

Snowmelt Infiltration and Runoff from Forested Hillslopes, Boreal Plain, Alberta

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EXTENDED ABSTRACT

There are large gaps in our understanding of the hydrology of forested uplands, wetlands and ponds on the western Boreal Plain region of Canada (Buttle et al. 2005; Devito et al. 2005). Recent climatic conditions have resulted in the drying of ponds and wetlands within this region. The long-term sustainability of these wetland ecosystems likely requires runoff inputs from adjacent upland forest hillslopes. Snowmelt is a critical water source on the Boreal Plain as it comprises 30–40% of annual precipitation inputs, occurs when plant uptake is minimal and may result in runoff over frozen soils. The objective of this research was to examine the potential for snowmelt runoff from forested hillslopes at the Utikuma Research Study Area (URSA) on the Boreal Plain of north central Alberta.

To understand the potential for snowmelt runoff in this region, it is necessary to examine the major controls over snowmelt water movement. The variables examined include: aspect (N, S) which controls energy input for melt, soil texture (sand, loam) which influences storage and transmission of water, and frozen soil moisture content (fall irrigation, non-irrigated) which determines the infiltrability of frozen soils. Three sites were chosen (jack pine canopy on sandy soil, aspen canopy on sandy soil, aspen canopy on loamy soil) with plots on N and S aspect slopes (~20% slope gradient).

In each plot, 4 runoff frames were constructed and instrumented to monitor surface runoff, soil moisture content and soil temperature. Additionally, a pan lysimeter was installed at each plot to measure snowmelt volume. Two of the four frames in each plot were irrigated with 40 mm of water in late October 2003. Over the melt period, snow depth and density were measured periodically, and snowmelt was measured using lysimeters. Recharge depth of snowmelt water was followed using an applied Br⁻ tracer and $\delta^{18}\text{O}$. In early June 2004, 2 frames in each plot (1 irrigated, 1 non-irrigated) were sampled for soil moisture content, Br⁻ and $\delta^{18}\text{O}$ concentrations with depth. Prior to, during and after snowmelt, samples of snow, snowmelt water, runoff water and groundwater were collected for analysis of Br⁻ and $\delta^{18}\text{O}$.

Greater snowmelt was measured from lysimeters on S-facing than on N-facing slopes. Total snowmelt ranged from 65 to 175 mm equivalent water depth. The maximum measured melt rate was 2 mm/h. There was little runoff from the frames (only 10 of 24 frames) (Figure 1). Substantial runoff only occurred from frames on S-facing slopes where concrete frost had developed at the forest floor/mineral soil interface during spring melt-refreeze events. The effects of late fall irrigation treatments were negligible as much of the irrigation water drained from the surface soils prior to freezing.

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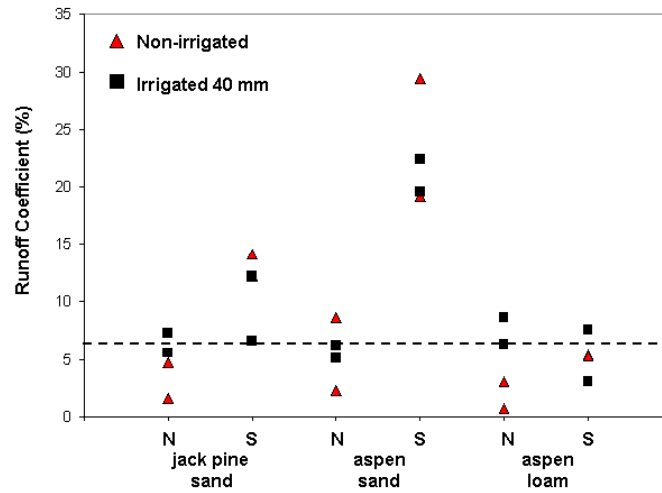


Figure 1. Snowmelt runoff coefficients (%) for non-irrigated (triangles) and irrigated (squares) runoff frames. Runoff coefficients less than 6% (horizontal dashed line) may indicate no runoff as the collection trough in runoff frame underlays ca. 6% of frame area.

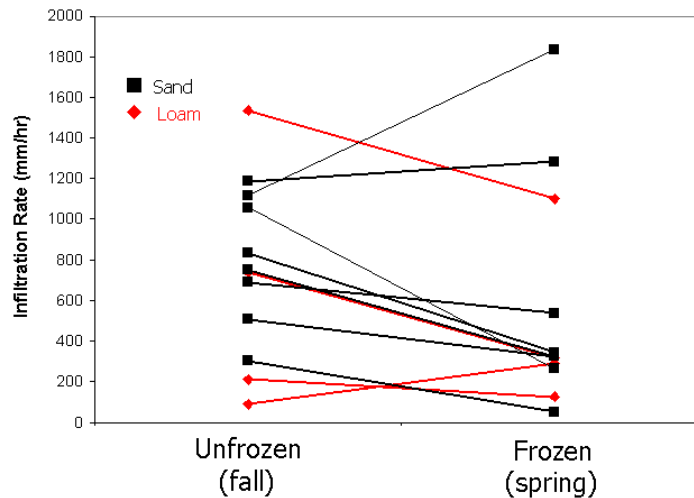


Figure 2. Infiltration rates measured using the single-ring method for unfrozen (October 2003) and frozen (April 2004) soil conditions. The unfrozen rates are steady-state rates, while the frozen rates are early-time rates.

Infiltration rates in frozen and unfrozen soils were measured using the single ring infiltration method. For unfrozen soils, the infiltration rate was calculated as the steady-state rate. For the frozen soils, early-time infiltration rates were used as the infiltration rate for frozen soils increases during the measurement period. Infiltration rates were high and were typically greater for unfrozen

thank frozen conditions (Figure 2). All measured infiltration rates were greater than the maximum measured melt rate.

The depth of snowmelt recharge on the hillslopes was measured by examining changes in soil moisture content, $\delta^{18}\text{O}$ and Br^- with depth. For the north-facing aspen-loam site, soil moisture and $\delta^{18}\text{O}$ indicate a depth of recharge of 80–100 cm (Figure 3a). For the south facing jack pine site on sand, snowmelt recharge may have exceeded 200 cm (Figure 3b). The recharge depth measured with the Br^- profiles (not shown) corresponds closely to those of $\delta^{18}\text{O}$ for both sites.

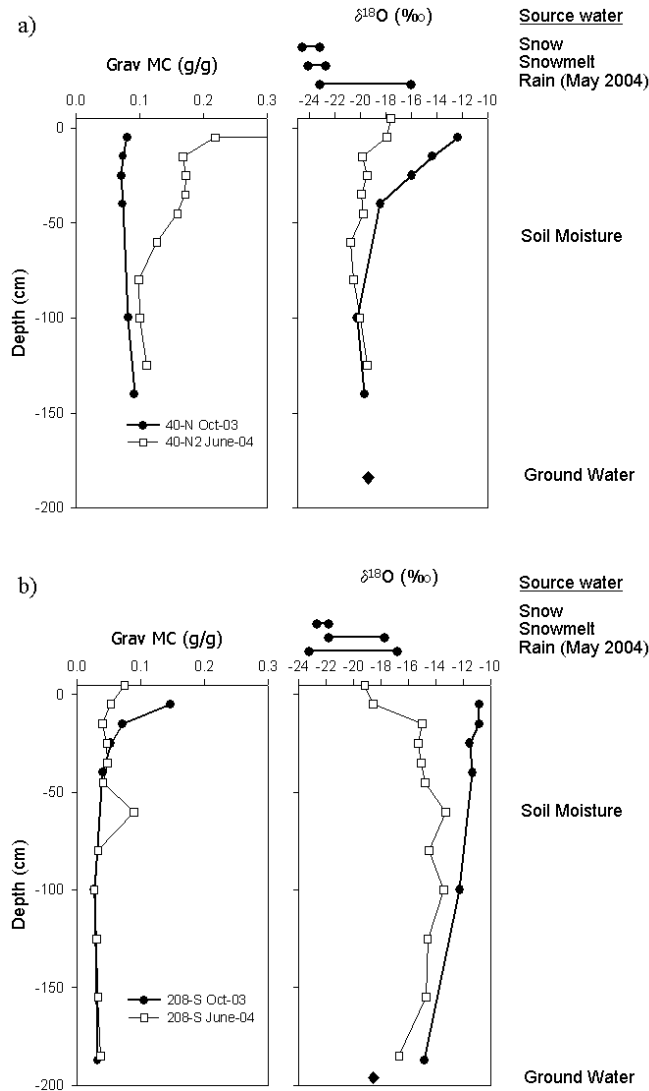


Figure 3. Depth profiles of soil moisture content and $\delta^{18}\text{O}$ for fall (Oct 2003) and spring (June 2004) for aspen canopy with loam soil (a) and jack pine canopy with sandy soil (b). Source water $\delta^{18}\text{O}$ concentrations were measured from February to June 2004.

The results of this study indicate that near-surface snowmelt runoff may not be a common occurrence on the Boreal Plain of northern Alberta. Snowmelt runoff was found where late winter and early spring snowmelt events resulted in re-freezing of melt water within the soil, leading to the development of a low permeability frost layer near the soil surface that acted to impede

infiltration. Fall soil moisture did not play a strong role in controlling infiltration versus runoff due to the ability of the soils to drain irrigation water rapidly prior to freezing and the ability to infiltrate and store water in the spring. Infiltration measurements indicated that frozen soils maintained high infiltration rates that far exceeded the maximum input rate of snowmelt water. On finer textured soils, snowmelt water infiltrated to a depth of 80–100 cm, while on sandy soils recharge occurred to a depth of 200 cm or more. The results indicate that snowmelt recharge to the groundwater is more likely on sandy than finer textured soils.

REFERENCES

- Buttle, JM, Creed, IF, Moore, RD. 2005. Advances in Canadian forest hydrology, 1999–2003. *Hydrological Processes* **19**: 169–200.
- Devito, KJ, Creed, IF, Fraser, CJD. 2005a. Controls on runoff from a partially harvested aspen-forested headwater catchment, Boreal Plain, Canada. *Hydrological Processes* **19**: 3–25.