GEOL4850 Groundwater Hydrology
Final Exam (5 problems, 100 points)
Dec 5- Dec 12, 2013, 3:30pm (ENV210E)
Collaboration in any way on the final exam is not allowed.

Problem 1. (25 points)

Figure 1 illustrates an unconfined aquifer that is bounded by two channels: one is at x=0 where the elevation of the water table above the base of the aquifer is 30 ft, and the other is at x=L=1000 ft, where the water table elevation above the base of the aquifer is 40 ft. The hydraulic conductivity is 1.5 ft/d. The area is subject to rainfall of 2.0 ft/year and evaporation of 1.8 ft/year.

(1) What is the average discharge per unit width at x=0?
(2) What is the average discharge per unit width at x=1000ft?
(3) Is there a water-table divide in the unconfined aquifer? Is so, where is it located?
(4) What is the maximum height of the water table in the unconfined aquifer?

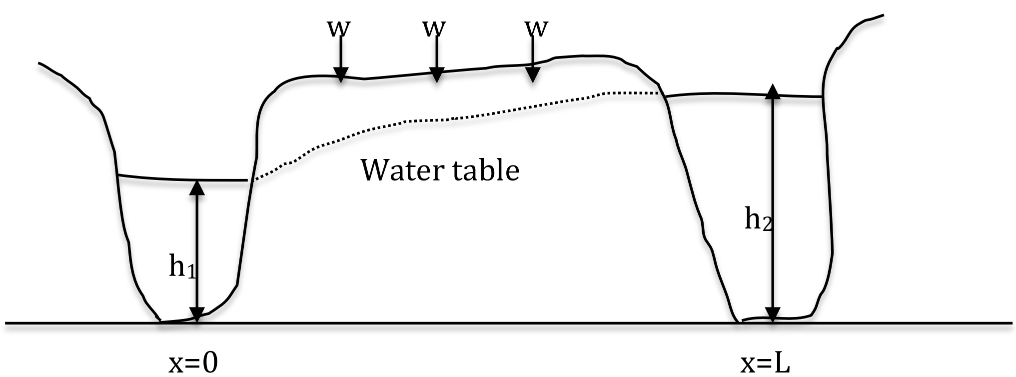

Fig.1

Problem 2. (25 points)

A well that is screened in a completely confined aquifer is to be pumped at a rate of 120,000 ft^3/day for 30 days. If the aquifer transmissivity is 8000 ft^2/day, and the storativity is 0.0005, what is the drawdown at distance of 50, 100, 200, 500, 1000, and 5000 ft? The values of the well function are given in the attached Appendix 1.

Problem 3. (25 points)

A confined aquifer is underlain by a 10.0-ft-thick leaky confining layer with a vertical conductivity of 0.03 ft/day. A well is screened in the confined aquifer and pumped at a rate of 200,000 ft^3/day for 30 days. If the transmissivity of the aquifer is 6000 ft^2/day and the storativity is 0.0002, what is the drawdown at distance of 100, 200, 500, 1000, and 5000 ft. Assume all assumptions are valid. The values of the well function are given in the attached Appendix 3.

Problem 4. (10 points)

The fresh water at a costal area has a density of 0.998 g/cm^3, and the underlying saline water has a density of 1.022 g/cm^3. If the fresh-water head is 3.2 m above the mean sea level, what is the depth to the salt-water interface?

Problem 5. (15 points)

A landfill is leaking leachate with a chloride concentration of 800 mg/L, which enters an aquifer with the following properties: hydraulic conductivity is 2.0×10^{-5} m/s, dh/dl=0.001, effective porosity n_e=0.22, the effective diffusion coefficient is 1.1×10^{-9}m^2/s. Compute the concentration of chloride in 2 years at a distance 20 m from the point where the leachate entered the ground water using the following equation:

$$C = \frac{C_o}{2}[erfc(\frac{L - v_x t}{2\sqrt{D_L t}}) + e^{(v_x L/D_L)} \times erfc(\frac{L + v_x t}{2\sqrt{D_L t}})]$$

where C is the concentration of chloride at distance of L, Co is the concentration of chloride at the contaminant source, v_x is the average linear velocity, t is time, and D_L is the longitudinal coefficient of hydrodynamic dispersion and give by:

$$D_L = 0.1108(\ln L)^{2.414} v_x + D*$$

where lnL is the natural logarithm of distance L, and D* is the effective diffusion coefficient. Erfc is the complementary error function and the values of the complementary error function are given in the attached Appendix 13.

Appendix 1 Values of the function $W(u)$ for various values of u

u	$W(u)$	u	$W(u)$	u	$W(u)$	u	$W(u)$
1×10^{-10}	22.45	7×10^{-8}	15.90	4×10^{-5}	9.55	1×10^{-2}	4.04
2	21.76	8	15.76	5	9.33	2	3.35
3	21.35	9	15.65	6	9.14	3	2.96
4	21.06	1×10^{-7}	15.54	7	8.99	4	2.68
5	20.84	2	14.85	8	8.86	5	2.47
6	20.66	3	14.44	9	8.74	6	2.30
7	20.50	4	14.15	1×10^{-4}	8.63	7	2.15
8	20.37	5	13.93	2	7.94	8	2.03
9	20.25	6	13.75	3	7.53	9	1.92
1×10^{-9}	20.15	7	13.60	4	7.25	1×10^{-1}	1.823
2	19.45	8	13.46	5	7.02	2	1.223
3	19.05	9	13.34	6	6.84	3	0.906
4	18.76	1×10^{-6}	13.24	7	6.69	4	0.702
5	18.54	2	12.55	8	6.55	5	0.560
6	18.35	3	12.14	9	6.44	6	0.454
7	18.20	4	11.85	1×10^{-3}	6.33	7	0.374
8	18.07	5	11.63	2	5.64	8	0.311
9	17.95	6	11.45	3	5.23	9	0.260
1×10^{-8}	17.84	7	11.29	4	4.95	1×10^{0}	0.219
2	17.15	8	11.16	5	4.73	2	0.049
3	16.74	9	11.04	6	4.54	3	0.013
4	16.46	1×10^{-5}	10.94	7	4.39	4	0.004
5	16.23	2	10.24	8	4.26	5	0.001
6	16.05	3	9.84	9	4.14		

Source: Adapted from L. K. Wenzel, *Methods for Determining Permeability of Water-Bearing Materials with Special Reference to Discharging Well Methods.* U.S. Geological Survey Water-Supply Paper 887, 1942.

Appendix 3 Values of the functions $W(u, r/B)$ for various values of u

u \ r/B	0.002	0.004	0.006	0.008	0.01	0.02	0.04	0.06	0.08	0.1	0.2	0.4	0.6	0.8	1	2	4	6	8
0	12.7	11.3	10.5	9.89	9.44	8.06	6.67	5.87	5.29	4.85	3.51	2.23	1.55	1.13	0.842	0.228	0.0223	0.0025	0.0003
0.000002	12.1	11.2	10.5	9.89	9.44														
0.000004	11.6	11.1	10.4	9.88	9.44														
0.000006	11.3	10.9	10.4	9.87	9.44														
0.000008	11.0	10.7	10.3	9.84	9.43														
0.00001	10.8	10.6	10.2	9.80	9.42	8.06													
0.00002	10.2	10.1	9.84	9.58	9.30	8.06													
0.00004	9.52	9.45	9.34	9.19	9.01	8.03	6.67												
0.00006	9.13	9.08	9.00	8.89	8.77	7.98	6.67												
0.00008	8.84	8.81	8.75	8.67	8.57	7.91	6.67												
0.0001	8.62	8.59	8.55	8.48	8.40	7.84	6.67	5.87	5.29										
0.0002	7.94	7.92	7.90	7.86	7.82	7.50	6.62	5.86	5.29										
0.0004	7.24	7.24	7.22	7.21	7.19	7.01	6.45	5.83	5.29	4.85									
0.0006	6.84	6.84	6.83	6.82	6.80	6.68	6.27	5.77	5.27	4.85									
0.0008	6.55	6.55	6.54	6.53	6.52	6.43	6.11	5.69	5.25	4.84									
0.001	6.33	6.33	6.32	6.32	6.31	6.23	5.97	5.61	5.21	4.83	3.51								
0.002	5.64	5.64	5.63	5.63	5.63	5.59	5.45	5.24	4.98	4.71	3.50								
0.004	4.95	4.95	4.95	4.94	4.94	4.92	4.85	4.74	4.59	4.42	3.48	2.23							
0.006	4.54				4.54	4.53	4.48	4.41	4.30	4.18	3.43	2.23							
0.008	4.26				4.26	4.25	4.21	4.15	4.08	3.98	3.36	2.23							
0.01	4.04				4.04	4.03	4.00	3.95	3.89	3.81	3.29	2.23	1.55	1.13					
0.02	3.35				3.35	3.35	3.34	3.31	3.28	3.24	2.95	2.18	1.55	1.13					
0.04	2.68				2.68	2.68	2.67	2.66	2.65	2.63	2.48	2.02	1.52	1.13	0.842				
0.06	2.30				2.30	2.29	2.29	2.28	2.27	2.26	2.17	1.85	1.46	1.11	0.839				
0.08	2.03					2.03	2.02	2.02	2.01	2.00	1.94	1.69	1.39	1.08	0.832				
0.1	1.82						1.82	1.82	1.81	1.80	1.75	1.56	1.31	1.05	0.819	0.228			
0.2	1.22						1.22	1.22	1.22	1.22	1.19	1.11	0.996	0.857	0.715	0.227			
0.4	0.702						0.702	0.702	0.701	0.700	0.693	0.665	0.621	0.565	0.502	0.210			
0.6	0.454						0.454	0.454	0.454	0.453	0.450	0.436	0.415	0.387	0.354	0.177	0.0222		
0.8	0.311						0.311	0.310	0.310	0.310	0.308	0.301	0.289	0.273	0.254	0.144	0.0218		
1	0.219									0.219	0.218	0.213	0.206	0.197	0.185	0.114	0.0207	0.0025	
2	0.049										0.049	0.048	0.047	0.046	0.044	0.034	0.011	0.0021	0.0003
4	0.0038											0.0038	0.0037	0.0037	0.0036	0.0031	0.0016	0.0006	0.0002
6	0.0004														0.0004	0.0003	0.0002	0.0001	0
8	0																		0

Source: After M. S. Hantush, "Analysis of Data from Pumping Test in Leaky Aquifers," *Transactions, American Geophysical Union*, 37 (1956):702–14.

Appendix 13 Values of the error function of x [erf (x)] and the complementary error function of x [erfc (x)]. Note that erfc (x) = 1 − erf (x) and erfc (−x) = 1 + erf (x).

X	erf (x)	erfc (x)
0	0	1.0
0.05	0.056372	0.943628
0.1	0.112463	0.887537
0.15	0.167996	0.832004
0.2	0.222703	0.777297
0.25	0.276326	0.723674
0.3	0.328627	0.671373
0.35	0.379382	0.620618
0.4	0.428392	0.571608
0.45	0.475482	0.524518
0.5	0.520500	0.479500
0.55	0.563323	0.436677
0.6	0.603856	0.396144
0.65	0.642029	0.357971
0.7	0.677801	0.322199
0.75	0.711156	0.288844
0.8	0.742101	0.257899
0.85	0.770668	0.229332
0.9	0.796908	0.203092
0.95	0.820891	0.179109
1.0	0.842701	0.157299
1.1	0.880205	0.119795
1.2	0.910314	0.089686
1.3	0.934008	0.065992
1.4	0.952285	0.047715
1.5	0.966105	0.033895
1.6	0.976348	0.023652
1.7	0.983790	0.016210
1.8	0.989091	0.010909
1.9	0.992790	0.007210
2.0	0.995322	0.004678
2.1	0.997021	0.002979
2.2	0.998137	0.001863
2.3	0.998857	0.001143
2.4	0.999311	0.000689
2.5	0.999593	0.000407
2.6	0.999764	0.000236
2.7	0.999866	0.000134
2.8	0.999925	0.000075
2.9	0.999959	0.000041
3.0	0.999978	0.000022
∞	1.00000	0.00000

An approximate solution, correct to within 0.7%, of the error function can be determined analytically from the following equation:

$$\mathrm{erf}\,(x) = \sqrt{1 - \exp\left(\frac{-4x^2}{\pi}\right)}$$