Adapting to Climate Change in the Oldman River Watershed, Alberta: A Discussion Paper for Watershed Stakeholders

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Preface

The research presented in this report was supported by a grant from the Climate Change Action Fund. We are grateful to the numerous people in Alberta who participated in the study by supplying resources and their time.

Additional material on the physical, institutional, and human characteristics of the Oldman watershed is available on the website created for this project, located at:

http://www.uoguelph.ca/gwmg/wcp_home/Pages/O_home.htm.

More information about the objectives and progress of this study can be found at:

http://www.uoguelph.ca/gwmg/ccaf02.htm

Executive Summary

The surface water and groundwater resources of the Oldman River watershed provide critical support for both human and natural systems. Surface water from the Oldman River, its tributaries, and local diversion and irrigation canals, is the primary source of water for human needs in the watershed, including water for irrigation, livestock watering, municipal drinking water, industry and commerce, recreation, and waste assimilation. Rural domestic water users rely on both surface water and groundwater to supply their needs. These human demands for water must be balanced with the water requirements of terrestrial and aquatic ecosystems. Balancing these demands involves recognition of a myriad of values, both human and ecological, and presents significant challenges, particularly in when considered in the context of climatic variability and change.

Water resources in the basin are stressed by contamination from urban and rural land uses and activities. Prior to upgrades to its wastewater treatment plant, treated wastewater from the City of Lethbridge was a significant source of pollution in the Oldman River. With respect to water quantity, ever-increasing demand for irrigation water, combined with recent droughts, has highlighted the potential for conflict among water use sectors, such as agriculture, industry, the natural environment, and wastewater assimilation. Due to the potential impacts of water shortages on local economic and social interests, adaptation to climate variability and change should be a priority. While climate change is predicted to increase total annual stream flow in the watershed, higher evaporation rates, reduced summer soil moisture, and earlier predicted peak stream flow may lead to drier summers, when irrigation and municipal demand for water is highest [22, 57]. Water sharing agreements, developed recently to deal with supply concerns in the southern tributaries of the basin, are an example of an adaptation to existing climatic variability. Numerous other types of adaptations exist that have the potential to reduce basin water users' vulnerability to climate change.

The purpose of this research was to examine the extent to which water use behaviours and water management laws, regulations, and organisations facilitate or constrain capacity to adapt to climate change at the watershed scale. This discussion paper presents major findings of the research relating to the nature and extent of adaptive capacity in the Oldman River watershed. It also outlines several recommendations for building capacity at the watershed scale and offers an opportunity for watershed stakeholders to comment on the ongoing research.

The research involved a review and evaluation of local and provincial institutional arrangements for water management, along with interviews with local and provincial officials knowledgeable about water management in the Oldman watershed. Documents analyzed included senior-government and local-level policies, legislation and regulations; reports; newspapers; academic literature; and websites.

While the research identified many challenges for water management at the provincial scale, only those with implications for the Oldman watershed are outlined here. The recommendations pertain to three major categories of discussion: the water allocation framework (under the Water Act); short-term actions taken by watershed stakeholders to cope with periods of low water; and long-term strategies for conserving water and enhancing supply. Three major challenges in the Oldman watershed relate to: altering attitudes to consider the potential impacts of climate change and reduced availability of water on all users, regardless of size or type of use; encouraging long-term protection of water resources; and assessing and accepting the role water conservation is likely to play in adaptation to climatic variability and change .

Table of Contents

1. Introduction

Changes in air temperature, precipitation, and the frequency and severity of drought events related to climate change could adversely affect agriculture and other sectors in the Oldman River watershed. The capacity of the Oldman watershed community to adapt to climate change is, in part, a function of the extent to which watershed organizations and individuals have the tools, authority, understanding, willingness, and resources to take action to reduce the vulnerability of social and economic structures reliant on water resources. The adaptive capacity of the Oldman watershed community will differ from that of other regions in Alberta and elsewhere, as it is influenced by distinctive local and regional factors. The aim of the research underlying this discussion paper was to identify barriers to adaptation within the watershed, to illustrate some of the strengths and weaknesses in existing institutional arrangements for water management, and to suggest ways to increase adaptive capacity and reduce the vulnerability of the area to climate change. In this discussion paper, the term "institutional arrangements" refers to provincial laws and regulations; local by-laws and plans; policies, guidelines and plans; and the various organizations that are involved in water management and land use planning.

1.1. Potential Effects of Climate Change on the Oldman River Watershed

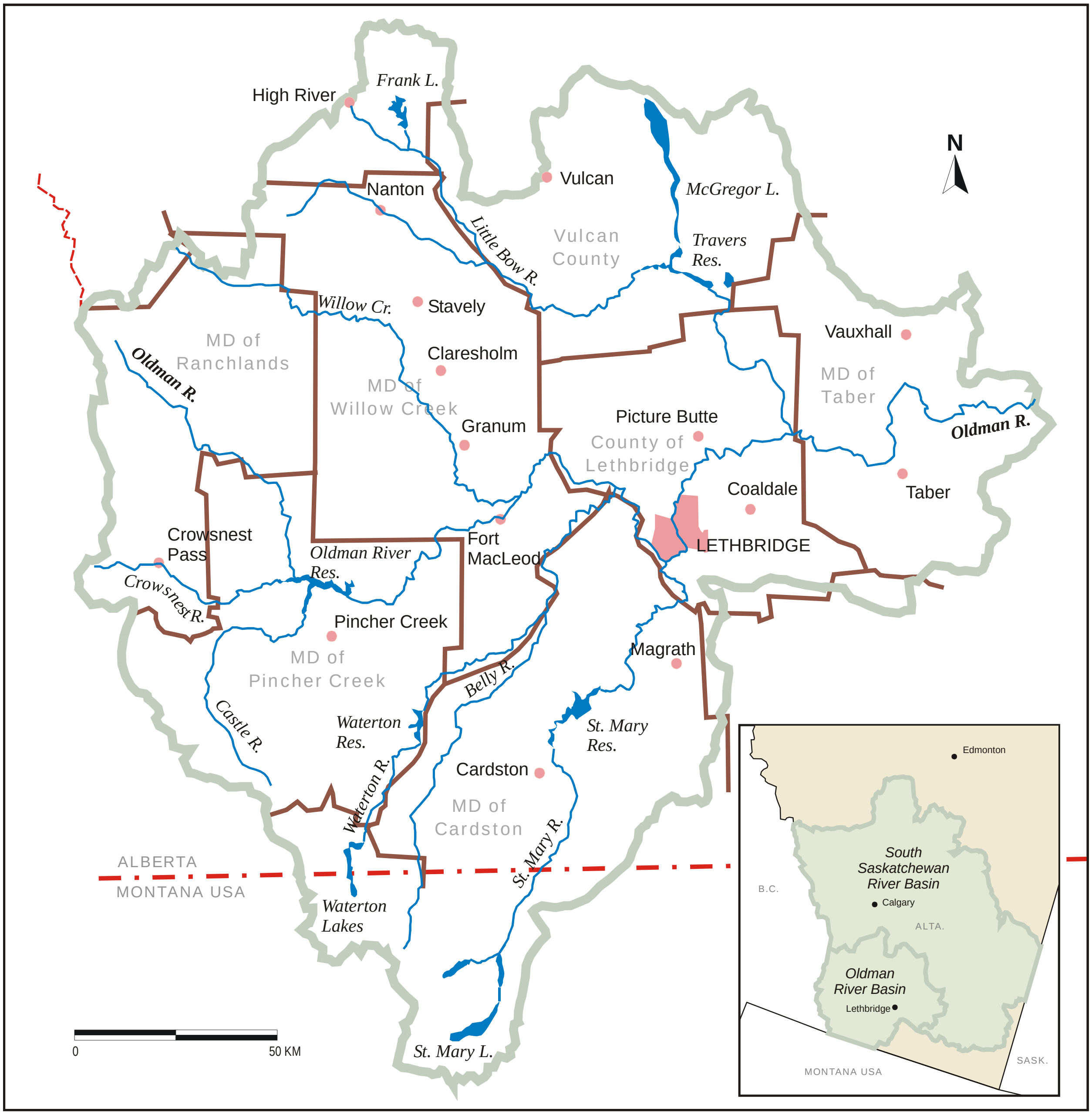
The Oldman River watershed covers an area of approximately 23,000 km^2 of southern Alberta, Canada, and 2,100 km^2 of northern Montana, in the United States. The basin is approximately 209 km in length from east to west, and 241 km wide from north to south (Figure 1). The Oldman watershed is divided into three distinct zones: the Cordillera (mountainous region), foothills (rolling transitional topography), and plains regions. The distinctive climate, hydrology, and landscape of the watershed have strongly influenced patterns of human settlement and water use in this semi-arid region.

The population of the basin is approximately 158,000 people. The City of Lethbridge is the largest settlement with a population of nearly 67,000. The majority of large water users (irrigation districts, industries, and municipalities) are wholly dependent on surface water sources. Only a few municipalities in the basin use groundwater resources to supplement surface water withdrawals (e.g., Town of Nanton). Because of the importance of water resources in this region, water management has been a focus of various governments for more than a century.

Approximately 60 percent of the annual discharge of the Oldman River and its tributaries is a result of spring mountain snow melt between April and July [75]. Stream flows are typically lowest during the months of August and September, making low water levels a particular concern in the late summer and fall [75]. Conditions in 2000 and 2001 emphasized the susceptibility of the region to drought [3, 4]. Anticipated future changes in climatic conditions are expected to produce more intense and numerous periods of drought [18].

Projections of climate change for the Oldman basin suggest average annual temperature increases in the range of 1-6ºC [18, 22, 57]. Although there are predicted increases in total annual precipitation, it should be noted that seasonal scenarios indicate that winter and spring will be wetter, and summer drier, due to increased evaporation rates from higher air temperatures [22, 57]. Typically, snow accumulation accounts for 70-90 percent of stream flow volume in the Oldman River. It is expected that precipitation in winter and spring will fall as rain rather than snow, changing the seasonal distribution of water availability, and resulting in decreasing soil moisture in the summer and fall [57]. It is also likely that stream flows will reach maximum discharge earlier, and there will be less flow during crucial irrigation periods when demand for water is greatest [22].

Figure 1: The Oldman River Watershed, Alberta



The Oldman River basin is likely to be adversely affected by climate change because of its semi-arid climate and intensive water-based development (e.g., irrigation, agricultural processing, municipal demand) [22]. Furthermore, increasing demand for water and decreasing supplies could be exacerbated by lower stream flows resulting from climate change, making it difficult to supply current water uses, let alone future needs. Increased irrigation demands due to reduced soil moisture could worsen the region's negative moisture balance and aggravate soil salinity problems [27, 43]. Higher evaporation rates from February to October will reduce soil moisture, making the region more vulnerable to drought, and further increasing demand for water [18, 39].

In addition to human systems, there is concern that natural aquatic and terrestrial environments will be altered by climate change. Cumulative moisture deficits will have a significant impact on the region's ecology, where natural systems are sensitive to fluctuations in surface and near-surface water balances [36, 44, 56]. Prolonged droughts lower the resistance of ecosystems to disturbance from hydro-climatic events [56]. Ecosystems may take decades to recover [56]. In southern Alberta, remaining wetland and natural grassland regions are considered vulnerable to climate change [12]. Other concerns include poorer water quality due to increased evaporation and reduced stream flow, which will affect the assimilative capacity of aquatic ecosystems [18, 42]; reduced aquifer recharge; and drying up of private wells [18]. Furthermore, an increase in the magnitude and frequency of extreme hydro-climatic events may result in larger, more frequent storms and floods that could trigger landslides in forested areas in the western portion of the watershed [43]. Thus, major water-related concerns associated with anticipated climate change in the basin relate to the following:

- the availability of water for current and future industrial, municipal, and agricultural needs;
- the ability to meet inter-provincial and international apportionment (water allocation) agreements;
- the impact of reduced stream flows on water quality and instream needs, such as fisheries; and
- potential changes in crop production and vegetation health.

1.2. Water Management and the Capacity to Adapt to Climate Change

The ability or capacity of a community to adapt to climate change is a function of the manner in which water resources are managed and allocated, among a host of other factors. Adaptive capacity is a concept widely accepted in the climate change literature [59, 67]. It usually refers to the adaptability of a nation, society, organization, group, or community (i.e., people living or working in a specific locality, such as a watershed). Adaptive capacity in the water sector is dependent, at least in part, on institutional factors such as the availability of implementation resources and knowledge, the legal authority to make necessary decisions, and the flexibility of institutional arrangements for water management. In the context of an agricultural watershed community, adaptive capacity is greatly influenced by the capacities of organizations (both governmental and nongovernmental) and individuals (agricultural operators and other rural landowners and residents), and the nature and strength of inter-organizational, inter-sectoral, and inter-personal networks. Adaptive capacity is important because it helps to reduce a community's vulnerability to periods of drought and water shortage.

Water law in Alberta is based on the "first-in-time, first-in-right" doctrine, meaning that the first person to put water to beneficial use is given the highest priority of use. Thus, a legacy of historical priorities and uses exists and continues to influence Alberta's water laws, rules, and regulations. Southern Alberta has been involved in water management since the Dominion of Canada's creation of the *Northwest Irrigation Act* (1894). When responsibility for water management was transferred to the Province of Alberta, the provincial *Water Resources Act* (1931) carried forward the system established by the federal government in 1894. Recent changes to Alberta's water allocation system include creation of the South Saskatchewan River Basin Regulation (1991), which limited the expansion of irrigation projects, and replacement of the *Water Resources Act* with the *Water Act* (1999). Major changes under the *Water Act* enabled temporary and permanent transfers or assignments of water (Section 82). The Director is designated by the Minister of Alberta Environment to administer all or part of the *Water Act*. In Alberta, regionally-designated Directors perform a variety of duties, including issuance, amendment, suspension and cancellation of registrations, approvals and licences (Sections 38, 42, 51, 55). Additionally, the Director holds tremendous discretionary powers to: issue water management orders; dictate water management areas and prioritize water use (with the exception of household uses) in areas when there is a dispute; and issue licence transfers (Sections 81, 84, 30). The *Water Act* also permits the Director to hold back a portion of water (up to 10 percent) during a licence transfer. This "Water Conservation Holdback" is designed to protect aquatic environments and facilitate implementation of water conservation objectives (Section 83).

The *Water Act* (1999) was created in part to help address concerns regarding the flexibility of the Province's water allocation system. Prior to creation of the Act, water licences were appurtenant (or attached to) the land. Thus, they could not be transferred separately from the land to which they were attached. Under the new *Water Act*, water licences may be transferred to existing uses, or to new or alternative uses, enabling diversification and the ability to acquire water for new uses. The South Saskatchewan River Basin (SSRB) has been identified as a water management area under the Act. The provincial government has undertaken the creation of the South Saskatchewan Water Management Plan, which includes the Oldman River sub-basin. The first phase of the plan was to develop a system for water allocation transfers in the SSRB and sub-basins (approved by Order-in-council, July 2002) [74]. As a result, the Southern Tributaries (St. Mary's, Belly, and Waterton rivers) have been closed to further allocation (Phase I). Phase II is directed at developing a management plan to balance human demand for water and the minimum river flows required for protection of aquatic environments [74]. Consideration is being given to the development of priorities for, and establishment of, water conservation objectives for instream flow requirements throughout the basin (Phase II).

There have been several other broad provincial water-related initiatives. For instance, the Province's *Water for Life* strategic planning exercise highlighted the need for greater involvement of local citizens in water management at the watershed scale and outlined priorities for research, planning, and conservation of provincial water resources [13]. The *Southern Alberta Sustainability Strategy* (SASS) is focused on involving Albertans in developing a vision of the future of southern Alberta and identifying desired environmental, social, and economic benefits for the region [11]. To some degree, this plan will address water resources in relation to local economic development.

To varying extents, these initiatives aim to address concerns regarding water resources. Recent droughts have highlighted existing and potential conflicts over water resources [49]. Climate change forecasts have led to worries that there will be additional stress on an already limited water supply [22, 27, 32, 57]. Balancing human and environmental needs for water, and protection of water supply and quality, are presently challenging and will remain so in the future.

The watershed has long been considered an optimal unit for management and planning of water resources because it is a complete hydrologic unit and an appropriate scale for the consideration of sustainability of water resource use [13, 48, 72]. Ideally, watershed management considers the cumulative effects of water takings on water resource availability [17]. Use of this approach could facilitate adaptation to climate change by considering the long-term sustainability of different water management options [41]. It is appropriate to consider the watershed context when making decisions about water allocation under climate change, since actions taken upstream have implications for downstream water users [16]. For these reasons, this research focuses on water allocation and water-related land use planning at the watershed scale, and considers the authorities, tools, and challenges of water allocation and water quantity management within the Oldman watershed.

Water allocation systems guide decisions about who gets water, how much water they get, and when. Water allocation goals may include water conservation, drought management, promotion of sustainable growth and development, protection of ecological systems, or adaptation to more severe and frequent low-water conditions due to climate change [28]. The climate change adaptation literature provides a range of potential options to respond to increased demand for water and limited resources. Traditionally, these have focused on water supply options (e.g., dams, locating additional sources), but more recently they have included adoption of demand side management and planning measures [29, 59]. Demand management options include adopting conservation practises to protect water resources (e.g., more efficient technologies), planning for long term water supply, and making adjustments to land use practices (e.g., types of crop grown, adoption of irrigation) [29, 32]. Demand management may also take the form of changes to institutions governing water use in order to increase flexibility in the face of changing conditions [16, 21]. Adaptations such as the implementation of small water resources projects to increase water storage, increased integration between existing water supply systems, and promotion of water conservation measures have been identified as ways of coping with, and adapting to, anticipated climate change on the Prairies [32].

A key consideration is the extent to which managers in the water sector continue to assume that future availability of water resources will be the same as it has been in the past, and base their decisions on historic precipitation levels and patterns. Making this assumption constrains adaptive capacity by limiting water managers' ability to take a precautionary, or planned, approach to mitigating the impacts of climate change.

2. Research Approach

In Canada, provinces have primary responsibility for developing and enforcing laws and regulations relating to water management, but local level organisations, such as municipalities and Alberta’s irrigation districts, are often major players in day-to-day water management and program implementation.

The climate change adaptation literature recognizes that adaptive capacity is influenced by the way institutional arrangements are structured, and their flexibility, legitimacy, and integration [16, 21].

- Flexibility is the ability to change water allocation structures in order to accommodate alternative, competing, or additional water uses.
- Legitimacy is facilitated by incorporation of meaningful stakeholder involvement, definition of clear roles and responsibilities for water management, existence of checks and balances within the water allocation process, and granting organisations appropriate authority to manage water resources and water-related land uses.
- Finally, integration is enhanced by consideration of all water uses (including environmental uses), incorporation of water-related land use planning, and stakeholder involvement on a watershed scale, which includes upstream and downstream interests.

In this research, targeted indicator questions were used to determine the extent to which institutional arrangements for water allocation and planning facilitate or constrain adaptive capacity at the local level in the Oldman River watershed (Box 1). The indicator questions guided a review of documents relating to institutional arrangements for water allocation, including legislation, regulations, reports, meeting minutes, newspaper articles, websites, and academic journal articles. In addition to the document analysis, 28 key informant interviews were conducted with local and provincial level persons with responsibilities for water management, familiarity with water resources or climate change, or responsibilities for water-related land use planning. Interview questions were based on the indicator questions in Box 1, and tailored to the individual's or organisation's roles and experiences with water management and knowledge of climate change.

Importantly, Box 1 is not a comprehensive list of all indicator questions used. Instead, it is a sample to demonstrate the type of information sought in the interviews. The indicator questions in Box 1 are not targeted to any level of organisation or scale of analysis, since it was recognized that some indicator questions were more appropriate for a provincial focus, while others dealt more with implementation, policy, and knowledge at the local level.

Box 1: Examples of indicator questions for flexibility, legitimacy, and integration.

Flexibility

- What discretionary powers, if any, do authorities have to restrict licence or permit issuing to protect groundwater or surface water supplies? Is there authority to consider such restriction at a watershed scale?
- To what degree could limitations be placed on a licence or permit to protect resources for periods of low water as a result of climate change?
- Do provincial policies make appropriate assumptions about resource availability both at present and under potential climate change? How, or to what extent, are these policies and arrangements relevant at the watershed scale? Are there inherent provisions for uncertainty in resource availability?
- To what extent are there opportunities under existing legislation, regulations, or policies to permit informal allocation of resources among stakeholders?
- Do present water allocation rules in each watershed permit re-allocation of water to reflect potential changes in the availability of the resource and sectoral or individual need?

Legitimacy

- Is there transparency in the water allocation process? To what extent is stakeholder participation provided for within the institutional arrangement for water allocation?
- To what extent are there inherent checks and balances within institutional arrangements for water allocation?
- To what extent are the roles and responsibilities for various agencies outlined?
- To what extent do the specific arrangements support the stated overall goals and objectives?
- To what extent does authority for the adoption of adaptive measures exist at appropriate scales (local vs. watershed/basin, or provincial)?
- To what extent are expectations of local agencies consistent with transfer of authority and resources to adequately manage those responsibilities?
- Do the authorities have appropriate and/or exclusive jurisdiction over the resources?

Integration

- To what extent do institutional arrangements promote adoption of additional adaptive measures for periods of low water?
- To what extent do institutional arrangements promote demand-side management and long-term protection of water resources through water-related land use planning and other practices that increase adaptive capacity?
- To what extent do institutional arrangements address the effect that a given arrangement will have on related institutions and institutional arrangements?
- To what extent do institutional arrangements provide for input about the development, implementation, and evaluation, of a program/policy/adaptive measure from a variety of senior agencies, other than the primary implementing agency?

3. Findings and Discussion

Adaptive capacity in the Oldman River watershed is a function of individual and organizational access to implementation resources, such as money, trained staff, and leadership; legal authority and other institutional considerations; the ability of water managers and others to assess current and future water needs; and water management processes, for instance stakeholder participation in decision-making and motivating adaptive behaviour. Each of these factors is influenced to varying extents by the flexibility, legitimacy, and integration of institutional arrangements for water and water-related land use management. The following discussion highlights factors that are facilitating or constraining adaptive capacity in the Oldman River watershed.

3.1. Implementation Resources

Much of the academic literature on capacity in the water sector identifies the need for organizations managing water resources to have adequate financial, technical, and human resources [1, 19, 30, 59]. Less commonly acknowledged, yet important, resources include leadership, the range of available alternatives for adapting to climate change, and the ability to resolve conflicts. When it comes to resources, watershed scale adaptive capacity is largely determined by the capacity of municipalities and other organizations (e.g., irrigation districts, local stewardship groups) in the watershed, although the capacity of individuals, particularly farmers, also is important.

Financial and Human Capacity

Financial and human capacity are not only challenges at the local level, but also at the regional and provincial levels. For example, during the research it was suggested that, in 2001, there may not have been enough Alberta Environment staff to administer and enforce priorities under the *Water Act* in the southern portion of the basin [49]. Fortunately, major water users in the Southern Tributaries were able to come to an agreement on water sharing, which lessened the administrative burden associated with water allocation [64]. All users who signed this agreement were assigned the same priority and the same percentage of the previous year's water use [3, 4].

Of course there are also challenges at the municipal level for maintaining water taking, water treatment, and water distribution infrastructure. For instance, in some of the northern watershed communities, such as the Town of Nanton, interest was expressed in joining a regional water supply scheme (with Calgary in this case) to lessen the burden of operating a system for a small community [73]. This strategy may have reduced the burden on the municipality, but it also would have divorced those supplied by the service from decision-making about rates, quality of service, and overall accountability of water provision.

Leadership

It is clear that Alberta Environment plays a significant role in water management in the Oldman Basin, both in administration of the water allocation system, and in planning and setting objectives for future water management (e.g., the SSRB planning process). The Expanded Main Canal Advisory Committee is an extension of the Main Canal Advisory Committee. The latter consists of managers of irrigation districts that share a main canal from the Southern Tributaries, who meet with Alberta Environment staff on a regular basis during the irrigation season [4, 49]. In order to address impending water shortages and rationing in 2000, this committee was expanded to include Alberta Agriculture, Food and Rural Development (AAFRD) officials, representatives from all irrigation districts, and private irrigation in the sub-watershed [4]. Alberta Environment, although not a voting member, attended all of the Expanded Main Canal Advisory Committee (St. Mary's River) meetings during 2001 to answer questions about how priority might be implemented under a variety of water supply scenarios and offer information about laws and policies [4, 61, 62, 63]. Several interviewees stressed the importance of having a knowledgeable and accessible Regional Director [20, 49, 61, 63]. The Regional Director and his staff give presentations and interact with the public on regular basis to increase awareness and knowledge about how the water allocation system is administered in Alberta. In addition to working in this capacity, Alberta Environment has cooperated with Alberta Agriculture, Food and Rural Development to promote education about water use and law in the agricultural sector. For example, web pages, particularly from the AAFRD site, have links to Alberta Environment on pages dealing with water and agricultural use (e.g., on-farm storage, irrigation, water conservation).

Leadership was also evident among interest-specific groups, such as the irrigation sector and municipalities. In the Oldman River basin, irrigation plays a significant role in water use and distribution. In recent years, irrigation districts have made investments in water conservation, and districts were key players in the successful 2001 water sharing agreement. Effort is being made by the Alberta Irrigation Projects Association (AIPA) to improve understanding of water resources and climate change through conferences [14]. AIPA also shares water-related information and knowledge derived from its experiences in water management on its website [37]. Furthermore, there have been efforts by irrigation districts to improve local wildlife habitat, in collaboration with Ducks Unlimited, by restoring valuable wetlands in southern Alberta. For instance, in partnership with Ducks Unlimited, St Mary's River Irrigation District (SMRID) provides water to 13 waterfowl projects covering almost 8,300 acres (3,374 ha). Reservoirs located throughout the SMRID system are recognized as providing critical staging wetlands for waterfowl (e.g., St Mary and Travers reservoirs) [15].

A number of initiatives at the watershed scale, including the Oldman River Basin Water Quality Initiative (ORBWQI), have focused on improving water quality. At a broader scale, the *Water for Life* strategic planning initiative [13] calls for development of local Watershed Planning and Advisory Councils to aid in setting priorities for water management and water-related land use planning. Each watershed is to have its own council commissioned to report on the watershed, establish goals, and promote local buy-in to activities or objectives selected by the council. These councils are intended to act as a liaison between provincial-level committees and the local governments in the watershed. However, at present, the council for the Oldman River watershed has yet to be established. Thus, currently, there is no single organisation or group leading water management at the watershed scale. The existing watershed management approach, typified by the SSRB planning process, takes into consideration the availability and quality of water resources for the purposes of water allocation and instream flow requirements. However, at present, there are limited connections between provincial level planning and grassroots or local organisations interested in water management. A possible hindrance is the possibility that goals and guidelines adopted by an individual Watershed Planning and Advisory Council may not coincide with local municipal goals or priorities. Thus, it is not clear at this time to what extent the councils will be able to influence water management and land use planning.

Range of Alternatives

Numerous alternatives for adapting to climate change exist. In the Oldman River watershed, alternatives include the following kinds of measures: water conservation, contingency planning, water use restrictions, increased storage, development of new supplies, and changing land and water management practices. In this section, alternatives available to two important local organizations, irrigation districts (IDs) and municipalities, are discussed.

Irrigation Districts and Agriculture

Irrigation is the largest water use in the basin, with roughly 87% of licensed appropriations [7]. Because many of the oldest (and thus highest priority) licenses are for irrigation, it is a high priority use throughout the Oldman River basin. The irrigation sector has the potential to enhance water use efficiency, and there have been substantial gains in this area, particularly over the last two decades. Many advances have taken the form of improved infrastructure, for example conversion of open irrigation ditches to piped water supplies and upgrades in the type of irrigation equipment used (e.g., from wheel move to sprinklers, particularly those with down spouts) [38]. Nevertheless, there is room for development of new technologies and continued conversion of old technologies to newer, more efficient ones.

Irrigation districts, especially the larger ones, have taken measures to promote water conservation and efficient use of water at both district and landholder scales. For example, districts have worked to develop strict scheduling guidelines, so that water is not piped through ditches or pipes when it is not needed. All districts have by-laws or policies that relate to limiting spillage, a prominent concern in the Taber Irrigation District (TID) in 1988 and the Lethbridge Northern Irrigation District (LNID) in 2002 [46, 65]. LNID has developed a new policy that allows it to limit the volume of water it distributes within the district on an annual basis, based on known resources for the season. In early spring the district publishes an estimate of known available resources so that irrigators are able to make management decisions (e.g., selection of crop variety, scheduling irrigation) based on a known distribution volume [45].

As well as scheduling, improvements in water distribution technologies, and by-laws limiting the amount of water available to an irrigator in any given year, expansion of storage is another option being seriously considered by irrigation districts. Historically, increased storage has been the approach taken to deal with water shortages or periods of excess demand for water. While on-stream water storage is considered ideal by many water managers, ID managers, and provincial water mangers throughout southern Alberta recognize that public support for new dams is weak, especially following the controversy relating to the construction of the Oldman River Dam. Hence, additional, smaller off-stream storage projects are being considered by some districts [20]. For example, SMRID, TID and Raymond Irrigation District (RID) have hired a consulting firm to examine the potential for new storage sites and expansion of existing storage facilities [66]. SMRID's experiences illustrate the role of storage. SMRID has enough storage to supply water for approximately two drought years. In 2001, it was accepted that there was not enough storage capacity to provide water for another dry year. Climate change, it was suggested by one interviewee, would be addressed through construction of additional storage [55]. Unfortunately, climate change may create a situation where water simply is not available to fill new reservoirs [49, 51].

Long-term planning represents another potential option for adapting to climate change. SMRID, TID and RID examined water supply, use, and management in their respective districts as part of the Southern Tributaries Irrigation Review studies. The objectives of these studies were 1) to identify and quantify current irrigation water demands and the state of irrigation water management in the three districts; 2) to quantify potential future irrigation demands; 3) to assess the potential for irrigation expansion; and 4) to assess the potential impact of irrigation expansion on irrigation farmers, districts, and the province [66]. Through this process, the viability of irrigation expansion in the region will be considered and promoted should the study recommend increasing the irrigated area. Irrigation expansion has, in the past, been an important adaptation to climatic variability to ensure the viability of agriculture in the region. However, increasing the irrigated area in the basin without taking account of anticipated climate changes and increased demand for water from other sectors could increase the area's vulnerability to climate change, reduce flexibility, and constrain adaptive capacity by stressing already scarce water supplies.

Finally, changes in management practices that improve capacity to adapt also are important. These could involve small changes to management practices, or the adoption of new technologies for responding to climate change. Agriculture has played a significant role in the development of the region historically, and continues to be an important land use in the watershed. Counties and municipalities in the watershed have identified agriculture as an important industry, both economically and socially. Agriculture is significantly affected by changes in climate averages, and, to a greater degree, by changes in extreme events [19]. Thus, some of the traditional approaches to increasing soil moisture and replenishing dugouts, such as construction of snow fences [54], will be ineffective if winters continue to be warmer, and periods of snowfall do not carry over to late spring.

Municipalities

Municipal by-laws regulating non-essential water use vary with respect to the types of water use regulated, and the degree of restriction on use. Most municipalities in the watershed have a water conservation by-law to restrict use during periods of reduced water availability, or for other water-related emergencies (e.g., contamination, emergency maintenance). Examples include:

- The Village of Nobleford and towns of Coaldale and Taber implemented water restriction by-laws in the summer of 2001; the towns of Taber and Vulcan implemented water use restriction by-laws in 2002.
- The Town of Vulcan's by-law establishes alternate day landscape watering and encourages watering in the early morning or evening (Town of Vulcan by-law No. 1285).
- The Town of High River adopted a more sophisticated staged by-law (by-law 4028/2002), meaning that as reservoir levels decrease, there are staged responses with increasing severity of restrictions, culminating in prohibitions on water use in excess of 2,000 gallons per day (9,092 litres/day) when reservoir levels drop to 50 %. In addition to responding to periods of low water, section 5 of the by-law prohibits wasting of water at any time.

Some municipalities have developed policies related to water conservation. For example, the Town of Fort Macleod has prepared a *Water Conservation Policy*, under which distribution system pressure can be lowered, and mandatory water restrictions can be imposed in the event of an emergency water shortage. The policy could be implemented if the municipality experienced difficulty maintaining treated water quality due to high levels of turbidity, insufficient raw water supplies, or a hazardous material spill into its surface water source. The City of Lethbridge has developed a *Water Rationing Policy* [25] that outlines a staged response to water shortages, although at the time of this research the policy had not yet been written into the City's water conservation by-law [40].

Other measures used by municipalities to promote water conservation by local residents include brochures and newspaper advertisements. For example, the Town of Coaldale and City of Lethbridge jointly published such a brochure [26]. The Town of Taber distributed brochures entitled *Xeriscaping* and *2000 Wise Water Use* [70, 71]. There was no evidence of adoption of retrofitting programs by watershed municipalities to improve water use efficiency or prepare for periods of limited water supply.

Municipalities in the Oldman River basin have not focused on drought management or long-term water supply strategies. However, an example of a municipality using such measures exists just north of the basin, in the Town of Okotoks. Some of the approaches used by the Town include setting objectives for maximum daily per capita water use, acknowledging the limited potential for development with existing water supplies (population to be capped at 25,000 to 30,000 inhabitants) [68], adopting aggressive water waste reduction programs and staged water restriction by-laws, and implementing strict retrofitting and renovation plans that require the use of water saving toilets (maximum 6L/flush) and showerheads (maximum 9.5L/min) (Town of Okotoks By-law 16-02). In addition to these measures, the Town has also developed a water management plan [69] outlining strategies for achieving sustainable water management. The plan outlines options for water supply, including finding potential transfer opportunities, adoption of new technologies, aggressive water conservation, and staff training in areas such as leak detection [69].

Barriers to adopting an approach similar to that of the Town of Okotoks in the Oldman River watershed include limited willingness to consider the potential consequences of climate change or increased climate variability, reliance on water storage rather than demand management measures, lack of understanding of existing water management regulations, and competing municipal priorities. One important barrier to change in municipal water management practices is the common perception that municipalities should not have to undertake water conservation programs because the amount of water they use is dwarfed by that used by the irrigation sector. Additionally, during this research it was evident that there was a widespread misconception among municipalities that municipal uses are protected as the highest priority of use under the *Water Act.* In actual fact, no such provision exists. Rather, there is a provision that states that during a declared water or public emergency, municipalities may compensate higher priority licence holders for a portion of their licence (*Water Act*, section 89(7)). According to local Alberta Environment staff, this clause has never been used [49]. Nevertheless, with the institution of water licence transfers and assignments, there is increased flexibility and opportunity for the permanent or temporary transfer of water to municipal uses.

Conflict Resolution

The potential for competition and conflict over water is high in the Oldman River basin. Recent drought events occurred in 1984-85, 1988-1990, and 2000-01. While there have been numerous drought events in the last few years, there is some indication that 20th century prairie stream flows, specifically, and water availability, generally, have been the highest in several centuries [23]. In other words, contemporary water management on the prairies may have developed during one of the wettest periods in centuries [23]. Existing climatic variability has posed a significant challenge to water managers. Future variability associated with climate change may magnify these challenges significantly, and result in conflict at several scales.

During the 2001 water shortage, water from the Oldman Dam was used to supplement flows to Saskatchewan in order to meet the apportionment agreement. This was the third consecutive year of low water. It was suggested during the research that if stream flow during the spring had not returned to normal levels, there would not have been enough supply to meet demand, even with a water sharing agreement like the one in 2001, where participants agreed to take only 60 percent of their 2000 water appropriation [4, 49, 64].

While the potential for conflict is high within the basin, inter-provincial and international water agreements warrant consideration also. For instance, water use in the Oldman River watershed has come under scrutiny from the United States. Montana Governor Judy Martz commented that Alberta irrigators have been unfairly taking too much water from the Milk and St. Mary's rivers for more than 80 years. The Governor has asked the International Joint Commission to revisit the 1921 water-sharing agreement between Canada and the U.S., to ensure that her state receives its allotted share of water resources [47]. These concerns were voiced as irrigation districts in southern Alberta consider expansion, and the Montana Department of Natural Resources and Conservation contemplates expanding and repairing an irrigation canal on the Milk River near the Canada-United States border.

Knowledge of Alberta's system of water allocation is fairly widespread among water managers in the Oldman River basin [49]. There is general interest in who gets water, how much water users get, and when they get the water, because of the high economic value of water resources within the region. The situation in 2001 and 2002 could have had municipalities, industry, and many other water users competing over limited resources. Instead, conflict was avoided by development of a water sharing agreement among most of the large water users in the region, which guaranteed 60 percent of total water used in the previous year to all licensees that participated [4]. This agreement was voluntary, and demonstrated that sharing water resources among licenced priorities was possible, and generally beneficial.

While the 2001 water sharing agreement is a good example of adapting water allocation during periods of shortage in Alberta, it may not always be an effective response to water scarcity. Higher priority licences are still able to call their priority, rather than share water, if they so choose. It is important to recognize that decision-making power regarding sharing agreements lies with those licensees who have historical priority and large allocations. This means that irrigation districts are critical players in any future water sharing agreement or other similar arrangements. Of course introduction of transfers and assignments under the *Water Act* could alter water use patterns across the basin, either permanently or temporarily.

Conflicts over water use also may occur in relation to environmental needs. During the last several years, there has been increasing awareness of the water needs of the natural environment and the availability of high quality water resources. Water allocation for the environment was addressed in the first phase of the SSRB planning process, resulting in a potential 10% conservation holdback on all permanent or temporary transfers of licences, and a moratorium on new licence approvals in the Belly, Waterton, and St. Mary's rivers [8]. The second phase of the planning process deals with instream flows, with special attention to the requirements of aquatic species and natural systems. It is likely that even with continued monitoring and planning, maintenance of instream flow objectives will be a contentious issue during periods of low water and drought.

3.2. Legal Framework

Legal frameworks for water allocation are significant factors that can facilitate or constrain adaptation to periods of drought and water scarcity. They can have a profound influence on adaptive capacity, specifically, and the potential for sustainable water management, in general.

Authority to Act

Alberta Environment has the authority to approve licences, to enforce water takings, and generally to administer the *Water Act* (1999). However, other organizations also have authority over certain aspects of water use. For instance, irrigation districts are authorized to allocate water to farmers on their rolls, based on agreements with individual farmers, and to implement across-the-board special measures such as LNID's use of water supply projections to determine volumes allocated to farmers in 2002. Furthermore, they have the authority to enter into water sharing agreements (as was done by several Southern Tributaries districts in 2001) [45]. Similarly, municipalities are able to restrict water use by users connected to municipal systems through the implementation of water restriction by-laws and other measures.

The case of the Town of Okotoks, discussed earlier, illustrates the authority and ability of municipalities to implement specific measures (by-laws, policies, plans) that promote sustainable water use, and thus contribute to enhanced adaptive capacity. Okotoks, with the support of its citizens, has taken a bold approach to long-term planning, which considers economic, social, and environmental resources and goals. For example, the Town has set a limit on the number of residents who can be supplied on a long-term basis with currently available water supplies, land resources, and infrastructure [69]. Other municipalities in Alberta have the same authority. However, those in the Oldman River basin do not appear to have taken full advantage of the range of alternatives they could use to increase adaptive capacity. For the most part, municipal and county plans do not offer specific policies regarding sustainable municipal water supplies, or water-related land use planning.

The Province of Alberta's *Water for Life* strategy introduces a new approach to water management involving a variety of partnerships. Watershed Planning and Advisory Councils are examples of potentially important local (watershed) level partnerships. Councils are to undertake research, generate "state of the basin" reports, present recommendations in watershed management plans, collaborate with land managers, support watershed stewardship groups, and provide advice to the Provincial Water Advisory Council [13]. However, as suggested by the above functions, they will not have any regulatory powers, and will have limited ability to offer financial or other incentives for adopting sustainable water management practices that increase adaptive capacity. It remains to be seen how effective the Watershed Planning and Advisory Councils will be in accomplishing their functions.

Institutional Constraints

Changes to the *Water Act*, and other recent policy measures, have drawn attention to water resources in the Oldman River basin. They also have provided more flexibility within the water management system, and facilitated public and stakeholder participation in policy making. However, several factors work against full use of some of the approaches and measures made possible by these institutional arrangements. For instance, while transfers and assignments under the *Water Act* provide for flexibility within the system, irrigation districts (the largest holders of high priority licences within the basin) indicated that they were not interested in permanent transfers of water leaving the districts [20, 34]. Assignments are temporary transfers of licences, providing little security for new industrial or other economic uses. While permanent transfers were not being considered by irrigation districts, some district interviewees suggested that long term assignment agreements to certain industries might be possible. While such an arrangement would provide some security for the user receiving the assignment, it is important to note that continued water availability would be up to the license holder, and that ultimately the relative priority of the license holder would influence the security of the user benefiting from the long-term assignment.

Recently there has been increased emphasis on the health of the aquatic environment in the Oldman basin. The second phase of the SSRB planning process was designed to address concerns about instream flows, and to determine ways to mitigate the impacts of high appropriation and alteration of natural water courses over the last century. The final report of the second phase is expected in mid-2004, and will provide recommendations for achieving instream flow objectives [9].

Even though there are no references to climate change in the *Water for Life* strategy document, there is interest in dealing with climate change at the provincial level. The Province's *Climate Change Action Plan* [33] outlines a provincial strategy to mitigate climate change impacts in Alberta. This document highlights general implementation goals and objectives to reduce emissions of greenhouse gases, conserve energy, and adapt to climate change. While this is an important policy objective for mitigating climate change, there has been no consideration of adaptation strategies to cope with the consequences of climate change on water resources specifically, as the strategy focuses on energy. It was expected that strategies to adapt to limited water resources under climate change would be examined and incorporated in the *Water for Life* planning process [60], but as mentioned earlier, climate change was not addressed in the final strategy. However, it is important to recognize that the document *Albertans and Climate Change: Taking Action* (2002) does highlight adaptation as an important part of dealing with climate change, although the emphasis is on energy resources and air quality rather than water resources [33].

3.3. Ability of Water Managers to Assess Current and Future Needs

Access to information is an essential prerequisite for adaptation to climate change. There is substantial information on water resources and use within the Oldman basin. There is a well-established stream gauge network throughout the basin that provides a relatively long record of stream flows and reservoir levels. This information is vital to understanding trends in water availability. Additionally, Alberta Environment provides near real-time water management data on its website, including basin and river advisories and warnings, forecasters' comments, and a water supply outlook (e.g., river flows, precipitation, lake and reservoir levels, water operations reports) [6]. Resources such as these are important for effective water management, including operation of the extensive works throughout the region, meeting apportionment agreement requirements, and decision making by individual water users and land owners (e.g., selection of crop type).

To support local agricultural decision-making, Agriculture Canada has been examining the way in which predicted changes in climate will affect soil moisture and spring planting dates [2, 50, 58]. Similarly, Alberta Environment has been assessing the four accepted global climate models pertinent to the western prairies. Findings from this work are being compared to the historic climate database to highlight changes in water availability and facilitate local agricultural decision-making about water resources [24]. Alberta Agriculture, Food and Rural Development is active in this area too, providing support and advice to irrigation districts relating to data processing, creation of water sharing and water rationing arrangements, and developing tools to measure and ration water during the 2000/2001 drought period [3, 24].

Alberta Environment, in collaboration with the Prairie Adaptation Research Collaborative, is conducting studies to examine water resources in the SSRB, including the extent of remaining glaciers, to determine potential future stream flows [53]. The aim is to provide meaningful estimates to government agencies involved in managing water resources, and to appropriators, such as irrigation districts, cities, and municipalities, about future water flows and availability. These undertakings provide useful information for water managers. AAFRD's information has been passed to local decision makers through its website and newsletters distributed to irrigators during the 2001 water rationing agreement period. As additional studies are completed, it will be important to make findings, recommendations, and information available to decision makers in a format useful at local and watershed scales. Water-related knowledge has improved in the basin due to groundwater studies in some of the southern counties. These studies are useful in the development of municipal water budgets, and can contribute to long-term planning for water resources. Although the majority of communities are surface water dependent, there are often inter-connections between surface waters and wells that draw from gravel aquifers adjacent to rivers [5, 31].

While research and knowledge are important prerequisites for water management, consideration of a range of management options is important for adaptation to climate change. Within the Oldman basin, improving water storage is still the primary approach taken to increasing water availability. It has been proposed that additional storage would capture precipitation whether it originally falls as rain or snow [49]. However, a "flashy" precipitation environment may mean that more water will have to be passed through the system to make additional space in reservoirs for new events, resulting in a change in management of the system and structures. Thus, additional storage should not be seen as the only necessary adaptation to anticipated climate change.

3.4. Complexity of Water Management

Numerous factors contribute to the complexity of water management, including conflict over water resources; adequacy of knowledge about existing programs, water uses, and water availability; and the nature and extent of stakeholder participation. Provincial government knowledge about, and concern for, climate change will need to be effectively communicated to local stakeholders in order to reduce vulnerability and encourage adaptation within all water use sectors. As the impacts of reduced water availability are felt, there will be increasing pressure on water sharing agreements and instream flow objectives in the Oldman watershed [10]. Unfortunately, motivating people to think and plan long-term is a significant challenge in the Oldman River basin. During the interviews conducted for this research it was clear that there is a strong perception in some sectors that there exists adequate storage to meet water needs, which has resulted in less interest in the cumulative effects of water takings and the potential effects of climate change on precipitation, water supplies, and water consumption.

Another barrier to effective adaptation in the Oldman River basin is the fact that there are numerous agencies involved in water allocation. Alberta Environment deals with both water allocation and water quality management in the region, creating a focus for basic water administration. However, Alberta Environment is advancing several policy initiatives with different, but seemingly similar, goals. According to interviewees, this creates confusion and frustration at the local level. For example, in addition to the SSRB water management planning process, largely focused on southern Alberta, the provincial *Water for Life* strategic planning initiative is soliciting local comments and concerns about water resources, and the *Southern Alberta Sustainability Strategy* is examining the potential for integrated resource management in southern Alberta. This overload and confusion, especially in southern Alberta, was recognized in some of the comments submitted to the *Water for Life* process [13].

The *Water for Life* process has recommended development of Watershed Planning and Advisory Councils that are expected to act as liaisons between local governments and the Province in each of the watersheds. In some regions, there are existing organizations that represent a broad cross-section of stakeholder groups (for instance the Bow River Basin Council). A subset of the Bow River Basin Council served as the Basin Advisory Committee

(BAC) during the SSRB planning process. While a BAC was established in the Oldman River watershed, securing stakeholder involvement and commitment to the process was a challenge [52]. ORBWQI was approached by Alberta Environment to take a lead role in establishment of a watershed advisory committee in the Oldman [35]. The primary goal of the ORBWQI has been to collaborate to conduct research regarding water quality in the basin, and report findings to industry, municipalities, and the public. As a watershed advisory committee, this group would be required to examine all aspects of water management, and take on additional members and responsibilities. While a watershed-scale advisory council could be extremely useful, interviewees suggested there is still confusion among the public regarding the role it will play and what authority, if any, it will have [35, 51].

Complexity of water management in the basin is not limited to government roles and programs, but also relates to the water allocation process itself. While Alberta Environment administrates the water allocation and licensing system, water management decision-making responsibility is distributed among the licensees themselves. In the Oldman basin this authority is largely tied to irrigation interests. While legislation has been adopted to permit transfers and assignments of water licences, there has been little or no willingness to make such transfers [34, 37, 55]. Users with historical priority are fully within their rights to preserve their interests in water and not engage in transfers. This could potentially represent a significant barrier to the redistribution of resources to new, competing, or alternative uses of water.

Water quality management is also important in the context of climate change. For example, some programs implemented across the province, such as *Cows and Fish* (Alberta Riparian Habitat Management Society), are dedicated to the protection of watercourses through creation of riparian buffer strips and implementation of other best management practices. The effectiveness of such programs will play an increasingly important role under climate change, as reduced flows, and higher temperatures and evaporation will likely increase the concentration of pollutants in water bodies. By implementing best management practices to protect water quality, the volume of pollutants entering watercourses can be significantly reduced. This is particularly important because surface waters are the primary sources of supply for crop, livestock, domestic, and municipal water uses [10]. The ORBWQI has been an important stakeholder group for the improvement of water quality awareness and research in the basin. However, the OBRWQI expects to disband in 2008, which could have implications for future water quality in the watershed [76].

4. Conclusions and Recommendations

Several characteristics of the Oldman River watershed make it an appropriate area in which to consider the capacity of communities to adapt to climate change in the water and agricultural sectors:

- Current agricultural, municipal, and industrial water users are already under strain in the Oldman River watershed. Reduced water availability, increased temperatures, and greater variability of supply as a result of climate change are likely to exacerbate existing conflicts and challenges among human water uses and instream needs for environmental systems.
- In addition to local water needs, international and inter-provincial water sharing and apportionment agreements will have to be respected. Reduced water availability will intensify water needs in all jurisdictions, resulting in additional scrutiny of agreements and the amount of water flowing across borders.
- Reduced water availability will place additional stress on instream flow objectives, as demand in all sectors increases. In addition, reduced stream flows will negatively affect water quality, which will have implications for human users and environmental quality.
- Water supplies for crop production are a significant concern due to the economic and social significance of agriculture in the basin.

Stakeholders working towards improving water management in the basin can facilitate adaptive capacity. Extensive knowledge of water resources and research at the provincial and federal levels, leadership and resources within provincial organizations, lengthy experience with historical droughts, and long-term dependence on surface water resources, have contributed to a water-based consciousness at the local level, especially in the agricultural sector of the Oldman River basin. Response to the recent 2000-2002 drought also has contributed to adaptive capacity in the basin, as local irrigation, municipal, and provincial government agencies worked together to develop a solution to reduced water availability. These partnership initiatives have built local capacity for water management and created leadership at the watershed level. However, limitations on adaptive capacity exist. Notably, dominant water use sectors, primarily agriculture and industry, are very sensitive to climate variability and change.

To minimize vulnerability to climate change, the watershed community should consider: adopting best management practices to reduce the potential for water quality problems related to climate change; assessing the cumulative effects of increased agricultural, industrial, and municipal use of water; enhancing education and awareness about climate change and appropriate adaptations for the agricultural industry; and facilitating adoption of municipal water conservation measures.

Based on the research conducted for this paper, it is possible to identify recommendations for consideration by stakeholders in different organizations involved in water management in the Oldman River watershed. Because of the strong interdependencies that exist among stakeholders, these recommendations span levels of government and stakeholder groups. Adaptation to climate change in the Oldman watershed will occur most successfully using a cooperative, multi-stakeholder approach that recognizes considerations such as the resources available to stakeholders, the constraints imposed by institutional arrangements, and the complexity of water management.

Adaptation to climate change requires knowledge of water resources. Monitoring of water resources, especially stream flow, precipitation, and snowfall accumulation, has significantly contributed to adaptive capacity in the watershed. Programs of this type should continue to be supported, and long-term programs to examine water quality throughout the basin should be established. Monitoring the quality of water on a regular basis contributes to a better understanding of what type of best management practices would be most effective, and where they should be implemented. Variations in water levels are expected to increase, and during low-water periods concentrations of pollutants will be higher. Impaired water quality will have serious implications for the region, as surface waters are the primary source of water supply for all water use sectors, including municipal drinking water. Thus, provincially-sponsored or cost-shared arrangements with local governments for the delivery of programs to local municipalities, landholders, and watershed organisations should be encouraged on a long-term basis to promote adaptive capacity.

Adaptive capacity could be enhanced by development of programs and materials that are targeted to specific groups and industries that highlight specific implications and impacts of climate change, and outline adaptation options. To date, in Alberta, there have been numerous strategic planning exercises at the provincial level. Practical application of recommendations generated by these strategic initiatives should be encouraged, through funded programs that facilitate adoption of best management practices and other adaptive measures. The goal should be to create a knowledge base concerning climate change that is accessible and relevant at the local level, so that local organisations and individuals have reliable and useable information on which to base decisions concerning water resources on a monthly, yearly, and long-term basis.

Water conservation is highlighted throughout the climate change literature as promoting adaptation. Stakeholders at all levels in the Oldman River watershed could do more to promote a water conscious society; for instance, by promoting responsible conservation of water within all sectors, and by water users of every size. Municipalities, for example, could promote a water conscious society by encouraging municipal water conservation through water use restrictions, public education, retrofitting programs, and long-term municipal planning for water resources. Furthermore, municipalities could consider planning approaches used by other municipalities, such as the Town of Okotoks, to promote the sustainable development of their communities based on local resource availability. Such approaches support water conservation objectives outlined in the *Water for Life* strategy.

Modifications to institutional arrangements for water management in Alberta could promote adaptation to climate change. For instance, increasing flexibility within the water allocation system by permitting water transfers and assignments has improved the ability to share water during periods of insufficient supply. However, it is important to recognize that constraints exist regarding water transfers and assignments. While these mechanisms could theoretically promote some flexibility within the existing water allocation framework, the legacy of entrenched historical water use patterns will continue to limit their use.

Enforcement of water use priorities is another key factor affecting adaptive capacity. During the research it was suggested that it would be difficult, if not impossible, to enforce priority of use during a serious drought given existing provincial human and financial resources. Given the likelihood that drought will become more frequent during the growing season, this could be a significant challenge in the near future, especially as competition for scarce water resources in the basin becomes increasingly fierce.

Adaptive capacity is strongly influenced by access to human and financial resources. When considering the development of any additional programs or levels of decision-making (e.g., watershed level organizations), the availability of these resources should be considered. One important consideration is support, both financial and technical, for the watershed advisory committees recommended by the *Water for Life* strategy. Furthermore, clear guidelines, rules and expectations for the advisory committees should be established to clarify their roles and responsibilities. Finally, revisions to the *Water for Life* strategy should more explicitly address climate change.

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