The answers to all questions must be given on these question sheets, using the reverse side if you need to.
No additional papers handed in by the candidate will be accepted or considered in the grading.

Name: ___________________________ Date: ___________________________

National Exams December 2015

98-Civ-A3, Municipal Engineering

3 hours duration

Notes:

1. 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.

2. Candidates should answer any 4 out of 5 questions. Do NOT answer 5 questions.
Candidates should cross out the question which they do not want to be marked, otherwise only the first four questions answered will be graded.

3. 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). Part marks will be given for incomplete answers, so do what you can for each question, but don’t spend an unreasonable amount of time to finish it.

4. 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.

5. This is an open book exam.

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

7. 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).
Question 1. **SHORT QUESTIONS**

Take note of the number of marks assigned for each question, and answer accordingly.
(25 marks total)

a) Population statistics for a town, covering a period of 120 years, are given in the table below. This town experienced a boom when industries started moving in following the First World War, but the population appears to be stabilizing.

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1890</td>
<td>135 000</td>
</tr>
<tr>
<td>1900</td>
<td>140 000</td>
</tr>
<tr>
<td>1910</td>
<td>150 000</td>
</tr>
<tr>
<td>1920</td>
<td>175 000</td>
</tr>
<tr>
<td>1930</td>
<td>210 000</td>
</tr>
<tr>
<td>1940</td>
<td>250 000</td>
</tr>
<tr>
<td>1950</td>
<td>290 000</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Population</td>
</tr>
<tr>
<td>1960</td>
<td>340 000</td>
</tr>
<tr>
<td>1970</td>
<td>375 000</td>
</tr>
<tr>
<td>1980</td>
<td>400 000</td>
</tr>
<tr>
<td>1990</td>
<td>425 000</td>
</tr>
<tr>
<td>2000</td>
<td>445 000</td>
</tr>
<tr>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
</tr>
</tbody>
</table>

i. Plot the data on the graph paper below and estimate the saturation population. (2 marks)

ii. Choose a mathematical model which is most appropriate for the data, and use it to predict the population for the year 2020. (3 marks)
b) If a river is to be used as a source of drinking water, protecting the influx of nutrients and pollutants can drastically reduce the complexity and costs of subsequent water purification. Give 3 such measures which can be taken for source protection, and explain very briefly, for each one, how these measures would work (½ mark each measure or explanation). (3 marks)

<table>
<thead>
<tr>
<th>Measures taken</th>
<th>How would they work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c) Cavitation is a problem which may be experienced in pumping systems which have been poorly designed.
   i. Briefly describe the symptoms of the problem. (1 mark)

   ii. What key factors are responsible for cavitation? Write down the key equations which would be used to quantify the problem, and define the key factors. (2 marks)

   iii. If a cavitation problem is detected in an existing system, what measures can be taken to solve the problem? (2 marks)

d) In cold climates, water and sewer pipes must be buried below the frost line in order to avoid freezing.
   i. If the freezing index for Moosonee, a town in Northern Ontario, is 4 081 degree-days (°F) or 2 267 degree-days (°C), determine the depth of cover required for pipes in this town. (2 marks)

   ii. What natural factors (excluding warmer or colder winters) may cause the depth calculated above to either decrease or increase? (2 marks)
d) iii. If the maximum desired burying depth is 2 m (common for more southern parts of Canada), suggest one engineering solution that can be implemented to allow the pipes to be buried at 2 m in Moosonee without any risk of water freezing. (1 mark)

e) A 300 mm diameter water main (Hazen-Williams coefficient 110) has flows ranging between 10 and 50 L/s. An engineer recommends installing an “angle lift” check valve in the pipe, which creates a headloss of 200 L/D (equivalent length/pipe diameter) when fully open. In order for the valve to remain open, the pressure drop across the valve must be a minimum of 2 psi (or 13.8 kPa or 1.4 m). Will the valve indeed remain fully open over the range of flows expected? (5 marks)

f) Many coastal communities use long outfall sewers to discharge their wastewaters into the ocean, in some cases having had only primary treatment. Give 2 advantages of this system, and 2 disadvantages (½ mark each = 2 marks).

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. **Sanitary sewers.**

   a) The design of sanitary sewers is constrained by minimum and maximum velocities, as well as by minimum pipe sizes. Explain why it is necessary to set such limits. (3 marks)

<table>
<thead>
<tr>
<th>Minimum velocity</th>
<th>Maximum velocity</th>
<th>Minimum pipe size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   b) Where in sanitary sewer systems is one likely to encounter velocities lower than the minimum? What measures can be taken to overcome this problem? (2 marks)

<table>
<thead>
<tr>
<th>Where</th>
<th>How to overcome the problem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   c) You are required to determine the diameter and slope of two reinforced concrete sewer pipes in series at the beginning of a system sanitary sewer collection system. The location of the pipes, manholes (MH), populations and areas being serviced, are given in the first table on the next page. You must also use the following information and constraints:

   - Minimum pipe diameter = 200 mm
   - Other available commercial sizes: 225, 300, 375, 450 mm
   - Manning’s “n” = 0.013 (assume constant)
   - Population per ha = 60
   - Per capita sewage contribution, average flow = 350 L/d
   - Infiltration and inflow = 6.0 m³/ha-d (constant)
   - Minimum allowable velocity = 0.6 m/s when full
   - Pipe must flow half full (d/D = 0.5) or less at average flow (10% exceedance is O.K.)
   - Minimum cover = 2 m

   To assist in your calculations, tables are given below with key data as well as empty columns, but you may create your own calculation tables if you wish.
c. i. Sketch a section view of the system (not to scale) showing key given information (5 marks).

ii. Complete the empty cells in the table below (6 marks)

<table>
<thead>
<tr>
<th>MH</th>
<th>Area serving this MH (ha)</th>
<th>Street elevation (m)</th>
<th>Pipe # and MHs linked</th>
<th>Length (m)</th>
<th>Sanitary sewage flow (m³/s)</th>
<th>Infiltration flow (m³/s)</th>
<th>Total flow (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>28</td>
<td>35.3</td>
<td>1 A-B</td>
<td>110</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>30</td>
<td>34.1</td>
<td>2 B-C</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>33.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

iii. Complete as many cells as necessary in the table below to finalize your design. Empty columns are available if you wish to use them. You must give the pipe diameter, velocity when full, and the actual depth of flow. (9 marks)

<table>
<thead>
<tr>
<th>MH</th>
<th>Pipe #</th>
<th>Slope (m/m)</th>
<th>Pipe diameter (mm)</th>
<th>Velocity when full (m/s)</th>
<th>Depth of flow (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Working page for 2c).
3. **Pumps**

a) Explain briefly when it is appropriate to use pumps in parallel, and when in series. (2 marks)

b) A pumping system is required as described below. On the following page you will find head vs flow curves for a 13" Pentair-Aurora pump, two of which are available, if necessary, for this system. Note that the NPSH values which are given are in units of feet. Graph paper is also given if needed. Details of the flows, pipes, fittings and other information are as follows:

**Flows:** minimum demand 0.20 m³/s at 40 m pressure; maximum demand 0.32 m³/s at 25 m.

**Pipes:** All have Hazen-Williams C = 100
- **Intake:**
  - Length: 200 m
  - Elevation: 2 m below the centre-line of the pump
  - Minor fittings: 1 entrance, 2 bends, 1 check valve, 1 gate valve, 1 contraction, 1 manifold split (if needed for two parallel pumps)
- **Outlet:**
  - Length: 2.5 km
  - Minor fittings: 1 expansion, 1 check valve, 1 gate valve, 1 manifold join

**“k” values for the minor head-losses for each fitting:**
- Entrance: 0.2
- Bend: 0.4
- Check valve: 0.8
- Gate valve: 0.3
- Contraction: 0.07
- Expansion: 0.08
- Manifold join: 0.25
- Manifold split: 0.01

**Other information:**
- Water temperature is 10°C; vapour pressure is 1.2 kPa (0.12 m); atmospheric pressure 101 kPa (10.2 m).

Determine whether the available pump(s) will be satisfactory under all conditions of flow. (23 marks)
4. **Roads: Snow melting, trenchless technologies, stormwater runoff and culvert design. (25 marks total)**

   a) In cold climates with significant snowfalls, salt is generally used on the roads to melt the snow and ice. Recently, the tendency has been to use sand and/or small gravel instead.

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

   **Salt** (1 mark):

   **Sand** (1 mark):

   **Gravel** (1 mark):

   b) "Trenchless technology" is an alternative to digging up and replacing older sewer pipes which are leaking or may be expected to leak shortly.

   i. **Briefly describe the process.** (1 mark)

   ii. **Give two benefits and two disadvantages, compared to conventional trenches?** (2 marks total)
4 c) Stormwater calculations and culvert design. (19 marks).

i. A culvert is to be designed to handle the 50-yr stormwater runoff from a 22.3 ha site. The runoff coefficient is 0.8, the time of concentration is 10 minutes, and the rainfall intensity $i$ (mm/h) for this area can be obtained from the following formula, where $t$ is in minutes:

$$ i = \frac{4.750}{t + 27} $$

Calculate the flow to be handled by the culvert (m$^3$/s). (5 marks)

ii. A 54" (1.4 m) diameter pipe will be used as a culvert. A culvert capacity chart for this pipe is given on the following page. Note that “HW” means headwater (or water depth). The pipe length $L = 60$ m, and the pipe slope $S_o = 0.01$ m/m.

Determine whether inlet or outlet control governs the flow in this culvert pipe. (8 marks)

iii. Determine the outlet velocity of flow (m/s) under these conditions. (6 marks)
5. **Essay: Safety in Municipal Engineering (25 marks total)**

The operation of municipal systems affects the public directly, but the design, operation, and maintenance impact construction and maintenance workers as well. Under each heading below, give one example of a municipal system or service, and explain how the work of a municipal engineer such as yourself can improve the safety of the system or service. Use a different example in each case. Where possible, provide numerical values. Note the marks available for each section.

a) Construction worker on a municipal project. (7 marks)

b) Operator of a municipal system. (5 marks)
5. Essay question (contd.)
   
c) Maintenance worker. (7 marks)

   d) General public. (6 marks)