Universiti Tun Hussein Onn Malaysia

# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER I
## SESSION 2023/2024

| | | |
|---|---|---|
| COURSE NAME | : | GROUND WATER ENGINEERING |
| COURSE CODE | : | BFW 40403 |
| PROGRAMME CODE | : | BFF |
| EXAMINATION DATE | : | JANUARY/FEBRUARY 2024 |
| DURATION | : | 3 HOURS |
| INSTRUCTIONS | : | 1. ANSWER **ALL** QUESTIONS IN **PART A** AND **TWO (2)** QUESTIONS IN **PART B**<br>2. THIS FINAL EXAMINATION IS CONDUCTED VIA<br>☐ Open book<br>☒ Closed book<br>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) Briefly explain the importance of groundwater recharge in terms of water cycle role.

(3 marks)

(b) Relate the important concept in the groundwater system and water balance equation in response to stresses and boundary conditions.

(6 marks)

(c) In a year, water balance for a lake included 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 $\Delta S$ = 55 mm/year. Estimate the net groundwater flow for the lake. Comment groundwater flow from this answer.

(8 marks)

(d) Discuss the most effective approach for assessing the new water table on-site and provide an example for each method.

(8 marks)

**Q2** (a) Describe **THREE (3)** factors are considered in the assessment of contamination potential that can influence the susceptibility of an area to contamination.

(6 marks)

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

(8 marks)

(c) Relate with an example **TWO (2)** common techniques used for artificial recharge for groundwater systems.

(5 marks)

(d) The water level in a well was measured to be 5 meters before a rainfall event and 7 meters after the event. The specific yield of the aquifer is 0.3. The peak water level rise attributed to the recharge period is 0.4 meters with the area recharge zone is 1000 $m^2$. Using WTF method calculate the recharge rate and conclude your answer.

(6 marks)

**PART B**

**Q3** (a) Describe the steps to conduct a groundwater subsurface survey using the resistivity method.

(3 marks)

(b) Using the concept of resistors connected in parallel and the formula to calculate the equivalent resistance, determine the value of the equivalent resistance for a combination of 5 resistors. The resistors have a uniform resistance of 100 ohms, and each has been cut into equal parts of a length and sectional area before being connected in parallel.

(6 marks)

(c) A river and a canal run parallel to each other L = 500 m apart as shown in **Figure Q3.1** comes with a fully penetrating unconfined aquifer with a hydraulic conductivity of 0.3 m/day. The water surface elevation in the river is 1.25 m lower than in the canal where the depth is 5 m.

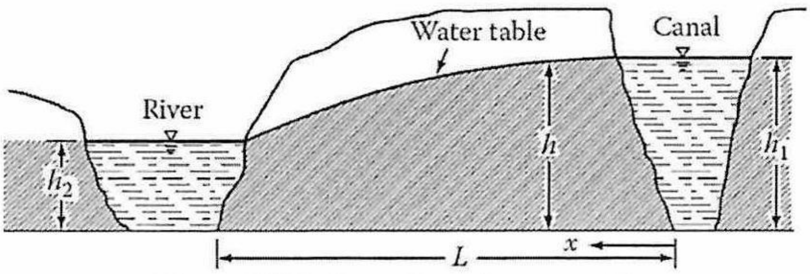


**Figure Q3.1:** Open channel cross section

Assuming no recharge, find

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

(4 marks)

(ii) discharge into the river. Justify the seepage value in $m^3/(m/day)$ and flow direction.

(4 marks)

(d) Find the time it takes for a leachate to move from a landfill to a borehole located 2 km away in homogeneous silty sand unconfined aquifer with a hydraulic conductivity of $K = 4 \times 10^{-5}$ m/s, an effective porosity of 0.45 and observing that the water table drops 10 m from factory to the borehole. Comments your result based on type of soil.

(8 marks)

**Q4** (a) Discuss and give an example of the groundwater movement can affect water quality in several ways.

(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 a period of 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) A stratum of clean sand and gravel between two channels has a hydraulic conductivity K = 0.1 cm/s and is supplied by water from a ditch ($h_0$ = 6.5 m deep) that penetrates to the bottom of the stratum. If the water surface in the second channel is 4 m above the bottom of the stratum and its distance to the ditch is x = 150 m (which is also the thickness of the stratum), illustrate and distinguish the unit flow rate in the gallery.

(8 marks)

(d) Ten wells are in a valley setting. Glacial material underlies the land surface and a confined sandstone aquifer underlies the region. All wells are shown in **Figure Q4.1** and **Table Q4.2.**

(i) Calculate head values and plot on the map the groundwater table contour lines.

(6 marks)

(ii) Based on the plotting result from **Figure Q4.1**, sketch the groundwater flow on the map.

(2 marks)

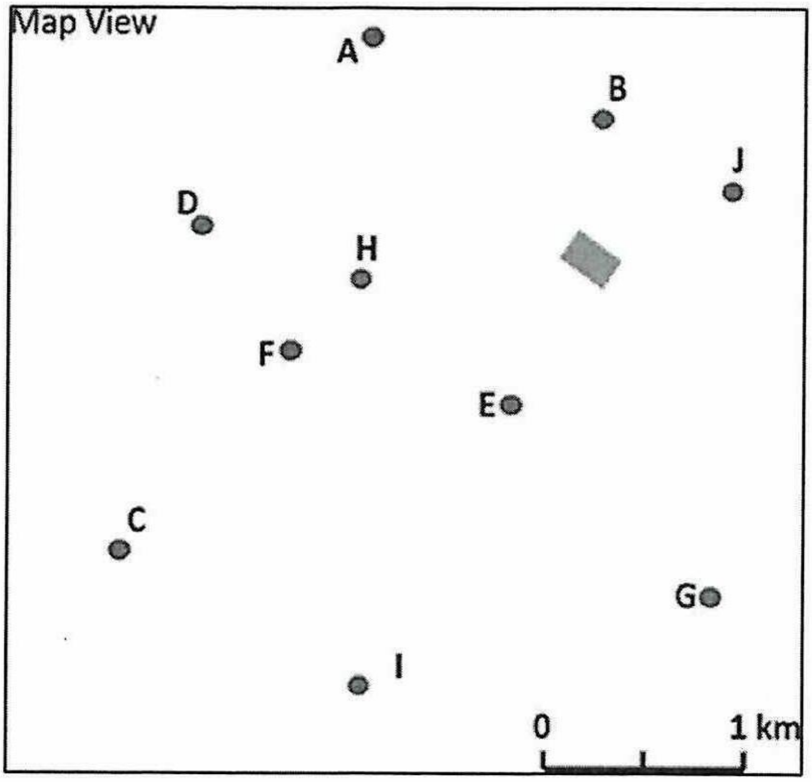


**Figure Q4.1**: Map view for the study area

**Table Q4.2**: Water level data

| Well name | Total well depth (m) | Top of casing elevation (m) | Water level (m) |
|---|---|---|---|
| A | 150 | 1105 | 57 |
| B | 160 | 1100 | 39 |
| C | 170 | 1108 | 76 |
| D | 150 | 1100 | 59 |
| E | 180 | 1098 | 67 |
| F | 160 | 1090 | 57 |
| G | 180 | 1080 | 53 |
| H | 170 | 1079 | 41 |
| I | 180 | 1070 | 50 |
| J | 170 | 1100 | 41 |

Data: All water levels (WL) are measured at depths below the top of casing (TOC) elevation. TD is the total well depth below the land surface. The head measurement is at the bottom of each well.

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

(3 marks)

(b) Based on **Figure Q5.1** provide an interpretation of 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)

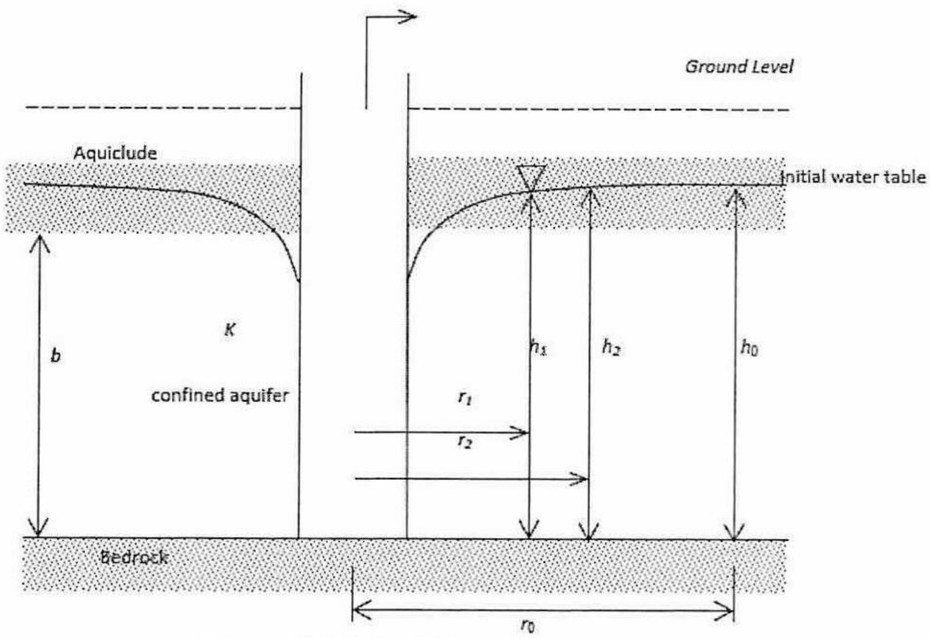


**Figure Q5.1**: Aquifer profile

(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 200 L/s and drawdowns were measured in an observation well located 45 m away from the pumping well. Calculate the transmissivity and storage coefficient of the confined aquifer by the Cooper-Jacob Method.

(8 marks)

**Table Q5.1**: Pumping test

| 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 on your pattern of a forecasting method.

(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

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

$$h^2 = c_1x + c_2$$

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

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

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

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

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

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

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

$$R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots$$

$$1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots\ldots$$

$$R = Sy\Delta h \qquad Q = -KA\frac{dh}{dx}$$

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