NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF TECHNICAL AND ENGINEERING EDUCATION AND TRAINING

PTE6257 Groundwater Modelling

Main Examination

December 2024

This examination paper consists of seven (3) printed pages

Time allowed:	3 hours
Total marks:	100
Examiner:	Mr. P. P. Makokoro
External Examiner:	Dr. Kahanji

INSTRUCTIONS

1. Answer any **FOUR** questions.
2. Sub-division marks are shown in brackets
3. Begin each question on a fresh page and number it.

MARK ALLOCATION

QUESTION		MARKS
1		25 marks
2		25 marks
3		25 marks
4		25 marks
5		25 marks
6		25 marks

Question 1.

    a. Explore the implications of climate change on groundwater resources.
        (15 marks)

    b. How can groundwater models be adapted to asses the impacts of climate change?   (10 marks)

Question 2

    a. Explain the hydrological cycle and it's significance in groundwater modelling.
        (15 marks)

    b. With aid of **sketches,** explain the difference between unconfined and confined aquifers.   (10 marks)

Question 3

Using sub-headings given below, show how groundwater modelling inform policy decisions regarding water resource management.

(i)	Resource Assessment	(5 marks)
(ii)	Impact Analysis	(5 marks)
(iii)	Water Allocation and Use	(5 marks)
(iv)	Public Engagement and Education	(5 marks)
(v)	Regulatory Framework Development	(5 marks)

Question 4

    a. Using the information given below on Darcy's Law equation, discuss it's application in groundwater modelling under the headings given below.

Darcy's Law describes the flow of fluid through porous media and is fundamental to groundwater flow modeling. The law states that the flow rate (Q) through a porous medium is proportional to the hydraulic gradient and the cross-sectional area through which the fluid flows.

Mathematical Formulation

Flow Rate (Q): The volume of water flowing through a cross-section per unit time.

Hydraulic Gradient (i): The change in hydraulic head (h) per unit distance (L) in the direction of flow:

$$i = \frac{\Delta h}{\Delta L}$$

Darcy's Law Equation:

The basic form of Darcy's Law can be expressed as:

$$Q = -KA\frac{\Delta h}{\Delta L}$$

Where:

- Q = flow rate (m³/s)
- K = hydraulic conductivity of the porous medium (m/s)
- A = cross-sectional area perpendicular to the flow direction (m²)
- Δh = difference in hydraulic head (m)
- ΔL = distance over which the head difference occurs (m)

i. Goundwater Simulation   (4 marks)
ii. Hydraulic Conductivity Estimation   (4 marks)
iii. Aquifer Testing   (4 marks)
iv. Contaminant Transport Modelling   (4 marks)
v. Water Resource Management   (4 marks)
vi. Integration with other Laws   (4 marks)

b. Who is regarded as the 'Father of Hydrology and Engineering'?
                                             (1 mark)

Question 5

a. Define the following terms as used in Groundwater Hydrology:
   i. Porosity   (1 mark)
   ii. Recharge   (1 mark)

b. You are tasked with assessing the potential impact of a new agricultural irrigation project on the local groundwater table. An unconfined aquifer in the area has the following characteristics:
   - Hydraulic Conductivity (K): 15 m/day
   - Aquifer Thickness (b): 10 m
   - Initial Water Table Elevation (h_1): 20 m
   - Water Table Elevation after irrigation starts (h_2): 15 m
   - Area of influence due to irrigation: 500 m²
   - Distance over which head difference occurs: 100m

   Tasks:
   i. Calculate the change in hydraulic head (Δh) due to the irrigation project.
                                             (3 marks)
   ii. Determine the flow rate (Q) into the aquifer using Darcy's Law.
                                             (5 marks)
   iii. Estimate the time (t) it would take to reach the new water table elevation if the recharge rate is constant at 5 m³/day.   (5 marks)

c. A confined aquifer has the following properties:
   - Hydraulic Conductivity (K): 20 m/day
   - Transmissivity (T): 200 m²/day
   - Initial Water Level (h_1): 30 m
   - Water Level After Pumping (h_2): 25 m
   - Pumping Rate (Q): 50 m³/day
   - Radius of Influence (r): 150 m

You are to analyze the impact of pumping on the aquifer.

Tasks:

i.   Calculate the drawdown (s) in the aquifer.   (2 marks)

ii.   Determine the effective radius of influence (Re) using the Theis equation.   (4 marks)

iii.   Estimate the time (t) it would take for the water level to drop from h_1 to h_2 if the aquifer is pumped at the given rate.   (4 marks)