Homework 5 - Due November 29

1) There is a contamination spill that occurs over a small area. The total mass of the spill is 10000 kg. There is a net flow from South to North and there are several wells located at distances of 100m, 1km and 10km north of the spill.

The Darcy velocity q=1 m/day and the porosity of the medium is 0.3. The dispersivity is 0.01 m. Take the retardation coefficient as R=2. Molecular diffusion is negligible.

Calculate the concentration at each of the wells over a period of 100 years and plot figures of concentration vs. time. (Be very careful with the choice of time steps at which to plot the concentrations; if you do not pick them well you will miss the plume entirely and it will look like nothing happened – HINT: estimate when you think the peak would arrive and resolve around that time).

Imagine the retardation coefficient were actually 4. How would these curves look now?

2) Two point spills occur at the exact same time. Each spill can be modeled as a point initial condition of mass 1kg. The first spill occurs at x=-1m and the second at x=1m. The system has no flow and there is a diffusion coefficient of .2m^2/day.

Solve for the concentration field in the system. Plot the concentration at x=0 over 200 days.

3) A geophysicst provides you with the following dataset for 1^{st} and 2^{nd} moments of a contaminant plume. Use the data set to estimate the velocity and dispersion coefficient. Describe clearly what you are doing. Be careful with noise in the dataset.

Time(days)	m1 (m)	m2 (m^2)
1.00	22.17	492.01
6.21	136.95	18756.30
11.42	249.87	62440.19
16.63	401.47	161184.49
21.84	452.70	204947.94
27.05	601.15	361390.35
32.26	725.47	526313.95
37.47	742.94	551969.10
42.68	959.66	920952.31
47.89	1130.50	1278043.35
53.11	1151.56	1326106.11
58.32	1264.26	1598378.90
63.53	1295.82	1679169.51
68.74	1535.12	2356627.28
73.95	1711.16	2928082.28
79.16	1631.99	2663400.82
84.37	1730.69	2995296.76
89.58	1911.57	3654139.43
94.79	2095.38	4390664.14
100.00	2323.28	5397667.36

4) A point spill with a mass of 100 kg occurs at a time t=0. The system has a Darcy velocity of 0.5 m/day and the porosity of the medium is 0.2. After 20 days an identical spill occurs at the exact same location. The retardation coefficient is equal to 2.5. The dispersivity is 0.2m and molecular diffusion is negligible.

Write a mathematical expression of the concentration field as it evolves in space and time. Plot the concentration at a distance x= 25m and x=50m over 100 days.

5) There is a continuous source of a contaminant located at x=0. The contaminant is released at a constant concentration of 10mg/l. The Darcy velocity is 2m/day, the porosity is 0.25, the retardation coefficient is 2 and the dispersivity is 2m.

In the lab it is observed in a well-mixed batch reactor that the contaminant degrades as

dC/dt=-0.01 C

The contaminant has been released over many many years and the solute plume can be considered to have attained steady state. Assuming that the degradation rate measured in the lab can be used for field calculations calculate the steady state concentration field. How far downstream do you have to go for the concentration to have degraded to 25%, 10%, 5%, 1% and 0.1% of the maximum source concentration.

6) A field hydrologist has measured the extent of a contaminant plume and come up with the following expression for the contaminant distribution

C=127 exp(-0.002 x)   for x>0 with concentration in units of mg/l and x is in meter.

The local village wants to drill a well, but the authorities are concerned about chronic exposure to the contaminant, which is a carcinogen. It is deemed that people will be exposed by ingestion and inhalation, but that dermal exposure will be minimal.

For ingestion you can take the cancer potency factor as 2.4 $x10^{-2}$ kg d/mg. People who are exposed will typically be exposed for 5 out ever 7 days. We consider the risk over a lifetime of 70 years with a typical residence time in a certain area of 28 years. Assume the average person in this community weighs 58 kg and that they take in 2.5 liters of water per day.

For inhalation you can take the cancer potency factor as 1.4 $x10^{-2}$ kg d/mg. People who are exposed will typically be exposed for 6.5 out ever 7 days. We consider the risk over a lifetime of 70 years with a typical residence time in a certain area of 28 years. Assume the average person in this community weighs 58 kg and that they take in the equivalent of 4.5 liters of water per day by inhalation.

If the acceptable health risk R is to be less than $10^{-6,}$ at what minimum value of x should the well be located. What if it were 10^{-5} or 10^{-4}? Which of the two exposure routes results in greater risk? If you could eliminate this exposure pathway would there be much impact on the well location?