# NATIONAL EXAMS MAY 2012

# 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 $8\frac{1}{2}''$ 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 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 *conceptual models of runoff, hydraulics of closed pipe systems* and *water distribution systems.*

(8) (i) Conceptual runoff models are frequently used for both forecasting and predictions. Briefly describe three (3) important properties of conceptual models of runoff, how such models can be used and verified.

(ii) Consider water flowing though a Concrete pipe having length $L$ of 300 $m$, diameter $d$ of 600 $mm$ and a full flow rate of 400 $L/s$. Calculate the following and identify any assumptions you make:

(2) (a) The average fluid velocity $V$ in $m/s$.

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

(2) (c) Pipe friction loss $H_f$ in $m$.

(6) (iii) Briefly explain the basic principles of the Hardy-Cross method used to anlyze water distribution systems. Use figures, tables and/or equations to provide your explanation.

## Problem 2

Provide answers to the following questions related to *precipitation and snow melt, stormwater collection system design* and *wastewater collection system.*

(6) (i) Consider the various hydrologic processes in a typical watershed and briefly explain why only a fraction of precipitation or snow melt is converted to infiltration.

(6) (ii) Briefly explain the function or importance of the following components/concepts of a stormwater collection system design:

(a) Hydraulic radius of a pipe;

(b) Peaking factor (e.g., Harmin-Babbit Formula); and

(c) Time of concentration

(8) (iii) Briefly explain the function or importance of the following components of a wastewater collection system:

(a) Drop manhole structures;

(b) Infiltration/inflow; and

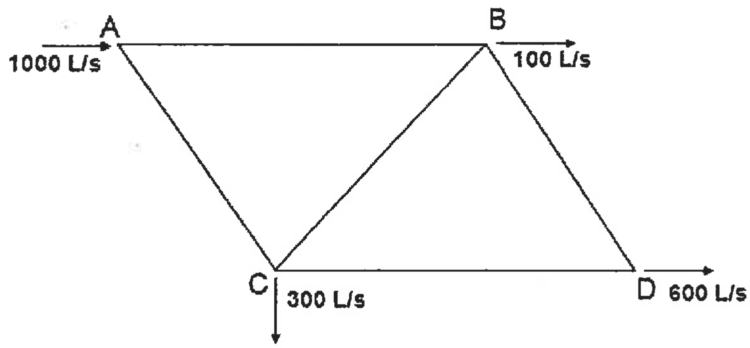
(c) Combined sewer system

## Problem 3

Provide answers to the following questions related to *pipe networks* and *basic pumps or prime movers*.

(8) (i) Solve for the flows in each pipe of the pipe network below using the Hardy-Cross or similar method, given the following pipe lengths (L) and corresponding diameters (d):

| Pipe | Length (m) | Diameter (mm) |
|---|---|---|
| AB | 400 | 300 |
| BC | 600 | 150 |
| CD | 400 | 200 |
| AC | 500 | 200 |
| BD | 500 | 250 |




(4) (ii) Provide a schematic of a typical System Head Curve showing two (2) pumps in parallel operation. Show the individual and combined system curve, the operating point and shutoff head in each case.

(4) (iii) Briefly explain two (2) methods to control water hammer in water distribution systems caused by the starting and stopping of pumps.

(4) (iv) Briefly explain two (2) reasons for the use of booster pumping stations.

## Problem 4

Provide answers to the following questions related to *sanitary sewers design*, *runoff control system design* and *probability frequency hydrograph analysis* related to *floods*.

(6) (i) You have been asked by the project manager to design a sanitary sewer to convey a peak flow of 5 $m^3/s$ when flowing full with a bedding slope of 5%. The senior engineer advises that the flow velocity must be greater than 0.6 $m/s$ and less than 7 $m/s$ and that a PVC pipe with a Manning's $n$ of 0.015 is to be used. Calculate the required diameter $d$ in $mm$ for this sewer.

(6) (ii) Briefly describe one (1) on-site and one (1) off-site stormwater runoff quality control system. For each system, provide one (1) advantage and one (1) disadvantage to their use from the perspective of a municipality that is expected to operate and maintain these systems over a 25-year design life.

(8) (iii) Given the maximum annual instantaneous flows form the French River in Ontario over a 20-year period (below), *explain the method* of fitting this data to a curve of best fit to determine the magnitude of the flood equalled or exceeded once in 25, 50 or 100 years .

| Year | Discharge ($m^3/s$) | Year | Discharge ($m^3/s$) | Year | Discharge ($m^3/s$) | Year | Discharge ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| 1930 | 330 | 1935 | 350 | 1940 | 630 | 1945 | 300 |
| 1931 | 420 | 1936 | 300 | 1941 | 530 | 1946 | 350 |
| 1932 | 500 | 1937 | 530 | 1942 | 400 | 1947 | 400 |
| 1933 | 700 | 1938 | 630 | 1943 | 390 | 1948 | 500 |
| 1934 | 350 | 1939 | 830 | 1944 | 230 | 1949 | 600 |

## Problem 5

Provide answers to the following questions related to *components* and *processes* of the *natural hydrologic cycle* and *stormwater collection system design.*

(5) (i) Provide a schematic showing the natural hydrologic cycle identifying five (5) key processes and briefly explain three (3) important interactions between any two (2) of the five (5) processes.

(5) (ii) Briefly explain the connection between watershed hydrologic modelling and the efficient design of storm sewers.

(5) (iii) Briefly explain how infiltration or inflow is taken into account when designing stormwater collection systems.

(5) (iv) Briefly explain why drop structures or overflows are used in the design of stormwater collection systems.

## Problem 6

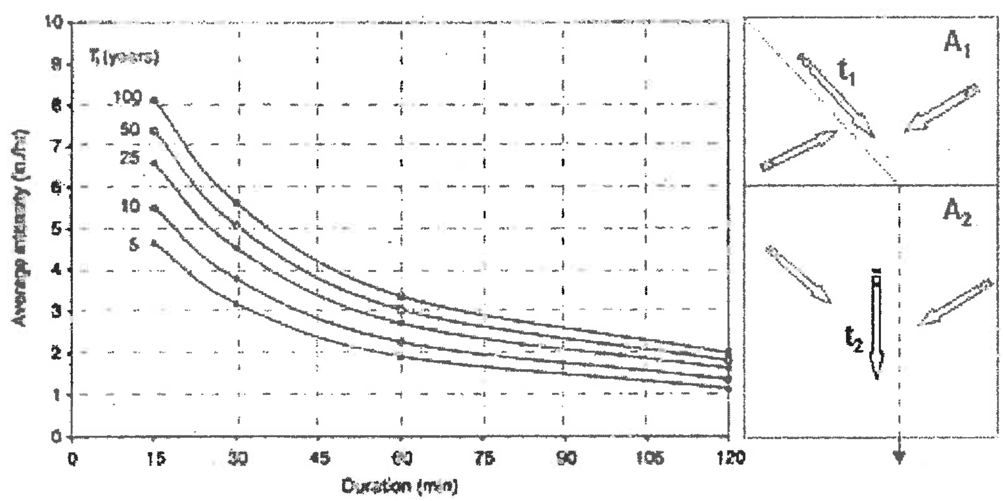
Provide answers to the following questions related to *urban stormwater management* and *intensity-duration frequency (IDF) analysis curves.*

(6) (i) Explain the purpose and key design basis of a *stormwater dry pond* for quantity or quality control of surface runoff from an urban watershed.

(6) (ii) Assume that a stormwater management pond is discharging to a cold-water fishery receiver with a regulated maximum water temperature of 10 *°C* (this temperature is to be maintained even during summer). Suggest two (2) approaches, either pond design or other mitigating measures, to reduce temperature impacts from the pond discharge events. Provide a sound engineering argument for your suggestions.

(8) (iii) Use the Rational Formula to determine the 100-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 this area. Use the following design information:

| Area Label | Area (*ha*) | Runoff Coefficient C | Time of Concentration t (*min*) |
|---|---|---|---|
| A1 | 30 | 0.6 | 60 |
| A2 | 40 | 0.4 | 105 |



## Problem 7

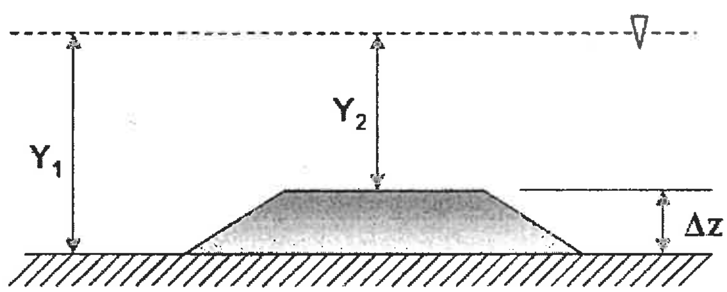
Provide answers to the following questions related to *open channel flows* under *uniform* and *gradually varied flow* conditions and *streamflow*.

(i) A concrete lined rectangular channel experiences uniform flow at a normal depth of 5 *m*. The base width is 15 *m*. Using an appropriate Manning's $n$ and a bed slope $S_o$ of 2 % calculate the following:

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

(4) (b) Froude number $Fr$ and flow regime (e.g., supercritical, subcritical).

(7) (ii) Assume that the channel has a flowrate of 20 $m^3/s$ at a normal flow depth $Y_1$ of 3 *m*. Calculate the depth of flow $Y_2$ in a section of the channel, 20 *m* downstream, in which the bed rises $\Delta Z$ equal to 0.8 *m*. Consider the figure below, assume frictional losses are negligible and you may use the *specific energy* equations between the two sections.




(6) (iii) Briefly explain how a stream stage-discharge relationship is generated and how it can be used to determine the crest height of a river during a large storm event.

# Marking Scheme

1. (i) 8, (ii) (a) 2, (b) 2, (c) 2, (iii) 6 marks, 20 marks total
2. (i) 6, (ii) 6, (iii) 8 marks, 20 marks total
3. (i) 8, (ii) 4, (iii) 4, (iv) 4 marks, 20 marks total
4. (i) 6, (ii) 6, (iii) 8 marks, 20 marks total
5. (i) 5, (ii) 5, (iii) 5, (iv) 5 marks, 20 marks total
6. (i) 6, (ii) 6, (iii) 8 marks, 20 marks total
7. (i) (a) 3, (b) 4, (ii) 7, (iii) 6 marks, 20 marks total