Name:________________________________ Date:____________________

National Exams December 2011

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 submit, with the answer paper, 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. **Candidates must hand in this examination paper, on which they may perform some of their calculations, as well as their answer booklets.**

Marks

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

2 a) Construction of a bridge onto an island close to a major city has made it possible to develop this entire island for residential use. Which population projection model would be the best one to use to predict the population over the design life of the water treatment and wastewater treatment plants. These plants will service this island exclusively. Explain your reasoning.

3 b) There is a popular conception amongst some land-scape designers, foresters, gardeners, etc., that a large tree "will draw up the groundwater table". Given your knowledge of well hydraulics, is that correct? Explain with a diagram, if you can.

2 c) 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 to make strange noises. Explain what is probably happening and what can be done to avoid this problem.

2 d) Even though virtually complete disinfection of drinking water at a municipal water treatment plant can be achieved through the application of ultraviolet light or ozone, why is it still necessary to always add chlorine or chloramines to the water before it is pumped to the consumer?

3 e) 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?

2 f) When would a drop manhole be used in a sanitary sewer system, and what is the special characteristic of such a manhole?

5 g) A city councillor made a proposal for a new bylaw which would limit the distance allowed for houses in <u>NEW</u> subdivisions to be offset from the sidewalk. This was vigorously contested by another councillor representing the developer of that new subdivision. What could be the reason for proposing the new bylaw? Give a numerical example with your answer (note the number of marks available).

2 h) Explain how it is possible for a storm sewer, which has been designed to flow full, to carry a flow slightly higher than that design flow, <u>without backing up.</u>

4 i) A storm sewer pipe is laid under soil and trench conditions such that Marston's formula is applicable. Would the design loads for reinforced concrete or polyethylene pipes of the same diameter be equal? Give a numerical example to explain your answer.

Marks

Question 2. Water supply (25 marks total)

A community with a population of 10,000 people in 2010 proposes to build a new intake system in a nearby lake to satisfy the future water demands for their community. It is your assignment to design a 600-m long intake conduit (raw water gravity pipe) to transport the water from the river intake to a wet well. To help you in your design, the following data were collected by the Municipal Engineering Department for the community:

- The Urban Planning Office says that the community has been experiencing a geometric rate of population growth of 2% per year. It was concluded that this rate of growth is expected to continue for the next 25 years due to new industrial developments in the region.

- Past records of water consumption for similar communities in the province have shown that due to water savings measures, the residential water use per capita has been decreasing linearly over time at an average rate of 3 L/cap•d each year.

- In 2010, the total water supplied to the residents and industries of the community was 1.6×10^6 m^3. (i.e. the present average demand)

- The industrial demand in 2010 was 1,000 m^3/d and the Urban Planning Office expects it to double by the year 2035.

- The Water Treatment Facility personnel say that 5% of the water delivered to the water treatment plant is used for backwashing of filters

Assume that the end of the design life of the intake pipe will be in the year 2035 and that all fire flow comes from storage.

The pipe itself will include two fully-open gate valves (minor headloss coefficient K = 0.2), and two long-radius elbows (K = 0.6). There is also, of course, an inlet to the pipe (considered to be a square entrance (K = 0.5)) and an exit to the reservoir (K = 1.0).

Based on this information, evaluate (for the end of the design life)

10 a) the required capacity of the pipe (m^3/d).

5 b) the commercial pipe (cast iron) diameter (in mm) required to carry the flow. Assume a velocity in the pipe at the end of the design life of 1 m/s.

10 c) the head loss (in m) through this pipe, including all minor losses.

Total 25

Question 3. Water distribution alternatives. (25 marks total)

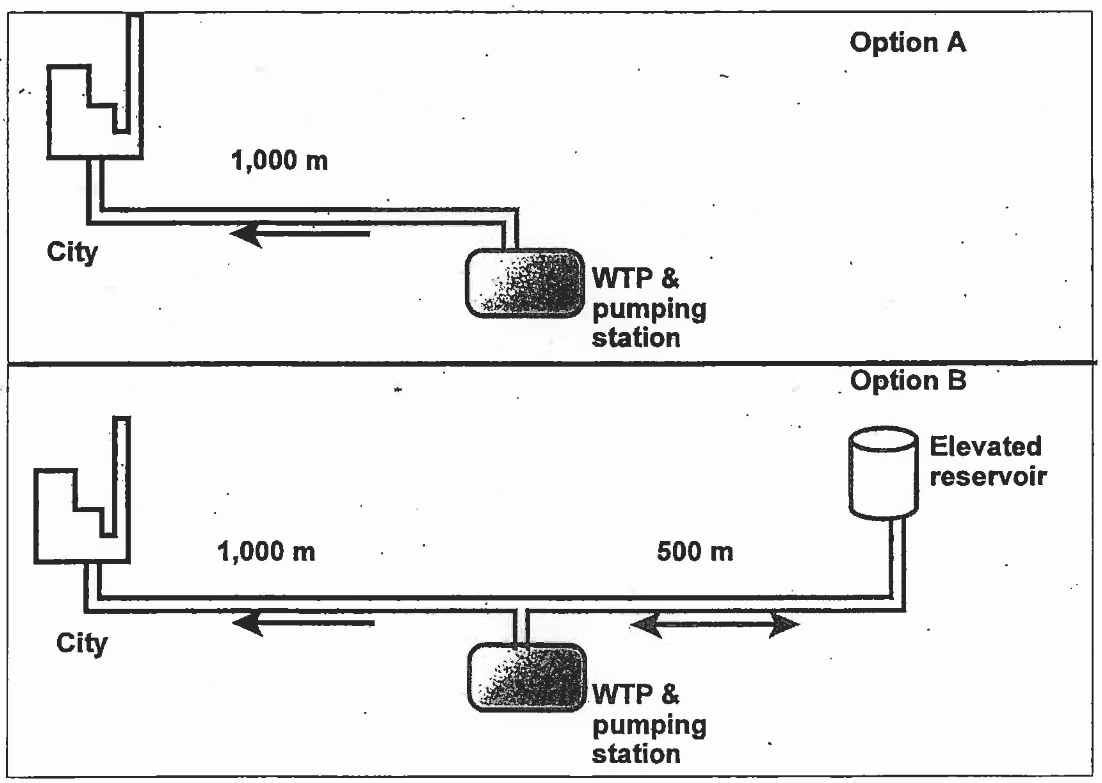
You are required to compare two options for a water system to a city of 90,000 inhabitants. The quantitative basis of comparison will be the pumping head required at the water treatment plant (WTP). This pump must be capable of supplying water under worst-case scenarios, i.e. within the limits given below.

The cast-iron main pipe (Hazen Williams coefficient 130) joining the WTP to the city, and to the reservoir (if there is one), will be the same diameter.

<u>Option 1</u>: No elevated reservoir for service storage (to accommodate fluctuations in the flow resulting from fluctuations in the demand). The service storage would be included in a ground-level reservoir at the WTP. First design the pipe for this option, then use the same one for Option B.

<u>Option 2</u>: An elevated reservoir for service storage, located on a hill outside the town. In this case, you may 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.

A layout of the two systems is shown diagrammatically below.



Key information:

Peak daily consumption: 26,000 m^3
Maximum velocity in main pipe: 3 m/s Minimum velocity (option A only): 0.3 m/s
Maximum allowable pressure in the city: 500 kPa
Minimum allowable pressure in the 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.

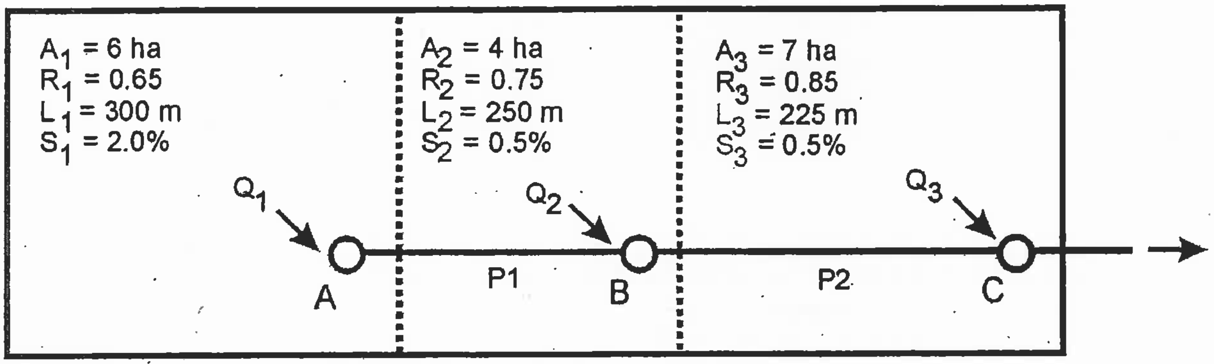
The service storage volume available in the elevated reservoir is 5,600 m^3 and the maximum water level is 40 m relative to the datum level of the city, which is assumed to be flat.

Marks

Marks	Design parameter and units	Value
3	Main pipe diameter (same for both options; commercial pipe sizes only: 400, 450, 500, 600, 750, 900 mm)	
5	Maximum pumping head required at WTP for Option A (kPa)	
3	Describe scenarios to be considered during a 24 h period.	
12	Maximum pumping head required at WTP for Option B (kPa)	
2	Other factors to consider	

Question 4. Storm water analysis and pipe design (25 marks total)

A storm water system is to be designed for the region shown on the figure below.
Note: 1 ha = 10 000 m^2



The data shown on the figure include the drainage area (A_i), rational coefficient (R_i), overland flow distance (L_i) and average ground slope along the direction of flow to the inlet (S_i) for each of the areas. The 5-year return period rainfall intensity-duration relationship for this region is:

$$i = \frac{750}{t^{0.8} + 3}$$

where i is the rainfall intensity (mm/hr) and t is the rainfall duration (minutes). The inlet time may be calculated using the following empirical relationship:

$$T = 0.0192 \cdot \frac{L^{0.77}}{S^{0.385}}$$

where L is the overland travel distance (m), S is the slope of the tributary area (m/m), and T is the inlet time (minutes).

Fill in the blank spaces of the table on the next page, designing for a return period of 5 years. Follow the design criteria listed below and attempt to minimize excavation. Note the distribution of marks.

- minimum velocity = 0.75 m/s at design flow
- maximum velocity = 3.5 m/s at design flow
- minimum cover = 2.0 m
- Manning's roughness coefficient = 0.013 under full flow conditions
- design pipes to flow approximately full at or near the design flow but ensure that d/D is not below 0.70 at the design flow (where d is the depth of flow in the pipe and D is the pipe diameter)
- use only the following commercial sizes of reinforced concrete pipes: 310, 380, 460, 530, 610, 690, 760, 840, 910, 1070, 1220, 1440, 1520, 1680 (mm)
- the invert drop through manhole B should be at least 0.10 m

Marks	Pipe characteristics	Pipe P1	Pipe P2
2	Cover at ends of pipe (m)	at A = 2.00	at B =
		at B = 2.00	at C =
	Ground elevations at ends of pipe (m)	at A = 50.00	at B = 49.60
		at B = 49.60	at C = 49.10
2	Invert elevations at ends of pipe (m)	at A = 46.93	at B =
		at B = 46.53	at C =
	Pipe length (m)	200	250
1	Pipe slope (m/m)	0.002	
2	Pipe diameter (mm)	1070	
2	Q_{full} (m^3/s)		
2	V_{full} (m/s)		
6	Q_{design} (m^3/s)		
4	V_{design} (m^3/s)		
4	d/D at design flow		

Marks

Question 5. Impact of climate change on municipal water, wastewater and stormwater infrastructure systems. (25 marks total)

It is well accepted in the engineering community that recent climate changes are likely responsible for the more frequent occurrence, and with greater extremes, of precipitation leading to floods, etc., and of a wider range of air temperatures than was experienced previously. All of these have an impact on the performance of current municipal water systems which have been designed and built without taking climate change into consideration.

10 a) Describe in as much detail as possible (i.e. from an engineering perspective) what effects the abovementioned extreme events have on municipal water infrastructure systems.

15 b) Take at least two equations (or groups of equations) which have traditionally been used in the design of the systems described in part (a), and suggest how they might be modified to accommodate the new reality. Give numerical examples to illustrate your points.