National Exams May 2010

07-Str-B11, 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 calculator is permitted; a 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. 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: $q_l = -\frac{\sum_{loop} k_i Q_i |Q_i|^{n-1}}{n\sum_{loop} k_i |Q_i|^{n-1}}$, n = 1.852 (Hazen-Williams)
   - Total Dynamic Head: TDH = $H_s + H_f$; H_s=static head; H_f=friction losses

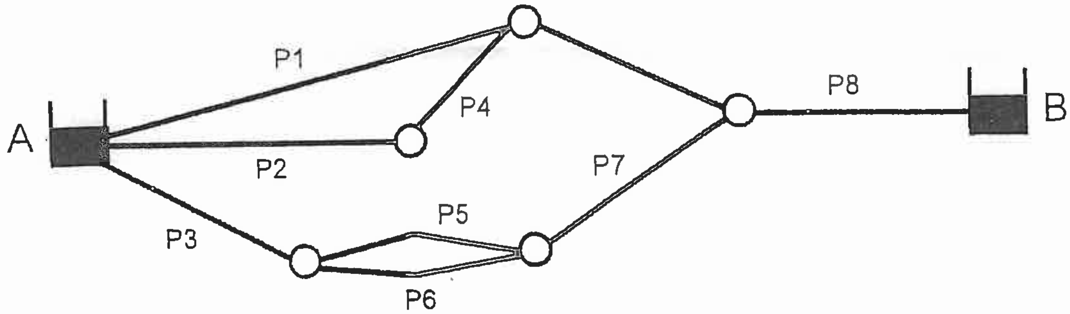
5. Unless otherwise stated, (i) assume that local losses and velocity head are negligible, (ii) that the given values for pipe diameters are nominal pipe diameters and (iii) that the flow involves water with a density ρ = 1,000 kg/m^3 and kinematic viscosity ν = 1.31 x 10^{-6} m^2/s.

/20 1. Eight pipes connect an upstream reservoir A (water elevation 75 m) to an elevated tank (water elevation 45 m). Each pipe has a 250 mm diameter, is 500 m long and has a 'C' value of 140.

a) Determine the total flow through this pipe system.

b) If the diameter of the pipes is increased to 300 mm, what will happen to the total flow through the system?

c) If valves along pipes 5 and 6 are closed in the system, what will happen to the total flow through the system?



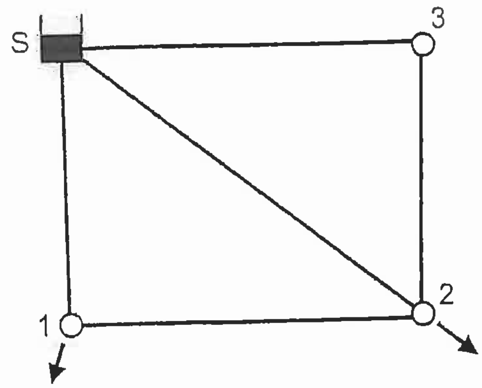
/20 2. A small water distribution network is fed by a reservoir (S) with fixed water elevation of 65 m. The demand at node 1 is 300 L/s, the demand at node 2 is 600 L/s, and there is no demand at node 3.. All pipes are at an elevation of 10 m and have properties given in the table below.

Pipe	Length (m)	Diameter (mm)	'C' Factor
S-1	800	400	100
S-2	1400	500	80
S-3	1200	400	120
3-2	800	450	100
1-2	1200	450	90

a) Determine the flow in all pipes.

b) Describe in words what will happen to the distribution of steady-state pipe flows if the pipe that connects the reservoir to Node 2 is closed.

c) Describe in words what will happen to the distribution of steady-state pipe flows and nodal pressures if demand at Node 3 is increased to 500 L/s (the pipe that connects the reservoir to Node 2 is open again).



/20 3. The water surface in a large reservoir (A) is 40 m above datum while the surface elevation of a second reservoir (C) is at 10 m above datum (as indicated in the sketch below). A 750 mm pipe with a length of 5,000 m and a Hazen-Williams 'C' of 130 connects the reservoirs. There are two identical pumps installed in a series operation in the pumping station. Each pump has the following head-discharge curve

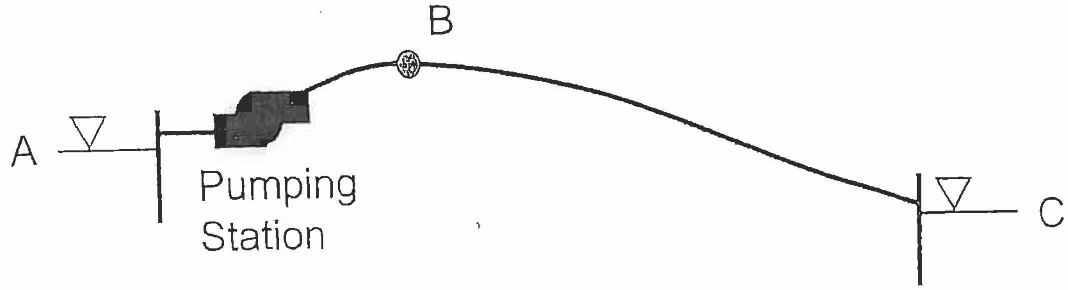
$$H = 20 - 9\ Q^{1.8}$$

in which H is the total dynamic head of the pump (in metres) and Q is the pump discharge (in cubic metres per second).

a) Determine the flow in the pipeline system. Determine the maximum ground elevation at location B (located 1200 m from the upstream reservoir) to provide a minimum pressure head of 25 m at location B.

b) If the ground elevation at location B is 12 m, what flow can the two pumps in series provide while meeting a minimum pressure head of 25 m at location B?

c) Would you recommend series or parallel operation of this system? Why?

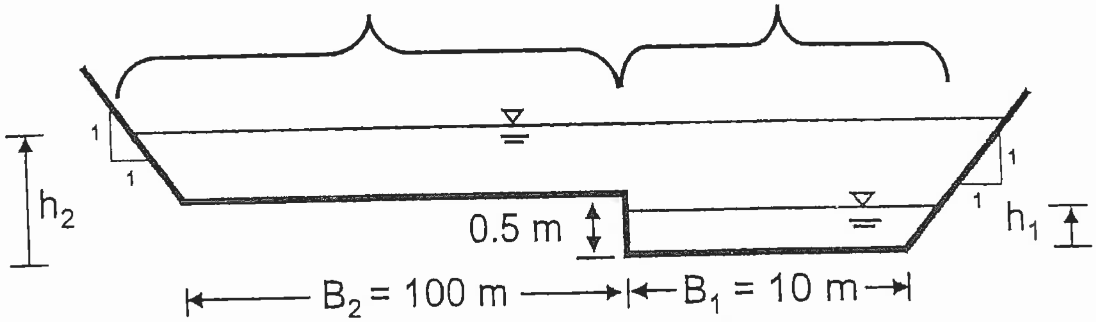


/20 4. The cross section of a river is shown below. The main river channel is lined with short grass and has a Manning's n of 0.035. The over bank area is lined with dense brush and has a Manning's n of 0.150. The longitudinal slope of the river is 0.2%.

a) Compute the water depth, h_1, if the dry weather flow is 1.0 m^3/s. Is the water depth contained in the main channel?

b) Compute the water depth for a flood flow of 30 m^3/s.

c) Show that the best hydraulic section (minimum wetted perimeter for a given cross sectional area) for a rectangular channel occurs when the water depth y is one half the channel width (B).



Not To Scale

/20 5. A 350 mm pipe connects two reservoirs with water levels of 65 m and 25 m, respectively. The pipe centerline is at a fixed datum of 10 m. The pipe has a length of 2,000 m and a 'C' factor of 135.

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) Write the full waterhammer equations for compressible, non-uniform and unsteady flow conditions in the reservoir-pipe system.

d) Discuss the similarities and differences between the three flow conditions in a), b), and c).

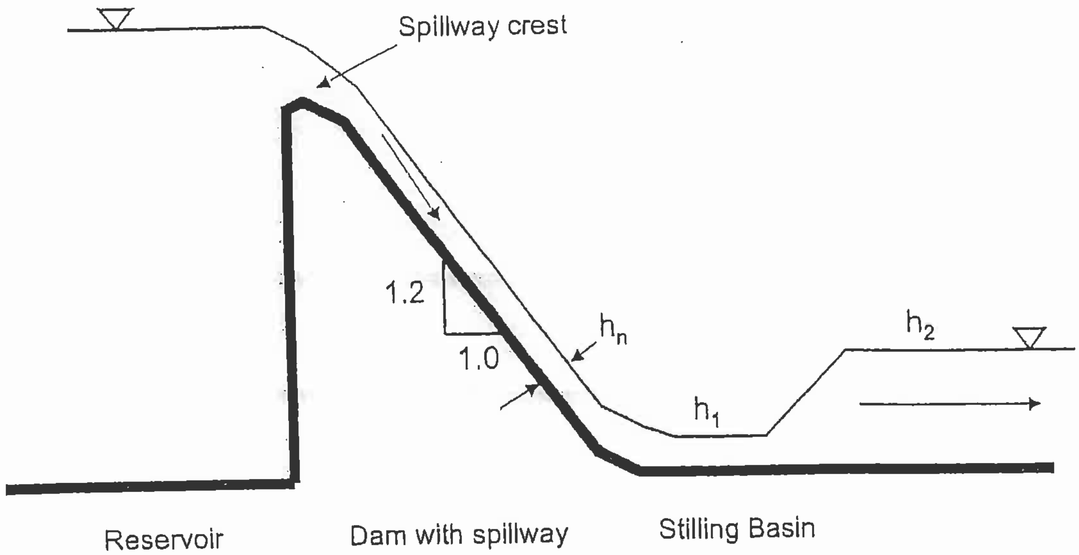
Not to Scale

/20 6. Flow passes over the crest of the dam shown below and into a spillway which has the shape of a rectangular channel. Assume that the flow from the reservoir passes through critical depth at the spillway crest. The spillway of the dam is 80 m in length. The spillway has a width of b = 10 m and a slope of 1.2 vertical on 1.0 horizontal. The spillway has a Manning's n = 0.013.

a) For a discharge of 7.0 m^3/s per meter width of the spillway channel, determine the normal depth h_n along the spillway.

b) Determine the flow velocity and the Froude number along the spillway. Is the flow sub- or super-critical?

c) Determine the downstream depth h_2 and flow velocity V_2 after the hydraulic jump in the stilling basin when the discharge is 6.0 m^3/s per meter width of the spillway. The depth at the toe of the dam is h_1 = 0.4 m. The stilling basin has a rectangular shape with a width of b= 10 m.


Spillway crest
1.2
1.0
hn
h1
h2
Reservoir
Dam with spillway
Stilling Basin