

Quantifying the Groundwater Storage-Discharge Dynamics of a First-Order Watershed in the Canadian Rockies

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The eastern slopes of the Canadian Rocky Mountains are the source of major rivers that provide the main water supply for downstream communities across the Prairie Provinces. These rivers exhibit two distinct stages during the year: a four-to-five-month summer high-flow period driven by snowmelt, glacial melt, and rain, and a seven-to-eight-month winter low-flow period modulated by groundwater storage and discharge from mountain headwaters. Commonly occurring alpine landforms, now acknowledged as alpine aquifers, such as talus slopes, moraines, and alpine meadows are responsible for storing and discharging the majority of groundwater in headwater environments. Recent small-scale studies have discerned a non-linear storage-discharge relationship expressed by these aquifers that can be represented with a relatively simple exponential function, although there has otherwise been limited progress upscaling our current small-scale understanding of alpine aquifers to the river-basin scale. In turn, this has inhibited our ability to accurately simulate and predict the low-flow period of mountain rivers in large-scale hydrological models.

This study aims to help upscale our knowledge of alpine aquifers, by exploring the capability of the aforementioned simple exponential function to accurately emulate the storage-discharge dynamics of a first-order watershed located in the Canadian Rockies, compared to a distributed physically-based groundwater flow model implemented in the same area.

The Opabin Spring watershed (OSW), located within the Lake O'Hara research basin in British Columbia was utilized for this study. The OSW was chosen, as numerous field-based studies have previously been conducted there, enabling use of geophysical data, a distributed snowmelt model, and measured hydrological properties of the pertinent aquifers to construct and parameterize the groundwater flow model.

The performance of the simple exponential function and distributed groundwater flow model were evaluated using measured stream discharge and previously calculated watershed storage, derived from a water balance approach. The exponential function simulated watershed discharge well, with a Log Nash-Sutcliffe score of 0.75 compared to the 0.88 score yielded by the distributed groundwater flow model. Both the function and model simulated the watershed storage dynamics to the same level of accuracy. Collectively, this suggests that the function likely has the capability to be integrated as the baseflow component in a large-scale hydrologic model and strengthen its capacity to quantify and predict the low-flow regime of major rivers originating in headwater environments. In turn, this will enable downstream communities to develop sustainable science-based water management policies to ensure water security for the present and future.