National Exams May 2010

04-Geol-A2, Hydrogeology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM. Any non-communicating calculator is permitted.
3. FIVE (5) questions constitute a complete exam paper. The first five questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. Most questions require an answer in essay format. Clarity and organization of the answer are important.
6. Assume water density = 1,000 kg/m^3, water viscosity = 0.001 kg/m-sec, g = 9.81 m/s^2.

Marking Scheme

1. (a) 6 mks, (b) 6 mks, (c) 2 mks, (d) 6 mks
2. (a) 5 mks, (b) 5 mks, (c) 5 mks, (d) 5 mks
3. (a) 9 mks, (b) 2 mks, (c) 9 mks,
4. (a) 7 mks, (b) 7 mks, (c) 6 mks
5. (a) 7 mks, (b) 2 mks, (c) 7 mks, (d) 4 mks
6. (a) 7 mks, (b) 7 mks, (c) 6 mks

1. The bottom of a lake is at an elevation of 91.1 m.a.s.l. and the water level in the lake is at an elevation of 102.1 m.a.s.l. The lake is separated from an underlying sandy aquifer by a layer of sediments with a thickness of 2.1 m A piezometer (used to measure water levels) is installed at the top of the aquifer below the lake sediments with the piezometer screen (where the water level in the soil is measured) at an elevation of 89.0 m.a.s.l. The water level in the piezometer is 102.2 m.a.s.l. A water balance on the lake indicates that the inflow of water through the bottom of the lake at the time of measurement was approximately 100 m^3/day and the surface area of the bottom of the lake was 15,000 m^2.
   a) Determine the water pressure head (in m. H_2O) and the water absolute pressure (in Pa) at the bottom of the lake (i.e. at 91.1 m.a.s.l.) and at the piezometer screen (i.e. at 89.0 m.a.s.l.)
   b) Estimate the intrinsic permeability of the sediments between the lake bottom and the aquifer.
   c) If the porosity of the sediments in the lake bottom is 0.4, how long would potential contaminants in the aquifer take to move by advection from the aquifer into the lake?
   d) At what elevation would the water level in the lake have to be so that there was no water flow between the aquifer and the lake (velocity of zero across the sediments)?

2.
   a) A sample of moist sand had a weight of 23.142 g. After drying the weight of the sample was 21.108 g. The sand mineral (solid) density was 2.73 g/cm^3. Determine the porosity, bulk density, void ratio, and moisture content of the original soil sample if the original sample volume was 11.872 cm^3.
   b) In a constant head permeameter test done on a 3 cm diameter, 5 cm long soil sample, the head difference across the sample was 2 cm, and 50 mL of water were collected in 10 minutes. The water density and viscosity were 998.9 kg/m^3, and 0.0008 kg/m-sec for the test. Determine the soil intrinsic permeability.
   c) An aquifer consisted of a 7 m thick fine sand horizontal layer ($K = 1.0 \times 10^{-4}$ cm/sec) at the bottom, a 8 m thick coarse sand horizontal layer ($K = 1 \times 10^{-2}$ cm/sec) in the middle, and a 5 m thick silty sand horizontal layer ($K = 1 \times 10^{-5}$ cm/sec) at the top of the aquifer. Determine the effective hydraulic conductivity for horizontal and vertical flow in the aquifer.
   d) If recharge was applied to the top of the aquifer in (c), the aquifer was fully water saturated, the bottom and left boundaries were impermeable, and flow exited the right boundary of the aquifer, draw a possible flow net for the aquifer.

3.

a) A 10 cm diameter, fully screened pumping well located in a 50 m thick confined aquifer withdraws water at a rate of 10 L/sec until steady water levels are produced. At this time the water level in the pumping well is 10 m above the top of the confined aquifer, and the water level in a fully screened monitoring well located 50 m from the pumping well is 20 m above the top of the confined aquifer. Determine the hydraulic conductivity of the aquifer.

b) Determine the groundwater Darcy velocity in the aquifer at the location of the monitoring well for the conditions in (a).

c) A 10 cm diameter, fully screened pumping well located in a 50 m thick unconfined aquifer withdraws water at a rate of 10 L/sec until steady water levels are produced. At this time the water level in the pumping well is 10 m below the original water table elevation of the unconfined aquifer, and the water level in a fully screened monitoring well located 50 m from the pumping well is 5 m below the original water table elevation of the unconfined aquifer. Determine the hydraulic conductivity of the aquifer.

4.

a) A pump test is conducted in a fully confined aquifer. The well pumps at 8 l/sec for 24 hours. Determine the drawdown in an observation well 100 m from the pumping well 24 hours after the start of the pump test. The aquifer is 30 m thick, hydraulic conductivity 2×10^{-3} cm/sec and a specific storativity of 3.0×10^{-5} m^{-1}.

b) The well in (a) is turned off 24 hours after it is turned on. A second pumping well that is 75 m from the observation well is turned on at this point in time and pumps continuously at a rate of 4 l/sec. Determine the drawdown in the observation well after the second well has been pumping for 30 hours.

c) If the well in (b) is turned off after 30 hours, determine the drawdown in the observation well 12 hours after this well was turned off.

5.

a) A pump test is conducted in a leaky confined aquifer. The well pumps at a rate of 10 l/sec for 24 hours. Determine the drawdown in an observation well 120 m due north of the pumping well 24 hours after the start of the pump test. The aquifer is 25 m thick, has a hydraulic conductivity of 1×10^{-3} cm/sec and a specific storativity of 1.0×10^{-5} m^{-1}. The overlying aquitard is 10 m thick, hydraulic conductivity of 1×10^{-6} cm/sec, and you may assume negligible aquitard storage.

b) What would be the effect of aquitard storage on drawdown?

c) From analysis of the pump test in (a) it was determined that the aquifer was bounded by an essentially impermeable boundary that was 200 m due east of the pumping and monitoring wells. Assuming that the aquifer could be considered fully confined (negligible aquitard leakage), determine the drawdown at the monitoring well after 24 hours.

d) Sketch qualitatively correct drawdown plots (drawdown vs time on log-log scale) for an ideal infinite confined aquifer, a leaky aquifer, and an aquifer bounded by an impermeable boundary.

6.

a) Discuss the concept of safe yield for an aquifer and any complexities associated with the concept.

b) What is "water spreading" and how and why is it implemented? Contrast water spreading to recharge basins.

c) What are the causes of saltwater encroachment, and what measures can be taken to minimize this process?

Table 5.1

Values of $W(u)$ for values of u (from Wenzel, 1942)

u	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
$\times 1$	0.219	0.049	0.013	0.0038	0.0011	0.00036	0.00012	0.000038	0.000012
$\times 10^{-1}$	1.82	1.22	0.91	0.70	0.56	0.45	0.37	0.31	0.26
$\times 10^{-2}$	4.04	3.35	2.96	2.68	2.47	2.30	2.15	2.03	1.92
$\times 10^{-3}$	6.33	5.64	5.23	4.95	4.73	4.54	4.39	4.26	4.14
$\times 10^{-4}$	8.63	7.94	7.53	7.25	7.02	6.84	6.69	6.55	6.44
$\times 10^{-5}$	10.94	10.24	9.84	9.55	9.33	9.14	8.99	8.86	8.74
$\times 10^{-6}$	13.24	12.55	12.14	11.85	11.63	11.45	11.29	11.16	11.04
$\times 10^{-7}$	15.54	14.85	14.44	14.15	13.93	13.75	13.60	13.46	13.34
$\times 10^{-8}$	17.84	17.15	16.74	16.46	16.23	16.05	15.90	15.76	15.65
$\times 10^{-9}$	20.15	19.45	19.05	18.76	18.54	18.35	18.20	18.07	17.95
$\times 10^{-10}$	22.45	21.76	21.35	21.06	20.84	20.66	20.50	20.37	20.25
$\times 10^{-11}$	24.75	24.06	23.65	23.36	23.14	22.96	22.81	22.67	22.55
$\times 10^{-12}$	27.05	26.36	25.96	25.67	25.44	25.26	25.11	24.97	24.86
$\times 10^{-13}$	29.36	28.66	28.26	27.97	27.75	27.56	27.41	27.28	27.16
$\times 10^{-14}$	31.66	30.97	30.56	30.27	30.05	29.87	29.71	29.58	29.46
$\times 10^{-15}$	33.96	33.27	32.86	32.58	32.35	32.17	32.02	31.88	31.76

Table 5.2
Values of *W(u r/B)* (after Hantush, 1956)*

u \ r/B	0.01	0.015	0.03	0.05	0.075	0.10	0.15	0.2	0.3	0.4
0.000001										
0.000005	9.4413									
0.00001	9.4176	8.6313								
0.00005	8.8827	8.4533	7.2450							
0.0001	8.3983	8.1414	7.2122	6.2282	5.4228					
0.0005	6.9750	6.9152	6.6219	6.0821	5.4062	4.8530				
0.001	6.3069	6.2765	6.1202	5.7965	5.3078	4.8292	4.0595	3.5054		
0.005	4.7212	4.7152	4.6829	4.6084	4.4713	4.2960	3.8821	3.4567	2.7428	2.2290
0.01	4.0356	4.0326	4.0167	3.9795	3.9091	3.8150	3.5725	3.2875	2.7104	2.2253
0.05	2.4675	2.4670	2.4642	2.4576	2.4448	2.4271	2.3776	2.3110	1.9283	1.7075
0.1	1.8227	1.8225	1.8213	1.8184	1.8128	1.8050	1.7829	1.7527	1.6704	1.5644
0.5	0.5598	0.5597	0.5596	0.5594	0.5588	0.5581	0.5561	0.5532	0.5453	0.5344
1.0	0.2194	0.2194	0.2193	0.2193	0.2191	0.2190	0.2186	0.2179	0.2161	0.2135
5.0	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011

u \ r/B	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5
0.000001									
0.000005									
0.00001									
0.00005									
0.0001									
0.0005									
0.001									
0.005									
0.01	1.8486	1.5550	1.3210	1.1307					
0.05	1.4927	1.2955	1.2955	1.1210	0.9700	0.8409			
0.1	1.4422	1.3115	1.1791	1.0505	0.9297	0.8190	0.4271	0.2278	
0.5	0.5206	0.5044	0.4860	0.4658	0.4440	0.4210	0.3007	0.1944	0.1174
1.0	0.2103	0.2065	0.2020	0.1970	0.1914	0.1855	0.1509	0.1139	0.0803
5.0	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0010	0.0010	0.0009

*Trans. Amer. Geophys. Union, 37, p. 702–714. Copyright by Amer. Geophys. Union.