Multiple lines of evidence for nested groundwater flow in west-central Alberta

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ABSTRACT
As part of evaluating Alberta's groundwater inventory, the Alberta Geological Survey (AGS) has recently completed a hydrogeological characterization project for a 22,000 km^2 region in west-central Alberta. This forested region is relatively unpopulated and has become a focal point for unconventional shale-gas development, which uses large volumes of water. Headwater rivers in this region rely on baseflow sourced from bedrock formations, which appear to exist within a nested groundwater system. For such a large area of interest, we bring together multiple lines of evidence to support our conceptualization of the nested groundwater system. Geological characterization of bedrock formations to a depth of nearly 1.5 km show a highly heterogeneous shallow unit of varying thickness (Paskapoo Formation) over a more extensive 2-layer mudstone/sandstone sequence (Wapiti Formation). Hydraulic heads within the shallow unit generally reflect present-day topography. Groundwater sampling indicates TDS is less than 800 mg/L in the shallow groundwater, and ^{3}H and SF_6 concentrations having an apparent age of 30 to 50 years. More detailed pressure-vs-depth measurements suggest localized groundwater flow adjacent to the headwater rivers, whereas dominantly vertical (downward) groundwater flow across the shallow unit. In the deeper 2-layer formation, hydraulic heads mimic the regional upland areas somewhat, but also indicate an underpressured region associated with the Western Canadian Sedimentary Basin. In this deeper portion of the groundwater system, provincial-scale mapping indicated that TDS varies from 600 to 8,000 mg/L, and opportunistic sampling found elevated ^{4}He concentration, corresponding to an apparent age of about 135,000 years. The combination of geological and hydrogeological information including tracer-based residence time provides multiple lines of evidence for the nested groundwater flow, which has important implications for regulating groundwater, and in-turn unconventional shale-gas development in Alberta.