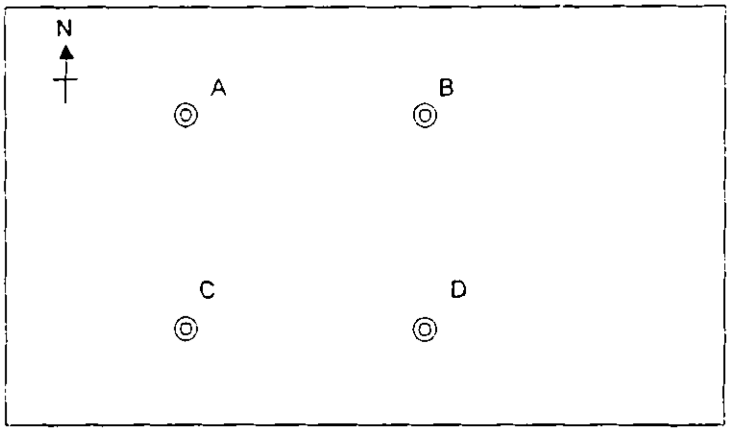
UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING
CIV 549 - GROUNDWATER FLOW AND CONTAMINATION

Final Examination, December 2001
Examiner: C.A. Kennedy

NAME: STUDENT ID:

Instructions
1. This is an open-book examination.
2. Non-programmable, silent, self-powered, electronic calculators are permitted.
3. Answer all four question. Use the back of the page if you require further space.
4. If doubt exists as to the interpretation of any question, a clear statement of any assumptions made should be included with the answer.

Question 1 (10 marks)



Four wells (A, B, C and D, shown above) are screened in a saturated, homogeneous, confined, horizontal aquifer of uniform thickness 12 m.
Well A is due north of well C, by a distance of 200 m.
Well B is due north of well D, by a distance of 200 m.
Well C is due west of well D, by a distance of 200 m.

(a) Given that the flow field is perfectly uniform and horizontal, use the data in the table below to establish the magnitude and direction of the hydraulic gradient.

Well	Top of casing (m)	Depth to water level (m)
A	190	12
B	192	20
C	191	7
D	195	17

(b) A pumping test is conducted at well D, using a pumping rate of 112 m^3/day. Drawdown is observed at an observation well that is 11.4 m from D.

Using the Theis method of solution, a match point for the type curve is as follows:

$W(u) = 1$ drawdown = 38 cm
$1/u = 1$ time = 10 mins.

Estimate the transmissivity (in m^2/s) and storativity of the aquifer.

(c) Regular tritium isotope measurements are taken at well C. A peak tritium concentration of 19.3 TU was observed in March 1993. Estimate the date and magnitude of the peak isotope concentration at well B. Assume that the porosity of aquifer material is 0.30.

Question 2 (10 marks)

A slug of contaminant is instantaneously released into an aquifer of porosity, n=0.32, and saturated hydraulic conductivity, $K = 5 \times 10^{-4}$ m/s. The contaminant is released with a concentration, C_0, of 100 mg/l over an area of 1 m^2 and it is distributed throughout the entire depth of the aquifer.
The contaminant follows a uniform flow field of hydraulic gradient i = -0.01. The sand has longitudinal and transverse dispersivity values of 1.0 m and 0.1 m respectively.

Contaminant concentrations are observed at a monitoring well situated 45 m along the principal axis of flow, downstream of the source.

(a) Assuming that the contaminant is conservative, determine the time (in days) at which the centre of mass reaches the monitoring well. Use the appropriate solution to the 2-D advection-dispersion equation to establish the peak concentration at this time.

(b) It is suspected that the contaminant may be slightly retarded as it moves through the aquifer. Sketch a graph showing how the concentration at the monitoring well after t = 40 days will vary for retardation factors, R, ranging from 1.0 to 2.0. Show a few pertinent calculated values of concentration on your graph. For what value of R is the maximum contaminant concentration observed after 40 days?

Question 3 (10 marks)

(a) Explain the process of calibrating a groundwater flow model. What is the purpose of model calibration? What variables are usually involved in the calibration? How do you judge whether a calibration is satisfactory. Use at least one diagram to aid in your explanation.

(b) For assignment 4 of the course you produced a simplified model of groundwater flow in aquifer 5.2 at the Schwelvollert. Discuss specific changes that you could have made to better calibrate your model.
In what other ways could the model have been improved (explain with detail)?

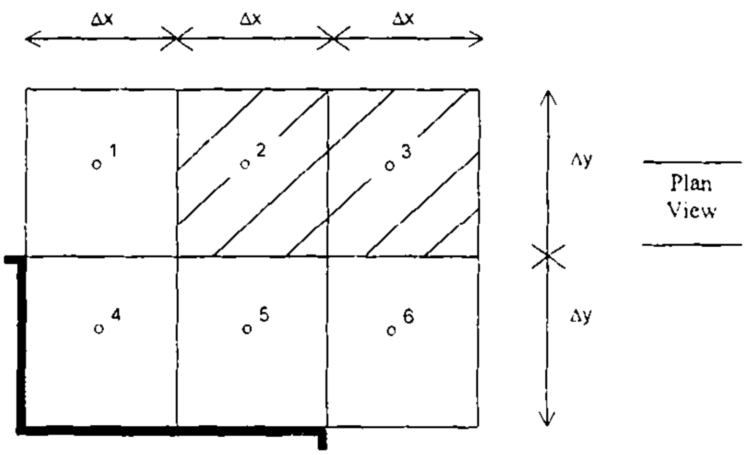
Question 4 (10 marks)

Use the finite difference method to discretize the following 2-D steady state groundwater flow equation:

$$\frac{\partial}{\partial x}\left(T_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T_y \frac{\partial h}{\partial x}\right) = R$$

where R is annual recharge (in mm/year) and T is transmissivity.

Form a matrix equation for solving the hydraulic heads in the unconfined aquifer shown below, assuming uniform recharge, R, over the aquifer. Assume that there is no flow across the boundaries of the aquifer except at the fixed head river boundary as shown. (You don't have to solve the equation).



River Boundary
Head = H_0

$T_1 = T_4 = T_5 = T_6 = T_A$
$T_2 = T_3 = T_B$