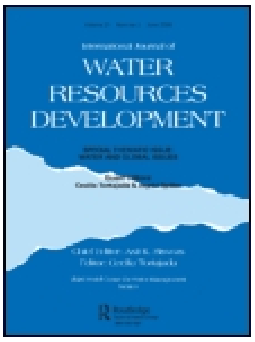

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Changing Roles in Canadian Water Management: A Case Study of Agriculture and Water in Canada's South Saskatchewan River Basin

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ABSTRACT *This paper explores changing roles in Canadian water management, by focusing on a case study of agriculture and water in Western Canada. Challenges in water management include unequal adaptive capacity, gaps in water and climate data, locally relevant options, short- and long-term planning, among others. This empirical study offers insight for improved water management decision-making for all regions. There is a need for improving and integrating water management with climate scenarios, collecting more and better water/climate data, improving water governance and long-term planning, and developing strong communication channels between governance organizations and local communities. Positive trends towards effective and adaptive water management include the incorporation of watershed groups, basin planning, and the use of multidisciplinary approaches to guide decision-making.*

Introduction

Canada is perceived by many to be water-rich, yet renewable fresh water supply is a limiting factor. The southern, most-populated region of the country has about "2.6 percent of the world water supply"(Sprague, 2007, p. 25). Semi-arid areas experience water shortages, and increasing demands for water have led to moratoriums in water allocations. The competition for water, coupled with stressors from climate variability and risks of a changing climate, have placed governance organizations under pressure for improvements to water management.

The 1987 Federal Water Policy states, "Put simply, Canada is not a water-rich country" (Environment Canada, 1987, p. i.). It is recognized as visionary; most of the water management issues it identified remain valid today, including the need for integrated water resource management, citizen engagement and consideration of climate change impacts on water supplies. A growing body of current literature expresses similar concerns to the

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1987 policy. Much of the literature calls for improved water governance arrangements to clarify roles for all orders of government and to reduce fragmentation, with some calling for an updated nationally developed water strategy (e.g. Banks & Cochrane, 2005; Bakker, 2007; Conference Board of Canada, 2007; Morris *et al.*, 2007; de Loë, 2008; Bakker & Cook, 2011).

How relevant are these water management changes and challenges in a local context? How relevant are they in the context of global environmental change? This paper answers these questions by focusing on a case study in the South Saskatchewan River Basin (SSRB) in Western Canada. Research was undertaken to assess community vulnerabilities to climate-induced water stress, and the capacity of governance agencies to help reduce these vulnerabilities. Water management challenges were identified, with recommendations to strengthen capacity and rural resilience. An overview of the institutional patterns of Canadian water governance is presented, followed by a brief discussion of the water challenges facing the agricultural sector, the largest consumer of water in this basin. As an empirical example, the SSRB highlights water management and data challenges in Canada.

Evolving Water Management: Successes and Challenges

Canada was founded as a nation in 1867. Water management was instrumental in nation-building, with water resources generally viewed from the perspective of "supply" and economic development for a variety of needs: shipping and transportation canals; a source for energy (steam power, hydro-electricity, thermal power); industrial and manufacturing needs; wastewater processing; irrigated agriculture; and recreation. By the 1980s, Canadians became increasingly aware of natural resource limitations and of risks associated with environmental damage. Canada placed more emphasis on environmental protection measures and sustainable water management principles.

After several serious waterborne disease outbreaks from 2000 to 2005, Canada increased its efforts to incorporate source water protection plans and management of water by "watersheds" with participatory planning to respect all stakeholders and the environment, while recognizing water has economic value (Hurlbert *et al.*, 2009a; Government of Alberta, 2006; Développement durable, Environnement et Parcs Québec, 2002).

In spite of these positive trends towards sustainability and the desire to incorporate economic, social and environmental matters in decision-making, water governance in Canada still faces significant challenges. Water management is the primary responsibility of provincial governments, but, in reality, involves the shared jurisdictions of all orders of government (local, provincial, federal, First Nations) and a variety of non-government organizations. Table 1 lists a simplified summary of key water governance agencies within the SSRB, and is quite typical of the vast array of institutions involved in Canadian water governance.

The effectiveness of water governance is undoubtedly challenged by the sheer number of stakeholders and institutional arrangements. The jurisdictional separation of powers between provinces and the federal government is viewed by some to be fragmented (Bakker & Cook, 2011; de Loë & Kreutzwiser, 2007; Saunders & Wenig, 2007; Johns & Rasmussen, 2008). The literature notes significant challenges with interagency coordination, duplication of effort and limited long-term planning. Another fundamental issue noted is the process of data gathering, data management and data dissemination.

Table 1. Key water governance agencies in the South Saskatchewan River Basin, 2009 (updated; see Hurlbert *et al.*, 2009, and Corkal *et al.*, 2007, for a greater description of agency roles and responsibilities).

Orders of government	Key ministries/ water managers	Other principal ministries/institutions with major water responsibilities					
Alberta	Alberta Environment (AB Env)	Health	Agriculture	–	Transportation & Utilities	Alberta Research Council	Other ministries; watershed groups
Saskatchewan	Saskatchewan Watershed Authority (SWA)	Health	Agriculture	Environment	Sask Water	Saskatchewan Research Council	Other ministries; watershed Groups
Local municipalities	Utilities	Utilities: water and wastewater treatment; environmental protection from development and land use; local and regional public health protection					
Canada	Environment	Health	Agriculture	Natural Resources Canada	Fisheries & Oceans	National Water Research Institute	Other ministries; First Nations
	Alberta Env; SWA	**Provincial water management authority:** water allocations, licensing, water use and apportionment, hydrology, planning, source water protection					
Simplified summary of key water responsibilities	*Environment:* environmental protection & research; weather & climate change science; *Health:* public health protection (drinking water, wastewater); Regional Health District support; *Agriculture:* Agricultural programs & research; promotion of adoption of Agricultural Best Management Practices to protect the environment from potential agricultural contamination; *Provincial Utilities:* municipal water supply, distribution, hydroelectricity, energy; *Academic research/institutes:* water, environmental monitoring, contamination & protection, land use; *Natural Resources:* groundwater mapping, forestry, energy, minerals, climate change adaptation; *Watershed groups/river basin councils:* watershed planning and source water protection; *First Nations:* water management on FN lands; interactions with other orders of government						
	Selected key agencies with inter-jurisdictional water responsibilities in the SSRB						
Inter-governmental	International Joint Commission	The IJC represents the Governments of Canada and the United States. The IJC addresses water use and quality of boundary waters affecting both nations. With respect to the SSRB, the Boundary Water Treaty includes clauses for water flow in the St. Mary and Milk Rivers, and the inter-basin transfer of water from the St. Mary to the Milk. This agreement affects Montana (USA) and Alberta, Saskatchewan, and Manitoba (Canada).					
	Prairie Provinces Water Board	Federal-Provincial Board (Environment Canada, Agriculture and Agri-Food Canada-PFRA/AESB, Alberta Environment, Saskatchewan Watershed Authority, Manitoba Water Stewardship). The PPWB administers, monitors, and reports on inter-provincial water flows and allocations, and water quality, on rivers crossing the Prairie Provinces of Alberta, Saskatchewan, and Manitoba.					
Unique federal pan-prairie agency	Prairie Farm Rehabilitation Administration; Agri-Environment Services Branch	The Federal government created PFRA, a branch of Agriculture and Agri-Food Canada, in 1935 as an emergency response to address soil & water issues from catastrophic multi-year prairie droughts. The agency's mandate included applied research leading to agricultural adaptations for better soil and water conservation practices, improved rural agricultural water supply management (water supply, water quality, irrigation, climate/drought adaptations). In 2009, PFRA evolved into the Agri-Environment Services Branch with a national mandate to advance agri-environmental sustainability and innovation.					

With the many different local, provincial and federal agencies involved, water data-sets are not standardized, and while there is a general interest in transparency and public accountability for water data, it is neither a small nor a simple task to develop data-sets that are interchangeable and shareable by all concerned agencies.

Canada's Water Resources and Agriculture

Agriculture and the agri-food industry in Canada account for 8.3% of Canada's gross domestic product. Agriculture is practiced on approximately 7% (67.5 million ha) of Canada's land base, with 82% of this occurring on the Canadian Prairie Provinces (Environment Canada, 2004). Agriculture relies on having sufficient good-quality water to produce safe food. Conversely, surface and groundwater supplies are at risk of contamination from agricultural practices and may be depleted if agricultural demands are excessive. The Canadian agricultural sector is the largest sector for water consumption, utilizing about 4.5 billion m^3 of water annually. About 85% of agricultural water withdrawals are used for irrigation, predominantly in Western Canada, and about 15% of agricultural water withdrawals are utilized for livestock production (Environment Canada, 2004).

Water management in rural Canada is also challenged by population distribution, unique geographic and regional characteristics, and varying water quality. Many rural areas are sparsely populated. The agricultural sector and over 4 million rural Canadians (about 13% of Canada's population) do not have access to the same types of regional water infrastructure as urban Canadians do. Most agricultural producers and rural citizens rely on private self-managed water supplies. Securing access to sufficient quantity and good-quality water is challenging and costly. About 20% to 40% of rural wells in Canada do not meet safe drinking water quality guidelines; rural water quality can be problematic for agricultural needs and rural people, and can pose issues for public health (Corkal *et al.*, 2004; Charrois, 2010). Agricultural and private water supplies are tested infrequently, if at all, and while owners are responsible for their own water, there are calls for local, provincial and federal governments to provide better water information and resources targeted to rural citizens (e.g. enhanced education and awareness programs, better standards, and evidence-based educational, research and training programs for rural water users). There is limited water-quality data for rural private water supplies, which could compromise their effective management.

The agricultural sector and agricultural agencies have recognized their critical roles in water management, for both the sector's and rural needs, and also for reducing agricultural contamination risks. Measures to conserve water and use improved water quality in agricultural production are being investigated and adopted. Environmental farm planning and agricultural beneficial (or best) management practices (BMPs) to protect water supplies are increasingly being adopted as the sector practices environmental stewardship (Corkal *et al.*, 2004; Corkal & Adkins, 2008).

As noted, consumptive water use is an issue for irrigated agriculture. Water supply is the key issue for dryland (rainfed) agriculture, which is reliant solely on timely rains and soil moisture for successful crop production (see Figures 1 and 2). In semi-arid western Canada, dryland crops are largely restricted to grains, oilseeds and grasses, due to limited growing days and precipitation. Annual precipitation in the southern areas of Saskatchewan and Alberta is about 300 to 400 mm (Environment Canada, 2004), which is a limitation for crops requiring higher water demands. Dryland producers are very

Figure 1. Canada's agricultural land.

vulnerable to climate conditions and environmental influences, a situation that will worsen if variability increases in the future. Drought is, of course, one of the most serious hazards for dryland agriculture. The Canadian Disaster Database identifies "prairie drought" as the number-one most costly disaster in Canada, recurring 4 times in the top 5 national disasters and 11 times in the top 20 national disasters during the period from 1900 to 2010 (Public Safety Canada, 2010). The 2001 and 2002 drought years affected large areas across Canada, but were most severe in Alberta and Saskatchewan. This drought was estimated to have caused a $3.6 billion drop in Canadian agricultural production, a $5.8 billion drop in Canada's gross domestic product, and 41,000 job losses (Conrad, 2009; Wheaton *et al.*, 2005; Wheaton *et al.*, 2010). Water issues for agriculture clearly have economic, social and environmental impacts that can affect the sustainability of the sector and communities.

For Canada, global warming may actually present opportunities for agricultural operations that require warmer temperatures (e.g. increased cropping diversity and higher-value crops may be possible). However, to take full advantage of any new opportunities from a warmer climate, different cropping practices, new water management strategies and infrastructure, and better knowledge of climate variability will be required. Global warming and climate change are also expected to generate risks for the agricultural sector, mainly an increase in variability (e.g. droughts, floods, storms and extreme weather events), which

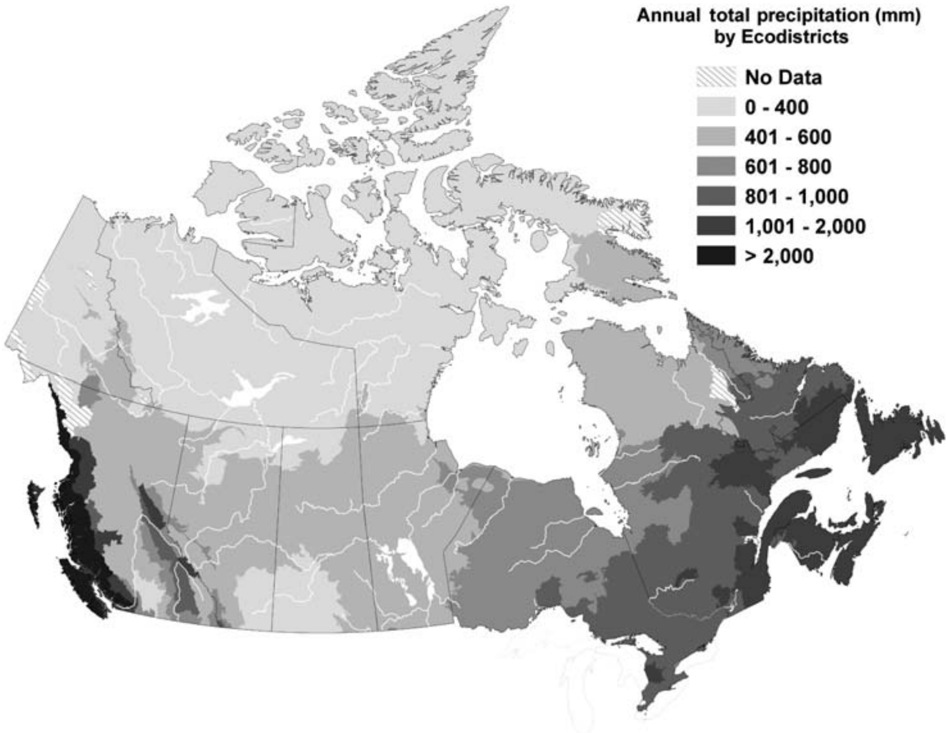

Figure 2. Canada's annual precipitation by ecodistrict.

could have significant economic impacts (Wall *et al.*, 2007; Lemmen *et al.*, 2008). For some areas of the prairies, scientists estimate that future increases in temperatures and precipitation will result in less available plant moisture in summers, due to increasing evaporation and reduced summer precipitation, and larger and more intense droughts (Sauchyn, 2007; Wheaton & Kulshreshtha, 2010). Such changes would cause social and economic impacts to communities, industry and infrastructure, and increase the need for more water and climate data, new options for water management, and agricultural preparedness plans.

A Case Study: The South Saskatchewan River Basin

Rural communities face a variety of stressors and impacts, which are mediated by local capacity to mobilize and organize responses, including institutional support. Organizational capacities and instruments of Canadian water governance have implications for local communities. This final section reviews these capacities and explores some implications for rural communities within the SSRB.

This review is based on the Institutional Adaptations to Climate Change (IACC) study in the South Saskatchewan River Basin (Diaz *et al.*, 2009a; Diaz *et al.*, 2009b). During the years 2004 to 2009, research was conducted on the vulnerabilities of rural communities to climate and climate-induced water stress. Data was obtained by conducting semi-structured interviews and focus group discussions, involving all water users and institutions involved in water management, including all orders of government. The vulnerability assessment model considered past and present vulnerabilities, and used climate modeling to develop insights into future vulnerabilities. The IACC research assessed local adaptive capacity and the ability of regional water governance to help reduce vulnerabilities. Six rural communities were studied in Alberta and Saskatchewan. A full spectrum of water governance institutions were interviewed: water users, groups and associations, watershed and basin councils, First Nations, environmental groups, community representatives, and experts from local, provincial, and federal government agencies.

The South Saskatchewan River Basin

The SSRB spans the provinces of Alberta and Saskatchewan, covering 168,000 km^2, with a highly variable geography and climate, and a population of approximately 2.2 million people (Bruneau *et al.*, 2009). About 65% of the population is concentrated in major urban centres, the largest of which are Calgary and Saskatoon. Its major rivers are mountain-fed, and the region is characterized principally as semi-arid, with the majority of the region receiving less than 345 mm of annual precipitation (Toth *et al.*, 2009). Figure 3 shows the geographical distribution of the basin, its larger rivers, and the precipitation distribution. Agriculture is one of the most significant economic activities in the region. Agriculture is characterized by extensive farming, principally dryland field crops producing grains and oilseeds, with rangeland supporting livestock production, as shown in Table 2 (Bruneau *et al.*, 2009; Diaz & Gauthier, 2007; Hurlbert *et al.*, 2009a).

The SSRB is located within a region that was severely affected by the multi-year droughts of the 1920s and 1930s, which caused serious social, economic and environmental impact, and resulted in the abandonment of many settled farming areas (Gray, 1996; Marchildon

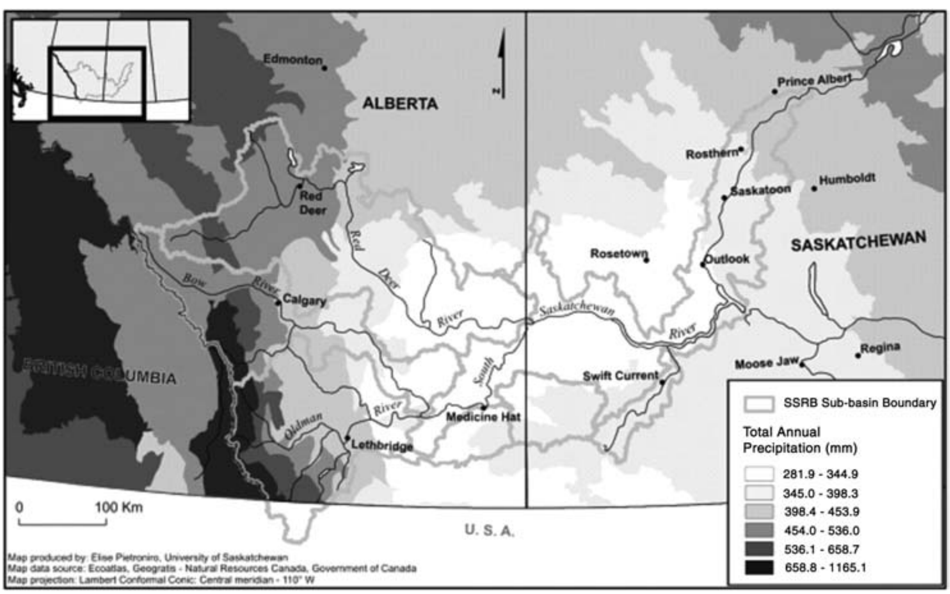

Figure 3. South Saskatchewan River Basin and annual precipitation.

Table 2. Farm types, land use, and livestock production in the SSRB, 2001.

	SSRB - Alberta	SSRB - SK	SSRB total
Number of farms[1]	**19,600**	**9,000**	**28,600**
Primarily livestock	53%	24%	44%
Primarily grains	47%	76%	56%
Livestock (million head)			
Cattle (includes dairy cows)	2.83	0.45	3.28
Density (head per ha)[2]	0.596	0.297	0.524
Hogs	6.06	1.12	7.18
Density (head per ha)	1.277	0.737	1.146
Poultry	1.27	0.23	1.50
Density (head per ha)	0.268	0.152	0.240
Land use on farms (million ha)	**9.89**	**5.34**	**15.23**
Cropping[3]	42%	53%	46%
Pasture	48%	28%	41%
Fallow and other use	10%	19%	13%

[1] Number of farms includes all operations with annual receipts greater than $2,499.
[2] Density based on hectares of land allocated to pasture.
[3] As a percentage of land allocated to farms. (Total SSRB area is 16.78 million ha.)
Source: Statistics Canada Census of Agriculture, 2002.

et al., 2008, 2009). Today the region supports a vibrant and diverse economy, and accounts for the vast majority of Canadian grains, oilseeds and livestock production. This was achieved by successful agricultural adaptations to the highly variable climate within the region: improved soil conservation and tillage practices, enhanced agricultural water development projects, and use of irrigation to augment water supplies during periods of water shortages (Bruneau *et al.*, 2009).

Today, irrigation in the SSRB (Figure 4) is practiced on about 5% of the land base, yet accounts for roughly 18% of the agricultural gross domestic product within the basin (Bruneau *et al.*, 2009). Table 3 shows that irrigation is, by far, the largest "consumer" of water, accounting for over 90% of all consumptive water uses, and withdrawing about 22% of the natural river flow (Bruneau *et al.*, 2009). Water supplies are fully allocated in the Alberta portion of the basin, but water remains available for further allocations in the Saskatchewan portion. Irrigators and agricultural producers are presently advocating for additional irrigation expansion in Saskatchewan, which has potential to expand its irrigated land from 81,000 ha to 400,000 ha (Brace Centre for Water Resources, 2005). However, environmental groups express concern about construction of new dams, reservoirs and increased water pressures, and advocate water conservation before further development (Saskatchewan Environmental Society, 2008). Such divergent viewpoints clearly demonstrate the contrasting interests of different stakeholders, and pose a challenge to water management decision-making.

Water Governance in the Basin

Water governance in the SSRB is depicted in Table 1, and includes many institutions from all orders of government, non-government organizations, and local community groups representing different civil society interests. The main water management agencies at the provincial levels are Alberta Environment (AE) and the Saskatchewan Watershed

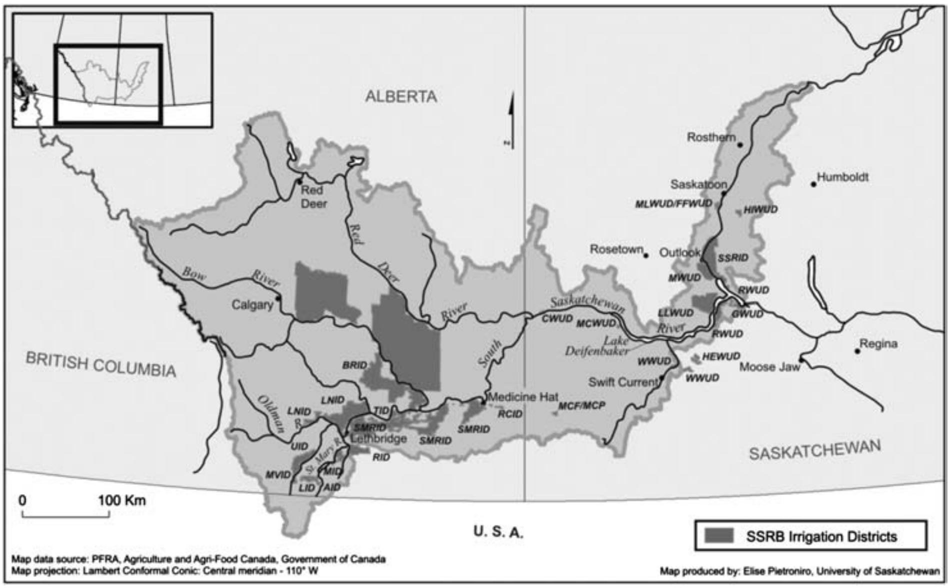

Figure 4. SSRB irrigation districts. *Source*: Bruneau *et al.*, 2009.

Authority (SWA). In Alberta, the Ministry of the Environment has key responsibility for collection of environmental water quality and flow data, environmental protection enforcement, and water research studies, as well as for water allocation. In Saskatchewan, SWA has the key water management role, but shares some responsibilities with the provincial Ministry of the Environment and SaskWater, an agency responsible for water infrastructure. Water treatment for municipal drinking water is the responsibility of local municipalities; however, drinking water quality is monitored by provincial health agencies (usually in comparison to federal guidelines). The provincial health agencies enforce corrective actions to protect citizens from risk of waterborne disease outbreak.

Federal agencies play key roles in regional water management. Environment Canada is instrumental in water research (quantity, quality, environmental research) and some environmental regulation. Natural Resources Canada collects water data and maps groundwater aquifers. The Department of Fisheries and Oceans is concerned with healthy aquatic ecosystems and fish habitat, while Indian and Northern Affairs Canada is responsible for constructing water and wastewater infrastructure at First Nations Communities. Parks Canada is concerned with water resources on national parks. Agriculture and Agri-Food Canada is concerned with agriculture and its interactions with water resources, as noted in the previous section. The Prairie Provinces Water Board is a unique federal-provincial prairie agency that oversees the 1969 Master Agreement on Apportionment for water flowing across the three prairie provinces of Alberta, Saskatchewan and Manitoba (Bruneau *et al.*, 2009). The board includes subcommittees responsible for water flow apportionment, water quality, and groundwater; it has successfully administered the shared provincial water resources since it was created in 1948. The International Joint Commission is concerned with water crossing international boundaries between Canada and the United States.

Table 3. Water diversions, return flow and consumption in the SSRB.

	Water diversions		Return flow		Consumption	
	Million dam^3	Share of natural flow	Million dam^3	Share of total diversions	Million dam^3	Share of natural flow
Non-irrigation demand[1]	**0.51**	**5.9%**	**0.36**	**71%**	**0.16**	**1.8%**
Municipal	0.31	3.5%	0.24	77%	0.07	0.8%
Livestock	0.07	0.8%	0.02	28%	0.05	0.5%
Industrial	0.05	0.6%	0.02	40%	0.03	0.3%
Thermal Hydro	0.09	1.0%	0.08	88%	0.01	0.1%
Irrigation demand[2]	**2.52**	**29.1%**	**0.59**	**23%**	**1.93**	**22.3%**
Total supply[3]	8.67				8.67	

[1] Based on 1996 data which is the last year in which comprehensive demand data was collected.
[2] The Alberta portion of the SSRB contains approximately 79% of the irrigated land in the SSRB (600,000 ha).
[3] Total supply in million cubic decameters is based on estimated average natural flow from 1961–1990 (Toth *et al.*, 2009). One cubic decameter is a volume of 10 m × 10 m × 10 m; 1 dam^3 equals 1,000 m^3.

The agricultural sector is increasingly engaged with water management agencies and watershed groups. Both provinces have integrated local citizens into local water advisory committees. This represents a significant step in establishing more democratic forms of water governance.

The Challenge of Climate Change

Future hydroclimate scenarios under global warming suggest that natural variability will be altered. Climate change research suggests that warming of the atmosphere and oceans will amplify the already large annual and decadal differences for this region (Kharin *et al.*, 2007). Winters are expected to be warmer and wetter, and summers are expected to be hotter and drier. While scenarios do not forecast flow changes with certainty, the median future flows for several scenarios show natural river flow reductions ranging from 4% to 13%, as shown in Figure 5 (Martz *et al.*, 2007). Such reductions would have a significant impact on irrigated agriculture and overall water management within the SSRB. Greater future climate variability may increase the risk of extreme events (droughts, floods, storms), and risks from diseases and pests affecting crops and plants, and could pose serious challenges for agricultural production, water availability and water quality.

Looking back in post-settlement time, the most severe prairie droughts occurred in the 1920s and 1930s. Modern agriculture and current economic activities within the South Saskatchewan River Basin subsequently adapted to the basin's highly variable climate and

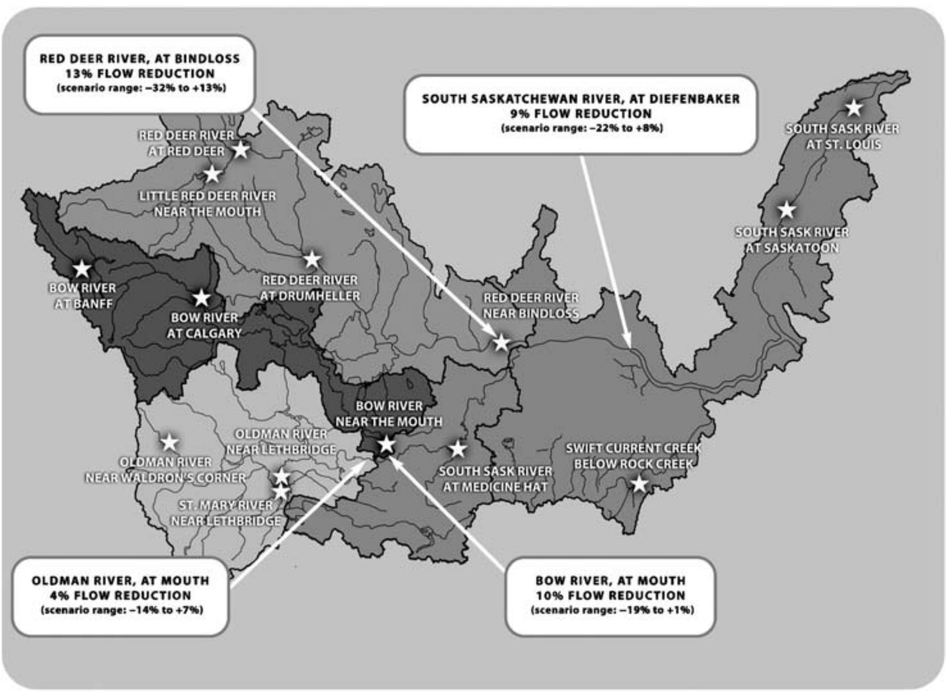

Figure 5. SSRB river flow climate scenarios, 2039–2070. *Source*: Martz *et al.*, 2007.

water supply. This success was achieved in large part by significant social and institutional effort (Gray, 1996; Bruneau *et al.*, 2009). Droughts in the past 40 years have caused serious economic impacts in the SSRB, but the region's current resiliency has been generally sufficient to cope with the resulting economic losses, social stress and environmental impacts.

Longer-term historic climate variability is a different scenario. Figure 6 plots Oldman River flow departures for the years 1375–2003. Tree-ring data was analyzed as a surrogate to reconstruct streamflow (updated data; the methodology is described in Axelson *et al.*, 2009). The 1962–90 hydrologic period (a common reference period for water managers) is plotted as the "normal" zero-baseline flow. Departures above zero are "wetter years" and below zero are "dryer years."

This historic time series illustrates a large inter-annual and inter-decadal variability in the hydrologic regime. The tree ring data captures recorded droughts, including those of 2001–02, the 1980s, and the 1920s–1930s. The tree rings show more severe negative departures in the early 18th century, with longer periods of low flow during the 1840s to 1870s, a period when explorers advised the colonial government that the Canadian Plains were unsuitable for agriculture (Sauchyn *et al.*, 2003).

This 628-year hydrologic time series illustrates that, by extending the reference hydrology from decades to centuries, our perspective of the reliability and variability of water supplies within the SSRB changes. The basin may in fact have a greater natural hydrologic variability than has been recorded during the last 110 years, the period used by decision-makers to manage water flow. This surrogate historic data shows that the SSRB

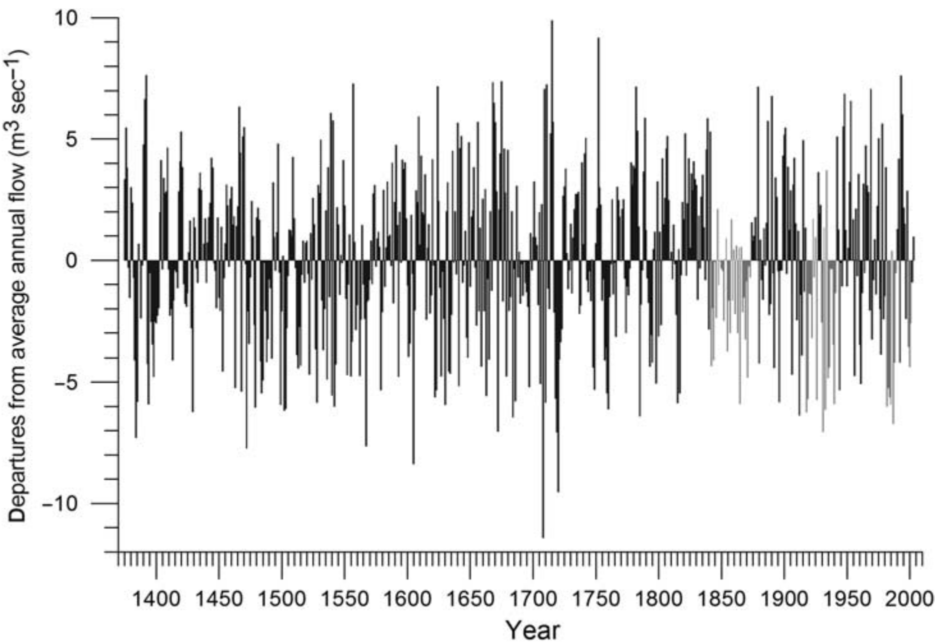

Figure 6. Historic Oldman River flow departures, 1373–2003 (updated from Axelson *et al.*, 2009). *Note*: The light gray shading highlights recent severe or prolonged droughts (2001–02, the 1980s, the 1920s–1930s and 1842 to the 1870s).

may experience a wider natural variability, with recurrent multi-year dry or wet periods. This clearly has implications for water management within the basin, should repeated historic extremes (floods, droughts) recur. This emphasizes a need to collect more and better climate and water data to mitigate risks and uncertainties in scenario modeling. Improved data can provide water managers with better information for operational planning (e.g. climate impacts on river flow, soil moisture, inter-annual forecasting).

Stakeholder and Water Governance Research: The IACC Findings

Rural communities and agricultural producers are exposed and sensitive to a variety of climate variability-related events. Changes in temperature, precipitation, and frequency of storms impact rural livelihoods and economic activities. For producers, the dominant climate hazards are extreme events and departures from expected "normal" conditions. Vulnerabilities to climate are always linked to other external conditions (e.g. economic crises) and external institutions (e.g. water governance systems). The rural history of the SSRB has been one of continuous adaptation to multiple sources of risk. A variety of practices, processes, systems, and infrastructure have been tried and adopted by producers, communities and rural households to reduce risk and find new coping opportunities. However, the IACC research shows that stakeholder adaptive capacity is not evenly distributed among social sectors within the SSRB, due in part to access to resources, types of agriculture, institutional capacities, local and regional planning strategies, operational needs, local expertise and co-ordination, and so on (Diaz, Hadarits, & Barrett-Deibert, 2009; Wandel *et al.*, 2010).

The IACC research found that existing adaptive capacity was shaped considerably by larger decision-making frameworks, especially by different orders of government and governance networks. Successful adaptations occurred with institutional responses to crises. Alberta created the Special Areas Boards to address land management issues in an extremely vulnerable geographic area; Canada created the Prairie Farm Rehabilitation Administration to seek adaptations for prairie agriculture, investigate soil and water conservation methods, develop scientific knowledge for sustainable agricultural practices (i.e. reduced soil tillage), manage marginal lands, construct and research agricultural water supply methods, and so on (Diaz *et al.*, 2009b; Diaz, Hadarits, & Barrett-Deibert, 2009). These institutional developments have benefited rural communities, farmers and ranchers by strengthening their adaptive capacity to deal with normal climate variability and, to a certain extent, with extreme variability; some limitations of their adaptive capacity were demonstrated during the 2001–2002 droughts, which caused serious economic impacts. If the SSRB is exposed to greater natural or future climate variability, several institutional challenges need to be addressed to enhance capacity, build coping resilience and seek new opportunities to help the sector and rural communities. Some examples include: increase stakeholder engagement and integration in water management decision-making, develop local planning responses for short-term and longer-term needs, and increase local and regional dialogue (Diaz *et al.*, 2009a; Wandel *et al.*, 2009; Hurlbert *et al.*, 2009b). The IACC research can be summarized into three key areas to achieve improved water management and decision-making (Diaz *et al.*, 2009b; Diaz, Hadarits, & Barrett-Deibert, 2009).

The first one is the need for *improving and integrating water management with consideration of historic and future climate scenarios*. There is a need for both short-term (5 years) and long-term planning (10–20 years or more). This would allow a stable and clear vision of what is required to sustain water resources for both the present and future needs of the agricultural sector and rural communities. The IACC research found that rural communities and stakeholders expressed concerns over frequent water management changes resulting from differing approaches, often affected by political or governance changes. Rural stakeholders indicated a need for all orders of government to develop flexible and long-term policies and programs to address local needs, local ecology, and exposure to extreme events (drought, flood). It would be beneficial to develop drought preparedness plans, and to plan for future opportunities from a warming climate (Hurlbert *et al.*, 2009a). The 2001–2002 droughts highlighted the need to address water allocation issues during times of surface water shortages (Wandel *et al.*, 2009). In consideration of climate change impacts, governance organizations have emphasised mitigation but stakeholders see a need to develop adaptation planning responses. Orders of government are now seeking ways to reduce vulnerabilities; some activities could easily be reoriented to assist with improving adaptive capacity (e.g. developing response plans to extreme events). Longer-term plans can integrate mitigation and adaptation, include options for water management decision-makers, and develop systematic planned adaptive responses for sectors, local communities and regions. Climate and water problems, as with most environmental challenges, have been termed "wicked problems." Their complexity means they cannot be contained within traditional disciplines or sectoral boundaries; they require broader interdisciplinary and multidisciplinary approaches with citizen engagement (Batie, 2008; Brown *et al.*, 2010). Mainstreaming and integrating climate and water planning responses with multiple sectors and stakeholders is essential. It will be critical to consider local and regional drivers, natural and future climate variability, and water management planning for economic activities and new opportunities.

A second area is related to *improving the operational effectiveness of water governance and longer-term planning*. Roles and responsibilities between agencies can be more clearly identified. Improved inter-agency co-ordination and simplified governance mechanisms are repeated themes in the literature, and were also identified by the IACC research. Current arrangements are viewed as being too complex for both stakeholders and government agencies. Water governance includes many organizations with some overlapping mandates, sometimes leading to confusing responses or unclear directions.

A key requirement for effective water governance is ensuring all agencies have and share sufficient data to aid in decision-making. Institutional and water data complexity have sometimes resulted in gaps in availability of water data for water management decisions and future planning (water quality, quantity and actual use patterns, groundwater supplies, climate data). While considerable water data exists, it is difficult to make longer-term future adaptive plans without more comprehensive water resource and climate scenario data. Planners are uncertain of availability and use trends, and stakeholders expressed concern regarding uncertainty over sustainable levels of water extraction. Some aquifers are feared to be in an overdraft situation. Some respondents described gaps in surface water quantity and use monitoring. They claimed that considerable data was available for municipal and industrial use, but not all municipalities collect usage data. Some expressed concern that measures employed to calculate water use by irrigators needed to be improved. While estimates could be made by surrogate measures such as pumping capacity, these estimates did not reflect actual use or provide data that might inform more efficient water use management strategies at the local and regional scale.

Respondents also indicated a need to link water data with climate data. Data challenges are complex, in part because data management systems are not always compatible between agencies, a common problem for most areas of the world.

Data collection, management and scenario-planning for water and climate are essential for operational requirements and adaptive responses. Applying short- and long-term planning scenarios would be helpful for all stakeholders. Baseline plans and multidisciplinary and interdisciplinary responses would be beneficial in establishing stakeholder and institutional roles and could strengthen the integration of stakeholders, and water governance arrangements.

Water and climate data management systems are not only an indicator of healthy institutional systems. They are the fundamental components of "informational capital," an important determinant of adaptive capacity. As relevant as other forms of capital (e.g. economic, social, human, natural/environmental) informational capital contributes to better knowledge of the existing resources, and facilitates their management in situations of uncertainty or surprise. The existence and good use of a solid accumulation of information capital is a must in ensuring the sustainability of rural livelihoods and the agricultural sector, particularly when confronting environmental stress.

Finally, the third area is related to *developing strong communication channels between water governance institutions and local communities*. The IACC rural stakeholders expressed a concern over what they believe is an increasing separation between the local communities and higher orders of governance institutions. Rural people feel marginalized from the centres of power. Higher orders of government and its institutions were seen as both far away in physical presence and unavailable because of time pressures. Rural people stated that local concerns, challenges and issues were not understood by distant, non-local levels of government institutions. The creation of watershed groups with increased citizen engagement has been a very positive development to reduce this gap. However, a real challenge exists in sustaining and empowering these groups to develop local adaptive responses. Watershed groups essentially rely on volunteers, and their contributions towards longer-term roles in water management decisions may be difficult to sustain (Hurlbert *et al.*, 2009a, 2009b). Water resource planning and management decisions will be more effective if governance institutions can increase the engagement and empowerment of citizens and stakeholders. Such participatory planning adds a different degree of complexity and uncertainty to water governance, but such engagement is expected to lead to improved water management decisions. Local stakeholders bring ownership and will implement solutions and adaptations that are locally relevant and likely more sustainable. Moreover, the robust integration of local groups with water governance institutions will certainly increase a two-way dialogue between governments and rural communities. This would increase the likelihood of enhancing local relevance and buy-in to solutions, and could lead to constructive water management decisions that better target local vulnerabilities.

Conclusions

Canadian water management is facing increasing stress from water availability, water use, and environmental pressure. In the case of the South Saskatchewan River Basin, the agricultural sector is a significant water user in its production of food. Competition for water is increasing. Historic and future climate scenarios indicate a wider variability in climate and water supply than is currently used by planners and water managers. A wider variability will impact water availability and quality, and means water management decisions will face new stress. The Institutional Adaptations to Climate Change research found numerous existing challenges with unequal adaptive capacity, gaps in water and climate data, locally relevant options, and short- and long-term planning, among others. As an empirical case study, the SSRB research offers insight for improved water management decision-making in all regions of the world. Recommendations include a need for improving and integrating water management with historic and future climate scenarios, improving the operational effectiveness of water governance and long-term planning, and developing strong communication channels between governance institutions and local communities. Successful adaptive responses need to be locally relevant, and implemented by local decision-makers. The incorporation of watershed groups, basin planning, and interdisciplinary and multidisciplinary water management approaches are all positive steps that will help effective and adaptive water management decisions. Historic adaptations have often occurred in response to crises. A changing climate may in fact present new opportunities, if we have the foresight to adapt.

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