Groundwater Connections

Groundwater Research in the West Nose Creek Watershed

ADAPTED PRIMARY LITERATURE ARTICLE

Introduction

This article provides a *review* of current research on *groundwater-surface water interaction*, *groundwater and ecology of surface waters*, and *community-based well monitoring*. The review is based on research conducted in the West Nose Creek (WNC) watershed located north of Calgary (*Figure 1*) and St. Denis National Wildlife Area in southern Saskatchewan. The research is led by Dr. Masaki Hayashi, a ***hydrologist*** from the University of Calgary.

Underlying WNC watershed is the ***Paskapoo Formation,*** a bedrock formation containing one of the largest ***aquifer*** systems in the Canadian prairies (Grasby *et al.* 2008). Use of groundwater from this aquifer system has increased over the past decade, particularly between Calgary and Edmonton (Grieef and Hayashi 2007). Therefore, understanding how groundwater interacts with surface water and ecological processes, along with long-term monitoring of water wells is critical for future development and sustainable management of groundwater in this region.

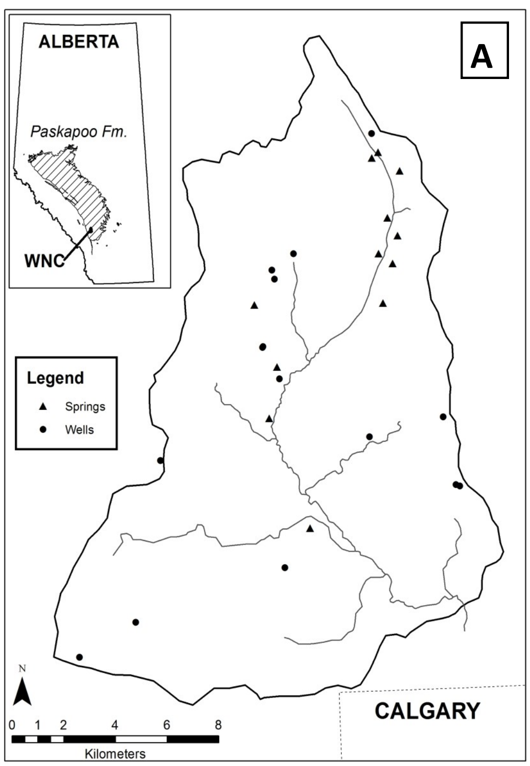

Figure 1. **A)** Location of Paskapoo Formation (image insert) and West Nose Creek watershed (WNC) in relation to Calgary (Adapted with permission from Grieef and Hayashi, 2007 and Green, 2007); **B)** Photo of West Nose Creek.

Prior Research on Groundwater Flow

Prior research predicted that groundwater generally moves from high (upland) to low (depression) areas within a region (Toth 1980). ***Recharge*** is thought to occur in uplands and ***discharge*** to occur in low areas containing surface water such as streams, ponds, or wetlands (*Figure 2*).

Hydrologist:

A scientist that studies properties, distribution, and circulation of water on and below earth's surface and in the atmosphere.

Paskapoo Formation:

A bedrock formation containing one of the largest aquifer systems in the Canadian Prairies.

Aquifer:

A body of rock or sediment below the surface that holds groundwater.

Recharge:

Addition of water to the water table as a result of the infiltration of rain and snowmelt.

Discharge:

The movement of groundwater from the subsurface to the surface.

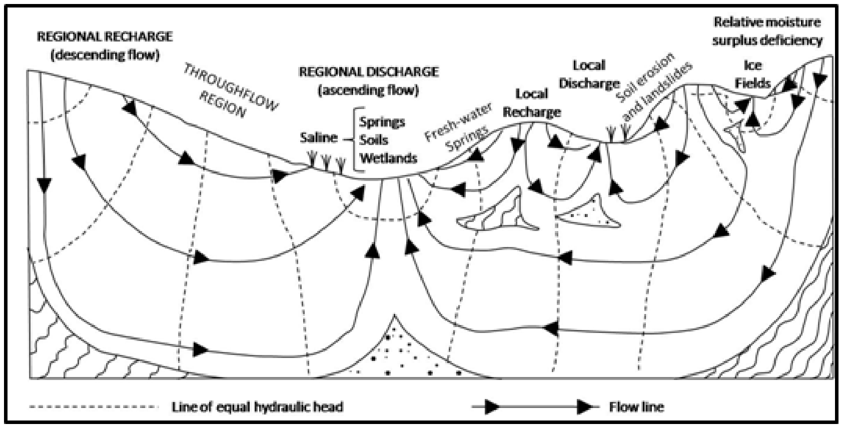

Figure 2. Idealized groundwater flow ***conceptual model***: recharge at high topographic areas, groundwater flow from high to low areas, and discharge into low areas (Adapted with permission from Toth 1980).

Groundwater storage in aquifers can also change over time, depending on the amount of recharge and discharge (*Recharge – Discharge = Change in GW Storage*). More recharge and/or less discharge over time will increase groundwater storage. Recharge and discharge in a natural system does balance over time and GW storage does not change much from an average value.

However, this balance can be altered by pumping water from aquifers through wells, which ***drawdown*** water levels. Long-term pumping of groundwater can alter groundwater discharge into surface water and groundwater storage in the region (*Recharge – Discharge – Pumping = Change in GW Storage*). Therefore, it is very important to increase our understanding of how (and how much) groundwater is recharged, discharged, and pumped in order to develop sustainable management of groundwater in a region.

Current Research on Groundwater Recharge

Between 80,000 and 10,000 years before present, massive ice sheets covered and shaped the prairie landscape. The ice sheets melted at different rates, leaving behind an undulating topography of ***uplands*** and ***depressions*** (*Figure 3*).

Figure 3. Typical upland-depression landscape of Canadian prairies with snowmelt collecting in depressions (Photo Credit: Masaki Hayashi).

Groundwater Storage:

The amount of groundwater in an aquifer.

Drawdown:

The lowering of the water level in an aquifer due to the pumping of groundwater.

Topography:

The shape of the physical landscape features.

Uplands:

The area of high or hilly lands. The high point within the landscape topography.

Depressions:

The low lying areas of the landscape topography.

Infiltrates:
The movement of water from the surface into the soil.

Infiltration rate:
The rate water moves from the surface into the soil.

Transpiring:
The process of plants releasing water vapour from their leaves.

Depression focused recharge:
Groundwater recharge that occurs through infiltration under low lying depressions.

Evapotranspiration
The loss of water from the soil through evaporation and transpiration from plants.

Springs:
The emergence of groundwater to the land surface.

Baseflow:
The flow in a stream during dry periods.

Glacial Till:
Unsorted sediment deposited during the last glaciated period.

Permeability:
The ability of a material to allow the passage of liquid through it.

Spring Outlet:
The clearly defined point where groundwater emerges at the surface of the land.

A research team (Hayashi *et al.* 1998) examined the hydrology of St. Denis National Wildlife Area near Saskatoon, Saskatchewan, which has very similar to the topography of southern Alberta. The team found that as winter sets in, water in the soil begins to freeze and snow covers most of the ground most of the winter. During the winter some of the snow blows into the depressions. In the spring the snowmelt becomes runoff over the frozen soil, also collecting in the depressions. As the soil thaws, water ***infiltrates*** the soil below the depressions.

The team also observed that during the growing season the ***infiltration rate*** was greatest during the day when plants were ***transpiring*** and reduced at night. This process caused most of the infiltrating water to flow laterally away from the depression and up toward the upland areas to be used by plants (*Figure 4*). As a result, of all the water collecting in the depressions only a very small fraction becomes groundwater recharge. For example, in 1994 only 2 mm of the 376 mm total annual precipitation – less than 1% – became groundwater recharge.

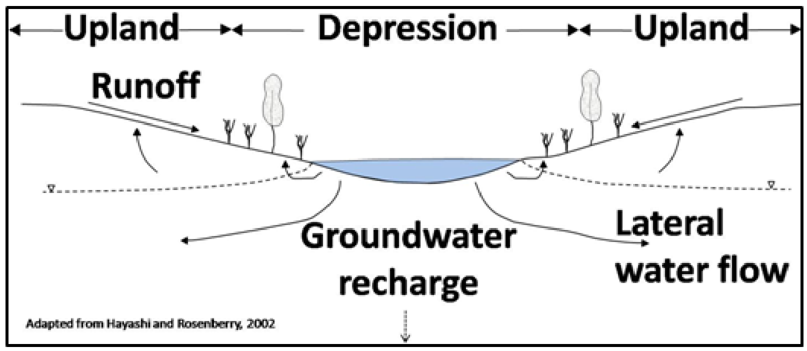

Figure 4. Depression focused recharge. Arrows indicate water runoff, flow, and recharge. Dashed line indicates water table (Adapted with permission from Hayashi *et al.* 1998).

The same research team (van der Kemp *et al.* 2003) also found that changes in land-use in and around the depressions can impact infiltration rates and water flow. For example, changes in vegetation around the depressions can impact snowmelt capture, runoff, and lateral moisture flow in the soil subsurface due to changes in height of vegetation, soil openings, and ***evapotranspiration*** *rates*. Many of the small depressions can also gradually dry up throughout the spring and summer months with these changes. These results highlight how important wetlands, ponds, prairie sloughs, and surrounding vegetation in the uplands are to groundwater recharge in prairie landscapes.

Current Research on Groundwater Discharge

In the WNC watershed, ***springs*** are not only accessed for household and agricultural use, but also provide localized groundwater discharge that contribute to ***stream baseflow*** (*see, Figure 1* for location of springs). An undergraduate research project conducted by Nathan Green (2007) focused on the influence of geology on springs and the connection between spring discharge and stream baseflow in the WNC watershed.

Nathan noted that the geology in this watershed is composed of low permeability ***glacial till*** near the surface followed by interbedded ***lower permeability*** siltstones and mudstones, and ***higher permeability*** sandstones (*Figure 5*). Groundwater originates from depression focused recharge areas and moves laterally through the more permeable sandstone layers, where it emerges at a ***spring outlet***. Although the upper sandstone layer discharges the majority of groundwater, some can reach deeper layers. Nathan also noted that all but one spring in WNC watershed was governed by this geology.

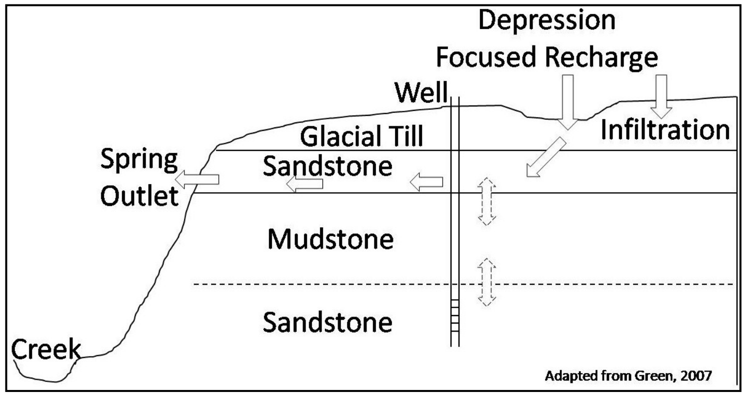

Figure 5. Typical spring outlet from exposed sandstone layer at the edge of the creek channel. Solid arrows indicate groundwater flow; dashed arrows indicate flow to deeper layers (Adapted with permission from Green 2007).

An aerial video was taken in late winter to locate springs within the WNC watershed by identifying ice mounds forming around springs. The total spring discharge in the watershed was then calculated by manually measuring discharge from 40-45% of the springs and estimating remaining spring discharge using the aerial video. It was estimated that 75-90% of all spring discharge came from the measured springs and the total discharge of all springs was in the same ***order of magnitude*** as the WNC stream baseflow.

Nathan also noted differences in discharge rates among the springs, possibly due to nearby pumping wells and/or fractures in the bedrock. This research not only increased our understanding of how springs help maintain stream baseflows, but also showed that more research is required to understand what causes differences in discharge rates.

Figure 6. Photo of Nathan Green sampling a spring in West Nose Creek .

This current research also helps increase our understanding that groundwater recharge and discharge in this region is ***localized*** and not as ***diffuse*** as presented in the idealized conceptual model presented in *Figure 2.* In addition, it showed that groundwater and surface water are connected and therefore, should be considered as one and the same resource for ***sustainable water management*** in this region.

Order of Magnitude:

Range of values between a lower and upper value that is ten times as large. For example, 50 is one order higher than 5.

Localized:

Restricted to a particular location or place.; concentrated

Diffuse:

Spread out over a wide area, not concentrated.

Sustainable water management:

The management of water resources to ensure water is available for current and future users. The users include both humans, animals and natural ecosystems.

Groundwater & Ecology of Surface Water

Hayashi and Rosenberry (2002) note that continuous exchange of groundwater with surface water also helps to maintain stable temperatures, water levels, and ***nutrient cycles*** in surface waters (creeks, ponds, wetlands). This exchange has an impact on ecological processes and organisms living in and around surface waters. For example, many fish species are dependent on stable water temperatures. Water levels impact light depth penetration of the surface water, influencing types of vegetation and organisms living in surface waters. Groundwater exchange also affects nutrient cycling and what lives in the surrounding ***riparian*** and ***hyporheic zones***. This review article highlights the need to monitor changes in baseflows, water levels, and vegetation in and around surface waters. The change can indicate change in water table levels due to drought, land-use change, or over-pumping in a region.

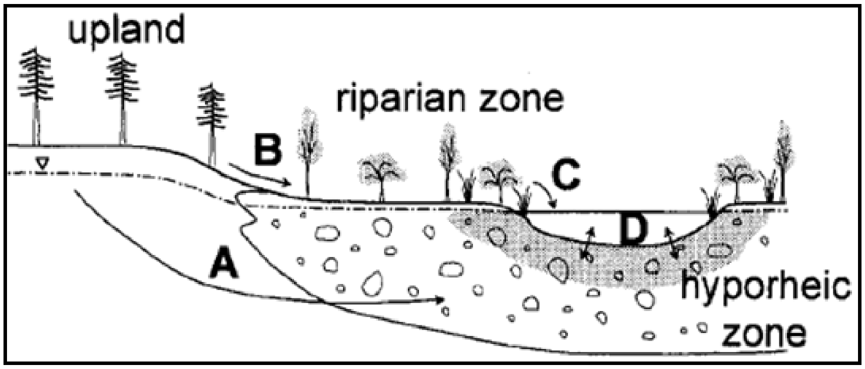

Figure 7. Typical location of water table (dashed line) and water flow pathways (arrows) of: A) groundwater, B) run-off, C) from vegetation, D) exchange in hyporheic zone (Adapted with permission from Hayashi & Rosenberry 2002).

Impact of Overpumping from Water Wells

As water is pumped from a well it causes a drawdown of the water table near the well. As pumping or number of wells increase in an area a larger drawdown can occur, possibly impacting local spring discharge, stream baseflow, and ecological processes. For example, as population increased (*Figure 8A*), there was increased pumping from the town water wells in Irricana. This increased pumping decreased the water table levels as far away as 1 km from the well (*Figure 8B*).

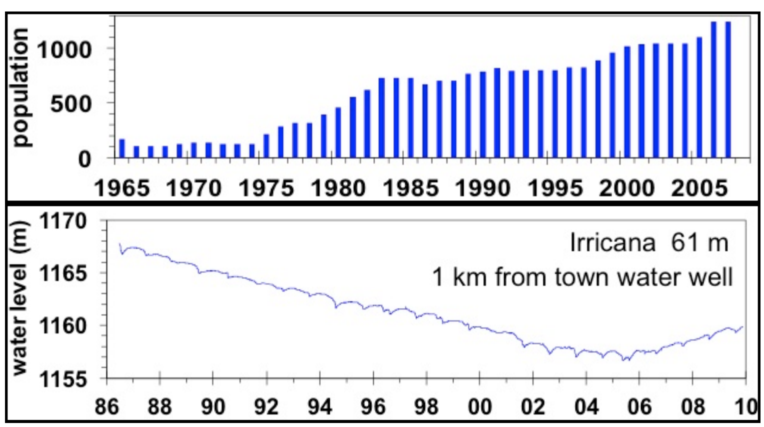

Figure 8. A) Population increase in Irricana from 1965 to 2005 (From: *www.altapop.ca/sources.htm*); ***B)*** Water level drawdown 1 km from town water well (Adapted with permission from Alberta Environment).

Nutrient cycles:

The continuous movement of nutrients (organic and inorganic matter) through an ecosystem. This cycling of nutrients allows for biological growth and development.

Riparian zone:

The zone between land and surface water bodies composed of plants. It is where the groundwater level is near the surface.

Hyporheic zone:

The zone of sediment beneath and around a stream channel where groundwater has a certain portion of surface water mixed in.

Community-based well monitoring:

A program which uses volunteer community members to monitor the water level in their personal wells.

Rocky View Well Watch:

A web based program, where water level data from participating wells can be submitted and viewed.

Watershed approach:

The use of a surface watershed boundary to study the water system as a whole , including groundwater and surface water interactions.

Sustainable water management:

The management of water resources to ensure water is available for current and future users. The users include both humans, animals and natural ecosystems.

Community-based Well Monitoring

The WNC watershed has not yet experienced significant groundwater storage decline. However, as population and development increases so does demand on groundwater, as it is the primary source of water supply for municipal, domestic, agricultural, and industrial use in this region (Grieef & Hayashi 2007). In order to help prevent negative impact on springs, stream baseflows, or ecological processes, it is important to establish long-term monitoring of groundwater .

As such, Lisa Grieef from Alberta Environment (Calgary) and Dr. Hayashi developed a ***community-based well monitoring*** network in cooperation with well owners to collect well water level data (*Figure 9A*) in twenty existing wells in the WNC watershed (*Figure 9B*). This water level data not only provides early detection of groundwater overuse, but also helps establish natural fluctuations in seasonal and yearly averages.

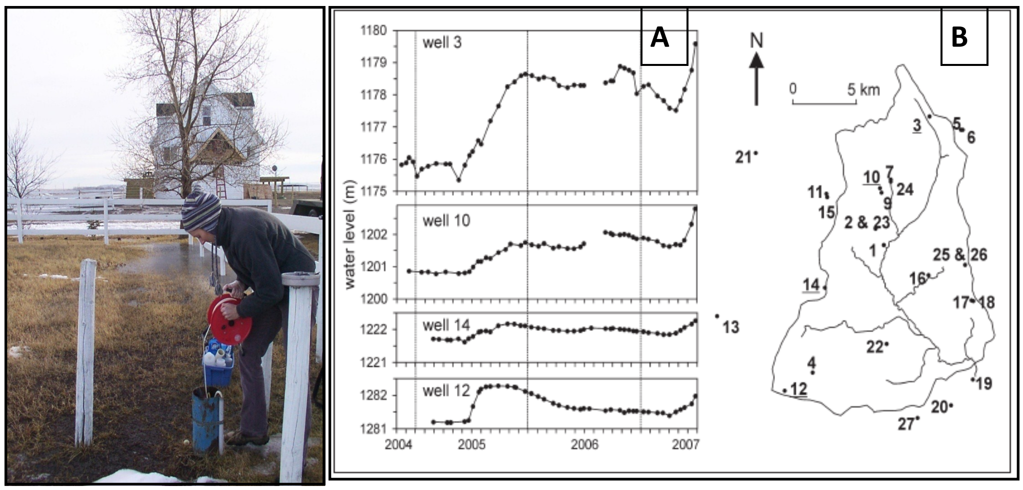

Figure 9. A) Water levels in four representative wells (2005-2007); ***B)*** Location of groundwater monitoring wells in WNC watershed (Adapted with permission from Grieef & Hayashi 2007).

The Rocky View County has implemented the pilot program in six other watersheds. Residents can upload and explore water level data through the ***Rocky View Well Watch*** website [http://rockyview.geocens.ca]. The program provides a cost-effective approach for groundwater monitoring and engagement of residents in sustainable groundwater management in this region.

Conclusions and Further Research

This research has shown that it is important to take a ***watershed approach*** in order to better understand, monitor, and manage groundwater. Groundwater, surface water, and ecological processes are interconnected through hydrological processes such as recharge, discharge, and exchange.

The research has also shown that it is possible to monitor groundwater levels through a low-cost community-based well monitoring network. The data helps establish seasonal and yearly fluctuations, as well as potential impact on water levels, stream baseflows, and ecological systems from increased number of wells or over-pumping in a region.

However, in order to be able to predict what sort of impact increased groundwater use will have, we need wide spread long-term monitoring. We also need to increase our understanding of groundwater flow within and between aquifers of this region, in addition to understanding localized groundwater-surface water interactions.

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For more information please contact:

Department of Geoscience
University of Calgary
ES118 - 2500 University Drive NW
Calgary, Alberta
T2N 1N4

Phone: 403-210-5401
E-mail: hydro@ucalgary.ca