National Exams December 2017

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. Marking Scheme can be found on Page 6.

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: $q_l = -\frac{\sum_{loop} k_i Q_i |Q_i|^{n-1}}{n\sum_{loop} k_i |Q_i|^{n-1}}$, $n = 1.852$ (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/m^3 and kinematic viscosity υ = 1.31 x 10^{-6} m^2/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 136, an internal diameter of 350 mm, and a length of 155 m. Nodes 1 through 5 have a maximum day demand of 1.5 L/s. Node 5 also carries a fire flow of 60 L/s.

a) Determine the steady-state pressure head at Node 4 during maximum day demand + fire flow at Node 5.

b) Determine the steady-state pressure head at Node 5 during maximum day demand (no fire flow at Node 5).

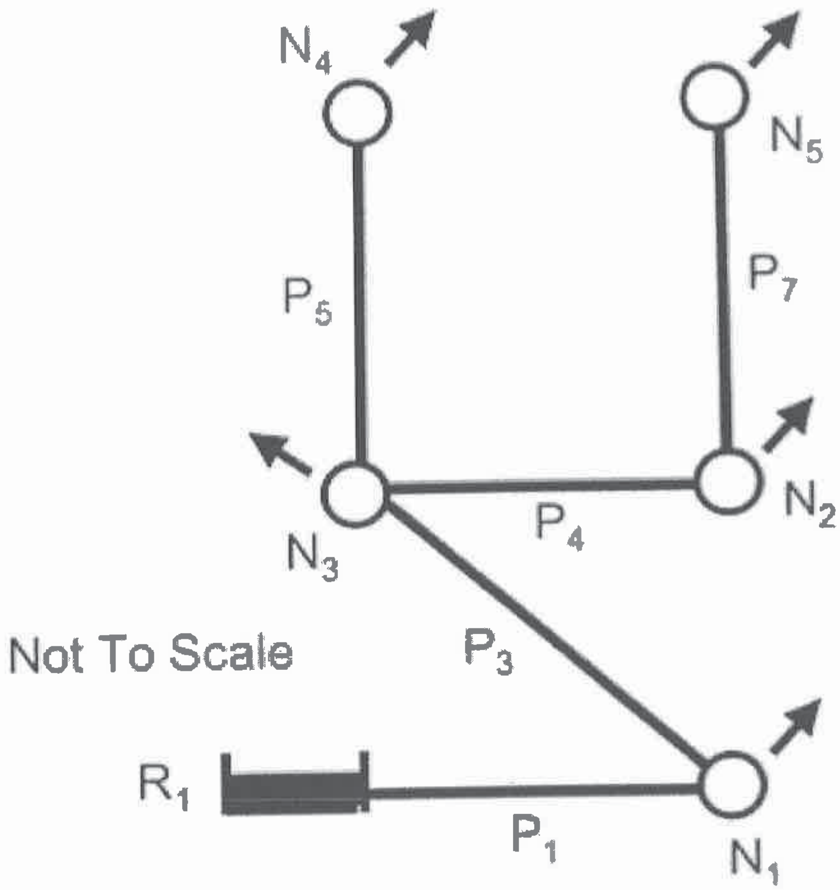

Figure 1. Water supply system.

/20 2. Ten identical pipes connect an upstream reservoir A (water elevation 80 m) to a downstream reservoir B (water elevation 65 m) (Figure 2). All the pipes are at 25 m elevation. Each pipe has a 350 mm diameter, is 350 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.

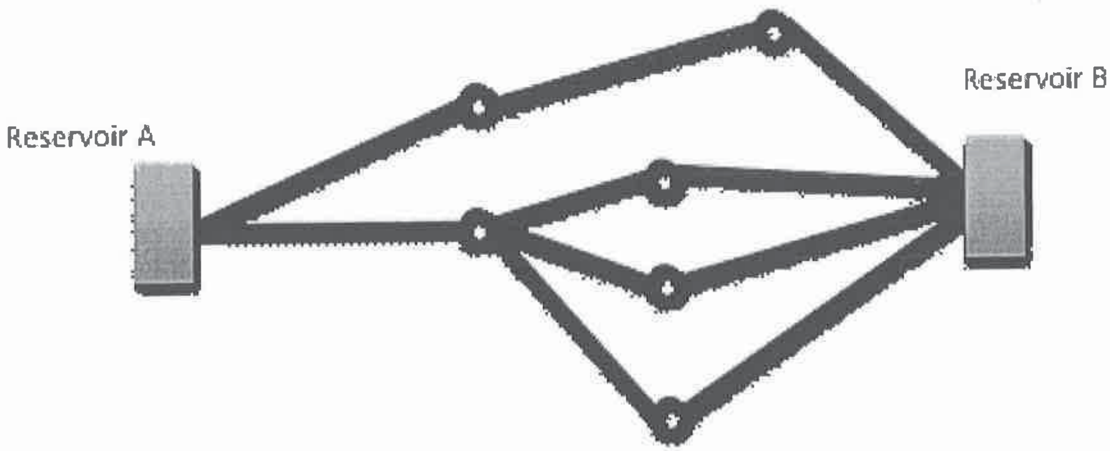

Figure 2. Ten-pipe system.

/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 valve discharge constant is Es = 0.33 $m^{5/2}/s$. The discharge in the system is 0.7 m^3/s.

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

where Q = discharge (m^3/s), Es = valve discharge constant ($m^{5/2}/s$), Hu/s = upstream head, Hd/s = downstream head.

a) When the valve is partially closed (τ-value is equal to 0.75), calculate the hydraulic grade line in the downstream reservoir.

b) When the valve is closed further, the τ value is lowered to τ = 0.22. If the water level in the downstream reservoir remains fixed at the level computed in b), compute the new discharge in the transmission pipeline.

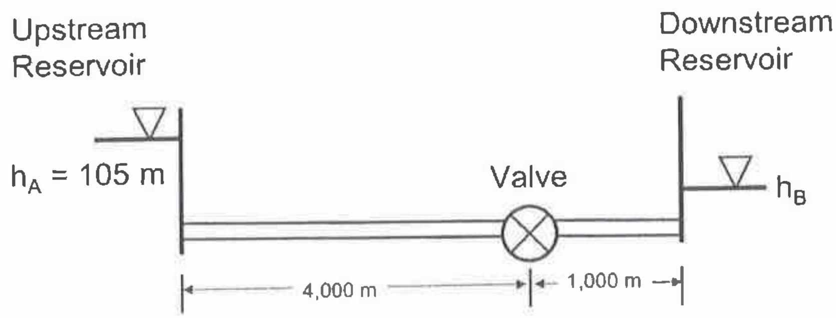

Figure 3. Water transmission system.

/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 100, an internal diameter of 250 mm, and a length of 300 m. 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.

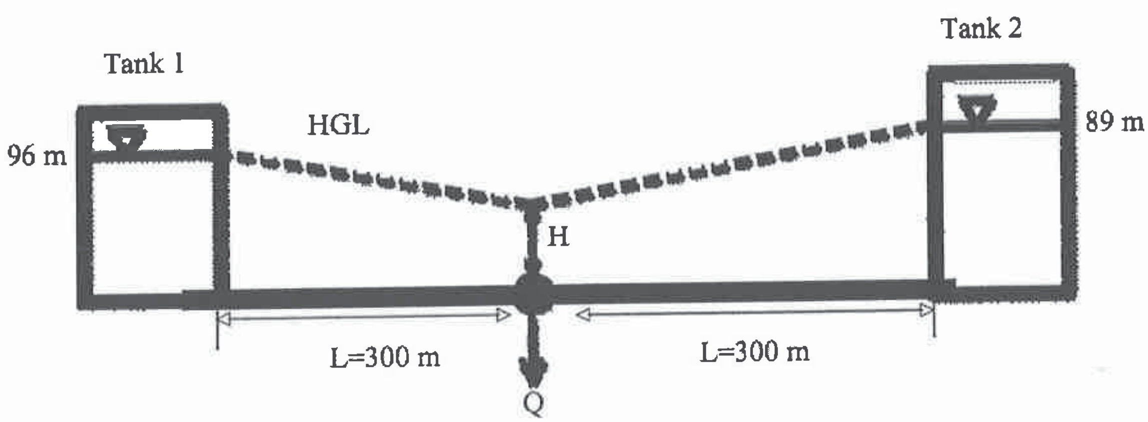

Figure 4. Water supply system.

/20 5. The spillway of a dam discharges into a rectangular channel (Figure 5). The hydraulic jump indicated below occurs in the rectangular channel. The rectangular channel is B = 6.5 m wide. The flow from the spillway is 20 m^3/s, and the depth z1 upstream of the hydraulic jump is 0.2 m.

a) Write the momentum equation for the hydraulic jump.

b) What is the downstream depth z2?

c) Why is the momentum equation a more suitable analysis tool than the energy equation for describing the hydraulic jump?

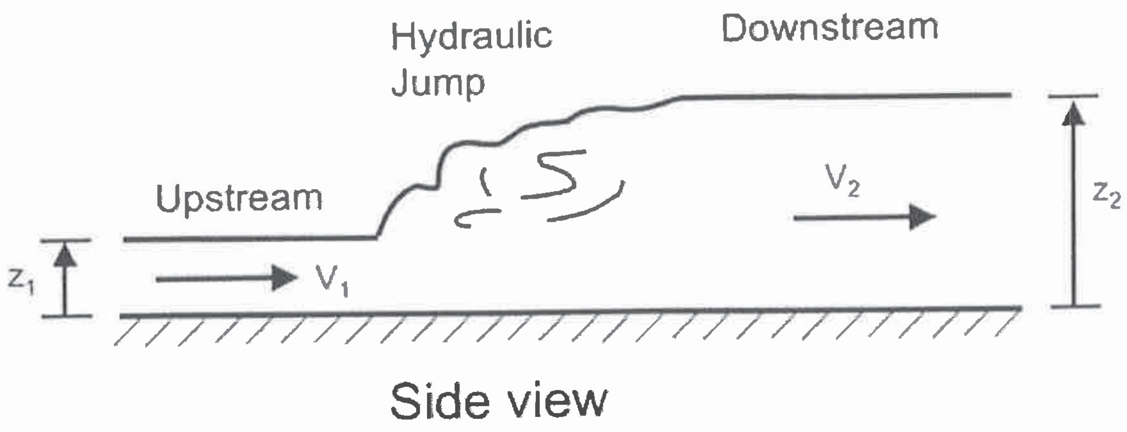

Figure 5. Hydraulic jump.

/20 6. A road cross-section is 8 m wide (from edge to edge of pavement), with a 2% crossfall slope from the centreline and is bounded by curbs (Figure 6). The Manning's 'n' for asphalt is 0.013 and the longitudinal slope of the roadway is 0.015.

a) Calculate the water depth in the road cross-section when the flow is 1 m^3/s.

b) The flood flow is expected to increase by 15% with a change in climate. Under these new conditions, calculate the water depth in the road cross-section. Can the road "contain" the new climate-adjusted flow within the roadway section?

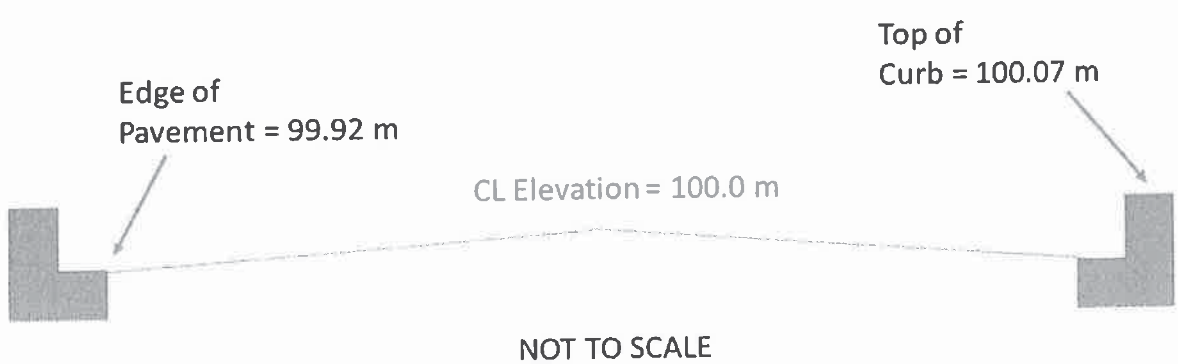

Figure 6. Roadway cross-section.

Marking Scheme

1. (a) 10 marks; (b) 10 marks
2. (a) 10 marks; (b) 10 marks
3. (a) 10 marks; (b) 10 marks
4. 20 marks
5. (a) 7 marks; (b) 7 marks; (c) 6 marks
6. (a) 10 marks; (b) 10 marks