Recharge Processes in the Lower Portneuf River Valley Watershed

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ABSTRACT

In the lower Portneuf River Valley (LPRV), the Mink Creek and Gibson Jack watersheds are part of a ground water recharge corridor that supplies more than 80% of the annual recharge to the municipal aquifer system (Welhan, 2006). These watersheds also contain the majority of the more than 600 septic drain fields that contribute more than six metric tons of nitrate-nitrogen annually to the LPRV aquifer (Meehan, 2004). Past water sampling focused on ground water quality, so information on recharge sources, flow rates and flow paths within this vital recharge corridor has been unavailable until now.

In April and July, 2014, eight private water wells in this area were sampled for \(^{3}H\), \(^{14}C\) and stable isotopes to determine whether ground water residence times within the recharge corridor can be estimated. Sampling focused on bedrock wells deeper than 100 meters that should be minimally impacted by septic leachate; five, in the least-developed watersheds areas (representing flow systems ca. 5 - 7 km in length), and three wells in the watersheds’ discharge zone (ca. 10 - 12 km flow path).

Sampling sites for this study were selected to minimize septic influence, but only three of eight wells proved to be free of septic influence (i.e., < 0.2 mg/l NO\(_3\)-N) and could be evaluated for approximate \(^{14}C\) “ages” (Figure 3).

DISCUSSION

Approximate \(^{14}C\) corrections were developed for the three samples with NO\(_3\)-N < 0.2 mg/l based on the mixing fraction of the high- dissolved inorganic carbon (DIC) thermal end-member determined in Figure 7. A fourth sample, with \(^{14}C\) activity just above detection, indicates a mean residence time of approximately 100 years in septic-impacted water.

The corrected \(^{14}C\) mean residence times for a range of possible \(^{13}C\) compositions of Cambrian and Proterozoic carbonates in the study area represent maximum estimates because the dilution correction for the thermal DIC source (assumed to be \(^{14}C\)-dead) provides an estimate of \(^{14}C\) activity in local DIC prior to mixing, but this DIC is itself a mixture of soil zone and carbonate-derived DIC within the local flow system, for which an independent correction cannot be derived.

These tentative \(^{14}C\) residence time estimates suggest that local ground water flow rates in the Mink Creek watershed may greatly exceed 50 meters/year depending on the dilution fraction of locally derived carbonate DIC and the \(^{14}C\) composition of these carbonates. If corroborated, such high ground water flow rates could implicate paleokarst units in the uplands area of the watershed.

INTERPRETATION OF RESULTS

Results suggest that locally recharged ground water in these watersheds has a mean residence time of the order of \(< 200\) to \(2000\) years (Figure 3), although these estimates are, at best, tentative. Such residence times indicate mean linear ground water flow rates from the nearest recharge zone could exceed 50 meters/year. This is within the range of flow rates expected in upland fractured crystalline and carbonate bedrock but very short-residence times could point to the involvement of known contaminant units in the upland areas.

More importantly, the LPRV’s conceptual recharge model may need to be revised if the temperature and \(^{3}H\)/\(^{14}C\) isotope data have been interpreted correctly. Locally recharged meteoric water (estimated at ca. 8 \(^{18}O\) at D\(_{2}O\) derived from local snowpack) appears to mix with thermal water (ca. 25 \(^{18}O\)) reflecting deep, regional-scale flow from distant (and/or fossil) recharge sources. This thermal component, postulated to rise along bedrock faults within the LPRV watershed, severely limits our ability to interpret \(^{18}O\) in terms of ground water residence times.

The most significant result of this study is the finding that non-local recharge sources contribute to the LPRV aquifer system. If corroborated, ground water temperature variations in the LPRV will need to be evaluated to determine whether non-local recharge is volumetrically important to the aquifer’s water balance and management of the municipal water supply.

GEOHYDROLOGIC SETTING

The study area is located in the lowest part of the Mink and Gibson Jack Creek watersheds (Figure 1), situated over the LPRV aquifer system’s most important recharge corridor. Previous work has shown that the area is heavily impacted by septic leachate, characterized by Cl\(^{-}\) and SO\(_4\)-enrichments. The study area is also heavily affected by septic effluent (Figure 2).

Figure 2 – Major ion composition of some of the 2014 samples (red) relative to data from Meehan (2004), in blue.

Figure 3 – Radiostotope data and best estimates ground water residence times, based on a Pearson-type correction for a thermal water component.

Figure 4 – Available stable isotope data for precipitation (A) and ground water (B) in the study area. Shallow ground water samples in (B) were collected ~1600 m (2000 ft) higher in elevation than the 2014 well waters in the lower Mink Creek drainage.

Figure 5 – Temperature variations relative to \(D_{2}O\) are assumed to reflect mixing of local ground water recharged at Wild Horse Divide (ca. 8 \(^{18}O\)) and a warm, isotopically light ground water. A two-component mixing analysis explains the observed ionic variations in Figure 6 and constrains the thermal component’s T at approximately 24 \(\pm 3\) \(^{\circ}\)C (Figure 7).

CONCLUSIONS

The outcomes of this study are by no means conclusive, the results being dependent on various assumptions, hypotheses, and minimally constrained interpretations. Chief among these is the source of warm water observed in many of the sampled wells in this and previous studies. If warm ground water enters the local flow system from the graben-bounding fault east of the LPRV (where thermal wells are known to occur), then future \(^{14}C\) dating is not recommended. However, if the residence time estimates determined in this study prove to be reasonable accurate, it suggests that snowpack-derived recharge may travel quite rapidly from the uplands, possibly through upland paleokarst bedrock units.

Figure 9 – Subsurface hydrogeology along cross section A-A’ (Figure 1) as constrained by the modeled bedrock geometry and Tertiary basin fill after Reid’s (1997). Possible deep thermal water and local meteoric flow path trends are marked with colored arrows. Sampled wells and depths are plotted to scale.

Figure 8 shows all available ground water temperature data in the study area (Meehan, 2004) and Figure 9 depicts hypothetical ground water flow paths that could explain the spatial distribution of elevated temperatures. The possibility that water from as deep as 1 km can rise along bedrock faults and unconformities in the Mink and Gibson Jack Creek watersheds begs the question of whether it represents a significant source of recharge to the LPRV aquifer and the municipal water-supply system.

Figure 8 – All available temperature data showing spatial distribution of warm well water in the study area.