A Monte Carlo simulation approach for flood risk assessment

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INRS CENTRE EAU TERRE ENVIRONNEMENT UNIVERSITÉ DE RECHERCHE

European Geosciences Union General Assembly 2016
Vienna | Austria | 17–22 April 2016

I. Introduction

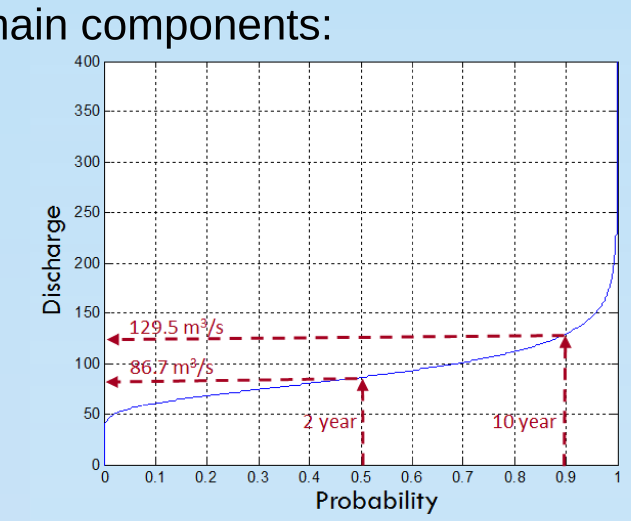
Brigham is a small municipality located in southern Quebec (Canada). It is often affected by overflows of the Yamaska River, which can occur up to two or even three times per year. The implementation of disaster management and mitigation measures has become a major priority for this municipality. The first step in such a process is to assess the flood risk and the possible damage related to this risk level. To do this, a Monte Carlo simulation approach was proposed to estimate the mean annual damage for each residence at risk in the municipality.

II. Methods

A Monte Carlo simulation based approach that combines hazard information with vulnerability related aspects was developed in order to improve the knowledge about this flooding risk. This approach integrates four main components:

1. Hydrological modeling

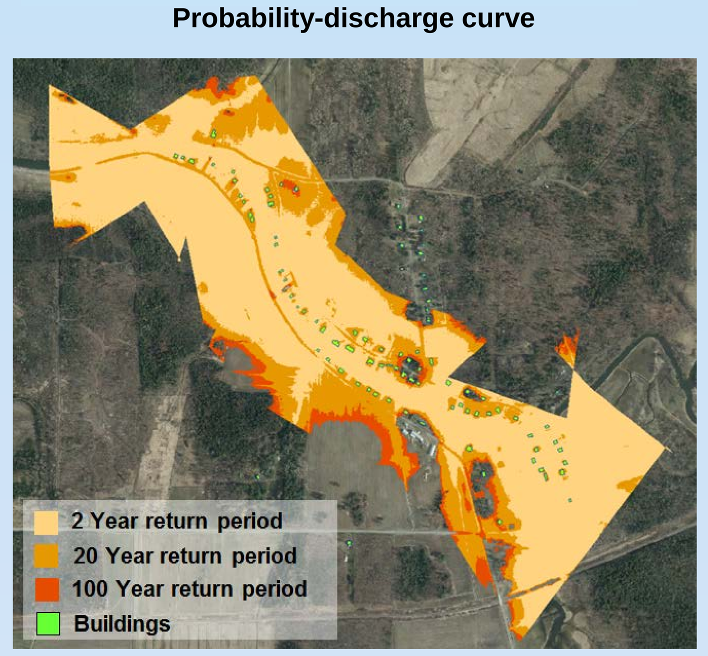
- Establishing a probability-discharge function which associate each measured discharge to its probability of occurrence (return period).
- Based on a hydrologic frequency analysis of maximum annual flows.



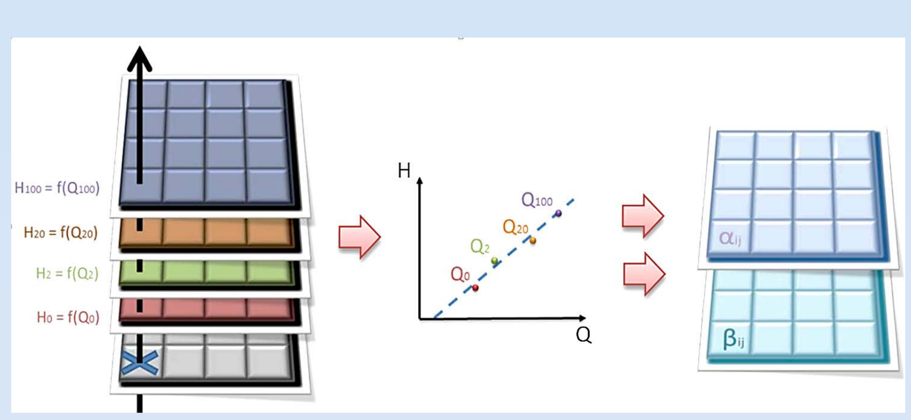
Probability-discharge curve

2. Hydraulic modeling

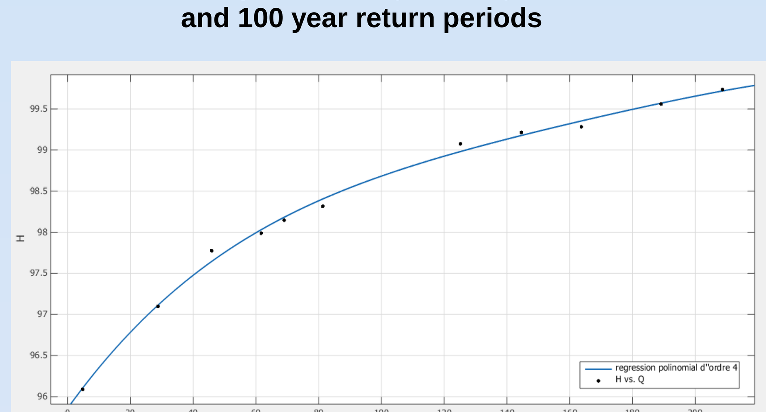
- Establishing the relationship between the discharge and the water stage at each building located in the study area.
- Based on HEC-RAS hydraulic modelling software to obtain the water stage reached by the river for 2, 20, and 100 year return periods and the related floodplain boundaries.
- Defining the relationship between the water level and the discharge information by a polynomial regression function.



Floodplains for 2 year, 20 year and 100 year return periods



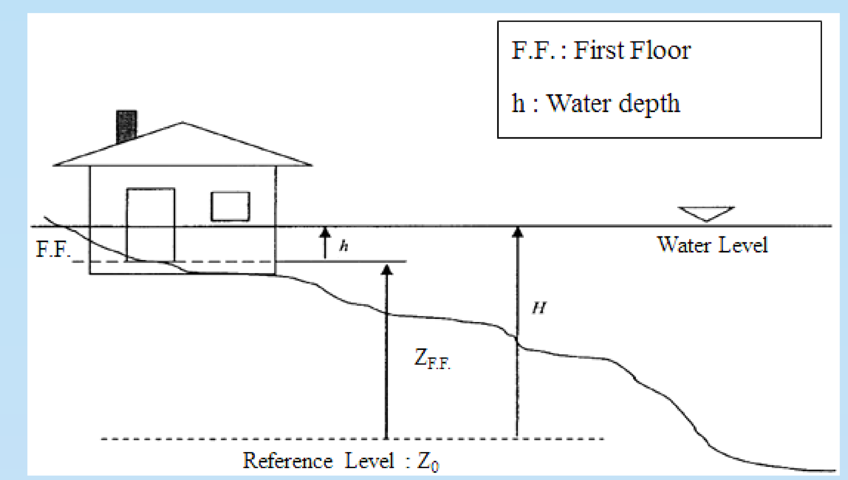
Definition of the discharge-stage function



Example of discharge-stage curve

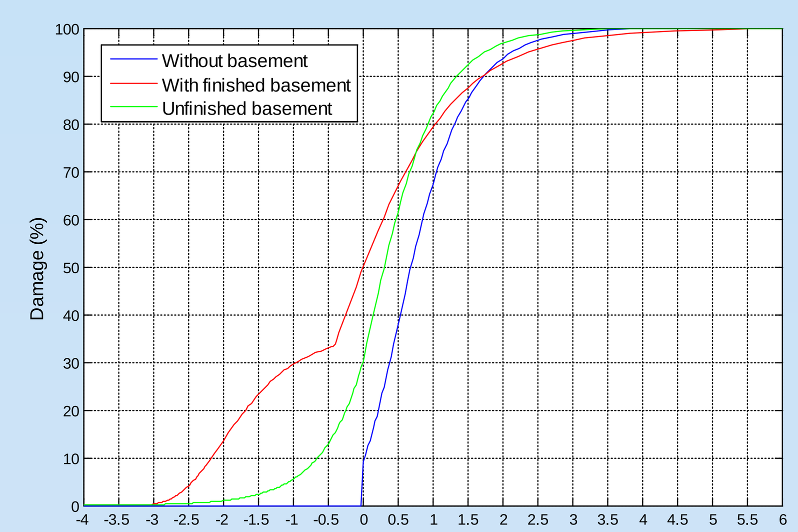
3. Damage study

- Assessing the damage of each building using stage-damage curves.
- The damage is estimated according to the water depth defined as the difference between the water level and the elevation of the building first floor.

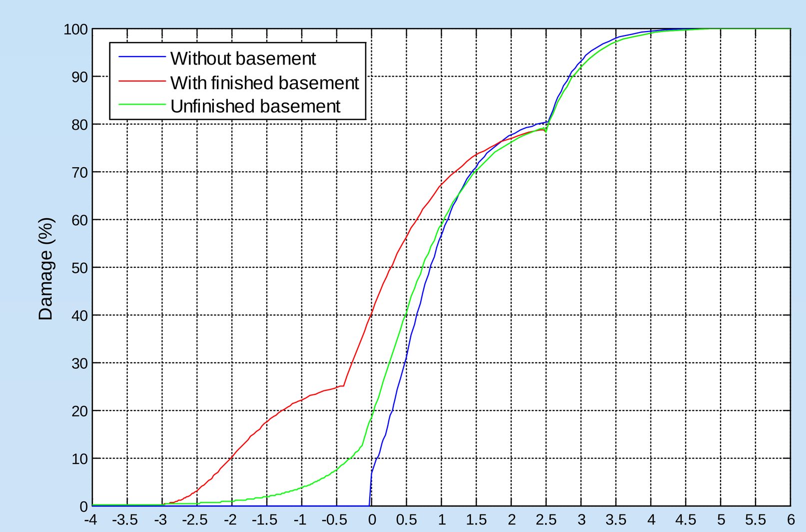


Definition of water depth : $h = H - Z_{F.F.}$

- The damage curves are developed according to the Quebec habitat typology [1].
- These curves depend on the building characteristics such as the presence of basement and the floors number.



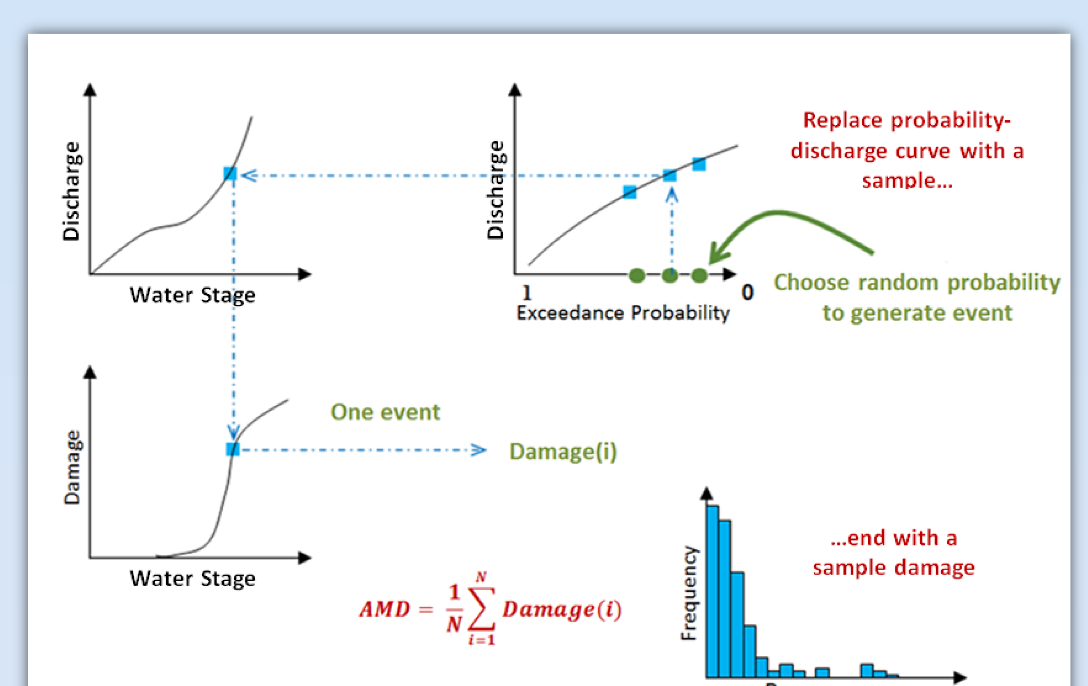
The damage curves for one floor buildings



The damage curves for two floor buildings

4. Monte Carlo simulation [2]

- Sampling the probability-discharge relationship in order to generate a flood event.
- Determining the corresponding water stage using the discharge-stage relationship of each building.
- Converting the water stages to damage values using the stage-damage curves.
- Calculating the average damage resulting from this simulation which represents an assessment of the average annual risk of flooding sustained by the buildings in the study area.

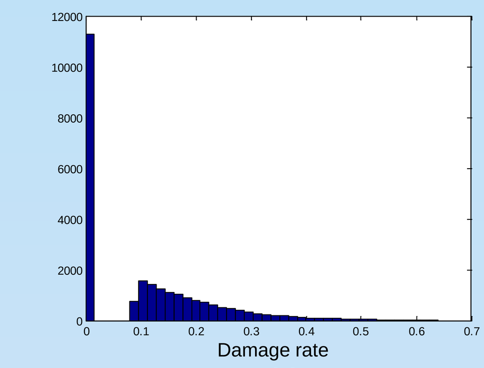


$$AMD = \frac{1}{N}\sum_{i=1}^{N} Damage(i)$$

Monte Carlo simulation method

III. Results

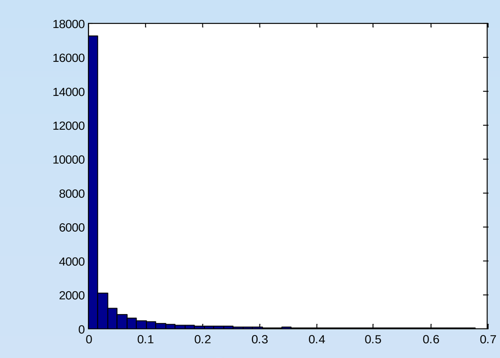
1. One floor with basement dwelling



Damage histogram

First Floor Height	1.13 m
Building Value	22 000 $
Annual Mean Damage(%)	10.93 %
Annual Mean Damage ($)	2 405 $

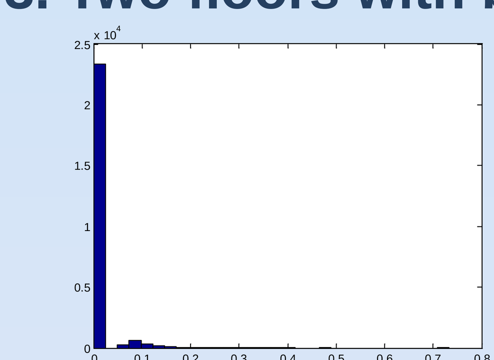
2. One floor without basement dwelling



Damage histogram

First Floor Height	0.6 m
Buliding Value	25 600 $
Annual Mean Damage(%)	3.48 %
Annual Mean Damage ($)	890 $

3. Two floors with basement dwelling



Damage histogram

First Floor Height	0.98 m
Buliding Value	22 000 $
Annual Mean Damage(%)	0 %
Annual Mean Damage ($)	0 $

IV. Conclusions and future work

Because it is estimated for all the buildings in the high flood risk areas, the "global mean annual damage" provides a better assessment of the real flood risk. Results from this study will be useful for local authorities to support their decisions for flood risk management and prevention. Flood mitigation measures based on a quantitative analysis are more relevant. In order to further exploit the results of this study, a 2D hydraulic modelling will be applied. Also, the vulnerability of the population and of the infrastructures will be considered.

V. Bibliography

[1] L. Bonnifait, Développement de courbes submersion-dommages pour l'habitat résidentiel québécois, 2005

[2] B. Faber, Flood Risk Analysis considering 2 types of uncertainty, Hydrologic Engineering Center (HEC), US Army Corps of Engineers

VI. Acknowledgments

Sécurité publique Québec
Centre d'expertise hydrique Québec
Brome-Missisquoi.ca