A stochastic modelling approach to forecast real-time ice jam flood severity along the Saint John River, New Brunswick, Canada

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ABSTRACT

Ice jam floods (IJF) are a major concern for many riverine communities, government and non-government authorities and companies in the northern hemisphere. Ice jam related flooding can result in millions of dollars of property damages, loss of human life and adverse impacts on ecology. Ice jam flood forecasting is a challenging job as its formation mechanism is chaotic and depends on numerous unpredictable hydraulic and river ice factors. In this study, Modélisation environnementale communautaire – surface hydrology (MESH), a semi-distributed physically-based land-surface hydrological modelling system was used to acquire a 10-day flow forecast, an important boundary condition for the river ice modelling. A stochastic modelling approach was then applied to simulate hundreds of possible ice-jam scenarios using the hydrodynamic river ice model RIVICE within a Monte-Carlo Analysis (MOCA) framework for the Saint John River from Fort Kent to Grand Falls. First, an 8-day outlook was simulated to provide insight on the severity of ice jam flooding during spring breakup. Then, 3-day forecasts were modelled to provide longitudinal profiles of exceedance probabilities of ice jam flood staging along the river during the ice-cover breakup. Overall, results show that the stochastic approach performed well to estimate maximum probable ice-jam backwater level elevations for the spring 2021breakup season.

OBJECTIVES

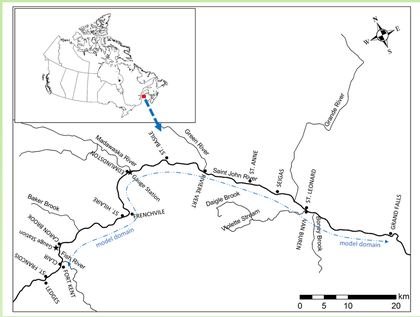
The specific objectives are

- to develop a stochastic modelling framework for operational real-time ice-jam flood forecasting system along the Saint John River, New Brunswick
- to provide an ice-jam flood outlook for spring ice-cover breakup
- to forecast probable maximum ice-jam backwater level elevation

STUDY SITE

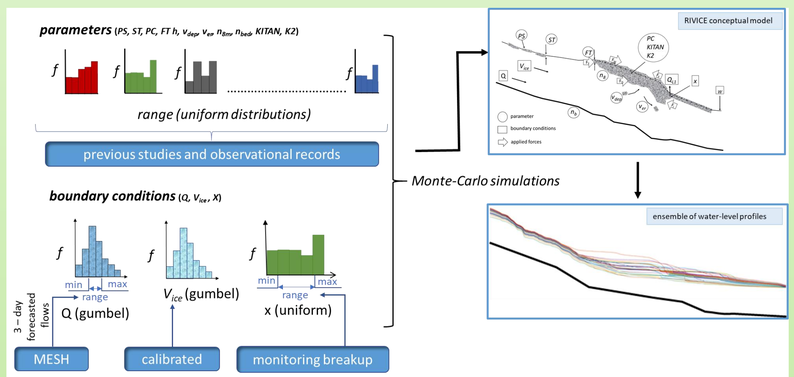
The Saint John River, New Brunswick, Canada

- The study domain extends from the Fort Kent to Grand Falls
- Major ice-jam floods during the spring breakup occurred in 1987, 1991, 1993, 2009, 2012
- The river ice hydraulic model RIVICE was used to simulate ice-jam backwater level elevation downstream of the Edmundston



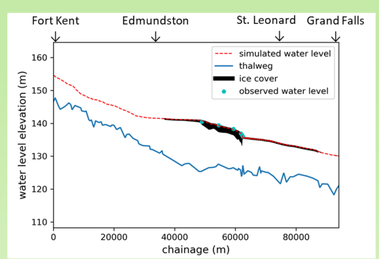
STOCHASTIC FRAMEWORK

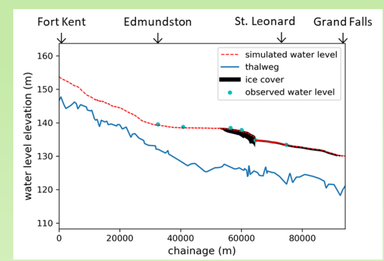
- A deterministic hydraulic model RIVICE was placed into Monte-Carlo Analysis (MOCA) framework to simulate hundreds of probable ice-jam scenarios
- The parameter and boundary condition value inputs were randomly extracted from either uniform or extreme probability distribution functions
- Upper and lower ranges of uniform distribution were extracted from previous studies and observation records
- The extreme values distribution of the inflowing ice volume was calibrated using historical observations
- The maximum and minimum range of 3-day forecasted spring streamflow from the MESH output was used to constrain the frequency distribution of the breakup discharges



RIVICE CALIBRATION AND VALIDATION

The RIVICE model along the Saint John River from Fort Kent to Grand Falls was calibrated and validated using the ice-jam events occurred during spring breakup in 1991 and 2009, respectively.

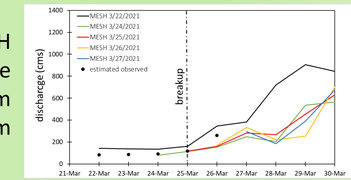




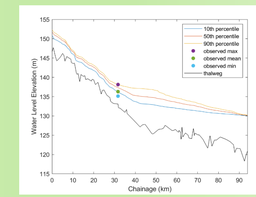
data sources: Tang and Beltaos, 2008; Beltaos et al. 2012

RESULTS – Spring breakup 2021

MESH output:
The forecasted streamflow from MESH output at the USGS gauge station along the Saint John River near Fort Kent (upstream boundary of the RIVICE model domain) from 22nd to 27th March 2021.

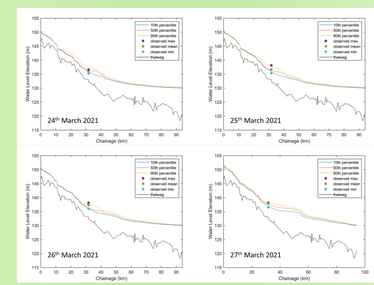


Ice-jam flood outlook:
An overview of ice-jam backwater level conditions from 22nd to 30th March was simulated using MESH forecasted flow range along the river



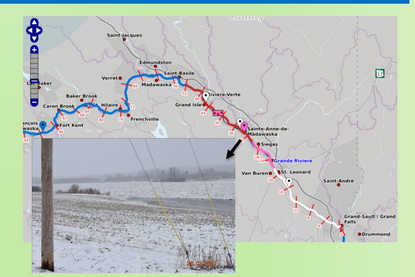
3 –day probable maximum ice-jam backwater level elevation forecast:

Each day the probable 3- day 10th , 50th , and 90th percentiles of ice-jam water level profiles were established from a forecasted ensemble of backwater level profiles.



CONCLUSIONS

The stochastic framework was able to forecast the maximum ice-jam water level that occurred on 28th March 2021 at Edmundston gauge station due to a large ice-jam formation at Sainte-Anne-de-Madawaska.



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