National Exams May 2018

16-Civ-A5, Hydraulic Engineering

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a **CLOSED BOOK** examination. The following are permitted:

    - **one** 8.5 x 11-inch aid sheet (both sides may be used); and
    - **One of two calculators is permitted - any Casio or Sharp approved model**

3. This examination has a total of **six** questions. You are required to complete any **five** of the six exam questions. Indicate clearly on your examination answer booklet which questions you have attempted. The first five questions as they appear in the answer book will be marked. All questions are of equal value. If any question has more than one part, each is of equal value.

4. Note that 'cms' means cubic metres per second; 1 inch=2.54 cm.

5. The following equations may be useful:

    - Hazen-Williams: $Q = 0.278CD^{2.63}S^{0.54}$, $S=\Delta h/L$
    - Mannings: $Q = \frac{A}{n}R^{2/3}S^{0.5}$, $S=\Delta h/L$
    - Darcy-Weisbach: $\Delta h = \frac{fL}{D}\cdot\frac{V^2}{2g} = 0.0826\frac{fL}{D^5}\cdot Q^2$
    - Loop Corrections: $q_i = -\frac{\sum_{\text{loop}} k_i Q_i |Q_i|^{n-1}}{n\sum_{\text{loop}} k_i |Q_i|^{n-1}}$, $n = 1.852$ (Hazen-Williams)
    - Total Dynamic Head: TDH = $H_s + H_f$, H_s=static head; H_f=friction losses

6. Unless otherwise stated, (i) assume that local losses and velocity head are negligible, (ii) that the given values for pipe diameters are nominal pipe diameters and (iii) that the flow involves water with a density ρ = 1,000 kg/m³ and kinematic viscosity υ = 1.31 x 10^{-6} m²/s.

/20 1. A branched pipe network conveys water from reservoir R1 with constant water level of 65 m to 5 nodes, all at elevation of 20 m (Figure 1). All pipes are made of PVC material and have a Hazen-Williams 'C' factor of 140, and internal diameter of 502 mm. Nodes 1 through 5 have a maximum day demand of 1.5 L/s. Node 5 also carries a fire flow of 20 L/s.

a) If the steady-state pressure head at Node 5 during maximum day demand + fire flow at Node 5 is 40 m, what is the length of all the pipes in the system (assuming that all the pipes have equal length)?

b) Given the maximum day demand + fire conditions in part a) and the calculated pipe length found in part a), calculate the pressure head at Node 4 when the 'C' factor of the pipes is reduced to 130.

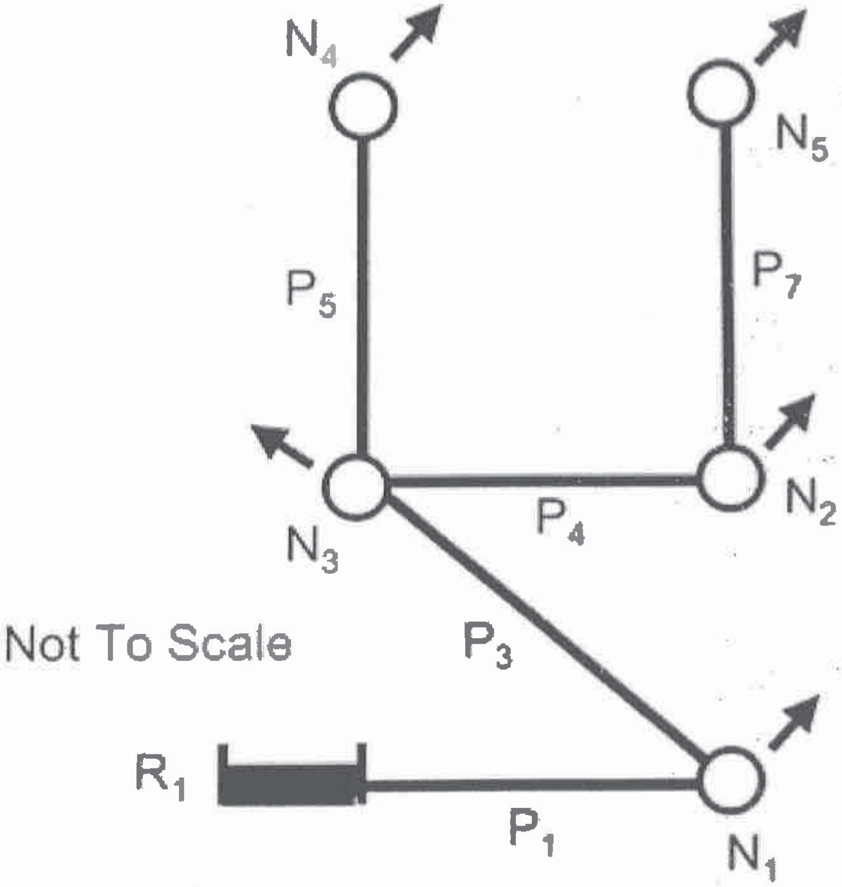

Figure 1. Water supply system.

/20 2. Ten identical pipes connect an upstream reservoir A (water elevation 95 m) to a downstream reservoir B (water elevation 70 m). The elevations of the pipe nodes are given by dashed contour lines with the contour elevations indicated (in metres). Each pipe has a 250 mm diameter, is 200 m long and has a 'C' value of 130.

a) Determine the total flow through this pipe system.

b) Determine the maximum and minimum pressure head in the system.

c) Which branch conveys the highest flow: Branch P1-P2-P4-P5-P8 or Branch P3-P6-P7-P9? Why?

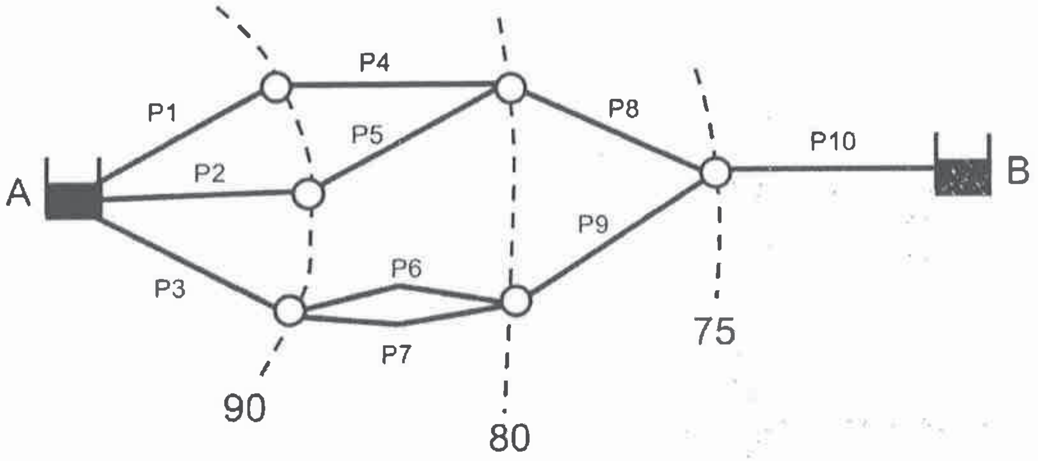

Figure 1. Network of pipes that carries flow from upstream reservoir A to downstream reservoir B.

/20 3. A transmission pipeline that conveys water from an upstream reservoir to a downstream reservoir is indicated in Figure 3. The transmission main has a valve along its length that controls the discharge in the system. The discharge through the valve is computed with the valve equation below. The pipeline has a length of 5,000 m, a Hazen-Williams 'C' factor of 110, and an inner diameter of 450 mm. The upstream reservoir has a water level of 105 m. The downstream reservoir has a water level of 70 m. The discharge in the system is 0.7 m³/s.

$$Q = \tau E_s \sqrt{H_{u/s} - H_{d/s}}$$

where Q = discharge (m³/s), Es = valve discharge constant ($m^{5/2}/s$), Hu/s = upstream head, Hd/s = downstream head.

a) Calculate the valve discharge constant Es when the valve is partially closed (tau = 0.5)?

b) With the discharge constant calculated in part a), determine the tau value for the valve when the flow in the system is 0.7 m^3/s and the water level in the downstream reservoir is 30 m.

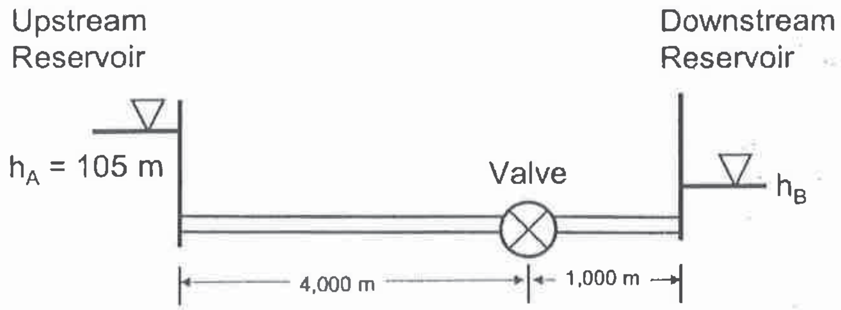

Figure 3. Water transmission system.

/20 4. Two elevated tanks supply water to a demand node with a valve at its outlet (Figure 4). The elevated tanks are cylindrical and have diameters of 5 m. The initial water level in Tank 1 is 96 m and the initial water level in Tank 2 is 89 m. The valve is half open and has a discharge coefficient of 0.15 $m^{5/2}/s$. The initial steady-state flow through the valve is 350 L/s. The valve discharges to the atmosphere. Both pipes have a Hazen-Williams 'C' factor of 110, an internal diameter of 300 mm, and a length of 300 m.

a) Assuming quasi-steady conditions in the system, determine the pressure head at the demand node and the flow in the pipes in the first three time steps of the simulation. Use a time step of 15 seconds to carry out the quasi-steady state simulation.

b) Describe with words and hydraulic concepts how the draining time of the tanks will be affected if the 'C' factor of the pipes is decreased to 80.

c) Describe with words and hydraulic concepts how the draining time of the tanks will be affected if the pipe size is increased to 500 mm.

d) Describe with words and hydraulic concepts how the draining time of the tanks will be affected if the tank diameter is increased to 10 mm.

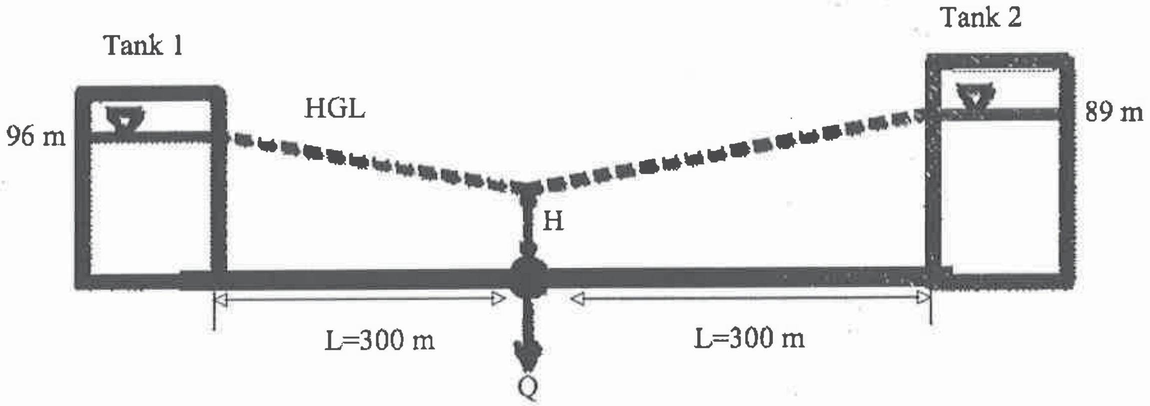

Figure 4. Water supply system.

/20 5. A sluice gate is closed suddenly downstream of a rectangular channel. During a brief period of time after the closure of the gate, the upstream water surface profile at times t = 0, t = Δt, and t = Δt (indicated in Figure 5) are observed. Based on the appearance of the water surface profiles in Figure 5, discuss whether the kinematic wave model or the dynamic wave model would be more appropriate to describe the hydraulic conditions in the channel. Structure your answer in terms of the mathematical terms in one of these models as well as key concepts such as steady flow, unsteady flow, uniform flow, non-uniform flow, momentum, inertia, compressibility and any other relevant concepts.

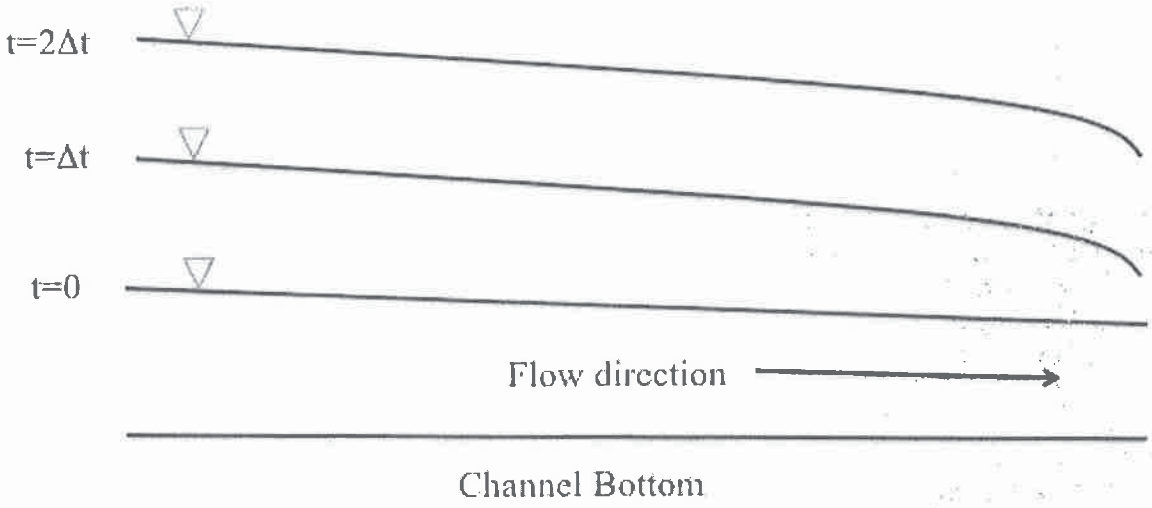

Figure 5. Water surface profile at times t = 0, t = Δt, and t = 2Δt in rectangular channel after sudden closure of sluice gate.

/20 6. A trapezoidal channel carries a flow of 3.0 m^3/s. The trapezoidal channel has a bottom width of 10 m and 3 to 1 side slopes (three horizontal units to 1 vertical unit). The Manning's 'n' for the channel is 0.023 and its longitudinal slope is 0.0015.

a) What should be the design height of this channel considering a 10% freeboard?

b) The channel leads to a broad-crested weir where flow measurements are taken and critical depth occurs. Calculate critical depth just upstream of the broad-crested weir.

c) Given your calculations in a) and b), are flow conditions well upstream of the broad-crested weir sub-critical or super-critical?

d) If you can, draw a diagram of specific energy and on this diagram show the progression from sub- or super-critical conditions to critical conditions between the upstream section and the broad-crested weir.