Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	GROUNDWATER ENGINEERING
COURSE CODE	:	BFW 40403
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER **ALL** QUESTIONS IN **PART A** AND **TWO (2)** QUESTIONS IN **PART B** 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

PART A

Q1 (a) Explain briefly the groundwater application and contribution to Malaysia's issues.

(3 marks)

(b) Explain **THREE (3)** methods to estimate aquifer storage change in a water balance system.

(6 marks)

(c) Calculate the net groundwater flow for the lake given the following annual water balance components: rainfall (P) = 1145 mm/year, evaporation (E) = 830 mm/year, surface inflow (I) = 45 mm/year, surface outflow (O) = 124 mm/year, and change in storage (ΔS) = 55 mm/year. Then, provide an analysis of the significance of groundwater flow.

(8 marks)

(d) Discuss_the important role of groundwater in providing reliable public water supplies in Malaysia.

(8 marks)

Q2 (a) Provide **TWO (2)** examples of diseases and toxins that may result from groundwater contamination and discuss the impact on wildlife.

(5 marks)

(b) An aquifer has a hydraulic conductivity of 2×10^{-5} m/s, a hydraulic gradient of 0.003 m/m, an effective porosity n_e = 0.2, and an effective diffusion D = 0.5×10^{-9} m^2/s. A chloride solution with a concentration of 500 mg/L penetrates the aquifer along a line source. Estimate by appropriate equations for the chloride concentration at a distance of 20 m from the point of entry, after 2 years.

(9 marks)

(c) Explain **TWO (2)** benefits of the techniques used for artificial recharge for groundwater systems and illustrate each benefit with a specific example.

(4 marks)

(d) Discuss **THREE (3)** primary parameters; physical, chemical, and mineralogical used to assess groundwater quality according to drinking water standards in Malaysia. Recommend **THREE (3)** examples of mineral water products available in the Malaysian market, highlighting their unique mineral compositions and health benefits.

(7 marks)

PART B

Q3 (a) Explain the importance of conducting a groundwater subsurface survey before drilling the well.

(3 marks)

(b) Using the concept of groundwater survey, compare the effective ways to find groundwater sources with copper or metal in conventional practice rather than the resistivity method.

(6 marks)

(c) A river and a canal run parallel to each other with a separation distance, L = 400 m as shown in **Figure Q3.1** comes in an unconfined aquifer with a hydraulic conductivity of 0.45 m/day. The water surface elevation in the river is 1.25 m lower than in the canal where the depth is 5 m.

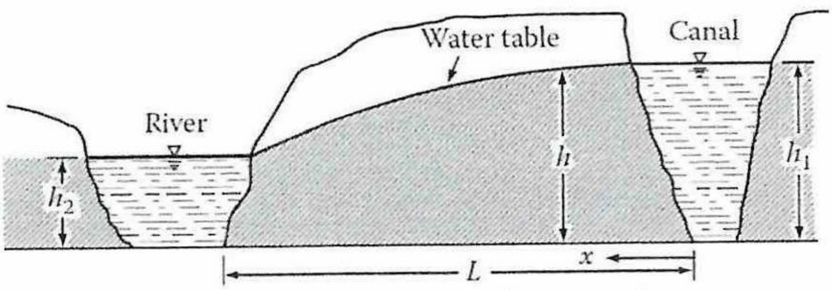

Figure Q3.1: Open channel cross-section

Assuming no recharge, analyze

(i) water table elevation midway between the river and the canal.

(4 marks)

(ii) discharge and seepage value in $m^3/(m/day)$ into the river. Justify with a sketch or statement of the flow direction.

(4 marks)

(d) Evaluate and categorize the soil type based on the leachate migration time from a landfill to a borehole located 2.5 km away in a homogeneous silty sand unconfined aquifer with a hydraulic conductivity of $K = 3 \times 10^{-5}$ m/s, an effective porosity of 0.4 and observing that the water table drops 10 m from factory to the borehole.

(8 marks)

Q4 (a) Discuss the steps to plot the direction of groundwater flow on the map.

(3 marks)

(b) A field sample of an unconfined aquifer is packed in a test cylinder. The length and diameter of the cylinder are 1 m and 10 cm, respectively. The field sample is tested for 15 minutes under a constant head difference of 16.7 cm. As a result, 65.8 cm^3 of water is collected at the outlet. Compute the hydraulic conductivity of the aquifer sample and classify the type of soil based on **Table Q4.1.**

(6 marks)

Table Q4.1: Typical values of hydraulics conductivity and materials of layer

Materials	Range of K (m/day)
Clay soils (surface)	0.2
Deep clay beds	10^{-8} - 10^{-2}
Loam soils (surface)	0.1 - 1
Fine sand	1 - 5
Medium sand	5 - 20
Coarse sand	20 - 100
gravel	100 - 1000
Sand and gravel mixes	5 - 100
Clay, sand, and gravel mixes (till)	0.001 – 0.1

(c) There are 3 piezometers in an unconfined sand aquifer as shown in **Figure Q4.1**. The heads are h_A = 104.56 ft, h_B = 104.53 ft, and h_C = 103.42 ft respectively. The rate of recharge is estimated to be 1.25 ft/yr. The average horizontal hydraulic conductivity of the sand based on testing is K_x = 8 ft/day. Assume that in the vicinity of these three piezometers, the vertical velocity, V_z equals the recharge rate. Estimate

(i) the vertical hydraulic conductivity, K_v using the heads at wells A and B.

(4 marks)

(ii) the horizontal velocity, V_x using heads at wells B and C.

(4 marks)

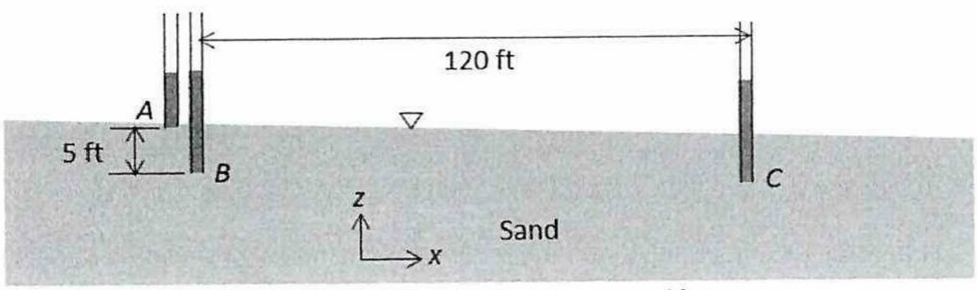

Figure Q4.1: Piezometers in an aquifer

(d) Eight wells are tabulated near the Gombak River in Malaysia. The region is characterized by a tropical rainforest climate with high annual rainfall. Laterite soil underlies the land surface and a confined sandstone aquifer exists beneath the region. All wells are shown in **Figure Q4.2**.

(i) Sketch the contour line on the map by using the values provided.

(4 marks)

(ii) Based on the plotting result from **Figure Q4.2**, sketch the direction of groundwater flow on the map.

(4 marks)

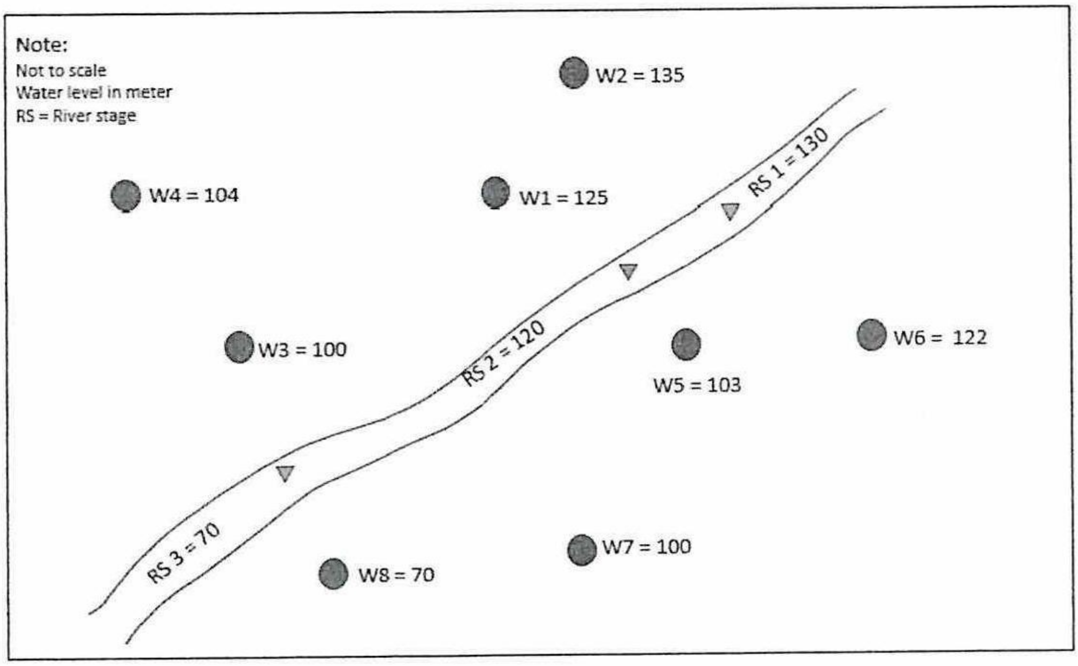

Figure Q4.2: Map view for the study area

(Note: Answer on this map and attach with answer script)

Q5 (a) Describe the wash drilling method from the civil engineer's perspective.

(3 marks)

(b) Based on **Figure Q5.1** explain the transition from the fundamental equation of radial flow (Q = AV) to its application in the derivation process for flow in an aquifer.

(6 marks)

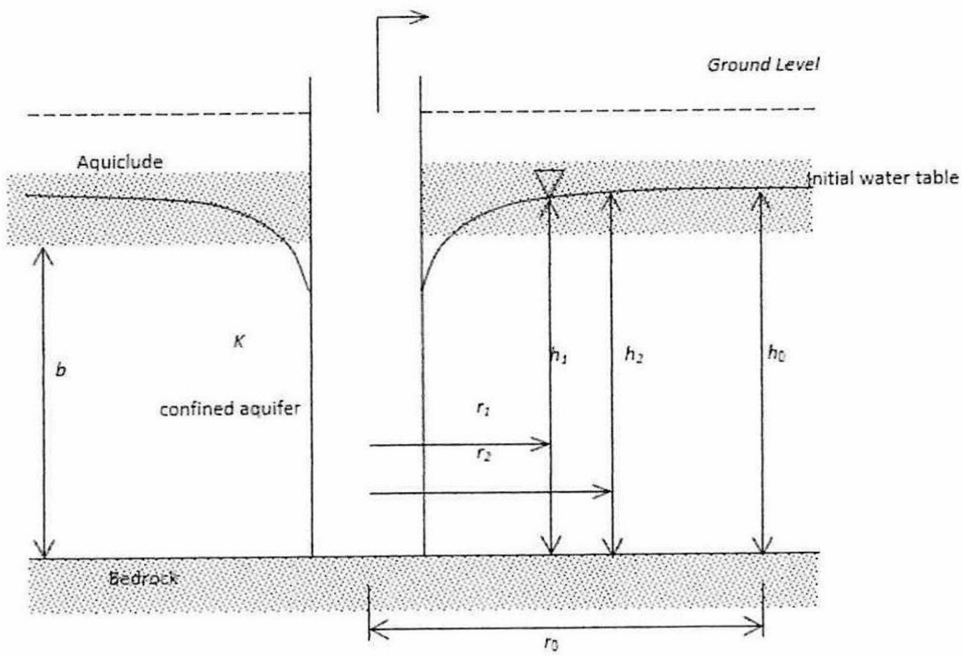

Figure Q5.1: Aquifer profile

(c) A time-drawdown pumping test was conducted in a groundwater basin as shown in **Table Q5.1**. A pumping well a confined aquifer was pumped at a constant rate of 13.89 L/s and drawdowns were measured in an observation well located 45 m away from the pumping. Calculate the transmissivity and storage coefficient of the confined aquifer by the Cooper-Jacob method.

(8 marks)

Table Q5.1: Pumping test data

Elapsed Time (min)	Drawdown (m)	Elapsed Time (min)	Drawdown (m)
2	0.37	24	2.37
3	0.58	30	2.60
4	0.75	40	2.78
5	0.89	50	2.90
6	1.03	60	3.06
7	1.12	80	3.10
8	1.26	120	3.14
10	1.41	180	3.20
14	1.69	240	3.26
18	2.15	360	3.33

(d) A step test was carried out in 2-hour steps. **Table Q5.2** shows data obtained for yield (Q) and corresponding drawdown (s_w) in the pumping well. Determine the value of losses and percent of well efficiency drops. Comment your answer.

(8 marks)

Table Q5.2: Pumping and drawdown data

Step	Q (l/s)	s_w (m)
Rest	0	0
1	14.7	1.43
2	31.5	3.46
3	44.4	5.41
4	57.6	8.90

- END OF QUESTIONS -

APPENDIX A

EQUATIONS

$$d^2(h^2)/dx^2 = 0$$

$$h^2 = c_1x + c_2$$

$$q = -Kh\left(\frac{dh}{dx}\right) = K(h_1^2 - h_2^2)/2L$$

$$K = \frac{\forall L}{Ath} \qquad K = \frac{r^2L}{R^2t}\ln\frac{h_1}{h_2}$$

$$u = \frac{r^2S}{4tT} \qquad q = \frac{K}{2x}(h_o^2 - h^2) \qquad s = \frac{QW(u)}{4\pi t}$$

$$T = \frac{2.3Q}{4\pi\Delta s'} \qquad T = K \qquad S = \frac{2.25Tt_0}{r^2}$$

$$v = \frac{K}{n_e}dh/dx \qquad A = \pi r^2 \qquad Q_s = -K_s\frac{dh}{dx}A$$

Travel time = L / v

$$v = q/n_e = Ki/n_e$$

$$Q_z = -K_z\frac{dh}{ds}A \qquad V_z = -K_z\frac{dh}{ds} \qquad V_x = -K_x\frac{dh}{ds}$$

$$Q = -KA\frac{dh}{dx}$$

$$\alpha_L \approx 0.0175L^{1.46} \qquad p_e = vL/D_L \qquad D_L = \alpha_L v + D^*$$

$$C(x,t) = \frac{C_0}{2}\left[erfc\left(\frac{x - vt}{2\sqrt{D_Lt}}\right) + \exp\left(\frac{vx}{D_L}\right)erfc\left(\frac{x + vt}{2\sqrt{D_Lt}}\right)\right]$$