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 2-sided \((8\frac{1}{2}" \times 11")\) AID SHEET prepared by the candidate allowed.

3. The candidate may use one of two calculators, the Casio or Sharp approved models. Note that you must indicate the type of calculator being used. 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 equally weighted at twenty (20) points for a total of a possible one-hundred (100) points for a complete paper.
Problem 1

Provide answers to the following questions related to hydraulics of closed pipe systems, design of sanitary sewers and stormwater collection system design.

(6) (i) You have been asked by the project manager to design a sanitary sewer to convey a peak flow of 10 m$^3$/s when flowing 80% full with a bedding slope of 3%. The senior engineer advises that the flow velocity must be greater than 1 m/s and less than 10 m/s and that a concrete pipe with a Manning's $n$ of 0.025 is to be used. Calculate the required diameter $d$, in mm, for this sewer.

(6) (ii) For a 250 mm sanitary sewer, the recommended minimum and maximum slope is 0.28% and 12%, respectively. Provide a brief explanation for the minimum and maximum slope recommendations and give an example of an alternative design to avoid the steep slopes in sanitary sewer design.

(8) (iii) Given an 800 mm diameter storm sewer with depth of flow ($h$) of 500 mm, Manning $n$ of 0.02 and slope of 2%, calculate the discharge ($Q$) and velocity ($V$). At what depth is the approximate peak discharge through this pipe? You may use the diagram and equations below to assist you in answering this question.

\[ h = \frac{D}{2} \left[ 1 - \cos \left( \frac{\theta}{2} \right) \right] \]

\[ A = D^2 \left[ \frac{\theta - \sin \theta}{8} \right] \]

\[ P = \frac{D \theta}{2} \]

\[ Q = \frac{A}{n} \left[ \frac{A}{P} \right] \frac{\theta - \sin \theta}{\theta^{5/3}} - \frac{20.16 n Q}{D^{8/3} S_0^{1/2}} = 0 \]
Problem 2

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

(i) A clay tile lined trapezoidal channel experiences uniform flow at a normal depth of 3 m. The base width is 6 m and the side slopes are equal at a H:V of 1:2. Using an appropriate Manning's n and a bed slope $S_o$ of 2 % calculate the following:

(4)
(a) The discharge flow rate $Q$, in m$^3$/s.
(b) Reynolds number $Re$ and type of flow (i.e., laminar or turbulent).
(c) The Froude number $F$ associated with this flow and hydraulic significance.

(8) (ii) Assume that the channel has a flowrate of 10 m$^3$/s at a normal flow depth $y_1$ of 2 m. Calculate the depth of flow $y_2$ in a section of the channel in which the bed rises $\Delta Z$ equal to 0.5 m. See figure below, assume frictional losses are negligible and consider the specific energy at the two sections 1 and 2.

![Diagram showing channel with depth $y_1$ and $y_2$ and bed rise $\Delta Z$.]
Problem 3

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

(10)  (i) Name any three (3) of the nine (9) processes (1 to 9) in the figure below and briefly explain how you would quantify these processes to better understand the hydrologic cycle.

(5)  (ii) Briefly explain how the intensity duration frequency (IDF) curves for a large municipality are generated and used to design a stormwater collection system for a 50-year return design storm.

(5)  (iii) The runoff coefficient $C$ is an important variable of the rational method that is most susceptible to error. Explain the importance of $C$ and provide two (2) methods that may be used to correct for errors associated with $C$ values.
Problem 4

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

(i) A grass lined channel is commonly used as a surface runoff control system. Provide three (3) design considerations, three (3) performance criteria that determine the effectiveness of the system and two (2) operation and maintenance issues to ensure the longevity of the system.

(ii) Using the diagram below of a cross section of an extended detention pond, briefly explain the primary design function of the coarse aggregate, perforated riser, baffle and emergency spillway.
Problem 5

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

(i) In the absence of representative runoff data, conceptual models are necessary for flood predictions. The US EPA SWMM model uses the following conceptual view (diagram below) to model runoff from a catchment. Briefly explain how this model with the use of Manning's equation, provides a good way to estimate the surface runoff per unit area, Q.

(ii) Briefly describe the meaning of stream stage and rating curve related to streamflow and how they may be measured in the field.

(iii) The Log-Pearson Type III distribution is a statistical technique for fitting frequency distribution data to predict the design flood for a river at some location. Briefly explain the use of this statistical technique in predicting flooding events, give two important factors needed for the predictions and provide an advantage and a disadvantage of this technique.
Problem 6

Provide answers to the following questions related to open channel flow, network design and the basic pumps or prime movers:

(5) (i) Briefly explain the significance and use of the Froude Number (F) in open channel hydraulics. Give one circumstance where F is large for flow in an open channel.

(10) (ii) For a flow rate of 50 L/s, determine the pressure at points A and C in the three pipes in series (shown below) using the pipe system details provided in the figure. Assume a fully turbulent flow for all cases and that the pressure head at point A is 30 m.

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D_1 = 30 cm  D_2 = 20 cm  D_3 = 40 cm
L_1 = 2000 m  L_2 = 1000 m  L_3 = 2000 m
f_i = 0.022  f_i = 0.025  f_i = 0.021
z_A = 20 m  z_B = 25 m  z_C = 32.5 m  z_D = 37.5 m
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(5) (iii) The figure below shows four curves related to a system with two pumps operating in series. Briefly explain what curves A, B, C and D refer to and give the corresponding head (m) and flow (L/min) of the system operating point.
Problem 7

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

(4)  (i) Water distribution system calibration is often done by field tests to estimate the friction factor (C) in the Hazen-Williams equation. Using the Hazen-Williams equation, provide an example with an explanation of how you could conduct a field test in an existing water distribution system to determine C.

(6)  (ii) Determine the approximate pump head in m needed to deliver water from reservoir R-1 to reservoir R-2 (see figure below) at a rate of 1000 L/s. Compute the friction head losses using the Hazen-Williams equation and pipe characteristics (L, D and C) provided in the figure.

![Diagram of water distribution system with reservoirs and pipes]

(5)  (iii) The demand to reservoir R-2 tripled to 3000 L/s during a peak event that lasted 6-hours. Briefly describe (no detailed calculations are necessary) two methods that would allow the systems to satisfy this demand and in your description, provide one advantage and one disadvantage for each method.

(5)  (iv) Briefly describe the primary function of a drop manhole indicating conditions under which a drop manhole is recommended and one hydraulic design issue that needs to be addressed when designing drop structures (such as drop manholes).