CHAPTER 7

Sensitivity Analysis

Evaluating Alternative Futures

Global Warming - Climate Change, Irrigation and Adaptation in the Prairie Economy

Global warming is now accepted as a current and future reality by many scientists and policy makers. Irrigation will represent an important adaptation option for a warmer and wetter Saskatchewan by storing and distributing water financed by the irrigation economy. The Intergovernmental Panel on Climate Change (IPCC) in the 4th Assessment Report warns that climate change impacts may be far-reaching and adverse. Most climate change models[53] agree on the direction of these changes, although the predicted magnitude of change does vary. In 2007 the IPCC documented many of the changes now underway and identified the possible impacts due to changes in extreme weather and climate events to the mid to late 21st Century. The anticipated effects of these types of changes on the Canadian Prairies and Saskatchewan are summarized below.

Table 50 - IPCC Possible Impacts of Climate Change in the Canadian Prairies and Saskatchewan

Climatic Phenomenona and direction of trend	Likelihood of future trends	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*	Increased yields in colder environments decreased yields in warmer environments increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increased over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to water logging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	*Likely*	Land degradation; lower yields/crop damage and failure; increased risks of livestock deaths and wildfire	More widespread water stress	Increased risk of food and water shortage; malnutrition; water- and food borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Executive Summary for Policy Makers, Intergovernmental Panel on Climate Change, 2007					

53 General Circulation Model, GCM

Climate changes will directly affect both local agriculture and the world's food supply. The exact outcomes of what happens to any given region experiencing climate change will depend on the specific changes and the region's capacity to adapt to the changes. Irrigation can be seen as a part of any adaptation strategy. Climate change presents crop production with prospects for opportunity and loss for nearly all aspects of agriculture including cropping and livestock production, water resources, human health, industry, rural settlement and the economy. Typical agricultural impacts that might be expected in Saskatchewan include:

- **Water supplies will change.** Agriculture exists as an industry through its ability to manage its water supplies for crops and animals. Climate change will modify rainfall, evaporation, runoff, and soil moisture storage. Any changes to total seasonal precipitation and its pattern of variability through the year will be important. Winter snow packs may no longer be the cumulative reservoir of moisture to recharge the soils during a smaller spring run-off. Moisture stress related to drought during flowering, pollination, and grain-filling is harmful to most crops and particularly so for corn, soybeans, and wheat. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress; as a result there will be a need to develop crop varieties with greater tolerance to drought and to reduce the reliance on rains and snow and to develop alternative sources of water supply in the form of storage, irrigation and on farm water supply systems.

- **An increased frequency of extreme weather events is expected – droughts, storms or floods.** These can provide disasters or opportunities to agriculture depending upon the location of the events, the local crop physiology and the local capacity to adapt and benefit from the new environment. In many parts of the world where crops grow close to their heat limits, drought may prove disastrous. For others who might develop alternative sources of water supplies such as irrigation, agriculture can become sustainable in spite of recurring drought conditions.

- **Increased concentration of C02 in the atmosphere can enhance crop growth**. The process of plant growth will change. Thus wheat, rice and soybeans respond well to increased C02. Crops may use less water even while they produce more carbohydrates. This dual effect will likely improve water-use efficiency - the ratio between crop biomass and the amount of water consumed.

- **Higher temperatures in middle and higher latitudes, will extend the length of the potential growing season**, allowing earlier planting of crops in the spring, earlier maturation and harvesting, and the possibility of completing two or more cropping cycles during the same season. Crop-producing areas may expand towards the pole in Canada and Russia, although yields in higher latitudes will likely be lower due to the less fertile soils in the north.

- **Soil fertility and erosion** - Higher air temperatures will translate into warmer soils that can allow for the more rapid natural decomposition of organic matter and increase the rates of other soil processes that affect fertility. Additional application of fertilizer may be needed to counteract these processes and to take advantage of the potential for enhanced crop growth that can result from increased atmospheric CO_2. This may lead to increased environmental risk as chemicals migrate into air and water pathways and soil is lost from windstorms removing a farmer's most valuable natural asset.

- **Pests and diseases** – Warmer climates create conditions that are more favorable for insects and pests. New insect and pest management strategies will be required.

- **Rising sea levels will affect many of the world's agricultural producing areas**. Global warming predicts a rise of sea level ranging from 0.1 to 0.5 meters by the middle of the next century. This level of increase will pose a threat to agriculture in low-lying coastal areas, where impeded drainage of surface water and of groundwater, as well as intrusion of sea water into estuaries and aquifers, might take place. The loss of these regions as agricultural production regions would have very direct effects on the markets for many crops and animals and the sources of supply. Saskatchewan does not qualify for any of these effects, but might be able to replace some of the agricultural supplies that originate in these areas.

Predicted climate changes suggest a warming on the higher northern latitudes, the northern polar region and earth's mid-continental areas including the Canadian Prairies. A recent Natural Resources Canada report suggests some rather adverse impacts on the Canadian Prairie region that may include[54]:

- ***Increases in the water scarcity*** represents the most serious climate risk in the Prairie Provinces; rainfall distribution may change with more in the winter and less in the summer growing season.

- ***Extreme weather events*** in the form of longer droughts or storms.

- ***Ecosystems will be impacted by shifts in bioclimate***, changes in fire and insect disturbances, stressed aquatic habitats, and the introduction of non-native species, with implications for livelihoods and economies dependent on ecological services.

- ***The Prairies are losing some advantage of a cold winter***. Cold winters limit pests and diseases, facilitate winter operations in the forestry and energy sectors, and provide access to remote communities through the use of winter roads.

- ***Communities dependent on agriculture and forestry*** are highly sensitive to climate variability and extremes. Droughts, which can have associated economic impacts of billions of dollars, wildfires and severe floods, are projected to occur more frequently in the future.

Many of these climatic changes would affect the performance of dryland agriculture in Saskatchewan. In particular, higher temperatures and more variable precipitation may increase risks for dryland production systems. In addition, the rainfall pattern is also predicted to change, as more soil moisture would be available earlier than now, but much of this may evaporate due to less severe winters. Grounds not frozen may lead to more percolation of water with lesser quantity available at the seeding time and water may no longer be available to crops. Recent GCM scenarios estimates[55] suggest the South Saskatchewan River Basin will experience by 2050, higher precipitation in winter in the form of rainfall due to rising temperatures and less in summer.

Warmer temperatures imply there will be a longer growing season, but there will also be less precipitation in summer, and therefore less available soil moisture. The projected changes in temperature will influence snow accumulation in the mountains, which feed the rivers that communities depend on for their water supply. Decreases in river flows and changes in the dominant flow season shifting from summer to spring will cause river flows to decrease in throughout the summer and fall months. Increased temperatures will result in increased evaporation from soil and storage dugouts, rivers, lakes and reservoirs.

Furthermore, the frequency of dry spells, and/or droughts is also expected to increase under the future climate regime. According to Lapp, Sauchyn and Toth (2008), in future climates,

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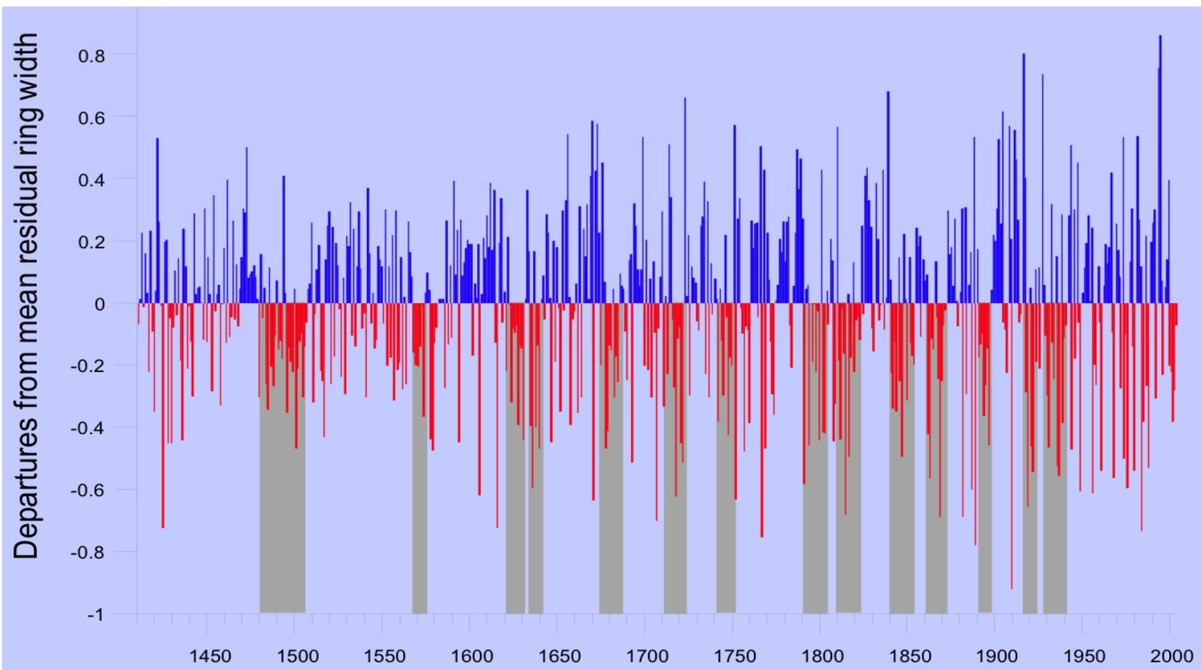
[54] Sauchyn and Kulshreshtha (2009) in Lemmen, Warren and Lacroix (2007)

[55] Lapp, Sauchyn and Toth (2008)

droughts are expected to become more frequent and prolonged. Tree ring data and chronology that can identify wet, dry and drought periods in Prairie history identifies many severe periods of drought (Figure 29). Weather records found in tree rings go back more than 1,000 years and allow estimates to be made of past climates. Sauchyn notes: *If we choose our samples carefully, there is a strong statistical relationship between tree ring growth and climate factors. By establishing a relationship between current climate records and tree ring widths, we can use the same formula to determine what the weather and climate were like for each annual ring, preceding the measurement of weather. We have found that prior to the 20th century, the Prairies were affected by periods of decade-long drought. From statistical analysis, we have determined that there is a good chance that a decade-long drought will occur sometime this century.* [56]

Figure 29 Wildcat Hills Tree Ring Chronology, 1411 - 2005



Legend: Periods of Drought Source: Sauchyn, D. (2006)

Many climatologists believe that devastating droughts like the 1930s Dust Bowl are not abnormal when viewed in larger historic context.[57] A 2005 report suggests the northern Great Plains droughts recurred at roughly 160-year intervals. [58] Fire was a key player in the drought cycle and an important factor in regenerating plant life the Plains. Physical evidence of the droughts was found in lake beds where layers charcoal reveal prairie grass fires, soil erosion and moister periods of grass growth. Annual layers preserved in the lake's sediments span some 10,000 years. The findings may be representative of past weather conditions throughout the northern Great Plains, an area including the Dakotas, eastern Montana and Wyoming, western Minnesota, and the adjacent Canadian areas of southern Manitoba, Saskatchewan, and Alberta. Scientists therefore expect the cycles to continue, possibly with a boost from global warming.

Longer droughts can have devastating effects on the regional economy. For the 2001 – 2002 drought years the economic and environmental impacts have been estimated as:

- Agricultural production dropped an estimated $3.6 billion for the 2001 and 2002 drought years, with the largest loss in 2002 at more than $2 billion.

[56] Goertzen, J. (2001)
[57] Schindler, D.W. and Donahue, W.F. (2006)
[58] Brown, K.J. et al. (2005)

- Gross Domestic Product fell some $5.8 billion for 2001 and 2002, with the larger loss in 2002 at more than $3.6 billion.
- Employment losses exceeded 41,000 jobs, including nearly 24,000 jobs in 2002.
- Severe wind erosion events occurred, even with the improvements provided by conservation tillage. Soil degradation by wind erosion can have long lasting effects on production (Wheaton et al., 2005).
- Livestock production was especially difficult due to the widespread scarcity of feed and water.
- Water supplies that were previously reliable were negatively affected, and several failed to meet the requirements. Adaptation projects were numerous and ranged from repairing existing dams, dugouts, and wells to developing new dugouts and wells. Also livestock were culled and/or moved to areas where forage and water were more accessible. Communities required supplemental water from various sources, including creeks and rivers and additional water development projects.
- Multi-sector effects were associated with the 2001 and 2002 droughts, with documented impacts on agricultural production and processing, water supplies, recreation, tourism, health, hydro-electric production, transportation and forestry.
- Long-lasting impacts included soil and other damage by wind erosion, deterioration of grasslands, and herd reductions.

The Sauchyn and Kulshreshtha [59] study of adaptation to climate change in the Prairies suggests that *"irrigation is the primary adaptation of agriculture in dry environment. It reduces the impact of drought and other farm risks, supports higher crop diversity, increases profit margins, and improves the long term sustainability of smaller farm units…..Whereas climate change and adaptation have yet to be explicitly addressed at the institutional level of irrigation districts and government agencies, there is evidence that adaptation and increased irrigation efficiency are being contemplated by individual irrigators."*

Sensitivity to Differences in Discount Rates

The analysis has been completed on the basis of three discount rates – 1%, 3% and 5%. Returns to the five projects increase as the discount rate declines. Cost benefit returns are positive at all rates of interest for both the irrigated agricultural scenario and for the diversified value added irrigated agricultural scenario. Currently the real cost of money has fallen to around 3% in real terms reflecting the middle range adopted for the analysis.

It is important to consider two additional items in the sensitivity of the project to the discount rates adopted for decision making. First, the longer term and transformational aspects of the projects provide a clear rational for adopting lower discount rates for evaluation. These lower rates better recognize the longer term nature of the project and its transformational potential for the future of rural central Saskatchewan. Public policy decisions are meant to provide a basis for the widespread benefits to society both today and for future generations. The higher returns identified in the costs benefit ratios for lower discount rates reflect these wide societal benefits.

Table 51 - Comparison of Cost Benefit Ratios

	COST BENEFIT RATIO AT A 1% DISCOUNT RATE		COST BENEFIT RATIO AT A 3% DISCOUNT RATE		COST BENEFIT RATIO AT A 5% DISCOUNT RATE	
EVALUATION SCENARIO	Irrigated Agriculture	Agricultural Diversified Development	Irrigated Agriculture	Agricultural Diversified Development	Irrigated Agriculture	Agricultural Diversified Development
Total Impacts	5.95	22.44	4.67	17.54	3.82	14.28

[59] Sauchyn and Kulshreshtha (2008) p. 297

Difference from 5% Discount Rate Ratios	+2.13	+12.16	+0.85	+3.26	-	-

Secondly, the adoption of higher discount rates effectively reduces the benefits of future activity. In the multiple contexts of sustainability of the economy and society, the intergenerational transfer of wealth, the emerging long term adaptation requirements of global warming it is more than ever critical that future impacts be taken into account in current public policy decision making and investment. This requires the consideration of lower discount rates where the benefits of future investments can more fully be taken into account.[60]

Adjusting the Timing of Development

Irrigation in Saskatchewan has been very slow in developing. During the nearly forty years since the formal opening of the Gardiner Dam in 1967, other parts of the world have invested in, or rehabilitated major water works, expanded irrigated acreage and spent money on farm irrigation and related agricultural value added activities. In fact, irrigation investments that had been made in regional water supplies on the west side of Lake Diefenbaker have unaccountably been abandoned and earlier public investments have been wasted by not developing the resource.

In order to evaluate the benefits of adopting a faster strategy of irrigation implementation in the Lake Diefenbaker area, the pace of irrigation was increased and a 20 year development scenario was again evaluated under three discount rates reviewed previously for both the Irrigated Agriculture Evaluation Scenario and for the Diversified Agricultural Development Scenario. The results of the Cost Benefit evaluation of this faster pace of irrigation development are shown below in Table 52 and compares economic returns against the base case scenario for the area[61]. It clearly demonstrates the benefits of advancing the pace of development.

Faster irrigation development increases returns. Further analysis shows improved and positive cost benefit ratios for both the Irrigated Agriculture and of the Agricultural Development scenarios based on a shorter twenty year period of implementation (Table 52). It is clear that the continued delay in expanding Saskatchewan's irrigation resource bears real costs to developing the irrigation resource opportunity.

Table 52 - Comparison of Cost Benefit Ratios under a 40 Year Irrigation Adoption Scenario (Base Case) and a Faster 20 Year Irrigation Adoption Scenario

EVALUATION SCENARIO	COST BENEFIT RATIO AT A 1% DISCOUNT RATE		COST BENEFIT RATIO AT A 3% DISCOUNT RATE		COST BENEFIT RATIO AT A 5% DISCOUNT RATE	
	Irrigated Agriculture	Agricultural Diversified Development	Irrigated Agriculture	Agricultural Diversified Development	Irrigated Agriculture	Agricultural Diversified Development
Base Case 40 Year Adoption						
Direct Impacts	1.67	11.33	1.19	8.51	0.87	6.63
Total Impacts (Including Indirect and Induced Effects)	5.95	22.44	4.67	17.54	3.82	14.28
Faster Development 20 Year Adoption						
Direct Impacts	2.36	13.64	1.66	9.92	1.20	7.52
Total Impacts (Including Indirect and Induced Effects)	7.78	27.25	5.91	20.63	4.71	16.37
Increase in Cost Benefit Ratios From Faster Development						

[60] See Technical Annex
[61] The base case for the Lake Diefenbaker Area is presented in Volume I.

Direct Impacts	+0.69	+2.31	+0.47	+1.41	+0.33	+0.89
Total Impacts (Including Indirect and Induced Effects)	+1.83	+4.81	+1.24	+3.09	+0.89	+2.09

These findings are contrary to the public policies towards irrigation that have been practiced in Saskatchewan through much of the 20th Century, where support for irrigation has been intermittent. Public investments have been made in essential water infrastructure that has been left incomplete. As a result there has been no related investment in either irrigated agriculture or the value added agricultural investments that would have accompanied the expanded irrigated acreage. The results can still be seen in the landscape on the westside of Lake Diefenbaker where an irrigation canal provides a fertile location for scrub trees and investments in water control structures remain abandoned.

Finances and Benefits Distributions

The Brace Centre (2005) notes that: *Who should pay for the cost of developing irrigation has been a major controversy in Canada. Although internationally, such developments are recognized to be the responsibility of the national and regional governments, such unanimity does not exist in Canada (p.28)*. Studies examining the distribution of benefits from irrigation all show that while producers are significant beneficiaries of irrigation investments, the majority of the benefits flow outside the farm to the province and the rest of Canada. For this reason irrigation financing has traditionally been supported by governments who have not required irrigators to pay for the full cost of irrigation, since most irrigation benefits accrue beyond the farming community.

The distribution of benefits changes with the development of forward and backward linkages around the irrigation economy. When value chains develop around irrigation the levels of local benefits increase. However, irrigation developments that have not developed an extensive network of linkages effectively lose the full range of benefits to other areas, often outside of Saskatchewan. Such was the case in Saskatchewan in the 1984 evaluation of benefits where nearly 60% of the benefits escaped to the rest of Canada. The average of the distributions of the studies completed to 2002 suggest that producers would receive about one fifth of the benefits, the province about half of the benefits and the remaining thirty percent would accrue to Canada and the rest of the world. This evaluation suggests a similar distribution of benefits.

Table 53 Geographic Distribution of Benefits Associated with Major Irrigation Projects in Western Canada

Project	Date	Province	Author	Distribution of Benefits		
				Producers	Province	Canada and Rest of World
Blood Indian Reserve	1982	Alberta	Underwood McLellan	40%	40%	20%
Southern Alberta	1984	Alberta	Manning & Anderson	9%-35%	91% – 65%	
Alberta Irrigation Projects Association	1984	Alberta	Underwood McLellan	15.7%	65.4%	18.9%
Lake Diefenbaker Development Area	1985	Saskatchewan	Kulshreshtha	21.7%	20.1%	58.2%
Association of Irrigators of Manitoba	2002	Manitoba	Kulshreshtha and Grant	7%	76%	17%
Saskatchewan Irrigation Projects Association	2008	Saskatchewan	Clifton Associates Ltd.	21%	79%%	

It is estimated that when a fully developed irrigation value chain is developed around the irrigation districts in Saskatchewan reviewed in this study, the share of the distribution of benefits to producers and the local rural area will rise to capture more benefits for the local area and the province. The provincial fiscal returns from these levels of project investment and activity are substantial. In the Lake Diefenbaker area alone, approximately $635 million would be paid in provincial income taxes over the life of the project. Slightly higher levels of fiscal returns might be expected for the Government of Canada.