

Homework No. 3: Soils and Water (due 28 March)

1. Assume a soil has a dry bulk density of 1.05 g cm^{-3} and the density of the solid particles is 2.65 g cm^{-3} . (a) What is the porosity of the soil? (b) If all the pores in the soil are filled with water, what is the volumetric water content, θ (θ is the volume of water divided by the bulk volume, usually done on a per cubic centimeter basis)? (c) What is the bulk density of the saturated soil in part b? (d) Under which of these two conditions (a or b) is a landslide most likely to occur, and why?

2. Dr. Khoa has a farm where he is trying to grow maize (corn in American English). At field capacity his soil averages 0.25 cm of water per centimeter of depth. (a) If the soil is 50. cm deep, what is the total amount of water in the soil? (b) What is the plant available water content of Dr. Khoa's soil in centimeters? (c) If the evapotranspiration rate is 2 mm/day and the water content at wilting point is 0.06 cm per centimeter of soil, how long can Dr. Khoa's maize crop continue to grow and survive, assuming that the plant roots extend throughout the entire soil depth?

3. After a series of rains and dry periods, we measure the pressure potential in Dr. Khoa's field at a depth of 10 cm (A) and a depth of 50 cm (B). The pressure potential at 10 cm is at -0.5 bars, while the pressure potential at 50 cm is just at field capacity (defined as -0.33 bar). (a) Calculate the total head at A and B. (b) What is the hydraulic gradient between these two points? (c) Is the water flowing upwards or downwards?

4. Wetlands in the U.S. are protected by federal law. One of the criteria for a wetland is that the water table must be within 0.15-0.45 m of the soil surface for "a significant period (usually a week or more) during the growing season in an average year". The idea is that if the water table is relatively close to the surface, the soil will be saturated due to capillary rise and the site therefore will meet the criterion for a wetland soil. We wish to determine if the soil will be saturated when the water table is 0.30 cm below the soil surface.

(a) Calculate the equilibrium (hydrostatic) pressure in centimeters of pressure head at the soil surface when the water table is 0.30 cm below the surface (ignore the drying effects of evapotranspiration). (b) You want to build houses on this land and make lots of money, so you hope the area does not qualify as a wetland. You note the presence of worms on your property and you carefully measure the worm holes and find they have an average diameter of 5.0 mm. The scientific literature and the local farmer suggest that worms usually come to the surface to feed at night, their burrows are more or less vertical, and that their burrows often extend to 60-100 cm below the soil surface. Using the attached table with the properties of water, (a) calculate the capillary pressure in these worm holes assuming a groundwater temperature of 20°C . Remember that the capillary pressure (C_p) for a circular tube is: $C_p = -2 \gamma / R$, where γ is the surface tension of water in dynes cm^{-1} , and the units for dynes cm^{-1} are $\text{g}^{-1} \text{sec}^{-2}$.

(b) Convert the capillary pressure to pressure head units by dividing by the density of water (1.00 g cm^{-3}) and gravity (980 cm sec^{-2}).

(c) Would the worm holes be filled with water to the surface (answer yes or no)?

4 (more challenging, so optional!). It can be argued that the real importance of worm burrows and other macropores is their importance as pathways of preferential flow.

(a) Calculate the asymptotic (final) infiltration rate in cubic centimeters per second from a ring infiltrometer 20.0 cm in diameter when the field-saturated hydraulic conductivity is 1.5 cm hr^{-1} and the hydraulic gradient is equal to -1.0. (b) A field study (Bouma et al., *Soil Science Society of America Journal*, 1982) found an average of one worm burrow per 2.0×10^2 square centimeters and measured flow rates of 2.0 cubic centimeters per second per burrow. Using these values and the basic information on worm burrows in question #3, calculate: (i) the number of worm burrows likely to be found within the area of your infiltration ring (use two significant figures and partial burrows are OK), and (ii) the percent increase in the asymptotic infiltration rate due to the worm burrows.

5. A controversial site was studied to determine if it met the soil criterion for a wetland. In order to hydrologically model this site, minimally-disturbed soil cores were taken and the soil moisture release curve was determined for each core. The following data were obtained for a soil described as a clayey silt (sample #1) and an unknown soil from Dr. Lee's farm (sample #4).

Suction (kPa)	Saturation	
	Sample 1	Khoa soil
0	1.000	1.000
1.0	0.979	0.957
2.9	0.954	0.905
4.8	0.923	0.865
7.0	0.886	0.803
9.3	0.848	0.714
12.8	0.819	0.652
16.8	0.787	0.594
20.0	0.752	0.572
26.7	0.713	0.526
33.0	0.683	0.471
49.0	0.598	0.354
100	0.476	0.290
500	0.325	0.160
1500	0.109	0.070

The measured porosity of sample 1 was 47 percent. (a) Calculate the volumetric water content (θ) for sample no. 1 at: (i) saturation (assuming no trapped air), (ii) field capacity (33 kPa), and (iii) wilting point (1500 kPa). (b) Calculate and compare the available water (field capacity - wilting point) for samples #1 and 4 in dimensionless terms (e.g., cm of water per cm of soil depth). Assume a porosity of 52% for Dr. Lee's soil. (c) Is sample #4 likely to be finer-textured or coarser-textured than sample #1? Justify and explain your answer using the data presented and the results of your calculations.

6. (a) Calculate the pressure potential, Φ_p ($\Phi_p = \text{density of water} \times \text{gravity} \times \text{height of a column of water}$) in dynes cm^{-2} (one dyne is one $\text{g cm}^{-1} \text{sec}^{-2}$) at a depth of 3.00 m in a swimming pool with a water temperature of 30°C . Remember that pressure is expressed in terms of force per unit area. (b) Convert this pressure to: (i) kPa (kiloPascals); (ii) bars; and (iii) pressure head.

7. Calculate the gravitational potential Φ_g ($\Phi_g = \text{density of water times gravity times the difference in elevation}$) for the same location as in #6. Use the surface of the swimming pool as the gravitational reference plane, z_0 . (b) How are the answers for #6 and #7 related, and why?

8. You want to calculate the flow of water into a stream from the adjacent riparian zone. You put a well 10.0 m from the stream, and find the water level in the well is 0.70 m below the ground surface, and this is 0.30 m higher than the water level in the stream. The soil depth at the well is 1.2 m, and the saturated hydraulic conductivity of the soil is 5×10^{-4} cm/second. Calculate the number of liters that is flowing from the hillslope to the stream per day for each meter of stream length. (Hint: use Darcy's Law).