OLLSCOIL NA hÉIREANN, GAILLIMH
NATIONAL UNIVERSITY OF IRELAND, GALWAY

(International Postgraduate Hydrology Courses)

M.Sc. (Hydrology)
Spring Examinations 2000

APPLIED HYDROLOGY III

Examiners: Professor P. E. O'Connell
Professor Conleth Cunnane
Mr. Tiernan Henry, M.Sc.
Dr. Frantisek Dolezal

Time allowed is *three* hours. Attempt any *five* questions.

---

1. Answer any *eight* of the following. (*Each answer is worth 2.5 marks.*)

(i) What is the difference between the *water table* and the *potentiometric surface*?
(ii) There are *six* basic properties of fluids and porous media that must be known to properly describe groundwater flow. List the six properties.
(iii) What is the difference between *specific storage* and *storativity* in confined aquifers?
(iv) What is the difference between *trending heterogeneity* and *discontinuous heterogeneity* in reference to the distribution of hydraulic conductivity?
(v) Are (i) *permeability* and (ii) *hydraulic conductivity* affected by changes in groundwater temperature? Briefly explain your answer.
(vi) The water level change in an aquifer at some distance from a pumping well is a function of what?
(vii) What is the difference between a *recharge* and a *discharge boundary*?
(viii) What is the *Tan Law* and what is its use in understanding groundwater flow?
(ix) Is the *moisture content* of a soil sample the same as its *percentage saturation*? *Briefly* explain your answer.
(x) The following equation describes groundwater flow under what flow conditions?

$$\frac{d}{dx}(T_x \frac{dh}{dx}) + \frac{d}{dy}(T_y \frac{dh}{dy}) + q_s(x,y,t) = S\frac{dh}{dt}$$

2. Answer both (i) and (ii) below.

(i) Answer *all* parts of the question.

(a) What is the *limiting condition* for use of the Cooper-Jacob modified Theis method? *(2 marks.)*

(b) What *field conditions* determine the use of the Cooper-Jacob methods? *(2 marks.)*

(c) A well is cased into a confined aquifer and pumped at the rate of 1500 m^3/day. An observation well is located 350 metres from the pumping well where drawdown is recorded.

The drawdown per log cycle is determined to be 0.7 metres, and $\mathbf{t_0}$ is determined to be 1.1 minutes.

What are the values of *Transmissivity* and *Storativity* for the aquifer? *(6 marks.)*

(ii) Answer *both* parts of the question.

(a) Give two advantages and two disadvantages of using pumping tests. *(4 marks.)*

(b) A production well is installed in an aquifer, and pumped at a rate of 1100 m^3/day. The aquifer is 12.5 metres thick and has a hydraulic conductivity of 10 m/day. The storativity is estimated to be 0.001. A fault is located 50 metres from the well.

What is the drawdown at the midpoint between the well and the fault after pumping for all of May and June? *(6 marks.)*

3. Answer *both* parts of the question.

(i) A confined aquifer has a uniform thickness of 25 metres and is 12 kilometres wide. Two observation wells are located 800 metres apart in the direction of flow. The aquifer is homogeneous and isotropic, with a hydraulic conductivity of 1.04 m/day. Hydraulic head at Well 1 is measured to be 68 metres, and hydraulic head at Well 2 is measured to be 57 metres.

What is the *total daily flow* through the entire width of the aquifer? *(4 marks.)*

(ii) The hydraulic conductivity of an unconfined, homogeneous aquifer is estimated to be 10^{-4} m/second. The effective porosity is 0.22. The sand and gravel deposit in which the aquifer is found has a uniform thickness of 40 metres. Two wells are installed 200 metres apart in the direction of flow. The

water level in Well 1 is five metres below the land surface and the water level in Well 2 is 7.5 metres below the surface.

(a) What is the discharge per unit width of the aquifer? *(2 marks.)*
(b) What is the average linear groundwater velocity at Well 2? (2 marks.)
(c) What is the elevation of the water table at 170 metres from Well 1 (and 30 metres from Well 2)? *(2 marks.)*

4. *Indicate*, on your answer sheet, legibly and unambiguously, the symbols (e. g. (i)-(a), (ii)-(c), etc.) corresponding to the appropriate answers to each of the following multiple-choice questions (with only *one* answer to each question):

(i) The following statement is valid in relation to the *kinematic porosity*:
(a) it is equal to the ratio of the average pore velocity to the volumetric flux,
(b) the speed with which a cloud of ideal tracer moves in a heterogeneous saturated rock depends of the volumetric flux only and not on the kinematic porosity of the rock,
(c) if a tracer which undergoes adsorption and desorption on the walls of pores is used to estimate the average pore velocity then the resulting kinematic porosity will be overestimated.

(ii) The following statement is valid in relation to an *anisotropic porous medium*:
(a) its porosity is different in differently oriented cross-sections,
(b) the average pore velocity vector is not always colinear with the hydraulic head gradient,
(c) the average pore velocity vector is not always colinear with the volumetric flux vector.

(iii) The equation $T_{xx}\dfrac{\partial^2 h}{\partial x^2}+T_{yy}\dfrac{\partial^2 h}{\partial y^2}=0$ is applicable to:
(a) the steady flow in an anisotropic and homogeneous confined aquifer, provided that the principal directions of anisotropy coincide with the coordinate axes,
(b) the steady flow in an anisotropic and heterogeneous confined aquifer, provided that the principal directions of anisotropy coincide with the coordinate axes,
(c) the steady flow in an anisotropic and homogeneous confined aquifer in which the principal directions of anisotropy do not coincide with the coordinate axes.

(iv) In the case of a *steady radially symmetrical flow* of groundwater towards a pumping well:
(a) the volumetric flux divergence is zero everywhere,
(b) the hydraulic head gradient is a zero vector everywhere,
(c) the second derivative of the drawdown s with respect to the radial distance from the well r is zero everywhere.

(v) The *Dupuit-Forchheimer assumption* means that:
(a) the specific yield is taken as constant, not depending on the actual depth of the groundwater table,
(b) the transmissivity of an unconfined aquifer is taken as constant and equal to the product of the horizontal hydraulic conductivity and the average saturated thickness of the aquifer,
(c) the gradient of groundwater table elevation is taken instead of the hydraulic head gradient at all points within the aquifer which lie on the same vertical line.

(vi) The *no-flow boundary condition* means that:
(a) the scalar product of the volumetric flux and the unit normal vector to the boundary is zero,
(b) the volumetric flux at the boundary is a zero vector,
(c) the hydraulic head gradient is always parallel to the boundary.

(vii) If piezometers installed at different depths within the same geological formation indicate that the pressure head is the same at all depths, it means that:
(a) the vertical component of groundwater flow is zero,
(b) the groundwater moves downwards and its volumetric flux is equal to the vertical hydraulic conductivity of the formation,
(c) the magnitude of the vector of the hydraulic head gradient must be unity.

5. *Examine* the figure on the following page, taken from Anderson, M.P., and Munter, J. A., 1981, *Water Resources Research* 17(4): 1139-1150. It presents the results of simulation of a two-dimensional transient groundwater flow through the part of an aquifer which interacts with a lake (the black spot). The right-hand side and the bottom of the aquifer are taken as no-flow boundaries. The boundary condition on the left-hand side is a constant head. The model assumes, for simplicity, that the entire flow region is saturated at all times, i.e., no groundwater table is modelled. The numbers ascribed to the equipotential lines are hydraulic heads, as explained in the caption. The water level in the lake is also indicated.

Try to guess:

(i) what type of boundary condition is imposed on the top boundary of the flow region and whether or not this boundary condition varies in time,

(ii) how the initial condition is defined,

(iii) whether the water is flowing, at the time instants specified, from the aquifer into the lake or oppositely,

(iv) what the term "stagnation point", as used in the figure caption, means.

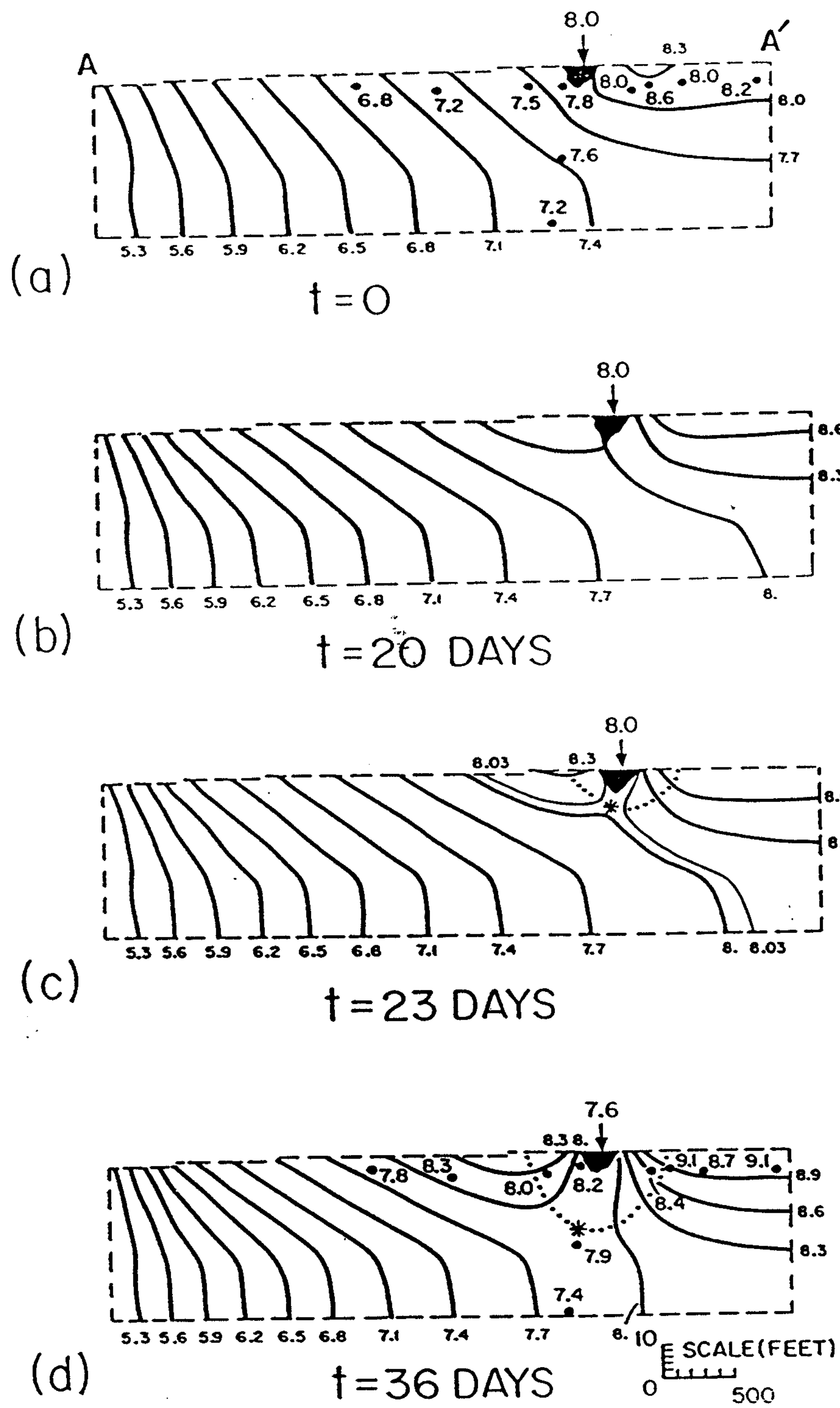

Fig. 6. Simulated head distribution. (*a*) Initial steady state head distribution for April 14. (*b*) Transient head distribution for May 4 (t = 20 days). (*c*) Transient head distribution for May 7 (t = 23 days). (*d*) Transient head distribution for May 20 (t = 36 days). Asterisk shows the location of the stagnation point, and the dotted line shows the location of the groundwater divide separating the shallow flow system from the deeper system. Dots on (*a*) and (*d*) indicate the locations of piezometers used by *Jaquet* [1974, 1976], and numbers next to the dots are heads measured in the field in feet above a reference datum defined to be 1590 ft (484.6 m) above mean sea level.

6. *Examine* the following figure taken from Anderson, M. P., and Woessner, W. W, 1992: *Applied groundwater modelling*. Academic Press, San Diego, pp. 112-113.

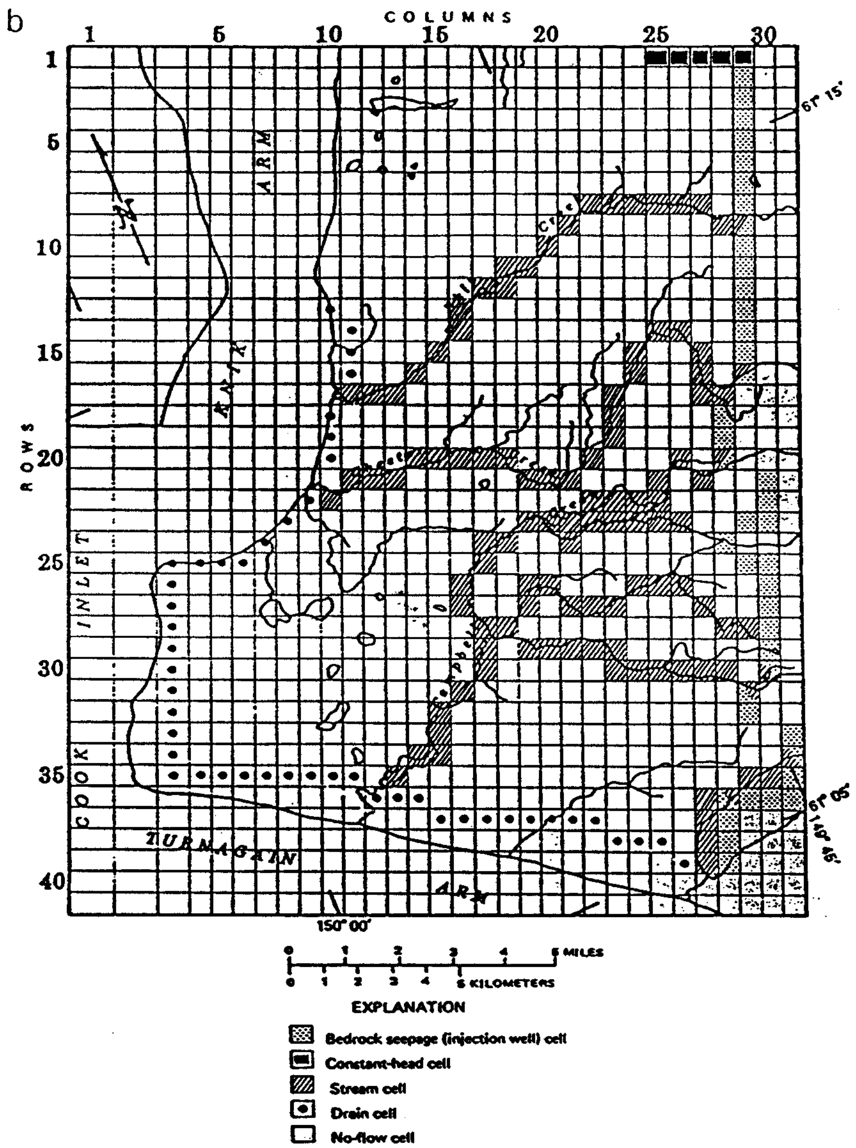

Fig. 4.8 Specified flux boundaries.

(b) Injection wells in columns 28–30 are used to represent lateral seepage from adjacent bedrock into the unconfined upper layer of a two-layer model of the area around Anchorage, Alaska. Also note the use of drain cells to represent wetland areas adjacent to Cook Inlet and stream cells to represent leakage to partially penetrating streams. Constant-head nodes (row 1) and no-flow conditions are also used to define boundary conditions (Patrick et al., 1989).

List all types of boundary conditions used in the figure and *explain* why they are used. *Try to guess* why some of the rivers and lakes within the flow region are not represented by stream cells.