National Exams May 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.

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: $q_l = -\frac{\sum_{\text{loop}} k_i Q_i |Q_i|^{n-1}}{n\sum_{\text{loop}} k_i |Q_i|^{n-1}}$, $n = 1.852$ (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 penstock system carries water from an upstream water reservoir to a downstream reservoir. The penstock pipes are 700 mm in diameter with a 'C' factor of 125 and a length of 4,000 m. The water elevation in the upstream reservoir is 1010 m and the water elevation in the downstream reservoir is 998 m.

a) Calculate the flow through a single penstock with these pipe properties.

b) If a second penstock is installed in parallel to the first one, calculate the flow through the combined penstock system. Is the combined flow higher or lower? Why?

/20 2. A transmission pipeline that conveys water from an upstream reservoir to a downstream reservoir is indicated below. 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 4,500 m, a Hazen-Williams 'C' factor of 110, and an inner diameter of 450 mm. The upstream reservoir has a water level of 102 m. The valve discharge constant is Es = 0.33 $m^{5/2}/s$.

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

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 discharge in the transmission pipeline.

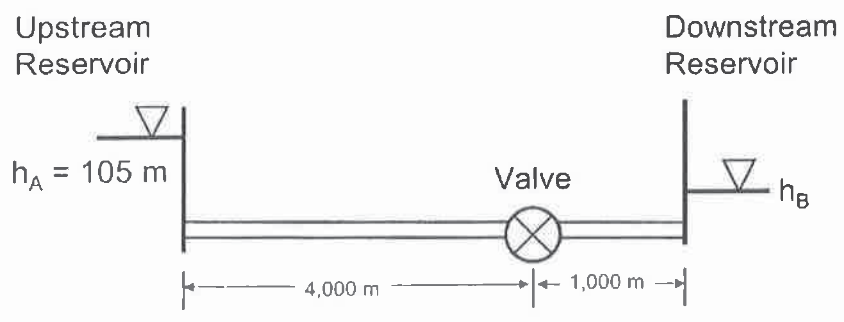

Figure 1. Reservoir-pipe system with valve.

/20 3. An elevated tank with a fixed water level of 71 m supplies water to the distribution network shown in Figure 1. The network has 5 pipes with the following parameters: Length = 420 m, Hazen-Williams 'C' factor = 117, and

Diameter = 205 mm. The 2 demand nodes in the network are at an elevation of 11 m. The demand at the 2 demand nodes are: Q_2 = 200 L/s and Q_3 = 50 L/s. A valve along pipe 3 (P3) is initially closed.

a) Determine the hydraulic grade line (HGL) value at nodes N2 and N3.

b) If valves along pipes P1 and P3 are closed, describe the expected change in water age at nodes N2 and N3 in the system. Give hydraulic reasons in your explanation.

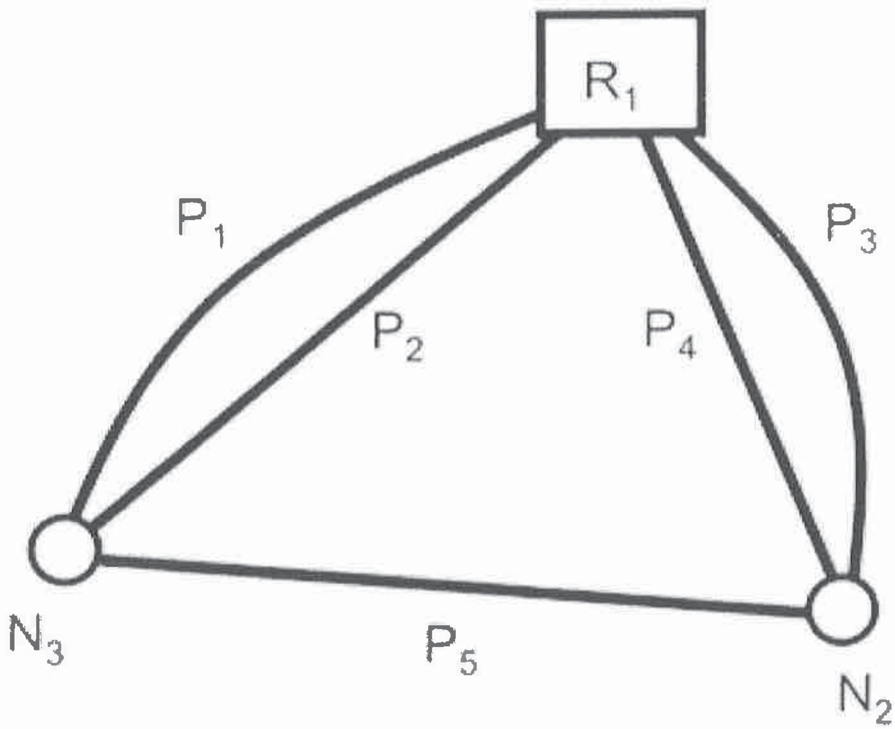

Figure 2. Network layout.

/20 4. The spillway of a dam discharges into a rectangular channel. 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?

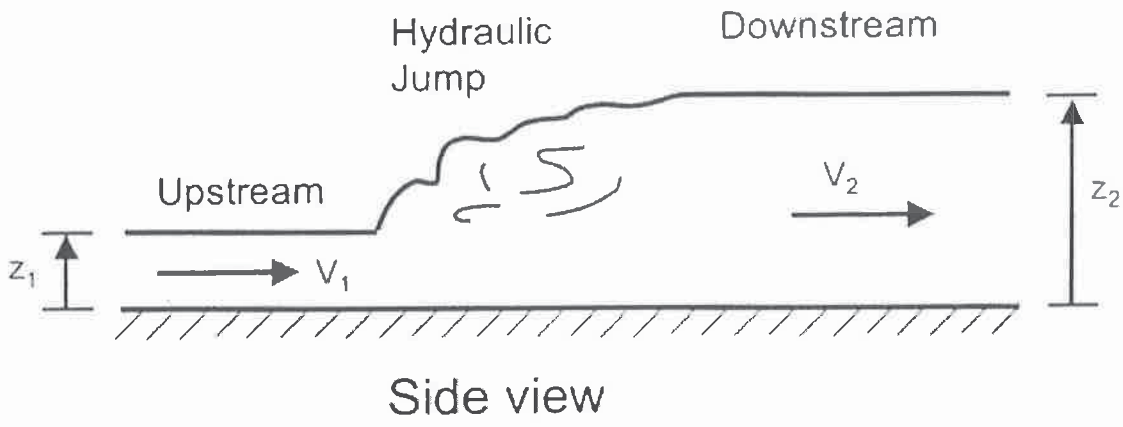

Figure 3. Hydraulic jump.

/20 5. A sudden slope failure causes a large amount of gravel and rock material to slide into a river. This failure completely blocks the flow of the river.

a) Describe the hydraulic conditions just upstream and downstream of the blockage immediately following the slope failure. Structure your explanation in relation to continuity, momentum, and energy principles. Be as specific as possible.

b) Write the St-Venant equations that describe the unsteady, non-uniform flow conditions that might prevail immediately after the slope failure. Describe each term of the St-Venant equations.

/20 6. A rectangular channel carries a flow of 3.0 m^3/s. The rectangular channel has a width of 11 m and sides of height 2.5 m. The Manning's 'n' for the channel is 0.015 and its longitudinal slope is 0.002.

a) Calculate the normal depth in the channel.

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.