Simulation of hydrological impacts of forest wildfire for Bow River headwater basins in the Canadian Rockies

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This study evaluates the hydrological impacts of forest wildfire in Bow River headwater basins above Calgary using the Cold Regions Hydrological Modelling platform (CRHM). Hydrological models were created in CRHM for Bow River at Banff (~2192 km2), Bow River above Calgary (~7824 km2), and Elbow River above Calgary (~1192 km2). These models were parameterized from local research results, rather than calibration, to represent relevant streamflow generation processes: wind redistribution of alpine snow, gravitational snow transport on steep mountain slope, glacier accumulation and melt, intercepted snow from forest canopies, infiltration to frozen and unfrozen soils, hillslope sub-surface water redistribution, and evapotranspiration from forests and alpine tundra. Models were driven by the near-surface outputs from the 4 km Weather Research and Forecasting (WRF) model for 15 water years (WY, October 2000-September 2015). The streamflow simulations showed reasonable predictions compared to the observed streamflow, with Nash-Sutcliffe efficiency ranging from 0.38 for Elbow River at Sarcee Bridge, Calgary and Bow River at Lake Louise to 0.75 for Bow River at Banff, and model bias ranging from -0.25 for Bow River at Lake Louise to -0.02 for Pipestone River at Lake Louise. Then, simulations of forest wildfire were conducted for five scenarios: low, moderate, and high fire severities as well as fire-induced soil hydrophobicity under moderate and high fire severities. CRHM results showed that as the canopy density was decreased due to fire impacts, the lower intercepted snow sublimation and intercepted rain evaporation was offset by greater surface snowpack sublimation and evapotranspiration for all basins. For all basins, the annual snowmelt volume for all scenarios was comparable to that from the reference simulation despite lower annual peak SWE and earlier snowmelt. The streamflow regime was complicated by the responses of individual hydrological processes counterbalancing one another and demonstrated insensitivity forest fire impacts, except for the effects of hydrophobicity in soils under the high fire scenario. In this scenario, higher overland flow contributions to streamflow in the Bow River and Elbow River basins above Calgary resulted in respective increases of 29% and 42% in mean annual streamflow volume, 134 m3 s-1 and 30 m3 s-1 in mean annual peak discharge, and 123% and 103% in the June 2013 flood volume.