validation of the model performance and in strategies for reducing model uncertainties [6-9]

SENSITIVITY ANALYSIS OF HYDRAULIC MODEL

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1. Context

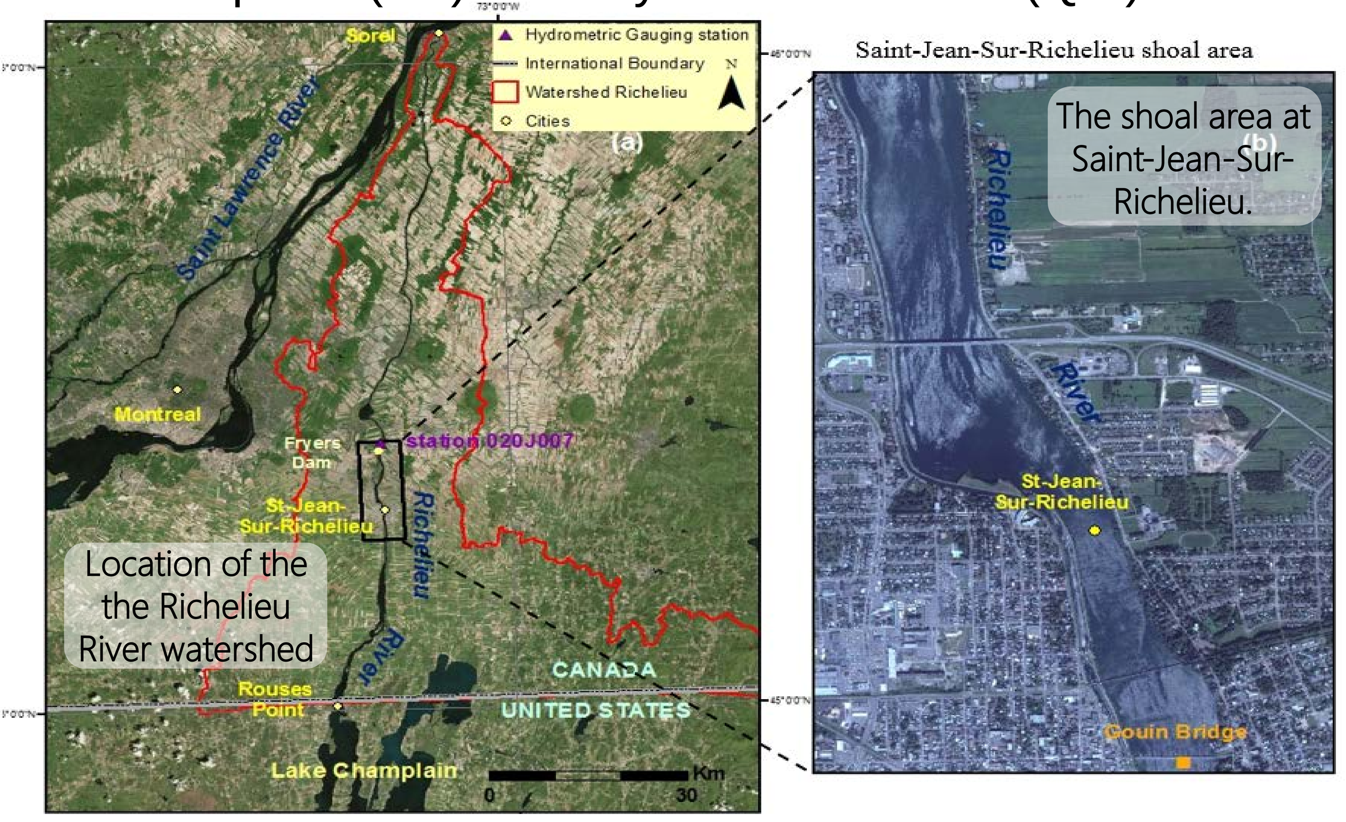
The accuracy of flood inundation models is directly related to the uncertainty of the involved input variables. Knowledge of the source, type and magnitude of these uncertainties is crucial for understanding and interpretation of hydraulic results and decisions for improving model capacities and accuracy of predictions. A spatially distributed sensitivity analysis (SA) is applied to investigate the relative influence of the input variables and their impacts on the model outputs. In practice, SA generally requires a large number of Monte-Carlo type simulations accompanied with extensive computational efforts, which makes these standard methods tedious. In this study, a novel and efficient method is proposed using derivative-based sensitivity indexes and the Gaussian quadrature sampling.

2. Objectives

The main objective is to propose an efficient method for determination of the relative influence of three essential input parameters most commonly considered by flood inundation models: flow rate, Manning's n coefficient, and topography.

3. Study area

The Richelieu River is located southeast of Montreal, Canada. The modelled domain extends between Rouses point (NY) and Fryers Island Dam (QC).



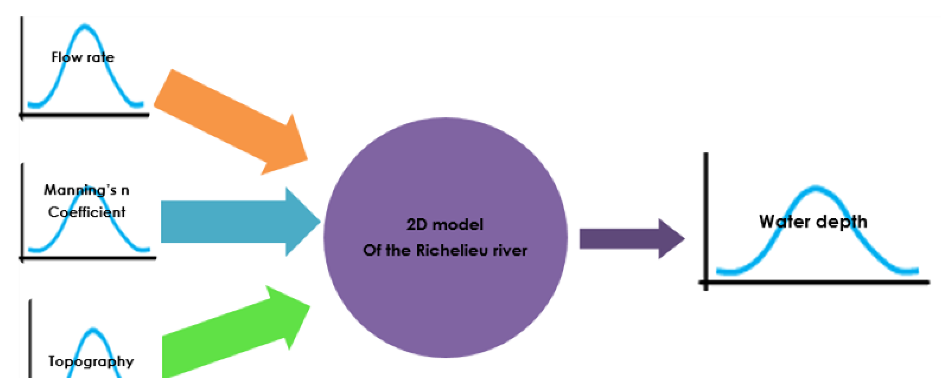
4. 2D hydraulic model: the Richelieu River

The simulations are based on a two-dimensional finite element hydrodynamic modelling applying the H2D2 software [1]. Three input parameters are considered :

❖ Flow rate: observed flow series measured at Fryers rapids station, QC, (1970-2011).

❖ Manning's n coefficient: calibrated Manning's n coefficient for the Richelieu channel ranges from 0.02 to 0.036.

❖Topography: Digital Elevation Model (DEM) of the Richelieu River with reported vertical accuracy within 25 cm.



Data input and output for a 2D model

5. Methodology

Derivative-based sensitivity index

- The method modifies the value of one of the input parameters and keeps the remaining two equal to their initial values to compute the changes in the model output.
- The relative sensitivity index (S) for each model parameters :

$$S = \frac{(R-R_b)}{(P-P_b)} * \frac{P_b}{R_b}$$

where :

S= relative sentivity index

R= result (model output)

P= parameter(model input)

b=base scenario value

Abscissas and weights for the standard normal distribution

n	z_i	ω_i
0	0	1
2	$-1, +1$	$\frac{1}{2}, \frac{1}{2}$
3	$-\sqrt{3}, 0, +\sqrt{3}$	$\frac{1}{6}, \frac{2}{3}, \frac{1}{6}$

Sampling strategy

- The three-point Gauss Quadrature method is applied for sampling of the variable points.

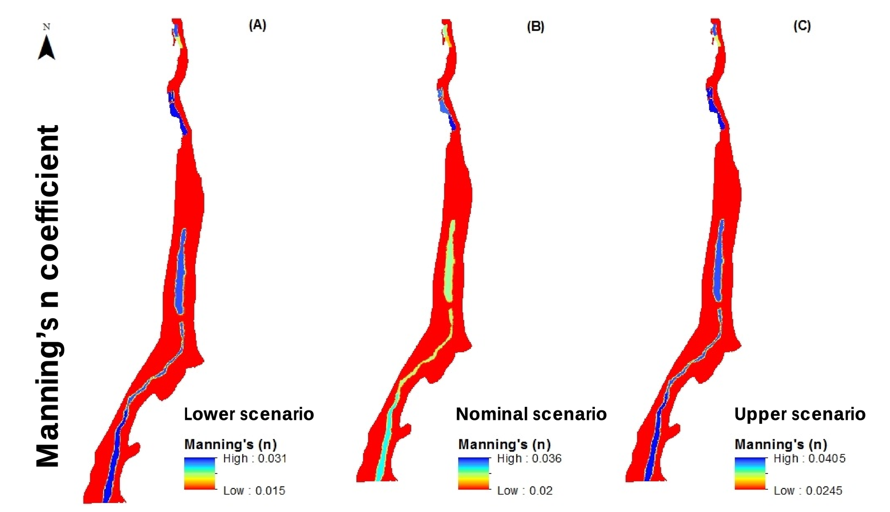
6. Results

Setting input variables

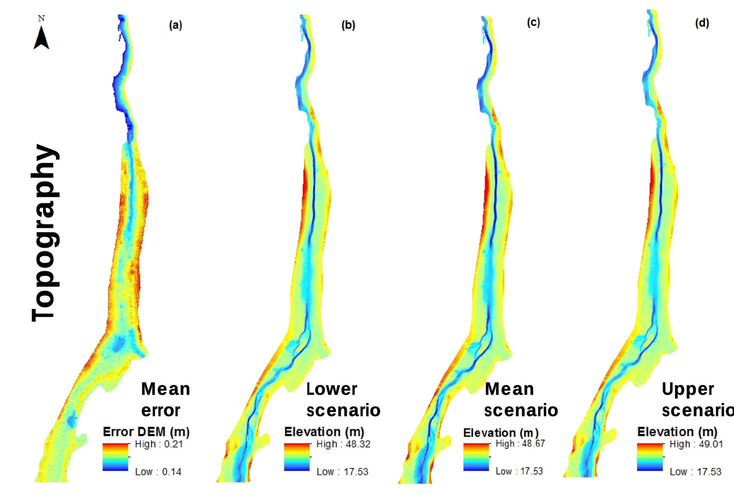
Flow rate

μ	σ	$x_i - \sqrt{3}\sigma$	$x_i + \sqrt{3}\sigma$
759	39.4	682	836
824	36	755	897
936	33.7	870	1000
1113	39.4	1040	1190

Three values of each flow case

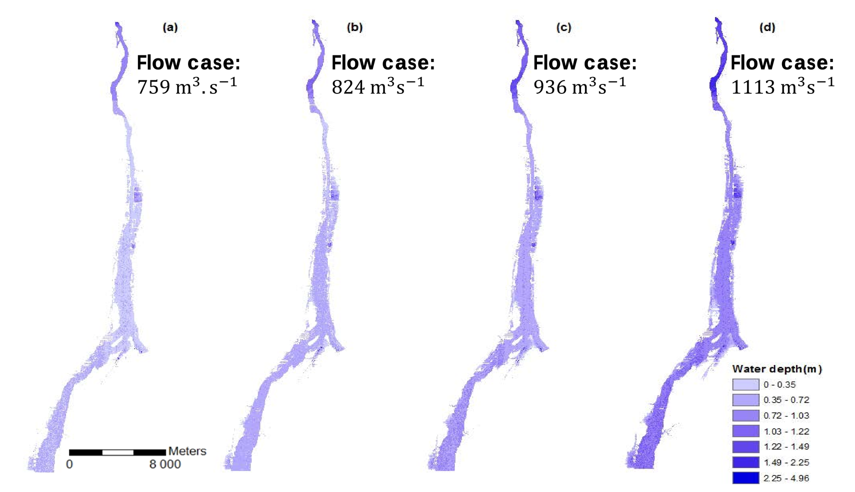


Three realizations of Manning's n coefficient



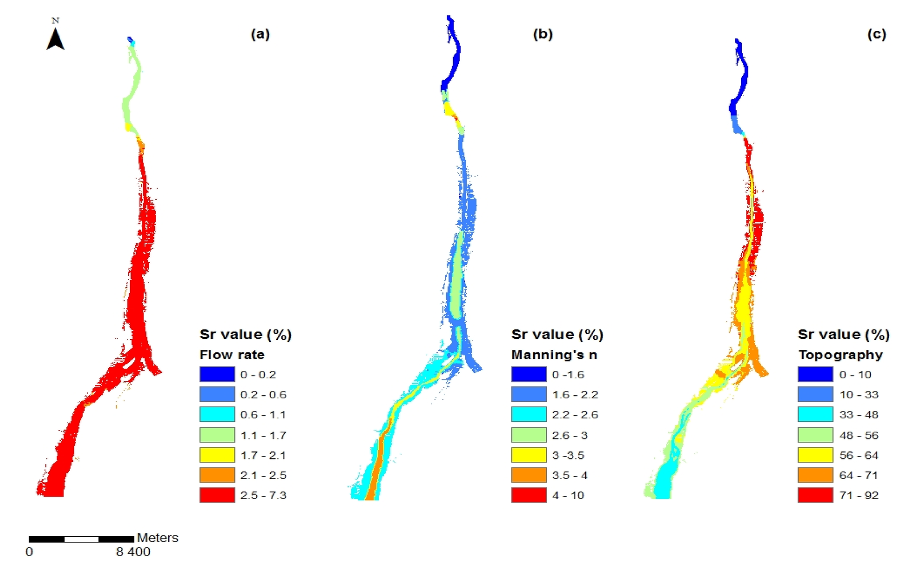
Three realizations of the topography

Water depth model outputs

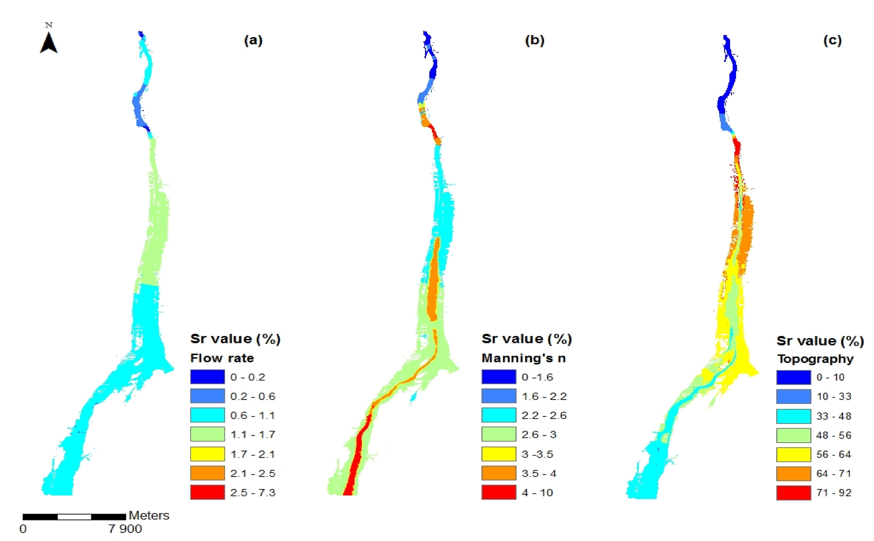


Predicted water depth with the 2D hydraulic model for four flow rates

Sensitivity analyses



Standard Sensitivity of the simulated flow depths to each of the three input variable (A) flow rate, (B) topography, and (C) Manning's n coefficient, for the flow case of 759 $m^3.s^{-1}$



Standard Sensitivity of the simulated flow depths to each of the three input variable (A) flow rate, (B) topography, and (C) Manning's n coefficient, for the flow case of 1113 $m^3.s^{-1}$

7. Conclusions

The proposed SA method revealed a promising alternative to the standard Monte Carlo analyses. It requires relatively low computational effort to provide a relatively accurate assessment of the uncertainty of model outputs. The results indicate that the topography, in particular that of the shoal, was the most critical input variable with highest impact on the flood predictions. The effect of the topography on water depths was, however, attenuated for higher flow. The Manning's n coefficient and the flow rate, on the other hand, had comparatively less effects on the model results.

References

[1]. Secretan, Y., H2D2 Software. 2013.

Acknowledgment

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