Challenges and Model Limitations in Predicting Streamflow in the Canadian Prairie Region

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Research Summary

Under Project 3.1 an article discussing the current flood forecast systems across Canada was published in Vol. 1 of Flash FloodNet, where a number of challenges were highlighted. One challenge is to develop better hydrologic models for the prairie region. A common problem of Prairie hydrology is how to better include the impact of potholes in hydrologic models. Prairie hydrology (see Fig.) has been studied for many decades, so it is well established that surface runoff in prairie regions often drains into depressions, forming wetlands or potholes. These depressions are closed basins which retain water for longer periods and do not contribute flow to the stream under normal conditions. During times of high runoff, the storage capacity of many depressions can be exceeded, causing a fill-and-spill process to occur. Once the depressions are filled, the overflow water connects them and starts to flow to the stream. Consequently, temporary streams can form, resulting in a dynamic increase in the contributing area for runoff. At some point, the movement of water stops, causing a break in the interconnection of wetlands, and consequently reducing the contributing area. The dynamic nature of these isolated potholes makes hydrological processes of the prairie region difficult to quantify.

Relatively few studies have examined the impact of potholes on the hydrology of a watershed. The FFC of Manitoba has employed and tested a combination of hydrologic models to better depict the presence of potholes and the fill-and-spill process of potholes. However, in most cases, either a lumped concept of wetlands was adopted or the fill-and-spill of the potholes was missing.

The potential benefit of wetlands, their disappearance, and the limited number of catchment-scale studies on potholes have resulted in a pressing need for further research on the impact of potholes on the hydrology of the Prairie region. Partly due to the interest of FloodNet partners (Manitoba and Saskatchewan forecasting centres), this study aims to develop the SWAT model for the Upper Assiniboine River basin at Kamsack, a basin that is dominated by potholes. SWAT is a physically-based and semi-distributed model that has routines for wetland, pond, reservoir and potholes. We modified the potholes representation of the SWAT model at the Hydrologic Response Unit (HRU) level to attempt to capture the dynamics of the contributing and non-contributing areas caused by the fill-and-spill of potholes. We then calibrated the modified model at a daily time scale using the Sequential Uncertainty Fitting v.2 package. The performance of the model showed a maximum KGE of 0.78 and 0.80 in the calibration and verification process, with an acceptable range of uncertainty. We observed a significant improvement in replicating stream flow using this novel approach and foresee that it will effectively improve the predictive power of SWAT for this highly complex study. Hydrologic modelling of prairie potholes is a common problem both in Canada and the US. To bring expertise and to test various techniques on Canadian prairie watersheds, this project is undertaken in close collaboration with Dr. Grey Evenson (Environmental Protection Agency, US). The knowledge gained through our model development will not only help FFCs in Canada but would also help centres south of the border.