

GEOL 3060 Groundwater, Final Exam 2011

Name \_\_\_\_\_ ID# \_\_\_\_\_

Select the most correct answer. Answer the questions on the exam sheet. Each question is worth one mark, for a total of 80. There is one bonus question.

1. True or false, groundwater almost always flows through underground rivers and lakes?

- a) True.
- b) False.

2. Which of the following are the six most basic physical properties which must be measured to quantify groundwater flow?

- a) fluid density, fluid viscosity, hydraulic conductivity, solid material compressibility, fluid compressibility, porosity.
- b) fluid density, fluid viscosity, permeability, solid material compressibility, fluid compressibility, porosity.
- c) fluid density, fluid viscosity, hydraulic conductivity, solid material compressibility, fluid compressibility, gravity.
- d) none of the above

3. Specific storage is defined as

- a) the amount of groundwater below the water table.
- b) the volume of water that discharges from a spring per day.
- c) the volume of water released from storage per unit decline in hydraulic head per unit volume of saturated formation.
- d) the volume of water released from storage per unit decline in elevation head per unit volume of saturated formation.

4. Hydraulic conductivity depends on

- a) fluid density and viscosity
- b) pore size, tortuosity, and degree of pore connections
- c) acceleration due to gravity
- d) all of the above.

5. True or false, all materials with a high porosity always have a high hydraulic conductivity.

- a) True.
- b) False.

6. Pressure head is expressed as energy per unit

- a) mass of water
- b) volume of water
- c) weight of water
- d) length of water.

7. The effective hydraulic conductivity for flow parallel to layers is

- a) the weighted geometric mean of hydraulic conductivities of each layer.
- b) the weighted arithmetic mean of hydraulic conductivities of each layer.
- c) the weighted harmonic mean of hydraulic conductivities of each layer.
- d) the weighted lognormal mean of hydraulic conductivities of each layer.

8. An aquifer of thickness 1000 cm has a specific storage of  $8.3 \times 10^{-8} \text{ m}^{-1}$  and a porosity of 0.30. What is the storativity of this aquifer?

- a)  $8.3 \times 10^{-3}$
- b)  $8.3 \times 10^{-4}$
- c)  $8.3 \times 10^{-5}$
- d) none of the above

$$\left( \frac{8.3 \times 10^{-6}}{9.8} \right) = (0.3)(4.6 \times 10^{-10}) + \alpha$$
$$8.469 \times 10^{-7} = 1.38 \times 10^{-10} + \alpha$$

9. What is the compressibility of the aquifer skeleton in Question 8? Water density =  $1.0 \text{ g/cm}^3$  and water compressibility =  $4.6 \times 10^{-10} \text{ m}^2/\text{N}$ .

- a)  $7.1 \times 10^{-9} \text{ m}^2/\text{N}$
- b)  $7.1 \times 10^{-10} \text{ m}^2/\text{N}$
- c)  $7.1 \times 10^{-11} \text{ m}^2/\text{N}$
- d) none of the above

$\alpha = ?$

$$S_s = \rho_f g (\beta_n + \alpha)$$

$$8.3 \times 10^{-6} = (1)(9.8)(0.3)(4.6 \times 10^{-10}) + \alpha$$

10. Hydraulic conductivity is directly proportional to permeability in

- a) clay.
- b) sand.
- c) gravel.
- d) all of the above.

$$1.38 \times 10^{-10} + \alpha$$

11. True or false, hydraulic conductivity is best measured at the microscopic scale?

- a) True.
- b) False.

12. Water release mechanisms from a confined aquifer are

- a) fluid expansion due to decrease in fluid pressure.
- b) reduction in  $n$  (porosity) due to an increase in effective stress.
- c) a and b
- d) none of the above

13. Select (in order) the most appropriate hydrogeological terms for glaciofluvial, glaciolacustrine, and dolostone bedrock.

- a) aquitard, aquifer, aquitard.
- b) aquifer, aquitard, aquifer.
- c) aquitard, aquitard, aquifer.
- d) aquifer, aquifer, aquitard.

14. Name the developer of the following equation:  $v = R^2 \Delta P / (8L\mu)$

- a) Poiseuille.
- b) Theis.
- c) Cooper.
- d) Neuman.

15. Which of the following is used to map areas of recharge and discharge?

- a) topography maps.
- b) a piezometer network.
- c) tritium concentration in groundwater.
- d) all of the above.

16. To calculate the average groundwater velocity, which of the following is not required?

- a) hydraulic conductivity.
- b) hydrodynamic diffusion coefficient.
- c) effective porosity.
- d) hydraulic gradient.

17. Three common types of glacial sediments in southwestern Ontario are:

- a) till, glaciolacustrine, glaciofluvial
- b) till, dolostone, glaciofluvial
- c) glaciofluvial, granite, till
- d) glaciolacustrine, till, glacial lake sediments.

18. True or false, the average groundwater velocity in a fractured granite ( $n_e = 0.01$ ) is less than in a silt sediment ( $n_e = 0.3$ )? (Assume that the hydraulic conductivity and hydraulic gradient are the same for both materials.)

- a) True  
 b) False.

19. True or false, the average groundwater velocity is always less than the specific discharge,  $q$ .

- a) True  
 b) False.

20. True or false, the  $^3\text{H}/^3\text{He}$  ratio can be used to calculate an apparent age of groundwater from a single water sample.

- a) True  
 b) False.

21. True or false, variation in land topography can significantly affect local and regional groundwater flow patterns?

- a) True  
 b) False.

22. True or false, Dupuit developed an equation for groundwater flow in an unconfined aquifer?

- a) True.  
 b) False.

23. True or false, flow lines are always perpendicular to equipotential lines?

- a) True.  
 b) False.

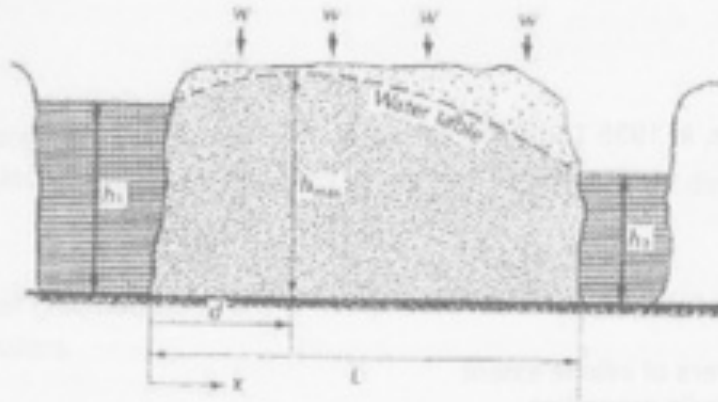
24. Which of the following is not usually considered an assumption of hand drawn flow nets?

- a) Darcy's law is valid.  
 b) Steady state.  
 c) Three-dimensional flow system.  
 d) All boundary conditions are known.

25. True or false, in the following equation  $q' = K p H / l$

- a) True.
- b) False.

Refer to the figure given below for questions 26 - 28. The hydraulic conductivity of the aquifer is 14.5 m/d. The value of  $h_1$  is 17.6 m and value of  $h_2$  is 15.3 m. The distance,  $L$ , from  $h_1$  to  $h_2$  is 525 m. There is an average rate of recharge of 0.007 m/d.



▲ FIGURE 4.19

Unconfined flow, which is subject to infiltration or evaporation.

26. What is the average discharge per unit width at  $x = 0$  m?

- a)  $-1.79 \text{ m}^3/\text{day}/\text{m}$
- b)  $-0.79 \text{ m}^3/\text{day}/\text{m}$
- c)  $0.79 \text{ m}^3/\text{day}/\text{m}$
- d) none of the above

27. Where is the water table divide located?

- a) 113 m
- b) 262.5 m
- c) 226 m
- d) none of the above

28. What is the maximum height of the water-table?

- a) 18.7 m
- b) 20.3 m
- c) 17.8 m
- d) none of the above

29. Which set of conditions best describes this groundwater flow equation:

$$K \frac{d^2h}{dx^2} = 0$$

- a) One-dimensional, Homogeneous, Steady-state
- b) One-dimensional, Homogeneous, Transient
- c) Two-dimensional, Homogeneous, Steady-state
- d) One-dimensional, Heterogeneous, Steady-state

30. True or false, the water table is always an equipotential line?

- a) True.
- b) False.

31. True or false, in 1935 Theis developed a pumping test for ideal unconfined aquifers?

- a) True
- b) False.

32. Which of the following is not an assumption of the Theis pumping test solution?

- a) horizontal layers of infinite extent.
- b) uniform hydraulic properties.
- c) horizontal and vertical flow to the well.
- d) constant pumping rate.

33. Select the developers of this equation (Leakage =  $K'(h_0 - h)/b'$ ) for leakage through an aquitard.

- a) Hantush and Jacob.
- b) Neuman and Witherspoon.
- c) Darcy and Poiseuille.
- d) Theis and Jacob.

34. True or false, an impermeable boundary across a confined aquifer increases the amount of drawdown in an observation well during a pumping test?

- a) True.
- b) False.

35. Which of the following is not an advantage of slug tests?

- a) measure parameters in situ.
- b) measure hydraulic conductivity and storativity simultaneously.
- c) only one well is required.
- d) none of the above.

36. Which of the following is a stage in drawdown versus time when pumping water from an unconfined aquifer?

- a) initially reacts as a confined aquifer.
- b) water table begins to decline.
- c) drawdown follows Theis with  $S = S_y$
- d) all of the above.

37. True or false, when pumping water from an unconfined aquifer, only horizontal flow of water occurs?

- a) True.
- b) False.

38. The Cooper-Jacob straight-line method of analyzing pumping test data is most applicable to

- a) long times.
- b) early times.
- c) unconfined aquifers.
- d) slug tests.

39. To account for a constant-head boundary when estimating drawdown using the Theis solution the two terms are

- a) subtracted.
- b) added.
- c) multiplied.
- d) divided.

40. For the Hvorslev test

- a) water is pumped from a well.
- b) a steel slug is added to the well.
- c) soil and water are both assumed to be incompressible.
- d) all of the above.

41. Which of the following is not an assumption of the Hantush-Jacob method:

- a) upper aquitard is leaky
- b) aquifer is incompressible
- c) flow through aquitard is vertical

42. A well that pumps at a constant rate of  $500 \text{ m}^3$  per day has achieved equilibrium so that there is no change in the drawdown with time. The well taps a confined aquifer that is 24 m thick. An observation well 20 m away has a head of 220 m above sea level; another observation well 40 m away has a head of 230 m above sea level. What is the value of aquifer transmissivity?

- a) 5.5 m/day
- b)  $5.5 \text{ m}^2/\text{day}$
- c)  $11 \text{ m}^2/\text{day}$
- d) none of the above

$\frac{\text{m}^2}{\text{day}}$

43. In question 42, the hydraulic conductivity of the aquifer is

- a) 0.23 m/day
- b) 132 m/day
- c) 4.4 m/day
- d) none of the above

44. A community is installing a new well in a regionally fully confined aquifer with a transmissivity of  $147.7 \text{ m}^2/\text{day}$  and a storativity of 0.0005. The planned pumping rate is  $60 \text{ m}^3/\text{day}$ . The drawdown after 30 days of pumping at a distance of 100 m from the pumping well is

- a) 0.29 m
- b) 0.20 m
- c) 0.25 m
- d) none of the above

45. If the aquifer in Question 44 is not fully confined, but is overlain by a 3-m thick leaky confining layer with vertical hydraulic conductivity of  $4.4 \times 10^{-4} \text{ m/day}$  would the drawdown be

- a) equal to the value of drawdown in Question 44
- b) greater than the value of drawdown in Question 44
- c) less than the value of drawdown in Question 44
- d) none of the above

46. What is the rate of leakage through the confining layer (aquitar) in Question 45?

- a)  $3.7 \times 10^{-5} \text{ m/day}$
- b)  $3.7 \times 10^{-6} \text{ m/day}$
- c)  $3.7 \times 10^{-7} \text{ m/day}$
- d) none of the above

47. A slug test is performed by lowering a metal slug into a piezometer of inside diameter 5 cm and screen length = 50 cm. If the time for water level to recover to 37% of the initial change is 12 minutes, the value of the hydraulic conductivity is

- a)  $1.6 \times 10^{-1}$  cm/min
- b)  $1.6 \times 10^{-2}$  cm/min
- c)  $1.6 \times 10^{-3}$  cm/min
- d) none of the above

48. When pumping water from an unconfined aquifer, which of the following applies

- a) have both horizontal and vertical flow.
- b) lower the water table.
- c) drain pores.
- d) all of the above.

49. Which of the following is not an advantage of a pumping test?

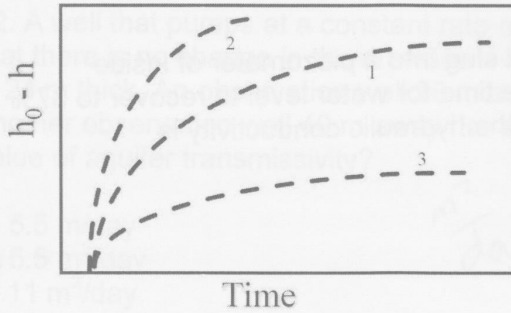
- a) measure parameters in situ.
- b) average parameters over a small, localized volume.
- c) measure T and S simultaneously.
- d) average parameters over a large volume.

50. True or false, for the Neuman and Witherspoon formula, both vertical and horizontal flow are accounted for?

- a) True
- b) False

51. In the diagram shown on next page, which is the correct order for curves labelled 1, 2, and 3?

- a) impermeable boundary, ideal, constant head boundary
- b) constant head boundary, impermeable boundary, ideal,
- c) ideal, impermeable boundary, constant head boundary
- d) ideal, constant head boundary, impermeable boundary



52. What are the disadvantages of pumping tests?

- a) \$\$ High cost.
- b) Non-uniqueness of T and S results.
- c) Disposal of potentially contaminated water?
- d) All of the above.

53. A capture well is pumping at a rate of  $1500 \text{ m}^3/\text{day}$  from a confined aquifer with a hydraulic conductivity of  $425 \text{ m/day}$ , an initial hydraulic gradient of  $0.00098$ , and a saturated thickness of  $22 \text{ m}$ . What is the maximum width of the capture zone?

- a)  $\pm 18.9 \text{ m}$
- b)  $\pm 81.9 \text{ m}$
- c)  $\pm 180.9 \text{ m}$
- d) none of the above

54. In question 53, what is the distance from the well to the stagnation point?

- a)  $-26.1 \text{ m}$
- b)  $-52.2 \text{ m}$
- c)  $-2.61 \text{ m}$
- d) none of the above

55. What is the distance travelled (in m) in one year of a non-reactive contaminant in groundwater if the effective porosity is  $0.28$ , the hydraulic conductivity is  $1 \text{ cm/hr}$ , and the hydraulic gradient is  $0.03$ .

- a)  $0.0011$
- b)  $939$
- c)  $9.39$
- d) none of the above.

56. In question 55, if the porosity is 0.32 and the bulk density of the geological material is  $1.63 \text{ g/cm}^3$ , what is the distribution coefficient for a reactive contaminant that only travels half of the distance that the non-reactive contaminant travels in one year.

- a)  $1.96 \times 10^{-3} \text{ cm}^3/\text{g}$
- b)  $1.96 \times 10^{-4} \text{ cm}^3/\text{g}$
- c)  $1.96 \times 10^{-5} \text{ cm}^3/\text{g}$
- d) none of the above

57. In terms of investigating a site with contaminated groundwater,

- a) the site history is not important.
- b) the nature and behaviour of contaminants must be known.
- c) the geology of the site is not important information.
- d) installation of monitoring wells is always the first step.

58. An objective of installing monitoring wells is

- a) to measure the hydraulic head below the water table.
- b) to measure the hydraulic head above the water table.
- c) to obtain unrepresentative groundwater samples.
- d) none of the above.

59. In terms of groundwater monitoring material selection,

- a) carbon steel is the most expensive.
- b) PTFE has the highest strength.
- c) stainless steel is the least susceptible to corrosion.
- d) carbon steel is the least expensive.

60. Bentonite

- a) has a low CEC and a high pH.
- b) is a low permeability material when exposed to water.
- c) is a low permeability material when it is dry.
- d) is only available in a liquid state.

61. Groundwater monitoring well screens

- a) permit free flow of water into the well pipe.
- b) prevent fine particles from plugging the well pipe.
- c) can be made from slotted plastic pipe.
- d) all of the above.

62. True or false, sand (or gravel) filter packs are used in non-collapsing cohesive sediments?

- a) True.
- b) False.

63. The two main solute transport processes in groundwater are:

- a) advection and dispersion.
- b) diffusion and advection.
- c) diffusion and dispersion.
- d) none of the above.

64. Which of the following is not one of the causes of pore-scale dispersion?

- a) velocity profile across a pore.
- b) pore pathway tortuosity.
- c) different pore sizes.
- d) none of the above.

65. Which of the words given below best fills the blank in the following sentence? The product of \_\_\_\_\_ and groundwater velocity can be used to estimate hydrodynamic dispersion.

- a) dispersivity.
- b) diffusion.
- c) hydraulic conductivity.
- d) porosity.

66. True or false, solute concentration decreases away from a source due to hydrodynamic dispersion?

- a) True.
- b) False.

67. The distribution coefficient,  $K_d$ , is

- a) the slope of a nonlinear adsorption isotherm.
- b) the intercept of a linear adsorption isotherm
- c) the slope of a linear adsorption isotherm.
- d) proportional to the hydrodynamic dispersion of a material.

68. True or false, the retardation coefficient of a contaminant is always less than 1?

- a) True.
- b) False.

69. How does temporary adsorption of a contaminant to a solid particle surface affect the contaminant's dispersion?

- a) it has no effect at all.
- b) it increases the amount of dispersion.
- c) it decreases the amount of dispersion.
- d) none of the above.

70. Processes that attenuate a contaminant in groundwater may include

- a) biological degradation.
- b) precipitation.
- c) oxidation.
- d) all of the above.

71. True or false, for a sloping water table the capture zone will be elongated in the up-gradient direction?

- a) True.
- b) False.

72. To assess the vulnerability of a region to groundwater contamination, which of the following must be determined?

- a) depth to the water table.
- b) geology of aquifers.
- c) groundwater flow direction.
- d) all of the above.

73. A definition of the term safe yield is

- a) maximum groundwater pumping volume without lowering long-term reserves.
- b) minimum groundwater pumping volume required to increase long-term reserves.
- c) maximum groundwater pumping volume according to the size of the well.
- d) maximum groundwater pumping volume according to the size of the pump.

74. In reference to capture zone analysis, which statement given below is most correct:

- a) the stagnation point is located up-gradient from the pumping well
- b) the stagnation point is located down-gradient from the pumping well
- c) the stagnation point is located above the pumping well
- d) none of the above.

75. A funnel and gate groundwater remediation system has a

- a) high permeability cut-off wall with a wide gate.
- b) low permeability cut-off wall with a wide gate.
- c) low permeability cut-off wall with a narrow gate.
- d) high permeability cut-off wall with a narrow gate.

76. Which of the following statements is false

- a) DNAPLS are not generally found near the water table
- b) LNAPLS are generally found near the water table
- c) Tritium is never used in water treatment
- d) Guelph drinking water source is Lake Ontario.

77. True or false, natural attenuation can be an effective contaminated groundwater remediation strategy?

- a) True.
- b) False.

78. An in situ groundwater remediation method is

- a) air sparging.
- b) funnel and gate.
- c) reactive wall.
- d) all of the above.

79. True or false, under rapid groundwater flow, diffusion is more important than dispersion in reducing peak concentration of a groundwater contaminant?

- a) True.
- b) False.

80. The main type of groundwater contaminant at the Seymour recycling site is

- a) heavy metals
- b) gasoline
- c) organic chemicals
- d) none of the above.