A Monte Carlo simulation approach for flood risk assessment

Hachem Agili1, Karem Chokmani1, Khalid Oubennaceur1, Jimmy Poulin1, and Pascal Marceau2
1Institut National de la Recherche Scientifique, Centre Eau Terre Environnement, Québec, Canada
2Ministère de la Sécurité Publique, Québec, Canada

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.

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 modeling 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.

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.
   • 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.

   • 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 “average 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 modeling will be applied. Also, the vulnerability of the population and of the infrastructures will be considered.

III. Results
1. One floor with basement dwelling
   • First Floor Height 1.13 m
   • Building Value 22 000 $
   • Annual Mean Damage(%) 10.31 %
   • Annual Mean Damage ($) 2 405 $

2. One floor without basement dwelling
   • First Floor Height 0.6 m
   • Building Value 25 600 $
   • Annual Mean Damage(%) 3.48 %
   • Annual Mean Damage ($) 800 $

3. Two floors with basement dwelling
   • First Floor Height 0.98 m
   • Building 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 modeling 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

VI. Acknowledgments