National Exams December 2011

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. Where needed, assume that the density of water is 1000 kg/m^3 and the viscosity of water is 0.001 kg/m-sec.

Question 1

a) A soil has a soil solid particle density of 2.6 g/cm^3 and a bulk density of 1.8 g/cm^3. Determine the porosity of the soil.

b) A fully confined aquifer has a specific storativity of 2.5×10^{-6} m^{-1}, a thickness of 35 m, a width of 2200 m and a length of 2000 m. What volume of water would be pumped to lower the piezometric head in the aquifer by 1.2 m?

c) An unconfined aquifer has a specific yield of 0.07 and is square in shape with each side having a length of 800 m. What volume of water would be released from the aquifer if the water table was lowered by 2.2 m?

d) The water pressure head at the bottom of a 15 m thick aquitard is 72 m. The water pressure head at the top of the aquitard is 60 m. Determine the hydraulic head gradient and the direction of water flow across the aquitard.

e) The soil in an aquifer system is determined to have a horizontal hydraulic conductivity tensor with $K_{xx} = 2 \times 10^{-3}$ cm/sec, $K_{xy} = 3.0 \times 10^{-4}$ cm/sec, and $K_{yy} = 10^{-4}$ cm/sec. If the aquifer has dh/dx = 0.02, and dh/dy = -0.015, determine the Darcy velocities in the x and y directions in the aquifer and the overall magnitude and direction (show a sketch with angle identified in degrees) of the Darcy velocity vector.

Question 2

A landfill cap is constructed, in descending order, of a 50 cm thick layer of topsoil ($k = 10^{-13}$ m^2), a 40 cm thick lateral drainage layer ($k = 2 \times 10^{-10}$ m^2), and a 110 cm thick barrier layer ($k = 2 \times 10^{-16}$ m^2).

a) Determine the average vertical and horizontal hydraulic conductivities of the landfill cap.

b) If a heavy rainstorm produces water ponding on the topsoil layer to a depth of 2.5 cm determine the volumetric water flow rate through a 1 m^2 area of the barrier layer. Assume that the cap is completely saturated, but the waste layer immediately below the cap is unsaturated.

c) If the layers of cap are inclined at an angle of 15° below the horizontal and water flows vertically downwards through the topsoil towards the lateral drainage layer due to the 2.5 cm of ponding on the upper surface of the topsoil layer, determine the direction of water flow through the lateral drainage layer, assuming the entire system is fully saturated. Include a diagram.

Question 3

a) An unconfined aquifer is pumped at steady state at a rate of 5 L/min. The saturated thicknesses measured at two monitoring wells, located 10 and 50 m from the pumping well are 26 and 28 m, respectively. Determine the hydraulic conductivity of the aquifer and the water table elevation 25 m from the pumping well.

b) A confined aquifer consists of a 20 m thick layer of coarse sand ($K = 10^{-2}$ cm/sec) above a 30 m thick layer of fine sand ($K = 10^{-3}$ cm/sec). A well of 20 cm diameter is pumping water from the entire depth of the aquifer and aquifer conditions are at steady state. Determine the drawdown at the well if the pumping rate is 10 L/min and the aquifer is bounded by constant head boundaries in all directions at a radial distance of 100 m from the well.

Question 4

A pump test is conducted in an aquifer that is characterized as fully confined. The well pumps at a rate of 7.5 L/sec for 12 hours, and then pumps at a rate of 5 L/sec for an additional 12 hours and is then shut off completely. Determine the drawdown in the aquifer at a point 100 m from the pumping well **(a)** 12 hours after the start of the pump test, **(b)** 24 hours after the start of the pump test **and (c)** 36 hours after the start of the pump test. The aquifer is 40 m thick, has a hydraulic conductivity of 1.3×10^{-3} cm/sec and a specific storativity of 1.2×10^{-5} m^{-1}

Question 5

a) A fully confined aquifer is bounded by a constant head boundary that is 200 m directly west of a pumping well. Determine the drawdown at a point 100 m directly north of the pumping well after the well pumps for 12 hours at a rate of 5 L/sec if the aquifer is 20 m thick, has a hydraulic conductivity of 10^{-2} cm/sec and a specific storativity of 1.0×10^{-4} m^{-1}.

b) If the boundaries were impermeable boundaries instead of constant head boundaries determine the drawdown if all other conditions were the same as in (a).

c) Explain what features can produce constant head and impermeable boundaries for aquifers.

d) Explain the principles that you used in calculating the drawdowns in (a) and (b) and why these apply to these situations.

Question 6

An aquifer, with a thickness of 30 m, a hydraulic conductivity of 2×10^{-3} cm/sec, and a specific storativity of 2×10^{-5} m^{-1} is bounded above by a 12 m thick aquitard with a hydraulic conductivity of 5×10^{-7} cm/sec.

a) Determine the drawdown after 24 hours at an observation well 100 m from a well that has been pumping at 15 m^3/hr for 24 hours.

b) List the assumptions involved in the method used to determine the drawdown in (a).

c) Discuss the impact of the pumping from the aquifer on the aquitard properties and potential problems that may develop with reference to any historical events you may be aware of.

Question 7

a) Give a list of three devices/methods that can be used to measure water discharge rates during pump tests.

b) List three methods to estimate hydraulic conductivity of soil in an aquifer and discuss the associated scale of measurement of each method

c) What would the effect of an increase in barometric pressure be on drawdown measured during a pump test?

d) What is the purpose of step drawdown test?

e) What is the purpose of a borehole dilution test?

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.