# NATIONAL EXAMS DECEMBER 2017

# 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.

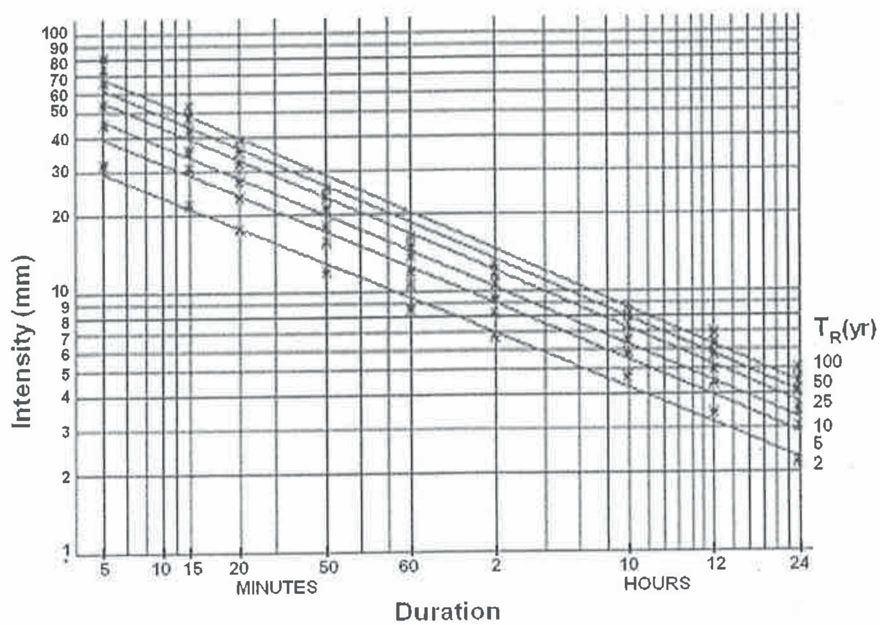
# Problem 1

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

(8) (i) Provide a schematic showing the natural hydrologic cycle identifying four (4) key components and briefly explain three (3) main interactions between the processes.

(7) (ii) Use the Rational Formula to determine the 100-year design peak runoff ($m^3/min$) for the catchment areas (A1 and A2 in table below). Assume that the intensity duration frequency (IDF) curves (in figure below) are applicable for this area. Use the following design information.

| Area Label | Area (*ha*) | Runoff Coefficient C | Time of Concentration t (*min*) |
|---|---|---|---|
| A1 | 20 | 0.5 | 70 |
| A2 | 30 | 0.8 | 100 |




(5) (iii) The runoff coefficient *C* is the variable in the rational method that is most susceptible to errors. Explain the meaning of *C* and suggest two (2) methods that may be used to reduce its susceptibility to errors in a large urban watershed.

## Problem 2

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

(7) (i) Briefly describe three (3) important properties of conceptual models of runoff and give an example of such a model and how it would be used.

(7) (ii) Explain the derivation and use of the stage-discharge approach in predicting streamflow. In your explanation, discuss two (2) key parameters that affect the confidence level of the predicted streamflow over a 25-year period.

(6) (iii) Given the maximum annual instantaneous flows from the Rainy River in Northern Ontario over a 12-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 40 or 80 years .

| Water Year | Discharge $(m^3/s)$ | Water Year | Discharge $(m^3/s)$ | Water Year | Discharge $(m^3/s)$ |
|---|---|---|---|---|---|
| 1950 | 420 | 1954 | 550 | 1958 | 830 |
| 1951 | 530 | 1955 | 500 | 1959 | 730 |
| 1952 | 650 | 1956 | 530 | 1960 | 600 |
| 1953 | 820 | 1957 | 630 | 1961 | 690 |

## Problem 3

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

(10) (i) Briefly explain how on-site and end-of-pipe urban stormwater management (STWM) systems are used to reduce downstream flooding and erosion. As part of your explanation, provide two (2) key design principles and two (2) objectives of a wet-pond.

(10) (ii) Describe three (3) methods of runoff control indicating one advantage and one disadvantage for each method.

## Problem 4

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) Consider water flowing though a corrugated steel pipe having a length $L$ of 1200 $m$, a diameter $d$ of 600 $mm$ and a full flow velocity of 3 $m/s$. Calculate the following:

(a) The average flow rate $Q$ in $m^3/min$.

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

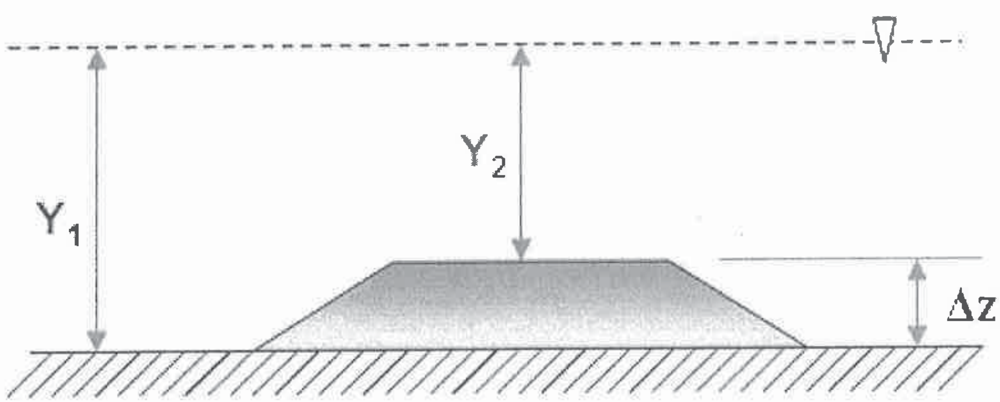
(c) Pipe head loss $H_f$ in $m$.

(ii) A grass lined trapezoidal channel experiences uniform flow at a normal depth of 4 $m$. The base width is 5 $m$ and the side slopes are equal at a H:V of 1:3. 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 $m^3/s$.

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

(7) (iii) Assume that the channel has a flowrate of 15 $m^3/s$ at a normal flow depth $Y_1$ of 3 $m$. Calculate the depth of flow $Y_2$ in a section of the channel in which the bed rises $\Delta z$ equal to 0.6 $m$. See figure below, assume frictional losses are negligible and consider the *specific energy* at the two sections.



# Problem 5

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

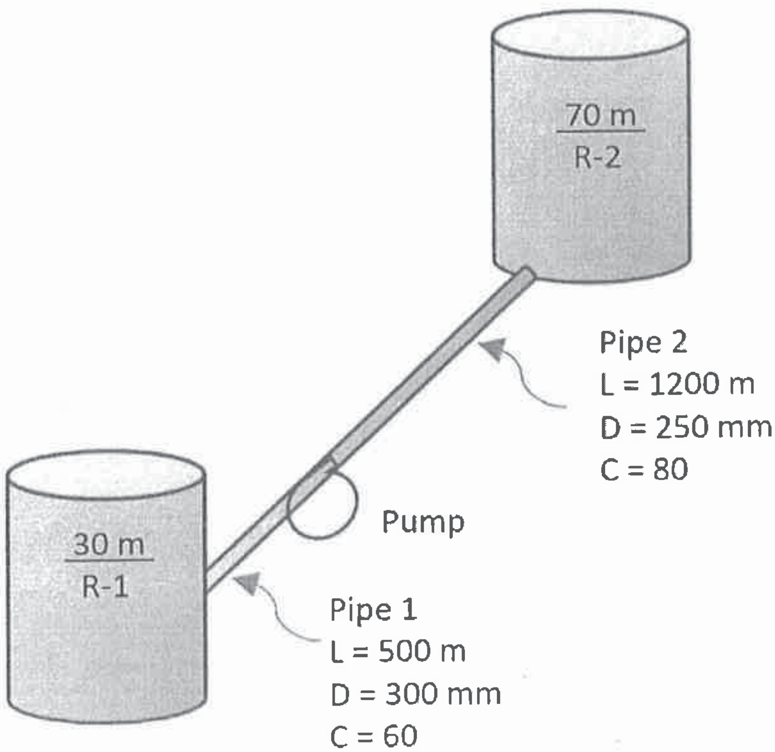
(6) (i) Briefly explain two (2) good locations to locate a water storage reservoir within a distribution system and give three (3) reasons why.

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

(a) Sanitary forcemain; and

(b) Sanitary drop manhole structure;

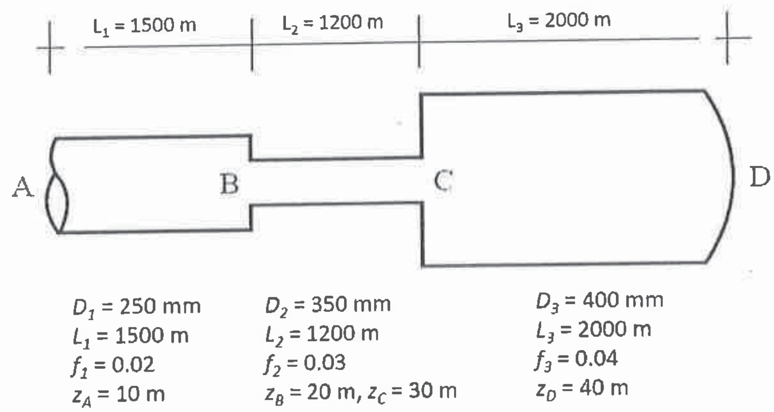
(8) (iii) Determine the approximate pump head in $m$ needed to deliver water from reservoir R-1 to reservoir R-2 shown (see figure below) at a rate of 150 $L/s$. Compute the friction head losses using the Hazen-Williams equation and pipe characteristics ($L$, $D$ and $C$) provided in the figure. Clearly state any assumptions.



# Problem 6

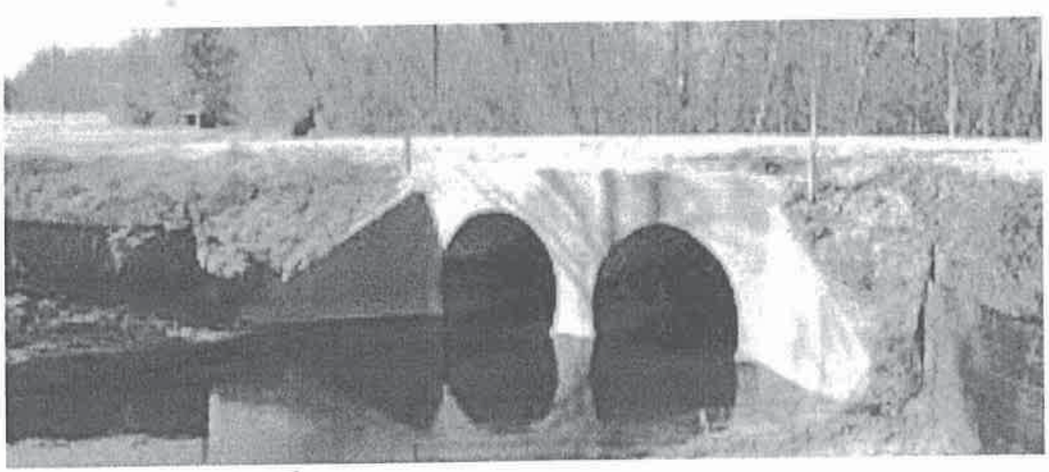
Provide answers to the following questions related to *pipe networks*, *network design* and the *design of sanitary sewers.*

(8) (i) For a flowrate of 100 L/s, determine the pressure head at points B and D in the series of pipes shown below. Assume fully turbulent flow in all cases and pressure head at point A is 50 m. Clearly state any assumptions made.




(6) (ii) Briefly explain the Hardy Cross or a similar method used in network designs and as part of your explanation, discuss how the two (2) key conservation principles are applied.

(6) (iii) 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 85% full with a bedding slope of 3%. The senior engineer advises that the flow velocity must be greater than 0.6 $m/s$ and less than 6 $m/s$ and that a corrugated steel pipe with a Manning's $n$ of 0.02 must be used. Calculate the required diameter $d$ in $mm$ for this sewer.



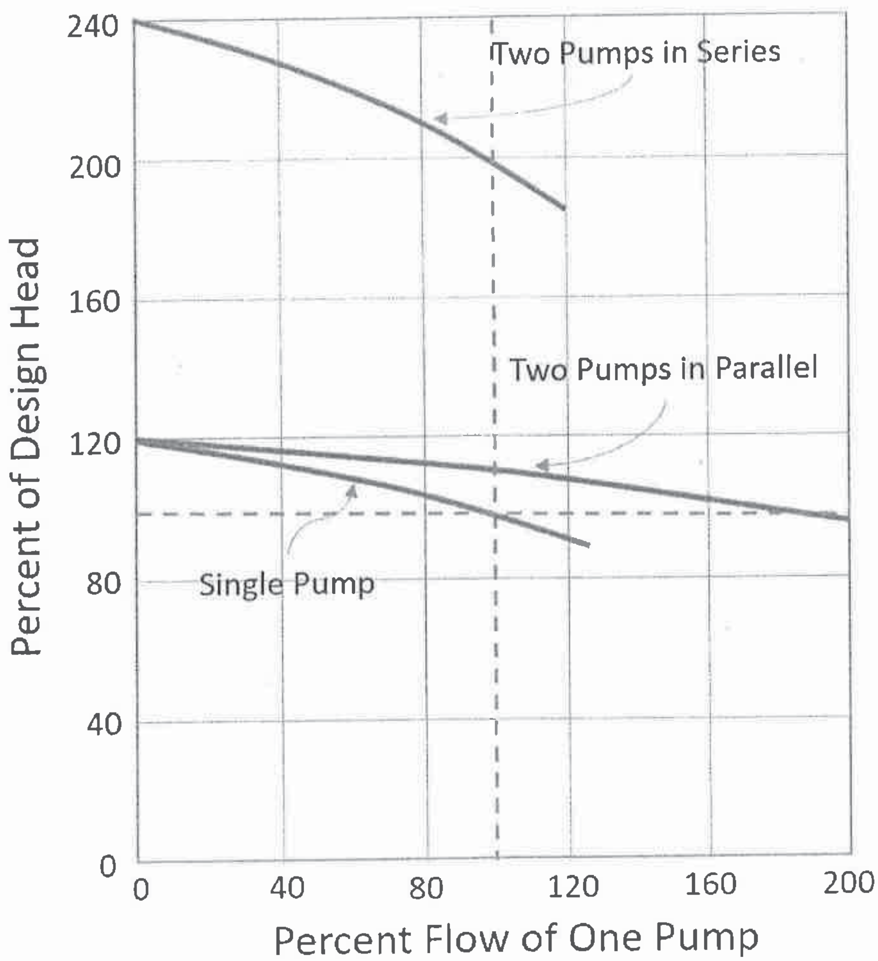
## Problem 7

Provide answers to the following questions related to *stormwater collection system design* and *basic pumps or prime movers*.

(8) (i) Give an example of a minor and a major stormwater collections system components and briefly explain the primary function of each system and how they integrate within an urban stormwater collection system design.

(7) (ii) With reference to pumped systems, briefly explain what cavitation is, under what conditions it occurs and one (1) way to eliminate or reduce its undesirable effects.

(5) (iii) In the schematic below, briefly explain the "Two Pumps in Series" curve delivers the same flow at twice the head and the "Two Pumps in Parallel" curve delivers twice the flow at the same head with reference to the the "Single Pump" curve.



# Marking Scheme

1. (i) 8 (ii) 7, (iii) 5 marks, 20 marks total
2. (i) 7, (ii) 7, (iii) 6 marks, 20 marks total
3. (i) 10 (ii) 10 marks, 20 marks total
4. (i) 6, (ii) (a) 4, (b) 3 (iii) 7 marks, 20 marks total
5. (i) 6, (ii) 6, (iii) 8 marks, 20 marks total
6. (i) 8, (ii) 6, (iii) 6 marks, 20 marks total
7. (i) 8, (ii) 7, (iii) 5 marks, 20 marks total