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# Snowmelt and rain-on-snow events: is a simplified modeling approach possible ?


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# OUTLINE

- Introduction – Why ?
- Rain-on-snow processes
- Available models
- Simplified approach
- Case study
- Discussion

# INTRODUCTION – WHY ?

- Most important floods result from spring snowmelt
- Such floods may be augmented by rain-on-snow events

**Rain-on-snow (ROS) events have a complex generation mechanism and are dependent on air temperature and associated precipitation types (rain or snow) as well as the areal extent and thickness of the snowpack**

# INTRODUCTION – WHY ?

- CC: a shift from snowmelt-dominated flooding to rain-on-snow or rainfall-runoff flooding in some areas

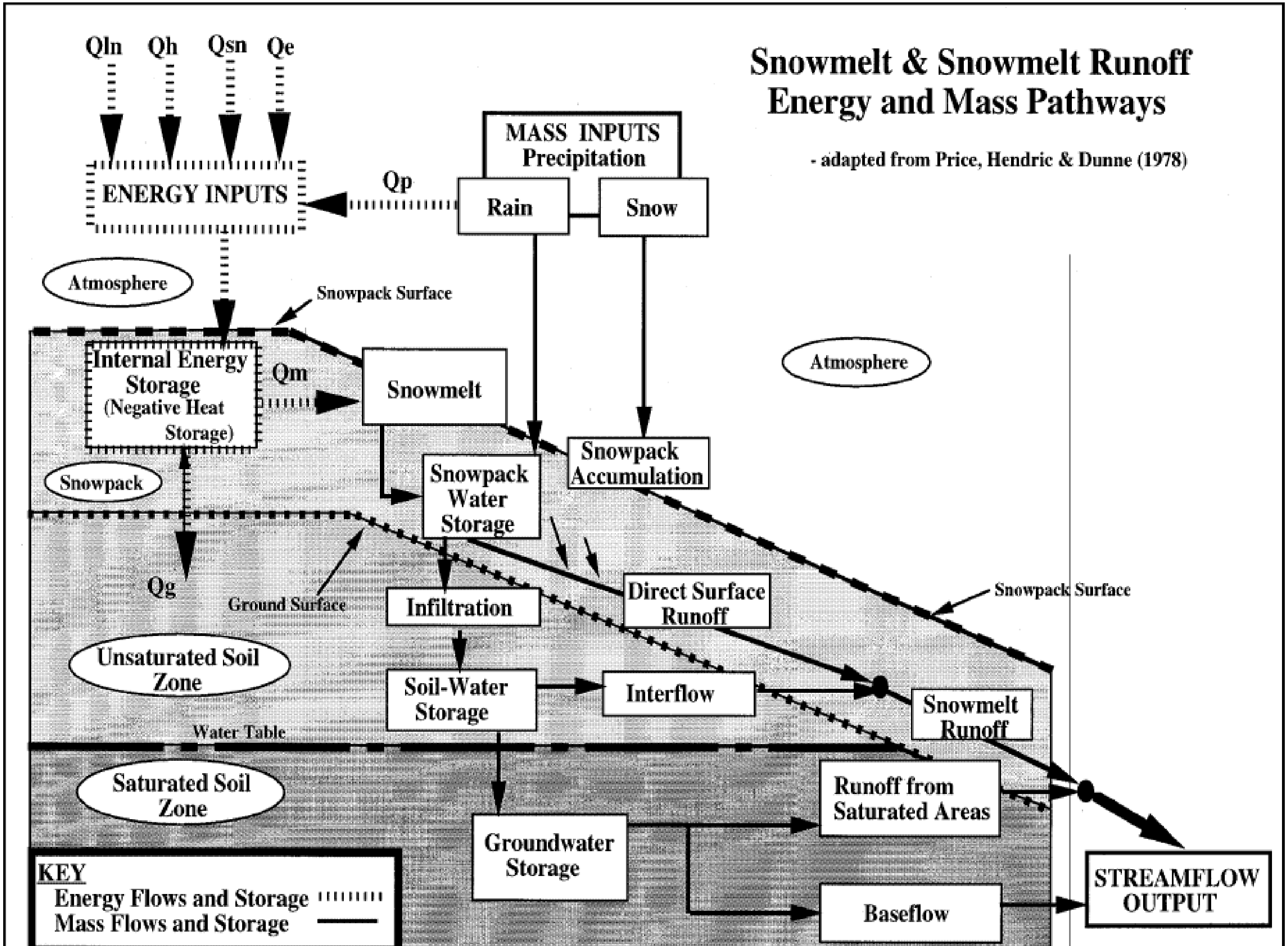
- Historically, snowmelt and rain-on-snow have been the most frequent flood-generating processes in southern ON

# RAIN-ON-SNOW PROCESSES

- Rain-on-Snow is a complex phenomena
- Many variables need to be considered (temperature, humidity, wind speed, snowpack conditions, forests, rain…)
- Complex physics and many possible combinations of parameters

**DIFFICULT TO MODEL IN A DESIGN SITUATION**

# RAIN-ON-SNOW PROCESSES

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# RAIN-ON-SNOW PROCESSES

## SNOW WATER EQUIVALENT (SWE) COULD VARY A LOT

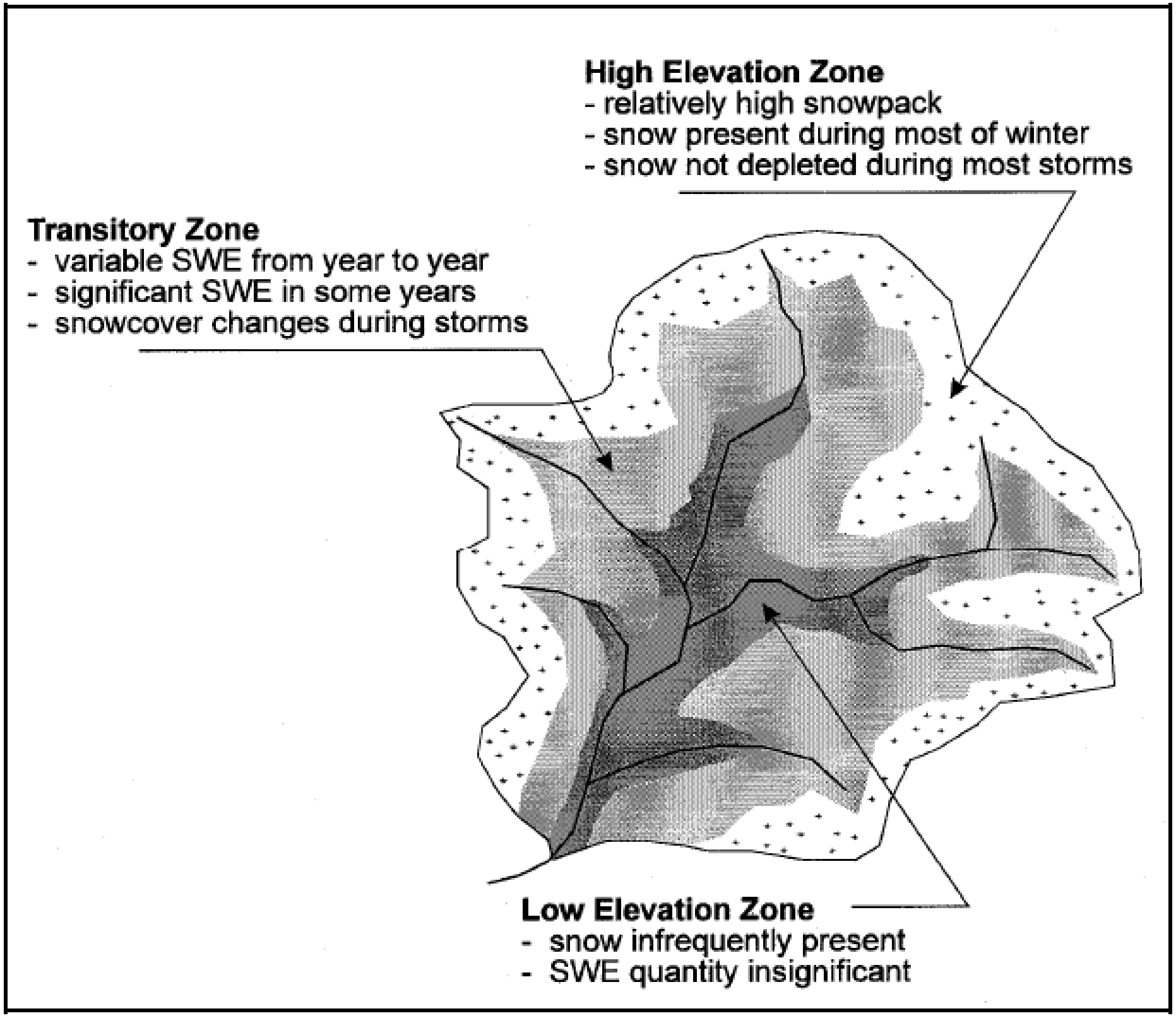
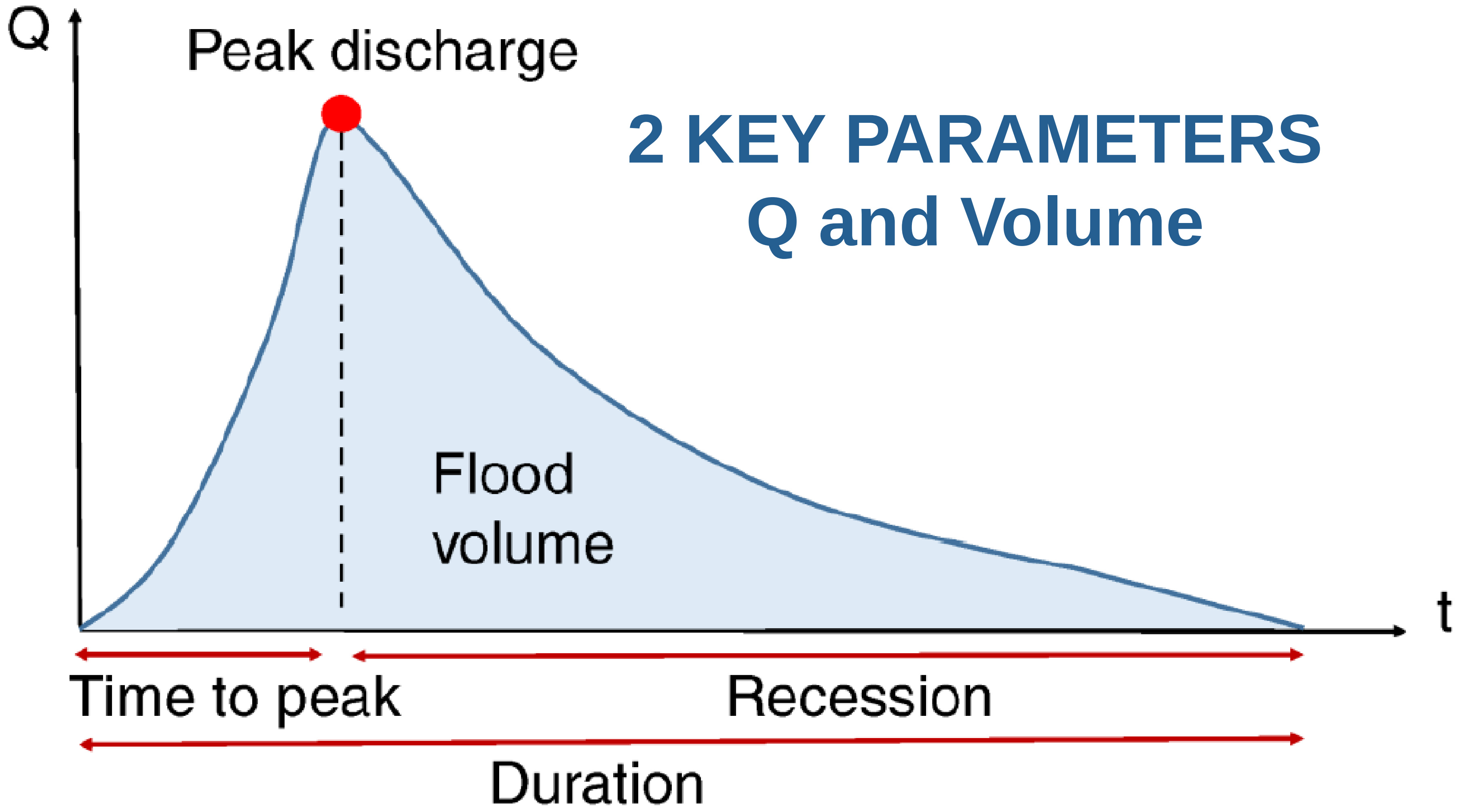



Figure 4-4. Illustration of SWE variation in a mountainous basin with rain on snow

# RAIN-ON-SNOW PROCESSES




## 2 KEY PARAMETERS
## Q and Volume

# RAIN-ON-SNOW PROCESSES

## IMPORTANCE OF ROS EVENTS FOR PEAK ANNUAL FLOWS VARY WITH SCALE OF BASINS

**LARGE – MEDIUM - SMALL**

| | | |
|---|---|---|
| **Snowmelt dependent** | **ROS dependent** | **Rainfall dependent** |

**Basin Elevation also plays a role**

# AVAILABLE MODELS

## 2 MAIN CATEGORIES

1) Simple index models based on **temperature** and rainfall
2) more complex models based on energy budgets

**On balance, the energy budget approach may not reduce the uncertainty inherent in the simpler temperature index approach, unless extensive meteorological data are available.**

# AVAILABLE MODELS

## MOST SIMPLE MODELS

### DEGREE-DAYS METHOD

snowmelt is proportional to the difference between air temperature and a threshold melt temperature

$$M = M_f \cdot (T_a - T_b)$$

**The method is most accurate when melt is dominated by heat input due to radiation and the pack is ripe at 0°C and ready to melt.**

# AVAILABLE MODELS

## ENERGY BUDGET APPROACH TO MODEL SNOWPACK AND SNOWMELT

Much more demanding in both meteorological data (net radiation, temperatures, humidity and wind speed) and parameter values.

Some studies have showed no clear advantage of the more complex models when comparisons were made for a variety of catchments and over a number of years of data.

# PROBLEMS AND COMPLEXITY

## MODELLING ROS IN A DESIGN CONTEXT

- **Water equivalent of the snow is the main parameter. It depends on both its depth and profile of density, both of which change over time as the snowpack structure evolves and ripens.**
- **How much snow there is to melt is also very variable**

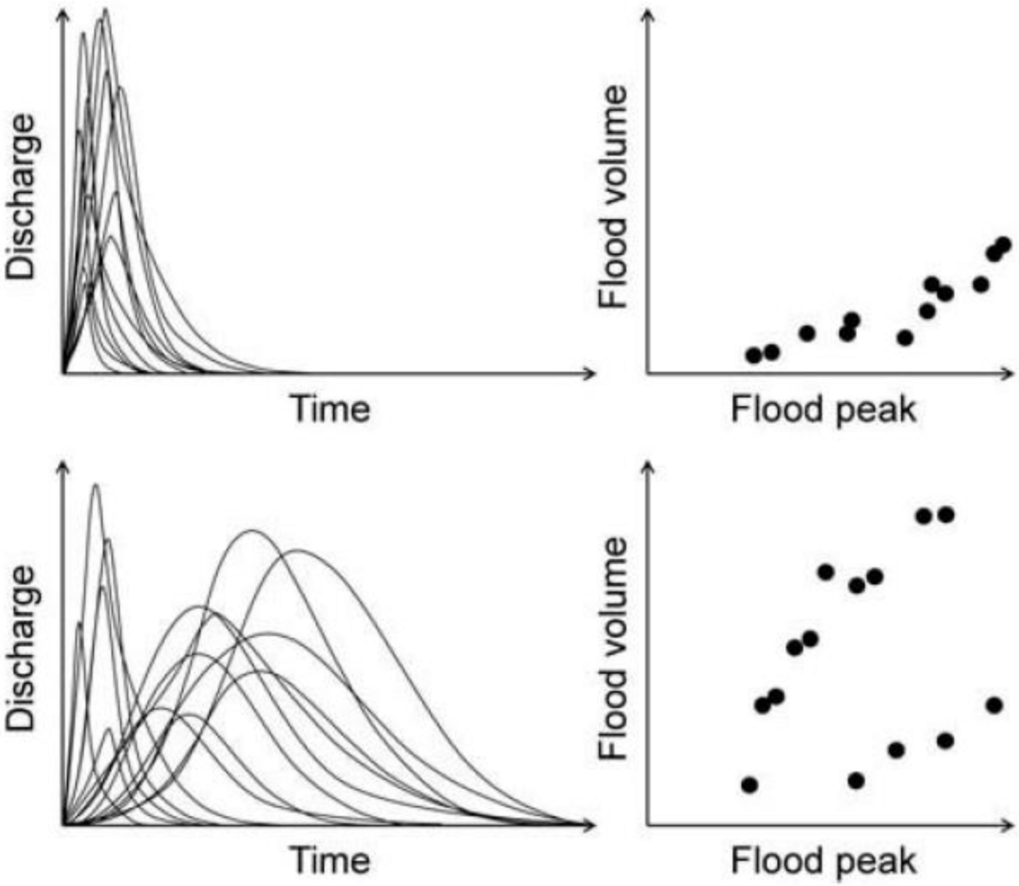
## DESIGN SITUATIONS

**Peak discharges of given return periods**

**Volumes of given return periods**

# SIMPLIFIED APPROACH

**Dependence between flood peaks and volumes**

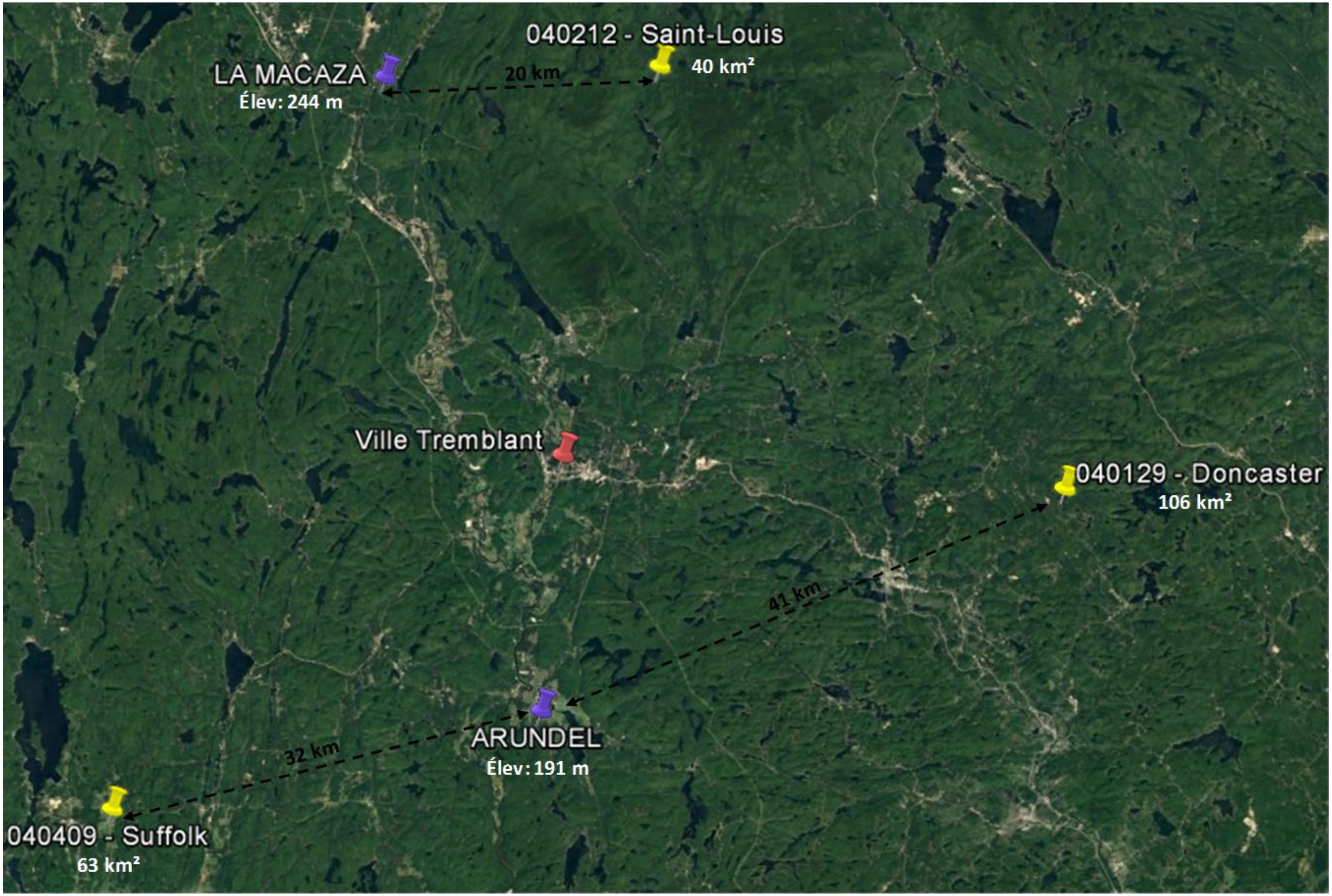


# SIMPLIFIED APPROACH

## MODELLING ROS IN A DESIGN CONTEXT

- Analysis of discharge and volumes at Spring
- Determination of interdependance
- Use of adjacent stations to determine average pattern for hydrograph
- Define a shape of ROS design rainfall
- Adjust the shape so that a given peak discharge could be reproduced
- Apply on site

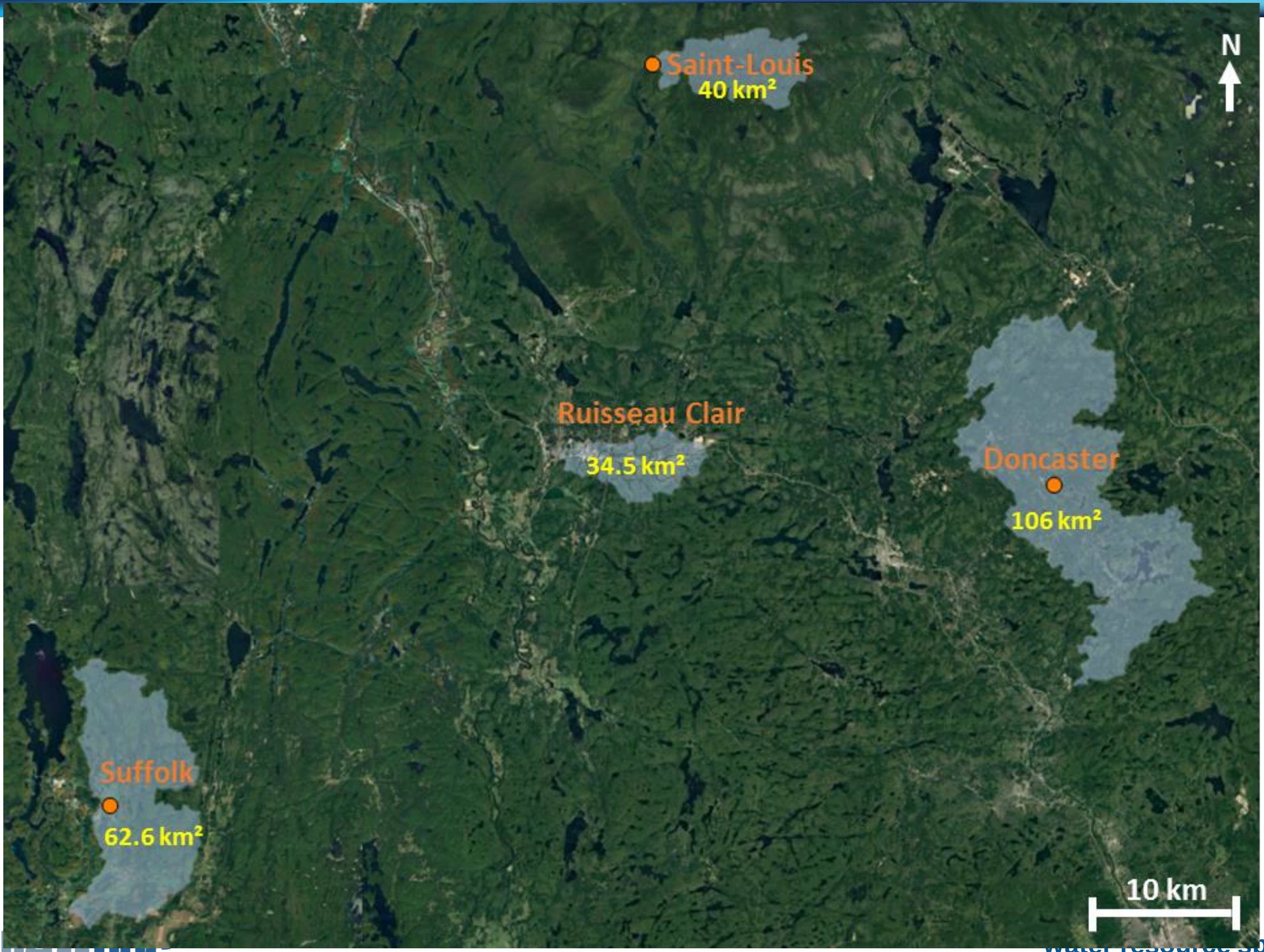
# CASE STUDY



040212 - Saint-Louis
40 km²
LA MACAZA
Élev: 244 m
20 km
Ville Tremblant
040129 - Doncaster
106 km²
41 km
ARUNDEL
Élev: 191 m
32 km
040409 - Suffolk
63 km²

# CASE STUDY

# CASE STUDY



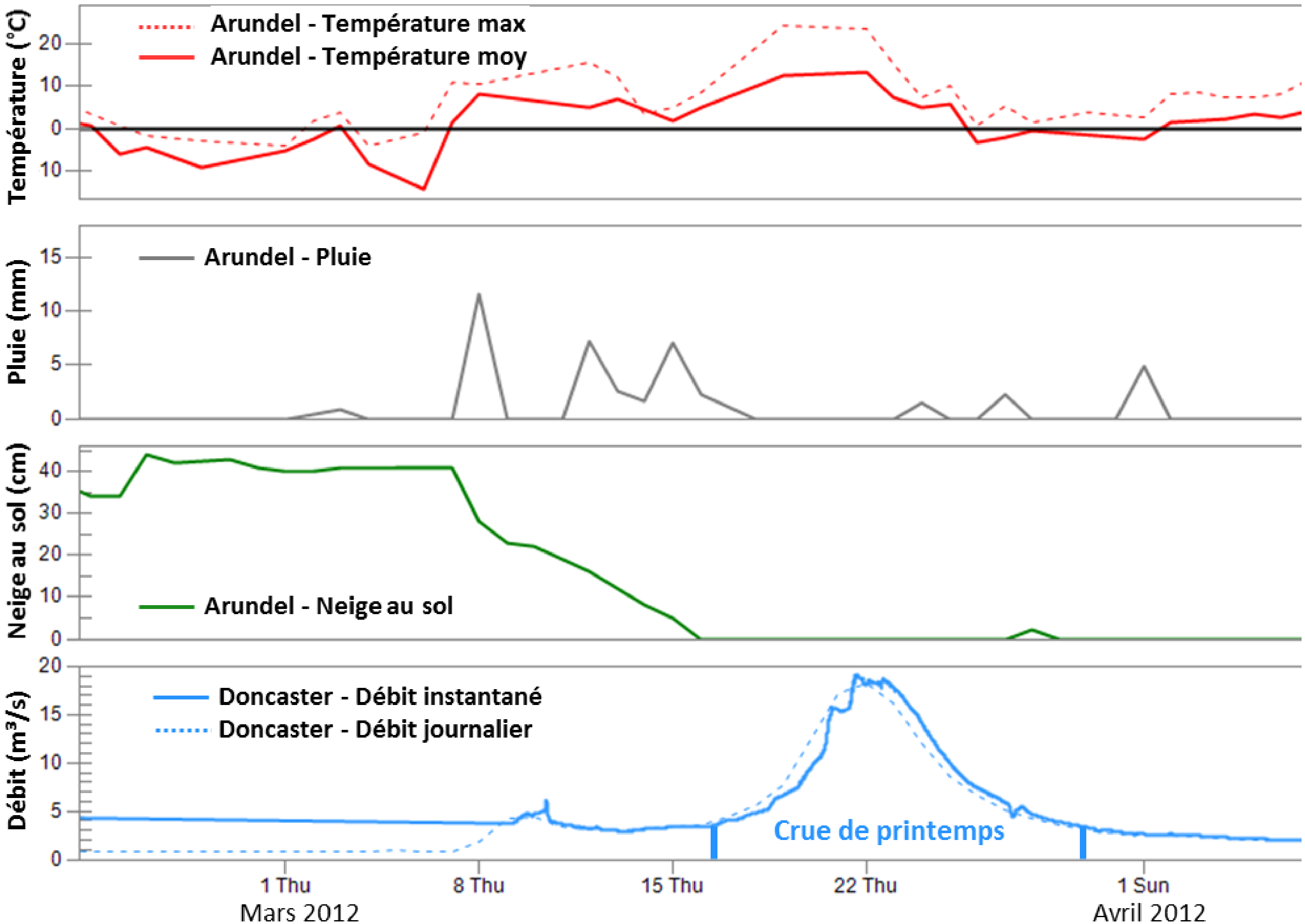
N
Saint-Louis
40 km²
Ruisseau Clair
34.5 km²
Doncaster
106 km²
Suffolk
62.6 km²
10 km

# CASE STUDY

## ANALYSES OF PARAMETERS AT SURROUNDING STATIONS

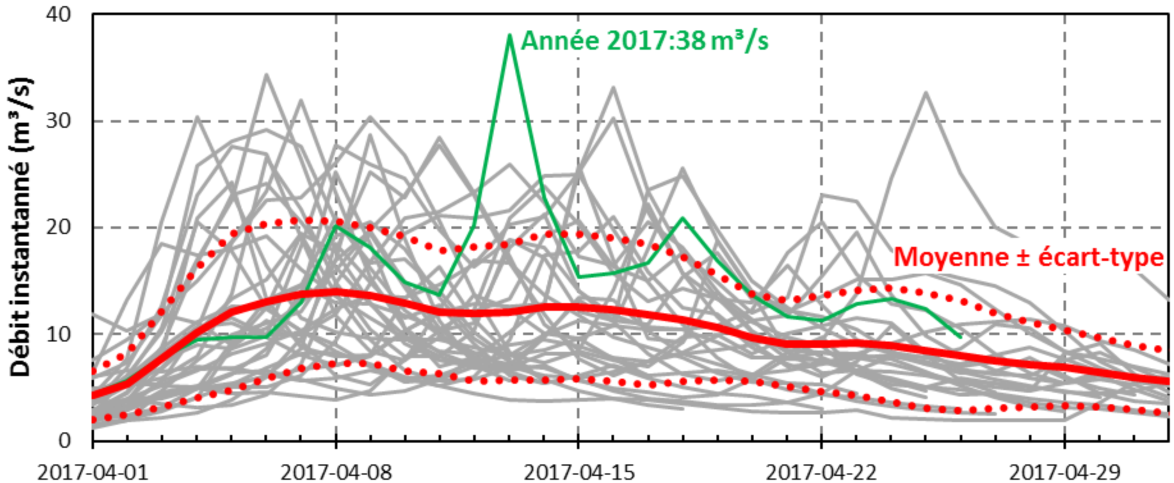
- **PEAK DISCHARGES**
- **RUNOFF VOLUMES**
- **DURATION OF SPRING RUNOFF**

# CASE STUDY

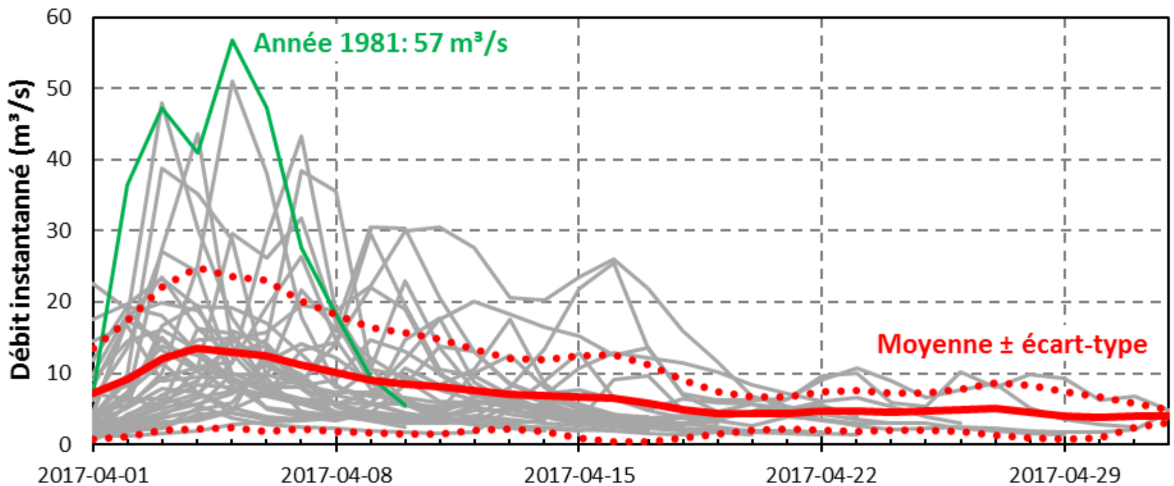


Température (°C)
20
10
0
10
Arundel - Température max
Arundel - Température moy
Pluie (mm)
15
10
5
0
Arundel - Pluie
Neige au sol (cm)
40
30
20
10
0
Arundel - Neige au sol
Débit (m³/s)
20
15
10
5
0
Doncaster - Débit instantané
Doncaster - Débit journalier
Crue de printemps
1 Thu
8 Thu
15 Thu
22 Thu
1 Sun
Mars 2012
Avril 2012

# CASE STUDY



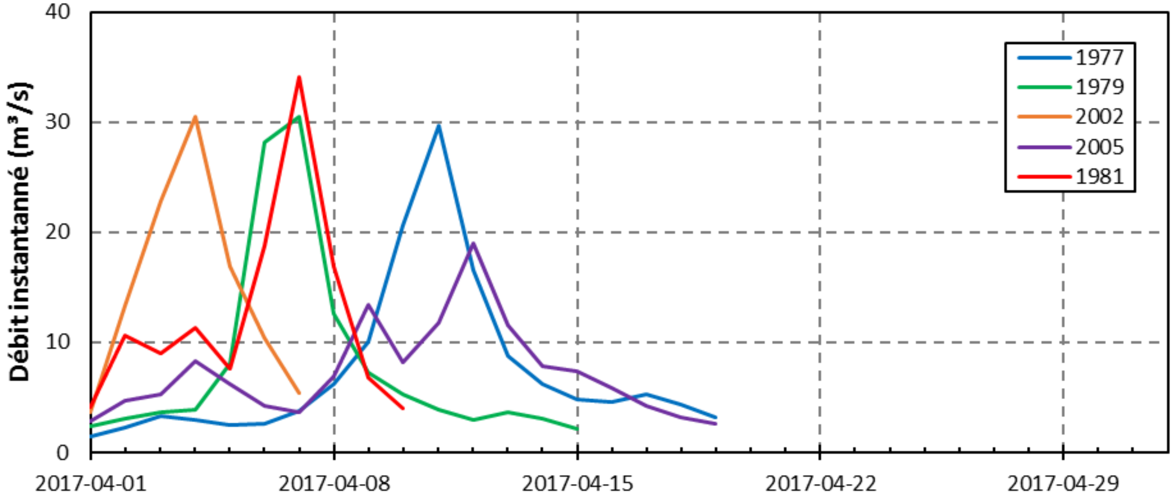
a) Station Doncaster



b) Station Suffolk

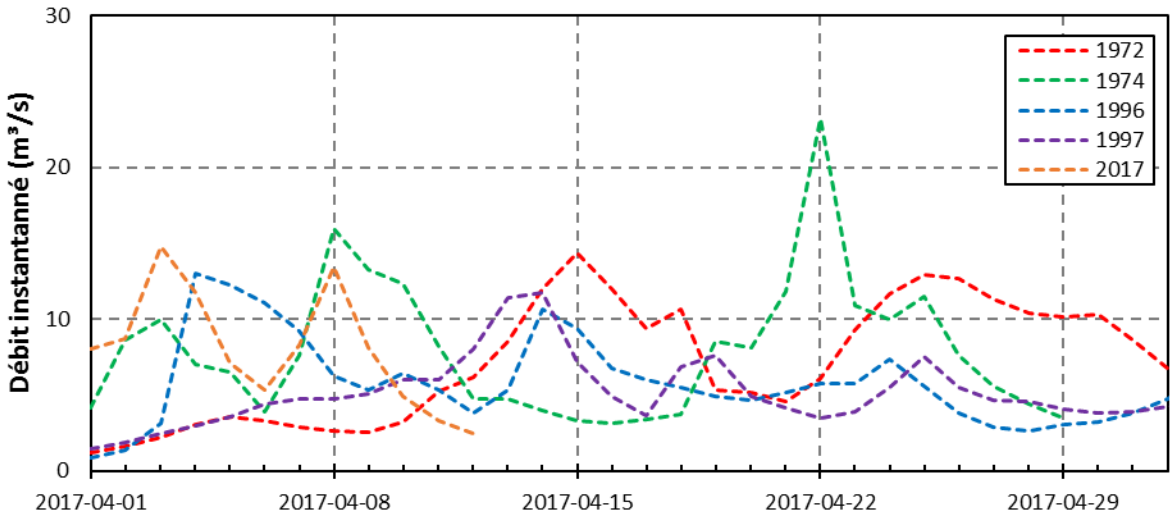
# CASE STUDY

5 largest discharge events




a) Les 5 plus grands débits

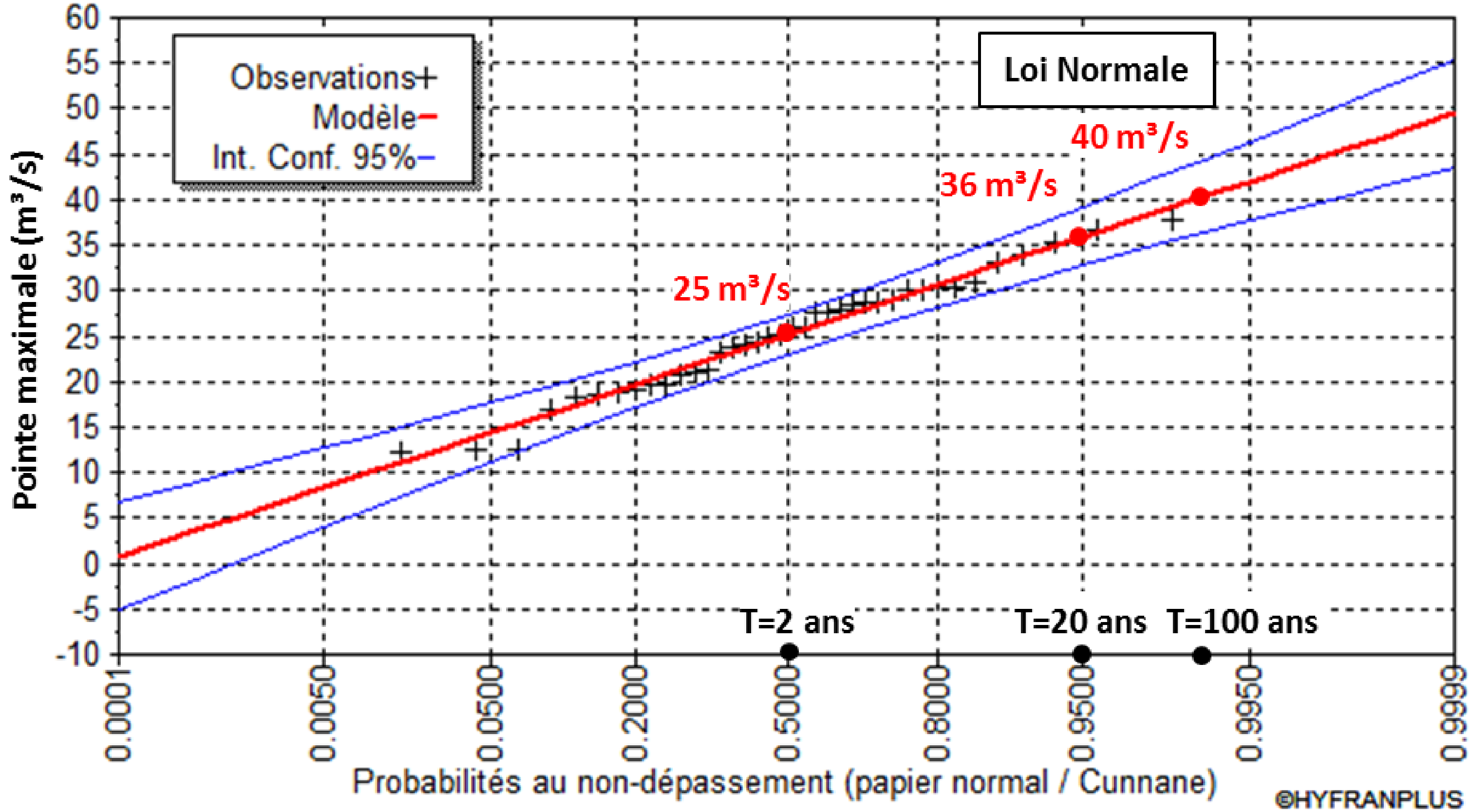
5 largest volume events




b) Les 5 plus grands volumes de ruissellement

# CASE STUDY

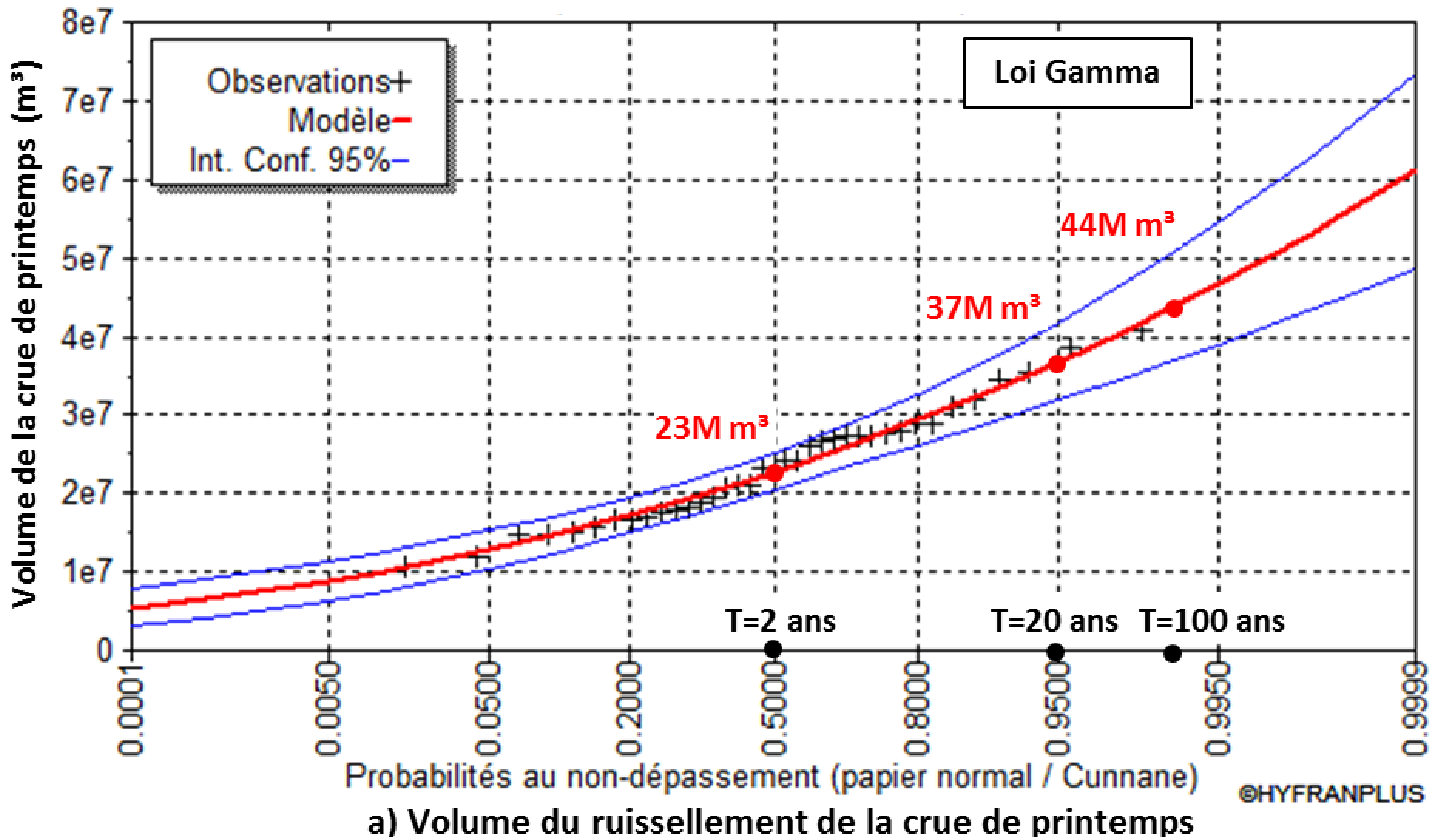
## Statistics on peak discharges



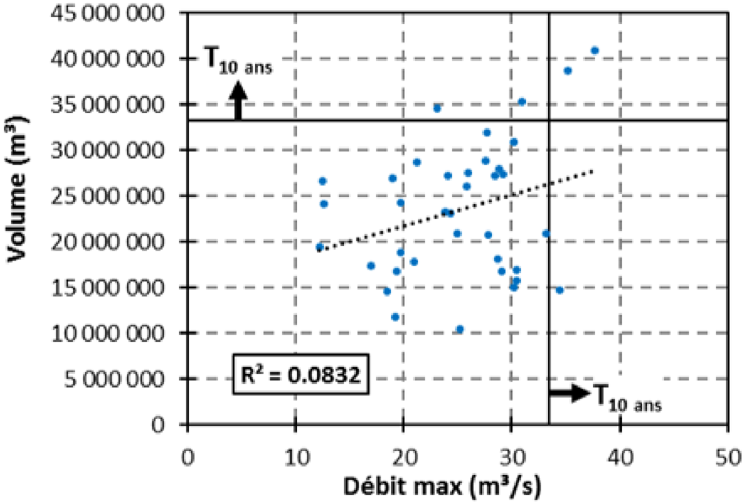

a) Statistiques pour la saison du printemps

# CASE STUDY

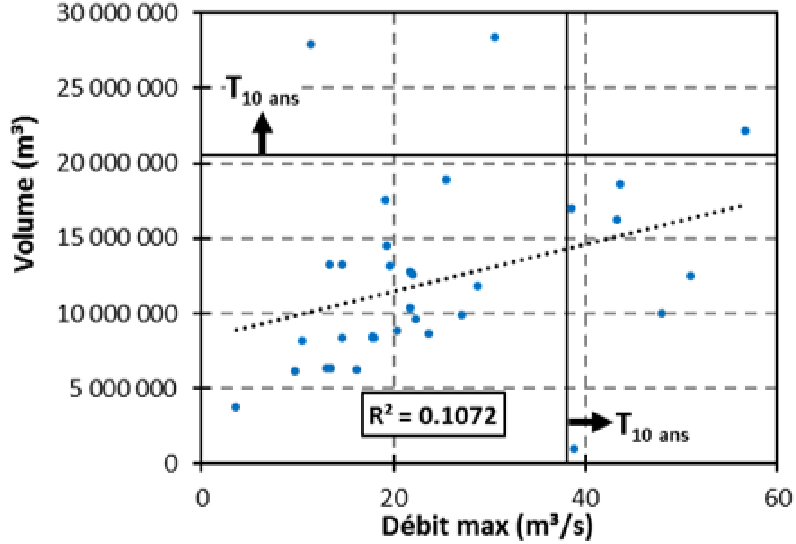
## Statistics on volumes



# CASE STUDY

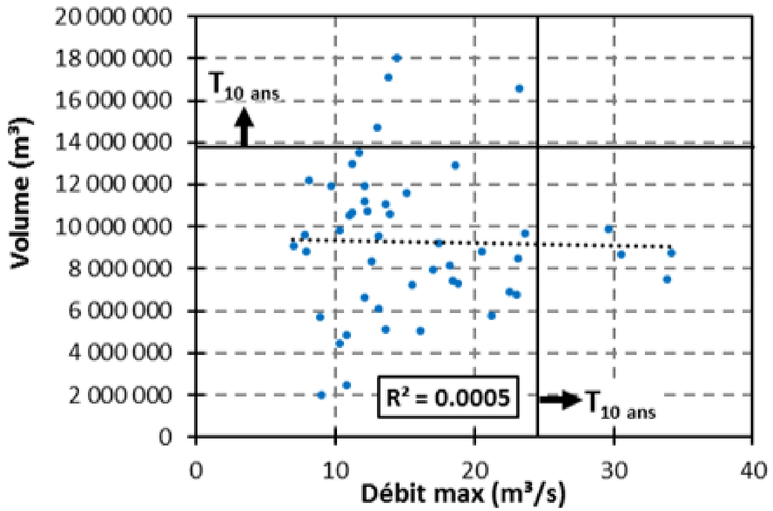



a) Station Doncaster




b) Station Suffolk

Dependence for the 2 variables (Q and V)




c) Station Saint-Louis

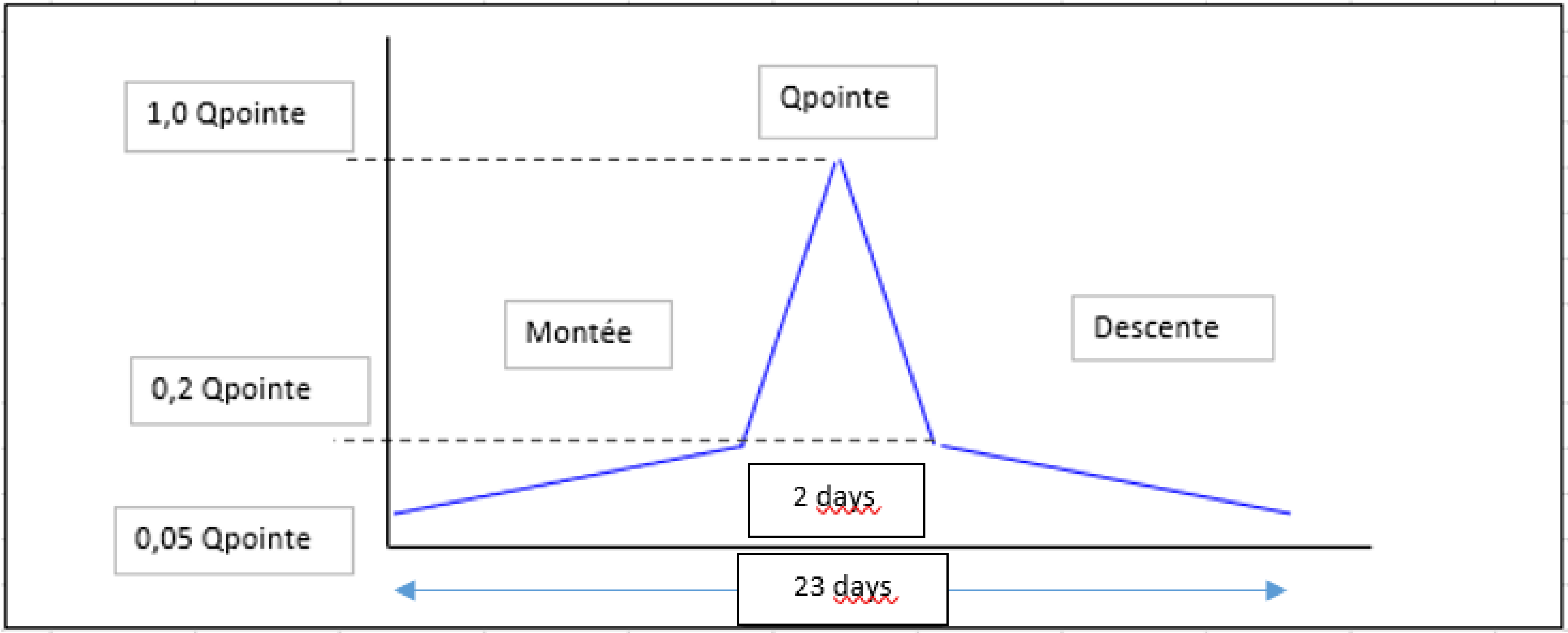
# CASE STUDY

## Combined probabilities – Q and V

| Station | Doncaster | Suffolk | Saint-Louis |
|---|---|---|---|
| X ($T_{2\ ans}$) | 0.11 | 0.28 | Independent |
| X ($T_{5\ ans}$) | 0.68 | 0.45 | Independent |
| X ($T_{10\ ans}$) | 0.87 | 0.37 | Independent |

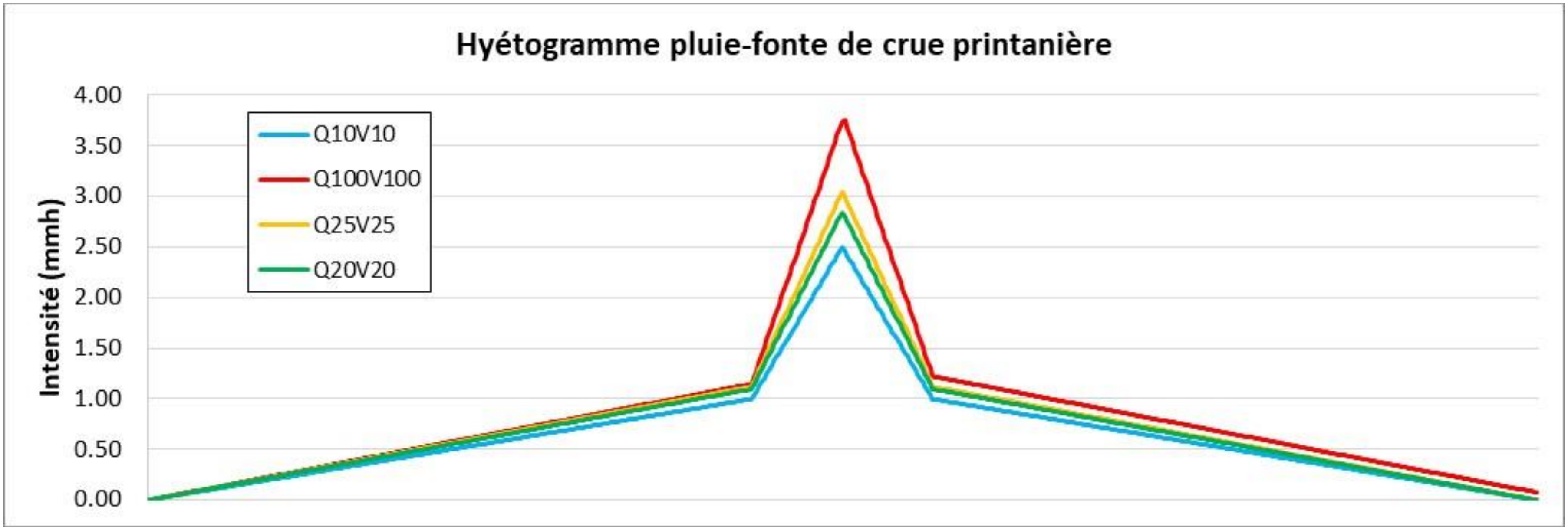
# CASE STUDY

## Definition of a rainfall pattern based on adjacent watershed



# CASE STUDY

## Definition of a ROS rainfall pattern
## Combination of Q and V



# CASE STUDY

## Hydraulic simulations finally completed using runoff modeling with ROS design rainfall

- Frozen soils (decreased infiltration)
- Assuming runoff in urban areas similar to rural areas

# CONCLUSION

- Although ROS events are the principal runoff mecanisms, lack of modelling approach in a design context
- Could increase with CC
- Simplified models should be developed and verified