

## Ollscoil na hÉireann, Gaillimh

SUMMER EXAMINATION 2000

(International Postgraduate Hydrology Courses)

M.Sc. Degree (Hydrology)

## HYDRAULICS

Examiners: Prof. P. E. O'Connell  
 Prof. C. Cunnane  
 Mr. A.M. Cawley  
 Dr. I. O'Neill

Time allowed: **Three Hours.**Attempt any **Five** Questions.

1. (a) The mass and momentum conservation equations for unsteady flow in pipes subject to water hammer, expressed in terms of pressure,  $P$ , and velocity  $v$  are:

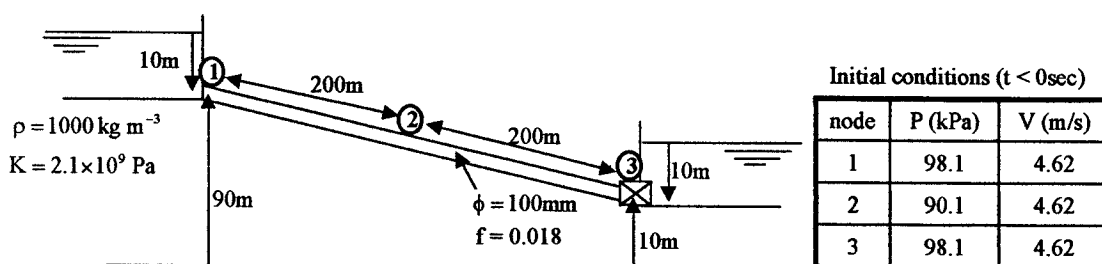
$$\frac{1}{\rho} \frac{\partial P}{\partial t} + \frac{v}{\rho} \frac{\partial P}{\partial x} + C_o^2 \frac{\partial v}{\partial x} = 0$$

$$\frac{1}{\rho} \frac{\partial P}{\partial x} + \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} + \frac{f}{2D} v|v| - g \sin \theta = 0$$

Derive the corresponding characteristic equations. Show that the speed of a pressure wave through the pipe can be taken as  $C_o$ .

(8marks)

- (b) A 100mm diameter pipeline of total length 400m connects two reservoirs. A control valve is located at the entry to the lower Reservoir. If valve closure is instantaneous, calculate the pressure variation at the mid-point (node 2) and at the valve end (node 3) of the pipeline (see accompanying diagram for details). The initial conditions to this problem are given below.



In calculating the wave celerity you may assume that the pipeline is rigid and the fluid bulk modulus  $K$  is  $2.1 \times 10^9$  Pa. In your calculations use a constant friction factor  $f = 0.015$ . Perform calculations for two time steps only!

(12marks)

2. (a) Water is flowing at a discharge of  $2 \text{ m}^3/\text{s}$  in a channel of triangular cross-section. The channel side slopes are at  $45^\circ$  and the flow depth is  $2.5\text{m}$ .

Calculate: the Froude number; hydraulic depth; and alternate depth.

(6 marks)

- (b) A trapezoidal channel has a  $3\text{m}$  wide base and sides sloping at  $45^\circ$ . The channel conveys a discharge of  $23\text{m}^3/\text{s}$  at a uniform depth of  $3\text{m}$ .

The channel has a local constriction formed by raising the sides to a vertical position.

Calculate the depth of water in the constriction, neglecting local head losses.

What is the minimum height of a hump that could be installed in the constriction to produce critical depth there?

(14 marks)

3. (a) Indicate what you understand by the following terms related to open channel flow.

- (i) Control sections
- (ii) Water surface profile classification
- (iii) Conveyance

(6 marks)

- (b) An hydraulic jump is observed in a channel of triangular cross-section with sides at  $45^\circ$ . The depths upstream and downstream of the jump are  $0.9\text{m}$  and  $1.2\text{m}$  respectively.

Estimate the discharge in the channel.

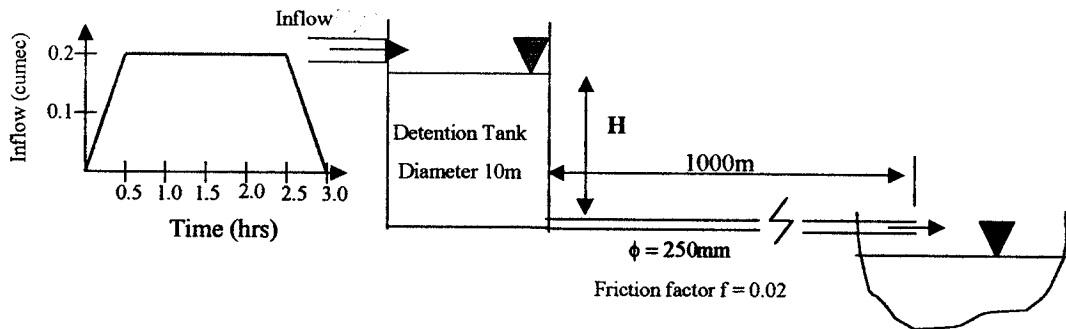
(6 marks)

- (c) There is a change of slope from  $0.005$  to  $0.006$  in a long channel which can be considered wide. The normal depth for the upstream region is  $1.5\text{m}$  and Manning's  $n$  is  $0.015$  throughout the channel.

Find the depth of flow at the cross-section where the slope changes, showing all calculations and explaining your reasons.

(8 marks)

4. (a) A tall 10m diameter detention tank is connected to a river by a horizontal storm outflow pipe, 1000m in length and 250mm in diameter. The runoff from a small urban area is collected and inflows to this detention tank prior to entering the river course. Determine the reduction in peak discharge between the inflow and outflow hydrographs. The inflow hydrograph is detailed in the accompanying diagram. In your calculations use a time step of 30 minutes and assume that the friction factor  $f = 0.02$ . (Please note that the peak outflow discharge requires calculations over six time steps.)



(15 marks)

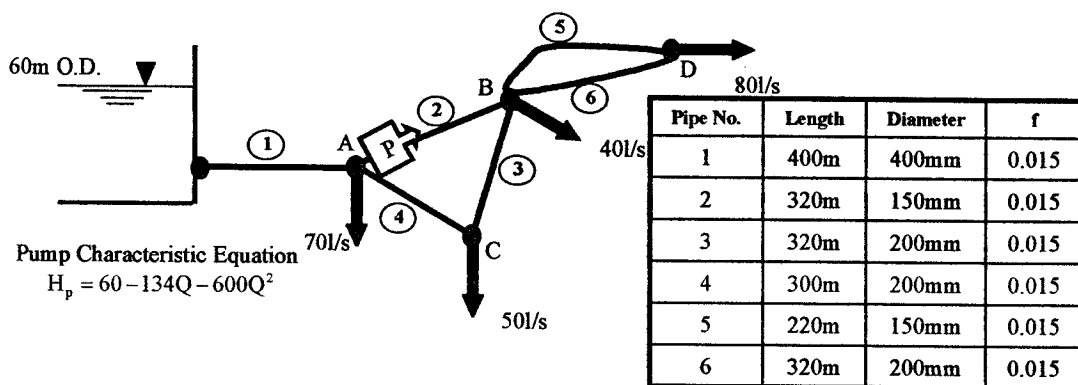
- (b) Indicate how you would solve the above problem if a pump were installed on the storm outlet pipe having a pump characteristic of the form  $H_p = a_0 + a_1Q + a_2Q^2$ .

(5 marks)

5. (a) Describe the Linear Matrix and Hardy Cross Methods for analysing pipe network systems. Outline the advantages that the linear matrix method has over the Hardy Cross Method.

(8 marks)

- (b) Using any solution method of your choice, calculate flow rates in individual pipes of the pipe network detailed in the accompanying diagram. Solve for two iterations only and neglect shock losses.



(12 marks)

6. (a) Describe any numerical method for solving the St. Venant Equations.

(5 marks)

(b) Describe the simplifications associated with the kinematic and diffusion wave models. What effect will each model have on a Flood Hydrograph?

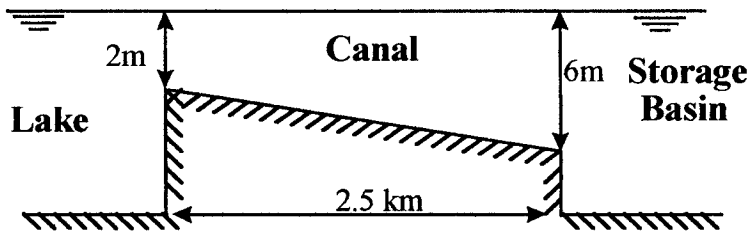
(5 marks)

(c) Discuss (briefly, in listed points) the limitations and advantages of the characteristic method for solving the Saint Venant Equations.

(5 marks)

(d) A rectangular canal of length 2.5 km connects a lake to an artificial storage basin as described in the accompanying diagram. If the water level in the storage basin is suddenly reduced, how much time will it take before the level in the lake starts to change?

Sketch roughly the progress of the disturbance on a time - distance graph.



(5 marks)