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BACKGROUNDER

THE WATER SERIES

Protecting Groundwater:

The Invisible but Vital Resource

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In this issue...

Why a pan-Canadian strategy, guided by five major principles, is needed to deal with threats to the quality and quantity of groundwater in Canada.

The Author of This Issue

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The Study in Brief

Nearly 10 million Canadians, including about 80 percent of the rural population and many small- to medium-sized municipalities, rely on groundwater for their everyday needs. However, Canadians living in large cities and most government officials tend to ignore groundwater and its management. This asymmetry of interests has resulted in fragmented knowledge of groundwater locations, their quantity, quality and how groundwater supplies are changing over time in Canada.

Prudent governance of Canada's groundwater resources is required in the face of numerous challenges. Threats to groundwater include rapid urbanization, recharge rates of aquifers in a changing climate, agricultural intensification and increased contamination, among others. However, overall, Canada has yet to experience large-scale over-exploitation of groundwater resources and much of its groundwater remains of good quality. The time is right to establish the legal, regulatory and management systems, along with the necessary monitoring provisions, to overcome the threats to this valuable resource.

An effective groundwater management strategy would adhere to five major principles for sustainability. They are: protection from depletion; protection from contamination; ecosystem viability; allocation to maximize groundwater's contribution to social and economic well-being; and the application of good governance.

Empirically informed groundwater management supported by a well-designed system of incentives and adequate enforcement of regulations is increasingly imperative. Given the challenges that lie ahead, meaningful cooperation by three levels of government is required to manage Canada's groundwater sustainably.

A recent Ipsos-Reid poll showed that Canadians consider water to be the country's most important natural resource – more important than oil or natural gas. Yet, paradoxically, the "oil and gas reservoirs in this country are better understood than the groundwater reservoirs."[1]

As this paradox suggests, a sense of urgency has arisen over the need to understand and protect Canada's valuable groundwater resource. Maintaining the quality and quantity of groundwater in Canada faces present and emerging challenges. Threats to Canadian groundwater include rapid urbanization, the impact of climate change on the recharge of aquifers and water quality, burgeoning energy production, agricultural intensification and increased contamination. The growing practice of hydraulic fracturing (or "fracking") shale deposits to release natural gas, for instance, poses a potential threat to groundwater, especially where insufficient hydro-geological knowledge is available. Another example: some river waters in the southern Prairies are fully allocated in licenses to access the water and a shrinking spring snow pack and glaciers in the Rockies further lower groundwater contributions to surface water flows and levels.

Meanwhile, several areas across the country have experienced declining water tables or inadequate reserves to meet urban expansion. Among them: Ontario's York Region, home to rapidly growing cities such as Markham and Richmond Hill, and the Kitchener-Waterloo region; Alberta's Lacombe/Ponoka region near Red Deer; some Prairie sites in the South Saskatchewan River basin; and interior British Columbia locations such as Langley and in the Okanagan basin. Unless effective water conservation measures resolve these potential shortages, communities will require alternative supplies from distant sources.

That said, overall, Canada has yet to experience large-scale over-exploitation of groundwater resources and much of its groundwater remains of good quality. This means Canada has an opportunity to establish the legal, regulatory and management systems, along with the necessary science and monitoring to overcome threats to this valuable resource.

Background

Nearly 10 million Canadians, including about 80 percent of the rural population and many small- to medium-sized municipalities, rely on groundwater for their everyday needs. Furthermore, numerous agricultural and industrial operations count on groundwater for their production processes.

However, Canadians living in large cities and most government officials tend to ignore groundwater and its management. This asymmetry of interests has resulted in fragmented knowledge of groundwater locations, their quantity, quality and how groundwater supplies are changing over time in Canada. Further, the programs on groundwater do not match the more extensive, *but still inadequate*, measurements and studies of our surface and atmospheric waters.

An effective groundwater management strategy should adhere to the five major principles for sustainability first developed in 2009 by the Expert Panel on Groundwater of the Council of Canadian Academies (CCA). They are: protection from depletion; protection from contamination; ecosystem viability; allocation to maximize groundwater's contribution to social and economic

Much of the material in this *Backgrounder* is drawn from a report of the Council of Canadian Academies (CCA), entitled, *Sustainable Management of Groundwater in Canada* (2009). The author, J. P. Bruce, was chair of CCA's Expert Panel on Groundwater that produced the report. The major contributions of the other panel members are gratefully acknowledged. The complete list of panel members and the full report are available on the CCA web site, http://www.scienceadvice.ca/en/assessments/completed/groundwater.aspx and in hard copy from the Council of Canadian Academies, Ottawa. The contribution of Colin Busby, James Fleming and a number of other reviewers who provided valuable input and advice for this *Backgrounder* is also greatly appreciated, as is the word processing of several drafts by Ruth Bruce.

1 Karen Brown, ADM Environment Canada, cited in Nowlan (2005).

well-being; and the application of good governance. The effective pursuit of these principles requires a base of scientific knowledge and an understanding of effective governance.

The necessary scientific knowledge includes long-term data on climate and on the surface waters that control rates of aquifer recharge. Hydro-geological information on groundwater movement is also required, as is data on water temperature trends and aquifer chemical composition and pollutants. A related challenge is to design legal and governance mechanisms that ensure such knowledge is available, and to apply that knowledge to protect water quality and its equitable allocations for use.

This *Backgrounder* discusses one example, in the Oak Ridges Moraine region north of Toronto, to demonstrate how application of these principles results in sustainable groundwater management. Based in part on this positive experience, this paper presents a set of policies and actions that are needed for wise and sustained use of groundwater resource values for the future.

What is Groundwater?

Many people think of groundwater as an underground lake or river. In fact, it is more like water held in the pores of an underground sponge, called an aquifer. In Canada, great volumes of water are held in underground coarse-grained sediments and highly fractured rock. Indeed, there is more water underground in Canada than in all its lakes, rivers and ponds together.

Groundwater forms an important part of the hydrologic cycle. It interacts with lakes, ponds and wetlands and is the main source of flow in most rivers during dry periods. Since groundwater is replenished through rain or snowmelt seeping through overlying soil or fissures in rock, the calculation of recharge rates from climatic and soils data is vital in licensing sustainable groundwater withdrawals. Potential rates of sustainable extraction also depend upon groundwater flow, which in turn is affected by the permeability of the aquifer. Good estimates of groundwater flow require a prior understanding of how sub-surface sediments and rocks have been deposited.

One must also take into account that horizontal or vertical groundwater flow is much slower than in a river on the surface. Thus, once contaminated, an aquifer can take much longer than a river or lake to cleanse naturally.

Current Issues

As noted, sound groundwater governance requires adequate knowledge but authorities in many regions of Canada lack sufficient knowledge on groundwater resources and usage. For example, while groundwater sustains flows and influences water quality in many tributary rivers entering the Laurentian Great Lakes, the quantity of direct groundwater exchange to and from the lakes is not well known. Such exchanges, as well as inflow from surface water tributaries, affect both lake water quality and lake levels on both sides of the border. Among the potential threats from groundwater cited in a report to the International Joint Commission (IJC 2008) are the following:

- Bacteria from human and animal fecal waste are common in the basin's groundwater due to leakage from septic systems and sanitary sewers.
- 1990s surveys found that 14 percent of wells, on the Ontario side, exceeded guidelines for nitrogen compounds, which have potential infant health impacts and are nutrients that contribute to over-enrichment of the lakes.
- Including locations on both sides of the border, there may be more than one million underground storage tanks in the basin, of which 5 to 35 percent are suspected of leaking, and many contain toxic substances.

In short, there are potential threats to achievement of the clean water objectives established by the long-standing Canada/USA Great Lakes Water Quality Agreement, but the knowledge of net groundwater movement to the lakes is inadequate to assess the severity of these threats. The IJC has advised governments of the large gaps in knowledge

on both sides of the border, but survey and scientific efforts to date are entirely inadequate, particularly on the Canadian side.

A second example where inadequate groundwater knowledge and regulation may have adverse effects is in the Alberta Oil Sands projects area, with respect to both surface mining and deep well injection methods. In 2007, the Alberta Research Council identified a number of groundwater related issues that should be addressed in this region, including the interaction between Athabasca River flow and groundwater, and the effects of increased surface mining activity and associated changes in land cover on groundwater quality and quantity (ARC 2007). Other serious issues were raised about possible leakage from waste water tailing ponds and transboundary effects in Northwest Territories and Saskatchewan.

A third example of current groundwater issues occurs in fertilized agricultural areas where nitrogen concentrations in groundwater, in a few locations, approach or exceed levels recognized as harmful to infants. Among these locations are parts of Prince Edward Island, where stricter manure and fertilizer controls have now been put in place (Government of P.E.I. 2008), areas in southern Ontario and the Prairies, and the Abbotsford aquifer in British Columbia, where contamination from agriculture appears to be affecting parts of the transboundary aquifer shared with the state of Washington. Agriculture Canada is supporting studies in nine different watersheds across Canada to determine best practices to reduce this problem.

Finally, municipalities often have difficulty determining the land areas that should be protected to ensure recharge of good quality water to local aquifers. For example, one municipal leader reported that in an effort to preserve aquifer recharge areas, multiple consultants were engaged to advise on the area and location of lands to be protected to preserve aquifer recharge areas. The outcome: three different modelling results from the three consultants that gave widely different-sized areas and locations, and posed a serious dilemma for the municipal council (CCA 2009).

Sustainable Groundwater Management

Given the knowledge needs and governance experience in Canada, what guidelines should be followed to better protect and manage this hidden water resource? The following five CCA panel principles, in detail, should be used as a starting point to determine whether groundwater management practices are sustainable (CCA 2009):

- **Protection of groundwater supplies from depletion:** Withdrawals must be maintained at a level that does not create significant long-term declines in regional water levels.
- **Protection of groundwater quality from contamination:** Groundwater quality must not be compromised by degradation of its chemical or biological character.
- **Protection of ecosystem viability:** Groundwater withdrawals must not significantly impinge on the contribution of groundwater to surface water supplies and the support of ecosystems. However, human uses will inevitably have some impact on pristine ecosystems.
- **Achievement of economic and social well-being:** Groundwater allocations must be designed to maximize their potential contribution to social well-being as measured in both economic and non-economic values.
- **Application of good governance:** Decisions as to groundwater use must be made transparently through informed public participation with full account taken of ecosystem needs and intergenerational equity.

Regulatory actions, effectively enforced, are an important prerequisite for moving toward these sustainability principles. One province, British Columbia, currently does not even require licensing of groundwater withdrawals. In testing a number of regional case studies against these criteria, sustainable groundwater management in Canada unfortunately appears to be the exception, not the rule (CCA 2009).

Recommendations for Better Groundwater Management

Solutions to groundwater problems are heavily dependent on thorough scientific studies based on intensive measurement programs and a political willingness to act on the evidence. In the Oak Ridges Moraine case, large-scale suburban development threatened this vulnerable environment, including its groundwater. As a result, the province imposed land-use zoning to protect recharge and prevent contamination from urban development. This action was vital to protect the ecosystems in streams and lakes fed by groundwater from the moraine (see Box 1).

Applying the aforementioned five principles throughout the rest of the country would help focus Canadian efforts on: **1**) data collection, coordination, inventories and availability; **2**) computer modelling (see next section); **3**) interjurisdictional and inter-agency cooperation; **4**) protection of drinking water quality; and **5**) pricing or other mechanisms to provide incentives for efficiency in use. A legal and governance framework to enable or require these measures is essential.

Data Collection, Coordination, Inventory and Availability

For surface waters, Environment Canada maintains the Water Survey of Canada (WSC), which, through federal-provincial cost-shared agreements, provides for water-quantity measurement networks and a national accessible water resource database, but with a dwindling number of monitoring stations in recent decades. This fundamental need, a readily available database for groundwater, is lacking. It is a truism to say that "if you do not measure it, you cannot manage it."

While the Geological Survey of Canada (GSC) of Natural Resources Canada has developed an embryonic national groundwater database – the Groundwater Information Network (GIN) – some provinces do not yet contribute to the GIN, and measurement programs to provide data on groundwater quality and quantity and on actual uses are spotty, at best. Greater input from provinces and enhancement of the GIN is a natural first step to improved groundwater management.

The GSC has a small unit that is systematically, but slowly, documenting the extent and nature of major aquifers in Canada. Some provinces already have comprehensive inventories of their aquifers. Drillers' well-water records are mostly retained and made available by all provinces. However, much of the valuable hydro-geological data from boreholes, obtained by private consultants often working at the community level, are not archived and are subsequently lost for later use. Analysis of streamflow measurements during low-flow periods, when most flow comes from groundwater discharge, can provide valuable information on the state of groundwater quality and fluctuations in quantity.

As well, climatic data, essential to determining recharge rates and safe yields, are scarce for many groundwater recharge areas. If wise stewardship of this vital resource is to be achieved, all levels of government must contribute more extensively to measurement and assessment of our water resources, from precipitation to groundwater. Coordination of measurement methods and more extensive sharing of information on data holdings would increase the value of measurement investments.

Numerical Modelling

Computer modelling of groundwater recharges and flows can be used to assess and measure urbanization effects and cumulative impacts and thus provide for sustainable pumping rates. Models of water movement and chemistry are also useful in determining how best to minimize potential groundwater contamination by the transport of pollutants from abandoned contaminated sites. According to the federal government, there are some 6,000 of these contaminated sites, such as old service stations, factories, etc., (Government of Canada 2005). Publicly available reports on these sites and their potential groundwater effects could minimize

Box 1
Oak Ridges Moraine: Cooperative Regional Management of Groundwater (CCA 2009)

The moraine, from north of Trenton on the east to the Niagara Escarpment on the west, has long been a focus of attention by municipalities, river basin conservation authorities, the Ontario government and Natural Resources Canada. It is an area where hydrologic processes are extremely important. Four rapidly growing municipalities, 65,000 private wells, industrial uses and 38 golf courses depend directly on this groundwater. Groundwater flow systems tend to be shallow and linked to surface-water streams flowing south to Lake Ontario and northward into Lake Simcoe and the Kawartha Lakes. Extensive study and measurements by three levels of government led to a comprehensive database and to a numerical model of quantities and flows to inform management decisions. This knowledge, development pressures in the region and public concern led to *Ontario's Oak Ridges Moraine Conservation Act*, 2001. For the first time in Ontario, this Act put in place land-use restrictions in areas needed to protect groundwater. This example of sustainable groundwater management illustrates the fundamental importance of scientific measurement and understanding, the need for three-level intergovernmental cooperation and a willingness to act on the part of local and provincial governments.

hazards. Models could determine the necessary recharge protection zones.

Obtaining better information and models to protect our groundwater is within our grasp. Indeed, some of the world's best groundwater modellers do their research in Canada's academic institutions. Their techniques need to be more extensively used in devising government regulations and industrial operations. As well, training programs for government officials and private consultants on state-of-the-art modelling methods need to be strengthened.

Interjurisdictional and Inter-agency Issues

Another cause of inadequate groundwater management lies in the division of relevant powers and responsibilities among the three levels of government. Local governments are responsible for most aspects of land use, water supply and sewage treatment, but usually have the least scientific and financial resources to draw upon. Meanwhile, provinces own the resource and provide the framework policies for water allocation, sewage management and regional development. These policies guide, but can also constrain local governments.

The federal government is responsible for trans-border aquifers and surface waters shared with the United States. Ottawa also has oversight over interprovincial water disputes along with waters in federal lands and aboriginal communities. It is also responsible for protection of the inland fishery. As well, hydrogeological and other water research is funded or undertaken mainly by the federal government.

This type of overlapping interjurisdictional problem has been successfully addressed by the European Union under its Water Framework Directive (2000), including its Groundwater Directive of 2006 (Lagacé 2010). Canada could profit by following the European Union example.

Groundwater is managed sustainably when considered in the context of the whole water cycle, beginning with precipitation and moving through surface water, groundwater, transpiration by plants and finally to evaporation, usually on a river-basin

geographical scale. However, the Canadian division of jurisdictions and the tendency of most governments to pigeonhole into three different agencies the responsibility for surface waters, groundwater and climate defies a more beneficial holistic approach. Fortunately, some mechanisms have been found to cut across the bureaucratic divisions.

Arguably, the most successful cross-cutting arrangement in Canada for groundwater management systems is the river-basin conservation authority approach in Ontario. These community-based organizations, with some provincial support, are able to integrate diverse agencies and governments to address protection and sustainable management of both groundwater and surface waters. The Oak Ridges Moraine success story could not have been achieved without its watershed Conservation Authorities. It is even possible for adjoining river-basin authorities to work together in cases where the groundwater shed does not coincide with the surface watershed or catchment area. Other provinces have begun moving toward a river-basin approach, but in most cases these need stronger support, as indeed they do in the much of Ontario.

From a resource management perspective, cooperation among local governments, provinces and federal agencies needs to be improved. There are, however, a few notable examples of cooperation, such as the federal-provincial Prairie Provinces Water Board for the eastward flowing Saskatchewan River system and related groundwater. Also the Canadian Council of Ministers of the Environment (CCME) has recently shown renewed interest in cooperating on groundwater matters in their Water Framework, with five main goals, released in 2010. This is a promising initiative, but follow-up actions are urgently needed.

Drinking Water Quality

Drinking water quality is generally managed provincially or locally. The Canadian Medical Association reported 1,775 boil water advisories in 2008 including 114 in First Nations communities. Further improvements are obviously needed. Since the Walkerton, Ont. tragedy of 2000, it has been generally recognized that a multi-barrier approach is needed to ensure high-quality water from the tap. This includes protection of source water quality in aquifers or surface waters, effective water treatment plants and a non-contaminated distribution system.

However, such an approach is not consistently applied in Canada. For example, only Ontario has introduced source water protection legislation, although some other provinces are moving in this direction. Enforcement of regulations at each barrier is a task of significant magnitude, made especially difficult because of lack of full cost-recovery for water supply. Independent assessments conclude that Canada's drinking water guidelines and their application are not as stringent as in the European Union, and that in the latter case, cooperation has led to strong actions and enforcement (Lagacé 2010).

Pricing

Many of the problems noted above are due, in part, to the low water prices throughout Canada, often not covering costs of management, delivery, treatment and development. Other problems stem from the lack of effective water quality and quantity regulations and their enforcement.

Compared to other OECD countries, Canada has the lowest average price per litre for municipal waters and the highest consumption per capita (CCA 2009, Fig. 5.1). The European Union's Water Framework Directive on "full-cost pricing" even includes the environmental costs of withdrawals. Some member countries also charge a groundwater extraction royalty or tax as they would on other natural resources.

There is some evidence that these charges, in addition to raising revenue for monitoring and environmental measures, provide incentives for innovation and reduced water demand, especially by industrial users. All Canadian government levels must move to a water pricing system that

includes full costs of delivery and waste water treatment, but also covers the costs of larger, well-trained staffs, adequate to effectively allocate, manage and protect the resource and its safe and efficient delivery. A full-cost pricing regime would also promote water conservation, important to ensure groundwater sustainability as populations grow (Renzetti and Kushner 2004). Of course, water must always be managed and priced in a way that the poorest of Canadians still receive clean water.

Conclusion

Empirically informed groundwater management supported by a well-designed system of incentives and adequate enforcement of regulations is increasingly imperative. Allocation of well-trained staff and funding for groundwater monitoring, research and management has not kept pace with Canadian demand. Nor have the relevant legal and governance structures for water kept pace in many parts of Canada.

Challenges in coming decades, such as growing urban and industrial water-use demands, along with climate change, will escalate the requirements for managing groundwater sustainably. If these are not met, there may be serious consequences for water users, public health and ecosystems.

The well-being and health of current and future generations, as well as continuing economic benefits from many agricultural and industrial enterprises, rely on the continued availability of good quality groundwater. A pan-Canadian water strategy needs to follow the steps identified above. Also required is meaningful cooperation by three government levels to manage Canada's groundwater sustainably. The increasing public concerns over Canada's water should help to drive this critical agenda.

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