National Exams December 2010

**98-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
   - a Casio or Sharp approved calculator is permitted.

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. The following equations may be useful:

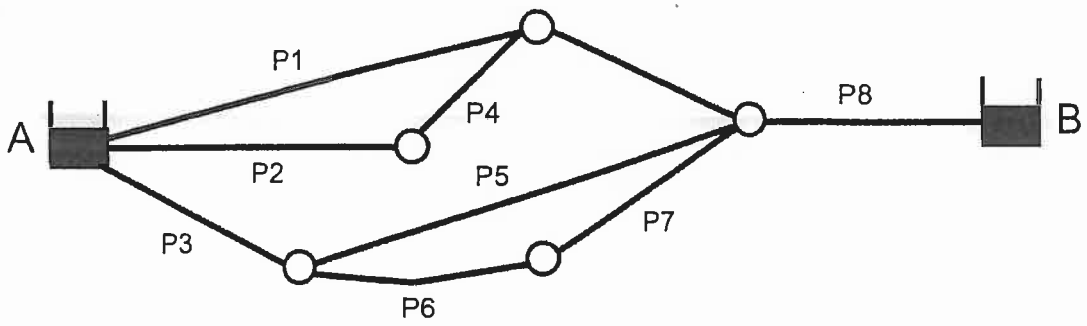
   - Hazen-Williams: $Q = 0.278CD^{2.63}S^{0.54}$, $S=\Delta h/L$
   - Manning's: $Q = \frac{A}{n}R^{2/3}S^{0.5}$, $S=\Delta h/L$
   - Darcy-Weisbach: $\Delta h = \frac{fL}{D}\cdot\frac{V^2}{2g}$
   - Loop Corrections: $q_l = -\frac{\sum_{\text{loop}} k_i Q_i |Q_i|^{n-1}}{n\sum_{\text{loop}} k_i |Q_i|^{n-1}}$,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

5. 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 $\rho$ = 1,000 kg/m$^3$ and kinematic viscosity $\upsilon$ = 1.31 x 10$^{-6}$ m$^2$/s.

/20 1. Eight pipes connect an upstream reservoir A (water elevation 85 m) to a downstream reservoir (water elevation 35 m). Each pipe has a 350 mm diameter, is 450 m long and has a 'C' value of 120.

a) Determine the total flow through this pipe system.

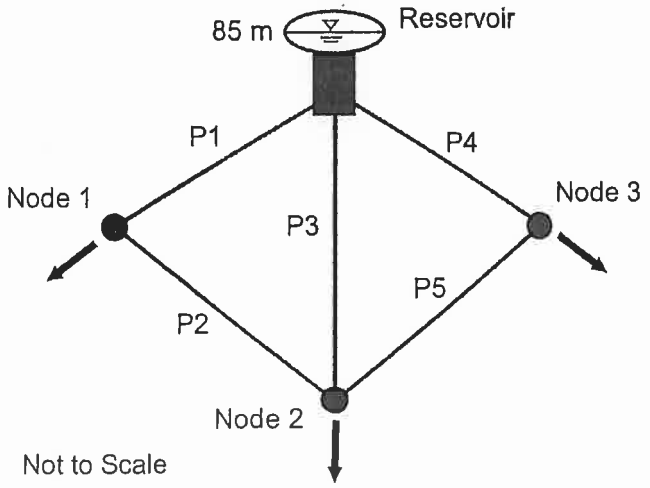
b) If the diameter of the pipes is increased to 400 mm, what will happen to the total flow through the system? Explain in words only.



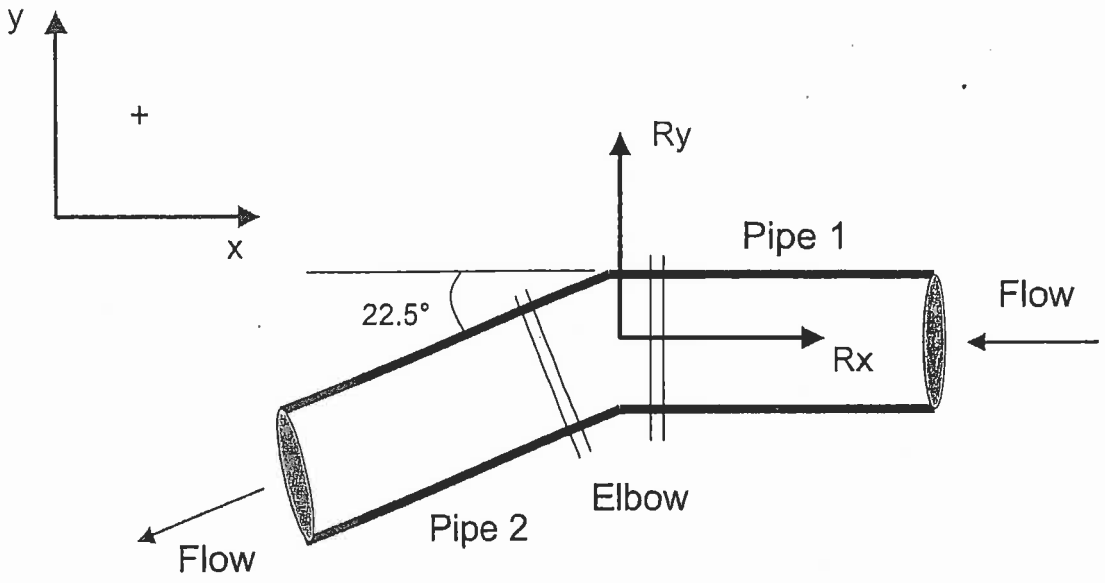

/20 2. A small water distribution network is fed by a reservoir with fixed water elevation of 85 m. The demand at node 1 is 150 L/s, the demand at node 2 is 450 L/s, and demand at node 3 is 235 L/s. All pipes are at an elevation of 15 m, have a diameter of 300 mm, a length of 500 m, and a Hazen-Williams 'C' factor of 130.

a) Determine the pressure head at node 3 if pipes 3 and 4 are closed.

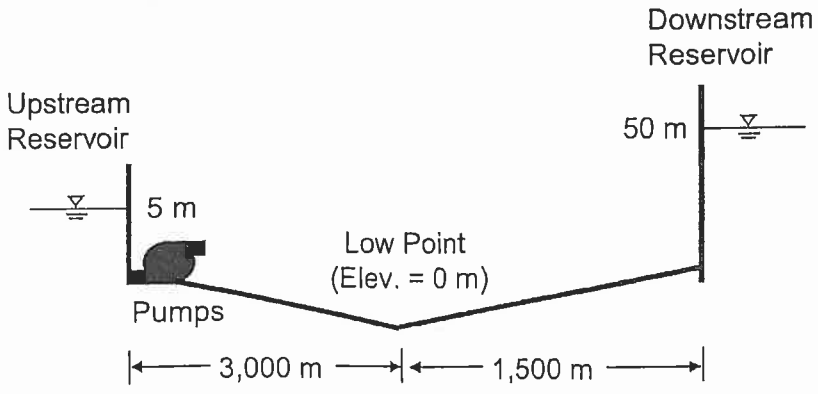
b) Determine the flow in all pipes if only pipes 4 and 5 are closed.



/20 3. A water main conveys 1.5 $m^3/s$ of water at 10°C. A section of the water main has an elbow that deflects the flow downward at an angle of 22.5 degrees from horizontal (see figure). The upstream pipe (Pipe 1) has a diameter of 600 mm and the downstream pipe (Pipe 2) has a diameter of 550 mm. The operating pressure in the water main is 750 kPa. Calculate the forces Rx and Ry that must be applied to the elbow to hold it in place?




/20 4. A pump forces water through a 4.5 km long pipeline. Water is conveyed from an upstream reservoir (water level of 5 m) to a downstream reservoir with water level of 50 m. The pipe has a diameter of 350 mm and a Hazen-Williams 'C' factor of 140. Two pumps are connected in parallel at the upstream reservoir. Each pump has a characteristic curve described by TDH = 80 - 10 $Q^2$, in which TDH is the total dynamic head of the pump (in metres) and Q is the pump discharge in $m^3/s$.




Not to Scale

a) Estimate the total flow supplied by the two pumps in parallel.

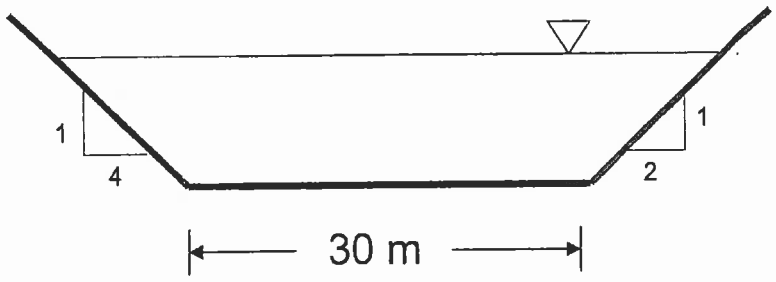
b) For the flow calculated in a), what is the pressure head at the low point?

/20 5. A trapezoidal open channel carries a steady-state flow of 2 $m^3/s$. The bottom width of the channel is 30 m, and the side slopes are indicated in the figure below. The channel is lined with short grass and has a Manning's n of 0.035. The longitudinal slope of the channel is 0.3%.

a) Calculate the critical depth in the open channel.

b) Calculate the normal depth in the open channel.

c) Based on a) and b), is the flow supercritical or sub-critical?




/20 6. 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.

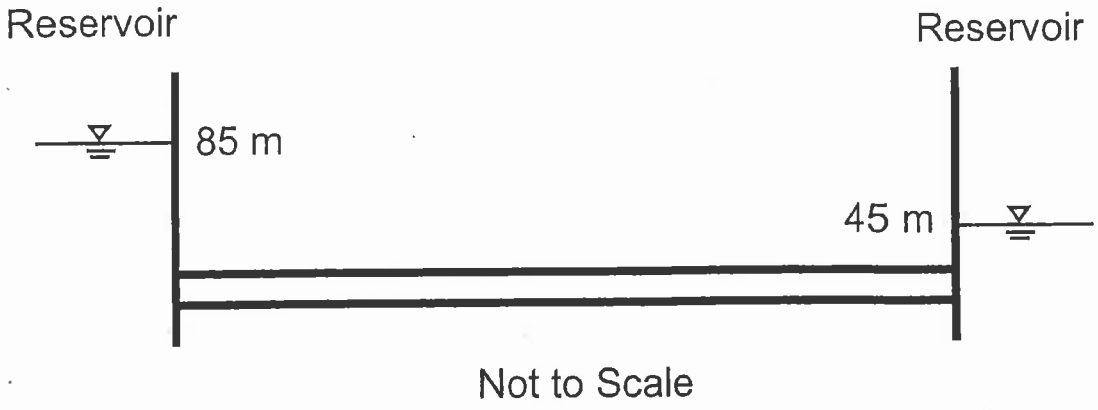
b) Located immediately upstream of the blockage is a storm water sewer outfall from a small town. What potential impact(s) can the river blockage have on the sewer outfall and town? Be as specific as possible.

/20 7. A pipe connects an upstream reservoir with water level at 85 m to a downstream reservoir with water level at 45 m. The pipe centerline is at a single elevation of 15 m.

a) Write the governing equations that describe the quasi-steady state conditions in the reservoir-pipe system.

b) Write the rigid water column model equations that describe incompressible, uniform and unsteady flow conditions in the reservoir-pipe system.

c) Discuss the similarities and differences between the two flow conditions in a) and b).



## Marking Scheme

1. 20 marks total (3 parts times roughly 7 marks each)
2. 20 marks total (3 parts times roughly 7 marks each)
3. 20 marks total (3 parts times roughly 7 marks each)
4. 20 marks total (3 parts times roughly 7 marks each)
5. 20 marks total (4 parts times 5 marks each)
6. 20 marks total (3 parts times roughly 7 marks each)