Government of Saint Lucia

Ministry of Infrastructure, Port Services and Transport

Hurricane Tomas Emergency Recovery Project

Hydraulic assessment for flood risk assessment in Soufrière, Fond St Jacques and Dennery

Report # 2: Drainage Designs Standards and Flood Risk Mapping

Annex 1

May 2014

Partner:

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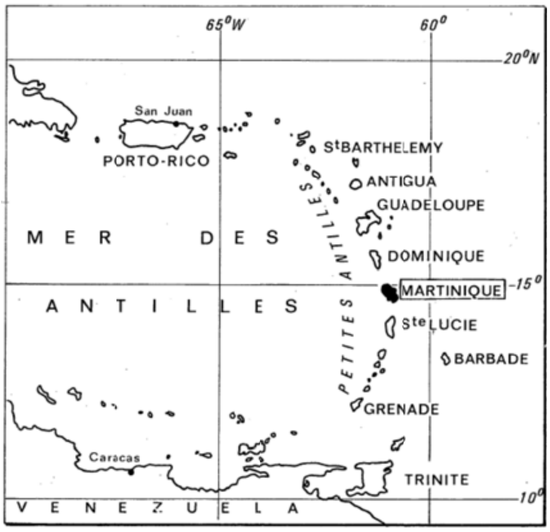
Chapter 1. General context – hydrological analysis in Martinique

1.1 Saint Lucia and Martinique location



Saint Lucie and Martinique are both part of the Windward Island from Lesser Antilles.

They are separated by the Saint Lucia Chanel which is about 33 km long.

They have the same volcanic activity origin (still efficient and due to the movement between Atlantic and Caribbean plates).

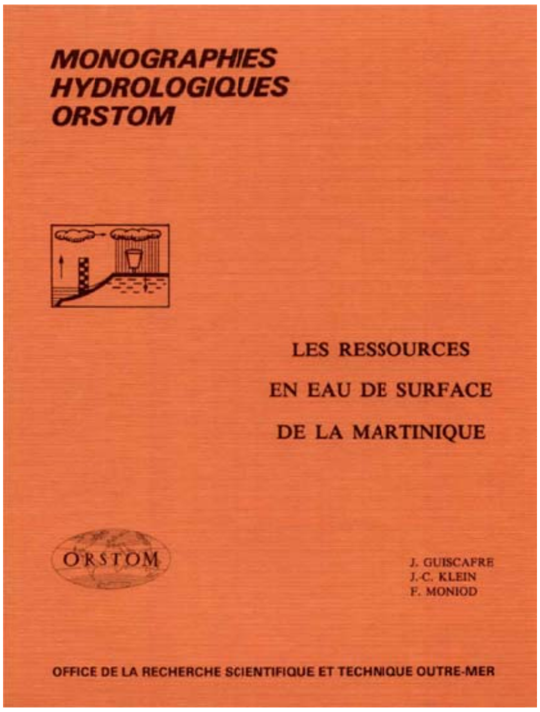
Because of their promiscuity, they are undergoing the same climate that causes the same effects on similar watersheds (flash floods, sediment transport processes, torrential hydraulic, soil erosion, ,…)

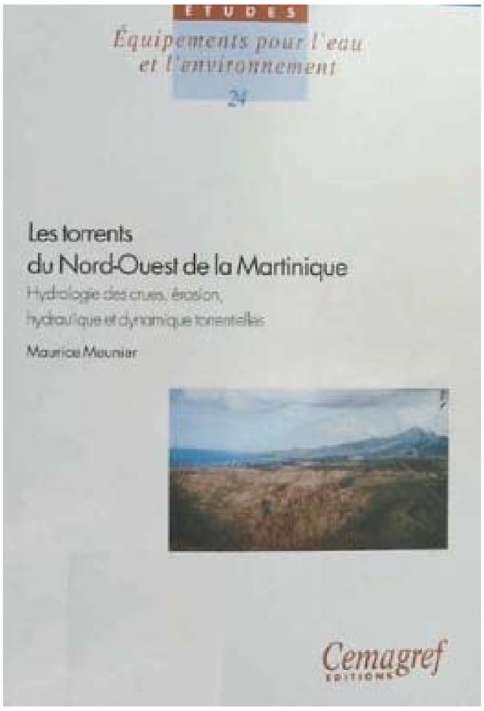
For all those reasons and because there is still a lack of statistics in Saint Lucia we have been taking interest in hydrologic studies in Martinique.

1.2 Statistical studies in Martinique

There are 2 main studies in Martinique which have established the foundation for estimating hydrological parameters for specifics watersheds:

- Hydrological monographs, “Les ressources en eau de surface de la Marinique”, ORSTOM, 1975,
- Martinique Northwest Torrents, CEMAGREF, 1999.





1.2.1 ORSTOM’s study, 1976

This study considered about 112 rainfall stations located in the entire Island.

After the analysis of data available, different types of stations were used for specific analysis:

- For yearly rainfall analysis, 107 stations were used with a total of 1 760 stations-years;
- For the monthly rainfall analysis, 39 stations were used;
- For daily rainfall analysis, 25 stations were used;
- For a shorter length of rainfall analysis (shorter than 24 h), 5 stations were used.

The next illustration localizes the stations (little black cross on the map).

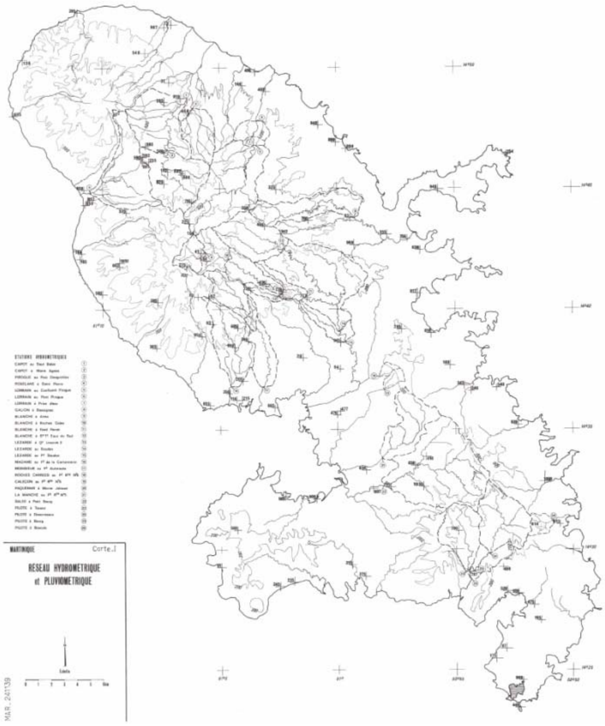


Figure 1 : Overview of rainfall stations and rivers gauges in Martinique

The conclusion of this study is given hereunder.

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The yearly rainfall analysis permitted to build the annual rainfall map as shown below:

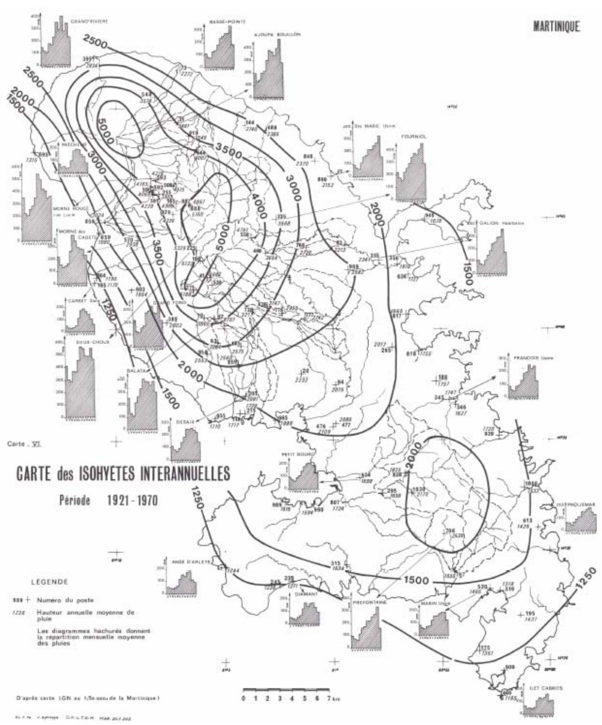

Figure 2 : Map of annual rainfall distribution in Martinique

In comparison to Saint Lucia rainfall distribution, we can see that the values are similar with a maximum above 4000 mm due to a relief a little bit higher in Martinique.

But more generally, the rainfall distribution follows the altitude, as in Saint Lucia.

Then, the study proves that the rainfall from duration "d" (less than 24 h) could be correlated with the annual value at the same place.

This correlation is given in the following table:

Duration < 1 h			
$H(d,T) = 55 \times d^{0,62} \times T^{0,22+0,07 \log t}$			
1h < Duration < 24 h			
Yearly rainfall	< 2 500 mm	2 500 mm – 3 500 mm	> 3 500 mm
East Coast	$H(d,T) = 45.d^{0,27}.T^{0,25}$	$H(d,T) = 50.d^{0,30}.T^{0,25}$	$H(d,T) = 55.d^{0,35}.T^{0,25}$
West coast	$H(d,T) = 45.d^{0,27}.T^{0,25}$	$H(d,T) = 50.d^{0,30}.T^{0,25}$	$H(d,T) = 50.d^{0,30}.T^{0,25}$

"d": rainfall duration

"T": Return Period

1.2.2 CEMAGREF's study, 1999

This study was ordered by local authorities working for French Government to provide a method that will be used in flood risk prevention plans, for torrential risks in the northern part of Martinique Island.

The analysis has completed the Orstom Study with 20 more years of collected data.

The principle of an equation correlating rainfall (H) with the return period $T^{0,25}$ is reconsidered as the research made by Meteo France (French official office for analyzing and predicting weather) and others studies all over the world proved that a Gumbel adjustment is more appropriate.

Also they looked for a Gumbel Law adjustment:

$$P(x) = e^{-e^{-\frac{x-x0}{g}}}$$

where P is the probability of non-exceedance and x the random variable (rainfall).

Using the Neperian logarithm, this equation becomes:

$$x = x_0 + g.(-LN(-LN(P)))$$

With P = 1/(1-T) (T: return period):

$$x = x_0 + g.(-LN(-LN(1-1/T)))$$

X_0 correspond to a position variable ant g to the gradex.

This method has been adjusted with data available from different rainfall stations successfully.

Once the main law was chosen, parameters x_0 and g had to be determined.

For this determination, the Orstom data were completed by 20 more years available in 1997 and 30 rainfall stations (useful for rainfall duration below 24 hours) .

Station	City	Altitude	Duration	Annual rain
Molières	Le Prêcheur	320	19	
Gde Savane	Le Prêcheur	675	11	
Aileron 1	Ajoupa Bouillon	840	17	2823
Aileron 2	Saint Pierre	820	6	5435
Alma	Fort de France	460	15	4583
Bois Neuf	Ducos	90	23	1653
Crève-Coeur	Sainte-Anne	40	21	1440
Deux Choux	Fond Saint Denis	605	14	5189
Dominante	Morne Rouge	455	19	3697
Dumauze	Fort de France	1010	14	4189
Fougainville	Rivière Pilote	30	23	1807
Lézarde 2	Gros Morne	170	9	3308
Marie-Agnès	Morne Rouge	360	14	4334
Morne Bellevue	Gros Morne	690	32	4174
Palourde	Gros Morne	505	11	4642
Plateau Sable	Morne Rouge	370	32	3642
Poste Colon	Fort de France	315	15	2243
Sainte Cécile	Morne Rouge	395	38	5036
Choiseul	Case Pilote	116	19	1427
La Manzo	Ducos	70	17	2141
Morne des Cadets	Fond St Denis	510	26	3096
Desaix	Fort de France	144	56	1906
Pointe des sables	Fort de France	25	14	1961
Aéroport	Le Lamentin	3	36	2084
Caravelle	Trinité	33	20	1042
Gallion	Trinité	4	14	1854
Acajou	François	20	7	1890
Bellevue	François	50	7	2053
Cemagref	Lamentin	16	9	2324
Fourniols	Ste Marie	270	5	3406

Table 1 : Rainfall stations used by Cemagref

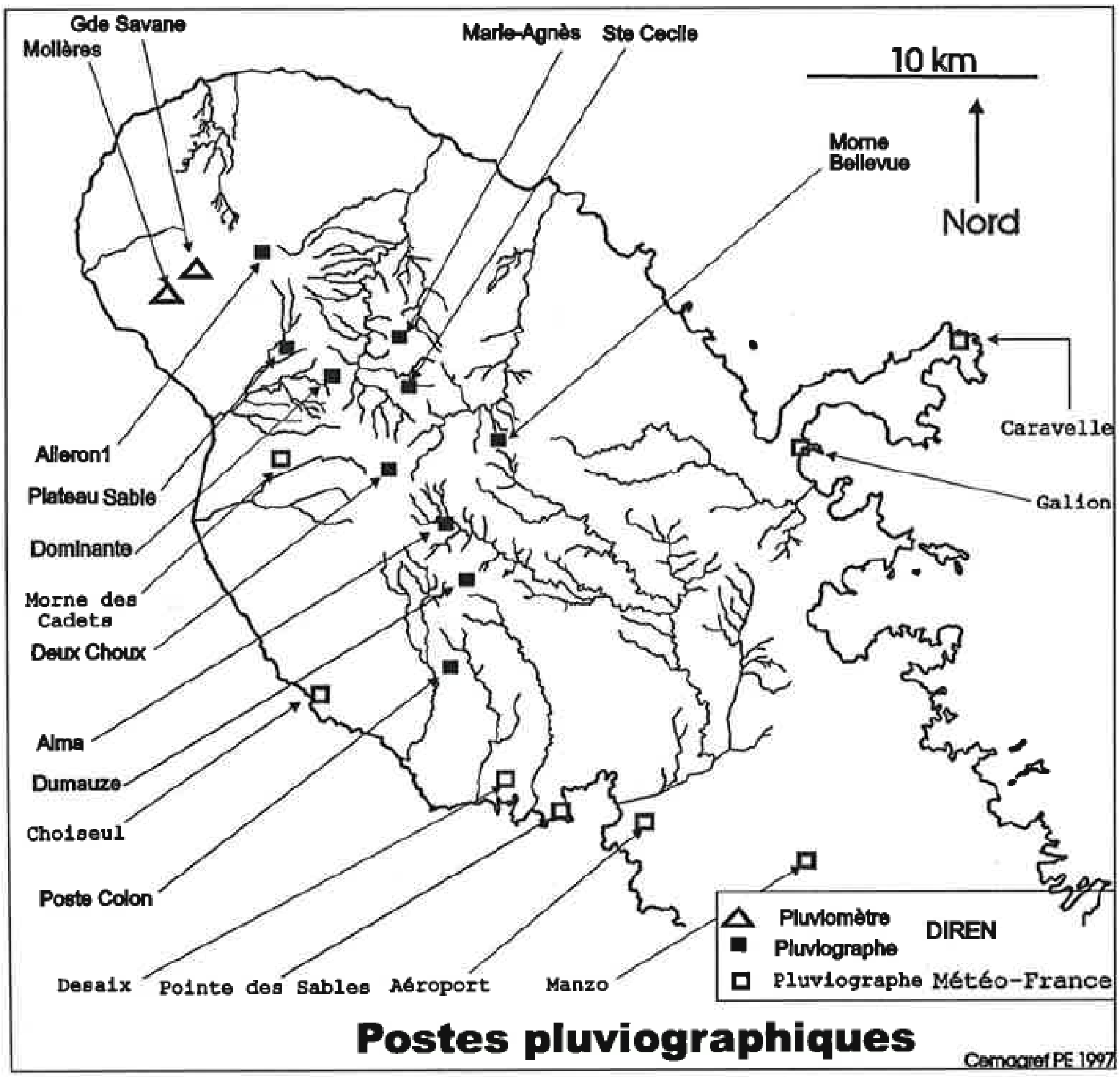

Figure 3 : Rainfall stations used by Cemagref

As the Orstom could highlight, rainfall is correlated with the altitude which is correlated with the yearly rainfall.

Cemagref also tried to find the correlation with yearly rainfall with the Gumbel Law.

The analysis concludes that x_0 (position parameter) and g (gradex) relies on the location of the station which can be modeled in two parameters α and β depending themselves from the yearly rain:

$$\alpha = 0{,}0006 * Yearly\ rainfall\ (mm) + 11$$

$$\beta = 0{,}0045 * Yearly\ rainfall\ (mm) + 28$$

They could define the following equations for x_0 and gradex:

$$x_0 = \beta * (length\ of\ rainfall)^{(0.45-0.04*LN(length\ of\ rainfall))}$$

$$g = \alpha * (length\ of\ rainfall)^{(0.55-0.04*LN(length\ of\ rainfall))}$$

Finally, combining those two equations and the general Gumbel law, we can estimate the rainfall (x in millimeter) for a smaller duration than 24 hours by this general equation:

$$x = \left[(0{,}0045 * Yearly\ rainfall\ (mm) + 28) * (length\ of\ rainfall)^{(0.45-0.04*LN(length\ of\ rainfall))}\right] + \left[(0{,}0006 * Yearly\ rainfall\ (mm) + 11) * (length\ of\ rainfall)^{(0.55-0.04*LN(length\ of\ rainfall))}\right] * (-LN(-LN(1-1/T)))$$

This equation is applicable for :

- **return period between 2 and 100 years for Martinique Island**
- **and for rainfall duration between 1 and 24 hours.**

Chapter 2. Application for Saint Lucia

2.1 Martinique and Saint Lucia similarities

Although Martinique is bigger than Saint Lucia (nearly twice the size), the northern part of the island, as geographical and topomorphological similarities:

- Mountains with steep slopes
- Small watersheds (10-20 km²)
- Altitudes up to 1117 meter high for Piton du Carbet (second highest peak in Martinique) and 950 meter high for Mount Gimie
- Same latitude.

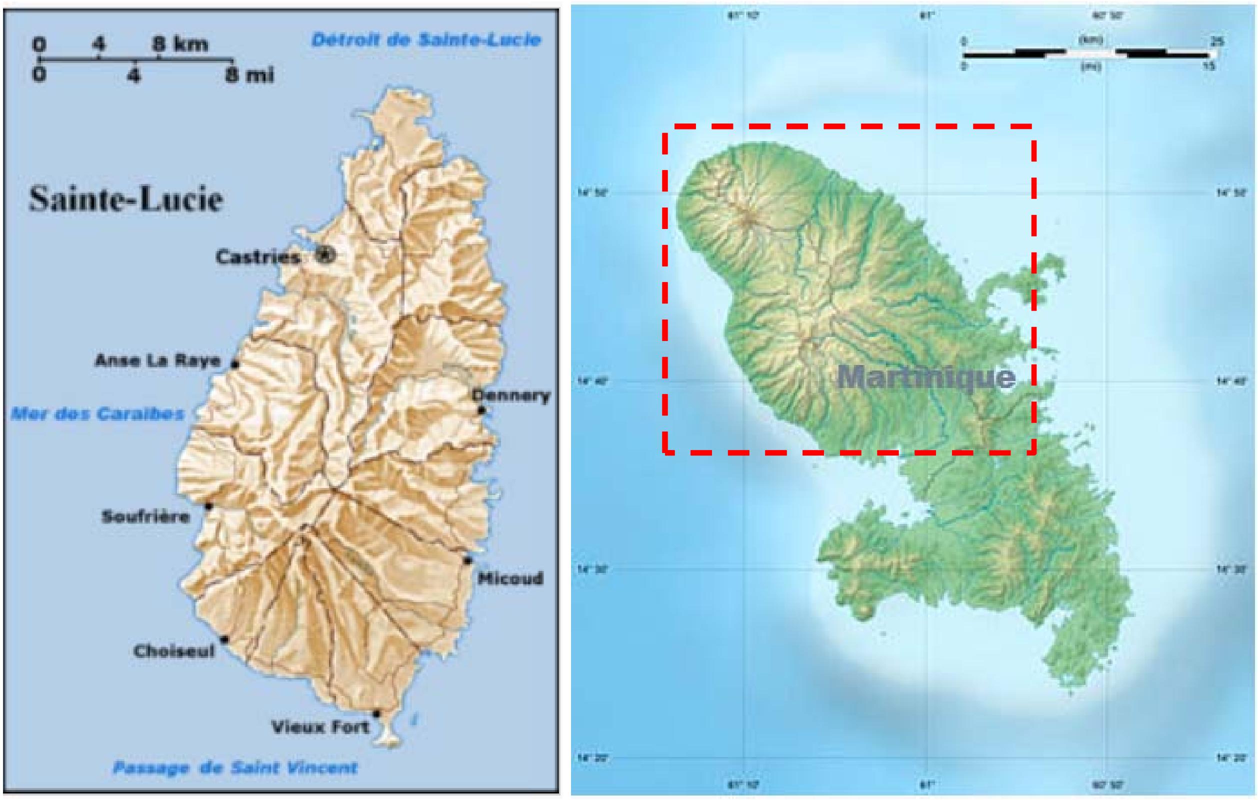

Figure 4 : similarities between Northern Martinique (highlighted in red) and Saint Lucia

2.2 Application in Saint Lucia

2.2.1 Peak flow calculation

To estimate the peak flows in each catchment suited in Soufrière, Fond Saint Jacques or Dennery, the equation mentioned in page 9 has been solved by considering:

- For the rainfall duration: the concentration time (which correspond to the worst rainfall event for the considered catchment);
- For the yearly rainfall parameters: the weighted average of yearly rainfall (established by Chris Cox, 2003) considering the area concerned by class.

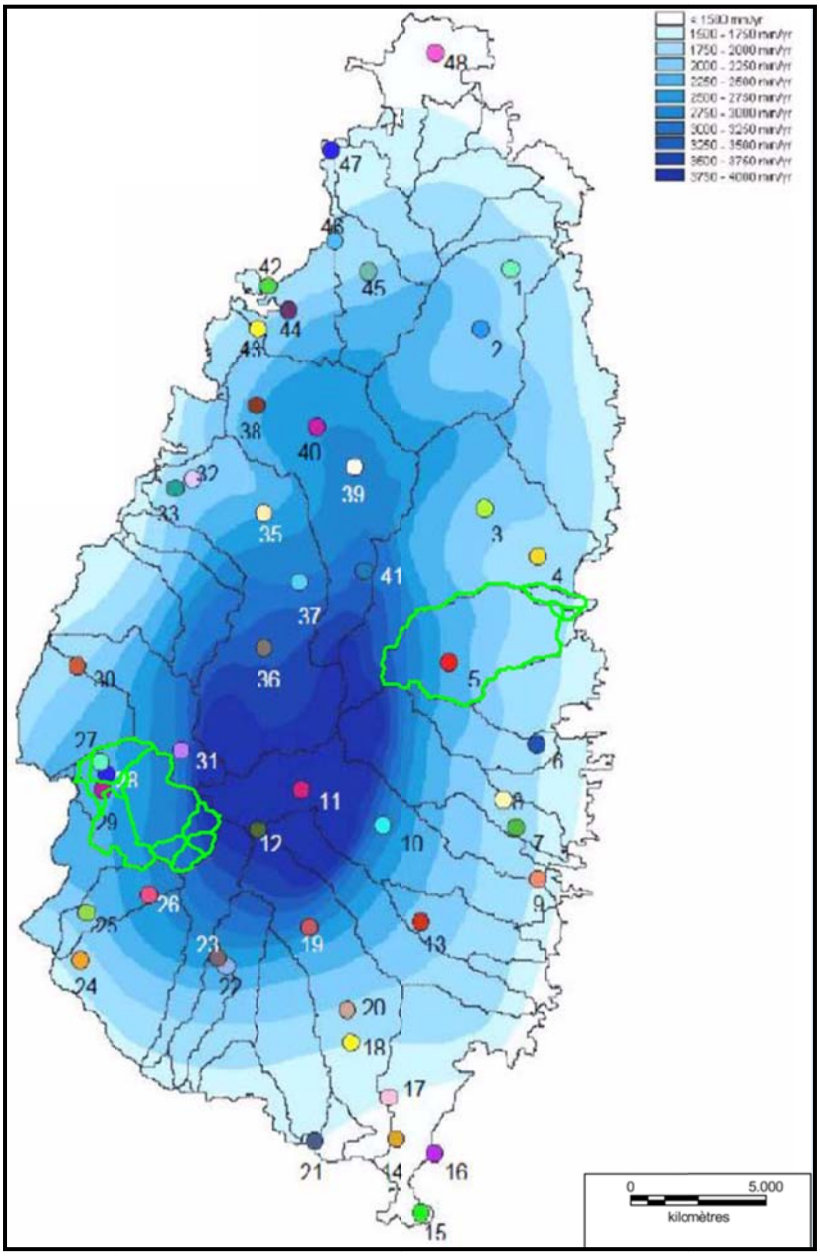

Figure 5 : Map of annual rainfall distribution and studied watersheds

2.2.2 Hydrographs

2.2.2.1 Equation used

Standards hydrographs are determined with the analysis made in Martinique by ORSTOM.

There are estimated considering following parameters:

- Time required to reach the maximum flow **(t_m) = 0.33 x S $^{(0.2)}$**
- Time required to reach a low water level **(t_d) = 1.25 x S $^{(0.4)}$**
- Parameter for water level decrease **(b) = 10 x exp $^{(-0.02xS)}$**

  where S is the area from the considered catchment.

Then the first part of hydrograph (increase of water level) is a linear equation:

- **$Q(t) = Q_P \times (t/t_m)$**

where: Q(t) is the flow at the time t

Q_P is the peak flow

The second part of the hydrograph is a hyperbolic equation:

- **$Q(t) = Q_P \times [t_d - (t-t_m)] / [t_d + b \times (t-t_m)]$**

2.2.2.2 Equation origin

The hydrograph form analysis is based on 10 hydrometric stations from north par of Martinique.

The catchment superficies studied are between 1.98 km² to 66 km² with a majority around 10-35 km²:

Station	S km2
PAQUEMAR	1,98
ALMA	4,3
GROS MORNE	13,0
MADAME	14,3
Station des EAUX du SUD	17,1
FOND PERRET	22,2
LORRAIN	26,0
SAUT BABIN	34,1
SOUDON	62,5
Pont SOUDON	66,7

Table 2 : Hydrometric stations used to determine hydrograph's geometry

They are located on the following Map.

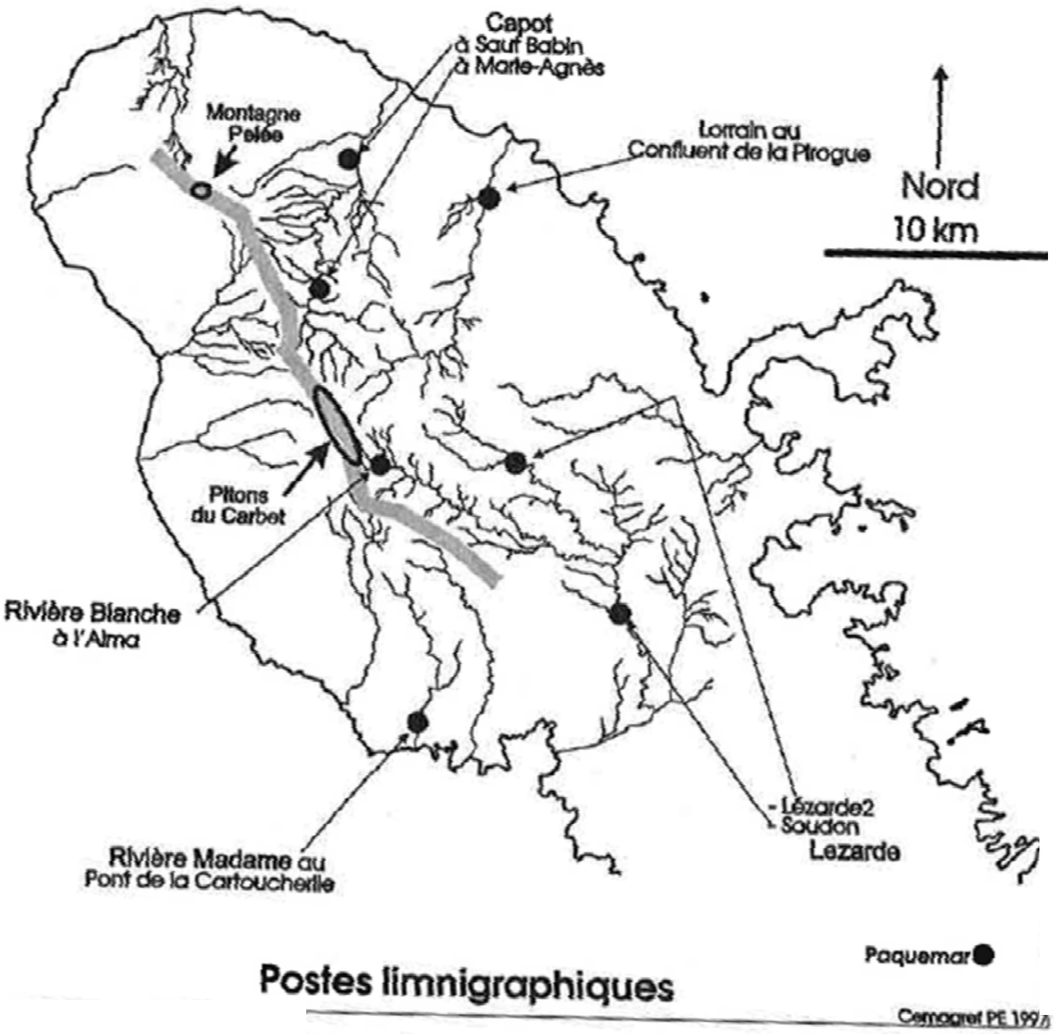

Figure 6 : Hydrometric station location (Cemagref study)

The hydrographs parameters are the result of analyzing the water level (and by the way the flow by using the rating curves) for all flood registered in the 10 gauging stations mentioned before (more than 10 years of registrations).

Results are applicable for watersheds with area between 4 and 50 km².

- Études générales
- Assistance au Maître d'Ouvrage
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- Formation

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