ORDRE DES INGÉNIEURS DU QUÉBEC

May 2017 SESSION

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

14-BR-A6 HYDROLOGIE

Question 1 (20 points)

A dam, with an expected life of 100 years, will be built over a period of 3 years. The statistical data of the annual maximum flows Q of the Black River on which the dam will be built are the following:

Mean annual flow Q_{mean} = 620 m^3/s

Standard deviation S = 175 m^3/s

Y_{mean} = 6.573 with y = ln(Q)

Standard deviation S_y = 0.291

The data correspond to period 1961 - 2000.

a) Calculate **the return period T** of the maximum flood, knowing that the risk of flooding during the lifetime of the structure (100 years) is limited to 10%. (5 pts)
b) For a 1000-year return period, calculate the corresponding **Q_T flow rate** assuming that the maximum river flows follow a normal distribution. (5 pts)
c) What is the probability that a peak flow of 950 m^3/s **will be exceeded** at least once during the construction period (3 years) of the structure? Assume that the flows follow a log-normal distribution. (5 pts)
d) Flow measurements taken between 1921 and 1960 on the Black River were found in archives. The average maximum flow and standard deviation of this time series are 580 m^3/s and 165 m^3/s, respectively. Check the hypothesis that the mean maximum flow values of samples taken in 1961-2000 and in 1921-1960 **are statistically similar** with a significance level of 5%. (5 pts)

Question 2 (20 points)

The village of La Haute Montagne is worried that the river which passes through the village leaves its bed because of a significant warming of the temperature in the coming days. The watershed, with an area of 150 km^2, is located in a mountainous area and is covered with a snowpack.

Measurements using a snow sampler show that:

- In the lower portion of the watershed, the snow water equivalent is 30 mm
- In the upper portion of the watershed, the snow water equivalent is 100 mm

Caracteristics of the lower and upper portions of the watershed are as follows:

	Lower portion	Upper portion
Mean elevation (m)	200	700
% of watershed	40	60
% forest / % agricultural	0 / 100	100 / 0

Meteorological forecasts (temp and precip) are as follows, estimated at 200 m elevation :

Day 1: $T_{mean} = 7^oC$, P = 12 mm

Calculate the total runoff volume, in m^3, produced on the watershed at the end of this day.

The snow melting equations to be used are as follows:

Wooded sites : $M = 2.3\ T_{mean} + 0.0126\ T_{mean}\ P$ M in mm/day, T_{mean} in ^oC, P in mm

Clearings : $M = 2.7\ (T_{mean}+4.4) + 0.0126\ T_{mean}\ P$

Infiltration is assumed to be zero. The liquid holding capacity of the snowpack is 5% of its mass. The decrease in temperature with the elevation is 6^oC per 1000 m.

Question 3 (20 points)

Tables 1 and 2 show the intensity of a rain fall event in mm/h during each of the time intervals where precipitation occurred and the resulting hydrograph in m^3/s. Direct runoff begins at 3:00 am and ends at 6:00 pm. The area of the catchment area is 25 km^2. Knowing that the infiltration capacity of the soil is constant throughout the rainfall event:

a) Determine the **1-cm, 3-hour unit hydrograph** corresponding from the observations given in Tables 1 and 2 below. To do this, you will have to calculate the direct runoff, evaluate the infiltration index ϕ and determine the duration of the corresponding net rainfall. (12 pts)

b) For the same watershed, a 9 mm/hour net rainfall of three hours duration is occurring, immediately followed by a 12 mm/hour net rainfall of three hours duration. The rain started at 00:00 hours. Determine **the peak flow rate** of the resulting hydrograph by assuming a constant base flow rate of 10 m^3/s. (8 pts)

TABLEAU 1

Time (hours)	Precipitation (mm/h)
0h00 – 3h00	0
3h00 – 6h00	40
6h00 – 9h00	15
9h00 – 12h00	5

TABLEAU 2

Time (hours)	Flow (m^3/sec)
0h00	16
3h00	16
6h00	48
9h00	69
12h00	54
15h00	32
18h00	16
24h00	15

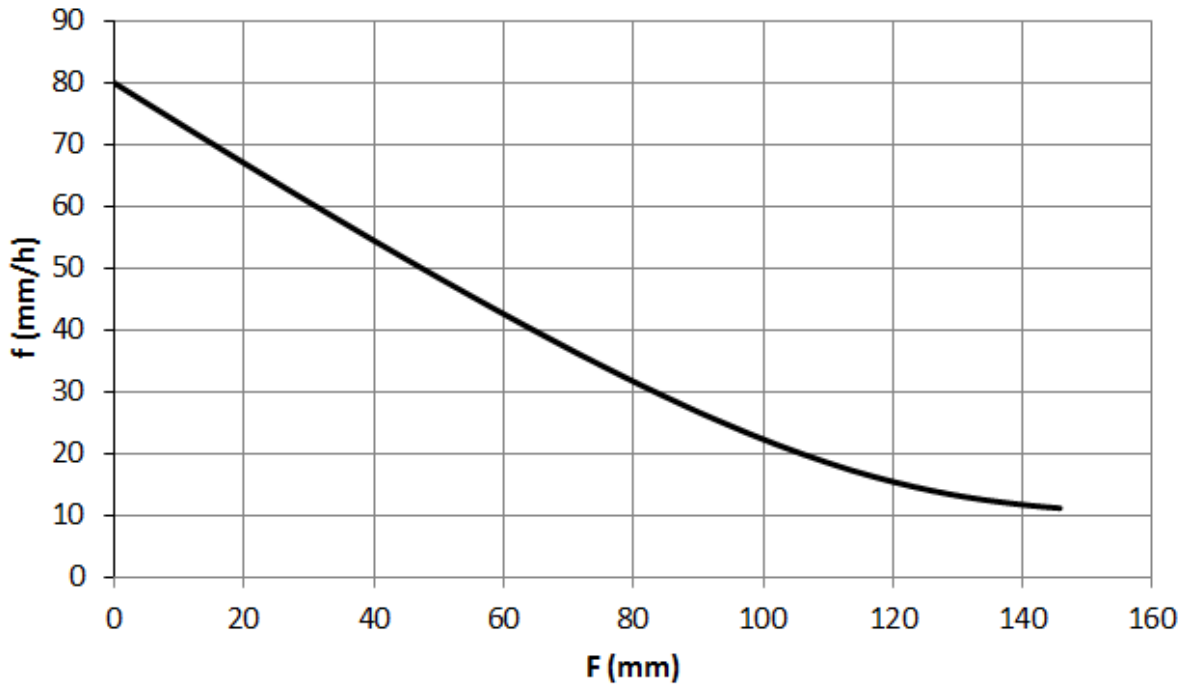
Question 4 (20 points)

Determine the net rainfall hyetograph from the total precipitation hyetograph below. Assume that infiltration follows the Horton model with the following parameters, which depend on soil type:

f_0 = 80 mm/h
f_c = 10 mm/h
k = 0.75 h^{-1}

Also, F_0 = 82 mm at time t = 0

T (hour)	0h00 – 1h00	1h00 – 2h00	2h00 – 3h00
P (mm)	10	25	10



Question 5 (20 points)

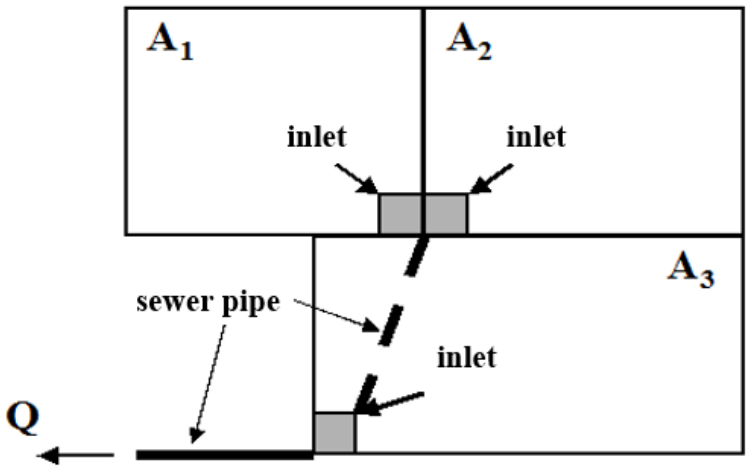
For the drainage basin shown below located in Ste-Foy, Qc, find the peak flow **at each stormwater inlet** for a 10-year return period and design flow **for each of the two stormwater sewer pipes** using the rational method. Use the IDF curve on the next page.

The characteristics of the drainage basins are as follows:

	Basin A1	Basin A2	Basin A3
Runoff coefficient	0.6	0.5	0.45
Area (ha)	2.13	2.29	2.66
Time of concentration (min)	8	10	15

The characteristics of the storm sewer pipe in basin A3 are as follows:

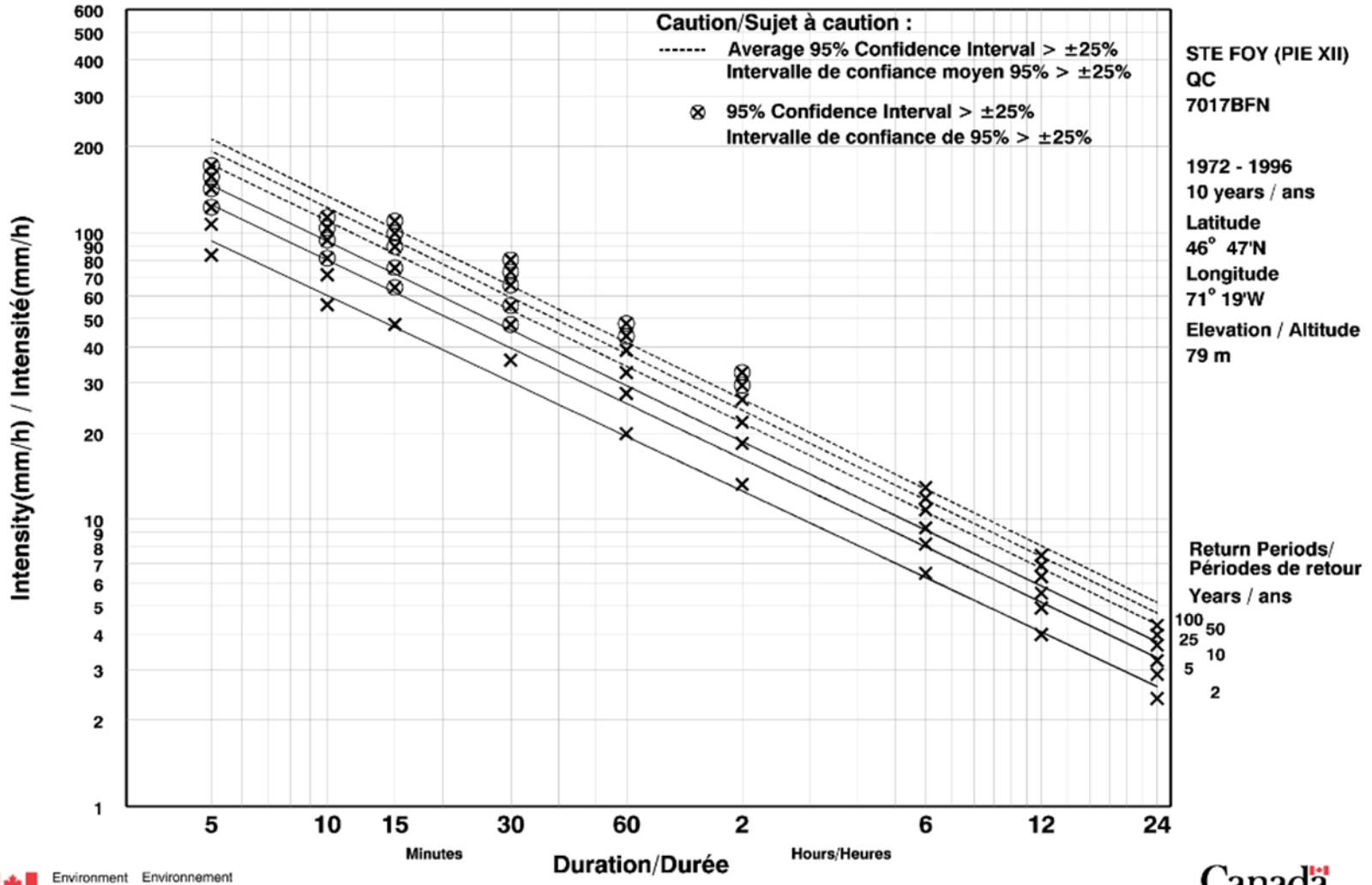
Length = 240m
Flow velocity = 0.9 m/s



Short Duration Rainfall Intensity-Duration-Frequency Data

2012/02/09

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



Environment Canada Environnement Canada

Canada