

WATER FLOW

DARCY'S LAW  $J_w = -K_{SAT} \frac{\partial H}{\partial z}$  OR  $Q = -K_{SAT} A \frac{\partial H}{\partial z}$

Dec  
2002

BUCKINGHAM-DARCY LAW  $J_w = -k(\gamma_m) \frac{\partial H}{\partial z}$

POISEUILLE'S LAW  $Q = -\frac{\pi R^4 \rho g \Delta H}{8 \eta L}$

ASSUME  $\eta = 1 \times 10^{-2} \frac{g}{cm \cdot sec}$

$\rho = 1 g/cm^3$

$g = 9.8 m/sec^2$

CHEMICAL TRANSPORT

CONVECTION ①  $J_{lc} = J_w C$

DIFFUSION ②  $J_{ld} = -D_{ls} \frac{dc}{dx}$  ③  $D_{ls} = D_{lw} \theta_v \left\{ \frac{r}{R} \right\}$

DISPERSION ④  $J_{lh} = -D_{lh} \frac{dc}{dx}$  ⑤  $D_{lh} = \lambda \bar{v}$

⑥  $D_e = D_{ls} + D_{lh}$

⑦  $\bar{v} = \frac{J_w}{\theta_v} = \frac{L}{t_b}$

$\bar{v}$  = Ave. velocity

$J_w$  = WATER FLUX

$t_b$  = BREAKTHROUGH TIME

⑧  $R = 1 + \frac{\rho_b K_d}{\theta_v}$

$K_d$  = SORPTION COEF.

$\rho_b$  = BULK DENSITY

$R$  = RETARDATION COEF.

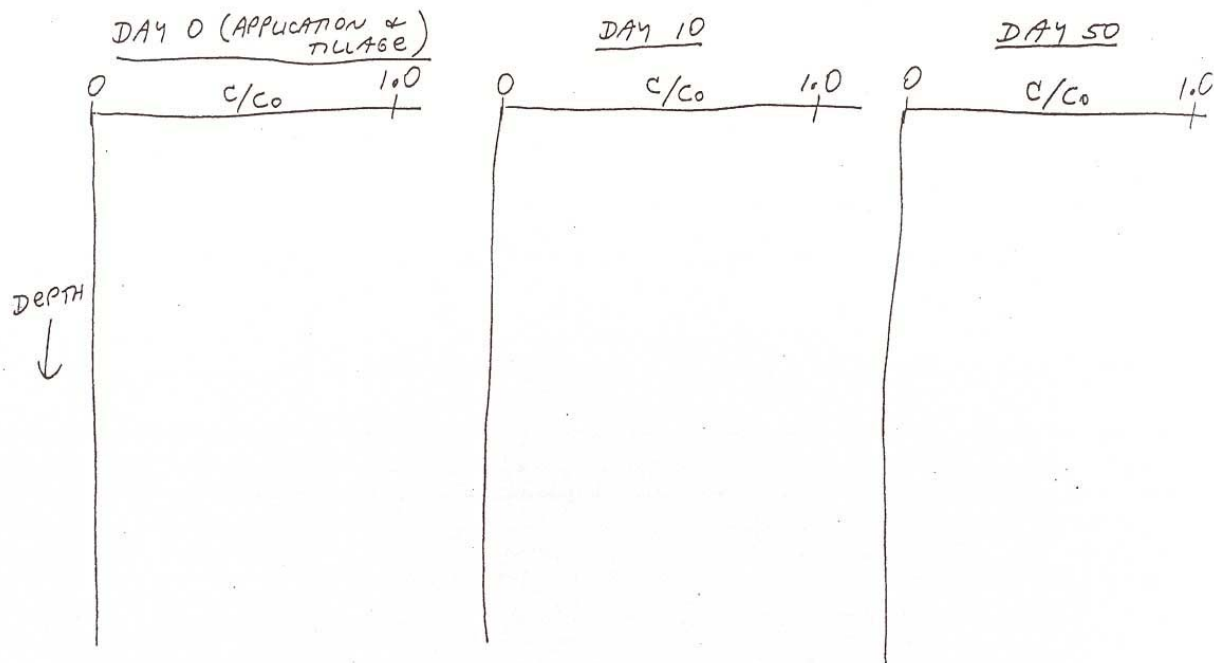
Name \_\_\_\_\_

AGRY 560 Final Exam  
December 12, 2002 (150 points)

- (9) 1. In the lectures about tile drainage and water quality, we discussed that the presence of tile drainage generally decreases the losses of certain substances and increases the loss of others (loss being defined here as the loss of materials from the agricultural field and into the surface water ditches and streams). Give an example of a) a substance (chemical or material) that usually has greater total losses once tile drains are installed, and b) a substance that usually has less total loss once tile drains are installed. Assume that the land is already in agricultural production and that it is a naturally poorly-drained soil (ie it is wet and needs some type of drainage for adequate crop production).
- c) Explain why (a) has increased and (b) has decreased (ie what are the processes that are changed in fields with tile drainage vs. those without).

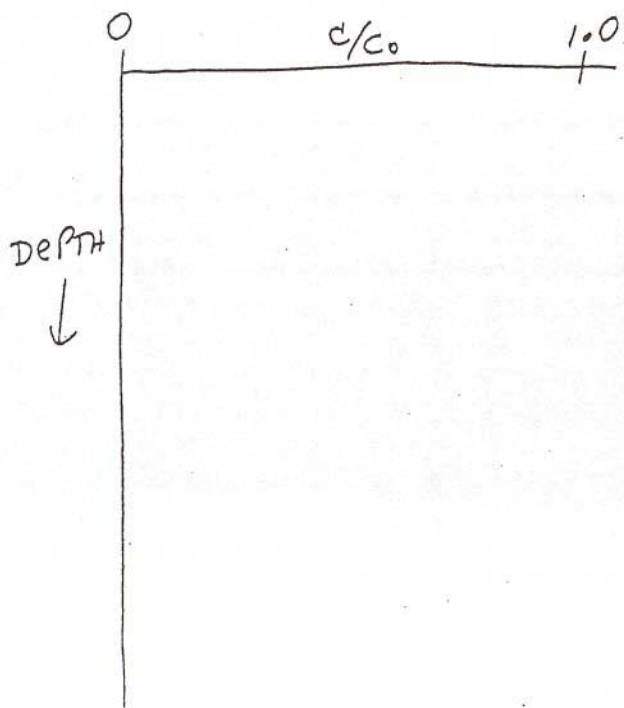
(18) 2. A chemical (non-sorbing, non-interacting, non-degrading) is sprayed on the soil surface and then uniformly tilled into the surface 10 cm of soil. Assume the soil is a uniform, homogeneous soil (no “preferential flow”).

- a) Sketch a graph of relative concentration ( $C/C_0$ ) vs. depth in the soil profile, for the following 3 times: 1) immediately after the uniform tillage operation, 2) after 10 days of steady leaching, and 3) after 50 days of steady leaching. (NOTE: The graphs of times 2 and 3 are semi-qualitative; you cannot know the exact curve without more information).
- b) Discuss the shapes and locations of the curves and why you drew them as you did, i.e., discuss the main processes involved in chemical transport. **You should include a discussion of equations 1-6 from the first page, what the symbols mean and how they represent the processes, why each term is needed, etc.** (use the back of this paper for more space to write)



(9). 3. What is "preferential flow?" Discuss and explain the concept. Why is it important?

(9) 4. If preferential flow was also occurring in the situation given in question #2 how might the curve look, for concentration vs. depth at 10 days (i.e. your middle graph)? Sketch the comparison here, for no preferential flow vs. some preferential flow. Note that there are several possible scenarios for exactly how this curve might look--give one of them and clearly explain what the curve shows, and why you drew it the way you did.



- (12) 5. In the recent past, one of the approaches to describing chemical transport through soils has been to use various “2-region models.” We discussed the "classic version" of 2-region models in class, namely, the mobile-immobile water model. We also briefly discussed the transfer function model approach of Jury, and how we applied it to our tile-drained field.

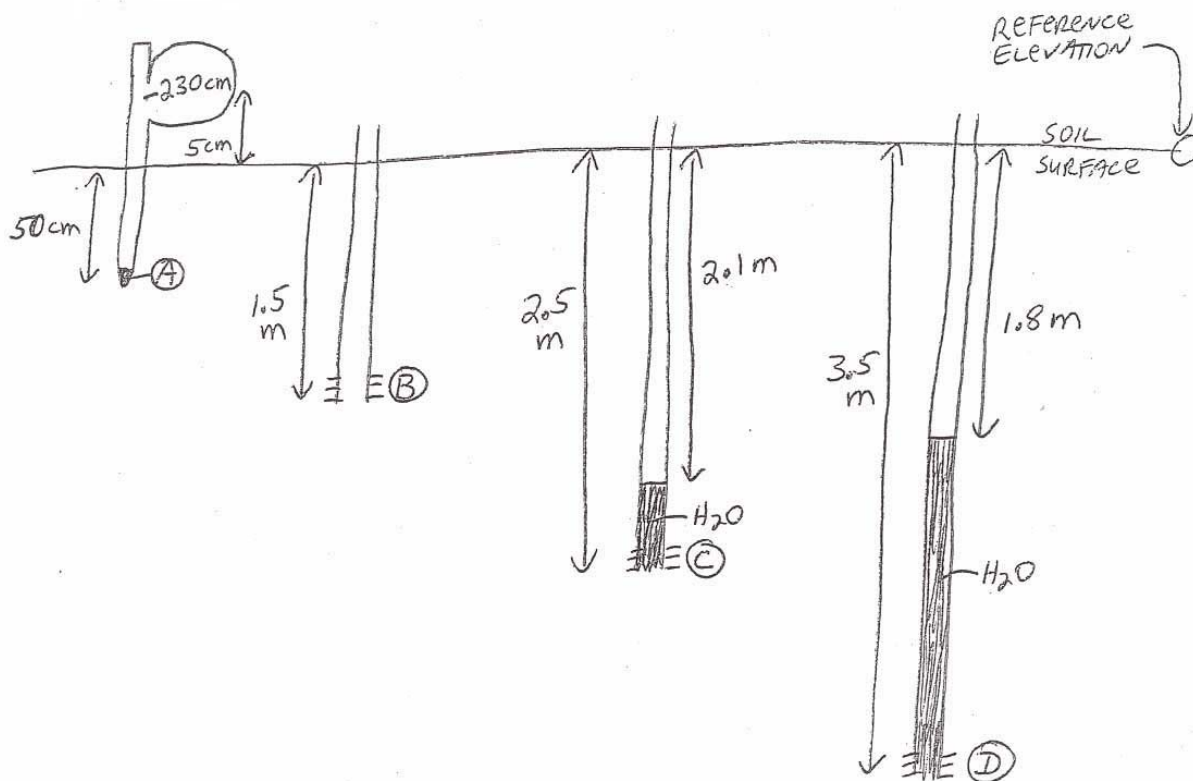
Describe the mobile-immobile water model for chemical transport. Draw a picture to help you in your discussion. Also draw a graph of chemical concentration vs. time for the mobile-immobile water model as compared with the standard convection-dispersion (CDE) model. Include in your discussion such topics as a) what is the reason this model was developed, what conditions does it try to describe, etc., b) what are the assumptions of the model (there are 3 major ones), c) why does the outflow vs. time graph look the way you drew it, d) anything else you deem important.

- (4) 6. What are "anaerobic microsities"?
- excess  $O_2$  on aggregate edges caused by rapid drainage
  - brown mottles in a predominantly gray subsoil
  - anaerobic soil conditions throughout the profile due to flooding
  - lack of  $O_2$  in the centers of aggregates even though pores between aggregates are well-aerated
- (4) 7. What is the minimum volume of large pores that is considered necessary so that aeration problems will not exist in a soil?
- 5%
  - 10%
  - 15%
  - 20%
- (4) 8. In the aggregate size distribution lab, if the moist samples had been broken to pass through a 12mm screen rather than the usual 8mm screen, and then wet sieved with the usual nest of sieves of 4.76mm, 2mm, and 0.21mm, what would the maximum possible value for MWD be?
- 4.76mm
  - 6.38mm
  - 8.38mm
  - 14mm
- (9) 9. In each of the following pairs of conditions, underline the condition that would likely have the highest  $CO_2$  concentration (and lowest  $O_2$  concentration), and briefly describe why.
- poorly drained soil / well-drained soil
  - low fertility cropland / manured cropland
  - sandy soil / clay soil

- (12) 10. I heard someone say, "Field capacity is the soil water content at which the soil completely stops draining."

Tell me what is wrong with the statement above, and give me a better definition and explanation of "field capacity." You should write your answer in approximately two to three paragraphs, written so that students who have completed one course in basic soil science could understand what field capacity is and why it is important.

(10) 11.



One tensiometer and three piezometers are installed in the soil as shown.

- 1) Calculate pressure head, elevation head, and total hydraulic head for the soil at points A, B, C, and D. (Note that at one of those points you do not have enough information to calculate pressure head and total hydraulic head).
- 2) What is the "best estimate" of the water table depth in this soil?
- 3) What would the pressure head ( $h_p$ ) be at point B, if point B was in equilibrium with the water table? (use the water table estimate from part 2 above)

- (15) 12. You are working to clean up a large chemical spill that occurred 20 years ago near West Lafayette. At that time a tank ruptured and large amounts of chloride ( $K_d = 0 \text{ cm}^3/\text{g}$ ) and a non-degradable industrial chemical ( $K_d = 0.27 \text{ cm}^3/\text{g}$ ) were spilled on the ground. Weather records show that the net infiltration over that time period has been about 300 cm of water. You take soil cores and determine soil properties as listed below (you may not actually need all of this data, but you wanted to be sure you have everything measured).
- Calculate the current depth of the chloride peak and the industrial chemical peak, assuming only downward flow in the unsaturated zone, and no degradation.
  - If the water table depth is 25 m, calculate the expected future arrival time of each of the chemicals at the water table (assuming that the climate doesn't change).

Data collected

$$\theta_v = 0.32$$

$$\text{B.D.} = 1.40 \text{ g/cm}^3$$

$$\text{P.D.} = 2.65 \text{ g/cm}^3$$

$$\text{Organic C} = 1.8\%$$

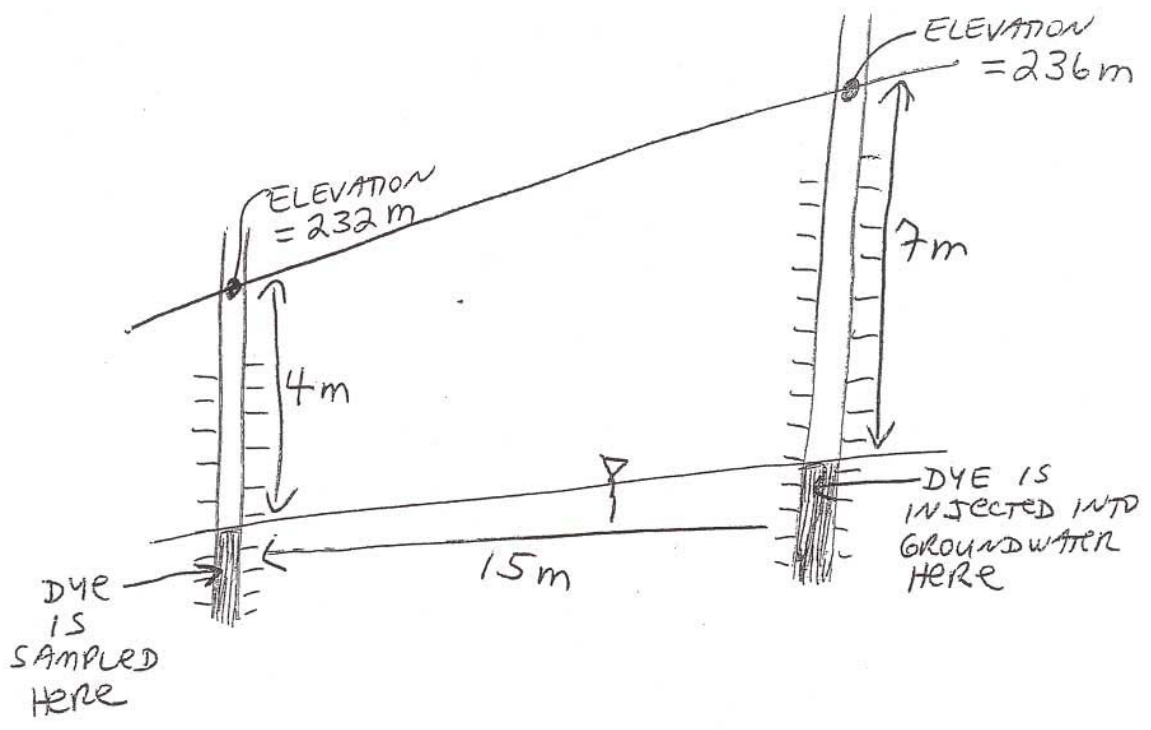
$$K_{\text{sat}} = 16 \text{ cm/day}$$

(15) 13. You are trying to determine the groundwater flow characteristics near a popular State Park. You install some wells in the area, two of which are shown in the diagram. You make a number of measurements and a series of tests to determine what you need to know. Data you may or may not need are given below.

- a) Calculate the water flux between the two wells (we want **final units of cm/yr**).
- b) Calculate the horizontal chemical flux of a tracer dye, if its concentration in the groundwater surrounding the injection well is 32 mg/liter (assuming piston flow and no adsorption). (flux must have **final units of  $\frac{mg}{cm^2 yr}$** )
- c) How long would it take for the non-sorbed dye to travel from the injection well to the other well? (**Final answer should be in units of yr**)

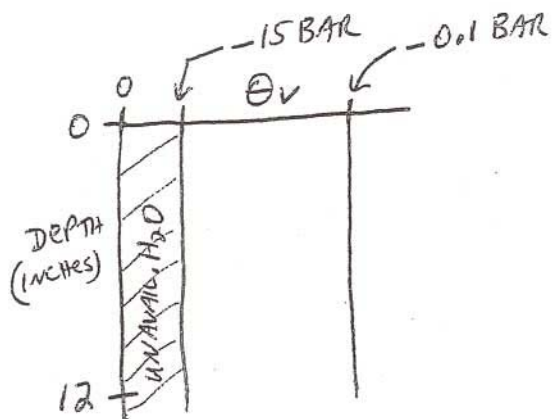
Data collected

$K_{sat} = 42 \text{ cm/day}$   
 $\theta_v \text{ of saturated zone} = 0.40$   
 $P.D. = 2.65 \text{ g/cm}^3$   
dye conc = 32 mg/liter



- (10) 14. We have a 12 inch depth of uniform sandy loam in a golf green. How many inches of irrigation water do we need to bring the entire depth of sandy loam from initially dry conditions (-15 bar) up to our estimate of field capacity (-0.1 bar)?

(NOTE--We do this calculation assuming that the irrigation water will redistribute in the soil so that it is uniformly wetted to field capacity within 24 hrs after irrigation.)



$$BD = 1.38 \text{ g/cm}^3$$

$$\theta_g - 0.1 \text{ bar} = 0.185 \text{ g/g}$$

$$\theta_g \text{ at } -15 \text{ bar} = 0.052 \text{ g/g}$$

- (10) 15. We started with a fully saturated soil profile, and then we covered it with plastic and allowed drainage to occur. After one week the measured water contents were as shown below. How much volume of water (liters) was drained from the 0 - 60 cm depth per  $\text{m}^2$  of soil surface area? CARE WITH UNITS IS ESSENTIAL TO WORK THIS PROBLEM CORRECTLY. **Final units required : liters/ $\text{m}^2$**

<u>DEPTH (cm)</u>	<u><math>\theta_{V(\text{INITIAL})}</math> (<math>\frac{\text{cm}^3}{\text{cm}^3}</math>)</u>	<u><math>\theta_{V(\text{FINAL})}</math> (<math>\frac{\text{cm}^3}{\text{cm}^3}</math>)</u>
0-10	0.45	0.20
10-30	0.45	0.25
30-60	0.45	0.33

OR, ILLUSTRATING GRAPHICALLY,

