Potential contamination of drinking water in private wells during floods in southern Quebec, Canada: an integration of water geochemistry, risk perception and behavioural changes

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1- Context

In Quebec, spring floods are recurring natural events that have been intensifying with climate change, with major occurrences documented in 2017, 2019, and 2023, when snowmelt combined with heavy rainfall (MELCC, 2021; Radio-Canada, 2023). In addition to causing significant property damage, these floods pose heightened public health risks—particularly concerning the safety of drinking water in areas reliant on private wells. This project adopts an interdisciplinary approach to better understand and mitigate contamination risks in the context of flooding, by combining methods from both natural and social sciences.


Fig.1: Residential well in Quebec

20% of Quebec's population relies on groundwater as their primary source of drinking water (MELCC, 2020).

2- Study area

The municipality of Stoneham-et-Tewkesbury is located in the MRC of La Jacques-Cartier, within the administrative region of Capitale-Nationale. Covering an area of 685 km² and home to a population of 9,682, this municipality borders the Quebec City agglomeration, just 25 km away (Statistics Canada, 2021). Three rivers flow through this territory: the Huron River, the Hibou River, and the Jacques-Cartier River (Stoneham-et-Tewkesbury, 2024).

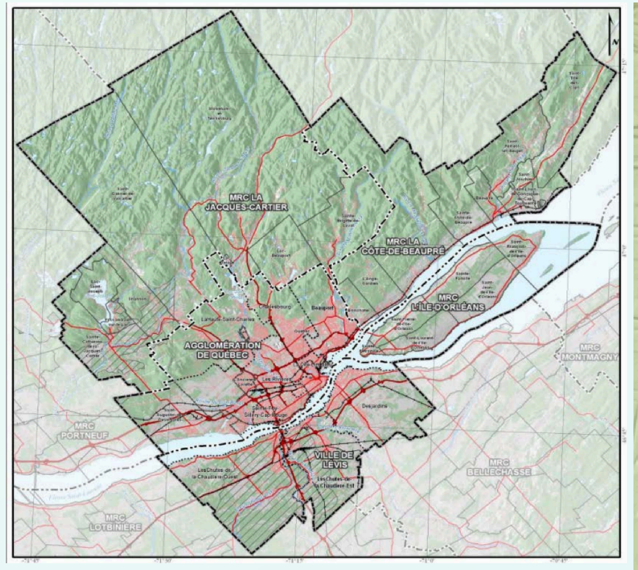
Fig.2: Map of the territorial coverage of the Groundwater Knowledge Acquisition Program (PACES) (MELCC, 2013)

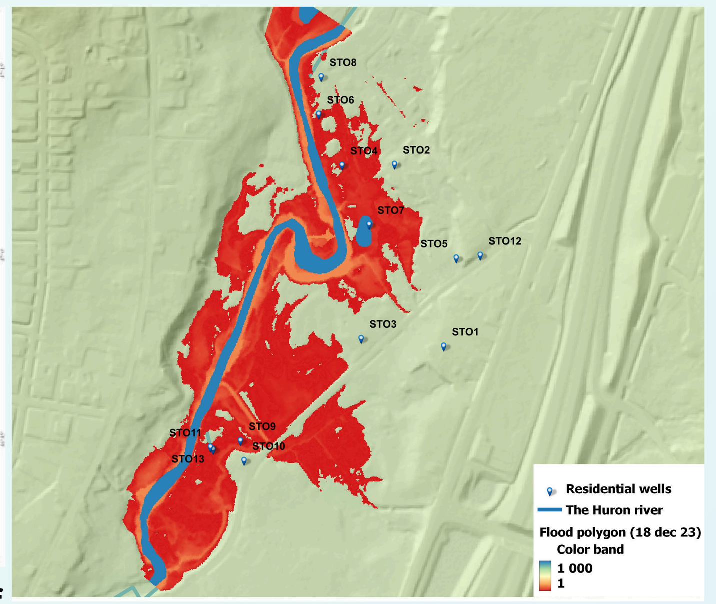

Fig.3: Location of wells in relation to the floodplain (December 2023)


Fig.4: Huron River

3- Flooding in Stoneham


Fig.5: Flooded streets in July 2023

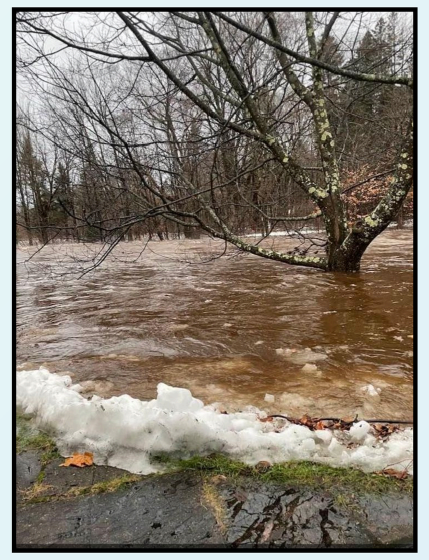
Fig.6: Major flood event in December 2023


Fig.7: Flooding in November 2019

4- Main Objectives

Natural Sciences Objectives:

1. Identify contamination risk factors
2. Assess contamination duration
3. Map spatial extent of contamination

Social Sciences Objectives:

1. Perception of well water quality
2. Water use practices during floods
3. Stakeholder roles and strategies

Co-develop practical recommendations to reduce risk and enhance resilience

5- Methods

Between May 2023 and July 2024, fifteen field campaigns were conducted. Water samples were collected and analyzed for a range of physical, geochemical, isotopic, and microbiological parameters

Physical interaction between surface water and wells

Pumping-corrected water level

$$\alpha_i = \left|\frac{h_{i+1} - h_i}{t_{i+1} - t_i}\right|$$

αi > α max

Stable Isotopes of Water (^{18}O)

Contamination of wells

Cations

Anions (nitrate, fluoride) (NO_3^-)

Microorganisms


E. coli
Total coliforms

In summer 2024, 10 semi-structured interviews were conducted with private well owners. Municipal actors were also consulted to better understand perceptions and issues related to water management in the context of flooding

6- Results

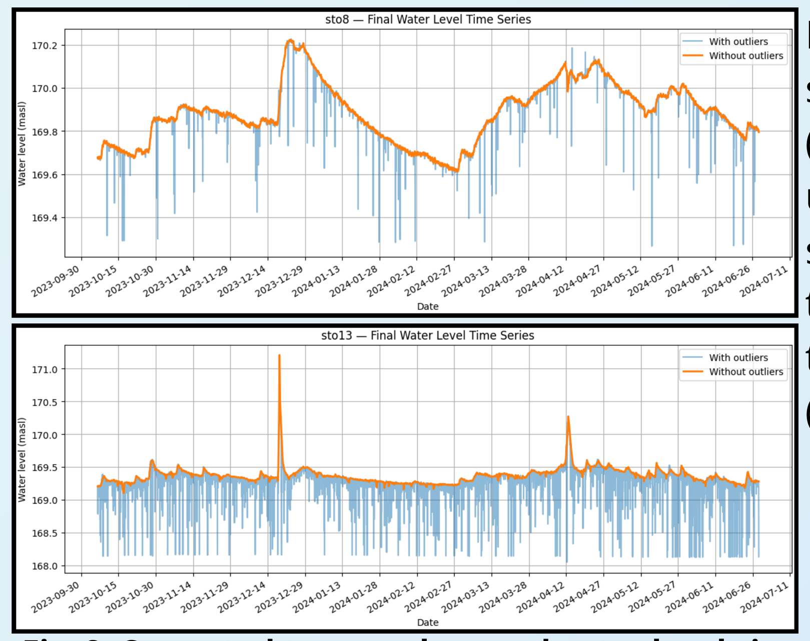
Fig. 8: Corrected temporal groundwater levels in wells (Oct. 2023 – Jun. 2024)

Residential wells show strong pumping effects (outilers) due to domestic use (e.g., washing, showering). Correcting for this is essential to obtain the true groundwater level (Fig.8).

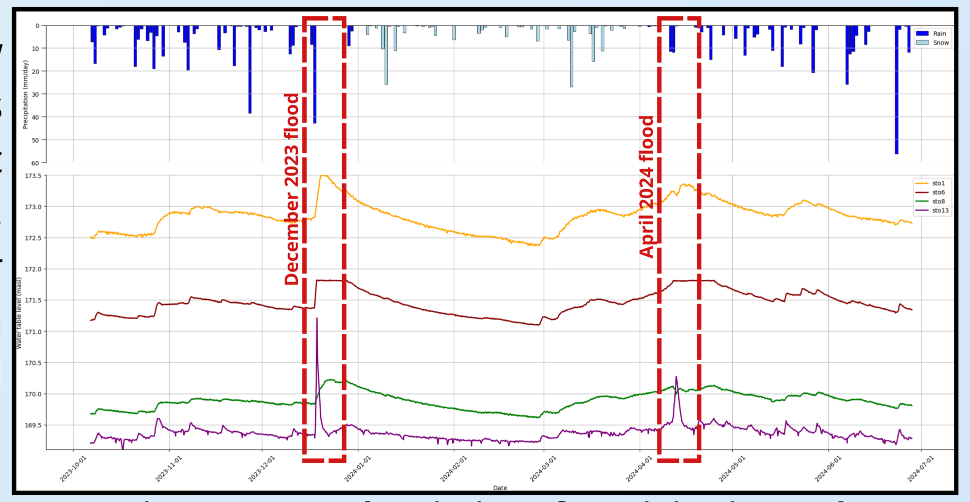

Fig. 9: Temporal variation of precipitation and groundwater levels in wells (oct. 2023–jun. 2024)

During floods, groundwater levels rise abruptly and synchronously across wells, suggesting either surface water intrusion or a rapid response of the aquifer. The return to baseline can show a broad peak (e.g., Sto-1, Sto-6, Sto-8 – non-flooded wells) or a narrow one (e.g., Sto-13 – flooded well). Sto-13 displays both the sharpest and highest peak, indicating possible surface water intrusion in this highly flood-prone well.(Fig. 9)

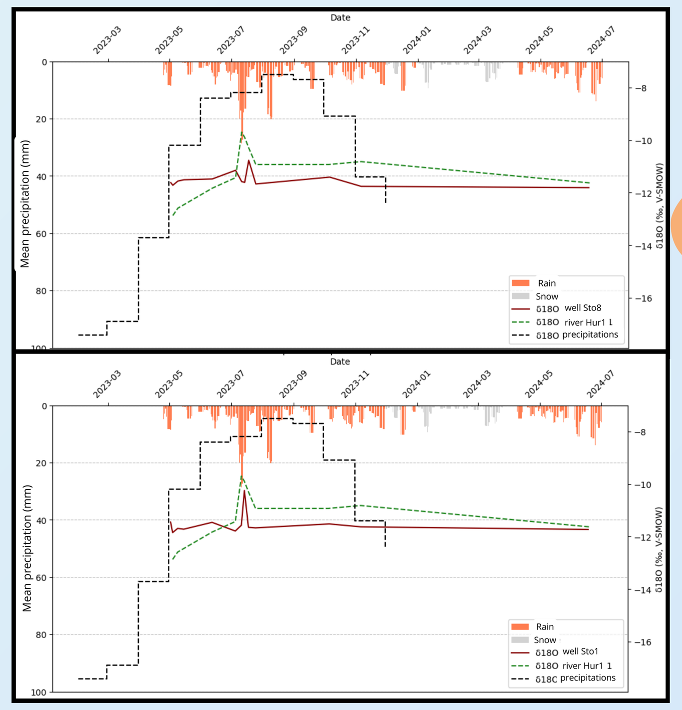
Fig. 10: Isotopic variation – rain, wells, river (jan. 2023–jun. 2024)

Sto-1 (Fig. 10) (non-flooded, upstream, +20 m): sharp peak → direct surface water input ? river intrusion via aquifer?
Sto-8 (Fig.10) (non-flooded, near river): isotopic rise with lag → river intrusion via aquifer? Rainfall?

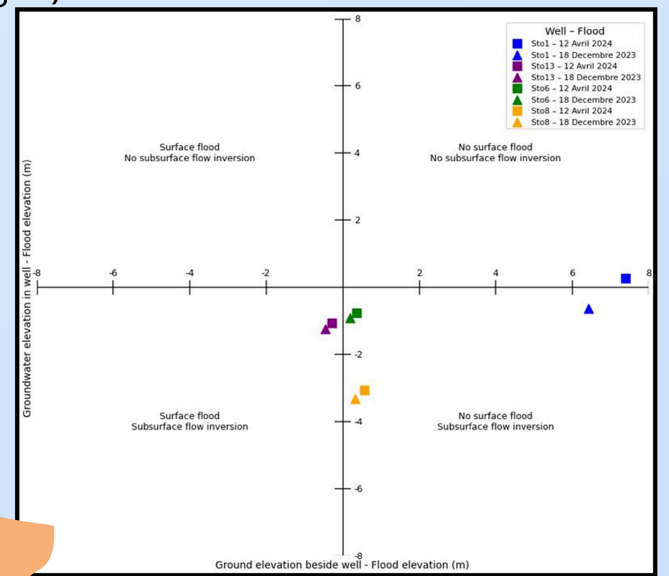
Fig. 11: Well vulnerability by flood event (surface flooding and/or aquifer intrusion)

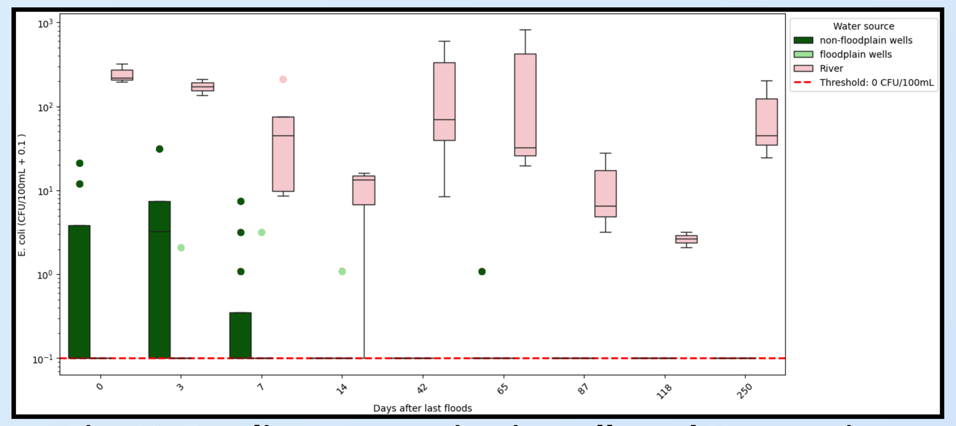
Fig. 12: E. coli concentration in wells and Hurons river

Chemical standards are met in all wells and in the river. Microbial contamination (E. coli, coliforms) exceeds limits in both.

Well disinfection with bleach is not sufficient and must be repeated after each flood or heavy rain.

- 4/7 owners haven't tested their well water; in some cases, for more than 19 years since purchasing or building their property.
- During floods, nearly all participants (n=6) reported no change in behavior.

Well owners' behaviors and perceptions during floods increase their vulnerability. Preventive actions are rare, and limited knowledge reduces risk awareness.

7- Conclusion

This study highlights that wells remain vulnerable to contamination regardless of their location relative to the floodplain. Not only floods, but also heavy rainfall can impact water quality. Most well owners lack the information needed to assess water safety. To address this, awareness workshops will be held in May 2025 to strengthen resilience and promote safer practices.

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