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An improved runoff generation algorithm for physically based watershed modelling in the Canadian prairies

Kamrul Hossain (1,2), Amin Elshorbagy (1,2), Bharath Raja (1,2), Bruce Davison (3), and Howard Wheater (2)

(1) Department of Civil, Geological, and Environmental Engineering, University of Saskatchewan, Saskatoon, Canada (amin.elshorbagy@usask.ca), (2) Global Institute for Water Security, University of Saskatchewan, Saskatoon, Canada , (3) Environment and Climate Change Canada, Saskatoon, Canada

Runoff generation algorithms in hydrological models developed for the Canadian prairie conditions are required to address challenges such as unique lateral hydrological processes, pothole and wetland processes, cold region hydrological processes, streamflow variability, complex land surfaces, variable contribution of drainage area, and dynamic connectivity of surface storage. Modélisation Environmentale–Surface et Hydrologie (MESH) is a widely used physically based hydrological model developed by Environment and Climate Change Canada (ECCC) that has capabilities to address these challenges. Existing runoff generation algorithms in MESH are either physically based or conceptual. In the physically-based WATROF algorithm, overland flow is governed by Manning's equation once a specified ponding limit has been reached, and sub-surface flow is governed by Richards' equation. The conceptual PDMROF algorithm is based on the probability distribution model (PDM) concept and has been found to be suitable for watersheds in the prairie ecozones of Canada, whereas the suitability of the physically based algorithm is limited to non-prairie watersheds. PDMROF has a limitation of having no interflow component, although there is evidence of sub-surface connectivity and small amount of interflow during peak flow in the prairies. In this study, an improved runoff generation algorithm is proposed by replacing WATROF's simple ponding limit with the PDMROF approach of determining the water available for overland flow. The utility of the improved algorithm is evaluated by application over three watersheds located in the prairie and boreal plain ecosystems of Canada. A comparative study to identify the appropriate runoff generation algorithm for the prairie and boreal plain ecosystems is also carried out. Results showed that the improved algorithm performs better than the existing ones in the prairies and reasonably well in the boreal forests, where the physically-based approach (WATROF) is found to be the most suitable.