CHALLENGES AND OPPORTUNITIES ASSOCIATED WITH EXPANDING THE IRRIGATION SECTOR IN SOUTHERN ALBERTA

A Report Prepared for The Alberta Land Institute, September 2014

by

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1 INTRODUCTION

1.1 STUDY BACKGROUND

Irrigation is the largest consumer of surface water in Southern Alberta, and any expansions of the irrigated land base over the next 25 years will increase both agricultural water and land requirements. Such expansion would occur within a larger context of ongoing socio-economic development that is driving additional demands for limited land and water resources, and increasing concerns about cumulative environmental effects. Consequently, identification and quantification of the effects of land, water, agricultural and financial policies on economic, social, and environmental systems in the South Saskatchewan River Basin will be necessary to ensure sustainable management of the region.

The Alberta Land Institute (ALI), through the University of Alberta, is supporting a three-year multidisciplinary research project aimed at identifying the relationships between irrigated agriculture and economic, environmental, social and policy factors, and identifying and assessing the effects of alternative policy and management options on the irrigation sector and the province over the next 25 years. The first stage of the research involves conducting a foundational study to 1) catalogue current policies related to irrigation in Alberta and potentially-applicable policies for a sustainable expansion of irrigation, and 2) examine how these policies may promote or constrain change in the irrigation sector based on a review of relevant literature and discussions with stakeholders.

1.2 STUDY PURPOSE AND SCOPE

The objective of the first stage was to research, develop and deliver a report that 1) identifies and examines the current and the future challenges and opportunities for expanding the irrigation sector in Southern Alberta, and specifically in the South Saskatchewan River Basin over the next 25 years; and 2) identifies land-use, water management, agricultural, and financial policies that should help to ensure a sustainable expansion of the irrigation sector.
This report brings together and interprets a variety of literature on current and future challenges and opportunities associated with irrigation expansion in Southern Alberta along with the insights from a workshop discussion with multisectoral stakeholders in Southern Alberta. Furthermore, a set of potential policy and management strategy options that have received local attention, both in literature and in workshop discussions, is also provided, including background on each option and its potential contribution to addressing challenges and improving opportunities for the irrigation sector over the next 25 years.

1.3 REPORT OUTLINE

Following this introductory section, section 2 provides an overview of Alberta's irrigation sector with an emphasis on the South Saskatchewan River Basin (SSRB) as well as a discussion of the current status of the *Water for Life* strategy goals. Section 3 then provides an overview of the study methodology, criteria used to retrieve studies believed to be relevant for this research project, and a description of the workshop discussion held in January 2014 with stakeholders in Lethbridge, Alberta. Current and future challenges and opportunities for the irrigation sector in Southern Alberta are discussed in detail in sections 4 and 5, while potential changes that have both positive and negative aspects (e.g., climate change) are discussed in section 6. Section 7 presents a list of the possible policies and management options for the irrigation sector that have received local attention – as identified through the literature review and workshop discussions – and background on each of the policies listed, followed by a summary of the report and its objectives in section 8.

Metric units (SI) are used throughout the report unless mentioned otherwise. Abbreviations and acronyms used in the report are shown in brackets following the first use of the full name or term.

2 OVERVIEW

2.1 IRRIGATION IN ALBERTA

The irrigated area within the province of Alberta represents 65% of the total irrigated area in Canada, and most is concentrated in the southern part of the province. Although irrigation occurs on only 4% of the cultivated land of Alberta, its production represents 18.4% of Alberta's agri-food gross domestic product, exceeding the productivity of dryland farming by 250 to 300% (AIPA 2001). Major food processing industries have evolved in Southern Alberta, where the longer growing season, high heat units and the relatively secure water supply support production of specialty crops (potatoes, beans, sugar beets).

Irrigation also is the largest consumer of surface water and is a major economic driver in Southern Alberta, with 97% of the total irrigation in the province located in the South Saskatchewan River Basin. The basin has a semi-arid climate with an annual precipitation of between 200 mm and 500 mm (Martz et al. 2007). Irrigation there is organized into the thirteen irrigation districts shown in Figure 1 that together represented 84% of the total irrigated area of the basin as of 2012, with the balance coming from more than 2,200 private irrigation projects (ARD 2013b) (TABLE 1).

Water resources in Southern Alberta are under increasing pressure from economic growth – with growth of urban populations, agriculture and industry – which drives greater water demands in the basin, and threats of increased weather variability and climate change that may reduce river flows or change their timing. Approval of the Water Management Plan for the South Saskatchewan River Basin (SSRB) in August 2006 added additional pressure, closing three of the four sub-basins to new water licenses. Moreover, any expansion of the irrigated land base over the next years will confront a challenge in both water and land, rather than in water only. As a result, the planning process in terms of water and land will change in order to cope with the increasing demand given the same water allocations while balancing the social, economic and environmental needs of the region.

TABLE 1: Irrigated Areas in Alberta in 2012

		Irrigation Area (ha)
13 Irrigation Districts		555,210
Private Irrigators		
	Peace River	1,360
	Athabasca River	800
	North Saskatchewan River	10,870
	South Saskatchewan River	105,710
	Milk River	7,610
Total Private Irrigation		126,350
Total Alberta Irrigation		681,560

Source: ARD (2013b)

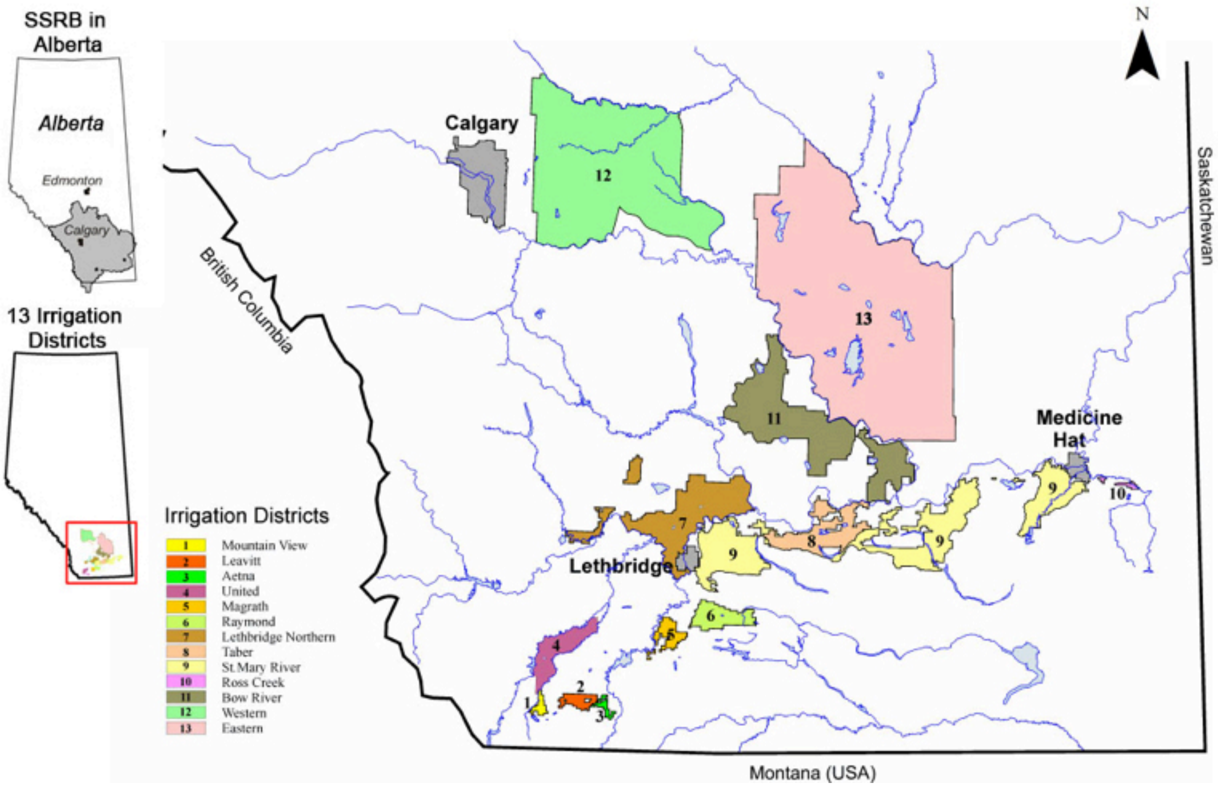


Figure 1: Thirteen irrigation districts in Southern Alberta (Modified after ARD n.d.)

2.2 THE SOUTH SASKATCHEWAN RIVER BASIN

The South Saskatchewan River Basin (SSRB) extends from the Rocky Mountain Continental Divide in Alberta into south-central Saskatchewan. In Alberta, it has a watershed area of 112,800 km^2, of which 41% is in the Red Deer sub-basin, 22% in the Oldman, 24% in the Bow, and 12% in the South Saskatchewan River sub-basin (ARD 2010). Although the basin occupies only 17% of Alberta's total area, it supplies approximately 58% of the total 9.6 million m^3 water allocation in the province (Alberta Environment (AENV) 2007). About 70% of the annual basin runoff is supplied from the Rocky Mountains and foothills (Ashmore and Church 2001) primarily through spring snowmelt (Tanzeeba and Gan 2011).

The actual surface water consumption by all sectors in the SSRB in Alberta is estimated to be approximately 40% of the total water volume allocated for use in 2009 (AMEC 2009), with irrigation representing about 84% of the total consumptive use and concentrated in the Bow River and Oldman River Basins (TABLE 3 and TABLE 4). Additionally, approximately 77% of the private irrigators in Alberta are located in the SSRB (ARD 2013b). These private irrigators are responsible for the installation and maintenance of the infrastructure needed to convey water from the river to the land as well as the irrigation equipment used on the land itself (Nicol et al. 2010a).

Although the SSRB is agriculturally-intensive, it is also highly urbanized. About 88.8% of the population live in urban centers (cities, towns and villages), 10.5% live in rural areas, and an additional 0.7% live on First Nations Reserves (AMEC 2009).

TABLE 2: Water allocations, withdrawal and consumption for the different sectors in SSRB in Alberta

	Allocation (dam³)	Withdrawal (dam³)	Consumption (dam³)
Municipal	776,354	279,323	68,048
Irrigation	3,688,100	2,032,101	1,665,881
Livestock	62,030	n/a	49,972
Commercial	18,457	n/a	14,032
Petroleum	66,790	n/a	24,243
Industrial	71,416	n/a	51,233
Other Sector	304,504	n/a	107,732
Total	*4,987,651*	*2,311,424*	*1,981,141*
Water withdrawal (%) to total allocation			40%
Irrigation consumption percentage of the total			84%

Consumption: use that renders the water unavailable for further use in a river basin through evaporative losses, pollution, o incorporation into products. Consumption figures are provided by water-use sector. Figures are based on recorded data where such data are available. Source: AMEC (2009).

TABLE 3: The 13 Irrigation Districts in Southern Alberta

	Irrigation District	Year ID Formed	Assessment Roll Area as of 2012	Area Actually Irrigated as of 2012	Expansion Limit	Water License allocation	Irrigation Water Allocation	Average Diverted Volume**	Top Four Crops by Area in 2012
			hectare			*dam³*			
Oldman River Basin	Aetna	1945	1,771	1,132	2,023	11,101	10,238	4,698	*Grass Hay, Alfalfa Hay, Tame Pasture, Barley*
	Leavitt	1936	1,959	1,872	2,428	14,802	13,568	7,734	*Alfalfa Hay, Grass Hay, Alfalfa Two cuts, Barley*
	Lethbridge Northern	1919	71,869	71,869	91,864	412,540	364,350	206,638	*Barley, Corn Silage, Canola, Alfalfa Hay*
	Magrath	1926*	7,406	5,736	7,406	41,939	41,026	17,634	*Alfalfa Hay, Canola, Barley, Hard Spring Wheat*
	Mountain View	1923	1,463	217	1,716	9,868	9,868	3,929	*Grass Hay, Native Pasture, Barley, Greenfeed*
	Ross Creek	1949	446	355	490	3,700	3,700	1,268	*Alfalfa Hay, Barley, Canola*
	Raymond	1925*	18,778	16,009	18,818	99,913	94,362	40,262	*Alfalfa Hay, Canola, Barley, Hard Spring Wheat*
	St. Mary River	1968*	151,286	136,962	166,731	890,579	875,777	472,122	*Hard Spring Wheat, Canola, Dry Peas, Durum Wheat*
	Taber	1917	33,488	31,070	37,312	194,891	185,023	114,518	*Hard Spring Wheat, Potatoes, Alfalfa Hay, Barley*
	United	1921	13,914	9,168	13,921	81,669	80,436	24,734	*Canola, Barley, Native Pasture, Alfalfa Two cuts*
Bow River Basin	Bow River	1968*	94,829	84,263	105,218	555,070	552,134	372,947	*Hard Spring Wheat, Canola, Canola Seed, Barley*
	Eastern	1935*	119,229	119,280	125,857	939,919	933,751	649,272	*Tame Pasture, Hard Spring Wheat, Canola, Alfalfa Two cuts*
	Western	1944*	38,764	21,239	38,445	195,385	191,067	153,297	*Canola, Barley, Alfalfa Two cuts, Tame Pasture*

*Formation of an irrigation district from existing irrigated areas
**Average volume 1976-2012
Source: ARD (n.d., 2013a)

TABLE 4: Number of reservoirs and water storage as a percentage of water licenses

Irrigation district(s)	ID reservoirs	Provincial reservoirs	Percentage
Bow River	6	3	100%
Eastern	12		58%
Western	2		7%
Lethbridge Northern	3	2	143%
St. Mary River, Taber, Magrath, Raymond	18	4	89%
Mountain View, Leavitt, Aetna		1	24%
United	1		4%
Ross Creek		1	125%

Source: ARD (2013a)

2.3 *WATER FOR LIFE*: WHERE ARE WE?

Concerns about population growth, drought and agricultural and industrial development led the Government of Alberta to develop the *Water for Life: Alberta's Strategy for Sustainability* plan in 2003 (Alberta Environment (AENV) 2003). The strategy states that current and future water demands arising from the need to ensure economic growth, support a growing population, and provide healthy rivers and lakes, may eventually exceed the available supply. Thus, it aims to manage Alberta's water resources more sustainably and wisely. The strategy identifies three main goals as well as specified outcomes for the short-, medium-, and long-term that will help guide and measure the success of a strategy in achieving these goals. In 2007, the Minister of Environment, Rob Renner, requested that the Alberta Water Council undertake a review of the Water for Life strategy. The Council presented recommendations in a January 2008 report (Alberta Water Council 2008), and the strategy was renewed in November 2008 (Government of Alberta 2008a) with an action plan released in November 2009 (Government of Alberta 2009).

General actions for the Water for Life strategy revolve around three core areas of focus, which include "water conservation", the most applicable topic to the expansion of irrigated agriculture. The water conservation component of the strategy aims to improve the overall efficiency and productivity of water use in Alberta by 30 per cent by 2015 from the base year of 2005 (AENV 2003). Although meeting these objectives is not mandatory, and there is no statutory basis in Alberta law requiring water users to maximize the efficiency of water use (Droitsch and Robinson 2009), the Alberta Irrigation Projects Association (AIPA 2010) voluntarily prepared the "Irrigation Sector Conservation, Efficiency, Productivity Plan, 2005 – 2015", also called the CEP plan, with eight targets to address efficiency and productivity. The progress made by the irrigation districts on the targets set out in the CEP plan covering the period 2005 – 2012 is described in an interim report (AIPA 2013), which states that the gains in efficiency and productivity from 2005 through 2012 have been 22% and 17%, respectively. These total CEP gains amount to 39%, which exceeds the 30% target, and were reached by increasing the percentage of irrigated acreages with low pressure pivots from 47% in 2005 to 66% in 2012; lining canals and laterals or converting them into pipelines; increasing automation in conveyance systems; and growing crops that require less water – in particular, substituting forages with oilseeds and specialty crops. As a result, the average irrigation diversion has declined from 2.2 million dam^3 in 2005 to approximately 1.7 million dam^3 in 2012 (note that 1 million dam^3 equals 1 billion m^3 and 811 000 acre-feet). Further, growth of 2.2% has been accommodated through water savings as a result of efficiency improvements. Finally, the Government of Alberta (2010b) recently reviewed a number of management tools to meet water conservation and productivity objectives of the Water for Life action plan.

3 METHODOLOGY

A discussion of irrigation expansion in the context of socio-economic development and environmental considerations involves actors from a number of groups, including the irrigation community, multiple government agencies, urban and rural municipalities, environmental groups, and agri-food industries. Therefore, the research team attempted to gain insight into irrigation sector expansion risks and trade-offs by using multiple sources of information and also to integrate alternative perspectives, namely through a literature review and discussions with multidisciplinary stakeholders.

The objective of the literature review was to examine and present the challenges and opportunities associated with irrigation expansion in Southern Alberta, and to provide a comprehensive, easy-to-access list of suitable alternative policy and management options for irrigation sector development and expansion over the next 25 years. The literature presented in this report is a summary of published articles in scholarly journals and grey literature (Alberani et al. 1990; Jeffery 2000). Grey literature refers to information produced at all levels of government, academia, business and industry which is not controlled by commercial publishing groups (GL '99) and is not necessarily peer-reviewed. Relevant literature was identified and retrieved in a three step process, as follows:

1. Appropriate databases were identified. Using information from the University of Alberta libraries, 10 databases were identified. These databases were (descriptor of each database as given by the provider in parenthesis; and sorted in alphabetic order): AgEcon Search (agricultural and applied economics), Google Scholar (interdisciplinary), Proquest (Dissertations and theses in Canada, the U.S. and the EU), ScienceDirect (scientific, technical, medical, business and economics literature), Scirus, (science, technology and medicine), Scopus (science, technology, medicine, social sciences), SpringerLink (multidisciplinary), Web of Science (science and social sciences) and Statistics Canada (government publication). The period of the literature review extends from 1989 to 2014.
2. Appropriate keywords for the literature search were identified. The keywords used for this review include: agriculture in Alberta, agricultural policy, climate change, dams, droughts, environmental risks, food processing, incentives, irrigation districts, irrigation expansion, irrigation management options, irrigation opportunities, irrigation risks, land use, land use changes, land use policy, livestock, market-based instruments, South Saskatchewan River basin, Southern Alberta, water conservation, water diversion, water for life, water policy, water pricing, water trading, and water use efficiency.
3. Articles were filtered based on the relevance of the document to the research topic. In total, 113 articles were selected and presented in the report.

In addition to the literature review, a number of stakeholders representing the agricultural sector in Southern Alberta participated in a one-day workshop in Lethbridge, Alberta, in January

2014. The group of fourteen participants included irrigators, ranchers, irrigation district representatives and board members, economists, government policy advisors and representatives (ARD, ESRD, and Economic Development), academics and business representatives. Others groups approached included Agriculture and Agri-Food Canada (AAFC), Ducks Unlimited, the Potato Growers Association, the Canadian Cattlemen Association, and municipal water planning agencies; however they were not able to attend. Also in attendance were four members of the project Advisory Panel, five members of the research team and one member representing the Alberta Land Institute. Therefore, 24 people in total attended the workshop.

The workshop was divided into four sessions that focused on,

1. The current state of irrigation in Alberta,
2. Desired future states for Alberta's irrigation sector,
3. Stressors and constraints on the current state and future expansion, and,
4. Desirable management actions and policy reforms.

Participants were divided into four groups, each of which was assigned a table. Focus group participants were pre-assigned to each table to provide intersectoral perspectives, and to ensure equal representation from the agricultural sector at each table. Further, each table had at least one member of the research team and one member of the project's advisory panel. It is worth noting that consensus was not required of the participants; instead, the conversations focused on providing information for consideration in the research.

Firstly, the discussions centred on physical assets and current problems associated with irrigation, water supply, land-use and land value, the state of current infrastructure, productivity and profitability levels of irrigated and dryland agriculture, and irrigation management practices and technology adoptions. Secondly, participants shared their vision for irrigated agriculture in the province over the next 25 years. They were also able to identify a number of preferred outcomes related to changing agricultural productivity, water allocation and use, land-use, and agri-food business expansions. The third conversation session discussed stressors on the current irrigation system and constraints to achieving their vision of irrigation into the future. Finally, the fourth set of conversations focused on exploring the possible actions, policy options and reforms, and management strategies in terms of land-use, water, agriculture, and finances to alleviate current stressors and to facilitate reaching their desired future state. Throughout the discussions, participants aimed to balance "the triple bottom line" of social, economic, and environmental benefits of irrigation in Southern Alberta for the future, as well as the trade-offs involved in preferred options. The discussions resulted in a list of policy and management options involving the government, irrigators, agri-business groups, and environmental groups.

The participants were asked five questions, listed below. However, they were free to depart from them to express their concerns and to raise questions to help shape the research priorities. The questions were,

- What is the current state of irrigated and dryland agriculture in the irrigation districts of Southern Alberta?
- Where should irrigation and dryland agriculture in Alberta be going over the next 25 years? What is your vision of the future of irrigation in the province? And what are your "burning questions"? What would you ask an oracle?
- What constraints/stressors do we face for changes into the future? Ranked list of biggest problems?
- What can help us reach this vision of the future? For example, government policies, subsidies, infrastructure, other social, economic or environmental factors?
- You can also provide a set of policies that you would like to see debated or enacted. Finally, please rank the policies mentioned above (including your suggested policies) based on their importance to your group

Because participation was anonymous, the focus group at each table was assigned a number; that table number is used below to identify the source of the comments. For example, DT1 refers to discussion table 1, and DT2, DT3 and DT4 refer to tables 2, 3, and 4 respectively.

4 CHALLENGES FACING THE IRRIGATION SECTOR

4.1 DEMOGRAPHIC CHANGES AND POPULATION GROWTH

AMEC (2009) provided two independent population projections for the SSRB based on both census data and municipal growth rates and Alberta Health and Wellness growth rates (AHW 2007) to 2030. They show an increase in the basin's population from 1.65 million in 2006 to 2.34 million by 2030 in one scenario, and to 2.59 million in a second scenario – growth of 43% and 57%, respectively.

The participants remarked that the increase of population in Alberta will cause a loss of irrigated land and agriculture in general. They provided the example of Medicine Hat, where approximately 2000 ha (or roughly 5,000 acres) of prime agricultural land is being lost to the construction of a ring road (DT2 2014). They stated that population growth is most likely to result in land fragmentation, rather than affect than the types of crops being grown. At a larger scale, agriculture in Alberta might adapt to capture global markets driven by world population increases and especially changing Asian diets (DT2; DT3; DT4 2014).

However, it is not likely that municipalities, in terms of basic human needs, will compete with irrigation for water. For example, Alberta's thirteen irrigation districts approved a declaration in 2011 ensuring that in times of drought in Southern Alberta, human and livestock needs will be met before those of irrigated agriculture (News Wire 2011). However, it is evident that during droughts irrigation might face greater shortages as the population grows.

4.2 THE LABOUR MARKET

The aging of farmers and ranchers, and concerns about passing agricultural lands and traditions to the next generation, are major stressors for agricultural producers in Southern Alberta. Attracting and retaining both trained and affordable labour in agriculture, with its unfortunately low profile in terms of career choice, and the competition from other sectors (e.g., oil) is a serious challenge for irrigation expansion. In addition, young ranchers often view the work as unfavourable and tedious, which adds more pressure to the agricultural labour market (DT2; DT3; DT4 2014). The resulting reduction in the percentage of the population involved in agriculture may reduce the influence of the broader farming community on politics and government policy (DT2; DT3 2014)

During the workshop some participants pointed out that the aging and low entrance of ranchers into the market are among the main reasons that the cattle and calves market is not expanding (DT2 2014). Expansion may still occur, however, given the increasing demand from developing countries (DT4 2014), which are changing their diets towards greater consumption of animal products as their incomes rise (Delgado 2003). Additionally, there was also concern expressed about farm succession planning, and taxation issues related to succession were among the greater challenges identified (DT2 and DT4 2014).

4.3 PUBLIC PERCEPTION

> *"Public perception and the competition for water between agriculture and recreation is always a constraint"* (DT1 2014).

> *"Canada's current ad hoc approach to building public support (a.k.a. social licence) for resource development is inadequate to the challenges ahead of us. A more systematic approach is required before stakeholders can hope to begin reversing current trends"* (Cleland 2014, p.1).

How the public views agriculture in Alberta – which is related to the agricultural sector's "social license to operate" – influences the ability of irrigation to expand, since government policies are affected significantly by public opinion (DT1; DT2; DT3; DT4 2014). As noted earlier, the majority of the population in the SSRB is urban, and the urban proportion continues to increase. Workshop participants stated that urban residents therefore have political "clout", and the broader farming community has less influence on politics and government policy, including the decisions taken with regard to agriculture and rural development (DT2; DT3 2014). Furthermore, recreational interests may influence reservoir management, as in case of Chestermere Lake reservoir in Alberta, which is an irrigation reservoir that is operated now primarily for recreational purposes (DT3 2014; Bewer et al. 2012).

Participants noted that the public constantly hears more about other sectors (e.g. oil sands) and how they are driving Alberta's economy compared to irrigation (DT2 2014) – a bias that leads to incomplete information to both consumers and producers (DT2 2014). However, the situation is not necessarily straightforward, since the

> *"…return on investment in irrigation might be a negative value currently, as dryland is producing as much as irrigation; analysis would have to look at many years of compared outputs, as well as value-added food processing"* (DT2 2014)

> *"Without irrigation, there wouldn't be big companies in Southern Alberta – like McCain and Rogers Sugar – and there wouldn't be the big feedlots in Feedlot Alley, either"* (DT2 2014)

4.4 ENVIRONMENT

A challenge facing the irrigation sector is the increasing pressure from environmental lobby groups, which urge farmers to limit use of water for anything agriculture-related (DT2 2014). Workshop participants also described "indirect" competition from agricultural producers and lobbies in neighbouring regions, which have funded environmental groups within Alberta to increase public pressure for policy changes that result in raised costs to irrigated agriculture in the province (DT1 2014). Further, the increased public demand for high-quality water in the river systems could be a challenge as well (DT2; DT3 2014).

Irrigation water quality is not currently a challenge for irrigators, although a number of participants worried about increased fertilizer from crops, pesticides from urban centres and water contamination from treated municipal wastewater effluents – an example was estrogen from birth control pills (DT2; DT3 2014). However, land degradation is a major concern, and irrigation effects on soil quality have been widely studied around the world. The development of irrigation has been found to be associated with the loss of fine soil particles, leaching of nitrogen and phosphorus and secondary soil salinity (Essiet 1990; Kitila et al. 2013; McDowell et al. 2011; Zhang et al. 2009). Such studies are lacking for Southern Alberta. Any further studies with similar results would draw the attention of farmers, landowners, scholars and other stakeholders with potentially adverse effects on irrigation expansions in the region.

In terms of biodiversity, irrigation can affect surface runoff, and can have a significant effect on surrounding flora and fauna, but the literature suggests inconsistent effects. McGinness et al. (2013) and Cook and Faeth (2006) showed that irrigated areas were refuges for arthropods compared to other land uses around Pheonix, Arizona. However, McGinness et al. (2013) also found that irrigation led to less structural complexity in the surrounding floodplain woodlands in the Murrumbidgee River catchment in South-east Australia. Some workshop participants raised the issue of invasive species as well. Recently, for example, zebra mussels were found in Lake Winnipeg – these mussels are a major concern to irrigators because they could clog irrigation pipes. Further, with a changing climate, other pest species that were not able to tolerate the winter cold might now able to survive in a warming climate (DT2 2014).

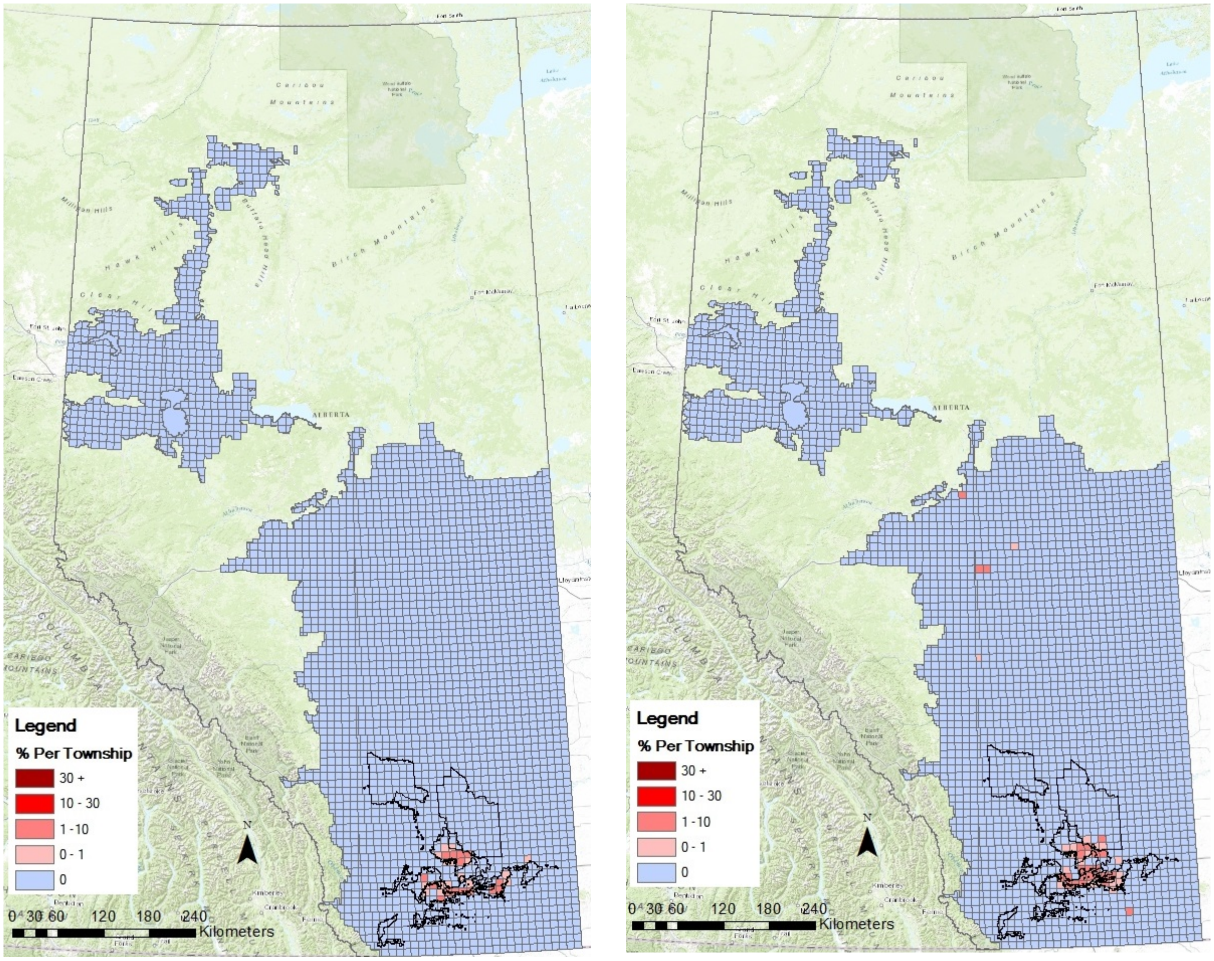
5 OPPORTUNITIES

The irrigated area within the 13 irrigation districts has increased gradually since the early part of the twentieth century, with accelerated growth in the 1970s and 1980s (Bennett et al. 2013). Expansion has been possible within existing licensed allocations because average diversions for irrigation have reduced and efficiency has increased, as discussed in section 2.3.

Over the two decades from 1993-2002 and 2003-2012, the total irrigated farm area increased by 0.72% and 0.38% per year, respectively. From 2003 to 2012, forage areas decreased, while specialty crop areas increased (ARD 2013b). Potatoes made a large contribution to the change, with the irrigated area for potatoes increasing from 8700 ha in 1995 to over 18000 ha in 2012 – a rapid increase that paralleled the expansion of world-class agri-food processing companies in Southern Alberta, including Lamb-Weston and McCain Foods. Crop inventory maps released by Agriculture and Agri-Food Canada (AAFC) reveal that several high value-added crops, such as sugar beets and potatoes, are only cultivated in irrigation districts (Figure 2), because of the large amounts of water essential for their growth. Thus, any expansion of irrigation is likely to encourage farmers to grow more of these valuable crops. The Irrigation Water Management Study Committee (2002) estimated a gross return from irrigation of $965 per ha, which was more than three times the return from dryland agriculture, based on real data from 1999 in the South Saskatchewan River Basin. Samarawickrema and Kulshreshtha (2008) explained in detail the benefit of irrigated farms relative to drylands: additional water supply from irrigation not only offsets the adverse impact of drought, but also increases productivity because the high summer temperatures in the SSRB help increase evapotranspiration, which leads to greater crop growth when moisture is not constrained.

Workshop participants indicated that changes in the crop mix in Alberta are essential. They argued for more investment in high-value crops and stated that producers are likely to broaden their crop mixes to adopt a strategic crop mix that lessens the risk involved with changes in crop prices. Also they believe that crop insurance will facilitate the increase of high-value crops (DT1 2004) and noted that high crop prices in recent years tended to increase the profitability of dryland agriculture (DT2 2004). However, high crop prices have also shrunk the livestock industry, as input costs increased (DT4 2014). Finally, they pointed out that the quality of irrigated crops is a market asset for Alberta. For example, potatoes grown in Alberta have the lowest active ingredients of pesticides per acre, which is a crop characteristic the potato industry should exploit to expand (DT3 2004).

High-cost irrigation facilities and irrigation water rights also raise the value of agricultural land. Based on agricultural land transaction values provided by ARD (2014), we estimate that the agricultural land value in irrigated districts is about 1.5 times the average value for the province. This difference increases the potential assets of irrigation farmers and may stimulate them to protect agricultural land. The protection of irrigated land and its greater productivity may help to increase the exports of agri-food and economic growth in Alberta given any expansion in irrigation.



(a) (b)

Figure 2: The average pattern of (a) sugar beets and (b) potatoes in Alberta (2010- 2012)

Using the Farm Financial Impact and Risk Model (FFIRM), Bennett et al. (2013) concluded that water supply deficits had no impact on the net farm income (NFI) during a recent period of irrigation expansion (1991-2009, an increase of 4.58% compared to the 1991 irrigation acres), due largely to the improved water management in irrigation districts. They also predicted that water supply deficits would cause only a small reduction in NFI in a projected expansion scenario of an 8.24% increase compared to the 2009 irrigation acres. However, more generally, with continuous irrigation expansion and its associated increasing water demand, we would expect water supply deficits to be the main obstacle to further development of irrigation: "Water is the liquid gold of the future", according to a workshop participant (DT2 2014).

In terms of water quality, workshop participants noted that irrigation water quality in Southern Alberta is generally good – an advantage that should be promoted. It may also be an asset for us in the future, and campaigns with slogans like “Food grown with water from the Rockies” could be used to market Alberta’s food products globally (DT2 2014).

Finally, in addition to natural resources, participants stated that Alberta’s openness to innovation and risk-taking is high compared to other regions around the world, regardless of the climatic risks (DT1 2014). This openness increases its ability to accommodate more irrigation expansion, agriculture production and agri-food business development.

6 CHALLENGE OR OPPORTUNITY?

6.1 CLIMATE CHANGE

"Agricultural production, more so than any other form of production, is impacted by the weather." Stroh Consulting, 2005 as cited in Lemmen et al. (2008)

The South Saskatchewan River Basin is strongly dependent on surface water. That dependency makes the basin one of Canada's most vulnerable watersheds to the potential impact of climate change (Martz et al. 2007). Therefore, it is essential to understand the possible hydrological impact of climate change on river flows in the SSRB (Tanzeeba and Gan 2011). In their study of physical, hydrological and socio-economic impacts of climate change on the SSRB, Martz et al. (2007) found that climate change would shift the social, economic and environmental priorities and activities of the basin due to a significant decrease in summer flows, increased drought, increased aridity and increased irrigation demands.

A Government of Canada report on climate change (Lemmen et al. 2008) provides general conclusions regarding impacts of, and vulnerabilities to, climate change in terms of physical and biological systems in Canada (water resources, ecosystems, agriculture, forestry, energy, and so on). Its chapter on the Prairies (Sauchyn and Kulshreshtha 2008) identifies a number of positive impacts, where benefits could result from warmer and longer growing seasons and a warmer winter, as well as negative impacts, which may result from changes in precipitation timing, increased drought and pest risks, and excessive moisture. Amiro et al. (2014) present the thoughts of twenty-three experts, professional agrologists from the federal and provincial governments, and industry and university representatives, on Prairie agriculture to 2050 in response to climate change. Some expect that the Prairies will gain opportunities that presently occur further south, and others expect that warmer winters by 2050 will probably not change agriculture on the Prairies. However, the change in frequency of extreme events will likely alter some agricultural practices.

6.1.1 Impacts on water supply

Changes in precipitation and temperature due to climate change are the primary controlling factors for water availability in any basin (Islam and Gan 2014). Rood et al. (2005) revealed a historical decline in the mean annual discharge of many of the rivers that drain Rocky Mountain watersheds, including the SSRB tributaries. On a seasonal basis, historical stream discharge data have revealed slightly-increased winter flows, advanced spring peak flows and a more gradual rising limb of the annual hydrograph, and considerably decreased summer flows, especially in late summer and early autumn (Rood et al. 2008). An analysis for declining stream flow records in Southern Alberta conducted by St. Jacques et al. (2010) concluded that the decline is due to hydroclimatic changes, probably from a warming climate. However, records reflect both global warming effects and direct human impacts from intensive water use and development activities in Southern Alberta, which obscured the natural hydrology of some of the rivers in the region.

Over the next 25 years, the SSRB is expected to experience an increase in temperature and a significant decrease in the mean annual average and maximum stream flows due to climate change, despite the increase in predicted precipitation (Islam and Gan 2014; Tanzeeba and Gan 2011). Tanzeeba and Gan (2011) suggested that the projected increase in evaporative losses due to increased temperature will offset the projected precipitation increase. In a continuation of the historical trend, the basin is also expected to experience decreases in future annual and summer stream flows, and snow water equivalent, and an earlier onset of spring runoff (Tanzeeba and Gan 2011). Shepherd et al. (2010) projected considerable declines in summer flows in the Oldman River Basin but increases in winter and early spring flows, with an overall decline in annual discharge of between 3% and 9% over the period 2005–2055. In contrast, Larson et al. (2011) and MacDonald et al. (2011) projected decreases in spring flows from snowmelt for the 21st century. Lapp et al. (2009) also found decreased stream flows for the South Saskatchewan River and its tributaries and a shift of the dominant flow season from summer to spring for some rivers. Pietroniro et al. (2006) estimated decreases in the mean annual flows by the 2050s by 13%, 10%, 4% and 8.5% for the Red Deer River at Bindloss, Bow River at the mouth, Oldman River at the mouth, and South Saskatchewan River at Lake Diefenbaker, respectively. Indeed, the "…future water availability in Southern Alberta does not look encouraging, even without considering the expected increasing water demands of a growing economy and population" (St. Jacques et al. 2010, p.4). The previous reviewed studies justify the concerns raised by DT1 (2014) during the workshop that expanding irrigation is associated with the risk of uncertainty of future water supplies and the inability to "rest in the face of a potential decrease in the water supply".

6.1.2 Impacts on crops and livestock

Climate change may affect crop yields and production as much as it affects stream flows in rivers, with considerable variation in crop responses to climate change, including both gains and losses (Lemmen and Warren 2004). Workshop participants were concerned about the implications of climate change for both water supply and water demand (DT4 2014). Generally, the demand for water for irrigation and livestock is expected to rise with increasing temperatures and expansion in these sectors. Their concerns were matched in a recent study by Islam and Gan (2014), who projected an increase in percentage of the number of years with water deficit for irrigation districts to approximately 10% for the period from 2010–2039 compared to 3% in the past. Further, "Because they have the privilege of getting water instead of their junior counterparts, senior private irrigation users will not be affected [significantly] by the impact of climate change in 2010–2039" (Islam and Gan 2014, p.340), whereas they predicted an increase in the percentage of years with water deficits to 16-24% for junior private irrigators over the same period, as compared with 11% in the past.

Among the impacts of climate change on crops in Alberta, McGinn et al. (1999) indicated a positive impact of climate change on crop yields and diversity, where yields of canola, corn, and wheat in Alberta may increase by between 21% and 124%. Lemmen and Warren (2004) described possible positive and negative impacts of climate change on agriculture crops in Canada, stating that the net impact on Canadian crops is uncertain, and depends largely on the adaptation measures undertaken. For example, Singh et al. (1998) suggested that in Quebec, corn, sorghum, canola, sunflowers, potatoes, tobacco and sugarbeets may benefit, whereas yields of wheat, soybean, green peas, onions, tomatoes and cabbage are likely to decrease. Other impacts on crops due to changes in meteorological variables in the Canadian Prairies were described in Wang et al. (2012) and He et al. (2012). Qian et al. (2013) predicted a longer growing season for the Prairies and Amiro et al. (2014) suggested that the two crops showing the most potential to increase in response to longer growing seasons are corn and soybeans.

In Alberta, there are more than 7 million head of livestock (cattle and calves, sheep and lambs, and pigs), although numbers have decreased almost 20 per cent over the past 10 years. Livestock and livestock products accounted for more than $4.8 billion in farm cash receipts in 2012 (ARD 2013a). However, despite the economic importance of livestock operations to Alberta, few studies have examined potential climate change impacts for livestock in Alberta (Lemmen and Warren 2004).

Recently, a wetter climate and longer growing season have benefitted dryland agriculture in Alberta (DT2; DT4 2014). Indeed, dryland agriculture is experiencing new opportunities for cultivation of crops that used to be grown only on irrigated lands (DT2 2014). Into the future, most regions of Canada are expected to experience warmer conditions, longer frost-free seasons, and increased evapotranspiration with climate change. Further, the positive effects of warmer temperatures and enhanced atmospheric CO_2 concentrations on crop growth may offset the negative impacts of increased moisture stress and accelerated crop maturation time, assuming no changes in pest and pathogen outbreaks (Lemmen and Warren 2004). Sauchyn and Kulshreshtha (2008) also suggested that enhanced opportunities for agriculture in the Prairies may result from continued expansion of the growing season, increased heat units, and milder and shorter winters.

7 POTENTIAL POLICY AND MANAGEMENT STRATEGY OPTIONS

A set of adaptation options, proposed below, has the potential to 1) address challenges discussed earlier, 2) introduce and increase opportunities for irrigation expansion, and 3) reduce vulnerability of the irrigation sector to future risks. Options include land, water, agricultural, and financial policies. The report does not quantify the effects of such policy options or reforms, but rather gives an overview based on the literature and workshop discussions.

Several policy instruments have received significant local attention in Southern Alberta. A large number of studies, both academic and technical, were reviewed to identify a list of possible policy options and management strategies. The studies had a variety of purposes, including:

- Identifying policy suggestions and reforms,
- Giving recommendations for improvements and implementation of different policy options,
- Examining potential policy instruments to conserve water to expand irrigated agriculture and maximize economic gains, and,
- Raising research questions about other non-traditional policies, in addition to surveys that could help policy makers to shape publically-accepted policies and management options for the Province's agriculture sector.

The identified policy and management options were compiled and listed in TABLE 5, followed by a description of the policies and their effects from the literature and the workshop discussions.

TABLE 5: Potential policy and management strategy options identified for the irrigation sector in Southern Alberta

	Adamowicz and Horbulyk	Adamowicz et al. (2010)	AECOM (2009)	AEDA (2008)	AEDA (2013)	Alberta Water Council (2007)	Alberta Water Council (2009)	Alberta WaterSMART (2013)	Ali and Klein (2014)	AWRI (2009)	Bennett et al. (2013)	Beveridge et al. (2010)	Bjornlund et al. (2007)	Bjornlund et al. (2009)	Bjornlund et al. (2013a)	Bjornlund et al. (2013b)	Bjornlund et al. (2013c)	Coffi et al. (2011)	Droitsch and Robinson (2009)	Government of Alberta	Hall et al. (2012)
Alternative water supplies								X													
Incentives for water conservation			X										X						X		
Integration of water and land-use policies						X				X		X							X	X	
Irrigation management practices													X	X							
Joint management of surface and groundwater																			X		
Maintain an agricultural land base																				X	
On-farm water efficiency			X										X	X	X						X
Optimize crop mixes																				X	
Prioritize basic human needs				X		X			X	X									X		
Private individuals and groups to hold water for environmental purposes							X			X						X	X		X		X
Proportional water sharing									X						X				X		
Public awareness and involvement in policy and management planning			X			X	X			X									X	X	
Restrain increase of irrigated acres											X										
Return flow management				X	X		X	X		X											
Water conservation for the environment				X		X	X			X						X	X		X	X	X
Water conveyance system enhancement			X	X												X					
Water pricing	X												X		X			X			
Water reuse and recycling				X	X			X		X											
Water storage			X	X																	
Water trading	X	X	X	X			X		X	X			X		X	X	X	X	X		X
Water use monitoring and measurement, data collection			X	X		X	X			X									X		
Watershed preservation						X						X								X	

TABLE 5: Potential policy and management strategy options identified for the irrigation sector in Southern Alberta (continued)

	He and Horbulyk (2006)	He and Horbulyk (2010)	He et al. (2012)	Horbulyk (2005)	Horbulyk (2010)	Horbulyk and Lo (1998)	Ko and Donahue (2012)	Minister's Advisory Group (2009)	Nicol and Klein (2006)	Nicol et al. (2008)	Nicol et al. (2010)	Pentney and Ohrn (2009)	Ploeg (2010)	Ploeg and Sommerfeld (2011)	Russenberger et al. (2011)	Sandor et al. (2010)	Wilkie (2005)
Alternative water supplies													X				X
Incentives for water conservation					X						X		X			X	X
Integration of water and land-use policies								X				X					
Irrigation management practices										X	X						
Joint management of surface and groundwater				X				X									X
Maintain an agricultural land base																	
Optimize crop mixes		X	X														
On-farm water efficiency	X						X		X	X	X						
Prioritize basic human needs																	
Private individuals and groups to hold water for environmental purposes							X	X							X		
Proportional water sharing			X														
Public awareness and involvement in policy and management planning													X				X
Restrain increase of irrigated acres																	
Return flow management																	
Water conservation for the environment							X	X				X	X		X	X	
Water conveyance system enhancement				X									X				X
Water Pricing	X	X			X					X	X		X	X			X
Water reuse and recycling				X									X				X
Water storage	X							X									
Water Trading	X	X	X	X		X	X	X	X		X	X			X	X	X
Water use monitoring and measurement, data collection					X								X			X	X
Watershed preservation																	

7.1 WATER TRADING

Market-based policy instruments help to reallocate water resources efficiently both between existing users, and between existing and new users. One such instrument, a water market, allows voluntary reallocation between water users, so that water can be moved to more efficient and high-value uses. The Water Act permits both temporary transfers of water allocations and permanent transfers of water rights. Further, under the Irrigation Districts Act, irrigated land owners can transfer water licenses to other irrigators within the same irrigation district, given the approval of the District's Board of Directors (Nicol et al. 2010b).

Water trading provides an incentive to conservation, encourages cooperation between water users, and generates money to offset costs of infrastructure upgrades (Wilkie 2005). Water can also be allocated to the environment through a water conservation objective (WCO) license. Under current legislation, however, only the government can hold such a license, and may withhold up to 10 per cent of the water from a license being transferred to protect the aquatic environment or to implement a WCO. This holdback applies to both permanent and temporary transfers, but only to the volume of water being transferred.

Water trading is constantly debated in Alberta, with little support from the irrigation sector (Bjornlund et al. 2007). Indeed, workshop participants were worried that if the province moved to a "true" water market, the water licenses would go to the highest-cost user – which could mean that oil companies would buy water rights or environmental groups could buy water rights and "dump [the water] back in the river". However, participants were not opposed categorically to water markets but rather were concerned about the negative effects if the market were set up poorly. An additional fear was that water license holders could refuse to sell their rights, which might impede economic development (DT2 2014). Finally, an unexpected consequence of trading is that some irrigation users may find selling water more profitable than utilizing their allocations for crop production (Ali and Klein 2014). For example, In Australia, rice has a gross margin of approximately A$200 (C$201) per tonne; at allocation prices higher than that, rice growers often choose to sell their water allocations, rather than sow a crop (National Water Commission 2011). Bjornlund et al. (2013) describe the public's views towards water sharing in SSRB in greater detail.

Interestingly, water trading can also provide a perverse incentive to use more water:

> "*...the introduction of transferable water entitlements in heavily allocated rivers can make the restoration of minimum flows even more difficult because they create incentives to put to use water that might previously have been available to the river system through return flows*"
> (Adamowicz et al. 2010, p.14)

By 2008, there had been approximately 28 water rights transfers in Alberta since the introduction of water transfers in the 1996 Water Act legislation (Droitsch and Robinson 2009). In comparison, Australia's southern Murray-Darling basin, which contains most of the irrigated agriculture in the basin, had approximately 22,000 allocation trades (short-term trades to use the water) in the period of 2007-08 and approximately 2,700 entitlement trades (long-term trades to access the water) (National Water Commission 2011). Bjornlund (2006) describes how Australian irrigators have used markets as a risk management tool. Further, the economic implications of water trading in Southern Alberta were investigated by Ali and Klein (2014), He and Horbulyk (2010), and He et al. (2012).

Some conceivable barriers to the implementation of water markets and trading, as well as some underlying reasons for the opposition of water markets in Alberta, were described in Adamowicz et al. (2010), AEDA (2008), Alberta Water Council (2009), and Bjornlund et al. (2013a). Further, the Alberta Water Council (2009) provided a set of 23 recommendations – subject to existing legislation in the form of the Water Act – to promote and improve the water allocation transfer system in Alberta.

7.2 WATER PRICING

"We've been treating water as a free good. If beer were a free good, we'd have a shortage of beer too" Terry Veeman, Edmonton Journal (Brooymans and Hanneke 2003), as cited in Ploeg (2010, p.76)

Water pricing is one of two market-based policy instruments (water trading and water pricing) that can be used for irrigation water management to promote conservation and the wise use of water. It involves attaching "prices" (government-determined rather than market-based[1]) to the use of water – even if that "price" is later refunded to the users (Horbulyk 2010).

Horbulyk (2010) discussed operational and administrative requirements to implement a water pricing system in Alberta, and Adamowicz and Horbulyk (1996) reviewed the use of water markets and water pricing to address problems associated with water allocation. He and Horbulyk (2006, 2009) studied the effect of water pricing on changes to cropping areas and cropping patterns, as well as the economic welfare of the Bow River Basin. Ploeg (2010) discussed the promise of pricing to encourage water-use efficiency, promote conservation, and encourage investment in and adoption of new water-saving technologies and innovations, as well as its potential drawbacks, and some critiques of pricing – for example, setting a water price is unfair because there is no substitute to water. Wilkie (2005) suggested the use of pricing as a potential demand-management policy instrument in Alberta. More generally, Bjornlund et al. (2007) reviewed a set of international experiences on water pricing. They found that the literature is inconclusive in terms of the ability of pricing to reduce water demand. While a

[1] Market prices are economically determined while administered prices are politically determined and may not reflect the water's economic "value" or true "price". The former is the result of market interactions while the latter is the result of a political decision to charge a nominal amount for consuming a good or service (Ploeg 2010).

number of the studies showed positive responses, other experiences were negative. They also surveyed irrigators in Southern Alberta on the use of economic instruments to achieve the *Water for Life* goals, as well as other approaches to achieve efficiency improvements. Dinar and Subramanian (1998) reviewed water pricing experiences across 22 countries in various sectors, and revealed different reasons to charge for water, including cost recovery, redistribution of income, improvement of water allocations, and water conservation. High-income countries were relatively more open to reforming water pricing policies (Dinar and Subramanian 1998).

In practice, the majority of irrigation water users in Alberta pay for the energy costs of pumping water through the irrigation system – a use-related cost that is, on average, doubled for private irrigators due to higher pump lifts (AECOM 2009). Participants noted that energy costs are currently reducing water use, and that such an effect can be seen as a form of water pricing (DT1; DT3 2014). More generally, irrigators are concerned that,

> *"Water pricing, if it is too blunt an instrument, will rack the industry. It is not a constraint in itself but if done poorly could be a nightmare"* (DT1 2014).

7.3 PROPORTIONAL WATER SHARING

A proportional allocation policy aims to reduce allocations to all users in an equal proportion, as opposed to the current seniority-based system (Ali and Klein 2014). Proportional sharing is proposed for Southern Alberta by Droitsch and Robinson (2009, p.23), who state that "…water licences should be converted to water 'shares' that entitle the holder to a portion of the water available for diversion in each time period. While water licences currently provide the right to withdraw a fixed volume of water, a water share would provide the right to withdraw a percentage of water available on a seasonal basis up to a specified maximum volume limit". Ali and Klein (2014) showed gains for the irrigation sector with implementation of the policy. In contrast, He et al. (2012) found that although proportional water sharing could clearly benefit those who might otherwise be denied water during shortages, it was less clear that the policy would bring overall gains, and if it brought gains, how large they might be. Note that a more detailed description of operational definitions of proportional allocation systems and their applications in other parts of the world is available in He et al. (2012). However, as stated above, a number of workshop participants did not support policy options like proportional sharing and said that the current "first-in-time, first-in-right", or FIT-FIR, system should not be touched.

7.4 WATER USE MONITORING AND MEASURING

Horbulyk (2010) suggests that monitoring water distribution through conveyance, drainage and reservoir works can promote water conservation and increase the efficiency of water use, through providing users with direct feedback about their own practices relative to targets and community norms. Metering and monitoring of water withdrawals and return flows is considered a prerequisite for implementation of other policy options, and particularly water pricing. It also provides accurate baseline information on water use as compared with effects of improvements in the irrigation water sector.

Proper monitoring and measuring requires implementing automated response systems, also referred to as SCADA systems, for water conveyance structures. However, these systems of electronic control and radio communications equipment are expensive – especially if the basin is large and irrigation-intensive, like the SSRB. AECOM (2009) estimated that the incremental cost to monitor and automate these conveyance systems would add, on average, another four to six percent to the cost of re-developing those works. Given the value of the conveyance systems in 2009, the cost to install these systems is estimated as being in the order of $90 to $100 million.

A number of studies argue that reporting both withdrawals and return flows would provide the information needed to manage watersheds on a real-time basis, support management decision-making, and provide incentives for users both to conserve water and to use diverted water more efficiently (Alberta Water Council 2007; AWRI 2009; Droitsch and Robinson 2009; Sandor et al. 2010; Wilkie 2005). Furthermore, measuring the total supply of water (surface and ground water) was also identified as a key ingredient in making effective water management decisions (Wilkie 2005). Finally, AEDA (2008) recommends implementation of monitoring and reporting of actual water use by private irrigators, the largest consumptive users of water in the Red Deer River sub-basin.

7.5 INCENTIVES FOR WATER USE CONSERVATION

Incentives are positive measures designed to encourage certain actions or behaviours. Examples include cash subsidies, tax breaks, credits, and grants, or low interest loans (Wilkie 2005). The application of incentive programs to irrigation would generally benefit both the irrigators and the government of Alberta by saving more water, and thus 1) increase the water productivity and 2) contribute to irrigation expansion by reallocating the saved water to irrigation expansion. Saved water could also cover the water demands of agriculture-related activities, such as livestock farming and agri-food processing, or of other water-use sectors.

Participants during the workshop expressed concern that incentive programs could fail if they require producers to change their businesses models too much: "You don't want to have an incentive in place that makes you shift your business structure in order to take advantage of it" (DT1 2014). Moreover, participants stated that monetary incentives should be reasonable, as the capital cost of adopting, developing, and implementing upgraded systems has been borne primarily by irrigators. They pointed to the "Growing Forward" program from Alberta Agriculture and Rural Development, which encourages irrigators to replace less efficient equipment with low pressure pivots. However, the value of the $5,000 incentive was debated by workshop participants in terms of the cost of a pivot, which can be typically $100,000 (AIPA 2013), and in terms of the incentive value, which is per-farmer or producer rather than per pivot. The Eastern Irrigation District (EID) has used monetary incentives to encourage conversion to higher efficiency systems in the recent years. For example, the district's Farm Improvement Incentive Program rewards farmers for converting to a more efficient method of irrigating that conserves water. In 2012 the EID board approved 57 farm improvement grants totaling $382,500; 45 of these were for converting to low pressure pivots, and the remainder were for land leveling, converting to wheels, gated pipe, and relocating drains to accommodate pivots (EID 2012). More generally, two survey studies revealed that both district and private irrigators preferred cash subsidies to subsidized borrowing rates and accelerated depreciation as incentives to invest in more efficient irrigation technologies (Bjornlund et al. 2009; Nicol et al. 2010a). Therefore, the real challenge is not only to achieve greater water conservation through incentives but to do so without affecting agricultural productivity. Furthermore, any incentive program that conserves water will face the question of how the saved water should be used and who should receive the benefits (DT1 2014).

A number of studies have also explored or analyzed incentives as a policy option in Southern Alberta. A survey by Bjornlund et al. (2007) indicated low support from irrigators for economic instruments as policy options, including incentives. Droitsch and Robinson (2009) and Sandor et al. (2010) proposed developing return-flow water conservation credits or compensation for returned allocations and financial incentives to encourage the wise use of water. Horbulyk (2010) suggested, after a review of water pricing, to adopt a "refundable approach" that returns fee revenues to the users while preserving users' incentives to use water efficiently. Nicol et al. (2010a) and Ploeg (2010) argued that financial incentives might stimulate investments in new irrigation technologies that improve water use efficiency, but that the incentives would need to be reasonable, and that people would have to know the technology exists, at the very least. Wilkie (2005) indicated that the lack of financial incentives is discouraging upgrades and better use of water – a point also made by DT1 (2014), who also identified incentive examples including tax breaks, credits, and grants or low interest loans.

7.6 IRRIGATION MANAGEMENT PRACTICES

Irrigation management practices include changes to crop mixes, changes in irrigation scheduling, efficient use of fertilizers and pesticides, deficit irrigation, reductions in irrigation water use based on optimum crop water requirements, increases to watering at night and during cooler weather, and monitoring soil moisture conditions (Ali 2011; Burton 2010). In general, Southern Alberta is in a fairly good position with regard to irrigation management practices. For instance, Nitschelm et al. (2011) examined irrigation practices in six irrigation districts (Bow River, Lethbridge Northern, Magrath, Raymond and St. Mary River), and focused on fields with the most efficient means of water delivery and application. They found that producers utilizing the most efficient means of water delivery (pipeline) and water application (low pressure pivots) met an average of 91% of optimal crop water use. However, one-sixth of these high-efficiency field sites were irrigated only to 57-80% of crop water requirements, suggesting that there are still opportunities for improved irrigation management practices.

According to a survey by Bjornlund et al. (2007), irrigators in Southern Alberta tend to aim for water use efficiency through modification of existing equipment and purchase of new equipment, with less emphasis on gains from changing management practices. These low expectations suggest that educational and information programs might improve the understanding of the potential benefits associated with different management practices. This approach was also suggested by DT4 (2014) during the workshop, who advocated for more agricultural extension services. In fact, water use efficiency gains from such improvements may be high and comparable to gains from improvements to irrigation technologies. Additionally, improving irrigation management practices is less capital-intensive compared to upgrading irrigation technologies, which might be limited due to financial and other constraints that impede investment by irrigators (Bjornlund et al. 2009).

7.7 IRRIGATION INFRASTRUCTURE ENHANCEMENT

A recent estimate by AIPA (2010) suggested that a 4.6% improvement in water use efficiency in the irrigation sector alone would result in savings equal to the total consumptive water use of all municipalities in the SSRB. Such efficiency improvements may occur on-farm, or within the larger irrigation district systems.

7.7.1 On-farm system enhancement

Conversion to improved irrigation technologies, from gravity and wheel-move systems to low-pressure centre pivot systems, has already occurred on approximately 66% of the total irrigation system acres in the 13 Irrigation Districts (ARD 2013b). As a result, the estimated overall irrigation efficiency is 78%. Perhaps because of this relatively high efficiency, some of the workshop participants saw the Water for Life challenge of increasing water efficiency by 30% as unrealistic, since there are relatively few opportunities for further technological improvements in irrigation systems. Further, recall that the irrigation sector has already achieved a combined increase in efficiency and productivity of 39%, which likewise suggests that efficiency improvements are approaching their limit and that any additional efficiency gains will decrease with time. Bjornlund et al. (2007) concluded that the greatest gains can be made in the Southern Tributaries irrigation districts through improvements in on-farm efficiency. However, these districts account for only 8% of irrigated land, and so any change would have limited impact on water-use efficiency in the SSRB.

Nicol et al. (2008) conducted a survey of irrigators in the Raymond and Taber Irrigation Districts that focused on both the motivations for irrigation producers to implement new technologies and the impediments to investment in further improvements. They found that the motivations were to increase crop yields, save energy and labour costs, and save water. The impediments were that producers already used all the practical water-saving practices, their financial situation did not permit further investment, and they faced poor commodity prices and physical field limitations for upgrades. The study also revealed that 73% rated the ability to irrigate more land during drought as a very important reason for adopting improved technologies and management practices, that adopting improved technologies has been occurring at a decreasing rate, and that the rate is likely to continue decreasing in the future.

Finally, variable rate sprinkler irrigation (VRI) technology on self-propelled centre-pivot and linear-move irrigation systems offers a new option (Evans 2014; Evans et al. 2012). VRI systems allow variation of the application duration and water depth applied – rather than uniform application – though cycling sprinklers on and off. A VRI system consists of a pivot irrigation system retrofitted with sprinkler control valves, a pivot-positioning system, and electronic control panel. Benefits of the system include reduction in water use, increase in yield, and reduction in energy use. However, the high cost of the different components of the system and the limited research-to-date on VRI systems are problematic. In Alberta, there were two operational VRI systems in 2012; several more were to be installed in 2013 (Tomasiewicz et al. 2013).

7.7.2 Water conveyance and distribution systems enhancement

Open channels in irrigation district conveyance systems face water losses from seepage and evaporation, and to return flows. The Government of Alberta responded in the 1970s to increasing seepage losses and return flows with a conveyance-infrastructure rehabilitation program, known today as the Irrigation Rehabilitation Program (IRP) (AECOM 2009). Workshop participants stated that they would like to see an increase in the cost-sharing percentage from the government and they believe a considerable water saving from such upgrades in the conveyance systems would result (for example, converting canal systems into pipelines) (DT2; DT3 2014). For instance, González (2012) evaluated the potential for water saving in an “ideal case” scenario in WID by fully rehabilitating the conveyance system and replacing the remaining gravity and wheel move systems with more efficient centre pivot system. She found that the total district demand could decrease by up to 10% as a result of reduced on-farm and system losses.

7.8 WATER STORAGE

Expanding or enhancing on-stream and off-stream storage may buffer the effect of periods of water shortage, and therefore benefit both irrigators and the aquatic environment. Water can be retained during high-flow times for later release during low flows both to supply water users and to help to achieve in-stream flow objectives (AECOM 2009).

In Alberta, it is estimated that 2.4 million dam^3 of water (26% of the Province's annual supply) is currently used; furthermore, the Interprovincial Master Agreement on Apportionment stipulates that 50% of the annual water supply flow to Saskatchewan (AEDA 2008). Thus, approximately 25% of the region's average annual flow could be captured for use in Alberta, but instead flows to Saskatchewan because of a lack of storage facilities. AECOM (2009) argues that developing new on-stream storage, or enhancing existing storage, is an efficient and cost-effective form of water storage, since such facilities can typically capture all run-off and sustain instream flows in times of low flow. Off-stream reservoirs provide opportunities for capturing return flows for reuse, increased recreational activities, fish and wildlife habitat, as well as adjoining wetland developments. However, reservoirs also have disadvantages: they cause water loss through evaporation, have high construction and maintenance costs, and can harm the aquatic and riparian environments (Polzin and Rood 2000; Rood and Mahoney 1990; Rood et al. 2003), particularly in already-stressed river reaches. A well-known example is the cottonwood decline downstream from the St. Mary (Rood and Heinze-Milne 1989; Rood et al. 1995), Waterton (Rood and Heinze-Milne 1989) and Oldman Dams in Alberta (Rood et al. 1999).

Alberta Environment recently identified and compiled an inventory database of potential water storage sites (AENV 2005). Three years later, they released a second study that assessed potential storage sites and diversion scenarios (AENV 2008). The study made clear that its purpose was to identify potential sites for further evaluation and not to suggest where any future dams should be built. Workshop participants noted that climate change projections suggest runoff will occur earlier in the year, and so late-season irrigation water will have to come from storage rather than from river flows (DT3 2014). In general, increasing both on- and off-stream storage was advocated by the participants (DT1; DT2; DT3 2014). However, they said that reservoirs might remove land from agricultural production, which would not be desirable (DT1 2014).

7.9 ALTERNATIVE WATER SUPPLIES

Supply-side solutions increasingly relate to small-scale provision, where individuals, industry, and business take responsibility for meeting some of their own water needs (Ploeg 2010). A number of other surface freshwater resources for water supply are available, such as desalination of brackish water, rainwater harvesting and water reuse and recycling. Further, such supplies can be used to meet the demands of other sectors (municipal and commercial, industrial, energy, etc.), rather than purely for irrigation use, allowing more room for water supply for irrigation expansion.

Ploeg (2010) explored some of the potential promises, pitfalls, and perspectives and acceptability of such alternative water sources in Alberta. Desalination, for example, is only practical in close proximity to the coast, and rainwater harvesting offers little relief during either a severe or prolonged drought. Further, Alberta's guidelines for rainwater harvesting (Government of Alberta 2010b) only cover rainwater collected on roofs and only water for residential use. To complicate matters, Alberta Municipal Affairs states that once the rain water hits the ground and is collected in a storage pond or is carried to the river, the resulting stormwater is owned by the Crown and is managed under existing licenses (Alberta WaterSMART 2013). Wilkie (2005) identified several concerns associated with such alternatives including water quality, cost, lack of information, lack of pilot projects, and lack of knowledge.

Finally, groundwater offers another source of water supply. It is not yet used widely as a water source for irrigated agriculture in Southern Alberta, perhaps because surface water has provided sufficient irrigation water to this point and is of higher quality than groundwater. However, it is possible that there will be increased applications for groundwater allocation for agriculture with no additional surface water available. A number of studies promoted the integrated management of both groundwater and surface water in Southern Alberta (Droitsch and Robinson 2009; Minister's Advisory Group 2009). However, the groundwater system and its interconnection to surface water in Southern Alberta is not well understood due to lack of groundwater information and data inventory in the Province (Minister's Advisory Group 2009; Pentney and Ohrn 2008; Ploeg and Sommerfeld 2011). This might be a reason that integrated management has not occurred. Ploeg (2010) identified a number of impediments to alternative water sources, including the requirement of research, development, and technological expertise. In addition, it will also involve new investments to establish pilot projects to assess feasibility, illustrate benefits, determine costs, and identify facility and system upgrades.

7.10 PUBLIC AWARENESS AND INVOLVEMENT

Public perception of irrigation is a challenge to its expansion. Increasing public awareness of irrigation – and particularly the value of local food production – may be a useful approach in increasing support for the irrigation sector. Benefits could include a reduction in individual and overall water use by all users, rather than a focus on irrigation only (Wilkie 2005), the supply of new labour for irrigated agriculture, public support for agricultural infrastructure, and possible expansions in the irrigation sector and in agri-food businesses. Public awareness as a policy option is discussed in more detail in Ploeg (2010).

Workshop participants said that positive media reports about the irrigation industry would be helpful (DT2 2014). Others suggested that there should be more effort – public, media, and more broadly social – to bring agricultural awareness to young people in Alberta's cities (DT4 2014).

7.11 LAND-USE POLICIES

To balance Alberta's rapid economic growth with environmental conservation, the Government of Alberta released the Land-use Framework (LUF) in 2008 after consulting a wide spectrum of stakeholders (Government of Alberta 2008b). The LUF is consistent with the province's previous land-use policies, such as the Green and White Areas initiated by Premier Manning in 1948 and the Policy for Resource Management of the Eastern Slopes introduced by Premier Lougheed in 1977. Both of the policies divided the entire province into different land-use regions, and prioritized land uses in each region. The LUF also complements the province's existing policies: Water for Life, the Clean Air Strategy for Alberta, and Alberta's 2008 Climate Change Strategy. One of the LUF's main promises is to divide Alberta into seven regions and develop a land-use strategy for each region.

The regional plan for the South Saskatchewan region, which covers the South Saskatchewan River Basin and the Milk River Basin, has been completed and comes into effect on September 1, 2014 (Government of Alberta 2014). The regional plan provides a variety of strategies and policies for land, water, air, and ecological services. Here, we highlight several policies relevant to our study, including advancing watershed management, maintaining an agricultural land base, supporting irrigated agriculture, and increasing opportunities for value-added agricultural products.

7.11.1 Watershed preservation

The LUF and the South Saskatchewan Regional Plan (SSRP) highlight the ecological function of watersheds in Alberta, such as storage of water against drought and nutrient removal from surface water. To ensure both the quantity and quality of the water for agricultural uses, Beveridge et al. (2010) suggested that each region should maintain a baseline for the amount of land in a given watershed that is preserved in its natural state, and they also advocated the continuous promotion of public awareness and understanding of the value and importance of watersheds.

7.11.2 Maintaining an agricultural land base

Because an agricultural land base is essential for sustainable growth of agricultural and agri-food industries, the conversion and fragmentation of agricultural land must be minimized. The SSRP recommended that contiguous blocks of agricultural land be preserved, since both contribute to the diversification of the agricultural economy. In addition to governmental efforts, the SSRP also suggested that voluntary actions by landowners are important and that they be encouraged to preserve agricultural land.

7.11.3 Restrained increase of irrigated acres

Irrigation is known to be beneficial to the preservation of agricultural lands. Samarawickrema and Kulshreshtha (2008) explained in detail the benefits of irrigated farms versus dryland. Specifically, the irrigated water supply offsets adverse impacts of drought to a great extent. Further, irrigation reduces the production uncertainty/risk associated with a lack of precipitation, which otherwise is a major concern for farmers. The multiple policies mentioned above – water pricing, proportional water sharing, and irrigation infrastructure enhancement – could all be implemented to support the development of irrigation districts. However, irrigation expansion should be restricted, since Alberta's water supply is not limitless (Droitsch and Robinson 2009). The Irrigation Districts Act states that any addition of irrigation acres should not bring risk, particularly water deficit, to either the new or existing irrigation acres.

7.11.4 Optimizing crop mixes

Finally, the SSRP suggests that Alberta should further expand value-added agri-business and create more opportunities for value-added agricultural products. To determine optimal land uses in the 13 irrigated districts, positive mathematical programming (PMP) has been adopted in case studies (He and Horbulyk 2010; He et al. 2012). This method aims to maximize farmers' profits given a set of land, social, and technology constraints. With the aid of PMP method, He et al. (2012) showed that, with optional water allocation policies (proportional reduction allocation policy versus seniority allocation policy), the total irrigated area in Southern Alberta could increase by 1–13% even with 10-40% less water supply. And the researchers' results also indicated that the proportions of certain high value-added crops (e.g., dry beans, potatoes, sugar beets) always increased, whereas other crops usually deceased in different water shortage and allocation scenarios.

8 SUMMARY

This report resulted from an intensive literature review and a workshop-based dialogue with stakeholders and decision-makers. It provides background information on current and future challenges to, and opportunities for, the irrigation sector over the next 25 years. The literature review summarized 113 journal articles, government documents, and grey literature documents. It was reinforced with insights gained from dialogues with irrigation-sector stakeholders – a group of fourteen participants including irrigators, ranchers, irrigation district representatives and board members, economists, government policy advisors and representatives (ARD and ESRD), academics and business representatives, and a total of 24 participants.

Among the challenges facing the irrigation sector are population growth and demographic change, labour-market competition from other sectors, a lack of trained, affordable labour and the aging of producers, competition for water with other sectors and the maintenance of a social license to operate. Opportunities for expansion of the irrigation sector appear to be high given the increase in water-productivity and corresponding decrease in water diversion over the last decade, which makes expansion possible within existing water license allocations. Additionally, workshop participants commented on Alberta's openness to innovation and risk-taking, which is high compared to other regions around the world. This openness should accommodate more irrigation expansion, increased agricultural production of high-value crops and agri-food business development.

A set of potential policy and management strategy options that have received local attention, both in the literature and through discussions with multidisciplinary stakeholders, was also provided, including a discussion of each option and its potential contribution to addressing challenges and improving opportunities for the irrigation sector over the next 25 years. Examples of potential policy options include: market-based economic instruments, water storage and infrastructure upgrades, incentives for water conservation, public education and involvement, and alternative land-use policies.

Finally, the report identified a variety of land and water management strategies for assessment through "system dynamics" and other methodologies that will give the research team and decision-makers the opportunity to 1) improve understanding of the causes of likely changes in key variables of the irrigated agriculture sector in Southern Alberta, 2) evaluate their consequences and the effects of policy responses, 3) structure knowledge and characterize risks and uncertainty in the irrigation sector as well as possible trade-offs, and 4) place changes in one system in the context of other socio-economic and environmental changes.

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