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Numerical modelling of heat transfer in a talik beneath the Kuuguluk River at Salluit, northern Québec, Canada

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The Inuit community of Salluit in northern Quebec, Canada, is located in the continuous permafrost zone where finding a sustainable supply of drinking water is challenging. A well drilled in fractured rock aquifer in a talik beneath the Kuuguluk River is used as a source of water in this community. Moreover, while everything freezes up in winter, very large icing forms each year in the floodplain of Kuuguluk River which regularly cracks due to high water pressure in the talik underneath the icing, water seeps through the cracking and increases the icing extent. To delineate the spatial extent of the talik, a geophysical investigation, including electrical resistivity tomography, was carried out in spring 2011. The thermo-hydraulic conditions of the riverbed have also been monitored since 2014 to measure the water pressure underneath the icing and assess the vulnerability of this groundwater resources to climate change.

While the water level in the Kuuguluk River varies from 0.4 to 1.0 m in summer time following the precipitation events, the water pressure can be as high as 3.1 m in winter underneath the icing. This water pressure is enough to crack the icing. Sharp water level decrease events of few decimeters due to water pressure release through icing fracturing were also recorded. Following the geophysical investigation, a conceptual cryogeological model of the talik has been developed to support a 2D numerical model of conductive heat transfer in Cast3M. Dirichlet boundary conditions were applied at the surface and Neumann boundary conditions on the sides and bottom of the 2D model. The complex heat transfer at ground surface is simulated using empirical relationships between the surface and air temperatures found from monitoring of thermo-hydraulic conditions of the riverbed, floodplain, and plateau surrounding the river. Based on the simulation results, the presence of the talik is due to the current thermal conditions along the riverbed. Moreover, the extent of the simulated talik is also consistent with that derived from the electrical resistivity model.

For a more realistic simulation, ground heterogeneity and groundwater flow in the talik will have to be taken into account in a 3D numerical model to understand the formation of icing along the Kuuguluk River in winter.