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Isotope-based hydrograph separation in large rivers: assessing flow sources and water quality controls in the oil sands region, Canada

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Hydrograph separation using stable isotopes of water is used to partition streamflow sources in the Athabasca River and its tributaries in the oil sands region of northern Alberta, Canada. Snow, rain, groundwater and surface water contributions to total streamflow are estimated for multi-year records and provide considerable insight into runoff generation mechanisms operating in six tributaries and at four stations along the Athabasca River. Groundwater, found to be an important flow source at all stations, is the dominant component of the hydrograph in three tributaries (Steepbank R., Muskeg R., Firebag R.), accounting for 39 to 50% of annual streamflow. Surface water, mainly drainage from peatlands, is also found to be widely important, and dominant in three tributaries (Clearwater R., Mackay R., Ells R.), accounting for 45 to 81% of annual streamflow. Direct runoff of precipitation sources including rain (7-19%) and snowmelt (3-7%) account for the remainder of sources. Fairly limited contributions from direct precipitation illustrate that most snow and rain events result in indirect displacement of pre-event water (surface water and groundwater), due in part to the prevalence of fill and spill mechanisms and limited overland flow. Systematic shifts in the groundwater:surface-water ratios, noted for the main stem of the Athabasca River and in its tributaries, is an important control on the spatial and temporal distribution of major and minor ions, trace elements, dissolved organics and contaminants, as well as for evaluating the susceptibility of the rivers to climate and development-related impacts. Runoff partitioning is likely to be a useful monitoring tool for better understanding of flow drivers and water quality controls, and for determining the underlying causes of climate or industrial impacts.