Groundwater in British Columbia: Management for Fish and People

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In British Columbia, as in other jurisdictions, there is a growing awareness that groundwater depletion is a serious resource management issue. The first populations to suffer the results of declining aquifer levels and reduced streamflows are the resident organisms of aquatic ecosystems, as their needs compete directly with the water needs of new and existing housing developments and agricultural, recreational, and commercial operations. Negative impacts are already apparent in some streams, particularly in the most groundwater-dependent and arid areas of the province. Some valuable fish stocks may already be on the edge of extinction due to surface water and groundwater extraction (Rosenau and Angelo 2003; Douglas 2006). In some areas, long-term changes to aquifers are also putting the security of drinking water supplies at risk (Golder Associates Ltd. 2005); these worrisome trends are only predicted to worsen with climate change.

A 2006 report (Government of Canada *et al.* 2006) associates current climate change in British Columbia with wetter winters and drier summers, meaning longer summer drought periods that increase water demand just as water supply is at its minimum. In addition, decreased snow accumulation in the British Columbia (BC) Interior is predicted to reduce surface water availability for human use, potentially leading to an increase in demand for groundwater extraction. In some areas, wetter winters can mean increased snowpacks, resulting in intensified spring flooding. All of this will have negative consequences for fish, particularly the longer low-flow periods (Nelitz *et al.* 2007a, 2007b). Better stewardship of surface and groundwater is needed to ensure that affected water supplies are sustainable into the future for the benefit of both humans and ecosystems.

This article summarizes a recent project that synthesized information on the interaction between groundwater and fish (Douglas 2006). Groundwater policy and two examples of groundwater management are also examined. This article also builds on the overview of groundwater hydrology included in a previous issue of Streamline (Smerdon and Redding 2007).

Groundwater Policy in British Columbia

In North America, groundwater policy and management practices vary by jurisdiction. In many jurisdictions, groundwater is poorly managed because of outdated laws enacted when the science of hydrology was poorly understood. With the exception of industrial-scale projects requiring extraction rates greater than 75 L/s, BC landowners have the right to extract water from the ground regardless of the effect on surface water. Wells can be drilled on private land without any government permissions or permits. British Columbia remains the sole jurisdiction in Canada that has no general permitting requirements for groundwater extraction (Nowlan 2005).

While management of groundwater extraction is not currently regulated in British Columbia, some measures are now taking effect to manage the quality of groundwater. Approximately 25% of British Columbia's population relies on groundwater as a drinking water source (Smerdon and Redding 2007). After the Walkerton incident in Ontario—where groundwater was contaminated by E. coli bacteria, leading to several fatalities—the BC government began shifting its groundwater policy to better regulate water quality. The result is the Groundwater Protection Regulation (Province of BC 2004) under the *Water Act* (Province of BC 1996). The first phase of this regulation took effect in 2004 and was fully enacted in 2007; further phases are under development. This new law provides certain protections against the contamination of groundwater, but does not address groundwater extraction. However, under the changes to the *Water Act*, there is a mechanism for regulating groundwater extraction in local areas if it is specifically addressed in a Water Management Plan.

Approximately 25% of British Columbia's population relies on groundwater as a drinking water source

Water Management Plans are intended to address local issues and can cover both surface water and groundwater. The scope of each plan will be based on the local water management issues. Once the affected local government and the province agree on a final plan, it will be made into law with an implementation regulation. One plan currently in progress in the Township of Langley is discussed later in this article.

British Columbia lags behind other North American jurisdictions in its regulation of groundwater extraction. These regulatory aspects of groundwater policy are discussed in more detail by Nowlan (2005) and Christensen (2007). As described in Christensen (2007), provincial officials currently have no way of assessing the full extent of groundwater usage, let alone regulating groundwater use to mitigate environmental impacts. Fisheries concerns are effectively ignored under the current governance approach. The absence of appropriate legislation results in missed opportunities to address important concerns, such as (Christensen 2007):

- assessing the potential effect of groundwater usage on existing users, the environment, and the long-term sustainability of the aquifer;
- examining hydrologic connections between groundwater sources and threatened aquatic ecosystems;
- managing rates of aquifer depletion (or "mining");
- ensuring the prevention of salt-water intrusion in coastal areas;
- reviewing the location of groundwater extraction to manage quality and quantity concerns;
- metering and reporting of groundwater use;
- reviewing the purpose and efficiency of proposed groundwater uses;
- ensuring protection of aquatic ecosystems; and
- creating an administrative process for preventing or resolving conflicts between users.

British Columbia could embrace many regulatory options to improve management of groundwater, including:

- permitting for all extraction above a certain threshold;
- licences for wells above a certain capacity;
- specified pumping and water quality objectives that must be maintained;
- a setback distance from existing wells, and
- mandatory assessments to be prepared by groundwater users.

Other considerations could include conditions to protect the environment, and opportunities for public feedback (Christensen 2007).

Humans and Ecosystem Competition for Groundwater

A pumping well in direct hydraulic connection with a stream can draw down groundwater levels, creating flow toward the well and away from the stream. When pumping rates are sufficiently high, declining groundwater levels near the well will induce flow of the surface water into the aquifer. This leads to streamflow depletion as water demand increases (Sophocleous 2002). This phenomenon is particularly acute in dry areas such as Arizona, where groundwater pumping has dried up or degraded 90% of the state's once perennial desert streams, rivers, and riparian habitats (Glennon 2002). These issues are pertinent to British Columbia, as the current legislative framework for water management does little to consider environmental values, including fish habitat.

The United States has more advanced problems related to the prolonged overuse of groundwater, and these can be instructive to BC resource managers. In the Cosumnes River watershed in California, over-withdrawal of groundwater has converted the river to a predominantly "losing" stream (losing flows to the underlying aquifer), practically eliminating base flows (Fleckenstein *et al.* 2004). Declining fall flows, to the point of a dry riverbed for much of the migration period between October and December, limit the ability of the river to support the large fall runs of chinook salmon that were historically present (Glennon 2002). To restore the watershed's hydrology, a net recharge of 200–300 million m^3/yr would be required to reconnect the regional aquifer with the channel and re-establish perennial base flows (Fleckenstein *et al.* 2004).

Despite the evident crises in water management in North America, particularly in dry areas, useful information for managing groundwater/surface water interactions is often scarce and expensive to obtain, and fisheries and other resource managers rarely deal with groundwater at a watershed scale. There is very little scientific literature that directly addresses groundwater use relative to base flows and fish habitat needs (Douglas 2006). Little effort has gone into identifying the interconnections between surface and groundwater in Canadian jurisdictions (Brandes *et al.* 2005). This reflects a general lack of proper groundwater management for ecosystem needs, as well as the difficulty and expense of groundwater management on a useful scale for management decisions.

The Importance of Groundwater for Fish

One method of describing the importance of groundwater flows for fish is to ask, "Where does streamflow come from when there is no direct runoff in the form of rain or snowmelt?" These base flows are sustained largely by groundwater discharges (USGS 2007). A recent literature review (Douglas 2006) has highlighted the critical relationship between various salmonid species and groundwater (Table 1), and reiterated the importance of groundwater for maintaining aquatic habitat, due to the interconnection between groundwater and surface water. Water is constantly being exchanged between the surface and the shallow aquifers that underlie streams (Marti 2005). Deeper aquifers are also usually replenished by rainfall and streamflow, and provide sources of flow to rivers and lakes (Poole and Berman 2001).

Decreasing groundwater discharge to streams can decrease habitat area as well as create a physical barrier to fish passage—especially since periods of upstream migration generally coincide with annual low flow. Groundwater also provides thermal refugia in both summer and winter (Hayashi and Rosenberry 2002); decreases in groundwater availability can seriously affect the temperature regime. Groundwater temperature is generally close to the average annual temperature, and thus is cooler than surface water in summer and warmer than surface water in winter. A great deal of literature refers to the cooling/warming effects of groundwater that help fish reproduce and survive the seasons (Power *et al.* 1999). Fish prefer to spawn in groundwater upwelling areas because these remain ice-free over the

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winter, allowing for egg survival as well as increasing the rate of egg development (Power *et al.* 1999). Cooling groundwater inflows to streams are often responsible for fish survival in summer waters hot enough to kill, or warm enough to exhaust fish before they are ready to spawn (Berman and Quinn 1991; Baird and Krueger 2003). This issue is particularly important in the BC Interior, where some salmon runs are on the edge of survival due to extreme temperatures that are exacerbated by surface and groundwater extraction for human use (R. Bailey, Fisheries and Oceans Canada, pers. comm., 2006).

Changes to groundwater supply also affect water quality. Groundwater provides nutrients to the stream (Hayashi and Rosenberry 2002); with decreased groundwater inflow, the nutrient input will decrease. Additionally, there is a direct relationship between dissolved oxygen and water temperature. When decreased groundwater inputs cause stream temperature to increase, the levels of dissolved oxygen will drop while fish metabolic rates increase (Materna 2001). Salmonids need oxygen-rich water, and decreases in oxygen levels add to the physical stress already experienced due to increased temperature (Materna 2001; Richter and Kolmes 2005).

The situation in the Walla Walla River Basin in Washington and Oregon may be instructive regarding future water issues and solutions in British Columbia. A local watershed council (a stakeholder group supported by state legislation) has been working to restore water flows favourable for spawning and rearing, following endangered species listings for bull trout and summer steelhead. Groundwater and surface water extraction for irrigation have heavily affected this basin. There has been a large focus on surface flows in the Walla Walla Basin (particularly since the river has had a long history of drying up), but water budgets that include groundwater have recently been developed. A regional hydrologic simulation model was developed for part of the basin, which tested scenarios of groundwater pumping, infiltration basin operations (artificial recharge to replenish the aquifers), surface water extraction, and climate change inputs (Walla Walla Basin Watershed Council 2006). Since water is taken from two aquifers as well as from surface water, the model must be able to simulate the interaction between aquifers, an artificial recharge project area, and the effect on rivers and springs (Petrides 2006). Integrating groundwater in the understanding of watershed hydrology is needed in areas of British Columbia that are experiencing water management issues related to unsustainable water extraction.

Table 1. The importance of groundwater to fluvial fishes (after Power *et al.* 1999)

Groundwater role	Fall/Winter	Summer/Fall
Base flows	Maintains free-flowing water, channels, and habitat through winter low flows	Maintains base flows through dry periods
Stream temperature	Prevents/delays ice formation and influences thickness and break-up; provides areas with water temperature 0°C	Reduces daily stream temperature fluctuations, delays cooling in fall
Water quality	Supplies dissolved oxygen and nutrients to stream; buffers water quality changes through hyporheic exchange	Helps maintain stream productivity through nutrient inputs; stimulates macrophyte growth; and buffers water quality changes through hyporheic exchange
Habitat	Determines size/quality of winter refugia; affects winter mortality and carrying capacity	Provides protection from lethal temperatures

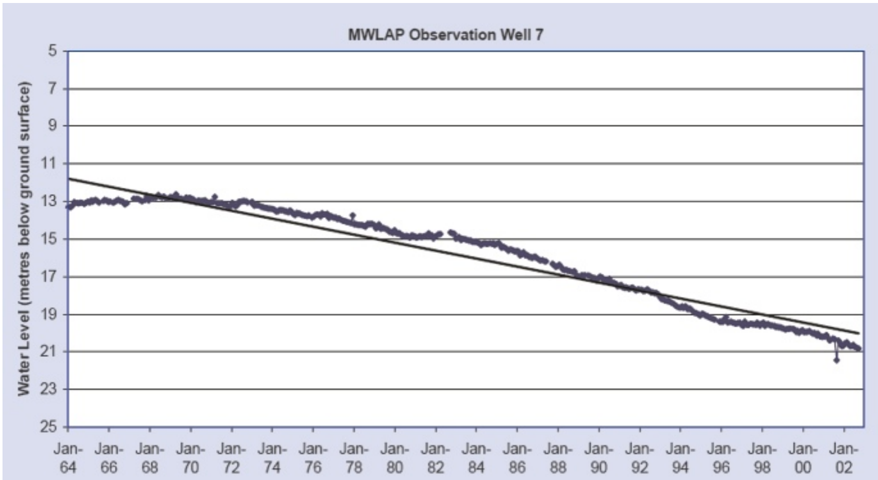
Groundwater Management in British Columbia: Case Studies

The following two case studies demonstrate different approaches to improve the integrated management of groundwater and surface water within the current policy framework in British Columbia.

Township of Langley Water Management Plan

In the Township of Langley, water management challenges include the stresses on water quantity and quality caused due to increasing population growth and development. The Township relies heavily on groundwater for its municipal supply, and recent studies indicate long-term declines in water levels in the most heavily used aquifers (Figure 1). The Township of Langley began work on a Water Management Plan in 2006, and the plan was due on December 31, 2007. Some new form of groundwater management and regulation was required to prevent water conflicts and risks, including risks to fish. In addition, some aquifers are susceptible to contamination, and the Township wishes to proactively maintain water quality.

While the primary focus of Langley's water planning was on water supply for human use (both domestic and industrial), fish were specifically mentioned in the terms of reference for the Water Management Plan (B.C. Ministry of Environment 2006). The Township contains a significant amount of fish habitat—an estimated 700 km of fish-bearing streams (B.C. Ministry of Environment 2006)—and some of this habitat is at risk from groundwater pumping. Fish species present include seven salmonids and two endangered species: the Nooksack dace and the Salish sucker (B.C. Ministry of Environment 2006). These endangered fish are particularly reliant on small groundwater-fed streams. Groundwater modelling (Golder Associates Ltd. 2005) suggests that compared with pre-development conditions, baseflows of streams overlying four of the heavily used aquifers have already decreased between 12 and 70%. While there is considerable uncertainty associated with model estimates, they are cause for concern. If



Golder Associates Ltd. 2005

Figure 1. Water level data over time from a B.C. Ministry of Environment observation well.

development continues according to plans, one creek may begin recharging the aquifer below rather than receiving base flows, which will have negative consequences for aquatic habitat. Increasing groundwater pumping to support ongoing development puts water resources at risk.

The Township aims to provide safe and sustainable groundwater for its community while also protecting fish habitat, and the water management plan will assist with achieving this goal. The public was invited to review and comment on draft versions of the plan; the draft plan has now been submitted to the B.C. Minister of Environment. It includes recommendations to require drilling authorizations for all new or altered water supply wells. The draft plan also recommends a riparian setback for new large wells next to a fish-bearing stream, and encourages the Province to improve water management by integrating groundwater and surface water allocation.

Nicola Water Use Management Plan

In the Nicola Valley (Figure 2), residents have taken a grassroots approach to protecting their water resources. Development pressures are driving their concerns about having adequate water to sustain existing and projected uses. Currently, water supply for fish is inadequate at certain times of year. This problem will only be exacerbated by climate change, the effects of which are already being seen in the valley in the form of increased average temperatures, droughts, and the mountain pine beetle infestation (Nelitz *et al.* 2007b).

Water temperature is a major fisheries issue in the Nicola watershed. Cooling groundwater flows may be the only

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Figure 2. The Nicola River below Nicola Lake.

reason fish can survive when ambient water temperatures exceed lethal limits—though continued groundwater extraction is calling into question the long-term survival of fish stocks (R. Bailey, Fisheries and Oceans Canada, pers. comm., 2006).

Surface water licences have been issued in the watershed since 1871, and extensive withdrawals—mainly for irrigation—have had major effects on fish habitat in this watershed (Rosenau and Angelo 2003). As surface water is now fully allocated, much of the ongoing water demand will likely have to be met by constructing wells that tap into the valley-bottom alluvial aquifers that supply the Nicola River and tributaries with base flows and thermal refugia for salmon.

A Water Use Management Planning (WUMP) process was developed in the Nicola Valley to address water conflicts and to help manage water sustainably. This process may be a model for other areas, as it has successfully engaged the various affected members of the community in consensus-based decision-making. Studies are still underway to understand the issues, and this process has been slowed by a lack of financial resources. An important data gap that is being addressed is an assessment of groundwater and surface water supplies and their interaction. The end result of this process will be a form of ongoing community management of water; methods for achieving this are also under study (Nicola WUMP 2007).

Co-ordinated community-based initiatives like this one are our best hope for managing water use and conflicts in arid areas like the Nicola Valley. With this type of planning, there is potential to improve conditions for fish, or to mitigate some impacts of increased development. Making a positive and lasting difference for fish will be chal-

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lenging given the various pressures affecting fish habitat, but the Nicola WUMP stakeholders are keen to succeed in addressing fisheries and other values. Community input is key in making difficult decisions and trade-offs to reflect the values of society as a whole.

Conclusions

Resource managers in British Columbia and elsewhere need policy and technical support to manage groundwater quantity and quality in a sustainable manner that meets the needs of humans and ecosystems. In many areas of the province, there is an opportunity to better manage groundwater before sensitive fish stocks are extirpated and before aquifers are depleted to the point that they can no longer sustain both humans and ecological processes. Groundwater legislation has been evolving in British Columbia, but government policy has not yet caught up to the need to manage and regulate groundwater extraction. This aspect of groundwater management will likely improve as awareness grows; it is hoped this will be soon enough to avert serious water conflicts and irreversible ecological damage.

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