National Exams December 2012

98-Civ-A3, Municipal Engineering

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to include with their answer a clear statement of any assumptions made.

2. This is an open book exam.

3. Candidates may use one of two calculators, the Casio or Sharp approved models.

4. The exam has 5 questions, of which 4 must be answered. Candidates MUST answer Question 1. Then they may answer any 3 out of the remaining 4 questions. DO NOT ANSWER FIVE QUESTIONS.

5. Each question carries a maximum of 25 marks, for a total of 100. Try to arrange your time in accordance with the value of the question (hence slightly less than 2 minutes per mark).

6. Please take care to give your answers clearly and logically. State any assumptions which you need to make, as well as any sources of information used which are not in the examination paper (for example, a table or page number in a textbook).

7. The answers to all questions must be given on this question sheet, using the facing (blank) side if necessary. No additional papers handed in by the candidate will be accepted or considered in the grading.
Marks

Question 1. YOU MUST ATTEMPT THESE QUESTIONS. Note the number of marks for each question, and answer accordingly. (25 marks total)

2  a) For any new large-scale municipal projects, engineers must choose a design life to guide the design. Give two benefits of choosing a “short” design life (say 10 years) vs. a “long” design life (say 50 years).
   Short:
   -
   -

   Long:
   -
   -

b) Most Canadian cities have an abundant water supply, hence some members of the public may question the need to invest in water-saving devices. Furthermore, they may suggest that the loss of water through leakage in water distribution systems is not a serious problem. Give two reasons why domestic water-saving devices should be encouraged, and two reasons why leakage should be minimized.

2  Water-savings devices:
   -
   -

2  Leakage:
   -
   -

c) How is it possible for contaminated water to enter the water distribution system, once the water has left the municipal water treatment plant? What should be done to avoid this occurrence?

1  How does it enter?

2  Solution:

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d) In addition to domestic sewage, sanitary sewers may carry some industrial wastewaters and gases. Sulfur can be a component of such gases. List the two forms of sulfur which could arise in a sewer, briefly explain how each one is formed, and describe the problem which each type of sulfur gas can cause.

1 Forms:

1 How formed:

1 Problems caused:

2 e) A pump located at ground level is used to pump water from a well and into a forced main (i.e. a pressure pipe) to a water treatment plant. An engineer notices that when the water level in the well drops to a very low level, the pump efficiency drops significantly and the pump starts making clicking noises. Explain what is probably happening and what can be done to avoid this problem.

Cause:

Solution:

2 f) The correct spacing of stormwater inlets is crucial if flooding of the road is to be avoided. Describe in general terms how the spacing of the inlets would be different for two extreme cases:

- Case 1, the road is almost horizontal for several km

- Case 2, the road has a steep slope of 6% for 1 km

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A 300 mm diameter smooth concrete sanitary sewer (Manning's "n" = 0.014) was designed to flow \( \frac{2}{3} \) full (in terms of depth). The intended slope was 0.002. Calculate the flow in the pipe.

In fact, the pipe was actually laid at a slope of 0.0015 because during construction some hard rock was encountered. For the same flow as in the original design, what is the new depth of flow?

In cold climates with significant snowfalls, city workers have been spreading salt on the roads to melt the snow and ice. Recently, the tendency has been to use sand and/or small gravel instead.

Briefly describe the reasons for this change.

What impact does each road treatment - salt, sand, and gravel - have on the storm sewers?

Salt:

Sand:

Gravel:

Total 25
Question 2. Water consumption and distribution (25 marks total)

6 a) In the year 2000, total Canadian water consumption was 1,494 m$^3$/cap, domestic water consumption averaged 0.335 m$^3$/cap-d, and the population was 31 million. Calculate the actual and the equivalent population for a town which has a record of the following volumes consumed over that entire year, assuming that the per capita domestic water consumption is the same as that for the entire country. How does this town compare to the Canadian average, in terms of non-domestic usage?

<table>
<thead>
<tr>
<th>Category</th>
<th>$m^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>$8.03 \times 10^6$</td>
</tr>
<tr>
<td>Commercial</td>
<td>$4.62 \times 10^6$</td>
</tr>
<tr>
<td>Industries</td>
<td>$5.07 \times 10^6$</td>
</tr>
<tr>
<td>Public</td>
<td>$3.55 \times 10^5$</td>
</tr>
<tr>
<td>Fire</td>
<td>$7.61 \times 10^4$</td>
</tr>
<tr>
<td>Losses</td>
<td>$6.82 \times 10^5$</td>
</tr>
</tbody>
</table>

Give your answers in the following table:

<table>
<thead>
<tr>
<th>2 marks</th>
<th>2 marks</th>
<th>2 marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual population</td>
<td>Equivalent population</td>
<td>Non-domestic usage compared to Canadian average?</td>
</tr>
</tbody>
</table>

Show your calculations below, or on the facing page.
b) When water pipes which have been in place for many decades are dug up from below city streets, their inside diameters are frequently smaller than the original diameter. Explain why this occurs.

c) A problem sometimes encountered with water in elevated storage tanks is "ageing". Explain why this occurs, and why it is a problem. What is the solution?

d) You are required to determine the pumping head required at a water treatment plant (WTP) and to complete the table on Page 7. Calculations may be shown on the facing pages. This pump must be capable of supplying water under worst-case scenarios, i.e. within the limits given below. The cast-iron main pipes (Hazen Williams coefficient 130) joining the WTP to the city and to the reservoir will be the same diameter. An elevated reservoir for service storage is located on a hill outside the town. Assume that the pump always pumps at the mean flow of the peak daily consumption. Also assume that at the lowest demand, the reservoir is at its maximum level.

Key information:

- Peak daily consumption: 26,000 m$^3$
- Maximum velocity in pipe: 3 m/s
- Max. allowable pressure in city: 500 kPa
- Min. allowable pressure in city: 200 kPa
- Maximum demand: 35 m$^3$/min
- Minimum demand: 7.5 m$^3$/min
- Assume that the pressure loss at the most distant point in the water distribution pipes of the city is 50 kPa at minimum flow and 150 kPa at maximum flow. This pressure loss is linearly correlated with the water demand (hence at the mean flow the pressure loss would be 100 kPa). You may neglect the short connecting pipes and all minor headlosses in your calculations.

The service storage volume available in the elevated reservoir is 5,600 m$^3$ and the maximum water level is 40 m relative to the datum level of the city, which is assumed to be flat.

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A diagrammatic layout of the systems is shown below.

<table>
<thead>
<tr>
<th>Design parameter and units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Main pipe diameter (must be one of the available commercial pipe sizes only: 400, 450, 500, 600, 750, 900 mm)</td>
<td></td>
</tr>
<tr>
<td>2 Describe scenarios to be considered during a 24 h period.</td>
<td></td>
</tr>
<tr>
<td>9 Maximum pumping head required at WTP (kPa)</td>
<td></td>
</tr>
<tr>
<td>1 Other factors to consider</td>
<td></td>
</tr>
</tbody>
</table>
8 of 16 pages

3. **Water supplies for fire protection**

1 a) Codes describing the methods to be used for assessing water flows for fire protection are available for many jurisdictions. Give the name of the Code which you will use below, and the jurisdiction to which it applies, or the organisation/authority which has developed the code.

4 b) Both potable water and water for fire flows are provided by the same water purification and distribution system. Compare the requirements for each. In what way could the requirement for one adversely affect the other, and vice versa.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Potable water</th>
<th>Fire flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative effect of requirement for one type on the other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A warehouse is used by a major textbook supplier for storage of these books in preparation for surges in demand at the start of the academic year. These books are considered to be easily combustible but not free-burning. The warehouse is 8 m high (equivalent to a 2-storey building) and also has a basement, which is 20% above grade, under the full surface area of the building (including the loading area). You can assume that both levels are filled with books to capacity. The warehouse borders a residential area. The horizontal dimensions are 50 m x 30 m. The building itself is made entirely of bricks to look like a neighbourhood house, and it is protected by an automatic sprinkler protection system. The building occupies a corner lot. On both sides of the building, separated by 3 m, are several row-houses, of similar height to the warehouse, but these row-houses have a depth of 25 m (in the direction away from the street). The warehouse and row-houses are off-set from the street by 5 m.

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Marks

4  i) Sketch a plan of the warehouse, street, and neighbouring town-houses, giving key dimensions. The sketch need not be to scale.

10  ii) Calculate the required fire flow (L/min), using the Code mentioned in (a) above. List your assumptions.

Fire flow (L/min):

Assumptions:
If a town reservoir is being designed with this particular site as the one for critical fire flow, what would be the fire-fighting storage volume for the design (m$^3$)?

How many fire hydrants are required and what type would they be? Assume that the fire hydrants are located on the street line, on the same side of the street as the warehouse. Show the fire hydrant(s) on the sketch.

Total 25
Storm flows and flow calculations in pipe flowing full and partially full.

A 900 mm inside diameter cast iron combined sewer, 1 km long, has been carrying storm water runoff for almost 20 years from houses and their large gardens in a suburb which has had very little development. Basement floors in these houses are 2.5 m below ground level. The ground slope is 0.029 (m/m), and the pipe slope is 0.030 (m/m). The manhole (MH) shaft at the upstream end of the pipe extends 4.5 m from the ground surface to the crown of the pipe. The temperature of the water is 15°C. The pipe never flowed full. With changing climate and urbanization, however, rainfall events and flows have become more extreme in the area, and the regional council is concerned that the water should not backup from the pipe.

4 a) Prepare a sketch of the system on the grid below. You can exaggerate the vertical scale.

5 b) What is the flow that can be carried currently in the pipe, if the pipe is flowing full but not under pressure?

Justify the values chosen for coefficients such as the Manning coefficient, and give your sources. Show calculations below, or on the facing page.

Manning coefficient:

Flow (m³/s):

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Rainfall frequency-intensity-duration curves for the region are given below. If the pipe drains a watershed of 0.5 km², what rainfall intensity can be tolerated under present conditions without backup, and what would be the return period (years)? You may assume an inlet time of 15 minutes, and that this flow enters the pipe at the upstream MH. Also, neglect wastewater flows from the houses. Show calculations below or on the facing page.

**Short Duration Rainfall Intensity-Duration-Frequency Data**

Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

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**Caution/Sujet à caution:**
- Average 95% Confidence Interval > ±25%
- Intervalle de confiance moyen 95% > ±25%
- 95% Confidence Interval > ±25%
- Intervalle de confiance de 95% > ±25%

MISSISSAGI ONT
ON 6093210
1971 - 1996
22 years / ans
Latitude 46° 26'N
Longitude 83° 23'W
Elevation / Altitud 225 m

Return Periods/ Périodes de retn
Years / ans
100 50 25 10 5 2

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Since the pipe was reaching the end of its design life, it was decided to replace it with a (new) reinforced concrete pipe of the same diameter. What would be the depth of flow in the new pipe, for the conditions established in (b) above?
With the new pipe in place, what flow into the upper MH would cause the water to surcharge in this MH to ground level, and flood the basement of a house at the downstream end of the sewer pipe?

Would such a flow have been provided by Hurricane sandy, which resulted in a 100-yr flood of 15 minutes duration over the same area, and complete saturation of the soil (runoff coefficient = 1.0)?

Total: 25
Essay: Infrastructure and sustainability

Much of the infrastructure which the majority of Canadians who live in large cities are enjoying was built many decades ago, and no provision was made for regular maintenance. As a result, failures occur which are extremely disruptive to everyday life. The concept of “sustainability” is meant to guide the design and operation/maintenance of such systems so that future generations are not subject to these problems. In your essay on this subject:

a) Explain the concept of “sustainability”

b) Give at least two examples where infrastructure was NOT conceived and/or built in a sustainable fashion

c) For those same examples, describe how suitable designs will result in cities which 50 years from now will not experience these same problems.

Note: Be sure to focus on MUNICIPAL infrastructure, and if possible, include numerical values and even design parameters to support your comparisons between b) and c) above.

Start your essay below, and continue on the following page.