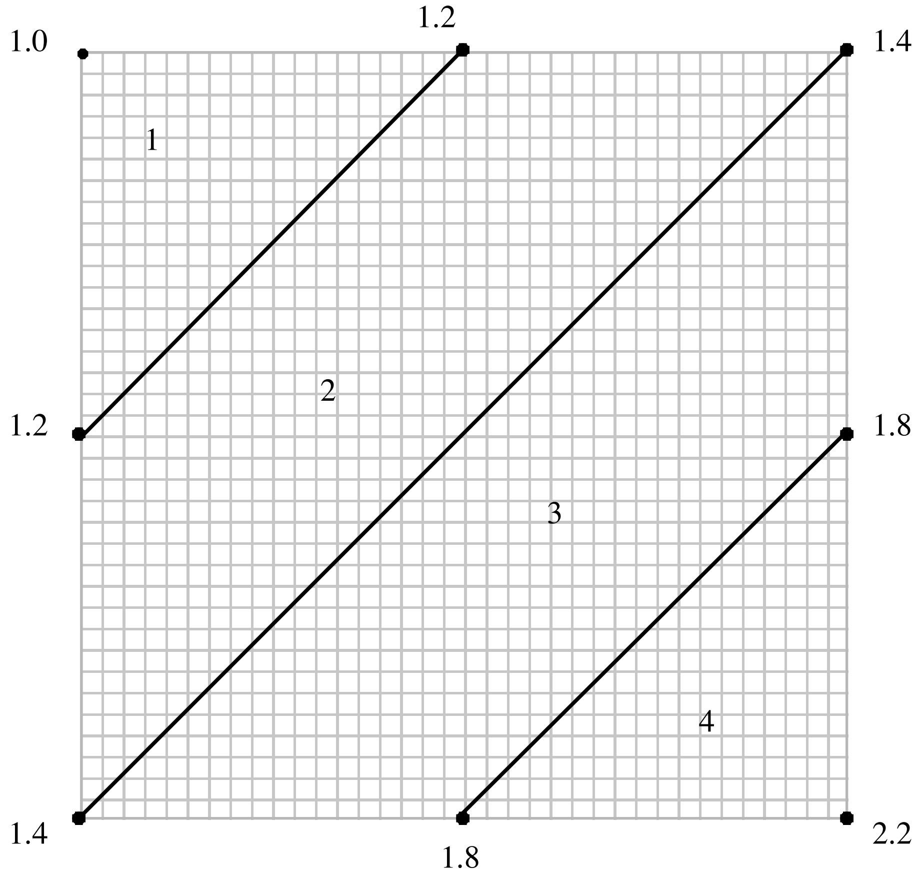
Precipitation Map



$$EUD = \frac{\sum A_i d_i}{\sum A_i}$$

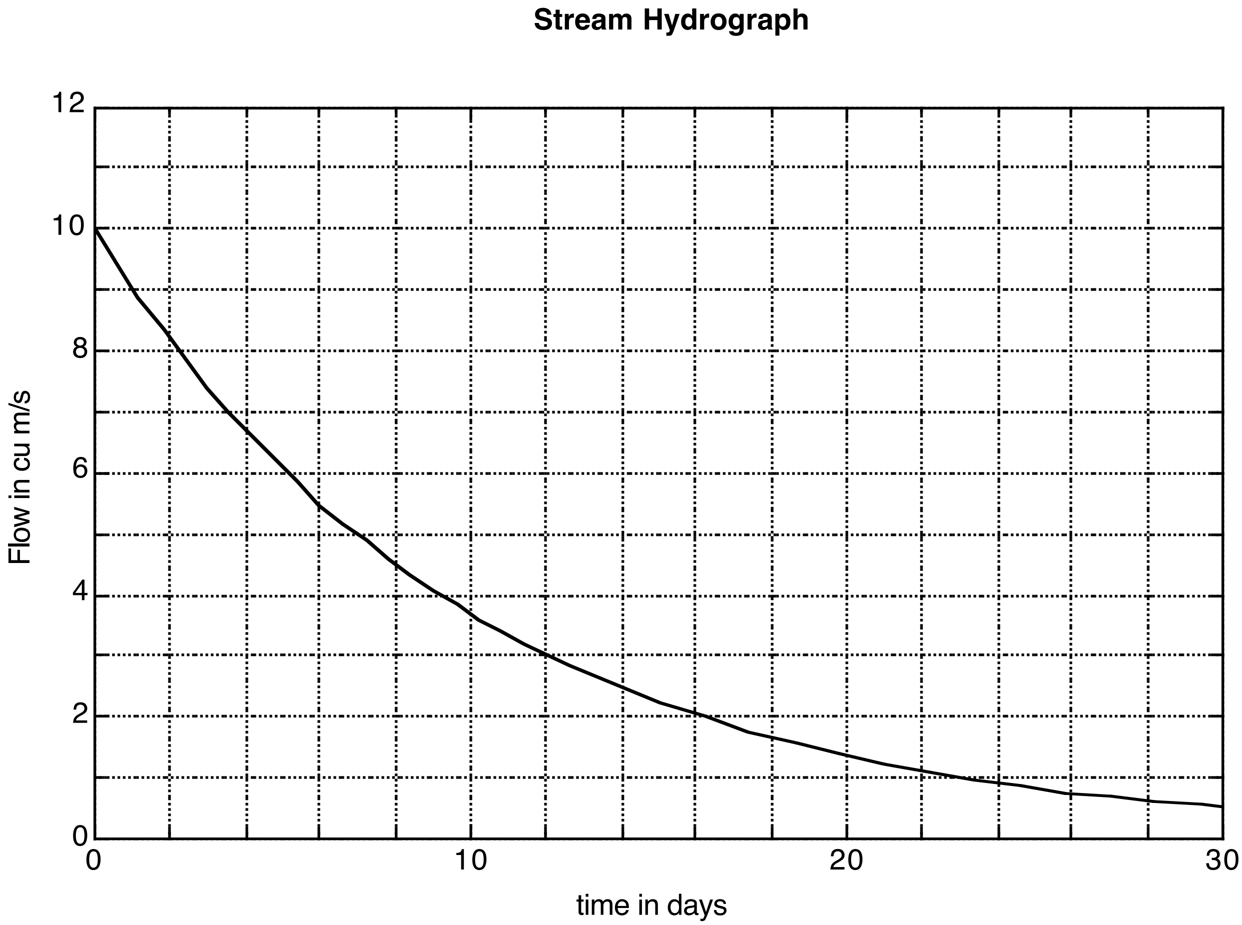
c. By drawing Isoheytal lines.

Precipitation Map



$$EUD = \frac{\sum A_i d_i}{\sum A_i}$$

5. Consider the stream hydrograph shown below. What equation do we use to describe simple recession. Estimate the recession constant for this graph, and use it to find the baseflow after 40 days of recession.



We can write this exponential curve as

$$Q = Q_0 e^{-r\,t}$$

Here Q_0 is the flow rate at time 0. If we pick a time and read off the flow rate, we can find r. Once we know r, we can find the flow at 40 days.

$$\begin{aligned}
t &= 16 days \quad Q = 2\,cu\ ft/s \\
Q_0 &= 10 cu\ ft/s \\
Q &= Q_0 e^{-r\,t} \\
e^{-r\,t} &= \frac{Q}{Q_0} \\
r &= -\frac{1}{t}\ln\left(\frac{Q}{Q_0}\right) \\
&= -\frac{1}{16}\ln\left(\frac{2}{10}\right) \\
&= 0.101 days^{-1}
\end{aligned}$$

$$\begin{aligned}
Q_0 &= 10 cu\ ft/s \\
Q &= Q_0 e^{-r\,t} \\
Q &= 10 cu\ ft/s \cdot e^{-0.101\cdot 40} \\
&= 0.176 cu\ ft/s
\end{aligned}$$

5. A V-notch weir is used to measure the flow of a stream. Explain how this is done. If the height of the water in the weir is 2 inches, what is the flow rate in cfs and cu m/s?

$$Q = 2.54\,h^{3/2} = 2.54\left(\frac{2}{12}ft\right)^{3/2} = 0.1728\,ft^3/s$$

$$Q = \frac{0.1728\,ft^3}{s}\cdot\left(\frac{0.3048m}{1ft}\right)^3 = 4.894\times10^{-3}m^3/s$$

6. Describe what an infiltration curve is and how it is used.

An inflitrration curve shows the rate at water is absorbed by soil as a function of time. When used with a precipitation curve, the infiltration curve can be used to predict ponding and when surface water will begin to accumulate.

7. Using the tables provided, find for each

d_{60}: the grain size that is 60% finer by weight
d_{10}: The effective grain size (the grain size that is 10% finer by weight)
C_u: The uniformity coefficient

What does it mean for a sample to be "well sorted" and how can you judge this from the shape of the grains size distribution curve. Are either of these samples well sorted?

(Same problem as in Exam 2)

8. What is Darcy's Law. Use it relationship to find the Hydraulic conductivity for the following conditions

Cylindrical sample has radius 10cm
Difference in head is 1cm over a length of 1m
Flow is 100 cc

You would really need the time overwhich the flow occurs to compute a numerical value.

$$Q = KA\frac{\Delta h}{L}$$

$$K = \frac{QL}{A\Delta h} = \frac{(100cm^3/t)\cdot 100cm}{\pi(10cm)^2\cdot 1cm} = \frac{31.83}{t}$$

9. Using the information in 8, define the intrinsic permeability of the sample in Darcy. Take

$$\rho = 1g/cm^3$$
$$\mu = 0.02$$

Once again, you really need a time to get a numerical value

$$K = K_i \frac{\rho g}{\mu}$$

$$K_i = \frac{K\mu}{\rho g} = \frac{\frac{31.83}{t}(cm/s)\cdot 0.02 g/s\cdot cm}{1.0 g/cm^3 \cdot 980 cm/s^2} = \frac{1.326\times 10^{-8}}{t} cm^2$$

$$K_i = \frac{1.326\times 10^{-8}}{t} cm^2 \cdot \frac{1\ darcy}{10^{-8} cm^2} = \frac{1.326\times 10^{-8}}{t} darcy$$

Is this a high or low intrinsic permeability.

10. Use the Hazen method and the information in 3, 5, and 6 to find the shape factor for the sample. Comment on this factor if you can.

As before, you need the time overwhich the flow in the permameter occured. You would also need the d_{10} value.

$$K = C\, d_{10}^{\ 2}$$

$$C = \frac{K}{d_{10}^{\ 2}} = \frac{\frac{31.83}{t}(cm/s)}{d_{10}^{\ 2}}$$

11. At a location that is 250m above sea level, a fluid has a pressure of 1000 N/m^2 and the fluid density is 1.02 x 10^3 kg/m^3. The fluid is flowing with a v = 0.5 x 10^{-6} m/s,

a. What is the total energy per unit mass.

$$E_{tm} = \frac{v^2}{2} + gz + \frac{P}{\rho}$$

$$= \frac{(0.5\times 10^{-6} m/s)^2}{2} + 9.8\cdot 250 + \frac{1000}{1020}$$

$$= 2.45\times 10^3 J/kg$$

b. How much of this energy is potential energy, “pressure potential energy” and kinetic energy? Would it be reasonable to drop the kinetic energy term?

$$\frac{v^2}{2} = \frac{(0.5\times 10^{-6} m/s)^2}{2} = 1.25\times 10^{-13} J/kg \qquad gz = 9.8\cdot 250 = 2.45\times 10^3 J/kg$$

$$\frac{P}{\rho} = \frac{1000}{1020} = 0.98 J/kg$$

The kinetic energy term can savely be ignored here.

c. Assuming smooth laminar flow, suppose the elevation dropped to 50 m above sea level If the pressure remains the same, how fast does the fluid now need to flow for the total energy per unit mass to remain constant? What is this speed in meters/year? Does this seem reasonable?

The energy remains constant, so

$$E_{tm} = \frac{v^2}{2} + gz + \frac{P}{\rho}$$

$$2.45 \times 10^3 J/kg = \frac{v^2}{2} + 9.8 \cdot 50 + \frac{1000}{1020}$$

$$\frac{v^2}{2} = 2.45 \times 10^3 J/kg - 9.8 \cdot 50 - \frac{1000}{1020}$$

$$= 1.96 \times 10^3$$

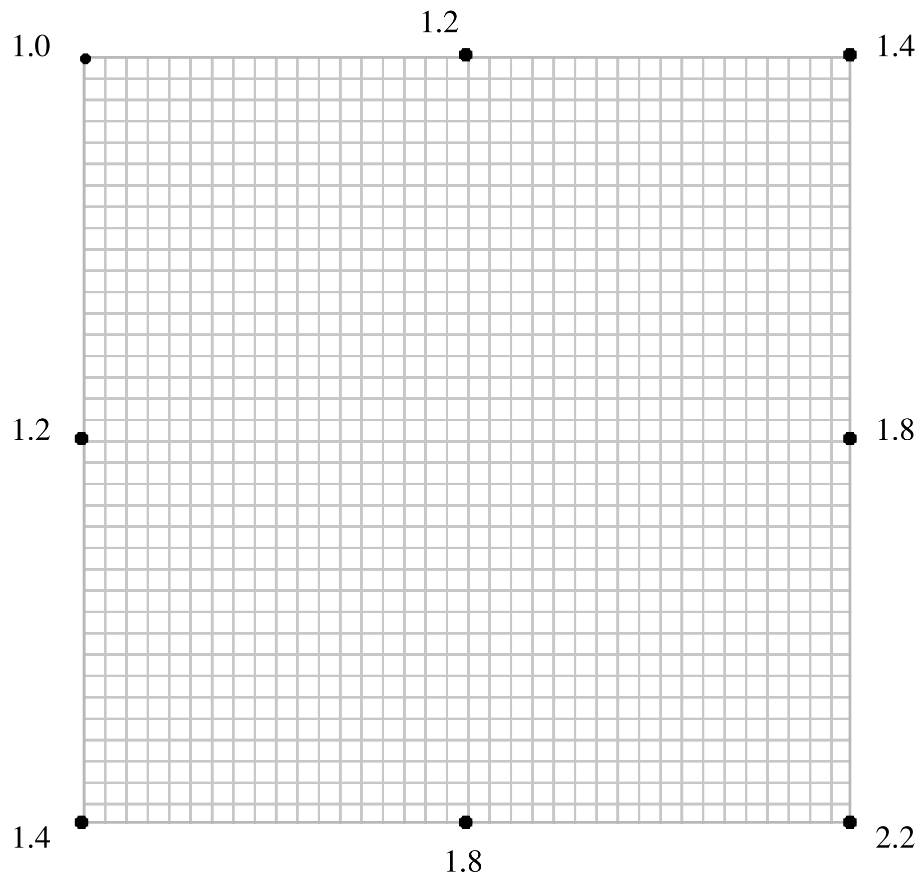
$$v = \sqrt{2 \cdot 1.96 \times 10^3} = 62.6 m/s$$

$$= \frac{62.6m}{s} \cdot \frac{3.15 \times 10^7 s}{yr}$$

$$= 1.97 \times 10^7 m/yr$$

In this scenerio, the water effectively falls without friction over a distance of 200m. We have created a waterfall. In this case, the speed could be this high. This is unrealistic for groundwater in most scenerios...

Precipitation Map



Each square represents 100m. Assume the measurements shown are in cm.

Conversions, equations, etc.

$$\rho_{water} = 1 g / cm^3$$

$Q = 2.54\, h^{3/2}$ for a triangular weir.

$$c_{water} = 1 \frac{cal}{g \cdot °C}$$

$$c_{ice} = 0.5 \frac{cal}{g \cdot °C}$$

$$L_{fusion} = 79.7 \frac{cal}{g}$$

$$V_{tp} = \frac{Q_0\, t_1}{2.3026} \quad (potential\ groundwater\ dischg)$$

$$V_t = \frac{V_{tp}}{10^{(t/t_1)}} (volume\ of\ dischg\ remaining\ at\ time\ t)$$