**OLLSCOIL NA hÉIREANN, GAILLIMH**
NATIONAL UNIVERSITY OF IRELAND, GALWAY

EH 305 – Hydrology and Hydrogeology

**SUMMER EXAMINATIONS 2003**

Examiners: Professor K.J. Beven
Professor C. Cunnane

*Time allowed: three hours*
*Attempt five questions with at least two from each section*

*Separate answer books are not required*

## SECTION A

1. (a) Explain why the physical properties of water, such as melting point and specific heat capacity differ substantially from those of other halides such as $H_2S_e$ and $H_2S$. *[6 marks]*

(b) What consequence does this effect have on the functioning of life on earth? *[2 marks]*

(b) The oceans contain approximately 1370 million $km^3$ of water. If the average temperature of these oceans increased by 0.1°C over a decade, how much extra energy was absorbed per year during that period? Take specific heat capacity of water to be 4.2 kJ/kg. *[4 marks]*

(c) Enumerate the most prominent green house gases and state briefly how changes in these have affected or will affect
(i) global temperatures
(ii) the weather or local climate of NW Europe *[8 marks]*

2. (a) Describe briefly the function and operation of a current meter *[6 marks]*

(b) Current meter measurements provide the following data at a river gauging site, at which water depth d = 1 m.

| Location of CM above river bed, m | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
|---|---|---|---|---|---|
| Velocity, m/s | 0.63 | 0.80 | 0.92 | 1.05 | 1.05 |

Draw the velocity profile on graph paper, calculate the average velocity and show it on the above graph and calculate the discharge per unit width of river. *[6 marks]*

*Question 2 continued overleaf...*

(c) It is common practice during river flow gauging to approximate the mean velocity at any portion of a river cross-section by the velocity measured at a depth 0.6d or by the average of the velocities measured at 0.2 d and 0.8 d where d = depth of water at that location.

Investigate whether the measured data, reported above, support this practice or not. *[8 marks]*

3. (a) The rainfall depths recorded in a year at each of four raingauges on a catchment and their corresponding Thiessen polygon sub-areas are as follows:

| Raingauge No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Rainfall, mm | 700 | 950 | 1200 | 1050 |
| Thiessen area, $km^2$ | 25 | 27 | 16 | 19 |

Calculate the average annual rainfall on the catchment for that year. *[4 marks]*

If the runoff from the catchment for that year was equivalent to 1.4 $m^3/s$ determine the amount of evaporation, in mm, that occurred during that year *[4 marks]*

How much energy did this evaporation require? *[2 marks]*
*[Assume an average water temperature of 10°C]*

(b) An irrigation canal is rectangular in shape, 5 m wide and laid to a bed slope of 1:500. The following discharge measurements were made at different times in the canal.

| Measurement No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Water Depth, m | 0.2 | 0.5 | 0.9 | 1.7 | 2.2 |
| Discharge, $m^3/s$ | 0.55 | 2.50 | 6.00 | 15.50 | 22.00 |

Verify that these data support the hypothesis that the discharge – water depth relationship can be described by either the Manning or the Chezy open channel flow formulae, $Q = AR^{2/3} S^{1/2}/n$ or $AC(RS)^{1/2}$, and determine the most suitable value of n or C for this canal. *[10 marks]*

4. (a) Describe briefly the processes of interception and infiltration. *[6 marks]*

Explain what is meant by a control volume and show how it is used in the context of infiltration to derive the continuity equation

$$\frac{\delta\theta}{\delta t} + \frac{\delta q}{\delta z} = 0$$

for vertical flow through a porous medium. *[4 marks]*

(b) Explain the terms field capacity and soil moisture deficit (SMD) as applied to soil water. *[2 marks]*

Explain how SMD affects the process of evaporation from a vegetated soil. *[4 marks]*

In a grassland location SMD was 80 mm at the end of June. During July the potential evaporation and rainfall for that location were 80 mm and 30 mm respectively. Calculate the actual evaporation at that location in July. *[4 marks]*

## SECTION B

5. (a) Distinguish, with the help of neat sketches, between unconfined and confined aquifers and comment on (i) how water is supplied to each; (ii) the destination(s) of water which enters aquifers. *[6 marks]*

Calculate water pressure at a point 3 m below the water table and at a point 0.3 m above the water table in an unconfined aquifer. *[4 marks]*

(b) Define the terms Specific Yield and Specific Retention as applied to aquifers *[2 marks]*

An unconfined aquifer has a Specific Yield of 0.26 and an areal extent of 250 $km^2$. How much water, in $m^3$ has to be removed in order to lower the water table by 1.5 m? *[4 marks]*

Aquifer compressibility is defined as $\alpha = (-db/b)/(-dP)$ in the usual notation. If $\alpha = 1.5 \times 10^{-8}$ $m^2/N$ in a particular confined aquifer by how much will the potentiometric surface be changed due to an aquifer subsidence of 0.05 m? *[4 marks]*

6. (a) Explain what is meant by Darcy's Law for flow through porous media and show that it is analogous to the Hagen-Poisseuille equation for laminar flow through pipes, namely $\Delta H = 32\ \mu\ Lv / \rho g D^2$ *[8 marks]*

(b) A homogeneous confined aquifer is 20 m thick and has a hydraulic conductivity of 8 m/day. Two observation wells, placed 1500 m apart, have potentiometric head values of 60 m and 58.5 m respectively. Calculate the flow rate in the aquifer, per 1000 m width of aquifer, in the direction between the two wells. *[6 marks]*

(c) The following equation, in the usual notation, relates to the hydraulic head of an aquifer

$$\frac{\delta^2 h}{\delta x^2} + \frac{\delta^2 h}{\delta y^2} = \frac{S_s}{K}\frac{\delta h}{\delta t}$$

State whether the aquifer is

(i) homogeneous
(ii) isotropic with respect to hydraulic conductivity. *[4 marks]*

What does the quantity $S_s$ represent? *[2 marks]*

7. (a) What is meant by the use of test well pumping for evaluation of an aquifer? What kind of information can be gained from such tests?

(b) An ideal confined aquifer is 30 m thick and has hydraulic conductivity of 11 m/day. The aquifer storativity is 0.00035. What is the maximum allowable pumping rate if the drawdown in the neighbourhood of the well i.e. within 1 m, is to be limited to 3 m after 2 days of pumping? *[6 marks]*

(c) A confined aquifer was pumped continuously at a rate of 20 $m^3$/hour. At an observation well located 100 m away, the drawdown was observed to be 2.0 m after 100 minutes and 3.5 m after 1000 minutes (16 hours 40 min.). Using this information determine the values of aquifer transmissivity, T, and storativity, S.

*Use may be made of the attached semi-logarithmic paper.* *[8 marks]*

8. (a) State the Dupuit assumptions used in determining an expression for flow through an unconfined aquifer. [3 marks]

(b) In an unconfined aquifer water table elevations are denoted $h_1$ and $h_2$ at two points located distance L apart. Show that the distance, d, from point 1 to the water table divide is given by

$$d = \frac{L}{2} - \frac{K}{w}\frac{h_1^2 - h_2^2}{2L}$$

where K = hydraulic conductivity and w = recharge per unit area. *[5 marks]*

(c) An irrigation canal runs parallel to the edge of a lake at a distance 500 m from it. The ground between them is underlain by a shallow, homogeneous sandy aquifer of hydraulic conductivity 0.6 m/day. Rainfall in the area is 600 mm/year and actual evaporation is 400 mm/year.

(i) Determine the location of the water table divide and the water table elevation at that point.

(ii) Determine the discharges, per km length of canal, into the lake and into the canal.

(iii) Show that these outflows are consistent with the recharge i.e. confirm the water balance. *[12 marks]*