ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2012 SESSION

Open book examination
Calculators : only authorized models
Duration : 3 hours

98-CIV-B4 HYDROLOGIE

Question 1 (20 pts)

It is proposed to build a residential development in a 5-ha watershed located near Sherbrooke. The following data are provided:

Watershed prior development:

- 70% forest with CN = 58
- 30% agricultural land with CN = 86

Urbanised watershed:

- 30% forest with CN = 58
- 35% grassed area with CN = 69
- 35% houses, streets, paveways, etc. with CN = 98

Determine the volume of runoff, in m^3, of the watershed prior and after development for a precipitation of 60-min duration and 10-year return period. The Intensity-Duration-Frequency (IDF) curve is given by:

$$i = \frac{519}{t^{0,682}} \quad mm/h$$

With time t given in minutes

Question 2 (20 points)

A 140 km^2 watershed in a mountainous area is covered by a snowpack. The snowpack water equivalent values are 40 mm and 100 mm, respectively, in the lower and upper portions of the watershed. The following is given:

	Lower portion	Upper portion
Mean elevation (m)	200	1200
% of watershed	60	40
Vegetation cover	100% agricutural	100% forest

The following meteorological conditions (air temperature and precipitation) are forecasted at 200 m elevation:

Day 1 : $T_{moy} = 8^oC$, P = 15 mm

Day 2 : $T_{moy} = 12^oC$, P = 0 mm

Compute the <u>total volume of runoff, in m^3</u>, generated in the basin after these two days. Snowmelt equations to be used are:

<u>Forested areas</u> : $M = 0.23\ T_{moy} + 0.0126\ T_{moy}\ P$ M en cm/day, T_{moy} in ^oC, P in cm

<u>Open areas</u> : $M = 0.27\ (T_{moy}+4.4) + 0.0126\ T_{moy}\ P$

<u>Assumptions :</u>

1. Infiltration is zero.
2. The snowpack is capable of holding liquid water corresponding to 3% of its mass.
3. Air temperature decreases with elevation at a rate of 6^oC per 1000 m.

Question 3 (20 points)

The unit hydrograph (UH) in the table below corresponds to an excess rainfall, or net precipitation, of 1 mm depth and 2-hour duration:

Time (h)	0	1	2	3	4	5	6	7	8	9
Flow (m^3/s)	0	7.5	22.5	48.8	78.8	75.0	48.8	26.3	7.5	0

a) What is the surface area of the watershed, in km^2? (5 pts)
b) Determine the 1-hour, 1 mm unit hydrograph for this watershed using the S-curve unit hydrograph method. (15 pts)

Question 4 (20 points)

The following data is given for an urban watershed :

- Watershed surface area: A=121.4 ha
- Watershed length : L=1981 m
- Average slope of the watershed : S=1.48%
- CN of the watershed : 92

a) Plot the triangular synthetic SCS hydrograph corresponding to 1-mm direct runoff (or rainfall excess). Indicate on the graphic the following infirmation : peak discharge q_p, time to peak t_p, time base, and rainfall excess duration D. (10 points).

The equation for the time of concentration is given by :

$$t_c = \frac{0.1362\, L^{0.8}\left[\frac{1000}{CN} - 9\right]^{0.7}}{\sqrt{S}}$$

where t_c is in minutes, L in meters and S en %

b) Calculate the watershed peak discharge corresponding to the net hyetograph below : (10 points)

Time (minutes)	0-10	10-20	20-30
Excess rainfall (mm)	6	0	4

Question 5 (10 points)

The following statistics were retrieved from a 85-year time series of maximum annual flows measured at staton 001 of the aux Brochets River:

$$Q_{mean} = 150\ m^3/s$$

$$s = 50 m^3/s$$

where Q_{mean} is the average of the maximal annual flows and s is the standard deviation.

a) Calculate $\mathbf{Q_{50}}$ **et** $\boldsymbol{Q_{100}}$ assuming that the maximum annual flow time series follow a normal distribution. (5 pts)
b) What is the probability that a maximum annual river discharge of 200 m^3/s will be exceeded during 3 consecutive years ? (5pts)

Question 6 (10 points)

Calculate the watershed average precipitation depth of a storm with the following information:

Station	**1**	**2**	**3**	**4**	**5**
Storm precipitation depth (mm)	20	25	missing	30	34
Total annual precipitation (mm)	900	950	980	940	1050
Station gage weight	0.2	0.24	0.16	0.15	0.25