National Exams December 2012

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. Water density = 1000 kg/m^3, water viscosity = 0.001 kg/m-sec,

   g = 9.81 m/s^2, water compressibility = 5.1 x 10^{-10} Pa^{-1}

Marking Scheme

1. (a) 4 mks, (b) 4 mks, (c) 4 mks, (d) 4 mks, (e) 4 mks
2. (a) 8 mks, (b) 6 mks, (c) 6 mks,
3. (a) 6 mks, (b) 4 mks, (c) 4 mks, (d) 6 mks,
4. (a) 7 mks, (b) 8 mks, (c) 5 mks
5. (a) 7 mks, (b) 7 mks, (c) 6 mks
6. (a) 8 mks, (b) 7 mks, (c) 5 mks
7. (a) 7 mks, (b) 7 mks, (c) 6 mks

1. A 40 m thick fully confined aquifer has a porosity of 0.36, hydraulic conductivity of 3.2×10^{-3} cm/sec and specific storage of 4×10^{-6} m^{-1}.

a) Determine the intrinsic permeability of the aquifer soil.

b) Determine the compressibility of the aquifer skeleton.

c) Determine how much water could be removed from a circular area with a radius of 120 m, if the aquifer piezometric surface was lowered 1 m.

d) Discuss the difference between specific yield and storativity.

e) If the aquifer was unconfined and the specific yield was 0.15, determine how much water could be removed from a circular area with a radius of 120 m, if the aquifer piezometric surface was lowered 1 m.

2. A confined aquifer contains two layers, an upper layer of fine sand that is 25 m thick with a permeability of 3×10^{-12} m^2, and a lower layer of coarse sand that is 35 m thick with a permeability of 4.5×10^{-11} m^2.

a) Calculate the effective horizontal and vertical hydraulic conductivities of the entire aquifer.

b) From a multilevel piezometer installed in the aquifer, it was determined that at one location the water pressure head at the top of the aquifer was 25 m of water, and the water pressure head at the bottom of the aquifer was 86 m. Determine the vertical Darcy velocity through the aquifer at this location and the water pressure head at the interface between the two layers.

c) Two piezometers were installed in the aquifer at locations 200 m apart. It was determined that flow in the aquifer was horizontal in both layers, and the water levels in the two piezometers were 250 and 245 m. Determine the volumetric flow rate through the entire aquifer if it was 200 m in extent in the direction perpendicular to the groundwater flow direction.

3. Two wells are drilled 250 m apart in a 1500 m wide unconfined aquifer with hydraulic conductivity of 4×10^{-3} cm/sec, , one directly downstream from the other. The bottom of the aquifer is 42 m below the ground surface. The water level is 8 m below the ground surface at one well, and 10 m below the ground surface at the second well. The aquifer porosity is 0.33. Aquifer recharge is negligible.

a) Determine the total flow through the aquifer.

b) Determine the head at a point halfway between the wells.

c) Determine the porewater (linear) velocity at the halfway point.

d) If the vertical recharge to the aquifer is 0.25 m/year and all other conditions are unchanged determine the head at a point halfway between the wells.

4. A 20 m thick fully confined aquifer has a hydraulic conductivity of 10^{-3} cm/sec and a specific storage of 1×10^{-5} m^{-1}. A pump test is conducted in the aquifer with a well screened across the entire depth of the aquifer. Water is extracted from the aquifer at a rate of 1000 m^3/day for a period of 24 hours. The well is then turned off.
 a) Determine the drawdown after 24 hours at an observation well that is 100 m from the pumping well.
 b) Determine the drawdown after 48 hours at an observation well that is 100 m from the pumping well.
 c) List five assumptions used in the calculations in parts a and b.

5. A 60 m thick fully confined aquifer is bounded on one side by a river that acts as a constant head boundary. The aquifer hydraulic conductivity is 2×10^{-3} cm/sec, the porosity is 0.35, and the specific storativity is 1.5×10^{-5} m^{-1}. A well located 150 m east of the river is pumped at 2 m^3/sec for 24 hours and then turned off.
 a) Find the drawdown measured at an observation well located 120 m due south of the pumping well at 24 hours.
 b) If instead of a river, the aquifer was bounded on the east by an impermeable boundary, determine the drawdown measured at an observation well located 120 m due south of the pumping well at 24 hours.
 c) Discuss the assumptions used in answering (a) and (b).

6. A 30 m thick aquifer has a hydraulic conductivity of 3.5×10^{-3} cm/sec, and a specific storativity of 2.0×10^{-5} m^{-1}. Water is pumped from the aquifer at 6.5 L/sec.The aquifer is bounded above by a leaky aquitard (2.5m thick, hydraulic conductivity of 2×10^{-7} cm/sec) and below by an aquiclude.
 a) Determine the drawdown at an observation well located 60 m from the pumping well 30 hours after the start of pumping.
 b) List the assumptions in the method used in answering part (a) and discuss qualitatively the effect of these assumptions.
 c) Discuss the effect of pumping on the aquitard properties.

7.

a) A slug test was conducted in a confined aquifer in a well that had a casing diameter of 10 cm, a screened section radius of 18 cm, and a screened section length of 2.5 m. The water level in the well at the beginning of the slug test was 0.5 m above the original level. After 4 seconds the water level in the well was 0.16 m above the original level. Determine the hydraulic conductivity of the aquifer.

b) A slug test was carried out in an unconfined aquifer using a well with a casing radius of 7.5 cm, a screened section radius (including gravel pack) of 10 cm, a screened section length of 2 m. At the beginning of the slug test the water level in the well was 0.7 m above the original water level in the well. After 15 seconds the water level in the well was 0.05 m above the original water level. Determine the aquifer hydraulic conductivity if the radius of influence of the well was 85 m.

c) A slug test was conducted in a confined aquifer in a well with a casing radius of 5 cm, and a screened section radius of 5 cm. The Cooper-Bredehoeft-Papadopolous curve matching method was used to determine aquifer storativity and transmissivity. The match point was t_1 = 15 seconds (for $Tt/r_c^2 = 1$) and the best match was to the curve for log μ = -4. Determine the storativity and transmissivity of the aquifer.

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.