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

Final Examination – Monday April 29th, 2002 – 110 minutes
Answer all three questions.

Name: _____

Include extra sheets, as needed, and return entire packet

Question	Points	Score
1	100	
2	100	
3	100	
Total	300	

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.

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

2. Thin-walled piston sampler.

3. Bubbling pressure, p_b.

4. Jet grouting.

5. Brooks-Corey permeability relation.

6. Capillary pressure, p_c

7. Leveret J-curve.

8. Fick's law.

9. Effective solubility.

10. Minimum ganglion length, h_{min}.

Question 2

A variety of DNAPL solvents, have been found in surficial soils and within the bedrock at a site in southern Nevada. The site comprises 5 *m* of silty alluvium, overlaying highly fractured tuffs.

The watertable is 30 *m* below the ground surface, and the main locations of free product are as discrete lenses in the alluvium, and within the bedrock fractures.

1. Describe an appropriate (direct) site investigation for this site to:
    a. Evaluate geology and hydrogeology.
    b. Determine the extent of NAPL (free product) and dissolved product contamination.
    c. Determine the potential for continued migration within the vadose zone and in the groundwater zone.

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

2. The bulk hydraulic conductivity, of the fractured volcanic rocks is of the order of 10^{-2} *cm/s*, and the matrix conductivity is very low, of the order of 10^{-10} *cm/s*, with a porosity of 3%. The unsaturated overlaying alluvium has a porosity of 25%, and a saturated conductivity of 10^{-4} *cm/s*.

Identify, and describe the operating principles of two remedial techniques that may be applied to this site to remove or contain the bedrock source NAPLs. For each of these two applicable techniques, identify three factors that make the technique particularly applicable to the site.

Use note form to answer if you wish.

Question 3

A two-component DNAPL cocktail has been spilled through the vadose zone in a sand aquifer and has reached and penetrated the saturated zone. Soil samples are taken from the saturated zone within (an arbitrary) part of the aquifer where a dissolved plume is presumed to have developed. The sample is centrifuged to remove the pore fluids, and the fluid assayed to determine aqueous concentrations, c_a. Components are desorbed from the solid grains to define the presumed equilibrium sorbed concentrations, c_s. The porosity of the sand aquifer is n=25%, the bulk density is ρ_b=1200 kg/m^3, and the mean volumetric moisture content in the vadose zone is θ=5%. The mean soil temperature is 20^oC. Solubility of each of the components approximately triple with an increase in temperature from 20^o to 60^oC. The non-dimensional Henry's law coefficient, H, approximately doubles over the same temperature range.

Component	c_a *mg/l*	c_s *mg/kg*	Henry's Law Coef. $H(20^oC)$ *[dimensionless]*	Mole fraction, X_i *%*
Trichloroethane (TCA)	0.13×10^3	325	0.4	60
Methyl Chloride	0.6×10^4	600	0.6	40

Component	Gaseous Conc. $c_g(20^oC)$ *mg/l*	Aqueous Conc. c_a (60^oC) *mg/l*	Gaseous Conc. C_g (60^oC) *mg/l*
Trichloroethane (TCA)			
Methyl Chloride			

1. Complete the missing entries in the table above.

2. Approximately 10,000 *l* of the cocktail is to be removed from the system. Evaluate the time taken to remove this material from the aquifer if the system is flushed with water at 20^oC, at a rate of 40 m^3/day. Assume that mole fraction approximates mass fraction, and that mean density of the NAPL is 1400 kg/m^3.

3. If sparging is used, at ambient temperature of 20^oC and throughput is also 40 m^3/day, estimate the time needed to remove all free product from the aquifer. State any assumptions.

4. To improve removal rates, steam is injected into air sparging wells. These rapidly raise temperatures of the recirculating fluids to 60^oC. This decreases viscosity of water, and together with the higher applied pressures, enables a larger throughput of fluid to flush the system. If the steam injection results in concurrent circulation of 60 m^3/day of 60^oC water and 60 m^3/day of 60^oC sparged air through the system, evaluate the rate of removal. How long will it take to clean the system for each of the components? Which method of removal, air sparging or water, is the most effective agent of removal?