Abdelhafid Bousouf University Center - Mila

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Sanitation

– Lesson 3 –

Chapter 3 : Evaluation of flow rates to be collected

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Course Objectives 3

This course aims to provide the theoretical and methodological foundations necessary for

the assessment of the flow rates to be collected in the hydraulic networks, taking into account the

different water sources, climatic variations and technical constraints.

General objectives

• Understand the fundamental principles of calculating the flow rates to be collected.

• Identify water sources and their impacts on network design.

• Apply the sizing methods for collection and evacuation systems

waters.

1. Introduction

After the drinking water has been used, the so-called "wastewater" is discharged into a network.

which must be able to discharge at any given moment a flow rate roughly equal to that consumed without

No risk of reflux.

2. Sizing of the sanitation network

2.1 Determination of flow rates

2.1.1 Stormwater

The study of a stormwater drainage network requires the determination of the

Flow rates to be evacuated. There are several methods for evaluating the flow rate. The two methods...

The most commonly used are:

1. The rational method

2. The superficial method

3. The Mac-Math model

4. The Malet-Gauthier model, etc.

- Choosing a suitable model depends on several factors:

ÿ The surface area of the catchment area

ÿ The nature of the soil

ÿ The slope

ÿ The roughness of the structures

2.2 The rational method

The rational method consists of estimating flow rates based on a division of the basin slope in sector (A1, A2 , A3,…, An) limited by isochrone lines.

Isochrones: "Corresponding to the same instant" (or "the same duration")), such as Water falling onto sub-basin A1 respectively A2....An ; reaches the outlet at the end of ÿt respectively 2 ÿt....n ÿt (Figure 1).

Note:

In hydrology, in the case of a watershed, an isochrone line is formed by the set points where a drop of water takes the same amount of time to trickle down to the point calculation characteristic (generally, the outlet).

Fig. 1: Division of the basin into isochrone curves

This is the oldest, most widely used, and easily applicable method for the small towns and villages. The general formula is as follows:

With :

Q : Rainfall flow rate (m3 /s)

k : intensity correction coefficient taking into account rainfall in space, of which the The determination depends on the elongation of the pelvis.

C : runoff coefficient specific to the sub-basin

A : basin area (ha)

I: maximum rainfall intensity (in l/s/ha)

3. Defining the parameters

3.1 Watershed (A)

The catchment area is defined as the collection area that gathers the waters of runoff concentrates them towards the outlet point called the outlet.

A watershed is characterized by its surface area, its average slope, its length

hydraulics and its runoff coefficient.

The division of the catchment area depends on the type of sanitation system chosen.

For separate and unitary systems, the division encompasses the roof area and

roadway, however, for the pseudo-separate system, it includes the right-of-way of the lanes, the

parking lots and green spaces.

3.1.1 Watershed division

Watershed division involves determining, for each segment, the area it must

sanitize.

To proceed with the division of the basin into elementary sub-basins (area of influence) it

The following must be taken into consideration:

- • Contour lines

- • Natural boundaries (wadi, thalweg, etc.)

- • The nature of the soil

- • Population density

- • Roads and highways

- • The slope of the terrain

- **Watershed area :** the area is assessed by dividing it into shapes

simple geometric shapes.

3.1.2 The return period of the rainfall event

Sanitation works must ensure a sufficient degree of protection against

flooding or strain on the networks.

The degree of protection to be ensured is a compromise between the aspiration for protection

absolute, which is economically unfeasible, given the random nature of

rainy events, and the concern to limit the cost of the investment.

We are thus led to appreciate the more or less exceptional nature of thunderstorms by

their overshoot frequency F, or by their return period T = 1 / F.

The choice of the return period is made by the competent authority (usually the owner).

(of work) depending on:

• the risk to local residents;

• the risk to the environment of the structure;

• the risk to the structure;

3.2 The runoff coefficient Cr

It is the ratio of the volume of water that runs off a surface to the volume of water

fell on that same surface.

It plays a leading role in assessing peak rainfall flows; which are used to

Network sizing. Its value varies from 0.05 to 1, depending on several factors:

ÿ The nature of the soil

ÿ The slope of the land

ÿ The land use pattern ÿ The

population density ÿ The

duration of rainfall

ÿ Air humidity

Generally speaking, the runoff coefficient is considered to be

being the rate of impermeability of the sub-basin.

With :

Aimp : Waterproof surface

At : Total surface area of the sub-basin

The following approximate values are used:

Table 2.I: Runoff coefficient as a function of the area of influence:

Area of influence	Cr
Completely impermeable surface (roofs, roads, sidewalks...)	0.90
Paving with wide joints.	0.60
Unpaved roads and asphalt	0.35
Gravel paths	0.20
Wooded areas	0.05

Table 2.2: Runoff coefficient according to urbanization categories:

Area of very dense urbanization	Runoff coefficient
Densely populated residential area	0.90
Less densely populated residential area	0.60 – 0.70
Residential area	0.40 – 0.50
Residential neighborhoods	0.20 – 0.30
Squares, gardens, meadows	0.05 – 0.20

Table 2.3: Runoff Coefficient as a Function of Population Density

Density of population	Cr
20	0.23
30 − 80	0.20 − 0.27
80 − 150	0.25 − 0.34
150 − 200	0.30 − 0.45
200 − 300	0.60 − 0.62
300 − 400	0.60 − 0.80
400–600	0.70 − 0.90
600 − 700	0.70 − 0.90

Table 2.4: Runoff coefficient as a function of slope:

Slope I	Average runoff coefficient		
%	Culture	Wooded Land	Rocky Terrain
0 ÿ I ÿ 10	Cr = 1.5 I	Cr = I	Cr = 2 I
10 ÿ I ÿ 20	Cr = 0.05 + I	Cr = 2/3(0.05 + I)	Cr = 4/3(0.05 + I)
I > 20	Cr = 0.15 + I/2	Cr = 2/3(0.15 + I/2)	Cr = 4/3 (0.15 + I)

3.2.1 Determination of the Weighted Runoff Coefficient

In the case where the surface of the basin in question is made up of several feeding areas "Ai"

to which the runoff coefficients "Cri" are assigned, the coefficient of

weighted runoff:

With :

Crp : weighted runoff coefficient

Ai : elementary surface

 Cri : runoff coefficient corresponding to Ai   .

Example

C1 = 0.20; A1 = 2ha

C2 = 0.3; A2 = 1.5 ha

C3 = 0.05; A3 = 1.8ha

C4 = 0.10; A4 = 2.5ha

Find Ceq

Solution :

- At point 1

C = C1 = 0.20

- At point 2

C=

=0.24

- At point 3

C=C1*A1+C2*A2+C3*A3/A1+A2+A3

= 0.18

- At point 4

C=C1*A1+C2*A2+C3*A3+C4*A4/A1+A2+A3+ A4

=0.15

3.2.2 Determination of intensity

The average rainfall intensity is the amount of water that falls during a unit of

time.

The intensity is expressed as a function of the parameters **a** and **b** by the "Montana" formula:

$$i \ (T, F) \ (mm/h) = a. \ tcb$$

a and b are Montana parameters that are functions of rainfall and are valid for a return period T

and a given duration of rainfall tc.

Note = MONTANA coefficients vary according to region and return period.

Example :

T = 10 years (10-year rainfall event)

Time interval tc = 15 mm

- regional values of a and b:

a = 6.7 b = 0.55

i = 1.51 mm/h

3.3 Concentration Time

The duration t of the downpour that produces the maximum flow rate Q is taken to be equal to the time of concentration.

The time of concentration is defined as the time it takes for a water particle

to travel the longest hydraulic path from the basin boundary to the outlet

$$Tc = 0.127.$$

Depending on the characteristics of the drained basin, the concentration time is estimated respectively according to:

a. VENTURA (Ray):

Tc = concentration time in hours
S = surface area of the catchment area in km²

.p = Slope in m/m

Area of validity between 1 and 20 km² or greater than 10 km² depending on the works.

b) TURRAZA:

Tc = concentration time in minutes

S = surface area of the catchment area in hectares

L = longest hydraulic path in meters

p = slope in m/m

c) VEN TE CHOW:

Tc = concentration time in minutes

L = longest hydraulic path in meters

p = slope in m/m Range of validity for agricultural catchment areas of 1 to 2 hectares.

Note : It is complicated to determine the range of validity of the time formulas.

concentrations, especially since, according to the literature, for the same formula, the times of

validity varies.

o **Temps de concentration;**

Le temps de concentration ou plus long parcours de l'eau se compose de:

- Du temps t_1 mis par l'eau pour s'écouler dans les canalisations:

$$t_1 = \frac{L\,(Longueur)}{V\,(Vitesse\ de\ l'eau)}$$

- Du temps t_2 mis par l'eau pour atteindre le premier ouvrage d'engouffrement ou bouche d'égout en surface. D'après Caquot:

$$t_2 = I_p^{-4/11}$$

Ip = pente moyenne de cheminement hydraulique sur la surface du sol (m/m).

- Du temps t_3 du ruissellement dans un bassin qui ne comporte pas de canalisation:

$$t_3 = \frac{L}{11\sqrt{I_p}}$$

Concentration time can therefore have three aspects:

The basin does not contain any pipes: **tc = t3**

The basin includes a surface run followed by a pipe: **tc = t3 + t1**

The basin is urbanized and includes a main pipeline and tertiary connections:

tc = t2 + t1.

　　　　The Tc of an urban catchment is the longest time it can take for water

which flows into this catchment area to reach the sewer outlet. The value of the entry time

is a function of:

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- The average slope of the ground surface towards the sewer outlet.

- The distance that the water must travel, on the surface, to reach the sewer outlet.

- The nature of the surface over which the water must flow

$$Tc = Te + Tf$$

Te: The time it takes for water running off the surface to reach the mouth

sewer (entry time) or the longest time.

Tf: The water flow time along the sewer network, it is in

function of the flow velocity.

Note that:

- For the end sections:

We take: **Te = 5 min, Tf = L/60*Ve**

- For intermediate sections:

Ti = T(i-1) + Li/60*V(i-1)

- **Méthode simplifiée de calcul de tc pour une zone urbanisée**:

On admet un temps de circulation superficielle égale à 5 mn et une vitesse en égout égale à 1 m/s :

$$tc = t_1 + t_2 = \frac{L}{V} + 5 \text{ mn} \qquad tc \text{ (mn)} = \frac{L\ (m)}{60\ m/mn} + 5 \text{ mn}$$

The concentration time of an urban basin, composed of several sub-basins (some land and buildings), is the sum of the longest water flow times of runoff time *to* reach the sewer outlet and flow time in the pipe *tf.*
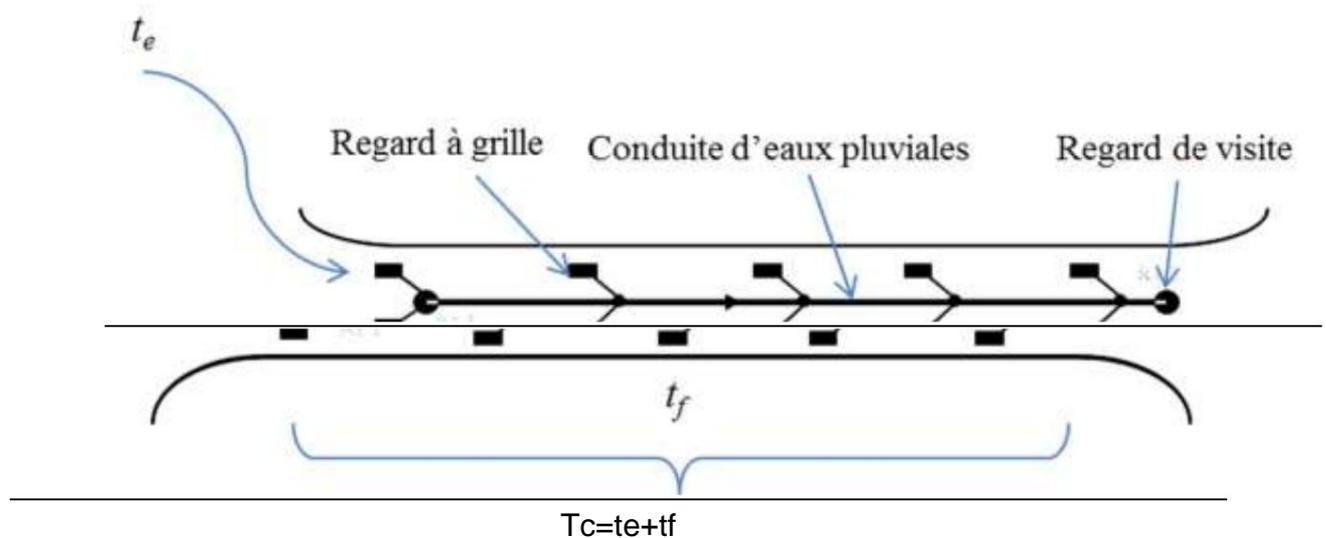
$$Tc=te+tf$$

Figure 2: Urban watershed

3.4 The Assumptions of the Rational Method

The following assumptions are therefore made:

• The peak flow rate is proportional to the average intensity of the downpour over time. concentration.

• The intensity of the downpour in mm/h is uniform, in time and space, over the entire drained basin

• The peak flow rate Q_p in m3 /s of the runoff hydrograph is a function of the precipitate flow rate i.

• Finally, the runoff coefficient is invariable from one downpour to another.

3.4.1 Calculation Procedure

1. Divide the basin into elementary sub-basins corresponding to junctions of sections, Change of direction;

2. Evaluate and calculate the different parameters

3. Calculate the cumulative surface areas multiplied by their runoff coefficient corresponding

4. Evaluate the flow rate and consider the maximum flow rate.

3.4.2 Validity of the rational method

This method is used for limited areas (generally less than 10 ha) the result is even lower due to the correct estimation of the coefficient of runoff, therefore it is applicable to areas where the concentration time does not exceed

not 30 minutes. However, it is not likely to be used only for large areas.

because of the length of calculations it would entail.

3.4.3 Average Slope

The average slope of a sub-basin is generally taken to be equal to the average slope of the

collector that serves it. When the path of the runoff water has no slope

(slope), the slope will be calculated as the ratio between the difference in the upstream and

downstream along the length of this route.

3.5 The superficial method

a. *General formula*

This method is proposed by Mr. CAQUOT who developed a formula including

all the data involved in formulating runoff points, y

including climatic coefficients.

The most recent studies, confirmed by experimental verification, have made it possible to

fix the numerical value of the coefficients of this expression:

$$Q_p = k^{i/u} I^{v/u} C^{i/u} A^{w/u}$$

$$Q_{brut} = k^{1/u} \cdot I^{v/u} \cdot C^{1/u} \cdot A^{w/u} \qquad K = \frac{0{,}5^b \cdot a}{6{,}6} \qquad u = 1 + 0{,}287 \cdot b \qquad v = -0{,}41 \cdot b \qquad w = 0{,}95 + 0{,}507 \cdot b$$

K: characteristic coefficient; **a** and **b :** are the Montana coefficients, a>0, b<0

$Q_{corrigé}$

A : surface du bassin versant (ha)   I : pente moyenne du bassin versant (m/m)

C : Coefficient de ruissellement, il dépend de la nature du sol et du degré de son imperméabilité

K : coefficient caractéritique   0,86 0,86 0,21 0,70

En Algérie les paramètres a et b sont égales à a = 4 et b=-0,5 pour une période de retour de 10 ans

K = 0,86   u = 0,86   v = 0,21   w = 0,7

$$Q_{brut} = k^{1/u} \cdot I^{v/u} \cdot C^{1/u} \cdot A^{w/u} \qquad\qquad Q_{brut} = 0{,}84 \cdot I^{0{,}24} \cdot C^{1{,}17} \cdot A^{0{,}81}$$

In this expression, all parameters are functions of a(F) and b(F), which are themselves **i(t,F) =**
linked by the relationship: **a(F) t b(F)**

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With :

i(t,F): maximum rainfall intensity of duration (t in minutes is between 5 min and 120 min) and frequency (F)

Qp : rainfall flow rate (m3 /s)

I: average slope of the basin (m/m)

C: runoff coefficient of the basin

A: basin surface area (ha)

K: expression coefficient: $K = 0.5\ b(F)$. ÿ(F) /6.6

U: expression coefficient $U = 1 + 0.287\ b\ (F)$

V: expression coefficient $V = -0.41\ b\ (F)$

W: expression coefficient $W = 0.95 + 0.507\ b\ (F)$

This formula is valid for watersheds of average elongation " $M = 2$ "

Table 2.5: The different forms of the formula as a function of the period of back

Return period	The formula
10 years	$Q = 1.430\ I^{0.29}\ Cr^{1.20}\ A^{0.78}$
5 years	$Q = 1.192\ I^{0.30}\ Cr^{1.21}\ A^{0.78}$
2 years	$Q = 0.834\ I^{0.834}\ Cr^{1.22}\ A^{0.77}$
A year	$Q = 0.682\ I^{0.32}\ Cr^{1.23}\ A^{0.77}$

For the region, they would meditate and have a return period of 10 years; the previous formula is written

$$Q = 1.29\ I^{0.21}\ Cr^{1.14}\ A^{0.83}$$

3.5.1 Elongation coefficient

The elongation coefficient **M** is considered to be the ratio between the length of the longest hydraulic path **L** and the side of the square of the equivalent surface that of the basin in question $M = \dfrac{L}{\sqrt{A}}$

With :

A: the surface area of the sub-basin (ha)

The purpose of this coefficient is to provide a certain degree of accuracy in the evaluation of the flow rate.

If the value of the coefficient **M** is different from **2,** the flow rate will be corrected by a factor of correction **m** which is given by the formula:

$$m = \left[\frac{M}{2}\right]^{[0.84\, b(F)/(1-b(F)F)]} = \left[\frac{M}{2}\right]^{[-0.42]}$$

With :

M: coefficient of elongation

b(F): parameter for expressing rainfall

f: the adjustment factor for peak flow in the expression for concentration time

(F= - 0.287)

Qp corresponds to a raw value; this must take into account the coefficient **m** of the form of basin.

Q p corrected = m Qpbrute

3.5.2 The Assumptions and Calculation Basis of the Model

The method is also based on three assumptions, which are:

4. Peak flow can only be observed at the outlet if the downpour has a duration of
   less than or equal to the concentration time.
5. The peak flow rate is proportional to the average intensity of the downpour over time.
   concentration.
6. The peak flow rate has the same return period as the intensity that causes it.

3.5.3 Limitations of Application of the CAQUOT Model

   • The network should not be under load for maximum throughput because the model of
        CAQUOT allows the determination of maximum flow rates in the various
        sections
   • The total surface area of the basin must be less than 200 ha
   • The runoff coefficient must be between 0.20 and 1.00
   • The slopes will be between 0.002 and 0.05 m/m
   • When it comes to assembling elementary basins, the ratio of
        Minimum and maximum slopes do not exceed 20
   • The elongation coefficient must be greater than 0.8

3.6 Evaluation of equivalent parameters of a group of basins.

     The surface formula developed above is valid for a basin of

homogeneous physical characteristics. Applying the model to a grouping of sub-

heterogeneous basins with individual parameters Aj, Cj, Ij, Lj (main drain length), Qpj

(peak flow of the basin considered alone), requires the use of equivalence formulas for

the parameters "A, C, I and M" of the grouping.

These formulas differ depending on whether the basins constituting the grouping are in *"series"* or

in   *"Parallel"* are expressed below:

Table 2.6: Characteristics of each sub-basin grouping:

Mass assembly	Parallel assembly
$A\ Ai \atop \ddot{y}=i\mathbin{=\!}$	$A\ Ai \atop \ddot{y}=i\mathbin{=\!}$
$Creq = \dfrac{\displaystyle\sum_{i=1}^{N} Cry\ Ai}{\displaystyle\sum_{i=1}^{N} Ai}$	$Creq = \dfrac{\displaystyle\sum_{i=1}^{N} Cry\ Ai}{\displaystyle\sum_{i=1}^{N} Ai}$
$I\acute{e}q = \left(\dfrac{\displaystyle\sum_{i=1}^{N} Li}{\displaystyle\sum_{i=1}^{N}\left(\dfrac{Li}{\sqrt{II}}\right)}\right)^{2}$	$I\acute{e}q = \dfrac{\displaystyle\sum_{i=1}^{N} IQi}{\displaystyle\sum_{i=1}^{N} Qi}$
$M = \dfrac{\sum L\,j}{\sqrt{\sum A\,j}}$	$M = \dfrac{L}{\sqrt{\sum_{HAS}}}\ (Qmax)$

4. Evaluation of domestic wastewater

Wastewater flow assessment focuses primarily on quality estimation

liquid waste from homes and places of business

4.1. Average cancellation fee

- ~~Method 1 :~~ Domestic wastewater constitutes a significant portion of the flow rate.

    To evacuate, this flow rate is calculated based on the average flow rate of drinking water.

$$Q_{moyeu} = KQ_{moyAep}$$

With :

Qmoy eu: the average flow rate of wastewater.

QmoyAep : the average flow rate of drinking water.

K: coefficient representing the percentage of water consumed that will be discharged

K = 70 – 80%.

- We take 70% QmoyAep in the case of a rural region.

- We take 80% QmoyAep in the case of an urban region.

The 20-30% represents losses of drinking water in the pipes, infiltration, and washing.

streets, watering gardens….

The flow rate of drinking water is calculated by:

$$C_{moyj} = \frac{P_f d}{1000} \qquad (m^3/_j)$$

With :

Cmoy j: the average daily consumption.

d: the allocation (the water requirement for one inhabitant l/day/inhabitant).

Pf: future population.

Or:

$$Qmoyj = Kr. \ DN \ /86400 \ (l/s)$$

With :

Qmoyj: Daily wastewater discharge rate (l/s).

Kr: Rejection coefficient; it is estimated that 80% of the drinking water consumed

is rejected. D: Daily drinking water allocation, estimated at 150 l/day/inhabitant.

N: Total number of inhabitants, N = 4654 inhabitants (example).

- **2nd method:**

The wastewater flow rate can be estimated directly from the average water production.

worn (of).

$$Q_{moyeu} = \frac{P_f d'}{86400} \qquad (l/_s)$$

With :

d' Average wastewater production (l/day/inhabitant) is given in the following table:

Table 2 – 7: Average wastewater production as a function of the number of inhabitants.

Number of inhabitants	d' (l/d/inhabitant)
>2000	100
2000 – 5000	115
5000 – 10,000	125
10,000 – 20,000	145

20,000 – 100,000	160
< 100,000	190

• **3rd method :**

If the number of inhabitants is not available, the concept of population density can be used.

population.

So the future population number:

$$P_f = dA$$

With :

d: density (inhabitant/dwelling/ha)

A: total area (ha)

4.2. Peak wastewater flow

The wastewater flow rate is not constant; it varies according to the seasons, days, and hours. For

To calculate the maximum flow rate through the sewage network, it is therefore necessary to allocate

the average flow rate of a point coefficient.

$$Q_{peu} = k_p Q_{moyeu}$$

Generally, the peak coefficient is estimated by the following relationship:

$$K_p = 1.5 + \frac{2.5}{\sqrt{Q_{moyeu}}}$$

If Qmoy ÿ 2.8 l/s Kp = 3

4.3. Wastewater from equipment

Various public services are called facilities: educational, health, tourist,

administrative and various other public utility services. The estimate is based on the

number of people who frequent the place and the funding allocated for each activity, to

Example titles: – Schools: 10 liters/day/student. – Middle School: 15 liters/day/student. – Shower: 50 liters/customer.

Mosque: 20 l/worshipper.

Conclusion

The assessment of the flow rates to be collected in a wastewater network relies on several methods

adapted to local specificities. An accurate estimate not only ensures a good

network operation, but also preventing overflows and problems

environmental factors associated with wastewater and stormwater.

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Useful links

- https://youtu.be/_0AJpF7DUIA
- https://youtu.be/-iXnLcSsi7s
- https://youtu.be/ssWBpYIsIr4

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