National Exams May 2014

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. Unless otherwise specified, use water density = 1000 kg/m^3, water viscosity = 0.001 kg/m-sec, and g = 9.81 m/s^2

04-Geol-A2, Hydrogeology

Question 1

a) Explain why the transmissivity of an unconfined aquifer can vary with time.

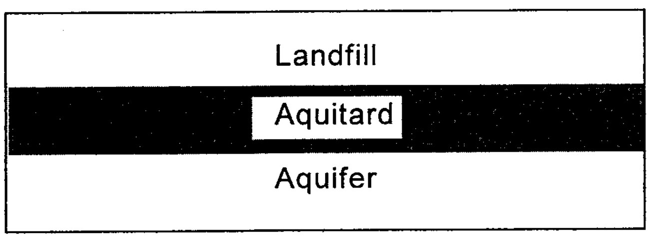
b) A soil sample has the following characteristics:

Moist soil mass	1025 g
Total sample volume (V_t)	660 cm^3
Oven dried soil solids mass (M_s)	952 g
Grain density (ρ_s)	2.62 g/cm^3

Find the dry bulk density, porosity, void ratio, saturation, and moisture content of the sample.

c) A landfill has been designed with a clay aquitard that separates the waste from the aquifer. The clay is 3 m thick with a permeability of 10^{-17} m^2. A piezometer measuring the water level at the top of the aquitard contains 0.5 m of water.

What would the hydraulic head need to be at the bottom of the aquitard if you wanted to induce a Darcy velocity *upwards* of 1×10^{-3} m/yr through the aquitard? What would the pressure be (in Pa) at the same point and WHY might inducing an upward velocity be a good idea?



Question 2

a) An aquitard consists of two soil layers. The upper layer is 10 m thick with a hydraulic conductivity of 5×10^{-6} cm/s. The lower layer is 15 m, with a hydraulic conductivity of 2.5×10^{-7} cm/s. Determine the effective hydraulic conductivies of the aquitard for horizontal and vertical flow. Also, determine the water pressure head (in m) between the to soil layers if the water pressure head at the top of the aquitard is 30 m and the water pressure head at the bottom of the aquitard is 56 m.

b) A fresh water (water density = 1000 kg/m^3) aquifer is separated from an underlying saline (density = 1120 kg/m^3) aquifer by a 15 m thick aquitard. A well screened at the top of the aquitard in the fresh water aquifer contains 10 m of fresh water. A well screened at the bottom of the aquitard in the saline aquifer contains 3m of saline water. Determine the direction of water flow across the aquitard. Explain your reasoning.

Question 3

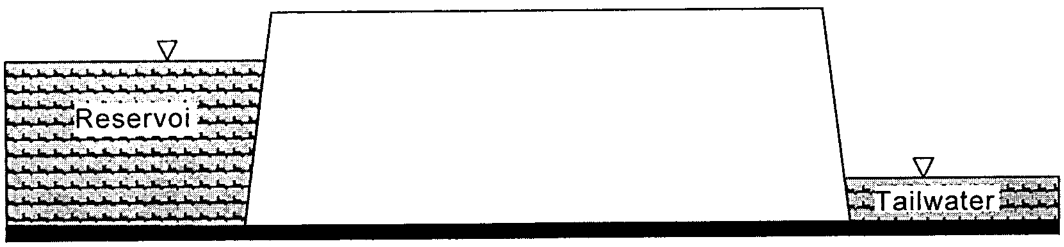
a) A new subdivision is being built and the confined aquifer located nearby is being evaluated as the possible source of potable water for the residents. The average daily requirement is 1,000 cubic meters. A consulting company has installed two wells in the confined aquifer. The wells are screened at the same depth and are 1.2 km apart horizontally. The depth to water in well #1 is 20 m while the depth to water in well #2 is 26.5 m. Initial measurements show that the hydraulic conductivity of the aquifer is 10^{-3} cm/s, the average depth is 22 m, and it spans 5 km. Will the aquifer be suitable for the new subdivision?

b) Three piezometers are all located in the same aquifer. Piezometer A is located 3200 m due south of peizometer B, and piezometer C is situated 2000 m from both piezometers A and B, due east of the line A-B. The surface elevations of piezometers A, B and C are 532 meters above sea level (m.a.s.l.), 521 m.a.s.l., and 506 m.a.s.l., respectively. The depth to water in piezometer A is 25 m, in B is 46 m and in C is 6 m. Construct a flow net showing the direction of groundwater flow and the equipotential lines (lines of equal hydraulic head). Calculate the hydraulic gradient. If the aquifer is a silty sandstone with a hydraulic conductivity of 10^{-6} m/s and thickness if 12 m, calculated the discharge per unit width.

Question 4

a) A well (10 cm radius) in an unconfined aquifer pumps at 5 L/s and has a steady state water level, measured from the bottom of the aquifer, of 50 m. The radius of influence of the well is 200 m and the initial unconfined aquifer depth is 55 m. Determine the hydraulic conductivity of the unconfined aquifer and the steady state water level at an observation well 80 m from the pumping well.

b) An earthen dam is constructed on an impermeable bedrock layer as shown below. It is 123 m across (distance from the water in the reservoir to the tailwaters below the dam). The average hydraulic conductivity of the material used in the dam construction is 1.33 m/day. The water in the reservoir is 18.5m deep and the tailwaters below the dam are 4.6 m deep. If there is a recharge rate of 0.007 m/day, what is the head at a point 80 m from the reservoir?



Question 5

A pump test is conducted in an aquifer that is characterized as fully confined. The aquifer is 60 m thick has a hydraulic conductivity of 10^{-4} cm/s and specific storativity of 1×10^{-5} m^{-1}. It is bounded by a 10 m aquitard.

a) If the well pumps at a rate of 5 L/s for 12 hours, and then pumps at a rate of 10 L/s for a further 12 hours and is then shut off completely. Determine the drawdown in the aquifer at a point 200 m from the pumping well 24 hours after the start of the pump test **and** 36 hours after the start of the pump test, assuming the aquitard is impermeable.

b) If the well is bounded on the north by a river 100 m away (runs east-west), what is the drawdown at an observation well 150 m east of the well at 12 hours from start of pumping, assuming the aquitard is impermeable?

c) If the aquitard had a hydraulic conductivity of 10^{-9} m/s, what would the drawdown be at the observation well at 12 hours after pumping if aquitard storage is negligible? (assume no river in this question)

Question 6

a) Describe the difference between storativity and specific yield with respect to type of aquifer and method of water release.

b) For the same pumping rate, time, and distance from the pumping well, in what order (from smallest to biggest) would you expect the drawdown to be for a confined aquifer, leaky confined aquifer and confined aquifer bounded by an impermeable boundary.

c) How is groundwater velocity determined from a borehole dilution test? (you can use words or equations to answer this question)

d) List three methods to determine the hydraulic conductivity of soil at a site.

e) Discuss the advantages and disadvantages of slug tests compared to pump tests.

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.