THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF MINERAL ENGINEERING
GEOEE 408 CHARACTERIZATION OF GROUNDWATER SYSTEMS

Final Examination - Tuesday May 5th
1 hour 50 minutes
$\bar{R} = 8.206 \times 10^{-5} (atm.m^3)/(mol.^oK)$

Name: _____

SSN: _____

Question	Points	Score
1	70	
2	90	
3	90	
Total	250	

Question 1

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

1. Core barrel and wireline system.

2. Electro osmotic remediation.

3. Resistivity mapping and sounding.

4. Aqueous retardation coefficient, R_a.

5. Henry's law coefficient, H.

6. Capillary pressure, p_c.

7. Permeability, k, and hydraulic conductivity, K.

8. Cone penetrometer testing.

9. Longitudinal dispersion coefficient, D_L.

10. Gaseous retardation coefficient, R_g.

Question 2

A two component DNAPL cocktail has been spilled through the vadose zone in a sand aquifer and has reached and penetrated 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 $\rho_b = 1200\ kg/m^3$ and the mean volumetric moisture content in the vadose zone is $\theta = 5\%$. The mean soil temperature is 20^oC. Solubility of each of the two components approximately triple with an increase in temperature from 20^oC to 60^oC. Henry's law coefficient, H', approximately doubles over the same temperature range.

Component	c_a mg/l	c_s mg/kg	Henry's law coeff., $H'(20^oC)$ $(atm.m^3)/mol.$	Mole fraction, X_i $\%$
Trichloroethane (TCA)	0.13×10^3	325	1.8×10^{-2}	60
Methylene Chloride	0.6×10^4	600	2.0×10^{-3}	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)	_____	_____	_____
Methylene 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 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 sparge or water, is the most effective agent of removal?

Question 3

TCE has been found as free product in the subsurface at a petroleum refinery on alluvial deposits along the Mississippi. The free product is present in interbedded sands and clays to at least a depth of 160 feet. Bedrock is at least 300 feet deep at this site.

1. Describe an appropriate (direct) site investigation for this site to:

   (a) Evaluate stratigraphy and geology.

   (b) Determine the extent of NAPL (free product) and dissolved product contamination.

   (c) Determine the potential for offsite migration of the aqueous plume.

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

2. The site investigation indicates that the horizontally bedded sands and shales are laterally well connected, and bed thicknesses are of the order of one to three feet. Individual conductivities of the clay and sand units are of the order of 10^{-7} and $10^{-3} cm/s$, respectively. The system is water saturated to the ground surface. Free product contamination covers at least one quarter of a square mile.

   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.