NATIONAL EXAMS MAY 2009

04-Env-A2, Hydrology and Municipal Hydraulics 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 Exam with a candidate prepared 8.5 x 11 double sided Aid-Sheet allowed.

3. Candidates may use one of two calculators, the Casio or Sharp approved models. Write the name and model designation of the calculator on the first inside left hand sheet of the exam work book.

4. Any five(5) questions constitute a complete paper. Only the first five(5) answers as they appear in your work book(s), will be marked.

5. Each question is worth a total of 20 marks with the section marks indicated in square brackets ( ) at the left margin of the question. The complete Marking Scheme is also provided on the final page. A completed exam consists of five (5) answered questions with a possible maximum score of 100 marks.

Problem 1

Provide answers to the following questions related to *components* and *processes* of the *natural hydrologic cycle*, *precipitation*, *runoff*, *storm frequency* and *duration analysis*.

(i) Compare and contrast the following hydrologic terms related to the hydrologic cycle.

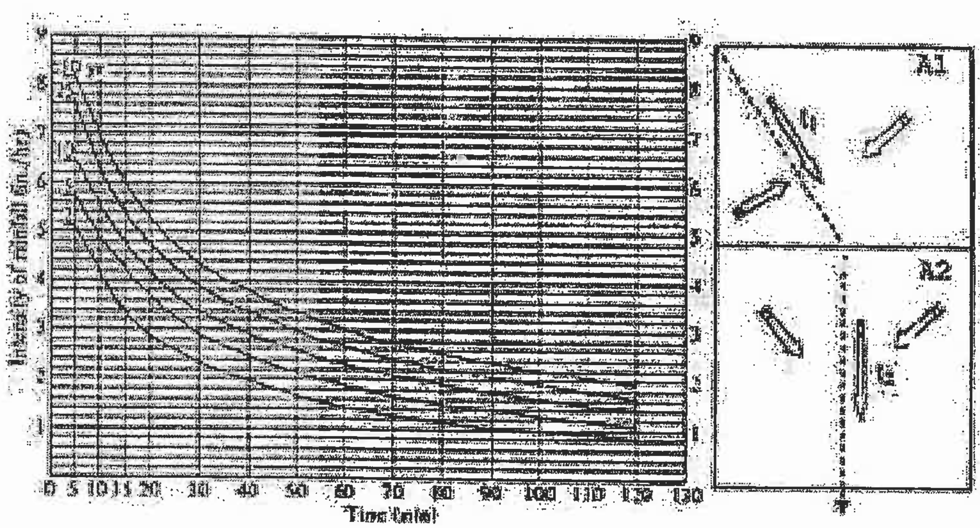
(3) (a) Infiltration and baseflow

(3) (b) Evaporation and evapotranspiration

(3) (c) Surface runoff and groundwater flow

(6) (ii) Use the Rational Formula to determine the 25-year design peak runoff (m^3/min) for the catchment areas (A1 and A2) shown below. Assume that the intensity duration frequency (IDF) curves given below are applicable for these areas. Use the following design information:

Area Label	Area (*ha*)	Runoff Coefficient C	Time of Concentration t (*min*)
A1	25	0.3	50
A2	50	0.7	120



(5) (iii) Briefly explain two (2) assumptions associtated with the Rational Formula and how they affect the calculated peak flow rate.

Problem 2

Provide answers to the following questions related to *conceptual models of runoff*, *streamflow* and *probability frequency hydrograph analysis* related to *floods*.

(6) (i) Briefly explain the importance of calibration in runoff conceptual models and explain two (2) aspects of calibration that cause difficulties.

(ii) Briefly explain how the following measuring devices can be used to measure *streamflow*:

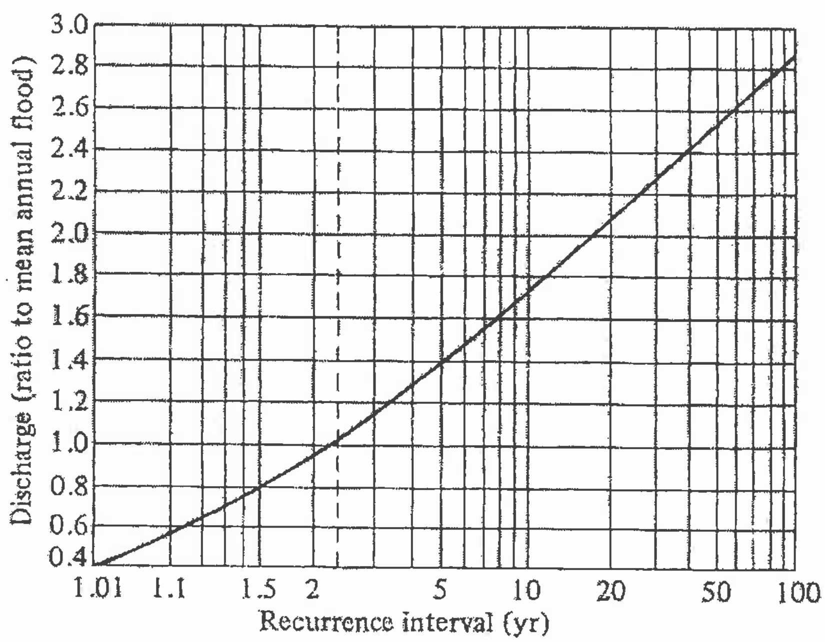
(5) (a) Parshall flume; and

(5) (b) V-notch weir.

(4) (iii) Using the regional frequency curve below, determine the 20-year peak flood flow for a 1000 hectare drainage basin. Assume that the mean annual flood flow coefficient C is 25 and regression equation is given by:

$$Q = C \cdot A^{0.7}$$

where Q = mean annual flow (m^3/s)
A = drainage area in (km^2)



Problem 3

Provide answers to the following questions related to *hydraulics of closed pipe systems, open channel flows* under *uniform* and *gradually varied flow* conditions.

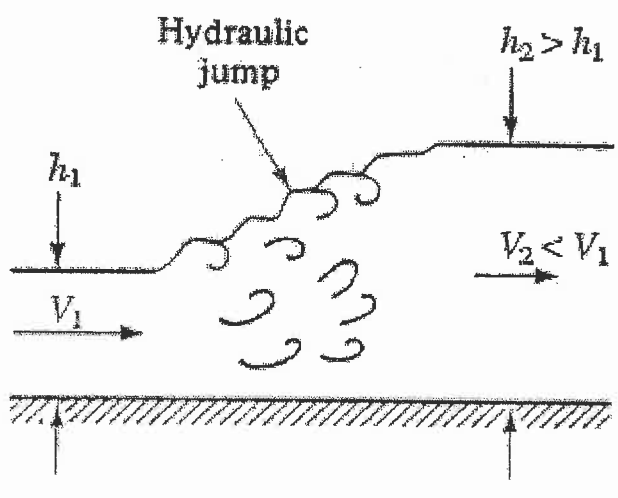
(6) (i) A sewer pipe of diameter D = 1 m at a slope S of 1% (1 m vertical drop over a horizontal distance of 100 m) carrying sewage from a small town and discharging into a river. The sewer pipe is concrete with a Manning's roughness coefficient n=0.2. Assuming that the sewage has the characteristics of water, calculate the maximum pipe capacity and the type of flow under these conditions (i.e., laminar or turbulent).

(ii) A concrete tile lined channel with a rectangular cross-section experiences uniform flow at a normal depth of 5 m. The base width is 6 m. Using an appropriate Manning's n and a bed slope S_o of 3 %, calculate the following:

(4) (a) The discharge flow rate Q in m^3/s; and

(3) (b) Reynolds number Re and type of flow (i.e., laminar or turbulent).

(7) (iii) The upstream depth and velocity are $h_1 = 2\ m$ and $V_1 = 5\ m/s$ (see figure below). Use continuity and momentum conservation to calculate the downstream depth h_2 and velocity V_2. Assume that friction can be ignored.



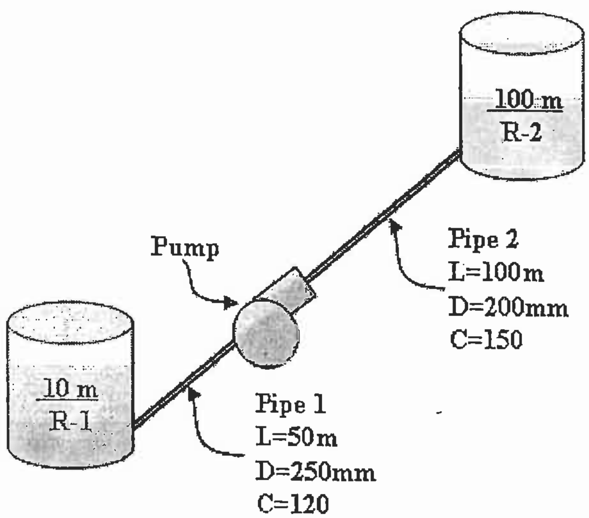
Problem 4

Provide answers to the following questions related to *water distribution systems, storage reservoirs* and a *wastewater collection system.*

(5) (i) Briefly explain how the conservation of energy equation (below) is taken into account in the analysis and design of water distribution systems. Note that the subscripts 1 and 2 in the energy equation below refer to two points in a water network system.

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + \sum h_p = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \sum h_L + \sum h_M$$

(5) (ii) Determine the approximate pump head in m needed to deliver water at a rate of 200 L/s from reservoir R-1 (10 m level) to reservoir R-2 (100 m level) shown in the figure below. Compute the friction head losses using the Hazen-Williams equation and pipe characteristics (*L*, *D* and *C*) provided in the figure.



(5) (iii) The demand to reservoir 2 (R-2) is doubled to 400 L/s during a peak event that lasts 4-hours. Briefly describe, without detailed calculations, two methods that would allow the distribution system to satisfy the peak event.

(5) (iv) Calculate the minimum slope of a 300 mm diameter plastic sanitary sewer to convey a peak flow of 4 ML/d and ensure that a minimum 0.6 m/s scour velocity is met at a low flow of 1 ML/d. Clearly state any necessary assumptions.

Problem 5

Provide answers to the following questions related to *sediment transport, hydrualics of closed pipe systems* and *stormwater collection system design.*

(5) (i) The Rouse number P dictates the mode of sediment transport. Explain what this equation represents physically and provide values of P which mean that sediment shows little movement and the sediment is in suspension. Recall that the Rouse number may be given as :

$$P = \frac{w_s}{k \cdot u_*}$$

where w_s= particle settling velocity

k = Von Karman's constant

u_*= particle shear velocity

(5) (ii) Briefly explain how the concept of conservation of mass equation (below) is used in the hydraulic analysis of closed pipe systems. Note that the j refers to a specific pipe node and S to the storage in the closed pipe system.

$$\sum_{j=1}^{n} (Q_{in} - Q_{out})_j - \frac{dS}{dt} = 0$$

(iii) Briefly explain the function and key hydraulic principles of design for the following stormwater collection system components:

(5) (a) Stormwater pumping station

(5) (b) Culvert

Problem 6

Provide answers to the following questions related to *urban stormwater management* and *runoff control system design.*

(5) (i) Briefly describe an appropriate design for a stormwater management (STWM) pond that is capable of removing more than 80% TSS and 40% TP from the runoff of a 10 hectare industrial park.

(5) (ii) Briefly explain the primary difference in the design basis of a dry and wet ponds. In the case of a wet pond, provide a sketch showing the main structure that maintains a desired water level in the pond.

(5) (iii) Briefly explain the benefit of on-site stormwater management facilities versus end-of-pipe facilities. In your answer, provide an example of each.

(5) (iv) Explain how on-site and end-of-pipe urban stormwater runoff control systems may be used to reduce downstream flooding and erosion during a 1:100 year design storm event. In your explanation, provide the key design objectives for the end-of-pipe system *only.*

Problem 7

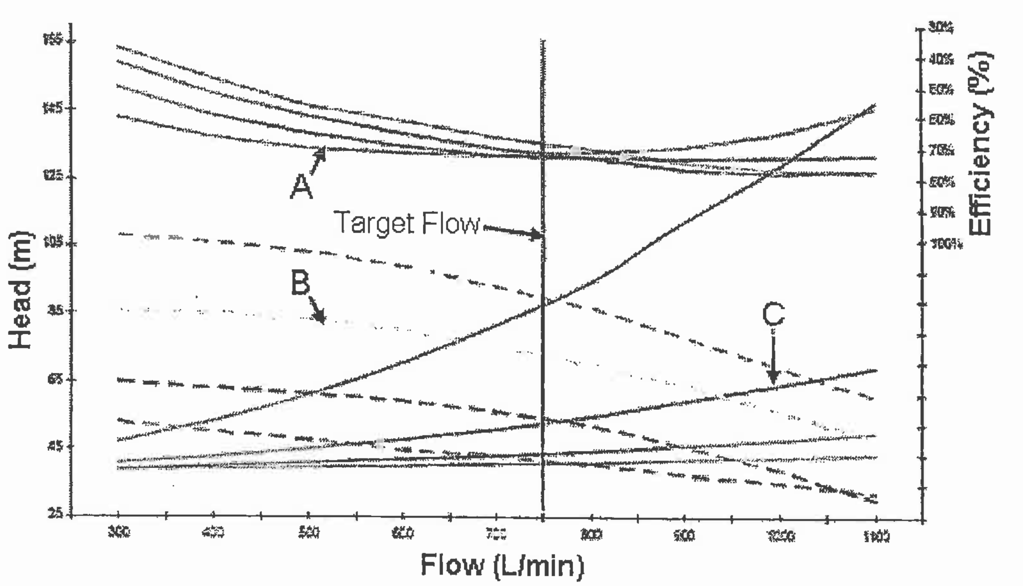
Provide answers to the following questions related to *basic pumps or prime movers* by considering the figure below:

(5) (i) From the figure below, identify the system, pump performance and efficiency curves (A, B or C) and estimate the highest operating point giving the pump head, flow and efficiency.

(5) (ii) Briefly explain, using a sketch of the pump-system curves when it is advisable to use pumps in parallel or in series for a system expansion. In your sketch, you should identify the existing operating point and the new operating point for the system expansion.

(5) (iii) From the figure below, identify the system curve with ample pipe capacity and the one with limited pipe capacity and explain how you might increase the system capacity in an affordable way.

(5) (iv) Briefly explain, when two pumps operate in parallel, why the combined flow (Q_s in L/min) delivered is not simply the flows of the individual pumps added together and why the total flow capacity depends on the system curve.



Marking Scheme

1. (i) (a) 3, (b) 3, (c) 3, (ii) 6, (iii) 5 marks, 20 marks total
2. (i) 6, (ii)(a) 5, (b) 5, (iii) 4 marks, 20 marks total
3. (i) 6 (ii) (a) 4, (b) 3, (ii) 7 marks, 20 marks total
4. (i) 5, (ii) 5, (iii) 5, (iv) 5 marks, 20 marks total
5. (i) 5, (ii) 5, (iii) (a) 5, (b) 5 marks, 20 marks total
6. (i) 5, (ii) 5, (iii) 5, (iv) 5 marks, 20 marks total
7. (i) 5 (ii) 5 (iii) 5 (iv) 5 marks, 20 marks total