

**THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ENERGY AND GEO-ENVIRONMENTAL ENGINEERING
GEOEE 408 CONTAMINANT HYDROLOGY**

**Final Examination – Tuesday May 3rd, 2005 – 110 minutes
Answer all questions.**

Name: _____

Include extra sheets, as needed, and return entire packet

Question 1

Define the following terms, and identify the units [MLT] of the quantity, where relevant. Be as specific and as exhaustive in your definitions as possible.

Question	Points	Score
1	100	
2	100	
3	100	
Total	300	

1. Non-dimensional Henry's law coefficient, H .

2. Advection-Dispersion equation, $\frac{\partial c}{\partial t} = D_L \frac{\partial^2 c}{\partial x^2} - v_a \frac{\partial c}{\partial x}$.

3. Split spoon sampler.

4. Raoult's Law.

5. MT3D.

6. Gaseous retardation factor, R_g .

7. Breakthrough curve.

8. Relative permeability, $k_r(S_w)$.

9. Darcy's law.

10. Steam Enhanced Extraction, SEE.

3. Determine how long it takes for the dissolved TCE plume to reach the water-table following the initiation of the spill. Assume plug-flow and no dispersion.

4. What will be the annual TCE loading at the water-table?

5. Based on these results, determine the time taken to deplete the spilled material using natural aqueous washing.

6. The site is covered with an impermeable membrane when the facility is closed at the end of year 10. If the vadose zone is vented by circulating air (at a mean temperature of 20°C) horizontally at a rate of 400 m³/month, determine the rate of removal of TCE. How long will it take to remove the complete spill using this method?

Question 3

A chloride plume has been detected in central Pennsylvania 200 m from a landfill that has an impermeable liner. The landfill is cut into alluvial sands and gravels that overlay sedimentary bedrock of interbedded fractured sandstones and limestones. The alluvium is 20 m thick and covers highly fractured rocks. Both the sandstone and limestone units have moderate matrix porosity ~20%, but flow characteristics are dominated by the fractures at scales of between 1 m and 1 km (faults) in length. Fractures are present at 3 per meter in the weathered zone, and at a spacing greater than 2 meters below this. The plume has been detected in one well located half-way between the landfill and an adjacent river.

1. Describe an appropriate (direct) site investigation for this site to:
 - a. Evaluate stratigraphy and geology.
 - b. Determine the extent of the plume, and to ascertain what other components might be present in the plume.
 - c. Determine the likelihood that the plume does or does not originate from the landfill.

Use note form, if you wish, to itemize your choices and explain their relevance.

2. The site investigation indicates that the water table is within 1 m of the ground surface. Site investigation reveals that DNAPLs are present in the sediments both dissolved in water and sorbed to the solid, but not as free product. Aqueous concentrations are below 5% of the solubility limit.

The alluvium has a matrix hydraulic conductivity of 10^{-5} cm/s, and the rocks a bulk conductivity of 10^{-3} cm/s, similar in both the matrix and fractures.

Identify, and describe the operating principles of three remedial techniques that may be applied to this site. For each of these three applicable techniques, identify three factors that make the technique particularly applicable to the site. Use note form to answer if you wish.